DESIGN AND CONSTRUCTION OF AN ELECTRONIC STUDIO FLASH SYSTEM

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DEDICATION

This project is dedicated to Jehovah God the Almighty "The Father of Celestial light" (James 1:17). "The one whom by light from him, we can see light" (Psalm 36:9) and to his beloved son, Jesus who is "the light of the world and the light of life" (John 8:12), for guiding me throughout my undergraduate study by means of his word the Bible, which is "a lamp to my foot and a light to my roadway" (Psalm 119:105).

DECLARATION

I Uwalaka Ginikachi David declare that this project was done by me and has never been presented elsewhere for the award of a degree.

.... 21/07/10 ....

Uwalaka Ginikachi David   Date

....

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.... 09/03/10 ....

External Supervisor   Date

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ABSTRACT

The trendy nature in the fashion and modeling industries necessitates the need for quality picture images which reflects on the personality of the subject of focus. A flash unit therefore synchronizes with the camera to produce fine quality picture images to this effect. This project therefore looks into the design and construction of the flash unit and its consequent accessories to enhance lighting photography systems at par with modern trends. The design of the project also incorporates redundancy as back-up power supply system for effective operation and reliable performance.

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CHAPTER ONE

INTRODUCTION

In the early days of photography the only source of light was, of course, the sun, so most photography depended upon long days and good weather. This posed a problem to indoor photography where there is relatively little ambient light. Camera flash makes indoor photography possible without increasing exposure time. The problem with this is that any quick motion including the movement of the camera itself will cause a blur image. Electronic flashes provided a simple and cheap solution to this inherent problem in photography by momentarily increasing the light level to get a clear picture. Their sole purpose is to emit a short burst of bright light in optical synchronization with the release of the shutter of a camera thereby illuminating the room for the fraction of a second the film is exposed.[1]

1.1 Background Information

A flash is a device used in photography that produces an instantaneous flash of artificial light (typically around 1/1000 to 1/200 of a second) at a color temperature of about 5500 K to help illuminate a scene. While flashes can be used for a variety of reasons (e.g., capturing quickly moving objects, creating a different temperature light than the ambient light) they are mostly used to illuminate scenes that do not have enough available light to adequately expose the photograph. The term *flash* can either refer to the flash of light itself, or the electronic flash unit which discharges the flash of light. The vast majority of flash units today are electronic, having evolved from single-use flash-bulbs and flammable powders.

When a subject brightness is insufficient, a photography is performed while a flashlight is emitted in synchronism with a shutter operation. A camera is provided with a flashlight generating circuit for generating a flashlight. The flashlight generating circuit comprises a booster circuit, a main capacitor for storing an electric power boosted by the booster circuit, a flashlight emitting tube for emitting a flashlight by the electric power emanated from the main capacitor, and a trigger coil for generating a trigger voltage to be applied to a trigger electrode of the flashlight emitting tube.[2]

1.2 Motivation

Low intensity of the flash when using cameras using built-in flash circuits and the "red eye effect" caused by pictures taken in front of the face necessitates the design and construction of a flash unit that is separated from the camera. The technique involved requires pointing a flash upward onto a reflective surface which is the flash umbrella as encapsulated in the project.

1.3 Aims and Objectives

The major aim of this project is to design a flash circuit which emits a short burst of bright light in optical synchronization with the release of the shutter of a camera to get a clear picture. It also gives very accurate indication of the angle and quality that the flash will produce when fired because of its position. It further eliminates the problems associated with continuous lighting system such as irritation caused by excessive heat on the object of focus.[3]

1.4 Methodology

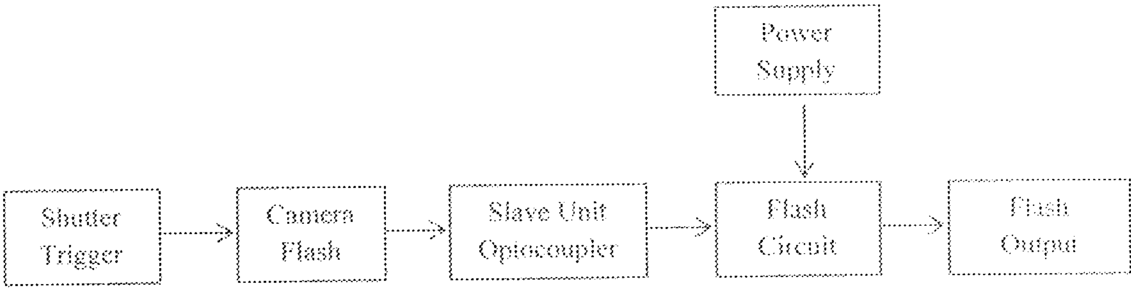
The main work of this project was broken down into the following stages:

1. Firstly, an in-depth investigation on the processes involved in the design and construction was carried out.
2. The circuit diagram was designed in line with component specifications.
3. The design was tested on the bread board using the components specified to determine its workability.
4. The components were then implemented on the vero board in accord with the design specifications with the assistance of the technical supervisor in the lab.
5. The tests were then carried out and results obtained.

1.5 Project Scope

The present project relates to the design of a flash unit such that when the subject brightness is so low that a proper exposure would not be provided without any artificial illumination, a flash unit is often used to project light toward the subject synchronously with the shutter release of a camera. To make a flash photography, it is necessary to charge the main capacitor up to the set voltage prior to the shutter release. The flash unit starts charging in response to an actuation of the flash charge switch. When a signal from a camera fires the flash unit, it causes stored high voltage electricity to pass through a sealed "tube" filled with xenon gas. This "excites" the gas, causing it to emit a brief burst of white light that is virtually the same neutral "color temperature" as noon daylight. Flash (and strobe) light can thus be unobtrusively blended with daylight.[4,5]

1.6 Block Diagram



1.7 Component Specifications

Resistors

33K orange orange orange...R1 1

390K orange white black........R2, R3 2

100K brown black black..........R4 1

1M brown black green..........R5 1

Capacitors

1000uF 16V electrolytic.........C1 1

47nF 500V.........................C2 1

3uF 400V polyester...........C3 1

430uF 350V C4 1

Semiconductors

1N4004.................................D1,2,3,4,5 5

LED D5 1

D965R4N NPN power amp Q1 1

MC-2 Optocoupler................Q2 1

Miscellaneous

Transformer T1	1
Trigger coil..............................T2	1
KCD-3 Power Switch Indicator 250V/15A....S1,S2	2
Xenon flashtube 75W	1
10W 56Ω J Series Inductor Filter(choke)........L1	1
10A / 250V plug fuse	1
Veroboard	1
PCB V3	1
AA 1.5V dc battery	4

CHAPTER TWO

LITERATURE REVIEW / THEORITICAL BACKGROUND

2.1 Literature Review

The first artificial light photography dates back as far as 1839, when L. Ibbetson used oxy-hydrogen light (also known as limelight) when photographing microscopic objects; he made a daguerreotype in five minutes which, he claimed, would have taken twenty-five minutes in normal daylight.

Other possibilities were explored Nadar, for example, photographed the sewers in Paris, using battery-operated lighting. Later arc-lamps were introduced, but it was not until 1877 that the first studio lit by electric light was opened by Van der Weyde, who had a studio in Regent Street. Powered by a gas-driven dynamo, the light was sufficient to permit exposures of some 2 to 3 seconds for a carte-de-visite.

Early flash photography was not synchronised. This meant that one had to put a camera on a tripod, open the shutter, trigger the flash, and close the shutter again - a technique known as open flash. Certainly early flash photography could be a hazardous business. It is said, for example, that Riis a historical photographer, working during this period, twice managed to set the places he was photographing on fire!

The earliest flashes consisted of a quantity of magnesium flash powder that was ignited by hand. Later, magnesium filaments were contained in *flash bulbs*, and electrically ignited by a contact in the camera shutter; such a bulb could only be used once, and was too hot to handle immediately after use, but the confinement of what would otherwise have amounted to a small explosion was an important advance. A later innovation was coating flashbulbs with a blue plastic coating to match the spectral quality to daylight balanced colour film as well as providing protection from the rare occasion when a flashbulb would crack during a flash. Later bulbs substituted zirconium for the magnesium which produced a brighter flash. It was not to be until 1927 that the simple flash-bulb was to appear, and 1931 when Harold Egerton produced the first electronic flash tube.[1]

As lighting techniques progressed and more "shooting" was done on location. A more natural effect was needed as was a more practical way of bringing lights to more cramped locations. Although large flat reflectors were always part of motion picture photography, they were oftentimes too cumbersome. All kinds of umbrellas began to show up on movie sets —— some were actually flats, but were built on collapsible umbrella type frames. The advantage of umbrellas was the obvious spreading effect of indirect or bounced light and always having a clean, neutral and portable bounce surface with the object.

In the very early sixties, a company in New York called PLR —— short for Photo-Lectronic-Research was building big power supplies for studio flash and was marketing a range of umbrellas to commercial photographers. There were some highly reflective fabrics that were being developed for NASA —— for eventual use as space suits —— theses materials were durable and could reflect back 85% of the light that shined on them. The clients included photographers like Avadon, Penn and some of the top fashion studios in New York then. Some of them called it soft-sharp lighting in that the shiner umbrella fabrics yielded a crisp lighting yet they had more spread enabling a wider set and tended to look more natural —— like hazy sunlight.

The fashion folks were the first group of photographers that totally embraced umbrellas — big umbrellas. They could render texture on full length subjects and groups of subjects without having to critically readjust for the models' every move. The trend was towards more action shots where high fashion dresses no longer had to be literally tacked to the floor for precise lighting.

As more portrait studios moved into color photography and electronic flash, the umbrella was part of the natural progression towards softer and more natural lighting. Studio flash units were pretty powerful, and still are, so even with a 2 or 3 f/stop loss in reflection off an umbrella — there is still plenty of light to accommodate working at comfortable apertures.[6]

2.2 Theoretical Background

Lighting plays a vital role in photography, particularly in studio photography. Commonly used studio lights comprise an incandescent lamp which provides steady illumination at a first, low intensity, and a flashtube, typically filled with Xenon gas or a combination of gases, which provides flash illumination at a second, much higher intensity but for a very brief period. The flashtube in the studio light may be triggered from an electrical signal such as from a wire connection to a camera or other studio light, a wireless connection using radio frequency (RF) transmitters and receivers, or may be triggered in "slave" fashion by a photosensor on the studio light detecting another flash as encapsulated in the project.[7]

2.21 Studio Lighting

Studio lighting can be broken down into two categories, continuous and flash. Traditionally, continuous lighting was always used in studio situations. However, in more recent years and in the vast majority of studios, electronic flash is now the norm. Tungsten (continuous) light has the advantage of being a little less expensive than flash, but unfortunately the many drawbacks outweigh this.

The main disadvantages of continuous light:

- It generally produces more heat than light, very uncomfortable!
- The light that it produces is not balanced to daylight.

This can make the subject very uncomfortable and due to the brightness, causes the iris of the eye to close right down. It is often the case that eyes look more attractive with a larger pupil. However, very good results can be obtained only with a flash unit that is separated from the camera, sufficiently far from the optical axis, or by using bounce flash, where the flash head is angled to bounce light off a wall, ceiling or reflector. This is due to the fact that with flash the iris does not react fast enough to be a problem.[8]

2.22 Modern Flash Technology

Today's flash units are often electronic xenon flash lamps. An electronic flash contains a tube filled with xenon gas, where electricity of high voltage is discharged to generate an electrical arc that emits a short flash of light. (A typical duration of the light impulse is 1/1000 second.) As of 2003, the majority of cameras targeted for consumer use have an electronic flash unit built in.

A flash is commonly used indoors as the main light source when there is not enough ambient light for a desired shutter speed. A *fill flash* or *fill-in flash* is a low powered flash added to ambient light to illuminate a subject close to the camera while using an exposure long enough to capture background detail. Another technique is to point a flash upwards onto a reflective surface, which may be a white ceiling or a flash umbrella, which reflects light onto the subject; this is called *bounce flash*. Bouncing creates a more natural light effect than direct flash without glare in the highlights and impenetrable shadows, but requires more flash power than a direct flash.

Flash units are commonly built directly into the camera. In addition, many cameras allow separate flash units to be mounted via a standardized *accessory mount* bracket often called a "hot shoe". In professional studio photography, flashes often take the form of large, standalone units, or *studio strobes*, that are powered by either special battery packs or connected directly to the mains and synchronized with the camera from either a flash synchronization cable, radio transmitter, or are light-triggered, meaning that only one flash unit needs to be synchronized with the camera, which in turn triggers the other units.[9]

2.23 Triggers and Slaves

Many professional photographers use a "trigger" and "slave" combination to fire remote manual flashes (and strobes). The trigger is on the camera, the slave on the flash. Trigger/slave systems can be light-activated or radio- or sound-activated. They often set up flashes all around a subject to achieve better lighting effects. In this arrangement, one master flash may be triggered by the camera shutter, while other flashes are triggered by the master. Some slave flash designs use the master flash's light itself as a trigger. The slave flash has a small light sensor that triggers the flash circuit when it detects a sudden pulse of light.

Light-activated trigger/slave combinations are normally best used in studios or at remote locations where other flashes won't interfere. Using any trigger/slave combination will reduce cord clutter on a studio floor.[6]

2.24 Umbrellas

The first thing to consider is that umbrellas are parabolic reflectors much like their standard flood light counterparts. The distribute light in a similar pattern. The main differences are, firstly, since the raw light source is aimed in at the umbrella (for bounce lighting), no direct rays from the lamp or flash tube fall directly on the subject, therefore the usual hot spot is diminished but not totally eliminated. For general use as a main light the primary light source, the lamp head or mono light, should be at a distance where it fills the umbrella to the edges. For best results the lamp head or mono light should allow for perfectly coaxial mounting, that is, the umbrella rod should go through the center of the unit whereby the flash tube and the modeling lamp are totally concentric to the umbrella rod. In that configuration, the distance from the flash tube to the periphery of the umbrella will be equidistant to the radius of the umbrella at all points yet closer to the center of the umbrella.

By changing the angle of incidence of the lighting, effects can be created that simulate spot lighting and conventional flood lighting. Using umbrellas with metallic surfaces of various reflectivities —— dull silver —— bright silver —— super silver —— non-textured silver —— will offer a myriad of effects. There are umbrellas of various designs and shapes —— some are shallower, while others are deeper —— still other have a flat area in the middle which again modifies the extent of the hot spot.

Most of this method is based of the angle of incidence rule:

The angle of incidence = The angle of reflection.

When a parallel beam of light is incident on the umbrella, it is scattered in all directions. Although apparently smooth, the umbrella has a parabolic texture and the fibres of which it is made slope in different directions relative to the incident light. Though the laws of reflection are obeyed at each point on the surface, the normals have many directions and the effect over the whole surface is a scattering of light in all directions. This type of reflection is called **diffuse reflection.**[3]

The inside surface of an umbrella was painted using bright silver latex paint and the angle of incidence theory.

2.25 Electronic Flash System Operation

Electric energy from a battery or a "mains" AC electricity supply is converted to high voltage (300 volts or more) and is used to charge a capacitor. The devices inside the flash unit convert low-voltage electricity to a much higher voltage. The converter often makes a high-pitch sound which you can hear when the unit is charging. The capacitor is permanently connected to two electrodes in a glass tube ("bulb") filled with xenon gas. At this stage, the gas does not conduct electricity and emits no light.

Another, small, capacitor is charged at the same time as the big one. When the flash unit needs to fire, this small capacitor is discharged through a transformer, which generates a pulse of very high voltage (several thousands of volts). This voltage is applied to a third electrode in the xenon tube. An electric field builds up and accelerates the electrons towards the positive electrode and the ions towards the negative electrode, as shown in Figure 2.1.

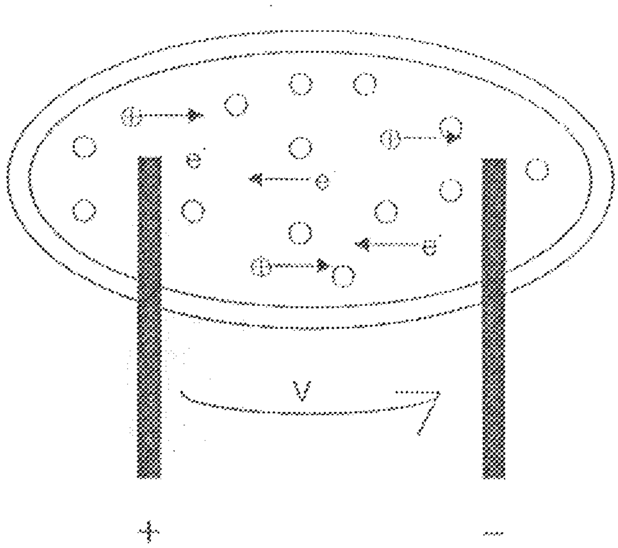


Figure2.1 Particles are accelerated towards the electrodes

The high-voltage pulse causes the gas to ionize. Ionization makes the gas conductive. When the flash unit is fired, by an electronic or other signal from the camera. the stored high-voltage current immediately passes through the wires in the tube and the big capacitor starts to discharge through the xenon gas. This "excites" the xenon gas, causing it to emit an extremely brief, bright flash of white light during this process as show in Figure 2.2 below.

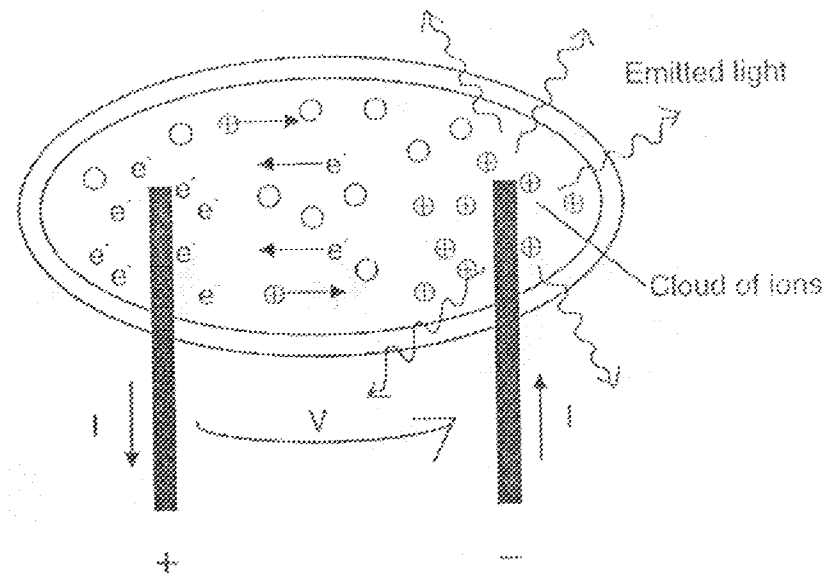


Figure 2.2 Light is emitted

Since the resistance of the gas is very low at this stage, the discharge is rapid, with the current **following an exponential curve**. About 1/1000 - 1/200 seconds later the capacitor is essentially empty, and the voltage has dropped so low that the xenon stops to conduct electricity, and the light pulse dies off. At this point, the process can be started from the beginning.[10]

Unseen secondary light is a common problem of studio photography whereby all kinds of "stray" light bouncing off studio walls, ceilings and floors cause over fill in spite of the lights being properly set up as to ratio by meter readings. Adjustments to the fill light or the tone of the studio walls will oftentimes fix the problem. In high key photography and in situations where photographers are restricted to a very simple 2 light set up — this unseen light can become an advantage.

CHAPTER THREE

DESIGN AND CONSTRUCTION

The circuit built in this project is to trigger a high voltage xenon flashtube using a dual power supply of 6 volt DC input and 230 volts AC mains from a power supply.

The circuit is constructed on a single veroboard.

3.1 Circuit Description

There are four parts to the circuit:

- The operation of 6V DC supply
- The operation of 230V AC mains supply
- The RC Network which controls the flash rate
- The Flash circuit

3.2 Operation of 6V DC Power Supply

A flash circuit is needed to turn a battery's low voltage into a high voltage in order to light up a xenon tube. This comprises of an oscillator centered around transformer T1 (Figure 3.2)

3.2.1 Oscillator

This is a self-oscillating circuit centered around T1 (Figure 3.2). The oscillator's main elements are the primary and secondary coils of the transformer, another inductor (the feedback coil), and a transistor, which acts as an electrically controlled switch as shown in

Figure 3.1. From Faraday's law of Electromagnetic Induction and Lenz law, a fluctuating magnetic field, generated by fluctuating electric current, will cause a voltage change in a conductor. The working principle of a transformer is to run current through one inductor (the primary coil) to magnetize another conductor (the secondary coil), causing a change in voltage in the second coil. Transformers therefore need fluctuating current (AC current) to work properly.[11]

When the flash charge switch S_2 is turned on, a short burst of current flows from the battery through the feedback coil to the base of the transistor. Applying current to the base of the transistor allows current to flow from the transistor collector to the emitter -- making the transistor briefly conductive. The bias current is determined by two equivalent resistances of $390K\Omega$ each.

The circuit provides this fluctuation by continually interrupting the DC current flow -- it passes rapid, short pulses of DC current to continually fluctuate the magnetic field. Applying power turns on Q1 (DN965R transistor) via current flow through R2 causes current to flow in the primary winding of T1 (Figure 3.2).

The oscillation causes an increase in the primary current that flows through the primary coil, i.e. a collector current that flows to the collector of the oscillation transistor. The burst in current causes a change in voltage in the secondary coil, which in turn causes a change in voltage in the feedback coil. This voltage in the feedback coil conducts current to the transistor base, making the transistor conductive again, and the process repeats. The circuit keeps interrupting itself in this way, gradually boosting voltage through the transformer. As a result, an electromotive force induces a current through a secondary coil which then passes through a rectifying diode letting the current flow in one direction thereby changing the fluctuating current from the transformer back into steady direct current.[12]

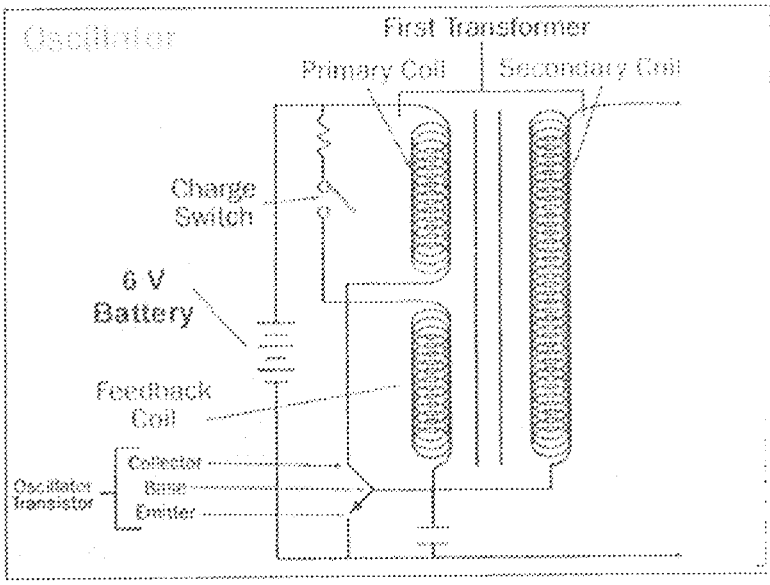


Figure 3.1 Schematic representation of Oscillator circuit.

The turns ratio between the primary winding (pins 1 & 4) of T1 and the secondary winding (pins 2 & 5) is high (10 turns to 600 turns resp.) So the voltage induced at pin 2 is high. This alternating voltage is half-wave rectified by diode D3 which then charges capacitor C4. This produces a DC voltage across C4. This voltage is negative (due to orientation of D3).

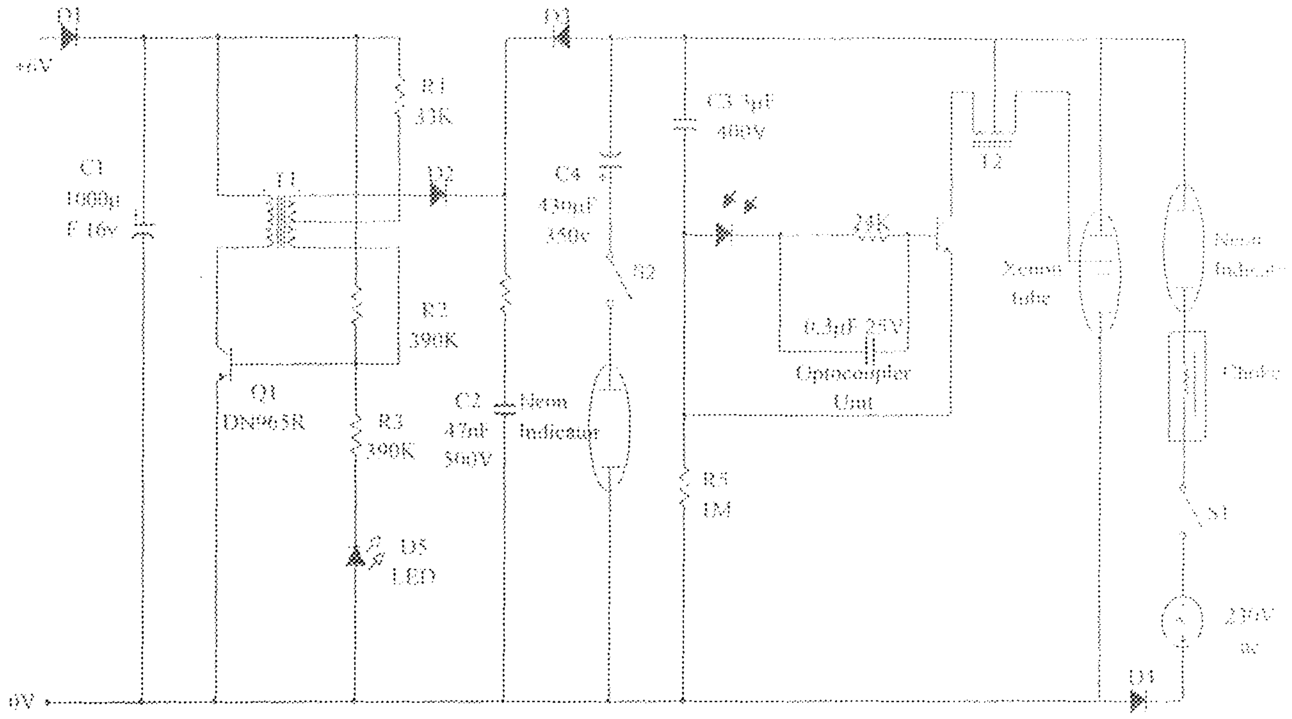


Figure 3.2 Main circuit diagram for the flash unit.

3.3 Operation of 230V AC Mains Supply

A power switch was used to indicate when the 230V AC mains feed the circuit. The main input of the 230V AC mains is connected to a half wave rectifier diode which was built into the circuit. From this rectifier there are two outgoing wires: the positive and negative which provide about 300-350 VDC to the circuit. For the positive wire, a series inductor filter (choke) was used to limit the current so that the capacitor charge was regulated and not violent. The operation of such a filter depends on the fundamental property of an inductor to oppose any sudden changes to the current flowing through it thereby presenting high impedance to the AC components in the filter output.

3.4 RC Network

Capacitor C3 is charged at a rate determined by resistors R2. This charging rate determines the flashrate.

3.41 Flash Rate

This is determined by the RC network of C3 and R2. The time constant of the RC network is given by the equation T = R x C.

$T = 1\times10^6 \times 3\times10^{-6} = 3s$

This is the time it takes to reach full voltage V if the rate of rise were maintained. It is defined as the time during which the capacitor voltage actually rises to 0.632 of its final steady value.[13] Reducing T will reduce the charge time and increase the flash frequency rate. Conversely, increasing T will increase the charge time and reduce the flash rate.

The flash rate is also inversely proportional to the values of R2 and C3.

3.42 Brightness

The value of the main capacitor C4 determines linearly the brightness of the flash tube.

3.5 Flash Circuit

This comprises four stages:

1. Charging of the main capacitor
2. The optocoupler unit
3. The trigger circuit

4. The Flash output (discharge tube)

3.5.1. Charging of the Main Capacitor

This is achieved through any of the dual sources of power supply.

During the 6V DC operation, the DC voltage is across capacitor C_2. Instantaneous current flows and charges the main capacitor through a rectifying diode. The high-voltage current then acts as a rectifier – letting the current flow in one direction - by changing the fluctuating current from the transformer back into steady direct current.

For a single phase AC half wave rectification, the average value which corresponds to the DC value can be determined. It gives a periodic waveform with only half cycle diodes which has an average value as shown in Figure 3.3.

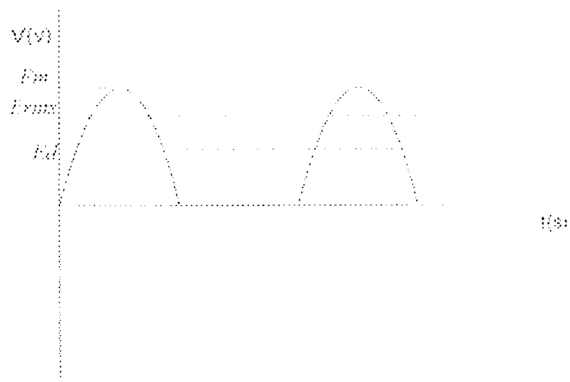


Figure 3.3 Half wave ac rectification

E_d is the average value which corresponds to the DC value

E_{rms} is the root mean square value

$$E_d = \frac{1}{2\pi}\int_0^{\pi} E_m \sin wt d(wt)$$

$$= \frac{E_m}{2\pi}[-\cos\theta]_0^{\pi}$$

$$= \frac{E_m}{2\pi}[-\cos\pi - (-\cos 0)]$$

$$= \frac{E_m}{2\pi}[2]$$

$$= \frac{E_m}{\pi} volts$$

The root mean square value is given by $E_{rms} = \frac{E_m}{\sqrt{2}}$

For a 6V DC input, E_d = 6V

Therefore, $6V = \frac{E_m}{\pi}$

$E_m = 6V \times \pi = 18.85V$

The root mean square value is given by $E_{rms} = \frac{E_m}{\sqrt{2}} = \frac{18.85}{\sqrt{2}} = 13.33V$

$E_{rms} = E_1$ which is the rms value of the emf induced in the primary winding of the oscillation transformer. Therefore E_1 = 13.33V.

E_2 is the rms value of the emf induced in the secondary winding of the oscillation transformer.

$N_1 = 5t$ which is the number of turns in the primary of the oscillation transformer

$N_2 = 300t$ which is the number of turns in the secondary of the oscillation transformer

$$\frac{E_2}{E_1} = \frac{N_2}{N_1} = \frac{300t}{5t} = 60$$

$$E_2 = E_1 \times 60 = 13.32 \times 60 = 799.72V$$

The peak value of the emf induced in the secondary winding of the oscillation transformer is given by $\sqrt{2} \times 799.72 = 1130.97V$

The average value of the voltage that will be stored in capacitor C_2 during the oscillation is given by $\frac{113.97}{\pi} = 360V$

The average value (DC value) is then used to charge up capacitor C_4 the main capacitor.

Let V_c= potential difference across C_4, I_c= charging current.

q=charge on the capacitor plate which is given by $C_4 \times V_c$

The applied voltage V is always equal to the sum of the resistive drop ($I_c R$) and the voltage across capacitor (V_c).

$$V = I_cR + V_c \quad (1)$$

$$i_c = \frac{dq}{dt} = d\frac{(C \times V_c)}{dt} = C\frac{dV_c}{dt} \quad (2)$$

$$V = Vc + CR\frac{dV_c}{dt} \quad (3)$$

$$-\frac{dV_c}{V - V_c} = -\frac{dt}{CR} \quad (4)$$

Integrating both sides

$$\int\frac{-dV_c}{V - V_c} = \frac{-1}{CR}\int dt \quad (5)$$

$$\log(V - V_c) = \frac{-1}{CR} + K \quad (6)$$

where K is the constant of integration whose value can be found from initial known conditions.

At the start of charging when t = 0, V_c.

Substituting these values in (6)

$$\log_e V = K \quad (7)$$

Hence equation (6) becomes

$$\log_e(V - V_c) = \frac{-t}{CR} + \log_e V \quad (8)$$

$$\log_e\frac{V - V_c}{V} = \frac{-t}{CR} \quad (9)$$

where $CR = \lambda =$ time constant

$$\frac{V - V_c}{V} = e^{-t/\lambda} \quad (10)$$

$$V_c = V(1 - e^{-t/\lambda}) \quad (11)$$

From equation (11), the time it takes (t), for the capacitor toreach voltage of 300V can be determined.

$$360(1 - e^{-t/\lambda}) = 300$$

$\lambda = 3s$ as earlier calculated

$$1 - e^{-t/3} = \frac{300}{360} = 0.833$$

$$e^{-t/3} = 1 - 0.833 = 0.167$$

$$\frac{-t}{3} = \ln 0.167 = -1.792$$

$$t = 3 \times 1.792 = 5.38s$$

When the negative half cycle of the 230V ac input is applied, the diode is forward biased and hence is turned on. This allows the triggering capacitor C_3 to charge up to peak value of input voltage V_{ip}. After being fully charged, the capacitor holds the charge till input ac supply to the rectifier goes positive. During the positive half cycle, the capacitor attempts to discharge however, it cannot discharge through the diode which being now reversed biased is off. Hence, it discharges through the main capacitor C_4. During the next negative half cycle, when the rectifier voltage exceeds the capacitor C_3 voltage, C_3 is again charged instantaneously to V_{ip}. When the input voltage goes positive, the diode opens forcing C_3 to discharge through C_4. In this way, C_4 sees a nearly constant dc voltage across it at all times.[14]

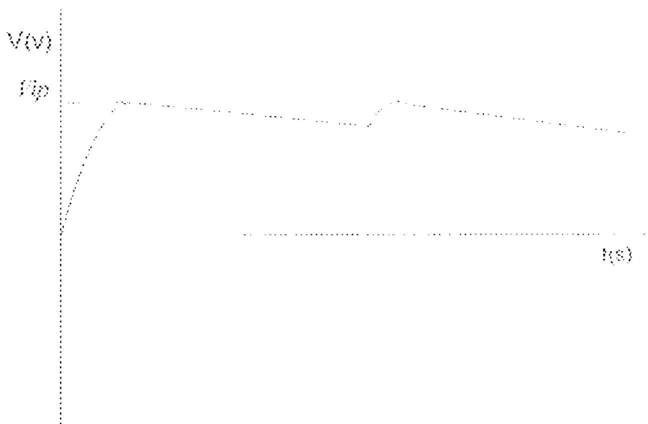


Figure 3.4 Filtering Action (rectified dc output)

$$V_{ip} = V_{rms}\sqrt{2} = 230 \times \sqrt{2} = 325.27V$$

It can be proved that dc voltage across C_4 is given by

$$V_{dc} = V_{ip} \times \left(\frac{2fC_3R_2}{1 + 2fC_3R_2} \right) \quad (12)$$

Therefore,

$$V_{dc} = 325.27 \times \left(\frac{2 \times 50 \times 3 \times 10^{-6} \times 1 \times 10^{6}}{1 + 2 \times 50 \times 3 \times 10^{-6} \times 1 \times 10^{6}} \right) = 324.19V$$

The time that C_4 charges to 300V can be determined from the equation

$$V_c = V(1 - e^{-t/\lambda})$$

$$324.19\left(1 - e^{\frac{-t}{3}}\right) = 300$$

$$1 - e^{\frac{-t}{3}} = \frac{300}{324.19} = 0.925$$

$$e^{\frac{-t}{3}} = 1 - 0.925 = 0.075$$

$$\frac{-t}{3} = \ln 0.075 = -2.60$$

$$t = 2.60 \times 3 = 7.80s$$

The maximum energy stored in the main capacitor is given by $E = \frac{1}{2}CV^2$ (13)

where C is the capacitance and V is the maximum voltage across the capacitor

From the capacitor rating, this value is given by

$$E = \frac{1}{2} \times 430 \times 10^{6} \times 350^2 = 26.34J$$

The maximum power rating of the capacitor is 5226W.

Power is defined as the rate of expenditure of energy with time.

$Power = \frac{Energy}{time}$ therefore time $= \frac{\text{Energy}}{\text{Power}}$ which gives the time for a flash output discharge

$$t = \frac{26.34J}{5226J/s} = 5.04 \times 10^{-3}s \cong \frac{1}{198}s$$

The value of the capacitor voltage of the main capacitor C_1 voltage after a flash output discharge can thus be determined from the equation

$$V_c = Ve^{-t/\tau} \qquad (14)$$

Therefore, $V_c = 300e^{-5.04\times10^{-3}/\tau} = 299.5V$

The energy stored in the capacitor before the flash output discharge is calculated as

$$E = \frac{1}{2} \times 300^2 \times 430 \times 10^{-6} = 19.35J$$

The energy stored in the capacitor after the flash output discharge is calculated as

$$E = \frac{1}{2} \times 299.5^2 \times 430 \times 10^{-6} = 19.22J$$

The energy released by the flash output discharge is calculated as

$$E = 19.35J - 19.22J = 0.13J$$

The power delivered by the flash circuit during a discharge is calculated as

$$P = \frac{E}{t} = \frac{0.13J}{5.04 \times 10^{-3}s} = 25.8W$$

The time required for the capacitor voltage to attain any value of V_c from an initial value of V_0

during the charging cycle is given by

$$t = \lambda \ln\left(\frac{V - V_0}{V - V_c}\right) \tag{15}$$

For the 6V dc supply, $t = 3\ln\left(\frac{360 - 299.5}{360 - 300}\right) = 0.03s$

For the 230V ac supply, $t = 3\ln\left(\frac{324.19 - 299.5}{324.19 - 300}\right) = 0.06s$

This oscillating action produces the high-pitch whine heard when the flash unit is charging up. The capacitor circuit is also connected to a neon light indicator switch which indicates when the main capacitor is fully charged.

The positive and negative terminals of the main capacitor are connected to the two electrodes on the flash tube, but unless the xenon gas is ionized, the flash tube can't conduct the current, so the capacitor can't discharge.

3.5.2 The Optocoupler Unit

An optocoupler is a device that uses a short optical transmission path to transfer a signal between elements of a circuit, typically a transmitter and a receiver, while keeping them electrically isolated — since the signal goes from optical signal to an electrical signal, electrical contact along the path is broken. The device uses a combination of a light source and a photosensitive detector. The coupling is achieved by light being generated on one side of a transparent insulating gap and being detected on the either side of the gap without an electrical connection between the two sides.[15] The device used in the circuit incorporates a photodiode in its operation.

A photodiode is a two terminal junction device which is operated by first reverse biasing the junction and then illuminating it. A reverse biased PN junction has a small amount of reverse saturation current i_s due to thermally generated electron-hole pairs. The number of these minority carriers depends on the intensity of light incident on the junction. When the diode is in a glass package, light can reach the junction and thus change the reverse current. The basic biasing arrangement, construction and symbol of a photodiode are shown in Figure 3.5[16]

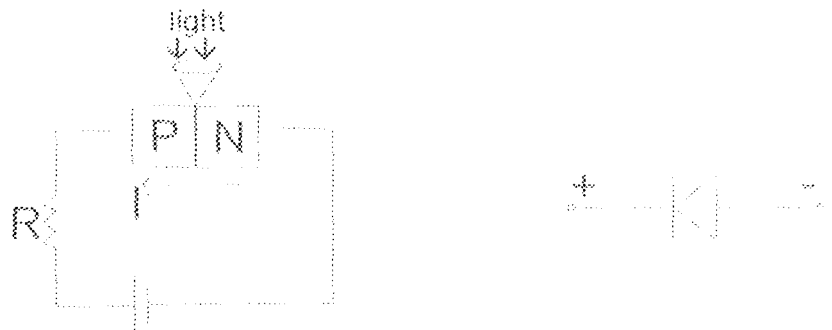


Figure 3.5 P-N Junction for a photodiode.

As seen, a lens has been used in the cap of the unit to focus maximum light on the reverse biased junction. The active diameter of the device is about 2.5 mm but it is mounted in a standard TO-5 package with a window to allow maximum incident light. A photodiode can turn its current ON and OFF in nanoseconds hence it is one of the fastest photo detectors. The output current and voltage are dependent on the amount of incident light and the light intensity supplied by the camera flash. This acts as a switch thereby energizing the primary terminal of the triggering coil by providing short dc current pulses through the collector terminal of the transistor embedded in the circuitry.

3.5.3 The Trigger Circuit

This comprises:

1. The triggering capacitor; which feeds the triggering system when the flash is fired. A ceramic capacitor rated at 0.3μF, 400V is employed due to its availability.
2. The triggering transformer: a coil which will receive the 300V from the trig. Transformer and will turn it to several Kilovolts, in purpose of igniting the xenon gas inside the tube.

A trigger coil comprises a primary winding, a secondary winding, a package incorporating both of them, a common terminal to which one end of the primary winding and one end of the secondary winding are connected, a primary terminal to which another end of the primary winding is connected, and a secondary terminal to which another end of the secondary winding is connected, whereby a current conducts between the primary terminal and the common terminal to generate on the secondary terminal a trigger voltage to be applied to a trigger electrode of a flashlight emitting tube. The common terminal has a pin-like shape extending to pass through the package, one end of which is connected to the circuit board.[17]

In the three-terminal type of trigger coil, the primary winding, which is relatively large in diameter, and the secondary winding, which is relatively small in diameter, are wound at the same place of the common terminal and are mounted on the circuit board by soldering. A ferrite core of about 2 cm in length was obtained.

The primary consisted of a single layer of wire of about 4 turns covering about 1 cm. The core was covered with a non conducting tape. The secondary consisted of single layer of wire of about 60 turns covering about 4 cm. The core was covered with a layer of electrical tape. Another few turns were wound near the center of the coil. This winding was covered with a few layers of electrical tape, with about 2 cm of thin wire stuck out.

When the primary coil of the triggering coil is energized, the 300V from the main capacitor is across it. Therefore, $E_{rms} = \frac{300V \times \pi}{\sqrt{2}} = 666.43V$

$E_{rms} = E_1$ which is the rms value of the emf induced in the primary winding of the trigger coil.

Therefore, E_1=666.43V

E_2 is the rms value of the emf induced in the secondary winding of the trigger coil.

N_1=4t which is the number of turns in the primary winding of the trigger coil.

N_2=60t which is the number of turns in the secondary winding of the trigger coil.

$$\frac{E_2}{E_1} = \frac{N_2}{N_1} = \frac{60t}{4t} = 15$$

$$E_2 = E_1 \times 15 = 666.43 \times 15 = 9996.5V$$

The average value (dc) of the voltage across the discharge tube is given by

$$\frac{9996.5 \times \sqrt{2}}{\pi} = 4500V = 4.5KV.$$

There are two wires that will command the triggering:

i. The trigger capacitor wire (thick) which is connected to the negative terminal of the flash tube.

ii. The trigger transformer wire (thick) which is connected directly to the flash tube trigger terminal.

These wires have a potential of around 300V, which could be harmful to the flash circuitry. Cable wires are thus used to insulate this high voltage.

3.5.4 The Flash output (Discharge tube)

A flash tube is an electric glow discharge designed to produce intense incoherent full spectrum white light for very short durations. It comprises a hermetically sealed glass tube which is filled with a noble gas usually Xenon and electrodes to carry electric current to the gas. Xenon is used mostly because of its good efficiency converting nearly 50% of electrical energy into light. The electrodes protrude into each end of the tube and are sealed to the glass using solder seals for a very strong mechanical seal.[18]

The electrodes of the flash discharge tube as shown in figure 3.6 are connected to the main capacitor. Once ionized or "triggered" a spark will form between the electrodes, allowing the capacitor to discharge. The sudden surge of electric current quickly heats the gas to a plasma state where electrical resistance becomes low.

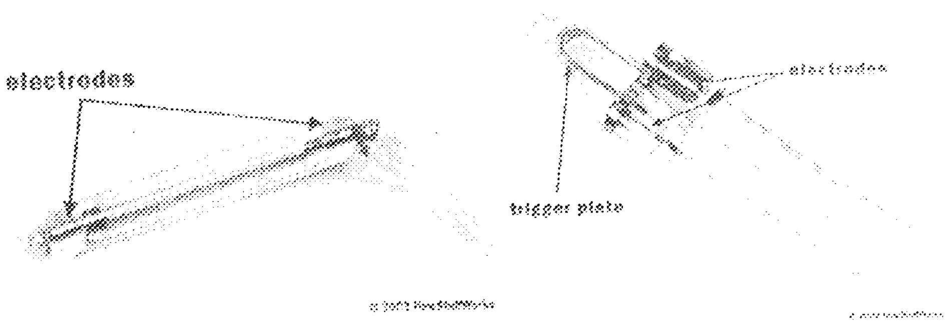


Figure 3.6 Xenon flash tube electrodes with trigger plate.

This transformer boosts the 300-volt current from the capacitor up to 4500 volts, and passes the high-voltage current onto the metal plate next to the flash tube. The momentary high voltage on the metal plate introduces free electrons thereby providing the necessary energy to ionize the xenon gas, making it conductive. The triggering capacitor voltage is used to move electrons between the two electrodes. The flash lights up in synch with the shutter release.

The maximum value of the overall efficiency for the transformer coupled flash output is given by

$$\eta_{overall} = \frac{P_{o(ac)}}{P_{in(dc)}} = 0.5 \text{ or } 50\%$$

Where P_o is the instantaneous power output of the flash tube and P_{in} is the Power supplied by the flash circuit.

The power delivered by the flash circuit during a discharge was calculated as 25.8W.

Therefore $P_{o(ac)} = P_{in(dc)} \times 0.5 = 25.8 \times 0.5 = 12.9W$

The Xenon short arc lamp has an overall luminous efficacy of approximately 13 lumens per watt for the 75 W rating. Therefore, the light energy radiated out by the flash tube is given by

$$13 \times 12.9 = 167.7 lumens$$

3.6 Casing Construction and Accessories

The narrow outlet of a flask cylinder was cut transversely. It was bored and a stainless steel plate was fitted as a closure using bolts and nuts. A welded steel handle was then bored through the midpoint of the cylinder in which a tripod stand could be fitted. The components were then wrapped using masking tapes to provide insulation from high voltage. They were enclosed in the cylinder. The inner layer of an umbrella was coated with silver latex to give a diffused reflection of the bounced flash.

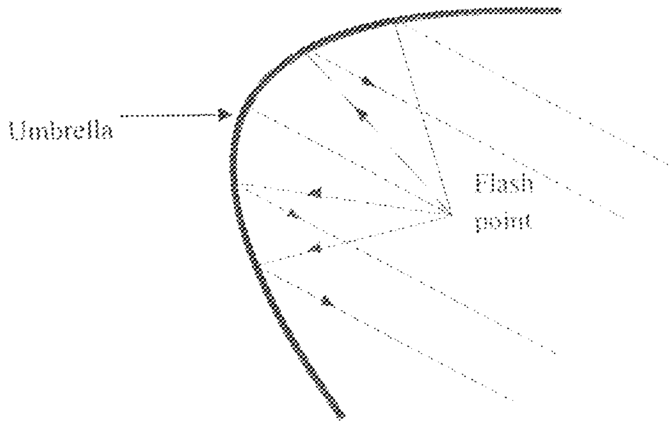


Figure 3.7 Diffused reflection of the bounced flash.

This works on the principle of the reflective characteristics of a parabola as shown in Figure 3.7.

Poor soldering was the most likely reason when the circuit did not work. All solder joints were checked carefully. All components were checked in their correct position on the veroboard. The diodes and electrolytic capacitor were checked for their polarities. Transistor Q1 was checked for its biasing configuration. The metal tab was nearest the transformer.

CHAPTER FOUR

TESTS, RESULTS AND DISCUSSION

4.1 Testing specifications

The circuit components were soldered on a veroboard. The entire system was then powered, using each of the dual power sources sequentially. The steps involved in the battery operation (dc source) are outlined as follows:

i. A battery compartment was connected to the dc circuit through its terminal.

ii. 4 penlight batteries (AA 1.5V each) were inserted following the (+)(-) as indicated.

iii. The optocoupler unit was then connected into its terminal for synchronization.

iv. A humming sound was heard showing that the unit is in good operation.

v. The neon lamp indicator was lit red as the capacitor charged to capacity.

The steps outlined in the ac operation were as follows:

i. The red ON/OFF was slid and the plug was connected to the ac mains.

ii. The same procedures were involved as shown in the battery operation for (iii-v)

The capacitor value was then measured using a voltmeter. The shutter of a digital camera was then actuated to produce a flash. The flash unit synchronized instantaneously with the camera flash and a brighter flash was radiated. At full capacity, the circuit flashed at about 3 flashes per second. This is determined by the RC network ($R=1M\Omega$, $C=3\mu F$). The recycle time is the time taken for the capacitor to charge to its maximum value after the maximum flash rate.

4.2 Results

The new capacitor value was measured and recorded in the table below.

Table 4.1 Results obtained

	Initial voltage charge up	Charge time taken	Residual voltage after initial flash	Charge time taken	Residual voltage after max flash rate	Recycle time
Battery	301.5V	10s	297.5V	~(0-1)s	291.4V	6s
Ac	300.6V	9s	296.7V	~(0-1)s	290.8V	4s

It can be seen that deviations occur from the calculated values expressed in chapter three. This is generally due to the drops in the internal resistances of the component used in the circuitry. The 6V dc source depleted each time the capacitor charged. This leads to increase in oscillation cycles required to step up the voltage thereby increasing the charge time. This also explains the minimum discrepancies in the results obtained.

The capacitor was shorted (discharged) using an electric bulb with terminal wires whenever there was an unsuccessful firing attempt. This is to ensure safety from the high voltage stored in the capacitor. A flash tube operates at high voltage with current high enough to be deadly. The energy stored in a capacitor can remain long after power has been disconnected. In addition, the charging system can be equally deadly. It is very imperative to note that great care must be exercised when dealing with high voltage circuitry since the trigger voltage can deliver a painful shock which may cause involuntary body movements that might cause contact with other high voltage points.

The best position of the umbrella is found to be at an angle of illumination 65° wide from the object of focus.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the project analysis, it can be seen that an electronic flash circuit with dual power unit can be designed and constructed using cheap and available components. If introduced into the market, it limits the need for dependence on foreign electronic units.

It is also noteworthy to point that redundancy as back-up power supply system is achieved in the design of the project for effective operation and reliable performance since it is impossible as well as impractical to avoid power outages. The dc operation therefore serves a redundant or back-up power supply system to ensure continuity of service.

Some design constraints though have to be met as enumerated in the recommendations below.

5.2 Recommendation

i. A discharge switch should be made for the main capacitor (a small capacitor of 10µF can be used to provide a discharge path) to prevent accidental shock after unsuccessful firing attempts.

ii. A jockey switch operation should be incorporated to properly distinguish AC and DC operations.

These specifications could be implemented in a future design of the project.

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