DESIGN AND DEVELOPMENT OF A SMART STREET LIGHTTING SYSTEM FOR REAL-TIME MONITORING

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BY

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All information in this document has been obtained and presented in accordance with academic rules and ethical conduct.

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ABSTRACT

This thesis focuses on the design and development of a smart street light system aimed at optimizing energy efficiency and enhancing urban safety through real-time monitoring and adaptive control. The proposed system integrates an (Light Emitting Diode) LED lamp, an LED driver, an LDR (Light Dependent Resistor) sensor, and an ultrasonic sensor, all managed by an ATmega328P microcontroller. The LDR sensor monitors ambient light levels to determine the time of day and adjust the street light's operation accordingly. During daylight, the system conserves energy by keeping the LED lamp off. At night or in low-light conditions, the ultrasonic sensor detects the presence of pedestrians or vehicles in the vicinity.

The system's adaptive control is designed to respond dynamically to detected objects. If the ultrasonic sensor identifies an entity, the system activates LED Brightness Mode, ensuring full illumination for safety and visibility. Conversely, if no movement is detected, the system transitions to LED Dimming Mode, reducing the light intensity to save energy while maintaining minimal illumination. This approach balances energy conservation with the need for adequate lighting.

The design also incorporates a MOSFET to regulate the LED lamp's power and an SMPS (Switched-Mode Power Supply) to manage voltage conversion and distribution. The LED driver ensures proper functioning of the LED lamp, while the ATmega328P microcontroller coordinates the sensors and controls the lighting modes based on real-time inputs. The system is evaluated for performance and efficiency in various scenarios to validate its effectiveness in reducing energy consumption while maintaining safety and visibility in urban environments. The outcomes demonstrate the potential of smart street light systems to contribute to more sustainable and intelligent urban infrastructure.

Overview of the Thesis

Chapter 1. Provides the Introduction of the system.

Chapter 2. Discussion about the Lighting Design Principle and Provides the information of Different types of Street Lights. And also Discuss about the LEDs and working Principle.

Chapter 3. Description of the Instruments Used for designing the light source along with The circuit diagram & flowchart.

Chapter 4. Implementation of the Proposed System along with this Operation.

Chapter 5. Full description of Evaluation and Testing in Laboratory.

Chapter 6. Deals with Conclusions and future scope.

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CHAPTER-1: INTRODUCTION

INTRODUCTION:

Urban infrastructure is continuously developing to fulfil the requirements of contemporary society, with an increasing focus on sustainability and energy efficiency. The domain of street lighting, a fundamental element of urban infrastructure, is one where innovative approaches can significantly influence both energy usage and public safety. This study introduces the concept and execution of a smart street lighting system that caters to these demands by incorporating Light Dependent Resistor and ultrasonic sensors.

The primary aim of this intelligent street lighting system is to enhance energy efficiency while offering real-time monitoring and improved safety. Through the utilization of LDR sensors, the system can identify the presence of sunlight and guarantee that street lights are inactive during daylight, thus conserving energy. As evening arrives, the system switches to a dimming mode, providing essential lighting with minimal energy consumption.

An essential aspect of this system is its flexible response to motion detection. Ultrasonic sensors are pivotal in this role, identifying motion in the proximity of the street lights. Upon detecting movement during dimming mode, the LED lights' brightness intensifies, enhancing visibility and safety for pedestrians and vehicles. This dynamic adaptation not only enhances security but also contributes to more effective energy utilization by providing full brightness only when necessary.

To conclude, the smart street lighting system delivers a sustainable and adaptable approach to urban lighting management. It is in line with current objectives for efficient infrastructure, minimizing energy wastage, and enhancing public safety through advanced sensor integration and intelligent lighting management.

1.1 BACKGROUND

In modern urban settings, the implementation of effective street lighting is imperative for safeguarding public safety, minimizing energy expenditure, and accommodating fluctuating traffic patterns. Conventional street lighting systems generally function on a predetermined timetable, often resulting in superfluous energy consumption and diminished illumination efficacy. Recent advancements in sensor technology present a valuable opportunity to formulate a more advanced street lighting system that adapts in real-time to prevailing conditions. Through the integration of Light Dependent Resistor (LDR) sensors and ultrasonic sensors, this initiative seeks to improve the efficiency and adaptability of street lighting, thereby contributing to more intelligent and sustainable urban management.

1.2 LITERATURE REVIEW:

The literature on smart and energy-efficient street lighting systems highlights significant advancements and trends in technology and implementation. Morente and García (2019) review the impact of LED street lighting on energy efficiency, noting that LED technology offers substantial improvements over traditional lighting, including energy savings and reduced environmental impact. They also discuss various control methods such as adaptive lighting systems that further optimize energy use. [1]

Aman, Simmhan, and Prasanna (2013) provide a comprehensive overview of energy management systems (EMS), focusing on their current state and emerging trends. The paper emphasizes the role of advanced technologies and real-time monitoring in enhancing energy efficiency across various sectors. It highlights the integration of smart grids and advanced analytics as key developments in EMS. [2]

García-Castro and Herrera (2018) review adaptive street lighting control systems, which adjust lighting based on environmental conditions and traffic patterns. The review underscores the benefits of these systems in reducing energy consumption and improving lighting quality through sensor-based controls and adaptive strategies. [3]

Alavi and Lim (2020) explore wireless communication technologies for smart cities, discussing their applications and the challenges associated with them. The paper covers technologies such as IoT and 5G, emphasizing their role in enhancing urban management and connectivity, while also addressing issues related to security and network reliability. [4]

Yu, Zhang, and Gjessing (2014) examine cloud-based vehicular networks, focusing on efficient resource management. The paper discusses how cloud computing can optimize vehicular networks, providing insights into resource allocation and network performance. [5]

Zanella et al. (2014) delve into the Internet of Things (IoT) for smart cities, outlining how IoT technologies facilitate smart city applications. They address the potential of IoT in improving urban infrastructure and services, highlighting its integration into smart city ecosystems. [6]

Hernández and Hernández (2017) discuss the role of smart lighting in Barcelona's smart city initiatives, emphasizing how smart lighting contributes to urban sustainability and efficiency. The study showcases the impact of intelligent lighting systems on city management and energy use. [7]

Manville (2017) reviews Los Angeles's LED street lighting implementation, providing insights into the lessons learned from this smart city project. The paper explores the benefits and challenges faced during the transition to LED technology. [8]

Johansen and Andersen (2016) analyze smart lighting in Copenhagen, focusing on how it enhances urban sustainability. The paper highlights the city's efforts in integrating smart lighting to improve energy efficiency and urban quality of life. [9]

Ferreira and Almeida (2017) present a cost-benefit analysis of smart street lighting systems through a case study. They evaluate the economic and operational benefits of implementing smart lighting technologies, demonstrating their value in urban settings. [10]

Khan and Salah (2018) review IoT security, discussing block chain solutions and open challenges. The paper addresses the security concerns associated with IoT and explores block chain technology as a potential solution to enhance data protection. [11]

Gungor and Hancke (2009) cover the challenges and design principles of industrial wireless sensor networks. The paper highlights the technical approaches and issues in deploying wireless sensor networks in industrial environments, providing valuable insights into their design and implementation. [12]

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1.3 PROBLEM STATEMENT

Traditional street lighting systems frequently exhibit inefficiency, operating at constant brightness levels regardless of actual traffic dynamics or ambient light conditions. This scenario culminates in excessive energy consumption and inadequate lighting across varying traffic situations. There exists a pressing need for a smart street lighting system capable of accurately detecting and responding to fluctuations in both pedestrian and vehicular traffic, in addition to variations in ambient light, to optimize energy utilization while ensuring sufficient visibility and safety.

1.4 OBJECTIVES

1. To Develop an Intelligent Street Lighting System: Formulate a sophisticated street lighting system that amalgamates LDR sensors, ultrasonic sensors, and advanced counting sensors to continuously monitor and adjust lighting conditions in a dynamic manner.

2. To Optimize Energy Consumption: Employ LDR sensors to differentiate between daytime and nighttime, thereby enabling the system to deactivate lights during daylight hours and modulate brightness at night according to real-time traffic conditions.

3. To Enhance Safety and Visibility: Integrate ultrasonic sensors to detect motion and elevate LED brightness in areas with high traffic density, thereby enhancing visibility and safety for both pedestrians and vehicles.

1.5 STUDY AND SCOPE

The research concentrates on the development and evaluation of a smart street lighting system that incorporates an array of sensor technologies to achieve dynamic control over lighting conditions. The scope encompasses:

- **Integration of LDR Sensors:** To ascertain ambient light levels and regulate lighting in accordance with diurnal cycles.
- **Utilization of Ultrasonic Sensors:** To monitor motion and modify light intensity in regions with elevated traffic, thereby improving safety and visibility.
- **System Implementation and Testing:** Develop and implement the smart street lighting system in a designated urban locale to assess its performance, efficiency, and effects on energy consumption and safety.

1.6 METHODOLOGY

To commence, it is essential to ascertain the output current and voltage specifications of the LED driver that is interfaced with the LED lamp. This initial measurement will yield a foundational comprehension of the power characteristics exhibited by the lamp when subjected to standard operational parameters. Upon the documentation of these measurements, the subsequent phase necessitates the engineering of a system that facilitates the reduction of voltage from the primary supply of 230V to 12V and ultimately to 5V, which is requisite for the operational components of the control system, including the Arduino Uno, LDR sensor, and Ultrasonic sensor.

The architectural design of the system comprises the amalgamation of an LDR sensor and an Ultrasonic sensor alongside the Arduino Uno. The LDR sensor functions to gauge the intensity of ambient illumination, whereas the Ultrasonic sensor is employed to identify objects in proximity to the lamp. These sensors serve as pivotal elements in modulating the operational parameters of the LED lamp in accordance with prevailing environmental conditions.

Following the installation of the sensors within the system, the control algorithm is uploaded to the Arduino Uno. This algorithm governs the behaviour of the lamp predicated on the inputs received from the LDR and Ultrasonic sensors. For example, the LED lamp may activate upon the detection of low light levels by the LDR sensor or in response to the proximity of an object as identified by the Ultrasonic sensor.

With the system architecture established and the control algorithm successfully uploaded, it is imperative to connect the system to the 230V supply via a Switched Mode Power Supply (SMPS) and to wire the input of the LED driver in a parallel configuration. This arrangement guarantees that the system acquires the requisite power levels for its operation, while simultaneously preserving the capability to modulate the LED lamp based on sensor data.

Upon achieving operational status for the system, it is important to measure the current and voltage ratings of the LED lamp under a variety of conditions: during daylight (characterized by elevated ambient light levels), during dimming (characterized by reduced ambient light levels), and in instances where motion is detected by the Ultrasonic sensor. These assessments will yield valuable insights into the manner in which the system regulates power consumption across diverse scenarios, thereby reflecting the efficacy of the sensor-based control system in enhancing energy utilization.

CHAPTER- 2: Street Light Design Principle

2.1 Illuminance based design parameter:-

2.1.1 Maintained Average Illuminance:

The term Maintained Average Illuminance denotes the average level of illuminance that remains constant on the road surface over the lifespan of the street lighting system. This factor holds significant importance in the design of street lighting as it is crucial for ensuring the safety and visibility of drivers, pedestrians, and cyclists.

Key Aspects:

- Illuminance: Illuminance is defined as the quantity of light falling on a surface, typically measured in lux (lx), especially on the road surface in street lighting applications.
- Maintained Illuminance: Represents the illuminance level after the light output from the lamps has decreased over time due to various factors such as aging, dirt accumulation on the luminaire, and environmental conditions.
- Initial vs. Maintained: While initial illuminance pertains to the light level right after the installation of the street lighting system, maintained illuminance refers to the diminished light level anticipated after a period of system operation.
- Design Considerations: Engineers must carefully plan the system to ensure that the maintained illuminance meets the minimum requirements even at the end of the lighting system's lifespan, considering factors like light depreciation.
- The standards for maintained average illuminance may differ based on the country, type of road, and its usage, often guided by organizations like the Illuminating Engineering Society (IES) or national standards bodies.

2.1.2 Overall Uniformity of Illuminance:

The concept of Overall Uniformity of Illuminance in the realm of street light design pertains to the assessment of how evenly light is dispersed over a roadway or a designated area. This factor stands as a pivotal parameter in the domain of lighting design, ensuring consistent visibility and diminishing regions of high contrast which may prove to be distracting or perilous to motorists and pedestrians.

- Uniformity Ratio is conventionally presented as a ratio denoted by
  $U_0 = E_{min} / E_{avg}$
  Where
  E_{min} signifies the minimum illuminance recorded at any point on the roadway, and
  E_{avg} represents the average illuminance across the same area.
- A heightened uniformity ratio denotes a more uniform spread of light. Specifically, a perfect uniformity, indicated by a ratio of 1 (a rarity and often superfluous), contrasts with a ratio closer to 0, signifying a markedly inconsistent illumination.

The paramount role of good overall uniformity in establishing a secure and pleasant nocturnal environment underscores its critical status in the formulation of street lighting systems.

2.1.3 Longitudinal Uniformity of Illuminance:

The measurement known as Longitudinal Uniformity of Illuminance is a specific criterion utilized in the realm of street lighting design to assess the evenness of light distribution throughout the extent of a thoroughfare. In contrast to overall uniformity, which pertains to the entire area, longitudinal uniformity focuses on the uniformity of light levels along the path of travel (usually along the central axis or lanes of the road).

Key Elements:

- Calculation of Longitudinal Uniformity Ratio: This is typically determined by the formula:
  $U_L = E_{min, Long} / E_{max, long}$
  Where:
  $E_{min, long}$ denotes the minimum illuminance along the longitudinal axis (centerline) of the road.
  $E_{max, long}$ signifies the maximum illuminance along the same axis.

Ensuring the longitudinal uniformity of illuminance is paramount in guaranteeing that roadways receive uniform lighting throughout their expanse, thereby fostering safer and more pleasant driving circumstances.

2.1.4 Transverse Uniformity of Illuminance:

The concept of Transverse Uniformity of Illuminance pertains to the uniform spread of light across the breadth of a road or roadway surface. It represents a fundamental factor in the design of street lighting, guaranteeing consistent visibility throughout all lanes, thereby reducing the likelihood of dark areas or regions with excessive brightness.

Essential Points:

- Calculation of Transverse Uniformity Ratio: Typically, transverse uniformity is determined by the ratio of the minimum illuminance to the average illuminance spanning the width of the road:

  $U_T = E_{min,\ trans} / E_{avg,\ trans}$

  In this equation:

  $E_{min,\ trans}$ denotes the minimum illuminance recorded across the road's width (perpendicular to the travel direction).

  $E_{avg,\ trans}$ signifies the average illuminance measured across the same zone.
- Significance: Transverse uniformity plays a crucial role in ensuring uniform lighting of the entire road surface, diminishing disparities between different sections of the road and enhancing the visibility of pedestrians, vehicles, and obstacles across all lanes.

The uniformity of illuminance in the transverse direction is vital for guaranteeing even light dispersion across the entire width of a road, thereby enhancing safety and visibility for all road users. Attaining the desired uniformity necessitates thoughtful design considerations and meticulous planning, especially on wider or more intricate road networks.

2.2 Luminance Based Design Parameter:

2.2.1 Maintained Average Luminance:

Maintained Average Luminance in the context of street lighting design pertains to the mean level of brightness observed on a road surface by the human eye, accounting for variables such as lamp aging and dirt accumulation. Luminance, quantified in candelas per square meter (cd/m²), denotes the quantity of light reflected from a surface, directly influencing visibility and safety on the roadway.

Key Points:

- Maintained Luminance: This concept denotes the luminance level subsequent to the reduction in light output due to aging of lamps, dirt accumulation, and other environmental influences. The primary objective is to ensure that despite these factors diminishing the initial luminance, the lighting system continues to offer sufficient brightness.
- Calculation: The determination of maintained average luminance involves considering the original luminance provided by the lighting design and applying maintenance parameters that factor in depreciation over time.

2.2.2 Overall Uniformity of Luminance:

The concept of Overall Uniformity of Luminance in the design of street lighting pertains to the uniform distribution of luminosity across a road surface, as perceived by the human eye. Ensuring this uniformity is crucial to guarantee that the road is evenly illuminated, thus reducing areas of high contrast that might hinder visibility and safety for drivers and other road users.

Key Points:

- Distinction between Luminance and Illuminance: Luminance quantifies the brightness of a surface as observed by an individual, expressed in candelas per square meter (cd/m²), whereas illuminance measures the quantity of light reaching the surface (measured in lux). Luminance is more closely associated with visibility, making it a fundamental parameter in street lighting.
- Calculation of Uniformity Ratio: The overall uniformity of luminance is commonly computed through the formula:

$U_0 = L_{min} / L_{avg}$

Where:

(L_{min}) represents the minimum luminance on the road surface.

(L_{avg}) denotes the average luminance on the road surface.

- Objective: The objective of achieving optimal overall uniformity of luminance is to prevent areas of excessive brightness or darkness, thereby offering a consistent and pleasant visual setting for drivers. This uniformity aids in reducing eye strain and ensuring that road conditions are easily discernible.

Standard Values:

- Urban Streets: For main urban roads and highways, the expected overall uniformity of luminance typically ranges from 0.4 to 0.6, indicating that the minimum luminance should be 40% to 60% of the average luminance.
- Residential Areas: In less frequented residential streets, the prescribed uniformity ratio might be lower, generally around 0.3 to 0.4.(Source: CIE 115:2010 "Lighting of Roads for Motor and Pedestrian Traffic")

2.2.3 Longitudinal Uniformity of Luminance:

The longitudinal uniformity of luminance in street lighting design pertains to the consistency of brightness on the road surface in the direction of travel or road length. This metric is fundamental in ensuring that drivers encounter uniform brightness as they progress, thereby reducing the probability of encountering areas with excessive contrast that could hinder visibility and lead to visual discomfort.

Key Points:

- Distinction between Luminance and Illuminance: Luminance denotes the perceived brightness of the road surface by the human eye (measured in candelas per square meter, cd/m^2), while illuminance represents the light amount reaching the surface (measured in lux). Longitudinal uniformity of luminance emphasizes the even distribution of this perceived brightness along the road's length.
- Uniformity Ratio: The longitudinal uniformity of luminance is commonly quantified as:

  $U_L = L_{min, long} / L_{max, long}$

Where:

($L_{min, long}$) signifies the minimum luminance along the road's longitudinal axis (length).

($L_{max, long}$) denotes the maximum luminance along the same axis.

- Objective: Attaining satisfactory longitudinal uniformity guarantees that drivers do not encounter significant brightness fluctuations during their journey on the road. This contributes to consistent visibility and diminishes eye strain resulting from frequent adjustments to varying light intensities.

2.2.4 Transverse Uniformity of Luminance:

Transverse Uniformity of Luminance in street lighting design pertains to the evenness of brightness distribution across the width of a roadway. This parameter is essential in guaranteeing uniform illumination of all lanes and adjacent areas of a road. Maintaining proper transverse uniformity is key in preventing significant luminance discrepancies that could hinder a driver's visibility of the entire road surface, consequently decreasing accident risks and enhancing overall safety.

Key Points:

- The concept of transverse uniformity of luminance revolves around the equitable distribution of perceived brightness from one side to the other across the road width.
- Calculation of Uniformity Ratio: The typical formula for determining transverse uniformity of luminance is as follows:

  $U_T = L_{min, trans} / L_{avg, trans}$

  Where:

- ($L_{min, trans}$) represents the minimum luminance observed across the transverse axis (width) of the road.
- ($L_{avg, trans}$) denotes the average luminance along the same axis.
- Objective: The primary aim of achieving good transverse uniformity is to ensure adequate illumination of all road sections, especially the edges and centre line where pedestrians, cyclists, and vehicles may be present. This uniformity serves to diminish contrasts between different road areas and enhance overall visibility.

Typical Values:

- Highways and Major Roads: For roads with multiple lanes, particularly those with high traffic flow, the requisite transverse uniformity ratio is typically higher, often falling within the range of 0.5 to 0.7.
- Urban and Residential Streets: In less busy roads, the prescribed uniformity ratio may be slightly lower, usually ranging from 0.4 to 0.6.

2.3 Type of Lamps used in Street Lighting:

Various types of street lights are available, each exhibiting distinct characteristics, benefits, and suitable uses. Enumerated below are some commonly encountered street light variants:

1. High-Pressure Sodium (HPS) Lamps:

Characteristics: These lamps emit a yellow-orange light and possess a high luminous efficacy.

Advantages: Noteworthy features include energy efficiency, prolonged lifespan, and suitability for foggy conditions.

Applications: Typically found illuminating roadways, parking lots, and industrial zones.

2. Low-Pressure Sodium (LPS) Lamps:

Characteristics: Emitting a monochromatic yellow light, these lamps exhibit very high luminous efficacy.

Advantages: Significantly energy-efficient with an extended lifespan.

Applications: Primarily deployed in areas where minimizing light pollution is imperative, such as observatories.

3. Metal Halide (MH) Lamps:

Characteristics: These lamps emit a bright white light and offer good color rendering.

Advantages: Notable for their superior color rendering in comparison to sodium lamps, especially beneficial in high visibility areas.

Applications: Commonly utilized in sports stadiums, expansive public spaces, and specific urban environments.

4. Light Emitting Diode (LED) Lamps:

Characteristics: These lamps emit light in a variety of colors, boasting high luminous efficacy and an extended lifespan.

Advantages: Known for their energy efficiency, low maintenance requirements, good color rendering, and immediate on/off functionality.

Applications: Increasingly favored for diverse street lighting purposes due to their energy-saving attributes and versatility.

5. Induction Lamps:

Characteristics: These lamps operate by utilizing magnetic fields to produce light, ensuring a lengthy lifespan.

Advantages: Recognized for their energy efficiency, durability, and good color rendering capabilities.

Applications: Commonly implemented in areas necessitating long-lasting and dependable illumination.

6. Fluorescent Lamps:

Characteristics: Emitting a white light with moderate luminous efficacy, these lamps are notable for their efficiency.

Advantages: Energy-efficient with good color rendering properties.

Applications: Relatively uncommon in street lighting, yet utilized in select pedestrian zones and pathways.

7. Solar Street Lights:

Characteristics: Functioning with the aid of solar panels for electricity generation, these lights typically incorporate LED lamps.

Advantages: Noteworthy for their sustainability, cost-saving potential, and ability to be installed in remote regions lacking access to the power grid.

Applications: Widely deployed in rural areas, developing regions, and environmentally conscious urban settings.

Fig No-2.1: Different Types of Lamp Use for Street

2.4 The LEDs Based Street Light

The light-emitting diode (LED) is a semiconductor device (PN junction Diode) that produces light when an appropriate voltage is applied to the terminals; the recombination of electrons with electron holes within the device results in the release of energy in the form of photons. This process is referred to as electroluminescence, and the hue of the emitted light (corresponding to the photon's energy) is determined by the semiconductor's energy band gap. An LED serves as a light source and should not be mistaken for a light fixture or luminaire; rather, it is a constituent of the complete fixture.

2.4.1 Working Principle of LED

The operation of an LED involves a PN junction Diode, functioning similarly to a standard Diode when it is forward biased. In this scenario, the N-type semiconductor is more heavily doped than the P-type, thereby establishing the P-N junction. Essentially, aluminium-gallium-arsenide (AlGaAs) material is utilized in LEDs. Initially, the atoms of this material are strongly bonded, impeding the conduction of electricity in the absence of free electrons. By introducing impurities, known as doping, additional atoms are incorporated, thereby disrupting the material's equilibrium. These impurities, in the form of extra atoms, can either introduce free electrons (N-type) into the system or extract existing electrons from the atoms (P-Type), leading to the formation of "holes" in the atomic orbits. In both scenarios, the material becomes more conductive, enabling electrons to move from the anode (positive) to the cathode (negative) in N-type material and vice versa in P-type material when an electric current is applied. Due to the semiconductor characteristic, current will never flow in opposite directions in these instances. Based on the aforementioned explanation, it is evident that the brightness of light emitted from a source (such as an LED) relies on the energy level of the emitted photons, which, in turn, is contingent upon the energy liberated by electrons transitioning between atomic orbits in the semiconductor material. It is known that elevating the energy level is necessary to propel an electron from a lower orbital to a higher one; conversely, when electrons descend from higher to lower orbitals, energy is released. LEDs effectively leverage these phenomena. Owing to P-type doping, electrons within LEDs shift by descending from higher orbitals to lower ones, releasing energy in the form of photons (i.e., light). The greater the separation between these orbitals, the higher the brightness of the emitted light. The operational mechanism of LEDs is illustrated in the following figure.

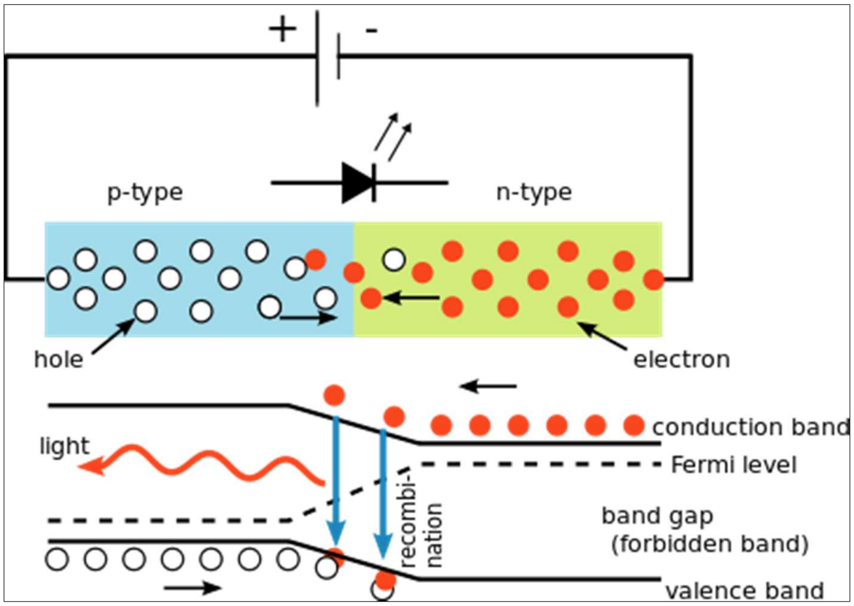

Fig No-2.2: Working of LEDs

2.4.2 Use of LED Compare to other Lamp in Street lighting:

LED streetlights present numerous advantages when contrasted with conventional street lighting alternatives such as incandescent or fluorescent lamps. The following is a comparative analysis of LED streetlights in relation to other prevalent lighting types: [16,17,18]

1. Energy Efficiency:

- LEDs: Exhibit remarkable energy efficiency by converting the majority of their energy into luminous output rather than thermal energy. This characteristic results in diminished electricity consumption.
- Incandescent: Demonstrate lower efficiency, as they generate significant amounts of heat. Consequently, they require more electrical power to yield an equivalent quantity of light.
- Fluorescent: Offer greater efficiency compared to incandescent options, yet fall short of the efficiency levels attained by LEDs. Their energy consumption remains elevated relative to their light output when juxtaposed with LEDs.

2. Lifespan:

- LEDs: Possess an extensive operational lifespan, frequently exceeding 50,000 hours. This characteristic minimizes the necessity for recurrent replacements.
- Incandescent: Feature a brief operational lifespan, typically approximating 1,000 hours.
- Fluorescent: Have a moderate lifespan, generally ranging from 7,000 to 15,000 hours.

3. Maintenance Costs:

- LEDs: Incur lower maintenance costs attributable to their protracted lifespan and robust durability.
- Incandescent: Result in elevated maintenance costs owing to their abbreviated lifespan and the frequent requirement for replacements.
- Fluorescent: Present moderate maintenance costs, yet these remain higher than those associated with LEDs due to the necessity for more frequent replacements.

4. Light Quality:

- LEDs: Deliver high-quality, directional illumination characterized by excellent color rendering capabilities and adjustable color temperatures.
- Incandescent: Produce a warm and consistent light, albeit with limited control over light direction and color temperature.
- Fluorescent: May exhibit varied light quality, occasionally yielding a harsh or flickering illumination; however, recent advancements have led to improvements in newer models.

5. Environmental Impact:

- LEDs: Are more environmentally sustainable as they are devoid of mercury, exhibit high efficiency, and possess a prolonged lifespan, thereby mitigating waste.
- Incandescent: Are less environmentally sustainable due to elevated energy consumption and the frequency of replacements.
- Fluorescent: Contain mercury, which poses significant environmental and health hazards if the bulbs are broken or improperly disposed of.

6. Instant On:

- LEDs: Offer immediate attainment of full brightness without any requisite warm-up period.
- Incandescent: Achieve instant full brightness.
- Fluorescent: Typically necessitate a warm-up duration to reach full brightness.

In summation, LEDs are frequently favored for street lighting applications due to their superior efficiency, extended lifespan, reduced maintenance costs, and ecological advantages.

Chapter 3: Design and Development of the Lighting Control System

Introduction:

The system integrates an LED lamp with an LED driver to efficiently control lighting based on environmental conditions and object detection. It employs an LDR (Light Dependent Resistor) sensor to monitor natural light levels and an ultrasonic sensor to detect the presence of nearby entities, such as pedestrians or vehicles. An ATmega328P microcontroller manages the system, executing code to control and optimize the lighting functions.

Objective:

The objective of this system is to enhance energy efficiency and safety by automatically adjusting the LED lamp's brightness based on real-time light levels and the detection of nearby objects. The LDR sensor ensures that the lamp operates only when necessary, while the ultrasonic sensor enables dynamic lighting adjustments to provide adequate illumination based on the presence of people or vehicles.

3.1 Components Used: The required components to design this system and their work function is given below:

LDR Sensor (Light Dependent Resistor):

A Light Dependent Resistor (LDR), frequently referred to as a photo resistor, represents a category of resistor whose resistance varies in accordance with the quantity of light incident upon its surface. The resistance exhibited by an LDR diminishes as the luminosity intensifies and conversely escalates when the light intensity diminishes. This characteristic renders LDRs particularly advantageous for the quantification of light levels and they are prevalently employed in various applications, including automated lighting systems, light metering devices, and security alarm systems.

Key Characteristics:

- Sensitivity to Light: The LDR possesses a pronounced sensitivity to visible spectrum light, rendering it exceptionally suitable for determining the presence or absence of illumination within a specified environment.
- Resistance Range: Under conditions of darkness, the resistance of an LDR may attain values as high as several megaohms (MΩ), whereas, under bright illumination, this resistance may reduce to a few hundred ohms.
- Response Time: LDRs are characterized by a relatively protracted response time, signifying that they require a brief duration to adapt to fluctuations in light intensity.

Applications:

- Automatic Street Lighting: LDRs are employed to facilitate the automatic activation of streetlights in the absence of daylight and their deactivation upon the presence of adequate illumination.
- Light Meters: These devices are utilized in photographic apparatus to quantify the intensity of light and to accordingly modulate exposure settings.
- Alarm Systems: LDRs can serve in security systems to identify variations in light levels, thereby signaling a potential intrusion.

Within the framework of my system, the LDR sensor is implemented to ascertain the presence of daylight, thereby assisting in the determination of whether the LED lamp ought to be activated or deactivated.

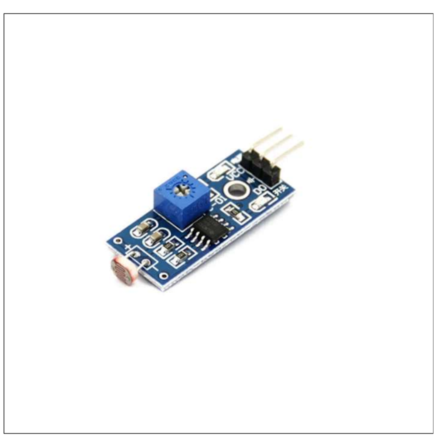

Fig No-3.1: LDR Sensor (Light Dependent Resistor)

Ultrasonic Sensor (HC-SR04):

The HC-SR04 is an extensively utilized ultrasonic sensor engineered to ascertain distances through the utilization of sound waves. Its prominence in fields such as robotics, automation, and various sensor-based applications is attributable to its precision and user-friendliness. The sensor functions by transmitting an ultrasonic sound wave and subsequently measuring the duration required for the echo to return after reflecting off an object.

Key Characteristics:

- Operating Principle: The HC-SR04 operates based on the principles of echolocation. It emits a sound pulse at a frequency of 40 kHz, which propagates through the atmosphere. Upon encountering an object, the sound wave reflects back to the sensor, which then quantifies the time taken for the pulse to return and computes the distance to the object.
- Distance Measurement: The sensor is capable of measuring distances spanning from 2 cm to 400 cm (1 inch to 13 feet) with an accuracy of approximately 3 mm. This attribute renders it suitable for a diverse array of applications, encompassing proximity sensing and object detection.
- Components: The HC-SR04 module comprises four pins—VCC, Trigger, Echo, and GND. The Trigger pin is designated for emitting the ultrasonic pulse, whereas the Echo pin is responsible for receiving the reflected pulse. The operational requirement of the sensor is a 5V power supply.
- Response Time: The sensor exhibits an expedient response time, characterized by a typical cycle duration of around 10 milliseconds, thereby making it appropriate for real-time applications.

Applications:

- Obstacle Detection: Employed in robotic systems for the purpose of detecting obstacles and facilitating navigation around them.

- Automated Systems: Incorporated into parking systems to ascertain the proximity of vehicles and activate alarms or relevant actions.
- Level Measurement: Utilized in liquid level monitoring systems to gauge the height of liquids within tanks.
- Security Systems: Implemented to detect motion or the presence of objects within a specified area.

Working Principle:

1. Triggering: The microcontroller transmits a 10µs pulse to the Trigger pin to commence measurement.

2. Sound Wave Emission: The sensor generates an ultrasonic sound wave at a frequency of 40 kHz.

3. Echo Reception: Upon the sound wave encountering an object, it reflects back to the sensor, which receives it via the Echo pin.

4. Distance Calculation: The duration required for the sound wave to traverse to the object and return is quantified. The distance is subsequently computed using the formula:

Distance = (Time * Speed of Sound) / 2

(The division by 2 accommodates the round-trip journey of the sound wave.)

In my system, the HC-SR04 ultrasonic sensor is employed to detect the movement or presence of objects (such as pedestrians, vehicles, etc.) in proximity to the LED lamp. This data can be utilized to modulate the lighting in accordance with the presence of nearby objects, enhancing the system's efficiency and responsiveness.

Fig No-3.2: Ultrasonic Sensor (HC- SR04)

Arduino Uno:

The Arduino Uno is acknowledged as one of the most prevalent and extensively utilized microcontroller boards within the Arduino ecosystem. It has been meticulously engineered to serve as an accessible platform for both novices and seasoned professionals, thereby enabling users to embark on a diverse array of electronics-related projects. The Uno is frequently the initial board that individuals engage with while acquiring knowledge regarding microcontrollers, programming, and hardware interfacing.

Key Features:

- Microcontroller: Central to the Arduino Uno is the ATmega328P microcontroller, which is an 8-bit AVR microcontroller developed by Atmel (currently under Microchip Technology). It operates at a clock frequency of 16 MHz, encompasses 32 KB of flash memory designated for program storage, 2 KB of SRAM, and 1 KB of EEPROM.

- Digital I/O Pins: The Uno is equipped with 14 digital input/output pins, of which 6 are capable of functioning as PWM (Pulse Width Modulation) outputs. These pins are utilized for reading digital signals (such as those from buttons or sensors) or for controlling devices such as LEDs, relays, and motors.
- Analog Input Pins: The board is furnished with 6 analog input pins, which facilitate the reading of signals from analog sensors (including temperature sensors or potentiometers) and their conversion into digital values via a 10-bit ADC (Analog-to-Digital Converter).
- Communication Interfaces: The Arduino Uno presents a variety of communication modalities:
- USART (Serial Communication): The board incorporates an integrated USB-to-serial converter, which enables communication with a computer through USB. This functionality is also employed for the uploading of programs to the board.
- I2C and SPI: These communication protocols permit the Uno to interface with additional microcontrollers, sensors, and modules.
- Power Supply: The Arduino Uno can be energized through USB (5V) or an external power source (ranging from 7V to 12V). It features an integrated voltage regulator that guarantees a consistent 5V output for both the board and its associated components.
- Reset Button: The Uno comprises a reset button that restarts the program currently executing on the board. This feature is advantageous for debugging or for rebooting the device without the necessity of disconnecting the power supply.
- USB Interface: The board possesses a USB-B port for establishing a connection with a computer. The USB interface serves dual purposes: providing power and facilitating serial communication, which includes the uploading of code to the microcontroller.
- Programming: The programming of the Arduino Uno is conducted through the Arduino IDE (Integrated Development Environment), which is a user-centric software platform. The IDE utilizes a streamlined version of C/C++ and offers a comprehensive assortment of built-in functions to simplify the programming process.
- Bootloader: The ATmega328P integrated within the Arduino Uno is equipped with a pre-installed bootloader, which facilitates the uploading of new code without the requirement of an external programmer. The bootloader occupies a minor segment of the flash memory (approximately 2 KB).

Applications:

Prototyping: The Arduino Uno is frequently employed for the expedited development of electronic projects, ranging from rudimentary circuits to intricate systems.

Learning and Education: Owing to its user-friendly nature and comprehensive documentation, the Uno is extensively utilized in academic environments for the instruction of electronics, programming, and embedded systems. Home Automation: The board is capable of managing domestic appliances, illumination, and security systems through the utilization of sensors and actuators.

Robotics: The Uno is a favored option for the construction of robotic systems, facilitating control over motors, sensors, and communication with ancillary devices.

IoT Projects: The Uno can be linked to the internet (with supplementary modules) to develop Internet of Things (IoT) applications, such as remote surveillance or intelligent devices.

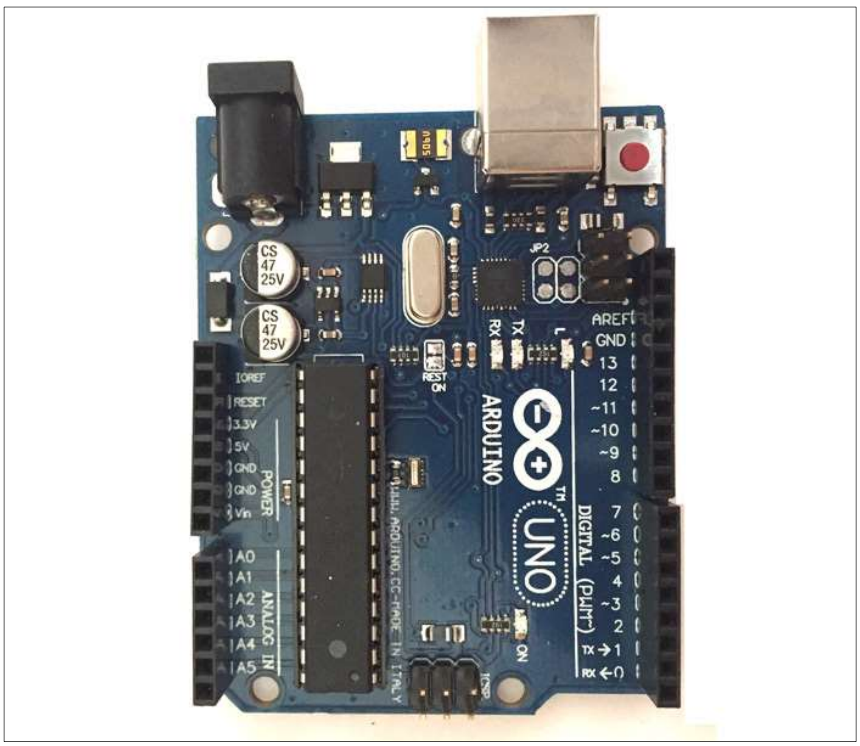

Fig No-3.3: Arduino Uno

IC AT Mega 328p:

The ATmega328P represents a widely recognized microcontroller within the AVR family, engineered by Atmel, which is currently integrated into Microchip Technology. Its extensive utilization in diverse embedded systems underscores its role as the foundation for numerous development platforms, notably the renowned Arduino Uno. This microcontroller is distinguished by its optimal amalgamation of features, minimal power consumption, and user-friendliness, rendering it suitable for a broad spectrum of applications ranging from basic hobbyist endeavors to sophisticated industrial systems.

Key Features:

- Processor Core: The ATmega328P functions as an 8-bit microcontroller predicated on the AVR RISC (Reduced Instruction Set Computing) architecture. It possesses the capability to execute the majority of instructions within a single clock cycle, thereby facilitating a high instruction throughput.
- Clock Speed: The microcontroller is capable of operating at a peak clock frequency of 20 MHz, which provides an advantageous equilibrium between performance and power consumption.

Memory:-

1. Flash Memory: It is equipped with 32 KB of in-system programmable flash memory designated for the storage of program code.

2. SRAM: The microcontroller comprises 2 KB of SRAM (Static Random-Access Memory) intended for temporary data retention during the execution of programs.

3. EEPROM: It also includes 1 KB of EEPROM (Electrically Erasable Programmable Read-Only Memory) for the preservation of non-volatile data, including configuration parameters.

- GPIO Pins: The ATmega328P is furnished with 23 general-purpose input/output (GPIO) pins, which may be configured as either digital inputs or outputs. A subset of these pins is endowed with alternative functionalities, encompassing PWM (Pulse Width Modulation), analog-to-digital conversion, and communication interfaces.
- Timers and Counters: This microcontroller incorporates three timers (two of which are 8-bit and one that is 16-bit) that can be employed for an array of timing operations, including the generation of PWM signals, the measurement of time intervals, or the creation of delays.

Communication Interfaces:

1. USART: This facilitates serial communication with ancillary devices.

2. SPI: A synchronous serial data protocol that enables communication with peripheral devices.

3. I2C (TWI): A two-wire interface designed for interaction with other microcontrollers and sensors.

- Analog-to-Digital Converter (ADC): The ATmega328P features a 10-bit ADC encompassing 6 multiplexed channels (or 8 channels in certain packages), enabling the conversion of analog signals (for instance, from sensors) into digital values for further processing.
- Power Consumption: The design of the ATmega328P prioritizes low power consumption, rendering it appropriate for applications reliant on battery power. It incorporates multiple power-saving modes, including idle, power-down, and power-save modes.
- Operating Voltage: The operational voltage range for the microcontroller spans from 1.8V to 5.5V, thus ensuring compatibility with an extensive array of power supply options.

Applications:

1. Embedded Systems: It finds application in a multitude of embedded systems for the execution of control and automation tasks.

2. Arduino Platform: The ATmega328P serves as the microcontroller for the Arduino Uno and an assortment of other Arduino-compatible boards, thereby achieving substantial popularity among hobbyists, students, and developers.

3. IoT Devices: This microcontroller is frequently utilized in Internet of Things (IoT) devices for the purposes of sensing, controlling, and communicating with other devices.

4. Industrial Automation: It is employed within industrial control systems for the tasks of monitoring and automation.

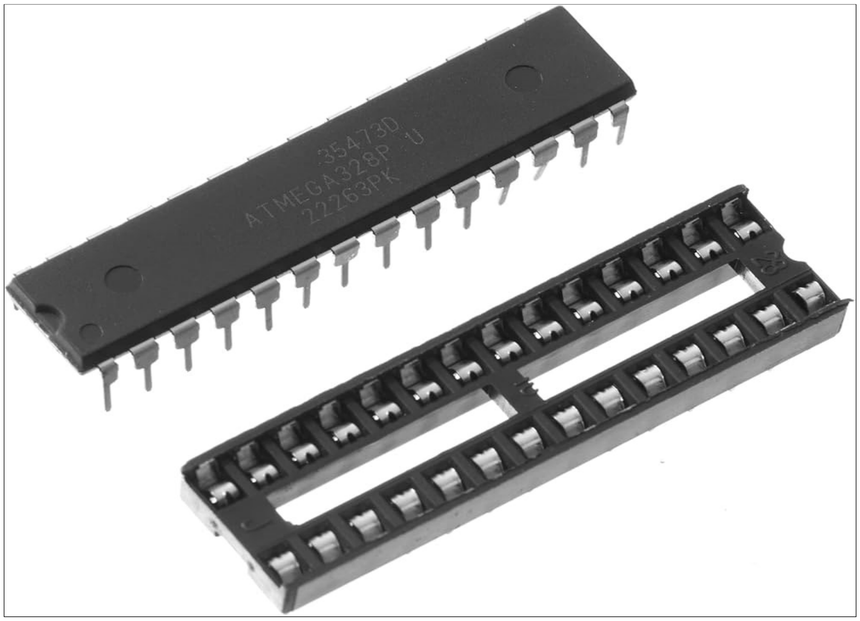

Fig No-3.4: IC AT Mega 328p

MOSFET (IRFZ44N):

The IRFZ44N constitutes a specific variant of a Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET), categorized as a power MOSFET, which is extensively utilized in electronic circuitry for the purposes of signal amplification and switching. The preference for MOSFETs in power electronics can be attributed to their capability to manage substantial currents and voltages while exhibiting relatively low on-resistance, thereby enhancing efficiency in switching applications.

Key Features:

- Type: The IRFZ44N is classified as an N-channel enhancement mode MOSFET, indicating that it becomes conductive (facilitating the flow of current) upon the application of a positive voltage to the gate in relation to the source.

- Drain-Source Voltage (VDS): The maximum permissible drain-source voltage for the IRFZ44N is 55V, delineating the upper voltage threshold that the MOSFET can withstand between the drain and source without experiencing breakdown.
- Continuous Drain Current (ID): The IRFZ44N is capable of accommodating a continuous current of up to 49A, provided it is adequately cooled. This elevated current handling capacity renders it appropriate for high-power applications.
- Gate Threshold Voltage (VGSth): The gate threshold voltage ranges from 2.0V to 4.0V, signifying that the MOSFET initiates conduction when the gate-to-source voltage surpasses this specified range.
- RDS(on) (On-Resistance): The IRFZ44N exhibits a low on-resistance of approximately 17.5 mΩ when fully activated, which serves to mitigate power loss and thermal generation during operation, thereby enhancing efficiency in switching applications.
- Power Dissipation: The maximum power dissipation capacity of the IRFZ44N is 94W when subjected to adequate cooling, reflecting the extent of power that the MOSFET can endure without succumbing to overheating.
- Switching Speed: The design of the IRFZ44N facilitates rapid switching capabilities, rendering it suitable for applications characterized by high frequency.

Applications:

- Switching Power Supplies: The IRFZ44N is frequently employed in power supply circuits, where it rapidly alternates between on and off states to regulate voltage and current levels.
- Motor Control: In contexts such as DC motor control, the IRFZ44N proficiently switches the high currents essential for motor operation.
- Lighting Control: Utilized in circuits designed for the regulation of high-power LED lighting or incandescent bulbs, the IRFZ44N is adept at managing elevated current requirements while preserving efficiency.
- Inverters and Converters: The IRFZ44N is commonly integrated into inverter and DC-DC converter circuits, wherein efficient switching is paramount for the conversion of electrical power.
- Amplifiers: Although predominantly utilized in switching contexts, the IRFZ44N can also be applied in linear configurations, such as those found in audio amplification systems.

Working Principle:

1. Gate Control: The MOSFET possesses three terminals: Gate (G), Drain (D), and Source (S). The gate functions to regulate the current flow between the drain and the source. The application of a voltage to the gate (with respect to the source) generates an electric field that facilitates the flow of current from the drain to the source.

2. Switching: In the absence of applied voltage to the gate, the IRFZ44N remains in an off state, signifying that no current traverses between the drain and source. Once the gate voltage surpasses the threshold voltage (VGS_{th}), the MOSFET activates, permitting current flow.

3. Efficiency: The low on-resistance (RDS(on)) characteristic ensures that the MOSFET incurs minimal power dissipation during conduction, which is critical for applications demanding high efficiency.

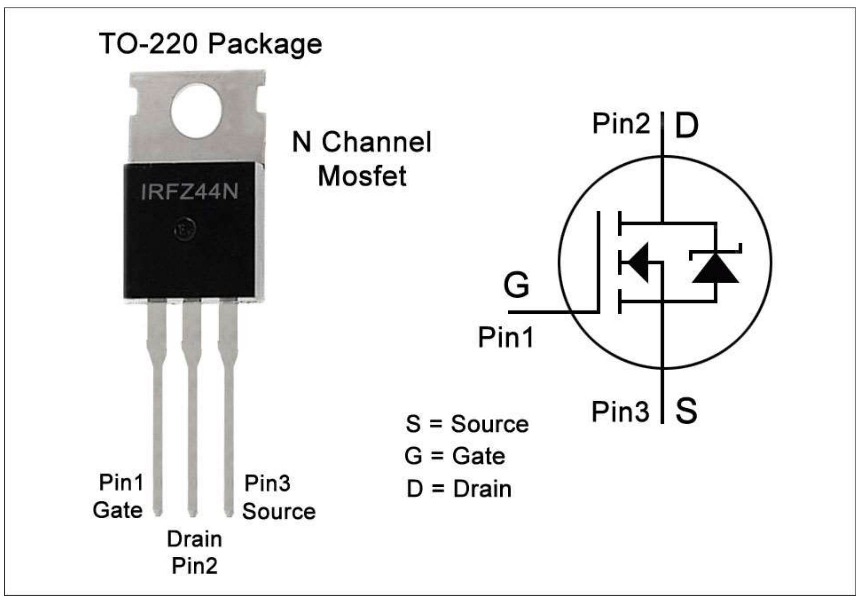

Fig No- 3.5: MOSFET (IRFZ44N)

SMPS (5V, 2Amp):

A Switched-Mode Power Supply (SMPS) constitutes an advanced electronic power supply mechanism that adeptly transforms electrical energy from one configuration to another while concurrently minimizing the dissipation of energy. The 5V, 2A SMPS stands as a prevalent power supply unit, engineered to deliver a stable output of 5V with a maximum current capacity of 2 amps. This particular variant of SMPS finds extensive application across a plethora of domains, encompassing the power supply for microcontrollers, single-board computers such as the Raspberry Pi, and an array of other low-power electronic apparatus.

Key Features:

- Input Voltage Range: Typically, SMPS units function within a broad input voltage spectrum, frequently ranging from 100V to 240V AC, thereby rendering them appropriate for deployment in diverse geographical locales characterized by varying electrical standards.
- Output Voltage: The SMPS generates a regulated output of 5V DC. This specific voltage is extensively employed for energizing digital electronic devices, USB-powered equipment, and other components operating at 5V.
- Output Current: The SMPS is capable of delivering up to 2A of current, which is adequate for powering a diverse array of devices, including microcontrollers, sensors, miniature motors, and additional low-power electronic systems.
- High Efficiency: Engineered for elevated efficiency, SMPS units frequently surpass an efficiency threshold of 80%. Such efficiency is attained through high-frequency switching mechanisms, which significantly mitigate power loss and thermal output when juxtaposed with linear power supplies.
- Compact Size: Owing to the optimized efficiency and design of SMPS units, they are generally characterized by a compact and lightweight form factor, facilitating their integration into an extensive variety of electronic systems.
- Overcurrent Protection (OCP): The SMPS incorporates overcurrent protection features to avert potential damage to both the power supply and the connected devices in scenarios involving short circuits or excessive load conditions.
- Overvoltage Protection (OVP): The SMPS is equipped with inherent overvoltage protection mechanisms to shield connected devices from voltage surges that could otherwise result in damage.
- Thermal Shutdown: Numerous SMPS units are endowed with thermal shutdown protection, which autonomously disables the power supply in the event of overheating, thus preventing damage to the unit and enhancing safety.

- Ripple and Noise: SMPS units are meticulously designed to minimize ripple and noise in the output voltage, thereby providing a stable and clean 5V supply that is suitable for sensitive electronic circuitry.

Applications:

- Microcontroller Power Supply: The 5V, 2A SMPS is particularly well-suited for energizing microcontroller-centric projects, such as those utilizing Arduino or ESP8266/ESP32 boards, as it delivers a consistent voltage coupled with sufficient current for various sensors and modules.
- Single-Board Computers: This SMPS is frequently employed to energize single-board computers, including the Raspberry Pi, which necessitate a stable 5V supply with adequate current to support peripherals such as keyboards, mice, and USB devices.
- LED Lighting: Low-power LED strips and modules typically require 5V power supplies, and a 5V, 2A SMPS can effectively fulfil the power requirements of these lighting solutions.
- USB Chargers: The SMPS can be utilized in USB charging devices for smartphones, tablets, and other USB-powered equipment, supplying the requisite 5V output with sufficient current capacity.
- Battery Charging: The SMPS is applicable in battery charging circuits for small lithium-ion or nickel-metal hydride (NiMH) batteries, where a regulated 5V supply is essential.

Fig No- 3.6: SMPS (5V, 2Amp1)

MOSFET Driver (IR2011):

The IR2110 represents a sophisticated high-voltage, high-speed driver specifically engineered for driving both low-side and high-side MOSFETs within half-bridge and full-bridge configurations. Its extensive application in diverse power electronics domains includes motor drives, inverters, and switching power supplies.

Key Features:

- Dual Driver: The IR2110 functions as a dual driver for both high- and low-side configurations, thereby facilitating control over the high-side and low-side MOSFETs in various bridge architectures. This characteristic renders it particularly adept for managing half-bridges, full-bridges, and push-pull circuits.
- High Voltage Capability: The operational capacity of the IR2110 encompasses a high-side floating supply voltage (VB) reaching up to 500V, thereby positioning it as an optimal solution for high-voltage applications.

- High-Speed Operation: The IR2110 exhibits proficiency in high-frequency operations, characterized by typical rise and fall times ranging from 10 to 20 ns, which enables it to drive MOSFETs effectively in high-speed switching scenarios.
- Bootstrap Circuitry: The integration of bootstrap circuitry within the IR2110 for the high-side driver simplifies the overall design process while minimizing the necessity for external components. The bootstrap capacitor is instrumental in supplying the requisite gate drive voltage for the high-side MOSFET.
- Separate Logic and Power Grounds: The architecture of the driver incorporates distinct connections for logic and power grounds, which serves to mitigate noise and enhance signal integrity in applications that demand high power.
- Under-Voltage Lockout (UVLO): The IR2110 is equipped with under-voltage lockout protection mechanisms applicable to both high-side and low-side drivers. This feature guarantees that the MOSFETs remain deactivated unless the supply voltage is adequate to fully activate them, thus averting partial turn-on scenarios that could lead to potential damage.
- Input Logic Compatibility: The driver inputs are designed to be compatible with standard CMOS and TTL logic levels, facilitating seamless interfacing with microcontrollers, FPGAs, and other digital circuitry.
- Low Quiescent Current: The IR2110 is characterized by its minimal quiescent current consumption, thereby ensuring efficiency in power-sensitive applications.

Applications:

- Motor Control: The IR2110 is extensively utilized in motor control circuits to manage the high-side and low-side MOSFETs within H-bridge configurations, thereby allowing for precise modulation of motor speed and direction.
- Switching Power Supplies: Its application extends to DC-DC converters and various switching power supplies for the purpose of driving the MOSFETs responsible for regulating power conversion.
- Inverters: The IR2110 finds application in inverter circuits, particularly in renewable energy systems (such as solar inverters) and uninterruptible power supplies (UPS).
- Class D Amplifiers: In the domain of audio applications, the IR2110 is employed to drive MOSFETs within class D amplifiers, which are recognized for their high efficiency.

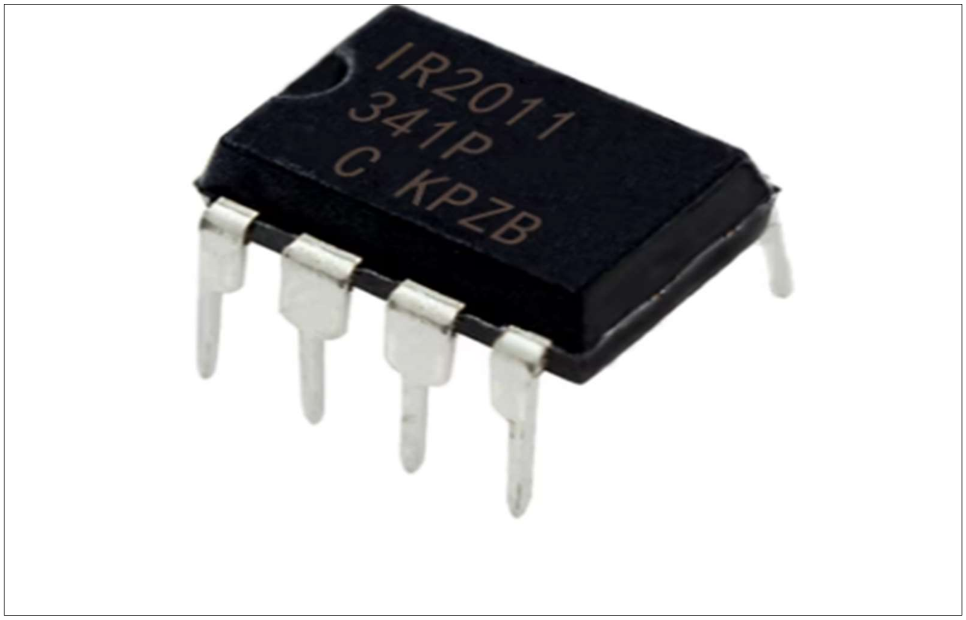

Fig No- 3.7: MOSFET Driver (IR2011)

Resistor (10k, 10E):

Resistors represent essential elements within electronic circuits, serving to restrict current flow, distribute voltage levels, and execute a variety of additional functions. The two particular resistors referenced—10kΩ and 10Ω—serve as instances of resistors characterized by differing resistance values, and their applications are dictated by their respective resistance characteristics.

1. 10kΩ Resistor

- Resistance Value: 10,000 ohms (10kΩ).
- Color Code: The color bands associated with a 10kΩ resistor generally consist of brown (1), black (0), orange (multiplier of 1,000), along with a tolerance band (for instance, gold indicating ±5% tolerance).
- Power Rating: Typical power ratings for resistors encompass 1/4W, 1/2W, 1W, etc. The determination of power rating is contingent upon the specific application.

Applications:

- Pull-Up or Pull-Down Resistor: A 10kΩ resistor frequently functions as a pull-up or pull-down resistor within digital circuits. For instance, it may be connected between an input pin of a microcontroller and the supply voltage to establish a known state when the input is not actively driven.
- Filtering and Signal Conditioning: In conjunction with capacitors, 10kΩ resistors are commonly employed in RC (Resistor-Capacitor) filters for the purpose of signal conditioning, including implementations in low-pass or high-pass filter configurations.

2. 10Ω Resistor

- Resistance Value: 10 ohms (10Ω).
- Color Code: The color bands corresponding to a 10Ω resistor include brown (1), black (0), and black (multiplier of 1), along with a tolerance band (for example, gold for ±5% tolerance).
- Power Rating: Similar to the 10kΩ resistor, the power rating is dependent upon the specific application and may range from 1/4W to higher ratings based on the circuit's requirements.

Applications:

- Current Sensing: A 10Ω resistor is frequently utilized in current sensing applications. By measuring the voltage drop across the resistor (applying Ohm’s Law, V = IR), one can ascertain the current traversing the circuit.
- Current Limiting: In circuits where it is necessary to restrict the current to a defined value, such as safeguarding LEDs or other sensitive components, a 10Ω resistor may be employed to diminish the current to a more secure level.
- Load Resistor: A 10Ω resistor can function as a load resistor to evaluate or simulate a load within a circuit, particularly in the context of power supplies and amplifiers.

General Characteristics of Resistors:

- ➢ Ohmic Value: The resistance value of a resistor is quantified in ohms (Ω), and it delineates the degree to which the resistor impedes the flow of electric current.

- Tolerance: The tolerance parameter signifies the extent to which the actual resistance value may deviate from the specified value. Common tolerances include ±1%, ±5%, or ±10%, with lower tolerances representing greater precision.
- Power Rating: The power rating of a resistor delineates the maximum power it can dissipate without incurring damage. This rating is computed based on the product of the current passing through the resistor and the voltage across it ($P = IV = I^2R = V^2/R$).
- Temperature Coefficient: This characteristic reflects the degree to which the resistance value fluctuates with temperature changes. Lower temperature coefficients are favored in precision-oriented applications.

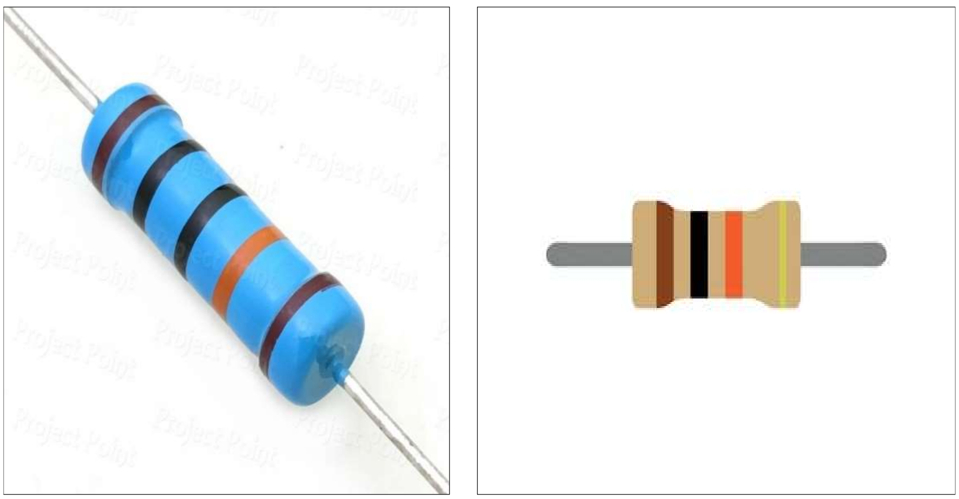

Fig No- 3.8: RESISTOR (10K, 10E)

Voltage Regulator (LM7805):

The LM7805 represents a widely utilized linear voltage regulator that delivers a consistent 5V output derived from a higher input voltage. This component belongs to the 78xx series of fixed voltage regulators, wherein "xx" denotes the specific output voltage. The LM7805 is frequently employed across diverse electronic circuits to furnish a regulated 5V power supply suitable for microcontrollers, sensors, and other devices operating on 5V logic levels.

Key Features:

- Fixed Output Voltage: The LM7805 guarantees a regulated 5V DC output, rendering it particularly advantageous for energizing circuits and devices that operate at 5V logic levels.

- Input Voltage Range: The input voltage for the LM7805 must be maintained within the range of 7V to 35V. It necessitates a minimum of 2V above the output voltage to function effectively, which accounts for the minimum input requirement of approximately 7V.
- Output Current: The LM7805 is capable of delivering a maximum output current of up to 1.5A, contingent upon the input voltage and thermal parameters. Nonetheless, sufficient heat dissipation is imperative when functioning at elevated current levels.
- Thermal Protection: The LM7805 incorporates thermal shutdown mechanisms, which automatically deactivate the regulator in the event of overheating, thereby safeguarding both the device and the associated circuit from potential damage.
- Short-Circuit Protection: The regulator is designed with internal short-circuit current limiting features, which serve to protect the device from damage resulting from unintended output short circuits.
- Overvoltage Protection: The LM7805 is equipped with safeguards against input overvoltage scenarios, thereby ensuring the safety of the device and its connected circuitry in the event of voltage surges.
- Low Noise: The LM7805 delivers a low-noise output, making it particularly suitable for both analog and digital circuits where a pristine 5V power supply is essential.

Applications:

- Microcontroller Power Supply: The LM7805 is frequently employed to supply a stable 5V power source to microcontrollers such as Arduino, AVR, PIC, and other devices utilizing 5V logic levels.
- Sensor Power Supply: Numerous sensors and modules necessitate a 5V power supply. The LM7805 guarantees that these components receive a stable voltage, thereby enhancing accuracy and overall performance.
- Battery-Powered Projects: Within battery-operated projects, the LM7805 can be utilized to reduce voltage from a higher battery voltage (such as 9V or 12V) down to 5V, ensuring the reliable operation of devices requiring 5V.
- Communication Modules: The LM7805 is often employed to power communication modules, including Bluetooth, Wi-Fi, and RF modules, which generally demand a stable 5V power supply.

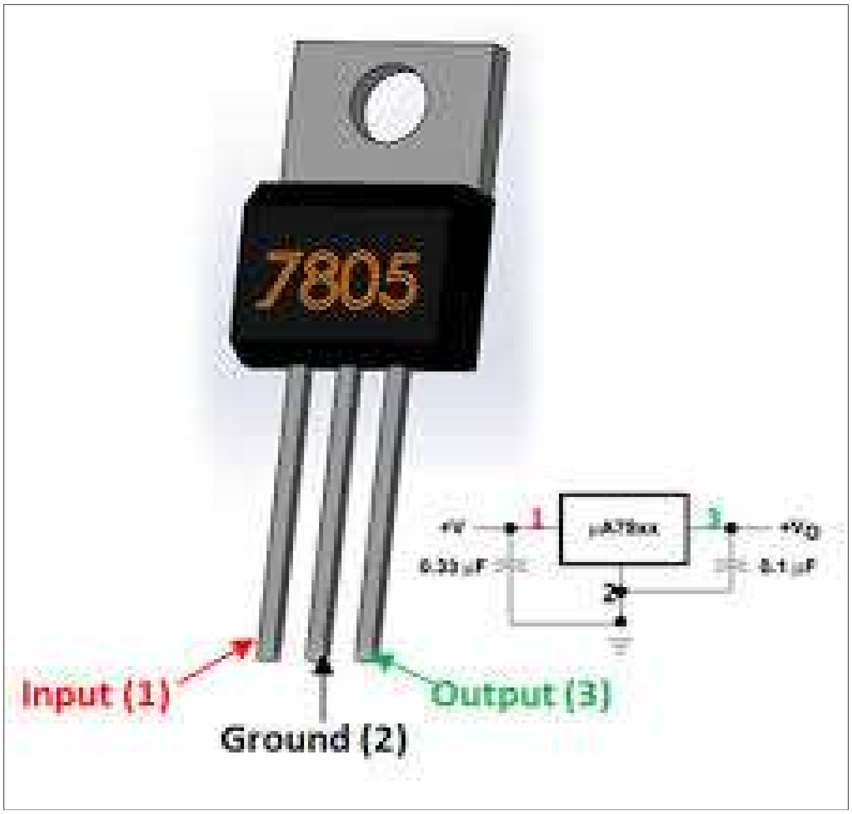

Fig No- 3.9: VOLTAGE REGULATOR (LM7805)

Capacitor (10µF/25V, 0.1µF**):**

Capacitors constitute passive electronic elements that are capable of storing and discharging electrical energy within a circuit. They exist in a variety of configurations and capacitance values, each tailored for specific applications based on the intended use. The two capacitors referenced—10µF/25V and 0.1µF—are frequently utilized in electronic circuits for functions including filtering, coupling, and decoupling.

1. 10µF/25V Capacitor

- Capacitance Value: 10 microfarads (µF).
- Voltage Rating: 25 volts (V).
- Type: This particular capacitor may be classified as either an electrolytic or ceramic capacitor. Electrolytic capacitors are predominantly used for this capacitance value and are typically polarized, denoting the presence of a positive and a negative terminal.

Applications:

- Power Supply Filtering: The 10μF capacitor is commonly employed in power supply circuits to mitigate voltage fluctuations. It functions as a reservoir that delivers current during instances of voltage drops, thereby diminishing ripple and noise.
- Decoupling: Within digital and analog circuitry, a 10μF capacitor is utilized for the decoupling of various circuit stages. It aids in isolating different sections of the circuit from high-frequency interferences and mitigates potential disruptions between components.
- Bypass Capacitor: In audio circuitry, a 10μF capacitor can be deployed to bypass specific frequencies, facilitating the passage of higher frequencies through designated areas of the circuit while obstructing others.

2. 0.1μF Capacitor (100nF)

- Capacitance Value: 0.1 microfarads (μF) or 100 nanofarads (nF).
- Voltage Rating: Generally, these capacitors have a voltage tolerance ranging from 16V to 50V or greater.
- Type: 0.1μF capacitors are predominantly ceramic capacitors, characterized by their non-polarized nature, allowing for installation in a circuit without the necessity for orientation consideration.

Applications:

- Decoupling and Bypass: The 0.1μF capacitor is extensively utilized as a decoupling capacitor in electronic circuits. It is strategically positioned in proximity to the power pins of integrated circuits (ICs) to filter out high-frequency noise and stabilize supply voltage, thereby preventing power supply noise from adversely influencing the operation of sensitive components.
- Signal Coupling: For signal coupling purposes, the 0.1μF capacitor permits the passage of alternating current (AC) signals between stages of a circuit while obstructing direct current (DC) components, which is crucial in audio and communication circuits.

General Characteristics of Capacitors:

- Capacitance: The capacitance value (quantified in Farads) signifies the extent of electric charge that the capacitor is capable of storing. An increase in capacitance correlates with a greater capacity for charge retention.

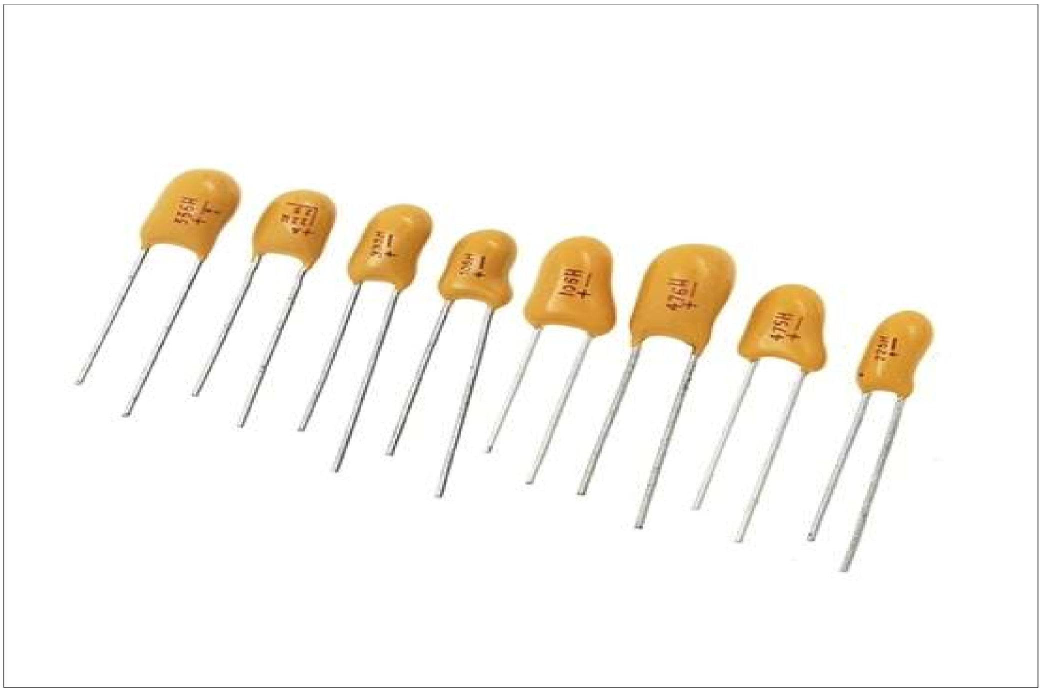

Fig No- 3.10: VOLTAGE REGULATOR (LM7805)

- Voltage Rating: The voltage rating delineates the upper limit of voltage that the capacitor can endure without experiencing breakdown. It is imperative to select a capacitor with a voltage rating that exceeds the maximum voltage it is likely to encounter within the circuit.
- ESR (Equivalent Series Resistance): This parameter represents the internal resistance of the capacitor, which influences its operational efficacy, particularly at elevated frequencies. Capacitors exhibiting lower ESR are favored for high-frequency and power-related applications.

- **Table for bill of Materials**

SL NO	PART NUMBER	DESCRIPTION	MANUFACTURER	QUANTITY
01	HC SR04	Ultrasonic Sensor, measures the distance to an object using ultrasonic sound waves	OSEPP Electronics LTD	01
02	GL5537 LDR	LDR Sensor, decreases resistance with respect to receiving luminosity (light) on the component's sensitive surface.	Senba Sensing Tech.	01
03	IRFZ44N	Mosfet, used in applications that require high current and voltage switching	Generic	01
04	IR2011	Mosfet Driver, high power, high speed power MOSFET driver with independent high and low side referenced output channels.	IRF[International Rectifier]	01
05	LM7805	Voltage Regulator, most commonly used Positive Regulator in Electronic circuits to lower down the voltage from the higher input voltage	Continental Device India Ltd (CDIL)	01
06	Resistor(10K, 10E)-1206, 1206S4J0100T5E	Small size and lightweight resistor. Thick Film Resistors	10K- YAGEO 10E-	04

07	IC ATMega 328p	A 8-bit microcontroller made by Microchip Technology that's part of the ATMEGA family	Microchip Technology	01
08	Capacitor(10uF, 0.1uF)- EXV106M025S9BAA, SMP255FC6100MD32TV32	Radial Aluminium Electrolytic. Safety Capacitors 630V 310 VAC 0.1 uF	Samsung	03
09	PB2 Connector	Connector and Cable seal	Vital Electrocomp	04
10	SMPS(5V, 2Amp)	Small in size, based on CT5503S Charging control IC with built in 800V/3A BJT for high voltage switching control.	Generic	01

3.2 System Architecture and Flowchart:

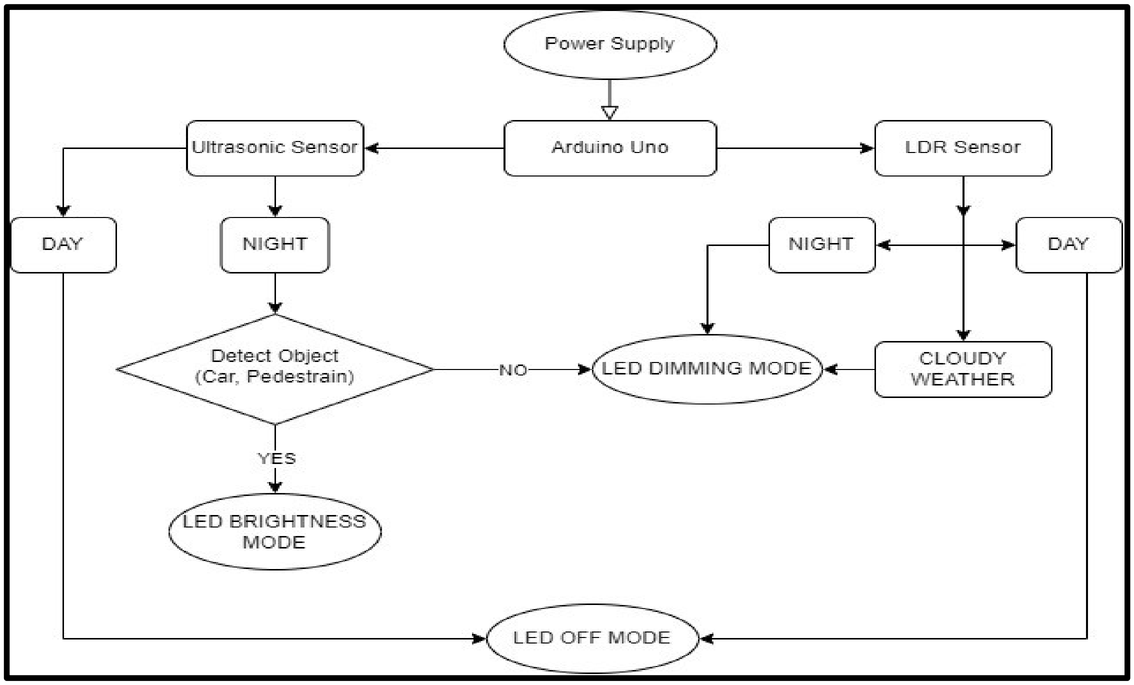

Fig No-3.11: Flowchart of this System

The flowchart presented illustrates the operation of an automated LED streetlight system, designed to optimize energy consumption while ensuring adequate lighting based on environmental conditions and object detection. The system is powered by a central power supply and controlled by an Arduino Uno microcontroller, which interacts with an LDR (Light Dependent Resistor) sensor and an ultrasonic sensor.

The system begins by determining whether it is daytime or night time using the LDR sensor. During daytime, when ambient light levels are high, the LED streetlight remains off, entering the LED OFF Mode to conserve energy. If the LDR sensor detects low ambient light levels, indicative of night time or cloudy weather, the system transitions to different modes of operation.

In night time conditions, the system further relies on the ultrasonic sensor to detect the presence of objects such as cars or pedestrians. If an object is detected, the system switches to LED Brightness Mode, where the LED streetlight operates at full brightness to ensure visibility and safety. If no object is detected, the system enters LED Dimming Mode, reducing the brightness to conserve energy while still providing some level of illumination.

During cloudy weather, even in the daytime, the LDR sensor may detect reduced light levels. In this scenario, the system operates similarly to night time by switching to LED Dimming Mode to maintain appropriate lighting levels.

The flowchart efficiently outlines how the system intelligently adjusts the streetlight's brightness based on real-time conditions, ensuring both energy efficiency and enhanced public safety. This approach is particularly suitable for smart city applications, where optimizing energy use in street lighting is essential.

3.3 Circuit Diagram and Hardware Setup:

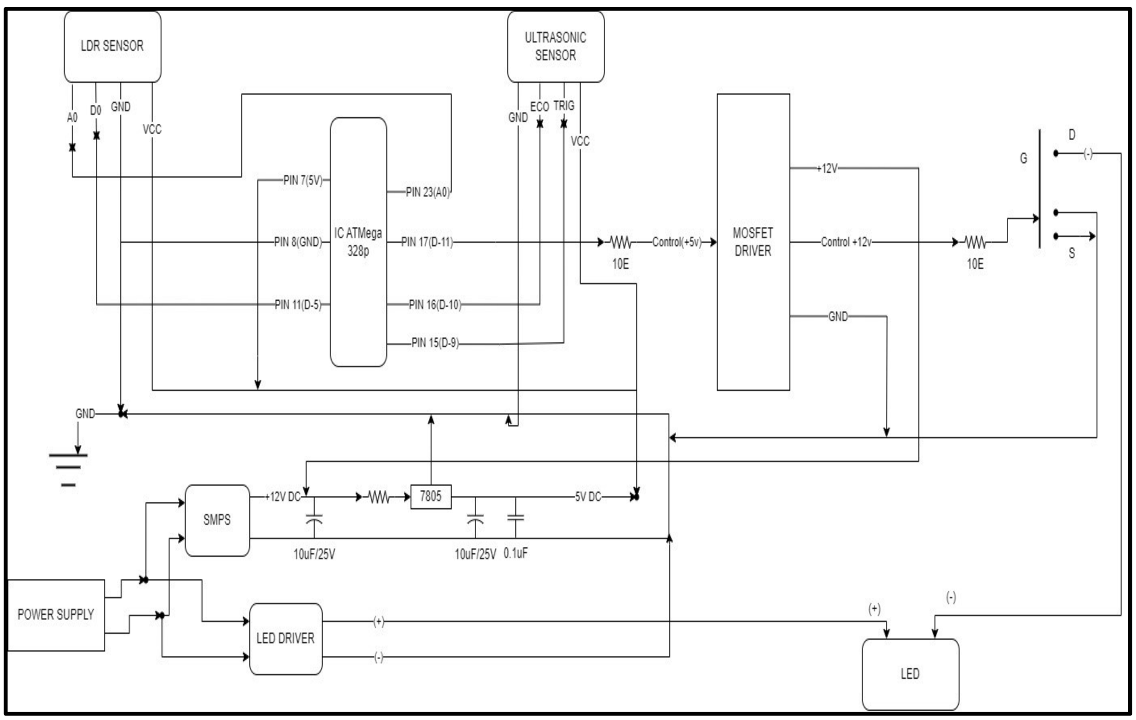

Fig No-3.12: Circuit Diagram 1 of the proposed System

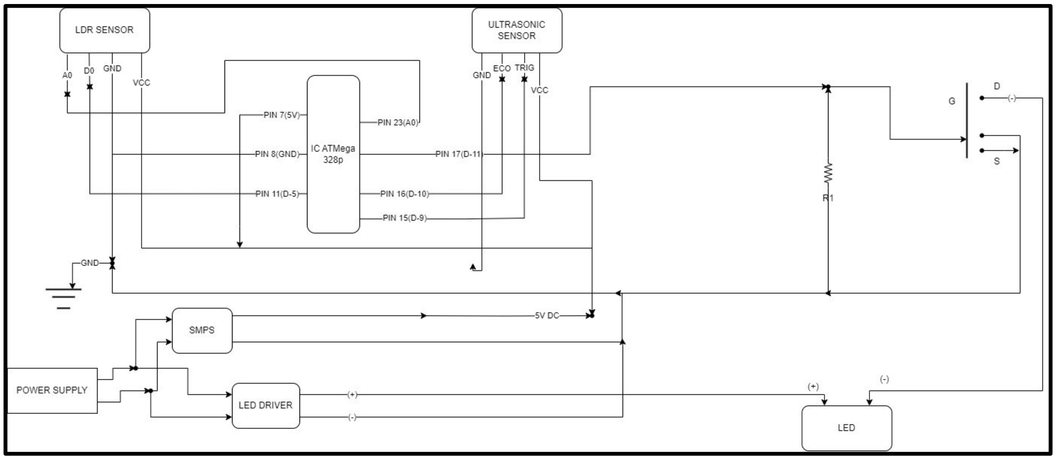

Fig No-3.13: Circuit Diagram 2 of the proposed System

Circuit Description:

1. LDR Sensor Module:

A0 Pin: Connected to Arduino Uno digital pin 23.

D0 Pin: Connected to Arduino Uno digital pin 5.

GND: Connected to Arduino Uno GND.

VCC: Connected to Arduino Uno 5V.

2. Ultrasonic Sensor:

TRIG Pin: Connected to Arduino Uno digital pin 9.

ECHO Pin: Connected to Arduino Uno digital pin 10.

GND: Connected to Arduino Uno GND.

VCC: Connected to Arduino Uno 5V.

3. MOSFET:

Gate: Connected to Arduino Uno digital pin 11 through a 10kΩ resistor. The other end of the Resistor is connected to GND.

Drain: Connected to the negative side of the LED.

Source: Connected to GND.

4. Power Supply:

- **SMPS (5V, 2A):**

Positive Output: Connected to the 5V input of the Arduino Uno and to the positive side Of the LED driver.

Negative Output: Connected to the GND of the Arduino Uno and to the negative side of the LED driver.

- **LED Driver:**

Positive Input: Connected to the positive output of the SMPS.

Negative Input: Connected to the GND of the SMPS and the source of the MOSFET.

5. LED Lamp:

Positive Side: Connected to the positive output of the LED driver.

Negative Side: Connected to the drain of the MOSFET.

How It Works:

1. LDR Sensor Operation:

The LDR sensor detects ambient light levels. When it's daytime or there is sufficient ambient light, the LDR sensor output will signal the Arduino to keep the LED OFF.

When ambient light levels drop (nighttime or cloudy), the Arduino will be triggered to check the status of the ultrasonic sensor.

2. Ultrasonic Sensor Operation:

The ultrasonic sensor measures the distance to nearby objects. If an object (e.g., a vehicle or pedestrian) is detected, the Arduino signals the MOSFET to switch to full brightness mode.

If no object is detected, the system switches to dimming mode, providing reduced brightness.

3. MOSFET Control:

The Arduino controls the MOSFET gate through a digital pin. The 10kΩ resistor connected between the gate and GND ensures that the MOSFET is in a defined state when not actively driven by the Arduino.

When the MOSFET is turned on (Gate HIGH), it allows current to flow from the drain to the source, powering the LED lamp through the LED driver. When turned off (Gate LOW), it prevents current flow, turning the LED lamp off or reducing its brightness.

4. Power Supply:

The SMPS provides a stable 5V power supply to the Arduino Uno and the LED driver. The LED driver converts this 5V to the necessary voltage for the LED lamp. The MOSFET controls the LED lamp based on signals from the sensors.

This setup allows the LED streetlight system to dynamically adjust its brightness based on ambient light and the presence of objects, optimizing energy use while ensuring adequate illumination.

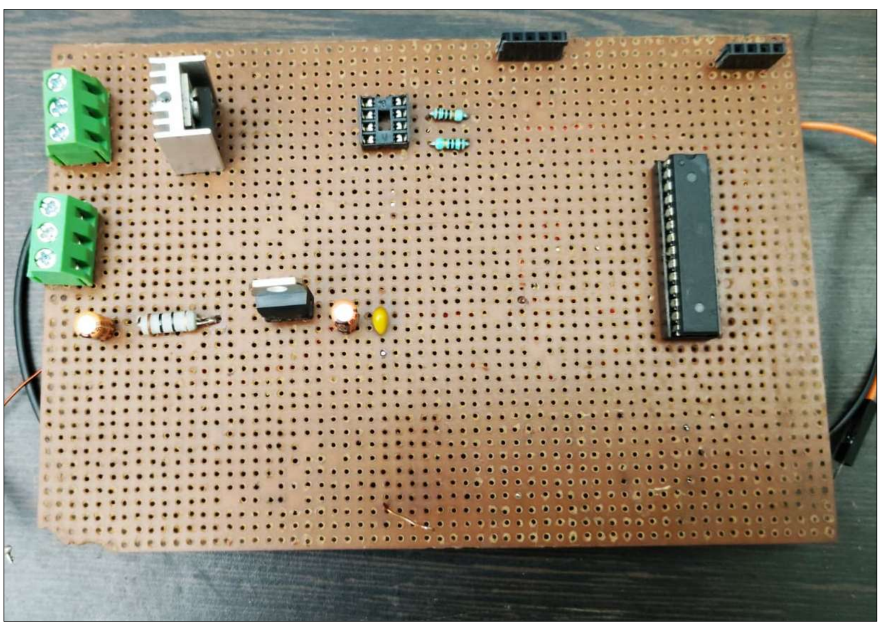

Fig No-3.14: Switching Circuit for Circuit Diagram- 1

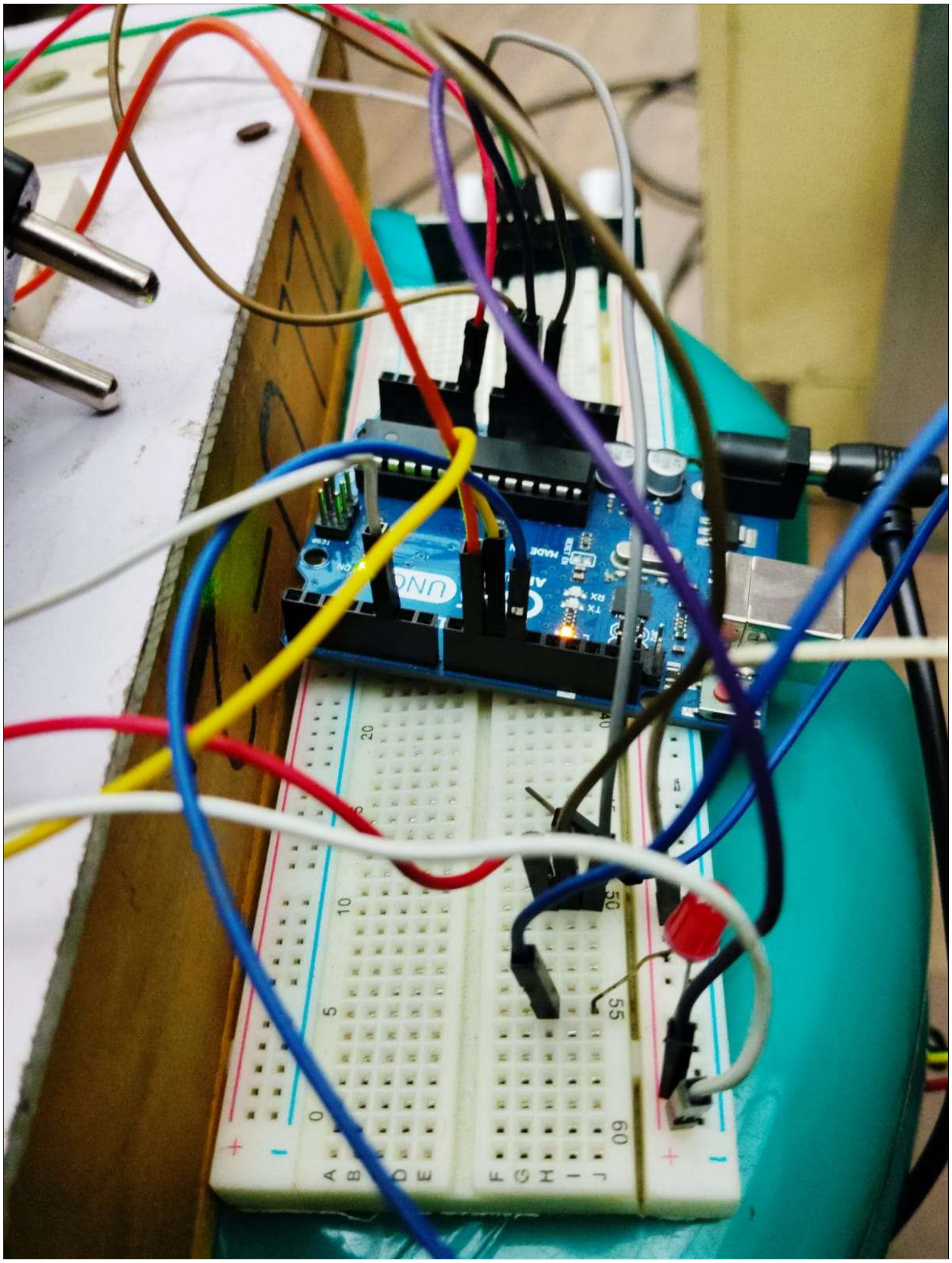

Fig No-3.15: Circuit Diagram for the Switching Circuit

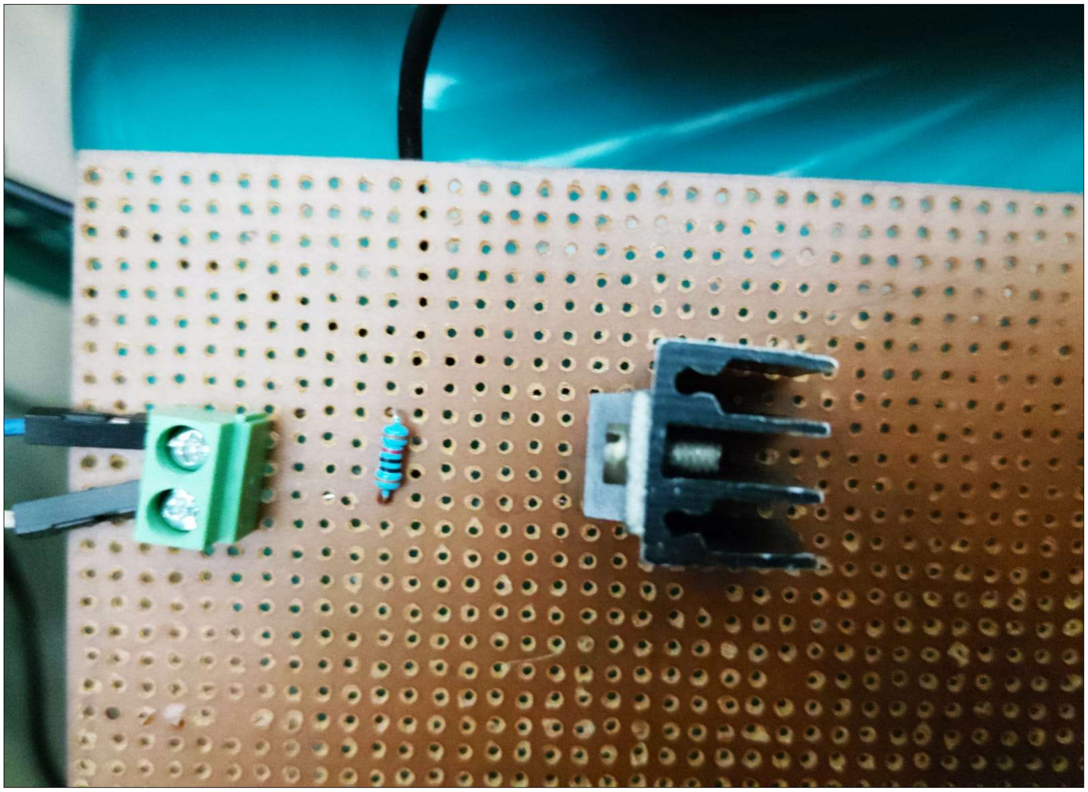

Fig No-3.16: Switching Circuit for Circuit Diagram-2

Chapter 4: Simulation and Implementation of the Controller

In this project, Simulate and implement a controller designed by using C++ language code to manage the operation of an LED streetlight system integrated with sensors. The simulation phase will focus on testing the controller's response to varying environmental conditions and sensor inputs, such as light intensity and object detection. The objective is to ensure that the controller efficiently adjusts the LED brightness based on real-time data, optimizing energy consumption while maintaining adequate illumination.

The algorithm for the Arduino AIDES sensor code is written to process input from an LDR (Light Dependent Resistor) and an ultrasonic sensor. The LDR sensor detects ambient light levels, determining whether it is day or night, while the ultrasonic sensor detects the presence of objects nearby. The algorithm controls the LED's brightness, switching between different modes (off, dimming, full brightness) based on the sensor data. This approach enables smart and adaptive lighting, reducing energy usage during low-traffic periods and ensuring maximum brightness when needed for safety.

4.1 Software and Algorithms:

By using the Arduino IDE (Integrated Development Environment) constitutes a software framework utilized for the composition, compilation, and transmission of code to Arduino microcontroller boards.

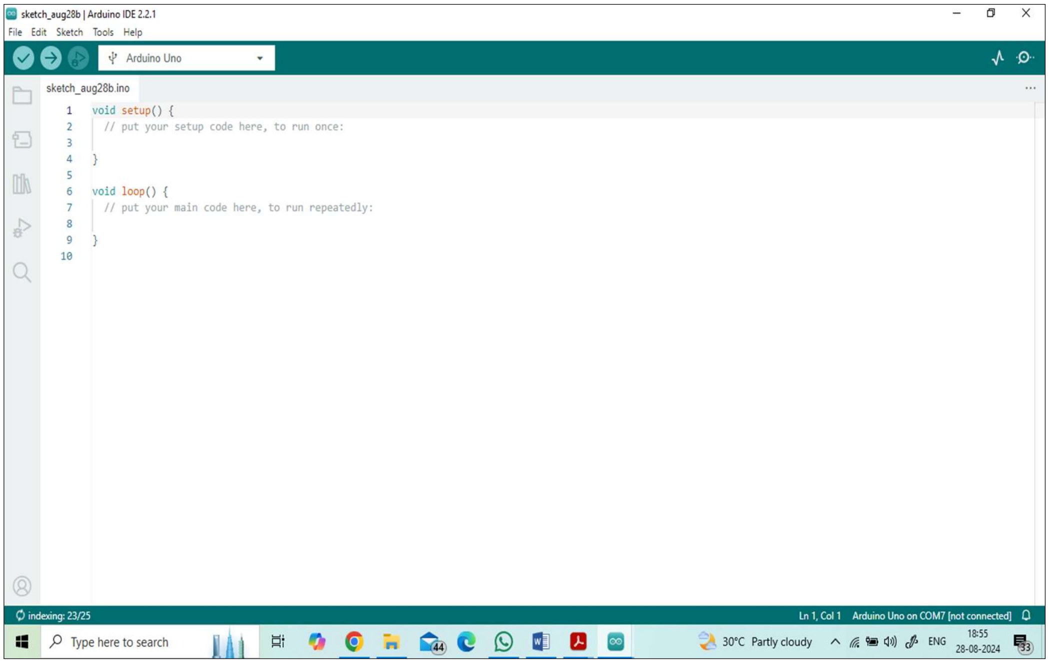

Fig No-4.1: Ardunio IDE Software Coding Page

In this software we create a code and verify the code for processing the developed system. When the code verified then uploaded in the Arduino Uno through USB cable.

Part 1: LDR Sensor Integration:

The Light Dependent Resistor (LDR) Sensor serves the purpose of measuring the levels of ambient illumination. The output generated by the sensor is utilized to ascertain the distinction between day and night, which subsequently regulates the operational states of the LED, determining whether it should be activated, subdued, or deactivated.

LDR Sensor Code:

```
const int ldrPin = 5;   // Digital pin for LDR Sensor

const int ledPin = 11;  // Pin for the LED


void setup() {

  pinMode(ldrPin, INPUT);

  pinMode(ledPin, OUTPUT);
```

```
  Serial.begin(9600);
}

void loop() {
  int pinState = digitalRead(ldrPin);

  if (pinState == HIGH) {
    // Nighttime: Check for object presence (handled by ultrasonic sensor)
    // (This part would call the ultrasonic sensor function)
  } else {
    // Daytime: Turn off the LED
    digitalWrite(ledPin, LOW);
  }

  delay(200); // Adjust delay as needed
}
```

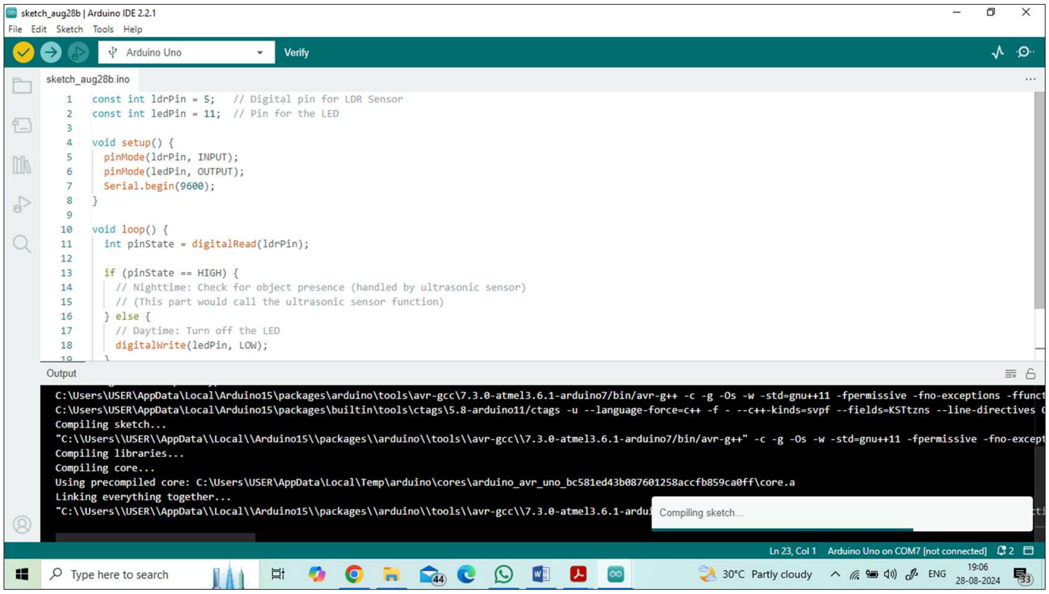

Fig No-4.2: Compiling the LDR Sensor Code in Software

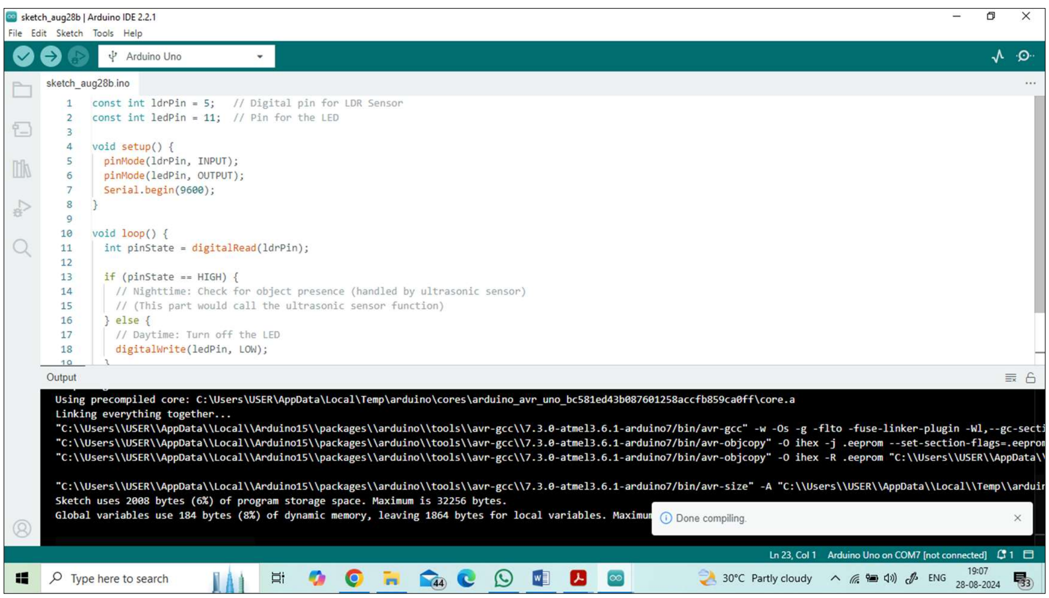

Fig No-4.3: LDR Code compiling done

Algorithm Employed: Ambient Light Detection: The Light Dependent Resistor (LDR) sensor evaluates the intensity of ambient light. In instances where the intensity falls below a predetermined threshold (signifying nighttime), the sensor generates a HIGH signal. Conversely, during daytime conditions, the sensor produces a LOW signal, resulting in the deactivation of the LED.

Part 2: Ultrasonic Sensor Integration:

The Ultrasonic Sensor (HC-SR04) is employed to ascertain the proximity of surrounding objects. Should an object be recognized within a predetermined range (for instance, less than 30 cm), the LED is activated or adjusted in brightness in accordance with the measured distance.

Ultrasonic Sensor Code:

```
const int trigPin = 9;    // Trig pin for Ultrasonic Sensor

const int echoPin = 10;   // Echo pin for Ultrasonic Sensor

const int ledPin = 11;    // Pin for the LED



void setup() {

  pinMode(trigPin, OUTPUT);

  pinMode(echoPin, INPUT);

  pinMode(ledPin, OUTPUT);

  Serial.begin(9600);

}



void loop() {

  int distance = getDistance();



  if (distance < 30) {
```

```
    // Object detected, turn on the LED
    digitalWrite(ledPin, HIGH);
  } else {
    // No object detected, dim the LED
    analogWrite(ledPin, 50);  // Adjust the divisor based on desired dimming level
  }

  delay(200); // Adjust delay as needed
}

int getDistance() {
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);

  return pulseIn(echoPin, HIGH) * 0.034 / 2;
}
```

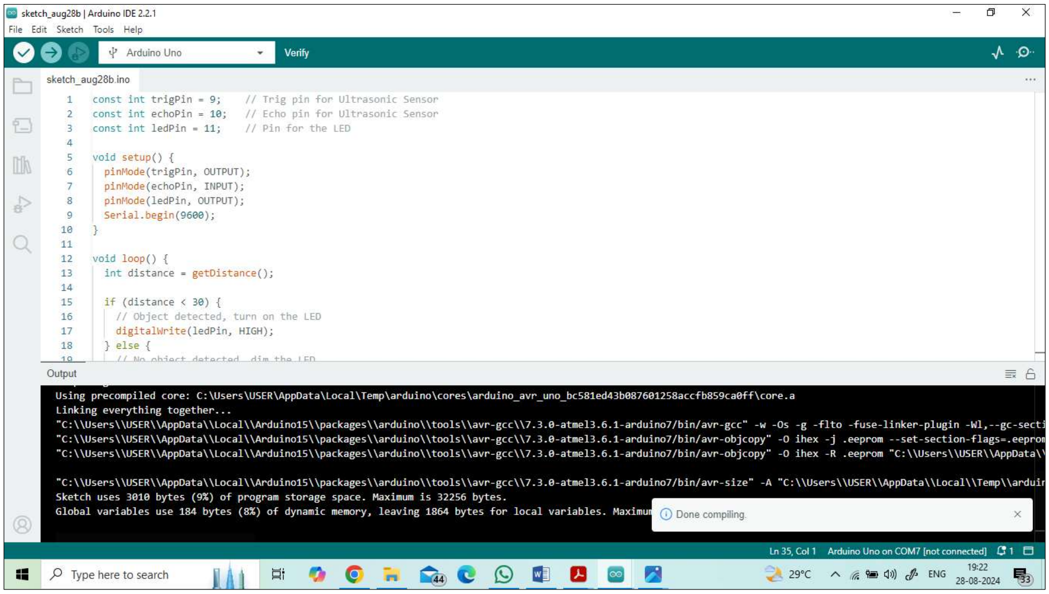

Fig No-4.4: Compiling the Ultrasonic Sensor Code in this Software

Algorithm Used:

Distance Measurement: The ultrasonic sensor emits an acoustic pulse and records the duration required for the echo to return. The distance is computed utilizing the equation:

Distance (in cm) = Duration×0.0342 / 2

Object Detection: In the event that the measured distance falls below a specified threshold (for example, 30 cm), the LED is illuminated. Conversely, if no object is identified (distance exceeding 30 cm), the LED's brightness is reduced.

Combined System Code:

```
const int trigPin = 9;   // Trig pin for Ultrasonic Sensor
const int echoPin = 10;  // Echo pin for Ultrasonic Sensor
const int ldrPin = 5;   // Digital pin for LDR Sensor
const int ledPin = 11;   // Pin for the LED


void setup() {
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  pinMode(ldrPin, INPUT);
```

```
  pinMode(ledPin, OUTPUT);
  Serial.begin(9600);
}

void loop() {
  int pinState = digitalRead(ldrPin);

  if (pinState==HIGH) {
    int distance = getDistance();
    if (distance < 30) {
      // Object (car/man) detected under the LED, turn on the LED
      digitalWrite(ledPin, HIGH);
    } else {
      // No object detected, dim the LED
      analogWrite(ledPin, 50);  // Adjust the divisor based on desired dimming level
    }
  } else {
    // Daytime, turn off the LED
    digitalWrite(ledPin, LOW);
  }

  delay(200); // Adjust delay as needed
}

int getDistance() {
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);

  return pulseIn(echoPin, HIGH) * 0.034 / 2;
}
```

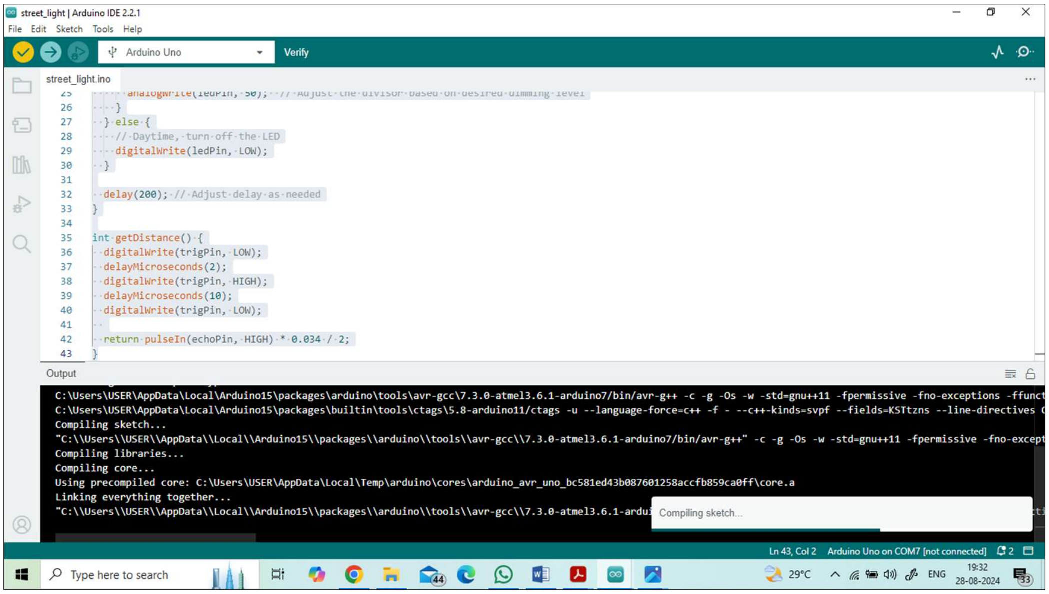

Fig No-4.5: Compiling the Combine Sensor Code in This Software

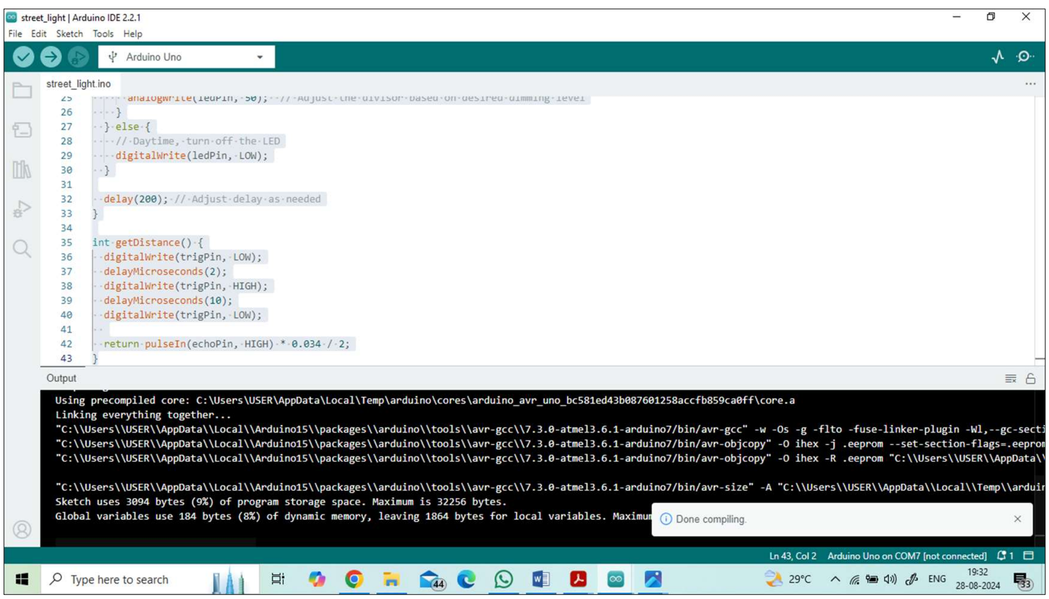

Fig No-4.6: Compiling Done the Combine Sensor Code in This Software

Combined System Algorithm:

The system amalgamates both the LDR and ultrasonic sensors for the purpose of LED regulation:

Ambient Light Check:

Initially, the system evaluates the ambient light intensity through the LDR sensor. During daylight hours, the LED remains deactivated irrespective of object detection. In contrast, during nocturnal hours, the system advances to the object detection phase.

Object Detection:

The ultrasonic sensor quantifies the distance to detected objects. In instances where an object is identified within a defined range, the LED is illuminated. If no object is identified, the LED's brightness is diminished.

This methodology guarantees that the LED operates solely during night time while concurrently responding to the presence of objects, thereby conserving energy and facilitating automated control.

4.2 Sensor Integration:

In accordance with our experimental configuration, we are integrating an LDR sensor along with its corresponding module (which consists of a diode, variable resistor, and fixed resistor) interfaced with an Arduino Uno to quantify light intensity originating from solar and various alternative sources. Below is a detailed exposition of the integration process:

Hardware Setup:

1. LDR Sensor (5mm):

Connections:

- Digital Pin 5 (Arduino Uno): This pin is designated for a digital signal (for instance, activating an event when light intensity surpasses a predefined threshold).
- GND (Arduino Uno): This is connected to the ground to ensure circuit completion.
- 5V (Arduino Uno): This provides the necessary power to the LDR sensor module.
- A0 (Analog Pin on Arduino Uno): This pin captures the analog voltage output from the LDR sensor, which is indicative of the light intensity.

2. LDR Sensor Module Components:

- Diode: This component is conventionally employed to avert reverse current, thereby safeguarding the circuit.
- Variable Resistor (Potentiometer): This allows for the modulation of the sensitivity of the LDR sensor. It facilitates precise adjustments to the resistance, thereby influencing the LDR sensor's response to light.
- Fixed Resistor: This component collaborates with the LDR to establish a voltage divider, converting variations in light intensity into voltage changes that the Arduino can interpret.

Integration and Code:

Subsequently, we shall integrate the sensors into a cohesive system that interprets light intensity and modulates sensitivity via the variable resistor.

```
int ldrPin = A0;          // Analog pin connected to LDR sensor

int ldrValue = 0;         // Variable to store LDR value

int threshold = 500;      // Example threshold value for light intensity

int ledPin = 11;          // Digital pin to control an LED or other device


void setup() {

  pinMode(ledPin, OUTPUT);  // Set digital pin as output

  Serial.begin(9600);       // Start serial communication

}


void loop() {

  ldrValue = analogRead(ldrPin);  // Read the value from the LDR sensor

  Serial.print("LDR Value: ");    // Print label
```

```
  Serial.println(ldrValue);       // Print the actual value


  // Check if light intensity exceeds the threshold
  if(ldrValue < threshold) {
    digitalWrite(ledPin, HIGH);   // Turn on LED or activate device
  } else {
    digitalWrite(ledPin, LOW);    // Turn off LED or deactivate device
  }


  delay(500);  // Wait for 500 milliseconds
}
```

1. Hardware Integration:

- The LDR sensor module is interconnected as delineated above.
- The variable resistor is calibrated to determine the requisite light sensitivity threshold.
- The diode guarantees that the circuit remains protected from possible reverse voltage occurrences.

2. Arduino Code:

Presented below is a straightforward code example designed to read the light intensity and output the value to the serial monitor:

Explanation:

- Analog Reading: The code retrieves the analog value from the LDR sensor linked to `A0`. This value correlates with the light intensity.
- Threshold Comparison: The LDR output is evaluated against a threshold (which may be modified according to specific requirements). If the light intensity falls below this threshold

(indicating reduced illumination), the system initiates an action (such as activating an LED connected to digital pin 5).

- Adjustable Sensitivity: The variable resistor incorporated within the LDR module permits fine-tuning of the sensor's sensitivity to achieve the desired light levels.

To facilitate the integration of the Ultrasonic Sensor (HC-SR04) with the Arduino Uno for the purpose of detecting objects in proximity to a lamp, one would adhere to the following procedural steps:

Hardware Setup:

1. Ultrasonic Sensor (HC-SR04):

Connections:

- VCC (5V): Establish a connection to the 5V pin on the Arduino to supply power to the sensor.
- GND: Connect to one of the GND pins available on the Arduino.
- Trig (Trigger) - Digital Pin 9 (Arduino Uno): This particular pin emits a brief pulse to initiate the ultrasonic wave emission.
- Echo - Digital Pin 10 (Arduino Uno): This pin functions to detect the echo and record the duration taken for the ultrasonic wave to return.

Working Principle of Ultrasonic Sensor:

- Trigger Pulse: The Arduino dispatches a brief 10µs pulse to the Trig pin, prompting the sensor to produce an ultrasonic burst (sound wave).
- Echo: The emitted sound wave propagates through the air, collides with an object, and subsequently reflects back. The Echo pin receives this returned wave, while the Arduino calculates the time elapsed for the sound wave to complete its journey.
- Distance Calculation: The measured time is utilized to ascertain the distance to the object, relying on the established speed of sound.

Integration and Code:

Presented herein is a sample code that acquires the distance from the ultrasonic sensor, which can subsequently be employed to actuate the lamp or initiate alternative actions when an object is recognized within a predetermined range:

```
const int trigPin = 9;    // Trigger pin connected to Digital Pin 16

const int echoPin = 10;    // Echo pin connected to Digital Pin 15

long duration;             // Variable to store the time it takes for the wave to return

int distance;              // Variable to store the distance calculated

int lampPin = 11;          // Pin to control the lamp (using an LED for example)


void setup() {

  pinMode(trigPin, OUTPUT);  // Set trigPin as output

  pinMode(echoPin, INPUT);   // Set echoPin as input

  pinMode(lampPin, OUTPUT);  // Set lampPin as output

  Serial.begin(9600);        // Initialize serial communication at 9600 bps

}


void loop() {

  // Clear the trigPin

  digitalWrite(trigPin, LOW);

  delayMicroseconds(2);


  // Trigger the ultrasonic pulse

  digitalWrite(trigPin, HIGH);

  delayMicroseconds(10);
```

```
  digitalWrite(trigPin, LOW);

  // Read the echoPin and calculate the duration of the echo pulse
  duration = pulseIn(echoPin, HIGH);

  // Calculate the distance (duration divided by 2, and multiplied by the speed of sound)
  distance = duration * 0.034 / 2;

  // Print the distance to the serial monitor
  Serial.print("Distance: ");
  Serial.print(distance);
  Serial.println(" cm");

  // Check if the object is within a certain range (e.g., less than 50 cm)
  if (distance < 50) {
    digitalWrite(lampPin, HIGH);  // Turn on the lamp (LED)
  } else {
    digitalWrite(lampPin, LOW);   // Turn off the lamp (LED)
  }

  delay(500);  // Wait for 500 milliseconds before the next loop
}
```

Explanation:

- Trigger and Echo: The Arduino transmits a pulse via the `trigPin` and subsequently measures the time interval for the echo to return via the `echoPin`.

- Distance Calculation: The code computes the distance to the object predicated on the duration of the echo. The formula applied is:
  Distance (in cm) = (Duration * 0.034)/2
  In this formulation, `0.034` represents the speed of sound in cm/µs.
- Object Detection: Should an object be detected within a defined range (for instance, 50 cm), the Arduino is capable of initiating a response, such as activating a lamp or LED.
- Serial Monitor: The computed distance is relayed to the serial monitor for purposes of debugging and oversight.

4.3 Testing and Calibration:

First, Connect the developed system to a computer or laptop with the Arduino IDE software installed. Upload the compiled code to the Arduino Uno. Once the code is uploaded, connect the SMPS (Switched-Mode Power Supply) to the Arduino Uno to supply 5V power from the 230V mains. On the other hand, connect the LED driver's input side to the 230V power source in parallel with the SMPS.

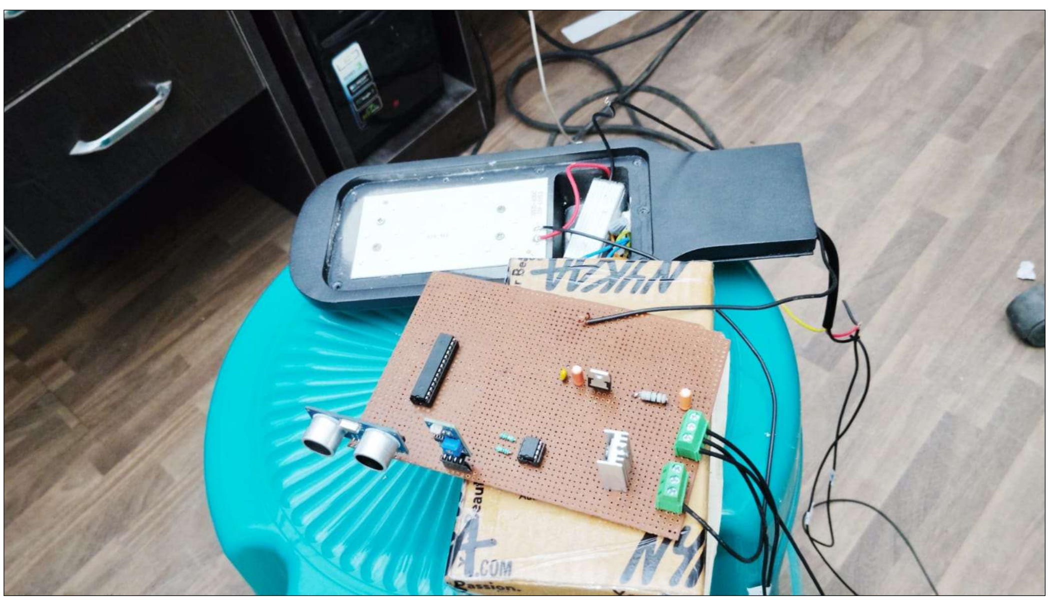

Fig No-4.7: Circuit Diagram of this System by using Switching Circuit

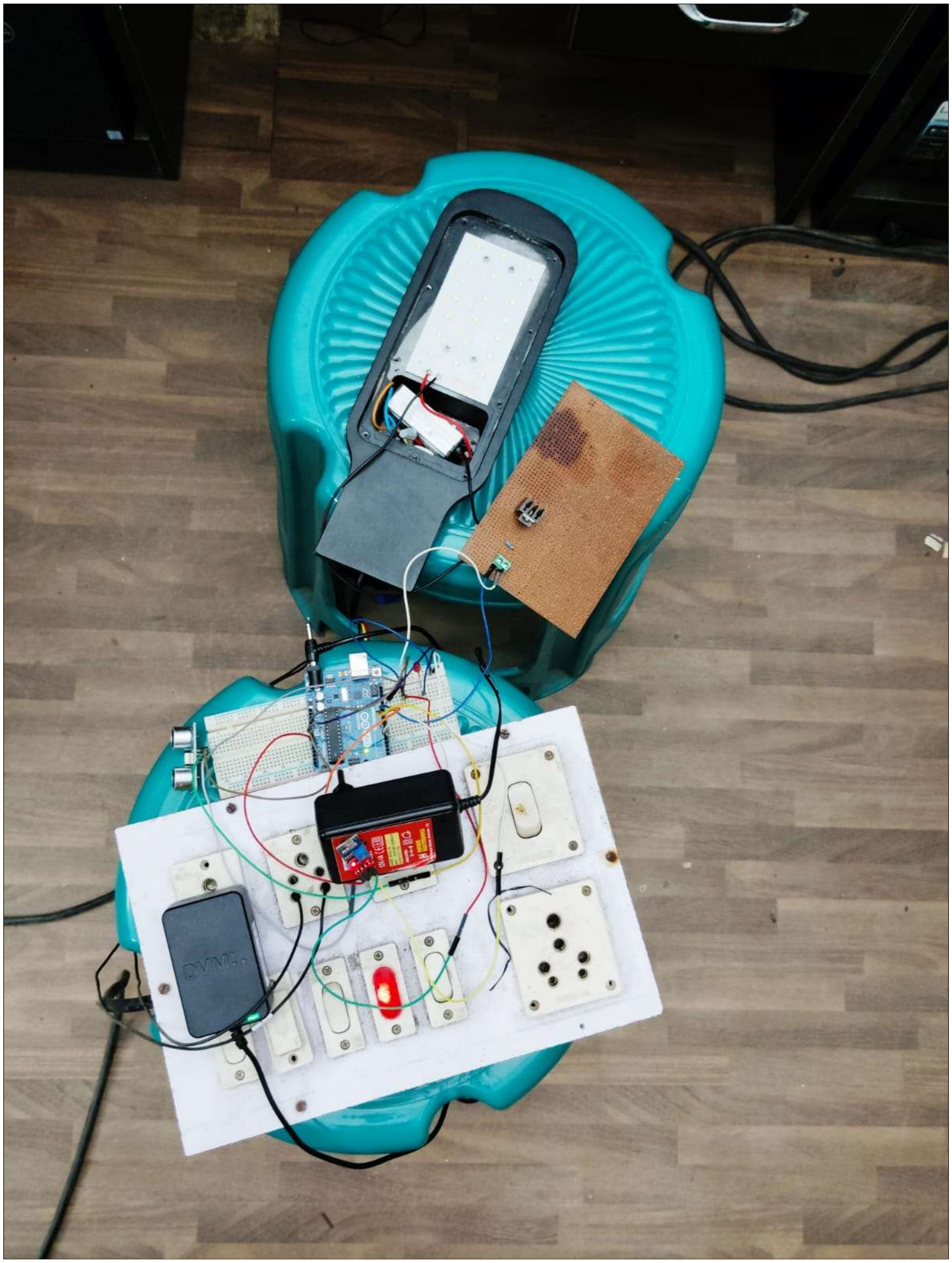

Fig No-4.8: Circuit Diagram of this System by Using Design-2

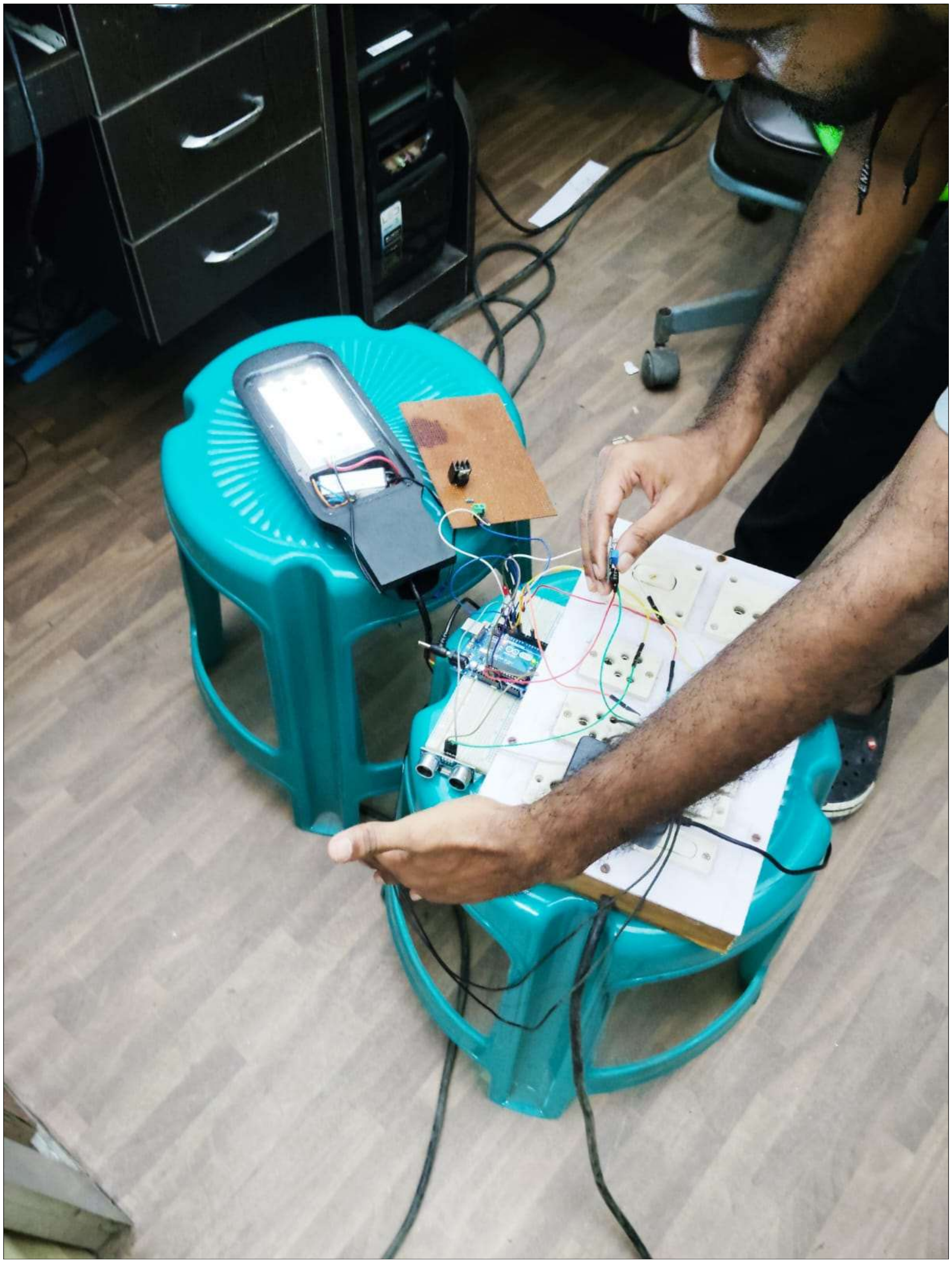

Fig No-4.9: Sensors are testing in the Lab

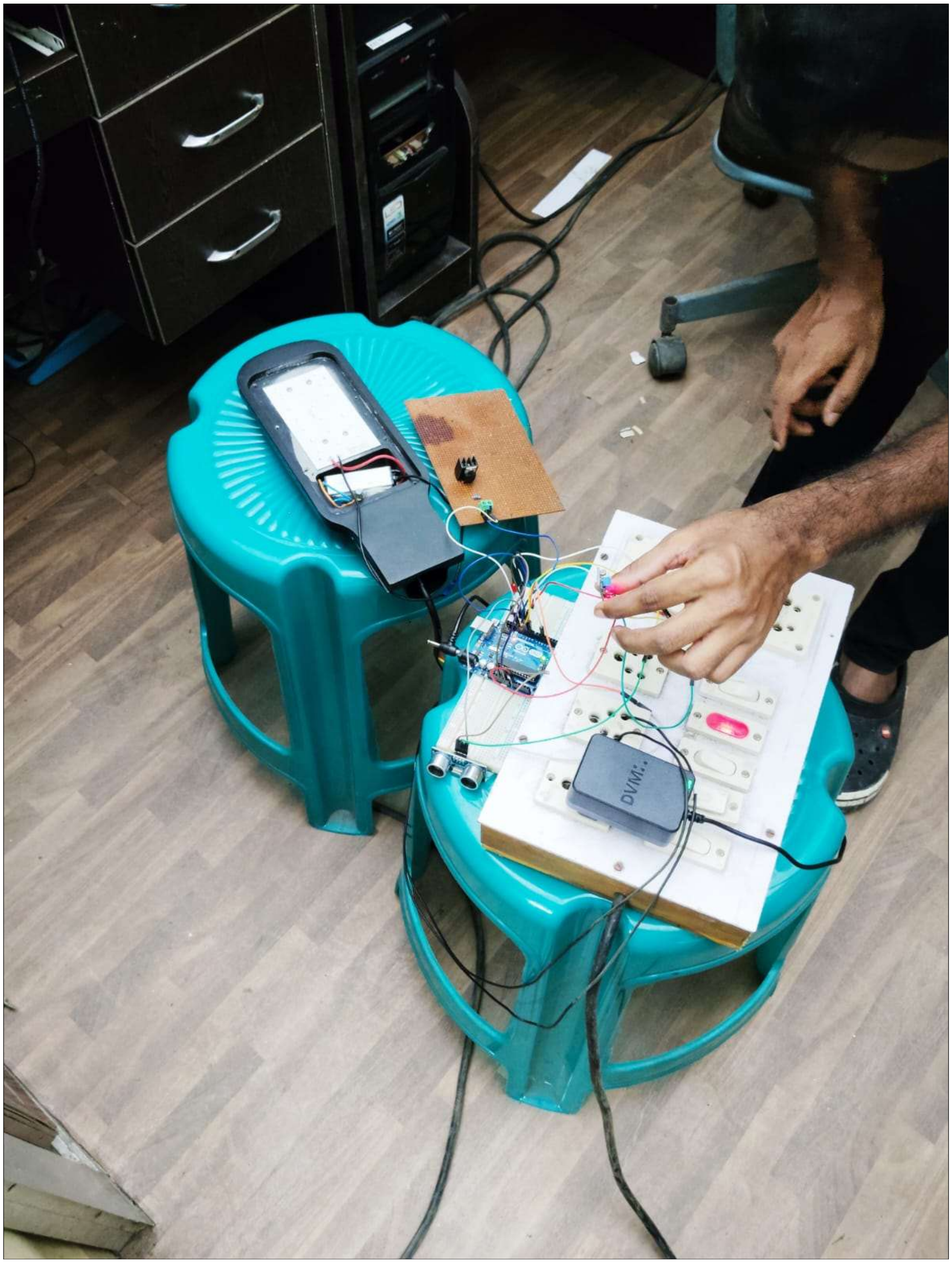

Fig No-4.10: Testing the System in the Lab

4.4 Operation:

4.4.1 Daylight Mode: In day time the light led is off condition. That is showing in the below Pic-4.11.

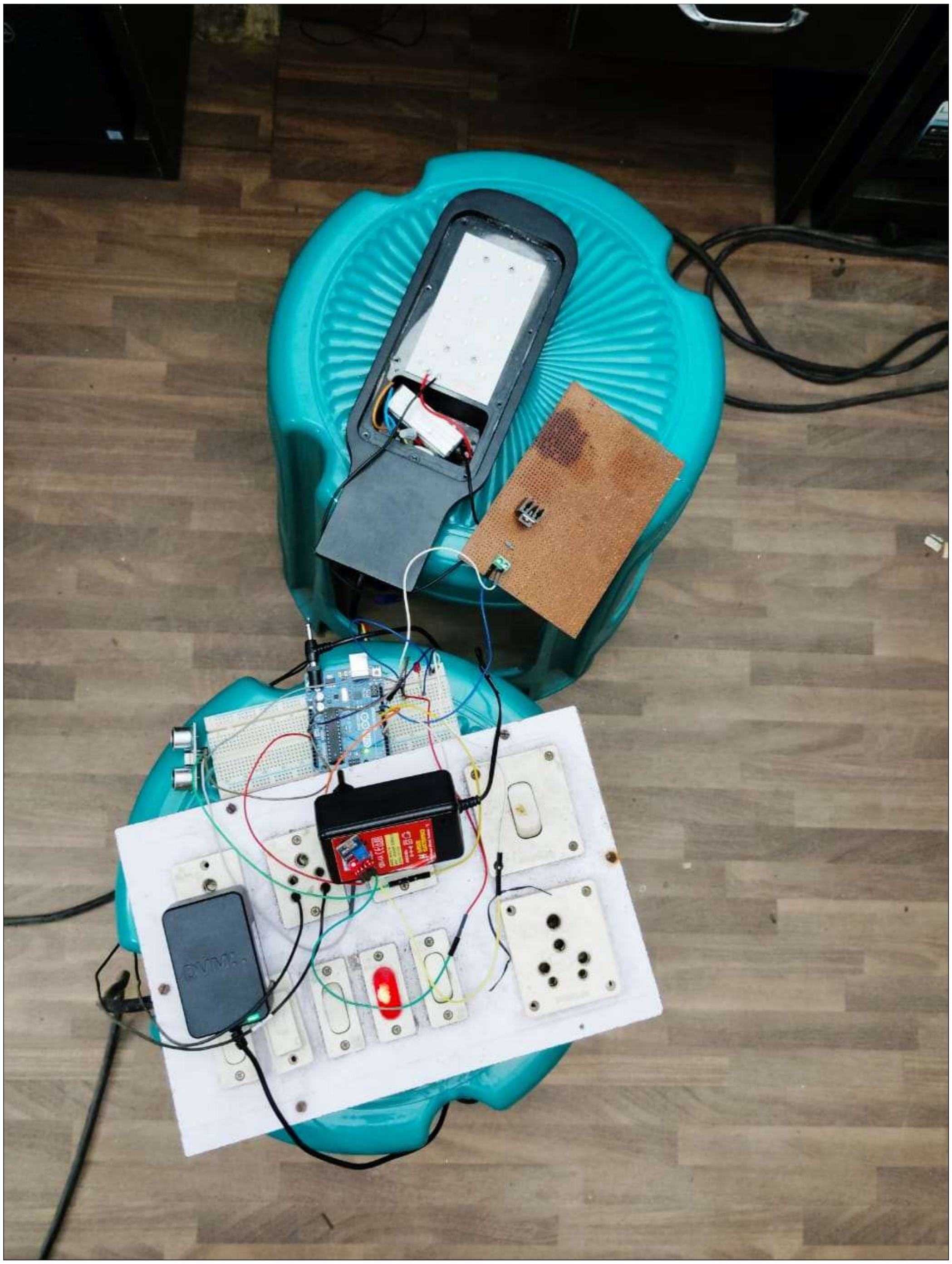

Fig No-4.11: In Day Time the LED is Off Mode

4.4.2 Night Mode: In night time if there is no object detect then the LED is dimming condition. That is showing in the below Pic-4.12.

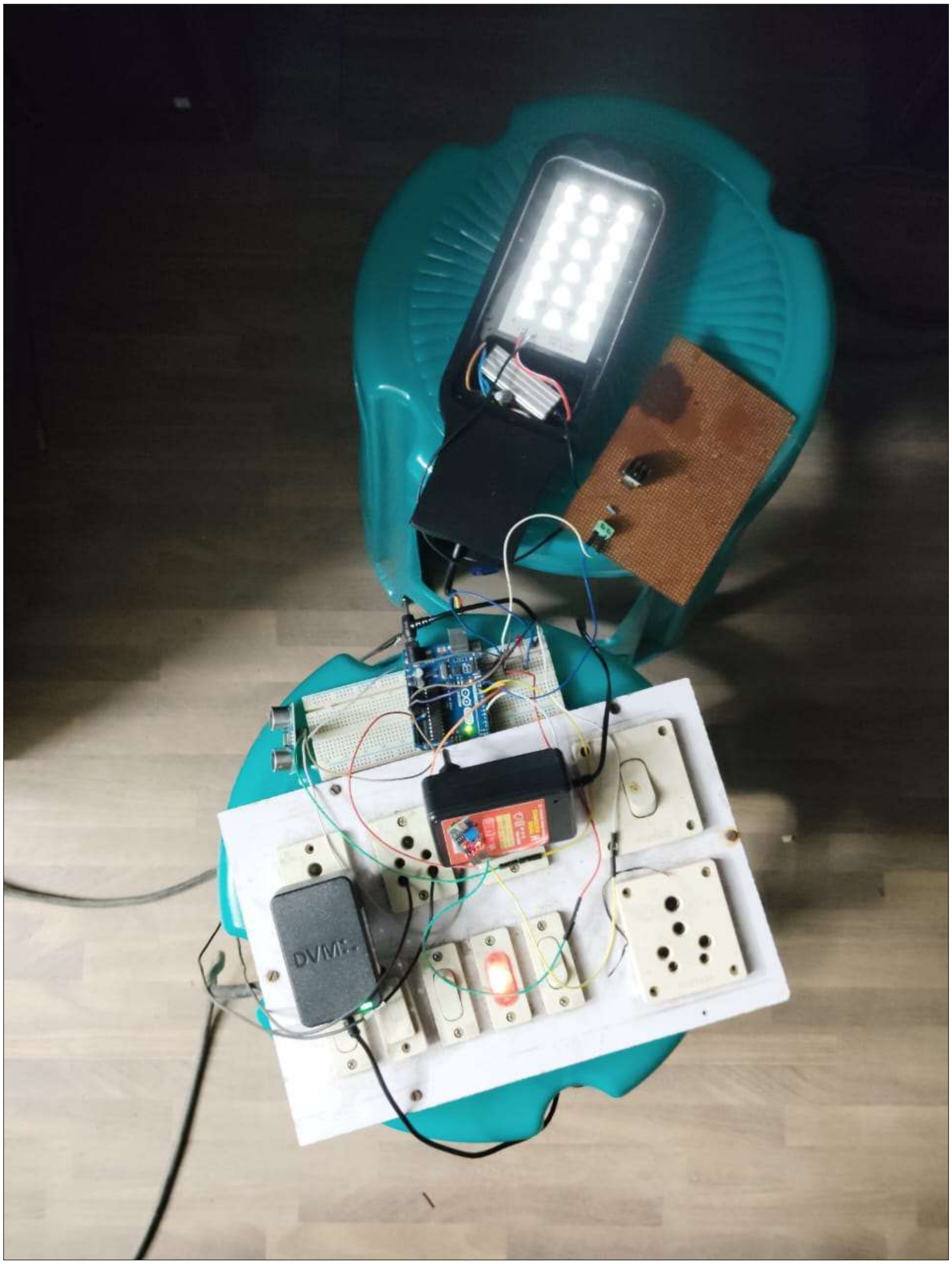

Fig No-4.12: In Night Time the LED is Dimming Mode

4.4.3 Motion Detection: In night time if object is detect then the LED is bright condition. That is showing in the below Pic-4.13.

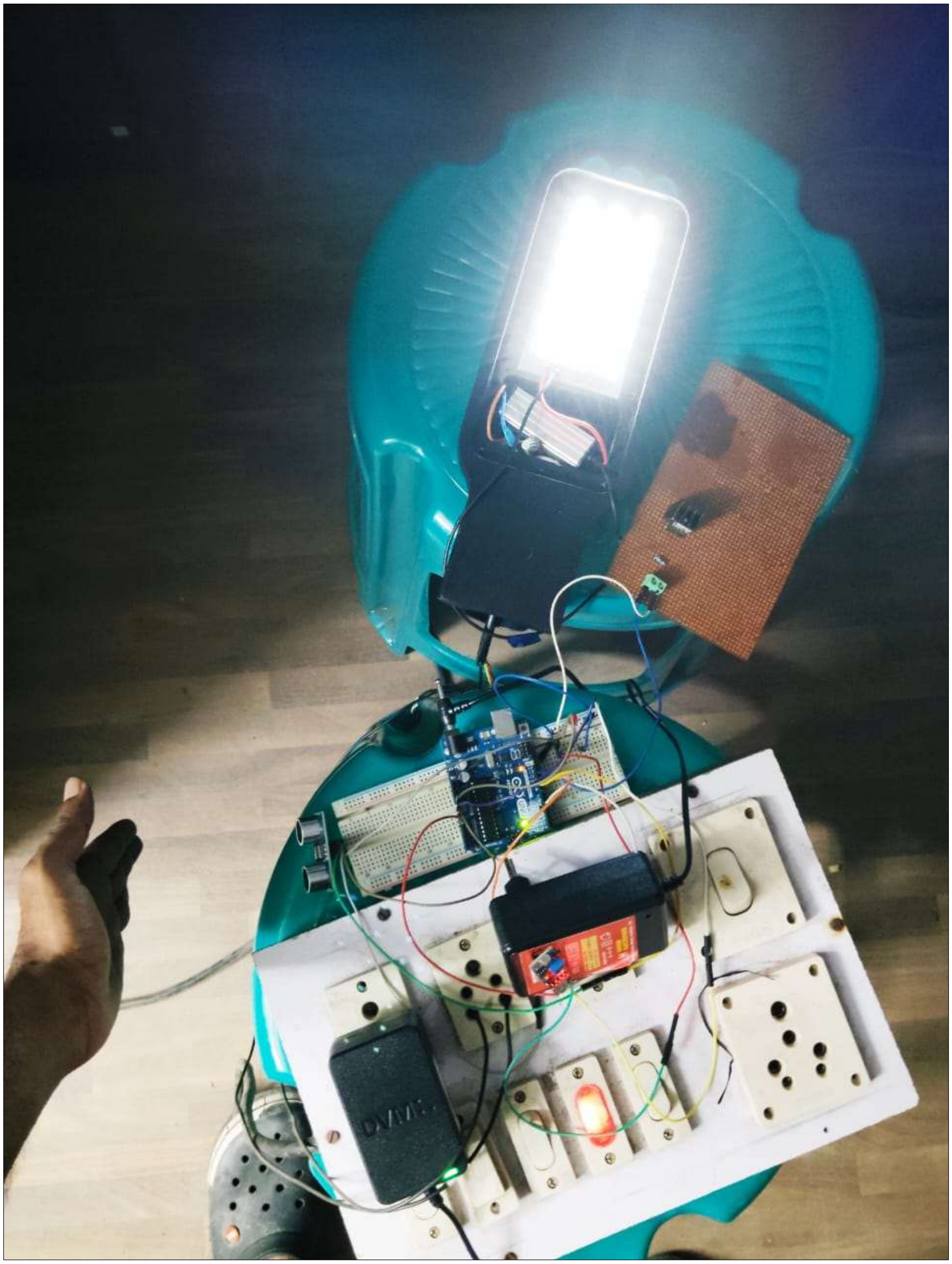

Fig No-4.13: In Night Time When the Object is Detected Then the LED is Bright Mode

Chapter 5: Result and Analysis

The results have collected reflect the performance of an LED lamp under different operational modes, specifically in terms of voltage, current, and light quality as measured by a CRI meter [CL70F]. Here's an interpretation of these results:

LED Only (No Switching Circuit):

- Power:-20w
- Voltage:- 45.94 Volt
- Current:- 2.25 Amp

These values indicate that when the LED is fully operational, it requires an input voltage of 45.94 volts and draws a current of 2.25 amps to produce a power output of 20 watts. This power rating represents the amount of energy the LED consumes while emitting light, and the voltage and current values are necessary to ensure that the LED operates efficiently and within its specified performance range. Properly supplying these values is crucial for the longevity and brightness of the LED, ensuring it functions optimally in its intended application.

With Switching Circuit:

This part of the experiment introduces a switching circuit that modulates the LED lamp based on sensor inputs (LDR for light intensity and Ultrasonic for object detection).

✓ **IN NIGHT TIME (Dimming Mode):-**

- Voltage:-32.63 Volt
- Current:- 0.001 Amp
- Lux:- 10.1
- CCT:- 5721K
- D_{uv} :- 0.0109
- Ra:- 81.7

In this mode, the lamp is dimmed, resulting in significantly reduced power consumption (voltage drop to 32.63V and current drop to 0.001A). The illuminance (E) is quite low at 10.1 lux, indicating a dim lighting condition, suitable for low-light environments. The Correlated

Color Temperature (CCT) remains relatively high (5721K), meaning the light maintains a cool white appearance even at reduced intensity. The D_{uv} (Distance from the black body locus) is positive but small, indicating a slight deviation towards a greener or more yellowish tint. The CRI (Color Rendering Index) is decent at 81.7, meaning the light renders colors fairly well, even in dimming mode.

✓ **IN NIGHT TIME (Detected Mode):-**

- Voltage:-38.76 Volt
- Current:-0.007Amp
- Lux:- 20
- CCT:- 6110K
- D_{uv}:- 0.0109
- Ra:- 81.9

When the Ultrasonic sensor detects motion, the lamp increases its output, reflected by higher voltage (38.76V) and current (0.007A) compared to the dimming mode. The light intensity (lux) also doubles to 20 lux, providing brighter illumination. The CCT further increases to 6110K, indicating an even cooler white light. The CRI remains stable at 81.9, meaning color rendering is consistent across different modes.

✓ **IN DAY TIME:-**

- Voltage:-0 Volt
- Current:-0 Volt

In the daytime mode, the system completely turns off the lamp, as indicated by the zero voltage and current. This reflects the energy-saving feature of the system, where the lamp only operates when necessary (e.g., at night or when motion is detected).

Analysis:

- The results suggest that the system is functioning as intended, with different modes providing varying levels of light output and energy consumption. The dimming mode is highly energy-efficient, consuming minimal power while still providing adequate lighting. In contrast, the detected mode provides more light, suitable for areas requiring enhanced visibility, albeit at a slightly higher power consumption. During the day, the system conserves energy entirely by turning off the lamp.

- The CRI meter results also confirm that the light quality remains relatively stable across different modes, with minimal variation in color temperature and color rendering. This indicates that the system not only saves energy but also maintains consistent light quality, which is crucial for environments where both energy efficiency and lighting quality are important.

Chapter 6: Conclusion and Future Scope

The smart street light system designed and developed in this thesis successfully demonstrates significant improvements in energy efficiency and urban safety through real-time monitoring and adaptive control. By utilizing an LDR sensor to gauge ambient light levels and an ultrasonic sensor to detect nearby movement, the system optimally adjusts the LED lamp's brightness, reducing energy consumption while ensuring adequate illumination. The integration of the ATmega328P microcontroller effectively coordinates these sensors and controls, validating the system’s capability to balance energy conservation with functional requirements.

Future work could explore integrating additional sensors and connectivity options, such as Wi-Fi or IoT capabilities, to enhance remote monitoring and control. Additionally, incorporating machine learning algorithms could enable predictive adjustments based on historical data and patterns. Expanding the system's application to various environmental conditions and urban settings will further validate its effectiveness and adaptability in diverse real-world scenarios.

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Appendix

Datasheet of the MOSFET Driver used to Design the System:

International
IOR Rectifier

Data Sheet No.PD60217 Rev A

IR2011(S) & (PbF)

HIGH AND LOW SIDE DRIVER

Features

- Floating channel designed for bootstrap operation
  Fully operational up to +200V
  Tolerant to negative transient voltage, dV/dt immune
- Gate drive supply range from 10V to 20V
- Independent low and high side channels
- Input logicHIN/LIN active high
- Undervoltage lockout for both channels
- 3.3V and 5V input logic compatible
- CMOS Schmitt-triggered inputs with pull-down
- Matched propagation delay for both channels
- 8-Lead SOIC is also available LEAD-FREE (PbF)

Product Summary

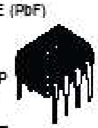
V_{OFFSET}	200V max.
I_O+/-	1.0A /1.0A typ.
V_{OUT}	10 - 20V
$t_{on/off}$	80 & 60 ns typ.
Delay Matching	20 ns max.

Applications

- Audio Class D amplifiers
- High power DC-DC SMPS converters
- Other high frequency applications

Packages

8-Lead SOIC
IR2011S
also available
LEAD-FREE (PbF)

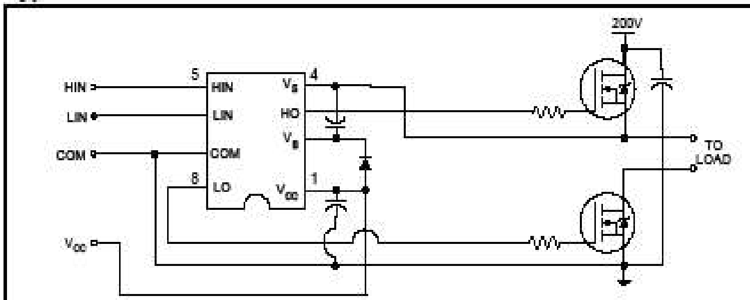


8-Lead PDIP
IR2011

Description

The IR2011 is a high power, high speed power MOSFET driver with independent high and low side referenced output channels, ideal for Audio Class D and DC-DC converter applications. Logic inputs are compatible with standard CMOS or LSTTL output, down to 3.0V logic. The output drivers feature a high pulse current buffer stage designed for minimum driver cross-conduction. Propagation delays are matched to simplify use in high frequency applications. The floating channel can be used to drive an N-channel power MOSFET in the high side configuration which operates up to 200 volts. Proprietary HVIC and latch immune CMOS technologies enable ruggedized monolithic construction.

Typical Connection



(Refer to Lead Assignments for correct configuration). This/These diagram(s) show electrical connections only. Please refer to our Application Notes and DesignTips for proper circuit board layout.

www.irf.com 1

Datasheet of the Ultrasonic Sensor (HC-SR04) used to Design the System:

HC-SR04 Ultrasonic Sensor

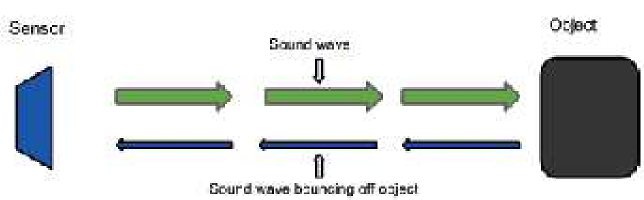
Elijah J. Morgan

Nov. 16 2014

The purpose of this file is to explain how the HC-SR04 works. It will give a brief explanation of how ultrasonic sensors work in general. It will also explain how to wire the sensor up to a microcontroller and how to take/interpret readings. It will also discuss some sources of errors and bad readings.

1. How Ultrasonic Sensors Work

Ultrasonic sensors use sound to determine the distance between the sensor and the closest object in its path. How do ultrasonic sensors do this? Ultrasonic sensors are essentially sound sensors, but they operate at a frequency above human hearing.



The sensor sends out a sound wave at a specific frequency. It then listens for that specific sound wave to bounce off of an object and come back (Figure 1). The sensor keeps track of the time between sending the sound wave and the sound wave returning. If you know how fast something is going and how long it is traveling you can find the distance traveled with equation 1.

Equation 1. $d = v \times t$

The speed of sound can be calculated based on the a variety of atmospheric conditions, including temperature, humidity and pressure. Actually calculating the distance will be shown later on in this document.

It should be noted that ultrasonic sensors have a cone of detection, the angle of this cone varies with distance, Figure 2 show this relation. The ability of a sensor to

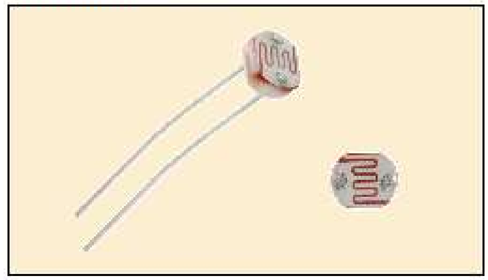
Datasheet of the LDR Sensor (For 5mm) used to Design the System:

PHOTORESISTORS

5mm, 12mm, & 20mm LDR Radial Lead Types

Description

Photoconductive cells are sensors that allow you to detect light. They are small, inexpensive, low–power, easy to use, and don't wear out. NTE's light–dependent resistors (LDR) are photoresistors whose resistance decreases with increasing incident light intensity. In other words, when it is dark, they have a high electrical resistance and when it is light, their electrical resistance is low.



Features

- Epoxy Encapsulated
- Small Size
- Reliable Performance
- Quick Response
- High Sensitivity
- Good Characteristic of Spectrum

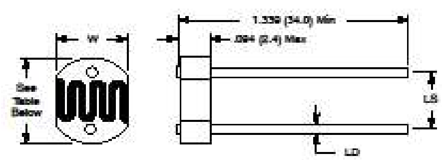
Typical Applications

Digital Applications

- Automatic Headlight Dimmer
- Night/Streetlight Control
- Photoelectric Control
- Industrial Control
- Security System

Analog Applications

- Camera Exposure Control
- Automatic Gain Control



	Lead Diameter (LD)
5mm	.020 (0.5)
12mm	.028 (0.7)
20mm	.036 (0.9)

Specifications

Spectral Response Peak:
5mm Types: 540nm
12mm & 20mm Types: 560nm
Ambient Temperature Range: –30° to +70°C

NTE Type	Dimensions			Max. DC Voltage	Power Dissipation (mW)	Light Resistance (10Lux)(KΩ)	Dark Resistance (MΩ)	$\gamma \frac{100}{10}$	Response Times (ms)	
	Diameter	W	LS						Increase	Decrease
02–LDR1	.201 (5.0)	.169 (4.3)	.134 (3.4)	150	100	50 – 100	5.0	0.8	20	30
02–LDR2	.201 (5.0)	.169 (4.3)	.134 (3.4)	150	80	5 – 10	0.2	0.5	30	30
02–LDR3	.201 (5.0)	.169 (4.3)	.134 (3.4)	150	100	100 – 200	10.0	0.9	20	30
02–LDR4	.201 (5.0)	.169 (4.3)	.134 (3.4)	150	100	30 – 50	3.0	0.7	20	30
02–LDR12	.472 (12.0)	.405 (10.3)	.353 (9.0)	250	200	5 – 10	1.0	0.6	30	30
02–LDR13	.472 (12.0)	.405 (10.3)	.353 (9.0)	250	200	10 – 20	2.0	0.6	30	30
02–LDR14	.472 (12.0)	.405 (10.3)	.353 (9.0)	250	200	30 – 50	5.0	0.7	30	30
02–LDR15	.472 (12.0)	.405 (10.3)	.353 (9.0)	250	200	50 – 100	8.0	0.8	30	30
02–LDR20	.787 (20.0)	.787 (20.0)	.593 (15.1)	500	500	5 – 10	1.0	0.6	30	30
02–LDR21	.787 (20.0)	.787 (20.0)	.593 (15.1)	500	500	10 – 20	2.0	0.6	30	30
02–LDR22	.787 (20.0)	.787 (20.0)	.593 (15.1)	500	500	30 – 50	5.0	0.7	30	30
02–LDR23	.787 (20.0)	.787 (20.0)	.593 (15.1)	500	500	50 – 100	8.0	0.8	30	30

Soldering Notes:

1. Soldering times should be kept as short as possible.
2. The soldering iron should be positioned at least 4mm from the ceramic base.

Terms

- Light Resistance:
  Measured at 10Lux with standard light A (2854K color temperature) and 2H pre–illumination at 400–600Lux prior to testing.
- Dark Resistance:
  Measured 10 seconds after pulsed 10Lux.
- Gamma Characteristic:
  Between 10Lux and 100Lux and given by: $T = \frac{\log(R10 / R100)}{\log(100 / 10)} = \log(R10 / R100)$
  R10, R100 cell resistance at 10Lux and 100Lux. The error of T is +0.1.

Datasheet of the MOSFET (IRFZ44N) used to Design the System:

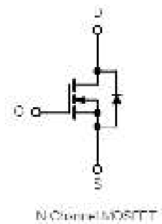
EVVOSEMI®
THINK CHANGE DO

IRFZ44N

60V N-Channel MOSFET

General Description

The IRFZ44NS/IRFZ44N uses advanced trench technology and design to provide excellent $R_{DS(ON)}$ with low gate charge. It can be used in a wide variety of applications



Product Summary

V_{DS}	60V
I_D (at V_{GS}=10V)	50A
$R_{DS(ON)}$ (at V_{GS}=10V)	< 12mΩ
$R_{DS(ON)}$ (at V_{GS}=4.5V)	< 16mΩ

Absolute Maximum Ratings(TA=25℃ unless otherwise noted)

Parameter		Symbol	Value	Unit
Drain-Source Voltage		V_{DS}	60	V
Gate-Source Voltage		V_{GS}	±20	V
Drain Current-Continuous[Note3]	TC=25℃	I_D	50	A
	TC=100℃		33	A
Drain Current-Pulsed[Note1]		I_{DM}	200	A
Avalanche Energy[Note4]		E_{AS}	64	mJ
Maximum Power Dissipation	TC=25℃	P_D	105	W
Storage Temperature Range		T_{STG}	-55 to +150	℃
Operating Junction Temperature Range		T_J	-55 to +150	℃

Thermal Resistance

Parameter	Symbol	Min.	Typ.	Max	Unit
Thermal Resistance,Junction-to-Case	$R_{θJC}$	-	-	1.4	℃/W

Rev:2023A2 1