# Microchip's On-Board Charger Solution for Electric Vehicles White Paper


## ABSTRACT

The adoption of electric vehicles worldwide necessitates effective charging solutions. This white paper examines the fusion of Microchip's dsPIC33 Digital Signal Controllers (DSC) with Silicon Carbide (SiC) technology, which offers a comprehensive system solution and systemic design approach to develop an on-board charger (OBC).

Designers can enhance efficiency, reliability and scalability in OBC systems by leveraging the advanced control capabilities of Microchip's dsPIC33C DSC family, the MCP14C1 isolated SiC gate driver and the performance of mSiC™ MOSFETs.


**FIGURE 1: Standard EV Charger Connects to an EV's On-Board Charger**

## EMERGING TRENDS IN THE ON-BOARD CHARGER MARKET: SHAPING THE FUTURE OF ELECTRIC VEHICLE CHARGING

The on-board charger market is undergoing a transformative evolution, driven by emerging trends that are reshaping the landscape of EV charging. Outlined below are the focus areas that are redefining future designs of on-board charger solutions.

**Increasing Power Levels**: redefining charging speed and convenience to improve the end-user experience.

**Bi-Directionality**: smart energy management and connectivity by supporting vehicle-to-grid (V2G), vehicle-to-home (V2H), vehicle-to-load (V2L) and vehicle-to-vehicle (V2V) functionalities, which enables bi-directional power management of on-board chargers.

**Compact Design with Integration**: the emphasis on compact design and integration in on-board chargers is fundamental for efficiency and flexibility in EV charging systems. The integration of low voltage DC-DC converters is critical to efficiently convert high voltage power (400V or 800V) to low voltage (12V or 48V), along with support for different AC inputs (single-phase or three-phase).

The convergence of trends in the on-board charger market signifies a shift towards advanced, user-centric charging solutions and prioritizes speed, efficiency and connectivity. As EVs continue to gain momentum in the automotive industry, the adoption of high-power, bi-directional and integrated on-board chargers will play a pivotal role in shaping the future of EV charging infrastructure and driving sustainable transportation practices on a global scale.

## THE ROLE OF ON-BOARD CHARGERS FOR ELECTRIC VEHICLES

OBCs play a pivotal role in the seamless operation of EVs. These sophisticated devices are tasked with the crucial function of converting alternating current (AC) from the grid into direct current (DC) that can be stored in the vehicle’s battery. The efficiency and reliability of OBCs directly impact the overall performance and user experience of EVs, making them a key focus area for EV manufacturers.

Microchip’s dsPIC33C DSCs have emerged as a game changer in the realm of EV technology. Known for their advanced peripherals and robust performance, dsPIC33 DSCs offer a compelling solution for developing cutting edge OBCs that meet the evolving needs of modern transportation.

## ON-BOARD CHARGER SYSTEM REQUIREMENTS

Key requirements for OBCs include high efficiency, compact physical size, and high reliability ratings to ensure optimal performance and longevity in EVs. Thermal management is critical to ensure proper operation and longevity of OBC systems, especially at higher power levels. OBC systems must comply with relevant safety standards and regulations governing EV charging infrastructure, such as IEC 61851 and SAE J1772. OBC systems should support communication interfaces for seamless integration with the vehicle's onboard network and external charging infrastructure. Design optimization, component selection and manufacturing processes also contribute to achieving cost-effective OBC solutions without compromising quality or reliability.

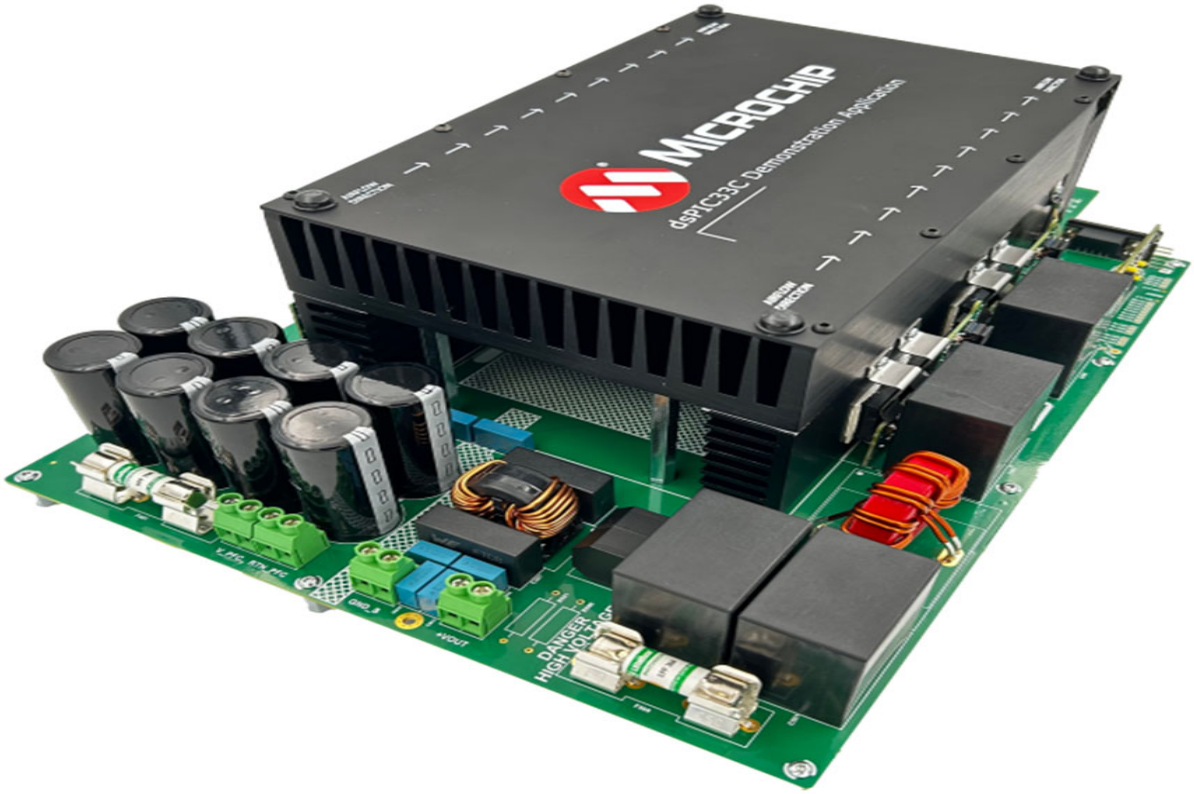
## MICROCHIP’S COMPREHENSIVE SYSTEM SOLUTION IN ON-BOARD CHARGERS

Microchip's OBC solution provides seamless integration of key components, including the dsPIC33 DSC, MCP14C1 isolated SiC gate driver, mSiC MOSFET in an industry-standard D2PAK-7L XL (TO-263-7L XL) package and CAN solutions, facilitating rapid development and deployment of OBC systems.

Microchip’s dsPIC33 DSC, MCP14C1 isolated SiC gate driver, and mSiC MOSFETs stand out as key components in an OBC system. The compatibility and interoperability of Microchip's components ensure smooth communication and operation within the OBC system, minimizing integration challenges and development time.

**FIGURE 2: Totem-Pole PFC Demonstration Application**


**FIGURE 3: DC-DC Converter Demonstration Application**

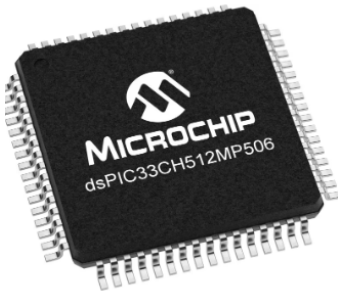


## MICROCHIP'S dsPIC33C DIGITAL SIGNAL CONTROLLERS

Microchip's dsPIC33 family of DSCs feature a 100 MIPS dsPIC® DSC core with an integrated DSP and enhanced peripherals. The dsPIC33 family offers key benefits in OBC applications. The high-performance core and high-speed peripherals work together efficiently and help meet the demanding requirements for controllers in OBC applications.

The dsPIC33 product family also has many features that help simplify functional safety certification for ASIL-B/C focused automotive safety-critical applications. The dsPIC33 family of devices include ISO26262 functional safety packages, FMEDA report, safety manual, diagnostic libraries etc.

**FIGURE 4: dsPIC33C DSC Dual Core**




## KEY FEATURES AND BENEFITS OF USING MICROCHIP'S dsPIC DSCs IN ON-BOARD CHARGERS

### Dual Core Architecture

The dsPIC series features a dual core architecture, with one core dedicated to handling high-performance signal processing and controlling tasks, such as Power Factor Correction (PFC), while the other core manages control and communication functions. This separation of functions enhance system efficiency, allowing the dsPIC to handle complex control algorithms and communication protocols simultaneously without compromising performance.

### High-Speed Signal Processing

With its advanced digital signal processing capabilities, the dsPIC can efficiently implement complex algorithms for power conversion, control, and modulation. High-speed signal processing enables precise regulation of voltage and current waveforms, improving power quality and efficiency in the charging process.

### Flexible Communication Interfaces

Microchip's dsPIC supports various communication interfaces, such as Controller Area Network (CAN) and Local Interconnect Network (LIN), which enable seamless integration with the vehicle's onboard network. Flexible communication interfaces facilitate real-time monitoring, diagnostics and remote management of the charging process, enhancing user experience and system reliability.

### Integrated Analog and Digital Peripherals

The dsPIC integrates a wide range of analog and digital peripherals, including Analog-to-Digital Converters (ADCs), Digital-to-Analog Converters (DACs), Pulse-Width Modulation (PWM) Modules and communication interfaces. Integrated peripherals simplify system design and reduce component count, minimizing board space and reducing overall system cost.

### Advanced Control Algorithms

The dsPIC's high-performance digital signal processing capabilities enable the implementation of advanced control algorithms for PFC, voltage regulation, current limiting and fault detection. Advanced control algorithms optimize charging efficiency, minimize energy losses, as well as ensure safe and reliable operation under operating conditions.

### Enhanced Safety and Protection Features

Microchip's dsPIC enables implementation of advanced safety and protection features, including overcurrent protection, overvoltage protection, overtemperature protection and insulation monitoring. These safety features enhance system reliability and protect against potential faults or hazards, ensuring safe operation of the OBC in EVs.

### Development Tools and Software Support

Microchip provides comprehensive development tools and software support for the dsPIC DSC platform, including Integrated Development Environments (IDEs), software libraries, and application notes. Development tools and software support streamline the design process, accelerate time to market, as well as facilitate system integration and testing. Microchip also provides reference solutions that provide a jump start to customers developing OBCs. These reference solutions enable a faster time to market and provide customers with the flexibility to add differentiated features to the system.

As you can see, Microchip's dsPIC DSC offers several advantages for OBC applications in EVs, including dual core architecture, high-speed signal processing, integrated peripherals, flexible communication interfaces, advanced control algorithms, enhanced safety features, comprehensive development tools and software support. These advantages enable efficient, reliable and cost-effective implementation of OBC solutions, contributing to the widespread adoption of E-Mobility.

## MICROCHIP’S MCP14C1 ISOLATED SiC GATE DRIVER

The MCP14C1 is an isolated SiC gate driver optimized to drive, via UVLO, mSiC MOSFETs from Microchip. The MCP14C1 will source and sink 5A of current. It will be offered with split output configuration to enable ease of implementation when using external gate resistors for pull-up and pull-down adjustment. This eliminates the need to use an external diode to manage pull-up and pull-down drive schemes. The internal isolation is realized via Microchip’s internally developed capacitive isolation, allowing for a robust solution to reject noise in the system, ultimately to help avoid unintended triggering of the driver. The MCP14C1 is offered in two different packages, one in SOIC-8 wide-body which supports higher voltage isolation requirements and another offered in SOIC-8 narrow-body. The MCP14C1 is AEC-Q100 Grade 1 qualified to support automotive applications.

**FIGURE 5: MCP14C1 SiC Gate Driver**

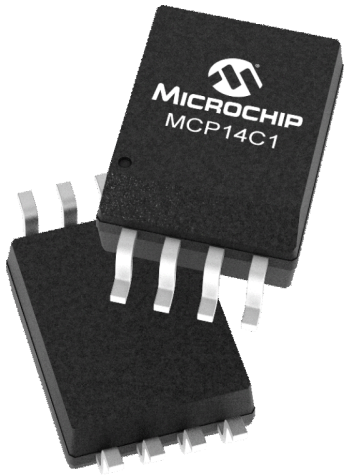


**FIGURE 6: Power Factor Correction (PFC) for On-Board Charger**

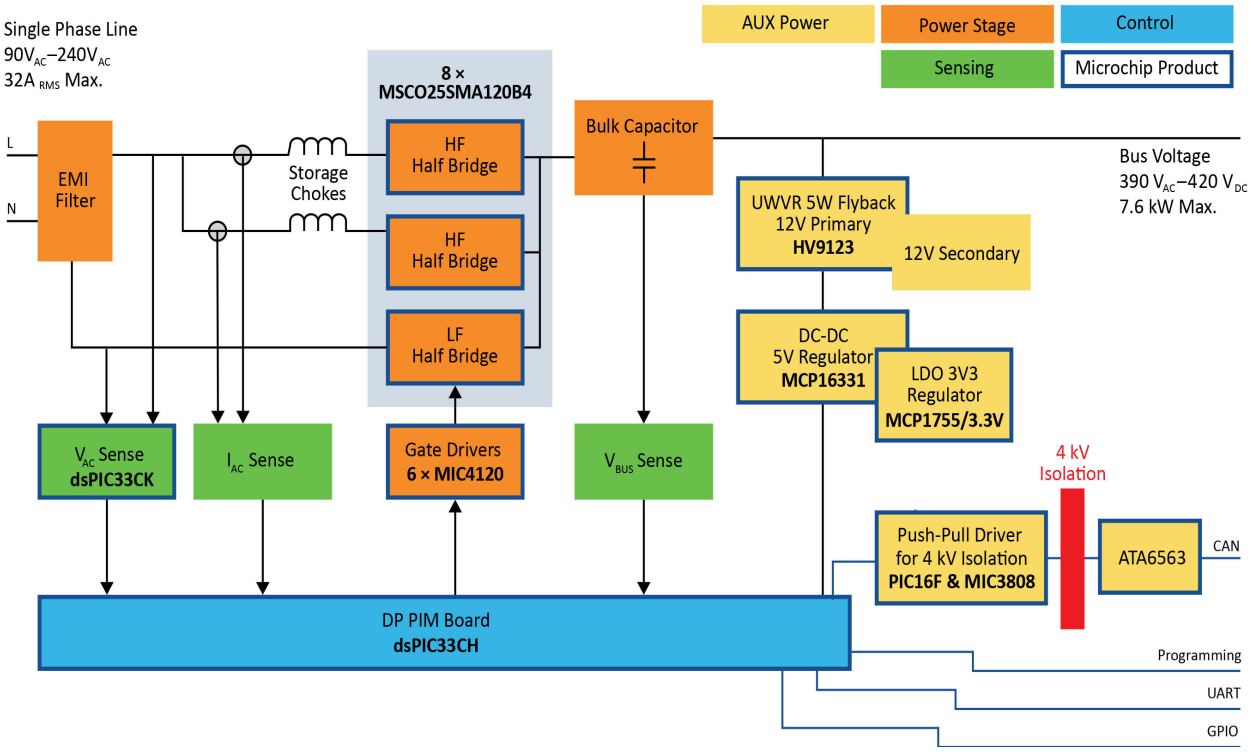
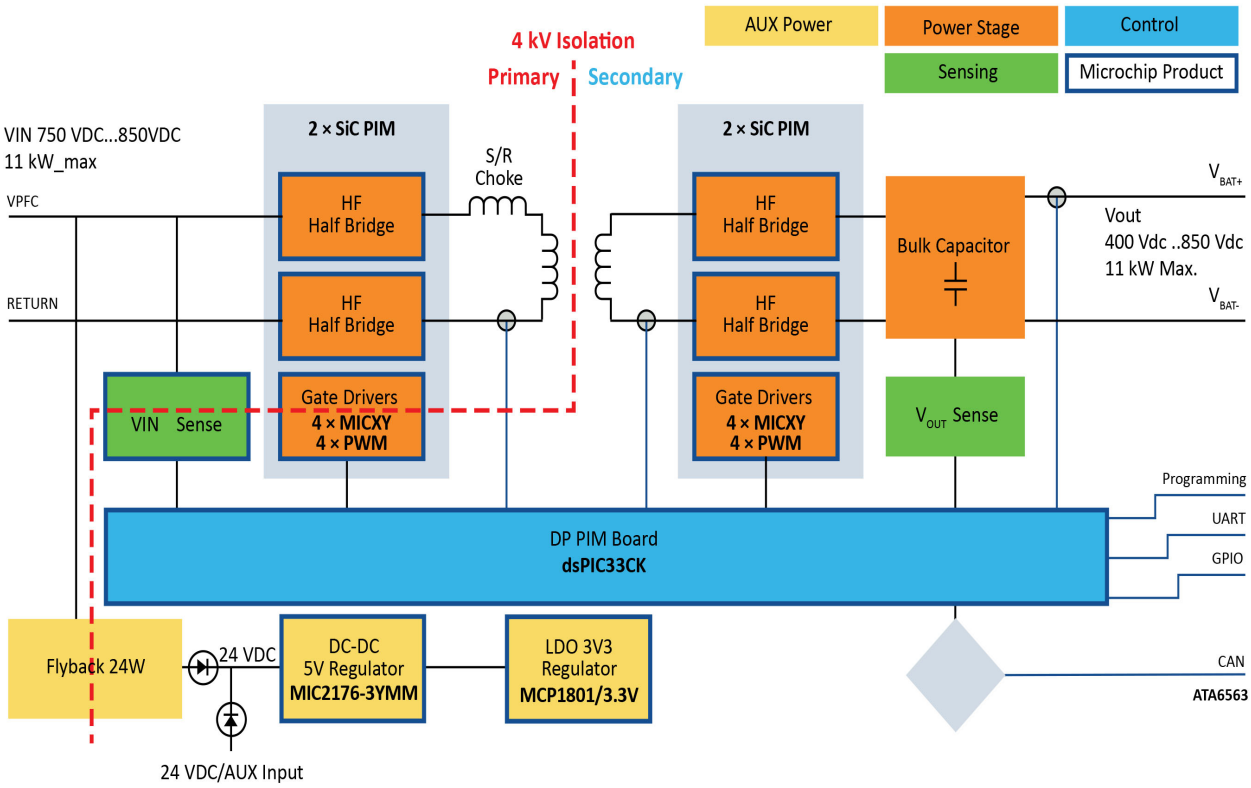



**FIGURE 7: DC-DC Converter for On-Board Charger**



## MICROCHIP'S mSiC MOSFETS

Microchip's SiC solutions in OBC systems offers numerous advantages over traditional silicon-based designs. In addition, D2PAK-7L XL packages maximize the superior properties of SiC semiconductor material to enhance performance, efficiency and reliability in OBC applications.

## KEY HIGHLIGHTS OF MICROCHIP SiC SOLUTIONS IN ON-BOARD CHARGERS

Newly introduced surface mount SiC MOSFET options are ideal for both 400V and 800V EV applications, especially space constrained applications such as an OBC. The mSiC MOSFET in a D2PAK-7L XL surface mount package is AEC-Q101 qualified, includes five parallel source sense leads to reduce switching losses, increase current and decrease inductance.

### Wide Range of Discrete Packages and Power Module Configurations

Microchip provides a wide breadth of discrete packages and power module configurations suitable for various power levels and application requirements in on-board chargers. mSiC MOSFETs with Low $R_{DS(on)}$ over Temperature: Microchip's mSiC MOSFETs feature among the lowest $R_{DS(on)}$ over temperature in the industry, allowing clients to use a higher-rated $R_{DS(on)}$ compared to competitor devices. This contributes to improved cooling requirements that reduce system cost in OBC designs.

### High Fidelity Device Models for Simulation

Microchip offers high-fidelity device models supporting SPICE and PLECS® simulations, enabling accurate performance prediction and optimization during the design phase of OBC systems, reducing time-to-market.

### Rugged and Reliable Gate Oxide

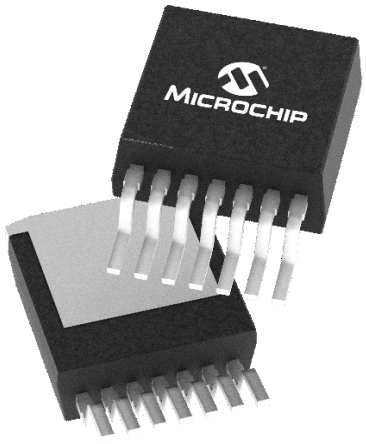
Microchip's SiC devices undergo rigorous testing, including static and dynamic accelerated gate stress tests, to confirm ruggedness and reliability. This ensures no drift in threshold voltage and $R_{DS(on)}$ over time, enhancing the longevity and stability of on-board charger systems.

### Dual Source Supply Chain Strategy for SiC

As SiC technology is a key and trending technology, supply risk can be high. Microchip mitigates this risk by employing a dual source supply chain strategy, ensuring stable and consistent supply of SiC components for OBC.

By leveraging Microchip's mSiC solutions, designers can benefit from comprehensive support, high-performance components, reliable device models and accelerated design tools, enabling the rapid development of efficient, reliable and competitive OBC systems for electric vehicles.

**FIGURE 8: SiC MOSFET in D2PAK-7L XL (TO-263) Package**



## COMPLETE SYSTEM SOLUTIONS FOR ON-BOARD CHARGERS FROM MICROCHIP

In addition to providing cutting-edge Digital Signal Controllers, gate drivers and SiC components, Microchip also offers comprehensive system IC packages tailored for OBC systems. These integrated circuits encompass a wide range of functionalities including power management, communication interfaces and advanced security features to help ensure a robust and efficient solution for an OBC.

**CAN (Controller Area Network)**: provides robust and reliable communication between the OBC and other vehicle systems. It facilitates data transmission about charging status, error messages and other diagnostics, which are critical for vehicle performance, monitoring and maintenance.

**Temperature Sensor**: essential for monitoring the temperature of critical components within the OBC. It helps in managing thermal performance, ensuring the charger operates within safe temperature ranges and preventing overheating, which can lead to hardware failure.

**Operational Amplifier (Op Amp)**: used for signal conditioning in the OBC, enhancing the accuracy of measurements for current and voltage. This precision is crucial for the efficiency and safety of the charging process, as well ensuring the correct charging currents and voltages are applied to the battery.

**Security**: addresses the growing need for cybersecurity in automotive applications. Microchip's security solutions are designed to protect the OBC from unauthorized access and tampering, securing data communication and software integrity, crucial for maintaining system reliability and user trust.

**Clock**: delivers accurate timing solutions, which are vital for coordinating the operations within the OBC. A stable and precise clock improves the performance of digital control algorithms and system synchronization, enhancing overall system reliability.

**DC-DC Converters and LDO (Low Drop-Out) Regulators**: provides efficient power management within the OBC, converting and regulating voltages across various subsystems. DC-DC converters help in stepping down high voltages from the battery, whereas LDO regulators provide clean and stable low-voltage supplies for sensitive electronics, improving the energy efficiency and safety of the system.

## PICK YOUR POWER WITH MICROCHIP

Microchip's comprehensive system solution from "dsPIC DSCs through mSiC solutions" can help engineers designing OBC applications to accelerate time-to-market and significantly reduce design complexities. As a trusted supplier to automotive OEMs and Tier 1s, Microchip provides the main technology to implement an OBC system, which also streamlines supply chain management. Beyond providing the control, gate drive, power stage and other components, Microchip also offers firmware, software, reference solutions and technical support throughout the development process.

By choosing Microchip, designers can significantly speed time-to-market and achieve optimal results in performance. For more information about Microchip's OBC solutions for EVs, visit Microchip's website.