STUDIES ON INNOVATIVE REAL TIME ESTIMATIONS OF LIFE CYCLE ANALYSIS OF LED USING ARDUINO MICRO CONTROLLER

A thesis submitted towards partial fulfilment of the requirements for the degree of

MASTER OF TECHNOLOGY
IN
ILLUMINATION SCIENCE, ENGINEERING & DESIGN

Submitted by

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REGISTRATION NO.: 154540 of 2020-21
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July,2023

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It is hereby declared that this thesis contains literature survey and original research work by the undersigned candidate, as part of his MASTER OF TECHNOLOGY IN ILLUMINATION TECHNOLOGY & DESIGN, studies during academic session 2020-2021.

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Acknowledgement

I have immense pleasure in expressing my profound gratitude and sincere thanks to my respected thesis advisor **Prof. (Dr.) Suddhasatwa Chakraborty** for his valuable guidance, constant encouragement, useful suggestions, keen interest and timely help in completing this thesis successfully. It has been an excellent opportunity for me to work under her supervision. I am also expressing my gratitude towards **Mr. Parthasarathi Satvaya**, Director, of SISED, Jadavpur University, for his guidance.

I would like to acknowledge my sincere thanks and respect to **Mr. Santosh Sahoo**, Visiting Helper of Illumination Engineering Laboratory for his enormous support.

I would like to thank **Prof. (Dr.) BISWANATH ROY,** Head of the Department, Electrical Engineering, Jadavpur University for providing the necessary facilities required to carry out this thesis.

I also want to express my thankfulness to **Mr. Aishwarya Dev Goswami** & **Mr. Jyotipriya Roy**, Research Scholar, Illumination Engineering for helping me throughout the course of this project work and also for their untiring efforts for improvement of the work. I also thankfully acknowledge the assistance and help received from all the research scholar as well as lab assistants for their sincere, spontaneous and active support during the preparation of this work.

Last but not the least, I would like to thank **Mr. Tanmoy Raha, Mr. Sounak Ghosh** and **Mr. Trisanu Nandy** and all my friends who helped me directly in completing my thesis successfully.

Further, I also take this opportunity to thank all the teachers who taught me and shared their knowledge with me. I must express my heartiest thanks to my juniors, seniors and my alma matter Jadavpur University.

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Abstract

Designing more environmentally friendly lighting solutions is a significant problem for the lighting sector. Although the advancement of LED technology has greatly increased their energy efficiency, additional efforts are required to reduce not only the energy consumption but also the use of essential materials found in electronic components in order to create a sustainable design. This can be done by developing new modular and reconfigurable designs that can swap out disposable generic LED luminaires for specialised, sustainable products with high functional value. These designs should be supported by an assessment of the product's environmental performance throughout its entire lifecycle. First, an LCA comparison between a new luminaire and an old product for usage in an industrial setting was conducted. The study's findings revealed a 30% reduction in the environmental impact categories most affected by energy use in the use stage (like climate change and primary energy demand), while a 50% reduction in the resource depletion impact category related to the elements. The latter is primarily due to the shrinkage of the total circuit board area for the LED modules and the adoption of LEDs with lower environmental impact made possible by removing the substantial contribution from the gold bond wire. Second, a number of possibilities are put out based on modularity and replacement to alter the LED luminaire life cycle in order to make it more sustainable in terms of the impact on energy and materials. There is a scenario that examines the best times to use LED luminaires in terms of energy and material efficiency. The subject of replaceable components is covered in two additional scenario computations. One scenario looks into whether replacing the LED module on a regular basis reduces the principal energy demand category and offers benefits. The final scenario looks into the possibility of replacing an LED module due to a malfunction.

Overview of the thesis

In recent years, there has been a growing interest in sustainable technologies, and LED (Light Emitting Diode) lighting is one such area that has gained significant attention due to its energy efficiency and long lifespan. Life Cycle Analysis (LCA) is a methodology used to assess the environmental impact of a product throughout its entire life cycle, including its production, use, and disposal. Real-time estimations of LCA can provide valuable insights into the environmental performance of LED lighting systems.

To achieve real-time estimations of LCA for LEDs, one approach is to utilize an Arduino microcontroller. Arduino is an open-source electronics platform that provides a programmable microcontroller and a variety of input/output interfaces. It is widely used by hobbyists, researchers, and professionals for developing innovative applications.

The basic concept behind using Arduino for real-time estimations of LCA involves measuring and analysing various parameters related to LED lighting systems. This can include factors such as power consumption, operational time, brightness levels, and temperature. By collecting and processing this data in real-time, it becomes possible to estimate the energy efficiency and environmental impact of the LED system throughout its life cycle.

Here are the key steps involved in implementing real-time estimations of LED LCA using Arduino:

- Sensor Integration: Connect appropriate sensors to the Arduino board to measure relevant parameters. For example, a current sensor can be used to monitor power consumption, a timer module to track operational time, a light sensor to measure brightness levels, and a temperature sensor to monitor LED temperature.
- Data Acquisition: Use Arduino programming language (based on C/C++) to read sensor data at regular intervals. This data is then stored in variables or arrays for further processing.
- Data Processing: Analyse the collected sensor data to calculate energy consumption, operational hours, brightness levels, and other relevant parameters. This can involve performing calculations, applying mathematical models, or using pre-defined formulas.
- LCA Estimation: Utilize the processed data to estimate the environmental impact of the LED system. This can be done by comparing the energy consumption with known benchmarks, considering the energy sources used, and applying LCA methodologies to calculate indicators such as carbon footprint, energy payback time, or ecological footprint.
- Visualization and Reporting: Present the estimated LCA results in a meaningful way, such as through graphical interfaces, LED displays, or

data logging. This allows users to understand the environmental performance of the LED system in real-time.

- By implementing real-time estimations of LED LCA using Arduino, it becomes possible to monitor and optimize the energy efficiency and environmental impact of LED lighting systems. This information can be utilized in various applications, including building management systems, smart lighting solutions, and sustainability assessments.
- It is important to note that the specific implementation details and sensor choices may vary depending on the requirements and objectives of the LED LCA estimation project. However, Arduino provides a flexible and accessible platform for integrating sensors, collecting data, and performing real-time calculations, making it a suitable choice for such applications.

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INTRODUCTION

The stages of an LED light source's lifespan, from production and use to eventual disposal or recycling, are referred to as the LED (Light-Emitting Diode) life cycle. Due to its energy efficiency, prolonged lifespan, and advantages over conventional lighting, LED technology has been increasingly popular in recent years.

The production of LEDs is the first step in the life cycle. This entails the production of semiconductor materials that are utilised to make LED chips, such as gallium arsenide. The chips are then put together onto a circuit board and protected by a case. LEDs are produced and then given to wholesalers and merchants who then sell them to customers. Traditional incandescent or fluorescent lighting fixtures are replaced with LED lighting in a variety of contexts, including residential, commercial, and industrial ones.
Compared to traditional lighting technologies, LEDs are noted for using a large amount less electricity. They function at lower temperatures, lowering heat emissions and improving handling safety. Compared to conventional bulbs, LED lights may operate for tens of thousands of hours on average. End of Life: LED lights eventually approach the end of their useful lives. Unlike traditional bulbs, LEDs gradually dim over time rather than failing abruptly. An LED light is deemed to have reached the end of its useful life when it can no longer generate an acceptable level of light output. Recycling and proper disposal of LED lights are essential for reducing their negative effects on the environment. LEDs are made of a variety of materials, including lead and small amounts of other potentially dangerous materials including copper and aluminium. The proper disposal and recycling of LED lights can be handled through recycling programmes or specialised electronic waste facilities, assuring the recovery of valuable materials while minimising environmental harm.

OBJECTIVE

The objective of considering the LED life cycle is to evaluate and understand the various stages and factors that contribute to the overall lifespan and sustainability of LED lighting systems. By examining the life cycle of LEDs, we can identify areas for improvement, implement more efficient and environmentally friendly practices, and make informed decisions regarding LED technology.

Here are some specific objectives related to the LED life cycle:

Assessment: Evaluate the environmental impact of LED lighting systems throughout their life cycle, including the extraction of raw materials, manufacturing processes, transportation, use, and disposal or recycling.

Energy Efficiency: Understand and promote the energy-saving benefits of LEDs compared to traditional lighting technologies. Determine ways to optimize LED designs and manufacturing processes to reduce energy consumption during the use phase.

Durability and Reliability: Improve the quality and longevity of LED products by conducting research on materials, components, and manufacturing techniques. Enhance product design to ensure that LEDs can withstand various environmental conditions and provide reliable performance throughout their operational life.

Environmental Impact: Minimize the environmental footprint of LED production, including the reduction of greenhouse gas emissions, water usage, and waste generation. Promote the use of eco-friendly materials, energy-efficient manufacturing processes, and responsible waste management practices.

End-of-Life Considerations: Develop strategies for the proper disposal or recycling of LEDs to minimize environmental harm. Explore methods to recover valuable materials from discarded LED products and encourage the adoption of recycling programs to prevent electronic waste accumulation.

Lifecycle Cost Analysis: Conduct comprehensive cost analyses that account for the entire lifespan of LED lighting systems, including upfront costs, energy consumption, maintenance, and disposal expenses. Determine the long-term economic benefits of LEDs and provide guidance for decision-makers on the financial feasibility of LED adoption.

Education and Awareness: Raise awareness among consumers, businesses, and policymakers about the importance of considering the LED life cycle. Educate stakeholders about the environmental and economic advantages of LEDs and provide information on sustainable practices related to LED lighting.

By focusing on these objectives, we can promote the development and adoption of LED lighting systems that are energy-efficient, environmentally friendly, and economically viable throughout their life cycle.

HISTORY OF LIGHT BULBS

In 1802, Humphry Davy invented the first electric light. He experimented with electricity and invented an electric battery. When he connected wires to his battery and a piece of carbon, the carbon glowed, producing light. His invention was known as the Electric Arc lamp. In 1835, the first constant electric light was demonstrated, and for the next 40 years, scientists around the world worked on the incandescent lamp, tinkering with the filament (the part of the bulb that produces light when heated by an electrical current) and the bulb's atmosphere (whether air is vacuumed out of the bulb or it is filled with an inert gas to prevent the filament from oxidizing and burning out). These early bulbs had extremely short lifespans, were too expensive to produce or used too much energy.

1840, British scientist Warren de la Rue enclosed a coiled platinum filament in a vacuum tube and passed an electric current through it. The design was based on the concept that the high melting point of platinum would allow it to operate at high temperatures and that the evacuated chamber would contain fewer gas molecules to react with the platinum, improving its longevity. Although an efficient design, the cost of the platinum made it impractical for commercial production.

In 1850 an English physicist named Joseph Wilson Swan created a "light bulb" by enclosing carbonized paper filaments in an evacuated glass bulb. And by 1860 he had a working prototype, but the lack of a good vacuum and an adequate supply of electricity resulted in a bulb whose lifetime was much too short to be considered an effective producer of light. However, in the 1870's better vacuum pumps became available and Swan continued experiments on light bulbs. In 1878, Swan developed a longer lasting light bulb using a treated cotton thread that also removed the problem of early bulb blackening.

On July 24, 1874 a Canadian patent was filed by a Toronto medical electrician named Henry Woodward and a colleague Mathew Evans. They built their lamps with different sizes and shapes of carbon rods held between electrodes in glass cylinders filled with nitrogen. Woodward and Evans attempted to commercialize their lamp, but were unsuccessful. They eventually sold their patent to Edison in 1879.

Next, 1879, Thomas Alva Edison patented & after one year in 1880 start to commercialising incandescent light bulb

Edison and his researchers tried to enhanced the quality of the filament, firstly going through the procedure of testing carbon, next platinum

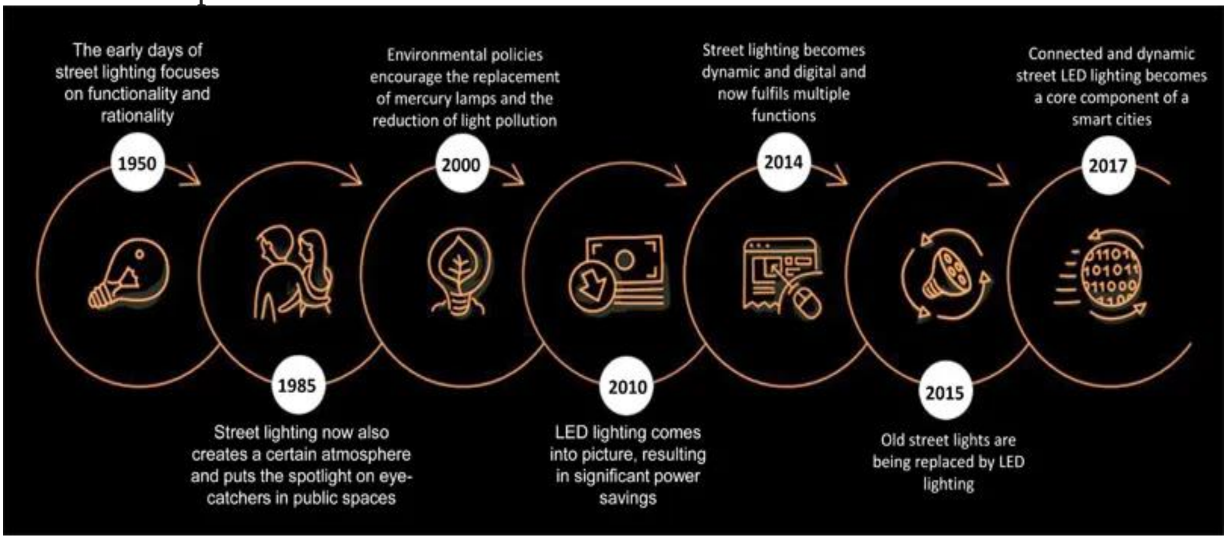
MARKABLE DATES:

- 1906 - The General Electric Company were the first to patent a method of making tungsten filaments for use in incandescent lightbulbs. Edison himself had known tungsten would eventually prove to be the best choice for filaments in incandescent light bulbs, but in his day, the machinery needed to produce the wire in such a fine form was not available.
- 1910 - William David Coolidge of General Electric improved the process of manufacture to make the longest lasting tungsten filaments.
- 1920s - The first frosted lightbulb is produced and adjustable power beam bulbs for car headlamps, and neon lighting.
- 1930s - The thirties saw the invention of little one-time flashbulbs for photography, and the fluorescent tanning lamp.
- 1940s - The first ’soft light’ incandescent bulbs.
- 1950s - Quartz glass and halogen light bulb are produced
- 1980s – New low wattage metal halides are created
- 1990s – Long life bulbs and Compact Fluorescent bulbs make their debut.

3. SMART STREET LIGHTING

Smart street lights are sensor-enabled LED fixtures that provide dynamic illumination, dimming lights when they are not needed and brightening automatically when illumination is required, such as when cars or pedestrians are passing.

The primary purpose of smart street lighting was energy efficiency by adjusting the light intensity based on a number of parameters. Today, new technologies are transforming light fixtures into multifunctional interactive systems that can communicate with their environment. This creates masses of data, which provide fertile soil for innovative services and solutions that are paving the way to smart urban development.



A smart, connected lighting system is part of a local, wireless, decentralised network with a local intelligence. It is connected to the internet (IoT) and to a central data and management platform in the cloud. It is equipped with smart sensors, integrated devices and cameras to respond to its environment dynamically and interactively.

VARIOUS TYPES:

Incandescent Lamp: Incandescent Street light bulbs use tungsten-halogen filament which are commonly used in theatres and stadiums. They have high efficiency, brightness and good colour rendition, but their lifespan is shorter than other types of bulbs.

Advantages:

- It's the cheapest light
- Can easily consume to large voltage & current ranges; can work with DC & AC power
- Colour rendition is great

Dis-Advantages:

- In heat generation, most energy consumption is wasted (Efficiency rate is only 10 lumens/watt)
- It has high maintenance cost & very short life Span (around 1,200 hours)

Applications: Floodlights, headlights, stadium lights, sports field lights.
Fluorescent Lamp: It contains argon & mercury gasses which help erupt the lamp. This kind of street light bulb encases a metal electrode in both ends.
Advantages:

- More efficient than incandescent outdoor lamps.
- Less heat emission than incandescent lamps.

Dis-Advantages:

- You cannot use a dimmer switch with it.
- Consumed a longer time to heat up and then reached the point of full intensity brightness
- Hazardous as it contains mercury
- Sensitive to cold temperatures and windy environments

Applications: Parking lot area and perimeter street lighting.

Mercury Vapor Lamp: An older version of the mercury vapor light can be easily identified with its bluish-green illumination and people gets irritate because of this.
Today, though having a few mercury vapor street lights, as most of them were replaced with the more efficient sodium lamps for street lighting.
Pros: More efficient than incandescent bulb and fluorescent bulb.

Cons:

- At the end of its life cycle, it cycle
- Compare to other types of bulb, it gets dimmer very quickly.
- It produces ultraviolet rays means it emits hazardous

High Pressure sodium (HPS) Street Light Bulb: In today's society, one of the most common bulbs are HPS lamp. It produces white light through a mixture of different gases; & highly preferred because of less maintenance.
Pros:

- HPS lamps are also more efficient than the earlier light bulb versions. It also produces yellow-orange illumination.

Cons:

- Before turning on, it can take a few moments.
- At the end-of-life cycle, it produces reddish colour.
- It burns at the end of its light. For current regulation & change the voltage, it needs a transformer or ballast.

Low Pressure Sodium (LPS) Street Light Bulb: This kind of lamps are like the HPS lamps, but they emit exclusively warm or yellow light. It is highly efficient as compared with its predecessors, but it also takes a few minutes before turning on.

Pros:

- Has a longer lifespan than HPS.
- Less glare than the HPS.

Cons:

- Its CRI is zero.
- It only emits a single wave of yellow light that’s why the colours cannot be easily identified.

Application: It’s used as lighting under the bridge & inside the tunnels.

Metal Halide Street Light Bulb: Metal halide bulb is highly suitable for wider area such as sports field, because it emits true white light. Metal halide can survive up to 10,000 to 12,000 hours on average.

Pros:

- Metal Halide lamp have a good colour rendition.
- They have an improved CRI around 85.

Cons:

- It has high brightness, which responsible for light pollution.
- They explode or shatter during failure.

Application: Used in streetlights, parking lot lights, and stadium lights; warehouses, schools, hospitals and office buildings and city and high-end street lighting.

Ceramic Discharge Metal Halide Lamp: It is an improvement of the metal halide lamp. It replaces HPS and mercury vapor lamps at it produces clearer light with improved CRI (78–96). It produces better colour retention. CDM lamps are far better than tungsten filament incandescent bulbs in terms of efficiency (80 to 117 LM/Watts).

Induction Lamp: It has a long lifespan and is energy efficient. It cannot work properly in high temperatures (35 degrees Celsius and above).

Pros:

- A much greater lifespan (10,000 hours).
- Compare to incandescent, the efficiency is higher.

Cons:

- In low mounting application, it cannot be used.
- It has a larger size, which inhibits it from effective light control.

Compact Fluorescent Lamp (CFL) Street Light Bulb: CFL bulb working like fluorescent bulb, but it mimics the physical feature of incandescent bulb. People can easily distinguish CFL lights with their tubular loops.

Pros:

- Compared with fluorescent lamp, CFL bulb lasts longer & more efficient.
- Its beam spread is more controlled than fluorescent lamp.

Cons:

- CFL requires a ballast.
- The lighting intensity can lessen at half of its life cycle.

Light Emitting Diode: LED street light bulb is the most energy efficient option for outdoor lighting purposes. It have an extremely long lifespan (50,000 hours), but it also does not emit toxic chemicals like mercury lamps. LED lamp produces blue/white light. It is easy to turned on as warm up is not needed. It also does not produces ultraviolet Rays.

Pros:

- It has energy efficient with less heat emission.
- Directional light (over 180 degrees, unlike other lights with 360 degrees light direction).
- It is Very high-quality light.
- It has low maintenance costs.

Cons:

- Very expensive.

Phosphor-Converted Amber (PCA) LED Street Light Bulb: PCA LED lights are new on the market. PCA LED promises a highly efficient lighting solution with good colour rendition. PCA LED is a monochromatic amber light that produces yellowish glow. It is very pleasing to the eyes, and has a higher lighting efficiency.

Pros:

- It has long lifespan & has decorative properties.
- Wildlife-friendly because of their amber lighting colour
- Energy efficient like traditional LED’s

Cons:

- It’s huge expensive.

Narrow-Band Amber (NBA) LED Street Light Lamp: Narrow-Band Amber (NBA) LED street light bulb is a new LED innovation. It emits yellow or a warm colour, rather than the traditional LED colour (blueish-white).

NBA LED is promised to render good quality colour, so as not to make illuminated things look grey (like LPS lamps). Currently, it is high-priced but are very energy efficient.

3.1 LITERATURE REVIEW

Smart street lighting systems have gained significant attention in recent years due to their potential for energy savings, cost efficiency, and enhanced functionality. This literature review aims to explore the existing research and advancements in the field of smart street lighting, focusing on the key benefits, technologies, challenges, and future prospects.

For a civilization to advance and for a nation's economy to grow sustainably through mobility, a well-designed street lighting system is essential. The effectiveness of the street illumination directly affects how well-functioning the transportation system is. An estimate of the GDP loss due to accidents was provided in a 1999 study by Rune Elvik in Norway. The analysis was based on data gathered for incidents that occurred between 1990 and 1999 in 12 different nations and the loss these accidents caused. Aside from encouraging economic development, effective road lighting also guarantees the safety of drivers and pedestrians at night. Furthermore, a well-planned street lighting system can cut down on crime at night in public areas by up to 20%. In a 2014 study of incidents on Indian roadways, Pandian Pitchipoo found that 80% of accidents happened at night. Road geometry, weariness, and low visibility were cited as accident causes. Visual factors were found to be the cause of 47% of accidents in a survey to discover the categories of causes accounting for accidents. Another technique called FARE (Factor Relationship), which analyzes the reasons, was used to further justify the study. According to the FARE analysis, visual elements account for 51% of accidents, which is consistent with the traditional survey approach. Consequently, a path towards potential key causes to stop accidents from happening was found and worked. According to earlier research, it was possible to achieve a considerable reduction of 19% in nighttime traffic accidents in India by improving the country's current road lighting schemes.[3] The effectiveness of street lighting has a significant impact on driver performance, particularly in terms of Visibility Level (VL) and Reaction Time (RT), according to quantitative and qualitative research findings. [4] According to research, a considerable part of generated electricity is used for street lighting, raising serious concerns. In the Indian context, the average yearly use of electrical power for street lighting is about 22%, indicating the need for efficiency to solve this pressing issue.[4] An innovative method termed PWM (Pulse Width Modulation) dimming has been developed in the quest for energy optimization. This method makes it possible to adjust the luminous intensity of LED street lights. However, using PWM dimming has certain disadvantages because it may harm both the LED driver and the LED itself. The process's extreme high-frequency switching is what causes these results. The development of the beam angle switching method is a recent advancement in LED technology. Based on the volume of traffic, this method enables individual control of LED strips inside a particular LED luminary. Beam angle switching is one of the many possible strategies that stands out as a highly effective way to cut energy use. According to research, a 40% reduction in power use can greatly help bring down the total amount of electricity used for lighting from 22% to 11%. Implementing the beam angle switching method can also help cut down on carbon emissions in general. The Target Illuminance (TI) should never rise above 15%, in accordance with CIE 115:1995 recommendations. To simulate and assess the efficacy of the beam angle switching technique for LEDs, a miniature duplicate of an actual street lighting setting was made for this lab-based investigation. This strategy was successfully implemented by utilizing a wireless communication network and the MQTT protocol. In order to confirm the accuracy of the lab simulation in comparison to actual street lighting circumstances, important illumination characteristics including Illuminance, Uniformity Distribution, Luminance, and Object Contrast were examined. These photometric or illumination parameters act as reference points to confirm the applicability of the simulated experiment to real-world street lighting conditions.

3.2 WORLD SHIFTING TO LED LIGHT

1955 OLEG VLADIMIROVICH LOSEV published a paper outlining LEDs and their application. Then, 1955 RUBIN BRUNSTEIN reported Infrared Emission from GaAs, GaSb and InP Semiconductors. Next 1961 ROBERT BIARD and GARY PITTMAN produced and patented the first infrared LED. After that, at 1962 NICK HOLONYAK invented the first LED to emit visible red light. 1964 IBM introduces red LEDs to their computer circuit boards. Next, 1972 M.GEORGE CRAFORD created the first yellow coloured LED using one red and one green chip. 1980 Several large corporation were racing to create brighter and more reliable LEDs using the newly developed Gallium Aluminium Arsenide. 1996 SHIMIZY files a patent for a planar white light source based on a blue, red and green LED for RGB white black lighting in full colour displays. 2002 white LEDs become commercially available for $80-$100 per bulb.

LED Replacement Bulbs:

With performance improvements and dropping prices, LED lamps can affordably and effectively replace 40, 60, 75, and even 100-Watt incandescent bulbs. It's important to read the Lighting Facts Label to make sure the product is the right brightness and colour for its intended use and location.

HOLIDAY LIGHTS:

LEDs consume far less electricity than incandescent bulbs, and decorative LED light strings such as Christmas tree lights are no different. Not only do LED holiday lights consume less electricity, they also have the following advantages:

- Safer: LEDs are much cooler than incandescent lights, reducing the risk of combustion or burnt fingers.
- Sturdier: LEDs are made with epoxy lenses, not glass, and are much more resistant to breakage.
- Longer lasting: The same LED string could still be in use 40 holiday seasons from now.
- Easier to install: Up to 25 strings of LEDs can be connected end-to-end without overloading a wall socket.

WHAT IS LED?

LED stands for light emitting diode. An LED is a semiconductor device, generating light through a process called electroluminescence. When you pass an electric current through semiconductor material, it emits visible light. As such, an LED stands in exact contrast to a photovoltaic cell, which is the cell used in solar arrays to convert visible light into electricity.

Advantages:
-Low wattage
-Long life
-No external circuitry required (no ballast needed to limit current, it can be plugged directly into AC power and will self-regulate power through its own resistivity)
-Can be manufactured into flat flexible panels, narrow strings, and other small shapes
-Can be made into waterproof computer monitors which are more durable and light weight than LCDs or Plasma screens.
-Not directional like LCDs when used as a computer monitor, looks good at all angles
-EL displays can handle an impressive -60 C to 95 C temperature range, which LCD monitors cannot do

Disadvantages:
-Not practical for general lighting of large areas due to low lumen output of phosphors (so far)
-Poor lumens per watt rating, however typically the lamp is not used for high lumen output anyway
-Reduced lumen output over time, although newer technologies are better than older phosphors on this point
-Flexible flat EL sheets wear out as they get flexed, durability is being worked on
-The lamps can use significant amount of electricity: 60-600 volts
-Typical EL Needs a converter when used with DC sources such as on watches (to create higher frequency AC power, this is audible)

LED lighting can now be found across all applications in the market, from use in small keychains to football stadium flood lighting. LED technology is the most efficient way to convert electrons into photons, and it also offers features such as longer lifetime, superior integration with lighting controls, better optical control, improved dimmability, and colour-shifting. From a circular economy perspective, LED light sources have the least environmental impact, offering the best options when looking across the whole product life cycle. The energy efficiency – or “efficacy” for light sources – is expected by the US Department of Energy to continue to improve through 2050, further reducing the environmental impact and lowering running costs. More improvements are incentivised because higher efficacy means more light per chip (so fewer chips are needed in each light source) and lower electrical currents (so LED drivers can be reduced in size and last longer).

LED lighting is already highly cost-effective compared to conventional light sources, especially incandescent, halogen and fluorescent lamps. Direct, drop-in replacement LED products have been developed by the industry so that fixtures do not need to be changed. These drop-in LED retrofit solutions allow existing fixtures to remain in place while the end user can benefit from substantially lower running costs. Compared to incandescent, LED lamps offer 80-90% energy savings. Compared to fluorescent, they achieve 50-60% savings.

LED retrofit tubes can have payback periods as short as four months (replacing linear fluorescent lamps). For general lighting service (A-type) LED lamps, the payback can be instantaneous or just a matter of weeks when compared with tungsten-filament light sources and compact fluorescent lamps (CFLs) – thereafter the LED products last typically for five to ten years depending on the lamp lifetime and usage, generating even more savings.

Compared with fluorescent lighting technologies, LED lighting systems are much easier to integrate with smart controls to create intelligent and responsive living environments in homes, offices and cities – delivering light when and where it's needed. LED technology also offers substantial benefits for households that are off-grid, and given its durability and efficiency, this sector converted to LED more than a decade ago.

1. Long Lifespan

Compared to the lifespan of your average incandescent bulb, the lifespan of a LED light is far superior. The average incandescent bulb lasts about a thousand hours. The lifespan of an average LED light is 50,000 hours. Depending on how you use it, its life may be as long as 100,000 hours. This means that an LED light can last anywhere from six to 12 years before you need to replace it. That is 40 times longer than an incandescent bulb.

Even if you're using fluorescent, metal halide or sodium vapor lights, an LED light will last at least two to four times longer.

As such, savings extend not only to replacement costs but also to the maintenance costs of your company's lighting bill.

2. Energy Efficiency

Another one of the leading LED lighting advantages is their energy-efficient operation. You can measure the energy efficiency of a lighting source in useful lumens, which describes the amount of lighting that the device emits for each unit of power, or watt, that the bulb uses. In the past, we measured light by how many lumens it produced, but the reality is that some of these lumens go to waste. LED lighting produces less waste light and more useful lumens than other lighting solutions.

If you replaced all the lighting in your office, school or other facility with LEDs, you could see as much as a 60% to 70% improvement in your overall energy savings. In some cases, the improvement could be as great as 90%, depending on what kind of lights you are replacing and what kind of LED lights you are using. These improvements in energy efficiency are directly correlated with financial savings. When you replace a traditional light source with an LED light source, your energy usage is going to plummet, making LED lights are a smart investment for the bottom line of any business!

3. Improved Environmental Performance

It is becoming increasingly important for companies to become eco-friendly. Customers increasingly want environmentally friendly options and using an environmentally friendly light source can help companies reduce their energy use, as well as attract a socially conscious consumer base.

The environmental benefits of LED lighting also extend to their manufacturing process. Many traditional lighting sources, like fluorescent lighting and mercury vapor lights, use mercury internally as part of their construction. Because of this, when they reach the end of their lifespans, they require special handling. You do not have to worry about any of these issues with LED lights.

4. The Ability to Operate in Cold Conditions

Traditional lighting sources don’t like cold weather. When the temperature drops, lighting sources, particularly fluorescent lamps, require a higher voltage to start, and the intensity of their light diminishes.

LED lights, on the other hand, perform better in cold temperatures by about 5%. This is why LED lights are a better choice for lighting needed in freezers, meat lockers, cold storage spaces or refrigerated display cases. Their ability to perform so efficiently in cold weather also makes them the perfect choice for lights in parking lots, lights used to illuminate the perimeters of buildings and lights used in outdoor signage.

5. No Heat or UV Emissions

If you've ever tried to change an incandescent light bulb right after it goes out, you know how hot they get when they're in use. Many traditional lighting systems like incandescent bulbs turn more than 90% of the energy they use to heat, allocating only 10% of energy to actual light production.

LEDs emit almost no heat, and most of the light they emit is within the visible spectrum. This feature is one reason that medical experts are looking at LEDs as a possible solution for Seasonal Affective Disorder (SAD), which affects many people during the darker months of the year.

It also makes LEDs ideal for illuminating works of art that will degrade or break down over time with exposure to UV rays.

6. Design Flexibility

LEDs are very small (about the size of a spec of pepper). This means that they can be used in almost any application. Remember, their original use was as an indicator light in a circuit board. If you combine them in bunches, you create a traditional bulb. If you string together a series of LED lights, you create a line or series of lights — like a string of Christmas lights.

Think of the options this gives you for lighting in your facility. LED devices can be so small you can use them for illuminating everything from a shop floor to a major league football stadium.

7. Instant Lighting and the Ability to Withstand Frequent Switching

If you're looking for a light that needs to come on quickly, choose LED technology. LED lights can turn on and off instantly. If you're using a metal halide lamp, for instance, you need to be prepared for a warm-up period. Think of how a fluorescent light flickers when you turn it on and often takes two or three seconds before its fully lit. These are some of the complications that can be circumvented by installing LED lights.

Also, traditional lighting sources have a shorter lifespan if you frequently switch them on and off. LED lights are not affected by frequent switching. It does not cause any reduction in their lifespan or efficiency.

This feature makes LEDs an ideal solution for your business if you need your lights to come back on immediately after a blackout or a power surge. This capability is also useful if you want your lights to come on promptly when an employee opens a building early in the morning before the sun comes up.

Since LEDs are unaffected by switching on and off, they can be rapidly cycled for flashing light displays or applications that require sensors that frequently switch from on to off and back again.

8. Low Voltage Operation

If your business is in a location where flooding may occur, you want to be able to light your facility with devices that require as little voltage as possible. LEDs are perfect for this because they operate on very low voltage. When you use a low-voltage system in areas that may be prone to flooding, you are protecting your staff and others from potentially harmful or fatal shocks. If, during a flood clean-up, someone mistakenly touches some electrical component, a low-voltage lighting system that generates 12 volts is much safer than a line voltage system that generates 120 volts.

This also makes them extremely useful to use outdoors where other lighting solutions might not meet with local codes.

9. Dimming Capabilities

LEDs perform well at almost any power percentage, from about 5% to 100%. Some lighting sources, such as metal halide, perform less efficiently when dimmed. Sometimes, you cannot dim them at all.

The opposite is true for LED lighting. When you use less-than-full power on an LED light, it operates more efficiently. This feature leads to other benefits, as well. It increases the lifespan of the bulb, and it means that you are using less energy, thereby reducing your energy costs.

It’s important to note that you cannot use traditional equipment for dimming lights when using LEDs. They need hardware that is specific to their technology.

10. Directionality

Every conventional lighting technology emits light at 360° around the light source. This means that if you want the light to illuminate a specific area, you'll need to purchase accessories to channel or deflect the light in the desired direction.

If you don't use something to reflect or redirect the light, you'll waste energy lighting areas that don't require illumination, which will result in higher energy costs.

An LED light, however, only lights up an area of 180°, which makes LED lighting perfect when you need recessed lighting in an industrial kitchen, hallway or bathroom. It's also ideal for lighting artwork, not only because it will not degrade the artwork but also because you won't lose any of the lighting power to the back of the light source.

3.3 DISCUSSION ON STREET LIGHT:

A street light, light pole, lamp pole, lamp post, street lamp, light standard, or lamp standard is a raised source of light on the edge of a road or path. Similar lights may be found on a railway platform. When urban electric power distribution became ubiquitous in developed countries in the 20th century, lights for urban streets followed, or sometimes led.

Many lamps have light-sensitive photocells that activate the lamp automatically when needed, at times when there is little-to-no ambient light, such as at dusk, dawn, or at the onset of dark weather conditions. This function in older lighting systems could be performed with the aid of a solar dial. Many street light systems are being connected underground instead of wiring from one utility post to another. Street lights are an important source of public security lighting intended to reduce crime.

Early lamps were used by Greek and Roman civilizations, where light primarily served the purpose of security, both to protect the wanderer from tripping on the path over something or keeping the potential robbers at bay. At that time, oil lamps were used predominantly, as they provided a long-lasting and moderate flame. A slave responsible for lighting the oil lamps in front of Roman villas was called a *lanternarius*. In the middle Ages, so-called "link boys" escorted people from one place to another through the murky, winding streets of medieval towns.

Before incandescent lamps, candle lighting was employed in cities. The earliest lamps required that a lamplighter tour the town at dusk, lighting each of the lamps. According to some sources, illumination was ordered in London in 1417 by Sir Henry Barton, Mayor of London though there is no firm evidence of this.

Public street lighting was first developed in the 16th century, and accelerated following the invention of lanterns with glass windows, which greatly improved the quantity of light. In 1588 the Parisian Parliament decreed that a torch be installed and lit at each intersection, and in 1594 the police changed this to lanterns. Still, in the mid17th century it was a common practice for travellers to hire a lantern-bearer if they had to move at night through the dark, winding streets. King Louis XIV authorized sweeping reforms in Paris in 1667, which included the installation and maintenance of lights on streets and at intersections, as well as stiff penalties for vandalizing or stealing the fixtures. Paris had more than 2,700 streetlights by the end of the 17th century, and twice as many by 1730. Under this system, streets were lit with lanterns suspended 20 yards (18 m) apart on a cord over the middle of the street at a height of 20 feet (6.1 m); as an English visitor enthused in 1698, 'The streets are lit all winter and even during the full moon!' In London, public street lighting was implemented around the end of the 17th century; a diarist wrote in 1712 that 'All the way, quite through Hyde Park to the Queen's Palace at Kensington, lanterns were placed for illuminating the roads on dark nights.

A much-improved oil lantern, called a *réverbère*, was introduced in 1745 and improved in subsequent years. The light shed from these réverbères was considerably brighter, enough that some people complained of glare. These lamps were attached to the top of lampposts; by 1817, there were 4,694 lamps on the Paris streets. During the French Revolution (1789–1799), the revolutionaries found that the lampposts were a convenient place to hang aristocrats and other opponents.

GAS LAMP LIGHTING:

The first widespread system of street lighting used piped coal gas as fuel. Stephen Hales was the first person who procured a flammable fluid from the actual distillation of coal in 1726 and John Clayton, in 1735, called gas the "spirit" of coal and discovered its flammability by accident.

William Murdoch (sometimes spelled "Murdock") was the first to use this gas for the practical application of lighting. In the early 1790s, while overseeing the use of his company's steam engines in tin mining in Cornwall, Murdoch began experimenting with various types of gas, finally settling on coal-gas as the most effective. He first lit his own house in Redruth, Cornwall in 1792.[11] In 1798, he used gas to light the main building of the Soho Foundry and in 1802 lit the outside in a public display of gas lighting, the lights astonishing the local population.

The first public street lighting with gas was demonstrated in Pall Mall, London on 28 January 1807 by Frederick Albert Winsor.

In 1811, Engineer Samuel Clegg designed and built what is now considered the oldest extant gasworks in the world. Gas was used to light the worsted mill in the village of Dolphinholme in North Lancashire. The remains of the works, including a chimney and gas plant, have been put on the National Heritage List for England. Clegg's installation saved the building's owners the cost of up to 1,500 candles every night. It also lit the mill owner's house and the street of millworkers' houses in Dolphinholme.

In 1812, Parliament granted a charter to the London and Westminster Gas Light and Coke Company, and the first gas company in the world came into being. Less than two years later, on 31 December 1813, the Westminster Bridge was lit by gas.

Following this success, gas lighting spread outside London, both within Britain and abroad. The first place outside London in England to have gas lighting, was Preston, Lancashire in 1816, where Joseph Dunn's Preston Gaslight Company introduced a new, brighter gas lighting. Another early adopter was the city of Baltimore, where the gaslights were first demonstrated at Rembrandt Peale's Museum in 1816, and Peale's Gas Light Company of Baltimore provided the first gas streetlights in the United States. In the 1860s, streetlights were started in the Southern Hemisphere in New Zealand.

In Paris, public street lighting was first installed on a covered shopping street, the Passage des Panoramas, in 1817, private interior gas lighting having been previously demonstrated in a house on the rue Saint-Dominique seventeen years prior. The first gas lamps on the main streets of Paris appeared in January 1829 on the place du Carrousel and the Rue de Rivoli, then on the Rue de la Paix, place Vendôme, and rue de Castiglione. By 1857, the *Grands Boulevards* were all lit with gas; a Parisian writer enthused in August 1857: "That which most enchants the Parisians is the new lighting by gas of the boulevards...From the church of the Madeleine all the way to rue Montmartre, these two rows of lamps, shining with a clarity white and pure, have a marvelous effect." The gaslights installed on the boulevards and city monuments in the 19th century gave the city the nickname "The City of Light."

Oil-gas appeared in the field as a rival of coal-gas. In 1815, John Taylor patented an apparatus for the decomposition of "oil" and other animal substances. Public attention was attracted to "oil-gas" by the display of the patent apparatus at Apothecary's Hall, by Taylor & Martineau.

The first modern streetlamps to use kerosene (1000 pieces) were in service in Bucharest, Romania in 1857, setting thus a new world record. In Brest, street lighting with kerosene lamps reappeared in 2009 in the shopping street as a tourist attraction.

ARC LAMPS:

The first electric street lighting employed arc lamps, initially the 'Electric candle', 'Jablotchkoff candle', or 'Yablochkov candle' developed by a Russian, Pavel Yablochkov, in 1875. This was a carbon arc lamp employing alternating current, which ensured that both electrodes were consumed at equal rates. In 1876, the common council of the City of Los Angeles ordered four arc lights installed in various places in the fledgling town for street lighting.[16]

On 30 May 1878, the first electric streetlights in Paris were installed on the avenue de l'Opera and the Place d'Étoile, around the Arc de Triomphe, to celebrate the opening of the Paris Universal Exposition. In 1881, to coincide with the Paris International Exposition of Electricity, streetlights were installed on the major boulevards. [17]

The first streets in London lit with the electrical arc lamp were by the Holborn Viaduct and the Thames Embankment in 1878. More than 4,000 were in use by 1881, though by then an improved differential arc lamp had been developed by Friedrich von Hefner-Alteneck of Siemens & Halske. The United States was quick in adopting arc lighting, and by 1890 over 130,000 were in operation in the US, commonly installed in exceptionally tall moonlight towers.

Arc lights had two major disadvantages. First, they emit an intense and harsh light which, although useful at industrial sites like dockyards, was discomforting in ordinary city streets. Second, they are maintenance-intensive, as carbon electrodes burn away swiftly. With the development of cheap, reliable and bright incandescent light bulbs at the end of the 19th century, arc lights passed out of use for street lighting, but remained in industrial use longer.

INCANDESCENT LAMP:

The first street to be lit by an incandescent lightbulb was Chesterfield Street, in Chesterfield. The street was lit for one night by Joseph Swan's incandescent lamp on 3 February 1879. Consequently, Newcastle has the first city street in the world to be lit by electric lighting. The first city in the United States to successfully demonstrate electric lighting was Cleveland, Ohio with 12 electric lights around the Public Square road system on 29 April 1879. Wabash, Indiana lit 4 Brush arc lamps with 3,000 candlepower each, suspended over their courthouse on 2 February 1880, making the town square "as light as midday".

Kimberley, Cape Colony (modern South Africa), was the first city in the Southern Hemisphere and in Africa to have electric streetlights – with 16 first lit on 2 September 1882. The system was only the second in the world, after that of Philadelphia, to be powered municipally.

On 9 December 1882, Brisbane, Queensland, Australia was introduced to electricity by having a demonstration of 8 arc lights, erected along Queen Street Mall. The power to supply these arc lights was taken from a 10 hp Crompton DC generator driven by a Robey steam engine in a small foundry in Adelaide Street and occupied by J. W. Sutton and Co. In 1884 Walhalla, Victoria, Victoria, had two lamps installed on the main street by the Long Tunnel (Gold) Mining Company. In 1886, the isolated mining town of Waratah in Tasmania was the first to have an extensive system of electrically powered street lighting installed. In 1888, the New South Wales town of Tamworth installed a large system illuminating a significant portion of the city, with over 13 km of streets lit[26] by 52 incandescent lights and 3 arc lights. Powered by a municipal power company, this system gave Tamworth the title of "First City of Light" in Australia.

On 10 December 1885, Härnösand became the first town in Sweden with electric street lighting, following the Gådeå power station being taken into use.[28]

MODERN TECHNOLOGY:

Today, street lighting commonly uses high-intensity discharge lamps. Low-pressure sodium (LPS) lamps became common place after World War II for their low power consumption and long life. Late in the 20th century high-pressure sodium (HPS) lamps were preferred, taking further the same virtues. Such lamps provide the greatest amount of photopic illumination for the least consumption of electricity. However, white light sources have been shown to double driver peripheral vision and improve driver brake reaction time by at least 25%; to enable pedestrians to better detect pavement trip hazards and to facilitate visual appraisals of other people associated with interpersonal judgements. Studies comparing metal halide and high-pressure sodium lamps have shown that at equal photopic light levels, a street scene illuminated at night by a metal halide lighting system was reliably seen as brighter and safer than the same scene illuminated by a high-pressure sodium system.

Two national standards now allow for variation in illuminance when using lamps of different spectra. In Australia, HPS lamp performance needs to be reduced by a minimum value of 75%. In the UK, illuminances are reduced with higher values S/P ratio.

New street lighting technologies, such as LED or induction lights, emit a white light that provides high levels of scotopic lumens, allowing streetlights with lower wattages and lower photopic lumens to replace existing streetlights. However, there have been no formal specifications written around Photopic/Scotopic adjustments for different types of light sources, causing many municipalities and street departments to hold back on implementation of these new technologies until the standards are updated. Eastbourne in East Sussex, UK is currently undergoing a project to see 6000 of its streetlights converted to LED and will be closely followed by Hastings in early 2014. Many UK councils are undergoing mass-replacement schemes to LED, and though streetlights are being removed along many long stretches of UK motorways (as they are not needed and cause light pollution), LEDs are preferred in areas where lighting installations are necessary.

Milan, Italy, is the first major city to have entirely switched to LED lighting.

In North America, the city of Mississauga (Canada) was one of the first and biggest LED conversion projects, with over 46,000 lights converted to LED technology between 2012 and 2014. It is also one of the first cities in North America to use Smart City technology to control the lights. DimOnOff, a company based in Quebec City, was chosen as a Smart City partner for this project.

Photovoltaic-powered LED luminaires are gaining wider acceptance. Preliminary field tests show that some LED luminaires are energy-efficient and perform well in testing environments.

In 2007, the Civil Twilight Collective created a variant of the conventional LED streetlight, namely the Lunar-resonant streetlight. These lights increase or decrease the intensity of the streetlight according to the lunar light. This streetlight design thus reduces energy consumption as well as light pollution.

ADVANTAGES:

Major advantages of street lighting include prevention of automobile accidents and increase in safety. Studies have shown that darkness results in numerous crashes and fatalities, especially those involving pedestrians; pedestrian fatalities are 3 to 6.75 times more likely in the dark than in daylight. At least in the 1980s and 1990s, when automobile crashes were far more common, street lighting was found to reduce pedestrian crashes by approximately 50%. Furthermore, in the 1970s, lighted intersections and highway interchanges tended to have fewer crashes than unlighted intersections and interchanges.

Some say lighting reduces crime, as many would expect. However, others say any correlation (let alone causation) is not found in the data.

Towns, cities, and villages can use the unique locations provided by lampposts to hang decorative or commemorative banners. Many communities in the US use lampposts as a tool for fundraising via lamppost banner sponsorship programs first designed by a US based lamppost banner manufacturer.

DISADVANTAGES:

The major criticisms of street lighting are that it can actually cause accidents if misused, and cause light pollution.

<u>Health and safety:-</u>

There are two optical phenomena that need to be recognized in streetlight installations.

- The loss of night vision because of the accommodation reflex of drivers' eyes is the greatest danger. As drivers emerge from an unlighted area into a pool of light from a streetlight their pupils quickly constrict to adjust to the brighter light, but as they leave the pool of light the dilation of their pupils to adjust to the dimmer light is much slower, so they are driving with impaired vision. As a person gets older, the eye's recovery speed gets slower, so driving time and distance under impaired vision increases.
- Oncoming headlights are more visible against a black background than a grey one. The contrast creates greater awareness of the oncoming vehicle.
- Stray voltage is also a concern in many cities. Stray voltage can accidentally electrify lampposts and has the potential to injure or kill anyone who comes into contact with the post.

There are also physical dangers to the posts of streetlamps, other than children climbing them for recreational purposes. Streetlight stanchions (lamp posts) pose a collision risk to motorists and pedestrians, particularly those affected by poor eyesight or under the influence of alcohol. This can be reduced by designing them to break away when hit (known as frangible, collapsible, or passively safe supports), protecting them by guardrails, or marking the lower portions to increase their visibility. High winds or accumulated metal fatigue also occasionally topple streetlights.

LIGHT POLLUTION:

ASTRONOMY-

Light pollution can hide the stars and interfere with astronomy. In settings near astronomical telescopes and observatories, low pressure sodium lamps may be used. These lamps are advantageous over other lamps such as mercury and metal halide lamps because low pressure sodium lamps emit lower intensity, monochromatic light. Observatories can filter the sodium wavelength out of their observations and virtually eliminate the interference from nearby urban lighting. Full cut off streetlights also reduce light pollution by reducing the amount of light that is directed at the sky, which also improves the luminous efficiency of the light.

ECOSYSTEM- Streetlights can impact biodiversity and ecosystems—for instance, disrupting the migration of some nocturnally migrating bird species. In the Netherlands, Philips found that birds can get disoriented by the red wavelengths in street lighting, and in response developed alternative lighting that only emit in the green and blue wavelengths of the visible spectrum. The lamps were installed on Ameland in a small-scale test. If successful, the technology could be used on ships and offshore installations to avoid luring birds towards the open sea at night. Bats can be negatively impacted by streetlights, with evidence showing that red light can be least harmful. As a result, some areas have installed red LED streetlights to minimise disruption to bats. A study published in Science Advances reported that streetlights in southern England had detrimental impacts on local insect populations. Streetlights can also impact plant growth and the number of insects that depend on plants for food.

ENERGY CONSUMPTION-

As of 2017, globally 70% of all electricity was generated by burning fossil fuels, a source of air pollution and greenhouse gases, and also globally there are approximately 300 million streetlights using that electricity. Cities are exploring more efficient energy use, reducing streetlight power consumption by dimming lights during off-peak hours and switching to high-efficiency LED lamps. Many councils are using a part-night lighting scheme to turn off lighting at quieter times of night. This is typically midnight to 5:30 AM, as seen by the sign on the right. There have, however, been questions about the impact on crime rates. Typical collector road lighting in New York State costs $6,400/mile/year for high pressure sodium at 8.5 kW/mile or $4,000 for light-emitting diode luminaires at 5.4 kW/mile.[76] Improvements can be made by optimising directionality and shape, however. Transitioning to wide angle lights enabled the doubling of distance between streetlights in Flanders from 45 m to 90 m, cutting annual street lighting electricity expenditures to €9 million for the 2150 km long network that was retrofitted, corresponding to ca. €4186/km. A number of street light control systems have been developed to control and reduce energy consumption of a town's public lighting system. These range from controlling a circuit of street lights and/or individual lights with specific ballasts and network operating protocols. These may include sending and receiving instructions via separate data networks, at high frequency over the top of the low voltage supply or wireless.

Street light controllers are smarter versions of the mechanical or electronic timers previously used for street light ON-OFF operation. They come with energy conservation options like twilight saving, staggering or dimming. Many street light controllers come with an astronomical clock for a particular location or a Global Positioning System (GPS) connection to give the best ON-OFF time and energy saving.

BEACON LIGHTING

Decorative but functional lamps in the Plaza at sunset, Samaipata, Bolivia

A modest steady light at the intersection of two roads is an aid to navigation because it helps a driver see the location of a side road as they come closer to it, so that they can adjust their braking and know exactly where to turn if they intend to leave the main road or see vehicles or pedestrians. A beacon light's function is to say "here I am" and even a dim light provides enough contrast against the dark night to serve the purpose. To prevent the dangers caused by a car driving through a pool of light, a beacon light must never shine onto the main road, and not brightly onto the side road. In residential areas, this is usually the only appropriate lighting, and it has the bonus side effect of providing spill lighting onto any sidewalk there for the benefit of pedestrians. On Interstate highways, this purpose is commonly served by placing reflectors at the sides of the road.

ROADWAY LIGHTING

High-mast lighting along Highway 401 in Ontario, Canada

Conventional streetlights are used instead of high-mast lighting near airport runway approaches due to the negative effects caused by the latter.

Because of the dangers discussed above, roadway lights are properly used sparingly and only when a particular situation justifies increasing the risk. This usually involves an intersection with several turning movements and much signage, situations where drivers must take in much information quickly that is not in the headlights' beam. In these situations (a freeway junction or exit ramp), the intersection may be lit so that drivers can quickly see all hazards, and a well-designed plan will have gradually increasing lighting for approximately a quarter of a minute before the intersection and gradually decreasing lighting after it. The main stretches of highways remain unlighted to preserve the driver's night vision and increase the visibility of oncoming headlights. If there is a sharp curve where headlights will not illuminate the road, a light on the outside of the curve is often justified.

If it is desired to light a roadway (perhaps due to heavy and fast multi-lane traffic), to avoid the dangers of casual placement of street lights, it should not be lit intermittently since this requires repeated eye readjustment, which causes eyestrain and temporary blindness when entering and leaving light pools. In this case, the system is designed to eliminate the need for headlights. This is usually achieved with bright lights placed on high poles at close, regular intervals so that there is consistent light along the route. The lighting goes from curb to curb.

Further information: pedestrian crossing Lighting.

Safe cycling with a dedicated bicycle path with street lights in London

CYCLE PATH LIGHTING

Lights similar to street lights are used at train stations; these are at London King's Cross

A man performing maintenance on a street light in Tokyo

A *Fietspad* or bicycle path in the Netherlands with street lighting

Policies that encourage utility cycling have been proposed and implemented, including lighting bike paths to increase safety at night.

4. DIFFERENT COMPONENTS OF THE PROPOSE SYSTEM

4.1 LoRa Ra-02

The SEMTECH SX1278 transceiver was the foundation for the Ra-02 wireless transmission module. LoRa spread spectrum technology has a 10,000-metre communication range. Strong anti-jamming abilities as well as an air wake-up feature. high power output of +20 dBm and a sensitivity of -148 dBm. The Ra-02 may be used for extremely long-range spread spectrum communication, and it is compatible with FSK remote modulation and demodulation quickly, which solves the problem that the typical wireless design cannot take into consideration distance, anti-interference, and power consumption. The Ra-02 addresses the issue that the standard wireless design cannot take into account distance, anti-interference, and power consumption. It may be used for exceptionally long-range spread spectrum communication and is compatible with FSK remote modulation and demodulation swiftly.

Features:
LoRa ™ spread spectrum modulation technology
Receive sensitivity as low as -141 dBm
Excellent resistance to blocking
Supports preamble detection
Supports half-duplex SPI communication
Programmable bit rate up to 300Kbps
Supports FSK, GFSK, MSK, GMSK, LoRa ™ and OOK modulation modes
Supports automatic RF signal detection, CAD mode and ultra-high-speed AFC
Packets with CRC, up to 256 bytes - small package with double volume stamps

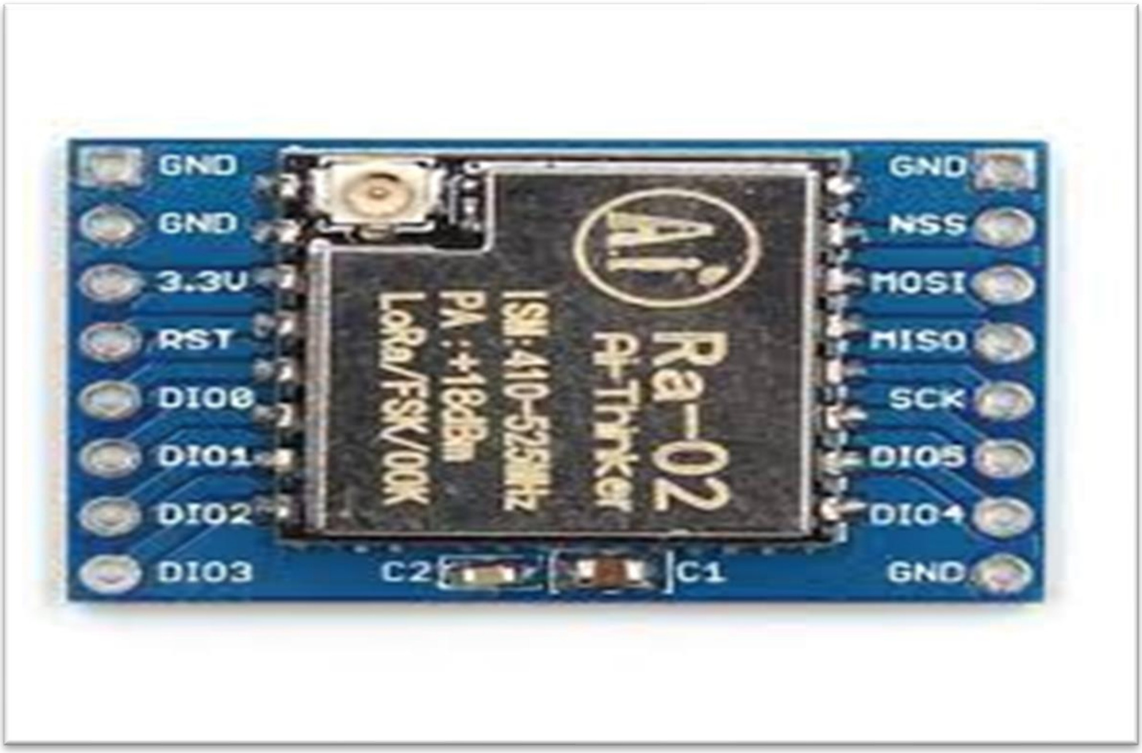


Fig: 4.1 LoRa Ra-02

4.2 ARDUINO UNO Module

A microcontroller board called Arduino Uno is based on the ATmega328P (datasheet). It has a 16 MHz quartz crystal, 6 analogue inputs, 14 digital input/output pins (of which 6 can be used as PWM outputs), a USB port, a power jack, an ICSP header, and a reset button. It comes with everything required to support the microcontroller; to use it, just plug in a USB cable, an AC-to-DC adapter, or a battery to power it. Both an external power supply and a USB connection are options for powering the Arduino Uno board. The power source is automatically chosen. Either a battery or an AC-to-DC adapter (wall wart) can provide external (non-USB) power. A 2.1mm center-positive plug can be used to connect the adapter by inserting it into the board's power connector. Battery leads may be placed into the POWER connector's GND and Vin pin headers. The board may run off of a 6-to-20-volt external source. The 5V pin, however, may deliver less than five volts if supplied with less than 7V, and the board may become unstable. The voltage regulator could overheat and harm the board if more than 12V is used. The suggested range is 7-12 volts.

Specification:

- Microcontroller: ATmega328P

- Operating Voltage: 5V
- Input Voltage (recommended): 7-12V
- IN out Voltage (limit): 6-20V
- Digital I/O Pins: 14 (of which 6 provide PWM output)
- PWM Digital I/O Pins: 6
- Analog Input Pins: 6
- DC Current per I/O Pin: 20 mA
- DC current for 3.3V Pin: 50 mA
- Flash Memory: 32 KB (ATmega328P) of which 0.5 KB used by bootloader
- SRAM: 2 KB (ATmega328P)
- EEPROM: 1 KB (ATmega328P)
- Clock Speed: 16 MHz
- LED_BUILTIN: 13
- Length: 68.6 mm
- Width: 58.4 mm
- Weight: 25 g

These are the power pins:

Vin: Rather than the 5 volts from the USB connection or other regulated power sources, the Arduino/Genuino board's input voltage when it is powered by an external power source. This pin can be used to access voltage that has been supplied via the power jack or to feed voltage to it.

5V: This pin provides a regulated 5V output from the board's regulator. The board can receive power from the USB connector (5V), the DC power port (7–12V), or the board's VIN pin (7–12V). Bypassing the regulator by applying power to the 5V or 3.3V pins can harm your board. We do not suggest it.

3V3: an internal regulator-generated 3.3-volt supply. 50 mA is the maximum current draw.

GND: drilled pins.

IOREF: The microcontroller's voltage reference is provided via this pin on the Arduino/Genuino board. The IOREF pin voltage can be read by a properly constructed shield, which can then choose the proper power supply or enable voltage translators on the outputs to operate with 5V or 3.3V.

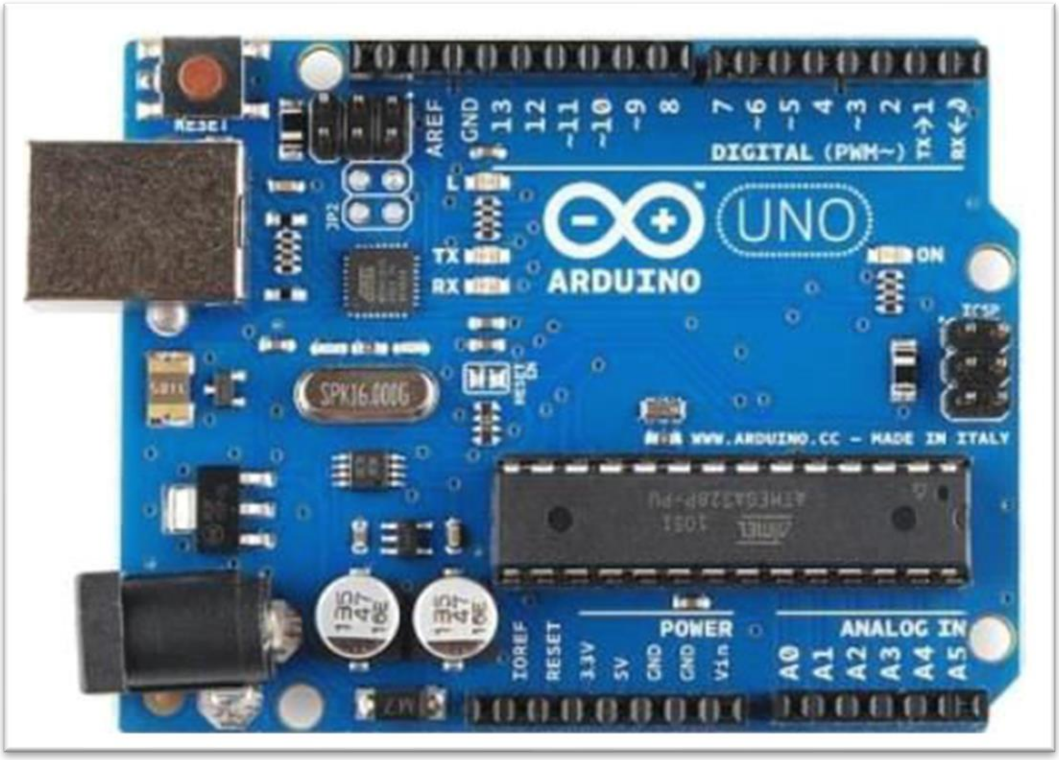


Fig: 4.2 Arduino Uno Module

4.3 COMMUNICATION SYSTEM

A communications system, often known as a communications network, is a grouping of separate telecommunications network systems, relay stations, tributary stations, and terminal equipment that may typically be interconnected and operated as a single unit. A communications system's components work together, share same goals, follow similar protocols, respond to controls, and are technically compatible.

One way to communicate is through telecommunications, which is used in journalism, mass media, sports broadcasting, etc. The process of transferring intentional meanings from one entity or group to another using signals and semiotic norms that are mutually understood is known as communication.

The medium via which a signal travels is simply referred to as a communication channel. Electrical signals can be sent using either directed or unguided medium. Any medium that may be steered from transmitter to receiver via connected wires is referred to as guided media. The medium used for optical fibre communication is an optical (glass-like) fibre. Other directed media could be twisted-pairs, telephone wire, coaxial cables, etc. Any communication route that places distance between the transmitter and receiver is referred to as unguided media. Air serves as the communication medium for radio and RF. For RF transmission, the only medium is air, however for other applications, such as sonar, the medium is typically water since sound waves can efficiently travel through some liquid mediums. Since there are no wires to connect the transmitter and receiver, both types of media are regarded as unguided. Almost anything can be used as a communication channel, from the void of space to solid metal; nonetheless, some mediums are favoured more than others. This is so that different sources can communicate through varyingly efficient subjective media.

4.3.1 LoRa MODULE

The term "LoRa" (short for "long range") refers to a specific, exclusive radio communication method. Based on chirp spread spectrum (CSS) technology, it uses spread spectrum modulation techniques. The system architecture and communication protocol are specified by LoRaWAN (Wide Area Network). The International Telecommunication Union (ITU) has recognised LoRaWAN as an official ITU-T Y.4480 standard.The open, non-profit LoRa Alliance, of which SemTech is a founding member, is in charge of overseeing the continuous development of the LoRaWAN protocol.

Together, LoRa and LoRaWAN define a Low Power, Wide Area (LPWA) networking protocol that focuses on key Internet of Things (IoT) requirements like bi-directional communication, end-to-end security, mobility, and localization services and is designed to wirelessly connect battery-operated devices to the internet in regional, national, or global networks. This sort of network differs from a wireless WAN that is intended to link users or organisations, carry more data, and use more power due to its low power, low bit rate, and IoT application.

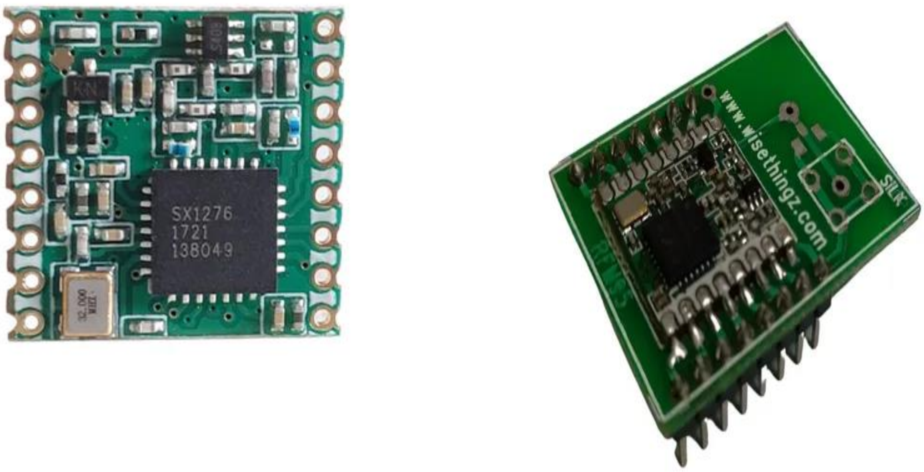


Fig: 4.3.1 LoRa Module

4.4 SENSORS

A sensor is an apparatus that generates an output signal to sense a physical occurrence.
A sensor is, in the broadest sense, a device, module, machine, or subsystem that recognises events or changes in its surroundings and transmits the data to other electronics, typically a computer processor.
Sensors are employed in several applications that most people are unaware of, such touch-sensitive lift buttons (a tactile sensor) and lamps that can be dimmed or brightened by touching the base. The uses of sensors have grown beyond the conventional disciplines of temperature, pressure, and flow measurement, for example, into MARG sensors, thanks to advancements in micromachinery and user-friendly microcontroller platforms. Potentiometers and force-sensing resistors are two common examples of analogue sensors. They are used in a variety of areas of daily life, including as manufacturing and machinery, aerospace, automobiles, and robots. Other sensors that measure the chemical and physical characteristics of materials include optical sensors for determining refractive index, vibrational sensors for determining fluid viscosity, and electro-chemical sensors for determining fluid pH.

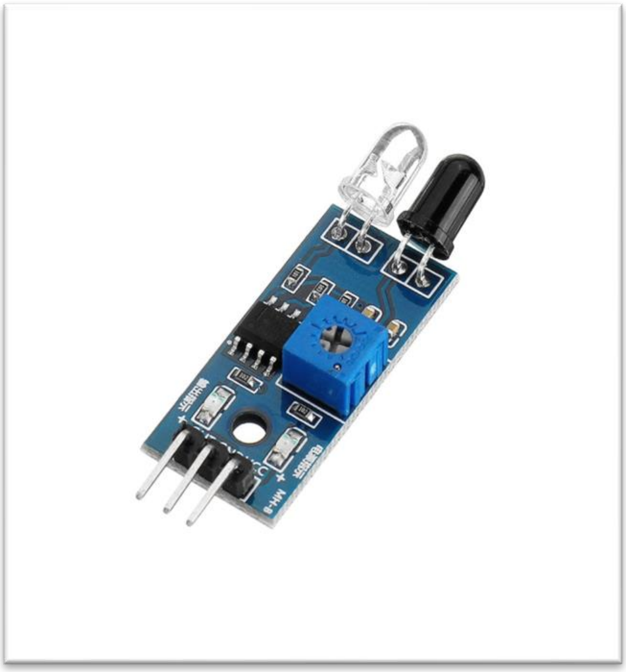


Fig: 4.4 Infrared Obstacle Avoidance IR Sensor Module

4.4.1 TEMPERATURE & HUMIDITY SENSOR

TEMPERATURE SENSOR: Temperature sensors are tools that monitor temperature and detect cold and heat, converting the information into an electrical output. Everyday objects like residential water heaters, thermometers, refrigerators, and microwaves all use temperature sensors. Temperature sensors have several uses, notably in the geotechnical monitoring industry. Temperature sensors are instruments made to gauge an object's level of coolness and heat. A temperature meter's operation is controlled by the voltage applied across the diode. The resistance of the diode determines how much the temperature changes. Resistance decreases with decreasing temperature and vice versa. Resistance across the diode is measured, and the result is translated into readable temperature units and displayed in numerical form over readout units. These temperature sensors are used in the geotechnical monitoring industry to measure the internal temperatures of buildings like dams, bridges, and power plants. The voltage across the diode's terminals is how temperature sensors function. The temperature rises in tandem with an increase in voltage. The voltage between the base and emitter terminals of the transistor in a diode then decreases. Additionally, there are temperature sensors that operate under the premise that variations in temperature lead to changes in stress. various metals have various linear coefficients of expansion in a vibrating wire thermometer. In order for any temperature change to immediately effect the tension in the wire and its natural vibration frequency, it primarily comprises of a magnetic stretched wire of high tensile strength with two ends fixed to any dissimilar metal. Aluminium can be used to create the dissimilar metal since it has a higher linear expansion coefficient than steel. The same read-out unit that is used for other vibrating wire sensors can also be used for temperature monitoring when the temperature signal is converted into frequency. The temperature change is detected by the specifically designed vibrating wire sensor, which then transforms the temperature change into an electrical signal that is sent to the reading out unit as a frequency.

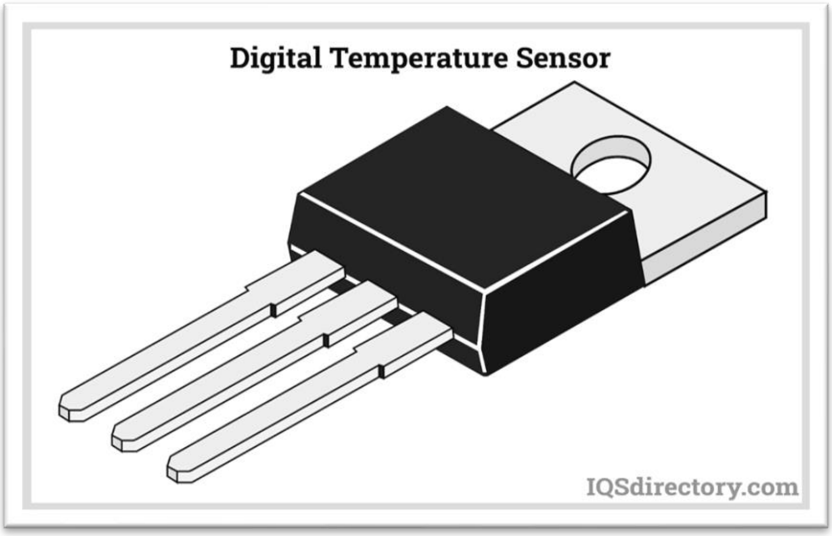


Fig: 4.4.1 Temperature Sensor

HUMIDITY SENSOR: Hydrocarbon polyelectrolyte is used as a moisture sensing substance in conventional electric resistance variable humidity sensors. Because of this, the sensors are typically not heat-resistant enough to be employed at temperatures of 60 °C or higher. They degrade when exposed to airborne oil and cigarette smoke, which is another issue. Electrical resistance significantly dropped when fluorinated pitch-deposited coating was breathed on, but it soon increased when the operation was halted. Then, efforts were made to figure out how to create a humidity sensor that excelled in humidity response sensitivity, heat resistance, and durability. A thin layer was created on the surfaces of two different types of comb-shaped electrodes with various electrode spacing using vacuum deposition of fluorinated pitch. The electrical resistance of the acquired fluorinated pitch sensors was measured under the following circumstances while they were at rest in a thermostatic chamber.

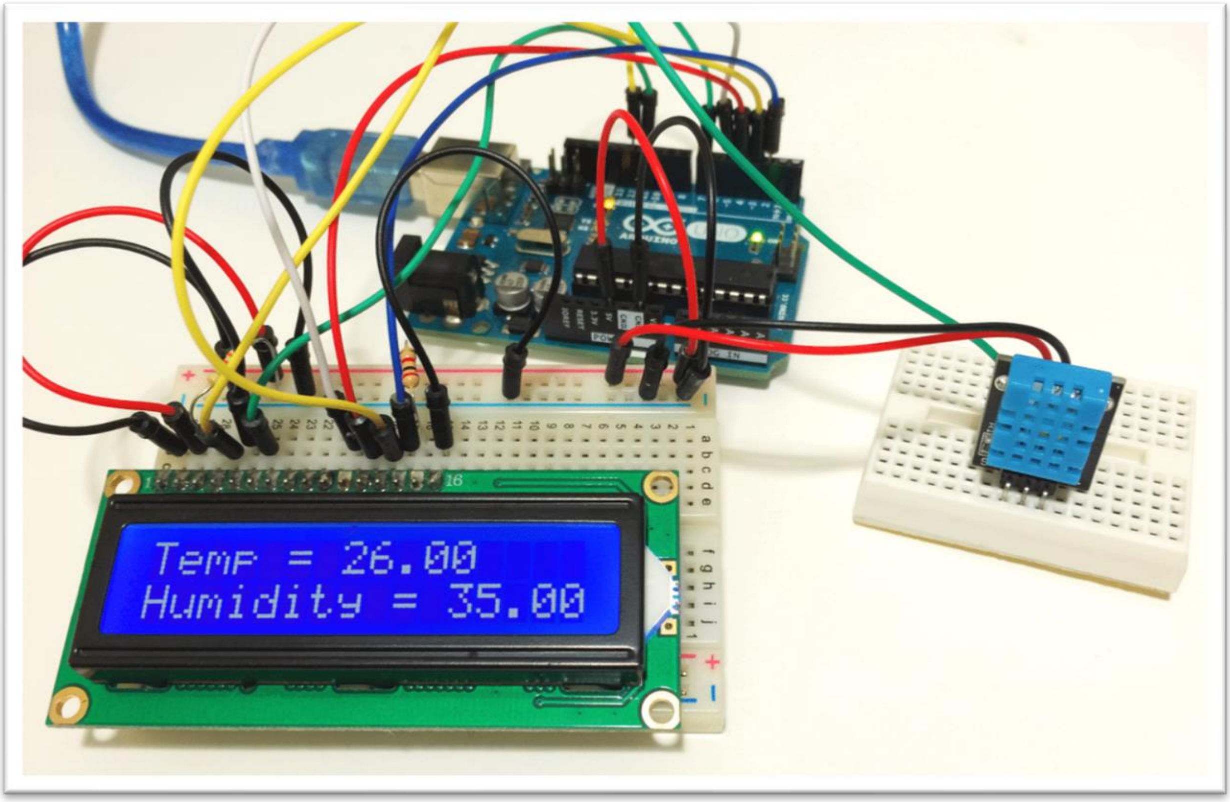


Fig: 4.4.1 Humidity Sensor on an Arduino

4.4.2 LIGHTING SENSOR

Light sensors appear to be quite simple. They detect light in the same way as a thermometer detects temperature and a speedometer detects speed. We perceive temperature and speed in a straightforward manner, making them simple concepts. But light is incredibly intricate. Since temperature and speed are intense qualities, they are independent of an object's mass or size. Light can be measured either extensively by dividing by the area, in which case the amount of light collected depends on the size of the collector (for example, a huge solar array collects more light than a little solar phone charger). Illuminance, which is measured by light sensors, is a more versatile quantity than light source brightness. The light sensor can be used to determine relative distance from the source because the illuminance diminishes as the sensor travels away from a constant light.

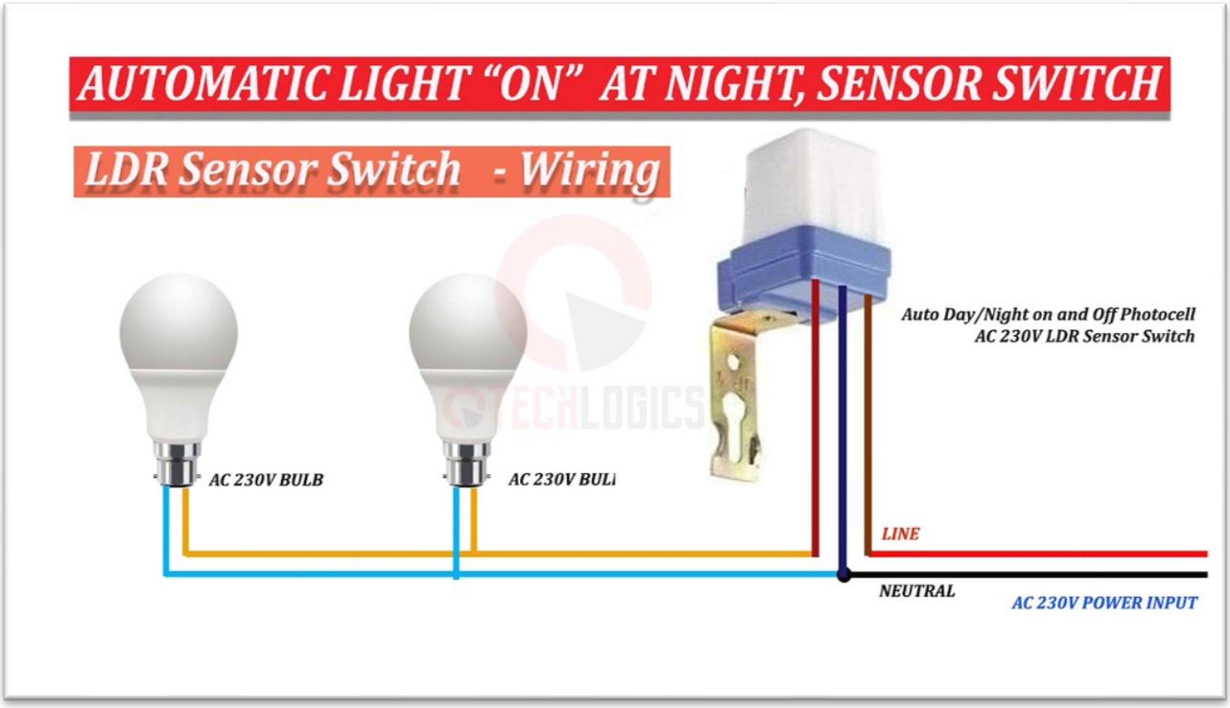


Fig: 4.4.2 Lighting Sensor

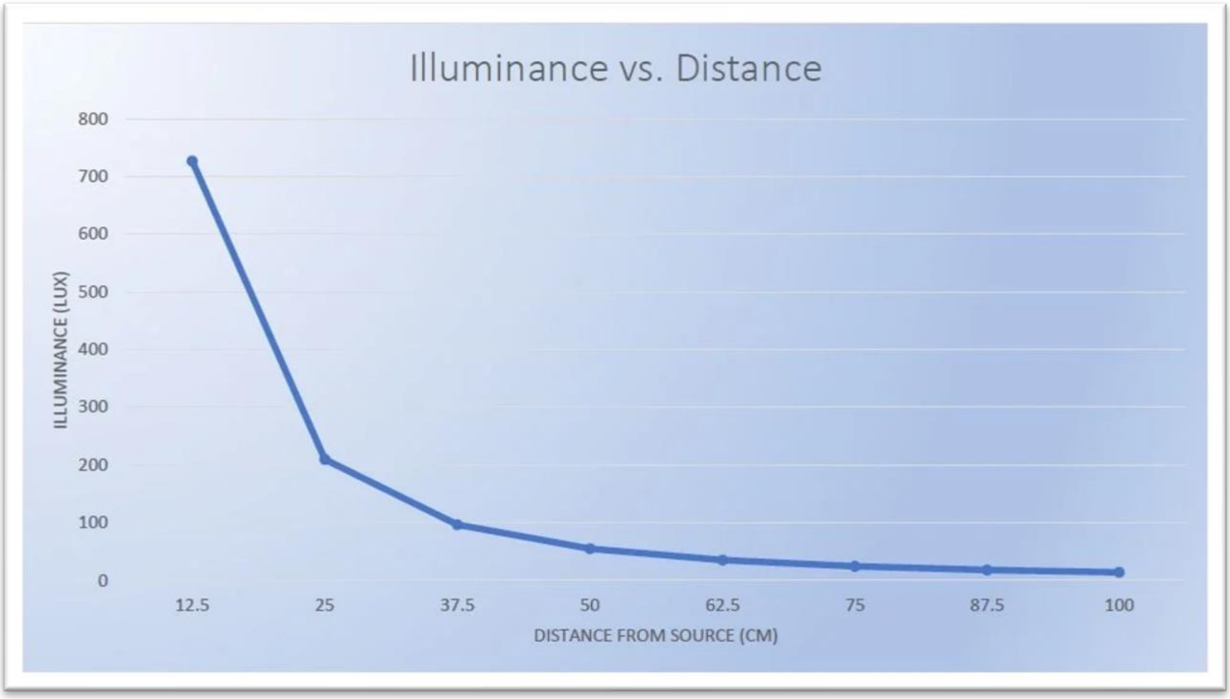


Fig: 4.4.2 Graph shows Illuminance vs Distance

4.4.3 REAL TIME CLOCK MODULE

A real-time clock (RTC) is an electronic timekeeper that most frequently takes the form of an integrated circuit. RTCs are present in practically any electronic device that requires a means of accurately maintaining the time of day, although the word frequently referring to the components in personal computers, servers, and embedded systems. Even though keeping time is possible without an RTC, doing so has advantages. Low power requirements (essential when using backup power) liberate the primary system for urgent tasks sometimes more precise than alternative techniques. By comparing the current time as indicated by the RTC of the GPS receiver with the time when it last received a signal, it is possible to reduce the starting time of the device. The prior ephemeris is still valid if it has only been a short while. Real time clocks are not used in all motherboards. Real time clocks may not be required at all (as in the Arduino system architecture) or they may be excluded to save money (as in the Raspberry Pi system architecture). For an Arduino, recording the current date and time serves a variety of functions. It can be utilised for logging and recording reasons. For instance, timestamps are required for capturing meteorological data on an Arduino weather station. Another illustration is a digital clock or calendar made with an Arduino. Arduino-based clocks use the current time to trigger scheduled commands or serve as a timer for reminders using the Arduino's I/O pins. Knowing how to obtain the current date and time depends on the project. The current date and time can be obtained in a number of ways. It can be obtained from a time server, a GPS device, or a real-time clock (RTC).

Real-Time Clock (RTC) - An integrated circuit that maintains track of time is known as a real-time clock, or simply an RTC. In the case that the main power source is cut off, it uses a backup battery to keep the time.

Global Positioning System (GPS): A GPS gadget uses satellite communication to pinpoint its location in any part of the world. Time information is included in the GPS data. A time server is a computer connected to a network that distributes time across the network by reading the time from a reference clock. An atomic clock, a radio clock, or another time server can act as a time server's clock source. Due to its low power consumption, an RTC is a very common and reliable source of time and date in an embedded system like an Arduino.

Fig : 4.4.3 Real Time Clock Module

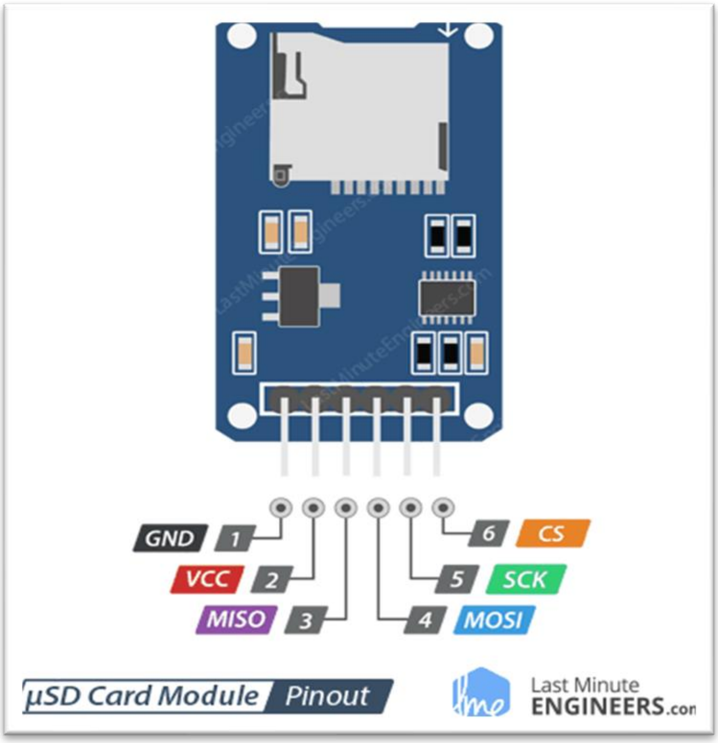
4.5 MICROSD TF CARD ADAPTER & READER MODULE

Microsd TF Card Adapter:

Two main parts make up the microSD card module:

The operating voltage of a typical microSD card is 3.3 V. Because of this, we are unable to directly link it to circuits that require 5V logic; in fact, any voltages higher than 3.6V run the risk of irreversibly damaging the microSD card. For this reason, the module has an internal ultra-low dropout voltage regulator that can control voltage up to 3.3V. A 74LVC125A logic level shifter chip is also included in the module, enabling simple and secure connection with your preferred 3.3V or 5V microcontroller without endangering the SD card. On the front, there is a microSD card socket. Every microSD memory card will function flawlessly. A microSD card should always be inserted in the direction specified on the module.

Fig: 4.5 Microsd TF Card Adapter



4.6 5 VOLT RELAY MODULE

A 5v relay is an automatic switch that is commonly used in an automatic control circuit and to control a high-current using a low-current signal. The input voltage of the relay signal ranges from 0 to 5V.

Pin1 (End 1): It is used to activate the relay; usually this pin one end is connected to 5Volts whereas another end is connected to the ground.

Pin2 (End 2): This pin is used to activate the Relay.

Pin3 (Common (COM)): This pin is connected to the main terminal of the Load to make it active.

Pin4 (Normally Closed (NC)): This second terminal of the load is connected to either NC/ NO pins. If this pin is connected to the load, then it will be ON before the switch.

Pin5 (Normally Open (NO)): If the second terminal of the load is allied to the NO pin, then the load will be turned off before the switch.

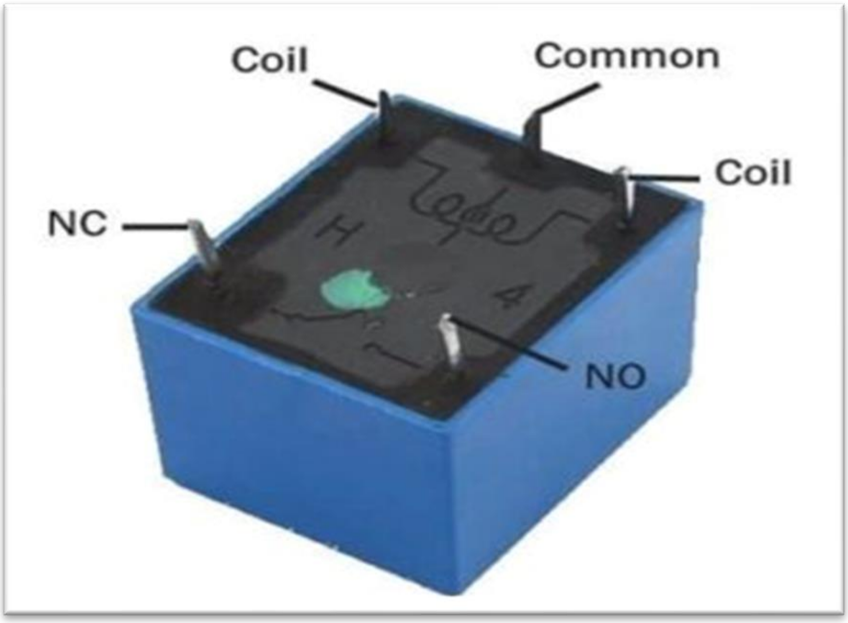


Fig: 4.6 5 VOLT RELAY MODULE

4.7 POWER ADAPTER (9 VOLT DC POWER)

A source of electricity for electronics. Power adapters plug into a wall socket and change AC current into a single DC voltage. They are sometimes known as "AC adapters" or "chargers." The power adapter is the external component of the power supply for a laptop. Computers require various DC voltages. Internal circuits produce the additional DC volts. One internal device houses the desktop PC power supplies and converts AC to all DC voltages.

Power adapters can also be used for other things, such as to output a different AC voltage instead of DC. See USB charger, wall wart, wall tap, power strip, power supply, and power distribution unit.

A DC adapter changes alternating current into direct current, whereas an AC adapter changes alternating current from one voltage to another. Since the latter is more frequently in use, DC adapters are frequently referred to as AC adapters. This type of feed is often used in small electrical and electronic devices. For example, battery chargers, or anything chargeable like old iPods, cameras, mobile phones, and many other items. Anything from shavers and rechargeable flashlights to computer speakers and modems. The adaptor converts AC wall power to 9-volt DC for powering most instrument pedals and other 9-volt battery devices. The tip negative, sleeve positive power supply can handle 500mA to power even your most power hungry devices.

Fig: 4.7 Power Adapter

4.8 2.8-WATT LED BULB

An electric light that uses light-emitting diodes (LEDs) to produce light is known as an LED lamp, LED light bulb, or LED light. LED bulbs can be much more expensive than typical fluorescent lamps and are significantly more energy-efficient than comparable incandescent lamps. The highest-performing LED lights on the market today have efficiency of 200 lumens per watt (Lm/W).Compared to incandescent bulbs, commercial LED lamps have a lifespan that is many times longer. The efficiency of LED lamps is lower than the efficiency of the LED chips they use since they need an electronic LED circuit to operate from mains power lines. To work with lamp dimmers designed for incandescent lamps, the driver circuit may need particular features. LEDs don't require any warm-up time before reaching their maximum brightness. Contrary to fluorescent lighting, frequent on and off cycles do not shorten life. As an LED ages, its light output gradually declines. Surface mount LED module arrays are frequently used to create LED lamps, which typically replace incandescent or compact fluorescent bulbs with wattages ranging from 0.5 to 200. The light is more directed, or emitted as a narrower beam, which is a key distinction from other light sources.

Fig: 4.8-Watt LED Bulb

4.9 MICROSD CARD

A sort of removable flash memory card used to store data is called a microSD. Secure Digital is referred to as SD, and microSD cards are frequently referred to as uSD or mSD.The cards are utilised by mobile devices such as handheld game consoles, cameras, and mobile phones. It is the smallest memory card available; at 15 mm 11 mm 1 mm (about the size of a fingernail), it is one-fourth the size of an SD card that is the standard size. Small microSD cards can be made to fit in gadgets that have slots for conventional SD, miniSD, Memory Stick Duo cards, and even USB with the use of adapters. However, not all of the various cards can be combined. In order to allow users to use microSD cards in devices that only accept normal SD cards instead of microSD cards, many microSD cards are offered with a standard SD converter.TransFlash and microSD cards are identical and interchangeable, except microSD supports the SDIO mode. By connecting a device in place of a memory card, this enables microSD slots to support non-memory tasks like Bluetooth, GPS, and Near Field Communication. A more recent version of the MicroSD called MicroSDHC is not backwards compatible. Despite the fact that third party software is available for some devices, some older devices cannot use the newer format. The sizes of microSD cards range from 64 MB to 32 GB, but the sizes of microSDHC cards range from 4 GB to 64 GB. croSDXC memory card sizes ranging from 8GB come in a variety of capacities ranging from 64 MB to 32 GB.
The larger ones come in miThey come in sizes ranging from 8 GB to 1 TB, although larger ones called microSDXC memory cards.

Fig: 4.9 MicroSD Card

5. MODE OF COMMUNICATION SYSTEM

The sizes of microSD cards range from 64 MB to 32 GB, but the sizes of microSDHC cards range from 4 GB to 64 GB. croSDXC memory card sizes ranging from
8GB come in a variety of capacities ranging from 64 MB to 32 GB.
The larger ones come in miA communications system, often known as a communications network, is a grouping of separate telecommunications network systems, relay stations, tributary stations, and terminal equipment that may typically be interconnected and operated as a single unit.

5.1 VARIOUS TYPES OF WIRELESS COMMUNICATION SYSTEM

When a smart system requires remote access or control, there are many wireless communication methods that can be used. There are six of these frequently used modes among them. They include:

- ✓ 2G/GSM Communication
- ✓ Internet/IPV4 Communication
- ✓ Bluetooth
- ✓ ZIGBEE
- ✓ WAN
- ✓ LP-WAN (LoRa)

5.1.1 2G/GSM Communication

A second-generation digital cellular radio access technology for Europe was created by ETSI SMG and GSM (Global System for Mobile Communications), and it is still in use today.This technology developed further over time and was given the name GERAN (GSM/EDGE Radio Access Network):

- ♦ General Packet Radio Service (GPRS)
- ♦ High Speed Circuit Switched Data (HSCSD)
- ♦ EDGE stands for Enhanced Data Rates for Global Evolution.

The analogue 1G (first generation) cellular networks were replaced by 2G networks. Short message service (SMS) and multimedia messaging service

(MMS) are then introduced as time goes on. A digital, circuit-switched network designed for full duplex voice communication was originally described by the GSM standard. The down link frequency range for the GSM standard is 935-960 MHz, and the uplink frequency range is 895-915 MHz. As time went on, it also incorporated data communications using circuit-switched transport, packet data transfer using GPRS, and Enhanced Data Rates for GSM Evolution (EDGE). This GSM trademark is owned by GSM Association. GSM is a second-generation (2G) technology that shares airwaves utilising time-division multiple access (TDMA). The 3G UMTS code division multiple access (CDMA) technology and the 4G LTE orthogonal frequency-division multiple access (OFDMA) technology standards published by the 3GPP are not included in the GSM standard. The Subscriber Identity Module, sometimes known as a SIM card, is a remarkable feature of GSM (Fig. 4.1). The SIM is a removable smart card that stores the user's phone book and subscription details. This enables the user to keep their data even after moving phones. By simply switching the SIM, the customer can even switch operators while keeping the handset. There are three types of discrete networks in the GSM standard:

- The base stations and their controllers are included in the base station subsystem.
- Network and Switching Subsystem - referred to as the "core network" at times, this component of the network most closely resembles a fixed network.
- The third alternative is the GPRS Core Network, which enables packet-based Internet connections.
- The OSS, or operations support system, is just network upkeep.

Fig: 5.1.1 SIM (subscriber identity module)

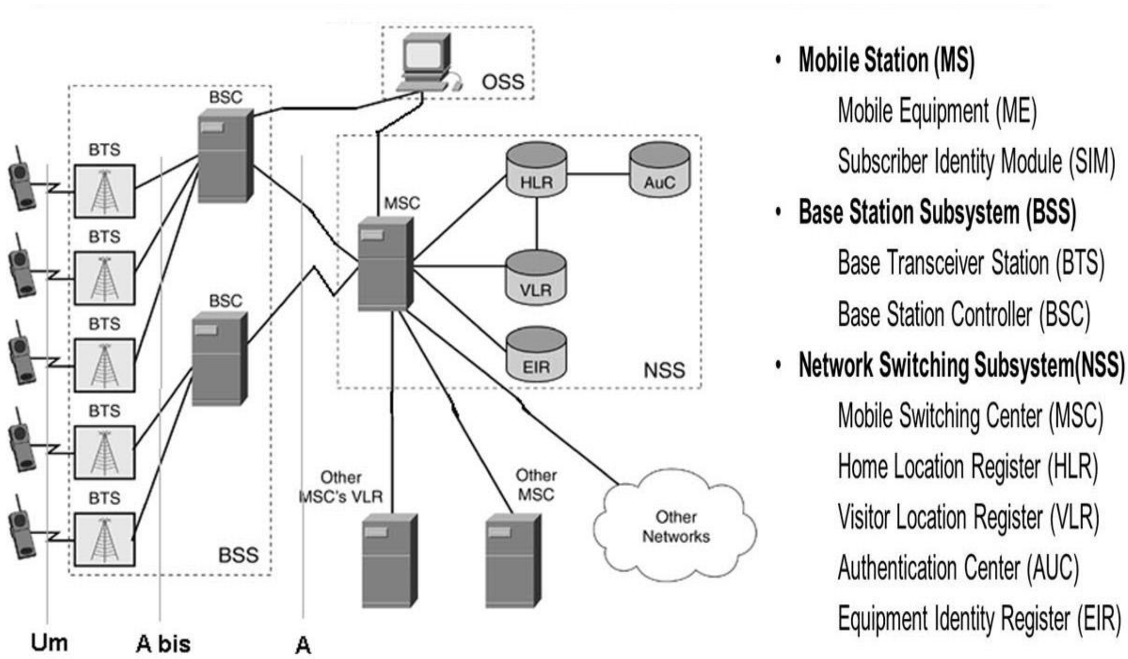


Fig: 5.1.1 GSM network structure

A call or text request is typically sent to the nearest mobile tower (BTS) when we want to call or text a specific number. This tower then converts the request for an electro-magnetic signal into a light pulse and sends it via fiber-optic cable to the base station controller (BSC), which then sends it to our home mobile switching centre (MSC 1) and searches the home MSC (MSC 2) of the requested number.

When it is located, our home MSC 1 sends the request to that number's home MSC 2. If the person we want to reach is in the zone of its home MSC 2, it will receive the call request sent by that MSC. If the person is outside of the zone, the home MSC 2 determines the person's current location and sends the request to that area's MSC 3. The person will eventually receive the request from that foreign MSC 3. The data (which might be a voice message, text message, MMS, etc.) can be transmitted to that individual utilising the established channel once a secure connection has been made. These elements combine to form the extensive GSM communication network.

5.1.2 Internet/IPV4 Communication

The Internet Engineering Task Force (IETF) first introduced the Internet Protocol (IP) standard for routing Internet traffic and other packet-switched networks in 1982. IPv4 is the fourth iteration of this standard. Despite having a 32-bit address space, IPv4 is the most popular implementation of the protocol.

Network part of IPv4: The network component identifies the unique variation assigned to the network. The network component also specifies the network's allocated category.

- Host component: A machine on your network can be uniquely identified by its host component. Each host is given access to this portion of the IPv4 address.
- The network portion of each host on the network is the same, but the host portion must differ for each host.
- The IPv4 subnet number is the optional component. Local networks with a large number of hosts are separated into subnets and given subnet numbers.

Advantages of IP V4:

- IPv4 security allows encryption to maintain security and privacy.
- The IPV4 network allocation is substantial and currently contains about 85000 useful routers.
- Without NAT, connecting multiple devices across a large network becomes simple.

- This is a model of communication that offers both cost-effective and high-quality knowledge transfer.
- Redefining IPV4 addresses allows for faultless encoding.
- Because addressing is collectively done more successfully, routing is far more scalable and cost-effective.
- In multicast organisations, network data communication becomes much more specialised.
- Limits the expansion of the internet for current users and makes it difficult for new users to use the internet.
- IPv4 Internet Routing is ineffective.
- IPv4 requires a lot of labour and is labour-intensive, complex, slow, and prone to errors.
- It's not required to use security features.
- Due to the highly high overhead associated with adding it on, it is challenging to feature support for future desires because it restricts the ability to connect things through IP.

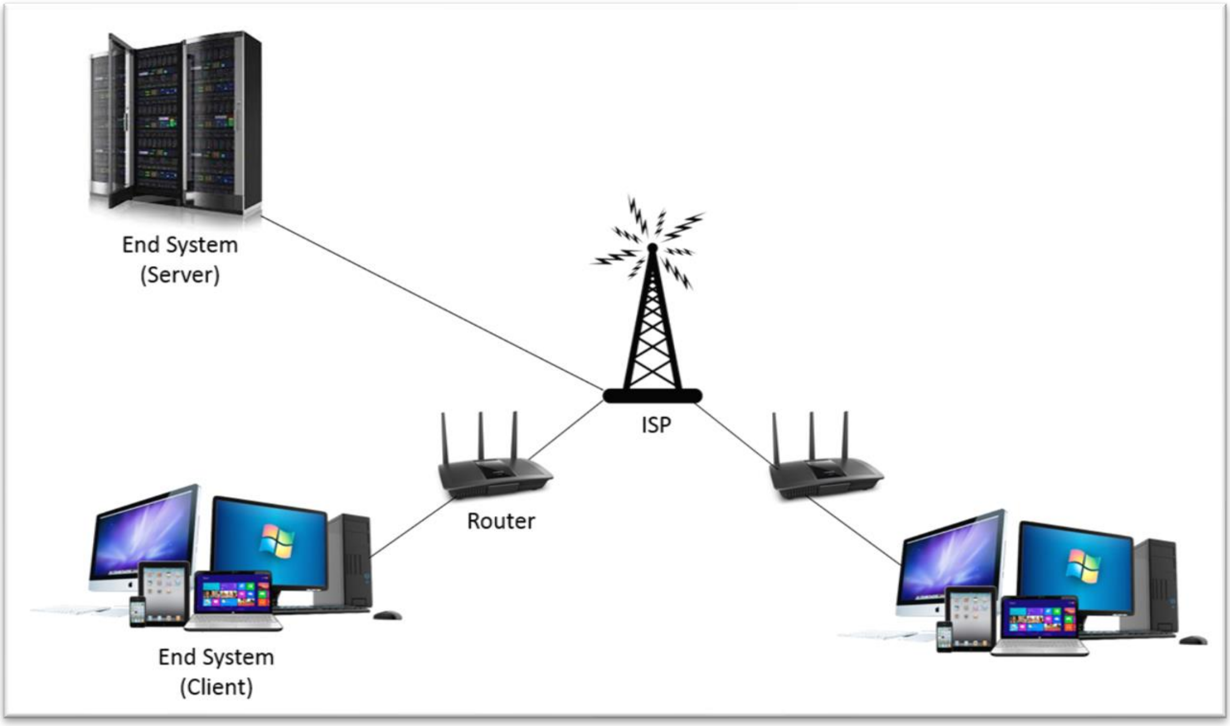


Fig: 5.1.2 Internet/IPV4 Communication

5.1.3 BLUETOOTH COMMUNICATION

Bluetooth only clings to the idea of using radio waves to send and receive data. It can be paired with another Bluetooth-enabled device, but for the connection to work, the two devices must be close enough to communicate. When two devices begin to share data, they create a network known as a piconet, which can hold up to five additional devices.

Things to keep in mind using Bluetooth:

- 720 kbps is the Bluetooth transmission speed.
- It is wireless, Bluetooth.
- A low-cost short-distance radio communications standard is Bluetooth.
- Bluetooth is reliable and adaptable.
- With the aid of Bluetooth, practically any gadget may be linked to another device without the usage of cables.
- A piconet is the fundamental component of Bluetooth's architecture.

BLUETOOTH ARCHITECTURE

Piconet: One primary node, referred to as the master node, and seven active subsidiary nodes, referred to as slave nodes, make up the Piconet type of Bluetooth network. As a result, we can state that there are 8 active nodes in total, all of which are located 10 metres apart. One-to-one or one-to-many communication between the primary and secondary nodes is possible. Slave-slave communication is not conceivable; only communication between the master and slave is potentially feasible. Additionally, it has 255 secondary nodes that are parked; these nodes cannot participate in communication unless they are activated.

Scatternet: It is created by combining different piconets. A slave who is present in one piconet can serve as the primary or master in another. This type of node can transmit a message to its slave in the other piconet when it is serving as a master after receiving it from a master in one piconet. A bridge node is the name for this kind of node. In two piconets, a station cannot be mastered.

Fig: 5.1.3 Bluetooth Communication System

BLUETOOTH PROTOCOL STACK

The radio frequency (RF) layer describes the specifics of the air interface, such as frequency, the usage of frequency hopping, and transmit power. It converts the data into RF signals and conducts modulation and demodulation. The physical features of Bluetooth transceivers are described. It distinguishes between connection-less and connection-oriented physical links.

Baseband Link Layer: The baseband, which is analogous to the MAC sub layer in LANs, is the digital heart of a Bluetooth system. It handles addressing, packet format, timing, power control, and piconet connection setup.

Link Manager protocol layer: It manages links that have already been formed, including mechanisms for authentication and encryption. It is in charge of establishing the linkages, keeping an eye on their condition, and gracefully terminating them in response to instructions or errors.

It is also referred to as the Bluetooth protocol stack's "heart," or the Logical Link Control and Adaption (L2CAP) Protocol layer. It enables communication between the Bluetooth protocol stack's upper and bottom layers. Data packets received from upper layers are packaged into the shape that lower layers require. Segmentation and multiplexing are also done by it.

SDP stands for Service Discovery Protocol, which is the layer that it operates at. It enables finding the services offered by a different Bluetooth-enabled gadget.

It is a protocol to replace the cabal. RF communication layer. It stands for Radio Frontend Component in abbreviation. With WAP and OBEX, it gives a serial interface. Additionally, it offers serial port emulation using the L2CAP (logical link control and adaption protocol). The ETSI standard TS 07.10 is the foundation of the protocol.

The acronym OBEX stands for Object Exchange. It is a protocol for exchanging objects between two devices in communication.

The abbreviation WAP stands for Wireless Access Protocol. It is used to access the internet.

TCS: Telephony Control Protocol is the abbreviation for it. It offers a phone service. This layer's primary duties are group administration and call control (setup and release) for the gateway that serves numerous devices.

User interaction with the application is made possible by the application layer.

5.1.4 ZIGBEE

For communication, Zigbee employs a mesh network architecture. A mesh network is a local area network (LAN), wireless local area network (WLAN), or virtual local area network (VLAN) that uses either a full mesh topology or a partial mesh topology for decentralised communication.

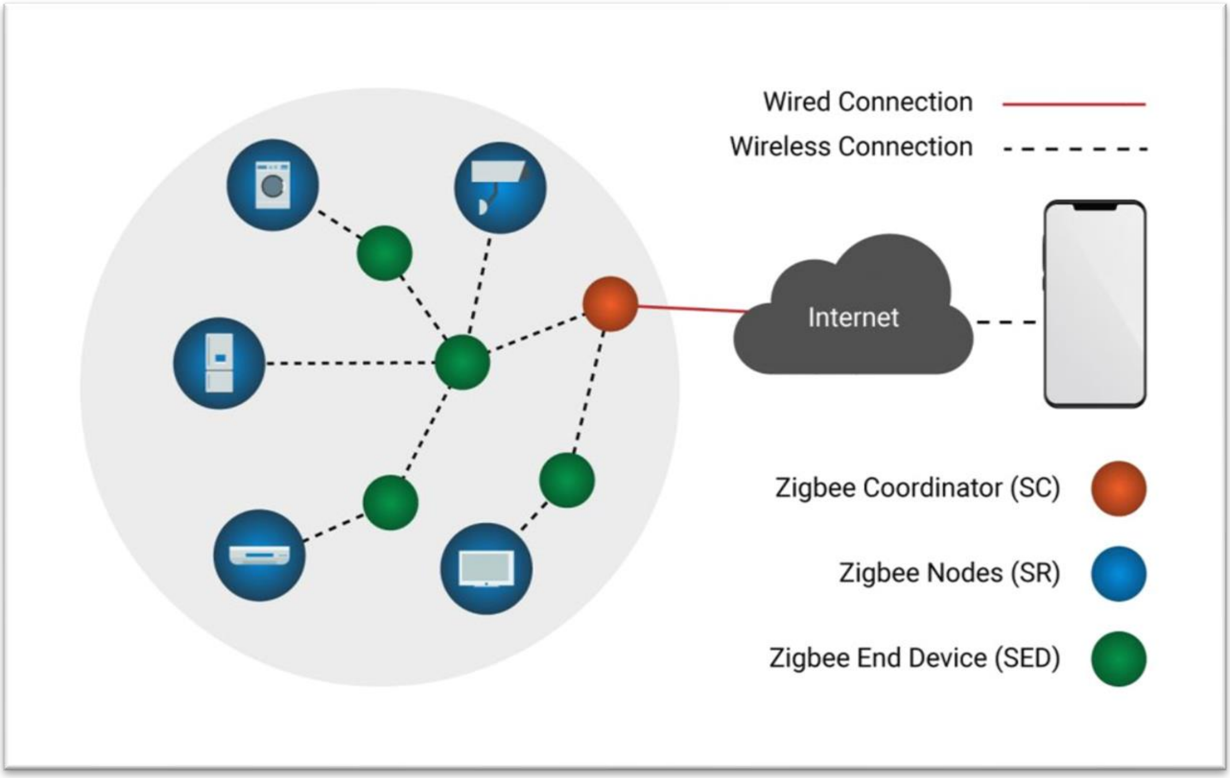


Fig: 5.1.4 ZIGBEE Communication

Another low-cost, low-power wireless technology that can be used to connect with numerous small-scale, low-powered components is called Zigbee. It adheres to the high-level communication standards known as IEEE 802.15.4, which are used to build personal area networks (PANs). Due to its low power consumption, depending on power output and ambient factors, the transmission distance ranges from 10 to 100 metres line-of-sight. In order to reach farther-off devices, Zigbee devices use a mesh network of intermediary devices to relay data across long distances. Zigbee is frequently used in applications with slow data rates. Zigbee's maximum speed is 250 kbit/s, which makes it ideal for sporadic data transmissions from sensors or input devices. In order to reach farther-off devices, Zigbee devices use a mesh network of intermediary devices to relay data across long distances. Low data rate applications that need secure networking and a long battery life frequently use zigbee technology. (Symmetric encryption keys of 128 bits are used to safeguard Zigbee networks.) The network's root is created by the Zigbee coordinator (ZC), which can also connect to servers or the internet. It may also serve as a connection point for two Zigbee networks. This gadget wirelessly transmits data to Zigbee routers (ZR), which then function as wifi routers and can broadcast data at a variety of band frequencies between 748 MHz and 2.4 GHz.

5.1.5 WAN

The technology that links your offices, data centres, cloud apps, and cloud storage is known as a wide-area network (WAN). Because it includes numerous locations dispersed across a particular geographic area, or perhaps the entire world, it is known as a wide-area network. The majority of the time, WANs use public internet to transfer data between offices, whereas the final destination for the data is a private network unique to each site (node). With the help of WAN technology, data may then be sent as needed to other ISPs after being connected to the ISP via broadband.

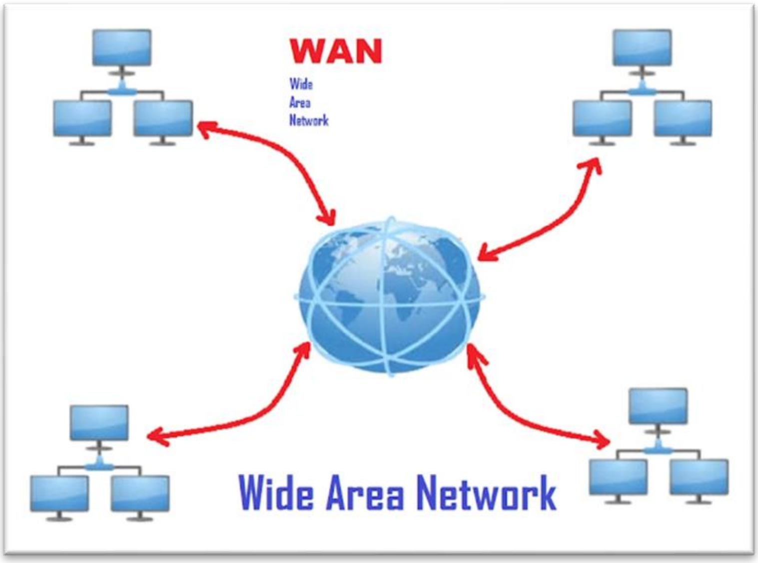


Fig: 5.1.5 Image of WAN Network

Features of WAN-

- A WAN has the capacity to connect numerous computers over a sizable area. A WAN enables your other sites to access the same information in real-time if you need to connect locations over a broad geographic area, such as a region or country.

- Connect LANs, MANs, and other networks to your WAN to provide a comprehensive experience.

- Typically designed with redundancy and resilience so that your end customers that are connected to your WAN won't be impacted if there is a line outage typically private networks for a single company.

5.1.6 LoRa MODE OF COMMUNICATION

The system architecture and communication protocol are specified by LoRaWAN (Wide Area Network). The International Telecommunication Union (ITU) has recognised LoRaWAN as an official ITU-T Y.4480 standard. The open, non-profit LoRa Alliance, of which SemTech is a founding member, is in charge of overseeing the continuous development of the LoRaWAN protocol. Together, LoRa and LoRaWAN define a Low Power, Wide Area (LPWA) networking protocol that focuses on key Internet of Things (IoT) requirements like bi-directional communication, end-to-end security, mobility, and localization services and is designed to wirelessly connect battery-operated devices to the internet in regional, national, or global networks. LoRa uses license-free sub-gigahertz radio frequency bands, such as those at 433 MHz, 868 MHz (for use in Europe), 915 MHz (for use in Australia and North America), and 923 MHz (for use in Asia). This sort of network differs from a wireless WAN, which is intended to connect consumers or businesses and transfer more data while utilising more power, in that it uses low power, low bit rates, and IoT.

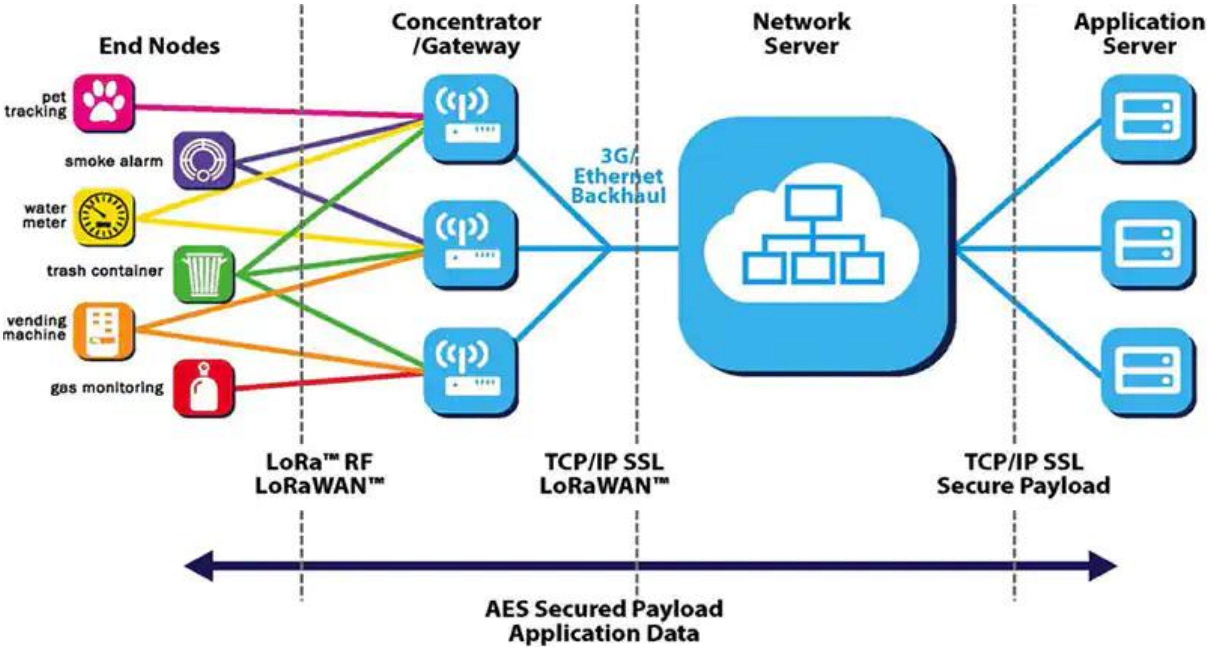


Fig: 5.1.6 LoRa Communication

With a fixed-bandwidth channel of either 125 KHz or 500 KHz (for uplink channels) or 500 KHz (for downlink channels), LoRa offers a trade-off between sensitivity and data rate. LoRa is a proprietary spread-spectrum modulation technique derived from existing Chirp Spread Spectrum (CSS) technology. LoRa also employs orthogonal spreading factors. By making adaptive optimisations of each linked end node's power levels and data rates, the network is able to prolong the battery life of connected end nodes.

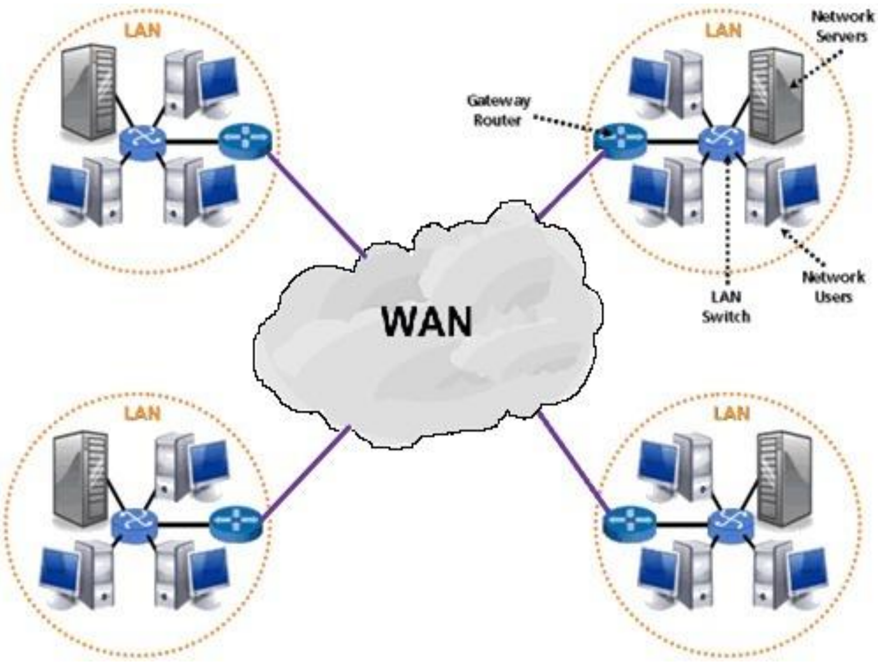


Fig: 5.1.6 Image of LoRa WAN

Since the upper networking layers were lacking, LoRa defines the lower physical layer. One of the many protocols created to specify the top levels of the network is LoRaWAN. The LoRa Alliance maintains LoRaWAN, a cloud-based media access control (MAC) layer protocol that primarily serves as a network layer protocol for LPWAN gateway and end-node device communication management. The long-range communication link is made possible by the LoRa physical layer, while LoRaWAN defines the network's communication protocol and system architecture. Additionally, LoRaWAN is in charge of controlling all devices' communication frequencies, data rates, and power. Asynchronous devices in the network only communicate when they have data to send. A number of gateways receive data packets sent by an end-node device and route them to a central network server. Data are subsequently sent to application servers. High dependability is demonstrated by the technology under moderate load. It does, however, experience some performance problems when sending acknowledgements.

6. DATA LOGGING

To analyse activities, spot trends, and assist in making predictions about the future, data logging is the process of capturing, storing, and displaying one or more datasets.

There are four main steps in the data logging process:

- The data is collected and stored by a sensor from one or more sources.
- Then, a microprocessor executes fundamental measurement and logic operations like addition, subtraction, transfers, and comparisons of numbers.
- Data from the data logger's memory unit is subsequently sent to a computer or other electronic device for analysis.
- Following analysis, the data is represented visually in a knowledge graph or chart.

6.1 Types of Data

- ILLUMINANCE
- TEMPERATURE
- HUMIDITY

6.1.1 ILLUMINACE LOGGING:

Total light flux per unit area incident on a surface is known as illumination. In general, it denotes the area's potential to be illuminated by incident light. This measurement's unit is lux, and the tool used to measure it is called a luxmeter. These are expressed as lux (lx) in SI units. It is equal to lm•m2, or lumens per square metre. The phot, or 10,000 lux, is the unit of illumination in the CGS system.

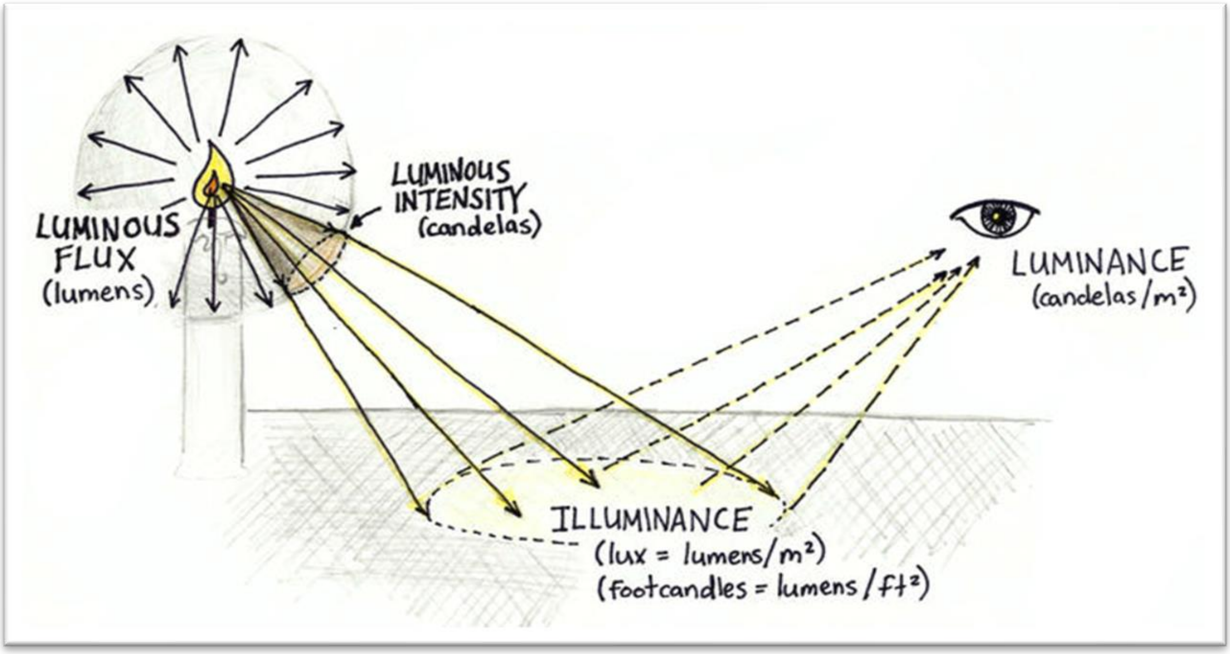


Fig: 6.1.1 Image of photometric component

The suggested system does a great job of sensing the ambient light levels around the street light pole. As a smart system, it continuously detects light level (illuminance) and saves or logs data into a microSD card for later use, such as training an AI-based street light controller or predicting the weather. There is a 30-second break between every two measures. For convenience, it records the lux value with this tag and applies a time tag to each measurement. Illuminance logging is handled by the electrical component BH1750FVI. It has a high resolution and lux levels between 1 and 65535. No matter whether we connect the component to a 5 volt or a 3.3-volt source, the positive voltage regulator of this component, model number XC6206, can provide a fixed output of 3 volts for the installed light sensor. After receiving power, the sensor here senses the ambient light intensity and transmits the information to the Arduino Mega 2560 microcontroller board, which then saves the data in a 'txt' format one by one to a file folder made in a selected microSD card. The I2C bus interface is used to connect the microSD card to the microcontroller. Additionally, a microSD card adaptor module is possible.

```
Date,Time,Illuminance lux
2020/4/1,23:43:21,0.00 lux
2020/4/1,23:43:25,22.50 lux
2020/4/1,23:43:33,21.67 lux
2020/4/1,23:43:42,4.17 lux
2020/4/1,23:43:51,21.67 lux
2020/4/1,23:43:54,23.33 lux
2020/4/1,23:43:58,23.33 lux
2020/4/1,23:44:7,21.67 lux
2020/4/1,23:44:16,21.67 lux
2020/4/1,23:44:19,22.50 lux
2020/4/1,23:44:28,22.50 lux
2020/4/1,23:44:31,22.50 lux
2020/4/1,23:44:40,43.33 lux
2020/4/1,23:44:49,20.83 lux
2020/4/1,23:44:57,20.83 lux
2020/4/1,23:45:6,20.83 lux
2020/4/1,23:45:15,20.83 lux
2020/4/1,23:45:24,20.83 lux
2020/4/1,23:45:27,20.83 lux
2020/4/1,23:45:34,20.83 lux
2020/4/1,23:45:41,20.00 lux
2020/4/1,23:45:49,20.83 lux
2020/4/1,23:45:58,20.00 lux
2020/4/1,23:46:7,23.33 lux
Date,Time,Illuminance lux
2020/4/1,23:43:21,0.00 lux
2020/4/1,23:43:30,21.67 lux
2020/4/1,23:43:39,21.67 lux
2020/4/1,23:43:47,21.67 lux
2020/4/1,23:43:56,21.67 lux
2020/4/1,23:44:5,21.67 lux
2020/4/1,23:44:11,21.67 lux
2020/4/1,23:44:18,21.67 lux
2020/4/1,23:44:25,21.67 lux
2020/4/1,23:44:32,21.67 lux
Date,Time,Illuminance lux
2020/4/1,23:43:21,21.67 lux
2020/4/1,23:43:28,21.67 lux
2020/4/1,23:43:34,21.67 lux
2020/4/1,23:43:41,21.67 lux
2020/4/1,23:43:48,21.67 lux
2020/4/1,23:43:55,21.67 lux
2020/4/1,23:44:1,21.67 lux
2020/4/1,23:44:8,21.67 lux
```

Fig: 6.1.1 Example of data collected by BH1750FVI

6.1.2 TEMPERATURE LOGGING

A temperature data logger, often known as a temperature monitor, is a portable measurement device that has the ability to independently record temperature data over a specified time period. After been recorded, the digital data can be accessed, inspected, and assessed. A data recorder that is optimised or designed for temperature probes or sensors—or, in the case of a humidity and temperature logger, humidity sensors as well—is known as a temperature data logger. A data logger is an electrical gadget that may record various measurements. It typically runs on batteries and takes one or more sensor inputs before sampling and storing the data at regular intervals. The logger is recovered and the data is downloaded into a PC for examination at the conclusion of the acquisition period. There is no longer a need for field visits thanks to some data loggers, which even send the measurement findings to a PC or another device. A logger can be made small and light by directly integrating a thermistor or thermocouple with it in one package. Its drawback is that it needs to be situated where the temperature will be measured. Because the electrical components in the device must operate within a working temperature range, this prevents internal sensor loggers from being used in high temperature situations. However, it makes them handy for recording in-transit temperatures, which may be necessary when shipping artwork or perishable goods like eggs. The temperature sensor or sensors and the recording mechanism that samples the sensor at regular intervals and records the measurement result are the two fundamental components of every temperature logger. This sensor can be positioned close to the recording system or integrated directly into it.

6.1.3 HUMIDITY LOGGING

The pharmaceutical sector, manufacturing procedures, storage facilities, test facilities, and many other areas place a high value on the long-term recording of humidity and temperature conditions. The temperature and humidity data can be statistically analysed after being logged. This offers useful knowledge about issues that may affect people's health and the calibre of goods. They are simple to operate and incredibly accurate. Wirelessly, through a network, or directly using the HW4 software are all ways to access the data. The data can be saved in Excel files or the tamper-proof LOG mode. The measured data from the data logger is tracked and saved redundantly online on a server or PC for increased security. High levels of flexibility in use and easy system maintenance are made possible by a wide variety of interchangeable probes. In pharmaceutical production procedures, storage, testing facilities, and many other sectors, long-term data monitoring of humidity and temperature conditions is crucial. After being recorded, the temperature and humidity data can be statistically analysed to map or optimise a specific process or storage area, providing important information on the circumstances that affect people's lives and the quality and efficacy of products. A tool used to measure humidity is called a hygrometer. Hygrometers are available in both analogue and digital forms, although as modern digital hygrometers are more precise, they are more frequently utilised.

6.2 DATA LOGGING PROCEDURE:

Data logging is the practise of gathering and archiving data over time in various environments or systems. It entails keeping track of numerous events. Simply said, it involves gathering information about a certain, quantifiable issue or topics, regardless of the technique employed.

There are four main steps in the data logging process:

- The data is collected and stored by a sensor from one or more sources.
- Then, a microprocessor executes fundamental measurement and logic operations like addition, subtraction, transfers, and comparisons of numbers.
- Data from the data logger's memory unit is subsequently sent to a computer or other electronic device for analysis.
- Following analysis, the data is represented visually in a knowledge graph or chart.

Data collection, measurement, storage, analysis, and alerting are all supported by a data acquisition system (DAQ), which is made up of both hardware and software components. The key distinction between a data logger and a data collecting system is independence. An independent device known as a data logger normally works with or without a computer. To operate, a data collecting system needs to be connected to a computer system. Beyond that, a data logger and a DAQ have quite different use cases. A data acquisition system is made to quickly handle sensor data for a limited amount of time. This makes a DAQ the perfect choice for cutting-edge use cases including aeronautical telemetry recording, automotive combustion analysis, military ballistics testing, and vibration analysis.

7. BLOCK DIAGRAM & FLOW CHART:

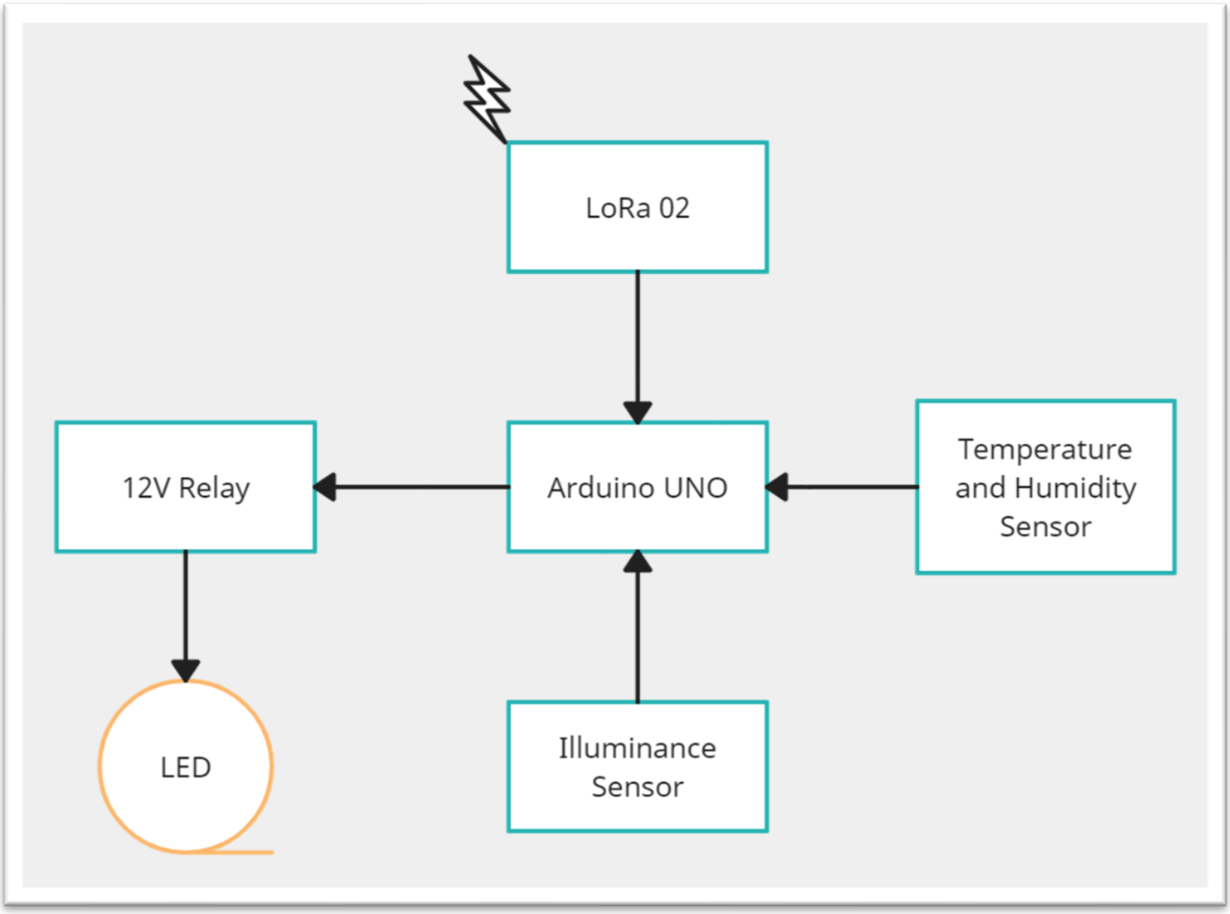


Fig: 7.1 Block Diagram of Transmitter

Along with an illumination sensor, a lora module, and temperature and humidity sensors, the transmitter circuit also included these connections. The Arduino was connected to a 12-volt relay, which handled much of the switching necessary to keep the LED on for 2 minutes and off for 3 minutes. Every day after turning on the transmitter circuit, the system was reset. The sensor would then start collecting data as the testing LED turned on for two minutes. The receiver circuit received the averaging and trans-meeting data and presented it on the GUI. After the data was displayed on the GUI, the LED would switch off for three minutes. Over the course of three months, this process was repeated.

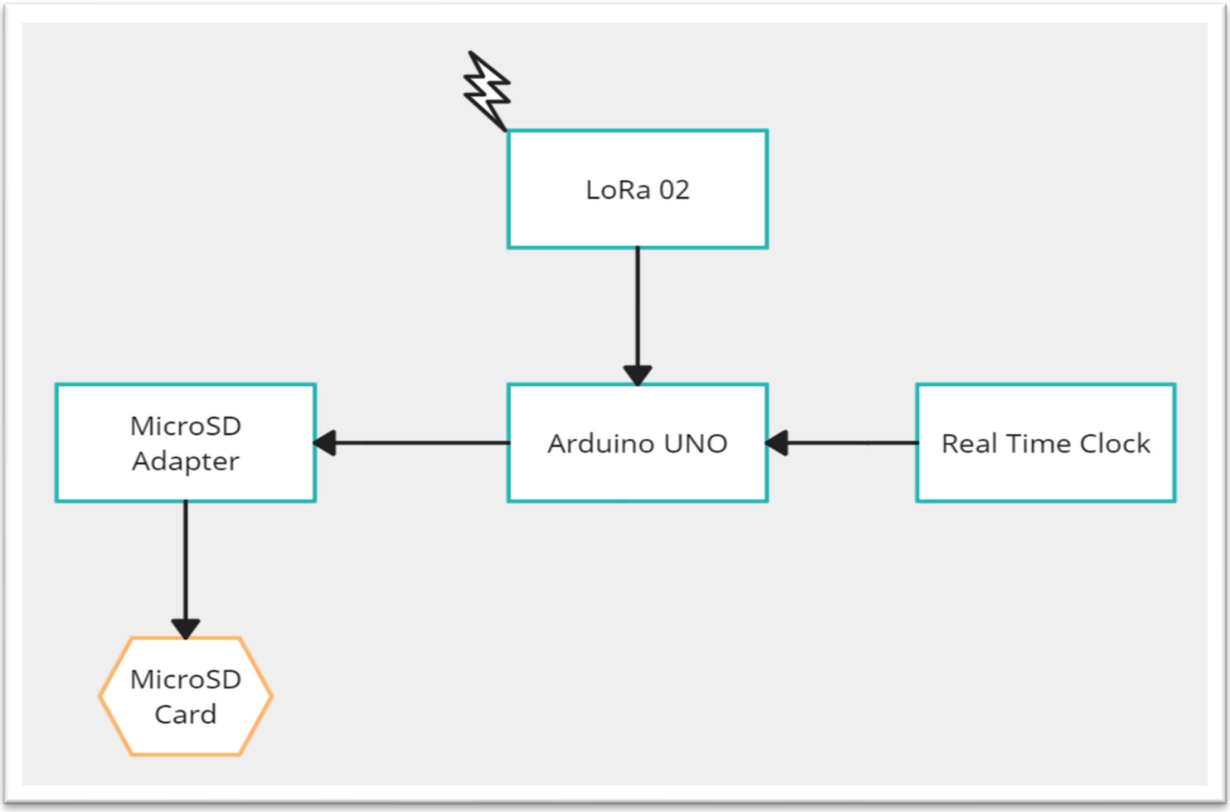


Fig: 7.2 Block Diagram of Receiver

We created a module that resembled a paper box, into which the receiver circuit was installed. The desk in the room where I was sitting on the first level was where he stored the receiver circuit. Before the device would start and the system would initialize, I would go ahead and turn on the receiver circuit. The receiver circuit receives the data and converts it bit by bit into a string. The bit-by-bit data was converted, and then the data on the micro-SD card was logged so that it could be better understood. The entire system was occasionally tested once again if no data could be obtained. For three months, this entire treatment was carried out.

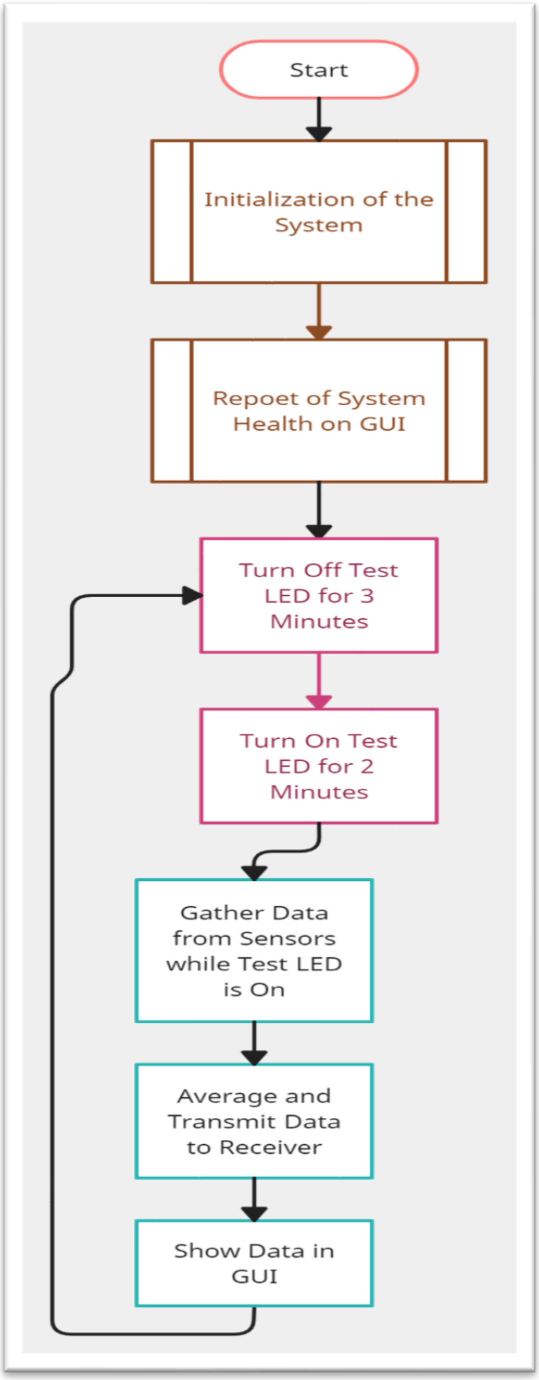


Fig: 7.3 Flow Chart of Transmitter Circuit

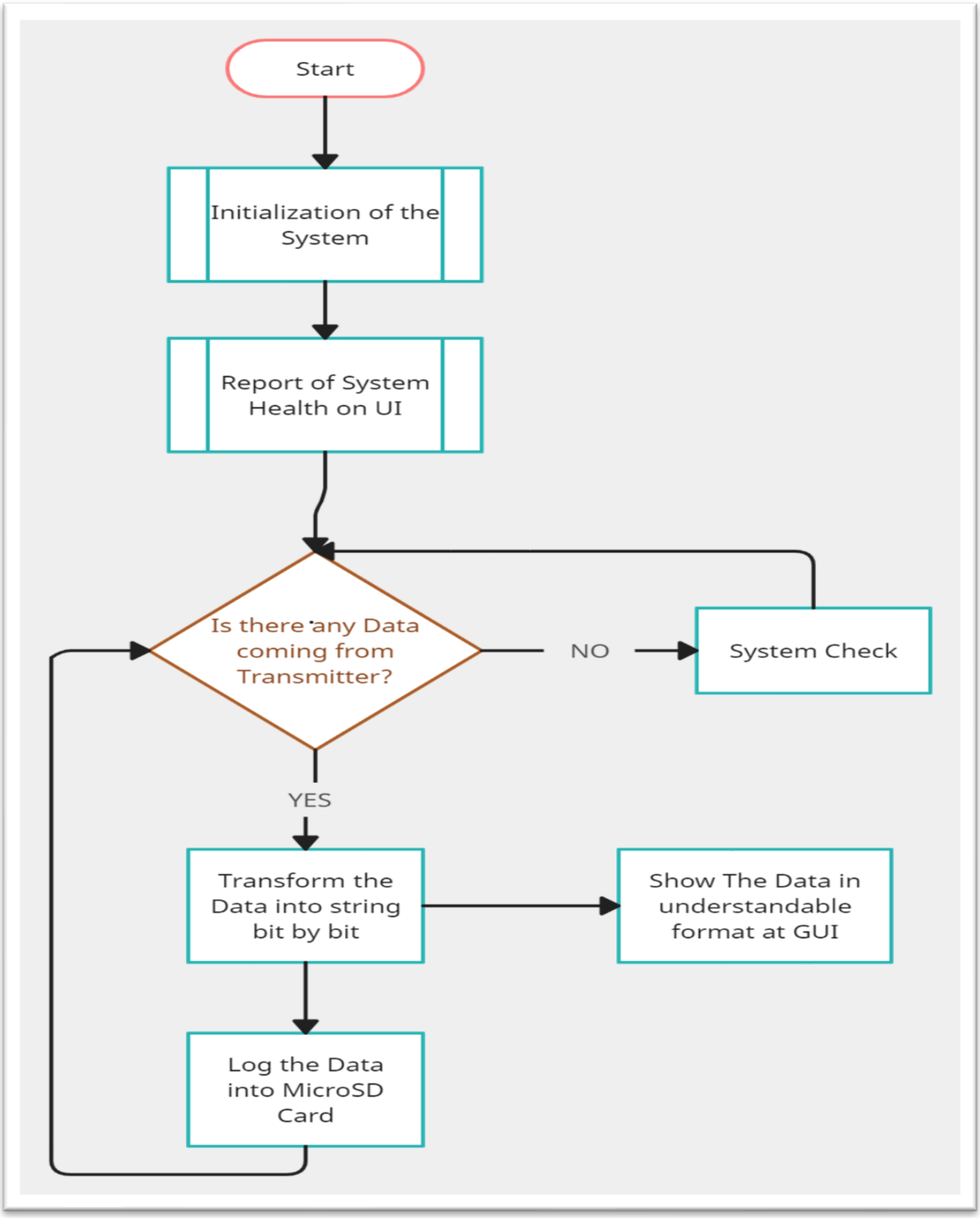


Fig: 7.4 Flow Chart of Receiver Circuit

8. CIRCUIT DIAGRAM OF THE DEVELOPED SYSTEM:

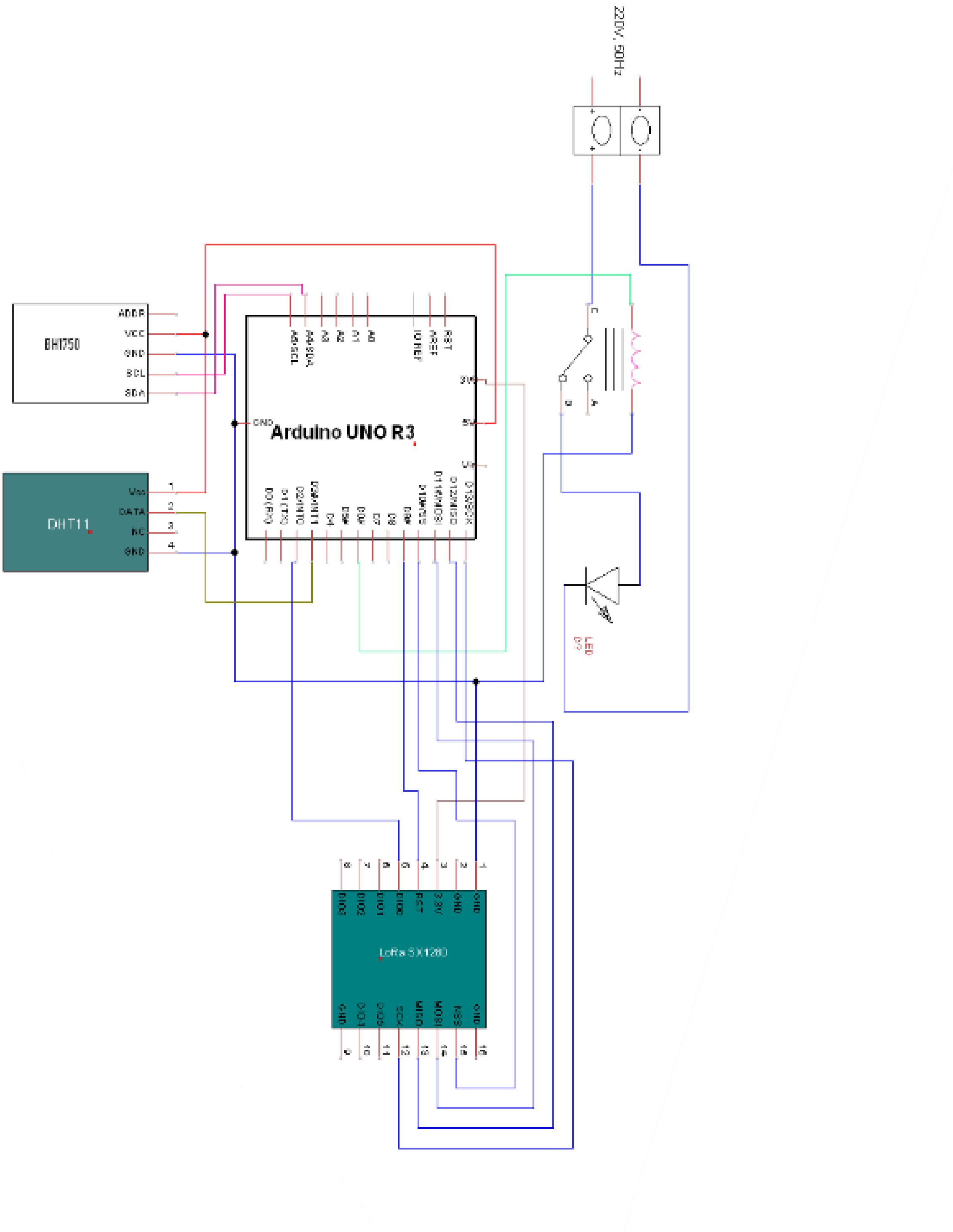


Fig: 8.1 Circuit Diagram of The Transmitter Circuit

Module SX1280 Pin - Arduino Uno Pin. If your module runs at higher voltages, VCC should be 3.3V (or 3.3V regulator output). (SPI Clock pin) GND - GND SCK – SCK.SPI Master in Slave Out pin, abbreviated MISO, The SPI Master Out Slave In pin, or MOSI, for chip select (SS/CS) in SPI communication, NSS is a digital pin (such as pin 10 or any other accessible digital pin).

BUSY - Digital pin (9 or any other accessible digital pin), used to determine whether the module is in use. For module reset, use a digital pin such as 8 or any other available digital pin. Digital pins (such as 7, 6, 5, or any other available digital pins) for interrupt handling include DIO1, DIO2, and DIO3.

BH1750 module VCC pin should be connected to Arduino Uno 5V pin. The BH1750 module's GND pin should be connected to the Arduino Uno's GND pin. A4 pin on the Arduino Uno should be connected to the SDA (Serial Data) pin on the BH1750 module. A5 pin of the Arduino Uno should be connected to the SCL (Serial Clock) pin on the BH1750 module. Pull-up resistors on the SDA and SCL channels might already be present in some BH1750 modules. If not, you can add pull-up resistors of 4.7 k ohm between the breadboard's SDA and 5V pins and SCL and 5V pins. Place the DHT11 sensor on the breadboard. Connect the Arduino Uno's 5V pin to the VCC pin of the DHT11 device. Connect the Arduino Uno's GND (ground) pin to the GND (ground) pin of the DHT11 sensor. Connect the Arduino Uno's digital pin to the DHT11's OUT pin. Let's use digital pin 2 for this demonstration. Next, connect a 10k ohm resistor to the DHT11's OUT pin and VCC (5V) pin. For single-wire communication, this resistor serves as a pull-up resistor.

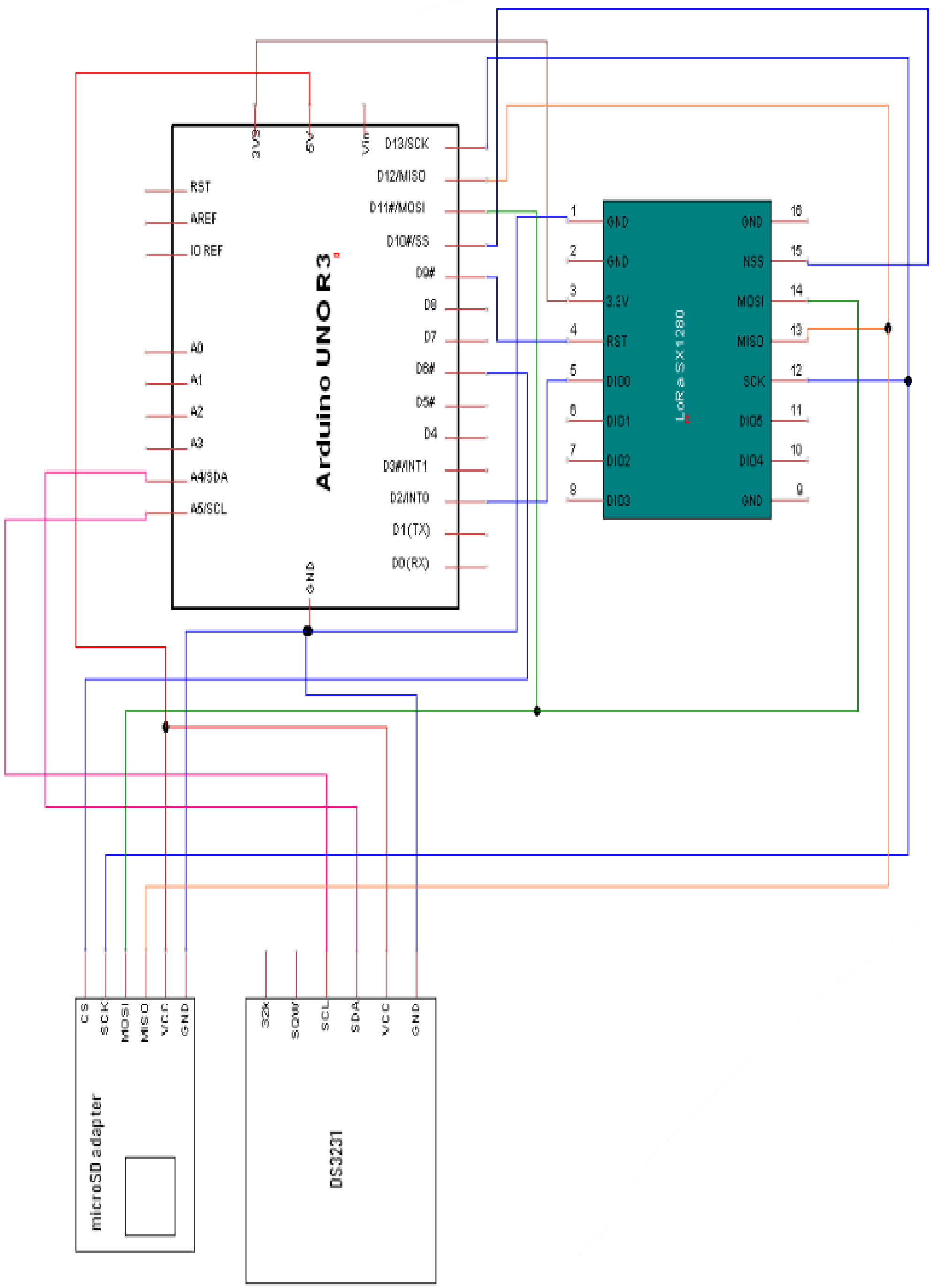


Fig: 8.2 Circuit Diagram Of The Receiver Circuit

The 3.3V and GND pins of the Arduino Uno should be connected to the VCC and GND pins of the LoRa module, respectively. Make sure the Arduino and the LoRa module are connected at the correct voltage level (typically 3.3V for LoRa modules). Connect the LoRa module's NSS (Slave Select) pin to an Arduino Uno digital pin, such as pin 10. Connect the Arduino Uno's SCK (Serial Clock), MOSI (Serial I/O), and MISO (12) pins to the LoRa module's SCK (Serial Clock) pin. Connect the LoRa module's DIO0 and DIO1 pins to the Arduino Uno's two different digital pins. In order to communicate data transmission and reception events, these pins are utilized for interrupts. Connect the LoRa module's RESET pin to the Arduino Uno's RESET. The Arduino Uno's 5V port should be connected to the microSD adapter's VCC/5V.Join the Arduino Uno's GND and the microSD adapter's GND.Pin 12 of the Arduino Uno should be connected to MISO on the microSD adapter. Pin 11 of the Arduino Uno should be connected to MOSI on the microSD adapter.SCK on the microSD card should be connected to pin 13 on the Arduino Uno.Pin 10 on the Arduino Uno is the place to connect the microSD adapter's CS to. DS3231 module VCC pin should be connected to the Arduino Uno 5V pin. Put a wire between the DS3231 module's GND pin and the Arduino Uno's GND (Ground) pin.SDA (data) pin of the DS3231 module should be connected to the Arduino Uno A4 (analog input 4) pin. The DS3231 module's SCL (clock) pin should be connected to the Arduino Uno A5 (analog input 5) pin. To keep the DS3231 RTC module operating and keeping the time even when the main Arduino is shut off, make sure it has a separate power source (often a 3V coin cell battery).

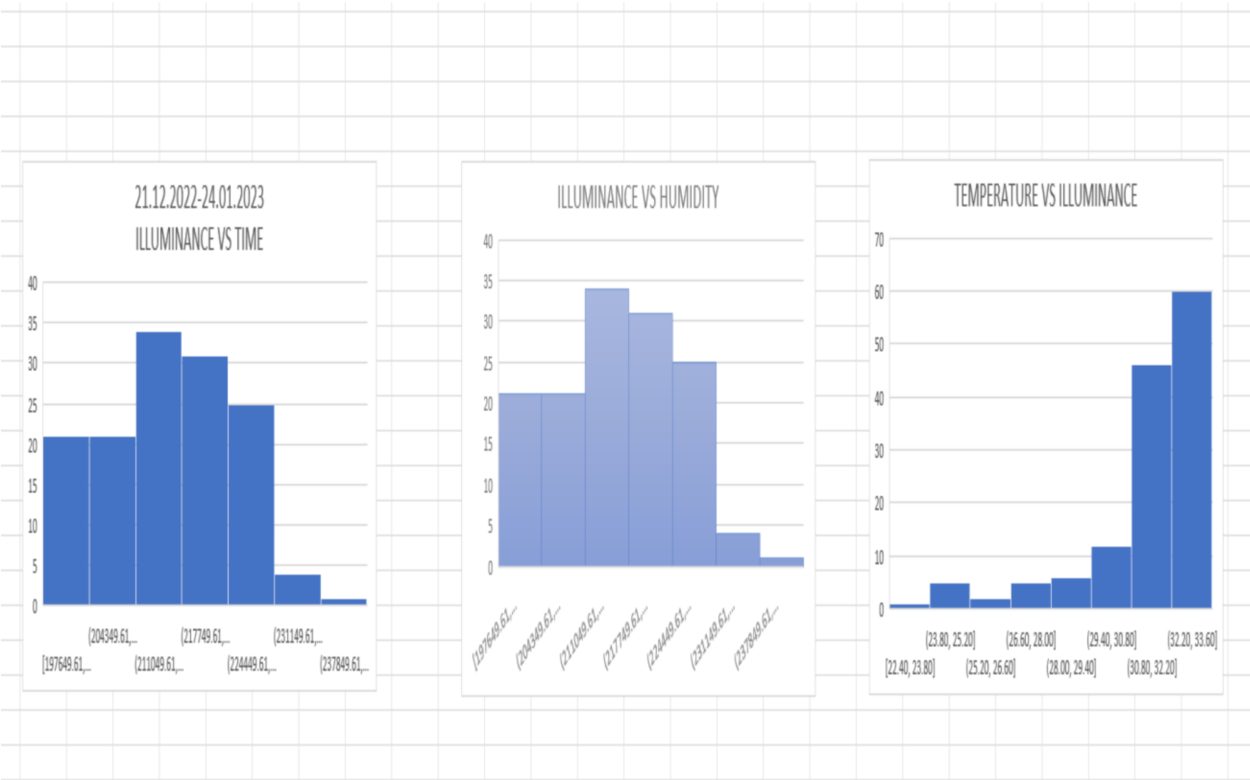
9. EXPERIMENTAL RESULTS:

I have taken two dates as examples to show here. I have created graphs in three combinations of temperature humidity illuminance & time. I have randomly taken the data of 20 dates & then divided the twenty dates into four parts with five dates each. I have created three graphs in three combinations with the data of these five dates.

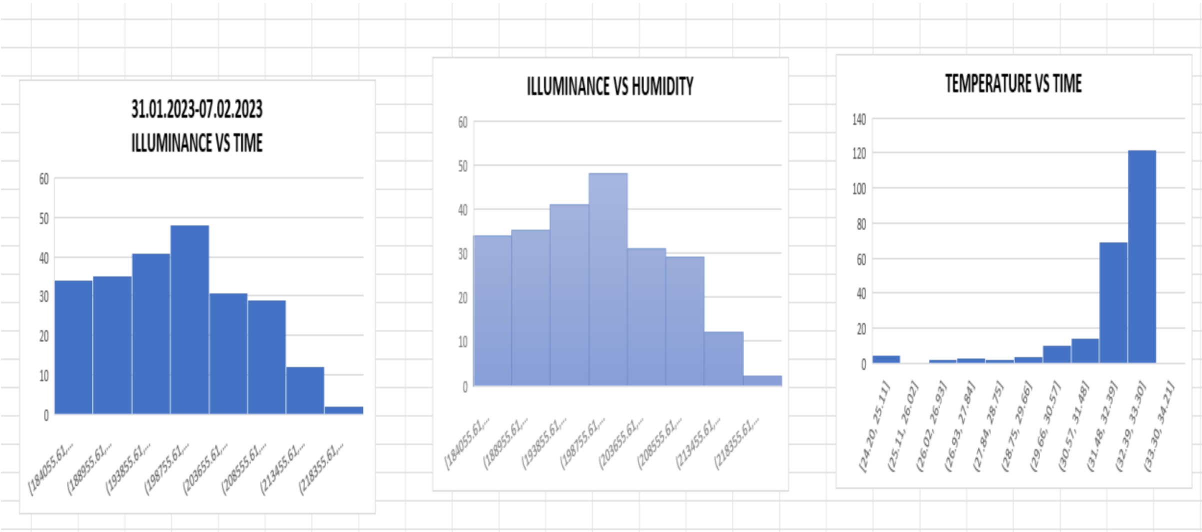
DATE	Time	Illuminance	Humidity	Temp in C	Temp in F
28-12-2022	14:07:31	224094.69	52.80	29.10	84.38
28-12-2022	14:12:31	216690.83	49.70	30.30	86.54
28-12-2022	14:17:32	213820.88	47.70	30.90	87.62
28-12-2022	14:22:32	230527.91	46.10	31.30	88.34
28-12-2022	14:27:33	211130.39	45.00	31.50	88.70
28-12-2022	14:32:33	219899.33	44.00	31.70	89.06
28-12-2022	14:37:34	221871.23	42.90	31.70	89.06
28-12-2022	14:42:34	217861.06	42.50	31.80	89.24
24-01-2023	13:37:03	230933.64	52.70	22.40	72.32
24-01-2023	13:42:04	205441.70	48.10	24.90	76.82
24-01-2023	13:47:04	224253.63	44.50	26.80	80.24
24-01-2023	13:52:05	209451.05	42.10	27.90	82.22
24-01-2023	14:11:41	232154.42	40.90	24.20	75.56
24-01-2023	14:16:42	215136.38	36.60	26.80	80.24
24-01-2023	14:57:56	228342.36	65.30	26.20	79.16
24-01-2023	15:02:57	235185.30	60.20	28.10	82.58
24-01-2023	15:07:57	214053.13	57.10	29.20	84.56
24-01-2023	15:12:58	213743.94	55.10	29.80	85.64
24-01-2023	15:17:58	225771.44	54.00	30.20	86.36
24-01-2023	15:22:59	221002.38	53.20	30.50	86.90
24-01-2023	15:27:59	226733.16	52.80	30.60	87.08
24-01-2023	15:33:00	208311.03	52.40	30.70	87.26
24-01-2023	15:38:00	224652.63	52.00	30.80	87.44
24-01-2023	15:43:00	208993.92	51.70	30.90	87.62
24-01-2023	15:48:01	209451.05	51.50	30.90	87.62
24-01-2023	15:53:01	209907.98	51.20	31.00	87.80
24-01-2023	15:58:02	216612.23	51.10	31.10	87.98

Fig: 9.1 Image of Collected Data In Excel Sheet

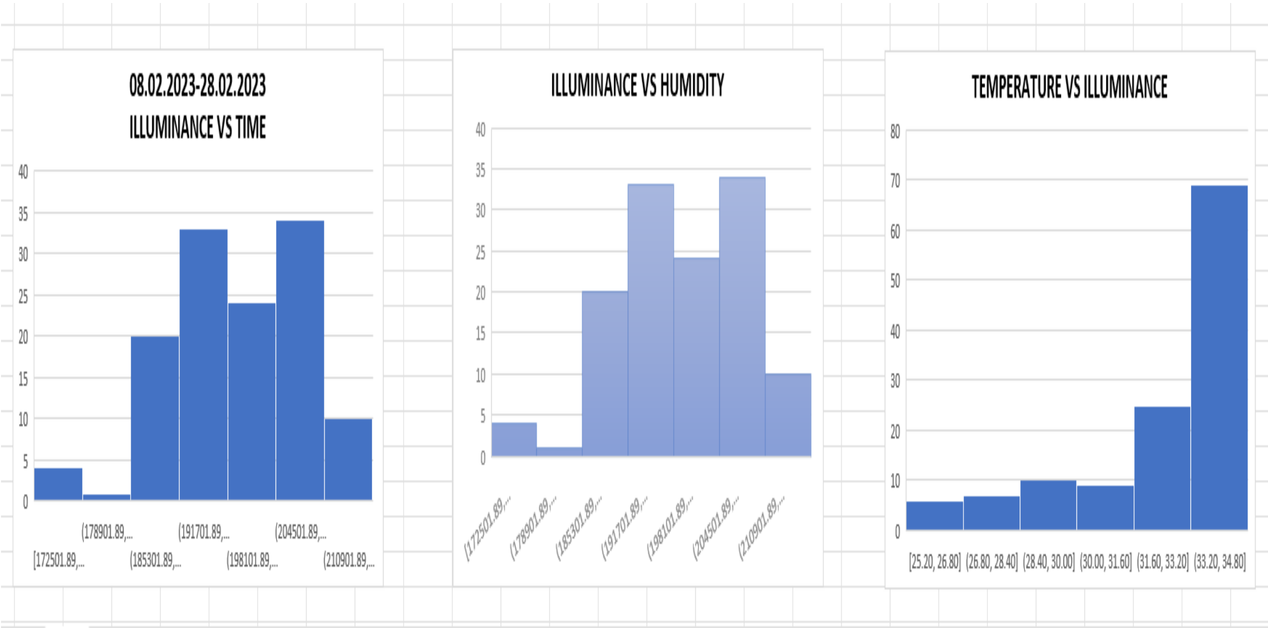
The first graph according to each date is Y axis denotes Illuminance & X axis denotes Time. The second graph of each section will have Humidity on the y-axis and Illuminance on the y-axis. And at the end of each section, time will be on the Y axis and temperature will be on the X axis.



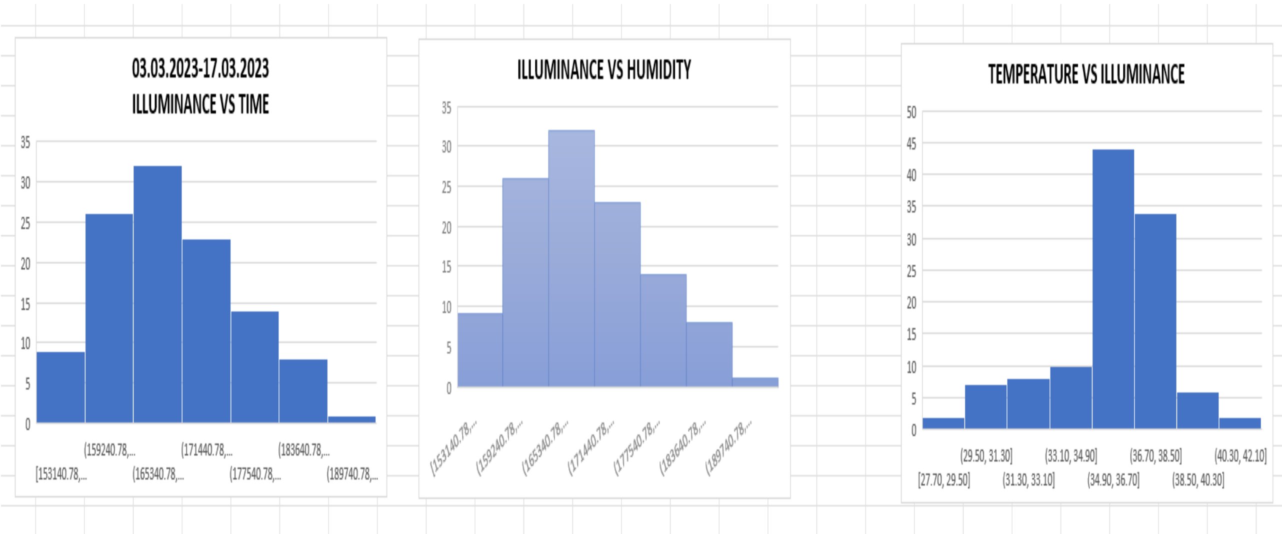
In the first series there are five dates in the graph is 21.12.2022-24.01.2023 .



In the second series there are five dates in the graph is 31.01.2023-07.02.2023



In the third series there are five dates in the graph is 08.02.2023-28.02.2023



& the last series there are five dates in the graph is 03.03.2023-17.03.2023

Localization of illumination has changed with time, but our long-term experiment of three months did not show any such changes. We can conclude that if we took bem angle switching in a particular strip led or in a particular home led it will be good for LED it doesn’t harm LED. This is due to the LED being on for 2 minutes and off for 3 minutes with time.

From second graph we conclude that, If humidity of the ambient weather is increasing or decreasing actually the change of the ambient of weather does not change lux output. We can using beam angle switching techniques on a streetlight because a particular streetlight is situated in open Area with open sky in every season the humidity will change accordingly with the season So it doesn’t affect the light output. So for over a long range the humidity does not affect.

For the third graph we can say, If light output is increases the temperature will also increase, Because we are doing beam angle switching in a particular LED We’re turning on the led for two minutes and off the led for three minutes, So for continuing this cycle the led junction will heat up. Because basically it’s a P-N junction diode.

9.1 EXPERIMENTAL SETUP:

- SPHERE
- TRANSMITTER CIRCUIT
- RECEIVER CIRCUIT

SPHERE:

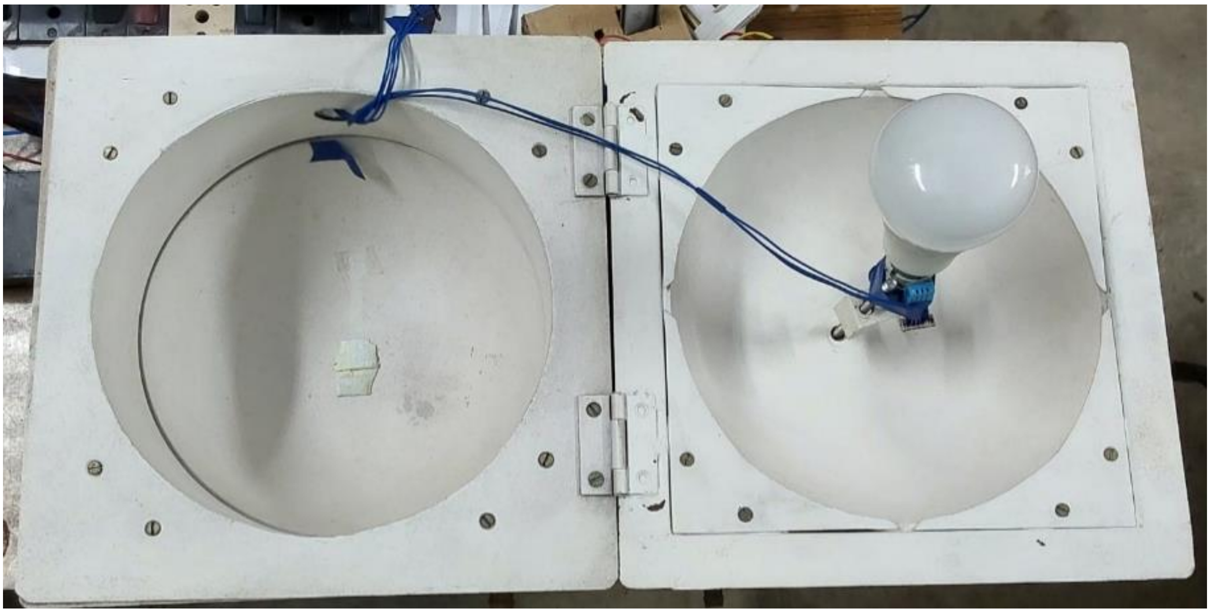


Fig: 9.1 Image of Sphere

Fig: 9.1 Image of Diagram

I took a sphere from a university laboratory that had a good coating of barium sulphate. The reason we always want to do this is because the sphere is completely white for the coating of barium sulphate so that the light is perfectly reflected. Inside the sphere is a 2.8-watt LED along with a humidity sensor, an illuminance sensor, and a temperature sensor. All these sensors and LEDs are connected to our transmitter circuit. The entire setup was prepared and kept in our five-floor lab and I used to take all the data from the receiver circuit sitting on the first floor.

TRANSMITTER CIRCUIT:

The transmitter circuit was attached to the sphere itself.
Temperature and humidity sensors were connected in the transmitter circuit along with illumination sensor and lora module.

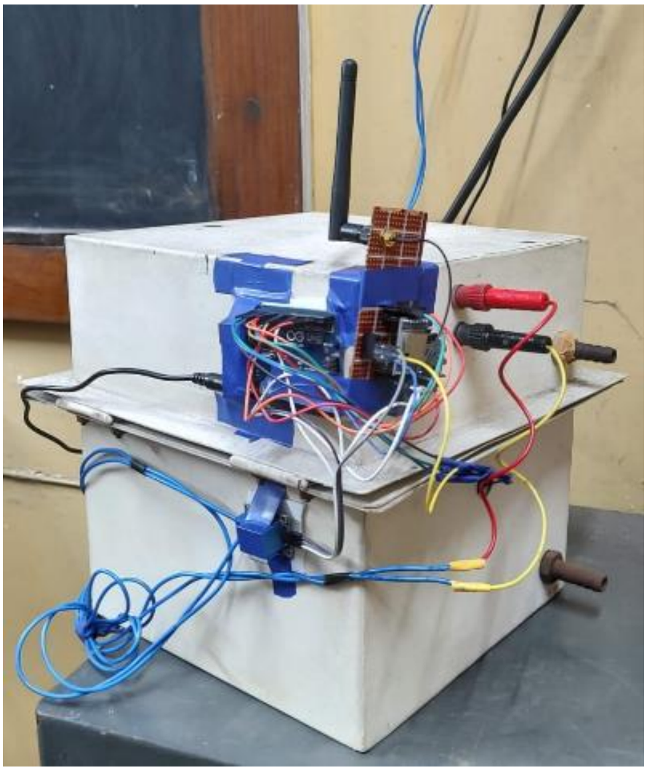


Fig: Transmitter Circuit Attached with The Sphere

A 12-volt relay was attached to the Arduino which mainly did the switching that kept the LED on for 2 minutes and off for 3 minutes.

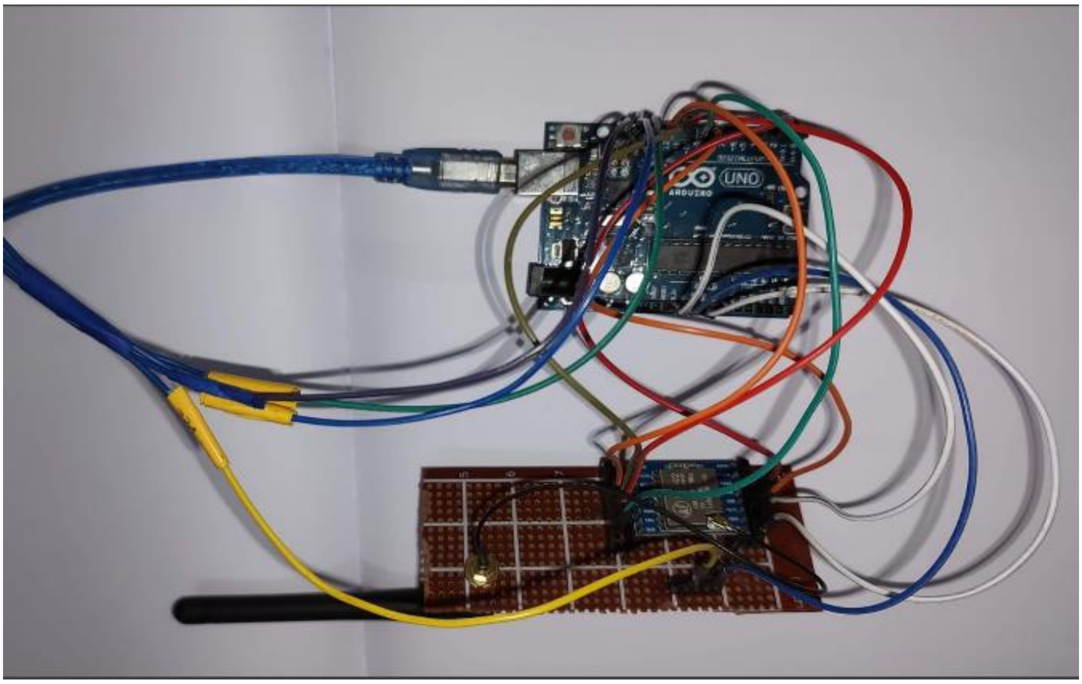


Fig: Transmitter Circuit

The system was initialized every day after switching on the transmitter circuit. Then the testing LED would turn on for two minutes and the sensor would gather data. Averaging and trans-meeting data were sent to the receiver circuit which displayed it on the GUI, After showing the data in the GUI, the LED would turn off for three minutes. This process was repeated over three months.

RECEIVER CIRCUIT:

We built a paper box-like module into which the receiver circuit was fitted. The receiver circuit was kept on his desk on the first floor in the room where I was sitting.

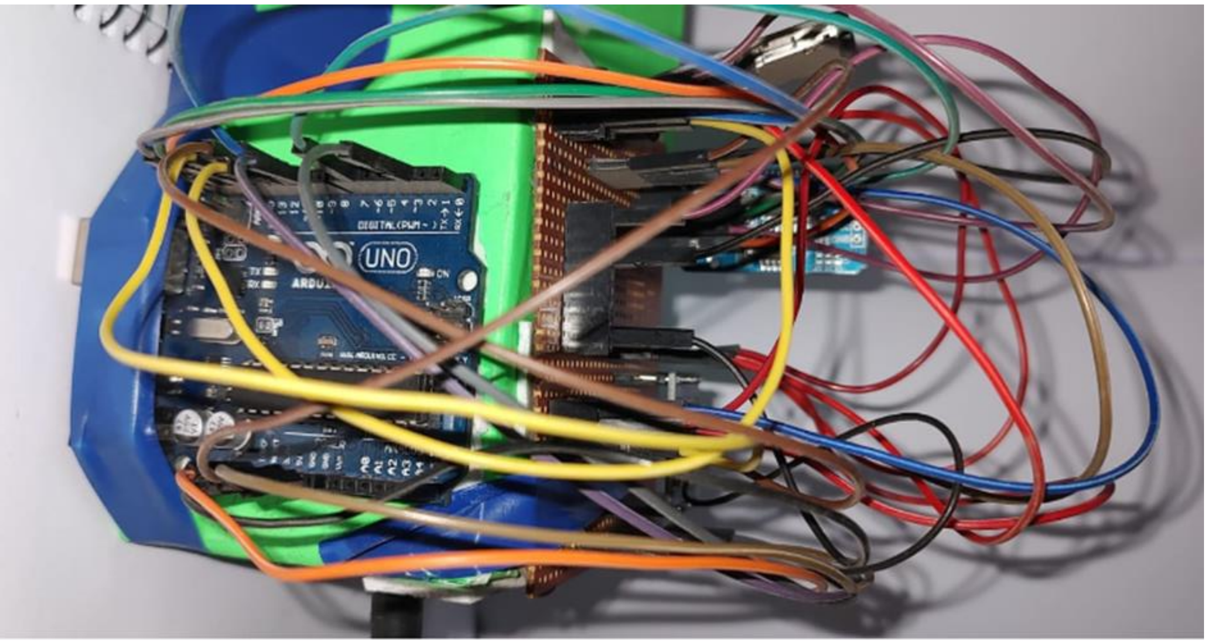
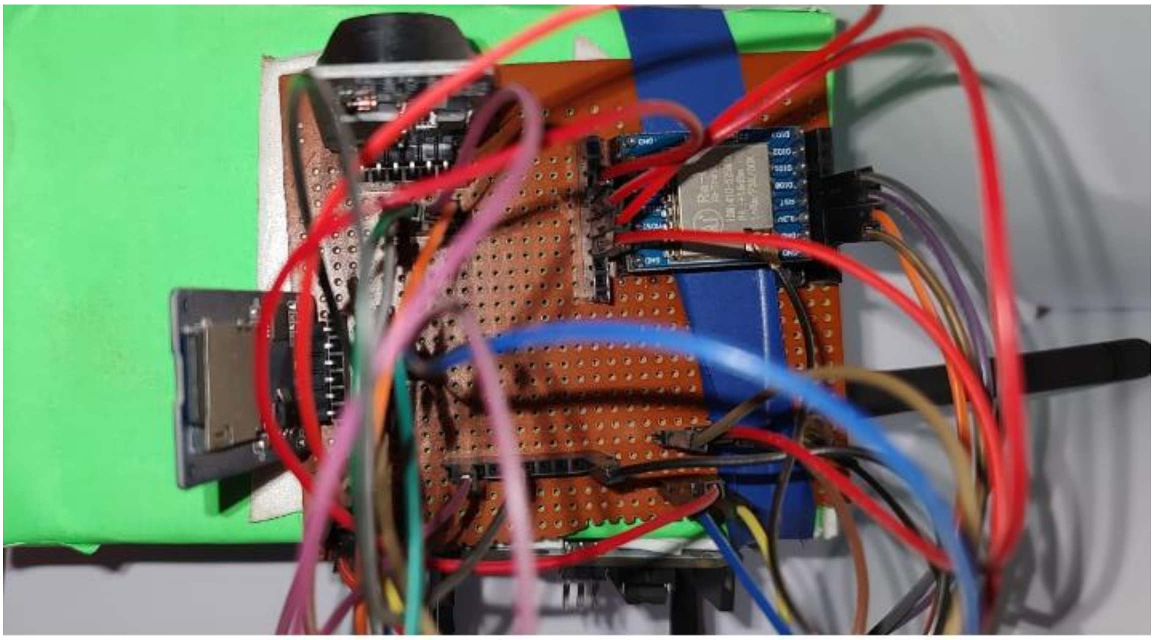


Fig: Receiver Circuit



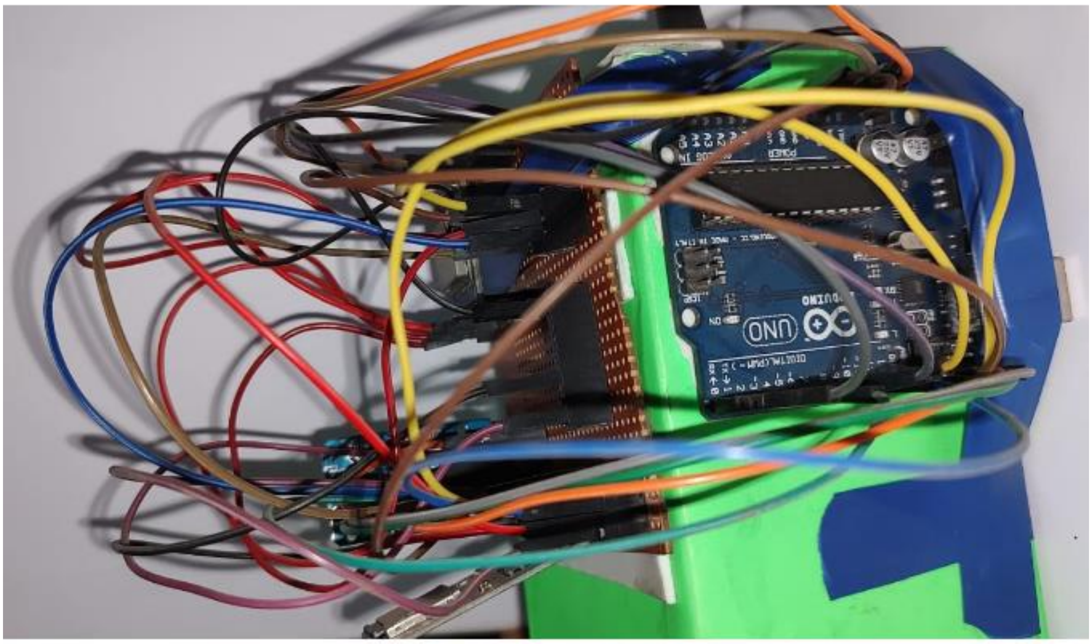


Fig: Receiver Circuit

First, I would go and turn on the receiver circuit and then the thing would start and the system would initialize. The receiver circuit catches the data and transforms that data into string bit by bit. The data was formatted in a suitable GUI so that it could be better understood, After the bit-by-bit data is transformed, the micro-SD card data is logged. Sometimes if no data could be received, the whole system was checked again. This entire procedure was followed for three months.

10. CAUSE OF THE DEVELOPED SYSTEM:

The cause of developing a system for innovative real-time estimations of life cycle analysis (LCA) of LED using an Arduino microcontroller can be attributed to several factors:

- Environmental Awareness: LED lighting has gained popularity due to its energy efficiency and longer lifespan compared to traditional lighting sources. However, it is important to understand the complete life cycle impact of LED lighting to make informed decisions. Developing a system for real-time LCA estimations promotes environmental awareness and helps individuals and organizations understand the environmental footprint of LED lighting.
- Sustainable Design and Manufacturing: By integrating an Arduino microcontroller into the system, it becomes possible to collect and analyze data throughout the entire life cycle of an LED. This includes assessing the environmental impact of LED production, transportation, usage, and disposal. By gaining insights into the different stages of an LED's life cycle, manufacturers can identify areas for improvement, optimize processes, and design more sustainable products.
- Decision-Making and Policy Support: Governments, regulatory bodies, and organizations often require accurate and up-to-date information for making informed decisions and formulating policies. A real-time LCA estimation system provides valuable data for policymakers to evaluate the environmental impact of LED lighting and establish guidelines and regulations to promote sustainable practices.
- Consumer Education: With increasing awareness and interest in sustainability, consumers are becoming more conscious of their purchasing decisions. A real-time LCA estimation system can empower consumers by providing transparent information about the environmental impact of LED products. This knowledge allows consumers to make environmentally responsible choices and support companies that prioritize sustainability.
- Research and Innovation: Developing an innovative system for real-time LCA estimations of LED lighting can contribute to ongoing research and innovation in the field. By continuously monitoring and analyzing data, researchers can identify trends, evaluate the effectiveness of sustainability initiatives, and develop new technologies and practices to minimize the environmental impact of LED lighting further.

Overall, the development of a system for real-time LCA estimations of LED using an Arduino microcontroller aligns with the goals of promoting sustainability, enabling informed decision-making, and fostering innovation in the lighting industry.

11. CONCLUSION & FUTURE SCOPE:

The use stage, followed by the production stage, are the life cycle stages that have the most impact on LED luminaires, it may be inferred. Therefore, the most efficient eco-design techniques to lessen environmental impact are those that reduce power consumption, including raising luminaire luminous efficacy, incorporating dimmers, cutting down on the amount of time that luminaires operate when not in use through smart lighting controls (like occupancy and light sensors), and cutting back on the use of virgin materials, particularly those that are crucial. Because they have a lower impact, the transit and end-of-life phases are given less attention in eco-design. If human-eco-nomic resources are scarce or for quick environmental impact assessments, they should be removed from the system boundaries of the assessment. When comparing LED lighting products, the functional unit definition is crucial. The functional unit developed in this study is completed and more appropriate for the comparative LCA of LED luminaires, in contrast to prior LCA-based studies of lighting goods. This study offers fresh perspectives on how to choose appropriate functional units and appropriate scenarios for the comparative life-cycle assessments of LED lighting products. It also offers eco-design suggestions, which add to our understanding of how to make LED luminaires more environmentally friendly.

The future scope of innovative real-time estimations of life cycle analysis (LCA) of LED using Arduino microcontrollers is promising. Here are a few potential areas of development and application:

- Enhanced Data Collection: Arduino microcontrollers can be used to collect real-time data on various parameters of LED devices, such as power consumption, temperature, brightness, and operating hours. This data can be used to estimate the life cycle of LEDs and identify patterns or factors that affect their performance and efficiency.
- Energy Optimization: By continuously monitoring and analyzing the data collected from LEDs, Arduino-based systems can optimize energy consumption and reduce waste. This could involve adjusting brightness levels based on ambient lighting conditions or implementing dynamic power management strategies to maximize energy efficiency.
- Predictive Maintenance: Arduino microcontrollers can enable predictive maintenance systems for LEDs by monitoring various operational

parameters. By analysing trends and deviations from normal behavior, predictive algorithms can identify potential issues or failures in advance, allowing for timely maintenance and replacement, thus extending the life cycle of LEDs.

- Sustainability Assessments: Arduino-based LCA estimations can help assess the environmental impact of LEDs throughout their life cycle. By collecting data on energy consumption, raw material extraction, manufacturing processes, transportation, and end-of-life disposal, it becomes possible to quantify the environmental footprint of LED technologies accurately.

- User Feedback and Interaction: Arduino microcontrollers can be integrated into LED lighting systems to gather user feedback and preferences. This information can be used to optimize lighting settings, adapt to user preferences, and provide personalized lighting experiences while considering energy efficiency and sustainability.

- Smart Grid Integration: With the increasing adoption of smart grids and Internet of Things (IoT) technologies, Arduino-based LED systems can be seamlessly integrated into the grid infrastructure. This integration enables bidirectional communication between LEDs and the grid, allowing for dynamic load balancing, demand response, and efficient energy management.

- Real-Time Visualization: Arduino microcontrollers can be utilized to create real-time visualizations of LED performance and LCA estimations. This visual feedback can help users, designers, and stakeholders understand the impact of their choices, identify areas for improvement, and make informed decisions regarding LED technology adoption.

12. REFERENCES:

- Rune Elvik "How much do road accidents cost the national economy?"

- Alzubaidi, Safaa, and Prashant Kumar Soori. "Study on energy efficient street lighting system design." In 2012 IEEE International Power Engineering and Optimization Conference Melaka, Malaysia, pp. 291-295. IEEE, 2012

- Rajakarunakaran Sivaprakasam, Pandian Pitchipoo".Analysis of Prime Reasons for Night Time Accidents in Public Transport Corporations Conference Paper · January 2014

- Transport Research Wing. Ministry of Road Transport and Highways. Govt. of India. Road Accidents in India – 2019.

- Liu, Yu-Nan, Yu-Jen Liu, Yi-Chian Chen, Hsin-Yi Ma, and Hsiao-Yi Lee. "Study of pulse width modulated LED for enhancing the power efficiency of dye-sensitized solar cells." Optik 158 (2018): 1567-1574.

- Hu, Chih-Lin, Tzu-Kuan Chan, Yunh-Chun Wen, Thitinan Tantidham, Snit Sanghlao, Boonsit Yimwadsana, and Pattanasak Mongkolwat. "IoT-based LED lighting control in smart home." In 2018 IEEE International Conference on Applied System Invention (ICASI), pp. 877-880. IEEE, 2018.

- Manish Kumar, Ravinder Kumar, Ritula Thakur, "ZIGBEE BASED SMART STREET LIGHT CONTROL SYSTEM USING LABVIEW", International Journal of Innovative Research in Science, Engineering and Technology, ISSN(Online): 2319-8753 ISSN (Print): 2347-6710, April 2016.

- T Bhavani, I.Vijayalakshmi, "ZIGBEE BASED REMOTE CONTROL AUTOMATIC STREET LIGHT SYSTEM", International Journal of Research, ISSN(Online) : 2348-795X ISSN (Print) : 2348-6848, Oct 2016.

- Srikanth M, Sudhakar K N, "ZIGBEE BASED REMOTE CONTROL AUTOMATIC STREET LIGHT SYSTEM", International Journal of Engineering Science and Computing, ISSN-2321 -3361, 2014.

- Anita Gehlot, Rajesh Singh, Raj Gaurav Mishra, Adesh Kumar, “IOT AND ZIGBEE BASED STREET LIGHT MONITORING SYSTEM WITH LABVIEW”, International Journal of Sensor and Its Applications for Control Systems, ISSN: 2287-8467, 2016.

- Weaver, David R. "The suprachiasmatic nucleus: a 25-year retrospective." Journal of biological rhythms 13, no. 2 (1998): 100-112.

- António José Santos, Fernando Bívar, Victor Ágoas. “Human Centric Lighting: New Paradigm or Common Sense ?” February, 2017.

- Houser, K. W., P. R. Boyce, J. M. Zeitzer, and M. Herf. "Human-centric lighting: Myth, magic or metaphor?." Lighting Research & Technology

- Boyce, Peter Robert. Human factors in lighting. Crc Press, 2003.

- Dijk, Derk-Jan, and Charles A. Czeisler. "Contribution of the circadian pacemaker and the sleep homeostat to sleep propensity, sleep structure, electroencephalographic slow waves, and sleep spindle activity in humans." Journal of Neuroscience 15, no. 5 (1995): 3526-3538.

- Campbell, Scott S., Derk-Jan Dijk, Ziad Boulos, Charmane I. Eastman, Alfred J. Lewy, and Michael Terman. "Light treatment for sleep disorders: Consensus

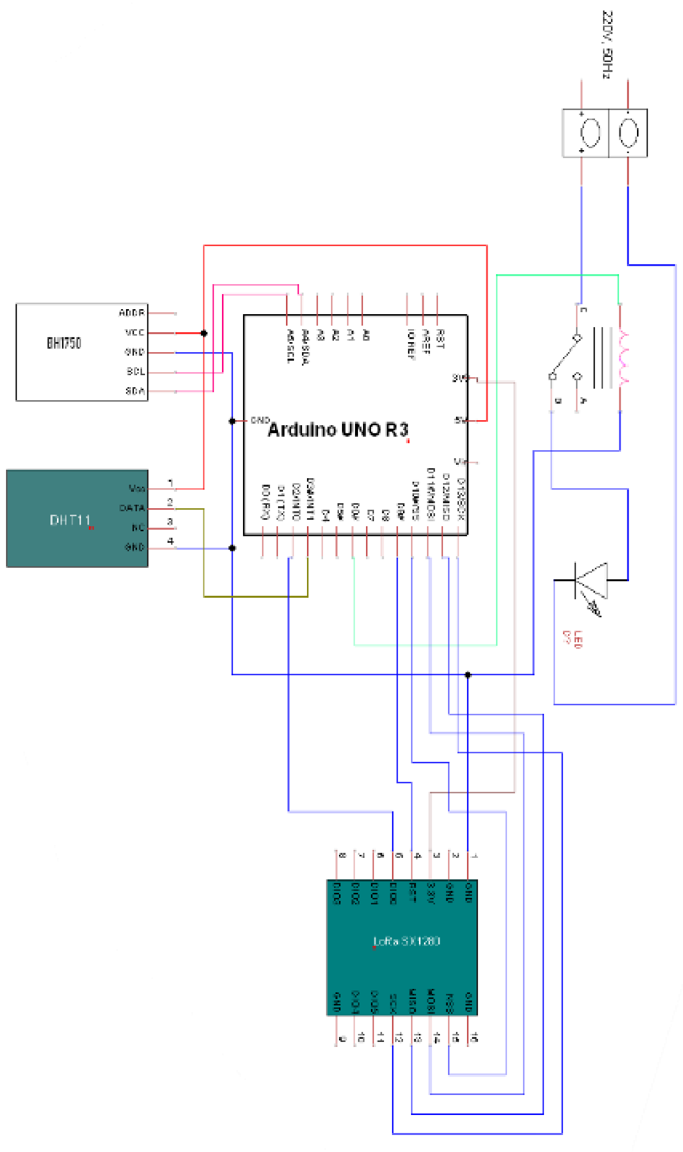
- Ruger, Melanie, Marijke CM Gordijn, Domien GM Beersma, Bonnie de Vries, and Serge Daan. "Time-of-day-dependent effects of bright light exposure on human psychophysiology: comparison of daytime and nighttime exposure." American Journal of Physiology-regulatory, integrative and comparative physiology 290, no. 5 (2006): R1413-R1420.

- Kaida, Kosuke, Masaya Takahashi, and Yasumasa Otsuka. "A short nap and natural bright light exposure improve positive mood status." Industrial health 45, no. 2 (2007): 301-308.

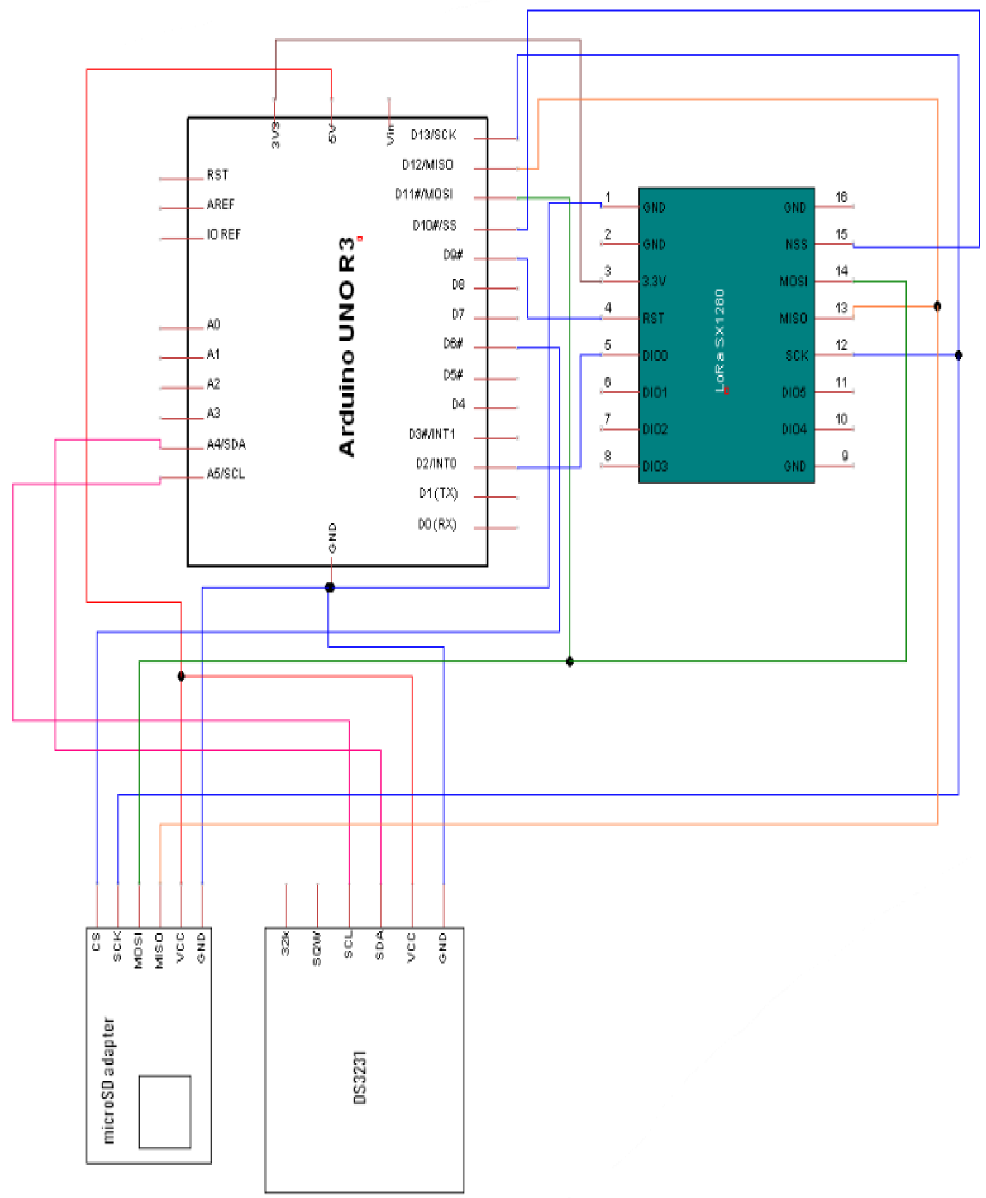
- Vandewalle, Gilles, Sophie Schwartz, Didier Grandjean, Catherine Wuillaume, Evelyne Balteau, Christian Degueldre, Manuel Schabus et al. "Spectral quality of light modulates emotional brain responses in humans." Proceedings of the National Academy of Sciences 107, no. 45 (2010): 19549-19554.

13. APENDIX 1:

Pinout Diagram Transmitter Circuit



Pinout Diagram Receiver Circuit



14. APENDIX 2:

Program Code:
<u>Transmitter Code</u>

```
#include <SPI.h>

#include <LoRa.h>

#include <Wire.h>

#include <BH1750.h>

int relay = 6;

int i = 0;

float lux = 0;

float lux1 = 0;

float avg_lux = 0;

float actual_avg_lux = 0;

String msg = "";

BH1750 lightMeter;

//int counter = 0;

void setup()

{

  Serial.begin(9600);

  Serial.println("LoRa Sender is working");

  if (!LoRa.begin(433E6))

  {

    Serial.println("Starting LoRa is failed!");

    while(1);

  }
```

```
  pinMode(6, OUTPUT);
  //pinMode(10, OUTPUT);
  //digitalWrite(vcc, HIGH);

  // Initialize the I2C bus (BH1750 library doesn't do
this automatically)
  // On esp8266 devices you can select SCL and SDA pins
using Wire.begin(D4, D3);
  Wire.begin();

  lightMeter.begin();
  Serial.println(F("BH1750 Test"));
}

void loop()
{
  digitalWrite(relay, LOW);
  Serial.println("LED is ON");
  for(i=0;i<19;i++)
{
  delay(10000);
  lux = lightMeter.readLightLevel();
  lux1 = (lux1 + lux);
}
  avg_lux = lux1/18;
```

```
  lux1=0;
actual_avg_lux = ((0.000000645577*(pow(avg_lux,3)))-(0.000338559*(pow(avg_lux,2)))+(0.128392*avg_lux)+0.244231);


  Serial.print("Light:  ");
  Serial.print(actual_avg_lux);
  Serial.println(" lx");
  digitalWrite(relay, HIGH);
  Serial.println("LED is OFF");
  delay(120000);


  msg = "Illuminance is " + (String)actual_avg_lux + "lux";


  Serial.print("Sending message ");
  Serial.println();
  Serial.println(msg);


  LoRa.beginPacket();
  LoRa.print(msg);
  LoRa.endPacket();
  msg="";


}
```

Receiver Code

```
#include <SPI.h>
#include <LoRa.h>

#include <SD.h>
#include <RTClib.h>

#define PIN_SPI_CS_1 10
#define PIN_SPI_CS_2 6
#define FILE_NAME "log.txt"

RTC_DS3231 rtc;

File myFile;

String str="";

void setup()
{
  pinMode(PIN_SPI_CS_1, OUTPUT);
  pinMode(PIN_SPI_CS_2, OUTPUT);
  Serial.begin(9600);

  if (!rtc.begin()) {
```

```
    Serial.println(F("Couldn't find RTC"));
    while (1);
  }
  Serial.println(F("Real Time Clock Initialized"));

  //Setup for date
  if (rtc.lostPower()) {
    Serial.println("RTC lost power, lets set the time!");
    rtc.adjust(DateTime(F(__DATE__), F(__TIME__)));
  }

  rtc.adjust(DateTime(2022, 12, 8, 14, 19, 20));

  digitalWrite(PIN_SPI_CS_1, HIGH);
  digitalWrite(PIN_SPI_CS_2, LOW);
  if (!SD.begin(PIN_SPI_CS_2)) {
    Serial.println(F("SD CARD FAILED, OR NOT PRESENT!"));
    while (1); // don't do anything more:
  }

  Serial.println(F("SD CARD INITIALIZED."));
  Serial.println(F("--------------------"));
```

```
  digitalWrite(PIN_SPI_CS_1, LOW);
  digitalWrite(PIN_SPI_CS_2, HIGH);
  Serial.println("LoRa Receiver started");

  if (!LoRa.begin(433E6))
  {
    Serial.println("Starting LoRa failed!");
    while (1);
  }
  Serial.println("LoRa Receiver is working");
}

void loop()
{
  digitalWrite(PIN_SPI_CS_1, LOW);
  digitalWrite(PIN_SPI_CS_2, HIGH);
  int packetSize = LoRa.parsePacket();
  delay(10);
  if (packetSize!=0)
  {
    Serial.println("Received value of illuminance '");
    Serial.println(packetSize);
    while (LoRa.available())
    {
      str=str+((char)LoRa.read());
```

```
      }
      Serial.print(str);
      Serial.print("' with RSSI ");
      Serial.println(LoRa.packetRssi());

  // open file for writing
    digitalWrite(PIN_SPI_CS_1, HIGH);
    digitalWrite(PIN_SPI_CS_2, LOW);

    myFile = SD.open(FILE_NAME, FILE_WRITE);

    if (myFile) {
      Serial.println(F("Writing log to SD Card"));

      // write timestamp
      DateTime now = rtc.now();
      myFile.print(now.year(), DEC);
      myFile.print('-');
      myFile.print(now.month(), DEC);
      myFile.print('-');
      myFile.print(now.day(), DEC);
      myFile.print(' ');
      myFile.print(now.hour(), DEC);
      myFile.print(':');
      myFile.print(now.minute(), DEC);
```

```
    myFile.print(':');
    myFile.print(now.second(), DEC);

    myFile.print("  "); // delimiter between timestamp
and data

    // write data
    myFile.print("Received Data = ");
    myFile.print(str);
    myFile.println(", "); // delimiter between data

    myFile.write("\n"); // new line

    myFile.close();
  } else {
    Serial.print(F("SD Card: error on opening file "));
    Serial.println(FILE_NAME);
  }
  str="";
  delay(2000); // delay 2 seconds
  // To store the received message in a string,
uncomment line 16 and 24.
  }
}
```

15. APENDIX 3:

Data Sheet of Used Components

Arduino Uno Microcontroller

Features

- **ATMega328P** Processor
  - **Memory**
    - AVR CPU at up to 16 MHz
    - 32KB Flash
    - 2KB SRAM
    - 1KB EEPROM
  - **Security**
    - Power On Reset (POR)
    - Brown Out Detection (BOD)
  - **Peripherals**
    - 2x 8-bit Timer/Counter with a dedicated period register and compare channels
    - 1x 16-bit Timer/Counter with a dedicated period register, input capture and compare channels
    - 1x USART with fractional baud rate generator and start-of-frame detection
    - 1x controller/peripheral Serial Peripheral Interface (SPI)
    - 1x Dual mode controller/peripheral I2C
    - 1x Analog Comparator (AC) with a scalable reference input
    - Watchdog Timer with separate on-chip oscillator
    - Six PWM channels
    - Interrupt and wake-up on pin change
  - **ATMega16U2 Processor**
    - 8-bit AVR® RISC-based microcontroller
  - **Memory**
    - 16 KB ISP Flash
    - 512B EEPROM
    - 512B SRAM
    - debugWIRE interface for on-chip debugging and programming
  - **Power**
    - 2.7-5.5 volts

BH1750 FVI:

ROHM SEMICONDUCTOR — Technical Note

Ambient Light Sensor IC Series

Digital 16bit Serial Output Type Ambient Light Sensor IC

BH1750FVI

No.11046EDT01

●**Descriptions**

BH1750FVI is an digital Ambient Light Sensor IC for I^2C bus interface. This IC is the most suitable to obtain the ambient light data for adjusting LCD and Keypad backlight power of Mobile phone. It is possible to detect wide range at High resolution. (1 - 65535 lx).

●**Features**

1) I^2C bus Interface (f / s Mode Support)
2) Spectral responsibility is approximately human eye response
3) Illuminance to Digital Converter
4) Wide range and High resolution. (1 - 65535 lx)
5) Low Current by power down function
6) 50Hz / 60Hz Light noise reject-function
7) 1.8V Logic input interface
8) No need any external parts
9) Light source dependency is little. (ex. Incandescent Lamp. Fluorescent Lamp. Halogen Lamp. White LED. Sun Light)
10) It is possible to select 2 type of I^2C slave-address.
11) Adjustable measurement result for influence of optical window
(It is possible to detect min. 0.11 lx, max. 100000 lx by using this function.)
12) Small measurement variation (+/- 20%)
13) The influence of infrared is very small.

●**Applications**

Mobile phone, LCD TV, NOTE PC, Portable game machine, Digital camera, Digital video camera, PDA, LCD display

●**Absolute Maximum Ratings**

Parameter	Symbol	Ratings	Units
Supply Voltage	Vmax	4.5	V
Operating Temperature	Topr	-40～85	℃
Storage Temperature	Tstg	-40～100	℃
SDA Sink Current	Imax	7	mA
Power Dissipation	Pd	260※	mW

※ 70mm × 70mm × 1.6mm glass epoxy board. Derating in done at 3.47mW/℃ for operating above Ta=25℃.

●**Operating Conditions**

Parameter	Symbol	Ratings			Units
		Min.	Typ.	Max.	
Vcc Voltage	Vcc	2.4	3.0	3.6	V
I^2C Reference Voltage	VDVI	1.65	-	Vcc	V

Real Time Clock Module:

General Description

The DS3231 is a low-cost, extremely accurate I²C real-time clock (RTC) with an integrated temperature-compensated crystal oscillator (TCXO) and crystal. The device incorporates a battery input, and maintains accurate timekeeping when main power to the device is interrupted. The integration of the crystal resonator enhances the long-term accuracy of the device as well as reduces the piece-part count in a manufacturing line. The DS3231 is available in commercial and industrial temperature ranges, and is offered in a 16-pin, 300-mil SO package.

The RTC maintains seconds, minutes, hours, day, date, month, and year information. The date at the end of the month is automatically adjusted for months with fewer than 31 days, including corrections for leap year. The clock operates in either the 24-hour or 12-hour format with an AM/PM indicator. Two programmable time-of-day alarms and a programmable square-wave output are provided. Address and data are transferred serially through an I²C bidirectional bus.

A precision temperature-compensated voltage reference and comparator circuit monitors the status of V_{CC} to detect power failures, to provide a reset output, and to automatically switch to the backup supply when necessary. Additionally, the $\overline{RST}$ pin is monitored as a pushbutton input for generating a reset externally.

Applications

- Servers
- Telematics
- Utility Power Meters
- GPS

Pin Configuration appears at end of data sheet.

Features

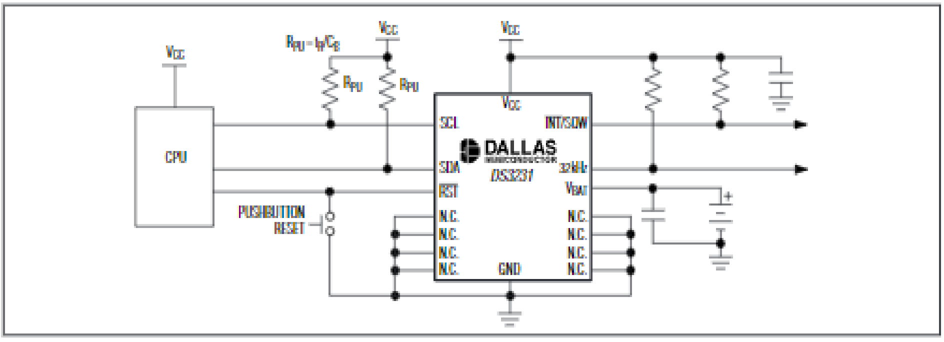
- ♦ Accuracy ±2ppm from 0°C to +40°C
- ♦ Accuracy ±3.5ppm from -40°C to +85°C
- ♦ Battery Backup Input for Continuous Timekeeping
- ♦ Operating Temperature Ranges
  - Commercial: 0°C to +70°C
  - Industrial: -40°C to +85°C
- ♦ Low-Power Consumption
- ♦ Real-Time Clock Counts Seconds, Minutes, Hours, Day, Date, Month, and Year with Leap Year Compensation Valid Up to 2100
- ♦ Two Time-of-Day Alarms
- ♦ Programmable Square-Wave Output
- ♦ Fast (400kHz) I²C Interface
- ♦ 3.3V Operation
- ♦ Digital Temp Sensor Output: ±3°C Accuracy
- ♦ Register for Aging Trim
- ♦ $\overline{RST}$ Input/Output
- ♦ UL Recognized

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE	TOP MARK
DS3231S	0°C to +70°C	16 SO	DS3231
DS3231SN	-40°C to +85°C	16 SO	DS3231N
DS3231S+	0°C to +70°C	16 SO	DS3231+
DS3231SN+	-40°C to +85°C	16 SO	DS3231N+

+Denotes lead-free

Typical Operating Circuit



Purchase of I²C components from Maxim Integrated Products, Inc., or one of its sublicensed Associated Companies, conveys a license under the Philips I²C Patent Rights to use these components in an I²C system, provided that the system conforms to the I²C Standard Specification as defined by Philips.

For pricing, delivery, and ordering information, please contact Maxim/Dallas Direct! at 1-888-629-4642, or visit Maxim's website at www.maxim-ic.com.

MicroSD Card :

Transcend

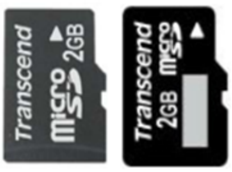
Description

Transcend microSD card series are non-volatile, which means no external power is required to retain the information stored on it. Besides, it is also a solid-state device that without moving parts to skip or break down. Based on original NAND flash chip, Transcend microSD can offer an incredible combination of fast data transfer, great flexibility, excellent security and incredibly small size.

Features

- ROHS compliant product.
- Operating Voltage: 2.7 ~ 3.6V
- Operating Temperature: -25 ~ 85°C
- Durability: 10,000 insertion/removal cycles
- Fully compatible with SD card spec. v1.1
- Comply with SD Association File System Specification
- Mechanical Write Protection Switch with microSD adapter
- SD Host allows MultiMediaCard upward compatibility
- Form Factor: 11mm x 15mm x 1mm

Placement



Front

Back

Pin Definition

Pin No.	SD Mode			SPI Mode		
	Name	Type	Description	Name	Type	Description
1	DAT2	I/O/PP	Data Line [Bit2]	RSV		Reserved
2	CD/DAT3	I/O/PP	Card Detect / Data Line [Bit3]	CS	I	Chip Select
3	CMD	PP	Command / Response	DI	I	Data In
4	V_{DD}	S	Supply voltage	V_{DD}	S	Supply voltage
5	CLK	I	Clock	SCLK	I	Clock
6	V_{SS}	S	Supply voltage ground	V_{SS}	S	Supply voltage ground
7	DAT0	I/O/PP	Data Line [Bit0]	DO	O/PP	Data out
8	DAT1	I/O/PP	Data Line [Bit1]	RSV		Reserved

S: Power Supply; I:Input; O:Output; PP:Push-Pull