

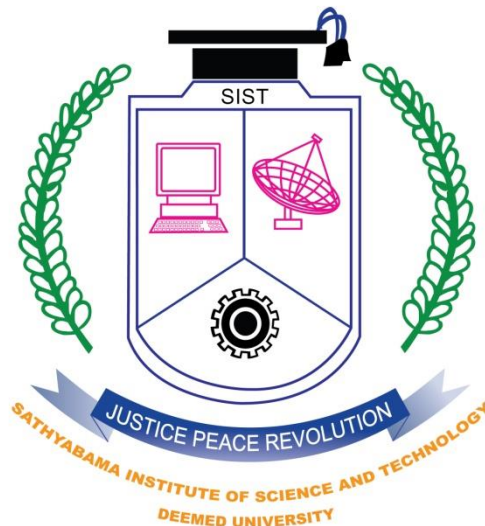
BATTERY MANAGEMENT SYSTEM FOR ELECTRIC VEHICLES

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering Degree in
Electrical and Electronics Engineering

by

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**DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
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SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **KEERTHANA M S** (Reg. No. 39140023) and **PRITHI K** (Reg. No. 39140043) who carried out the project entitled "**BATTERY MANAGEMENT SYSTEM FOR ELECTRIC VEHICLES**" under our supervision from November 2022 to April 2023.

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ABSTRACT

The Battery Management System (BMS) is a critical component in Electric Vehicles (EVs) that ensures the safe and optimal performance of the battery pack. This abstract outlines the importance of a BMS and burning prevention in EVs. The BMS monitors the state of charge, temperature, and voltage of each battery cell and balances the cells to avoid overcharging or discharging, which can lead to reduced battery life or even fire incidents. The burning prevention system involves the use of sensors, software, and other safety measures to detect and mitigate potential risks of battery fires in EVs. With the rapid growth in the EV market, BMS and burning prevention systems are essential for ensuring the safety and reliability of EVs.

Our system monitors and stores parameters that provide an indication of the lead acid battery's state of charge, voltage, current, and the remaining charge capacity in a real-time scenario. Wireless local area network is used as the backbone network. The information collect from all the associated battery clients in the system is analyzed. The malfunction of the battery is monitored continuously and sudden charge & discharge voltage of battery bank and battery conditions are viewed with help of IoT module. When a temperature of the battery reaches the threshold, the battery output is suddenly cut off and a buzzer sounds an alert.

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LIST OF SYMBOLS AND ABBREVIATIONS

BMS	- Battery Management System
SOC	- State of Charge
SOH	- State of Health
BSL	- Battery Safety Limit
CC	- Constant Current
CV	- Constant Voltage
Li-ion	- Lithium-ion
ECU	- Electronic Control Unit
CAN	- Controller Area Network
BCI	- Battery Council International
FMEA	- Failure Modes and Effects Analysis
HV	- High Voltage
LV	- Low Voltage
EV	- Electric Vehicle
HEV	- Hybrid Electric Vehicle
PHEV	- Plug-in Hybrid Electric Vehicle
BEV	- Battery Electric Vehicle
C-rate	- Charging or discharging rate relative to battery capacity
kW	- Kilowatt
kWh	- Kilowatt hour
DC	- Direct Current
AC	- Alternating Current
MCU	- Microcontroller Unit

CHAPTER 1

INTRODUCTION

1.1 GENERAL

The industrial process expansion has become very complex in the electronics system. In such developing industrial field fault detection and fault isolation is very important. This proposed work reduces the system in identifying the fault in the EV. The vulnerable part in the EV is the battery. Battery performance is influenced by factors such as depth of discharge (DoD), temperature and charging time. This paper attempts to provide the current level and voltage level using Internet of Things. By depending on the output of the battery fault can be analyzed.

The battery is a device that converts the chemical energy into electrical energy through electrochemical reaction. Lead Acid battery is the most commonly used battery in UPS. To know the present status of the battery some important parameters are to be measured in regular interval. The important parameters are terminal voltage, load current, discharge current, room temperature of each battery used in the battery. The UPS that are used in the industries require electric power for smooth operation. The systems are equipped with lead acid batteries as an alternate source of electric power.

Battery management system (BMS) forms a crucial system component in various applications like electric vehicles (EV), hybrid electric vehicles (HEV), uninterrupted power supplies (UPS), telecommunications and so on. The accuracy of these systems has always been a point of discussion as they generally give an error of maximum 10% considering all the parameters together. Batteries are the heart of the automation system, and its applications are more in all the fields, where the electrical supply requires. The periodical monitoring/observations are required for battery source to provide continuous power to the load without any interruption.

1.2 MOTIVATION FOR THE SELECTION OF PROBLEM

The motivation for selecting a battery management system (BMS) and burning prevention system for electric vehicle (EV) batteries as a project can stem from several key factors:

Safety: Ensuring the safety of EV batteries is of paramount importance as they store large amounts of energy and are susceptible to various risks, including thermal runaway, overcharging, and short-circuiting, which can lead to battery fires or explosions. The motivation for this project may arise from the need to develop robust BMS and burning prevention systems to monitor, protect, and prevent such safety hazards, ensuring the safe operation of EV batteries and minimizing the risk of accidents.

Reliability: EV batteries need to be reliable to ensure the efficient and uninterrupted operation of the vehicle. The BMS plays a crucial role in monitoring and managing the battery's performance, state of charge (SOC), and state of health (SOH), as well as protecting it from overvoltage, undervoltage, overcurrent, and other adverse conditions. The motivation for this project may arise from the need to design and implement a reliable BMS and burning prevention system that ensures the optimal performance and longevity of EV batteries, thereby enhancing the overall reliability of the EV.

Battery performance optimization: Maximizing the performance and efficiency of EV batteries is a critical aspect of electric vehicle technology. The BMS can help optimize battery performance by managing charging and discharging rates, balancing cell voltages, and preventing overcharging or over-discharging. The motivation for this project may arise from the goal of developing an advanced BMS and burning prevention system that can optimize the performance, capacity, and lifespan of EV batteries, thereby enhancing the overall performance and range of the EV.

Compliance with standards and regulations: EVs and their batteries are subject to various safety standards and regulations, such as those set by the IEEE, ISO, and other regulatory bodies. The motivation for this project may arise from the need to ensure compliance with these standards and regulations related to BMS and battery burning prevention, which are crucial for the safe and reliable operation of EV batteries, as well as for regulatory compliance and market acceptance of EVs.

Innovation and technological advancement: The field of electric vehicles and battery technology is continuously evolving, and there is a constant drive towards innovation and technological advancement. The motivation for this project may arise from the desire to contribute to the advancement of BMS and battery burning prevention technology, by developing novel approaches, algorithms, and techniques that can improve the safety, reliability, and performance of EV batteries, and potentially pave the way for future advancements in the field.

Environmental sustainability: Electric vehicles are considered to be a more environmentally sustainable transportation option compared to conventional internal combustion engine vehicles, as they produce zero tailpipe emissions. The motivation for this project may arise from the desire to contribute to the advancement of EVs as a sustainable transportation option by developing a robust BMS and burning prevention system that ensures safe and efficient operation of EV batteries, minimizing the environmental impact of EVs.

Overall, the motivation for selecting a battery management system and burning prevention system for electric vehicle batteries as a project can be driven by the need for safety, reliability, battery performance optimization, compliance with standards and regulations, innovation, technological advancement, and environmental sustainability, with the ultimate goal of advancing electric vehicle technology and ensuring the safe and efficient operation of EV batteries.

1.3 OVERVIEW

A battery management system (BMS) for electric vehicles (EVs) is a key component that monitors and controls the charging and discharging of the battery cells. It ensures the safety, efficiency, and longevity of the battery pack by preventing overcharging, over-discharging, and overheating.

The BMS continuously measures and balances the cells' voltage, temperature, and state of charge to ensure that all cells are operating within their safe limits. It also communicates with the vehicle's electronic control unit (ECU) to determine the available battery capacity and range.

Furthermore, the BMS performs various functions to prevent battery pack damage and optimize performance, such as:

- Cell balancing: Distributes the charge among the cells to ensure that they are all at the same voltage level, which maximizes the pack's capacity and extends its life.
- Thermal management: Monitors the temperature of the cells and controls the cooling system to prevent overheating, which can cause fires or explosions.
- Fault detection and diagnosis: Detects any abnormal behavior or malfunctions in the pack and alerts the driver or initiates actions to prevent damage.

To prevent burning or fire in an EV, the BMS and other safety measures should be followed. The most important safety measure to prevent burning or overheating is to maintain the battery pack's temperature efficiently. The battery pack temperature should be kept between 20°C to 35°C. The cooling system should be properly designed and installed to allow for an efficient heat management system.

Moreover, to prevent overcharging, the battery management system should be accurately measuring the state of charge of the battery, such as controlling the charging system to avoid over-voltage conditions, and the voltage levels should be

kept at a safe level. This will prevent any charging current being applied to the battery pack that may ignite the battery electrolyte.

In conclusion, a battery management system (BMS) is crucial for ensuring the safety, efficiency, and longevity of an EV's battery pack. Additionally, proper precautionary measures should be taken to prevent any kind of burning or fire caused by battery overheating or overcharging.

CHAPTER 2

LITERATURE SURVEY

2.1 MAJOR FINDINGS FROM LITERATURE SURVEY

Atzori et; al (2017) proposes Understanding the Internet of Things: Definition, potentials, and societal role of a fast-evolving paradigm. *Ad Hoc Netw.* 2017, 56, 122–140. The Internet of Things (IoT) has been inscribed in this review paper. Internet of Things is a keyword to cover various challenges related to internet and the web to the real physical world. We know that, today internet has already taken an important part of everyday life and it has also dramatically changed the lives of human being. The most important factor of this invention is, integration or combination of several technologies with the communication system solutions. The most applicable factors of IoT are the identification and tracking various factors for smart objects. The universal sensing networks is enabled by Wireless Sensing Networks (WSN) and these technologies cuts across many areas of modern day living. The escalation of these devices in a communicating and actuating network will create the Internet of Things (IoT). Here the sensors and actuators combine easily with the environment around us and the information is shared across various platforms in order to develop a common operating picture (COP). Internet of Things predicts the future that, the advance digital world and the physical world will get linked by means of proper information and wireless communication system technologies. In this survey paper they have mentioned the visions, concepts, technologies, various challenges, some innovation directions, and various applications of Internet of Things (IoT).

C. Wu et; al (2015) proposes "Research on overcharge and over discharge effect on Lithium-ion batteries", *Proc. IEEE Veh. Power Propul. Conf.*, pp. 1-6, 2015. The purpose of this study is to diagnose and analyses the overcharge and over discharge fault of lithium-ion battery. Through the dynamic simulation model, the phenomenon of overcharge and over discharge fault for automotive lithium-ion battery (LIB) was discussed, and the fault diagnosis effect was summarized. The results of this study show that the fault diagnosis analysis of LIB can achieve good results. It is of certain

application value for diagnosis of LIB with different parameters. Therefore, it's concluded that the overcharge and over discharge faults of automotive LIB are likely to jeopardize the using effect of the batteries, which should attract more attention of relevant automobile manufacturers.

López-Benítez et; al (2017) proposes Prototype for Multidisciplinary Research in the context of the Internet of Things. *J. Netw. Comput. Appl.* 2017, 78, 146–161. This work proposes a novel mathematical approach to accurately model data traffic for the Internet of Things (IoT). Most of the conventional results on statistical data traffic models for IoT are based on the underlying assumption that the data generation follows standard Poisson or Exponential distribution which lacks experimental validation. However, in some of the use case applications a single statistical distribution is not adequate to provide the best fit for the inter-arrival time of the data packets generation. Based on the real data collected for over 10 weeks using their customized experimental IoT prototype for smart home application, in this paper they have established this very fact, citing barometric air pressure as an example.

This paper presents a remote online monitoring system for the operation of lead-acid battery group in telecommunication base stations. Combining the General Packet Radio Service (GPRS) communications and Internet connections, the system realizes data transmission between remote acquisition modules and data services center. The collected data of battery parameters in the center are analyzed and processed, and then it can be monitored by using any standard browser distributed worldwide if access permission is given. Both battery users and battery manufactures can use the system for the battery power management, maintenance and troubleshooting.

O. A. Mohamad et; al (2016) proposes Design and implementation of real time tracking system based on arduino intel galileo", *Electronics Computers and Artificial Intelligence (ECAI) 2016 8th International Conference on* with the rapid increase in advancement in the world of technology, it has become highly important to the people to have the flexibility to monitor and control their physical property as well as personal data. Although physical transportation systems have made it easier for people to

travel, it has also become a hazard in several ways. Therefore, a real-time tracking device has been designed in this project to cater to the issues of monitoring of vehicles. In this paper, we developed a system using Arduino Uno R3, Global System for Mobile (GSM) device and Global Positioning System (GPS) to track the exact and accurate position of the vehicle at a location. Arduino IDE software is utilized to code the Arduino Uno R3 and its microcontroller. The system is also equipped with display facilities to show the information to the user. The latitude and longitude of the vehicle's location are displayed on Liquid Crystal Display (LCD). Furthermore, two software is utilized to display the data. ThingSpeak was used to display the trend of the vehicle's motion by using charts of latitude and longitude, and Freeboard is utilized to display the same information in the form of a map. This map could easily be read by the user to pinpoint the exact location of the vehicle at any given time. It will be highly useful to monitor the exact locations of the delivery vehicle used by food-related businesses. Finally, by having latitude and longitude, users can successfully track their vehicle location on electronic maps using internet. Thus, the entire system has been tested thoroughly in real time and it is said to function successfully in helping users to locate their vehicles in the event of a theft.

Xia, Velandia et; al (2016) proposes industrial internet of things: Crankshaft monitoring, traceability and tracking using RFID. *Robot.Comput.Integr. Manuf.* 2016, 41, 66–77. M.; Li, T.; Zhang, Y.; de Silva, C.W. Closed-loop design evolution of engineering system using condition monitoring through internet of things and cloud computing.

This paper considers the stochastic scheduling of a two-machine flow shop robotic cell with controllable inspection times. The inspection here is performed by a multi-function robot which can inspect identical parts with two alternatives for the inspection strategy: either at the back of the upstream machine or in transit between upstream and downstream machines. A characteristic of the inspection process is that its time is changed by altering the inspection cost. If the inspection time is reduced, more failures in parts may result regardless of when failures are identified. The

challenge is therefore to find a suitable trade-off between inspection time and internal and external quality costs to increase reliability benefits.

Yong Tian et; al (2017) proposes an optimal nonlinear observer for state-of-charge estimation of lithium-ion batteries”, Industrial Electronics and Applications (ICIEA), 2017 12th IEEE Conference. State-of-Charge (SOC) information is very crucial for the control, diagnostics and monitoring of Li-ion cells/batteries. Compared to conventional data-driven or equivalent circuit models often employed in battery management systems, electrochemical battery models have the potential to give physically accurate the SOC information by tracking the Li-ion concentration in each electrode. In this paper, two nonlinear observer designs are presented to estimate Li-ion battery State-of-Charge based on reductions of an electrochemical model. The first observer design uses a constant gain Luenberger structure whereas the second one improves it by weighing the gain with the output Jacobian. For both observer designs, Lyapunov's direct method is applied and the design problems are converted to solving LMIs. Simulation results are included to demonstrate the effectiveness of both observer designs.

2.2 BLOCK DIAGRAM OF BATTERY MONITORING SYSTEM

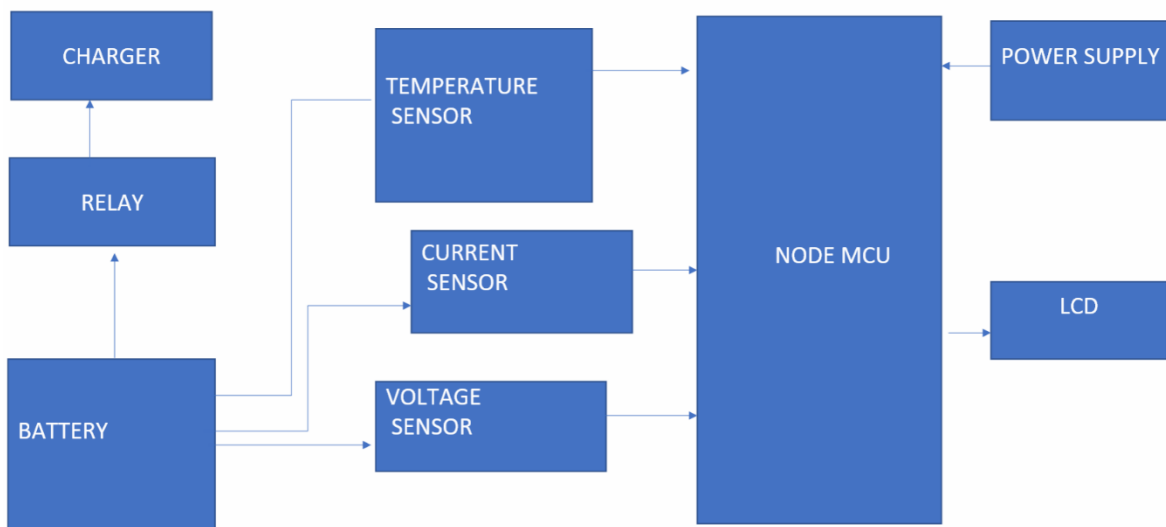


Fig 2.1: Existing system block diagram

2.3 OPEN PROBLEMS IN BATTERY MONITORING SYSTEM

One major problem in previous battery management systems was insufficient thermal management. As electric vehicle battery packs were charged and discharged, they generated heat that needed to be dissipated to prevent the batteries from overheating and potentially causing a fire. In some cases, battery management systems failed to detect and mitigate high temperatures, resulting in battery fires. The existing system block diagram is shown in the figure 2.1.

To prevent battery fires, we should use advanced battery management systems with improved thermal management capabilities. These systems monitor each cell in the battery pack and adjust the charging and discharging rates to maintain safe temperatures. In the event of a fault, such as a short circuit, the system can also disconnect the battery pack to prevent further damage.

In addition to thermal management, electric vehicles should also have other safety features to prevent battery fires, such as crash detection and prevention systems, as well as fire suppression systems. These safety features work together to ensure that electric vehicles are as safe as possible for drivers and passengers.

2.4 DISADVANTAGES

- Overheating and overcharging occurs, batteries are burnt.
- IOT is not present which would be easy to get information through mobile.
- We cannot display the conditions in it.

2.5 PROBLEM IDENTIFICATION

- It must measure individual cell voltages.
- The BMS must measure temperatures at different points as close as possible to the battery.

- It must measure currents flowing through it.
- The BMS should communicate information to control units and undertake action to ensure the battery will be operated within safety limits.
- The BMS should balance battery cells passively or actively.
- And, the BMS should provide thermal management.

CHAPTER 3

AIM AND SCOPE OF THE PRESENT INVESTIGATION

3.1 AIM OF THE PROJECT

The aim of battery management and burning prevention of electric vehicles is to ensure the safe and reliable operation of the vehicle's battery system, while minimizing the risk of fire or other hazards.

Battery management systems (BMS) are responsible for monitoring and controlling the state of charge, temperature, and other key parameters of the battery to ensure that it operates within safe limits. The BMS also provides early warning of potential faults or issues with the battery system, allowing for timely maintenance and repairs.

In addition to BMS, other safety features are incorporated into electric vehicles to prevent battery fires and other hazards. These can include thermal management systems to regulate the temperature of the battery pack, as well as electrical safety features such as fuses and circuit breakers to prevent electrical faults and short circuits.

The aim of battery management and burning prevention is to ensure that electric vehicles are as safe and reliable as possible, while also promoting the wider adoption of electric vehicles as a sustainable and environmentally friendly transportation option. By providing confidence in the safety and reliability of electric vehicles, battery management and burning prevention can help accelerate the transition to a low-carbon transportation system.

3.2 SCOPE OF THE PROJECT

The development of efficient and reliable battery management systems and burning prevention techniques is crucial for the widespread deployment of electric vehicles. The current state of research indicates that multi-objective optimization methods, machine learning-based methods, and advanced sensor technologies, along with flame retardant coatings, ventilation systems, and thermal management techniques, are promising areas for further studies. By integrating these innovations,

we can enhance the safety, performance and durability of the battery systems of electric vehicles.

Lithium-ion batteries are commonly used as a power source in current electric cars. In electric cars, nominal pack voltages will range from 300 to 800 volts.

Because batteries make up such a large part of an electric car, keeping the voltages low and in order to ensure the safety of the electric vehicles, batteries are critical.

The Battery Management System (BMS) is necessary to keep EV Batteries safe from overheating. BMS is essential not only for the safe operation of electric vehicles but also for their efficient operation.

3.3 OBJECTIVES

The objectives of the proposed work are as follows

- To monitor and store parameters that provide an indication of the state of charge, state of health, voltage, current, temperature and the remaining charge capacity in a real-time scenario.
- To automatically limit the power output of the vehicle when overheating of the battery is observed.

3.4 IEEE STANDARDS FOLLOWED

IEEE has several standards related to battery management systems (BMS) for electric vehicles (EVs). These standards provide guidelines, specifications, and best practices for the design, operation, and safety of BMS in EVs.

IEEE 1725: "Standard for Rechargeable Batteries for Cellular Telephones": This standard provides requirements for the design, testing, and use of rechargeable batteries in cellular telephones, including BMS requirements for lithium-ion batteries used in EVs. It covers aspects such as battery chemistry, cell protection, thermal management, charging, and discharging.

IEEE 2464: "Guide for Capacity and Power Loss Characterization of Energy Storage Devices in Electric Vehicle Applications": This guide provides guidelines for evaluating the capacity and power loss characteristics of energy storage devices, including batteries used in BMS for EVs. It covers measurement methods, data analysis, and reporting for capacity and power loss characterization of batteries under various operating conditions.

IEEE 2848: "Standard for Rechargeable Batteries for Electric Vehicle Energy Storage Systems - IEEE/SA Battery Working Group": This standard provides requirements for the design, testing, and use of rechargeable batteries in EV energy storage systems, including BMS requirements. It covers aspects such as battery chemistry, cell protection, thermal management, charging, discharging, and safety features.

IEEE 2993: "Recommended Practice for Functional Safety Analysis of Battery Management Systems for Electric and Hybrid Electric Vehicles": This recommended practice provides guidance for functional safety analysis of BMS for EVs and hybrid electric vehicles (HEVs). It covers aspects such as hazard identification, risk assessment, functional safety requirements, and validation of BMS for EVs.

IEEE 2030.5: "Standard for Smart Energy Profile Application Protocol - Application Layer": This standard provides a communication protocol for interoperability between EVs, EV charging stations, and utility grids. It includes provisions for BMS communication and data exchange between EVs and charging stations, allowing for efficient and safe charging and discharging of EV batteries.

3.5 CONSTRAINTS

Safety regulations and standards: Compliance with relevant safety regulations and standards, such as those set by the IEEE, ISO, and other regulatory bodies, is a key constraint for BMS and battery burning prevention systems. These regulations and standards may cover aspects such as thermal management, voltage limits, current limits, protection against short circuits, and other safety considerations.

Battery chemistry and characteristics: Different types of batteries, such as lithium-ion, lithium-polymer, or solid-state batteries, have their own unique characteristics, limitations, and constraints that need to be considered in the design and operation of the BMS and burning prevention system. For example, the charging and discharging rates, temperature limits, state of charge (SOC) and state of health (SOH) monitoring, and protection mechanisms may vary depending on the battery chemistry.

System complexity and integration: BMS and burning prevention systems for EV batteries may involve complex electronics, sensors, algorithms, and communication interfaces, which can pose constraints related to system complexity, integration, and interoperability. Ensuring seamless integration with the EV's power electronics, vehicle control system, and other subsystems while maintaining reliability and performance can be challenging.

Cost and budget: Cost considerations, including budget constraints, can impact the design, development, and implementation of a BMS and burning prevention system for EV batteries. Balancing cost-effectiveness with safety, reliability, and performance requirements can be a constraint, especially in cases where cost reduction is a priority.

Energy efficiency: Maximizing the energy efficiency of the BMS and burning prevention system is important to minimize energy losses, optimize battery performance, and extend battery life. However, achieving high energy efficiency may pose constraints related to system design, component selection, and operational strategies.

Scalability and flexibility: Considerations for scalability and flexibility, such as accommodating different battery configurations, cell chemistries, and EV platforms, can pose constraints on the BMS and burning prevention system design. Ensuring adaptability and flexibility for future technological advancements and changes in battery technologies and EV requirements is a challenge.

Operational conditions: Operational conditions, such as temperature extremes, humidity, vibrations, and other environmental factors, can impact the performance and reliability of the BMS and burning prevention system. Meeting operational requirements under different conditions can pose constraints on the system design and performance.

It's important to carefully analyze and address these constraints during the design, development, and implementation of a BMS and burning prevention system for EV batteries to ensure that the system meets safety, performance, and reliability requirements while being cost-effective and adaptable to different operational conditions.

3.6 TRADEOFF

Sensing Accuracy vs. Cost: Higher accuracy in battery state estimation, such as state-of-charge (SOC), state-of-health (SOH), and temperature sensing, may require more sophisticated sensors and measurement techniques, which could increase the cost of the BMS. Balancing the desired accuracy with the associated cost is important, considering the specific safety requirements and budget of the project.

Early Warning vs. False Alarms: Implementing early warning systems and safety mechanisms to detect potential battery overheating or thermal runaway events may require sensitive detection algorithms and monitoring systems. However, there may be tradeoffs between the sensitivity of the detection system and the potential for false alarms, which could cause unnecessary disruptions or interventions. Striking the right balance between early warning and false alarms is crucial for effective burning prevention while minimizing disruptions.

Safety Features vs. Complexity: Implementing safety features, such as thermal protection devices, fire suppression systems, and emergency shutdown mechanisms, may increase the complexity of the BMS and the overall EV system. Balancing the desired safety features with the associated complexity and potential impact on system

performance, reliability, and cost is important to ensure effective burning prevention without compromising other aspects of the EV system.

System Response Time vs. False Positives: Rapid response time in case of a battery overheating or burning event is critical for effective burning prevention. However, there may be tradeoffs between the response time and the potential for false positives, where the system may trigger unnecessary interventions or shutdowns due to false alarms. Optimizing the system response time while minimizing false positives is crucial for effective burning prevention without causing unnecessary disruptions.

Battery Performance vs. Safety: BMS optimization strategies for battery performance, such as maximizing power output and driving range, may require higher energy consumption and increased load on the battery, potentially affecting battery safety. Balancing the desired battery performance with safety considerations, such as thermal management, voltage and current limits, and safety margins, is crucial for effective burning prevention and ensuring the safe operation of the EV.

Cost vs. Safety: Implementing advanced safety features, redundant safety mechanisms, and safety-certified components may increase the cost of the BMS and the overall EV system. Balancing the desired level of safety with the associated costs is important, considering the budget constraints of the project and the safety requirements of the EV battery.

System Integration vs. Flexibility: Integrating the BMS and burning prevention system with the overall EV architecture, including battery pack, power electronics, and vehicle control systems, may require tight integration and customization. However, there may be tradeoffs between system integration and flexibility, where customization may impact the flexibility to adapt to potential changes in battery technology, EV platforms, and regulatory requirements. Balancing system integration with flexibility is crucial for ensuring effective burning prevention while maintaining adaptability to future changes.

These are some potential tradeoffs that may need to be considered in a BMS and burning prevention project for EV batteries. It's important to carefully analyze and weigh the tradeoffs based on the specific safety requirements, project goals, and constraints to make informed decisions during the development and implementation process.

3.7 PREREQUISITES

- A high-performance battery that can store and discharge energy efficiently.
- An intelligent electronic control unit to manage the battery.
- Sensors and communication devices to monitor and collect data on battery performance.
- A reliable charging system capable of safely charging the battery.

3.8 ASSUMPTIONS

- The battery will be properly charged and maintained to ensure its longevity.
- The battery management system will be properly installed and calibrated to prevent overcharging and overheating.
- The electric vehicle will be operated according to manufacturer's instructions and safety guidelines.
- The battery will not be subjected to extreme environmental conditions such as excessive heat or cold temperatures.

CHAPTER 4

HARDWARE AND PROJECT DESCRIPTION

4.1 HARDWARE CIRCUIT DIAGRAM

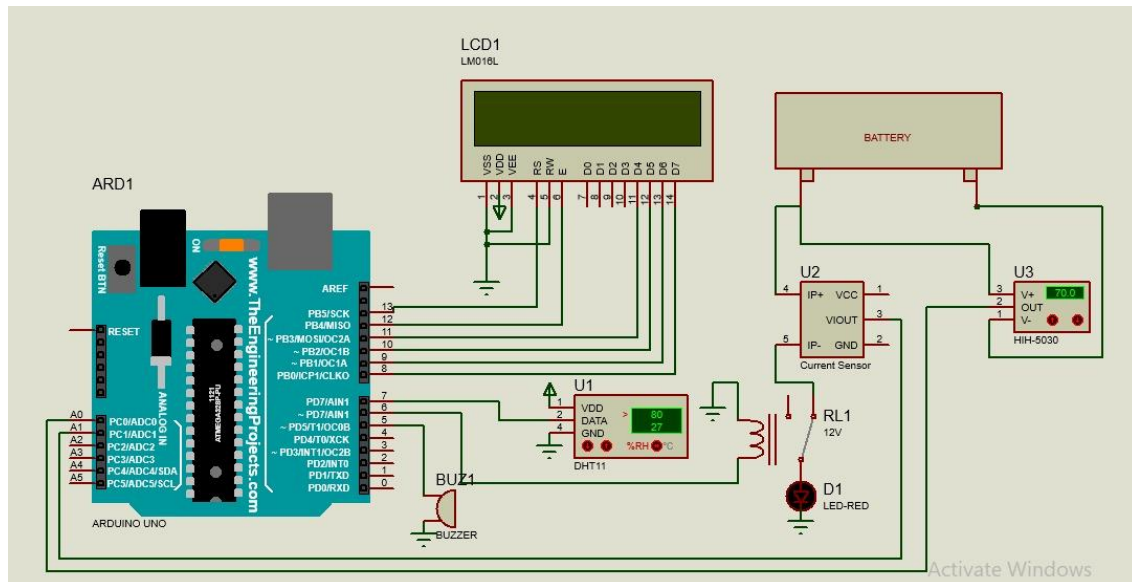


Fig 4.1: Circuit diagram

4.2 EXPLANATION

Our proposed system uses Arduino microcontroller, Temperature sensor, Voltage sensor, Current sensor, Lcd Display, Buzzer, Relay and Node MCU. The circuit diagram is shown in the figure 4.1. Temperature sensor is used to measure the temperature level of battery and display the temperature on LCD display then the Current and Voltage sensor is used to measure the current and voltage level of the battery. The buzzer alerts the user and the relay shuts off the battery output power if the battery temperature level suddenly reaches a specified level or threshold limit. The Node MCU is used to continuously upload battery information to an IoT webpage that is available for viewing by the owner or other authorized users

4.3 HARDWARE COMPONENTS

The list of hardware components that are required are:

- Arduino UNO (Microcontroller)
- RPS
- Temperature sensor
- Voltage sensor
- Current sensor
- Battery
- LCD
- LED
- Buzzer
- Relay
- Node MCU

4.3.1 *Arduino UNO*

Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board. To do so you use the Arduino programming language (based on Wiring), and the Arduino Software (IDE), based on Processing.

Over the years Arduino has been the brain of thousands of projects, from everyday objects to complex scientific instruments. A worldwide community of makers - students, hobbyists, artists, programmers, and professionals - has gathered around this open-source platform, their contributions have added up to an incredible amount of accessible knowledge that can be of great help to novices and experts alike.

Arduino was born at the Ivrea Interaction Design Institute as an easy tool for fast prototyping, aimed at students without a background in electronics and programming. As soon as it reached a wider community, the Arduino board started changing to adapt to new needs and challenges, differentiating its offer from simple 8-bit boards to

products for IoT applications, wearable, 3D printing, and embedded environments. All Arduino boards are completely open-source, empowering users to build them independently and eventually adapt them to their particular needs. The software, too, is open-source, and it is growing through the contributions of users worldwide.

4.3.1.1 Input and Output

Arduino - ArduinoBoardUno Each of the 14 digital pins on the Uno can be used as an input or output, using `pinMode()`, `digitalWrite()`, and `digitalRead()` functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms.

The Uno is one of the more popular boards in the Arduino family and a great choice for beginners. The Arduino uno diagram is shown in the figure 4.2.

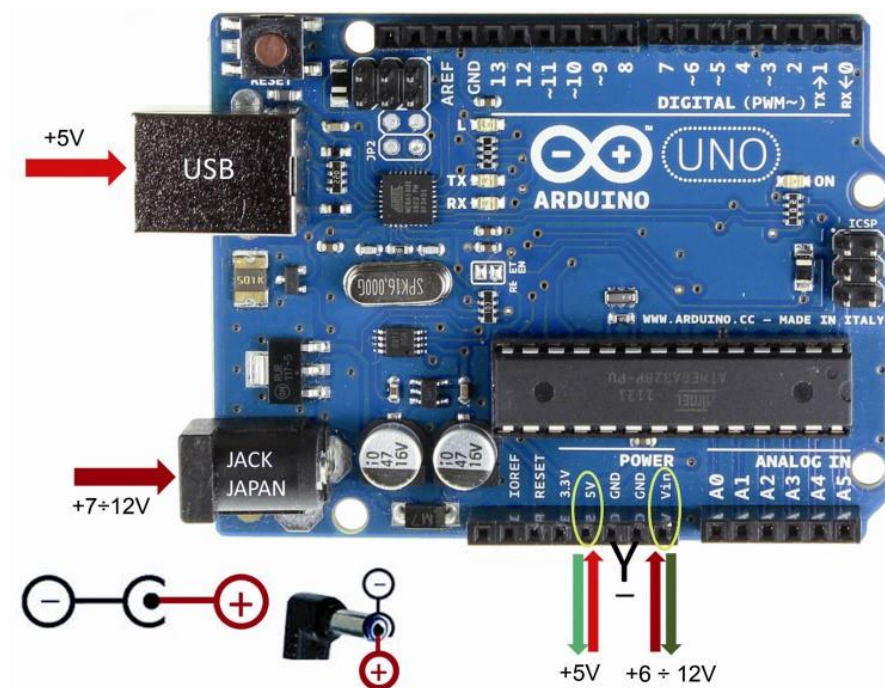


Fig 4.2: Arduino UNO

Table 4.1: Arduino UNO specifications

Microcontroller	ATmega328P – 8 bit AVR family microcontroller
Operating Voltage	5V
Recommended Input Voltage	7-12V
Input Voltage Limits	6-20V
Analog Input Pins	6 (A0 – A5)
Digital I/O Pins	14 (Out of which 6 provide PWM output)
DC Current on I/O Pins	40 mA
DC Current on 3.3V Pin	50 mA
Flash Memory	32 KB (0.5 KB is used for Bootloader)
SRAM	2 KB
EEPROM	1 KB
Frequency (Clock Speed)	16 MHz

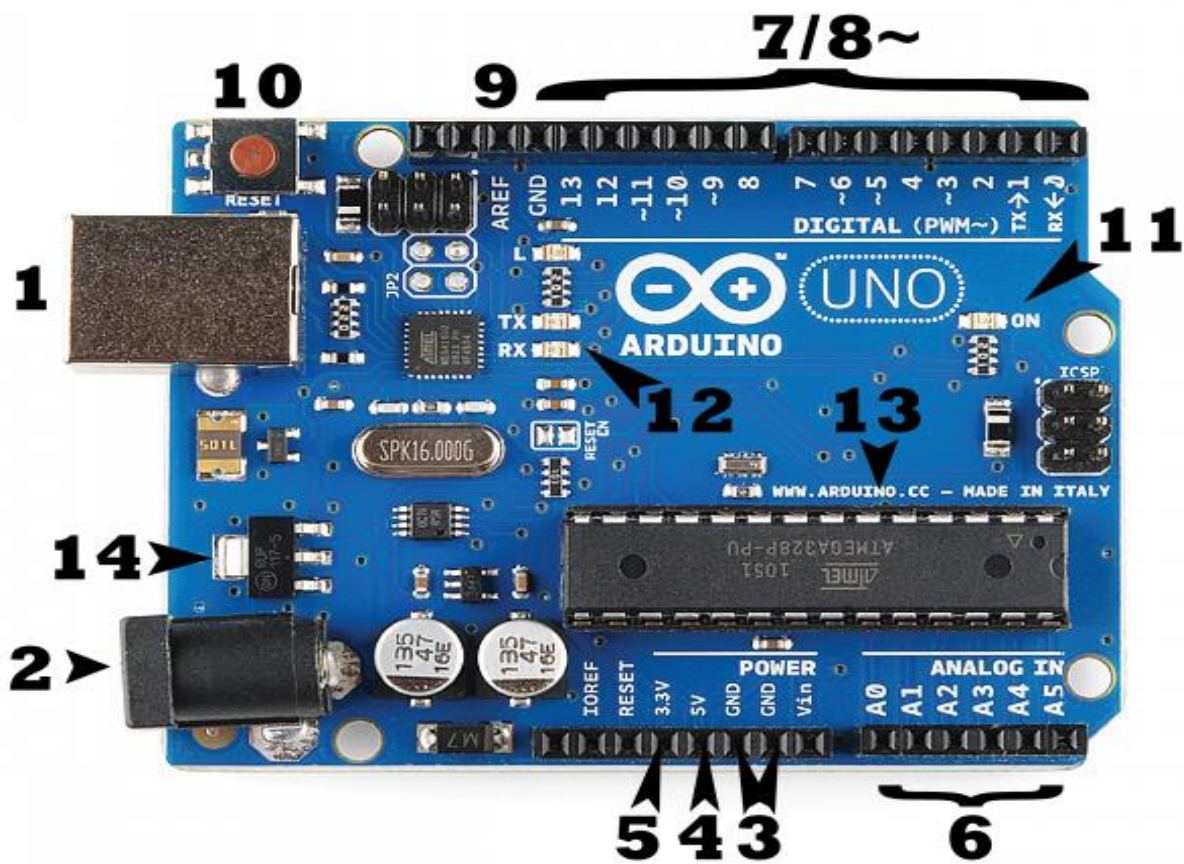


Fig 4.3: Arduino UNO pinout

4.3.1.2 Power (USB / Barrel Jack)

Every Arduino board needs a way to be connected to a power source. The Arduino UNO can be powered from a USB cable coming from your computer or a wall power supply that is terminated in a barrel jack. In the picture above the USB connection is labelled **(1)** and the barrel jack is labelled **(2)**. The USB connection is also how you will load code onto your Arduino board.

4.3.1.3 Pins (5V, 3.3V, GND, Analog, Digital, PWM, AREF)

The pins on your Arduino are the places where you connect wires to construct a circuit (probably in conjunction with a breadboard and some wire).

They usually have black plastic 'headers' that allow you to just plug a wire right into the board. The Arduino has several different kinds of pins, each of which is labelled on the board and used for different functions.

GND (3): Short for 'Ground'. There are several GND pins on the Arduino, any of which can be used to ground your circuit.

5V (4) & 3.3V (5): As you might guess, the 5V pin supplies 5 volts of power, and the 3.3V pin supplies 3.3 volts of power. Most of the simple components used with the Arduino run happily off of 5 or 3.3 volts.

Analog (6): The area of pins under the 'Analog In' label (A0 through A5 on the UNO) are Analog In pins. These pins can read the signal from an analog sensor (like a temperature sensor) and convert it into a digital value that we can read.

Digital (7): Across from the analog pins are the digital pins (0 through 13 on the UNO). These pins can be used for both digital input (like telling if a button is pushed) and digital output (like powering an LED).

PWM (8): You may have noticed the tilde (~) next to some of the digital pins (3, 5, 6, 9, 10, and 11 on the UNO). These pins act as normal digital pins, but can also be used for something called Pulse-Width Modulation (PWM).

AREF (9): Stands for Analog Reference. Most of the time you can leave this pin alone. It is sometimes used to set an external reference voltage (between 0 and 5 Volts) as the upper limit for the analog input pins.

4.3.1.4 Reset Button

Just like the original Nintendo, the Arduino has a reset button (**10**). Pushing it will temporarily connect the reset pin to ground and restart any code that is loaded on the Arduino.

This can be very useful if your code doesn't repeat, but you want to test it multiple times. Unlike the original Nintendo however, blowing on the Arduino doesn't usually fix any problems.

4.3.1.5 Power LED Indicator

Just beneath and to the right of the word "UNO" on your circuit board, there's a tiny LED next to the word 'ON' **(11)**. This LED should light up whenever you plug your Arduino into a power source. If this light doesn't turn on, there's a good chance something is wrong. Time to re-check your circuit.

4.3.1.6 TX RX LEDs

TX is short for transmit RX is short for receive. These markings appear quite a bit in electronics to indicate the pins responsible for serial communication.

In our case, there are two places on the Arduino UNO where TX and RX appear once by digital pins 0 and 1, and a second time next to the TX and RX indicator LEDs **(12)**.

These LEDs will give us some nice visual indications whenever our Arduino is receiving or transmitting data (like when we're loading a new program onto the board).

4.3.1.7 Main IC

The black thing with all the metal legs is an IC, or Integrated Circuit **(13)**. Think of it as the brains of our Arduino.

The main IC on the Arduino is slightly different from board type to board type, but is usually from the AT mega line of IC's from the ATMEL company. This can be important, as you may need to know the IC type (along with your board type) before loading up a new program from the Arduino software. This information can usually be found in writing on the top side of the IC. If you want to know more about the difference between various IC's, reading the datasheets is often a good idea.

4.3.1.8 Voltage Regulator

The voltage regulator **(14)** is not actually something you can (or should) interact with on the Arduino. But it is potentially useful to know that it is there and what it's for.

The voltage regulator does exactly what it says – it controls the amount of voltage that is let into the Arduino board. Think of it as a kind of gatekeeper; it will turn away

an extra voltage that might harm the circuit. Of course, it has its limits, so don't hook up your Arduino to anything greater than 20 volts.

4.3.1.9 ATmega 328

ATmega-328 is basically an Advanced Virtual RISC (AVR) micro-controller. It supports the data up to eight (8) bits. ATmega-328 has 32KB internal built in memory. This micro-controller has a lot of other characteristics.

ATmega 328 has 1KB Electrically Erasable Programmable Read Only Memory (EEPROM).

This property shows if the electric supply supplied to the micro-controller is removed, even then it can store the data and can provide results after providing it with the electric supply.

Moreover, ATmega-328 has 2KB Static Random Access Memory (SRAM). Other characteristics will be explained later. ATmega 328 has several different features which make it the most popular device in today's market. These features consist of advanced RISC architecture, good performance, low power consumption, real timer counter having separate oscillator, 6 PWM pins, programmable serial USART, programming lock for software security, throughput up to 20 MIPS etc. ATmega-328 is mostly used in Arduino.

ATmega328 is an eight (8) bit micro-controller as shown in pin diagram figure 4.4. It can handle the data sized of up to eight (8) bits. It is an AVR based micro-controller. Its built-in internal memory is around 32KB. It operates ranging from 3.3V to 5V. It has an ability to store the data even when the electrical supply is removed from its biasing terminals. Its excellent features include the cost efficiency, low power dissipation, programming lock for security purposes, real timer counter with separate oscillator.

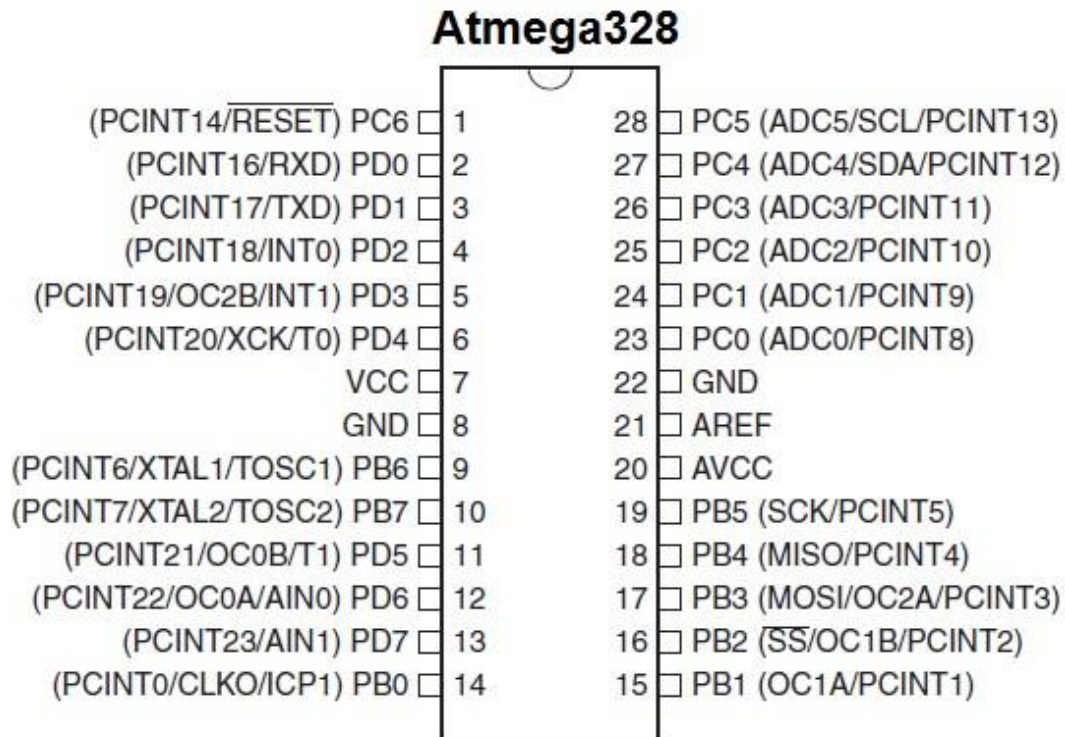


Fig 4.4: Pin diagram

4.3.2 RPS (Regulated Power Supply)

Regulating source is an inventory of electrical force. A device or system that allows electrical or different kinds of power to a yield burden or gathering of burdens is known as a force source unit or RPS. This word is normally applied to electrical energy supply, less regularly to mechanical, and infrequently to other members. An RPS diagram is shown in the figure 4.5. A force source might include a force appropriation system just as essential or auxiliary well springs of energy,

- Conversion of any kind of electrical quantity to another ideal structure and power, normally includes changes over AC line voltage to an all-around controlled low voltage dc for electronic devices. Low voltage, low force dc power source unit is usually incorporated with the devices they supply, like computers and hardware.
- Battery Management Systems.

- Chemical power modules and different types of energy stockpiling frameworks.

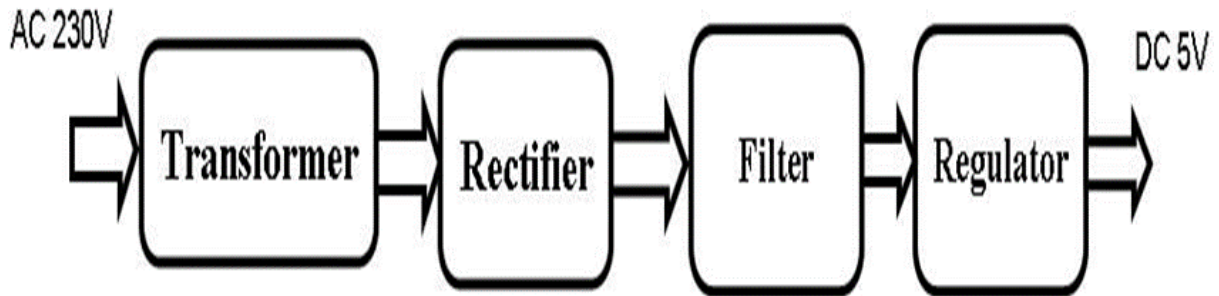


Fig 4.5: RPS

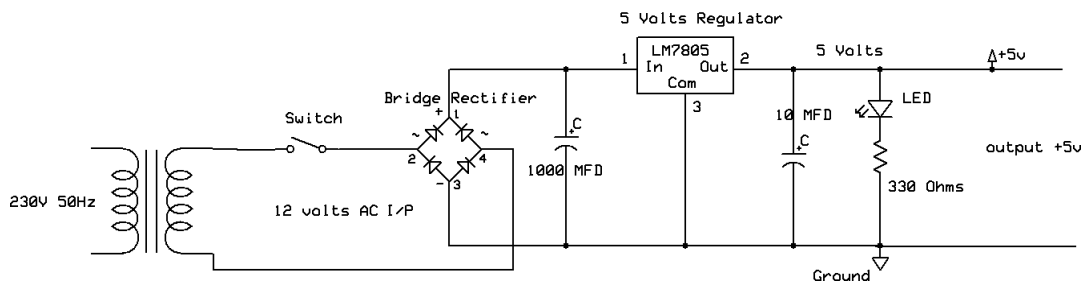


Fig 4.6: Circuit diagram of RPS with Led connection

The Circuit diagram of RPS with Led connection is shown in the above figure 4.6. The main components that are used in the above figure are

- AC supply mains (230V)
- Transformer
- Bridge rectifier (Diodes)
- Capacitors
- Voltage regulators (IC 7805)
- Resistors
- Light emitting diode (LED)

4.3.3 Temperature sensor

DHT11 is a low-cost digital sensor for sensing temperature and humidity. This sensor can be easily interfaced with any micro-controller such as Arduino, Raspberry Pi etc., to measure humidity and temperature instantaneously.

DHT11 humidity and temperature sensor is available as a sensor and as a module. The difference between this sensor and module is the pull-up resistor and a power-on LED. DHT11 is a relative humidity sensor. To measure the surrounding air this sensor uses a thermistor and a capacitive humidity sensor.

Working Principle of DHT11 Sensor

DHT11 sensor consists of a capacitive humidity sensing element and a thermistor for sensing temperature. The humidity sensing capacitor has two electrodes with a moisture holding substrate as a dielectric between them. Change in the capacitance value occurs with the change in humidity levels. The IC measure, process this changed resistance values and change them into digital form. The DHT11, a temperature sensor is shown in the figure 4.7.

For measuring temperature this sensor uses a Negative Temperature coefficient thermistor, which causes a decrease in its resistance value with increase in temperature. To get larger resistance value even for the smallest change in temperature, this sensor is usually made up of semiconductor ceramics or polymers. The temperature range of DHT11 is from 0 to 50 degree Celsius with a 2-degree accuracy. Humidity range of this sensor is from 20 to 80% with 5% accuracy. The sampling rate of this sensor is 1Hz .i.e. it gives one reading for every second. DHT11 is small in size with operating voltage from 3 to 5 volts. The maximum current used while measuring is 2.5mA.

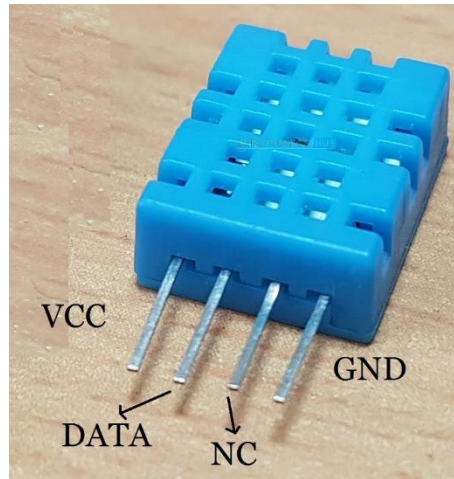


Fig 4.7: DHT11 sensor

DHT11 sensor has four pins- VCC, GND, Data Pin and a not connected pin. A pull-up resistor of 5k to 10k ohms is provided for communication between sensor and micro-controller.

4.3.4 Voltage sensor

A voltage sensor is an electronic device that measures and monitors the electrical potential difference, or voltage, between two points in an electrical circuit. It is commonly used in various applications, including power systems, industrial processes, consumer electronics, and automotive systems. The voltage sensor plays a critical role in ensuring the safe and efficient operation of electrical equipment by providing accurate voltage measurements and transmitting the information to other devices or systems for further processing or control.



Fig 4.8: Voltage sensor

A typical voltage sensor consists of several key components, including a sensing element, signal conditioning circuitry, and an output interface as shown in figure 4.8. The sensing element is the part of the voltage sensor that comes into contact with the electrical circuit and converts the electrical voltage into a measurable signal, which is then processed by the signal conditioning circuitry. The signal conditioning circuitry amplifies, filters, and isolates the signal to ensure accurate and reliable measurements. The output interface provides the means for transmitting the processed voltage measurement to other devices or systems, such as analog or digital output signals, communication protocols, or display interfaces.

4.3.5 Current sensor

A current sensor is an electronic device used to measure and monitor the flow of electric current in a circuit. It is widely used in various applications, including power systems, motor control, battery management, renewable energy systems, and industrial processes. Current sensors play a crucial role in providing accurate current measurements, which are essential for monitoring and controlling electrical systems, ensuring safety, efficiency, and performance.

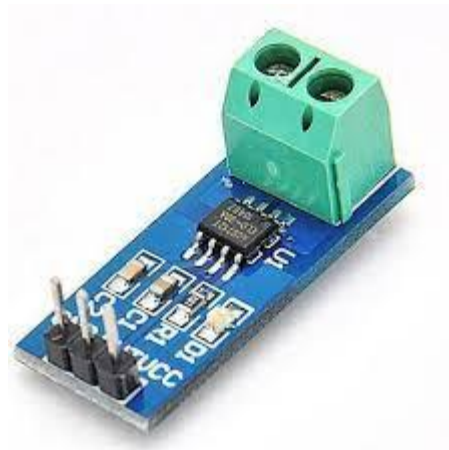


Fig 4.9: Current sensor

A typical current sensor consists of several key components, including a sensing element, signal conditioning circuitry, and an output interface as shown in figure 4.9.

The sensing element is the part of the current sensor that comes into contact with the electrical current-carrying conductor and generates a measurable signal proportional to the current. The signal conditioning circuitry processes the signal, providing amplification, filtering, and isolation to ensure accurate and reliable measurements. The output interface provides the means for transmitting the processed current measurement to other devices or systems, such as analog or digital output signals, communication protocols, or display interfaces.

Current sensors can be designed to measure different types of current signals, including DC (direct current) or AC (alternating current) currents, and can have various input and output current ranges, accuracy levels, and response times depending on the specific application requirements. They can also measure different current levels, ranging from low currents in milliamperes to high currents in kiloamperes or even higher.

Some current sensors also incorporate additional features, such as overcurrent protection, temperature compensation, fault detection, or galvanic isolation, to enhance their performance and reliability in challenging environments or critical applications.

In conclusion, a current sensor is a critical component in electrical systems that enables accurate measurement and monitoring of current levels. It plays a crucial role in various applications by providing essential current measurements for monitoring, control, and protection. By converting current into measurable signals, processing them, and providing output interfaces for communication or control, current sensors contribute to the safety, efficiency, and performance of electrical systems. Proper selection, installation, and calibration of current sensors are essential to ensure their accurate operation and reliable performance in diverse applications.

4.3.6 Battery

A 12V battery is a type of rechargeable battery that provides a nominal voltage of 12 volts. It is commonly used in a wide range of applications, including automotive, marine, recreational vehicles, uninterruptible power supply (UPS) systems, solar power systems, and portable electronics. The 12V battery is a popular choice for powering various devices and systems due to its relatively high voltage output and versatility.



Fig 4.10 Battery

A typical 12V battery is composed of one or more electrochemical cells connected in series to produce a total voltage of 12 volts. The cells are usually enclosed in a durable plastic or metal case and contain an electrolyte and one or more electrodes that undergo chemical reactions to generate electrical energy. The most common types of batteries used to produce 12V output are lead-acid batteries and lithium-ion batteries. A picture of the battery is shown in the figure 4.10.

Lead-acid batteries are a type of rechargeable battery that uses lead plates and sulfuric acid as the electrolyte. An IEEE 1725 standardized battery is used here.

They are widely used in automotive applications and other high-current applications due to their ability to deliver high power outputs. Lead-acid batteries are

relatively inexpensive and have a long history of reliable performance, although they are relatively heavy and require periodic maintenance.

Lithium-ion batteries are a type of rechargeable battery that uses lithium ions to generate electrical energy. They are known for their high energy density, lightweight, and long cycle life. Lithium-ion batteries are commonly used in portable electronics, electric vehicles, and solar power systems due to their high-power density and lightweight design. They are generally more expensive than lead-acid batteries but offer higher performance and convenience in many applications.

In conclusion, a 12V battery is a common type of rechargeable battery that provides a nominal voltage of 12 volts. It is widely used in various applications due to its versatility, including automotive, marine, recreational vehicles, UPS systems, solar power systems, and portable electronics. Whether it's a lead-acid or lithium-ion battery, proper handling, charging, and maintenance are essential to ensure its safe and reliable operation. The selection of the appropriate type of 12V battery depends on the specific requirements of the application in terms of power output, energy density, weight, and cost considerations.

4.3.7 LCD

To display accurate messages, we use the LCD Module. Analyzing a smart two-line LCD display, 16 characters per line used to directors. A 2x16 Line Alphanumeric LCD display is shown in the figure 4.11. Although D0 to D7th bit are Data lines, RS, RW and EN pins only control rods and anchors remaining + 5V, - 5V and GND should be provided to feed. Where RS is the Select Register, RW is Read Write and EN pin Allow as shown in figure 4.12.

The most popular type t LCD regulator is a HITACHI 44780 that provides a visual interface in the middle controller and LCD. These LCDs are very easy to work with regulator as they have financial knowledge.



Fig 4.11: 2x16 Line Alphanumeric LCD display

The LCD requires three control lines (RS, R / W and EN) and 8 (or lines of information. The number in the information lines depends on the operating system. Whenever it works in 8-bit mode and then 8+ information lines and three control lines for example 11 lines are required. In addition, whenever a 4-bit mode is used and then 4+ information lines and three control lines for example 7 lines are required. How can we choose which mode to use? It is straightforward with the possibility that you have enough information lines to go in 8-digit mode and if there is a binding time.

The ENABLE pin is used to link existing information to information pins. A low-level signal is needed to connect the data. LCD deciphers also make our order right now the EN line is dropped down. If you do not lower EN, your lead will never be implemented.

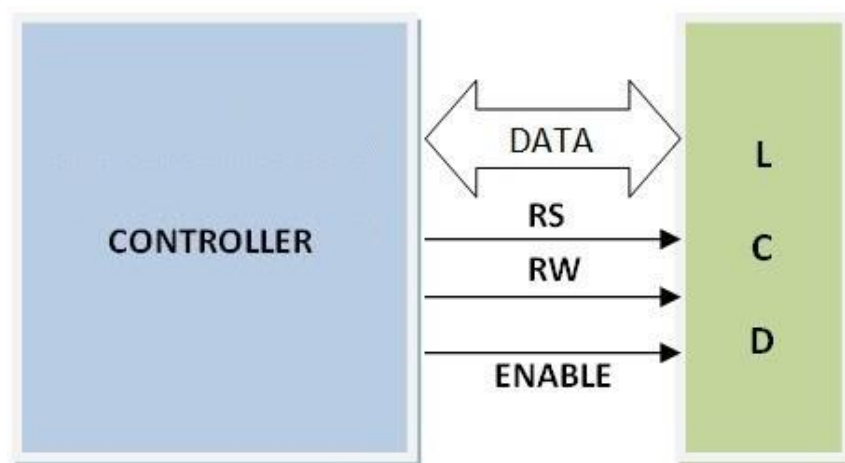


Fig 4.12: Basic LCD screen

4.3.7.1 Description

This is the 16th feature in the 2-line display. Dark content on Green foundation. It uses the same HD44780 optical chipset. Interface code is clearly accessible. We will need 11 standard I / O pins to connect to this LCD screen. Includes LED backlight.

4.3.7.2 Pin

Most LCDs with 1 controller have 14 pins and LCDs with 2 regulators with 16 pins (two pins are added to both LED backlights). The display of the pin appears in the figure 4.15.



Fig 4.13: LCD screen



Fig 4.14: LCD Background

4.3.7.3 LCD Background

Fortunately, there is a popular standard that allows us to talk to many LCDs that do not pay much attention to their manufacturer. The standard is referred to as the HD44780U, which refers to the controller chip that receives data from an external source (8051) and communicates directly with the LCD.

Pin No.	Name	Description
Pin no. 1	VSS	Power supply (GND)
Pin no. 2	VCC	Power supply (+5V)
Pin no. 3	VEE	Contrast <u>adjust</u>
Pin no. 4	RS	0 = Instruction input 1 = Data input
Pin no. 5	R/W	0 = Write to LCD module 1 = Read from LCD module
Pin no. 6	EN	Enable signal
Pin no. 7	D0	Data bus line 0 (LSB)
Pin no. 8	D1	Data bus line 1
Pin no. 9	D2	Data bus line 2
Pin no. 10	D3	Data bus line 3
Pin no. 11	D4	Data bus line 4

Fig 4.15: Character LCD pins with 1 Controller

4.3.7.4 Circuit Description

Above is a very straightforward program. Control Port is an open source / open channel producer. While many of the same ports have internal pull-out pins, not much is missing. So by mixing two 10K external pull-outs, the circuit is more integrated with a wider range of PCs, some of which may not have internal drawing addresses. The Character LCD pins with 2 Controller is shown in figure 4.16.

Pin No.	Name	Description
Pin no. 1	D7	Data bus line 7 (MSB)
Pin no. 2	D6	Data bus line 6
Pin no. 3	D5	Data bus line 5
Pin no. 4	D4	Data bus line 4
Pin no. 5	D3	Data bus line 3
Pin no. 6	D2	Data bus line 2
Pin no. 7	D1	Data bus line 1
Pin no. 8	D0	Data bus line 0 (LSB)
Pin no. 9	EN1	Enable signal for row 0 and 1 (1 st controller)
Pin no. 10	R/W	0 = Write to LCD module 1 = Read from LCD module
Pin no. 11	RS	0 = Instruction input 1 = Data input

Fig 4.16: Character LCD pins with 2 Controller

We made no effort to include data transfer in exchange. So we tightened the cords to the R / W line of the LCD board, into writing mode. This will not cause a conflict of interest in the transportation of information lines. We are therefore unable to reverse the interior of the LCD Busy Flag advising us if the LCD consents and threatened to prepare for the final lead. This issue is being addressed by the known embedding of our system.

4.3.8 Buzzer

A buzzer is a small yet efficient component to add sound features to our project/system. It is very small and compact 2-pin structure hence can be easily used on breadboard, Perf Board and even on PCBs which makes this a widely used component in most electronic applications. Figure 4.17 is the picture of a buzzer.



Fig 4.17: Buzzer

There are two types are buzzers that are commonly available. The one shown here is a simple buzzer which when powered will make a Continuous Beeeeeeppp.... sound, the other type is called a readymade buzzer which will look bulkier than this and will produce a Beep. Beep. Beep. Sound due to the internal oscillating circuit present inside it. But the one shown here is most widely used because it can be customized with help of other circuits to fit easily in our application.

This buzzer can be used by simply powering it using a DC power supply ranging from 4V to 9V. A simple 9V battery can also be used, but it is recommended to use a

regulated +5V or +6V DC supply. The buzzer is normally associated with a switching circuit to turn ON or turn OFF the buzzer at required time and require interval.

Table 4.2: Buzzer Pin Configuration

Pin Number	Pin Name	Description
1	Positive	Identified by (+) symbol or longer terminal lead. Can be powered by 6V DC
2	Negative	Identified by short terminal lead. Typically connected to the ground of the circuit

4.3.8.1 Applications of Buzzer

- Alarming Circuits, where the user has to be alarmed about something.
- Communication equipments.
- Automobile electronics.
- Portable equipments, due to its compact size.

4.3.9 Relay

A relay is an electromechanical device used to control the flow of electrical current in a circuit. It is commonly used in various applications, including industrial automation, telecommunications, automotive systems, home appliances, and electronic devices. Relays are widely used for their ability to switch high currents or voltages with a low-

power control signal, making them essential components in many electrical and electronic systems. The picture of a relay is shown in figure 4.18.



Fig 4.18: Relay

A typical relay consists of several key components, including a coil, an armature, and contacts. The coil is an electromagnetic winding that is energized when a control signal, typically a low-voltage electrical current, is applied to it. The energized coil creates a magnetic field that attracts the armature, which is a movable component connected to the contacts. The armature moves in response to the magnetic field, causing the contacts to open or close, depending on the relay type and configuration.

The contacts in a relay are the switching elements that control the flow of electrical current. There are typically two sets of contacts in a relay, known as normally open (NO) and normally closed (NC) contacts. In the resting state, the NO contacts are open, and the NC contacts are closed. When the coil is energized, the armature moves, and the contacts change their state. In a NO relay, the contacts close, allowing current to flow through the relay, while in an NC relay, the contacts open, interrupting the current flow.

Relays come in various types and configurations, including electromechanical relays, solid-state relays (SSRs), latching relays, and reed relays, among others. Electromechanical relays use physical contacts and mechanical movement to switch

the current, while SSRs use semiconductor devices to achieve the same function without mechanical parts. Latching relays have two stable states and do not require continuous power to maintain their state, while reed relays use a small hermetically sealed glass tube with contacts that open and close based on the position of a magnet.

In conclusion, a relay is an essential electromechanical device used to control the flow of electrical current in a circuit. It consists of a coil, an armature, and contacts that open or close in response to an energized coil. Relays are widely used in various applications for their ability to switch high currents or voltages with a low-power control signal. Proper selection, installation, and use of relays are crucial for ensuring their reliable operation in different systems and applications.

4.3.10 Node MCU

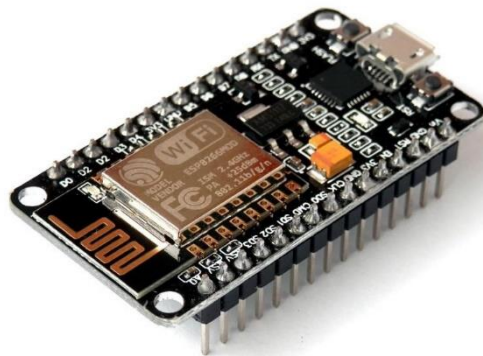


Fig 4.19: Node MCU

The ESP8266 NodeMCU CP2102 board has ESP8266 which is a highly integrated chip designed for the needs of a new connected world is shown in the figure 4.19. It offers a complete and self-contained WiFi networking solution, allowing it to either host the application or to offload all Wi-Fi networking functions from another application processor.

ESP8266 has powerful on-board processing and storage capabilities that allow it to be integrated with the sensors and other application-specific devices through its GPIOs with minimal development up-front and minimal loading during runtime. Its high degree of on-chip integration allows for minimal external circuitry, and the entire solution, including the frontend module, is designed to occupy minimal PCB area.

The ESP8266 NodeMCU development board – a true plug-and-play solution for inexpensive projects using WiFi. The module arrives pre-flashed with NodeMCU firmware so they're ready to go – just install your USB driver (below). ESP-12 Lua Nodemcu WIFI Dev Board Internet Of Things board contains a full ESP8266 WiFi module with all the GPIO broken out, a full USB-serial interface, and a power supply all on the one breadboard-friendly package.

This board is pre-flashed with NodeMCU – a Lua-based firmware for the ESP8266 which allows easy control via a neat scripting language – Lua – so you're ready to go in just a few minutes.

The ESP-12 Lua NodeMCU WIFI Dev Board Internet Of Things with ESP8266 is an all-in-one microcontroller + WiFi platform that is very easy to use to create projects with WiFi and IoT (Internet of Things) applications.

The board is based on the highly popular ESP8266 WiFi Module chip with the ESP-12 SMD footprint. This WiFi development board already embeds in its board all the necessary components for the ESP8266 (ESP-12E) to program and upload code. It has a builtin USB to serial chip upload codes, 3.3V regulator, and logic level converter circuit so you can immediately upload codes and connect your circuits.

4.3.10.1 Features

- Open-source, Interactive, Programmable, Low cost, Simple, Smart, WI-FI enabled.
- Arduino-like hardware IO.

- Integrated TR switch, balun, LNA, power amplifier and matching network.
- Integrated PLL, regulators, DCXO and power management units.
- Onboard USB to serial chip to easily program and upload codes from the Arduino IDE.
- Embeds logic level converter circuits.
- Has onboard 3.3V regulator to ensure enough power to function as your go-to WiFi chip.
- Easy access to the GPIO pins for easy prototyping.
- ESP-12E Processor.
- Easy to use breadboard friendly form factor.

4.4 SOFTWARE REQUIRED

- Arduino IDE
- Embedded C
- Thingspeak

4.4.1 *Arduino IDE*

Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board. To do so you use the Arduino programming language (based on Wiring), and the Arduino Software (IDE), based on Processing.

Over the years Arduino has been the brain of thousands of projects, from everyday objects to complex scientific instruments. A worldwide community of makers - students, hobbyists, artists, programmers, and professionals - has gathered around this open-source platform, their contributions have added up to an incredible amount of accessible knowledge that can be of great help to novices and experts alike.

Arduino was born at the Ivrea Interaction Design Institute as an easy tool for fast prototyping, aimed at students without a background in electronics and programming. As soon as it reached a wider community, the Arduino board started changing to adapt to new needs and challenges, differentiating its offer from simple 8-bit boards to products for IoT applications, wearable, 3D printing, and embedded environments. All Arduino boards are completely open-source, empowering users to build them independently and eventually adapt them to their particular needs. The software, too, is open-source, and it is growing through the contributions of users worldwide.

4.4.1.1 *Why Arduino?*

The Arduino software is easy-to-use for beginners, yet flexible enough for advanced users. It runs on Mac, Windows, and Linux. Teachers and students use it to build low-cost scientific instruments, to prove chemistry and physics principles, or to get started with programming and robotics. Designers and architects build interactive prototypes, musicians and artists use it for installations and to experiment with new musical instruments. Makers, of course, use it to build many of the projects exhibited at the Maker Faire, for example. Arduino is a key tool to learn new things. Anyone - children, hobbyists, artists, programmers - can start tinkering just following the step-by-step instructions of a kit, or sharing ideas online with other members of the Arduino community.

There are many other microcontrollers and microcontroller platforms available for physical computing. Parallax Basic Stamp, Netmedia's BX-24, Phidgets, MIT's Handyboard, and many others offer similar functionality. All of these tools take the messy details of microcontroller programming and wrap it up in an easy-to-use package. Arduino also simplifies the process of working with microcontrollers, but it

offers some advantage for teachers, students, and interested amateurs over other systems:

- **Inexpensive** - Arduino boards are relatively inexpensive compared to other microcontroller platforms. The least expensive version of the Arduino module can be assembled by hand, and even the pre-assembled Arduino modules cost less than \$50
- **Cross-platform** - The Arduino Software (IDE) runs on Windows, Macintosh OSX, and Linux operating systems. Most microcontroller systems are limited to Windows.
- **Simple, clear programming environment** - The Arduino Software (IDE) is easy to-use for beginners, yet flexible enough for advanced users to take advantage of as well. For teachers, it's conveniently based on the Processing programming environment, so students learning to program in that environment will be familiar with how the Arduino IDE works.
- **Open source and extensible software** - The Arduino software is published as open-source tools, available for extension by experienced programmers. The language can be expanded through C++ libraries, and people wanting to understand the technical details can make the leap from Arduino to the AVR C programming language on which it's based. Similarly, you can add AVR-C code directly into your Arduino programs if you want to.
- **Open source and extensible hardware** - The plans of the Arduino boards are published under a Creative Commons license, so experienced circuit designers can make their own version of the module, extending it and improving it. Even relatively inexperienced users can build the breadboard version of the module in order to understand how it works and save money.

4.4.2 Embedded C:

Embedded c is a set of language extension for the C Programming language by the C Standards committee to address commonality issues that exist between C extensions for different embedded systems. Historically embedded C programming requires nonstandard extensions to the C language in order to support exotic features

such as fixedpoint arithmetic, multiple distinct memory banks, and basic I/O operations. Embedded C uses most of the syntax and semantics of standard C, e.g., main() function, variable definition, data type declaration, conditional statements(if, switch, case), loops(while, for), functions, arrays and strings, structures and union, bit operations, macros, etc. During infancy years of microprocessor-based systems, programs were developed using assemblers and fused into the EPROMs. There used to be no mechanism to find what the program was doing. LEDs, switches, etc. were used to check for correct execution of the program. But they were too costly and were not quite reliable as well. As time progressed, use of microprocessor-specific assembly-only as the programming language reduced and embedded systems moved onto C as the embedded programming language of choice. C is the most widely used programming language for embedded processors/controllers.

4.4.3 Thingspeak

ThingSpeak is an open-source Internet of Things (IoT) platform that allows users to collect, analyze, and visualize data from IoT devices. It provides a cloud-based infrastructure that enables developers and researchers to build IoT applications quickly and easily. IEEE 2030.5 "Standard for Smart Energy Profile Application Protocol - Application Layer" is used here.

- **Features:** ThingSpeak offers several features that make it suitable for IoT projects, including data collection and storage, data analysis, data visualization, and support for various IoT protocols such as MQTT and REST API. It also provides integration with other popular platforms such as MATLAB, which allows for advanced data analysis and processing.
- **Data Channels:** ThingSpeak uses data channels to store and manage data collected from IoT devices. Data channels are created based on specific fields, and each field can store a single value at a time. Users can define their own

fields and specify data types such as numeric, string, or boolean, depending on the type of data being collected.

- **Data Visualization:** ThingSpeak offers built-in data visualization tools that allow users to create customizable charts, gauges, and maps to visualize their data in real-time. These visualizations can be embedded in websites or shared with others.
- **REST API:** ThingSpeak provides a REST API that allows developers to interact with the platform programmatically. This enables integration with other applications and systems, making it easy to collect and analyze data from IoT devices.
- **MATLAB Integration:** ThingSpeak has native integration with MATLAB, a popular data analysis and processing tool. This allows users to leverage the advanced data analysis capabilities of MATLAB for processing data collected from IoT devices.
- **Customizable IoT Applications:** ThingSpeak allows users to create their own customizable IoT applications by combining different features and tools. Users can define their own data channels, visualizations, and processing rules to build tailored IoT applications to suit their specific needs.
- **Security:** ThingSpeak provides security features such as SSL/TLS encryption, API key authentication, and user access control to ensure data privacy and security.

- **Community and Support:** ThingSpeak has an active community of users and developers who share knowledge, ideas, and resources related to IoT and ThingSpeak. The platform also provides documentation, tutorials, and technical support to assist users in building their IoT projects.
- **Pricing:** ThingSpeak offers a free tier with limited features, as well as paid plans with additional features and higher usage limits. The pricing model is based on the number of data channels and the frequency of data updates.
- **Deployment Options:** ThingSpeak can be deployed on the cloud or on-premises, depending on the requirements of the project. It supports cloud hosting on the ThingSpeak.com platform or can be self-hosted on your own server.

4.5 BLOCK DIAGRAM OF BATTERY MANAGEMENT SYSTEM

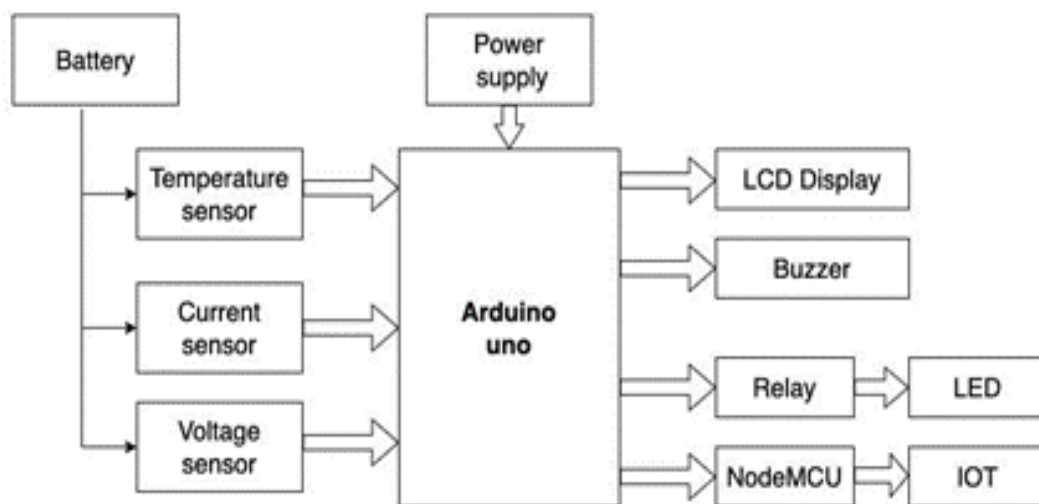


Fig 4.20: Block diagram of battery management system

4.6 BATTERY MANAGEMENT SYSTEM EXPLANATION

The proposed system for battery management and protection of electric vehicles aims to improve the safety and performance of these vehicles. The block diagram of the battery management and protection system is shown in the figure 4.20. The system will include several components that work together to follow IEEE 2993 standard (Recommended Practice for Functional Safety Analysis of Battery Management Systems for Electric and Hybrid Electric Vehicles) and prevent any dangerous accidents caused by combustion.

The battery management system (BMS) will be responsible for monitoring the battery's state of charge, temperature, and overall health. This information will be communicated to the vehicle's onboard computer, which will adjust the vehicle's performance accordingly. The BMS will also be responsible for balancing the cells in the battery pack to ensure that they are all charging and discharging at the same rate, which is critical for maintaining the battery's longevity and safety.

The burning prevention system will be designed to detect any potential fires in the vehicle and take immediate action to prevent them from spreading. This will happen by monitoring temperature and smoke levels within the vehicle and shutting off the power supply to any affected systems.

Overall, the proposed battery management and burning prevention system will be critical in promoting the safety and performance of electric vehicles. By managing the battery's health and preventing any potential fires, users can have peace of mind while driving their electric vehicles, knowing that they are being protected by this comprehensive safety system.

4.7 STATE OF CHARGE ESTIMATION

State of charge is defined as the available amount of battery as the percentage of rated capacity of the battery. Figure 4.21 depicts the state of charge of a battery.

State of charge gives a crucial support to battery management system to assess the state of the battery which helps the battery to operate within the safe operating range by controlling charging and discharging. It also increases the life span of the battery.

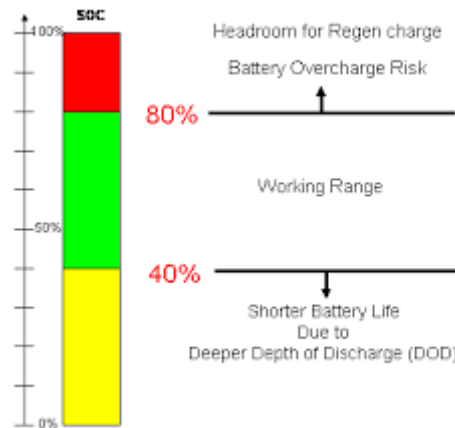


Fig 4.21: State of charge of a battery

$$\text{SOC}/\% = 100(Q_0 + Q)/Q_{\max} = \text{SOC}_0/\% + 100(Q/Q_{\max})$$

Where,

Q_0/mAh = Initial charge of the battery.

Q/mAh = The quantity of electricity delivered by or supplied to, the battery. It follows the convention of the current: it is negative during the discharge and positive during the charge.

$Q_{\max}/\text{mAh}$ = The maximum charge that can be stored in the battery.

$\text{SOC}_0/\%$ = The initial state-of-charge (SOC/%) of the battery.

If the battery is new: $Q_{\max} = C_r$ and $Q_0 = 0.5Q_{\max}$ generally. C_r is the rated capacity of the battery as given by the manufacturer.

If the battery is fully charged: $Q_0 = Q_{\max}$ and $\text{SOC}_0 = 100\%$.

4.8 STATE OF HEALTH ESTIMATION

State of health estimation describes the state of the battery with respect to the newly manufactured battery. It gives information regarding the available amount of discharging capacity during its lifetime. The SOH in EV use to describe the ability to drive the specific distance.

SOH is defined as the ratio of the maximum battery charge to its rated capacity. Figure 4.22 depicts the state of health of a battery.

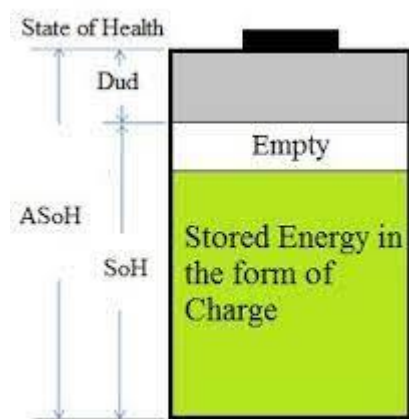


Fig 4.22: State of health of a battery

$$\text{SOH}/\% = 100(Q_{\max}/C_r)$$

Where,

$Q_{\max}/\text{mAh}$ = The maximum charge available of the battery.

C_r = The rated capacity.

4.9 WORKING MODULES

MODULE 1: All sensors (temperature, current, and voltage) gather data on battery parameters and send to the Arduino microcontroller.

MODULE 2: The battery information, including temperature, voltage, current, SOC, and SOH, is displayed on a Lcd display. IEEE 2848 standard is applied here.

MODULE 3: When a temperature reaches the threshold, the battery output is suddenly cut off and a buzzer sounds an alert as shown in the methodology flowchart in the below figure 4.23. IEEE 2993 standard (Recommended Practice for Functional Safety Analysis of Battery Management Systems for Electric and Hybrid Electric Vehicles) has been taken into account.

MODULE 4: All of the information is continuously uploaded on an IoT web page with the support of NodeMCU.

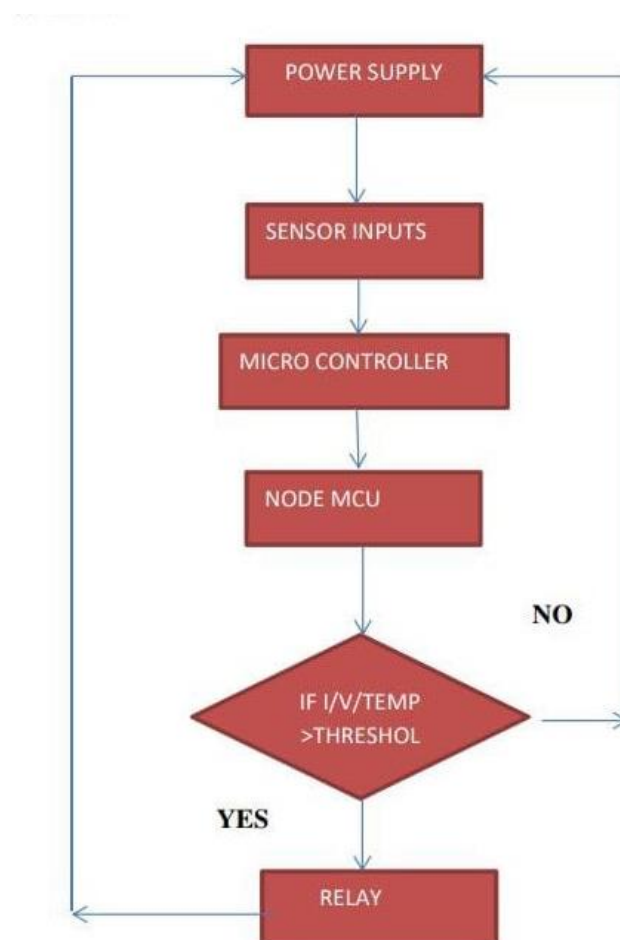


Fig 4.23: Methodology

4.10 ADVANTAGES

- Enhances battery life.
- Improves safety by preventing battery fires.
- Provides accurate battery monitoring.
- Increases efficiency of the EV.
- Helps comply with regulations.
- Smarter battery management system can achieve a better efficiency and power at the same time The proposed system will help us to avoid regular site visits, prevent battery failure, extend battery life, reduce maintenance cost and increase safety.
- Purchasing of Batteries / Cells through planned schedules, not emergency replacement.

4.11 APPLICATIONS

- Automotive industry.
- Household application.
- Industrial application.

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 HARDWARE OUTPUT

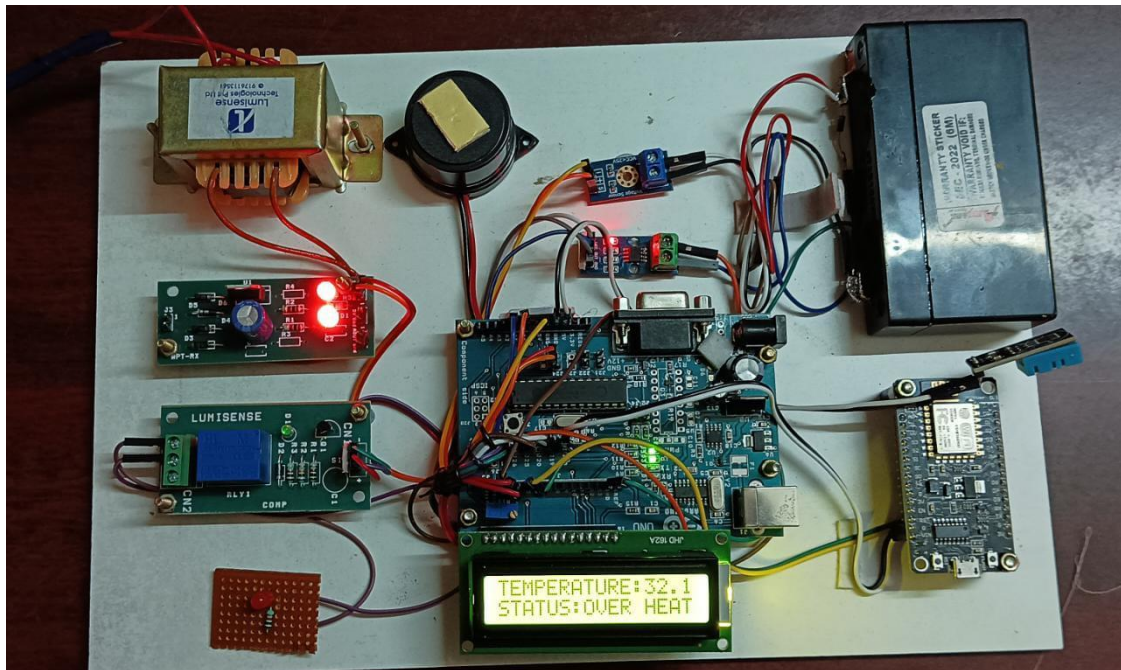


Fig 5.1: Overheating detected

When high temperature is detected as shown in figure 5.1, the Microcontroller unit in the NodeMCU sends a high signal to a relay module which turns off the power supply which is indicated by turning off of LED.

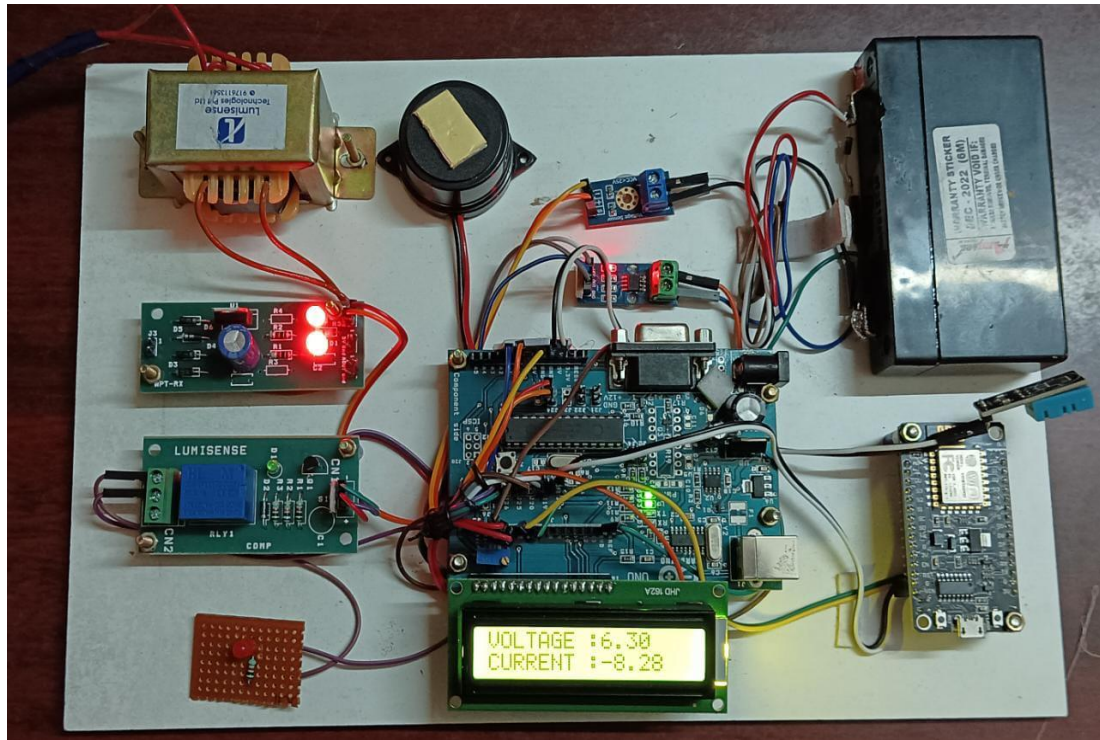


Fig 5.2: Current and voltage sensor values

The current and voltage sensor values are detected from the respected sensors and are displayed in the LCD screen as shown in figure 5.2.

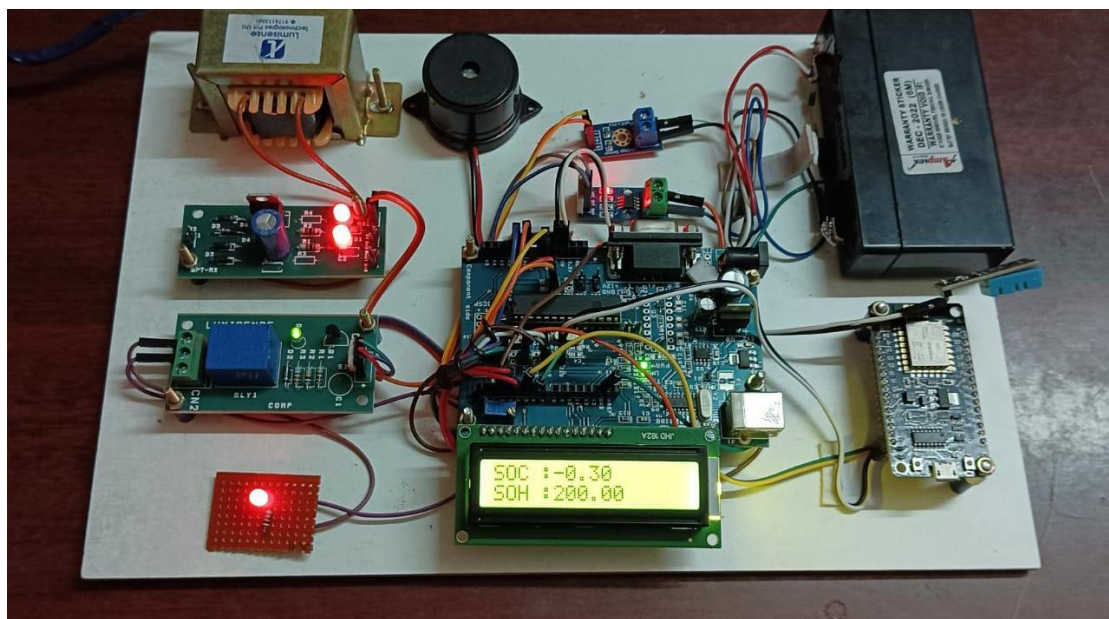


Fig 5.3: SOC and SOH values

The SOC and SOH values are calculated from the formulae and are displayed in the LCD display as shown in figure 5.3.

5.2 SIMULATION OUTPUT

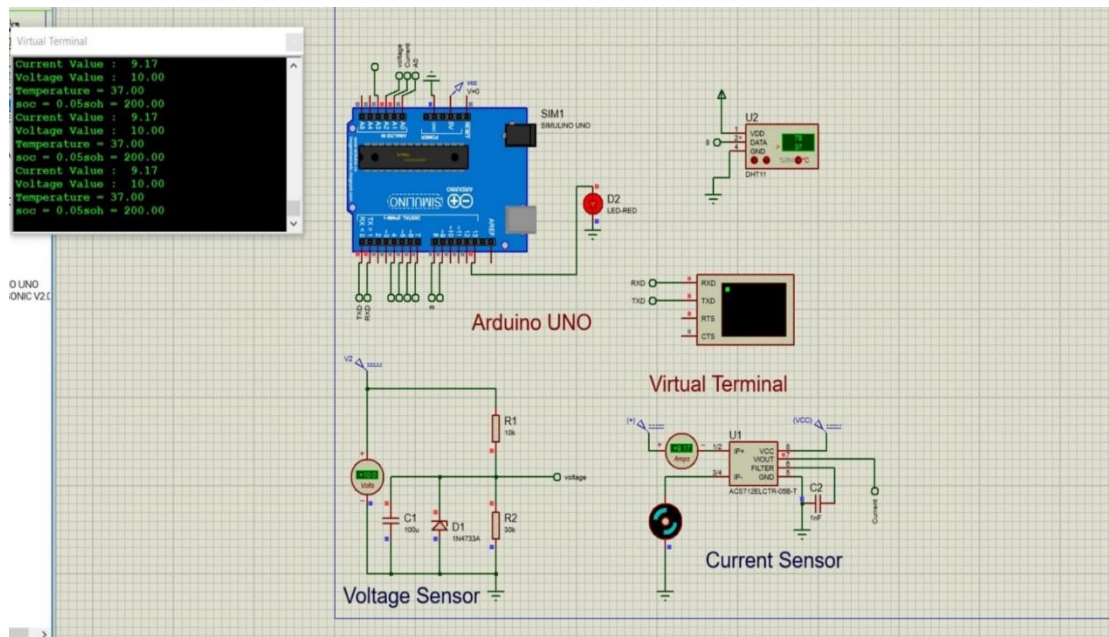


Fig 5.4: Simulation output

The output of the simulation for Battery management and protection system has been generated using Arduino IDE and proteus as shown in the above figure 5.4.

5.3 IOT DATA

The NodeMCU plays a vital role in this system, which senses the data from sensors and process the data. The Wi-Fi unit in the NodeMCU is used to send the data to the cloud, this data can be monitored continuously from anywhere in the world (where there is an active internet connection) and also whenever an excess current is detected at the supply the buzzer is activated to alert the administrator.

The graph referring to is a visual representation of data collected from an Internet of Things (IoT) based battery management system (BMS) for an electric vehicle (EV).

The BMS is a system that monitors and manages the battery pack of the EV to optimize its performance, efficiency, and lifespan.

The x-axis of the graph represents time, while the y-axis represents various parameters related to the battery performance.

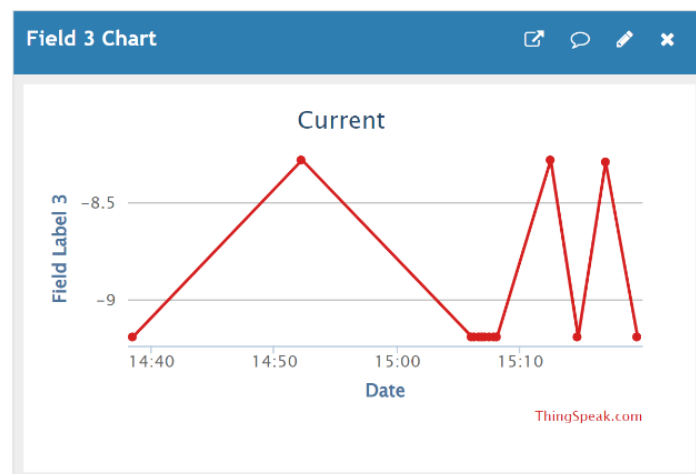


Fig 5.5: Photocopy of current graph using IOT

An IoT-enabled battery management system can provide valuable insights into the current status of electric vehicle batteries, prevent potential safety hazards, and ensure the optimal performance of the battery over its lifespan. The Current graph is a critical component of this system, providing real-time data on the current status of the battery to ensure the electric vehicle operates safely and efficiently. Figure 5.5 depicts the current graph using IOT.

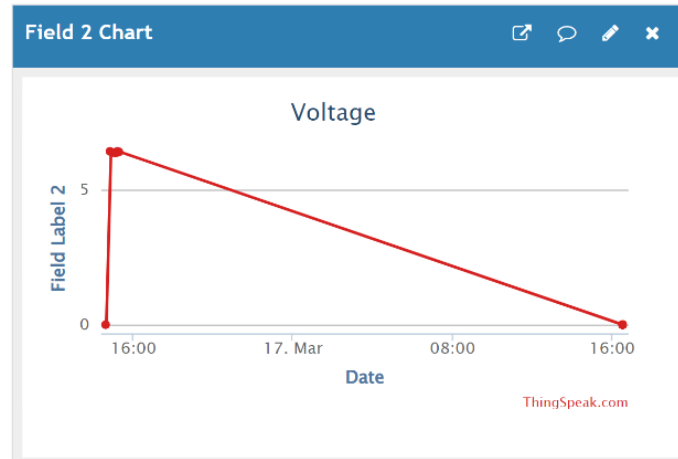


Fig 5.6: Photocopy of voltage graph using IOT

When the parameter is voltage, the x-axis of the graph represents time, while the y-axis represents the voltage of the battery pack, typically expressed in volts (V). The graph may display the historical voltage values of the battery over time, showing how the battery's voltage changes during different operating conditions.

The graph shows trends or patterns in the voltage values, providing insights into the battery's electrical behavior. For example:

Charging and Discharging Events: The graph may show the voltage values during charging events, indicating how the battery voltage increases over time as it is charged. It may also show the voltage values during discharging events, representing how the battery voltage decreases during EV operation as energy is drawn from the battery.

Voltage Profiles: The graph may show the voltage profiles of the battery during different stages of operation, such as during startup, normal operation, and shutdown. This can help identify any abnormal voltage behaviors, such as voltage spikes or drops, which may indicate issues with the battery's performance or health.

Voltage Range: The graph may show the voltage range of the battery, indicating the upper and lower limits of the acceptable voltage levels. Monitoring the battery voltage

within the acceptable range is crucial to ensure safe and reliable operation of the EV, as operating outside of this range may lead to overcharging, over-discharging, or other undesirable effects on the battery's performance and lifespan.

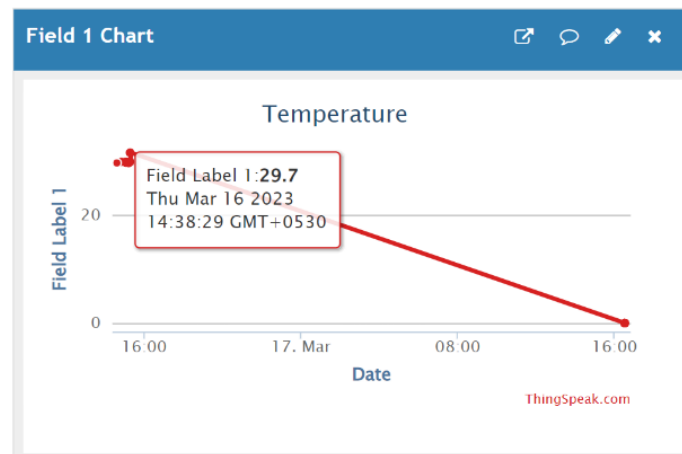


Fig 5.7: Photocopy of temperature graph using IOT

When the parameter is battery temperature, the graph would display the current temperature of the battery pack at different time points. It would show how the temperature changes over time, indicating the current temperature status of the battery as shown in the figure 5.7 and when the overheating occurs an alert will be triggered based on the graph values.

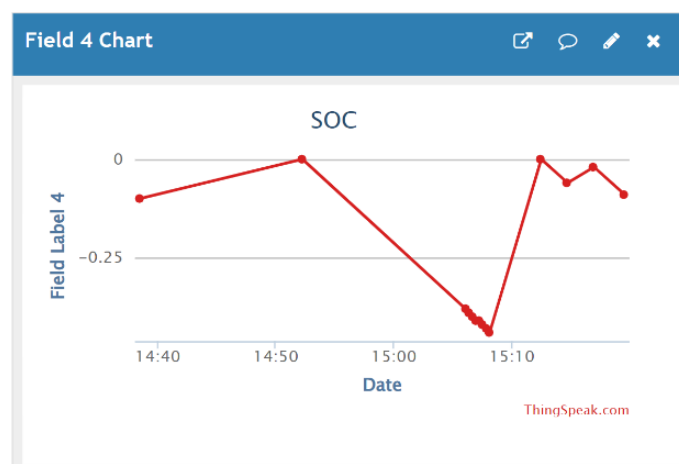


Fig 5.8: Photocopy of SOC graph using IOT

Similarly, when the parameter is SOC, the graph will show the percentage of charge remaining in the battery pack at different time points. It would display the current SOC value at a specific time as shown in figure 5.8, and the graph would update in real-time as the SOC changes with the battery charging or discharging.

The graph may show trends or patterns in the SOC values, providing insights into the battery's charging and discharging behavior. For example:

Charging and Discharging Events: The graph may show the SOC values during charging events, indicating how much the battery is being charged and how the SOC increases over time. It may also show the SOC values during discharging events, representing how much the battery is being discharged and how the SOC decreases during EV operation.

SOC Fluctuations: The graph shows fluctuations in the SOC values during driving, reflecting changes in driving conditions, regenerative braking, and other factors that affect the battery's charge level. These fluctuations can help identify the energy usage pattern of the EV and optimize driving behavior or charging strategies accordingly.

Charging and Discharging Efficiency: The graph shows the efficiency of charging and discharging processes by comparing the amount of energy input during charging with the amount of energy output during discharging. This can provide insights into the overall efficiency of the charging and discharging processes and help optimize charging strategies to improve the battery's performance and extend its lifespan.

The graph can provide real-time information on the current SOC of the battery, enabling EV operators to make informed decisions about when and how to charge the battery, plan driving routes, and manage energy consumption. It can also help detect any anomalies or issues with the battery's SOC, such as overcharging or deep discharging, triggering alerts or alarms in the IoT-based BMS for prompt action. By monitoring and managing the SOC of the battery using an IoT-based BMS, it is

possible to optimize the EV's energy usage, extend the battery's lifespan, and ensure reliable and efficient operation.

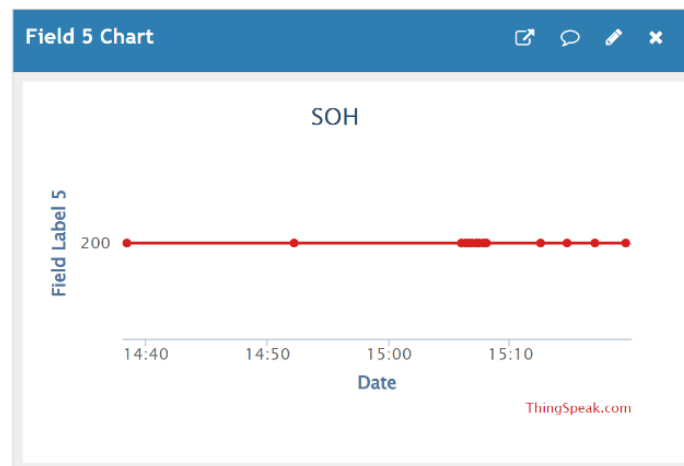


Fig 5.9: Photocopy of SOH graph using IOT

When the parameter being measured is SOH, the x-axis of the graph represents time, while the y-axis represents the SOH of the battery pack, typically expressed as a percentage. The graph as shown in figure 5.9 may display the historical SOH values of the battery over time, showing how the battery's health changes and degrades as it undergoes usage cycles and aging.

The graph shows trends or patterns in the SOH values, providing insights into the long-term performance of the battery. For example:

Initial SOH: The graph may show the initial SOH of the battery when it is first put into service. This provides a baseline reference for the battery's health at the beginning of its operational life.

Aging Trend: Over time, the graph may show a declining trend in the SOH values, indicating that the battery's health is gradually degrading due to usage, temperature, and other factors.

This trend can help identify the rate of battery degradation and estimate its remaining useful life.

Anomalies: The graph may show any significant changes or anomalies in the SOH values, such as sudden drops or spikes, which may indicate unusual events or conditions that have affected the battery's health. These anomalies can trigger alerts or alarms in the IoT-based BMS, enabling prompt action to address potential issues.

The graph can provide valuable information for EV operators and maintenance personnel to assess the health and performance of the battery pack over time. This data can be used to optimize charging strategies, schedule maintenance activities, and make informed decisions about battery replacement or refurbishment. By monitoring and managing the SOH of the battery in real-time using an IoT-based BMS, it is possible to maximize the lifespan, efficiency, and safety of the EV battery, ensuring reliable and sustainable operation.

CHAPTER 6

SUMMARY AND CONCLUSIONS

6.1 SUMMARY

Battery management system (BMS) is an essential component in electric vehicles (EVs) to monitor, control and maintain the state of the battery. It is responsible for predicting range, preventing overcharging, detecting faults, balancing cell voltages, and preserving the battery's life span. The BMS also ensures that the battery is used in a safe and optimal manner to avoid any accidents or hazards.

In addition to the BMS, burning prevention is a crucial feature in EVs to prevent fire incidents caused by battery malfunction. The burning prevention system monitors the temperature and voltage of the battery and detects any abnormalities such as overcharging or overheating. Once any anomaly is detected, the system takes immediate action to prevent a potential fire breakout by disconnecting the battery or signaling the driver to park the vehicle in a safe location.

Together, the BMS and burning prevention system ensure that EVs are safe, efficient, and sustainable transportation options for the present and future generations.

6.2 FUTURE SCOPE

- Improved battery management algorithms: With the advent of artificial intelligence and machine learning technologies, there is a lot of scope for developing better algorithms to manage the life of electric vehicle batteries. These algorithms can predict battery aging, optimize charging cycles, and improve energy efficiency.

- Advanced energy storage technologies: There is a growing need for energy storage technologies that can provide higher energy density and longer cycle life for electric vehicle batteries. Research is underway to develop solid-state

batteries, which are expected to offer higher energy density and faster charging times.

- **Battery recycling:** Proper recycling of electric vehicle batteries is crucial to prevent environmental damage. Several research projects are focused on developing more efficient and sustainable battery recycling methods.
- **Enhanced thermal management systems:** Thermal management is a critical issue for electric vehicle batteries as overheating can damage them. Advanced thermal management systems that can provide better cooling and heating for batteries can improve their performance and prolong their lifespan.
- **Integration with smart grid technologies:** As electric vehicle adoption increases, it becomes important to integrate EVs with smart grid technologies. Battery management systems can be used to monitor the energy consumption of EVs and optimize their charging cycles to minimize the impact on the grid.
- **Improved safety features:** Electric vehicles need to be equipped with advanced safety features to prevent battery fires and other accidents. Battery management systems can be enhanced to provide better monitoring of battery temperature, voltage, and current, to detect any potential hazards early and prevent accidents from occurring.

6.3 CONCLUSION

The fully electrically operated vehicles will come in future because of depleting fossil fuels and will definitely create an impact in everyone's life. At this time the battery management system will be major phenomena that every electric vehicle manufacturing company will be looking for. It is clear that an electric vehicle totally depends on the source of energy from a battery.

In this work, the idea of monitoring the performance of the vehicle using IoT techniques is proposed, so that the monitoring can be done directly. The system is capable to detect degraded battery performance and sends notification messages to the user for further action.

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