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# Internet of Things (IoT) based Dual-Axis Solar Tracker

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**ABSTRACT:** The goal model was to develop a laboratory prototype of a solar tracker, which can enhance the performance of the photovoltaic modules in solar energy. The main operating principle of the device is to keep the photovoltaic modules constantly aligned with the sunbeams or any light source, which maximizes the exposure of the photovoltaic module to the sun's radiation. As a result, the photovoltaic module can obtain more output power. The working of this model includes Hardware design and implementation, together with software programming for the microcontroller unit of the Dual-Axis Solar Tracker.

The system utilized an ATmega328P microcontroller to control the motion of two servo motors, which rotate the photovoltaic module on two axes, and the amount of rotation is determined by the microcontroller, based on inputs received from four photo sensors located next to the photovoltaic module. At end of the project, a functional Dual-Axis Solar Tracker was designed and implemented. It repeatedly kept the photovoltaic module aligned with the sun or any light source. This design of the Dual-Axis Solar Tracker<sup>[2]</sup> can also be the reference and starting point for the development of more advanced systems in the future.

**KEYWORDS:** Photovoltaic module (Solar Panel), Photo Sensor (Light dependent resistor LDR), Photovoltaic energy (Solar Energy), Photo (Light), Arduino UNO (Microcontroller, PWM (Pulse-width Modulation), IDE (Integrated Development Environment)

## I. INTRODUCTION

In the present era, the usage of fossil fuels has become high. So now different types of renewable energy have become a topic of interest for numerous researchers, investors, and decision-makers of all time worldwide. These renewable energies also include hydroelectricity, bioenergy, solar energy, geothermal energy, tidal power, etc. Because of their renewability property, they are considered favorable replacements for all non-renewable resources. Besides those types of energy photovoltaic energy (PV energy) is the most available resource. However, this technology is widely used in residences and solar power plants nowadays. But thanks to the research and development team for improving the performance and reducing the cost of them.

Even though the Photovoltaic module has advantages, it was still far from replacing older sources in the market. Despite being a huge challenge to maximize the power output of the photovoltaic system in some areas that don't receive a high amount of direct sunlight. We require still more advanced technologies to improve the capability of Photovoltaic materials used to make the modules. Not only the material but also the design. However, the same problem was faced by society. Aiming for that purpose, this project had been carried out to support the development of such promising technology. The tracking method was one of the main methods of increasing efficiency.

A tracking system helps us achieve this by keeping the photovoltaic module aligned at the appropriate angle with the sun ray at any time. The main intention of this project was to build a prototype of a photo-tracking system on a smaller scale. And compare the output efficiency from the mounting method and single-axis method. The Dual-Axis Solar Tracker collects energy from the sun or light source from East, West, North, and South angles. They function on two axes- 'primary' and 'secondary'. The primary axis helps the tracker to move from East to West, and the secondary axis helps the tracker to move from North to South. Hence, they are called Dual-Axis Solar Tracker.

II. HARDWARE

Arduino UNO

This is the microcontroller board based on the ATmega328P, which provides an open-source, prototyping platform. Its simplicity makes it ideal for hobbyists and professionals. They have 14 input & output pins out of which 6 can be used as PWM (Pulse-width Modulation) outputs, 6 analog inputs, a 16MHz crystal oscillator, a USB connection, a Power jack, and a reset button. Has everything needed to support the microcontroller; simply connect it to a computer with a USB cable and power it with an AC to DC adapter or battery. The input voltage of the UNO board varies from 7V to 20V. It has 32KB of Flash Memory, 1KB of EEPROM, 0.5KB of Preinstalled Flash Memory, and 2KB of SRAM. GND means Ground pins which act as a pin with zero voltage. ICSP pin means the In-Circuit Serial Programming pin which allows programming using the firmware of the Arduino board. Vin is the input voltage. AREF (Analog Reference) pin is used to feed as a reference voltage to the Arduino UNO board from the external power supply. And easily be programmed using C language. Fig.1. shows all the main components of the Arduino UNO.

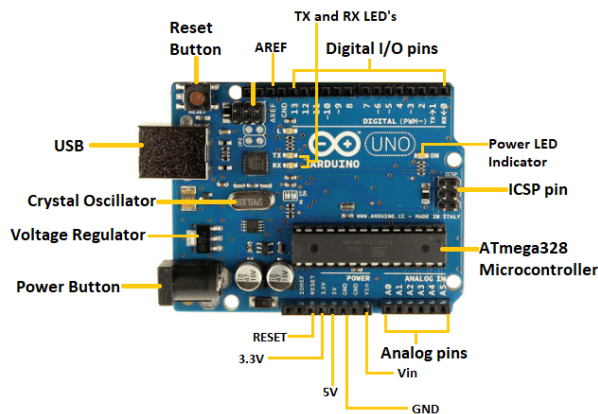


Fig. 1. Arduino UNO. (Components)  
(HTTPS:// javatpoint.com)

LDR (Light Dependent Resistor)

Photo-resistor or LDR is a device whose resistance is a function of the incident electromagnetic radiation. Therefore, they are light-sensitive devices. Since their conductance depends on light, they can also be called Photoconductors, Photo-Conductive Cells, or Simply Photocells. They are usually made up of semiconductor materials having high resistance. They work on the principle of photoconductivity. Photoconductivity is an optical phenomenon in which the material is more when the light is absorbed by the material. The most common type of LDR has a resistance that falls with an increase in the light intensity falling upon the device. The resistance of an LDR may typically have ~5000Ω (ohms) in Daylight and ~20000000Ω (ohms) in the Dark. Since this has a large variation between these figures. Fig .3. shows the graph of resistance in dark, Average Light, and Bright light.



Fig. 2. LDR. (Light Dependent Resistors)

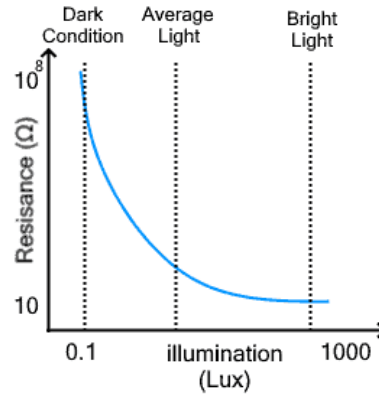


Fig. 3. Graph of Conductance. (<https://www.electricaltechnology.org>)

**Servo motor(SG90)**

A DC servo motor consists of a feedback potentiometer, micro gearbox, motor drive, Small DC motor, and electronic feedback control loop. It is like a normal DC motor. This servo can approximately rotate up to 180° (degrees), 90 degrees in each direction. Withholds voltage starting from 4.8V to 6V. Which produces a torque of 2.5 Kg/cm, weighs 14.7g(grams), and speed of 0.1s(sec). Fig.4 Shows the visuals of the servo motor and Fig.5 shows the wire connections while its usage.



Fig. 4. Servo Motor SG90.( <https://robocraze.com>)

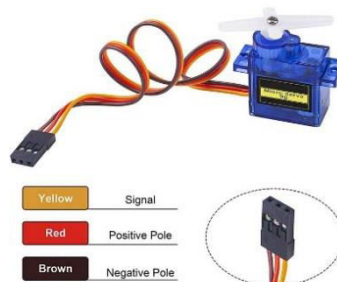


Fig. 5. Wire connections of Servo Motor. ( <https://betuservo.com>)

**Photovoltaic Module (Solar Panel)**

The assembly of photovoltaic solar cells mounted in a frame. They capture sunlight as a source of radiant energy and convert it into electric energy in direct current (DC) electricity. This gives 6 VDC max output, 1W max power output, and has an operating temperature of +32° - +158° F (Fahrenheit), which is 0 to +70° C (Celsius).

Fig. 6. Shows visual of solar panel.



Fig. 6. Photovoltaic Module (Solar Panel). (<https://smarrtronik.com>)

### III. SOFTWARE

#### Arduino IDE

Arduino Software has a text editor for feeding the code, a text console, a toolbar, a message area, and a series of menus. It helps us to connect the Arduino hardware to upload programs and communicate with them. It uses simple C-Programming. This IDE helps to monitor the movement of Trackers and data retrieved from the LDR on the live screen called Serial monitor. Fig. 7. Shows the outline of the Arduino IDE.

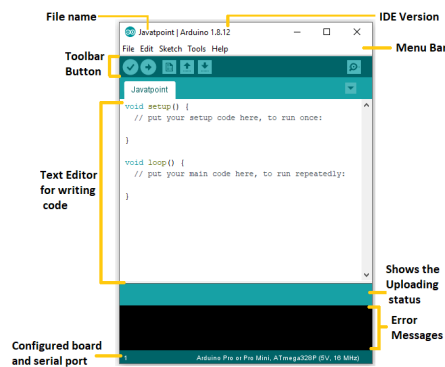


Fig. 7. Arduino IDE . (<https://www.javatpoint.com>)

### IV. LDR WORKING

#### LDR Working

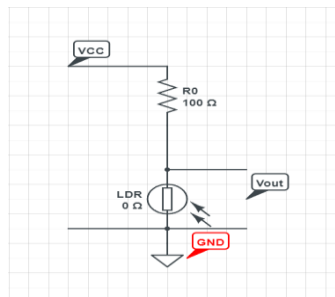


Fig. 8. Arduino IDE . (<https://www.circuitlab.com>)

The resistivity of the LDR<sup>[3]</sup> depends on the intensity of the light and it varies as said above in the hardware (II.B). Higher intensity of light lower would be the resistance value and due to this, the voltage across the output terminals gets lowered. Fig. 8, shows How the LDR is set up for the tracking system by using a Potential divider circuit.

The LDR senses the analog input voltage which is between 0V to 5V (volts) and provides the digital numbers at the output which generally ranges from 0 to 1023. Arduino IDE feedbacks to the microcontroller.

### Programming and Equations.

Programming is done by using C-Programming which made us get these results in no time. A simple average calculation technique is used to manipulate the directions of the high-intensity light according to which the microcontroller could proceed to manipulate and send signals to the respective servo motor.

```
//capturing analog values of each LDR
int topl = analogRead(ldrtopl);
int topr = analogRead(ldrtopr);
int botl = analogRead(ldrbotl);
int botr = analogRead(ldrbotr);
```

Here, ‘topl’ refers to Top Left LDR, ‘topr’ refers to Top Right LDR, ‘botl’ refers to Bottom Left LDR, and ‘botr’ refers to Bottom Right LDR. Refer Fig.9.



Fig. 9. Position of LDR

### Equations

```
// calculating average
int avgtop = (topl + topr) / 2;
int avgbot = (botl + botr) / 2;
int avgleft = (topl + botl) / 2;
int avgright = (topr + botr) / 2;
```

Here, ‘avg’ represents an average of the Top, Bottom, Right, and Left.

Using simple if conditions the microcontroller decides the direction of the tracker to be aligned. Then the tracker finally adjusts its position sensing the maximum intensity of light falling perpendicular to it and stays till it rectifies further change in light. The sensitivity of the LDRs depends on the point source of light. It hardly shows effects on diffuse

lighting conditions. Fig. 10 shows the use of if conditions to manipulate the direction of a photovoltaic module or servo motor.

```

if (avgleft > avgright)
{
  servohori.write(servoh -1);
  if (servoh > servohLimitHigh)
  {
    servoh = servohLimitHigh;
  }
  delay(10);
}
else if (avgright > avgleft)
{
  servohori.write(servoh +1);
  if (servoh < servohLimitLow)
  {
    servoh = servohLimitLow;
  }
  delay(10);
}
    
```

Fig. 10. 'If and elseif' conditions for movements of tracker

### V. WORKING

The LDRs placed above the Photovoltaic Module sense the sensitivity of light depending on which they are converted to a range of 0 to 1023 and send the data to the Arduino. The average from each LDRs taken by simple calculations made by Arduino using C-Programming. Thereafter the average from each direction is taken and given to the if condition present in the code. Which manipulates and decides the movement of the tracker taking two directions top & bottom, and right & left. If the average of the top LDRs is greater than the bottom LDRs, then we assign the servo to move upwards. Similarly, when the average of the bottom LDRs is greater than the top LDRs it moves downwards. When the average of the right LDRs is greater than the left LDRs then the servo moves to the right. Similarly, when the average of the left LDRs is greater than the right LDRs, then it moves to the left. Fig.11. shows the completed laboratory Model of the Dual-Axis Solar Tracker.

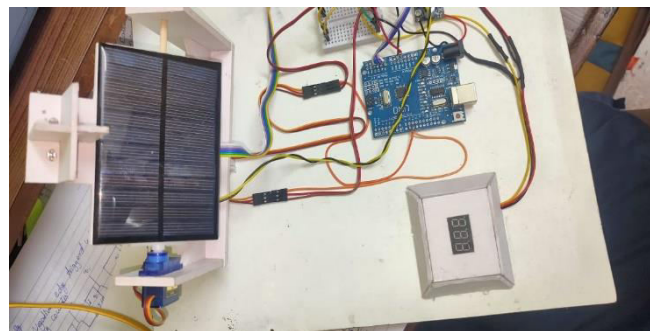


Fig. 11. The working Model of Dual-Axis Solar Tracker.

### VI. CONCLUSION

In conclusion, the Internet of Things (IoT) based Dual Axis Solar Tracker represents a significant advancement in the field of renewable energy. By incorporating IoT technology into solar tracking systems, we can maximize the efficiency of solar panels, optimize energy generation, and contribute to a more sustainable future. The Dual Axis Solar Tracker utilizes real-time data and connectivity to monitor and control the position of solar panels. This allows for precise alignment with the sun's position throughout the day, ensuring maximum exposure to sunlight and increasing energy production. The integration of IoT enables remote monitoring and management, providing flexibility and convenience for system operators.

The benefits of this technology extend beyond improved energy generation. The IoT-based Dual Axis Solar Tracker enhances system reliability by detecting and addressing issues promptly. With the ability to collect and analyze data on performance and environmental conditions, predictive maintenance can be implemented, reducing downtime and increasing the lifespan of the solar tracking system. Moreover, the IoT connectivity enables seamless integration with

smart grid systems. The Dual Axis Solar Tracker can actively participate in demand response programs, adjusting its operation based on grid conditions and energy demand. This intelligent interaction with the grid promotes grid stability, reduces peak load, and contributes to a more efficient and resilient energy infrastructure.

Furthermore, the environmental impact of the Dual Axis Solar Tracker is significant. By maximizing energy production, it minimizes the reliance on fossil fuels and reduces greenhouse gas emissions. It harnesses clean and renewable solar energy, contributing to a greener and more sustainable planet. In summary, the IoT-based Dual Axis Solar Tracker represents a technological breakthrough in the solar industry. Its integration of IoT capabilities revolutionizes solar tracking systems, improving energy efficiency, reliability, and integration with the smart grid. With its environmental benefits and potential for widespread adoption, this innovation holds great promise in advancing the transition to clean and sustainable energy sources.

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