Application Overview

Fast DC EV Charging

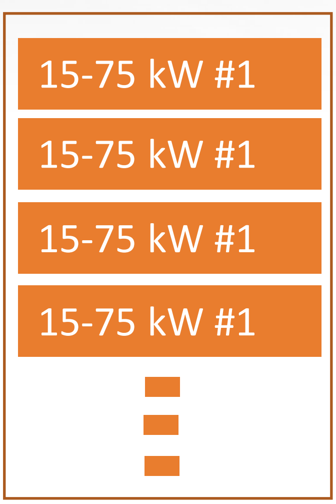
Updated: March 2022

Industry	• Industrial – Electrical Vehicle Charging, Electrical Vehicle Service Equipment (EVSE)
Applications	• Fast DC chargers (normally range between 50 kW – 150 kW) and Ultrafast DC Chargers (normally range 100 kW – > 400 kW).

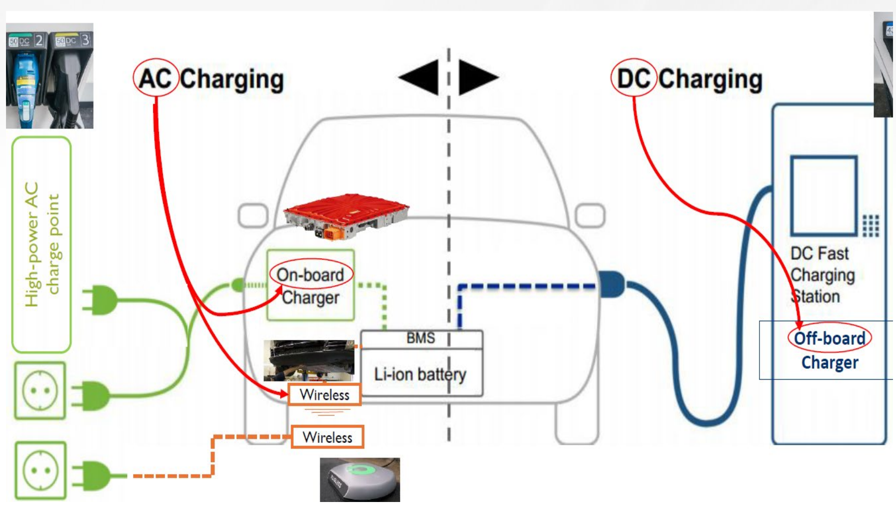
SYSTEM PURPOSE

- DC EV chargers are used to charge the batteries of Electric Vehicles (EVs) by delivering DC power into the vehicle. **Expected growth of Fast DC chargers is at ~CAGR = 30% for the next 5 years.**
- DC Charging by-passes the On-Board Charger (OBC) on the vehicle used for AC charging (max. 22 kW) and therefore can deliver **higher power ratings** to the batteries (typically 50 kW to >400 kW), to reduce the charging time. DC chargers are sometimes referred to as ‘fast’ and ‘ultra fast’ chargers. With typical EV battery capacities ranging from 50 – 120 kWh, fast DC chargers could enable 15min charging times. Different vehicles also have various limitations on their charging rates.
- DC chargers consist of an AC/DC stage and a subsequent DC/DC stage, that converts the AC power from the grid into DC and delivers it to the vehicle charging port at the required voltage and current levels for the batteries.

SYSTEM IMPLEMENTATIONS (INFRASTRUCTURE LEVEL)



Parallel blocks (15 – 75 kW) for high powers



The focus of this document is DC charging enabling fast charge times.

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SYSTEM DESCRIPTION

EV Charger Levels and Types

The EV chargers of today fall into three main categories, separated mainly by their power level.

- **Level 1** is 120V, typically comes from household outlet, and adds 3-5 miles per hour of charging.
- **Level 2** is 220V, available at home, workplace, or public locations, and adds 12-80 miles per hour of charging depending on the power output. Level 2 chargers can deliver up to 6.6kW of charging power, making them capable of charging the average EV in about four to eight hours.
- **Level 3** are much larger DC quick chargers and the fastest type of charging nowadays, adding 3-20 miles per minute of charging.
    - Only available at commercial locations that have access to three-phase power from their local utility provider, these systems can add more than 100 miles or more of range to an EV battery in just 30 minutes, as opposed to taking hours (which would be entirely impractical for most users).

A DC fast charger adds 60 to 80 miles of range per 20 minutes of charging time, while level 2 charger adds just 10 to 20 miles of range for an hour of charging time, making fast DC chargers very desirable solution to solve many of the consumer challenges. The three types are shown in the figure below.

Within the different EV charging designs, there are various standards applied which include different vehicle-to-charger communications protocols and several different charger interface connector designs.
The communications protocols are shown in figure below.

	System A CHAdeMO (Japan)	System B CATARC (PRC)	System C COMBO1 (US)	System C COMBO2
Connector				

SYSTEM DESCRIPTION

- **Power levels** for DC chargers range from 50 kW up to 400 kW (and higher). In most cases several power blocks are stacked and run in parallel (ranging from 15 – 60 kW and above). The battery size of vehicles releasing nowadays range from 50-120 kWh.
- The **front end** of the DC charger consist of a three-phase Power Factor Correction (PFC) boost stage, implemented in a variety of topologies (2 or 3 level) and uni- or bi-directional. The voltage level from the grid 400 (EU) / 480 (US) are boosted up to 700 – 1000 V (and targeting higher).
- A subsequent **DC-DC isolated stage** converts the bus voltage into the required output voltage. The output voltage aligns with EV battery voltages (typically 400 V or 800 V) and need to cover the voltage charging profiles. Therefore, the DC-DC output range might swing from 150 V up to 1500 V. Specific implementations might be optimized for the 400 V or 800 V level
- Power stages are increasingly employing **SiC based** power integrated modules (PIM). IGBTs or hybrid solutions are also possible, as well as discrete implementation. Beyond the main power devices, gate driver ICs, power supply ICs (LDOs, SMPS), communication transceivers, op-amps etc. are also part of the system.
- **Communications and connectivity** are a cornerstone of EV Chargers, fulfilling different functions: between stacked modules on the power stage (CAN, PLC, RS485 open to OEM), between vehicle and charger for the charging sequence (CAN or PLC, defined by protocol), external connectivity for payment, service management, maintenance, software upgrades, …. BLE, WiFi4, LTE, …).
- There are several **standards and protocols** worldwide that define the requirements for DC charging, such as the IEC-61851 / SAE1772, GB/T, standards and the CHAdeMO, Combined Charging System (CCS) or Tesla Supercharger protocols.

ADDITIONAL CONSIDERATIONS

Trends

Power levels of DC chargers are actively being pushed higher to reduce charging times. Similarly, **voltage levels** (both in DC bus and output) are driven higher to improve efficiency and adapt to higher EV battery voltages. SiC technologies (higher V_{BD}) are reinforcing and supporting these trends. **Power integrated modules (PIM) are being rapidly adopted** for the benefits of compactness, superior thermal management, reliability and manufacturability. Higher switching frequencies with WBG also allow for more compact and lightweight systems.

Topologies overview for three-phase PFC and DC-DC stages

PFC and DCDC stages are being implemented in a variety of topologies in the market. The PFC typically come in three-switch **Vienna (unidirectional), NPC, A-NPC, T-NPC (bi-directional replacing diodes) or six-switch (bi-directional)** most commonly. The DCDC is normally implemented **as full bridge or phase-shift LLC and variations**, and in a **Dual Active Bridge (DAB) architecture for bidirectionality**. These architectures described above include **two-level** and **three-level systems**, where **600 V – 650 V or 900 – 1200 V** switches and power diodes will be required, respectively. **onsemi can support all such configurations in a modular approach with PIMs or with discrete components.** SiC based power modules are gaining share as the preferred option for such applications. IGBT or hybrid solutions are an alternative.

SiC power integrated modules (PIM) optimized for Fast DC EV Charging

A dedicated new off-the-shelf family of PIMs is being released for fast DC EV charging with **SiC 1200 V and 900 V breakdown voltage ratings**. Half bridge and full bridge topologies in F1 and F2 packages exhibiting **notably low RDSons (6 mOhm – 40 mOhm),** superior thermal performance and excellent reliability with the patented SiC termination structure from onsemi. Beyond that, there is the possibility of alternative configuration for specific projects.

Wired and wireless communications

The charging synchronization communication between charger and vehicle is mandated by the protocols discussed. CHAdeMO establishes CAN, while CCS establishes PLC as the bus, and more specifically the HomePlug Green PHY with dedicated controllers for that. Other communications within the power stage will be open to the OEM decision (CAN, PLC, RS485 mostly), as well as for external connectivity BLE, Wifi4/6, LTE, RF. Except for the HomePlug Green PHY, on portfolio can support most of the other technologies described.

Energy Storage Systems (ESS) integration and solar power

Fast and Ultrafast charging stations might involve in some cases ESS integration, along with solar power generation. Storage systems would draw energy during grid valley hours or from the solar systems and release it along the day to maximize the effective operating time of charging stations. In such cases DC-DC converters could hang from a high voltage bus to charge the EVs. In such cases onsemi can have a closer look to support opportunities.

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Application Overview

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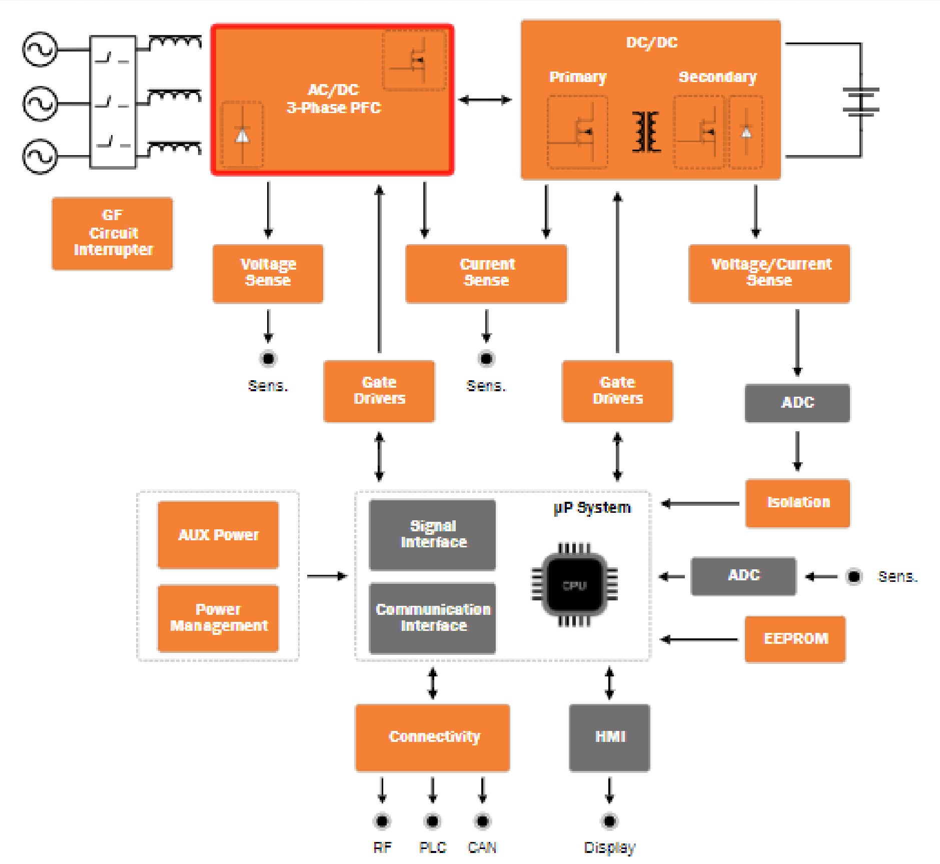
ELECTRONIC CONTROL MODULE



System Requirements	Solution	Outcomes
High efficiency, power density and voltages	• SiC power modules with low RDSon (6 – 40 mOhm) and 900 V and 1200 V break down voltages like NXH010P120MNF2	• **Maximize energy delivery** and reduce **system size** → simplifies deployment
Superior thermal management	• SiC discrete technology with broad MOSFET and diodes portfolio with patented termination structure for ruggedness	• Reduces **cooling effort**, extend life-time and decrease **complexity** and weight
Integrated and robust driving systems	• **NCP51561** isolated High speed Dual Channel MOS/SiC driver 5 kV / 9A **Broad family portfolio of isolated drivers with integrated functionalities**	• Greater system level **reliability** in harsh environment • Fastest switching transitions to maximize efficiency even at high frequncies

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Fast DC EV Charging

onsemi Advantages

Systems solution expertise and long experience - + 5 years focus on EV Charging systems with a dedicated expert application teams for excellent application support worldwide. onsemi makes a difference in helping customers find the right solution for their needs. An array of reference design development as well as developments on SiC driver optimization.

Leading power modules and SiC technologies with a comprehensive overall portfolio

Long time expertise in the modules market with continuous investment in enhanced packaging technology, Superior SiC features with patented termination for ruggedness. Power devices, analog ICs, auxiliary power, sensing protections and connectivity portfolio round out the portfolio.

Silicon-carbide reliability - Some engineers have concerns about SiC reliability vs Si in respect to **'high electric field induced failure' and 'gate oxide weakness due to intrinsic interface defect'**. onsemi addresses these challenges among others with patented die terminations of SiC technology, optimized process design based on empirical evidence and industry leading manufacturing excellence and validation process with 'in built reliability processes. onsemi is one of the very few suppliers with a fully integrated value chain for SiC, from Wafer, Epi to products. This is a differential factor to deliver high-quality and high-reliability systems with SiC.

Fully integrated supply value chain - In-house raw wafers manufacturing and assembly, one of the few players in the industry with such high integration for power devices. Ensures highest quality standards, operational excellence and faster reaction capabilities.

Gate drivers - Broad and deep portfolio of high drive current isolated drivers with a wide range of safety features that allow for integration and design flexibility with industry standard packages. The portfolio maximizes the benefits of fast driven WBG switches with high CMTI immunities. Equally importantly, onsemi also provides hardware for rapid driver evaluation and reference SiC driving systems including the isolated supply to facilitate new design development.

onsemi Advantages

Auxiliary power - onsemi has several PSR options (with opto-isolation or PSR). The NCV1362 primary side regulation (PSR) PWM controller is an excellent fit for this socket along with **SJ MOSFETs from 650 – 950 V.**

Ref. designs:

https://www.onsemi.com/support/evaluation-board/seco-hvdcdc1362-15w-gevb,
https://www.onsemi.com/support/evaluation-board/seco-hvdcdc1362-40w-gevb

Sensing – Amplifiers, Comparators, Current Sense Amplifiers (CSA): Cost competitive portfolio that matches our competitors.

Power management - LDOs – onsemi is #1 supplier for Voltage Regulators. Offers a wide portfolio and dependent on customer needs parts can be provided with very low RMS noise down to 4.4uVrms, excellent PSRR greater than 90dB and very low Iq.

Communications and connectivity - CAN, iso-CAN and PLC portfolio for the power stage.. Wireless: BLE, RFID; NFC solutions available from onsemi.

DEVELOPMENT TOOLS AND RESOURCES

Auxiliary power

https://www.onsemi.com/support/evaluation-board/seco-hvdcdc1362-15w-gevb

https://www.onsemi.com/support/evaluation-board/seco-hvdcdc1362-40w-gevb

Gate drivers

https://www.onsemi.com/support/evaluation-board/seco-gdbb-gevb

Gate driver supplies

https://www.onsemi.com/support/evaluation-board/seco-lvdcdc3064-igbt-gevb

https://www.onsemi.com/support/evaluation-board/seco-lvdcdc3064-sic-gevb

DEVICE TABLE

Block	Taxonomy	WPN (Web Part Number)	WPN Description
PFC and DCDC	SiC MOSFETs	NTBG080N120SC1	Silicon Carbide MOSFET, N-Channel, 1200 V, 80 mΩ, D2PAK−7L
		NTH4L040N120SC1	Silicon Carbide MOSFET, N-Channel, 1200V, 40 mΩ, TO247-4LD
		NTBG015N065SC1	Silicon Carbide MOSFET, N-Channel, 650V, 15.3 mΩ, D2PAK−7L
		NTBG045N065SC1	Silicon Carbide MOSFET, N-Channel, 650V, 43.5 mΩ, D2PAK−7L
		NTH4L022N120M3S	Silicon Carbide MOSFET, N-Channel, 1200V, 22 mΩ, TO247-4LD
	SiC Power Modules	NXH006P120MNF2	SiC Modules, Half Bridge 2-PACK 1200 V, 6 mohm SiC MOSFET, F2 Package
		NXH010P120MNF2	SiC Modules, Half Bridge 2-PACK 1200 V, 10 mohm SiC MOSFET, F2 Package
		NXH020U90MNF2	SiC Modules, Vienna 900V, 10mohm SiC MOSFET & 1200V, 100A SiC Diode, F2 Package
	Silicon Carbide (SiC) Diodes	FFSD0465A	SiC Diode - 650V, 4A, DPAK
		FFSH30120ADN	SiC Diode, 1200V, 30A, TO-247-2, Schottky Diode
		FFSH3065B	Silicon Carbide Schottky Diode 650V 30A TO247
		FFSH40120ADN	SiC Schottky Diode, 1200 V, 40 A
		NDSH40120CDN	2x 50A, 1200V TO247-3LD Gen2 SiC Diode
		NDSH50120C	50A, 1200V TO247-2LD Gen2 SiC Diode
	Rectifier	ISL9R18120G2	18A, 1200V, STEALTH™ Diode
		ISL9R30120G2	30A, 1200V, STEALTH™ Diode
	IGBTS	FGHL75T65MQD	IGBT - 650 V 75 A FS4 medium switching speed IGBT
		FGY75T95SQDT	IGBT - 950 V 75 A Field stop trench IGBT
		FGY60T120SQDN	IGBT, Ultra Field Stop -1200V 60A
DCDC	AC/DC - DC/DC regulators	NCP4390, FAN7688	Advanced Secondary Side LLC Resonant Converter Controller with Synchronous Rectifier Control
		NCP3064	Boost / Buck / Inverting Converter, Switching Regulator, 1.5 A, with On / Off Function
		NCP3237	8 A Integrated Synchronous Buck Regulator
Drivers	Gate Drivers	NCP(V)51705	SiC MOSFET Driver, Low-Side, Single 6 A High-Speed
		NCD(V)57000/1	Isolated high current and high efficiency IGBT gate driver with internal galvanic isolation.
		NCD(V)57080/90A	Isolated High Current Gate Driver
		NCD(V)57252	Isolated Dual-Channel IGBT/MOSFET Gate Driver
		NCP(V)51561	Isolated 5 kV High Speed Dual MOS/SiC Drivers

Fast DC EV Charging

DEVICE TABLE (CONTINUED)

Block	Taxonomy	WPN (Web Part Number)	WPN Description
Isolation	**Digital Isolators**	NCID9211	High Speed Dual-Channel, Bi-Directional Ceramic Digital Isolator
		NCID9401	High Speed Quad-Channel Digital Isolator
Auxiliary Power	**AC/DC - DC/DC regulators**	NCP10670	Enhanced Off line Switcher for Robust and Highly Efficient Power Supplies
		FSL336	650V Integrated Power Switch with Error Amp and no bias winding for 9Watt offline buck converters
		FSL337	Green Mode Fairchild Buck Switch
		FSL518A/H	High Performance 800 V Off-line Switcher with HV Startup and SenseFET
		FSL538A/H	High Performance 800 V Off-line Switcher with HV Startup and SenseFET
		NCP11184	30 W 800V Off-line Switcher with HV Startup
		NCP11185	40 W 800V Off-line Switcher with HV Startup
		NCP11187	50 W 800V Off-line Switcher with HV Startup
	AC/DC - DC/DC controllers	NCP1252	PWM Controller, Current Mode, for Forward and Flyback Applications
		NCP12700	Ultra Wide Input Current Mode PWM Controller
		NCP1362	Automotive Primary Side PWM Controller for Low Power Offline SMPS
		NCP1342	Quasi-Resonant Flyback Controller with Valley Lock-Out Switching
		NCP1568	AC-DC Active Clamp Flyback PWM Controller
	SiC MOSFETs	NTH4L160N120SC1	Silicon Carbide MOSFET, N-Channel, 1200 V, 160 mΩ, TO247−4L
		NTHL160N120SC1	Silicon Carbide MOSFET, N-Channel, 1200 V, 160 mΩ, TO247−3L
Protection	**Ground Fault Circuit Interruptors**	FAN4147	Ground Fault Interupter
		NCS37014	Self Test GFCI controller compliant with UL943
Voltage / Current sense	**Voltage Sense**	NCS2333	Precision Operational Amplifier, Low Power, Zero-Drift, 30 µV Offset
		NCS4333	Operational Amplifier, 30 µV Offset, 0.07 µV/°C, Low Power, Zero-Drift
	Current Sense	NCS214R	Current Sense Amplifier, 26V, Low-/High-Side Voltage Out, Bidirectional Current Shunt Monitor
		NCS211R	Current Sense Amplifier, 26V, Low-/High-Side Voltage Out, Bidirectional Current Shunt Monitor
		NCS704X	Current Sense Amplifier, 80V Common-Mode Voltage, Bidirectional
Power Management	**LDOs**	NCP164	300mA LDO Regulator, Ultra-Low Noise, High PSRR with Power Good
		NCP715	LDO Regulator, 50 mA, Ultra-Low Iq
		NCP730	LDO Regulator, 150 mA, 38 V, 1 uA IQ, with PG
	DC/DC	NCV3064	Buck / Boost / Inverting Converter, Switching Regulator, 1.5 A, with On/Off Function
		NCP4390	Advanced Secondary Side LLC Resonant Converter Controller with Synchronous Rectifier Control
		FAN7688	Advanced Secondary Side LLC Resonant Converter Controller with Synchronous Rectifier Control
		NCP6324	Synchronous Buck Converter, 3 MHz, 2.0 A
		NCV6323	Synchronous Buck Converter, 3 MHz, 2 A
		NCV6323F	Synchronous Buck converter up to 1.6 A DC, Wettable flank DFN8, 2x2 mm (0.8 mm thickness), 0.5 mm pitch package
		NCV6357	Synchronous Buck Converter, Processor Supply, I2C Programming, 5.0 A
		NCV91300	Configurable 3.0 A PWM step down converter
Comms	**PLC**	NCS5651	Power Line Communcation (PLC) Driver, 2 Amp
	CAN	NCV7349	CAN Transceiver, High Speed, Low Power
		NCV7351	CAN/CAN FD Transceiver, High Speed
		NCV7357	CAN FD Transceiver, High Speed
		NCV7343	CAN FD Transceiver, High Speed, Low Power
	BLE	RSL10	Radio SoC, Bluetooth® 5 Certified, SDK 3.5 / SIP
		RSL15	Bluetooth® 5.2 Secure Wireless MCU

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