System Solution Guide

On Board Charger (OBC)

Updated: OCT-2023

Industry	• Automotive – Vehicle Electrification
Applications	• On Board Charger (OBC) is used to charge the high voltage battery pack of Battery Electric Vehicles (BEV) and Plugin Hybrid Electric Vehicles (PHEV). It is integrated directly into the vehicle's design and enables the conversion of AC power from the grid into DC power suitable for the vehicle's battery pack. This technology allows EV owners to conveniently recharge their vehicles at home or at public charging stations. • In China the term New Energy Vehicle (NEV) is used to encompass BEV, PHEV and Fuel Cell Electric Vehicles (FCEV), which use electric motor but rely on hydrogen fuel cells instead of a large battery. FCEV may incorporate a low power OBC, but it is not a standard.

System Purpose

- Development and integration of OBC continues to scale up as tougher CO2 emission standards accelerate the development of EVs. Given the charging landscape with an insufficient number of fast Level-3 DC charging stations worldwide, the OBC is not going away any time soon.
- The OBC unit enables charging from the AC grid when the vehicle is parked and connected to a supporting Level-1 or Level-2 charging station or connected to a wall outlet using an approved charging cable. Major stream is “Level-2 OBC”, 7KW – 22KW range of charging power.
- PHEVs and BEVs are a step up from Mild Hybrid Electric Vehicles (MHEVs). These vehicles require a high voltage battery system as well as the supporting modules to operate it, including OBCs. PHEVs reduce the average CO2 emissions from vehicles while BEVs have no CO2 emissions from the vehicle. Consumer expectations for vehicle performance can be maintained across these vehicle types with the exception of range anxiety for BEVs. Work is ongoing worldwide to address these concerns.

System Implementations

Plugin Hybrid Electric Vehicle (PHEV)	Battery Electric Vehicle (BEV)
• OBC is lower power and lower cost due to lower power levels and battery capacity. • 1 phase AC: 3.3kW, 6.6kW or 7.2kW power rating. • Note that in many countries a maximum of 3.7kW – 4.2kW per phase will limit this. • Can be plugged in almost anywhere at lower power levels (1.4kW – 1.8kW). • Increased power levels may be implemented to allow for faster charging. • Reduced emissions based on mission profile.	• Higher cost OBC due to higher power levels and more complexity. • 1 phase AC: 6.6kW or 7.2kW power rating. • 3 phase AC: 11kW up to 22kW for higher end BEVs. Trending towards higher power tiers to reduce charging time. • Higher power tiers may require utility upgrades in certain countries. • Note that in many countries a maximum of 3.7kW – 4.2kW per phase will limit this. • Can be plugged in almost anywhere at lower power levels (1.4kW – 1.8kW), but not preferred. • DC fast charge bypass option. • No emissions.

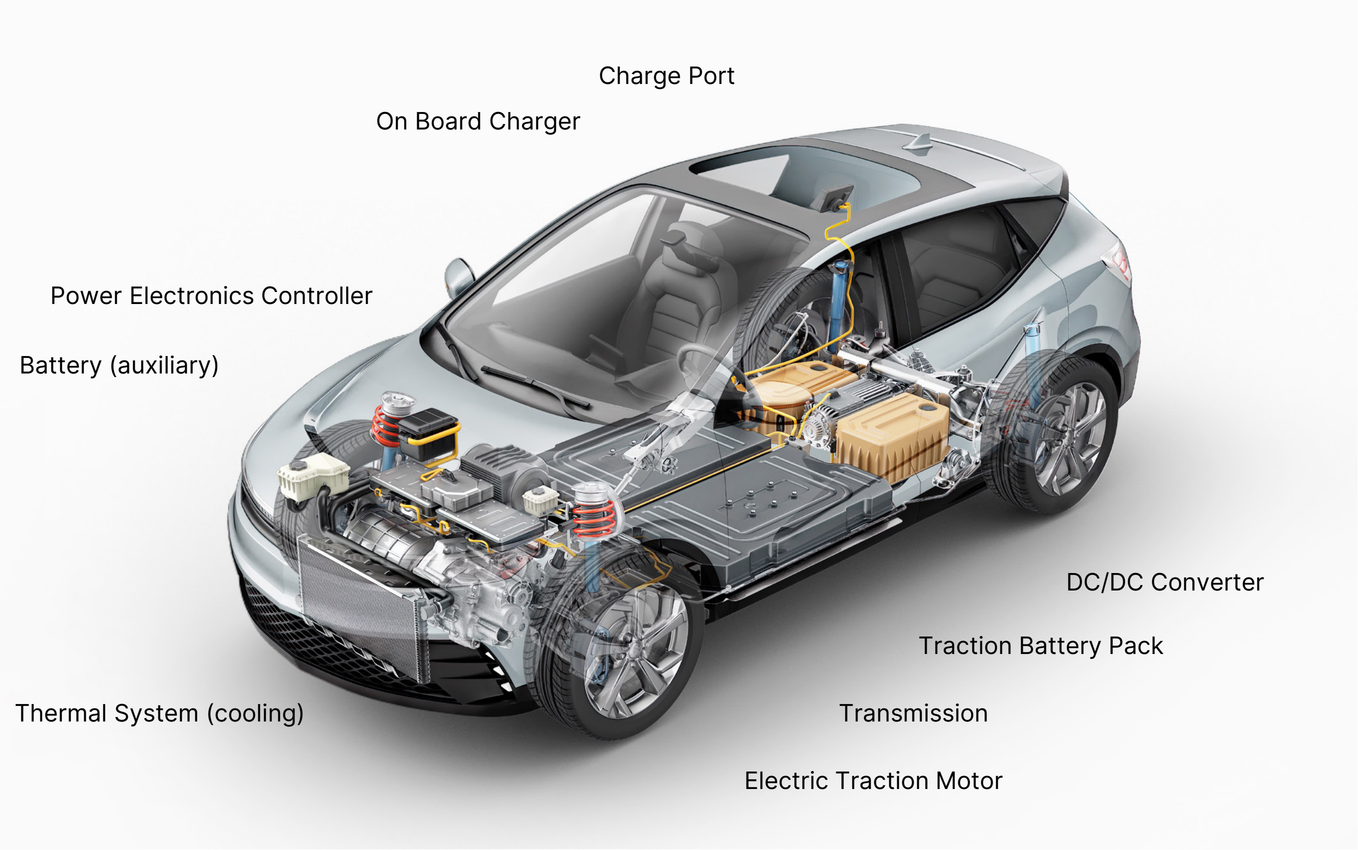
System Description

PHEVs and BEVs contain a module used for charging the high voltage battery pack known as the **On Board Charger (OBC). The main function of the OBC is to convert an input grid AC voltage to an output DC voltage** with the appropriate output current and voltage level for the battery pack to charge. AC input is usually 1 phase for low power OBC and 3 phase for higher power OBC. Additionally it must perform this charging function **while implementing Power Factor Correction (PFC)** which aligns the voltage and current phases to minimize impact to the AC grid. FCEVs can have a low power OBC to charge their battery, but it is not a standard.

- It must be considered during the design phase of OBC what is the target power level in kW (peak & continuous), Input voltage range, number of AC phases and overall efficiency.
- For all power stages (PFC, Primary and Secondary DCDC), the correct topology must be considered in terms of efficiency and total cost. Also, for individual stages, the option of analog controller IC or a digital control solution with the appropriate switching frequencies must be selected.
- Since most EVs can be charged **using a DC fast charger, the OBC provides a bypass functionality** to charge DC battery directly as there is no need for AC/DC conversion.

As the name suggests these “On Board” Charger modules are located on the vehicle and due to the power levels will have air or liquid cooling to help with thermal management. Depending on the architecture, the OBC output may need to operate down to less than 250VDC and operate as high as 850VDC when charging the main vehicle battery pack.

- Space constraints relate to power density targets and necessary isolation at the board level. Isolation could apply to communication, feedback signals and gate drivers.



Market Information and Trends

Trends

Migrating to higher power tiers and higher voltages. OBC designs today support a variety of voltages and power tiers but the designs are evolving along with the evolution of the electrical power train. A need to support powers of 11kW to 22kW while also supporting higher battery voltages up to 800V is underway.

- **onsemi**, as proven supplier of power modules into high power automotive applications is ready for 800V battery systems transition thanks to its 1200V SiC MOSFETs and APMs. With among the highest power density with the Automotive Power Module (APM) technology, supplying modules to Tier 1 and OEM customers for 10+ years.
- Electrification is spreading to buses, vans, Heavy-Duty & Agriculture vehicles and ships. These **emerging markets** push OBC development into further higher power tiers, typically above 22kW. APM32 SiC modules can provide here an efficient solution.
- **onsemi** gate drivers pair very well with its power stage solutions, exhibiting great noise immunity and efficiency at Miller Plateau. Isolated gate driver portfolio has grown with more options for high power SiC MOSFETs and continuing coverage for Si MOSFETs and IGBTs.

While many OBC implementations are unidirectional (grid to vehicle) **there is a gradual adoption of bidirectional capability, allowing both grid to vehicle and vehicle to grid charging with BEVs**. Topologies of individual power stages must be adapted to allow bidirectional capability. This makes most sense for BEVs where battery energy capacity is much higher than in PHEVs.

The importance of an OBC can be explained by looking at the existing charging infrastructure. There are three classifications or “levels” of chargers for a battery electric vehicles.

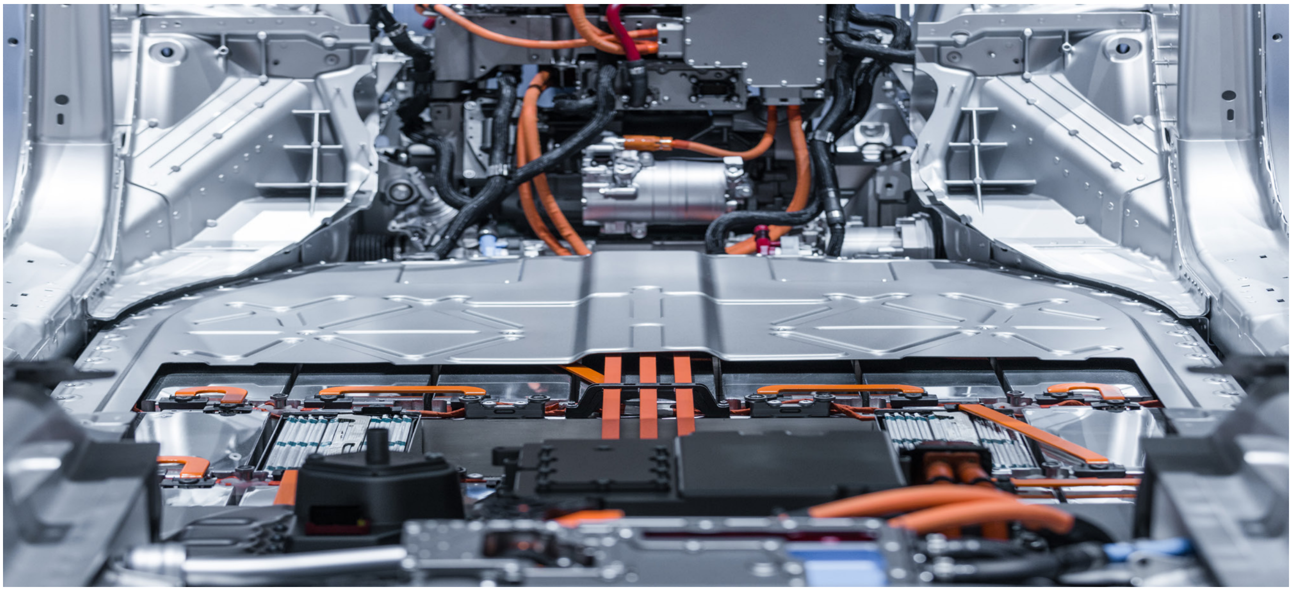
- Level 3 DC chargers provide very fast charge times but it is an expensive solution. Ideal for highway and heavy commercial installations. Far fewer installations exist compared to level 2.
- Level 2 chargers are an interface between a higher power AC source and the EV’s OBC. Very cost-effective solution for light commercial and small business installations. Rapidly growing capacity segment which relies on the cars installed OBC.
- Level 1 chargers are little more than a plug interface between a 15A-20A outlet and the EV’s OBC. Allows charging at home or from any outlet, but at an impractically slow rate.

Charger Type	Typical Power	Output	Notes	# in US
Level 1	1.2 kW	AC	• Charges battery via OBC • Charge time limited by wall outlet max power.	1 per BEV
Level 2	3 kW to 19kW	AC	• Charges battery via OBC • Charge time may be limited by charger output or OBC power capacity	>130 000 (rapid growth)
Level 3	50 kW to 350+ kW	DC	• Bypasses OBC and directly charges DC battery • Charge time limited by charger output or battery limitations	>35 000 superchargers

System Description - Standards

Compliance with ISO26262, an international functional safety standard, is essential for the development of electrical and electronic systems in road vehicles. Its primary goal is to minimize the risk of hazards caused by system failures in vehicles, addressing potential dangers such as software glitches, sensor errors, and hardware malfunctions. It provides an automotive-specific approach for determining risk classes known as ASILs, which can vary based on customers and worldwide regions. (ASIL QM,A,B,C,D) Requirements can go as high as ASIL-D. The standard also defines guidelines to minimize the risk of accidents and ensure that automotive components perform their intended functions.

- **onsemi**, with its long history as a leading provider of automotive products, understands the challenge to reduce costs, combined with increasing demands on performance and safety. Expertise and Implementation of ISO 26262 at onsemi is a key in providing cost effective solutions to customers, without compromising on safety.
- It enables the company to offer optimal architectures and solutions by identifying safety requirements assigned to integrated circuits and other automotive components. Focusing on the important failure modes and their prevention.



- Since the deployment of ISO 26262, **onsemi** has developed and introduced ASICs and standard products with safety requirements ranging from ASIL A to ASIL D.
- **onsemi** is a member of the ISO 26262 workgroup and the semiconductor sub-workgroup.
- All **onsemi** automotive design centers have been trained on Functional Safety (FuSa) and ISO 26262. **onsemi** has integrated the requirements of ISO 26262 into its Quality Management System, and a dedicated organization has been put in place to manage functional safety within the company.

Solution Overview

Integrated APM16 Modules for HV Applications (OBC)

The [APM16 family](#) **(APM = Automotive Power Module)** has a variety of solutions for the PFC stage, primary side DCDC stage as well as secondary rectification side using combinations of **Si SJ MOSFET** and **Si or SiC diode** technologies. APM16 modules are **capable of supporting 400VDC battery systems**.

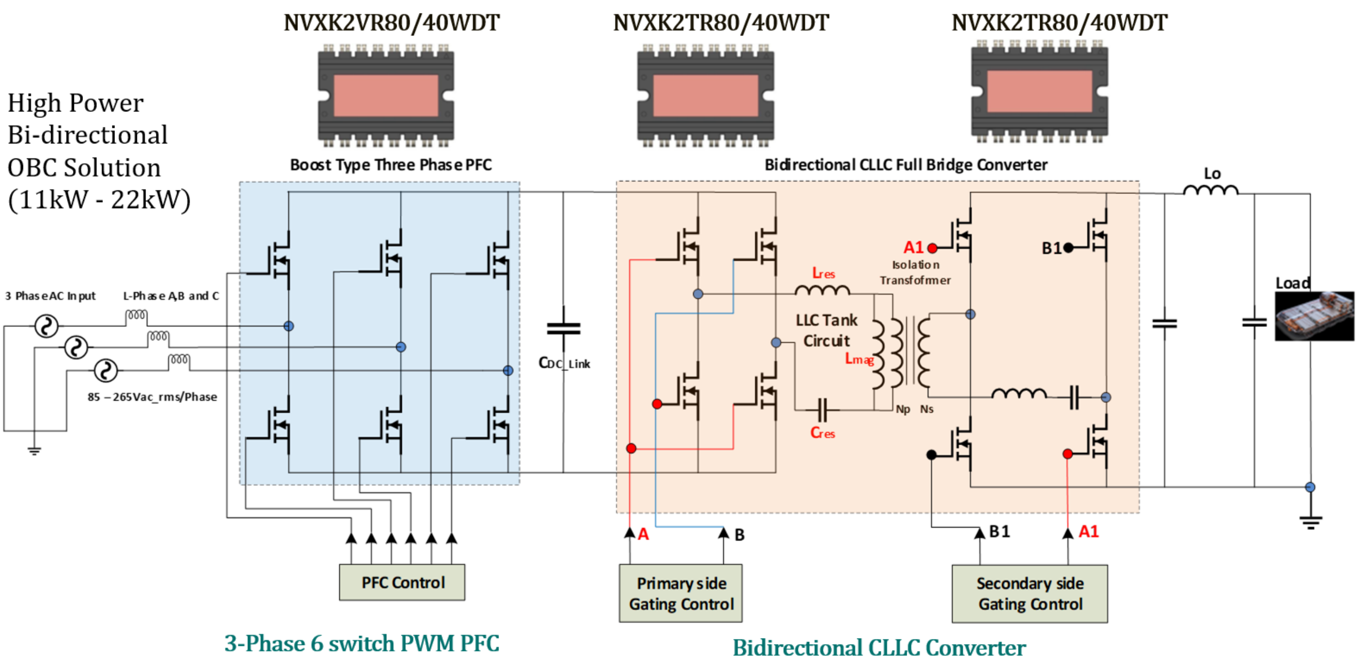
- Advantages of using the APM16 module technology are reduction in form factor, improved thermal design, lower stray inductance, lower internal bond resistance, increased current capability, improved EMC performance and increased reliability as compared to discrete solutions.
- These devices are compliant to IEC-60664-1 for functional and reinforced isolation up to VAC 5kV/1sec. APM16 modules are qualified under AECQ-101 and AQG-324 (automotive module standard). APM16 designs can utilize **onsemi** gate drivers and current sense amplifiers to complete the OBC power conversion solutions.

Integrated APM32 Modules for HV Applications (OBC)

The **APM32 family** **(APM = Automotive Power Module)** is ready for 800V battery systems and higher power OBC thanks to integrating 1200V SiC devices. Vienna rectifier module featuring 1200 V 80 mΩ SiC MOSFET and SiC and Si diodes. Dual half bridge modules featuring 1200 V 40 mΩ (80 mΩ) SiC MOSFETs mounted on different substrates. App note about employing a 1200V SiC module and provided benefits in terms of electrical and thermal performance as well as power density.

- APM packaging technology is designed and manufactured internally allowing more control for thermal optimization (not out-sourced like some competitors). **onsemi** also provides flexible packaging options as well as manufacturing options allowing customers to purchase bare die, discretes or modules.

<u>APM32 1200V SiC Power Modules</u>

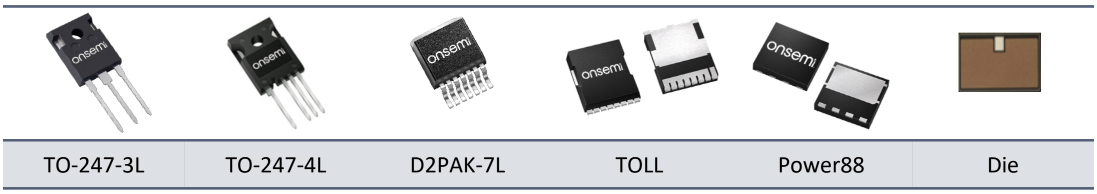


Solution Overview

SiC MOSFETs vs Si SJ MOSFETs vs IGBTs

SiC MOSFETs can be used in PFC, primary side DCDC and secondary side rectification (bidirectional) and are **the recommended technology for 800VDC battery systems.** This technology offers the **highest efficiency and power density as compared to IGBTs or Si SJ MOSFETs.** In many designs using SiC MOSFETs, there is a potential for a hybrid solution where some power stages of the OBC may use IGBTs or Si SJ MOSFETs as well.

- **In 400VDC battery systems SiC MOSFETs can provide efficiency improvements of 0.2% - 0.5%** if used in traditional boost or interleaved boost topologies and improvements in power density and efficiency when used for primary side DCDC or secondary side rectification (bidirectional). An even larger benefit is possible when SiC MOSFETs are used in higher power tiers where efficiency is critical to reducing thermal loads.
- Recommended solutions are 1200V SiC MOSFETs for 800VDC battery systems and 650V SiC MOSFETs for 400VDC battery systems. **SiC MOSFET technology is the recommended solution for any battery voltage when using Totem Pole PFC.**



Si SJ MOSFETs can be used for PFC, primary side DCDC and secondary side rectification (bidirectional). They work well for PFC in traditional boost, bridgeless boost and Vienna rectifier designs but are at a disadvantage when used in Totem Pole PFC. This disadvantage in hard switching Totem Pole PFC is due to the reverse recovery losses of the body diode and the inability to function in Continuous Conduction Mode. **Si SJ MOSFETs offer higher switching speeds than IGBTs and higher efficiency.** For OBC battery voltages of 400VDC nominal, 650V Si SJ MOSFETs are well suited for both primary side rectification and secondary side rectification in bidirectional designs.

IGBTs can be used for PFC and primary side DCDC. **IGBTs do not have an internal body diode and require packaging to include a diode internally or add external diode in parallel. A hybrid IGBT will include a SiC diode in the package.**

- For PFC, IGBTs can be used in most topologies and may be used for the “low-speed leg” of Totem Pole PFC even when other technologies are used for the “high-speed leg”. **IGBTs can be used in lower power tier designs when cost is a factor for primary side DCDC conversion.**
- The slower switching speeds and lower efficiencies will have to be considered acceptable for the design when compared to Si SJ MOSFETs or SiC MOSFETs. IGBTs can be also used for secondary rectification in bidirectional designs for lower power tiers however this is not typical due to the higher switching losses (as compared to Si SJ or SiC MOSFETs).

Solution Overview

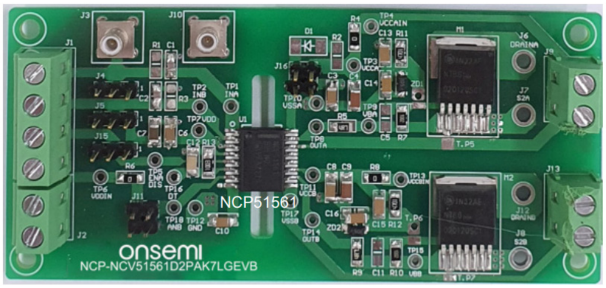
Si Diodes vs SiC Diodes

Si diodes are used in OBC PFC stages as well as secondary side rectification (unidirectional designs) in 400V battery systems. SiC diodes become better choice for 800V battery systems due to their advantageous power density, higher voltage ratings and no reverse recovery losses. SiC diodes are also used with lower voltages to improve efficiency.

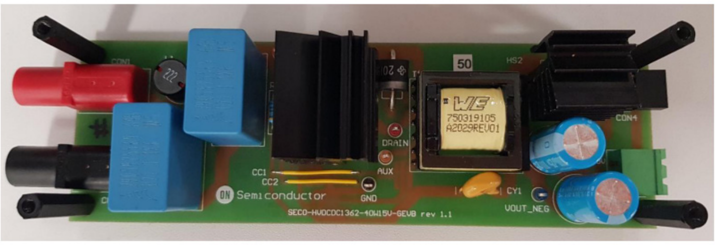
Gate Driver & Digital Isolation

Multiple isolated gate driver IC solutions for SiC MOSFETs (**NCV51705** / **NCV51561C/D**), IGBTs (**NCV57xxx**) and Si SJ MOSFETs (**NCV51561A/B, NCV511xx**) are available. Galvanic isolation roadmap is further improving propagation delay and higher CMTI.

- Isolation strategies can vary from customer to customer and the **NCIV9xxx family** of digital isolators can be used to further address these requirements on communication lines.
- Wide portfolio of gate driver evaluation boards allows fast prototyping. For testing our gate drivers with any solution: Gate drivers plug-and-play ecosystem [SECO-GDBB-GEVB]



Isolated dual–channel gate driver NCV51561



SiC Auxiliary Power Supply with NCV1362 controller

Power Tree

Isolated power in the form of a flyback DCDC topology can be used to isolate power planes with the **NCV1362 controller** which can then feed an SBC or discrete LDO power ICs. It supplies from 20W up to 40W output power. For the auxiliary power supply on the 12V VBUS **onsemi** has NCV898031 flyback controller IC that requires a opto-feedback solution.

System-Basis-Chips (SBC) are optimized based on customer requests and can match customer needs for communication, power, specific features etc. Customers can also choose from list of standardized SBC adapted for popular applications. SBC like the **NCV7471C or NCV745x** combine the functionalities of system power sequencing, communication bus interface requirements as well as a built-in DC/DC converter supplying the 5V rail.

Additional rails can be generated using LDOs such as the **NCV8170 / NCV816x** or **NCV87xx**. For further noise enhancements related to the gate drivers the **NCV3064 controller** can be used to generate isolated rails for the required switching technology. **onsemi** offers a wide portfolio with very low RMS noise down to 4.4uVrms, excellent PSRR greater than 90dB, very low Iq and 150°C junction rating. Pin to pin compatible devices. Power Good (PG) pin.

Solution Overview

Analog Signal Chain

[NCV2191x](#) or **NCV20xxx** op-amps can be used for voltage measurements while **NCV21xR** current sense amplifiers can be used for low side current sensing in HV applications. For low side sensing applications the common-mode range of -0.3V to +26V is acceptable. For more tolerance on the negative voltage side of the range the NCV7041 family should be considered with the common-mode input range of -5.0V to +80V (gain options of 14, 20, 50 and 100).

NCV225x comparators along with the **NVT211** temperature sensor and **NCV431** shunt voltage reference allow for monitoring a variety of system information with high accuracy.
Make sure to choose amplifiers with right bandwidth, offset and desired drift.

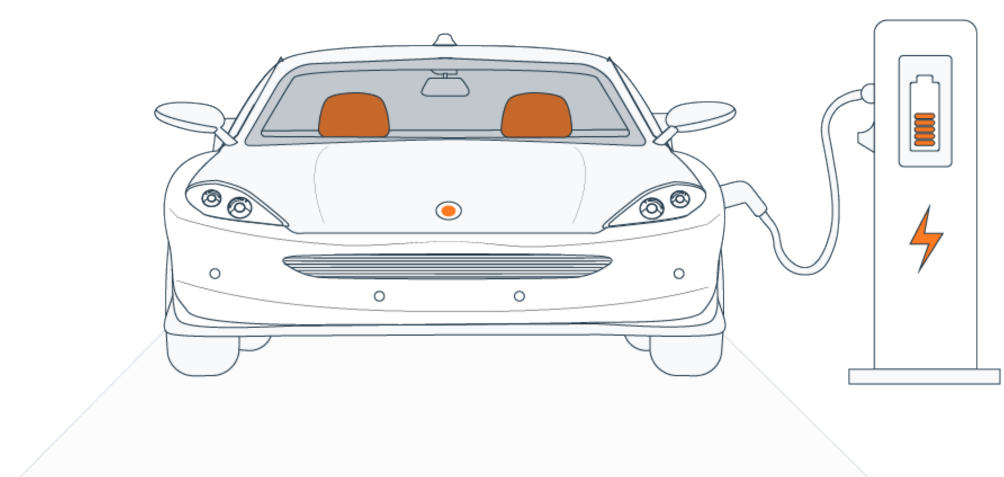
IVN & CAN ESD Protection

onsemi develops CAN and CAN-FD devices from day 0 for automotive customers. These products are qualified at all the major automotive OEMs and offering a full portfolio addressing LIN, CAN, CAN-FD and FlexRay.

- Options for both **CAN** and **CAN-FD** transceivers like **NCV734x** are available along with an upcoming offering for **isolated CAN**.
- Communication interface lines should have protection from transient events by incorporating devices such as the **SZNUP2124** and **SZNUP2125.**

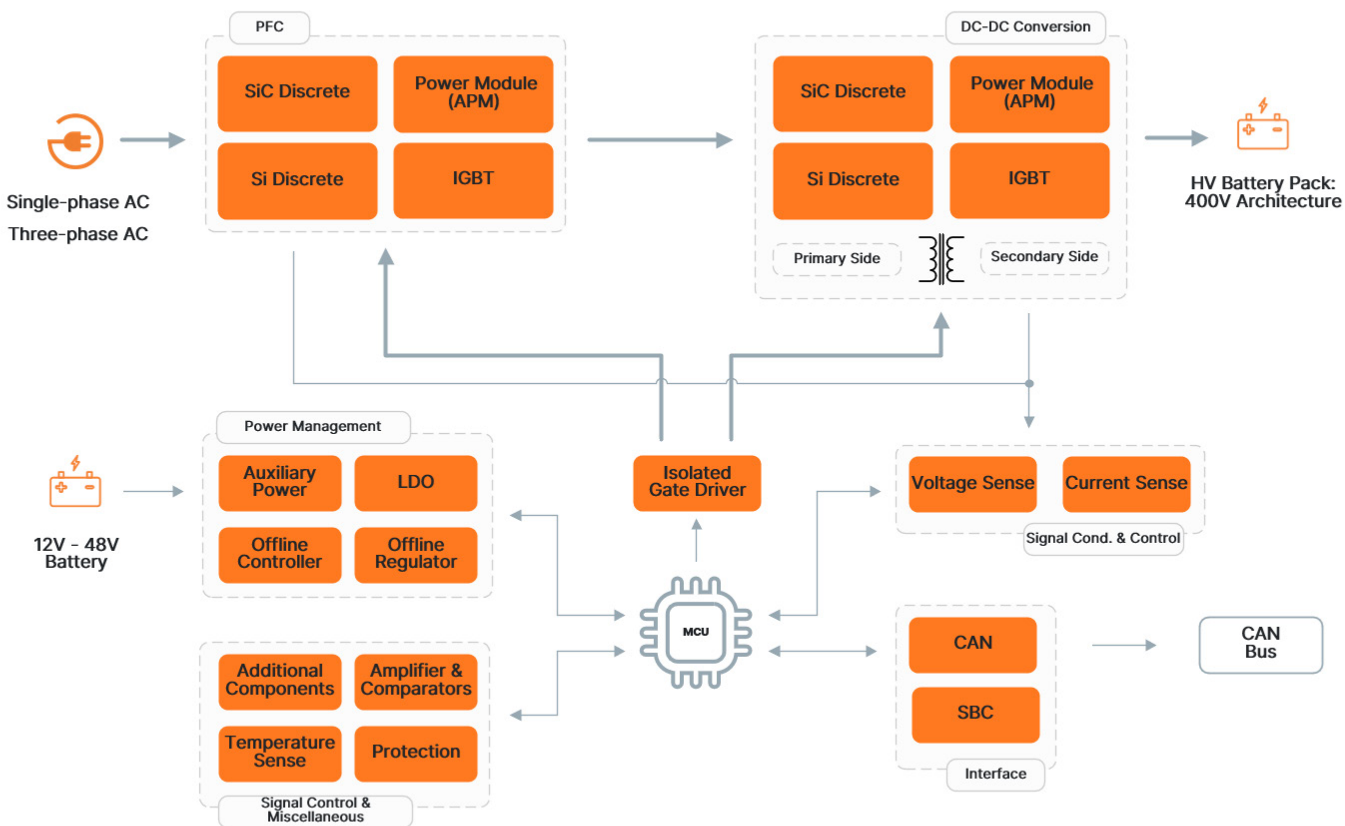
Mechanical and Thermal Considerations

Mechanical packaging constraints may affect electrical component choices for height, mass etc. Thermal management should be addressed also on system level whether to use air or liquid cooling.
It is important to consider choice of materials and component packaging to assist with thermal management.
See onsemi APMs app note for improved thermal performance and learn more.



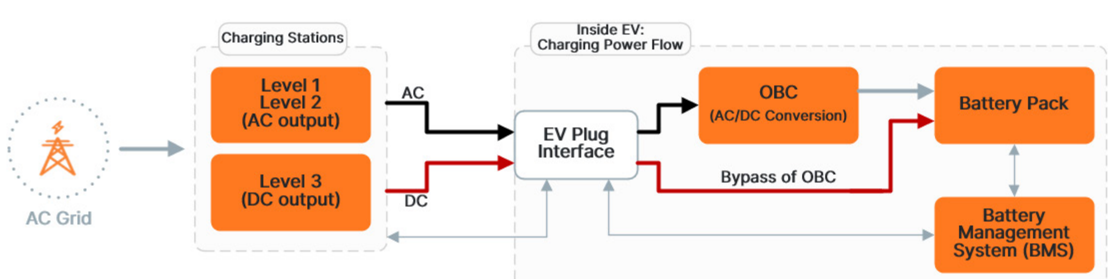
Solution Overview – Block Diagram

On Board Charger for 400V battery architecture



System Level Diagram of EV Charging

There are three classifications or “levels” of charging stations. Level 1 & 2 deliver AC power into the vehicle’s OBC which charges DC battery with the appropriate output current and voltage. Level 3 are the “off-board” DC charging stations which bypass vehicle’s OBC and supply high-voltage DC with up to 400 A directly to the vehicle’s battery.



Recommended Products

Suggested Block	Part Number (PN)	PN Description, Comments
	400V Battery Systems	
Power integrated Modules APM16 for PFC and DC-DC Stage	FAM65CR51DZx FAM65CR51XZx FAM65CR51ADZx FAM65CR51AXZx	Boost Converter Stage modules for Multiphase and Semi-Bridgeless PFC. Totem Pole variant. Integrated Si 650V MOSFETs, Diodes: Si 600V or SiC 650V
	FAM65HR51DS1/2 FAM65HR51XS1/2 NXV65HR51DZ2 NXV65HR82DS1/S2 NXV65HR82DZ1/Z2	Half-Bridge modules for LLC and PSFB DC-DC Converter. Various substrates and lead forming options. Integrated Si 650V MOSFETs (51mΩ or 82mΩ Rds(on) Optional snubber capacitor for improved EMI
	Application recommended 650V APM16 Modules	
	400V Battery Systems	
Si MOSFETs (SUPERFET III family**)**	NVB125N65S3	Si MOSFET 650 V, 24 A, 125 mΩ, D2−PAK
	NVHL082N65S3HF	Si MOSFET 650 V , 40 A, 82 mΩ, TO-247 fast recovery
	NVH040N65S3F	Si MOSFET 650 V , 65 A, 40 mΩ, TO-247
	Application recommended Si SJ MOSFETs	
SiC MOSFETs (M2 family)	NVH4L095N065SC1	EliteSiC MOSFET, 70 mΩ, 650V, 31A, TO247−4L
	NVBG060N065SC1	EliteSiC MOSFET, 44 mΩ, 650 V, 46A, D2PAK−7L
	NVH4L025N065SC1	EliteSiC MOSFET ,21mΩ, 650V, 96A, TO247−4L
	Application recommended SiC M2 MOSFETs	
IGBT with co-packed diode (FS4 family)	AFGB30T65SQDN	IGBT 650V, 30A, Si diode, D2PAK
	AFGHL50T65SQD	IGBT, 650V, 50A, Si diode, TO-247-3LD
	AFGHL75T65SQDC	Hybrid IGBT, 650V, 75A, SiC diode, TO-247-3LD
	Application recommended IGBTs	
SiC Schottky Diode (D2 family)	FFSD0865B-F085	650V , 8A , DPAK (single diode)
	FFSH2065B-F085	650V , 20A , TO-247-2L (single diode)
	FFSP4065BDN-F085	650V , 40A , TO-220-3L (2diodes in 1 package) Common cathode 40A per device, 20A per leg.
	Application recommended SiC D2 diodes	
Si Diode	Application recommended Si diodes	
	800V Battery Systems	
Power integrated Modules APM32 for PFC and DC-DC Stage	NVXK2KR80WDT	Vienna Rectifier power module for PFC stage. With SiC 1200V, 20A, 80 mΩ MOSFETs. Auto qualified per AEC-Q101 and AQG324.
	NVXK2TR40WXT NVXK2TR80WDT	Dual Half-bridge power module for DC-DC stage, SiC MOSFETs Auto qualified per AEC-Q101 and AQG324 1200V, 27A, 40 mΩ 1200V, 20A, 80 mΩ

Recommended Products

Suggested Block	Part Number (PN)	PN Description, Comments
800V Battery Systems		
SiC MOSFETs (M1 family)	NVH4L020N120SC1	EliteSiC MOSFET,1200V, 20 mΩ, 102 A (max), TO247−4L
	NVBG080N120SC1	EliteSiC MOSFET,1200V, 80 mΩ, 30 A (max), D2PAK−7L
	NVHL040N120SC1	EliteSiC MOSFET,1200V, 40 mΩ, 60 A (max), TO247−3L
	Application recommended SiC M1 MOSFETs	
	M1 SiC MOSFETs family is designed for lowest $R_{DS(ON)}$ with high switching speed, ultra low gate charge $Q_{G(TOT)}$ and low capacitance C_{OSS}	
SiC MOSFETs (M3S family)	NVH4L022N120M3S	EliteSiC MOSFET,1200V, 22 mΩ, 89 A (max), TO247−4L
	NVBG070N120M3S	EliteSiC MOSFET,1200V, 70 mΩ, 36 A (max), D2PAK−7L
	NVH4L040N120M3S	EliteSiC MOSFET,1200V, 40 mΩ, 54 A (max), TO247−4L
	Application recommended SiC M3S MOSFETs	
	M3S SiC MOSFETs family uses a new technology optimized for low switching losses, further reducing gate charge $Q_{G(TOT)}$ and capacitance C_{OSS} while maintaining low $R_{DS(ON)}$	
SiC Schottky Diode (D1, D3 family)	FFSB10120A-F085	EliteSiC diode 1200V , 10A , D1, D2PAK (single diode)
	FFSH20120A-F085	EliteSiC diode 1200V , 20A , D1, TO-247-2L (single diode)
	NVDSH50120C	EliteSiC diode 1200V , 50A , D3, TO-247-2L (single diode)
	Application recommended SiC D1, D3 diodes	
Gate Drivers		
Gate Drivers for SiC and Si MOSFETs	NCV51561	Dual Channel Gate Driver, 5 kVrms Isolation, 4.5/9 A, with 17V UVLO
	NCV51563	Dual Channel Gate Driver, 5 kVrms Isolation, 4.5/9 A, with 17V UVLO High Channel-to-Channel spacing (creepage)
	NCV5106	High Voltage gate Driver IC, 2 outputs for high+low side or half-bridge configuration.
	NCV51705	Low-Side Single 6A Driver designed for SiC MOSFETs. High-Speed.
	NCV7520	FLEXMOS programmable low-side MOSFET pre-driver. For driving logic-level MOSFETs in automotive power management.
	Application recommended gate drivers for SiC MOSFETs.	
	Application recommended gate drivers for Si MOSFETs.	
Gate Drivers for IGBTs	NCV57090	Single-Channel Gate Driver for high current and power applications. 5 kVrms Isolation, Active Miller Clamp
	NCV57000 NCV57001	Single-Channel Gate Driver for high current and power applications. 5 kVrms Isolation, Active Miller Clamp, DESAT protection
	NCV57080xx	Single-Channel Gate Driver for high current applications, 3.75 kVrms Options with: Miller Clamp/Negative Power Supply/Separate outputs
	NCV57252xx NCV57255xx	Dual-Channel Output IGBT Driver,2.5 or 5 kVrms Isolation Configurable as Low/High-Side Half-Bridge driver.
	Application recommended gate drivers for IGBTs.	
Gate Driving Buffer BJT	NSV60600MZ4	Low VCE Buffer BJT, PNP, 60V, 12A
	NSV60601MZ4	Low VCE Buffer BJT, NPN, 60V, 12A
Half-Bridge Gate Driver	NCV57200 NCV57201	Isolated High Side & Non-Isolated Low Side. Deadtime & interlocks protection. (Two independent inputs)

On Board Charger (OBC)

Recommended Products

Suggested Block	Part Number (PN)	PN Description, Comments
Controllers & Auxiliary Power Supplies		
Controllers, Converter, Switching regulator	NCV898031	Non-Synchronous SEPIC / Boost Controller, 2 MHz. Rich Features. Optimized for pre-regulation (3.2-40 Vin DC) Adjustable output.
	NCV12711	Peak current-mode PWM controller: 4-45 Vin DC. Rich features. Great for 12 V & 24 V Automotive Auxiliary Power Supplies.
	NCV3064	Buck/Boost/Inverting Switching Regulator. 1.5 A DC Adjustable output, precise reference, multi-purpose.
	NCV6323F-xx	Buck converter, Synchronous, PWM. Up to 1.6 A DC. DC-DC converter. Various Fixed Output Voltages. Optimized to supply sub-systems.
	Application recommended automotive DC-DC converters and controllers.	
Offline Regulators	NCV1076 NCV1060 NCV1063	Automotive High-Voltage Switching Regulator. Integrated Current mode controller with 670V MOSFET. Provided with different features and packages.
Offline controllers: PWM control, LLC control	NCV3843B	Current Mode PWM Controller, suited for driving power MOSFETs Designed for DC-DC converter applications.
	NCV4390	Secondary side PFM controller for LLC resonant converters with synchronous rectifier control.
	NCV1362	Primary side Flyback Controller. Integrated features for easy control of high−performance off−line power supplies
	NCV1397xx	Resonant Mode Controller with Integrated HV Drivers. Can be utilized in half bridge resonant topologies like LLC resonant converters.
LDO		
LDO Regulator	NCV8163	250mA, High PSRR, Very Low Noise, 1uF COUT, TSOP-5 & XDFN4
	NCV8164	300mA, High PSRR, Very Low Noise, 1uF COUT 150C Power Good, Fixed & Adjustable output options, WDFNW6 & DFNW8 packages
	NCV8189	500mA, High PSRR, Very Low Noise, 1% accuracy, 150C, Power Good, Fixed & Adjustable output options, WDFNW6 & DFNW8 packages
	NCV59801	1A, High PSRR, Very Low Noise 1% accuracy 150C Power Good Fixed & Adjustable output options WDFNW6 & DFNW8 packages
	NCV8718xx	300mA, 24 Vin max, 4uA Iq, Fixed & Adjustable Vout options WDFN6 package
	NCV1117xx	1A, High PSRR, (up to 20 Vin) Adjustable and fixed output options.
	NCV8730xx	150mA, Low Iq 1uA (2.7-38 Vin range) Adjustable and fixed output options, PG ideal for power sequencing.
	Application recommended Post-Regulation LDOs.	
Power Management : Protection		
eFuse	NIV6150 NIV6350	Resettable fuse 200 mΩ (85 mΩ) $R_{DS(ON)}$ Reverse current protection. Fast response Overvoltage clamp and undervoltage lockout.
	NIV3071	eFuse 4 channels. Ideal for 12V up to 48V applications, Vin 8V to 60V, 10A when channels are parallel (2.5A continuous current per channel)

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Recommended Products

Suggested Block	Part Number (PN)	PN Description, Comments
CAN Transceivers (In Vehicle Networking)		
CAN (CAN-FD) Transceivers	NCV7343	Low Power & High Speed, INH, Wake-up, Error Detection.
	NCV7342 NCV7344 NCV7349	Low Power & High Speed Transcievers Various packages, features and pin functions.
	NCV7446	Dual Transceiver, Low Power & High Speed . Wake-up
	Application recommended CAN Transceivers for In Vehicle networking.	
CAN Protection, ESD Protection	SZNUP3125 SZNUP2124 SZNUP2125	Protects CAN transceivers from ESD and other harmful surge events. Bidirectional protection for each data line. Options for 32V, 24V Dual Line CAN/CAN-FD/CAN+LIN Bus Protector.
	SZESD8704xx	Unidirectional High Speed Data Line Protection.
System Basis Chip (SBC)		
System Basis Chip (SBC)	NCV7450	SBC with CAN FD transceiver, LDO (5V/250mA) & HS Driver
	NCV7451	SBC with CAN FD transceiver, LDO (5V/250mA) & Wake Function
	NCV7471C	SBC with CAN/CAN-FD + 2 LIN transceivers, Boost-Buck DC-DC (5V/500mA) and LDO (5V/50mA)
Analog Signal Chain		
Low Power & Precision **Operational Amplifier**	NCV21874	Zero-Drift, 45 µV Offset, 0.4 µV/°C
	NCV21911xx	36V, 2 MHz GBW, Low Noise, Zero-Drift, 25 µV Offset
	NCV2007x	36V, 3MHz, Rail-to-rail output
	NCV20231xx	36V, 3 MHz GBW, 0.95 mV Input Offset. Wide supply range 2.7 V to 36 V.
	NCV333xx NCV2333 NCV4333	Low Power Zero-Drift Op-Amp, 10 µV (30 µV) Offset, 0.07 µV/°C low offset drift, space saving packages. Single, Dual and Quad channel configuration.
	Application recommended automotive Low Power & Precision Op-amps.	
Low Voltage Comparator	NCV2250	Push-Pull, High Speed, 50 ns propagation delay
	NCV2252	Open Drain, High Speed, 50 ns propagation delay
	NCV2901 NCV2903	36V, Low Offset Current +/- 5.0 nA, Single or Split Supply, Input Common Mode Voltage to GND level
Current Sense Amplifier (CSA)	NCV7041	CSA for high voltages (HV) with high resolution. Best for High-side sensing in HV applications. V_{CM} 80V, Bi-directional. Gain Options: 14, 20, 50, 100 V/V
	NCV7030	V_{CM} 80V, Uni-directional, 100 kHz BW, Gain Options: 14, 20 V/V 0.3 % gain error over the entire temperature range
	NCV21674	V_{CM} 40V, Uni-directional, Low Offset Voltage 100µV and Drift 1µV/C
	NCV210, NCV211 NCV213, NCV214	Low offset & zero drift architecture. Bidirectional. For both Low-side and High-side sensing. Multiple Gain Options: 50, 100, 200, 500 V/V
Temperature Sensing	NVT210CMxx NVT211CMxx	Digital Temperature monitor ±1°C with series resistance cancelation. Under/Over-temperature alarm. Serial Interface (i2c, SMBus)

Recommended Products

Suggested Block	Part Number (PN)	PN Description, Comments
Miscellaneous components		
Voltage Level Translator	NLV9306USG	Dual Bidirectional, Translation between various voltage levels Low propagation delay (max 1.5ns), I2C SMBus
	NLVSX4014MUTAG	4-Bit configurable Dual Bidirectional translator, 100 Mbps
Automotive EEPROM	NV24C64xx	64-Kb I2C
	CAV24C512xx	512-Kb I2C
	NV25320xx	32-Kb SPI
Precision Voltage Reference	SC432BVSNT1G NCV431	Programmable Voltage Reference, Temperature compensated Low Cathode Current, Shunt Regulator
Digital Isolation	NCIV9211 NCIV9311 NCIV9401	High Speed 2/3/4 Channels Digital Isolator, Galvanically isolated Allows Isolated PWM control, Isolated Communication/Diagnostics

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Technical Documents

Note that reference designs may contain non-automotive parts to support functionality.

Type	Description & Link
Ref Design (Evaluation Board)	6.6kW Totem Pole PFC Eval Board for OBC
Ref Design (Evaluation Board)	11kW 3 Phase OBC Eval Board (PFC & LLC Platform)
Ref Design (Evaluation Board)	6.6kW OBC Using SiC devices (PFC & LLC application)
Ref Design (Evaluation Board)	Dual-channel isolated SiC gate drivers for OBC
Ref Design (Evaluation Board)	Isolated Supply for IGBT Gate Driver with NCV3064 Controller
Ref Design (Evaluation Board)	Isolated Supply for SiC Gate Driver with NCV3064 Controller
Ref Design (Evaluation Board)	40W SiC Auxiliary Power Supply for HEV & BEV applications
Ref Design (Evaluation Kit)	Reference design (kit) of CLLC bidirectional DC-DC stage for 6.6kW OBC
Ref Design (Evaluation Board)	Primary Side PWM Controller for flyback application
Video	OBC Short Walkthrough
Webinar	Adopting SiC for OBC and DC/DC Power Conversion
Ref Design Note	LLC Converter in OBC Applications [TND6318/D]
Application Note	OBC 3 Phase PFC Converter [AND9957/D]
Application Note	Electric Vehicle OBC System Design & Simulation Using Power Modules [AND9813/D]
Ref Design Note	6.6kW OBC Reference Design [TND6320/D]
Design Note	3.3kW OBC Reference Design [DN05107/D]

Solution Overview – Topologies

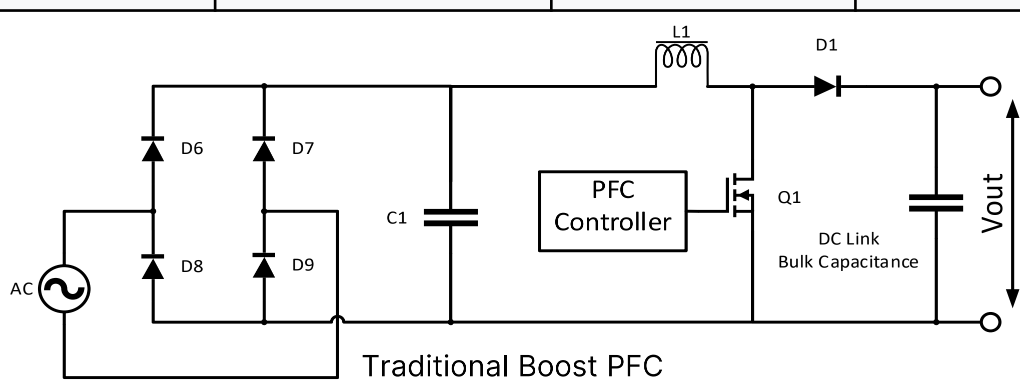
	PFC Stage Topologies (Traditional Boost w/ 1 or 2 channel interleaved, totem-pole)	Primary Side DCDC Topologies & Technologies	Secondary Side Rectification & Technologies
Unidirectional	• 1 phase traditional boost, 2 channel interleaved traditional boost or Totem Pole. • Vienna rectifier and 3 or 4 leg bridge can be used for 3 phase designs.	• LLC is the mainstream solution. Alternative design uses Phase Shifted Full Bridge (PSFB)	• Si diode bridge or SiC diode bridge. (only low power tier) • MOSFET full bridge.
Bidirectional	• Totem Pole designs for 1 phase AC. • Totem Pole (3 or 4 leg bridge) for 3 phase AC designs. (most common solution) • There is a modified Vienna rectifier that allow bidirectional operation, but rarely used	• CLLC is the mainstream solution.	• **Si SJ MOSFETs** can be used in any of these but at higher power tiers the losses become more significant. It will have low efficiency at low Vout condition. • **IGBTs** are not a great solution for this but in low power / low cost designs customers may use them. • **SiC MOSFETs** are dominant at the higher power tiers and may be used at the lower power tiers to improve efficiency
General	• **Si SJ MOSFETs** used for boost and bridgeless boost at <7.2kW power tiers. At 11kW and 22kW may be OK for Vienna based on type of Vienna design. • **IGBTs** can be used for all topologies but losses at 11kW and 22kW make their use less likely. Possible use in higher power tiers for the low-speed leg of totem pole PFC. • **SiC MOSFETs** can be used at all power tiers and all topologies. They have the best performance at the higher power tiers. They may be used in lower power tiers to improve efficiency as well. • **SiC diodes** can be used in all power tiers and topologies that require SiC diodes to gain the efficiency benefit of no reverse recovery losses. • **Si diodes** can be used in all power tiers but losses are more noticeable at higher power tiers.	• **Si SJ MOSFETs** can be used for 400V systems at the lower power tiers (<7.2kW) • **IGBTs** typically only used for PSFB but again for lower power tiers and lower cost designs customer may still use IGBTs. Won't be used in 11kW and 22kW designs. • **SiC MOSFETs** can be used in all power tiers for both 400V and 800V battery systems. Recommended solution for 800V systems. Best performance and efficiency.	-

Solution Overview – Topologies

Power Factor Correction (PFC) Topologies

- Typical PFC solutions for OBC will vary based on the number of input AC phases from the grid and output power level [kW] of the OBC unit. There are many different solutions for PFC in OBC and we list most common examples.
- For single phase AC input OBC modules, expect to see traditional boost, bridgeless boost or Totem Pole (all with optional multi-channel interleaved solutions). Most likely interleaved solution is 2 channels. 3 channel interleaving is feasible but the cost vs. benefit may be minimal. If the design is bidirectional then the PFC stage is going to be the Totem Pole topology.
- For 3 phase OBC modules, expect to see Vienna Rectifier and 3 or 4 leg bridge PFC (Totem Pole) topologies. 3 leg bridge PFC is for modules that have 3 phase inputs but no neutral, whereas 4 leg bridge PFC has 3 phase inputs (3 fast legs) as well as a neutral (4th “slow” leg). Fast legs and slow leg would switch at different frequencies. If the design is bidirectional then the most cost-effective PFC stage is going to be the 4 leg bridge (Totem Pole) topology.

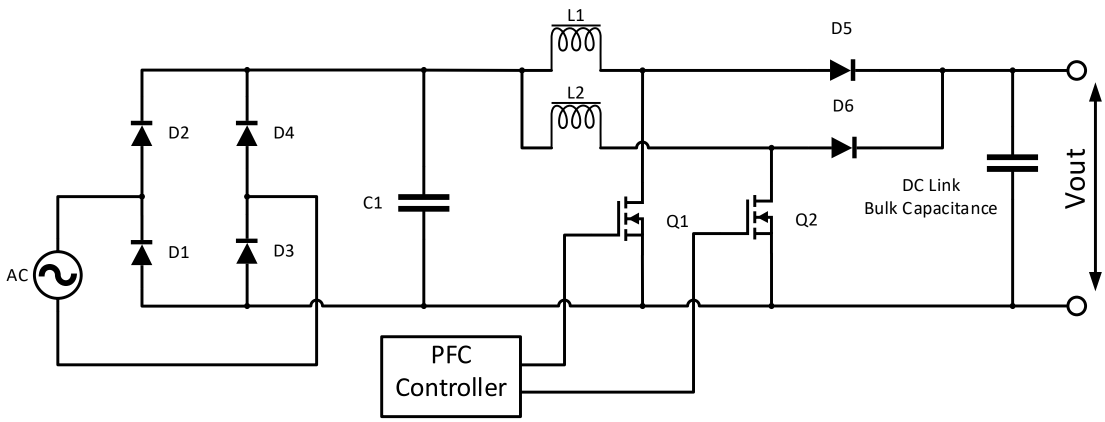
	SiC Diode	SiC MOSFET	IGBT	Si SJ MOSFET
Strengths	• No reverse recovery losses • Higher efficiency than Si diode • Simple solution for 800V systems • Improved power dissipation	• Best power density • Best efficiency in higher power tiers • Improved power dissipation • Higher switching frequencies with low losses • Can be used in nearly every topology for PFC • Best solution for 800V systems	• Mature technology • Lower cost • Can be used in traditional boost, Totem Pole and 3 or 4 leg bridge. • Often used in “slow” leg of Totem Pole PFC with other technologies used in the “fast” leg.	• Mature technology • Higher switching frequencies • Can be used in most topologies for PFC but not preferred for Totem Pole PFC • Good solution for 400V battery systems
Challenges	• Cost vs benefit for 400V battery systems	• Newer technology • Cost vs benefit for 400V battery systems	• Lower switching frequencies	• Body diode reverse recovery in Totem Pole PFC • Not for 800V battery systems



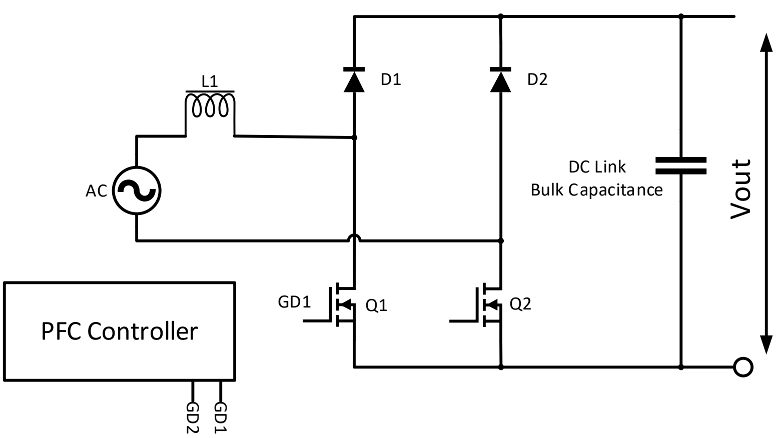
Traditional Boost PFC
Simplified Detail

Solution Overview – Topologies

Power Factor Correction (PFC) Topologies (Continued)



Traditional Boost 2 Channel Interleaved PFC

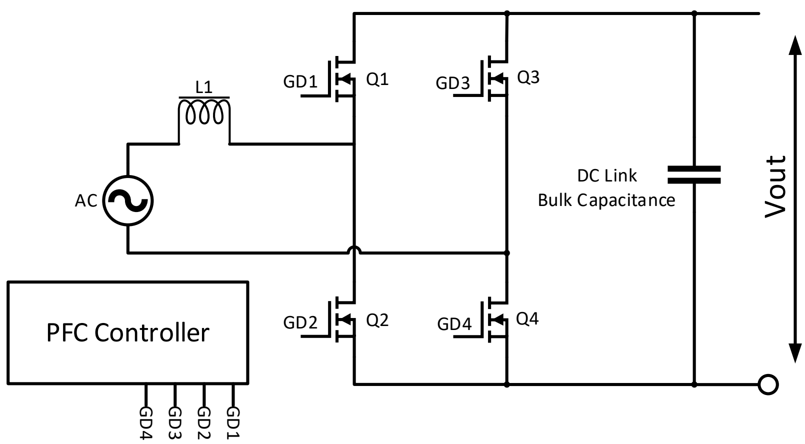


Bridgeless Boost PFC

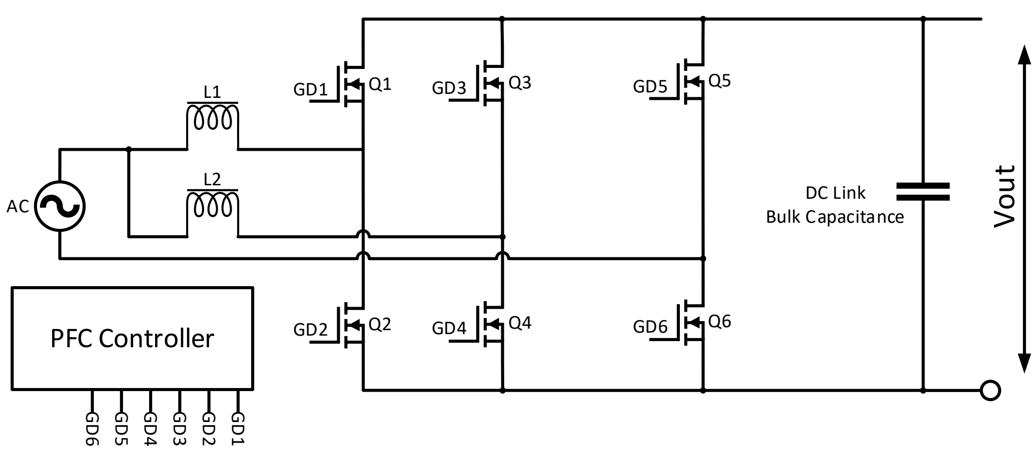
***Simplified Details**

Solution Overview – Topologies

Power Factor Correction (PFC) Topologies (Continued)



Totem Pole PFC

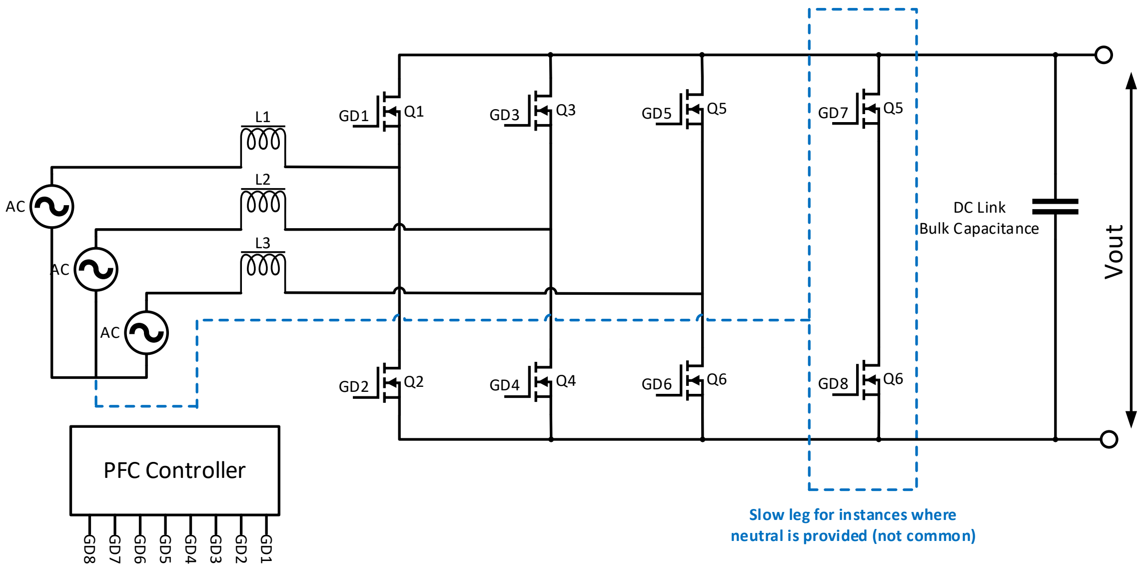


Totem Pole 2 Channel Interleaved PFC

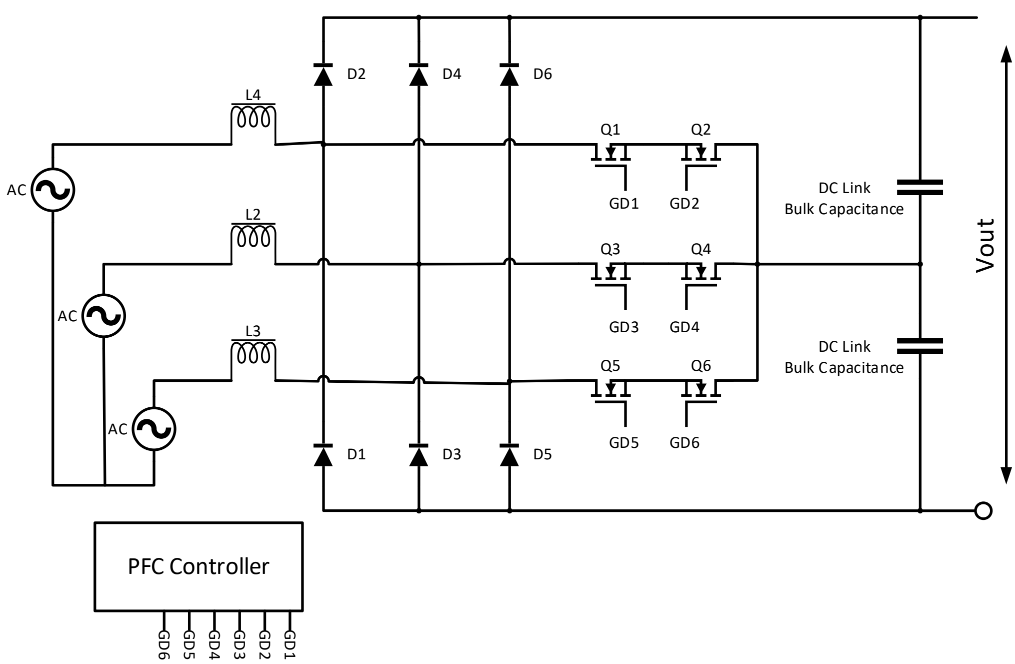
***Simplified Details**

Solution Overview – Topologies

Power Factor Correction (PFC) Topologies (Continued)



3 or 4 Leg Bridge / Totem Pole PFC



Vienna Rectifier PFC (Other Variants Possible)

***Simplified Details**

Solution Overview – Topologies

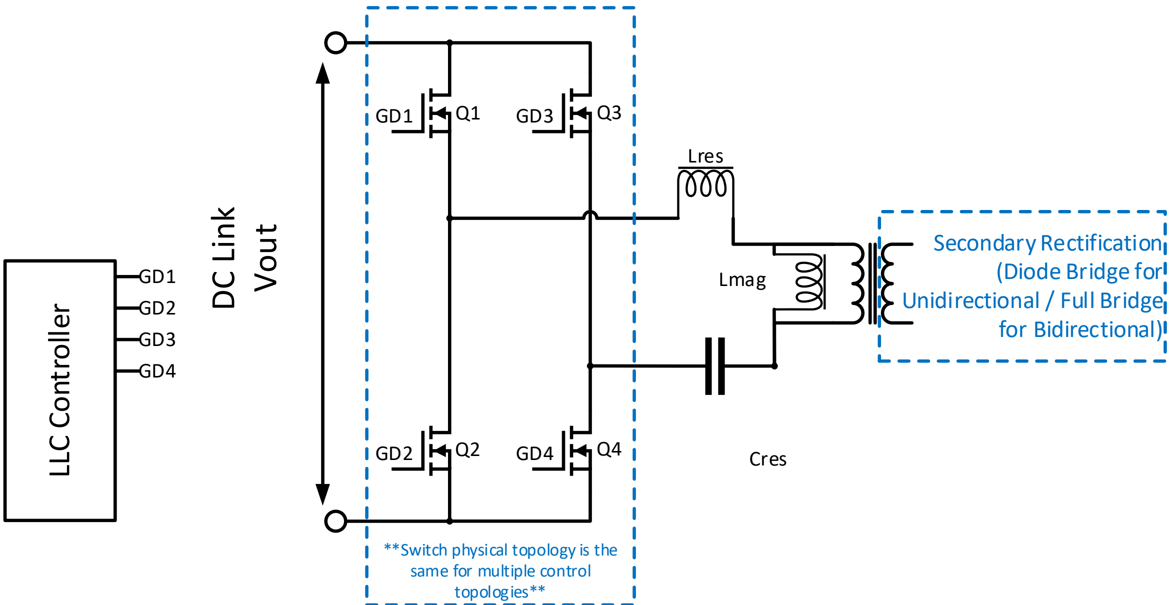
Primary Side DCDC Topologies

- Primary side DCDC conversion is typically achieved using LLC, CLLC or Phase Shifted Full Bridge (PSFB) topologies. Another term that might come up is Dual Active Bridge (DAB) but this actually includes both the primary and secondary rectification and is used in bidirectional designs. The most common solution for a unidirectional system is LLC and for a bidirectional system is CLLC. Certain bidirectional designs may use PSFB or some other variant. SiC MOSFETs and Si SJ MOSFETs can be used for all the different scenarios in primary side rectification, but IGBTs is only recommended for a PSFB topology. There are cost vs. benefit tradeoffs to consider for each solution, some of which are summarized in the table below.
- For 400VDC systems, any 650V technology could be used in the design (Si SJ MOSFET, SiC MOSFET, IGBT). Cost and efficiency targets of the OBC are the main decision-making factors.
- For 800VDC systems, 1200V SiC MOSFETs own the dominant trend although it is possible to use Si SJ MOSFETs if VBUS is a split architecture (400VDC + 400VDC).
- Regardless of the methodology used (LLC, CLLC, PSFB, DAB) the primary side rectification is almost always some version of full bridge switching. Therefore, while the components and transformer may have differences, 4 switches is the most common approach for primary side DCDC conversion.

	SiC MOSFET	IGBT	Si MOSFET
Strengths	• Best efficiency in higher power tiers • Improved power dissipation • Higher switching frequencies with low losses • Best solution for 800V systems	• Mature technology • Lower cost	• Mature technology • Higher switching frequencies • Higher efficiency than IGBT • Good solution for 400V battery systems
Challenges	• Newer technology • Cost vs benefit for 400V battery systems	• Lower switching frequencies	• Not recommended for 800V battery systems

Solution Overview – Topologies

Primary Side Rectification Topologies



Primary Side Rectification - Full Bridge LLC

NOTE: Other control topologies exist but the requirement for 4 switches on the primary side is very common.

***Simplified Details**

Solution Overview – Topologies

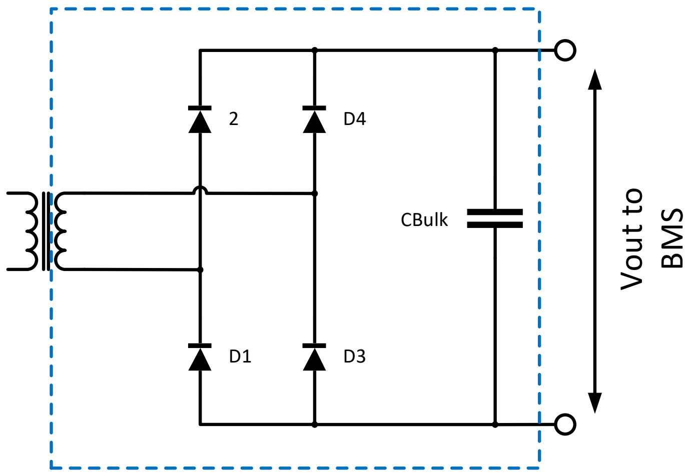
Secondary Side Rectification Topologies

- On the secondary side of the transformer the simplest solution is a diode bridge for rectification. This works as long as the design is unidirectional (grid to vehicle only). Depending on desired system efficiency, output voltage and system cost these diodes may be Si or SiC. SiC is the best choice for 800V battery or if the system needs to achieve more efficiency (SiC diodes have no reverse recovery characteristic).
  Full bridge solution with Si or SiC MOSFETs could be used to improve system efficiency in unidirectional designs, with higher cost to implement.
- For bidirectional OBC designs: Si or SiC MOSFET full bridge is required for bidirectional functionality. IGBT switching losses typically prevent this technology from being used on the secondary (higher power tiers). Si MOSFETs are acceptable for 400V battery systems but will exhibit efficiency drop-off at low load. SiC MOSFETs can provide the highest efficiencies in both 400VDC (650V SiC MOSFETS) and 800VDC (1200V SiC MOSFETs) battery systems, making 1200V SiC MOSFETs the absolute recommendation for 800VDC battery systems.

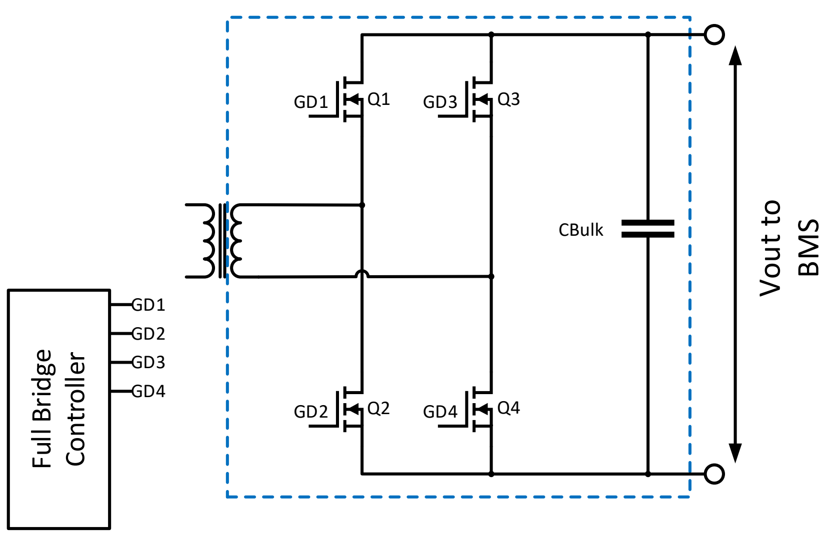
	SiC Diode	SiC MOSFET	IGBT	Si SJ MOSFET
Strengths	• No reverse recovery losses • Higher efficiency than Si diode • Simple solution for 800V systems • Improved power dissipation	• Best power density • Best efficiency in higher power tiers • Improved power dissipation • Higher switching frequencies with low losses • Best solution for 800V systems	• Lower cost if lower efficiency is acceptable	• Mature technology • Higher switching frequencies • Good solution for 400V battery systems
Challenges	• Cost vs benefit for 400V systems	• Newer technology • Cost vs benefit for 400V systems	• Not common • Lower switching frequencies • Lower efficiency	• Not for 800V battery systems

Solution Overview – Topologies

Secondary Side Rectification Topologies (Continued)



Secondary Rectification Diode Bridge – Unidirectional (Grid to Vehicle) Only



Secondary Rectification 4 Switch Full Bridge– Bidirectional (Grid to Vehicle & Vehicle to Grid) Only

***Simplified Details**

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