DESIGN AND CONSTRUCTION OF AUTOMATIC STREETLIGHT CONTROLLER

BY

SHAIBU SALAWU IDRIS

REG.NO: - 2000/10668EE

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING, SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY.

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER – STATE, NIGERIA.

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NOVEMBER 2005.

DECLARATION

This thesis titled "Automatic streetlight controller" is prepared by me and it is a record of my personal work under the supervision of Engineer MUSA D. ABDULLAHI. I hereby declare that this work has not been submitted else where for any degree. All literatures consulted have been duly acknowledged by means of references.

[signature]	2/12/2005
SHAIBU SALAWU IDRIS	Date

CERTIFICATION

This thesis titled "Design and construction of Automatic street controller" by SHAIBU SALAWU IDRIS has been read and approved to meet the requirements for the award of Bachelor degree in Electrical and computer Engineering, Federal University of Technology, Minna.

ENGR. MUSA .D. ABDULLAHI
Supervisor

Date: 6/12/2005

ENGR. MUSA .D. ABDULLAHI
Head of Department

Date: 6/12/2005

External Examiner

Date

DEDICATION

This project work is dedicated to my Lord ALMIGHTY ALLAH (S.W.T) Unto whom I solemly declare my total Submission in form of prayers, scarifies, living and death and in whose mercy I have been able to complete this course of study successfully.

ACKNOWLEDGMENT.

First and foremost, my unreserved gratitude goes to Almighty Allah the creator, the protector and the sustainer of the universe for having endowed me with the intellectual capability right from childhood till this point of writing the project work.

I proceed forthwith to show my appreciation to my beloved parents Mallam Salawu Shaibu and Mallama Saratu Yusuf for all their concern and care for me right from childhood till this present moment. I pray to Allah to preserve their life to reap the fruit of their hard labour.

I am grossly indebted to my Supervisor ENGR. MUSA D. ABDULLAHI whose experience, educative suggestions and constructive criticisms has brought this work to limelight. More also my sincere thanks to the Head of Department of Electrical and Computer Engineering, Engr. Musa D. Abdullahi and the entire staff of the Department, Federal University of Technology, Minna.

My special gratitude goes to my leader Mallam Dan Muse Abdullahi whose counseling, encouragement, patience and understanding of my various problems has made a great change in my life.

I wish to specially acknowledge, with love and gratitude my able Salawu .A. Mamudu without whose support and much needed companionship my staying on campus would have been a miserable one,

My appreciation is incomplete if my gratitude is not expressed to my dear ones and friends who have in one way or the other touched my life. At home they are: Bro Salihu Abdullahi, Sister Ramatu and all my Younger ones, Aunt Rekiyat Abu, Uncle Sumaila Yusuf, mallam Muhammad Yusuf, Mallam Shaibu O. Yahaya Mallam Yakub .O. Jimoh, Mallama Hawawu .O. Jimoh.

In the school they are: - Mallam Salawu mamudu, Mallam Tbrahim Aliyu, mallam Abdul Rahman.S Usman, and the entire 500L class 2005 Electrical and Computer Engineering, Federal University of Technology Minna.

Finally, I thank Allah for his blessings, protection and guidance throughout my stay in the university and at all other times.

ABSTRACT

This project is the design of a high efficiency streetlight controller. The design is based on the Light Dependent Resistor (LDR), which is the major component of the circuit connected as a sensor, and an op-amp connected as a comparator.

The circuit is used to detect the voltage level of the impute pulse generated from the day and night ambient light intensity of the atmosphere or from another means.

The sensor and the comparator form the switching mode voltage level detector circuit, which acts by means of a drive (Transistor relay) to control the switch either ON/OFF streetlight automatically.

The simplicity of the design is the result of appropriate selection of materials and this even result in the lightweight nature of the model.

The automatic street lighting control is highly economical and safer to operate in the sense that it is devoid of man's constant interference.

This prototype designed project could be modified to control a real life street lighting system by incorporating a contactor (three phase) such that the relay now operates the exciter coil.

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LIST OF SYMBOLS

I	=	Current
V	=	Voltage
Vo	=	Output voltage
Vin	=	Input voltage
Vd.c	=	D.C voltage
Ic	=	Collector current
I_B	=	Base current
I_E	=	Emitter current
A.C.	=	Alternating current
D.C	=	Direct current
A	=	Ampere
mA	=	Milliampere
N_p	=	Primary turns
N_s	=	Secondary turns
R_v	=	Variable resistor
r	=	Ripple
LDR	=	Light Dependent Resistor
D	=	Diode
C	=	Capacitor
f	=	Frequency
t	=	Time
H_z	=	Hertz
W	=	Watts

P	=	Power
PIV	=	Peak inverse voltage
Op-qmp	=	Operational amplifier
B	=	Base
C	=	Collector
E	=	Emitter
NPN	=	Negative – positive –negative

CHAPTER ONE

1.1 INTRODUCTION

Many years back, switching systems use basically manual operations, which required an operator. The discovery of light dependent devices like photo resistors, photocell and phototransistors, which responds to light intensity, can be applied to reduce the involvement of mankind in power switching operations. As a result of these, man-made error is reduced and life becomes more comfortable to live. In the past, bulky power components and hence a large control current were used in switching components like switchgear and contactors. Bulky control components were found to be less reliable, occupying much space, requiring considerable high initial capital cost and high cost of maintenance. They are also prone to adverse electrical hazard since they operate on high current.

Subsequent research in the field of electronic engineering has led to the invention of miniaturized components such as integrated circuits and semi conductor devices which need to operate on a low voltage to control a heavy load current with light reliability factor and at a cheaper rate.

Among thousands of control systems to assist mankind to become independent of human intervention is the street light controller, which is an electronic device that automatically turns on street-lighting at night and turns it off during the day.

The controller requires a regulated 12 V d.c. Power supply for its operation. The device has a light dependent resistor (LDR) acting as light illumination sensor and an operational amplifier (op-amp) as a comparator for comparing the night and day voltages across the sensor.

During the day, enough light falls on the LDR, its resistance becomes low and the voltage developed across it is inadequate to bias the transistor to cut – off. However, at night, when there is no illumination falling on the LDR, its resistance becomes higher and enough voltage is developed across the LDR to forward-bias the transistor. Thus, the bulbs of the street lighting turn ON automatically at night and OFF during the day by the action of the controller.

1.2 THESIS MOTIVATION

The motive behind the design is the need to turn power off during day time when our street-lighting should not be left on without switching off by the manual operator and also the need to provide clear visibility for motor traffic and pedestrians during cloudy weather. This will conserve electric power, aid traffic flow and ever prevent accidents.

1.3 PROBLEM DEFINITION AND METHODOLOGY

The problem faced by manually operated switch for streetlights in our residential area and industries are enumerated below:

i. Problem connected with attendant as manual operator.

ii. Problem of power wastage during the day when operator fails to put off the lighting; and.

iii. Problem associated with switching-on the streetlight during a stormy and cloudy weather.

The above problems are completely solved in this Project, which is "Design and Construction of an Automatic Street-light Controller". The device turns the streetlights on during cloudy weather automatically without an operator.

CHAPTER TWO

2.1 LITERATURE REVIEW

Switch controller systems are becoming increasingly automated, particularly with respect to sensing and communicating hazards and vulnerabilities, and to a lower but still considerable extent, with respect to response and action.

This situation is true in both crime related applications, such as intrusion detection devices and fire protection (extinguishing) and alarm systems. Street lighting in often referred to as road lighting or public lighting, which includes lighting of pedestrian walkways, subways and buildings. The provision of the street lighting also acts as crime deterrent.

One of the references to street lighting development was in 1405 when Aldermen of the City of London, England, was made responsible for ensuring that every house adjoining the highway was provided a lit candle or lanterns from dusk until 9 p.m. Since then the technology of the street lighting has made great advances particularly in view of the recent development of new light sources and the increased density of fast moving traffic.

One design approach is based on the principle of "Silhouette vision" with the lighting being arranged so that the surrounding surfaces appear lit, with any vehicle, pedestrian and object appearing on the Silhouette.

The first controller to put streetlight ON and OFF was the lamp higher, which went around lighting gas lamps. For many years, the cheapest and most reliable systems have been the dial time switch. This is a clock driven by a synchronous electric motor.

The solar dial is set compensating and allowing for the daily variation in switching ON and OFF times.

The advantage of solar dial time switch is that its automatic switching of street lighting was based on average day light condition and but it needed resetting after every power cut. This is a very strong argument for a switching device controlled by ambient day light conditions, which, for example, switches ON where there is a fog or when it gets dark early because of overcast sky.

The modern photoelectric cell fulfils this requirement and it is being used extensively for new street lighting. A photoelectric cell can be seen generally on top of posts controlling individual lamps, but it is often wired to a relay, which in turn switches many lights.

The Industrial Revolution came with the technology for the design of mechanical switching systems consisting of levers and gears, which are bulky, and at the same time producing wear and unreliability.

With the emergence of the computer age, electronic switching circuits using discrete components tends to be more reliable than the mechanical counterpart because they are lighter in nature and operates faster.

Suleiman Saliu Adekson designed and constructed a switch controller, which he titled "Light Activated Switch Control" [6]. In his work the switch control has to be preset to a given resistance at room temperature. Hence this work is not accurate because during stormy or cloudy day when light intensity reduces and temperature decreases resulting in poor visibility, the switch control ought to be ON by itself. To this end, a better result could be achieved by incorporating a Zener diode to discriminate the reference voltage across the comparator such that whenever there is voltage difference between the sensor (LDR) and the reference, the streetlight is turned ON.

2.2 PROJECT OUTLINE

This project consists of six chapters for ease of comprehension. Chapter one is the introductory part. The motivation behind the project and problem definition and methodology were discussed.

Chapter two deals with the literature review and the Project outline. Also contained are previous problems encountered by earlier designers and the approaches made towards solutions.

Chapter three has the theoretical background of the components used in the project.

Chapter four deals with the system design, calculation and decision taken on selecting appropriate components for the circuit.

Chapter five includes system construction and testing of the circuit while chapter six consists of general conclusion, problems encountered, limitation, application and possible recommendation. Also include in this chapter are the relevant test consulted.

CHAPTER THREE

THEORETICAL BACKGROUND

3.1 INTRODUCTION

The design and construction of this project is based on the available device and other components, which are incorporated to form different units of the system. Each unit consists of different electronic components, which perform different operations necessary for the overall operations of the system.

The Automatic controller comprises of four units namely: the power unit, the control unit, the switching unit and finally the out put. This is shown in the block diagram of fig 3.1.

The theory and properties of each element of the block diagram, which enable them to be used for different purposes, are discussed in this chapter.

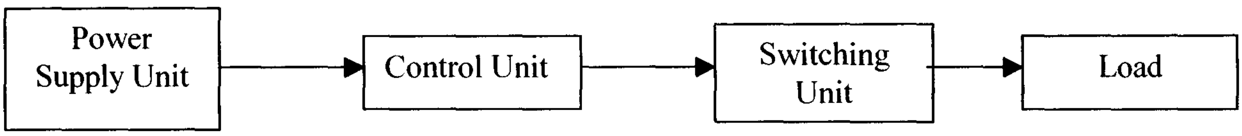


Fig. 3.1: Block diagram of the controller.

3.2 POWER SUPPLY UNIT

Almost, if not, all electronic devices and circuits require a d. c supply for their operation. Dry cells and batteries are forms of d. c sources and have the advantages of being portable and ripple free. However, they need frequent replacements and are therefore, expensive as compared to conventional a.c. supply; it is advantageous to convert a. c. supply to d.c. voltage.

The process of converting the a.c. voltage involves voltage transformation, rectification, filtration and regulation all of which are accomplished by the use of transformer, rectifier and voltage regulator circuit, the arrangement of which are shown in fig. 3.2.

Meanwhile, the following characteristics are to be considered in the choice and design of power supply:

i. Maximum and minimum demand of the system.
ii. Maximum and minimum current demand of the system.
iii. Regulation.
iv. Ripple factor.
v. Efficiency.

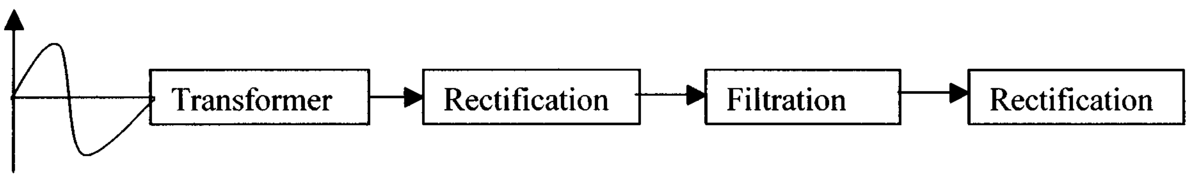


Fig. 3.2: Block diagram of regulated d.c power supply

3.2.1 Transformation

Transformation is a process of converting a.c. voltages from one voltage to another through the use of either step up or a step down transformer.

A transformer is a device with no moving parts that changes the value of the line voltage to that required producing the proper d.c. Voltage output after rectification. Mostly in electronics, a.c. voltage is stepped down to suit the requirement of the solid-state electronic devices and circuit fed by the d.c. Power supply.

Transformer consists of two windings insulated form each other and wound on the same iron core. The primary coils receive the input voltage, while the secondary coil provides the output voltages.

Fig .3.3 shows the schematic structure of a transformer.

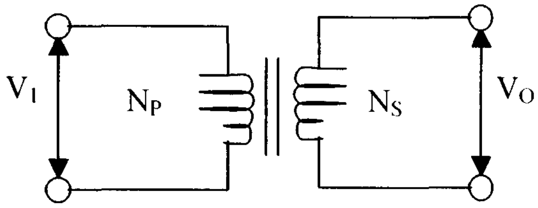


Fig. 3.3: schematic diagram of a transformer

For an ideal transformer, the primary winding of flux is sinusoidal.

Therefore, flux $\phi = \phi$ mSinwt

But e.m.f. $e = \frac{NdO}{dt}$ ———————— (3.1)

$e = \frac{Nd\,\phi\,Sinwt}{dt}$ ———————— 3.2

$e = WN\,\phi\,Sinwt$ ———————— 3.3

If flux ϕ varies simusoidally, the rms value of induced emf is obtained from the factor ω

therefore, rms value of emf per turn = 1.11 x $4\phi m$= 4.4 $F\phi m$ ———————— (3.4)

Now rms value of the induced emf in whole of primary winding = (induce emf/turn) x number of primary turns

Therefore, $E_1 = 4.44F\,N_1\phi m$ ———————— 3.5

Similarly, $E_2 = 4.44FN_2\,\phi m$ ———————— 3.6

From equations (3.5) and (3.6)

$\frac{E_1}{E_2} = \frac{N_1}{N_2} = K$ ———————— 3.7

Where K is the voltage transformations ration. [5]

3.2.2 **Rectification**

Rectification is the process by which a.c. Voltage is converted into d.c.voltage with the use of rectifier. A rectifier in an electronic device, which offers a low resistance to flow of current in the direction known as the reverse bias direction.

Rectification can be half-wave depending on the application. In this project work, emphasis is laid on the full wave bridge rectifier, which is the most frequently used circuit for electronic d.c. Power supplies. It requires four diodes arranged in bridge form as shown in fig. 3.4

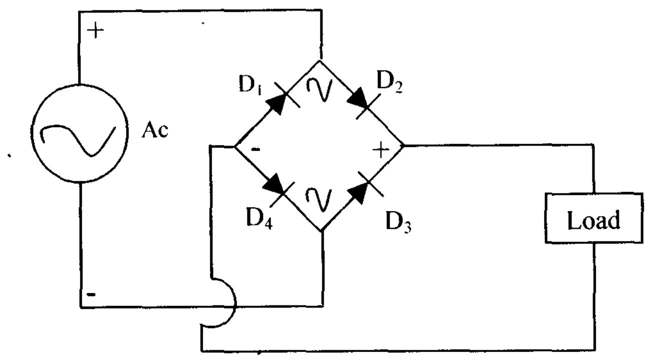


Fig. 3.4. A full-wave bridge rectifier

During the positive half cycle, diode D_1 and D_3 become reversed biased (OFF) where as D_2 and D_4 are forward biased (ON) while during negative input half cycle D_1 and D_3 are forward biased producing a pulsating d.c. Output voltage. The output voltage waveform of the conducting diodes is as shown in fig. 3.5.

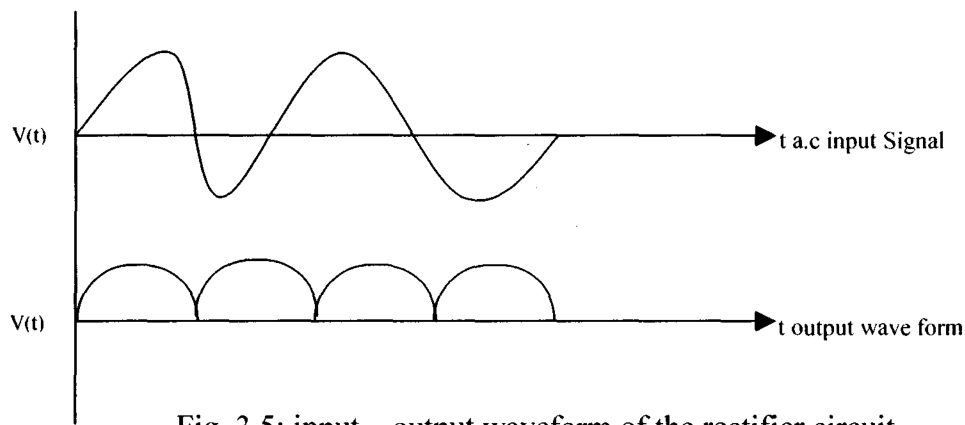


Fig. 3.5: input – output waveform of the rectifier circuit.

3.2.3 Filtration

Filtration is the process by which fluctuations or ripples present in the output voltage supplied by the rectifier is removed using filter.

A filter circuit consists of single capacitor connected across a pulsating d.c. Voltage, which smoothens out the voltage ripple, this effect, is traced to the property of a capacitor to change and store energy during the non – conducting half – cycle [5]. The effectiveness of a capacitive filter is determined by three factor:

i. The size of the capacitor.

ii. The value of the load

iii. Time between pulsation (ripple)

The ripple voltage in giver by

$V_r = Vpp - Vrms$ ———————— 3.8

Also, $Vr = Id.c$ ———————— 3.9

Hence, $C = \frac{Idc}{2f\,(Vpp\text{-}Vrms)}$ ———————— 3.10

Where $Idc = \frac{2\,Irms \times \sqrt{2}}{\pi}$ ———————— 3.11

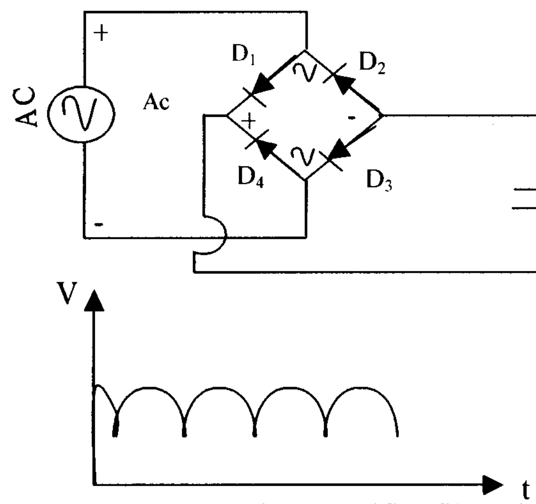


Fig. 3.6: Bridge rectifier filter circuit and output waveform.

3.2.4 Voltage Regulation

Voltage regulation is a process by which the terminal voltage of the d.c. Supply is made constant even when a.c. input voltage to the transformer varies or the voltage varies. Zener diode and integrated circuit voltage regulator are used for this purpose. [2]

3.3 CONTROL/SENSORY UNIT

In this unit, the detailed analysis and operation of the components that make the control/sensory unit shall be discussed. This unit comprises of series combination of photo detector and op-amp acting as a voltage comparator.

The photo detector in this arrangement provides a signal corresponding to the light intensity changes. The mode of operation of photo detector is analyzed below.

3.3.1 PHOTO DETECTOR.

Photo detectors are semiconductor devices that can detect optional signals through electronic processes.

They convert the optical signal variation into electrical variations that are subsequently amplified and further processed. The photo detector used in this project is a photo resistor. Sa photo resistor also Called Light Dependent Resistor (LDR), is a semiconductor device whose resistivity decreases (i.e. conductivity increases) with intensity of light falling on it. [4]

3.3.2 STRUCTURE AND SYMBOL OF A PHOTO RESISTOR

The structure of a photo resistor is shown in fig. 3.7(a). It consists of photoconductive semiconductor, which may be lead sulphide, cadmium sulphide, lead substrate (glass, mica or ceramic). The metallic electrodes are made to the

Photoconductive layer and the entire structure is enclosed in a case with a window to admit incident light. The symbol of photo resistor is as shown in fig. 3.7 (b).

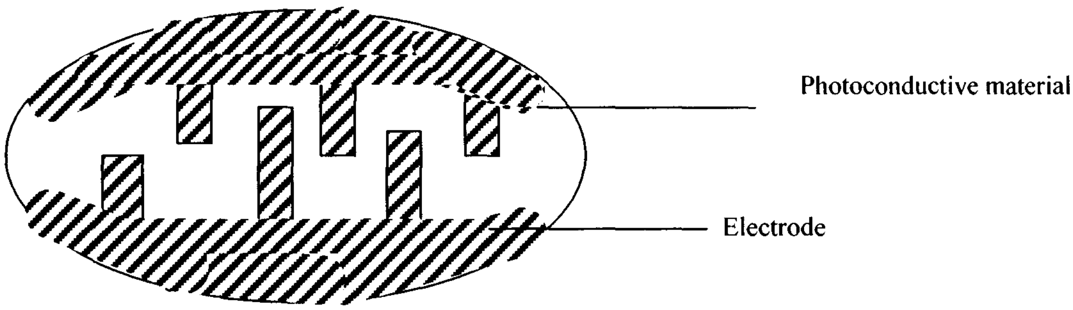


Fig. 3.7 (a) Typical structure of LDR

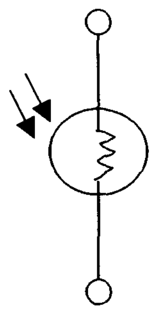


Fig. 3.7 (b) symbol of LDR.

Fig. 3.7: Typical structure and symbol of LDR.

3.3.3 Characteristics of a photo resistor

The properties of LDR are strongly dependent not only on the energy band gap of the material but also on the nature and density of the impurity centre and crystal defects. In order that a current could flow through the device, the semiconductor layer has a very high resistivity and only a very low current is flowing in the device. The current is due to the intrinsic conductivity of the semiconductor and is called the "dark current".

When there is light incident on the device, the resistivity of the semiconductor decreases and a photocurrent begins to flow.

The sensitivity or characteristics curve of a typical LDR device is shown in fig. 3.8.

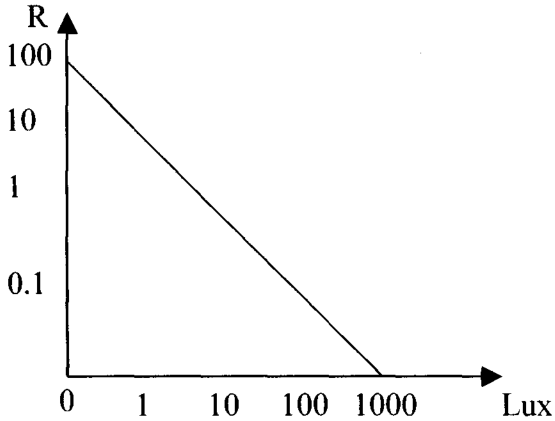


Fig. 3.8: Characteristic curve of LDR

3.4 OPERATIONAL AMPLIFIER.

An operational amplifier (op-amp) is a linear integrated circuit with high gain that is capable of performing linear and non-linear amplification and signal processing functions. Op-amp is powered from dual power supply of opposite polarity. Most op-amp circuit feed back that is the output terminal is connected usually via a resistor or capacitor or combination of the two to one of the input terminals. The circuit symbol is shown in fig. 3.9

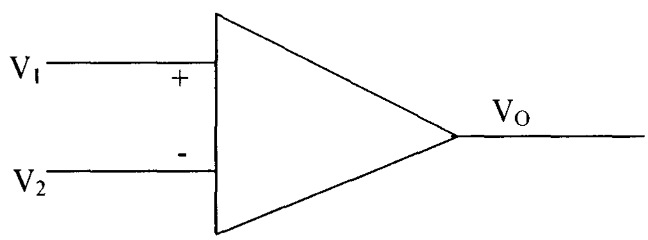


Fig. 3.9: Circuit symbol of op-amp.

Basically, there are different types of op-amp circuits. The common ones are: inverting amplifier, non-inverting amplifier, summer, integrator, differentiator and comparator circuit. In this project work restriction is made to op-amp as a comparator.

3.4.1 PROPERTIES OF AN IDEAL OP-AMP.

The ideal op-amp is easy to understand for it obeys two golden rules:

i. The input current drawn by op-amp is zero.

ii. The output – voltage is whatever makes the input voltages equal.

The properties are as follows:

i. The input impedance is infinite

ii. The output impedance is zero

iii. The open loop gain approaches infinity

iv. Bandwidth is infinite

3.4.2 COMPARATOR CIRCUIT.

Comparators are special types of an op-amp circuit without feedback used to compare a signal voltage on one of the input terminals with a reference voltage on the other input terminal.

When the signal voltage differs from the reference voltage the output of the comparator changes from low to high and vice verse [3]. Fig. 3.10 shows a comparator circuit.

The input signal is connected to the inverting input, when V_I is greater than V_{ref}, the output voltage goes high but when V_I is less than V_{ref} the output goes low. The comparator can drive a relay connected to it via a transistor to control a variety of devices such as heater, lamps, motors, etc.

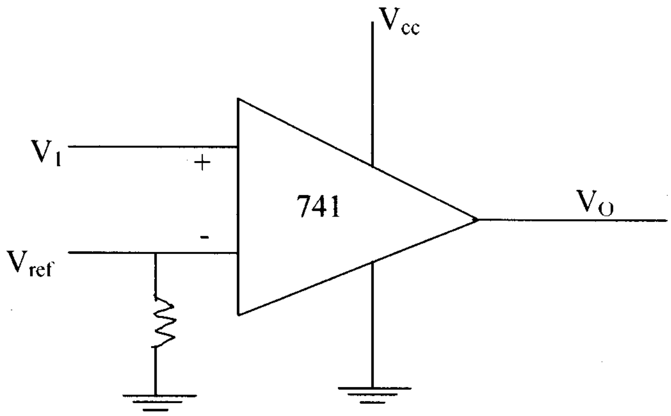


Fig. 3.10: schematic diagram of comparator circuit.

3.5 SWITCHING UNIT

The switching unit comprises of transistor and a relay for triggering the circuit with response to the signal from the control unit.

3.5.1 TRANSISTOR.

The transistor is a three terminal semiconductor device usually manufactured from either Si or Ge. Transistors are used in amplifying electrical signal or act as an electronic switch. There are basically two types of transistors, the Bipolar Junction Transistor (BJT) and the Field Effect Transistor (FET). Restriction is made to BJT in this project.

The BJT consist of a combination of two junction diodes available in two basic convention, namely

(i) NPN (ii) PNP

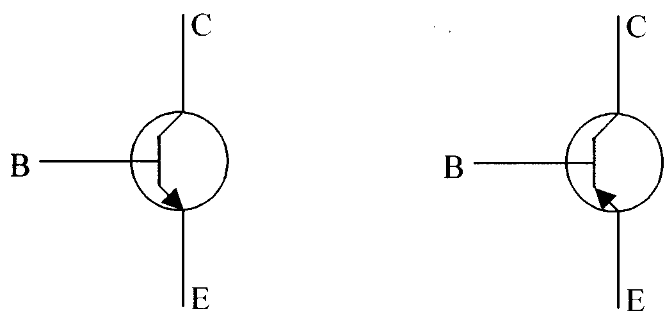


Fig. 3.11: transistor symbols

Its properties meet the following rules:

1. The collector must be more positive than the emitter.
2. The base-emitter and base-collector circuits behave like diode.
3. Any given resistor has maximum values of I_C, I_B, and V_{CE}.
4. If rules 1 – 3 are properly observed, I_C will be approximately proportional to I_B.

$I_C = hfeI_B - \beta IB$ ——————— 3.12.

3.5.2 CONFIGURATION OF BJT TRANSISTOR.

There are three major configuration of BJT namely, common-base CB, Common – emitter CE, and common-collector CC but CE configuration is used because it provides high value of current gain, voltage and power gain at reasonable high resistance as compared to other configurations.

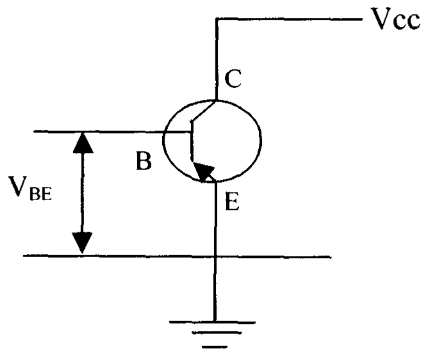


Fig. 3.12: Common-Emitter Configuration of Transistor

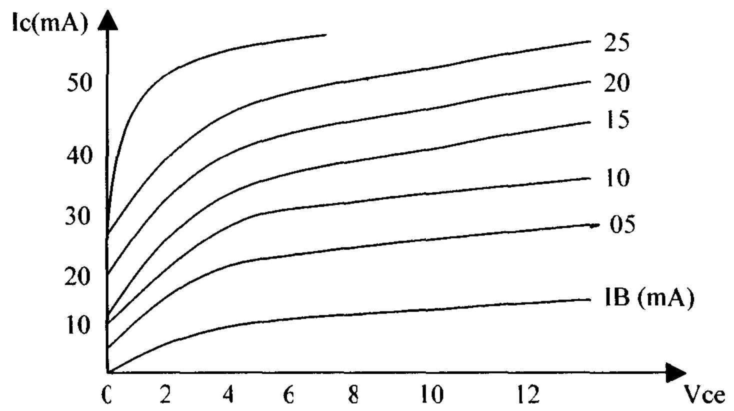
3.5.3 THE COMMON-EMITTER CONFIGURATION.

The CE configuration has a grounded emitter that is common to both base and collector as shown in fig. 3.12 above. In the CE configuration, the input current and output voltage are taken as independent variables while the input voltage and output current are dependent variables and can be written as

$V_{BE} = F_1 (V_{CE} I_B)$ – (1) Input characteristic curve

$I_C = F_2 (V_{CE} I_B)$ – (2) Output characteristic curve

These curves are shown in figures below



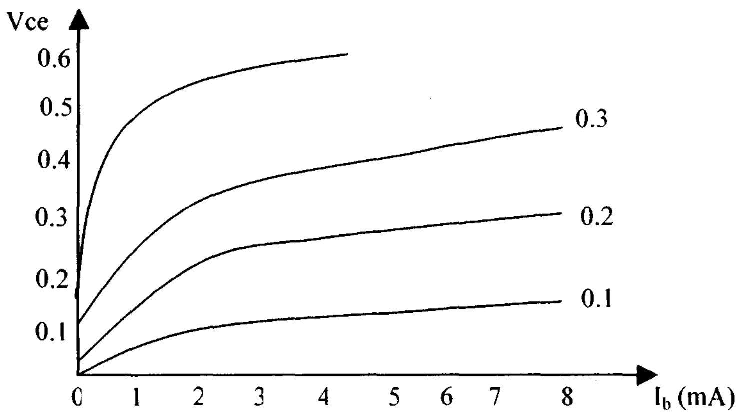


Fig. 3.13: CE input and output characteristic curves

3.5.4 TRANSISTOR AS SWITCH.

Transistor in electronic circuit is not only used in amplifying electrical signal but also they could be employed as an electronic switch. Ideal transistor switches are built around a common-emitter configuration, which biases such that it operates on the two extreme end of d.c load line i.e. cut-off and saturation regions.

In the switching circuit of fig. 3.14(a), if the input voltage is the base and emitter terminals are reverse biased and no base current or emitter current flows and the operation is at point 1 in fig. 3.14(b), the transistor is therefore operating at cut-off. The collector current is practically zero except for the leakage current Ico and V_{cE} is almost equal to Vcc at cut-off and the transistor switch whose contacts are the collector and emitter terminal is open.

A positive voltage pulse is applied to the input terminal, forward biases the emitter-base junction, which causes an appreciable base current to move the operating point to 2 in fig.3.14(b). An increase in base current above 60μA produces no further effect on the collector current and the transistor is said to be operating in the saturation region. In saturation region collector base voltage is near zero, the base current $I_B = I_C/hfe$ and the collector current becomes limited by load R_L with value $I_C = V_{CC}/R_L$ supplying the base current will make the transistor to reach saturation more quickly thereby reducing the rise time.

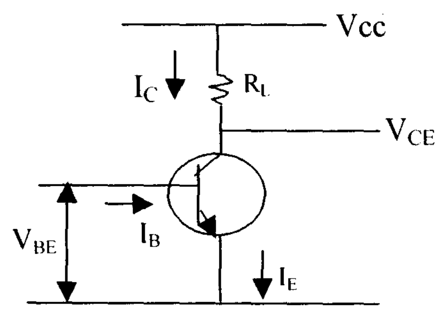


Fig. 3.14(a)

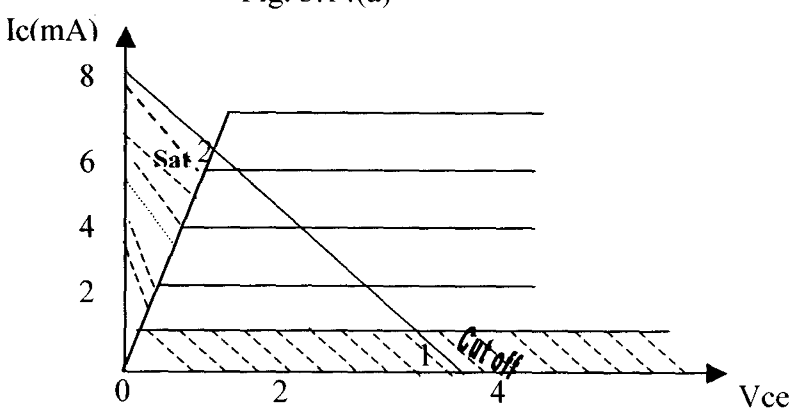


Fig. 3.14(b)

Fig. 3.14: diagram of transistor switch and its characteristic curve.

The voltage drops across the closed switch circuit is V_{CE} (sat). The basic equation for the above CE circuit is;

$$V_{CE} = Vcc - IcR_L \qquad 3.13$$

At saturation Ico is neglected whence Ic = 0 because $I_E = O$

Therefore $V_{CE}(sat) = Vcc$ also $I_B = Ic/hfe$.

At cut-off when I_B is maximum, Ic is also maximum ,$V_{CE} = Vcc - IcR_L$.

Therefore Ic = Ic (max)

Bipolar junction transistor has zero power consumption in switching mode and hence no heating effect which results in large power gain [7].

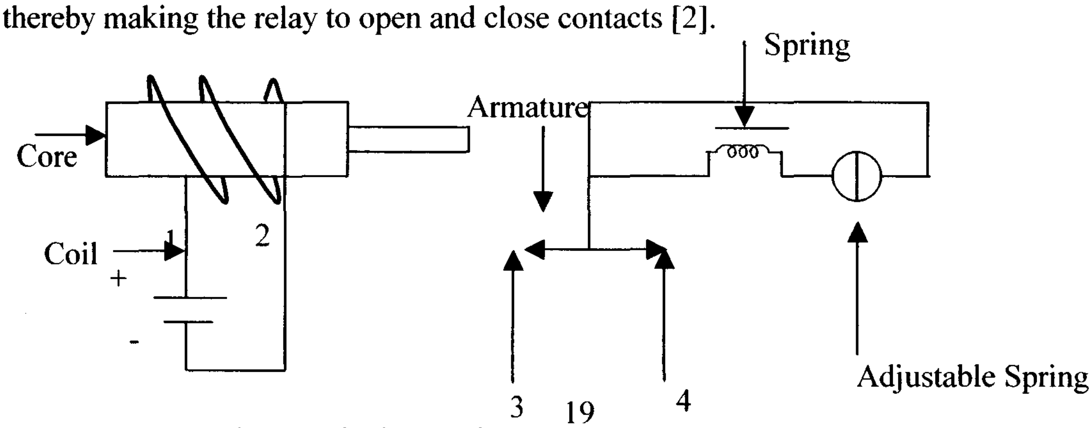
3.6 RELAY

A relay is an electromagnetic device that opens or closes contacts to effect the operation of other device in the same circuit or different circuit. Thus, relays are used for protective and control device for switching, indicating and for transmission of signals.

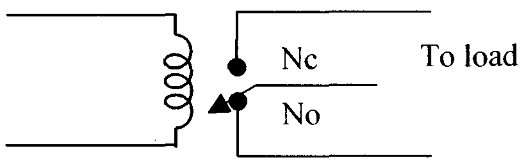
However, in this project work, relay is being used as a switching device.

3.6.1 PRINCIPLE OF OPERATION OF RELAY.

Relay operates on the principle of electromagnetic attraction. As shown in fig. 3.15 below, when the terminals 1 and 2 are connected to source, an electromagnetic is formed and the armature is attracted to the core. If there is sufficient current to overcome the restoring force of the spring, causes the contact 3 to close while contact 4 opens thereby making the relay to open and close contacts [2].



(a) Single pole double throw relay.



(b) Relay coil and circuit symbol

Fig. 3.15: schematic diagram of relay and its symbol.

3.7 ZENER DIODE.

The Zener diode is a junction diode that has a specific reverse breakdown voltage. Unlike the rectifier diode, the Zener diode is operated at its breakdown voltage. Fig. 3.16 shows the characteristic curve of Zener diode. In the forward direction, it behaves in the same way as rectifier diode. When reversed biased, no current flows until the Zener reaches its breakdown voltage then current suddenly begins to flow.

At breakdown, the voltage across the zener diode remains constant for large change in current. Zener diodes are used for shunt stabilization for voltage reference as used in this project to discriminate the reference voltage of the comparator with respect to the signal voltage.

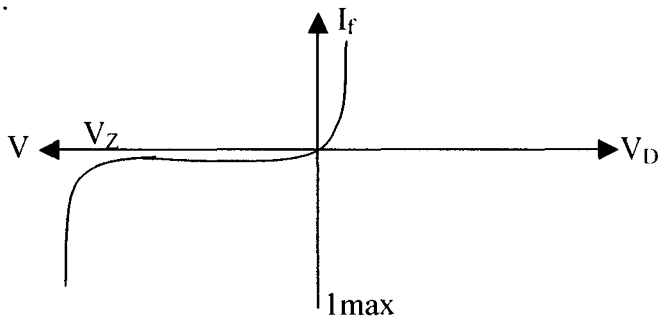


Fig. 3.16: characteristics of zener diode.

3.8 LIGHT EMITTING DIODE.

The light emitting diode (LED) is semiconductor device, which emits visible light when forward biased. The colours of emitted light depends on the type of the material used and are always encased in order to protect their delicate wires. It is rugged and has a life of more than ten thousand hours. The symbol of the light emitting diode is as shown in fig. 3.17

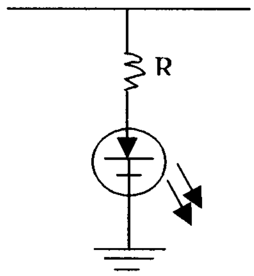


Fig. 3.17: symbol of LED

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CHAPTER FOUR

SYSTEM DESIGN

4.1 INTRODUCTION

This chapter deals with the design procedure, calculations and selections of components used in the construction of this project.

4.2 TRANSFORMER SELECTION.

The transformer selection for this project work was purely made ,base on the maximum and minimum values of operating voltage and current which are essential for transformer selection. Also, the supply from the mains must be considered.

The supply form the mains considered for this project is 220 – 240v, 50HZ. The power rating of the transformer was calculated based on the maximum current that will flow in the circuit at full load, which is estimated in table 4.1.In accordance with the current rating of the various components that make up the complete circuit diagram of the controller.

Table 4.1: Transformer Selection.

Components	Quantity	Maximum Current	Total Max. (A)
BC 337 Transistor	1	0.5	0.5
OPR 12 LDR	1	0.45	0.45
741 op-amp	1	1	1
Relay	1	5	5
LED	1	1	1
Others	1	1	1
Total			8.95 A

Given 10% allowance of total current = 0.895A

Total = 8.19A

Expected maximum current = 8.95 + 0.895 = 9.935A. This implies that at worst case maximum expected current is approximately 9.935A. If a 220 – 240/12v, 50HZ transformer is chosen, the power rating of the transformer assuming unity power factor is

$$P = VI \qquad \text{———————} \qquad 4.1$$

P = 12 x 9.935 = 119. 22VA = 0.119KVA

Therefore, the specification of the chosen transformer is as follows.

Primary Voltage = 240V

Secondary Voltage = 12V

Power Rating = 0.119KVA

Current Rating = 500mA

4.3 BRIDE RECTIFIER SELECTION.

The four diode rectifier used have the following rating:

Maximum voltage = 25V

Maximum forward current = 1.5A

The peak value of the full wave signal is Vp

$Vp = \sqrt{2}\ Vrms$ – (4.2)

Vrms = 12V

Therefore $Vp = \sqrt{2}$ x12 = 16.97V

Hence, diode N4001 was chosen with peak inverse voltage of 25V

4.4 CAPACITOR SELECTION.

The capacitor used was calculated based on the following approximate analysis equation.

$$C = \frac{Vd.c/Vr}{2f\,R_L} \qquad \text{———————} \qquad 4.3$$

Where C = Capacitor

f = frequency

Vd.c = d.c. Voltage from the transformer

Vr = ripple Voltage

R_L = load resistance

If 2% ripple is assumed.

Vd.c/Vr = 50

$$C = \frac{Vd.c/Vr}{2fR_L} = \frac{50}{2x50x400} = 1250\mu f$$

With this value of capacitor calculated, 2200µf, 25v capacitor was chosen because of the fact that the larger the value of capacitor, the more electrons it can store and the lens ripple [6].

4.5 SELECTION OF REGULATOR.

The three terminals fixed voltage regulator used to regulate the input voltage to the circuit was chosen form the following series as spelt out in manufacturer's specification sheet.

i. 109 series regulator for (0.3) – (5v) range

ii. 7800 series regulator for (5) – (24v) range

iii. 7900 series regulator for (-5) – (-24v) range

Hence, the 7812-voltage regulator was chosen to handle the 12V circuit.

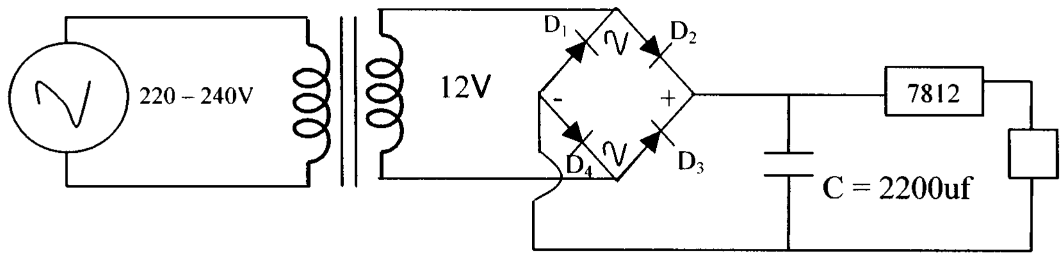

Fig. 4.1. Complete power Supply Unit Diagram

DESIGN OF OP-AMP (741)

The op-amp in this circuit is used as a voltage comparator because it has no feedback resistance and is used to compare voltage of the two input V_1 and V_2.

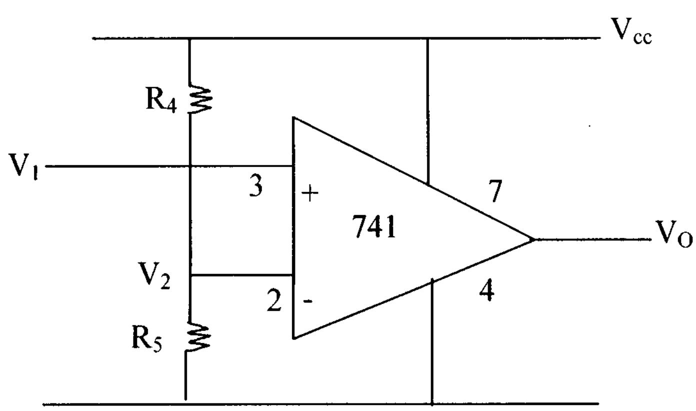

Fig. 4.2: op-amp circuit.

4.6.1 TYPICAL CHARACTERISTICS OF 741 OP-AMP.

Ao = open loop gain = 100dB

Zin = input impedance = 1MΩ

Zo = output impedance = 150Ωl

I_{io} = input offset current = 200nA

I_b = input bias current = 500nA

Us (max) = Maximum supply voltage = ± 15V

Vi (max) = maximum input voltage = $\pm$ 13V

Vo (max) = maximum output voltage = $\pm$ 14V

V_{io} = Differential input offset voltage = 2mA

Is = supply current = 2.8mA

Pc = power consumption = 85mw

From the above characteristics, from the specification (data) sheet, the 741 op-amp is chosen for the design to compare the two-voltage level at the input. R4 and R5 are chosen to be equal, so by using voltage rule.

$$V_{R5} = \frac{R_5}{R_4 + R_5} Vo \quad \text{———} \quad 4.4$$

$$\text{But } Av = \frac{Vo}{V_{R5}} = \frac{R_4 + R_5}{R_5} = \frac{R_4}{R_5} + 1$$

Since $R_4 = R_5$, then

$Av = 1+1 = 2$

In this design, R_4 and R_5 were chosen to be 15kΩ

DESIGN OF LDR

LDR (ORP 12) is light sensitive variable resistor made from Cds or Cdse whose resistance is high with little or no illumination vice versa. The technical specification of typical ORP 12 is shown below.

4.7.1 TECHNICAL SPECIFICATION OF ORP 12 LDR

Peak spectral response 610nm

Cell resistance at i) 50 lux 2.4kΩ

ii) 100 lux 130Ω

dark resistance ≥ 10MΩ

Maximum Voltage is 110v (a.c. or d.c.)

Maximum Power dissipation at 25°C = 200mw

The LDR circuit diagram

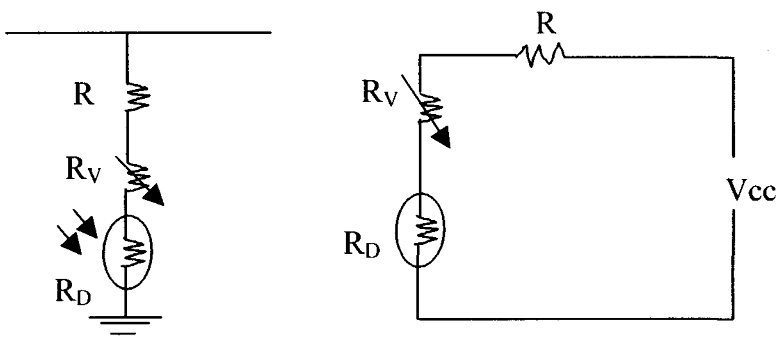

Fig. 4.3: LDR sensory and equivalent circuit.

If the resistance of the LDR is given as RD, then the equivalent circuit of the section will be $V_{RD} = \left(\frac{R_D}{R_I + R_D + R_V} \right) V_{CC}$

Hence, the LDR (ORP12) is chosen for reins project design.

4.8 DESIGN OF BC 337 TRANSISTOR.

A general-purpose medium power BC 337 (BJT) transistor was used for the project design and it has the following characteristics properties.

Ic (max) = 500mA

hfe = 100

V_{CE} = 50 V

Frequency = 200MHZ

V_{CE} (sat) = 0.3V

Power dissipation = 625mw

Vmin = ± 5V

V_{BE} = 0.7v

$$I_C(sat) = \frac{V_{CC} - V_{CE}(sat)}{R_L} = \frac{12 - 0.3}{400} = 29.5mA$$

$$\text{But } I_B = \frac{I_C}{h_{fe}} = \frac{29.5x10^{-3}}{100} = 0.295mA$$

$$R_6 = R_B = \frac{V(min) - V_{EB}}{I_B} \qquad \text{———} \qquad 4.5$$

$$R_6 = R_B = \frac{5 - 0.7}{0.295x10^3} = 14.57x10^3 = 14.7k\Omega$$

A stand value of 15KΩ was used for R_6.

4.9 SELECTION OF RELAY.

The relay selected form the Relay manufacturer's specification sheet has the following properties;

V =12Vd.c

I = 5A

R = 400Ω

4.10 LEDS DESIGN.

The limiting resistor used in this project is shown in fig .4.5. The specification for LED is:

Voltage range is (1.5 – 2.5v)

Maximum Current rating 11mA

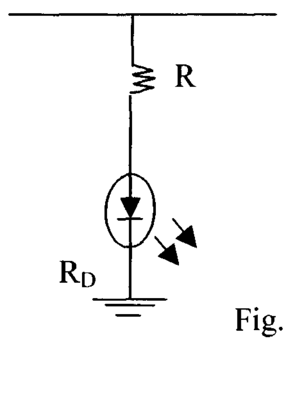

Fig. 4.4: LED Design

By assuming $V_f = 2.5$ forward voltage drop of the LEDS

$$I = \frac{Vcc - V_f}{R} \qquad 4.6$$

$$R = \frac{Vcc - V_f}{I} = \frac{12 - 2.5}{11mA} = 0.84k\Omega$$

A standard value of R = 1kΩ is used for R_1 and R_7.

4.11 ZENER DIODE SELECTION.

The forward characteristics are the same for ordinary (rectifier) diode. The reverse characteristics are the same. They are:

Zener voltage (V_Z) = 6.2V

Minimum Current to sustain breakdown (Imin) = 200mA

Maximum Current limited by maximum power dissipation (Imax) = 350mA.

Power rating = 4w

Therefore, from the above specification, 1N650 Zener diode was chosen.

CHAPTER FIVE

CONSTRUCTION AND TESTING

5.1 CONSTRUCTION.

Construction is the process of putting together all the various subsystems of the controller discussed in the previous chapters on breadboard and tested. The satisfied results were then mounted on zero board and soldered. The construction process depends on the Complete circuit diagram shown in fig. 5.3 and 5.4

5.2 COMPONENTS TESTING.

This involves testing each of the components used in this project-using MULTIMETER so as to ensure that good and exact components are used in conformity with the design circuit. This is necessary because the use of faulty components could result in malfunctioning of the design.

5.3 EXPERIMENTAL SET-UP.

The block diagram of the circuit below illustrates the experimental setup of streetlight controller system. The supply is a 12V d.c source. This is used to supply the system circuit at +12V with a maximum current of 1A. The oscilloscope was used to monitor the voltage level at different points while the multimeter was also used in taking the readings.

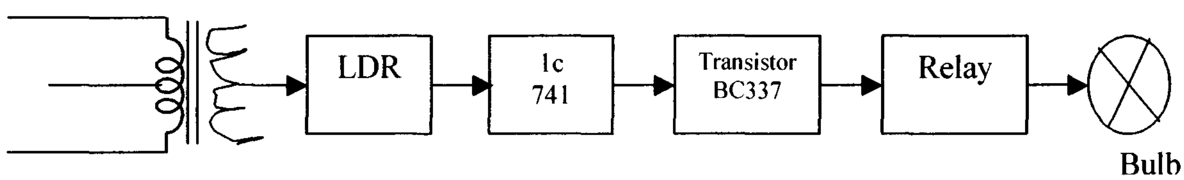

Fig. 5.1 Block diagram of street light controller.

5.3 SYSTEM OPERATION.

The complete circuit diagram of fig. 5.3 below shows that the LDR and R_V constitute a voltage divider network which forward biases the emitter base of T. when enough light falls on the LDR, its resistance is low, the developed voltage across LDR is inadequate to drive T, sufficiently to energize the relay (k). So T is cut off and no power is applied to the load. However, when there is little or no illumination on the LDR, the resistance increases dramatically.

The voltage at the surface of LDR rises. If the components of the circuit are properly chosen enough forward bias of the Base-emitter is developed to increase the collector current appreciably. This current energizes the relay coil thereby closing the normally opening contact; thus power is applied to the load.

However, if the load is a streetlight bulb it will be turned ON automatically as nightfalls and turn OFF at daybreaks. Rv is a sensitivity control, which is adjusted for the level of light as desired to turn OFF the bulbs.

5.4 SYSTEM TESTING.

During testing, the contact terminals of the relay were connected to the prototype. With the supply of 12v d.c, 1A, is turned ON, the bulbs turn ON as the light intensity decreases and turn OFF as the intensity increases.

5.5 CASING CONSTRUCTION.

An insulated metal case is used to house this design circuit after its completion. The case was perforated on each side to give room for ventilation and heat dissipation from the transformer and some other components.

The case dimension is shown in fig. 5.2 below.

Factors considered before the choice of dimension are:

i. Space occupied by the components

ii. Portability of the project

iii. Allowance (Space) for heat dissipation.

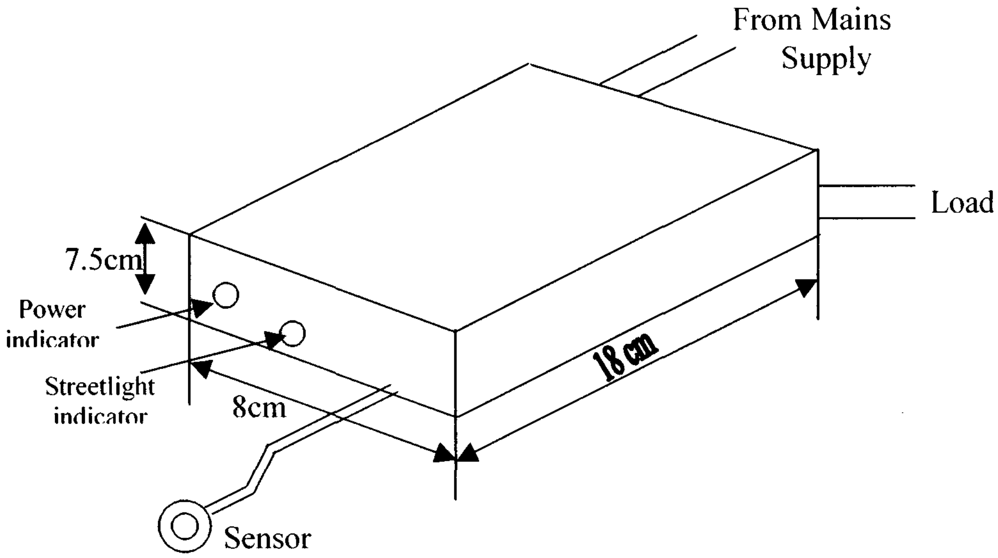

Fig. 5.2: Case design.

5.6 BILL OF ENGINEERING MEASUREMENT AND EVALUATION.

Cost plays a vital role in any engineering design and construction. The cost of any project determine how prosperous that particular project is going to be used. In view of this cost estimation of the streetlight controller is shown in the table 5.1.

BILL OF ENGINEERING MEASUREMENT AND EVALUATION

S/N	DESCRIPTION	QUANTITY	UNIT	RATE	AMOUNT (₦: K)
1	240/12v step down transformer	1	Lot	150	150
2	IN 4001 diode	5	Lot	10	50
3	741 op-amp	1	Lot	100	100
4	25v, 2200µf	1	Lot	50	50
5	7812 (Regulator)	1	Lot	50	50
6	5v LED	2	Lot	10	20
7	Resistor (1K)	3	Lot	10	30
8	Resistor (15K)	3	Lot	10	30
9	5 K (variable)	1	Lot	50	50
10	2.5V Zener diode	1	Lot	10	10
11	BC 337 (Transistor)	1	Lot	50	50
12	LDR	1	Lot	400	400
13	12v relay	6	Lot	150	150
14	Vero board	1	Lot	100	100
15	Flexible cable	10 yards	Lot	10	100
16	Bolt and nuts	6	Lot	10	100
17	Streetlight model	1	Lot	1000	1000
18	Metal Casing	1	Lot	500	500
19	Connectors	3 pairs	Lot	15	45
	Total				₦ 2915

Table 5.1

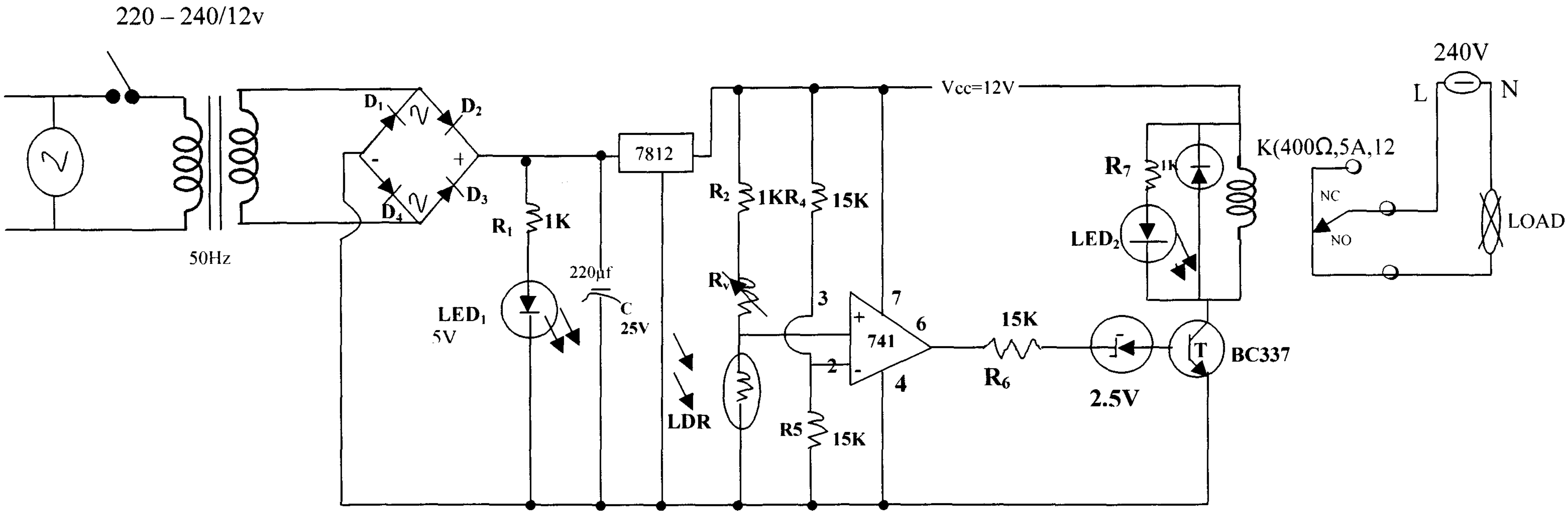

Fig.5.3 Complete Circuit Diagram for Street Light Controller.

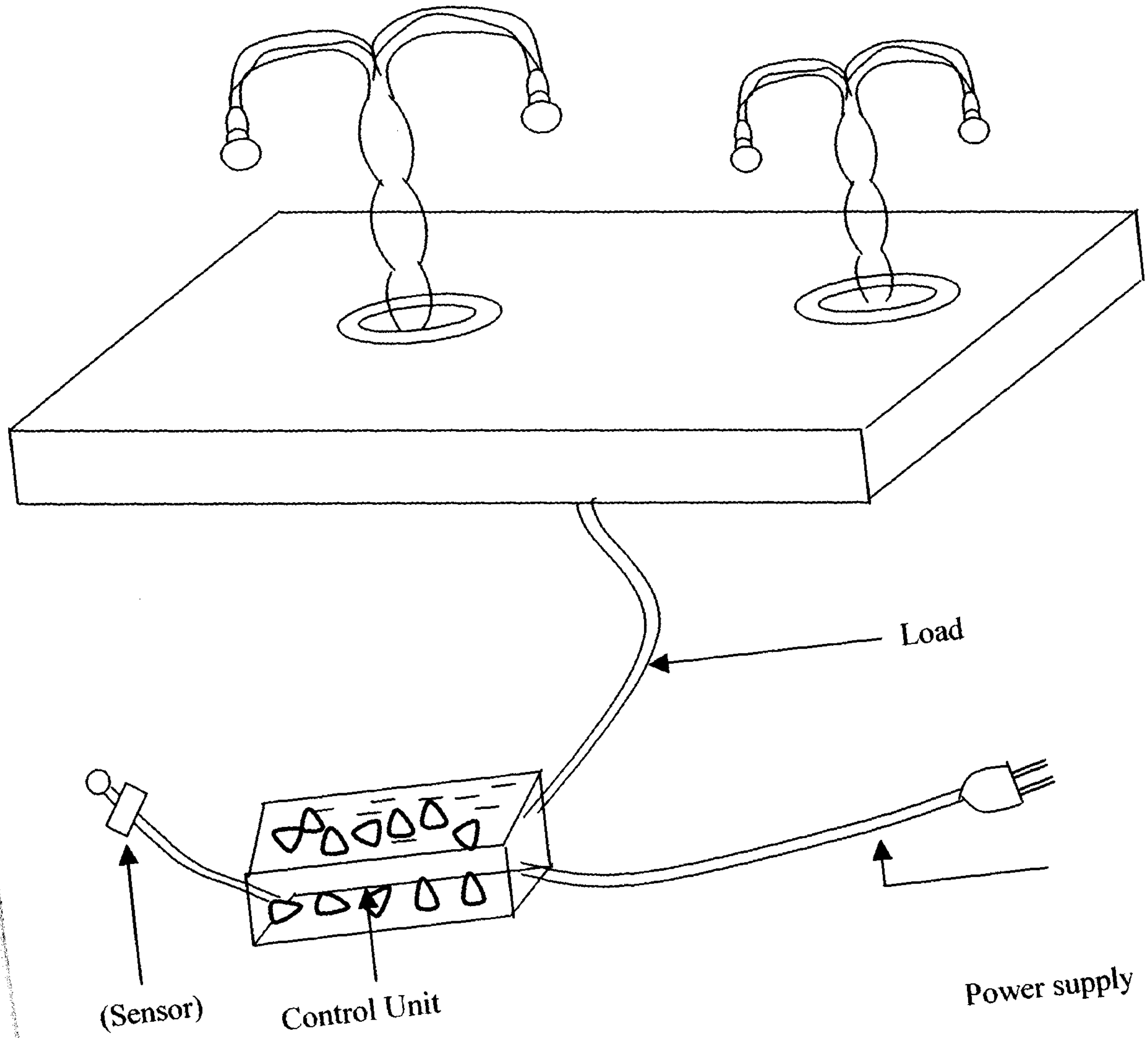

Fig. 5.4 Circutit construction

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 APPLICATIONS AND LIMITATION

The streetlight controller designed and constructed has many applications depending on the input signal from the sensor. Apart from streetlight, it has application in Automatic switch control, automatic door and security lighting

This design may not be applied directly to three-phase streetlight unless a contactor is incorporated in the circuit for high durability of the system.

6.2 PROBLEM ENCOUNTERED

The various problems encountered in this project design are enumerated below:

i. Finance

ii Non-availability of some component

iii Components setting in breadboard and Vero board

iv Soldering Problem

6.3 CONCLUSION.

The aim of this project is to design, construct and test an automatic streetlight controller which has been achieved. In fact, the setup was tested with the street prototype for some period, and desired result was obtained.

A lot of experience has been acquired in this process within the time frame available. The author was able to apply most of the knowledge acquired in the classroom to practical life problem.

In conclusion, this project in addition to its motive has exposed the author to some problems encountered in electrical/electronic design work and behaviour of instruments, the general precautions needed in design, construction and testing. It has exposed me to few of the challenges expected of a graduate after leaving the university environment.

6.4 RECOMMENDATION

The design has been achieve by using discrete component such as resistors, Zener diode and Ic, etc where the exact value of any of the component could not be found, the equivalent value could be used.

Due to sensitivity of this work, further work is necessary to improve on the performance and operation of the system. The controller system could be improved upon by using microprocessor base system for better performance and higher efficiency.

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