Texas Instruments

Application Report
SLUA805–February 2017

Fault Monitoring for High-Availability Systems Using the bq769x0

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ABSTRACT

The bq769x0 monitor family provides a complete solution of monitoring and protection for battery voltage and current related faults, but also protects the battery system by self-monitoring for internal hardware faults. There are high-availability applications, such as in a drone battery management system, where this unexpected FET turn off is undesirable. In such applications, faults like XREADY, which are caused by an internal hardware fault but turns off the power FETs, are undesirable. This document covers an example how one might add additional conditions to faults, such as XREADY in the bq76930 and bq76940, and presents design considerations to help designers implement them.

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1 Introduction

The bq769x0 monitor family can protect the battery from faults but it lacks the ability to mask those faults. This can become an issue when it comes to the XREADY fault protection present in the bq76930 and bq76940 as it will disable both the CHG and DSG FETs, which cuts the power to the load. Because the bq769x0 cannot mask a fault, any protection implemented by this monitor might be undesirable. With the addition of an MCU host is it possible to bypass the faults and create system-appropriate responses. This allows the bq769x0 to monitor the status of the battery but not interrupt its function without meeting additional criterion.

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2 Circuit Block Diagram

Figure 1 shows a block-level implementation of bypassing XREADY. This circuit implements the bq769x0 as a monitor with an MSP430 as the MCU for the host. This circuit also implements the bq2970 for short-circuit protection. In this application, the bq769x0 does not control the power FETs but instead the MSP430 is the power FET controller. This is evident by having the CHG and DSG pins of the bq769x0 open and not powered. By having the MCU control the power FETS, its processing capability can be used to add additional requirements before opening or closing the CHG and DSG FETs. With the MSP430 controlling the power FETs, there is additional level translation and driver logic that is needed due to the voltage requirement needed to drive power FETs with a high-current capability.

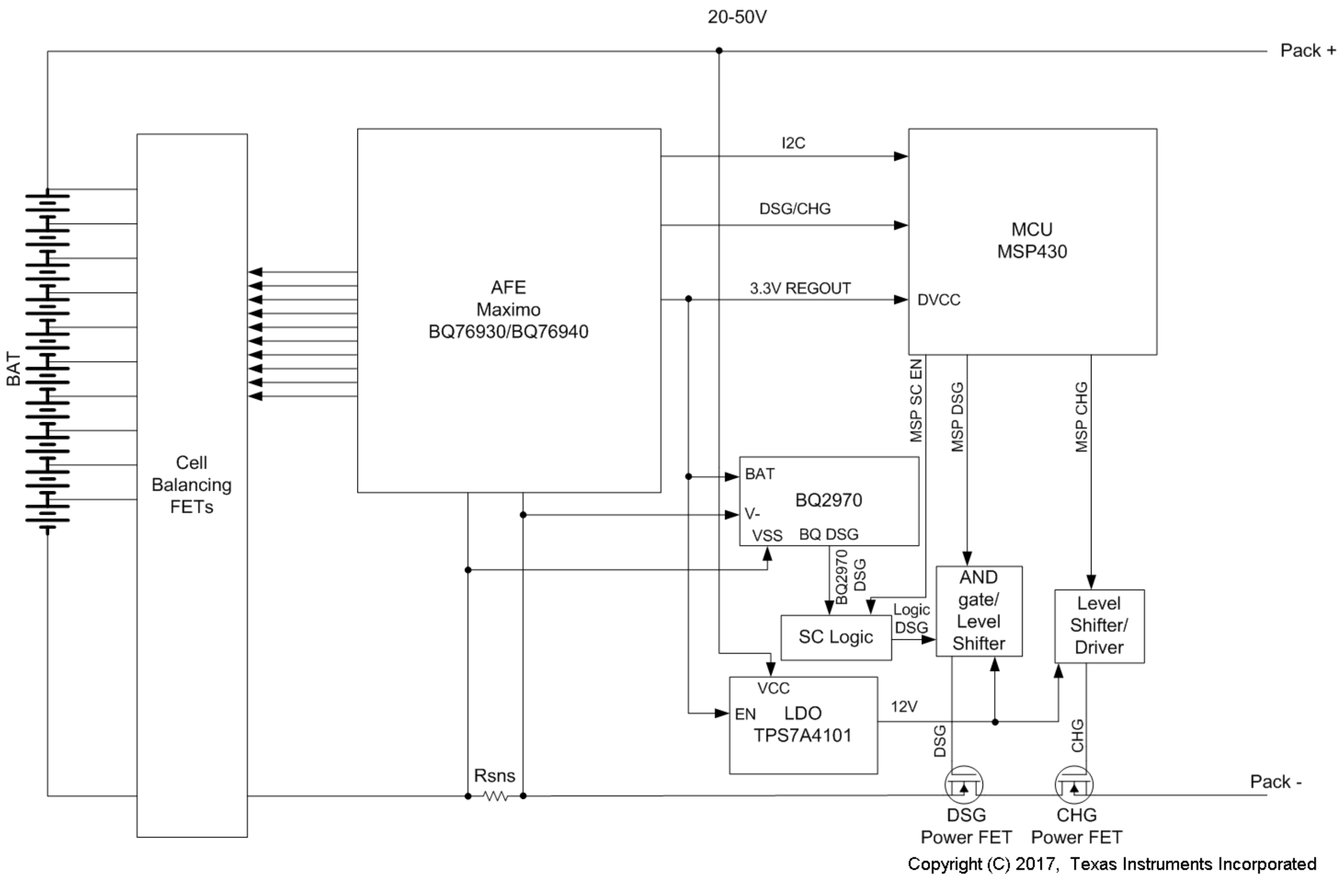

Figure 1. Circuit Block Diagram

3 Faults and Delays

When using an MSP430 as the FET controller, the delays for fault protection are different because of latency of the MSP430 code. This comes into effect when checking for an XREADY fault situation prior to any FET changes. Depending on how the XREADY fault was triggered, there can be situations where multiple faults are on in addition to XREADY and therefore, faults need to be ranked according to importance. Since XREADY can fault due to the upper cells in a battery, it is necessary for the ADC to have read and verified the voltage readings prior to proceeding. Depending on the application, there might be a need for a delay after reading the initial signal to ensure that XREADY was not triggered along with other faults. The MCU can provide different levels of protection depending on the system mode of operation.

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Using the MSP430 as a FET controller we gain the benefit of adding different conditions for faults. While this document is focused on masking XREADY, in certain systems one might want to change the conditions for different faults, or the system response to the fault, or both. For example, in a drone application an undervoltage (UV) or overvoltage (OV) fault might not warrant a shutdown, instead letting the user decide the appropriate action. For those situations, similar techniques can be applied as presented in this document. In this system the main communication for fault checking is the MSP430 polling the SYS_STAT register of the bq769x0. It is also possible to use the DSG and CHG pins as interrupts for the MSP430 for a quicker response time. Figure 2 shows a possible example of a fault procedure to mask XREADY.

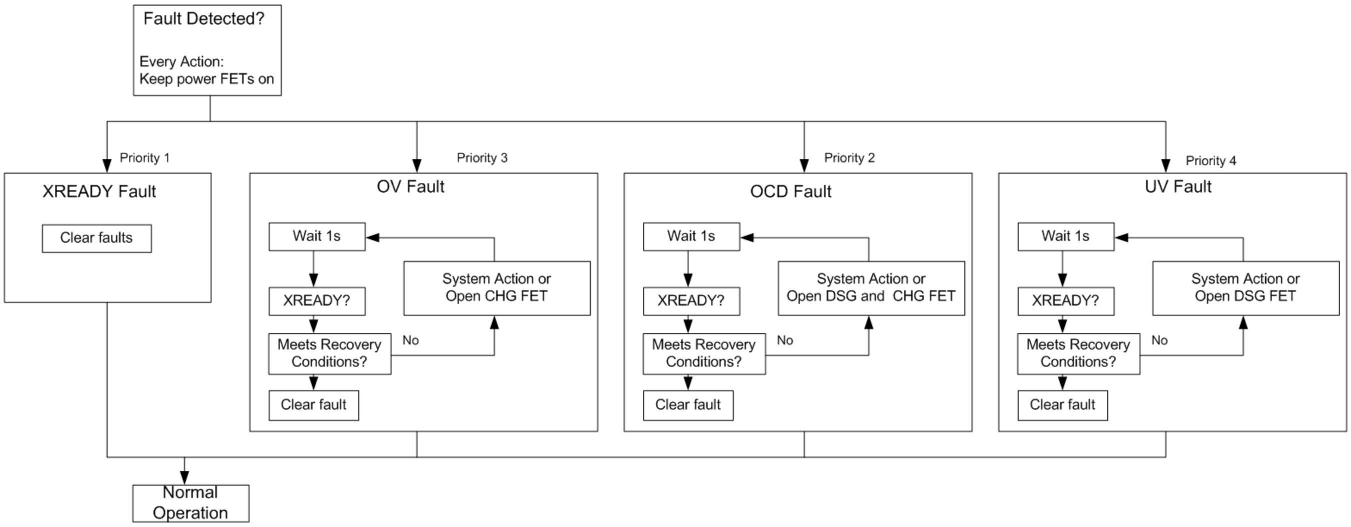

Figure 2. Programming Logic Example

The MSP430 is able to adequately protect the battery by switching the appropriate FETs on or off. In terms of an OV or UV it can toggle adequately, as shown in Figure 3 and Figure 4. In these graphs the FET pins of the bq769x0 CHG and DSG pins are turned on for display purposes to show the difference in timings of the FETs, but would otherwise remain off because the MCU is doing the power FET control. It is important to note that the SYS_STAT registers in the bq769x0 toggle after the set delay for each fault. For quicker response time from the MSP430 it would be necessary to lower the delays on the bq769x0. For accuracy, it might be necessary to take into the account the processing delays and register data acquisition methods.

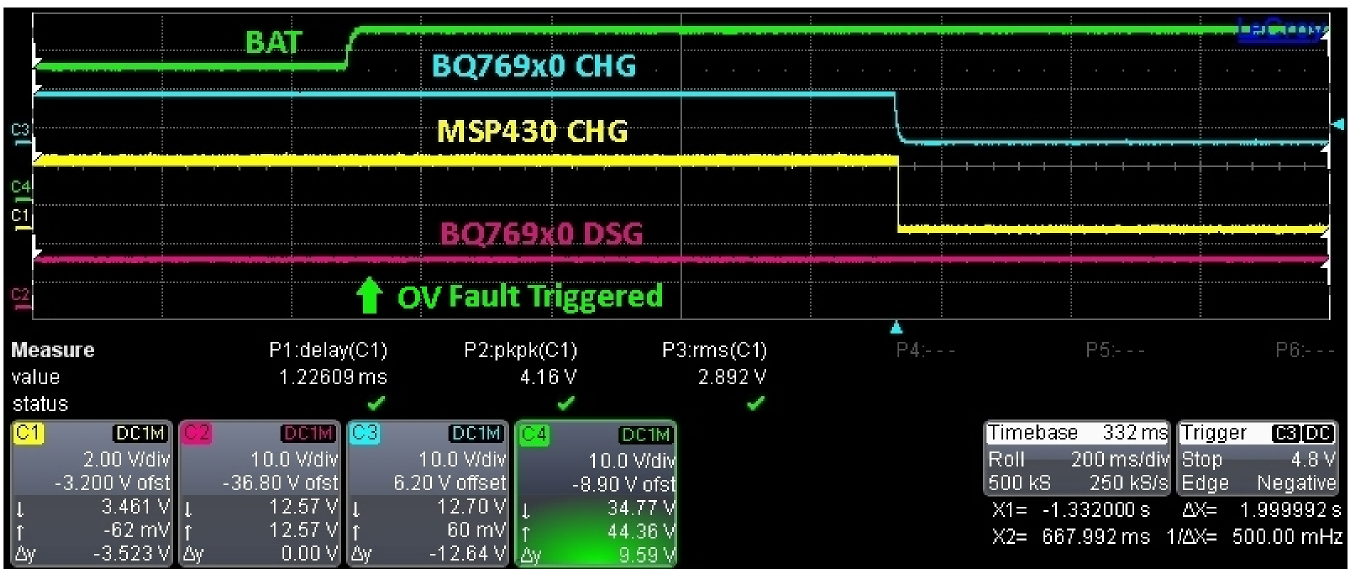

Figure 3. Overvoltage Fault

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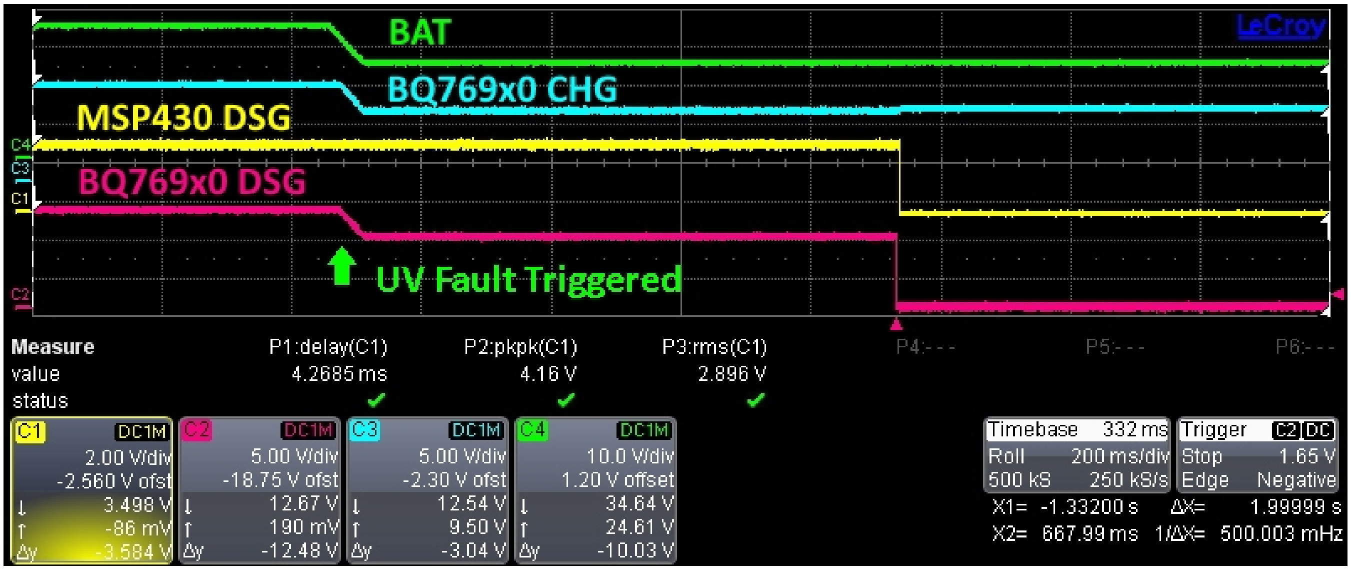

Figure 4. Undervoltage Fault

The main goal of the circuit in Figure 1 is to keep XREADY from turning off the FETs. Without an MSP430 to control the FETs, the bq769x0 would toggle both the charge and discharge FETs off in the event of an XREADY fault. When given adequate time, the MSP430 is able to see this fault and act accordingly. In Figure 5 the MSP430 was able to detect that an XREADY fault had occurred but did not turn off the FETs and therefore ignored the fault. Note that the delay between XREADY and the CHG and DSG outputs going low is expected.

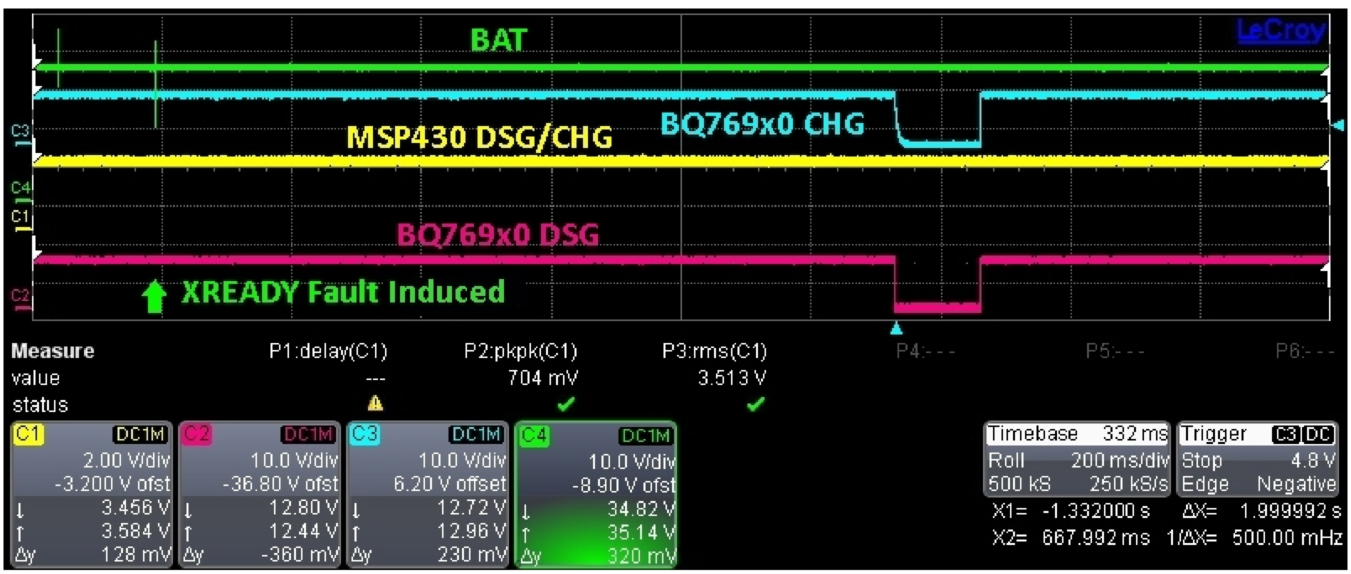

Figure 5. XREADY Fault

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Due to the additional delays because of the MCU latency, short-circuit (SC) faults that need a 1 ms or quicker response time will not be able to trigger within the time frame. Due to this, a bq2970 is implemented to run in parallel to check for SC faults. The bq2970 in this application has the same functionality as a current sense amplifier with a comparator but in a smaller size and lower cost. One of the benefits of using a bq2970 is that it is able to run off of the REGOUT pin of the bq769x0 along with the MSP430. This removes any additional power converters needed to power these devices. The OV and UV faults of the bq2970 will never trigger since the BAT input of the device is connected to REGOUT of the bq769x0. As the bq2970 is used only for its SC fault capability in this application, it is necessary to raise the OCD threshold so that it does not trigger.

The bq2970 SC fault detection works by comparing V_{SNS}, measured between VSS and the V- pin, to a preprogrammed threshold in the bq2970. If the threshold is reached, then the bq2970 will turn off its DSG pin which will turn off the power DSG FET. In this situation the sense resistor (R_{SNS}) of the bq769x0 is used to create this voltage difference to trigger the bq2970. This device has a short 250-µs SC delay which is comparable to the bq769x0 SC delay.

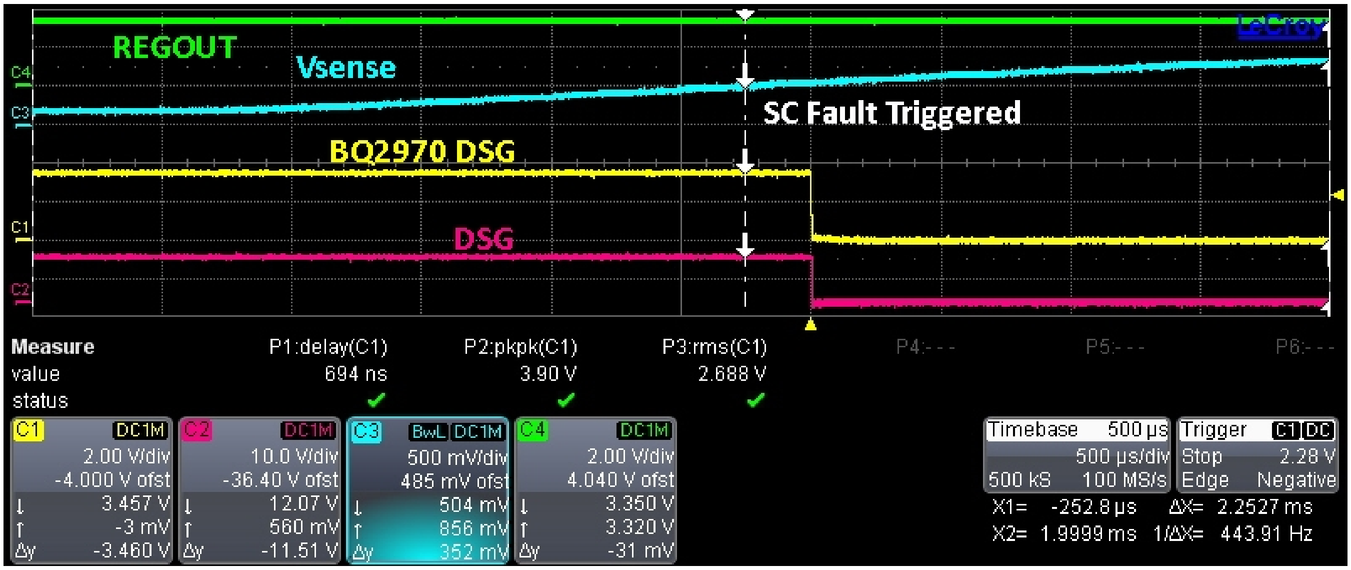

Figure 6. Short-Circuit Fault

One additional consideration is that the bq2970 and MSP430 pins are limited by REGOUT. This causes the FET pins to toggle at a max of 3.3 V which is not enough to drive a power FET to saturation and so the use of a level shifter is needed. This makes it necessary to include an LDO to power the voltage translation circuitry. In the circuit diagram (Figure 1), this is shown as a TPS7A4101, this is an LDO that is connected to the top battery cell with an enable feature for lower power consumption.

4 Recovery

The MCU is the host of the bq769x0 and is responsible for clearing the registers and toggling the power FETs by using its GPIO. This part of the host's responsibility is left unchanged in this application. In the SC protection side, the bq2970's autorecovery feature might create issues if it is not taken into account. This is because the bq2970 SC fault recovery feature tries to recover 8 ms after the fault occurred and might turn on the power FETs prematurely. With 2 protection devices, the MSP430 and the bq2970, working in parallel, the additional logic to combine both of the controls is shown in the Figure 1 as SC Logic. This example recovery logic takes advantage of the bq2970 autorecovery and makes sure the MSP430 is required for recovery.

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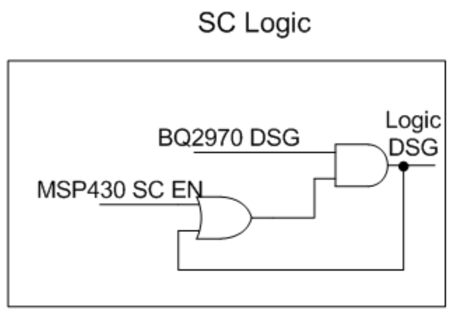

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Figure 7. SC Logic Example

5 References

For additional information, refer to the following documents, available at www.ti.com .

- *bq769x0 3-Series to 15-Series Cell Battery Monitor Family for Li-Ion and Phosphate Applications* data sheet (SLUSBK2)
- *bq76930 and bq76940 Evaluation Module* (SLVU925)
- *10s Battery Pack Monitoring, Balancing, and Comprehensive Protection. 50A Discharge Reference Design* (TIDUAR8)

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