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Connectivity

# The EV Charging Infrastructure Designbook: Volume 3

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# Content

# The EV Charging Infrastructure Designbook:

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**This is the third part of a series of guides for designers involved in electric vehicle (EV) charging station projects. In this part, we will consider the connectivity functions required and how these should be implemented. The following text will cover the functions needed in EV charging, as well as a review of the pros and cons of multiple wireless and wired technology options. Home wall box plus public fast charging station designs will be included – with both discrete and modular approaches being discussed.**

As the world responds to the climate crisis, the adoption of electric vehicles is accelerating quickly. While the EVs themselves might grab the headlines, the growth of the EV market also depends critically on the charging infrastructure available. The roll-out rate of charge stations and their associated infrastructure is now also rising exponentially – at around 50% year-on-year. Fast charger installations are showing the most growth. Both public and private charger networks are being installed, with government funding being allocated in many countries.

The International Energy Agency (IEA) reported nearly half a million public chargers installed in 2021 [1], and the global average in 2021 was 10 EVs per public charger and 2.4kW per EV. In Europe, the EV charging infrastructure market is expected to grow at a compound annual growth rate (CAGR) of more than 30% through to 2030, with Germany alone aiming to have a million public charge points by this date [2]. Home charger installation rates are higher still, with one prediction saying there will be 35 million globally by 2026 [3]. With prices at $600 to over $1000 each, the market for wall boxes alone is in the order of tens of billions of dollars.

While there are multiple different types of EV charger, they share a common requirement – they need to be connected to central infrastructure of some sort. This connectivity enables user authentication, charge scheduling, billing and energy use monitoring. The charger must also have some form of user interface, and may also connect to the user's smartphone.

There are many communications options available in the market, so a charge point designer needs to consider what is the best solution for their particular needs. In this design guide, we will introduce many of the factors that need to be considered. Both wired and wireless technologies will be looked at, various standards considered, and some examples given of components that can be used.

# The challenge

There are three basic types of communication to consider. First between the end user and the charge point, then between the vehicle itself and the charge point, and then between the charge point and the charging infrastructure. This link to the infrastructure could be based on communication with software running in the cloud, while the user may also use an app to connect to cloud data.

## Connectivity use cases

Why do charge points need connectivity? For a start, as part of the charging process, the vehicle exchanges data with the charging point, such as the technical details of what kind of vehicle it is, as well as the relevant billing information. Smart metering capabilities can show the user how much energy they are consuming, and how much it is costing - which can help them choose when to charge.

For the energy utility, the information from the charge point shows them how much energy is being used, and therefore how much they need to produce and supply to that location. It also enables them to correctly bill the user. In the future, 'vehicle to grid' systems will also be able to send energy from a car's battery back to the main electricity grid, with managing of this also being dependent on information from the charge point.

Another important use for connectivity is firmware and software updates - so charge point functions can be updated when needed, without human intervention on site. Additionally, charge points require load balancing, to manage the power demands on the electricity infrastructure (this will be looked at in more detail later). Also, multiple charge points at one location have to be controllable together, to make configuration and management simple.

It should be noted that charging points must communicate with their energy supplier - for example to ensure demand does not peak too suddenly (such as at the start of a time period with a cheaper charging tariff). By incentivising customers to charge at different times, the overall demand can be kept at manageable levels, and the available power resources may be shared fairly between all the EVs being charged.

Each EV charge point generates large amounts of data, estimated at around 100MB to 500MB per month [4]. This data can be used to analyse customer behaviour, enabling service improvements to then be realised.

For connectivity between the charge point and the user, we can generally assume the user has a smartphone, so they can access an app to control charging - although the charge point should provide its own user interface, for people without smartphones. The user opens the app, and can then employ it to connect to the charge point, control payments and so on. The charging point should be able to take payment using a standard credit card, as well as any options it may offer for payment via an app, or Apple or Google Pay.

## Reliability is key

To help consumers overcome 'range anxiety', it must be easy to find working charge points, which means the change points must provide up-to-date information on their status and availability [5].

For the charge point operator, reliability is paramount. If a charge point is inoperable, then they will lose revenue, and their market reputation will be put at risk. It is therefore essential that a non-operable charge point can report its status - so that action can be taken.

Reliability has been a serious issue in the past, with consumers reporting wasted journeys to out-of-action charge points, although it is acknowledged that the situation is improving. Problems with communication between a charge point and the back office systems (such as payment processing) is one of the more common causes of downtime [6], highlighting the need for reliable wired or wireless links.

EV charge point connectivity must be flexible enough to handle increases in complexity and scale, as more points start to be rolled out. Provisioning, management and monitoring has to be simple and effective, and it must be possible to detect and resolve any issues rapidly, in order to minimize downtime.

Of course, the connectivity must be secure and resilient, so as to protect against the risk of cyberattacks. Consumers need to feel confident about handing over their financial details, and any hack that takes a charge point out of action will be problematic. If not properly set up, Wi-Fi can be more vulnerable to security breaches than cellular or wired connections.


## Roles within the EV charging sector

**To give a little context, we should look briefly at the different layers and functions involved in the EV charging sector. These are as follows:**

- Charge Point Operator (CPO) - A CPO manages the charge point itself, and is the public face of the infrastructure that users interact with. It may own the location, the equipment or both. Alternatively, it may provide a 'Charging as a Service' solution.
- Electro-Mobility Service Provider (eMSP) - While a CPO may operate a network of charge points, an eMSP will facilitate consumer use of networks operated by multiple CPOs, ideally via just a single account.
- Electric Vehicle Supply Equipment (EVSE) - This is where the grid meets the vehicle. Designing, manufacturing and delivering charge point equipment is the role of EVSE suppliers. A system integrator may also be involved, to put together hardware and software from one or more EVSE suppliers. The system is likely to use modules or sub-systems, provided by specialist manufacturers, for example to handle the payment system.

# Technology options - Wireless

The first decision when considering charge point connectivity is whether to use wired, wireless or a combination. In many cases, particularly where many charge points are in one location, wireless will prove simplest. Even if a fast fibre connection is available to a charging site, running cable to each charge point may be difficult, complex and expensive too.

Standard wireless protocols will often be the best choice - cellular (4G or 5G), Wi-Fi or Bluetooth. Deploying wireless networks is quick and straightforward, with the cost and disruption of laying a new cable network avoided. In practice, providing Wi-Fi, Bluetooth and cellular is likely to be a good solution, giving the user options, and ensuring that communications are resilient.

The wireless connectivity may be implemented in different ways. It could be as simple as a cellular modem, with a standard SIM card, that is factory-installed by the EVSE supplier as part of the charge point. Alternatively, some locations need complex gateways and routers, supporting multiple charge points, with a local wireless connection to each point, and backhaul via either fibre or cellular.

While cellular is available nearly everywhere, it has the disadvantage that there are some holes in coverage, for example in an underground parking garage. Small femtocell deployments can, however, fill in these gaps. While 4G is better established, with much wider coverage, 5G has the advantage of being able to support a higher density of devices in any particular area.

Wi-Fi enables beamforming to be used, which allows the radio to focus the transmission or reception towards one particular charging station or area. By putting energy in one specific direction, the radio communication will be more stable.

Bluetooth is well developed in terms of mesh networking, and there a lot of mesh SDKs available, which OEMs can use and build with. Bluetooth modules can be employed which allow the OEM to construct their software quickly and easily, via simple AT Command programming, without requiring extensive software expertise.


***Figure 1:*** *PAN9026 wireless module*

For wireless communication between the charge point and user, Bluetooth is a familiar name for consumers, making connection with it user-friendly and accessible. Multi-radio modules, which provide both Wi-Fi and Bluetooth, can present a compact, cost-efficient solution.

For authentication of the user, at the moment this is often done by verifying the user's credit card information, which can be via NFC. Another approach is to use Bluetooth Low Energy (BLE) to validate the presence of the right user at the charging station, by identifying their smartphone – but this still can be vulnerable to being relayed, so an additional PIN number or bio-authentication is required. Appropriate security should also be implemented across all wireless technologies, such as supporting the latest WPA standards for Wi-Fi.

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## Wi-Fi and Bluetooth solutions

A dual-band Wi-Fi solution can provide more flexibility and reliability, enabling 5GHz communications to be utilised. This avoids potential congestion at 2.4GHz – as this band is also assigned to Bluetooth, other wireless technologies (such as Zigbee and Thread), and even baby monitors and microwave ovens.

For example, the PAN9026 from Panasonic is a dual-band (2.4GHz and 5GHz) combo module, providing 802.11 a/b/g/n Wi-Fi, Bluetooth Classic and BLE operation. The PAN9028 is another module in the PAN902x family, with 802.11ac capabilities for use cases where higher data rates are needed.

The modules in the PAN902x family have beamforming capabilities, and support the highest relevant security standards. They are certified for multiple regions, which simplifies roll-out in different countries. These modules each include a built-in antenna, and can also be used with an external antenna option, increasing design flexibility.

For Bluetooth-only projects, Panasonic offers the PAN178x series. This is a standalone BLE module with a mesh stack option available. It is highly optimised for low-power transmission and lower data rates.

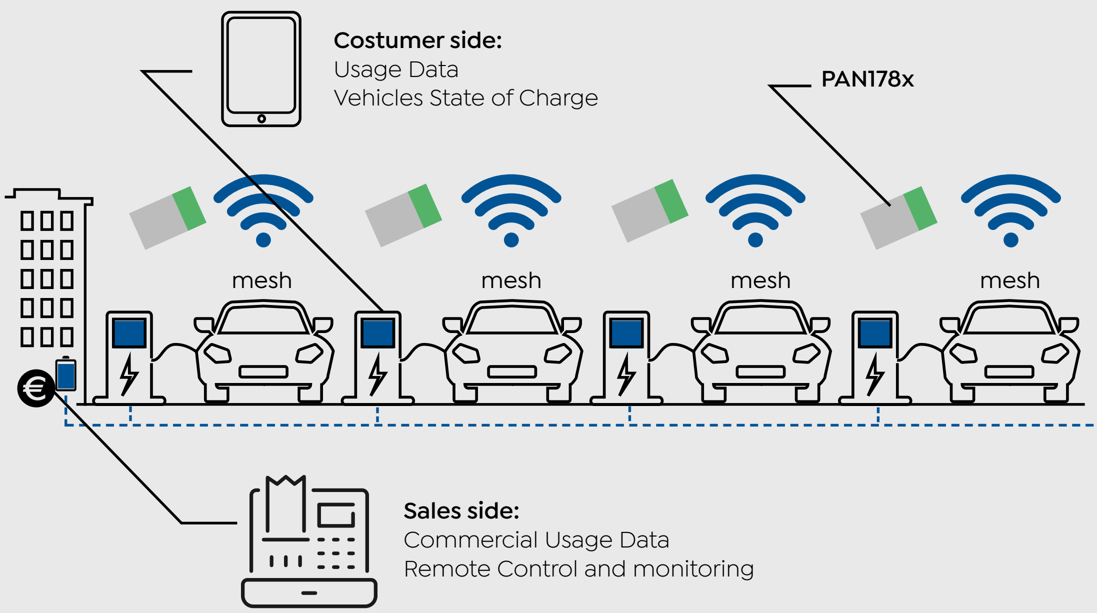


***Figure 2:*** *mesh system based on PAN178x Bluetooth module [courtesy of Panasonic]*

# Technology options - Wired

As discussed earlier, in many cases it may be simplest for the charge points to connect to their infrastructure using a wireless connection. This may be connected directly to an operator's mobile network, or a central controller at the charge point location - which then provides a fast fibre connection to the Internet.

Wired connections are essential in one role - between the vehicle and the charge point. There is a well-defined set of standard interfaces that specify all the details of this communication - for example, IEC 61851-1 includes how to communicate the maximum current of the charging station to the car. Another requirement is for safety information to be transmitted, such as ground force interruption.

The charge point needs to be able to turn a relay on and off, for instance to disconnect the power if any safety problem is detected. A driver component is required to control the relay, such as the NCV7721 or NCV7723B bridge drivers from onsemi. Using a full bridge driver, rather than just a basic half bridge, improves reliability and therefore safety.

For DC chargers, there is another standard to be aware of - IEC 15118. This has a whole software stack for High Level Communication (HLC). It is similar to HomePlug AV, and needs a dedicated software PHY.

## Modular blocks use twisted pair Ethernet

Another need for wired connectivity to address is that a charge point may be built from modular blocks connected together. onsemi can provide 25kW building blocks which can be combined together - for example, using a combination of 12 modules would give a charge point rated at 300kW.

These modules need to communicate with each other, typically using a proprietary interface of some sort. In the past, this might have relied on multiple control wires in a point-to-point arrangement. Nowadays, it is better to use a single Ethernet twisted pair cable to replace all these wires, using IP connectivity and running at 10Mbps. Through the 10BASE-T1S standard, Ethernet communication is possible without needing to use a router-based system, thus reducing the amount of hardware required. With this Ethernet connectivity in place, the modules can be interrogated from a simple external web browser for diagnostics - for example, to spot any problems such as low output voltages or an unusually high temperature.

The NCN26010 from onsemi is an example of an Ethernet controller for this type of twisted pair infrastructure. It is 10Base-T1S compliant, and has very good noise immunity. It includes power conditioning and MAC/PHY software, and can replace various wired protocols - such as HART, FieldBus, CAN, RS485, RS232 and FlexRay.

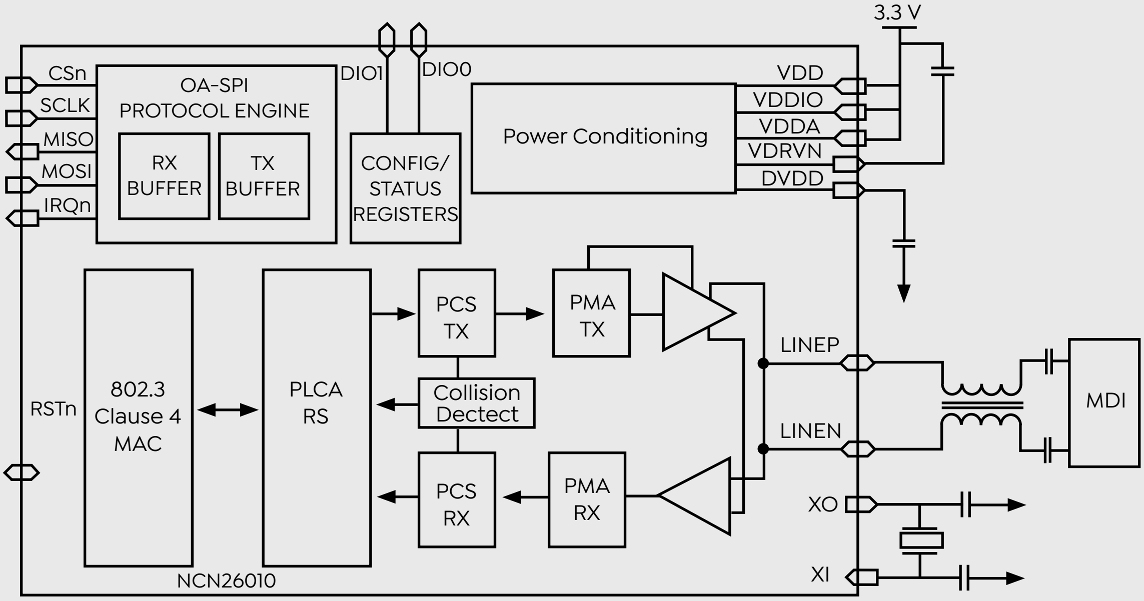


***Figure 3:*** *Functional block diagram of the NCN26010 Ethernet controller [courtesy of onsemi]*

The NCN26010 can also be used with a BLE interface, such as onsemi's RSL15. This provides a subsystem that addresses two issues for OEMs - low-cost interconnection within the charge point (so remote diagnostics capabilities can be implemented), and secondly BLE connectivity to improve security.

## Design in practice

So now, it is time to look at a couple of other practical issues that need to be considered in EV charge point designs.

### Antennas and passives

As well as the components already discussed in this guide, there are many others that must be specified. As we will see, it is not all about the digital and analogue elements. For example, in any wireless system, the antenna is important to achieve reliable connectivity, and the right multiband antenna should be selected if Bluetooth and Wi-Fi are both used at a charge point.

***Figure 4*** shows the many wireless communication systems in a modern car, and the various technologies that they use. While many of these rely on standard antennae, including the battery management system, there are others that require a custom antenna.

Designers likewise need to ensure that the relevant passives, such as capacitors, are rated for use at the necessary RF frequencies in their system. Of course, components should also be tested and qualified to the appropriate automotive standards, such as AEC-Q200. Although AEC-Q200 does not include antennae, AVX tests its automotive A-Series antennae following AEC-Q200 requirements and procedures as closely as possible.

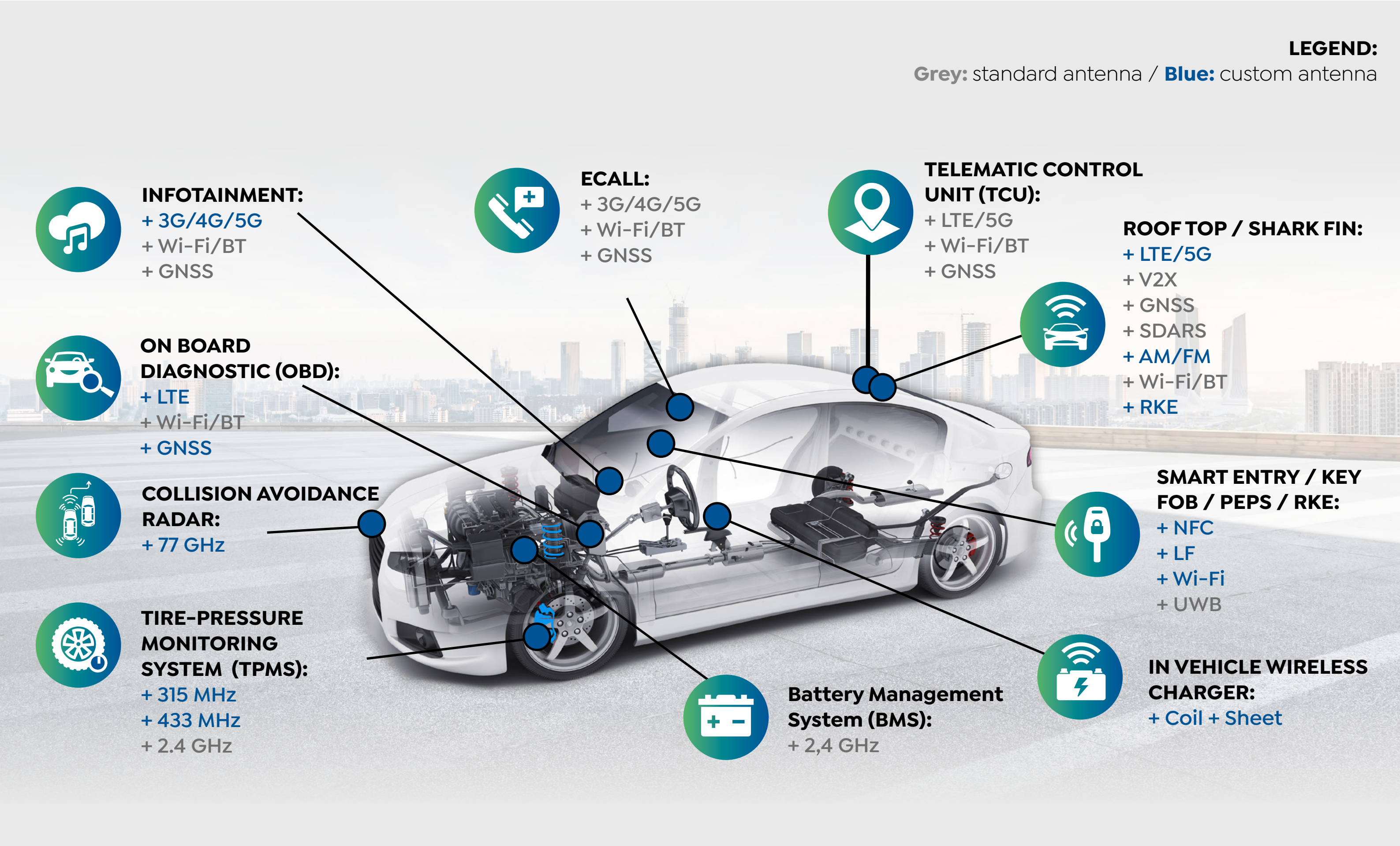


***Figure 4:*** *Antenna systems for automotive [courtesy of Kyocera AVX]*

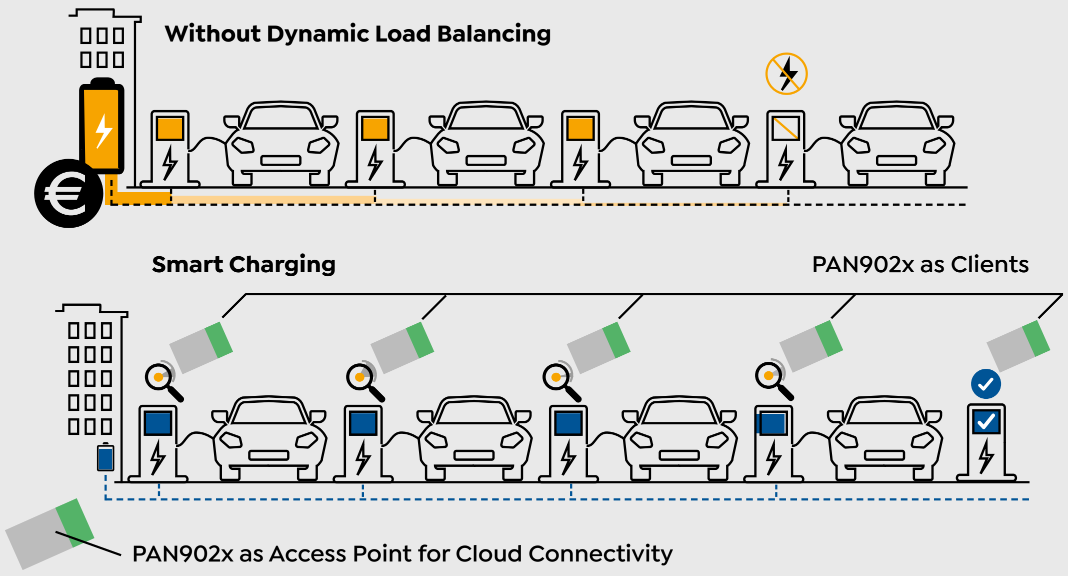


***Figure 5:*** *Load balancing using a PAN902x module as an access point [courtesy of Panasonic]*

## Load balancing

Load balancing is another use case where reliable connectivity is necessary. In a location where there are several charging stations, if multiple vehicles come in and charge at the same time, this can overload the building's capacity (see ***Figure 5***). It may also require the operator to pay more to the utility company and cause problems with the infrastructure itself.

This is where the concept of load balancing comes in. This would basically allow each vehicle to use only a certain amount of energy within the building's supply. For example, if we had 44kW of supply at a location and there were four vehicles charging at the same time, the smart charging infrastructure would allow only about 11kW to be allocated to each vehicle.

To make this possible, there must be connectivity at each charge point. Then, the central controller can dictate how much power may be used at each point so that it does not disrupt the whole building's capacity or cause any damage to the infrastructure. The ISO 15118 standard defines the information that the EV and charge point need to exchange, in order to match supply and demand of power.

## Conclusions

Looking ahead, the biggest challenge around charge points (in the near future at least) may be simply keeping up with the exponential growth of the EV market. With sales around the globe exploding, there is pressure on operators to roll-out new charge points at an ever-greater pace, while not compromising uptime or resilience. Further on, we may also see more implementation of Vehicle-to-Grid (V2G) systems - as the industry moves towards smart grid infrastructure.

The fundamental challenges will stay the same - it is essential for charge points to be highly reliable, with minimal downtime, and the ability to function for years with zero (or certainly minimal) on-site human intervention. Charge point connectivity systems need to be flexible enough to adapt to future changes, and scalable to support large roll-outs. Most importantly, they must provide a simple, consistent interface for users.

By choosing the right combination of communications technologies, and implementing them with the right components, charge point designers can ensure they meet these challenges head on - with reliable, fully-featured products that consumers will appreciate.

This guide has introduced the design elements of the connectivity required for EV charging. In other design guides, we consider the power stages of EVs, the control circuitry necessary and the related software.

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## Questions?

If you have any questions about the topics discussed in this guide, or you're ready to take the next step with your design, **reach out to our EV charging expert**s - they're some of the best in the industry.


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