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Over Current Protection Of Electric Car Charging Station

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Abstract: This paper presents the development of an overcurrent protection circuit for electric vehicle (EV) charging stations. The main objective is to ensure safe and efficient charging while preventing battery damage due to excessive current. The system utilizes an ESP32 microcontroller interfaced with an ACS712 current sensor to enable real-time current monitoring. When an overcurrent condition is detected, the ESP32 instantly disconnects the power using a 5V relay. A 16x2 LCD is used to notify users of current values and fault states. Experimental validation under simulated overcurrent confirms that the system responds effectively, contributing to improved battery safety and operational reliability.

Index Terms - Electric Vehicle (EV), Overcurrent Protection, ESP32 Microcontroller, ACS712 Current Sensor, Smart Charging, Relay Cutoff, Real-Time Monitoring, Embedded System, Battery Safety, Power Electronics.

I. Introduction

With the global shift towards electric vehicles (EVs), there is a growing need for reliable and advanced charging infrastructure. Traditional protection methods such as fuses and circuit breakers often fall short in addressing the rapid and variable demands of modern EV charging systems, particularly in fast-charging scenarios where swift detection and response to overcurrent conditions are critical.

This project introduces an intelligent protection mechanism that surpasses conventional systems by offering real-time current monitoring, automatic fault isolation, and an intuitive user interface. The goal is to design and implement a compact, microcontroller-based system capable of promptly detecting overcurrent events and safely disconnecting the load to prevent equipment damage. The prototype serves as a proof-of-concept, showcasing how embedded technologies can significantly improve the safety and reliability of EV charging infrastructure.

The primary objectives of this project include:

- **Real-Time Monitoring**: Utilize the ACS712 current sensor to detect real-time charging current.
- **Automated Fault Detection**: Employ an ESP32 microcontroller to analyze sensor data and initiate protection protocols.
- **User Interface**: Use a 16x2 LCD display to inform users about system status and faults.
- **Scalability and Cost Efficiency**: Design a solution using affordable components suitable for widespread deployment.

II. Block Diagram

The block diagram of the system outlines the interactions between major components and the flow of data and power. Power is supplied by a 12V DC adapter and regulated to appropriate levels for each module. The ACS712 current sensor is placed in series with the EV load, providing a voltage proportional to current. This signal is monitored by the ESP32's ADC. User inputs via push buttons enable setting thresholds and controlling charging operations. The ESP32 processes the input and output signals, manages the display, and controls the relay via a driver circuit. In case of overcurrent, the ESP32 signals the relay to open, isolating the EV load. The LCD provides real-time current readings and alerts. This modular structure allows easy testing, debugging, and scalability for enhanced versions.

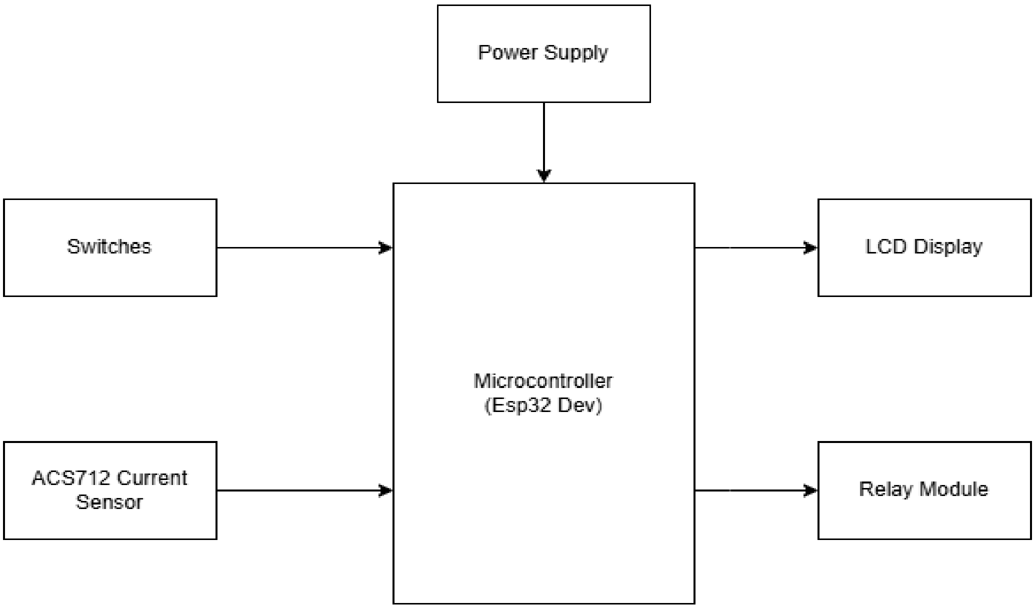

Fig 1. Block Diagram

III. System Design

The architecture includes:

- **Sensing Unit**: ACS712 sensor for analog current measurement.
- **Processing Unit**: ESP32 microcontroller programmed in Arduino IDE.
- **Control Unit**: Relay for circuit disconnection.
- **User Interface**: LCD and push buttons for interaction.

The overcurrent protection system is built upon four primary components: the sensing unit, processing unit, control unit, and user interface, each performing a specific function to ensure safe electric vehicle charging.
The sensing unit employs the ACS712 current sensor, which continuously monitors the current flowing to the electric vehicle battery. This sensor generates an analog voltage proportional to the actual current. It enables real-time detection of abnormal current conditions, allowing the system to identify overcurrent events before they cause harm.
The processing unit is handled by the ESP32 microcontroller, which receives analog signals from the sensor and converts them into digital values. Using a predefined threshold (such as 1 ampere), the ESP32 determines whether the current is within safe limits. If the measured current exceeds this limit, the controller promptly activates the protection logic and communicates with the control unit to disconnect the load.
The control unit comprises a 5V relay module, which acts as an electronic switch. During normal operation, the relay remains closed, allowing current to flow to the EV battery. When triggered by the ESP32 during an overcurrent event, the relay opens, disconnecting the circuit and halting the charging process to prevent potential damage.

The user interface consists of a 16x2 LCD and a set of push buttons. The LCD provides live feedback by displaying current readings and system messages such as “Charging On” or “Overcurrent Detected.” The push buttons allow users to interact with the system, including adjusting the current threshold, starting or stopping the charging process, and resetting the system after a fault.

IV. METHODOLOGY

The design methodology involves:
- Accurate sizing of protection components such as fuses and relays for 1A threshold.
- Integration of the ACS712 current sensor with ESP32 for real-time analog current sensing.
- Relay logic driven by ESP32 to disconnect power when overcurrent is detected.
- Use of a 16x2 LCD to continuously display current readings and status messages.
- Testing with controlled resistive loads to validate response time and fault detection reliability.

The system is powered by a 12V adapter and assembled on a perforated PCB for compactness and modularity.The ESP32 microcontroller reads the current value from the ACS712 sensor, compares it to a user-defined threshold, and controls the relay accordingly. When an overcurrent condition is detected, the microcontroller immediately disables the relay, stopping the charging process and displaying an alert.

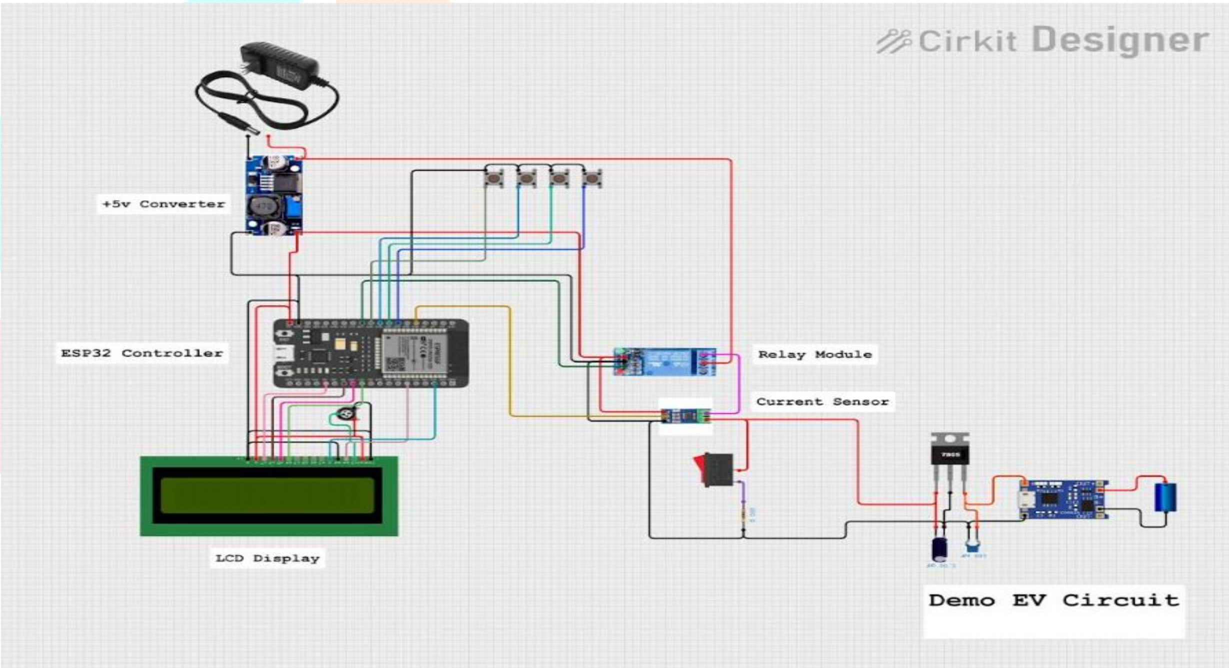

Fig 2 . Circuit Diagram

V. IMPLEMENTATION

The prototype integrates real-time protection with immediate disconnection upon overcurrent detection. Users can control charging through Start/Stop buttons and adjust the threshold with Increment/Decrement buttons. The LCD provides feedback including current readings and fault status. Powered by a 12V 2A adapter, the system uses a TP4056 module to manage charging of a 3.7V lithium-ion battery. Relay switching is software-controlled based on sensor data and user settings, enabling dynamic and interactive operation.

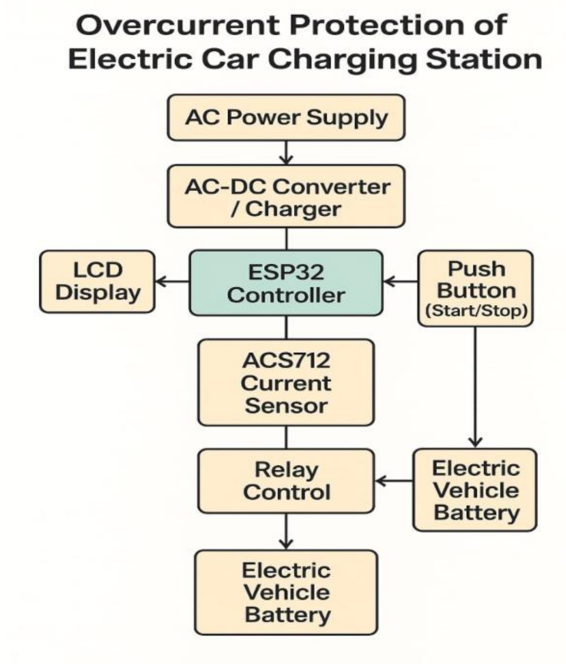

Fig 3 . Flow Diagram

VI. PROTOTYPE BUILDING

To demonstrate the functionality of the overcurrent protection system, a working prototype was developed using compact and cost-effective components. The entire circuit was assembled on a perforated PCB, ensuring a clean and organized layout. The ESP32 microcontroller served as the central unit, interfaced with the ACS712 current sensor, relay module, LCD display, and input buttons. The hardware was powered using a 12V DC adapter, and connections were made using jumper wires and terminal headers to allow flexibility during testing. Special care was taken to separate high-voltage and low-voltage sections on the board to maintain electrical safety. The design also included mounting components securely to avoid displacement during handling. This prototype allowed successful validation of the system's behavior under normal and fault conditions, enabling real-time response and easy monitoring. It served as a practical model for understanding the system's working and can be further refined for real-world applications.

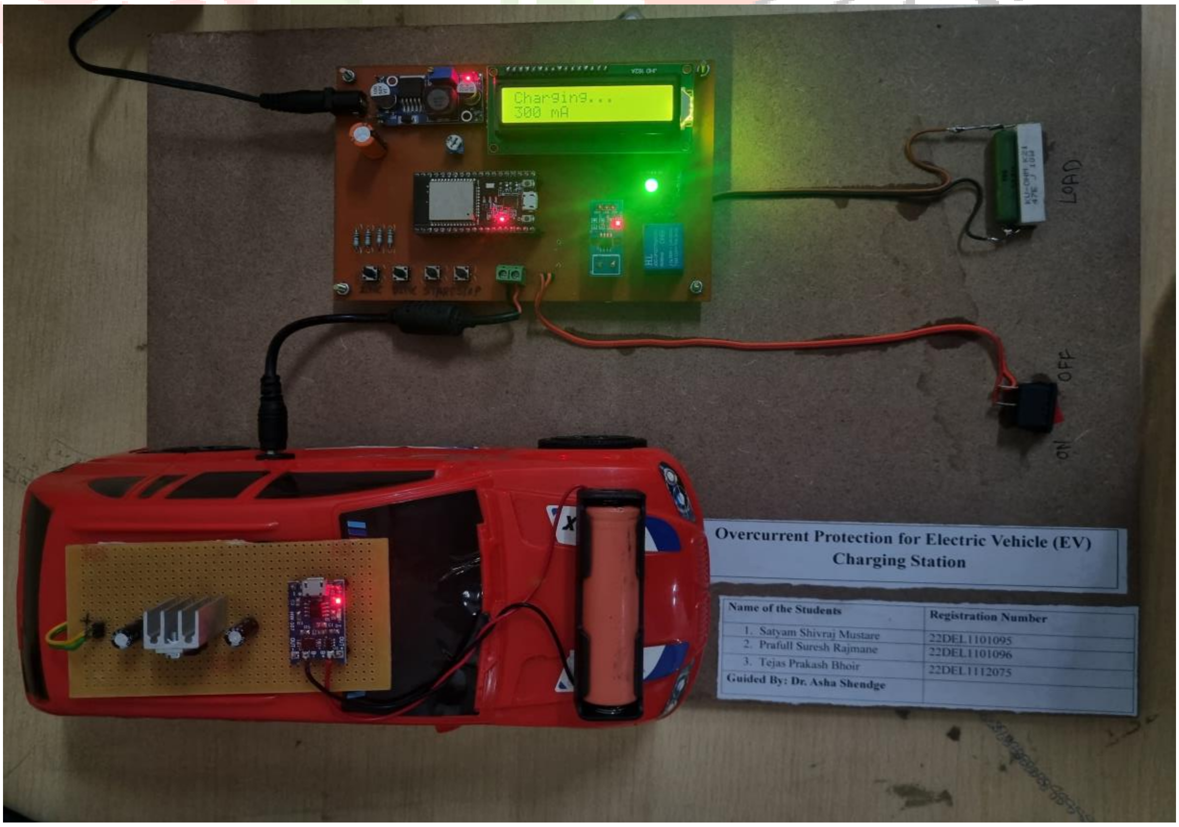

Fig 4 . Prototype Project

VII. RESULTS AND DISCUSSION

During standard charging operations, the current remained within the predefined safe limit, allowing the relay to maintain an uninterrupted connection. However, when an intentional overcurrent scenario was introduced, the system responded rapidly by deactivating the relay in just a few milliseconds. Simultaneously, the LCD notified the user with a clear warning message. This quick and automated response plays a critical role in protecting connected equipment and avoiding potential damage. Key benefits of the system include its low cost, straightforward design, real-time current tracking, and user-friendly operation. On the downside, the system currently operates with a fixed current threshold and lacks capabilities for remote notifications. Future enhancements may include integration with IoT platforms, support for mobile-based monitoring, and the ability to adjust current limits dynamically based on load conditions.

Test No.	Load Condition	Expected Current (A)	Measured Current (A)	Protection Status	Relay Response	Result
1	Normal Load	0.75	0.76	Within Limit	Remains ON	Charging Continues
2	Overload Simulated	1.20	1.22	Exceeded Threshold (1A)	Turns OFF	Charging Stopped (Overcurrent Detected)
3	Light Load	0.50	0.49	Within Limit	Remains ON	Charging Continues
4	Short Circuit Fault	>2.00	2.10	Dangerous Overcurrent	Turns OFF	Charging Stopped Instantly
5	Fluctuating Load	0.90 – 1.10	1.05	Brief Overcurrent	Turns OFF	Relay Disengaged
6	Disabled Protection	1.50	1.48	No Threshold Set	Remains ON	Risk of Overheating and damage to car

The overcurrent protection system developed in this project offers both technical reliability and practical usability. At its core, it provides continuous real-time monitoring of the EV charging current and initiates immediate disconnection if abnormal conditions are detected. This swift response mechanism helps prevent hazards such as overheating, electrical faults, or damage to connected components. By utilizing affordable, readily available hardware—including the ESP32 microcontroller, ACS712 current sensor, and a relay module—the system remains cost-efficient and scalable for wider implementation.

Its modular design enables easy incorporation into existing or newly installed charging stations without the need for significant modifications. From a user perspective, the interface—comprising push buttons and a 16x2 LCD—makes configuration straightforward and status messages easy to interpret, reducing the need for technical intervention. Its compact build further supports installation in limited-space environments such as home garages, apartment complexes, or small commercial units.

The system is adaptable to various applications. In households, it offers added safety and protects domestic wiring during EV charging. In commercial areas like shopping centers or office parking lots, it provides reliable protection across multiple charging stations. For industrial use, such as EV fleet hubs or transportation depots, it enhances equipment longevity and system reliability. It also fits well in rural or remote areas where stable power delivery and fault isolation are essential. Beyond its current capabilities, the design serves as a solid foundation for future integration with smart technologies, including IoT-based remote monitoring and AI-driven analytics.

VIII. CONCLUSION

The proposed overcurrent protection system demonstrates a reliable, responsive, and cost-effective solution for enhancing the safety of EV charging stations. Through real-time current monitoring and automated disconnection, the system ensures efficient fault response. Its compact hardware design and successful testing under simulated conditions confirm its potential for deployment in residential and light-commercial EV charging applications

IX. FUTURE SCOPE

The current system demonstrates a reliable and affordable solution for overcurrent protection in electric vehicle charging setups, but there remains considerable potential for future enhancement. One of the most promising directions involves integrating wireless communication capabilities such as Wi-Fi, GSM, or Bluetooth to enable remote monitoring and alert systems. This would allow users to receive real-time notifications about charging status and fault events directly on their smartphones or computers. Additionally, implementing adjustable current thresholds through software settings or mobile apps would offer greater flexibility for different types of electric vehicles and charger ratings. The system could also benefit from incorporating data logging features to track historical performance, detect patterns, and support preventive maintenance. For scalability, multi-channel protection could be added to manage several charging points simultaneously. In the long term, integration with IoT platforms and cloud-based analytics could enable predictive fault detection using machine learning, further increasing system intelligence and reliability. These advancements would not only improve safety and functionality but also align the system with evolving smart grid technologies and modern EV infrastructure standards.

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