DESIGN AND IMPLEMENTATION OF A MOTION-SENSOR LIGHTING SYSTEM

BY

IBHAZE, GODSTIME EMMANUEL

EEE/18/6736

SUPERVISOR:

DR. M. O. OYELEYE

SUBMITTED TO

THE DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

FEDERAL UNIVERSITY OF TECHNOLOGY AKURE ONDO STATE

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF

BACHELOR OF ENGINEERING (B.ENG) DEGREE IN ELECTRICAL

ENGINEERING

OCTOBER 2024

CERTIFICATION

This document attests that the technical report presented accurately reflects the final-year undergraduate project work conducted by IBHAZE, GOD'STIME EMMANUEL with Matriculation number: EEE/18/6736 in the Department of Electrical and Electronics Engineering at the Federal University of Technology, Akure. The report adheres and has been prepared in accordance with the department's regulations and guidelines for report submission, and it is submitted as partial fulfillment of the requirements for the award of a Bachelor of Engineering (B.Eng.) degree in Electrical and Electronics Engineering.

Ibhaze, Godstime Emmanuel ……………………..

(Student) Signature and Date

Dr. M. O. Oyeleye ……………………..

(Supervisor) Signature and Date

Dr. M. R. Adu ……………………..

(Head of Department) Signature and Date

DEDICATION

I dedicate this work to the Almighty God and my family.

ACKNOWLEDGEMENT

I express my profound gratitude to God Almighty, the monarch of the universe, the source from which my being stems from, the source of knowledge and understanding, and for my journey thus far as an undergraduate.

My sincere appreciation goes to my supervisor Dr. M.O. Oyeleye for his exceptional support. His supervison provided me with knowledge within and beyond the scope of my project, he thought me discipline and keeping up with deadlines. His words of encouragement was instrumental in the completion of my Project.

I thank the Head of the department of Electrical and Electronics Engineering, Dr. M. R. Adu, and the entire teaching and non-teaching staff of the department for their effort throughout my undergraduate studies.

My deepest appreciation goes to my family, Mr. E. Ibhaze and Mrs. J. Ibhaze for their support in every humanly way possible, my father's timely calls and words of prayer were a constant source of strength, my mother's boundless love and care which is so tangible even from a distance, my siblings Faith, Unity, and Moses who have been the sweetest being anyone could ever ask for, the calls, the gifts, their listening hears were of great encouragement to me.

I heartily thank my friends they have been a great support system to me, my roommate Mr. O. Ajayi, whose contribution I do not take lightly and Mrs. Y. L. Shanu, whose contribution I do not take lightly. Also, I thank my colleague Mr. I. J. Jayeola who was wonderful in the implementation of the project, working with him was indeed a wonderful experience.

ABSTRACT

This technical report presents the design and implementation of a motion sensor light control system aimed at enhancing and optimizing energy efficiency and automation of the lighting system at the top floor corridor of the School of Engineering and Engineering Technology, Federal University of Technology Akure. The system employs a Light Dependent Resistor (LDR) sensor and Passive Infrared Receiver (PIR) sensor to detect human movement within a specified range of 35 meters, triggering the activation of lighting only when movement is detected at below 100 Lux light level. The method used is both simulation and transferred of simulated result to practical reality. The simulation is based on the Wokwi Free Online Simulator while the practical reality was based on the use of existing lamps, selection of Arduino Uno, five Passive Infrared Receiver (PIR) Sensor, Light Dependent Resistor (LDR) Sensor, and Relay Module. The simulation results show that the practical of the simulation is feasible. Practical implementation results shows that the cost of energy in using motion sensor per year in the entire building corridors is seven hundred and sixty thousand, two hundred and thirty-three naira, sixty kobo (₦760,233.60). The total cost of implementing the system in the entire building is ₦865,200. The motion sensor lighting system is cost effective over years of usage since the implementation cost will be recovered over 1.138years. Additionally, the system also offers security awareness which aids in detecting unauthorized movements in the building. Motion sensor lighting control system is recommended for a use in the corridor of an educational buildings or any other edifices corridor or walkway.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

A motion sensor lighting system is designed to turn on a light only when motion is detected and when the surrounding environment is sufficiently dark. In recent years, improvements in sensor technology and automation have transformed various aspects of daily life, including the field of lighting control systems. Traditional lighting systems often operate with manual "ON" and "OFF" which have led to energy waste and unnecessary burden due to high electricity bills (Firdaus and Mulyana, 2018). This project builds upon the unsuccessful project carried out at the last floor of the School of Engineering and Engineering Technology, Federal University of Technology Akure, focusing on the design and implementation of a motion-sensor lighting system aimed at addressing this challenge.

The design and implementation of a motion-sensor lighting system not only promises improved energy efficiency and cost savings but also enhances, convenience and accessibility (Metallidou *et al*., 2020). Lighting control strategies are vital in reducing building energy consumption which can achieve more than 50% energy savings (Xu *et al*. 2017). Motion sensors represent a significant advancement in lighting control, enabling lights to respond intelligently to occupancy within predefined zones (U.S. Department of Energy, 2019).

Another benefit of this project lies in the security importance by detecting and responding to movement within a specified area thereby detecting unauthorized entry or movement within the specified area (Metallidou *et al*., 20203).

The earlier iteration of this project encountered issues of control malfunctions (Burnt out of control system during testing). By reworking the burnt control system, this project aims to overcome the aforementioned problem by contributing practical insights and innovations to the field of automated lighting control systems thereby enhancing the functionality of the existing lighting system. Through systematic analysis and implementation, we aim to overcome past limitations and deliver a refined solution that meets the evolving demands of modern environments.

1.1 PROBLEM STATEMENT

The motion sensor lighting system project that was initially carried out at the last floor of the School of Engineering and Engineering Technology (SEET), Federal University of Technology Akure (FUTA) used a linear voltage regulator integrated circuit L7805CV, relay and some other electronic components which got burnt on test running. Therefore, the problem addressed by this project is to re-design and implement a new motion-sensor lighting system with a control circuit using a micro-controller, Passive Infrared Receiver (PIR) sensors, Light Dependent Resistor (LDR) sensor and a relay module to achieve the project aim.

1.2 AIM OF THE PROJECT

The aim of the project is to design and construct a motion-sensor lighting system.

1.3 OBJECTIVES OF THE PROJECT

The specific objectives are to:

i. re-design existing lighting system,

ii. design an electronic circuitry integrating motion sensors with redeemed existing lighting system,

iii. construct a motion-activated lighting system,

iv. verify the effectiveness of objective a and b through simulation, and

v. performance of physical evaluation through testing.

1.4 SIGNIFICANCE OF THE PROJECT

The significance of implementing a motion-sensor lighting system lies in its potential to reduce energy wastage and also to improve security alertness. Lighting are the next largest electricity end-user by 20% after air-conditioning load for about 58%, followed by office equipment and others of 22% (Wagiman *et al*. 2019). By automatically switching off lights in unoccupied areas or when natural light is sufficient, this project will reduce electricity usage and reduce energy consumption hence energy bill reduction. \

1.5 SCOPE OF THE PROJECT

The scope of this project is focused on the design and implementation of control system for the existing lighting system at the Top floor corridor of the School of Engineering and Engineering Technology, Federal University of Technology Akure. It focuses on designing a robust control system that seamlessly integrates the Passive Infrared Sensors, LDR(Light Dependent Resistor) Sensor, Relay Module and the Arduino micro-controller.

CHAPTER TWO

LITERATURE REVIEW

This chapter provides a comprehensive overview of motion-sensor technology in lighting systems, emphasizing their effectiveness, drawbacks, and advancements, particularly in the context of energy efficiency and user behavior. To reduce electricity costs for customers, one approach is to enhance energy efficiency by using energy-efficient appliances and turning off electrical devices when they are not needed (Martini *et al*., 2018). A better energy usage results in fewer energy bills, less grid load and less environmental impact. Many electrical consumers in Nigeria squander the limited electrical supply without implementing any conservation measures.(Adelakun *et al*., 2014). Traditional lighting systems often operate inefficiently by remaining active regardless of actual occupancy or ambient light level without automatic control of ON and OFF, leading to unnecessary energy consumption and increased utility costs. This inefficiency in light control poses financial burdens on residential and commercial entities and contributes to environmental concerns. Notwithstanding, good lighting quality will improve good lu minance in building and facilitate good work and improve performance, thus must be achieved in required space (Oyeleye and Makanju, 2020). Lighting control strategies are vital in reducing energy consumption which can achieve more than 50% energy savings (Xu *et al*., 2017).

In conventional occupancy based batch lighting control systems, when the presence of any user is detected in an area, a controller switches all or several corresponding lights on, and when the absence is detected for a given delay period, it switches off the lights. Efforts have been made to improve the approaches for the lighting system for better efficiency and low power consumption.

Richu and NarcissStarbell proposed a system which reduces the power consumption of the street light system about 30% compared to older design. This system is fully automated. It also uses Zigbee so that control station also analyze all the performance of the system (Richu and NarcissStarbell, 2014).

According to RajaR and Udhayakumar smart sensor, helps for monitoring of energy usage thus avoidance of energy wastage. Conventional lamp are powered by AC grid but for LED DC supply is sufficient to provide power. Dimming of light can also be achieved by using appropriate protocol helps in energy and power saving. Replacing the conventional lamp by LED makes 44% energy saving (RajaR and Udhayakumar, 2014).

A low cost, wireless, adaptable sensor based smart lighting system which makes use of PIR sensor and motion sensor is helpful for controlling the light intensities and power consumption using LED lighting. Dimming of light is achieved using PIR sensor only in presence of obstacles around it. This facilitated energy and power conservation (Michele Mango *et al*., 2015)

2.1 COMPARATIVE STUDIES ON MOTION-SENSOR LIGHTING SYSTEM

Waste of lighting energy occurs if the users have lack of energy efficiency awareness (Pandharipande & Newsham, 2018). Recently, lighting system is equipped with motion detection sensors to detect movement in certain areas such as corridors and car parks. The motion detection sensors will automatically turn on the lighting in that area when occupant is detected and will turn off the lighting when the room is no longer occupied. With the use of sensor, the building energy consumption can be reduced(Jin *et al*., 2018). The system will automatically turn on all the lights once the sensor detects any occupants (Xu *et al*. 2017). Moreover, the manual switching on and off gives the highest reduction in energy consumption and provide more personal satisfaction towards occupants' visual comfort as compared to sensing-based lighting control system (Gilani and O'Brien, 2018). Occupants can turn on or off the lights when necessary. The main issue is to increase the energy efficiency awareness among the occupants to manually switch off the light when they leave the office. The simple lighting control system is usually implemented in existing buildings (Pandharipande and Newsham, 2018; Wang *et al*., 2016). However, the attitude of occupants in switching off manually the lights when they leave the room become the main obstacle in achieving the energy savings target. Thus, the automatic lighting system is the best solution for buildings' energy efficient practices.

2.2 CONTROL IN LIGHTING SYSTEM

In the context of a lighting system, control refers to the mechanisms and technologies that manage the operation of lighting fixtures. This includes the ability to turn lights on and off, adjust their brightness, change their color temperature, and automate these functions based on various inputs such as time of day, occupancy, or daylight availability. Controls can be manual, where users operate switches or dimmers directly, or automatic, where sensors and programmed logic dictate lighting behavior without human intervention. The objective of lighting control is to adjust the ON/OFF status or dimmer level of LED lights to achieve optimal illumination for convenience and productivity while minimizing power consumption. Since artificial lighting and environmental illumination are interrelated, they cannot be considered independently. By effectively utilizing natural light, such as daylight and reflected light, the need for artificial lighting can be significantly reduced. Thus, integrating both sources of light in the design of a lighting project can greatly enhance energy efficiency (Gaspare and Mehrdad, 2015).

2.3 MOTION SENSOR TECHNOLOGY AND TYPES

A motion sensor is an electronic device designed to detect physical movement within a specified area and convert it into an electrical signal. This signal can be utilized to control various devices such as lighting systems. Motion sensors play a crucial role in enhancing energy efficiency and security in both residential and commercial environments. Due to advancements in technology, motion detection can now be achieved by monitoring changes in an object's speed or direction within the field of views(Moe *et al.*, 2020). In lighting systems, motion detectors are strategically placed to activate lights upon detecting movement. This not only enhances convenience by automating lighting control but also contributes to energy savings by ensuring lights are only operational when needed. In applications such as halls or large public venues, integrating motion sensor technology in lighting systems ensures that illumination is responsive to human presence, thereby optimizing both safety and energy efficiency.

Motion sensors used in light control systems can be categorized into several types based on their technology and application. Some commonly used motion sensors are:

a) **Passive Infrared Receiver (PIR) Sensors**: Passive Infrared Receiver (PIR) is an infrared-based sensor; as the name implies, “Passive” means the device does not emit any infrared radiation. It detects motion by sensing changes in infrared energy emitted by humans or animals moving within their field of view. Typically used indoors for occupancy sensing in offices, homes, and commercial spaces. The most widely used motion detection sensor relies on passive infrared (PIR) technology to sense movement, such as when a person approaches a door. This sensor is most effective at detecting changes in heat within its field of view as the heat mass moves through it (Shoewu *et al.*,2020). PIR will be considered in this project due to the fact that PIR sensors stand out due to their effective detection mechanism based on infrared radiation changes, energy efficiency leading to cost savings, reliability with low false alarm rates, wide coverage capabilities requiring fewer units for large areas, easy integration with smart technologies, user-friendly operation requiring little maintenance or adjustment after installation, and versatility across various applications. These attributes make PIR sensors an optimal choice for enhancing safety and convenience in indoor settings.

b) **Ultrasonic Sensors**: It emits ultrasonic waves and detects changes in the reflection pattern caused by moving objects. It is also effective for detecting motion in larger spaces and areas with obstructions where line-of-sight is not required.

c) **Microwave Sensors**: It emits microwave signals and detects changes in the reflected signal caused by moving objects. It can penetrate walls and barriers, making them suitable for applications where coverage of large areas or through obstacles is necessary.

d) **Dual Technology Sensors**: It combines both PIR and ultrasonic or microwave technology to improve reliability and reduce false triggers. It requires both technologies to activate before triggering the lighting system, reducing the chances of false alarms.

e) **Camera-Based Sensors**: It uses video analytic to detect motion and presence. It can provide additional data such as occupancy patterns and crowd detection, but require higher installation and maintenance costs.

f) **Acoustic Sensors**: It detects motion based on sound waves or acoustic signals generated by movement. It is also used in specific applications where other sensor types may not be suitable, such as detecting motion in noisy environments.

2.4 DIFFERENT TYPES OF LAMPS: POWER CONSUMPTION AND HEAT DISSIPATION

Lamps are essential components in lighting systems, and they come in various types, each with distinct characteristics regarding power consumption and heat dissipation. Understanding these differences is crucial for selecting the appropriate lamp for energy saving. When discussing different types of lamps, it is essential to consider their energy-saving capacities and the amount of heat they dissipate (Electrical Installation, 2024). This analysis will cover the most common types of lamps: Incandescent, Halogen lamps, Compact Fluorescent Lamps (CFLs), and Light Emitting Diodes (LEDs).

2.4.1 Incandescent Lamps

The working principle of an incandescent lamp involves the heating of a tungsten filament by an electric current. As the filament heats up, the electrons in the tungsten material undergo constant energy changes, emitting light through incandescence. This results in the production of a continuous electromagnetic spectrum with a temperature-dependent wavelength distribution.

Power consumption: Incandescent lamps typically convert 5-8% of electrical energy into visible light when operated at a filament temperature of 2600-2800 K (Gendre, 2017)..

Energy efficiency: The energy efficiency ranges from 3.5 to 25 lm/W, depending on the lamp type. Standard lamps have an efficiency of 3.5-20 lm/W, while halogen lamps achieve 9-25 lm/W, with higher efficiency for halogen lamps due to the use of a tungsten-bromine cycle and higher gas fill pressure (Gendre, 2017)..

Heat dissipation: The rest of the electrical energy (around 92-95%) is lost as heat, primarily through the filament, contributing to significant thermal losses. To limit material evaporation and reduce heat loss, incandescent lamps are filled with a protective gas atmosphere, and the filament is often coiled or compacted. The filament temperature for standard lamps lies in the 2600-2800 K range, while halogen lamps operate at 2800-3200 K, requiring higher temperatures and leading to more efficient heat dissipation (Gendre, 2017).

Figure 2.1: Incandescent Lamps(Source: Siti *et al.*, 2022)

2.4.2 Halogen Lamps

The halogen lamp operates on the same principle of incandescence as a conventional incandescent lamp, where an electric current heats a tungsten filament to emit light. However, the key difference is the halogen cycle, which enhances the lamp's performance and lifespan. In the halogen cycle;

i. a tungsten atom evaporates from the filament due to the high temperature.

ii. it reacts with a halogen gas (typically bromine) to form a tungsten-halogen compound.

iii. compound travels through the gas phase and reaches the filament, where the high temperature breaks the compound, returning the tungsten atom to the filament and releasing the halogen atom to start the cycle again.

This cycle allows the lamp to operate at higher temperatures (3000-3500 K) than conventional incandescent lamps (2800 K), improving its efficiency and longevity (Kitsinelis and Kitsinelis, 2015).

Power consumption: Halogen lamps consume similar power to conventional incandescent lamps but are more efficient in converting electrical energy to light.

Energy efficiency: Halogen lamps achieve 30 lm/W luminous efficacy, significantly higher than the typical incandescent lamp efficiency (5-8% light conversion).

Heat dissipation: Due to the higher operating temperatures (3000-3500 K), halogen lamps emit more heat compared to conventional lamps. However, the use of quartz glass and higher internal gas pressure (several atmospheres) reduces tungsten vaporization, which helps improve lifespan and minimize heat loss. Despite this, a substantial portion of the energy is still lost as heat, although the halogen cycle enhances the lamp's efficiency by recycling tungste (Kitsinelis and Kitsinelis, 2015).

Figure 2.2: Halogen Lamps(Source: "Light Sources", 2015)

2.4.3 Compact Fluorescent Lamps (CFLs)

CFLs operate by passing an electric current through a tube filled with argon gas and a small amount of mercury vapor. This current generates ultraviolet (UV) light, which excites a phosphor coating inside the tube. The phosphor then reacts by emitting visible light.

Power consumption: CFLs consume less power compared to incandescent lamps.

Energy efficiency: CFLs have an efficacy of 25-70 lm/W, making them more energy-efficient than incandescent lamps, which typically have an efficacy of 10-15 lm/W. CFLs have a longer lifespan, ranging from 7500 to 10,000 hours (Jayaweera, 2014).

Heat dissipation: CFLs are more efficient in converting electrical energy to light, so they generate less heat than incandescent lamps. However, they still produce some heat, but it is considerably lower compared to incandescent lamps. The heat dissipation is moderate due to the electric discharge within the tube, but the design minimizes excess heat compared to older technologies like incandescent bulbs.

Figure 2.3: Compact Fluorescent Lamps(Source: "Compact fluorescent lamp," 2024)

2.4.4 Light Emitting Diodes (LEDs)

LEDs (Light Emitting Diodes) are solid-state electro-chemical light sources. When the diode is forward-biased (electrical current flows through it), light is generated. The light produced is monochromatic, and the color depends on the materials used in the LED. White light can be produced by using phosphors, similar to the coatings in fluorescent and HID lamps.

Power consumption: LEDs consume very little power compared to traditional lighting sources like incandescent and CFL lamps. They are highly efficient at converting electrical energy to light.

Energy efficiency: LED lamps typically have an efficacy between 40-55 lm/W, which is significantly higher than incandescent lamps and CFLs. Their life expectancy is around 100,000 hours, making them much longer-lasting and more energy-efficient (Jayaweera, 2014).

Heat dissipation: Despite their high energy efficiency, heat dissipation is a critical factor for the longevity of LEDs. Poor heat management can significantly shorten their lifespan. Therefore, proper packaging and heat dissipation mechanisms are essential in LED lamps to maintain optimal performance and prevent overheating.

Figure 2.4: Lighting Emitting Diodes(Source: Surface mounted LED panel light round, 2024)

2.5 PASSIVE INFRARED RECEIVER (PIR) SENSORS

Passive Infrared sensor is a device used to detect motion by receiving infrared radiation. The PIR is a sensor designed to sense the presence of human being within a radius of its field-of-view (Odat *et al.* 2017). All objects, whether living or non-living, that have a temperature above zero degrees Celsius emit infrared radiation. This radiation is invisible to the human eye and can be detected by specialized electronic equipment. The term "passive" in passive infrared (PIR) refers to the detector's function of passively absorbing infrared energy. PIR sensors can gather data on an object's position, acceleration, and speed. A PIR motion detector consists of a PIR receiver that monitors changes in the surrounding temperature. If the temperature shifts rapidly, such as when a person moves through its detection area, the installed controller will trigger a signal (Swagatam, 2022).

PIR sensors are typically used in small, enclosed spaces to detect major motions such as occupants moving in and out of a room. They are less active at picking up small movements like sitting at a desk typing. They have a nominal limit of about 4.5 meters (but lower mounting heights might be more practical) and the sensor must have direct line of sight with the moving object to detect movement. They should not be mounted close to heating, ventilating and air conditioning (HVAC) supply registers, which can disrupt their detection. PIR sensors have a thin film sensing material that generates electricity when exposed to heat. When an object passes in front of a background like a wall or the ground, the sensor detects the change in signal and converts that change into a pulse that sends a signal to a controller for a light. PIR sensors are passive; they do not actively send out signals. Because they are passive, they require very little power, which makes PIR sensors an ideal sensor technology for wireless sensors. The working principle of a PIR sensor is shown in Figure 2.1

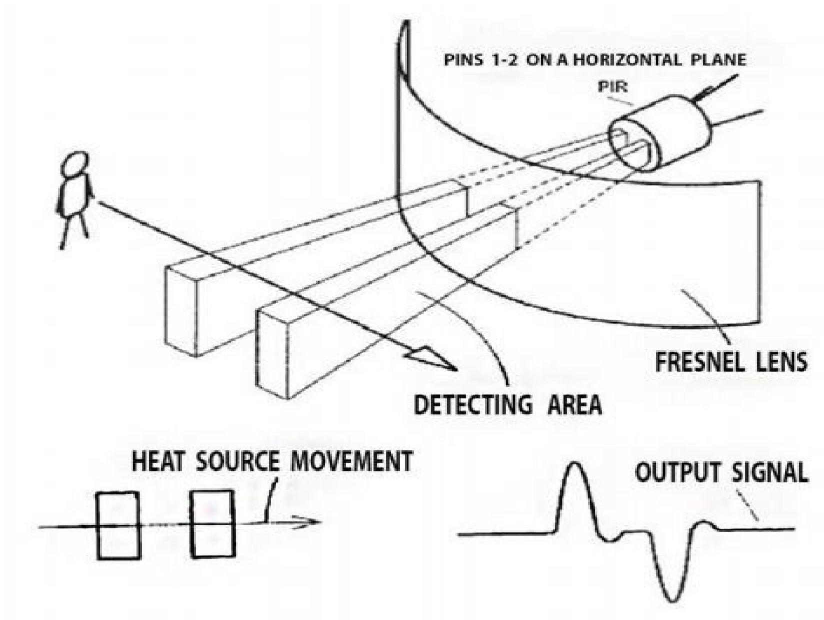

Figure 2.5: Working Principle of PIR Sensor (Source: "PIR Sensor Module," 2024.)

The solid-state passive infrared sensor consists of thin-film pyroelectric heat-sensing material mounted on a printed circuit board containing the necessary electronics to interpret the signals from the sensor. When a warm object like a person passes by, the sensor detects the heat, which causes a positive differential change between the two halves of the sensor. When the warm body leaves the sensing area, the sensor generates a negative differential change. These change pulses are what is detected. The assembly is contained in a housing with a plastic window that allows in infrared radiation. The window itself may be molded plastic that is faceted. Each facet is a Fresnel lens that focuses the infrared energy or there might be segmented parabolic mirrors within the house that focus the infrared energy. The window plastic can also serve as a filter to limit the wavelengths to 8-14 micrometers, which is closest to the infrared radiation emitted by humans, to minimize false positives.

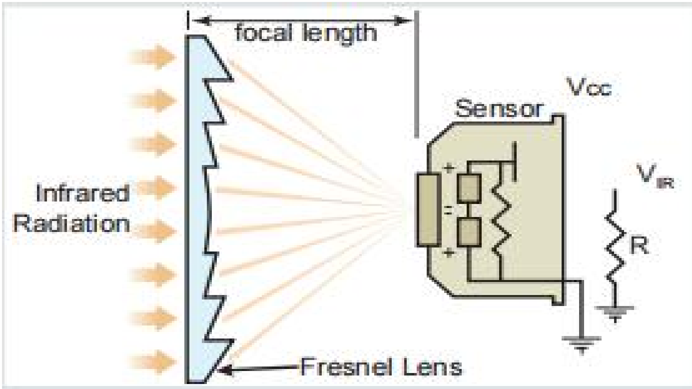

Figure 2.6: Anatomy of a Passive Infrared Sensor (Source: U.S. Department of Energy, 2019)

2.6 LIGHT DEPENDENT RESISTOR (LDR) SENSOR MODULE

LDR sensor module is a low-cost digital sensor as well as analog sensor module, which is capable to measure and detect light intensity. This sensor also is known as the Photoresistor sensor. This sensor has an onboard Light Dependent Resistor (LDR), that helps it to detect light. This sensor module comes with 4 terminals. Where the "DO" pin is a digital output pin and the "AO" pin is an analog output pin. The output of the module goes high in the absence of light and it becomes low in the presence of light.

Table 2.1: LDR Sensor Module PIN Description (Source: Electroduino, 2024)

PIN NO	PIN NAME	DESCRIPTION
1	VCC	+5 V power supply Input Pin
2	GND	Ground (-) power supply Input Pin
3	DO	Digital Output Pin
4	AO	Analog Output Pin

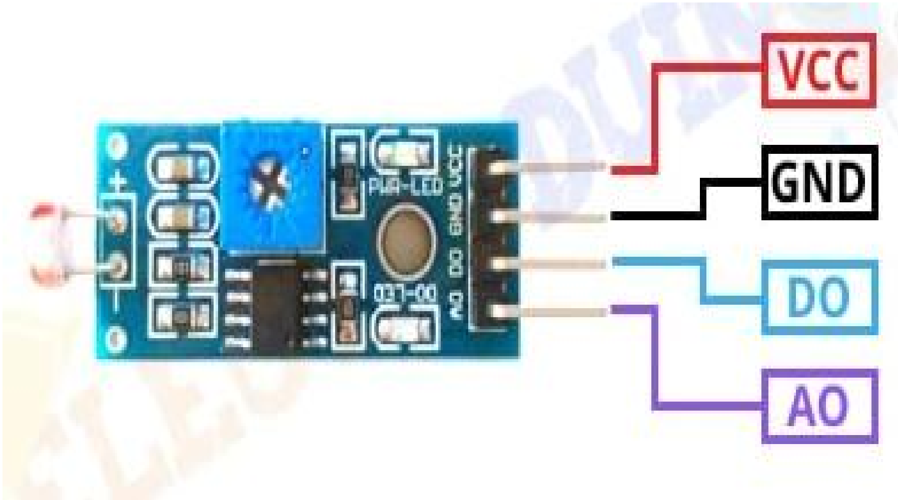

Figure 2.7: LDR Sensor Module (Source: Electroduino, 2024)

LDR as the name states is a special type of resistor that works on the photoconductivity principle which means that resistance changes according to the intensity of light (Riza *et al*. 2023). LDR is a type of passive electronic sensor to detect light. It is made up of two conductors separated by an insulator which becomes more conducting when exposed to high levels of light intensity, forming a variable resistor in the circuit. This allow it to measure the amount and brightness or darkness within its environment and provide information accordingly.

It works on the principle of photoconductivity whenever the light falls on its photoconductive material, it absorbs its energy and the electrons of that photoconductive material in the valence band get excited and go to the conduction band and thus increasing the conductivity as per the increase in light intensity. The energy in incident light should be greater than the bandgap gap energy so that the electrons from the valence band got excited and go to the conduction band. The LDR has the highest resistance in dark around 1012 Ohm and this resistance decreases with the increase in Light. As regarding the property of LDRs, the amount of light entering the LDR the inversely proportional to the resistance of the sensor, and the graph is hyperbolic in nature.

LDR light sensors are typically used as part of automated lighting control systems for energy conservation purposes such as dimming lights based on natural daylight that can be detected outside without human interention. LDR can be used to measure light brightness, detect object color, detect day or night.

2.7 ARDUINO

The Arduino platform, introduced in 2005, was designed to offer an affordable and user-friendly solution for students, and professionals to create devices that interact with their environment through sensors and actuators. Built on simple microcontroller boards, Arduino is an open-source computing platform used to build and program electronic devices. It functions similarly like other microcontrollers, acting as a mini computer that takes inputs and controls outputs for various electronic devices. Additionally, Arduino can transmit and receive data over the internet using various shields.

The Arduino platform consists of the Arduino development board and the Arduino Integrated Development Environment (IDE) for code development. The boards are equipped with 8-bit Atmel AVR microcontrollers or 32-bit Atmel ARM processors, which can be easily programmed using C or C++ in the Arduino IDE. Unlike other microcontroller boards, Arduino only entered the electronic market a few years ago and was initially used for small-scale projects. However, over time, more people in the electronics community have started adopting Arduino for their own projects(Leo, 2018).

The development board also allows users to upload new code via a USB cable. The Arduino IDE offers a simplified platform that runs on standard personal computers, enabling users to write programs for Arduino using C or C++.

2.7.1 Types Of Arduino Board

Table 2.2 shows a list of the different types of Arduino Boards available along with its microcontroller type, crystal frequency and availabilities of auto reset facility.

Table 2.2: Types of Arduino Board (Source: Leo, 2018)

S/N	ARDUINO TYPE	MICROCONTROLLER	CLOCK SPEED
1	Arduino Uno	ATmega328	16 MHz with auto-reset
2	Arduino Duemilanove / ATmega328	ATmega328	16 MHz with auto-reset
3	Arduino Nano	ATmega328	16 MHz with auto-reset
4	Arduino Mega 2560 or Mega ADK	ATmega2560	16 MHz with auto-reset
5	Arduino Leonardo	ATmega32u4	16 MHz with auto-reset
6	Arduino Mini w/ ATmega328	ATmega328	16 MHz with auto-reset
7	Arduino Fio	ATmega328	8 MHz with auto-reset
8	Arduino BT w/ ATmega328	ATmega328	16 MHz with auto-reset
9	LilyPad Arduino w/ ATmega328	ATmega328	8 MHz (3.3V) with auto-reset
10	Arduino Pro or Pro Mini	ATmega328	16 MHz with auto-reset
11	Arduino NG	ATmega8	16 MHz with auto-reset

2.7.2 Arduino Hardware

The Arduino Development Board is made up of several components that work together to ensure its functionality. The key components that contribute to its operation are:

a) **Microcontroller**: This is the central component of the board, acting as a mini computer. It is capable of receiving and sending commands or data to the connected peripheral devices. The type of microcontroller varies across different boards, and each one comes with its own set of specifications.

b) **Power Jack**: This is used to provide the board with a regulated voltage, typically between 9 and 12 volts.

c) **USB Port**: A crucial port on the board, the USB plug allows for the uploading of programs to the microcontroller via a USB cable. It also supplies a regulated 5V power to the Arduino board when the external power supply is not connected.

d) **Internal Programmer**: The microcontroller can be programmed by uploading the software code through the USB port, without the need for an external programmer.

e) **Reset Button**: A button on the board that resets the Arduino microcontroller when pressed.

f) **Analog Pins**: The board includes several analog input pins (typically A0 to A7), which are used for analog input and output. The number of these pins can vary depending on the board model.

g) **Digital I/O Pins**: The board features digital input pins (typically ranging from 2 to 16), which are used for digital input and output. The total number of these pins also differs across different boards.

h) **Power Supply and Ground Pins**: The board contains pins that provide 3.3V, 5V, and ground connections.

2.7.3 Arduino Software

The program code written for Arduino is referred to as a "sketch." The software used to create these sketches is called the Arduino IDE. This IDE includes the following components:

a. **Text Editor**: This is where you can write the simplified code using a C++-like programming language tailored for Arduino.

b. **Message Area**: This area displays error messages and provides feedback when saving or exporting code.

c. **Text:** The console shows text output from the Arduino environment, including detailed error messages and other relevant information.

d. **Console Toolbar:** This toolbar contains buttons such as Verify, Upload, New, Open, Save, and Serial Monitor. In the bottom-right corner of the window, it also shows information about the Development Board and the Serial Port currently in use.

```
#define pin 13 // pin is a variable in which 13 is stored.
void setup() {
  pinMode(pin, OUTPUT); // Delcearing pin number 13 as OUTPUT.

}

void loop() {
  digitalWrite(pin, HIGH); // Here the pin will get 5v
  delay(1000); // It will generate a time delay of 1 second
  digitalWrite(pin, LOW); // Here the pin will get 0v
  delay(1000); // It will generate a time delay of 1 second

}
```

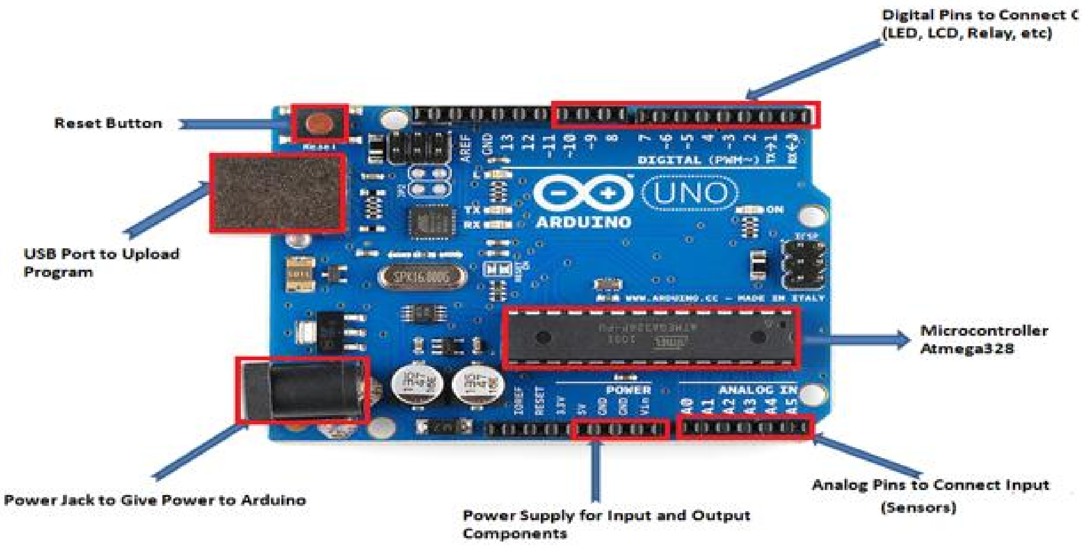

Figure 2.8: A labled diagram of an Arduino Board and IDE (Source: Leo, 2018)

2.8 RELAY

A relay is a simple electronic device consisting of a switch, an electromagnetic coil, and an iron shaft. It operates when electric current flows through the coil, generating a magnetic field that moves the switch, allowing a larger current to flow. The key feature of this component is that its compact design can control higher currents. Over time, relays have been used as essential components in various electronic systems, such as vehicle lighting, electronic networks, television, and radio. In the 1930s, they were even used in basic computing devices, which have since been replaced by microprocessors from companies like

Intel and AMD. The main advantages of relays are their ability to control current and electrical voltage, as well as their capacity to handle high voltage levels up to their maximum limit. Before the advent of microprocessor technology, relays were commonly used in machines that operated sequentially, such as in injection molding, blow molding, and conveyor belt systems (Tjandi and Kasim 2019).

Figure 2.10 shows the circuit diagram of a 5V relay module.

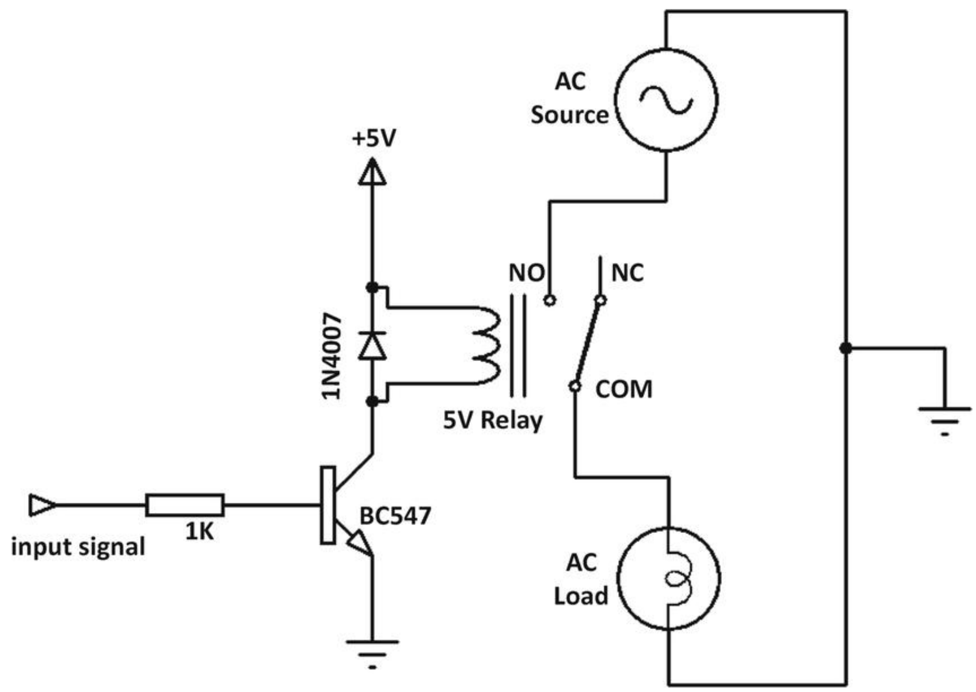

Figure 2.9: Circuit diagram of a 5V relay module (Source: Ema, 2020)

2.9 FUTURE TRENDS OF SMART BUILDING LIGHTING SYSTEMS

Smart building is one of vital elements in smart city concept. A smart building can provide intelligent facilities for building's occupants with better understanding on current building information through communication system such as humidity, temperature, lighting and weather (Asri *et al.,* 2019). A smart building lighting system in Figure 2.10 is also equipped with Internet-of-Things (IoT) based smart lighting control systems to support the emerging trend of future smart buildings. The IoT based smart lighting control system is designed to improve the building energy efficiency through Building Energy Management System (BEMS) (Jin *et al.* 2018). There are three conceptual layers approach for the smart lighting control system which consists of Layer 1 for sensing, delivery, and management layer, followed by Layer 2 for processing and modelling and finally, Layer 3 for smart building services which in this case provide visual comfort towards buildings' occupants (Kumar *et al.* 2017). Information obtained from the lighting system will be the input for the illumination level, and linked with other facilities such as heating, ventilating and air conditioning (HVAC) control services. Thus, all these valuable data can be obtained through Wi-Fi access and the information are available for further analysis on the building energy management control system to achieve energy-efficient building (Wagiman *et al.* 2019; Pandharipande & Newsham, 2018).

Smart building is the combination of the architectural design, interior design, mechanical and electrical system to make sure all the control and automation systems are easily controlled without human interference (Firdaus & Mulyana, 2018). The lighting system in a smart building can be operated in several different modes, which are Manual, Auto, and Hybrid for various applications (Wagiman *et al.* 2019). The wireless sensor and actuator network will collect the data based on the use of smart personalized LED light of the occupants in the building (Kumar *et al.* 2017). The sensing, delivery, and management layer collect the data and provide it as inputs that are required from the sensors for the IoTs to become as an ecosystem. The main components are the sensors and actuators that can be self configured and controlled through the Internet, different monitors, and available software. The common language and data model are needed to deal with the heterogeneity of the data source (Hernández-Ramos *et al.* 2015). The sensors of lighting systems can be used to monitor the electrical energy consumption and provide data for the management to re-evaluate the lighting control strategies. Table 2.3 shows a comparison between the lighting control system in the existing building and smart building. There are several factors that have been identified for building energy efficiency improvement. As an example, existing buildings still use simple lighting control systems which are easily installed whereas smart building uses the IoT based BEMS including the smart lighting control system. (Pandharipande & Newsham, 2018).

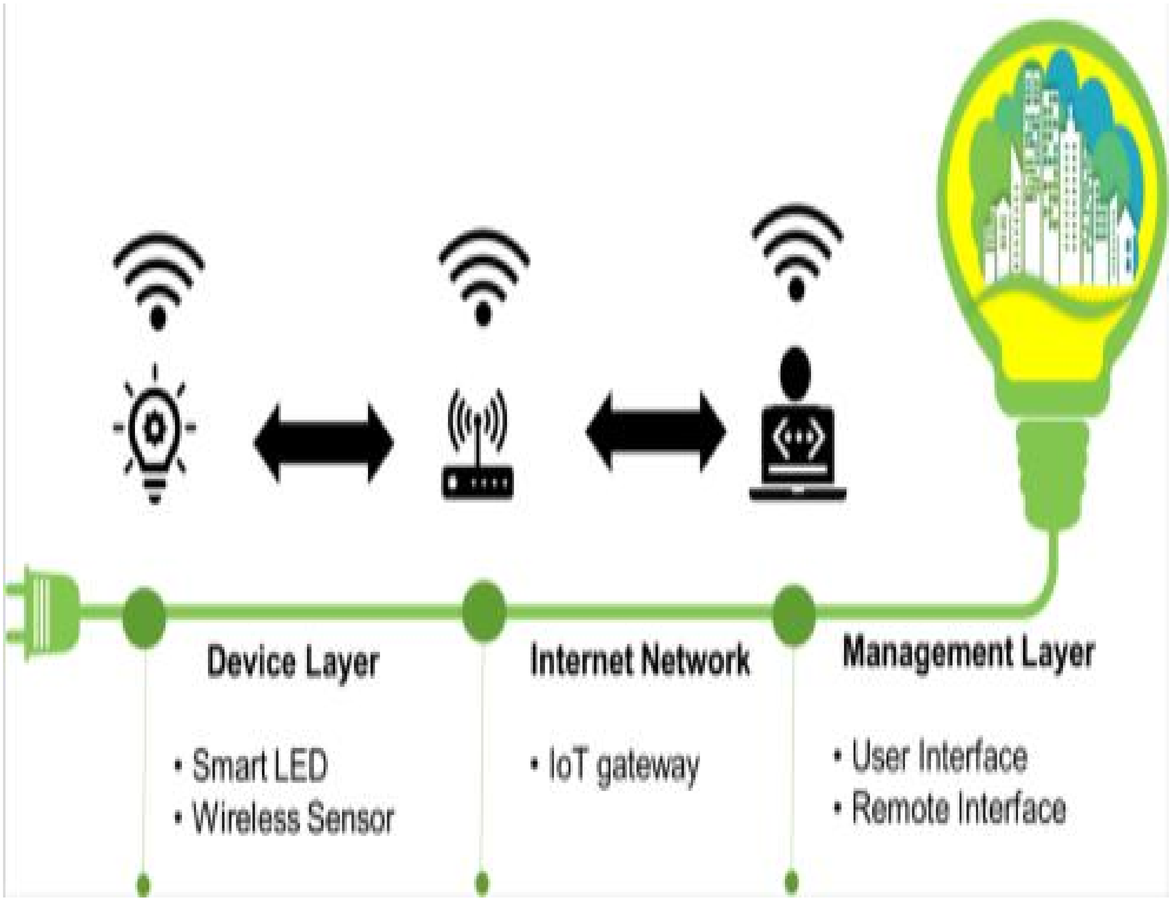

Figure 2.10**:** Lighting system in smart building (Source: Baharudin, N. H. *et al.* 2021)

Table 2.3: Comparison between existing buildings with current lighting control system and smart building (Source: Baharudin, N. H. *et al.* 2021)

S/N	**PARAMETERS**	**EXISTING BUILDING**	**SMART BUILDING**
1	Installation cost	Low	High
2	Building energy consumption	High	Low
3	Operation mode	Manual	Auto and Hybrid
4	Monitoring of building energy consumption	Difficult	Easy
5	System error severity and maintenance	Need human interference to locate the error	No human interference is needed to locate the error
6	Cyber-security	No effect	Severe effect

CHAPTER THREE

CONSTRUCTION METHODOLOGY

This chapter provides a detailed description of the design and implementation of a motion-sensor lighting system using Arduino Uno micro-controller, Passive Infrared (PIR) sensors, a Light Dependent Resistor (LDR) module, and a relay module at the top floor corridor of the School of Engineering and Engineering Technology, Federal University of Technology Akure. The system is intended to automate lighting control based on ambient light and the detection of human motion in predefined areas. This system enhances energy efficiency and improves convenience in lighting control for various environment.

3.1 BLOCK DIAGRAM

The implementaion and design of the motion-sensor lighting system is presented in Figure 3.1.

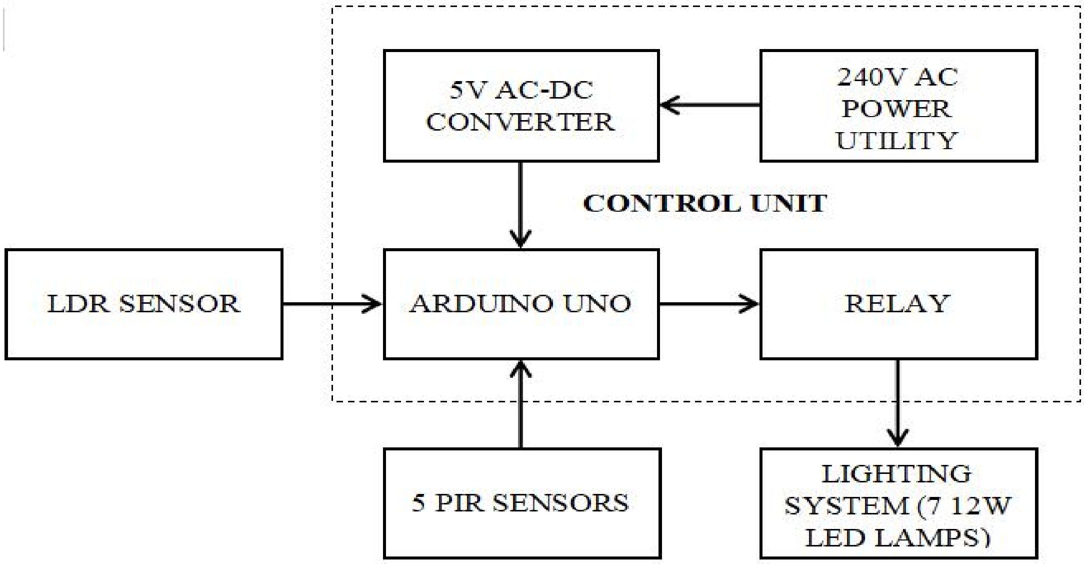

Figure 3.1: Block Diagram of Motion Sensor Lighting System

This section outlines the key components used in the motion-sensor lighting system, along with their functions.

3.1.1 Arduino Uno

The Arduino Uno's specifications with 14 digital input/output pins which interfaced easily with the LDR sensor, 5 PIR sensors, and a relay module is selected in this work.

3.1.2 Power Supply

The power supply, 240V ac is used to provide supply voltage to converter. This provides 5V dc output to Arduino input.

3.1.3 Light Dependent Resistor (LDR) Module

The LDR module used in this project has an onboard Light Dependent Resistor (LDR) that helps it to detect light. The relationship between LDR resistance (R) and light intensity (I) is governed by the following equation:

$$R = \frac{500}{I} \qquad \text{Equation (1)}$$

(Source: Setya *et al*., 2019).

where R is Resistance of LDR at a given light intensity (kΩ) ; I is Light intensity (in lux).

The calculation of LDR resistance based on the required Light intensity was calculated using equation 1. Light intensity (I) was assumed to be 100 lux for the 7 lamps to turn ON. The resistance of the LDR was set to 5 kΩ with the help of the onboard potentiometer. The digital output pin of the LDR module was connected to the digital pin 2 of the Arduino Uno with the VCC and GND pins connected to the 5V input pin and GND pin respectively.

3.1.4 Passive Infrared Receiver Sensors (HC-SR501)

PIR sensor HC-SR501 is used for this project because of its cost effectiveness. The PIR sensors detect infrared radiation emitted by humans to sense motion (Five PIR sensors were placed in strategic areas in the corridor to detect movement in various directions; the PIR sensors were fixed based on their detection range of 7 meters. The five PIR sensors were used to cover a total distance of over 30 meters. The jumper set of the sensors were set to non-repeatable trigger (L-Mode) which causes the sensors to output high during the delay time period. All the VCC and GND pins of the PIR sensors were connected to the 5V input pin and GND pin of the Arduino respectively while each of the output pin of the PIR sensors were connected to the digital input pin 3, 5, 6, 10 and 12 of the Arduino.

3.1.5 Relay Module

The relay module used in this project is a single channel 5V DC relay module with a switching voltage of 240V AC, 10A. The relay module is controlled by the Arduino through the GND, DO and VCC terminal, the DO pin of the relay module is connected to pin 4 of the Arduino while the VCC and GND pins are connected to the 5V input pin and GND pin respectively. The other end of the relay module consists of the NC, COM and NO terminals which are connected to the terminals of the manual switch to achieve a two-way switching operation of the lighting system.

3.1.6 Lighting System (LED)

The lighting system used in this project is existing seven 12W LED lamps capable of producing 300lux which .serves as the final output that is controlled by the relay module. The neutral terminal of the lamp is connected to the neutral terminal of the power utility while the live terminal of the lamp is connected to the COM pin of the relay module.

3.1.7 Proteus and Wokwi Design

The system's circuit diagram was designed with Proteus and was also simulated with Wokwi free online simulator.

3.1.8 Switch

Two switches were used for this project, one was used as a manual switch while another was used as an automatic switch.

3.1.9 Circuit Diagram

The circuit diagram of the research was connected and is shown in Figure 4.1.

CHAPTER FOUR

RESULT ANALYSIS AND DISCUSSION

This chapter outlines the results of implementing a motion sensor lighting system utilizing a Passive Infrared Receiver (PIR) sensor, a Light Dependent Resistor (LDR) sensor, an Arduino Uno, and a relay module in the top-floor corridor of the School of Engineering and Engineering Technology (SEET), Federal University of Technology Akure. The system's functionality was assessed through both simulations and practical implementation. The circuit diagram using Proteus is presented in Figure 4.1.

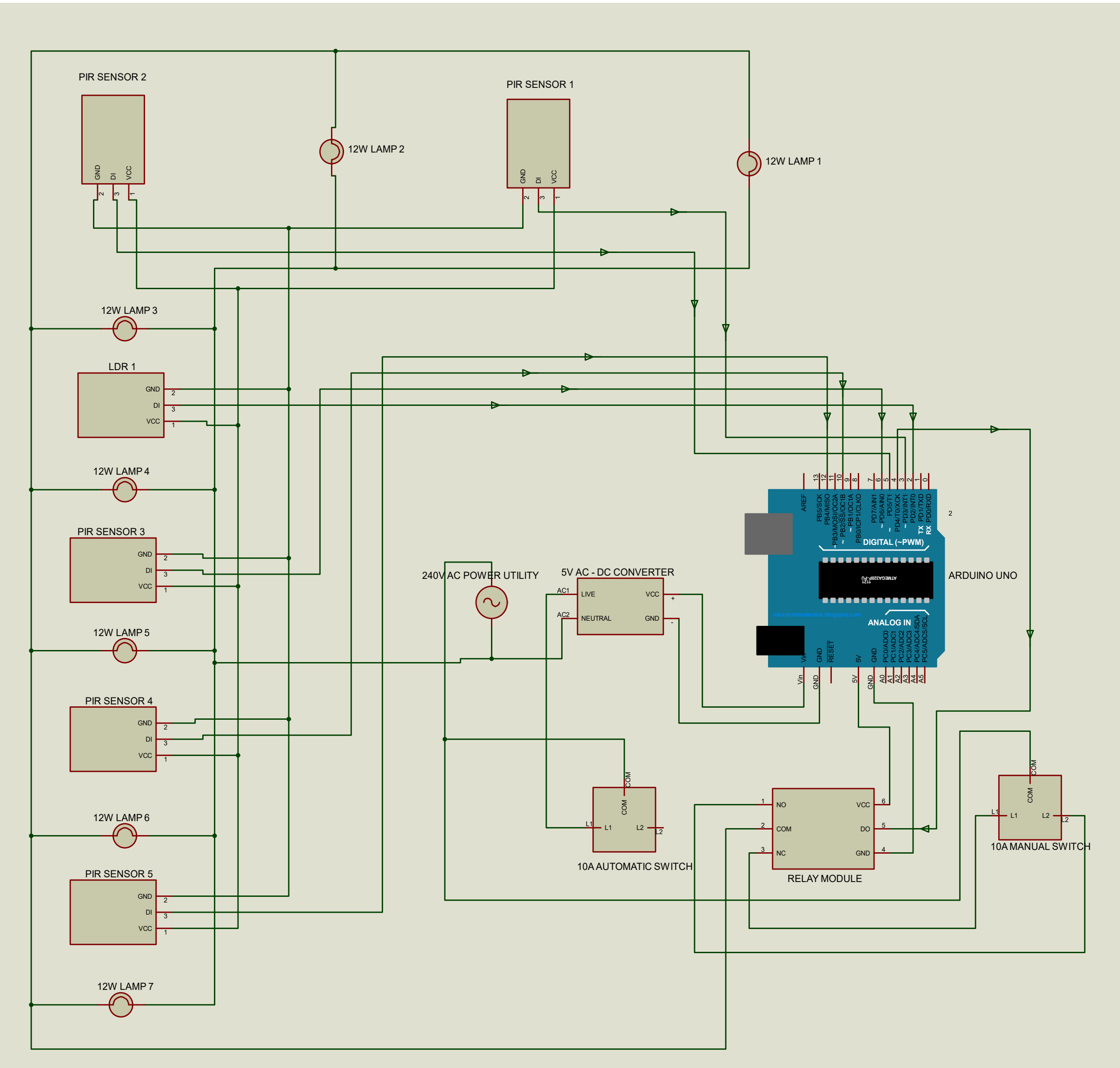

Figure 4.1: Circuit Diagram of the Motion Sensor Lighting System

4.1 SIMULATION RESULTS

The simulation of the Motion Sensor Lighting System was carried out using the Wokwi Simulator and the result is presented in Figure 4.2–Figure 4.5.

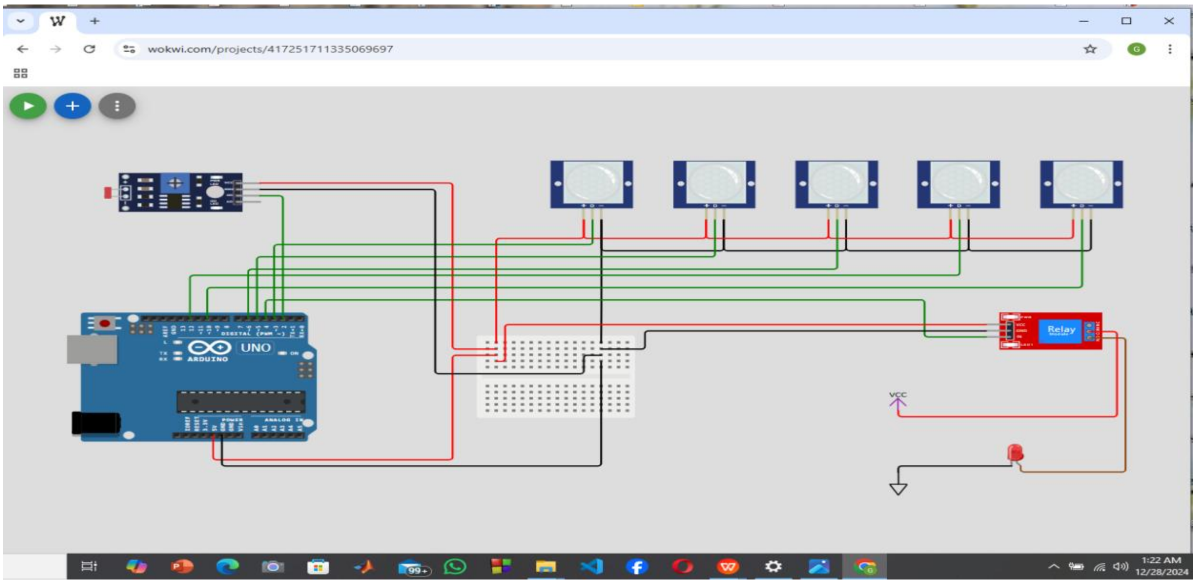

Figure 4.2: Wokwi Simulation Environment of the Motion Sensor Lighting System

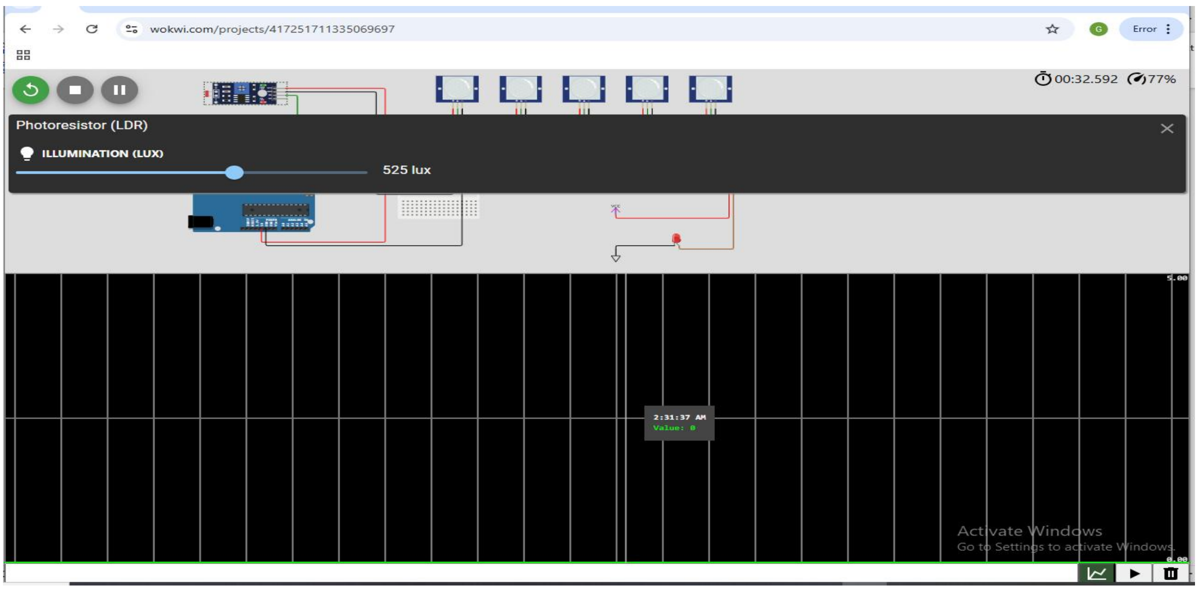

Figure 4.3: Daytime simulation results of lighting system

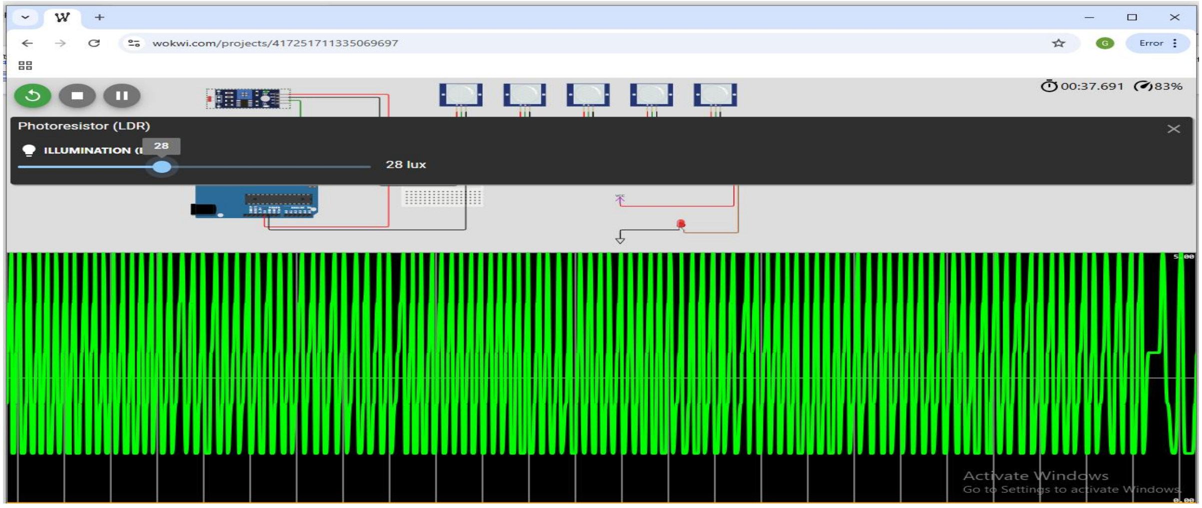

Figure 4.4: Nighttime simulation results with no motion detection

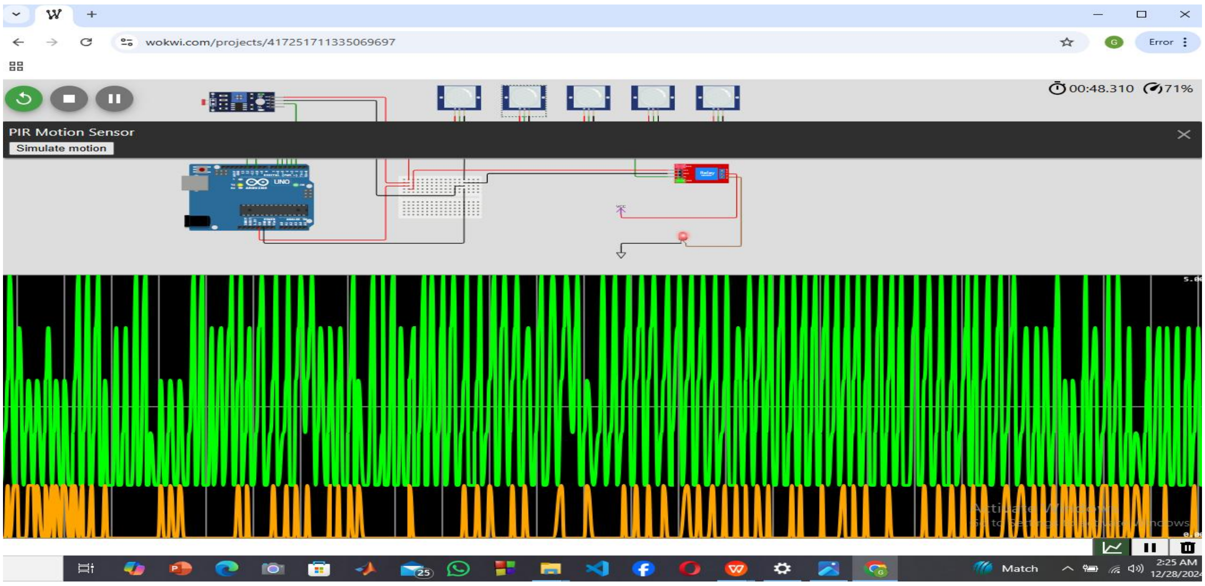

Figure 4.5: Nighttime simulation results with motion detection

Figure 4.2 shows the simulated environment consisting of five PIR sensors for motion detection, a LDR sensor for detecting ambient light intensity, a relay module, an arduino uno microcontroller, a breadboard, and a LED which represents the lighting lamp.

Figure 4.3 shows the simulation result of motion detection during the day where no motion is detected. Notably, the graph has no waveform indicating that when luminance levels exceed 100 lux in the simulation, the LED remains off regardless of motion detection

Figure 4.4 shows the nighttime simulation results of motion detection when no motion is detected and the LDR illumination is below 100 lux. The green waveform illustrate the system's response (night) confirming that the LED remains off in the absence of motion.

Figure 4.5 shows the nighttime simulation results of motion detection where motion is detected and the LDR illumination is below 100 lux. The green waveform illustrates night atmosphere while the orange waveform illustrate human movement confirming that the LED remains on as long as motion is detected.

4.2 PRACTICAL RESULTS

The system was assembled and tested at the last floor corridor (25%) of the School of Engineering and Engineering Technology (SEET), Federal University of Technology Akure. The implementaion result is presented on Figure 4.6. The implementation results are presented in Figure 4.7– Figure 4.10 and Table 1.

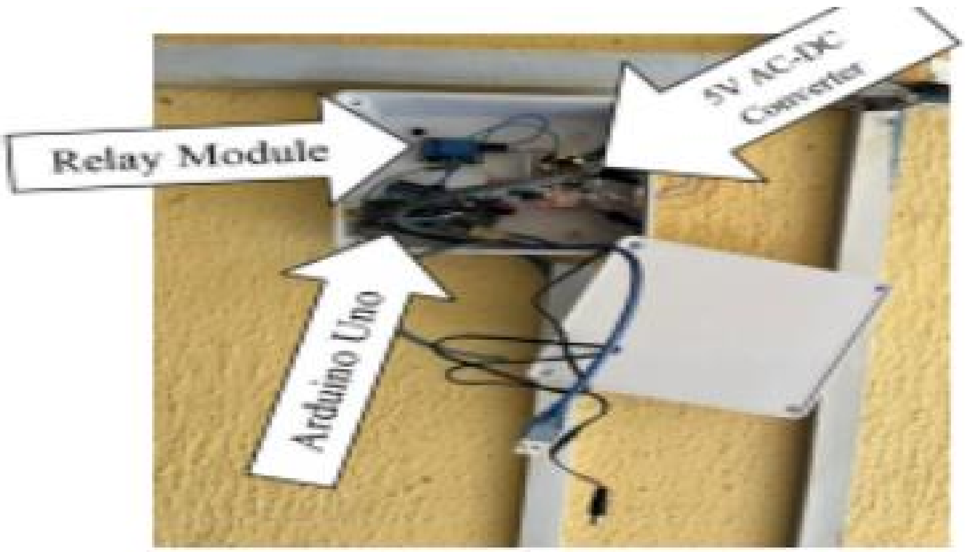

Figure 4.6: Control System implementaion and Installation

Figure 4.7: Daytime testing of the motion sensor lighting system

Figure 4.8: zero motion at Night

Figure 4.9: Stationary Human at Night

Figure 4.10: Movement of human being at Night

Figure 4.7 the result shows that the light remains off despite human movement in the area. This confirms the system's ability to detect and respond to daylight levels, preventing unnecessary illumination and promoting energy efficiency.

Figure 4.8 illustrate the system's nighttime performance when no motion is detected while Figure 4.9 shows the system performance in the presence of stationary human. These results show that the lighting system remains off, leveraging the PIR sensor's capability to distinguish between static and dynamic conditions. In the absence of motion, the system conserves energy by maintaining an inactive state. Furthermore, the system's intelligent design ensures that stationary individuals within the vicinity do not trigger unnecessary illumination.

Figure 4.10 demonstrates the system's functionality at night when motion is detected. Upon detecting motion within the specified 35-meter range, the lighting system activates, providing illumination to the area. As long as motion is present, the lighting system remains on, ensuring sufficient lighting for safety and security purposes. Table 4.1 presents Energy Comparison of Manual Switching and Motion-Sensor Switching Lighting System and Bill of Engineering Measurement and Evaluation is presented in Table 4.2.

Table 4.1: Energy comparison of Manual Switching and Motion-Sensor Lighting System

<table>
<tr><th>LIGHT SWITCHING MODE</th><th>12 W LED LAMP</th><th>OPERATIONAL TIME (TO): 7pm - 7am</th><th>TOTAL POWER (TP): 7 X 12 WATTS</th><th>ENERGY CONSUMPTION (TO X TP)</th><th>ENERGY COST (1kW hr = ₦209.5)</th><th>ENERGY SAVED /DAY =MS-Ms (kWH r)</th><th>COST OF ENERGY SAVED / DAY(₦)</th><th>COST OF ENERGY SAVED / MONTH(N) FOR 25% OF A FLOOR</th><th>COST OF ENERGY SAVED / YEAR (N) FOR 25% OF A FLOOR</th><th>COST OF ENERGY SAVED / YEAR (N) FOR 100% OF A FLOOR</th><th>COST OF ENERGY SAVED / YEAR (N) FOR 100% OF 3NOS OF BUILDING TOTAL FLOORS</th><th>ENERGY SAVED %</th></tr>
<tr><td>Manual Switching(MS)</td><td>7</td><td>12</td><td>84</td><td>1.008</td><td>211.18</td><td rowspan="2">0.84</td><td rowspan="2">175.98</td><td rowspan="2">5,279.40</td><td rowspan="2">63,352.80</td><td rowspan="2">253,411.20</td><td rowspan="2">760,233.60</td><td rowspan="2">83.33</td></tr>
<tr><td>Motion sensor(Ms)</td><td>7</td><td>2</td><td>84</td><td>0.168</td><td>35.2</td></tr>
</table>

Table 4.1 shows that 83.33% of energy is saved from motion sensor switching as compared to Manual Switching.

The cost of energy in using motion sensor per year in the 25% of in the 2nd floors is #63,352.80. The cost of energy in using motion sensor per year in the entire building covering 3 floors is seven hundred and sixty thousand, two hundred and thirty-three naira, sixty kobo (#760,233.60) in the same floor.

This projection highlights the vast potential for energy efficiency and cost savings that the Motion Sensor Lighting System offers. This innovation is an attractive solution for sustainable and cost-effective lighting.

Additionally, the system also offers security awareness which aids in detecting unauthorized movements in the building. From Table 4.2, the cost of 25% of implementing the system in the 2nd floor is seventy two thousand and one hundred naira (#72,100). Deductively, the total cost of implementing the system in the entire building is eight hundred and sixty five thousands and two hundred naira (#865,200). It follows that the motion sensor lighting system is cost effective over years of usage since the implementation cost will be recovered over 1.138yrs.

Table 4.2: Bill of Engineering Measurement and Evaluation (BEME)

S/N	DESCRIPTION	QTY	UNIT RATE(₦)	COST(₦)
1	Arduino Uno Board	1	15,000	15,000
2	Relay Module	1	2000	2,000
3	LDR Sensor Module	1	2000	2,000
4	PIR Sensor	5	2500	12,500
5	Ethernet CAT 5	20 yards	1000	20,000
6	1mm2 Double Core Cable	4 yards	500	2,000
7	3×3 Surface PVC Pattress	4	400	1,600
8	3×3 PVC Pattress	1	1000	1,000
9	6×6 PVC Junction Box	1	2000	2,000
10	Screws	20	15	300
11	12volts AC To DC Converter	1	3000	3,000
12	Trunking Pipes	2yards	1200	2,400
13	Jumper Wires	1	5000	5,000
14	Insulating Tape	2	400	800
15	Breadboard	1	1500	1500
16	2 Gang 2 way Switch	1	1000	1000
	TOTAL			72,100

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSIONS

Through careful design, simulation, and physical testing, the objectives of this project were achieved, and the system was able to demonstrate its effectiveness in practical scenarios. The success of this project underscores the potential of automated lighting systems in contributing to smarter, more energy-efficient building management.

The design and implementaion of a motion-sensor lighting system represent a significant step forward in energy conservation and security enhancement. This project addressed the limitations of motion sensor inability to operate in the previous implementation at the last floor of the researched educational edifice. The simulation results show that the practical of the simulation is feasible.

The cost of energy in using motion sensor per year in the entire building covering 3 floors is seven hundred and sixty thousand, two hundred and thirty-three naira, sixty kobo (₦760,233.60). This innovation is an attractive solution for sustaining energy efficiency and cost savings that the Motion Sensor Lighting System offers. The total cost of implementing the system in the entire building is ₦865,200. The motion sensor lighting system is cost effective over years of usage since the implementation cost will be recovered over 1.138years.This projection highlights the vast potential fornable and cost-effective lighting.

Additionally, the system also offers security awareness which aids in detecting unauthorized movements in the building.

5.2 RECOMMENDATIONS

Motion sensor lighting control system is recommended for a use in the corridor of an educational buildings or any other edifices corridor or walkway.

REFERENCES

Adelakun, A., Adewale, A., Abdulkareem, A., & Olowoleni, J. (2014). Automatic Control and Monitoring of Electrical Energy Consumption Using PIR Sensor Module. *International Journal of Scientific & Engineering Research*, 5(5), 493–496.

Alex, R. S., & Starbell, R. N. (2014). Energy efficient intelligent street light system using Zigbee and sensor. *International Journal of Engineering and Advanced Technology (IJEAT)*, 3(4), 485-489.

Asri, N. A, Ibrahim, R., & Jamel, S. (2019). Designing a model for smart city through digital transformation. *International Journal of Advanced Trends in Computer Science and Engineering*, 8(1.3):345-51.

Baharudin, N. H., Mansur, T. M. N. T., Ali, R. & Sobri1, N. F. A. (2021). International Journal of Advanced Technology and Engineering Exploration. *Smart lighting system control strategies for commercial buildings: A review*, 8(74), p. 51.

Compact fluorescent lamp. (2024). *Wikipedia, The Free Encyclopedia. Retrieved September* 3, 2024, from https://en.wikipedia.org/wiki/Compact_fluorescent_lamp

Electrical Installation. (2024). *The different lamp technologies*. Electrical Installation. Retrieved December 15, 2024, from https://www.electrical-installation.org/enwiki/The_different_lamp_technologies

Ema, R. (2020). Relay module circuit diagram [Image]. ResearchGate. https://www.researchgate.net/profile/Romana-Ema/publication/341570650/figure/fig3/AS:1009798157983744@1617766050058/Relay-module-circuit-diagram.ppm

Firdaus, R., Mulyana, E. 2018. Smart building lighting system. In: *IOP Conference Series: Materials Science and Engineering*, vol. XXX, 1-7. IOP Publishing.

Gaspare, B. & Mehrdad, M. (2015). Daylighting Control and Simulation for LED-Based Energy. *Energy-Efficient Lighting System*, 12(1); 1-1. doi: 10.1109/TII.2015.2509423.

Gendre, M. F. (2017). *Incandescent lamps*. Springer International Publishing Switzerland.

Gilani, S., & O'Brien, W. (2018). A preliminary study of occupants' use of manual lighting controls in private offices: a case study. *Energy and Buildings*, 159, 572-586.

Haq, M., Hassan, M., Abdullah, H., Rahman, H., Abdullah, M., & Said, D. (2014). A review on lighting control technologies in commercial buildings, their performance and affecting factors. *Renewable and Sustainable Energy Reviews,* 33, 268-279.

https://www.oemsecrets.com/articles/hc-sr501-pir-motion sensor#:~:text=The%20HC%2DSR501%20sensor%20is,well%20as%20on%20extreme%20temperatures.

Hernández-Ramos, J.L., Moreno, M.V., Bernabé, J.B., Carrillo, D.G., Skarmeta, A.F. (2015). SAFIR: Secure access framework for IoT-enabled services on smart buildings. *Journal of Computer and System Sciences*, 81(8):1452-63.

Jayaweera, A. (2014). Energy analysis & effects on power utility of LED's compared to conventional bulbs. University of Gavle. https://www.diva-portal.org/smash/get/diva2:807732/FULLTEXT01.pdf

Jin, X., Wang, G., Song, Y., & Sun, C. (2018). Smart building energy management based on 30-36.

Kitsinelis, S., & Kitsinelis, S. (2015). *Light sources: Basics of lighting technologies and applications*. CRC Press.

Kumar, A., Kar, P., Warrier, R., Kajale, A., & Panda, S.K. (2017). Implementation of smart LED lighting and efficient data management system for buildings. *Energy Procedia*, 143:173-8.

Louis, L. (2018, July). Working principle of Arduino and using it as a tool for study and research. *International Journal of Control, Automation, Communication and Systems (IJCACS)*, 1(2), 21-23.

Mango, M., Poloneli, T., & Benini, L. (2015). A low cost and highly scalable wireless sensor network solution to achieve smart LED light control for green buildings. *IEEE Sensors Journal*, 15(5), 3162-3169.

Martini, I., Riyanto, I., Adiyarta, K., & Suparmoko, M. (2018). An effort to lower electricity bills in university buildings through the use of automatic lighting switches. *Pertanika Journal of Social Sciences & Humanities*, 26, 11–19.

Mendoza, S. (2021, March 19). HC-SR501 PIR Motion Sensor. oemsecrets.com.

Moe, M. T., Swe, S. S. & Zaw, T. T. (2020). Security System with PIRSensor. *Iconic Research and Engineering Journals*, 4(6): 77 – 82.

Odat, E., Shamma, J. S., & Claudel, C. (2017). Vehicle classification and speed estimation using combined passive infrared/ultrasonic sensors. *IEEE Transactions on Intelligent Transportation Systems*, 19(5), 1593–1606.

Oyeleye, M.O. and Makanju, T. D. (2020). Electrical Lighting Load Estimation Prior to Design. *Proceedings of 6th UMaT Biennial International Mining and Mineral Conference, Tarkwa, Accra, Ghana*, pp. 137-142.

Pandharipande, A., & Newsham, G. R. (2018). Lighting controls: evolution and revolution. *Lighting Research & Technology*, 50(1), 115-128.

PIR module. (n.d.). SunFounder. Retrieved September 3, 2024, from https://docs.sunfounder.com/projects/esp32-starter kit/en/latest/components/component_pir_module.html

Prasad, L. (2022, September 20). What is Relay? How it Works? Types, Applications, Testing. ElectronicsHub. https://www.electronicshub.org/what-is-relay-and-how-it-works/

RajaR., & Udhayakumar, K. (2014). Development in smart sensor network for energy saving. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, 3(Special Issue 2)*, 217-221.

Metallidou, C. K., Psannis, K. E., & Egyptiadou, E. A. (2020). Energy efficiency in smart buildings: IoT approaches. IEEE Access, 8, 63679-63699.

Riza, H.S., Ain, S., Bambang, S., Dawi, Y., Andyika, P.U. (2023). AIP Conference Proceedings. *Analysis of light dependent resistor sensors on resistance and light intensity in solar power plants,* 2824(1), p. 1

S.(2023, September 18). What Are Jumper Wires: Know by Colour, Types and Uses. Wiltronics. https://www.wiltronics.com.au/wiltronics-knowledge-base/what-are-jumper-wires/

Setya, W., Ramadhana, A., Hananda, P., Santoso, A., Malik, A., & Chusni M. M. (2019). Design and development of measurement of measuring light resistance using Light Dependent Resistance (LDR) sensor. *Journal of Physics Conference Series,* 1402(4): 044102

Shoewu, O.O., Ayangbekun, O.J., & Johnson, E. O. (2020). Design and Construction of Micro-Controller Based IntrusionDetector. *International Journal of Innovative Research in Electronics and Communications*, 7(4): 1 – 6.

Siti, A., Rahmadhani, F., Rahmaniar & Zuraidah, T.(2022). An Efficiency Analysis of Use of Recycled Light. 5(2): 17564.

Surface mounted LED panel light round (Ø300mm, 24W, 2500lm). (n.d.). CDivine. Retrieved September 3, 2024, from https://cdivine.com.ng/shop/surface-mounted-led-panel-light-round-%CF%86300mm-24w-2500lm/

Swagatam, P. (2022). International Journal of Research Publication and Reviews. *Motion Detector Alarm and Security System,* 3(11), 1104-1108.

Tjandi, Y., and Kasim, S. (2019). Electric control equipment based on Arduino relay. Journal of Physics: Conference Series, 1244, 012028. https://doi.org/10.1088/1742-6596/1244/1/012028

U.S. Department of Energy. (2019). Wireless occupancy sensors for lighting controls: Applications guide for federal facilities, p. 2. Retried from (https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.energy.gov/femp/articles/wireless-occupancy-sensors-lighting-controls-applications-guide-federal-facility&ved=2ahUKEwjk_Ye-2-SHAxVxUaQEHRc2GJwQFnoECBAQAQ&usg=AOvVaw1ahWRusrd6ihpmBaYbxB8)

Wagiman, K. R., Abdullah, M. N., Hassan, M. Y., & Radzi, N. H. (2019). A review on sensing-based strategies of interior lighting control system and their performance in commercial buildings. *Indonesian Journal of Electrical Engineering and Computer Science*, 16(1), 208-215.

Wang, C., Yan, D., & Ren, X. (2016). Modeling individuals' light switching behavior to understand lighting energy use of office buildings. *Energy Procedia, 88*, 781-787.

Wikipedia contributors. (2024, May 1). Arduino Uno. In Wikipedia. Retrived from (https://en.m.wikipedia.org/wiki/Arduino_Uno)

Wikipedia contributors. (2024, December 15). *Motion detector*. Wikipedia. https://en.wikipedia.org/wiki/Motion_detector#:~:text=This%20is%20the%20type%20most,light%20(passive%20and%20active%20sensors)

Xu L, Pan Y, Yao Y, Cai D, Huang Z, Linder N. 2017. Lighting energy efficiency in offices under different control strategies. *Energy and Buildings*. 138:127-39.

APPENDIX

Program Code from Arduino IDE

```
const int pirSensorPins[] = {3, 5, 6, 10, 12};  // PIR sensor pins
const int ldrPin = 2;  // LDR module pin
const int relayPin = 4;  // Relay module pin
const int numPirSensors = sizeof(pirSensorPins) / sizeof(pirSensorPins[0]);

bool pirSensorStates[numPirSensors] = {false};
bool pirSensorPreviousStates[numPirSensors] = {false};
unsigned long pirSensorDebounceTimes[numPirSensors] = {0};

const int debounceTime = 50;  // Debounce time in milliseconds
unsigned long motionDetectedTime = 0;  // Time when motion was last detected
const int lightOnDuration = 5000;  // 5 seconds

void setup() {
  Serial.begin(9600);
  for (int i = 0; i < numPirSensors; i++) {
    pinMode(pirSensorPins[i], INPUT);
  }
  pinMode(ldrPin, INPUT);
  pinMode(relayPin, OUTPUT);
}

void loop() {
  int ldrValue = digitalRead(ldrPin);
  Serial.print("LDR Value: ");
```

```
Serial.println(ldrValue);

if (ldrValue == HIGH) {
  // Nighttime mode
  Serial.println("Nighttime mode");
  for (int i = 0; i < numPirSensors; i++) {
    int pirSensorValue = digitalRead(pirSensorPins[i]);
    Serial.print("PIR Sensor ");
    Serial.print(i + 1);
    Serial.print(" Value: ");
    Serial.println(pirSensorValue);

    if (pirSensorValue != pirSensorPreviousStates[i]) {
      pirSensorDebounceTimes[i] = millis();
    }

    if (millis() - pirSensorDebounceTimes[i] > debounceTime) {
      if (pirSensorValue != pirSensorStates[i]) {
        pirSensorStates[i] = pirSensorValue;

        if (pirSensorStates[i] == HIGH) {
          // Motion detected, turn on light
          Serial.println("Motion detected, turning on light");
          digitalWrite(relayPin, HIGH);
          motionDetectedTime = millis();
        }
      }
    }
```

```
      pirSensorPreviousStates[i] = pirSensorValue;
    }

    // Check if 5 seconds have passed since motion was detected
    if (millis() - motionDetectedTime >= lightOnDuration) {
      // Turn off light
      Serial.println("Turning off light");
      digitalWrite(relayPin, LOW);
    }
  } else {
    // Daytime mode, turn off light
    Serial.println("Daytime mode, turning off light");
    digitalWrite(relayPin, LOW);
  }

  delay(50);
}
```