Application Note

Achieving Fast Short-Circuit Recovery Using BQ76952

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ABSTRACT

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The BQ76952 family of analog front ends (AFEs) is widely used in battery management system (BMS) solutions for various applications — such as BBUs, electric two-wheelers, power tools, and residential energy storage systems — owing to its high sampling accuracy, integrated high-side drivers, low power consumption, rich protection features, support for random power-up sequencing, compatibility with 3-16S batteries, and strong cell balancing capabilities. This paper introduces the short-circuit protection recovery mechanism of the BQ76952 based on internal configurations and proposes a method to achieve fast short-circuit recovery suitable for application scenarios with specific timing requirements for short-circuit recovery and hiccup mode operation.

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1 Introduction

Short-circuit protection is one of the most critical functions of an AFE, serving to safeguard the safety and reliability of the battery and the entire BMS system during short-circuit conditions. Typically, short-circuit trip delay is a key performance metric for evaluating short-circuit protection, aiming to execute rapid short-circuit protection to secure the entire system. Meanwhile, false triggering caused by capacitive loads must also be avoided. However, in certain applications such as high-power low-side discharge scenarios, short-circuit recovery delay is equally important and warrants careful attention. This paper analyzes the built-in short-circuit protection mechanism of the BQ76952 and proposes a recovery approach based on System Config mode for scenarios requiring fast short-circuit recovery.

2 Short-Circuit Recovery Mechanism of BQ76952

2.1 Short-Circuit Recovery Mechanism of BQ76952

The BQ76952 device integrates short circuit in discharge (SCD) protection using a dedicated comparator that monitors the differential voltage between the SRN–SRP pins and triggers an SCD alert or fault when the voltage exceeds a programmable threshold VSCD. The VSCD threshold is programmable to 10mV, 20mV, 40mV, 60mV, 80mV, 100mV, 125mV, 150mV, 175mV, 200mV, 250mV, 300mV, 350mV, 400mV, 450mV, and 500mV, and is set by the **Protections:SCD:Threshold** configuration register. SCD protection can be enabled using the **Settings:Protection:Enabled Protections A:[SCD]** configuration bit.

类别	子类别	名称	类型	最小值	最大值	默认值	单位
Protections	SCD	Threshold	U1	0	15	0	—

When a short-circuit event is first detected, the SCD circuit triggers an alert signal and subsequently triggers a fault after a programmable detection delay **SCD_DLY**, which can be set to fastest, or set from 15μs to 450μs in 15μs steps. The fastest setting detects a short circuit using only the comparator delay, which can be less than 1μs depending on threshold overdrive. This delay is configured via the **Protections:SCD:Delay** configuration register. When an SCD fault is triggered, the device turns off the DSG FET if autonomous FET control is configured in **Settings:Protection:DSG FET Protections A**. The CHG FET may also be autonomously disabled based on the settings in **Settings:Protection:CHG FET Protections A**. After a programmable delay given by **Protections:SCD:Recovery Time**, the device recovers (if configured for autonomous recovery).

类别	子类别	名称	类型	最小值	最大值	默认值	单位
Protections	SCD	Recovery Time	U1	0	255	5	s

2.2 BQ76952 Short-Circuit Recovery Time

However, in practical scenarios, even if we configure **Protections: SCD:Recovery Time** to the minimum value of 0, a significant short-circuit delay still exists (approximately 1s). This delay is caused by the combination of firmware execution and FET EN delays. Under normal circumstances, this delay time is safe, preventing potential circuit damage and battery loss caused by excessively rapid recovery times. However, in specific scenarios, this delay may prevent certain system functions from being realized.

In BMS systems without a pre-discharge circuit, hiccup startup is required to detect capacitive loads on the load side; under normal conditions, repeated short discharges during hiccup mode determine whether the Pack-side voltage can rise to a safe threshold, thereby distinguishing capacitive loads from short-circuit events. However, when the system has a large capacitive load or experiences quiescent current/self-discharge, excessively long discharge intervals prevent the Pack-side voltage from establishing properly, resulting in false identification of a short-circuit event.

Figure 2-1 shows the startup waveforms of the BQ76952 simulating a large capacitive load and self-discharge condition. The system is set to a battery voltage of 12V, a capacitive load of 470uF, and a self-discharge current of 5mA. The BQ769562 short-circuit protection threshold is configured to 2.5A, the short-circuit recovery time is set to 0, and the DDSG pin is configured as 0xA2 synchronized drive signal. As shown in the figure, the BMS Pack-side voltage waveform pack fails to build up due to self-discharge, causing the discharge FET drive waveform DDSG to repeatedly trigger shutoff, ultimately leading to startup failure.

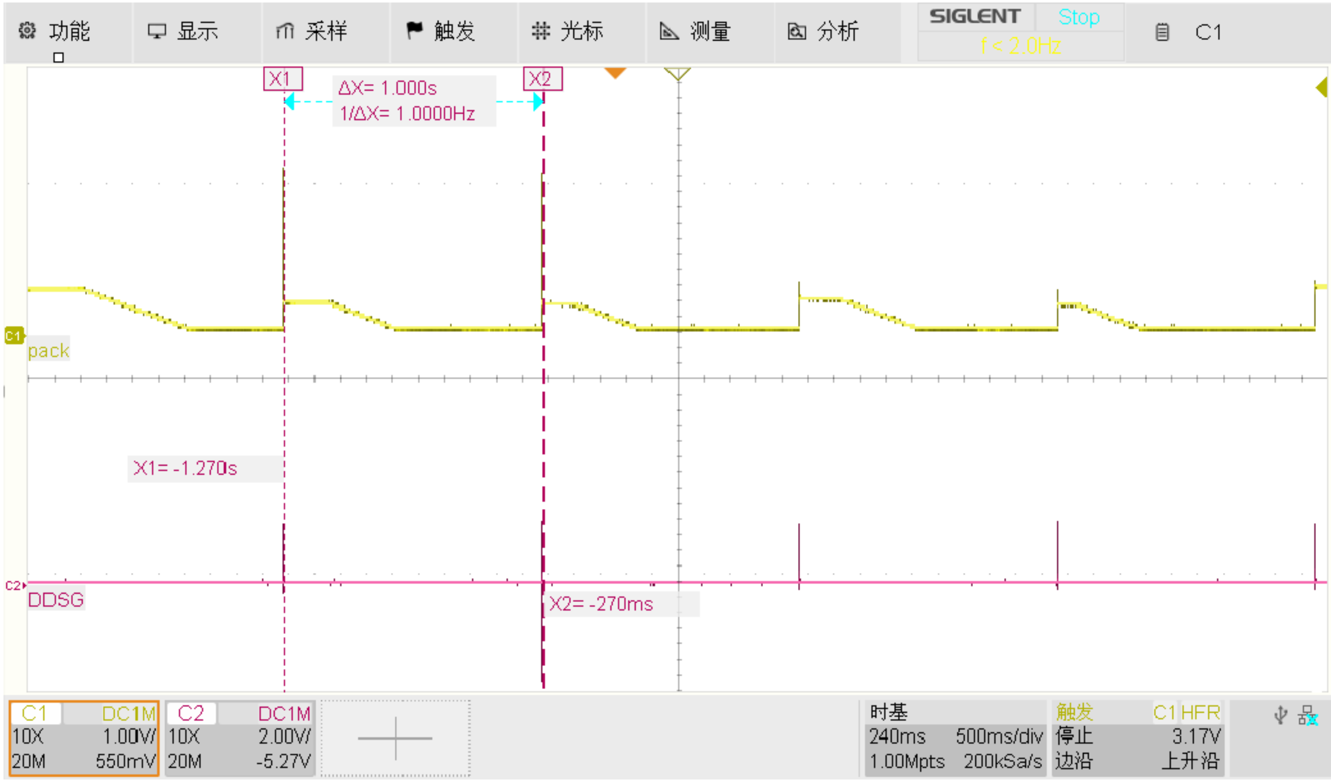


Figure 2-1. BQ76952 Short-Circuit Recovery Time

3 Introduction to Recovery Method via CONFIG UPDATE + FET TEST

This section introduces a method to achieve fast short-circuit recovery using the Config Update and FET TEST functions. This approach resets short-circuit protection alerts via Config mode and rapidly turns on the discharge FET (DSG FET) via the FET TEST function. The following sections first provide a detailed introduction to these two functions.

3.1 Overview of CONFIG UPDATE and FET TEST Functions

CONFIG_UPDATE is a special mode used to modify data memory settings. In this mode, the device automatically turns off protection FETs and suspends normal firmware operation as well as all measurement and protection monitoring. The host can then modify data memory settings (by writing data directly to RAM or instructing the device to program RAM data into OTP). The basic steps are as follows:

1. Place the device into CONFIG_UPDATE mode by sending the 0x0090 ENTER_CFG_UPDATE() subcommand. If the FETs are in the ON state, the device automatically disables them.
2. Wait for the 0x12 Battery Status()[CFGUPDATE] flag to be set.
3. Modify settings as needed by writing updated data memory settings (refer to Data Memory Access for more information).
4. Send the 0x0092 EXIT_CFG_UPDATE() command to resume firmware execution.

FET control is divided into two modes: autonomous control mode (Settings:Manufacturing:Mfg Status Init[FET_EN]=1) and test mode (Settings:Manufacturing:Mfg Status Init[FET_EN]=0). In both modes, FET actions can be controlled by the host.

FET TEST is a command used to test FET state toggling. Under this command, the device will not enable FETs unless a FET test subcommand is sent. In this mode, the device can still enable FETs based on body diode protection. The 0x0022 FET_ENABLE() subcommand can be used to toggle the [FET_EN] bit setting. The FET test subcommands are shown below:

子命令	说明
0x001C PDSGTEST()	仅在 FET 测试模式下起作用，切换 PDSG FET 状态
0x001E PCHGTEST()	仅在 FET 测试模式下起作用，切换 PCHG FET 状态
0x001F CHGTEST()	仅在 FET 测试模式下起作用，切换 CHG FET 状态
0x0020 DSGTEST()	仅在 FET 测试模式下起作用，切换 DSG FET 状态

When using FET TEST, note the following points:

1. In FET test mode, only DSGTEST(), CHGTEST(), PDSGTEST(), and PCHGTEST() can be used to control FET turn-on or turn-off; the AFE responds faster to FET test subcommands
2. DSG_PDSG_OFF(), CHG_PCHG_OFF(), ALL_FETS_ON(), ALL_FETS_OFF(), and FET_CONTROL() cannot be used in FET test mode
3. Enabled protections will also automatically turn off or recover FETs, with enabled protections having the highest priority in determining FET switching states
4. Body diode protection will also automatically turn FETs on or off
5. The AFE will not automatically turn off the CHG FET in sleep mode (Settings:FET:FET Options [SLEEPCHG]=0)
6. Automatic transition from Precharge/Predischarge mode to Charge/Discharge mode will not occur

In the following section, this paper details how to achieve fast short-circuit recovery using the CONFIG UPDATE and FET TEST functions.

3.2 Basic Concept and Detailed Steps of Fast Short-Circuit Recovery

Achieving fast short-circuit recovery on the BQ76952 involves two key requirements. First, the fault state machine must be reset rapidly; second, the DSG FET must be turned on quickly while maintaining reliable protection. The detailed steps and explanations are provided below:

- **Step1:** MCU monitors Safety Status A and waits for the short-circuit event (SCD) to trigger
- **Step2:** Disable the FET_EN function to ensure subsequent FET_TEST functions trigger correctly

- **Step3:** Enter Config Update mode, disable short-circuit protection, reset the fault state machine, and exit Config Update
- **Step6-9: Re-enable short-circuit protection in** Config Update mode to ensure future short-circuit events trigger protection properly.
- **Step10:** Use the FET TEST command to turn on the DSG FET; at this time, the FET remains governed by protection functions.
- **Step11:** Re-enable FET_EN, allowing the BQ76952 to resume autonomous control.

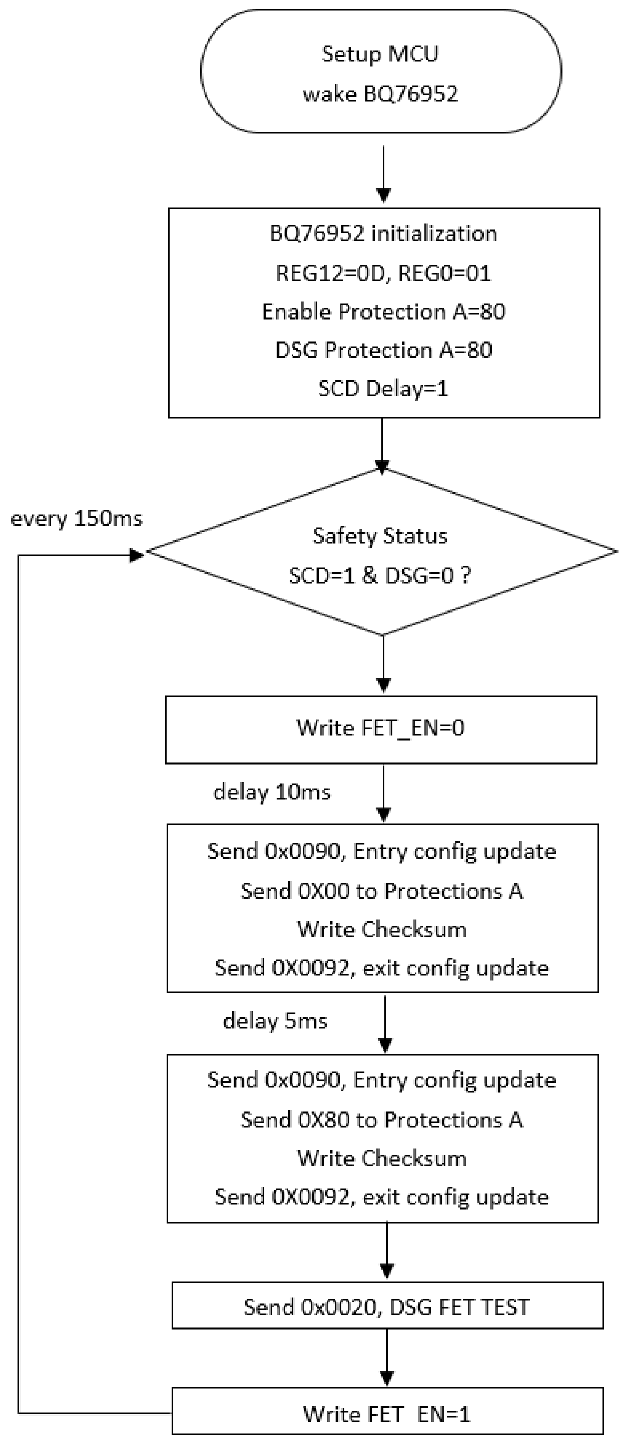


Figure 3-1. Program Flowchart for Fast Short-Circuit Recovery

4 Experimental Setup and Results

This test utilizes the BQ76952EVM, a DC load, and a DC power supply; the specific wiring diagram is shown below:

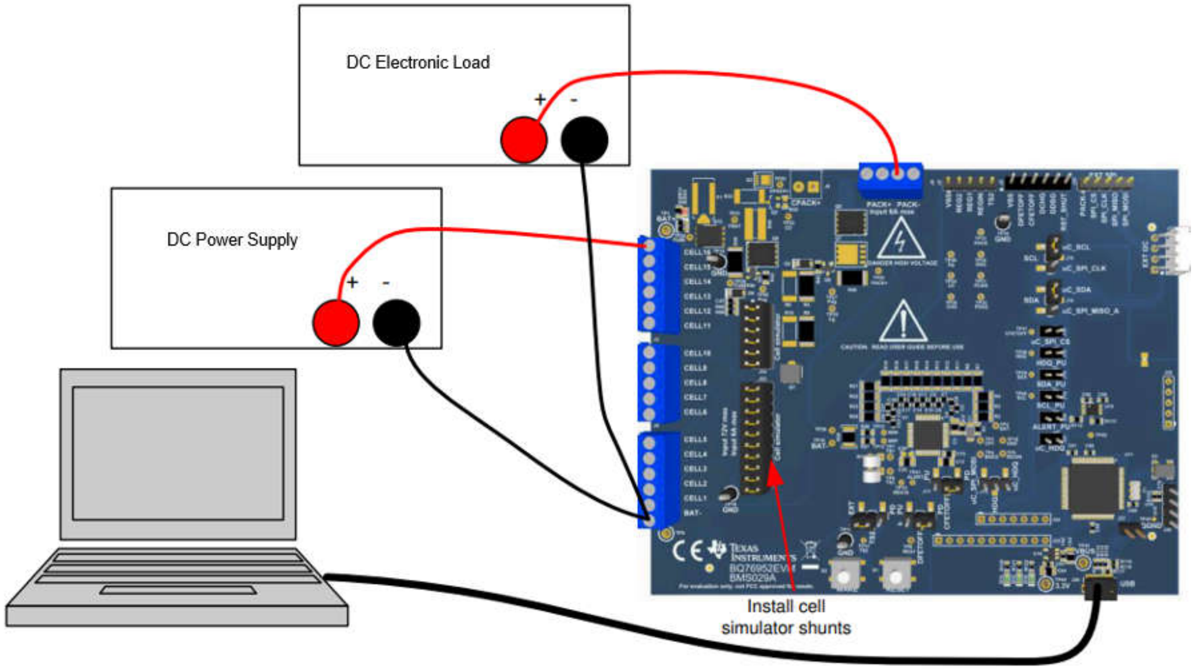
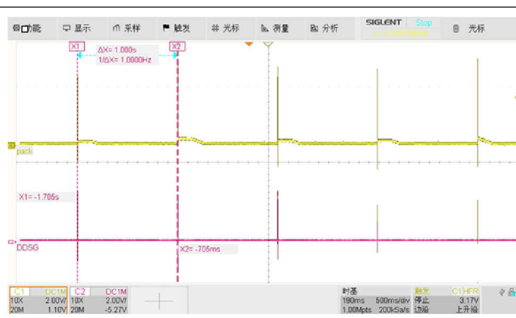
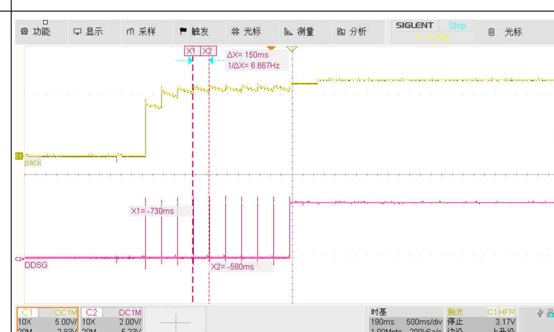


Figure 4-1. BQ76952 Wiring Diagram & Experimental Setup

As shown in Figure 4-1, the DC Power Supply provides battery-side power, while the DC Electronic Load is used to simulate Pack-side quiescent current, with a 470uF capacitor configured at the electronic load side to simulate a capacitive load. Configured with Vin=12V, SCD Threshold=2.5A, SCD delay=50us, and electronic load set to 5mA, this experiment compares the recovery delays between autonomous chip recovery and the Config Update method.

Table 4-1. BQ76952 Short-Circuit Recovery Comparison Results

	Autonomous Recovery	Fast Recovery
Delay Time	1000ms	150ms
Test Waveforms		

As shown in Table 4-1, DDSG represents the discharge FET drive signal, and Pack represents the Pack-side voltage waveform. Under autonomous short-circuit recovery of the BQ76952, the recovery time is fixed at 1s, and the Pack-side voltage fails to establish due to the capacitive load and quiescent current, leading to false identification of short-circuit events; using the method introduced in this paper, the delay time does not depend on the BQ76952 autonomous recovery time, but rather on the 150ms loop interval configured in the program for detecting SCD events, which can be adjusted according to design needs to satisfy system requirements.

The reference pseudo-code is as follows:

```
if(gTaskSCD)// every 150ms enter
{
    SafeyStatusA = BQ769x2_ReadStatusA();

    DDSG_Status = DL_GPIO_readPins(GPIOA, DDSG_PIN_0_PIN);

    if((SafeyStatusA & 0x80) && (DDSG_Status == 0x00))
    {
        CommandSubcommands(SET_CFGUPDATE);

        BQ769x2_SetRegister(EnabledProtectionsA, 0x00, 1);

        CommandSubcommands(EXIT_CFGUPDATE);

        CommandSubcommands(FET_ENABLE);

        CommandSubcommands(SET_CFGUPDATE);

        BQ769x2_SetRegister(EnabledProtectionsA, 0x80, 1);

        CommandSubcommands(EXIT_CFGUPDATE);

        CommandSubcommands(DSGTEST);

        CommandSubcommands(FET_ENABLE);

        CommandSubcommands(SLEEP_DISABLE);
    }
```

5 Conclusion

The BQ76952 device family offers a comprehensive set of protection features. This paper provides an alternative fast short-circuit protection recovery approach based on FET TEST mode to accommodate diverse requirements in BQ76952 BMS applications. For device and configuration details, please refer to the datasheet and technical reference manual.

6 References

1. *BQ76952 3-Series to 16-Series High-Accuracy Battery Monitor and Protector for Li-Ion, Li-Polymer, and LiFePO4 Battery Packs Datasheet (Rev. B)*
2. *BQ76952 Technical Reference Manual (Rev. B)*
3. *Using Low-Side FETs with BQ769x2 Battery Monitor Family (Rev. A)*
4. *Microcontroller Code Examples for BQ769x2 Battery Monitors*