Key Circuits for Electric Vehicle Charging Systems

Electric vehicles (EVs) are set to revolutionize modern mobility. Their adoption is gaining momentum globally and this is becoming evident through public infrastructure - with charging stations appearing across cities and highway routes more frequently. In fact, the growth forecasts for the EV charger market are in the 18% CAGR range for the next five years[1]. Arrow is set to play a key role in the EV revolution, supporting industry growth through its spectrum of power, control, sensing, and communication technologies for EVs and DC fast charging stations.

Let's look at how EV charging works:

EV batteries, like all other batteries, are commonly DC (Direct Current) devices and use DC power for charging and discharging. Each time a battery is plugged into a charger, the grid AC power is converted to DC to allow charging to occur. In the case of electric vehicles, it is commonly the onboard charger that converts the current from AC to DC power, in addition, it carries out other required signal conditioning so the battery can be charged. DC fast-charging stations are the exception to this as they charge the vehicle battery directly by converting the AC power before it enters the vehicle, eliminating the need for onboard power conversion. DC fast charging stations deliver several other benefits including, significantly higher current levels and faster charging times compared to AC methods.

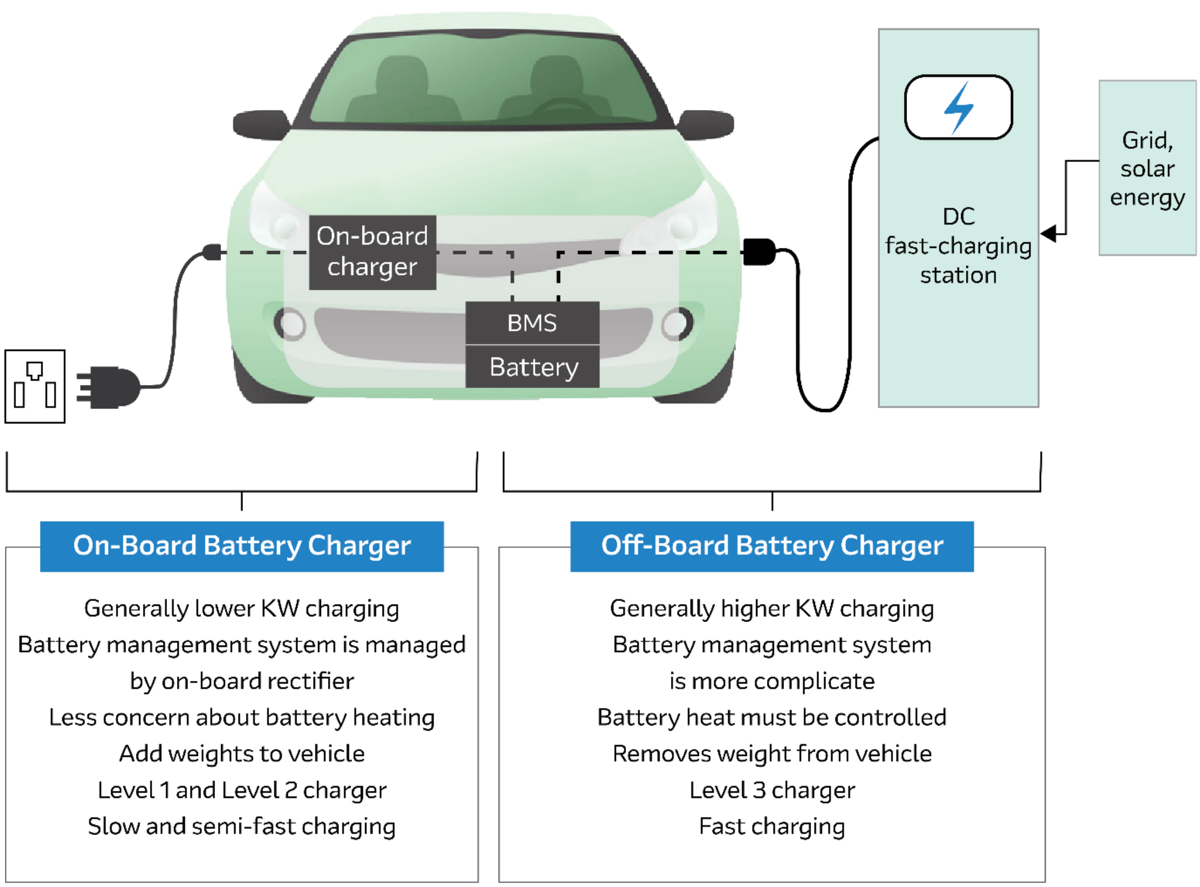

Figure 1: On-board vs. off-board charging

EV Battery Charger Levels

Just like there are various types of vehicle fuel, there are distinct electric vehicle charger levels that are determined by power intervals and time-to-recharge characteristics. As indicated in the table below, Level 1 and Level 2 battery chargers refer to onboard chargers and are confined within the vehicle. Level 1 EV chargers have the longest charging times and draw power from the grid as they plug directly into household power outlets where available. Level 2 charging takes less time to charge compared to Level 1 and is commonly found in public areas such as parking lots, grocery stores, and worksites but is also available for home charging stations. Level 1 and 2 charging work from single-phase or three-phase AC power outlets. Level 3 is the fastest level of charging available and refers to commercial DC fast charging stations. The fast charge functions at this level are shared between the charging station and the EV's onboard charger. The commonly used converter topologies in these EV charging levels include unidirectional and bidirectional isolated or non-isolated configurations.

Power level types	**Level 1**	**Level 2**	**Level 3**
Grid Voltage	120 V_{AC} (US) 230 V_{AC} (EU)	240 V_{AC} (US) 400 V_{AC} (EU)	208-600 V_{AC} or V_{DC}
Power range	≤3.7kW	3.7-22kW	>50kW
Approximately charging time	11-36 hours	1-6 hours	0.2-1 hours
Charger topology	On-board	On-board	Off-board
Grid supply type	1-phase	1-phase or 3-phase	3-phase
Charging type	Slow charge	Semi-fast charge	Fast charge
Battery capacity	15-50kW	15-50kW	15-50kW

Five Key Circuits for EV Charging Systems

To get the best mileage and efficiency out of a battery charge, EVs adopt a modular approach to drivetrain, energy storage, and conversion systems. These components function as part of the following circuit assemblies:

1. **On board charger (OBC)** is installed inside the EV to convert grid native AC power (drawn from an external power supply) to DC power to charge the vehicle's battery. OBCs can also provide power conditioning in the way of charge rate monitoring and protection. Depending on the vehicle class, charging systems with up to 22 kW loading power can be installed. The use of chargers in the vehicle places very high-quality requirements on suppliers of electronic components.

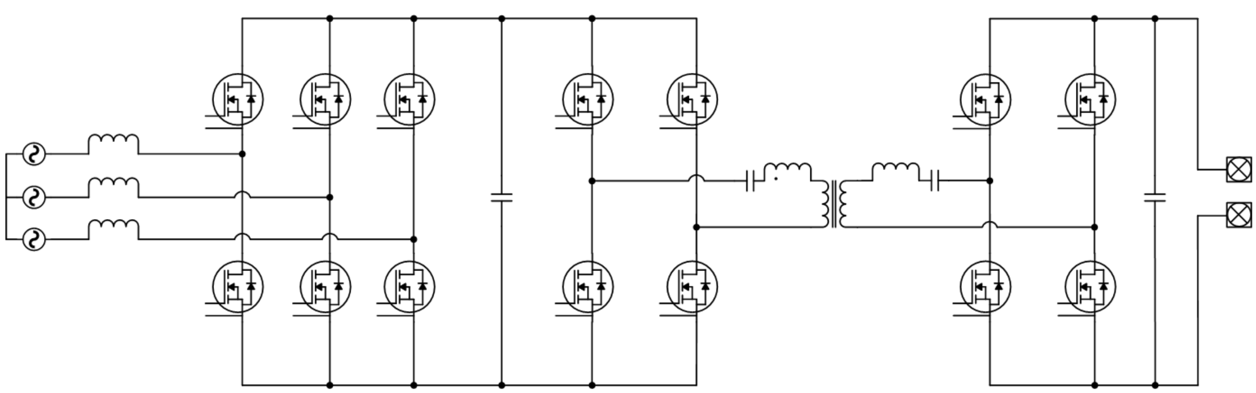

Figure 2: Higher-power bidirectional OBC designs (11 kW/22 kW)
(images source Wolfspeed)

2. **Battery management systems (BMS)** are responsible for safe, reliable battery operation including the management of charging and discharging cycles. The electric control circuits of the BMS allow it to identify, monitor, and control voltages, temperature, capacity, state of charge, power consumption, remaining battery life, charging cycles, and other parameters. The BMS is a critical EV component and is designed to communicate with various in-vehicle systems to perform real-time charge and discharge functions based on the vehicle's performance i.e sudden braking and accelerating.

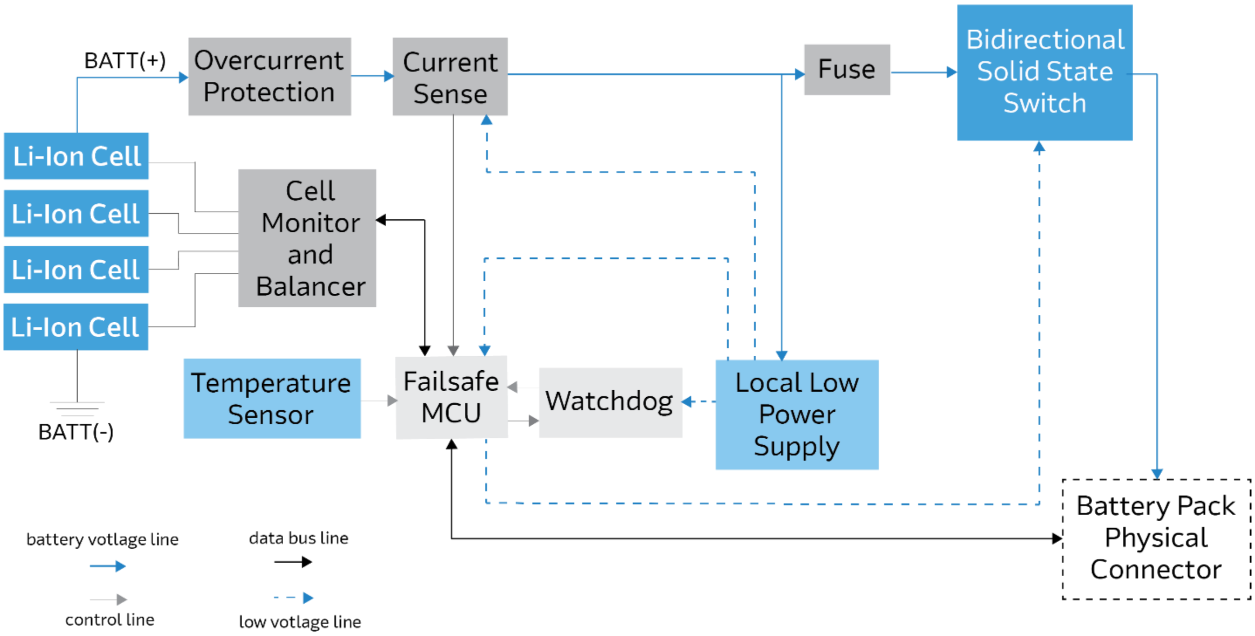

Figure 3: Battery Management System
(image source: All About Circuits)

3. **DC/DC converter** draws DC power from the battery, converts it, and adjusts the voltage level to sufficiently power the systems in demand. This conversion takes place in real-time as many of the systems function co-dependently, requiring them to work in unison to avoid failure which would prove critical. In terms of configuration, the high-voltage battery is connected to the internal 12VDC network via the DC/DC converter. The internal DC network provides power to the accessories and bias to the local switching converters.

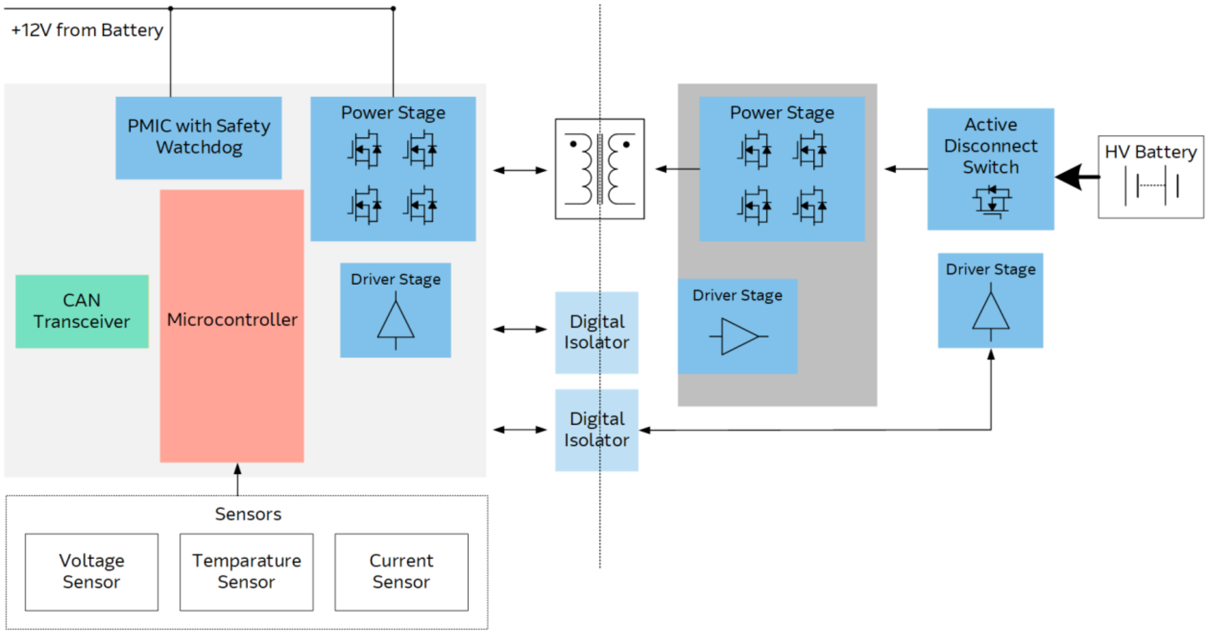

Figure 4: DC/DC converter for 12V sub-systems
(image source: Infineon)

4. **The main inverter** is designed to convert DC power to AC to drive the vehicle's electric motor. The main inverter can also gather the energy released through regenerative braking and feed it back to the battery. The traction inverter converts the high-voltage DC from the battery to the three-phase AC needed by the motor.

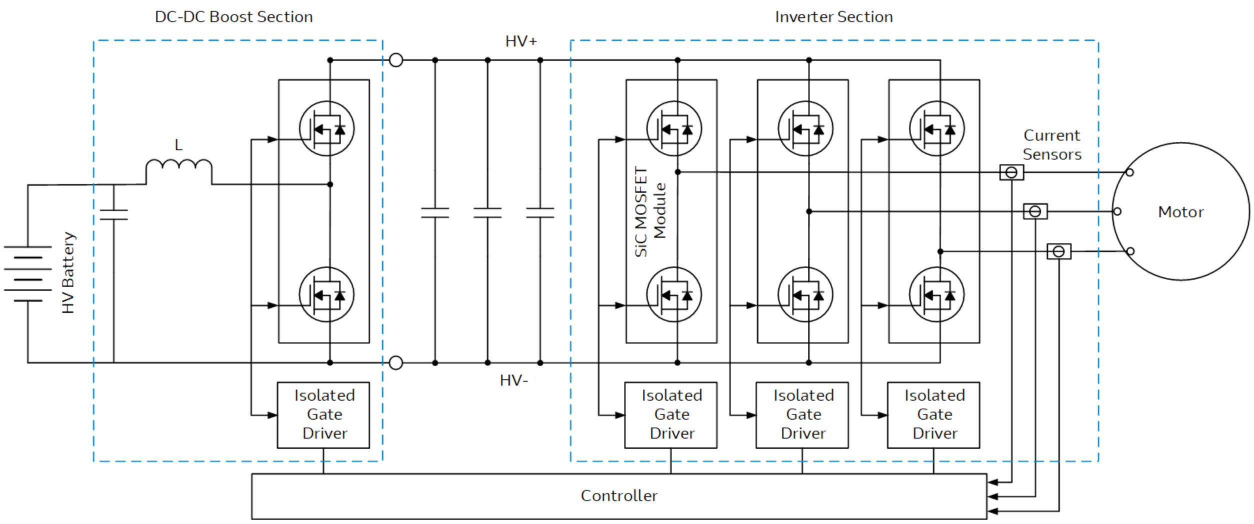

Figure 5: The 3-phase traction inverter using three SiC MOSFET-based half-bridge modules
(source: Wolfspeed)

5. **DC Fast Charging** stations deliver DC power directly to the vehicle's battery without the need for conversion via the onboard charger, greatly accelerating charge times. DC fast charging station typologies are built to address three main power categories ≤ 50 kW for city use, 150 kW for highways, and 350 kW for supercars/trucks/buses. These chargers are modular-type designs commonly made up of 20 kW subunits that are connected in series to reach higher DC power voltages. DC fast chargers are high-powered level 3 chargers

that draw on a three-phase AC power supply converting it prior to entering the vehicle. The fast-charging station controller manages the control algorithms according to the charging level. Safety measures in this method of charging are managed both directly by the charger and the battery management system (BMS).

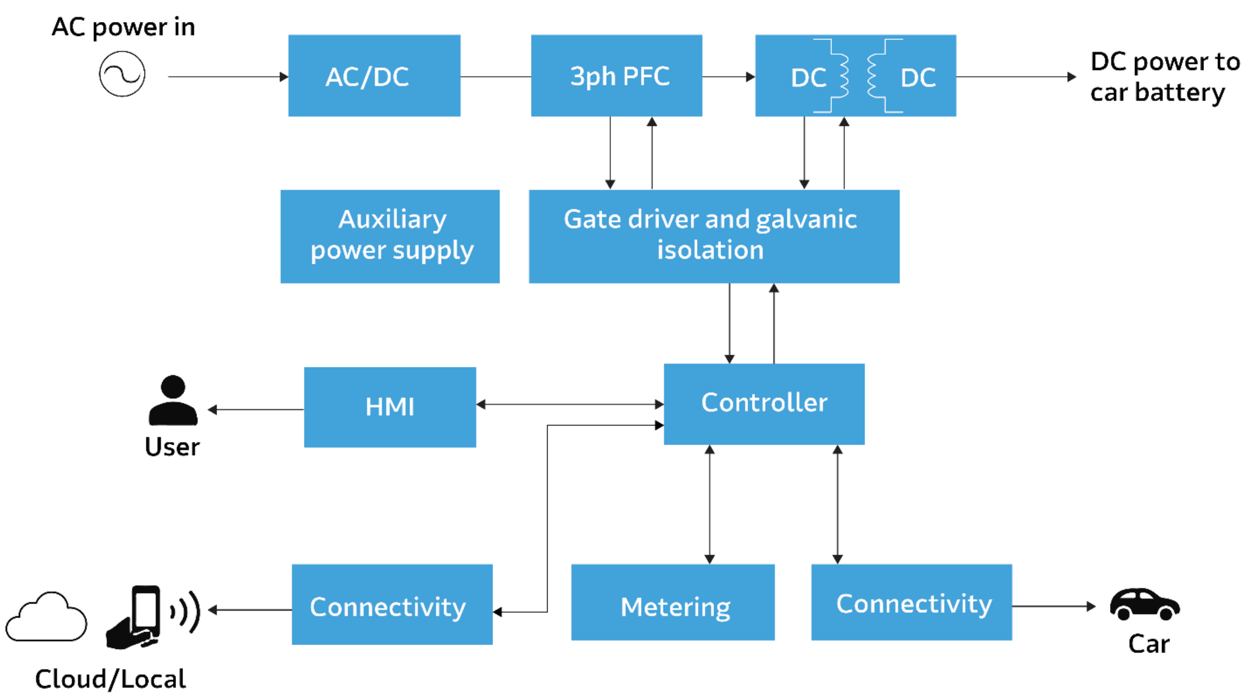

Figure 6: DC Fast Charging Block Diagram

Summary

The revolution and evolution of modern mobility are closely aligned with global zero-emission and sustainability targets. This shift towards decarbonization in the automotive industry is seeing exponential growth in the electric vehicle market as a key enabler to lowering emissions. Governments across the world are drawing up new regulations and incentives to fuel EV introduction. There is also increasing investment and a need for faster, more efficient charging infrastructure and battery technology to support this growth.

Arrow has the know-how, technical expertise, and technology to drive all levels of EV and EV charging design. Our advanced portfolio of power, control, sensing, and communication technologies is backed by our trusted technology partner network.

Our dedicated automotive team has a deep knowledge of your industry and speaks the automotive language. We can help you evaluate new technologies and provide AECQ products and platform support, as well as services to guide your vision.

References

1. Electric Vehicles - Worldwide
2. The role of Battery Management System (BMS) in electric vehicles