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# Design and Development of an Automatic Lighting Control and Energy Optimization System

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**Abstract**
Most electrical lighting systems installations are of a basic nature. They are usually controlled only by means of a manually operated light switch. This leads to unnecessary energy usage and wastage resulting into unreasonable electrical costs. The main reason for this is the light intensity generated by the lighting devices that is usually at a constant intensity regardless of the current light intensity conditions in a particular space. Most of the time lights remain on in unoccupied spaces. That being the case an intelligent system (automatic lighting control and energy optimization system) is imperative for controlling both the switching of the lights and intensity as per prevailing lighting conditions.
The intelligent system checks for presence and light intensity. The lights come on when the space is occupied at the right intensity. The lights stay on for a pre-determined period once the space is vacant.
With the implementation of such a system, there is huge potential to reduce on the energy usage because the lights are only on when needed and to the right light intensity which is proportional to electrical energy delivered to the lights.
The objective of this project is to demonstrate the energy saving benefits of implementing automatic light control system that optimize light intensity and the controlling of switching on and off for energy saving purposes.

**Keywords:** Corporate, Social, Responsibility Brand Reputation

## 1. Introduction
Lighting is one of the main sub-systems of a building's electrical system that consumes large amounts of energy after heating ventilation and air conditioning systems (HVAC). Lighting systems accounts for 20% to 45% of the total energy used in buildings (Khairul Rijal Wagiman & Mohd Noor Abdullah, 2018).
As the economies and populations expand, there has been an increasing demand for electrical energy that has led to a critical inadequate supply of this resource in some countries, hence implementation of control measures such as loading shedding. It is therefore imperative to formulate ways and means to use this resource in a more optimal and sustainable manner. Artificial lights (bulbs) account for 15% of electricity consumption globally (Gabrielle Dreyfus 2015).
With population growth and increased urbanization expected to drive about 50% rise in lighting demand by 2030 (Gabrielle Dreyfus 2015), it is important to encourage energy optimization technologies for artificial lighting.
Most lighting systems have not been effectively implemented leading to inefficient use of energy. This is due to factors such as; poor daylight utilization in conjunction with artificial lighting systems. In circumstance were natural light and artificial lighting are integrated the light used are not energy efficient.
It is therefore right to implement an intelligent or automatic lighting system technologies to enhance optimize energy usage.

### 1.1 Background of Study
As global energy demand continues to rise alongside growing concerns about climate change, the need for efficient energy usage has become more critical than ever. Buildings, which account for a significant portion of global energy consumption—approximately 40%—play a pivotal role in this issue. Lighting, in particular, is one of the major contributors to energy waste, especially in commercial, residential, and industrial environments where lights are often left on unnecessarily (IEA, 2021). This not only increases electricity costs but also contributes to environmental degradation, calling for innovative solutions to

optimize energy use.

Automatic lighting control systems present an effective solution to this problem by managing lighting based on real-time needs. These systems rely on technologies such as occupancy sensors, daylight sensors, and timers, which adjust lighting based on human presence, natural light availability, and the time of day. For example, occupancy sensors automatically turn off lights when no one is present in a room, while daylight sensors adjust the intensity of artificial lighting to complement the available natural light (Ahmad *et al*., 2019). Research suggests that such systems can cut lighting energy consumption by as much as 50%, leading to significant cost savings and reduced environmental impact (Khan *et al*., 2020).

The integration of smart technologies further enhances the performance of lighting control systems. The Internet of Things (IoT), for instance, enables remote monitoring and control of lighting systems, allowing users to track energy consumption and adjust settings from any location (Sharma *et al*., 2021). Additionally, AI-based algorithms are being explored to predict lighting patterns based on factors such as occupancy, time of day, and weather conditions, thus further optimizing energy usage (Mistry *et al*., 2022).

Despite these advancements, several barriers remain to the widespread adoption of these systems. High initial costs, the complexity of retrofitting existing infrastructure, and a lack of widespread awareness about the benefits of energy-efficient lighting systems continue to hinder their integration into many buildings (Saha & Basak, 2020). To address these challenges, this study proposes the design and development of an automatic lighting control and energy optimization system that is both affordable and easy to integrate, aiming to make such technologies more accessible and promote greater energy efficiency.

By focusing on cost-effective solutions that can be scaled across different types of buildings, this research aims to contribute to the reduction of energy consumption, lower electricity bills, and help mitigate the broader environmental impact associated with inefficient lighting practices.

### 1.2 Motivation and significance of study

This study has been inspired by the deficit in electrical energy in the world over due to the rapid increase of population and improved standard of life over the years, which has seen the need for street lighting, schools, hotels, industries, shopping malls, mining and homes. The rate of demand is faster than the rate at which new electrical energy sources are being constructed and expanded to the ever-growing demand on the power system. The unattended lights in building spaces such as offices and homes also provides the motivation for the design of the automatic light control and energy optimization system. It has being observed that lights will be left on in unoccupied spaces hence leading to unnecessary use of electrical energy by the lights staying on when they are not in use. This project is relevant in that it seeks to demonstrate the need for implementation of technologies to save or reduce on the amount of unnecessary energy used up by lighting in poorly implemented lighting systems. The automatic lighting control and energy optimization system will attempt to demonstrate the use of technology to reduce on the electrical energy usage. The technology works on the following parameters; checking for occupancy of a room or space and measuring the intensity of light. If the room or space is occupied the technology will make a decision to switch on the lights but only if the measured light intensity is inadequate for that application as per WHO world health organization. Correct light level intensity is important for comfort and safety of occupants of a space or room. The right amount of light level intensity also play a significant role in the productivity and efficiency of workers in a work place, it also improves the safety levels.

### 1.3 Scope of study

A prototype system consisting of a microcontroller “Arduino”, motion detection sensor, light detection sensor (LDR) and light emitting diodes (LED) lamps are used to achieve the design concept. A carton box is used to simulate and emulate a room scenario with varying light level conditions. The energy usage monitoring is achieved by means of a Digital Multi-Meter, which is used to measure the voltage levels being delivered to the LED lamps. An artificial light is used to emulate natural light.

### 1.4 Problem statement

The growing demand for energy, coupled with the environmental challenges posed by excessive energy consumption, has led to increased interest in energy optimization solutions. Buildings, particularly those in residential, commercial, and industrial sectors, account for a significant share of global energy consumption, with lighting being one of the primary contributors to this inefficiency. According to the International Energy Agency (IEA), inefficient lighting contributes substantially to both high electricity costs and environmental degradation (IEA, 2021).

Traditional lighting systems often fail to optimize energy use, as lights are frequently left on in unoccupied rooms or during daylight hours, resulting in significant energy wastage. While some technologies, such as timers and manual controls, can partially address this issue, they fail to offer the flexibility and intelligence required for optimal energy management. Furthermore, many existing lighting systems are not integrated with smart technologies, limiting their ability to respond dynamically to changing conditions like occupancy, ambient light, or time of day.

Automatic lighting control systems have emerged as a promising solution to this problem, using sensors and intelligent algorithms to reduce energy consumption by adjusting lighting based on real-time data. However, despite the potential benefits of these systems, their adoption has been slow due to factors such as high initial costs, integration complexities, and a lack of awareness about their advantages. These barriers prevent the widespread implementation of energy-efficient lighting solutions, which could otherwise lead to significant reductions in energy use, cost savings, and a smaller environmental footprint.

The problem, therefore, is the need for a cost-effective, scalable, and easy-to-integrate lighting control system that can optimize energy consumption in various types of buildings. This research aims to address this gap by designing and developing an automatic lighting control and energy optimization system that is accessible to a wide range of users and can contribute to both energy efficiency and environmental sustainability.

### 1.5 Main objective
Design and develop an Automatic Lighting Control and Energy Optimization System and demonstrate the energy saving potential of the system.

#### 1.5.1 Specific objective
1. Design the hardware and circuit.
2. Design a system to optimize energy used by lighting installation.
3. Develop a system that control and optimize energy by lighting installation.

### 1.6 Research questions
1. How to design the system hardware
2. How to design a system that optimizes electrical energy in lighting installation
3. How Develop a system that control and optimize energy by lighting installation.

### 1.7 Conceptual Frameworks
The conceptual framework for the design and development of an automatic lighting control and energy optimization system revolves around key concepts such as sensor technologies, energy optimization, user interaction, and smart technologies. The system's primary objective is to reduce energy consumption while maintaining necessary lighting levels, achieved through the integration of occupancy sensors, daylight sensors, and intelligent algorithms. These sensors monitor environmental conditions, such as room occupancy and natural light availability, and dynamically adjust the lighting to ensure efficiency. Energy optimization is a central concept, involving the real-time monitoring and adjustment of lighting to match demand, reducing waste and lowering electricity costs.

The framework also incorporates user behavior and control, acknowledging that while the system is designed for automation, users can interact with it through interfaces like mobile apps or central controllers. This interaction allows users to tailor settings based on their specific needs, which in turn influences overall energy savings. The use of smart technologies, particularly the Internet of Things (IoT) and Artificial Intelligence (AI), further enhances the system's capabilities by enabling remote monitoring, control, and the system's ability to learn and adapt over time. For instance, AI can predict usage patterns and autonomously adjust settings, optimizing energy consumption based on factors such as occupancy and time of day.

In terms of variables, the system's independent factors include sensor technologies (motion and daylight sensors), user behavior, and the demand for lighting in various spaces. The dependent variables are energy consumption, cost savings, and environmental impact. These variables interact within the framework to drive the system's performance, ensuring that lighting is used efficiently while minimizing energy waste and reducing costs. Ultimately, the conceptual framework emphasizes the interconnectedness of sensor technologies, user input, and smart capabilities to create an efficient, adaptive system that not only meets lighting needs but also contributes to sustainability and energy conservation.

### 1.8 Definition of Terms
1. **Automatic Lighting Control System (ALCS):** A system designed to automatically adjust the intensity and operation of lighting in response to real-time environmental conditions such as occupancy, ambient light levels, and time of day, with the goal of optimizing energy use.
2. **Energy Optimization:** The process of reducing unnecessary energy consumption while maintaining the required lighting levels, often achieved through the use of automated systems that adjust lighting based on real-time data.
3. **Occupancy Sensors:** Devices that detect the presence of people in a room or space and trigger the activation or deactivation of lighting based on occupancy, thereby ensuring lights are only on when needed.
4. **Daylight Sensors:** Sensors that measure the amount of natural light entering a space and adjust the intensity of artificial lighting to maintain desired illumination levels, ensuring that energy is not wasted when sufficient daylight is available.
5. **Internet of Things (IoT):** A network of interconnected devices that communicate and exchange data over the internet, allowing for remote monitoring, control, and automation of systems such as lighting, thereby enhancing energy efficiency.
6. **Artificial Intelligence (AI):** A branch of computer science that enables machines to perform tasks that typically require human intelligence. In the context of lighting control systems, AI algorithms can predict lighting patterns based on user behavior and environmental conditions, optimizing energy use.
7. **Energy Consumption:** The amount of electrical power used by lighting systems, measured over a specific period, which is influenced by factors such as the efficiency of the lighting control system and the duration of light usage.
8. **Cost Savings:** The reduction in electricity costs resulting from the implementation of energy-efficient lighting control systems that minimize unnecessary energy consumption.
9. **Environmental Impact:** The effect of energy consumption on the environment, particularly in terms of carbon emissions and resource depletion. The use of energy-efficient lighting systems aims to reduce the overall environmental footprint.
10. **Smart Technologies:** Technologies that incorporate automation, sensors, and connectivity to improve functionality and efficiency. In lighting systems, this includes IoT and AI capabilities that allow for intelligent, adaptive lighting management.
11. **User Interaction:** The process by which users engage with the lighting control system, either by adjusting settings manually or via automated features, influencing how energy is consumed and managed within a space.
12. **Demand Response:** The ability of a system to adjust its operation based on external factors, such as time of day or occupancy, to optimize energy usage and reduce demand during peak times.
13. **Lighting Demand:** The level of lighting required in a space, which can vary depending on factors such as the time of day, occupancy, and the presence of natural light.
14. **Scalable Solution:** A system or technology that can be expanded or adapted to different sizes and types of buildings, ensuring broad applicability and the potential for widespread adoption.

15. **Smart Lighting:** Lighting systems that use sensors, automation, and advanced technologies to adjust lighting levels based on real-time conditions, improving energy efficiency and user comfort.

### 1.9 Organization of the thesis
This thesis has five chapters that include:

**Chapter One:** Discusses introduction, Motivation and significance of study, scope of study, problem statement, objectives and Organization of the thesis.

**Chapter Two:** Discusses introduction, review of literature and related works.

**Chapter Three:** Discusses introduction, Methodology and system components and summary.

**Chapter Four:** Discusses introduction, results, operation, and summary.

Chapter Five has the conclusions and recommendations, references and appendix

### 1.10 Summary
This chapter highlights the motivation and significance, scope of the project, problem definition it also includes the main objectives. The origination of the report is also addressed here.

The overall objective of the project is to design and develop a system that will control lights and ensure energy used by the lighting installation is efficiently used.

## 2. Literature Review
### 2.1 Overview
This literature review will discuss the various methods used to control lights and energy optimization techniques and methods. It will include the review of the various lighting technologies and system used to optimize energy. Various light control methods are used to conserve energy and make lighting systems more efficient. The most common methods include on/off via a light switch, manual dimming, Photo sensors, Occupancy sensors and Clock switches. For example, manual-dimming controls enable occupants of a room to adjust the light output or illuminance/brightness, which is proportional to energy usage hence this results into energy savings through reduced power delivery. Photo sensors are used to; automatically turn on and off lighting systems based on detected illuminance. Occupancy sensors are designed to sense a presence. When incorporated into a lighting system occupancy sensor can be used to turn on and off lights based on detection of motion within a space.

### 2.2 Review of the literature
#### 2.2.1 Background of energy saving techniques and lighting systems
In order to achieve greater energy sustainability, two main factors have been raised: electricity generation with renewable energy and energy saving. The rising cost of energy makes indoor lighting techniques as one of the most important contributors to energy saving in most of the industrialized countries. Therefore, the history of indoor lighting is not exclusively linked to the development of new light sources, having impact on energy saving and sustainability.

For a long time energy saving techniques have been implemented for lighting systems such as; the use of day light switches that regulate the switching of lights dependent on the light levels in the atmosphere. The day light switch will only turn on the light when it is dark. This application is good for outdoor and security lights.

Another method that has been in use to optimize the use of electrical energy by the lighting system is the use of timing techniques. In this technique timers are used to control the switching on and off of the lighting system by use of predetermined times.

One of the methods that have been in use for a long time to reduce on energy consumed by artificial lights has been the use of energy efficient lights. Normal light bulbs that have been in use for a long time since the invention of the light bulb are mightily energy inefficient. This is due to the technique or science used to generate light that involves the heating of the filament. A filament is a coil in the bulb made from metal called tungsten that has a high melting point. The incandescent bulb generates light by running an electric current through the filament; it heats up and subsequently generates light.

Daylight optimization is one of the methods used technique to minimize the use of electrical energy by artificial lighting systems installed in buildings.

### 2.3 Types of lighting systems
#### 2.3.1 Incandescent bulbs
Incandescent bulbs where originally developed in the late 1800s. The incandescent bulbs produce light by passing electrical current through a tungsten metal wire suspended in an atmosphere inside a glass bulb called a filament. The electric current causes the filament to heat up so much that it glows and produces visible light and a lot of heat. Of the energy that goes into the incandescent filament, only 10 to 15 percent is emitted as light; the rest is emitted as heat. These bulbs are widely used because they are cheaper relative to the more efficient light.

The figure below shows an incandescent bulb and its components. (lighting research center, https ://www.lrc.rpi.edu/resources/publications/lpbh/061Incandescent.pdf)

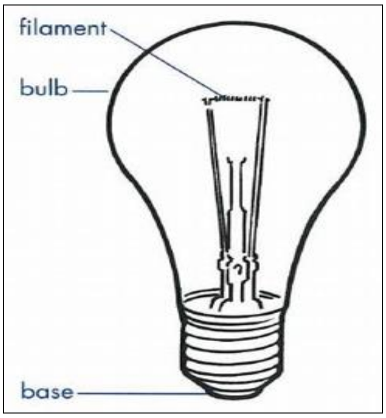



**Fig 2.1:** Incandescent bulb

#### 2.3.2 Fluorescent lighting
Compact fluorescent light (CFLs) are direct retrofits for incandescent lamps, which incorporate an electronic ballast and phosphor-lined glass tube. An electrical arc is struck at the tube’s electrodes, causing the mercury atoms to emit ultraviolet (UV) light, exciting the phosphor coating and emitting visible light. CFLs were developed in the 1970s, and are essentially a miniaturized version of a linear fluorescent lamp (LFL). Compared to incandescent lamps,

CFLs use approximately 75 per cent less electricity while producing the same amount of light and last about ten times longer. Linear fluorescent lamps operate in the same manner as described for CFLs. Table 2.1 provides more details. They do not incorporate a ballast, and thus require a dedicated fixture incorporating a ballast to operate. Linear fluorescent lamps are typically classified by their tubular diameter (most common are: T12 = 38mm, T8 = 25mm, T5 = 16mm) and by their length and wattage. (Accelerating the Global Adoption of ENERGY-EFFICIENT LIGHTING, United Nations Environment Programme, 2017, p21)

**Table 2.1:** The shows the floroscent afficacy compact vs linear lamps

| Characteristic | CFL typical quantity | LFL typical quantity |
|---|---|---|
| Luminous efficacy range | 50 – 70 lm/W | 80 - 110 lm/W |

Fluorescent lighting system usually uses more watts than the rated lamp wattage because the ballast also consumes power. The fluorescent lamps are however significantly more efficient than incandescent lamps. Linear and U-shaped fluorescent lamps are more efficacious than compact fluorescent lamps.

**Fig 2.2:** Compact fluorescent lamp

**Fig 2.3:** Fluorescent tubes lamps

### 2.3.3 High Intensity Discharge

High-intensity discharge lamps (HID lamps) are a type of electrical gas-discharge lamp that produces light by means of an electric arc between tungsten electrodes housed inside a translucent or transparent fused quartz or fused alumina arc tube. The tube is filled with a noble gas and often also contains suitable metal or metal salts. The noble gas enables the arc's initial strike. Once the arc is started, it heats and evaporates the metallic mixture. Its presence in the arc plasma greatly increases the intensity of visible light produced by the arc for a given power input, as the metals have many emission spectral lines in the visible part of the spectrum.

The High intensity discharge (HID) lamps. These are in various types that include mercury vapor, metal halide, and high-pressure sodium lamps. The HIDs lamps contain some of the most efficient lamps. High intensity discharge lamps all require a ballast for their operation. Although they are more efficient than incandescent lamps and can be inexpensive, mercury vapor lamps are not as efficient as most fluorescent lamps or other HID lamps of equivalent light output. Metal halide lamps are more efficient than mercury vapor lamps and have a higher Color rendering Index CRI. (Accelerating the Global Adoption of ENERGY-EFFICIENT LIGHTING, United Nations Environment Programme, 2017, p22).

**Fig 2.4:** Picture of high intensity discharge lamp

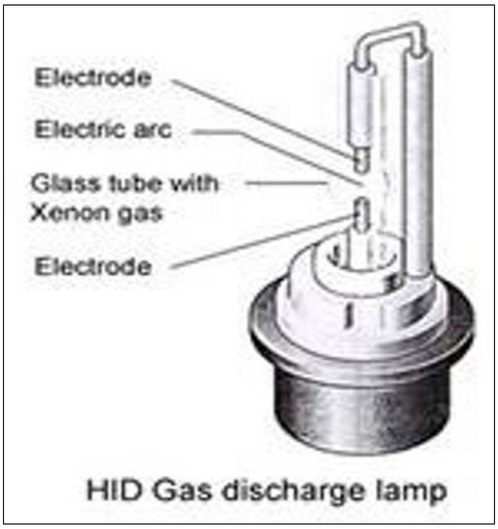



**Fig 2.5:** Figure of high intensity discharge lamp with components labeled

### 2.3.4 Light Emitting Diode

Light Emitting Diodes are constructed from semiconductor materials such as gallium arsenide, gallium phosphide or gallium arsenide phosphide. Their principle of operation is not different from a normal diode. It is a forward biased P-N junction semiconductor that emits visible when current flows through it. Below are pictures of a single LED and multiple LEDs forming a single light source Fig 2.6 and 2.7 respectively.

**Fig 2.6:** Single LED light

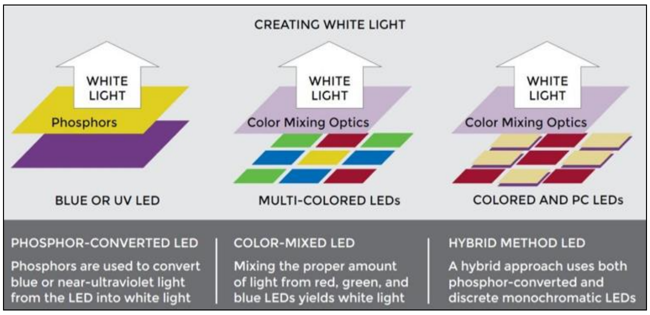
**Fig 2.7:** An array of LEDs

### 2.4 Energy saving techniques in lighting systems

### 2.4.1 LED energy saving technique

LED lamps and luminaires are rapidly expanding into general illumination applications all over the world. As LED technology improves in performance and becomes less expensive, this market expansion will accelerate, replacing traditional light sources with more efficient and better performing LED technology.

LEDs offer unique characteristics that make them a compelling source of light. They are compact, have long life, resist breakage and vibration, offer their best performance in cold operating environments, are instant-on and some models are dimmable. Depending on the drive circuit and LED array in a particular light source, LEDs can also be adjusted to provide different colored light or color temperatures of white. Unlike incandescent and fluorescent lamps, LEDs are not inherently white light sources. Fig 2.8 shows the different ways that white light can be achieved with LEDs. (United Nations Environment Programme, 2017)




**Source:** www.energy.gov/eere/ssl/led-bsics

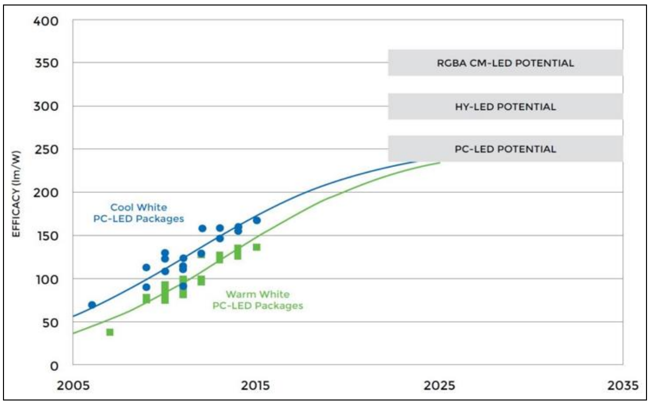
**Fig 2.8:** Producing white light with LEDs

LEDs are highly energy efficient when measuring light output for watts of electricity input. In the market today, the most efficacious LED lamps operate at around 130 lumens per watt. Table 2.2 provides more details. This is more than double the energy performance of a CFL and over 10 times more efficient than an incandescent lamp.

**Table 2.2:** Light emitting diode (LED) lighting typical performance specification

| CHARACTERISTIC | LED LAMP TYPICAL QUANTITY | LED LUMINAIRE TYPICAL QUANTITY |
|---|---|---|
| LUMINOUS EFFICACY RANGE (INITIAL) | 60 – 130 lm/W | 80 – 150 lm/W |
| LAMP LIFETIME | 15,000 – 30,000 hr | 20,000 – 60,000 hr |
| COLOUR RENDERING INDEX (RA) | 70 – 95 | 80 – 95 |
| CORRELATED COLOUR TEMPERATURE | 2,700 – 6,500 K | 2,700 – 6,500 K |
| DIMMABLE? | If dimmable driver | If dimmable driver |

Fig 2.8 shows the projected performance improvement expected for LED products. The figure shows the historic and projected performance improvement for LED packages under specific operating conditions.13 LED packages are the LED light sources used in lamps and luminaires that are already very efficient. Their performance varies significantly with the operating temperature of the LED and the electrical current density. LEDs operate with efficacies of 220 lumens per watt, under favourable conditions. The grey-shaded bars show the potential for further improvement with phosphor-converted blue or violet LEDs (PC-LED), hybrid mixtures containing additional red emitters (HY-LED) and with four or more primary emitters covering the whole spectrum (RGBA CM-LED). (United Nations Environment Programme, 2017)




**Source:** U.S. Department of Energy, Energy Efficiency and Renewable Energy Division

**Fig 2.9:** Efficacies of commercial LED packages measured at 25°C and 35 A/cm2 current density

### 2.4.2 Lighting controls techniques

#### 2.4.2.1 Introduction

Lighting control ranges from simple wall switches to complex dimming systems networked with other systems. Lighting control methods include local switching and dimming, presence detection, daylight linked and time operated. Controllers can be implemented that react to presence detection, daylight availability or time of day. Alternatively, manual control can be deployed which is cheaper to install but relies on human interaction and contact to turn lights off when they are not needed.

There are two types of lighting control analogue and digital. The Lighting control is a tool that performs and inspires, it’s important that the right lighting is used at the right time. Lighting controls help ensure that lighting is delivered at the right level for certain areas or workspaces. Lighting controls can be used for a range of applications such as dimming, presence detection and to switch off lights when there is sufficient daylight. (Greg Batten 16 July 2015).

A combination of a lighting controls system and energy-efficient lamps and luminaires produces the best possible outcome in terms of lighting performance in a building. Lighting controls systems can save a further 20 – 40 per cent of energy consumption for lighting. They constantly monitor usage and ambient light levels, and only run lighting when it is needed. (United Nations Environment Programme, 2017) Below is an array or matrix of lighting control systems or methods.

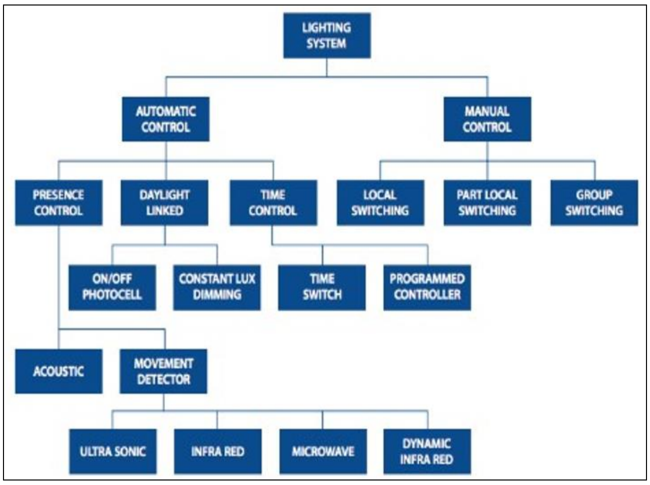



**Fig 2.10:** Light control matrix

#### 2.4.2.2 Manual light control

It consists of a manual on/off switch. The occupants in the building must remember to turn them on when they enter the room and turn them off when they leave to save on energy. With these types of lighting control, using energy efficient light bulbs, like LEDs and CFLs, with basic switches, can help reduce electric bills (Conserve energy future).

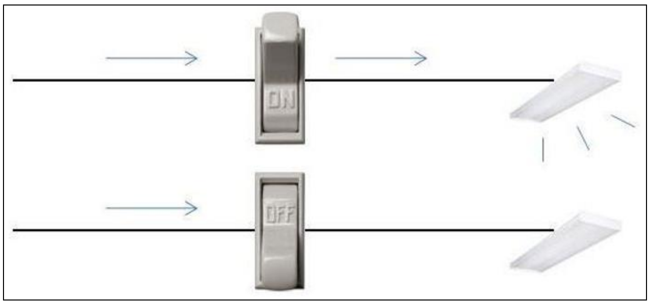



**Fig 2.11:** Manual light switches

Manual control is a simple strategy providing users the capability of choosing light levels either in steps (switching) or over a wide range with smooth transitions between levels (dimming).

According to LBNL, this strategy can result in 31% average lighting energy savings. (Craig Dilouie, 2017)

Basic dimming, using a dimmer-switch in addition to ON/OFF, it can alter current flowing through the load during the ON state, which raises or lowers light output. Here we see a dimmer placed on the line, with the output being continuous dimming over the load’s dimming range. (Craig Dilouie, 2017).

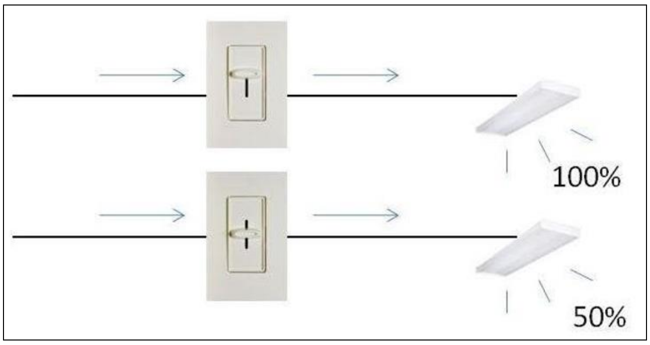



**Fig 2.12:** Manual dimming linear switches

Manual switching maybe: ON/OFF or multilevel via separate ON/OFF control of separate ballasts/drivers or luminaires. Dimming may be continuous, providing smooth transition across a dimming range, or stepped, providing either an abrupt or a smooth transition between two or more fixed outputs.

Manual controls are either permanently wired like a standard wall switch or ceiling mounted pull switch that can either be used for switching or dimming. They are the cheaper method of lighting control but not necessarily the best method of energy efficiency, as it requires manual switching. Manual control can be used in certain rooms that only require manual switching to match the sites activities. Manual on and auto off requires the occupant to manually turn on the lights when entering the space but the controller will automatically switch them off when nobody is present in the space. Remote control enables the lighting to be manually addressed with a hand held or wall mounted controller.

**2.4.2.3 Presence control**

Occupancy sensors are used to detect the presence of people and turn the lights off when an illuminated space is unoccupied. These systems incorporate intelligence into the designs to avoid false or too frequent turning off for the light fixtures.

The use of various sensors allows the operation of lamps whenever they are needed. These sensors detect the presence of humans, motion, timing or occupancy and based on the sensor output, it switches the lamps ON and OFF. Types of these controls include infrared sensors, automatic timers, motion sensors (PIR and ultrasonic sensors). (James Benya; Peter Schwartz, Advanced lighting guidelines, 2003, p19).

**Fig 2.13:** Motion or presence detection sensors

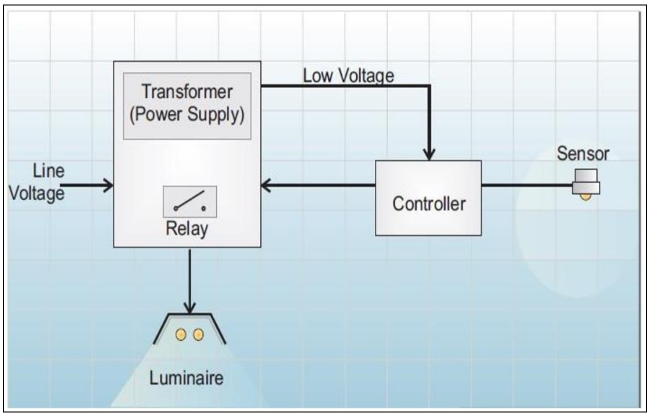



**Fig 2.14:** Motion or presence detection control system

**2.4.2.4 Timer control**

Managing lighting according to the time of day is one of the earliest control regimes, or strategies, applied to reduce lighting electricity use, in effect automatically operating the lighting during hours of occupation. This technique is still relevant today where applications like shopping malls can still benefit from this type of managed operation. Time control may use fixed times, such as the opening hours of a mall, or astronomical times, such as sunrise and sunset. The Fig 2.15 below illustrates this system, lighting system controlled by a timer. The lights come on at 6AM and off at 6PM in yellow, according to predetermined timers in the timer.

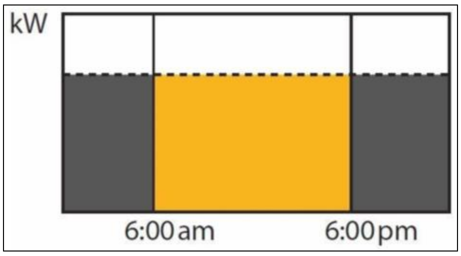



**Fig 2.15:**

However, in the office and workplace the rigidity of a time schedule is no longer valid because of the need to accommodate flexible working hours. In many lighting control applications timed events have taken on a new role altering the mode of operation rather than actually affecting the lighting directly. Time control can also be used to initiate a load shedding function, when the lighting levels are restricted for a specific period e.g. when cleaners are operating outside working hours. (Lighting control guide, 2018) They are various types of lighting control timer on the market and these are selected as per requirement. The two main types include electronic and mechanical.

**2.5 Types of lighting control timers**

**2.5.1 Introduction**

A timer is a control device that outputs a signal at a preset time after an input signal is received. There are two main types of light timers these are mechanical and electronic timers, and come as hardwired or plug-in modules.

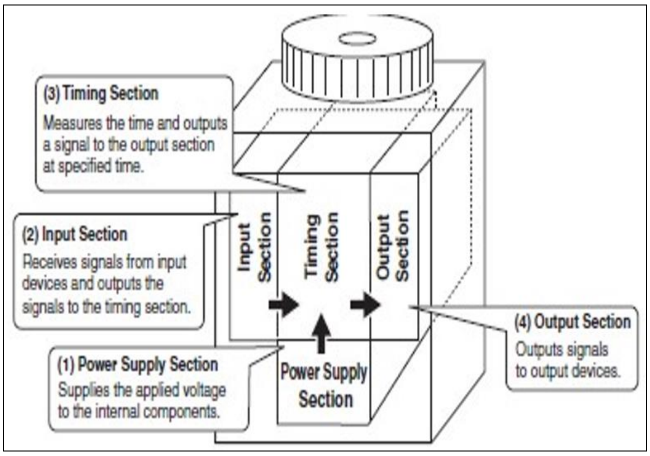



**Fig 2.16:** Mechanical timer with component explanation

**2.5.2 Mechanical timers**

Mechanical or analog timers are very similar to setting a watch or using the time knob on a toaster oven. The spring-loaded mechanical design keeps track of the time. Some give you the option to set as many on/off periods as you want within a 24-hour period. Other timers limit the operating time to a maximum of 60 minutes. The mechanical design ensures that the circuit will be completely cut off at the end of the specified time. Mechanical timers are durable, reliable, and convenient. Due to their strength and simplicity, mechanical, spring-wound timers are often used for lights. (Onetime service, 2018) The Fig 2.17 shows modern mechanical timers.


**Fig 2.17:** Mechanical Timer


**Fig 2.18:** Mechanical timer

### 2.5.3 Electronic Timers

There are various types of electronic timers; however they will not be discussed here as it is beyond the scope of this study.

Digital or programmable timers allow the option to set the switch to turn on and off at specific times. They are similar to some mechanical timers since they can have multiple on/off cycles in a 24-hour period, but they can be scheduled for more than one day. Similar to a programmable thermostat, you can set a 7-day schedule with the exact on/off times. (Onetime service, 2018)

Here below is a figure of an electronic Timer.

**Fig 2.19:** Digital timer


**Fig 2.20:** Electronic Timer

### 2.6 Daylight linked control

Managing artificial lighting with respect to the availability of natural light is arguably both the most obvious thing to do and the most difficult to deliver. The simplest form of daylight-linked operation is found in street lighting where individual photocells determine the switch ON and OFF points at dusk and dawn. In a roof lit area the energy savings delivered by lighting controls will justify the use of up to 20% glazing. (Lighting control guide, 2018)

**Fig 2.21:** Daylight control street lighting

## 2.7 Zoning control

Control zoning is an important aspect of lighting control system design, as zoning is the mechanism through which lighting controls are assigned to lighting loads. A control zone is defined as one or more light sources controlled simultaneously by a single control output. Zones may be organized in accordance with energy codes, desired energy savings and flexibility, common lighting equipment (e.g., fluorescent vs. LED), space characteristics (e.g., furnishing and finishes), tasks, daylight availability and lighting schedules.

Smaller control zones (higher granularity of zones in a space or building) introduce greater flexibility and typically higher energy savings. For this reason, a majority of energy codes regulate control zoning by imposing limits on area. (James Benya; Peter Schwartz, Advanced lighting guidelines, 2003)

## 2.8 Recommended light levels

The table below provides recommended light levels from the IESNA Lighting Handbook and LPD levels from the IECC 2021 (using the Space-By-Space Method for calculations). The LPD l evels should continue to drop with subsequent codes and as LED lighting becomes more energy efficient.

The required light levels are indicated in a range because different tasks, even in the same space, require different amounts of light. In general, low contrast and detailed tasks require more light while high contrast and less detailed tasks require less light.

Please keep in mind that this chart is not comprehensive. The IESNA Lighting Handbook has pages and pages of various categories.

**Table 2.3:** (Archtoolbox, 2021)

| **Room Type** | **Light Level (FOOT CA NDLES)** | **Light Level (Lux)** | **IECC 2021 Lighting PO WER Density (Watts PE R SF)** |
|---|---|---|---|
| Cafeteria - Eating | 20-30 FC | 200-300 lux | 0.40 |
| Classroom - General | 30-50 FC | 300-500 lux | 0.71 |
| Conference Room | 30-50 FC | 300-500 lux | 0.97 |
| Corridor - General | 5-10 FC | 50-100 lux | 0.41 |
| Corridor - Hospital | 5-10 FC | 50-100 lux | 0.71 |
| Dormitory - Living Quarte rs | 20-30 FC | 200-300 lux | 0.50 |
| Exhibit Space (Museum) | 30-50 FC | 300-500 lux | 0.31 |
| Gymnasium - Exercise / Workout | 20-30 FC | 200-300 lux | 0.90 |
| Gymnasium - Sports / Ga mes | 30-50 FC | 300-500 lux | 0.85 |
| Kitchen / Food Prep | 30-75 FC | 300-750 lux | 1.09 |
| Laboratory (Classroom) | 50-75 FC | 500-750 lux | 1.11 |
| Laboratory (Professional) | 75-120 FC | 750-1200 lux | 1.33 |
| **Room Type** | **Light Level (Foot CA NDLES)** | **Light Level (LUX)** | **IECC 2021 Lighting PO WER Density (Watts PE R SF)** |
| Library - Stacks | 20-50 FC | 200-500 lux | 1.18 |
| Library - Reading / Studyi ng | 30-50 FC | 300-500 lux | 0.96 |
| Loading Dock | 10-30 FC | 100-300 lux | 0.88 |
| Lobby - Office/General | 20-30 FC | 200-300 lux | 0.84 |
| Locker Room | 10-30 FC | 100-300 lux | 0.52 |
| Lounge / Breakroom | 10-30 FC | 100-300 lux | 0.59 |
| Mechanical / Electrical Ro om | 20-50 FC | 200-500 lux | 0.43 |
| Office - Open | 30-50 FC | 300-500 lux | 0.61 |
| Office - Private / Closed | 30-50 FC | 300-500 lux | 0.74 |
| Parking - Interior | 5-10 FC | 50-100 lux | 0.15 |
| Restroom / Toilet | 10-30 FC | 100-300 lux | 0.63 |
| Retail Sales | 20-50 FC | 200-500 lux | 1.05 |
| Stairway | 5-10 FC | 50-100 lux | 0.49 |
| Storage Room - General | 5-20 FC | 50-200 lux | 0.38 |
| Workshop | 30-75 FC | 300-750 lux | 1.26 |

### 2.9 Gaps in literature review

Despite the extensive body of research on automatic lighting control systems and energy optimization, several gaps remain that hinder the full realization of these systems' potential in real-world applications. One key gap is the lack of comprehensive system designs. While much of the existing literature focuses on specific components of lighting control, such as occupancy and daylight sensors, few studies offer a holistic approach that integrates these technologies into a cohesive, scalable system. A complete solution that balances sensor integration, algorithms, and user interfaces for various building types is still underexplored. Another significant gap is the issue of cost-effectiveness and affordability. Although much research emphasizes advanced technologies like IoT and AI, there is limited attention given to creating low-cost, accessible solutions for energy optimization, especially in developing regions or for retrofitting older buildings. The high initial installation costs remain a barrier to widespread adoption, and further exploration of budget-friendly sensor technologies and smart controllers is needed.

Additionally, there is a lack of research on the challenges of integrating automatic lighting systems into existing building infrastructure. Many older buildings are not equipped with the necessary wiring or network capabilities to support advanced systems, making retrofitting a significant challenge. Research that addresses cost-effective retrofitting solutions or strategies to overcome integration issues in older structures is limited. User adaptability and interaction with these systems also remain under-examined.

While technological efficiency is well-researched, there is less focus on how different user groups—such as tenants, building managers, or homeowners—interact with and adapt to these systems in everyday use. Understanding user behavior, customization preferences, and interface design could significantly improve user adoption and energy savings. Finally, while the potential of AI and IoT for energy optimization is widely acknowledged, there is limited research on their practical integration in lighting control systems. AI's ability to predict and adjust lighting based on user patterns and environmental data, as well as IoT's role in remote control and monitoring, offers significant opportunities but remains insufficiently explored in the context of lighting control and energy optimization. Addressing these gaps will contribute to more effective, accessible, and widely adopted lighting control systems.

## 3. Methodology

### 3.1 Introduction

Here we will have an overview of the components and methods used to achieve the implementation of the project. The success of the project is based on the integration of different hardware and software components. Sensors, software, microcontroller and other components such as batteries, power supplies, resistors, LEDs have been integrated to create a system.

### 3.2 System components

#### 3.2.1 Microprocessor

A microprocessor is processor whose elements have been miniaturized into one or a few integrated circuits (Dr. William Stallings, 2013). The microprocessor consists of thousands of electronic switching circuits. As with any logic operation, each circuit can be either ON or OFF. It follows that the operation that is effected by a microprocessor must be a binary one. Instructions fed into a microprocessor are in binary digits. The form of the instruction must be a series of ones and zeros which relate to circuits being closed or open. Typically, a circuit which is ON would supply a signal of about 5 V and a circuit which is OFF would supply a signal of 0V. The byte are fed into a microprocessor either by a sequence of pulses, which is known as asynchronous action, or all pulses at one time, which is known as synchronous action. The former is a serial operation while the latter is a parallel operation. The rate at which bits are fed into a microprocessor is determined by a clock which typically, for low-speed microcontrollers like the ones on Arduino microcontroller, operates at 16 MHz. Thus in serial operation 16 000 000 bits can be handled every second. In order to make sense of a sequence of input information, the microprocessor has to be able to obey a number of instructions. It also requires a memory in which input information can be stored. The memory requires an addressing system so that it is known where the information is stored and, equally, from whence it can be recalled. The input information comes in two distinct forms: instructions and data. Both are expressed in binary form but the microprocessor must be capable of distinguishing between them. The instructions relate to a particular section of the memory arrangement. This section is termed the read-only memory, or ROM. This has a set of instructions manufactured into it and they cannot be changed.

Also, when the microprocessor is switched off, the instructions remain permanently in the ROM and are called non-volatile. Thus if a microprocessor is given the instructions to place a byte of data in store, the instruction code introduced causes a number of instructions retained in the ROM to be recalled and the resulting effect is that the data are placed in the next available register. Implicit in this observation is the alternative form of memory, i.e. one in which information can be temporarily stored. This form of memory is termed a random-access memory or RAM. A RAM comprises a large number of stores, each of which has an address; therefore, when we insert an information byte, we require an associated address indicating the particular location in which it is to be stored. Similarly, we need to know the address should we wish to recall the information byte. Unlike a ROM, the information stored in a RAM is lost when it is deenergized. The RAM is therefore said to be volatile.

The microprocessor therefore can be seen to operate on the interaction of a number of interacting processes. At the heart of these interactions is the accumulator. This can be considered as the section where the main activity takes place. Thus, when it is proceeding through a series of operations, the changes in the information process take place in the accumulator. Typically, a sequence of events could require two or three changes, at which stage the processor would have gone as far as it could. The result can then be stored in the RAM, clearing the accumulator ready for the next series of operations. The control of the sequence may come either from the ROM or from another section of the RAM in conjunction with the ROM.

The central processing unit is the microprocessor chip containing the accumulator. It is connected to the ROM and to the RAM by three sets of circuits, or buses. The address bus relays the direction of the data to be stored or recalled from memory in order that the correct storage system is used. The data is however transferred through the data bus.

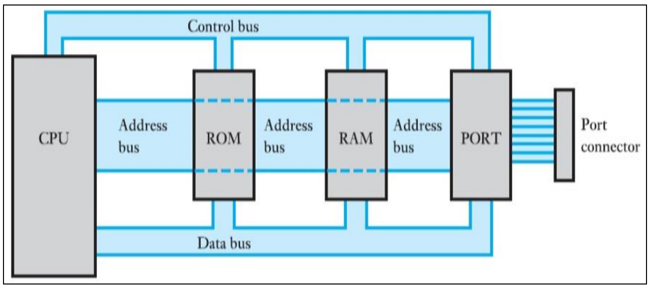



**Fig 3.1:** Diagram of the microprocessor

The changing of the address or bus permits the following of data to be directed to a different destination. The diagram also shows the control bus, which carries the instructions for the organization of the sequence of operations including the commencement and termination of the sequences.

Finally, the port is the circuitry which connects the microprocessor system to the world around it. In the limited content of this report it is not possible to explain fully the operation of each of the parts of a microprocessor system.

### 3.2.2 Microcontroller

A microcontroller is computer system whose processing unit is a microprocessor. A basic microcontroller includes a microprocessor, storage, and an input/output facility, which may or may not be on one chip (Dr. William Stallings, 2013). A microcontroller basically includes many elements of a computer system where a microprocessor is only the CPU.

## 3.3 Arduino UNO Microcontroller

### 3.3.1 General overview

The Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins of which 6 can be used as Pules Width Modulation outputs, 6 analog inputs, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; it connects to a computer with a USB cable or power it with a AC-to-DC adapter or battery. "Uno" means one in Italian and was chosen to mark the release of Arduino Software (IDE) 1.0. The Uno board and version 1.0 of Arduino Software (IDE) were the reference versions of Arduino, now evolved to newer releases. The Uno board is the first in a series of USB Arduino boards, and the reference model for the Arduino platform. The figure below shows the Arduino UNO mega.

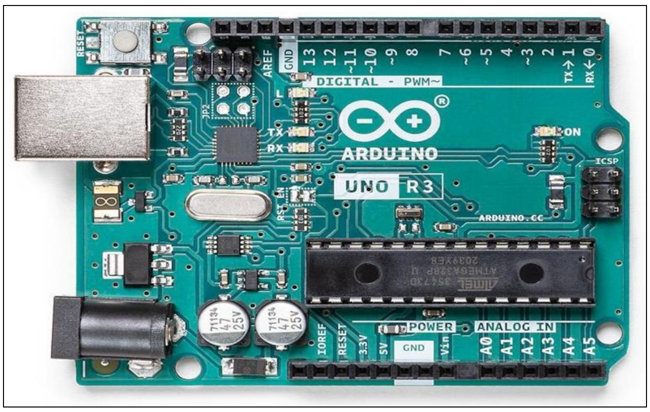



**Fig 3.2:** Arduino microcontroller

### 3.3.2 Technical specifications

**Table 3.1:** Microcontroller technical specifications

| | |
|---|---|
| Microcontroller | ATmega328P |
| Operating Voltage | 5V |
| Input Voltage (Recommended) | 7-12V |
| Input 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 | 53.4 mm |
| Weight | 25 g |

### 3.3.3 Board architecture

The diagrams below indicate the board layout, pin configuration and general architecture.

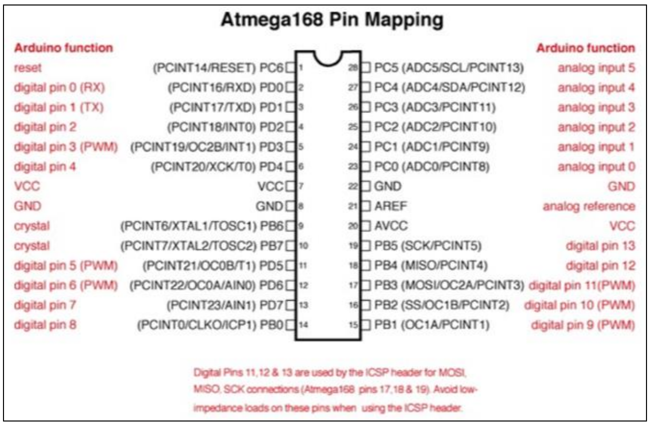



**Fig 3.3:** Microcontroller pin identification

Each of the 14 digital pins on the Uno can be used as an input or output, using pinMode(),digitalWrite(),and digitalRead( ) functions. They operate at 5 volts. Each pin can provide or receive 20 mA as recommended operating condition and has an internal pull-up resistor (disconnected by default) of 20-50k ohm. A maximum of 40mA is the value that must not be exceeded on any I/O pin to avoid permanent damage to the microcontroller. In addition, some pins have specialized functions:

- Serial: 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
- External Interrupts: 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.
- PWM: 3, 5, 6, 9, 10, and 11. Provide 8-bit PWM output with the analogWrite() function.
- SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication using the SPI library.

- LED: 13. There is a built-in LED driven by digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.
- TWI: A4 or SDA pin and A5 or SCL pin. Support TWI communication using the Wire library.

The Uno has 6 analog inputs, labeled A0 through A5, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and the analogReference() function.
There are a couple of other pins on the board:

- AREF. Reference voltage for the analog inputs. Used with analogReference().Reset. Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

### 3.3.4 Arduino power supply

The Arduino Uno board can be powered via the USB connection or with an external power supply. The power source is selected automatically.
External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the GND and Vin pin headers of the POWER connector.
The board can operate on an external supply from 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may become unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The power pins are as follows:

- Vin. The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- 5V.This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 12V), the USB connector (5V), or the VIN pin of the board (7-12V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage your board. We don't advise it.
- 3V3. A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- GND. Ground pins.
- IOREF. This pin on the Arduino board provides the voltage reference with which the microcontroller operates. A properly configured shield can read the IOREF pin voltage and select the appropriate power source or enable voltage translators on the outputs to work with the 5V or 3.3V.

### 3.3.5 Arduino memory

The ATmega328 has 32 KB (with 0.5 KB occupied by the bootloader). It also has 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the EEPROM library).

### 3.3.6 Arduino programming

The Arduino Uno can be programmed with the Arduino Software IDE. Select "Arduino Uno from the Tools > Board menu (according to the microcontroller on your board).
The ATmega328 on the Arduino Uno comes preprogrammed with a bootloader that allows uploading new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files).The bootloader can be bypassed and program the microcontroller through the ICSP (In-Circuit Serial Programming) header using Arduino ISP or similar.

## 3.4 Transformer

### 3.4.1 Introduction

A transformer is a device which uses the phenomenon of mutual induction to change the values of alternating voltages and currents. One of the main advantages of alternating current transmission and distribution is the ease with which an alternating voltage can be increased or decreased by transformers. In this project the transformer play a cardinal role to transformer voltage level to usable levels for the microcontroller, its secondary side is that coupled to another system called the rectifier and regulation for conversion of voltage from AC to DC and stability for the desired power type of the microcontroller. The combination of these components makes up a power supply, which will be discussed in the following chapters in detail.
Losses in transformers are generally low and thus efficiency is high. Being static they have a long life and are very stable. Transformers range in size from the miniature units used in electronic applications to the large power transformers used in power stations; the principle of operation is the same for each.
A transformer is represented in Figure 3.6 consisting of two electrical circuits linked by a common ferromagnetic core. One coil is termed the primary winding which is connected to the supply of electricity, and the other the secondary winding, which may be connected to a load.

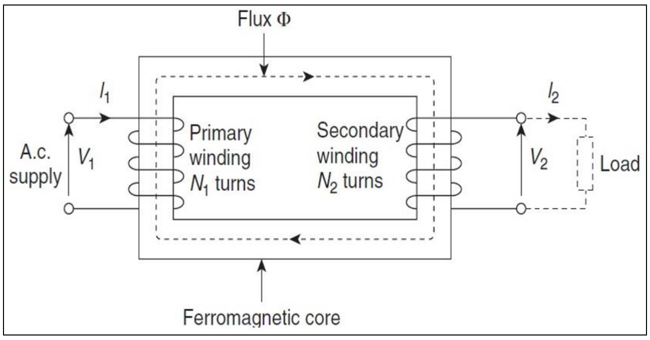



**Fig 3.4:** Transformer schematic diagram

### 3.4.2 Transformer construction

The simple elements of a transformer consist of two coils having mutual inductance and a laminated steel core. The two coils are insulated from each other and the steel core. Other necessary parts are some suitable container for assembled core and windings; a suitable medium for insulating the core and its windings from its container; suitable bushings (either of porcelain, oil-filled or capacitor-type) for insulating and bringing out the terminals of the winding from the tank. In all types of transformers the core is constructed of transformer sheet steel laminations assembled to provide a magnetic path with minimum air gap. The steel used is of high silicon content, sometimes heat treated to provide a high permeability and low hysteresis losses at the usual operating flux densities. The eddy current loss is minimized by laminating the core, the laminations being insulated from each other by a light coat of core-plate varnish or by an oxide layer on the surface. The thickness of laminations varies from 0.35 mm for a frequency of 50 Hz to 0.5 mm for a frequency of 25 Hz. The core laminations (in the form of strips) are joined as shown in Fig 3.7. (B.L. Theraja and A.K. Theraja, 2005)

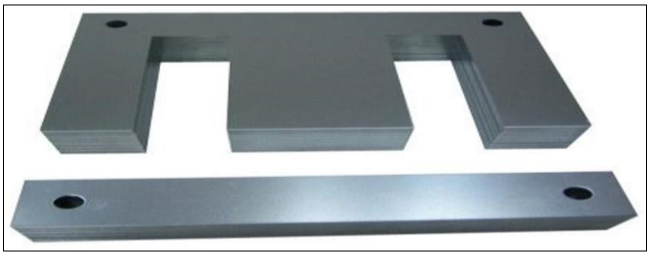


**Fig 3.5:** Transformer core laminations

It is seen that the joints in the alternate layers are staggered in order to avoid the presence of narrow gaps right through the cross-section of the core. Such staggered joints are said to be 'imbricated'. Constructionally, the transformers are of two general types, distinguished from each other merely by the manner in which the primary and secondary coils are placed around the laminated core. The two types are known as; core-type and shell- type. Another recent development is spiral-core or wound-core type, the trade name being spirakore transformer. In the so-called core type transformers, the windings surround a considerable portion of the windings as shown schematically in Fig 3.8.

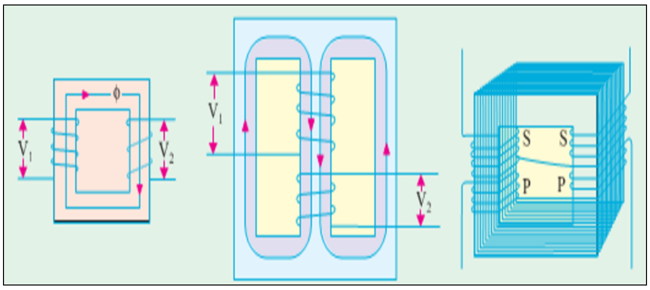



**Fig 3.6:** Core, shell and spiral type transformer See Appendix B for actual transformer picturs

In the simplified diagram for the core type transformers in Fig 3.8 above, the primary and secondary windings are shown located on the opposite legs (or limbs) of the core, but in actual construction, these are always interleaved to reduce leakage flux. As shown in figure above on the far right, half the primary and half the secondary winding have been placed side by side or concentrically on each limb, not primary on one limb (or leg) and the secondary on the other.

### 3.4.3 Transformer principle of operation

When the secondary is an open-circuit and an alternating voltage is applied to the primary winding, a small current called the no-load current flows, which sets up a magnetic flux in the core. This alternating flux links with both primary and secondary coils and induces in them an e.m.f of E1 and E2 respectively by mutual induction. The induced e.m.f. E in a coil with N turns is given by E=−N(d/dt) volts, where d dt is the rate of change of flux. In an ideal transformer, the rate of change of flux is the same for both primary and secondary and thus E1/N1 =E2/N2 hence the induced e.m.f. per turn is constant. Assuming no losses,

E1 =V1 and E2 =V2 Hence V1/N1 = V2/N2 Or V1/V2 = N1/N2

(V1/V2) is called the voltage ratio and (N1/N2) the turns ratio, or the 'transformation ratio' of the transformer. If N2 is less than N1 then V2 is less than V1 and the device is termed a step-down transformer. If N2 is greater then N1 then V2 is greater than V1 and the device is termed a step-up transformer. When a load is connected across the secondary winding, a current I 2 flows. In an ideal transformer losses are neglected and a transformer is considered to be 100 percent efficient. Hence input power=output power, or V1I1 =V2I2 i.e. in an ideal transformer, the primary and secondary ampere-turns are equal

Thus V1 /V2 = I2/ I1

Combining equations (1) and (2) gives: V1 /V2 = N1/N2 = I2/I1

The rating of a transformer is stated in terms of the volt-amperes that it can transform without overheating. With reference to Fig. 21.1(a), the transformer rating is either V1/I1 or V2/I2, where I2 is the full-load secondary current. (Edward Huges, 2008).

## 3.5 Power supply

### 3.5.1 Introduction

Power Supply is an electronic device that supplies required power to the circuitry of the device. The purpose of a mains power supply is to convert the power delivered to its input by the alternating mains electricity supply into power available at its output in the form of a smooth and constant direct voltage. There are three major types of power supplies:

- Unregulated Power Supply
- Linear Regulated Power Supply
- Switching
- Ripple Regulated Power Supply.

These power supplies convert AC input to DC output voltage. Common power supplies of daily use include Cell Phone charging adaptors, laptop computer charging adaptors, Uninterrupted Power Supply (UPS) Computers or electronic circuits are very delicate. A heavy 220Vs of current or AC current can damage the circuit but a constant DC current at low voltage is safe for the electronic circuits (Sheikh Muhammad Ibraheem, 2020).
The basic PSU has four main stages, illustrated in Fig 3.8.

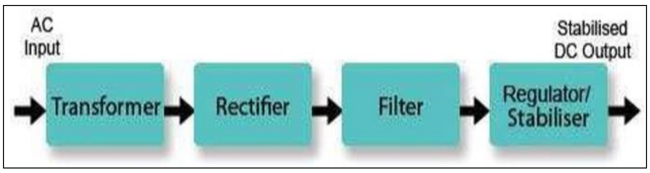



**Fig 3.7:** Power Supply Block Diagram

In a basic power supply the input power transformer has its primary winding connected to the mains (line) supply. A secondary winding, electro-magnetically coupled but electrically isolated from the primary is used to obtain an AC voltage of suitable amplitude, and after further processing by the PSU, to drive the electronics circuit it is to supply. The transformer stage must be able to supply the current needed. If too small a transformer is used, it is likely that the power supply's ability to maintain full output voltage at full output current will be impaired. With too small a transformer, the losses will increase dramatically as full load is placed on the transformer. As the transformer is likely to be the most costly item in the power supply unit, careful consideration must be given to balancing cost with likely current requirement.
In this project regulated power supply is used to achieve a stable power to the microcontroller, this ensures that the microcontroller operates correctly without any glitches. Unstable power bring about undesired operation of the electronics due to the fluctuation in the power

### 3.6 Rectifier
### 3.6.1 Half Wave Rectification
A single silicon diode may be used to obtain a DC voltage from the AC input as shown in Fig 3.10. This system is cheap but is only suitable for fairly non-demanding uses. The DC voltage produced by the single diode is less than with the other systems, limiting the efficiency of the power supply, and the amount of AC ripple left on the DC supply is generally greater. The half wave rectifier conducts on only half of each cycle of the AC input wave, effectively blocking the other half cycle, leaving the output wave shown in Fig 3.10.

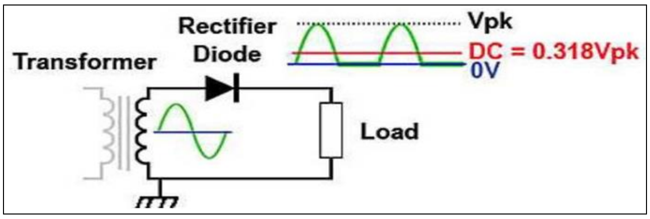



**Fig 3.8:** Half wave rectifier

As the average DC value of one half cycle of a sine wave is 0.637 of the peak value, the average DC value of the whole cycle after half wave rectification will be 0.637 divided by 2, because the average value of every alternate half cycle where the diode does not conduct, will of course be zero. This gives an output of: Vpk x 0.318 this figure is approximate, as the amplitude of the half cycles for which the diode conducts will also be reduced by about 0.6V due to the forward voltage drop (the depletion layer p.d.) of the silicon rectifier diode. This additional voltage drop may be insignificant when large voltages are rectified, but in low voltage power supplies where the AC from the secondary winding of the mains transformer may be only a few volts, this 0.6V drop across the diode junction may have to be compensated for, by having a slightly higher transformer secondary voltage. Half wave rectification is not very efficient at producing DC from a 50Hz or 60Hz AC input. In addition the gaps between the 50 or 60Hz diode output pulses make it more difficult to remove the AC ripple remaining after rectification.

### 3.6.2 Full Wave Rectification
If a transformer with a center tapped secondary winding is used, more efficient full wave rectification can be used. The center-tapped secondary produces two anti-phase outputs, as shown in Fig 3.11.

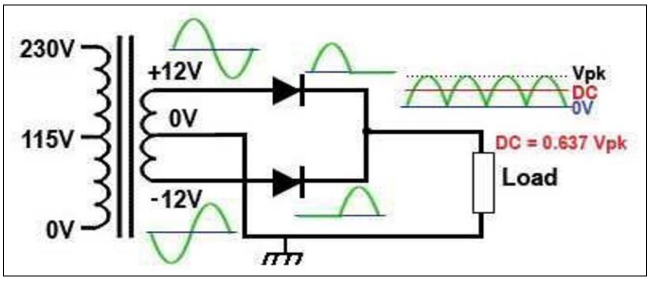



**Fig 3.9:** Full wave rectifier

If each of these outputs is 'half wave rectified' by one of the two diodes, with each diode conducting on alternate half cycles, two pulses of current occur at every cycle, instead of once per cycle in half wave rectification. The output frequency of the full wave rectifier is therefore twice the input frequency. This effectively provides twice the output voltage of the half wave circuit; Vpk x 0.637 instead of Vpk x 0.318 as the 'missing' half cycle is now rectified, reducing the power wasted in the half wave circuit. The higher output frequency also makes the smoothing of any remaining AC ripple easier. Although this full wave design is more efficient than the half wave, it requires a center tapped (and therefore more expensive) transformer.

### 3.6.3 The Bridge Rectifier
The full wave bridge rectifier uses four diodes arranged in a bridge circuit as shown in Fig 3.12 to give full wave rectification without the need for a center-tapped transformer.

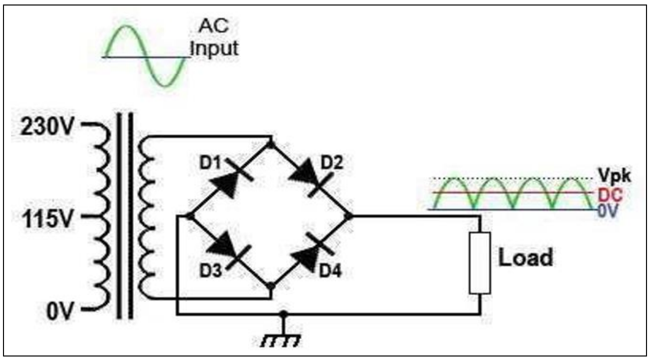



**Fig 3.10:** Bridge rectifier see Appendix C for actual rectifier

An additional advantage is that, as two diodes (effectively in series) are conducting at any one time, the diodes need only half the reverse breakdown voltage capability of diodes used for half and conventional full wave rectification. The bridge rectifier can be built from separate diodes or a combined bridge rectifier can be used. The current paths on positive and negative half cycles of the input wave are shown in Fig 3.13 and Fig 3.14. It can be seen that on each half cycle, opposite pairs of diodes conduct, but the current through the load remains in the same polarity for both half cycles.

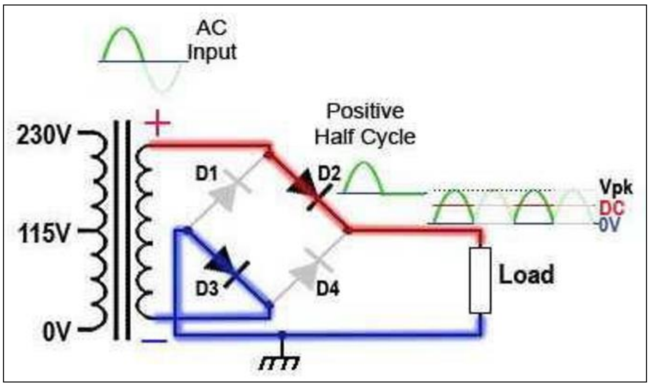



**Fig 3.11:** Positive half cycle rectification

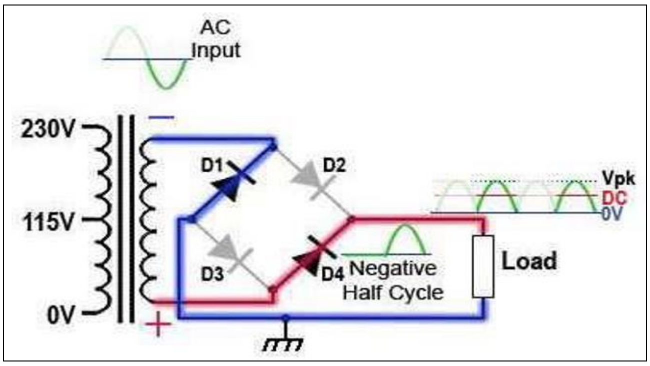



**Fig 3.12:** Negative half cycle rectification

### 3.6.4 Filter Circuit

The purpose of the introduction of the filter in the power supply is to smooth the output generated from the rectifier. The output generated from the rectifier is mixed AC and DC but this output is not good for the usage so a filter is required to purify the output of rectifier and provide a constant DC signal. An RC filter can easily perform the job but the problem with this filter is that it is load dependent. As given below.

$$Vr = \frac{Vout}{fCRl}$$

According to the formula above the value of capacitance is dependent on the value of load resistor. If the value of load resistor is changed then the ripple will be changed and then the capacitance value also needs to be changed. This type of filter can be used in power supplies. Here the requirement is to use such kind of circuit which is not just economically efficient but also must be easy to understand and use. So an LC filter is used which is independent of the output. This means that no matter whatever load is connected to the circuit. The ripple factor will not be changed and the output will remain constant DC

$$Vr = \frac{1}{6\sqrt{2}\,w^2LC}$$

So according to the above formula the ripple factor is independent of the load.

### 3.7 Batteries

Another good stable and reliable source of direct current for powering electronic devices is batteries.

A battery converts chemical energy into electrical energy by a chemical reaction. Usually the chemicals are kept inside the battery. It is used in a circuit to power other components. A battery produces direct current (DC) electricity that flows in one direction, and does not switch back and forth. The figure below shows batteries.

**Fig 3.13:** Set of AA 1.5 volts batteries

### 3.8 Transistor

#### 3.8.1 Introduction

The transistor works both as a switch and amplifier. In this project the switch principle is being used to transfer heavy current to heavy loads as the microcontroller cannot handle heavy current loads such as lighting in this case. The microcontroller is used to control the transistor that in turn breaks and makes the circuit for the lighting systems.

The transistor also has the ability to break and make an electrical circuit at high operating frequency. This provides the opportunity to use the transistor for Pulse Width Modulation on the lighting. The PMW is used to control the brightness of the lights.

In the subsequent paragraphs the construction and principle of operation of the transistor will be discussed. Bipolar transistors are one of the main 'building blocks' in electronic systems and are used in both analogue and digital applications. The devices incorporate two pn junctions and are also known as bipolar junction transistors (BJTs). It is common to refer to bipolar transistors simply as 'transistors', the term FET being used to identify the field-effect transistor. Bipolar transistors get their name from the fact that current is carried by both polarities of charge carriers (that is, by electrons and by holes), unlike FETs, which are unipolar. Bipolar transistors generally have a higher gain than FETs and can often supply more current. However, they have a lower input resistance than FETs, are more complicated in operation and often consume more power. The scope of this report will look at the bipolar transistors and their physical construction, operation and characteristics. Fig 3.16 shows a real life picture of a transistor used in the project.

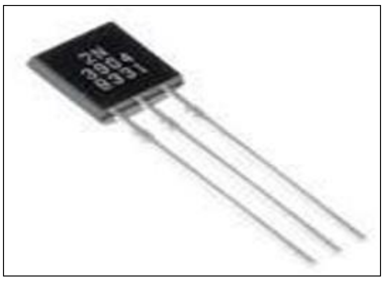


**Fig 3.14:** NPN transistor

### 3.8.2 Construction
Bipolar transistors are formed from three layers of semiconductor material. Two device polarities are possible. The first is formed by placing a thin layer of p type semiconductor between two layers of n-type material to form an npn transistor. The second is formed by placing a thin layer of n-type material within two layers of p-type material to give a pnp transistor. Both types of device are widely used and circuits often combine components of these two polarities. The operation of the two forms is similar, differing mainly in the polarities of the voltages and currents (and in the polarities of the charge carriers involved). Fig 3.16 shows the form of each kind of transistor. It can be seen that in each case the sandwich construction produces two pn junctions (diodes). However, the operation of the transistors is very different from that of two connected diodes. As the operation of npn and pnp transistors is similar.

**Fig 3.15:** Transistor diagrams PNP and NPN

### 3.8.3 Bipolar transistor operation
The npn or pnp structure produces two pn junctions connected 'back to back', as shown in Fig 3.18. If a voltage is connected across the device between the collector and the emitter, with the base open circuit, one or other of these junctions is reverse biased, so negligible current will flow. If a transistor was nothing more than two 'back-to-back diodes', it would have little practical use. However, the construction of the device in particular, the fact that the base region is very thin it allows the base to act as a control input. Signals applied to this electrode can be used to produce, and control, currents between the other two terminals. To have a better understanding we will consider the circuit configuration shown in Fig 3.18.

The normal circuit configuration forms an npn transistor is to make the collector more positive than the emitter. Typical voltages between the collector and the emitter (*VCE*) might be a few volts. With the base open circuit, the only current flowing from the collector to the emitter will be a small leakage current ***ICEO***, the subscript specifying that it is the current from the Collector to the Emitter with the base Open circuit. This leakage current is small and can normally be neglected. If the base is made positive with respect to the emitter this will forward bias the base–emitter junction, which will behave in a manner similar to a diode. For small values of the base-to-emitter voltage (*VBE*) very little current will flow, but as *VBE* is increased beyond about 0.5 V (for a silicon device), the base current begins to rise rapidly. The fabrication of the device defines that the emitter region is heavily doped, while the base is lightly doped. The heavy doping in the emitter region results in a large number of majority charge carriers, which are electrons in an npn transistor. The light doping in the base region generates a smaller number of holes, which are the majority carriers in the p-type base region. Thus, in an npn transistor, the base current is dominated by electrons flowing from the emitter to the base. In addition to being lightly doped, the base region is very thin. Electrons that pass into the base from the emitter as a result of the base–emitter voltage become minority charge carriers in the p-type base region. As the base is very thin, electrons entering the base find themselves close to the space-charge region formed by the reverse bias of the base–collector junction. While the reverse-bias voltage acts as a barrier to majority charge carriers near the junction, it actively propels minority charge carriers across it. Thus, any electrons entering the junction area are swept across into the collector and give rise to a collector current. The design of the device ensures that the majority of the electrons entering the base are swept across the junction into the collector. Thus, the flow of electrons from the emitter to the collector is many times greater than the flow from the emitter to the base. This allows the transistor to function as a current-amplifying device, with a small base current generating a larger collector current. As conventional current flow is in the opposite direction to the flow of the negatively charged electrons, a flow of electrons from the emitter to the collector represents a flow of conventional current in the opposite direction, as shown in Fig 3.18. This phenomenon of current amplification is referred to as transistor action.

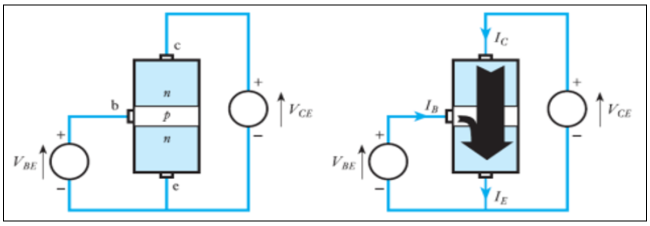


**Fig 3.16:** Transistor schematic circuit diagram showing flow of current

## 3.9 Passive Infrared Sensor PIR
### 3.9.1 Introduction
The Passive infrared sensor is an electronic device that measure infrared light radiating from objects in its field of view. The PIR sensors application in this project is to control the switching on of the lights through the sensing of a presence in a space and send a signal to the mi-crocontro ller input. This signal is knows as input signal to the microcontroller and provides information to the software in the microcontroller to execute the code that controls the switching on and off of the signal output for lights. The working and construction of the PIR sensor will be explained in the follow-ing paragraphs under this topic.

### 3.9.2 Operation of PIR sensors
A few mechanisms have been used to focus the distant infrared energy onto the sensor surface. The window may have Fresnel lenses molded into it. Alternative-ly, sometimes PIR sensors are used with plastic segmented parabolic mirrors to focus the infrared energy; when mirrors are use d, the plastic window cover has no Fresnel lenses molded into it. A filtering window (or lens) maybe used to limit the wavelengths to 8-14 micrometers, which is most sensitive to human infrared radiation (9.4 micrometers being the strongest). The PIR device can be thought of as a kind of infrared 'camera', which remembers the amount of infrared energy focused on its surface. A person entering the monitored area is detected when the infrared energy emitted from the intruder's body is focused by a Fresnel lens or a mirror segment and overlaps a section on the chip, which had previously been looking at some much cooler part of the

protected area. That portion of the chip is now much warmer than when the intruder wasn't there. As the intruder moves, so does the hot spot on the surface of the chip.

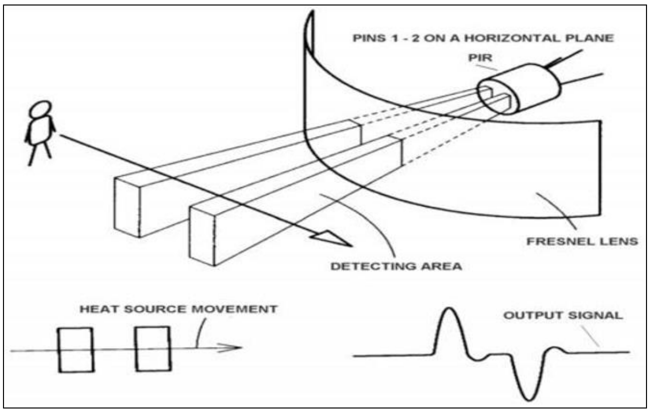



**Fig 3.17:** Diagram showing PIR working mechanism

At the heart of the sensor is the pyro-electric material. This material generates energy when exposed to radiation. When a body emitting infrared passes across the sensor, the intensity of the incoming radiation with respect to the background increases. As a result, the energy generated by the sensor also increases. Suitable signal conditioning circuits convert the energy generated by the sensor to a suitable voltage output.

### 3.10 Light Dependent Resistors (LDR)

#### 3.10.1 Introduction

LDR or light dependent resistor is also known as photo resistor, photocell, and photoconductor. It is a one type of resistor whose resistance varies depending on the amount of light falling on its surface. When the light falls on the resistor, its resistance changes.

These resistors are often used in many circuits where it is required to sense the presence of light. The LDR sensor application in this project is to sense the intensity of the light brightness and provide a signal to the microcontroller as an input. The value of the light read by the sense is used to manipulate the code of the PWM. The value is used to compare to reference value in the software.

#### 3.10.2 Operation of LDR

This resistor works on the principle of photo conductivity. It is nothing but, when the light falls on its surface, then the material conductivity reduces and also the electrons in the valence band of the device are excited to the conduction band. These photons in the incident light must have energy greater than the band gap of the semiconductor material. This makes the electrons to jump from the valence band to conduction.

**Fig 3.18:** Light Dependent Resistor LDR

These devices depend on the light, when light falls on the LDR then the resistance decreases, and increases in the dark. When a LDR is kept in the dark place, its resistance is high and, when the LDR is kept in the light its resistance will decrease.

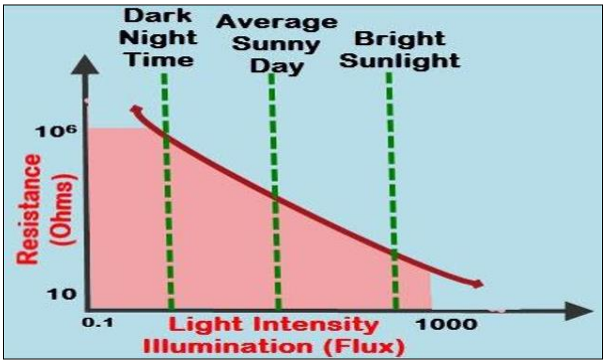



**Fig 3.19:** The figure shows the intensity against the resistance of the photo sensor

### 3.11 Pulse Width Modulation

In order to achieve the variation of the light intensity and subsequent power delivery to the lights, a strategy or technique known as Pulse Width Modulation (PWM) has been deployed through the use of software via the microcontroller.

Pulse-width modulation (PWM) is a method of reducing the average power delivered by an electrical signal, by effectively chopping it up into discrete parts. The average value of voltage fed to the load is controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to the off periods, the higher the total power supplied to the load. It is one of the primary methods of reducing the output. PWM is particularly suited for running inertial loads such as motors, which are not as easily affected by this discrete switching, because their inertia causes them to react slowly. The PWM switching frequency has to be high enough not to affect the load, which is to say that the resultant waveform perceived by the load must be as smooth as possible.

The rate or frequency at which the power supply must switch can vary greatly depending on load and application. For example, switching has to be done several times a minute in an electric stove; 100 or 120 Hz double of the frequency of 50Hz in normal power supply, in a lamp dimmer; between a few kilohertz (kHz) and tens of kHz for a motor drive; and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies. The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on and power is being transferred to the load, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle.

In electronics, many modern microcontrollers integrate PWM controllers exposed to external pins as peripheral devices under firmware control by means of internal programming interfaces. These are commonly used for direct current (DC) motor control in robotics and other applications. With PWM the duty cycle of the power delivery can be effectively managed. This is what makes it possible to deliver power of varying magnitude to the load.

Duty cycle is the ratio or percentage of how long a signal stays on or high in period. The duty cycle is the ratio of the pulse width to the period (Edward Hughes, 2008).

Fig 3.22 shows five different duty cycles. If the duty cycle is at 25% only 25% of the voltage will be delivered to the load, same 50% duty cycle 50% voltage will be delivered to the load.

The formula for duty cycle is Duty Cycle =Turn ON time/ (Turn ON time + Turn OFF time).

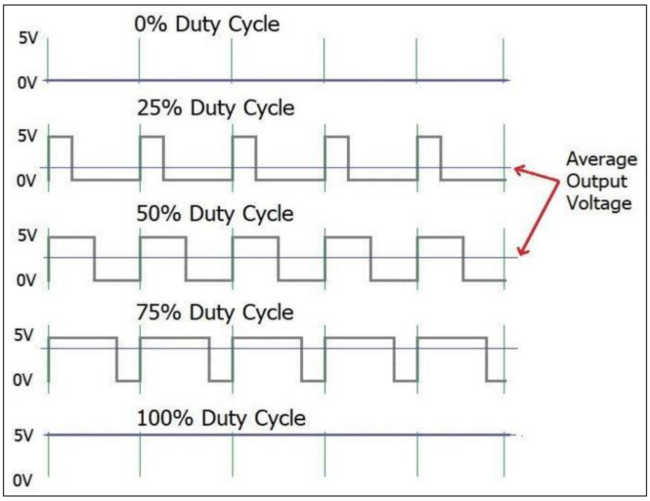



**Fig 3.20:** Five Duty cycle presented above

### 3.12 Resistors

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements, and terminate transmission lines, among other uses.

In this project the resistor is being used to limit the current flow to the transistor base to achieve correct triggering current.

**Table 3.2:** Resistor color code

Resistor color code table

| Color | Color | 1st Band | 2nd Band | 3rd Band Multiplier | 4th Band Tolerance |
|---|---|---|---|---|---|
| Black | | 0 | 0 | x1Ω | |
| Brown | | 1 | 1 | x10Ω | ±1% |
| Red | | 2 | 2 | x100Ω | ±2% |
| Orange | | 3 | 3 | x1kΩ | |
| Yellow | | 4 | 4 | x10kΩ | |
| Green | | 5 | 5 | x100kΩ | ±0.5% |
| Blue | | 6 | 6 | x1MΩ | ±0.25% |
| Violet | | 7 | 7 | x10MΩ | ±0.10% |
| Grey | | 8 | 8 | x100MΩ | ±0.05% |
| White | | 9 | 9 | x1GΩ | |
| Gold | | | | x0.1Ω | ±5% |
| Silver | | | | x0.01Ω | ±10% |

Ohms law shows the function of the resistor.

Ohm's law states that the current through a conductor between two points is directly proportional to the voltage across the two points. Introducing the constant of proportionality, the resistance, one arrives at the usual mathematical equation that describes this relationship:

$$I = \frac{V}{R}$$

Where I is the current through the conductor in units of amperes, V is the voltage measured across the conductor in units of volts, and R is the resistance of the conductor in units of ohms. More specifically, Ohm's law states that the R in this relation is constant, independent of the current. If the resistance is not constant, the previous equation cannot be called Ohm's law, but it can still be used as a definition of static/DC resistance. Ohm's law is an empirical relation which accurately describes the conductivity of the vast majority of electrically conductive materials over many orders of magnitude of current. Appendix D shows resistor.

### 3.13 Measuring electrical quantities

#### 3.13.1 Introduction

A wide range of instruments is available for measuring voltages and currents in electrical circuits. These include analogue ammeters and voltmeters, digital multi-meters, and oscilloscopes. This report will discuss how the electrical quantity measurements are conducted in electrical circuits; it will also discuss the digital multi-meter since it is the instrument being used to monitor the voltage and the current drawn by the system to determine the power consumption.

#### 3.13.2 Measuring voltage in a circuit

To measure the voltage between two points in a circuit, the meter leads or test probes are placed between the two points across a component in the circuit. For example, to measure the voltage drop across a component the meter is connected the across the part as shown in Fig 3.23.

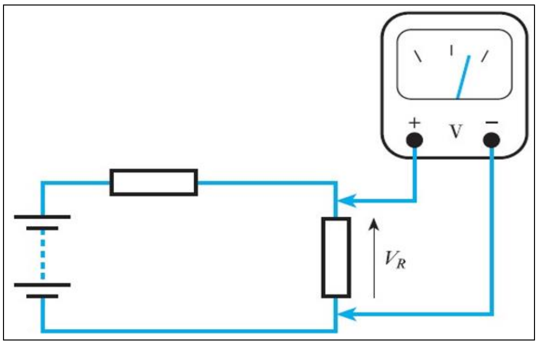



**Fig 3.21:** Voltmeter measuring voltage across a component $V_R$

#### 3.13.3 Measuring current in a circuit

To measure the current flowing through a circuit or a component, the meter called an ammeter is connected in series with the element, as shown in Fig 3.24. The ammeter is connected in this fashion so that conventional current flows from the positive to the negative terminal.

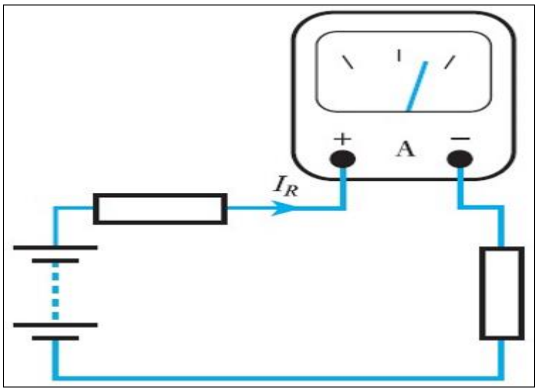



**Fig 3.22:** Ammeter measuring current in an electrical circuit

### 3.13.4 Digital multi-meter

The digital multi-meter displays the measured values in digital form through an LCD screen. It is capable of measuring different parameter such resistance, potential difference (voltage), Current and continuity. The digital multi-meter has a selector switch or a dial that is used to select the parameter intended to be measured.

The meter normally has a very high input resistance when used as a voltmeter and a very low input resistance when measuring currents, this minimizing the loading effects. While these instru ments are capable of measuring voltage, current and resistance, they are often (inaccurately) referred to as digital voltmeters or simply DVMs. At the heart of the meter is an analogue-to-digital converter (ADC), which takes as its input a voltage signal and produces as its output a digital measurement that is used to drive a numeric display LCD. Measurements of voltage, current and resistance are achieved by using appropriate circuits to generate a voltage proportional to the quantity to be measured. When measuring voltages, the input signal is connected to an attenuator, which can be switched to vary the input range. When measuring currents, the input signal is connected across an appropriate shunt resistor, which generates a volt.

age proportional to the input current. The value of the shunt resistance is switched to select different input ranges. In order to measure resistance the inputs are connected to an ohms converter, which passes a small current between the two input connections. The resultant voltage is a measure of the resistance between these terminals. In simple DMMs, an alternating voltage is rectified, as in an analogue multi-meter, to give its average value. This is then multiplied by 1.11 (the form factor of a sine wave) to display the corresponding r.m.s. value. This approach gives inaccurate readings when the alternating input signal is not sinusoidal. It is for this reason, more sophisticated DMMs use a true r.m.s. converter, which accurately produces a voltage proportional to the r.m.s. value of an input waveform. Fig 3.25 shows a typical hand-held DMM.


**Fig 3.23:** Digital Multi-meter

### 3.14 System design

### 3.14.1 Program flowchart

Fig 3.26 is a flowchart representing the flow or execution of the software or algorithm control code in the microcontroller.

### 3.14.2 System code (software)

He code below is the control code for the microcontroller to compare and adjust the light intensity according to the set value of light intensity. The code also processes the input of the presence and determines whether to bring on the lights or not to.

//The code below is meant to control the lighting system by regulation the light intensity to the right illuminosity. The lighting system only comes on with the detection of a presence. With no presence the light stay off and with a presence the lights come on to the set light intensity. When the space becomes unoccupied the lights stay on for a pre-determined time then automatically switch off/*

```
int led = 9;              // the PWM pin the LED is attached to
int brightnessLevel = 0;     // how bright the LED is int
analogPin = A0;        // LDR pin
int lightIntensity = 0;     // write or output light intensity int
pirPin = 4;           // PIR Out pin  int pirStat = 0;          //
PIR status

void setup() {

  pinMode(led, OUTPUT); // declare pin 9 to be an output:
pinMode(pirPin, INPUT); //declare pin 4 to be output:
  Serial.begin(9600); // initialize serial communications:

}


void loop() {

  pirStat = digitalRead(pirPin);
  // if there is presence execute code and turn on light if the
light intensity is lower than required;   //if no presence is
detected donot turn on lights:
 if (pirStat == HIGH){

 int lightSensor = analogRead(analogPin);// measure light
intensity:


if(brightnessLevel <= 254){   if (lightSensor < 245)
  {
    brightnessLevel = brightnessLevel + 1 ;// Increase light
intensity if below the threshold

   }
}


if(brightnessLevel >=-5)//excute code below if the light the
brightness value is greater than -5:
{       if (lightSensor >= 252)   {     brightnessLevel =
brightnessLevel -1; // decrease  light intensity if above the
threshold:

  }
}
```

```
 lightIntensity = constrain(brightnessLevel,0,255);
analogWrite(led, lightIntensity);

Serial.println(lightSensor);// print the analog value:
Serial.println(brightnessLevel);
Serial.println(lightIntensity);

 delay(0); // wait for 30 milliseconds to see the dimming effect
 } else{ analogWrite(led, 0);}
}
```

### 3.14.3 System hardware

The hardware is comprised of a bread board, cables, microcontroller, LED lights, Batteries, battery holder, power supply and a presence and a light sensing sensor LDR.

The components are connected together through conductors, cables and soldering.

Below are Figures of the listed project components.


**Fig 3.25:** Batteries and battery holder

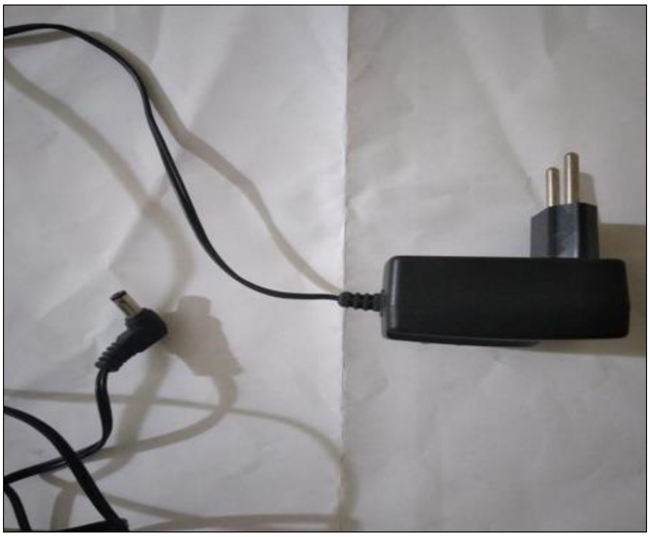


**Fig 3.26:** Power supply

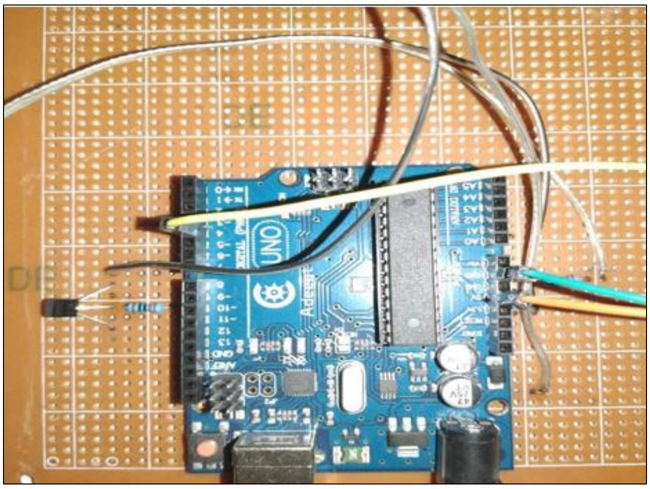



**Fig 3.27:** Microcontroller on bread board

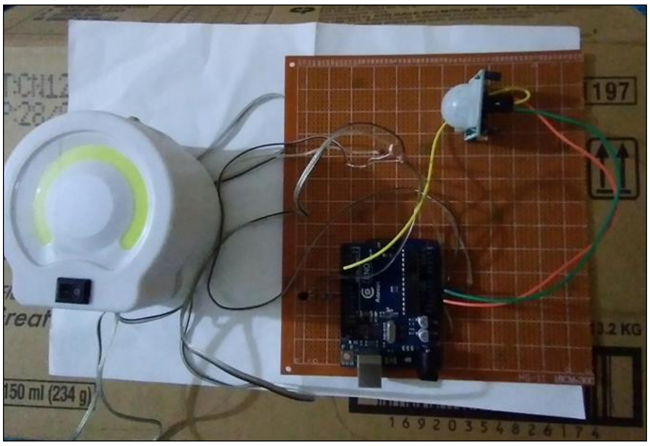



**Fig 3.28:** Overview of system hardware with Cables,bread board, microcontroller, LDR and presensce sensor

### 3.15 System simulation

The system design has been simulated using the Proteus software. The simulation effectively represent the physical system. Here it is possible to have a perception of the behavior of the system. The figure 3.13 below is a picture of the software simulation.

Appendix E shows the LDR values being processed.

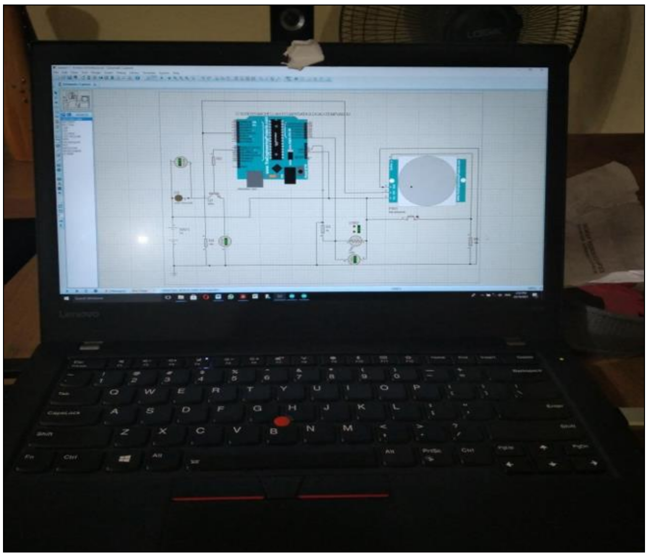


**Fig 3.29:** System simulation laptop using Proteus simulation software

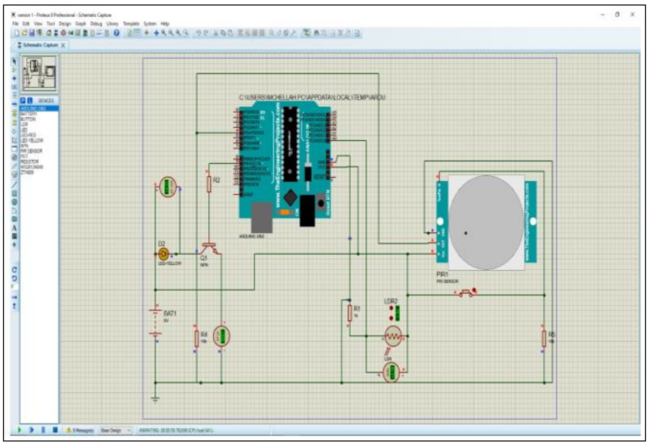


**Fig 3.30:** Screen grab of simulation software

# 4. Results

## 4.1 Introduction

In this chapter we will concentrate on discussing the outcome of the build. This will include: A system without any control system, system using presence sensor to control the lights and the use of day light optimization with a combination of artificial lights.

The prototype is using a cartoon box for a room simulation where the lamps, motion sense and light intensity sensors are mounted.

## 4.2 System without control system

Here the system does not incorporate any fancy sensors to regulate the power delivered to the lights. The system only has a switch, power source and lights. With this system the power is delivered is at 100 percent at all times regards of the following conditions: unoccupied space and adequate natural light. The table below shows the power being consumed.

**Table 4.1:** Power results over 1 minute interval

| | Power usage without control | | |
|---|---|---|---|
| Time | Power W | Voltage V | Current A |
| 1min | 0.94975 | 2.9 | 0.3275 |
| 2min | 0.94975 | 2.9 | 0.3275 |
| 3min | 0.94975 | 2.9 | 0.3275 |
| 4min | 0.94975 | 2.9 | 0.3275 |
| 5min | 0.94975 | 2.9 | 0.3275 |

### 4.2.1 Principle of Operation

The lighting system without control is a basic setup with only a switch as a control mechanism. The system uses a manually operated light switch to turn on and off the lights. Hence the control of the light is at the discretion of the operator of the light switch. The figure below shows a simple circuit or diagram of this system under test.

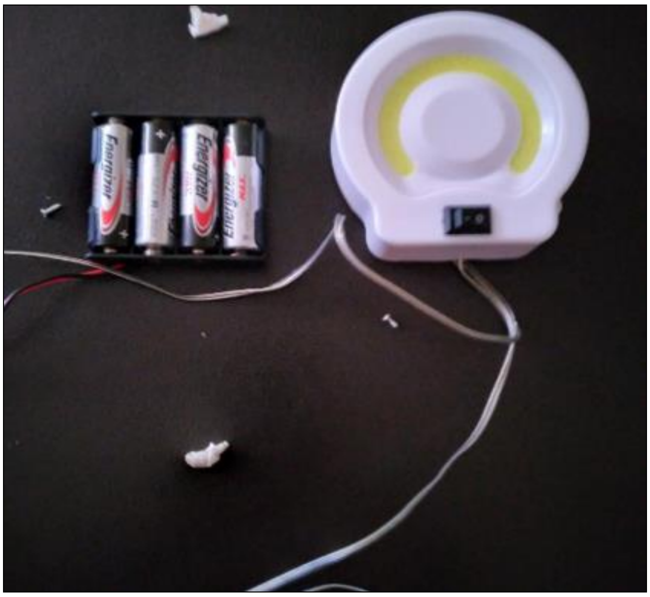



**Fig 4.2:** Actual picture of the lighting system without intelligent control

## 4.3 Light control and Energy optimization with control system result

### 4.3.1 Principle of Operation

The ALCEOS system principle of operation is based on the combination of different components and technologies.

The system uses sensors to monitor and control the operation of the ALCEOS. The sensors provide data information input to the microcontroller.

The passive infrared PIR sensor is used as a presence sensor. When the PIR detects a presence it provides an input to the microcontroller, this initiates the execution of the algorithm and turns on the lights at the required light intensity level. If no presence is detected the algorithm will not execute because no input signal is provided to the microcontroller. The algorithm below shows part of this software.

The light dependent resistor LDR measures the light intensity level and provides an input to the microcontroller inform of a varying resistance hence providing a varying voltage level as an input signal. Depending on the intensity of the level the microcontroller software has three code algorithms to execute. If the light intensity level is sufficient the microcontroller executes line of code or algorithm not to bring on the lighting. The second condition, the algorithm may increment or decrement the light level output to achieve the required light level.

The lights will stay on only for a predetermined time and as long as there is presence being sensed.


**Fig 4.3:** Digital multi-meters measuring current and voltage being drawn by the lighting system

**Fig 4.4:** Lighting system off due to no presence sensed, hence no measured values being displayed on the digital multi-meters LCDs

**Fig 4.5:** Diagram of ALCEO system overview showing the inputs and output

```
int led = 9;                // the PWM pin the LED is attached to
int brightnessLevel = 0;      // how bright the LED is int
analogPin = A0;          // LDR pin int lightIntensity = 0;      //
write or output light intensity int pirPin = 4;              // PIR
Out pin
int pirStat = 0;           // PIR status

void setup() {

  pinMode(led, OUTPUT); // declare pin 9 to be an output:
pinMode(pirPin, INPUT); //declare pin 4 to be output:
Serial.begin(9600); // initialize serial communications:
}

void loop() {
 pirStat = digitalRead(pirPin);
 // if there is presence execute code and turn on light if the
light intensity is lower than re quired;
 //if no presence is detected donot turn on lights:
 if (pirStat == HIGH){

 int lightSensor = analogRead(analogPin);// measure light
intensity:


if(brightnessLevel <= 254){
  if (lightSensor < 245)
  {
   brightnessLevel = brightnessLevel + 1 ;// Increase light
intensity if below the threshold

   }
}


if(brightnessLevel >=-5)//excute code below if the light the
brightness value is greater tha n -5: {
   if (lightSensor >= 252)   {   brightnessLevel =
brightnessLevel -1; // decrease light intensity if above the
threshold:

  } }


 lightIntensity = constrain(brightnessLevel,0,255);
analogWrite(led, lightIntensity);

Serial.println(lightSensor);// print the analog value:
Serial.println(brightnessLevel);
Serial.println(lightIntensity);

 delay(0); // wait for 30 milliseconds to see the dimming
effect
 }
 else{ analogWrite(led, 0);}
}
```

**Fig 4.6:** Lights on after a simulated presence, digital multi-meter showing measured values

**Table 4.2:** Sampled values over varying simulated light conditions

| Power usage table | | |
|---|---|---|
| power W | Voltage V | Current A |
| 0 | 0 | 0.00001 |
| 0.002358 | 1.8 | 0.00131 |
| 0.0228 | 1.9 | 0.012 |
| 0.108 | 2 | 0.054 |
| 0.1365 | 2.1 | 0.065 |
| 0.1617 | 2.1 | 0.077 |
| 0.348 | 2.4 | 0.145 |
| 0.4125 | 2.5 | 0.165 |
| 0.4602 | 2.6 | 0.177 |
| 0.8642 | 2.9 | 0.298 |
| 0.885 | 3 | 0.295 |

### 4.4 Summary

Implementing intelligent systems to control and optimize energy for lighting systems is imperative as through testing and simulation the results have demonstrated significant benefits. It clear that if such systems as the Automatic Light Control and Energy Optimization (ALCEOS) are employed, there are long term benefits in energy usage and cost saving.

The systems are more beneficial in commercial spaces such as malls, public facilities such as Hospitals, government (public) buildings, street lighting, factories and churches. These institutions will see a significant benefit verses the use of traditional lighting control system through a manual light switches.

The system will also provide a relief on the energy demand on the supply system making scarce energy resource available for other potential users. From the information or results generated in the exercises conducted it is evident that energy savings with ALCEOS is quite significant, from 85% to 95% depending on the lighting condition. This is true especially when there is sufficient natural light.

The gains are huge when daylight is optimized especially in commercial and public buildings due to high volume of human traffic in the day that demands for lighting for their task execution.

## 5. Conclusion and Recommendation

### 5.1 Introduction

This chapter discusses the conclusions and recommendations coming out of this project.

### 5.2 Conclusion

In this project, a complete working model using an Arduino microcontroller, LED lights, light dependent resistor and passive infrared sensor has been used to implement the Automatic Light

Control and Energy Optimization System

The project included the study of energy saving system in many applications. The Automatic Light Control and Energy Optimization System is not limited to any particular application; it can be used anywhere were energy saving and control maybe suitable, with a little modifications in software coding according to requirements. This concept not only ensures that this work will be usable in the future but also provides the flexibility to adapt and extend, as needs change.

The main advantage of the developed Automatic Light Control and Energy Optimization System is that it can fitted in existing wiring setup and thus saves the initial installation cost of a system. The system is simple and cost effective as it is based on basic microcontroller. The daylight is integrated with artificial light system which saves energy and LED lamp gives more lumen per watt thus greatly saving energy.

The system will also provide a relief on the energy demand on utility companies making the scarce energy resource available for other potential users. From the information or results obtained in the exercises conducted it is evident that the energy savings with ALCEOS is quite significant, from 85% to 95% depending on the lighting condition. This is true especially when there is sufficient natural light. The gains are huge when daylight is optimized especially in commercial and public buildings due to high volume of human traffic in the day that demands for lighting for their task execution.

### 5.3 Recommendations

In this project we connected all the sensors to microcontroller with the wires. This can be developed with wireless technology such that sensors can be placed in different places. This sensor will activate the microcontroller with the signals instead of using wires. In this system the number of persons present in the room (Person counter) can be included and also the data transmission from sensors to microcontroller can be implemented through wireless such that the system will become a scalable one in the sense a single system can able to control a large number of rooms.

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