System Solution Guide

48V Starter Generator

Updated: MAR-2024

Industry	• Automotive – Vehicle Electrification
Applications	• One of the foundational steps in vehicle electrification involves the integration of an internal combustion engine (ICE) and an electric motor, resulting in the creation of mild hybrid electric vehicles (MHEVs). Serving as a crucial milestone toward full vehicle electrification, MHEVs are well-received by drivers who are not yet ready to transition to fully electric cars. • As 12V systems are stretched to their limit, the automotive industry is now migrating to 48V systems. This transition aims to increase available power, reduce wire and connector size, and accommodate additional electrical content and higher power consumption.

System Purpose

The hybrid power solution for MHEVs is achieved by a Starter Generator powered by a 48V lithium-ion battery. Whether in the form of a Belt Starter Generator (BSG) or Integrated Starter Generator (ISG), it plays a dual role by serving as a replacement for traditional starter and alternator modules while simultaneously enhancing the ICE functionality.

By making certain changes to an existing car design, car manufacturers can easily implement 48V mild hybrid technology and offer it as a standard feature in their new models, meeting the customer demand around the world. MHEVs are a cheaper green option, that strikes a balance between environmental responsibility and financial practicality, making them a desirable choice for customers.

Starter Generator has been the traditional focus for 48V in reducing emissions and improving fuel efficiency in ICE vehicles, as well as other emission reduction technologies including electric turbochargers, exhaust-gas recirculation (EGR) pumps, and electrically heated catalyst. The higher voltage does a more efficient job at operating power hungry components.

Market Information and Trends

Recently, 48V accessories have begun to enter the market in Battery Electric Vehicle (BEV) applications. Higher voltage accessories provide the same benefits to BEV accessories, where 800V of a BEV is impractical. With the availability of 48V power on vehicles, traditional 12V accessories will migrate to the 48V bus, beginning with the highest loads in the system.

Globally, the MHEV market has been growing steadily, but not as fast as the markets for BEV and Plug-in Hybrid EV (PHEV). This shows that consumers prefer vehicles that can get power from the grid. However, MHEVs still have a large share in the global electric vehicle market because they are cheaper and more convenient, as they do not need a charging station.

System Description

Starter Generator in mild hybrid electric vehicles (MHEV)

MHEVs are vehicles that combine a combustion engine (ICE) with a 5kW to 25kW electric motor, also known as the Belt Starter Generator (BSG) or Integrated Starter Generator (ISG). The BSG/ISG effectively combines the functionality of the starter motor and alternator, creating a MHEV hybrid vehicle.

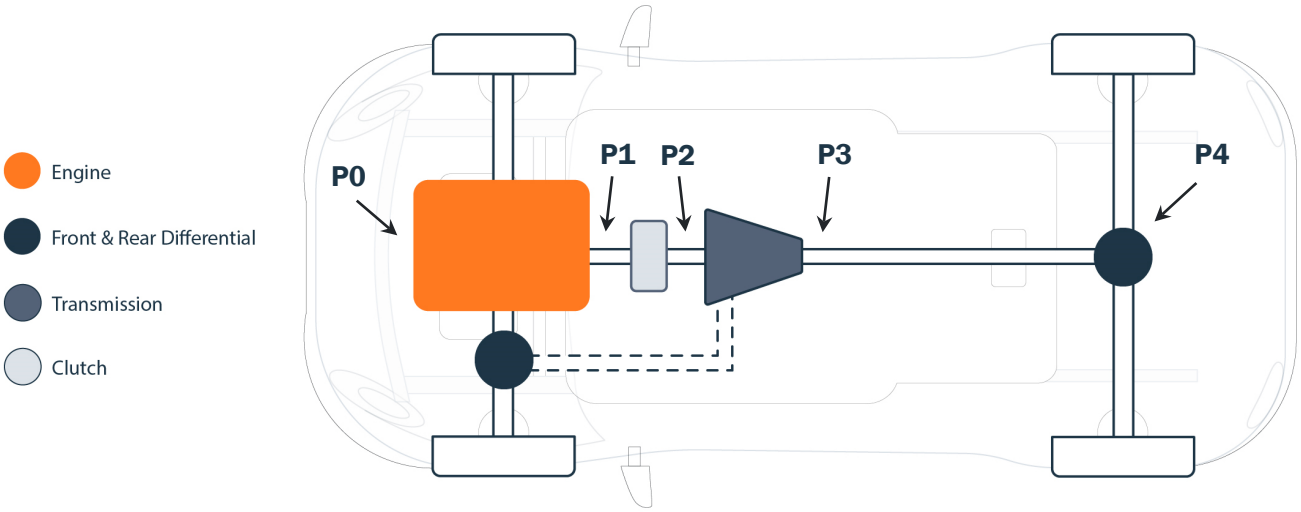
Implementing the BSG/ISG on an ICE vehicle enables additional functionality such as start-stop, energy recovery during coasting/braking, energy generation from the ICE, and even electric drive (or boost) depending upon the vehicle. These features can be so subtle that the driver may not even notice that their MHEV is different from a traditional ICE vehicle, except when the ICE shuts down during usage.

The functionality and performance are determined by where in the powertrain the BSG/ISG is positioned. Figure 1. displays the possible placement positions of the Starter Generator in the MHEV powertrain. Table 1. on the following page details the technical capabilities for each position. Integration cost and complexity increase with the added capability. **P0 – P4 are the current designated positions, each providing varying levels of capability and design challenges for the system.** The positioning also determines whether the device is a BSG (P0 or possibly P2) or an ISG (P1, possibly P2, P3 & P4).

If mounted at P0 or P1, the device's functionality is limited to start-stop and energy recovery. Although P0 and P1 locations are easier places to integrate the unit, the benefit on emissions is the lowest here, as there is no energy recovery if the ICE is not rotating. Belt drive systems will be limited in power due to belt slippage and maximum applied torque. In contrast, direct drive integrations that use gear mesh or a direct connection to the crankshaft can achieve higher power output.

In the P2, P3, and P4 variants, the ICE can be disconnected from the driveline, allowing for electric drive at lower speeds as well as regenerative energy while coasting or braking with the ICE off. Energy recovery functionality is truly regenerative, as the e-machine has a connection to the driveline and will continue to spin even with the ICE off. Locations P3 and P4 enable maximum energy recovery. Installing an ISG at the P4 position in a front wheel drive vehicle will allow for all wheel drive functionality with a properly sized lithium-ion battery.

Figure 1 : Topologies for the mild hybrid Starter Generator and its placement in the vehicle powertrain.



P0 – Belt-driven Starter-Generator (BSG)

P1 – Crankshaft Starter-Generator

P2 – Transmission input shaft →BSG/ISG

P3 – Transmission output shaft → ISG

P4 – Drive on rear axle or differential → ISG

System Description

Starter Generator in mild hybrid electric vehicles (MHEV)

Installation location and coupling mechanism of BSG/ISG units will affect the peak output power (from 5kW up to 25kW). If mounted at P0 or P1, functionality is limited to start-stop and energy recovery. Table 1 shows the overview of different starter generator positions and its added functionality

- Location P0 peak power is limited by the belt linkage. Energy recovery or generation requires the ICE to be On in order to spin the e-machine.
- Location P1 is a direct connection to the engine crankshaft and does not suffer from slippage related to a belt, resulting in higher peak output power and torque as compared to P0.
- When positioned further back in the drivetrain (P2-P4), energy recovery is possible during coasting or braking when the ISG is functioning as a generator. The motion of the vehicle will turn the rear axle or driveshaft, even if the ICE is off. As the ISG is now independent of the ICE, more aggressive ICE shutdown algorithms are possible which allows for greater CO2 reduction. In these positions, electric drive is possible, meaning the vehicle can be moved by the ISG while functioning as a motor. This can be useful in start-stop traffic or for moving off from a standstill before engaging the ICE for higher speeds.

Table 1 : Functional variations based on the P0-P4 positions within the MHEV.

Location	P0	P1	P2	P3	P4
e-Machine Type	BSG	ISG	BSG / ISG	ISG	ISG
Capabilities	Start-Stop, Energy Recovery	Start-Stop, Energy Recovery	Improved Start-Stop, Improved Energy Recovery & Electric Drive	Improved Start-Stop, Improved Energy Recovery & Electric Drive	Improved Start-Stop, Improved Energy Recovery & Electric Drive
Powertrain Linkage	Engine – Toothed Belt	Engine – Direct to Crankshaft	Transmission Input – Side Connected Toothed Belt or Integrated Gear Mesh	Transmission Output – Gear Mesh	Rear Axle or Differential – Gear Mesh
Disconnect from ICE	No	No	Yes	Yes	Yes
Integration Cost	Lower	Medium	Higher	Higher	Higher
Energy Recovery – While Braking	Good	Better	Best	Best	Best
Energy Recovery – with ICE Off	No	No	Yes	Yes	Yes
Electric Drive	No	No	Yes	Yes	Yes
Electric Boost	Yes	Yes	Yes	Yes	Yes

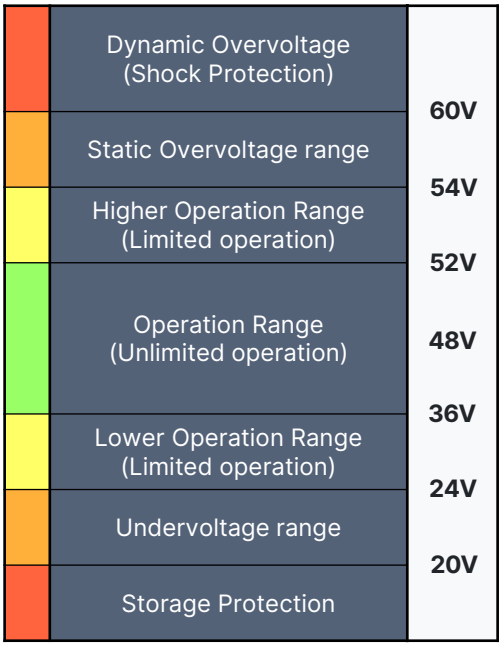
System Description

DC-DC Converter

MHEVs typically have two batteries; the 'traditional' 12V lead-acid battery and a 48V lithium-ion (Li-Ion) battery. When in energy recovery or generation modes, the BSG/ISG charge the 48V battery pack and the **DC–DC converter ties the 12V and 48V power nets together.**

- The 12V battery powers many of the 'legacy' systems like infotainment, door modules, engine control and safety, while the 48V battery powers higher loads, such as **Electric Power Steering, E-Turbo, pumps, suspension and HVAC**. 48V battery also powers the BSG/ISG to start the vehicle or provide electric boost/drive.
- DC-DC converter is most often designed as bidirectional with power levels ranging from **1 kW up to 3 kW**. (3kW in Step-down mode, 1kW in Step-up mode) **Most common topology is non-isolated bidirectional synchronous step-down converter**.
- DC-DC converter is designed for the nominal battery voltages 12V and 48V but must be ready to operate outside of the nominal, allowing room for operating voltages above and below. Voltage level changes due to state of battery charge and other factors.
- Find more information in System Solution Guide: **48V-12V DC-DC Converter**

Find System Solution Guide on the web



Voltage Levels for 48V System Specified by ISO 21780:2020

Standards and compliance

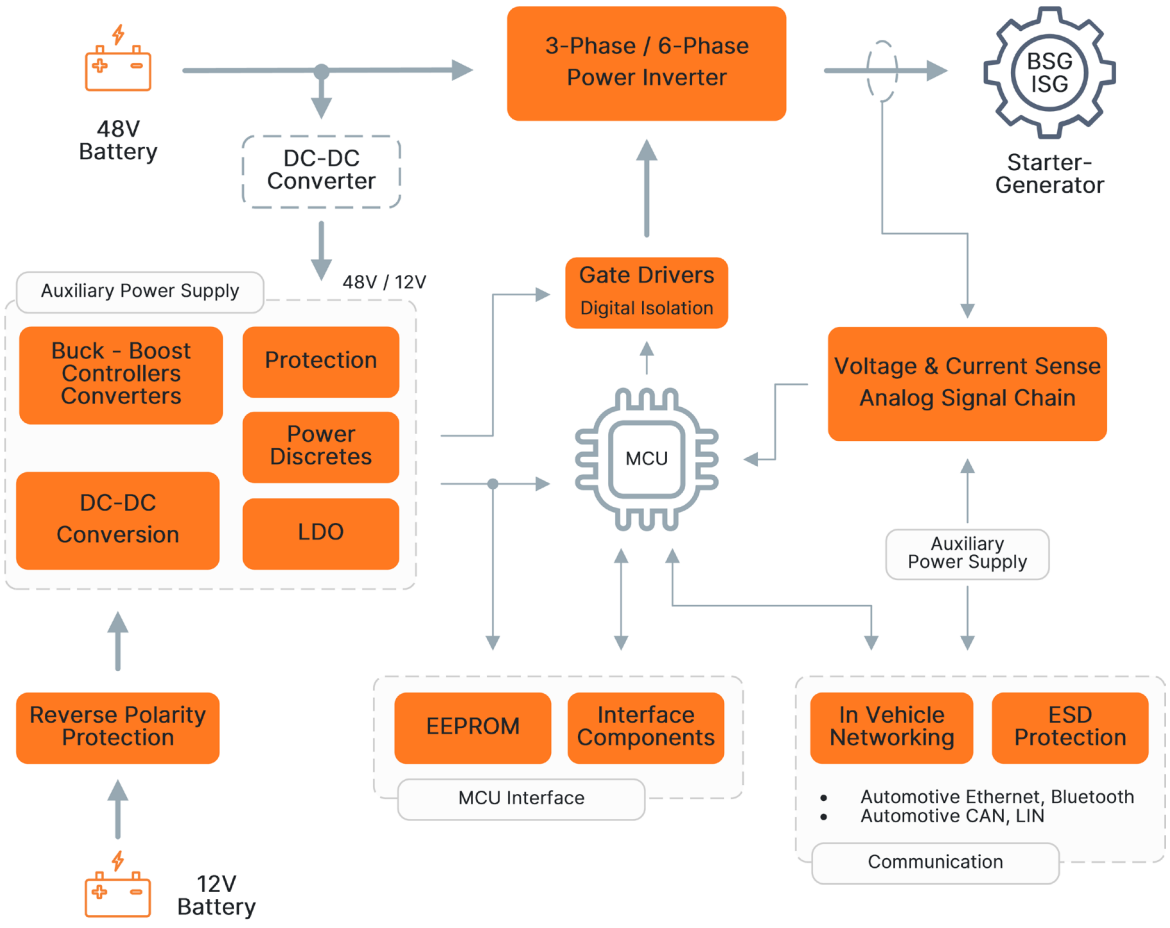
Compliance with ISO 26262, an international functional safety standard, is essential for the development of electrical and electronic systems in road vehicles. Its primary goal is to minimize the risk of hazards caused by system failures in vehicles, addressing potential dangers such as software glitches, sensor errors, and hardware malfunctions.

Specific standards for 48V systems in EVs, components and their testing have emerged with the first LV148 which was later superseded by German **VDA320**. Current standard is **ISO 21780:2020** that supersedes VDA320. Additional standards for safety and testing of electrical vehicles are **ISO 6469**, **ISO 21498.**

- **Component redundancy on 48V power net is crucial** for ensuring the reliability and resilience of the electrical system. This will be one of the driving factors in the development and wider adoption of 48V Systems. In the event of a single component failure, redundant elements serve as backup, preventing system-wide disruptions. This is particularly significant in safety-critical systems such as those controlling braking, steering, and airbags.
- **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. onsemi's expertise and implementation of ISO26262 are the key to providing customers cost effective solutions, without compromising safety.

Solution Overview

Block Diagram of Starter Generator traction drive, power and interface components



Starter Generator (BSG, ISG) traction drive is very similar to the inverter construction of other EVs (BEV, PHEV), but it operates on 48V voltage level. **80V and 100V MOSFETs** are used to source the current from 48V battery to apply AC current to motor windings. Gate Drivers create PWM signals to switch MOSFETs at required frequency. **Half-bridge APMs** configured to drive 3-Phase and 6-Phase motors provide alternative to power discretes.

Current Sense Amplifiers (CSA) are available to monitor current applied to phase windings of the motors with broad portfolio of components for signal processing and conditioning of sensor data. **EEPROM** serves for parameter storage. **CAN and LIN transceivers** ensure fast and reliable communication within the automotive network. To support MCU operation, **ESD protection devices** with fast transient clamping capability and low capacitances protect integrity of critical signals.

Find Interactive Block Diagram on the Web

Solution Overview

Power Inverter – 3 Phase or 6 Phase Motor Design

The BSG/ISG unit is a permanent magnet or inductive motor capable of accepting 48V. Traditionally, driving the phase windings is a dedicated 3-Phase inverter network, 6 power switches arranged as 3 half-bridges, with 80V or 100V Power Trench MOSFETs.

6-Phase Inverter is more advanced approach which results in better performance including **higher efficiency, wider range torque, better starting torque, minimal torque ripple and softer acoustic noise**. It doubles the number of power switches. The 6-Phase approach also allows for continued functionality should one of the motor phases experience a fault and dis-engage from the system.

Pulse width modulation (PWM) techniques and advanced motor control switching patterns apply the voltage across the three windings of the induction motor, generating AC current through the motor's phases, producing the torque required to propel the vehicle. This AC current can be adjusted for both amplitude and frequency by changing the PWM commutation patterns controlling both motor speed and torque.

onsemi offers advanced semiconductor technologies suitable for BSG/ISG designs. High power discrete MOSFETs and integrated power module solutions are optimized for motor control and other 48V applications.

- T10 discrete MOSFETs with shielded gate trench technology provide ultra low $R_{DS(ON)}$, low noise, EMI, minimized overshoots and industry leading body diode (low Q_{rr}, T_{rr}). T10 aims to enhance performance, improve efficiency, reduce ringing, minimize overshoots and noise.
- The APM17 family (APM = Automotive Power Module) is a series of integrated dual half bridge (2-phase) modules, which are easily connected externally to form a single half bridge suitable for twice the phase current. **Three modules may be configured as the power inverter that can drive a 3−Phase motor or 6−Phase motor**. Figure 2 shows the 3−Phase and 6−Phase configurations with the APM17 module.

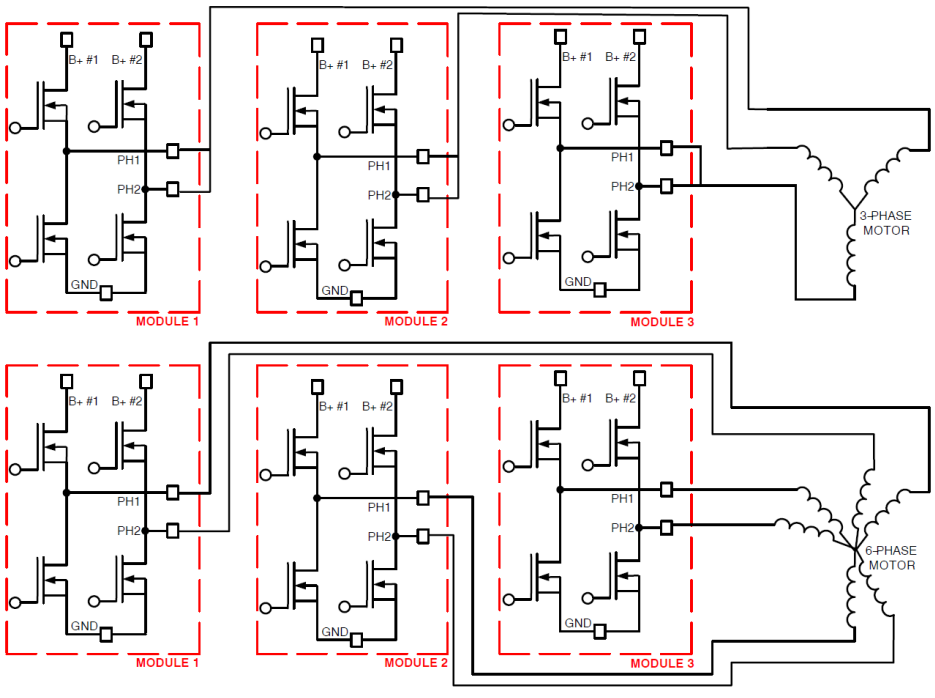


Figure 2: Combining 3 APM17 modules in 3-Phase or 6-Phase Motor Drive Arrangements

Solution Overview

T10 MOSFET Technology: 40V-80V Low & Medium Voltage MOSFETs

T10 is **onsemi's** latest technology node after the successful T6/T8 generations. **The new shielded gate trench technology improves efficiency, low output capacitance and figures of merit with lower $R_{DS(ON)}$ and gate charge Q_G.** T10-M features an application-specific architecture with the lowest $R_{DS(ON)}$ and a soft body diode, specifically optimized for motor control and load switch. On the other hand, T10-S is designed for switching applications, prioritizing lower output capacitance. While this does mean it sacrifices a small amount of $R_{DS(ON)}$, the overall efficiency is better, particularly at higher frequencies.

- Overall reduction in $R_{DS(ON)}$ and gate charge Q_G, lower Rsp ($R_{DS(ON)}$ vs Area)
- Improved FOM (Rds x Qoss/Q_G/Qgd) enhances performance and overall efficiency.
- Industry leading soft recovery body diode (Qrr, Trr) reduces ringing, overshoots and noise.

With the T10, a power inverter can be designed as a highly effective discrete solution, allowing gate drivers to be placed near MOSFETs and making the current path shorter. Besides the inverter, T10 can serve various novel 48V and legacy 12V applications, where 40V and 80V MOSFETs are required. Furthermore, T10 100V MOSFETs are currently in development.

Table 2 examines two **80V T8/T10 MOSFET** generation examples. The first compares MOSFETs of the same die size. T10 manages to decrease $R_{DS(ON)}$ from 1.7 mΩ to 1.24 mΩ, while keeping a constant gate charge. The second comparison involves the same max $R_{DS(ON)}$, but with a smaller die size in the case of T10. On the other hand, this achieves a significant reduction in the total gate charge.

Wafer Thinning

For low voltage FETs, the substrate resistance can be a significant percentage of the $R_{DS(ON)}$. Hence, using lower resistivity substrates, and thinning the wafers becomes critical as technology advances. In the T10 technology, onsemi managed to reduce wafer thickness which cuts down the substrate contribution to $R_{DS(ON)}$ from approximately 50% to 22% in the case of 40V MOSFET. The thinner substrate also improves the thermal performance of the device.

Table 2 : Comparison of onsemi T8 and T10 80V MOSFET technologies and main device parameters

		Largest Die size on SO-8FL		Same max $R_{DS(ON)}$, smaller die on T10	
Parameter	Unit	T8	T10	T8	T10
		NVMFS6H800N	NVMFS1D5N08X	NVMFS6H824N	NVMFWS4D5N08X
$V_{GS(TH)}$	V	2.4	2.4 – 3.6	2.4	2.4 – 3.6
Typ $R_{DS(ON)}$	mΩ	1.7	1.24	3.7	4.0
Max $R_{DS(ON)}$	mΩ	2.1	1.43	4.5	4.5
C_{ISS}	pF	5530	5888	2470	1700
C_{OSS}	pF	760	1690	342	490
C_{RSS}	pF	27	25	11	7
$Q_{G(TOT)}$	nC	85	83	38	24

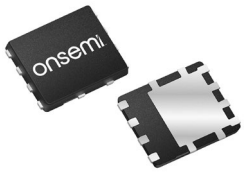
Solution Overview

T10 MOSFET Technology: Competitive Position

The following tables show the position of onsemi 40V T10 MOSFETs in comparison with competitor devices having similar parameters.

Table 3 : onsemi T10 40V best performers

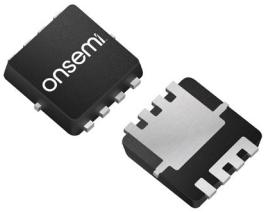
	$R_{DS(ON)}$ max at 10V (mΩ)	Qg(tot) at 10V (nC)	Ciss (pF)	Coss (pF)	Crss (pF)
NVMFWS0D4N04XM (SO-8FL)	0.42	132	8550	5613	203
NVTFWS1D3N04XM (µ8FL)	1.43	36	2291	1686	80
NVMFWS2D9N04XM (SO-8FL)	3.1	15.7	1000	645	12.3



SO – 8FL (DFNW5)
NVMFWS0D4N04XM

Table 4 : onsemi and competition comparison : ≈1 mΩ $R_{DS(ON)}$ 40V device specs

	$R_{DS(ON)}$ max at 10V (mΩ)	Qg(tot) at 10V (nC)	Ciss (pF)	Coss (pF)	Crss (pF)
onsemi (T10M 40V)	1.01	54	3570	1930	29
Competitor A	1.03	81	5291	1602	65
Competitor B	1	91	6666	1644	309
Competitor C	1.24	86	5309	1521	138
Competitor D	1.14	55	4560	2940	320



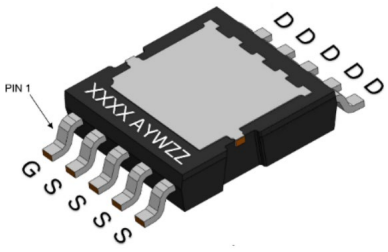
µ8FL (WDFNW8)
NVTFWS1D3N04XM

Top Side Cooling Packages (TCPAK57)

MOSFETs are often chosen for their power capabilities and compact size. However, the heat dissipation with traditional SMDs is not ideal, with heat being dissipated primarily through the PCB.

To adress this issue and further improve application size, a new Top Cool MOSFET package has been developed that exposes the lead frame (drain) of the MOSFET on the top side of the package. This method avoids cooling through the PCB. The TCPAK57 is compact 5.1 x 7.5 mm package. Read more in Top Cool Package for Power Discrete MOSFETs Application Note.

- NVMJST0D9N04C 40V version has the lowest $R_{DS(ON)}$ 1.07 mΩ .
- NVMJST2D6N08H 80V version has the lowest $R_{DS(ON)}$ 2.8 mΩ .



TCPAK57 with exposed drain on top of the MOSFET package.

Solution Overview

Automotive Power Modules APM17 for 48V Power Inverter

APM17 is a series of integrated 80V MOSFET modules in a variety of packages that have been designed specifically for high current, high power density designs of 48V MHEV and low voltage traction applications. **Three modules may be configured to drive a 3−Phase or 6−Phase motor**. Each APM17 module consists of 2 High-Side and 2 Low-Side 80V MOSFETs that can be connected as double or single half-bridge by combining 2 phase-out power terminals.

APMs elevate highly integrated and compact design with low stray inductance & better electromagnetic interference (EMI). Having the power MOSFET dies close to each other contained in one package reduces the package parasitics, provides more headroom for maximum V_{DS} voltage and reduces the switching losses. Efficient current handling removes necessity for high current path in PCB.

The series offers options for the insulating ceramic DBC substrate to provide standard and premium thermal performance. Various **$R_{DS(ON)}$** ratings (**0.58 mΩ - 0.76 mΩ per MOSFET**) can match the end user's current requirements, and a variety of pin−out options can enable different system designs.

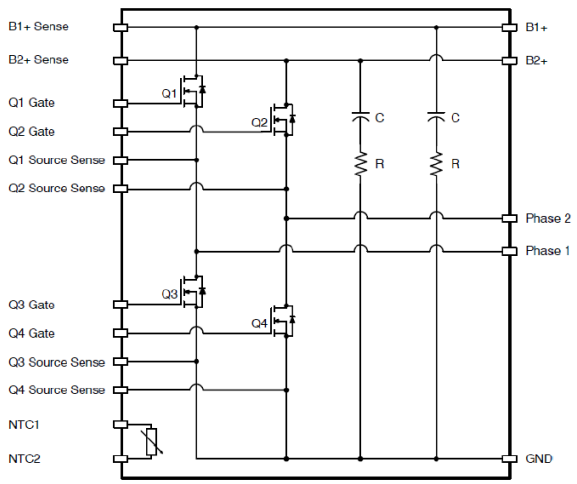
Introduction to onsemi High Current Dual Half Bridge Modules for Automotive MHEV applications Application Note.

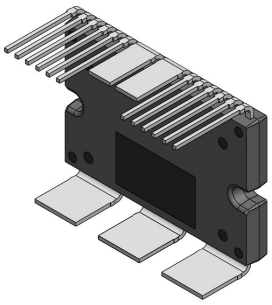
AMP17 series examples: NXV08H250DT1, NXV08H400XT1

APM17 series Features & Parameters:

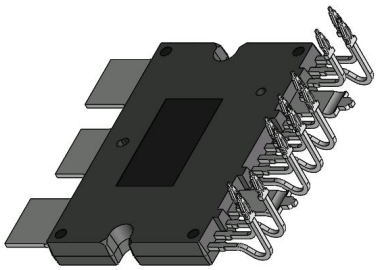
- **Low stray inductance**: APM17 can enable total less than 15nH for 25kW 48V Inverter System.
- **Low junction-case thermal resistance** R_{THJC} between 0.19 °C/W and 0.54 °C/W.
- **Compact design for low total module resistance.**
- Better EMI with dual R&C snubber (1Ω, 15nF).
- Each module is fitted with a temperature−sensing NTC with 25 °C value of 10 kΩ.
- High voltage isolation is tested to 3 kVAC for 1 second.
- Package varieties: Standard, Pressfit, Side PCB-mount pins.
- Package size: 45 x 30 x 5 mm

APM17 Dual Half Bridge Module

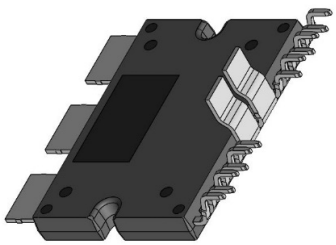




Standard Pins



Pressfit Pins



Side PCB-mount Pins

Solution Overview

Automotive Power Modules (APM) for MHEV and 48V Applications

onsemi offers more APM series in a variety of packages that are designed for 48V auxiliaries, 48V battery switch and DC-DC Converter. APM12, APM19 and APM21 come with different configurations and features integrated into a single module. APM12, APM19, APM21 series recommended products.

Several power switches integrated into a single module enable higher power density, making the systems thermally and electrically more efficient as well as lighter and smaller. APMs provide added value when the full application is integrated. There are significant savings at system level: The mechanical design and assembly techniques are key factor to achieving these savings.

Table 5: APM applications in MHEV 48V architecture

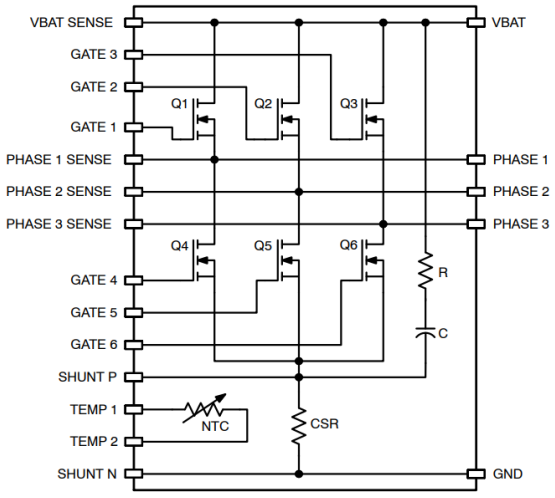
APM12 , APM17	APM17	APM19, APM21	APM19
3x APM17 for 6 phase Inverter solution (15- 25kW)	2-Channel back-to-back MOSFET (Disconnect switch)	48V Power Auxiliaries (E-Compressor, E-Turbo and more)	2x APM19 for 6-phase 3kW interleaved DC-DC converter

APM12 is a proven, reliable and smaller 80V single phase inverter module, NXV08A170DB2, with current sensing, temp sensing and snubber circuit. It can be stacked and turned into n-Phase Motor Inverter by using times n-APM12 modules.

The NXV10V160ST1 **APM21** integrates six **100V MOSFETs** (3x Half-Bridge) with $R_{DS(ON)}$ 1.8 mΩ and R_{THJC} 0.36 °C/W. Integrating also R & C snubber and NTC for temperature sensing. It can handle typical 48V 3-phase high-power auxiliary applications like E-Turbo, HVAC E-Compressor, various pumps and fans.

APM19 modules: integrate a 3−phase MOSFET bridge (six 80V MOSFETs) and precision shunt resistor for current sensing, NTC for temperature sensing, and R & C snubber circuit.

- FTC03V85A1 is optimized for building a 1.5kW 48V−12V interleaved DC−DC converter topology. Two modules can create a 6-phase 3kW Converter. With max $R_{DS(ON)}$ 2.6 - 3.5 mΩ, R_{THJC} 1.0 °C/W.
- NXV08V110DB1 is optimized as 3−phase inverter bridge for variable speed motor drive that can be used in 48V auxiliaries and electrical power steering.



APM19 3-Phase MOSFET bridge

Solution Overview

Gate Drivers for 80V and 100V MOSFETs : Starter Generator application

The FAD3151MXA and FAD3171MXA are versatile **single channel floating automotive gate drivers 110V, 2.5A**, suitable for driving high−speed power MOSFETs up to 110 V. The drivers are designed for 48V BSG/ISG and other 48V applications, with features like desaturation protection, soft shutdown, fault reporting capability, UVLO protection. Integrated Charge Pump to support 100% Duty Cycle Operation (FAD3171MXA only). Immunity against severe **negative transients and ground offset up to −80 V**.

Active System-Fault Protection

By controlling the gate driver fault FLT pins on high side or low side, an active system short−circuit protection can be achieved. This allows a short reaction time to turn off the affected channels upon a fault detection. Active system fault protection can prevent overvoltage conditions and disturbances in the 48 V supply network and at the same time bring the motor to safe state, improving safety in motor control application such as a 48V BSG/ISG.

To allow current generated by the motor to discharge in the motor winding, the active turn on of the opposite channels can be programmed within the microcontroller (FLT-High, FLT-Low on Figure 3). How to program the microcontroller fault-control logic on both High-Side and Low-Side MOSFETs is described in Application note AND90251/D .

Figure 3 shows an example of motor control application with active system protection and highlighted current flow.

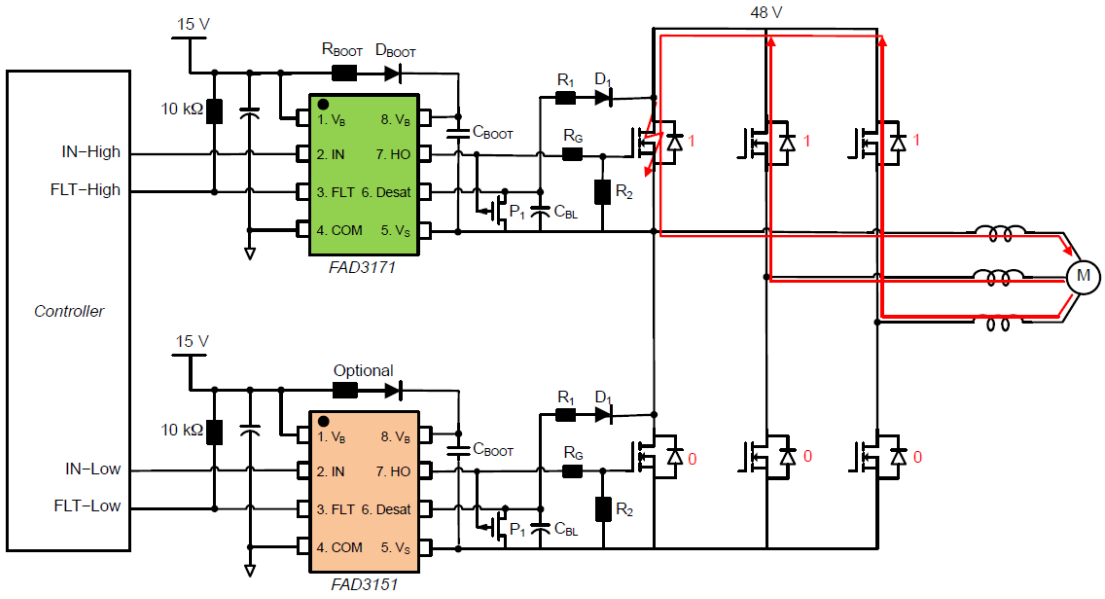


Figure 3: Gate Driver in a 3−phase Motor Control Application, Operating in Active System Protection

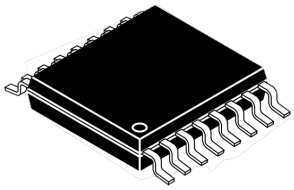
Solution Overview

NCV77320 Inductive Position Sensor Interface

The NCV77320 is an inductive position sensor interface that, in combination with a PCB, forms a **system to measure angular or linear positions accurately**. The sensor is ready to serve customers with safety critical applications in both EVs and ICE vehicles. It can meet up to **ASIL D safety in redundancy applications**. The NCV77320 is primarily designed to address accelerator pedal applications but can be used in any rotary & linear application that requires an accurate position sensing if there is a match in speed (max 10 800 RPM) and output protocol.

Choosing **onsemi** state of the art inductive technology improves the EMC robustness, particularly in the DC domain. Unlike a magnet based solution, inductive technology is immune to stray magnetic fields by its construction. This is an important advantage versus solutions using a magnet, as strong DC currents become more and more present with the vehicle electrification.

- NCV77320 system is insensitive to temperature variations.
- Easy to implement redundancy: Two sensors can be stacked with perfect alignment.
- 3 available output communication interfaces: Analog Output, SENT interface (fast and slow channel), SPI channel.
- Calibration procedure of the NCV77320 is making use of the Evaluation Kit hardware and GUI software. The **sensor calibration** is explained in AND90226/D application note (required webpage login & approval).



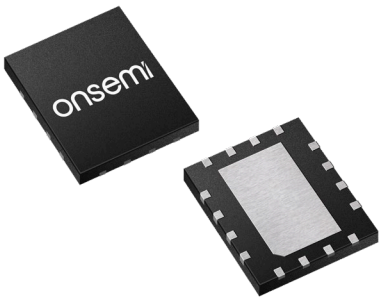
TSSOP-16
5.1 x 6.4 mm

Typical NCV77320 End-Product Applications	
• Accelerator Pedal Sensor	• Throttle Body Sensor
• Steer by wire sensor	• Transmission Range Sensor in Gear Box
	• Exhaust Gas Recirculation Sensor

Electronic Fuse (eFuse) NIV3071

NIV3071 eFuse can protect up to 4 independent 48V or 12V downstream loads from output shorts, overloads and overcurrent events. A power source can safely drive 4 protected independent loads at 2.5A continuous current each. eFuse can be configured into a single channel protection to drive a single continuous load current of up to 10A.

- The eFuse can improve robustness and reliability of the 48V electrical architecture by building redundant networks. Small 5x6mm package.
- Great for implementing **automotive zonal control units** (zonal architecture), guarantee protection and robustness of the localized ECUs throughout the vehicle.
- To learn more about the NIV3071 eFuse and its role in system redundancy, refer to:
  - 48V-12V DC-DC Converter System Solution Guide
  - The NIV3071 eFuse Advantages in Automotive Applications (Application Note)



WQFN16 , 5x6 mm, CASE 510CM

Solution Overview

NCV2023x Family of low power Operational Amplifiers

NCV2023x is a **low power OpAmp family** with a wide **supply range of 2.7 V to 36V**, **0.595 mA supply current** and input offset voltage as low as ±0.95 mV max at 25°C. It provides low offset voltage, without sacrificing the performance or paying the premium of the precision OpAmps. Rail to rail output allows wider dynamic range of operation. Output voltage swings closer to the supply rails, without any degradation in the output.

Availability in single - NCV20231, dual - NCV20232, quad - NCV20234 channel configurations.

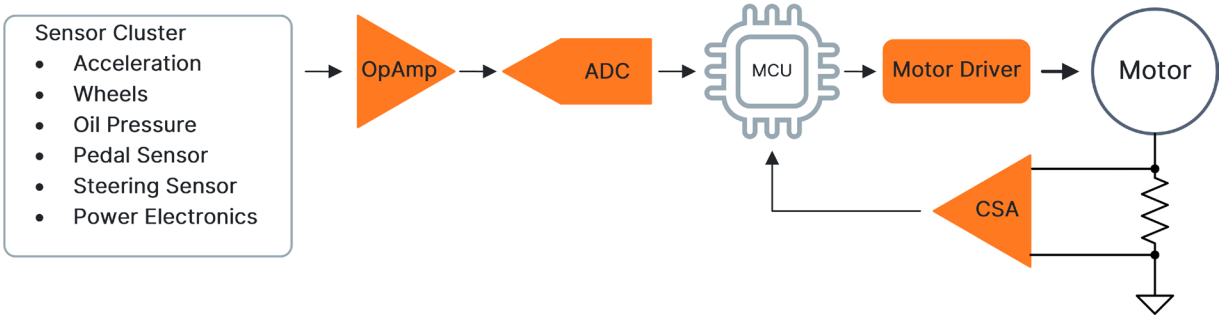
- Offset Voltage: ±0.95 mV max (25°C)
- Offset Drift: ±2 µV/°C max
- Unity Gain Bandwidth: 3 MHz
- CMRR: VSS to (VDD–1.35)V

The NCV2023x OpAmps family are excellent choice for sensor signal conditioning in various blocks and inside electronic control units. Ability in current sensing: High Side Current Sense up to 36V Common Mode. Low Side Current Sense Common Mode to Ground.

NCV7041 Current Sense Amplifier

The NCV7041 is a high voltage, high resolution, current sense amplifier. It features gain options of 14, 20, 50, and 100 V/V, with a **maximum ±0.3% gain error** over the entire temperature range. It has a **wide common-mode input voltage range from –6 V to 80 V**. The NCV7041 can perform unidirectional or bidirectional current measurements across a sense resistor in a variety of automotive applications.

- Gain Bandwidth: 100kHz
- Input Offset Drift: ±3 µV/°C max
- Input Offset Voltage: ±300 µV max
- CMRR: 85dB min



NCV8730 Wide Input Voltage Range LDO

The NCV8730 is a next generation CMOS LDO regulator designed for up to 38V input voltage and 150mA output current. It provides ultra–low quiescent current of only 1µA, which makes this device ideal solution for applications that are always on. Additionally offering excellent load/line transient regulation and output Power-Good function to reset MCU. Available packages : TSOP-5 and WDFN-6.

- Support Automotive transients
- Can suppress inrush current to protect IC
- Fixed & Adjustable Voltage Options Available: 1.2V to 24V
- Ideal for always-on applications
- Can reset MCU to avoid malfunction
- 290mV typical dropout at 150mA of output current, 3.3Vout

Recommended Products

Suggested Block	Part Number (PN)	PN Description, Comments
Automotive Power Module (APM) Solutions for 48V Systems		
APM17M Dual Half Bridge Module	NXV08H350XT1	APM 80V , $R_{DS(ON)}$ 0.76 mΩ , R_{THJC} 0.21 °C/W (per FET) Standard Pins
	NXV08H300DT1	APM 80V , $R_{DS(ON)}$ 0.58 mΩ , R_{THJC} 0.49 °C/W (per FET) Standard Pins
	NXV08H400XT1	APM 80V , $R_{DS(ON)}$ 0.58 mΩ , R_{THJC} 0.19 °C/W (per FET) Standard Pins
	NXV08H400XT2	APM 80V , $R_{DS(ON)}$ 0.58 mΩ , R_{THJC} 0.19 °C/W (per FET) Side PCB-Pins
	NXV08H250DPT2	APM 80V , $R_{DS(ON)}$ 0.71 mΩ , R_{THJC} 0.53 °C/W (per FET) Pressfit Pins
	All modules are optimized for 48V main inverter to drive 3-Phase or 6-Phase motor. Integrated NTC temp. sensing, double snubber R & C (1Ω, 15nF).	
APM17	NXV08B800DT1	2-Channel back-to-back MOSFET Module, 80V, $R_{DS(ON)}$ 0.59 mΩ. Optimized for battery or load switch, replacing mechanical Relay.
APM19 3 Phase MOSFET bridge	FTC03V85A1 NXV08V080DB1 NXV08V110DB1	Integrated 3-phase MOSFET bridge, 80V, $R_{DS(ON)}$ 1.7 - 3.5 mΩ (Max per FET) Optimized for 1.5-3kW 48V-12V DC-DC Converter (interleaved topology) or 48V Auxiliaries.
	Integrated Shunt resistor for current sensing, NTC temp. sensing, snubber R & C.	
APM21 3 Phase MOSFET bridge	NXV10V160ST1	Integrated 3-phase MOSFET bridge, 100V, $R_{DS(ON)}$ 1.8 mΩ (Max per FET) Optimized for 48V E–Compressor and other 48V high-power Auxiliaries.
AMP12 Half Bridge	NXV08A170DB2	Half Bridge module (Single Phase), 80V, $R_{DS(ON)}$ 0.99 mΩ (Max per FET) Integrated Shunt resistor, NTC, Snubber C.
40V – 100V APMs	APM12, APM19, APM21 available power modules.	
	APM17 80V available power modules.	
Medium Voltage MOSFETs 100V, 80V		
Si MOSFETs 100 V rated	FDBL86062_F085	N-Power MOSFET 100V, 300A, 2.0 mΩ , TOLL
	NVMTS1D6N10MC	N-Power MOSFET 100V, 273A, 1.7 mΩ , PWR88
	NVMFS3D6N10MCL	N-Power MOSFET 100V, 132A, 3.6 mΩ , SO-8FL pack.
	Application recommended 100V-120V N-MOSFETs (single & dual configuration)	
Si MOSFETs 80 V rated	NVBLS0D8N08X	N-Power MOSFET 80V, 457 A, 0.8 mΩ, T10 Technology, TOLL pack.
	NVMFS1D5N08X	N-Power MOSFET 80V, 253 A, 1.43 mΩ, T10 Technology, SO-8FL pack.
	NVMFS1D9N08X	N-Power MOSFET 80V, 201 A, 1.9 mΩ, T10 Technology, SO-8FL pack.
	NVMFWS6D2N08X	N-Power MOSFET 80V, 71 A, 6.2 mΩ, T10 Technology, SO-8FL pack.
	NVMFS3D5N08XT1G	N-Power MOSFET 80V, 119 A, 3.5 mΩ, T10 Technology, SO-8FL pack.
	NVMJST2D6N08H	N-Power MOSFET 80V, 131A, 2.8 mΩ , Top Cool Package (TCPAK57)
	T10 Shielded Gate Technology features significantly lower $R_{DS(ON)}$ in smaller packages, further improved soft reverse recovery diode. Increased power capability and figure of merit ($Q_G/R_{DS(ON)}$).	
	Application recommended 80V N-MOSFETs (single & dual configuration)	

Recommended Products

Suggested Block	Part Number (PN)	PN Description, Comments
Medium Voltage MOSFETs 60, 40V		
Si MOSFETs 60V rated	NVMTS0D7N06C	N-Power MOSFET 60V, 464A, 0.72 mΩ , TDFNW8 pack.
	NVMJS1D4N06CL	N-Power MOSFET 60V, 262A, 1.3 mΩ, LFPAK56 pack.
	NVMYS2D2N06CL	N-Power MOSFET 60V, 185A, 2.0 mΩ, LFPAK56 pack.
Si MOSFETs 40 V rated	NVMFWS0D4N04XM	N-Power MOSFET 40V, 509A, 0.42 mΩ , T10 Tech., SO-8FL pack.
	NVMFWS0D5N04XM	N-Power MOSFET 40V, 414A, 0.52 mΩ , T10 Tech., SO-8FL pack.
	NVMFWS1D1N04XM	N-Power MOSFET 40V, 233A, 1.05 mΩ , T10 Tech., SO-8FL pack.
	NVMFWS004N04XM	N-Power MOSFET 40V, 66A, 4.7 mΩ, T10 Tech., SO-8FL pack.
	NVMJST1D2N04C	N-Power MOSFET 40V, 451A, 1.25 mΩ , T6 Tech., Top Cool (TCPAK57)
	NVMJST3D3N04C	N-Power MOSFET 40V, 157A, 3.3 mΩ , T6 Tech., Top Cool (TCPAK57)
	NVMJST1D6N04C	N-Power MOSFET 40V, 314A, 1.65 mΩ , T6 Tech., Top Cool (TCPAK57)
	T10M is best-in-class 40V Trench Technology with lowest Rdson in 5x6 package (Down to 0.42mΩ)	
	EV Applications capable 40V N-MOSFETs (Id > 50A)	
Gate Drivers & Isolation		
Gate Drivers Junction Isolated (100V -130V)	FAD3151MXA FAD3171MXA	110V, 2.5A, Single Channel Floating Gate Driver, Negative Transient −80 V, Desaturation & UVLO protection , (Charge Pump 3171 only)
	NCV51513	130 V, 2.0/3.0 A Half-Bridge Driver , EN & Interlock, Rise/Fall times 9ns/7ns
	NCV51511	100 V, 3.0/6.0 A High & Low side Driver, Integrated Bootstrap, Ideal for Half bridge or Synchronous Buck Configuration.
	NCV51313	130 V, 2.0/3.0 A High side Driver, 20ns Fast Propagation Delay, High dv/dt immunity up to 50 V/ns and negative transient immunity
	Application Recommended Junction Isolated Gate Drivers (Medium Voltage)	
Gate Drivers 600V Junction Isolated	FAN7171	600V, 4A, SOIC-8, High-Side (Low-Side) Gate Drive
	FAD7191	600V, 4.5A, SOIC-8, High & Low-Side Gate Drive
	NCV5183	600V, 4.3A, SOIC-8, High & Low-Side Gate Drive
	Application Recommended Junction Isolated Gate Drivers (600V target Voltage)	
Digital Isolation	NCIV9210 NCIV9211 NCIV9311 NCIV9401 NCIV9411	Galvanically isolated 2kV, high speed, bidirectional 2/3/4 Channels Digital Isolators. Allows Isolated PWM control, Communication / Diagnostics. Utilizing onsemi patented galvanic off−chip capacitor isolation technology and optimized IC design for high insulation and noise immunity.
	Application Recommended Digital Isolators	
BJT	NSS1C301CT	100 V, 3.0 A Low VCE(sat) NPN BJT, control units and general purpose.
	BC846BPDW1	65V, 0.1 A Dual NPN/PNP Complementary BJT, general purpose amplifiers.
	Available Automotive BJTs (<100V)	

Recommended Products

Suggested Block	Part Number (PN)	PN Description, Comments
Auxiliary Power		
Buck Converter and Controller	NCV1034	Synchronous PWM Buck Controller. Vin up to 100V. 25kHz - 500kHz programable switching frequency. Drives 2 external N-MOSFETs, 2A Driver.
	NCV6324	Synchronous Buck Converter, 3 MHz, 2.0 A
	NCV890104	Buck Switching Regulator, 1.2 A, 2 MHz, Programmable Spread Spectrum, Adjustable RSTB
	NCV6323F	Buck converter, Synchronous, PWM. Up to 1.6 A DC. Various Fixed Output Voltages. Optimized to supply sub-systems.
	NCV81277A	Multiple Phase Buck Controller with PWM_VID and i2c interface. Supports up to 4 Phases. Vin up to 20V. UVP, OVP, OCP protection.
	Application recommended components for Step-Down DC-DC conversion.	
Buck / Boost / Inverting Converter	NCV33163	Buck / Boost / Inverting Converter - Switching Regulator, 2.5 A, Vin up to 60V. Requires minimum number of external components
	NCV3064	Buck / Boost / Inverting Converter - Switching Regulator, 1.5 A, Vin up to 40V. Optimized for high-frequency operation
	Automotive DC-DC Converters, Step-Up and Step-Down.	
Controllers for DC-DC Power Conversion	NCV1362	Primary side Flyback Controller. Integrated features for easy control of Low Power automotive auxiliary power supplies.
	NCV8871	Non-Synchronous Boost Controller. Can be used in Flyback configuration.
	NCV898031	Non-Synchronous SEPIC / Boost Controller, 2MHz. Peak Current Mode Control, UVLO, Internal Soft-Start.
	NCV12711	Peak current-mode PWM controller: 4-45 Vin DC. Rich features. Suitable for 12 V & 24 V Auxiliary Power and Flyback topology.
	Automotive DC-DC Controllers, Step-Up and Step-Down.	
LDO Regulator	NCV8163	250mA, High PSRR, Very Low Noise, 1uF COUT, TSOP-5 & XDFN4
	NCV8164 NCV8189 NCV59801	300mA, 500mA, 1A Version, High PSRR, Very Low Noise, Power Good, Fixed & Adjustable output options, WDFNW6 & DFNW8 packages
	NCV8718	300mA, 24 Vin max, 4uA Iq, Fixed & Adjustable Vout options WDFN6 package
	NCV1117	1A, High PSRR, (up to 20 Vin), Adjustable and fixed output options.
	NCV8730	150mA, Low Iq 1uA (2.7-38 Vin range) Adjustable and fixed output options, PG ideal for power sequencing.
	Application recommended automotive LDOs.	

Recommended Products

Suggested Block	Part Number (PN)	PN Description, Comments
Protection Devices , Diodes		
eFuse	NIV6150 NIV6350	Resettable fuse 200 mΩ (85 mΩ) $R_{DS(ON)}$ Reverse current protection. Vin 10V, Overvoltage clamp and Undervoltage lockout.
	NIV3071	eFuse 4 channels. Vin 8V - 60V, Ideal for 48V applications, 10A when channels are parallel (2.5A continuous current per channel)
Protected power switches	FPF2895V	28 V, 5 A Power switch, Features OCP, OVP, Reverse current protection
	NCV47722 NCV47822	40V, 350mA, High Side Switch : Single / Dual version, Adjustable Limit
	Application recommended Protected Power Switches	
Diodes	NRVB1240MFS	40 V, 12A $I_{F(AV),}$ 150A $I_{FSM(max)}$ Schottky Power Rectifier, SO-8FL
	NRTS15100PFS	100V, 15A $I_{F(AV)}$, 200A $I_{FSM(max)}$ Trench Schottky Rectifier , TO-277
	NSVBASH16MX2WT NSVBAV99W	100V Small Signal switching diode, Single (Dual), General automotive applications (Steering, Protection, Control units)
	Application recommended discrete power diodes	
	Automotive recommended small signal diodes	
Zener Diodes	1SMB59 1SMA59	3 W (1.5W) Zener Diode, Zener Voltage Range up to 200V (68V)
	Automotive recommended zener diodes (Vz > 15V)	
Analog Signal Chain		
Inductive Position Sensor	NCV77320	Highly accurate inductive measurement of angular and linear positions. Max speed 10 800 RPM, ASIL B (D) safety, improved EMC.
Low Power & Precision **Operational Amplifier**	NCV21874	Zero-Drift OpAmp, 45 µV Offset, 0.4 µV/°C
	NCV21911xx	Precision OpAmp 36V, 2 MHz GBW, Low Noise, Zero-Drift, 25 µV Offset
	NCV2007x	OpAmp 36V, 480uA supply, 3MHz, 4mV offset, Rail-to-rail output
	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, NCV2252	High Speed, 50 ns propagation delay, Push-Pull or Open Drain variant.
	NCV2901, NCV2903	36V, Low Offset Current +/- 5.0 nA, Single or Split Supply,
Current Sense Amplifier (CSA)	NCV7041 NCV7030	CSA, V_{CM} 80V, Bi- or Uni-directional. BW 100kHz, Gains : 14, 20, 50, 100 V/V
	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
	Application recommended automotive CSA	
Temperature Sensing	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
In Vehicle Networking (Automotive Ethernet & Bluetooth)		
Automotive Ethernet	SZESD9901MX2 SZESD9902M	ESD Protection TVS Diode: Single (Double). Compliance with 100/1000 BASE−T1 Ethernet, and other high speed data networks.
Automotive Bluetooth	NCV-RSL15	Bluetooth 5.2 Wireless MCU based on ARM Cortex-M33.
	onsemi supports its Bluetooth ICs with a comprehensive yet easy−to−use Software Development Kit (SDK) that provides sample code and applications, tools, IDE.	
In Vehicle Networking (CAN, LIN) , System Basis Chip (SBC)		
CAN (CAN-FD) Transceivers	NCV7343	Low Power & High-Speed, INH, Wake-up, Error Detection.
	NCV7342 , NCV7344 NCV7349	Low Power & High-Speed Transceivers Various packages, features and pin functions.
	NCV7446	Dual Transceiver, Low Power & High Speed . Wake-up
	Application recommended CAN Transceivers for In Vehicle networking.	
LIN Transceivers	NCV7329 NCV7422	Single (Dual) LIN Transceiver, Transmission up to 20kbps. Integrated Slope Control. Undervoltage, Transient, Thermal protection. TxD Timeout
	Application recommended LIN Transceivers for In Vehicle networking.	
CAN, LIN Protection, ESD Protection	SZNUP3125 SZNUP2125	Protects CAN, LIN transceivers from ESD and other harmful surge events. Bidirectional protection for each data line.
	SZESD8704	Unidirectional High Speed Data Line Protection. (USB 3.1 , USB-PD)
	Recommended ESD and surge protection for CAN, LIN bus	
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)
MCU Interface and Miscellaneous Components		
Voltage Level Translator	MC14504B	Hex non-inverting level shifter, CMOS/TTL to CMOS. Shifting any supply between 5 and 15 V.
	NLVSX5004	Level Translator, 4-Bit, 100 Mbps
Automotive EEPROM	NV24C64xx	64-Kb I2C
	CAV25010	1-Kb SPI
	Automotive Recommended EEPROM	
Voltage Reference and Supervisors	SC432BVSNT1G NCV431	Programmable Voltage Reference, Temperature compensated Low Cathode Current, Shunt Regulator
	NCV308	Voltage Supervisor with programable delay and reset
	NCV33161	Universal automotive Voltage Monitor , up to 40V

Development Tools and Resources

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Technical Documents

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

Type	Description & Link
Reference Design (Evaluation Board)	LDO Regulator NCV59801 Demo Board
Reference Design (Evaluation Board)	NCV77320 Inductive Position Sensor chip
Reference Design (Evaluation Board)	NIV3071 eFuse Testing and Evaluation Board
Reference Design (Evaluation Board)	12V/1A Primary side regulation without AUX winding (12V Auxiliary power)
Reference Design (Evaluation Board)	CAN Driver Shield (NCV7342 Transciever) Evaluation Board
Webinar	48V Mild Hybrid Systems
Webinar	Automotive 48V Systems enabled by onsemi solutions
Blog	48-Volt Systems for MHEV and Beyond
Application Note	Introduction High Current Dual Half Bridge Modules for Automotive MHEV Applications [AND90235/D]
Application Note	The NIV3071 eFuse Advantages in Automotive Applications [AND90247/D]
Application Note	FAD3151MXA, FAD3171MXA Gate Driver Applications [AND90251/D]
Application Note (Web Login is Required)	Top Cool Package for Power Discrete MOSFETs [AND90190/D]
White Paper	Power Conversion in Mild Hybrid Electric Vehicles [TND6317/D]
White Paper (Web Login is Required)	Optimizing Power Efficiency and Performance for Hybrid and Electric Vehicles [TND6388/D]
White Paper (Web Login is Required)	Engineering Essentials: Choosing Between Digital Isolators or Optocouplers [TND6387/D]
Tutorial	Basics of In-Vehicle Networking (IVN) onsemi products [TND6015]

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