# DESIGN AND CONSTRUCTION OF A PHOTOCELL SWITCH

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A PROJECT REPORT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE IN THE DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING.
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## DECLARATION

I hereby, declare that this project is an original work of mine and has not in any way been presented in any form to the best of my knowledge for the award of a diploma or degree.

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# CERTIFICATION

This is to certify that this project, titled " The Design and Construction of a Photocell Switch" was carried out by Umar Zangina under the supervision of Engr. M. S Ahmed and submitted to the Electrical and Computer Engineering Department, Federal University of Technology, Minna in partial fulfillment of the requirement for the award of Bachelor of Engineering (B.Eng) degree in Electrical and Computer Engineering.

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Project Supervisor

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Sign and Date

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Head of Department

Sign and Date

DR. T.A AKINBULIRE
External Supervisor

Sign and Date

# DEDICATION

This project is dedicated to REAL MADRID FOOTBALL CLUB and her players especially ZIDANE, HELGUERA, FIGO, R. CARLOS AND RAUL

## ACKNOWLEDGEMENT

First and foremost I would like to thank the Almighty Allah for making me see the culmination of my studies.

My sincere gratitude goes to my supervisor ENGR. M.S AHMAD for his guidance and constructive criticism.

I would like to appreciate the effort and dedication of the following lecturers, Mr. Paul Attah, Dr. (Engr) Y A Adediran, ENGR. Musa Abdullahi, Mr. Jonathan Kolo, Mr. Jacob, Tsado, Mr. Rumala and Mr. Emmanuel Eronu all for influencing my future.

My profound appreciation goes to my parents, brothers and sisters for without their support, understanding and tolerance, I wouldn't have made it far.

I finally would like to acknowledge the tolerance and love of my friends' in class and at home. May the Almighty Allah guide you wonderful people. Amen

## ABSTRACT

The design and construction of photocell switch is intended to ease the labour, improve safety and to increase the efficiency of operation compared to manually and mechanically operated switches, which require human effort to press a button or to turn a knob. This photocell switch depends on light for it operation. When a flash or light is been used to activate this phototransistor, it generates a sine wave signal, which is used to trigger a monostable circuit. The output of the monostable, which is directly, connected to the J.K flip-flip toggles the output, of the J. K flip-flop and this is fed into a bistable multivibrator. The bistable output switches on a transistor to energize a relay, which closes its contact, and supply power to any load on the socket. The supply power goes off when a second flashlight strikes the base of the phototransistor.

## TABLE OF CONTENT

# CHAPTER ONE

## GENERAL INTRODUCTION

### 1.1 INTRODUCTION

The existence of switch in general is as long as the existence of electricity. Many kinds of switches have existed since the creation of electricity for switching purposes. The switching systems that existed are mostly mechanically operated. The operation of these kinds of switching systems requires human efforts to press the button in order to close or open the circuit. These kinds of switches include toggle switch, three-way switch e.t.c. Some other manually operated switches make use of switchgear to turn an electrical system ON or OFF. This involves mechanical operations with semi-automatic devices such as contacts and relay to improve the safety and efficiency of the operation.

But, due to the dynamism in the field of electrical and electronic technology great progress has been made and many more manually and mechanically operated devices have been replaced with remote or automatically operated devices for easy labour safety and efficiency.

The photocell memory switch is a light sensitive switch whose operation is based on the photodiode located at the collector to based junction. The device is used to switch the system OFF and ON by flashing light on it.

This photocell switch was designed with opto -electronic devices (i.e. device that are dependent on light). The most important thing about this device is that it can remember one memory state. When a flash or light is been used to activate the device to energize the equipment or an appliance it will maintain, this position until another beam of flashlight is directed to the phototransistor again to reverse its operation.

### 1.2 OBJECTIVES AND MOTIVATION

Switches are used in many electrical appliances for the purpose of opening and closing a circuit. In the past many kinds of switches have existed. These include the Toggle switch, the three-way switch e.t.c. However these switches require human effort to press the button of the switch before ON or OFF current contacts can be made. More so, some of these manually operated switches make use of switchgears for ON and OFF operations.

This photocell memory switch is based on latest technology. This will improve the safety of human life as well as reducing human effort to press a bottom before an operation can take place. But the operation of a photocell switch uses light at long distances to ON or OFF an appliance or equipment i.e. the photocell switch was designed specifically in such a way that it can only be opened or closed by flashing a beam of light on the base of base of the phototransistor.

Finally with intricate and improve design, the photocell memory switch is one step ahead of previous existing switches in terms of reliability, safety, efficiency and security: for example, if the device is used to ON or OFF any personal equipment or appliance any person without a source of light can not change the state of the device.

## 1.3 LITERATURE SURVEY

It is on record that researches and implementation of switches took off almost at the same time with the discovery of electricity.

In $20^{th}$ century when the need for automatically operated switching devices became pertinent, some semi-automatic switching devices were developed but not well advanced to meet up with the development of the new era. Hence, there are still relatively few text that deal extensively with this very important aspect of electrical engineering.

However, for the purpose of this project some texts were consulted, some of the texts used were the electronic fundamentals by JOHN D RYDER and electronic technology by D C GREEN. These books introduce the fundamentals of switches and some different kinds of switches.

Also, in this group of texts is a text, titled the 555 - timer Application source with experiments by Howard M. Belin. The text deals with the application of 555 timer, the mode of operation its connections and a detailed explanation about the internal circuit of a 555 timer.

More so, higher electrical engineering by J Shepered, H. N Morton and L.F Spencer was consulted for the fundamentals of relays, the uses of relays and their general application.

And lastly, a textbook on electrical technology by B.L Theraja and A.K Theraja was consulted. This text deals with multi-vibrator circuits, the theories of transistor and other components used in the project.

## 1.4 PROJECT LAYOUT

Generally, this project write-up was classified comprehensively into four chapters. Chapter one is the general introduction, which includes, introduction, motivation / objective, literature survey and project layout.

A brief history of switches was given and some of the previously existing switches were discussed and their methods of operation were briefly analyzed.

Chapter two of this project discusses the system design and analysis. This includes the design, description and the general operation of the project.

In addition, the project was divided into five units namely, the power unit, the rectification unit, the wave shapping unit, the sensoring unit and the bi-stable multi-vibrator unit.

The method, procedure and the requisition of the device to achieve the above objective are contained in this chapter. Careful research into the wide application of 555-timer integrated circuit photocell (phototransistor), the relaxation oscillation (bi-stable muliti-vibrator circuit) was also included

Chapter three basically consists of the operation, construction and testing. In this chapter, the operation requirement was discussed in details, and how the different units are interrelated with one another. This chapter summarizes how the casing was done, and how the circuit was tested and the results obtained.

Furthermore, the chapter contains how the various components used in the project were tested to check if they were in good working condition.

The last chapter, which is chapter four, is the conclusion and recommendation. In this, all the other three chapters were encapsulated. More so, the usefulness of the project was discussed. And lastly, how to meet up with the contemporary technological development was analyzed

# CHAPTER TWO

## SYSTEM DESIGN AND ANALYSIS

### 2.1 DESIGN DESCRIPTION

Designs are better explained (discussed) if various components and the inter connections of these components are explained.

However, the design of photocell switch was explained following the same precept.

### 2.2 THE POWER SUPPLY CIRCUIT

Most of the device and circuit require the direct current (D.C) source. However, there voltages are not high and their replacement must be frequent and therefore, conventional A.C power supply are better economically. Since domestic A.C power supply is the most convenient and economical source of power, it is advantageous to convert this alternating voltage usually ($220V_{rms}$) to D.C voltage (usually smaller in value)

The function of the power supply is for the conversion of the alternating current (A.C) to the required D.C voltage.

A typical power supply consist of five stage as shown in fig 2 1

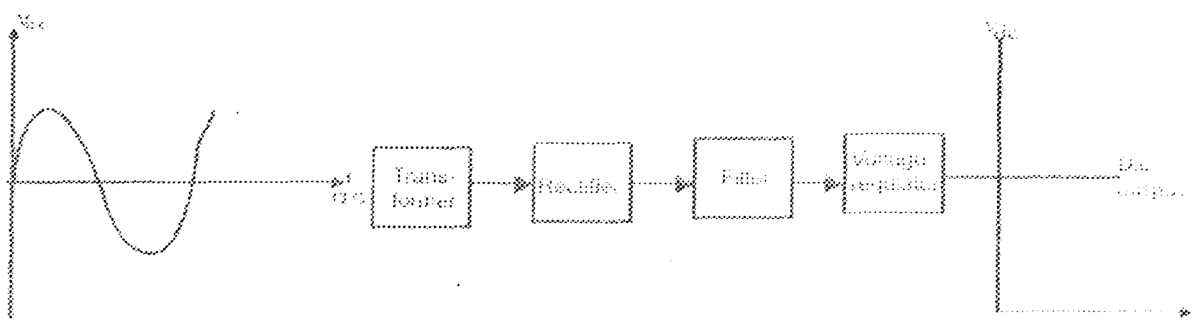


**Fig 2.1 Block diagram of a power supply circuit**

### 2.3 TRANSFORMER

The transformer is one of the principal reasons for the wide spread of A.C power supply systems. For it makes possible electrical generation at the most economical generator voltage and power transfer at the most economic transmission voltage and power utilization at the most suitable voltage for the particular utilization device.

The transformer is also widely used in low power electronic and control circuits. There it performs such function as matching the impedances of a source end and its load for maximum power transfer, insulating one circuit from another or isolating direct current while maintaining A.C continuity between two circuits.

The basic function of a transfer is either to step-up or to step-down the A.C supply voltage to suit the requirement of the solid state electronic devices and the circuits fed by the D.C power supply to provide isolation from the supply unit. However, in this project, the transformer was used to step down the 220V, 50Hz to 12V 50Hz a.c voltage.

## 2.4 RECTIFICATION

This is a process of converting an A.C voltage into a pulsating D.C voltage through the use of one or more diodes which are uni-directional

Generally, silicon diodes are used for power supply rectification, they have the advantage of low-internal voltage drop and also provide a maximum current rating.

The most common and ideal used rectifier are half-wave, full-wave and also the bridge rectifiers. However, the bridge rectifier was used in this project

### THE BRIDGE RECTIFIER

This is more complex than the half wave rectifier and the full wave rectifier. It consists of four diodes arranged in a bridge form in such a way that two of the diodes forward bias, while the other two are reverse bias. Fig2.2 below shows the schematic of a bridge rectifier and its input and output waveforms.

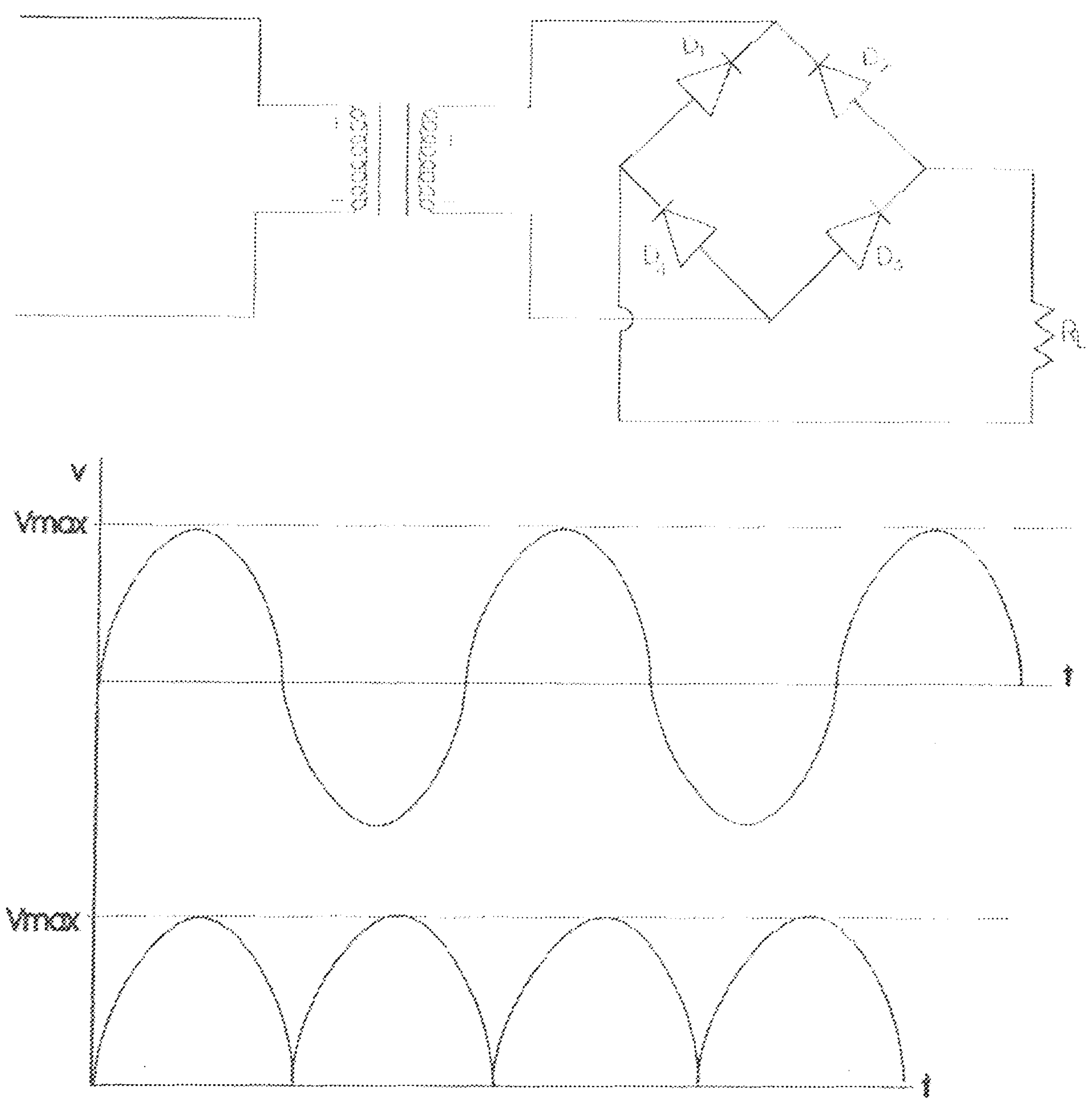


Fig 2.2 Bridge rectifier and its input and output waveforms

## 2.5 THE 555 TIMER

555 timer is a highly versatile low cost integrated circuit that is specifically designed for precision timing application but which can also be used in a variety of monostable mode, astable mode and the Schmitt trigger application. The 555 monolithic timer is a highly stable contriver capable of producing time delay or oscillation.

The 555-timer integrated circuit has many attractive features. It can operate from any supply voltage ranging from 4.5 -16V

The 555-timer is available in an 8-pin dual in-line (pin) package in both bi-polar and CMOS forms. A 14-pin package that contains two 555 timer is also available.

### 2.5.1 OPERATION

The 555 timers can basically be operated in three modes.

These are:

i- Timing mode

ii- Monostable mode

iii- Astable mode

#### i TIMING MODE

When used in the timing mode, the 555 timer can readily produce accurate tiny periods that can be varied from a few micro seconds to several hundreds of seconds via a simple A.C network.

Timing period can be started via a trigger command signal. The time is precisely controlled by one external resistor and a capacitor.

#### ii MONOSTABLE MODE

When used in the monostable mode the 555 timer integrated circuit produces output pulse with typical rise. The 555 timer can be made to produce pulse width modulated pulse (P.W.M) in this mode by feeding fixed frequency clock pulses to the trigger terminal of the integrated circuit and by feeding the modulating signal control voltage terminal.

#### iii. ASTABLE MODE

When used in astable mode, both frequency and the duty cycle of the waveform can be accurately controlled with two external resistors and one capacitor. The free-running frequency and the duty cycle are both accurately controlled with two external resistors and one capacitor.

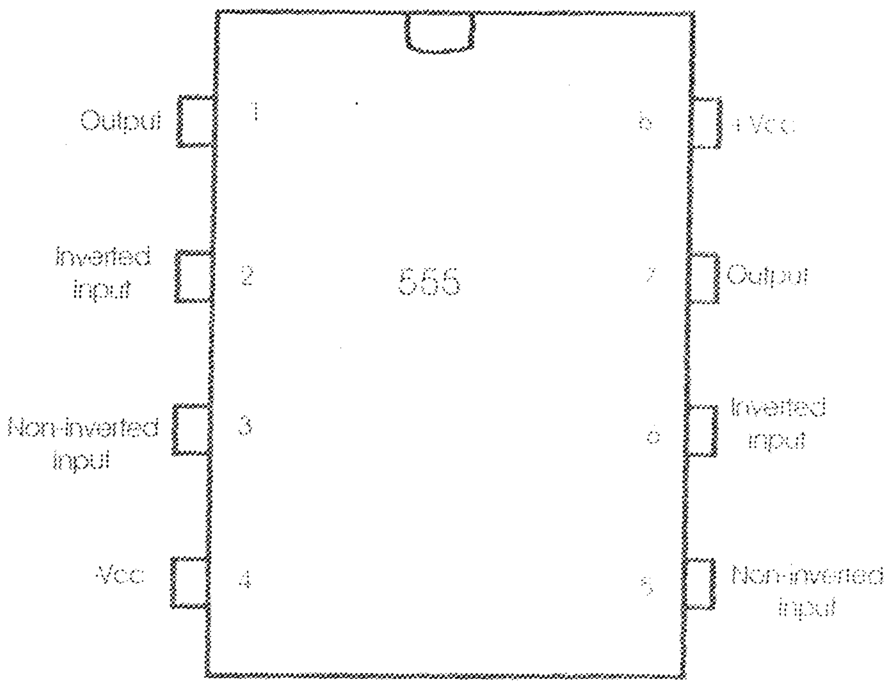


Fig 2.3 555 timer IC

### 2.5.2 8-PIN DUAL IN LINE VERSION OF 555 TIMER

The 555 timer is made up of two diodes, 16-resistor, 23-transistor, two voltage capacitor operational amplifier (op-amps), 1 R-S flip-flop, an output stage and one transistor. The two diode, 16 resistor, and 23 transistor are arranged in such a way that one voltage potential which comprises the 5Ω resistor in series and is connected across the integrated circuit supply lines. Details regarding connections to be made are as follows.

PIN 1

This is the ground pin and should be connected to the negative of the supply voltage.

PIN 2

This is the trigger input. Negative voltage gaping pulses applied to this pin when falling below one-third Vc cause the capacitor output to change state. The output level then switches from low to high. The triggered pulse must be of shorter duration than the timer interval set by an external C R network, otherwise, the output remains high until the trigger input is driven high again.

PIN 3

This is the output pin and is capable of sinking a source load requiring up to 200mA and can drive the circuit. The output voltage available is approximately $V_C$ to 1.7V.

PIN 4

This is the reset pin and is used to reset the flip-flop that controls the state of the output pin 3. Reset is activated with a voltage level of between 0V -. 4V and forces the output to be low regardless of the state of the flip-flop inputs. If reset is not required then pin 4 should be connected to the same point as pin 8 to prevent accidental resetting.

PIN 5

This is the control voltage input. A voltage applied to this PIN allows device timing variation of the external timing network. Control voltage may be varied between 45% to 90% of the $V_C$ value in monostable mode.

In the astable mode, the variation is from 1.7V to the full value of the supply voltage. The pin is connected to the internal voltage divider so that a voltage measurement from here to the ground should read two-third of the voltage applied to pin 8. If then, pin 5 is not used it should be by - passed to the ground. Typically using a 0.01µF capacitor. This helps to maintain the noise immunity.

PIN 6

This is the threshold input. It resets the flip-flop and hence drives the input low if the applied voltage uses above the two-third of the voltage applied to pin 8.

PIN 7

This is discharge pin. It is connected to the collector of an NPN transistor while the emitter is grounded. Thus, when the transistor is turned ON, pin 7 is effectively grounded. Usually, the external timing capacitor is connected between PIN 7 and ground and it is then discharged when transistor goes ON.

PIN 8

This is the power supply pin and is connected to the positive side of the supply. The voltage applied may vary from 4.5V - 16V, although devices which operate up to 18V, are also available.

In this project a mono stable mode was used.

## 2.6 MONO STABLE MULTI- VIBRATOR DESIGN

To output a pulse from pin 3 of the multi-vibrator, the trigger pulse amplitude required is $1/3V_{CC}$.

Hence; trigger pulse = 1/3 (12) = 4V.

Output pulse (amplitude and width) depends on the circuit components

Output voltage amplitude = $V_{CC}$ = 12V

Width of the output pulse is equal to the time constant of the capacitor

Let the pulse stay for 0.2mS

Also, let the external capacitor value be chosen as 0.1μF.

Using the relation. T = 1.1RC Seconds, the value of R can be evaluated.

Thus,

$0.2 \times 10^{-3} = 1.1R(0.1 \times 10^{-6})$

$R = 1.8K\Omega$

Hence, with C = 0.1μF, R = 1.8KΩ, mono stable pulse width may likely be 0.2mS.

## 2.7 MONO STABLE 555 IC

### PRINCIPLE OF OPERATION

Mono stable 555 IC output a single pulse from its pin 3 whenever it receives a triggering pulse from pin 2.

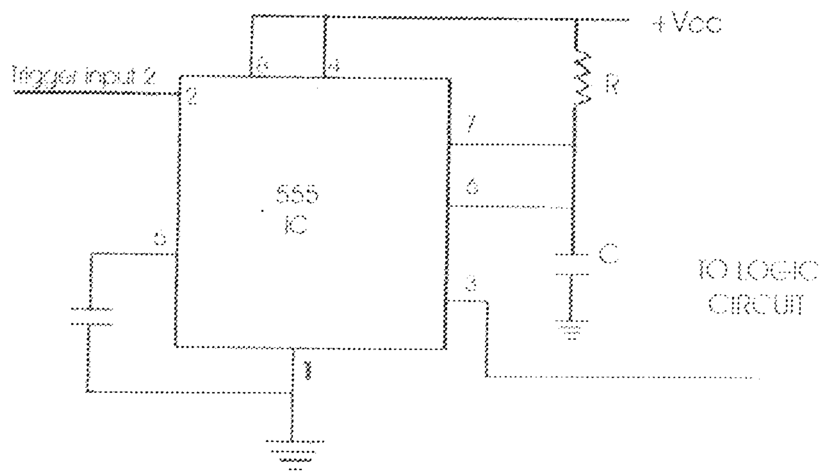


fig 2.4 monostable 555 IC

**2.8 J K FLIP- FLOP**

**PRINCIPLE OF OPERATION**

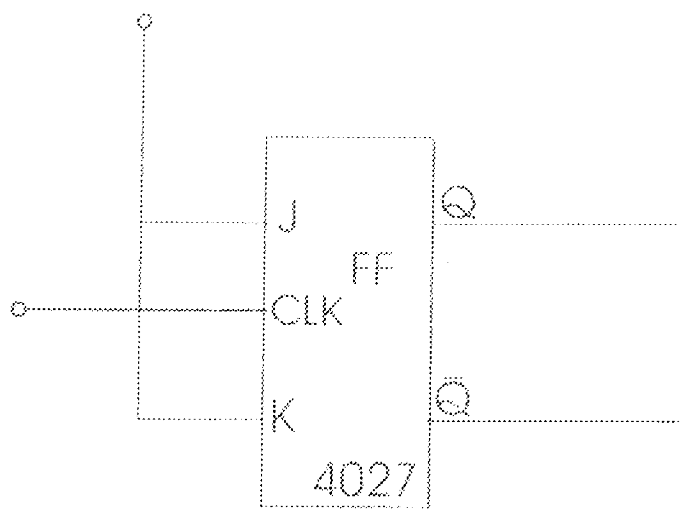


Fig 2.5 J K flip-flop

With J and K inputs high, a clock pulse from its clock input causes the output (Q and Q*) to toggle, i.e to change state. Another clock pulse causes the output to change back to its initial stage

## 2.9 MULTI-VIBRATOR

Multi-vibrators are electronic switching circuits, which depend on positive (regenerative) feedback for their operation. They are also known as relaxation oscillators

There are three basic types of multi-vibrators. The three basic types are classified according to the stability of their operating states.

They are:

i. The astable mode

ii. The monostable mode

iii. The bi-stable mode

### 2.9.1 THE ASTABLE MULTI-VIBRATOR

This type continuously oscillates back and forth between two semi-stable states.

### 2.9.2 THE MONOSTABLE MULTI-VIBRATOR

This type has one stable states. It can be switched to the semi-stable state and return to the stable state after a fixed delay period

### 2.9.3 THE BI-STABLE MULTI-VIBRATOR

This type has two stable states between which it can be switched. The bi-stable multi-vibrator is used in this project.

## 2.10 BISTABLE MULTI-VABRATOR DESIGN

From the circuit it can be seen that $R_5 - R_7 - D_5$ form a voltage divider across $Q_2$.

$\Rightarrow$ for $Q_2$ to conduct $V_{B2}$ must greater than or equal to 0.7V

Therefore, $V_{CC} - 0.7 = VR_5 + VR_7$

Where $VR_5 = I_2R_5$ (Voltage across $R_5$)

$VR_7 = I_2R_7$ (Voltage across $R_7$)

$V_{CC} = 12V$

Alternatively, $VR_5 = \frac{R_5}{(R_5 + R_7)} (V_{CC} - 0.7)$ ............ ................(1)

Assuming $VR_5 = 1/2V_{CC} = 6V$

Let $R_5 = 1K\Omega$

Then $R_7$ can be evaluated from equation (1)

$1/2V_{CC}$ is equal to $1K(V_{CC} - 0.7) / 1K + R_7$

$1/2V_{CC} (1K + R_7) = V_{CC} - 0.7(1K)$

$R_7 = (V_{CC} - 0.7) \times 10^3 / (1/2V_{CC}) - 1K$

For $V_{CC}$ = 12V , $R_7$ = 0.88KΩ = 880Ω

This implies that, for $R_5$ = 1K, $R_7$ = 880Ω, base of $Q_2$ can be kept at 0.7V

Similarly, let $R_4$ = $R_5$ = 1KΩ.

$VR_4 = R4 (V_{CC} - 0.7)/ R_4 + R_6)$

Let $VR_4 = VR_5 = 1/2V_{CC}$ , then

$R_6$ can be evaluated

$1/2V_{CC}$ is equal to $1K(12 - 0.7) / 1K + R_6$

$1/2V_{CC} ( 1K + R_6) = 1K ( 12 - 0.7)$

$R_6 = 1K ( 12 - 0.7) / 1/2V_{CC} - 1K$

$R_6$ = 880Ω

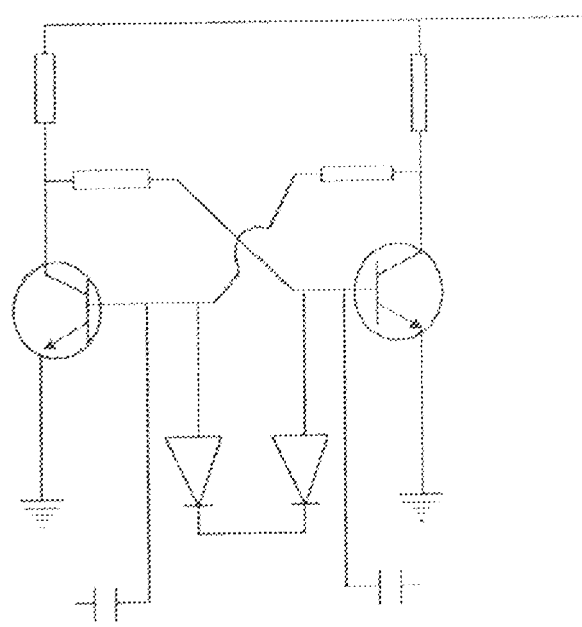

Fig 2. 6 bi-stable multivibrator

## 2.11 RINCIPLE OF OPERATION

Supposing that transistor 1 is ON, the voltage - dividing resistor then, is designed so that the low collector voltage of the ON transistor is sufficient to keep the other transistor OFF under the steady state conditions. Hence if transistor 1 is

ON, transistor 2 is held OFF. If a positive trigger pulse is now routed through diode $D_1$ to the base of transistor 1, the base potential falls and transistor 1 tasks less circuit. The collector potential of transistor 1 is used and hence, the base potential or transistor 2 rises. Transistor 2 starts conducting and then precipitate amplification follows to turn transistor 2 ON and to cut transistor 1 OFF. The circuit remains in this state until a positive reset pulse is applied through $D_2$ to the base of transistor 2. This will turn transistor 2 OFF and transistor 1 ON.

## 2.12 SWITCHING TRANSISTOR DESIGN

Let the output of the bi-stable multi-vibrator circuit be 85% of $V_{CC}$.

This implies that an amplifier (switching transistor) with gain of 1.2 is required to obtain an output voltage of 12v for the relay coil

By formula, voltage gain $A_V = \beta RC / R_{in}$ .......................(1)

Where RC the resistance of relay coil.

$R_{in}$ is the input resistance of the transistor given as

$Rin = \beta R_E + R_B$

Where $R_B$ is the base resistor of the transistor

Now, since $R_E = 0$

This implies that $\beta R_E = 0$

Therefore, $R_{in} = R_B$

Equation one becomes:

$A_V = \beta R_C / R_B$

Take $\beta$ of the transistor = 50

Let $R_C = 100\Omega$ (relay coil resistance)

$R_B$ can now be evaluated as

$1.2 = 50 (100) / R_B$

$\Rightarrow R_B = 4.2K\Omega$

Current flowing through the relay coil is $I = V / R_C$

$= 12 / 100 = 0.12A$

## 2.13 PRINCILPLE OF OPERATION OF A SWITCHING TRANSISTOR

The switching transistor is expected to operate at cut off and saturation region in order to energize or de-energize the relay coil.

## 2.12 THE RELAY

A relay is a switch, which is closed or opened by the operation at an electromagnet. It was originally designed by Henry to solve a problem met in the early telegraph chat. The circuit operation of relay is shown below.

A small current could cause the electromagnet $M_1$ to tip the pivoted iron armature. A cover toward, the magnet, C is a stationarv contact. When A touches C, the circuit at the right completes and the voltage source can cause a large current in the nearby controlled device.

Relays are used to control switches at remote locations

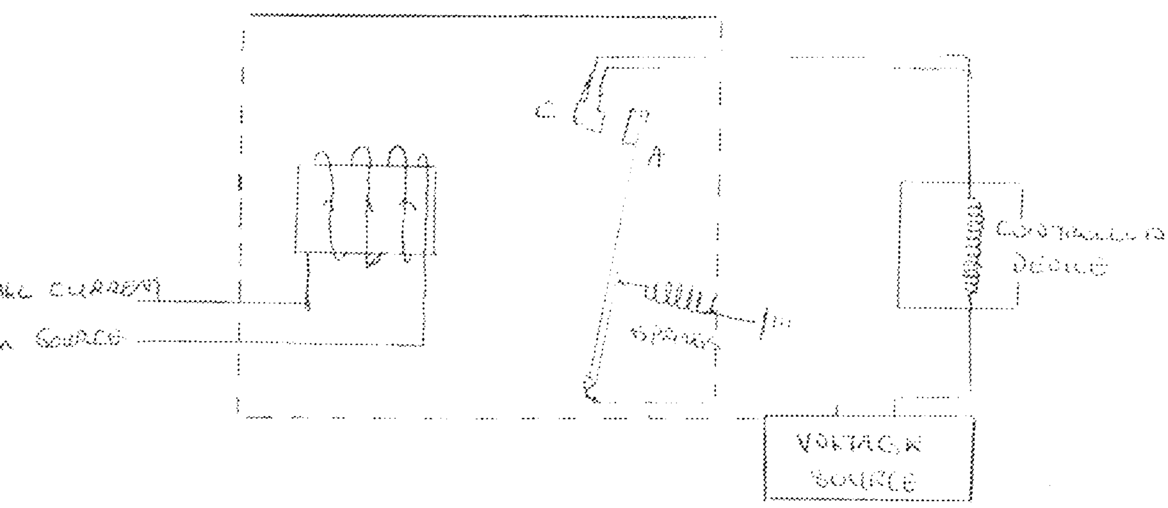


Fig 2.7 THE RELAY

flop to toggle. As the J K flip flop toggles the state of the bi- stable multi- vibrator changes, that is Q3 conducts at saturation while Q2 goes to cut OFF.

With Q3 at saturation, its collector voltage falls to nearly zero. Hence, transistor Q4 goes OFF. This implies that no current flows in the relay coil, hence, the contacts opens to disconnect the wall socket from the mains supply

### 3.2.1 CONSTRUCTION

The construction involves putting the various components on Vero board. The components were tested before fixing them into the Vero board. The following tests were carried out.

a **RESISTORS:** The resistances of these components were measured with a multi meter.

b. **CAPACITORS:** The capacitors were discharged of their initial charge. Then, a multi meter was used to test for open circuit or short circuit of the capacitor.

c **DIODES**: The resistances of the diodes were measured using a multi meter. The resistances were low when forward biased and high when reverse biased.

d. **TRANSISTORS:** A multi meter was also used to measure their resistances. A low resistance will be obtained in the forward direction and a high resistance in the reverse direction if the transistor is good.

e. INTEGRATED CIRCUITS. The IC testing was carried out on the IC check for the presence of D.C voltage at the appropriate terminals. The importance of this check is to reduce the rigours of trouble shooting after soldering. After testing, the components were fixed into the Vero board for soldering. The soldering iron and the lead were used. IC sockets were also used to prevent over heating of ICs and also to provide ease in the replacement of ICs if the originals are faulty.

## 3.3 CASING

It is important that the casing must be well ventilated since ICs and other temperature sensitive components were used. The casing was done with wood sheet for proper mechanical protection of the components. A satisfactory external finishing was also embarked upon to achieve a good market price.

The Vero board was belted to the casing and the phototransistors were put in a place where the phototransistor can receive maximum light radiation from the light source. Adequate openings were also provided on the top of the casing to allow heat built up generally to be removed from the casing.

## 3.4 TESTS AND RESULT

The circuit was connected to a socket and a load (radio receiver) was connected to the circuit. A torchlight was used to flash a beam of light on the base of the phototransistor. At the initial stage the circuit was OFF immediately, the light was flashed, the circuit came ON. It remained in the ON state until another beam of light was flashed on the base of the phototransistor for the second time then, the radio receiver was OFF. This means that the circuit functioned as desired.

# CHAPTER FOUR

## CONCLUSIONS AND RECOMMENDATIONS

### 4.1 CONCLUSION

The design and construction of the photocell switch was successfully carried out as prescribed in the previous chapter of this thesis.

The system is made up of the sensoring unit, rectification unit, wave shapping unit, bi-stable unit, multi-vibration unit and the activation unit. However, each unit is of equal importance as the other, since the failure of one can lead to the malfunctioning of the whole system.

The circuit was constructed using a few components therefore, the need for only but few spare parts and thus, a very low cost is required to implement the system.

### 4.2 RECOMMENDATIONS

The bi-stable multi-vibrator circuit could be obtained in a single IC chip without necessarily going through the rigours of constructing it using the transistors as prescribed in chapter three. However, the limitation of this method is that, the circuit must be disconnected from the main supply before changing the state of the device that is, if the device is at the ON state, for one to change it to OFF state circuit must be disconnected from the main supply. But using the method prescribed in this project, the state of the device can be changed effectively without disconnecting the circuit from the mains supply.

Since the design can still be improved upon, therefore, this will serve as a stepping-stone for whosever is interested in the modernization of the system.

Furthermore, the system can be improved upon to meet up with the challenges of new era of computer software, Internet e.t.c meaning a software could be developed for the system, to be able to monitor the intensity of the light needed to turn ON or OFF the system.

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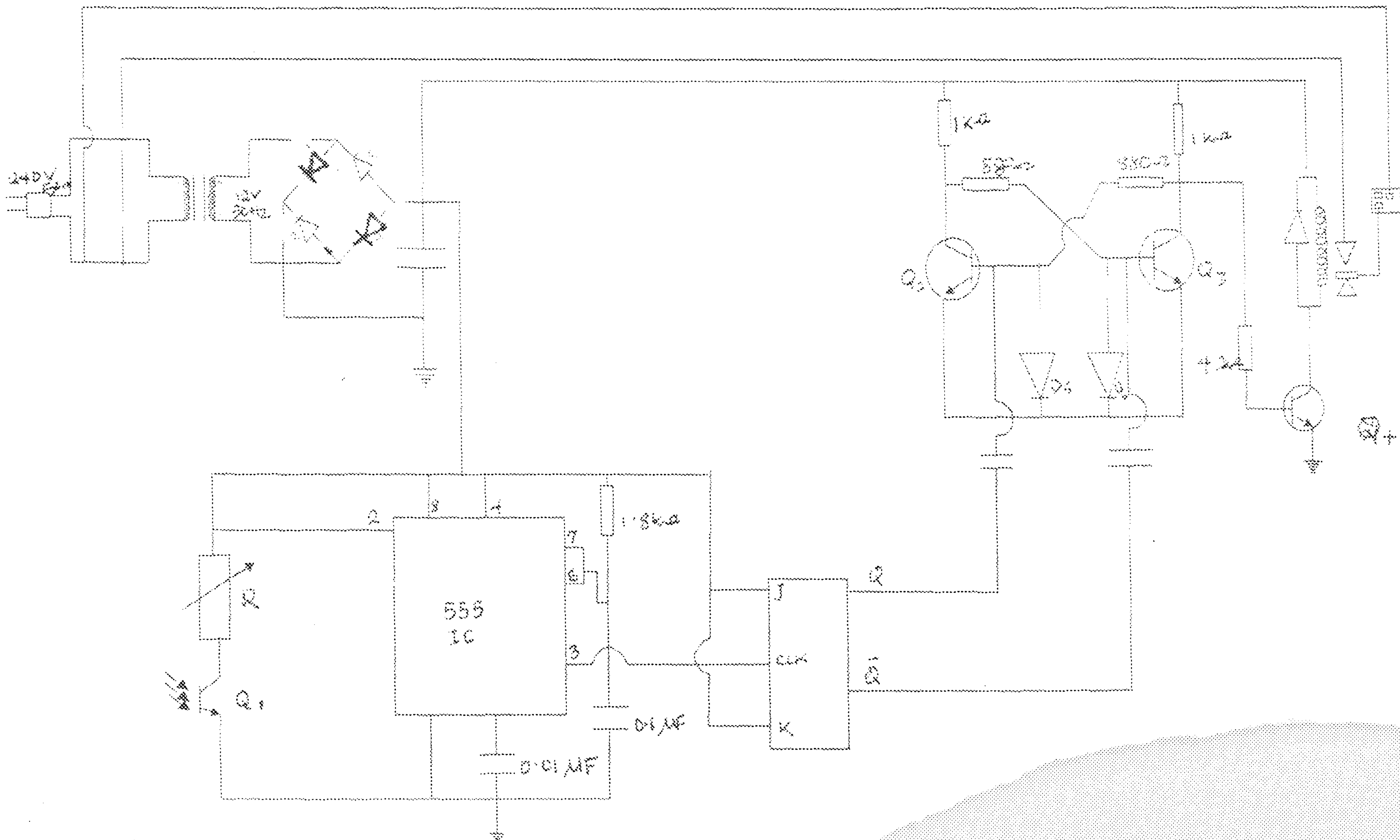


Circuit diagram of a photo cell