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Low Cost Intelligent Battery Charging via Advanced Free Wheel Traction Energy with SOC Fault Management System

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ABSTRACT: The rapid advancement of electric vehicles (EVs) has increased the demand for reliable and intelligent battery management systems, particularly with the integration of emerging wireless charging technologies. One of the major challenges in current EV systems is maintaining battery safety, efficiency, and longevity under varying operating conditions. Inadequate monitoring can lead to issues such as overcharging, deep discharge, overheating, and unexpected failures, which compromise both performance and user safety. Additionally, existing systems often lack real-time communication features and fail to provide immediate alerts to drivers, increasing the risk of accidents or system damage. The integration of wireless charging further complicates battery management due to fluctuations in power transfer efficiency and environmental factors. To address these challenges, this system emphasizes continuous monitoring and protection of the EV battery through a smart and integrated approach. The proposed model combines a vehicle drive motor with a dynamo-based DC charging mechanism to enhance energy utilization and ensure efficient power conversion. Multiple sensors are deployed to track critical battery parameters such as voltage, temperature, and current, enabling real-time condition analysis and early fault detection. Furthermore, Bluetooth communication facilitates seamless data transmission to a PC interface, allowing users to monitor battery status remotely. The system also incorporates safety alerts, including vehicle ON/OFF notifications during incoming calls, thereby improving driver awareness and overall operational safety.

KEYWORDS: Low-cost battery charging, intelligent charging system, freewheel traction energy recovery, state of charge (SOC) management, fault detection system, energy efficiency optimization, smart battery management system

I. INTRODUCTION

The transportation of temperature-sensitive pharmaceutical products such as vaccines, insulin, blood samples, and biological medicines requires strict environmental control to maintain their effectiveness and safety. Many medicines must be stored within a specific temperature range, typically between 2°C and 8°C, to prevent degradation. Any deviation during transportation may result in reduced potency, financial loss, and serious health risks. Maintaining an uninterrupted cold chain during transit is therefore a critical requirement in modern healthcare logistics.

Traditional medicine transportation systems rely on passive cooling methods such as ice packs and insulated containers. However, these systems lack real-time monitoring, automated temperature regulation, and secure delivery verification mechanisms. In many cases, temperature excursions go undetected until delivery, compromising the quality of the medicine. Additionally, conventional delivery systems do not provide authentication-based access control, increasing the risk of tampering or unauthorized access.

To address these challenges, this paper proposes a Smart Medicine Monitoring and Secure Transportation System that integrates environmental sensing, active cooling, real-time location tracking, communication, and electronic access control. A DHT11 sensor is used to continuously monitor temperature and humidity inside the container. When the temperature exceeds the predefined threshold, a Peltier-based thermoelectric cooling module is automatically activated to maintain safe storage conditions. A GPS module provides continuous location tracking, while a GSM module enables SMS-based communication for alerts and delivery confirmation.

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The system includes start and end control switches to define the transportation cycle. Upon reaching the destination, an automated SMS notification is sent to the customer. The electronic lock mechanism is released only after receiving authorized confirmation, such as a one-time password (OTP), ensuring secure and authenticated delivery. Additionally, real-time data is updated to an IoT platform and displayed locally on an LCD for monitoring purposes. The proposed system enhances cold chain reliability, improves security, and provides real-time visibility throughout the transportation process. By combining monitoring, automation, and authentication mechanisms, the system offers a comprehensive solution for safe pharmaceutical logistics.

OBJECTIVES

The rapid advancement of electric vehicle technology has emerged as a significant step toward achieving sustainable and environmentally friendly transportation systems. With increasing concerns over fossil fuel depletion, air pollution, and climate change, electric vehicles have gained widespread attention as an alternative to conventional internal combustion engine vehicles. However, despite their advantages, electric vehicles face several technical challenges, among which battery management is one of the most critical. The performance, safety, and lifespan of an electric vehicle largely depend on the efficiency and reliability of its battery system. Improper battery handling can lead to severe issues such as overheating, overcharging, deep discharge, and even thermal runaway, which may cause system failure or hazardous situations. These challenges become even more complex with the integration of advanced technologies such as wireless charging, where maintaining consistent power transfer and monitoring battery conditions becomes more difficult. In conventional electric vehicle systems, battery monitoring is often limited and lacks real-time analysis, which reduces the ability to detect faults at an early stage. Additionally, traditional charging methods rely on physical connections, which are prone to mechanical wear, safety risks, and user inconvenience. Wireless charging technology offers a promising solution by eliminating the need for cables and enabling seamless energy transfer. However, it introduces new challenges such as variations in charging efficiency, alignment issues, and environmental influences. Therefore, there is a growing need for an intelligent and adaptive battery management system that can operate efficiently under these conditions while ensuring safety and reliability. The proposed system addresses these challenges by introducing a smart battery management approach that integrates continuous monitoring, efficient energy utilization, and real-time communication. The system combines a vehicle drive motor with a dynamo-based DC charging mechanism, which allows partial energy recovery during operation and improves overall efficiency. Multiple sensors are employed to monitor critical battery parameters such as voltage, current, and temperature, enabling accurate condition assessment and early fault detection. The system also incorporates Bluetooth communication to transmit data to a PC interface, allowing users to monitor battery performance remotely. Additionally, safety features such as vehicle ON/OFF alerts during incoming calls enhance driver awareness and reduce distractions. This project aims to develop a reliable, cost-effective, and scalable solution that improves battery performance, enhances safety, and supports the advancement of electric vehicle technology.

II. LITERATURE SURVEY

2.1 Narawit Pahaisuk. (2025) " Intelligent Battery Management System for Electric Vehicles Using GRU and K-Means Clustering "

Narawit Pahaisuk proposed an advanced Intelligent Battery Management System (BMS) for electric vehicles that integrates deep learning and clustering algorithms to enhance battery monitoring accuracy and predictive fault detection. The study identifies that conventional BMS architectures rely primarily on rule-based estimation techniques and fixed threshold comparisons, which are insufficient for handling nonlinear battery dynamics and time-dependent degradation patterns.

2.2 Jinwen Li (2025) " Battery Fault Detection and Early Warning for Electric Vehicles"

Jinwen Li presented a comprehensive battery fault detection and early warning system designed to address safety risks and performance degradation in electric vehicle battery packs. The research emphasizes that battery failures often develop gradually due to cell imbalance, internal resistance variation, thermal inconsistencies, and abnormal current fluctuations, which are difficult to detect at early stages using traditional threshold-based monitoring systems.

2.3 Vyshnav V. R. (2025)
"Smart IoT-Integrated Battery Management System with SOC, SOH, and SOP Monitoring"

Vyshnav V. R. proposed a Smart IoT-Integrated Battery Management System (BMS) that enhances electric vehicle battery intelligence through continuous monitoring of State of Charge (SOC), State of Health (SOH), and State of Power (SOP), addressing the growing demand for real-time connectivity and predictive maintenance in modern EV ecosystems. The study recognizes that conventional battery monitoring systems operate locally with limited analytical

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capability and lack remote accessibility, making it difficult to track long-term battery degradation trends or implement data-driven maintenance strategies.

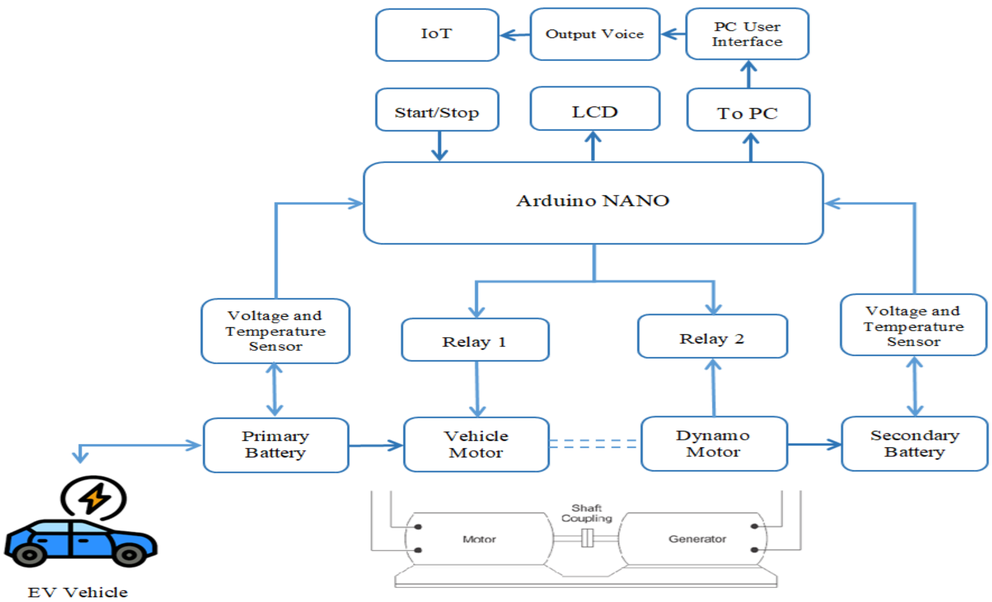
2.4 Kolla Ramya Sree (2025)

"Thermal Management System for Electric Vehicle Batteries"Kolla Ramya Sree presented an advanced Thermal Management System (TMS) for electric vehicle batteries aimed at addressing the critical challenge of temperature instability in lithium-ion battery packs. The study highlights that temperature is one of the most influential factors affecting battery performance, lifespan, and safety, particularly during high-speed driving, rapid acceleration, and fast-charging operations. Excessive heat generation can accelerate electrochemical degradation, reduce capacity retention, and in extreme cases trigger thermal runaway, leading to severe safety hazards.

2.6 Existing system

In the current electric vehicle ecosystem, battery management systems are implemented with basic monitoring and control functionalities, primarily focusing on maintaining voltage and current limits during charging and discharging operations. Most conventional systems rely on wired charging methods, where physical connectors are used to transfer power from the charging station to the vehicle battery. Although these systems are widely used, they present several limitations in terms of efficiency, safety, and user convenience. The battery monitoring process in many existing systems is either limited or not continuously updated, which reduces the ability to detect faults such as overheating, overcharging, or deep discharge in real time. As a result, the battery may operate under unsafe conditions, leading to reduced lifespan and potential system failures.Existing battery management systems often lack advanced communication capabilities, which means that users cannot remotely monitor battery status or receive immediate alerts regarding system performance. In many cases, the driver becomes aware of battery issues only after noticeable degradation or failure occurs. Furthermore, traditional systems do not efficiently utilize energy during vehicle operation, as there is no mechanism for recovering or supplementing battery charge while the vehicle is in motion. This leads to increased dependency on external charging infrastructure and reduces overall energy efficiency.With the introduction of wireless charging technology, additional challenges arise in the existing systems. Wireless charging requires precise alignment and stable power transfer, but most conventional battery systems are not designed to adapt to these variations. This can result in inconsistent charging performance and energy loss. Moreover, the absence of intelligent monitoring and adaptive control mechanisms makes it difficult to maintain optimal charging conditions. Safety is another major concern, as current systems do not provide integrated alerts or driver assistance features to prevent distractions or hazardous situations. Overall, the existing systems are limited in their ability to provide efficient energy management, real-time monitoring, and enhanced safety, highlighting the need for an improved and intelligent solution.

III. PROPOSED BLOCK DIAGRAM



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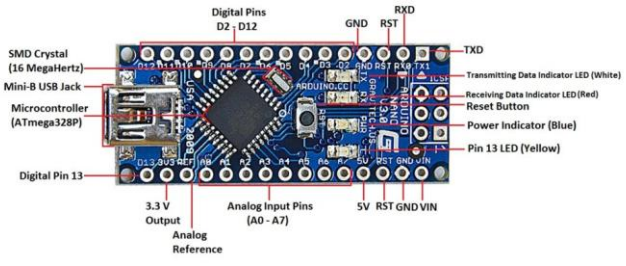
IV. HARDWARE DESCRIPTION

4.1) Arduino Uno (ATmega328P)

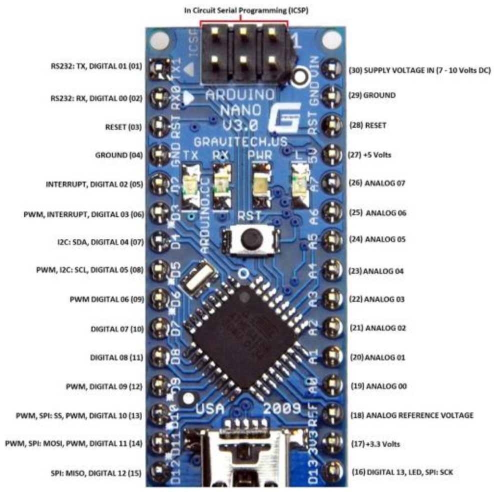
Arduino Nano has similar functionalities as Arduino Demilune but with a different package. The Nano is inbuilt with the ATmega328P microcontroller, same as the Arduino UNO. The main difference between them is that the UNO board is presented in PDIP (Plastic Dual-In-line Package) form with 30 pins and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



Arduino Nano V3.0 Pinout

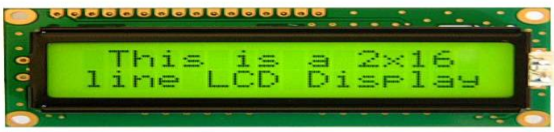
www.CircuitsToday.com

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



Arduino Nano V3 - Pin Description

Lcd (Liquid Crystal Display)



LCD Display

BUZZER

beeps, or modulated sounds, depending on the circuit design and the intended application. A buzzer is a widely used audio signalling device that emits sound when activated. It is commonly found in various electronic circuits and systems where audible alerts or notifications are necessary. Buzzers operate by converting electrical energy into sound energy, often through mechanisms involving piezoelectric effects or electromechanical vibration. The device is simple in construction but serves a crucial role in alerting users to specific events, warnings, or operational statuses in both consumer and industrial electronics. Buzzers can emit continuous tones, intermittent

V. CONCLUSION

In conclusion, the proposed electric vehicle battery management system with integrated wireless charging support represents a significant advancement in modern EV technology, focusing on safety, efficiency, and intelligent energy management. The system successfully addresses the critical challenges associated with conventional battery systems, such as lack of real-time monitoring, inefficient energy utilization, and limited safety mechanisms. By incorporating a dynamo-based DC charging mechanism along with the vehicle drive motor, the system enhances energy efficiency by enabling partial energy recovery during operation, thereby reducing dependence on external charging sources. The integration of multiple sensors for monitoring voltage, current, and temperature ensures continuous assessment of battery conditions, allowing early detection of faults and preventing potential damage.

Furthermore, the implementation of Bluetooth communication enables real-time data transmission to a PC interface, providing users with remote monitoring capabilities and improved system awareness. The inclusion of intelligent safety features, such as vehicle ON/OFF alerts during incoming calls, enhances driver safety by reducing distractions and improving operational control. The system's ability to adapt to wireless charging conditions ensures stable and efficient power transfer, overcoming the limitations of traditional charging methods. Overall, the proposed system demonstrates a reliable, cost-effective, and scalable solution that improves battery lifespan, enhances safety, and supports the growing demand for efficient electric vehicle technologies. This project contributes to the advancement of smart and sustainable transportation systems, paving the way for future innovations in electric mobility.

VI. FUTURE SCOPE

- Integration of advanced wireless charging technologies with improved alignment and higher efficiency to ensure consistent power transfer under varying conditions.
- Implementation of artificial intelligence and machine learning algorithms for predictive battery health analysis and early fault diagnosis.
- Development of a cloud-based monitoring system to enable real-time data access, storage, and large-scale analytics for multiple vehicles.
- Incorporation of GPS and IoT connectivity for vehicle tracking, smart navigation, and integration with intelligent transportation systems.
- Enhancement of safety features by adding automated emergency response systems and advanced driver assistance alerts.
- Use of high-efficiency energy storage technologies such as solid-state batteries to improve performance and lifespan.
- Integration of renewable energy sources such as solar-assisted charging systems to further reduce dependency on grid power.
- Development of a mobile application interface for user-friendly monitoring and control of battery parameters.
- Implementation of advanced thermal management systems to improve battery stability under extreme environmental conditions.
- Collaboration with automotive industries and research organizations to enhance system scalability and adopt next-generation EV technologies.

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