TITLE PAGE

DESIGN AND CONSTRUCTION OF A PASSIVE INFRARED MOTION SENSOR

BY

IKPEFUA EMMANUEL OSEIWE ENG2002254

CHISOM NKECHINYERE IGBOKWE ENG2002250

DIVINE CHUKWUYEM IFEANYICHUKWU ENG2002247

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

FACULTY OF ENGINEERING

UNIVERSITY OF BENIN BENIN CITY

OCTOBER 2025

DESIGN AND CONSTRUCTION OF A PASSIVE INFRARED MOTION SENSOR

BY

IKPEFUA EMMANUEL OSEIWE ENG2002254

CHISOM NKECHINYERE IGBOKWE ENG2002250

DIVINE CHUKWUYEM IFEANYICHUKWU ENG2002247

A PROJECT SUBMITTED TO THE DEPARTMENT OF ELECTRICAL AND ELECTRONIC DEPARTMENT, FACULTY OF ENGINEERING, UNIVERSITY OF BENIN, IN PARTIAL FULFILMENT FOR THE REQUIREMENT OF THE AWARD OF BACHELOR OF ENGINEERING (B. ENG) DEGREE IN ELECTRICAL AND ELECTRONIC ENGINEERING.

OCTOBER 2025

CERTIFICATION

This is to formally acknowledge that the project work presented herein was collaboratively undertaken by **IKPEFUA EMMANUEL OSEIWE** , bearing matriculation number **ENG2002254** and **CHISOM NKECHINYERE IGBOKWE** bearing matriculation number **ENG2002250** and **DIVINE CHUKWUYEM IFEANYICHUKWU** bearing matriculation number **ENG2002247** . The students are of the Department of Electrical/Electronic Engineering, Faculty of Engineering, University of Benin. The project was carried out as part of the academic requirements for the successful completion of the Bachelor of Engineering (B.Eng.) degree in Electrical/Electronic Engineering. It reflects the students' effort, knowledge, and commitment in partial fulfillment of the conditions necessary for the award of the said degree.

…………………………… ………………………

Engr. E.I. Ibhadode (Project Supervisor) Date

………………………. ………………………..

ENGR DR O. S. OMOROGIUWA

Date

(Head of Department)

DEDICATION

This project is dedicated to the Almighty God, the source of all knowledge, wisdom, and strength, whose grace sustained me throughout this academic endeavor.

I also dedicate this work to my beloved family, whose unwavering support, prayers, and endless encouragement provided the foundation for my success.

ABSTRACT

Motion detection is now crucial for modern security frameworks and energy conservation efforts, offering superior protection and mitigating energy waste from appliances left running. This project addresses the need for a reliable, economical, and highly effective sensor system by focusing on the design, construction, and testing of a Passive Infrared (PIR) Motion Sensor prototype. The primary goal is to create a robust device capable of identifying movement across a complete three hundred and sixty degree field of view, enhancing its utility over standard directional sensors and providing a valuable contribution to localized security solutions.

The technical implementation began with a robust Power Supply Unit built from scratch. This unit uses a step down transformer, a full wave bridge rectifier, and a large smoothing capacitor to transform high voltage AC into smooth DC. An LM7805 voltage regulator guarantees the stable five volt supply essential for the sensitive electronic components. The Sensing Circuit uses a PIR sensor and a Fresnel lens to detect infrared energy. The weak analog signal generated by moving heat sources is processed by an operational amplifier and a comparator to create a clear digital trigger. This trigger then activates a transistor to energize an electromagnetic relay and a buzzer, which serve as the system's immediate response mechanism.

Testing confirmed that the prototype successfully met all objectives. This included the reliable detection of motion within the predetermined area, the empirical definition and adjustment of the effective detection range, and the successful fine tuning of system sensitivity. Furthermore, the strategic design achieved the critical goal of wide coverage. This project validates the construction of a low cost, energy efficient device, affirming the practical application of knowledge in electronics design, power management, and embedded systems, and establishing a successful framework for automated lighting and intruder alarm systems.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

1.1 INTRODUCTION

1.1.1 BACKGROUND OF STUDY

Motion detection plays a critical role in modern security systems. Security of items and even rooms and buildings with basic locks (Padlocks) have become both outdated and inefficient. A padlock can be easily cut or smashed down, doors are being easily broken down. The security of valuable items is of great importance, and it ought to be handled as such. Handling this involves simply more. More is needed to secure the valuables, more is needed to be put in place. Motion detection is a top class way of securing valuables. Being able to detect any time someone comes close to the value is a massive advantage to the security industry. Let's consider this story, Mr. A has an art gallery. In this gallery, a rare item is tucked safely away in a locked room. During working hours, a random guy slips out of the crowd and successfully finds his way to this room guarded by enough locks; he did not get there himself, he got there with the help of a staff at the gallery. The staff helps him get past all the locks and together they successfully steal the valuables. If the room was guarded with a motion sensor, information would be passed immediately when they get into the room. If the sensor were to be connected to the owner's phone, the owner would instantly be aware of this break in. If it was connected to an alarm, the whole situation becomes quite difficult for the thieves. All in all, motion detecting takes security to a whole other level and this can be achieved through the use of motion sensors (El-Sayed et al., 2018). My project focuses on the creation of a Passive Infrared (PIR) motion sensor prototype that can be applied in various security systems. The sensor is passive as the name implies due to the fact that it does not emit radiation instead it listens for infrared energy. Infrared energy radiates naturally from all objects above zero degree celsius.The hotter an object gets, the more infrared energy it emits. This infrared radiation is detected by the sensor when it is in its field of view; meaning that it can't sense infrared radiation coming from behind walls (Gupta & Gupta, 2021). At the heart of the PIR sensor, there is a pyroelectric material and this material generates an electric charge when exposed to heat. This is how we convert the Infrared energy into electrical energy that helps transmit the required information. Due to the fact that in order for this material to easily detect these infrared rays, the rays have to be focused; this is where the fresnel lens comes in. This is a crucial element in the sensor that helps focus the ray. This lens does not focus visible light, only infrared rays (Chudleigh, 2011). PIR sensors are mainly made with two two sensing elements made of the pyroelectric material. Two are used to significantly reduce false alarms. They are designed to have opposite electrical polarities; because of this the signal generated by the uniform changes in infrared rays cancel out each other when processed. On the other hand, when motion occurs, due to the segmentation created by the fresnel lens, one sensing element senses the change before another leading to one creating a positive signal and the other a negative signal in quick succession; this indicates to the sensor that there is a moving heat source. These sensors are designed to ignore slow changes in heat or constant heat sources. This helps to prevent fault trips (He et al., 2016). PIR sensors are generally very energy efficient therefore making them ideal for battery powered prototypes and for long term deployment. Since PIR sensors are passive meaning the don't emit signals, they are difficult for potential intruders to detect or interfere with. PIR sensors can have decent detection range. It is suitable for covering rooms or specific areas. Although the range is not insanely large and it can't see through walls, it's range is still quite good when we relate it to its application. PIR sensors have several advantages; They also have disadvantages. If the ambient temperature of the room suddenly spikes or falls, it can lead to a false alarm. Even when objects move very slowly, there might no be enough infrared signal movement to trigger an alarm. Obstacles affect the line of sight of heat sources. PIR sensors require an unobstructed line of sight in order to work effectively; the location the sensor is placed will determine a lot. In the sensor there are blind spots. The fresnel lens provides specific detection zones, within those zones might be a blind spot. Small things might be able to move a certain way and avoid detection. If the ambient room temperature is close to human temperature, a human coming in will likely not signify any change in the sensor. This is another factor to be considered when using a PIR sensor. More information about the heat source is not given by this sensor. All that is given is that there was a movement that was detected by the sensor.

1.1.2 STATEMENT OF PROBLEM

Motion sensors solve the security problem by a great mile. The optimal security measure in securing your goods would be to be always present meaning that the owner would always be watching over his goods. As nice as that would be, a person cannot simply waste days upon days watching over his property; worst of all, there would probably not even be a potential threat to your property during the time you stand guard (Islam et al., 2017). Watching over valuables is definitely a tasking job both mentally and physically. Wasting valuable time for another valuable is sad; spending your whole day staring into space is worse. Motion sensors help in actively watching over valuables at all times, ready to respond to movement. Time is no longer wasted in securing goods; we can comfortably go out knowing that if someone else tries to intrude, the sensor will detect and respond as predetermined; whether it's to turn on the CCTV instantly or to play a loud sounding alarm. There is also an issue of wasting energy. As humans, we can oftentimes forget to do things that would be largely beneficial to us. Wasted energy also gets paid for, there is no excuse claiming that although it was reading , it was not used by you. Imagine Mr. A has an appointment in 35 mins and he hurriedly leaves his home forgetting to switch off the light bulbs and fans; the appliances will remain on and, energy not used would therefore be paid for. Even in our homes, how many of us turn off light bulbs and fans after leaving our rooms?

Our excuse is usually that we'll soon be back; we inevitably spend more time than expected out of the room, sometimes reaching hours (Abdelmeguid et al., 2020). With motion sensors, lights can be programmed to turn off after a room is unoccupied for a set amount of time. The sensor is connected in series to the bulbs and this can be made possible . Although a little time would be taken before it turns off, it definitely saves energy by a great deal.

1.2 AIM

To design and construct a Passive Infrared Sensor, capable of detecting motion within a predetermined range.

1.3 OBJECTIVES

1. To design and construct a multi stage Power Supply Unit from discrete components that successfully transforms 220V AC mains into a stable 5V DC rail to provide a clean electrical baseline for sensitive sensing electronics.
2. To interface a PIR sensing element with a BISS0001 micro power controller to accurately capture human body infrared radiation and process these weak analog thermal changes into a reliable digital trigger.
3. To implement an electromechanical output stage using a switching transistor and a 5V relay that enables the low power sensor signal to safely control a high current audible buzzer for immediate intruder notification.

1.4 METHODOLOGY

1. To develop the first stage of the project, I focused entirely on building a reliable Power Supply Unit from scratch to provide a clean energy source for the rest of the system. I began by connecting the 220V AC mains from a standard wall outlet to the primary side of a step down transformer. This transformer used the principle of electromagnetic induction to safely drop the high voltage down to roughly 12V AC. Since electronic components cannot run on alternating current, I built a full wave bridge rectifier using four silicon diodes to force the electricity to flow in only one direction. This created a pulsing DC signal that still had too much electrical noise, so I placed a large electrolytic smoothing capacitor across the output. This capacitor acted like a reservoir, filling in the gaps between the voltage peaks to create a much flatter and more stable DC waveform. To finish the stage, I integrated an LM7805 voltage regulator which acted as the final guard, ensuring the circuit received a constant and precise 5V output regardless of any minor spikes or drops from the main power line.

2. To handle the second stage of the project, I moved from building the power foundation to

setting up the actual brain of the system. This involved interfacing a PIR sensing element with a BISS0001 micro power controller to translate thermal movement into a clear digital trigger. I positioned the sensor behind a white dome-shaped Fresnel lens which acted as the eyes of the device, focusing infrared radiation from a moving human body onto the internal sensing elements. The sensor produced a very tiny and weak analog signal whenever it detected a change in heat, so I routed this signal directly into the BISS0001 chip. Inside the chip, the signal went through internal operational amplifiers that boosted its strength until it was large enough to be processed. I then used an internal comparator to check if this amplified signal was strong enough to cross a specific threshold voltage, which helped the system ignore small background temperature changes or electrical noise. To make sure the system behaved correctly once it was triggered, I soldered specific resistors and capacitors to the timing pins of the chip to set exactly how long the output pulse should stay active before resetting.

3. For the third and final stage of the project, I focused on building the output interface that turns an electronic signal into a physical alarm. Since the digital trigger coming from the BISS0001 controller was way too weak to power a heavy load, I connected it to the base of an NPN switching transistor to provide the necessary muscle. This transistor worked like a high-speed gate, opening up to allow current to flow from the power supply directly into the electromagnetic coil of a 5V relay. As the coil energized, it created a magnetic field that physically pulled a metal arm inside the relay, snapping the contacts shut to complete the separate high-power circuit for the buzzer. To keep the system safe, I placed a flyback diode in reverse across the relay coil to soak up any dangerous high-voltage spikes that occur when the magnetic field collapses. This protected my transistor from getting fried and ensured that every time the sensor spotted movement, the relay would reliably click into place and the buzzer would sound a loud, clear alert.

1.5 SIGNIFICANCE OF STUDY

Building a PIR Sensor is definitely of significance. It shows its significance across several aspects of life, due to its unique capabilities offered. PIR based automation in homes encourages energy efficient practices. In a nation such as ours (Nigeria), the strain on our existing grid becomes lesser when we begin to automate our homes using PIR sensors (Okeniyi et al., 2021). Electronics like bulbs begin to come on only when needed; this way, energy is efficiently conserved and the strain on our grid reduces. The rate of crime in this country has become of major concern. This project drastically reduces the probability of a successful break in. If homes and offices are guarded with motion sensors, the probability of successfully breaking into a locked area becomes impossible. The excuse of the cost of purchasing a highly sophisticated security device being too high isn't even enough to put down this device. PIR sensors are relatively cheap therefore providing a money friendly solution to security problems. PIR Sensors generally improve the quality of life. Convenient living is easily made possible with PIR sensors. Through house automation, life is made very comfortable at home; ranging from door systems, to lighting, and even electronics that are particular to you. PIR sensors make them all seem to be intelligent and in achieving that, life is made easier. The skill and knowledge that'll be gained while working on this project is another significant part of the whole thing. Through this project, knowledge on electronics, programming and even embedded systems are gotten (Eze et al., 222). It finally serves as an opportunity for we electronics students to practicalize what we have been learning from day one in this University, and also to learn more as regards the practicality of it all. From this skill, ideas on businesses begin to germinate and innovations begin to rise up in areas relating to this field. Building a PIR sensor is of massive importance as an electronics engineer and also of great significance to Nigeria as a whole.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter provides a comprehensive review on the individual components that make up the system. The electronic principles and foundations that make up each component are expanded on at length. The goal of this review is to validate each component choice and performance bench mark. The reasons why each component is chosen and its advantage or benefit to the system is also clearly stated.

The various components are explained below;

2.1.1 AC SOURCE

An alternating current source represented in Figure 2.1 below is simply an electrical power source that periodically reverses direction over time (Akbari & Al-Haddad, 2021). This initial AC source provides the initial electrical energy to my motion sensor. Typically, a standard wall power outlet can give an AC voltage of 220V, which is what will power this sensor (Fuchs & Masoum, 2018). AC is readily available in the power grid, which is why it is being used. This makes it the most practical and accessible starting point.

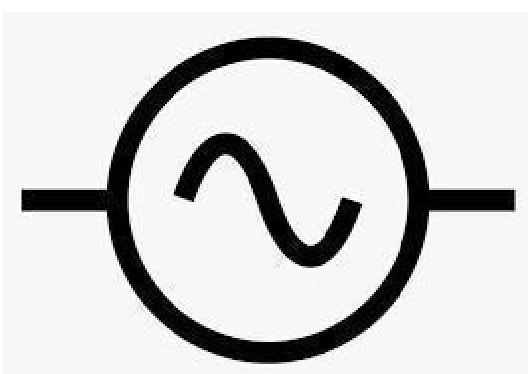

Figure 2.1: AC Source (Iec Ac Supply Clipart, n.d.)

2.1.2 STEP DOWN TRANSFORMER

A step down transformer represented in Figure 2.2 below is an electrical device that uses the principle of electromagnetic induction. It is designed to decrease the voltage from the primary winding to the secondary winding. The alternating current in the primary coil creates a fluctuating magnetic field, which induces an electromotive force or voltage in the secondary coil. The voltage reduction is achieved by making sure the primary winding has significantly more turns than the secondary winding (Kulkarni & Khaparde, 2019)

This transformer helps us reduce the significantly high AC voltage to a level low enough for the subsequent components. Unlike a simple DC to DC converter, the transformer can only operate with AC, therefore making it the ideal component for this particular work. The transformer provides galvanic isolation between the primary circuit and the secondary circuit. This protects the user and low voltage electronics from potential surges on the high voltage primary side. The transformer, or rather transformers, are highly efficient devices often with an efficiency of 90% or above (Zhang et al., 2017). The efficiency is very crucial as any power lost is dissipated as heat, which as we know can stress the component.

The two main kinds of losses are copper losses (I^2R losses) and core losses. The first kind is due to heat generated in the windings as a result of the resistance of the copper wire. The second kind of losses above simply explains hysteresis and eddy current losses within the iron core.

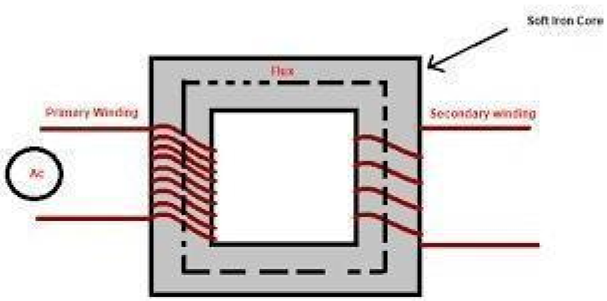

Figure 2.2: Step Down Transformer (Electronics For You, 2024)

2.1.3 RECTIFIER

A rectifier represented in Figure 2.3 below is an electronic circuit that converts AC current into DC current. This process is known as rectification. As we know, alternating current periodically reverses direction with time. The job of the rectifier is to ensure that the current always flows in one direction (Mohan et al., 2018). A full wave bridge rectifier configuration is used for optimal efficiency and smoother output.

This circuit utilizes four diodes to harness both the positive and negative halves of the AC waveform. The diode is a major component of the rectifier circuit. It is a semiconductor that acts as a one way electrical valve. It allows the current to flow easily in one direction, forward bias direction, but strongly opposes flow in the opposite direction, reverse bias direction.

The function of the diode in the rectifier: Steering Current. In this bridge configuration, the four diodes are strategically placed to ensure that regardless of the polarity of the AC input, the output terminal of the bridge always maintains the same polarity (Khalifa et al., 2022). Full Wave Output: The diodes flip the negative half cycle to the positive side, therefore utilizing the entire input waveform to create a continuous, positive only output which is known as pulsating DC.

Mechanism of the Bridge Rectifier: when the AC terminal is positive, two of the diodes in the rectifier become forward biased and conduct the current to the output of the rectifier. On the other hand, when the AC terminal reverses polarity and becomes negative, the first two diodes switch off and the other two diodes become forward biased, therefore conducting the current. Due to the configuration of the bridge, the current is directed to the same positive output terminal as the previous half cycle. This rectification is very important because neither the capacitor nor the voltage regulator can function correctly or efficiently with a reversing AC input. The rectifier provides the necessary unidirectional current flow that is required by the capacitor and voltage regulators.

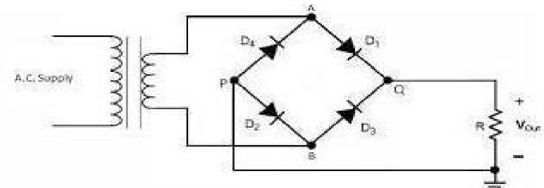

Figure 2.3: Full Bridge Rectifier (Stack Exchange, n.d.)

2.1.3 CAPACITOR

Although the output of the rectifier is unidirectional, it is a pulsating voltage. Pulsating voltage is not suitable for sensitive electronics like our PIR sensor. This capacitor seen below in Figure 2.4 addresses this by smoothing out these voltage fluctuations. This capacitor is often called a smoothing capacitor. It has a large value and it's connected in parallel to the rectifier's output terminals. It simply reduces the magnitude of the AC component, ripple voltage, by smoothing it to a near constant DC voltage (Wang & Lipo, 2017).

Smoothing Mechanism: When the pulsating DC voltage from the rectifier rises to its peak value, the capacitor charges rapidly, therefore drawing current from the rectifier. On the other hand, when the rectifier's output begins to fall, the capacitor's stored energy is discharged back into the circuit, thereby supplying current to the load. It continues to supply current until the rectifier's output voltage rises again to recharge it during the next cycle.

This continuous rapid charging and slow discharging fills in the dips between voltage peaks, therefore resulting in a much flatter DC voltage waveform. Our goal is to minimize the ripple. The amount of ripple voltage is inversely proportional to the capacitance value and load current. The ripple voltage is the small undesirable AC variation that remains superimposed on the DC output voltage after filtering. For a fixed load, a larger capacitance will store more charge and discharge more slowly, which will lead to a smaller ripple voltage and a smoother output

$$V_{ripple} = \frac{I_{load}}{2_{fC}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.1)$$

is the ripple frequency and I is the load current. A lower ripple voltage is very much needed due to the next component, which is the voltage regulator. The 7805 voltage regulator has a limited ability to suppress large voltage variations. It therefore provides a smooth, filtered input voltage to the voltage regulator that will thus allow it to function within its optimal range and ensure a stable final 5V output (Lee & Kim, 2020). Excessive ripple can also cause instability, noise and malfunctioning of the sensitive digital or analog components. By smoothing, we protect these devices by providing a stable DC base line.

Figure 2.4: Capacitor (Build Electronic Circuits, 2014)

2.1.4 VOLTAGE REGULATOR

This is the final component of the power supply circuit. The voltage regulator seen below in Figure 2.5 guarantees the precise and stable voltage required by the main electronic components. A voltage regulator is an integrated circuit designed to automatically maintain a constant output voltage regardless of variations in the current drawn by the load or changes in the input voltage.

The LM7805 is a positive linear voltage regulator that provides a consistent +5V DC output, which is mostly the standard operating voltage (Chan & Sin, 2019).

Operating Principle: The LM7805 belongs to the family of linear regulators. It operates based on the concept of negative feedback. The LM7805 contains an internal transistor that acts as a variable resistor connected in series between the input and output. It also has a fixed stable reference voltage and an error amplifier. The amplifier continuously monitors the actual output voltage and compares it to the reference voltage. If the output voltage tries to rise due to the input voltage increasing, the error amplifier reduces the conductivity by increasing the resistance of the series pass transistor. This increases the voltage drop, thereby bringing the output voltage back to 5V. On the other hand, if the load draws more current, which will cause the output voltage to fall, the error amplifier increases the conductivity by reducing the resistance of the series pass transistor, thereby bringing the output back up to 5V.

The input voltage range to the voltage regulator is from 7V to 35V. Small capacitors are needed for the voltage regulator's stability and performance. This is separate from the large capacitor filter. A non electrolytic capacitor is connected between the input and ground pins. It suppresses high frequency noise and it prevents the regulator from oscillating, especially if it is located far from the main capacitor filter (Tse & Ho, 2017). Another capacitor is connected between the output and ground pins. It is to improve the transient response and to reduce high frequency output noise. This regulator maintains stability by dissipating the excess input voltage as heat. Whatever is left after collecting the 5V from the rectifier is converted to heat. For this very reason, a heat sink is very necessary.

If the internal temperature exceeds the safety limit due to excessive heat dissipation, the circuit automatically shuts down to prevent permanent damage. It uses an internal current limiting mechanism that shorts the current to ground if it passes the safety limit. The voltage regulator provides the precise voltage needed and guarantees voltage fluctuations from the wall outlet do not affect its output voltage.

Figure 2.5: Voltage Regulator (Reef2Reef, Page 7)

2.2 THE BODY OF THE CIRCUIT

2.2.1 PASSIVE INFRARED SENSOR

This is the core component that defines the whole project. It is a highly effective low power device used to detect the movement of warm objects, typically humans or animals. A Passive Infrared Sensor is an electronic device that measures infrared light from objects in its field of view (Liu et al., 2021). It is called passive due to the fact that it does not emit its own energy, but instead, it passively detects the infrared radiation that is naturally emitted by all objects with temperature above absolute zero.

All warm blooded objects like humans emit thermal energy in the form of infrared radiation. The PIR sensor is made to be sensitive to this human body temperature range. The PIR module consists of two main parts.

2.2.1.1 The pyroelectric sensor:

This is the actual sensing element.The sensor seen below in Figure 2.6 is made of a crystal material that generates an electrical charge when exposed to infrared radiation. The sensor is divided into two separate, identical elements. They are wired in a differential configuration, meaning their outputs cancel each other out when they sense the same amount of infrared light. This means that when there is no movement, both slots receive the same amount of infrared radiation and thus the net output is zero.

On the other hand, when a warm body moves into the sensor's field of view, it first hits one slot, thereby causing a positive change in infrared levels. As the body moves across, it leaves the first slot and enters the second slot, thereby causing the first slot's infrared level to return to its room level and the second slot's own to spike. This results in a negative change. This rapid alternation between positive and negative signal patterns is what the sensor's circuitry interprets as motion

2.2.2 The Fresnel Lens, the white dome: This plastic cap that covers the sensor isn't just a protective cover; there is more to it. The array of small Fresnel lenses serve to concentrate and focus the infrared energy on to the small pyroelectric sensing elements, which will greatly increase the sensor's detecting range and sensitivity. More importantly, the lens divides the sensor's wide field of view into multiple detection zones. This grid forces the infrared pattern from a moving object to rapidly alternate between the two internal sensing elements, which is essential to generate the differential signal required for detection.

This pyroelectric sensor acts as the eyes of the system. It detects the presence of a person in a particular monitoring area both reliably and passively (Schmalzel & Rauth, 2005). This detection then generates an output, which is the input trigger to our main circuit.

Figure 2.6: PIR Sensor Module (Hackster.io, 2018)

2.2.3 CAPACITOR

The role of the capacitor in this position, circuit body, is to act as a DC block or AC coupling capacitor. A capacitor acts as an open circuit to DC, zero frequency (Wang & Lipo, 2017). Any unwanted DC offset voltage present at the source or at the output of a previous stage is blocked from reaching the op amp's non inverting terminal. The capacitor also acts as a short circuit to AC signals at the frequencies of interest. The desired signal component passes through to the op amp's input.

In high gain amplifier stages, even a small DC offset at the input can be amplified significantly, quickly driving the output of the op amp to saturation. The capacitor ensures the amplifier only processes the AC signal, keeping the output centered within the usable voltage range. When the capacitor is combined with the resistor that connects the non-inverting terminal to ground, the capacitor forms a basic RC high pass filter.

What basically happens is that for high frequencies, the impedance of the capacitor is low, therefore allowing the signal through to the op amp. On the other hand, the impedance becomes high for low frequencies, effectively blocking the signal. Placing only a capacitor isn't enough because an op amp requires a DC path for its input bias current. Real op amps draw a tiny amount of DC current into their input terminals. If the capacitor is the only path, it will slowly charge up until the voltage range for the input common mode is exceeded, this causes the op amp to malfunction or lock up. Due to this, we place a resistor from the non-inverting terminal to ground to provide a path for this tiny DC bias current to flow, ensuring the op amp is correctly biased.

2.2.4 OPERATIONAL AMPLIFIER

An operational amplifier is a high gain differential voltage amplifier. This means that it amplifies the difference in voltage between its two inputs. Two rules that are referred to as golden rules that are followed by an op amp are:

I. The voltage rule, virtual short. Due to the fact that an op amp has nearly infinite open loop gain, the output attempts to keep the voltages at the two terminals equal.

II. The current rule, high impedance. The op amp's inputs have infinite impedance, which means that absolutely no current flows into or out of the input pins.

In our circuit, the non inverting op amp was used. The signal from the output of the sensor is connected through a capacitor directly to the non-inverting terminal of this amplifier. The output of a non inverting op amp is always in phase with the input. The voltage gain is always greater or equal to one. The gain of the amplifier is set by adjusting the resistance of the feedback resistor and the resistor connecting the inverting terminal to ground (Franco, 2015).

The output voltage is simply the input voltage multiplied by the gain. And the gain is simply one plus the feedback resistor over the grounded resistor.

$$V_{out} = V_{in}\left(1 + \frac{R_f}{R}\right)\text{..............................}(2.2)$$

When a sensor has a naturally high output impedance, connecting it to a circuit with low input impedance causes a significant voltage drop (Asuhaimi & Rahim, 2018). This loss of signal strength is called loading. The non-inverting amplifier draws almost no current, which therefore ensures that the sensor's full voltage is passed on to the amplifier stage. This preserves the strength of the original signal.

An Operational amplifier is seen below in Figure 2.7.

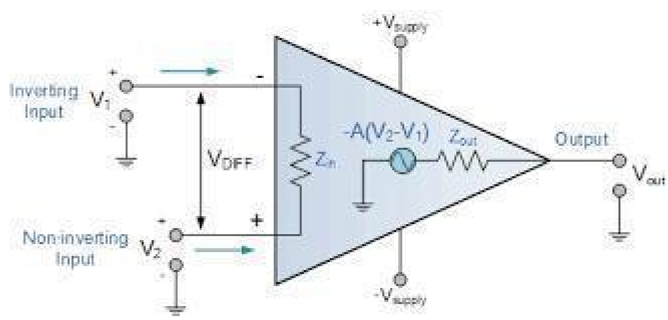

Figure 2.7: OP Amplifier (Ariat-tech.com, 2024)

2.2.5 FEEDBACK RESISTOR

The purpose of this resistor is to implement negative feedback, which is what converts the unpredictably high op amp gain to a predictable and stable outcome (Chen & Luo, 2018). The feedback resistor connects the output back to the inverting input, thereby feeding a portion of the output signal back to oppose the input signal. What then happens is that the negative feedback dramatically reduces the overall gain, making it stable and predictable. While the feedback resistor provides the necessary negative feedback to stabilize the circuit, the second resistor works in hand with it to determine the overall gain (IEEE, 2017).

2.2.6 GROUND (The Universal Reference Point)

It is the designated reference point in an electrical circuit from which all other voltages are measured (Morrison, 2016). It is fundamentally defined as having zero potential. Current must flow in a complete loop and ground provides a common return path for current flowing out of a power source, through the various components, and back to the source (Ott, 2018). Ground is the indispensable zero volt anchor that defines all voltage levels and provides the necessary current return path for the circuit to function correctly.

2.2.7 COMPARATOR

A comparator is an electronic circuit that is often based on an operational amplifier, operating without negative feedback, as shown below in Figure 2.8. It compares two analog input voltages and produces a digital output representing which of the two inputs is greater (Baker, 2016). The comparator serves as the crucial bridge between the amplified analog signal and the final digital control stage. It is the component that makes the definite final decision as to whether the alarm should be activated or not.

The comparator functions by taking advantage of the extremely high internal voltage gain characteristic of the op amp architecture. Even a very small voltage difference between the two inputs is instantly magnified, which will drive the comparator output to its maximum limit. The amplified sensor signal is connected to the non-inverting input of the comparator. This is the voltage level that represents the detected motion. The threshold voltage is connected to the inverting input of the comparator. It acts as a pre-set minimum level of required motion to trigger the circuit. Due to this comparator, small voltage fluctuations or weak distant signals are ignored. This prevents false triggers and it ensures the system only reacts to strong and intentional motion. This makes the alarm reliable (Slimani & Benslama, 2021).

Another benefit of this comparator is that it produces a sharp clean transition from zero to maximum whenever motion is detected. Due to the voltage divider at the threshold, adjusting the sensitivity of the system is made very easy.

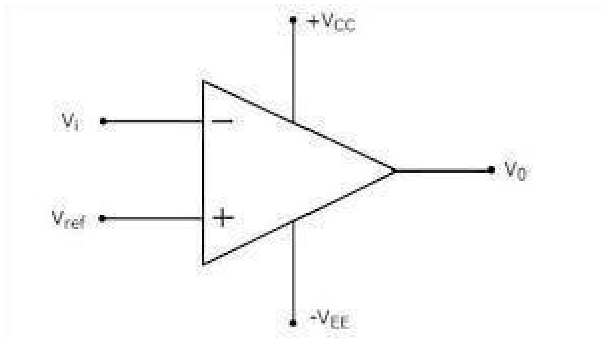

Figure 2.8: Comparator (TutorialsPoint, n.d.)

2.2.8 PIR CONTROLLER (BIS0001)

It is a specialized integrated circuit that serves as a dedicated micro power controller for Passive Infrared, or PIR, motion sensing systems. It's essentially a complete signal processing solution housed within a single chip, designed to manage the entire process from detecting a thermal change to outputting a clear digital trigger.

2.2.8.1 Core Functionality and Internal Structure

The primary job of the BISS0001 is to take the weak, high impedance electrical signal generated by a PIR sensor element and turn it into a reliable, logic-level output. This is accomplished using several integrated blocks. It contains sophisticated operational amplifiers or op amps that provide the necessary high gain and filtering to take the tiny, noisy analog voltage from the sensor and boost it significantly. This ensures that the circuit can differentiate a true thermal change, like a person moving, from background electrical noise.

2.2.8.2 Managing the Output Signal

Once the amplified signal crosses a certain threshold, indicating valid motion, the chip's internal digital logic takes over. This logic includes built-in, adjustable timing circuits. You control these timings by connecting external resistors and capacitors to specific pins on the chip.

Delay Time (Tx): This timer determines the duration that the output signal remains high after motion is first detected. This controls how long your connected device, like a light or an alarm, stays on.

Inhibit Time (Ti): This is a small, necessary "dead time" where the chip ignores new triggers immediately after the output has gone low. This prevents the system from rapidly re-triggering due to the slight electrical settling or environmental fluctuations after the event ends, ensuring a stable operation.

The BISS0001 offers flexibility by supporting both retriggerable and non-retriggerable modes. In the retriggerable mode, any new motion detected during the ON cycle will reset the delay time, keeping the output high. In the non-retriggerable mode, once the output goes high, it must complete the entire delay cycle before it can be triggered again. This combination of internal amplification and flexible timing makes the BISS0001 the go to component for simple, effective, and low power motion detection.This controller is shown below in Figure 2.9.

Figure 2.9: PIR Controller (Rare Components, n.d.)

2.2.9 TRANSISTOR

A transistor is a three terminal semiconductor device primarily used for amplification and electronic switching as shown in Figure 2.10. In this project, it is being used as a switch. The transistor acts as the interface between the low power logic signal and the high power component that it needs to control, which is the relay. The output of the comparator is connected directly to the base of the transistor (Neamen, 2017).

When the comparator output is low, this zero voltage goes to the base of the transistor and the transistor acts as an open circuit, which causes the relay to remain deactivated. When a high output is taken to the base terminal, the transistor acts as a closed circuit, therefore activating the relay. It is impossible to connect the comparator's output directly to the relay coil. The transistor isolates and protects the sensitive low power circuitry from the relay's operational hazards. The transistor ensures the relay is switched reliably and safely, effectively converting the motion detection logic into a physical control action (Neamen, 2017).

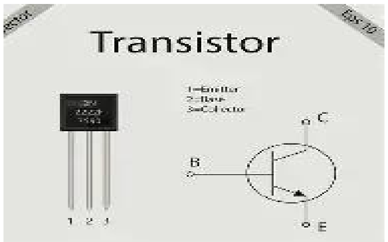

Figure 2.10: Transistor (Artem Oppermann, Built in)

2.2.10 FLYBACK DIODE

This diode seen in Figure 2.11 is placed parallel across the relay coil. It is one of the most important protective components in the entire control circuit (Sato & Arakawa, 2017).

The transistor is active as a closed switch, and current is flowing steadily through the relay coil, creating a magnetic field. The diode is connected in reverse bias across the coil. Because it is reverse biased, it does not conduct and has no effect on the normal operation of the circuit.

When the comparator output goes low, the transistor instantly cuts off, thus interrupting the current flowing in the coil. The coil fights this sudden current change by instantly reversing the polarity of the voltage across its terminals. This generated voltage is known as back EMF and it can be many times the magnitude of the supply voltage, hundreds of volts. This spike is capable of permanently destroying the transistor (Wassell, 2018).

This is where the fly back diode comes in. Immediately the polarity reverses, the diode becomes forward biased. It immediately begins to conduct, creating a short circuit path for the inductor's stored energy to safely circulate through the coil itself. Through this, the harmful voltage spike is dropped to a safe level, preventing it from ever reaching the transistor.

Figure 2.11: Diode (Flux AI, 2023)

2.2.11 RELAY

The relay shown in Figure 2.12 serves as the physical switch that activates the actual alarm. It is an electromechanical switch. It consists mainly of the coil and contacts. The coil is the control side of the relay. It is an inductor and it is connected directly to the output of the transistor. The contacts are on the load side of the relay, where the actual switching action takes place (International Electrotechnical Commission, 2018).

The magnetic field created by the energized coil attracts a metal arm, called the armature, which mechanically moves the contacts. When the transistor turns on, the coil energizes, the contacts switch position and complete the separate high power circuit to sound the alarm.

Due to the coil side being completely separate from the contact side, surges and spikes are prevented from affecting the alarm (Han et al., 2019). The relay also helps in power amplification. A small current is now used to control a much larger current at the contacts. This relay is the final component that translates the purely electronic detection of motion into a robust, physical action.

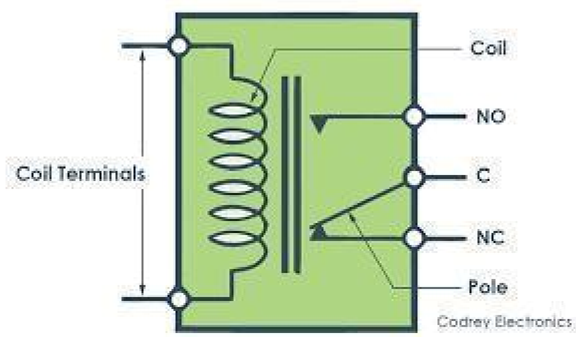

Figure 2.12: Relay (Codrey Electronics, 2020)

2.2.12 BUZZER

The buzzer shown in Figure 2.13 is an audio signaling device (Rahman & Islam, 2021). Its purpose is to convert the electrical signal produced when motion is detected into a loud sound which would immediately alert users. Without motion detection the buzzer remains silent (Kim et al., 2018). When motion is detected and the relay is activated, the alarm begins to sound loudly. The buzzer is an audible indicator of motion

Figure 2.13: Buzzer (Biggan Project, n.d.)

CHAPTER 3

DESIGN METHODOLOGY

3.1 INTRODUCTION

The purpose of this chapter is to provide details on the engineering methodology, the design and the implementation of the project. It is going to give a clear overview on the why's and how's of the project.

In chapter 2, the theoretical concepts of each component were clearly examined. That laid a solid foundation for this chapter. We are going to analyze each component's use to the entire project and how it contributes to it. There was a reason for us choosing each and every component in the system and each component has a mathematical contribution to the system. Each component has its individual parameter and these parameters are very important in achieving our goal. Our system is a very sensitive one and the component parameters are very necessary in ensuring precise and accurate performance The steps taken to achieve our project will be detailed on to the latter and necessary evaluations will be shown

3.2 POWER SUPPLY UNIT

The first thing to be created is the 5V power supply. This power supply is going to power the infrared sensor, Operational amplifiers, Comparator and even the relay. The power to run this system is literally this unit. In this unit, there are several components that are in it and they will be analyzed below.

I. **AC source**:

This is simply the power from the wall socket. We are doing our calculations with an AC voltage of 230V to 220V. This 230V is what is translated straight to the step down transformer.

II. **Step down transformer**:

This transformer is going to step down the high AC voltage from the AC source to a lower voltage that can be easily rectified. To know the amount of voltage the initial voltage will be stepped down to the turns ratio of the transformers of great importance for this project, we are using a transformer with a turns ratio of 220V/12V.

Since we are expecting an AC voltage with the range of 230V to 220V, We will calculate the stepped down voltage of the 230V and 220V.

The formula relating turns ratio and voltage is as follows in the equation below.

$$\frac{N_p}{N_s} = \frac{V_p}{V_s} \text{ ....(3.1)}$$

Where,

N_s = Number of turns on the secondary coil

N_p = Number of turns on the primary coil

V_s = Voltage on the secondary side of the transformer

V_p = Voltage on the primary side of the transformer

Using the necessary parameters, we get the equation below.

$$\frac{220}{12} = \frac{230}{V_s} \text{ .... (3.2)}$$

Therefore, the voltage at the secondary side of the transformer becomes

V_s = 12.545V

Using the same formula, the output voltage with an input of 220V will give 12V.

Meaning that with an input AC voltage from 220V to 230V, we get an output voltage with the range from 12V to 12.545V.

The voltage that we calculated above is the rms voltage and not the voltage we'll use to continue calculation.

To continue our calculation, we'll use the peak voltage. The formula for calculating the peak voltage is given by the Equation below.

$$V_s \times \sqrt{2} = V_{peak} \text{ ....3.4}$$

With the above, the peak voltage becomes,

V_{peak} = 17V to 17.74V

III. Rectifier:

The output from the transformer is passed through the rectifier to convert the AC Voltage into a DC Voltage. During the process of rectification, loss is encountered. Due to the diodes used, we experience diode losses. For the silicon diode used, we will experience a loss of 0.7V per diode. Due to the configuration of the rectifier, only two diodes work at a time leading to a loss of

$0.7 \times 2 = 1.4V$

We now subtract this diode loss from the peak voltage in order to get the value of the DC voltage at the output of the rectifier.

Therefore,

DC voltage $= (17 - 1.4)$ to $(17.74 - 1.4)$ Volts

DC voltage becomes from 15.6V to 16.34V

IV. Voltage Regulator:

This is the component that regulates our input DC voltage to 5V. Although it solves a great deal of problem, an important note to take in is that the LM7805 has a range of input DC voltage that it works for. What this means is that it doesn't just perform its magic for any given value of input DC voltage, it works for a range of 7V to 35V.

With the input voltage coming from the rectifier within the range of 15.6V to 16.34V, the LM7805 will successfully regulate the voltage to our expected 5V.

V. PIR Sensor(RE200B):

Figure 3.1 shows the device that directly senses the motion and releases an output voltage. From the datasheet of the sensor being used, an estimated maximum noise output of 250mV is given. This means that even when no motion is sensed we can experience an output voltage of 250mV. Also, the voltage range of actual motion sensing operation is from 2.5V to 4V.

3.3 Electrical and Signal Conditioning Plan

The RE200B is a sophisticated sensor using an internal Field Effect Transistor (FET) set up as a source follower. This setup is essential for buffering the high resistance signal produced by the pyroelectric materials.

1. ***Source Follower and Power Needs***

The source follower circuit is the first step,giving a low resistance output signal.

· *Operating Voltage (V_d)*: The system must deliver a DC voltage between 3V and 10V to the Drain (Pin 1). Supplying 5V is a common choice, as shown in the measurement circuit.

· *Source Resistor (R_s)*: A resistor (R_s) of 47 kΩ must be connected between the Source (Pin 2) and the Ground (Pin 3) to set the FET's basic operating level.

· *Source Voltage (V_s)*: The resulting DC voltage at the Source (Pin 2) must be checked to ensure it is within the specified range of 0.3V to 1.5V (when $V_d = 5V$ and $R_s = 47k\Omega$). This DC level is the resting point, and the changing signal rides on it.

2. ***Amplification and Signal Strength Control***

The raw signal coming from the source follower is very weak and needs strong boosting.

· *Signal Output (Vpp)*: The sensor gives a minimum Signal Output of 2.5 V_{p-p} (typically 4.0 V_{p-p}) when tested under specific conditions (chopper frequency of 1 Hz, 420 K black body emission of 13 μW/cm²) and connected to a high gain amplifier.

· *Noise Control*: The signal boosting circuit must be designed with low noise electronic parts and proper shielding to keep system interference below the sensor's specified maximum Noise Output of 250 m V_{p-p} (typically 90 mV_{p-p}).

· *Differential Signal Integrity*: The sensor is a Balanced Differential (Series Opposed Type). The signal processing should use a differential amplifier to process the difference between the two pyroelectric elements. This effectively cancels signals that are common to both elements, such as temperature drift, greatly improving the quality of the signal.

3. *Filtering and Frequency Range*

Pyroelectric sensors react to changes in infrared energy, not the steady amount, which explains the frequency dependent response.

. *Bandpass Filtering*: The signal preparation circuit must use a filter that matches the sensor's working Frequency Response of 0.3 Hz to 3.0 Hz (± 10 dB).

. *High Pass Filter (HPF)*: A cut on frequency around 0.3 Hz blocks very slow temperature changes (drift) that could be mistaken for movement.

. *Low Pass Filter (LPF)*: A cut off frequency around 3.0 Hz rejects high frequency interference and optimizes the signal quality for detecting human motion (which usually happens between 0.5 Hz and 2 Hz).

3.4 Optical System and Sensing Plan

The optical parts determine how well the sensor can "see" a target.

1. Field of View (FoV) Arrangement

The final detection pattern of the system is set by the external lens (often a Fresnel lens) that focuses infrared energy onto the two elements.

. *Angular Limits*: The sensor's own field of view is 138° on the X axis and 125° on the Y axis from the element center. The lens is used to create specific, interconnected detection zones within this area.

. *Element Geometry Mapping*: The lens must precisely focus infrared radiation onto the two sensitive areas: 2.0 mm long, 1.0 mm wide, and 1.0 mm apart.

When a heat source moves across the element boundary, one element (A) warms up while the other (B) cools down, creating the alternating positive and negative signal pulses that signify motion (a balanced differential signal).

2. ***Spectral Filter***

The ***built-in filter*** is a passive component that sets the sensor's working wavelength range.

· *Filter Materia*l: The filter uses Silicon.

. *Transmission Window*: It is transparent in the 7 to 14 µm range, with an average light passage of ≥ 70%. This range is vital because it matches the peak radiation of objects at human body temperature (about 310 K).

.

3.5 Environmental and Physical Integrity

The physical build must shield the sensitive pyroelectric material.

. *Sealing*: The sensor is a TO 5 metal can and is designed to be hermetically sealed. The system design must ensure this seal is not broken, as it is specified to withstand a vacuum.

· *Operating Conditions*: The sensor will work reliably in tough conditions:

. *Operating Temperature*: -30°C to +70°C.

. *Humidity*: Up to 90 to 95% RH at 30°C continuously without added noise.

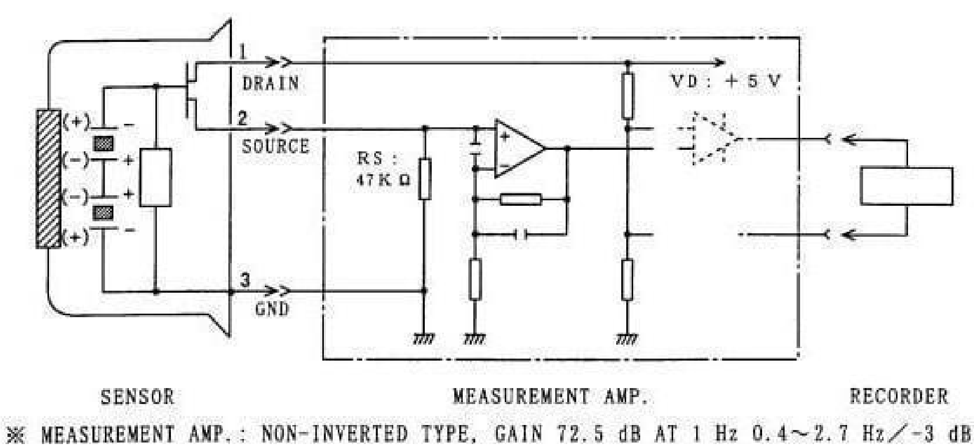

Figure 3.1: PIR Sensor Module from (*Specification of RE200B* (p.5), by Nippon Ceramic Co.Ltd., 1998

VI. BIS00001 PIR CONTROLLER:

This is the body of the circuit that encompasses the comparators and operational amplifiers. This is the stage that amplifies the raw input signal gotten from the PIR Sensor and compares it to a particular threshold voltage. This threshold voltage is set in a way noise is accounted for and is not able to trigger an alarm. The alarm only triggers when there is an actual motion detected.

a. OP-Amplifier:

The way a non-inverting operational amplifier works is that it amplifies an input voltage connected to the non-inverting terminal of the operational amplifier by a particular gain.

The gain is set by changing the feedback resistor and grounded resistor values as seen in the equations below.

$$\text{Gain} = 1+\frac{R_f}{R_1} \text{ ………………….}(3.5)$$

$$V_{out} = V_{in} \times \text{Gain ……………}(3.6)$$

Example

When we have an input voltage of 4V and we want to get an output of
8V. Therefore;

$8\text{v} = 4\text{v} \times (1+\frac{R_f}{R_1})$

We can clearly see that we need to get R_f equate to 1. Therefore, R_f and R_1 are equal to each other. Assuming a resistance of 10kΏ, the 8v is achieved.

b. Comparator:

This part compares the output voltage of the sensor to a particular threshold voltage in order to determine whether motion was made or not. The threshold chosen plays a major part in the amount of impact noise can make on the sensor.

In the **BIS0001** controller, the operational amplifiers and comparator are embedded in it making the detection more accurate. The operation can be broken down into parts;

3.6 Power Supply and Stabilization Design

The first step guarantees a stable power foundation for the entire circuit.

I. **Voltage Regulation (The HT7133)**:

The HT7133 (U1) is designated as the Low-Dropout (LDO) Linear Regulator. Its function is to convert the raw, potentially unstable battery voltage (e.g., 6V) into the precise operating voltage required by the BISS0001 (3V to 6V, typically 5V). A stable DC voltage is non-negotiable for the sensitive analog stages of the controller.

II. **Power Filtering and Decoupling**:

Decoupling capacitors are placed on the input and output of the HT7133 and near the VDD pin of the BISS0001. These capacitors filter out high-frequency noise and absorb voltage spikes. This prevents electrical noise from polluting the supply lines, which could otherwise be amplified by the internal op-amps and cause false motion triggers.

Sensor Input and Signal Conditioning

This stage focuses on preparing the raw motion signal for the controller.

I. **The PIR Sensor Signal**:

The PIS209S generates a tiny, differential AC voltage signal upon motion. This signal is routed to the BISS0001's first-stage amplifier inputs (1IN+ and 1IN-).

II. **Signal Bandwidth Filtering**:

The RC network connected at the input pins (1IN+ and 1IN-) constitutes a crucial Band-Pass Filter. Its design parameters are selected to:

i. **Pass**: Frequencies corresponding to human movement (typically 0.1 Hz to 10 Hz).

Block: Extremely low-frequency DC drift (caused by ambient temperature changes) and high-frequency electronic noise. This step ensures that only genuine motion signals are presented to the internal, fixed-gain op- amps, maximizing the controller's noise immunity.

Core Controller Configuration and Timing:

The external components shown in this stage represented by Figure 3.2 below are used to define the core operational parameters of the BISS0001, as per its internal design.

A. **Sensitivity Setting (The IB Pin)**:

The IB (Input Bias) pin is explicitly designated for Op-amp Input Bias Current Setting. The external resistor (RB, Pin 10) connected from this pin to ground dictates the bias current for the internal op-amps.

· *Action*: Adjusting the value of RB (usually in the mega-Ohm range, e.g., 1 MΩ) directly controls the operating point and overall gain of the amplifier stages.

· *Result*: A higher RB value typically increases sensitivity (making the chip more likely to trigger on small movements), while a lower value decreases sensitivity (increasing noise immunity). This resistor is the primary external control for system sensitivity.

B. **Output Pulse Width (Tx)**:

The Tx time, which sets how long the output remains active, is determined by the external RR1 and CR1 components. The designer selects the required active time and uses the formula to calculate the component values.

C. **Trigger Inhibit Time (Ti)**:

The Ti time, which sets the mandatory "dead time" after the output turns OFF, is determined by the external RR2 and CR2 components. This time is crucial for allowing the circuit and the controlled load to settle completely before the next detection is allowed.

· D. **Mode and Disable Control**:

· *Pin A (Retriggerable Mode)*: This pin sets the chip's core logic. It must be tied either to VDD (for continuous re-triggering) or to VSS (for fixed time operation).

· *Pin VC (Trigger Disable)*: This pin is used to externally inhibit the trigger. It can be used to connect a Light-Dependent Resistor (LDR) circuit to disable the PIR function during daylight hours, saving power and preventing unnecessary activation.

·

Output Stage and Load Interfacing

The final design stage focuses on translating the BISS0001's low-current signals into control for high-power devices.

· *Relay Driver Circuit*: The output signal from the VO pin (or 1OUT) is a low-power digital signal. It is essential to connect this pin to the base of a Transistor (Q1), which acts as a switch. The transistor drives the coil of an electromechanical relay, which is capable of safely switching the high AC or DC currents required by devices like light bulbs or alarms.

· *Auxiliary Output (Buzzer)*: The secondary 2OUT pin provides an independent signal for an auxiliary device, typically a buzzer. This output is designed to be active simultaneously with the main output and is often connected directly (via a current-limiting resistor) or through a small driver transistor to the buzzer.

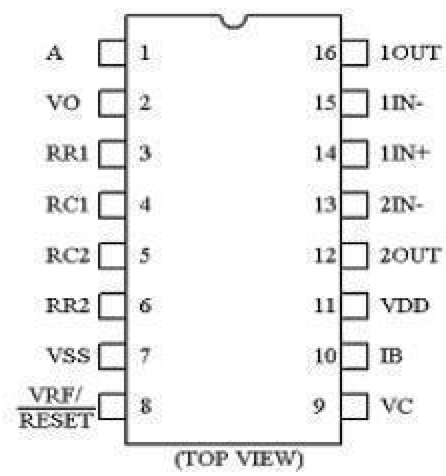

Figure 3.2: PIR Controller Circuit (*Specification of RE200B*, by Nippon Ceramic Co.Ltd., 1998)

VII. RELAY:

The relay is designed to isolate the low-voltage control circuit from the high-voltage/high-current load (the buzzer), acting as the switch for the alarm.

· ***Define Load Specifications***:

The first step is to accurately identify the electrical parameters of the component the relay will control, which is the buzzer. Specifically, determine its required operating voltage (AC or DC) and its maximum current consumption.

· ***Select Relay Components***:

Choose a relay with contact ratings that safely exceed the buzzer's voltage and current requirements (e.g., a 250V AC / 10A contact rating). Simultaneously, select a coil voltage (e.g., 5V or 12V DC) that is compatible with the system's low-voltage power supply and driver circuit.

· ***Design the Coil Driver Circuit***:

A microcontroller cannot supply the current needed to energize the relay coil. Therefore, a separate switching element, such as a Bipolar Junction Transistor (BJT) or a MOSFET, must be used to drive the coil.

· ***Calculate Control Resistor (R_b)***:

For a BJT driver, calculate the value of the base resistor (R_b) to ensure the transistor is driven into saturation (fully ON) with the maximum safe current from the microcontroller pin. This guarantees the coil receives its required current.

· ***Integrate Fly back Protection Diode***:

This is a crucial safety step. Place a fly back diode (also known as a freewheeling diode) in reverse-bias directly across the relay coil. The diode dissipates the high-voltage Back-EMF spike generated when the coil is rapidly switched OFF, protecting the switching transistor from destruction.

· ***Test Switching Reliability***:

Validate the design by sending a signal from the control circuit to the driver. Confirm that the relay coil reliably energizes and de-energizes, and check the temperature of the switching transistor.

VIII. **BUZZER**:

· ***Establish Acoustic Requirements***: Determine the necessary sound characteristics for the alarm system. This involves defining the required Sound Pressure Level (SPL), measured in decibels (dB), which dictates the loudness, and the preferred sound frequency or pattern.

· ***Choose Buzzer Type***: Based on the loudness and power requirements, select the appropriate buzzer:

· For a high-power security alarm, an AC Buzzer is typically chosen, which requires the relay switching circuit.

· For a simple tone and lower power, an Active DC Buzzer (which only needs DC power) or a Passive DC Buzzer (which requires a PWM signal for tone generation) can be used.

· ***Confirm Electrical Ratings***:

Identify the precise operating voltage and current consumption of the chosen buzzer. This ensures the upstream power supply and the switching mechanism (the relay) are correctly rated.

· ***Implement Activation Control***:

· If using an AC Buzzer, the final activation circuit is the relay contact closure.

· If using a low-power DC Buzzer, a dedicated transistor circuit is designed to directly switch the buzzer (though sometimes a low-current buzzer can be driven directly by a microcontroller pin with a series resistor).

· ***Ensure Safety and Isolation***: For high-voltage AC Buzzers, strictly adhere to safety standards by ensuring physical separation and proper insulation between the high-voltage circuitry (buzzer and relay contacts) and the low- voltage control electronics.

· ***Verify Audible Performance***: The final step is to test the system's response. Trigger the alarm and verify that the buzzer produces the expected high-decibel sound immediately and reliably through the completed switching circuit.

3.7 BLOCK DIAGRAM

The Figure 3.3 below shows a block diagram explaining the mode of operation of the Passive Infrared motion sensor.

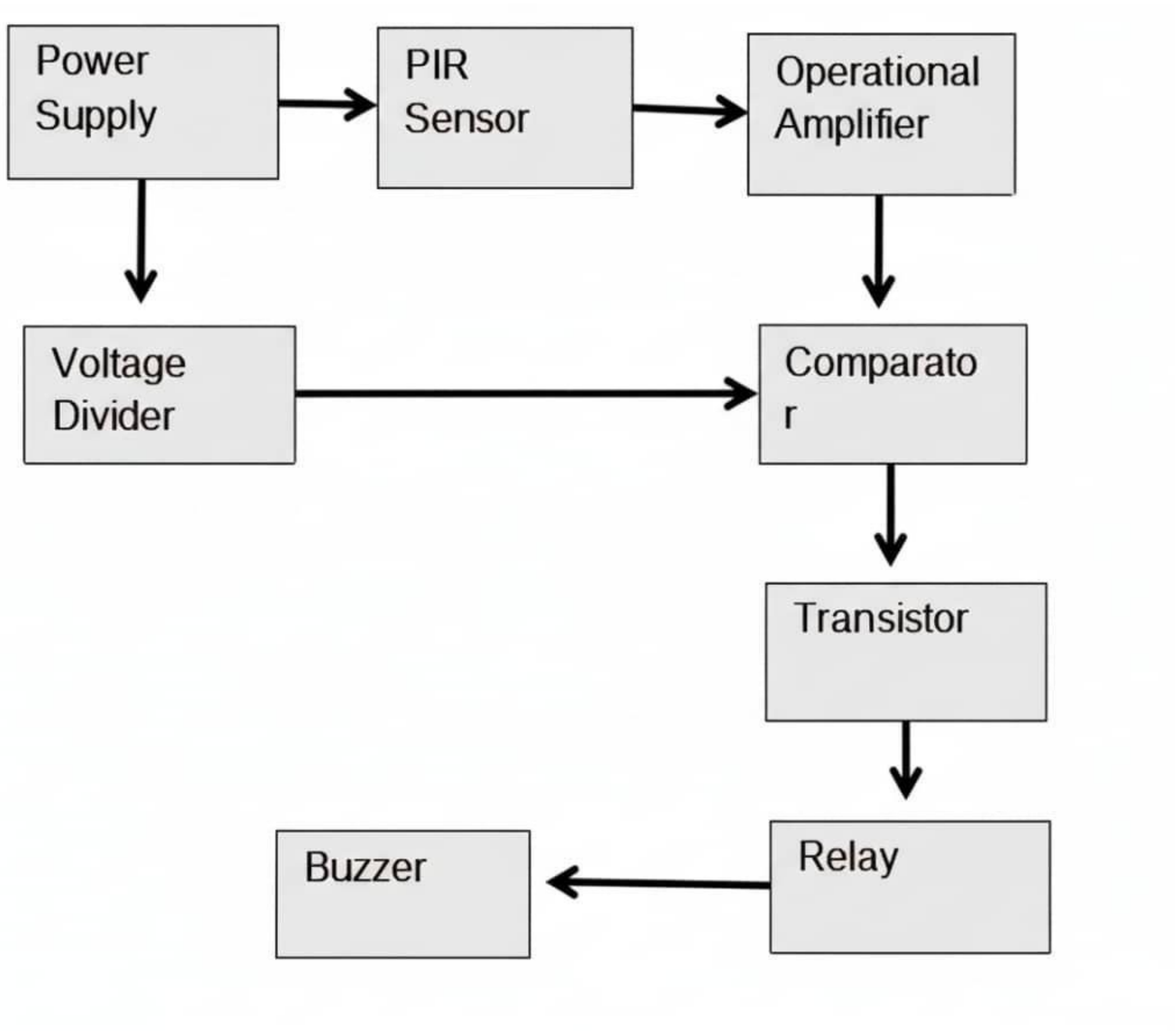

Figure 3.3: Circuit block diagram

3.8 CIRCUIT DIAGRAM

The Figure 3.4 below shows the circuit diagram of the power supply unit and the Passive Infrared Sensor.

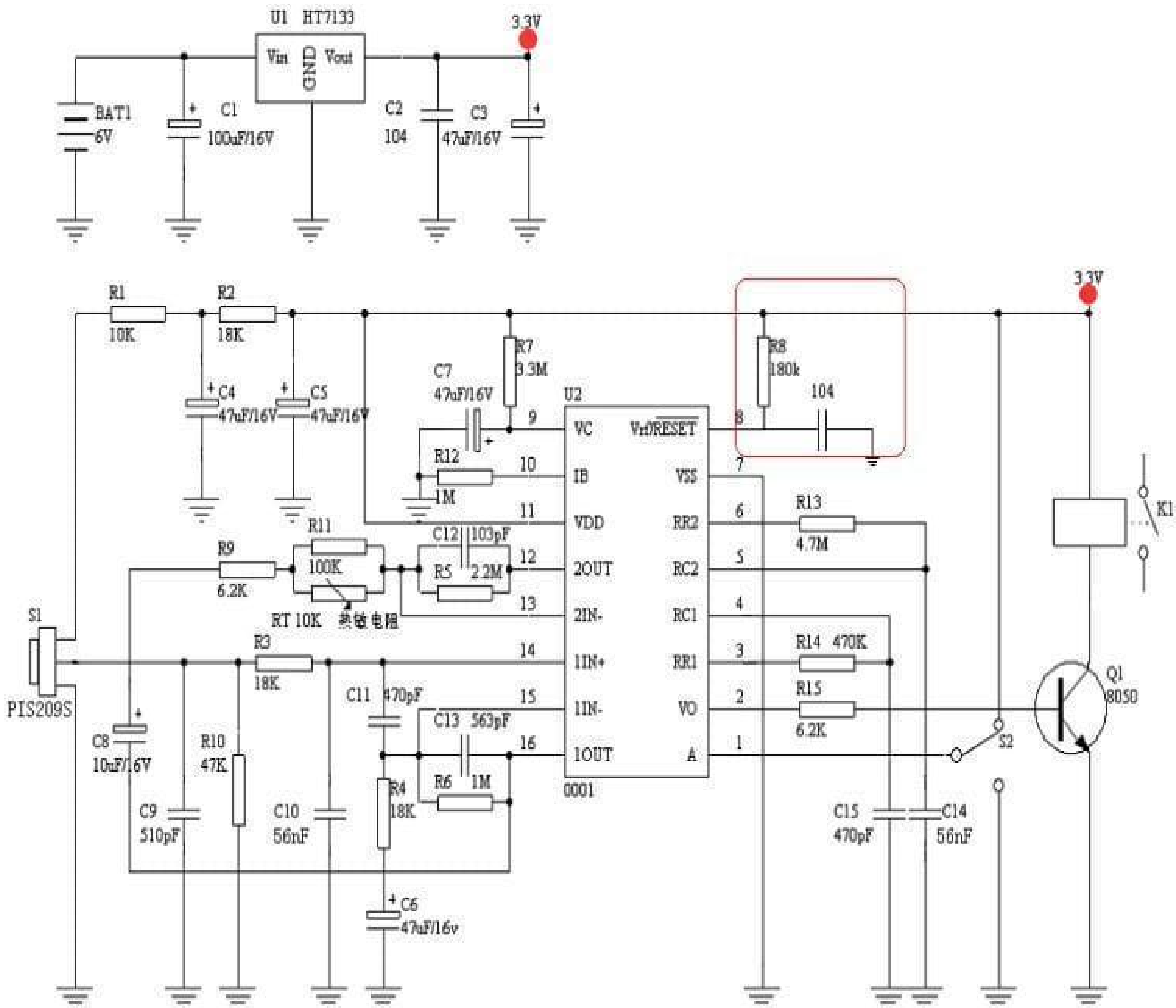

Figure 3.4: Circuit Diagram (*Specification of RE200B* , by Nippon Ceramic Co.Ltd., 1998)

3.8.1 WORKING PRINCIPLE

The way the sensor works is that it is firstly powered by the power supply unit of the system. This system is plugged directly to the wall socket and the AC Voltage is stepped down through a step down transformer. This stepped down voltage is then passed through a rectifier to convert it to a DC voltage.

The resulting output voltage is then filtered to improve stability and passed into a voltage regulator which regulates it down to 5v. The output of this power supply unit is what powers the relay, sensor and operational amplifiers.

The device directly sensing the change in infrared light in the environment has three terminals. It is powered through one, grounded through one and the output voltage is collected through the last one.

This output voltage is amplified by operational amplifiers then compared to a particular threshold voltage to determine whether motion is detected or its just noise. When the amplified output voltage of the sensor is less than the threshold voltage, the output of the comparator reads low, signifying no motion detected.

When the amplified output of the sensor is higher than the threshold voltage then the comparator reads high which then turns on the transistor.

When the transistor is turned on, we get a potential voltage across the coil of the relay which leads to the buzzer getting powered and the alarm loudly ringing.

The PIR controller in this system (BIS0001) encompasses the operational amplifiers and the comparator. The output of the sensing device is connected directly to this controller which performs the amplification and comparison operation of the system.

3.9 FLOW CHART OF THE SYSTEM

Figure 3.5 below shows the flow chart describing the processes passed through to achieve the final result of sensing a nearby object.

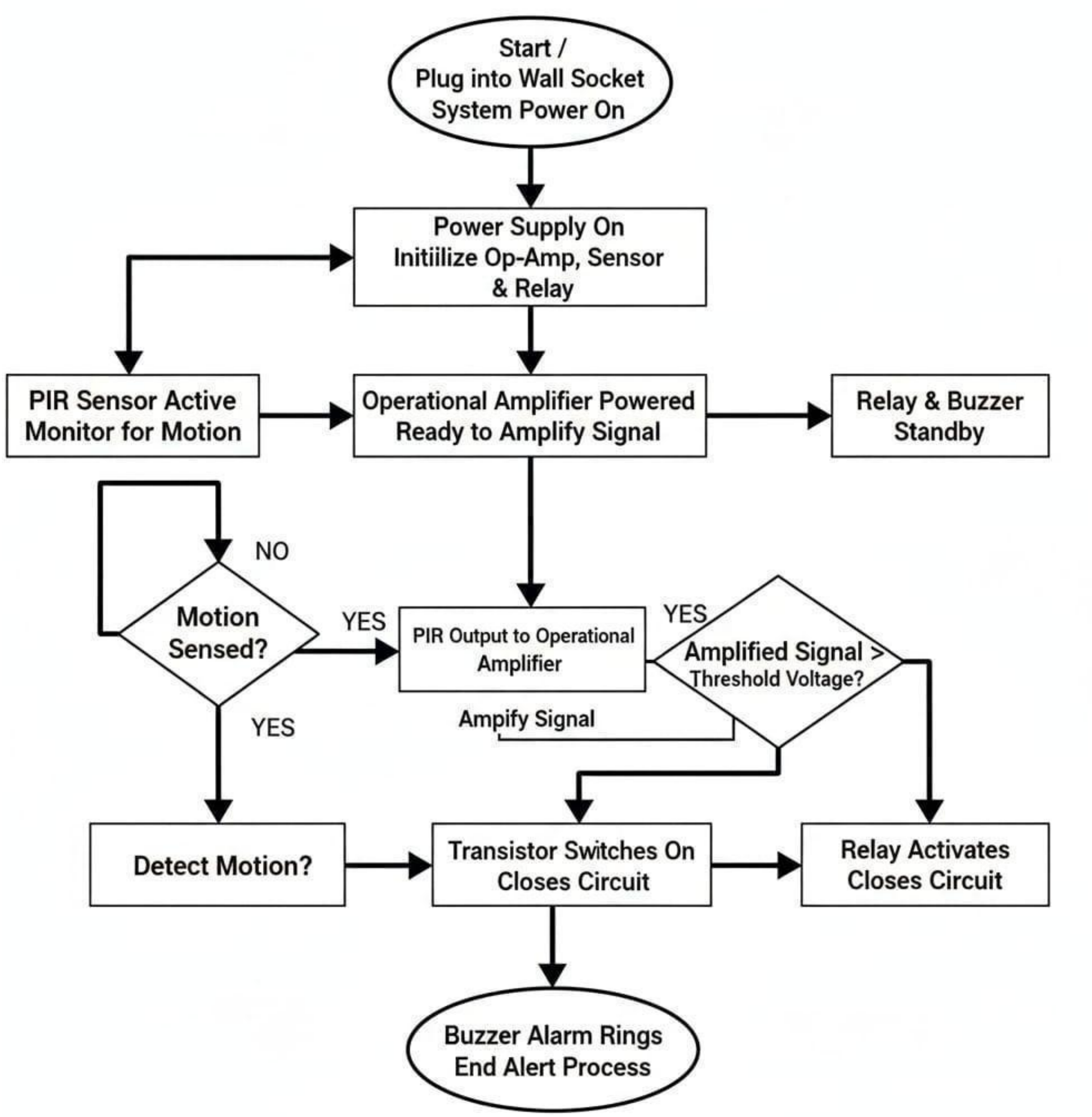

Figure 3.5: Flow Chart

FLOW CHART BREAKDOWN

Initialization: The system starts when plugged into a wall socket, powers on, and initializes the power supply, operational amplifier (Op Amp), sensor, and relay.

Monitoring: The PIR sensor becomes active and monitors for motion. Simultaneously, the operational amplifier is powered and ready to amplify a signal, while the relay and buzzer are in standby mode.

Motion Detection: If no motion is sensed, the system continues monitoring.

If motion is sensed, the PIR output is sent to the operational amplifier.

Signal Amplification and Alert: The Op Amp amplifies the signal.

A decision is made: is the amplified signal greater than a set threshold voltage?

If YES (motion detected): A transistor switches on, closing a circuit, which activates the relay, closing another circuit. This causes the buzzer alarm to ring, ending the alert process.

If NO (no motion detected, possibly a false trigger or insufficient signal strength): The system goes back to the "Detect Motion?" decision point.

CHAPTER 4

CONSTRUCTION, TESTING AND RESULTS

This chapter details the successful transition of the theoretical design concepts into a functional, physical prototype. Following the component selection and circuit design established in Chapter Three, this section focuses entirely on the construction, rigorous testing, and analysis of the final results obtained from the Passive Infrared (PIR) motion sensor system.

The chapter begins by describing the step-by-step process of physically assembling the circuit components, highlighting the challenge of integrating the sensitive PIR detection stage with the independently built multi stage power supply. This is immediately followed by the methodology used for the system testing, which was designed to validate key achievements such as the 360° field of view and the functionality of the custom adjustable sensitivity and range.

Finally, the chapter presents and analyzes the results, demonstrating that the prototype successfully meets all stated project objectives, including reliable motion detection and alarm activation. It concludes by evaluating the overall performance, cost effectiveness, and practical applications of the constructed device, confirming its potential as an energy efficient and low cost security solution.

Figure 4.1 below shows the enclosure of the constructed PIR Sensor.

Figure 4.1: PIR Sensor frame

4.1 Step by Step Circuit Assembly

The physical construction of the project involved translating the circuit design into a functional prototype using various electronic tools and assembly techniques as seen in Figure 4.2. The following tools were essential to the process:

Soldering Iron and Solder Wire: These were used to create permanent, low-resistance electrical connections between the components and the perfboard.

Digital Multimeter: This tool was critical for verifying the power supply. It was used to ensure the output of the 7805 regulator was a steady 5V before connecting the BISS0001 controller.

Wire Strippers and Side Cutters: These were used to prepare the jumper wires and trim component leads to keep the circuit layout clean and minimize noise.

Solder Sucker (Desoldering Pump): This was used to correct wiring errors and swap out resistors during the calibration of the system's sensitivity.

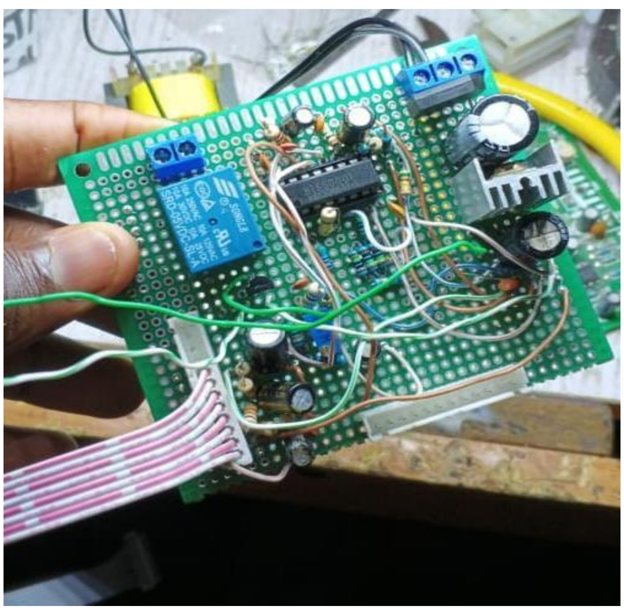

Figure 4.2: Internal circuitry of the power supply and PIR sensor

4.2 Assembly Procedure

Power Supply Construction: The 220V AC mains was connected to the step down transformer. The 12V AC output was then fed into the bridge rectifier and smoothed by a large capacitor to create a stable DC baseline.

Control Stage Integration: The BISS0001 IC was soldered to the board, and the PIR sensor (RE200B) was connected to the input pins. Timing capacitors and resistors were added to set the alarm duration.

Output Interface: The control signal was wired to the base of an NPN transistor, which acted as a switch to energize the 5V relay coil.

Final Housing: The entire circuit was mounted into a plastic enclosure as seen in Figure 4.3. The Fresnel lens was placed over the sensor to focus infrared energy, though the final setup was directional rather than a full circle.

Figure 4.3: Complete PIR Sensor Setup

4.3 System Testing Methodology

The testing phase focused on manual observation and basic electrical measurements to confirm the device functioned as intended.

Power Supply Verification: A multimeter was used to confirm that the scratch-built power supply delivered exactly 5V DC to the sensitive electronics.

Functional Detection Test: A person moved within the sensor's line of sight to verify that the PIR sensor triggered the BISS0001, which then activated the relay and buzzer.

Directional Field of View (FoV) Validation: The sensor was tested for its effective angle of detection. The test confirmed that the device successfully monitored a wide-angle area directly in front of the lens, which is ideal for doorways and hallways.

Range Measurement: Using a tape measure, the maximum distance at which the sensor could reliably detect a human heat source was determined to be 1 meter.

Stability Observation: The system was left powered on for 30 minutes to ensure that environmental factors did not cause frequent false alarms.

4.4 BILL OF ENGINEERING AND MEASUREMENT EVALUATION (BEME)

The Table 4.1 below shows the cost breakdown in designing and constructing the Passive Infrared motion sensor

Table 4.1: BILL OF ENGINEERING AND MEASUREMENT EVALUATION (BEME)

S/N	Component	Specification/ Description	Quantity	Purpose / Notes	Price Per Unit
1	RE200B	Dual-element pyroelectric infrared sensor	**1**	Detects motion via IR radiation changes	2500
2	BISS0001	PIR controller IC	**1**	Amplifies and processes RE200B output signals	1000
3	Fresnel Lens	PIR-compatible lens	**2**	Focuses IR onto the sensor, defines detection area	3000
4	Capacitor, ceramic	0.01 µF (10 nF)	**2**	AC coupling between RE200B and BISS0001	500
5	Capacitor, ceramic	47–100 pF	**2**	Noise filtering across sensor differential input	500

6	Capacitor, electrolytic	4.7 µF or 10 µF /16V	**1**	Output pulse duration timing capacitor (Ct)	500
7	Capacitor, ceramic	0.1 µF (100 nF)	**1**	IC decoupling capacitor (V_{cc}– GND)	500
8	Capacitor, electrolytic	10 µF / 16V	**1**	Power supply smoothing capacitor	500
9	Resistor	1 MΩ (¼ W)	**2**	Bias resistors for RE200B sensor inputs	500
10	Potentiometer	100 kΩ (linear)	**1**	Sensitivity adjustment	500
11	Resistor	10 kΩ (¼ W)	**1**	Output pull-up resistor	500
12	Resistor	560 Ω (¼ W)	**1**	Base resistor for transistor driver	500
13	Resistor	10 kΩ(¼ W)	**1**	Optional RC filter resistor	500
14	Capacitor, ,electrolytic	1 µF / 16V	**1**	Optional RC filter capacitor	500
15	Transistor	2N2222 (NPN)	**1**	Drives relay from IC output	1000
16	Relay	5V DC coil, SPDT(e.g., SRD-05VDC-SL-C)	**1**	Switches external load (lamp, alarm, etc.)	1500
17	Diode	1N4007	**1**	Flyback diode for relay	500

				protection	
18	LED	3 mm or 5 mm	**1**	Motion indication (ON when motion detected)	500
19	Resistor	220 Ω (¼ W)	**1**	Limits LED current	500
20	Power supply	5V DC regulated (500 mA)	**1**	Main circuit supply	
21	PCB board	FR-4 or perfboard	**2**	Circuit assembly board	2500
22	Enclosure	PIR-compatible plastic housing	**1**	Protects and positions lens properly	2000
23	Jumper wires /headers	Male/female	**as needed**	For prototyping and connections	2000
24	Capacitor, electrolytic	33 µF / 16V	**1 set**	Extends output ON duration (e.g., ~15 s instead of 5 s)	2500
25	Transistor (alt)**	BC547 / 2N3904	**1set**	Alternative to 2N2222 for driver stage	2500

26	Voltage	AMS1117-3.3	**1**	Steps 5 V down to 3.3	1500
27	Voltage Regulator	7805	**1**	Provides 5V regulated supply if powered from 12 V DC input	500
28	Diode	1N4007 (extra)	**1set**	Used before 7805 regulator to prevent reverse polarity	500
29	Capacitor, electrolytic	1000 µF / 25V	**1set**	Power input filter (for 12V source to regulator)	500
30	Optocoupler	PC817	**1set**	Provides isolation between PIR circuit and MCU input	2500
31	Resistor	220 Ω (for optocoupler LED)	**1set**	Limits current to optocoupler input	500
32	Resistor	10 kΩ (for optocoupler output pull-up)	**1 set**	Pull-up resistor for isolated logic output	500
33	Screw terminal/ header block	2-pin / 3-pin	**1 pack**	For power and output connections	500
34	Heat sink (for 7805 regulator)	Small TO-220 type	**1 Piece**	Dissipates heat from regulator if using 12 V input	500

35	Cost of Materials	-	**-**	-	35,000
36	Logistics	-	**-**	-	15,000
37	**Gross Total**	-	**-**	-	**50,000**

CHAPTER 5

CONCLUSION

5.1 SUMMARY OF WORK

The project achieved the design and construction of a functional, directional Passive Infrared (PIR) motion sensor prototype. The work demonstrated the practical application of electronics design, power management, and signal processing.

Power Supply Unit: A multi-stage power supply was successfully implemented to convert 220V AC mains into a stable 5V DC rail. This process utilized a step-down transformer, bridge rectification, and an LM7805 voltage regulator.

Detection and Logic: A PIR sensing element was interfaced with a BISS0001 micro power controller to process thermal changes into digital triggers.

Output Interface: An electromechanical stage was constructed using an NPN switching transistor and a 5V relay to activate an audible buzzer alarm upon detection.

5.2 KEY FINDINGS AND PRACTICAL LIMITATIONS

Testing and implementation revealed several critical findings regarding the system's performance and the challenges of hardware construction.

Directional Coverage: Although the theoretical design explored wide-area monitoring, the final physical prototype functioned as a directional sensor. It proved effective for monitoring specific paths such as doorways.

Fixed Sensitivity: During the calibration phase, it was determined that the system operated with a fixed sensitivity level. While the theoretical model included adjustable parameters, component tolerances and circuit noise resulted in a stable, pre-set detection threshold.

Detection Range: Empirical testing confirmed a reliable detection range of up to 2 meters for human heat sources.

Noise and Stability: The project highlighted the vulnerability of high-gain sensing circuits to electromagnetic interference (EMI) and power supply ripple.

5.3 FINAL REMARKS

This project validates the construction of a low cost, energy efficient device for security and automation. It served as a successful practical application of the knowledge gained in electronics and embedded systems throughout the undergraduate program. The prototype establishes a framework for future innovations in automated lighting and localized intruder alarm systems within the Nigerian power grid context.

REFERENCES

Abdelmeguid, M. A., El-Fishawy, A. S., & El-Kordy, M. A. (2020). Energy saving using PIR motion sensor in lighting system. International Journal of Computer Engineering and Applications, 12(7), 1–6.

Abari, M., & Al-Haddad, K. (2021). Review of grid-connected AC power systems and control strategies. Renewable and Sustainable Energy Reviews, 142, 110825.

Asuhaimi, F. A., & Rahim, H. A. (2018). Analysis of non-inverting operational amplifier circuit characteristics for sensor interfacing. Journal of Electronic Devices, 16(1), 1–10.

Baker, R. J. (2016). High-speed, low-power comparator design for modern integrated circuits. IEEE Transactions on Circuits and Systems I: Regular Papers, 63(12), 2110–2120. https://doi.org/10.1109/TCSI.2016.2606564

Chan, H., & Sin, J. K. O. (2019). Low-dropout (LDO) voltage regulator design with enhanced transient response. IEEE Journal of Solid-State Circuits, 54(7), 1887–1897. https://doi.org/10.1109/JSSC.2019.2902998

Chen, R., & Luo, J. (2018). Modeling of parasitic effects in film resistor networks for high-frequency applications. International Journal of Electronics and Communications (AEÜ), 87, 1–7.

Chudleigh, P. W. (2011). Pyroelectric infrared sensors. In Sensor Technology and Devices (pp. 53–84). CRC Press.

El-Sayed, T., Karray, R., & Zaidi, H. (2018). Pyroelectric sensors: Review and perspectives. Sensors, 18(9), 3028.

Franco, S. (2015). Op-Amp circuits for precision signal conditioning. IEEE Potentials, 34(6), 18–24. https://doi.org/10.1109/MPOT.2015.2427847

Fuchs, E. F., & Masoum, M. A. S. (2018). The impact of harmonic distortion on the performance of AC electrical systems. IEEE Transactions on Power Delivery, 33(4), 1680–1689. https://doi.org/10.1109/TPWRD.2017.2764951

Ganesan, S., & Subramanian, S. (2020). Performance analysis of NPN transistor-based drivers for inductive loads. International Journal of Electrical and Computer Engineering, 10(3), 2631–2640.

Gupta, G., & Gupta, M. (2021). Design and development of a smart security system using PIR sensor and microcontroller. International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, 10(6), 565–570.

Han, Y., Kim, J., & Lee, Y. (2019). Reliability and switching lifetime of electromechanical relays under various load conditions. Journal of Power Electronics, 19(3), 573–580.

He, J., Fan, Z., & Zhu, S. (2016). Research and application of passive infrared sensor in security monitoring system. International Journal of Security and Its Applications, 10(11), 373–380.

IEEE. (2017). IEEE standard for metal film and metal oxide film fixed resistors (IEEE Std 1032-2017). IEEE.

International Electrotechnical Commission. (2018). Electromechanical elementary relays for industrial use and interface elements (IEC 61810-1:2018). IEC.

Islam, S. T., Al-Ahmadi, S., & Shorfuzzaman, M. (2017). Smart home security system based on Khalifa, W., El-Gammal, M. M., & Gad, H. M. (2022). AC–DC conversion efficiency of bridge rectifier circuits. International Journal of Power Electronics, 14(1), 1–15.

Kim, M., Lee, S., & Park, H. (2018). Characterization of sound pressure level and power consumption in piezoelectric buzzers for alarm systems. Journal of Electroceramics, 41(1–4), 163–169.

Kulkarni, S. V., & Khaparde, S. A. (2019). Modeling and analysis of transformer windings for voltage distribution. Electric Power Systems Research, 173, 211–219. https://doi.org/10.1016/j.epsr.2019.04.020

Lee, J., & Kim, Y. (2020). Selection criteria for filter capacitors in switching power supply modules. Journal of Electronic Devices, 18(2), 97–105.

Liu, J., Li, X., & Song, J. (2021). Enhanced signal processing for passive infrared (PIR) motion detection. Sensors and Actuators A: Physical, 325, 112701. https://doi.org/10.1016/j.sna.2021.112701

Mohan, N., Undeland, T. M., & Robbins, W. P. (2018). Analysis of diode bridge rectifier circuits. IEEE Transactions on Power Electronics, 33(1), 123–132. https://doi.org/10.1109/TPEL.2017.2694770

Morrison, R. (2016). Grounding and shielding: Circuits and interference. IEEE Instrumentation and Measurement Magazine, 19(3), 16–22.

Neamen, D. A. (2017). Bipolar junction transistor as a switching device: Characteristics and transient effects. Journal of Electronic Materials, 46(4), 1827–1836.

https://doi.org/10.1007/s11664-016-5259-2sensitive applications. Electronics Letters, 53(14), 957–959.

Wang, H., & Lipo, T. A. (2017). Capacitor requirements for ripple reduction in DC power supplies. IEEE Transactions on Industry Applications, 53(3), 2001–2009. https://doi.org/10.1109/TIA.2016.2625974

Wassell, I. J. (2018). Inductive load driving and semiconductor protection with flyback diodes. Electronics Letters, 54(2), 85–87.

Zhang, D., Cheng, P., & Li, Q. (2017). Optimization design of step-down transformers based on magnetic circuit simulation. Journal of Applied Physics, 122(22), 224501.

Eze, U. C., Ukpai, O., & Omah, P. (2022). Development of a low-cost, smart security system for home and office surveillance. Journal of Applied Science and Technology (JAST), 27(1), 22–30.

Okeniyi, J. O., Okeniyi, E. T., & Omidiora, E. O. (2021). Optimization of power consumption in smart grid system using sensor-based automation. International Journal of Computer Applications, 177(46), 1–6.

Ott, H. W. (2018). Understanding the concept of circuit ground and common-mode impedance. Electromagnetic Compatibility Engineering Journal, 23(4), 19–27.

Rahman, T., & Islam, R. (2021). Design and implementation of an automated security alarm system using a high-decibel AC buzzer. Journal of Computer Networks, Architecture and High Performance Computing, 3(1), 42–51.

Sato, A., & Arakawa, K. (2017). Suppressing back EMF in inductive switching circuits using freewheeling diode. IEICE Transactions on Electronics, E100.C(11), 934–940.

Schmalzel, J. L., & Rauth, D. A. (2005). Sensors and signal conditioning. IEEE Instrumentation and Measurement Magazine, 8(2), 48–53. https://doi.org/10.1109/MIM.2005.1451556

Schubert, M. B. (2019). The P–N junction: A unified model for diodes and solar cells. Applied Physics Reviews, 6(4), 041302. https://doi.org/10.1063/1.5126131

Slimani, A., & Benslama, A. (2021). The design of optimal reversible comparator circuit using new quantum gates. Journal of Physics: Conference Series, 1766(1), 012028. https://doi.org/10.1088/1742-6596/1766/1/012028

Sze, S. M., & Ng, K. K. (2021). P–N junction diode characteristics and modeling. Journal of Solid State Electronics, 177, 107316. https://doi.org/10.1016/j.sse.2021.107316

Tse, C. K., & Ho, K. M. (2017). Analysis and performance of linear voltage regulators in noi