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AHMEDABAD UNIVERSITY | School of Engineering and Applied Science

DUAL AXIS SOLAR TRACKER

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ABSTRACT

Solar energy is fast becoming a very important means of renewable energy resource. With solar tracking, it will become possible to generate more energy since the solar panel can maintain a perpendicular profile to the rays of the sun. Even though the initial cost of setting up the tracking system is considerably high, there are cheaper options that have been proposed over time. This project discuses the design and construction of a prototype for solar tracking system that has a single axis of freedom. Light Dependent Resistors (LDRs) are used for sunlight detection. The control circuit is based on Arduino. It was programmed to detect sunlight via the LDRs before actuating the servo to position the solar panel. The solar panel is positioned where it can receive maximum light. As compared to other motors, the servo motors can maintain their torque at high speed. They are also more efficient with efficiencies in the range of 80-90%. Servos can supply roughly twice their rated torque for short periods. They are also quiet and do not vibrate or suffer resonance issues. Performance and characteristics of solar panels are analyzed experimentally. Selected solar panel is at 12V which can generate approx. 12V and from that Voltage We can run the 2 motors and There is LM317 for constant voltage output.

LITERATURE REVIEW

1 Solar cell

A **solar cell** is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon. It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage, or resistance, vary when exposed to light. Solar cells are the building blocks of photovoltaic modules, otherwise known as solar panels.

The operation of a photovoltaic (PV) cell requires three basic attributes:

- The absorption of light, generating either electron-hole pairs or excitons.
- The separation of charge carriers of opposite types.
- The separate extraction of those carriers to an external circuit.

2. Sunlight

Sunlight is light coming from the sun Basically it's measure in terms of lux

One lux is equivalent to one lumen per square meter;

$$1\ \mathrm{lx} = 1\mathrm{lm} * m^{-2} = 1\ \mathrm{cd} * \mathrm{sr} * m^{-2}$$

i.e. a flux of 10 lumen, concentrated over an area of 1 square meter, lights up that area with illuminance of 10 lux [1]. Sunlight ranges between 400 lux and approximately 130000 lux, as summarized in the table below.

Time of day	**Luminous flux (lux)**
Sunrise or sunset on a clear day	400
Overcast day	1000
Full day (not direct sun)	10000 – 25000
Direct sunlight	32000 – 130000

3 Elevation angle

The elevation angle is used interchangeably with altitude angle and is the angular height of the sun in the sky measured from the horizontal. Both altitude and lavation are used for description of the height in meters above the sea level. The elevation is 0 degrees at sunrise and 90 degrees when the sun is directly overhead. The angle of elevation varies throughout the day and depends on latitude of the location and the day of the year.

4 Azimuth angle

This is the compass direction from which the sunlight is coming. At solar noon, the sun is directly south in the northern hemisphere and directly north in the southern hemisphere. The azimuth angle varies throughout the day. At the equinoxes, the sun rises directly east and sets directly west regardless of the latitude. Therefore, the azimuth angles are 90 degrees at sunrise and 270 degrees at sunset

Benefits and demerits of solar energy

There are several benefits that solar energy has and which make it favorable for many uses.

Benefits

♣Solar energy is a clean and renewable energy source.

♣ Once a solar panel is installed, the energy is produced at reduced costs.

♣ Whereas the reserves of oil of the world are estimated to be depleted in future, solar
energy will last forever.

♣ It is pollution free.

♣ Solar cells are free of any noise. On the other hand, various machines used for pumping

oil or for power generation are noisy.
♣ Once solar cells have been installed and running, minimal maintenance is required. Some solar panels have no moving parts, making them to last even longer with no maintenance.
♣ On average, it is possible to have a high return on investment because of the free energy solar panels produce.
♣ Solar energy can be used in very remote areas where extension of the electricity power grid is costly.

Disadvantages of solar power

♣ Solar panels can be costly to install resulting in a time lag of many years for savings on energy bills to match initial investments.
♣ Generation of electricity from solar is dependent on the country's exposure to sunlight. This means some countries are slightly disadvantaged.
♣ Solar power stations do not match the power output of conventional power stations of similar size. Furthermore, they may be expensive to build.
♣ Solar power is used for charging large batteries so that solar powered devices can be used in the night. The batteries used can be large and heavy, taking up plenty of space and needing frequent replacement.
Because merits are more than the demerits, the use of solar power is considered as a clean and viable source of energy. The various limitations can be reduced through various ways.

DESIGN AND IMPLEMENTATION

Light Sensor Theory and Circuit of Sensor Used

Light detecting sensor that maybe used to build solar tracker include phototransistors, photodiodes, LDR and LLS05. A suitable, inexpensive, simple and easy to interface photo sensor is analog LDR which is the most common in electronics. It is usually in form of a photo resistor made of cadmium sulfide (CdS) or gallium arsenide (GaAs). Next in complexity is the photodiode followed by the phototransistor.

Light Dependent Resistor Theory

The simplest optical sensor is a photon resistor or photocell which is a light sensitive resistor these are made of two types, cadmium sulfide (CdS) and gallium arsenide (GaAs). The sun tracker system designed here uses two cadmium sulfide (CdS) photocells for sensing the light. The photocell is a passive component whose resistance is inversely proportional to the amount of light intensity directed towards it. It is connected in series with capacitor. The photocell to be used for the tracker is based on its dark resistance and light saturation resistance. The term light saturation means that further increasing the light intensity to the CdS cells will not decrease its resistance any further. Light intensity is measured in Lux, the illumination of sunlight is approximately 30,000 lux.

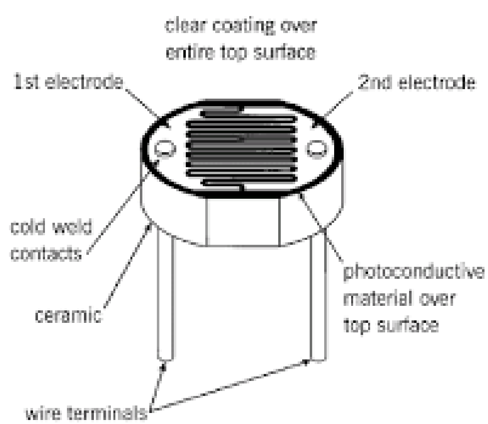
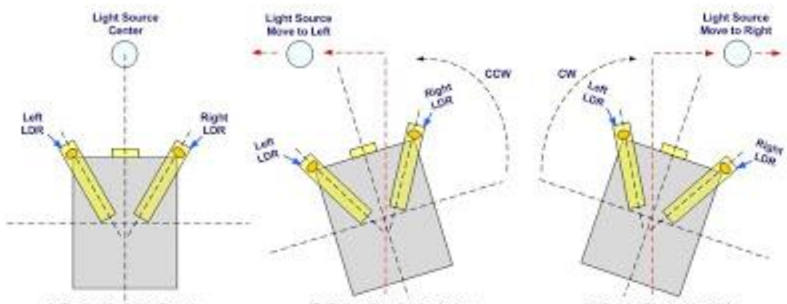


Figure 3
Typical Construction of a Plastic Coated Photocell

Normally the resistance of an LDR is very high, sometimes as high as 1000 000 ohms, but when they are illuminated with light resistance drops dramatically. When the light level is low the resistance of the LDR is high. This prevents current from flowing to the base of the transistors. Consequently, the LED does not light. However, when light shines onto the LDR its resistance falls.

The concept of using two LDRs



A. Facing the Light Source
B. Rotate Counterclockwise: Light source move to left
C. Rotate Clockwise: Light source move to right

Concept of using two LDRs for sensing is explained in the figure above. The stable position is when the two LDRs having the same light intensity. 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 to track the light source.

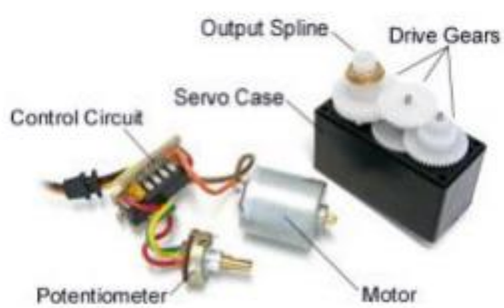
Light sensor design

The solar tracker makes use of a Cds photocell for detecting light. There was use of a complementary resistor with a value of 10k. With the resulting configuration, the output voltage will increase with increase in light intensity. The value of the complementary resistor is chosen such that the widest output range is achieved. The photocell resistance is measured under bright light, average light and dark light conditions. The results are listed in the table below.

Measured Resistance	Comment
50 KΩ	Dark light conditions (black vinyl tape placed over cell)
4.35 KΩ	Average light conditions (normal room lighting level)
200 Ω	Bright light conditions (flashlight directly in front of cell)

Servo motor

Servo motors are used for various applications. They are normally small and have good energy efficiency. The servo circuitry is built inside the motor unit and comes with a position able shaft that is fitted with a gear. The motor is controlled with an electric signal that determines the amount of shaft movement.



Components of the servo motor

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. If the shaft is not at the right position, the motor is turned in the right direction. The desired position is sent through electrical pulses via the signal wire.

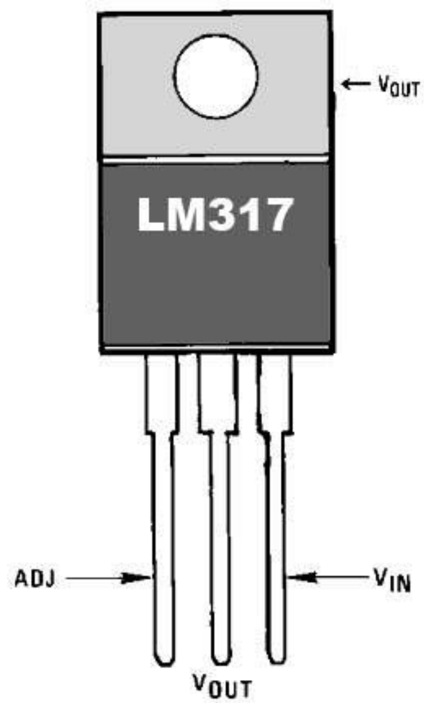
The speed of the motor is proportional to the difference between the actual position and the position that is desired. Therefore, if the motor is close to the desired position, it turns slowly. Otherwise, it turns fast. This is known as proportional control.

Advantages and disadvantages of servo motors

For applications where high speed and high torque are required, servo motors are the better option. While stepper motors peak at around 2000 RPM, servos are available at much faster speeds. Servo motors also maintain torque at high speed, up to 90% of the rated torque is available from servos at high speeds. They have an efficiency of about 80-90% and supply roughly twice their rated torque for short periods. Furthermore, they do not vibrate or suffer from resonance issues. Servo motors are more expensive than other types of motors. Servos require gear boxes, especially for lower operation speeds. The requirement for a gear box and position encoder makes the designs more mechanically complex. Maintenance requirements will also increase.

Voltage regulation

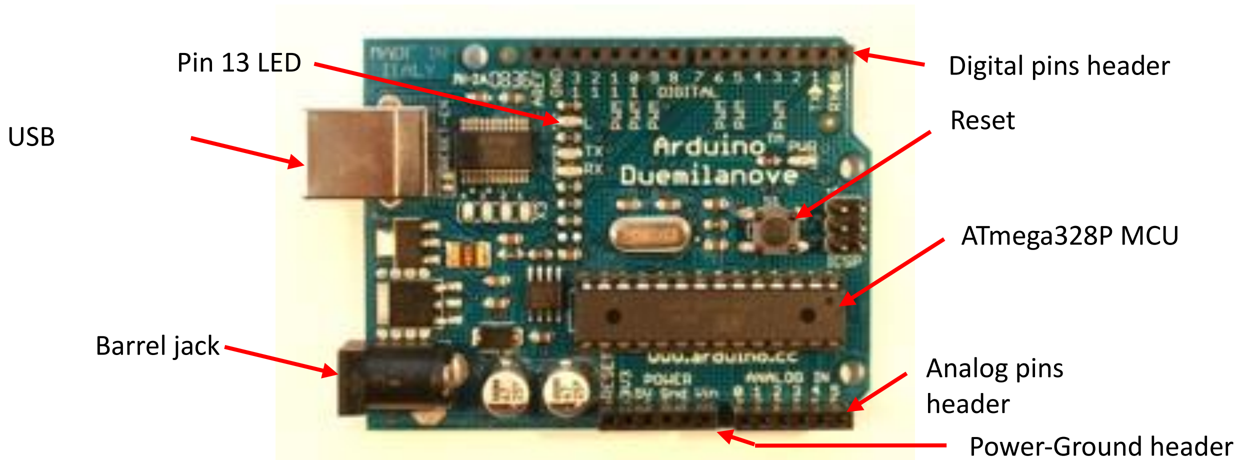
Voltage regulators are designed to automatically maintain voltages at a constant level. The LM317 voltage regulator is used. Voltage sources in circuits could be having fluctuations and thus not be able to give fixed voltage output. The voltage regulator IC maintains the output voltage at a value that is constant. The LM317 provides +12V regulated power supply. Capacitors are connected at the input and output depending on respective levels of voltage



Pin No.	Function	Name
1	Input Voltage	Input
2	Adjustable	ADJ
3	Regulated output 12V	Output

Arduino UNO

A microcontroller often serves as the “brain” of a mechatronic system. Like a mini, self-contained computer, it can be programmed to interact with connected hardware and/or a user, much like a PC connected to a small network of hardware. As the computer industry has evolved, so has the technology associated with microcontrollers. Every year microcontrollers become much faster, have more memory, and extend their input and output feature sets, all the while becoming even cheaper and easier to use.



Technical Specification

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB of which 0.5 KB used by bootloader
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz

Rechargeable battery

A rechargeable battery is a type of electrical battery which can be charged, discharged into a load, and recharged many times, while a non-rechargeable or primary battery is supplied fully charged, and discarded once discharged. It is composed of one or more electrochemical cells. The term "accumulator" is used as it accumulates and stores energy through a reversible electrochemical reaction. Rechargeable batteries are produced in many different shapes and sizes, ranging from button cells to megawatt systems connected to stabilize an electrical distribution network. Several different combinations of electrode materials and electrolytes are used, including lead–acid, nickel cadmium (NiCd), nickel metal hydride (NiMH), lithium ion (Li-ion), and lithium ion polymer (Li-ion polymer).

Algorithm for Motor Control

The algorithm gives the description of the general steps undertaken for the project:

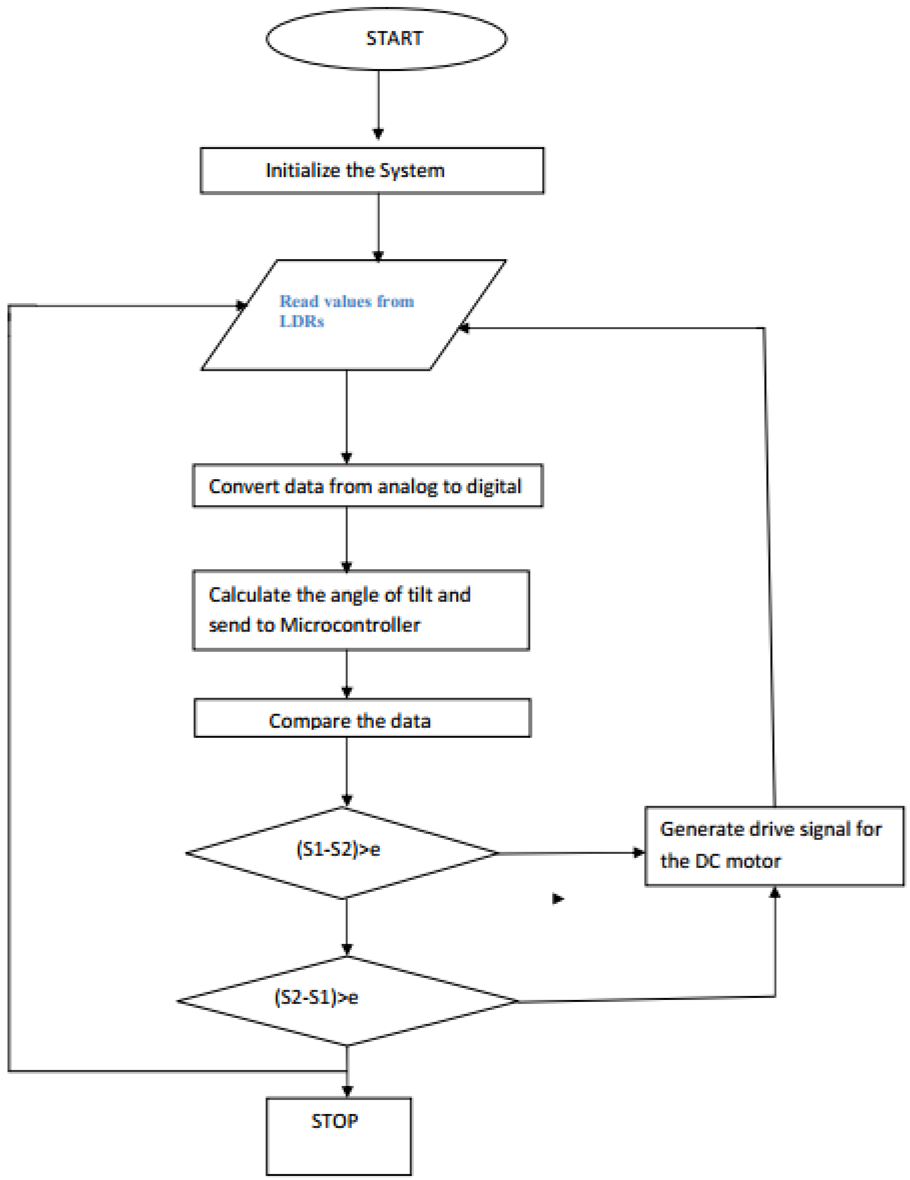
1. There is input of the voltages from the two LDRs.

2. The inputs are analog. They are converted to digital values that range between 0-1023.

3. The two digital values are compared and the difference between them obtained.

4. The difference between the values obtained is the error proportional angle for the rotation of the servo motor.

5. If the LDR voltages are the same, the servo stops. Otherwise, the servo rotates until the difference is the same.


START
Initialize the System
Read values from LDRs
Convert data from analog to digital
Calculate the angle of tilt and send to Microcontroller
Compare the data
(S1-S2)>e
Generate drive signal for the DC motor
(S2-S1)>e
STOP

Calculation

Total Mass Calculation

Motor 1 (Circular plate)

Element Name	Quantity of Element	Mass of Element (gm)
Circular plate	1	40
Side plate	2	60
Motors	2	18
Panel plate	1	30
Panel	1	82
Support plate of solar	2	20
Total Mass		250

Safe Mass = 300 gm

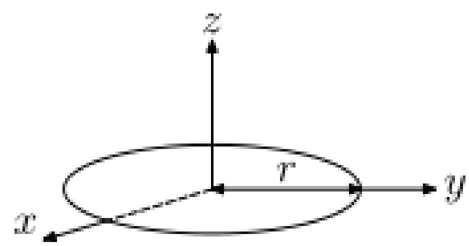
Motor 2(Side plate)

Element Name	Quantity of Element	Mass of Element (gm)
Side plate	1	18
Motors	2	60
Panel plate	1	30
Panel	1	82
Support plate of solar	2	20
Total Mass		201

Safe Mass = 250 gm

Inertia Calculation

Motor 1



Radius = 10 cm Safe Mass = 300 gm

$$I(x) = I(y) = \frac{mr^2}{2}$$

$$\frac{mr^2}{2} = \frac{0.3 * (0.1)^2}{2}$$

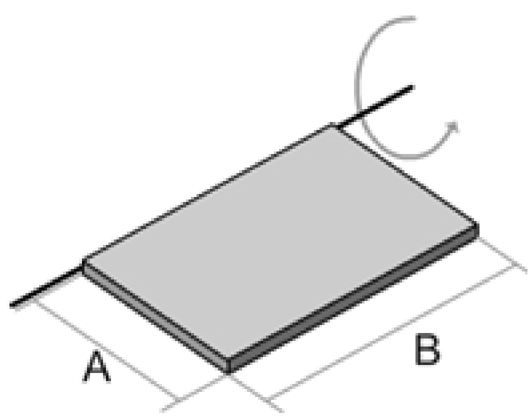
$$I(x) = I(y) = 1.5 \times 10^{-3}\ kg * m^2$$

$$I(z) = mr^2$$

$$I(z) = 0.3 * (0.1)^2$$

$$I(z) = 3 \times 10^{-3} kg * m^2$$

Motor 2



Length(B) = 7 cm Width(A) = 4 cm

Safe mass = 250 gm

$$I(x) = \frac{mA^2}{12}$$

$$I(x) = \frac{0.25(4 * 10^{-2})^2}{12}$$

$$I(x) = 3.33 \times 10^{-5}\ kg * m^2$$

$$I(y) = \frac{mB^2}{12}$$

$$I(y) = \frac{0.25(7 * 10^{-2})^2}{12}$$

$$I(y) = 1.02 \times 10^{-4}\ kg * m^2$$

$$I(x) = \frac{m(A^2 + B^2)}{12}$$

$$I(x) = \frac{0.25(65 * 10^{-4})}{12}$$

$$I(x) = 1.354 \times 10^{-4}\ kg * m^2$$

So, Calculated Torque

For Motor 1 = 3 $kg * cm^2$

Motor 2 = 1 $kg * cm^2$

Arduino Code

```
#include <Servo.h> // include Servo library

// 180 horizontal MAX
Servo horizontal; // horizontal servo
int servoh = 180;   // 90;     // stand horizontal servo

int servohLimitHigh = 180;
int servohLimitLow = 0;

// 65 degrees MAX
Servo vertical;   // vertical servo
int servov = 45;    //   90;     // stand vertical servo

int servovLimitHigh = 80;
int servovLimitLow = 15;


// LDR pin connections
//  name  = analogpin;
int ldrlt = 0; //LDR top left - BOTTOM LEFT
int ldrrt = 1; //LDR top rigt - BOTTOM RIGHT
int ldrld = 2; //LDR down left - TOP LEFT
int ldrrd = 3; //ldr down rigt - TOP RIGHT

void setup()
{
  Serial.begin(9600);
// servo connections
// name.attacht(pin);
  horizontal.attach(9);
  vertical.attach(10);
  horizontal.write(180);
  vertical.write(45);
  delay(5000);
}

void loop()
{
  int lt = analogRead(ldrlt); // top left
  int rt = analogRead(ldrrt); // top right
  int ld = analogRead(ldrld); // down left
  int rd = analogRead(ldrrd); // down rigt

  // int dtime = analogRead(4)/20; // read potentiometers
  // int tol = analogRead(5)/4;
  int dtime = 2 ;
  int tol = 2;

  int avt = (lt + rt) / 2; // average value top
```

```
  int avd = (ld + rd) / 2; // average value down
  int avl = (lt + ld) / 2; // average value left
  int avr = (rt + rd) / 2; // average value right

  int dvert = avt - avd; // check the diffirence of up and down
  int dhoriz = avl - avr;// check the diffirence og left and rigt


  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.print(tol);
  Serial.print(" ");


  if (-1*tol > dvert || dvert > tol) // check if the diffirence is in the
tolerance else change vertical angle
  {
  if (avt > avd)
  {
    servov = ++servov;
     if (servov > servovLimitHigh)
     {
      servov = servovLimitHigh;
     }
     delay(10);
  }
  else if (avt < avd)
  {
    servov= --servov;
    if (servov < servovLimitLow)
  {
    servov = servovLimitLow;
  }
  delay(10);
  }
  vertical.write(servov);
  }

  if (-1*tol > dhoriz || dhoriz > tol) // check if the diffirence is in
the tolerance else change horizontal angle
  {
  if (avl > avr)
  {
    servoh = --servoh;
    if (servoh < servohLimitLow)
    {
```

```
    servoh = servohLimitLow;
    }
    delay(10);
  }
  else if (avl < avr)
  {
    servoh = ++servoh;
     if (servoh > servohLimitHigh)
     {
     servoh = servohLimitHigh;
     }
     delay(10);
  }

  horizontal.write(servoh);
  }
   delay(50);

}
```

Fabrication Steps And procedure

The key to this project is having a functional structure to put it on. To do this we need access to a laser cutter and some quarter inch wood or acrylic (or you can glue two 1/8th inch pieces together.

Next the Two **Servo motors** are mounted on the bottom of the piece.

For sensors, we have used four light sensitive (detecting) resistors, also known as LDRs. Again, these are super common and you can often find them in outdoor garden lights or indoor night lights. They work by changing their resistance level based on how much light is hitting them. The lighter, the less resistance they have.

Program works by comparing the resistance of the four sensors and moving servos.

LDRs are used as the main light sensors. Two servo motors are fixed to the structure that holds the solar panel. The program for Arduino is uploaded to the microcontroller. The working of the project is as follows.

LDRs sense the amount of sunlight falling on them. Four LDRs are divided into top, bottom, left and right.

For east – west tracking, the analog values from two top LDRs and two bottom LDRs are compared and if the top set of LDRs receive more light, the vertical servo will move in that direction.

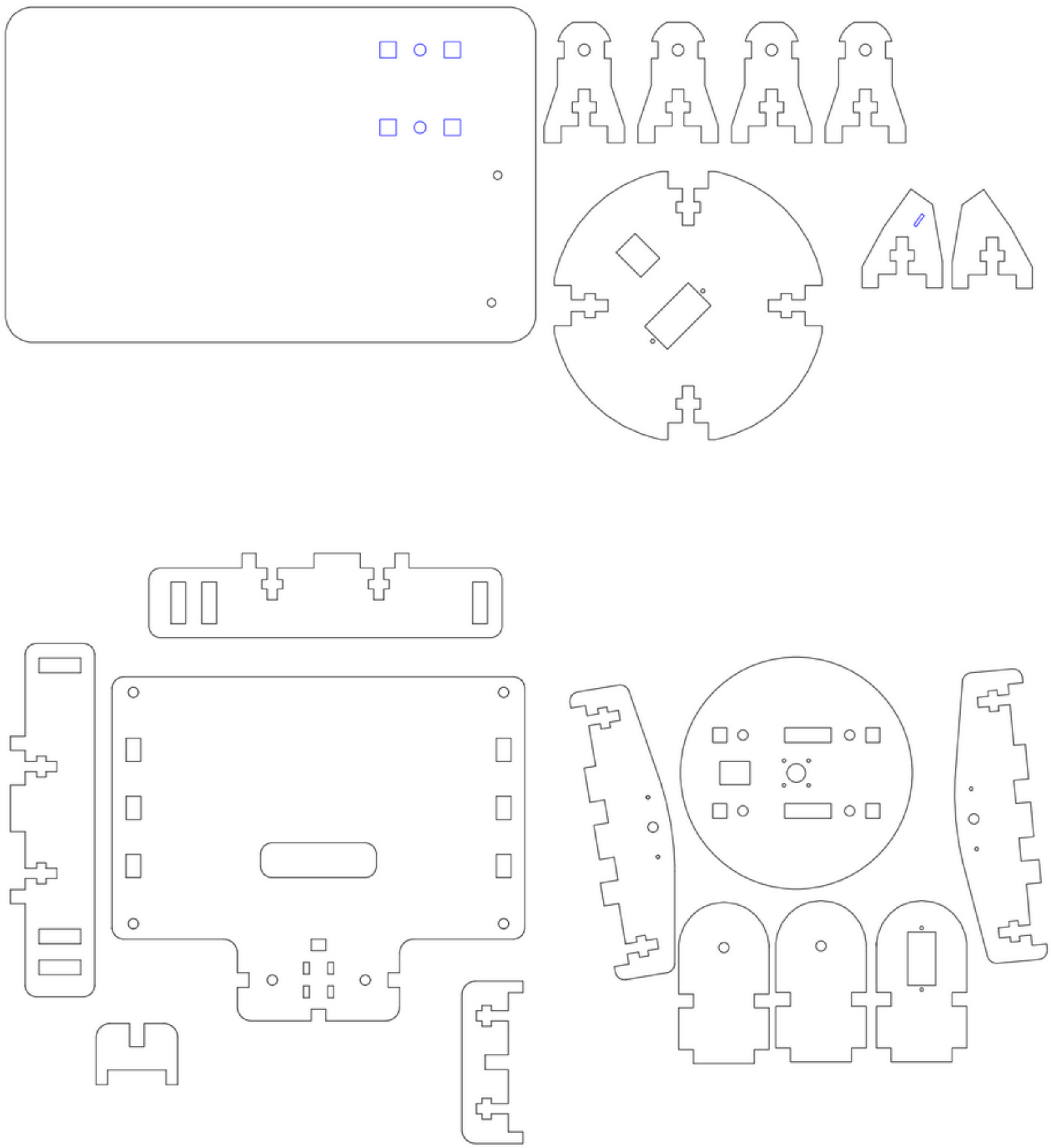
If the bottom LDRs receive more light, the servo moves in that direction.

For angular deflection of the solar panel, the analog values from two left LDRs and two right LDRs are compared. If the left set of LDRs receive more light than the right set, the horizontal servo will move in that direction.

If the right set of LDRs receive more light, the servo moves in that direction.

AutoCAD Design (Laser Cutting)

Initially we made a prototype design for that tracker then made AutoCAD modeling using approx. dimension. That picture is shown below



Now that AutoCAD file convert into the (.dxf) file for laser cutting. Full process is in the video part.

Assembly

STEP 1: After Laser cutting , Attach the servos to their mounts

The **Servo** is mounted on the bottom of the circular plate. Line the servo up with the screw holes, and then we use the two **Servo** screws to secure it in place. Once in place make sure it's secure and fixed. We have done the same thing with second **Servo motor.** we have mounted it on the "back" of the mount with the two screws it came with.

STEP 2 : Attach the servo arms to their mounts

We have attached the **Servo Arm** to two of the holes using two Size 2 Wood Screws.

STEP 3: Building the base

Take the base plate, the four legs, and the large round piece that now has a **Servo** attached to it. First attach the four legs to the round servo holder. The **Servo** needs to be inside all the legs, between the base plate and the round servo holder. Now fit the four legs into the base plate

STEP 4: Building the top

Take the large solar array face. We assembled the two triangle wings on the bottom of the top plate, the small rounded corner square piece, and the two small sensor divider pieces using screws and nuts.

STEP 5: Build the center

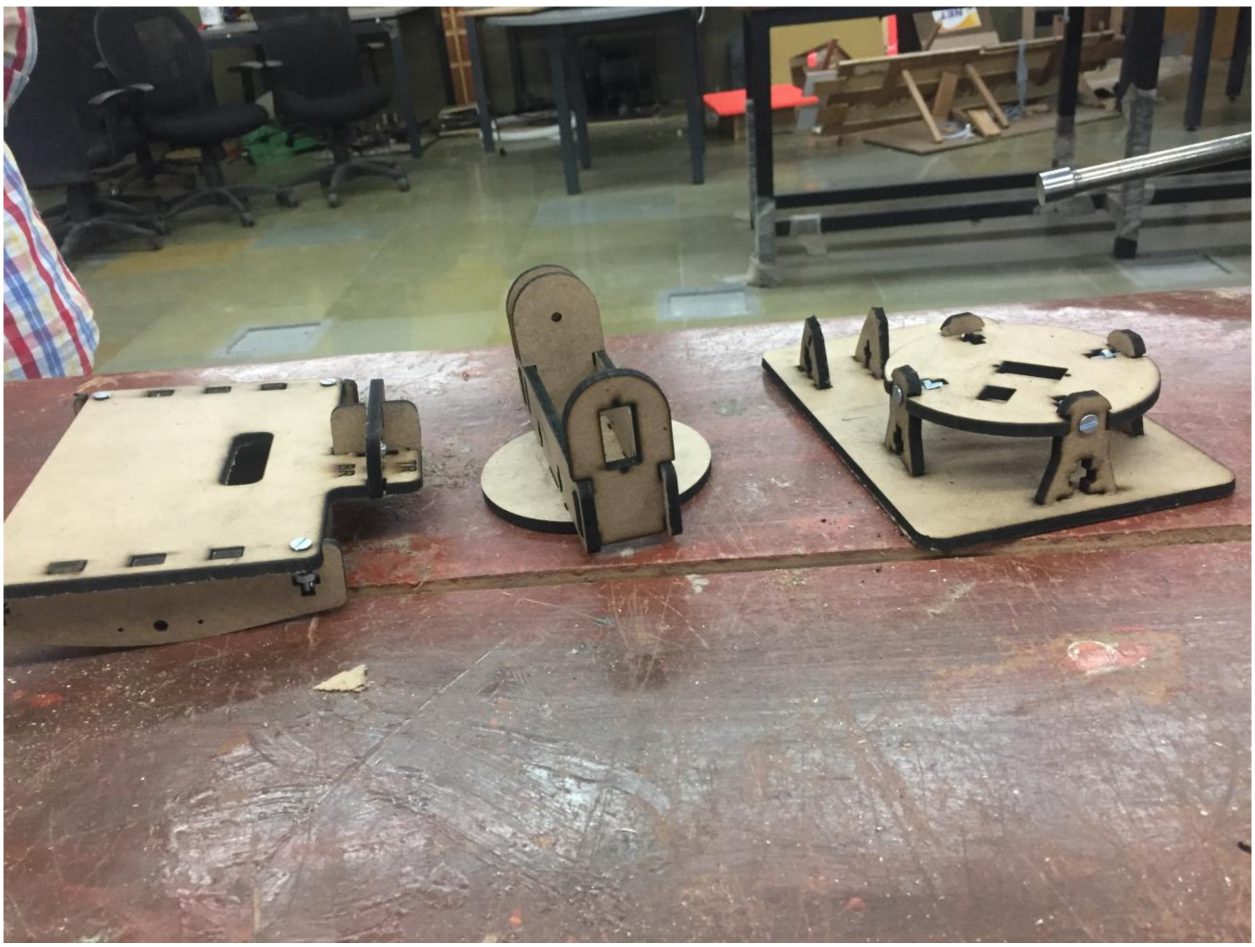
Take the two long pieces, the second servo mount, attach them together, and then placed them into place on the round board.

STEP 6: Fix the base servo on side plate

Servo motors move in 180 degrees. Since we don't need full 180-degree range on our servos we set "zero" degree to specific locations. The second Servo is near where Arduino will go, and the Center is at a 45-degree angle compared to the Base**.** we have used one of the two small Servo Machine Screws to secure the Center and Base together.

STEP 7: Fix the center servo

Push the Servo Arm attached to the Top into the Center Servo. Turn it counter clockwise until it stops. We want the **Top** to be parallel to the Base. Attach the Top part**.**



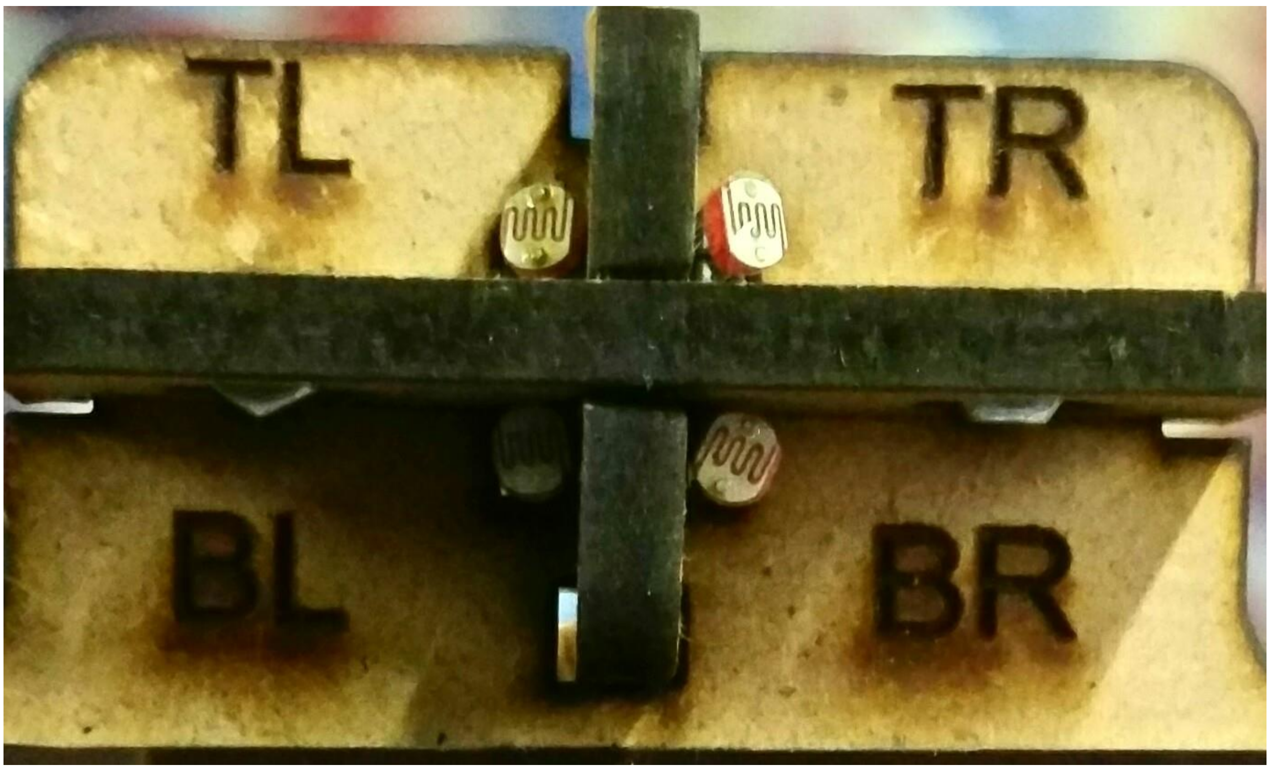
STEP 8: Attach the Arduino

All the connection of motor placed into the Arduino.

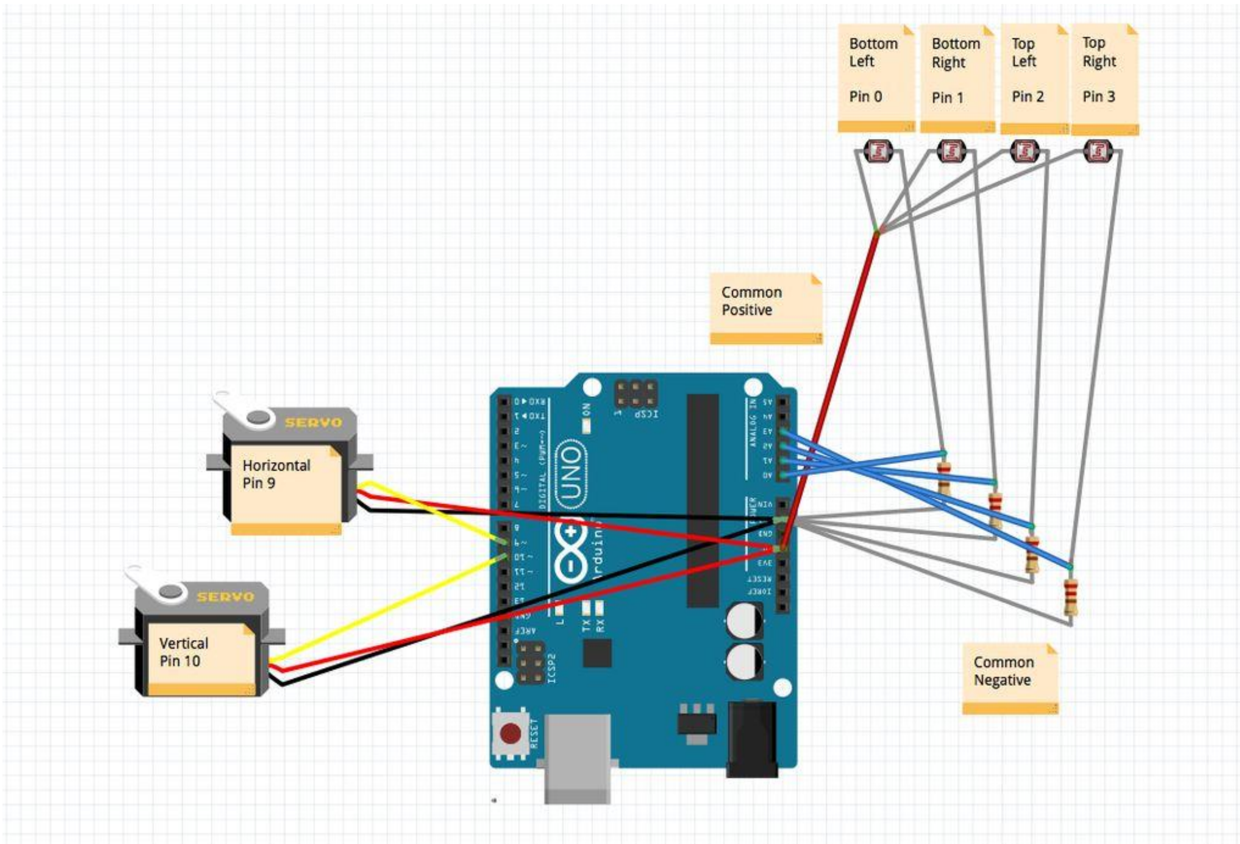
STEP 9: Assemble the Sensors

All the sensors are placed on the top plate. Which will sense through Arduino.

4 LDRs Picture is shown below

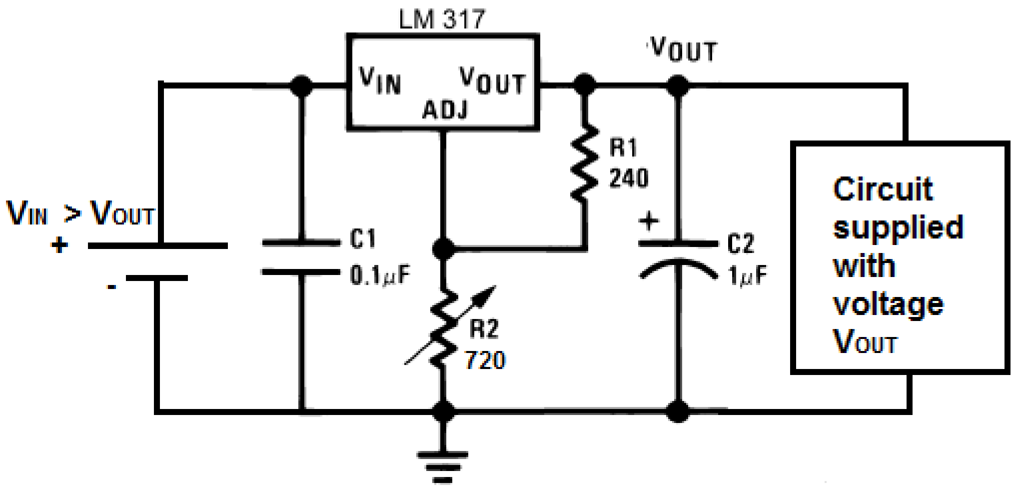


Circuit Diagram



Now from above diagram we can show that 4 LDRs are connected with Arduino. Also, Servo motors are also connected with the Arduino. When Sunrays detect by the LDRs then it will transmit the value to the Arduino. As per code Servo motor rotation will decide and set to an optimum position which can maximum amount of Power.

Voltage Regulator Circuit



For Constant voltage output We are using the LM317 Chip for it.

As linear regulators, the LM317 and LM337 are used in DC to DC converter applications.

Linear regulators inherently waste power, the power dissipated is the current passed multiplied by the voltage difference between input and output. In use an LM317 commonly requires a heat sink to prevent the operating temperature rising too high. For large voltage differences, the energy lost as heat can ultimately be greater than that provided to the circuit. This is the trade-off for using linear regulators which are a simple way to provide a stable voltage with few additional components. The alternative is to use a switching voltage regulator which is usually more efficient but has a larger footprint and requires a larger number of associated components.

In packages with a heat-dissipating mounting tab, such as TO-220, the tab is connected internally to the output pin which may make it necessary to electrically isolate the tab or the heat sink from other parts of the application circuit. Failure to do this may cause the circuit to short.

How to define the R_1 and R_2 Value?

By using Simple equation, we get the both resistor values

$$v(out) = v(ref)\left(1 + \frac{R(2)}{R(1)}\right) + I(ref) * R(2)$$

Neglecting Error terms,

$$v(out) = v(ref)\left(1 + \frac{R(2)}{R(1)}\right)$$

Calculation of Finding R_1 and R_2

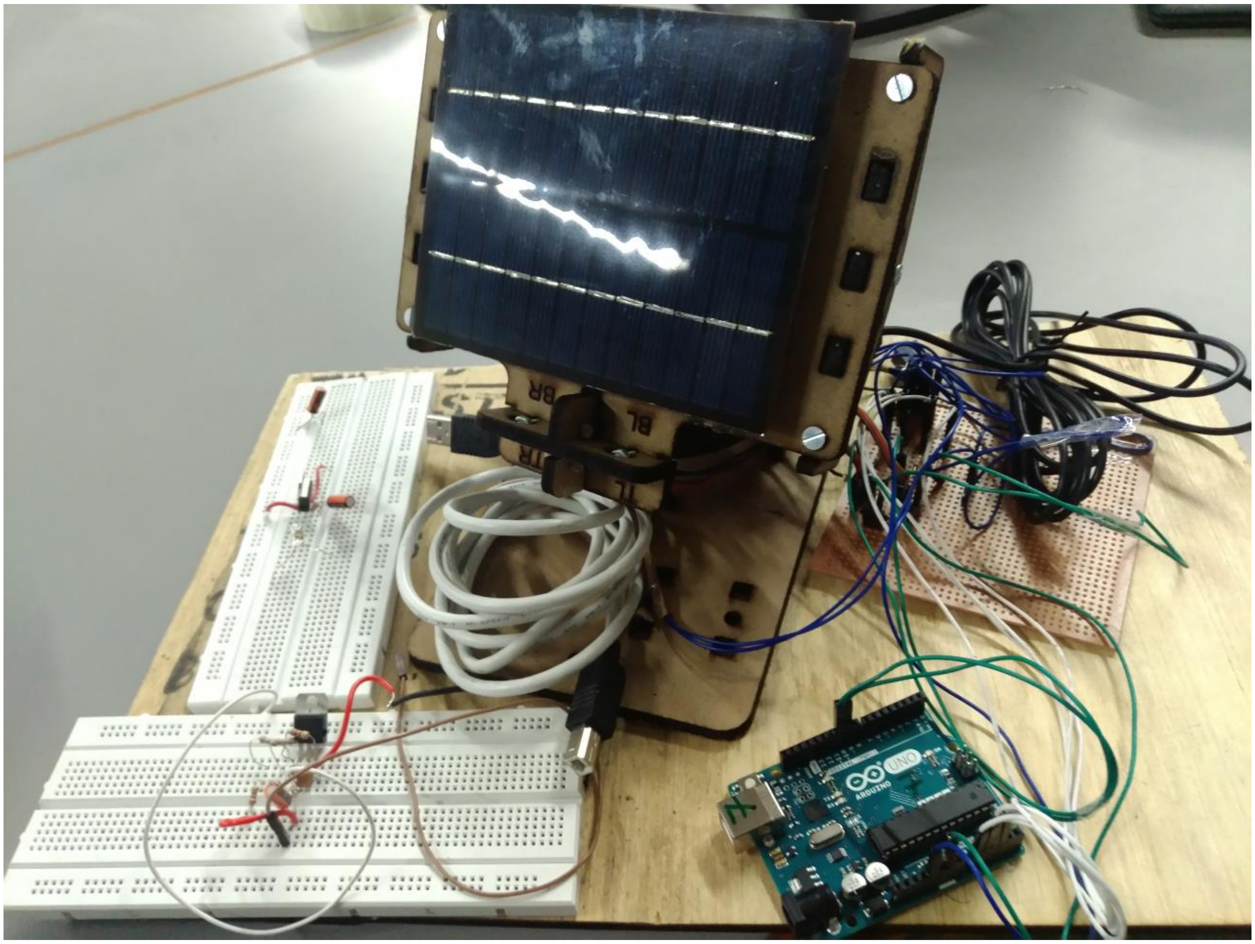
$$v(out) = 9V$$

$$v(ref) = 1.25V$$

$$\left(1 + \frac{R(2)}{R(1)}\right) = 7.2$$

$$\frac{R(2)}{R(1)} = 6.2$$

Final Model



Acknowledgement

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