DESIGN AND CONSTRUCTION OF AN INTRUDER/BURGLAR ALARM USING DUAL INFRARED SENSORS

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Electrical and Computer Engineering,
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degree

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DEDICATION

I dedicate this work to all the victims of the world. Your time will come.

DECLARATION

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

Abdullahi U. Faruq
Name of Student

Name of Supervisor

Abdullahi Faruq 12/10/2006
Signature and Date

Signature and Date

Name of H.O.D.

Name of External Examiner

Signature and Date

Signature and Date

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ABSTRACT

Taking into cognizance the rising crime rate in everyday life, this project aims to provide security protection for the homes of everyone. This security device employs infrared beams to protect the sanctity of our homes. Breaking an infrared ray beamed across say, a door, will trigger an audio alarm and cause lights to flash. It also recommends ways by which the police will use such devices to better protect the citizenry.

TABLE OF CONTENTS

CHAPTER ONE: INTRODUCTION

CHAPTER TWO: LITERATURE REVIEW

CHAPTER THREE: DESIGN ANALYSIS

CHAPTER FOUR: CONSTRUCTION, TESTING AND RESULTS

CHAPTER FIVE: CONCLUSION

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

With the socio-economic state of Nigeria, crime (most especially violent crime) is an everyday reality. It runs the gamut from simple break-ins to political assassinations.

It is then prevalent on every citizen to protect their lives/property as they deem fit since the State has failed in its role as protector. Making the structures that house our families and businesses burglar-proof is the first step in that direction.

The infrared intruder alarm is designed to secure all access points (e.g. doors and windows) against unauthorized entry. Its basic make up is a transmitter sending a continuous infrared (IR) beam to a receiving and logic comparison circuit. Breakage of this beam will sound an audio alarm/siren and set a light emitting diode (LED) to flash, indicating where such breach has occurred.

1.2 PROJECT OBJECTIVES AND METHODOLOGY

This project is motivated by a desire to contribute to the security of the community, and of the individual citizen specifically. It will try to solve the problem of an affordable security device for the common man by using locally sourced materials.

Although low cost is an important factor in the design, efficiency and quality will not be compromised. Durability is another quality incorporated into the system as the common man tends to treat things commonly.

Since the basic function of engineering is to simplify –while improving the quality of- life, this system strives to be a worthy engineering project. The project will be constructed as a prototype, showing just the possibilities afforded by such a system.

1.3 SCOPE OF PROJECT

This project is intended to show the response of a system in which two sections are connected though an infrared beam. As such, only the basics of such a project are used. The various ways in which the output of such a system can be used is also demonstrated.

1.4 PROJECT LAYOUT

The project write-up is divided into five (5) chapters; chapter 1 presents a general introduction to the infrared intruder alarm. Chapter 2 deals with the literature review of the subject, as well as its application. Chapter 3 is a deconstruction and explanation of the system itself on a stage-by-stage basis. Chapter 4 discusses the construction, testing and results obtained from such tests. Chapter 5 gives recommendation and conclusion

CHAPTER TWO

LITERATURE REVIEW

2.1 HISTORY AND DEVELOPMENT

Laying detection lines across open spaces has been with us for a while. Most primitive (forest-dwelling) civilizations-such as the Incas of Peru - had perfected the use of tripwires connected to booby traps[1]. Even in the present day, the United States Army still use tripwires connected to fragmentation-type landmines on the battle field, they obviously learnt some things from the Vietcong during the Vietnam war.[2] With the discovery of infrared radiation in 1800, it was only a matter of time before the beams would be used as "trip-rays".

The astronomer, Sir Frederick William Herschel (1738 – 1822) was carrying out work with regards to light in the late 18th century. During this period, he got to wondering how much each band of the spectrum contributed to heating an object. He devised an experiment to determine just this. Sir William refracted sunlight through a glass prism and put thermometers with blackened bulbs -to better absorb the heat- in each region. He noticed that the heat radiated by each colour increased from the violet to the red part of the spectrum. To find out if there was more to this than met the eye, literally, he placed another thermometer beyond the red part of the spectrum. To his amazement, there seemed to be as much heat here as in the rest of the spectrum combined. He called this radiation "Calorific Rays" [3].

Over the years, developments have been made to Sir William's work including but not restricted to Gustav Kirchhoff's Black Body theorem (1859); Max Planck's solution of the Black Body theorem by quantizing allowable energy transitions (published in 1900); Einstein's development of the photoelectric effect and determination of the photon (early 1900s) and W.R. Larson's discovery of the infrared detection properties of HgCdTe all helped in the advancement of infrared studies[4].

2.2 THEORETICAL BACKGROUND

Infrared radiation is electromagnetic radiation of wavelength longer than that of visible light, but shorter than that of radio waves. The name means "below red" (infra is Latin for below). Wavelengths for infrared radiation are between approximately 750nm and 1mm. Optical telecommunications (in the near infrared region) is an important area of telecommunication use [5]. It is often separated to different frequency bands because of availability of light sources, transmitting/absorbing materials (fibers) and detectors.

The Earth's surface and the clouds absorb visible and invisible radiation from the sun and re-emit much of the energy as infrared back to the atmosphere. Certain substances in the atmosphere, chiefly cloud droplets and water vapor, but also carbon (IV) oxide, methane, nitrous oxide, sulfur hexafluoride and chlorofluorocarbons, absorb the infrared and re-radiate it in all directions including back to Earth. Thus the "greenhouse effect" keeps the atmosphere and surface much warmer than if the infrared absorbers were absent[6].

2.3 APPLICATION OF INFRARED

Infrared radiations have found relevance in the following fields:

Night Vision - Infrared is used to pick up images where there is insufficient visible light to see an object. The radiation is detected and turned into an image on a screen, hotter objects showing up in different shades than cooler objects. Simple infrared sensors were used by British, American and German forces in World War II as night vision aids for snipers [2]. The same principle is also used in infrared photography, where infrared filters are used to capture the section of the infrared spectrum known as near infrared (wavelength: 0.75 -1.4 micrometers).

Thermography - IR radiation can be used to remotely determine the temperature of objects (if the emissivity is known). This is termed thermography or, in the case of really hot objects in the near-infrared or visible spectrum, pyrometry. It finds use mostly in industrial and military installations.

Heating - Infrared radiation is used in infrared saunas to heat the occupants and to remove ice from the wings of aircraft. Infrared can be used in cooking and heating foods as it heats only opaque, absorbent objects and not the air around them[4,5].

Communication – IR data transmission is also employed in short range communication among computer peripherals and personal digital assistants (PDAs) and appliance remote controls. The beam from an infrared light-emitting diode is modulated to encode the data. These devices conform to the standards published by the Infrared Data Association, IrDA.

Spectroscopy – Infrared radiation spectroscopy is the study of the composition of (usually) organic compounds, finding out a compounds structure and composition based on the percentage transmittance of IR radiation through a sample. [4]

Biological – There are animals, such as the pit viper, which have IR detection abilities. The pit viper has two infrared sensory pits on its head with which it scans for prey even in the dark [7].

CHAPTER THREE

DESIGN ANALYSIS

3.1 PRINCIPLE OF OPERATION

The operation of the circuit lies fully on the transmission of infrared rays to a fixed photodiode. The transmitter stage consists of an infrared diode, transmitting rays of light from the infrared spectrum. The receiver consists of a photodiode assembly. Two receiver stages are needed to detect where the infrared beam has been broken.

The photodiode (PD in fig.3.1) is connected to a voltage comparator, whose output goes low when the infrared beam is broken and clocks a flip-flop.

A D flip-flop (IC_2) is employed in the design, this is to cause a continuous alarm to be sounded until it is put off (or reset). The flip-flop also activates an LED to indicate which zone has been intruded upon. This is achieved using two D flip-flops. The LEDS are connected to the outputs of the flip-flop. Once the comparator sends a high-to-low pulse to the clock of the flip-flop, it toggles and lights the relevant LED.

The system takes in a power supply of +9V dc, which is taken from the mains through a step-down transformer; there is also a back-up supply taken from a battery. Once the mains supply fails, the system automatically switches to the alternate supply.

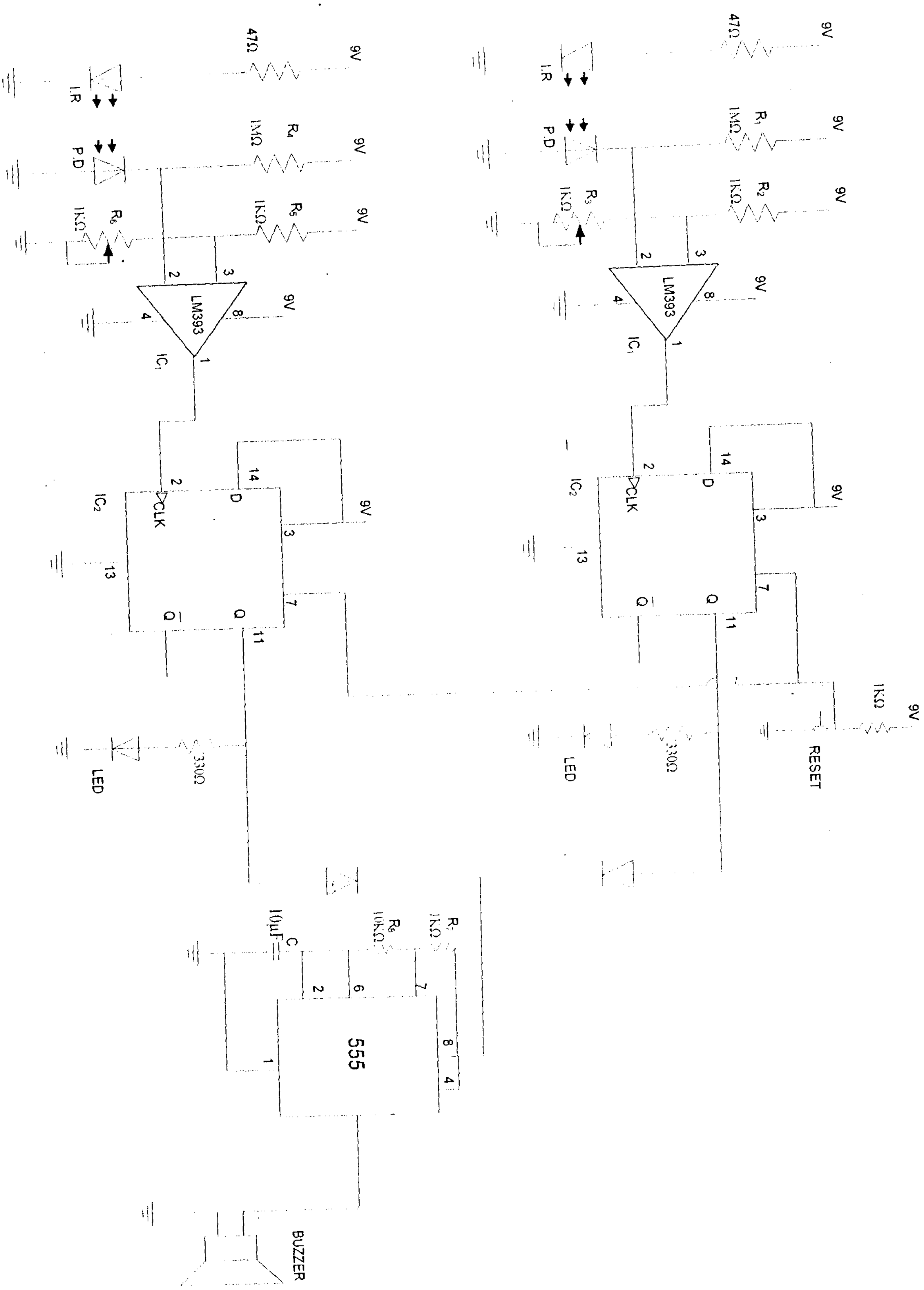

Figure 3.1: Complete Circuit Diagram

3.2 DESIGN SPECIFICATION

Supply Voltage ....+9V dc (Mains)

+9V dc (back-up)

Maximum Current..............1.5A

Infrared Range..................500mm (Prototype)

3.3 BLOCK DIAGRAM

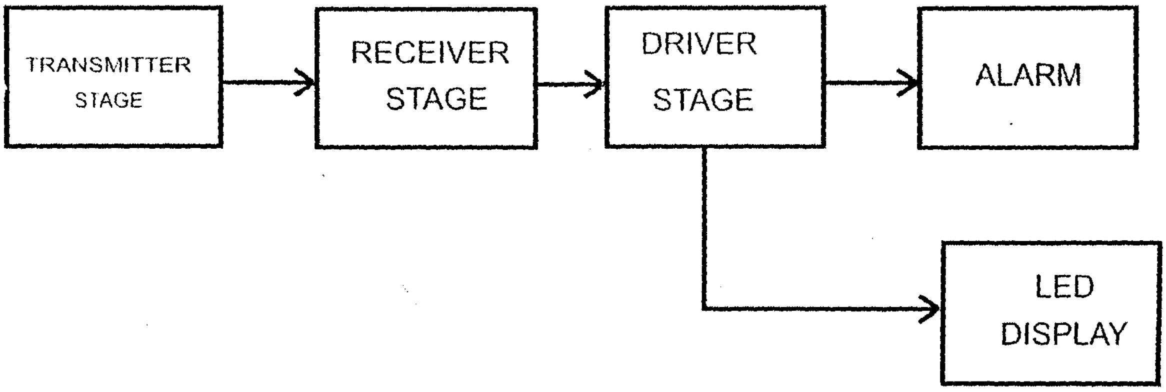

Figure 3.2: System Block Diagram

3.4 TRANSMITTER STAGE

The transmitter stage consists of an infrared diode and a limiting resistor. The infrared diode is forward –biased to meet the electrical condition on which it operates. The transmitter is shown in fig 3.3:

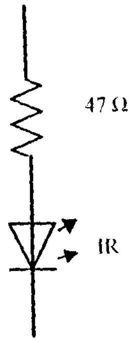

Figure 3.3: Schematic Diagram of Transmitter Unit

For the IR diode to be forward-biased ,

Maximum Forward Voltage, V_f = 1.7V dc

Maximum Forward Current, I_f = 150mA

Input Voltage, V_+ = +9v dc

The series resistance, R, will be:

$$R = \frac{V_+ - V_F}{I_F} = \frac{9 - 1.7}{150mA}$$
$$R = 48.6\Omega$$

Since 48.6 Ω is not a standard value, a preferred value of 47 Ω was chosen.

3.5 RECEIVER STAGE

The receiver stages employ a photodiode as receiver and a voltage comparator to enable its output device to other stages. A schematic of the pin layout of the voltage comparator used (LM 393) is given in fig.3.4:

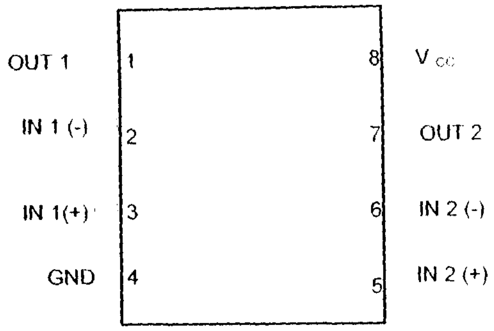

Figure 3.4: Pin Assignment for LM393N

A photodiode was used as the main IR receiver, due to its ability to resist interference from ambient light sources when compared to other optical devices. The photodiode (PD) is operated in the reverse-biased condition. In darkness, the photodiode has a high resistance (up to 1MΩ), hence a low forward current. With light falling on it, the resistance of PD drops. This change in resistance causes a change in the resistance across R_2 which is fed to the comparator IC_1 as shown in fig 3.5:

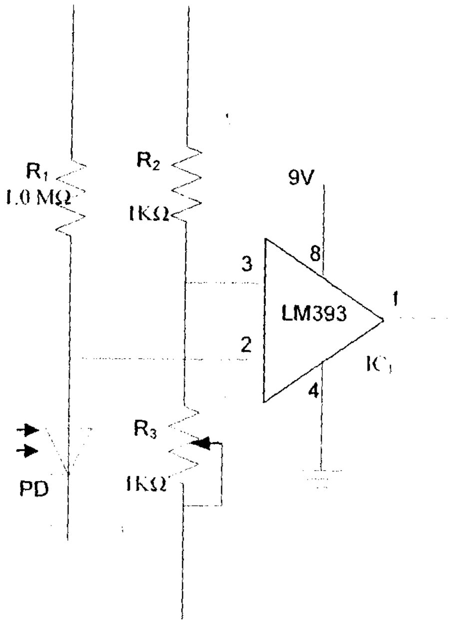

Figure 3.5: LM 393 Comparator Circuit for Receiver Unit

When there is no transmission from the IR diode, the resistance is approximately $1M\Omega$. The voltage divider network formed by the photodiode and resistance, R_1 is shown below

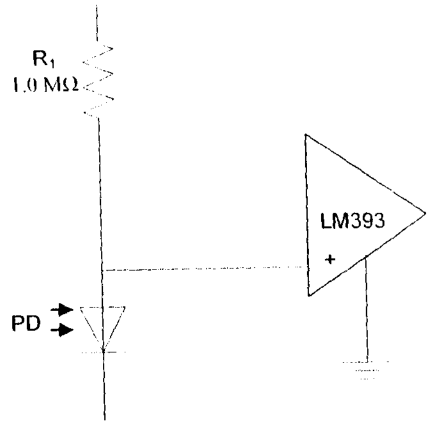

Figure 3.6: Voltage Divider Network for Comparison Circuit

R_1 is set at $1M\Omega$ to allow an appreciable drop in forward current). At V_+ =9v, the drop across the photodiode (PD) is

$$V_{PD} = \frac{PD \, x \, V_+}{R_1 + PD}$$

$$V_{PD} = \frac{10^6 x9}{10^6 + 10^6} = \frac{9}{2}$$

$V_{PD} = 4.5v$

On reception of infrared rays, the photodiode's resistance drops to about 3kΩ while V_{PD} reduces to 0 volts. The voltage comparator, the LM393, is used to compare this change in voltage given a reference generated by R_2 and R_3. A value is chosen for R_2 and R_3 calculated.

Let $R_2 = 1k\Omega$

Since the reference voltage should be just below 4V, let $V_{ref} = 4V$

$$V_{ref} = \frac{R_3 x V}{R_2 + R_3} =$$

$$\frac{9R_3}{10^3 + R_3} = 4$$

$$4R_3 + 4x10^3 = 9R_3$$

$$R_3 = 800\Omega$$

A preferred value of 1kΩ variable resistor was chosen, to allow variation of resistance in order to compensate for sensitivity of the receiver.

3.6 DRIVER STAGE

This section of the circuit comprises a D flip-flop. The D input is set at a high voltage level, while the CLEAR pin is also set at a high voltage level. This is to allow the outputs to toggle when a clock input is received.

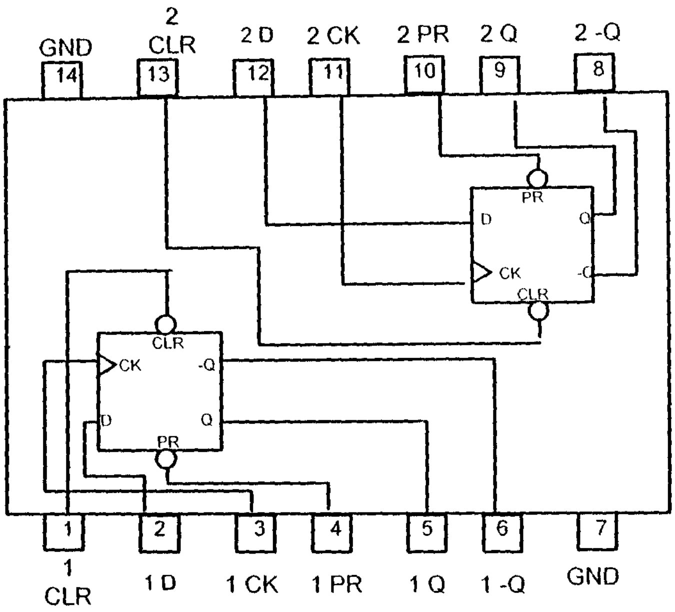

Figure 3.7: Pin Assignment for MM 74C74 dual D Flip-Flop

The D flip-flop outputs the data present at the D input to the Q output and this condition is sustained until a low voltage level is sent to the reset pin. The reset button is connected to the reset input of the D flip-flip.

The alarm is connected to the Q output, as such once it toggles the buzzer sounds

Table 3.1: Truth Table for a D Flip-Flop

				Output	
Preset	Clear	Clock	D	Q	-Q
L	H	X	X	H	L
H	L	X	X	L	H
L	L	X	X	H	H
H	H	↑	H	H	L
H	H	↑	L	L	H
H	H	L	X	Q_0	Q_0

H - Logic High

X - Either low or high logic level

L - Low logic level

↑ - Positive going transition of the clock

Q_0 - The output logic level of Q before the present input

3.7 ALARM UNIT

This uses a 555 timer in the astable mode to generate a frequency of about 7 Hz to drive the buzzer. The pin layout of the 555 IC is illustrated in the schematic:

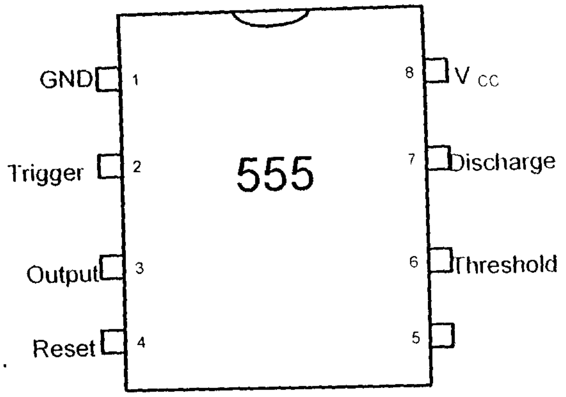

Figure 3.8: Pin Assignment for a 555 timer IC

The astable configuration of the 555 is as shown in fig 3.9:

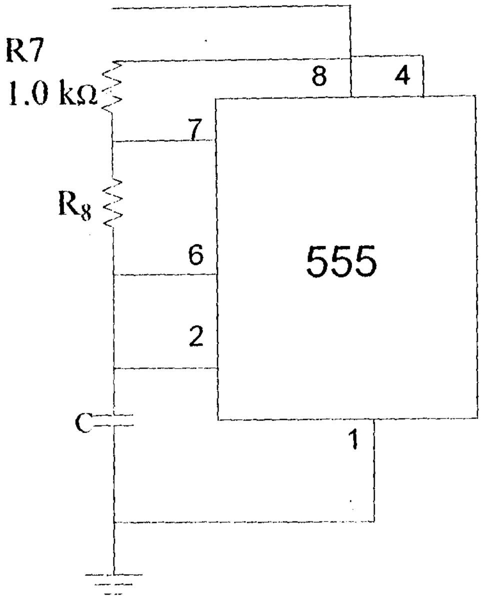

Figure 3.9: 555 IC in Astable Vibrator Mode

Frequency, $f = \frac{1.44}{(R_7 + 2R_8)C}$

Since f = 7Hz, to get the required frequency we choose values for R_7 and C and then calculate for R_8

Let R_7=1k and C = 10μf

$$7 = \frac{1.44}{(10^3 + 2R_8)10^{-5}}$$

$$7000 + 14R_8 = 1.44x10^5$$

$$14R_8 = 137000$$

$$R_8 \doteq 9.8k\Omega$$

Since 9.8 kΩ is not a standard value, a preferred value of 10 kΩ is chosen

3.8 POWER SUPPLY

All stages in the project are powered by a d.c. voltage of +9V. The power supply stage is of a linear supply type and involves a step-down transformer, filter capacitor, bridge rectifier and a voltage regulator. It also includes a relay to allow automatic switching to a back-up in case power supply to the unit has been tampered with.

Since the circuit uses 9V dc supply, a 9V voltage regulator was chosen which the 7809 IC is. This IC gives a regulated 9V supply if the input is greater than 9V. But if the input is greater than or equal to 16V, the IC starts to heat up which can lead to damaging the 7887. Therefore the input is pegged at 14V.

With the maximum current in the circuit being 1A, a 1A/600V rectifying diode, the 1N4007, was selected. The 1N4007 is a silicon diode and drops 0.6V across it, the bridge network is formed by four (4) rectifying diodes, and hence the drop across them will be: 2 x 0.6 = 1.2V

The input to the bridge network, V_P, will be (1.2+14) V =15.2V peak.

Transformer ratings are in rms values: Thus,

$$V_{rms} = \frac{V_p}{\sqrt{2}} = \frac{15.2}{\sqrt{2}} = 10.75V$$

With 10.8v not being a common transfer rating, a transformer of 12V was used making the transformer rating to be 220V/12V, 1000mA.

Capacitor value – This is calculated using a standard capacitor formula

$$I = C\frac{dv}{dt}$$

where I = maximum current

C = filtering capacitor value

dv or Δv – ripple voltage = % ripple x V_p

dt or Δt= time between peaks of a.c. voltage

since I = 1000mA, let % ripple = 20%

$$dv = \frac{20}{100} x 15.2$$

= 3.04 V

dt = ½ T = ½. 1/f = ½ x 1/50

= 0.01s

where T = Period

f = Frequency of ac voltage (50 Hz in Nigeria)

C= I(dt/dv)

= 10^{-3} (0.01/3.04)

=3. 289 *10^{-3} F

=3290 μF

Since 3048 μF is not a standard value, a preferred value of 3000 μF was chosen. The power supply circuit diagram is shown below:

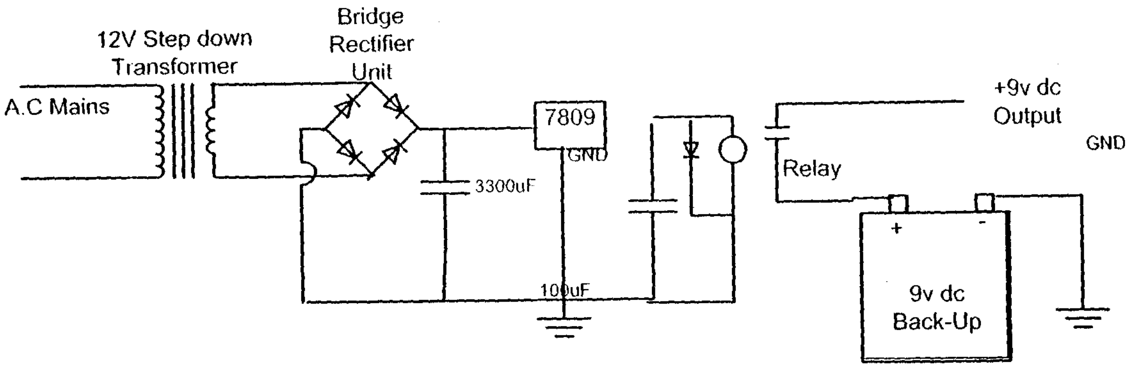

Figure 3.10: Power Supply Circuit

3.9LIST OF COMPONENTS

Table3.2: Components Used

S/ NO	COMPONENT	TYPE	QUANTITY
1	Resistor	47 Ω	2
		330 Ω	2
		1.0 k Ω	4
		10 k Ω	1
		1.0 M Ω	2
2	Capacitor	100 μF, 16V	1
		3300 μF, 16V	1

3	Push Switch		1
4	Diode	1N4007	6
5	Infrared Diode		2
6	Photodiode		2
7	Integrated Circuit	LM 393	2
		74C74	2
		ICM-7555D	1
		L7887	1
8	Transformer	220V/12V	1
9	Relay	6 V	1

CHAPTER FOUR

CONSTRUCTION, TESTING AND RESULTS

4.1 CIRCUIT CONSTRUCTION

The circuit was built on a veroboard and work carried out included the soldering of the components onto the board. The components were placed on the board and the connection paths pre-planned before soldering began to ensure an efficient circuit layout (no jumbling) and for ease of troubleshooting.

4.1.1 SOLDERING

Components were attached to the board using a low-voltage soldering iron and soldering lead. To ensure good joints, a hot soldering iron is essential. When soldering although it is important to make the joints hot, it should not be overheated as this could damage the component being soldered. It is also necessary that the iron not be cold as the solder lead would not flow properly, thus leading to a blob at the joint referred to as a dry joint.

Soldering iron was placed such that it was in contact with both the copper track on the board and the leg of the component. Solder lead was then applied. It would melt onto the track and flow up around the leg "plastering" it in place.

A problem sometimes encountered during soldering was the spill–over of solder thus bridging two (2) adjacent tracks. This is as a result of (improperly) handling the iron such as to heat neighboring tracks, common when using a soldering iron bit that is too large for the job at hand. This can culminate in a short–circuit of the bridged tracks, and subsequent failure of attached components if not dealt with.

It is vital that the track between the pins of ICs (or their holders) be broken using a blade so as not to short-circuit the IC.

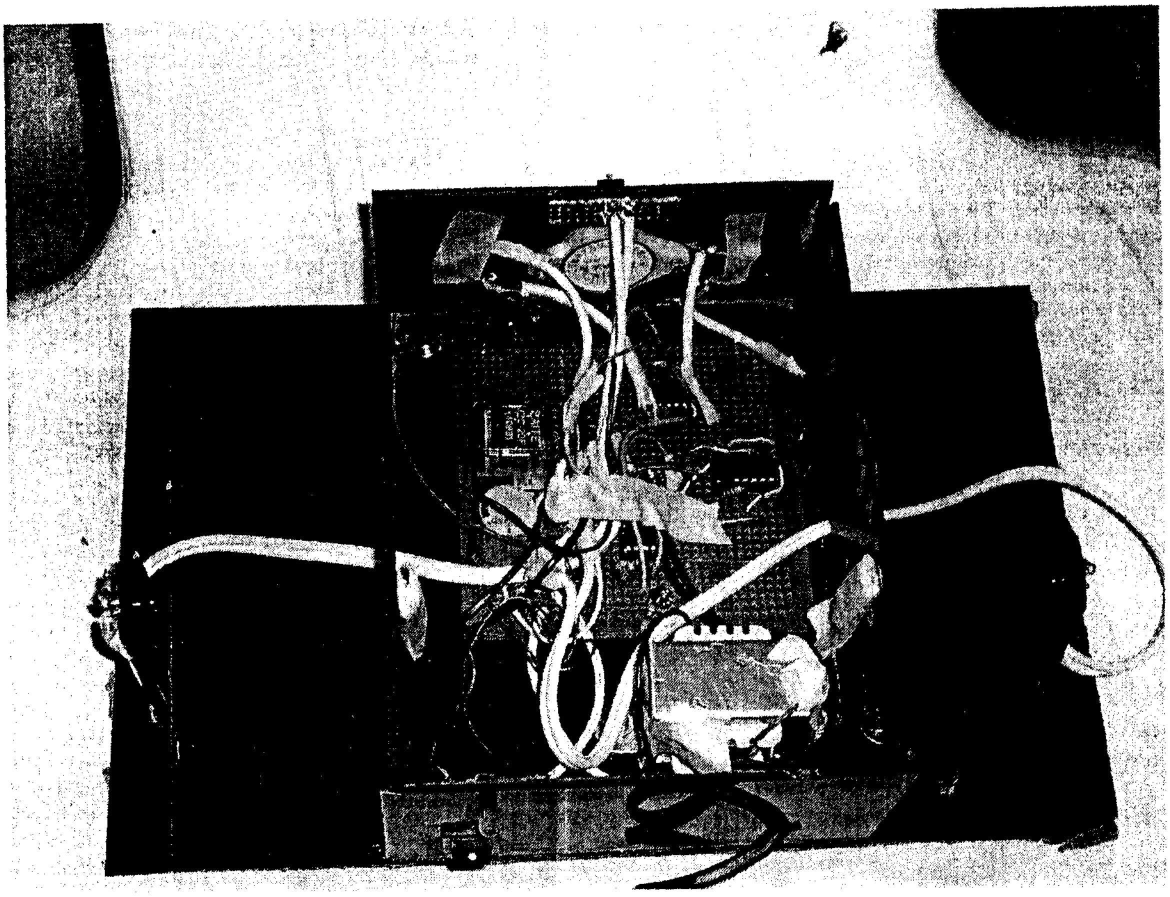

Plate 4.1: Completed Circuit of the Intruder Alarm

4.2 CASING CONSTRUCTION

The casing of the project was made from plastic glass (Plexiglas). The Plexiglas was cut and bent into the required forms to hold the circuit. Since the project is intended to be a simple prototype, the whole system was packaged into a single unit to demonstrate its operation. The different panels were then held together with glue.

Plate 4.2: Front View of Casing

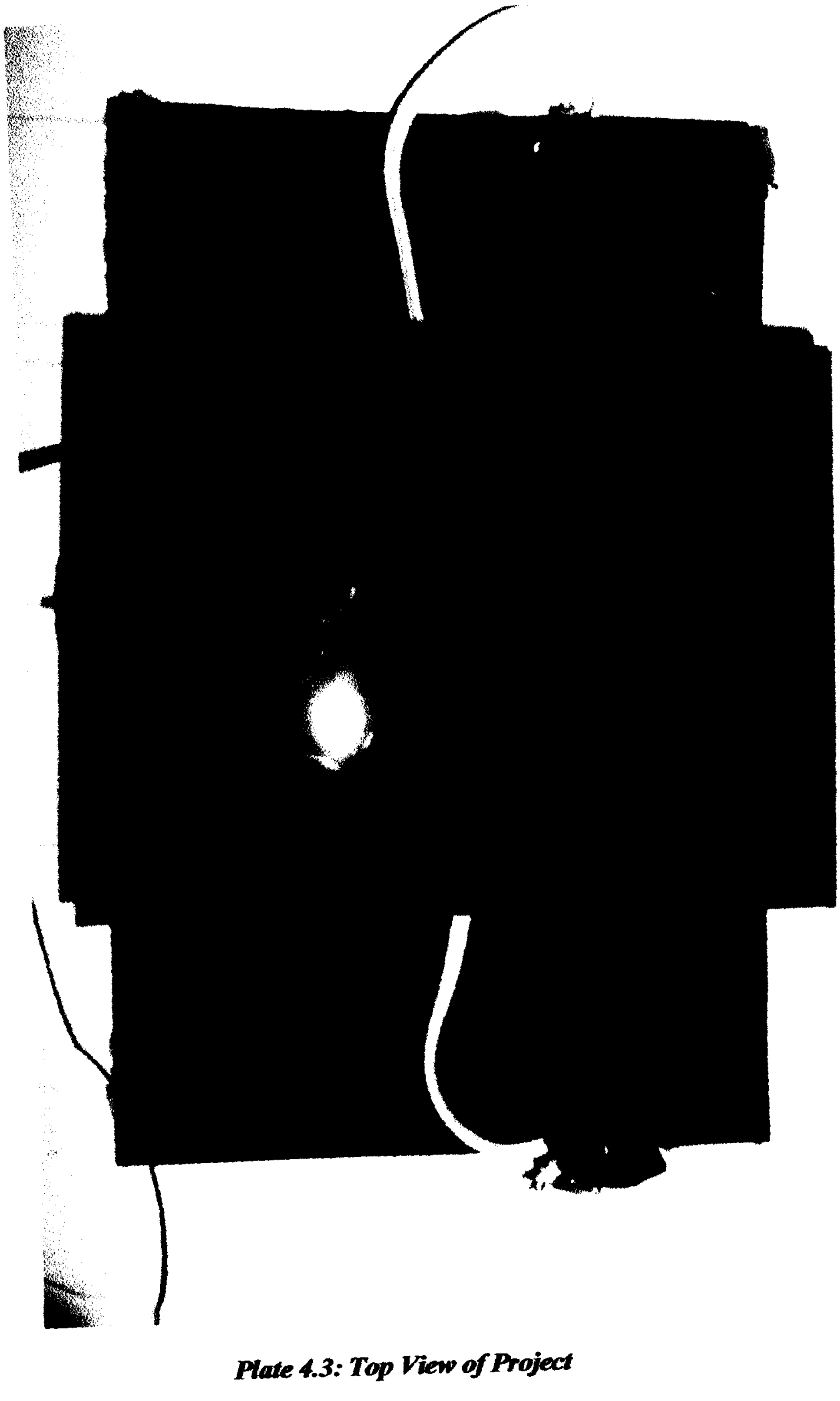

Plate 4.3: Top View of Project

4.3 CIRCUIT TESTING

The circuit was tested in two (2) phases: After design, the circuit was first simulated on a personal computer (PC) and then after construction it was physically tested.

4.3.1 SIMULATION

After the circuit design, the circuit operation was simulated on Multisim's Electronics Workbench. The response of the circuit was thus assessed as regards functionality. Success at this stage was the green light needed to move the project onto the construction stage.

4.3.2 PHYSICAL TEST

Upon completion of construction the circuit was tested through visual checks and electrical tests.

VISUAL TESTS: This was done before connecting the system to power mains.

Attention was focused on the following:-

- Whether components were properly connected and if their polarity was respected (in the case of transistors, diodes and electrolytic capacities) in the circuit.
- That all wire links were in the right place.
- It was ascertained if power supply leads were properly positioned and of the right polarity.
- All connection were carefully checked to ensure there were no solder bridges.

ELECTRICAL TESTS: With the project powered up, a voltmeter was used to confirm that the appropriate voltages were applied to the relevant points Active and passive components were also checked using a multimeter.

4.4 TESTING RESULTS

4.4.1 RESULTS.

The results gotten i.e. output voltages of ICs, output voltage of transformer etc. were the same as those of the analysis calculation. The input voltages as measured with a meter were in compliance with the circuit design. The frequency of the 555 IC was in line with requirements indicating the proper resistances and capacitance were used.

4.4.2 DISCUSSION OF RESULTS

All the results obtained from this project are in line with the design and construction of Infracted Burglar Alarm. This can be seen from the proper functioning of the project (lighting of LEDS and sounding of buzzer).

CHAPTER FIVE

5.1 CONCLUSION

It can be seen from the foregoing report that the design of an infrared alarm system, just like any other, requires careful planning and implementation.

Infrared beams were emitted from a transmitter to the receiver circuit. The absence of this beam would cause the instantaneous sounding of the buzzer. The receiver circuit incorporated a voltage comparator (breaking the beam would cause a rise of voltage on the receiver side) and a 555 timer IC to drive the buzzer.

The question of cost and available resources necessitated the scale of this project. However, it is intended as a building block to greater things.

5.2 RECOMMENDATION

To ensure that systems such as these provide the maximum protection possible, the Nigeria Police should be prepared to protect and serve by incorporating technology into their modus operandi. They should have a control center wired to individual buildings with infrared security system.

Although this system was implemented using hardwired logic, it could also be designed using soft wired logic. The use of software logic would open up a whole new world of possibilities.

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All IC information courtesy of AllDataSheets.com