DESIGN AND TESTING OF A OCCUPANCY SENSOR BASED LIGHT CONTROLLER

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Submitted By,

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Abstract

This thesis presents a sensor-based LED lighting controller system that works on the availability of occupants. The system utilizes Arduino Uno, LED strip, PIR sensor, RF Transmitter, Receiver and Relay module. Extensive testing demonstrates the system's ability to create a lighting environment that saves energy, based on occupants & activate light controller which will drive luminaires accordingly. The Project can be utilized for user comfort and well-being. The research highlights the potential benefits of sensor-based LED lighting control systems in various settings. Future work can focus on system optimization and exploring advanced control algorithms for mutually interactive lighting system.

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CHAPTER 1

INTRODUCTION

1.1 General Overview

Electricity is one of the most important resources in this century. We should conserve the electricity. In recent years, lighting world, lighting control system has been implemented attentively due to its potential for energy savings as well as for its' ability to create dynamic, aesthetic and adaptable lighting environments. But many times we come outside the room/hall and forget to turn off the lights/fan, thus the electricity is wasted.

Presently in India the per capita consumption of electricity is 1122 kWh which is far below the developed country like USA, Canada, UK and also one-third of the global per capita consumption. Ongoing developmental activities will results significant increment of per capita consumption in coming years.[1] Additional demand of power can be met using conventional and/or non-conventional sources. The burning of conventional sources increases the CO_2 emission which has adverse impact on environment.The electricity prices are also increasing rapidly day by day. As lighting utilizes one- third of global consumption of electricity, the above demands can be partially fulfilled by application of energy efficient lighting. This can be addressed by proper utilization of daylight along with efficient lighting control system which is the essential requirement for green building lighting system

and energy conservations. There are two types of lighting control systems used in practice viz., wired and wireless. The wireless lighting control system provides additional benefits over wired system like less installation costs and more flexibility of putting devices likes sensor based. The IR sensors identify the occupants and LDR senses the light level of the work plane and send the data to the controller as RF signal. Another work proposed a light control scheme based on passive RFID for a daylight integrated system where light level is sensed by RFID sensor. Residential lighting control system based on ZigBee wireless sensor network and fuzzy controller has been proposed.ZigBee sensors are used to collect daylight data and fuzzy controller controls the daylight and artificial lights.[2]

This thesis aims to contribute to this area of research by developing and testing a sensor based mutually controlled light by RF module wirelessly by using Arduino Uno & PIR sensor.

The literature review reveals several studies that RF controlled mutually interactive lighting system by occupant sensor effects lighting technologies by consuming less energy & by implementing Light controller can control multiple sensors along with the application. A daylight responsive RF light controller is designed and developed for a daylight-integrated artificial lighting system for a typical indoor space of commercial building. Sensor monitors the external daylight level and corresponding response is transmitted to the light controller wirelessly as RF signal. Light control logic is developed and embedded in the light controller to control the light output of lamps depending on the measured daylight level.[2] The developed light controller is also capable to monitor external daylight available at different window orientations and accordingly controls the light output of different lamps groups adjacent together.

The integration of sensor technology such as SR04 ultrasonic sensor, PIR sensor can control LED ambient lighting & save energy. Motion sensors can help you save on your bill without your having to do anything. They are responsible for turning on the light when they sense a presence and automatically turning it off when it

is no longer there. This way you avoid the risk, and expense, of having lights on where you don't need them.

1.2 Objectives

The primary objectives of this research is to develop sensor based mutually interactive wireless lighting system capable of identifying occupants and Switching lights wirelessly. The system aims to create energy saving lighting that supports radio frequency. Wastage of electricity is one of the main problems which we are facing nowadays. In our home, school, colleges or industry we see that fan/lights are kept on even if there is nobody in the room or area/passage. This happens due to negligence or because we forgot to turn lights off or when we are in a hurry. To avoid all such situations it is designed called "Sensor based mutually interacted RF controlled lighting system ". The secondary objectives is to develop occupant based automatic lighting control system designing which can also check & respond daylight illumination level based automatic lighting.

1.3 Steps of Execution

- Conduct an extensive review of research papers, journals and literature of sesnsor based lighting technologies, Radio Frequency Transmitter/ Receiver, Daylight responsive Light controller .
- Study of hardware, Arduino Uno Atmega328, PIR sensor, RF Transmitter, Receiver Module, Relay Module.
- Implement software algorithms, Arduino programming for Transmitter as well as Receiver along with motion sensor to acquire sensor data, process it and control Relay Switching for LED strip.
- Perform simultaneous testing and evaluation for proper synchronization of RF Tx & RF Rx along with PIR sensor.

- Analyze and check the obtained results, assessing the impact of the sensor based RF controlled lighting.
- Discuss the implementations of the findings, highlighting the potential benefits by automatic switching occupant based radio frequency controlled lighting for consuming less energy.
- Identifying areas for future research and development, suggesting possible enhancements and extensions to the system .

By following above mentioned approach, it is anticipated that this research will contribute to energy saving wireless lighting design to the existing body of knowledge on lighting control system. The results of this study may in form of design and implementation of lighting solutions that prioritize human well being and create more sustainable and adaptive lighting environments.

1.4 Outcomes (Expected/ Major)

By the hardware implementation occupant based wireless lighting design system is established. Based on occupant ,motion sensor detects the object & switch on the light for a while wirelessly. Auto cut system is implemented, so if no motion is detected it switches off the luminaire.

CHAPTER 2

THEORETICAL BACKGROUND

2.1 Occupancy Lighting and Sustainability

Passive infrared technology (PIR) PIR technology senses occupancy by detecting the difference between heat emitted from the human body in motion and the background space. Relying on a clear line-of-sight view, passive infrared sensors make 100% coverage cut off possible. These sensors utilize a unique Fresnel lens which divides the coverage area into zones, enhancing detection of small movement. With a full 360° of coverage, these sensors are able to control a wide range of applications, either individually, or for large areas, in zones that overlap. With a full 360° of coverage, these sensors are able to control a wide range of applications, either individually, or for large areas, in zones that overlap lighting control system incorporates communication between various system inputs and outputs related to lighting control with the use of one or more central computing devices.[2] Lighting control systems are widely used on both indoor and outdoor lighting of commercial, industrial, and residential spaces. Lighting control systems are sometimes referred to under the term smart lighting. Lighting control systems serve to provide the right amount of light where and when it is needed.

Lighting control systems are employed to maximize the energy savings from the lighting system, satisfy building codes, or comply with green building and

energy conservation programs. Lighting control systems may include a lighting technology designed for energy efficiency, convenience and security. This may include high efficiency fixtures and automated controls that make adjustments based on conditions such as occupancy or daylight availability. Lighting is the deliberate application of light to achieve some aesthetic or practical effect (e.g. illumination of a security breach). It includes task lighting, accent lighting, and general lighting.[2]

The major advantage of a lighting control system over stand-alone lighting controls or conventional manual switching is the ability to control individual lights or groups of lights from a single user interface device. This ability to control multiple light sources from a user device allows complex lighting scenes to be created. A room may have multiple scenes pre-set, each one created for different activities in the room. A major benefit of lighting control systems is reduced energy consumption. Longer lamp life is also gained when dimming and switching off lights when not in use. Wireless lighting control systems provide additional benefits including reduced installation costs and increased flexibility over where switches and sensors may be placed.

2.2 RF Module - PIR sensor and Relay

An RF module (short for radio-frequency module) is a (usually) small electronic device used to transmit and/or receive radio signals between two devices. In an embedded system it is often desirable to communicate with another device wirelessly. This wireless communication may be accomplished through optical communication or through radio-frequency (RF) communication. For many applications, the medium of choice is RF since it does not require line of sight. RF communications incorporate a transmitter and a receiver. They are of various types and ranges. Some can transmit up to 500 feet. RF modules are typically fabricated using RF CMOS technology.[3]

The term RF module can be applied to many different types, shapes and sizes of small electronic sub assembly circuit board. It can also be applied to modules across a huge variation of functionality and capability. RF modules typically incorporate a printed circuit board, transmit or receive circuit, antenna, and serial interface for communication to the host processor. PIR sensor acts as a motion detector, which is an electrical device that utilizes a sensor to detect nearby motion. Such a device is often integrated as a component of a system that automatically perform a task or alerts a user of motion in an area. They form a vital component of security, automated lighting control, home control, energy efficiency, and other useful systems.

A power relay module is an electrical switch that is operated by an electromagnet. The electromagnet is activated by a separate low-power signal from a micro controller. When activated, the electromagnet pulls to either open or close an electrical circuit.

The relay permits a small amount of electrical current to control high current loads. When voltage is supplied to the coil, small current passes through the coil, resulting in a larger amount of current passing through the contacts to control the electrical load.

By understanding the logic of RF Module and PIR sensor the project is synchronized this way such that whenever any motion detected PIR sensor sends trigger to RF transmitter which is synchronized to RF Receiver Module, RF Receiver decodes the signal & activates the relay module which is acting as light controller switch to switch ON the LED strip.

2.3 Energy saving using Sensor, Arduino Uno & LED strip

This device is using 'Arduino' and PIR Motion Sensor for detecting human presence in the room or the area for which it is installed and activates/ 'turn on'

the appliances (fountain in the present case) when someone comes in the proximity of the device / fountain say 7 feet and 'turns it off' when the person leaves. The built–in Passive Infrared (PIR) Motion Sensor turns on the connected lighting system when it detects motion in its coverage area. During the day, the built in Photocell Sensor saves electricity by deactivating the lights. You can reduce your electricity bills by using PIR Motion Sensors & Occupancy Sensors. Replacing a light switch with a PIR sensor can help save energy by keeping the lights off when no movement is detected in an area. First, LED lights save up to 90% energy compared to a traditional bulb with the same light output as referred to Fig. 2.1. When you buy a LED lamp or light bulb, you start saving money right away. For each light bulb you replace with a LED light, you will see immediate returns on a lower energy bill. Since the light output of individual light-emitting diodes is small compared to incandescent and compact fluorescent lamps, multiple diodes are often used together. In recent years, as diode technology has improved, high power light-emitting diodes with higher lumen output are making it possible to replace other lamps with LED lamps. One high power LED chip used in some commercial LED lights can emit 7,500 lumens for an electrical power consumption of 100 watts.[4] LED lamps can be made interchangeable with other types of lamps. Diodes use direct current (DC) electrical power; to use them from standard AC power they require internal or external rectifier circuits. LEDs are damaged by operating at high temperatures, so LED lamps typically include heat management elements such as heat sinks and cooling fins. LED lamps offer long service life and high energy efficiency, but initial costs are higher than those of fluorescent and incandescent lamps. It is estimated that switching to LED lighting over the next two decades could save $120 billion in energy costs, reduce the electricity consumption for lighting by 25%, and avoid 246 million metric tons of carbon emission. In Fig. 2.2, lamp classifications are mentioned as bellow.[4]

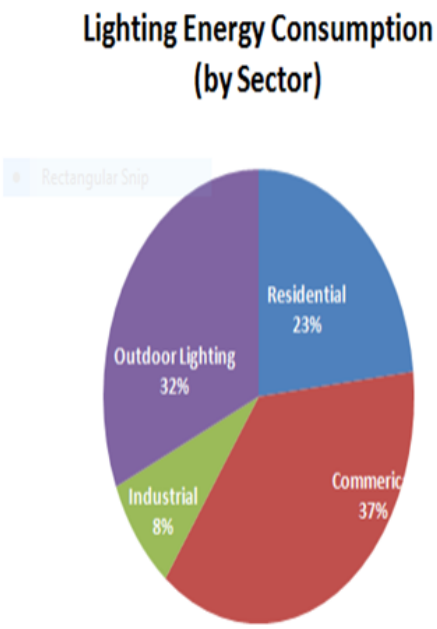

Figure 2.1: Lighting Energy Consumption

2.3.1 Light Emitting Diode

Light –Emitting Diodes (LEDs) have revolutionized the field of lighting with their energy efficiency, long lifespan, durability and design flexibility. LEDs are semi-conductor devices that emit light when an electric current passes through them. The circuit diagram of an LED typically consists of an LED chip, a power source, and a current limiting resistor. LEDs are highly efficient in converting electrical energy into visible light due to the electroluminescence process, where electrons and holes recombine within the semiconductor material, releasing photons. The color of the emitted light is determined by the materials and dopants used in the LED's construction. LEDs offer design flexibility, allowing for dynamic color-changing effects, precise dimming, and programmable lighting patterns. They have a longer lifespan compared to traditional lighting sources, reducing the frequency of replacements. LEDs are also durable, resistant to shock, vibration, and extreme temperatures, making them suitable for various indoor and outdoor applications. Advancements in LED technology have led to the development of smart

Figure 2.2: Lamp classification

lighting systems that provide intelligent and adaptive lighting solutions. With their energy efficiency, versatility, and ongoing technological advancements, LEDs continue to drive innovation in the lighting industry, offering exciting possibilities for sustainable, customizable, and intelligent lighting environments.[5]

Circuit Diagram and Working Principle of LEDs

The circuit diagram of an LED typically consists of an LED chip, a power source, and a current-limiting resistor. When a forward voltage is applied across the LED, electrons and holes recombine within the semiconductor material, releasing energy in the form of photons. This phenomenon, known as electroluminescence, generates visible light. The color of the emitted light is determined by the materials and dopants used in the LED's construction. In Fig. 2.3 internal

structure of LED is shown bellow.[5] The working principle of LEDs is based on the properties of semiconductor materials. LEDs are typically made from compounds such as gallium arsenide (GaAs), gallium phosphide (GaP), or gallium nitride (GaN). By carefully selecting the materials and adjusting the doping levels, LEDs can emit light across a wide range of wavelengths, including the visible spectrum.

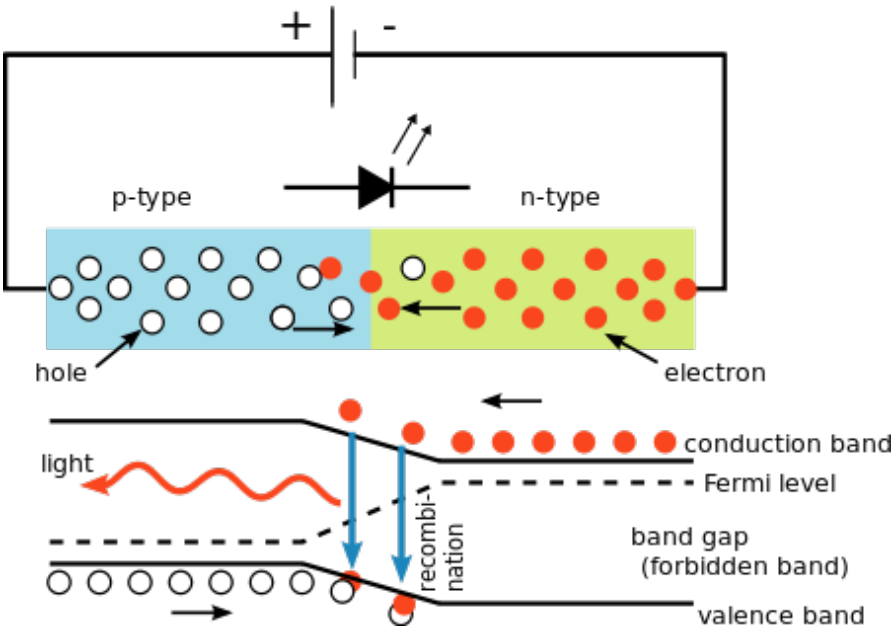

Figure 2.3: Internal structure of LED

Advantages of LEDs in Lighting

LEDs offer numerous advantages that make them highly suitable for lighting applications. Firstly, LEDs are highly energy-efficient, converting a significant portion of electrical energy into visible light. This efficiency translates into reduced power consumption and lower electricity bills. Moreover, LEDs have a longer lifespan compared to traditional lighting sources, reducing the frequency of replacements and contributing to sustainability. Different semiconductor material what is used for creating different color LED is mentioned bellow in Fig. 2.4.

LEDs also provide design flexibility, enabling the creation of diverse lighting scenarios. With individual control over each LED, it becomes possible to achieve

dynamic color-changing effects, precise dimming, and programmable lighting patterns. This flexibility allows for the customization of lighting environments to suit specific needs and preferences. Furthermore, LEDs are known for their durability and resistance to shock, vibration, and extreme temperatures. This robustness makes them suitable for various indoor and outdoor applications, including architectural lighting, automotive lighting, and decorative lighting.

Characteristics of Different Semiconductor Material

Color	Material	Flux (Lumens)	Watts (per 100 lumens)
Red	AlGaAs	30.6 – 51.7	1.8
Green	AlGaP	67.2 – 100	1.4
Blue	InGaN	23.5 – 30.6	4.2
White	YAG:CE	67.2 – 114	1.2

Notes:

1. Material selection determines colors
2. Different colors require different power
3. White is achieved one of two ways
   - Combine RGB (Red, Green, and Blue LED's)
   - Coat a blue LED with yellow phosphor

Figure 2.4: Characteristics of different semiconductor material

In recent years, advancements in LED technology have led to the development of smart lighting systems. These systems utilize features such as individual addressable LEDs, wireless connectivity, and sensors to provide intelligent and adaptive lighting solutions. By leveraging the advantages of LEDs, smart lighting systems offer enhanced energy efficiency, improved user comfort, and increased control over lighting parameters. In summary, LEDs have transformed the lighting industry with their energy efficiency, long lifespan, durability, and design flexibility. Their unique working principle and advantages make them an ideal choice for a wide range of lighting applications. The ongoing advancements in LED technology continue to drive innovation in the field, offering exciting possibilities for

creating sustainable, customizable, and intelligent lighting environments.[5]

2.3.2 Arduino Uno

Arduino Uno, in Fig. 2.5, is a widely used microcontroller board that provides an accessible and versatile platform for electronics prototyping and projects. It is based on the ATmega328P microcontroller and offers a range of input and output pins, making it suitable for controlling various devices and sensors.

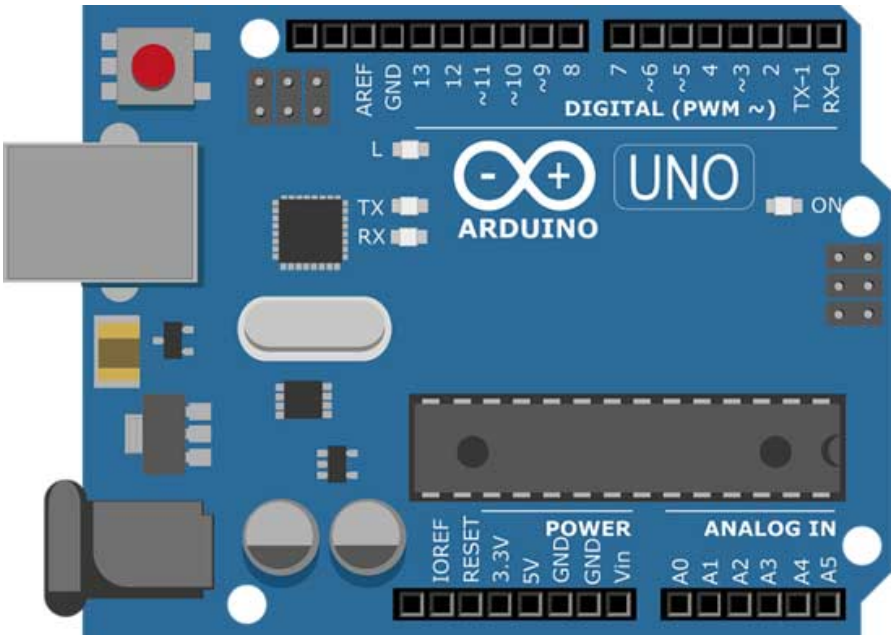

Figure 2.5: Arduino UNO Circuit Board

Features and Specifications

The Arduino Uno board is equipped with digital input/output pins (GPIO) and analog input pins, providing flexibility for interfacing with external components. It also includes a USB interface for programming and communication with a computer. The board operates at 5v and has a clock speed of 16MHz. It can be powered through the USB connection or an external power source. Arduino Uno is supported by an extensive ecosystem of libraries and resources, making it accessible even for beginners. The Arduino integrated development environment (IDE) simplifies the programming process, allowing users to write and upload code

to the board easily.

2.3.3 PIR sensor

PIR sensors allow you to sense motion, almost always used to detect whether a human has moved in or out of the sensors range. They are small, inexpensive, low power, easy to use and don't wear out. For that reason they are commonly found in appliances and gadgets used in homes or businesses. They are often referred to as PIR, "Passive Infrare", "Pyroelectric", or "IR motion" sensors. PIRs are basically made of a pyroelectric sensor (https://adafru.it/aKh) (which you can see below as the round metal can with a rectangular crystal in the center), which can detect levels of infrared radiation. Everything emits some low level radiation, and the hotter something is, the more radiation is emitted. The sensor in a motion detector is actually split in two halves. The reason for that is that we are looking to detect motion (change) not average IR levels. The two halves are wired up so that they cancel each other out. If one half sees more or less IR radiation than the other, the output will swing high or low. Along with the pyroelectic sensor is a bunch of supporting circuitry, resistors and capacitors. It seems that most small hobbyist sensors use the BISS0001 ("Micro Power PIR Motion Detector IC") (https://adafru.it/clR), undoubtedly a very inexpensive chip.[6] This chip takes the output of the sensor and does some minor processing on it to emit a digital output pulse from the analog sensor. Old & Newly developed sensor is shown bellow in Fig. 2.6 & Fig. 2.7.

Older PIRs looked like this:

New PIRs have more adjustable settings and have a header installed in the 3-pin ground/out/power pads

PIR sensors are more complicated than many of the other sensors explained in these tutorials (like photocells, FSRs and tilt switches) because there are multiple variables that affect the sensors input and output. To begin explaining how a basic sensor works, we'll use this rather nice diagram The passive infrared (PIR)

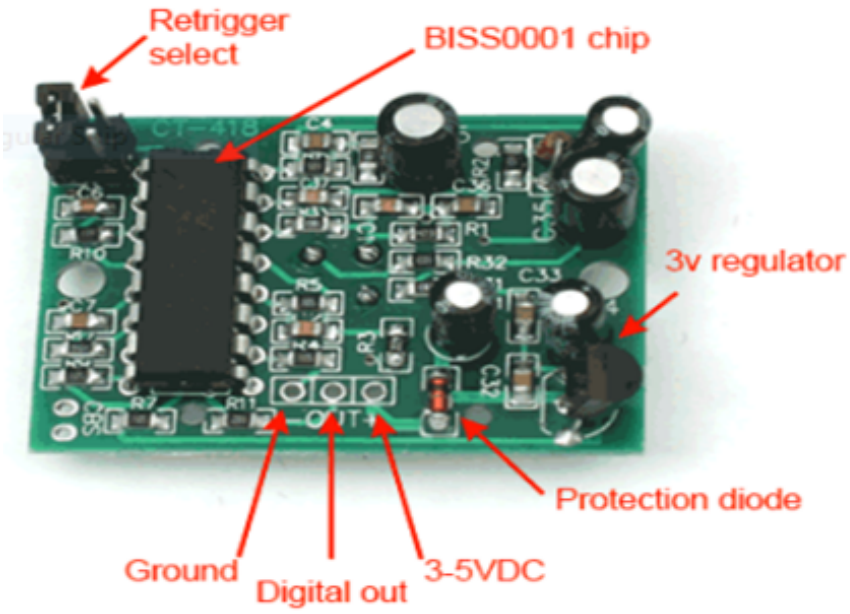

Figure 2.6: Old PIR Sensor

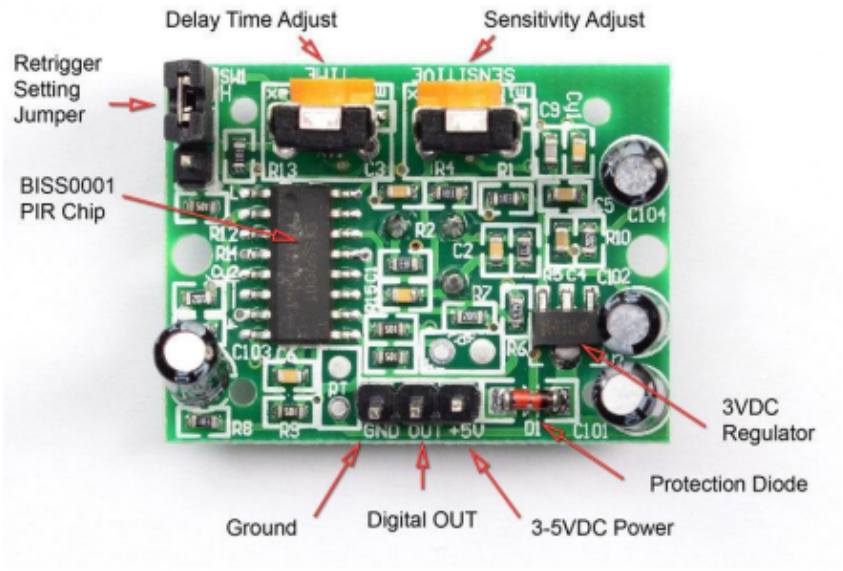

Figure 2.7: New PIR Sensor

sensor itself has two slots in it ,as shown in Fig. 2.8, each slot is made of a special material that is sensitive to IR. The lens used here is not really doing much and so we see that the two slots can 'see' out past some distance (basically the sensitivity of the sensor). When the sensor is idle, both slots detect the same amount of

IR, the ambient amount radiated from the room or walls or outdoors. When a warm body like a human or animal passes by, it first intercepts one half of the PIR sensor, which causes a positive differential change between the two halves. When the warm body leaves the sensing area, the reverse happens, whereby the sensor generates a negative differential change. These change pulses are what is detected.

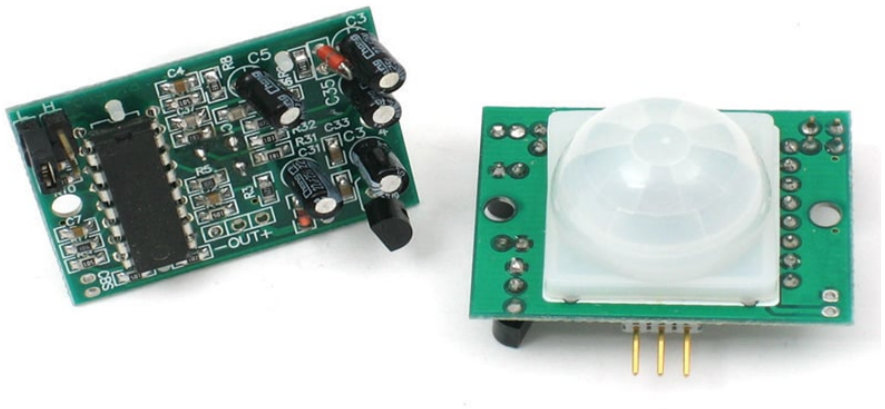

Figure 2.8: PIR Sensor Module

The PIR Sensor The IR sensor itself is housed in a hermetically sealed metal can to improve noise/ temperature/humidity immunity. There is a window made of IR-transmissive material (typically coated silicon since that is very easy to come by) that protects the sensing element. Behind the window are the two balanced sensors.

CHAPTER 3

LIGHT CONTROL SCHEME

3.1 Integration of LED strip with Microcontroller and Sensor

The Arduino Uno acts as the central control unit, coordinating the TX,RX integration ,presence detection and time measurement functionalities. With its versatility and ease of use, the ArduinoUno enables seamless integration and real time control of the entire system. By incorporating LED strip, one can precisely control light which is used as lighting controller. In Block diagram, Fig. 3.1, it is shown how two Arduinos are connected to RF Transmitter & receiver module.

3.1.1 Integration With Arduino Uno Microcontroller

Arduino Uno is utilized as central control unit which is acting as Encoder in Transmitter side & Decoder in Receiver side. With two Arduinos PIR sensor, TX module, RX module, Relay & Light Controller as LED strip all are mutually interconnected.[7]

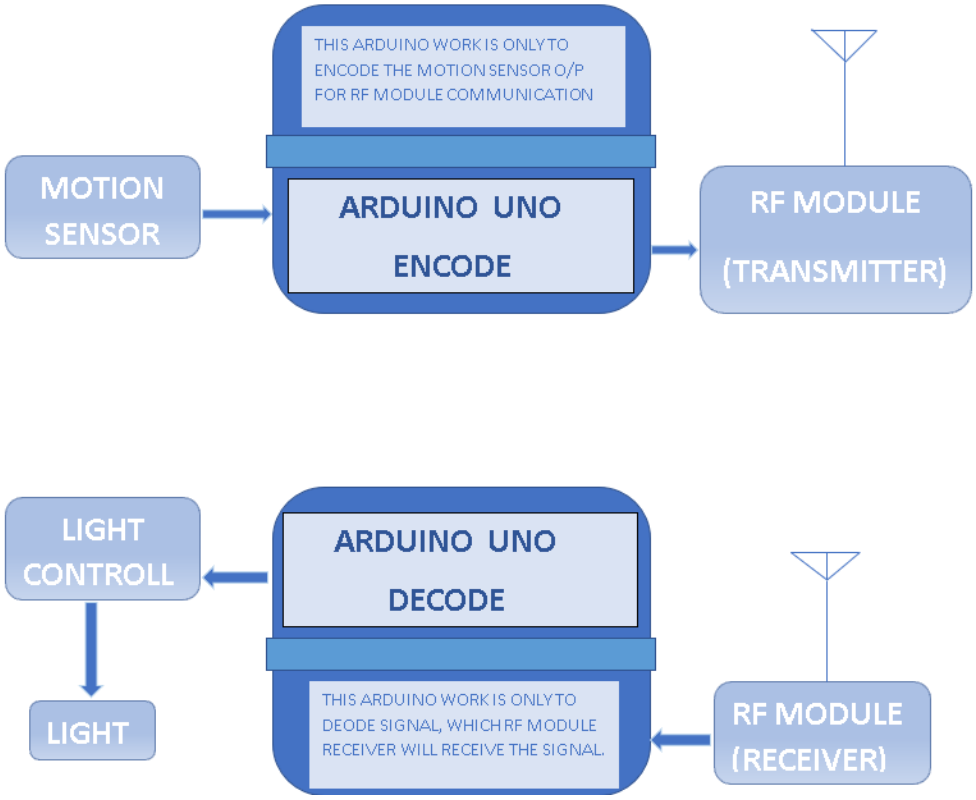

Figure 3.1: Block diagram of occupancy sensor based light controller

3.1.2 Integration with PIR sensor

The PIR (Passive Infrared) sensor is utilized for presence detection of occupants within 3m of the lighting environment. By measuring the distance & detecting the movement of the objects, it provides occupancy informations & trigger the I/P Arduino which is connected to RF Transmitter module & communication is established.[7]

3.1.3 Integration with RF Transmitter Module

Arduino Uno is connected with RF Transmitter module by programming it is synchronized.[5]

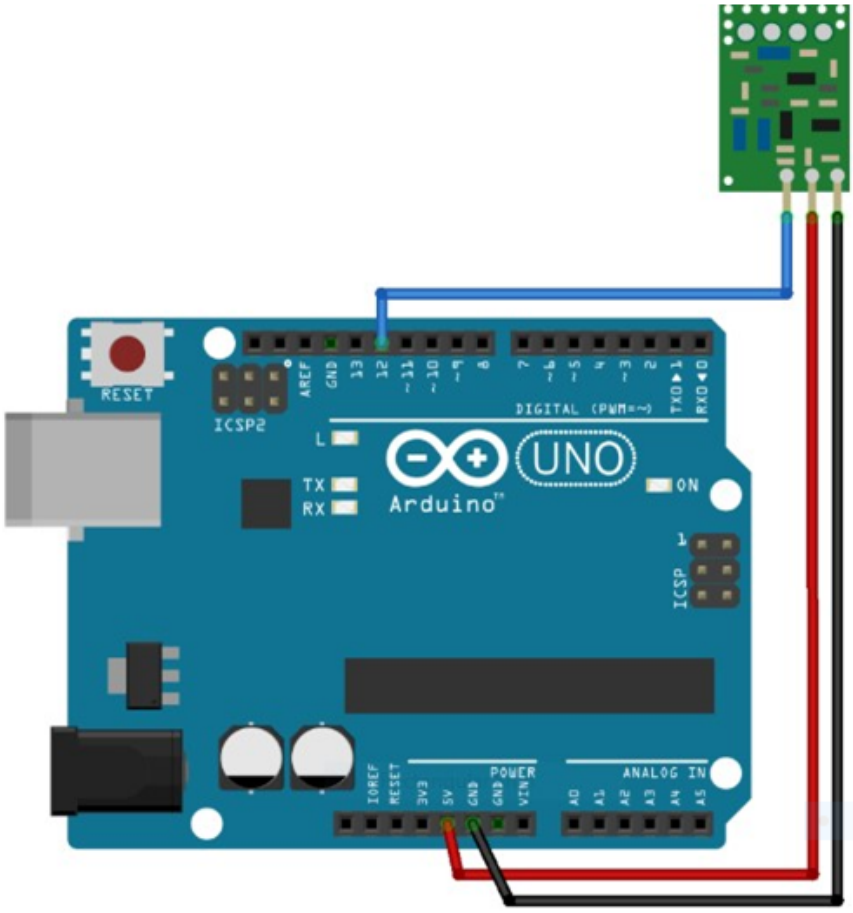

Figure 3.2: Ardunio UNO is connected with RF Transmitter

3.1.4 Integration with RF Receiver Module

Arduino Uno is connected with RF Receiver module by programming it is synchronized.[7]

3.1.5 Principle of Operation

The frequency band between 30 kHz and 300 GHz of the electromagnetic spectrum is known as Radio Frequency (RF). For remote control applications some license-free bands, the ISM-bands (Industrial, Scientific and Medical bands) are available. In practice, RF control uses any one of these frequencies, viz. 315, 434 and 868 MHz as RF carrier frequency. The developed system uses 434 MHz RF

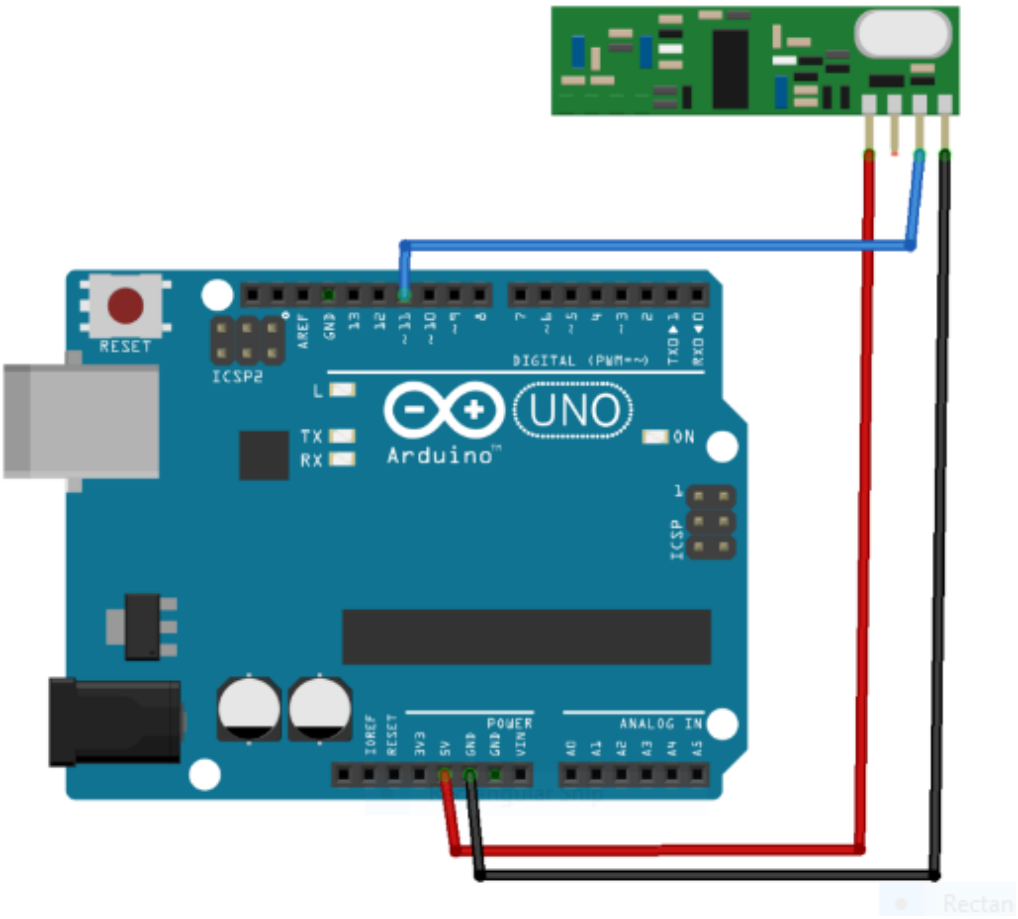

Figure 3.3: Arduino Uno is connected with RF Receiver

carrier frequency.[3]

The RF transmitter receives serial data and transmits it wirelessly through through its RF antenna. The transmission occurs at the rate of 1 Kbps – 10 Kbps. RF receiver receives the transmitted data and it is operating at the same frequency as that of the transmitter. "RF" refers to the use of electromagnetic radiation for transferring information between two circuits that have no direct electrical connection. Time-varying voltages and currents generate electromagnetic energy that propagates in the form of waves. As the RF waves move away from the transmitting antenna they move towards another antenna attached to the receiver, which is the final component in the wireless medium. The receiver takes the signal that it received from the antenna and translates the modulated signals and passes

them on to be processed.

3.1.6 Integration and Communication

Here, motion sensor detects the object/occupant & sends signal to RF transmitter through Arduino. Transmitter Ardunio encodes the signal for detection & synchronizes with receiver Arduino which then connects to RF receiver module & relay . The relay is used switching & driving the light controller LED strip.

3.2 Development of Code to control the system

3.2.1 Introduction

LED light controller is developed by Arduino Uno microcontroller. The RadioHead library provides an easy way to work with the 433 MHz transmitter/receiver with the Arduino. The goal is to syncronise RF Transmitter & Receiver module 1^{st}. Secondly to upgrade the source code for connecting PIR sensor with the Transmitter module so that it can respond properly & sends signal. Finally at the Receiver point receiver program code is updated to decode the input from the transmitter to relay module so that it can drive the light controller.[8]

3.2.2 Final Code

TRANSMITTER CODE

```
#include <RH_ASK.h>
#include <SPI.h> // Not actually used but needed to compile
RH_ASK driver;
int sensor = 7;
int val ;
char msg[2] = "";
void setup()
{
   Serial.begin(9600);   // Debugging only
    pinMode(sensor, INPUT);
   if (!driver.init())
        Serial.println("init failed");
}
void loop()
{
 val = digitalRead(sensor);
 Serial.println(val);
 itoa(val, msg, 10);
   driver.send((uint8_t *)msg, strlen(msg));
   driver.waitPacketSent();
   delay(1000);

}
```

RECEIVER CODE

```
#include <RH_ASK.h>
#include <SPI.h> // Not actualy used but needed to compile
RH_ASK driver;
char receive[32];
const int RELAY_PIN = 3;
void setup()
{
   Serial.begin(9600);  // Debugging only
   pinMode(RELAY_PIN, OUTPUT);
   if (!driver.init())
        Serial.println("init failed");
}
void loop()
{
   uint8_t buf[1];
   uint8_t buflen = sizeof(buf);
   if (driver.recv(buf, &buflen)) // Non-blocking
   {
    //int i;
     for (int i = 0; i < buflen; i++) {
      receive[i] = buf[i];
   }
    // Message with a good checksum received, dump it.
    Serial.print("Message: ");
    Serial.print((char*)buf);
    if (strcmp(receive, "1") == 0) {
      Serial.println(" YES");
      digitalWrite(RELAY_PIN, HIGH);}
      else{Serial.println(" NO");
      digitalWrite(RELAY_PIN, LOW);
     }
   }
```

3.2.3 Fabricated Circuit Diagram

The fabricated circuit diagram in a circuit maker software is shown bellow. (Fig. 3.4, Fig. 3.5)

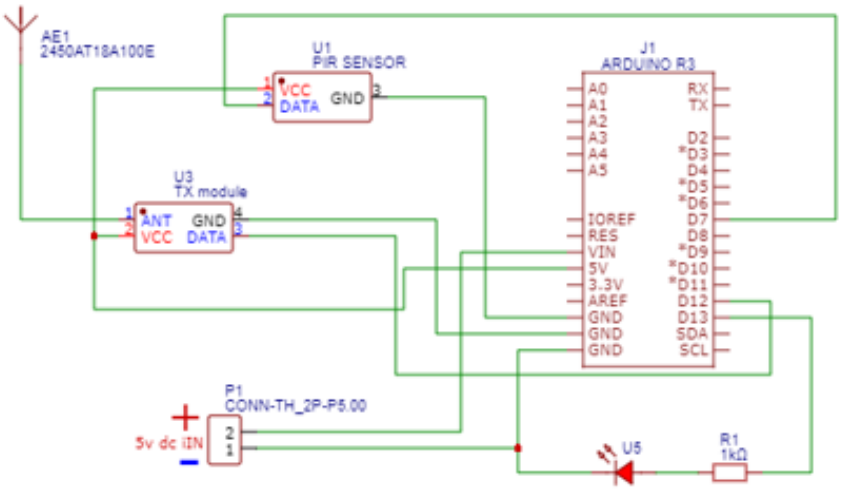

Figure 3.4: Transmitter Section

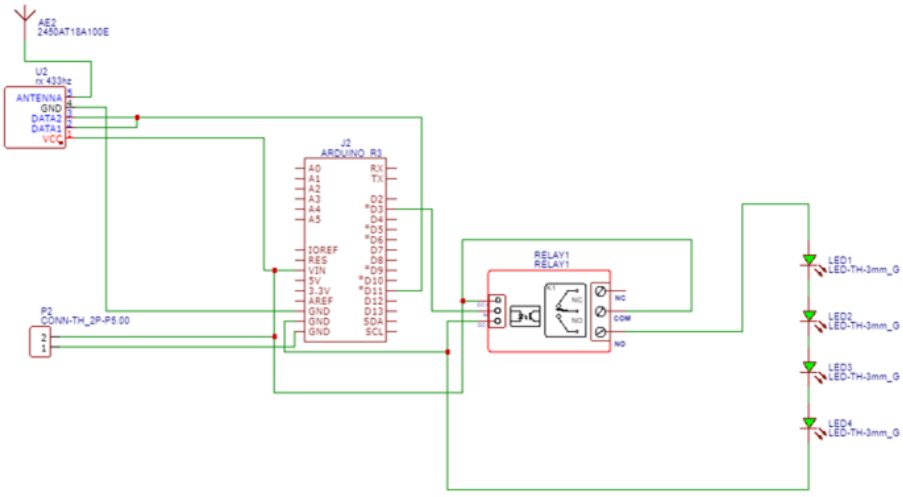

Figure 3.5: Receiver Section

3.2.4 Explanation

The code starts by initializing the necessary variables and pins in the setup function. Serial communication is established with a baud rate of 9600.

In the Transmitter section, the PIR sensor is initialized. Once the user /occupant moves, the sensor detects the motion which triggers the RF Transmitter. These values are then displayed on the serial monitor. If detection then "1" displayed & transmitted else "0" shows.

Next, the LED strip as light controller is connected by setting the analog output values for each pin through Relay Module. The RF receiver synchronized by the arduino code with transmitter for wireless switching of the relay module.The relay module then drives the light controller switching when movement/detection happens. Once the user /occupant moves, the sensor detects the motion which triggers the RF Transmitter as well as Receiver section. These values are then displayed on the serial monitor. If detection then "1" displayed & transmitted else "0" shows. Hence by applying the above source code & proper hardware connection in Transmitter as well as in Receiver section light controller response is established which can be used for driving luminaries.

3.2.5 Conclusion

By implementing the above algorithm and code, the Arduino Uno microcontroller can effectively control the LED strip based on the movement of occupants. This enables the creation of energy saving lighting environment and adjustments throughout the day to enhance visual comfort and promote various moods in indoor environments.

Feel free to modify and adapt the code according to your specific requirements, such as adding additional features or integrating with other sensors and modules.

CHAPTER 4

SYSTEM DESIGN AND FABRICATION

4.1 Introduction

The system design and fabrication process play a crucial role in the successful implementation of any electronic system. This section provides a detailed exploration of the system architecture, hardware components, and the step-by-step process involved in fabricating the system. By understanding the intricacies of the system design and the interconnections between different components, we can gain valuable insights into the functioning and effectiveness of the overall system.

The system architecture serves as a blueprint that outlines the flow of data and interactions between various hardware components. It establishes a framework for achieving the desired functionality and ensuring seamless integration between different modules. By studying the system architecture, we can comprehend the underlying principles governing the system's operation and identify potential areas for improvement.

A critical aspect of the system design is the selection and utilization of appropriate hardware components. Each component plays a specific role in accomplishing the system's objectives. Understanding the purpose and functionality of these

components is essential for ensuring their optimal utilization within the system. This section delves into the hardware components used in the system, such as the Arduino Uno microcontroller, LED strip, RF module (Tx & Rx), Relay module, and PIR sensor. We explore their individual contributions to the system and examine how they interact with each other.[9]

The step-by-step process of fabricating the system is another crucial aspect that will be discussed in detail. From the physical assembly of the components to establishing the necessary connections, this process guides the implementation of the system design. By following the outlined fabrication process, we can ensure the proper integration of hardware components and verify the functionality of the system. Through careful attention to detail and precise execution, the fabrication process ensures that the system operates as intended. This section aims to provide a comprehensive understanding of the system design and fabrication process. By examining the system architecture, hardware components, and fabrication steps, we can appreciate the intricate nature of the system and its potential applications. Understanding these aspects will serve as a foundation for further analysis, evaluation, and optimization of the system's performance.

4.2 Hardware Components

The Arduino Uno is a popular microcontroller board based on the ATmega328 microprocessor, shown in Fig. 4.1 bellow. It is widely used for prototyping and developing various electronic projects due to its ease of use and extensive community support.

4.2.1 Microcontroller (Arduino Uno)

* Microprocessor: ATmega328p[10]

  The ATmega328P is a widely used microcontroller based on the AVR architecture. It is at the heart of the Arduino Uno board and is commonly used

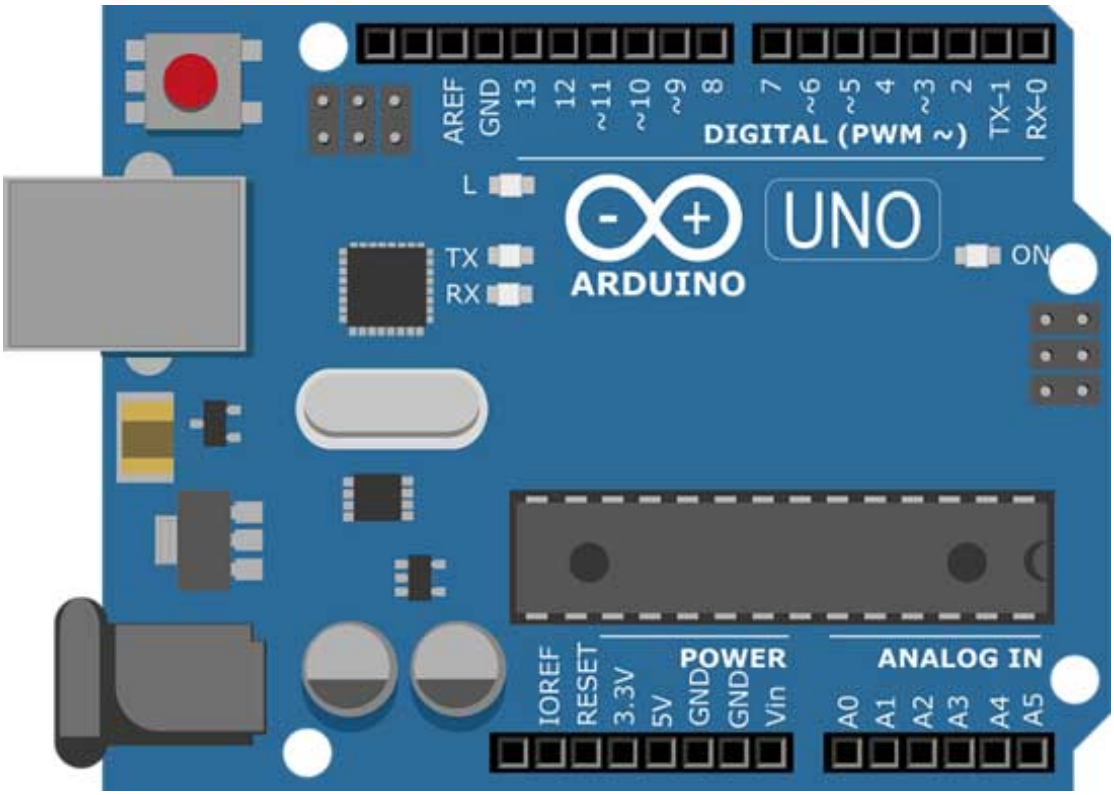

Figure 4.1: Arduino UNO Circuit Board

in various embedded systems and DIY projects. The ATmega328P offers a range of features and capabilities that make it suitable for a wide range of applications.[10]

Detail pin configurations of ATmega 328p Arduino Uno microcontroller is shown in Fig. 4.2.

* Architecture:

  The ATmega328P is based on the Harvard architecture, which separates program memory and data memory, allowing for simultaneous access to both.

* Clock Speed:

  It operates at a clock speed of up to 20 MHz, providing fast processing capabilities for executing instructions and handling data.

* Flash Memory:

  The ATmega328P has 32 KB of flash memory, which is used for storing the

program code. This allows for the implementation of complex and feature-rich applications.

* SRAM:

  It has 2 KB of SRAM (Static Random Access Memory) that provides temporary storage for variables, registers, and stack operations during program execution.

* EEPROM:

  The ATmega328P features 1 KB of EEPROM (Electrically Erasable Programmable Read-Only Memory), which allows for non-volatile data storage even when power is removed.

* I/O Pins:

  It has a total of 23 General Purpose 1/0 (GPIO) pins, which can be configured as either digital input/output or analog input pins. These pins provide connectivity to external devices and sensors.

* Analog-to-Digital Converter (ADC):

  The ATmega328P incorporates a 10-bit ADC with 6 multiplexed analog input channels. This enables analog voltage measurements for various applications, such as sensor interfacing.

* Timers and Counters:

  It includes three 16-bit timers/counters and one 8-bit timer/counter. These timers can be utilized for tasks such as generating PWM signals, measuring time intervals, and triggering events.

* Communication Interfaces:

  The ATmega328P supports multiple communication interfaces, including UART (Universal Asynchronous Receiver/Transmitter), SPI (Serial Peripheral Interface), and I2C (Inter-Integrated Circuit). These interfaces enable

communication with other devices, such as sensors, displays, and wireless modules.

* Power Management:

  The microprocessor features various power-saving modes, allowing for efficient energy consumption. It includes sleep modes that re- duce power consumption during idle periods, extending battery life in portable applications.

Components

In addition to the ATmega328P microprocessor itself, a typical setup using this microcontroller may also include the following components:

* Crystal Oscillator:

  The ATmega328P requires an external crystal oscillator to provide accurate timing and synchronization. A commonly used crystal oscillator is 16 MHz, which is connected to the microcontroller's XTALI and XTAL2 pins.

* Capacitors:

  Two capacitors are connected to the microcontroller to stabilize the voltage and ensure the proper functioning of the crystal oscillator. These capacitors are typically in the range of 10-22 picofarads (pF).

* Power Supply:

  The microcontroller requires a regulated power supply with a volt- age range of 1.8V to 5.5V. A suitable power regulator, such as a voltage regulator, is used to supply the appropriate voltage to the microcontroller.

* Pull-Up Resistors:

  Pull-up resistors are often used in conjunction with the microcontroller's GPIO pins to ensure proper logic levels for input signals. These resistors

provide a default high level when the external signal is not actively driving the pin.

The ATmega328P microprocessor is a versatile and powerful microcontroller that offers a range of features suitable for various embedded applications. Its rich set of peripherals, ample memory, and extensive I/O capabilities make it a popular choice among hobbyists, students, and professionals alike. When com bined with the Arduino development platform, the ATmega328P becomes an accessible and flexible option for prototyping and building innovative electronic projects.

* Analog Pins

The Arduino Uno has a total of six analog input pins labeled AD to A5. These pins can read analog voltages ranging from 0 to 5 volts. Each analog pin has a 10-bit analog-to-digital converter (ADC), allowing for precise measurement of analog signals. These pins are commonly used to read sensor values of light intensity, temperature, and potentiometer positions.

* Digital Pins

The Arduino Uno features a total of 14 digital input/output pins labeled from 0 to 13. These pins can be configured as either inputs or outputs. Digital pins 0 and 1 are also used for serial communication (RX and TX pins, respectively) with other devices. These pins operate at 5 volts and can be used for various purposes, such as reading switches, controlling LEDs, or interfacing with other digital devices.

Microcontroller Components

* Capacitors:

Decoupling Capacitors: These capacitors (typically 100nF) are placed near the power supply pins of the microcontroller (VCC and GND) to filter out the noise and provide stable power during operation.

* Reset Capacitor:

  A capacitor (typically 10 microfarad) is connected between the RESET pin and the ground to provide a stable reset signal during power-on or manual reset.

* Crystal Load Capacitors:

  The ATmega328P on the Arduino Uno uses an external crystal oscillator for accurate timing. Load capacitors (typically 22pF) are connected between the crystal pins (XTAL1 and XTAL2) and ground to stabilize the crystal's oscillation.

  USB Interface Capacitors: The USB interface on the Arduino Uno employs capacitors for signal filtering and protection.

* Resistors:

  The Arduino Uno board incorporates several resistors to provide necessary pull-up or pull-down configurations for specific pins and interfaces. Additionally, resistors may be used in external circuits connected to the Arduino Uno for current limiting or voltage division purposes.

* LEDs:

  The Arduino Uno includes built-in LEDs connected to digital pins 13 (labeled "L") and pin 5 (labeled "ON"). These LEDs provide visual indicators for program execution and power status, respectively.

* Voltage Regulator:

  The Arduino Uno utilizes a voltage regulator (typically an NCP1117) to regulate the incoming voltage from the power supply to a stable 5 volts for powering the microcontroller and other components on the board.[10]

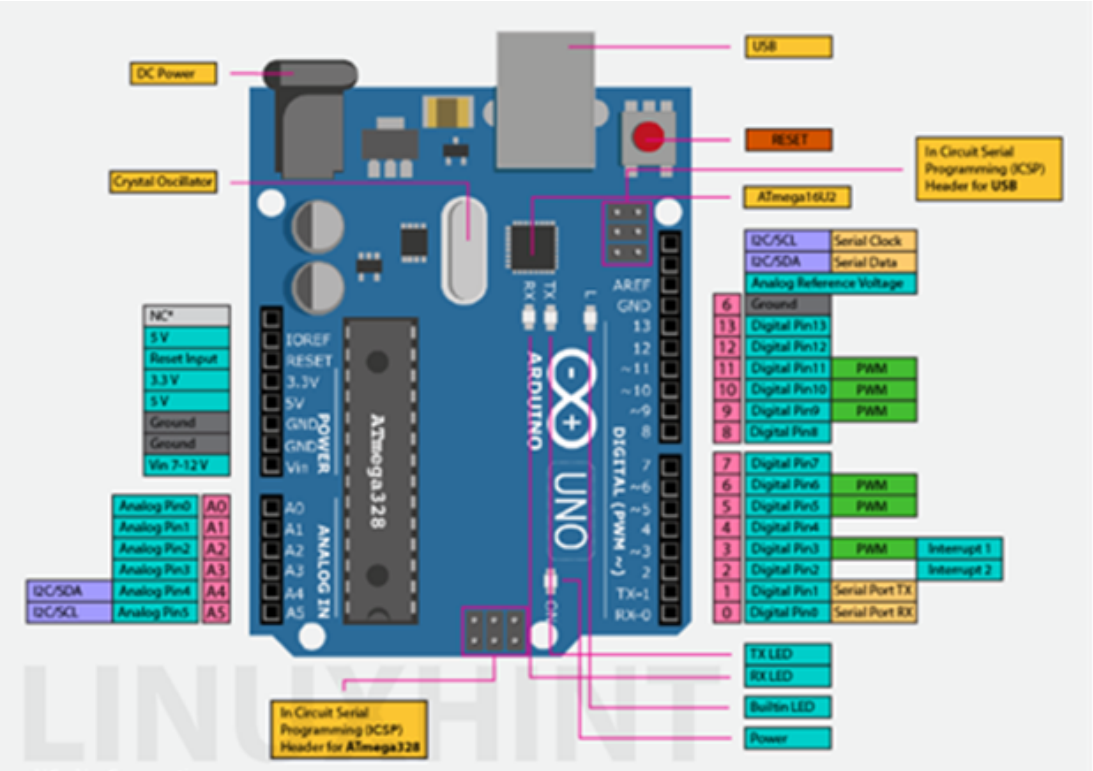

Figure 4.2: Arduino UNO Pin Description

4.2.2 LED Strip

LED strips come with several notable features:

* Individually Addressable LEDs:

  Each LED on the strip can be individually controlled, allowing for precise color manipulation and animation effects. This enables the creation of complex lighting patterns and dynamic visual displays.[10]

* High Brightness and Color Accuracy:

  LED strips are designed to provide high brightness levels and accurate color reproduction. The LEDs used in these strips emit vivid and vibrant colors, ensuring impressive lighting results.

* Flexible and Cuttable Design:

  The LED strips are flexible, allowing them to be easily bent, curved, or mounted on various surfaces. They can also be cut at designated points with-

out affecting the functionality of the remaining LEDs, offering customization options to fit different installation requirements.

* Easy Installation and Wiring:

  LED strips typically feature adhesive backing, making them easy to install on different surfaces. Additionally, they utilize a single-wire interface, simplifying the wiring process and reducing the complexity of the overall installation.

* Wide Voltage Range:

  These LED strips are designed to operate within a wide voltage range, typically ranging from 5V to 12V. This flexibility allows for compatibility with different power sources and ensures stability in various lighting setups.

* Compatibility with Controllers:

  LED strips are compatible with a range of LED controllers, microcontrollers, and popular platforms such as Arduino. This compatibility allows for seamless integration with existing lighting control systems and facilitates programming and customization of lighting effects.

* Multiple Length Options:

  LED strips are available in various lengths, typically measured in meters or feet. This allows users to choose the appropriate strip length based on their specific project requirements.

To power LED strips, a suitable power supply is connected to provide the required voltage and current. The power supply should be able to meet the power demands of the LED strip, considering factors such as LED brightness levels and the number of LEDs in use.

Application Examples [10]

LED strips find applications in various lighting scenarios, including:

* Home Decor and Ambient Lighting:

These LED strips can be used to create captivating lighting effects for home interiors, such as accent lighting, under-cabinet lighting, and mood lighting.

* Entertainment and Stage Lighting:

  LED strips are widely employed in stage performances, concerts, and other entertainment events to enhance visual effects and create immersive lighting atmospheres.

* Signage and Advertisement:

  The flexibility and vibrant colors of LED strips make them ideal for creating eye-catching signs, displays, and advertisement boards that grab attention and convey information effectively.

* Architectural Lighting:

  These LED strips are used in architectural lighting applications to illuminate buildings, bridges, and landmarks with dynamic and customizable lighting effects, enhancing their visual appeal. Single LED & LED strip is shown in Fig. 4.3, Fig. 4.4.

Figure 4.3: LED Strips

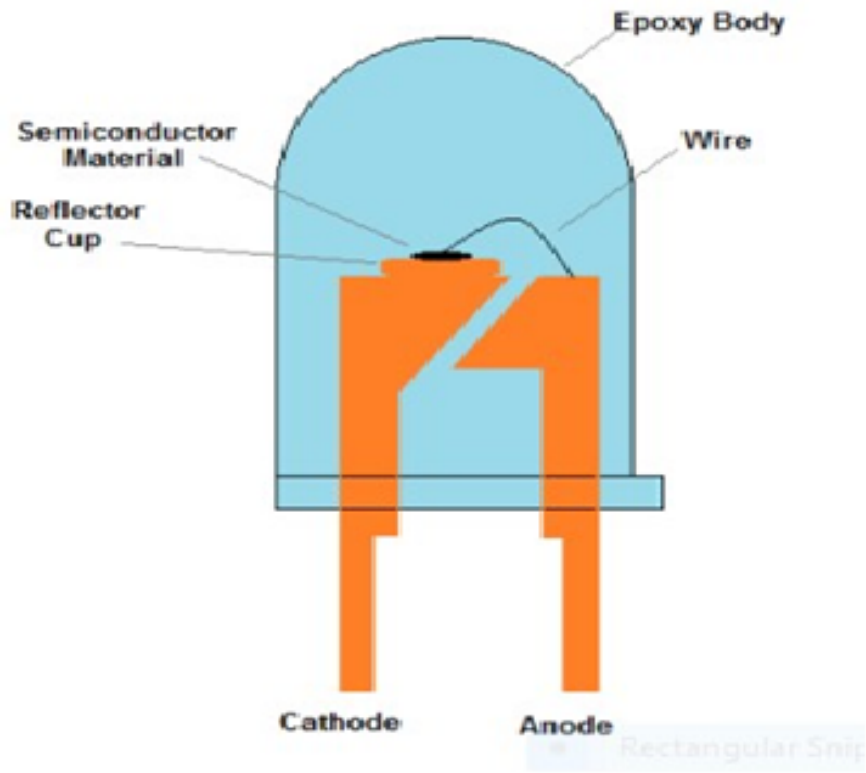

Figure 4.4: Internal structure LED

LED strips offer versatility, flexibility, and a wide range of lighting possibilities. Whether for personal projects or professional installations, these LED strips provide an exciting platform for creative lighting designs and captivating visual experiences.

4.2.3 LED Driver

Internal Components

The LED strip which is having driver chip inbuild consists of the following internal components:

* Microcontroller Unit (MCU): It incorporates a built-in microcontroller unit responsible for controlling the LED data transmission and generating the necessary signals for driving the LEDs. The MCU executes the program instructions stored in its memory to process the incoming data and control the behavior of the LEDs. Data Shift Register: It features a data shift

register that stores the color information for each LED. The shift register is responsible for receiving the data from the microcontroller and propagating it through the LED chain. It sequentially shifts the data to the subsequent LEDs in the chain.

* PWM Generator:

  To control the intensity of each LED, it utilizes a Pulse Width Modulation (PWM) generator. The PWM generator generates a variable duty cycle PWM signal for each LED based on the color information received from the data shift register. By adjusting the duty cycle of the PWM signal, the WS2811 can produce a wide range of colors and brightness levels.[10]

* LED Output Drivers:

  It is equipped with output drivers that are responsible for driving the LEDs connected to its output pins. These output drivers can source or sink current to control the LED cur- rents and illuminate the RGB LEDs accordingly. The output drivers are designed to handle the voltage and current requirements of the connected LEDs as shown in Fig. 4.6.

* Power Supply Regulation:

  It incorporates power supply regulation circuitry to ensure stable operation of the LED driver and protect it from voltage fluctuations or transients. It provides the necessary voltage levels to power the internal components and the connected LEDs, allowing for reliable and consistent performance.

* Communication Interface:

  It features a single-wire communication interface that allows for easy daisy-chaining of multiple devices. This interface simplifies the wiring and control of large LED installations, enabling the synchronization of lighting effects across a chain of LEDs.

The integration of these internal components within the LED driver chip, internal circuit referred in Fig. 4.5, provides a convenient and efficient solution for controlling addressable RGB LEDs. It offers flexibility, ease of use, and the ability to create stunning lighting effects in various applications, including architectural lighting, stage lighting, signage, and decorative lighting installations.[10]

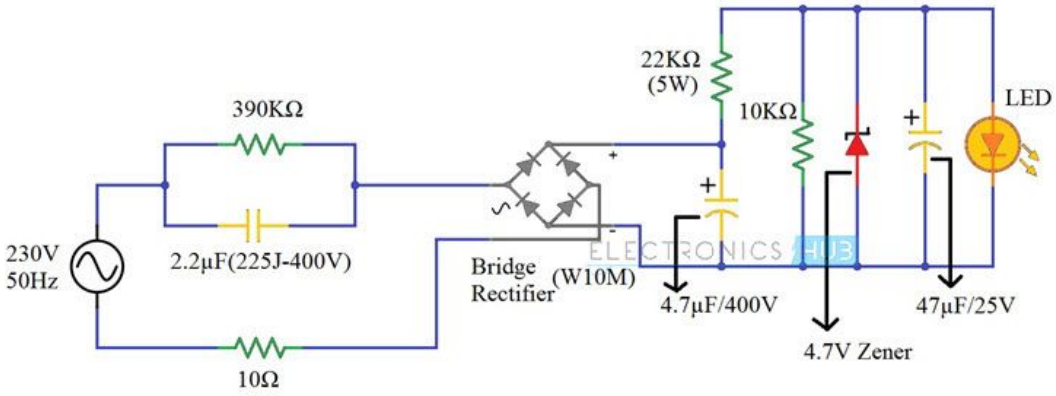

Figure 4.5: LED driver circuit diagram

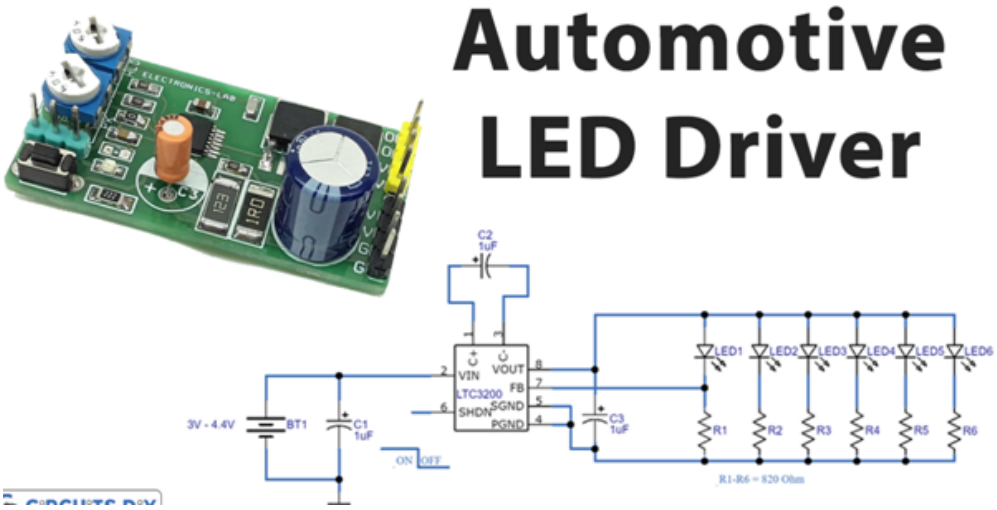

Figure 4.6: Automotive LED driver

4.2.4 Relay Module

The primary function of a relay module, shown in Fig. 4.7, is to switch electrical devices or systems on and off. It also serves to isolate control circuits, ensuring

that low-power devices, such as microcontrollers, can safely control higher voltages and currents. We have seen relay works on the principle of electromagnetic attraction when it gets energized it operates according to the signal given. Nowadays, this signal is given by the micro-controllers or microprocessors. These relays are also used in power system operations to detect and prevent the fault.

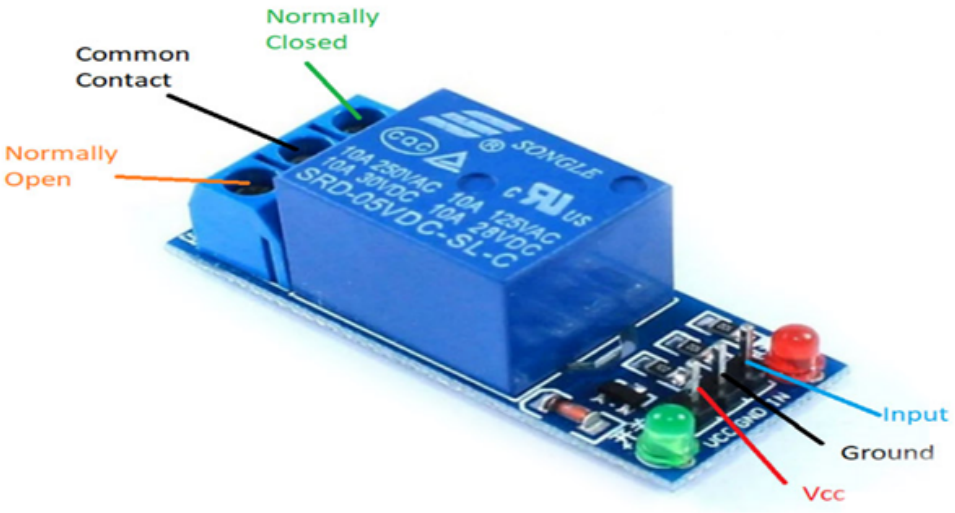

Figure 4.7: Relay Module

4.2.5 RF Tx, Rx Module

An RF transmitter module is a small PCB sub-assembly capable of transmitting a radio wave and modulating that wave to carry data. RF Transmitters and Receivers in collection, featuring diverse frequency options including 315MHz, 433MHz, 434MHz, 915MHz, and 2.4GHz. Our selection also includes the RFM69 series wireless communication module, specifically designed for seamless operation at the globally free application 965MHz ISM band.[9] Here we have used 433 Mhz RF Transmitter Receiver which are synchronized with Arduino in Fig. 4.9. These modules, shown in Fig. 4.8, enable reliable transmission and reception of radio signals between devices. Unlike infrared signals, RF communication is not affected by other infrared emitting sources and operates on specific frequencies. With the transmitter/receiver (Tx/Rx) pair working on different frequencies, our

RF Transmitter and Receivers effortlessly transmit serial data wirelessly via RF using their antennas.[9]

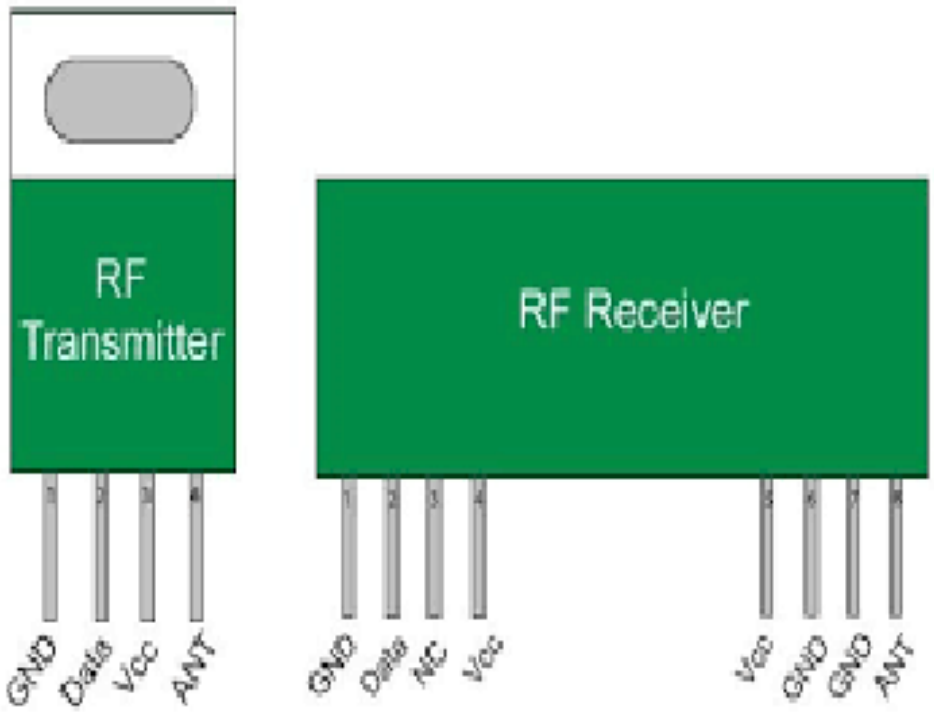

Figure 4.8: RF Module

4.2.6 PIR Sensor

PIR sensors allow you to sense motion, almost always used to detect whether a human has moved in or out of the sensors range. They are small, inexpensive, lowpower, easy to use and don't wear out. For that reason they are commonly found in appliances and gadgets used in homes or businesses. They are often referred to as PIR,"Passive Infrared", "Pyroelectric", or "IR motion" sensors.[6]

PIRs are basically made of a pyroelectric sensor (https://adafru.it/aKh) (which you can see below as the round metal can with a rectangular crystal in the center), which can detect levels of infrared radiation. Everything emits some low level radiation, and the hotter something is, the more radiation is emitted. The sensor in a motion detector is actually split in two halves.

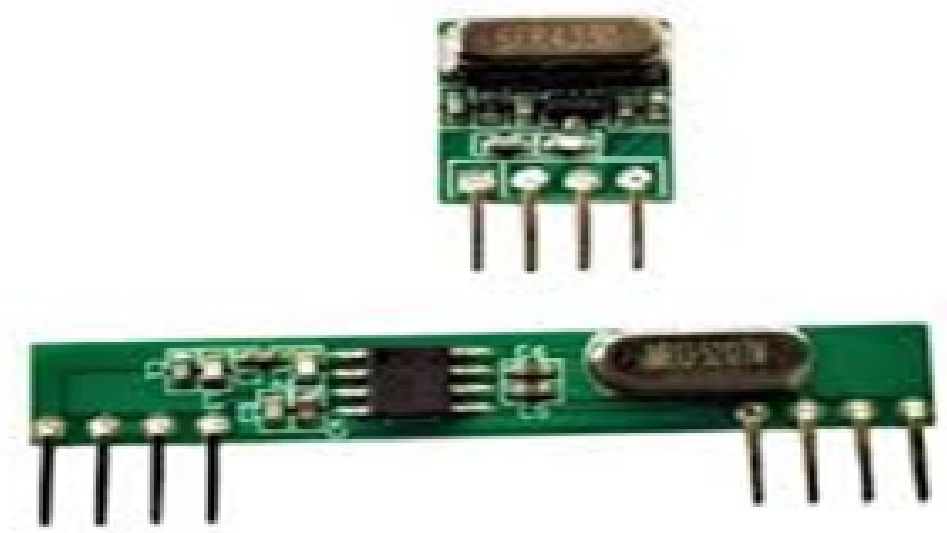

Figure 4.9: RF Module Practical

The reason for that is that we are looking to detect motion (change) not average IR levels. The two halves are wired up so that they cancel each other out. If one half sees more or less IR radiation than the other, the output will swing high or low. The passive infrared (PIR) sensor itself has two slots in it, each slot is made of a special material that is sensitive to IR. The lens used here is not really doing much and so we see that the two slots can 'see' out past some distance (basically the sensitivity of the sensor). When the sensor is idle, both slots detect the same amount of IR, the ambient amount radiated from the room or walls or outdoors. The internal blocks of PIR sensor is shown in Fig. 4.10.

When a warm body like a human or animal passes by, it first intercepts one half of the PIR sensor, which causes a positive differential change between the two halves. When the warm body leaves the sensing area, the reverse happens, whereby the sensor generates a negative differential change. These change pulses are what is detected. In Passive Infrared (PIR) Sensor, passive word indicates PIR Sensor

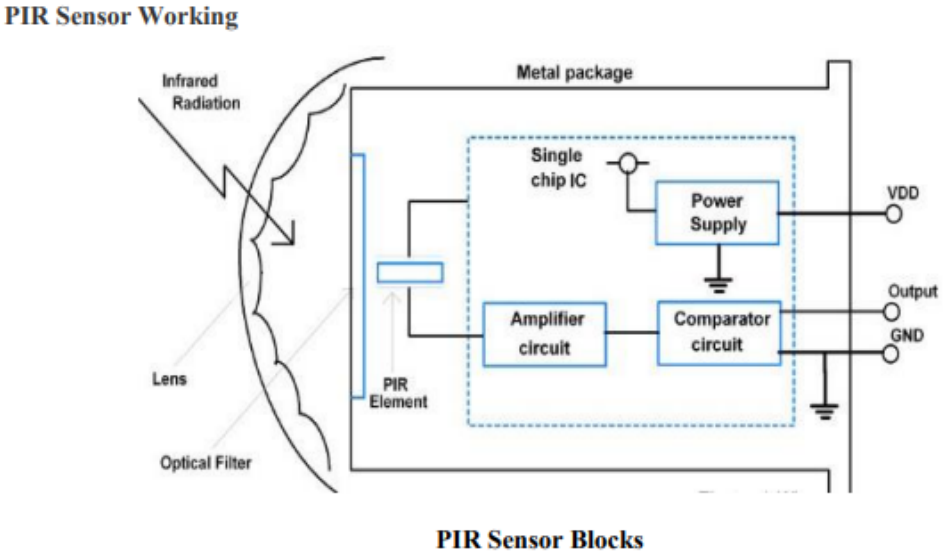

Figure 4.10: PIR Sensor

does not generate or radiate any energy for detection purposes. PIR Sensors don't detect or measure "HEAT"; they detect the infrared radiation emitted or reflected from objects. They are small, inexpensive, low power and easy to use. They are commonly found at home, medical, factories etc. areas.[6]

4.3 Fabrication

Circuit Diagram

Actual picture of the circuit that is tested in lab is mentioned bellow in Fig. 4.11

& Fig. 4.12.

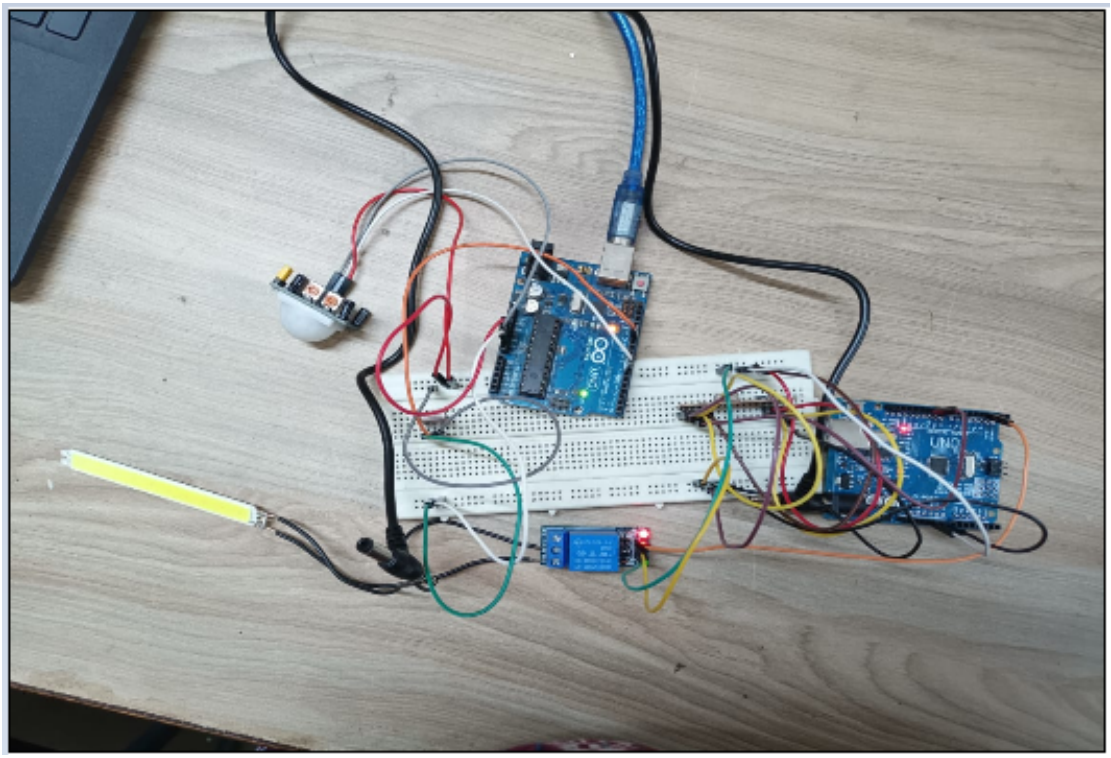

Figure 4.11: Circuit Diagram Top view

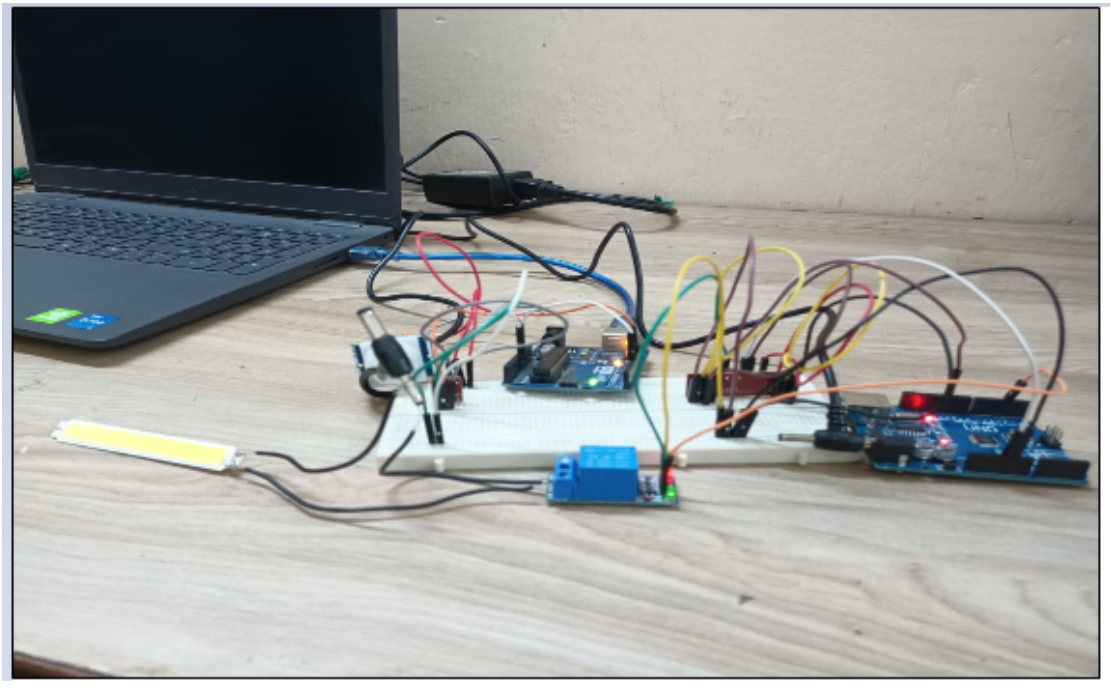

Figure 4.12: Circuit Diagram Front view

Components Used

1. Arduino Uno Transmitter

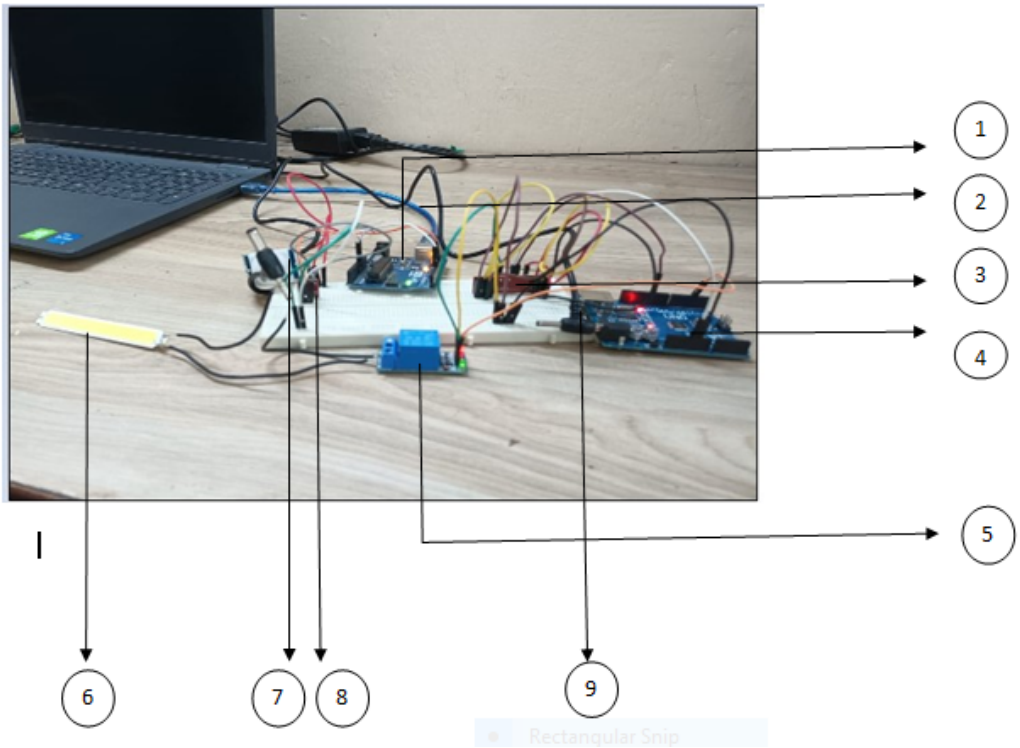

Figure 4.13: Fabricated Circuit

2. USB power cable

3. RF Receiver Module

4. Arduino Uno Receiver

5. 5v Relay Module

6. 5V DC LED strip

7. PIR Motion Sensor

8. RF Transmitter Module

9. Power Adaptor for Receiver Arduino

CHAPTER 5

TESTING AND EVALUATION

5.1 Introduction

The "Test and Evaluation" chapter aims to switching on the light controller and verify the response. This chapter presents the experimental setup, measurement procedure and analysis of the results. Additionally, the chapter explores the utilization of light controller for driving luminaires.

Lighting plays a crucial role in influencing human perception, mood, health & obviously in Energy consumption. Therefore, accurately designing the lighting controller different light environment is established. The energy saver light controller provides controlled luminaires based on occupants aiding in the assessment of their suitability for various applications.

The PIR motion sensor serves as the primary test instrument for this study. It offers precise and reliable detection of users, allowing for an accurate evaluation in serial monitor. This chapter includes a detailed description of the working principle, calibration process, measurement modes, and capabilities of the light controller.

By detecting the occupants by the sensor and both the RF module synchronized, detected o/p values obtained through the relay module which activates the light controller. The comparison between measured and calculated values provides

a comprehensive understanding of the accuracy and reliability of the employed methods.

Through this comprehensive test and evaluation process, we aim to gain valuable insights into the light scenes and their suitability for various application. The results obtained from this chapter will Full tribute to the overall understanding of lighting design and its inter will human perception and well-being.

The subsequent sections of this chapter will provide a detailed explanation of the experimental setup, measurement procedure, and analysis of the results of the utilization of the PIR sensor , RF Module & analysis the interpretation of the connection . Finally, the chapter will conclude with a comprehensive analysis and discussion of the findings.

5.2 Testing Procedure

Steps:

1. Initially, Input is given to RF transmitter to Arduino Uno (Start movement of any objects/hands near PIR sensor, which is activated after getting any motion)

2. Check Command in serial monitor of RF transmitter whether “0”/“1” is detected.

3. Check in RF receiver section microcontroller & detect the received signal in serial monitor of another computer screen whether receiver has received the signal or not. If the signal is received means both side communication is established.

4. Then at the execution step, Relay module is connected with the receiver, the relay module is automatically switches the light controller (LED strip) & output is obtained.

Testing of the system has been accomplished successfully shown bellow in Fig. 5.1.

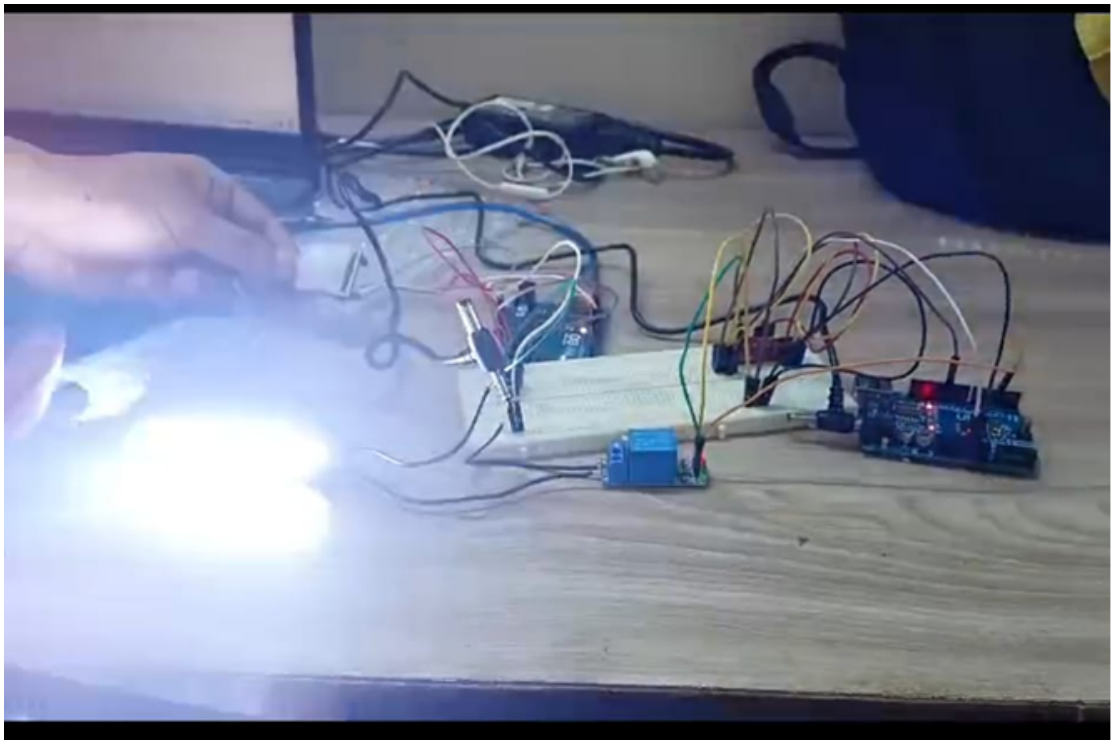

Figure 5.1: Tested Hardware

5.3 Applications

By this way the lighting controller is established which can control a series of luminaire. Lighting control systems are employed to maximize the energy savings from the lighting system, satisfy building codes, or comply with green building and energy conservation programs. Lighting control systems may include a lighting technology designed for energy efficiency, convenience and security. Nowadays, technology development encourage people to think creatively, not not only to explore new discoveries, but also to maximize existing technological performance to ease human work in everyday life.[8]

The need for an automatic control system is needed with the increasing activity of each individual community with various erratic activities and times. As a result, many activities in the household are delayed, such as turning on or turning off the

lights in every room at night and in the morning. Smart home system is one solution that suits the needs of the current automatic controllers. Smart home system is a home or building is equipped with an integrated technology with the help of the tool/tools which can be a computer or other device, for example a smartphone to provide all the comfort, safety, security and energy saving is automatic and programmed.

The smart home system can be used to control almost all equipment and equipment at home, from lighting settings to various household appliances, which can be done only by using sound, infrared light or remote control. In this study, a smart home system can be created for home light control system applications using Arduino Uno microcontroller via mobile-based wifi media. With this approach the user can control the home lights by turning off or turning on the home lights remotely through the mobile media. Thus the efficiency of electricity use becomes more maintained.

CHAPTER 6

CONCLUSIONS AND FUTURE WORKS

6.1 Conclusion

I summarize the key findings and conclusions based on the analysis conducted in our project. The main focus of the study was to develop a light controller for creating energy saving lighting . The RF module, Sensors, Relay along with two Arduino microcontroller are utilized to obtain these measurements.

Through the experiment, the LED strips responded successfully as per requirement. Initially the RF receiver when receives the signal which is obtained from RF transmitter through PIR sensor triggering, Relay module is activated as wireless switch & in serial monitor of the PC it first shows data as "0" /"1" as per occupant detection. Accordingly the entire system drives the light controller.

6.2 Future Works

Based on the findings of our study, several areas for future research and improvement can be identified:

6.2.1 Refinement of Measurement Techniques

Further exploration of measurement techniques and instruments may be necessary to accurately drive light sources that can work based on detecting illumination level by mutual interaction.[10] By further development of codes a series of light can be operated by the light controller.

6.2.2 Integration of Personalized Lighting Systems

With the advancement of smart lighting technologies, the development of personalized lighting systems tailored to individuals' preferences and needs becomes an interesting avenue for future research. Investigating the impact of personalized lighting on mood, productivity, and well-being could provide valuable insights for the design of adaptive lighting solutions.[10]

6.2.3 Impact of Lighting in Different Environments

Expanding the research to different environments, such as workplaces, healthcare facilities, and residential settings, would enable a comprehensive under-standing of how lighting influences human experiences and behavior in various contexts. Such studies could help in developing lighting guidelines and recommendations specific to different environments.[10]

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