
# On-Board Charger (OBC) + DCDC Converter

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# Contents

# 1. Introduction

The rapid electrification of the automotive industry has driven significant advancements in power electronics, particularly in On-Board Chargers (OBCs). Modern electric vehicles (EVs) demand compact, efficient, and multi-functional power conversion solutions to optimize charging times, reduce weight, and enhance overall energy efficiency. A critical evolution in this domain is the integration of high-voltage (HV) to low-voltage (LV) DCDC converters within the OBC, enabling a unified power delivery architecture that serves both traction battery charging and auxiliary power needs. The diagram below illustrates a typical EV powertrain architecture, highlighting the OBC's central role in managing energy flow from the charging station to the Traction battery pack. This architecture presents opportunities for semiconductor solutions, where Nexperia's portfolio of efficient, robust, and automotive-qualified components can play a pivotal role.

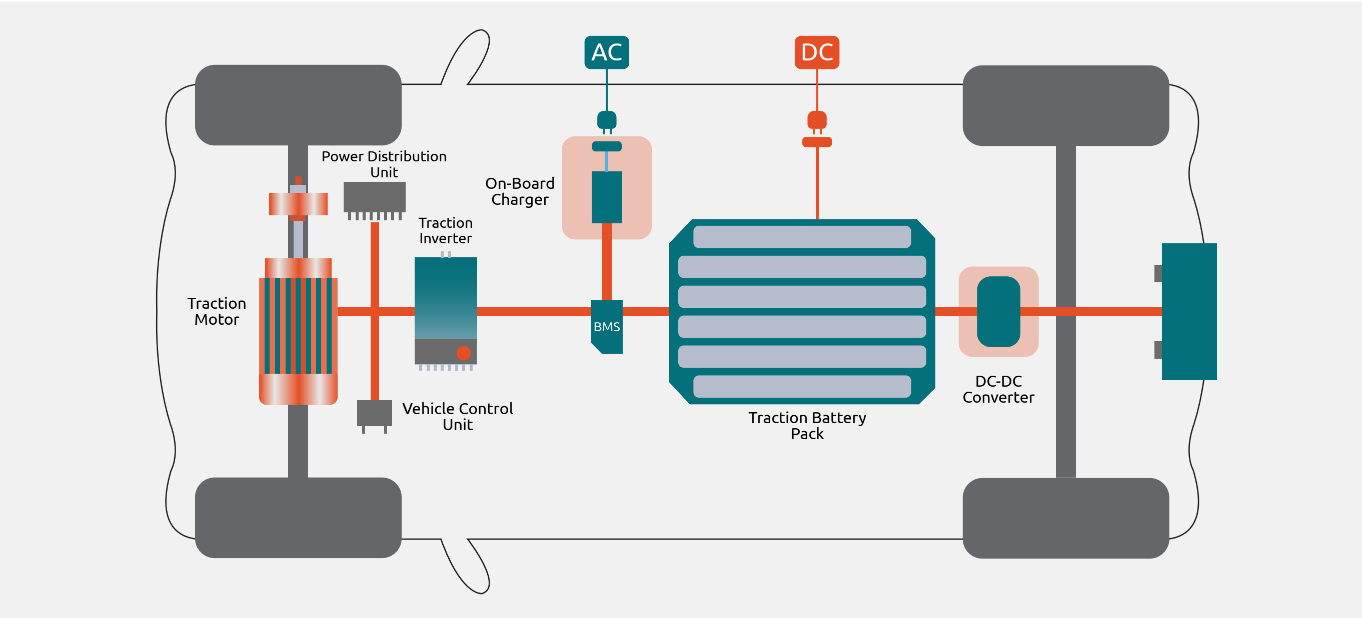



Fig 1. Electric vehicle powertrain architecture illustration showing the OBC and DCDC Converter

Traditionally, EVs relied on separate OBC and DCDC converter units as shown in Figure 1, this is leading to increased complexity, space constraints, and higher costs as power density requirements increased for faster charging capabilities. However, the latest designs merge OBC and DCDC Converter functions into a single power box, offering:

- **Space and weight savings** by eliminating redundant components for a more compact design
- **Improved efficiency** through shared thermal management and optimized power flow between the two systems
- **Bidirectional capability** by enabling the OBC to perform vehicle-to-load (V2L) and vehicle-to-grid (V2G)
- **Cost reduction** as fewer components can be used and simplifies powertrain assembly

This Techbook explores the architecture, design considerations, and future trends of OBC + DCDC integrated systems, providing engineers and industry professionals with insights into next-generation EV power electronics

# 2. Application Description

The electrification of vehicles demands highly efficient, compact, and cost-effective power electronics. A key innovation addressing these needs is the integration of On-Board Chargers (OBC) and high-voltage to low-voltage (HV-LV) DCDC converters into a single unit. This integration eliminates redundant components, reduces weight, and enhances functionality—critical for modern electric vehicles (EVs).

## Light-Duty Passenger Vehicles

Modern electric passenger vehicles demand compact yet powerful charging solutions that can accommodate daily commuting needs while supporting emerging vehicle-to-everything (V2X) functionalities. Integrated OBC + DCDC systems in this segment typically combine:

- AC charging capabilities ranging from 3.3 kW for basic models up to 22 kW for premium vehicles, supporting either/or single-phase and three-phase input configurations.
- LV DCDC power conversion between 1-3 kW to maintain 12/48 V auxiliary systems, including critical vehicle electronics and comfort features.

The automotive industry is witnessing a clear trend toward bidirectional 11 kW OBC systems paired with 2.5-3 kW DCDC converters in mid-range sedans, enabling practical vehicle-to-grid (V2G) implementations. Premium 800 V architectures are pushing the boundaries of OBC modules beyond 11 kW to 22+ kW coupled with 3-5 kW DCDC converters, to significantly reduce charging times while maintaining exceptional energy efficiency, (Yole Intelligence, 2024).

## Commercial Electric Vehicles

The operational demands of commercial EVs require higher power electronics solutions capable of supporting high-utilization scenarios. Depot-charged electric buses and delivery vans employ:

- 22 kW to 50 kW OBC systems designed for overnight charging at fleet facilities.
- 3 kW to 10 kW DCDC converters to power extensive LV loads including telematics, refrigeration units, and hydraulic systems.

As OEMs are implementing 50 kW OBC + 10 kW DCDC configurations in their electric buses, they are aiming at achieving remarkable system efficiencies even under continuous operation. These high-power systems incorporate advanced thermal management features and redundant safety mechanisms to ensure reliability throughout their life cycles.

## 2.1 Application Features

In EVs, On-Board Chargers (OBCs) and DCDC converters are critical subsystems that manage power conversion between the external AC grid, the high-voltage battery pack, and the vehicle's low-voltage electrical systems. Traditionally, these functions are implemented as separate modules, but emerging trends increasingly favor integrated solutions that combine OBC + DCDC functionalities into unified architecture, (Choi, 2023). This integration offers benefits in system compactness, efficiency, cost, and overall vehicle design complexity.

In the conventional approach, the OBC and the DCDC converter are implemented as distinct units with dedicated power stages and control boards, the application is shown in Figure 2.

The unified control board and communication interface reduces component count and simplifies system management. In addition, shared magnetic components such as transformers and inductors minimize losses and PCB area and contributes to enhanced thermal management and cost advantages due to consolidated packaging.

Integrated OBC + DCDC solutions merge the high voltage charging and auxiliary power conversion stages into a single unified converter system, sharing components and control to reduce size and improve efficiency. This approach is illustrated in Figure 3 and it often uses a 2-power stage performing both batteries charging and low-voltage supply duties.

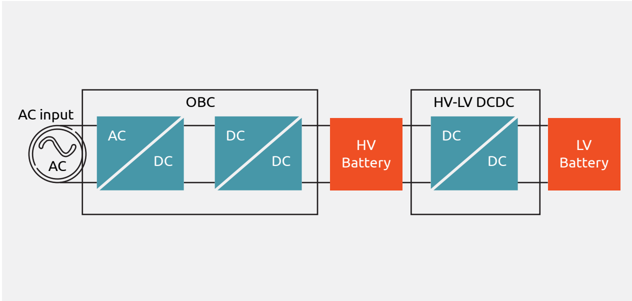



Fig 2. Conventional approach with the OBC and DCDC implemented as distinct units

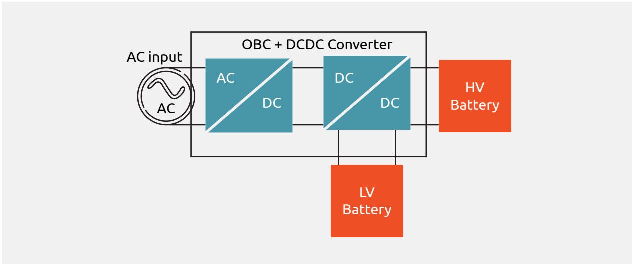



Fig 3. Integrated approach of combines OBC and DCDC Converter

The key design features of integrated OBC + DCDC Converters include:

- PFC (Power Factor Correction) stage for conversion from AC source to DC.
- A single DCDC Converter stage for performing both battery charging and low-voltage supply duties, often using multi-output converters or modular architectures.
- Control board for management of power level requirements and control of the charging process. It also facilitates communications with charging stations and other in-vehicle systems such as BMS and ECUs.

## 2.2 Trends in integrated OBC + DCDC Converter Systems

### High-Power Density Designs

The power electronics industry has made remarkable strides in increasing the power density of OBC + DCDC converter systems for electric vehicles. State of the art integrated OBC + DCDC modules now routinely exceed 5 kW/L, a significant improvement compared to the 1.5–2 kW/L density typical of discrete or older generation systems around 2018–2020, (Yole Group, 2023). This represents a 200–300% increase in power density. Improved heat sinks, high-conductivity interface materials, and, in some cases, direct liquid cooling further drive down the space needed for reliable operation.

### Bidirectional Power Flow Architectures

Bidirectional power flow in OBCs refers to the ability of the system to both charge the EV battery from the electric grid and to discharge energy from the EV battery back to external sources such as a home, the electricity grid, or other device. Conventional (unidirectional) OBCs only allow power to move in one direction: from the grid (AC) to the car battery (DC). However, modern OBCs are evolving beyond that to bidirectional charging. This enables additional various power flow beyond the conventional ones, such as:

- Vehicle-to-Grid (V2G): this implementation can support 11-22 kW bidirectional power transfer, allowing EVs to participate in grid stabilization and demand response programs.
- Vehicle-to-Load (V2L): this typically provides 3-7 kW of AC power for tools, emergency backup, or recreational uses.

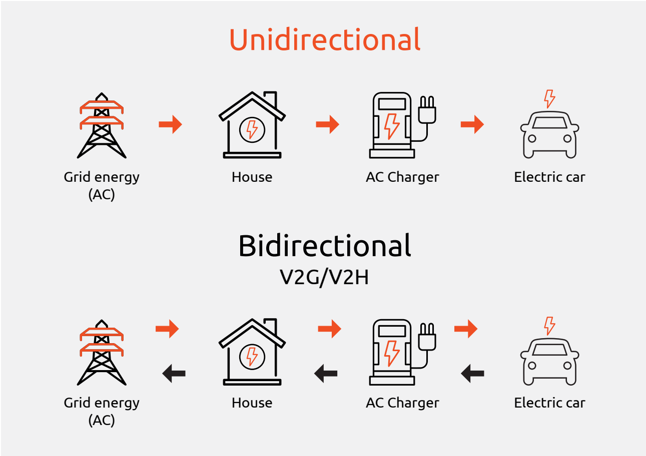



Fig 4. Unidirectional and bidirectional power flow is enabled by the design of an OBC

### 800V Architecture Expansion

The shift to 800 V battery systems (from legacy 400 V) is accelerating across premium EVs, commercial trucks, and even motorsports. This transition demands reengineered OBC + DCDC systems with Charging Speed breakthroughs.

### Increased use of Wide Band Gap Technologies

The adoption of wide-bandgap materials is fundamentally transforming OBC + DCDC design:

- Silicon Carbide (SiC) MOSFETs now enable switching frequencies up to 500 kHz, reducing passive component sizes by 40% while achieving 98% efficiency in 800 V systems.
- Gallium Nitride (GaN) transistors are penetrating the 3.3-7.7 kW segment, offering superior thermal performance and power density for compact vehicle applications.

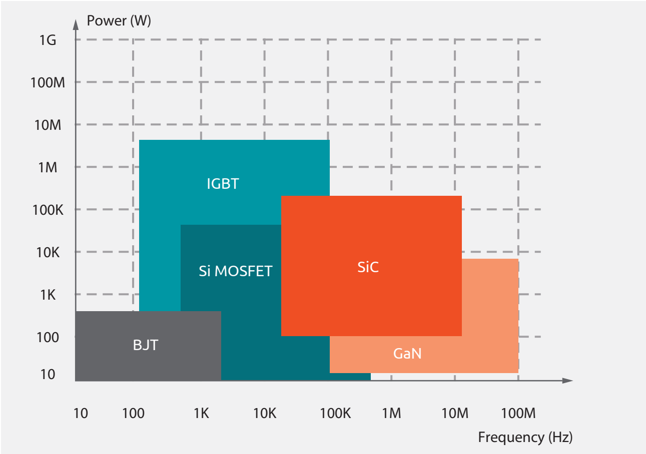



Fig 5. Switching frequencies of the power devices in OBCs, SiC/GaN enable higher switching frequencies

# 3. Block Diagram

The core functions of an integrated OBC + DCDC system are shown in Figure 6. This block diagram gives an overview of the key products that feature in an OBC + DCDC integrated system. The functional blocks within an OBC + DCDC Converter have been divided into four categories, PFC, HV DCDC converter with Primary and Secondary sides, HV-LV DCDC secondary side and the Control Board.

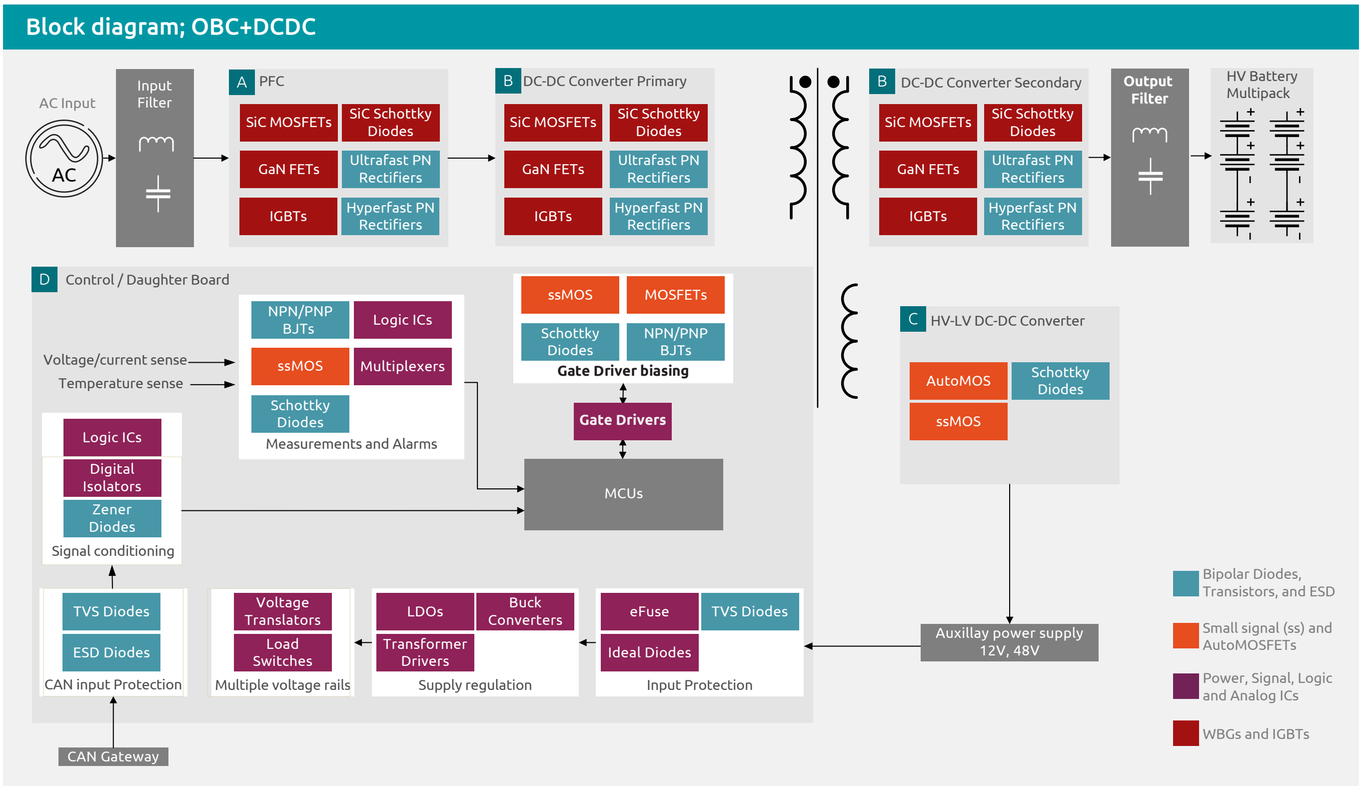



Fig 6. Block diagram of an integrated OBC + DCDC converter with Nexperia's products

## A. PFC (Power Factor Correction)

Ensures input current waveform follows voltage waveform and converts AC input to DC power (rectification). There are various topologies such as Totem-pole, Vienna, Boost converters, and full bridge rectifiers which are usually implemented. Factors such as number of AC supply phases, required power and efficiency, cost considerations can impact the final choice of topology.
The two most common topologies are discussed below.

### Bridgeless Totem-Pole PFC

Bridgeless Totem-Pole PFC is an advanced front-end AC-DC conversion topology widely adopted in OBCs, especially suitable for both single-phase and three-phase AC inputs as shown in with different schematics in Figure 7. Unlike traditional boost PFC designs that use a diode bridge rectifier at the input stage, the totem-pole PFC eliminates this bridge, significantly reducing conduction losses

The totem-pole PFC operates with two sets of switches:

- Fast-leg switches (e.g., SiC/GaN MOSFETs) operate at high switching frequencies to boost current and perform synchronous rectification.
- Slow-leg switches operate at line frequency (~50/60 Hz), acting as synchronous rectifiers around the AC line, reducing conduction losses versus diode equivalents.

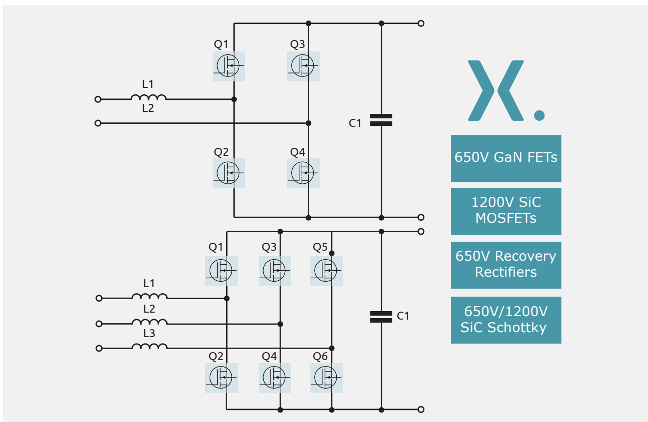



Fig 7. Circuit schematic and Nexperia parts for Totem Pole PFC a with a single-phase AC input and 3 phase

This architecture leverages very fast power switching devices such as SiC MOSFETs, GaN HEMTs, and SiC Schottky diodes or optimized recovery diodes — either individually or in combination — to achieve superior performance. For bi-directional power flow typical in vehicle-to-grid (V2G) applications, power semiconductor options extend to include IGBTs and GaN devices capable of bidirectional current conduction.

The Nexperia 4 kW analogue bridgeless totem-pole PFC evaluation board showcases advanced GaN technology on a 4-layer PCB with 2 oz copper outer layers and 1.5 oz copper inner layers for excellent thermal and current performance. It uses GAN039-650NTB GaN devices on both fast and slow switching legs, paired with a high-flux 480µH inductor (0.025 Ω DC resistance) optimized for 65 kHz operation. Designed for universal AC input and up to 4 kW output, this compact board provides high efficiency and low losses and is available for order through Nexperia website with full documentation to support design and prototyping, (Nexperia, 2025).

### Interleaved Boost PFC

This topology combines a traditional diode bridge rectifier with multiple boost converter phases operating in a carefully controlled phase-shifted manner to achieve superior performance as shown in Figure 8.

After the AC line is rectified by a standard diode bridge, the resulting unregulated DC is fed into two (or more) parallel boost converters. This interleaving effectively doubles the switching frequency seen by the input and output filters without increasing the switching frequency of each individual converter.

Splitting the power flow between multiple phases distributes the conduction and switching losses among parallel components. This alleviates thermal stress on individual devices, enhancing reliability and enabling higher total power output.
Each boost converter phase consists of a power switch (MOSFET or IGBT), an inductor, a freewheeling diode (or synchronous rectifier).

The Interleaved Boost PFC topology delivers key benefits in input current smoothness, thermal management, and efficiency, making it ideally suited for medium to high-power on-board chargers and power conversion systems where performance and reliability are paramount. Its modular nature also eases scalability and redundancy.

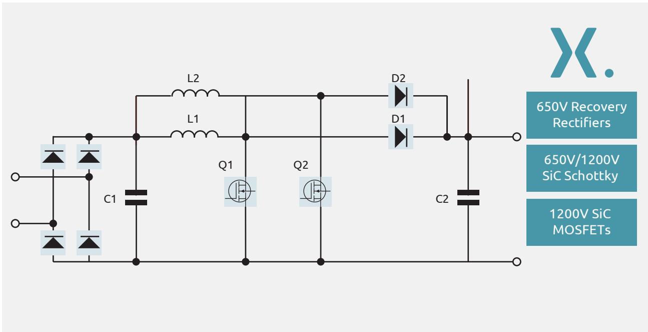



Fig 8. Interleaved  Boost PFC Converter circuit schematic

## B. HV DCDC Converter

Steps up or down the PFC output to battery voltage (400/800 V) and provides galvanic isolation for safety. Various topologies commonly used include LLC, CLLC, Dual Active Bridge (DAB) and Phase-Shifted Full Bridge (PFSB). An overview of LLC and the DAB are discussed below.

### LLC Resonant Converter

The LLC resonant converter stands as one of the most widely adopted topologies for high-voltage DCDC. Its popularity stems from the inherent ability to achieve soft-switching conditions—Zero Voltage Switching (ZVS) and Zero Current Switching (ZCS), which drastically reduce switching losses, electromagnetic interference (EMI), and thermal stresses on power devices. An example schematic is shown in Figure 9.

The primary side of the LLC converter has a full-bridge MOSFET inverter that drives the resonant tank (comprising a series resonant inductor, a resonant capacitor, and the magnetizing inductance of the transformer).

The secondary side employs synchronous rectification (using low RDS(on) MOSFETs or SiC Schottky diodes) to enhance efficiency at the output stage. A frequency transformer provides isolation and suitable voltage transformation ratios.

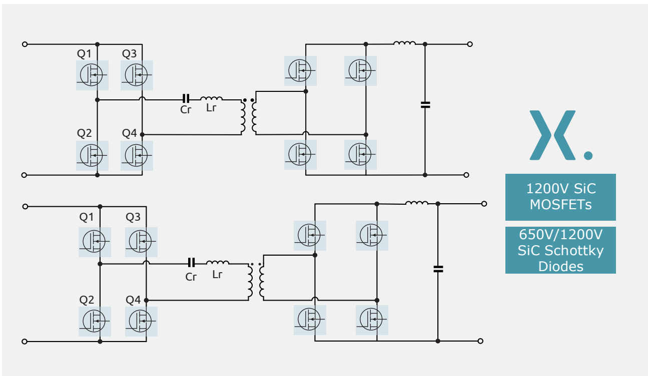



Fig 9. LLC resonant Converter circuit schematic example

### Dual Active Bridge (DAB)

This topology consists of two identical full-bridge inverter stages connected back-to-back via a high-frequency transformer as shown in Figure 10. Each H-bridge employs four synchronous semiconductor switches—commonly MOSFETs or IGBTs—to generate voltage waveforms across the transformer primary and secondary windings. This configuration provides galvanic isolation, voltage step-up/down capabilities, and bidirectional power flow. The Dual Active Bridge converter is a versatile, high-efficiency, bidirectional, isolated DCDC converter topology ideal for electric vehicle charging applications requiring V2G and V2L capability. Its phase-shift-based control enables smooth power flow in both directions, while soft-switching ensures high efficiency and reduces thermal stress. The DAB's ability to provide galvanic isolation and flexible voltage transformation makes it a cornerstone in modern EV power electronics architectures.

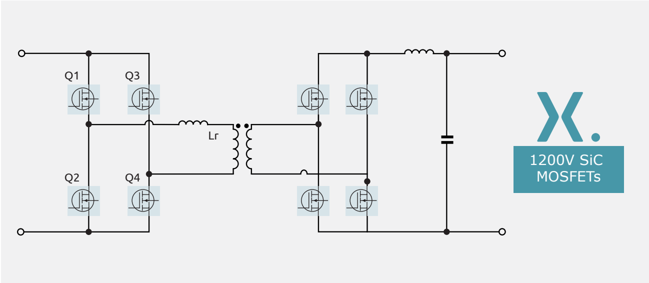


Fig 10. Dual Active Bridge circuit diagram

## C. HV-LV DCDC Converter

HV-LV DCDC converters are critical components in EVs, stepping down the high-voltage battery pack voltage (typically 400 V or 800 V) to standard low-voltage rails such as 12 V, 24 V, or 48 V. These low-voltage systems power essential auxiliary electronics, including ECUs, infotainment systems, lighting, sensors, and safety devices. The transformer coupling on the secondary side is typically realized using a multi-winding or multiport transformer with galvanic isolation and optimized magnetic coupling, often tailored to support simultaneous charging of both high-voltage and low-voltage batteries or auxiliary loads as shown in Figure 11.

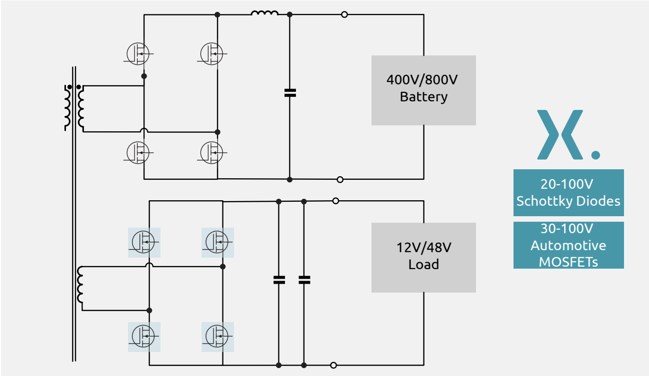


Fig 11. Example setup of the HV-LV DCDC converter with a synchronous MOSFETs on the secondary side.

## D. Control Board

The control board is the central intelligence hub of the electric vehicle charging systems, responsible for orchestrating all critical charging and communication functions. It implements sophisticated charging algorithms—such as Constant Current (CC) and Constant Voltage (CV) profiles—to ensure safe, efficient, and battery-friendly charging. Beyond power management, it handles communication protocols including CAN bus and emerging standards like ISO 15118 for seamless plug-and-charge interoperability with charging stations.

To maximize battery longevity and performance, the control board continuously monitors key parameters such as battery temperature and State of Charge (SoC), dynamically adjusting the charging strategy through adaptive algorithms. This ensures optimal charging speed while preventing thermal or electrical stress on the battery pack.

The control board architecture comprises several subsystems - including communication interfaces, signal processing, communication modules, gate driver circuits, and low voltage power suppl and management—working in concert to provide robust, reliable, and flexible operation tailored for today's stringent automotive standards.

### Communication interfaces

The communication interface subsystem of the control board is essential for seamless, secure, and high-speed data exchange between the vehicle battery systems, central control units, and charging stations. Leveraging standardized protocols like CAN and ISO 15118, combined with advanced signal conditioning and translational capabilities, the control board ensures synchronized system operation, enhances charging efficiency, and supports next-generation smart charging features vital for modern electric vehicles.

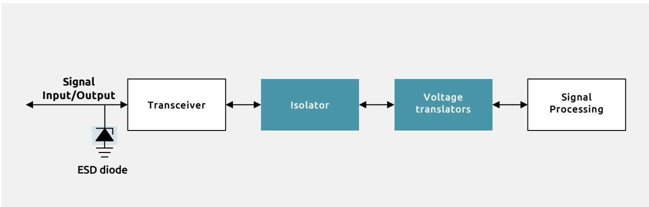


Fig 12. Functional sub-block for CAN communication signal path

## Signal processing

The signal processing subsystem within the integrated OBC + DCDC control board is indispensable for harnessing accurate sensor data, enabling noise-robust communication, and providing precise control signals. Using analog switches, multiplexers, Schmitt triggers, buffers, flip-flops, and discrete small-signal components, the system achieves high reliability, enhanced noise immunity, and optimal control essential for efficient and safe EV charging operations.

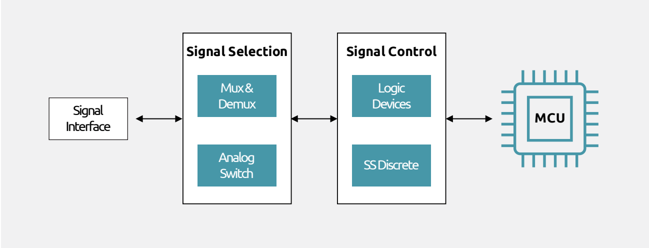



Fig 13. Illustration of the basic blocks for signal processing

## Gate driver circuits

Gate driver circuits form the crucial interface between low-level control logic and high-power SiC/GaN MOSFET switches, ensuring efficient, fast, and reliable switching in modern OBC + DCDC converter power stages. By leveraging TVS diodes, digital isolators, BJTs, and Schottky diodes, designers can build robust, isolated gate driver solutions that meet stringent automotive requirements for performance, safety, and electromagnetic compatibility.

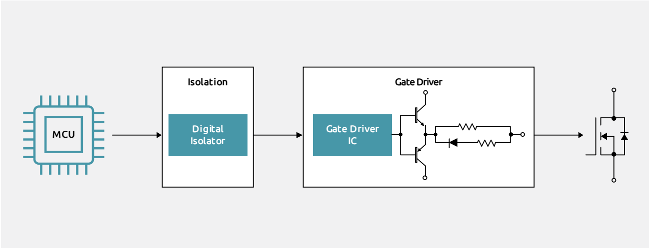



Fig 14. Illustration of key components for gate driver biasing circuits

## Power Supply and management

The control board in an integrated OBC + DCDC converter system relies on a robust and low-noise power supply and management architecture to guarantee stable and reliable operation of critical subsystems such as microcontrollers (MCUs), sensor arrays, gate drivers, and communication interfaces.

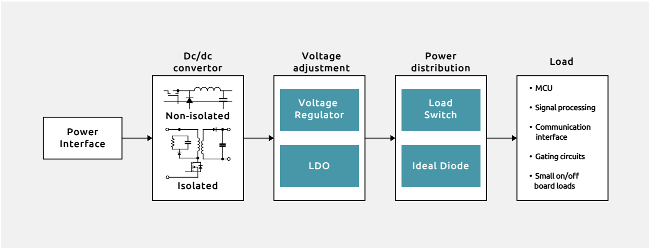



Fig 15. A variety of components can be used for either isolated or non-isolated power drive in the control board

# 4. Design Challenges and Solutions

## 4.1 Overcoming current imbalance and thermal hotspots when paralleling discrete SiC devices

Paralleling Silicon Carbide (SiC) MOSFETs is a common technique to increase current-handling capability in high-power OBC + DCDC designs. However, mismatches in device parameters and layout asymmetries can lead to:

- Unequal current sharing, causing some devices to overstress.
- Localized thermal hotspots, reducing reliability and lifespan.

Key cause of the imbalance:

- Threshold Voltage ($V_{th}$) Variation – Even small differences (e.g., ±0.5 V) between parallel SiC MOSFETs cause uneven turn-on/turn-off delays.

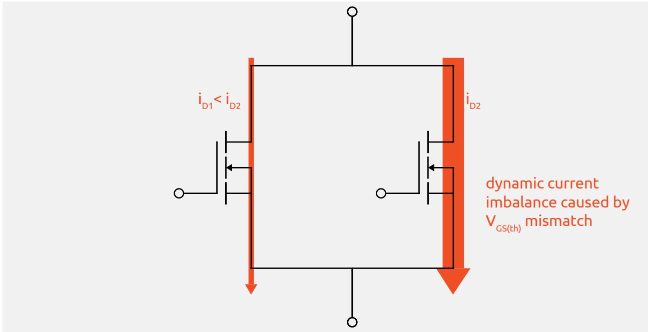



Fig 16. $V_{th1}$ and $V_{th2}$ mismatch leads to asymmetrical switching

## Nexperia Solutions

### 1. Nexperia's SiC MOSFETs have tight $V_{th}$ Tolerance

Nexperia's 1200 V SiC MOSFET portfolio features carefully binned devices characterized by a narrow threshold voltage distribution - typically with a maximum variation ($V_{th,max} - V_{th,min}$) of only 1.2 V. This tight $V_{th}$ tolerance significantly reduces turn-on delay mismatches in parallel or cascaded configurations, ensuring consistent and predictable switching performance. Such precision is achieved through a highly controlled fabrication process, providing system designers with reliable, repeatable MOSFET behavior that enhances overall converter efficiency and robustness.

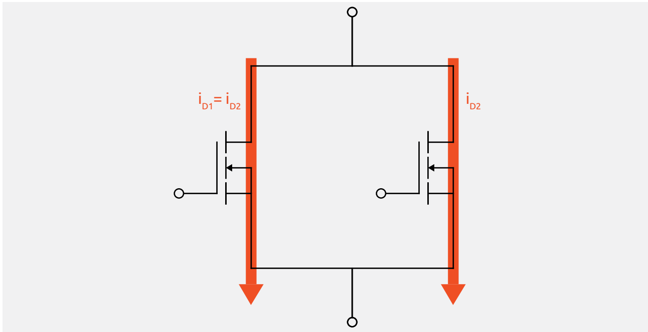



Fig 17. Nexperia's SiC MOSFETs have narrow Vth, to enable symmetrical switching in paralleled operation

### 2. Use devices with Kelvin Source Connection

Nexperia offers Automotive qualified SiC MOSFETS in TO-247-4L package with a dedicated Kelvin source pin to isolate gate loop from power loop. Additionally, TO-263-7 (D2PAK-7L) & X.PAK have both Kelvin source pins and provide low-inductance packages (<1 nH) with optimized pinouts. The Kelvin source connection proves a dedicated low inductance path for the gate drive return, in addition to reducing the effects of source inductance, it also improves switching synchronization in a paralleled device.  Table 1 shows the three packages with Kelvin pin from Nexperia's SiC MOSFETs products.

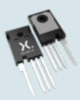
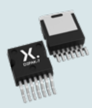
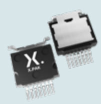
| | Package | | |
|---|---|---|---|
| $R_{DS(on)}$, typ, 25°C (mΩ) |  TO247-4L |  D2PAK-7L |  X.PAK |
| 17 | • | | • |
| 22 | | | |
| 30 | • | • | • |
| 40 | • | • | • |
| 60 | • | • | • |
| 80 | • | | • |

Table 1 Nexperia's 1200V SiC MOSFETs products by $R_{DS(on)}$ – all have similar $V_{th}$ tolerance

For in-depth insight into practical techniques and critical design considerations for paralleling power MOSFETs in high-power applications, refer to Application Note (AN50005, 2021). This comprehensive resource systematically analyzes how current-sharing imbalances between parallel MOSFETs are influenced by other key factors such as device parameter tolerances, PCB layout, thermal management, and gate drive configuration. The application note offers detailed guidelines and best practices to mitigate these imbalances - enabling designers to achieve reliable, efficient, and robust parallel operation of MOSFETs in demanding power electronic systems.

## 4.2 Minimizing reverse recovery losses in high-frequency high power rectification

In high-frequency power conversion stages - such as the output rectification of LLC or interleaved boost converters - diode reverse recovery becomes a major source of power loss and EMI. This is especially critical in OBC + DCDC converters operating at frequencies above 100 kHz.

Reverse recovery losses occur when a diode switches from conducting (forward-biased) to blocking (reverse-biased) and temporarily allows reverse current due to stored charge. This leads to:

- Increased switching losses in the rectifier didoes
- Voltage overshoot and ringing, stressing components
- Higher EMI, requiring additional filtering
- Thermal stress, reducing system reliability

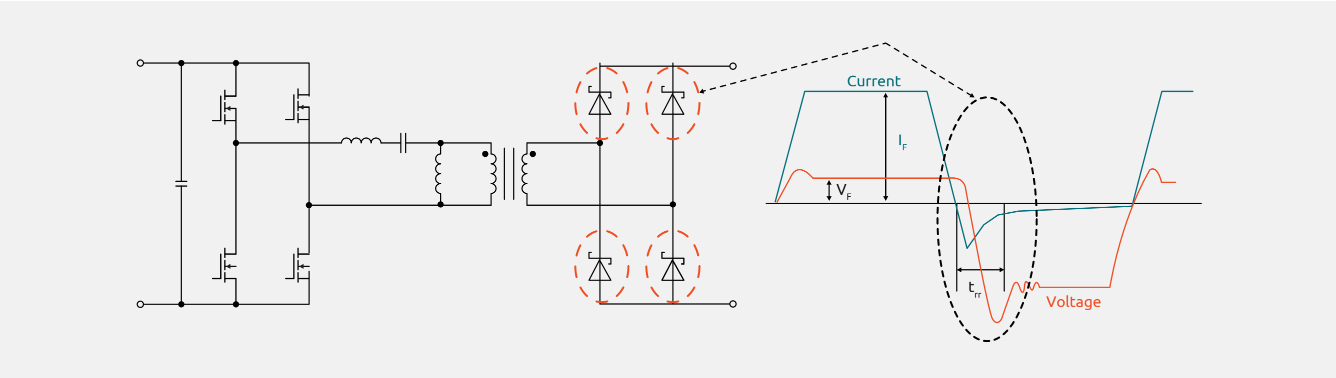



Fig 18. Illustration of the recovery losses in the rectifier stage of an LLC converter

These effects are amplified at higher switching frequencies, where the reverse recovery charge ($Q_{rr}$) becomes a dominant loss factor and EMI emission contribution.

## Nexperia Solutions

### 1. 1200 V/650 V SiC Schottky diodes with $Q_{rr}$~0

Nexperia offers a comprehensive range of 650 V and 1200 V Silicon Carbide (SiC) Schottky diodes that are optimized for high-frequency, low-loss rectification applications common in OBC + DCDC converters. These SiC Schottky diodes deliver leading-edge performance through temperature-independent capacitive switching and virtually zero reverse recovery charge ($Q_{rr}$), achieving an outstanding figure-of-merit ($Q_C \times V_F$) that balances low conduction and switching losses, refer to the white paper for more insights in Nexperia's SiC Schottky diodes characterization parameters, (Dr. Sebastian Fahlbusch, 2023).

Unlike conventional silicon Schottky diodes, where both majority and minority carriers contribute to the switching current—leading to higher $Q_{rr}$ - Nexperia's SiC Schottky diodes behave like pure Schottky diodes under typical operating conditions. Only majority carriers conduct current, producing purely capacitive switching behavior. This behavior significantly reduces stored charge, thereby lowering switching losses and improving overall converter efficiency.

Figure 19 illustrates reverse recovery effects when comparing the 650 V SiC diode (PSC1065) with a conventional 650 V silicon fast recovery rectifier under similar test conditions: forward currents of 5 A and 10 A, and a constant reverse voltage ($V_r$) of 400 V. The SiC diode exhibits almost constant reverse recovery characteristics over these parameters, with minimal nonlinear behavior compared to the silicon fast recovery diode. Nexperia's 650 V and 1200 V SiC Schottky diodes feature virtually zero reverse recovery charge, significantly reducing switching losses and electromagnetic interference (EMI). Their temperature-independent, ultrafast switching characteristics make them highly suitable for high-frequency converter applications, enhancing overall system reliability.

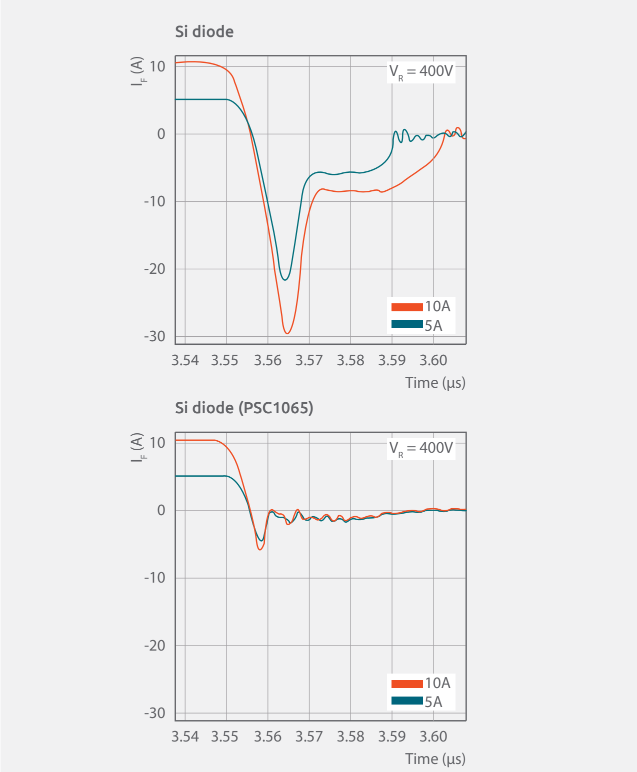



Fig 19. Comparison of reverse recovery behavior of Si and SiC diodes under various conditions

Recommended SiC Schottky diodes:

- PSC2065J-Q, PSC1065-Q and PSC1665J-Q are 650 V SiC Schottky diodes with negligible Qrr, ideally suited for high-voltage, high-frequency rectification in PFC and LLC stages.
- For 800 V battery architectures, the PSC20120J-Q 1200 V SiC diode family offers enhanced voltage margin and superior rectification performance.

**Nexperia SiC Schottky diodes features**


- Available in 650 V or 1200 V $V_{DS}$
- Zero forward and reverse recovery
- Temperature independent fast and smooth switching performance
- Outstanding figure of merit ($Q_c$ x $V_F$)
- D2PAK R2P, DPAK R2P, TO-220-2, TO-247-2 and Bare die options

Fig 20. Features of Nexperia SiC Diodes

These advanced devices are available in proven, robust packages such as TO-263 (D2PAK), TO-220-2, and TO-247, offering excellent thermal conduction and mechanical durability. Fully automotive-qualified, these packages ensure robust thermal management and long-term reliability in demanding automotive environments, making them the ideal choice for next-generation high-power rectification in automotive OBC + DCDC converters.

## 4.3 Preventing false triggering in SiC/GaN due to high dv/dt transition

In high frequency switching operation of OBC + DCDC converters, rapid voltage transients (high dV/dt) can accidentally trigger power devices like SiC or GaN MOSFETs. This phenomenon is especially critical in half-bridge and full-bridge topologies, where the switching node experiences sharp transitions.

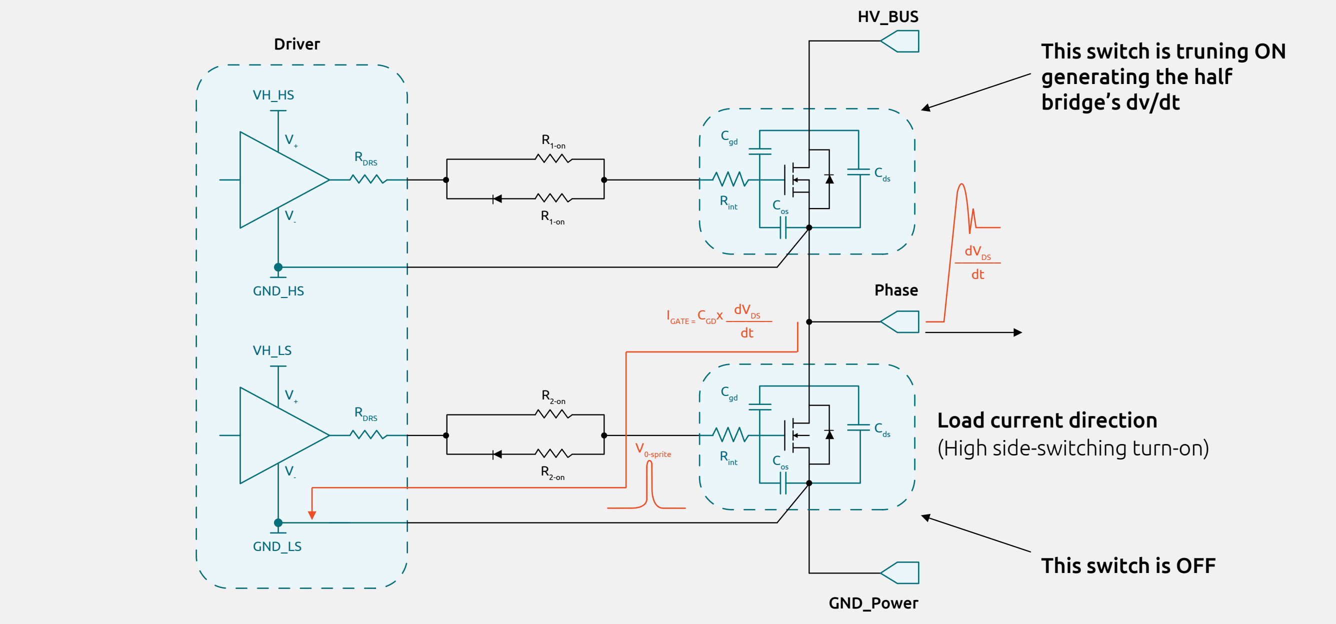



Fig 21. Half bridge topology likely to experience high transition in the phase node

As shown in Figure 21 when the upper MOSFET is turned on, with the lower MOSFET is turned off, the switching node generates a relatively large amount of dv/dt, - often exceeding 50–100 V/ns. This large dv/dt will be coupled at the gate level of the low side MOSFET through the parasitic capacitance CGD to induce what is known as the Miller current.

$$I_{Miller}=C_{GD}*\frac{dV_{DS}}{dt}$$

Miller current induced will in turn flow through the driver's output resistor to produce a positive transient voltage at the gate level. If this gate level voltage exceeds the gate turn-on threshold value, $V_{GS,th}$, false turn-on of the MOSFET will occur unintentionally leading to a short circuit operation of the half bridge. $V_{GS,th}$ has a negative coefficient change with temperature, meaning with increased temperature, the turn-on voltage gets lower. This implies that the chances of parasitic turn-off the MOSFET are accelerated at higher operating temperatures.

Consequences of parasitic turn-on include:

- Shoot-through currents in bridge legs
- Increased switching losses
- Device overstress or failure
- EMI issues and system instability

# Nexperia Solutions

## 1. Gate-Source Protection with TVS Diodes

TVS Diodes (e.g., PTVS series) can be placed directly at the gate to absorb voltage spikes, ensuring that the gate-source voltage remains within safe limits during fast transients as illustrated in Figure 22 at the MOSFET gate for protection

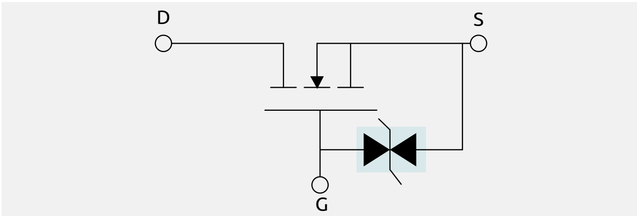



Fig 22. TVS Diode at the MOSFET gate for protection

A variety of power TVS diodes in various packages are available from Nexperia, shown in Figure 23.

**Suggested Nexperia TVS for SiC MOSFET gate protection:**


CFP3 (SOD123W)
2.6 X 1.7 1.0 mm*
$R_{th(j-sp)}$ = 18 K/W

CFP5 (SOD128)
3.8 X 2.5 x 1.0 mm*
$R_{th(j-sp)}$ = 12 K/W

CFP15B (SOT1289B)
2.6 X 1.7 1.0 mm*
$R_{th(j-sp)}$ = 3 K/W

- 400 W/600 W bidirectional TVS diodes in a variety of packages – CFP3, CFP5. CFP15B
- Very high surge robustness
- $V_{CL}$ selections from 12 V to >30 V, $V_{BR}$: 8.6 V to >25 V
- Very low dynamical resistance

Fig 23. Nexperia's unidirectional automotive grade TVS diodes portfolio

## 2. Negative gate bias during turn-off

Applying a negative voltage at the gate during the devices off state helps keep the MOSFETs firmly off, combating the miller-induced turn-on triggered by the high dv/dt at the phase node. Nexperia's SiC MOSFETs provides a comfortable margin for negative $V_{GS}$ at turn off with a minimum static turn-off gate voltage of -10 V. These devices can be controlled with bipolar gate voltage. Table 2 shows the reference data from the datasheet of 1200 V 30 mΩ SiC MOSFET – NSF030120D7A0-Q with $V_{GS,min}$ of -10 V and $V_{GS,max}$ of 22 V. These devices are recommended to be operated with $V_{GS}$ of -5 V to 18 V, providing a safe margin against parasitic turn on effects.

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{DS}$ | drain-source voltage | | | | 1200 | V |
| $V_{GS}$ | gate-source voltage | | -10 | | 22 | V |
| $I_D$ | drain current | $T_c$ = 25°C | | | 67 | A |
| | | $T_c$ = 100°C | | | 47 | A |
| $I_{DM}$ | peak drain current | pulsed; $t_p$ limited by $T_j$ (max) | | | 160 | A |
| **Static characteristics** | | | | | | |
| $R_{DS(on)}$ | | $V_{GS}$ = 18 V; $I_D$ = 40 A; $T_j$ = 25 °C | | 30 | 45 | mΩ |

Table 2. Nexperia's SiC MOSFET, NSF030120D7A0-Q with highlighted $V_{GS}$ from -10 V to 22 V

## 3. Desaturation (DESAT) protection circuits

A DESAT protection circuit continuously monitors the drain–source voltage ($V_{DS}$) of a power MOSFET during its ON state. When the device is fully turned ON, this voltage drop - known as the "saturation voltage"—remains low. However, during a short circuit or other fault condition, the current rapidly spikes and the $V_{DS}$ rises sharply as the device enters the saturation region. The DESAT circuit detects this abnormal increase and responds by swiftly turning the device off, protecting it from thermal runaway or catastrophic failure.

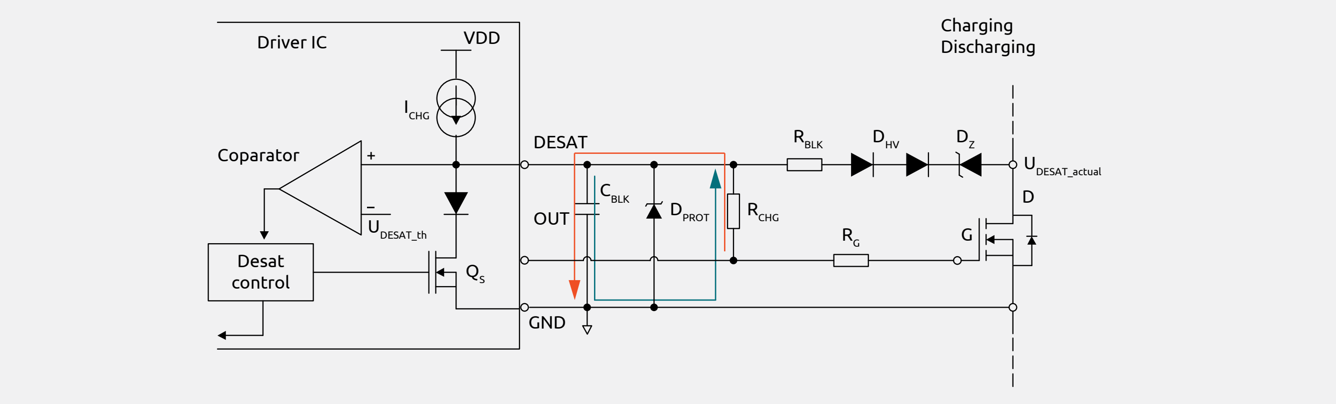



Fig 24. DESAT circuit with a diode, capacitor and resistor between the gate driver and power device

As shown in Figure 24, the key element of the DESAT circuit is the blocking diode, which must be a low-capacitance, fast-recovery device rated above the highest voltage present at the monitored node. In SiC MOSFET applications, ultrafast DESAT response—typically less than 200 ns—is critical, because SiC devices can fail rapidly under repeated short-circuit stress.

Nexperia's fast recovery rectifier portfolio is ideally suited for such demanding applications, offering 200 V to 650 V ultra-fast and hyper-fast switching rectifiers that are optimal for DESAT circuits.

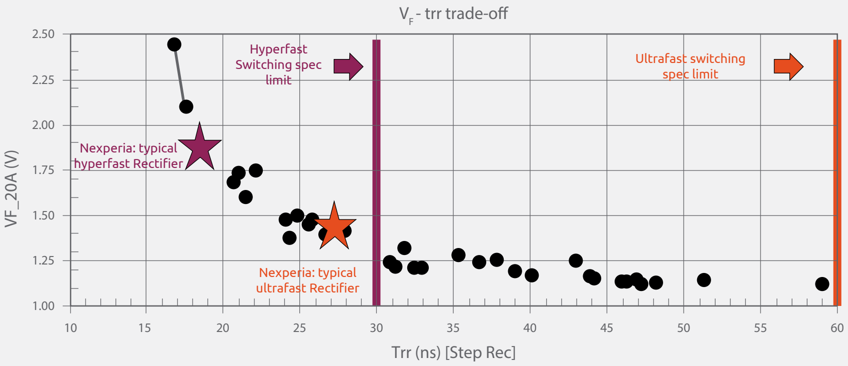



Fig 25. Nexperia's fast recovery rectifiers have some of the leading recovery times for DESAT circuits

As illustrated in Figure 25, Nexperia's ultrafast rectifiers achieve recovery times below 60 ns, while the hyperfast series switches in under 30 ns. For 1–10 A applications, these rectifiers are available in Clip Bond Flat Power Packages (CFP), including options such as CFP2-HP, CFP3, CFP5, and CFP15B in both single and dual configurations. For higher current requirements above 10 A, the D2PAK R2P package is ideal.

The PNE200xxx series offers 200 V rated rectifiers with forward current capabilities from 1 A to 10 A, while the PNU650xxx series covers 650 V applications. CFP3 and CFP5 packages are suitable for 1–3 A in this higher voltage range, and D2PAK R2P handles 10–30 A.

Both the PNE200xxx and PNU650xxx series deliver best-in-class performance for speed and reliability, exceeding the figures of merit achieved by competing solutions.

**Suggested Nexperia recovery rectifier for DESAT: PNU65010EP-Q**


- 650 V rated, suitable for high-voltage SiC DESAT circuits
- Forward current, $I_F$ > 1 A
- Typical switching time trr of 35 ns
- CFP5 package – other package options available such as CFP3
- AEC-Q101 qualified

Fig 26. Suggested Nexperia recovery rectifier for 650V applications

## 4.4 How to maintain glitch-free PWM signals for power devices

Pulse Width Modulation (PWM) signals are widely used in OBC + DCDC converters to control gate drivers, regulate output voltage, and manage switching sequences. In the OBC+ DCDC power stages, gate driver solutions are required to provide turn on/off signals to power devices such as SiC MOSFETs, Automotive MOSFETs, IGBTs, GaN FETs or Super Junction (SJ) MOSFETs. However, glitches or noise on the PWM signals can occur and signal integrity must be always assured.

If this fails, it can lead to:

- Unintended switching events in power MOSFETs
- Increased EMI and power losses
- Timing errors in control loops
- System instability or damage in worst-case scenarios

These glitches are often caused by:

- Signal reflections due to impedance mismatches
- Crosstalk from adjacent high-speed traces
- Voltage level mismatches between control ICs and gate drivers
- Noise coupling from high dV/dt switching nodes

Ensuring clean, noise-immune PWM signals is critical for reliable and efficient converter operation.

## Nexperia Solutions

Nexperia offers a range of components to ensure robust and glitch-free PWM signal conditioning:

### 1. Gate Driver solutions

Nexperia provides tailored gate driver solutions optimized for high efficiency, protection and PWM integrity for driving power devices in the PFC, HV DCDC and HV-LV DCDC converters as shown in Figure 27 below.

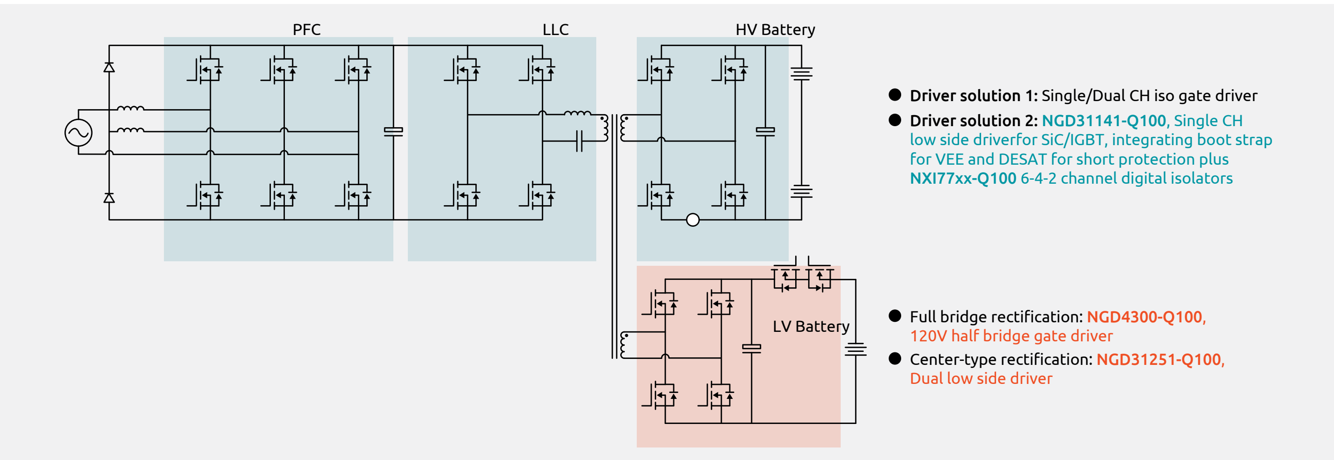



Fig 27. Gate driver solutions from Nexperia for OBC + DCDC Converter power devices

The NGD4300-Q100 is a rugged, automotive-qualified half-bridge gate driver designed specifically for controlling MOSFETs in half-bridge topologies, particularly those used to power low-voltage (LV) batteries on the secondary side of the HV-LV DCDC converter. The high source and sink current capability ($I_{pk}$ of +4 A (source) and –5 A (sink) at 12 V) of the NGD4300-Q100 enables MOSFETs to switch on and off rapidly, significantly reducing switching losses that translate directly to improved system efficiency. Its wide input voltage tolerance ranging from -10 V to +20 V protects the driver from voltage overshoot and undershoot on the PWM input line, mitigating false triggering and ensuring reliable gate drive signals even amid harsh EMI and switching noise typical in automotive power electronics. Test results have proved the performance of -10 V capability on both the high and low sides. In addition, the low propagation delay of just 10 ns (typ.) guarantees synchronous switching between half-bridge MOSFETs. This precise timing minimizes shoot-through risks and optimizes power stage performance.

The NGD31141-Q100 is a robust, non-isolated single-channel gate driver featuring symmetrical ±4 A source and sink peak currents, specifically optimized for driving wide bandgap SiC MOSFETs and IGBTs in demanding power stages such as power factor correction (PFC) and rectification circuits. It integrates critical features such as bootstrap circuitry and DESAT protection and ideal for robust and reliable gate drive in the high stress PFC and rectification stages. The DESAT function provides fast short-circuit detection by monitoring the device saturation voltage, enabling immediate gate turn-off to prevent catastrophic failure and enhance overall system robustness. This feature is vital in high-stress, high-voltage switching environments typical of PFC and rectification stages.

Since the NGD31141-Q100 is a non-isolated gate driver, it requires galvanic isolation on its PWM input to safely interface with high-voltage control systems and avoid galvanic coupling of noise or ground potential differences. To address this, Nexperia recommends pairing the NGD31141-Q100 with its NXI77xx-100 digital isolator series, as depicted in Figure 28 below.

NXI77xx Digital Isolators provide reliable galvanic isolation between the low-voltage control domain and the high-voltage power stage, preventing ground loops, common-mode noise injections, and ensuring signal integrity in harsh automotive environments.

These digital isolators feature industry-leading specifications, including:

- 5 kV RMS galvanic isolation voltage rating, offering robust protection compliant with stringent automotive isolation standards.
- Common-Mode Transient Immunity (CMTI) of 250 kV/µs, delivering exemplary noise immunity to withstand fast switching transients prevalent in SiC MOSFET-based power converter application

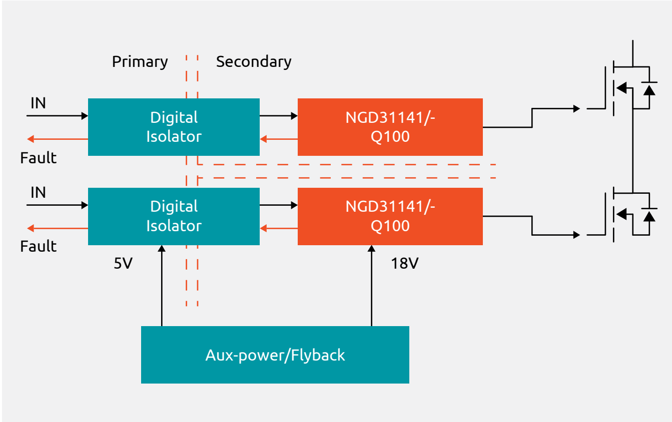



Fig 28. Configuration in isolation driving of SiC MOSFETs using and NXI77xx-Q100

Both NGD31141-Q100 and NXI77xx series are fully qualified AEC-Q100, ensuring operation under extended temperature and reliability conditions demanded by automotive safety-critical applications. Their combined use extends system reliability by protecting low-voltage controller circuits from hazardous HV transients, avoiding failure propagation through control inputs.

## 2. Current boost using BJTs and switching diodes

To ensure glitch-free PWM signals, Nexperia offers a range of high-speed, rugged bipolar junction transistors (BJTs as current boosters between gate drivers and MOSFET gates) effectively enhance PWM signal quality by eliminating glitches, stabilizing voltage levels, and supplying sufficient gate charge current. This approach supports robust MOSFET switching, lowers EMI, improves efficiency, and ultimately increases the reliability of OBC + DCDC converters.

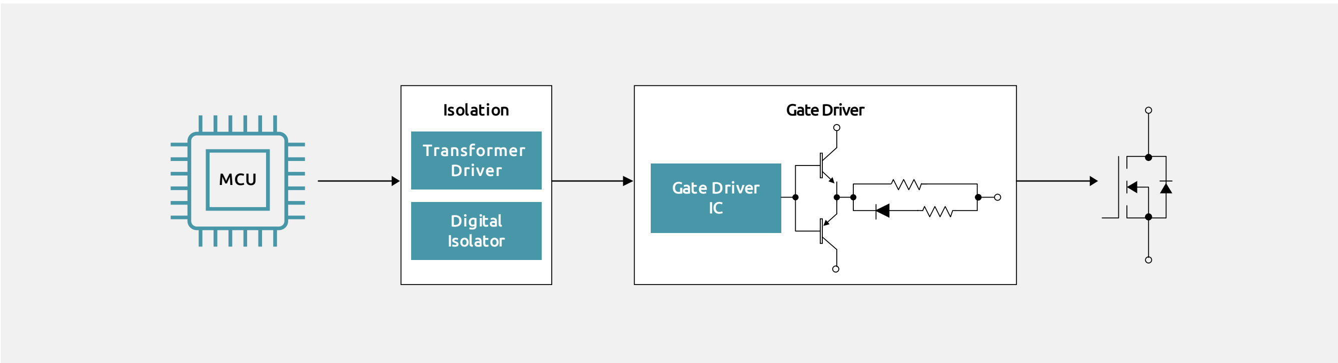



Fig 29. Nexperia's BJTs can be used a current booster between the gate driver and MOSFETs

Nexperia's portfolio includes fast-switching NPN and PNP BJTs with balanced gain and switching speeds, optimized for automotive and industrial power designs. Typical part numbers include BC846-Q which is a low noise, fast switching NPN small-signal transistor with a transition frequency ($f_T$) ~100 MHz. It is excellent for level shifting and low-current PWM buffering and comes in an SOT223 package. BSP50,115 is a high gain capability for medium load PW drive. Each NPN BJT has a complementary PNP transistor that can be used in the push-pull topology such as BC856-Q for matching with BC846-Q. Nexperia's AN90059 Power MOSFET Gate Driver Fundamentals application note illustrates a common use case where BJTs are configured as totem-pole (push-pull) current boosters between the PWM source and MOSFET gate, enhancing drive strength without risk of shoot-through due to complementary transistor operation with break-before-make driving.

## 4.5 Providing stable bias supplies for MOSFET gate drivers

Gate drivers play a critical role in ensuring precise and efficient switching of power MOSFETs and wide-bandgap (WBG) devices like SiC and GaN transistors. These gate drivers require well-regulated, low-noise bias voltage supplies to function reliably across varying operational conditions.

Typical bias voltages include isolated or non-isolated rails at +18V, +15 V, +12 V, +5 V, and in some cases, negative voltages such as -5 V for enhanced turn-off control.

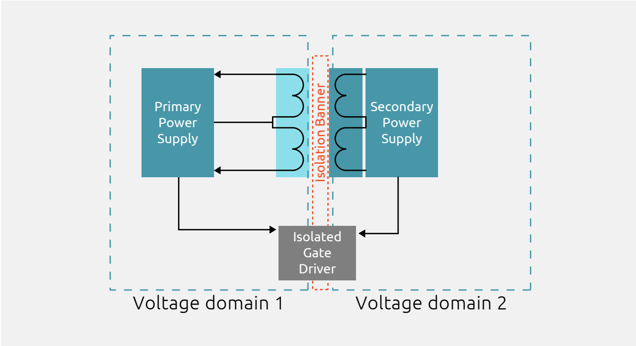



Fig 30. Illustration of an isolated power supply for a gate driver

However, delivering these bias voltages with the required stability and cleanliness poses several technical challenges:

- **Voltage Ripple and Noise:** High frequency switching in power stages can couple significant electrical noise into the gate drive supply lines. Excessive ripples or noise can cause erratic MOSFET switching, false turn-on/off events, or increased electromagnetic interference (EMI), ultimately degrading system performance and reliability.

- **Load Transients:** Sudden changes in gate charge demand—such as rapid switching transitions or fault conditions—can induce transient voltage dips or overshoots in the bias supply. These fluctuations risk under-driving or overdriving the gate, potentially causing increased losses or device stress.

- **Isolation Requirements:** In high-voltage topologies, isolated bias supplies are essential to safely deliver power and signals to the secondary side gate drivers while maintaining galvanic isolation from the primary and control domains. Ensuring robust isolation without compromising stability or noise immunity is critical.

- **Startup Sequencing and Undervoltage Lockout (UVLO):** Proper sequencing of the bias voltages during startup and shutdown phases is vital. Inadequate sequencing or lack of UVLO protection can lead to incomplete MOSFET gate drive activation or dangerous shoot-through conditions, risking device failure.

## Nexperia Solutions

Nexperia provides a range of components to build robust, efficient, and compact bias supply circuits for gate drivers:

### 1. Transformer Drivers for Isolated Supplies

Nexperia's NXF6505A/B-Q100 transformer driver offers a robust solution for providing stable, low-noise, isolated bias supplies for MOSFET gate drivers in OBC + DCDC converters. This specialized push-pull driver is optimized to deliver clean, regulated power from 2.25 V to 5.5 V supply rails with ultra-low EMI, supporting isolated power stages in compact form factors. The NXF6505A/B-Q100 drives low-profile center-tapped transformers with complementary 1.2 A peak output current, enabling power conversion above 6 W with high efficiency. NXF6505A/B-Q100 efficiently generates isolated bias voltages for gate drivers, essential for safely driving the primary or secondary side of wide bandgap MOSFETs. Its integrated slew rate control and Spread Spectrum Clocking (SSC) reduce switching noise and EMI, critical for sensitive gate driver bias supplies. Includes current limiting, undervoltage lockout (UVLO), thermal shutdown, and break-before-make circuitry to safeguard both the driver and downstream power stages, ensuring reliable operation under fault or extreme conditions. It is fully AEC-Q100 Grade 1 certified, ensuring dependable performance over the temperature range -55 °C to +125 °C. Packaged in a small 6-pin SOT8061-1 (TSOT23-6) package, making it well-suited for space-constrained automotive and industrial systems. A typical circuit schematic using NXF6505 is shown in the Figure 31 below. Nexperia also offers evaluation boards and design support to rapidly prototype and validate these 1.2 A isolated bias supply designs, this is available on the website at (NEVB-NXF6505BDA, 2024).

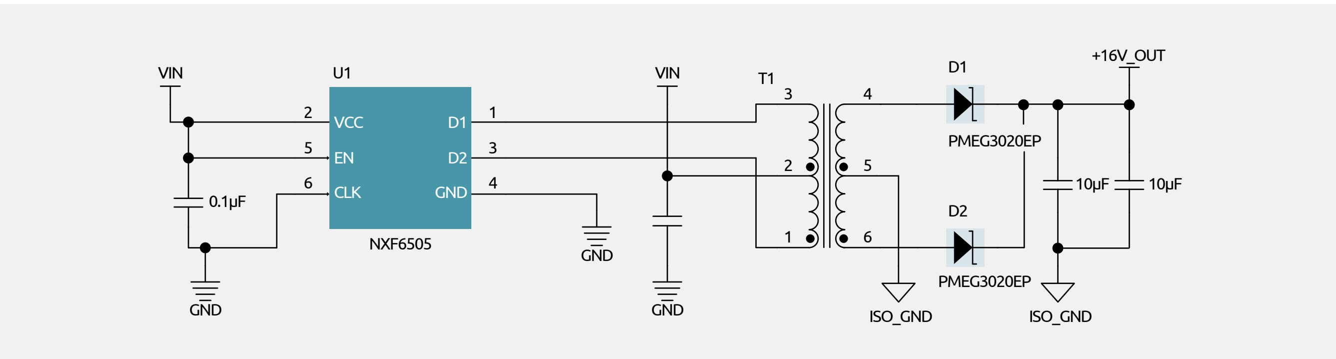



Fig 31. Circuit schematic using NXF6505 to drive center tapped transformer for isolated power supply regulation

## 2. Protection and voltage clamping using Zener diodes

Nexperia offers a broad range of automotive-grade Zener diodes engineered to deliver reliable, compact, and precise voltage regulation and protection in low-power management systems typical of OBC + DCDC converters. Covering a voltage range from 2.4 V up to 75 V with tolerance options of ±5%, ±2%, and in some cases ±1%, this extensive portfolio enables precise voltage clamping and stabilization tailored to diverse automotive electronics requirements.

Zener diodes play a critical role as compact and robust voltage clamps and references within power management ICs. They protect circuits from overvoltage conditions and ensure stable biasing for control components, as illustrated in Figure 32.

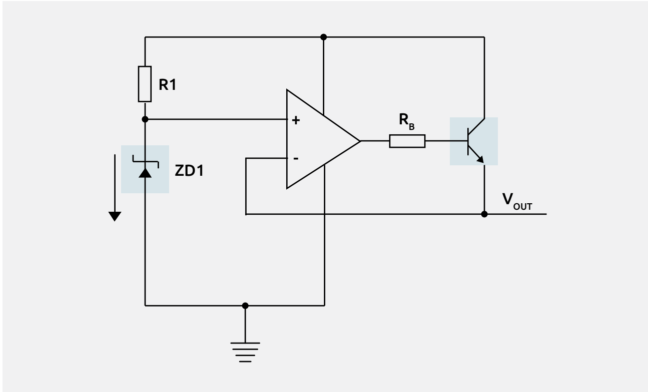



Fig 32. Application example of supply voltage stabilization using zener diodes

Example products that exemplify Nexperia's approach include the PZU6.2BL, delivering a nominal Zener voltage of 6.2 V with a power dissipation rating of 250 mW in a compact SOD882 (DFN1006-2) package.

Beyond the PZU B-selection series, primarily recommended for voltage clamping and protection, Nexperia's portfolio also includes:

- The BZX series, featuring a 50 μA operating point for low-power applications.

The PZU A-selection series offers high accuracy with ±1% voltage tolerance for applications requiring precise voltage regulation.

### Suggested Nexperia Zener Diodes

**BZX series**

- Operating point specified at 50 μA
- Working voltage range: nominal 1.8 V to 75 V
- Voltage tolerance about ± 5% (± 1 % available)

**PZU series**

- Low-differential resistance and low leakage Zener diodes
- Overswing proof design
- Working voltage range: nominal 2.4 V to 51 V
- Voltage tolerance B= ±5%, B2= ±2%

SOT23 | SOD323F (SC-90) | SOD323 (SC-76) | DFN1006BD-2 (SOD882BD-2)

Fig 33. Suggested Nexperia Zener Diodes

These automotive-qualified Zener diodes are packaged in a variety of small surface-mount formats such as SOT23, SOD882 (DFN1006-2), SOD123W, and SOD323, enabling dense board designs while maintaining excellent thermal performance and mechanical durability.

# 4.6 How to control seamless HV/LV energy transfer

In an integrated OBC + DCDC system, managing energy flow between the high-voltage (HV) traction battery and the low-voltage (LV) auxiliary systems is a critical and complex task. These systems must dynamically balance power delivery, ensure safety, and maintain efficiency across a wide range of operating conditions.

Key functional requirements include:

› Bidirectional Power Flow Coordination: In systems supporting V2G or V2L, the control logic must manage both charging and discharging paths while maintaining isolation and safety.

› Dynamic Load Management: LV loads (e.g., infotainment, lighting, ECUs) vary significantly during operation. The control system must adapt in real-time to prevent undervoltage or overcharge conditions of the LV auxiliary battery.

› Battery State Awareness: Accurate monitoring of battery State of Charge (SoC), temperature, and health is essential for optimizing energy transfer and protecting battery longevity.

› Synchronization of Multiple Power Domains: Coordinating HV and LV domains require precise timing and communication between microcontrollers, gate drivers, and sensors.

› Fault Detection and Isolation: Fast response to faults (e.g., short circuits, overvoltage) is necessary to prevent cascading failures across the powertrain.

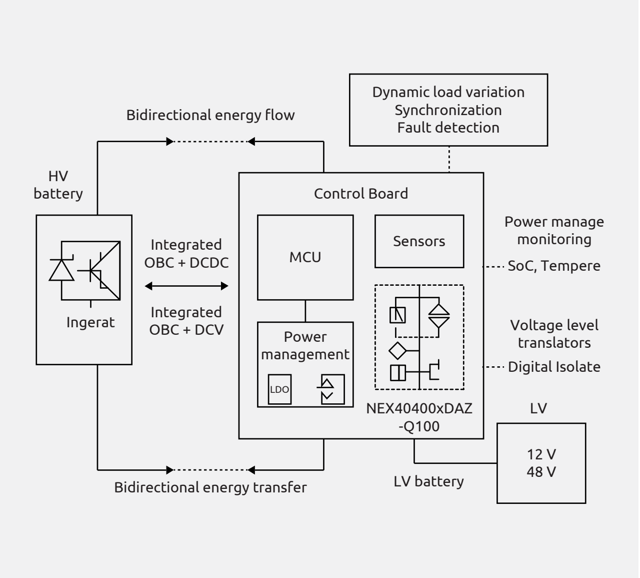



Fig 34. The control board is responsible for the seamless control of energy transfer within the OBC + DCDC Converter operation

## Nexperia Solutions

Nexperia offers a suite of components that simplify and enhance control of HV/LV energy transfer systems.

### 1. Precision Signal Conditioning using high speed logic interfaces

Coordinating the high-voltage (HV) and low-voltage (LV) domains is crucial for reliable power and control management in integrated OBC + DCDC systems. This coordination requires precise timing, robust communication, and strong noise immunity across distributed control nodes. The challenge is further heightened in automotive environments, where frequent transients, electromagnetic interference (EMI), and extreme temperature variations are commonplace.

Nexperia's logic IC families, including LVC, AUP, and HC series—offer a broad portfolio of building blocks such as buffers, logic gates, voltage level translators, and multiplexers that enable high-speed interface capabilities on control bus lines. Supporting data rates of up to several hundred MHz, these devices facilitate fast, reliable digital communication between microcontrollers, sensors, and power stages.

Their wide operating voltage range (1.2 V to 5.0 V) allows seamless bridging of both legacy and modern architectures. Additionally, ultra-low power variants (AUP, AXP series) help minimize standby current consumption in LV subsystems, supporting efficient sleep and wake-up functionality.

With over 3,000 orderable part numbers available, Nexperia's logic IC portfolio offers extensive package options—including leaded and leadless formats like XSON and VSSOP—perfectly suited to the space and reliability demands of automotive applications.

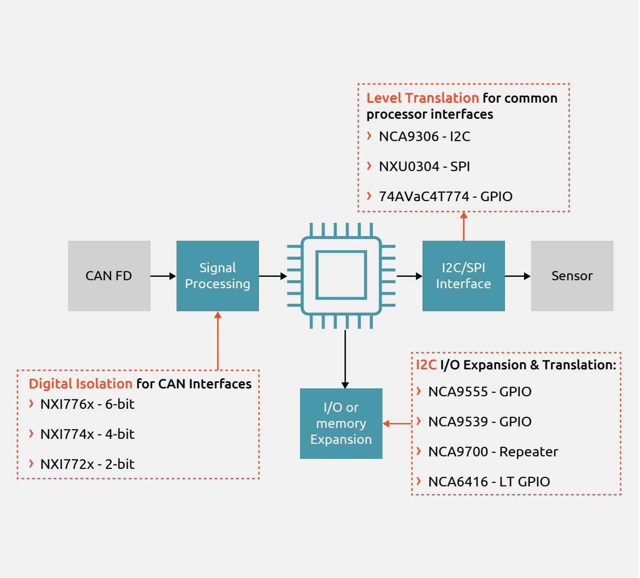



Fig 35. Logic ICs optimal for resolving various interface needs

## 2. Voltage Level Translation

As microcontrollers (MCUs), gate drivers, sensors, and power stages often operate at different logic voltage levels—such as a 3.3 V MCU controlling a 5 V gate driver or communicating with a 1.8 V sensor—voltage translation or level shifting is essential to ensure reliable, noise-immune, and safe data exchange without signal degradation or device damage in an OBC + DCDC system.

Nexperia offers a broad portfolio of automotive-qualified bidirectional and fixed-direction level translators optimized for seamless voltage domain bridging. These devices cover from 1.2 V up to 5.5 V supply voltages, supporting translation between legacy 5 V MCUs, modern 3.3 V and 1.8 V logic, and gate drivers operating at higher voltage thresholds. This versatility allows the MCU in the LV domain to control power stages or sensing equipment operating at different voltage domains without additional interface components. Typical propagation delays are in the low nanosecond range (often <5 ns), preserving fast, accurate control signals. A practical example is to consider controlling a 5 V SiC MOSFET gate driver from a 3.3 V microcontroller within the OBC + DCDC system. Using a single-channel bidirectional level translator such as the NXS0101GW-Q100, the MCU's 3.3 V control signals are shifted up to 5 V for accurate gate drive inputs. Similarly, feedback signals from the driver can be shifted down to the MCU's input level, ensuring reliable loop control without risk of damaging the MCU or driver.

For complex multi-wire buses like SPI or digital sensor interfaces, an 8-bit translating transceiver such as the NXB0108-Q100 enables seamless communication between different voltage domains with auto direction sensing and output enable control for safety and signal isolation. Various products are available in small footprint packages like XSON, VSSOP, and DFN, these translators are suitable for dense PCB layouts. The table 3 below shows various parts available for different interfaces to enable seamless control of functions within the control board.

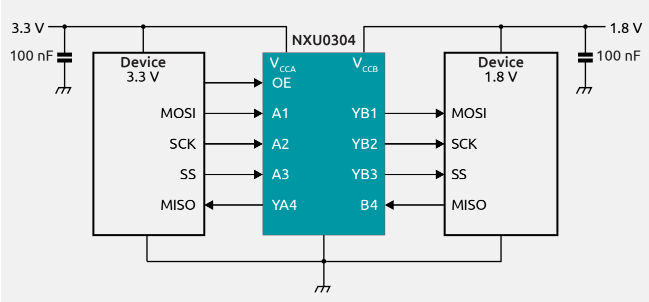


Fig 36. SPI application using voltage level shifting from 3.3 V to 1.8V

| Interfaces: | Voltage Translation 0.9 V - 5.5 V |
|---|---|
| 1-Bit GPIO \| Clock Signal \| FET Replacement | NXU0101 |
| 2-Bit GPIO \| 2-pin JTAG \| 2-wire UART | NXU0102 |
| 2-pin JTAG \| 2-wire UART | NXU0202 |
| 4-Bit GPIO | NXU0104 |
| 4-wire UART \| I2S \| PCM | NXU0204 |
| SPI \| 4-pin JTAG | NXU0304 |

Table 3 recommended part numbers from the NXUxxxx fixed direction voltage translators

Nexperia offers a variety of evaluation boards for voltage translation applications, such as the NEVB-NXU0104UL and NEVB-NXU0304, which are 4-bit evaluation boards designed to assess the performance and behavior of Nexperia's voltage translation ICs. These boards simulate real system conditions with input/output loading and signal conditioning features, enabling users to effectively validate device operation. The NXU0204 evaluation board, specifically, facilitates testing of Nexperia's 4-bit dual-supply voltage level translators with Schmitt-trigger inputs and 3-state outputs. Interested users can conveniently order these evaluation boards through Nexperia's website (NXU0204, 2025).

## 4.7 Minimizing power losses in LV systems

Modern 12 V or 48 V low-voltage (LV) networks supply power to critical subsystems - such as the control electronics in the OBC + DCDC converters—in electric and hybrid vehicles. As the complexity and density of these systems continue to grow, reducing power loss becomes essential for improving overall energy efficiency, thermal management, and vehicle range.

Key contributors to power loss in LV systems include:

- **Conduction Losses:** Voltage drops across MOSFETs and diodes during current flow result in wasted power, particularly significant at higher load currents.
- **Switching Losses:** In high-frequency buck converters and load switches, frequent switching events increase dynamic power dissipation, especially during rapid transitions.
- **Leakage and Quiescent Currents:** Even when idle, regulators, standby power supplies, and control circuits can draw small currents, gradually drain the LV battery and reduce system standby efficiency.
- **Reverse Current Flow:** Without proper ideal diode control, current can flow backwards through power stages or load switches, causing unnecessary energy loss and potential component stress.

Addressing these power loss mechanisms is critical not only for maximizing system efficiency and reliability, but also for meeting stringent automotive energy standards and minimizing heat buildup in compact electronic modules.

## Nexperia Solutions

Nexperia offers a broad portfolio of components optimized for low-loss LV power delivery.

### 1. Ultra-Low $R_{DS(on)}$ Automotive MOSFETs

Nexperia provides a comprehensive portfolio of high-performance, automotive-grade MOSFETs specifically engineered to minimize conduction losses in 12 V and 48 V LV power paths—crucial for efficient OBC + DCDC converter designs. Available in both traditional leaded and compact micro-leaded packages, these MOSFETs cover a wide voltage range from 40 V up to 150 V, addressing requirements across diverse usage.

With industry-leading ultra-low $R_{DS(on)}$ values—as low as 0.5mΩ - Nexperia MOSFETs significantly reduce voltage drop and heat dissipation during operation, enhancing overall system efficiency and thermal management, especially under high current loads.

A variety of package options—including LFPAK, MLPAK, CCPAK, and TOLL leadless types—provide designers with the flexibility to optimize for board space, thermal performance, and automated assembly. All devices are AEC-Q101 qualified to ensure robust, reliable performance in harsh automotive environments. Figure 37 illustrates Nexperia's wide range of package offerings to support the specific needs of HV-LV DCDC converter and power distribution designs.

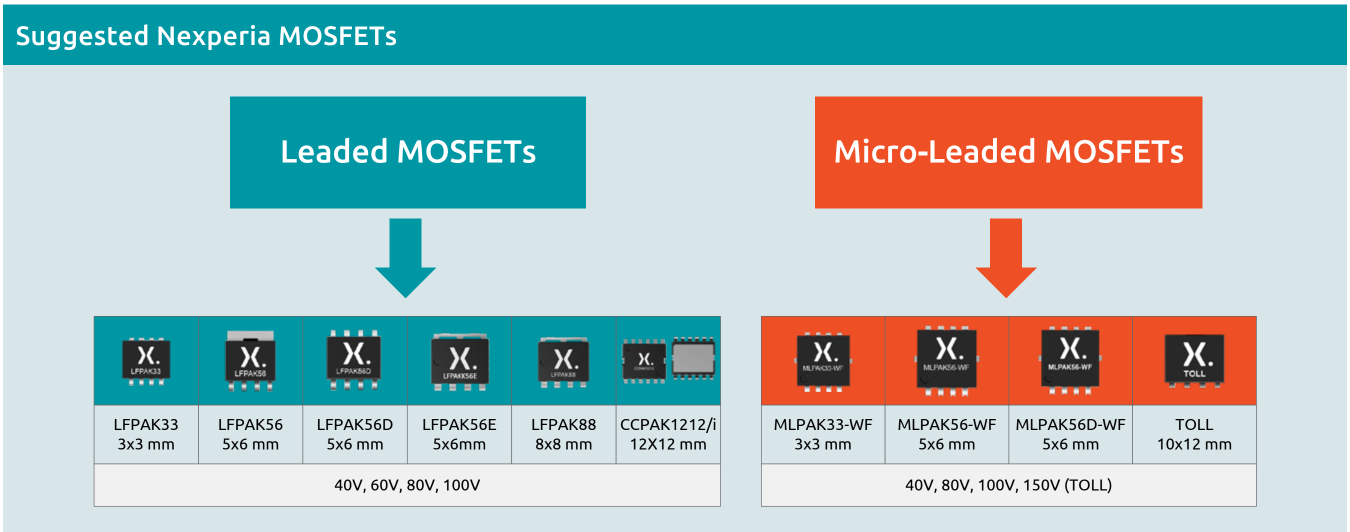



Fig 37. Automotive MOSFETs in either leaded or micro-leaded packages with enhanced $R_{DS(on)}$ performance

LFPAK (Loss Free Package) is Nexperia's flagship power MOSFET package featuring exposed, flexible lead-frame construction (with options like LFPAK33, LFPAK56, LFPAK88), originally developed for advanced automotive power applications. The exposed leads allow for mechanical compliance, reducing board-level stress and improving reliability, especially through aggressive thermal cycling and vibration. LFPAK is notable for its copper clip technology, replacing traditional wire bonds (DPAK/D2PAK) to minimize electrical resistance and thermal impedance, thus enhancing both power handling and efficiency.

## Suggested Nexperia MOSFETs

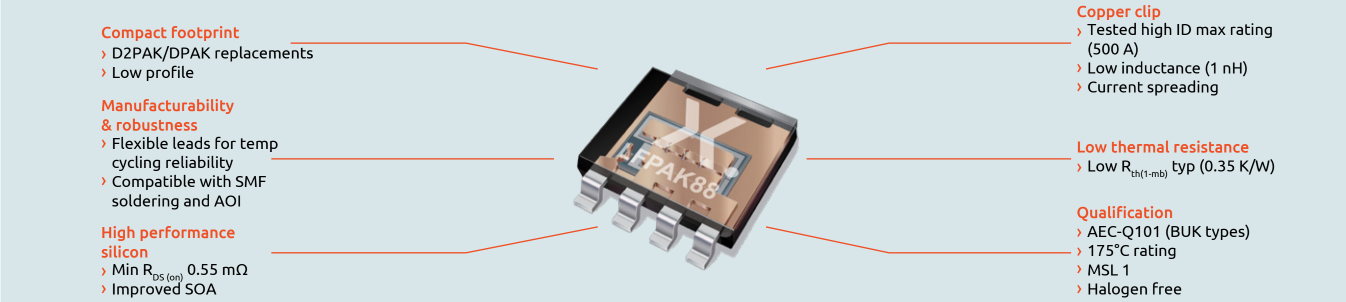



Fig 38. LFPAK value proposition (picture shows LFPAK88 for illustration)

MLPAK (Micro Lead frame Package) is designed for high-density, space-constrained automotive designs and shares the same board footprint as the LFPAK 33 or 56 variants, making them footprint-compatible for easy adoption. MLPAK employs robust micro-lead frames and offers low parasitic package inductance but is generally optimized for ultra-compact size and surface-mount capability rather than maximum current capacity. MLPAK also provides solid thermal performance thanks to close die-to-PCB coupling, but its smaller thermal mass and less flexible construction mean it has less headroom for extreme current or temperature cycling than LFPAK.

## Suggested Nexperia micro-leaded MOSFETs

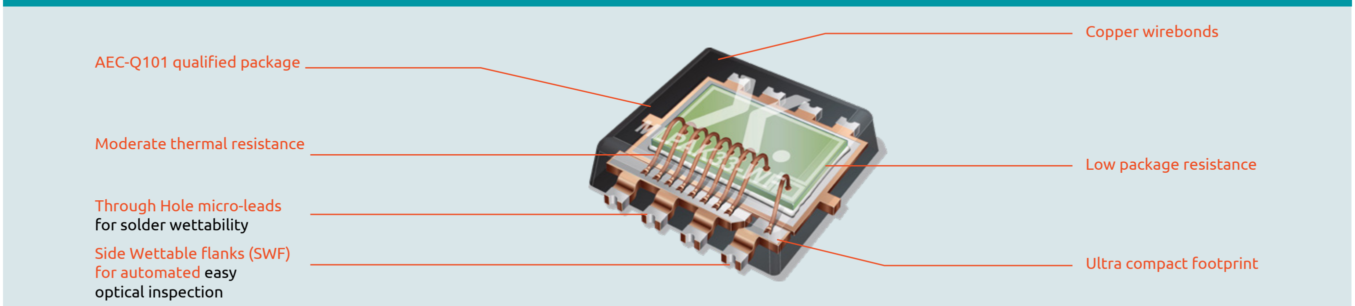



Fig 39. MLPAK features wire bonds and is a low resistance package - ideal for compact designs

Nexperia's Automotive MOSFETs use a vertical trench structure technology, with gate electrodes inserted deep into silicon. This increases channel density, drastically lowering the die's intrinsic $R_{DS(on)}$ without ballooning chip area. The combination of advanced trench silicon and advanced packages (like LFPAK) results in record-low $R_{DS(on)}$ and strong current handling, since the die can be larger, cooled more effectively, and efficiently connected to the PCB.

## 2. Schottky diodes with Low $V_F$ enables efficient rectification

Nexperia offers two complementary Schottky diode technologies—Planar (20 V to 60 V) and Trench (45 V to 100 V) Schottky diodes—both engineered to minimize switching and conduction losses as well as leakage currents in 12 V/48 V OBC + DCDC Converter power systems.

Trench Schottky diodes integrate advanced trench structures that enhance current handling and lower forward voltage. The trench design optimizes the electric field distribution within the diode, enabling higher breakdown voltages and lower conduction losses simultaneously. Their low VF and Qrr values make them ideal for freewheeling and synchronous rectification in high-frequency buck, boost, and flyback converters, where efficiency and thermal management are paramount. Trench Schottky diodes like PMEG6010ESB or PMEG6020ER block reverse current efficiently due to their low leakage (9 µA typical for PMEG6010ESB), while their fast response, low Qrr and low VF (typical values around 600–710 mV @ 1–2 A) reduce power dissipation across the switch. The availability of AEC-Q101 qualified variants allows designers to meet stringent automotive reliability standards, while compact packages enable miniaturization of power stages in OBC + DCDC systems.

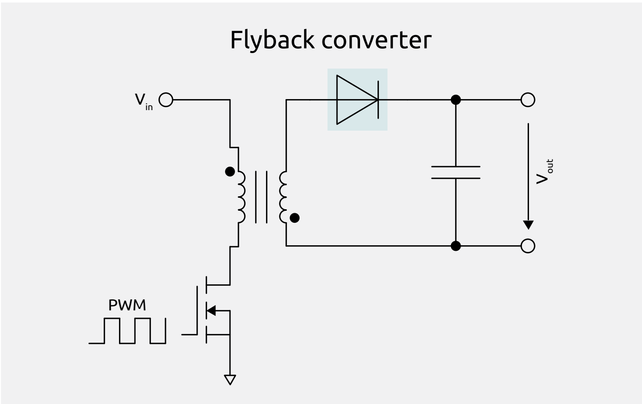



Fig 40. Trench Schottky in a flyback converter

Planar Schottky diodes utilize a planar structure with an integrated guard ring to enhance breakdown voltage and reduce leakage current. Their extremely low leakage current and robust voltage handling make them particularly well suited for low-power or standby circuits where minimizing battery drain is critical. While their forward voltage is slightly higher compared to trench diodes, their superior leakage and ruggedness make them the preferred choice for reverse polarity protection and low-loss rectification in low-voltage applications. Planar diodes like PMEG2020EXD-Q have forward voltage of 580 mV at 1 A with a blocking voltage of 20 V. The reverse leakage current is ultra-low, often below 1μA to a few μA at room temperature and this helps to maximize battery life in idle states.

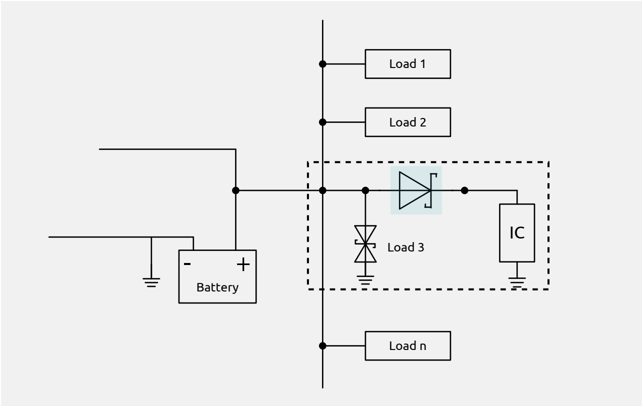



Fig 41. Planar Schottky can be used for reverse polarity protection

Both planar and trench Schottky didoes are served in the CFP (Clip-bonded Flat Power) packages designed to meet the stringent efficiency, thermal, and space requirements in OBC + DCDC converter designs, (Reza Behtash, 2025). The CFP package features a solid copper clip that acts as an efficient heat spreader, significantly improving thermal dissipation compared to traditional SMA/B/C packages with larger footprints. Junction temperatures up to 175 °C are supported, ensuring reliability in high-temperature operation. The copper clip and optimized lead frame design minimize package inductance, which is critical in high-frequency switching, this facilitates faster switching speeds and cleaner waveforms, improving overall converter efficiency. Nexperia offers over 100 devices in CFP packaging, including planar diodes optimized for ultra-low leakage and trench diodes optimized for very low forward voltage and fast recovery, with reverse voltages ranging from 20 V to 100 V and currents from 1 A to 15 A. Many are AEC-Q101 qualified, supporting automotive-grade reliability and board-level quality compliance.

**Suggested Nexperia micro-leaded MOSFETs SOD32HP CFP2HP**

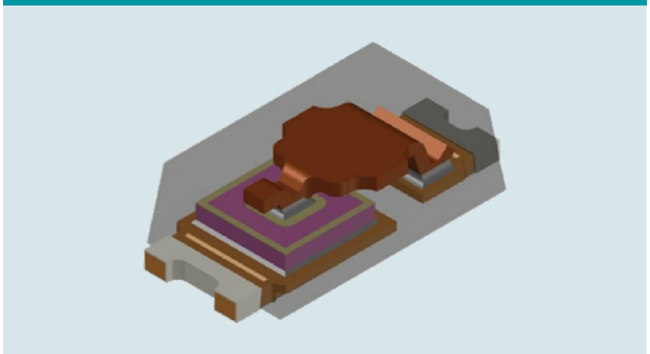


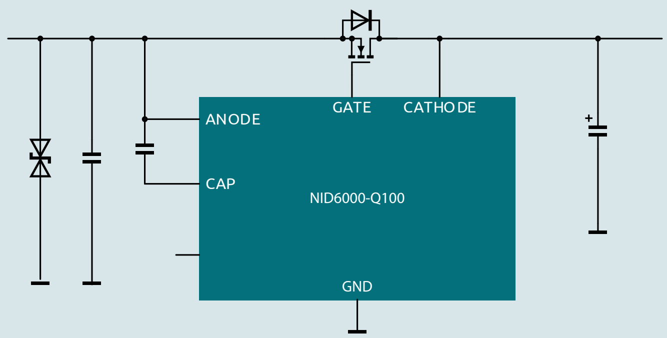
Fig 42. CFP2-HP at 2.65mm x 1.3mm x 0.68mm

## 3. Blocking Reverse Current Flow using ideal diodes

Efficient power management in automotive 12 V and 48 V LV systems requires minimizing conduction and switching losses in load switching and reverse polarity protection paths. Traditional diode-based solutions suffer from significant forward voltage drops, leading to wasted power and heat dissipation.

The NID6000-Q100 ideal diode controller provides a highly effective solution to dramatically reduce power loss by actively controlling an external MOSFET as a low-dropout diode replacement. This approach dramatically reduces conduction losses because the MOSFET's on-resistance RDS(on) is typically much lower than that of a diode's forward voltage drop, and the controlled gate drive feedback precisely switches the MOSFET on and off to maximize efficiency and prevent shoot-through conditions. Reverse current and reverse polarity situations are actively blocked, reducing unnecessary power dissipation and improving battery protection. NID6000-Q100 has an operating supply range of 3.2 V to 65 V, which works for both 12 V and 48V systems. With a -65 V input reverse voltage rating, the NID6000-Q100 safely withstands voltage transients and protects downstream electronics.

**Suggested Nexperia Ideal Diode Controller: NID6000-Q100**




- Automotive AEC-Q100 Qualified
- Operating Supply 3.2 V – 65 V, for 12 V and 24 V applications
- 20 mV regulated Anode to Cathode forward voltage drop
- 2.3 A peak gate turnoff current
- Reverse Current Blocking & Reverse Polarity Protection
- -65 V input reverse voltage rating
- Meets ISO 7637-2 transient requirement with TVS diode
- Functional safety capable (ISO 26262 and IEC 61508)

Fig 43. NID6000-Q100 with an external FET used for reverse polarity protection

# 4.8 Minimizing ripples in LV power supply systems

The low-voltage (LV) output—typically 12 V or 48 V—serves as the primary power source for highly sensitive components such as gate drivers, microcontrollers (MCUs), operational amplifiers, and signal conditioning circuits. These devices demand an exceptionally stable and low-ripple power supply to maintain precise operation, avoid malfunctions, and minimize electromagnetic interference (EMI) within the vehicle's complex electrical environment.

Key challenges include:

- Sensitive analog front ends and MCUs are susceptible to noise and ripple on the power rail, which can induce timing errors, bit-flips, inaccurate sensor readings, or communication glitches.
- Gate drivers require stable isolated voltage rails to ensure consistent MOSFET switching performance and prevent false triggering.
- Operational amplifiers and signal conditioning circuits rely on low-noise references to achieve accurate measurements critical for battery management and system diagnostics.

## Nexperia Solutions

Nexperia provides a range of components that help minimize ripple and stabilize LV outputs.

### 1. Low Dropout Regulators (LDOs) with ultra-Low Noise and High PSRR

LDOs are types of linear regulators with a low input-output voltage differential. They are good for cases where an inexpensive, simple power regulations is required, Figure 44 shows the difference between linear regulators and switching regulators in power conversion and low ripple power regulation, which are both applicable in OBC + DCDC low power conversion.

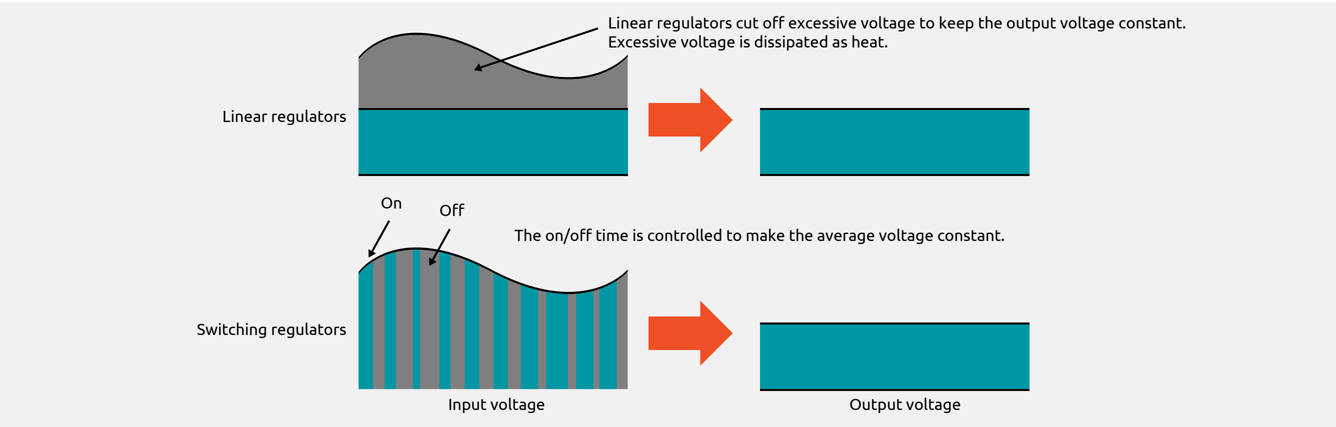



Fig 44. LDOs are linear regulators, switching regulators include boost-buck converters

Nexperia's AEC-Q100-qualified LDOs, such as the NEX90x30yPA-Q100 series and tracking LDOs like NEX91207-Q100, offer exceptional performance in automotive ripple-sensitive applications. Their benefits include:

- Ultra-low quiescent current ($I_Q$)—as low as 5.3 μA typical—prolongs battery life.
- High Power Supply Rejection Ratio (PSRR) effectively attenuates ripple and switching noise from the upstream DCDC converters. PSRR is a measure of how well a circuit rejects ripple coming from the input power supply at various frequencies as shown in Figure 45.

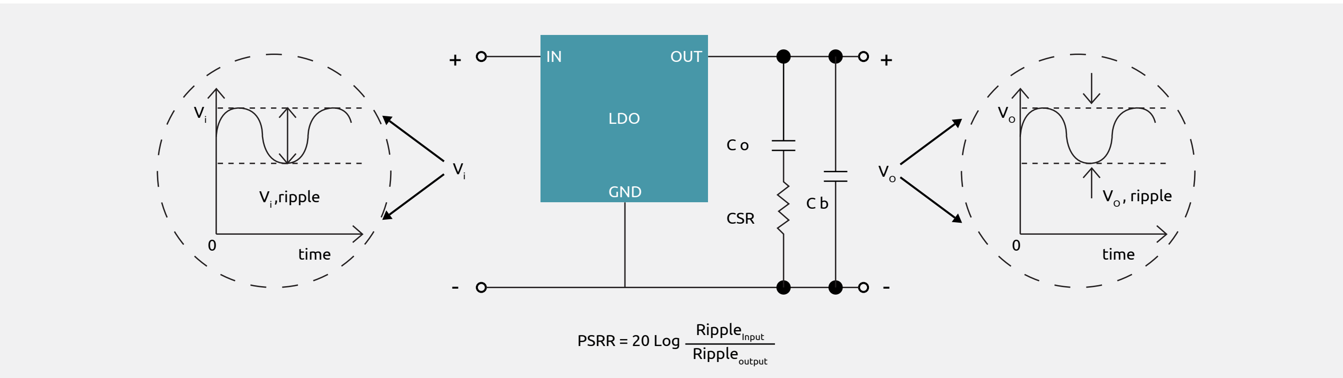



Fig 45. PSRR is a measure of the rejection of the ripples

Figure 46  shows the results of NEX91207-Q100 and demonstrates its superior PSRR performance across a wide frequency range.

Nexperia's LDO portfolio has a wide input voltage range (3 V to 40 V), and robust thermal design enable direct connection to 12 V auxiliary battery rails ensuring stable performance under transient load conditions. The maximum operating output current can be selected from 150 mA or 300 mA ranges with various thermally enhanced packages.

These LDO regulators effectively minimize ripple and noise on MCU and analog input rails, ensuring the precise signal integrity crucial for OBC + DCDC control and diagnostic functions. To assist designers, Nexperia provides the Ultra-Low $I_Q$ LDO evaluation board (NEX90530BPA-Q100 EVB), which allows comprehensive testing and performance evaluation of the NEX90530BPA-Q100 device. This LDO supports input voltages up to 40 V and delivers a maximum output current of 300 mA. The evaluation board can be found on Nexperia website , (UM90051, 2025).

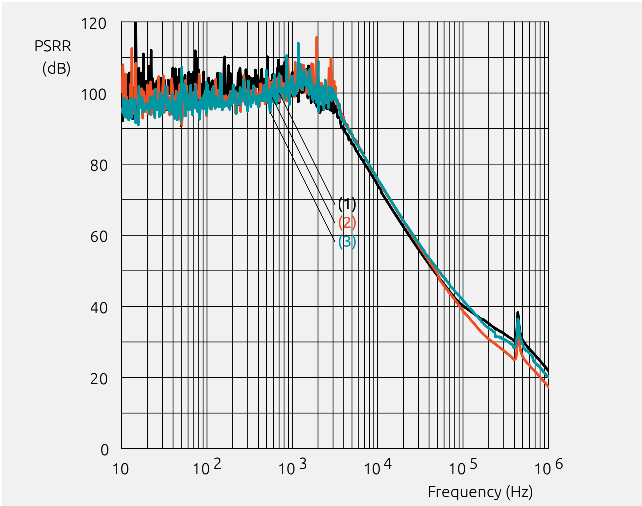



Fig 46. NEX91207-Q100 PSRR results

## 2. Synchronous Buck Converters — Efficient, Low-Noise Step-Down Regulation

An alternative to LDOs for powering control board devices is the use of switching regulators, as illustrated in Figure 47. A buck converter efficiently steps down the auxiliary supply voltage to provide stable power to components such as isolated gate driver primary stages and microcontrollers, as shown in Figure 48 below.

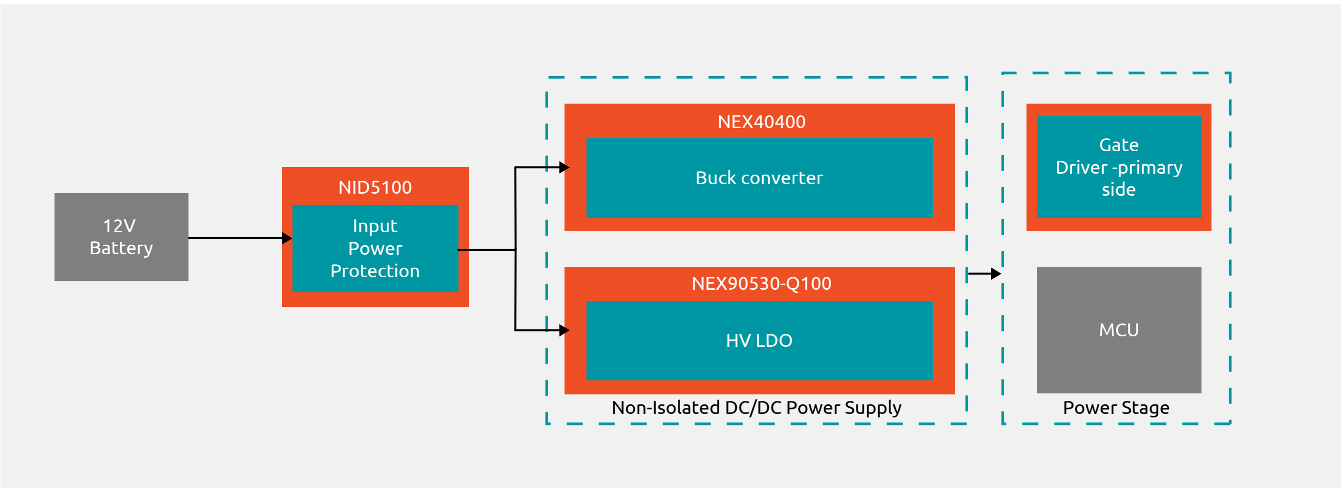



Fig 47. Both LDOs and Buck converters can be used in powering other devices with ripple free supply. Buck converters are useful for when the voltage drop is significantly larger

Nexperia's NEX40400xDAZ-Q100 synchronous buck converters deliver:

- High conversion efficiency (>90%) with integrated synchronous rectification, minimizing heat dissipation and improving overall system energy efficiency. Figure 48 below demonstrates the tested efficiency results with 1.05/2.1 MHz switching frequency in NEX40400 at fixed output voltage of 5 V.
- The NEX40400 series has a comprehensive protection feature, including overcurrent and thermal shutdown—ensuring robust operation in demanding automotive environments.
- The NEX40400 series has a wider spread spectrum modulation to spread switching noise energy over a broader frequency range, significantly reducing peak ripple amplitudes and EMI.

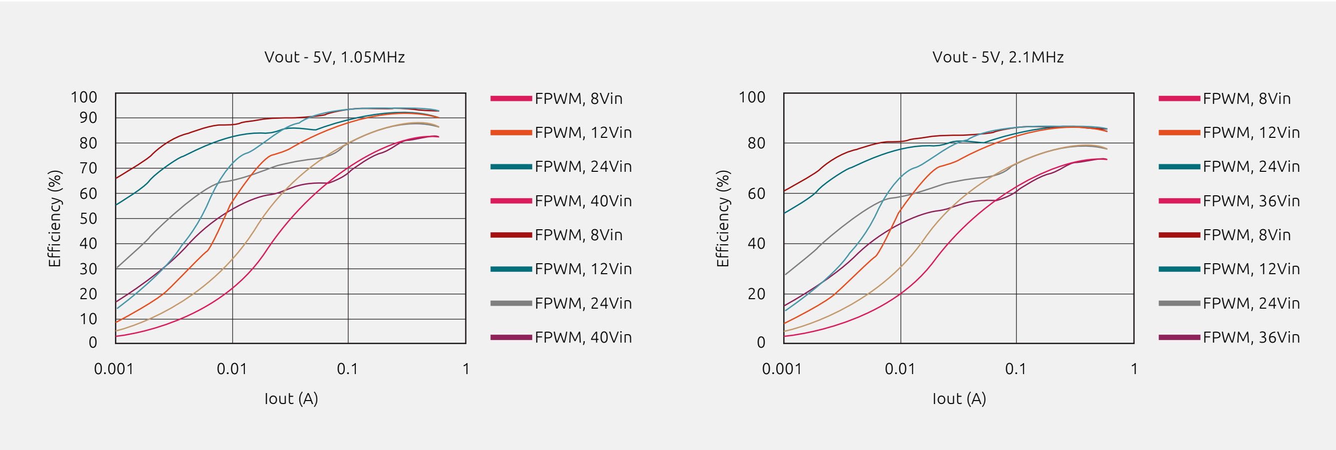



Fig 48. NEX40400 efficiency curve with different modulation techniques and frequencies

Buck converters serve as the foundation for generating low-voltage (LV) power rails, delivering stable output with minimized ripple and noise to protect sensitive downstream circuits. For designers, the NEX40400EVM-05 evaluation board is a reference design featuring the NEX40400 synchronous step-down (buck) converter, which operates from 4.5 V to 40 V input, provides up to 600 mA output current, and uses fixed-frequency PWM (1.05 MHz) switching. Assembled on a two-layer PCB, this board enables convenient testing and evaluation of the NEX40400's functionality and performance. The evaluation board is available for order through the Nexperia website (NEX40400EVM-05, 2025).

## 4.9 How to overcome ESD issues in sensitive communication interfaces

Modern OBC + DCDC systems rely on CAN (Controller Area Network) and LIN (Local Interconnect Network) buses for:

- Battery management system (BMS) communication
- Charging protocol handshaking (ISO 15118, DIN 70121)
- Vehicle diagnostics and telemetry

- ESD strikes (e.g., human-body model >8 kV during maintenance)
- Electrical fast transients (EFT) from load-dump events
- Cable discharge events (CDE) during connector mating

However, these low-voltage interfaces are vulnerable to:

ESD failures can lead to several fatal operational modes such as latch-up in transceivers (e.g., CAN PHY ICs), data corruption leading to charging interruptions and permanent damage to microcontrollers and other ICs inside the OBC + DCDC system.

## Nexperia Solutions

Nexperia offers dedicated automotive-grade ESD protection diodes specifically engineered for CAN/LIN communication buses. The CAN FD bidirectional ESD protection devices (PESD2CAN series) ensure signal integrity for high-speed data transmission up to 5 Mbps (CAN FD), while providing up to ±8 kV ESD protection (per ISO 10605) and ±30 kV surge immunity (per IEC 61000-4-2).

### 1. Automotive ESD Diodes for communication specific bus lines

The PESD2CAN series features ultra-low capacitance (0.5 pF typical, 0.7 pF max), which is critical for:

- Minimizing signal distortion in high-speed CAN FD networks (up to 8 Mbps in future implementations).
- Preserving rise/fall times (<5 ns) to meet ISO 11898-2 CAN physical layer requirements.
- Avoiding impedance mismatches in 120 Ω differential bus topologies.

These diodes are available in automotive-compliant packages (SOD-323, DFN1006-2 A) and support bus voltage levels from 12 V to 24 V, making them ideal for:

- 12 V LIN buses (PESD1LIN, 0.3pF capacitance).
- 24 V CAN systems in commercial vehicles (PESD2CANx-24V variant).
- 48 V mild-hybrid architectures (PESD5V0X1UD with 36 V working voltage).

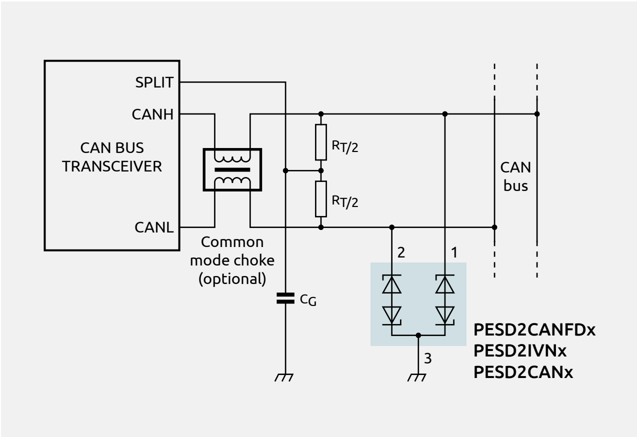



Fig 49. Typical application circuit using CAN FD ESD Diodes for protection

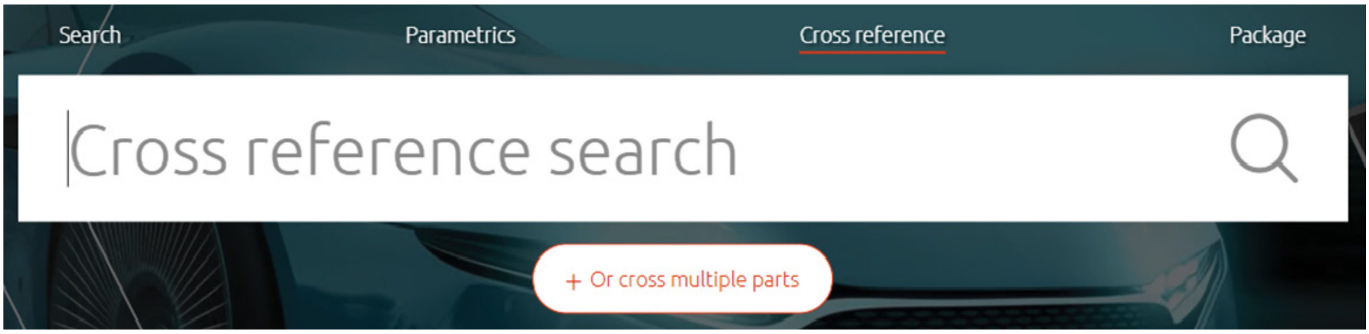
The specifications of ESD diodes are summarized in the following table.

| Interface | Product | Protection Level | Capacitance (max) | Package |
|---|---|---|---|---|
| CAN-FD | PESD2CANFDxx | ±30 kV<br>(IEC 61000-4-2) | 10 pF | SOT23, SOT323<br>DFN1110D-3<br>DFN1413D-3 |
| LIN | PESD1IVNx | ±30 kV | 17 pF | SOD323 |
| CAN/FlexRay | PESD2IVNx | ±30 kV | 17 pF | SOT23<br>SOT323<br>SOD882BD |

Table 4. Summary Automotive ESD Diodes for CAN, LIN and Flex ray

# 5. Recommended products

Nexperia offers a wide portfolio of discrete, wide band gap, analog and logic devices for OBC + DCDC Converters. To find an equivalent to the used device please refer to the Nexperia website, cross reference search.




## PFC and HV DCDC Converter

| Technology | Description | Key part numbers |
|---|---|---|
| **SiC MOSFETs** | 1200 V, 30/40/60 mΩ, TO263-7/TO263-7 packages | NSF030120D7A0-Q |
| | | NSF040120L4A0-Q |
| | | NSF040120D7A0-Q |
| | | NSF060120T2A0-Q |
| **SiC Schottky diodes** | 650 V, 10/16/20 A, DPAK/D2PAK packages | PSC20120J-Q |
| | | PSC2065J-Q |
| | | PSC1065J-Q |
| | | PSC1065H-Q |
| **Fast Recovery rectifiers** | 650V , Hyperfast (trr < 30 ns) and ultrafast (trr < 80 ns), CFP3/CFP5/D2PAK R2P packages | PNE650100EJ-Q |
| | | PNE650150EJ-Q |
| | | PNU650150AEJ-Q |
| | | PNU650100EJ-Q |
| **GaN FETs** | 650 V Cascode, 14-79 mΩ, CCPAK1212/ CCPAK1212i packages.<br>*Automotive qualification - 2026 | GAN039-650NBB |
| | | GAN039-650NTB |
| | | GAN041-650WSB |

## HV-LV DCDC Converter

| Technology | Description | Key part numbers |
|---|---|---|
| **Automotive MOSFETs** | N-channel 30/40/55/60/80/100 V, standard level MOSFETs.<br>LFPAK/MLPAK 33/56/88 packages. | BUK9Y13-60EL |
| | | BUK9Y19-100E |
| | | BUK7J1R4-40H |
| **Schottky Diodes** | Trench Schottky, 45 V to 100 V, 1 A to 15 A, CFP3/CFP5/CFP15 packages. | PMEG045T030EPD |
| | | PMEG045T050EPD |
| | | PMEG060T060CLPE |
| | | PMEG100V080ELPE-Q |

## Control Board – Power Supply and Management

| Technology | Description | Key part numbers |
|---|---|---|
| **Buck Converters** | 4.5 V to 40 V, 600 mA, synchronous step-down converter, SOT8061-1. | NEX40400ADA |
| | | NEX40400BDA |
| | | NEX40400CDA |
| | | NEX40400DDA |
| **Transformer Drivers** | Low-noise, 1.2 A push-pull transformer driver for isolated power supplies, SOT8061-1. | NXF6501-Q100 |
| | | NXF6505-Q100 |

| | | |
|---|---|---|
| **LDOs** | 150/300 mA, 40 V ultra-low Iq (5.3 µA) low-dropout voltage regulator in HTSSOP8. | NEX90X30-Q100 |
| **Load switches** | 5.5 V, 15-55 mΩ, current limit from 110mA to 6A, SOT8044-1 or SOT457. | NPS4053-Q100<br>NPS3005GP-Q100 |
| **Ideal diodes controller** | 3.2 V to 65 V, 60 uA Ideal diode controller in SOT457 plastic package | NID6000-Q100<br>*release soon |
| **Voltage Translators** | 1/2/4-bit dual supply translating transceiver; open drain; auto direction sensing | NXS, NXB series |
| **Schottky Diodes** | 30 V planar Schottky barrier diodes, SOT23 | BAT754 series<br>1PS70SB10-Q<br>BAS40-04-Q |
| **Zener Diodes** | > 2700 product types, 1.8 V to 75 V Zener Voltage, ±1% or ±5% tolerance, high power and low leakages options, SOD, DFN and SOT package varieties. | BZX84J<br>BZT52 series<br>PDZ-B-Q series<br>PZUxB_B2-Q |
| **Bipolar Junction Transistors (BJTs)** | 45 V, 500 mA NPN general-purpose transistors in SOT23 package | BC817-25QA; BC817-40QA<br>PNP complement: BC817QBH-Q series |
| **Small Signal MOSFETs** | 30-100 V, N-channel MOSFETs, low RDS(on), DFN, SC, WLCS and SOT packages | 2N7002<br>BUK4D110-20P<br>BUK6D120-40E |
| **TVS Diodes** | 400/600 W Transient Voltage Suppressor, Reverse standoff voltage range: 3.3-64V , SOD128 or SOD123W. | PTVSxP1UP<br>PTVSxS1UR |

## Control Board - Communication Interfaces

| Technology | Description | Key part numbers |
|---|---|---|
| **ESD Didoes** | LIN/CAN/FexRay ESD diodes, uni or bi-directional, DFN or SOD packages. | PESD1CANFD24LS-Q<br>PESD2CAN24LT-Q<br>PESD1IVN24LS-Q |
| **Digital Isolators** | 2/4/6 Channel Digital isolator, 5 kV galvanic isolation, 250 kV/µs CMTI. | NXI77xx-Q100 |

## Control Board - Signal processing

| Technology | Description | Key part numbers |
|---|---|---|
| **Standard Logic ICs** | Logic gates, Buffers, inverters, flip flops, latches in singular or multibyte circuits. | 74AHC00-Q100; 74AHCT00-Q100<br>74AHCT240-Q100<br>74ALVC32-Q100<br>74AVC4T245-Q100<br>74HCS04-Q100 |
| **Multiplexers** | 1.8 V general purpose SP8T-Z and 2x SP4T-Z analog switches with injection current control, micro packs, XSON, TSSOP16, SOT varieties, | NMUX1308-Q100<br>NMUX1309-Q100 |
| **Resistor Equipped Transistors** | 50-80 V, NPN or PNP RETs, various resistors combinations (single or dual), SOT23/SOT323/DFN1412D-3/DFN1110D-3/DFN1006B-3 | PDTA143/114/124/144EQA series<br>PDTB1xxxT series<br>PDTC124T series<br>PEMD12; PUMD12 |

## Control Board - Gate Driver Circuits

| Technology | Description | Key part numbers |
|---|---|---|
| **Gate Drivers** | 4 A, 120 V non isolated Half bridge or low side gate drivers, SOT packages | NGD4300-Q100<br>NGD31251D |
| **Bipolar Junction Transistors (BJTs)** | 45 V, 500 mA NPN general-purpose transistors in SOT23 package | BC817-25QA; BC817-40QA<br>PNP complement: BC817QBH-Q series |
| **Switching diodes** | Low leakage switching diodes, SOD and DFN low-profile packages. | BAS116-Q, BAV170-Q, BAV199-Q, BAW156-Q |

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