EV ON-BOARD CHARGER

Power factor corrected Smart charging module

19EEE381-OPEN LAB

Project Report

Submitted by

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Amrita School of Engineering
Department of Electrical and Electronics Engineering

Program Educational Objectives (PEOs)

PEO1:Graduate can demonstrate electrical and electronics engineering problem solving skill along with proficiency in communication and professional excellence in project management and execution.

PEO2:Graduate can be employable in engineering services including ICT enabled sectors and also motivated for entrepreneurship.

PEO3:Graduate will be competent for higher studies in world class universities and research in industrial organizations.

PEO4:Graduate will manifest social commitment, environmental awareness and moral and ethical values in professional and other discourses.

Program Specific Outcomes (PSOs)

PSO1: Build and manage electro dynamic systems using Knowledge on electrical technology and PSO1: Awareness of Future Technology: Develop solutions for future systems using smart technologies.

PSO2: Research and Innovation: Identify engineering challenges, approach using cutting edge research tools and execute innovative solutions.

BONAFIDE CERTIFICATE

This is to certify that the open lab project report entitled “EV ON-BOARD CHARGER”,

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is in partial fulfilment of the requirements for the award of the Degree of Bachelor of Technology in “Electrical and Computer Engineering” is a bonafide record of the work carried out at Amrita School of Engineering, Coimbatore

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ABSTRACT

With the increasing adoption of electric vehicles (EVs), onboard chargers (OBCs) play a crucial role in ensuring efficient and reliable charging. However, conventional OBCs often suffer from poor power factor, leading to inefficient power utilization, and compliance issues with power quality standards. Additionally, many OBCs either lack proper switching between charging modes or rely on inefficient techniques, which, when used for prolonged periods, can degrade battery health and reduce lifespan. To address these challenges, power factor correction (PFC) techniques and advanced switching techniques are employed to improve grid-side power quality and overall charger efficiency.

This paper presents the design and implementation of a power factor corrected smart onboard charger for EVs. The charger is designed for a 12V, 7Ah lead-acid battery and incorporates the Texas Instruments UC3854 integrated circuit for active PFC. The system enhances power quality by minimizing input current harmonics and achieving near-unity power factor. Additionally, a Raspberry Pi Pico W is integrated to intelligently switch between constant current (CC) and constant voltage (CV) charging modes, preventing overcharging and optimizing the charging process for improved battery lifespan and safety. The proposed design is also scalable and can be adapted for lithium-ion battery packs or larger battery banks by modifying the power stage and control parameters. Simulation and experimental results validate the effectiveness of the proposed design in improving charging efficiency while maintaining compliance with power quality standards.

Keywords— Power Factor Correction (PFC), Electric Vehicle (EV) Charger, Onboard Charger (OBC), UC3854, Lithium-Ion Battery, Constant Current (CC), Constant Voltage (CV), Raspberry Pi Pico W, Charging Mode Switching, Battery Health, Harmonic Reduction.

INTRODUCTION

The rapid adoption of electric vehicles (EVs) has increased the demand for efficient and reliable onboard chargers (OBCs). An onboard charger is responsible for converting AC power from the grid into a regulated DC voltage suitable for charging the vehicle's battery. However, conventional OBCs often suffer from poor power factor, leading to increased harmonic distortion, inefficient power utilization, and regulatory non-compliance with power quality standards. Additionally, many OBCs either lack proper switching between charging modes or rely on inefficient techniques, leading to prolonged operation in a single mode. This results in excessive stress on the battery, increased heat generation, and faster degradation of battery health, ultimately reducing its overall lifespan.

To address these challenges, this paper presents the design and implementation of a power factor corrected smart onboard charger for EV applications. The proposed system is designed for a 12V, 7Ah lead-acid battery and incorporates the Texas Instruments UC3854 integrated circuit for active power factor correction (PFC), ensuring near-unity power factor and minimized input current harmonics. This improves power quality, enhances grid compatibility, and reduces overall energy losses.

Furthermore, the charger includes a Raspberry Pi Pico W to intelligently manage the transition between constant current (CC) and constant voltage (CV) charging modes. This switching mechanism plays a crucial role in optimizing the charging process. The CC mode allows for fast initial charging by maintaining a steady current, while the CV mode prevents overcharging by gradually reducing the current as the battery reaches full capacity. This approach ensures improved battery health, prevents thermal runaway, and extends the battery’s lifespan.

The proposed charger is also designed with scalability in mind. By modifying the power stage and control parameters, it can be adapted for lithium-ion battery packs or larger battery banks, making it suitable for a range of EV applications. Simulation and experimental results validate the effectiveness of the design in improving charging efficiency while maintaining compliance with power quality standards. The following sections provide an in-depth discussion of the charger’s design, implementation, and performance evaluation.

PROBLEM STATEMENT

Conventional onboard chargers (OBCs) in electric vehicles (EVs) suffer from poor power factor, inefficient energy utilization, and improper charging strategies that degrade battery health. Many chargers lack power factor correction (PFC), leading to high harmonic distortion and non-compliance with power quality standards. Additionally, the absence of intelligent switching between constant current (CC) and constant voltage (CV) modes results in battery stress, overheating, and reduced lifespan.

To address these issues, a smart OBC with active PFC and an intelligent CC-CV switching mechanism is required to enhance power quality, optimize battery charging, and ensure long-term reliability

METHODOLOGY

The proposed power factor corrected smart onboard charger (OBC) is designed to improve power quality, optimize battery charging, and ensure long-term reliability. The methodology involves multiple stages, including system design, power factor correction, intelligent charging control, and performance validation.

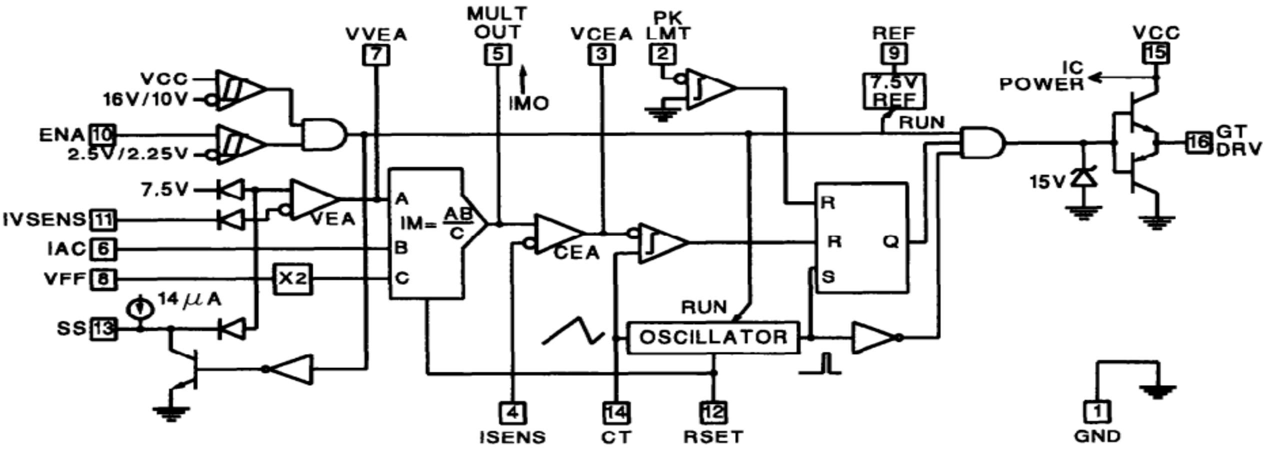

Fig. 1 Block Diagram of the System

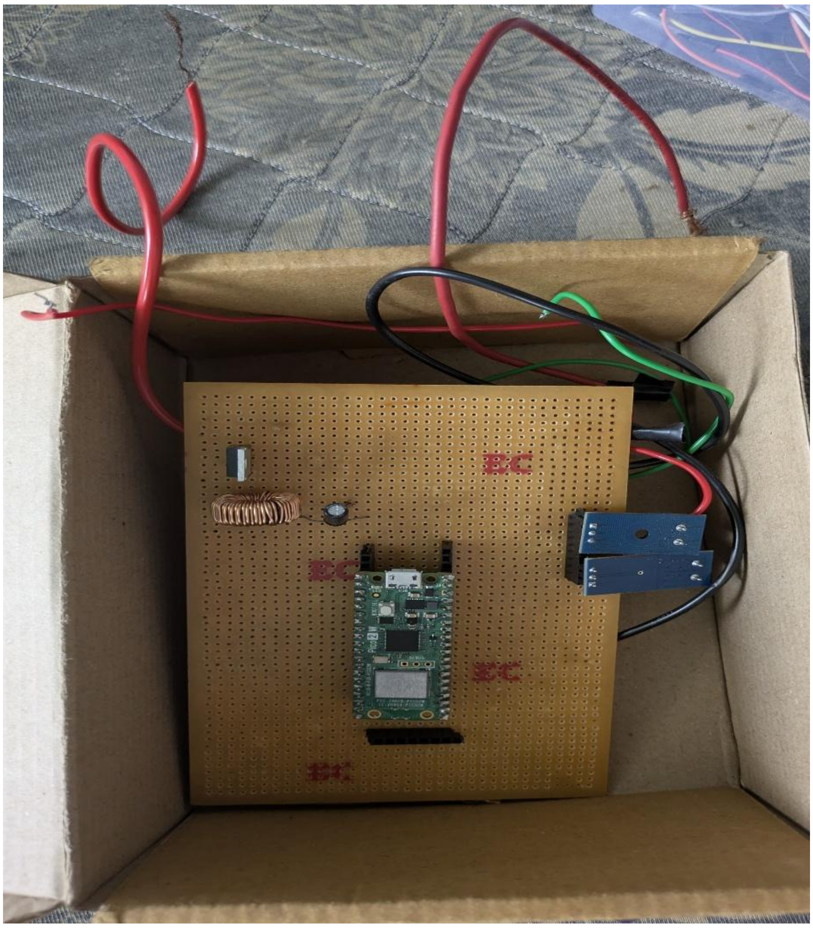

Fig.2 System setup

The above picture Fig.2 shows the experimental setup of the EV onboard charger orchestrates the functioning of various sensors and device.

1. System Architecture and Design

The OBC is designed for a **12V, 7Ah lead-acid battery** and is scalable to larger **lithium-ion battery packs**. The architecture consists of the following key components:

- **Power Factor Correction (PFC) Stage:** Utilizes the **Texas Instruments UC3854** IC to improve power quality by ensuring near-unity power factor and reducing input current harmonics.
- **DC-DC Conversion Stage:** Converts the rectified DC voltage to a regulated voltage suitable for battery charging.
- **Intelligent Charging Controller:** Uses a **Raspberry Pi Pico W** to dynamically switch between **constant current (CC)** and **constant voltage (CV)** charging modes.

2. Power Factor Correction (PFC) Implementation

To minimize harmonic distortion and improve efficiency, the **UC3854-based active PFC circuit** is used:

- **Input AC Rectification:** The AC mains input is rectified using a **bridge rectifier** and a **boost PFC converter** regulates the DC bus voltage.
- **Boost Converter Control:** The UC3854 adjusts the duty cycle of the boost converter to shape the input current waveform, ensuring near-unity power factor.
- **Current and Voltage Sensing:** The IC monitors input current and voltage, adjusting control signals to minimize total harmonic distortion (THD).

3. Intelligent CC-CV Charging Control

A **Raspberry Pi Pico W** is integrated to manage charging mode transitions:

- **Constant Current (CC) Mode:** When the battery voltage is low, the charger operates in CC mode, delivering a steady current to charge the battery quickly.
- **Constant Voltage (CV) Mode:** As the battery approaches full charge, the system switches to CV mode, maintaining a stable voltage while gradually reducing the charging current.

- **Transition Control:** The Pico W continuously monitors **battery voltage and current** using ADC inputs and triggers mode switching based on predefined thresholds.

- **Wireless Monitoring (Optional):** The Pico W's Wi-Fi capability allows for remote monitoring and control if required.

4. Scalability for Lithium-Ion Battery Packs

- The charger is designed to be **adaptable for different battery chemistries** by modifying the DC-DC conversion stage and control logic.

- For **higher voltage lithium-ion battery packs**, the **power stage can be upgraded**, and **BMS integration** can be added for improved safety and monitoring.

5. Simulation and Experimental Validation

- **Simulation:** The system is first modeled in **MATLAB/Simulink** to analyze power factor correction, charging behavior, and efficiency.

- **Prototype Testing:** The hardware for the **Power Factor Corrected Smart Onboard Charger (OBC)** was successfully designed and developed as per the proposed specifications. The system was implemented using the **UC3854 for active power factor correction (PFC)** and a **Raspberry Pi Pico W for intelligent CC-CV switching**. However, despite assembling and testing the hardware, the expected output could not be obtained due to unforeseen challenges.

6. Challenges and Reasons for Project Limitations

During the development of the UC3854-based PFC EV onboard charger, we encountered a critical issue where the IC failed to power up. After thorough analysis, the failure was attributed to design limitations within the current sensing and power supply circuit. The key reasons for this failure are as follows:

- **Excessive Voltage Drop Across the Shunt Resistor** – The shunt resistor used for current measurement had a higher-than-optimal resistance value. This likely caused a significant voltage drop, preventing the IC from receiving the required supply voltage, thereby inhibiting its operation.
- **Insufficient VCC Supply to the IC** – The UC3854 requires a stable VCC (typically 15V) for proper functionality. Due to the excessive voltage drop across the shunt resistor or potential miscalculations in the auxiliary power circuit, the IC may not have been supplied with adequate voltage to start up.
- **Possible Circuit Design or Layout Issues** – In addition to the shunt resistor selection, other factors such as incorrect component values, improper PCB trace routing, or grounding issues may have contributed to the failure. These could have affected power delivery and signal integrity, further preventing the IC from functioning as expected.

Addressing these issues in future iterations will involve optimizing the shunt resistor value, ensuring a stable power supply to the IC, and refining the circuit layout to minimize unintended voltage drops.

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