

DESIGN AND CONSTRUCTION OF A
SECURITY MOTION DETECTION
SYSTEM USING INFRA-RED.

BY

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TECHNOLOGY, MINNA.

NOVEMBER, 2007.

DEDICATION

THIS PROJECT WORK IS DEDICATED TO MY PARENTS.

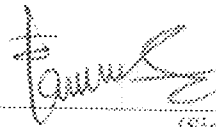
Thanks for the love, care and support.

DECLARATION

I, AJIBOYE OLADARIDE USMAN, declare that this project work was done by me and has not been presented elsewhere for the award of a degree. I also hereby relinquish the copyright to the federal university of technology, Minna.


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To sister Morenikeji, i appreciate your love. Thanks a million.

ABSTRACT

This project work is based on the use of infra-red technology to provide a high degree of security protection to homes, Banks, Hallways and Pathways, Museums etc.

The system uses reflective infra-red detection to sense motion. In this implementation, an unmodulated IR carrier signal is constantly generated by an IR generator. An IR receiver operating at the same frequency is placed closely-both facing the same direction. When there is reflection from a body passing the front of the transmitter-receiver pair, the transmitted IR signal is reflected towards the sensor.

The IR receiver module registers an output that turns ON a lamp relay driver momentarily. The lamp goes OFF after about 2 seconds if the motion is non-persistent. If it is, the IR detector module remains activated for as long as the motion is detected. The persistent motion after about 8 seconds causes an alarm circuit to be triggered on. The alarm and security lamp then stays ON until it is manually RESET by authorised personnel/guard. The system design is to provide a back-up DC power source in cases where there is power failure or if burglars tend to disconnect the AC mains.

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CHAPTER ONE

INTRODUCTION

1.1 Definition

Motion simply means the act of moving. It can be defined as a movement, action, gesture of a body or involving the change in position of a body depending on time [1]. Basically, there are four forms of motion;

- **Translational Motion:** It involves the movement of a body in a straight line so that every point on the body follows a parallel path and no rotation takes place.
- **Rotational Motion;** this is a turning motion like that of a wheel around an axis or a fixed point.
- **Random Motion;** this involves a disorderly motion with no pattern to its movement e.g. as in the case of gaseous particles.
- **Oscillatory Motion;** this is the movement of an object to-and-fro between two points e.g. Swinging Pendulum.

1.2 Motion Detectors [2]

A motion detector is any electronic device that can be capable of sensing movements and would usually give a feedback [e.g. Alarm] on the moving object.

Motion detectors are usually used as security devices to protect indoor areas, hall ways etc. where conditions can be more closely controlled. Motion detection systems use different methods to detect movements of which each method has its own advantage and

disadvantage. Many types of motion detectors can sense motion in total darkness without an intruder becoming aware that an alarm has been triggered.

Two major categories of motion detectors are the active detectors and passive detectors. Active detectors are those detectors that send out energy waves and wait to receive the reflected waves back from the objects. In this case, any disturbance to the transmitted wave pattern caused by a moving object will trigger an alarm. Examples of active detectors are the microwave and ultrasonic detectors. On the other hand, passive detectors do not send out signals rather, they receive signals such as change in light intensity, change in temperature etc from the environment. Examples include most infrared detectors.

Usually, detectors used in homes could detect movement in about $10\text{m} \times 10\text{m}$ area of space

1.3 History of motion sensors

Motion sensors have been used with alarm systems since the 1970's. Back then, motion sensors were based on ultrasonic technology. Though prior to this time, ultrasonic beams were used in experiments for measuring the depth of sea and also to detect submarines under water. Sound waves were emitted from a sensor and the resulting reflected sounds were analyzed to detect changes. When a change was detected, the motion sensor notified the alarm system's control panel, (or whatever it was connected to). These ultrasonic sensors were frequently blamed for triggering false alarms. A phone ringing, an alarm clock sounding, or the heating system coming on could all cause a false triggering alarm. A better solution was needed.

1.4 Dual-technology motion detectors

Many modern motion detectors use a combination of different technologies. These dual-technology detectors benefits with each type of sensor, and false alarm are reduced. All companies have the option to use PIR/Microwave Motion Detectors that have "Pet-Immune" functions which allow the detector to ignore pets that weigh up to 40 pounds (wireless models) or 80 pounds (hard-wired models).

Often, PIR technology will be paired with another model to maximize accuracy and reduce energy usage. PIR draws less energy than microwave detection, and so many sensors are calibrated so that when the PIR sensor is tripped, it activated a microwave sensor. If the later also picks up an intruder, then the alarm is sounded.

The best solution found and used today is based upon infrared technology (abbreviated "IR"). Other technologies, based upon microwave and radar were tried, but they never gained the popularity of infrared technology. Infrared sensors began to appear on the market in the 1980's. When they first came out, they were somewhat expensive, but as production ramped up and more manufacturers found ways to use them for different applications, the price dropped quickly. The most popular consumer uses of IR sensors are for motion sensing floodlights.

1.5 Applications of Motion Detectors

Radar is something that is in use all around us, although it is normally invisible. Air traffic control uses radar to track planes both on the ground and in the air, and also to guide planes in for smooth landings. Police use radar to detect the speed of passing motorists. You

even see a form of radar at many grocery stores when the doors open automatically! Obviously, radar is an extremely useful technology [3].

1.6 Aims and Objectives

The aim of this project work is to provide for a high security monitoring system in restricted areas like Homes, Banks, Museums, and Offices etc.

CHAPTER TWO

LITERATURE REVIEW

2.1 PREAMBLE

Motion detectors are devices that can sense the changes in the normal wave pattern of an area (motion) and gives a signal to show that motion is being detected.

An electronic motion detector contains a motion sensor that transforms the detection of motion into an electric signal. This can be achieved by measuring optical or acoustical changes in the field of view.

A motion detector may be connected to a burglar alarm that is used to alert the home owner or security service after it detects motion. There are several different kinds of motion detectors of which each has its own advantage and disadvantage.

There are many different ways to create a motion detector/ sensor. For example:

It is common for stores to have a beam of light crossing the room near the door, and a photo sensor on the other side of the room. When a customer breaks the beam, the photo sensor detects the change in the amount of light and rings a bell. The same thing can be done with ultrasonic sound waves, bouncing them off a target and waiting for the echo.

2.2 TYPES OF MOTION DETECTORS

There are various kinds of motion detectors of which the common ones are;

- Ultrasonic motion detector

- Microwave motion detector
- Radar motion detector
- Photo electric motion detector
- Video motion detector

2.2.1 Ultrasonic Motion Detector [4]

They are electrical devices that use sound at very high frequency to detect motion. The frequency of the sound detected is usually greater than the normal human hearing frequency range to boost its sensitivity.

Ultrasonic detectors use a pair of transmitter and receiver (usually clocked at the same frequency). The transmitter sends out sound of some certain frequency too high for the human ear to hear and the receiver picks up the reflected sound waves from the area under protection. Any motion made within this region of space will cause a distortion or shift in the frequency of sound transmitted (which results from the behaviour of sound waves when they are being compressed by moving objects). The receiver circuit detects the shift in frequency and thus gives off a signal. The frequency shift is called the "DOPPLER EFFECT".

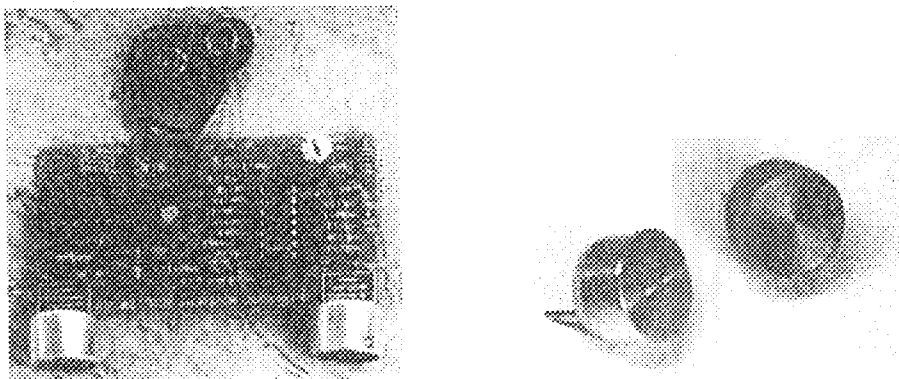


Plate 2.1: Picture of an Ultrasonic motion Detector.

2.2.2 Microwave Motion Detector [5]

Microwave motion detectors operate by transmitting microwave signal (electromagnetic fields) in the 'X' band. Any slight movement in the field disturbs the transmitted wave signal and subsequently an alarm is given off. These microwaves signals are generated by a "GUNN DIODE" operating at preset limit that do not affect humans. Also as the case of ultrasonic detectors, the detection of intrusion is related to the principle of Doppler shift frequency. Objects that fail to produce a signal or produces signals outside the tuned frequencies are ignored. Only object that fall within the range cause the sensor to generate an alarm signal.

2.2.3 Photo Electric Motion Detectors [6]

Photo electric motion detectors are active detectors that make use of a transmitter and receiver. The transmitter uses a light emitting diode (LED) as light source and transmits a consistent infrared beam of light to a receiver. The receiver consists of a photo electric cell that detects when the beam is present. If the photo electric cell fails to receive at least 90% of the transmitted signal for as brief as 75 milliseconds (time of an intruder crossing the beam), an alarm signal is generated. The beam is modulated at a very high frequency which changes up to 1000 times per second in a pattern that correlates with the receivers expectation to guard against a bypass attempt by using a substitute light source. In order to bypass the sensor, the angle of the beam and modulation frequency would have to be matched perfectly.

2.2.4 Radar Motion Detector [2]

The name RADAR which means Radio Detection and Ranging is an active sensor which came into use first in the early 1940's but afterwards, it has undergone substantial enhancement. Many grocery stores have automatic door openers that use a very simple form

of radar to detect when someone passes near the door. The box above the door sends out a burst of microwave radio energy and waits for the reflected energy to bounce back. When a person moves into the field of microwave energy, it changes the amount of reflected energy or the time it takes for the reflection to arrive, and the box opens the door. Since these devices use radar, they often set off detectors. Radar uses ultra high frequency radio waves to detect intrusion within a monitored area. Radar sensor transmits signals from an energy source in the ultra high frequency range of about 100MHz to 1GHz.

2.2.5 Video Motion Detector

Video motion detectors, abbreviated-VMD, use closed circuit television (CCTV) systems to provide both an intrusion and detection capability. They provide means for security personnel to immediately and safely assess alarms (possible intrusion). CCTV systems provide the added benefits of documenting the event of an intrusion and the characteristics of the intruder. Video motion detection sensors detect changes in the area. Video motion detectors monitor the video signals being transmitted from the camera. When a change in the signal is received, indicating a change in the image composition caused by some sort of movement in the field of surveillance, an alarm signal is generated, and the intrusion scene is displayed at the monitoring station.

2.3 INFRARED MOTION DETECTORS [3]

These are motion detectors that use infrared energy radiations. Infrared radiations exist in the electromagnetic spectrum at a wavelength that is longer than visible light. It can not be seen but it can be detected. Any object that generates heat also generates infrared radiation and these objects include animals and the human body whose radiation is greatest at a wavelength of about 9.4um. Infrared in this range will not pass through many types of

material that pass visible light such as ordinary window glass and plastic. However it will pass through, with some attenuation, material that is opaque to visible light such as germanium and silicon. An unprocessed silicon wafer makes a good IR window in a weatherproof enclosure for outdoor use. It also provides additional filtering for light in the visible range.

The detector (sensor) is the most critical component of any IR system since it is the singular device which converts optical energy into useful electrical signal. Hence the entire workability of circuit of any motion detector is solely dependent on the sensitivity of the sensor.

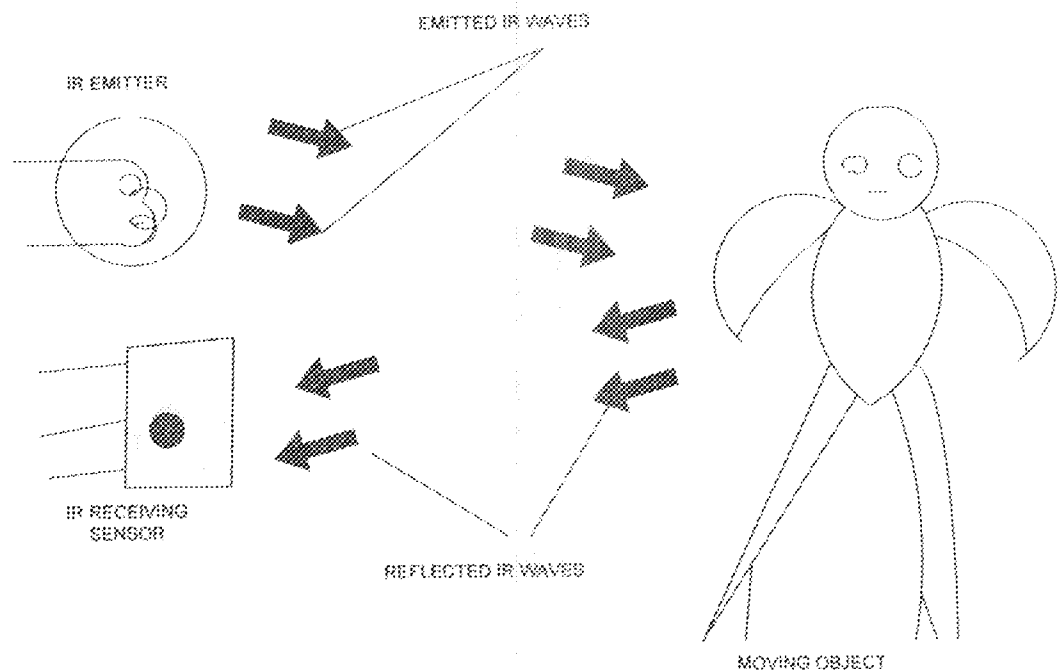


Fig 2.2: Diagrammatic Illustration of IR Motion detection System

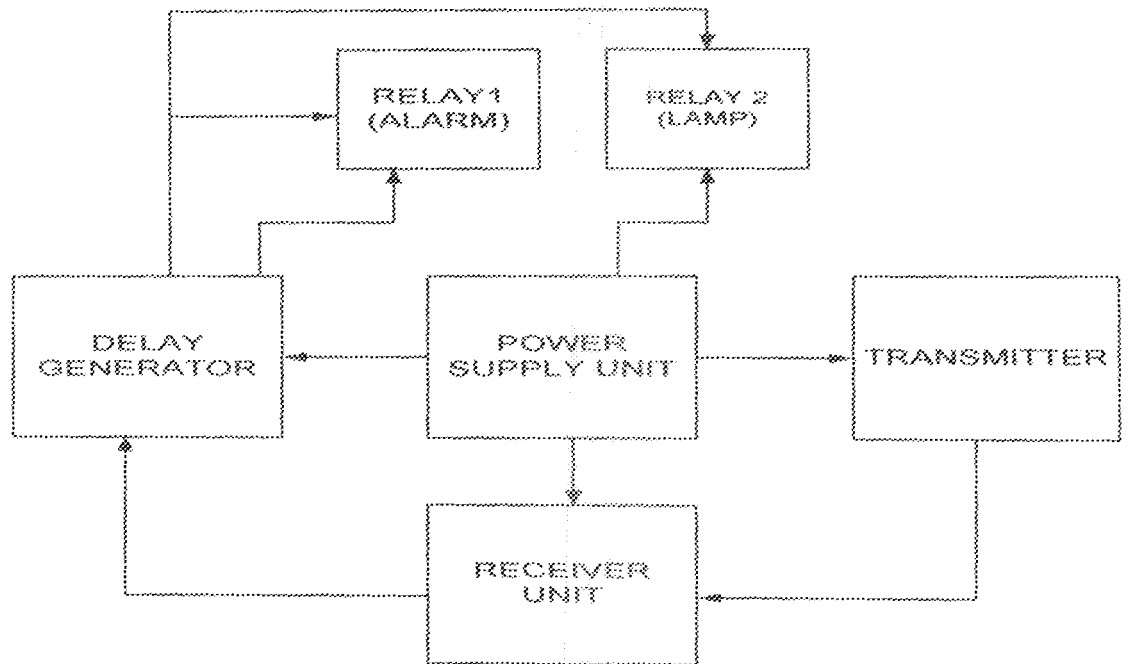


Fig: Block Diagram of IR Motion Detection System

Fig. 2.3: Block Diagram of IR Motion Detection System

CHAPTER THREE

DESIGN ANALYSIS

The security intrusion detection system was designed around the following under listed sub-systems.

1. The power supply
2. The IR transmitter sub-system
3. The IR receiver subsystem
4. Delay Generator and
5. The Relay Drivers.

These sub-systems will be analyzed separately as a block in the system.

3.1 Power Supply

The power supply is designed from a local AC source and a lead-acid rechargeable battery as a back-up when there is power failure. The mains derived power was derived using a 12V, 0.5A transformer connected to a full wave bridge rectifier as shown in fig. 3.0 below.

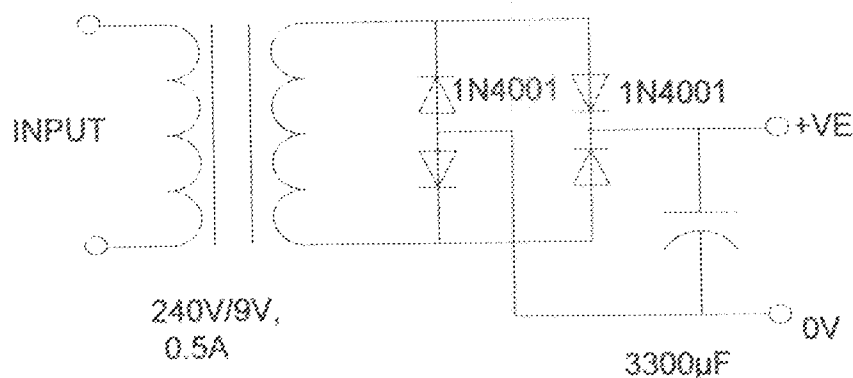


Fig 3.1: 240V-9V AC-DC CONVERTER

The 9V rms voltage was rectified and converted to a DC voltage with peak amplitude given by the expression: [7]

$$V_{\text{peak}} = (V_{\text{rms}} \times \sqrt{2}) \times 1.4 \quad 3.0$$

Where, V_{peak} = Peak value of DC voltage

V_{rms} = Root mean square value of input voltage

1.4= two diode V_f loss in the bridge rectifier.

The pulsating DC was smoothed by a 25V, 4700 μ F. The value of the smoothing capacitance was deduced from the relation;

$$Q = CV \quad \text{and} \quad Q = It \quad 3.1$$

$$CV = t\Delta I$$

$$C = t\Delta I / \Delta V \quad 3.2$$

Where: Q = Charge stored in capacitor

I = Load current

$$T = 1/F = 1/2F \quad (\text{for forward rectifier}) \quad 3.3$$

F = Mains frequency.

ΔV = Maximum allowable AC ripple on DC power

ΔI = Load current variations

Since; $C = t\Delta I / \Delta V$; $C = K\Delta I / \Delta V$

$$\text{Therefore } \Rightarrow C \propto 1/\Delta V \quad 3.4$$

From equation 3.4, decreasing C produces a corresponding reduction in ΔV , i.e. AC ripples. A 3300 μ F capacitance was hence used to keep ΔV to the minimum. Measured ΔV after smoothing was 20 mV. The power supply also includes a battery charging subsystem to maintain the connected lead-acid battery on charge. The lead-acid battery was charged using the configuration shown below.

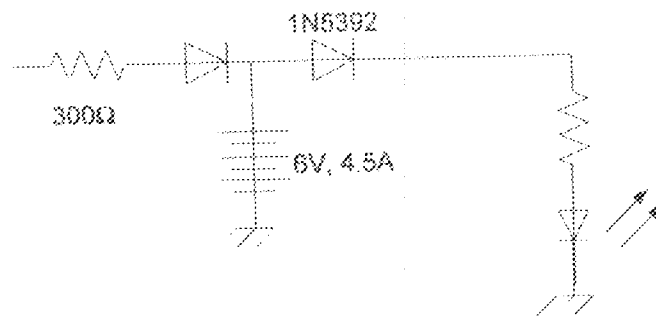


Fig.3.2: The charging Circuit.

The battery output was wired in an OR-Diode configuration to produce backup DC supply in the absence of the mains-derived DC power. A 7805 regulator lifted above ground was wired into the OR power summing network to supply power at all times when local mains is available.

The figure for the LM7805 regulator is shown below;

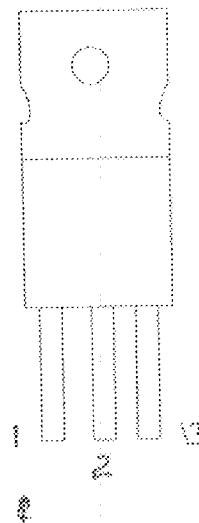


Fig. 3.3: LM7805 Pin identifications

The device is packaged in a TO-220 encapsulation and is rated for output current in excess of 1.5A over a 12V to 37V output range at a maximum package dissipation of 20W. It requires only two external resistors to set the output voltage.

3.2 INFRA-RED TRANSMITTER

It was designed around an NE555 multivibrator configured as an astable multivibrator chip running at 38 KHz. This mode of operation was chosen so as to generate a constant square wave form to be transmitted.



Fig. 3.4 Generated Square Wave-form by the Astable Multi-vibrator

The pin configuration for the NE555 multivibrator is shown below;

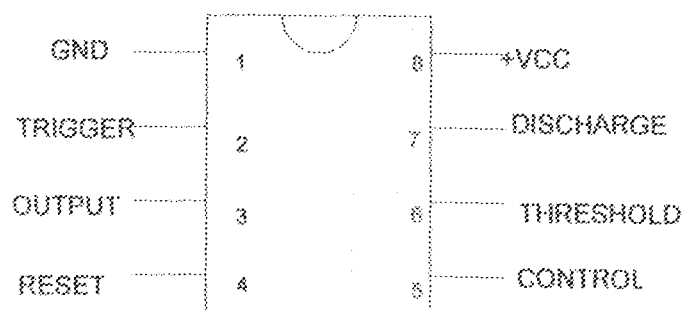


Fig. 3.5: NE555 pin configuration

When operated in the astable mode, the 555 timer generates a constant frequency output of

$$F = 1.44 / (R_A + 2R_B) C \text{ Hz}$$

3.5

Using the above equation, for the 38 KHz output, the values for the configuration were chosen for R_A and C . For easy setup, R_B was made variable. By varying R_B , the output was measured using a frequency meter until the required 38 KHz. The values of R_A , R_B and C used in this design to achieve the 38 KHz frequency are,

$$R_A = 1K\Omega, R_B = 50K\Omega \text{ (variable) and } C = 0.01\mu\text{F}$$

The multivibrator oscillator turns an IR emitter diode ON-OFF through a 100Ω resistor.

$$R_S = (V_S - V_{LED}) / I_{LED} = (5 - 2) / 0.03 = 100\Omega$$

3.6

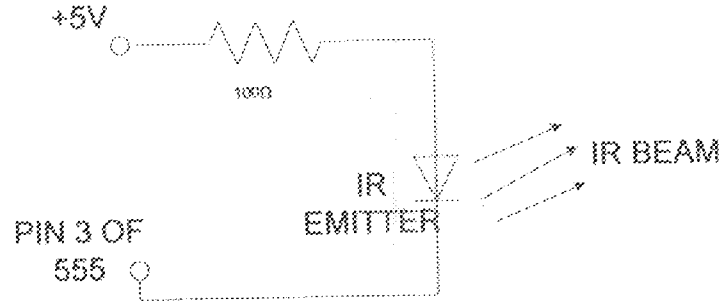


Fig. 3.6 IR Transmitter circuit

3.3 IR DETECTOR

An integrated circuit was used as the IR receiver to detect the reflected IR frequency. The transmitter and receiver units were placed side-by-side facing in the same direction. When no reflection occurs by a reflective body placed directly before the transmitter-

receiver, the generated IR signal is lost through space. When a body walks past the unit, the generated IR is reflected towards the sensor and conditioned to produce an output.

An NE555 IC configured as a monostable [8] and an IR sensor was used for the IR detection. The figure below shows the configuration circuit for the infra-red detection sub-system.

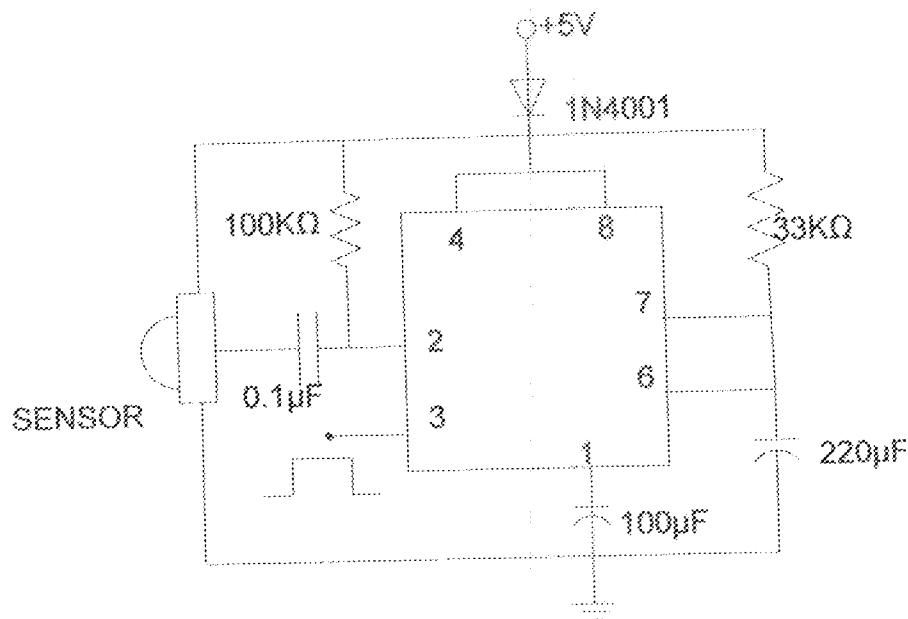


Fig. 3.7: Receiver circuit

An infra-red sensor was used to trigger the monostable every time an IR carrier is detected. In the absence of an IR signal, V0 switches LOW to trigger the 555 monostable that generates an output pulse. The width of the pulse (duration) is given by;

$$T = 1.1 RC$$

3.7

A 2 second pulse was used to activate the security lamp whenever motion was detected.

Hence the value of the components were chosen as

$$R= 22 \text{ K}\Omega, \text{ and } C= 100 \mu\text{F}$$

$$\text{Therefore, } T= 1.1 \times 22000 \times 100 \times 10^{-6}$$

$$T \approx 2.4 \text{ seconds}$$

This output pulse was fed into the relay circuit for the security lamp to be activated for about 2 seconds.

3.4 DELAY GENERATOR

The delay generator was built around a CD4060 counter/ oscillator IC. The CD4060 has several Q outputs from which the delay output was tapped from Q8. It was designed to generate approximately 8 seconds of delay

$$\text{That is; } 2^8 / (2 \times 16) = 8 \text{ seconds}$$

3.8

The delay output was used to latch an NPN-PNP relay drivers that in-turn activated an audio sounder and security lamp. This arrangement provides a time-delayed implementation in which the alarm is not sounded instantly upon detection of motion but, a period of time elapses before the alarm is enabled. This prevents spurious responses.

The CD4060 Oscillator Features include, [9]

- All Active Components embedded on Chip

- Has RC or Crystal Oscillator Configuration

- RC Oscillator Frequency of 690 kHz Min. at 15V

Its applications include,

- Use in Control counters

- As Timers

- As Frequency Dividers

- In Time Delay Circuits.

3.4.1 Description

CD4060BMS consists of an oscillator section and 14 ripple carry binary counter stages. The oscillator configuration allows design of either RC or crystal oscillator circuits. A RESET input is provided which resets the counter to the all 0's state and disables the oscillator. A high level on the RESET line accomplishes the reset function. All counter stages are master slave flip-flops. The state of the counter is advanced one step in binary order on the negative transition of ϕ (and $\bar{\phi}$). All inputs 0 and outputs are fully buffered. Schmitt trigger action on the input pulse line permits unlimited input pulse rise and fall times.

The CD4060 was wired with a base frequency of 16Hz. The CD4060 produces an audio tone of frequency given by the relation

$$F = 1 / (2.3 R_T C_T).$$

3.9

Where R_T = Resistance connected to pin 10

C_T = Capacitance connected to pin 9.

The time-out delay was based on this frequency and the selected Q output- Q8 was used to latch the counter once Q8 goes high.

The CD4060's pins are labelled as shown in the figure below;

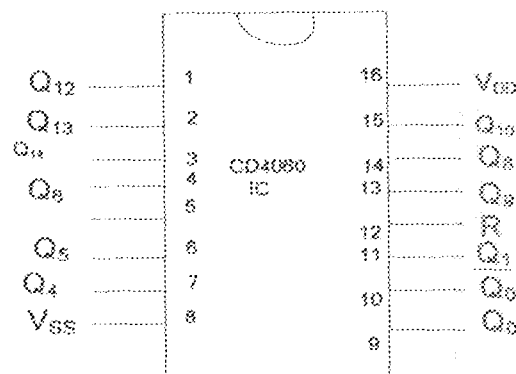


Fig 3.8: CD4060 IC Pin out

It was desired to latch the alarm unit ON once persistent motion is detected greater than 8 seconds. A means of locking the circuit ON once activated was required. The latching was realised using a feedback diode from Q8 to pin 11 of the CD4060 oscillator as shown in the figure below

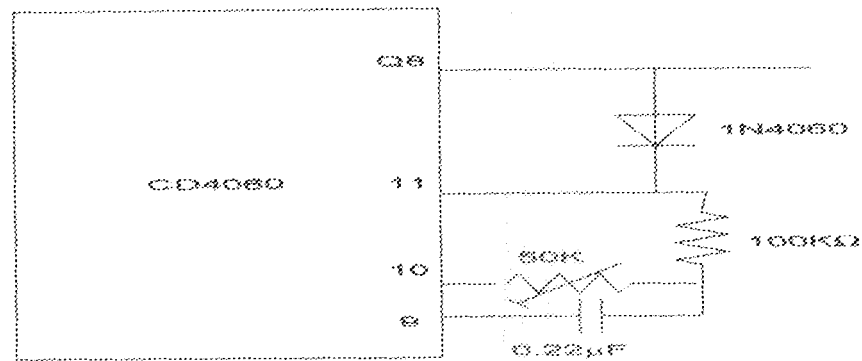


Fig. 3.9: CD4060 latching Using The feedback Diode

The delay generator is enabled when motion is selected and the IR receiver switches HIGH. If only a momentary motion is detected, the IR receiver module returns to the LOW state and the 4060 is disabled. However, if persistent motion is detected, the CD4060 is continuously enabled until Q8 goes HIGH. Once Q8 goes high, the CD4060 locks and it does not change state again. When the CD4060 locks the relay drivers are energised and both the alarm and the security lamp are ON infinitely until it is RESET manually by a reset switch.

3.5 MODE OF DETECTION OF MOTION

The system uses reflective infra-red detection to sense motion. In this implementation, an unmodulated IR carrier signal is constantly generated by an IR generator. An IR receiver operating at the same frequency is placed closely-both facing the same direction. When there is no reflection from a body passing the front of the transmitter-

receiver pair, the transmitted IR signal is reflected towards the sensor. The IR receiver module registers an output that turns the lamp relay driver ON momentarily. The lamp driver turns OFF after about 2 seconds if the motion is non-persistent. If it is, the IR detector module remains activated for as long as the motion is detected.

3.6. RELAY DRIVERS

The relay drivers each consist of one NPN and one PNP low power transistors.

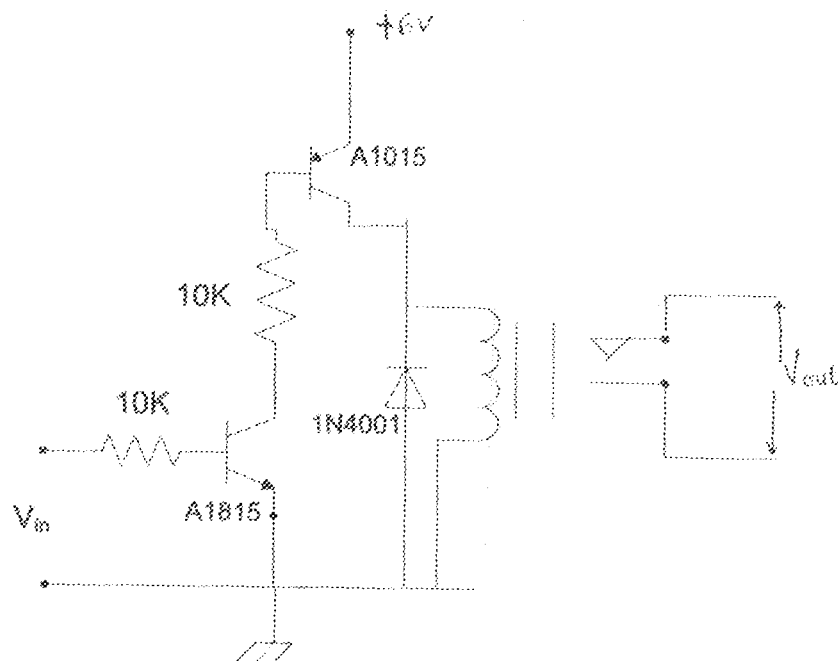


Fig.3.10. Relay Drivers

The relay is connected in the collector coil of the PNP transistor. When the input voltage, $V_b \geq V_{be}$, transistor Q1 switches ON forward biasing Q2 which then supplies current to the relay winding.

The relay has $R= 400\Omega$, $V= 6V$

Therefore, $I_{\text{relay}} = 6/400 = 0.015\text{A}$

3.10

But $I_{\text{relay}} = I_{\text{C (PNP)}} = \beta I_{\text{B}}$, where $\beta = 200$

3.11

$$\Rightarrow I_{\text{B}} = 0.015/200 = 75\mu\text{A}.$$

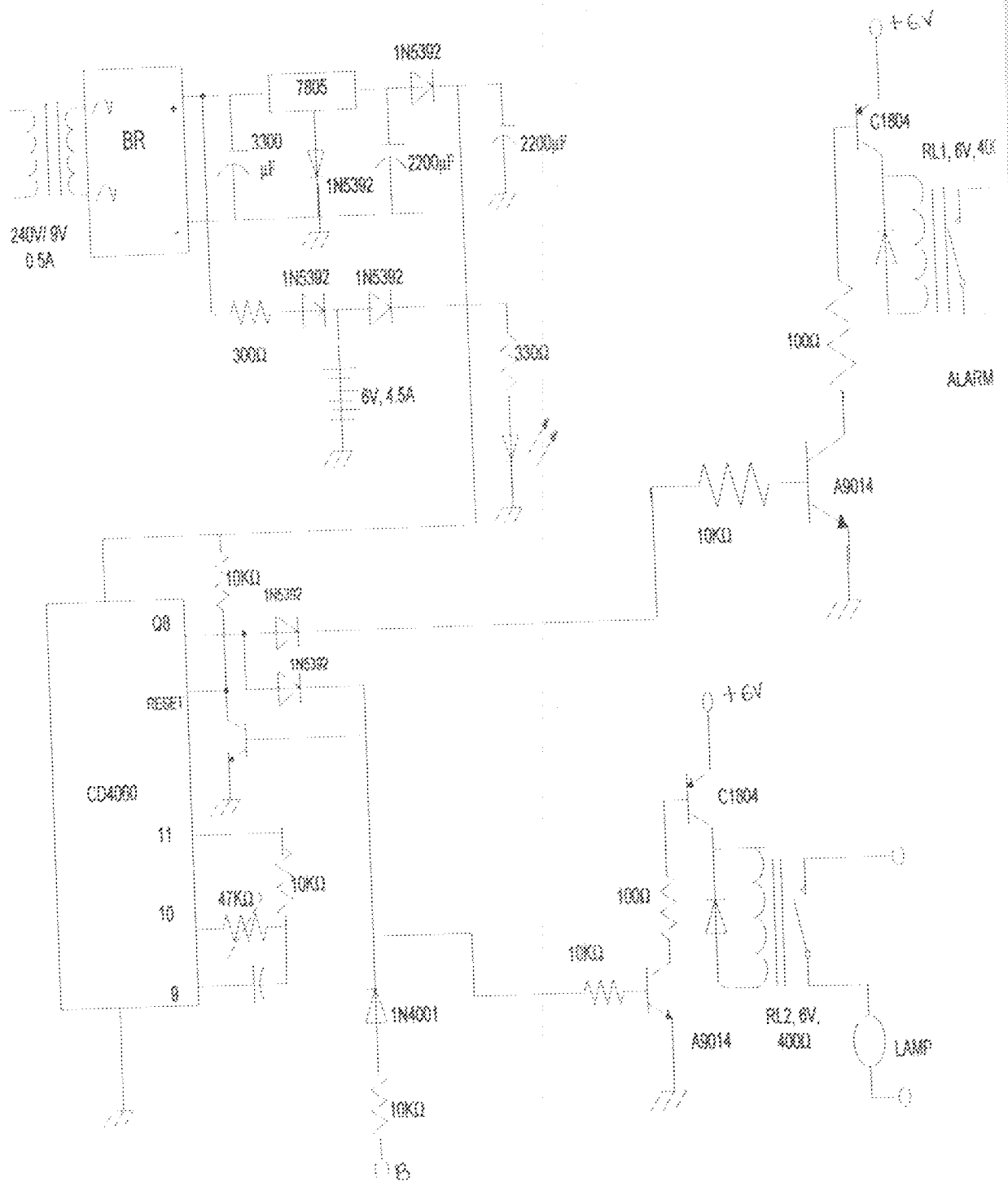


Fig. 3.11a. Complete Circuit diagram

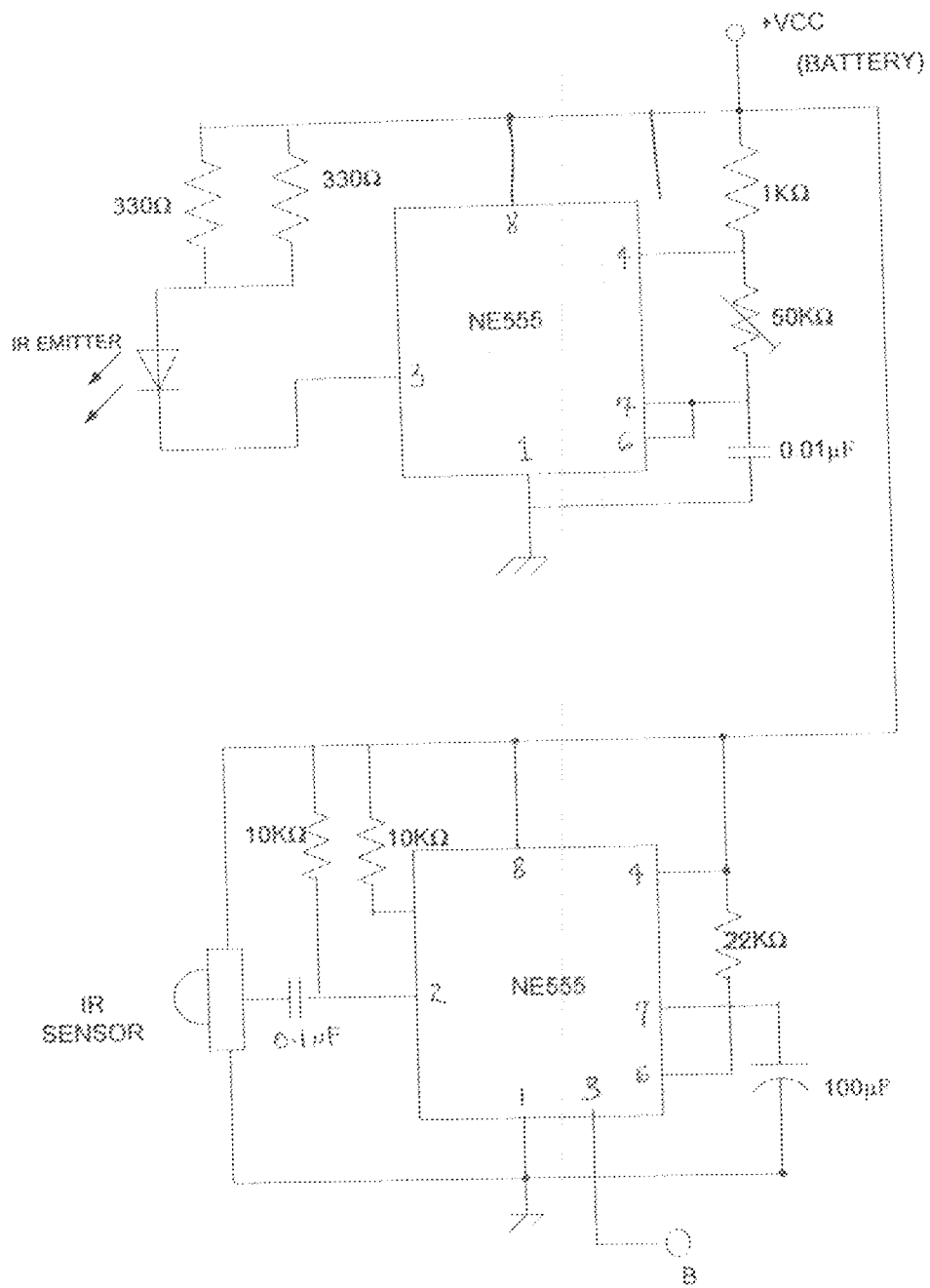


Fig.3.11b. Complete Circuit Diagram

CHAPTER FOUR

TESTS, RESULTS, AND DISCUSSIONS

4.1 Measurements

The workability of this project was first carried out using a bread boards. The desired objective was been achieved and the work was then transferred to a Vero board.

Testing and measurements was carried out in on a modular basis of the entire system. During the design, each module was constructed and first tested using the multimeter for its functional abilities. Therefore, any problem arising can be detected easily. Below are the steps taken in testing this project work;

- **POWER SUPPLY UNIT-** the power supply module on its own was tested to know if the required voltage level is actually delivered or not. The Multimeter was placed across in input terminals of A.C to ascertain the input voltage. Further more, the output voltage across the 7805 voltage regulator was measured to make sure it's delivering the required amount needed.
- **THE SENSOR UNIT-** since the basic workability of a circuit with sensor is solely dependent on the reliability of the sensor, it is therefore necessary to measure the output of the sensors. The frequency of the transmitter unit was measured using a frequency meter to ascertain that the transmitting frequency was maintained at the said 38 KHz. Also the receiving sensor unit was tested to be free from defects and that the sensitivity is not affected by other external factors.

- **OUTPUT OF RELAYS**-the corresponding impulse fed to the relays was measured and the values noted. it was ensured that the relays are having enough current source to trigger them on
- **DELAY GENERATOR**- measurement tests were also carried out on the output of the IC CD4060 and it was observed that the time delay of about 8 seconds was obtained.

4.2 Results of Measurements

Table 4.1

POWER UNIT	TEST	RESULTS
	Output current	7805 = 180mA
	Output voltage	7805 = 5V

Table 4.

SENSORY UNIT	TESTS	RESULTS
	FOR TRANSMITTI FREQUENCY	38KHz
	FOR IR SENSOR MONOSTABLE T1	prox. 2secs

4.3 Problems Encountered

Most folks have seen or used Motion Sensing systems with Motion Detectors in their home. If motion detectors were not used some may have alarmed and some may have alarmed much better now than

the early ultrasonic models, why can't they be used outdoors with an alarm system? Strangely, it still comes down to the issue of reliability. With motion detecting floodlights, if the sensor false alarms, the only consequences are the lights coming on for a few minutes. If an IR sensor connected to an alarm system fails, the sirens are set off and in some cases, the police may be dispatched to investigate. The noise of the sounding alarm sirens will surely aggravate the neighbours. And of course, we don't want a mob burning down our home because the alarm system is going off constantly! When IR motion sensors are used outdoors, they are more likely to cause false alarms. The most common cause of a false trip is rapidly changing weather conditions. For example, when a warm winds blow across the sensor.

More so, the problem of maximum distance covered is another setback. Because infrared beams have ranges to which they can go, it cannot be used for long distance motion detection.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

Finally, it can be concluded that the security level in restricted areas and homes can be increased appreciably by using the principles of infrared technology.

As a recommendation, I will advise that future work that will be carried out on infrared be further developed to increase the range with which the sensors will respond to.

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