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1. INTRODUCTION

The energy from the sun can be used to overcome the energy crisis generated by the scarcity of Fossil fuel resources. Solar energy is free and everywhere. Due to the decreasing of solar photovoltaic energy cost, it's superior in the renewable energy sources and widely utilized in many countries. Solar power is one of the most widely used alternative pathway in the renewable energy domains or sources. The global demand/installation and production of PV modules are parallel increasing exponentially for the past 10 years. Solar energy is a very large, inexhaustible source of energy. The power from the sun intercepted by the earth is approximately (1.8×1011) MW, which is many thousands of times larger than the present consumption rate on the earth of all commercial energy sources. To rectify the problems the solar panel should be such that it always receives maximum intensity of light. It has been seen since past that the efficiency of the solar panel is around 10-15% which is not meeting the desired load requirements. So, there is a need of improving the panel efficiency through an economical way. The most immediate and technologically attractive use of solar energy is through photovoltaic conversion. The physics of the PV cell is very similar to the classical p-n junction diode. In order to maximize the power output from the PV panels, one needs to keep the panels in an optimum position perpendicular to the solar radiation during the day.

Solar powered equipment works best when pointed at or near the sun, so a solar tracker can increase the effectiveness of such equipment over any fixed position, at the cost of additional system complexity. The tracker will enable the panel to follow the path of the sun and produce more power as it absorbs more sunlight. When the sun rays are incident on the solar cell, due to the photovoltaic effect, light energy from the sun is used to convert it to electrical energy. The solar tracking system is the most common method of increasing the efficiency of solar photo module.

This will tend to maximize the amount of power absorbed by PV systems. It is estimated that using a tracking system, over a fixed system, can increase the power output by 30% - 60% This study presents the efficiencies of energy conversion of photo module with solar tracking system and fixed photo module. Tracking system uses 4 photo resistors, which are mounted on the sides of the photo module. By these photo resistors the solar tracking system becomes more sensitive and it allows to determining a more accurate location of the sun and Arduino controller to control circuits to drive two motors used to move the solar panel so that sun's beam is able to remain aligned with the solar panel.

2. WHY SOLAR TRACKING SYSTEMS?

Sunlight has two components,

- Direct beam
- Diffuse sunlight

The direct beam carries about 90% of the solar energy. The diffuse sunlight that carries the remainder the diffuse portion is the blue sky on a clear day. As the majority of the energy is in the direct beam, maximizing collection requires the sun to be visible to the panels as long as possible. Solar Trackers generate more electricity than their stationary counterparts due to increased direct exposure to solar rays. This increase can be as much as 10 to 40% depending on the geographic location of the tracking system.

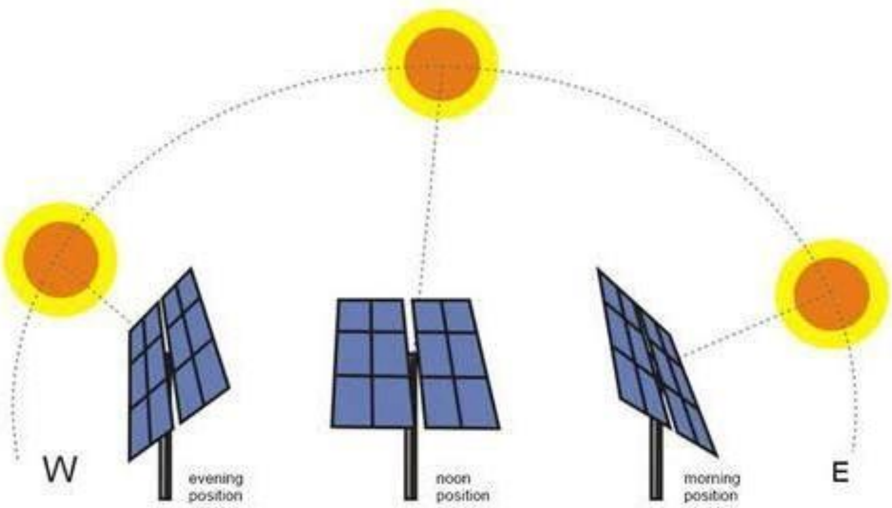


Figure 2-1:: Solar Tracking Panel

Dual axis trackers have two degrees of freedom that act as axes of rotation. These axes are typically normal to each other. The primary axis (the azimuth axis) is the one that is fixed with respect to the ground. The secondary (elevation axis) axis is the one referenced to the primary axis.

Dual axis trackers allow for optimum solar energy levels due to their ability to follow the Sun vertically and horizontally. No matter where the Sun is in the sky, dual axis trackers are able to angle themselves to be in direct contact with the Sun.

Two common implementations are tip-tilt dual axis trackers (TTDAT) and azimuth-altitude dual axis trackers (AADAT).

3. TYPES OF TRACKERS

There are a couple different types of trackers as well as ways to track the sun.

Active tracker is a tracker which is controlled by computer program (via an Arduino). This means that we use sensors to find the brightest source of light at all times. It uses motors and gear trains to direct the tracker as commanded by a controller, responding to the solar direction.

Passive trackers Passive energy systems use the sun's energy for heating and cooling purposes. Passive solar systems operate without reliance on external devices. They use passive collectors to convert rays into the sunlight.

The passive collectors are based on laws of thermodynamics which transfer heat from warmer to cooler surfaces. The overall success of a passive solar system depends on their overall orientation and the thermal mass of its walls.

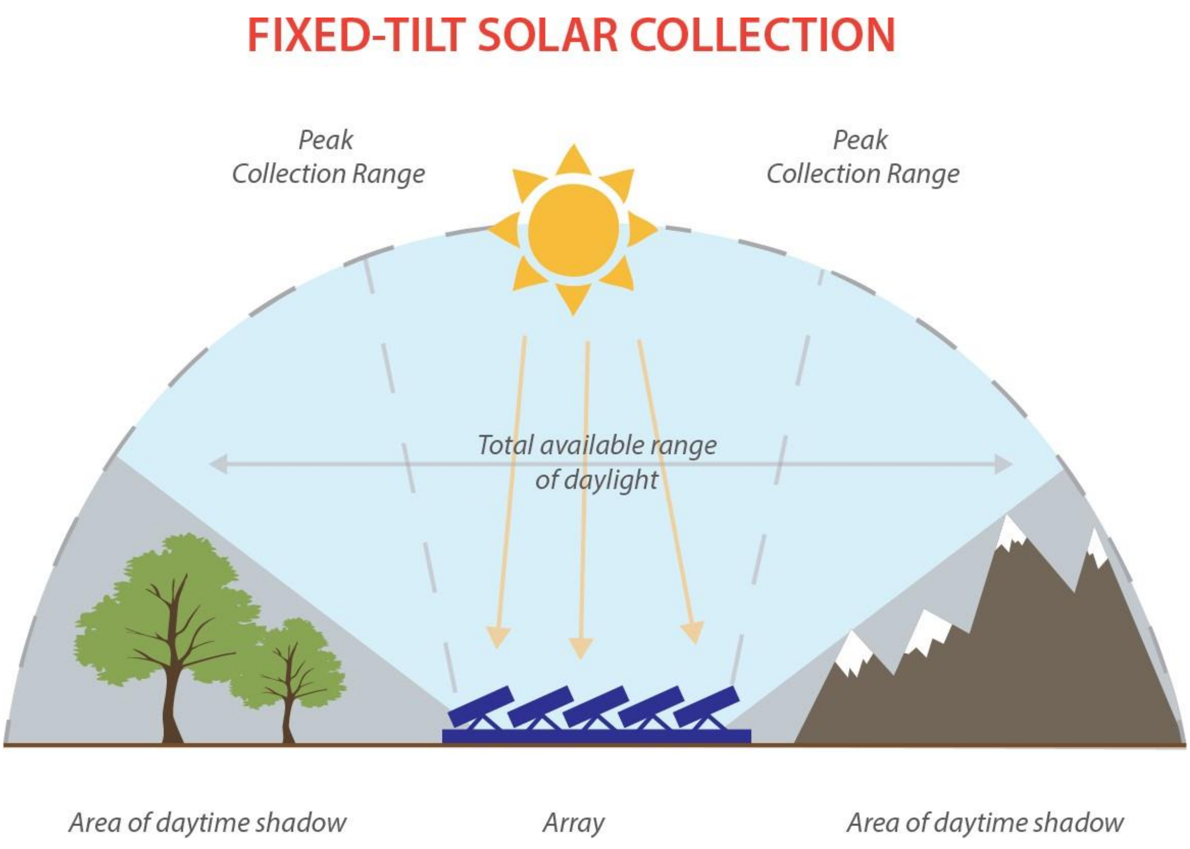


Figure 3-1: Fixed Solar Collection

Scheduled tracker uses a computer program that changes the angle of the panel based on the date, time, and physical location. It is in fact far more efficient provided everything is set up properly.

Dual axis tracker, means it tracks in both X and Y directions. That is, it goes left, right, up, and down. This means that once we have your set-up tracker we will never need to change or adjust anything, anywhere the sun moves the tracker will follow. This method gives the best results for power generation.

Single axis tracker, tracks just X or Y direction. That is, it turns left to right or just up and down. Typically, people will make an X axis (left to right) tracker and then just set their panel at 45 degrees for Y. This still gives really high amounts of power generation while at the same time eliminating half the moving parts.

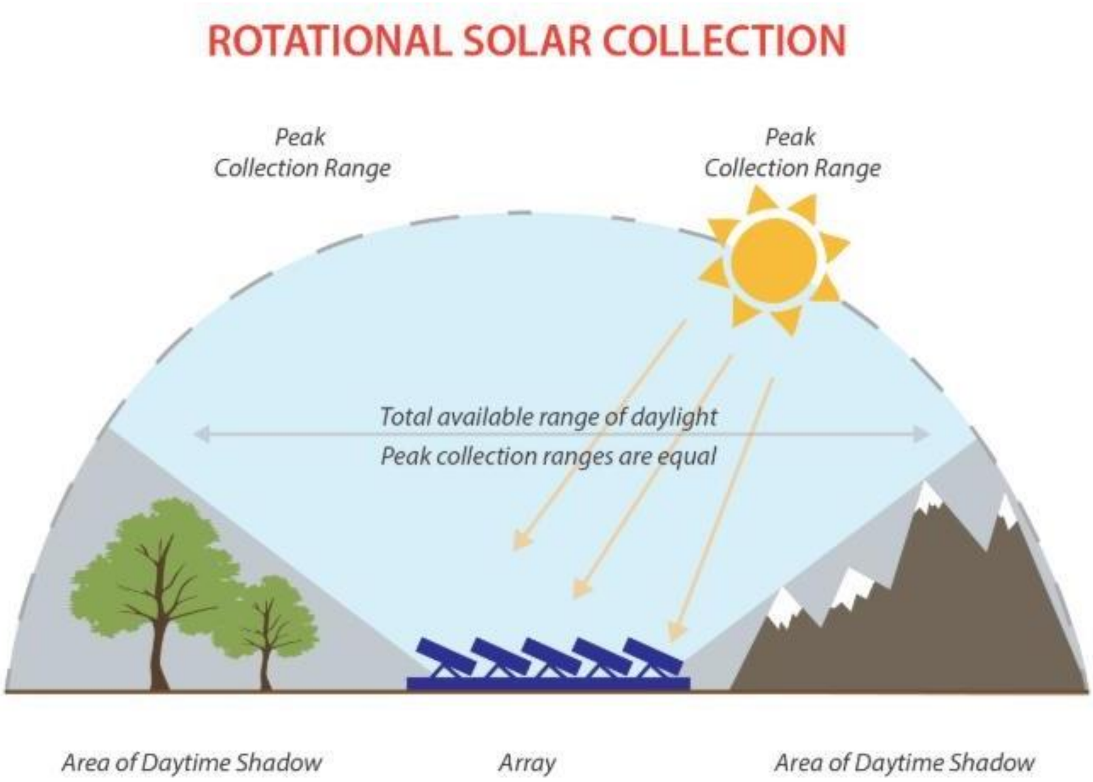


Figure 3-2:: Fixed Solar Collection

4. WORKING PRINCIPLE

Resistance of LDR depends on intensity of the light and it varies according to it. The higher is the intensity of light, lower will be the LDR resistance and due to this the output voltage lowers and when the light intensity is low, higher will be the LDR resistance and thus higher output voltage is obtained. A potential divider circuit is used to get the output voltage from the sensors (LDRs).

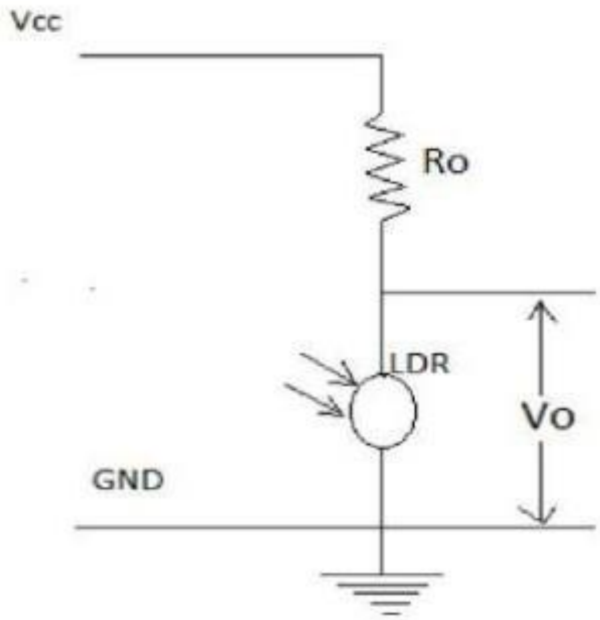


Figure 4-1:Voltage Divider Circuit

The LDR senses the analog input in voltages between 0 to 5 volts and provides a digital number at the output which generally ranges from 0 to 1023.Now this will give feedback to the microcontroller using the Arduino software (IDE).

The servo motor position can be controlled by this mechanism

- **Servo X:** Rotates solar panel along X direction
- **Servo Y:** Rotates solar panel along Y direction

The tracker finally adjusts its position sensing the maximum intensity of light falling perpendicular to it and stays there till it notices any further change.

The sensitivity of the LDR depends on point source of light. It hardly shows any effect on diffuse lighting condition.

5. SYSTEM WORKING ESSENTIALS

Methodology

To track the position of the sun speedily, the Arduino UNO controller should first calculate the theoretical elevation and azimuth angles as a rough adjustment of the automatic tracking mechanism. The theoretical value of altitude and azimuth angles that come from sun-earth relationships are translated into digital commands for driving servo motors to the corresponding position. Then, the system automatically trims the elevation and azimuth angle of the PV panel according to the feedback signal of the proposed LDR sensor module. The sensor module consists of four LDR-sensors.

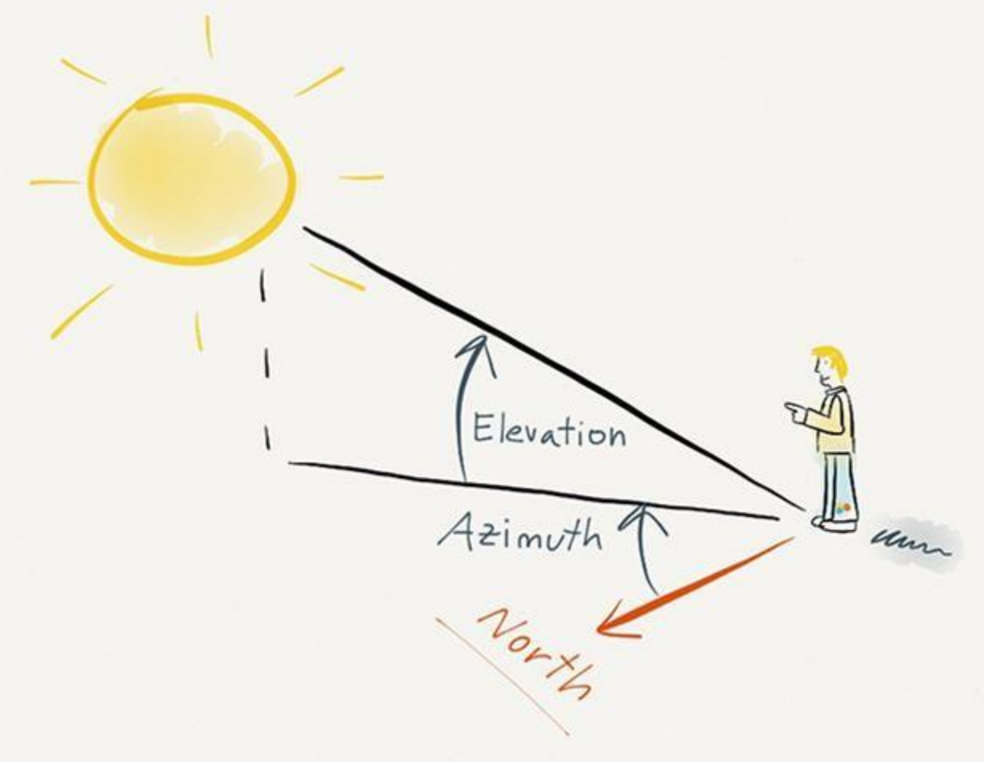


Figure 5-1:Azimuth and Elevation Angle

Software

The software parts comprise of a programming language that formulated using C programming. Arduino UNO controller uploaded with codes after compiling them.

Control Circuit

The main control circuit components are Arduino UNO controller, LDR, resistors and two geared servo motors.

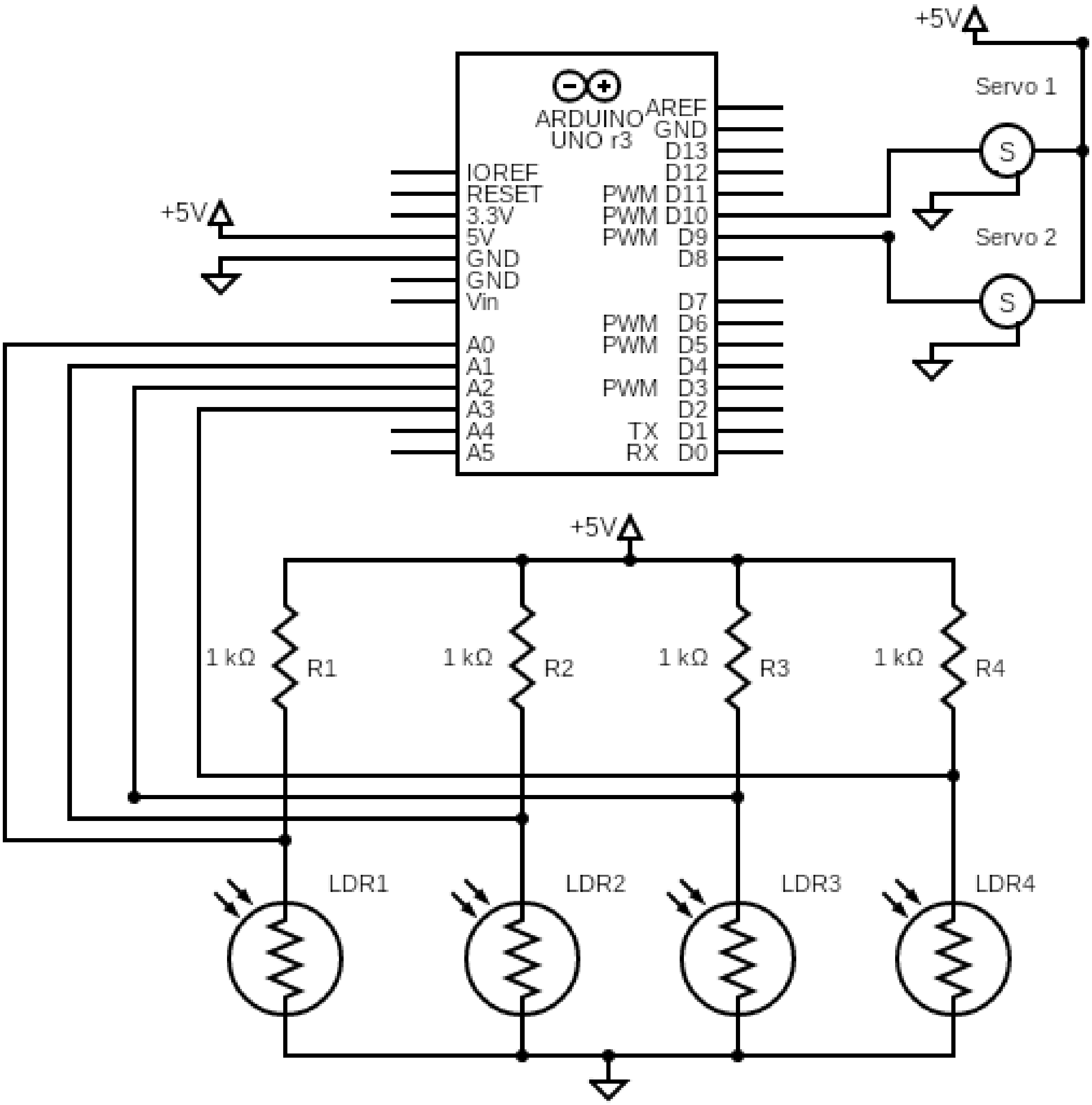


Figure 5-2:Circuit Diagram

6. FUNCTIONAL BLOCK DIAGRAM

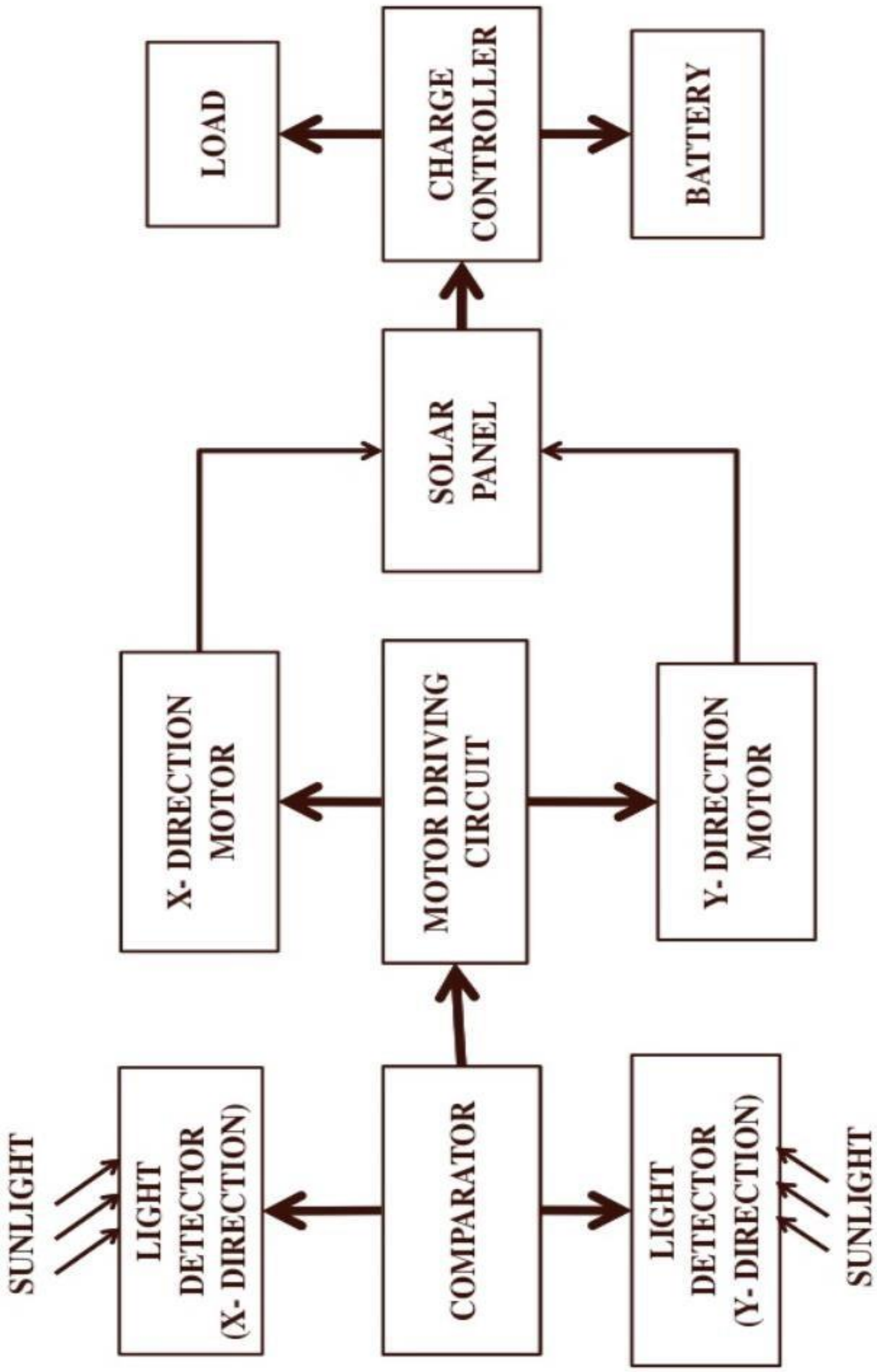


Figure 6-1:Functional Block Diagram

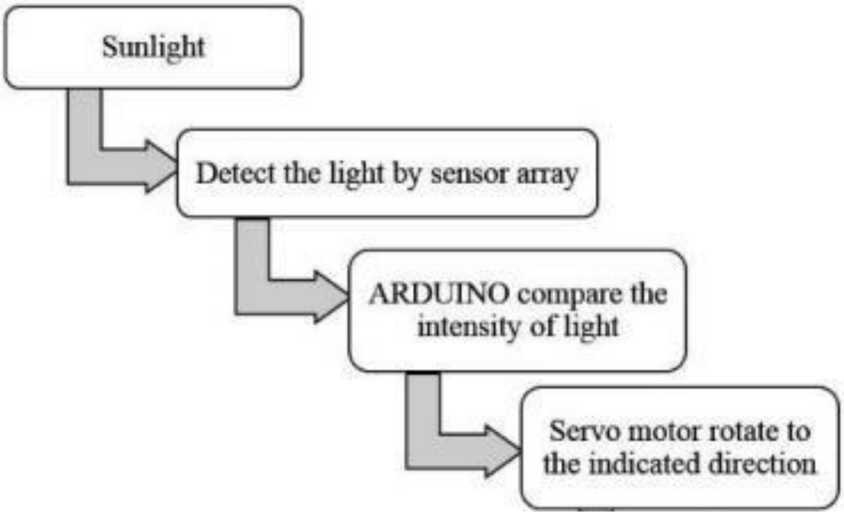


Figure 6-2:Working Principle of Dual Axis Tracker

Four LDR sensors are routed as input in Arduino analog pins A0, A1, A2, A3 routed to top right, top left, down left, downright sensors respectively. The pulse pin of servo was routed as output in Arduino digital out pins. The servo motors are connected to the solar panel module where the solar panel is placed. The solar panel terminals are connected to a charge controller, to which the battery and the load circuit are connected.

When sunlight falls on the Solar panel module, the LDR sensors detect the intensity of light and sends the corresponding data to Arduino development board. The Arduino development board analyses the azimuth angle and elevation angle based on the data received from the LDR sensors.

After analysing, the Arduino sends the signal to the servo motor. The servo motor rotates the solar panel module to the desired direction. The solar panel is connected to the charge controller which converts the received solar energy to electrical energy (i.e. Dc power). This charging module can be used to charge a battery and drive a load circuit with sufficient power.

The output and input power dissipated can be observed on the charging module LCD display, the load circuit can be any circuit such as mobile charging device using a USB cable.

7. HARDWARE DETAILS

The Components used are:

Light Dependent Resistor (LDR)

LDR are also known as photo conductors (or) photo resistors. It is usually in form of a photo resistor made of cadmium sulphide (CdS) or gallium arsenide (GaAs). This works on the principal of photo conductivity. LDR resistance decrease with increase in light intensity and vice versa. These are mainly used for sensing purpose in order to catch the solar energy and provide analog input to Arduino.

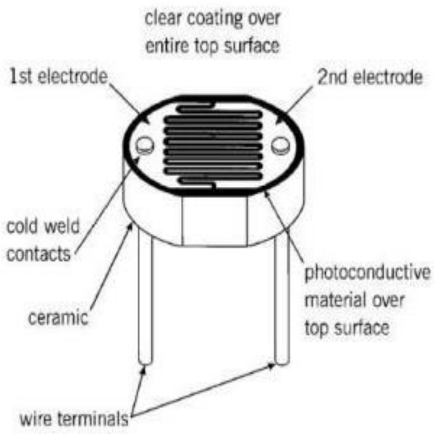


Figure 7-1:LDR Construction

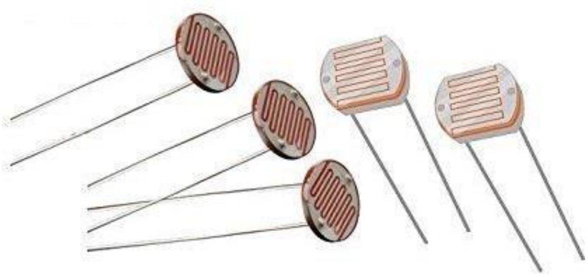


Figure 7-2:LDRs

When the light source moves, i.e. the sun moves from west to east, the level of intensity falling on both the LDRs changes and this change is calibrated into voltage using voltage dividers. The changes in voltage are compared using built-in comparator of microcontroller and motor is used to rotate the solar panel in a way so as to track the light source.

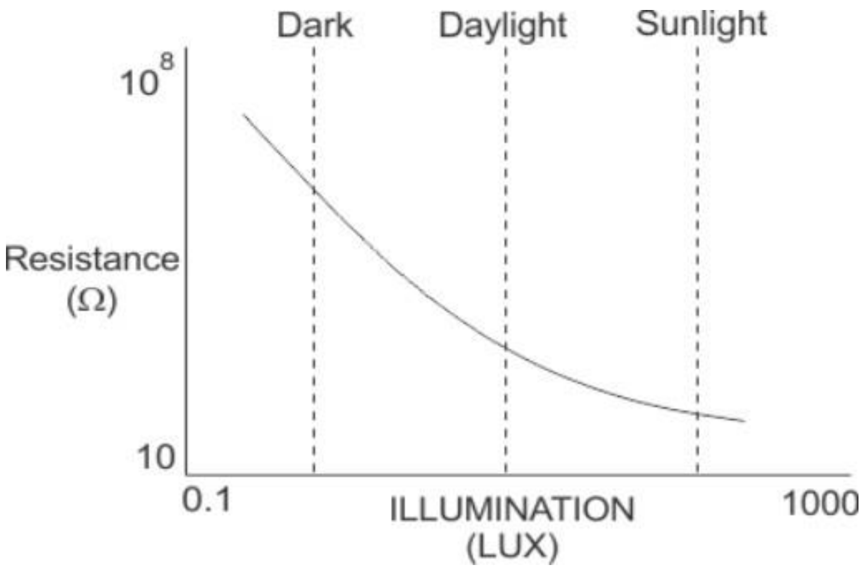


Figure 7-3:Variation in Light Intensity (LUX)

Servo Motor

Tiny and lightweight with high output power and have good energy efficiency. This servo has metal gears for added strength and durability. Servo can rotate approximately 180 degrees (90 in each direction).

Inside the servo there are three main components; a small DC motor, a potentiometer and a control circuit. Gears are used to attach the motor to the control wheel. As the motor rotates, the resistance of the potentiometer changes so the control circuit can precisely regulate the amount of movement there is and the required direction. When the shaft of the motor is at the desired position, power supply to the motor is stopped.

The speed of the motor is proportional to the difference between the actual position and the position that is desired. Therefore, if the motor is close to the desired position, it turns slowly. Otherwise, it turns fast. This is known as proportional control.

Figure 7-4:Servo motor MG90s

Specifications:

- Weight: 13.4 g
- Dimension: 22.5 x 12 x 35.5
- Stall torque: 1.8 kgf·cm (4.8V)
- Operating speed: 0.1 s/60 degree
- Operating voltage: 4.8 V – 6.0 V
- Dead band width: 5 µs

Servos are sent through sending electrical pulses of variable width, or pulse width modulation (PWM), through the control wire. There is a minimum pulse, maximum pulse and a repetition rate.

The servo motor expects to see a pulse after every 20 milliseconds and the length of the pulse will determine how far the motor will turn. For instance, a 1.5ms pulse makes the motor to turn in the 90 degrees position. If the pulse was shorter than 1.5ms, it will move to 0 degrees and a longer pulse moves it to 180 degrees.

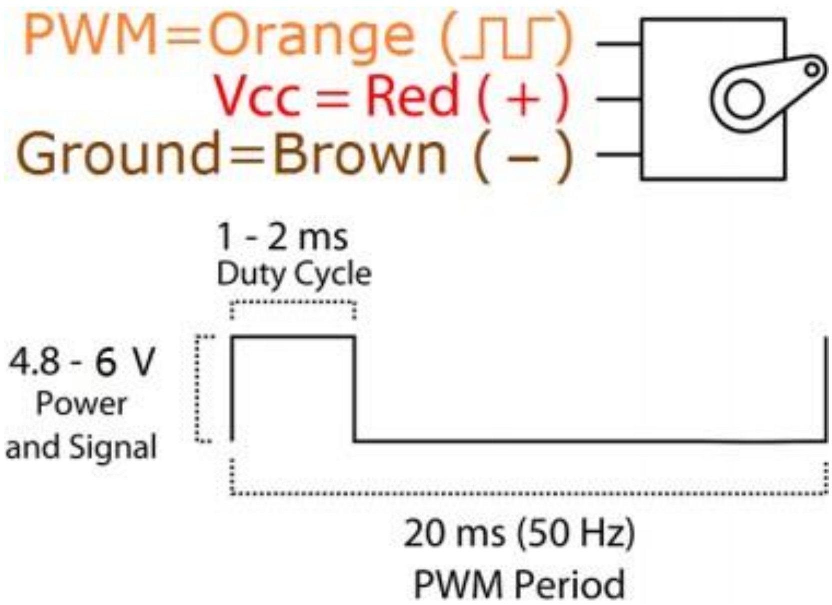


Figure 7-5:MG90s Pinout and PWM signal

Arduino Uno

Arduino Uno is a microcontroller board based on 8-bit ATmega328P microcontroller. Along with ATmega328P, it consists other components such as crystal oscillator, serial communication, voltage regulator, etc. to support the microcontroller. Arduino Uno has 14 digital input/output pins (out of which 6 can be used as PWM outputs), 6 analog input pins, a USB connection, A Power barrel jack, an ICSP header and a reset button.

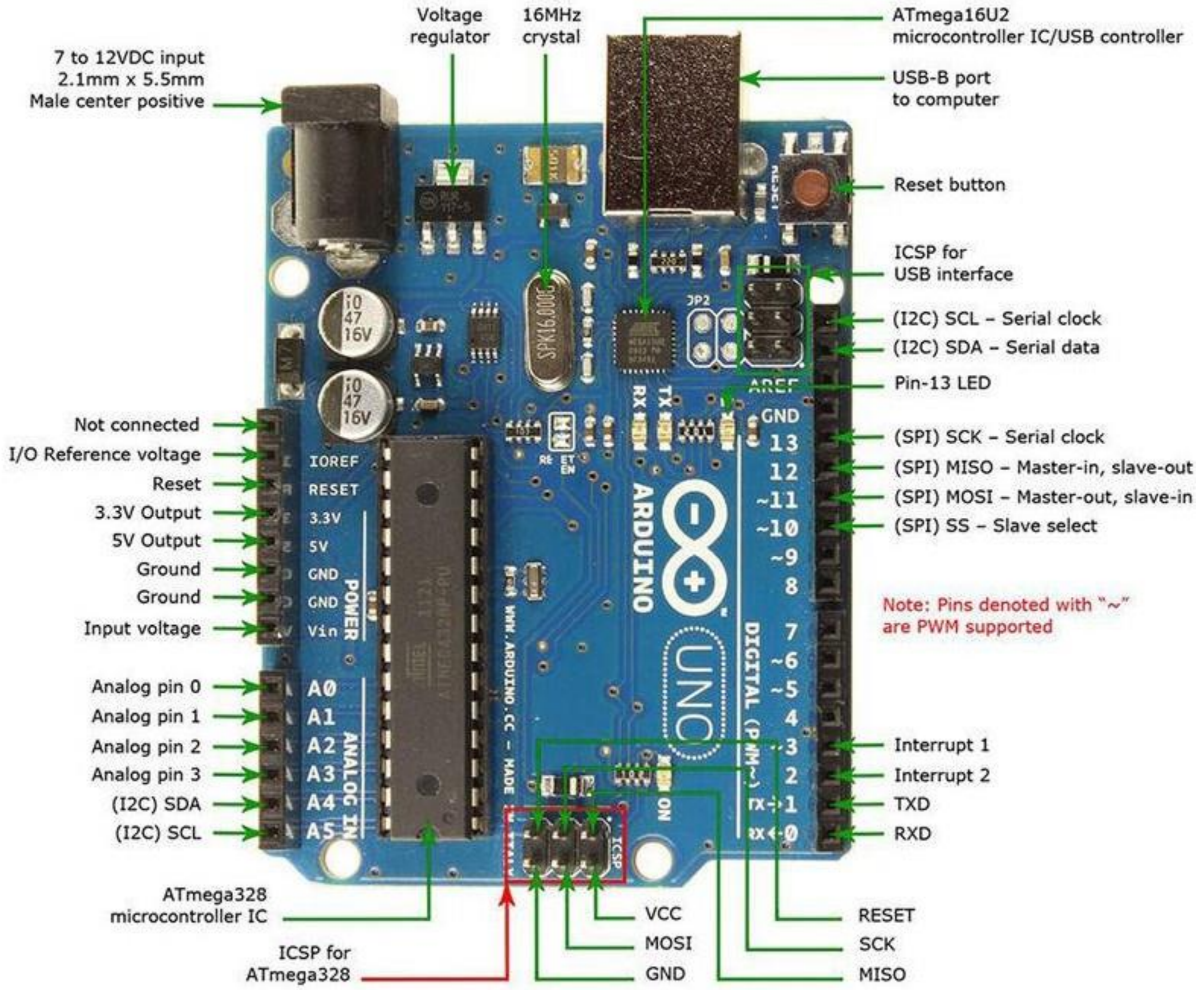


Figure 7-6:Arduino UNO pinout

The 14-digital input/output pins can be used as input or output pins by using pinMode(), digitalRead() and digitalWrite() functions in Arduino programming. Each pin operates at 5V and can provide or receive a maximum of 40mA current, and has an internal pull-up resistor of 20-50 K Ohms which are disconnected by default.

Arduino IDE (Integrated Development Environment) is required to program the Arduino Uno board.

Pin Description:

Pin Category	Pin Name	Details
Power	Vin, 3.3V, 5V, GND	Vin: Input voltage to Arduino when using an external power source. 5V: Regulated power supply used to power microcontroller and other components on the board. 3.3V: 3.3V supply generated by on-board voltage regulator. Maximum current draw is 50mA. GND: ground pins.
Reset	Reset	Resets the microcontroller.
Analog Pins	A0 – A5	Used to provide analog input in the range of 0-5V
Input/Output Pins	Digital Pins 0 - 13	Can be used as input or output pins.
Serial	0(Rx), 1(Tx)	Used to receive and transmit TTL serial data.
External Interrupts	2, 3	To trigger an interrupt.
PWM	3, 5, 6, 9, 11	Provides 8-bit PWM output.
SPI	10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK)	Used for SPI communication.
Inbuilt LED	13	To turn on the inbuilt LED.
AREF	AREF	To provide reference voltage for input voltage.

Table 7-1:Arduino Uno Pin Description

Arduino Uno Technical Specifications:

Microcontroller	ATmega328P – 8-bit AVR family microcontroller
Operating Voltage	5V
Recommended Input Voltage	7-12V
Input Voltage Limits	6-20V
Analog Input Pins	6 (A0 – A5)
Digital I/O Pins	14 (Out of which 6 provide PWM output)
DC Current on I/O Pins	40 mA
DC Current on 3.3V Pin	50 mA
Flash Memory	32 KB (0.5 KB is used for Bootloader)
SRAM	2 KB
EEPROM	1 KB
Frequency (Clock Speed)	16 MHz

Table 7-2:Arduino Uno Technical Specifications

Arduino IDE

- Arduino IDE is an open source software that is mainly used for writing and compiling the code into the Arduino Module.
- It is an official Arduino software, making code compilation too easy that even a common person with no prior technical knowledge can get their feet wet with the learning process.
- It is easily available for operating systems like MAC, Windows, Linux and runs on the Java Platform that comes with inbuilt functions and commands that play a vital role for debugging, editing and compiling the code in the environment.

Resistors

The resistors are connected in series with the LDRs, the output voltage will increase with increase in light intensity and with increase in light intensity the resistance decreases. The value of the complementary resistor is chosen 19 such that the widest output range is achieved.

Figure 7-7:Resistors 1K ohm

Mainboard 18650 Battery Charger PCB Module with LCD Display

Its is a step-up power module, input 3.5V to 4.8 V. it can provide a stable 5V output. It is used for phone charge or mobile power.

Features:

1. LCD display
2. Blue indicator light, automatically extinguished after 15 seconds
3. Input/output indicator
4. LED three lighting modes
5. Micro USB Input
6. Two standard USB Output

Description:

1. Press the button twice, LED on and enter the full bright mode.
2. Press again for one-time, LED brightness decreases, showing 25% brightness.
3. Press again for one time, Flashing LED.
4. Press the button twice, LED off
5. Module will stop working and stop output after long press of button (5 seconds).

Figure 7-8:18650 Charging Module & Pinout Diagram

Panasonic Lithium Ion NCR18650 Battery

This Panasonic NCR 18650B 3400 mAh Li-Ion Battery is a single cell compact and powerful battery cell with 3400 mAh huge capacity as compared to its 18650 battery families. This Li-ion battery is very convenient to install in all standard 18650 battery holder and can be soldered in your project where 3.7 Volt with high capacity is needed.

Features:

1. High energy density
2. High working voltage for single battery cells.
3. Pollution-free
4. Long cycle life
5. High performance and capacity
6. Good consistency and low self-discharge.
7. Lightweight, small size

Figure 7-9:Lithium-Ion Battery 18650

Solar panel

Solar energy is the photovoltaic cell which converts light energy received from sun into electrical energy Solar panels collect clean renewable energy in the form of sunlight and convert that light into electricity which can then be used to provide power for electrical loads. Solar panels are comprised of several individual solar cells which are themselves composed of layers of silicon, phosphorous (which provides the negative charge), and boron (which provides the positive charge). Solar panels absorb the photons and in doing so initiate an electric current.

The resulting energy generated from photons striking the surface of the solar panel allows electrons to be knocked out of their atomic orbits and released into the electric field generated by the solar cells which then pull these free electrons into a directional current. This entire process is known as the Photovoltaic Effect.

Figure 7-10:Solar Panel (12V, 250 mah)

Other Components Used

- Jumper wires (Male to Female)
- JST Connectors
- Breadboard
- Balsa Wood (3mm)
- Tools and stationery: Soldering gun, Modeling Blade, Glue, Insulation Tape
- Digital Multimeter and LUX Meter
- IDE Software

Figure 7-11: Other Components Used

8. ARCHITECHTURAL MODEL

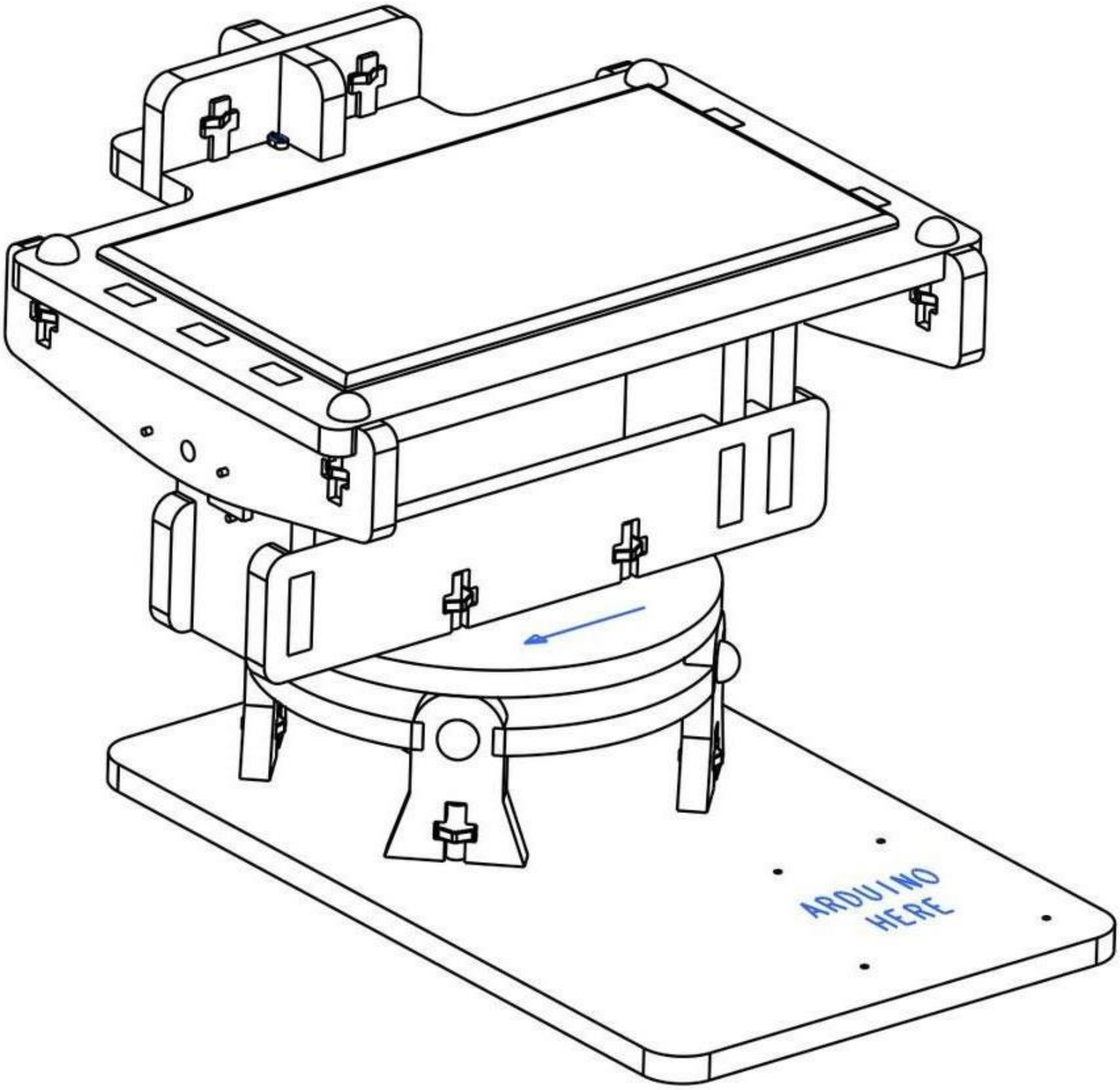


Figure 8-1:Architectural Model for Dual Axis Solar Tracker

9. FLOWCHART

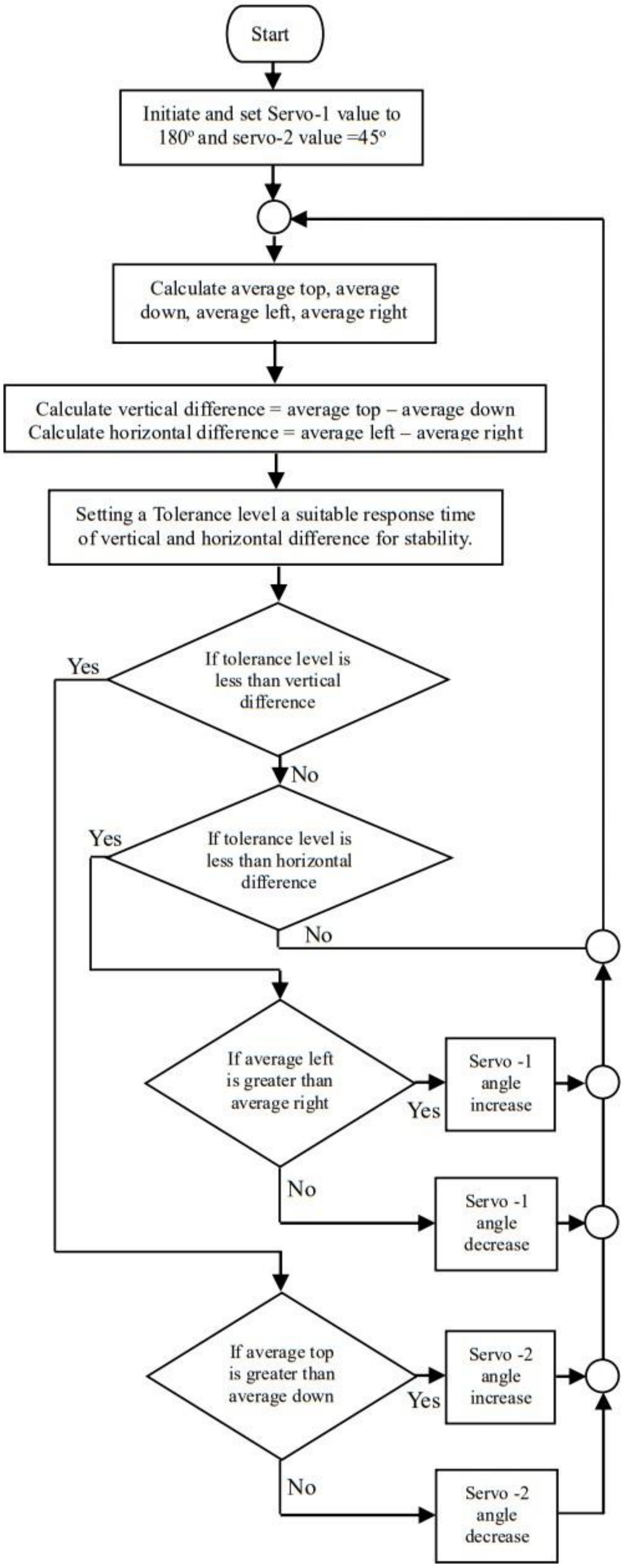


Figure 9-1:Flowchart Algorithm for Program code

10. Program Code

C Program for Driving the Dual Axis Tracking System

```
#include <Servo.h>

Servo horizontal;
int servoh = 180;

int servohLimitHigh = 180;
int servohLimitLow = 65;

Servo vertical;
int servov = 45;

int servovLimitHigh = 80;
int servovLimitLow = 15;

// LDR pin connections

int ldrlt = 0;
int ldrrt = 1;
int ldrld = 2;
int ldrrd = 3;

void setup()
{
Serial.begin(9600);
horizontal.attach(9);
vertical.attach(10);
horizontal.write(180);
vertical.write(45);
delay(3000);
}

void loop()
{
```

```
int lt = analogRead(ldrlt);
int rt = analogRead(ldrrt);
int ld = analogRead(ldrld);
int rd = analogRead(ldrrd);



int dtime = 10;
int tol = 50;

int avt = (lt + rt) / 2;
int avd = (ld + rd) / 2;
int avl = (lt + ld) / 2;
int avr = (rt + rd) / 2;

int dvert = avt - avd;
int dhoriz = avl - avr;

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;
}
}
vertical.write(servov);
```

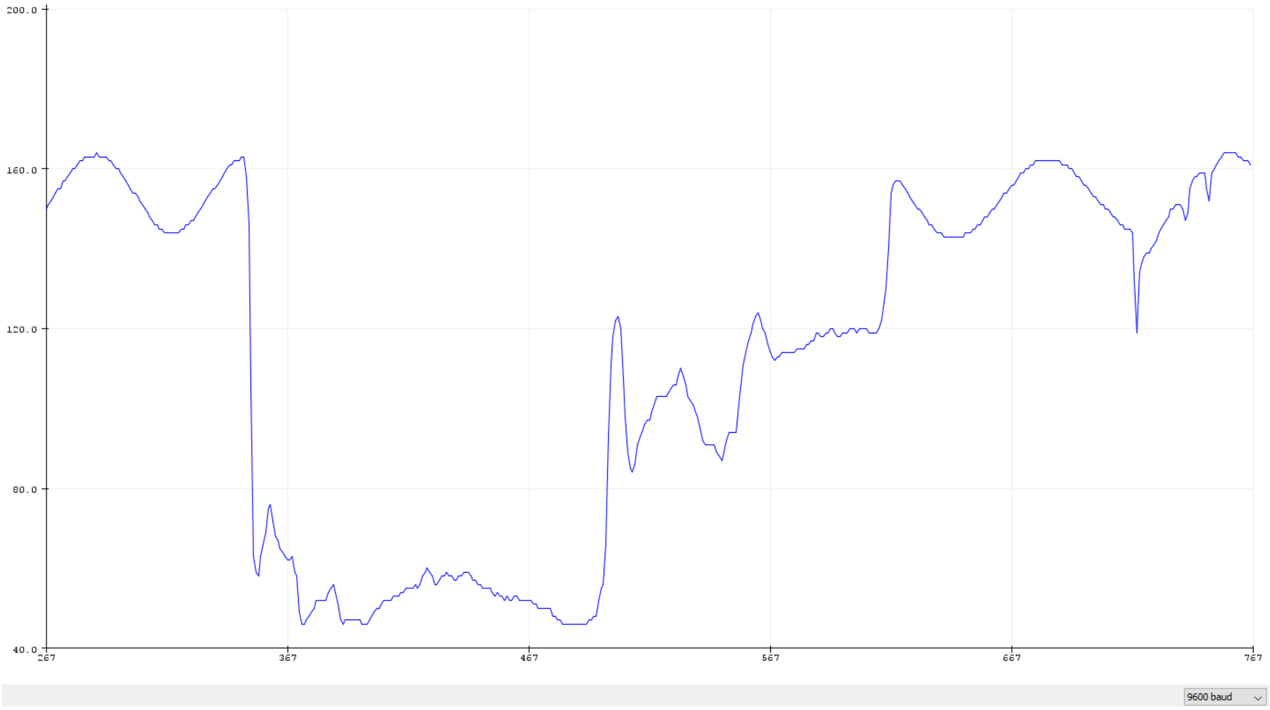
```
}

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);
}
delay(dtime);

}
```

Test Code for the Arduino LDR Sensor

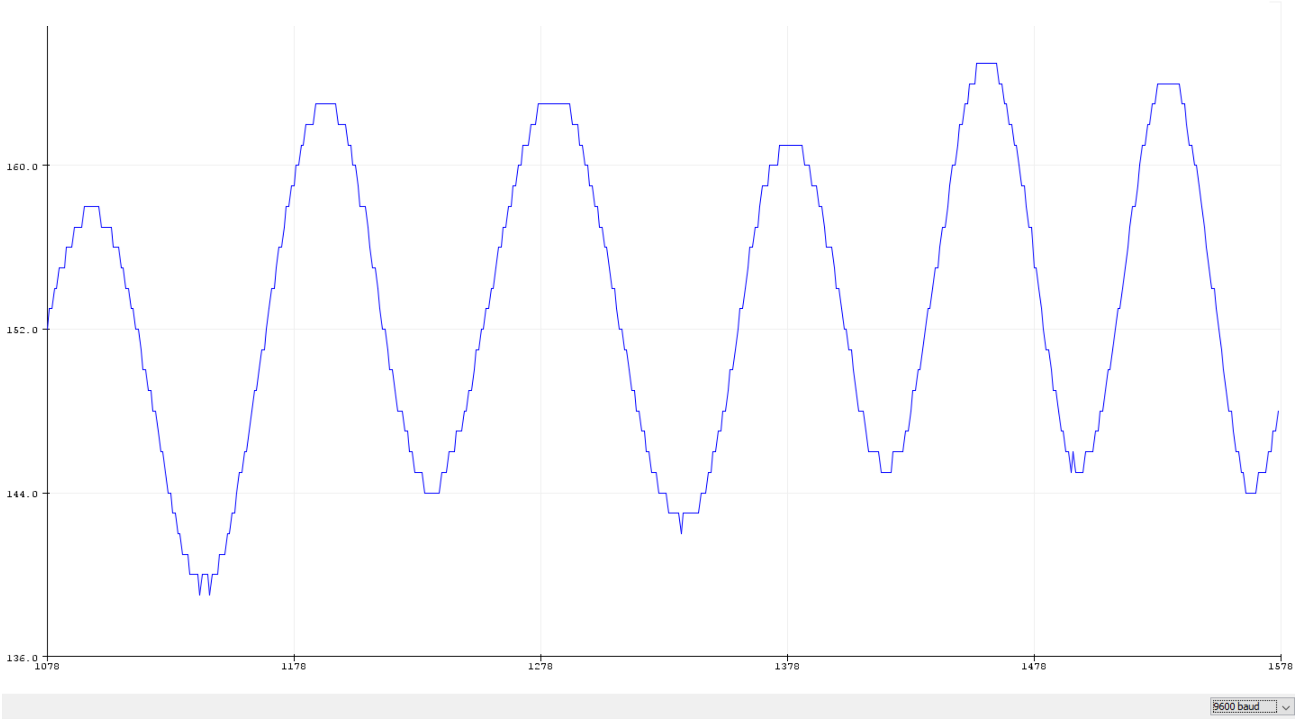
```
int sensorPin = A0;
int sensorValue = 0;
void setup ()
{
Serial.begin(9600);
}
void loop ()
{
sensorValue = analogRead(sensorPin);
Serial.println(sensorValue);
delay (100);
}
```

11.RESULTS

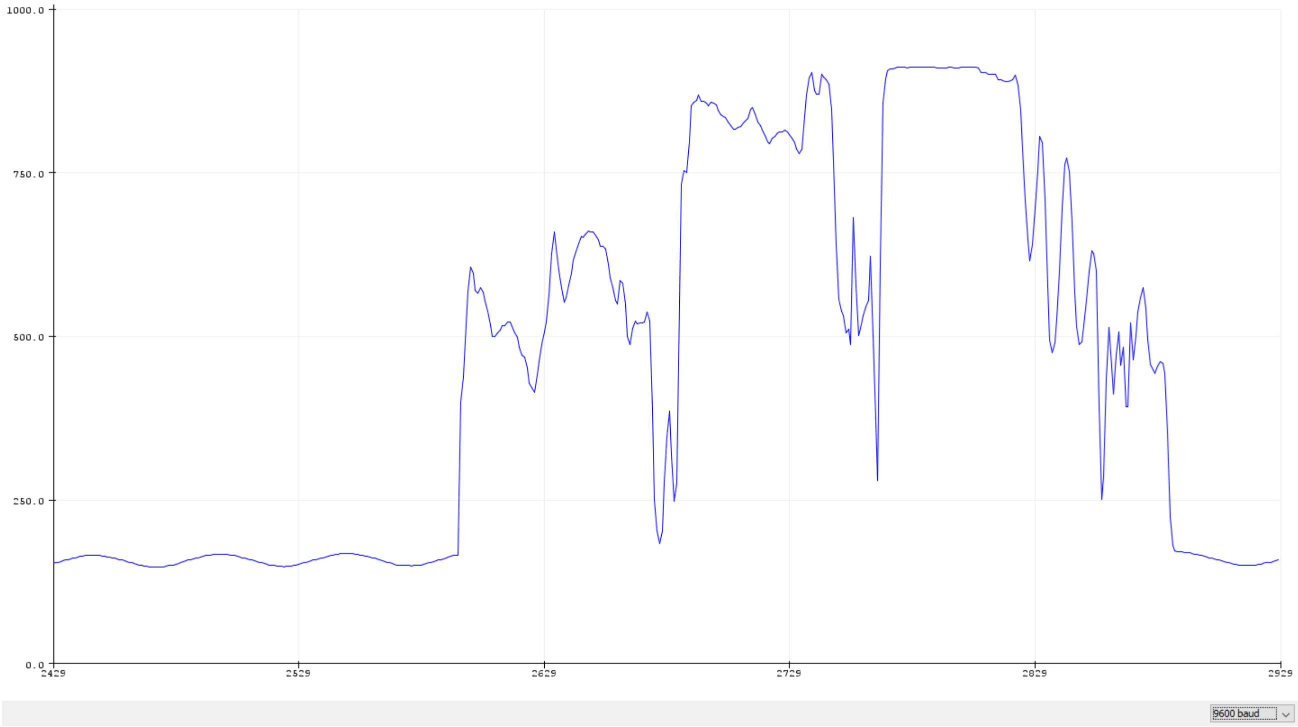
Testing the LDR



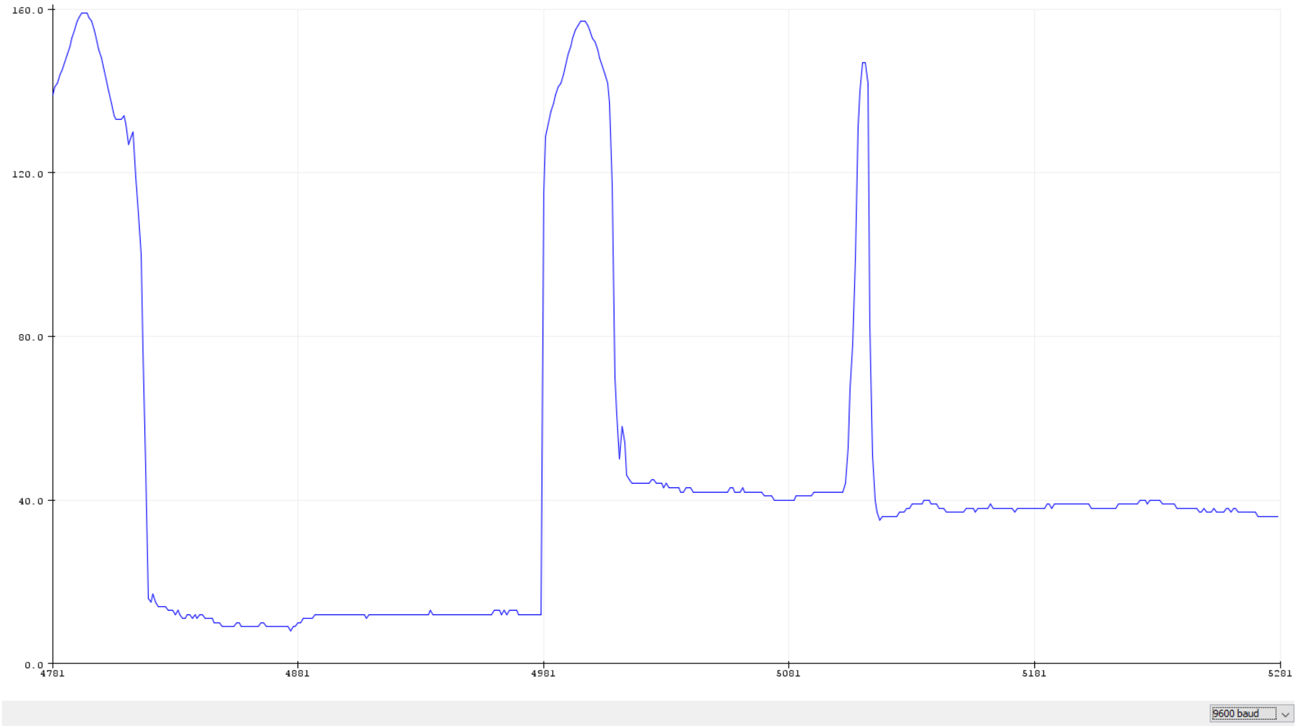
Graph 11-0-1:Light Intensity Vs Time plot at room light



Graph 11-0-2:Light Intensity Vs Time plot at Flash light



Graph 11-0-3:Light Intensity Vs Time plot At Daylight

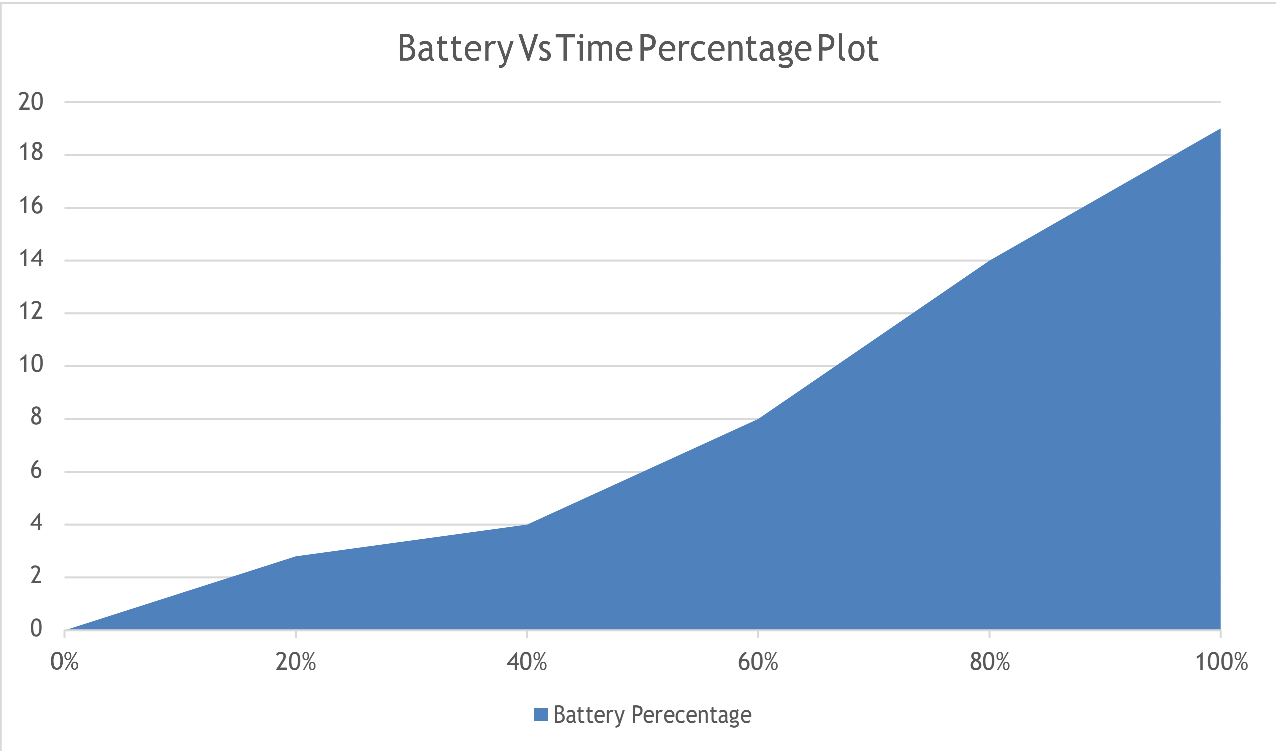


Graph 11-0-4:Light Intensity Vs Time plot At low/moon Light

Load Charging Characteristics

Battery Percentage (%)	Time Taken
20	3
40	4.1
60	7.6
80	14.1
100	18.5

Table 11-1:Battery Vs Time Table

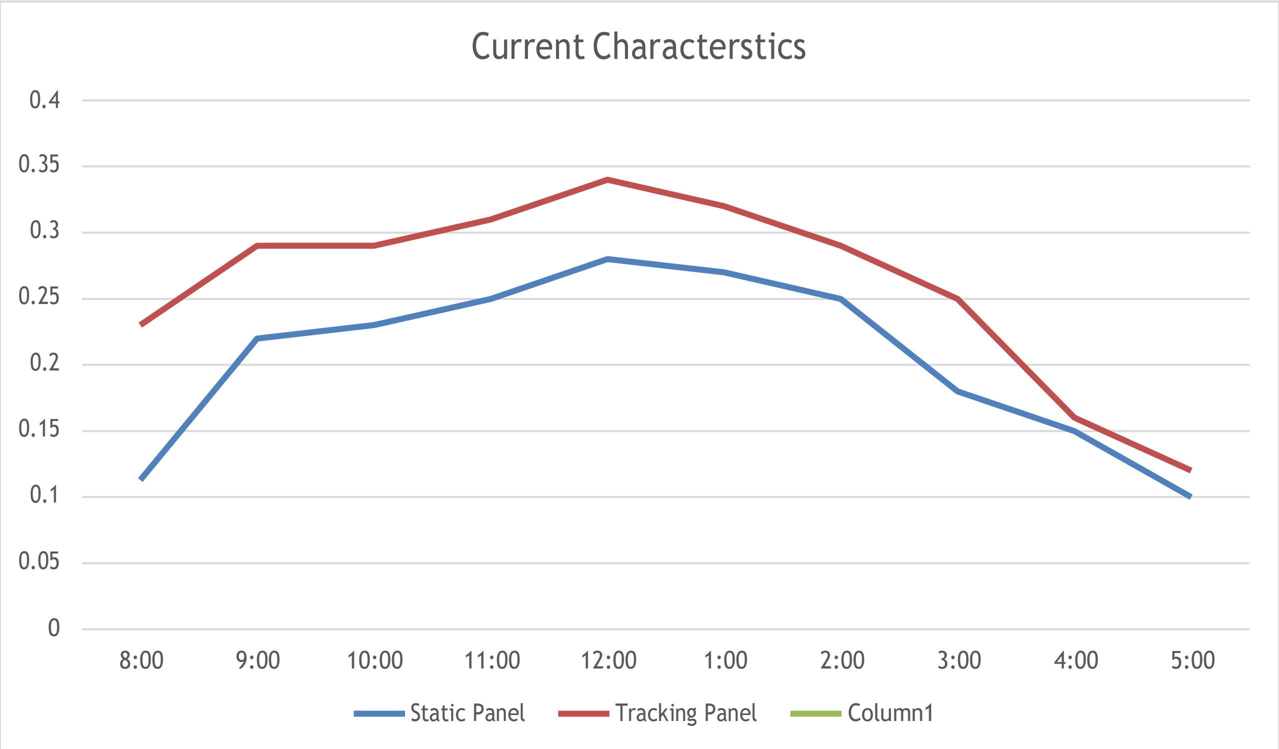


Graph 11-0-5:Time vs Battery Percentage Plot

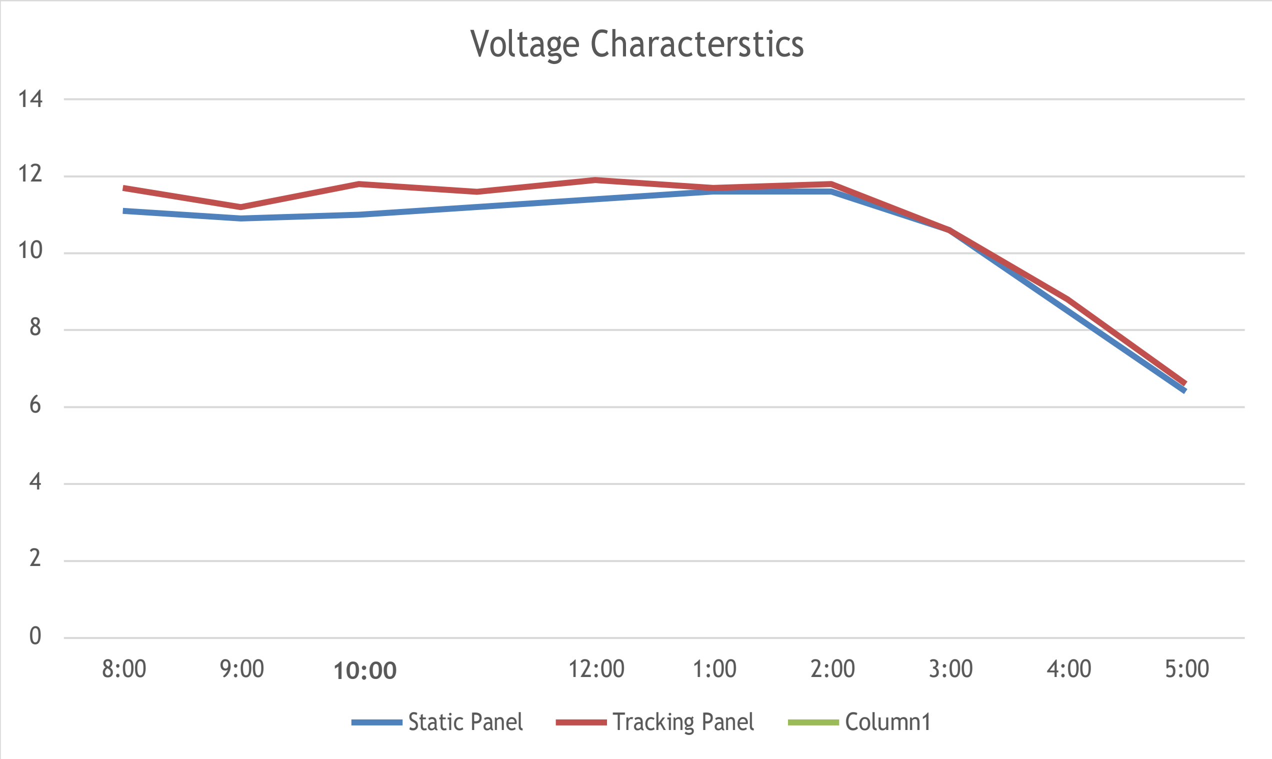
Time	Static panel		Tracking panel	
	Current (amperes)	Voltage (volts)	Current (amperes)	Voltage (volts)
8:00 am	0.113	11.1	0.23	11.7
9.00 am	0.22	10.9	0.29	11.2
10.00 am	0.23	11	0.29	11.8
11.00 am	0.25	11.2	0.31	11.6
12.00 pm	0.28	11.4	0.34	11.9
1.00 pm	0.27	11.6	0.32	11.7
2.00 pm	0.25	11.6	0.29	11.8
3.00 pm	0.18	10.6	0.25	10.6
4.00 pm	0.15	8.5	0.16	8.8
5.00 pm	0.10	6.4	0.12	6.6

Table 11-2:Current and Voltage Values

Current and Voltage Characteristics of Static and Tracking Panel



Graph 11-0-6:Current Characteristics

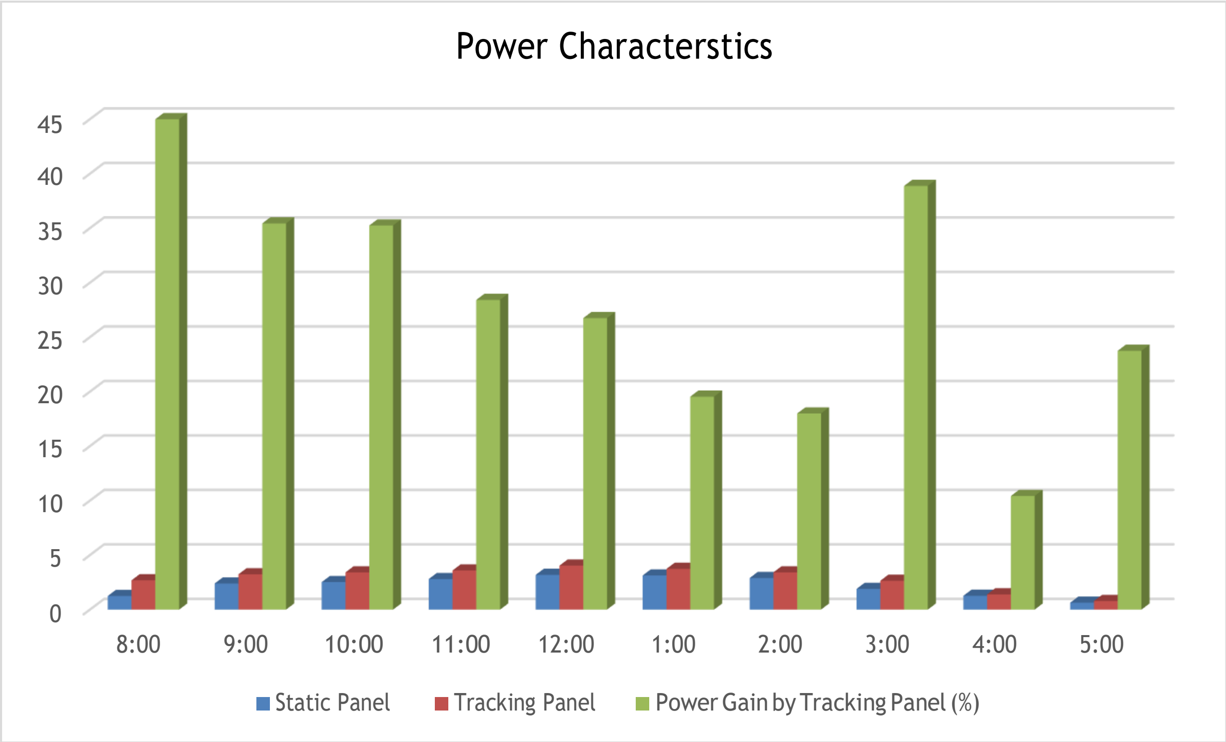


Graph 11-7:Voltage Characteristics

Time	Static panelPower	Tracking panelPower	Power gained by tracking panel(%)
8.00 AM	1.254	2.69	114.59
9.00 AM	2.398	3.24	35.44
10.00 AM	2.53	3.42	35.25
11.00 AM	2.8	3.59	28.42
12.00 PM	3.192	4.04	26.75
1.00 PM	3.132	3.74	19.54
2.00 PM	2.9	3.42	18
3.00 PM	1.90	2.65	38.88
4.00 PM	1.27	1.40	10.43
5.00 PM	0.64	0.79	23.75

Power Characteristics of Static and Tracking Panel

Table 11-3:Power Characteristics and Power Gain



Graph 11-8:Power Characteristics and Power Gain

12.PROJECT GALLERY

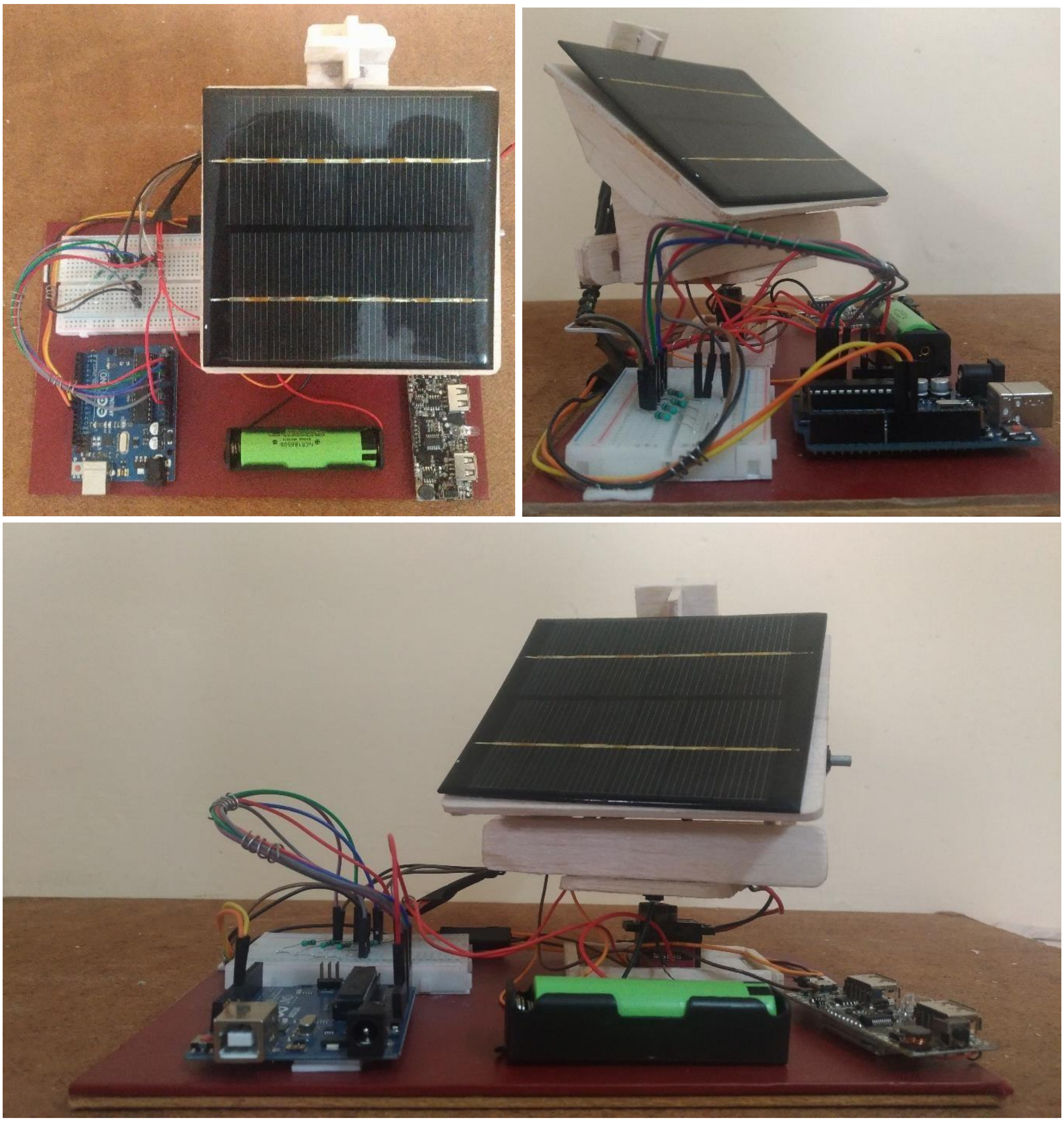


Figure 0-1:Project Gallery

13.Conclusion

In this 21st century, as we build up our technology, population & growth, the energy consumption per capita increases exponentially, as well as our energy resources (e.g. fossils fuels) decrease rapidly. So, for sustainable development, we have to think alternative methods (utilization of renewable energy sources) in order to fulfil our energy demand. In this project, Dual Axis Solar Tracker, we've developed a demo model of solar tracker to track the maximum intensity point of light source so that the voltage given at that point by the solar panel is maximum. After a lot of trial and errors we've successfully completed our project and we are proud to invest some effort for our society.

Now, like every other experiment, this project has couple of imperfections.

(i) Our panel senses the light in a sensing zone, beyond which it fails to respond.

(ii) If multiple sources of light (i.e. diffused light source) appear on panel, it calculates the vector sum of light sources & moves the panel in that point.

This tracking technology is very simple in design, low in cost and accurate in tracking. Several solar technologies are available on the market. But this dual axis tracking technology has higher energy gain comparing with both fixed solar panel and single axis solar tracking technologies.

14.REFERENCES

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