Application Note

How to Use UCC5880-Q1 to Detect the Module DS Short Failure

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ABSTRACT

With the continuous iteration and upgrading of inverter technology in EV/HEV, customers have put forward more stringent requirements for the FuSa (functional safety) and operational reliability of inverter systems. As the core switching device of inverters, IGBT power modules are prone to short-circuit failure, If the fault is not checked in advance and the system is started directly, secondary accidents such as secondary short circuits, overcurrent impact and thermal runaway are very likely to occur, causing irreversible damage to the drive circuit, battery and even load motor, as well as potential personal safety hazards, so that the isolated driver must complete non-destructive detection of IGBT module short-circuit failure in configuration mode to eliminate potential faults in advance. Focusing on TI UCC5880 high-performance isolated gate driver, this paper designs an IGBT module short-circuit failure detection scheme, elaborates the scheme principle, hardware design and configuration process in detail, which can help customer safety detection module short failure and prevents secondary accidents after module damage.

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Trademarks

1 Introduction Background

In current EV/HEV high-power inverter application scenarios, the probability of IGBT or SiC module short-circuit failure occurs due to overcurrent, overvoltage, overheating, device aging and other factors. Traditional driver schemes only realize short-circuit protection with Desat during system operation and cannot detect whether the module has failed before startup. Operation with faults directly leads to secondary faults, which greatly increases system safety risks. Therefore, preventive safety detection has become an industry rigid demand.

1.1 Functional Requirements

In order to achieve the non-destructive DS short-circuit detection, the functional requirement as below:

1. The isolated driver chip shall complete IGBT module short-circuit failure detection in configuration mode (non-switching operating state);
2. The detection process is non-destructive, without any damage to IGBT modules, drive circuits and main circuits.
3. Detection parameters are configurable, compatible with IGBT power modules of different voltage and current levels.
4. After detecting short-circuit failure, latch the fault immediately, upload fault signals and prohibit system startup.
5. The scheme has high integration, no need to add many peripheral devices, simplifies hardware circuit design and ensures system reliability.

1.2 Main Features of UCC5880-Q1

TI UCC5880 is a high-isolation and configurable gate driver specially designed for high-power IGBT and SiC MOSFET. Its integrated functions perfectly match the requirements of IGBT short-circuit failure detection, and the core features are shown in Figure 1-1 and below:

1. Built-in desaturation (DESAT) short-circuit detection circuit, 110ns ultra-fast fault response, and the detection threshold is configurable from 4V to 14V via SPI;
2. Integrated 10-bit high-precision ADC, which can sample DESAT pin voltage in real time and provide accurate data for failure judgment.
3. Support SPI serial configuration interface, which can set threshold, blanking time and other parameters in configuration mode.
4. Complete self-diagnosis and fault protection functions.
5. Ultra-high common-mode transient immunity (CMTI) of 150V/ns, excellent electrical isolation performance, preferred for high-voltage and high-power inverter scenarios.
6. INP input is ignored to prevent unknown behavior in configuration mode and realize non-destructive detection.

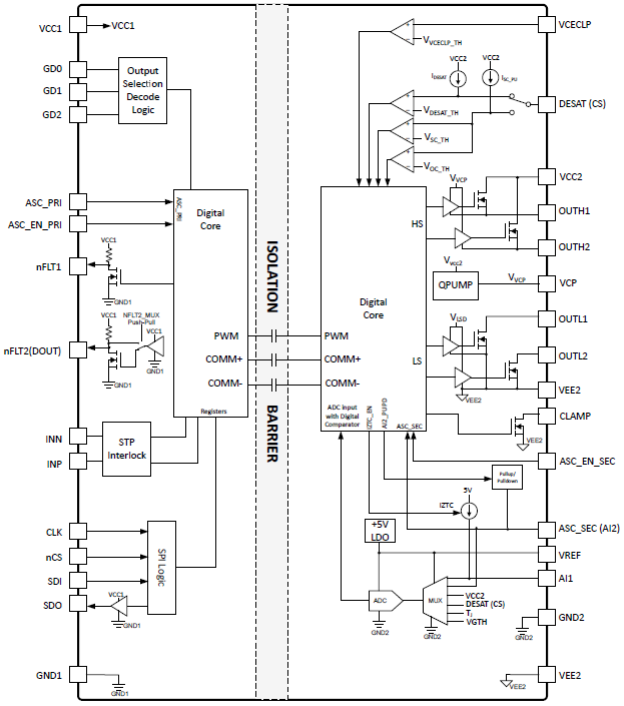

Figure 6-1. Functional Block Diagram

Figure 1-1. UCC5880-Q1 Block Diagram

When a normal IGBT module is in off-state, the collector-emitter presents high impedance, and the VCE voltage is close to the bus high voltage; When the IGBT module has short-circuit failure, the collector and emitter are in low-impedance conduction state, and the VCE voltage approaches 0V.

Relying on the DESAT detection function of UCC5880, this scheme applies weak detection current to the IGBT collector through the DESAT loop in configuration mode, collects the collector-emitter voltage signal as #none#shown, and compares the sampled voltage with the preset failure threshold through the built-in ADC and comparator of the chip to judge whether the IGBT has short-circuit failure. The IGBT is off state during the whole process without conduction action, realizing non-destructive detection, the detailed circuit are shown in #none#.

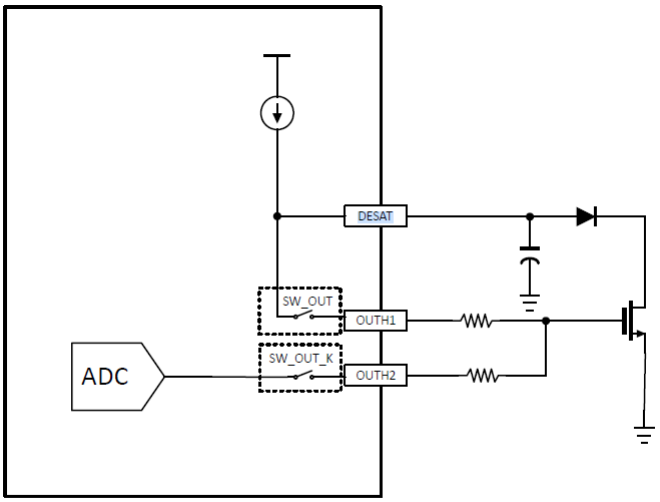

Figure 6-31. VGTH Monitor Effective Circuit

Figure 1-2. VGTH Monitor Effective Circuit

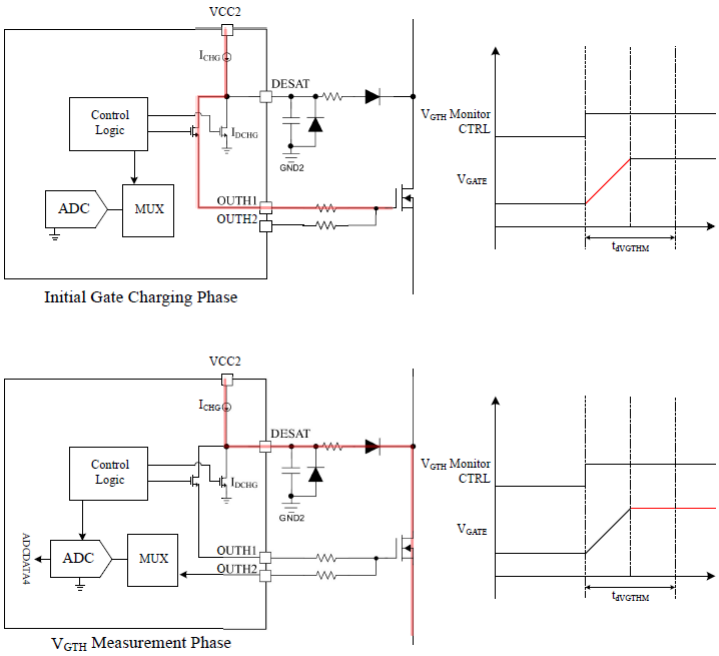

Figure 6-29. V_{GTH} Monitoring Circuit and Process

Figure 1-3. Monitoring Circuit and Progress

The ADC readings for cases with and without DS short are shown in Table 1-1, and the test waveform are shown in Figure 1-4.

Table 1-1. Comparison of voltage sampling with and without DS short

Item	ADC Value
Without DS short	The ADC value can be calculated using the equation in Datasheet section 6.3.5.7 Power Switch Threshold Measurements (VGTH)
With DS short	Gate voltage will be close to 0

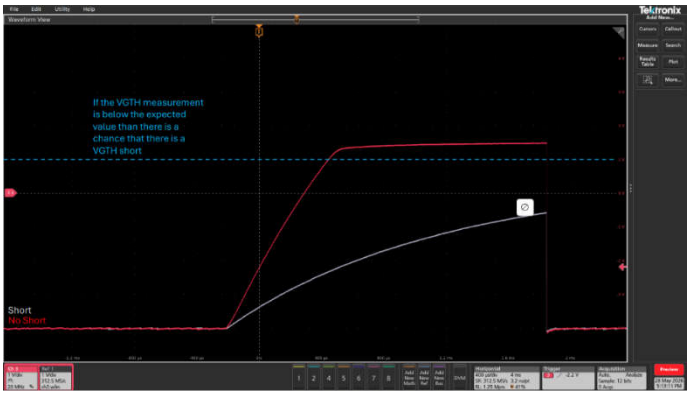

Figure 1-4. Comparison of Voltage Sampling With and Without DS Short

Hardware Circuit Design

DESAT detection loop are shown in #none#, UCC5880 DESAT pin is connected to IGBT collector through current-limiting resistor and fast recovery diode. The current-limiting resistor controls the detection current at microampere level, the fast recovery diode isolates reverse high voltage, and the filter capacitor suppresses interference to verify stable voltage sampling. The ADC values will differ based on your system and module condition and we recommend following the datasheet to keep the device within datasheet specifications.

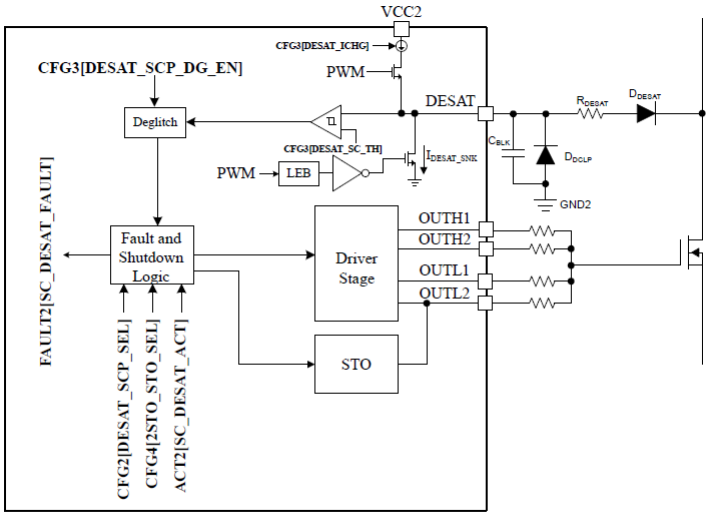

Figure 6-32. Block Diagram for DESAT Function

Figure 1-5. Block Diagram for Desat Function

1.3 SW Configuration Mode Detection Process

The main SW configuration is shown as follows:

1. System initialization: The main control MCU powers on and initializes UCC5880, enables SPI communication, sets the chip to configuration mode.
2. Parameter configuration: Configure DESAT detection threshold, ADC sampling parameters, fault blanking time and fault latch enable through SPI.
3. Detection loop startup: UCC5880 turns on DESAT detection loop, applies weak detection voltage, and waits for voltage signal stabilization.
4. Voltage sampling and judgment: The built-in ADC samples DESAT pin voltage and compares it with the preset threshold:
   a. Sampling voltage > failure threshold: IGBT module is normal.
   b. Sampling voltage ≤ failure threshold: IGBT module has short-circuit failure.
5. Fault handling:
   a. If normal, exit configuration mode and the system can start normally;
   b. If failed, latch the fault and upload fault signal.
6. Fault reset: If the fault disappears, the MCU sends a reset command through SPI to clear the fault latch and execute the detection process again.

1.4 Key Configuration Parameters

The key configuration parameters can refer below:

1. DESAT failure detection threshold: flexibly adjusted according to IGBT models;
2. ADC sampling mode: 10-bit high-precision DESAT voltage channel sampling;
3. Fault blanking time: filter interference signals to avoid false detection;
4. Drive output latch: INP input is ignored to prevent unknown behavior in configuration mode.
5. High reliability: Excellent isolation performance and anti-interference ability, preferred for harsh industrial and vehicle working conditions.

2 Test Results

This section summarizes the experimental waveform of DS short-fault detection based on the UCC5880-Q1 Iso gate driver IC. The test waveform reflect that the UCC5880 can accurately detect drain-source short-circuit events within the expected time window.

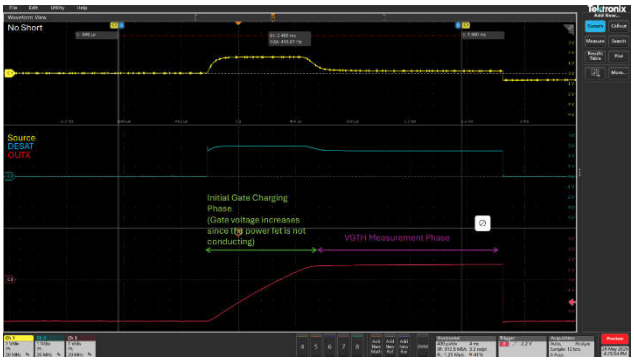

Figure 2-1. Without DS Short Test Waveform

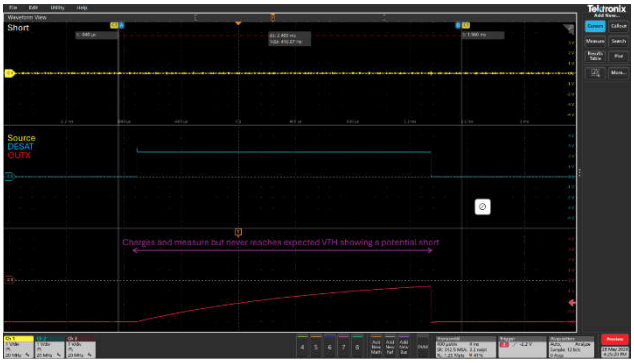

Figure 2-2. With DS Short Test Waveform

3 Summary

This scheme realizes accurate non-destructive detection of IGBT module short-circuit failure in configuration mode based on TI UCC5880 isolated driver chip, which can help customer to achieve pre-safety detection requirements for short circuit failure. It fundamentally eliminates secondary accidents caused by module failure, greatly improves the functional safety and operational reliability of inverter systems.

4 References

1. Texas Instruments, *UCC5880-Q1 Isolated 20A Adjustable Gate Drive IGBT/SiC MOSFET Gate Driver With Advanced Protection Features For Automotive Applications*, datasheet.

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