Application Note

Ground-Level Voltage Translation in Automotive Systems

Sakshi Markhedkar

ABSTRACT

Modern automotive systems increasingly rely on distributed electronics operating across multiple ground domain. Ground potential differences caused by high current loads, long cable runs, switching noise, or intentional ground offset scan disrupt low-voltage digital communication and compromise system reliability.

This application note introduces Texas Instruments Ground-Level Voltage Translation (TXG) family, and explains how the TXG family addresses static and dynamic ground offset issues enabling reliable communication across ground mismatches in automotive systems without requiring galvanic isolation.

Table of Contents

Trademarks

All trademarks are the property of their respective owners.

Copyright © 2026 Texas Instruments Incorporated

1 Introduction: The Automotive Ground Reality

In an preferred system, all ground references are equal. In real automotive designs, this assumption often breaks down due to shared common chassis ground, or operation across multiple ground domain in modern ECU designs resulting in DC ground shifts from stray parasitics and AC ground noise from mixed-signal circuitry. Common causes of ground mismatch include:

- High current loads causing DC ground shifts, particularly in traction inverters and electric power steering
- Long cable harnesses and remote modules
- High-frequency digital switching noise causing AC ground bounce
- Shared return paths between power and signal grounds
- Intentional ground offsets in redundant or zonal architectures
- Integration of diverse power domains such as 48V/24V/12V subsystems

Designers often attempt to manage ground mismatch using ground-plane partitioning, star grounding, discrete level-shifting circuits, or galvanic isolation. While effective in some cases, these approaches increase cost, PCB area, latency, and design complexity, especially when safety isolation is not required.

The Ground-Level Voltage Translation (TXG) family enables ground-level voltage translation by separating the two ground domains internally while preserving signal integrity. TXG devices provide a simple solution to tolerate both DC ground shifts and AC ground noise without breaking ground continuity or cost of isolation, while enabling rapid data processing for real-time communication and minimizing power draw to extend battery life.

Copyright © 2026 Texas Instruments Incorporated

2 Automotive Ground-Level Voltage Translation (TXG) Portfolio

The Automotive Ground-Level Voltage Translation (TXG) portfolio includes AEC-Q100 qualified, 1-bit, 2-bit, and 4-bit ground-level translators that can level shift both voltage and ground to enable communication across different power domains. These devices support ground-shift tolerance up to ±80V and AC noise rejection up to 130VPP (1MHz) while supporting common automotive signal interfaces. The TXG portfolio offers scalability with multiple channel count options and direction configurations in a compact form factor as shown in Table 2-1.

Key features include:

- Fixed-direction push-pull level shifting with separated GND: TXG80xx-Q1,TXG40xx-Q1,TXG10xx-Q1
- Auto bi-direction open-drain level shifting with separated GND: TXG8122-Q1
- Ultra-low delay to support fast communication (propagation delay < 8ns)
- Low channel-to-channel skew (< 2ns)
- Common-Mode Transient Immunity (CMTI) up to 1kV/us
- Schmitt trigger input to eliminate noisy signals
- Ioff supports partial-power-down mode operation
- Leaded and non-leaded package options

Table 2-1. Automotive Ground-Level Translators Product Portfolio

I/O Type	Number of Channels	Channel Direction	Interface	Ground DC Offset Voltage			Package Size		
				± 80V	± 40V	± 10V			
Push-Pull (1.71V-5.5V, 5mA drive, 250Mbps)	4 Ch	3 forward 1 reverse	SPI, PCM TDM/I^{2}S	TXG8041-Q1	TXG4041-Q1	TXG1041-Q1	RUC X2SON-14 4mm^2	DYY SOT-14 13.7mm^2	DBQ QSOP-16 29.4mm^2
		2 forward 2 reverse	UART	TXG8042-Q1	TXG4042-Q1	TXG1042-Q1			
	2 Ch	1 forward 1 reverse	UART	TXG8021-Q1	TXG4021-Q1	TXG1021-Q1	DSG WSON-8 4mm^2	DDF SOT-23-8 8.1mm^2	D SOIC-8 29.4mm^2
		2 forward 0 reverse	GPIO	TXG8020-Q1	TXG4020-Q1	TXG1020-Q1			
	1 Ch	1 forward	GPIO	TXG8010-Q1	TXG4010-Q1	TXG1010-Q1	DSE WSON-6 2.25mm^2		
Open-drain (Side 1: 3V-5.5V, 3.5mA sink, Side 2: 2.25V-5.5V, 50mA sink, 1MHz)	2 Ch	Auto Bi-directional	I^{2}C, SMBus	TXG8122-Q1	TXG4122-Q1	TXG1122-Q1	DSG WSON-8 4mm^2	DDF SOT-23-8 8.1mm^2	D SOIC-8 29.4mm^2

Copyright © 2026 Texas Instruments Incorporated

3 Automotive Application Examples using TXG Ground-Level Translators

3.1 Bridging Logic and Power Domains in 48V / 12V Automotive Systems

In modern 48V / 12V automotive systems in *Zone Control Module* and *12V/48V Power Distribution Box*, common application utilizes GaN based power stage designs, high power buck/boost, and half-bridges for zonal power architectures. In this architecture, the power stage and the gate driver often operate in a local reference domain that can move relative to the system/MCU ground. This creates a practical challenge as the control signals from system microcontroller (MCU) for the gate drivers (PWM/enable pins) are referenced to logic ground, but the GaN gate driver input pins (bootstrap/bias) can be referenced to a different *floating* ground. Further, the fast switching edges and high dV/dt at the half-bridge switch node can also inject ground noise.

As shown in Figure 3-1, the TXG8020-Q1 or TXG8010-Q1 helps to partition the *noisy power ground* at gate-driver domain from the *quiet logic ground* at MCU domain. The MCU drives digital I/O (PWM/EN) into TXG's A-side inputs, and the corresponding B-side outputs reproduce those signals referenced to the GaN driver domain with clean logic transitions. Key design notes:

- Domain definition matters: GNDA (quiet logic) and GNDB (driver local/switching) must be planned early so the PWM reference is correct where it terminates.
- Local decoupling on both rails: Decouple VCCA and VCCB close to the TXG device.
- Signal integrity: Keep PWM traces short, control return paths, and avoid routing B-side signals through noisy switch-node regions.
- Scalability: TXG offers 4-channel, 2-channel as well 1-channel options to level shift multiple related control signals (for example, PWM, enable, reset, interrupt) as well as popular digital interaces, reducing glue logic.

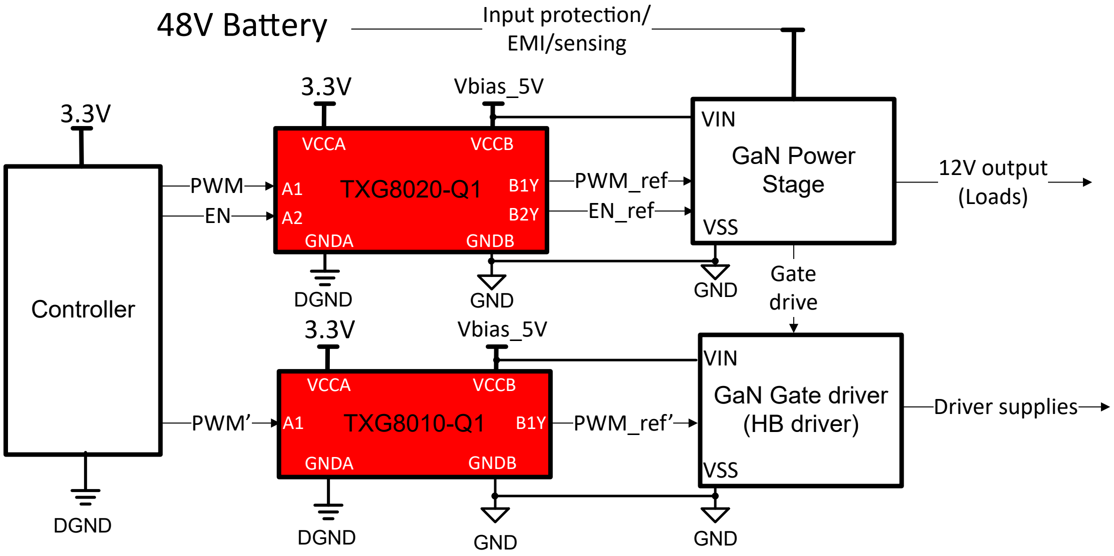

Figure 3-1. Block Diagram to Partition Ground in 48V/12V DC/DC Converter Using TXG8020-Q1

Copyright © 2026 Texas Instruments Incorporated

3.2 Simplifying Automotive Media Hub and USB Charging

In modern automotive *Auxiliary Systems* for multiport USB hub design, each USB PD controller operates from its local VBUS-referenced ground, while the central MCU resides in a separate 3.3V logic domain. Because ground offsets can exist between these domains, directly connecting the I²C lines can degrade noise margin and compromise communication reliability.

The TXG8122-Q1 is used as a bidirectional I²C ground-level translator between each PD controller and the MCU as shown in Figure 3-2. By tying one side to the PD controller's local supply/ground and the other side to the 3.3V domain of the MCU, the device re-references SDA and SCL to the appropriate ground while maintaining compliant logic thresholds. This enables robust multidomain I²C communication without requiring galvanic isolation, simplifying the overall power and interface architecture.

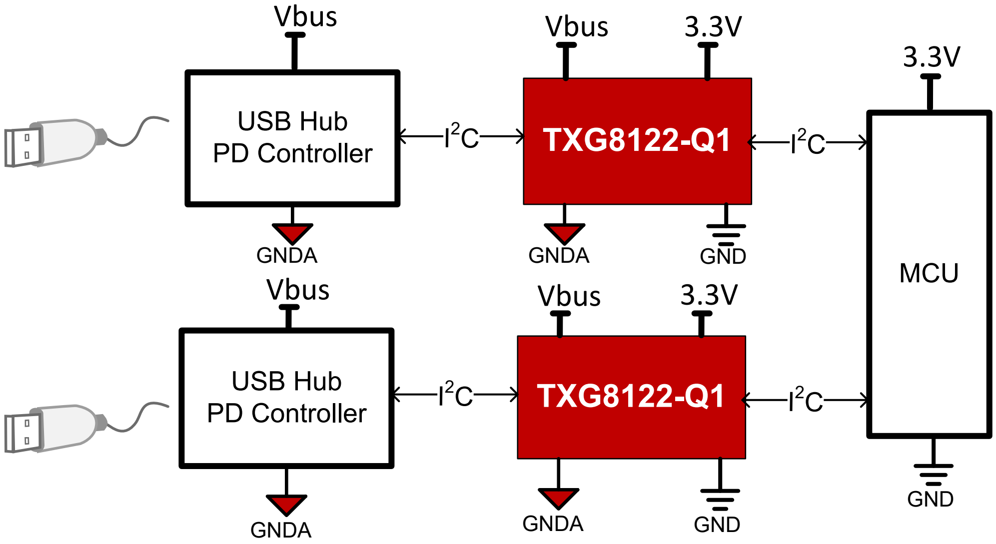

Figure 3-2. Block Diagram for Automotive Media Hub and USB Charging Using TXG8122-Q1

Copyright © 2026 Texas Instruments Incorporated

3.3 Robust Battery Monitoring in 48V Automotive Systems

In 48V automotive sensing module such as *HEV/EV Battery-Management System (BMS)* and high-accuracy Battery Management Unit (BMU) applications, communication between the system controller and cell-stack monitoring devices often spans domains with different logic voltages and ground references. Battery stacking enables higher voltages, longer runtime and improved energy capacity for EVs. The battery monitoring ICs measure voltages, temperatures, and cell balancing states across many series cells where small ground offsets and noise can occur. The system microcontroller operates in a regulated low-voltage logic domain (for example, 3.3V), while the battery monitoring IC and associated sensing circuitry may reside in a different I/O voltage domain due to system partitioning, shunt-based current measurement, and localized grounding strategies. In this architecture, each battery monitor measures a portion of the stack. The top monitor often sits at a ground reference near half the full pack voltage (such as 48V or 24V), and is therefore referenced to a different ground than the MCU, which prevents direct communication and introduces a ground offset. Ensuring reliable communication (across I²C or UART interface) between the controller and monitor domains is critical for accurate measurement, state estimation, and safe operation of the battery stack. When the system architecture does not require full galvanic isolation between these domains, meaning the ground potential differences remain within acceptable limits and safety isolation barriers are handled elsewhere, a simpler, non-isolated solution can be used.

As shown in Figure 3-3, the TXG8041-Q1 is implemented as a multichannel logic-level translator between the system MCU and the battery monitoring devices. TXG8041-Q1 bridges these domains by translating digital interface signals—including clock, GPIO, UART/SPI, and other control lines, between the MCU supply domain and the domain of the monitor. This level shifting verifies compliant VIH/VIL thresholds, prevents I/O overstress, and maintains signal integrity in the presence of automotive noise and ground potential variation. By placing the translator at the boundary between control and measurement subsystems, the design achieves robust cross-domain communication while preserving proper ground partitioning within the 48V architecture.

Figure 3-3 shows a similar implementation using the TXG8122-Q1 for I²C interfaces between mismatched logic rails while also re-referencing the signals to the local ground of each side.

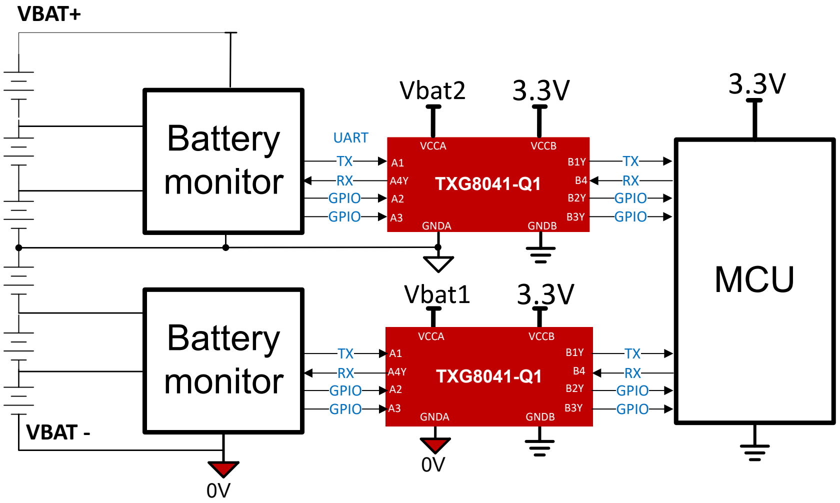

Figure 3-3. Block Diagram for Battery Monitoring in 48V Automotive Systems using TXG8041-Q1

Copyright © 2026 Texas Instruments Incorporated

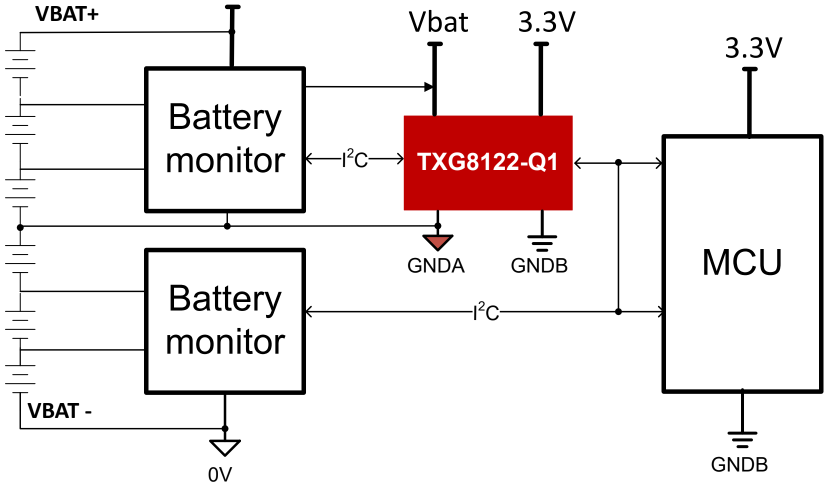

Figure 3-4. Block Diagram for Battery Management Unit System Using TXG8122-Q1

Copyright © 2026 Texas Instruments Incorporated

3.4 Simplifying Multiboard I/O Design

In the modern in-vehicle infotainment architectures such as *Automotive Display* and *ADAS & Infotainment Fusion Controller*, TXG1042-Q1 performs voltage-level translation across the board-to-board interface, allowing each PCB to operate from the native local I/O rail (for example, 3.3V on the host/SoC board and 1.8V on the peripheral board) as shown in Figure 3-5. This eliminates the need for a tracking supply to force match I/O voltages between the two PCBs. The rail management is simplified due to reduced power-tree coupling while maintaining reliable I/O compatibility across the connector.

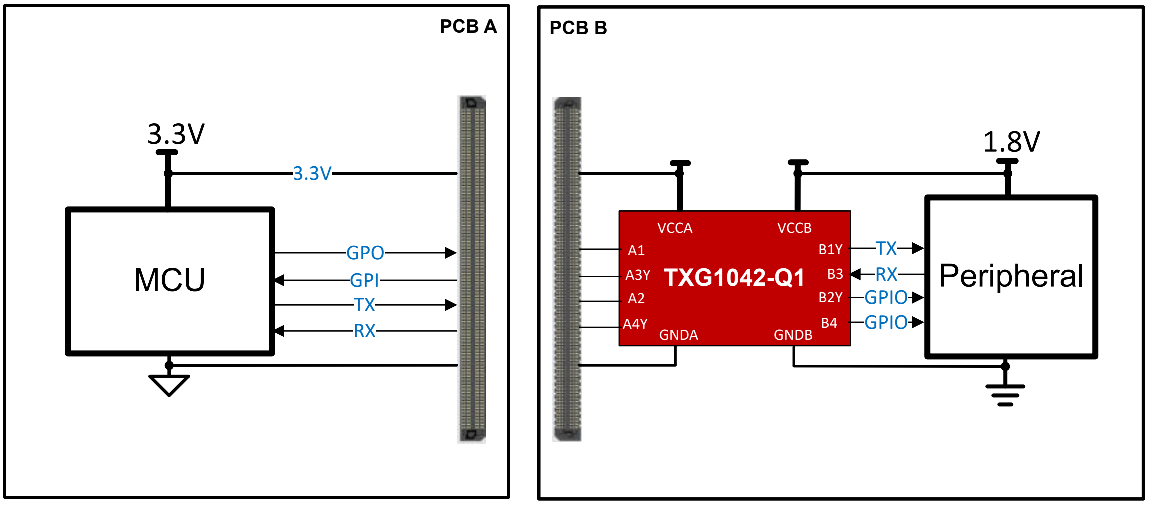

Figure 3-5. Block Diagram for Simplifying Multiboard I/O Design Using TXG1042-Q1

Copyright © 2026 Texas Instruments Incorporated

3.5 Automotive Audio Systems

In automotive audio amplifier and mixed-signal systems with precision analog components, Class-D amplifiers and high-speed data converters often introduce switching noise, ground bounce, and AC ground disturbances resulting in a noisy or unstable ground that can corrupt low-voltage digital interfaces and cause signal integrity issues between systems. Noise that carries to the audio converter (ADC/DAC) ground can introduce fluctuations in the reference voltage, leading to degraded performance, or distorted recording and playback.

Intentional ground shift can also be required for the negative rail in class D audio amplifiers to increase the total voltage swing available to the amplifier output to deliver higher power to the speaker for louder and cleaner audio playback. The TXG ground-level translators provide robust signal integrity by maintaining consistent logic thresholds and isolating sensitive control signals from noisy ground domains. As shown in Figure 3-6, the TXG8122-Q1 is used to isolate the MCU control signals on I^2C bus from audio circuitry and TXG4041-Q1 is used to isolate the audio data bus returning to the controller. The TXG device is also used to bridge the offset between the application SoC which sits on 0V ground and the Class-D power stage which sits on ±2.5V.

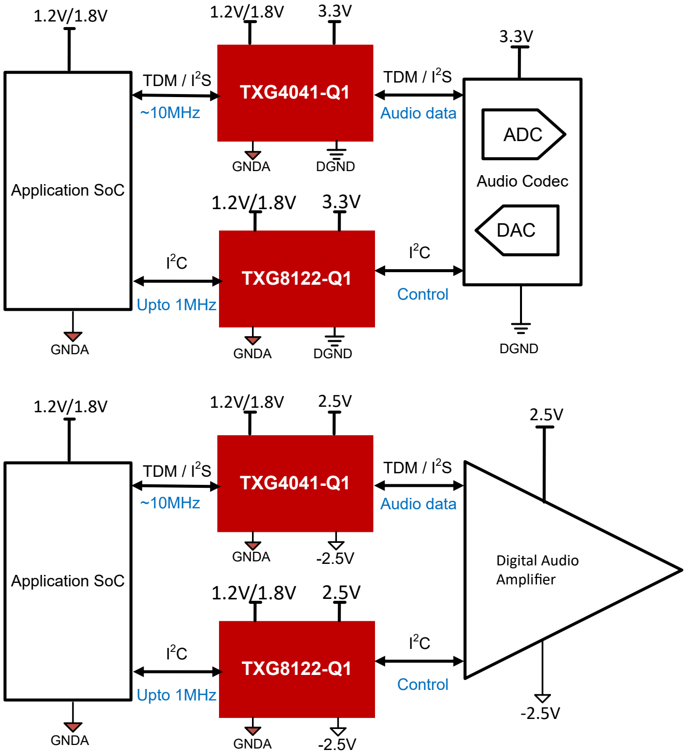

Figure 3-6. Block Diagram for Automotive Audio Systems Using TXG8122-Q1 and TXG4041-Q1

Copyright © 2026 Texas Instruments Incorporated

3.6 Redundant Safety for Electrical Power Steering Subsystem

In an electrical power steering subsystem, two microcontrollers are used to maintain continued operation during a failure event. Both MCUs communicate with each other, but one serves as a redundant backup in case the primary MCU stops functioning. While both MCUs are typically referenced to a common ground, high current loads in the system can introduce ground shifts between the two domains. Traditionally, digital isolators are used to manage these ground differences. However, galvanic isolation is not required in this case, and the TXG4041-Q1 is a more compact and cost-effective alternative as shown in Figure 3-7.

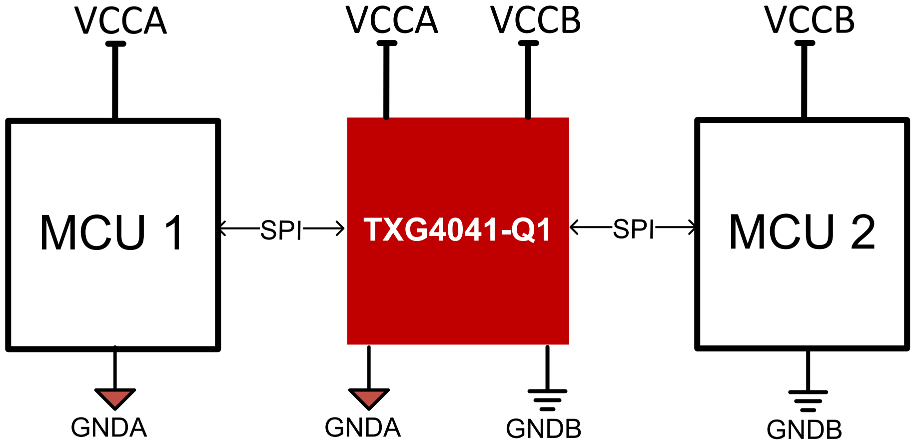

Figure 3-7. Block Diagram for Electrical Power Steering System using TXG4041-Q1

3.7 Robust IGBT Temperature Telemetry across Ground Domains

In a traction inverter, IGBT module temperature is commonly monitored using an NTC resistor embedded near the power switch or baseplate. The NTC forms a temperature-dependent voltage (typically through a bias and pull-up network) that is digitized by an ADC located in the inverter power domain, close to the sensing point. Placing the ADC near the IGBT/NTC minimizes analog trace length, improves immunity to high dV/dt switching noise, and helps preserve measurement accuracy in the electrically harsh inverter environment. The ADC communicates the conversion results to the main inverter controller over I²C, but the ADC side is referenced to a local ground that can shift relative to the MCU logic ground due to switching currents and ground bounce.

As shown in Figure 3-8, the TXG8122-Q1 is inserted in the I²C path to provide bidirectional SDA/SCL level translation and ground-domain re-referencing. With VCCA/GNDA tied to the MCU domain and VCCB/GNDB tied to the ADC domain, TXG8122-Q1 maintains compliant logic thresholds and improves noise margin across the interface, enabling robust temperature telemetry from the IGBT NTC sensing network without requiring galvanic isolation.

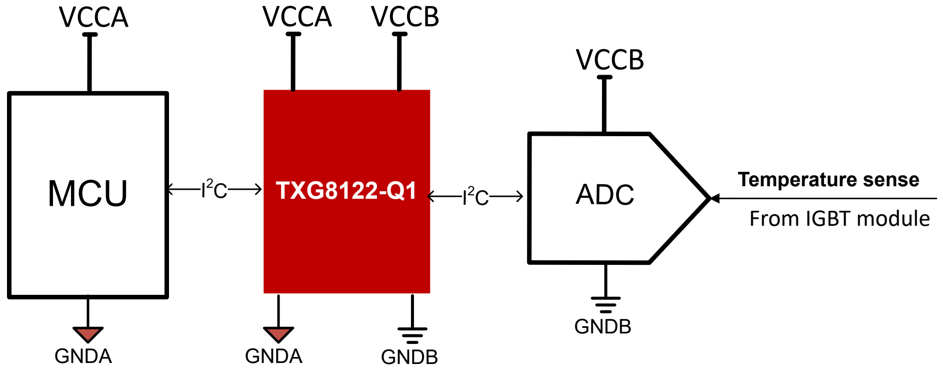

Figure 3-8. Block Diagram for IGBT Temperature Telemetry Using TXG8122-Q1

Copyright © 2026 Texas Instruments Incorporated

3.8 Mitigating Ground Bounce in Single-Ended Interfaces

In IVI architectures that use single-ended FSI such as head unit and digital cockpit processing, the interface can become more susceptible to ground bounce and board-to-board ground potential differences. As data rates increase, even small potential difference on ground between the source and sink boards can reduce effective noise margin, distort logic thresholds, and increase timing/jitter sensitivity at the receiver. To improve robustness, TXG1010-Q1 can be placed at the board-to-board boundary, as shown in Figure 3-9, as a tiny 2.25mm^2 ground-level translator that re-references the single-ended FSI signals to the local ground domain of the receiving side while also verifying compatible I/O logic levels. With VCCA/GNDA tied to the source I/O rail and VCCB/GNDB tied to the sink I/O rail, the translator helps decouple the high-speed interface from ground shifts across the interconnect, improving tolerance to ground bounce and maintaining clean logic transitions at the FSI receiver.

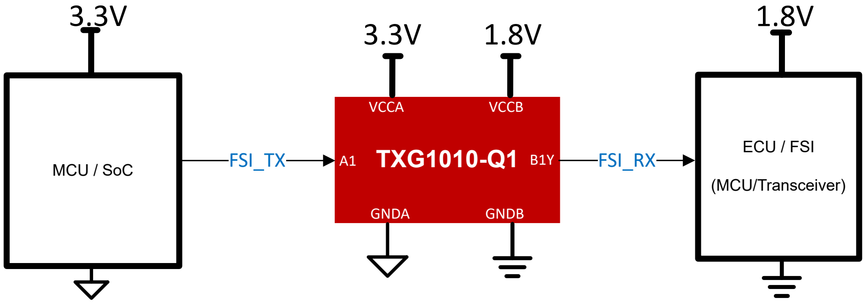

Figure 3-9. Block Diagram for Robust Single-Ended Interfaces using TXG1010-Q1

3.9 Reliable Communication in ADAS Camera

In an ADAS *Automotive Camera*, the main processor or safety MCU commonly operates from a 5V logic domain, while the serializer/deserializer (SerDes) device typically uses a 3.3V I/O rail. In distributed camera architectures, the MCU and SerDes can also reside on different ground regions, as the SerDes is often positioned closer to the image sensor and high-speed link circuitry. Ground shifts caused by cable return currents, EMI, and high-speed switching activity can reduce noise margin on low-speed control interfaces such as I²C used for configuration, diagnostics, and status monitoring.

The TXG8122-Q1 is inserted between the MCU and SerDes to provide bidirectional I²C voltage translation and ground-domain re-referencing as shown in Figure 3-10. By connecting VCCA to the 5V MCU domain and VCCB to the 3.3V SerDes domain, the device maintains compliant SDA and SCL logic thresholds while tolerating moderate ground offsets between GNDA and GNDB. This approach enables robust cross-domain communication without requiring galvanic isolation, improving system reliability while simplifying the multivoltage power architecture of the ADAS camera module.

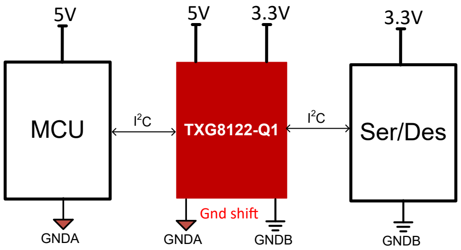

Figure 3-10. Block Diagram for ADAS Camera System Using TXG8122-Q1

Copyright © 2026 Texas Instruments Incorporated

4 When to Use TXG vs. Galvanic Isolation

TXG devices are recommended when ground mismatch exists but galvanic isolation is not required. They provide low latency, high-speed signaling, and cost-effective robustness for automotive interfaces such as I²C, SPI, UART, and GPIO.

- Use TXG when galvanic isolation is not needed but ground mismatch is a concern.
- Use TXG for low-voltage (upto 80V) static or dynamic immunity (CMTI 1kV/µs).
- Use ISO to break current loops and for safety applications.

Table 4-1. Ground-Level Translators vs Galvanic Isolators

Parameter	Ground-level Translators	Galvanic Isolators
Ground A to Ground B difference	Up to +80/-80V	> 1kV
Propagation delay	< 5ns	> 11ns
Channel-to-Channel Skew	0.35ns	4.7ns
Level shifting capability	1.71 – 5.5V	1.71 to 1.89V and 2.25V to 5.5V
Size	Smallest 1ch at 2.25mm^2, 2ch at 4mm^2	Smallest 2ch at 6mm^2
Common Mode Transient Immunity (CMTI)	1kV/µs	100kV/µs
Data rate	> 250Mbps	Upto 150Mbps
Galvanic barrier	No	Yes
Certifications (UL, VDE, Surge)	No	Yes
Leakage between Grounds	<100nA	<1nA
EMC (EFT, RI, IEC-ESD)	No	Yes
Cost per channel	Low	High
Use-case Fit	< 80V ground offset	High-voltage systems and safety certification

5 Getting Started

Designers can begin evaluating TXG portfolio using available TI application notes, technical articles, evaluation modules, and reference designs. TI E2E™ support forums provide additional technical assistance.

6 Summary

Modern automotive architectures distribute electronics across multiple voltage, power, and ground domains, making ground mismatch a recurring system-level challenge. High current loads, long harnesses, switching noise, intentional offsets, and zonal partitioning can introduce DC ground shifts and AC disturbances that degrade digital interface reliability. Conventional mitigation methods including grounding strategies, discrete level shifting, and galvanic isolation often increase cost, latency, power, and design complexity when safety isolation is unnecessary. Texas Instruments Ground-Level Voltage Translation (TXG) family offers a compact, scalable design by enabling simultaneous voltage and ground translation while preserving signal integrity.

With support for ground offsets up to ±80V, low propagation delay, strong noise immunity, and flexible channel options, TXG devices enable reliable cross-domain communication for interfaces such as I²C, SPI, UART, GPIO, and Audio across applications including power systems, battery monitoring, infotainment, audio, ADAS, and safety subsystems. By combining low-latency performance, small form factor integration, and cost-efficient robustness, the TXG portfolio allows designers to effectively manage ground-domain interactions while improving scalability, reliability, and architectural flexibility in next-generation automotive systems.

Copyright © 2026 Texas Instruments Incorporated

7 References

1. Texas Instruments, *Ground-level Translators portfolio*, portfolio.
2. Texas Instruments, *TXG804x-Q1 4-bit, ±80V Ground-Level Translator*, datasheet.
3. Texas Instruments, *TXG802x-Q1 2-bit, ±80V Ground-Level Translator*, datasheet.
4. Texas Instruments, *TXG8010-Q1 1-bit, ±80V Ground-Level Translator*, datasheet.
5. Texas Instruments, *TXG8122-Q1 ±80V Bidirectional Ground-Level Translator for I2C*, datasheet.
6. Texas Instruments, *TXG404x-Q1 4-bit, ±40V Ground-Level Translator*, datasheet.
7. Texas Instruments, *TXG402x-Q12-bit, ±40V Ground-Level Translator*, datasheet.
8. Texas Instruments, *TXG104x-Q1 4-bit, ±10V Ground-Level Translator*, datasheet.
9. Texas Instruments, *TXG102x-Q12-bit, ±10V Ground-Level Translator*, datasheet.
10. Texas Instruments, *Uneven grounds? Address offset challenges with novel ground-level translators*, technnical article.
11. Texas Instruments, *Not All Grounds are 0V*, application brief.
12. Texas Instruments, *TI's Latest Ground-Level Translators*, product overview.

Copyright © 2026 Texas Instruments Incorporated

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you fully indemnify TI and its representatives against any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale, TI’s General Quality Guidelines, or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products. Unless TI explicitly designates a product as custom or customer-specified, TI products are standard, catalog, general purpose devices.

TI objects to and rejects any additional or different terms you may propose.

Copyright © 2026, Texas Instruments Incorporated

Last updated 10/2025