Technical Article

Uneven grounds? Address offset challenges with novel ground-level translators

As systems become more compact, efficient and modular, designers face new challenges managing communication across different voltage domains. A primary example is the rise of <100V_{DC} architectures, including 48V systems in electrical vehicles (EVs), robotics and energy storage systems. These architectures avoid the complexity of high-voltage designs while maintaining power delivery efficiently, enabling smaller and more integrated designs. Parallel to this trend is the rise of modular design principles – optimized, interchangeable components tailored for specific functions. For example, consumer products such as power tools often rely on a single interchangeable battery, making it easier to charge and manage multiple devices.

As modular low-voltage systems become more popular, a new integration challenge emerges: enabling seamless communication between different voltage and ground domains. TI's ±80V ground-level translators, as represented in Figure 1, supports voltage translation from 1.71V to 5.5V across systems with different ground potentials, helping achieve reliable, compact and scalable system designs.

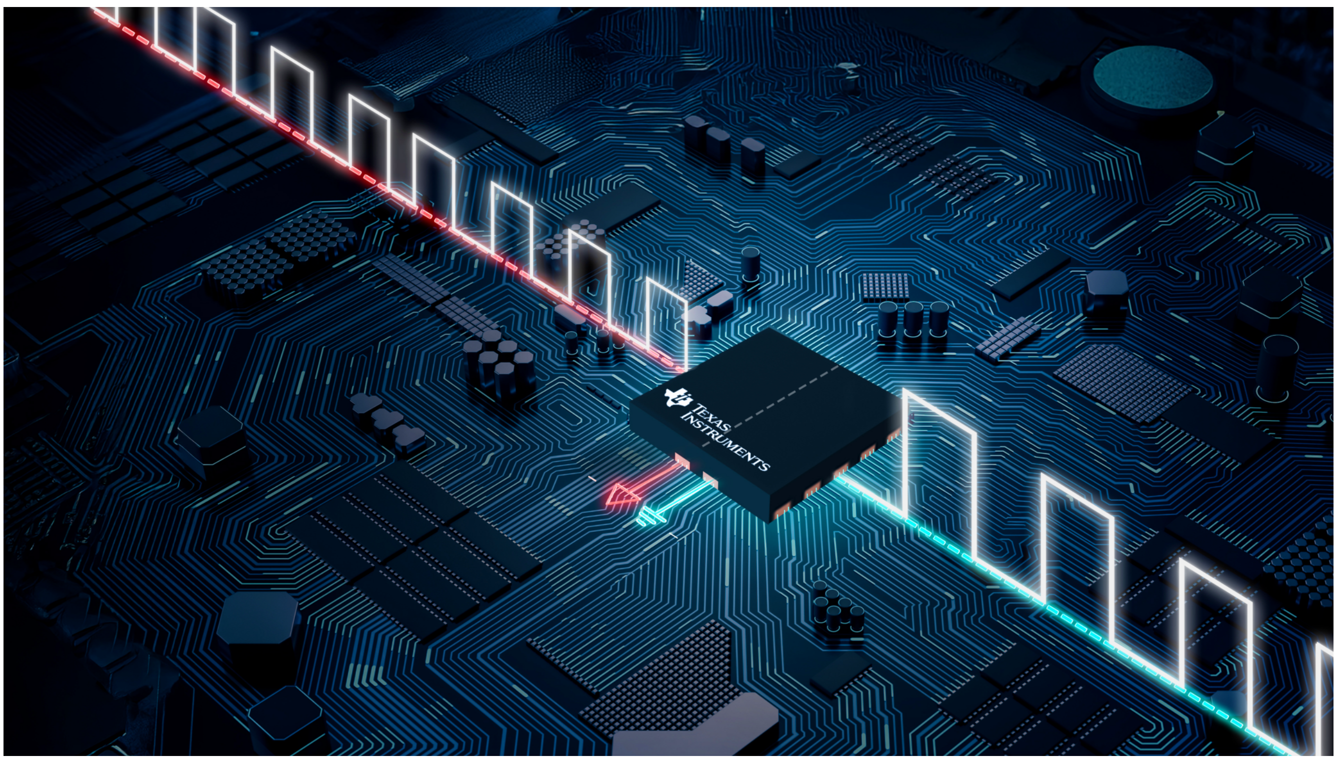

Figure 1. ±80V ground-level translators bridging different ground domains

To address ground offset for voltage ranges below 80V, designers have traditionally used galvanic isolation or discrete level shifters, but both come with complexity, size and cost trade-offs:

- Galvanic isolators are expensive, bulky and often limited in data rate and timing performance. Table 1 below highlights the differences between this solution and a ground-level translator.
- Discrete level shifters can handle unidirectional low-speed signals but are unreliable and not scalable. While low cost, the solution size is around 10mm^2 to 20mm^2.

Table 1. Table comparison between ground-level translator and galvanic isolators

Parameter	Ground-level translator	Digital isolator	Optocoupler
Data rate	250Mbps	100Mbps	<1Mbps
Propagation delay (typ)	3ns	10ns	100ns
Ch-Ch skew (typ)	0.2ns	3ns	10ns
Footprint (4-ch)	4mm^2	29mm^2	76mm^2
Cost per channel	Low	Higher	Low
Optimized for	<80V ground offset	High-voltage systems and safety certification	High-voltage systems and safety certification

The challenge of ground offset

Subsystems in modular designs operate with their own voltage and ground references. But when those systems come together, even small differences in ground potential can cause signal integrity issues and communication errors. As seen in Figure 2 and Figure 3, ground offset can stem from DC shifts or AC ground noise.

DC ground shift

Voltage differences can arise from trace resistance or long cabling. In multidomain systems, one domain may "float" several volts above or below another from localized load currents or asymmetrical grounding topologies, where one subsystem connects to the main ground with a short, wide trace and another subsystem connects to the ground plane with a long, narrow trace.

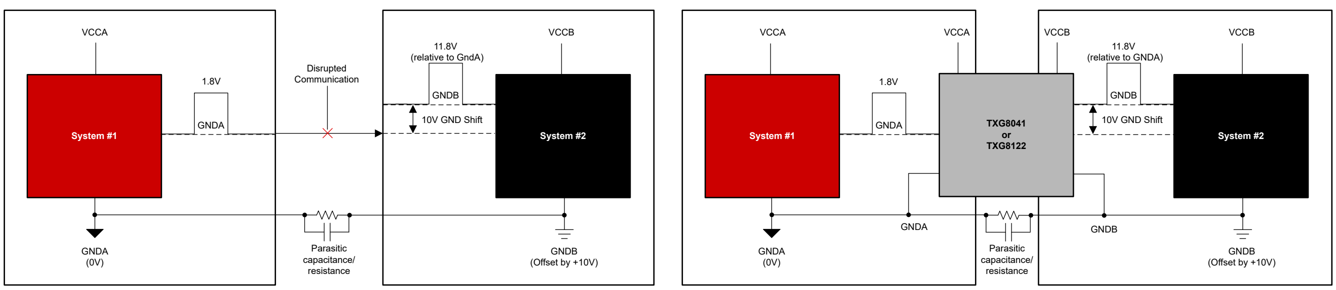

Figure 2. Addressing DC ground offset between systems using a ground-level translator

AC ground noise

In mixed-signal systems where digital, analog and power circuits coexist, AC ground noise is common. On the power side, this noise stems from large, fast-changing return currents generated by switching power components. On the digital side, high-speed signal transitions can inject transient currents into the digital ground. These fluctuations can shift the local ground potential, disrupting communication between subsystems that assume a common ground reference.

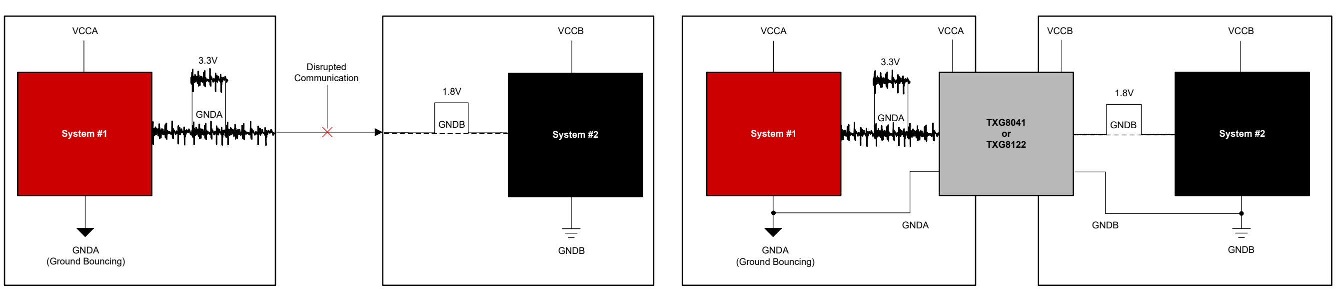

Figure 3. Addressing AC ground noise between systems using a ground-level translator

Ground-level translators designed for low-voltage systems

TI's ground-level translators support level-shifting of I/O voltages from 1.71V to 5.5V and address both DC ground offset up to ±80V and AC noise rejection up to 140Vpp at 1MHz, at one-seventh the size, and half the cost of more complex solutions. The TXG8041 supports push-pull outputs with <5ns propagation delay and 0.35ns channel-to-channel skew, enabling rapid data processing for real-time communication between systems up to 250Mbps. The TXG8122 supports open-drain configurations including I^2C and consumes half the power of existing solutions, minimizing power draw to extend battery life and reduce thermal loads. These translators deliver compactness through form-factor packages as small as 2.25mm^2, and scalability through multiple channel types and configurations.

Applications in 48V architectures

With 48V architecture picking up momentum with EV manufacturers, electronics design is backed by the latest International Organization for Standardization 21780 standard, which mandates specific testing for ground offset, ensuring reliable communication between devices operating at different ground potentials. In such systems, a control module operating at 48V may need to communicate with a 12V sensor, even if a few volts of ground offset exist because of layout or load conditions.

The TXG8041 supports communication across these mismatched domains up to ±80V ground offset, which covers transients of the 48V battery system and supports higher-speed SPI communication with its faster data rate and low propagation delay. As shown in Figure 4, the ground-level translators are available in packages as small as 2.25mm^2 for a 1-channel and 4mm^2 for four-channel configurations, significantly smaller than typical galvanic isolators.

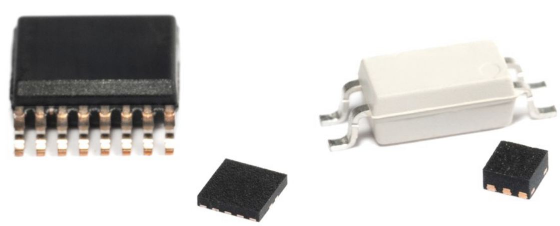

Figure 4. The TXG8041 in a 4mm2 SON package compared to a 7-times-larger 29mm2 galvanic isolator (left) and TXG8010 in a 2.25mm2 SON package compared to an 8-times-larger 19mm2 optocoupler (right)

Enabling battery-stack monitoring

Battery-powered systems such as appliances, e-bikes and energy storage systems are increasingly adopting stacked battery monitors to support higher voltages and longer runtimes. In these architectures, each monitor measures a portion of the stack. The top monitor often sits at a ground reference near half the full pack voltage (such as 24V), and is therefore referenced to a different ground than the system microcontroller (MCU), which prevents direct communication. This intentional topology introduces a ground offset. The TXG8122 enables I^2C communication, frequently used for communication between the MCU and battery monitors. This device also offers reduced power consumption during static bus conditions, while its 4mm^2 footprint facilitates miniaturization and flexible integration into modular systems.

Conclusion

Ground offset between systems has always existed, but is becoming increasingly common as low-voltage modular architectures gain traction. TI's ±80V ground-level translators provide a simple solution to this challenge – enabling voltage translation across different ground levels via interfaces like SPI or I^2C. You can now leverage this technology at a fraction of the size and cost of traditional approaches, with up to 2x faster performance, while maintaining signal integrity and reliable system operation.

Additional resources

- Read the application note, Not All Grounds are 0V.
- Get started with the TXGx04x 4-Channel Ground-Level Translator evaluation module.
- Discover our new portfolio of ground-level translators.
- Check out the application note, Key Voltage Considerations for Replacing a Photorelay With an Analog Switch.

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