Application Report
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bq769x0 BMS Configurations for Cordless Appliances

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ABSTRACT

The bq769x0 monitor family is suitable for cordless appliance battery management systems (BMS), such as robotic vacuums, due to its versatility in cell count and its high integration of features. It is often not clear how to design a BMS system due to the multitude of options and different design considerations. This document covers the basics of designing a BMS system and its related circuitry by using the bq769x0 device and presenting different examples and options for monitor configuration, protection, and the battery management controller. By selecting between the different examples, a designer will have designed a BMS schematic using the bq769x0 that can be used for 5 to 7 cell counts but the techniques can be applied to higher cell counts in the bq769x0 family. Project collateral discussed in this application report can be downloaded from the following URL: www.ti.com/lit/zip/SLUA810.

Contents

List of Figures

List of Tables

1 Introduction

There is a growing trend in cordless appliances, such as robotic vacuums, to have a decrease in size, and increases in power, safety, and battery life. Because of this, it is now common to see BMS implemented into the robotic vacuum market in which battery packs typically have 5 to 7 cells.

The bq769x0 family of monitors is the optimal solution for this application due to its many benefits such as:

- Cell count scalability
- Board scalability
- ADC integration
- Coulomb counting integration
- Low power consumption
- Passive cell balancing

These many benefits help reduce potential BOM cost, increase battery life, and create a smaller solution size. While the benefits of integrating a BMS into a cordless appliance are clear, it is often not clear how to develop a BMS system. Figure 1 shows an example BMS block diagram and Table 1 lists all the different customization options that will be discussed for it. From this BMS system and related circuitry, the designer can then expand, modify, and customize it to suit their system needs.

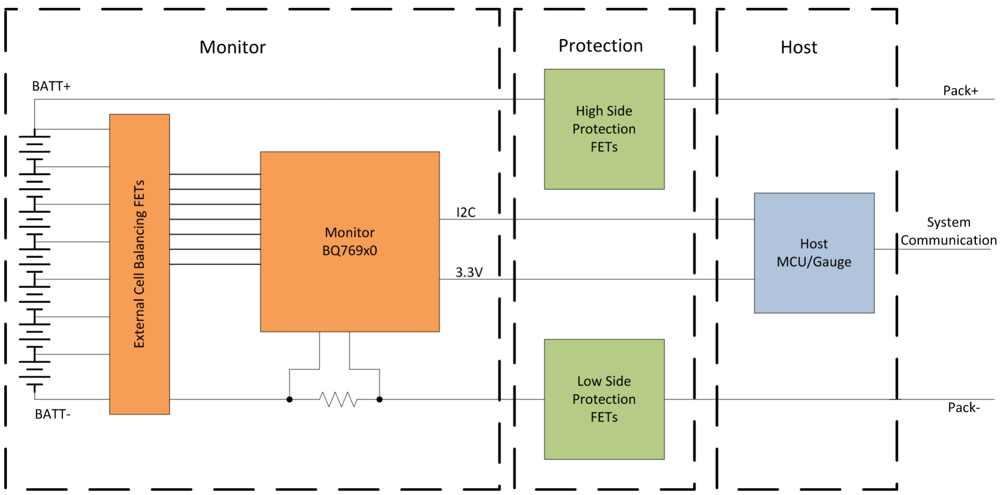

Figure 1. Circuit Block Diagram

Table 1. Customization Options

Monitor	Protection	Battery Management Controller
5S	No Protection FETs	bq78350
6S	Low-side Protection FETs using the bq769x0	MCU (MSP430 example)
7S	High-side Protection FETs using the bq76200	
5S with external FETs		
6S with external FETs		
7S with external FETs		

2 bq769x0 Monitor Configurations

2.1 bq769x0

For a BMS on a robotic vacuum, the bq769x0 monitor is a perfect fit due to its flexibility in implementation and highly integrated feature set. The integrated feature set includes ADCs and a coulomb counter which allows for rapid prototyping due to the reduced passive component count and ease of use. One of the biggest benefits of the bq769x0 family is its low power consumption which is due to the enabling and disabling of sub-blocks within the IC. In this section, there are examples of different cell configurations using the bq769x0 family to help with the design process. Aside from choosing the different cell count, it is necessary to scale the sense resistance value between pin SRP and SRN according to the required current thresholds.

2.2 Cell Configurations

As noted in the bq769x0 data sheet (SLUSBK2), section 8.1.1, the bq769x0 family is flexible in the number of cells. Each bq769x0 member has cell groups that are divided into sections of 5. For example, in the bq76920 there is only 1 cell group which is VC0-VC5 which is shown in Figure 3 while in the bq76930 there are 2 cell groups, VC0-VC5 and VC6-VC10. It is required that each cell group has a minimum of 3 cells connected. Because of this, the bq76930 cannot be used for 5S counts as, one of the cell groups will only have 2 cells connected, but the bq76920 can be used for 5S. In the case of unused cells, the unused cell pins are to be shorted to the highest-used VCx pins according to section 8.1.1 of the datasheet. Figure 3 and Figure 4 show the proper way to configure 6S and 7S cell count in the bq76930.

2.3 Internal Cell Balancing

Cell balancing is a critical feature for the run time of the device and the health of its cells as imbalanced cells are prone to overheating which can cause cell degradation. The bq769x0 family has integrated cell balancing FETs, which make it simple to implement cell balancing. This also lowers the number of external components required for balancing, which reduces the BOM cost and board area. When only using the internal FETs for cell balancing, the cell-balancing current is limited due to the size of the internal FETs and it might require more cycles to complete balancing in order not to exceed the package temperature rating. Low-pass filters are still required for the input of the cell pins that meet the requirements in section 6.3 of the datasheet. While boot switch is not shown, it is still necessary and SLUA769 goes over more detail on boot switch alternatives. Figure 2, Figure 3, and Figure 4 are examples of 5S, 6S, and 7S configurations using only the internal cell balancing.

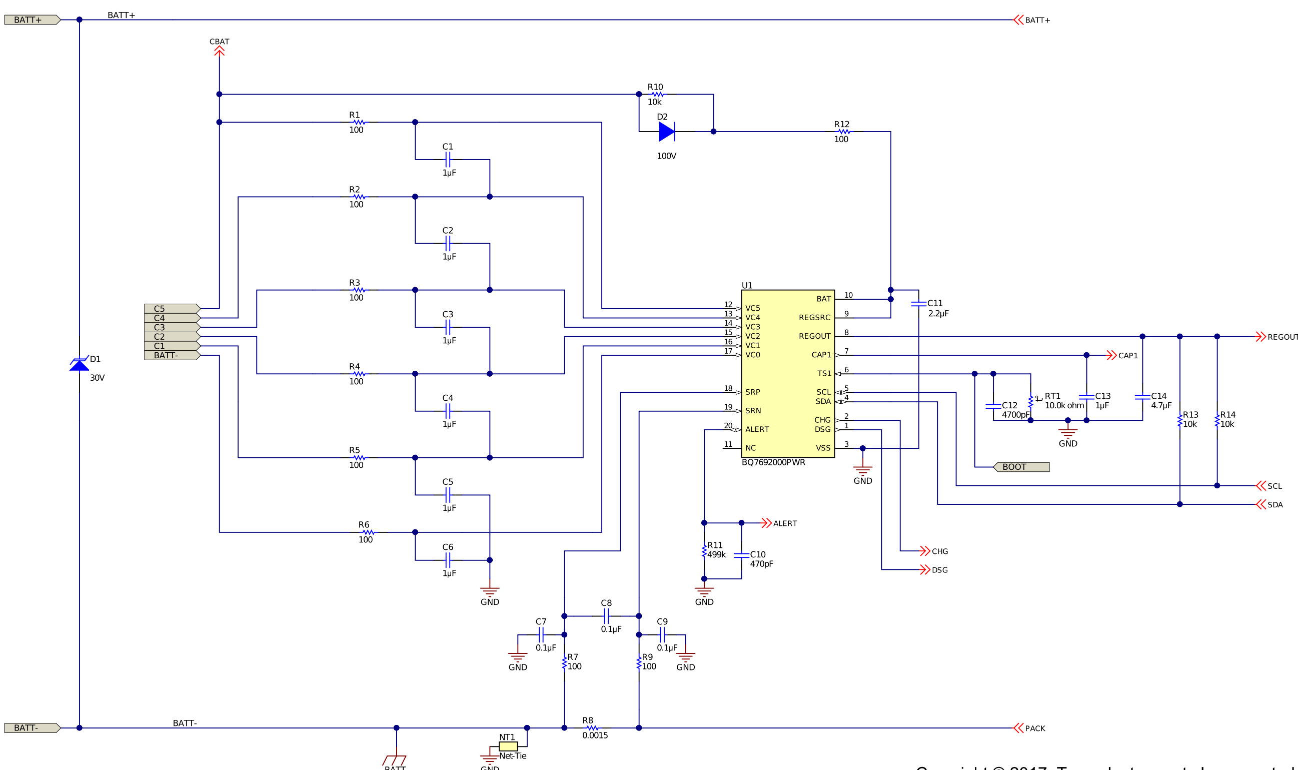

Figure 2. 5S bq76920 Configuration

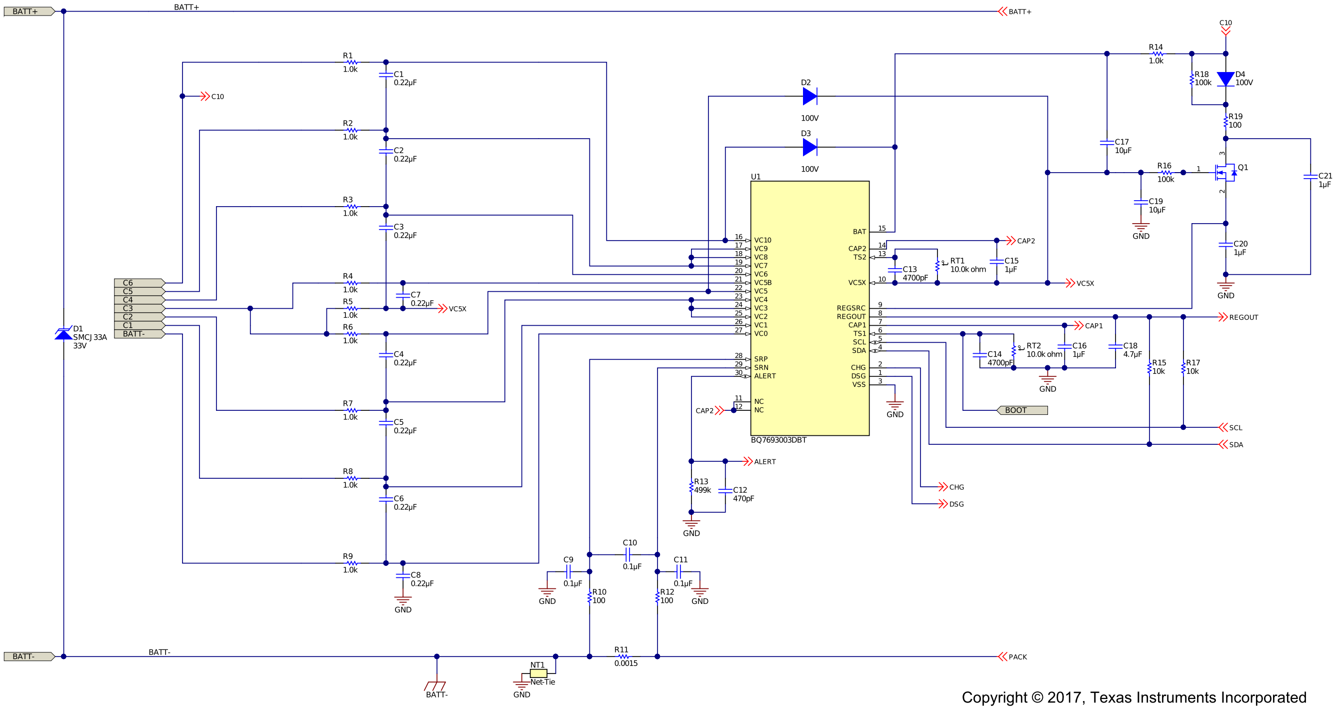

Figure 3. 6S bq76930 Configuration

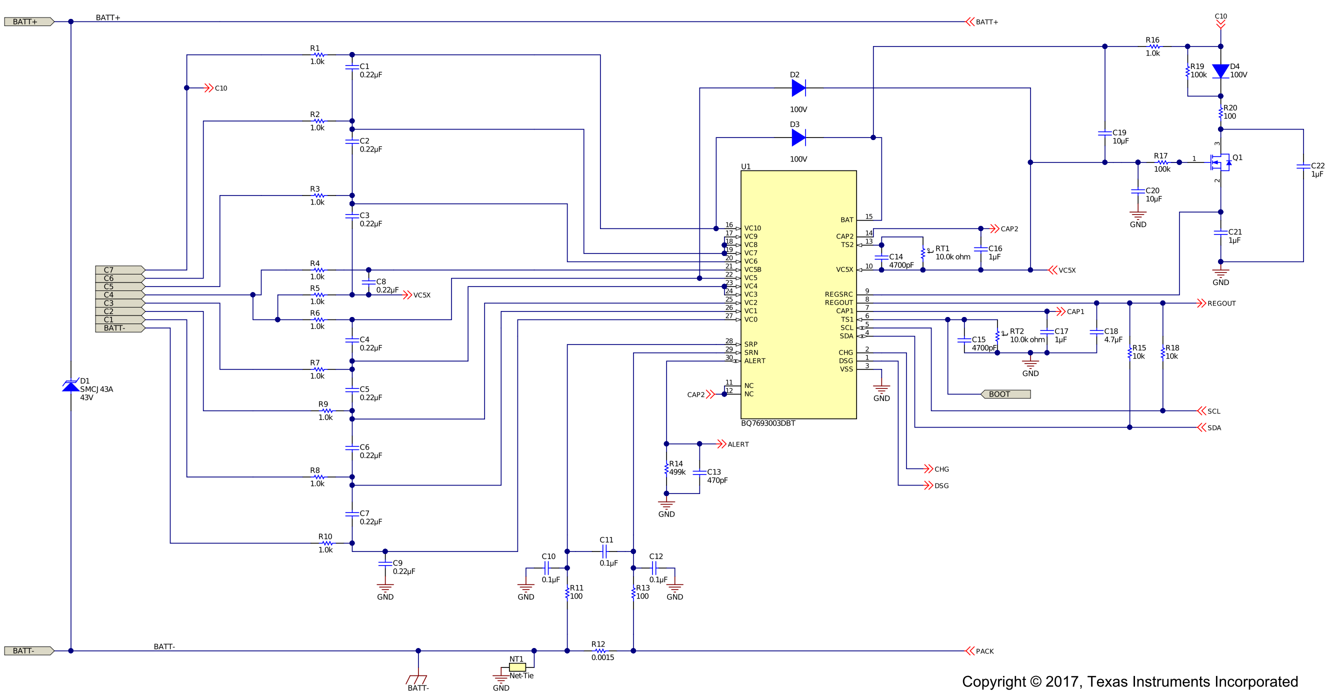

Figure 4. 7S bq76930 Configuration

2.4 External Cell Balancing

To speed up the cell balancing process, it is possible to implement external cell-balancing FETs on the bq769x0. For example, when using the bq78350 to control cell balancing, cell balancing activates during the charge phase of the cell. With a higher cell balancing current by using external FETs, the batteries will be able to recover from cell imbalance in less charge cycles. Figure 5, Figure 6, and Figure 7 are examples of 5S, 6S, and 7S configurations using external FETs for cell balancing. For additional information regarding external cell balancing, see SLUA749, section 4.

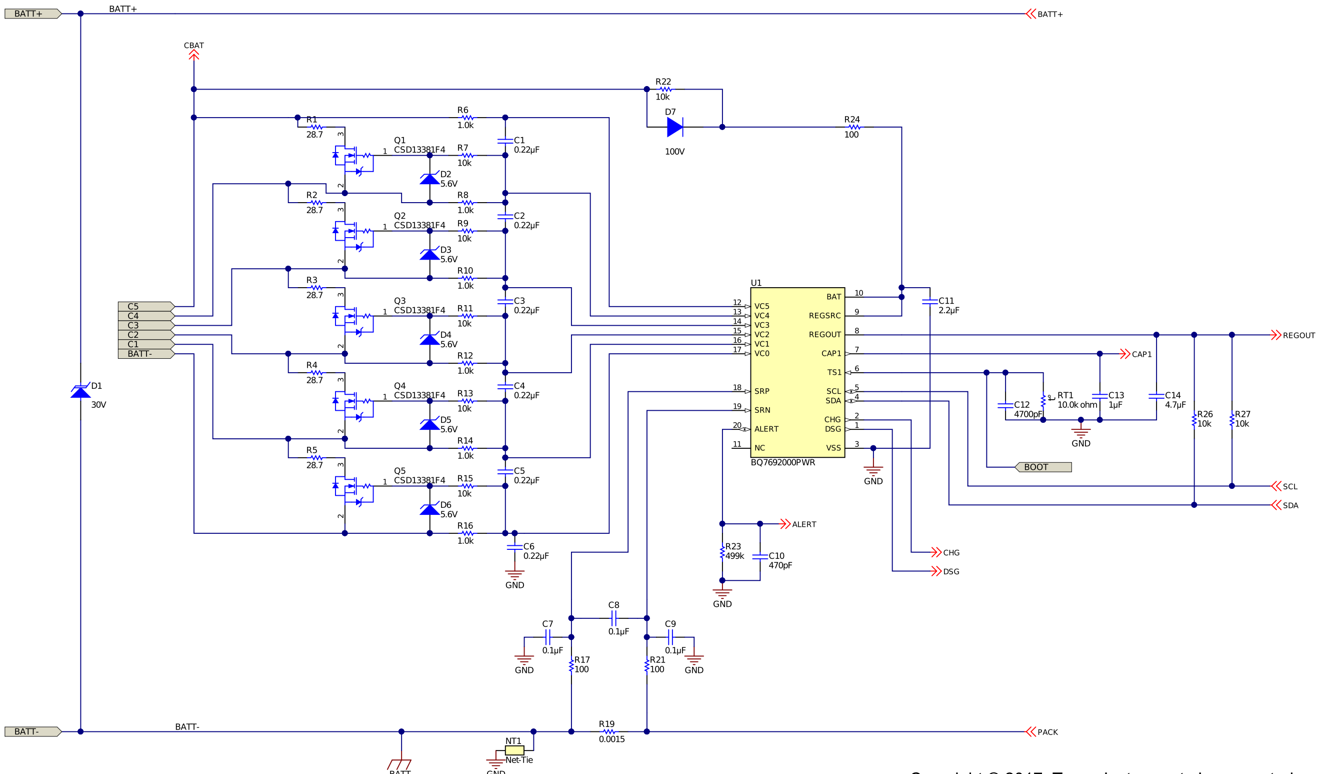

Figure 5. 5S bq76920 Configuration with External FETs

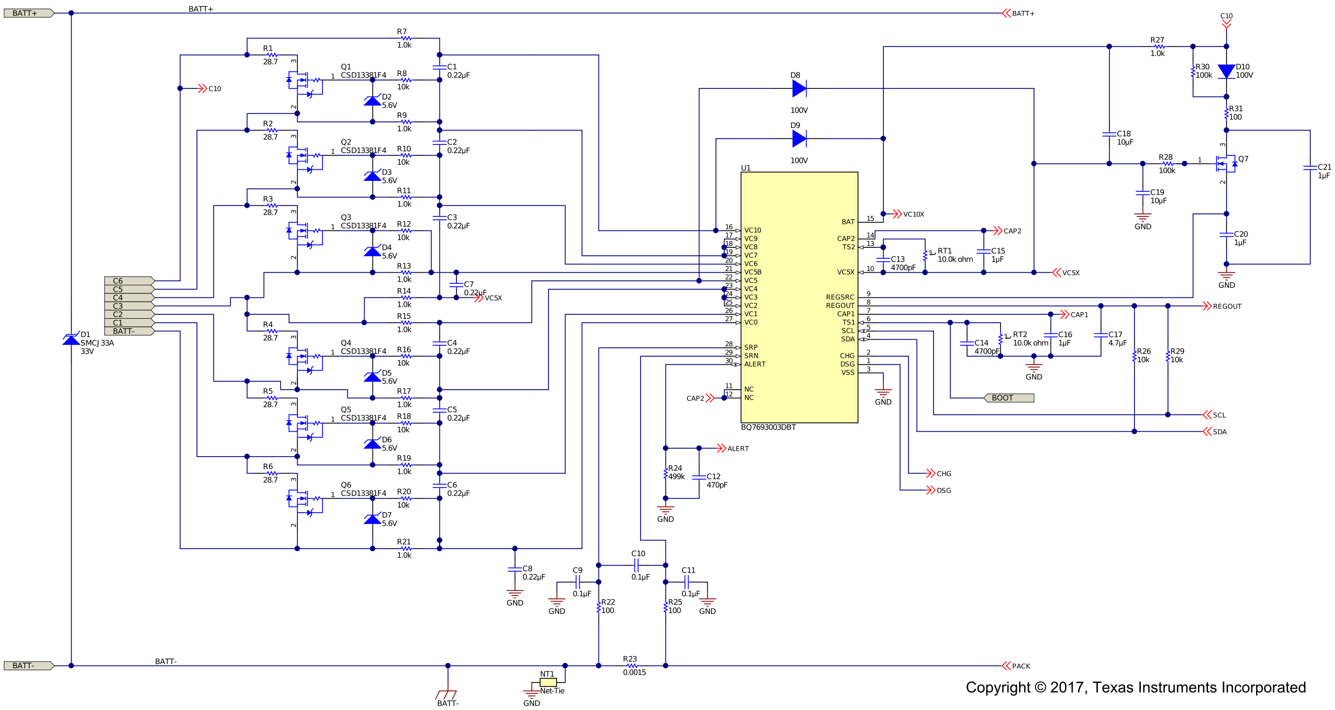

Figure 6. 6S bq76930 Configuration With External FETs

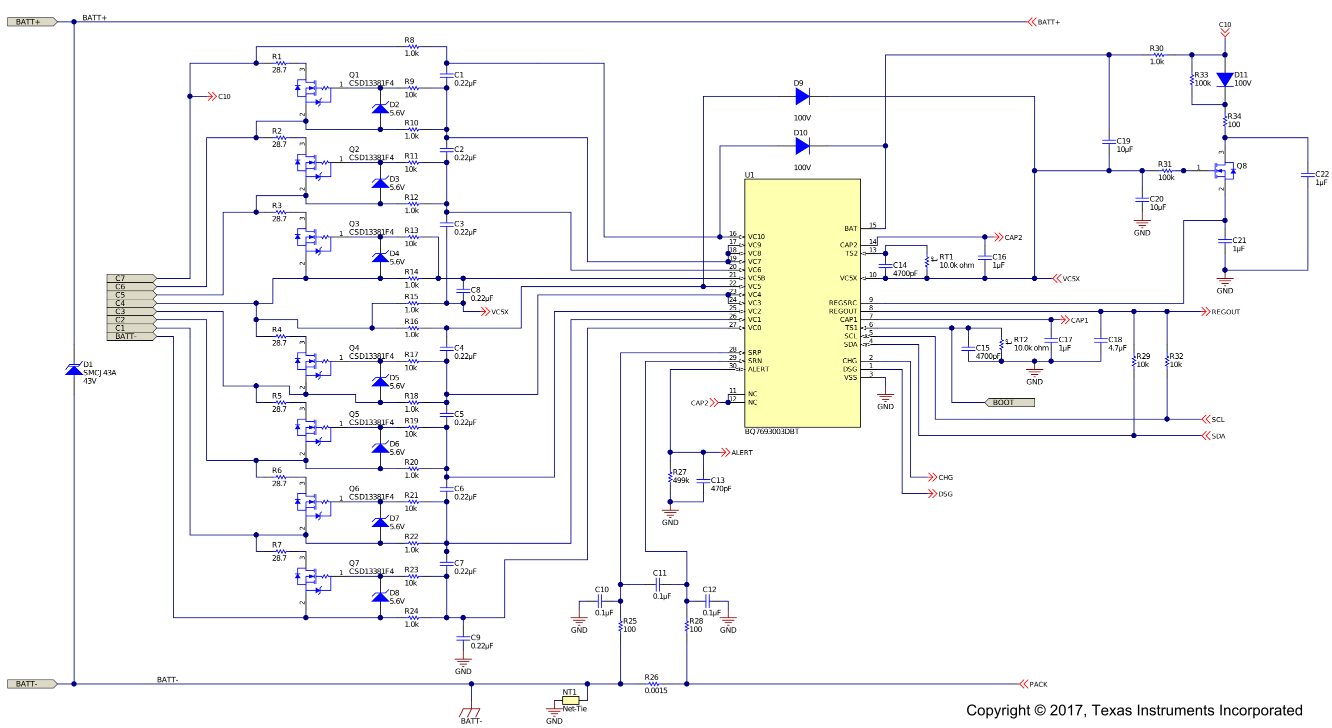

Figure 7. 7S bq76930 Configuration With External FETs

3 Protection Configurations

A bq769x0 can act as a monitor only, in which case a separate protection solution should be implemented, or it can drive low-side protection FETs directly or high-side protection FETs with the bq76200.

3.1 No Protection FETs

When a system design does not require the low-side nFET driver feature of the bq769x0, it is possible to leave the CHG and DSG pins floating and use the bq769x0 solely as a monitor. In this case, the nets BATT+ and PACK in the protection Figure 2 to Figure 7 become their respective exit terminals. This occurs in systems where the battery management controller is integrated with the system MCU.

3.2 Low-Side Protection FETs Using the bq769x0

By taking full advantage of the integrated low-side FET drivers in the bq769x0, it is simple to implement low-side protection, as shown in Figure 8. The main design process is covered in Section 8.2.2.1 of the data sheet. The bq769x0 also has the capability to drive parallel protection FETs for increased current capability. It is important to understand that when the FETs are off in low-side protection, the battery GND and system GND are not electrically connected, which can disrupt system communication. In integrated systems where the system side is also using the battery GND this might not be an issue, but to do this in systems with replaceable battery packs, it might require an exposed GND connection.

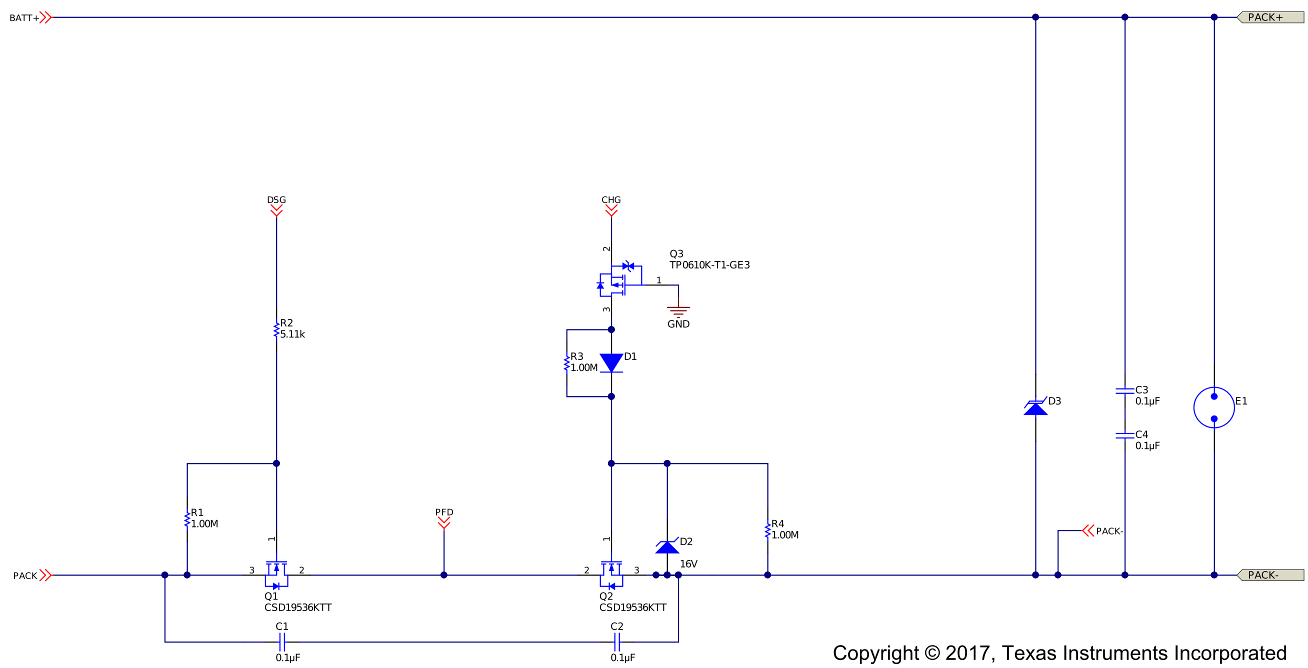

Figure 8. Low-Side Protection

3.3 High-Side Protection FETs Using the bq76200

When using the bq76200 in conjunction with the bq769x0, it is possible to have a low power, high-side, nFET protection system. The main benefit that high-side protection has over low-side protection is the lack of GND disconnection between the system and the host MCU and prevents any leakage path to comm when protected. In low-side protection there is the potential problem if PACK+ or PACK– is shorted, as it will bypass the protection features which can damage the system or the pack cells. High-side protection does not have this problem as there is no disconnect between BATT–, GND, and PACK– regardless of the protection state which allows a common ground with the system. Figure 9 shows the high-side nFET implementation of the bq769x0 using the bq76200. This bq76200 example also implements pre-charge for heavily discharged cells by providing an alternative low current path for charging the cells. The CP_EN, PMON_EN, and PCHG_EN are enables that can either be tied to a pull up to stay enabled or to a gauge or MCU for control.

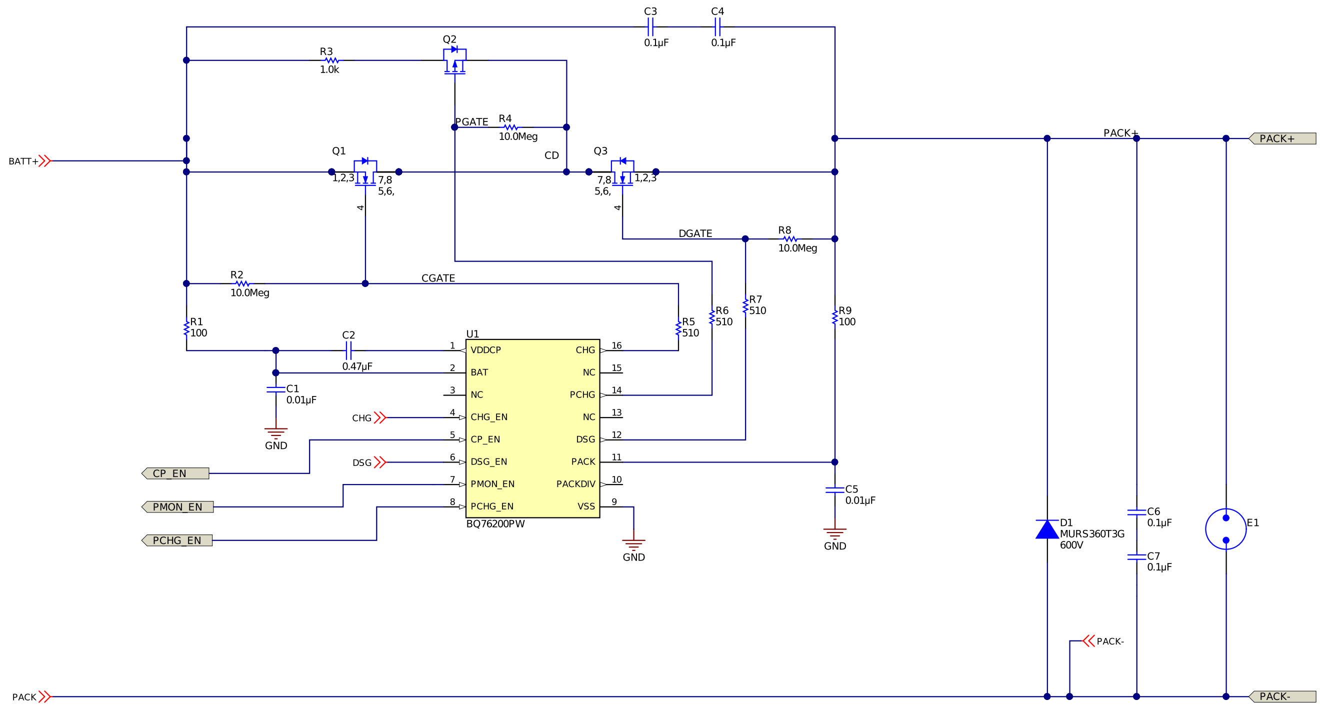

Figure 9. bq76200 High-Side Protection

4 Battery Management Controller Configurations

The bq769x0 monitor family communicates via I^{2}C to a host which handles the battery management controller functions such as system-on-chip (SoC) calculation and cell balancing control. A host is necessary for the bq769x0 monitor family because the bq769x0 cannot recover from faults without host intervention. A host can also implement features such as battery fuel gauge, and low-side pre-charge when low-side protection is in use. By using the integrated coulomb counter of the bq769x0, a host can add additional protection features such as charge overcurrent protection (OCC).

4.1 bq78350 Gauge Example Configuration

For the bq769x0 devices, TI offers the bq78350-R1 gas gauge and battery management controller to simplify the process of implementing a host. The bq78350-R1 offers a wide array of features such as accurate fuel gauging, LED and LCD indication driver, state-of-health (SoH) monitor, cell balancing, fault recovery, along with additional primary- and secondary-protection features. All these features can be programmed into non-volatile memory in the bq78350-R1 by using SMBus which minimizes any programming required on the user side. The system-side communication of this device is limited to SMBus. Example configurations for the bq78350 communicating with the bq76920 and bq76930 are shown in Figure 10.

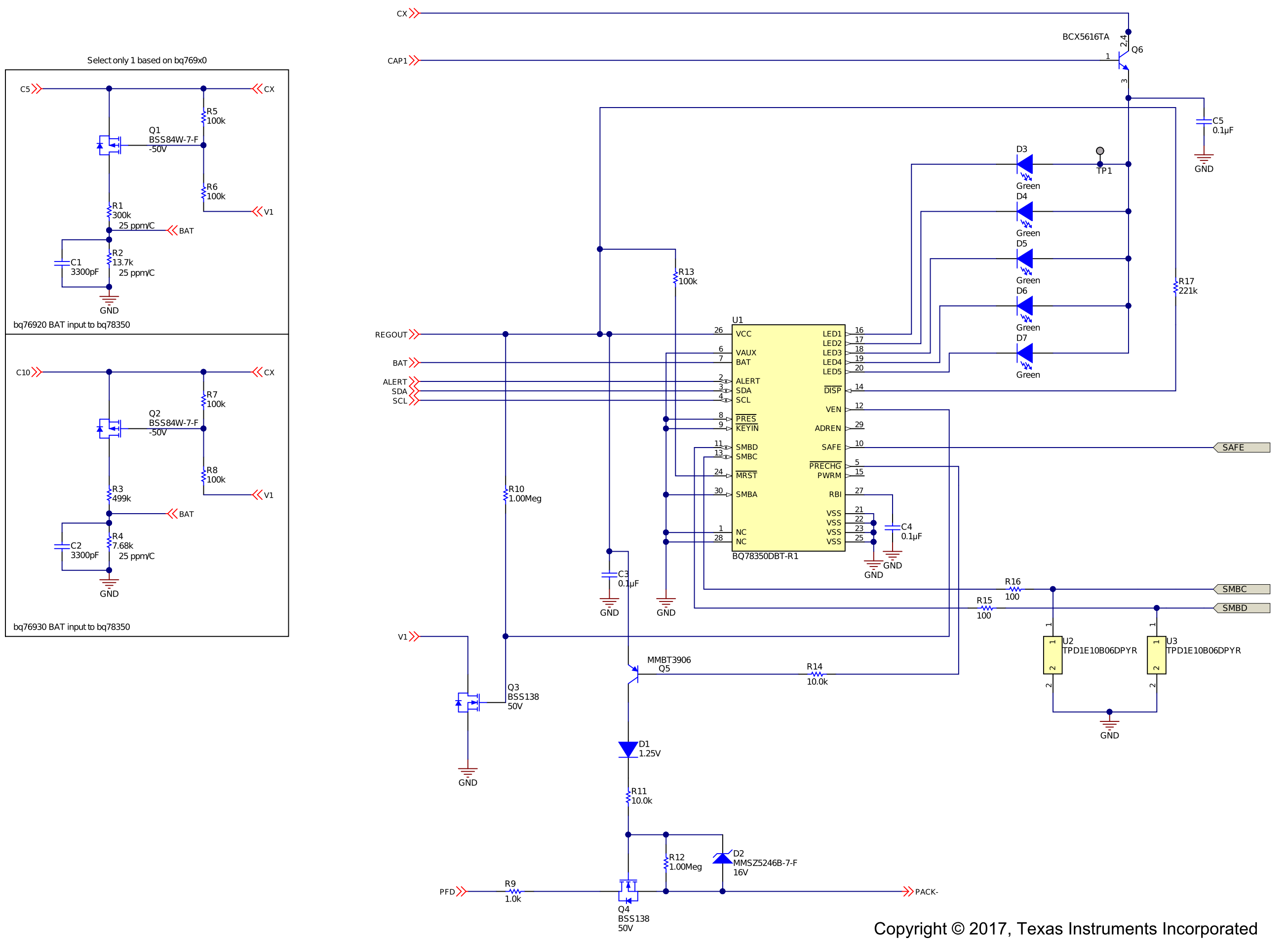

Figure 10. bq78350 configuration for bq76920 and bq76930

4.2 Host MCU MSP430 Example Configuration

An alternative to the bq78350 is an MCU, such as the MSP430, as the battery management controller. A host MCU offers system flexibility in situations that the bq78350-R1 fixed feature set cannot meet. An example in MCU flexibility is the system side communication protocols such as in Figure 11 from TIDA-00449, where the main system communication out of the MCU is UART. A unique flexibility an MCU has is that an MCU is also able to be programed as a protection FET controller in systems where the bq769x0 is acting solely as a monitor.

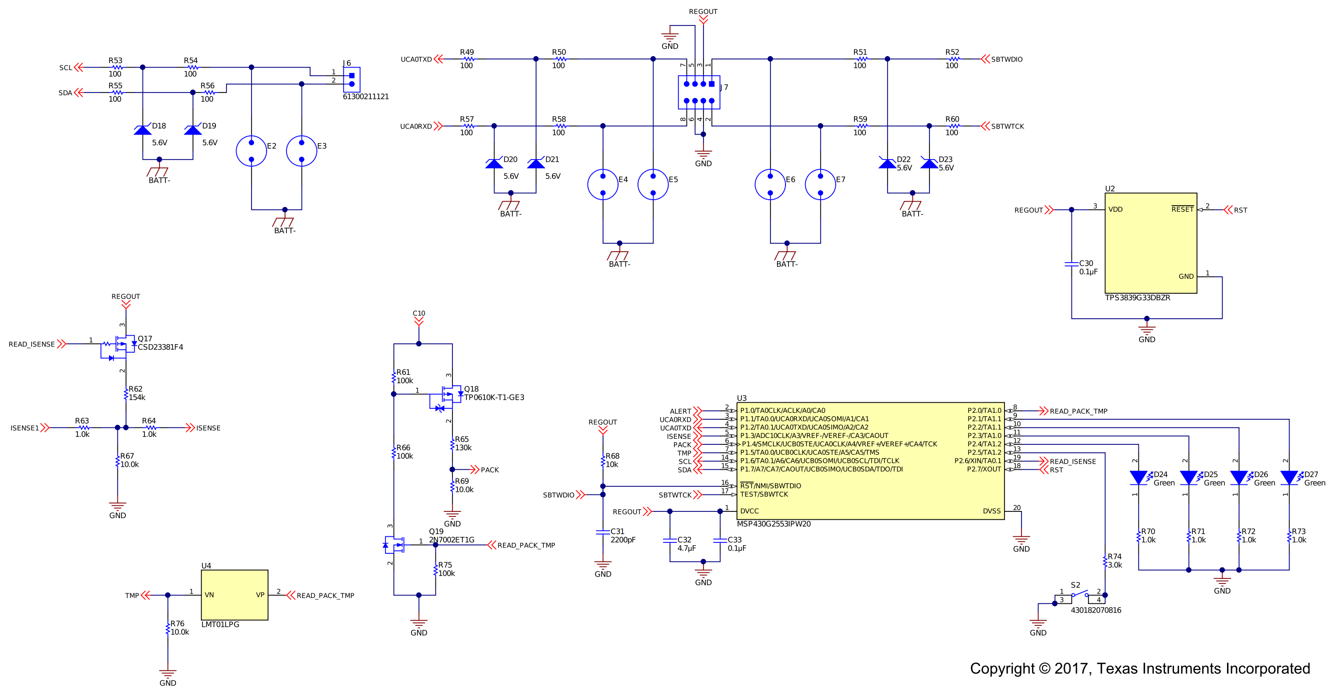

Figure 11. MSP430 Host Example Configuration

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)
- *bq76920 Evaluation Module User's Guide* (SLVU924)
- *10s Battery Pack Monitoring, Balancing, and Comprehensive Protection, 50-A Discharge Reference Design* (TIDUAR8)
- *bq769x0 Family Top 10 Design Considerations* (SLUA749)
- *bq769x0 Boot Switch Alternatives* (SLUA769)
- *bq78350-R1 CEDV Li-Ion Gas Gauge and Battery Management Controller Companion to the bq769x0 Battery Monitoring AFE* (SLUSCD0)
- *bq76200 High Voltage Battery Pack Front-End Charge/Discharge High-Side NFET Driver* (SLUSC16)
- *bq76200 Beyond the Simple Application Schematic* (SLUA794)

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