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Developing A 25-kW SiC-Based Fast DC Charger (Part 7): Auxiliary Power Supply Units For 800-V EV Chargers

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This article series[1-6] describes the development of a 25-kW EV charger based on SiC power modules and other power components from onsemi. Previous parts of this series have described the overall structure and specifications for this scalable, 25-kW fast dc charger design, and described the design of the hardware and control strategies for the two main power stages—the PFC stage and the dual active bridge dc-dc converter stage. At this point we are nearly done describing the design of the charger circuitry. However, one design consideration remains—the design of the auxiliary power supply.

An auxiliary PSU is used to power the controllers, drivers, communications components, and sensors of the submodules, while taking its input power from the dc link voltage. That's generally 400 V or 800 V based on the car maker's choice of battery. While 400-V batteries are currently dominant in the EV market, the trend is toward use of the higher-voltage batteries.

Nowadays, the shift from a 400-V dc-link voltage to an 800-V dc-link voltage in EV charging stations is extremely desirable to improve overall system efficiency. With higher dc-link voltage, the current required from the PFC stage is reduced, which allows us to use SiC MOSFETs with low current ratings. This helps in improving overall efficiency by increasing power density and reducing the system size.

In addition, 800-V EV batteries have their own benefits. These batteries allow faster charging with lower current at higher voltages. For example, it would take an hour to charge a 60-kWh battery at 400 V with 150-A current. However, the same battery can be charged in 45 minutes at 800 V with 100-A current. Lower current values help in avoiding large conductors (wires) and heating issues, making the 800-V dc-link an attractive solution for EV charging solutions.

With that in mind, the 25-kW fast dc charger solution from onsemi is designed in such a way that the auxiliary power supply (PSU) can be connected directly to the 800-V dc-link. In this case the auxiliary PSU must function at dc link voltage levels between 240 V and 900 V, which is required at system start up. As the PFC stage is powered on with a 400-V ac input, the dc link capacitors are charged first through the body diodes of the SiC MOSFETs and the dc link voltage reaches approximately 560 V. The auxiliary PSU starts up when the dc link voltage rises above 240 V.

This article describes the design of an auxiliary PSU using a reference design that was developed for EV applications. The focus here is on designing a power supply that will work for an 800-V dc link using a design based on the SECO-HVDCDC1362-40W-GEVB reference design with 15-V/40-W continuous output power. A similar reference design, the SECO-HVDCDC1362-15W-GEVB could also be used if 15-V/15-W continuous output power was the design requirement.

Auxiliary PSU Design

Our company, onsemi, has released two solutions for high-voltage auxiliary power supplies for 800-V and 400-V battery-based BEVs and PHEVs and delivering 15 W or 40 W. While these PSU designs were developed for use on-board EVs, they also serve the needs of external equipment with a similar high-voltage dc bus, such as fast EV chargers. In this case, Automotive Electronics Council (AEC-Q) qualified parts can be replaced by non-AEC-Q qualified parts, which helps in reducing overall BOM cost.

The SECO-HVDCDC1362-15W-GEVB[7](15-W solution) and the SECO-HVDCDC1362-40W-GEVB[8] (40-W solution) are two highly efficient high-voltage auxiliary power supplies for 400-V and 800-V battery-based electric vehicles and plug in hybrids (BEVs and PHEVs). The auxiliary power supplies are designed to provide a stable 15-V output with an output power of either 15 W or 40 W (depending on the SECO board) and can be connected to a dc link with a wide dc voltage range from 240 V to 900 V which makes the auxiliary power supply suitable for 400-V and 800-V battery systems. Fig 1. shows connection of the SECO-HVDCDC1362-40W-GEVB auxiliary PSU to the two main stages.

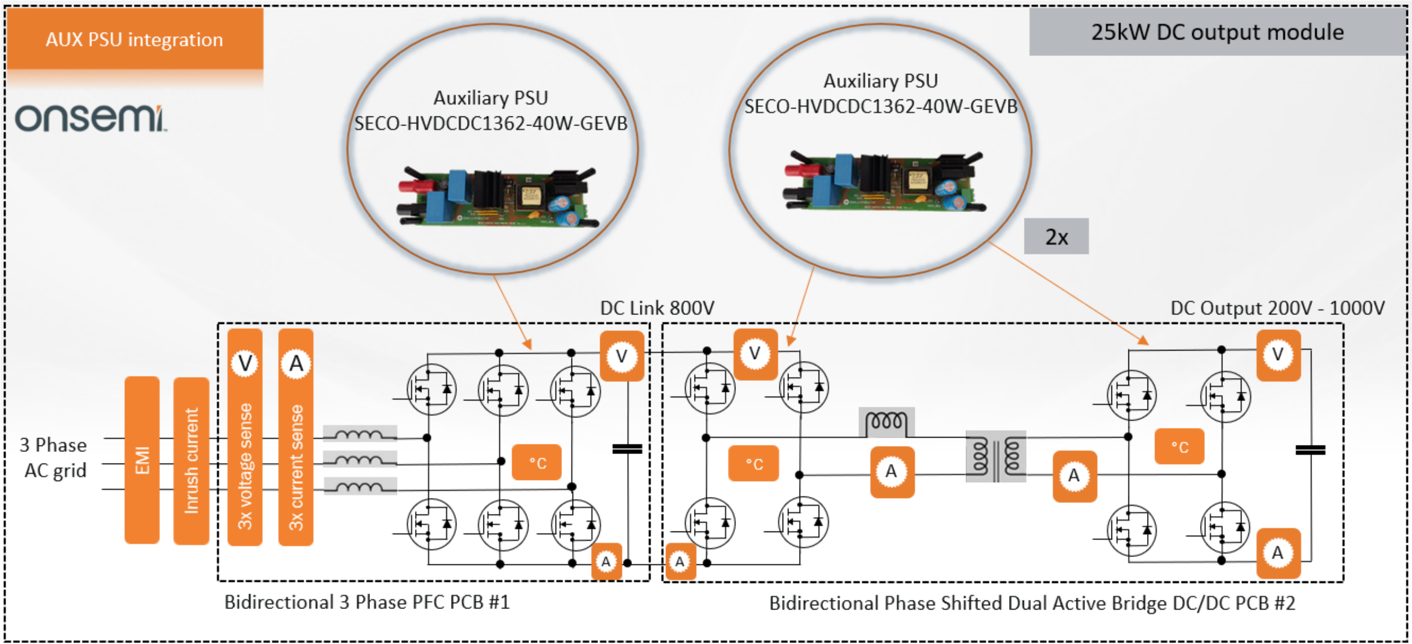

Fig 1. The 25-kW fast dc charger block diagram with auxiliary PSU connections highlighted.

The auxiliary power supplies are designed based on a flyback topology using a primary-side-regulated, quasi-resonant (QR) flyback controller. One of the biggest advantages of using a primary-side-regulated flyback controller is that it requires no optocoupled feedback, which improves the reliability of the power supply.

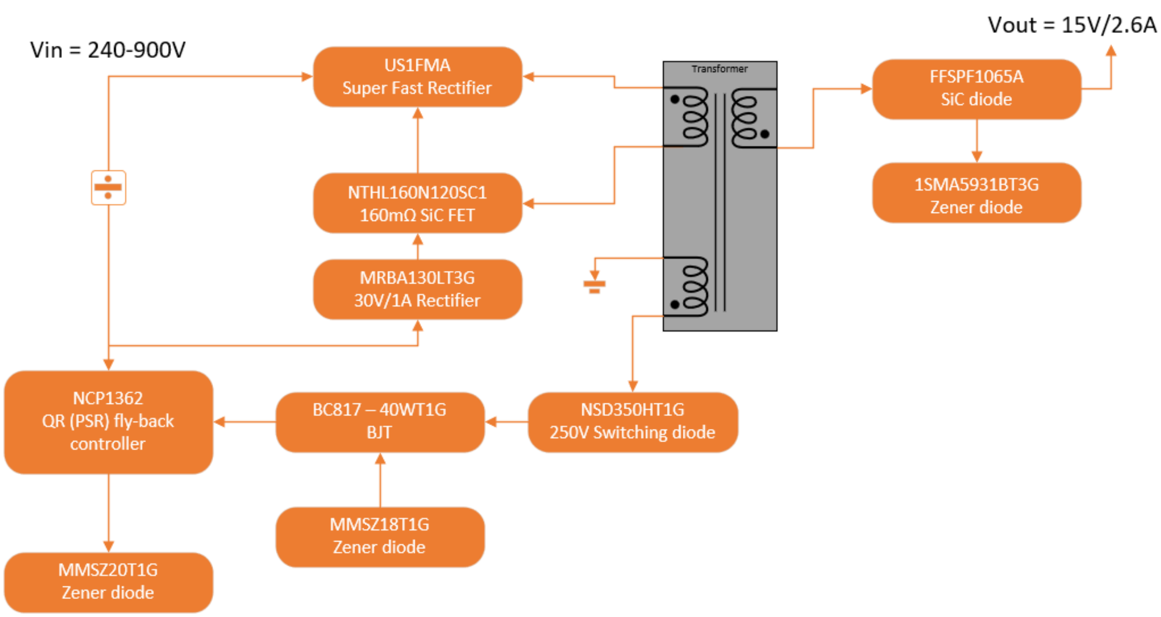

Fig 2. AUX PSU block diagram.

The design consists of the NCP1362 quasi−resonant peak current primary-side regulator (PSR) flyback controller; the 1200-V, 160-mW NTHL160N120SC1 SiC MOSFET (three-lead, cost-optimized), and the

FFSPF1065A SiC diode. The SiC FET has an ultra-low gate capacitance of 34 nC, which helps in reducing high-voltage transients and switching loss significantly. This helps in increasing the overall efficiency of the flyback stage and the power supply design.

The NCP1362 controller is designed to drive SiC FETs directly at 12 V without the need of a pre-driver, simplifying the overall power supply design. While the NCP1362 output is unipolar from 0 V to 12 V, this is enough to drive the SiC FET without driving it to its maximum V_{gs} for turn-on/off. A 5-kW 160-V TVS diode is used in the design to provide a hard-clamp protection for the SiC MOSFET. Eliminating the pre-driver provides many advantages such as

- Reduced component cost
- Reduced overall BOM by eliminating pre-driver and passive components for the pre-driver
- High stability due to fewer components and reduced parasitics
- Increased efficiency
- Simplified layout.

The dc charging module design follows IEC61851-1 guidelines, and the flyback transformer complies with IEC 61558-1 where the basic isolation for 1000-V working voltage needs to be 2.75 kVrms. The flyback transformer provides an isolation of 4 kV and is optimized to minimize the losses from the RCD snubber circuit. The RCD circuit helps in limiting voltage overshoots, transients and oscillations at high line voltages and provides a headroom of 100 V for the SiC FET.

Fig 3. shows output load transient response from 10% to 100% and Fig 4. shows load transient from 100% to 10% at 500-V dc input voltage. The absence of oscillations at voltage transitions demonstrates high stability.

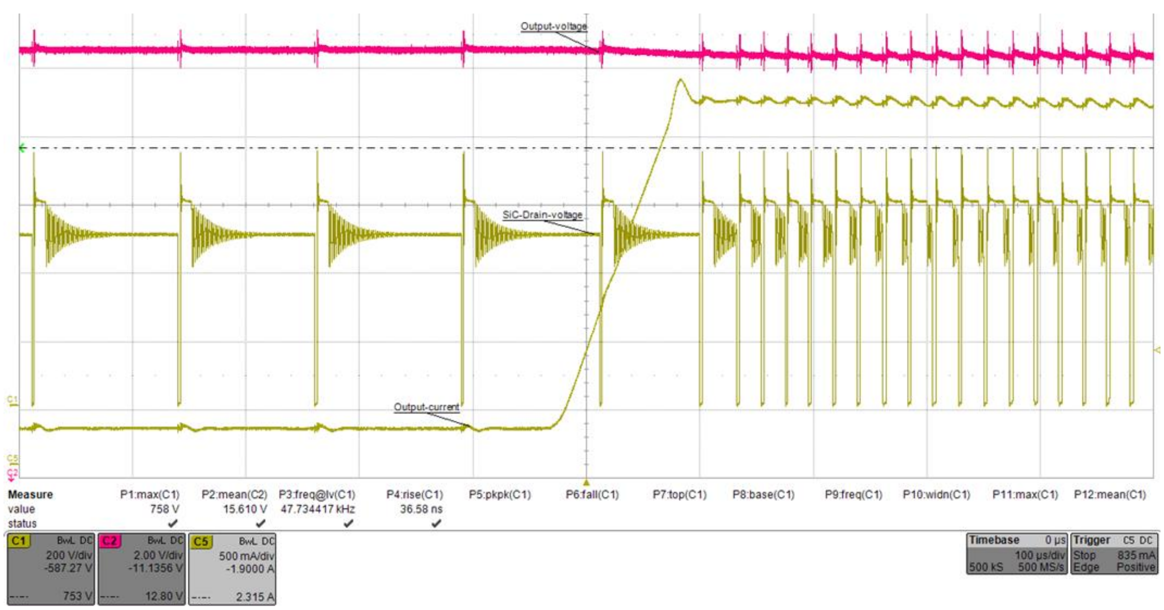

Fig 3. Load transients at 500 V from 10% to 100% output load power.

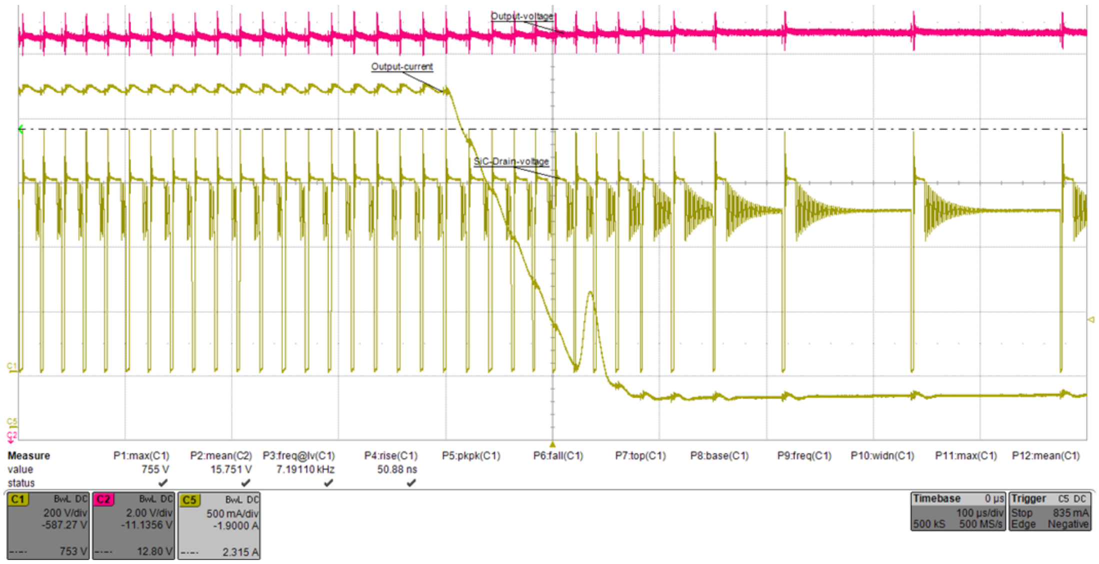

Fig 4. Load transients at 500 V from 100% to 10% output load power.

The SECO-HVDCDC1362-40W-GEVB design with industrial-grade parts is used in three different places in the 25-kW dc charging module because of its high-power capability. The first 40-W power supply is used in the PFC stage to power the SECO−LVDCDC3064−SIC−GEVB,[9] an isolated supply for gate drivers, providing the necessary stable voltage rails (-5 V and 20 V) as shown in Fig. 5, for efficient switching over a wide input voltage range.

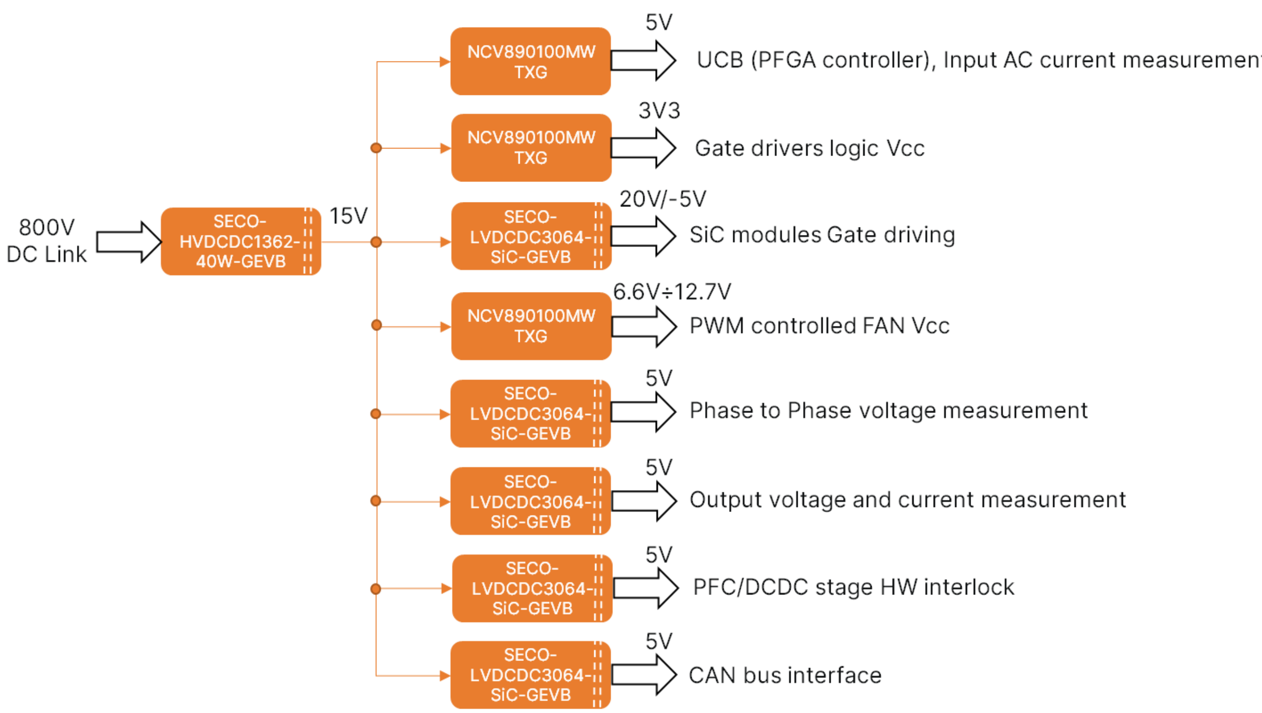

Fig 5. Use of the SECO-HVDCDC1362-40W-GEVB in the PFC stage.

The other two auxiliary PSUs are used in the dc-dc stage of the 25-kW platform power supply architecture as shown in Fig. 1. One is connected to the dc link and the other one is connected to the output as shown in Fig. 6. Doing this eliminates the need for an HV mechanical switch or relay. The Universal Controller Board (UCB) can deactivate the Aux PSU based on the selected dc-dc direction of operation as shown in Fig. 6.

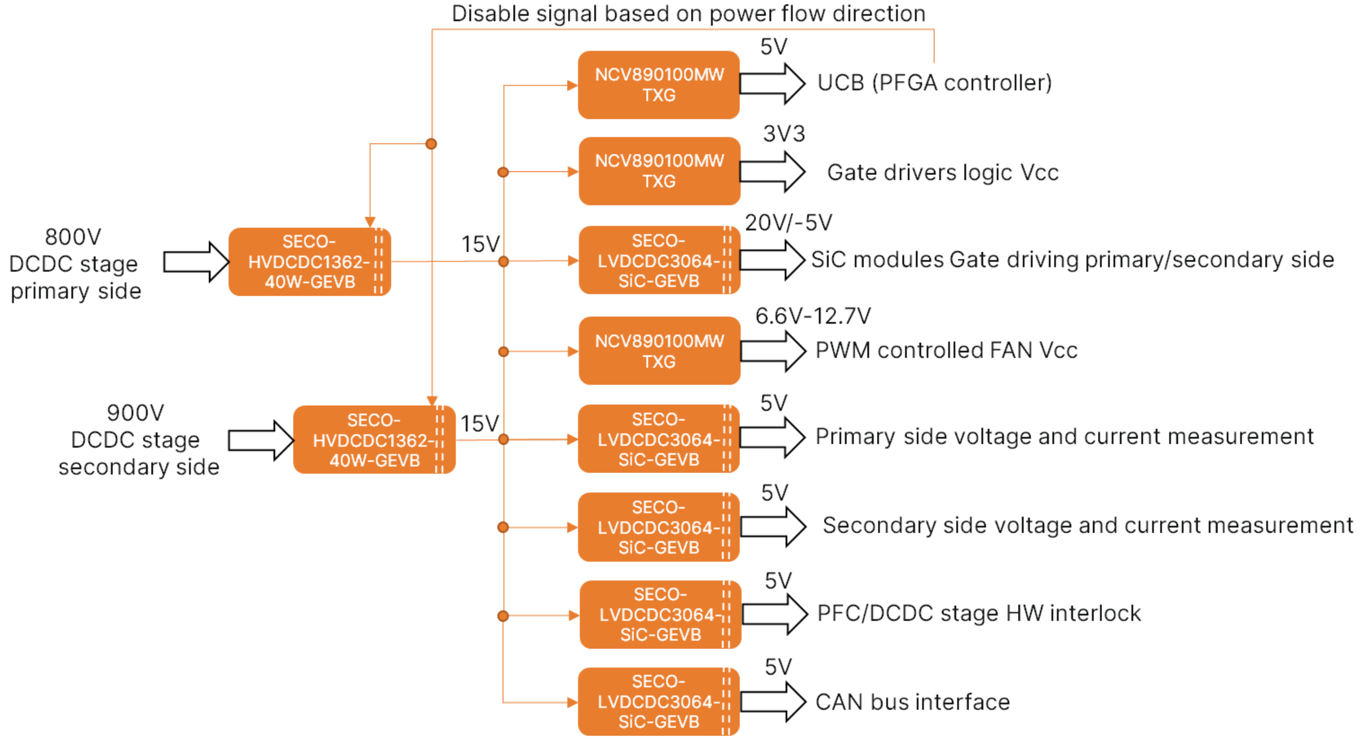

Fig 6. Use of the SECO-HVDCDC1362-40W-GEVB in the dc-dc stage.

Conclusion

The 800-V batteries and dc link systems are extremely desirable for the higher efficiency and faster charging time they enable for electric vehicles. While increasing the dc link voltage to 800-V helps in reducing the required current, it can be difficult to design an efficient auxiliary power supply that can be connected directly to 800-V bus voltages. This article shed light on the design of a fully integrated 25-kW fast dc charger and two auxiliary power supply solutions that can be directly connected to an 800-V dc line to power the low-voltage components in a fast dc charging solution.

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7. SECO-HVDCDC1362-15W-GEVB
8. SECO-HVDCDC1362-40W-GEVB
9. SECO−LVDCDC3064−SIC−GEVB

About The Authors

Karol Rendek is an applications manager at the Systems Engineering Center at onsemi. Karol joined onsemi in 2020. Previously, he spent nine years working as hardware engineer, system engineer and project manager in development of embedded systems, Class D amplifiers, rolling stock control and safety systems and industrial electric vehicle chargers. Karol has Master's degree and Ph.D. in Microelectronics from Slovak University of Technology in Bratislava. He spent three years during his Ph.D. study focusing on low frequency noise analysis of GaN HEMT transistors.

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Didier Balocco currently serves as the business marketing engineer for Europe at onsemi. He came to onsemi through the company's acquisition of Fairchild Semiconductor, which he joined in 2014 as a field application engineer (FAE) supporting the south of France, Spain and Portugal. Previously, Didier worked at AEG Power Solutions, formerly Alcatel Converters, as a research engineer for dc-dc and ac-dc converter design in a range of 1 W to 1 kW, mainly for telecom equipment. While at this company, he also managed the research activities. Among his projects, Didier worked on a 15-kW solar inverter module for a 150-kW cabinet in Dallas, Texas, USA. His main interests during this period were switched-mode power supplies, converter stability and modeling as well as high power factor rectifiers.

Didier has published more than 10 papers on power electronics and holds one patent. He received an engineering degree from the "École Nationale Supérieure d'Électronique et de RadioÉlectricité de Bordeaux", France and a Ph. D. degree in Power Electronics from the University of Bordeaux.

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Will Abdeh is part of the Applications Engineering team at onsemi. In this role, he's responsible for the marketing strategy of EV charging and factory automation, which involves launching new hardware platforms and driving new development opportunities. Will has launched several application-based hardware reference designs like Motor Development Kits and the Strata enabled H-Bridge Motor Driver kit. Will holds an MSE from the Ira A. Fulton Schools of Engineering at Arizona State University.

For further reading on designing EV chargers, see the How2Power Design Guide, locate the Application category and select "Automotive".