

Autolight: Smart Motion Detection Lighting System (Passive Infrared Sensor)

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ABSTRACT

This study presents the design and development of a Passive Infrared (PIR) motion-activated lighting system intended to reduce energy waste and improve safety in residential and community environments. The project focuses on a sensor-based approach that operates without the use of a microcontroller, demonstrating how a PIR sensor can directly control a lighting circuit through motion detection. The system detects changes in infrared radiation emitted by the human body and automatically activates an LED light when movement is present, while keeping the light off in the absence of motion.

The motivation for this project is rooted in common situations observed in Filipino households and barangay facilities, where lights are frequently left on unintentionally or manually operated lighting is neglected, leading to unnecessary electricity consumption and poorly lit areas. The methodology includes system planning, schematic design, component integration, and prototype testing under controlled indoor conditions. The prototype consists of a PIR sensor, LED light, resistors, power supply, and basic wiring components arranged to achieve reliable motion detection and automatic lighting response.

Results from initial testing indicate that the PIR-based system successfully detects human motion within its effective range and responds by activating the lighting output with minimal delay. The system demonstrates consistent performance for indoor lighting applications and shows potential for improving energy efficiency and safety. Observations also reveal limitations such as sensitivity to environmental temperature changes and restricted detection range.

Overall, the study confirms the feasibility of using PIR sensors for simple motion-activated lighting applications. The project highlights the potential of low-cost, sensor-based automation as a practical solution for households and community areas. Future improvements may include sensitivity adjustment, extended detection coverage, and integration with advanced control systems.

INTRODUCTION

This study presents the development of a Passive Infrared (PIR) Motion-Activated Lighting System that operates without the use of a microcontroller. The project aims to demonstrate the application of sensor-based automation by detecting human motion and activating an LED lighting circuit directly through a PIR sensor. Motionactivated lighting systems commonly utilize Passive Infrared sensors to detect changes in infrared radiation emitted by the human body, enabling automatic control of lighting systems (Liu et al., 2021).

The methodology of the study includes system design, schematic development, component integration, and prototype testing. The findings of this study support the suitability of PIR sensors for basic motion-based lighting applications and recommend further improvements such as sensitivity calibration, expanded detection range, and enhanced output control for real-world deployment.

Background Of the Study

The idea for this project was inspired by common experiences in Filipino households and community facilities where lights are often left on unintentionally. In many homes, electricity is wasted because individuals forget to

switch off lights, especially during nighttime or when they are in a hurry. This situation is frequently observed in areas such as hallways, bathrooms, and outdoor spaces.

Additionally, many barangays have narrow pathways or alleys (*eskinita*) that require lighting for safety, yet manual operation of lights is inconvenient and sometimes neglected. These everyday situations motivated the development of a simple and cost-effective solution using a Passive Infrared (PIR) sensor.

The use of PIR sensors in household lighting systems helps reduce unnecessary energy consumption caused by lights being left on unintentionally (Bhattacharjee & Das, 2019). By integrating motion-sensing technology into a basic lighting system, this project aims to provide affordable and automatic lighting that improves safety while minimizing electricity waste. The system is designed to be suitable for Filipino households, small businesses, and community areas.

Importance And Relevance Of The Study

This project is important because it addresses both convenience and energy efficiency in Filipino living environments. It benefits individuals, families, households, barangay facilities, small stores, schools, and community pathways that require reliable lighting without excessive electricity consumption.

The system is particularly relevant in areas where electricity costs continue to increase and where manual lighting systems are still widely used. By automatically activating lights when motion is detected, the system improves visibility and safety in poorly lit areas. PIR-based lighting systems have been shown to improve energy efficiency and enhance safety by ensuring that lighting is available only when needed (González & López, 2020).

Overall, the project demonstrates how simple sensor-based technology can provide practical, low-cost smart solutions that improve daily life in local communities.

Problem Statement

Many households experience wasted electricity due to lights being left on unnecessarily, while manual lighting systems limit convenience and safety in dark environments. This project aims to address inefficient lighting usage by implementing a PIR-based motion-activated lighting system.

Specific Problems:

1. Lights in homes, hallways, and bathrooms are frequently left on unintentionally.
2. Community pathways and barangay areas often remain poorly lit at night due to reliance on manual lighting.
3. Energy costs increase because of unnecessary electricity consumption.
4. Safety risks arise in dark areas without automatic lighting systems.

General Objective

To design and develop a microcontroller-free PIR motion-activated lighting system that automatically controls lighting based on human motion to reduce energy waste and improve safety.

Specific Objectives

1. To utilize a Passive Infrared (PIR) sensor for detecting human motion.
2. To design a switching circuit using discrete electronic components without a microcontroller.
3. To automatically activate a lighting load when motion is detected.
4. To evaluate the responsiveness and reliability of the system under indoor conditions.
5. To identify system limitations and recommend possible improvements.

Scope and Limitations

- The system detects only infrared-based human motion.
- Only basic LEDs are used; no high-power lighting modules yet.

METHODOLOGY

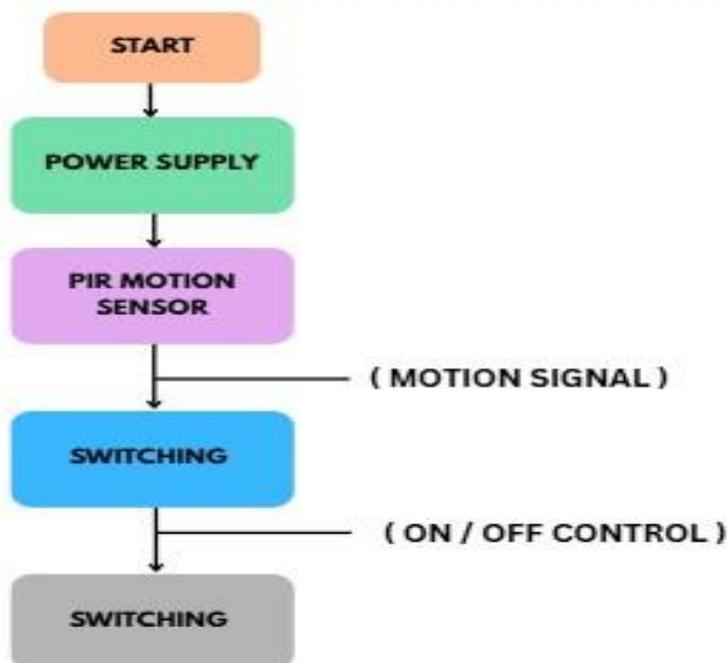
The study employed an experimental research design to evaluate the performance of a Passive Infrared (PIR) sensor-based motion-activated lighting system without the use of a microcontroller. The system was designed to directly control a lighting load through a transistor-driven relay circuit.

The PIR sensor continuously monitored infrared radiation changes within its detection range. When human motion was detected, the sensor generated a HIGH output signal, which was amplified using a BC547 transistor. This signal energized a 5V relay, allowing electrical current to flow to the lighting load. In the absence of motion, the relay returned to its normally open state, turning the light OFF to conserve energy.

The system was assembled using basic electronic components including a PIR sensor, transistor, relay module, resistors, diode, LED light, and an external 5V power supply. A flyback diode was installed across the relay coil to protect the circuit from back electromotive force (EMF).

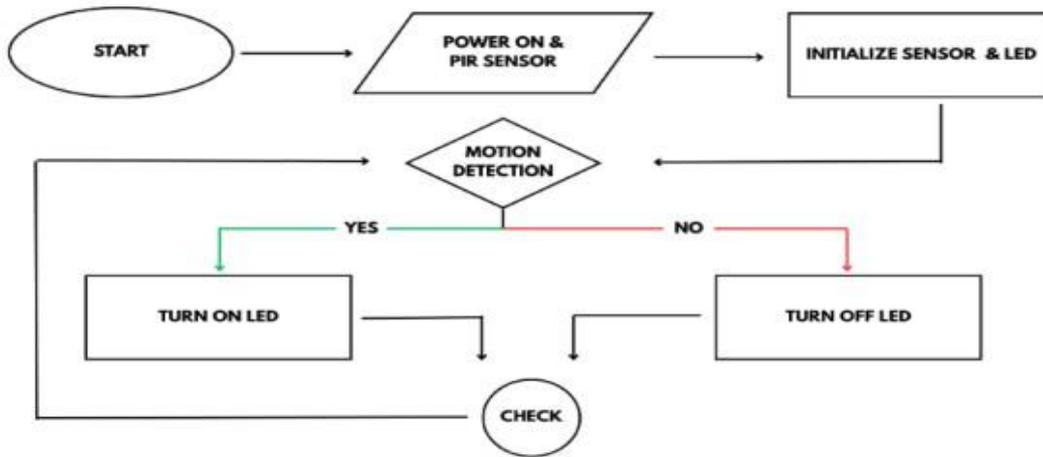
Testing was conducted by introducing human motion at varying distances from the sensor under controlled indoor conditions. Observations focused on detection range, response time, reliability, and system consistency. The collected results were analyzed to determine the feasibility of the system for residential and community lighting applications.

Block Diagram



It illustrates the detailed decision-making logic implemented in the system to control the light based on real-time motion detection. After the system is powered ON, the PIR motion sensor continuously monitors the surrounding area to detect human movement. When motion is detected, the PIR sensor sends a signal to the switching circuit, causing the light to turn ON and remain illuminated for a preset duration. If no motion is detected, the sensor outputs a low signal, and the switching circuit turns the light OFF to conserve energy. This process repeats continuously as long as the system is powered, ensuring automatic operation. The structured logic enables hands-

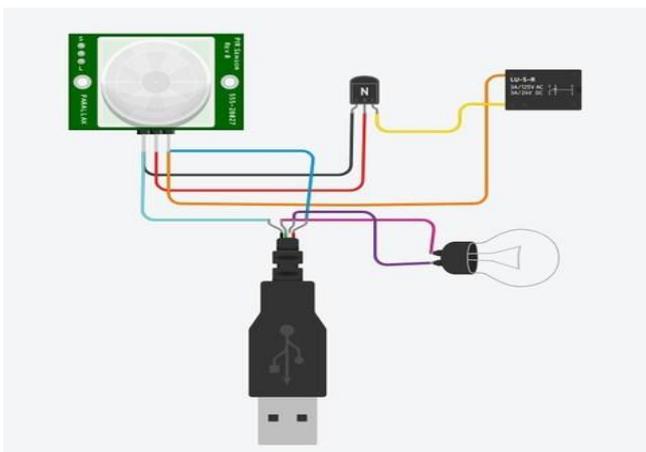
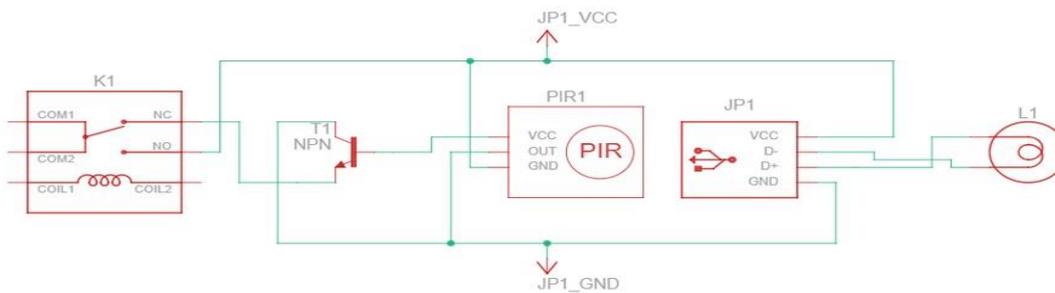
free lighting control, improves energy efficiency, and ensures the light is activated only when motion is present, making the system reliable, practical, and suitable for security and automation applications. Flowchart



It presents the overall operational flow of the PIR Motion-Activated Lighting System, illustrating how the system processes motion sensor input to automatically control the lighting output. The flow begins with system initialization, where power is supplied to the PIR motion sensor and the lighting circuit. After initialization, the system continuously monitors changes in infrared radiation to detect human motion. If motion is detected, the control circuit activates the light and keeps it ON for a short duration. After the delay period, the system returns to motion monitoring to determine whether the light should remain ON or be turned OFF. If no motion is detected, the system turns OFF the light to conserve energy. This process operates in a continuous loop, ensuring real-time motion detection and automatic lighting control without the need for manual operation.

Schematic Diagram

Figure 1. Tinkercad circuit diagram



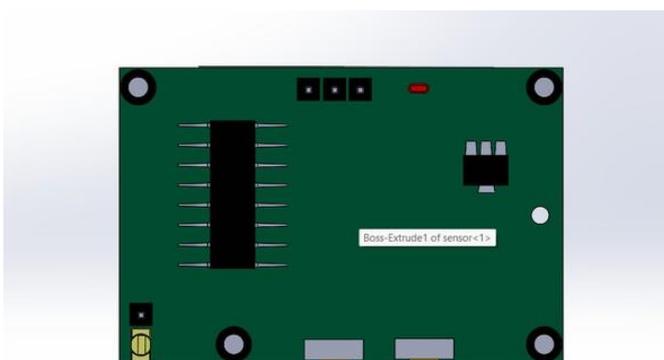
Component List and Functions

Variable / Component	Type (Input / Output)	Parameter Measured / Controls	Condition Or Range	System Response / Action
PIR Motion Sensor	Input	Detects motion (infrared/body heat)	Detects movement within ~3–7 meters; HIGH when motion detected	Sends HIGH signal to transistor circuit
BC547 Transistor	Controller / Driver	Amplifies PIR output signal	Base HIGH (~0.7V) or LOW	Turns relay ON when PIR is HIGH
220Ω Resistor	Passive / Control	Limits base current of transistor	Fixed resistance: 220Ω	Protects transistor from overcurrent
1N4007 Diode	Protection	Controls reverse voltage	Reverse-biased across relay coil	Prevents back-EMF damage when relay turns OFF
5V 5-Pin Relay	Output	Switches AC/DC load	Energized (ON) / De-energized (OFF)	Connects/disconnects power to light bulb
Light Bulb	Output	Illumination (ON/OFF state)	ON when relay is ON	Lights up when motion is detected
USB Wire	Power Connection	Transfers 5V supply	5V input from adapter/power source	Delivers power to the circuit
Female Jumper Wires	Connection	Signal and power routing	Continuous electrical connection	Connects all components together

Figure 2. Actual PIR motion sensor



Figure 3. Solidwork Assembly



Development / Implementation

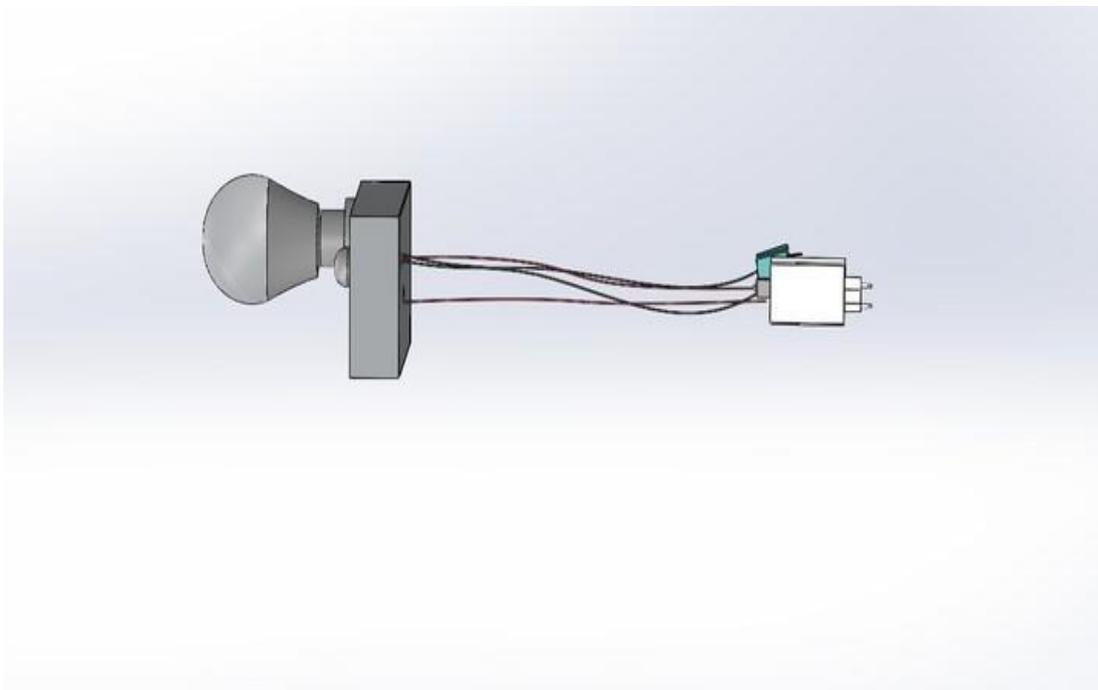
The system was developed to demonstrate an automatic lighting mechanism using a Passive Infrared (PIR) motion sensor and a relay module. The PIR sensor was used to detect human motion based on infrared radiation, while the relay acted as a switch to control the light load. When motion was detected, the PIR sensor generated a signal that activated the relay, allowing electrical current to flow to the light bulb.

The implementation process began with properly powering the PIR sensor and relay module using an external power supply. The output pin of the PIR sensor was connected to the relay input, while the light bulb was wired through the relay's normally open (NO) terminal. This configuration ensured that the light remained off by default and only turned on when motion was detected. After assembly, the system was tested under different motion distances to verify functionality and reliability.

Figure 3. Actual picture of Passive Infrared (PIR) Motion-Activated Lighting System



Figure 4. Solidwork Assembly



RESULT AND DISCUSSION

The developed motion-activated lighting system successfully demonstrated its ability to automatically control a light source using a PIR motion sensor and relay module. Based on the conducted tests, the system reliably detected motion at distances between 50 cm and 150 cm, with detection times ranging from approximately 1 to 2 seconds. Within this range, the light consistently turned on once motion was detected, indicating stable communication between the PIR sensor and the relay.

As the distance increased, a noticeable decline in detection performance was observed. At distances close to 200 cm, the sensor failed to trigger the relay, resulting in no light activation. This result highlights the inherent limitation of PIR sensors, which depend on changes in infrared radiation. When motion occurs farther from the sensor, the infrared signal becomes weaker and insufficient to activate the system.

The observed response delay can be attributed to the internal processing time of the PIR sensor and its sensitivity configuration. Despite this delay, the response time remained acceptable for practical indoor applications. Overall, the results confirm that the system is effective for use in enclosed or controlled environments such as hallways, rooms, and entrances, where motion occurs within a predictable range. However, for larger areas, additional sensors or higher-sensitivity components may be required to improve system performance.

Energy Consumption Analysis

To evaluate the energy-saving potential of the proposed system, a comparative analysis between manual lighting operation and PIR-based automatic lighting was conducted. In a typical household scenario, lights may remain ON for approximately 6–8 hours during the evening due to manual operation and user negligence.

Assuming a 10-watt LED bulb operating continuously for 8 hours, the total energy consumption would be approximately 80 watt-hours (Wh) per day. In contrast, the PIR-based lighting system activates the light only when motion is detected. Based on observation, the cumulative lighting duration using the PIR system was reduced to approximately 2–3 hours per day.

This results in an estimated daily energy consumption of 20–30 Wh, representing an energy reduction of approximately 62–75% compared to manual lighting operation. Although these values are based on estimated operating time, the results clearly demonstrate the system’s potential for significant energy savings in residential and community environments.

Testing Procedures

Test number	Test condition	Input/ action	Expected result	Actual result	Remarks
1	Power on test	Plug in 5V bulb	PIR sensor powers ON	pass	System powers on normally.
2	No motion detected	No movement in sensor range	Light bulb remains OFF	Pass	Sensor correctly ignores absence of motion.
3	Motion detected	Move hand/person in front of PIR	Light bulb turns ON	Pass	Motion detection works as intended.
4	Continuous motion	Stay within sensor range	Light remains ON	Fail	Light turns OFF unexpectedly; sensor may be misconfigured for continuous detection.
5	Motion stopped	Leave sensor range	Light turns OFF after delay	Pass	Delay timer works correctly.
6	Long idle time	No motion for several minutes	Light remains OFF	Pass	System remains idle as expected.
7	Near motion	Move hand close to PIR sensor	Light bulb turns ON	Pass	Sensor correctly detects nearby motion.

8	Far motion	Move hand 1–2 meters away	Light bulb turns OFF	Fail	Sensor fails to detect motion at longer distance; sensitivity may need adjustment.
9	Repeated motion	Move hand multiple times	Light turns ON consistently	Fail	Sensor intermittently misses repeated motion; possibly due to PIR retrigger settings.
10	Complete system check	Motion → no motion cycle	System works correctly	Pass	Overall system functions as expected under normal cycle.

Observation, Analysis and Interpretation

Based on systematic testing and observation, the PIR motion-activated lighting system demonstrated reliable performance under typical indoor conditions. The system consistently detected human motion within a short to moderate range (approximately 0.5 to 1.5 meters) and activated the lighting output with minimal delay. This confirms that the PIR sensor effectively detects variations in infrared radiation emitted by the human body and converts them into electrical signals suitable for triggering the relay circuit.

Analysis of the testing results indicates that the system performs optimally when motion occurs within the designed sensing range and field of view of the PIR sensor. However, performance degradation was observed as the distance between the motion source and the sensor increased. At distances beyond approximately 2 meters, motion detection became unreliable, resulting in delayed or absent light activation. This behavior is consistent with the known operational characteristics of PIR sensors, which rely on relative changes in infrared energy rather than absolute motion.

The intermittent failures observed during continuous or repeated motion scenarios suggest limitations in the sensor’s retriggering mechanism and internal delay settings. These findings imply that while the system is suitable for simple lighting automation, its performance is influenced by environmental conditions, sensor placement, and configuration. Overall, the observations confirm that the system functions as intended for small indoor areas, validating its practical applicability for residential and community use.

Problem Encountered And Solutions

Several challenges were encountered during the development and testing phases of the project. One of the primary issues was the inconsistent detection of motion during continuous presence within the sensor’s range. In some cases, the light turned off unexpectedly even when motion was still present. This problem was traced to the PIR sensor’s default delay and retrigger configuration, which limits continuous detection.

To address this issue, adjustments were made to sensor placement and testing procedures to ensure proper alignment with the expected motion path. Additionally, it was recommended that PIR sensors with adjustable sensitivity and delay controls be used in future implementations to improve detection reliability.

Another problem encountered was the limited detection range of the system. Motion beyond 1.5 to 2 meters was not consistently detected, reducing the system’s effectiveness in larger spaces. This limitation was mitigated by positioning the sensor closer to the target area and reducing environmental interference such as heat sources and obstacles.

Electrical noise and relay switching spikes were also identified as potential risks to component longevity. The inclusion of a flyback diode (1N4007) across the relay coil successfully protected the circuit from back electromotive force (EMF), ensuring stable and safe operation.

CONCLUSION

The study successfully designed and implemented a PIR-based motion-activated lighting system that automatically controls illumination based on human movement. The system demonstrated reliable performance within its effective detection range and showed potential in reducing unnecessary energy consumption while improving safety. Despite limitations in detection range and continuous motion handling, the results confirm that PIR sensors are a practical and cost-effective solution for basic lighting automation in residential and community environments.

Summary Of Findings and System Performance

The study successfully demonstrated the feasibility of a PIR-based motion-activated lighting system for energy-efficient and automated lighting control. The system responded accurately to human motion within its effective range and activated the lighting output with an acceptable response time of approximately 1–2 seconds.

Overall system performance was stable under controlled indoor conditions, with reliable ON and OFF transitions corresponding to detected motion and inactivity. The system effectively reduced unnecessary lighting operation by ensuring that the light remained off when no motion was present. While limitations were observed in detection range and continuous motion handling, these did not significantly affect the system's intended function for small-scale applications.

The results confirm that the developed prototype meets its design objectives and demonstrates consistent performance suitable for household and community environments.

Verification Of Objectives

The objectives of the study were successfully achieved based on experimental results and system evaluation:

- The PIR sensor effectively detected human motion through infrared radiation changes.
- The sensor output was successfully interfaced with the switching circuit to control the lighting load.
- The LED light was activated automatically upon motion detection.
- The system demonstrated acceptable responsiveness and operational reliability.
- Limitations related to detection range and retrigger behavior were identified and documented.

These outcomes verify that the system fulfills both the general and specific objectives of the project.

RECOMMENDATIONS

Future improvements to the system may include the use of PIR sensors with adjustable sensitivity and delay settings to enhance detection reliability. Integrating a microcontroller is recommended to allow better control, programmability, and additional features such as adaptive timing and diagnostics. For wider areas, the use of multiple sensors can improve coverage and reduce detection gaps. Lastly, further testing under different environmental conditions is recommended to evaluate long-term performance and system reliability.

Suggested Enhancements

To further improve system performance and expand its practical applications, several enhancements are recommended:

1. Adjustable Sensitivity and Delay Control

Incorporating a PIR sensor with adjustable sensitivity and delay settings would improve detection accuracy and reduce intermittent failures.

2. Multiple Sensor Integration

Using multiple PIR sensors can extend detection coverage for larger rooms, hallways, or outdoor pathways.

3. Microcontroller-Based Control

Integrating a microcontroller (e.g., Arduino) would allow programmable logic, adaptive timing, and improved motion handling.

4. Higher-Power Lighting Modules

Replacing basic LEDs with energy-efficient LED lamps or AC lighting modules would increase usability in real-world environments.

5. Environmental Compensation

Adding temperature compensation or filtering techniques would enhance reliability under varying ambient conditions.

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