Technical White Paper

Shrinking Solution Size and BoM Cost With Functional Isolation in your System Designs

TEXAS INSTRUMENTS

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ABSTRACT

The last decade has seen an exponential growth in consumption of semiconductors across various applications. This growth is assisted with major technical advancements in semiconductors that have enabled key advantages in system designs.

One of the key trends observed across various industrial applications is shrinking solution size. The advantage of a smaller system design is actually twofold. For one, shrinking solution size enables an increase in system throughput, with the same available board area. This is extremely critical for applications that require higher board density, like in Semiconductor Test and Measurement. Higher test resource counts are instrumental for testing integrated chips used in AI/ML applications with high I/O channel count.

Additionally, the designs get sleeker and more compact, reducing the overall space and cost with no change in system functionality. For instance, increasing power density (power per unit area) in pluggable chargers for faster, smaller, lighter for devices such as phones and laptops is necessary to facilitate the growth in power requirements in portable consumer electronics.

Functional isolation devices being smaller and cost effective can assist this trend in shrinking designs. This white paper introduces the concept of functional isolation in context with basic/reinforced isolation. It also illustrates various applications that make use of isolators that are trending across industry, and how functional isolators can be used to further decrease the solution size and cost.

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1 Introduction

1.1 Where are Digital Isolators Commonly Used?

Digital isolators are used in a breadth of applications, mainly for system robustness against high voltage stresses, surge protection and noise isolation.

Specifically, TI's digital isolators employ silicon dioxide (SiO_2) dielectric, which offers best-in-class isolation performance. Figure 1-1 illustrates the cross section of TI's isolation technology.

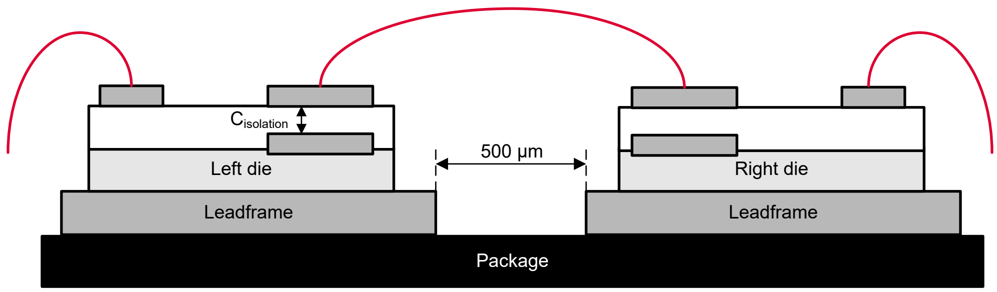

Figure 1-1. Cross Section View for TI's Silicon Dioxide-Based Isolators

TI's basic and reinforced isolators are certified as per standard bodies and undergo thorough testing to ensure compliance to safety certifications. Generally, safety certified digital isolators are available in industry standard SSOP or SOIC packages with at least >3.7mm creepage. In terms of their isolation performances, margins on the time-dependent dielectric breakdown (TDDB) performance and device lifetimes are taken to ensure superior system safety and certification compliance.

Some of the key applications that heavily use digital isolator are mentioned below :

- **High-speed Serial Peripheral Interface (SPI)** isolation in Factory automation
- **Pulse Width Modulation (PWM)** signal isolation from digital controller to gate-driver or Power FET's in various power supply topologies
- **High-speed communication signal isolation** across isolated programmable cards in semiconductor test

1.2 What is Functional Isolation?

Many times, the isolators are used in systems due to their intrinsic capability to block high-voltage common mode and their robustness to maintain signal integrity when subjected to high switching noises across the isolation barrier, and typically not for compliance with safety standards or certifications bodies that isolators are generally rated for.

For instance : Digital isolators are often times used inside Safety Extra Low Voltage (SELV) systems for blocking common mode of up to 60V. Within SELV systems, there is generally no safety requirement, like surge or lightning protection. Digital isolators in these designs are merely used for blocking high common mode and noise across the isolation barrier.

Such designs still make use basic or reinforced certified digital isolators in the non-safety stages, which might be an overkill.

1.3 Key Benefits of Functional Isolation

TI's functional isolators are key to such applications that require isolation for high voltage blocking and noise immunity, and not for to their certification compliance. These solutions are cost-effective replacements for applications that require isolation for ensuring proper system functionality, and not essentially system safety.

TI's functional isolators (ISO65xx) are available in industry standard packages, and additionally available in smaller, low-profile packages to enable high-channel density in compact system designs.

The following section covers various end equipments that can make use of functional digital isolators for conventional industry-wide applications.

2 Application Use Cases

2.1 Telecom Power Supplies

An uptick in investments towards Telecom infrastructure is being observed due to increase in demand for mobile data. This includes 5G and 6G infrastructure rollout that requires efficient, light, compact designs.

Historically, standard bus voltages Telecom equipment is -48V, generally derived from mains or battery backup. From a system perspective, -48V battery intrinsically increases system longevity by minimizing battery corrosion.

Most of the subsequent circuitry, however, is powered off a positive rail. Therefore, an isolated and a non-isolated DC-DC power stage becomes critical in telecom-power supply systems.

2.1.1 48V Isolated DC-DC

A standard H-Bridge stage is commonly implemented for an isolated DC-DC power source as shown in Figure 2-1. Digital controller generating PWM signals for switching Power FETs can be referenced to either the isolated or the non-isolated side. In Figure 2-1, the digital controller is referenced to the isolated side.

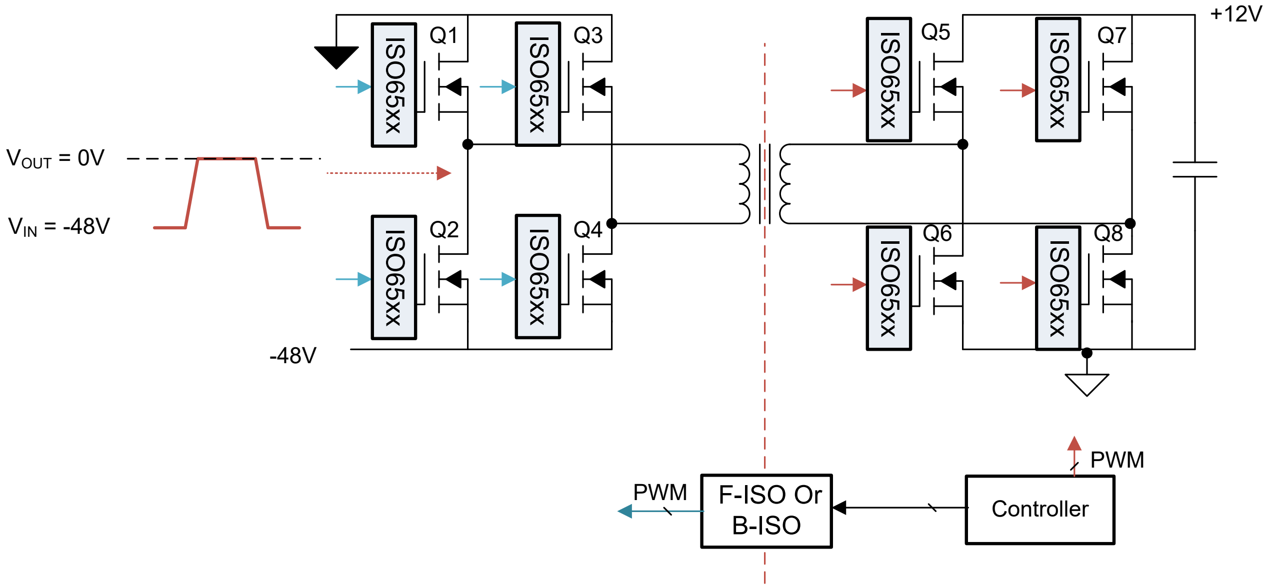

Figure 2-1. Typical 48V Isolated DC-DC Implementation Using ISO65xx

On the non-isolated side, high-side power FETs in the H-bridge require a level-shifted signal to enable FET switching. A blocking voltage of at least 100V would be necessary for this application along with immunity to high voltage switching noise (>100kV/us) across the barrier.

Functional isolation devices like ISO65xx are the right fit for this application, capable of V_{IOWM} > 200Vrms voltage across the barrier. A similar implementation can be used on the isolated side, where the isolator is used for high-voltage blocking. Low-side FETs in these designs may also choose to use of ISO65xx to match the propagation delays between the high side and low side.

The 48V DC-DC isolation barrier may also require just functional isolation where an ISO65xx can be used. In case basic isolation is needed across the power stage, TI's digital isolator families like ISO6741 can be picked for PWM communication across the barrier.

2.1.2 48V Non-Isolated DC-DC

Non-isolated Inverted Buck-Boost (IBB) topologies are ideal for Power amplifier applications where Power Supply Unit (PSU) output voltage needs to be changed based on the demand, derived from the -48V input.

A digital controller referenced to system ground is powered up using auxiliary power sources. This controller provides PWM signal as per the required output voltage level. A typical IBB implementation is as shown in Figure 2-2. Note that the switching power FETs (Q1 and Q2) are not referenced to the same reference node as the controller IC.

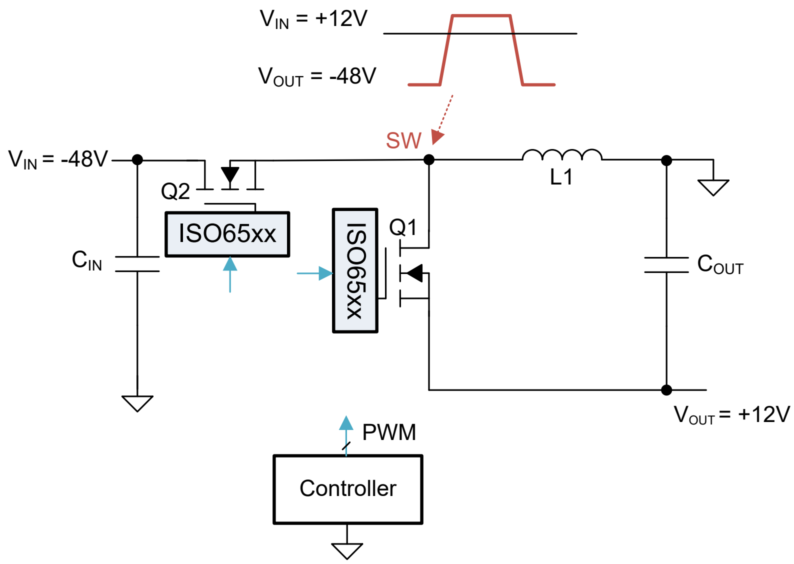

Figure 2-2. Typical Inverted Buck-Boost implementation With ISO65xx

ISO65xx family of functional isolators can be used to faithfully block the switching noise across the isolation barrier and level shift the PWM signal from the controller to the power FET. High immunity to common mode noise (100kV/us) is essential to ensure reliable system performance over device lifetime.

Functional Isolation working voltage (V_{IOWM}) needed between the controller and the FETs can be as high as 100V. ISO65xx blocks the common mode voltage for reliable FET operation.

2.2 Server Power Supply

Server Power Supply Unit (PSU) have various stages in their power supply for an efficient power delivery. This generally starts with the AC mains as the input source.

A typical block diagram for a server PSU stage is as shown in Figure 2-3.

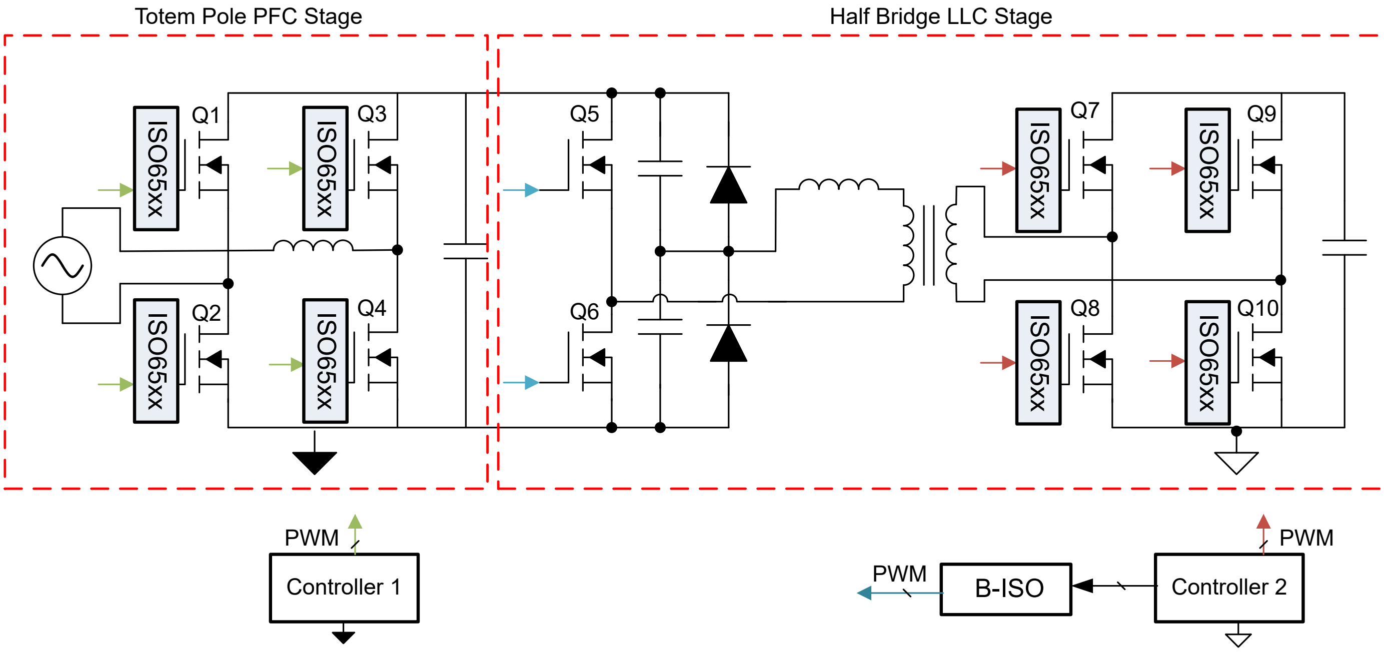

Figure 2-3. Typical Server Power Supply Unit (PSU) Implementation With ISO65xx

2.2.1 Totem-Pole Power Factor Correction Stage

A Power Factor Correction (PFC) stage is implemented to improve overall efficiency while rectifying incoming AC power to the DC bus voltage. Figure 2-4 depicts a typical PFC stage with a fast switching leg using power FETs (like GaN) and a slow switching leg.

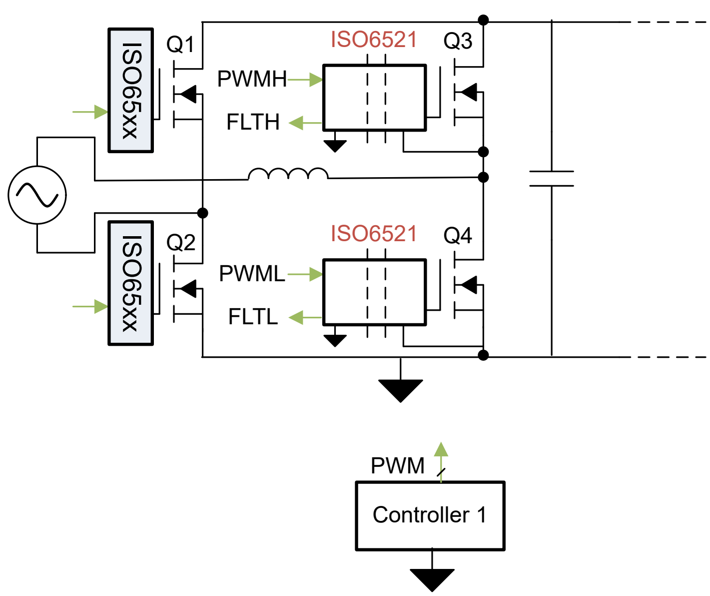

Figure 2-4. Totem Pole PFC Stage Using ISO6521

The switching control input comes from a controller that generates appropriate PWM signals. An isolator is generally used to block high voltage common mode and also withstand fast switching transients.

The ISO65xx family of devices are an area-optimized solution that can be used to block the high voltage common mode >400V and switching-noise of >100kV/us on across the isolation barrier.

2.2.2 Half-Bridge LLC Stage

A half-bridge LLC stage follows the PFC stage to step down the high voltage DC bus voltage to lower levels as per the system requirement. The controller is now locally referenced and generates the PWM control for switching the power FETs on the isolated side.

As illustrated in Figure 2-5, the half-bridge stage can also effectively make use of ISO65xx family of devices for high-side level shifting and blocking high-voltage switching transients of 100kV/us and beyond.

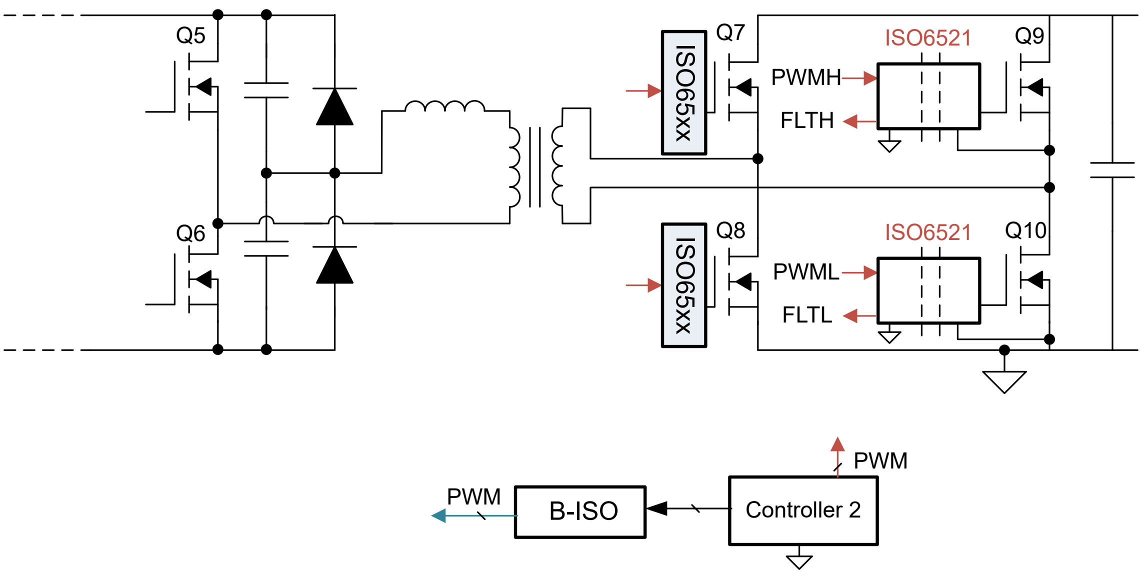

Figure 2-5. Half Bridge LLC Stage Using ISO6521

PWM control for the hot-side from controller 2 can employ a basic isolator such as ISO6741 to ensure the system isolation requirements are met.

2.3 AC - DC Power Supply in Pluggable Wall-Chargers

2.3.1 Introduction

As consumer electronics like mobile phones and laptops become faster and more feature-rich, the need for fast charging speeds is also growing at an exponential rate. This trend is appended with a shift towards smaller and denser adapters with higher power density. Power densities as low as 30W/in^3 are not uncommon in market today. Such high power densities are achieved by transitioning to faster switching Power FETs like GaN, which help condense the bulky magnetics needed for power conversion.

For instance, common AC-to-DC topologies in wall adapters in consumer markets is Quasi-resonant (QR) and Active-Clamp Fly-back (ACF). ACF Controllers such as TI's UCC28782 are used for generating the PWM signals needed for switching the power FETs.

2.3.2 Topology Details

A typical block diagram for an Active Clamp Flyback stage is as shown in Figure 2-6. The controller provides PWM signals for Power FETs (Q3 and Q4). Low-side FET (Q4) being referenced to primary ground can be provided directly from the ACF controller. However, providing PWM signal to high-side FET (Q3) can get challenging as Q3 is referenced to a high voltage switching node.

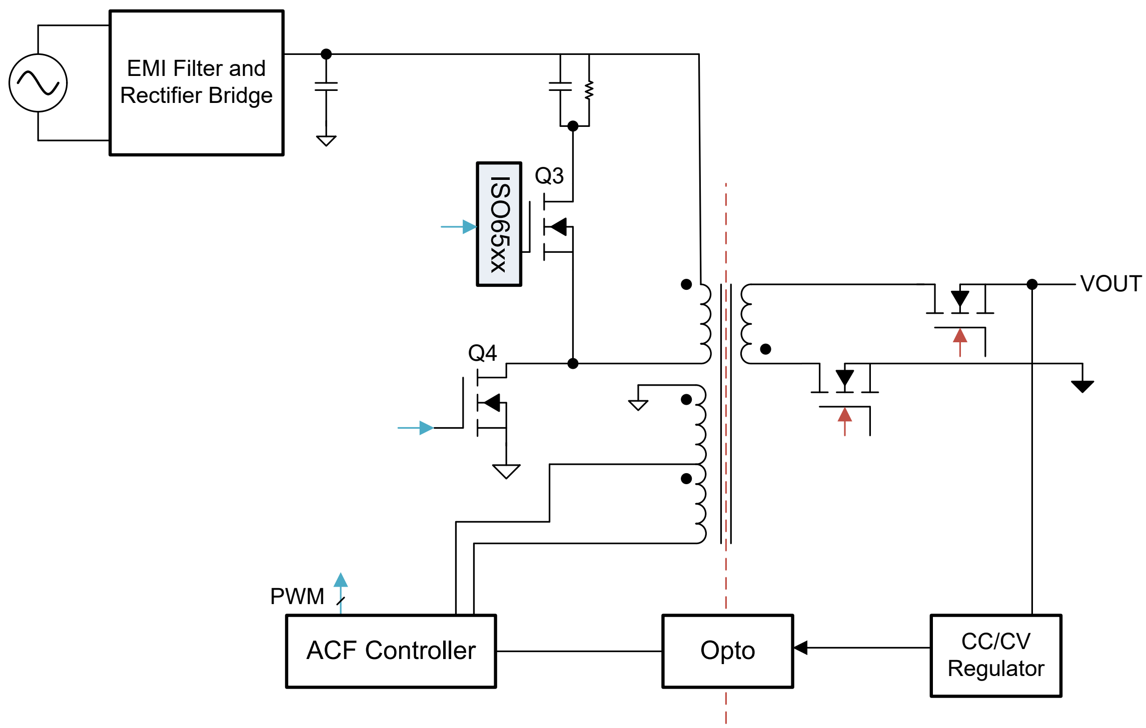

Figure 2-6. Typical Active Clamp Flyback implementation With ISO65xx

2.3.3 Using ISO65xx for Reliable PWM Signaling

A functional isolator like ISO65xx can be used between the controller and high-side FET for reliable system operation.

The ISO65xx family of devices are an excellent fit for this application. Functional isolators like ISO65xx can be used between ACF controller and the Power FET to block a high common mode and faithfully communicate PWM signal across the barrier under high-voltage transient conditions.

Functional Isolation working voltage (V_{IOWM}) needed for this application can be typically 400V, depending on the voltage input from AC Mains. Momentary high voltage transients may get induced in the system due to variants in the AC mains input or line surges, which the isolator needs to withstand.

Common mode transient immunity (CMTI) robustness is also essential to account for high-voltage switching activity from power FETs, as high as 100kV/µs.

2.4 Semiconductor Test and Measurement

The demand for semiconductor Integrated Chips (IC's) is ever increasing and is driving an increase in demand for more precise and dense semiconductor test equipments like Automated Test Equipment (ATE). An ATE is a dense test equipment that houses various test boards, each capable of sourcing or measuring various types of digital test patterns, arbitrary waveforms, powerful DC voltage sources, current sources etc. High density in resource count and shrinking board dimension is key to enable higher test throughput.

For instance, one of the resource in an ATE is a Source Measurement Unit (SMU) instrument that can both source current/voltage and measure current/voltage. SMU resource combines the functionality of two instruments (programmable power source and digital multimeter) in one. Depending on the specifications, some SMU's can also be stacked in series as shown in Figure 2-7 to achieve higher test voltages demanded by semiconductor technologies that require higher bias voltages.

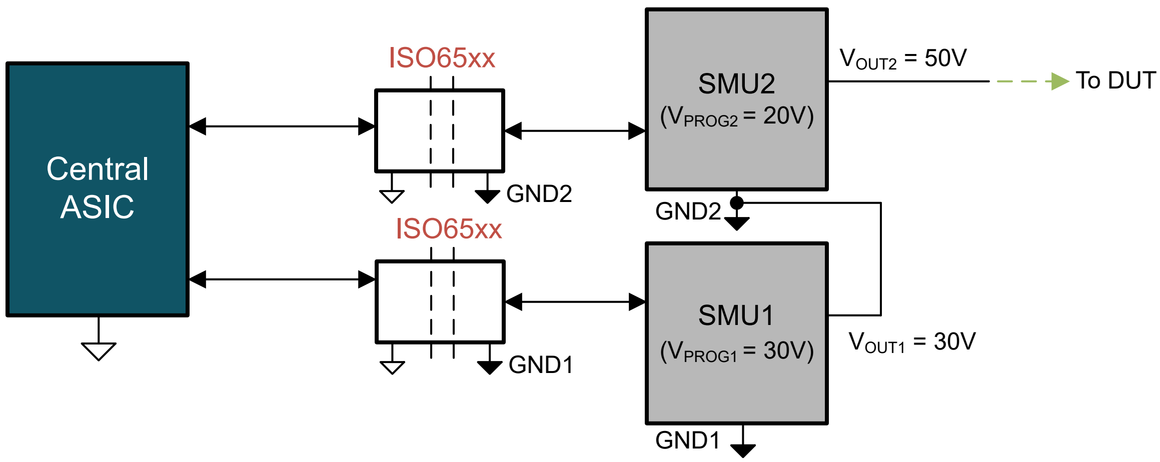

Figure 2-7. Stackable Isolated Source Measure Unit (SMU) Design Using ISO65xx

Functional isolators like ISO65xx provide the size advantage for space constrained applications, commonly seen in Test and Measurement cards. ISO65xx can be used between the central control ASIC and each SMU card. When multiple SMU cards are stacked, ISO65xx blocks high-voltage common without introducing leakage current across the barrier. Generally, each resource has a maximum voltage specification with respect to tester ground, which determines the functional isolator working voltage (V_{IOWM}) needed in the design.

3 Conclusion

Digital isolators are used in a breadth of applications across the industry. As discussed in this paper, many applications use isolators to block high voltage common mode and for immunity to high voltage transients, not for safety or system protection. TI's Functional isolators retain best-in-class high voltage blocking performance and common mode transient immunity for system functionality. In such applications, TI's functional isolators like ISO65xx can be used to condense system size and minimize cost.

4 References

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- Texas Instruments, *Isolation Glossary*
- ISO6521 product folder and data sheet
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- UCC28780 product folder and data sheet

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