Application Brief

Not All Grounds Are 0V

Sadia Khan

Industrial and automotive systems are using mixed-voltage designs for power optimization, improved performance, and cost reduction. Integration of diverse power domains become a challenge due to unintended ground mismatch. This occurs when the ground reference voltage between domains deviates from the expected 0V reference, ranging from a few volts to tens of volts. Ground shifts can disrupt communication between systems. Addressing this concern is key to reliable system performance.

How is Ground Mismatch Solved Today?

There are multiple methods today used by designers to address ground mismatch in systems. First, proper PCB grounding techniques are used such as dedicated ground planes , star grounding technique, and separating analog and digital grounds. However, this requires careful layout planning and can consume additional board space. If ground shift occurs after the board is already designed, this requires a complete redesign, leading to increased development time. Discrete level shifting is another technique, using resistor dividers or transistor-based circuits to interface across grounds. However, this design is not well-suited for systems with large ground potential differences, suffers from poor signal integrity and timing characteristics, and requires significant board space. Lastly, and perhaps the most commonly used, are galvanic based isolators which are used to decouple subsystems with different ground potentials. Isolators are often associated with higher costs and can introduce additional signal delays. This can also complicate power supply design since isolated sections require separate power sources.

TI's Latest Voltage and Ground-Level Translator

Texas Instrument's TXG family introduces a new method of mitigating ground mismatch in your system with a translator that can level shift both voltage and ground to enable communication across different power domains. TXG804x, TXG802x, and TXG8010 handles ground mismatch up to ±80V, level shifting of I/O voltages from 1.71V to 5.5V, and has a push-pull output for interfaces such as SPI, UART, I2S, and GPIOs. These devices support very high data rates of >250Mbps and low latency with <5ns propagation delay and 0.35ns channel-channel skew. TXG8122 also handles ground mismatch up to ±80V, level shifting of I/O voltages between 3V to 5.5V (Side 1) to 2.25V to 5.5V (Side 2), and has an open-drain output for interfaces like I2C.

Examples of Ground Shifting

There are several uses cases where ground mismatch can be an issue and is summarized below under three types of ground shifting: DC shift, AC Ground Noise, and Intentional Ground Shift.

DC Shift

Ground mismatch can occur due to DC shifts in a system and is shown in Figure 1. DC Shifts can be found when current flowing through a ground path causes a voltage drop because of the wire's parasitics. This creates a ground mismatch between two systems. This phenomenon is particularly common in systems with high current loads or long ground paths.

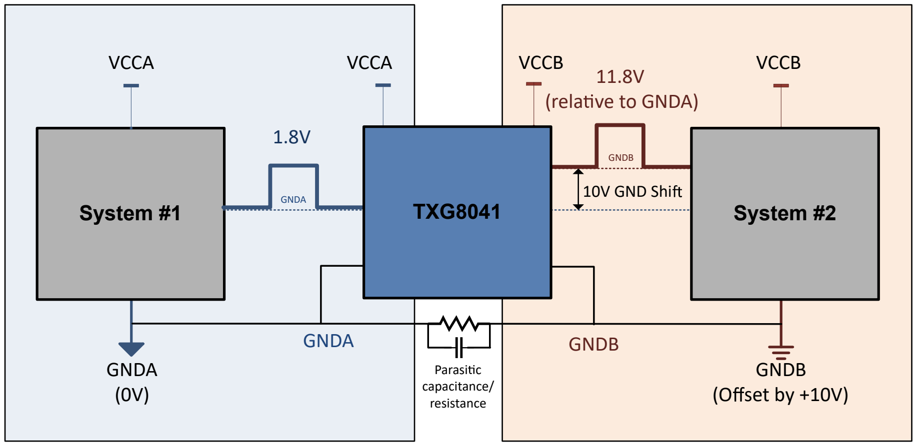

Figure 1. DC Shift

Figure 2 gives an example of an Electrical Power Steering (EPS) System. In this system, two microcontrollers (MCUs) 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 TXG8041 is a more compact and cost-effective alternative.

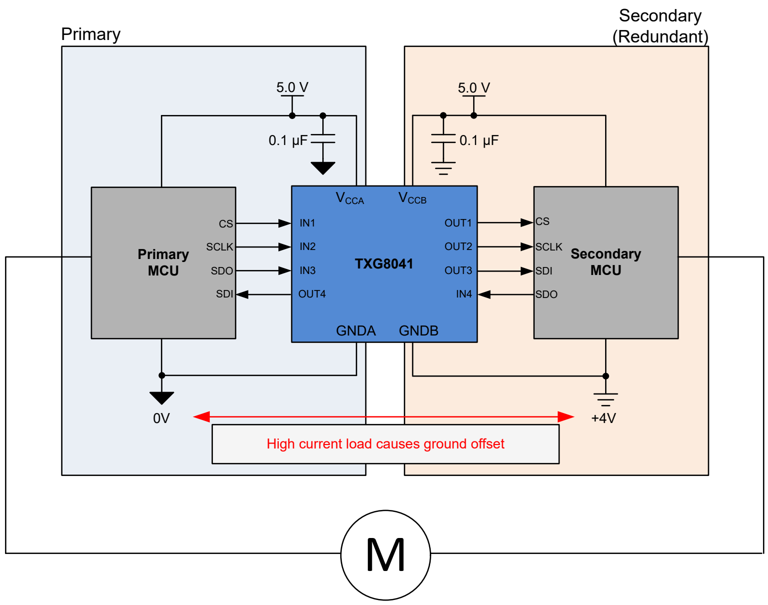

Figure 2. Electric Power Steering with TXG

Another example of DC shift can be seen in battery packs for cordless power tools. In battery pack systems, a battery management system (BMS) is usually used to control power delivery and monitor cell condition. One common design uses a low-side FET to connect the battery negative terminal to the pack ground, which serves as the common reference for the appliance–such as a power drill. When the FET is on, the battery's negative terminal is tied to the pack ground. When the FET is off, the battery's negative terminal effectively floats and can drift to a different reference level than the pack ground, potentially disrupting communication between the BMS and the power drills control circuitry. Traditionally, discrete components are used to level-shift between the battery negative terminal and pack ground. However, this can be completely replaced with an integrated TXG8021 as shown in Figure 3.

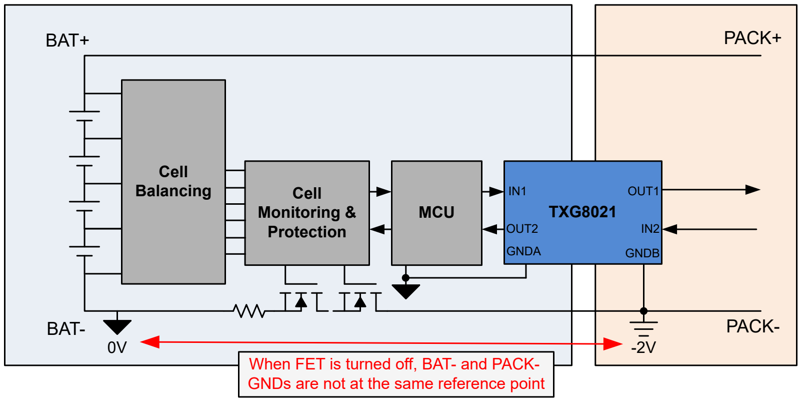

Figure 3. Cordless Power Tool with TXG

AC Ground Noise

AC noise refers to disturbances on the ground caused by dynamic changes, resulting in a noisy or unstable ground, as shown in Figure 4. This phenomenon is often called ground bounce and can also cause signal integrity issues between systems. In mixed-signal designs, this issue can arise when interfacing high-speed digital circuits with precision analog components.

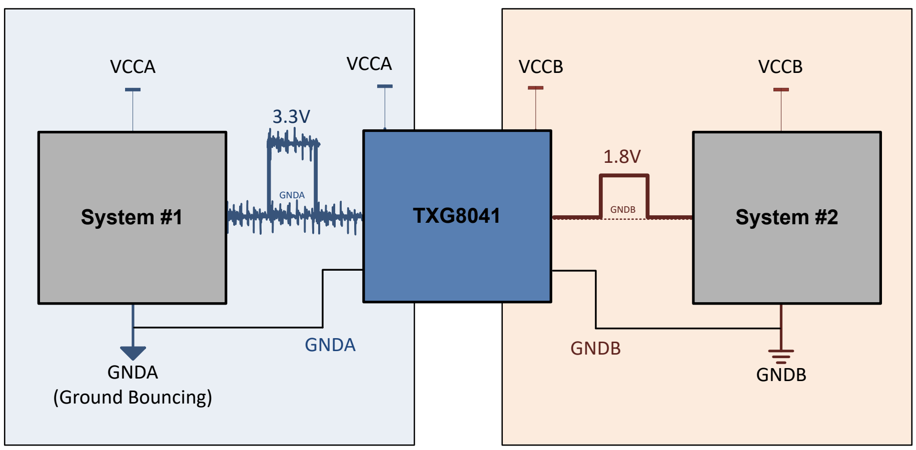

Figure 4. AC Ground Noise

Figure 5 shows an example in Test and Measurement applications where a Field Programmable Gate Array (FPGA) is referenced to digital ground and has to interface with a Digital-to-Analog Converter (DAC) that is referenced to power ground. Both grounds are ultimately connected together to establish a common reference but can be on separate ground planes on a PCB to help separate digital noise from sensitive analog circuitry. The digital side of the system can see rapid switching which can result in AC noise. Noise that carries to the power ground can introduce fluctuations in the DAC reference voltage, leading to degraded performance or distorted analog outputs. In the example below, TXG8042 is used to eliminate noisy grounds and enable the precise communication needed for accurate digital-to-analog conversion.

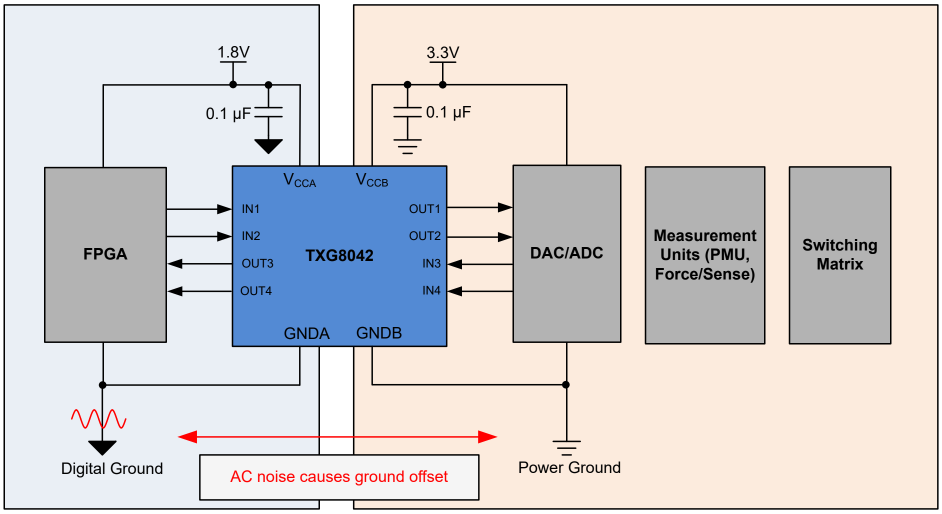

Figure 5. Semiconductor Test Equipment With TXG

Intentional Ground Shift

Intentional ground shift is when systems deliberately use an offset ground for the benefit of the system. An example of this is topologies with a negative voltage rail. This can be seen in GaN based power stage designs which use a -50V ground in Class D audio amplifiers to increase the total voltage swing available to the amplifier output. The larger voltage swing allows the amplifier to deliver higher root mean square (RMS) power to the speaker, which translate to louder and cleaner audio output. In the block diagram below, the TXG8010 single-channel device can be used to bridge the offset between the MCU which sits on 0V ground and the GaN Half-Bridge Power Stage which sits on -50V.

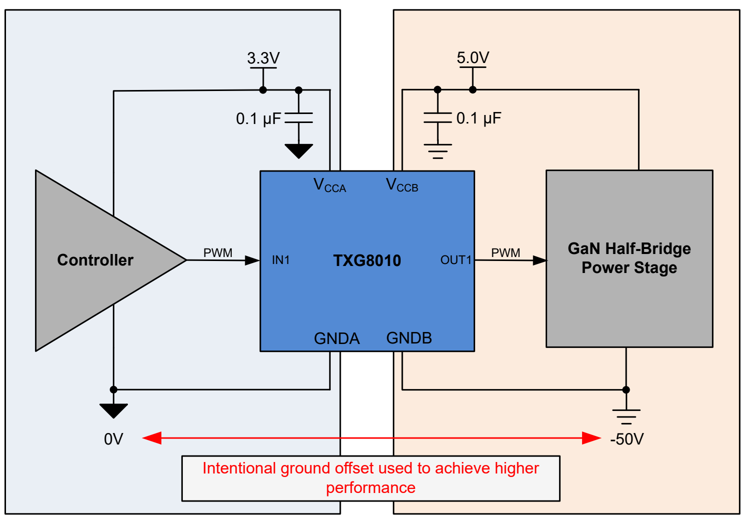

Figure 6. GaN Half-Bridge Power Stage With TXG

Battery stacking is also more common now as a way to support higher voltages, enabling longer runtime and improved energy capacity. This approach is frequently used in systems such as appliances, energy storage systems (ESS), and electric mobility applications. Because traditional battery monitors typically support only 16 cells in series per device, managing larger stacks often involves using multiple monitors across different voltage domains. In these systems, the TXG8122 facilitates communication over the I2C interface between the MCU at 0V ground and the top battery monitor, which can sit at voltages at 25V or higher.

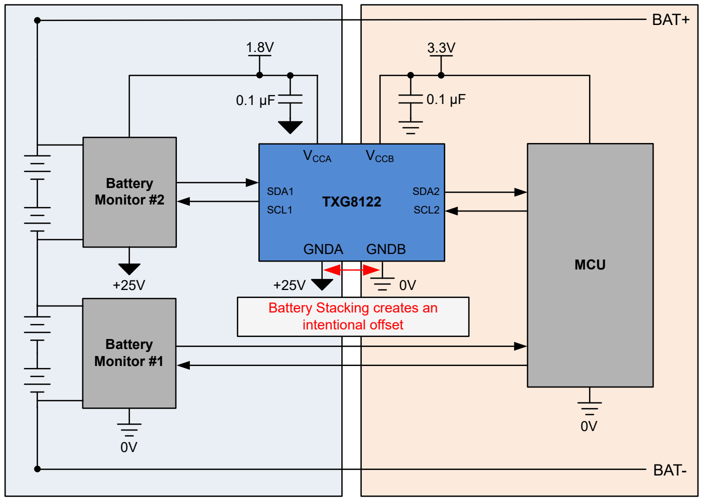

Figure 7. Battery Stacking With TXG

When to Use Ground-Level Translators

While galvanic isolators remain essential in high voltage and safety critical applications, understanding when to use a ground-level translator versus a digital isolator can help reduce system cost and size while improving performance. If safety is not a concern, transient voltages do not exceed 80V, and no isolation certifications are required, the family of ground-level translators is the best option. Following is a comparison between these two designs:

	Ground-Level Translator	Digital Isolator
GNDA to GNDB Difference	±80V	>3kV$_{RMS}$
Galvanic Barrier	No	Yes
GNDA to GNDB Leakage (VCC to GND shorted)	70nA	<1nA
Size (4ch)	4mm^2	29.4mm^2
Propagation Delay (3.3V)	5.8ns	18.5ns
Ch-Ch Skew (3.3V)	0.35ns	4.7ns
Data Rate	>250Mbps	100Mbps
Level Shifting Capability	1.71V to 5.5V	1.71V to 1.89V and 2.25V to 5.5V
Operating Temperature	-40 to 125°C	-40 to 125°C
CMTI	1kV/µs	100kV/µs
Certifications (UL, VDE, Surge)	No	Yes
EMC (EFT, RI, IEC-ESD)	No	Yes

Conclusion

Ground mismatch is an increasingly common challenge in modern systems. Whether caused by DC shifts, AC ground noise, or intentional offsets, ground potential differences can introduce serious communication, reliability, and signal integrity issues. TI's TXG family of ground-level translators offers a compact, cost-effective, and faster alternative to traditional methods, enabling seamless signal transmission across ground differences of up to ±80V. The portfolio offers scalability and design flexibility, empowering engineers to unlock new possibilities in a wide range of automotive and industrial applications.

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