

Charging ahead toward an EV support infrastructure



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Abstract

With increasing battery capacity and decreasing battery cost, electric vehicles (EV) are becoming more mainstream each day. Just as traditional internal combustion engine (ICE) automobiles spawned the need for more gas stations, so too will EVs demand the need for more public charging options.

Deployment of EV charging stations is challenging, but it also introduces new opportunities. To maximize the deployment of as many charging stations as possible, the technology that goes into a charging station must be efficient and cost-effective, offer secure payment and provide an overall great customer experience. Another challenge involves deploying a charging infrastructure that not only supports today's use cases of mostly short local trips, but also supports faster charging compared to home-based chargers to ease concerns about charge time on today's larger battery packs.

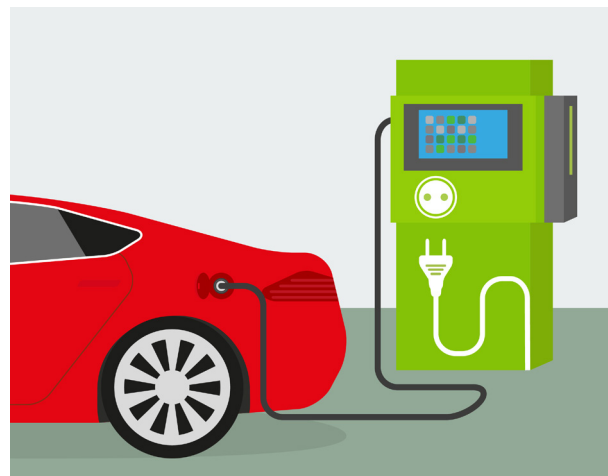
This white paper examines some of the marketplace forces that will drive further advancements in EV charging station design and affect the build-out of a more comprehensive support infrastructure.

Introduction

Although the deployment of EV supply equipment (EVSE) varies by region, global growth in the number of charging stations is expected to evolve from 1 million stations in 2014 to more than 12.1 million by 2020, according to IHS Market Research. Asia and Europe have led the way, due to country-sponsored deployment strategies. China, for example, has committed to implement a network of 4 million charging stations by 2020. The German government has a stated goal of replacing internal combustion vehicles with EVs by 2023. Such a goal, of course, would require an extensive charging support infrastructure that is open, convenient, easy to use and provides an optimal customer experience. The U.S., which has more EV automobiles than any other country, is currently pursuing an approach that relies on local

municipalities and EV manufacturers as well as private businesses.

Growth of this magnitude is sure to incentivize innovation in the design of charging stations and accelerate the deployment of a comprehensive EV support infrastructure.



EV charger types

You'll find charging stations installed in a number of settings: private garages associated with residential homes, public parking lots adjacent to a restaurant or office building, or commercial outlets like a convenience store. Currently, the Society of Automotive Engineers (SAE) defines three different levels of EVSE:

- **Level 1** EVSE uses a standard AC line current in the U.S., or single-phase 120 V at 12 to 16 A elsewhere. AC-to-DC power conversion takes place in the vehicle. These relatively inexpensive stations will recharge a completely discharged EV battery with a capacity of 24 kWh in approximately 17 hours.
- **Level 2** stations are based on a similar technology as Level 1, but can accept a more powerful 208 V–240 V polyphase input line at 15 A–80 A. This reduces the charge time for a completely drained battery to eight hours.
- **Level 3** differs from Level 1 and 2 in that AC-to-DC power conversion takes place in the charging station, so it's possible to supply a high-voltage DC line to the battery to shorten

the charging time. As a result, the cost of a Level 3 station is significantly greater. They can supply anywhere from 300 V–600 V at a maximum of 400 A. The approximate charging time will be around 30 minutes. Unlike Levels 1 and 2, which are more typical of residential installations where EVs recharge overnight, the more expensive Level 3 fast DC charging stations are usually found in public, shared settings.

Given the limitations and lower costs of Level 1 and 2 stations, some regions have devised novel approaches to EVSE deployment. One Asian country, where electric scooters are quite popular, has created a scooter battery exchange program. Instead of waiting for a battery to recharge, users exchange a depleted battery for one that is fully charged at local convenience stores. A smartphone app lets riders know where and when charged batteries are available.

What goes into a charging station?

With the exception of AC-to-DC power conversion in fast DC charging stations, most EV charging stations comprise identical or similar subsystems.

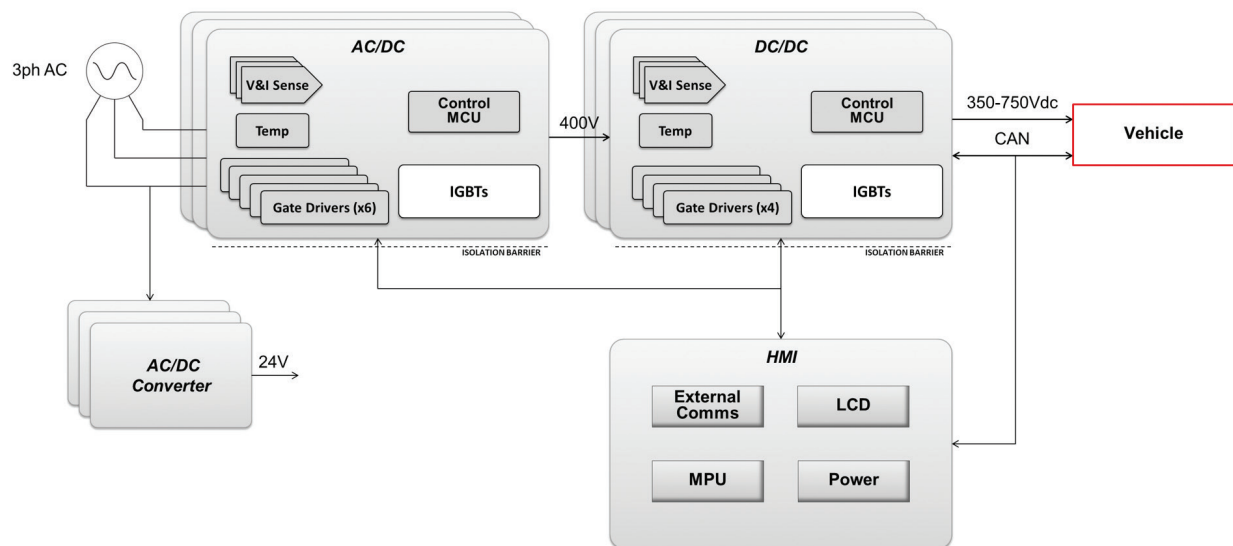


Figure 1. AC and DC EVSE system block diagram.

In addition to the power stage, the architecture is usually made up of some sort of central processing unit (CPU) such as a microcontroller (MCU) or microprocessor, communication subsystems for both internal data exchange and external communications, and a human machine interface (HMI). Some CPUs in the more sophisticated charging stations are multicore devices that may include a digital signal processing (DSP) core. In the short term, it may be acceptable for the user interface of a home charging system to be quite simple, but that may evolve as consumers expect more data or feedback about their car, battery and charging experience. For high-end charging stations in public or commercial areas, the graphical HMI is mandatory in order to convey information effectively, handle secure payment and enable greater operational interaction with end users.

Power stage

Efficiency in converting the AC power of the grid into the DC power that charges an EV battery is one of the most critical aspects of a charging station's power stage. Consequently, it's important to select the most effective conversion topology for a charging station's typical use case. For high-end Level 3 fast DC charging systems, topologies

include switched-mode rectifiers, Vienna rectifiers, interleaved power factor correction (PFC) or boost converters with continuous conduction mode (CCM). Another consideration is how quickly power can be drawn from the grid and transferred into the battery, which typically dictates implementing a three-phase approach to power conversion.

In many cases, the topology for fast Level 3 EVSE is a three-phase Vienna rectifier approach. Vienna rectifiers are found in telecommunications power supplies, uninterruptable power supplies and AC-drive converter systems. This type of rectifier is a unidirectional, three-phase pulse-width modulation (PWM) rectifier. When compared to a boost-type PWM rectifier, the Vienna topology is more power-efficient by a factor of two and has a less complex control scheme. In some instances, the efficiency of a Vienna rectifier has been verified at greater than 98 percent.

User interface

The user interface on a particular charging station could be as simple as several LED lights or a full-blown graphical touchscreen.

The former interface may be more appropriate for simpler charging units (such as those intended for residential garages). But as time goes on, end users

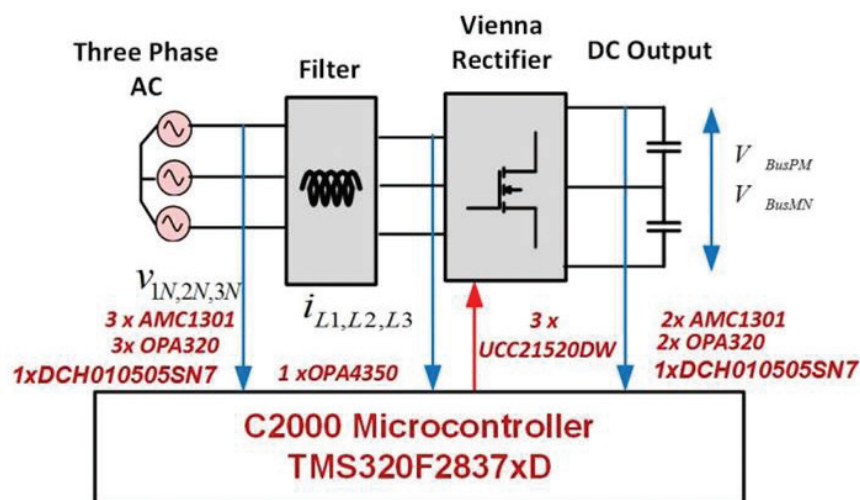


Figure 2. Vienna rectifier block diagram.

will expect more information, data and analytics about their battery and charging experience.

The latter interface—a full-blown touchscreen—will surely become more prevalent with the introduction of sophisticated fast charging stations as the result of the build-out of a public commercial EV support infrastructure. One very important piece of this build-out is the need for secure payment from different payment systems. The touchscreen could even evolve to having advanced video and graphics and digital signage displays while fast charge cycles conclude.

When implementing a graphical HMI, consider what type of processor will operate the subsystem. The scalable performance of some multicore processors not only meets the HMI needs of fast charging stations but also enables subsystem enhancement as new features and functionality are required. Of course, capacitive touchscreens have almost become the standard way to interact with consumers. Future features and functionality might involve a credit card reader, a billing system or a video feed for advertisements. Some technology suppliers provide an entire line of processors so that system designers can select the device that provides the right kind of performance today, yet be assured of easily scalable upward performance, with very little impact from a software and hardware design perspective.

The programmability of the HMI processor and the software development tools that accompany it are vital for simplifying the development of an effective graphical touchscreen interface. Some multicore processors include graphic accelerators and pre-programmed touchscreen features that significantly shorten development cycles.

Of course, [security](#) is a constant concern for practically all electronic systems, and the user interface can be a particularly vulnerable point of attack. Strong hardware-based security features

are practically essential to safeguard a system's intellectual property (IP), as well as financial information exchanged during transactions at a payment terminal.

Processor

As charging stations scale upward from the very simple to the complex, the need for higher-performance MCUs or processors to control and manage concurrently executing processes and subsystems becomes abundantly apparent. In particular, fast DC charging stations rely on racks of many power modules, which aggregate their power outputs to deliver a fast charge to the battery. A station might comprise as many as 30 10-kW power modules, for example. Each module would likely require one or more MCUs, interfacing with each other and with the station's main MCU or CPU. In this distributed and hierarchical processing environment, the MCUs and CPUs must closely coordinate with each other to deliver the amount of power needed to [recharge the battery quickly without overcharging or damaging it](#). To avoid safety issues like a faulty battery cell or a runaway charging condition requires close monitoring of the entire charging process.

Multicore MCUs made up of one or more general-purpose reduced instruction set computing (RISC) cores, as well as DSP cores with faster compute-intensive real-time processing capabilities, are often the most effective alternative to ensure that a system can react in a matter of microseconds and prevent any damage to either the charging station or the EV. Some of the more advanced MCUs integrate high-performance analog-to-digital converters, which are essential for effectively monitoring a control loop.

Communications subsystem

Although both wired and wireless communications can play several roles in charging stations and the

EVSE infrastructure in general, wireless technologies such as Wi-Fi®, *Bluetooth*®, zigbee, near field communication (NFC), 6LoWPAN and Sub-1 GHz have several key advantages that will likely accelerate their future deployment.

At a basic level, a charging station must be able to communicate with the vehicle before the charging process can even begin. For starters, it must verify the presence of an electrical receptacle on the EV that is compatible with the plug on the charging station. The EV must communicate the type of battery and its condition so that the charging station will know how to proceed. The battery capacity of EVs currently on the market varies greatly, from 6 kWh all the way up to 100 kWh or more. The charging station must also ascertain the potential capacity of each cell within the battery in order to optimize the charging process.

Currently, much of the information needed to initialize the charging process is communicated via a wired communications link using the Controller Area Network (CAN) protocol, but there is no reason why this could not be a wireless link. In fact, there are many good reasons why wireless connectivity should replace wired communications. For example, you could use NFC to communicate this information. As the driver moves the plug closer to the vehicle, NFC could communicate the type of plug it is to the charging station and confirm its compatibility with the receptacle on the vehicle. No matter the communication interface, Texas Instruments (TI) solutions support both wired and wireless approaches.

Any number of wireless communication protocols such as Wi-Fi or Bluetooth low energy could then communicate the characteristics of the battery to the charging station. In fact, Wi-Fi or Bluetooth low energy would have a decided cost advantage, since a wired communication network has to use expensive isolator devices to act as a barrier

between the high-voltage segment of the system and the low-voltage communications network. With wireless connectivity, no such isolation device would be necessary.

Besides the bill-of-materials (BOM), the widespread adoption of Wi-Fi, Bluetooth, zigbee and other technologies in smartphones, residential networking, home automation systems, smart power grids and other applications means that one or more wireless technologies could enable future enhancements to charging stations and the EVSE infrastructure. For example, a driver's smartphone might connect to a charging station via Bluetooth to facilitate the billing process. Or a charging station in a residential garage could connect to a home automation system via Wi-Fi and the home's electrical meter via zigbee. As a result, the charging station might delay the charging process until the middle of the night when utility rates are lower or when the home's use of electricity is at a low point. Users could receive updates about the progress of the charging process through their home automation system. Moreover, home automation systems might be able to automatically switch a home's power sources from the grid to the EV's battery when a power outage occurs. Wireless communications could form the backbone for these and other new features and functions that will surely emerge.

Charging station designers should also consider the security of every wireless communication channel, equipping and supporting any wireless interface chip with the strongest security tools, including strong encryption, secure storage and a totally secure boot process.

EV charging solutions

Texas Instruments is currently a major supplier to the emerging EV and EVSE infrastructure markets. TI already has a lengthy track record as a committed supplier to the automotive industry. Because of

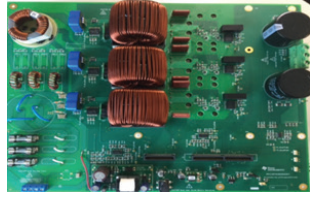


Figure 3. TIDM-1000 3 Phase Vienna Rectifier.

the longevity of the availability of its devices, their rugged reliability and durability, and thorough technical support, TI has become one of the leading technology suppliers to the automotive industry.

C2000™ MCUs, for example, represent a complete line of 32-bit microcontrollers that manage and control the various processes and subsystems functioning in an EV charging station. In fact, many C2000 MCUs, with their integrated analog-to-digital converters (ADCs), and advanced pulse width modulator (PWM) hardware have already been extensively adopted in a number of EVs as a crucial control processor in battery-management applications. Its 32-bit C28x DSP cores give C2000 MCUs versatility, powerful processing performance and heavyweight mathematical capabilities to

control a charging process involving three-phase rectifiers in real time while ensuring equipment safety. In power-conversion applications, C2000 MCUs are one of the most power-efficient and low-loss devices in the industry.

As one of the most popular processors for industrial HMI applications, the Sitara™ AM335x processor, as well as the rest of the Sitara processor system-on-chip (SoC) device family, not only has the resources targeted for processing a charging station's user interface, but the AM335x processor's easy-to-use programming tools and portfolio of on-chip capabilities give designers a head start on EVSE development projects. The AM335x processor has already been adopted as the standard HMI processor for EVSE in a major Asian country.

Based on an ARM® Cortex®-A8 processing core, Sitara AM335x SoCs feature a dual-core programmable real-time unit (PRU) as well as 3-D graphics accelerator. The scalable Sitara processor family also offers options for additional performance and features, such as the Cortex-A9-based AM43x

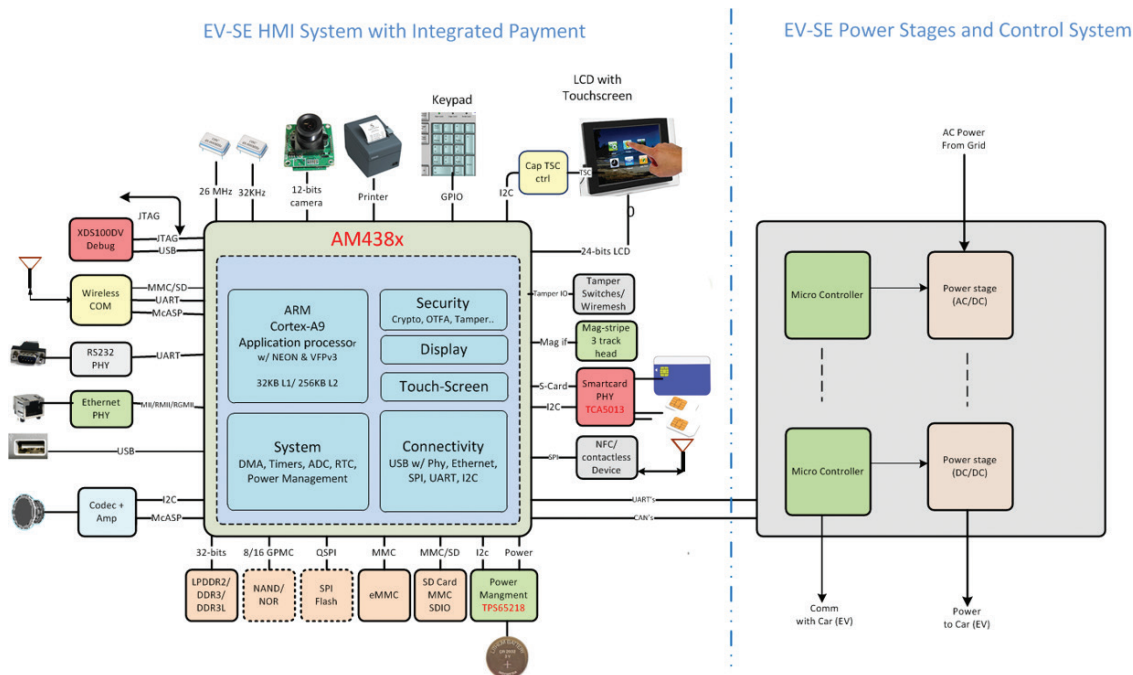


Figure 4. Sitara™ AM438x HMI system with integrated payment for EVSE.

processor with secure boot and integrated point-of-sale security, and the Cortex-A15-based AM57x processor with high-definition video capabilities. This gives you the assurance that over time, you can easily add new features and functionalities to a charging station's HMI subsystem without exhausting the processor's capabilities. For example, a charging station's HMI and billing system can easily be integrated into an AM43x-based solution thereby simplifying design, enhancing security and reducing overall BOM cost.

As we noted previously, multiple wireless communication technologies are dominating charging stations and the EVSE infrastructure. Wi-Fi, Bluetooth, zigbee, NFC, 6LoWPAN, Sub-1 GHz and other wireless technologies will all play their own roles. TI has one of the broadest portfolios of wireless solutions capable of meeting these needs.

In addition to high-performance, easy-to-design single-protocol devices, TI's portfolio includes many wireless MCUs that support multiple wireless technologies. For example, the SimpleLink™ ultra-low power wireless MCU portfolio supports a host of wireless protocols in the 2.4-GHz radio frequency (RF) band. The SimpleLink CC2630 device supports 6LoWPAN and zigbee, while the SimpleLink CC2640R2F wireless MCU supports Bluetooth low energy. Other SimpleLink devices like the CC1310 wireless MCU provide Sub-1 GHz connectivity, while the CC1350 wireless MCU connects to both Sub-1 GHz and Bluetooth low energy.

Devices in the WiLink™ 8 family of wireless connectivity chips include an integrated RF front end for both the 2.4-GHz and 5-GHz bands. This family supports Wi-Fi, Bluetooth classic and Bluetooth low energy protocols. The CC32xx family of Wi-Fi devices supports 802.11 b/g/n and is capable of 100-Mbps speeds.

TI designed its SimpleLink and WiLink chips and modules to ease the integration process so that product developers need not be RF experts to include wireless connectivity in their designs. All of the necessary resources, including the wireless protocols, are already integrated on-chip to simplify and shorten development cycles. Some of the modules that feature a wireless interface device also integrate an antenna and other resources to form a complete ready-to-implement wireless communications subsystem.

Given the presence of multiple wireless interfaces on charging stations and throughout the EVSE infrastructure, security must be a constant concern. All of TI's processors have a comprehensive suite of security tools and capabilities, including secure boot, a fast authentication process running on security co-processors, secure storage for cryptographic keys and other capabilities. In addition, wireless connectivity chips have

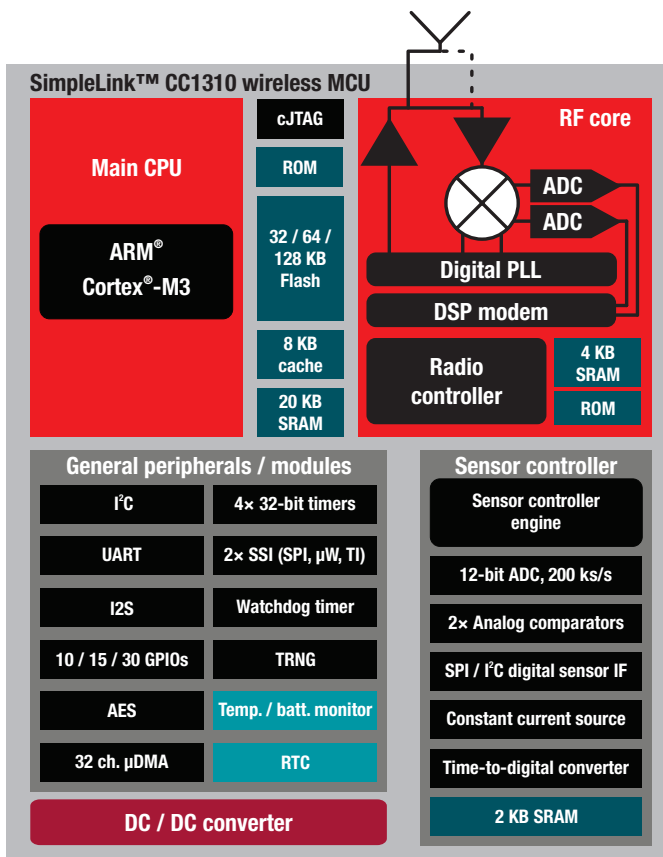


Figure 5. Block diagram of SimpleLink CC1310 wireless MCU.

implemented best-in-class security features such as Wi-Fi-protected access 2 (WPA2) and setup (WPS) on WiLink 8 devices.

Conclusion

Although EVs have been available for some time now, their limitations and the absence of a full-blown support infrastructure have discouraged some potential users. Both factors are being addressed and will be overcome. The mileage range of EVs on a single charge is increasing, and more and more charging stations are being installed at strategic locations.

Even so, there's still a long way to go before a complete charging infrastructure is in place. Experts predict that the number of charging stations deployed will mushroom dramatically over the next decade, creating a rare opportunity for charging equipment suppliers. Partnering with a technology supplier that has extensive experience in the automotive and EV industries, as well as a

comprehensive portfolio of technologies, is a first step in the right direction.

For more information

For more information on TI's charging station and EVSE solutions, visit the [EV Charging Infrastructure](#) pages.

To learn more about C2000's charging stations and EVSE offerings, visit TI's MCU [Electronic Vehicles](#) pages.

Read about how TI has also joined [CharIN](#) to drive innovation in the rapidly expanding electric vehicle charging market.

To learn more about Sitara Processors for EVSE charging stations, please visit [TI's Sitara Processors](#) webpage.

To learn more about the Capacitive Touchscreen Display Reference Design, please visit <http://www.ti.com/tool/TIDEP0015>.

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