CHAPTER ONE

INTRODUCTION

1.1 Background of Study

In a world where energy conservation and sustainability have become paramount, the quest for innovative and efficient lighting solutions has gained significant momentum. The ever-increasing demand for energy-efficient technologies has spurred the development of sensor-based systems that can intelligently adapt to environmental conditions. This final year project, titled "Design and Construction of a wireless Sensor-Based Lighting System," delves into the intersection of technology and energy efficiency to address the pressing need for smart lighting solutions. The primary objective of this project is to create an intelligent lighting system that leverages advanced sensors to monitor and respond to changes in the surrounding environment. Traditional lighting systems often operate on fixed schedules or user inputs, leading to energy wastage in unoccupied spaces. The proposed wireless sensor-based lighting system aims to overcome these limitations by incorporating state-of-the-art sensors that can detect factors such as motion, ambient light levels, and occupancy. By seamlessly integrating these sensors into the lighting infrastructure, the system will dynamically adjust illumination levels and power consumption based on real-time environmental conditions.

This project not only focuses on the theoretical aspects of sensor technology but also emphasizes the practical implementation and construction of a working prototype. Through meticulous design considerations, the system will be engineered to provide optimal lighting conditions, enhance user comfort, and contribute to significant energy savings. Moreover, the project will explore the potential integration of emerging technologies, such as Internet of Things (IoT) connectivity, to enable remote monitoring and control of the lighting system. As we embark on this journey of innovation, the project team recognizes the importance of contributing to sustainable practices in the field of computer engineering. The outcomes of this endeavor have the potential to influence future lighting technologies and inspire advancements in smart building infrastructure. By the end of this project, we aim to demonstrate a wireless sensor-based lighting system that not only meets the demands of modern energy-conscious societies but also sets a precedent for intelligent and adaptive lighting solutions.

A well-outlined street lighting system allows road users move around freely in the evening with great visibility, in well-being and comfort and improve the presence of the area. Lighting framework that is inadequately composed can prompt poor visibility which is not useful for any person on foot or driver. Regularly road lighting is ineffectively designed and not appropriately maintained which suggests that there are a substantial number of flawed and dead lights and uses out of date lighting innovation which expends a lot of vitality and monetary assets. Provision of street lighting is a standout amongst the essential duties of a city. wireless sensor-based lighting system is fundamentally utilized as a proficient method for power conservation and maintenance cost. This street lighting system is a vital method for increasing street wellbeing around evening time.

1.2 Statement of problem

There are several problems that led to the need for the design of this project. One of which is lack of automation in switching off and on light switches, which can result in lights being left on unnecessarily, leading to increased energy consumption and higher utility costs, apart from that is the increased energy consumption which contributes to a larger carbon footprint, which can be detrimental to the environment another problem that lead to the need for the design of a wireless sensor based lighting system is the Continuous operation of Led at all times even when not necessary can lead to a shorter lifespan for bulbs and other lighting components. Adopting a wireless sensor-based lighting system can address these issues by providing a more intelligent and responsive approach to lighting control, ultimately leading to energy savings, increased efficiency, and improved occupant comfort.

1.3 Aim and Objectives

The aim of the project "Design and Construction of wireless Sensor-Based Lighting System," is to develop an intelligent wireless lighting system that uses sensor technologies to control lighting system of a building or structure it also focuses on creating a system that dynamically adapts to environmental conditions, optimizing energy consumption and enhancing user experience. Through a comprehensive exploration of sensor integration, the project aims to demonstrate the feasibility and practicality of a wireless sensor-based lighting system, contributing to advancements in the field of electrical engineering and sustainable design.

The following objectives to achieve this aim are itemized below:

- This project seeks to design a wireless sensor-based lighting system that dynamically adjusts illumination levels based on real-time data, minimizing energy wastage and enhancing efficiency.
- Integrate a range of sensors such as motion detectors and occupancy sensors to enable real-time environmental monitoring.
- Design an algorithm that dynamically adjust illumination levels based on data received from the wireless sensors, optimizing energy efficiency while maintaining user comfort.
- Implement power-efficient strategies for both the sensor nodes and the overall lighting system, ensuring prolonged battery life and sustainable energy practices.

By addressing these challenges, the project endeavors to contribute to the development of a wireless sensor-based lighting system that not only reduces energy consumption but also provides a sustainable and intelligent solution for the evolving needs of modern lighting infrastructure.

1.4 Significance of Study

Wireless sensor-based lighting system holds significant importance due to several advantages & benefits it brings to various aspects of lighting management, energy efficiency, and overall building performance. Wireless sensor-based lighting systems enable intelligent control by adjusting lighting levels based on occupancy & ambient light conditions. This leads to significant energy savings by avoiding unnecessary illumination in unoccupied or well-lit areas, Reduced energy consumption directly translates to lower utility costs, making wireless sensor-based lighting systems a cost-effective solution in the long run.

1.5 Scope of System Design

- Designing for optimal energy consumption through intelligent control of lighting based on occupancy and ambient light conditions.
- Implementing sensors to detect the presence or absence of occupants in a space.

- Designing systems that dynamically adjust lighting intensity, color, and distribution.

Limitations of Project

The stated below are some limitations to the above stated design

- Regular maintenance may be required, and sensors may have a limited lifespan.
- Challenges in scaling the system to larger or more complex installations.
- Accuracy challenges in occupancy detection, leading to false positives or negatives.

Balancing the scope and addressing the limitations is crucial in designing a wireless sensor-based lighting system that effectively meets energy efficiency goals while providing reliable and user-friendly functionality.

1.6 Methodology

The system begins by powering on the microcontroller and sending a start signal to all connected components to it, thereafter it sends a read signal to the PIR module to Detect if a person has entered in to the premises. If the PIR motion sensor returns a high signal to mean that a person has entered the room, trigger the microcontroller to verify in the intensity of light needed in the room, to verify such the microcontroller send a read signal to the LDR module to checks the level of brightness / darkness of the room and calculates the needed amount of light that is needed in that environment leading the system to turn on the lighting system based on the light intensity value returned by the LDR Module.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The project draws inspiration from research on occupancy sensing and adaptive lighting control. Studies by Rea et al. (2013) highlight the significance of adaptive lighting, which adjusts brightness and color temperature based on occupancy and task requirements. The inclusion of occupancy sensors in the wireless sensor-based lighting system is expected to enhance adaptability and contribute to user-centric lighting solutions.

A critical aspect of the project is the integration of the wireless sensor-based lighting system with broader smart building solutions. Research by Lee et al. (2017) emphasizes the advantages of interconnected building systems for improved energy management and user experience.

The project aims to contribute to this body of knowledge by exploring effective strategies for seamless integration, allowing for centralized control and data exchange. Numerous studies have explored the integration of energy-efficient lighting technologies into wireless-based systems. Notably, Light Emitting Diodes (LEDs) have gained prominence due to their high luminous efficacy, long lifespan, and environmental benefits.

Research has focused on optimizing LED-based lighting systems for various applications to achieve significant energy savings. Previous works by Studies by Li and Lam (2015) have investigated intelligent lighting control strategies to enhance user experience and energy efficiency, Occupancy sensors, daylight harvesting, and adaptive lighting control algorithms have been explored to dynamically adjust illumination levels based on occupancy patterns and ambient light conditions. The goal has always been to create responsive systems that adapt to user needs while minimizing unnecessary energy consumption.

However, the integration of wireless sensor technologies in building management systems has gained substantial attention in recent years, driven by the increasing demand for energy-efficient solutions and advancements in the Internet of Things (IoT).

The project titled "Design and Implementation of Wireless Sensor-Based Lighting System" addresses the intersection of sensor technology and lighting systems, exploring the potential for enhanced energy efficiency, occupant comfort, and smart building integration. There has been extensive research focusing on developing smart environments by integrating data mining techniques into environments that are equipped with sensors and actuators.

2.2 Review of Related Works

The ultimate goal is to reduce the energy consumption in buildings while maintaining a maximum comfort level for occupants. However, there are few studies successfully demonstrating energy savings from occupancy behavioral patterns that have been learned in a smart environment because of a lack of a formal connection to building energy management systems. In this study, the objective is to develop and implement algorithms for sensor-based modelling and prediction of user behavior in intelligent buildings and connect the behavioral patterns to building energy and comfort management systems through simulation tools.

The results are tested on data from a room equipped with a distributed set of sensors, and building simulations through Energy Plus suggest potential energy savings of 30% while maintaining an indoor comfort level when compared with other basic energy savings HVAC control strategies.

The importance of energy efficiency in lighting systems has been a focal point in architectural and engineering research. Studies by Li and Lam (2015) emphasize the role of occupancy sensors in reducing unnecessary energy consumption by adjusting lighting levels based on real-time occupancy data. The proposed project aligns with this research, aiming to contribute to energy savings through the integration of wireless sensors.

2.3 Intelligent Lighting System Using Wireless Sensor Networks

In the previous designed system by A.A.Nippun Kumaar1, Kiran.G2, Sudarshan TSB3, there is no separate base station. One of the nodes will act as the base station. Base station's power is replenishable. Dynamic topology control is done by base station, by periodically ensuring the presence of all nodes and accepting new nodes on the run. Master node is the one acts as a base station as well as sensor node. Sensor node senses the environment and instructs the light level to the master node. Light control node will respond to the master node by dimming or brightening the light according to the data received. The sensor nodes are placed such that each sensor node ranges to two light ballast. This arrangement will make the light control precise.

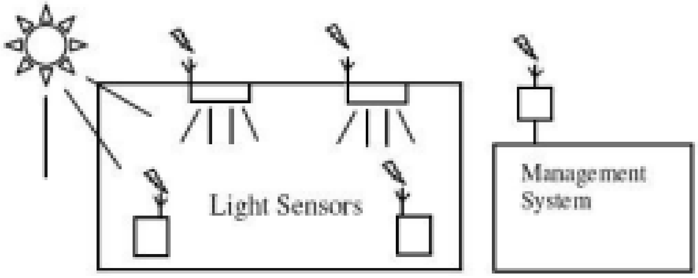

Figure 1: Wireless Daylight Substitution

Several challenges associated with the implementation of wireless sensor-based lighting systems are addressed in the literature. Issues such as reliability, security, and scalability have been investigated by researchers like Wang and Zhang (2016). The project recognizes these challenges and aims to contribute insights into mitigating these issues through careful system design, encryption protocols, and scalability planning.

Practical implementations and case studies have provided valuable insights into the real-world performance of wireless-based lighting systems.

These studies have evaluated system effectiveness, user satisfaction, and identified challenges encountered during deployment in diverse settings. In summary, previous works on wireless-based lighting systems have contributed significantly to advancing the field. The focus on energy efficiency, intelligent control, and user-centric design continues to shape the evolution of wireless lighting systems, with ongoing research addressing emerging challenges and pushing the boundaries of innovation in this domain.

CHAPTER THREE
METHODOLOGY

3.1 Introduction

In the pursuit of sustainable and intelligent building technologies, the design and implementation of wireless sensor-based lighting systems represent a significant stride towards enhancing energy efficiency, occupant comfort, and overall operational effectiveness. As the demand for smarter and greener solutions in the built environment continues to rise, integrating wireless sensor technology into lighting systems stands at the forefront of innovative approaches to address these challenges.

The focus of this methodology is to provide a comprehensive and systematic framework for designing and implementing a wireless sensor-based lighting system. The convergence of wireless sensors with lighting infrastructure promises dynamic control, adaptability, and improved resource utilization. By leveraging the capabilities of wireless communication and intelligent sensing, this methodology seeks to create an energy-efficient lighting ecosystem that not only responds to environmental cues but also aligns with the evolving paradigm of smart and connected buildings.

Key elements of the methodology include the selection and integration of advanced sensor technologies, wireless communication, and the development of a centralized control infrastructure. Emphasis is placed on the seamless coordination of sensors, ensuring real-time data exchange and responsiveness. The adaptive nature of the system will be explored, allowing for automatic adjustments based on occupancy patterns, ambient light conditions, and user preferences. Furthermore, this methodology acknowledges the importance of user interface design and human-centric considerations. The implementation process involves not only the installation of hardware components but also the development of user-friendly interfaces, allowing occupants and facility managers to interact with and customize the lighting environment. This approach aims to ensure that the technology is not only efficient but also intuitive, fostering user acceptance and engagement. As the methodology unfolds, it will delve into the intricacies of system scalability, addressing challenges associated with the integration of wireless sensor-based lighting solutions in various building sizes and types.

3.2 System Operation

The hardware implementation of a wireless sensor-based lighting system represents a technological advancement in the field of smart lighting solutions. This system utilizes wireless sensors to detect environmental conditions and human presence, optimizing lighting levels for energy efficiency and user comfort.

The system begins by powering on the microcontroller and sending a start signal to all connected components to it, thereafter it sends a read signal to the PIR module to Detect if a person has entered in to the premises. If the PIR motion sensor returns a high signal to mean that a person has entered the room, trigger the microcontroller to verify in the intensity of light needed in the room, to verify such the microcontroller send a read signal to the LDR module to checks the level of brightness / darkness of the room and calculates the needed amount of light that is needed in that environment leading the system to turn on the lighting system based on the light intensity value returned by the LDR Module.

3.3 Block diagram of system

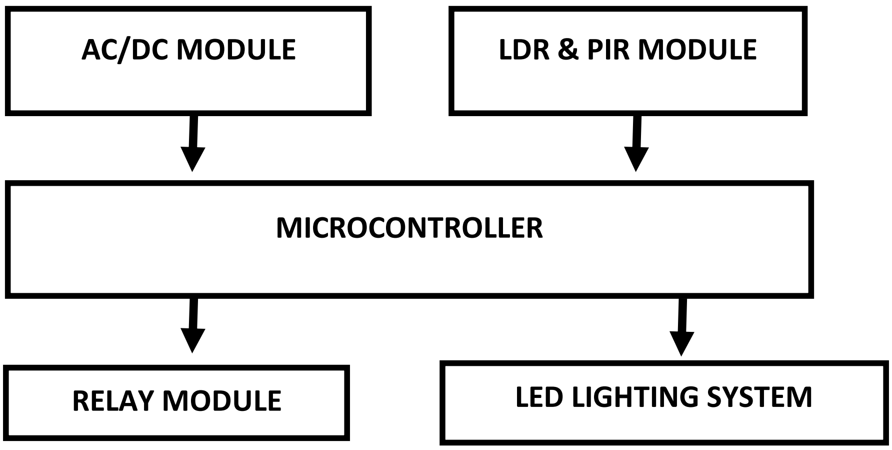

Figure 3.1: Block Diagram of Wireless Sensor Based Lighting System

A. **AC-DC Module:** Here microcontroller, LED indicators and sensors operates with DC 5V. Relay operates with 12VDC supply and this supply is provided by 12V DC, to obtain, we required to convert AC230V supply in to 12V-0- 12V by step down transformer and rectifier required to convert it in to DC 5V.

B. Microcontroller: We used here 8051 series AT89C51/52 microcontroller in which, external crystal required, reset required, it works on 3.5V to 5V it has 4-8 bit ports and it has program memory up to 4Kb/8kb program memory and operating frequency up to 20MHz clock frequency.

C. Reset and Oscillator Circuit: Any microcontroller requires oscillation frequency for its operation it can be internal for few microcontrollers has external also. This microcontroller requires external oscillator frequency. Reset circuit requires for the restart program from beginning it used when microcontroller hangs or if we required to stop the running condition with beginning process.

D. Sensors: Enter and exit sensors are developed with monostable multivibrator with 2 seconds time period for each interrupt. We can use LDR/ IR/ LASER sensors for detecting counts. Depending upon requirement we can place these sensors in proper manner with door frame. Relay driver is building NPN transistor in common emitter mode as transistor ON-relay ON and vice versa.

3.4 Hardware Components

- **PIR Motion sensor**: A PIR (Passive Infrared) motion sensor is a type of electronic sensor that detects motion by measuring changes in infrared radiation levels in its field of view.

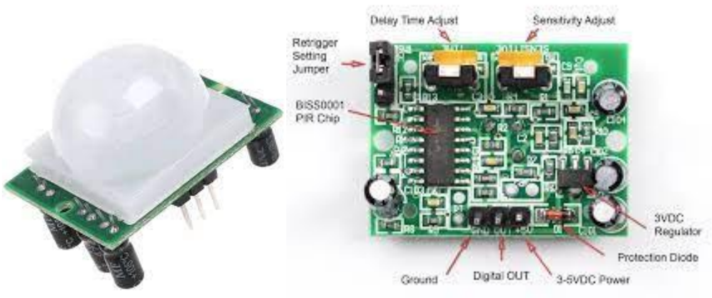

Figure 3.2: PIR Motion sensor front and rear view

These sensors are commonly used in various applications, including security systems, lighting control, and automation. Here's an overview of how a PIR motion sensor works and its key features:

How PIR Motion Sensors Work:

1. **Detection Principle:** PIR sensors detect changes in the infrared radiation emitted by objects in their detection range. Humans and animals emit infrared radiation as heat, and when they move, the pattern of infrared radiation changes.

2. **Pyroelectric Material:** PIR sensors typically use a pyroelectric material, which generates a voltage when exposed to changes in temperature. This material is sensitive to infrared radiation.

3. **Sensor Design:** The PIR sensor consists of a lens that focuses infrared radiation onto the pyroelectric sensor. The sensor is divided into segments, each responsible for detecting infrared radiation from a specific area.

4. **Output Signal:** The PIR sensor generates an electrical signal in response to motion. This signal is then processed by the associated electronics.

5. **Time Delay and Sensitivity Settings:** PIR sensors often have adjustable settings for time delay and sensitivity. Time delay determines how long the sensor should remain active after detecting motion, while sensitivity adjusts the detection range.

- **Light Dependent Resistor**: A Light Dependent Resistor (LDR), also known as a photo resistor, is a type of resistor whose resistance changes with the intensity of incident light. LDRs are widely used in various applications where light levels need to be sensed or controlled.

Figure 3.3: LDR Module and LDR

Operating Principle: When exposed to light, the semiconductor material in the LDR absorbs photons, creating electron-hole pairs. This process increases the conductivity of the material, leading to a decrease in resistance. Conversely, in darkness, fewer electron-hole pairs are generated, resulting in higher resistance. LDRs are versatile components that play a crucial role in light-sensitive applications, providing a cost-effective and reliable solution for detecting and responding to changes in light levels.

- **Power Supply:** convert 220V AC to 12V DC to enable the system to use less power but produce same or even more functionality, you can use a bridge rectifier along with a capacitor filter to smooth the rectified output. Additionally, a voltage regulator to stabilize the output voltage is used. Here's a basic diagram for a 220V AC to 12V DC power supply:

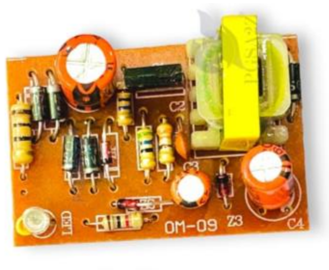

Figure 3.4: 220V – 12V Power supply

Power Supply Components:

1. **Bridge Rectifier (e.g., BR1):** Converts AC to DC.
2. **Filter Capacitor (e.g., C1):** Smoothens the rectified DC voltage.
3. **Voltage Regulator (e.g., 7812):** Stabilizes the output voltage at 12V.
4. **Load:** Represents the device or circuit that you want to power.

Notes:

1. The bridge rectifier and filter capacitor are rated appropriately for the given voltage and current requirements.
2. The voltage regulator (7812) ensures a stable 5V output, but we can choose a different regulator if necessary.
3. Capacitor C1 helps in reducing ripple in the DC output.

- **Microcontroller (Arduino Nano/ESP32/8266/ATMEG):** Arduino is an open-source electronics platform based on easy-to-use hardware and software. It consists of a microcontroller board and the Arduino IDE (Integrated Development Environment). Arduino is designed to be accessible to both beginners and experienced users, providing a versatile platform for creating interactive electronic projects.

Key Components:

1. Microcontroller Board (Arduino Board): The brain of the Arduino system, which contains the microcontroller chip. Popular Arduino boards include Arduino Uno, Arduino Nano, Arduino Mega, and others.
2. Arduino IDE: A software development environment used for writing, compiling, and uploading code to the Arduino board. It supports a simplified version of the C++ programming language.
3. USB Cable: Used to connect the Arduino board to a computer for programming and power.
4. Power Source: Arduino boards can be powered via USB, an external power supply, or batteries.

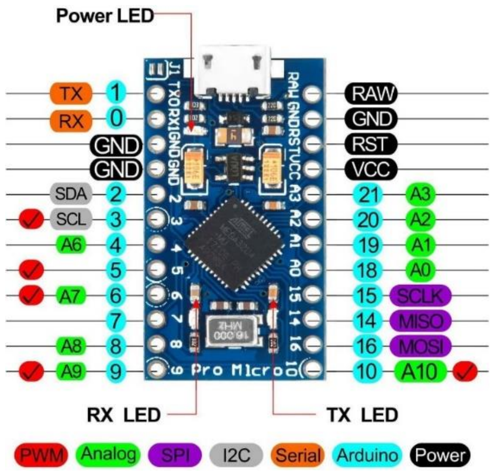

Figure 3.5: Arduino Nano Microcontroller

Key Features and Characteristics:

1. Open-Source: Arduino is open-source, meaning the design files, schematics, and source code are freely available for users to modify and distribute.
2. Versatility: Arduino is versatile and can be used in a wide range of applications, from simple LED projects to complex robotics and IoT (Internet of Things) systems.
3. Extensibility: Arduino can be extended with additional hardware modules called shields, which provide specific functionalities (e.g., GPS, WiFi, Bluetooth).

4. Cross-Platform: The Arduino IDE is available for Windows, macOS, and Linux, making it accessible to users on different operating systems.

- **Light Emitting Diode:** Light Emitting Diodes (LEDs) are semiconductor devices that emit light when an electric current pass through them.

Figure 3.6: 12V DC LED Strip

LEDs have become widely popular for various applications due to their energy efficiency, durability, and versatility. Here are some key features of LEDs:

Key Features:

1. **Energy Efficiency:** LEDs are highly energy-efficient, converting a significant portion of electrical energy into visible light. They consume less power than traditional incandescent and fluorescent lights.
2. **Long Lifespan:** LEDs have a longer lifespan compared to traditional light sources. They can last tens of thousands of hours, reducing the frequency of replacements.
3. **Instantaneous Light:** LEDs illuminate instantly when powered, with no warm-up time required. This is advantageous for applications where quick and responsive lighting is needed.
4. **Directional Emission:** LEDs emit light in a specific direction, reducing the need for reflectors and diffusers. This directional nature makes them ideal for applications where focused illumination is required.
5. **Durability:** LEDs are solid-state devices with no fragile components like glass or filaments. They are more resistant to shocks, vibrations, and environmental factors.

The integration of Light Emitting Diodes (LEDs) in this smart lighting system brings several advantages, making LEDs a crucial component for modern lighting solutions.

Smart Features: LEDs can be equipped with smart features such as color-changing capabilities, remote control, and connectivity to smart devices. These advanced features enhance the overall functionality and user experience of a smart lighting system.

In summary, the importance of LEDs in a smart lighting system lies in their energy efficiency, long lifespan, instantaneous response, color control, adaptability, and compatibility with smart controls. As smart lighting systems continue to evolve, LEDs play a pivotal role in shaping the future of energy-efficient, customizable, and intelligent lighting solutions.

- **Relay Module:** A relay module is an electrical device that consists of a relay and associated components mounted on a circuit board. It is commonly used in electronics and automation projects to control high-power electrical devices with low-power microcontrollers or other digital circuits. The relay module acts as an interface between the low-voltage control circuit and the higher-voltage load circuit.

Figure 3.7: Relay Module

Key Components of a Relay Module:

1. **Relay:** The core component, a relay is an electromechanical switch that opens or closes its contacts in response to an electrical signal. It allows low-power control signals to switch high-power loads.
2. **Driver Circuit:** The driver circuit is responsible for energizing the relay coil, causing the relay contacts to change state. It typically includes a transistor or optocoupler to isolate the low-voltage control circuit from the higher-voltage load circuit.
3. **Coil Terminals:** These terminals connect to the relay coil. When an electrical signal is applied to the coil, it generates a magnetic field that actuates the relay switch.
4. **Common (COM), Normally Open (NO), and Normally Closed (NC) Contacts:** The relay module usually has multiple sets of contacts. The common (COM) terminal is

common to both the normally open (NO) and normally closed (NC) terminals. When the relay is not energized, the common terminal is connected to the normally closed terminal. When the relay is energized, the connection switches to the normally open terminal.

5. **Connection Pins:** These pins provide external connection points for the control signal, power supply, and load connections.

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