“Aurdino based dual axies solar tracking system with real time sunlight intensity and energy output display”

PROJECT REPORT

Submitted in partial fulfillment of the requirements for the award of

Bachelor of Engineering
in
Electrical and Electronics Engineering
Submitted to

Visvesvaraya Technological University

Belagavi, Karnataka, 590 014(16)

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2025-2026

Department of Electrical and Electronics Engineering

CERTIFICATE

Certified that the project work entitled **"Aurdino based dual axies solar tracking system with real time sunlight intensity and energy output display"**is a bonafide work carried out by **BINDUSHRI (2ke22ee009), VINUTHA K M(2ke22ee057), MEGHARAJ H (2ke23ee402) And VENKATESH K (2ke23ee408),** in partial fulfilment for the award of degree of **Bachelor of Engineering** in **8th Semester, Electrical and Electronics Engineering** of **Visvesvaraya Technological University, Belagavi,** during the year **2025-2026**. It is certified that all corrections/suggestions indicated for internal assessment have been incorporated in the report deposited in the department library. The project report has been approved as it satisfies the academic requirements in respect of project work prescribed for the said degree.

(Dr. Vinoda.S)	(Dr. Vinoda.S)	(Dr. Manu T M)
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Name of the Examiners **Signature with Date**

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2025-2026

Department of Electrical and Electronics Engineering

CERTIFICATION FROM GUIDE

This is to certify that project work entitled "Aurdino based dual axies solar tracking system with real time sunlight intensity and energy output display",is carried out by students Bindushri (2KE22EE009), Vinutha K M (2KE22EE057), Megharaj H (2KE23EE402), Venkatesh K (2KE23EE408) under my direct supervision,for the award o the degree of Bachelor of Engineering of "Electrical and Electronics Engineering" of VTU,Belagavi,Karnataka.

To the best of my knowledge and belief,

(i) The work is carried out by the candidates only.
(ii) The work is not taken in its original form,from any other thesis or project reports.
(iii) The work is up to the desired standard both in the technical contact and the writeup.
(iv) Plagiarism percentage is 18%.

Date:

(Dr. Vinoda.S)
Guide and HOD

The project work as mentioned above is hereby recommended and forwaded for examination and evaluation.

DECLARATION

We, BINDUSHRI (2KE22EE009), VINUTHA K M (2KE22EE057), MEGHARAJ H (2KE23EE402) And VENKATESH K (2KE23EE408) students of 8th Semester B.E., K.L.E. Institute of Technology, Hubballi, hereby declare that the project work has been carried out by us and submitted in partial fulfillment of the requirements for the VII Semester degree of **Bachelor of Engineering in Electrical and Electronics Engineering** of Visvesvaraya Technological University, Belagavi during academic year 2025-2026

Date:

Place: Hubballi

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We would like to express my heart full thanks to all the teaching faculty and staff members of the department of Electrical and Electronics for constructive suggestion and constant encouragement.

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K. L. E. SOCIETY'S

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2025-2026

ABSTRACT

The project "Arduino Based Dual Axis Solar Tracking System with Real-Time Sunlight Intensity and Energy Output Display" is basically something we tried to build so that the solar panel can catch more sunlight instead of just sitting in one place. Normally the fixed panels don't move at all, so half the time they don't get proper sunlight. So we thought, okay, why not make it follow the sun on its own. For that we used an Arduino board which controls the whole thing.

We used LDR sensors, like four of them, to sense where the sunlight is more. When the light changes, the servo motors move the panel in that direction, both up-down and left-right. It's not always super smooth, but it works pretty decent after tuning. The LDRs basically tell the Arduino which side is brighter and the motors adjust according to that.

Apart from just tracking, we also added a small display to show the sunlight intensity and how much energy the panel is giving at that time. We connected voltage and current sensors, and the Arduino calculates the power and shows it on an LCD/OLED screen. It's actually helpful to see what's going on in real time, especially during testing in the college terrace.

Overall, the project tries to improve the amount of solar energy we can capture in a simple and low-cost way. It's not perfect but it definitely works better than a fixed panel. And honestly, we learned a lot by struggling with the wiring, coding issues, and all the adjustments, but in the end it came out pretty well.

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CHAPTER-1

INTRODUCTION

In today's world where energy demand is increasing like anything and people are seriously worried about environmental issues, renewable energy has kind of turned into an important thing for sustainable growth. Out of all the options we hear about, solar power actually comes out as one of the most available and clean sources, but still the problem is that the actual working of a PV system depends mainly on how much sunlight actually falls on the panel. Fixed panels just sit in one spot the whole day, so they can't keep up with the sun's angle and then obviously the power goes down a lot. Because of this only, solar tracking systems started coming up so that the panel can keep adjusting its position and stay pointed toward the sun. Basically, a solar tracker changes the angle of the panel so it stays at the right position as the sun moves in the sky. There are different kinds too like single-axis which moves in just one direction and dual-axis which moves in both directions and gives better accuracy. Many studies also say that using tracking systems can increase the energy output almost up to 40% compared to normal fixed ones, so they are pretty useful for renewable energy setups.

Our project called "Arduino-Based Dual Axis Solar Tracking System with Real-Time Sunlight Intensity and Energy Output Display" mainly tries to build a simple but effective tracking system using Arduino. We used LDR sensors which basically sense sunlight coming from different directions and according to that the Arduino controls two servo motors that move the panel in horizontal and vertical direction so it can follow the sun throughout the whole day. Apart from just tracking, we also added a real-time display system which shows sunlight intensity and the power output on an LCD or OLED screen so anyone using it can check the performance right there only. This helps to understand how sunlight angle and intensity affects the panel energy output and it's useful for learning, research and small renewable setups also. Overall, even though our project is not perfect and we struggled a lot honestly, it still gives an automatic and improved way to use solar energy properly and also shows how small autonomous renewable systems can be created for supporting a greener and more sustainable future.

1.1 Literature Survey

Lately the increasing demand for energy sources has driven significant investigation into solar energy systems. Among the promising methods, for sustainable electricity production is solar photovoltaic (PV) technology. Nevertheless the performance of solar panels is restricted because they are unable to track the sun's path throughout the day. To address this challenge scientists have created solar tracking mechanisms that can constantly adjust the solar panels to face the sun. The research indicates that axis solar trackers can considerably increase energy production by maintaining optimal sunlight exposure all day long.

Numerous research efforts have concentrated on creating and deploying solar tracking systems powered by microcontrollers. As reported by Patel et al. (2018) A solar tracking mechanism built on Arduino and utilizing dependent resistors (LDRs) attained an efficiency increase of up to 35% relative, to a stationary panel. This setup employed LDR sensors to measure sunlight intensity from four angles and operated two servo motors to modify the panel's tilt and rotation. This study emphasized the benefit of Arduino microcontrollers for affordable and dependable control solutions, in energy initiatives.

Singh and Mehta (2019) introduced a dual-axis tracker incorporating a closed-loop feedback mechanism utilizing LDRs to detect sunlight and DC geared motors to drive movement. Their design showed stability and minimized tracking inaccuracies even in fluctuating weather scenarios. The researchers concluded that sensor-driven control provides adaptability, to environmental variations compared to algorithmic or time-scheduled tracking methods. Kumar et al. (2020).

Various scholars have investigated hybrid and automated surveillance frameworks to enhance performance. Rahman et al. (2021) Created a dual-axis tracker combined with a enabled monitoring device presenting real-time data on sunlight intensity, voltage and current from the solar panel through an online dashboard. Their findings showed that observation of solar irradiance and power output aids, in assessing system efficiency and forecasting maintenance requirements. This idea motivated the incorporation of real-time visualization systems into designs, for educational purposes and small renewable energy installations.

In an investigation Sharma et al. (2020) Examined single-axis and dual-axis tracking systems utilizing Arduino Uno. Their results indicated that single-axis tracking enhanced energy output by around 20% whereas dual-axis systems provided gains, up to 40% to stationary setups. Nevertheless they pointed out that dual-axis mechanisms entail intricate mechanical designs and marginally increased actuator power usage highlighting the importance of effective power management techniques.

Recent improvements in tracking technologies involve utilizing sensors with precision and improved calibration. Research like Al-Hassan et al. (2022) Substituted LDRs with photodiodes and pyrano meters to acquire irradiance data. They applied voltage and current sensing circuits to determine real-time power output presenting the data on an LCD screen. Their design demonstrated that combining measurement and display features within the tracking system enables efficient performance assessment and practical application, in rural and isolated settings.

The analyzed literature consistently determines that an Arduino-based axis solar tracking setup with real-time monitoring provides an affordable and energy-saving approach to optimize solar panel efficiency. Although the majority of systems concentrate on the tracking process only a limited number include concurrent energy output and sunlight intensity visualization, which is useful, for teaching demonstrations and analytical uses. Hence a research deficiency persists in creating a system that merges effective dual-axis tracking, live irradiance monitoring and power output evaluation, within a compact and cost-effective configuration.

Hence, the present project aims to design and implement an Arduino-based dual-axis solar tracking system that not only tracks the sun’s position accurately but also measures and displays real-time sunlight intensity and energy output. This system builds upon existing research by integrating both automation and monitoring features in a single setup, thereby contributing to improved performance evaluation and better understanding of solar energy utilization.

1.2 Motivation

The main reason we decided to make an Arduino-based dual axis solar tracking system is basically to get better efficiency from solar panels because normally the panels just stay in one fixed angle and they lose a lot of sunlight when the sun moves during the day. With energy demand going up every year and fossil fuels getting used up faster, there is a big need for some smart, low-cost and eco-friendly methods to produce clean energy, so we thought this kind of tracking idea would help. Solar tracking gives a simple but effective way to make better use of sunlight without adding more panels or increasing the size, which is nice for small setups also. By using Arduino along with a sunlight intensity and energy output display, we tried to make a system that not only collects sunlight properly but also shows what's happening in real time so we can check the performance whenever we want. The whole motivation was to make something automated, useful, and still affordable, which can help in colleges, small projects, or even practical installations, and also support the idea of moving towards cleaner and greener energy in the future.

1.3 Objectives

The objectives formulated for the project are as follows

•To Build a dual-axis solar tracking system that automatically changes the solar panel's orientation in alignment, with the sun's motion to maximize energy capture.

•To employ an Arduino microcontroller, for precise management of sensors and motors guaranteeing accurate tracking performance.

•To measure real-time sunlight intensity via Light Dependent Resistors (LDRs). Utilize the information to ascertain the best alignment of the solar panel.

•To measure and display real-time energy output (voltage and current) of the solar panel on an LCD/OLED screen for easy monitoring.

•To examine the enhancement, in energy efficiency obtained by using tracking as opposed to a stationary solar panel arrangement.

•To create a dependable and energy-saving prototype that can be straightforwardly applied for small-scale or educational renewable energy uses.

•To promote awareness and understanding of automation in renewable energy systems for sustainable energy utilization.

The report ended with bibliography

CHAPTER-2

2.1 History and Background of Solar Tracking Systems

2.1.1 Early Development

•The idea of tracking originated in the 19th century as researchers and inventors started developing mechanisms that could autonomously track the sun to enhance the capture of solar energy.

•In 1860 Augustin Mouchot, an inventor created one of the earliest solar-powered engines employing a manually controlled parabolic reflector to concentrate sunlight. An initial version of solar tracking.

•By the early 20th century, as solar thermal collectors gained attention, researchers realized that sunlight incidence angle greatly affected energy efficiency, leading to the first mechanically controlled tracking systems.

2.1.2 Evolution with Technology

•From the 1960s, through the 1980s as photovoltaic (PV) cells gained prominence solar tracking systems advanced in complexity.

•Initial systems employed sensors along with clock-driven controllers to turn solar panels at a constant speed approximately mimicking the sun’s trajectory, in the sky.

•Later, with the advancement of microcontrollers and light sensors, systems became automatic and adaptive, adjusting panel positions based on real-time light intensity instead of pre-set angles.

2.1.3 Modern Era and Automation

•By the 2000s, embedded systems and microcontroller platforms such, as Arduino and Raspberry Pi transformed tracking rendering it cost-effective, programmable and compact.

•Contemporary models feature dual-axis movement enabling adjustments, in both azimuth (and elevation (vertical) directions to optimize solar energy absorption across different times of the day and seasons.

•Integration of IoT (Internet of Things), machine learning, and real-time data logging further improved efficiency and monitoring capabilities.

2.2 Major Previous Projects and Research Works

2.2.1 NASA's Solar Tracking Research (1970s–1980s)

NASA had done some early work on solar tracking way back in the 70s and 80s where they created solar concentrator systems that used mechanical tracking to focus sunlight onto the power units in spacecraft. This whole thing basically became the foundation for proper dual-axis tracking that we see today, and honestly it influenced a lot of solar technologies both in space and even later on earth.

2.2.2 University of Madrid – Dual Axis Solar Tracker (2005)

At the Universidad Politécnica de Madrid, researchers made a dual-axis tracking prototype that actually increased the output by around 35 to 40% when compared to the normal fixed panel setup. They used light sensors and stepper motors for the movement, and it was one of the early academic projects that actually did some proper cost-benefit analysis for these trackers, which helped other researchers understand if it's worth it or not.

2.2.3 NREL (National Renewable Energy Laboratory), USA

NREL carried out a lot of proper comparisons between single-axis and dual-axis systems and their results showed that dual-axis trackers can give almost up to 45% more annual energy output, especially in places where sunlight is really strong and direct. Their studies are kind of widely used now because they provide real data for choosing between the two systems.

2.2.4 Arduino-Based Solar Tracker Projects (2010s–Present)

In the last decade or so, many colleges and research groups started making their own Arduino-based solar tracking projects, mostly for engineering projects and academic studies. These usually use LDR sensors for checking sunlight in real time and sometimes include an LCD display to show sunlight intensity, voltage and current, power output and all that. These Arduino trackers became popular mainly because they are low-cost and easy to build, so they work well for small-scale solar setups, college labs and for students like us who want to learn practical renewable energy systems.

CHAPTER-3

METHODOLOGY

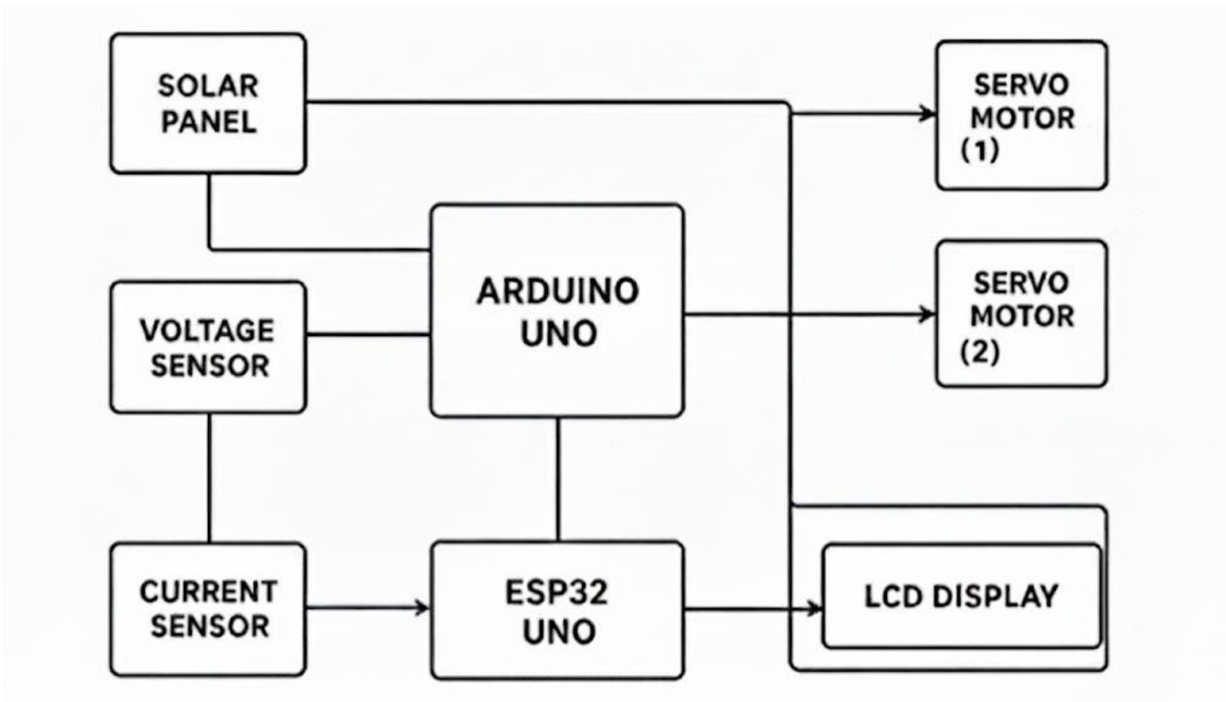


Fig 3.1 Block diagram

Fig 3.1 shows the block diagram which consists of solar panel, LDR sensors, LCD display, aurdino uno, DC gear motor and etc. Solar panel main power-generating component that converts sunlight into electrical energy.Its voltage and current are monitored to measure real-time energy output.

- Voltage Sensor**:** Measures the output voltage of the solar panel and sends it to Arduino.
- Current Senso**r:** Measures the current output of the panel.
- LDRs sense light intensity in four directions.
- Arduino determines which direction has maximum light.
- Servo motors adjust panel orientation toward that direction.
- Voltage and current sensors measure power generation.
- LCD shows real-time sunlight and energy output data.

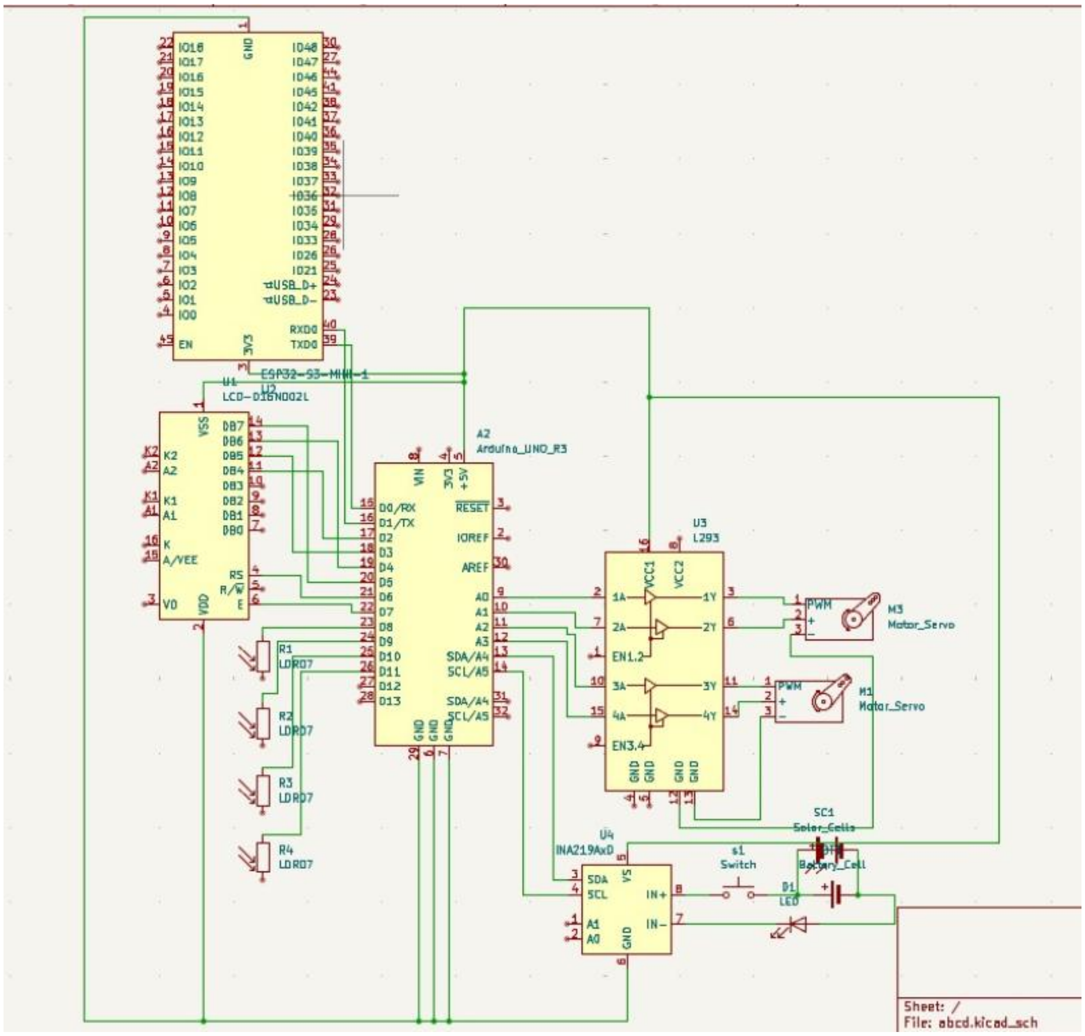


Fig3.2 Circuit diagram

Fig3.2 shows the circuit diagram with connections

- LDRs → Arduino: Detect sunlight direction.
- Arduino → L293D → Motors: Move panel to align with sunlight.
- INA219 Sensor: Measures real-time solar power output.
- LCD Display: Shows sunlight intensity and power data.
- Common Ground: Maintains reliable and stable circuit operation

3.3 Components used: The components in this project are readily available in market. The components used in this project are as fallows :

1. Arduino Uno (Microcontroller)
2. Light Dependent Resistors (LDRs)
3. Solar Panel
4. DC gear motor
5. Regulator
6. Power Supply/Lithium ion battery
7. Motor Driver Module
8. LCD Display
9. ESP32
10. INA219
11. L293

3.3.1 Arduino Uno

ATmega328 Arduino Uno Board Working and Its Applications

The Arduino Uno is basically this small microcontroller board that works on the ATmega328 chip, and honestly it's like the most used board by us students because it's simple and kind of easy to get used to once we start messing around with it. The name Uno means "one" in Italian, and they kept it because it was like the first proper or stable version in the Arduino series, at least that's what I understood. The board has around 14 digital pins and 6 analog pins and also this 16 MHz crystal which kinda helps the board run properly without hanging or something. It also has a USB port, reset button, power jack and those ICSP pins which honestly still confuse me sometimes but they are for direct programming stuff.

You can power the board through USB or even a small battery which is super helpful in our labs because half the time plug points are either broken or already taken by someone else. The ATmega328 chip has like this 8-bit RISC architecture… I don't remember the exact technical explanation but ya it works fast enough for most of the projects we do in college. This same chip is used in other Arduino boards like Nano, Pro Mini and few more.

When we connect the Uno to the laptop, we just upload the code from Arduino IDE and the board simply starts running whatever we wrote, so it makes doing small projects actually less stressful. I feel like this board is perfect for beginners and even final year work because it's reliable and literally there are tutorials and videos for almost everything related to it. The applications are like everywhere — robotics stuff, small automation setups, sensor testing experiments and many more things we try out.

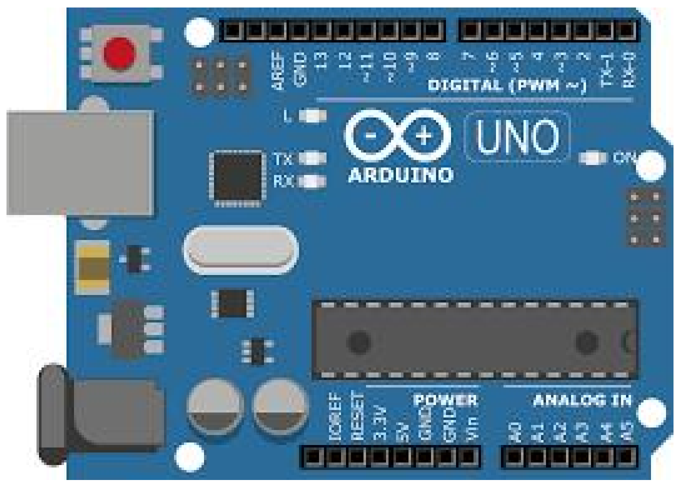


Fig 3.3 Arduino Uno ATmega328

Fig 3.3 shows Arduino Uno ATmega328

Features of Arduino Uno Board

The features of Arduino Uno ATmega328 includes the following.

- The operating voltage is 5V
- The recommended input voltage will range from 7v to 12V
- The input voltage ranges from 6v to 20V
- Digital input/output pins are 14
- Analog i/p pins are 6
- DC Current for each input/output pin is 40 mA
- DC Current for 3.3V Pin is 50 mA
- Flash Memory is 32 KB
- SRAM is 2 KB
- EEPROM is 1 KB

Arduino Uno Pin Diagram

The Arduino Uno board can be built with power pins, analog pins, ATmegs328, ICSP header, Reset button, power LED, digital pins, test led 13, TX/RX pins, USB interface, an external power supply. The Arduino UNO board description is discussed below.

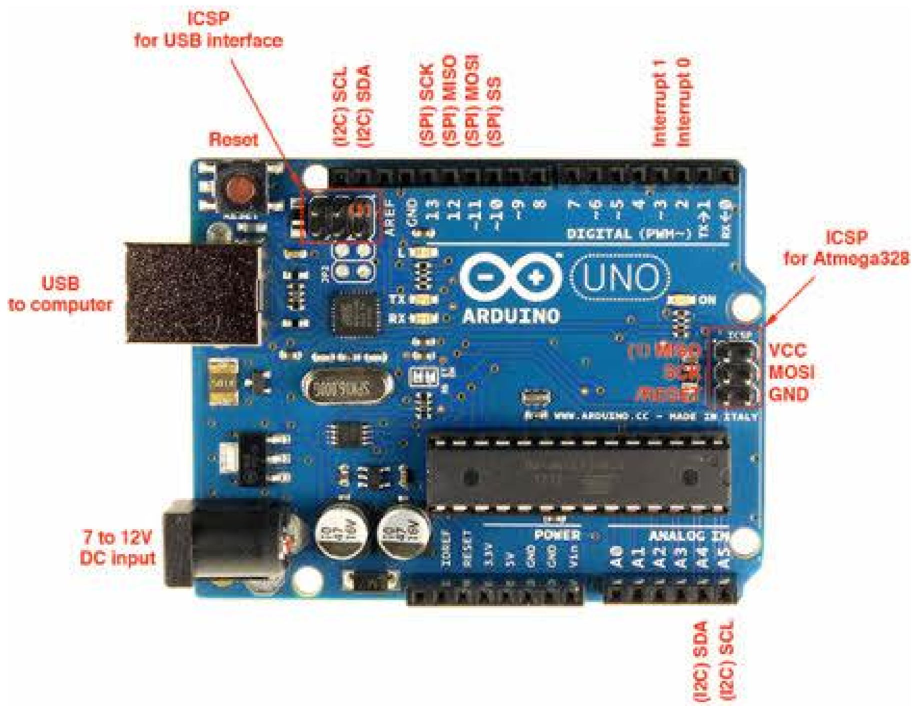


Fig3.4 Arduino Uno Board Pin Configuration

Fig3.4 shows Arduino Uno Board Pin Configuration

Power Supply

The Arduino Uno power supply can be done with the help of a USB cable or an external power supply. The external power supplies mainly include AC to DC adapter otherwise a battery. The adapter can be connected to the Arduino Uno by plugging into the power jack of the Arduino board. Similarly, the battery leads can be connected to the Vin pin and the GND pin of the POWER connector. The suggested voltage range will be 7 volts to 12 volts.

Input & Output

The 14 digital pins on the Arduino Uno can be used as input & output with the help of the functions like pinMode(), digitalWrite(), & Digital Read().Pin1 (TX) & Pin0 (RX) (Serial)**:** This pin is used to transmit & receive TTL serial data, and these are connected to the ATmega8U2 USB to TTL Serial chip equivalent pins.

- **Pin 2 & Pin 3 (External Interrupts):** External pins can be connected to activate an interrupt over a low value, change in value.
- **Pins 3, 5, 6, 9, 10, & 11 (PWM):** This pin gives 8-bit PWM o/p by the function of analogWrite().

- **SPI Pins (Pin-10 (SS), Pin-11 (MOSI), Pin-12 (MISO), Pin-13 (SCK):** These pins maintain SPI-communication, even though offered by the fundamental hardware, is not presently included within the Arduino language.
- **Pin-13(LED):** The inbuilt LED can be connected to pin-13 (digital pin). As the HIGH-value pin, the light emitting diode is activated, whenever the pin is LOW.
- **Pin-4 (SDA) & Pin-5 (SCL) (I2C):** It supports TWI-communication with the help of the Wire library.

AREF (Reference Voltage): The reference voltage is for the analog i/ps with analogReference().

Reset Pin: This pin is used for reset (RST) the microcontroller.

Memory : The memory of this Atmega328 Arduino microcontroller includes flash memory-32 KB for storing code, SRAM-2 KB EEPROM-1 KB.

Communication

The Arduino Uno ATmega328 offers UART TTL-serial communication, and it is accessible on digital pins like TX (1) and RX (0). The software of an Arduino has a serial monitor that permits easy data. There are two LEDs on the board like RX & TX which will blink whenever data is being broadcasted through the USB.

A SoftwareSerial library permits for serial communication on Arduino Uno digital pins and the ATmega328P supports TWI (I2C) as well as SPI-communication. The Arduino software contains a wired library for simplifying the utilization of the I2C bus.

Use of Arduino Uno

Arduino Uno can detect the surroundings from the input. Here the input is a variety of sensors and these can affect its surroundings through controlling motors, lights, other actuators, etc. The ATmega328 microcontroller on the Arduino board can be programmed with the help of an Arduino programming language and the IDE (Integrated Development Environment). Arduino projects can communicate by software while running on a PC.

Arduino Programming

Once the Arduino IDE tool is installed in the PC, attach the Arduino board to the computer with the help of USB cable. Open the Arduino IDE & select the right board by choosing Tools–>Board..>Arduino Uno, and select the right Port by choosing Tools–>Port. This board can be programmed with the help of an Arduino programming language depends on Wiring.
To activate the Arduino board & flash the LED on the board, dump the program code with the selection of Files–> Examples..>Basics..>Flash. When the programming codes are dumped into the IDE, and then click the button 'upload' on the top bar. Once this process is completed, check the LED flash on the board.

High Voltage Protection of USB

The Arduino Uno board has a rearrangeable poly fuse that defends the USB port of the PC from the over-voltage. Though most of the PCs have their own inner protection, the fuse gives an additional coating of safety. If above 500mA is given to the USB port, then the fuse will routinely crack the connection until the over-voltage is removed.

Physical Characteristics

The physical characteristics of an Arduino board mainly include length and width. The printed circuit board of the Arduino Uno length and width are 2.7 X 2.1 inches, but the power jack and the USB connector will extend beyond the previous measurement. The board can be attached on the surface otherwise case with the screw holes.

Applications of Arduino Uno

The applications of Arduino Uno include the following.

- Arduino Uno is used in Do-it-Yourself projects prototyping.
- In developing projects based on code-based control
- Development of Automation System
- Designing of basic circuit designs.

Features of the Arduino Uno Board:

- It is an easy USB interface. This allows interface with USB as this is like a serial device.
- The chip on the board plugs straight into your USB port and supports on your computer as a virtual serial port. The benefit of this setup is that serial communication is an extremely easy protocol which is time-tested and USB makes connection with modern computers and makes it comfortable.
- It is easy-to-find the microcontroller brain which is the ATmega328 chip. It has more number of hardware features like timers, external and internal interrupts, PWM pins and multiple sleep modes.
- It is an open source design and there is an advantage of being open source is that it has a large community of people using and troubleshooting it. This makes it easy to help in debugging projects.
- It is a 16 MHz clock which is fast enough for most applications and does not speeds up the microcontroller.
- It is very convenient to manage power inside it and it had a feature of built-in voltage regulation. This can also be powered directly off a USB port without any external power. You can connect an external power source of upto 12v and this regulates it to both 5v and 3.3v.
- 13 digital pins and 6 analog pins. This sort of pins allows you to connect hardware to your Arduino Uno board externally. These pins are used as a key for extending the computing capability of the Arduino Uno into the real world. Simply plug your electronic devices and sensors into the sockets that correspond to each of these pins and you are good to go.

3.3.2 Light Dependent Resistors (LDRs)

Fig3.5 Light Dependent Resistor

What is an LDR?

Fig3.5 shows Light Dependent Resistor An LDR is a photoelectric device. LDR stands for Light Dependent Resistor also known popularly as photo-resistor.

Working Principle of LDR

The semiconductor material used to make an LDR (later discussed in this article) is such that in the absence of light, the resistance of material increases as shown in the figure below.

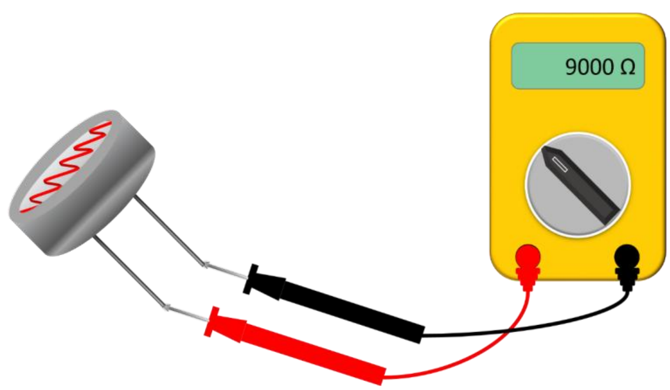


Fig3.6 Measurement of LDR resistance in dark condition

The resistance decreases as light strikes on it, as shown in the below figure. Providing power supply, allows the current to pass through the circuit.

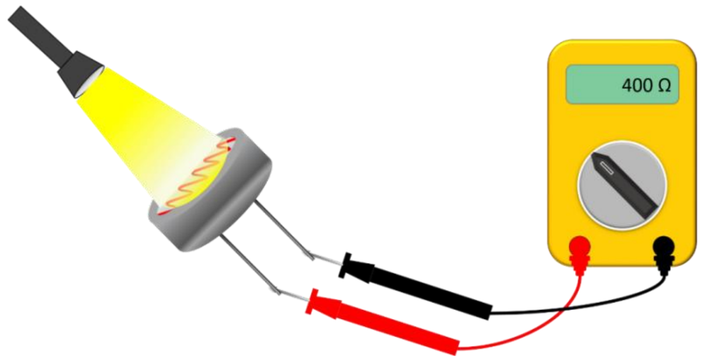


Fig3.7 Measurement of LDR resistance under illumination

You may have question in your mind that why there is a change in the resistance due to the absence or presence of light. The answer is – in a normal state, semiconductors have few free electrons. When light strikes on it, the free electrons gain enough energy to move through the material. Hence, the resistance of a semiconductor material varies.

Reading the above lines, I know what you may be thinking. You may be thinking that from where this energy comes. How simply light is giving energy?

Well, the answer to your above queries is 'photo effect'. Albert Einstein discovered that light striking on material surface is not only in form of waves. There must be tiny particles accompanying the waves. For this discovery in the year 1905, Einstein awarded noble prize. These particles are now popularly known as 'Photons'.The energy of a single photon is given by,

E=hf. Where,

E = energy of photon

f = frequency of light

h = Planck's constant

When a photon strikes on the material surface part of its energy is used to release an electron from material surface and remaining is used to impart kinetic energy to the electron.

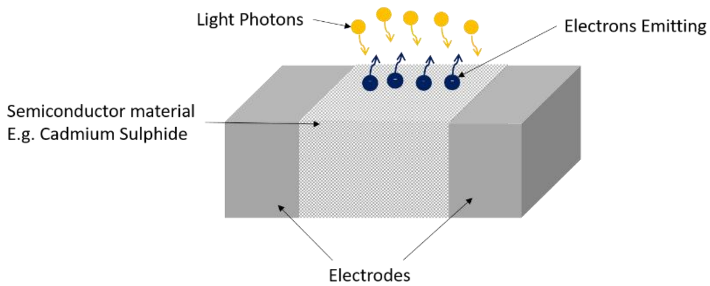


Fig3.8 Construction

Construction of an LDR

A photons energy is extremely low. Therefore it is necessary to have a substance of operating with such minimal energy. A few materials possess these characteristics.

Two examples are Cadmium sulfide and Cadmium selenide. The resistance of both these materials varies when exposed to light. The frequently used material, for making an LDR is Cadmium Sulfide.

Highly purified Cadmium sulfide in powder form mixed with a binding agent. Further, it is compressed and heated. The mixture becomes like a lump. It is then sandwiched between two electrodes in serpentine shape or zigzag shape as shown in the below figure. This disc is then either encapsulated in transparent resin or encased in glass in order to protect cadmium sulfide from contamination by the atmosphere.

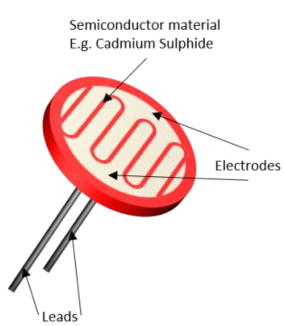


Fig3.9 Structure of LDR

APPLICATIONS

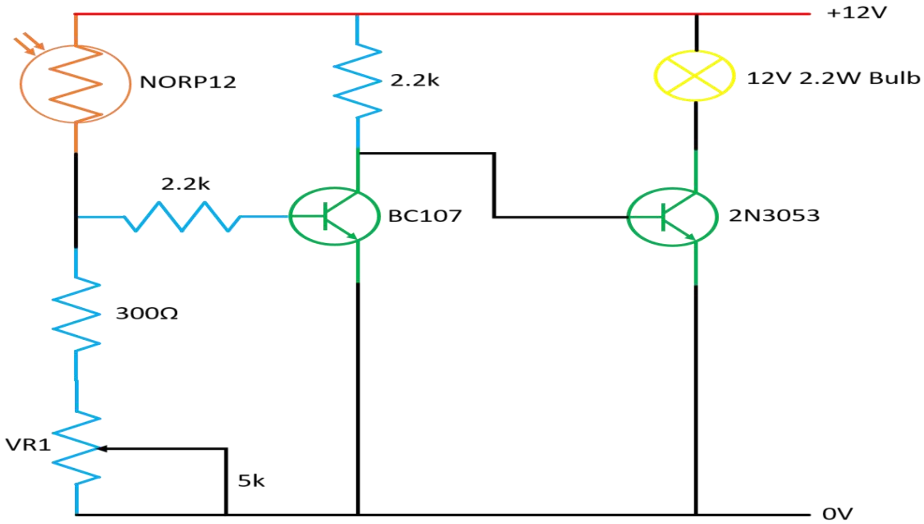


Fig3.10 Simple Automatic Room Lights Control

In the above circuit Fig3.10 LDR is responsible for detecting light. Whenever Light falls on LDR the resistance of LDR decreases and transistor BC107 turns ON. Due to this, the transistor collector goes low which turns OFF transistor 2N3053. In the darkness, the collector of BC107 goes high and due to that transistor 2N3053 turns ON and turns ON the bulb. The above circuit can control room lights.

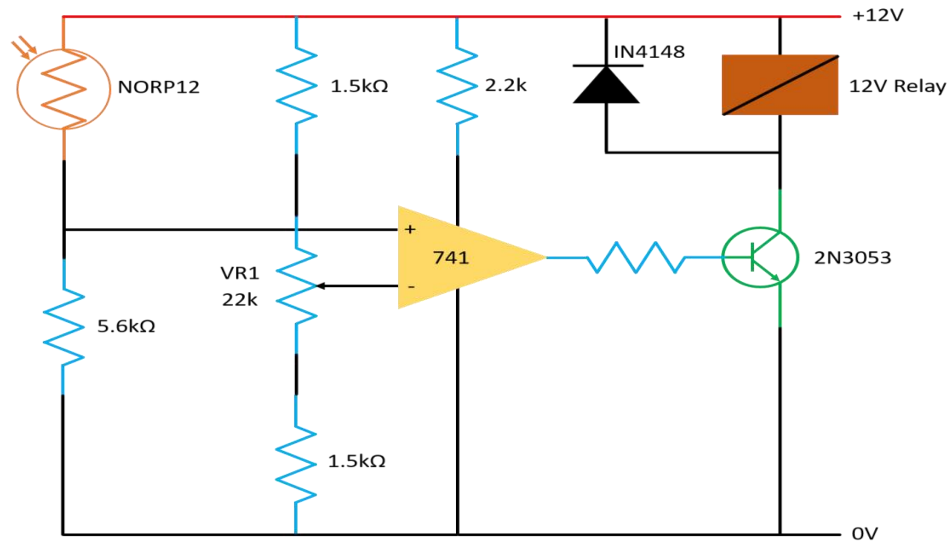


Fig3.11 Automatic Street Lights ON or OFF

Fig3.11 Automatic Street Lights ON or OFF .This circuit is more accurate and used for street lights control during sunrise or sunset. The circuit is very simple to understand. The op-amp acts as a comparator. It compares the voltage level at inverting and non-inverting pin and depending on that generates the output. The voltage level at the non-inverting pin depends on LDR resistance which decreases during day time and increases during night time.

Other applications of LDRs are:

- Automatic shutter control of the camera.
- Brightness control of TV screens and mobile screens.

Advantages

- The cost of the LDRs is very less and is easily available in the market.
- Connecting LDR in the circuit is very easy.

3.3.3 Solar Panel

Solar panel refers to a panel designed to absorb the sun's rays as a source of energy for generating electricity or heating.

A photovoltaic (PV) module is a packaged, connect assembly of typically 6×10 photovoltaic solar cells. Photovoltaic modules constitute the photovoltaic array of a photovoltaic system that generates and supplies solar electricity in commercial and residential applications. Each module is rated by its DC output power under standard test conditions (STC), and typically ranges from 100 to 365 watts. The efficiency of a module determines the area of a module given the same rated output – an 8% efficient 230 watt module will have twice the area of a 16% efficient 230 watt module. There are a few commercially available solar modules that exceed 22% efficiency[1] and reportedly also exceeding 24%.A single solar module can produce only a limited amount of power; most installations contain multiple modules. A photovoltaic system typically includes an array of photovoltaic modules, an inverter, a battery pack for storage, interconnection wiring, and optionally a solar tracking mechanism.The most common application of solar panels is solar water heating systems.The price of solar power has continued to fall so that in many countries it is cheaper than ordinary fossil fuel electricity from the grid .

Theory and Construction

Photovoltaic modules use light energy (photons) from the Sun to generate electricity through the photovoltaic effect. The majority of modules use wafer-based crystalline silicon cells or thin-film cells. The structural (load carrying) member of a module can either be the top layer or the back layer. Cells must also be protected from mechanical damage and moisture. Most modules are rigid, but semi-flexible ones are available, based on thin-film cells. The cells must be connected electrically in series, one to another. Externally, most of photovoltaic modules use MC4 connectors type to facilitate easy weatherproof connections to the rest of the system.

Modules electrical connections are made in series to achieve a desired output voltage and/or in parallel to provide a desired current capability. The conducting wires that take the current off the modules may contain silver, copper or other non-magnetic conductive transition metals.

Bypass diodes may be incorporated or used externally, in case of partial module shading, to maximize the output of module sections still illuminated.Some special solar PV modules include concentrators in which light is focused by lenses or mirrors onto smaller cells. This enables the use of cells with a high cost per unit area (such as gallium arsenide) in a cost-effective way.

What is solar PV?

solar PV is basically how light gets turned into electricity. Like, photons from sunlight somehow make voltage, which is called the photovoltaic effect. Sounds fancy I guess, but really it’s just sunlight making power.

They have these layers of semiconductor stuff, with the top and bottom layers having different charges or something like that. Honestly, I don’t know all the small details, but that’s pretty much how it works.

It’s kinda cool cause there’s no moving parts, you just have light hitting the material and boom, electricity. Sounds simple, but actually it’s kinda amazing when you really think about it. The semi-conducting material can be encased between a sheet of glass and or a polymer resin.

When exposed to daylight, electrons in the semi-conducting material absorb the photons, causing them to become highly energised. These move between the top and bottom surfaces of the semi-conducting material. This movement of electrons generates a current known as a direct current (DC).

Future solar technologies

- Research is currently underway to develop almost 100% transparent solar glass , which can be used in building applications. Organic polymer photovoltaics will be ultra-thin and more efficient than existing types, and could see windows transformed into electricity generators.
- Perovskite is a new type of solar cell which is more efficient than current types on the market. The technology is currently in refinement, as it has a number of flaws which would need to be resolved before it could be mass-produced.

3.3.4 DC gear motor

Geared DC motors can be defined as an extension of DC motor which already had its Insight details demystified. A geared DC Motor has a gear assembly attached to the motor. The speed of motor is counted in terms of rotations of the shaft per minute and is termed as RPM .The gear assembly helps in increasing the torque and reducing the speed. Using the correct combination of gears in a gear motor, its speed can be reduced to any desirable figure. This concept where gears reduce the speed of the vehicle but increase its torque is known as gear reduction. This Insight will explore all the minor and major details that make the gear head and hence the working of geared DC motor.

External Structure

Fig3.12 external structure of DC motor

At the first sight, the external structure of a DC geared motor looks as a straight expansion over the simple DC ones.

The lateral view of the motor shows the outer protrudes of the gear head. A nut is placed near the shaft which helps in mounting the motor to the other parts of the assembly.

Features of DC Gear Motors

- DC gear motors have a bunch of stuff going on. Like, the gears themselves can be plastic or metal, depends on what you need. There are different motor types too wound-field, permanent-magnet, brushless, intermittent duty.
- Brushed motors get their torque from the power you supply, using stationary magnets, commutation, and rotating electrical magnets. Brushless ones are a bit different, they use a soft magnetic core in the rotor or a permanent magnet, plus stationary magnets in the housing. Then there's uncommutated motors, like homopolar or ball bearing motors… kind of weird names but that's what they're called.
- Connection types are shunt, series, and compound. There are also motor constants, like Kv and Km, which matter if you wanna calculate performance. You can control speed pretty smoothly, even all the way down to zero, and you can reverse it without switching power circuits, which is kinda handy.
- Dynamic braking and regenerative braking are really useful if you need quick stops, so you might not even need a mechanical brake. Magnets can be rare earth, ceramic, or ferrite, depending on the motor. Winding resistance is important too—you don't want it to mess up your Km.
- Gear ratios come in different varieties like 28:1 or 18:1. Some motors are made for indoor use, some for outdoor. They can give a lot of torque at low speed, which is nice. And if you want, you can even get a DC gear motor custom-built for your size, power, torque, and how you wanna mount it.

3.3.5 REGULATED POWER SUPPLY(7805)

CIRCUIT DIAGRAM

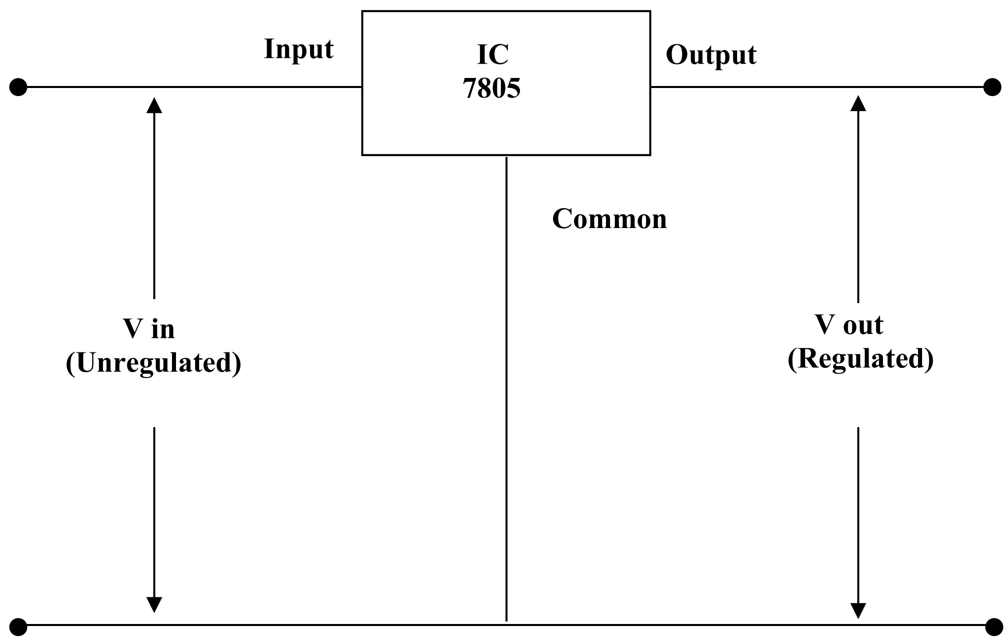


Fig3. 13 regulated power supply

Fig3. 13 regulated power supply A DC power supply system, which maintains constant voltage irrespective of fluctuations in the main supply or variation in the load, is known as Regulated Power supply.

The 7805 IC referred to fixed positive voltage regulator, which provides fixed voltage 5 volts. The 7805 regulator is known as fixed voltage regulator.

Fixed –Voltage regulator design has been greatly simplified by the introduction of 3-terminal regulator ICs such as the 78xx series of positive regulators and the 79xxx series of negative regulators, which incorporate features such as built-in fold back current limiting and thermal protection, etc. These ICs are available with a variety of current and output voltages ratings, as indicated by the 'xxx' suffix; current ratings are indicated by the first part of the suffix and the voltage ratings by the last two parts of the suffix. Thus, a 7805 device gives a 5V positive output at a 1a rating, and a 79L15 device gives a 15V negative output at a 100mA rating.

3-terminal regulators are very easy to use. The regulators ICs typically give about 60dB of ripple rejection, so 1V of input ripple appears as a mere 1mV of ripple on the regulated output. A rectified filter and unregulated DC voltage is given to pin of IC regulator. A bypass capacitor is connected between input and ground to bypass the ripples and oscillations. The output capacitor is connected between output and ground to improve transient response. The unregulated input is applied to the IC must be always more than the regulated output.

3.3.6 Power Supply/Lithium ion battery

Lithium-ion batteries are everywhere these days. You see them in laptops, PDAs, cell phones, iPods basically all over the place. People like them cause, weight for weight, they pack a lot of energy compared to other rechargeable batteries.

These batteries have also made the news sometimes. Yeah, cause every now and then they can catch fire. It’s not super common, like maybe two or three packs out of a million go bad, but when it happens, it’s kind of a big deal. Sometimes the failure rate can go up, and then you get these huge worldwide battery recalls, which cost manufacturers like millions of dollars.

Lithium-ion Battery Working Principle and Uses

lithium-ion battery is essentially a cell that employs lithium ions to convert chemical energy into electrical power. That’s essentially its operation. M. Stanley Whittingham, a American chemist is often regarded as the pioneer of lithium-ion batteries. He devised the concept of batteries in the late 1970s. It can basically be split into two main types depending on whether you can recharge them or not. There’s primary batteries, which you can’t recharge, and secondary ones, which you can recharge over and over again. I don’t really know all the tiny details, but yeah, that’s the main idea.

Fig3.14 Lithium ion battery

Advantages of Lithium-ion Battery

1. Lithium-ion batteries don’t lose charge fast like some other batteries, their self-discharge rate is pretty low.
2. They can store a lot of energy, like really high energy density.
3. Another cool thing is they don’t have that memory effect thing, so you can charge them anytime.
4. The life span is way longer too, like maybe ten times more than old school lead-acid batteries.
5. Charging them is also pretty fast compared to others.
6. They still work fine even in tough conditions, like high pressure or if the temperature goes up and down a lot.
7. They’re light and small, like 50-60% lighter than regular lead-acid ones.
8. Putting them in is not that hard either, installation is pretty easy.
9. They’re also flexible, not too bulky, and safe to use most of the time.
10. And yeah, you can get them in lots of different shapes and sizes, which is kinda nice.

3.3.7 Motor Driver Module

The motor driver module is a crucial interfacing component between the Arduino microcontroller and the DC motors or servo motors used for rotating the solar panel. Since the Arduino cannot supply the required current and voltage directly to drive the motors, the motor driver acts as a current amplifier—it takes the low-current control signals from the Arduino and provides sufficient current to the motors.

Working Principle

The motor driver module works on the principle of an H-Bridge circuit, which allows current to flow in either direction through the motor, enabling it to rotate clockwise or anticlockwise.
When the logic input signals from the Arduino change, the driver switches the polarity of voltage across the motor terminals, thus controlling the direction and speed of rotation.

Advantages

- Simplifies interfacing between Arduino and motors.
- Allows bidirectional control of motors.
- Provides overcurrent and thermal protection (in some models.
- Supports PWM control for smooth motor speed regulation.
- Compact and low-cost solution.

3.3.8 LCD Display

The battery which uses sponge lead and lead peroxide for the conversion of the chemical energy into electrical power, such type of battery is called a lead acid battery. The lead acid battery is most commonly used in the power stations and substations because it has higher cell voltage and lower cost.

Construction of Lead Acid Battery

The various parts of the lead acid battery are shown below. The container and the plates are the main part of the lead acid battery. The container stores chemical energy which is converted into electrical energy by the help of the plates.

1. Container : The container of the lead acid battery is made of glass, lead lined wood, ebonite, the hard rubber of bituminous compound, ceramic materials or moulded plastics and are seated at the top to avoid the discharge of electrolyte. At the bottom of the container, there are four ribs, on two of them rest the positive plate and the others support the negative plates.

The prism serves as the support for the plates and at the same time protect them from a short-circuit.The material of which the battery containers are made should be resistant to sulfuric acid, should not deform or porous, or contain impurities which damage the electrolyte.

2. Plate : The plate of the lead-acid cell is of diverse design and they all consist some form of a grid which is made up of lead and the active material. The grid is essential for conducting the electric current and for distributing the current equally on the active material. If the current is not uniformly distributed, then the active material will loosen and fall out.

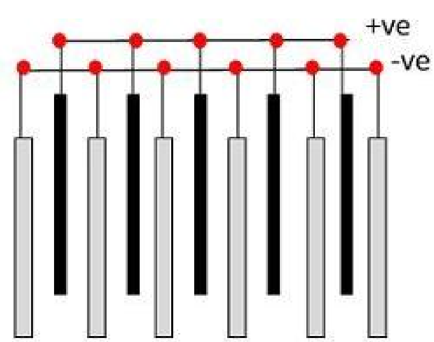


Fig3.15 Arrangements of plated in a lead acid battery

The grids are made up of an alloy of lead and antimony. These are usually made with the transverse rib that crosses the places at a right angle or diagonally. The grid for the positive and negative plates are of the same design, but the grids for the negative plates are made lighter because they are not as essential for the uniform conduction of the current.

The plates of the battery are of two types. They are the formed plates or plante plates and pasted or faure plates.

Plante's plates are used largely for stationary batteries as these are heavier in weight and more costly than the pasted plates. But the plates are more durable and less liable to lose active material by rapid charging and discharging. The plantes plate has low capacity weight-ratio.

Faure process is much suitable for manufacturing of negative plates rather than positive plates. The negative active material is quite tough, and it undergoes a comparatively low change from charging and discharging.

3. Active Material – The material in a cell which takes active participation in a chemical reaction (absorption or evolution of electrical energy) during charging or discharging is called the active material of the cell. The active elements of the lead acid are

Lead peroxide (PbO_2) – It forms the positive active material. The PbO_2 are dark chocolate broom in colour.

Sponge lead – Its form the negative active material. It is grey in colour.

Dilute Sulfuric Acid (H_2SO_4) – It is used as an electrolyte.

The lead peroxide and sponge lead, which form the negative and positive active materials have the little mechanical strength and therefore can be used alone.

4. Separators – The separators are thin sheets of non-conducting material made up of chemically treated leadwood, porous rubbers, or mats of glass fibre and are placed between the positive and negative to insulate them from each other. Separators are grooved vertically on one side and are smooth on the other side.

5. Battery Terminals – A battery has two terminals the positive and the negative. The positive terminal with a diameter of 17.5 mm at the top is slightly larger than the negative terminal which is 16 mm in diameter.

Working Principle of Lead Acid Battery

When the sulfuric acid dissolves, its molecules break up into positive hydrogen ions ($2H^+$) and sulphate negative ions (SO_4^{--}) and move freely. If the two electrodes are immersed in solutions and connected to DC supply then the hydrogen ions being positively charged and moved towards the electrodes and connected to the negative terminal of the supply. The SO_4^{--} ions being negatively charged moved towards the electrodes connected to the positive terminal of the supply main (i.e., anode).

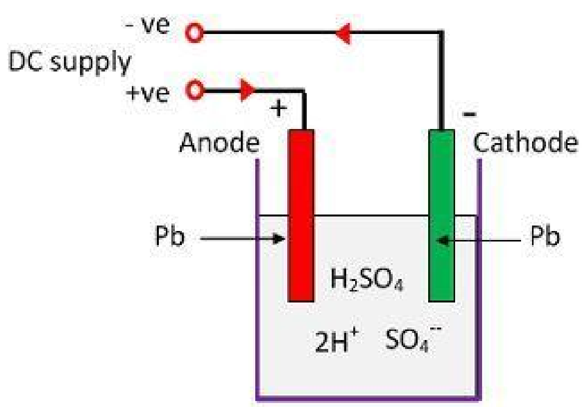


Fig3.16 Charging of lead acid cells

Each hydrogen ion takes one electron from the cathode, and each sulphates ions takes the two negative ions from the anodes and react with water and form sulfuric and hydrogen acid.

The oxygen, which produced from the above equation react with lead oxide and form lead peroxide (PbO_2.) Thus, during charging the lead cathode remain as lead, but lead anode gets converted into lead peroxide, chocolate in colour.

If the DC source of supply is disconnected and if the voltmeter connects between the electrodes, it will show the potential difference between them. If wire connects the electrodes, then current will flow from the positive plate to the negative plate through external circuit i.e. the cell is capable of supplying electrical energy.

Chemical Action During Discharging

When the cell is full discharge, then the anode is of lead peroxide (PbO_2) and a cathode is of metallic sponge lead (Pb). When the electrodes are connected through a resistance, the cell discharge and electrons flow in a direction opposite to that during charging.

The hydrogen ions move to the anode and reaching the anodes receive one electron from the anode and become hydrogen atom. The hydrogen atom comes in contacts with a PbO_2, so it attacks and forms lead sulphate ($PbSO_4$), whitish in colour and water according to the chemical equation.

$$PbSO_4 + 2H = PbO + H_2O$$

$$PbO + H_2SO_4 = PbSO_4 + 2H_2O$$

$$PbO_2 + H_2SO_4 + 2H = PbSO_4 + 2H_2O$$

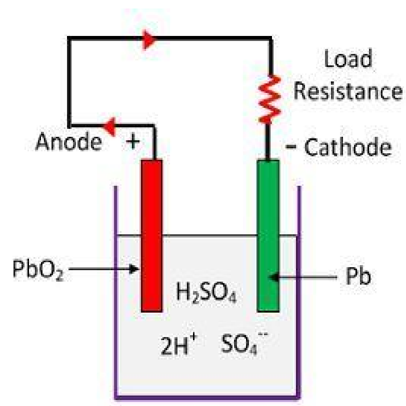


Fig3.17 Discharging of lead acid cells

The each sulphate ion (SO_4^{--}) moves towards the cathode and reaching there gives up two electrons becomes radical SO_4, attack the metallic lead cathode and form lead sulphate whitish in colour according to the chemical equation.

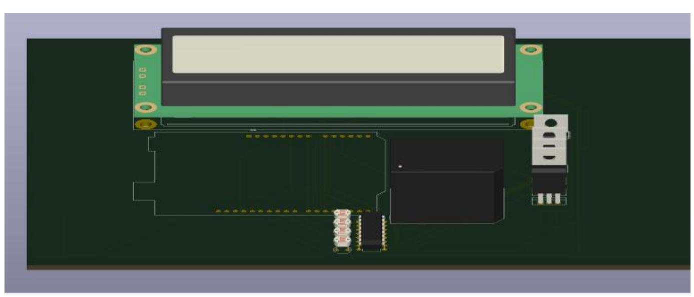


Fig3.18 LCD Display

3.3.9 ESP32

Categories	Items	Values
WiFi Paramters	WiFi Protocles	802.11 b/g/n
	Frequency Range	2.4GHz-2.5GHz (2400M-2483.5M)
Hardware Paramaters	Peripheral Bus	UART/HSPI/I2C/I2S/Ir Remote Contorl
		GPIO/PWM
	Operating Voltage	3.0~3.6V
	Operating Current	Average value: 80mA
	Operating Temperature Range	-40°~125°
	Ambient Temperature Range	Normal temperature
	Package Size	16mm*24mm*3mm
	External Interface	N/A
Software Parameters	Wi-Fi mode	station/softAP/SoftAP+station
	Security	WPA/WPA2
	Encryption	WEP/TKIP/AES
	Firmware Upgrade	UART Download / OTA (via network) / download and write firmware via host
	Ssoftware Development	Supports Cloud Server Development / SDK for custom firmware development
	Network Protocols	IPv4, TCP/UDP/HTTP/FTP
	User Configuration	AT Instruction Set, Cloud Server, Android/iOS App

Fig3.19 Major parameters of ESP32

Applications

- Smart home and IoT devices
- Motor control (like your solar tracker's BLDC driver)
- Sensor data logging and wireless transmission
- Robotics and automation systems
- Real-time monitoring systems

Advantages

- Low cost and high performance
- Built-in wireless communication
- Large community and Arduino IDE support
- Low power consumption modes

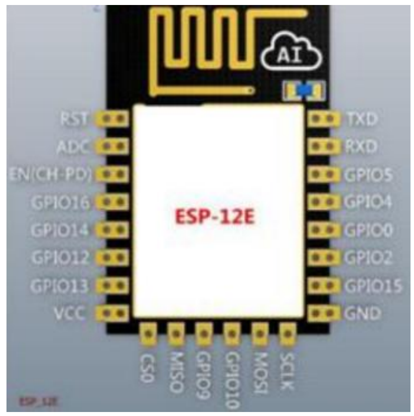


Fig3.20 ESP-32 Pin design

3.3.10 L293

Fig3.21shows the pin diagram of L293D Generally, L293D motor driver can control two motor at one time or called is a dual H-Bridge motor driver. By using this IC, it can interface DC motor which can be controlled in both clockwise and counter clockwise direction. The motor operations of two motors can be controlled by input logic at pins 2 & 7 and 10 & 15. Below shown the pin diagram of L293D motor driver

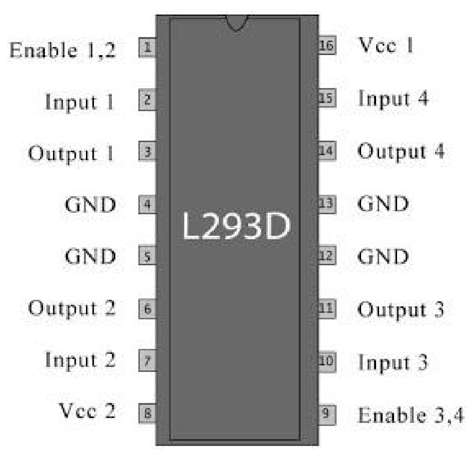


Fig3.21 pin diagram of L293D

Pin No	Function	Name
1	Enable pin for Motor 1; active high	Enable 1,2
2	Input 1 for Motor 1	Input 1
3	Output 1 for Motor 1	Output 1
4	Ground (0V)	Ground
5	Ground (0V)	Ground
6	Output 2 for Motor 1	Output 2
7	Input 2 for Motor 1	Input 2
8	Supply voltage for Motors; 9-12V (up to 36V)	Vcc 2
9	Enable pin for Motor 2; active high	Enable 3,4
10	Input 1 for Motor 1	Input 3
11	Output 1 for Motor 1	Output 3
12	Ground (0V)	Ground
13	Ground (0V)	Ground
14	Output 2 for Motor 1	Output 4
15	Input2 for Motor 1	Input 4
16	Supply voltage; 5V (up to 36V)	Vcc 1

Fig3.22 pin description of L293D motor driver

Fig3.22 shows the pin description of L293D motor driver Besides that, with this L293D driver motor it will control four DC motors at one time but with fix direction of motion. L293D has output current of 600mA and peak output current of 1.2A per channel. Moreover for protection of circuit from back EMF output diode are included within the L293D. The output supply hich is external supply has a wide range from 4.5V to 36V which has made L293D a best choice for DC motor driver. A simple schematic for interfacing a DC gear motor using L293D driver motor is shown below:

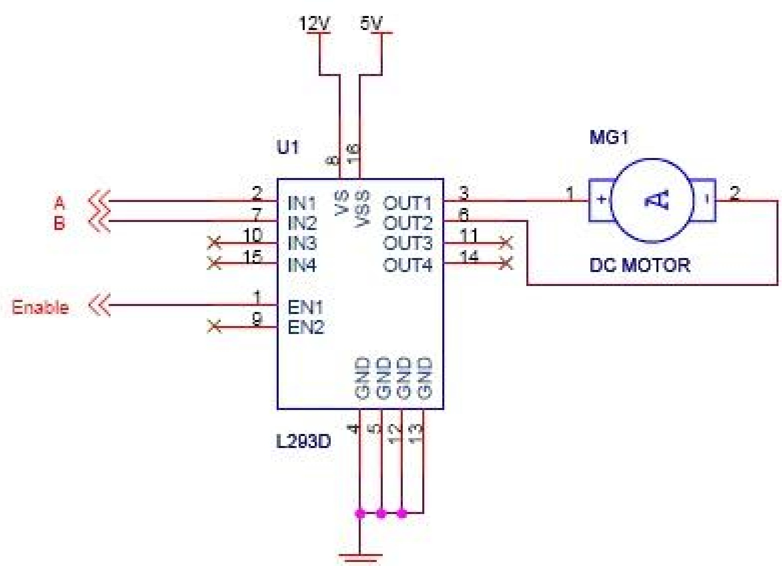


Fig3.23 interfacing a DC gear motor using L293D driver motor

The given Fig3.23 shows the interfacing of a DC gear motor with the L293D motor driver IC, which is used to control the direction and operation of the motor using low-power control signals. Since a microcontroller like Arduino cannot directly drive a motor due to current limitations, the L293D driver acts as an interface between the controller and the motor.

Truth Table

A	B	Description
0	0	Motor stops
0	1	Motor runs clockwise
1	0	Motor runs anti-clockwise
1	1	Motor stops

Fig3.24 truth table for L293D driver motor

The above Fig3.24 shows truth table for L293D driver motor For truth table above, the Enable has to be set to 1 and motor power used is 12V but it is depends on motor power that used (range 4.5V to 36V). The rotation of the DC motor can be control by combinations of A and B in programming assembling and from the truth table it is clear to explain the rotations of the motor. Picture below shown the connection of DC gear motor to L293D driver motor.

PROGRAM FOR ARDUINO UNO

```
#include <Wire.h>
#include <Adafruit_INA219.h>
#include <LiquidCrystal.h>

const int rs = 7, en = 6, d4 = 5, d5 = 4, d6 = 3, d7 = 2;
LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

const int s1 = 8, s2 = 9, s3 = 10, s4 = 11;
const int m1_in1 = A0, m1_in2 = A1;
const int m2_in1 = A2, m2_in2 = A3;

void setup() {
  lcd.begin(16, 2);
  lcd.print("Solar Tracker");
  delay(2000);
```

```
  lcd.clear();
  }
  ina219.setCalibration_32V_2A();

  Serial.begin(9600);
  Serial.println("Arduino Ready");
}

void loop() {

  int val1 = !digitalRead(s1);
  int val2 = !digitalRead(s2);
  int val3 = !digitalRead(s3);
  int val4 = !digitalRead(s4);

  if (val1 == HIGH) {
    digitalWrite(m1_in1, HIGH);
    digitalWrite(m1_in2, LOW);
  } else if (val2 == HIGH) {
    digitalWrite(m1_in1, LOW);
    digitalWrite(m1_in2, HIGH);
  } else {
    digitalWrite(m1_in1, LOW);
    digitalWrite(m1_in2, LOW);
  }

  if (val3 == HIGH) {
    digitalWrite(m2_in1, HIGH);
    digitalWrite(m2_in2, LOW);
  } else if (val4 == HIGH) {
    digitalWrite(m2_in1, LOW);
    digitalWrite(m2_in2, HIGH);
  } else {
    digitalWrite(m2_in1, LOW);
    digitalWrite(m2_in2, LOW);
  }
```

```
  float busVoltage = ina219.getBusVoltage_V();
  float current_mA = ina219.getCurrent_mA();
  float power_mW = busVoltage * current_mA;

  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("V:");
  lcd.print(busVoltage, 2);
  lcd.print("V I:");
  lcd.print(current_mA, 0);
  lcd.print("mA");

  lcd.setCursor(0, 1);
  lcd.print("P:");
  lcd.print(power_mW, 0);
  lcd.print("mW");

  Serial.print(busVoltage, 2);
  Serial.print(",");
  Serial.print(current_mA, 0);
  Serial.print(",");
  Serial.println(power_mW, 0);

  delay(2000);
}
```

CHAPTER-4

RESULTS AND DISCUSSION

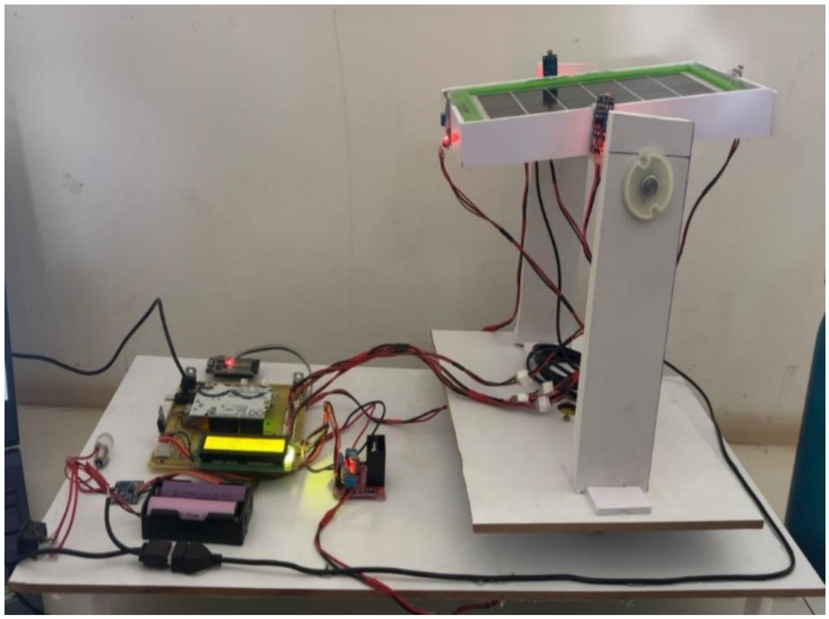


Fig: 4.1 Sectional view of the project module

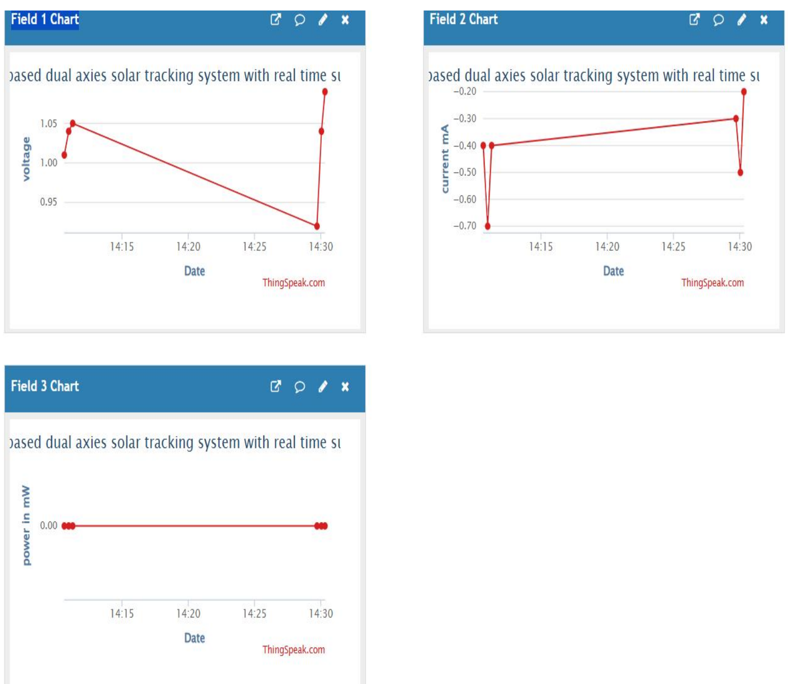


Fig 4.2: graphs of real time output

The above figure 4.1shows the sectional view of the developed project module, which is mounted on a wooden base for proper support.

The above figure4.2 shows the experimental results obtained from **Thingspeak** . The graphs are plotted using the real time values measured from the solar panel during different time intervals in the afternoon session.

Voltage Variation Graph

The voltage graph shows how the output voltage of the solar panel changes with time. At around 14:15 hrs, the voltage value is high because the panel is properly aligned towards the sun. As time increases, slight drop in voltage is observed around 14:30 to 14:35 hrs, which may be due to cloud cover or change in sunlight direction. Later, when the tracker adjusts its position, the voltage increases again. This shows that the dual axis tracking system is working and correcting the panel position automatically.

Current Variation Graph

The current graph shows the variation of output current in milliampere with respect to time. Initially the current is almost steady, but small fluctuations are seen as time progresses. This happens because current mainly depends on sunlight intensity, which changes frequently due to environmental conditions.At certain points, current suddenly drops or increases, which may be because the panel momentarily lost alignment before the motor corrected the position. This proves that tracking action is taking place continuously.

Power Output Graph

The power graph represents the calculated power output of the solar panel. Power is calculated inside Arduino using measured voltage and current values and then plotted. The graph shows that power output remains nearly constant for some time and then slightly varies.This variation clearly shows that dual axis tracking helps in maintaining better power output compared to fixed panel system.

Overall observation

The experiment proves that Arduino based dual axis solar tracking system gives better utilization of solar energy and also provides live monitoring of voltage, current and power through display and plotted results.

Date	API keys	current	voltage	power
2025-11-20	152	1	0	0
2025-11-20	153	1.05	0	0
2025-11-20	154	1.01	0	0
2025-11-20	155	1	0	0
2025-11-20	156	4.31	326.4	344
2025-11-20	157	4.26	323	338
2025-11-20	158	4.23	319.3	334
2025-11-20	159	4.2	319.3	328
2025-11-20	160	4.18	319.4	304
2025-11-20	161	4.21	319.6	322
2025-11-20	162	1.06	0	0
2025-11-20	163	1	0	0
2025-11-20	164	1.06	0	0
2025-11-20	165	1	0	0
2025-11-20	166	1.02	0	0
2025-11-20	167	0.98	0	0
2025-11-20	168	1.07	0	0
2025-11-20	169	4.3	330.4	324
2025-11-20	170	4.26	319.3	328
2025-11-20	171	4.2	318.8	328
2025-11-20	172	4.17	318.1	312
2025-11-20	173	4.2	318.2	318
2025-11-20	174	4.23	318.5	334
2025-11-20	175	1.05	0	0
2025-11-20	176	1.03	0	0
2025-11-20	177	1.01	0	0
2025-11-20	178	0.99	0	0
2025-11-20	179	1.05	0	0
2025-11-20	180	1.05	0	0
2025-11-20	181	1	0	0
2025-11-20	182	1.03	0	0
2025-11-20	183	1	0	0
2025-11-20	184	1.05	0	0
2025-11-20	185	1.03	0	0
2025-11-20	186	4.2	317.2	322
2025-11-20	187	4.2	317	330
2025-11-20	188	4.16	317	308
2025-11-20	189	4.25	321.6	338
2025-11-20	190	4.16	317.8	308
2025-11-20	191	4.18	316.8	322
2025-11-20	192	4.17	316.6	312
2025-11-20	193	4.15	317.3	322
2025-11-20	194	4.13	316.9	322
2025-11-20	195	4.13	317.5	312
2025-11-20	196	4.15	317.5	314
2025-11-20	197	4.16	317.7	324
2025-11-20	198	4.19	317.8	328
2025-11-20	199	4.2	317.9	322
2025-11-20	200	4.22	317.6	334
2025-11-20	201	4.19	317.6	318
2025-11-20	202	4.17	317.7	308
2025-11-20	203	0	316.7	330
2025-11-20	204	4.19	316.1	322
2025-11-20	205	4.16	316.5	312
2025-11-20	206	4.16	316.5	322

Fig 4.3: values of real time output according to graph

In ThingSpeak, the **API key** is a special authentication key provided by the platform to allow Arduino or any IoT device to send (write) or read data from a specific channel. When a channel is created in ThingSpeak, it automatically generates two main API keys: Write API Key and Read API Key. The Write API Key is used in the Arduino code to upload real-time values like sunlight intensity, voltage, current, and power to the ThingSpeak channel. Without this key, ThingSpeak will not accept any data from the hardware. The Read API Key is used to access or download the stored data for analysis, graphs, or CSV files. In the table shown in the project report, the API key value acts as a reference or index linked to the ThingSpeak channel data entries, helping to uniquely identify each uploaded dataset.

The table shows the real-time output data of the Arduino based dual axis solar tracking system recorded on a particular day. Each row represents one set of readings logged using an API key for identification. The current column indicates the output current of the solar panel, which changes with sunlight intensity while the voltage column shows the generated panel voltage that increases when the panel directly faces the sun and becomes zero during low sunlight or transition movement. The power column is calculated using the voltage and current values and represents the actual energy output of the system.

CHAPTER-5

CONCLUSION

The Arduino-driven axis solar tracking apparatus, featuring real-time sunlight intensity and energy output visualization effectively achieves its goal of enhancing solar power efficiency. Utilizing LDR sensors to identify the direction of sunlight brightness the system constantly modifies the solar panel's alignment, along both axes. This active tracking guarantees the panel stays perpendicular to the sun's rays all day long leading to greater energy collection than a stationary solar panel arrangement.

Combining the Arduino controller, motor drivers and servo/gear motors resulted in an responsive setup allowing for precise and fluid panel motion. The design also showed performance under different lighting conditions automatically adjusting whenever the sun's angle shifted. This underscores the system's efficiency, in world outdoor settings, where sunlight intensity continuously varies.

A further key aspect of the project is the real-time monitoring component, which shows sunlight intensity along side the related energy production. This assists users in grasping how environmental factors influence power generation while also enhancing the system's interactivity and informativeness. This display unit proves beneficial, for residential and small renewable energy uses, where ongoing performance tracking is important.

Overall, the project successfully combines sensing, tracking, and monitoring into a compact and cost-effective prototype. It demonstrates the advantages of solar tracking technology and provides a foundation for scaling the system to larger installations. With further enhancements such as weatherproofing, improved motors, and IoT-based data logging, this system has strong potential to evolve into a highly efficient and practical renewable energy solution.

BIBLIOGRAPHY

[1] This Duffie and Beckman book, Solar Engineering of Thermal Processes (3rd edition). Honestly this book is huge but it has all the solar basics. Wiley published it way back 2013.

[2] Then Kalogirou's Solar Energy Engineering, 2nd edition… this one had a lot of detailed stuff, sometimes too much, but yea it helped me understand some concepts that were just going above my head.

[3] Also checked M. A. Green's Third Generation Photovoltaics. It's old (2006) but still kinda useful to know how PV stuff evolved.

[4] I had to look at some standards also… this IEC 61724 thing about PV system performance. Honestly these standards are so dry to read but ya it's important.

[5] Esram and Chapman, the MPPT comparison paper, this one actually made sense after reading two times. Talks about max power point techniques and all, published in IEEE in 2007.

[6] Agarwal, Kumar, and Katiyar paper on dual-axis solar tracker design. Pretty helpful because I was literally stuck on how people normally analyse performance.

[7] There's also this Al-Asadi paper on Arduino based dual-axis tracking. Honestly this is closer to what I'm doing so I used it quite a bit.

[8] Then obviously, Arduino's own website for technical specs of UNO Rev3. I must have opened this page like 20 times while wiring stuff.

[9] I also checked Texas Instruments datasheet for INA219 (zero-drift current/power monitor). Datasheets are so confusing but anyway I managed.

[10] The Allegro ACS712 sensor datasheet — used it mainly to confirm how the Hall effect sensing actually behaves.

[11] And the L298N motor driver datasheet from STMicroelectronics. Without this I would've probably burned something lol.

[12] Rohm’s BH1750 datasheet for ambient light sensor, again had to check like pin details and everything because online info sometimes is wrong.

[13] Adafruit tutorial on interfacing INA219 with Arduino — honestly this made things much easier because the datasheet language was too much.

[14] SparkFun’s guide about solar tracker concepts and integrating light sensors. This one kinda explained things in simple terms which I badly needed.

[15] And lastly a review paper by Nabipoor and others about how solar tracking impacts PV performance. Helped me to justify in my report why tracking is even important.

APPENDIX-I

BILL OF MATERIAL

SL.NO	Components	Price
1	ESP32 Chip	500
2	Arduino Uno	300
3	L298N Motor Driver	300
4	DC Gear Motor * 2	500
5	Regulator * 4	100
6	Light Dependent Resistors(LDRs)	50
7	INA219	200
8	PCB Board	550
9	Lithium ion battery*2	200
10	LCD Display	250
11	Jump wires	200
12	Solar Panel 5w	1750
13	Adopter	250
14	Foam Sheet	600
	Total	5750 Rs

APPENDIX-II

PLAGIARISM CHECK

DrillBit

The Report is Generated by DrillBit Plagiarism Detection Software

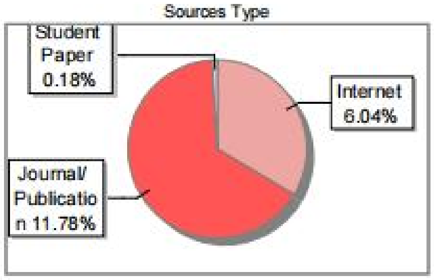
Submission Information

Author Name	BINDU SHRI
Title	AURDINO BASED DUAL AXIS SOLAR TRACKING SYSTEM WITH REAL TIME SUNLIGHT INTENSITY AND ENERGY OUTPUT DISPLAY
Paper/Submission ID	5119398
Submitted by	viswanath@kleit.ac.in
Submission Date	2026-01-05 12:53:17
Total Pages, Total Words	44, 10098
Document type	Project Work

Result Information

Similarity **18 %**

Sources Type



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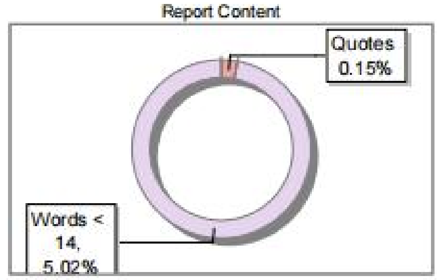

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