DESIGN AND CONSTRUCTION OF A DUAL AXIS SOLAR TRACKER SYSTEM

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A PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR OF ENGINEERING (B.ENG) IN THE DEPARTMENT OF ELECTRICAL/ELECTRONICS ENGINEERING UNIVERSITY OF BENIN, BENIN CITY, EDO STATE, NIGERIA.

OCTOBER, 2023

CERTIFICATION

This is to certify that the project work titled **DUAL AXIS SOLAR TRACKER SYSTEM** is the bona fide work carried out by **OMORODION IGHARO, MAT NO: ENG1704196** of university of Benin in the Dept. of Electrical Engineering, in partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering and that this project has not submitted previously for the award of any other degree, diploma and fellowship.

____________________________	____________________
ENGR DR (L.E) MRS OMOZE	**PROF. DR OGBEIDE**
SUPERVISOR	**HOD**

DEDICATION

This work is dedicated to God Almighty without whom this endeavor would not have been possible, my parents (MR and MRS IGHARO) and also to my church (HOPGC) for their immerse love and guidance.

ACKNOWLEDGMENT

Glory and praise are due to the omnipotent God, who has bestowed upon me the necessary enlightenment for the pursuit of my academic endeavor. I consider myself extremely fortunate to have had the opportunity to conduct this project under the supervision of Engr. (Dr.) L.E. Omoze, within the Department of Electrical Engineering at UNIBEN. I extend my heartfelt thanks and profound appreciation to my mentor for their unwavering support, invaluable guidance, and boundless encouragement. I would also like to express my gratitude to Prof. (Dr.) Ogbeide, the Head of the Department of Electrical Engineering, for providing the essential infrastructure and resources for this research. My appreciation extends to all the dedicated faculty members and staff within the Department of Electrical Engineering for their wholehearted cooperation, which played a pivotal role in bringing this project to fruition.

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ABSTRACT

s that incorporates the ATmega328P microcontroller for precise control of two servo motors. The primary objective is to enhance the energy efficiency of solar photovoltaic systems by optimizing the orientation of solar panels to track the sun's movement across both horizontal and vertical axes. The ATmega328P microcontroller serves as the central control unit, receiving real-time data from sun position sensors. By utilizing this data, the microcontroller calculates the optimal angles for the solar panels to maximize their exposure to sunlight throughout the day. The servo motors are responsible for executing these calculated movements, ensuring that the panels are constantly aligned with the sun. The research focuses on the detailed design and construction process of the Dual Axis Solar Tracker System, including the integration of the ATmega328P microcontroller. Performance evaluation includes tracking accuracy, energy yield, and cost-effectiveness. The findings demonstrate that this innovative solar tracking solution significantly enhances the energy capture capabilities of solar installations, making it a promising technology for improving the sustainability and efficiency of renewable energy systems in various applications.

ABBREVIATIONS AND ACRONYMS

LDR	Light Dependent Resistor
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
PV	Photovoltaic Cell
IDE	Integrated Development Environment
DC	Direct Current
ADC	Analog-to-Digital Converter
LUX	Luminous Flux (Lumens/m^2)
PWM	Pulse Width Modulation
ICSP	In-Circuit Serial Programming
USB	Universal Serial Bus
CMOS	Complementary Metal-Oxide-Semiconductor
RISC	Reduced Instruction Set Computer
MIPS	Million instructions per second
EEPROM	Electrically Erasable programmable Read-Only Memory
SRAM	Static Random Access Memory
I/O	Input/ Output
GND	Ground
VCC	Supply Voltage
AREF	Another RDF Encoding Form
PCINT	Pin Change Interrupt Library
RDF	Resource Description Framework

CHAPTER ONE

1.0 INTRODUCTION

Nigeria is located in the tropical region, positioned between 4 degrees latitude and 13 degrees longitude, and it typically receives around 6.25 hours of sunlight per day (Agusto, 2022). Presently, just 55.4% of Nigerian households have access to public electricity, and even when they do, it's not consistently reliable (World Bank Development, 2020). This unreliable power supply has prompted an increasing number of people, especially in rural areas, to explore alternative methods of generating their own electricity due to the high costs associated with using fossil fuels. Additionally, the use of fossil fuels contributes to environmental pollution, including the release of carbon dioxide (CO_2) and the resultant greenhouse effect, which leads to issues such as deforestation and air and water pollution.

Solar energy, which is harnessed directly from the sun, provides a sustainable alternative that doesn't emit carbon dioxide, thus helping to mitigate the greenhouse effect. The expansion of solar energy in Nigeria has the potential to create employment opportunities, and the renewable energy sector offers safer working conditions when compared to industries like coal mining and oil extraction. Solar energy is becoming increasingly dependable and eco-friendly.

As per the findings by Ahmet Aktaş in 2021, a sun-tracking system that operates on non-linear principles possesses the capacity to optimize the orientation of solar panels to maximize energy output. This study's objective is to create a solar tracking system based on Arduino technology, with the goal of improving the energy efficiency of solar photovoltaic panels by consistently aligning them at the most advantageous angle in relation to the sun.

Fig. 1.1: *View of a solar panel*

The sun is a vast source of energy, and we can effectively tap into this solar energy using photovoltaic cells and the effect of the photovoltaic cells to converts the sun’s energy into electrical energy. However, the regular PV cells have a low conversion efficiency. One key factor behind this is the direct correlation between the output of photovoltaic (PV) cells and the light's intensity. Since the sun's position varies constantly during the day and throughout the year, a fixed solar panel's effectiveness in capturing sunlight diminishes during specific periods. Solar photovoltaic cells perform optimally when they directly face the sun, while their efficiency decreases at other angles. To maximize energy production and improve efficiency, the use of solar trackers becomes essential. Solar tracking systems provide an appealing solution, particularly for developing nations, allowing them to integrate these systems into their solar infrastructure cost-effectively through software-based solutions.

1.1 AIM

- To design and construct a dual-axis solar tracker system that utilizes the ATmega328P microcontroller in the control of two servo motors.

- To improve the energy efficiency of solar photovoltaic systems by creating a reliable dual-axis solar tracker.

1.2 OBJECTIVE

- Design and construct a physical prototype of a dual-axis solar tracker system that integrates the ATmega328P microcontroller and two servo motors for solar panel orientation.
- Develop and implement precise sun tracking algorithms within the microcontroller to accurately determine the sun's position in real-time.
- Design the system to continuously adjust the position of solar panels to ensure they are optimally aligned with the sun's position, both horizontally and vertically.
- Conduct performance testing to measure the improvement in energy efficiency achieved by the dual-axis solar tracker system compared to static solar panels.

1.3 STATEMENT OF THE PROBLEM

The issue tackled by the project titled "Development and Fabrication of a Dual Axis Solar Tracking System" pertains to the ineffective utilization of solar power caused by the stationary positioning of solar panels. Conventional fixed solar panels lack the ability to adapt to the sun's motion along both the horizontal and vertical planes, leading to suboptimal energy capture and reduced overall efficiency. To tackle this problem, this project aims to create and build a dual-axis solar tracking system employing the ATmega328P microcontroller for managing the movement of two servo motors. This setup ensures that solar panels consistently align with the sun's position, thus optimizing energy harvesting efficiency.

1.4 METHODOLOGY

In the design and construction of the Dual Axis Solar Tracker System, a four step methodology was implemented to achieve the design. These are listed below:

I. **System Design and Planning**

Define the project objectives and scope, aligning them with the aims. A detailed specifications for the dual-axis solar tracker system was developed, considering tracking accuracy, components, and energy efficiency goals. Planning for the project timeline, allocation of resources, and establish a budget.

II. **Development and Testing**

The development of the dual-axis solar tracker system is carried out based on the design specifications. Assembling electronic and mechanical components, including the ATmega328P microcontroller, sensors, and servo motors. Develop and implement sun tracking algorithms in the microcontroller also, conducting rigorous testing to ensure the system's tracking accuracy and reliability.

III. **Performance Evaluation**

Measure the energy efficiency improvements achieved by the dual-axis solar tracker system compared to static solar panels. Calibrating and fine-tuning the system so as to optimize performance.

IV. **Documentation and Reporting**

Document the entire project, including design, construction, testing processes, and results. Prepare a comprehensive project report which summarizes the objectives, methodology, findings, and conclusions. The outcome of the project and demonstrate the functioning of the dual-axis solar tracker system to stakeholders and evaluators. Provide recommendations for further improvements or refinements based on project insights.

This four-step methodology outlines a streamlined process for achieving the project's aims, from initial design to final documentation and presentation. Regular testing, data collection, and collaboration are essential to ensure successful project completion.

1.5 SCOPE AND LIMITATION

In this project, our aim is to develop a dual-axis solar tracking system that operates on its own power. This system comprises two main parts: the power control system and the solar tracking mechanism. The tracking system will use a servo motor to adjust the device's position so that it always faces the direction of maximum solar intensity. Meanwhile, the power control system will manage the energy supply to the active components of the tracking system. The primary goal is to keep the solar photovoltaic panel consistently perpendicular to the sun throughout the day, thereby increasing its energy production for household use and ensuring self-sustained operation.

While we have intentionally limited the project's scope to fit within the given timeframe, there is ample opportunity for future improvements and expansions of this initial design. Nonetheless, this design functions as a functional small-scale model that could potentially be replicated on a larger scale. Some limitations of the project include:

1. Exposure to excessive rains can cause it to decrease in efficiency.
2. Due to its miniature and compact-able state it's cannot withstand boisterous wind.
3. For the cause of this project it's restricted to only charging of phones.

CHAPTER TWO

LITERATURE REVIEW

The shortage of electrical power has prompted modern society to actively seek solutions for meeting its energy requirements. As our civilization has expanded, the excessive consumption of conventional fuels due to human activities has raised sustainability concerns. The deficit in energy supply and its underlying causes have prompted us to embrace an optimistic approach by utilizing alternative resources at our disposal, like solar and tidal energy.

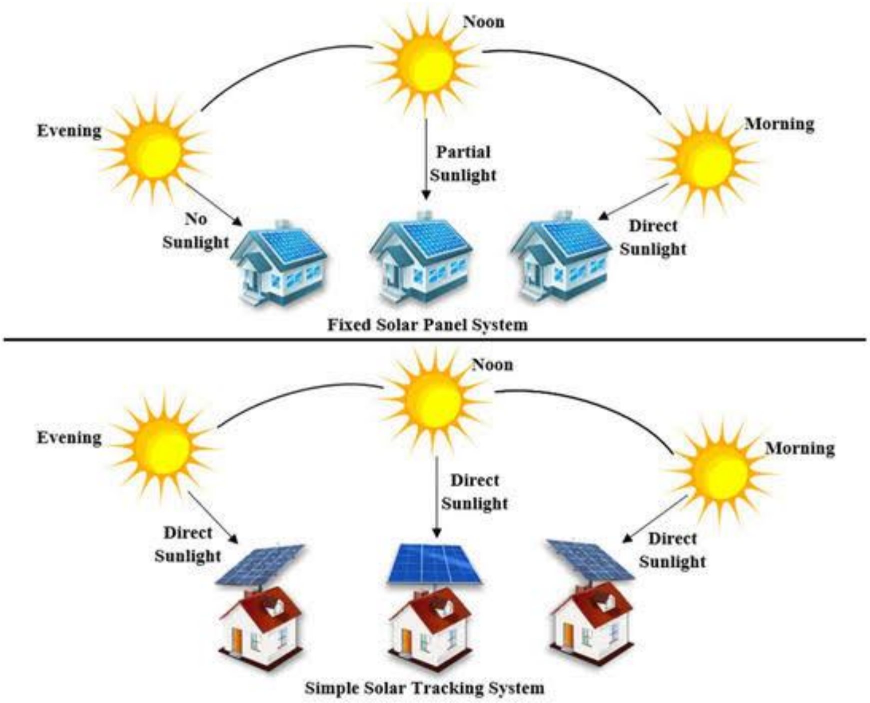

Fig 2.1: *Natural view of a Solar System.*

The Sun is recognized as a crucial source of energy, and solar energy stands out as an environmentally friendly option compared to other sources. Technological advancements have enabled us to harness solar energy for various purposes, including thermal energy, electricity generation, and fuel production. Photovoltaic (PV) system and Concentrated Solar Power (CSP) system are employed for converting absorbed solar energy into electricity. Solar tracking mechanisms enhance the utilization of this captured solar power within photovoltaic arrays, which consist of organized arrays of solar cells (Yung-Tung and China-Hong, 2002).

In 2017, Chaitali Medhane and Tejas Gaidhani devised a dual-axis solar panel model using a microcontroller, which their research illustrated to maximize power output and provide protection from adverse weather conditions by aligning the panel with incoming sunlight.

Imam Abadi, Adi Soeprijanto, and Ali Musyafa employed fuzzy logic to design a single-axis solar tracker, enhancing PV panel energy output by up to 47% when compared to stationary systems, all managed by an ATMEGA 328P microcontroller.

Back in 2010, Mohammed et al. introduced an automatic two-axis sun tracking system through a solar cooker, eliminating the need for manual adjustments throughout the day. Their experiments demonstrated that on regular sunny days, the water temperature within the cooker's tube reached 90°C.

S.B. Elagib and N.H. Osman developed a solar tracking system based on solar maps, aiming to reduce operator involvement, especially in remote areas with limited network coverage, thus optimizing energy efficiency.

In the Jordanian climate, M.M. Abu Khader conducted experiments to assess the advantages of employing two-axis sun tracking systems, revealing a 30-45% increase in power output on specific days compared to static systems.

Solar cells, also referred to as photovoltaic cells, are utilized to transform light energy into electricity. They function based on the photovoltaic effect, which is similar to the photoelectric effect, but with electrons remaining within the material to generate a voltage difference. Crystalline silicon is the most prevalent material for solar cells due to its efficiency and cost-effectiveness, available in two forms: mono-crystalline silicon with an efficiency rating of 15-20% and poly-crystalline silicon, which is less expensive but less efficient. Amorphous silicon cells perform well in high-temperature conditions but are generally less efficient. Alternative materials like cadmium telluride (CdTe) and copper indium gallium (di)selenide (CIGS) are employed in thin-film photovoltaic modules, offering cost-effectiveness compared to crystalline silicon (Mayank, 2014; Lee Wallende, Samantha Allen, 2022; Solar Square, 2022; Furkan and Mehmet, 2020).

Table 2.1: Types of Solar cell based on the material

CELL TECHNOLOGY		**TEMPERATURE RESISTIVITY**	**MODULE EFFICIENCY**
Cell	**Types**		
Crystalline Silicon	1. Mono-crystalline silicon (c-Si) 2. Poly-crystalline silicon (pc-S/ mc-Si)	Lower	13-19%
Thin Film Silicon	1. Amorphous Silicon (a-Si) 2. Cadmium telluride (CdTe) 3. Copper indium gallium (di)selenide (CIG/CIGS)	Higher	4-12%

There are various factors on which the efficiency of a solar cell depends, these include;

- Cell temperature.
- Energy Conversion Efficiency.
- Maximum power point tracking (Wang and Ge, 2016).

Solar panels consist of photovoltaic cells arranged to capture sunlight and convert it into electricity by exciting electrons within the cells with photons. The amount of sunlight solar panels receive is influenced by the sun's position (Levant, 2011).

The Sun, as a consistent source of radiation, provides natural energy that can be harnessed through solar panels. Various methods have been developed to use this energy as an alternative to non-renewable sources. This manipulation of solar energy is encouraged due to its numerous applications in conserving resources (Paniat and Tudorache, 2008).

Solar panels are employed to convert solar power into electricity. To maximize solar power collection, solar trackers are used to orient panels to face the sun at different angles. Solar panels can capture sunlight effectively only when the angle between the sun's rays and the panel is 90 degrees. However, at other times, when the angle differs, less solar power is collected. Solar tracking systems were introduced to overcome this limitation. Such systems aim to maintain a 90-degree angle between the sun's rays and the solar array. A solar tracking system typically comprises three modules:

- The Mechanism
- Driving Motors,
- Tracking Controller.

The system guarantees accurate motion tracking to trace the sun's trajectory all day long and is designed to endure harsh weather conditions. Solar tracking systems are divided into two main types: single-axis trackers and dual-axis trackers, as outlined by Reca-Cardena and Lopez-Luque in 2018.

Single-axis tracking, which is well-suited for smaller photovoltaic power installations, can be put into practice using three distinct tracking configurations:

- Inclined shaft installation
- South-north axis horizontal installation
- East-west axis horizontal installation.

The Single-axis trackers tracks the sun's movement in a single cardinal direction, and the methods mentioned earlier all work similarly. They calculate the sun's angle with the collector surface and adjust the collectors to follow the sun's movement, capturing a higher percentage of solar radiation (Change, 2015).

- Various implementations of single-axis tracking include
- Horizontal Single Axis Tracker (HSAT)
- Horizontal Single Axis Tracker with Tilted Module (HTSAT)
- Vertical Single Axis Tracker (VSAT)
- Tilted Single Axis Tracker (TSAT)
- Polar Aligned Single Axis Tracker (PSAT).

Dual-axis trackers have orthogonal rotational axes, with one fixed to the ground and called the primary axis, and the other being the secondary axis. Dual-axis trackers move both horizontally and vertically, maximizing solar energy capture. Common applications include

- Tip-Tilt Dual Axis Trackers
- Azimuthal Altitude Dual Axis Trackers (Kamrul et al., 2017).

Solar trackers can be categorized based on their driving mechanism as active solar trackers, which use electric motors like DC motors, and passive solar trackers, which rely on gravitational forces and Earth's movement.

Solar tracking controllers can be divided into two modules:

1. **Open Loop Control**: This approach relies on a microprocessor and incorporates a pre-defined model based on recorded sun movements throughout the day. Consequently, the microcontroller computes the time and establishes the sun's location at that particular moment. Geographical conditions do not affect this control system.

2. **Closed Loop Control/Feedback Controllers:** In this control system, photo-sensors are utilized to evaluate light intensity. These sensors are positioned on the panel's side and aid in detecting the sun's location.

The prototype used in this study is a horizontal single-axis tracker. The tracking system utilizes photosensitive sensors to monitor the sun's trajectory. This tracking method falls into the active solar tracking category, relying on a feedback control system or closed-loop control. It involves comparing light intensities, adjusting the solar panel to align with the direction of maximum available intensity. Consequently, the system operates based on feedback from prevailing weather conditions.

2.1 IMPACT OF LIGHT INTENSITY:

Variations in light intensity significantly influence the power output and also affecting various technical parameters such as the voltage, circuits current, shunt resistant, and the efficiency. Consequently, higher light intensities result in increased power output.

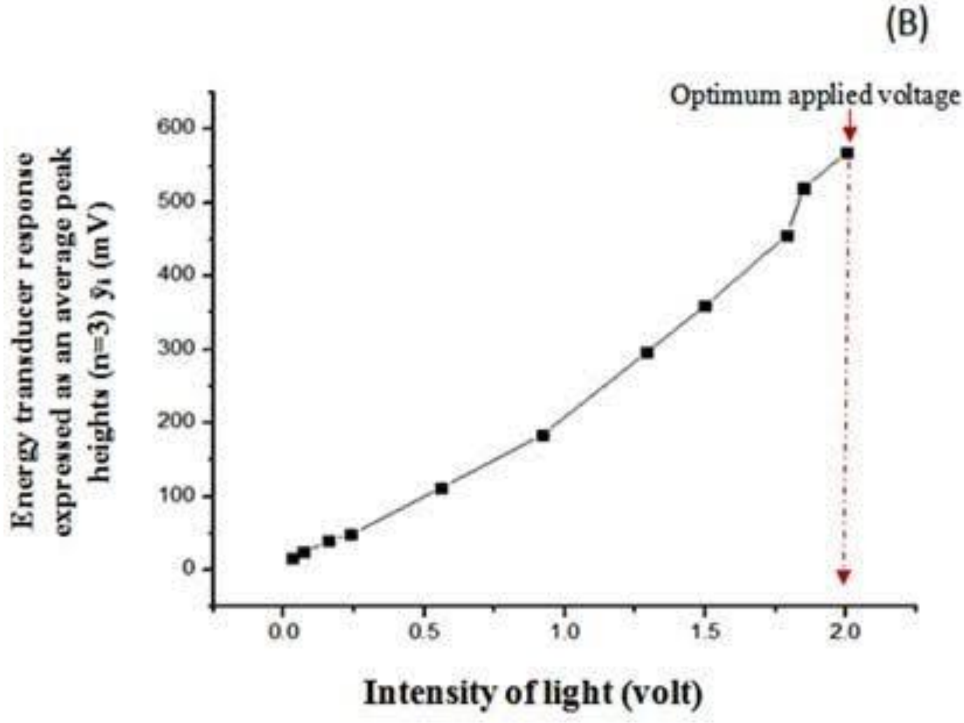

Fig. 2.2: *Variation of light energy with sunlight*

2.2 THE EFFICIENCY OF SOLAR PANEL

Efficiency holds a pivotal role in assessing the output quality of a specific device. Numerous factors have the potential to influence the efficiency of a solar panel, such as light intensity, the material composing the solar cell, temperature, and more. In this context, efficiency is defined as the ratio between the energy input received by the solar cell and the energy harnessed from the sun. Evaluating the efficiency of a solar panel entails the scrutiny of various parameters. One of these parameters is the maximum power, computed as the product of the open-circuit voltage (VOC), short-circuit current (ISC), and the fill factor (FF), as elucidated by Olaka in 2015:

$Pmax = VOCISCFF$

The efficiency (η) is subsequently determined as:

$\eta = Pin / Pmax$

Where Pin represents the total input power.

2.3 FUNDAMENTAL PROCESS

The primary goal of the automated solar tracking system is to optimize energy capture. To achieve this, the project was divided into distinct tasks using a modular approach. The light sensor's output signal forms the foundation for ascertaining the necessary direction for orienting the solar panel toward the sun's location. This movement is executed by a motor circuit, which follows the directives issued by the controller and the constraining button. The system's hardware components encompass a Light Dependent Resistor, Indicator, limiting button, Diodes, Resistors, Transistors (BJT), Micro-controller, variable resistors, and the assembly structure.

1) The pair of Light Dependent Resistors (LDRs) each serve to detect either sunrise or sunset, while the two Limiting buttons are responsible for identifying the starting and ending positions to halt the motor's operation.

2) Within the micro-controller's processor, there is programming that converts analog photocell voltage into digital values, creating output channels used to regulate the motor's rotation.

3) In the evening, a few minutes after sunset, the device automatically reorients itself. Due to the uneven vertical lighting on either side of the sun visor, the control circuit regulates the motor's motion. This action causes the receiving apparatus to pivot eastward, aligning the solar receiver with the ascending sun.

4) To maximize energy extraction during the day, the solar panel should be positioned approximately halfway between geographical east and west, tilted at an angle of roughly 30 degrees towards the south.

5) Variable resistors are employed to set a predetermined threshold, which the panels use as a reference point for aligning themselves to face the sun.

The design comprises two segments aimed at enhancing the capture of solar energy through a precise alignment process, thereby achieving optimal energy extraction. This performance in energy output is contrasted with that of a fixed solar panel, which receives morning and evening sunlight at oblique angles, consequently reducing the overall electricity generation each day.

Measurements were collected from both the stationary PV panel and the tracking mode at various time points throughout the day. In an ideal setting with minimal atmospheric disturbances, we performed theoretical calculations for surplus energy. This involved assuming maximum radiation intensity (I=1100w/m2) falling onto a surface oriented perpendicularly to the direction of radiation, with a day length of 12 hours (43,200 seconds).

The project's implementation comprises two primary sections: the microcontroller programming and the hardware component. In the microcontroller programming section, the program is written in the C language using Arduino Studio. Furthermore, the microcontroller can be conveniently cleared and reprogrammed online through the In-Circuit Serial Programming technique (ICSP).

The hardware segment is further categorized into various elements, such as the Light Dependent Resistor and limiting button, Microcontroller, Relays, Solar modules, variable resistors, power supply, and the assembly structure, as illustrated in Figure 5. The entire system can be regarded as being divided into the subsequent sub-units:

(a) Power supply; Light Dependent Resistors (Light sensors); Position sensor; Control unit

(b) Motor drives; and Panels

2.4 TYPE OF TRACKERS

- Chronological Tracker
- Passive Tracker
- Active Tracker

2.4.1 Chronological Tracker

A chronological tracker is a type of solar tracker that operates based on a predetermined schedule or a fixed time-based algorithm. It does not actively respond to real-time environmental or solar conditions. Instead, it follows a predefined pattern of movement to adjust the orientation of solar panels or other solar energy capture devices. For example, it might follow the path of the sun based on the time of day, adjusting the angle of solar panels at specific intervals. While it's a relatively simple and cost-effective tracking method, it may not be as efficient as more dynamic tracking systems that respond to changing sunlight angles throughout the day.

2.4.2 Passive Tracker

A passive solar tracker is a type of tracking system that relies on passive mechanisms, such as gravity or thermal expansion, to adjust the position of solar panels or mirrors to maximize solar energy capture. These trackers do not require external power sources or complex control systems. Instead, they use mechanical or thermal elements that respond naturally to environmental conditions. For example, a passive tracker might use a simple weighted pendulum to tilt a solar panel to the optimal angle as the sun moves across the sky. Passive trackers tend to be reliable and low-maintenance but may not be as precise or adaptable as active trackers.

2.4.3 Active Tracker

An active solar tracker is a sophisticated tracking system that actively monitors and responds to real-time environmental conditions, especially the position of the sun. These trackers use sensors, motors, and control algorithms to continuously adjust the orientation of solar panels or mirrors to optimize energy capture. Active trackers are highly efficient because they can adapt to changing sunlight angles, seasonal variations, and weather conditions. They can significantly increase the energy yield of solar systems by keeping the solar capture devices aligned with the sun's position throughout the day.

Active solar trackers employ electric or hydraulic mechanisms, along with some form of gearing system or actuator, to facilitate their motion. They utilize "light sensors," commonly known as LDR (light-dependent resistors), to gauge sunlight's light intensity, which guides the orientation of the solar modules. These light sensors are usually strategically positioned at various locations on the tracker within specially designed holders. When the sun is not directly facing the tracker, a variation in light intensity is detected between one LDR and another. This discrepancy prompts the system to determine the required adjustment direction with the assistance of a DC motor or stepper motor, ensuring the optimal extraction of energy. Nevertheless, this system exhibits a limitation on overcast days, as it may not function at peak efficiency due to cloud cover (Allen, 2011).

Each type of tracker has its advantages and disadvantages, and the choice of tracker depends on factors such as the specific application, cost considerations, and the desired level of energy efficiency.

2.5 DUAL AXIS

This solar tracking system incorporates both horizontal and vertical axes, allowing it to follow the sun's apparent movement by adjusting in two distinct directions. These two axis types are referred to as azimuth-altitude and tip-tilt. In solar tower applications, dual-axis tracking plays a vital role due to the potential angle discrepancies that occur when the mirror is situated at a considerable distance from the central receiver within the tower structure. Figure 2.3 provides a visual representation of a dual-axis tracker.

In the implementation of this project, a dual-axis tracker was chosen due to its capability to combine horizontal and vertical movement, enabling it to effectively track the sun's apparent shifts across the entire region in which it is installed, thus optimizing energy capture. There are also various techniques for driving solar trackers.

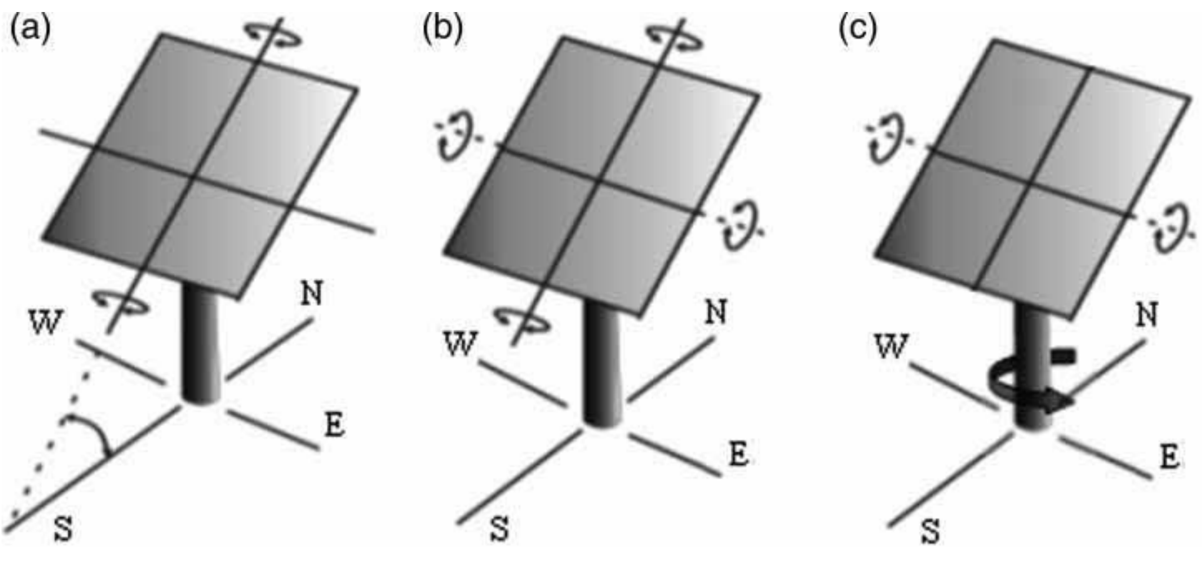

Fig 2.3 *View of dual axis solar panel movement*

Solar panel tracker drivers are utilized to minimize the angle between incoming light and a photovoltaic panel, with the aim of enhancing the assessment of energy extraction efficiency. The effectiveness of solar receptors is contingent upon the incident angle, where the output energy ideally correlates with the cosine of the incident angle.

To achieve this goal, a sun tracking mechanism, known as the tracker, can be integrated into the solar receptor, resulting in a performance boost of up to 75% when compared to fixed-type solar receptors (Duffie and Beckman, 2006). Solar tracker drivers can be categorized into three primary types based on their drive mechanisms and the sensing or positioning systems they employ. These categories include passive trackers, active trackers, and open-loop trackers. Refer to Figure 4 for a schematic representation classifying the different types of solar tracker drives.

2.6 MICRO-CONTROLLER

1. Micro-controller (Arduino Atemega 328P).

Arduino is employed for the creation of interactive devices that can accept inputs from various switches or sensors and manage a diverse array of physical outputs, including lights and motors. Arduino projects can operate independently or establish communication with computer software such as Flash, Processing, or MaxMSP. These boards can be either manually assembled or obtained in pre-assembled form, and the open-source Integrated Development Environment (IDE) can be freely downloaded.

Moreover, the Arduino Mega 328p is a microcontroller board built around the ATmega328p chip. It features 23 digital input/output pins, with 13 of them available for Pulse Width Modulation (PWM) output, as well as 6 analog inputs. Additionally, it includes 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an In-Circuit Serial Programming (ICSP) header, and a reset button. It comes complete with all the necessary components to support the microcontroller. You can easily connect it to a computer using a USB cable or power it through an AC-to-DC adapter or battery to begin working with it.Moreover, the Arduino programmer is based on the Processing Integrated Development Environment (IDE) and utilizes a modified version of the C and C++ programming languages, with C++ being employed for programming our Arduino microcontroller.

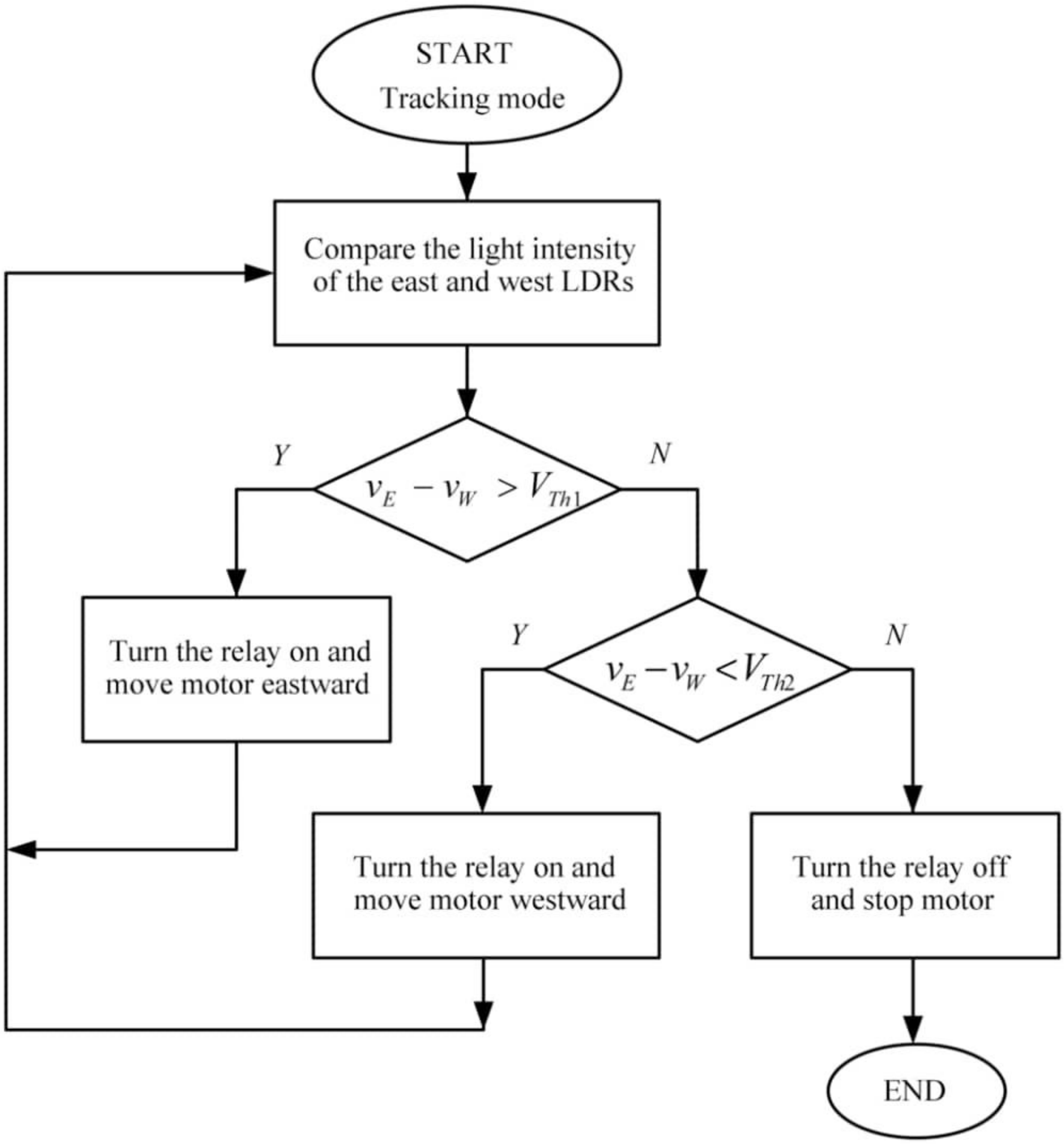

Fig 2.4: Flow chart diagram of control system

CHAPTER THREE

RESEARCH METHODOLOGY AND DESIGN

3.0 SYSTEM DESIGN

This chapter focuses on the design methodology and analysis applied in the development and planning of a solar tracker system. The purpose of this analysis is to ensure the selection of appropriate component values that optimize system performance and to elucidate the rationale behind their selection. The comprehensive content of this chapter delves into intricate details, including the complete circuit diagram and the operational mode of the system. This information is crucial for a comprehensive understanding of the solar tracker's design and functionality.

3.1 POWER SUPPLY SYSTEM

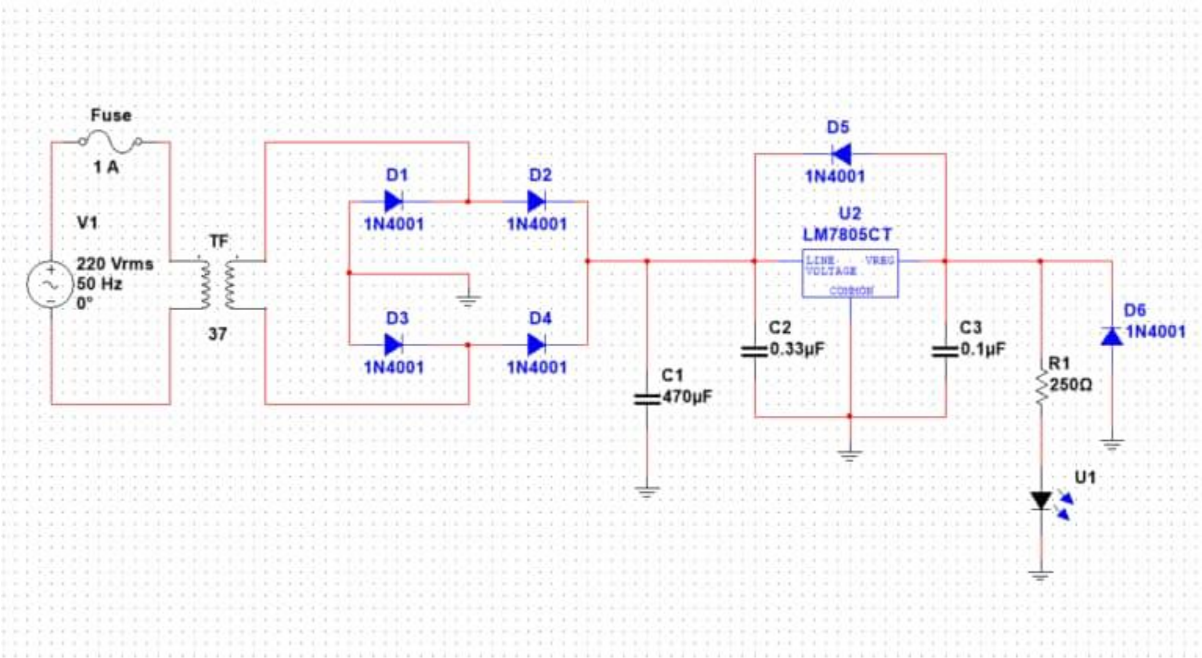

Fig. 3:1: *Power Supply System*

This is a step down transformer. A transformer voltage of 6Vac or above is required. The current should be enough to supply the requirement of the circuit.

$Recall: \frac{V_S}{V_P} = \frac{N_S}{N_P}$ … … … 3.1

For this circuit, the transformation ratio is 220:12

Where Vp = the voltage at the transformer primary

Vs = the voltage at the transformer secondary

Ns = the number of secondary turns of the transformer

Np = the number of primary turns of the transformer

$$V_s = 220\ x\ \frac{12}{220} = 12V$$

We have determined that the minimum input requirement for our chosen regulator IC is a specific value. Consequently, we require a transformer to reduce the main AC voltage to at least this value. Additionally, the rectifier has its inherent voltage drop, which amounts to 1.4V.

D1-D4: This is the rectifier circuit. The selected diodes should possess a peak inverse voltage (PIV) capability that can endure approximately double the peak voltage (V) of the transformer output and a forward current (D) that is 1.5 times the current that the transformer produces. This concept was proposed by Anindo Gosh on the following reference link: (Gosh, A. "Selecting the Right Bridge Rectifier.")

$$\mathrm{V}_p = \sqrt{2\mathrm{Vrms}} \quad \ldots\ldots\ldots\ 3.2$$

Where V_p is the peak voltage of the transformer output.

V_{rms} is the actual output voltage from the transformer = 12Vac

$V_p = \sqrt{2x12}$

$V_p = 1.414x12$

V_p = 16.97Vac

$$D_{(piv)} = 2\ x\ V_p \quad \ldots\ldots\ldots.3.3$$

Where $D_{(piv)}$ is the PIV of the rectifier diode

Therefore,

$$D_{(piv)} = 2x16.97$$

$$D_{(piv)} = 33.94$$

$$D_c = 1.5\text{x}300\text{x}10^{-3}$$

$$D_c = 0.45\text{A}$$

Where D_c is the forward current of the diode

Therefore, the required diode must have a:

$$\text{PIV} \geq 33.94\text{V}$$

$$\text{DC} \geq 0.45A$$

From diode catalogue, the IN4007 has the following characteristics:

$$\text{PIV} = 50\text{V}$$

$$\text{DC} = 1\text{A}$$

Consequently, the diode chosen is the IN4007

3.2 SELECTION OF A PROPER PARAMETER

Capacitor

Considerations to bear in mind when choosing an appropriate capacitor filter include its voltage capacity, power rating, and capacitance value.

Capacitance Rating

The capacitor's capacitance should be chosen to diminish the ripple voltage (Vs) to roughly 30% of the peak output voltage originating from the diodes. This specification has been established by the designer to guarantee a lower capacitance value.

$$V_\text{R} = 30\%\ of\ V_\text{DP} \dots\dots\dots \quad (3.4)$$

From equation 3.5, V_{DP} is given as 15.57

$$\text{V}_R = \frac{30}{100}x15.57$$

$$V_R = 4.67V$$

From the ripple voltage equation, we could get the capacitance

$$V_R = \frac{tmax}{z\ x\ f\ x\ C_1} \quad \dots \dots \dots (3.5)$$

Where V_R is the ripple voltage

I_{max} is the maximum current from the diodes/transformers (300mA) as earlier stated.

f is the frequency of supply

C is the capacitance of the capacitor in Farads.

V_R = 4.67V (from eqn 3.8)

V_R = (2FC) = I_{max}

$$C_1 = \frac{I_{max}}{V_R\ x\ 2\ x\ f} \quad \dots \dots \dots (3.6)$$

Where C_1 is the filter capacitor. Electrolytic capacitors come with a capacitance and a voltage rating.

Voltage Rating

The capacitor voltage must be at least 20 more than the secondary voltage or 150 of the output voltage from the diode.

$$V_c = 150\% \text{ of } V_{DP} \quad \dots \dots \dots (3.7)$$

Where V_{DP} is the peak output voltage from the diodes

But $V_{DP} = V_P - V_D$ … … … (2.5)

Where V_P is the peak voltage of the transformer which is calculated as 16.97v

V_D is the voltage drop of the diodes (0.7x2)

V_{DP} = 16.97 – 1.4

V_{DP} = 15.7V

$$\therefore V_C = 1.5\ x\ V_{DP} \quad \dots \dots \dots (3.8)$$

V_C is the voltage rating of the capacitor (C_1)

V_C = 1.5 x 15.57

$V_C = 23.6V$

UI: is the voltage regulator.

Regulator specifications 1:

- Maximum input voltage = 30V
- Maximum output voltage = 5.5V
- Operating temperature = $0^oc – 150^oc$

For effective Voltage regulation, the minimum input voltage should be:

$$V_{min} = V_{out} + V_{ref} \quad \dots \dots \dots (3.9)$$

This can be found in the LM78XX datasheet.

V_{min} = Minimum input voltage

V_{out} = required voltage: 5V

V_{ref} = Datasheet Stipulated voltage: 3V

$V_{min} = 5 + 3$

$V_{min} = 8V$

The voltage at the capacitor's output registers at 15.57 volts, which surpasses the minimum required input voltage of 8 volts. Consequently, this voltage regulator is deemed suitable for use. Thus, the selected regulator is: **U_1 = 7805**

Analog Comparator

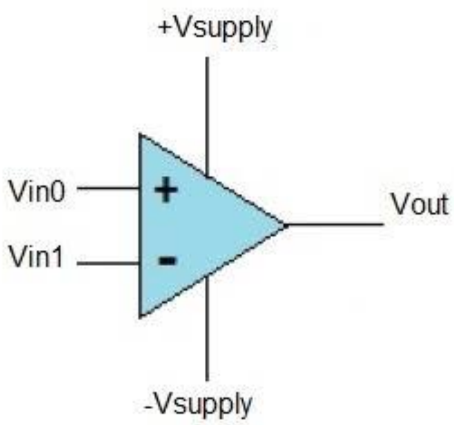

Fig. 3.2: *Analog Comparator*

It compared one input of the comparator with a reference voltage on the other input and provide a 1 or 0 output when one of the signal is greater than the other.

Selecting the Right Comparator

Choosing the appropriate comparator hinges on its propagation delay, as various comparators exhibit varying delay times. It's worth noting that this delay can be adjusted within the programming code of the device.

Mathematically; $\frac{V_1+V_2}{2}$ = Average time

Micro-Controller (Atmega328p)

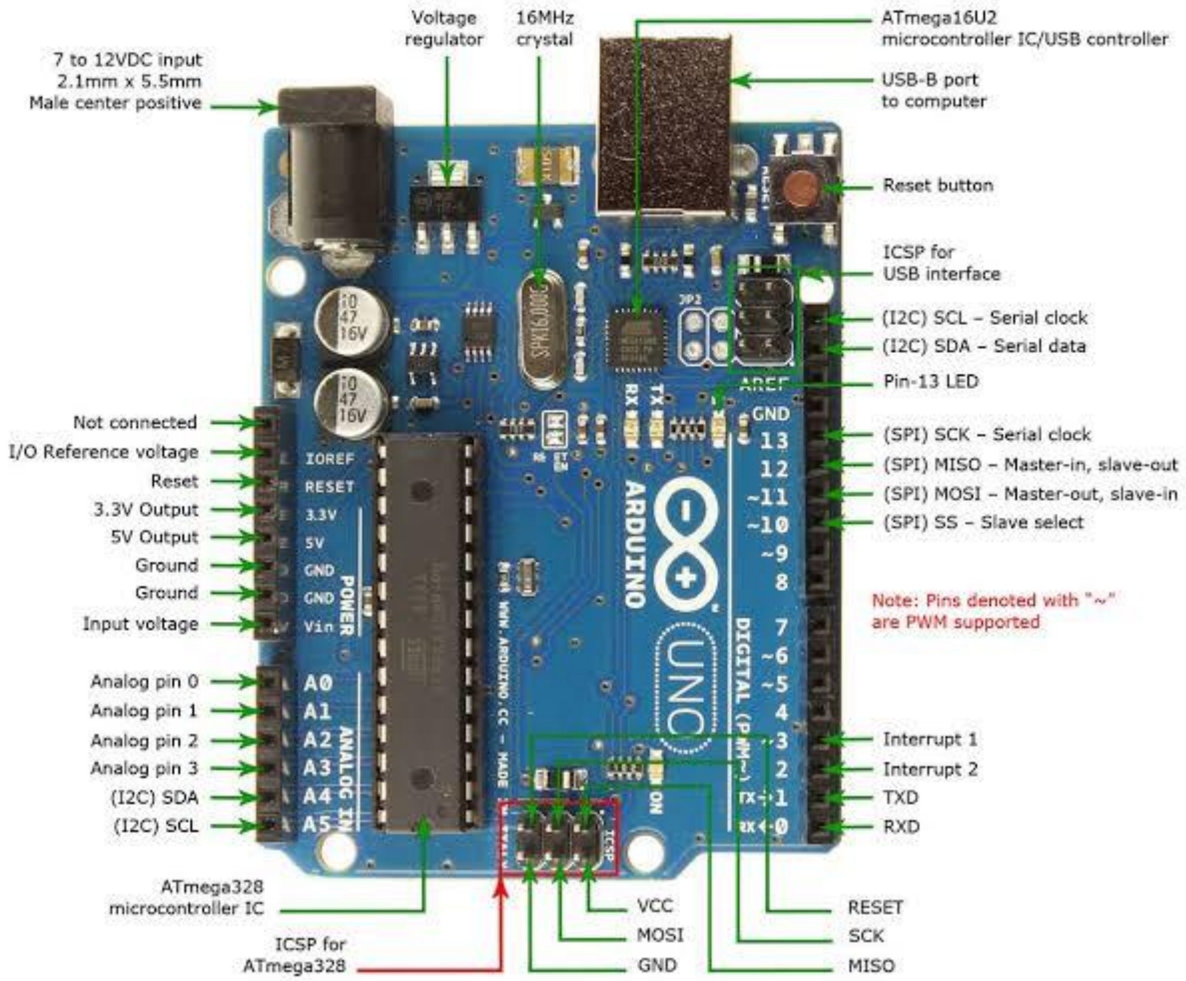

Fig. 3.3: *Arduino uno board*

3.2.1 Basis of Selection.

The ATmega microcontroller, which serves as the central component in numerous Arduino boards, encompasses a central processing unit (CPU) capable of executing both volatile and non-volatile memory instructions. It also includes a range of peripherals, including timers, communication interfaces, and analog-to-digital converters.

Specification

- IC type: AVR microcontroller.
- Core size: 8-bit.
- Speed: up to 20MHz.
- Number of I/O: 23.
- Program memory type: 32Kb (16K×16).
- Program memory size: Flash.
- EEPROM size: 1K×8.
- RAM size: 2K×8.

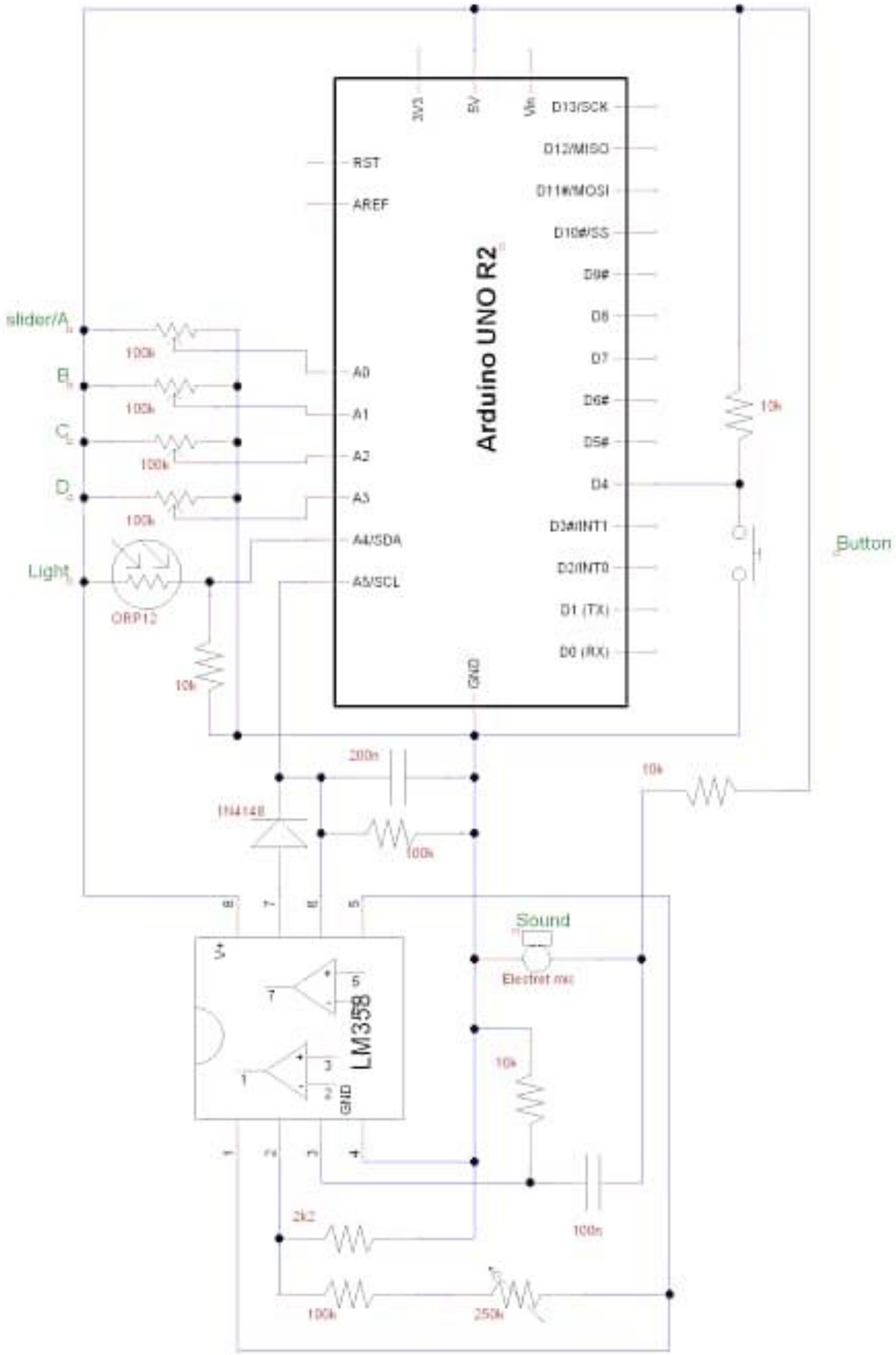

Fig. 3.4: Internal Structure of Arduino Uno Board

Servo Motor

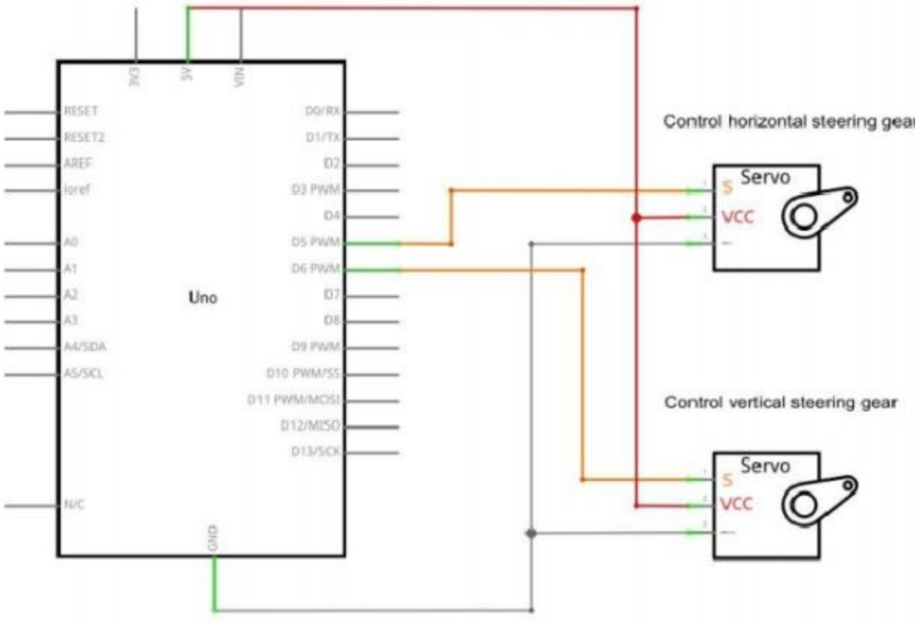

Fig. 3.5: Circuit diagram of a Servo Motor.

Principle of selection

1) Continuous working torque < motor rated torque.

2) Load inertia < 3 times motor inertia.

3) Instantaneous MAX torque < MIN torque of servo motor (when accelerating).

4) Continuous working speed < rated speed of motor.

3.3 CALCULATION

Calculating the moment of inertia of the servo disk.

$$JL \frac{MD^2}{8}$$

Assuming that the reduction ration of the reducer is 1:R, then the inertia of the load on the servo motor is converted to $\frac{JL}{R}$

Where;

M = mass.

D = diameter of disk.

From motor,

M=90g, d = 1.16

JL= 15.3kg.cm^2

3.3.1 Photoresistor

Selection of photo-resistor

Arduino lacks the capability to directly measure resistance; it can solely gauge voltage. Therefore, when selecting the specific type of photo-resistor, it's essential to ensure that the output voltage matches the input voltage.

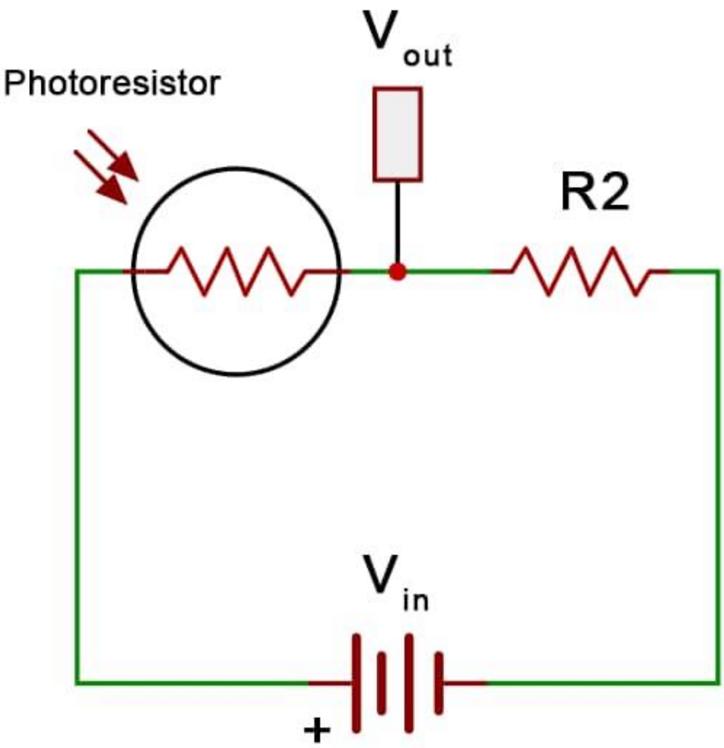

Fig.3.6: Circuit diagram of a *Photo-resistor*

Mathematically:

$V_{in} = V_{out}$

Using voltage divider rule,

$V_2 = \frac{R^1}{R_1 + R_2} V_1$

$V_2 = 4.91$ when $R_1 = 10K\Omega$

$\therefore\ V_1 = V_2$

Solar Panel

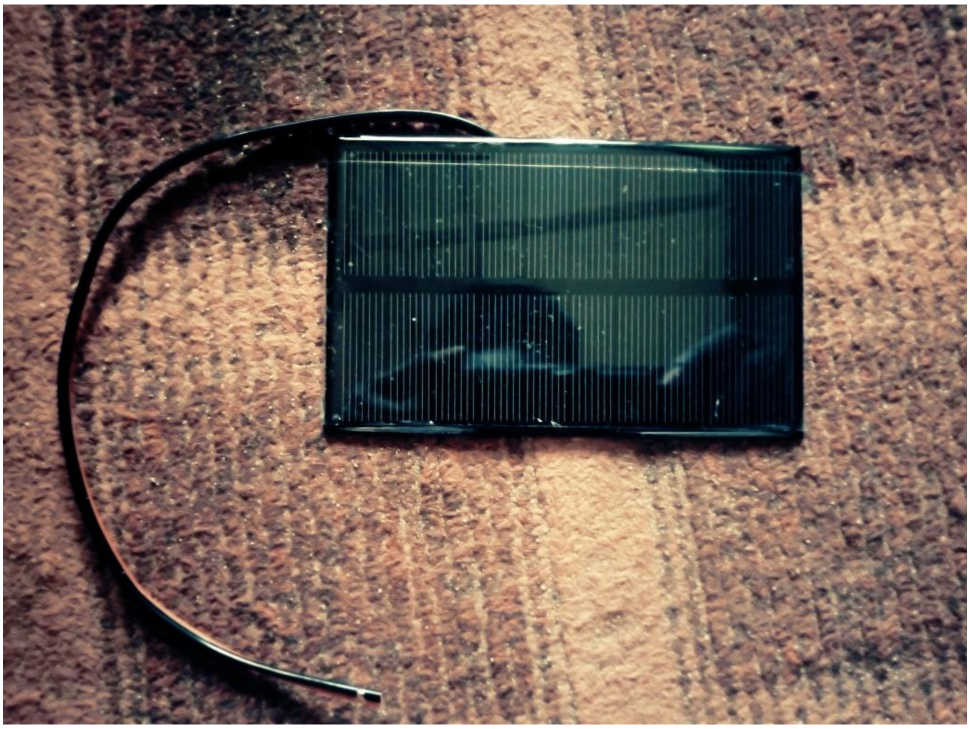

Fig 3.7: View of a Solar Panel (6.8cmx11cm)

The solar panel is constructed using silicon or another semiconductor material, encased within a metal panel frame and covered with a glass casing. When this material is exposed to sunlight's photons (tiny packets of energy), it emits electrons and generates an electrical charge.

Specifications

1) Voltage range: 4.8-9.8V.
2) Area: 6.8cm×11cm.
3) Current: less than 23mV.

Expansion Board

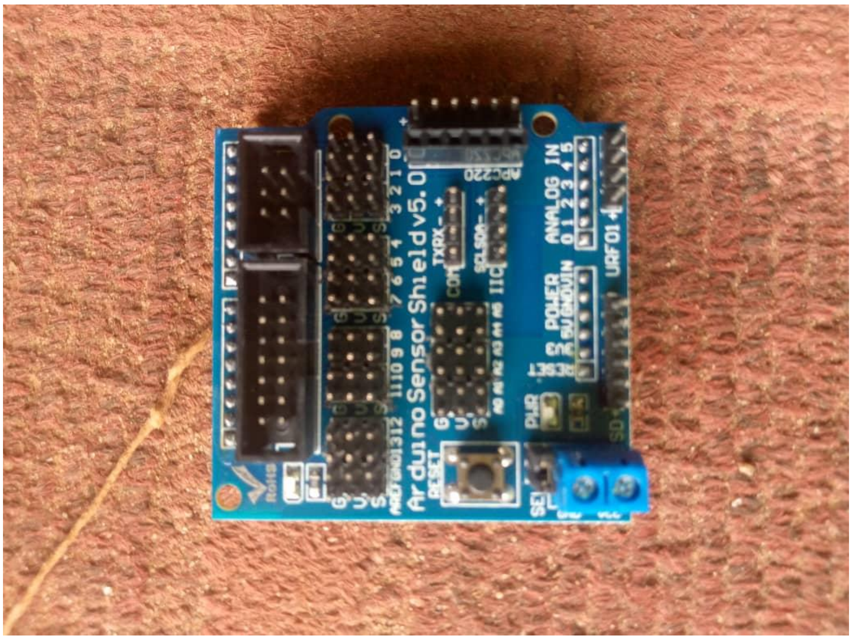

Fig 3.8: View of an Expansion Board

An electronics board, also known as an expansion board, serves to enhance a computer's functionality by plugging into an expansion slot on the computer's motherboard. These expansion boards feature edge connectors that establish an electronic connection between the motherboard and the card.

Jumper Wire

Fig. 3.9: View of a Jumper Wire (1.5mm)

A jumper wire is an electrical conductor that links distant points within an electrical circuit, commonly found on printed circuit boards. When you attach a jumper wire to a circuit, it allows you to create a shortcut or direct connection within the electrical circuit. These jumper wires are selected for the purpose of simplifying circuit modifications. The specific jumper wires used in this context have a 1.5mm diameter, chosen based on the voltage rating of the Arduino board.

3 Digit Micro Digital Tube

Fig 3.10 3 Digit micro Digital Tube.

There are used to measured voltage coming directly from the solar panel. Its measure voltage between 4.8V-30V and a current less 23mA.

3.4 METHOD OF ALIGNMENT

Before delving into the design of the sensing circuit, it's crucial to select the right method for aligning the solar panel. The solar panel itself measures 11cm by 6.8cm. Two alignment methods are available:

(a) **Two Axis Tilt:** This method entails tilting the array in two directions to maintain the desired position.

(b) **Rotate and Tilt:** This approach involves both rotating and tilting the array to keep it in the desired orientation.

For this project, the two-axis tilt method was chosen due to its flexibility and relative simplicity in terms of mechanical construction, as mentioned earlier.

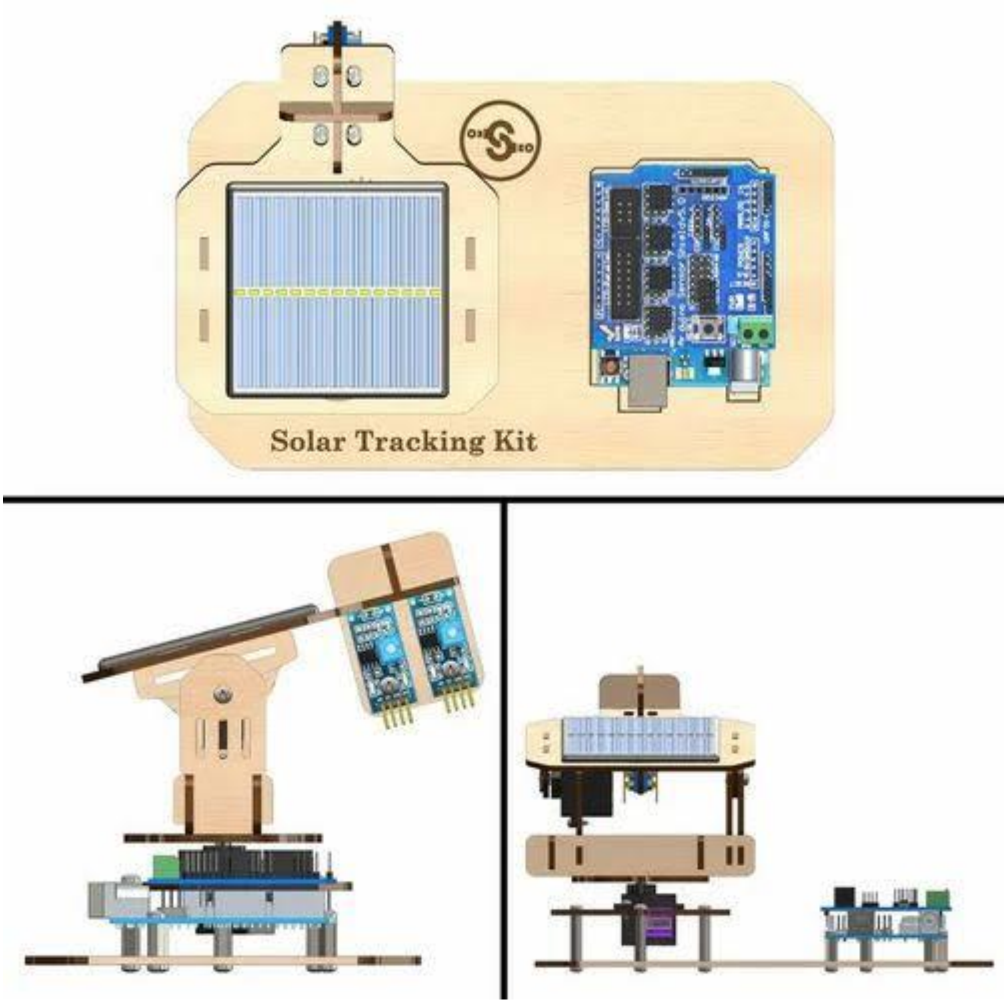

Fig. 3.11: Mechanical View of a Solar Tracker System

This system is employed to monitor the sun's radiation and orient itself precisely at a 90-degree angle to the solar rays. This positioning is crucial for optimizing the solar panel's energy conversion, as it operates most efficiently when aligned directly perpendicular to the sun's radiation. The system incorporates two voltage regulators: LM7805 and LM7806. When an AC voltage of 12 volts is supplied from the charger, these regulators generate 5 volts and 6 volts, respectively. The 5-volt output is directed to both the light-dependent resistors and the micro-controller, while the 6-volt output is directly supplied to the servo motor.

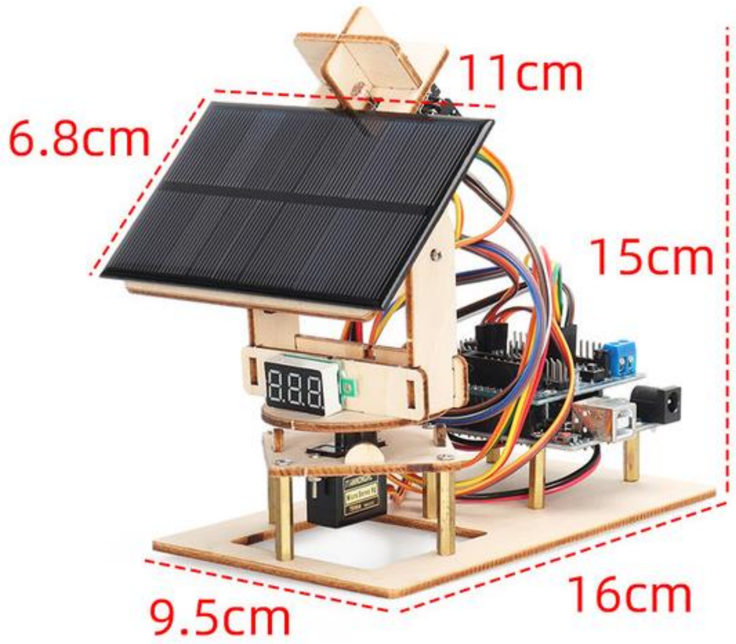

Fig. 3.12: Complete circuit diagram of a Solar Panel Tracker System

During nighttime, the Light Dependent Resistors (LDRs) remain inactive as they don't detect any solar rays. However, as solar radiation levels rise during the day, the four LDRs, operating in pairs, transform the solar radiation into analog signals. These signals are then transmitted to the micro-controller via pins 0, 1, 2, and 3, where the micro-controller conducts its comparisons. Subsequently, the micro-controller sends signals to the servo motor through pins 5 and 6. The servo motor performs necessary adjustments to ensure that the solar panel is accurately oriented toward the direction with the highest solar radiation intensity.

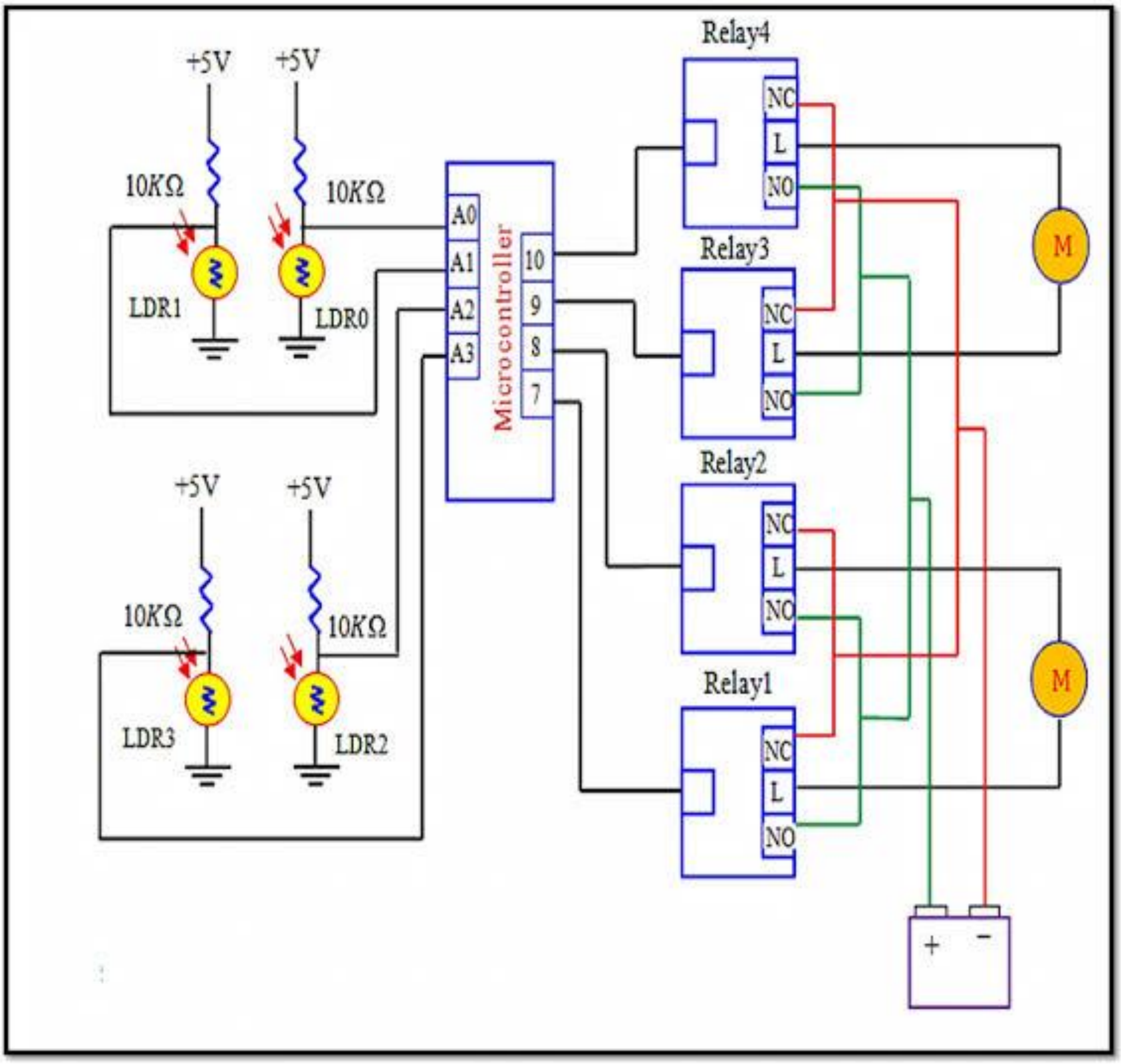

Fig. 3.13: The Complete circuit

CHAPTER FOUR

DISCUSSION AND ANALYSIS OF RESULT

4.1 DISCUSSION OF RESULT

4.1.1 Functionality Testing Results

The prototype underwent a series of rigorous functionality tests to validate its adherence to the initial design specifications. These assessments encompassed measurements of the tracker's angular error and power consumption. These data were then used to determine the system's power generation performance, allowing for a comprehensive comparison with other solar panel systems. This thorough testing process aimed to ascertain the prototype's efficacy and its competitive position relative to existing solar panel technologies.

4.1.2 Angular Error

The initial evaluation of the prototype involves assessing the angular disparity between a light source and the center of the tracker, which is commonly referred to as the angular error. This test aims to identify any discrepancies that may arise when the solar tracker initially aligns itself. Such discrepancies can lead to minor deviations from the intended orientation. The optimal alignment position is when the solar tracker registers a 90-degree angle, resulting in maximum light reception.

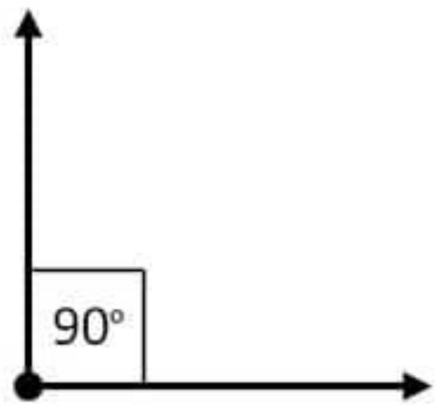

Fig. 4.1: Angular Error

4.1.3 Power Consumption Testing

To ensure that the tracking system produces more power than it uses, we performed an evaluation of the power consumption linked to each element within the system. To gauge the current traveling from the source cell to the tracker system, we utilized a single resistor with a known value of 0.49Ω, as depicted in Figure 15.

4.1.4 Experimental Results

The project's outcomes were derived from Light Dependent Resistors (LDRs) integrated into the solar tracking system and a stationary panel. These results were meticulously recorded and organized into tables during a four-day period. The LDRs' outputs were contingent upon the level of light intensity they received. Arduino offers serial communication capabilities through both digital pins 0 and 1, as well as via a USB connection to a computer. When these functions are enabled, pins 0 and 1 can be utilized for digital input or output purposes. Additionally, the integrated serial monitor in the Arduino environment can establish communication with the NodeMcu board. To collect the recorded data, a dedicated code was created, allowing for the retrieval of information from the LDRs.

4.1.5 Comparison

The readings from the pair of Light Dependent Resistors (LDRs) are intended to be monitored and documented at specific time intervals. These LDRs gauge the light's intensity, making them a reliable indicator of the energy reaching the surface of the solar panels. The intensity of light corresponds directly to the power generated by the panel.

Table 4.1: LDR Outputs for cloudy day on 7th September 2023

TIME	LDR1 (V)	LDR2 (V)
0620	0.266	0.280
0720	0.502	0.510
0820	1.755	1.935
0920	1.629	1.790
1020	1.901	1.800
1120	1.989	2.969
1220	1.984	1.991
1420	0.980	0.990
1520	0.951	0.895
1620	0.830	0.590
1720	0.125	0.982
1830	0.983	0.968

Table 4.2: LDR Outputs for bright sunny day on 2nd September 2023

TIME	LDR1 (V)	LDR2 (V)
0620	1.488	1.491
0720	2.807	2.841
0820	3.210	3.995
0920	3.991	3.989
1020	4.120	4.150
1120	4.600	4.655
1220	4.990	4.990
1320	4.880	4.991
1420	4.980	4.992
1520	4.941	4.892
1620	4.881	4.791
1720	3.962	3.930
1820	2.801	2.817

4.2 ANALYSIS

The tables reveal that the peak sunlight occurs around midday, with the highest values recorded between 1200 hours and 1400 hours. During the morning and late evening, sunlight intensity decreases, resulting in lower values compared to those during the day. At sunset, the tracking system is turned off to conserve energy and then reactivated in the morning. For the panel equipped with the tracking system, the LDR values are expected to be similar, as discrepancies trigger adjustments. Panel movement halts when the values match, signifying equal sunlight intensity received by the LDRs. In contrast, the fixed panel's values fluctuate, as it remains in a fixed position. Thus, the LDRs are typically not aligned with the sun's direction, except around midday when both are nearly perpendicular.

Days with minimal cloud cover exhibit lighter sunlight intensity, resulting in higher LDR outputs. On cloudy days, the tracking and fixed systems yield fairly similar values due to relatively constant light intensity. Any differences are negligible. The tracking system performs optimally in sunny conditions, capturing a significant amount of solar power for conversion. Regarding power output, the tracking system outperforms the fixed system because solar panel power generation hinges on light intensity. Greater light intensity translates to higher power output from the solar panel.

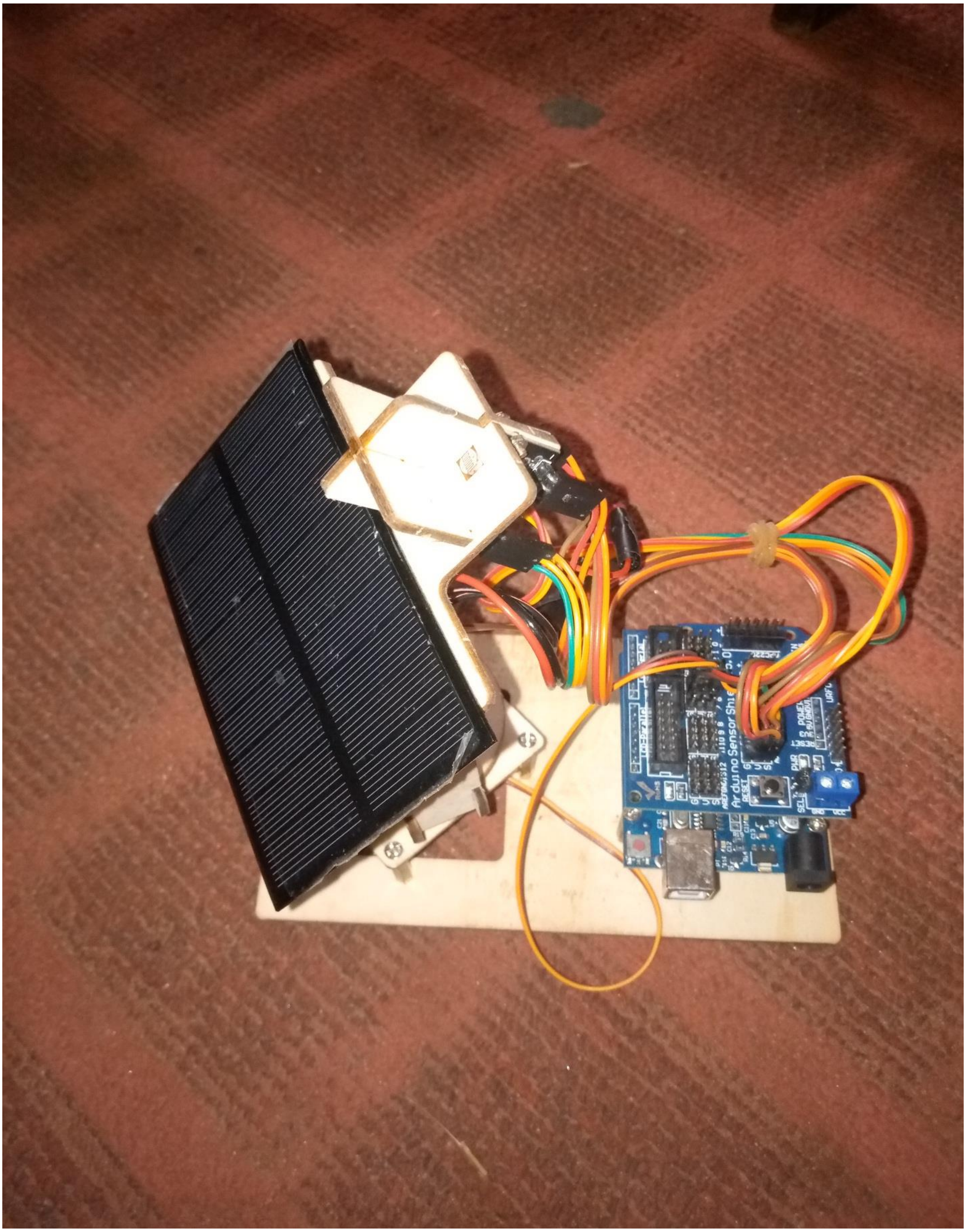

Fig 4.2: Complete Solar Panel Tracker System

CHAPTER FIVE

SUMMARY, CONCLUSION, AND RECOMMENDATION

5.1 SUMMARY

The project involved conducting experiments to gather results from a solar tracking system equipped with Light Dependent Resistors (LDRs) and a fixed-position solar panel. Data was collected and tabulated over four days to assess the performance of these systems. The LDRs provided measurements based on the light intensity they received, offering insights into the power reaching the solar panel. Communication between the Arduino and the computer via digital pins 0 and 1 was established to facilitate data collection.

The comparison of LDR outputs revealed distinct patterns between a cloudy day and a bright sunny day, recorded on different dates. On sunny days, light intensity was consistently high throughout the day, peaking around midday. In contrast, on cloudy days, the light intensity remained relatively constant, resulting in minimal differences between the tracking system and the fixed panel.

The analysis revealed that the most intense sunlight was observed during the midday hours, with peak values between 1200 and 1400 hours. During morning and late evening, sunlight intensity diminished. The tracking system was designed to follow the sun's path, stopping when both LDRs received equal sunlight intensity. In contrast, the fixed panel exhibited varying LDR values as it remained in a fixed position, except around midday when both LDRs aligned closely with the sun.

The results demonstrated that the tracking system was most efficient on sunny days, harnessing maximum solar power for conversion into energy. This efficiency was attributed to the direct correlation between light intensity and power output of the solar panel. Consequently, the tracking system outperformed the fixed panel, which experienced variations in LDR values due to its static position. On cloudy days, the differences in power output between the tracking and fixed systems were minimal because of the consistent light intensity.

In summary, the experiment results underscored the effectiveness of the solar tracking system in optimizing energy capture, particularly on sunny days, by ensuring the solar panel remained aligned with the sun's position throughout the day.

5.2 CONCLUSION

In today's world, where productivity is at its peak, energy stands as the fundamental cornerstone upon which our entire civilization relies. It is a known fact that energy cannot be created or destroyed; it can only be harnessed and stored. This project has been undertaken with the goal of pursuing this very objective – unlocking the path to efficient energy storage.

The continuous exploitation of various energy sources has inevitably led to scarcity issues, particularly when it comes to earthly resources. Among these sources, the sun, which has illuminated our universe since time immemorial and has given birth to life itself, stands as the primary and quintessential source of all energy.

From the perspective of energy storage, this project seeks to address this fundamental need. Many energy sources, apart from solar energy, are derived from the combustion of various materials, a process that results in the emission of copious amounts of pollution, progressively deteriorating our environment and atmosphere. In today's fast-paced and technologically driven world, where convenience and accessibility are paramount, there is a constant need to innovate and find unique solutions to fulfill our energy requirements.

It is crucial to recognize that the relentless pursuit of commercialization and the quest for wealth and power have left us somewhat oblivious to the impending scarcity of global resources. As a result, our planet is suffering. Healing the world has become an imperative mission, and this project serves as a beacon guiding us toward reducing pollution in energy storage, particularly when sourced from the sun. It aims to accelerate progress in a direction that prioritizes sustainability and environmental preservation.

5.3 RECOMMENDATION

Based on the results obtained from this project, several valuable recommendations can be made to further enhance its effectiveness and contribute to the broader goals of sustainable energy utilization:

1. **Optimize Solar Tracking Efficiency:** Given that the solar tracking system demonstrated its highest efficiency during sunny days, it's advisable to focus on optimizing the tracking mechanism. This could involve fine-tuning the tracking algorithm or considering advanced tracking technologies like dual-axis tracking to capture even more sunlight.
2. **Implement Energy Storage**: In order to mitigate the sporadic nature of solar energy, contemplate the incorporation of an energy storage system, like batteries, to store surplus energy produced when sunlight is abundant. This stored energy can subsequently be tapped into during instances of reduced sunlight, guaranteeing a more steady power source.
3. **Environmental Impact Assessment:** Continue monitoring and assessing the environmental impact of your solar tracking system. Quantify the reduction in pollution resulting from using solar energy and communicate these findings to raise awareness of the system's environmental benefits.
4. **Scalability**: Explore options for scaling up the solar tracking system for larger applications. Evaluate the feasibility of implementing this technology in commercial or industrial settings, where energy demands are higher.
5. **Maintenance and Reliability:** Develop a comprehensive maintenance plan to ensure the long-term reliability of the tracking system. Regularly inspect and maintain components to prevent downtime and maximize energy capture efficiency.

6. **Data Collection and Analysis**: Continue collecting data over extended periods to gain a more comprehensive understanding of system performance under various weather conditions and seasons. This will help refine the system and adapt it to changing environmental factors.
7. **Cost Analysis:** Conduct a detailed cost analysis to assess the economic feasibility of implementing the solar tracking system. Consider factors such as installation, maintenance, and energy savings to provide a clear return on investment (ROI) perspective.
8. **Community Outreach:** Educate and engage the local community about the benefits of renewable energy and the positive impact your project can have on reducing pollution and conserving resources. Encourage adoption of similar technologies at the individual or community level.
9. **Compliance**: Ensure that your project complies with all relevant regulations and standards for renewable energy installations. This will help streamline the approval process and ensure the project's legality and safety.
10. **Collaboration and Funding**: Seek partnerships with organizations, government agencies, or investors interested in renewable energy projects. Collaborative efforts and financial support can help accelerate the implementation and expansion of your solar tracking system.

By considering these recommendations and continuously improving your solar tracking system, you can contribute to a more sustainable energy future and promote the adoption of clean energy solutions.

REFERENCES

Al-Qattan, A. S., & Mahmoud, H. A. (2017). "Design and Implementation of an Automatic Solar Tracking System with a Parabolic Trough Concentrator." Energies, 10(12), 2112.

Al-Saadi, A., & Tariq, M. M. (2021). "Solar Tracking System with Arduino for Photovoltaic Applications." Energies, 14(3), 614.

Analysis and implementation of a solar tracker Rack system by A. A. Okandeji1,*, M. B. Olajide2, G. O. Olasunkanmi3andZ. O. Jagun4.

Anju, S., & Rakesh, N. (2018). "Implementation of Arduino Based Solar Tracking System." International Journal of Engineering and Advanced Technology, 7(2), 115-120.

Arduino Based Solar Tracking System by, Pravin Balbudhe, Ameya Mulik, Vineet Mulik, Kanchan Patil, and Komal Sontakke.

Kumar, N., & Jain, N. K. (2019). "Design and Development of Solar Tracking System using Arduino." Materials Today: Proceedings, 13, 1342-1345.

Mayank Kumar Lokhande, "Automatic Solar Tracking System," *International Journal of Core Engineering & Management*, October, 2014.

Prakash, S., Kumar, S., Singh, A. K., & Kumar, A. (2016). "Design and Implementation of a Solar Tracker System Using Arduino for Maximum Power Point Tracking." International Journal of Engineering Research and General Science, 4(2), 110-115.

Saeed, H. A., Mohammed, S. K., & Abbas, H. K. (2020). "Design and Implementation of a Solar Tracker System using Arduino." International Journal of Engineering and Applied Sciences, 7(8), 70-74.

Scott J Hamilton, "Sun-Tracking Solar Cell Array System," University of Queensland, Department of Electrical Engineering, 1999.

Solar Tracking Techniques and Implementation in Photovoltaic power plant by FazliA. Khalil1*, MuhammadAsif 1, Shahzad Anwar 2, Sana ul Haq1, and Farman Illahi1.

Suresh, K., Kumaravel, A., & Senthilkumar, R. (2021). "Development and Testing of Arduino-Based Solar Tracking System." International Journal of Energy Research, 45(5), 7496-7509.

Yoysankha Ghosh, Pabak Das, "Automatic Solar Tracking System" RRC Institute of Information Technology, 2019.

APPENDIX

SOURCE CODE (C+)

THE ALGORITHM

#include <Servo.h>

#define SERVOPINH 5 //Horizontal server

#define SERVOPINV 6 //Vertical server

#define dtime   50 //Delay parameter, the smaller the value, the faster the corresponding speed, and vice versa, the corresponding slower. The unit is millisecond. General value (10~100)

#define tol   50

/*Corresponding range of illuminance, the smaller the more sensitive, and vice versa (the value is 10~100, the sensitivity is different according to the different intensity of the ambient light, the indoor light source varies greatly, but the change under the sun is small)

The above 2 parameters are too small and will be extremely sensitive to subtle changes in light, which will cause jitter.

To eliminate jitter, you can use filter processing or adjust parameters to slow down the response time or sensitivity. */

// Horizontal server Settings

Servo horizontal; // Horizontal server

int servoh = 90;   // Default angle

```
int servohLimitHigh = 175;  //Left and right angle

int servohLimitLow = 5;     //Left and right angle


// Vertical server settings

Servo vertical;     // Vertical server

int servov = 90;     // Default angle


int servovLimitHigh = 100;  //

int servovLimitLow = 10;     //The maximum elevation angle is not easy to be too large, the sensor may withstand the rack


//Wiring ports for 4 sensors

const int ldrlt = A0; //Upper left

const int ldrrt = A1; //Upper right

const int ldrld = A2; //Lower left

const int ldrrd = A3; //Lower right


void setup()

{

  Serial.begin(9600);
```

```
  horizontal.attach(SERVOPINH);

  vertical.attach(SERVOPINV);

  horizontal.write(servoh);

  vertical.write(servov);

  delay(100);

  //Test operation

  //Test the operation of the vertical axis, pay attention to check whether there is a jam (or wire
winding).

  // for(int i=servovLimitLow;i<servovLimitHigh;i+=2)

  // {  vertical.write(i);

  //    delay(30);

  // }

  // //vertical.write((servovLimitLow + servovLimitHigh)/2);

  // delay(100);

  // //Test horizontal

  // for(int i=servohLimitLow;i<servohLimitHigh;i+=2)

  //  {  horizontal.write(i);

  //    delay(30);

  //  }

  //  //horizontal.write((servohLimitHigh + servohLimitLow)/2);
```

```
  //If there is no problem with the test, you can remove the code here.

}

void loop()

{

  int lt = analogRead(ldrlt); //up_l

  int rt = analogRead(ldrrt); //up_r

  int ld = analogRead(ldrld); //low_l

  int rd = analogRead(ldrrd); //low_r Read the illuminance value of 4 sensors separately



  int avt = (lt + rt) / 2; // up_l_r

  int avd = (ld + rd) / 2; // low_l_r

  int avl = (lt + ld) / 2; // left_up_low

  int avr = (rt + rd) / 2; // right_up_low Average the adjacent readings



  int dvert = avt - avd; // vertical-up-low

  int dhoriz = avl - avr;// horizontal-left-right Then calculate the average value of the upper and
lower rows and the average value of the left and right rows



//  Serial.print(lt);

//  Serial.print(",");
```

```
//  Serial.print(rt);

//  Serial.print(",");

//  Serial.print(ld);

//  Serial.print(",");

//  Serial.print(rd);

//  Serial.print ("      |    ");

//

//  Serial.print(avt);

//  Serial.print(",");

//  Serial.print(avd);

//  Serial.print(",");

//  Serial.print(avl);

//  Serial.print(",");

//  Serial.print(avr);

//  Serial.print(",   ");

//  Serial.print(dtime);

//  Serial.print(",   ");

//   Serial.println(tol);      //The serial port outputs the reading value. After the debugging is normal, you can delete this code to improve the corresponding speed.
```

```
//Check if the difference is within tolerance, otherwise change the vertical Angle

if (-1*tol > dvert || dvert > tol)

{

if (avt < avd)

{

  servov = ++servov;

   if (servov > servovLimitHigh)

   {

    servov = servovLimitHigh;

   }

}

else if (avt > avd)

{

  servov= --servov;

  if (servov < servovLimitLow)

{

  servov = servovLimitLow;

  Serial.println(servov);

}

}
```

```
  vertical.write(servov); //If the rotation angle of the servo is opposite to the light, use (180-servov) or (servov) to change the direction.
  }
  //Check whether the difference is within the tolerance range, otherwise change the horizontal angle
  if (-1*tol > dhoriz || dhoriz > tol)
  {
  if (avl < avr)
  {
    servoh = --servoh;
    if (servoh < servohLimitLow)
    {
    servoh = servohLimitLow;
    }
  }
  else if (avl > avr)
  {
    servoh = ++servoh;
     if (servoh > servohLimitHigh)
     {
```

```
    servoh = servohLimitHigh;
    }
  }
  else if (avl = avr)
  {
   // nothing
  }
  horizontal.write(servoh); //Steering gear rotation Angle and the light of the opposite with
(180-servOH) or (servOH) can be reversed
  }
   delay(dtime);
}
```