IOT BASED EV VEHICLE BATTERY FAULT DETECTION

A PROJECT REPORT

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INTERNAL EXAMINAR **EXTERNAL EXAMINAR**

DECLARATION

We affirm that the project work titled work titled **"IOT BASED EV VEHICLE BATTERY FAULT DETECTION "** is being submitted in partial fulfilment for the award of the degree of Bachelor of Engineering in Electronics and Communication Engineering is the record of original work by us under the guidance of Dr. T. Balamurugan M.E., Ph.D. It has not formed a part of any other project work submitted for the award of any degree or diploma, either in this or any other university.

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ABSTRACT

Electric Vehicles (EVs) are becoming increasingly popular due to their environmental benefits, but managing battery performance and safety remains a major concern. This project focuses on developing an intelligent Battery Management System (BMS) that uses sensors and a buzzer-based alert mechanism to notify the driver of critical battery conditions. Voltage sensors are used to continuously monitor the battery charge level. When the battery is fully charged, a notification is sent to the wheel driver, and if the battery level drops too low, the system activates a buzzer to alert the vehicle driver, helping to prevent sudden breakdowns. Additionally, battery temperature is a vital safety parameter.

A temperature sensor is used to detect if the battery is overheating. If high temperature is detected, the system triggers the buzzer to alert the driver and simultaneously turns on a cooling fan using a relay switch to stabilize the temperature. This dual-sensor approach ensures real-time monitoring and immediate alerts without the need for complex displays. The integration of voltage and temperature sensors with buzzer and relay control makes the system simple, reliable, and effective in improving battery safety and efficiency in EVs. This project enhances the reliability of EVs through automated safety responses.

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LIST OF ABBREVIATIONS

ABBREVIATION	EXPANSION
BMS	Battery Management Systems
SOC	state of charge
SOH	State Of Health
CAGR	Compound Annual Growth Rate
MOSFET	Metal Oxide Silicon Field Effect Transistors
IGBT	Insulated Gate Bipolar Transistor
ECU	Electronic Control Unit
HVAC	Heating, Ventilation and Air Conditioning
EPS	Electronic Position Switches
ICS	Industrial Control System
VFD	Variable Frequency Drives
FPBN	Fuzzy Probability Bayesian Network
PSU	Power Supply Unit
ATX	Advanced Taxation
TTL	Transistor-Transistor Logic
PWM	Pulse Width Modulation

CHAPTER 1

INTRODUCTION

1.1 General

The rapid adoption of electric vehicles (EVs) has led to increasing demands for efficient, safe, and intelligent battery management systems (BMS). A Battery Management System plays a critical role in monitoring and controlling the charging and discharging processes of an electric vehicle's battery pack. To enhance the effectiveness and reliability of these systems, the integration of Internet of Things (IoT) technology has emerged as a transformative solution.

This project focuses on developing an IoT-based Battery Management System (BMS) specifically designed for electric vehicles during the charging phase. The system leverages real-time data acquisition, cloud connectivity, and intelligent control algorithms to ensure optimal battery performance, safety, and longevity.

The proposed system continuously monitors key battery parameters such as voltage, current, temperature, state of charge (SOC), and state of health (SOH). Using IoT connectivity, this data is transmitted to a centralized server or cloud platform, allowing users and maintenance personnel to track the battery's condition remotely via mobile apps or web dashboards.

Moreover, the system can provide alerts and automated controls in the case of anomalies such as overcharging, overheating, or abnormal voltage levels. This not only enhances the safety and efficiency of EV charging but also contributes to extending battery life and reducing maintenance costs.

By integrating IoT into battery management, this project aims to contribute to smarter, more sustainable, and user-friendly electric vehicle infrastructure

1.2 Objective of the project

1. To design a real-time Battery Management System (BMS) that monitors both voltage and temperature parameters in electric vehicles (EVs).
2. To utilize voltage sensors for detecting high and low battery charge levels and generating appropriate notifications.

3. To alert the vehicle driver using a buzzer when the battery charge is low, ensuring timely action to avoid power loss or breakdown.
4. To provide a high battery charge indication to the wheel driver to optimize performance and prevent overcharging scenarios.
5. To implement a temperature sensor that monitors the battery temperature continuously to prevent overheating.
6. To activate a cooling fan via a relay switch when high temperature is detected, maintaining thermal safety of the battery.
7. To integrate sensor data with an automated response system using simple electronic components to reduce system complexity and cost.
8. To enhance the overall safety, reliability, and efficiency of electric vehicle operations through effective battery health monitoring and alert systems

1.3 Power Electronics

Power electronics is the field of electrical engineering related to the use of semiconductor devices to convert power from the form available from a source to that required by a load. The load may be AC or DC, single-phase or three-phase, and may or may not need isolation from the power source. The power source can be a DC source or an AC source (single-phase or three-phase with line frequency of 50 or 60 Hz), an electric battery, a solar panel, an electric generator or a commercial power supply. A power converter takes the power provided by the source and converts it to the form required by the load. The power converter can be an AC-DC converter, a DC-DC converter, a DC-AC inverter or an AC-AC converter depending on the application.

Grid-tied inverters are designed to feed into the electric power distribution system. They transfer synchronously with the line and have as little harmonic content as possible. They also need a means of detecting the presence of utility power for safety reasons, so as not to continue to dangerously feed power to the grid during a power outage.

The power electronics for electric vehicle market size was valued at $2.59 billion in 2018, and is projected to reach $30.01 billion by 2026, growing at a CAGR of 35.5% from 2019 to 2026. Power electronics is a circuitry device that transfers power from a source to a load in an efficient, compact, and robust mAIer to ensure convenient utilization. This device is used to control the conversion of electric power from one form to another using diodes, transistors, and thyristors.

In electric cars, power electronic is responsible for converting and controlling electric power in system. Some of the major power electronic rwincomponents and functionalities are used in electric vehicle system. These include inverter, converter, and on-board charger. Operations at high voltage or high current can be efficiently executed by utilizing power electronic devices, as they deliver faster switching rate at higher efficiency. In addition, power electronics control both unidirectional as well as bidirectional flow of energy, depending on the usage, and the regenerated energy can be sent back to utility.

Power electronic is a key technology used in various applications to optimize energy management, providing the conversion to operate motors, battery storage, and generators. Complex power electronics are represented as the interconnection of conversion blocks in AC/DC, DC/AC, DC/DC, and AC/AC. These complex electrical architectures in marine applications increase the need for power converters with high reliability and simple maintenance requirements.

Power electronics is used in EV that require high power electric energy to rotate the electric motors. Power modules reduce power loss, owing to their high frequency. In addition, the components such as silicon-based power MOSFETs and IGBTs are used as power electronic switches in the power train automotive electric and electronic systems for reducing the overall size.

The major factors that drive the power electronics for electric vehicle market growth include surge in demand for energy-efficient battery-powered devices, stringent emission regulations to reduce vehicle weight and emission, and government initiatives to balance environmental pollution and vehicle emission. However, high cost of vehicle and complexity in designing and integrating advance power electronic components in electric vehicles hinder the power electronics for electric vehicle market growth.

Furthermore, technological advancements in vehicle battery and increase in R&D activities are expected to create lucrative growth opportunities for the power electronics for electric vehicle market. In addition, power electronics support high input impedance and improved parallel current sharing, which increases the adoption of power electronic components in electric cars.

Power Electronics is a field that emerged rapidly in the past 50 years. Power Electronics as a discipline helps to control high current and high voltages (thus significant Power) by the means of semiconductors and modern control system engineering. Power Electronics now has major applications in field like power systems, home appliances and avionics and automotive. These sectors need systems to be controlled based on the amount of power delivery in an efficient mAIer. Thus, Power Electronics is pretty useful in these sectors.

Automotive Sector is seeing a surge of Power Electronics Engineering nowadays. Let's find out some applications of Power Electronics in modern EVs which are getting traction.

1.4 EV Vehicle

An EV is driven by motor. Modern EVs use mostly Induction Motors or Permanent Magnet Synchronous Motors. Such motors require Power Electronics for 2 reason, one being that these motors require 3-phase AC to run but the primary power source in an EV is battery pack which produces DC. Thus, a power electronics converter (DC to AC converter) is a primary requirement.

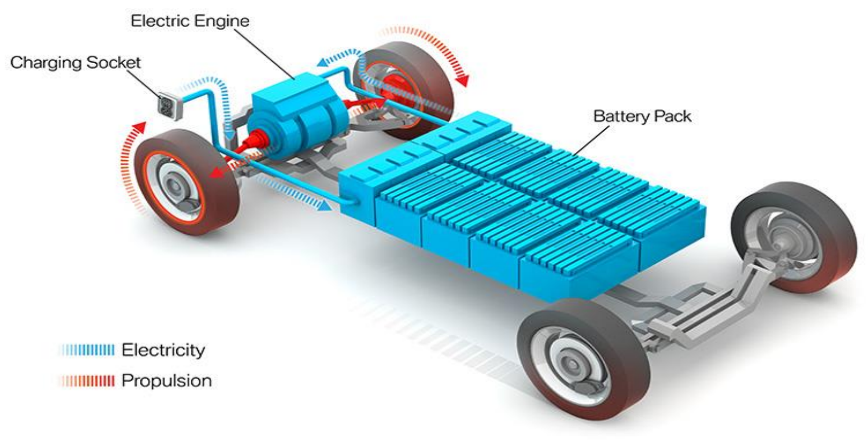


Fig 1.1. Vehicle Drivetrain

Second being that these motors require current and voltage to be controlled precisely for an efficient operation. Moreover, the power delivery to the motor must be as per the wishes of the driver's throttle. Thus, precise control is necessary. A 3-phase Voltage Source Inverter is used which is controlled by a Motor Control ECU. These inverters mostly use MOSFETS and IGBT as power switches. The switching can be controlled by the Motor Control ECU based on Field Oriented Control Algorithm or some other advanced control techniques.

Off-board chargers/On-board chargers, all are possible due to advances in Power Electronics. In crude terms, chargers are nothing but Rectifiers. Mostly Off-board chargers/fast chargers are 3 phase chargers and onboard chargers are single phase chargers. Fast chargers are 3-phase due to the reason that they consume a higher amount of power which can be supplied only through a 3-phase AC connection. Onboard chargers are generally single phase since they are low powered chargers and they can be used in user's residence.

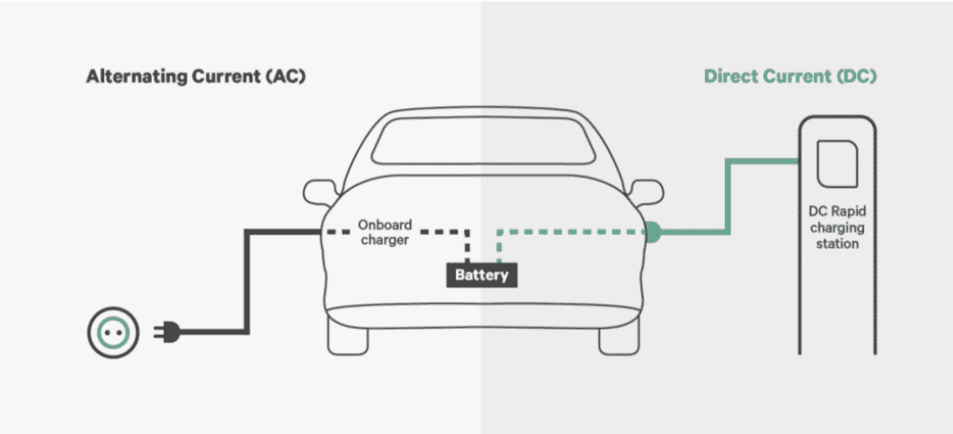


Fig.1.2. Vehicle Charging

However, modern chargers are more complicated than being a simple rectifier. Modern chargers mostly consist of a PF corrected rectifier at the input or stage 1 to reduce the harmonics injected into the grid from the load. This stage also ensures that AC is converted to DC. After 1st stage, the stage 2 consists of galvanically isolated DC-DC converter to buck or boost the DC voltage as per the demands of battery.

An EV also has an additional DC-DC converter to drive the lights, horns and to power the ECUs. This is required since the main source of power in an EV is a high voltage battery pack. This voltage will be in range from 48V (for a small low powered EV) to even upto 800 V for buses or trucks. However, the lights, horns, wipers and ECUs run on 12V/24V. Thus, the DC voltage has to be stepped down to lower voltage. These loads are generally referenced to the chassis ground which floats with respect to the high voltage battery pack ground. Thus, a transformer based galvanically isolated DC-DC converter is used for this purpose.

The application of Power Electronics is not restricted to only these applications mentioned above. There are other applications like driving compressors for Battery pack cooling, HVAC, EPS and many more. Any place, how small be it, if it requires power to be controlled, it requires power electronics.

1.5 problem statement

Battery storage serves as the backbone of any electric vehicle (EV), as it stores the essential energy required for propulsion and other operations. However, to extract the maximum output and ensure reliable power transfer, it is critical to integrate an efficient Battery Management System (BMS). A lack of proper monitoring, control, and protection mechanisms can lead to inefficient performance, reduced battery life, and potential safety hazards such as overheating, overcharging, or short circuits.

The proposed system addresses this gap by not only monitoring critical parameters such as current, voltage, and state of charge but also incorporating fault detection and protection mechanisms. Additionally, the system includes a user-friendly LCD display to inform users about battery status in real-time. Thus, the proposed model ensures enhanced performance, longevity, and safety of EV battery systems.

1.6 Summary

Traditionally, safety monitoring and automation systems were typically designed to meet the requirements of a single monitoring application. The EV application has already gone beyond the interconnection of a few large back-end systems, and more and more underground physical devices make the state of objects and their surroundings seamlessly accessible to software systems. As a matter of fact, most works are based on monolithic system architectures, which are brittle and difficult to adapt.

1.7 Literature Survey

1. On The Generation Of Anomaly Detection Datasets In Ev Control Systems

Author : L. P. Gómez, L. F. Maimo, A. H. Celdran,

Year : 2019

Description

In recent decades, EV Control Systems (ICS) have been affected by heterogeneous cyberattacks that have a huge impact on the physical world and the people’s safety. The techniques achieving the best performance in the detection of cyber anomalies are based on Machine Learning and, more recently, Deep Learning. Due to the incipient stage of cybersecurity research in ICS, the availability of datasets enabling the evaluation of anomaly detection techniques is insufficient. In this paper, we propose a methodology to generate reliable anomaly detection datasets in ICS that consists of four steps: attacks selection, attacks deployment, traffic capture and features computation. The proposed methodology has been used to generate the Electra Dataset, whose main goal is the evaluation of cybersecurity techniques in an electric traction substation used in the railway industry. Using the Electra dataset, we train several Machine Learning and Deep Learning models to detect anomalies in ICS and the performed experiments show that the models have high precision and, therefore, demonstrate the suitability of our dataset for use in production systems.

2. A Dynamic Decision-Making Approach For Intrusion Response In Ev Control Systems

Author : X. Li, C. Zhou, Y.-C. Tian, and Y. Qin,

Year : 2019

Description

EV control systems (ICSs) are facing more and more cybersecurity issues, leading to increasingly severe risks in critical infrastructure. To mitigate risks, developing an appropriate security strategy is of paramount importance. However, existing efforts on decision making in ICSs inherit some limitations, such as the lack of consideration of the strategy for securing both cyber and physical domains and a tradeoff between security and system requirements. To overcome these limitations, a decision-making approach is presented in this paper for intrusion response in ICSs. Aiming to determine the optimal security strategy against attacks promptly, it tries to secure the most "dangerous" attack paths and respond to functional failures. In this approach, measures that cover both cyber and physical domains are designed with in-depth analysis of attack propagation. They ensure the completeness of candidate security strategy space. A number of Pareto optimal solutions are determined from the strategy space through multi-objective optimization. The objective is to maximize the objective vector composed of security benefit, system benefit and state benefit. Then, these solutions are prioritized by using a distance-based evaluation method, which pursues the optimal protection ability by making the objective vector of the selected strategy closest to the ideal one. The effectiveness of the proposed approach is demonstrated with a case study on a simulated process control system.

3. Identifying And Anticipating Cyberattacks That Could Cause Physical Damage To Ev Control Systems

Author : M. G. Angle, S. Madnick, J. L. Kirtley, and S. Khan,

Year : 2019

Description

Physical control systems are increasingly controlled by reconfigurable, network-enabled devices to increase flexibility and ease commissioning and maintenance. Such capability creates vulnerabilities. Devices may be remotely reprogrammed by a malicious actor to act in unintended ways, causing physical damage to mechanical equipment, infrastructure, and life and limb. In this paper, past examples of actual damage to cyber-physical systems are shown, threats posed by software-controlled variable frequency drives (VFDs) are analyzed, and a small-scale version of an attack on ubiquitous VFD equipment is demonstrated.

4. A Fuzzy Probability Bayesian Network Approach For Dynamic Cybersecurity Risk Assessment In Ev Control Systems

Author : Q. Zhang, C. Zhou, Y.-C. Tian, N. Xiong, Y. Qin, and B. Hu,

Year : 2018

Description

With the increasing deployment of data network technologies in EV control systems (ICSs), cybersecurity becomes a challenging problem in ICSs. Dynamic cybersecurity risk assessment plays a vital role in ICS cybersecurity protection. However, it is difficult to build a risk propagation model for ICSs due to the lack of sufficient historical data. In this paper, a fuzzy probability Bayesian network (FPBN) approach is presented for dynamic risk assessment. Firstly, an FPBN is established for analysis and prediction of the propagation of cybersecurity risks. To overcome the difficulty of limited historical data, the crisp probabilities used in standard Bayesian networks (BNs) are replaced in our approach by fuzzy probabilities. Then, an approximate dynamic inference algorithm is developed for dynamic assessment of ICS cybersecurity risk. It is embedded with a noise evidence filter in order to reduce the impact from noise evidence caused by system faults. Experiments are conducted on a simplified chemical reactor control system to demonstrate the effectiveness of the presented approach.

5. Asset-Based Dynamic Impact Assessment Of Cyberattacks For Risk Analysis In Ev Control Systems

Author : X. Li, C. Zhou, Y.-C. Tian, N. Xiong, and Y. Qin,

Year : 2018

Description

With the evolution of information, communications, and technologies, modern EV control systems (ICSs) face more and more cybersecurity issues. This leads to increasingly severe risks in critical infrastructure and assets. Therefore, risk analysis becomes a significant yet not well investigated topic for prevention of cyberattack risks in ICSs. To tackle this problem, a dynamic impact assessment approach is presented in this paper for risk analysis in ICSs. The approach predicts the trend of impact of cybersecurity dynamically from full recognition of asset knowledge. More specifically, an asset is abstracted with properties of construction, function, performance, location, and business. From the function and performance properties of the asset, object-oriented asset models incorporating with the mechanism of common cyberattacks are established at both component and system levels. Characterizing the evolution of behaviors for single asset and system, the models are used to analyze the impact propagation of cyberattacks. Then, from various possible impact consequences, the overall impact is quantified based on the location and business properties of the asset. A special application of the approach is to rank critical system parameters and prioritize key assets according to impact assessment. The effectiveness of the presented approach is demonstrated through simulation studies for a chemical control system.

CHAPTER 2

SYSTEM ANALYSIS

2.1 Existing SYSTEM

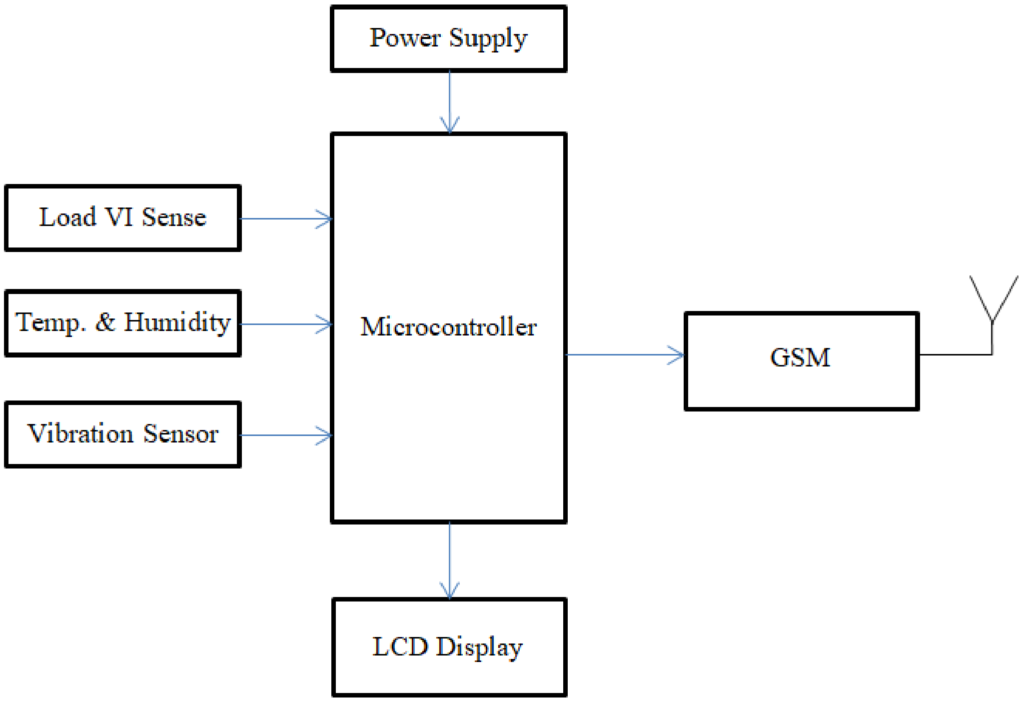


Fig.2.1.Existing Block Diagram

- The persons who are working in the EV have to face various environmental parameters in their EV. So to overcome that problem we are using Zigbee based intelligent helmet for coal miners.
- EV incidents were unpredictable and it has many factors the event of an accident, not only causes huge economic losses, but a direct threat to the safety of miners
- As an ICS is a cyber-physical system, the process of cybersecurity risk propagation in ICSs is different from that in general network systems.
- Most ICS attacks aim to vandalize ICS assets, which include humans, environment, and equipment.
- Traditionally, safety monitoring and automation systems were typically designed to meet the requirements of a single monitoring application.

- The application has already gone beyond the interconnection of a few large back-end systems.

Disadvantages

- Environmental accidents
- High Maintenance
- Unpredictable Incidents
- Safety issues
- Users to identify the levels for EV safety alarming
- Possibly to adjust monitoring and control rules to ensure the safety
- The accuracy to a large extent owing to its low accuracy as a single parameter
- A few large back-end systems, and more and more underground physical devices

2.2 proposed system

The proposed system is a smart and efficient Battery Management System (BMS) designed specifically for electric vehicles to enhance safety, performance, and reliability. It integrates voltage and temperature sensors to continuously monitor critical battery parameters in real time. When the battery charge reaches a high level, a signal is sent to the wheel driver to optimize driving functions and prevent overcharging. If the battery charge drops to a low level, a buzzer is activated to alert the vehicle driver, ensuring timely recharge and avoiding unexpected shutdowns. This system effectively uses a voltage sensor to detect both high and low charge conditions and generate precise alerts without the need for complex user interfaces. In addition to voltage monitoring, the system also includes a temperature sensor to measure the battery's thermal condition. If the battery temperature exceeds safe operating limits, the system not only triggers a buzzer to warn the driver but also automatically switches on a cooling fan through a relay to reduce the temperature. This automated response prevents potential battery damage and improves overall efficiency. The use of a relay makes the fan operation reliable and independent of manual intervention. By combining sensor technology with an audible alert system and automated cooling, the proposed system offers a cost-effective, real-time solution to ensure safe and optimal battery usage in electric vehicles. It reduces maintenance risks, extends battery life, and supports the development of safer, smarter EV technologies.

Advantage

1. **Real-time monitoring** of battery charge and temperature levels.
2. **Automatic alerts** through buzzer for quick driver notification.
3. **Enhanced battery safety** using temperature-based fan activation.
4. **Cost-effective system** with minimal components and wiring.
5. **Improved EV reliability** through proactive battery management.

2.3. Block Diagram

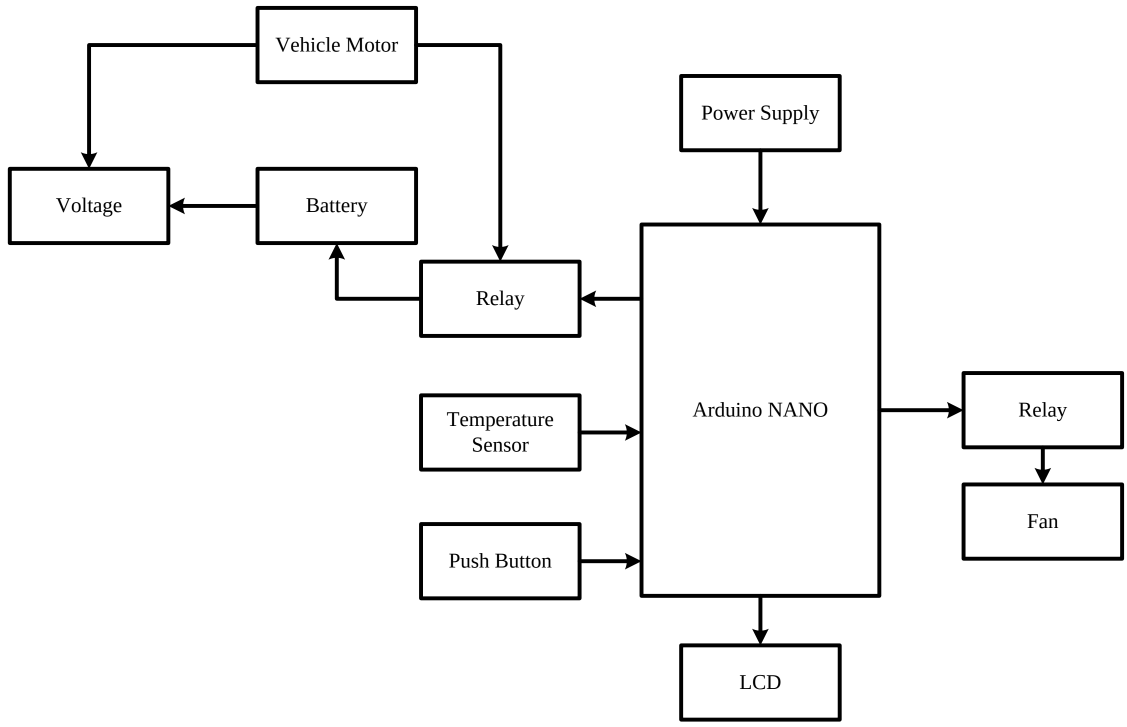


Fig.2.2. EV BMS

CHAPTER 3

SYSTEM REQUIREMENTS

3.1 Hardware Requirement

- Arduino NANO
- LCD display
- Power supply
- Voltage Sensor
- DC Motor
- Battery
- Relay
- Potentiometer
- Temperature sensor
- Push button
- Buzzer
- Fan
- Switch

3.2 Software Requirements

- Arduino IDE
- PyCharm

CHAPTER 4

SYSTEM DESCRIPTION

4.1 Hardware Description

4.1.1 Power Supplies

A power supply (sometimes known as a power supply unit or PSU) is a device or system that supplies electrical or other types of energy to an output load or group of loads. The term is most commonly applied to electrical energy supplies, less often to mechanical ones, and rarely to others.

This circuit is a small +5V power supply, which is useful when experimenting with digital electronics. Small inexpensive wall transformers with variable output voltage are available from any electronics shop and supermarket. Those transformers are easily available, but usually their voltage regulation is very poor, which makes then not very usable for digital circuit experimenter unless a better regulation can be achieved in some way. The following circuit is the answer to the problem.

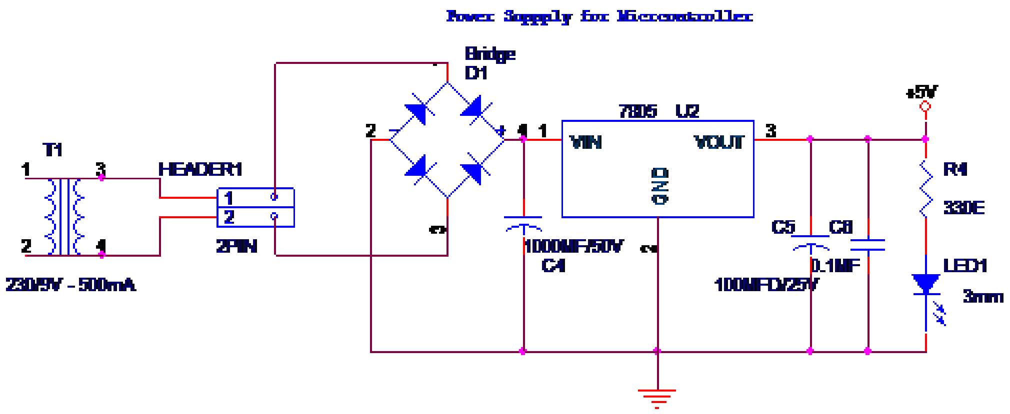


Fig.4.1. Block diagram of power supply

4.1.2 Transformer

A transformer is a device that transfers electrical energy from one circuit to another through inductively coupled wires. A changing current in the first circuit (the primary) creates a changing magnetic field; in turn, this magnetic field induces a changing voltage in the second circuit (the secondary). By adding a load to the secondary circuit, one can make current flow in the transformer, thus transferring energy from one circuit to the other. The secondary induced voltage V_S is scaled from the primary V_P by a factor ideally equal to the ratio of the number of turns of wire in their respective windings:

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$

By appropriate selection of the numbers of turns, a transformer thus allows an alternating voltage to be stepped up — by making N_S more than N_P or stepped down, by making it less.

A key application of transformers is to reduce the current before transmitting electrical energy over long distances through wires. Most wires have resistance and so dissipate electrical energy at a rate proportional to the square of the current through the wire. By transforming electrical power to a high-voltage, and therefore low-current form for transmission and back again afterwards, transformers enable the economic transmission of power over long distances. Consequently, transformers have shaped the electricity supply industry, permitting generation to be located remotely from points of demand. All but a fraction of the world's electrical power has passed through a series of transformers by the time it reaches the consumer.

Transformers are some of the most efficient electrical 'machines', with some large units able to transfer 99.75% of their input power to their output. Transformers come in a range of sizes from a thumbnail-sized coupling transformer hidden inside a stage microphone to huge gigavolt-ampere-rated units used to interconnect portions of national power grids. All operate with the same basic principles, though a variety of designs exist to perform specialized roles throughout home and industry.

The transformer is based on two principles: first, that an electric current can produce a magnetic field (electromagnetism) and, second, that a changing magnetic field within a coil of wire induces a voltage across the ends of the coil (electromagnetic induction). By changing the current in the primary coil, one changes the strength of its magnetic field; since the secondary coil is wrapped around the same magnetic field, a voltage is induced across the secondary.

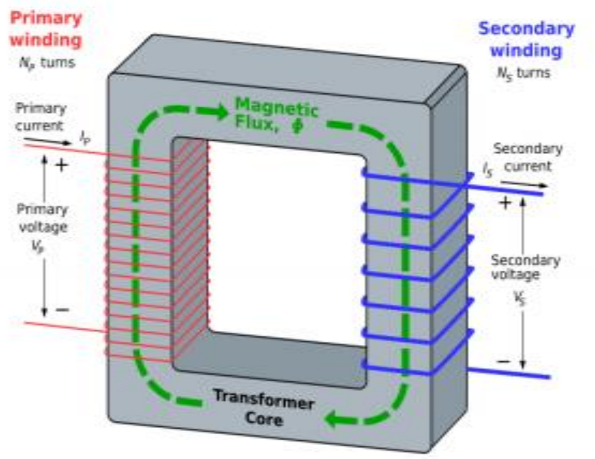


Fig.4.2.An ideal step-down transformer

A simplified an ideal step-down transformer design is shown in the above figure. A current passing through the primary coil creates a magnetic field. The primary and secondary coils are wrapped around a core of very high magnetic permeability, such as iron; this ensures that most of the magnetic field lines produced by the primary current are within the iron and pass through the secondary coil as well as the primary coil.

Rectifier

A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. The process is known as rectification. Rectifiers are used as components of power supplies and as detectors of radio signals. Mainly there are three types of rectifier i.e. half wave rectifier, full wave rectifier and Bridge Rectifier.

Half-wave rectifier

In half-wave rectification of a single-phase supply, either the positive or negative half of the AC wave is passed, while the other half is blocked. Because only one half of the input waveform reaches the output, mean voltage is lower. Half-wave rectification requires a single diode in a single-phase supply, or three in a three-phase supply. Rectifiers yield a unidirectional but pulsating direct current; half-wave rectifiers produce far more ripple than full-wave rectifiers, and much more filtering is needed to eliminate harmonics of the AC frequency from the output.

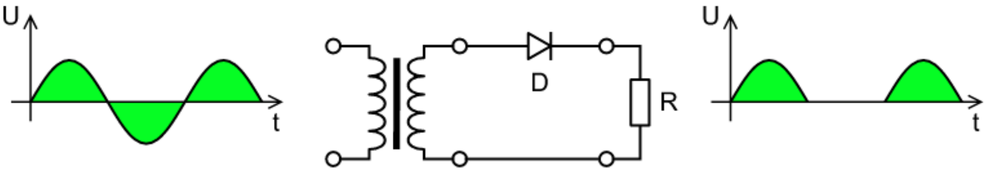


Fig.4.3.Half -Wave Rectifier

Full-wave rectifier

A full-wave rectifier converts the whole of the input waveform to one of constant polarity (positive or negative) at its output. Full-wave rectification converts both polarities of the input waveform to pulsating DC (direct current), and yields a higher average output voltage. Two diodes and a center tapped transformer are needed.

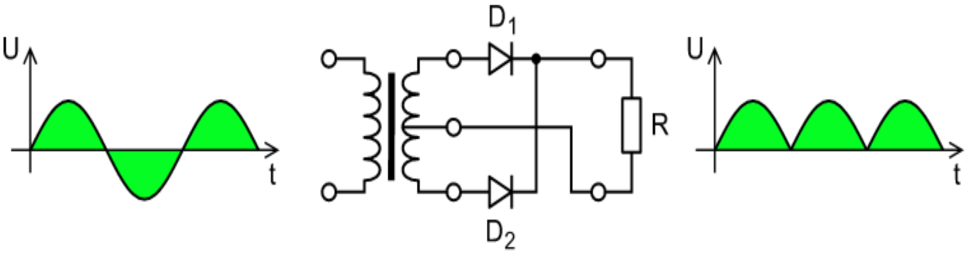


Fig.4.4.Full-Wave Rectifier

Bridge Rectifier

A diode bridge is an arrangement of four (or more) diodes in a bridge circuit configuration that provides the same polarity of output for either polarity of input. When used in its most common application, for conversion of an alternating current (AC) input into a direct current (DC) output, it is known as a bridge rectifier. A bridge rectifier provides full-wave rectification from a two-wire AC input, resulting in lower cost and weight as compared to a rectifier with a 3-wire input from a transformer with a center-tapped secondary winding. The essential feature of a diode bridge is that the polarity of the output is the same regardless of the polarity at the input.

Basic operation

According to the conventional model of current flow, current is defined to be positive when it flows through electrical conductors from the positive to the negative pole. In actuality, free electrons in a conductor nearly always flow from the negative to the positive pole. In the vast majority of applications, however, the actual direction of current flow is irrelevant. Therefore, in the discussion below the conventional model is retained.

In the diagrams below, when the input connected to the left corner of the diamond is positive, and the input connected to the right corner is negative, current flows from the upper supply terminal to the right along the red (positive) path to the output, and returns to the lower supply terminal via the blue (negative) path.

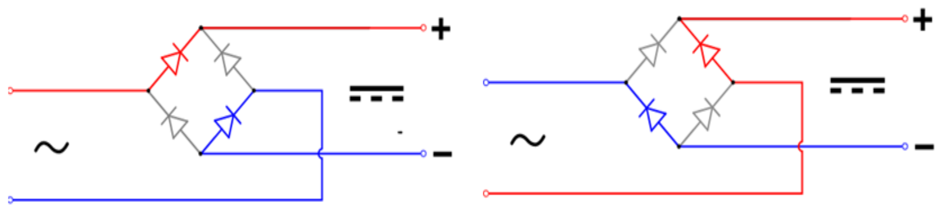


Fig.4.5.Operation of bridge rectifier

When the input connected to the left corner is negative, and the input connected to the right corner is positive, current flows from the lower supply terminal to the right along the red (positive) path to the output, and returns to the upper supply terminal via the blue (negative) path.

In each case, the upper right output remains positive and lower right output negative. Since this is true whether the input is AC or DC, this circuit not only produces a DC output from an AC input, it can also provide what is sometimes called "reverse polarity protection". That is, it permits normal functioning of DC-powered equipment when batteries have been installed backwards, or when the leads (wires) from a DC power source have been reversed, and protects the equipment from potential damage caused by reverse polarity.

IC Voltage Regulators

Voltage regulators comprise a class of widely used ICs. Regulator IC units contain the circuitry for reference source, comparator amplifier, control device, and overload protection all in a single IC. Although the internal construction of the IC is somewhat different from that described for discrete voltage regulator circuits, the external operation is much the same. IC units provide regulation of either a fixed positive voltage, a fixed negative voltage, or an adjustable set voltage. A power supply can be built using a transformer connected to the ac supply line to step the ac voltage to desired amplitude, then rectifying that ac voltage, filtering with a capacitor and RC filter, if desired, and finally regulating the dc voltage using an IC regulator. The regulators can be selected for operation with load currents from hundreds of milliamperes to tens of amperes, corresponding to power ratings from milliwatts to tens of watts.

Three-Terminal Voltage Regulators

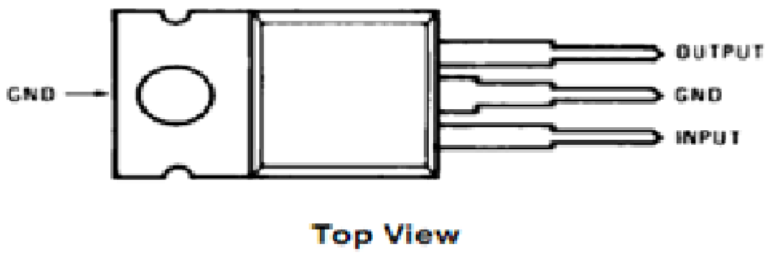


Fig.4.6. Three-Terminal Voltage Regulators

Figure shows the basic connection of a three-terminal voltage regulator IC to a load. The fixed voltage regulator has an unregulated dc input voltage, V_i, applied to one input terminal, a regulated output dc voltage, V_o, from a second terminal, with the third terminal connected to ground. For a selected regulator, IC device specifications list a voltage range over which the input voltage can vary to maintain a regulated output voltage over a range of load current. The specifications also list the amount of output voltage change resulting from a change in load current (load regulation) or in input voltage (line regulation). The series 78 regulators provide fixed regulated voltages from 5 to 24 V. Figure shows how one such IC, a 7805, is connected to provide voltage regulation with output from this unit of +5V dc. An unregulated input voltage V is filtered by capacitor C1 and connected to the IC's IN terminal. The IC's OUT terminal provides a regulated + 12V which is filtered by capacitor C2 (mostly for any high-frequency noise). The third IC terminal is connected to ground (GND). While the input voltage may vary over some permissible voltage range, and the output load may vary over some acceptable range, the output voltage remains constant within specified voltage variation limits. These limitations are spelled out in the manufacturer's specification sheets. There are two types of voltage regulator they are 78xx series and 79xx series.

78xx series

There are common configurations for 78xx ICs, including 7805 (5 V), 7806 (6 V), 7808 (8 V), 7809 (9 V), 7810 (10 V), 7812 (12 V), 7815 (15 V), 7818 (18 V), and 7824 (24 V) versions. The 7805 is the most common, as its regulated 5-volt supply provides a convenient power source for most TTL components.

Less common are lower-power versions such as the LM78Mxx series (500 mA) and LM78Lxx series (100 mA) from National Semiconductor. Some devices provide slightly different voltages than usual, such as the LM78L62 (6.2 volts) and LM78L82 (8.2 volts) as well as the STMicroelectronics L78L33ACZ (3.3 volts).

79xx series

The 79xx devices have a similar "part number" to "voltage output" scheme, but their outputs are negative voltage, for example 7905 is -5 V and 7912 is -12 V. The 7912 has been a popular component in ATX power supplies, and 7905 was popular component in ATX before -5 V was removed from the ATX specification.

Positive Voltage Regulators in 7800 series

IC Part	Output Voltage (V)	Vi (V)
7805	+5	7.3
7806	+6	8.3
7808	+8	10.5
7810	+10	12.5
7812	+12	13.6
7815	+15	17.7
7818	+18	21.0
7824	+24	27.1

4.1.3 Arduino Nano

Arduino Nano has similar functionalities as Arduino Duemilanove but with a different package. The Nano is inbuilt with the ATmega328P microcontroller, same as the Arduino UNO. The main difference between them is that the UNO board is presented in PDIP (Plastic Dual-In-line Package) form with 30 pins and Nano is available in TQFP (plastic quad flat pack) with 32 pins. The extra 2 pins of Arduino Nano serve for the ADC functionalities, while UNO has 6 ADC ports but Nano has 8 ADC ports. The Nano board doesn't have a DC power jack as other Arduino boards, but instead has a mini-USB port. This port is used for both programming and serial monitoring. The fascinating feature in Nano is that it will choose the strongest power source with its potential difference, and the power source selecting jumper is invalid.

Arduino Nano Pinout Description

Taking this pin-out diagram below as reference, we shall discuss all the functionalities of each and every pin.

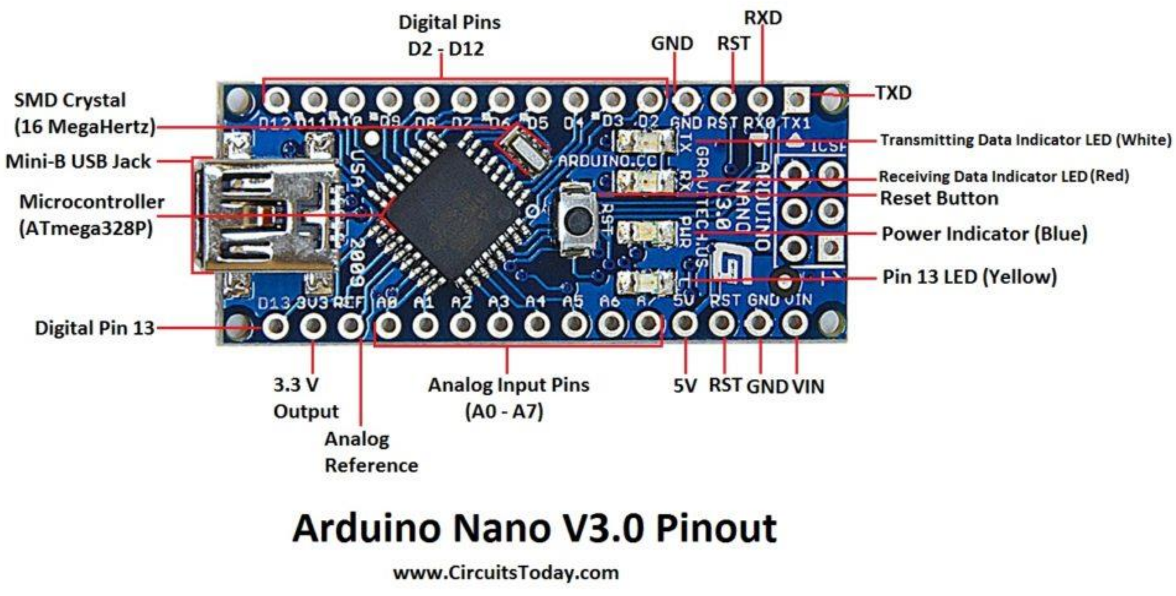


Fig.4.7. Arduino NANO V3.0 Pinout

We can infer from the image that Arduino Nano got 36 pins in total. We will see all the pins section wise as well as a detailed format at last.

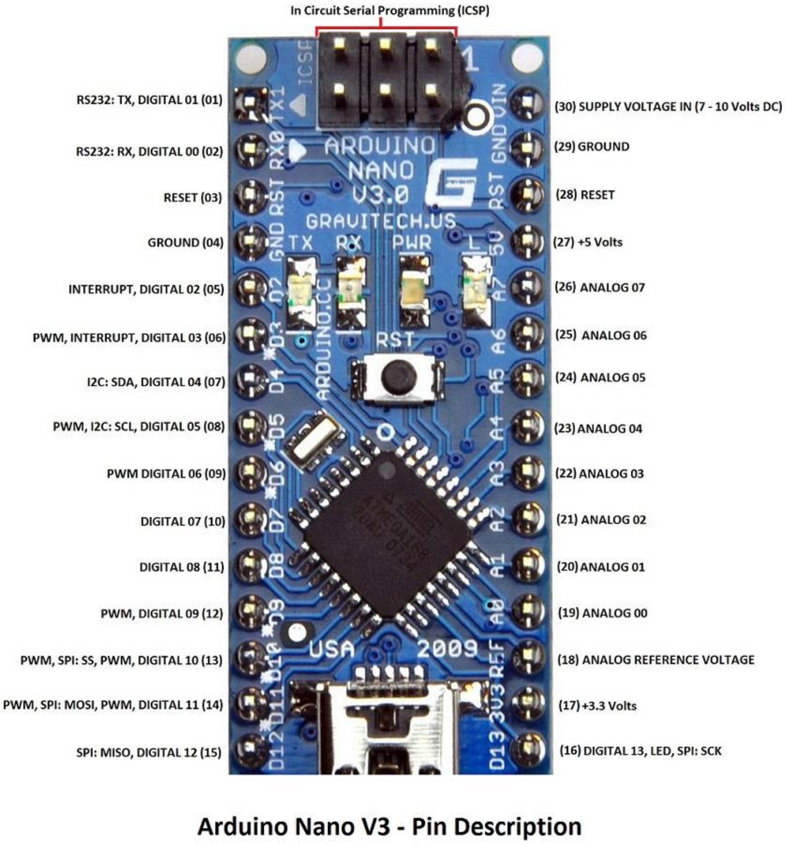


Fig.4.8. Arduino NANO V3- Pin description

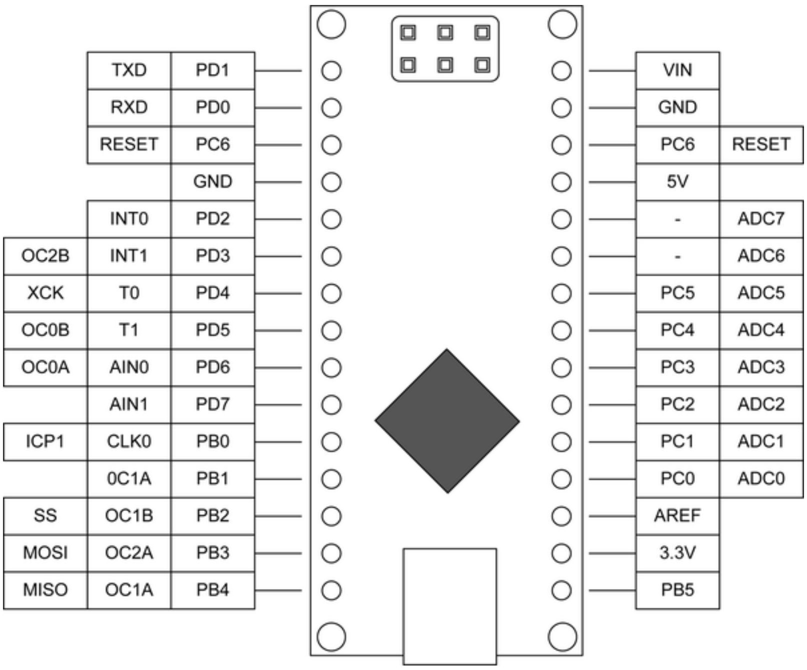


Fig.4.9. Arduino NANO Pin Diagram

Memory

Memory can be broadly divided into 3 classes:

- 32KB Flash memory –This is the storage space of the compiled program of which the boot loader uses 0.5 KB.
- 2KB SRAM – This is mainly used during run time.
- 1KB EEPROM –This is used for storing data that should not be erased upon switching off power.

Power Setup

The Arduino R3 operates at 5 Volts. It can either be powered through USB cable from the computer or through the DC jack provided on the Board.

The DC Jack

The voltage regulator 7805 is provided in the board for obtaining 5v regulated output voltage. The input voltage applied can be between 7-25 volts DC power.

USB Power

When powered through the USB, the 500mA Re-settable fuse on the USB power line is used to abstain the board from drawing current in excess.

USB Connectivity

Since the ATmega328 does not use USB communication directly, the need for a dedicated IC arises. FTDI FT232 IC is used to communicate between the microcontroller and USB serially .The drivers required for the Serial to USB converter has to be installed.

Hardware

The Arduino R3 / Arduino Uno Boards have 20 programmable I/O's.They are grouped mainly as

- Pins 0 to 13
- Pins 0 to 5 [Analog Inputs 0 to 5]

Digital I/O's

The 20 I/O’s can accept digital signals as input as well as outputs. The digital pins are numbered from 0 to 19.The Digital Pins can be used for controlling LED's, Relays and for accepting input from Push-Buttons, Digital Sensors

Analog I/O's

Analog inputs can be given to pins A0-A5.An inbuilt ADC analog to digital converter is present that converts analog voltages in the range of 0 to 5 volts to a 10-bit value. Analog sensors that sense changes in temperature or light can work with these inputs.

Analog Output

The six pins marked PWM are pins dedicated to produce Analog Output Signal.

They can produce analog voltages in the range of 0 to 5 volts with a resolution of 8-bits. They can be used for Intensity Control, Speed Control, Etc.

Communication

Serial Communication

The communication can be established with the computer or other arduino boards. For this purpose, the ATmega328 provides UART TTL (5V) serial communication, existing on digital pins 0 (RX) and 1 (TX). A FT232RL IC on the board paves the way for this serial communication over USB and appears as a virtual com port to the computer.

The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip

I2C Communication or Two Wire Communication

The Atmega328 provides I2C / Two Wire Communication through the Analog Pins A4 (SDA) & A5 (SCL). The Arduino software includes a Wire library to simplify use of the I2C bus. I2C Communication can be used for communicating with other microcontrollers / ICs.

SPI Communication

The Atmega328 supports SPI communication through pins 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). SPI communication is supported by the Arduino IDE using the SPI library. SPI Communication can also be used to communicate with other peripherals / ICs - SD Cards, Ethernet Controller, Etc.

Software Serial

In addition to the Hardware Serial Communication provided by the ATmega328, The Software Serial Library for Arduino allows the use of any pin on the board for additional Serial Communication.

Software

Arduino IDE

The Arduino IDE (Integrated Development Environment) is the software to program Arduino board. It is available as an open source in the internet.

Bootloader

The Bootloader is the Software that is loaded on to the ATmega 328 to facilitate programming of the ATmega328 from within the Arduino IDE. The Bootloader is loaded initially when the board is powered on / reset. Upon receiving a signal from the IDE that a new program needs to be uploaded it writes into the program memory of the microcontroller using serial communication for reception.

Programming

The programming in Arduino IDE is much similar to 'c' programming.

Setup () and Loop ()

There are two special functions that are a part of every Arduino sketch: setup () and loop ().

At the start of power or a reset, the setup () function is called once. It is used only for one time operations required at power on.

The loop () function takes care of the application code. It keeps on executing until the power supply is switched off. It is mandatory to include both the functions, whether needed or not,

Analog to digital converter:

The inbuilt ADC present in arduino board has a resolution of 10 bits. Any analog voltage in the range of 0-5 volts is converted to an equivalent digital value 0-1023.The resolution hence obtained is between readings of: 5 volts / 1024 units or, .0049 volts (4.9 mV) per unit. The input range and resolution can be changed using analog Reference(). The conversion time is about 100 microseconds (0.0001 s)- to read an analog input, hence the maximum reading rate is about 10,000 times a second.

4.1.4 Lcd (Liquid Crystal Display)

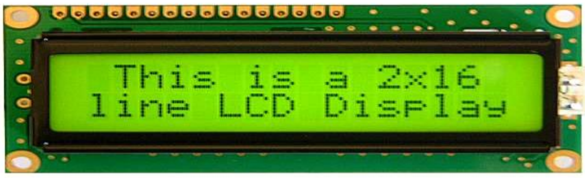


Fig.4.10. LCD Display

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits.

A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data. The command register stores the command instructions given to the LCD, The data register stores the data to be displayed on the LCD

The data is the ASCII value of the character to be displayed on the LCD.Liquid crystal displays are used for display of numeric and alphanumeric character in dot matrix and segmental displays. The two liquid crystal materials which are commonly used in display technology are nematic and cholesteric whose schematic arrangement of molecules is shown in fig. The most popular liquid crystal structure is the Nematic Liquid Crystal (NLC). In this all the molecules align themselves approximately parallel to a unique axis (director), while retaining the complete translational freedom. The liquid is normally transparent, but if subjected to a strong electric field, disruption of the well ordered crystal structure takes place causing the liquid to polarize and turn opaque. The removal of the applied electric field allows the crystal structure to regain its original form and the materials become transparent.

Based on the construction, LCD’s are classified into two types. They are,

(i) Dynamic scattering type

(ii) Field effect type.

Dynamic scattering type

The construction of the dynamic scattering liquid crystal cell is shown in the fig. The display consists of two glass plates, each coated with tin oxide ($SnO2$) on the inside with transparent electrodes separated by a liquid crystal layer,5μA to 50 μA thick. The oxide coating on the front sheet is etched to produce a single or multi- segment pattern of characters, with each segment properly insulated from each other. A weak electric field applied to liquid crystal tends to align molecule in the direction of the field. As soon as the voltage exceeds certain threshold value, the domain structure collapses and the appearance is changed. As the voltage grows further, the flow becomes turbulent and the substance turns optically homogenous. In this disordered state, the liquid crystal scatters light.

Thus, when the liquid is not activated, it is transparent. When the liquid is activated, the molecular turbulence causes light to be scattered in all directions and the cell appears bright. This phenomenon is called dynamic scattering

Field effect type

The construction of the field effect LCD display is similar to that of the dynamic scattering type, with the expectation that two thin polarizing optical filters are placed at the inside of each glass sheet.

The LCD material is of twisted nematic type which twists the light (change in direction of polarization) passing through the cell when the latter is not energized. This allows light to pass through the optical filters and the cell appears bright. When the cell is energized, no twisting of light takes place and the cell appears dull.

Liquid crystal cells are of two types (i) transitive type (ii) reflective type. In the transitive type cell both glass sheets are transparent so that the light from the rear source is scattered in the forward direction when the cell is activated. The reflecting type cell has a reflecting surface on one side of the glass sheet. The incident light on the front surface of the cell is dynamically scattered by an activated cell. Both types of cells appear quite bright when activated even under ambient light conditions.

Liquid crystals consume small amount of energy, in a seven segment display the current drawn is about 25 μA for dynamic scattering cells and 300 μA .

for field effect cells LCD's require ac voltage supply. A typical voltage supply to dynamic scattering LCD's are normally used for seven-segmental displays.

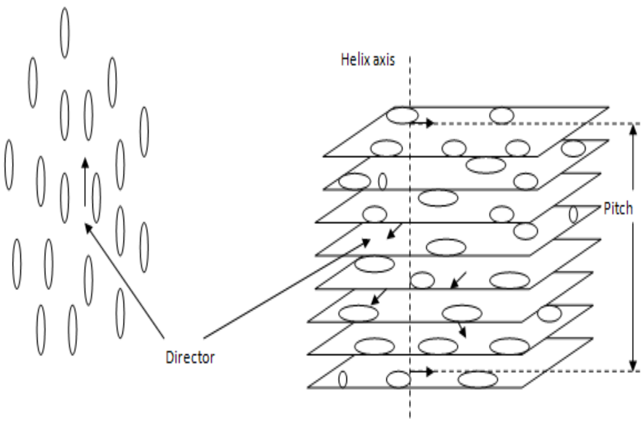


Fig.4.11. Schematic arrangement in liquid crystal

Features of LCD

- Operating voltage range is 3-20V ac.
- It has a slow decay time. Response time is 50 to 200 ms.
- Viewing angle is 100 degree.
- Invisible in darkness. Requires external illumination.
- Life time is limited to 50,000 hours due to chemical graduation.

Advantages of LCD

- The voltage required is small.
- They have low power consumption. A seven segment display requires about 140 W (20 W per segment).

Pin Description

Pin No	Function	Name
1	Ground (0V)	Ground
2	Supply voltage; 5V (4.7V – 5.3V)	VCC
3	Contrast adjustment; through a variable resistor	VEE
7	Selects command register when low; and data register when high	Register Select
8	Low to write to the register; High to read from the register	Read/write
9	Sends data to data pins when a high to low pulse is given	Enable
10	8-bit data pins	DB0
		DB1
		DB2
		DB3
		DB4
		DB5
		DB6
		DB7
11	Backlight VCC (5V)	Led+
12	Backlight Ground (0V)	Led-

4.1.5 Temperature Sensor

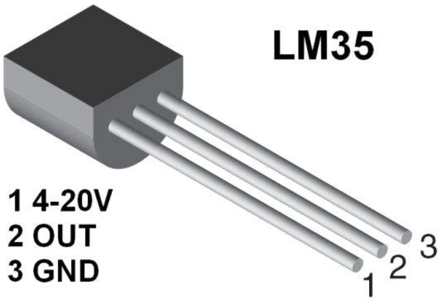


Fig. 4.12.Temperature Sensor

Features

- Calibrated directly in ˚Celsius (Centigrade)
- Linear + 10.0 mV/℃ scale factor
- 0.5℃ accuracy guarantee able (at +25℃)
- Rated for full −55˚to +150℃ range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than 60 µA current drain
- Low self-heating, 0.08℃ in still air
- Low impedance output

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ˚Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies at room temperature and over a full −55 to +150℃ temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 μA from its supply, it has very low self-heating, less than 0.1℃ in still air. The LM35 is rated to operate over a −55˚ to +150℃ temperature range, while the LM35C is rated for a −40˚to +110℃ range (−10˚with improved accuracy). The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package.

4.1.6 Voltage Sensor

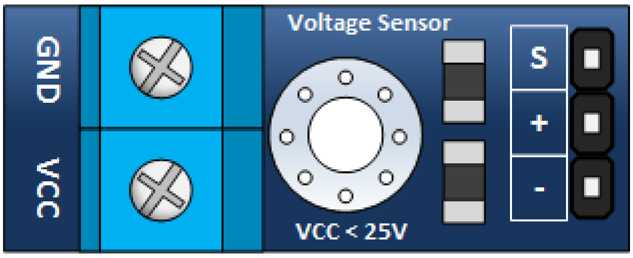


Fig.4.13. Voltage Sensor

INPUTS

- **GND –** This is where you connect the low side of the voltage you are measuring. Caution! : This is the same electrical point as your Arduino ground.
- **VCC:** The is where you connect the high side of the voltage you are measuring
- Outputs
- **S:** This connects to controller input.

Schematic

The schematic for this is pretty straight forward. As previously mentioned, it's just a couple of resistors. In fact, you could build your own in a pinch.

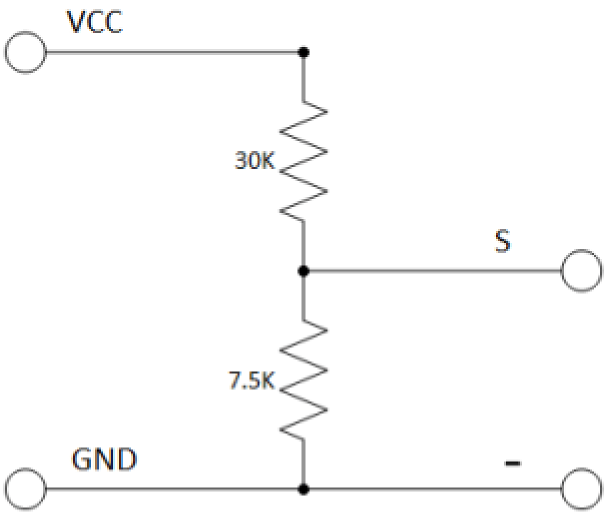


Fig.4.14.Schematic Diagram

4.1.7 Push Button

- A dedicated push button can reset the microcontroller or restart a process if needed.
- A push-button (also spelled pushbutton) or simply button is a simple switch mechanism to control some aspect of a machine or a process. Buttons are typically made out of hard material, usually plastic or metal.
- The surface is usually flat or shaped to accommodate the human finger or hand, so as to be easily depressed or pushed. Buttons are most often biased switches, although many un-biased buttons (due to their physical nature) still require a spring to return to their un-pushed state.

Fig.4.15.Push Button

4.1.8 Switch

power control refers to the ability to manually turn the Battery Management System (BMS) ON or OFF using a simple electrical switch. This switch is connected between the power source and the microcontroller or main circuit.

When the switch is in the ON position, it allows current to flow, powering the entire system. When turned OFF, it cuts off the power supply, safely shutting down the system.

Fig.4.16.Switch

4.1.9 FAN

Fan plays a vital role in maintaining a healthy and productive growing environment by ensuring proper air circulation and ventilation within the greenhouse structure. Greenhouses are enclosed spaces where temperature, humidity, and air quality need to be closely controlled to support optimal plant growth. Without effective air movement, greenhouses can become stagnant, leading to issues like mold, mildew, pest infestations, and heat stress in plants. A well-designed greenhouse fan system addresses these challenges by constantly moving air, reducing temperature fluctuations, and ensuring a uniform climate throughout the space. Typically mounted on the sidewalls or ceilings of the greenhouse, these fans come in various sizes and capacities, ranging from small exhaust fans for hobby greenhouses to large industrial units used in commercial agricultural operations. They are usually powered by electricity and are either manually controlled or automatically triggered by thermostats or humidity sensors. During hot weather, fans help exhaust excess heat and bring in cooler air, maintaining temperatures within a desirable range for photosynthesis and transpiration. In cooler weather, fans may be used in combination with heating systems to evenly distribute warm air, preventing cold spots and promoting consistent plant development.

Fig.4.17.Fan

Besides temperature regulation, greenhouse fans also contribute to improved gas exchange by reducing the accumulation of carbon dioxide and excess moisture. Proper airflow helps in strengthening plant stems and reducing the spread of airborne diseases. Moreover, fans prevent the layering of warm air at the top and cool air at the bottom, a phenomenon known as thermal stratification, which can negatively affect plant health. Some modern greenhouse fans are designed with energy efficiency in mind, utilizing brushless motors and adjustable speed settings to minimize power consumption while maintaining airflow effectiveness. In conclusion, the greenhouse fan is an essential component of a controlled environment agriculture system. It provides the necessary mechanical ventilation to keep air fresh, temperature balanced, and humidity levels optimal. Whether in a small-scale greenhouse or a commercial plant production facility, fans contribute significantly to improving plant health, productivity, and overall operational efficiency, making them indispensable in sustainable agricultural practices.

4.1.10 DC Motor

DC motors are integral components in robotic systems, providing the necessary mechanical movement to navigate the environment. In the context of the agricultural robot, the DC motor is used to power the robot's wheels or tracks, enabling it to move around the field autonomously. DC motors are ideal for robotics applications because of their simplicity, affordability, and efficient operation. The motor's rotational speed and torque can be easily controlled, making it a versatile choice for robotic systems that require precise movement and directional control.

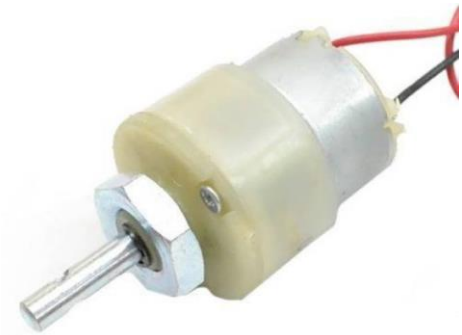


Fig.4.18.DC Motor

One of the key advantages of using DC motors in this robot is their ease of control. By adjusting the voltage supplied to the motor, the speed and direction can be precisely regulated. This control is typically achieved through a motor driver circuit, which enables the robot to move forward, backward, turn, and stop with high accuracy. In the proposed system, the DC motors are controlled via the Arduino Nano, which processes the signals received from the wireless communication module (HC-12) and sends commands to the motor driver to adjust the motor’s speed and direction.

Additionally, DC motors offer a good power-to-size ratio, which makes them suitable for mobile applications like this agricultural robot. They are compact and lightweight while still delivering sufficient power to move the robot across different terrains in the field. With the proper gearing and motor driver, DC motors can provide the necessary torque to handle the weight of the robot and any attached components, including the pesticide sprayer and sensors. This makes DC motors a reliable choice for ensuring that the robot can traverse the field, approach plants accurately, and perform the necessary disease detection and pesticide spraying tasks.

4.1.11 Battery

The battery is a critical component for the autonomous operation of the agricultural robot, providing the energy required to run the motors, sensors, control unit, and wireless communication module. For outdoor applications like precision agriculture, where the robot operates for extended periods, the battery needs to be reliable, long-lasting, and capable of providing sufficient power. Rechargeable lithium-ion (Li-ion) or lithium-polymer (LiPo) batteries are typically used in these applications due to their high energy density, lightweight nature, and long lifespan.

Fig.4.19.Battery

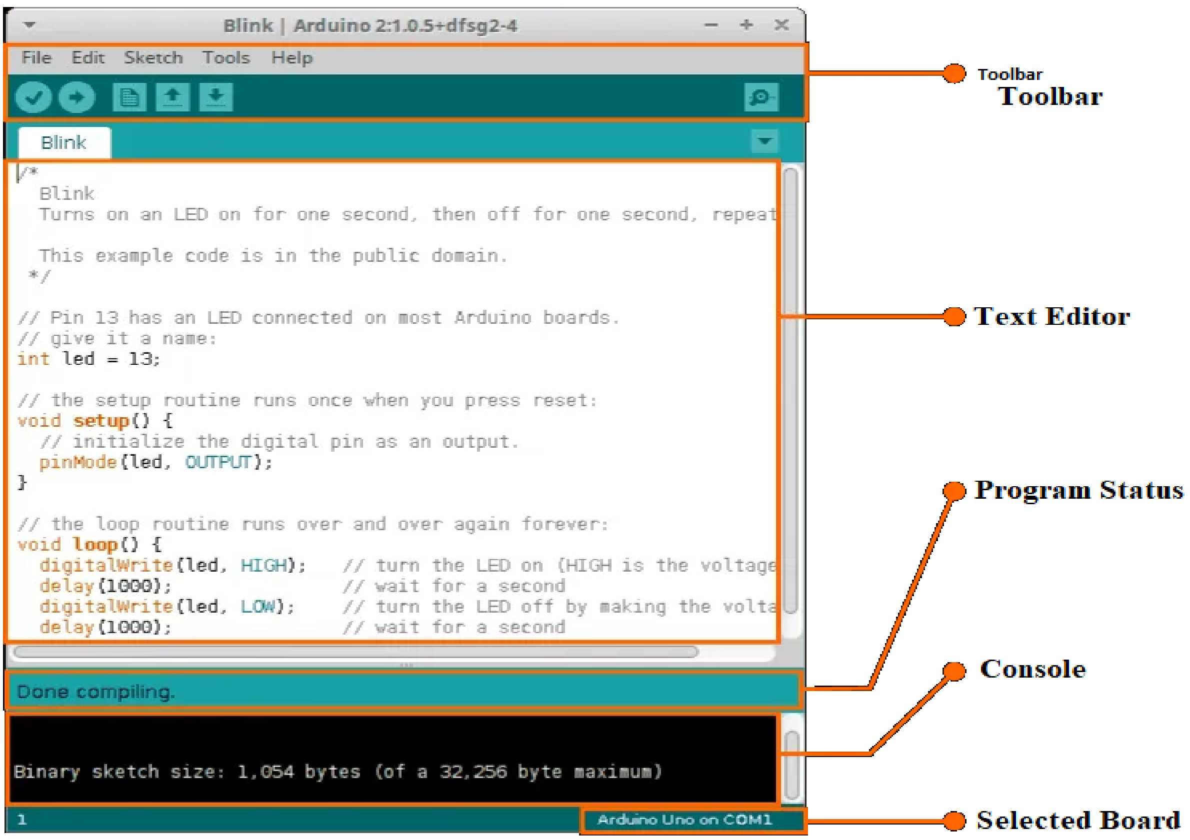
The robot's power requirements must be carefully calculated to ensure that the battery can supply enough energy for the entire system to function for a reasonable amount of time without requiring frequent recharging. The DC motors, which power the robot's movement, are one of the most power-hungry components, so the battery must have enough capacity to handle these demands while also powering the sensors and communication modules. The battery's voltage must also match the requirements of the components, and its size must be optimized for weight and space considerations, ensuring that the robot remains mobile and efficient.

In addition to providing power to the robot's components, the battery must also be managed properly to extend its life and ensure reliable performance. This involves implementing a battery management system (BMS) to monitor the battery's charge level, temperature, and health, preventing overcharging, undercharging, and overheating. The battery must be capable of charging quickly and efficiently to reduce downtime and ensure that the robot can continue working throughout the day. The use of solar panels as a supplementary power source can also be considered to extend the robot's operational time, making the system more sustainable and environmentally friendly.

4.2 Software Description

4.2.1 Arduino Software (IDE)

The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them.



- **Writing Sketches**

Programs written using Arduino Software (IDE) are called sketches. These sketches are written in the text editor and are saved with the file extension .ino. The editor has features for cutting/pasting and for searching/replacing text. The message area gives feedback while saving and exporting and also displays errors. The console displays text output by the Arduino Software (IDE), including complete error messages and other information. The bottom righthand corner of the window displays the configured board and serial port. The toolbar buttons allow you to verify and upload programs, create, open, and save sketches, and open the serial monitor.

Arduino IDE Tool Icon

- Verify Checks your code for errors compiling it.
- Upload Compiles your code and uploads it to the configured board. See uploading below for details. Note: If you are using an external programmer with your board, you can hold down the "shift" key on your computer when using this icon. The text will change to "Upload using Programmer"
- New Creates a new sketch.
- Open Presents a menu of all the sketches in your sketchbook. Clicking one will open it within the current window overwriting its content.
- Save Saves your sketch.
- Serial Monitor Opens the serial monitor.

Additional commands are found within the five menus: File, Edit, Sketch, Tools, Help. The menus are context sensitive, which means only those items relevant to the work currently being carried out are available.

File

- New Creates a new instance of the editor, with the bare minimum structure of a sketch already in place.
- Open Allows to load a sketch file browsing through the computer drives and folders.
- Open Recent Provides a short list of the most recent sketches, ready to be opened.
- Sketchbook Shows the current sketches within the sketchbook folder structure; clicking on any name opens the corresponding sketch in a new editor instance.
- Examples Any example provided by the Arduino Software (IDE) or library shows up in this menu item. All the examples are structured in a tree that allows easy access by topic or library.

- Close Closes the instance of the Arduino Software from which it is clicked.
- Save Saves the sketch with the current name. If the file hasn't been named before, a name will be provided in a "Save as.." window.
- Save as... Allows to save the current sketch with a different name.
- Page Setup It shows the Page Setup window for printing.
- Print Sends the current sketch to the printer according to the settings defined in Page Setup.
- Preferences Opens the Preferences window where some settings of the IDE may be customized, as the language of the IDE interface.
- Quit Closes all IDE windows. The same sketches open when Quit was chosen will be automatically reopened the next time you start the IDE.

Edit

- Undo/Redo Goes back of one or more steps you did while editing; when you go back, you may go forward with Redo.
- Cut Removes the selected text from the editor and places it into the clipboard.
- Copy Duplicates the selected text in the editor and places it into the clipboard.
- Copy for Forum Copies the code of your sketch to the clipboard in a form suitable for posting to the forum, complete with syntax coloring.
- Copy as HTML Copies the code of your sketch to the clipboard as HTML, suitable for embedding in web pages.
- Paste Puts the contents of the clipboard at the cursor position, in the editor.
- Select All Selects and highlights the whole content of the editor.
- Comment/Uncomment Puts or removes the // comment marker at the beginning of each selected line.
- Increase/Decrease Indent Adds or subtracts a space at the beginning of each selected line, moving the text one space on the right or eliminating a space at the beginning.
- Find Opens the Find and Replace window where you can specify text to search inside the current sketch according to several options.
- Find Next Highlights the next occurrence - if any - of the string specified as the search item in the Find window, relative to the cursor position.
- Find Previous Highlights the previous occurrence - if any - of the string specified as the search item in the Find window relative to the cursor position.

Sketch

- Verify/Compile Checks your sketch for errors compiling it; it will report memory usage for code and variables in the console area.

- Upload Compiles and loads the binary file onto the configured board through the configured Port.
- Upload Using Programmer This will overwrite the bootloader on the board; you will need to use Tools > Burn Bootloader to restore it and be able to Upload to USB serial port again. However, it allows you to use the full capacity of the Flash memory for your sketch. Please note that this command will NOT burn the fuses. To do so a Tools -> Burn Bootloader command must be executed.
- Export Compiled Binary Saves a .hex file that may be kept as archive or sent to the board using other tools.
- Show Sketch Folder Opens the current sketch folder.
- Include Library Adds a library to your sketch by inserting #include statements at the start of your code. For more details, see libraries below. Additionally, from this menu item you can access the Library Manager and import new libraries from .zip files.
- Add File... Adds a source file to the sketch (it will be copied from its current location). The new file appears in a new tab in the sketch window. Files can be removed from the sketch using the tab menu accessible clicking on the small triangle icon below the serial monitor one on the right side o the toolbar.

Tools

- Auto Format This formats your code nicely: i.e. indents it so that opening and closing curly braces line up, and that the statements inside curly braces are indented more.
- Archive Sketch Archives a copy of the current sketch in .zip format. The archive is placed in the same directory as the sketch.
- Fix Encoding & Reload Fixes possible discrepancies between the editor char map encoding and other operating systems char maps.
- Serial Monitor Opens the serial monitor window and initiates the exchange of data with any connected board on the currently selected Port. This usually resets the board, if the board supports Reset over serial port opening.
- Board Select the board that you're using. See below for descriptions of the various boards.
- Port This menu contains all the serial devices (real or virtual) on your machine. It should automatically refresh every time you open the top-level tools menu.
- Programmer For selecting a hardware programmer when programming a board or chip and not using the onboard USB-serial connection. Normally you won't need this, but if you're burning a bootloader to a new microcontroller, you will use this.
- Burn Bootloader The items in this menu allow you to burn a bootloader onto the microcontroller on an Arduino board. This is not required for normal use of an Arduino board but is useful if you purchase a new ATmega microcontroller (which normally comes without a bootloader). Ensure that you've selected the correct board

from the Boards menu before burning the bootloader on the target board. This command also set the right fuses.

Help

Here you find easy access to a number of documents that come with the Arduino Software (IDE). You have access to Getting Started, Reference, this guide to the IDE and other documents locally, without an internet connection. The documents are a local copy of the online ones and may link back to our online website.

Find in Reference This is the only interactive function of the Help menu: it directly selects the relevant page in the local copy of the Reference for the function or command under the cursor.

Sketchbook

The Arduino Software (IDE) uses the concept of a sketchbook: a standard place to store your programs (or sketches). The sketches in your sketchbook can be opened from the File > Sketchbook menu or from the Open button on the toolbar. The first time you run the Arduino software, it will automatically create a directory for your sketchbook. You can view or change the location of the sketchbook location from with the Preferences dialog.

- Tabs, Multiple Files, and Compilation

Allows you to manage sketches with more than one file (each of which appears in its own tab). These can be normal Arduino code files (no visible extension), C files (.c extension), C++ files (.cpp), or header files (.h).

Before compiling the sketch, all the normal Arduino code files of the sketch (.ino, .pde) are concatenated into a single file following the order the tabs are shown in. The other file types are left as is.

Uploading

Before uploading your sketch, you need to select the correct items from the Tools > Board and Tools > Port menus. The boards are described below. On the Mac, the serial port is probably something like /dev/tty.usbmodem241 (for an Uno or Mega2560 or Leonardo) or /dev/tty.usbserial-1B1 (for a Duemilanove or earlier USB board), or /dev/tty.USA19QW1b1P1.1 (for a serial board connected with a Keyspan USB-to-Serial adapter). On Windows, it's probably COM1 or COM2 (for a serial board) or COM4, COM5, COM7, or higher (for a USB board) - to find out, you look for USB serial device in the ports section of the Windows Device Manager. On Linux, it should be /dev/ttyACMx , /dev/ttyUSBx or similar. Once you've selected the correct serial port and board, press the upload button in the toolbar or select the Upload item from the Sketch menu. Current Arduino boards will reset automatically and begin the upload. With older boards (pre-Diecimila) that lack auto-reset, you'll need to press the reset button on the board just before starting the upload. On most boards, you'll see the RX and TX LEDs

blink as the sketch is uploaded. The Arduino Software (IDE) will display a message when the upload is complete, or show an error.
When you upload a sketch, you're using the Arduino bootloader, a small program that has been loaded on to the microcontroller on your board. It allows you to upload code without using any additional hardware. The bootloader is active for a few seconds when the board resets; then it starts whichever sketch was most recently uploaded to the microcontroller. The bootloader will blink the on-board (pin 13) LED when it starts (i.e. when the board resets).

Libraries

Libraries provide extra functionality for use in sketches, e.g. working with hardware or manipulating data. To use a library in a sketch, select it from the Sketch > Import Library menu. This will insert one or more #include statements at the top of the sketch and compile the library with your sketch. Because libraries are uploaded to the board with your sketch, they increase the amount of space it takes up. If a sketch no longer needs a library, simply delete its #include statements from the top of your code.
There is a list of libraries in the reference. Some libraries are included with the Arduino software. Others can be downloaded from a variety of sources or through the Library Manager. Starting with version 1.0.5 of the IDE, you do can import a library from a zip file and use it in an open sketch. See these instructions for installing a third-party library.
Third-Party Hardware
Support for third-party hardware can be added to the hardware directory of your sketchbook directory. Platforms installed there may include board definitions (which appear in the board menu), core libraries, bootloaders, and programmer definitions. To install, create the hardware directory, then unzip the third-party platform into its own sub-directory. (Don't use "arduino" as the sub-directory name or you'll override the built-in Arduino platform.) To uninstall, simply delete its directory.
Serial Monitor
This displays serial sent from the Arduino board over USB or serial connector. To send data to the board, enter text and click on the "send" button or press enter. Choose the baud rate from the drop-down menu that matches the rate passed to Serial.begin in your sketch. Note that on Windows, Mac or Linux the board will reset (it will rerun your sketch) when you connect with the serial monitor. Please note that the Serial Monitor does not process control characters; if your sketch needs a complete management of the serial communication with control characters, you can use an external terminal program and connect it to the COM port assigned to your Arduino board.
Preferences
Some preferences can be set in the preferences dialog (found under the Arduino menu on the Mac, or File on Windows and Linux). The rest can be found in the preferences file, whose location is shown in the preference dialog.

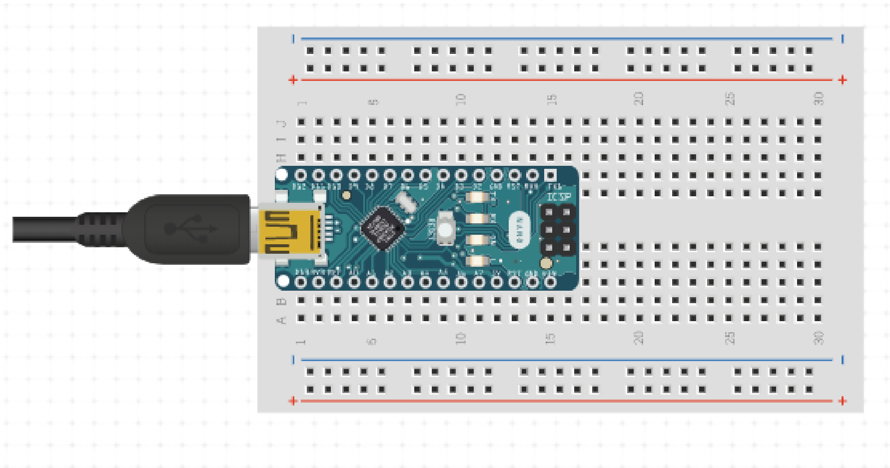
Boards

The board selection has two effects: it sets the parameters (e.g. CPU speed and baud rate) used when compiling and uploading sketches; and sets and the file and fuse settings used by the burn bootloader command. Some of the board definitions differ only in the latter, so even if you've been uploading successfully with a particular selection you'll want to check it before burning the bootloader.

Arduino Software (IDE) includes the built in support for the boards in the following list, all based on the AVR Core. The Boards Manager included in the standard installation allows to add support for the growing number of new boards based on different cores like Arduino Due, Arduino Zero, Edison, Galileo and so on.

- Started With The Arduino Nano

The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328P. It offers the same connectivity and specs of the UNO board in a smaller form factor.

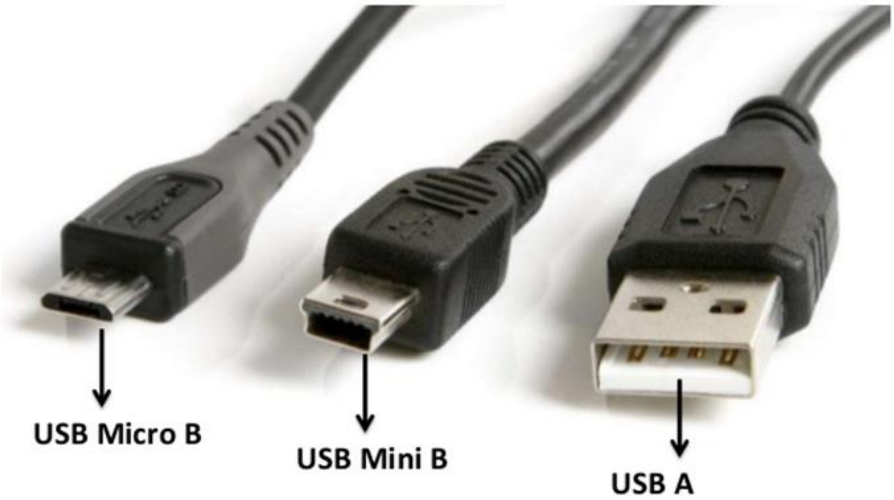


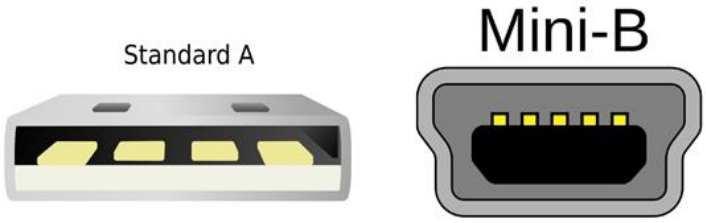
Arduino NANO Interface

The Arduino Nano is programmed using the Arduino Software (IDE), our Integrated Development Environment common to all our boards and running both online and offline. For more information on how to get started with the Arduino Software visit the Getting Started page.

Arduino Nano on the Arduino Desktop IDE

If you want to program your Arduino Nano while offline you need to install the Arduino Desktop IDE To connect the Arduino Nano to your computer, you'll need a Mini-B USB cable. This also provides power to the board, as indicated by the blue LED (which is on the bottom of the Arduino Nano 2.x and the top of the Arduino Nano 3.0).





NANO Interfacing USB Types of Port

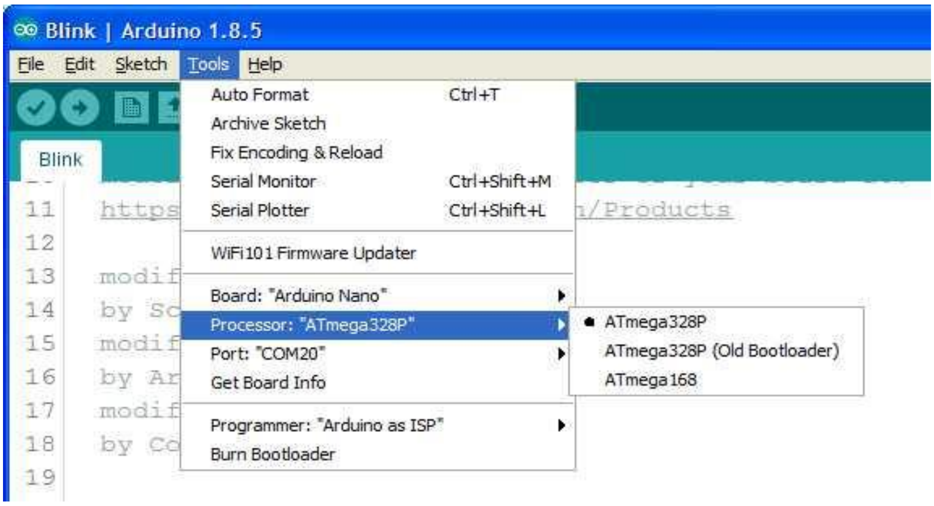
Open your first sketch

- Open the LED blink example sketch: File > Examples > 01.Basics > Blink.

Select your board type and port

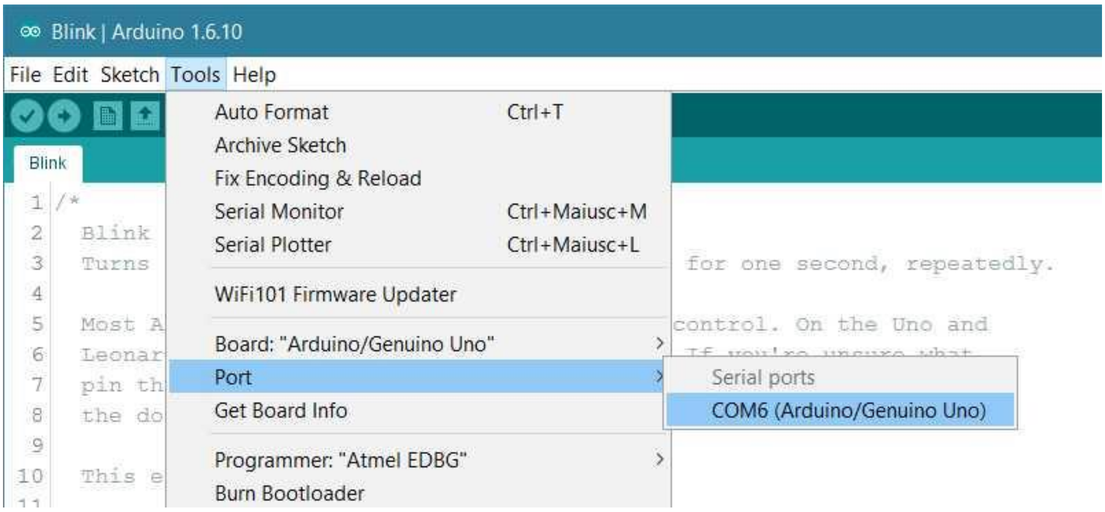
- Select Tools > Board > Arduino AVR Boards > Arduino Nano.

NOTE: We have updated the Nano board with a fresh bootloader. Boards sold by us from January 2018 have this new bootloader, while boards manufactured before that date have the old bootloader. First, check that Tools > Board > Boards Manager shows you have the Arduino AVR Boards 1.16.21 or later installed. Then, to program the NEW Arduino NANO boards you need to choose Tools > Processor > ATmega328P. To program old boards you need to choose Tools > Processor > ATmega328P (Old Bootloader). If you get an error while uploading or you are not sure which bootloader you have, try each Tools > Processor menu option until your board gets properly programmed.



Select the NANO Processor Type

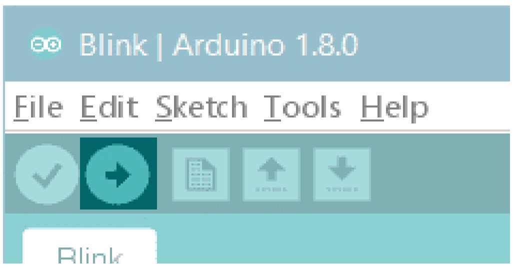
Select the serial device of the board from the Tools | Serial Port menu. This is likely to be COM3 or higher (COM1 and COM2 are usually reserved for hardware serial ports). To find out, you can disconnect your board and re-open the menu; the entry that disappears should be the Arduino board. Reconnect the board and select that serial port.



Select Board Type

Upload and Run your first Sketch

To upload the sketch to the Arduino Nano, click the Upload button in the upper left to load and run the sketch on your board:



Upload to Nano

Wait a few seconds - you should see the RX and TX LEDs on the board flashing. If the upload is successful, the message "Done uploading." will appear in the status bar.

4.2.2 PyCharm

PyCharm is a powerful and widely used Integrated Development Environment (IDE) developed by JetBrains specifically for Python programming. It stands out as one of the most popular tools among Python developers due to its feature-rich interface, intelligent code assistance, and seamless integration with modern development workflows. PyCharm supports both professional and community editions, catering to a wide range of users from beginners to advanced programmers. It offers smart code completion, real-time error detection, and on-the-fly code analysis, significantly enhancing coding efficiency and accuracy. The IDE supports various frameworks such as Django, Flask, and FastAPI, making it ideal for web development. Additionally, PyCharm provides excellent support for front-end technologies like HTML, CSS, and JavaScript when used in web projects. One of its notable features is the integrated debugger and test runner, which allows developers to debug their code and run unit tests within the same interface, improving productivity and reducing development time. PyCharm also supports version control systems like Git, SVN, and Mercurial, enabling effective collaboration in team-based projects. With its virtual environment integration, developers can manage dependencies and packages easily through tools like pip and conda. The IDE is compatible with major operating systems including Windows, macOS, and Linux, and supports remote development via SSH, Docker, and WSL. PyCharm's user-friendly interface, customizable themes, and plugin ecosystem provide a personalized development experience. For data scientists and machine learning practitioners, PyCharm supports popular libraries such as NumPy, pandas, scikit-learn, and TensorFlow, and offers integration with Jupyter Notebooks, making it a versatile platform for both software development and data science tasks. Overall, PyCharm streamlines the coding process, helps manage complex projects efficiently, and remains a top choice for developers seeking a professional and productive Python development environment.

4.3 Program 1:

```
from flask import Flask, render_template, flash, request, session,Response

from flask import render_template, redirect, url_for, request

#from wtforms import Form, TextField, TextAreaField, validators, StringField, SubmitField

from werkzeug.utils import secure_filename

import mysql.connector

import numpy as np

from tensorflow.keras.models import load_model

import joblib

import os

app = Flask(__name__)

app.config.from_object(__name__)

app.config['SECRET_KEY'] = '7d441f27d441f27567d441f2b6176a'



app.config['DEBUG']

model = load_model("temp_lstm_model.h5")
```

```
scaler = joblib.load("temp_scaler.save")

SEQ_LENGTH = 1

@app.route("/")

def homepage():

 return render_template('login.html')

@app.route("/adminhome")

def adminhome():

return render_template('adminhome.html')

@app.route("/iotdata")

def iotdata():

conn = mysql.connector.connect(user='root', password='', host='localhost', database='1batteryiot')

# cursor = conn.cursor()

 cur = conn.cursor()

 cur.execute("SELECT * FROM sensor_readings ORDER BY id DESC LIMIT 10")

 data = cur.fetchall()

 return render_template('iotdata.html',data=data)

@app.route("/preview")

def preview():

temp_input = float(request.args.get('data'))
```

```
 # Scale input
    temp_scaled = scaler.transform(np.array([[temp_input]]))
# Create sequence shaped input for LSTM (1, SEQ_LENGTH, features)
    input_seq = np.array([temp_scaled])
# Predict
    pred_prob = model.predict(input_seq)[0][0]
    predicted_label = "High" if pred_prob > 0.5 else "Low"
prediction = f"Predicted label for temperature {temp_input}°C is: {predicted_label}"
return render_template("result.html", prediction=prediction)
@app.route("/adminlogin", methods=['GET', 'POST'])
def adminlogin():
error = None
if request.method == 'POST':
if request.form['uname'] == 'admin' and request.form['password'] == 'admin':
return render_template('AdminHome.html')
else:
alert = 'Username or Password is wrong'
return render_template('goback.html', data=alert)
@app.route('/logout')
```

```
def logout():
 return render_template('login.html')
@app.route("/traindataset")
def traindataset():
import Main
return "Datatrain Successfull"
if __name__ == '__main__':
app.run(debug=True, use_reloader=True)
```

Program 2:

```
import serial
import mysql.connector
from datetime import datetime
import time
# Serial setup
arduino = serial.Serial('COM15', 9600, timeout=1)
time.sleep(2)  # Wait for the connection to initialize
# MySQL database configuration
db_config = {
```

```
    'host': 'localhost',        # Replace with your MySQL host
    'user': 'root',    # Replace with your MySQL username
    'password': '',# Replace with your MySQL password
    'database': '1batteryiot'   # Replace with your database name
}
while True:
    try:
        raw_data = arduino.readline().decode('utf-8').strip()
        if raw_data:
            print("📥 Received:", raw_data)
            data = raw_data.split()
            if len(data) == 3:
                print(data)
                Temp, Voltage,s = data
                date = datetime.now().strftime('%Y-%m-%d')
                time_now = datetime.now().strftime('%H:%M:%S')
                temp_float = float(Temp)
                voltage_float = float(Voltage)
            # Store the data in MySQL
```

```
            conn = mysql.connector.connect(**db_config)

            cursor = conn.cursor()

            insert_query = """

                INSERT INTO sensor_readings (date, time, temperature, voltage)

                VALUES (%s, %s, %s, %s)

            """

            cursor.execute(insert_query, (date, time_now, temp_float, voltage_float))

            conn.commit()

            cursor.close()

            conn.close()

time.sleep(1)  # Adjust the sleep time as needed

except Exception as e:

      print(f"An error occurred: {e}")

      break;
```

CHAPTER 5

RESULT & DISCUSSIONS

5.1 PROJECT SETUP

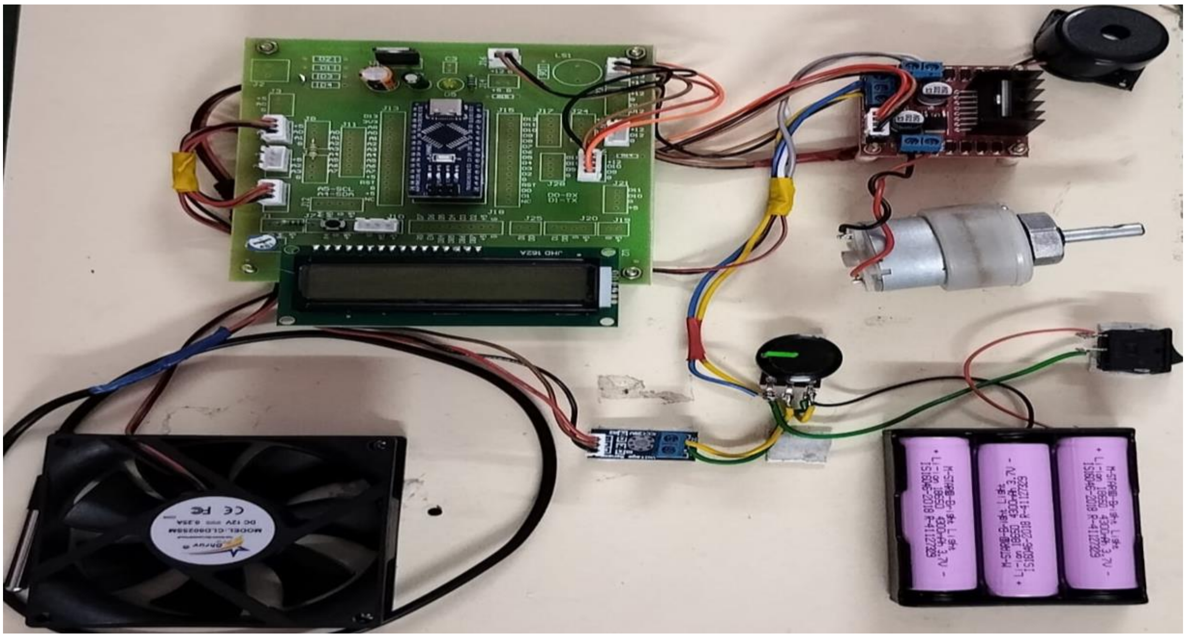


Fig.5.1.Project Setup

The implementation of the proposed Battery Management System (BMS) for electric vehicles demonstrated effective real-time monitoring and control of critical battery parameters, particularly voltage and temperature. During testing, the voltage sensor accurately detected both high and low charge levels of the battery. When the battery reached a high charge state, an indication was successfully sent to the wheel driver, enabling optimized operation without risking overcharging. Similarly, as the battery approached a low voltage threshold, the buzzer alert system functioned reliably, notifying the driver to initiate charging, thereby preventing unexpected vehicle shutdowns. The responsiveness of the buzzer ensured that alerts were immediate and clearly audible, contributing to timely decision-making by the driver.

The temperature sensing component also performed as intended. Under conditions simulating battery overheating, the temperature sensor detected the rise in temperature and immediately activated the buzzer to alert the driver. Simultaneously, the relay circuit engaged the cooling fan without manual intervention, allowing for efficient thermal management. This automatic fan operation effectively brought down the battery temperature to safe levels, demonstrating the system's ability to manage heat without compromising safety. The relay functioned smoothly and reliably, providing a seamless connection between the sensor input and actuator output. Overall, the integrated system proved to be efficient, simple, and highly functional in a controlled environment. It successfully achieved the goals of alerting and reacting to changes in battery condition without requiring complex interfaces or high-end components. The use of voltage and temperature sensors, combined with a buzzer and relay-controlled fan, resulted in a compact and cost-effective solution. This setup is highly suitable for small to mid-sized electric vehicles where battery management is crucial. The discussion confirms that the proposed system can significantly improve battery safety, reduce risks associated with overcharging and overheating, and contribute to extending the lifespan and reliability of EV batteries.

CHAPTER 6

CONCLUSION AND FUTURE WORK

6.1 CONCLUSION

The Battery Management System (BMS) for electric vehicles successfully demonstrated its ability to monitor and manage battery charge levels and temperature in real-time using voltage and temperature sensors. The system effectively provided alerts through a buzzer, ensuring that the driver was immediately informed about low charge or high temperature conditions. The automatic activation of a cooling fan via a relay during overheating conditions proved to be a reliable solution for thermal management. This project highlights a practical and low-cost approach to enhancing the safety, reliability, and efficiency of EV operations. The integration of sensor-based feedback with automated control responses helps minimize battery damage, extend battery life, and reduce maintenance issues. The system avoids complexity, making it easy to implement in various types of electric vehicles. Overall, the project contributes to building smarter and safer EV technologies that align with the growing need for sustainable transportation.

6.2 Future Work

In the future, the system can be expanded by integrating a digital display to show real-time battery status and temperature values. Adding wireless communication modules like Bluetooth or IoT platforms would enable remote battery monitoring and data logging. Machine learning algorithms could also be applied to predict battery failures or optimize energy usage based on driving patterns. Solar charging integration could further enhance energy efficiency. Enhanced alert systems like mobile notifications or dashboard indicators can provide more detailed user interaction. The system can be adapted to support multiple battery configurations. Lastly, advanced safety protocols such as automatic shutdowns can be introduced for extreme conditions.

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