# Tackling the challenges of electric vehicle fast charging

White Paper
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Infineon

## Abstract

In this white paper we explore the growing electric vehicle market and the demands it is placing on society to deliver battery-charging solutions that, as far as possible, emulate the ease of refueling that consumers and businesses experience today. The standards around electric vehicle chargers are explored along with the approaches and topologies that are gaining momentum in this unique application space. The experience of Infineon with existing system architectures, from power conversion to payment systems and security, are reviewed. This is then underpinned with an examination of a range of electronic components, evaluation systems and supporting software that will be crucial to the implementation of electric vehicle charging systems for years to come.

## Introduction

With the number of battery electric vehicles (BEV) models on the market steadily growing, and pressure from governments to drive vehicle emissions down to zero, BEVs are gaining traction. One of the biggest complaints about BEVs has been their range when compared to internal combustion (IC) engine vehicles. The large majority of available BEVs achieve ranges of around 160 km (100 miles) which is more than enough to cover the average daily commute, which often lies at around 10 to 20 kilometers [Reference 2, 3 & 4].

The car is, however, not a single activity transport tool. The daily commute is often combined with the school run, taking the kids to after-school activities, and a quick trip to the supermarket. Once all of these extras are considered, the charge level of such EVs lies uncomfortably close to empty for some consumers. And, unlike their IC counterparts, they cannot be simply fully refueled in a few minutes. Contemplating a longer journey, interspersed with stops for recharging, is simply not a tenable option.

Fueling of vehicles needs to take on a completely new approach. Our current concept, driving to, or stopping at, a refueling station, will remain relevant but perhaps only on longer journeys. It is more likely that charging of EVs will be undertaken while parked at our employers, while shopping, or at transport hubs, ensuring that the vehicle is ready for our onward journey.

## Charging options today

Most vehicles provide support for charging via a standard household single-phase alternating current (AC) supply, providing all consumers with the ability to charge their vehicle overnight at home. AC charging solutions range from simply connecting the vehicle to a household power outlet, to an in-cable control and protection device (IC-CPD), a small box that is integrated between the power outlet and the vehicle. Some solutions may be housed in a wall-mounted fixture known commonly as a “wall-box” charger. These often feature a communication element between power unit and vehicle, with grounding and protection contained inside.

Of course, the batteries themselves require a direct current (DC) supply for charging, and the conversion from AC to DC has to occur in charging electronics built into the vehicle. Design constraints, including space, cooling, efficiency and weight, all play a factor here which limits the amount of power that can be delivered during charging and, therefore, how quickly the battery can be charged.

The obvious way forward is to provide off-board universal DC chargers that can deliver power for a wide range of vehicles, potentially negating the need to include an AC/DC converter within the vehicle at all.

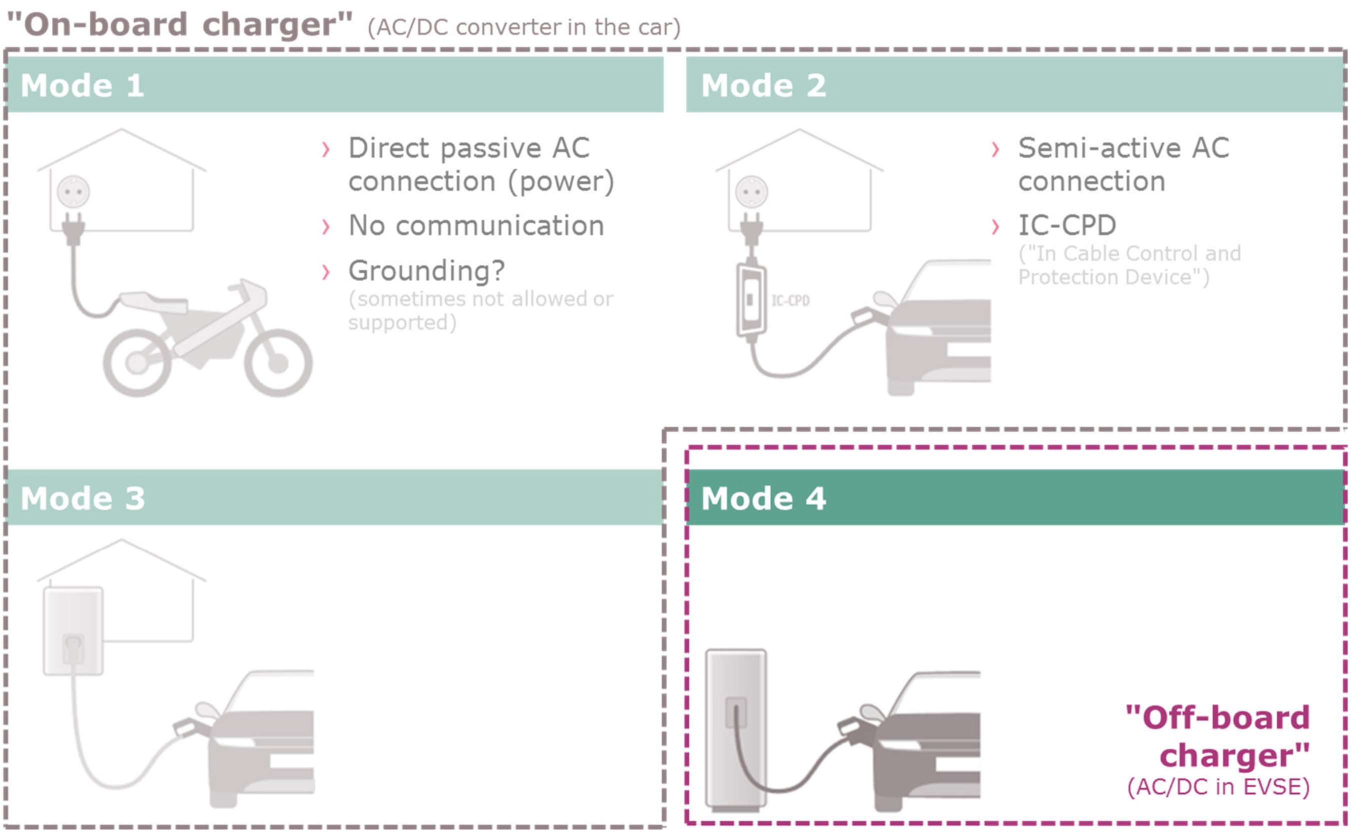



Figure 1: Various charging options for electric vehicles

The advent of such large battery capacity being spread across countries has given rise to a range of forward-thinking concepts, integrating these power sources into our daily power needs. Some consider leveraging these as part of a solar-power strategy, with homes and commercial buildings using renewable energy sources to charge EVs while making the power available again in the event of power outages or to flatten peak demand. This Vehicle-to-Building (V2B) approach has been tested in Detroit, USA, with a fleet of bi-directional Fiat 500e EVs [Reference URL 11].

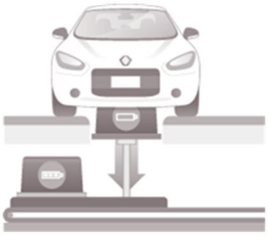
This idea is stretched even further to consider power needs at a national level, levelling out power demands in conjunction with a broader move to renewable energy with Vehicle-to-Grid (V2G) implementations. In the Netherlands, V2G has been trialed in collaboration with the Mitsubishi OUTLAND PHEV, a vehicle that stores as much energy as is used daily by the average household [Reference URL 13]. Such ideas place considerable extra demands on charging solutions, as they not only need to provide efficient AC/DC conversion, but must additionally perform DC/AC conversion to feed back into the grid. Charging standards reflect both the needs of V2B and V2G but there is limited clarity on the precise implementation nationally or internationally.

Other options, such as swapping out used batteries for charged batteries, do not seem to have gained wide support. However, in specific markets, such as India, there is traction in this solution, with solutions for 2 and 3-wheeled vehicles and busses [Reference 5 & 6].

**Inductive charging**

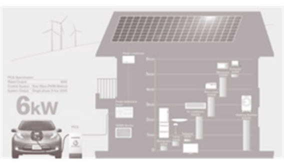
- Wireless energy transfer
- Inefficient, reactive power
- Position important

**Battery swapping**



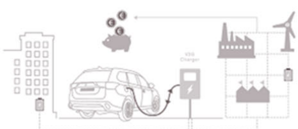
- Replace empty battery with a full one
- Customer does not need to wait

**Vehicle to building**




- Combination with Solar
- Backup

**Vehicle to grid**



- Peak load levelling
- Buffer for renewables

Figure 2: Alternative approaches to charging

Inductive charging remains the panacea, allowing vehicles to be charged by means of energy passed from a coil in the ground of a parking space to a coil integrated into the vehicle. While this method of charging has seen uptake for mobile handsets, the losses incurred along with alignment demands between the coils, coupled with the amount of power to be transferred, is relegating this approach to special cases currently.

## Fast DC charging architecture

If the convenience of IC vehicle refueling is to be replicated for EV users, considerable quantities of power needs to be made available at recharging stations. Typical 22 kW charging solutions provide AC charging, delivering enough energy for a further 200 km in around 120 minutes, making it ideal for the vehicle parked all day while its owner is at work. However, reducing the 200 km charging time to 16 minutes requires recourse to a 150 kW DC charging station. At 350 kW, the same amount of charge can be provided in close to the time spent today at a gas station – around 7 minutes. It should be noted that these faster charging times also rely on the vehicle's battery supporting such charging approaches.

This is the ultimate goal of fast DC chargers, which are now largely standardized in their architecture as are the range of output voltages and power transfer to be supported. The input supply is assumed to lie between 300 Vac and 400 Vac, which is converted via an AC/DC and DC/DC convertor to the DC voltage required by the attached vehicle. A channel for data transfer is also implemented. This provides information about the vehicle and the battery's charge state. The vehicle information and owner data can then be used as part of the final element, a secure data channel to handle billing.

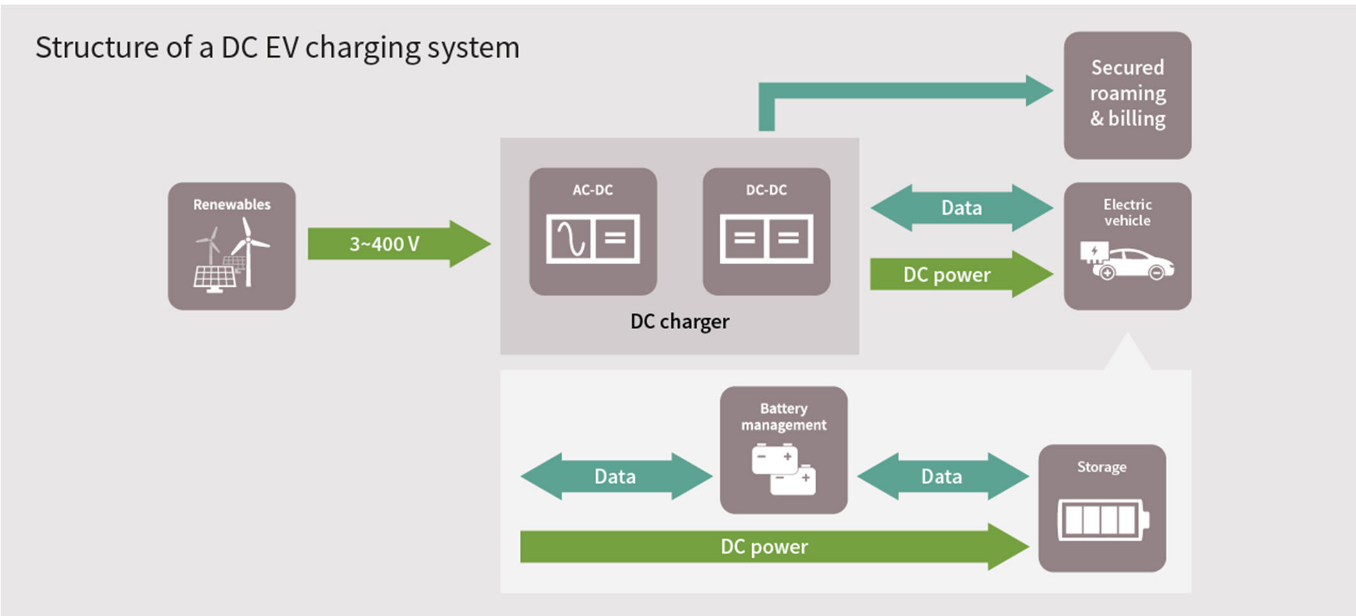



Figure 3: Basic structure of the charging system

An upper charging power of 350 kW is currently defined, although the majority of current implementations are limited to around 50 kW. The power connector definition accommodates this future power draw, supporting up to 1000 Vdc at 200 A.

For home use, power draw is limited by the local infrastructure. Despite the availability of two or three-phase supplies, a wall box charger will not support more than 22 kW of power. However, in environments prepared for the inclusion of large-scale EV charging, such as car parks and highway service areas, we can expect to find complete charging parks. Medium-voltage isolated transformers of 10 – 30 kV will supply high-power chargers, each capable of supplying up to 350 kW of power with the intention to ultra-fast charge multiple vehicles at full power simultaneously. With the isolation in the transformer, the power circuitry is simplified, and overall efficiency is improved.

Charging stations on the other hand will be most likely found in multi-story or shopping-center car parks. The charging points, similar in style and size to a gas pump, will be dimensioned to provide up to 150 kW of power. However, with power being drawn from a 3-phase low-voltage grid connection, not all chargers will be able to operate at full power simultaneously.

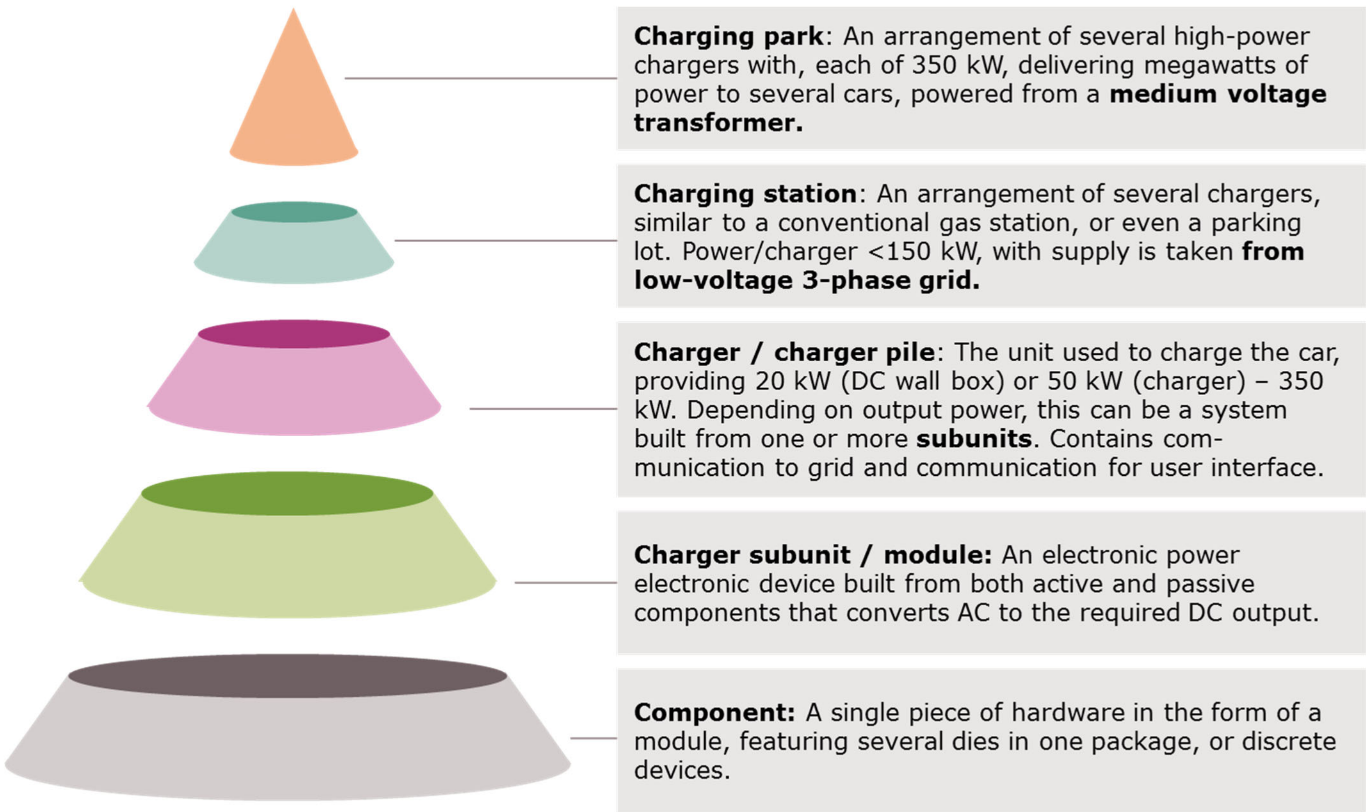



Figure 4: Overview of the DC-charging ecosystem

The charging points themselves are often defined as either a wall box or a charging pile, an upright unit as described above. The implementation of these could be anything from a single charging subunit, to multiple subunits that enable upgrading to higher charging powers as demand and need change in the coming years.

The charger subunits, often misleadingly referred to as modules, currently provide AC to DC conversion at powers of 15 kW to 20 kW. These are stacked to increase overall power available from the charging pile. With demand for higher charging speeds expanding, the trend toward using subunits dimensioned at around 50 kW or more each has already begun. The subunits themselves are constructed with a combination of discrete components or power modules, depending largely on the design specification to be achieved.

## Building upon standardization

Changing the energy source for vehicles has impact across a range of industries, involving new players that have hitherto had little or no interaction with the automotive industry. The exception here is the vehicle OEMs who have long had a relationship with the semiconductor industry, and are also in a position to provide the link to some of other players in this developing market.

Just as today, where vehicle OEMs are not operating their own refueling stations, they are not expected to focus on delivering the charging infrastructure side of EVs. This will be left to charger manufacturers who already have experience in developing power-management solutions for similar applications. These will be installed and managed by charge-point operators who will be looking to select the most energy efficient and cost optimized solutions. Their back-ends will manage demand forecasting for better energy pricing, and handle the secure payment mechanism. The final piece of the jigsaw are the energy providers whose support is required to ensure that the huge infrastructure projects come to fruition that will ensure the electricity grid delivers energy to where it is needed.

Standardization around the charging piles themselves has been undertaken to ensure consumers have a safe, simple, and, above all, universal means of charging their vehicles. In Europe and the US, interested parties, including Infineon, have coalesced around CharIN e. V., a group dedicated to developing and promoting the Combined Charging System (CCS). Their specification defines everything from the charging sequence and data communication, to the types of plug implemented. Similar organizations have also been established promoting alternatives such as CHAdeMO in Japan and GB/T in China, while Tesla has its own proprietary system.

The CharIN standard, which supports both AC and DC charging in a single connector, has been ratified with both national and international standards agencies. The AC charging complies with IEC 61851 section 1 and 22, while DC charging is covered by section 1 and 23. For the plugs and socket outlets, IEC 62196 should be referenced with Part 2 covering the Type 2 AC connector and Part 3 the Combo 2 DC connector (EU), and Part 1 the Combo 1 connector (US).

## Approaching fast charging

Battery charging can be approached as a constant-current application without the need to accommodate overload situations. Typical battery charging is implemented at ¼ C in constant-current (CC) mode, where C defines the charge or discharge rate of the battery over one hour. For around 80% of the charge process, the current remains constant, while the voltage applied rises steadily until it reaches the battery's Vmax. This takes around 4 hours for a 200 Ah battery pack. From this point onward, the battery is charged in constant-voltage (CV) mode.

Fast charging requires that the battery is charged at a rate of 2 C for an initial period of 20 minutes, followed by a phase at 1 C for 10 minutes, concluding at ½ C for a further 4 minutes. For a 200-Ah battery pack, the 80% charge level would be achieved within 34 minutes, equivalent to a range of around 300 km.

There are, however, several limitations to DC fast charging. Firstly, it is limited by the battery technology used. On top of this, the arrangement of the battery, its thermal management implementation, and the cell interconnects must also be considered.

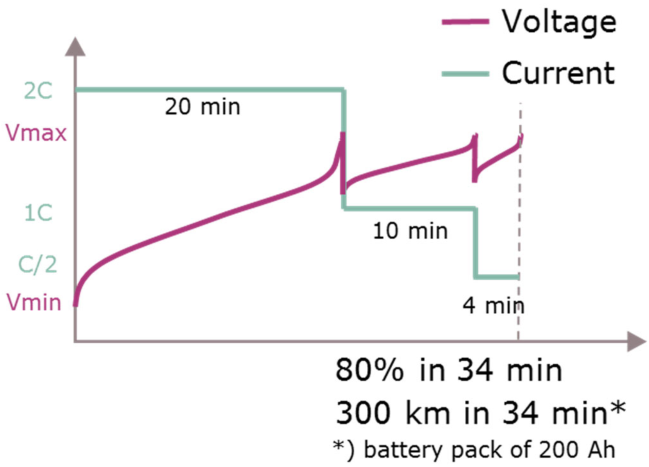



Figure 5: Typical fast charging profile

On the charger side, the CharIN specification envisages a maximum constant-current output of 500 A at 700 Vdc, with support up to 920 Vdc. This also requires that the battery system has some mechanism in place to handle the degradation associated with fast charging, along with insulation for up to 1000 Vdc. Efficiency of the final solution should be better than 95%, although this will rise to 98% in the future. It must not be forgotten that, at 300 kW, a 1% loss in efficiency is equivalent to 3 kW. Cables also contribute a loss of around 100 W per meter at a full load of 500 A.

The impact of power cycling is relatively low compared to other power applications. Thermal cycling is considered to have little to no impact in private installations, although it is a considerable challenge in the design of public charging stations. These could see private vehicles charged up to 5,000 times per year for 10 – 15 years of service, while chargers for public transport, such as busses, may see 30,000 cycles over 15 – 20 years of service.

## The architecture of a fast DC charger

The approach to high-power DC charger design primarily follows two basic approaches. One approach converts an incoming 3-phase AC supply into a variable DC output that feeds a DC/DC converter. The precise DC voltage is defined after communication with the vehicle. The alternative approach is to convert the incoming AC supply to a fixed DC output. This is then converted to the voltage required by the vehicle by the DC/DC converter. Both approaches are considered equally valid in this application with no overriding advantage or disadvantage in either. Rather than focus on the approach, the primary concerns are how the implementation minimizes the cooling effort required, delivers a high-power density, and reduces overall system size.

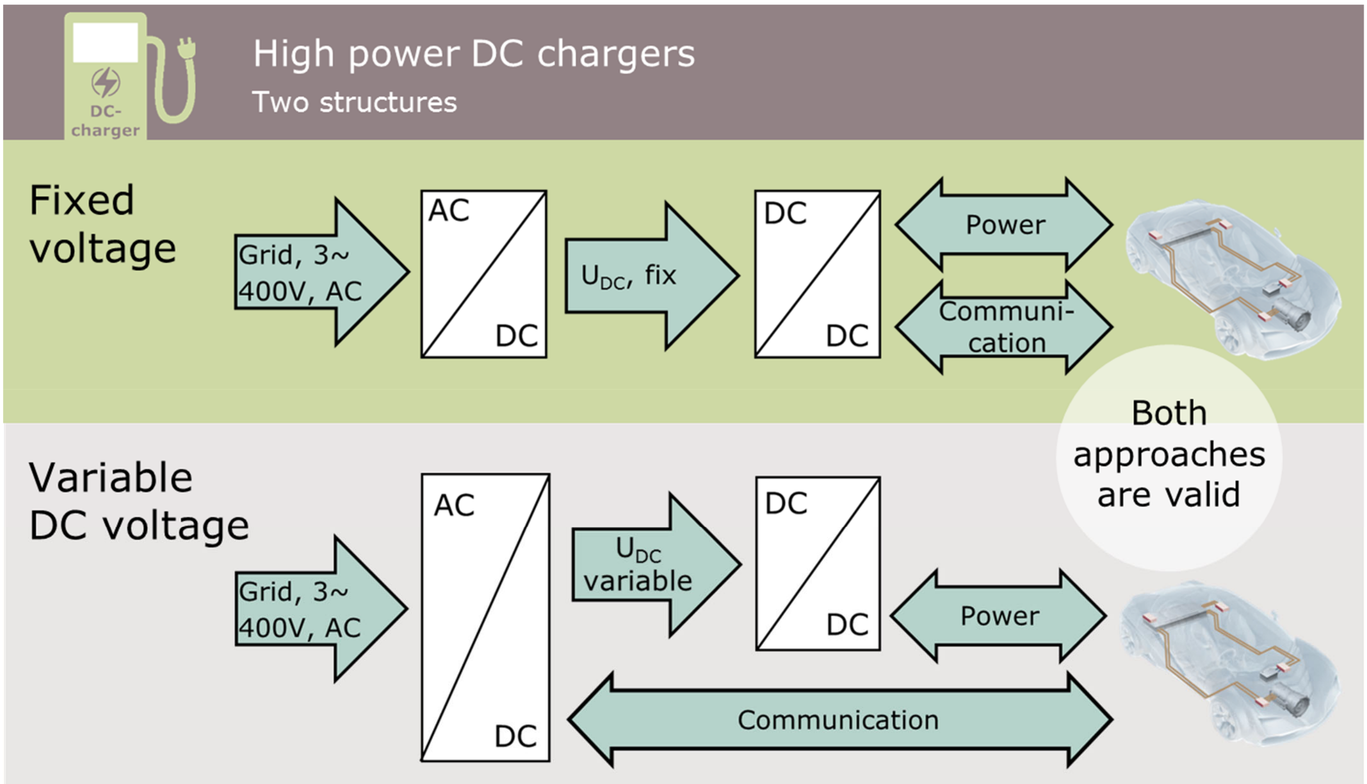



Figure 6: Block diagrams for two potential high-power DC charger approaches

High-power density demands that forced air cooling, the standard today, has to be implemented. However, next generation charging solutions are looking at liquid cooling solutions. Compact solutions necessarily need to consider higher switching speeds, in the range of 32 kHz to 100 kHz, to reduce the size of magnetic components.

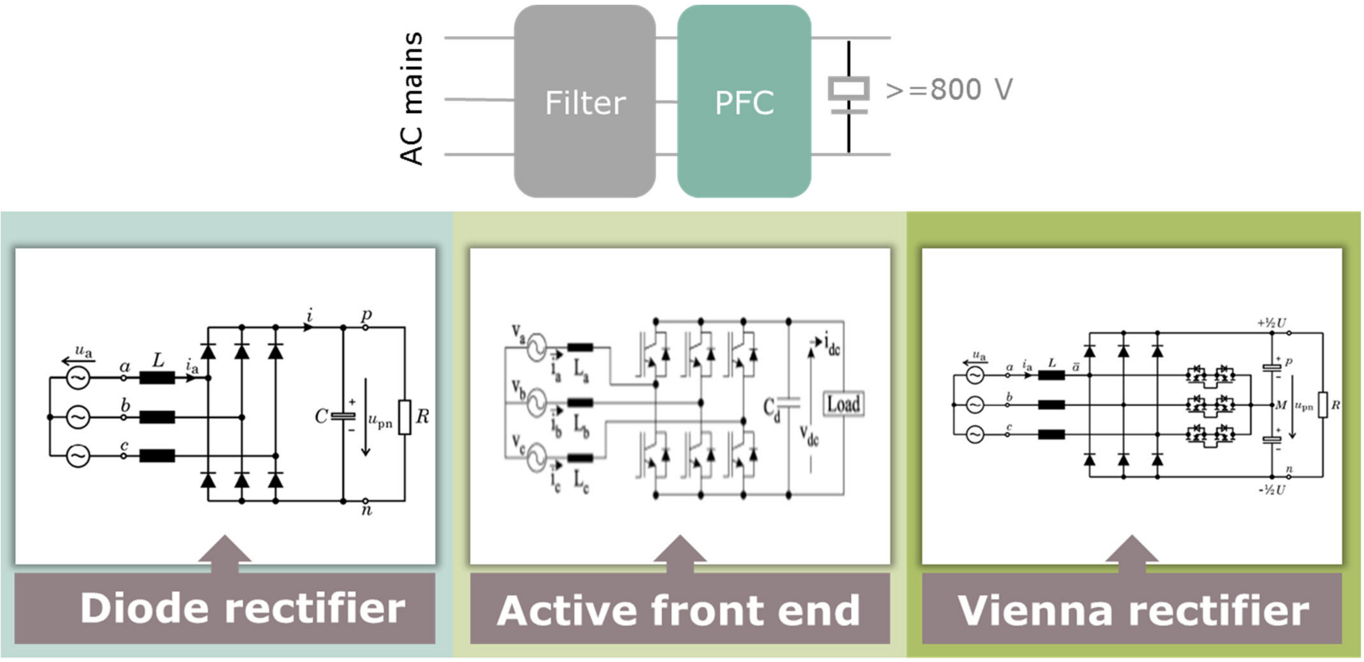



Figure 7: Rectifier and PFC options for the AC/DC converter

The simplest and most cost-effective approach to AC/DC conversion is a diode rectifier. However, this simplicity leaves designers with a fixed output voltage dependent on the local 3-phase supply voltage provided, together with an unfavorable total harmonic distortion (THD). The line current harmonic distortion can be improved upon through the implementation of a multi-pulse rectifier, but requires a more complex transformer and additional rectification diodes to implement.

A 3-phase active front end (AFE) tackles the issue of THD by providing a sine-shaped input current while offering a variable DC output voltage to the following stage. To accommodate the additional complexity, an isolated power supply is required for the gate drivers as well as filters at the inputs. However, the topology is well documented and understood, making it a proven solution suitable for this application.

Perhaps less well established, but increasingly popular, is the Vienna rectifier. This is a 3-phase, three level PWM rectifier requiring only three active switches, with a dual boost-type power factor correction (PFC). The output voltage can be controlled, and it remains operational even in the event of unbalanced mains or the loss of one phase. It is also robust since, in the event of a malfunction of the control circuit, there is no short circuit of the output or the front end. As with the AFE, the input current is sinusoidal, with various implementations being shown to achieve a power factor of up to 0.997, THDs of below 5%, and efficiencies of 97% or better.

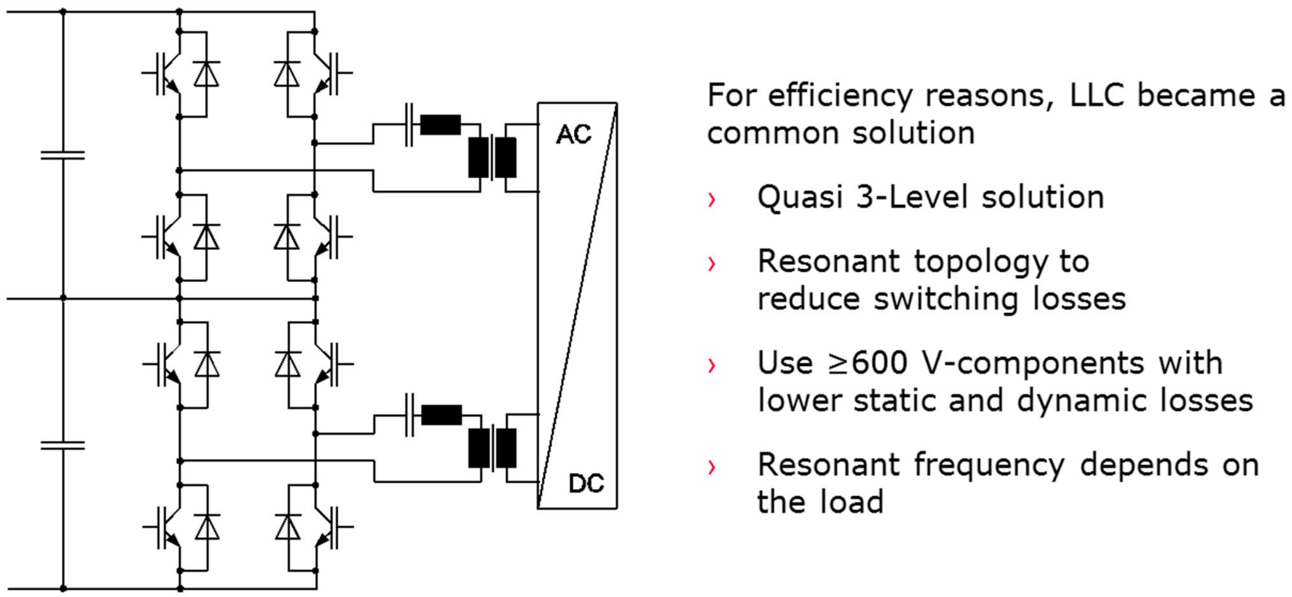



Figure 8: DC/DC conversion is primarily implemented with a series-parallel LLC resonant converter

In the DC/DC conversion stage, resonant topologies are often preferred due to their efficiency. When required by the overall implementation, the galvanic isolation can be implemented here. This design fulfils demand for higher power density and smaller volume, especially with the primary-side inductor integrated into the transformer. The zero-voltage switching (ZVS) reduces switching losses and contributes to overall higher system efficiency.

For grid-isolated architectures, multi-interleaved buck converters are the DC/DC topology of choice. This has the advantage of load sharing across phases, reduced ripple and filter size, but at the cost of a larger number of components.

## Approaches to fast DC charger implementation

The market in China is currently the most mature for fast DC charging, with a penetration of 80% (compared to 15% in EMEA and just 5% in the Americas). Here solutions of 15 kW and under are most prevalent, but it is expected that 20 kW will be the dominant subunit option by 2020, with significant numbers of 30 kW and 60+ kW units being shipped by 2023. This reflects the trend toward 350 kW high power charging. Infineon's broad portfolio of silicon solutions, coupled with years of system experience and understanding, means our teams are well placed to support engineers working on fast DC charging solutions. This starts at the power side, with power devices, power modules and gate driver ICs, along with microcontroller solutions programmed to attain every last percentage point of efficiency from the resulting application. Finally, trusted authentication solutions and security controllers are available for secure billing and system security.

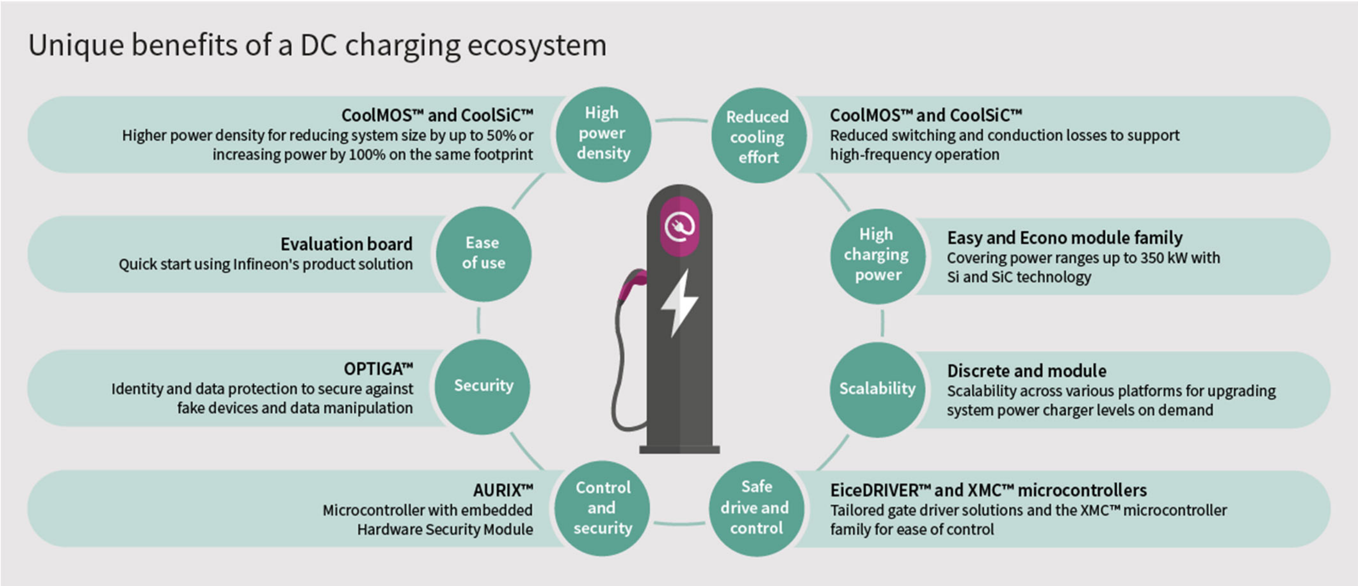



Figure 9: Infineon's offering for DC EV Charging designs

The recommended approach depends upon the total power output being targeted, as well as influencing the topology and manner of construction of the subunit. For wall-units and charging piles of 30 kW and below, discrete power devices are recommended, while at 350 kW power modules are advocated for the implementation. Between 50 and 150 kW the choice between using discrete power components or power module will need to be determined based upon environmental factors, space and price.

## Solutions for efficiently reaching 30 kW to 150 kW

It is common to build a fast charger using 15 kW to 30 kW subunits, then stack them to create a 150 kW EV charging solution. For 15 to 30 kW subunit and charger implementations based upon discrete devices, the Vienna rectifier is chosen for the PFC stage switching at 40 kHz. Assuming a 3-phase, 380 V / 50 Hz supply for an air-cooled system, a combination of TRENCHSTOP™ 5 IGBTs, coupled with CoolSiC™ Schottky diodes make for a good combination for solutions targeting cost-sensitive applications. The utilization of silicon carbide (SiC) diodes contributes around 0.8% efficiency improvements compared to traditional Si diodes, while also supporting 80% of more power output. Replacing the IGBTs with 600 V CoolMOS™ P7 SJ MOSFETs can contribute around a 0.5% efficiency improvement.

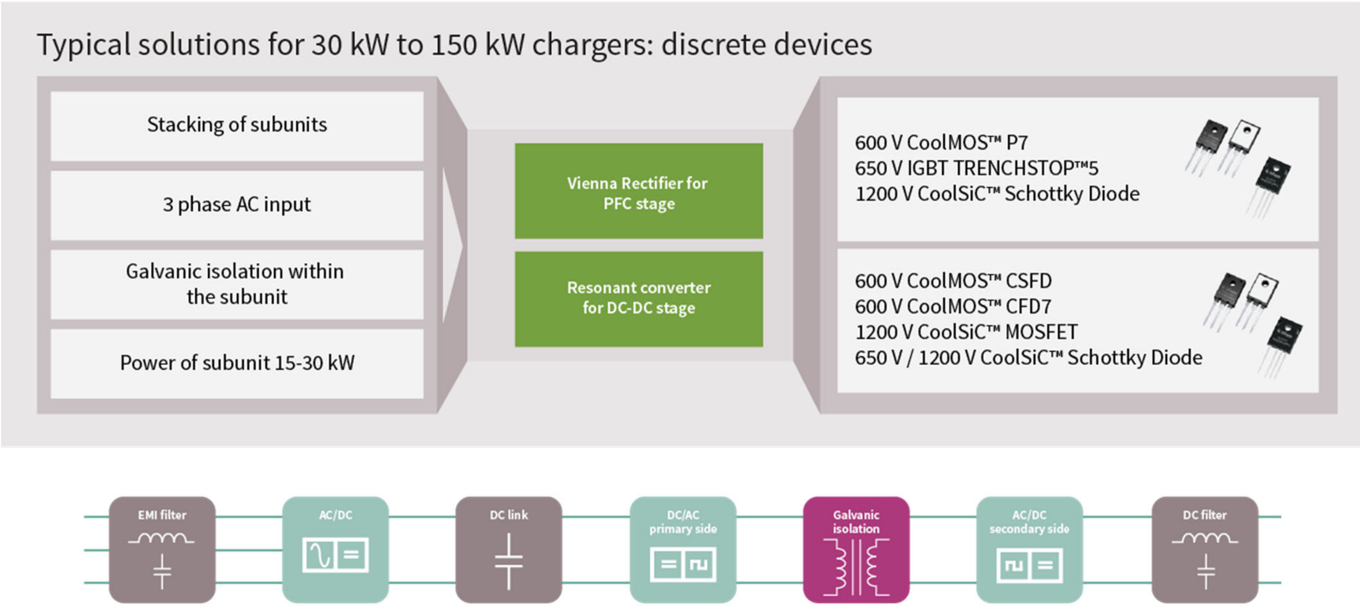



Figure 10: Typical topology for a charger made of discrete devices

For the DC/DC converter, a resonant converter is typically used for switching at up to 300 kHz and delivering 200 V to 700 V to match the charging voltage of the battery. Here the 600 V CoolMOS™ CSFD or, for an RDS(on) below 30 mΩ, the 600 V CoolMOS™ CFD7 MOSFETs, with their high-voltage super-junction technology, integrated fast body diode, coupled with CoolSiC Schottky diodes, achieve a respectable efficiency. However, when targeting highest efficiencies, a review of the CoolSiC™ MOSFET portfolio is advisable.

## Solutions for efficiently reaching 50 kW to 350 kW

When developing subunits that can be combined or upgraded to provide fast DC charging or chargers at the top end of the spectrum, a solution based upon power modules is recommend. At this power level, liquid cooling is preferred, although air cooling remains a possibility. The Vienna rectifier is implemented using CoolSiC™ Easy 2B modules with a switching frequency of 40 kHz. The DC/DC section leverages an interleaved 3-phase or multiphase buck converter, switching at up to 300 kHz. Here a combination of CoolSiC™ Easy 1B modules combined with discrete CoolSiC™ diodes make for a highly efficient combination.

The CoolSiC™ family offers the F3L15MR12WM1_B69, a Vienna rectifier topology device in its Easy 2B package. With an RDS(ON) of 15 mΩ, the devices provide high power density in a package that simplifies design implementation. The isolation gel-filled ceramic devices have a low capacitance and their switching losses are independent of temperature. Half-bridge topologies are available in both the Easy 2B and smaller Easy 1B packages, featuring RDS(ON) values as low as 6 mΩ.

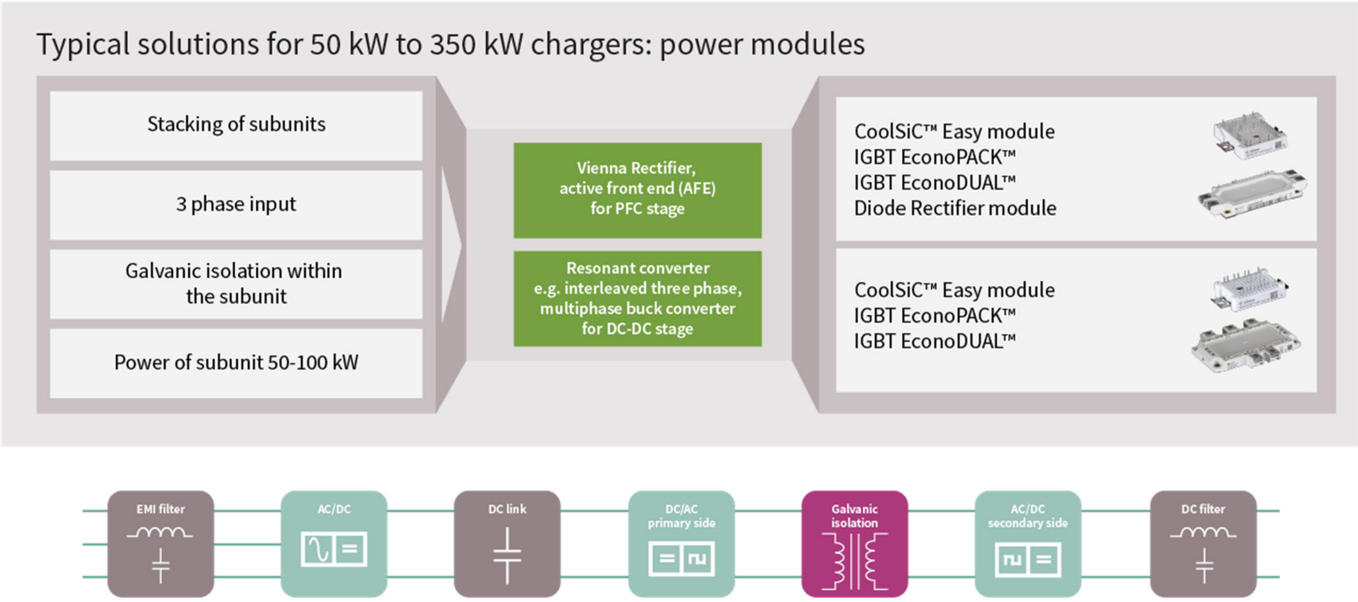



Figure 11: Typical topology for a charger made of module devices

A solution based upon IGBT technology is using EconoPACK™ 4 modules, coupled with an EconoBRIDGE™ silicon rectifier module. The EconoPACK™ 4 features robust injection-molded and ultrasonic-welded screw terminals, along with their PressFIT control pins for completely solderless connections.

## Selecting drivers and implementing control

Having selected the power components, the next step is to consider the gate drivers required. Here a portfolio of devices is offered to match the selected Si or SiC components in use. A range of isolation technologies are also provided, from junction isolation and silicon-on-insulator through to coreless transformer for galvanic isolation.

Drivers from the 1EDi EiceDRIVER™ compact family offer galvanically isolated single-channel solutions, supporting up to 1200 V input-to-input isolation. Their wide operating voltage of 3 to 17 V ensures that they can be interfaced with a range of control circuitry, such as microcontrollers, without recourse to any signal adaption. Rail-to-rail output of up to 6 A is supported, all built into a DSO-8 300-mil wide package option with 8 mm creepage distance. Two-channel devices are also available in the 2EDi family. Features such as two-level turn-off and soft turn-on simplify combating EMI challenges, while a range of protection features guarantee robustness.

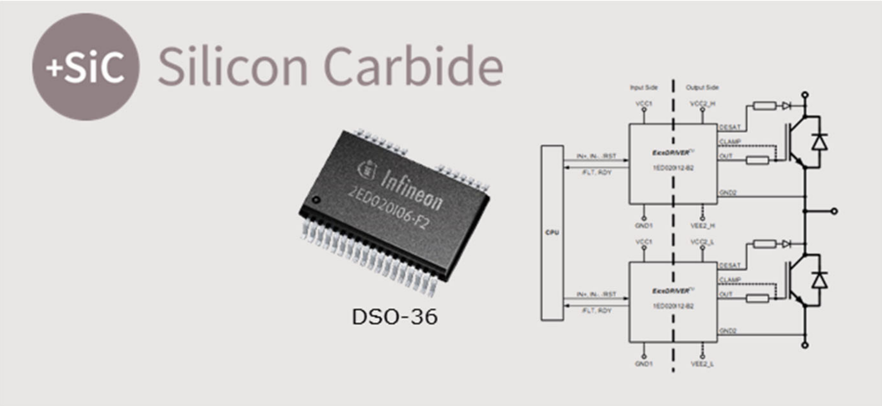



Figure 12: EiceDRIVER solutions

Microcontrollers form a fundamental part of completing the design of a power subunit. Intelligence is required in order to ensure communication with the BEV being charged, as well as intra-subunit communication for fast charging stacks. Finally, the control algorithm implementations used can be essential in providing sub-percentage point improvements in conversion efficiencies. As already highlighted, this translates into potential energy savings of several hundred watts per charging pile.

The XMC 4000 series of microcontrollers (MCU) have an impressive pedigree in industrial applications where deterministic control is of utmost importance. Pin-to-pin and software compatibility across the family offer flexibility when looking to increase functionality or optimize costs. Leveraging the Arm® Cortex®-M4, operating at up to 144 MHz, the family provides up to 2 MB of flash memory along with up to 352 kB of SRAM. They also include a wide range of communication interfaces, including up to 6 CAN peripherals.

Accurate analogue peripherals, such as analogue-to-digital converters (ADC), couple tightly with a comprehensive range of timers and flexible pulse-width modulation (PWM) modules, some of which offer a resolution of 150 ps. These are essential to support power topologies such as high-frequency LLCs, and simplify peak current control modes through integrated slope compensation, blanking, filtering and clamping circuitry.

Designed for challenging environments, the devices can operate at up to 125°C and are offered in a range of innovative packages. To ensure that customers have access to the devices over the entire lifetime of their products, the XMC 4000 range are included in the Infineon long-term availability program. To round off the offering, they are supported by the DAVE™ integrated development environment (IDE) and a range of DAVE™ apps that are built upon the XMC™ lib low-level drivers. Just like the hardware, the development software also comes with long-term support.

For more demanding applications, or applications where security or functional safety plays a key role, the AURIX™ family provides a natural alternative. This robust and reliable family of multicore MCUs, which scale from single to multicore options, can operate in ambient temperatures of up to 150°C and are regularly chosen for ASIL-D and SIL3 safety-relevant applications. Safety is supported in hardware by a range of mechanisms, including the use of lockstep cores, redundant peripherals, memory protection, and clock monitoring, to name just a few. The packaging of these devices is designed to be highly scalable, allowing designers to move easily to MCUs with more features when required. Like all Infineon MCUs, the AURIX™ range also offers long-term availability.

Operating at up to 300 MHz and featuring up to 6 MB of flash memory, these MCUs offer a range of high-speed interfaces, including CAN-FD and Ethernet. The direct memory access (DMA) is capable of operating without the CPU, leaving more performance available for the application code. The control of power conversion algorithms is supported by a 12-bit ADC sampling at up to 5 Msps, coupled with timer peripherals that provide a flexible range of pulse-width modulated (PWM) control outputs.

Finally, security is ensured by a Hardware Security Module (HSM) that provides an anchor of trust thanks to being in a separated logical protection domain. Supported by its own 32-bit MCU it offers secure boot, secure storage of encryption and authentication keys, an AIS31-compliant true random number generator (TRNG), along with hardware acceleration for symmetric and asymmetric cryptography.

## Implementing trust for payments and upgrades

Charging solutions are interconnected collections of smaller modules that are bound to cloud-connected services, which range from load balancing by utilities to payment services by banks. Security is, therefore, at the very center of the design solution. In addition to securing cloud-based services, application updates or power-stage control improvements may be developed that can be distributed as SOTA (software over the air) upgrades. Mutual authentication is a must to ensure that only authorized servers are allowed to distribute software patches or updates to authenticated BEV chargers. Additionally, when considering safety and system performance, hardware upgrades to a charging pile may require authentication to ensure only approved subunits and original parts are attached to the existing solution, avoiding inferior counterfeit parts. Finally, the integrity of the identity and service offering of a BEV charger can best be safeguarded with hardware security.

Implementation of such security would see the BEV charger's private keys stored as digital certificates on a discrete security controller. This, in turn, would establish an encrypted data channel for running secure data services to and from servers connected to the BEV charger. Data integrity and authentication of authorized users is essential in BEV charging, regardless of whether considering existing payment schemes or a future move to AI services and intelligent processing based upon block-chain technology.

Authenticating hardware replacements as original spare parts can be implemented using solutions from the OPTIGA™ family of embedded security solutions, such as an OPTIGA™ Trust B anti-counterfeit security chip. Housed in a tiny package with a footprint of just 1.5 x 1.1 mm, each chip features an elliptic-curve cryptography engine with user-defined keys and a true random number generator. All features are accessible via a single-wire interface (SWI) and code is available for the host MCU.

For more demanding control board integrity protection, developers can turn to the OPTIGA™ TPM trusted platform module. Compliant to the Trusted Computing Group's TPM 2.0 revision 1.38 specification, the device offers a security solution separated from the main processor for storage of critical data, such as private keys. This offers maximum protection and secures the integrity of the BEV charging unit along its entire lifecycle, offering secure in-field device provisioning to cloud-based key management services and securing data services like predictive maintenance solutions and application software updates. Also available in a small surface-mount package of just 5.0 x 5.0 mm, the device has been independently security evaluated and certified. An industrial grade version, offering extended lifetime and temperature ranges for in-field deployment of BEV chargers, will be available during the course of 2019.

## Evaluation of solutions and demonstration systems

To ease development, Infineon has developed various demonstration and evaluation systems and development tools. Specifically targeting power subunits, a 30 kW BEV charging demo board has been developed. Fitting comfortably inside a 350.5 x 400.0 x 86.2 mm housing, the demo provides a power density of 42.1 W/inch³. The air-cooled design leverages 1200 V CoolSiC™ Schottky diodes and 650 V TRENCHSTOP™ silicon IGBTs for the PFC and Vienna rectifier, and uses 1200 V CoolSiC™ MOSFETS and 650 V CoolSiC™ Schottky diodes for the DC/DC converter and half-bridge on the output. Gate drivers are sourced from the EiceDRIVER™ family.

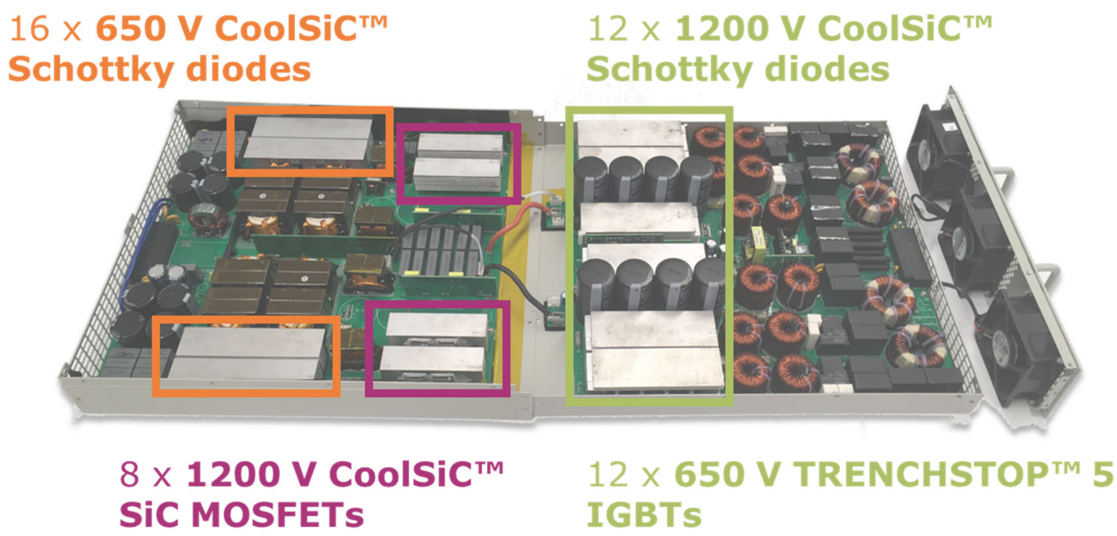



Figure 13: 30 kW fast BEV charger demonstrator

For those new to the world of silicon carbide technologies, evaluation boards are also available that enable analysis of the switching characteristics of CoolSiC™ MOSFETs contained within a buck or boost converter. They support both the discrete TO-247 3-pin and 4-pin devices as well as the Easy 1B half-bridge power modules.

Equally, the MCU offering is underpinned with the range of relax kits for the XMC4000 and starter board, and development kits for AURIX™ devices. The OPTIGA™ embedded security solutions can also be evaluated prior to selection thanks to a wide range of evaluation kits, some of which are designed to work together with the MCU development kits mentioned.

## Summary

With increasing pressure by governments and society to address the issue of rising $CO_2$ emissions, electric vehicles are now becoming a viable part of the solution. With issues of range abating, the key issue to resolve is that of battery charging that emulates the ease of fossil fuel refueling, especially for private citizens undertaking longer journeys, taxi services, and public transportation, such as busses.
A further potential benefit of the introduction of such a large quantity of battery storage is the prospect of injecting some of this energy back into our energy grid to level out spikes in demand. The development of the fast battery charging solutions needed requires the support of partners. Infineon’s engineers and development teams understand the application challenges, have experience in the field of power electronics design, and provide a joined-up portfolio of silicon and silicon carbide devices that design engineers can use to turn their concepts and ideas into secure and robust BEV charging solutions.

## Notes and references

1. Zero emissions – slide 5

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100 miles (160 km) to 315 miles (500 km)

3. Daily commute UK - https://www.telegraph.co.uk/news/uknews/road-and-rail-transport/10724224/Workers-commuting-further-than-ever-before.html
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17km (10.5miles)

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8. Multi-pulse rectifier - https://www.irjet.net/archives/V3/i1/IRJET-V3I1181.pdf

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