Application Brief

Understanding Common Mode Transient Immunity in Automotive Traction Inverter Isolated Gate Drivers

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Introduction

Isolated gate drivers are used in electric vehicle (EV) traction inverters to drive the electric motor power switches (insulated gate bipolar transistor [IGBT] or silicon carbide [SiC]) and convert the DC battery to AC power for the motor. Isolated gate drivers also provide low-to-high voltage galvanic isolation, preventing an unwanted flow of DC- and AC-power in the traction inverter, while enabling data and power transfer. Isolation is critical for protecting human occupants and low-voltage circuitry from high voltages and handling ground potential differences. Additionally, isolation reduces electrical noise and withstands common mode transients when the transistor switches high voltages at high slew rates at the power-ground end, with respect to the logic-level input ground.

Isolated gate drivers establish reliable switching performance in high dv/dt environments.

Figure 1 shows a simple diagram of an isolated gate driver.

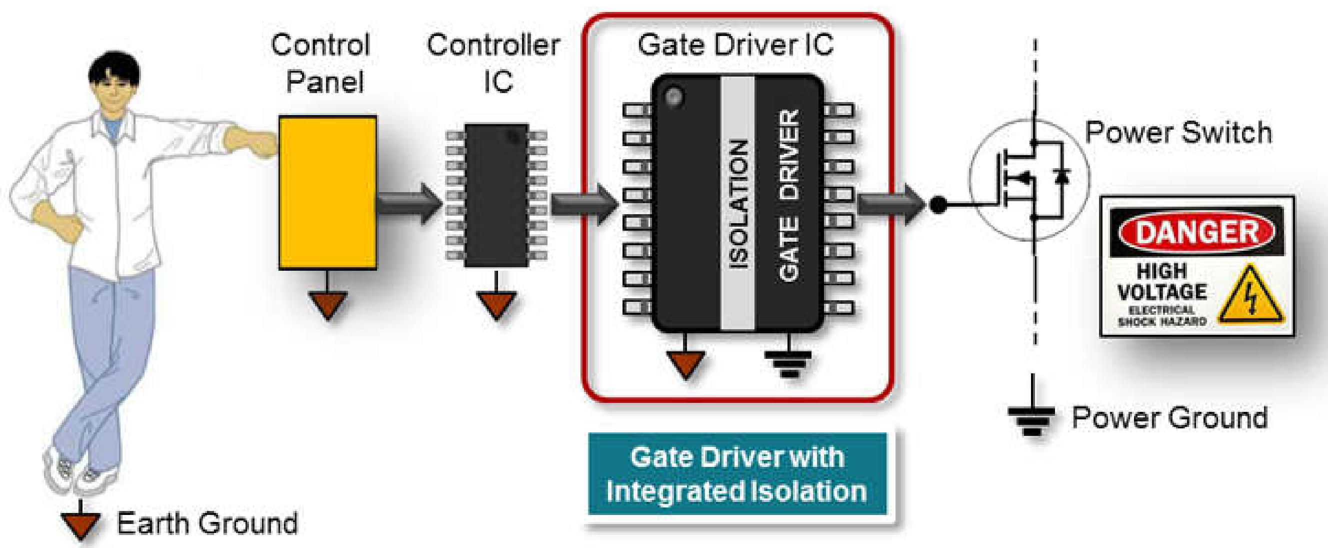

Figure 1. Isolated Gate Driver in a High-Voltage System

What is Common-Mode Transient Immunity?

The next generation of traction inverters requires more control, performance, and sophisticated sensing capabilities to leverage new power switch technologies, such as SiC FETs. SiC FETs are approaching switching frequencies of 30KHz or higher. Advantages of higher switching frequencies include a smaller filter size, faster control and response, and lower distortion.

Common-mode transient immunity (CMTI) is an important parameter of an isolated gate driver when operating in traction inverters. Traction inverters require high efficiency and minimal switching losses, leading to vastly increased dv/dt of a SiC MOSFET drain-source voltage. Specifically, CMTI refers to immunity to the voltage slew from the primary to the secondary side. CMTI is the maximum tolerable rate of the rise or fall of the common mode voltage applicable between two isolated circuits. The CMTI unit is normally kV/us or, equivalently, V/ns.

High CMTI means that the two isolated circuits, both transmitter side and receiver side, function well and without error within the data sheet specifications, when striking the insulation barrier with very high rising (positive) slew rate or high falling (negative) slew rate. Figure 2 shows a simplified CMTI test setup and the typical common-mode pulse waveform.

Establish that the IN and OUT signal in the simplified block diagram follows the appropriate logic when the VCM pulse is applied on the insulation barrier. Per the IEC 60747-17 standard, CMTI is tested up to the voltage listed in the data sheet and testing up to the maximum isolation working voltage (VIOWM) is an additional verification of isolation integrity. The IEC 60747-17 standard recommends determining the slew rate of common-mode pulse by measuring the slew rate from 20% to 80% of the final common-mode pulse amplitude (|VCM|).

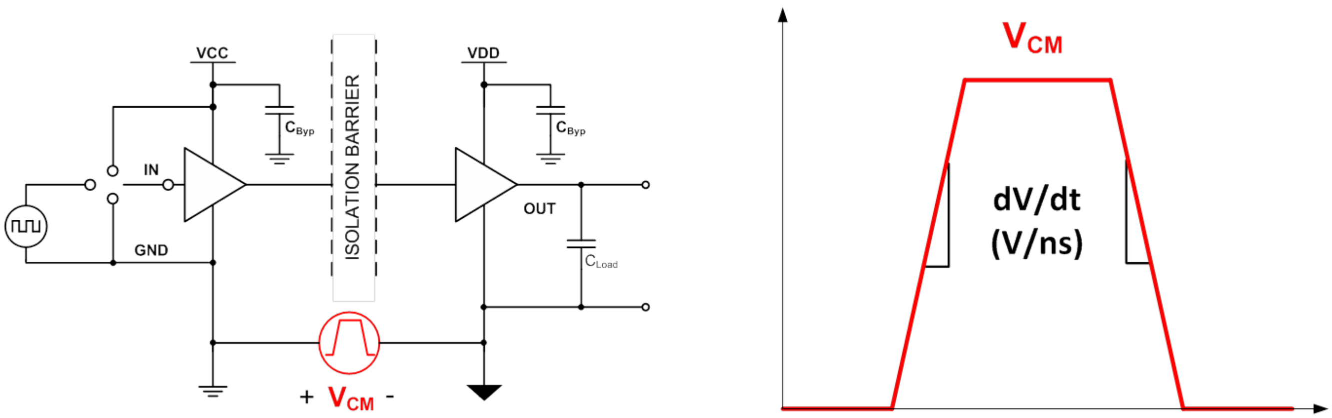

Figure 2. CMTI Test Set-Up

CMTI is critical for isolated gate drivers to handle differential voltages between two ground references. CMTI demonstrates the robustness of the gate driver to withstand rising and falling slew rates. Additionally, the presence of CMTI indicates detailed design in the circuitry and isolation components within the isolated signal chain.

Static Versus Dynamic CMTI

There are two types of CMTI: Static and Dynamic. Static CMTI is the testing condition where the input is tied to either logic high or logic low, and monitors the output state during the common mode transient (CMT) strike. Establish that the gate driver output remains in the specified high or low state within the CMTI specifications over the variation of processes, voltages, and temperatures.

Figure 3 shows an example of static CMTI measurement, with common mode high (CM_H) and common mode low (CM_L) pulses.

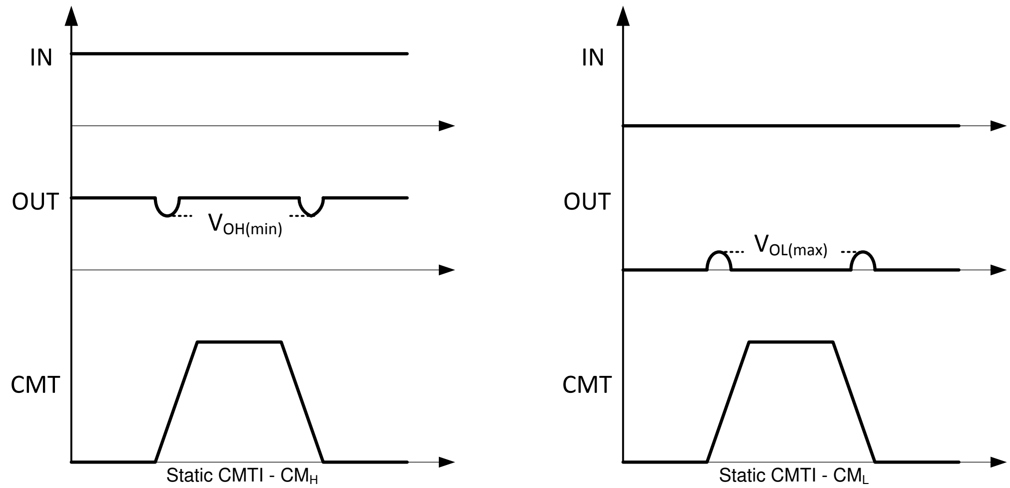

Figure 3. Static CMTI Measurement

Dynamic CMTI measures when the CMT strike occurs at a specific dynamic (switching) event. A dynamic event occurs when the CMT strike is applied on the rising or falling edge of a digital I/O signal. Another occurrence example is to test the robustness of the communication channel in advanced gate drivers with advanced internal communication. Figure 4 shows the second example.

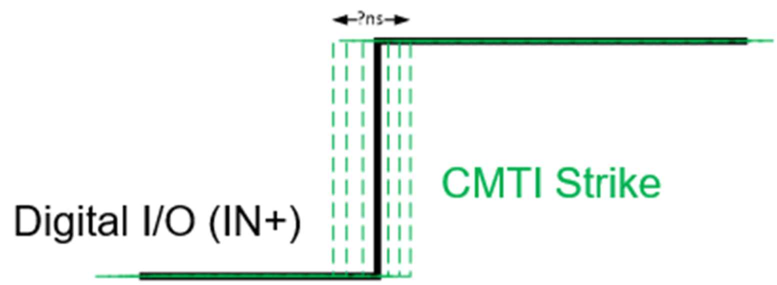

Figure 4. Traditional Dynamic CMTI

The criteria is still the same and the output is expected to remain in the correct logic state, either as or following the input. Figure 5 shows potential fault scenarios including:

- Missing pulse
- Excessive propagation delay
- High error
- Low error
- Output latch

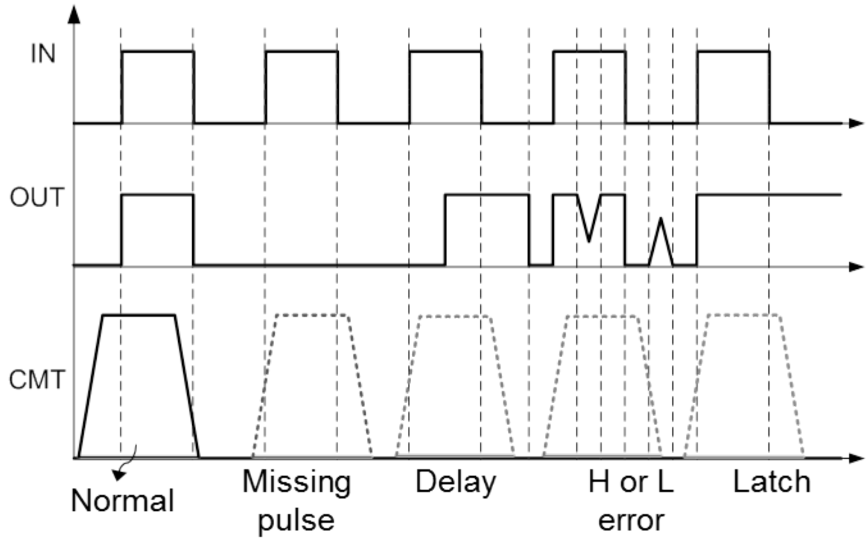

Figure 5. Dynamic CMTI Measurement – Normal versus Errors

Testing for Static/Dynamic CMTI

Figure 6 shows the equipment used to test for static or dynamic CMTI:

Static CMTI:

- Device under test (DUT = isolated gate driver)
- CMT generator
- Battery or isolated power
- High-performance measurement set-up

Dynamic CMTI:

- Device under test (DUT = isolated gate driver)
- CMT generator
- Battery or isolated power
- High-performance measurement set-up
- Signal synchronization
- Isolated probe

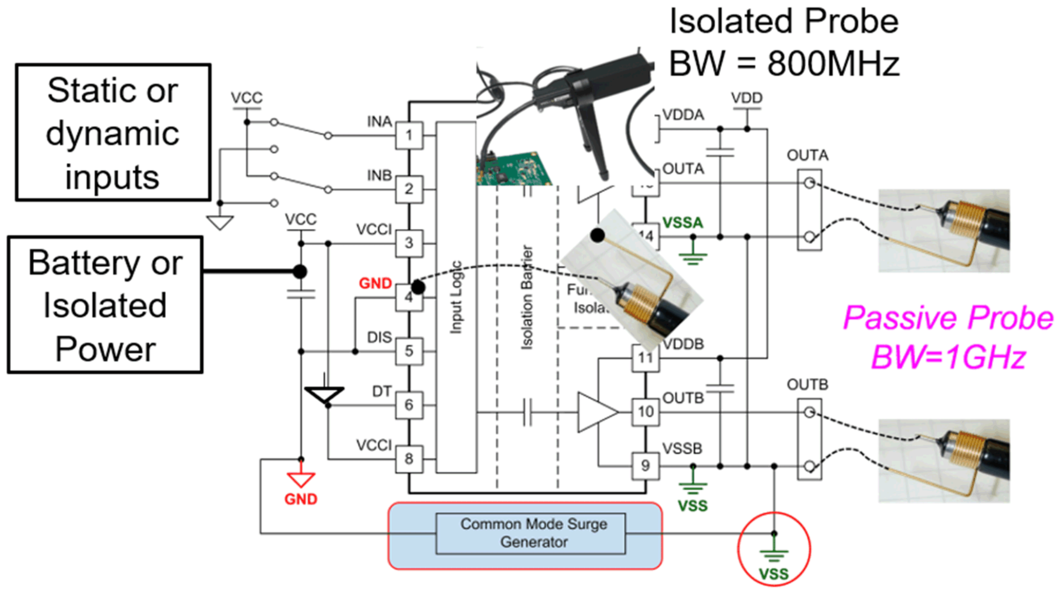

Figure 6. CMTI Measurement Set-Up and Equipment

The CMTI is a test that demonstrates the isolated gate driver immunity for common mode transients. CMTI performance includes testing of the newly released UCC5881-Q1 Functional Safety-Compliant programmable isolated gate driver with real-time variable gate drive strength and 16× DESAT threshold settings. Figure 7 shows the UCC5881-Q1 exhibits high performance during the dv/dt turn-off using 100 continuous inverter sinusoidal cycles.

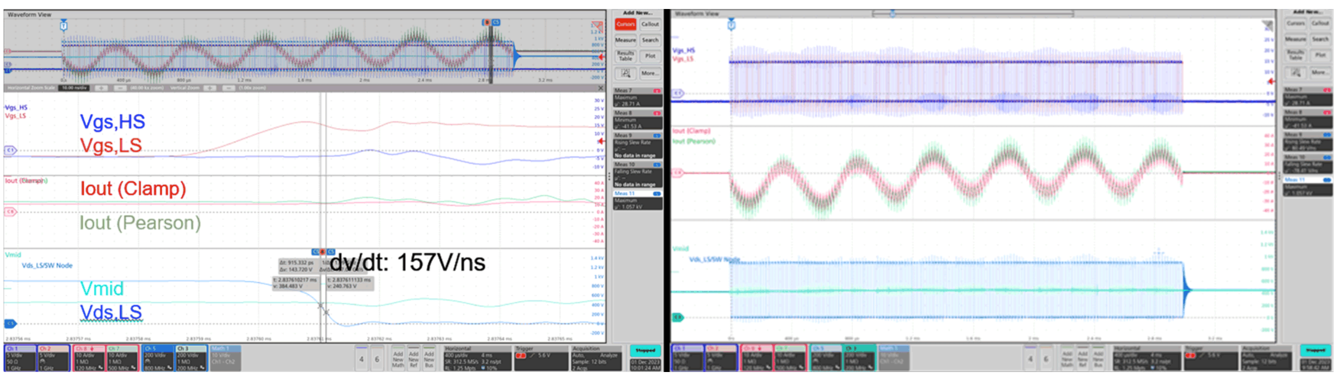

Figure 7. UCC5881-Q1 Turn-Off CMTI Strike Measurement (157V/ns) With 100 Continuous Inverter Sinusoidal Cycles

Conclusion

CMTI plays a significant role in the proper operation of an EV traction inverter. Substandard common mode immunity can lead to errors that impact system performance and safety.

To establish correct traction inverter operation, it is imperative for isolated gate drivers that drive advanced SiC FETs with high switching speeds and slew rates to use an isolation barrier that is immune to CMTI and demonstrates robustness in noisy switching environments. The same CMTI is applied regardless of switching frequency. As transient speeds increase, higher CMTIs are needed.

The UCC5881-Q1 is the latest programmable isolated gate driver for traction inverters with a specified 150V/ns maximum common mode slew rate from TI.

The UCC5881-Q1 performs well in application-level static and dynamic CMTI tests, and is a key component in TI's total solution for EV traction inverters.

Additional Resources

- Learn more about TI's isolation technology
- UCC5881-Q1 FuSa-compliant isolated gate drive with real-time variable gate drive strength
- Read about TI components that help to create high-performance traction inverters

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