CHAPTER 1

INTRODUCTION

The Internet of Things (IoT) is a system of related computing devices, digital and mechanical machines, objects, people with unique identifiers and potential transfer of data over a network without human-to-human or human-to computer interaction. Physical objects those are no longer disconnected from the virtual world, but can be controlled remotely through Internet services.

A smart world is nothing but Smart devices, Smartphones, Smart cars, Smart homes and Smart cities. “Smart” objects play a key role in the vision of IoT, since embedded communication and information technology would have the potential to revolutionize. With the growing presence of Wi-Fi and 4G-LTE wireless Internet access, the evolution towards omnipresent information and communication networks is already evident. According to the International Energy Agency (IEA), Renewable energy will be the fastest-growing source of electricity, in which wind and solar PV are technologically mature and economically affordable. But still there is increase in world’s demand for energy. Adopting Renewable Energy technologies is one of the advance ways of reducing the environmental impact.

The solar energy has many technologies types that can build. Among of that are electricity generation. The electricity generation has three ways are photovoltaic; concentrating solar and experimental solar power. The Photovoltaics (PV) has been mainly developed for small and medium-sized applications, from the calculator powered by a single solar cell to the PV power planet. The Photovoltaic Power System has three types are Photovoltaic Standalone system, Photovoltaic hybrid system and Photovoltaic Grid Tie system. The Solar Energy Monitoring System is a system which is developed using sensor and microcontroller technology to display the exact value of solar system. The system is separated into two parts are Solar Photovoltaic System and Solar Energy Monitoring System. This thesis will concentrate more on Solar Energy Monitoring.

Finally, in analysing the evolution of electricity and energy consuming sectors, it explores the prime role solar energy could play in the long-term future of our energy system.

Applications of the monitoring system are the Rooftop Solar, Ground mounted Solar, Solar cities, Smart villages, Micro grids and Solar Street lights. Consumer Products like solar water heating systems, Solar home lighting systems, solar lanterns, solar pumps, solar mobile chargers, solar cookers, LED solar torch, solar RO plant, solar fan, solar Inverters, etc. can be monitored through this project. Commercial Products like Solar traffic signals, solar road studs/blinkers can also be monitored through the proposed system. In India, frequent power cut is very common. Due to this issue, it is important to use renewable energy and monitoring it. By monitoring the energy forecast, households and communities who are using solar power can utilize their energy production and consumption during good weather.

1.1 Purpose

The solar energy plays an important role in the green energy field and is one of the important renewable energy sources. With new government initiatives coming every day, the amount of dependence on solar power is also increasing. This forms an important source of energy which is not only clean, but also an huge undeleting source of energy which can bridge the gap between the demand and supply or Energy. The solar photo voltaic panels convert the incident solar radiation into electricity which can be used for different applications. However the amount of energy generated by the solar panels is variable and depends on the nature of incident light as well as the inclination of the solar panels towards the sun. Most of the solar photovoltaic system are installed at one fixed angle and are not able to harness the maximum energy form the sun as sun moves from one end to another through the day. The amount of energy generated is also difficult to track as there is no system to measure the amount of energy produced or generated. The dust accumulated on the solar panels also reduces the efficiency of the solar panels as the incident light is not utilized completely. The Wind pressure also accounts to the life of the installed system as wind is responsible for most of the install PV plants. . The graph of energy consumption is getting increased day by day where as the energy resources are diminishing parallel. In order to balance the scarcity for electricity, various sources are used to generate electricity. For the generation of electricity, there are two ways: one is by conventional method and other one is nonconventional method. Some of the energy carriers like fossil fuels and nuclear fuels are also used, but they are not renewable resources (i.e., they are not ‘refilled’ by nature) and it is said to be non-conventional. In its broadest sense, sustainable power may varies according to location, time and climatic conditions. To maximize the energy generated this project implement the solar energy tracking system. The tracking system aligns the solar panel to particular direction and helps achieve maximum.

1.2 Document convention

The following conventions are used through the document and should be understood accordingly. The table below shows a list of all the conventions used in the document given below.

IDE	Integrated Development Environment
REST	Representational state transfer
API	Application Programming Interface
MCU	Microcontroller Unit
JSON	Javascript Object Notification
LCD	Liquid Crystal Display
IOT	Internet of Things
RTC	Real Time Clock

Table 1.1: list of all the conventions

1.3 Project Scope

The proposed project deals with the concept of solar energy monitoring and tracking using internet of things. In this modern world, Electricity is also added to the most basic needs in everyone’s life. The graph of energy consumption is getting increased day by day where as the energy resources are diminishing parallel. In order to balance the scarcity for electricity, various sources are used to generate electricity. For the generation of electricity, there are two ways: one is by conventional method and other one is nonconventional method. Some of the energy carriers like fossil fuels and nuclear fuels are also used, but they are not renewable resources (i.e., they are not ‘refilled’ by nature) and it is said to be non-conventional. In its broadest sense, sustainable power In this modern world, Electricity is also added to the most basic needs in everyone’s life. The graph of energy consumption is getting increased day by day where as the energy resources are diminishing parallel. In order to balance the scarcity for electricity, various sources are used to generate electricity. For the generation of electricity, there are two ways: one is by conventional method and other one is nonconventional method. Some of the energy carriers like fossil fuels and nuclear fuels are also used, but they are not renewable resources (i.e., they are not ‘refilled’ by nature) and it is said to be non-conventional. In its broadest sense, sustainable power may varies according to location, time and climatic conditions. For that the solar panel can be completely exposed to the sun’s radiation always. And hence the solar panel can be monitored by using Internet of Things. There are several Techniques which have been studied for the solar panel tracking system by using IoT. And the analyses about few techniques are delivered as follows.

CHAPTER 2

LITERATURE SURVEY

2.1 Existing system

Before starting with the project a brief study was made on the currently existing systems in this domain. The work carried out by notable research scholars is studied in depth and its excerpt is documented here in literature review.

This literature review reveals the detailed work that has been carried out till date on the topic of Solar Tracking. N. Othman, M. I. A. Manan, Z. Othman, S. A. M. AlJunid have designed a two-axis sun tracking system with the use of five LDRs and an Arduino UNO controller [1]. The objective of this research is to design and construct the automatic dual axis solar tracker for maximum sun energy utilization. The only point of worry is that this system should consume energy as minimum as possible so that the difference between power conversion and power consumption would increase and hence the net profit of the system. Arduino UNO controller has been used and it is programmed in C language. LDRs are used to detect the maximum sunlight position in the sky and the program written performs calculations and drives the servo motors to make PV panels perpendicular to the sun [1]. The sun not only travels from east to west but there is a change of angle in north to south direction also. So the north and south directions should also be taken care of. Dual axis trackers do that. These trackers track the sun on a horizontal as well as vertical axis. Because of this operating ability the dual axis trackers have more output power than the single axis trackers. Light Dependent Resistors are used to find the brightest spot of the sun in the sky. LDRs are connected to Arduino UNO controller which gets to know the position of the sun in the sky and hence rotates the motors towards the sun. Two Servo motors are used for panel rotation which also fulfils the low cost and lightweight criteria [1]. Md. Tanvir Arafat Khan, S.M. Shahrear Tanzil (2010) have designed and constructed a microcontroller based solar tracking system using LDRs to sense the intensity of sunlight and stepper motors to move the Photo-Voltaic (PV) panels in accordance with the sun [2]. Fabian Pineda, and Carlos Andres Arredondo (2011) have designed and implemented a two-axis sun module positioning by sensing the maximum brightness point in the sky. A geodesic dome based sensor has been built for the bright point tracking [3].Authors Salabila Ahmad et al. have designed and constructed an open loop two axes sun tracking system with an angle controller. The hardware is selected such as it will maximize the power collected and minimize the power consumed as the efficiency parameter lies in between these two power parameters [4]. Solar tracking also helps in transmitting sunlight to dark area like basement. Authors Jifeng Song et al. have implemented the high precision tracking system based on a hybrid strategy for concentrated sunlight transmission via fibres [5]. Author Cemil Sungur (2008) has presented the multi-axes sun tracking system with PLC control. The azimuth and altitude angles of the sun are calculated for a period of 1 year at 37.6º latitude where Turkey is located. According to these angles, an electromechanical system which tracks the sun according to azimuth and altitude angle is designed and implemented [6]. Authors A.chaib et al (2013) have presented the heliostat orientation system based on PLC robot manipulator. It is presented that by mounting certain no. of heliostats and facing them towards central power tower water can be heated and turbines can be driven for energy conversion purpose. By applying MATLAB program for determining the sun's position for heliostat orientation and by using PLC robot manipulator it is presented that maximum amount of energy gets converted from solar to electricity. Concentrated Solar Power (CSP) is used in this experiment [7]. Authors Tao Yu and Guo Wencheng (2010) have introduced automatic sun-tracking control system based on Concentrated Photo Voltaic (CPV) generation. CPV generation works effectively when light panels trace the sun accurately. Stepper tracking control technology is used. This control relies on control circuit with ARM and camera which can provide powerful computational capability [8].

2.2 Proposed system

The proposed system consists of development of IOT based solar energy monitoring and tracking system. The proposed system will monitor the power coming from the solar energy and push it to the Cloud using ThingSpeak platoform. The data monitored is voltage, current and the wind pressure. The Data can be visualized from anywhere in the world using Thingpeak over internet. The Total system is divided into following modules which we have implemented in this project.

- IOT based monitoring system:

The IOT based monitoring system consists of development of IOT based system which will monitor all the solar data and send it to the cloud from where it can be visualized using graphs. This consists of hardware connected to internet and sensor interfaced which will monitor the energy generated using the solar panel.

- The solar Panel tracking system

To maximize the energy generated this project implement the solar energy tracking system. The tracking system aligns the solar panel to particular direction and helps achieve maximum .

- Solar panel Dust cleaner machine

The solar panel dust cleaner machine is used to clean the machine if it is accumulated by dust. It consists of brushed motor and a dust sensor which will clean the panel when the dirt is accumulated on the panel.

- The wind Pressure direction reorientation module

This system will automatically realign one of the axes by using stepper motor . This module will sense the wind pressure and if it is above some threshold it will automatically realign the panel.

2.3 Comparison

From the above literature review it has been noticed that majority of the literature work has been done on just axis adjustment system. Other than maximum energy the problems are still prevalent in the corresponding field. Number of solar panels crack due to increased pressure or velocity of the wind. Other than that the monitoring of the system is also necessary. This project proposed the concept of IOT based tracking and monitoring system for solar energy.

CHAPTER 3

REQUIREMENT SPECIFICATION

3.1 Functional Requirements

System Features

This section deals with the feature that will be provided by the end product. The features of the product in detail are discussed here.

IOT based Monitoring system:

- The Developed module continuously monitors the parameters of the solar panel to determine the average energy generated
- This module will also push the Data to the internet using API so that it can be visualized from anywhere.

Solar panel tracking system:

- This module consists of development of solar panel tracking system which tracks the position of the sun and then adjusts it orientation so that the maximum energy can be harnessed.
- To Implement Resistor and RTC based approach for the tracking system which can permit tracking as per the sensor data or the tracking as per the time.

Solar panel Dust Cleaner:

- This module consists of development of solar panel dust cleaner system which will be mpounted on the panels and will automatically clean the panels when the dust is accumulated
- This module also consists Automatic detection of dust using advanced sensors and if the dust is not above some threshold the cleaner will get activated and clean the panels
- Should be light weight and easily adaptable to the other solar panels.

The wind pressure reorientation module:

- This module is used to determine the wind pressure acting on the solar panels and the reorient the panels so that the breaking of the panels is aviuded.

3.3 Non Functional requirements

This section describes the nonfunctional requirements of the project.

Performance

- The project should automatically connect to internet
- If the Internet is not available the same should be informer to the user. Without internet it is not possible to perform data transfer.
- The system should keep a track of time
- The system should be always connected to power
- The system should be able to call API effectively

Scalability

- The provision should be made for adding other parameters for monitoring
- The proposed system should be developed in such a way that it can be scaled to a commercial product with minimum modifications
- The Cloud API Servers should be chosen to balance the server load when the no of connected devices to the server increases.
- The system should be developed such that it can be easily developed on low cost for commercial scaling

Security

- The data security doesn’t play an important role in this project; hence SSL communication protocols (certificates) or data encryption is not required.
- The IOT system should provide safety and security of the data

Maintainability

- If any problem persists the system should be easily serviceable.
- Should have minimum maintenance.
- The system should be portable and consume least space should be futuristic and should be compatible with next versions of frameworks used.

Usability

- The system should be easy to use
- The system should provide easy method to keep a track of the solar energy generated..

Availability

- The system and server communication should be instant and available with maximum uptime and downtimes should be avoided.
- The Internet connection should be available
- The System should be always online.

3.4 Software Requirements

- Arduino IDE
- Easy EDA

3.5 Hardware requirements

The following hardware requirement is required for the project.

- ESP32 S WiFi SOC
- RTC
- LCD display
- Buzzer
- LDR module
- BMP180 Pressure Sensor
- A4988 Stepper Motor Driver
- Arduino Nano
- Motor Driver
- Voltage Sensor
- Current Sensor

CHAPTER 4

SYSTEM ANALYSIS AND DESIGN

4.1 Use Case Diagrams

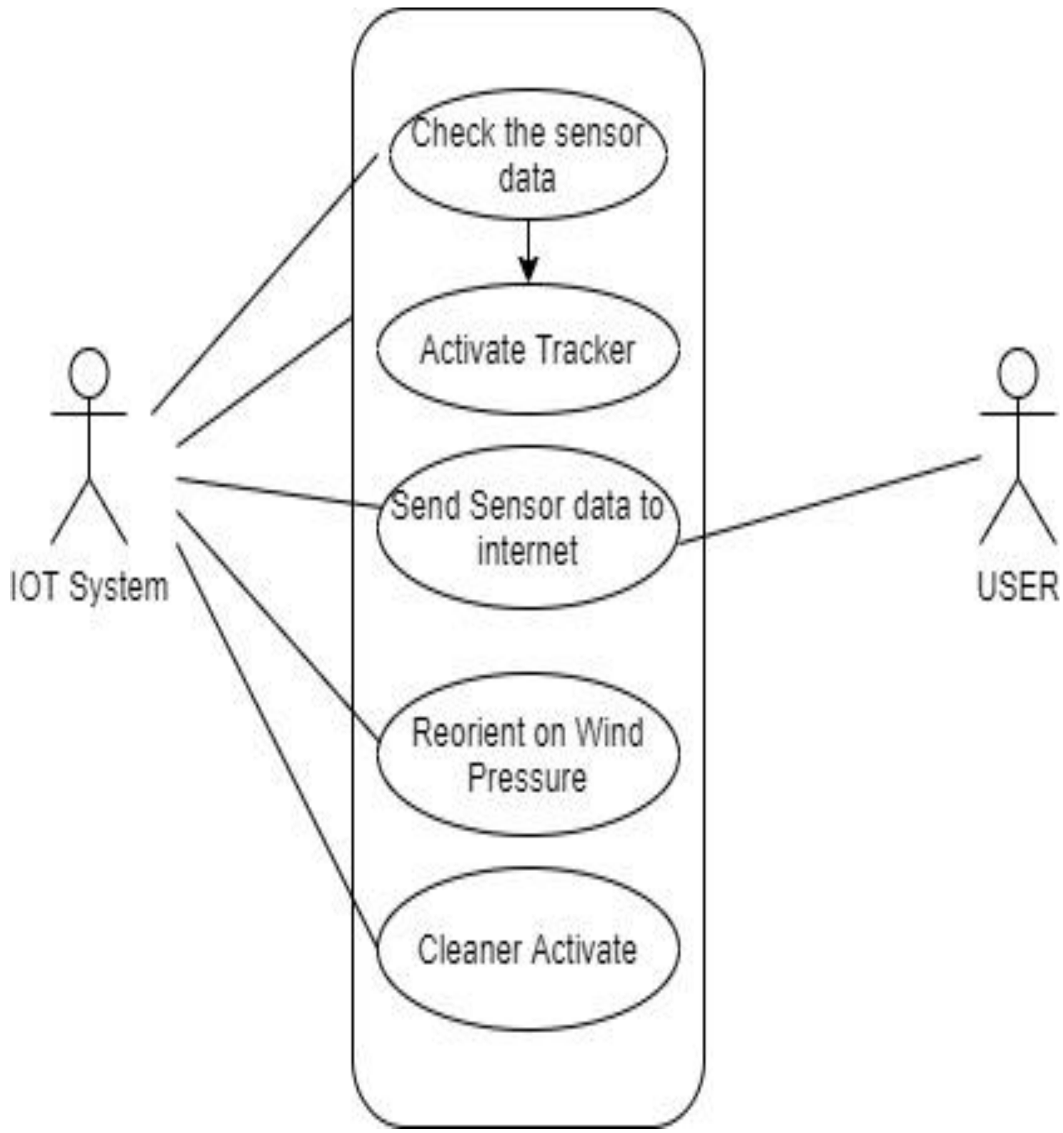


Fig 4.1: use case diagram

A use case diagram is a dynamic or behavior diagram in UML .use case diagrams module the functionality of a system using actors and use cases. Use cases are a set of actions, services, and functions that the system needs to perfrom.in this context, a ‘system’ is something being developed or operated, such as a web site. The “actors” are people or entities operating under defined roles within the system.

Use case diagrams are valuable for visualizing the functional requirements of a system that will translate into design choices and development priorities.

They also help identify any internal or external factors that may influence the system and should be taken into consideration.

They provide a good high level analysis from outside the system. Use case diagrams specify how the system interacts with actors without worrying about the details of how that functionality is implemented.

4.2 System Overview

The project deals with the development of IOT based solar monitoring and tracking system. As seen in the architecture diagram below the project consists of an IOT based solar monitoring system and a tracking system. The monitoring system consists of an ESP32 Module connected to internet which reads the data such as voltage, current and wind pressure through the sensor interfaced to the same and then sends them to the internet using WiFi. The wind pressure sensor detects the pressure of the wind and then automatically reorients the system in the direction of the lowest pressure to avoid any damage to the panels. The other part consists of the tracking system. The Light intensity sensors determine the region of maximum incidence and then control the panels orientation to be along that region. We have also implemented an RTC based Solar tracking system which adjusts the solar panels direction on the basis of the time. The dust sensor detects the dust levels on the solar panels and then activates the cleaning mechanism which cleans the solar panels.

4.3 System architecture

The architecture diagram is as shown below.

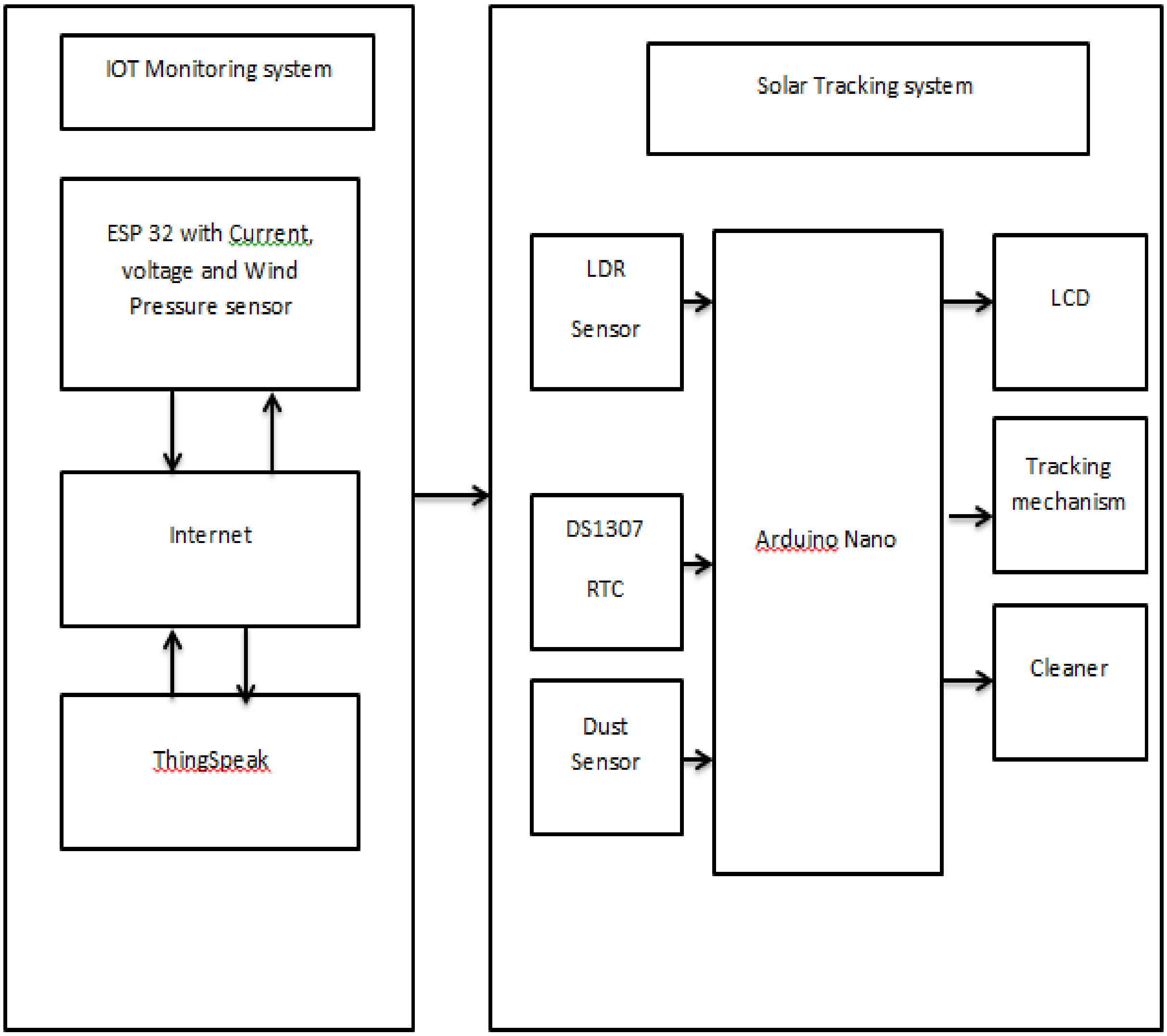


Figure 4.1: System architecture

4.3 Component Design

4.3.1 Flow Chart

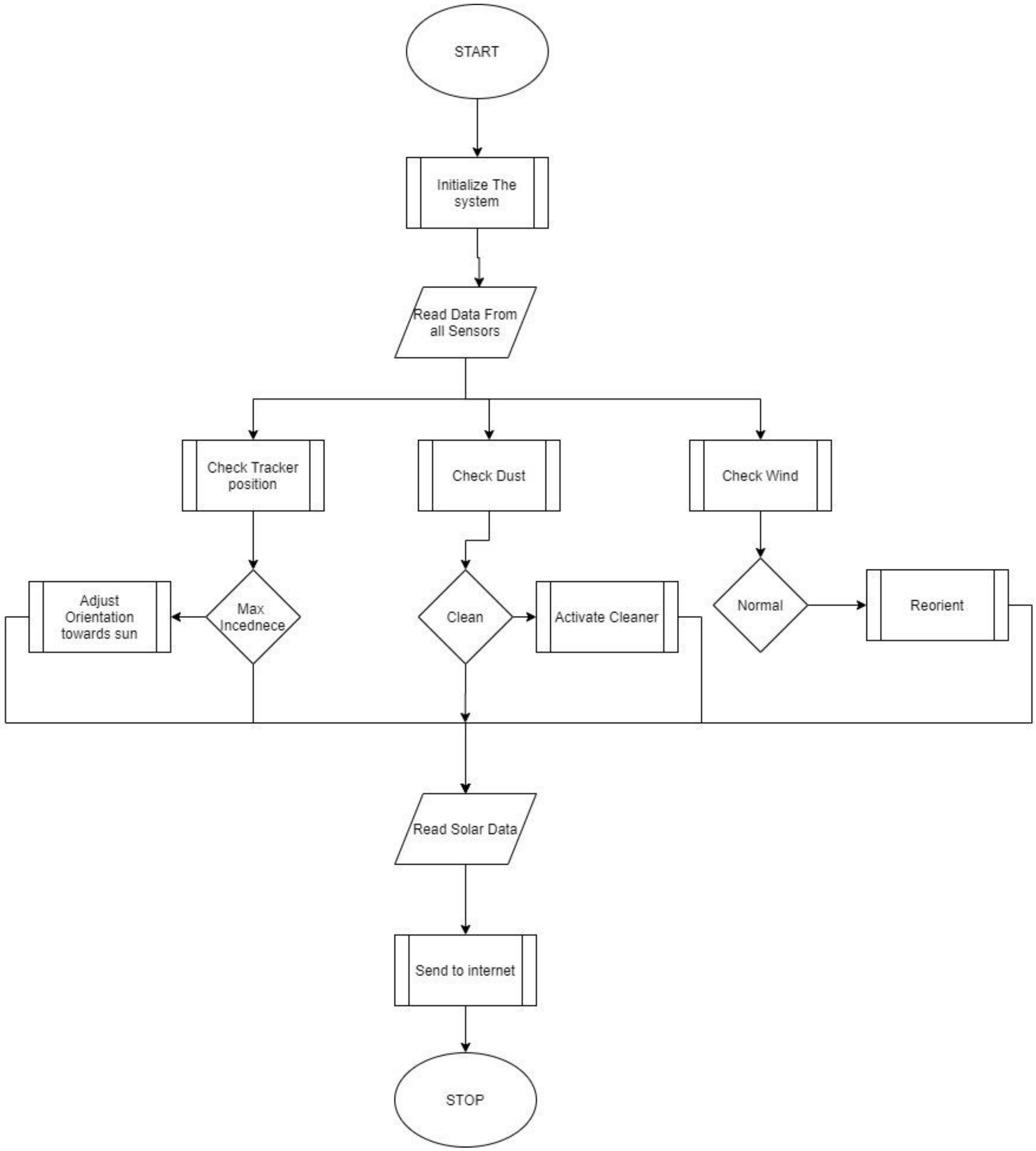


Figure 4.2: flowchart

4.3.2 Data Description

In our system we have sending data from the system to ThingSpeak to be able to visualize over the internet. The data is sent using Get request and can be visualized from the thingspeak panel.

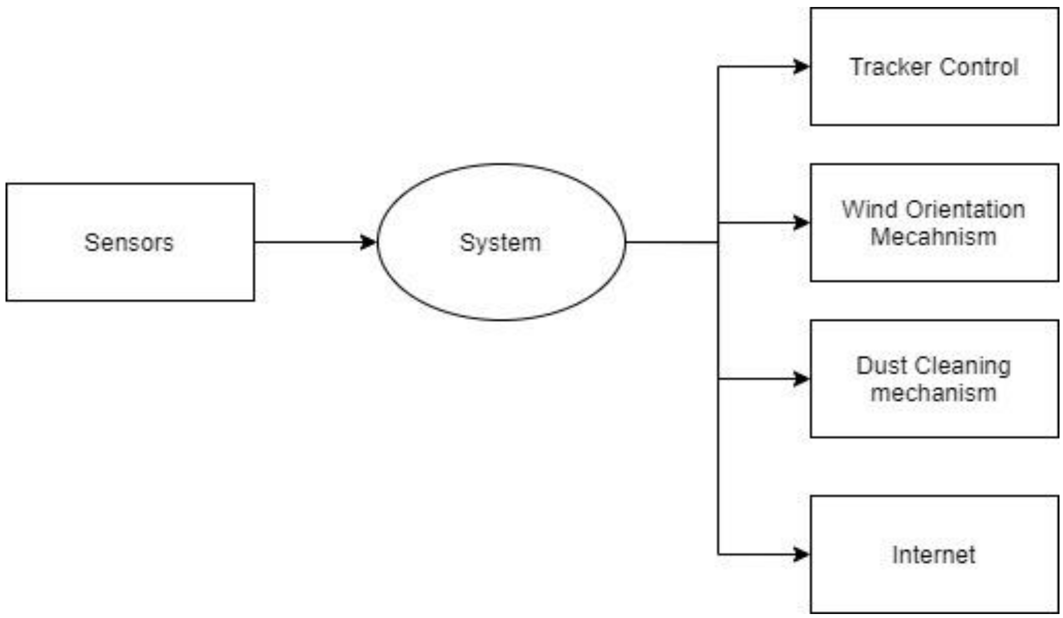


Figure 4.3: dataflow diagram

Data dictionary

Sl. No.	Field Name	Data format	Field size	description	example
1	Voltage	varchar	250	Voltage coming from solar panel	9.5V
3	Current	Varchar	250	Current consumed by load	0.5A
4	Pressure	varchar	250	Pressure of Wind	94522

CHAPTER 5

SYSTEM IMPLEMENTATION

5.1 Language Description

Arduino C:

The project used Subset of C language which is Arduino C which is based on the C/C++ and is used to program the microcontroller. Arduino, natively, supports a language that we call the Arduino Programming Language, or Arduino Language.This language is based upon the Wiring development platform, which in turn is based upon Processing, which if you are not familiar with, is what p5.js is based upon. It's a long history of projects building upon other projects, in a very Open Source way. The Arduino IDE is based upon the Processing IDE, and the Wiring IDE which builds on top of it.

When we work with Arduino we commonly use the Arduino IDE (Integrated Development Environment), a software available for all the major desktop platforms (macOS, Linux, Windows), which gives us 2 things: a programming editor with integrated libraries support, and a way to easily compile and load our Arduino programs to a board connected to the computer.

The Arduino Programming Language is basically a framework built on top of C++. You can argue that it's not a real programming language in the traditional term, but I think this helps avoiding confusion for beginners. A program written in the Arduino Programming Language is called **sketch**. A sketch is normally saved with the .ino extension (from Arduino). The main difference from "normal" C or C++ is that you wrap all your code into 2 main functions. You can have more than 2, of course, but any Arduino program must provide at least those 2.

One is called setup(), the other is called loop(). The first is called once, when the program starts, the second is repeatedly called while your program is running.

We don't have a main() function like you are used to in C/C++ as the entry point for a program. Once you compile your sketch, the IDE will make sure the end result is a correct C++ program and will basically add the missing glue by preprocessing it.

Everything else is normal C++ code, and as C++ is a superset of C, any valid C is also valid Arduino code. One difference that might cause you troubles is that while you can spawn your program over multiple files, those files must all be in the same folder. Might be a deal breaking limitation if your program will grow very large, but at that point it will be easy to move to a native C++ setup, which is possible. Part of the Arduino Programming Language is the built-in libraries that allow you to easily integrate with the functionality provided by the Arduino board.

5.2 Software Description

Arduino IDE:

The software used to program the microcontroller is the arduino IDE. Arduino is an open-source computer hardware and software company, project and user community that designs and manufactures kits for building digital devices and interactive objects that can sense and control the physical world. Arduino boards may be purchased preassembled, or as do-it-yourself kits; at the same time, the hardware design information is available for those who would like to assemble an Arduino from scratch.

The project is based on a family of microcontroller board designs manufactured primarily by Smart Projects in Italy, and also by several other vendors, using various 8-bit Atmel AVR microcontrollers or 32-bit Atmel ARM processors. These systems provide sets of digital and analog I/O pins that can be interfaced to various extension boards and other circuits. The boards feature serial communications interfaces, including USB on some models, for loading programs from personal computers. For programming the microcontrollers, the Arduino platform provides an integrated development environment (IDE) based on the Processing project, which includes support for C and C++ programming languages.

The arduino board is connected to pc and the program is burnt onto the microcontroller board. The figure below shows the arduino integrated development environment for compiling and uploading the programs to arduino board.

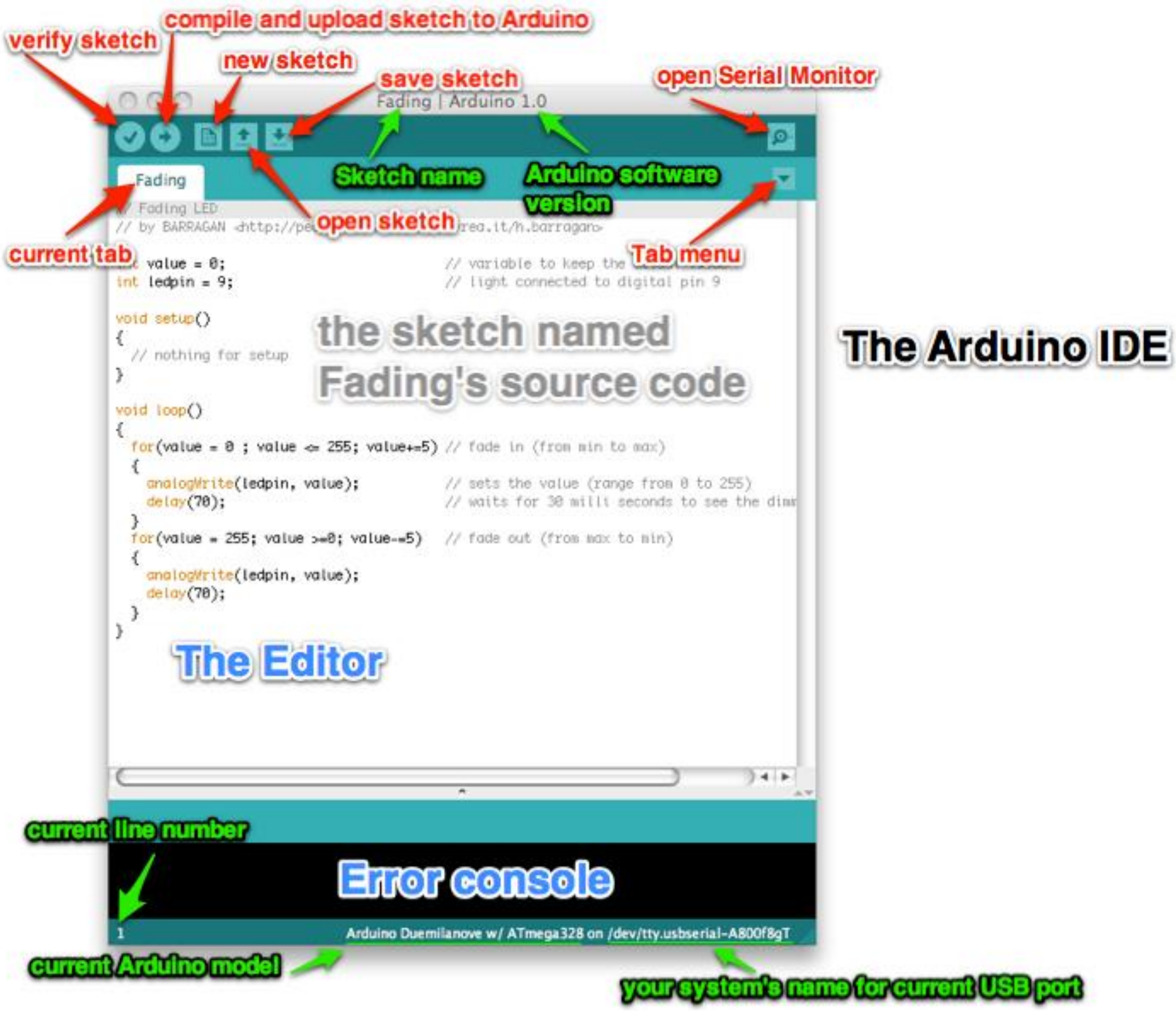
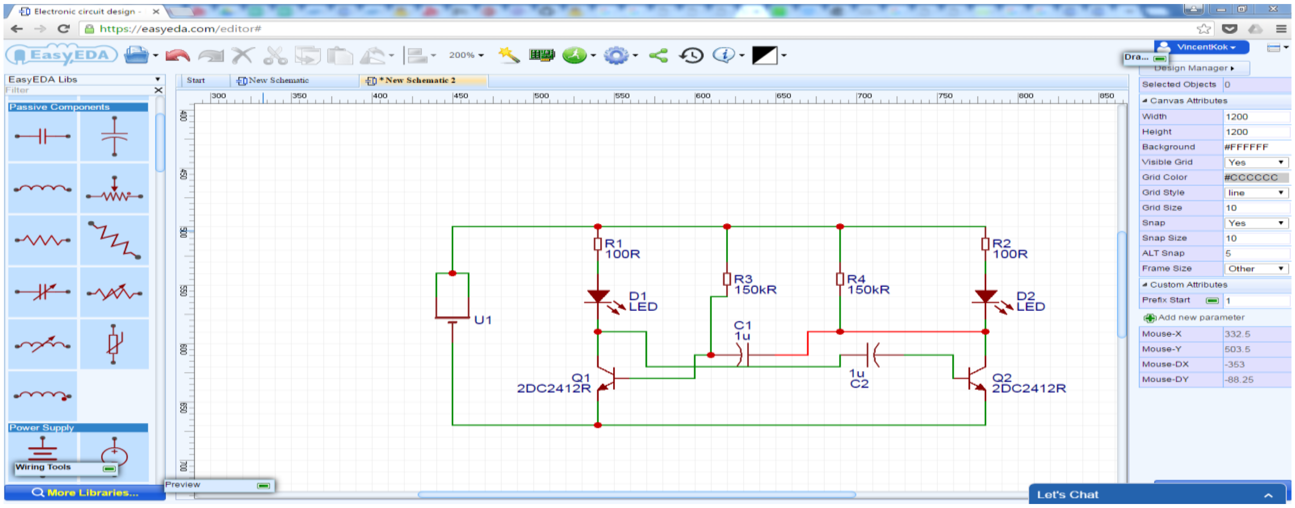


Figure 5.2: Arduino IDE

Easy EDA:

A great web based EDA (Electronic Design Automation) tool for electronics engineers, educators, students, market and enthusiasts. Easy EDA is free online software for creating circuit schematics, designing PCBs as well as simulating electronics circuits.



Circuit 5.1 : Easy EDA

ThingSpeak API:

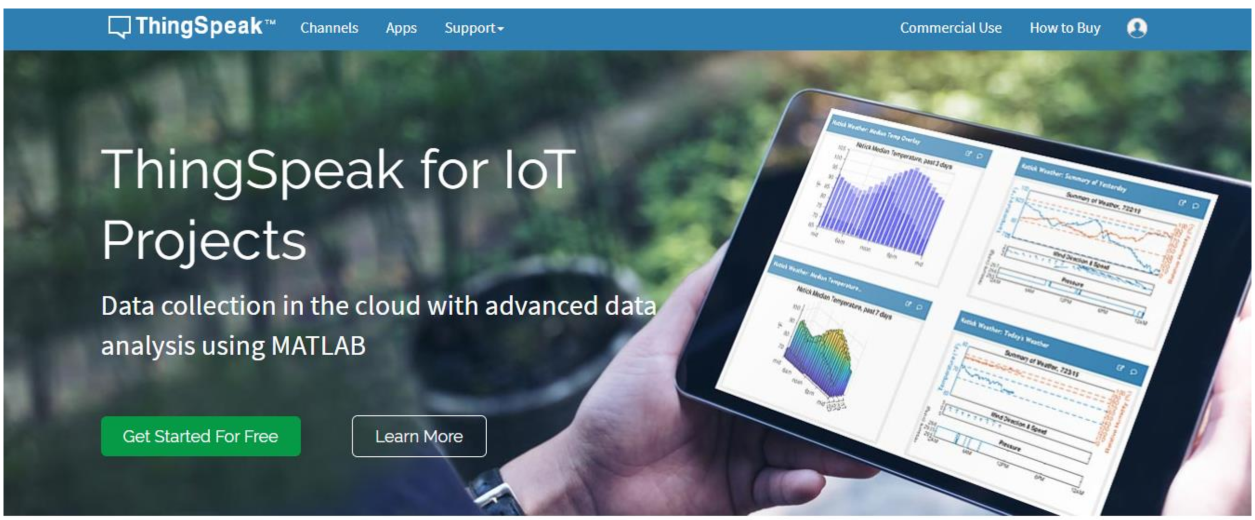


Figure 5.3 : ThingSpeak API

In this project we are using thingspeak to send the data to the cloud and monitor the system from there. ThingSpeak is an open-source Internet of Things (IoT) application and API to store and retrieve data from things using the HTTP and MQTT protocol over the Internet or via a Local Area Network. ThingSpeak enables the creation of sensor logging applications, location tracking applications, and a social network of things with status updates".

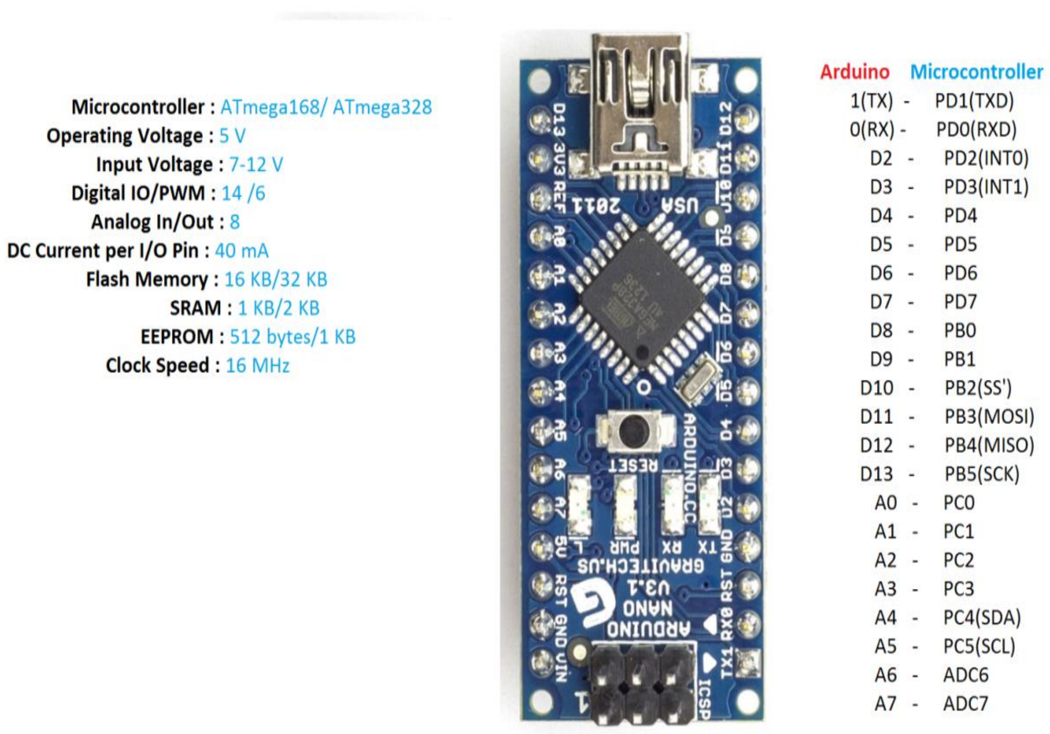
5.3 Hardware Description

The following hardware components are used in this project:

1. Arduino Nano

The high-performance Atmel 8-bit AVR RISC-based microcontroller combines 32KB ISP flash memory with read-while-write capabilities, 1KB EEPROM, 2KB SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/D converter (8-channels in TQFP and QFN/MLF packages), programmable watchdog timer with internal oscillator, and five software selectable power saving modes. The device operates between 1.8-5.5 volts.By executing powerful instructions in a single clock cycle, the device achieves throughputs approaching 1 MIPS per MHz, balancing power consumption and processing speed.

The figure below shows the microcontroller used in this project:



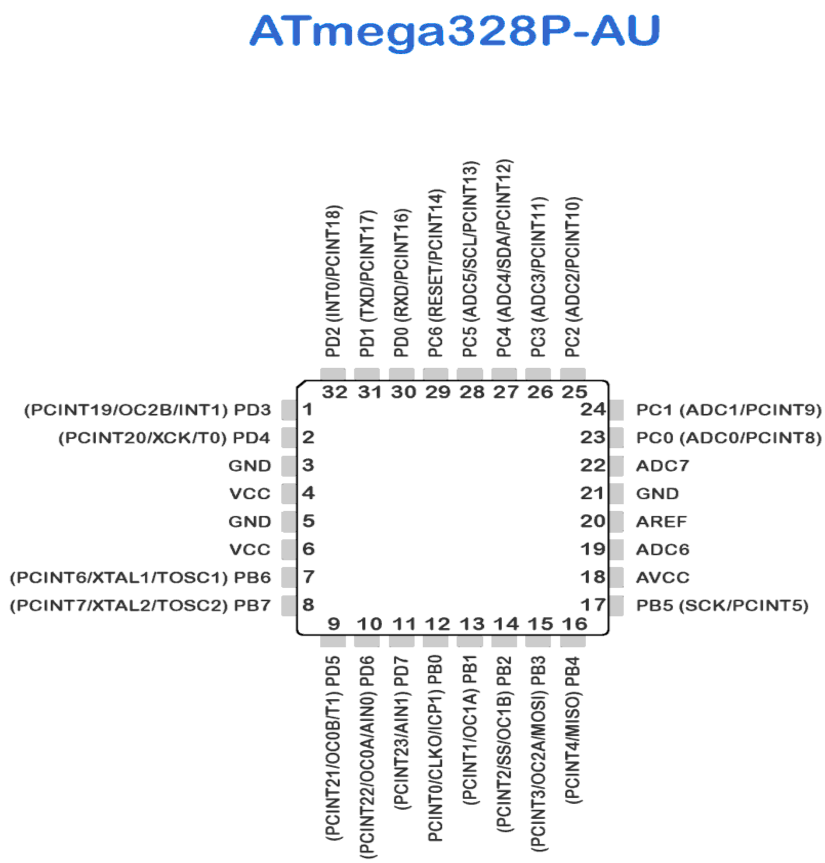


Figure 5.4 : Arduino Nano and microcontroller

1.I2C module

To connect LCD display 16×2 or 20×4 to Arduino you know you'll need at least 6 wires to connect, it means sacrificing some IO's that could be used for connecting other components such as sensors or motors. another way is to use 74HC595 Shift register for interfacing.

In the module left side we have 4 pins, and two are for power (Vcc and GND), and the other two are the interface I2C (SDA and SCL) . The plate pot is for display contrast adjustment, and the jumper on the opposite side allows the back light is controlled by the program or remain off for power saving. By default the module is configured with the address 0x27 , but you can change this address using the pins A0, A1 and A2 Jumper settings.

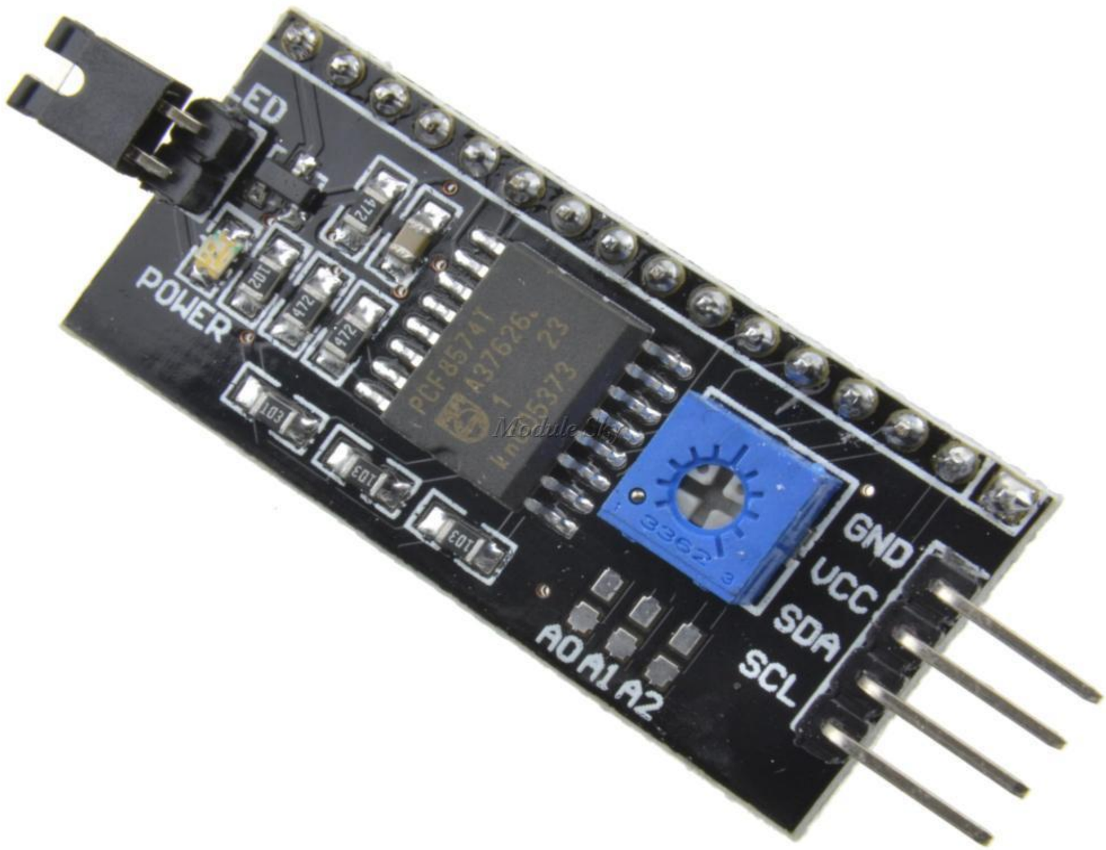


Figure 5.5 : 1.I2C module

2. LCD display

The liquid-crystal display has the distinct advantage of having a low power consumption than the LED. It is typically of the order of microwatts for the display in comparison to the some order of milliwatts for LEDs. Low power consumption requirement has made it compatible with MOS integrated logic circuit. Its other advantages are its low cost, and good contrast. The main drawbacks of LCDs are additional requirement of light source, a limited temperature range of operation (between 0 and 60° C), low reliability, short operating life, poor visibility in low ambient lighting, slow speed and the need for an ac drive.

A liquid crystal cell consists of a thin layer (about 10 u m) of a liquid crystal sandwiched between two glass sheets with transparent electrodes deposited on their inside faces. With both glass sheets transparent, the cell is known as *transmittive type cell.* When one glass is transparent and the other has a reflective coating, the cell is called *reflective type.* The LCD does not produce any illumination of its own. It, in fact, depends entirely on illumination falling on it from an external source for its visual effect.

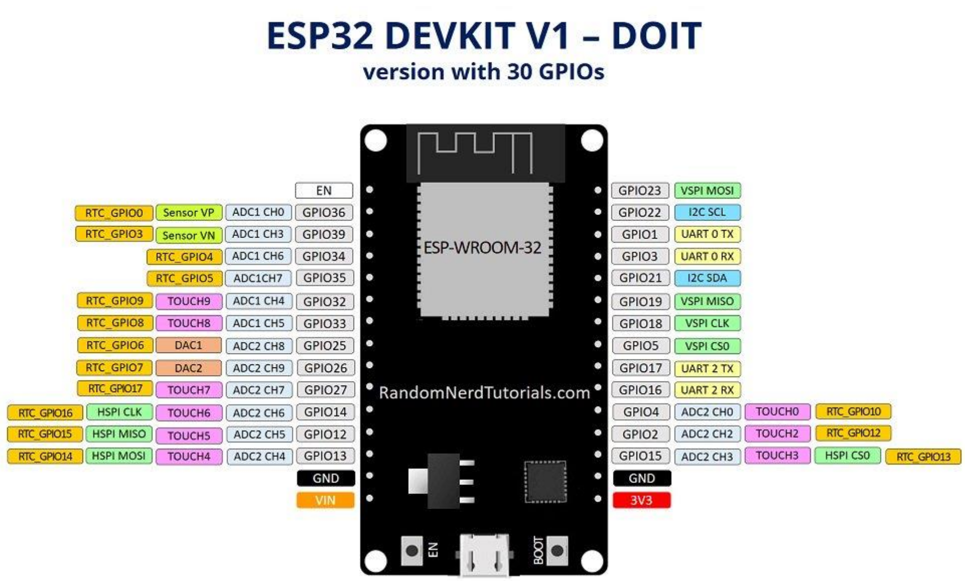
Figure 5.6 : LCD display

3. ESP32 Development Board

ESP32 is a series of low-cost, low-power system on a chip microcontrollers with integrated Wi-Fi and dual-mode Bluetooth. The ESP32 series employs a Tensilica Xtensa LX6 microprocessor in both dual-core and single-core variations and includes built-in antenna switches, RF balun, power amplifier, low-noise receive amplifier, filters, and power-management modules. ESP32 is created and developed by Espressif Systems, a Shanghai-based Chinese company, and is manufactured by TSMC using their 40 nm process. It is a successor to the ESP8266 microcontroller. NodeMCU is famous for the ESP8266E module with LUA programming language. Now this is more powerful NodeMCU with ESP32 on it.

Figure 5.7 : ESP32 Development Board

ESP32 is the big brother of ESP8266. It comes with dual core 32-bit processor, built-in WiFi and Bluetooth, more RAM and Flash memory, more GPIO, more ADC, and many other peripherals. NodeMCU ESP32 is ESP-WROOM-32 module in breadboard friendly form factor, you can develop your project in using this compact microcontroller on breadboard.



Features:

- NodeMCU based on ESP-WROOM-32 module
- Based on ESP32 DEVKIT DOIT
- 30 GPIO Version
- ESP32 is a dual core 32-bit processor with built-in 2.4 GHz Wi-Fi and Bluetooth
- 4MByte flash memory
- 520KByte RAM
- 2.2 tp 3.6V Operating voltage range
- In breadboard friendly breakout
- USB microB for power and Serial communication, use to load program and serial debugging too

4. Light Intensity sensor

The light sensor circuit is a simple electrical circuit, which can be used to control the (switch on and off) electrical load appliances like lights, fans, coolers, air conditioners, street lights, etc., automatically. By using this light sensor circuit, we can eliminate manual switching as the loads can be controlled automatically based on the daylight intensity. Hence, we can describe it as an automatic light sensor.

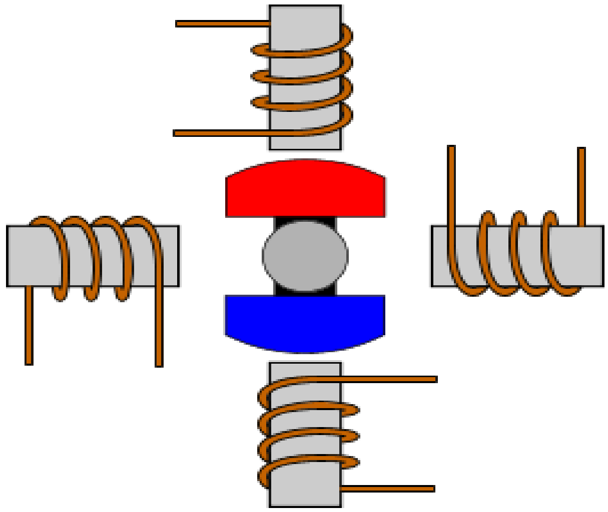
The light sensor circuit helps to evade the manual control of the street lights erected on highways which is risky and also causes wastage of power. The light sensor circuit consists of major electrical and electronic components such as light sensor, Darlington pair, and relay. To understand the working operation of the light sensor circuit, we must know a brief about the components used in designing the light sensor circuit.

There are different types of light sensors available such as photoresistors, photodiodes, photovoltaic cells, phototubes, photomultiplier tubes, phototransistors, charge coupled devices, and so on. But, LDR (Light Dependent Resistor or photoresistor) is used as a light sensor in this light sensor circuit. These LDR sensors are passive and doesn't produce any electrical energy.

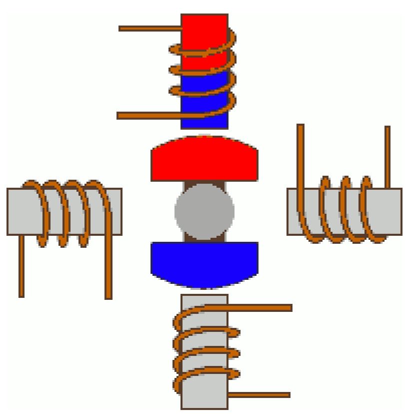
5. Stepper Motors:

First of all, a stepper motor is a motor. This means, that it converts electrical power into mechanical power. The main difference between them and all the other motors, is the way they revolve. Unlike other motors, stepper motors does not continuously rotate! Instead, they rotate in steps (from which they got the name). Each step is a fraction of a full circle. This fraction depends mostly from the mechanical parts of the motor, and from the driving method. The stepper motors also differs in the way they are powered. Instead of an AC or a DC voltage, they are driven (usually) with pulses. Each pulse is translated into a degree of rotation. For example, an 1.8o stepper motor, will revolve its shaft 1.8o on every pulse that arrives. Often, due to this characteristic, stepper motors are called also digital motors.

As all motors, the stepper motors consists of a stator an a rotor. The rotor carries a set of permanent magnets, and the stator has the coils. The very basic design of a stepper motor would be as follows:

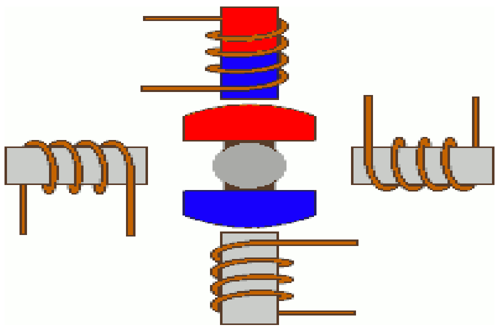


There are 4 coils with 90o angle between each other fixed on the stator. The way that the coils are interconnected, will finally characterize the type of stepper motor connection. In the above drawing, the coils are not connected together. The above motor has 90o rotation step. The coils are activated in a cyclic order, one by one. The rotation direction of the shaft is determined by the order that the coils are activated. The following animation demonstrates this motor in operation. The coils are energized in series, with about 1sec interval. The shaft rotates 90o each time the next coil is activated:



Wave drive or Single-Coil Excitation

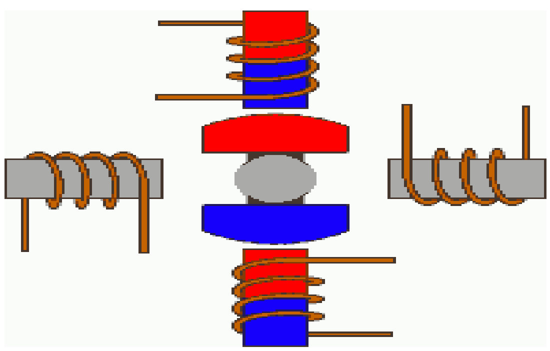
The first way is the one described previously. This is called Single-Coil Excitation, and means that only one coil is energized each time. This method is rarely used, generally when power saving is necessary. It provides less than half of the nominal torque of the motor, therefore the motor load cannot be high.



This motor will have 4 steps per full cycle, that is the nominal number of steps per cycle.

Full step drive

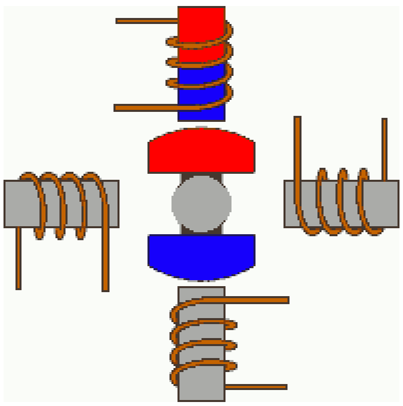
The second and most often used method, is the Full step drive. According to this method, the coils are energized in pairs. According to the connection of the coils (series or parallel) the motor will require double the voltage or double the current to operate that needs when driving with Single-Coil Excitation. Yet, it produces 100% the nominal torque of the motor.



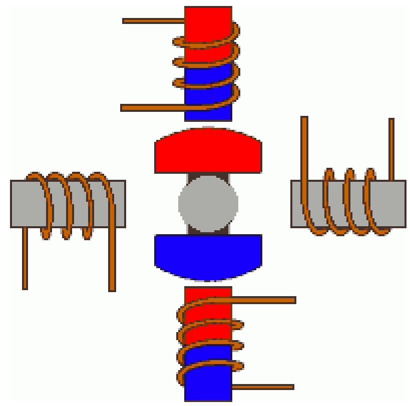
This motor will have 4 steps per full cycle, that is the nominal number of steps per cycle.

Half stepping

This is a very interesting way to achieve double the accuracy of a positioning system, without changing anything from the hardware! According to this method, all coil pairs can be energized simultaneously, causing the rotor to rotate half the way as a normal step. This method can be single-coil or two-coil excitation as well. The following animations make this clear:



Single-Coil excitation

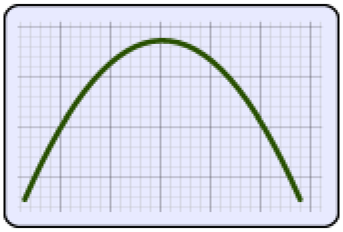


Two-Coil excitation

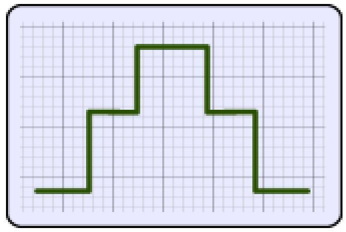
With this method, the same motor will have double the steps per revolutions, thus double the accuracy in positioning systems. For example, this motor will have 8 steps per cycle!

6. Microstepping

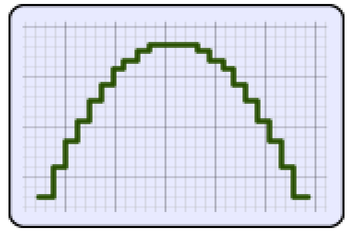
Microstepping is the most common method to control stepper motors nowadays. The idea of microstepping, is to power the coils of the motor NOT with pulses, but with a waveform similar to a sin waveform. This way, the positioning from one step to the other is smoother, making the stepper motor suitable to be used for high accuracy applications such as CNC positioning systems. Also, the stress of the parts connected on the motor, as well as the stress on the motor itself is significantly decreased. With microstepping, a stepper motor can rotate almost continuous, like simple DC motors.The waveform that the coils are powered with, is similar to an AC waveform. Digital waveforms can also be used. here are some examples:



Powering with sine wave

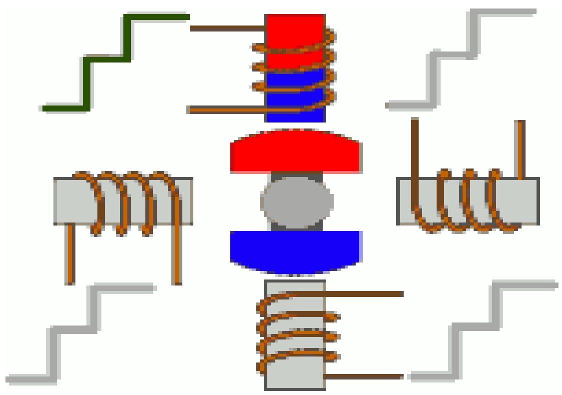


Powering with digital signal



Powering with high resolution digital signal

The microstepping method is actually a power supply method, rather than coil driving method. Therefore, the microstepping can be applied with single-coil excitation and full step drive. The following animation demonstrated this method:



Although it seems that the microstepping increases the steps even further, usually this does not happen. In high accuracy applications, trapezoidal gears are used to increase the accuracy. This method is used to ensure smooth motion.In this project Nema 17 stepper motors with micro stepping are used.

7. A4988 Stepper Motor Driver:

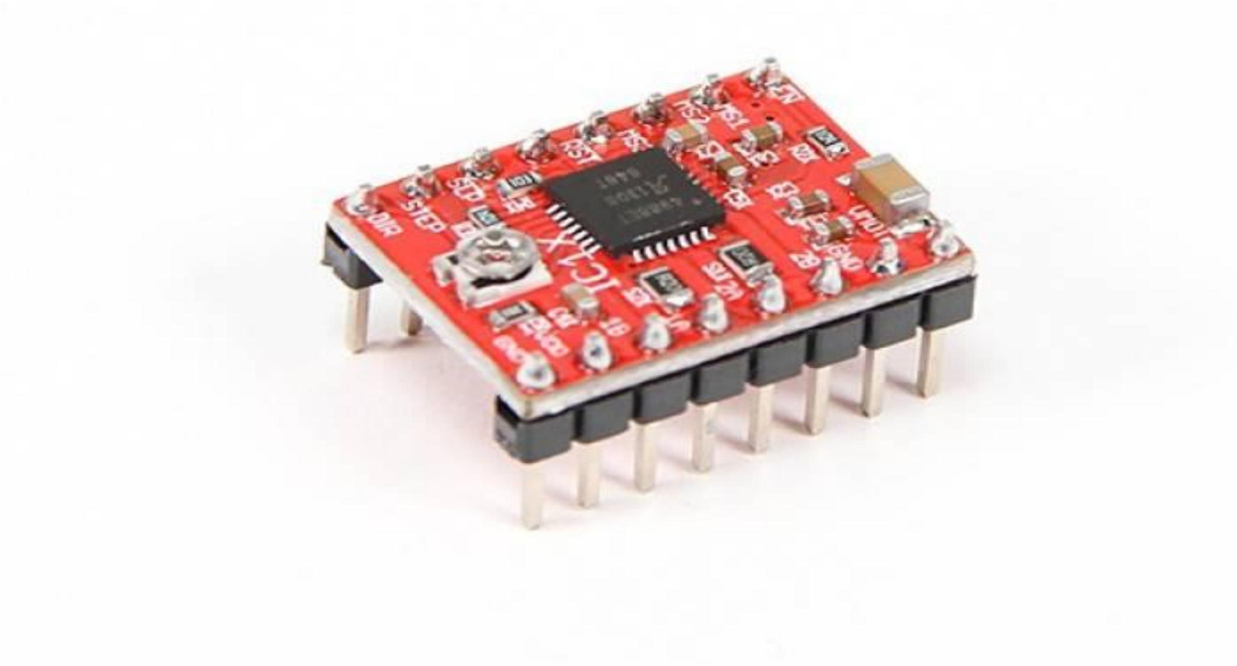


Figure 5.8 : A4988 Stepper Motor Driver

The A4988 driver Stepper Motor Driver is a complete micro-stepping motor driver with built-in converter, easy to operate. It operates from 8 V to 35 V and can deliver up to approximately 1 A per phase without a heat sink or forced air flow (it is rated for 2 A per coil with sufficient additional cooling).

A4988 driver Stepper Motor Driver includes a fixed off-time current regulator, the regulator can be in slow or mixed decay mode. The converter is the key to the easy implementation of the A4988.

There are no phase sequence tables, the high-frequency control interface programming etc. The application of A4988 interface is very suitable for a complex microprocessor is not available or overload. In the stepping operation, the chopping control in the A4988 automatically selects the current decay mode (slow or mixed). The mix decay current control scheme can reduce the audible motor noise, increased step accuracy, and reduced power consumption.

Provide internal synchronous rectification control circuitry, in order to improve the pulse width modulation (PWM) power consumption during operation.

Internal circuit protection includes thermal shutdown with hysteresis, under-voltage lockout (UVLO) and crossover current protection. Don’t need special power-up sequencing. A4988 uses surface mount QFN package (ES), the size is 5 mm × 5 mm, nominal overall package height is 0.90 mm, with an exposed thermal pad to enhance the heat dissipation function.

8.Voltage Sensor:

Voltage sensor consists of a voltage divider configuration to monitor the battery voltage. We are using two resisters in voltage divider configuration to make a voltage sensor.

9.Battery

The battery or power supply unit provides the required power to the entire system. As the goal of this project was to make this trolley portable and automated, it was necessary to choose an appropriate power system which could supply the requisite amount of the power to the entire system. The battery chosen for this project was 12 V, 1.2 AH battery. This can continuously supply a current of 1.2 Amp for one hour.

(12 V, 1.2AH battery)

The specifications of the battery are as follows:

Sl. No	Parameter	Value
1	Voltage	12 V
2	Current	1.2 Amp
3	Power	1.44 Watt

Table 5.1: battery specifications

RTC

The RTC is used to keep a track of time while reporting to IOT station. The RTC module used is DS1307 RTC. Real time clocks (RTC), as the name recommends are clock modules. The DS1307 real time clock (RTC) IC is an 8 pin device using an I2C interface. The DS1307 is a low-power clock/calendar with 56 bytes of battery backup SRAM. The clock/calendar provides seconds, minutes, hours, day, date, month and year qualified data. The end date of each month is automatically adjusted, especially for months with less than 31 days.

Pin Description of DS1307:

Pin 1, 2: Connections for standard 32.768 kHz quartz crystal. The internal oscillator circuitry is intended for operation with a crystal having a specified load capacitance of 12.5pF. X1 is the input to the oscillator and can alternatively be connected to an external 32.768 kHz oscillator. The output of the internal oscillator, X2 is drifted if an external oscillator is connected to X1.

Pin 3: Battery input for any standard 3V lithium cell or other energy source. Battery voltage should be between 2V and 3.5V for suitable operation. The nominal write protect trip point voltage at which access to the RTC and user RAM is denied is set by the internal circuitry as 1.25 x VBAT nominal. A lithium battery with 48mAhr or greater will backup the DS1307 for more than 10 years in the absence of power at 25ºC. UL recognized to ensure against reverse charging current when utilized as a part of conjunction with a lithium battery.

Pin 4: Ground.

Pin 5: Serial data input/output. The input/output for the I2C serial interface is the SDA, which is open drain and requires a pull up resistor, allowing a pull up voltage upto 5.5V. Regardless of the voltage on VCC.

Pin 6: Serial clock input. It is the I2C interface clock input and is used in data synchronization.

Pin 7: Square wave/output driver. When enabled, the SQWE bit set to 1, the SQW/OUT pin outputs one of four square-wave frequencies (1Hz, 4 kHz, 8 kHz, and 32 kHz). This is also open drain and requires an external pull-up resistor. It requires application of either Vcc or Vb at to operate SQW/OUT, with an allowable pull up voltage of 5.5V and can be left floating, if not used.

Pin 8: Primary power supply. When voltage is applied within normal limits, the device is fully accessible and data can be written and read. When a backup supply is connected to the device and VCC is below VTP, read and writes are inhibited. However at low voltages, the timekeeping function still functions.

5.4 Pseudo Code

This section deals with pseudo code used in the project.

THE IOT MEDICINE REMINDER

```
Function setup(){
        Set all Sensors are Inputs
          Set LCD  Output
          Enable WiFi
          Connect to Internet
          Initialize Tracking system
          Initialize Cleaning System
          Position Tracker to Base position
End
}
Function loop()
{
          Read the Sensor data
          Position tracker to maximum incidence
          Read Dust levels
          IF(Dust Level>Threshold);
                    Start Cleaner
          Read Voltage, Current and Wind Pressure
          Send to Internet
END
}
```

CHAPTER 6

TESTING AND VALIDATION

Testing is a process, which reveals errors in program. It is the measure quality measure employed during software development. During testing, the program is executed with a set of conditions known as test cases and output is evaluated to determine whether the program is performing as expected. The Primary and Larger objective of testing is to deliver quality software. Quality software is one that is devoid of errors and meets with a customer's stated requirements.

If errors are found then the software must be debugged to locate these errors in the various programs. Corrections are then made. The program/system must be tested once again after corrections have been implemented – this time with an additional objective of finding out whether or not corrections in one part of system have introduced any new errors elsewhere in the system.

Once all errors are found, then another objective must be accomplished that is check whether or not the system is doing what it is supposed to do. So another aspect of testing is that it must also ensure that the system meets with user requirements.

Techniques of testing are given below:

- Black Box Testing
- White Box Testing
- Equivalence Portioning
- Boundary Value Analysis
- Ad-hoc Testing

Testing Strategies

A testing strategy is a general approach to the testing process rather than a method of devising particular system or components tests. Different strategies may be adopted depending on the type of system to be tested and the development process used.

The testing strategies which discuss in this are:

- **Top-down testing** where testing starts with the most abstract component and works downwards .
- **Bottom-up testing** where testing starts with the fundamental components and works upwards.
- **Thread testing** which is used for systems with multiple processes where the processing of transaction threads its way through these processes.
- **Stress testing** which relies on stressing the system by going beyond its specified limits and hence testing how well the system can cope with over-load situations.
- **Back-to-back testing** which is used when versions of system are available the system are tested together and their outputs are compared.

Large systems are usually tested using a mixture of these testing strategies rather than any approach. Different strategies may be needed for different parts of the system and at different stages in the testing process. Whatever testing strategy is adopted, it is always sensible to adopt an incremental approach to sub-system and system testing. Number of software testing strategies is proposed. Testing begins at the module/well and works “outward” towards the integration of the entire computer based system. Different testing techniques are appropriate at different point of time. The developer of the software and independent test group conducts testing. Testing and debugging must be accommodated in any testing strategy.

6.1 Unit Testing

Unit Testing is a level of software testing where individual units/ components of a software are tested. The purpose is to validate that each unit of the software performs as designed. A unit is the smallest testable part of software. It usually has one or a few inputs and usually a single output. In procedural programming a unit may be an individual program, function, procedure, etc. In object-oriented programming, the smallest unit is a method, which may belong to a base/ super class, abstract class or derived/ child class. (Some treat a module of an application as a unit. This is to be discouraged as there will probably be many individual units within that module.) Unit Testing is normally performed by software developers themselves or their peers. In rare cases it may also be performed by independent software testers.

6.2 Acceptance Testing

Acceptance Testing is a level of the software testing where a system is tested for acceptability. The purpose of this test is to evaluate the system's compliance with the business requirements and assess whether it is acceptable for delivery.

Acceptance testing: Formal testing with respect to user needs, requirements, and business processes conducted to determine whether or not a system satisfies the acceptance criteria and to enable the user, customers or other authorized entity to determine whether or not to accept the system.

Usually, Black Box Testing method is used in Acceptance Testing. Testing does not normally follow a strict procedure and is not scripted but is rather ad-hoc. Acceptance Testing is performed after System Testing and before making the system available for actual use.

CHAPTER 7

IMPLEMENTATION

The implementation section describes the implementation of the project in details. This includes the hardware developed, Schematic Developed and PCB.

The hardware Developed:

The hardware development involves schematic and PCB development using Easy EDA software. The hardware is designed using the Easy EDA schematic capture and then the PCBs are fabricated to make the complete working of the project.

The printed circuit board (PCB) acts as a linchpin for almost all of today's modern electronics. If device needs to do some sort of computation-such as is the case even with the simple digital clock. Chances are there is the PCB inside of it. PCBs bring electronics to life by routing electrical signals where they need to go to satisfy all of the device's electronic requirements.

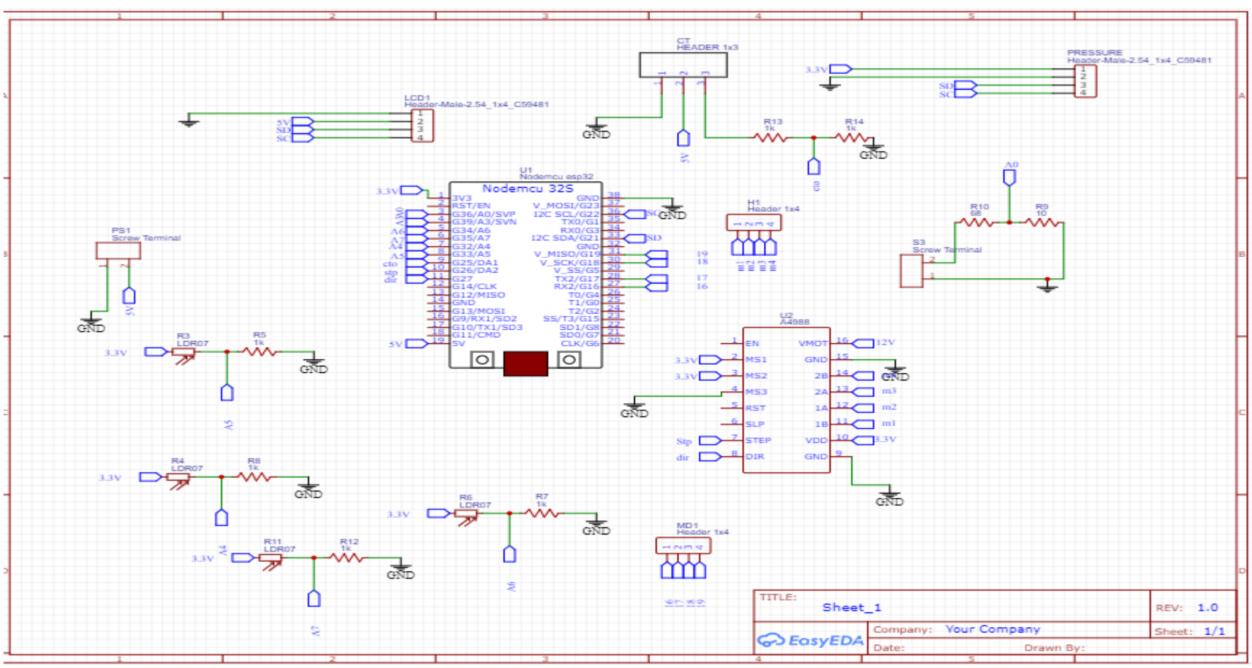
There are three main types of circuit boards that get manufactured on a consistent basis, and it's important to understand the differences between each so you can decide the right circuit board for your requirements. The three main types of circuit boards in current manufacture are:

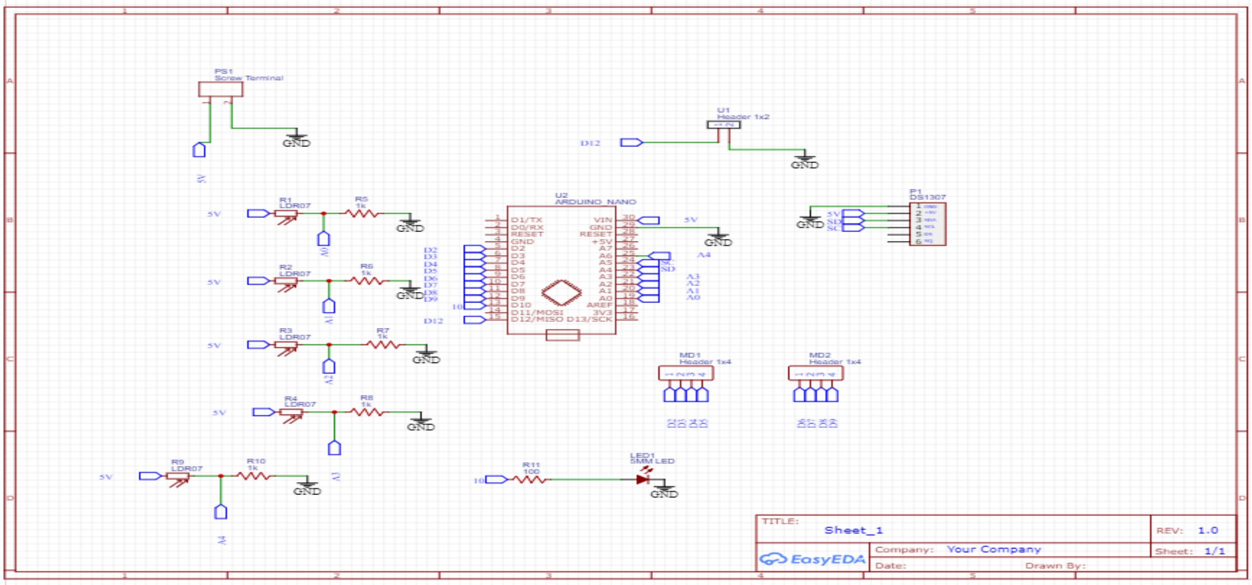
- **Single-Sided Circuit Boards:** These boards when made with a FR4 base have rigid laminate of woven glass epoxy material, which is then covered on one side with a copper coating that is applied in varying thicknesses depending on the application
- **Double-Sided Circuit Boards:** Double-sided boards have the same woven glass epoxy base as single-sided boards — however, in the case of a double-sided board, there is copper coating on both sides of the board, also to varying thicknesses depending on the application.
- **Multi-Layer Boards:** These use the same base material as single and double-sided boards, but are made with copper foil instead of copper coating — the copper foil is used to make "layers," alternating between base material and copper foil until the number of desired layers is reached.

Parts of PCB

- **Substrate:** The first, and most important, is the substrate, usually made of fiberglass. Fiberglass is used because it provides core strength to the PCB and helps resist breakage. Think of the substrate as the PCB's "skeleton".
- **Copper Layer:** Depending on the board type, this layer can either be copper foil or a full-on copper coating. Regardless of which approach is used, the point of the copper is still the same — to carry electrical signals to and from the PCB, much like your nervous system carries signals between your brain and your muscles.
- **Solder Mask:** The third piece of the PCB is the solder mask, which is a layer of polymer that helps protect the copper so that it doesn't short-circuit from coming into contact with the environment. In this way, the solder mask acts as the PCB's "skin".
- **Silk screen:** The final part of the circuit board is the silkscreen. The silkscreen is usually on the component side of the board used to show part numbers, logos, symbols switch settings, component reference and test points. The silkscreen can also be known as legend or nomenclature.

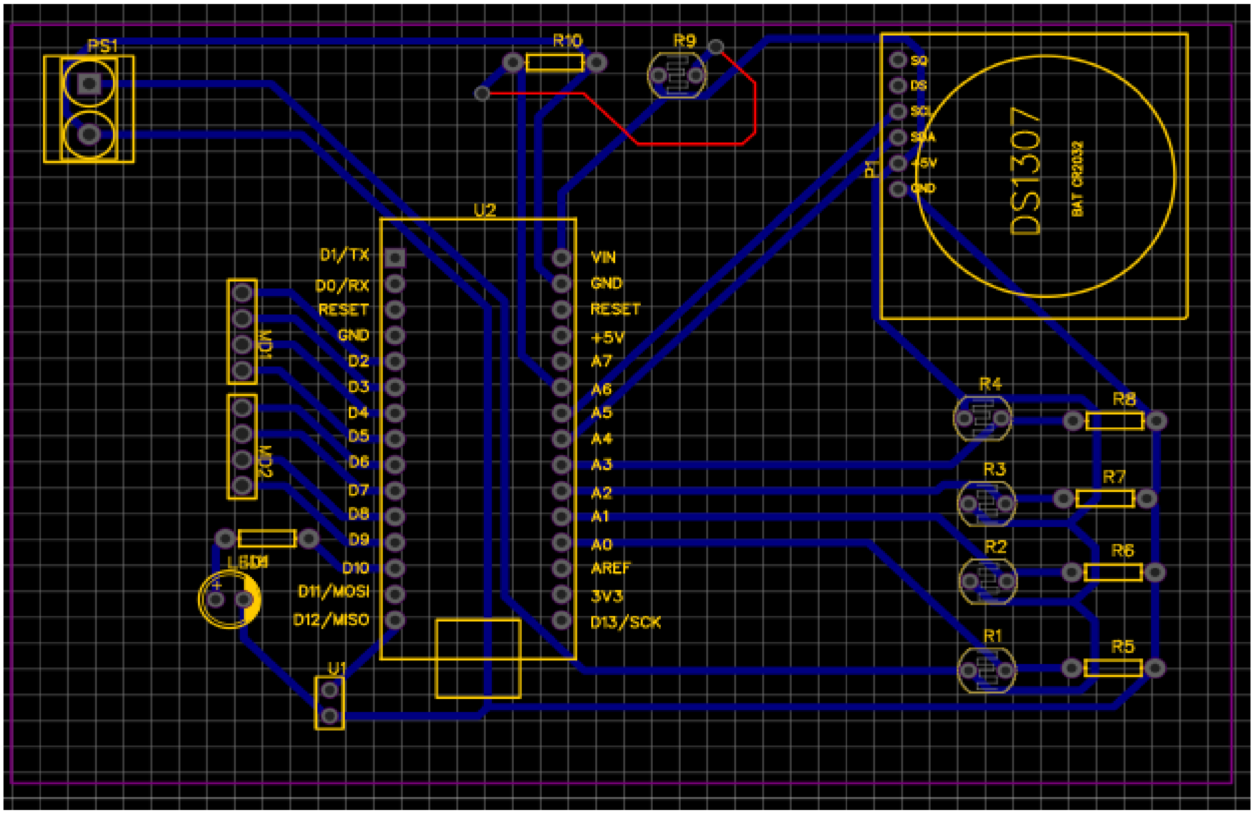
Schematic Developed:

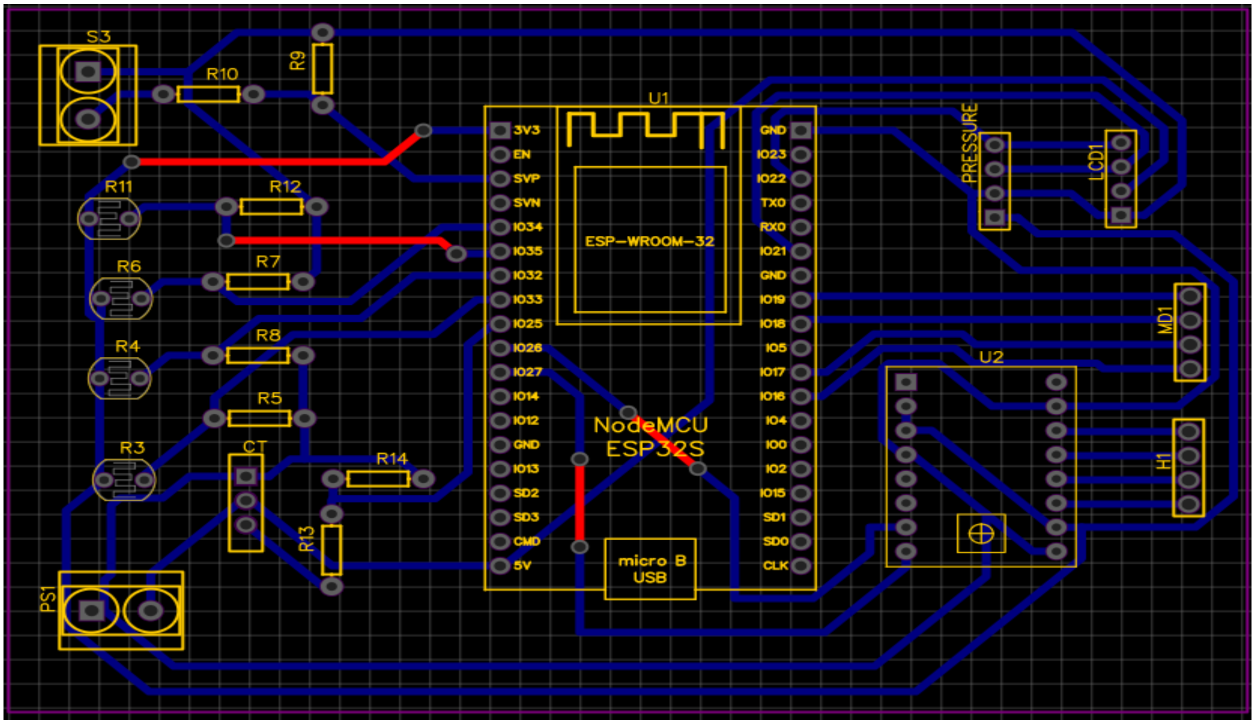




Circuit 7.1 : Schematic Developements

PCB Developed:





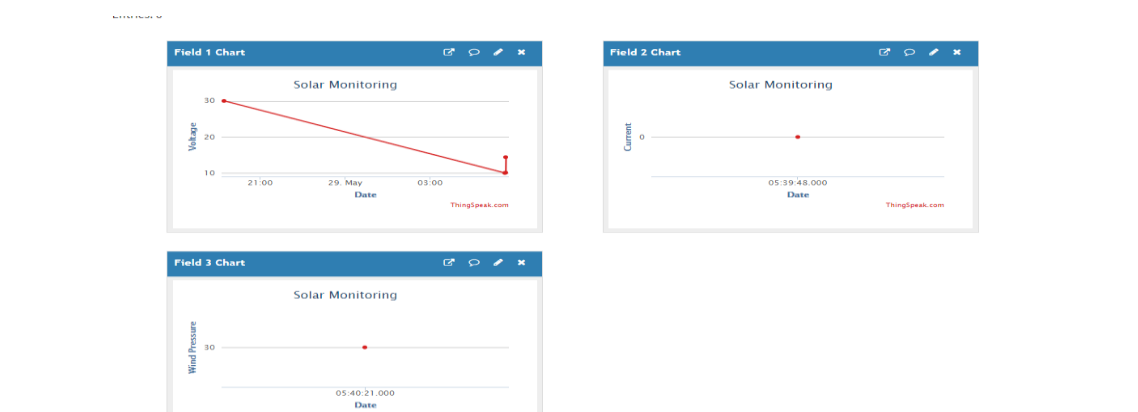
Circuit 7.2: PCB Developments

After the layout the hardware is fabricated on a CNC routing machine. The figure below shows the fabricated hardware.

Software API:

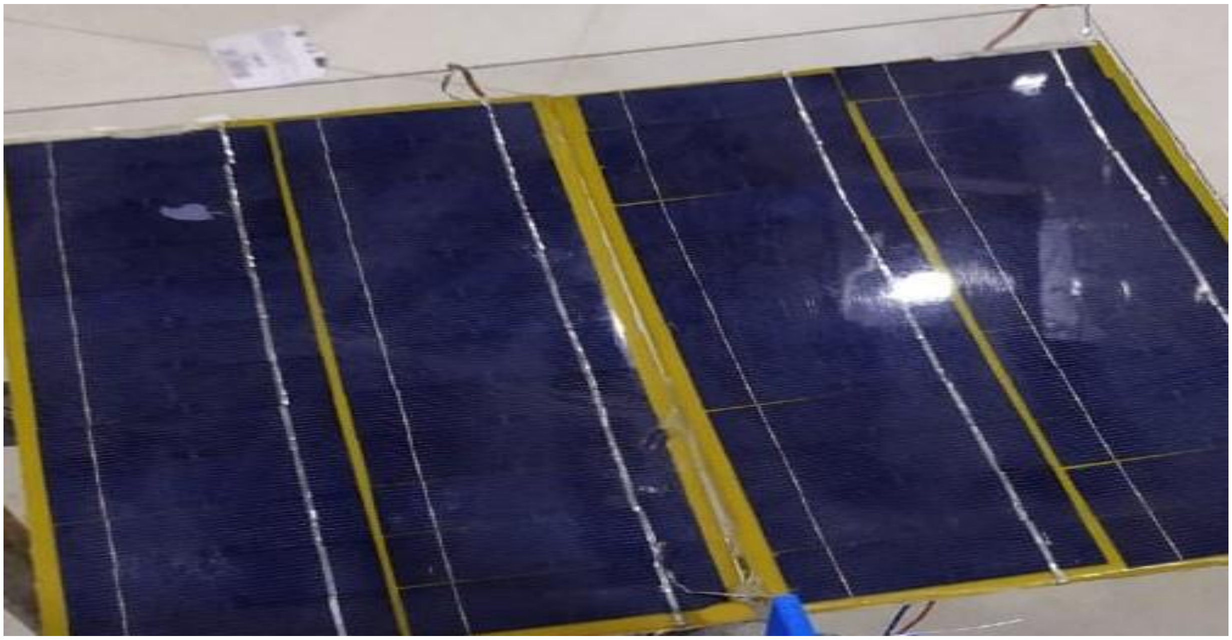
Complete Project:

The software API consists of calling the thingspeak API from the developed hardware and sending the data to the internet. The figure below shows the software API.



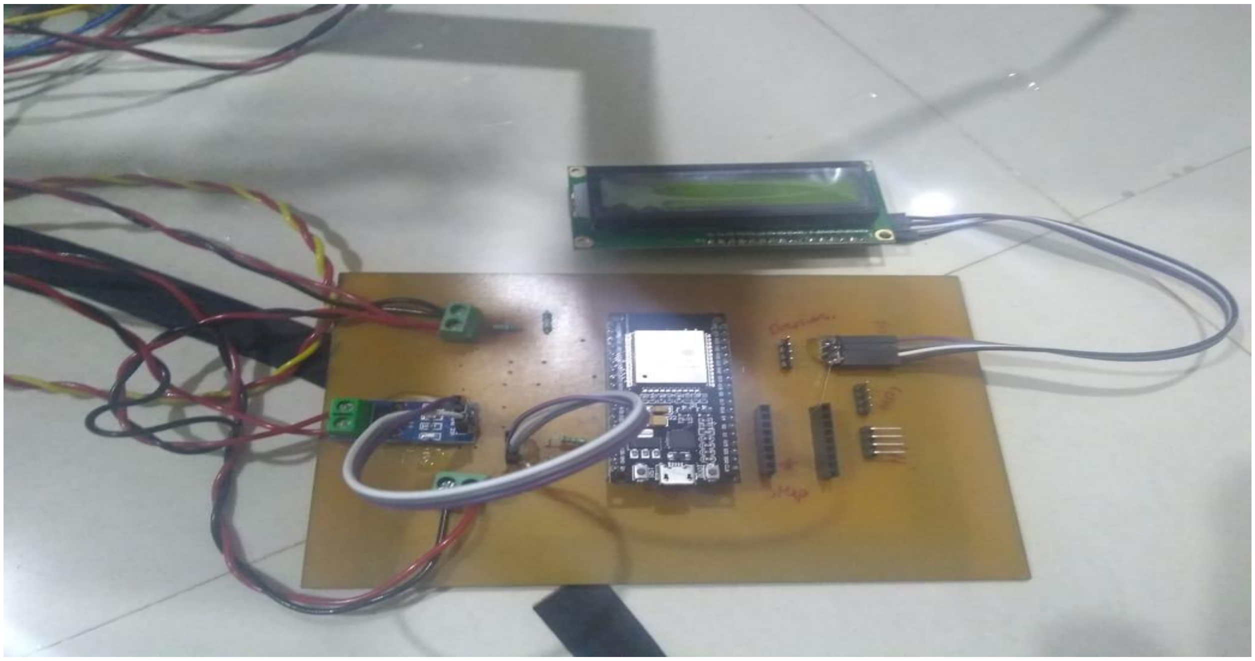
CHAPTER 8

SNAPSHOTS

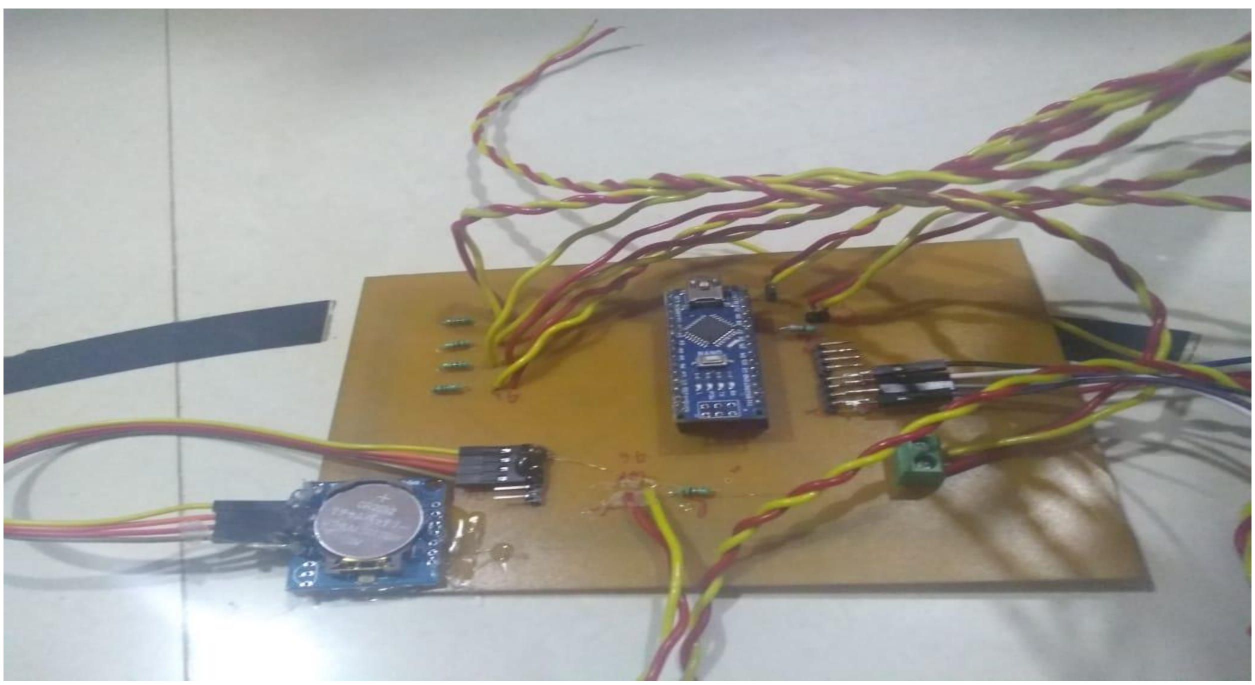


Snapshot 8.1: solar panels

Snapshot 8.2: sensor array

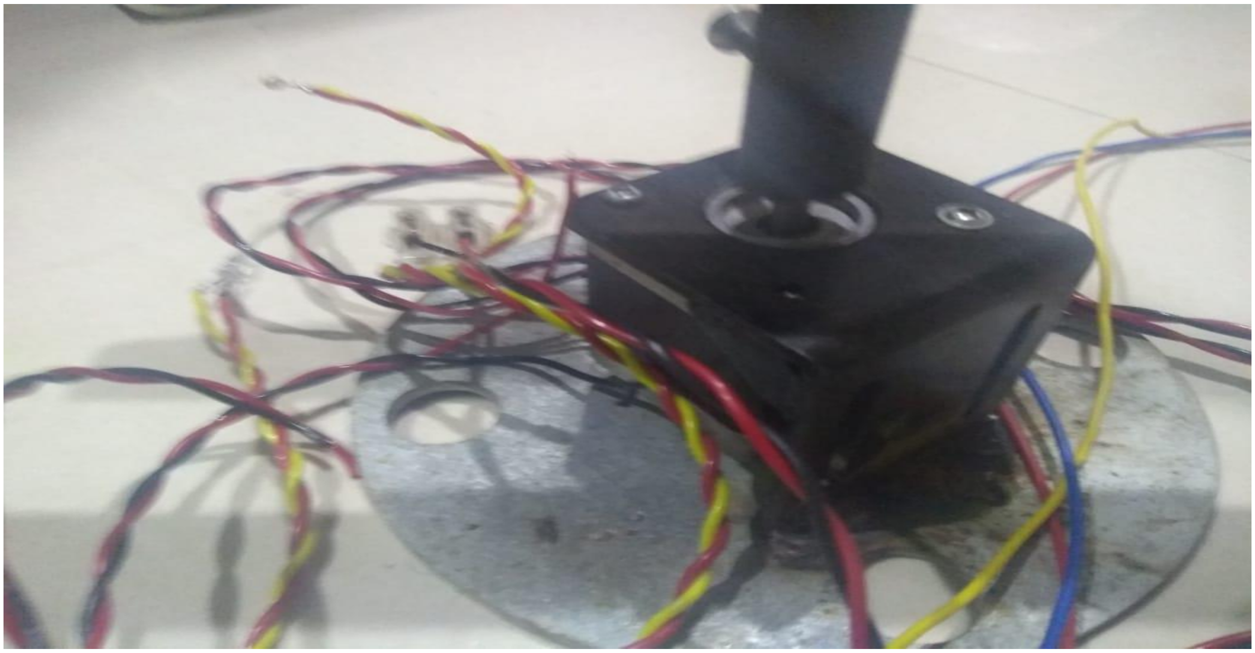


Snapshot 8.3: IoT power monitoring hardware

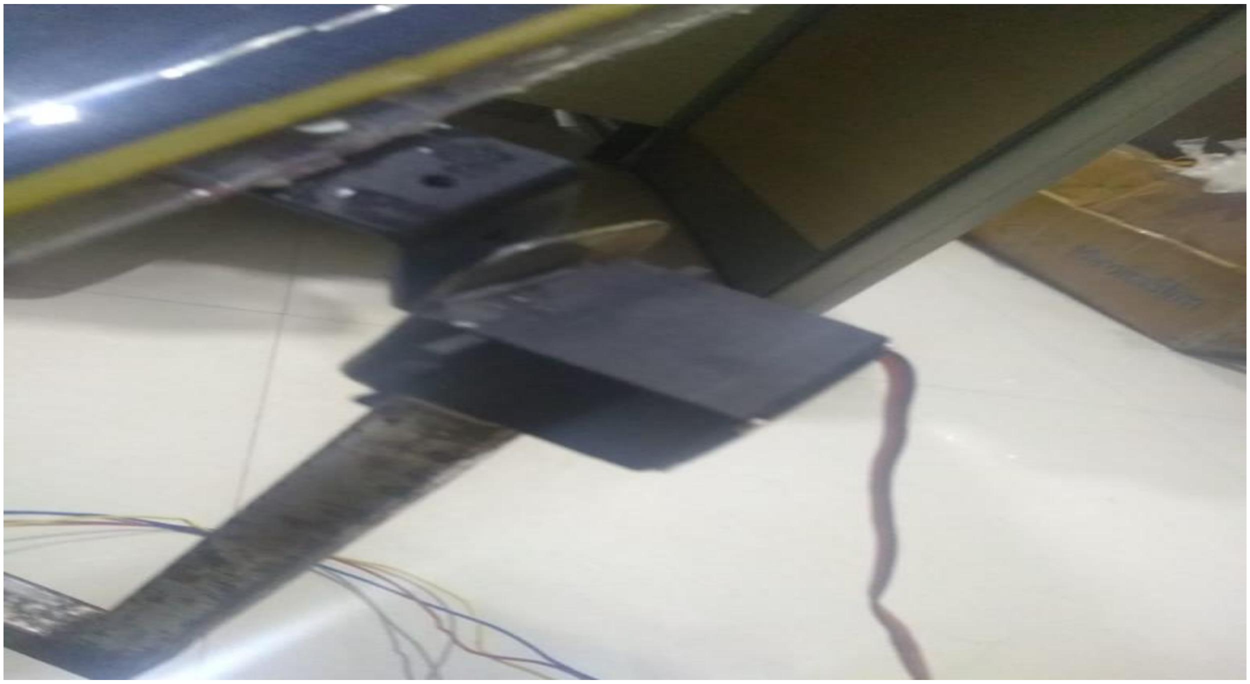


Snapshot 8.4: Tracking PCB with time and sensors

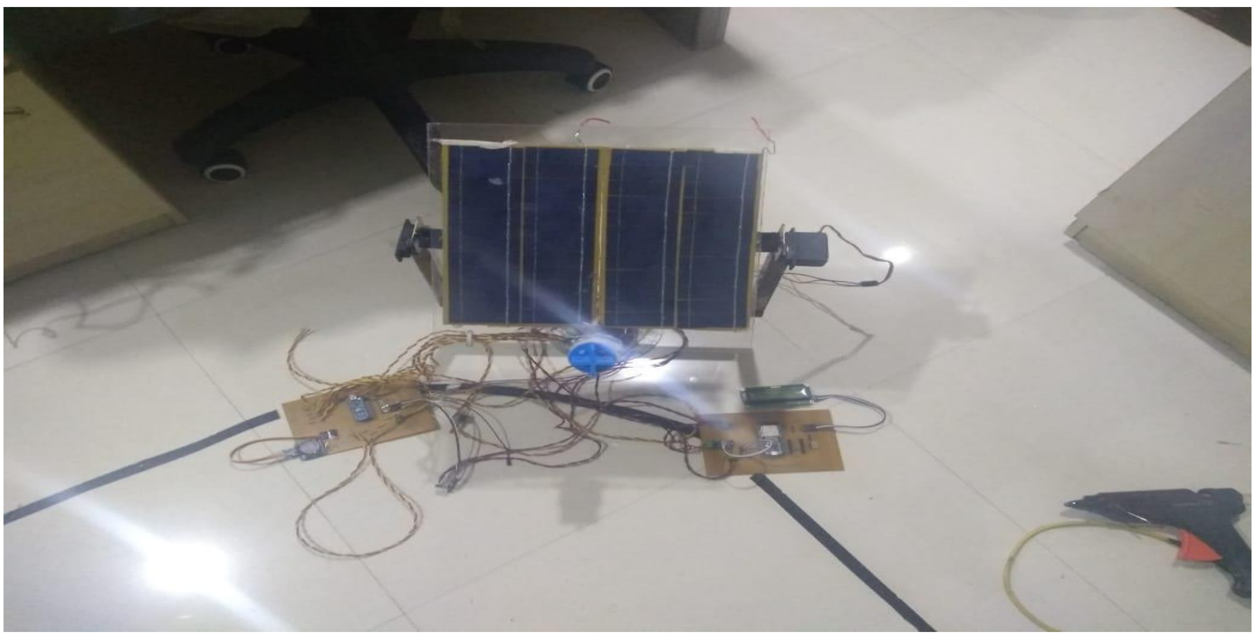
Snapshot 8.5: LCD display



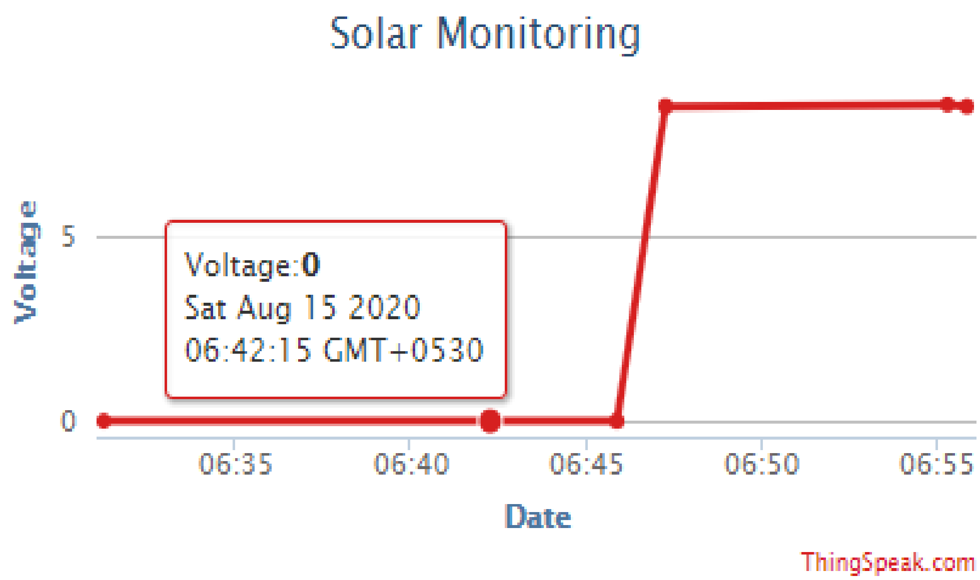
Snapshot 8.6: stepper motor



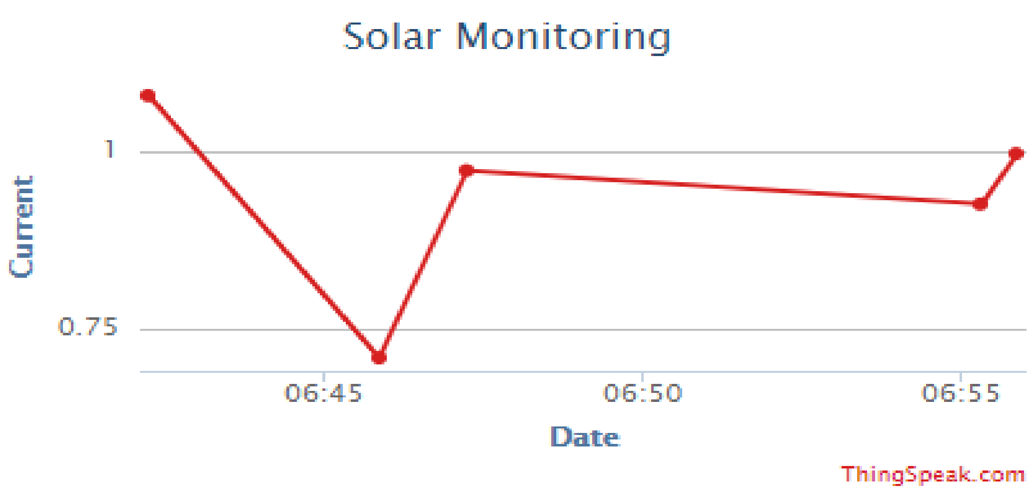
Snapshot 8.7 : Service motor for one axis



Snapshot 8.8: complete project



Snapshot 8.9: Voltage Graph panel

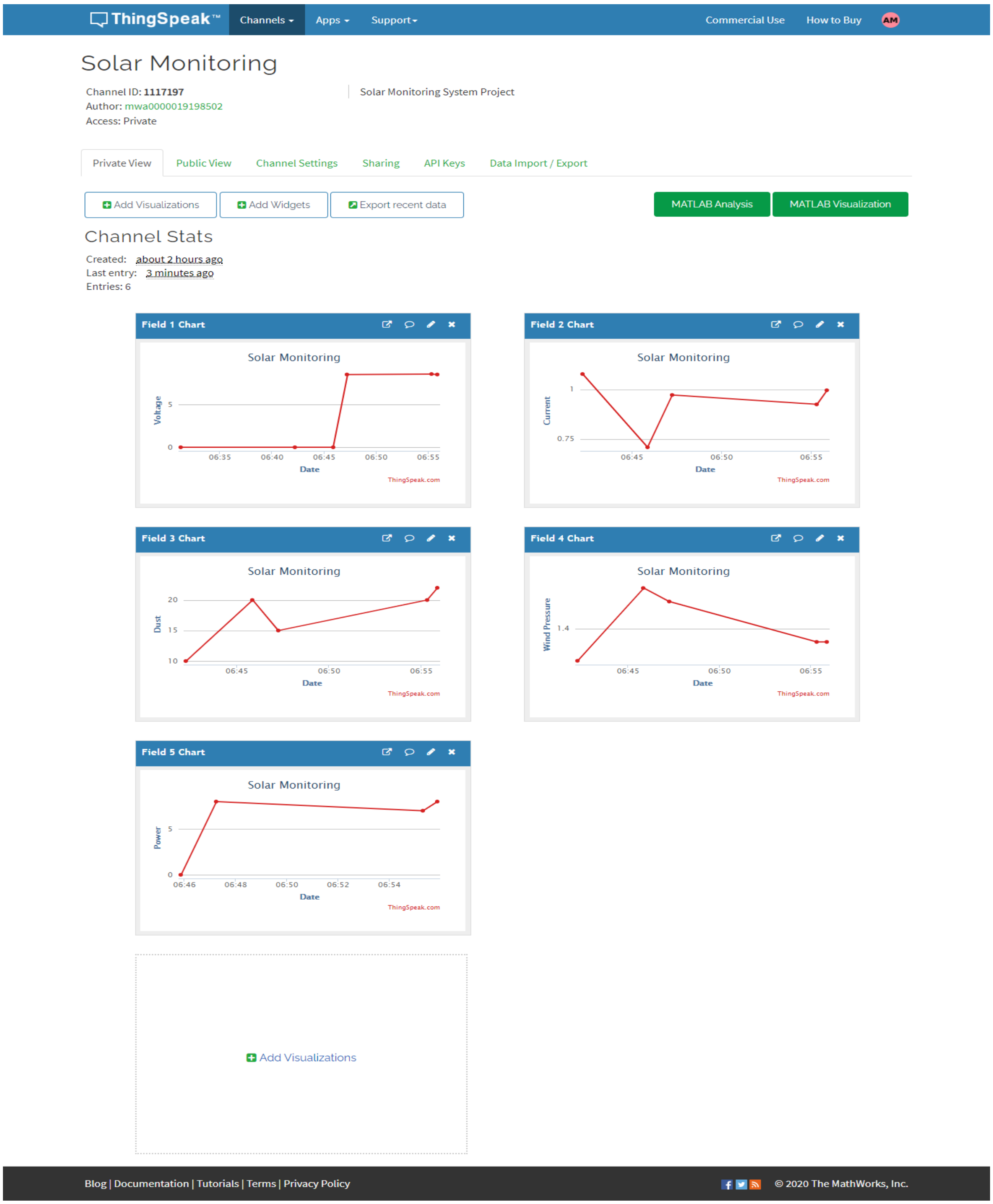


Snapshot 8.1: Current Graph Panel

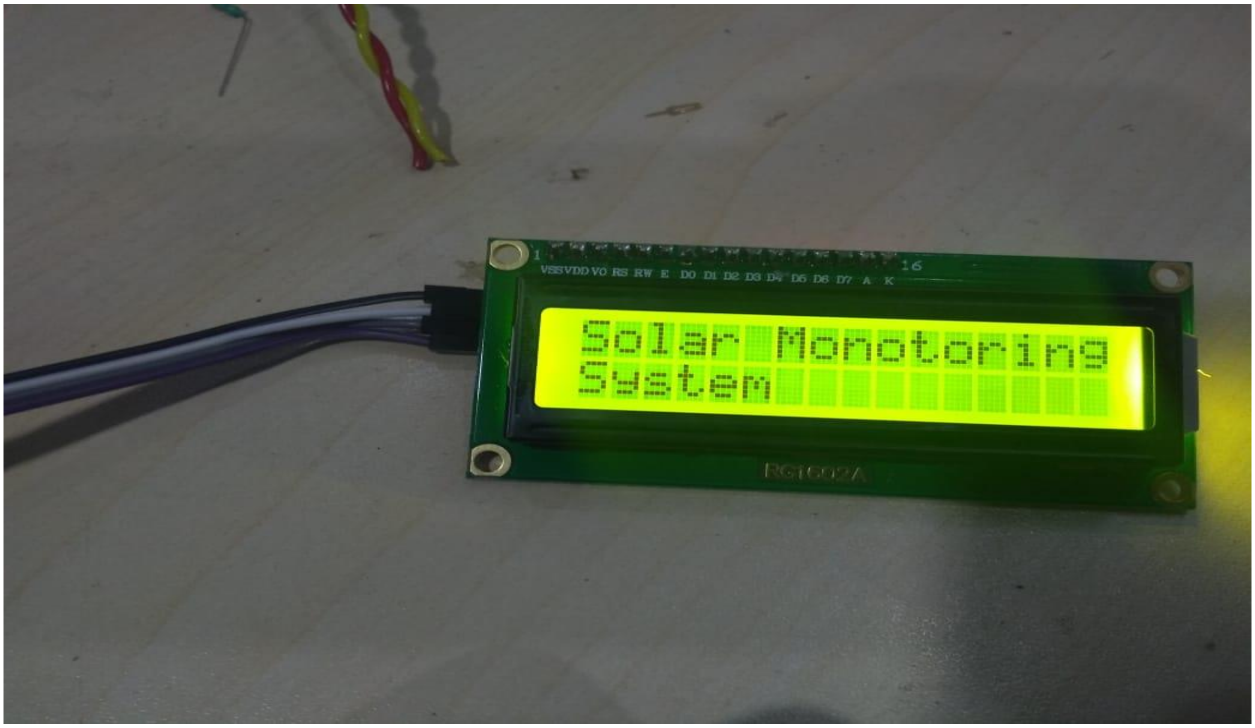
CHAPTER 9

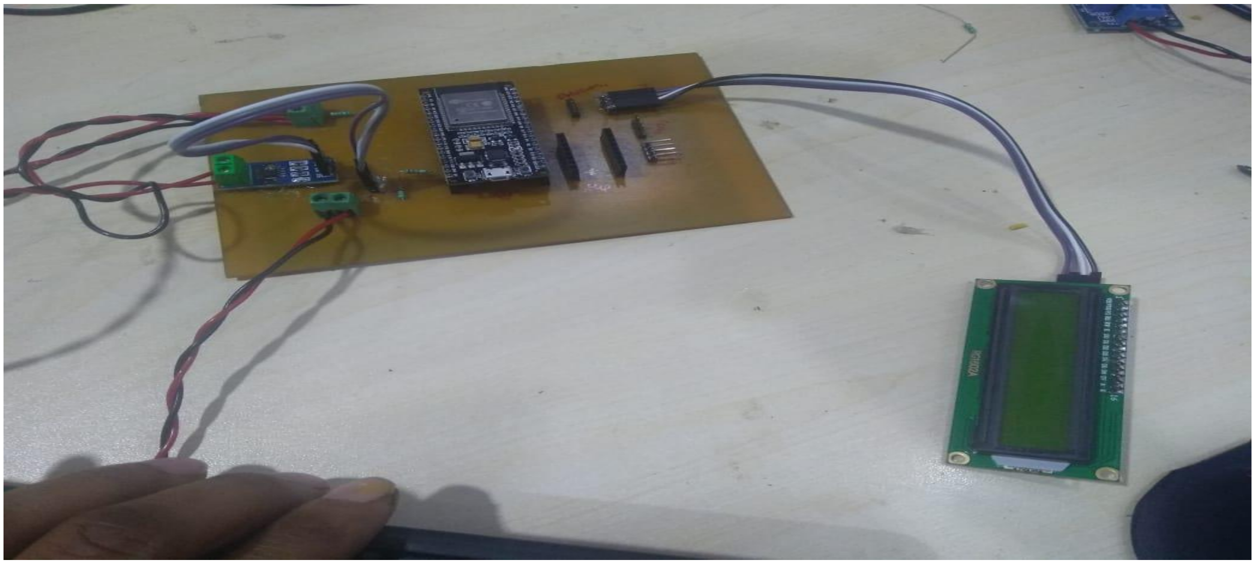
RESULT

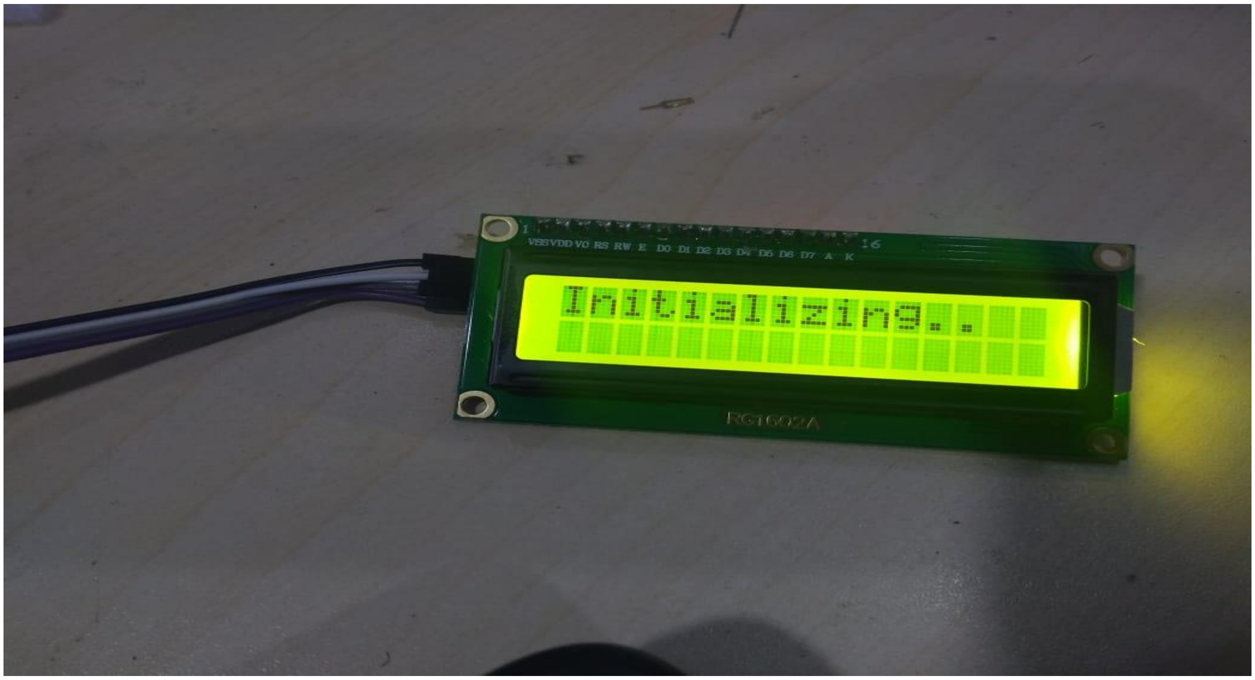
Complete Output of IOT solar Monitoring System:



Hardware Side Output:






VSS VDD V0 RS RW E D0 D1 D2 D3 D4 D5 D6 D7 A K
16
Initializing..
RG1602A

CONCLUSION

The proposed project consists of development of IOT based solar energy monitoring and tracking system. From the project we can conclude that the proposed project can help in efficient monitoring and control of solar energy using internet of things. The system provides the provision for the monitoring of the energy generated by the PV panels over internet of things. To maximize the energy the system also consists of tracking system which helps in harnessing the maximum energy. The dusty panel detecting and cleaning system will help to clean the dusty panels thereby maximing the energy. Thus the proposed project provides complete solution for IOT based solar energy monitoring and tracking system.

The project has wide scope for future modification. The project can be implemented on MPPT algorithms to track the maximum energy using control strategy of solar charge controller

CHAPTER 10

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