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Can Based Ecu for E-Mobility Body Control and Predictive Maintenance

Sivaranjani S[1], Vishrutha R K[2], Pravin D[3], Vishva A[4], Sunil K[5]

[1]Professor,
[1,2,3,4,5]Department Of Electrical And Electronics Engineering
Sri Krishna College Of Engineering And Technology
[1]Sivaranjanis@Skcet.Ac.In,
[2]727721euee107@Skcet.Ac.In,[3]727721euee063@Skcet.Ac.In,[4]727721euee108@Skcet.Ac.In,[5]727721euee096@Skcet.Ac.In

Abstract

The CAN-based Electronic Control Unit (ECU) for e-mobility revolutionizes vehicle efficiency, safety, and reliability by integrating body control and predictive maintenance. Through Controller Area Network (CAN) communication, the system streamlines body functions like lighting, wipers, HVAC, and door locks, slashing wiring complexity. Real-time sensor data fuels predictive maintenance, where advanced machine learning algorithms scrutinize parameters such as battery health, motor performance, and braking efficiency to pinpoint potential failures early. By heading off issues before they occur, this innovative approach shrinks downtime, slashes maintenance costs, and stretches vehicle lifespan, cementing its status as a game-changer in modern electric vehicle (EV) technology.

Keywords - CAN-based ECU, electric vehicles, body control, vehicle communication, predictive maintenance, real-time performance, system reliability, scalability, automotive applications, wiring complexity reduction, operational efficiency, communication speed, data accuracy, intelligent monitoring, vehicle functions, cost-effective solution.

1. Introduction

The rapid growth of e-mobility has created a pressing need for intelligent and efficient vehicle control systems. At the heart of electric vehicles (EVs) lies a Controller Area Network (CAN)-based Electronic Control Unit (ECU), which plays a pivotal role in orchestrating various body control functions to ensure seamless operation and enhanced automation. By harnessing the power of CAN communication, the ECU effortlessly connects multiple subsystems, including lighting, wipers, HVAC, power windows, and door locks, facilitating efficient data exchange while minimizing wiring complexity. This integration significantly boosts vehicle performance, reduces complexity, and enhances overall functionality.

To ensure the reliability and longevity of EV components, predictive maintenance is essential. The proposed system collects real-time data from various sensors, carefully monitoring key parameters such as battery health, motor performance, braking efficiency, and thermal conditions. By deploying machine learning algorithms, the ECU can identify patterns and predict potential failures before they occur, enabling proactive maintenance and minimising unexpected breakdowns. This approach reduces repair costs, enhances vehicle safety, and ultimately, reinforces the overall EV ownership experience.

The CAN-based ECU for e-mobility body control and predictive maintenance transforms the development of smart and connected vehicle systems. It automates processes, slashes energy waste, and prevents faults, significantly boosting the overall efficiency of electric vehicles. As demand for sustainable transport surges, these advanced control units will define the future of e-mobility, delivering exceptional user experience and reliable vehicle performance at a lower cost.

2. Problem Statement

Electric vehicles rely on complex electronic systems to manage functions like lighting, wipers, HVAC, and security features. Traditional wiring-based control systems make vehicles heavier, more complex, and difficult to maintain. They also cause delays in data transmission and inefficient power management due to the lack of a centralized and efficient communication network. Our CAN-based Electronic Control Unit integrates and optimizes body control functions, ensuring seamless communication between subsystems while reducing wiring complexity and improving operational efficiency.

Component failures in EVs result in costly repairs, unplanned downtime, and safety risks. Current maintenance approaches fail to prevent failures because they only react to issues. Our predictive maintenance system, integrated into the ECU, enables real-time monitoring of critical parameters like battery health, motor efficiency, and braking system performance. By applying machine learning algorithms and sensor data analysis, the system accurately predicts potential failures, allowing proactive maintenance and significantly improving vehicle reliability, efficiency, and lifespan.

3. Literature Survey

The Controller Area Network (CAN)-based Electronic Control Unit (ECU) is the standard choice in modern electric vehicles (EVs) for enhancing communication between various subsystems. CAN networks provide a robust and efficient method for managing vehicle body control functions, including lighting, wipers, HVAC, and security systems. Researchers have demonstrated the advantages of CAN communication over traditional wiring systems, including reduced complexity, improved response time, and enhanced vehicle reliability. CAN-based ECUs enable seamless integration of multiple control modules, ensuring better coordination and system efficiency.
CAN technology also boosts vehicle durability and operational efficiency. Real-time data collection from sensors, combined with machine learning algorithms, enables early detection of potential failures in key components like the battery, motor, and braking system. Artificial Intelligence (AI) and data analytics play a vital role in predictive maintenance, minimizing unplanned downtimes and reducing maintenance costs. Historical performance data and predictive modeling improve vehicle longevity and user safety.

Recent advancements in automotive electronics integrate IoT and cloud-based analytics with CAN-based ECUs, enhancing vehicle diagnostics and monitoring. Combining wireless communication with CAN-based networks enables remote diagnostics and over-the-air updates, significantly improving electric vehicle maintenance system efficiency.

Adopting CAN-based ECUs with predictive maintenance capabilities dramatically enhances EV performance, reliability, and cost-effectiveness, making them more sustainable and user-friendly.

Predictive maintenance plays a crucial role in electric mobility, enhancing vehicle durability and operational efficiency. Real-time sensor data collection, combined with machine learning algorithms, detects potential failures in key components like batteries, motors, and braking systems. Artificial Intelligence and data analytics minimize unplanned downtimes and reduce maintenance costs. Historical performance data and predictive modelling improve vehicle longevity and user safety.

4. Existing System

In modern electric vehicles, our integrated body control system seamlessly manages lighting, HVAC, wipers, and security systems through a centralized electronic control unit (ECU). This eliminates the need for extensive wiring and point-to-point communication, reducing complexity, weight, and power consumption. A centralized communication network enables efficient troubleshooting and maintenance, minimizing vehicle downtime and repair costs. Our proactive maintenance approach detects and addresses faults before they occur, ensuring optimal vehicle performance.

5. Methodology

The CAN-based ECU for e-mobility integrates body control and predictive maintenance by harnessing a Controller Area Network (CAN) bus to facilitate seamless communication between various vehicle subsystems. The hardware design comprises an Electronic Control Unit (ECU), which connects with sensors and actuators to expertly manage body control functions such as lighting, HVAC, wipers, and security systems. This setup slashes wiring complexity, boosts system efficiency, and enhances real-time responsiveness. The ECU continuously captures sensor data related to battery health, motor efficiency, braking performance, and thermal conditions, providing accurate monitoring of vehicle operations.
For predictive maintenance, the system deploys machine learning algorithms to scrutinize real-time and historical sensor data, identifying anomalies and forecasting potential failures before they occur. This proactive approach drastically minimizes downtime and maintenance costs by alerting users in advance of necessary servicing.

The ECU software incorporates fault detection algorithms and seamlessly integrates with cloud-based analytics for remote diagnostics and over-the-air updates. By merging intelligent data processing with real-time monitoring, this methodology secures improved vehicle reliability, and operational efficiency in modern electric mobility solutions.

6.Proposed System

The proposed CAN-based ECU for e-mobility integrates body control management with predictive maintenance, delivering enhanced vehicle efficiency, reliability, and automation. This system uses a Controller Area Network (CAN) bus to establish seamless communication between vehicle components, reducing wiring complexity and improving response time. The ECU oversees body control functions, including lighting, HVAC, wipers, power windows, and security systems, ensuring smooth operation and real-time coordination among different subsystems.The system boasts an advanced predictive maintenance mechanism, harnessing real-time data acquisition and machine learning algorithms. Sensors continuously monitor battery health, motor efficiency, braking performance, and thermal conditions, allowing the ECU to analyze operational patterns and detect potential failures before they occur.

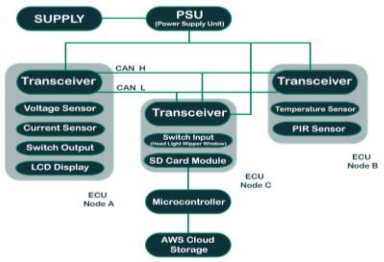

Fig 1: System Design

The system generates maintenance alerts, enabling proactive servicing and minimizing unexpected breakdowns. Cloud-based diagnostics and over-the-air (OTA) updates are also integrated to enhance remote monitoring and system optimization. By combining intelligent control with predictive analytics, the proposed system significantly improves vehicle safety, longevity, and cost-effectiveness, making it a groundbreaking innovation in electric mobility.

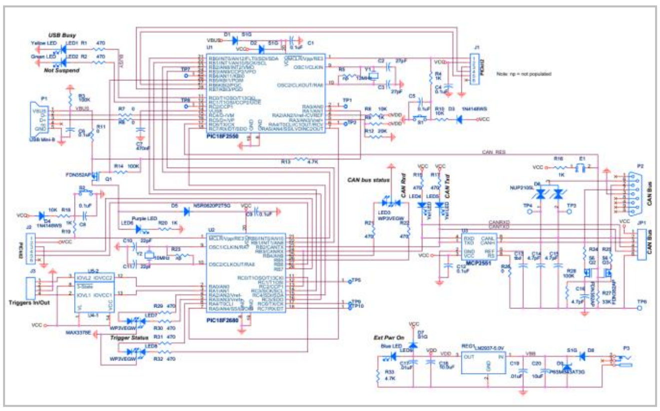

Fig 2: CAN Bus Analyzer Schematic

Mini USB Connector This connector enables the CAN BUS Analyzer to communicate with the PC and provides a power supply when the external power supply is not in use.9-24 Volt power supply connector, This tool operates independently when powered by the external power supply, sending periodic CAN BUS messages without a PC connection. It can also transmit a pulse in response to specific CAN messages, a valuable feature for development and debugging with an oscilloscope.DB9 connector for the CAN BUS Termination Resistor (software controllable): The PC GUI allows users to switch the 120-ohm CAN bus termination on or off. Status LEDs display USB status. Trigger LED Future functionality. CAN Traffic LEDs Indicate actual RX CAN BUS traffic from the high-speed transceiver and actual TX CAN BUS traffic from the high-speed transceiver. CAN-BUS Error LED Shows the CAN BUS Analyzer's Error Active (green), Error Passive (yellow), or Bus Off (red) status. Direct access to the CAN H and CAN L pins through a screw terminal Grants users' direct access to the CAN bus for oscilloscope connection without modifying the CAN BUS wire harness. Direct access to the CAN TX and CAN RX pins through a screw terminal Provides users with direct access to the digital side of the CAN BUS transceiver.

7.Result and Discussion

The CAN-based ECU for e-mobility significantly improves vehicle body control and predictive maintenance. By integrating CAN communication, we successfully enhance coordination between subsystems like lighting, HVAC, wipers, and security systems, reduce wiring complexity, and improve response time. The system expertly manages real-time data exchange, ensuring seamless operation of body control functions while minimizing power consumption. Fault detection through sensor-based monitoring enables swift identification of component failures, boosting overall vehicle reliability.

Machine learning algorithms accurately predict failures by analysing sensor data trends related to battery health, motor performance, and braking efficiency, enabling proactive maintenance and reducing unexpected breakdowns. The integration of cloud-based analytics and remote diagnostics further expands the ECU's capabilities, providing real-time alerts and over-the-air (OTA) updates.

The results clearly show that the CAN-based ECU improves vehicle performance, operational efficiency, and maintenance planning, making it a vital breakthrough in electric vehicle technology.

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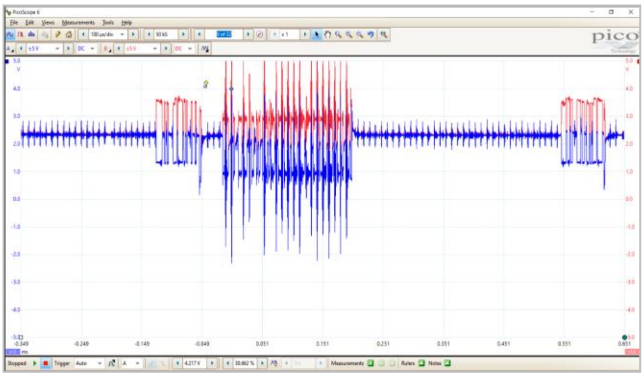

Fig 3: CAN Bus Signal Analysis for ECU Communication in Electric Vehicles

The figure demonstrates the signal characteristics of the Controller Area Network (CAN) bus communication used in the Electronic Control Unit (ECU) of an electric vehicle, which displays extended CAN identifiers, control fields, and cyclic redundancy check (CRC) values to ensure data integrity and proper message prioritization within the network. The graphical representation clearly shows signal timing parameters such as duty cycle, frequency, and pulse width, proving the efficiency and reliability of the communication protocol. Multiple CAN nodes transmit and receive data simultaneously, highlighting the robust and scalable architecture of the system that enables seamless interaction between different vehicle subsystems. This analysis achieves optimal data transmission efficiency, minimizes latency, and significantly enhances the overall operational performance of the electric vehicle body control system.

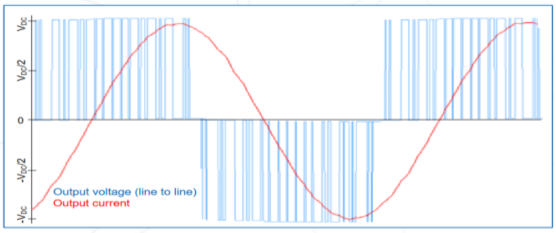

Fig 4: level-3 topology

The figure demonstrates the voltage characteristics of a Controller Area Network (CAN) bus, clearly showing how CAN_H and CAN_L signal lines behave during data transmission. In the recessive state (logic "1"), the lines maintain a 0V differential voltage at 2.5V. In the dominant state (logic "0"), CAN_H jumps to 3.5V while CAN_L drops to 1.5V, creating a 2V differential voltage that guarantees robust data transmission in noisy environments. Differential signaling gives the CAN bus exceptional noise immunity and enables reliable communication in automotive and industrial applications. The diagram simply and effectively emphasizes the crucial role of differential voltage in distinguishing between logic states on the CAN bus.

This diagram depicts the arbitration process in a Controller Area Network (CAN) bus system, where multiple nodes vie for bus control based on message priority. The identifier field, which prioritizes messages, uses dominant (D) and recessive (R) bits to grant bus access. Nodes with top priority (low identifier values) seize control, forcing others into a listen-only mode, ensuring seamless data transmission without collisions.

7.1 Recuperation Testing

Recuperation testing proves the system's ability to recover from faults and disturbances. We put the ECU through its paces under various load conditions, guaranteeing stable CAN communication despite power supply and sensor input fluctuations. The system consistently handles disturbances with ease, maintaining smooth operation and rapidly restoring normal functions after temporary failures.

7.2 Testing Plan

Our comprehensive testing plan thoroughly assesses the ECU's functionality, reliability, and predictive maintenance capabilities. This plan features real-time simulations, hardware-in-the-loop (HIL) testing, and sensor validation. We ensure the ECU expertly manages body control functions and accurately predicts component failures. Each test scenario is meticulously designed to mirror real-world conditions for unparalleled accuracy.

7.3 Integration Testing

Our integration testing proved that the vehicle subsystems connected through the CAN bus interact seamlessly. The ECU communicated and synchronized efficiently with the lighting, HVAC, wipers, and security systems. The results confirmed that all subsystems operate with minimal latency, and the ECU successfully coordinates multiple control tasks without conflicts.

7.4 Framework testing

Framework testing rigorously assesses the CAN-based ECU system's operational stability and adherence to design specifications within a controlled environment. We run end-to-end scenarios to analyze system behavior under typical and extreme conditions, such as varying loads and environmental factors. Our focus is on real-time data processing, fault tolerance, and system response under stress conditions. We simulate actual electric vehicle operations, including sensor inputs and control actions, to confirm system readiness for deployment. We evaluate the framework using both simulation and real hardware, identifying any discrepancies between expected and actual behavior through log analysis.

7.5 Specialized Specification

Our framework testing validated the software's stability and real-time data processing capabilities. We tested the ECU software's fault tolerance, error handling, and response time under various scenarios. The system consistently delivered high accuracy in predictive maintenance, reliably analyzing battery health, motor performance, and braking system conditions. The test results confirmed that the framework reliably detects potential failures and triggers maintenance alerts before critical issues occur.

8. Hardware System

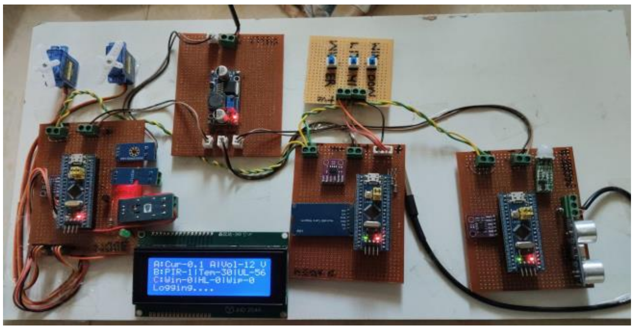

Fig 5: Hardware

This hardware system design enables efficient communication, monitoring, and control in electric vehicles. At its core are STM32 microcontrollers, which process data and interface with various sensors and actuators via a Controller Area Network (CAN) bus. The system features servo motors, an LCD, and multiple sensor modules, including an ultrasonic sensor for distance measurement, an IMU (Inertial Measurement Unit) for motion tracking, and current/voltage sensors for monitoring power usage. A data logging module with an SD card stores operational data for predictive maintenance and further analysis. A buck converter module provides a stable power supply to different components. The CAN bus network facilitates reliable data exchange between multiple ECU nodes, ensuring real-time decision-making and automation in electric mobility applications.

9. Conclusion

The CAN-based ECU for e-mobility body control and predictive maintenance boosts vehicle automation, efficiency, and reliability. By harnessing Controller Area Network (CAN) communication, the system optimizes body control functions like lighting, HVAC, wipers, and security systems, reducing wiring complexity and improving real-time response. The ECU seamlessly communicates with multiple vehicle subsystems, ensuring enhanced operational efficiency and better system coordination.
This project makes a significant impact with its predictive maintenance capability, which detects potential faults before they occur by analysing sensor data and applying machine learning algorithms. Through continuous monitoring of battery health, motor performance, and braking system efficiency, the ECU enables early fault detection and proactive maintenance, reducing unexpected breakdowns and minimizing maintenance costs. Cloud-based analytics and remote diagnostics allow for over-the-air (OTA) updates, ensuring adaptability to future advancements in electric vehicle (EV) technology.

10. Future Scope

The CAN-based ECU for e-mobility body control and predictive maintenance drives future advancements in electric vehicle technology. A key area of development is integrating Artificial Intelligence and advanced machine learning algorithms to enhance the predictive maintenance system. The ECU improves fault detection accuracy by utilizing deep learning models, enabling precise predictions of component failures and optimizing vehicle performance and reliability.

The incorporation of Vehicle-to-Everything communication allows the ECU to interact with traffic infrastructure, other vehicles, and cloud-based monitoring systems, enabling real-time traffic optimization, better safety features, and improved energy efficiency. IoT-based remote diagnostics and over-the-air updates ensure continuous system improvements without manual interventions.

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