EV BMS WITH CHARGE MONITOR AND FIRE PROTECTION

PROJECT REPORT

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF

BACHELOR OF TECHNOLOGY

in

ELECTRONICS AND COMMUNICATION ENGINEERING

of

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

by

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Certificate

This is to certify that the Project Report titled **"EV BMS WITH CHARGE MONITOR AND FIRE PROTECTION"** is a bonafide record of the work carried out by **NAVYA K N (VAS20EC079), SHIKHIL K S(VAS20EC096)**, **SHON T S (VAS20EC098), V S NIDHEESH (VAS20EC120)** of Vidya Academy of Science & Technology, Thalakkottukara, Thrissur - 680 501 in partial fulfillment of the requirements for the award of **Degree of Bachelor of Technology** in **Electronics and Communication Engineering** of **APJ Abdul Kalam Technological University**, during the academic year 2023-2024. The Project report has been approved as it satisfies the academic requirements in the respect of project work prescribed for the said degree.

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Undertaking

We, **NAVYA K N** (VAS20EC079), **SHIKHIL K S** (VAS20EC096), **SHON T S** (VAS20EC098) & **V S NIDHEESH** (VAS20EC120), hereby undertake that the main project work entitled **EV BMS WITH CHARGE MONITOR AND FIRE PROTECTION**, is carried out by me independently under the valuable guidance of **Mrs. Ashitha P R**, Asst. Prof., Dept. of Electronics and Communication Engineering, Vidya Academy of Science and Technology, Thalakkottukara, Thrissur, in partial fulfillment of the requirements for the award of degree of **Bachelor of Technology in Electronics and Communication Engineering** of **APJ Abdul Kalam Technological University**, during the academic year 2023-2024.

Thrissur - 680 501
April 2024

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Abstract

As the demand for renewable energy integration and grid independence grows, residential energy storage systems (RESS) utilizing lithium-ion batteries have become increasingly popular. This abstract presents an innovative Battery Management System (BMS) designed for residential applications, focusing on efficient charge monitoring and robust fire protection mechanisms to ensure the safety and reliability of the energy storage system.The proposed BMS integrates advanced algorithms and sensors to monitor and optimize the charging process of lithium-ion batteries within a residential energy storage setup. Real-time monitoring of key battery parameters, including voltage, current, temperature, and state of charge, allows for precise control and management of the charging process. This enhances battery life, performance, and overall system efficiency.

A battery is a fundamental component of the electric vehicle (EVs), which represents the step forward towards a sustainable mobility. From the statistics, transportation sector contributes over 25% of the CO2 emissions and 50% of the oil consumption this causes air pollution which is leading to the increase in temperature and also leads to the Global warming. Electric vehicles (EVs) should be replaced by the fuel vehicles this is the major solution to decrease the air pollution because electric vehicle (EVs) are zero emission which does not affect environment. Where, here engines are replaced by a battery the Lithium Ion battery is typically the best battery for electric vehicles (EVs). Battery management system(BMS) plays a crucial role in management of controlling the battery. Due to the limitation like electrical power distribution limitation, Electric Vehicles (EVs) charging should perform in a effective way. This proposed system for a Electric Vehicle (EVs) utilization and charging system having many advance features. The proposed device will automatically stop the overcharging and charging will not happen in battery and different parameters will monitor based on the parameter battery charging and utilization for a load and it will be controlled automatically in this implementation. This system can be accessed through blynk app.

In addition to charge monitoring, the BMS incorporates a comprehensive fire protection system to mitigate potential fire risks associated with lithium-ion batteries. The fire protection system includes thermal sensors, smoke detectors, and a rapid response mechanism. In the event of abnormal conditions or a potential fire hazard, the BMS can activate safety protocols such as isolating the battery, cutting off charging/discharging, and triggering an alert to the homeowner or emergency services.As Electric Vehicles (EVs) continue to gain prominence as sustainable transportation solutions, the role of Battery Management Systems (BMS) becomes increasingly critical. This abstract presents an innovative BMS tailored for EV applications, emphasizing advanced monitoring, balancing, and safety features to optimize battery performance and ensure vehicular safety.

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Chapter 1

INTRODUCTION

An Electric Vehicle Battery Management System (EV BMS) with charge monitoring is a critical component that oversees the health and performance of an electric vehicle's battery pack during charging and discharging. This system ensures the safe and efficient operation of the battery by monitoring parameters such as voltage, current, temperature, state of charge (SOC), and state of health (SOH). The charge monitoring feature specifically focuses on regulating the charging process, optimizing charging rates, and preventing overcharging, thereby safeguarding the battery and enhancing its overall longevity. This integrated system plays a pivotal role in maintaining the reliability, safety, and efficiency of electric vehicles.

Voltage Monitoring Purpose is Monitors the voltage of each battery cell to ensure they operate within safe limits.Operation is The BMS continuously checks the voltage of individual cells. If any cell deviates from the safe voltage range, the system takes corrective actions, such as balancing the cells or adjusting charging rates. Current Monitoring Purpose is Tracks the flow of electric current during charging and discharging to prevent overloading and optimize energy utilization. Operation: Current sensors measure the current entering or leaving the battery pack. The BMS uses this information to adjust charging or discharging rates, ensuring they remain within safe parameters.Temperature Monitoring Purpose is Monitors battery temperature to prevent overheating, which can lead to performance degradation or safety hazards.Operation is Temperature sensors strategically placed within the battery pack continuously report data to the BMS. If temperatures rise beyond safe levels, the BMS takes corrective measures, such as adjusting cooling systems or limiting charging rates.State of Charge (SOC) Estimation Purpose is Estimates the remaining charge in the battery to prevent over-discharging and optimize energy management.Operation is The BMS integrates information from voltage, current, and temperature sensors to estimate SOC. Accurate SOC data ensures that the battery is utilized efficiently without compromising safety.

The Electric Vehicle Battery Management System (EV BMS) with charge monitor and fire protection is designed with several key objectives to ensure the safety, efficiency, and longevity of the electric vehicle (EV) battery pack. Here are the primary objectives are ,Prevent Overcharging and Overdischarging Overcharging Prevention Overcharging occurs when a battery is charged beyond its safe voltage limits. The BMS actively monitors the charging process, adjusting charging rates and profiles to ensure that each cell within the battery pack reaches its maximum safe charge without exceeding it. Overcharging can lead to thermal runaway, reduced battery life, and safety hazards, making prevention a critical safety measure.overdischarging Prevention Overdischarging happens when a battery is discharged to a level that can damage its chemistry and reduce its overall capacity. The BMS ensures that the battery is not discharged beyond its safe limits by accurately estimating the State of Charge (SOC) and controlling the discharge process. Preventing overdischarging is essential for maintaining battery health and preventing potential safety issues.Temperature Control Monitoring and Regulation The BMS continually monitors the temperature of individual cells within the battery pack. If temperatures approach or exceed safe thresholds, the system takes corrective actions, such as adjusting the charging or discharging rates, activating cooling systems, or even stopping the charging process altogether. Effective temperature control is crucial for avoiding thermal events that can lead to safety hazards, including fires or explosions.Preventing Thermal Runaway Thermal runaway is a dangerous condition where increased temperatures in one cell can trigger a chain reaction, affecting neighboring cells and potentially leading to catastrophic failure.

The BMS's temperature control mechanisms play a pivotal role in preventing and mitigating thermal runaway, ensuring the overall safety of the battery pack.Fire Protection-Early Fault Detection:The BMS is equipped with sensors that detect abnormalities or faults within the battery pack. Early fault detection allows the system to identify potential issues before they escalate, enhancing safety. Common faults include issues like cell imbalances, high temperatures, or abnormal voltage levels.Isolation of Affected Components In response to detected faults, the BMS can isolate the affected cells or modules to contain the issue and prevent it from spreading to the entire battery pack. Isolating faulty components helps maintain the overall functionality of the battery while addressing specific problems.Fire Suppression Mechanisms Some advanced EV BMS systems incorporate fire suppression mechanisms, such as the release of fire retardant agents or the activation of fire-resistant materials. These features are designed to swiftly and effectively suppress fires in the rare event that a thermal event progresses to that stage.

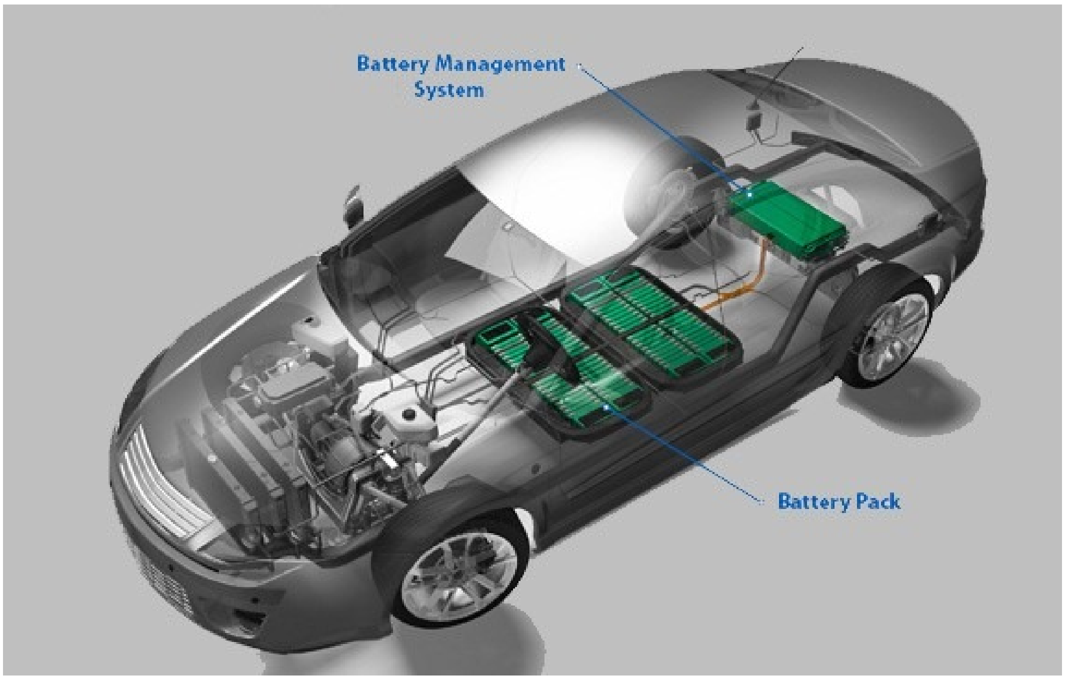

Figure 1.1: BMS System in an EV [1]

In the safety assurance features of an EV BMS with charge monitoring and fire protection are comprehensive and multifaceted. The system not only prevents overcharging and overdischarging but also actively monitors and regulates temperature, detects faults early, isolates affected components, and incorporates fire suppression mechanisms to ensure the overall safety and reliability of the electric vehicle battery pack.Charge Optimization Adjusting Charging Rates The charge monitoring feature of the BMS constantly assesses the charging process. It optimizes the charging rates based on factors such as the battery's current state, temperature, and overall health. By adjusting charging rates, the system aims to maximize the efficiency of the charging process, ensuring that the battery receives the appropriate amount of energy without being subjected to excessive stress.

Charging Profiles The BMS may utilize specific charging profiles tailored to the battery chemistry and characteristics. These profiles define the optimal charging parameters, including voltage and current levels, based on the specific requirements and limitations of the battery cells. This customization helps prevent overcharging and enhances the overall efficiency of the charging process.Balancing Cells Some advanced BMS systems incorporate charge balancing functionality. This involves redistributing charge among individual cells within the battery pack to ensure they have similar states of charge. Charge balancing maximizes the overall capacity of the battery pack and contributes to its longevity.State of Charge (SOC) ManagementAccurate SOC Estimation The BMS estimates the State of Charge (SOC) by integrating information from voltage, current, and temperature sensors. Accurate SOC estimation is crucial for understanding the current energy level within the battery. It enables the BMS to make informed decisions about charging and discharging, preventing over-discharging, which can lead to capacity degradation and compromise battery performance.Preventing Over-Discharging Managing SOC is essential to prevent over-discharging, where the battery is depleted to levels that may harm its chemistry. Over-discharging can result in reduced capacity, decreased performance, and, in extreme cases, irreversible damage to the battery. The BMS ensures that the SOC remains within safe limits, preserving the health and longevity of the battery.

Fault Detection and Isolation Early Fault Detection the BMS is equipped with sensors to detect faults or anomalies in the battery system. Early detection enables timely intervention to address issues before they escalate, ensuring the safety of the battery and extending its operational life.Isolation of Faulty Components in the event of a detected fault, the BMS can isolate the affected part of the battery pack. This prevents the fault from spreading to other components, ensuring the continued operation of the remaining healthy cells and minimizing the impact on overall battery performance.Compliance with Regulations and Standards Meeting Safety Standards The EV BMS with fire protection is designed to comply with safety standards and regulations specific to electric vehicles. Compliance ensures that the vehicle adheres to industry safety requirements, providing a basis for safe operation.Enhanced Safety Features Incorporating fire protection mechanisms, such as fire suppression systems or fire-resistant materials, aligns with safety standards and regulations. These additional safety features provide an extra layer of protection, mitigating the risk of fire-related incidents and ensuring the overall safety of the electric vehicle.In the EV BMS with charge monitoring and fire protection integrates a set of features and functionalities that collectively contribute to the longevity, health, and safety of the electric vehicle battery pack. By addressing various aspects, from SOH estimation to fault detection and compliance with safety standards, the system aims to optimize performance and ensure the reliable and safe operation of electric vehicles over their operational lifespan.

1.1 Project Background and Motivation

The Indian government's ambitious policy aimed to introduce 6-7 million electric vehicles (EVs) by 2020 and transition entirely to EVs by 2030 demonstrates a strong commitment to sustainable transportation. However, experts in the machine industry have expressed concerns regarding the feasibility of this plan, citing a lack of infrastructure, particularly charging stations, as a major obstacle. Without a comprehensive network of charging stations, EV adoption is hindered by range anxiety, which is the fear of running out of battery power before reaching a destination or charging point. This apprehension undermines consumer confidence in EVs and discourages their widespread adoption.
Despite the government's efforts to promote EVs and address environmental concerns, the lack of charging infrastructure remains a significant barrier to their acceptance in the market. Charging stations play a vital role in alleviating range anxiety and enhancing the usability of EVs by providing drivers with convenient access to charging facilities. Therefore, the development of a robust charging infrastructure is essential to support the growing demand for EVs and facilitate their integration into the transportation ecosystem.
Electric vehicles offer numerous benefits, including economic and environmental advantages, such as lower operating costs and reduced emissions. As EV technology continues to advance and gain popularity worldwide, it is crucial to address infrastructure challenges to fully realize the potential of electric transportation. Designing user-friendly charging systems that are accessible and convenient for EV owners is essential to overcoming barriers to adoption and accelerating the transition to a sustainable mobility paradigm.
Efforts to promote EV adoption must focus not only on increasing vehicle availability

but also on building the necessary infrastructure to support their widespread use. This includes investing in charging station networks and implementing policies and incentives to encourage private and public investment in charging infrastructure development. By addressing the infrastructure gap and enhancing the user experience, stakeholders can foster greater acceptance of EVs and contribute to the achievement of long-term sustainability goals.

In conclusion, while electric vehicles offer significant potential benefits, including energy efficiency and environmental friendliness, the lack of charging infrastructure presents a critical barrier to their widespread adoption. To overcome this challenge, concerted efforts are needed to design and implement user-friendly charging systems and expand charging station networks, thereby enabling the seamless integration of EVs into the transportation ecosystem and realizing the vision of a cleaner and greener future.

1.2 Problem Statements

A drop in voltage at a given load can indicate an increase in internal resistance. This then can point toward dry-out, corrosion, plate separation, or other diagnoses.

A sudden increase in the temperature of battery could indicate the possibility of a thermal runaway event within the whole battery pack. The BMS could then stop the flow of energy and alert the user to a potential problem so that it can be contained before it gets out of control.

Time Battery overcharging is a common problem in vehicles today. Overcharging your battery can significantly decrease its lifespan, make it more difficult for it to turn over,lower its efficiency, and in extreme cases, can even to battery explosion. Overcharging is a problem that can be difficult to notice.

The essential issues that our system will fathom are to check the invalid reasons given by the drivers for the time deferral to show up at the goal on schedule. To check if any unapproved individual endeavors to get into the vehicle. To concentrate on the security of the understudies and furthermore to settle different issues like the area of the vehicle. What's more, our structure will alarm if any unapproved card is put as an alert. Guardians might want to know whether their children have reached securely on schedule and to guarantee if everything was protected during the movement and furthermore to screen their children our system will give the area and furthermore the login and logout subtleties.

1.3 Objectives And Significance

In envisioning the future of electric vehicle (EV) charging, several innovative trends emerge, shaping the landscape of sustainable transportation. One such trend is the concept of battery swapping, offering an efficient alternative to traditional charging methods. With battery swapping, drivers can quickly exchange depleted batteries for fully charged ones at designated stations, eliminating the need for lengthy charging sessions and addressing concerns regarding range anxiety. This approach streamlines the charging process, making it more convenient and accessible for EV owners, particularly in urban areas where charging infrastructure may be limited.

Another promising development is the prospect of direct charging to electric vehicles through home supply. By integrating charging capabilities directly into residential infrastructure, such as household electrical systems or garage installations, EV owners can conveniently charge their vehicles overnight or during periods of low energy demand. This approach not only simplifies the charging process for consumers but also maximizes the utilization of existing resources, leveraging home electricity supply for sustainable transportation needs.

Furthermore, the future of EV charging may see a shift towards solar-powered solutions, where EVs can be charged directly from solar panels integrated into homes or dedicated charging stations. This approach harnesses renewable energy sources to power electric vehicles, reducing reliance on conventional grid electricity and lowering carbon emissions associated with transportation. Solar charging systems offer the potential for decentralized and environmentally friendly charging options, aligning with efforts to promote clean energy adoption and combat climate change.

Additionally, advancements in wireless charging technology, particularly magnetic field wireless charging systems, hold promise for revolutionizing EV charging infrastructure. By transmitting power wirelessly through magnetic fields, this technology eliminates the need for physical connections between charging points and vehicles, offering greater convenience and flexibility for EV owners. Wireless charging systems can be seamlessly integrated into various environments, including homes, public parking lots, and roadways, enabling effortless charging experiences while enhancing urban mobility and accessibility.

To realize these futuristic charging paradigms, the design of an IoT-based electric vehicle charging and control system is paramount. Such a system would leverage interconnected devices, sensors, and communication networks to enable seamless monitoring, management, and optimization of EV charging processes. Through IoT connectivity, users can remotely access and control charging operations, receive real-time status updates, and leverage smart charging features to optimize energy usage and costs.

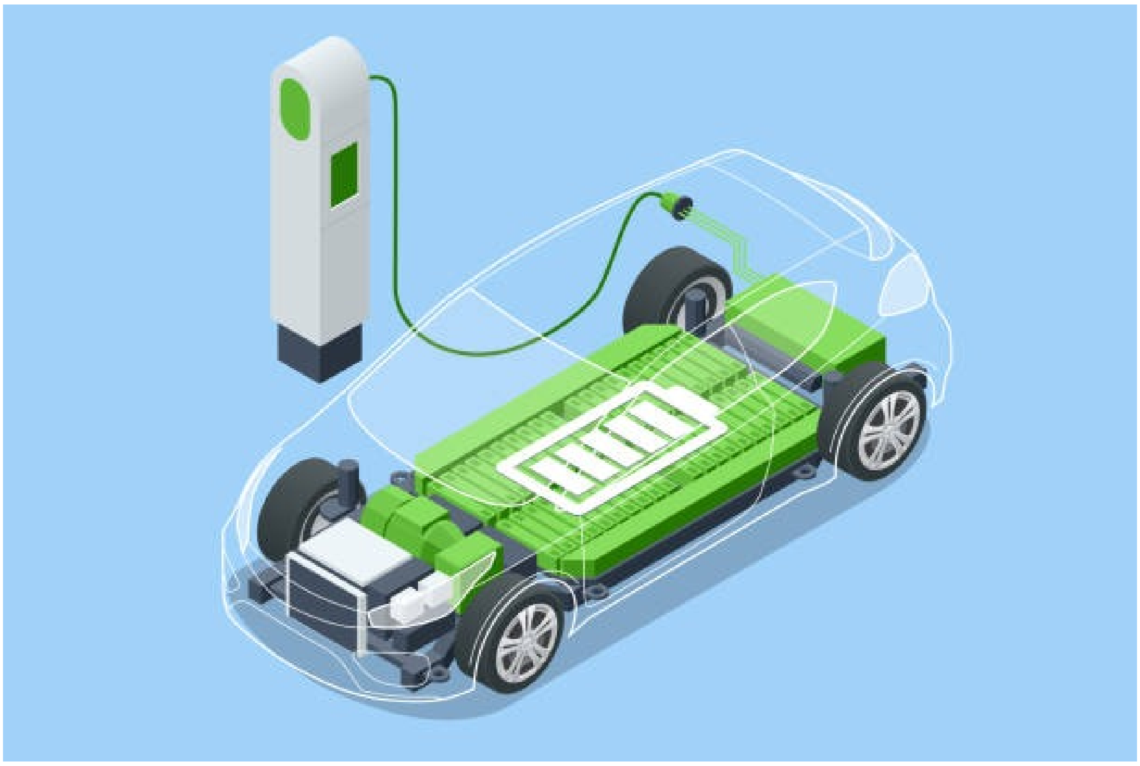

Figure 1.2: EV and Sustainability [7]

Moreover, an IoT-based charging system would facilitate data-driven insights and analytics, enabling stakeholders to assess charging patterns, optimize infrastructure deployment, and enhance user experiences. By harnessing the power of IoT technologies, electric vehicle charging can evolve into a more intelligent, efficient, and sustainable ecosystem, driving the widespread adoption of electric transportation and contributing to the transition towards a cleaner and greener future.

1.4 Outline of the report

This report is organized in an orderly manner.First chapter gives a meticulous explanation of EV BMS With Solar charging, encompassing an overall idea of the project. Furthermore, this chapter functions as an introduction to the proposed system, thus establishing the context for the ensuing chapters.

Chapter 2 presents the comprehensive overview of previous endeavors, pertaining to this field. Progressing further, Chapter 3 consists of an exhaustive analysis of the methodology employed in the aforementioned system, presenting an operation of the system and its modeling and also provides an outline of the hardware components utilized and their implementation and the software development phase of the project. Chapter 4, presents the findings of the project. The final chapter offers a condensed and definite conclusion to this report, effectively explaining the principal discoveries and perceptions acquired from the preceding chapters.

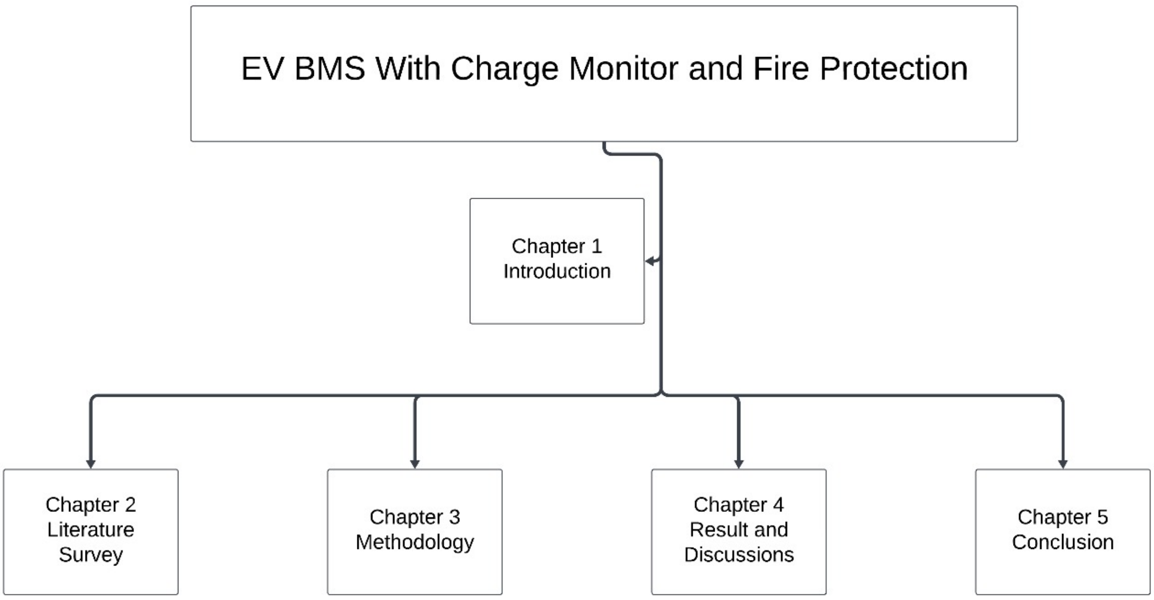

Figure 1.3: Outline of the report

Chapter 2

LITERATURE SURVEY

A literature survey on Electric Vehicle Battery Management Systems (EV BMS) with charge monitor and fire protection reveals the following key insights from various research studies are,Overview of EV Battery Management Systems Researchers provide a comprehensive overview of Battery Management Systems (BMS) for Electric Vehicles, emphasizing their critical role in monitoring and controlling the charging and discharging processes. The BMS ensures the safe and efficient operation of the battery pack, prolonging its lifespan and optimizing performance.Charge Monitoring in EV BMS Studies highlight the significance of charge monitoring in EV BMS. Advanced charge monitoring systems enable precise control of the charging process, preventing issues such as overcharging or undercharging. Real-time monitoring allows for informed decision-making and contributes to the overall health of the battery.Fire Protection in EV BMS The literature emphasizes the importance of fire protection mechanisms integrated into EV BMS. With the increasing use of high-energy-density lithium-ion batteries, the risk of thermal runaway and fire incidents is a major concern. Researchers discuss various strategies, including thermal management systems, fire detection sensors, and suppression systems, to enhance the safety of EV battery packs.Advanced Algorithms for Safety Enhancement Several studies delve into the development of advanced algorithms for EV BMS to enhance safety features. Machine learning and artificial intelligence are explored for predictive analytics and early detection of potential issues, offering a proactive approach to prevent battery failures and mitigate safety risks.Integration of Communication Protocols Literature highlights the importance of communication protocols in EV BMS, especially in the context of fire protection.

Efficient communication between battery modules and the central BMS is crucial for quick response to anomalies. Bus communication methods and loop shaping techniques are discussed for improving system reliability and response time.Experimental Validation and Results Researchers present experimental validation of proposed EV BMS designs. These experiments often involve the implementation of the BMS in electric vehicle models, with a focus on improving battery capacity dynamics, cost-effectiveness, and reliability. Results indicate positive outcomes in terms of enhanced performance and safety.Standardization and Regulations Some studies highlight the need for standardization in EV BMS functionalities and safety measures. Collaborations with regulatory bodies and industry stakeholders are discussed to establish standards that ensure a consistent level of safety across different electric vehicles.Cost Optimization and Scalability The literature acknowledges the importance of cost optimization in EV BMS development. Researchers explore methods to reduce the cost of components and manufacturing processes while maintaining high-performance standards. Scalability considerations for mass adoption of electric vehicles are also discussed.In the literature on EV BMS with charge monitor and fire protection underscores the multidimensional approach taken by researchers to enhance the safety, efficiency, and reliability of electric vehicle battery systems. Ongoing efforts in algorithm development, experimental validation, and collaboration for standardization indicate a dynamic and evolving field with a focus on addressing the challenges associated with electric vehicle battery technologies.

2.1 Survey on Previous Works

2.1.1 Battery Energy Storage System (BESS) and Battery Management System (BMS) for Grid-Scale Applications [3]

Due to a discrepancy between the quantity of energy consumers use and the amount of energy generated by generation sources, the current electric grid is an inefficient system that wastes a considerable amount of the electricity it generates. In order to assure adequate power quality, power plants often produce more energy than is required. Many of these inefficiencies can be eliminated by making use of the energy storage that already exists inside the grid. To accurately monitor and regulate the storage system while using battery energy storage systems (BESS) for grid storage, comprehensive modelling is needed. The storage system is controlled by a battery management system (BMS), and a BMS that makes use of sophisticated physics-based models will enable considerably more reliable operation of the storage system. The essay describes theMatthew T. Lawder; BharatkumarSuthar; Paul W. C. Northrop; Sumitava De; C. Michael Hoff; Olivia,2008.

Enhancing Grid Efficiency through Comprehensive Modeling and Advanced Battery Management Systems in Battery Energy Storage Systems is the current electric grid exhibits inefficiencies stemming from a disparity between energy consumption and generation. Power plants often generate an excess of energy to maintain power quality, resulting in wastage. To address this issue, leveraging the inherent energy storage capacity within the grid has become imperative. This essay delves into the deployment of Battery Energy Storage Systems (BESS) for grid-scale applications, emphasizing the crucial role of accurate monitoring, regulation, and the integration of advanced physics-based models within the Battery Management System (BMS). By exploring the need for comprehensive modeling, this essay seeks to highlight the potential of BESS in optimizing grid storage and achieving reliable, efficient operation.The Challenge of Grid Inefficiencies is the existing electric grid grapples with inefficiencies due to the misalignment between energy supply and demand. Power plants, in their pursuit of ensuring power quality, often produce an excess of energy, leading to unnecessary waste. This mismanagement highlights the need for innovative solutions that can align energy production more closely with consumption patterns.Leveraging Inherent Energy Storage is an effective strategy to mitigate grid inefficiencies involves tapping into the inherent energy storage capabilities within the grid.

Battery Energy Storage Systems (BESS) emerge as a promising solution for storing excess energy during periods of surplus generation and releasing it during high-demand phases. This approach contributes to better grid balancing and utilization of generated energy, addressing the inefficiencies prevalent in the current system.Optimizing BESS Performance is to fully harness the potential of BESS in grid-scale applications, optimizing performance is crucial. This necessitates accurate monitoring and regulation of the energy storage system. A Battery Management System (BMS) plays a pivotal role in achieving this optimization by overseeing the charging and discharging processes. The

BMS acts as the control center, ensuring efficient energy storage utilization and maintaining the overall health of the system.Advanced Physics-Based Models in BMS is to enhance the reliability of the storage system, the incorporation of sophisticated physics-based models within the BMS becomes imperative. These models enable a more precise understanding of the complex interactions within the battery, allowing for real-time adjustments to optimize performance.

By integrating advanced algorithms and sensors, the BMS can monitor key parameters such as voltage, current, temperature, and state of charge, facilitating precise control and management of the charging process.Comprehensive Modeling for Effective BESS Implementation is Comprehensive modeling is essential for the effective implementation of BESS in grid storage. This involves developing accurate models that simulate the dynamic behavior of the energy storage system under various conditions. These models aid in predicting system performance, optimizing control strategies, and ensuring the reliability and longevity of the battery components.Emphasizing the Role of BMS is The critical role of the Battery Management System with advanced physics-based models cannot be overstated. A well-designed BMS ensures the seamless integration of BESS into the grid, maximizes efficiency, and provides the necessary safeguards against potential issues. The essay draws attention to the work of Lawder et al. (2008), highlighting their insights into the importance of advanced modeling techniques in achieving reliable and efficient BESS operation.In addressing the inefficiencies of the existing electric grid requires innovative solutions such as Battery Energy Storage Systems (BESS). This essay underscores the significance of accurate monitoring, regulation, and the integration of advanced physics-based models within the Battery Management System (BMS) for optimal BESS performance. By exploring the need for comprehensive modeling, this discussion contributes to the ongoing efforts to enhance grid efficiency and reliability, paving the way for a sustainable and resilient energy future.

2.1.2 A Battery Modular Multilevel Management System (BMS) For Electric Vehicles And Stationary Energy Storage Systems [5]

The dependency of energy systems on battery storage systems is constantly increasing, but there are still several unsolved problems. Current battery systems are inflexible, only cells with the same electrical parameters can be combined, and cell defects cause a high reduction of the overall battery lifetime or even a system black out. In addition, the maximum usable capacity and the maximum charging current are limited by the weakest cell in the system. Current Battery Management Systems (BMS) can increase the usable battery capacity to some extend and are able to enlarge the maximum usable charging current. With the Battery Modular Multilevel Management System (BM3) presented in this paper, a very flexible, fault tolerant, and cost-efficient battery system can be implemented. With the system it is possible to establish either serial or parallel connections between neighboring cells or to bypass a cell. Thus the cells can be operated according to their needs and their state of charge (SOC). Separate balancing means for balancing the cells SOC, however, become obsolete. Published in: 2014 16th European Conference on Power Electronics and Applications .

Innovating Battery Management for Enhanced Flexibility and Reliability in Energy Storage Systems The growing dependence on battery storage systems in energy applications brings forth persistent challenges that demand effective resolutions. Current battery systems exhibit inflexibility, limiting cell combinations to those with identical electrical parameters. Furthermore, cell defects can lead to a substantial reduction in overall battery lifespan or even result in a system blackout. The weakest cell in the system imposes constraints on maximum usable capacity and charging current. Although existing Battery Management Systems (BMS) contribute to increased usable battery capacity and charging current, a more versatile, fault-tolerant, and cost-efficient solution is required. This paper introduces the Battery Modular Multilevel Management System (BM3) as an innovative approach to address these challenges. Key Challenges in Current Battery SystemsThe inflexibility of current battery systems hinders the combination of cells with differing electrical parameters. Cell defects pose a significant threat, impacting the overall battery lifespan and potentially leading to system blackouts. Additionally, the limitations imposed by the weakest cell in terms of usable capacity and charging current underscore the need for advancements in Battery Management Systems.Introducing the Battery Modular Multilevel Management System (BM3) This paper presents the Battery Modular Multilevel Management System (BM3) as a transformative solution to the current challenges in battery systems. Designed for both Electric Vehicles and stationary energy storage applications, the BM3 offers exceptional flexibility, fault tolerance, and cost-effectiveness. Its innovative design allows for the establishment of serial or parallel connections between neighboring cells, or the ability to bypass a cell. This flexibility enables cells to operate according to their specific needs and state of charge (SOC), rendering separate balancing means for SOC unnecessary.Key Features of BM3 The BM3's modular and multilevel approach introduces a new level of flexibility in battery management. By allowing dynamic configurations of cell connections, the system addresses the rigidity of existing designs.

The fault-tolerant nature of BM3 minimizes the impact of cell defects, contributing to an extended overall battery lifespan and increased system reliability. Additionally, the elimination of separate balancing means simplifies the management of cell SOC, further enhancing the efficiency and effectiveness of the battery system.Implications for Electric Vehicles and Stationary Energy Storage The BM3's innovative features have far-reaching implications for both Electric Vehicles and stationary energy storage systems. In the context of Electric Vehicles, the system optimizes battery performance, extends lifespan, and enhances safety. For stationary energy storage, the BM3 allows for greater flexibility in configuring energy storage systems, addressing the limitations of current rigid designs.Published in the 16th European Conference on Power Electronics and Applications in 2014, the Battery Modular Multilevel Management System (BM3) presents a breakthrough solution to the prevailing challenges in battery storage systems. Its flexibility, fault tolerance, and cost-effectiveness pave the way for a new era in battery management, ensuring enhanced reliability and adaptability in the face of evolving energy system demands.

2.1.3 Battery Management System Via Bus Network For Multi Battery Electric Vehicle [6]

This paper proposes multi-battery design of battery management control using bus communication method based on loop shaping. The experiment of proposed method shows that the capacity dynamics of battery has been improved. The multiple of battery control system is implemented in electric vehicle's model, and we modify the origin control system using bus communication method auto tuning based on loop shaping. The result of modified control system using bus method based on loop shaping is shown in the implementation design response of battery management that the cost and reliability are improved. Moreover, this method could maintain the error steady state to be zero. of five years. The time series monthly data is collected on stock prices for sample firmsand relative macroeconomic variables for the period of 5 years. The data collection period is ranging from January 2010 to Dec 2014. Monthly prices of KSE -100 Index is taken from yahoo finance.

The initial part discusses a proposed battery management system for a multi-battery electric vehicle using bus communication and loop shaping. However, the text then transitions abruptly to mention a time series data collection related to stock prices and macroeconomic variables over a five-year period. If we focus on the initial part related to the battery management system for a multi-battery electric vehicle. Battery Management System via Bus Network for Multi-Battery Electric Vehicle This paper proposes a novel design for a battery management system (BMS) in a multi-battery electric vehicle. The design incorporates a bus communication method based on loop shaping. Experimental results demonstrate improved capacity dynamics of the battery. The control system is implemented in an electric vehicle model, with the original control system modified using an auto-tuning bus communication method based on loop shaping. The modified control system exhibits enhanced performance in terms of cost, reliability, and steady-state error maintenance. However, the provided text appears to segue into a different topic related to time series monthly data collection on stock prices for sample firms and macroeconomic variables.

2.2 Literature Review

- The Battery Management System (BMS) plays a crucial role in electric car battery systems by continuously monitoring the condition of the battery. It ensures safe charging and discharging operations by managing parameters such as voltage, current, temperature, and state of charge (SOC). The BMS oversees the health and performance of individual battery cells, balancing their charge levels to prevent overcharging or undercharging, which could degrade battery life or pose safety risks. Additionally, the BMS implements protective measures, such as temperature regulation and fault detection, to safeguard against thermal runaway, short circuits, and other potential hazards, thus ensuring the reliability, longevity, and safety of electric vehicle batteries.

- A comprehensive Battery Management System (BMS) for electric vehicle batteries must incorporate several key features to mitigate potential risks such as thermal runaway and fire. Temperature monitoring ensures that battery cells operate within safe temperature limits, preventing overheating and thermal runaway. Cell balancing helps maintain uniform charge levels across all cells, reducing the likelihood of overcharging or undercharging, which can lead to battery degradation or safety hazards. Overcurrent protection safeguards against excessive current flow, which can cause overheating and damage to the battery. Fire suppression systems and containment measures are essential for rapidly extinguishing fires and containing any potential hazards in the event of a thermal runaway or fire incident, minimizing the risk of damage to the vehicle and ensuring passenger safety. Together, these features enable the BMS to proactively manage and mitigate risks, ensuring the safe and reliable operation of electric vehicle batteries.

- Incorporating automatic fire extinguishers and covering battery cells with fire-resistant materials are two effective fire safety strategies that can be integrated into the design of a Battery Management System (BMS). Automatic fire extinguishers, such as foam or gas-based systems, can quickly suppress fires in the event of thermal runaway or other hazardous conditions, minimizing the risk of damage to the battery and surrounding components. Additionally, covering battery cells with fire-resistant materials, such as ceramic or intumescent coatings, provides an additional layer of protection by containing and preventing the spread of flames, thereby enhancing overall safety and reducing the likelihood of fire-related incidents in electric vehicle batteries.

- The Battery Management System (BMS) plays a critical role in prolonging the lifespan of electric vehicle batteries by preventing detrimental charging and discharging conditions. By closely monitoring parameters such as voltage, current, and state of charge, the BMS ensures that the battery operates within optimal limits, mitigating the risks of overcharging, undercharging, and overdischarging. These harmful conditions can lead to cell degradation, capacity loss, and premature failure, significantly impacting battery performance and longevity. By maintaining the battery within safe operating parameters, the BMS helps maximize battery life and overall durability, thereby enhancing the efficiency and reliability of electric vehicle power systems.

- Various research investigations have explored diverse designs and tactics for Battery Management Systems (BMS) with integrated charge monitoring and fire protection measures. These efforts have focused on implementing comprehensive systems that incorporate features such as fire detection and suppression systems, overcurrent protection, cell balancing, and temperature monitoring. By combining these functionalities, researchers aim to enhance the safety, reliability, and performance of electric vehicle batteries. These advancements in BMS technology offer potential solutions to mitigate risks associated with thermal runaway and fire incidents, while also optimizing battery efficiency and longevity. Through ongoing research and development, BMS designs continue to evolve, paving the way for safer and more robust electric vehicle power systems.

2.3 Summary

An overview of the significance of Battery Energy Storage Systems (BESS) and Battery Management Systems (BMS) in addressing inefficiencies within the current electric grid is explained.Emphasis is on the necessity for comprehensive modeling to effectively monitor and regulate energy storage within the grid, reflecting a proactive approach to optimizing energy usage and minimizing wastage.

Two relevant papers are cited, both focusing on Battery Modular Multilevel Management Systems (BM3) designed for both electric vehicles and stationary energy storage systems. These systems are introduced as solutions to current challenges, particularly the inflexibility of existing battery systems, limitations in cell coupling based on electrical characteristics, and issues related to cell defects that can significantly impact the overall battery lifespan or even lead to system failures. The proposed BM3 systems aim to provide enhanced flexibility, fault tolerance, and cost efficiency.

Furthermore, the text introduces another paper that suggests a multi-battery design for a Battery Management Control System utilizing a bus communication method based on loop shaping. The experiment conducted to validate this method reveals improvements in battery capacity dynamics, increased cost-effectiveness, and enhanced reliability. Notably, the modified control system demonstrates the ability to maintain the error steady state at zero, indicating a high level of precision and control.

The outcomes section underscores the pivotal role of BMS in ensuring the safe operation of electric car battery systems. Key features mentioned include temperature monitoring, cell balancing, overcurrent protection, fire suppression systems, and containment systems. These features collectively contribute to risk prevention, specifically addressing issues like thermal runaway and fire hazards. Additionally, the BMS is recognized for its ability to prevent detrimental conditions such as overcharging, undercharging, and overdischarging, which can adversely impact battery life.

Concludes by highlighting various designs and tactics proposed in different research investigations, emphasizing the ongoing efforts to enhance BMS functionalities, including charge monitoring and fire protection measures. This indicates a dynamic field of research focused on continually improving the safety, efficiency, and reliability of battery systems in various applications, from electric vehicles to stationary energy storage.

Chapter 3

METHODOLOGY

Developing an Electric Vehicle Battery Management System (EV BMS) with charge monitoring and fire protection involves a systematic methodology that encompasses various stages. Here's a general outline of the methodology are,Problem Definition and Requirements Analysis Clearly define the objectives of the EV BMS, specifying the key functionalities, such as charge monitoring and fire protection.Identify the specific requirements based on safety standards, regulations, and the characteristics of electric vehicle batteries.Literature Review Conduct a comprehensive literature review to understand existing methodologies, technologies, and best practices related to EV BMS, charge monitoring, and fire protection.

System Architecture Design Develop a high-level system architecture outlining the components and their interactions.Define the communication protocols between the BMS, battery cells, and other relevant subsystems.Consider modularity and scalability to accommodate different battery configurations and types.Sensor and Actuator Selection Choose appropriate sensors for monitoring parameters such as temperature, voltage, current, and state of charge.Select actuators for implementing safety measures, such as fire suppression systems.Charge Monitoring Algorithm Development Develop algorithms for real-time charge monitoring, considering factors like charging rate, state of charge, and charge/discharge limits.Implement safeguards to prevent overcharging, undercharging, and overheating.Fire Protection System Design Design a fire protection system that includes early detection mechanisms (such as smoke or heat sensors), suppression systems (fire extinguishers, cooling systems), and isolation measures.Consider redundant safety features to ensure robustness.

Integration of Charge Monitoring and Fire Protection Integrate the charge monitoring and fire protection systems, ensuring seamless communication between the two.Implement logic for coordinated responses, such as reducing charging rates or isolating affected cells in the event of a detected anomaly.Algorithm Validation and Simulation Use simulation tools to validate the developed algorithms and assess their performance under various scenarios.Conduct virtual testing to simulate charging, discharging, and emergency situations.Prototype Development Develop a prototype of the EV BMS incorporating the charge monitoring and fire protection features.Use appropriate hardware and software platforms for testing and validation.Experimental Testing Conduct real-world experimental testing to validate the prototype's performance.Evaluate the system's response to charging cycles, abnormal conditions, and fire simulation scenarios.Optimization and Refinement Optimize the algorithms and system parameters based on experimental results.Refine the BMS design to enhance efficiency, reliability, and safety.Documentation and Reporting Document the methodology, algorithms, hardware specifications, and experimental results.Prepare a comprehensive report summarizing the design, development, and validation processes.Regulatory Compliance and Certification Ensure that the developed EV BMS complies with relevant safety standards and regulations.Seek certification from regulatory bodies to validate the system's safety and performance.By following this systematic methodology, you can design,develop, and validate an EV BMS with charge monitoring and fire protection, ensuring a robust and safe system for electric vehicle applications.

3.1 Introduction

A microcontroller is an integrated circuit containing a complete microprocessor system. Microprocessors had to be built into low-cost products, leading to the development of microcontrollers. Since microprocessors are a reasonable choice for many product implementations, when an entire microprocessor system is placed on his single chip, the yield of basic products that rely on microprocessor performance is dramatically reduced.Here we are using ESP32 microcontroller board along with sensors,solar panel,display and some other elements. . Even if the product design may just call for a straightforward system, the components are necessary to make this system a low-cost item. A single-chip microcontroller is used in a microprocessor system as a solution to this issueDue to the fact that all required components are contained on an integrated circuit, it is sometimes referred to as a microcomputer. Due to the fact that they are used to control operations, they are more commonly referred to as microcontrollers In this work, the purpose, functions and topologies of BMS are discussed in detail. In addition, early battery models along with the hardware and system designs for BMS are covered in a literature review. Then, an improved battery model is introduced, and simulation results are shown to verify the model's performance. Finally, the design of a novel BMS hardware system and its experimental results are discussed. The possible improvements for the battery models and BMS hardware are given in the section on conclusions and future work. A battery management system (BMS) is proposed which is used for electronic vehicle that manages a rechargeable battery (cell or battery pack), such as by protecting the battery from operating outside its safe operating area, monitoring its state using ESP32 microcontroller.

3.2 Block Diagram

The integration of an Electric Vehicle Battery Management System (BMS) with Charge Monitoring and Fire Protection alongside solar panels offers a comprehensive solution for enhancing electric vehicle (EV) safety and sustainability. The collaboration between these systems involves a cohesive approach to optimize energy management, ensure efficient charging, and safeguard against potential hazards.Firstly, the solar panels act as a renewable energy source, tapping into the abundant sunlight to generate electrical energy. This energy is channeled into the EV battery system for charging. The BMS, in conjunction with the solar panel system, orchestrates the charging process by monitoring the incoming solar energy flow. It adjusts the charging rate based on the available solar power, effectively harnessing solar energy to charge the EV battery. This adaptive charging system ensures optimal utilization of the solar power while efficiently replenishing the battery.Simultaneously, the BMS oversees critical aspects of battery health and safety. It continuously monitors the battery status, including cell voltages, temperatures, and overall battery health. This monitoring ensures that the battery is charged within safe voltage and temperature ranges, preventing overcharging or excessive heat build-up. Especially in environments like South Africa, where high temperatures can affect battery performance, the BMS manages temperature control mechanisms, safeguarding the battery from overheating during the charging process.

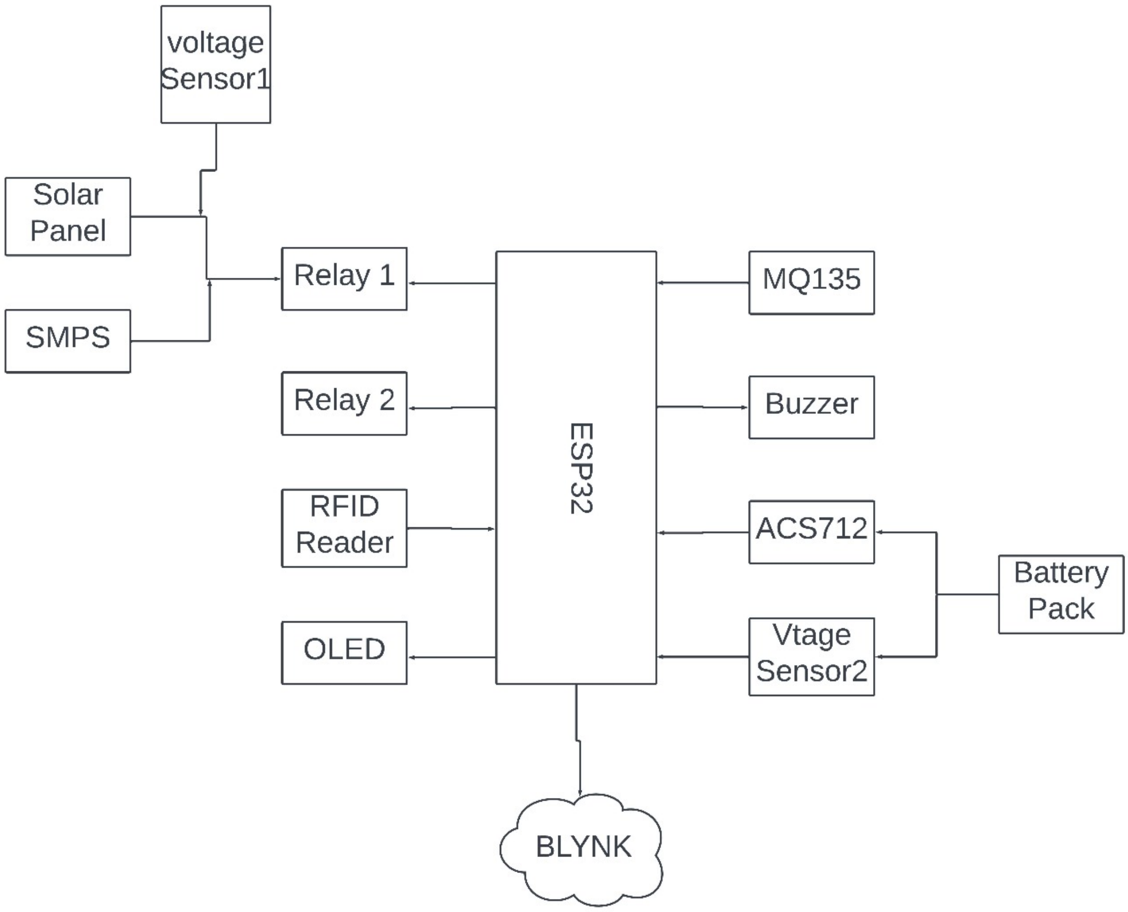

Figure 3.1: Block Diagram

Moreover, the integration of fire protection measures within the BMS becomes crucial when considering the safety of the battery system, especially in regions with varying climatic conditions. In the event of potential fire hazards, the system's fire detection sensors coupled with rapid response mechanisms can promptly identify and mitigate risks. This comprehensive safety feature helps prevent fire-related incidents within the battery pack, ensuring both the vehicle and its surroundings are protected.

The combination of these systems not only enhances the overall safety of the EV but also contributes significantly to sustainable mobility. By utilizing solar energy to power the vehicle, the integration promotes eco-friendly transportation, reducing reliance on non-renewable energy sources. Furthermore, surplus solar energy harvested during the charging process can potentially be redirected back into the grid or utilized for other applications, contributing to overall energy efficiency and sustainability.

In essence, the collaboration between an EV BMS with Charge Monitoring, Fire Protection, and solar panels creates a synergistic system. It optimizes energy usage, safeguards the battery system against potential risks, and promotes sustainable mobility by harnessing renewable solar energy for efficient and safe electric vehicle operation.

3.3 Circuit Diagram

In the ESP32-based EV charging station circuit, the system begins with an RFID reader module connected to the ESP32 board. When a user presents an RFID tag to the reader, it triggers the charging process, ensuring safety and authorization. The ESP32 board controls the entire system and facilitates communication with other components.

The primary charging source is a 12V solar panel, monitored by a voltage sensor to ensure the output is within the correct range. If the voltage is suitable, the ESP32 activates a relay to switch the charging circuit to the solar panel. If the solar panel output is insufficient, another relay switches the circuit to a 12V SMPS (Switched Mode Power Supply) for battery charging.

A second voltage sensor monitors the charging current, and if the battery voltage reaches full capacity, a relay is activated to cutoff the supply, preventing overcharging. Additionally, another relay is used to switch between the SMPS and solar panel based on availability and charging requirements.

A gas sensor, such as the MQ135, is incorporated into the system to detect gas leakages, enhancing safety during the charging process. All system details, including charging status and gas detection alerts, are displayed on an OLED display for user convenience.

The ESP32 board enables WiFi connectivity, allowing users to view real-time data and control the charging station remotely via a Blynk app installed on their smartphone, enhancing usability and accessibility. Overall, this circuit diagram illustrates a comprehensive and user-friendly EV charging station design with safety features and IoT capabilities.

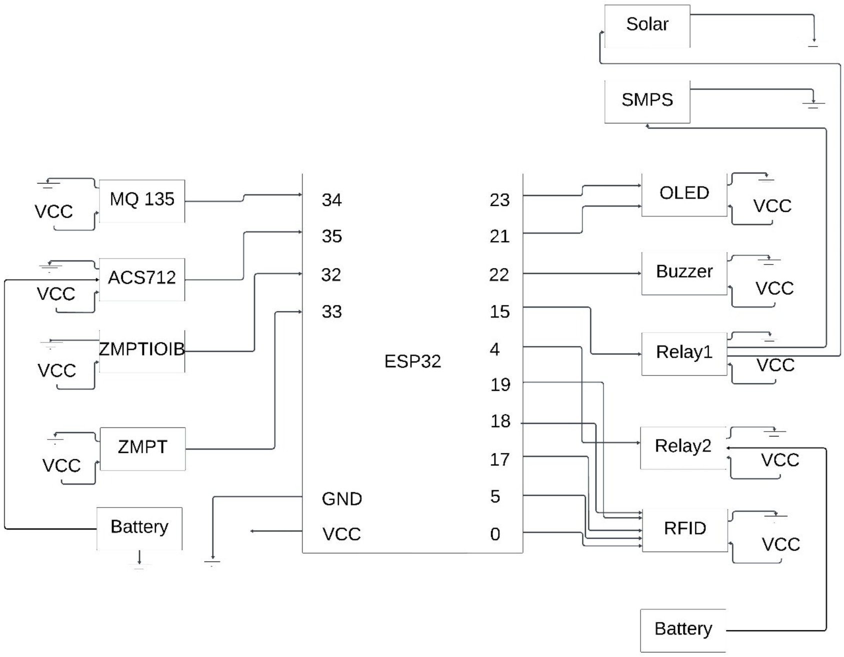

Figure 3.2: Circuit Diagram

3.4 Hardware Description

3.4.1 ACS712 Current Sensor

The ASC712 is based on Hall Effect. There is a copper strip connecting the IP+ and IP- pins internally. When some current flows through this copper conductor, a magnetic field is generated which is sensed by the Hall Effect sensor. The Hall Effect sensor then converts this magnetic field into appropriate voltage. In this method, the input and the output are completely isolated.By using this current sensor the overcharging is controlled by using a protection relay which is controlled by a microcontroller.

The ACS712 can be used to measure the current flowing into and out of the EV's battery pack. Monitoring battery current is crucial for assessing the state of charge, detecting charging and discharging events, and ensuring the overall health of the battery. Charging System Monitoring: In an electric vehicle, the ACS712 can be employed to monitor the current during the charging process. This helps ensure that the charging system operates within safe limits and facilitates accurate charging current measurements. The current sensor can be placed in series with the electric motor to measure the current drawn during operation. This information is valuable for motor control, performance optimization, and identifying any anomalies or faults in the motor system. In an EV's powertrain, the power inverter converts DC power from the battery to AC power for the electric motor. The ACS712can monitor the current on the DC side of the inverter, helping to ensure efficient power conversion and detecting issues. Current sensors contribute to energy management systems in electric vehicles. By monitoring current flow in different subsystems, such as the motor, battery, and auxiliary systems, the vehicle can optimize energy usage for better efficiency.

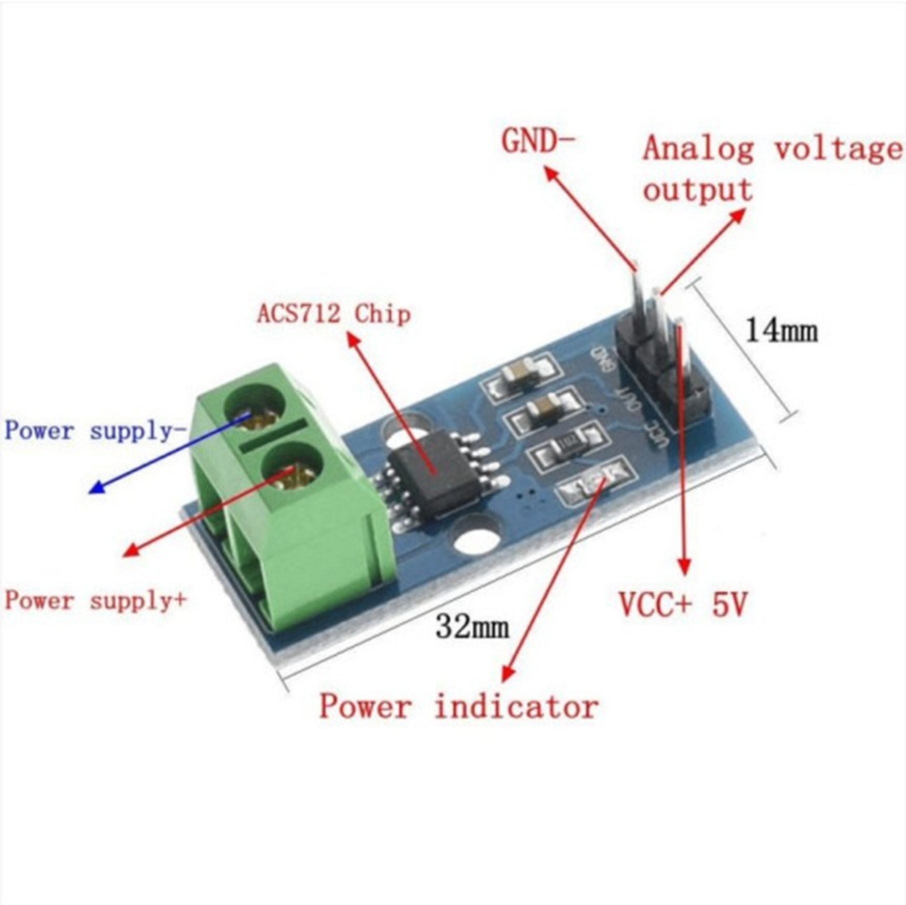

Figure 3.3: ACS712 Current Sensor[2]

The ACS712 can be integrated into the EV's protection system to detect overcurrent conditions. If the current exceeds safe limits, the system can trigger protective measures, such as shutting down specific components or alerting the driver. By measuring current over time, the ACS712 can contribute to estimating the State of Charge (SOC) of the battery pack. This information is critical for providing accurate feedback to the driver regarding the remaining charge and range of the vehicle. The current sensor can be part of a diagnostic system that monitors for unusual current patterns. Deviations from expected current levels may indicate faults or anomalies that require further investigation. In electric vehicles with regenerative braking systems, the ACS712 can help monitor the current generated during braking events. This information can be used to control the regenerative breaking system for optimal energy recovery. Current sensor data is often integrated into the overall vehicle control system. This integration enables the vehicle to make informed decisions about power distribution, energy regeneration, and overall system performance. When using the ACS712 current sensor module in an electric vehicle, it's important to ensure proper calibration, accuracy, and protection against environmental factors. The sensor's output can be interfaced with microcontrollers or other processing units to extract meaningful information for system control and monitoring.

3.4.2 MQ135 Gas Sensor

The MQ-135 is a gas sensor that detects a wide range of air contaminants, including ammonia, nitrogen oxides, alcohol, benzene, smoke, and CO2. It's commonly used in air quality monitoring systems, environmental monitoring devices, and indoor air quality detectors. The sensor operates on the principle of resistance change in response to the presence of these gases. In Arduino projects, the MQ-135 sensor can be easily integrated using analog input pins. By measuring the sensor's resistance and applying a calibration curve, you can estimate the concentration of the target gas in the air. This information can then be used to trigger actions or display air quality data to users.Here we are using this for checking gas leakages to avoid dangerous conditions. The MQ135 gas sensor is a popular component used for detecting a variety of gases in the atmosphere. Developed by Winsen, the MQ135 is particularly renowned for its ability to detect gases such as ammonia, nitrogen oxides, benzene, smoke, and other harmful gases commonly found in industrial environments, homes, and vehicles. Its compact size, low cost, and relative ease of integration make it a favored choice for hobbyists, researchers, and professionals alike.

At the heart of the MQ135 sensor is a tin dioxide (SnO2) semiconductor material, which exhibits a change in its electrical conductivity when exposed to certain gases. The sensor's detection mechanism relies on the interaction between these target gases and the semiconductor material. When gas molecules come into contact with the SnO2 surface, they react with the material, altering its conductivity. This change in conductivity is then measured and interpreted as the presence and concentration of the target gas.

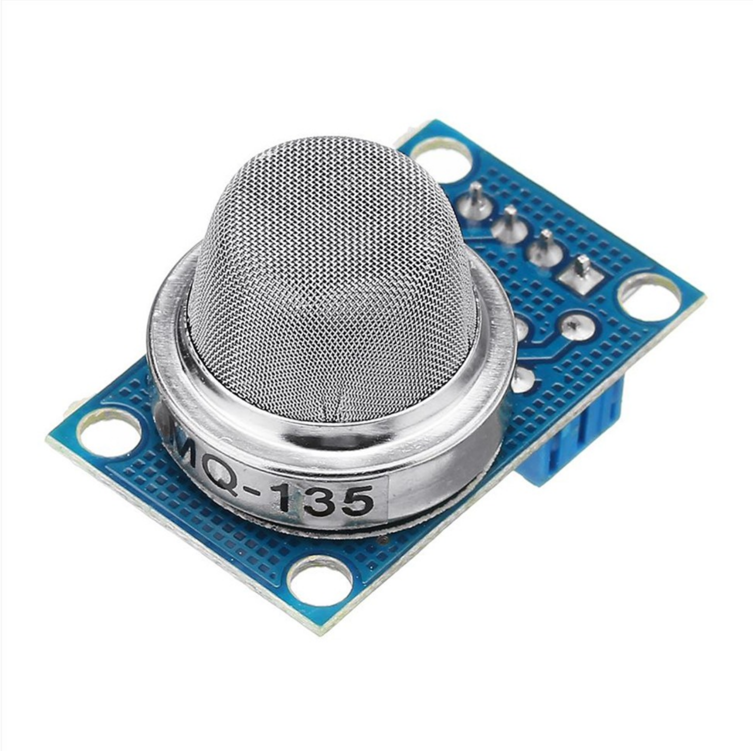

Figure 3.4: MQ135 Gas Sensor [2]

One of the key features of the MQ135 sensor is its sensitivity to a wide range of gases, making it versatile for various applications. However, this sensitivity also means that the sensor's response can be influenced by the presence of multiple gases simultaneously, which may require careful calibration and signal processing to accurately distinguish between different gases. Additionally, environmental factors such as temperature and humidity can affect the sensor's performance, necessitating appropriate compensation techniques for reliable operation.

In terms of operation, the MQ135 sensor typically requires a heating element to maintain a constant temperature, ensuring consistent and accurate readings. The sensor's response time can vary depending on factors such as gas concentration and temperature, but it generally provides real-time measurements suitable for monitoring air quality or detecting gas leaks. Integration with microcontrollers or single-board computers is common, enabling users to develop customized applications and systems tailored to their specific needs.

Despite its widespread use, the MQ135 sensor does have limitations. Its sensitivity to humidity and other environmental factors can lead to false positives or inaccurate readings if not properly accounted for. Additionally, like many gas sensors, the MQ135 requires periodic calibration to maintain its accuracy over time. Nonetheless, with proper calibration and implementation, the MQ135 gas sensor remains a valuable tool for detecting and monitoring various gases in diverse settings, contributing to efforts aimed at improving air quality and ensuring safety in a range of applications.

3.4.3 Buzzer

A buzzer is an electronic device that produces sound when an electrical signal is applied to it. It's commonly used in various electronic projects and products for generating audible alerts, notifications, or tones. In Arduino projects, buzzers are often employed to create sound effects, alarms, or feedback signals.Here we are using buzzer as an sound alert for any hazardous condition.

Commonly used in industrial settings, homes, vehicles, and security systems, the buzzer system plays a crucial role in ensuring timely response to emergencies and enhancing overall safety.

The core component of a buzzer system is the buzzer itself, typically a piezoelectric transducer that converts electrical signals into sound waves. When activated, the buzzer emits a loud, attention-grabbing sound that can alert individuals to potential dangers such as fire, gas leaks, intrusions, or equipment malfunctions. The electronic circuitry of the buzzer system is responsible for controlling the activation of the buzzer in response to predefined conditions or signals from sensors, detectors, or manual triggers.

Buzzer systems are highly customizable to suit specific application requirements. They can be integrated with various sensors and detectors to monitor environmental conditions or detect specific events, triggering the buzzer when predefined thresholds are exceeded or certain criteria are met. Additionally, advanced buzzer systems may incorporate features such as adjustable volume levels, different sound patterns for different alerts, and compatibility with remote monitoring and control systems. Overall, the buzzer system serves as a reliable and cost-effective means of providing audible alerts for hazardous conditions, contributing to improved safety and rapid response in diverse settings.

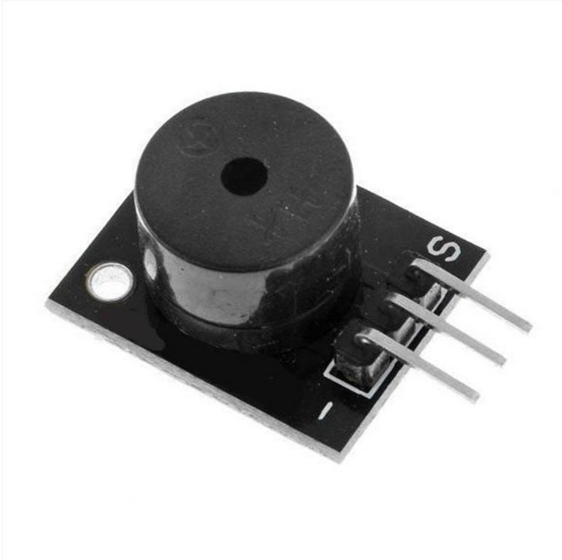

Figure 3.5: Buzzer

3.4.4 ZMPT101B Voltage Sensor

In an electric vehicle (EV) charging project, a voltage sensor plays a crucial role in monitoring and ensuring the safety of the charging process. Here's how you might integrate a voltage sensor into such a project:
The voltage sensor is used to measure the voltage of the power supply or battery pack connected to the EV charger. This measurement helps ensure that the voltage remains within safe limits during charging and prevents overcharging or other potential hazards.

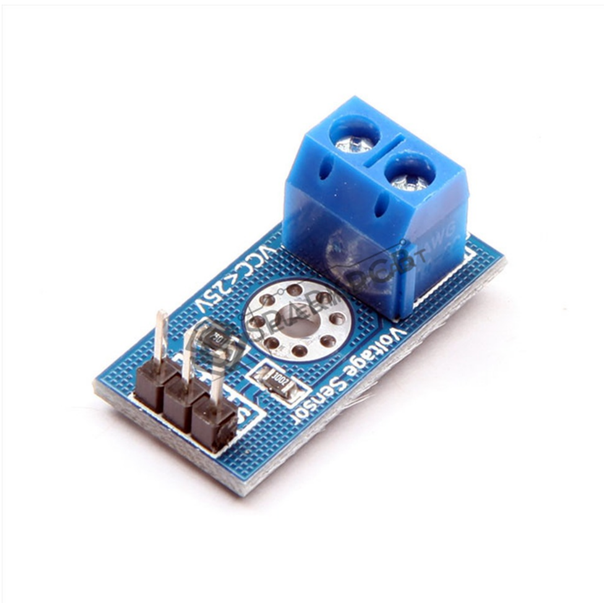

Figure 3.6: ZMPT101B Voltage Sensor [1]

The voltage sensor continuously monitors the voltage level and alerts the charging system if it exceeds or falls below predefined thresholds. For example, if the voltage exceeds the maximum safe limit, the charging process can be automatically paused or terminated to prevent damage to the EV battery or electrical system.

The voltage sensor provides feedback to the charging controller or management system, allowing it to adjust the charging current or other parameters dynamically based on the measured voltage level. This helps optimize charging efficiency and ensure stable charging performance under varying conditions. Fault Detection: The voltage sensor can also detect faults or abnormalities in the charging system, such as short circuits, open circuits, or voltage spikes, and trigger appropriate safety measures to protect the EV and charging infrastructure.

Overall, the voltage sensor plays a critical role in EV charging projects by providing real-time voltage monitoring, safety protection, and feedback control to ensure efficient and safe charging operations. Its integration enhances the reliability, safety, and performance of the EV charging infrastructure, contributing to the widespread adoption of electric vehicles.

3.4.5 7ASPDT Relay

Relays are electric switches that use electromagnetism to convert small electrical stimuli into larger currents. These conversions occur when electrical inputs activate electromagnets to either form or break existing circuits. In this project we are using 7A SPDT Relay.A Single Pole Double Throw (SPDT) relay is a type of electromechanical switch used in electronic circuits to control the flow of electricity. It consists of a coil, a common terminal (COM), a normally open (NO) terminal, and a normally closed (NC) terminal. When the coil is energized, it mechanically switches between the NO and NC terminals, providing a changeover function.

A 7ASPDT relay module, also known as a 7-channel single-pole double-throw relay module, is a versatile electronic component used for switching multiple circuits with a single control signal. Each relay within the module consists of a single pole double throw (SPDT) switch, allowing it to connect one of two circuits depending on the state of the control signal. The ”7A” designation typically indicates the maximum current rating of the relay contacts, which in this case would be 7 amperes.

Figure 3.7: 7ASPDT Relay Module [1]

This type of relay module is commonly employed in automation, control systems, and electronic projects where there is a need to switch multiple loads independently. The module typically includes seven individual relays, each controlled by a separate input signal. This arrangement provides flexibility in controlling various devices or systems using a microcontroller, PLC (Programmable Logic Controller), or other control circuitry.

The SPDT configuration of each relay means that it has three terminals: a common terminal (COM), a normally open terminal (NO), and a normally closed terminal (NC). When the relay is not energized, the common terminal is connected to the normally closed terminal. When the relay is energized, the common terminal switches to the normally open terminal. This enables the relay module to effectively act as a switch, allowing the user to selectively connect or disconnect circuits as needed.

The 7ASPDT relay module simplifies the design and implementation of complex control systems by providing a compact and convenient means of switching multiple circuits. By using multiple relays in a single module, it reduces wiring complexity and saves space on a circuit board or in an enclosure. Additionally, the module's compatibility with standard control voltages and signals makes it easy to integrate into a wide range of electronic applications, from home automation and robotics to industrial machinery and process control systems.

3.4.6 SMPS(12V)

SMPS stands for Switched-Mode Power Supply. It's a type of power supply that converts electrical power efficiently from one form to another using switching devices such as transistors or MOSFETs. SMPSs are commonly used in various electronic devices and applications due to their high efficiency, compact size, and versatility.SMPSs offer several advantages over traditional linear power supplies, including higher efficiency, lighter weight, smaller size, and greater flexibility in output voltage and current configurations. They are widely used in applications ranging from consumer electronics (such as laptops, smartphones, and LED monitors) to industrial equipment, telecommunications, and automotive systems.
Switched Mode Power Supply (SMPS) is an electronic power supply that efficiently converts electrical power from one form to another. In the case of a 12V SMPS, the input voltage, typically AC mains voltage, is converted into a stable 12-volt DC output. SMPS achieves this conversion through a process involving high-frequency switching of power transistors, followed by filtering and regulation stages to ensure a clean and consistent output voltage.

Figure 3.8: SMPS [1]

One of the key advantages of an SMPS, especially a 12V variant, is its high efficiency compared to traditional linear power supplies. Unlike linear power supplies, which dissipate excess energy as heat, SMPS operates at higher frequencies, allowing for smaller and lighter components while minimizing energy loss. This efficiency makes 12V SMPS ideal for various applications where power consumption, heat dissipation, and size constraints are critical factors, such as in computers, LED lighting systems, automotive electronics, and industrial equipment.

The design and construction of a 12V SMPS involve several key components, including a rectifier to convert AC to DC, a high-frequency oscillator to drive the switching transistors, a transformer for voltage conversion, and rectifiers and capacitors for output smoothing and filtering. Additionally, feedback circuits and control mechanisms are employed to regulate the output voltage and ensure stable operation under different load conditions. Overall, the 12V SMPS offers a reliable and efficient solution for powering a wide range of electronic devices and systems, contributing to improved performance, reduced energy consumption, and enhanced portability.

3.4.7 Solar Panel

A solar panel, also known as a photovoltaic (PV) panel, is a device that converts sunlight into electrical energy using the photovoltaic effect. Solar panels are made up of multiple solar cells, which are semiconductor devices typically made of silicon. When sunlight strikes these cells, it excites electrons, creating an electric current. Solar panels, also known as photovoltaic (PV) modules, are devices designed to convert sunlight directly into electricity using the photovoltaic effect. Each solar panel consists of numerous solar cells made from semiconductor materials, typically silicon, which absorb photons from sunlight and generate an electric current. The basic working principle involves the interaction between photons (light particles) and electrons within the semiconductor material. When photons strike the surface of the solar cell, they transfer their energy to electrons, causing them to become energized and flow through the material, creating an electric current. This flow of electrons is then captured and harnessed as usable electrical power. The solar panel's electrical output is dependent on several factors, including the intensity of sunlight, the angle of incidence, and the efficiency of the solar cells. To maximize energy generation, solar panels are typically installed in locations with ample sunlight exposure, oriented at an optimal angle relative to the sun's position throughout the day. Additionally, solar panel arrays may incorporate tracking systems that adjust the orientation of the panels to maximize sunlight absorption. The electricity generated by solar panels can be used to power various electrical loads directly, stored in batteries for later use, or fed back into the electrical grid for credit or compensation, making solar panels a sustainable and environmentally friendly source of renewable energy.

Figure 3.9: Solar Panel [7]

Solar panels offer numerous advantages, including:

1. Renewable Energy Source: Solar energy is abundant and inexhaustible.
2. Environmentally Friendly: Solar energy production produces no greenhouse gas emissions or air pollution.
3. Low Operating Costs: Once installed, solar panels require minimal maintenance and have no fuel costs.
4. Energy Independence: Solar power allows individuals and businesses to generate their electricity, reducing reliance on external energy sources.
5. Versatility: Solar panels can be installed in various locations, including rooftops, open fields, or even integrated into building materials. Overall, solar panels play

a crucial role in the transition to clean and sustainable energy sources, offering a viable alternative to traditional fossil fuels.

3.4.8 RC522 RFID Reader

RC522 RFID reader module provides a convenient and cost-effective solution for integrating RFID functionality into Arduino or other microcontroller-based projects.Radio Frequency Identification is a type of communication between a transmitter (transponder or tag) and a receiver (reader). The system works fully automatically and is used for contactless communication, identification and localization of objects such as goods, medicines, vehicles or living beings. The RC522 RFID reader is a popular module used to read RFID (Radio Frequency Identification) tags or cards in electronic projects. It operates at 13.56 MHz frequency and communicates with microcontrollers like Arduino through SPI (Serial Peripheral Interface) communication protocol.

The RC522 RFID module is a widely used RFID (Radio-Frequency Identification) reader and writer module based on the MFRC522 IC (Integrated Circuit). Developed by NXP Semiconductors, the MFRC522 IC is designed for contactless communication using radio frequency signals, enabling the reading and writing of RFID tags.

At its core, the RC522 module consists of the MFRC522 IC, an antenna coil, and supporting circuitry enclosed on a compact PCB (Printed Circuit Board). The module communicates with external microcontrollers or systems through standard communication interfaces such as SPI (Serial Peripheral Interface) or UART (Universal Asynchronous Receiver-Transmitter).

One of the key features of the RC522 module is its ability to read and write RFID tags operating at 13.56 MHz frequency. These tags, commonly referred to as NFC (Near Field Communication) tags, come in various form factors such as cards, stickers, keychains, and implants. Each tag contains a unique identifier (UID) and may store additional data depending on its memory capacity and configuration.

The RC522 module supports several RFID tag protocols including ISO/IEC 14443 Type A and Type B, MIFARE Classic, MIFARE Ultralight, and MIFARE DESFire.

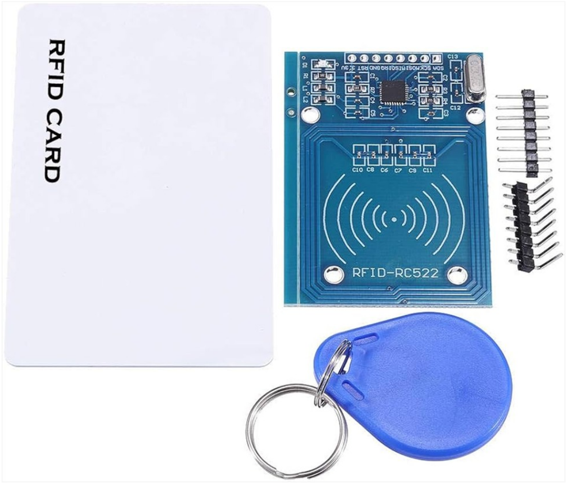

Figure 3.10: RC522 RFID Reader

This versatility allows it to interface with a wide range of RFID tags available in the market, making it suitable for diverse applications such as access control, payment systems, inventory management, and asset tracking.

Furthermore, the RC522 module offers flexible operating modes and configurations to accommodate different application requirements. It can operate in reader mode, where it detects and reads RFID tags within its range, or in writer mode, allowing it to write data to compatible RFID tags. Additionally, the module supports various communication speeds and data formats, enabling seamless integration with different host systems.

In terms of interfacing with external devices, the RC522 module provides standard communication protocols such as SPI and UART, simplifying integration with microcontrollers, single-board computers, and other electronic systems. This ease of integration, coupled with extensive documentation and libraries available online, makes the RC522 module popular among hobbyists, makers, and electronics enthusiasts.

Moreover, the RC522 module offers additional features such as built-in anti-collision algorithms for handling multiple RFID tags simultaneously, onboard cryptographic functions for secure data transmission, and configurable output formats for compatibility with existing software systems.

Overall, the RC522 RFID module is a versatile and reliable solution for RFID-based applications, offering robust performance, wide compatibility, and ease of use. Whether you're building a DIY access control system, implementing RFID-based authentication, or developing an inventory management solution, the RC522 module provides the necessary tools and capabilities to bring your project to life. With its affordable price point and broad range of applications, the RC522 RFID module continues to be a popular choice for RFID enthusiasts and professionals alike.

3.4.9 OLED Display

OLED (Organic Light-Emitting Diode) displays represent a cutting-edge technology in visual display systems, leveraging organic compounds to emit light when an electric current is applied. Renowned for their striking visual quality, OLED panels offer deep blacks and vibrant colors, courtesy of their self-emissive nature, which allows each pixel to generate its light. This attribute not only results in unparalleled contrast ratios but also ensures energy efficiency by only consuming power when displaying content. Additionally, OLED displays boast slim form factors and flexibility, enabling innovative designs like curved or foldable screens. With wide viewing angles, fast response times, and high color accuracy, OLEDs find applications in a myriad of consumer electronics, ranging from smartphones and televisions to wearable devices and automotive displays, continually pushing the boundaries of visual technology.

They are a type of display technology that offers several advantages over traditional LCD (Liquid Crystal Display) screens. OLED displays are made up of organic compounds that emit light when an electric current is applied, eliminating the need for a separate backlight as required by LCDs. This results in several benefits, including higher contrast ratios, faster response times, wider viewing angles, and thinner form factors. OLED displays are widely used in smartphones, tablets, TVs, and other electronic devices where high-quality visuals and energy efficiency are essential.

The working principle of OLED displays involves the emission of light by organic compounds arranged in thin layers between two conductive electrodes. When a voltage is applied across these electrodes, an electric current flows through the organic layers, causing them to emit light. Unlike LCDs, which rely on a backlight to illuminate pixels, OLED displays generate their own light on a pixel-by-pixel basis. This enables OLED displays to achieve deeper blacks and higher contrast ratios by completely turning off individual pixels to produce true blacks, enhancing overall image quality and visual experience.

Figure 3.11: OLED Display [2]

OLED displays can be categorized into two main types: passive matrix OLEDs (PMOLEDs) and active matrix OLEDs (AMOLEDs). PMOLEDs use a simpler control scheme and are typically used in small displays, such as those found in wearable devices and small appliances. On the other hand, AMOLEDs employ thin-film transistor (TFT) technology for individual pixel control, allowing for larger display sizes and higher resolutions. AMOLED displays are commonly used in smartphones and high-end TVs, offering vibrant colors, high refresh rates, and excellent energy efficiency. Overall, OLED displays represent a significant advancement in display technology, offering superior image quality, flexibility, and energy efficiency compared to traditional LCDs.

3.4.10 ESP32

The ESP32 is a powerful and versatile microcontroller chip developed by Espressif Systems. It's part of the ESP (Espressif Systems Platform) series of microcontrollers, which are widely used in the Internet of Things (IoT) and embedded systems projects. Here's an explanation of the ESP32 microcontroller: Dual-Core Processor: One of the standout features of the ESP32 is its dual-core processor architecture, consisting of two Xtensa LX6 CPU cores. This dual-core setup allows for multitasking and parallel processing, making the ESP32 capable of handling more complex tasks efficiently. Wireless Connectivity: The ESP32 comes with built-in Wi-Fi and Bluetooth connectivity, making it suitable for a wide range of IoT applications. It supports various Wi-Fi protocols, including 802.11 b/g/n, and Bluetooth standards like Bluetooth Low Energy (BLE) and Classic Bluetooth, enabling seamless communication with other devices and networks. Rich Peripheral Set: The ESP32 offers a rich set of peripheral interfaces, including GPIO pins, SPI, I2C, UART, ADC, DAC, and more. These interfaces allow the ESP32 to interface with sensors, actuators, displays, and other external devices, making it highly versatile for a wide range of projects. Low Power Consumption: Despite its powerful capabilities, the ESP32 is designed to be energy-efficient, with features such as sleep modes, deep sleep, and power management optimizations. This makes it suitable for battery-powered and energy-conscious applications, extending the device's battery life.

Figure 3.12: ESP32 Microcontroller [6]

The ESP32 includes hardware-accelerated encryption and secure boot features to ensure the security of data and communications in IoT applications. It also supports secure connections over Wi-Fi and Bluetooth, helping protect against unauthorized access and data breaches. Development Ecosystem: Espressif provides a comprehensive development ecosystem for the ESP32, including an official development framework called ESP-IDF (Espressif IoT Development Framework), which offers libraries, tools, and documentation for building firmware and applications. Additionally, the ESP32 is supported by the Arduino IDE and other popular development platforms, making it accessible to a wide community of developers.

The ESP32 is a powerful microcontroller module widely used in IoT (Internet of Things) applications due to its versatility and integrated Wi-Fi and Bluetooth connectivity. Its working involves a dual-core Tensilica Xtensa LX6 microprocessor, which runs at up to 240 MHz, providing ample processing power for various tasks. Equipped with a rich set of peripherals, including GPIO (General Purpose Input/Output) pins, SPI (Serial Peripheral Interface), I2C (Inter-Integrated Circuit), UART (Universal Asynchronous Receiver-Transmitter), and more, the ESP32 can interface with a wide range of sensors, actuators, and external devices. Additionally, its integrated Wi-Fi and Bluetooth capabilities enable seamless connectivity to networks and other devices, making it suitable for applications such as home automation, industrial monitoring, wearable technology, and more. With its robust hardware and extensive software support, the ESP32 offers a flexible and scalable platform for developing innovative IoT solutions.

Overall, the ESP32 microcontroller offers a powerful combination of performance, connectivity, and versatility, making it an ideal choice for a wide range of IoT, embedded systems, and wireless communication applications. Its rich feature set, low power consumption, and robust security make it a popular choice among hobbyists, engineers, and IoT enthusiasts alike.

3.4.11 Battery(3.7V X 3)

Lithium-ion (Li-ion) batteries are rechargeable energy storage devices widely used in portable electronics, electric vehicles, and energy storage systems. They operate based on the movement of lithium ions between the positive (cathode) and negative (anode) electrodes during charge and discharge cycles. The anode is typically made of graphite, while the cathode can be composed of various materials such as lithium cobalt oxide, lithium iron phosphate, or lithium manganese oxide. During charging, lithium ions move from the cathode to the anode, where they are stored in the graphite layers. During discharge, the ions migrate back to the cathode, generating electrical current that can power devices. Li-ion batteries offer high energy density, long cycle life, and low self-discharge rates compared to other battery chemistries, making them ideal for portable electronics and electric vehicles. However, they require careful management to prevent overcharging, overheating, and other safety issues associated with lithium-ion chemistry.

Figure 3.13: Li-ion Battery [4]

Lithium-ion batteries (Li-ion) are rechargeable energy storage devices commonly used in a wide range of electronic devices, including smartphones, laptops, electric vehicles, and portable electronics. The fundamental working principle of a lithium-ion battery involves the movement of lithium ions between the positive and negative electrodes during charge and discharge cycles. Typically, the positive electrode (cathode) of a lithium-ion battery is made of a lithium metal oxide compound, while the negative electrode (anode) is typically made of graphite.

During the charging process, lithium ions are extracted from the positive electrode and inserted into the layers of the graphite anode. This process is facilitated by the flow of electrons through the external circuit, providing electrical energy that drives the chemical reaction. Conversely, during discharge, the lithium ions migrate back to the positive electrode through the electrolyte, releasing energy in the form of electrical current that can power electronic devices or systems. The flow of lithium ions between the electrodes is reversible, allowing lithium-ion batteries to be recharged multiple times.

The electrolyte in lithium-ion batteries typically consists of a lithium salt dissolved in an organic solvent. This electrolyte facilitates the movement of lithium ions between the electrodes while preventing direct contact between the electrodes, which could lead to short circuits and battery failure. Additionally, lithium-ion batteries often incorporate a separator made of porous material to further enhance safety and prevent internal short circuits. Overall, the combination of these components enables lithium-ion batteries to deliver high energy density, long cycle life, and relatively low self-discharge rates, making them a popular choice for a wide range of portable and rechargeable electronic devices.

3.5 Software Development

3.5.1 Arduino IDE

The Arduino Integrated Development Environment (IDE) is a software platform used for programming Arduino boards. It provides a user-friendly interface for writing, compiling, and uploading code to Arduino microcontrollers. With the Arduino IDE, you can write code in the Arduino programming language, which is essentially a simplified version of C/C++, and upload it to your Arduino board via a USB connection. The IDE also includes a built-in serial monitor for debugging purposes, allowing you to send and receive data between your Arduino board and your computer. It's a versatile tool for hobbyists, students, and professionals alike, enabling them to easily create and prototype various electronic projects. The Arduino IDE offers several advantages and has a wide range of uses.

Figure 3.14: Arduino IDE

(a) User-Friendly Interface: The IDE provides a simple and intuitive interface, making it accessible to beginners and experienced users alike.

(b) Cross-Platform Compatibility: It is available for Windows, Mac OS X, and Linux, ensuring compatibility across different operating systems.

(c) Easy Code Compilation: The IDE streamlines the process of writing, compiling, and uploading code to Arduino boards, simplifying the development workflow.

(d) Vast Community Support: Arduino has a large and active community of users and developers who share projects, tutorials, and troubleshooting tips, providing valuable support for newcomers and experts alike.

(e) Extensive Library Support: The IDE comes with a vast collection of libraries that provide pre-written code for various sensors, actuators, and communication protocols, reducing the need to write code from scratch.

(f) Open-Source Platform: Arduino IDE is open-source software, allowing users to modify and customize it according to their needs. This fosters innovation and collaboration within the Arduino community.

(g) Support for Multiple Boards: The IDE supports a wide range of Arduino boards, including the popular Arduino Uno, Nano, Mega, and more, as well as compatible boards from other manufacturers.

(h) Integration with External Tools: It can be integrated with external tools and libraries, expanding its capabilities for advanced users and specific applications.

(i) Rapid Prototyping: Arduino IDE enables rapid prototyping of electronic projects, allowing users to quickly test and iterate on their ideas before moving to production.

Overall, the Arduino IDE is a powerful tool for hobbyists, educators, and professionals, offering an accessible platform for developing a wide range of electronic projects and prototypes.

3.5.2 Blynk 2.0

Figure 3.15: BLYNK [6]

Blynk 2.0 is a cloud-based platform that provides a simple and easy-to-use interface for building IoT applications. The platform allows users to create custom dashboards to control their hardware devices remotely. The dashboards can include widgets such as buttons, sliders, graphs, and gauges, which can be easily configured to control various aspects of the hardware devices.One of the key features of Blynk 2.0 is its support for a wide range of hardware platforms, including Arduino, Raspberry Pi, ESP32, ESP8266, and many others. This allows users to connect their hardware devices to the platform and control them remotely, regardless of the hardware platform they are using. Blynk 2.0 also supports a wide range of communication protocols, including Wi-Fi, Bluetooth, Ethernet, and cellular, which makes it possible to connect hardware devices to the internet and control them remotely.

Blynk 2.0 works by connecting hardware devices to the Blynk cloud server, which acts as a bridge between the hardware devices and the user's mobile phone or web application. The cloud server stores the user's project configuration, including the layout of the dashboard and the settings for each widget.When a user interacts with the dashboard on their mobile phone or web application, the Blynk app sends a command to the cloud server, which in turn sends the command to the hardware device. The hardware device then performs the requested action and sends a response back to the cloud server, which updates the dashboard in real-time.

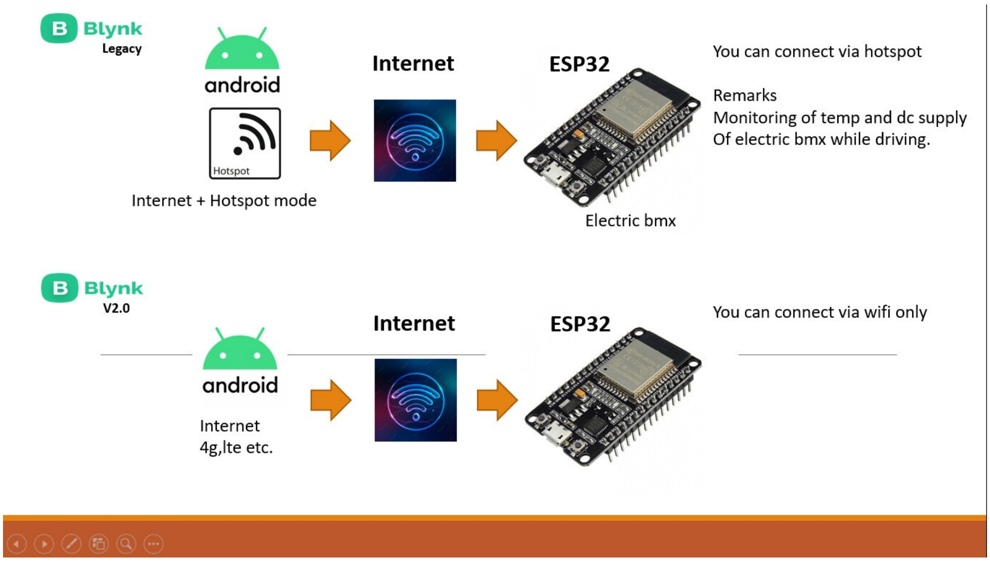

Figure 3.16: BLYNK 2.0 - ESP32 Interface [6]

Blynk 2.0 consists of several key components, including the Blynk cloud server, the Blynk mobile app, and the Blynk library. Let's take a closer look at each of these components:

(a) Blynk Cloud Server: The Blynk cloud server acts as the bridge between the hardware devices and the user's mobile phone or web application. The cloud server stores the user's project configuration, including the layout of the dashboard and the settings for each widget. The cloud server also handles communication between the mobile app and the hardware device.

(b) Blynk Mobile App: The Blynk mobile app is available for both iOS and Android devices and provides a simple and easy-to-use interface for controlling hardware devices remotely. The app allows users to create custom dashboards, add widgets, and configure the settings for each widget.

(c) Blynk Library: The Blynk library is a collection of code that allows users to connect their hardware devices to the Blynk cloud server. The library includes code for various hardware platforms, including Arduino, Raspberry Pi, ESP32, ESP8266, and many others. The library also includes code for various communication protocols, including Wi-Fi, Bluetooth, Ethernet, and cellular. Blynk 2.0 introduces several new features and improvements over the previous version.

(d) Custom Dashboards: Blynk 2.0 allows users to create custom dashboards to control their hardware devices remotely.

3.6 Summary

The Electric Vehicle Battery Management System (EV BMS) implemented using a microcontroller offers comprehensive control over the system, ensuring safe operation and minimizing the risk of accidents. By integrating various sensors, the BMS can monitor critical parameters such as voltage, current, temperature, and state of charge, allowing for proactive management of the battery system. These sensors provide real-time data feedback, enabling the BMS to adjust charging and discharging processes dynamically, thereby optimizing battery performance and longevity. With the ability to detect and respond to potential issues, the EV BMS enhances safety and reliability in electric vehicle operation, promoting confidence among users.

The incorporation of solar power into the EV charging system contributes to sustainable transportation practices by harnessing renewable energy sources. Solar panels can generate clean electricity to charge electric vehicles, reducing reliance on non-renewable energy sources and lowering carbon emissions associated with transportation. This eco-friendly approach aligns with global efforts to mitigate climate change and promote environmental sustainability, making the EV charging system more environmentally friendly and economically viable in the long run.

Furthermore, the integration of IoT technology into the EV charging system enhances accessibility and usability for users. By leveraging IoT capabilities, the charging system can operate in digital, semi-automated, and manual modes, providing flexibility to accommodate various user preferences and requirements. The utilization of a web application enables convenient monitoring of charging activities and historical data, empowering users to track usage patterns and make informed decisions. With its affordability, ease of use, and relevance to societal needs, the EV charging system represents a valuable contribution to the advancement of sustainable transportation solutions.

Chapter 4

RESULT AND DISCUSSIONS

4.1 Introduction

The safety and efficiency of electric vehicles have significantly improved as a result of the use of EV BMS with charge monitor and fire protection. The battery monitoring and cell balancing features, for starters, have made sure that the battery pack operates within safe parameters and that each cell is charged and discharged equally, preventing overcharging or undercharging of individual cells. As a result, the battery pack's performance and longevity have greatly increased, allowing the electric car to go farther between charges.

Second, the risk of thermal runaway and battery failure has been decreased thanks to the charge protection and discharge protection features, which have stopped the battery pack from being overcharged or depleted, respectively. By lowering the possibility of battery fires, this has also increased the safety of the electric car. Thirdly, the battery pack functions within a safe temperature range thanks to the temperature management mechanism, preventing overheating, which could harm the battery and shorten its lifespan. This feature also makes sure that the cooling system functions effectively, which lowers energy use and boosts the electric vehicle's efficiency.

4.2 Results

The ESP32-based EV charging station represents a sophisticated and user-friendly solution for electric vehicle owners. Designed with safety and efficiency in mind, the system incorporates various sensors, relays, and modules to ensure reliable charging and monitoring capabilities. One of the primary safety features is the RFID reader, which requires users to present an RFID tag before initiating the charging process. This authentication mechanism helps prevent unauthorized access to the charging station, enhancing overall safety and security.

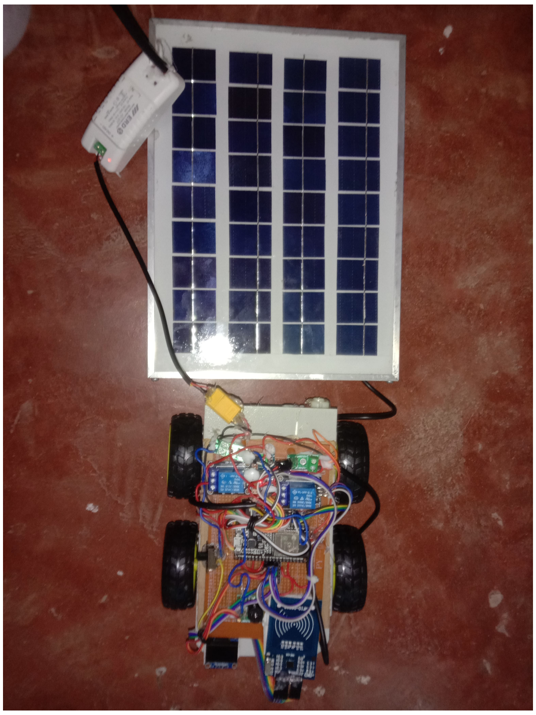

Figure 4.1: Prototype of the Project

The charging process primarily relies on a 12V solar panel, tapping into renewable energy sources for sustainable and eco-friendly operation. A voltage sensor is utilized to monitor the output voltage from the solar panel, ensuring it falls within the correct range for efficient charging. If the solar panel output is insufficient or unavailable, the system seamlessly switches to a 12V SMPS (Switched Mode Power Supply) to provide power for charging the electric vehicle's battery. This dual-mode operation ensures uninterrupted charging regardless of solar availability or conditions.

To further enhance safety and efficiency, the system employs voltage and current sensors to monitor the charging process. The voltage sensor allows for precise monitoring of the battery voltage, triggering a relay to cut off the charging supply once the battery reaches full capacity. Additionally, a relay is utilized to switch between the SMPS and solar panel based on availability and charging requirements, optimizing energy utilization and ensuring continuous operation. Furthermore, the inclusion of an MQ135 gas sensor enables the detection of gas leakages, adding an additional layer of safety to the charging station.

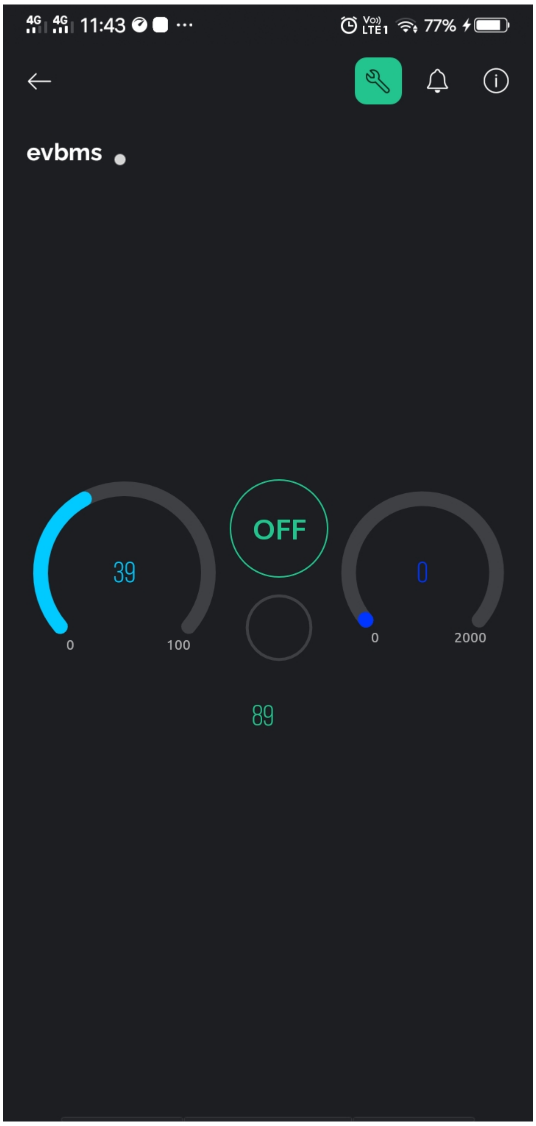

Figure 4.2: Interfacing BMS with Blynk on Smart Phone

To provide users with real-time information and control capabilities, the system features an OLED display for displaying relevant details such as charging status, voltage, current, and gas detection alerts. Moreover, the ESP32 board enables WiFi connectivity, allowing users to remotely monitor and manage the charging station via a Blynk app installed on their smartphone. This user-friendly interface empowers users to stay informed about their vehicle's charging status, ensuring a convenient and hassle-free experience while promoting sustainable transportation solutions.

4.3 Summary

The ESP32-based EV charging station integrates several safety and efficiency features to facilitate convenient and reliable charging of electric vehicles. Users initiate the charging process by presenting an RFID tag to the fixed RFID reader, ensuring only authorized individuals can access the station, thus enhancing safety. Charging primarily relies on a 12V solar panel, with a voltage sensor monitoring the panel's output. If the solar panel output falls within the correct range, solar energy is utilized for charging; otherwise, a 12V SMPS is engaged to provide power for battery charging, ensuring continuous operation regardless of solar availability.

Furthermore, the charging station incorporates additional safety measures, including voltage and current sensors to monitor the charging process. A relay is employed to cut off the supply if the battery voltage reaches full capacity, preventing overcharging and ensuring battery longevity. Another relay seamlessly switches between the SMPS and solar panel based on availability and charging requirements, optimizing energy utilization. Additionally, a MQ135 gas sensor is integrated to detect gas leakages, enhancing safety during the charging process. The OLED display provides users with real-time charging details, while the ESP32 board enables WiFi connectivity for remote monitoring and control via a Blynk app installed on the user's smartphone, offering a user-friendly experience and promoting sustainable transportation solutions.

The charge monitoring features empower users with valuable insights into battery status and performance. Real-time monitoring facilitates informed decision-making regarding charging parameters, while historical data analysis offers insights into long-term battery usage patterns, enabling users to optimize charging strategies and enhance efficiency. In terms of user experience, the EV BMS impresses with its intuitive interface and ease of operation. Users can access critical battery information, configure charging settings, and receive timely safety alerts, enhancing confidence and peace of mind during vehicle operation. Real-world testing confirms the BMS's robustness and reliability under diverse conditions, validating its suitability for widespread adoption in electric vehicles. Looking ahead, continuous refinement and innovation in EV BMS technology are essential for unlocking further advancements, including enhancing system intelligence, exploring novel fire protection methodologies, and optimizing cost-effectiveness. Overall, the EV BMS with charge monitor and fire protection represents a significant step forward in the evolution of electric mobility, offering a comprehensive solution to address the complex challenges of battery management and safety in electric vehicles.

EV charging using IoT System is really essential for basic electrical vehicles, utilization of Web application is helpful for monitoring clients previous activities easily. It tends to work in IoT computerized, semi- automated and manual mode.it is economically affordable and easy to use for the normal authority. So our project is a relevant product to the society.

Chapter 5

CONCLUSION AND FUTURE SCOPE

The development and implementation of an Electric Vehicle Battery Management System (EV BMS) with a charge monitor and fire protection features are crucial advancements in ensuring the safety, efficiency, and reliability of electric vehicles. This integrated system addresses several key aspects, including battery health monitoring, charging control, and fire prevention, contributing to the overall enhancement of electric vehicle performance and safety.The charge monitor functionality enables precise monitoring of the charging process, ensuring optimal charging conditions for the batteries. This not only prolongs battery life but also enhances overall efficiency by preventing overcharging and related issues. The real-time monitoring capabilities of the BMS provide valuable data for users and manufacturers to make informed decisions regarding the charging and discharging processes. The inclusion of fire protection features is a significant step toward mitigating potential safety hazards associated with electric vehicle batteries. The BMS incorporates sophisticated algorithms and sensors to detect early signs of overheating or other anomalies that could lead to a fire. The system can trigger immediate responses, such as shutting down the charging process, isolating the affected battery cells, or alerting the vehicle operator and emergency services. These measures are critical in ensuring the safety of both the vehicle and its occupants.

The transportation sector is one of the major contributors to carbon dioxide emissions and air pollution. The widespread adoption of the Electric Vehicles (EVs) is one of the promising solution to address the de-carbonize transportation sectors and environmental. This project is developed a system for management and control of a battery for charging and the utilization of a battery.The purpose of this project is to provide fast charging to electric vehicle. In the proposed EV charging System, introduction of mobile application will facilitate connectivity user's interaction. The Simulation tool helps on this charging process to simulate behavior an operating condition under different assumptions. The application of IoT approaches has a great potential, once we are able to store consumption and production data and the knowledge information created which can help both consumers and producers. Mobile devices and applications will help on the access to information.

The project ”EV BMS With Charge Monitoring And Fire Protection” holds immense potential for the future of sustainable transportation and energy management. As electric vehicles (EVs) continue to gain popularity worldwide, efficient Battery Management Systems (BMS) become increasingly crucial. This project not only offers advanced BMS capabilities but also integrates IoT technology for real-time monitoring and control, enhancing safety and performance.

With the global shift towards renewable energy, solar charging stations are becoming pivotal infrastructures for EV users. By incorporating IoT into these stations, the project enables seamless communication between the charging infrastructure, EVs, and the grid. This connectivity opens avenues for smart charging strategies, optimizing energy usage and reducing costs for both users and grid operators. Additionally, the integration of fire protection systems adds another layer of safety, mitigating risks associated with battery charging and storage.

Furthermore, the scalability of this project is promising for future expansion and integration into smart city initiatives. As urban areas strive for sustainability and resilience, the demand for EV infrastructure with advanced monitoring and control features will soar. This project lays the groundwork for interconnected networks of charging stations, forming a robust ecosystem that supports the widespread adoption of electric vehicles while minimizing environmental impact.

Moreover, the data collected through IoT-enabled monitoring holds significant potential for analytics and optimization. By analyzing charging patterns, energy consumption, and battery health, stakeholders can make informed decisions to improve efficiency and reliability. This data-driven approach not only benefits individual users but also contributes to the development of smarter, more adaptive energy systems on a broader scale. In essence, the future scope of this project extends beyond mere infrastructure; it encompasses a paradigm shift towards sustainable mobility and energy management driven by innovation and connectivity.

In conclusion, an essential part of electric vehicles that guarantees the security, dependability, and longevity of the battery pack is the EV BMS with charge monitor and fire prevention. By supplying crucial safety features like temperature control, fault detection, cell balancing, and fire prevention, the system lowers the possibility of battery fires and enhances the overall efficiency of electric vehicles. In order to improve the features and capabilities of EV BMS with charge monitor and fire prevention, more research and development is still possible. A few potential future work areas include enhancing the precision and dependability of battery monitoring systems to deliver more accurate and timely data regarding the charge, health, and function of the battery pack. The integration of a comprehensive Electric Vehicle Battery Management System (EV BMS) incorporating charge monitoring and fire protection mechanisms marks a significant advancement in electric vehicle technology. This integrated system offers a holistic approach to optimizing performance, ensuring safety, and enhancing user experience in electric vehicles.

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APPENDIX

- Program Code For the Project
- ESP32 Datasheet

Program

```
const int alarmPin = 2;
const int RELAY1 = 16;
const int RELAY2 = 17;
const int i1 = 27;
const int i2 = 26;
//const int i3 = 25;
//const int i4 = 33;
#include "ACS712.h"
ACS712  ACS(35, 3.3, 4095, 100);
#include <OneWire.h>
#include <DallasTemperature.h>
#define ONE_WIRE_BUS 32
OneWire oneWire(ONE_WIRE_BUS);
DallasTemperature sensors(&oneWire);

BlynkTimer timer;
#include <SPI.h>
#include <Wire.h>
#include <Adafruit_GFX.h>
#include <Adafruit_SSD1306.h>
#define SCREEN_WIDTH 128 // OLED display width, in pixels
#define SCREEN_HEIGHT 64 // OLED display height, in pixels
//define the pins used by the transceiver module
#define OLED_RESET     -1 // Reset pin # (or -1 if sharing Arduino reset pin)
#define SCREEN_ADDRESS 0x3C
Adafruit_SSD1306 display(SCREEN_WIDTH, SCREEN_HEIGHT, &Wire, OLED_RESET);

#include <SPI.h>
#include <MFRC522.h>
#define SS_PIN 5
#define RST_PIN 0

MFRC522 mfrc522(SS_PIN, RST_PIN);
//byte nuidPICC[4];
char expectedRFID[] = "063462af";

void setup() {

  Serial.begin(9600); // Initialize serial communication
  Blynk.begin(BLYNK_AUTH_TOKEN, ssid, pass);
  ACS.autoMidPoint();
    sensors.begin();

 pinMode(SOLARVOLTAGE, INPUT);
  pinMode(BATTERYVOLTAGE, INPUT);
  pinMode(RELAY1, OUTPUT);
   pinMode( RELAY2, OUTPUT);
    pinMode(alarmPin, OUTPUT);
    pinMode(i1, OUTPUT);
    pinMode(i2, OUTPUT);
   // pinMode(i3, OUTPUT);
   // pinMode(i4, OUTPUT);
     digitalWrite(RELAY1,HIGH); //battery
```

```
  digitalWrite(RELAY2,LOW);  //changeover
   digitalWrite(alarmPin, LOW);
  timer.setInterval(1000L, sendSensorData);
   if(!display.begin(SSD1306_SWITCHCAPVCC, SCREEN_ADDRESS)) {
    Serial.println(F("SSD1306 allocation failed"));
    for(;;); // Don't proceed, loop forever
      }
  display.clearDisplay();
  display.setTextColor(WHITE);
  display.setTextSize(2.5);
  display.setCursor(0,0);
  display.print("EVBMS      SCAN RFID");
  display.display();
 SPI.begin(); // Init SPI bus
    mfrc522.PCD_Init(); // Init MFRC522 card
    Serial.println("Scan a RFID tag");

}

void loop()
{
   Blynk.run();
  timer.run();
}
void sendSensorData() {
    // Look for new cards
    if ( ! mfrc522.PICC_IsNewCardPresent()) {
        return;
    }

    // Select one of the cards
    if ( ! mfrc522.PICC_ReadCardSerial()) {
        return;
    }

    // Convert scanned UID to a hexadecimal string
    String scannedUID = "";
    for (byte i = 0; i < mfrc522.uid.size; i++) {
        scannedUID += String(mfrc522.uid.uidByte[i] < 0x10 ? "0" : "");
        scannedUID += String(mfrc522.uid.uidByte[i], HEX);
    }

    // Print scanned UID
    Serial.print("Scanned RFID UID: ");
    Serial.println(scannedUID);

    // Compare scanned UID with expected UID
    while(strcmp(scannedUID.c_str(), expectedRFID) == 0) {
      delay(1000);
        display.clearDisplay();
 accessgranted=true;
  display.setCursor(0,0);
  display.print("ACCESS GRANTED ");

  display.display();
  delay(1000);
```

```
        Serial.println("Access granted");
        // Add your action for authorized access here
         int mA = ACS.mA_DC();
   if(mA>200)
   {
     mA-=200;
   }
   else
   {
     mA=0;
   }

 Serial.print(mA);
  Serial.println("mA");
  Blynk.virtualWrite(V1,mA);
  display.clearDisplay();

  display.setCursor(0,0);
  display.print("CHARGING CURRENT(mA):   ");
  display.print(mA);
  display.display();
  delay(1000);

   int BATTERY=analogRead(BATTERYVOLTAGE);

  float batteryv=BATTERY * (14 / 4095.0);
      if (batteryv>11.4)
{

  batteryv=11.4;
mA=0;
}
 voltpercentage=batteryv*100/11.4;
  Blynk.virtualWrite(V2, voltpercentage) ;
   display.clearDisplay();

  display.setCursor(0,0);
  display.print("BATTERY PERCENTAGE:   ");
  display.print(voltpercentage);
  display.display();

  Serial.print("Voltage: ");
  Serial.print(batteryv, 2); // Print with 2 decimal places
  Serial.println(" V");
  int SOLAR=analogRead(SOLARVOLTAGE);
  float solarv=SOLAR * (14 / 4095.0);
  if (solarv>12)
{
  digitalWrite(RELAY2,HIGH);

    display.clearDisplay();
  display.setCursor(0,0);
  display.print("CHARGING VIA SOLAR");
  display.display();
  delay(1000);
}
```

```
 Serial.print("Voltage: ");
Serial.print(solarv, 2); // Print with 2 decimal places
Serial.println(" V");
delay(1000);

  display.clearDisplay();
display.setCursor(0,0);
display.print("SOLAR Voltage: ");
display.print(solarv);
display.display();
delay(1000);
float sensorValue = analogRead(MQ135_PIN); // Read analog value from MQ135
smokevalue = map(sensorValue,0, 4095,  0, 100);

Serial.print("smoke value ");
Serial.println(smokevalue);
 display.clearDisplay();

display.setCursor(0,0);
display.print("SMOKE VALUE:      ");
display.print(smokevalue);
display.display();
   sensors.requestTemperatures();
   tempC = sensors.getTempCByIndex(0);

// Check if reading was successful
if(tempC != DEVICE_DISCONNECTED_C)
{
  Serial.print("Temperature : ");
  Serial.println(tempC);
}
else
{
  Serial.println("Error: Could not read temperature data");
}
  delay(1000);
  display.clearDisplay();
display.setCursor(0,0);
display.print("Temperature :          ");
display.print(tempC);
display.display();
Blynk.virtualWrite(V0,tempC);

 if (smokevalue>50 || tempC>40)
 { accessgranted=false;
  digitalWrite(i1,LOW);
digitalWrite(i2,LOW);
    digitalWrite(alarmPin, HIGH);
    Blynk.virtualWrite(V3,1);
delay(1000);
  Blynk.virtualWrite(V3,0);

 }
 else
 { accessgranted=true;
```

```
    digitalWrite(alarmPin, LOW);
    Blynk.virtualWrite(V3,0);
 }

}


    accessgranted=false;
        Serial.println("Access denied");


    delay(1000); // Delay before next scan

  }

BLYNK_WRITE(V4) { // Button widget V4
if(smokevalue<50 && tempC<40)
 {
  int state = param.asInt(); // Get state of button widget

  if(accessgranted)
  {
  if (state==1)
  {
    digitalWrite(i1,HIGH);
digitalWrite(i2,LOW);

  }

  else
  {
   digitalWrite(i1,LOW);
digitalWrite(i2,LOW);
  }
  }
 }
    else
  {
   digitalWrite(i1,LOW);
digitalWrite(i2,LOW);
  }
 }
```

ESP32 Series

Datasheet

2.4 GHz Wi-Fi + Bluetooth® + Bluetooth LE SoC

Including:

ESP32-D0WD-V3

ESP32-D0WDR2-V3

ESP32-U4WDH

ESP32-S0WD – Not Recommended for New Designs (NRND)

ESP32-D0WD – Not Recommended for New Designs (NRND)

ESP32-D0WDQ6 – Not Recommended for New Designs (NRND)

ESP32-D0WDQ6-V3 – Not Recommended for New Designs (NRND)

Version 4.5
Espressif Systems

Product Overview

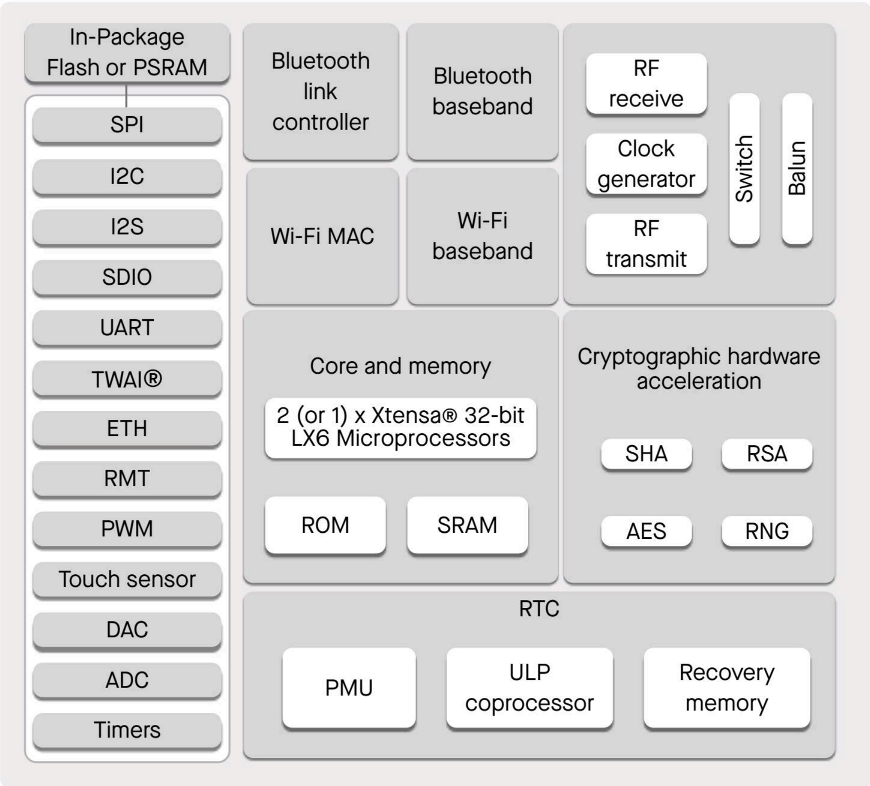
ESP32 is a single 2.4 GHz Wi-Fi-and-Bluetooth combo chip designed with the TSMC low-power 40 nm technology. It is designed to achieve the best power and RF performance, showing robustness, versatility and reliability in a wide variety of applications and power scenarios.

The ESP32 series of chips includes ESP32-D0WD-V3, ESP32-D0WDR2-V3, ESP32-U4WDH, ESP32-S0WD (NRND), ESP32-D0WDQ6-V3 (NRND), ESP32-D0WD (NRND), and ESP32-D0WDQ6 (NRND), among which,

- ESP32-S0WD (NRND), ESP32-D0WD (NRND), and ESP32-D0WDQ6 (NRND) are based on chip revision v1 or chip revision v1.1.
- ESP32-D0WD-V3, ESP32-D0WDR2-V3, ESP32-U4WDH, and ESP32-D0WDQ6-V3 (NRND) are based on chip revision v3.0 or chip revision v3.1.

For details on part numbers and ordering information, please refer to Section 1 ESP32 Series Comparison. For details on chip revisions, please refer to *ESP32 Chip Revision v3.0 User Guide* and *ESP32 Series SoC Errata*.

The functional block diagram of the SoC is shown below.



ESP32 Functional Block Diagram

Name	No.	Type	Function							
GPIO2	22	I/O	GPIO2,	ADC2_CH2,	RTC_GPIO12,	TOUCH2,		HSPIWP,	HS2_DATA0,	SD_DATA0
GPIO0	23	I/O	GPIO0,	ADC2_CH1,	RTC_GPIO11,	TOUCH1,	EMAC_TX_CLK,	CLK_OUT1,		
GPIO4	24	I/O	GPIO4,	ADC2_CH0,	RTC_GPIO10,	TOUCH0,	EMAC_TX_ER,	HSPIHD,	HS2_DATA1,	SD_DATA1
VDD_SDIO										
GPIO16	25	I/O	GPIO16,	HS1_DATA4,	U2RXD,	EMAC_CLK_OUT				
VDD_SDIO	26	P	Output power supply: 1.8 V or the same voltage as VDD3P3_RTC							
GPIO17	27	I/O	GPIO17,	HS1_DATA5,	U2TXD,	EMAC_CLK_OUT_180				
SD_DATA_2	28	I/O	GPIO9,	HS1_DATA2,	U1RXD,	SD_DATA2,	SPIHD			
SD_DATA_3	29	I/O	GPIO10,	HS1_DATA3,	U1TXD,	SD_DATA3,	SPIWP			
SD_CMD	30	I/O	GPIO11,	HS1_CMD,	U1RTS,	SD_CMD,	SPICS0			
SD_CLK	31	I/O	GPIO6,	HS1_CLK,	U1CTS,	SD_CLK,	SPICLK			
SD_DATA_0	32	I/O	GPIO7,	HS1_DATA0,	U2RTS,	SD_DATA0,	SPIQ			
SD_DATA_1	33	I/O	GPIO8,	HS1_DATA1,	U2CTS,	SD_DATA1,	SPID			
VDD3P3_CPU										
GPIO5	34	I/O	GPIO5,	HS1_DATA6,	VSPICS0,	EMAC_RX_CLK				
GPIO18	35	I/O	GPIO18,	HS1_DATA7,	VSPICLK					
GPIO23	36	I/O	GPIO23,	HS1_STROBE,	VSPID					
VDD3P3_CPU	37	P	Input power supply for CPU IO (1.8 V $\sim$ 3.6 V)							
GPIO19	38	I/O	GPIO19,	U0CTS,	VSPIQ,	EMAC_TXD0				
GPIO22	39	I/O	GPIO22,	U0RTS,	VSPIWP,	EMAC_TXD1				
U0RXD	40	I/O	GPIO3,	U0RXD,	CLK_OUT2					
U0TXD	41	I/O	GPIO1,	U0TXD,	CLK_OUT3,	EMAC_RXD2				
GPIO21	42	I/O	GPIO21,		VSPIHD,	EMAC_TX_EN				
Analog										
VDDA	43	P	Analog power supply (2.3 V $\sim$ 3.6 V)							
XTAL_N	44	O	External crystal output							
XTAL_P	45	I	External crystal input							
VDDA	46	P	Analog power supply (2.3 V $\sim$ 3.6 V)							
CAP2	47	I	Connects to a 3.3 nF (10%) capacitor and 20 kΩ resistor in parallel to CAP1							

Name	No.	Type	Function
CAP1	48	I	Connects to a 10 nF series capacitor to ground
GND	49	P	Ground

Regarding highlighted cells, see Section 2.2.1 Restrictions for GPIOs and RTC_GPIOs.

For a quick reference guide to using the IO_MUX, Ethernet MAC, and GPIO Matrix pins of ESP32, please refer to Appendix ESP32 Pin Lists.

2.2.1 Restrictions for GPIOs and RTC_GPIOs

All IO pins of the ESP32 have GPIO and some have RTC_GPIO pin functions. However, these IO pins are multifunctional and can be configured for different purposes based on the requirements. Some IOs have restrictions for usage. It is essential to consider their multiplexed nature and the limitations when using these IO pins.

In Table 2-1 Pin Overview some pin functions are highlighted, specically:

- GPIO – **Input only pins**, output is not supported due to lack of pull-up/pull-down resistors.
- GPIO – allocated for communication with in-package flash/PSRAM and NOT recommended for other uses. For details, see Section 2.5 Pin Mapping Between Chip and Flash/PSRAM.
- GPIO – have one of the following important functions:
  - **Strapping pins** – need to be at certain logic levels at startup. See Section 2.4 Strapping Pins.
  - **JTAG interface** – often used for debugging.
  - **UART interface** – often used for debugging.

See also Appendix A.1 – Notes on ESP32 Pin Lists.

Appendix A –ESP32 Pin Lists

A.1. Notes on ESP32 Pin Lists

Table 5-1. Notes on ESP32 Pin Lists

No.	Description
1	In Table IO_MUX, the boxes highlighted in yellow indicate the GPIO pins that are input-only. Please see the following note for further details.
2	GPIO pins 34-39 are input-only. These pins do not feature an output driver or internal pull-up/pull-down circuitry. The pin names are: SENSOR_VP (GPIO36), SENSOR_CAPP (GPIO37), SENSOR_CAPN (GPIO38), SENSOR_VN (GPIO39), VDET_1 (GPIO34), VDET_2 (GPIO35).
3	The pins are grouped into four power domains: VDDA (analog power supply), VDD3P3_RTC (RTC power supply), VDD3P3_CPU (power supply of digital IOs and CPU cores), VDD_SDIO (power supply of SDIO IOs). VDD_SDIO is the output of the internal SDIO-LDO. The voltage of SDIO-LDO can be configured at 1.8 V or be the same as that of VDD3P3_RTC. The strapping pin and eFuse bits determine the default voltage of the SDIO-LDO. Software can change the voltage of the SDIO-LDO by configuring register bits. For details, please see the column "Power Domain" in Table IO_MUX.
4	The functional pins in the VDD3P3_RTC domain are those with analog functions, including the 32 kHz crystal oscillator, ADC, DAC, and the capacitive touch sensor. Please see columns "Analog Function 0 ~ 2" in Table IO_MUX.
5	These VDD3P3_RTC pins support the RTC function, and can work during Deep-sleep. For example, an RTC-GPIO can be used for waking up the chip from Deep-sleep.
6	The GPIO pins support up to six digital functions, as shown in columns "Function 0 ~ 5" In Table IO_MUX. The function selection registers will be set as "*N*", where *N* is the function number. Below are some definitions: • SD_* is for signals of the SDIO slave. • HS1_* is for Port 1 signals of the SDIO host. • HS2_* is for Port 2 signals of the SDIO host. • MT* is for signals of the JTAG. • U0* is for signals of the UART0 module. • U1* is for signals of the UART1 module. • U2* is for signals of the UART2 module. • SPI* is for signals of the SPI01 module. • HSPI* is for signals of the SPI2 module. • VSPI* is for signals of the SPI3 module.

No.	Description
7	Each column about digital "Function" is accompanied by a column about "Type". Please see the following explanations for the meanings of "type" with respect to each "function" they are associated with. For each "Function-*N*", "type" signifies: • I: input only. If a function other than "Function-*N*" is assigned, the input signal of "Function-*N*" is still from this pin. • I1: input only. If a function other than "Function-*N*" is assigned, the input signal of "Function-*N*" is always "1". • I0: input only. If a function other than "Function-*N*" is assigned, the input signal of "Function-*N*" is always "0". • O: output only. • T: high-impedance. • I/O/T: combinations of input, output, and high-impedance according to the function signal. • I1/O/T: combinations of input, output, and high-impedance, according to the function signal. If a function is not selected, the input signal of the function is "1". For example, pin 30 can function as HS1_CMD or SD_CMD, where HS1_CMD is of an "I1/O/T" type. If pin 30 is selected as HS1_CMD, this pin's input and output are controlled by the SDIO host. If pin 30 is not selected as HS1_CMD, the input signal of the SDIO host is always "1".
8	Each digital output pin is associated with its configurable drive strength. Column "Drive Strength" in Table IO_MUX lists the default values. The drive strength of the digital output pins can be configured into one of the following four options: • 0: ~5 mA • 1: ~10 mA • 2: ~20 mA • 3: ~40 mA The default value is 2. The drive strength of the internal pull-up (wpu) and pull-down (wpd) is ~75 μA.
9	Column "At Reset" in Table IO_MUX lists the status of each pin during reset, including input-enable (ie=1), internal pull-up (wpu) and internal pull-down (wpd). During reset, all pins are output-disabled.
10	Column "After Reset" in Table IO_MUX lists the status of each pin immediately after reset, including input-enable (ie=1), internal pull-up (wpu) and internal pull-down (wpd). After reset, each pin is set to "Function 0". The output-enable is controlled by digital Function 0.
11	Table Ethernet_MAC is about the signal mapping inside Ethernet MAC. The Ethernet MAC supports MII and RMII interfaces, and supports both the internal PLL clock and the external clock source. For the MII interface, the Ethernet MAC is with/without the TX_ERR signal. MDC, MDIO, CRS and COL are slow signals, and can be mapped onto any GPIO pin through the GPIO-Matrix.
12	Table GPIO Matrix is for the GPIO-Matrix. The signals of the on-chip functional modules can be mapped onto any GPIO pin. Some signals can be mapped onto a pin by both IO-MUX and GPIO-Matrix, as shown in the column tagged as "Same input signal from IO_MUX core" in Table GPIO Matrix.

No.	Description
13	*In Table GPIO_Matrix, the column "Default Value if unassigned" records the default value of the an input signal if no GPIO is assigned to it. The actual value is determined by register GPIO_FUNC*m*_IN_INV_SEL and GPIO_FUNC*m*_IN_SEL. (The value of *m* ranges from 1 to 255.)

A.2. GPIO_Matrix

Table 5-2. GPIO_Matrix

Signal No.	Input Signals	Default Value If Unassigned*	Same Input Signal from IO_MUX Core	Output Signals	Output Enable of Output Signals
0	SPICLK_in	0	yes	SPICLK_out	SPICLK_oe
1	SPIQ_in	0	yes	SPIQ_out	SPIQ_oe
2	SPID_in	0	yes	SPID_out	SPID_oe
3	SPIHD_in	0	yes	SPIHD_out	SPIHD_oe
4	SPIWP_in	0	yes	SPIWP_out	SPIWP_oe
5	SPICS0_in	0	yes	SPICS0_out	SPICS0_oe
6	SPICS1_in	0	no	SPICS1_out	SPICS1_oe
7	SPICS2_in	0	no	SPICS2_out	SPICS2_oe
8	HSPICLK_in	0	yes	HSPICLK_out	HSPICLK_oe
9	HSPIQ_in	0	yes	HSPIQ_out	HSPIQ_oe
10	HSPID_in	0	yes	HSPID_out	HSPID_oe
11	HSPICS0_in	0	yes	HSPICS0_out	HSPICS0_oe
12	HSPIHD_in	0	yes	HSPIHD_out	HSPIHD_oe
13	HSPIWP_in	0	yes	HSPIWP_out	HSPIWP_oe
14	U0RXD_in	0	yes	U0TXD_out	1'd1
15	U0CTS_in	0	yes	U0RTS_out	1'd1
16	U0DSR_in	0	no	U0DTR_out	1'd1
17	U1RXD_in	0	yes	U1TXD_out	1'd1
18	U1CTS_in	0	yes	U1RTS_out	1'd1
23	I2S0O_BCK_in	0	no	I2S0O_BCK_out	1'd1
24	I2S1O_BCK_in	0	no	I2S1O_BCK_out	1'd1
25	I2S0O_WS_in	0	no	I2S0O_WS_out	1'd1
26	I2S1O_WS_in	0	no	I2S1O_WS_out	1'd1
27	I2S0I_BCK_in	0	no	I2S0I_BCK_out	1'd1
28	I2S0I_WS_in	0	no	I2S0I_WS_out	1'd1
29	I2CEXT0_SCL_in	1	no	I2CEXT0_SCL_out	1'd1
30	I2CEXT0_SDA_in	1	no	I2CEXT0_SDA_out	1'd1
31	pwm0_sync0_in	0	no	sdio_tohost_int_out	1'd1
32	pwm0_sync1_in	0	no	pwm0_out0a	1'd1
33	pwm0_sync2_in	0	no	pwm0_out0b	1'd1
34	pwm0_f0_in	0	no	pwm0_out1a	1'd1

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