Technical White Paper

Integrating EVCC, DCDC, and Host Subsystems: TI Automotive MCUs for Next-Generation EV Charging

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ABSTRACT

This white paper discusses the different combinations of architecture available between the charging inlet control system, DCDC, and host subsystems, the introduction of various charging standards across different regions, the requirements of the MCU, and selections available for those different architectures, and finally, the other function modules of the charging inlet control system.

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1 Introduction

With the rapid development of the global EV market, charging standards have been divided into different regional standards. These standards specify the physical interfaces, communication protocols, and charging signals of charging interfaces, so EVs are strictly and uniformly charged with the various manufacturer charging piles (see charging equipment in Figure 1-1). An EVs charging inlet control system, the electric vehicle communication controller (EVCC), is the subsystem of the EV powertrain responsible for interfacing with the charging piles and implementing the necessary protocols.

Charging inlet control systems are currently trending toward integration with other subsystems, such as DCDC and host subsystems in on-board charger (OBC) combinations, to adapt to the increasing integration needs of EV powertrains.

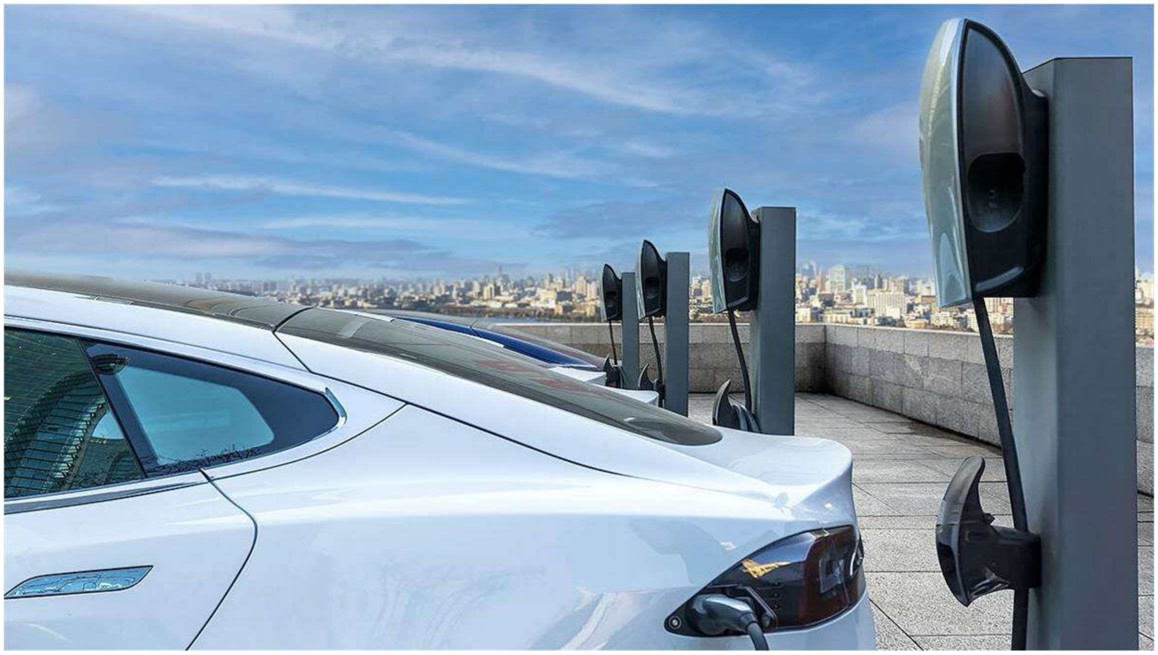

Figure 1-1. Charging Equipment

2 Charging Inlet, DCDC, and Host Architectures and Market Trends Toward Integration

The combination of a charging inlet control system with DCDC and host subsystems is divided into three main architectures, based on the integration level:

- Standalone
- Integration
- X-in-1

These architectures are shown in Figure 2-1.

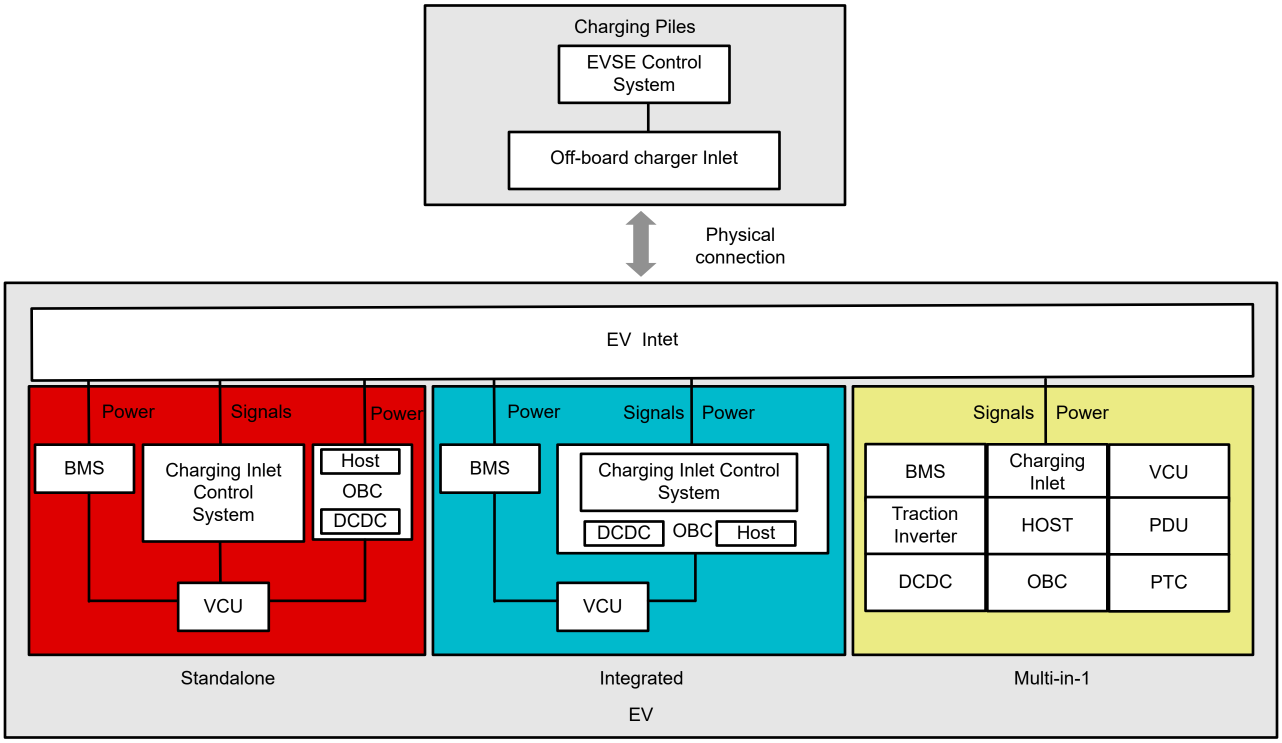

Figure 2-1. The Architecture of Charging Inlet, DCDC, and Host Subsystems

2.1 Standalone Architecture

In this type of architecture, the charging inlet control system is a standalone module placed near the EV inlet. The architecture is outside the OBC combo, independent of the DCDC and host subsystems. This architecture communicates between the vehicle and the public charging piles, to collect charging signals from charging piles and implement the necessary protocols. The charging signals are first parsed or converted by this independent module before being transmitted to other subsystems (OBC, BMS, or VCU).

The standalone module is usually applied in European (EU) and North American (NA) markets. The main work of this module is to wake up the OBC and implement protocol conversion. The module also covers various functions required by customized requirements: charging lock detection, LED indicators, contactor control, voltage and temperature detection, and more, as demonstrated in the BMW LIM module (see reference [1] in the *References* section and the Mercedes Benz CIC module). The charging inlet control system in Chinese markets has fewer functions compared to the EU and NA markets. For EVs that require exportation from China, adding an independent module to the OBC is possible, commonly referred to as an EVCC.

This standalone architecture provides significant flexibility and high compatibility. The architecture is easy to maintain, replace, and adapt to the requirements of different regions.

2.2 Integration Architecture

In this architecture, the charging inlet control system integrates with DCDC and host subsystems inside the OBC combo. Part of the integration is based on the mechanical and physical structures. Gradually, these subsystems are controlled by a multicore MCU, achieving integration in physics and control.

The main MCU of the charging inlet control system, not only covers the function of charging detection, but also detects the low voltage signals. The MCU takes part of the workload for monitoring the host and sampling the DC-DC. The functional safety level that the system can meet is affected by other subsystems, and therefore, the safety-level usually requires an elevation to meet the automotive requirements of ASIL B through ASIL D.

This structure is often witnessed in the Chinese market. Since the charging inlet control system has fewer functions and lower functional safety and cybersecurity requirements, achieving integration is easier. This architecture effectively utilizes MCU resources and helps meet integration trends. Additionally, this architecture allows the reuse of charging signal detection circuits, and auxiliary power rails in the OBC combo, and reduces signal and power wiring, which can provide cost benefits.

2.3 X-in-1 Architecture

At present, the multiple-in-one system is evolving from a mechanical structure integration to a deep integration of power electronics. Based on the existing VCU, users can integrate the other powertrain control modules (OBC DC/DC, BMS, traction inverter, and others) into a single controller—forming a power domain control platform. As one of the smaller subsystems, the charging inlet control system is flexibly integrate with others. In the future, trends toward this architecture are expected to increase due to increased demands for power density and volume in powertrains. To support this increased integration, the performance and capabilities of the main control MCU must increase, especially in memory, cores, and real-time processing.

3 Charging Standards Across Regions

Automotive charging protocols provide compatibility and interoperability between EVs and charging stations. These protocols regulate the charging interfaces, communication methods, and charging modes to standardize the electric vehicle charging process.

The are five main charging standards for four major regions and countries:

1. China: The Chinese general requirements are based on GB/T 18487-1 [reference 2].
2. North America: North America uses J17722 [reference 3] for CCS1.
3. Europe: Europe uses IEC61851-1 [reference 4] for CCS2.
4. Japan: Japan has a dedicated standard for DC charging with CHAdeMO/CHAOJI [reference 5].
5. Tesla: Tesla has established the NACS [reference 6] standards, which are widely applied in North America.

See the *References* section for more information on these standards.

3.1 AC Charging Inlet Standards

The AC charging inlet standards for the different countries and regions are shown in Table 3-1. The charging inlet pin consists of charging signals and a power output. The charging signals are CP (control pilot), PP (proximity pilot), and CC (contact confirmation) signals. Among these signals, the CP signal is the handshake signal between the EV and the EV supply. The PP signal is used to detect the connection status between the charging gun and the EV. The CC functions the same as the PP and is only used in GB/T 18487.

Table 3-1. AC Charging Inlet Standards

AC Inlet Charging Connection				
Standard	GB/T 18487	IEC 61851	SAE J1772	NACS
Region	CHN	EU (CCS2)	NA (CCS1)/JPN	NA
Power	L1/L2/L3/N	L1/L2/L3/N	L/N	L/N
Signals	CC/CP	PP/CP	PP/CP	PP/CP

3.2 DC Charging Inlet Standards

The DC charging inlet standards for the different countries and regions are shown in Table 3-2. Among these standards, the Chinese national standard, GB/T 20234 [reference 7], the CHAdeMO standard, and the Chao Ji standard, use CAN communication through the S+ and S– (C–H and C–L) pins. The DC communication protocols, DIN70121 and ISO15118 of CCS1 and CCS2, and NACS, use the PLC communication protocols for DC fast charging.

Table 3-2. DC Charging Inlet Standards

DC Charging Inlet Standards					
Standard	GB/T 20234	ISO15118 /DIN70121	CHAdeMO	CHAOJI	NACS
Region	CHN	EU (CCS2)/NA (CCS1)	JPN	CHN/JPN	NA (CCS1)
Power	DC+/DC–	DC+/DC–	DC+/DC–	DC+/DC–	L/N
Signals	CC1/CC2	CP/PP	SS1/SS2/DCP/PP	CC1/CC2	PP/CP

Table 3-2. DC Charging Inlet Standards (continued)

	DC Charging Inlet Standards				
Communication	CAN (S+/S–)	PLC (CP)	CAN (C–H/C–L)	CAN (S+/S–)	PLC (CP)
BIAS	A+/A– (1)	-	-	A+/A–(1)	-

(1) A+ and A– are the positive and negative output pins of 12V bias power supply.

Additionally, the CHAdeMO Association collaborated with China to develop an ultra-fast inlet capable of charging up to 900kW—the ChaoJi charging standard, referenced as CHAdeMO 3.0. These emerging fast-charging protocols continue to increase the charging power and speed of EVs. Recently, CharIN partnered with several OEMs and suppliers to introduce the MCS (megawatt charging system) charging inlet to meet the needs of trucks and buses.

As the electric vehicle market continuous to development, the charging standards are continuously updated and evolving. These updates include support for bidirectional communication protocols like V2X, PnC (plug and charge), and WPT (wireless power transfer) for smart charging management.

See the *References* section for more information on these standards.

4 TI Automotive MCUs for Next-Generation EV Charging

The selection of the main MCU for charging the inlet control system, DCDC, and host subsystems must consider the architecture integration level, see Figure 4-1.

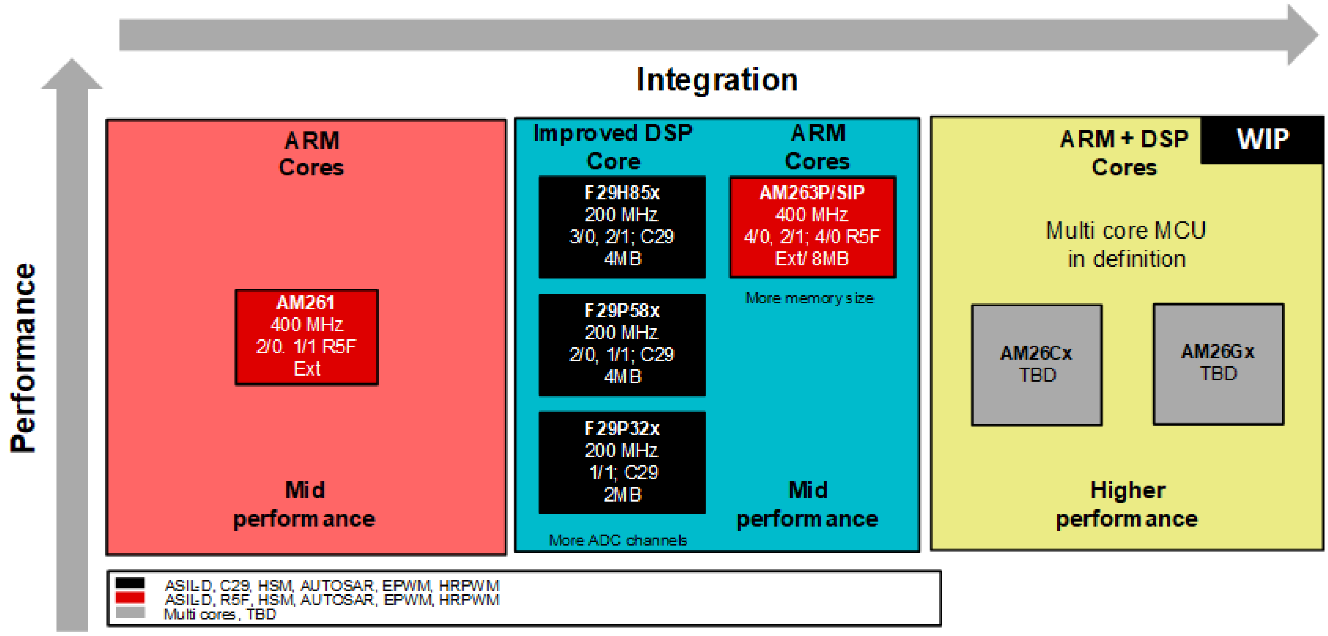

Figure 4-1. MCU Selection Recommendation

4.1 MCU Selection and Requirements for Standalone Architecture

Standalone architecture is more common in EU and NA regions, adapting to the CCS1, CCS2, and NACS standards with PLC communication—called the EVCC module or charging box. For some vehicles exported from Asia, the charging compatibility is achievable by adding this type of independent module.

This main task of the MCU is to assist the protocol conversion with PLC PHY, which has relatively large memory and cybersecurity requirements. The memory is occupied for charging identity recognition (EIM or PnC), openV2G, and AUTOSAR® . To support PnC (plug and charge) mode, security certificates are required to be realized by the HSM (hardware security module). Typically, around 400KB of RAM and 2M of flash storage is required for EVCC. An additional SPI, UART, or Ethernet interface, which communicates with the PLC Homeplug Green PHY, is also necessary.

The AM26x Sitara™ family of microcontrollers, incorporating the Arm® Cortex® -R5F cores, are built to meet the complex, real-time processing needs of automotive embedded products.

The AM261x-Q1 family of devices satisfy these processing requirements with the listed features:

- Two Arm® Cortex® -R5F cores, (1 lockstep, optional) up to 400MHz (1.6K DIMPS)
- External flash for flexible configuration, up to 1.5MB of on-chip SRAM
- Evita-full HSM with an Arm® Cortex® -M4 core, isolated controller
- Two CAN FD
- Six UART
- Four SPI
- Three I2C
- Three LIN
- GPIO options on all the multiplexed pins

4.2 MCU Selection and Requirements for Integration Architecture

This integration method is diverse. The charging inlet control system can be integrated in the OBC combo in physics. Deeper integration is achieved by using the same MCU with the DCDC and host subsystems. This form of integration is highly customized and seen in the global market where the charging standard is relatively simple and there are fewer functional safety requirements (especially prevalent in the Chinese market). In these instances, achieving integration is easier.

The resources required for the MCU are increasing. The MCU requires a higher number of ADC channels to sense multiple high-voltage and low-voltage signals for safety monitoring and DCDC control. The DCDC and host subsystems require redundant sensing, lock-step cores, and communication interfaces with end-to-end safing to meet the functional safety standard requirements for ASIL B through ASIL D. Additionally, the MCU requires higher computing power to meet the increased demand for DCDC high-frequency control resulting from increases of system power density.

The F29x series of C2000™ MCUs are an excellent choice for meeting the sufficient sensing resources and high-level functional safety requirements by providing:

- High-performance real-time control with the latest C29 core running at 200MHz. The C29 core currently delivers real-time performance (in cycles) that is four times faster than the Arm® Cortex® -M7 CPU with 480MHz frequency.
- The lockstep CPU core offers hardware-automated thread isolation and comprehensive memory protection to help meet functional safety standard requirements.
- Three 12b ADC converters and two 16b ADC converters with safety redundancy support, up to 80 channels.
- Systematic and random hardware capabilities that achieve the ISO 26262 standard of requirements up to ASIL D.
- Evita-full HSM with hardware accelerators to help meet the automotive security requirements of ISO 21434.

For systems with high integration and functional safety requirements, the AM263P and AM263P-SIP are options with increased memory, up to 8MB of flash memory.

4.3 MCU Selection and Requirements for X-in-1 Architecture

The multiple-in-one system places high demands on the number of cores in the MCU, real-time processing, low power consumption, security, and software development environment. The TI Sitara™ series of AM26C/Gx devices (with multiple cores) are in definition on the roadmap, providing robust hardware support for the development of integrated automotive systems.

5 System Block Diagram of a Charging Inlet Control System

The main architecture of a charging inlet control system typically consists of several key components and subsystems designed to maintain efficient, safe, and reliable charging for electric vehicles. Figure 5-1 shows an overview of the system block diagram. The block diagram is divided into five parts:

1. The main MCU
2. The communication module
3. The sensors

4. The peripheral functions
5. The bias supply

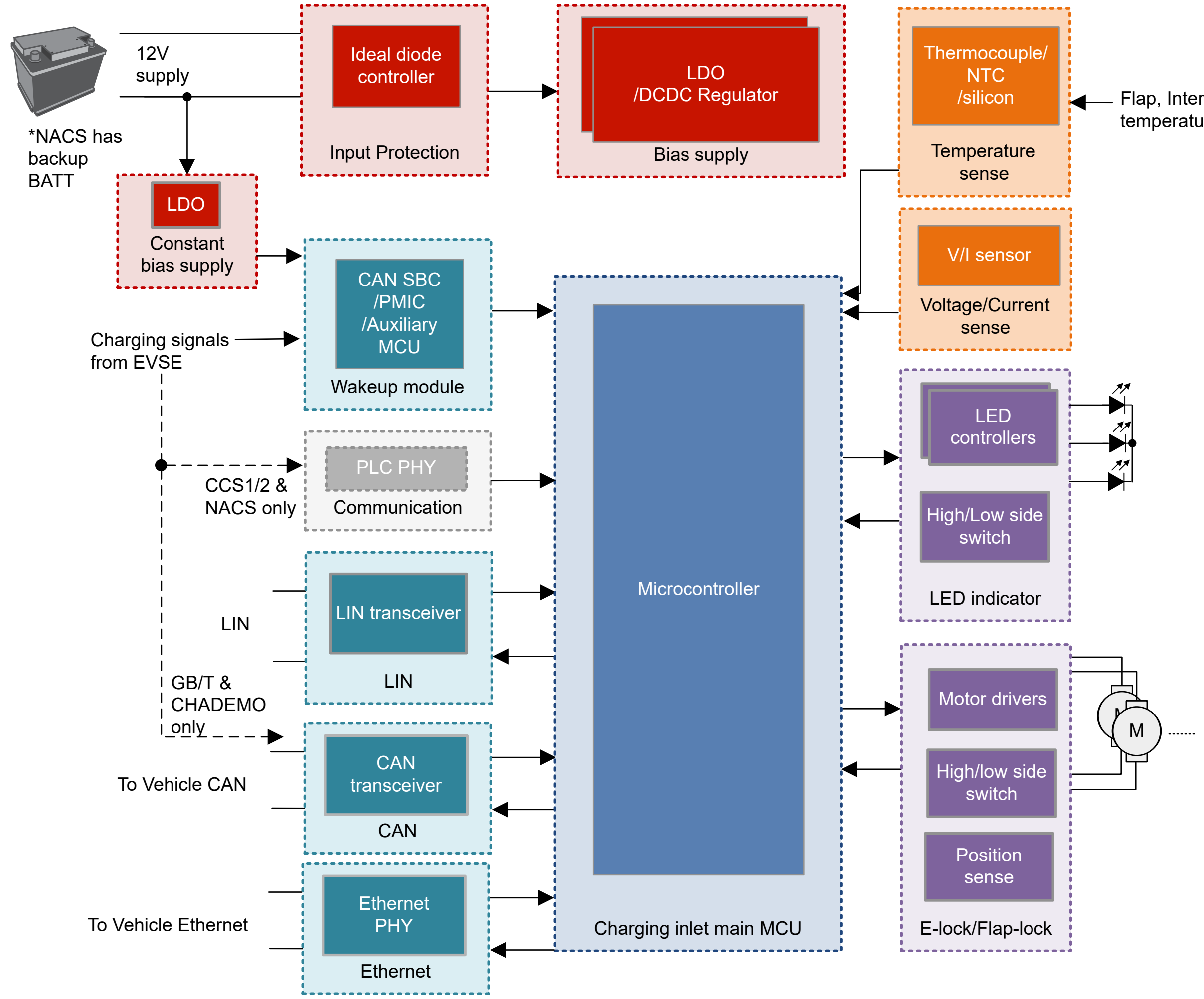

Figure 5-1. Charging Inlet Control System Block Diagram

6 Conclusion

The future development of electric vehicles moving toward greater integration, greater intelligence, and faster charging, providing users with a better driving experience and more sustainable travel options. In response, TI is investing in MCUs which can adapt to changing needs in architecture.

7 References

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