

bq769x0 Boot Switch Alternatives

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ABSTRACT

The simplified system schematic in the bq769x0 data sheet shows a boot switch to wake the bq769x0 battery monitor. While this is a simple solution, in some cases this switch will not meet the needs of the system. This application report describes proposed circuit alternatives for the boot switch that may be considered for system design.

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1 Simple Circuit

NOTE: The circuits in this application report are proposed and have typically not been built and tested with bq769x0. Circuits should be built, tested and evaluated thoroughly before incorporation into a production design.

The simplified circuit in the *Typical Applications* section of the bq769x0 data sheet shows a 10-k resistor and pushbutton switch between the VC1 terminal and TS1. This is a simple concept and works well in most cases. The VC1 voltage varies with the cell and state of charge, but typically the cell voltage, R_c filter resistor, and thermistor value result in a sufficient voltage to boot the monitor IC when the cell voltages and temperature are within suitable ranges. Where internal temperature sensing is used with the monitor IC, the thermistor should be replaced by a fixed resistor to keep the TS1 voltage in a safe range when the cell voltage may be high.

When the boot switch is activated after the system is running, the voltage for cell 1 and cell 2 may be altered by the current drawn through the cell input filter resistor R_c . Typically the switch ON time is low, and the cell voltages use some filtering, so this changed voltage may have little or no impact on the system. If the user were to hold the switch or the button were to stick, a noticeable system effect may be observed, depending on the resistor values used. Where the voltage change is objectionable, the switch could be fed directly from the cell 1 voltage. This eliminates the measured voltage change due to switch activation, however holding the switch loads the cell.

The external measured temperature is also altered if the boot switch is held closed while the system is running. The voltage through the switch sums at the TS1 pin with the voltage from the internal source while the temperature is being measured. The result is a higher voltage representing a lower temperature. How the system responds to this temperature depends on the filtering of the system. Because temperature measurements are taken only every 2 seconds, a short boot switch activation may not alter a temperature reading.

2 Shared Push-Button Switch

In some systems, a push-button may already exist to light a display. Expect that the button may activate another set of contacts to cause the boot condition. With a shared push-button, the user holding the push-button causes a load on the cell and altering of the temperature reading if using the external temperature monitoring. The limitations of the switch discussed in [Section 1](#) also apply to the shared button.

3 Microcontroller Control

The simplified schematic of the bq769x0 data sheet shows the microcontroller powered by the REGOUT of the monitor IC. This is perhaps the simplest circuit. In some systems however, the microcontroller may be powered by a separate regulator and be always on. In this case, the microcontroller could provide a signal to the TS1 pin to wake the monitor IC. Although the microcontroller does not know the time the monitor IC is making a temperature measurement, the microcontroller knows when the boot signal is needed and when the temperature value is altered by its application.

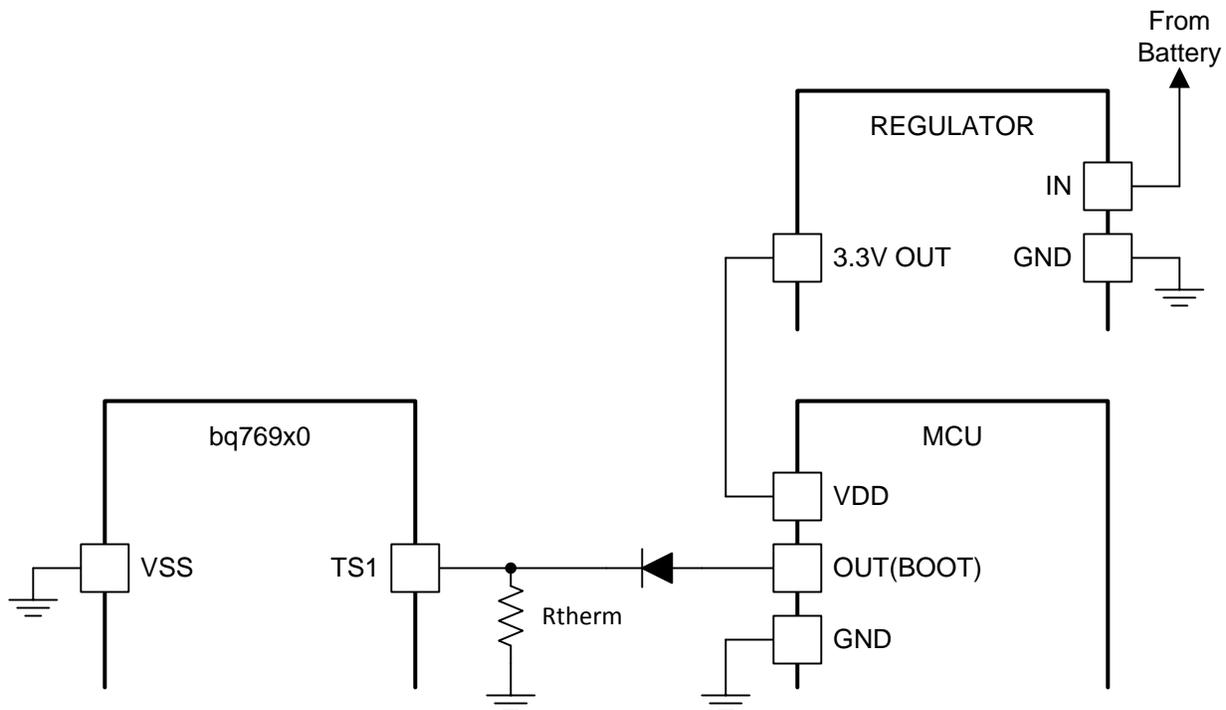


Figure 1. Independently Powered MCU Boot

4 Booting From an External Signal

When the simplified system, as shown in the bq769x0 data sheet, is shut down, the FETs are off and the PACK terminals are expected to show 0 V. In most systems, the power FETs will have some small leakage current. Additionally, the CHG pin provides some pulldown through the drive circuit and gate to the source resistor to give a pack voltage near the battery voltage. However the charger cannot provide charge current and an external signal for the charger to wake the monitor IC may be desired. The reference back to VSS for providing a ground for the external signal is high impedance. A circuit which will reference the TS1 signal from a voltage inside the battery may be desirable.

The circuit in Figure 2 provides the boot voltage from the pack voltage reference using an external signal from the charger. When the BOOT terminal is pulled high to PACK+ the TS1 pin of the monitor IC is provided with a voltage from the battery positive, limited by D1. This adds a load to the cells whenever the pullup is applied and applies a voltage to the TS1 pin. D2 prevents charge of the battery from a voltage applied between PACK+ and BOOT. D3 may be desired to prevent D1 from limiting the temperature range of the thermistor R1.

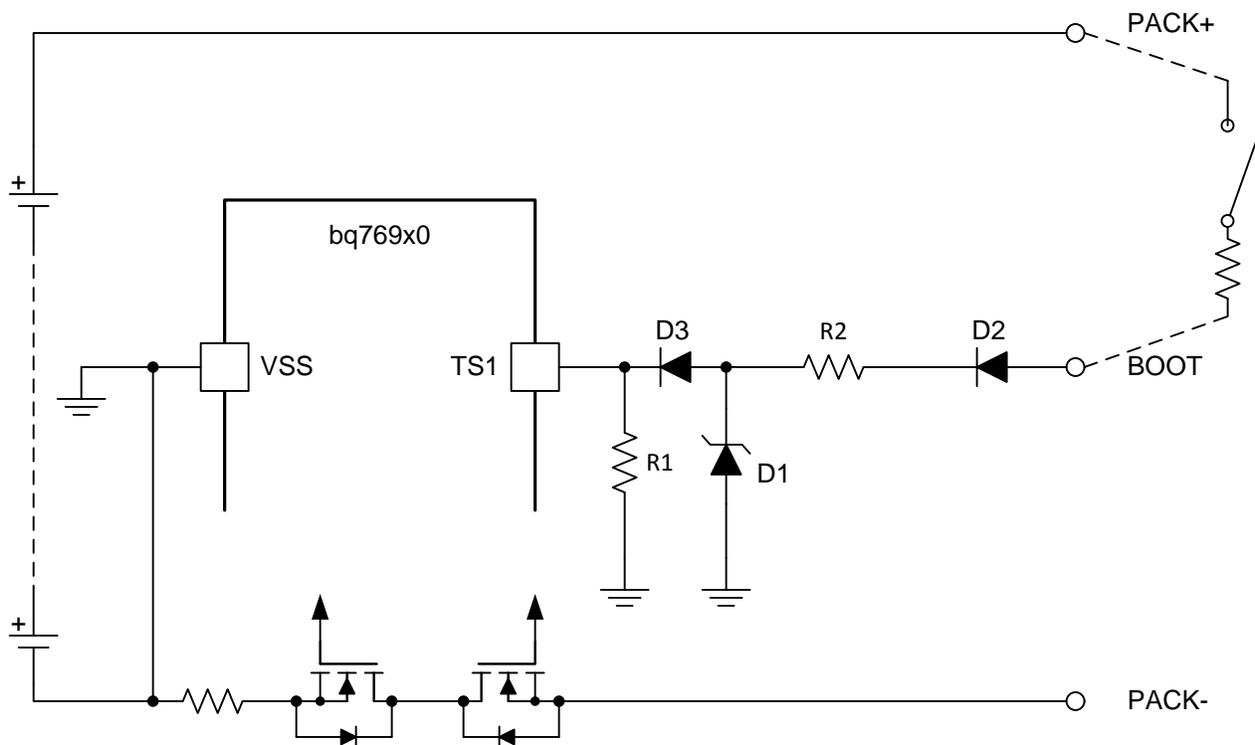


Figure 2. External Boot Signal, Low-Side Switch

The charger needs to determine when to apply the boot signal. If the charger maintains the BOOT signal too long, the temperature reading obtained on TS1 is altered. The pullup would also provide a load on the cells. Since the load is inside the protection loop, the battery cannot stop the discharge. AC coupling the boot signal could prevent a continuous discharge and may be suitable in some designs.

When communication with the gauge or microcontroller in the pack is desired, a high-side switch is typically desired. This is shown in Figure 3 with the similar circuit. This configuration allows control by an external logic level BOOT signal with a modest driver impedance. The current through the divider is provided from the charger supply even if the PACK+ voltage is not on. D3, as shown in Figure 2, prevents the temperature range from being limited by the D1 zener. Leaving the BOOT signal present affects the temperature readings.

A connection between PACK+ and BOOT also provides boot of the monitor IC and a discharge path, but unlike the circuit in Figure 2, the boot and discharge path is stopped when the FETs open.

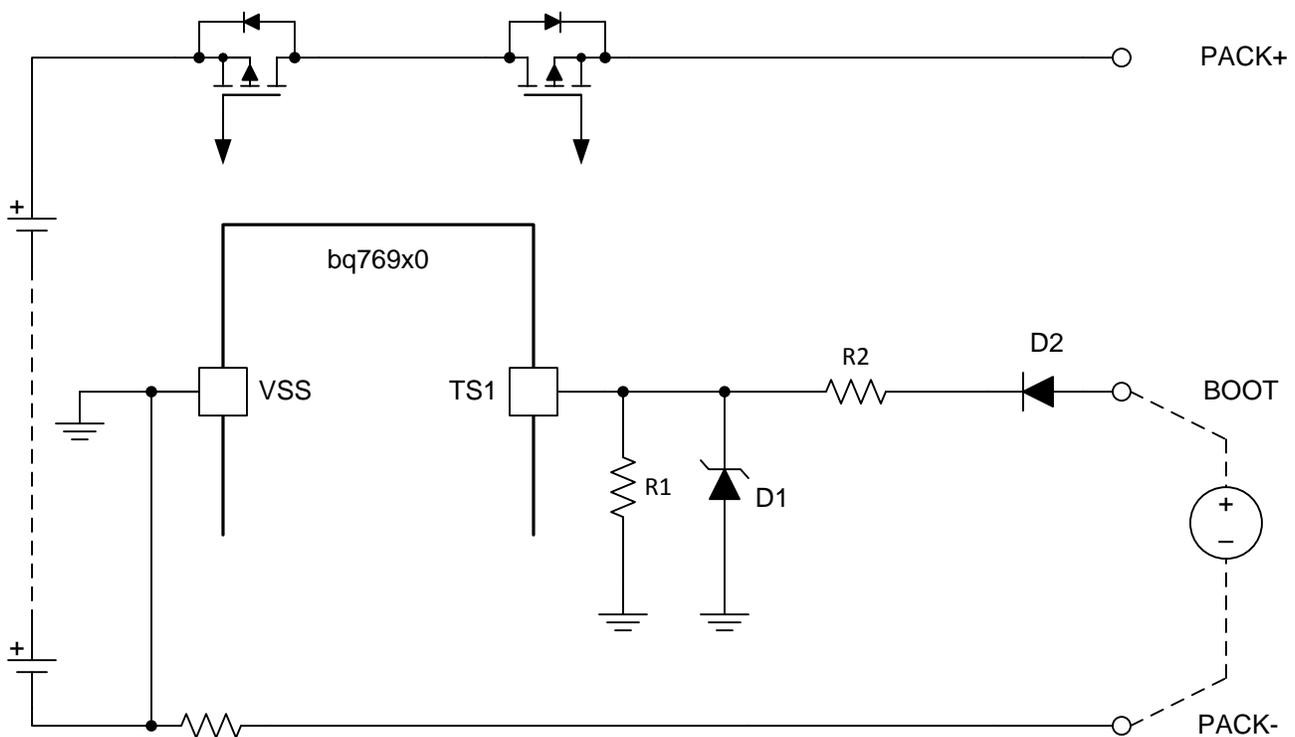


Figure 3. External Boot Signal, High-Side Switch

When no external signal pin is desired, charger behavior might be used to provide the control for a boot switch. This is shown in [Figure 4](#). When the charger voltage exceeds the battery voltage by more than the V_{gsth} of Q2, Q2 comes on drawing current through R3 and R4 and turns on Q1. Q1 provides current through R2 and R1 to provide the boot voltage to TS1. D1 prevents over voltage at the TS1 pin. D3 keeps the Q1 gate voltage safe when needed. D2 protects the Q2 gate when needed.

NOTE: R5 & D2 provide a charge path when the PACK voltage is sufficiently large compared to the battery voltage, so R5 should be large, D2 should be as large as allowed by Q2 limits, and the circuit should only be used where this current is considered safe.

Operation of this circuit requires the charger to provide a voltage higher than the battery voltage at least long enough for the battery to wake up. This is easily provided when the battery is nearly discharged or partially charged. When a fully charged battery is to be booted, the system charger may require a compatible characteristic voltage to wake the battery pack.

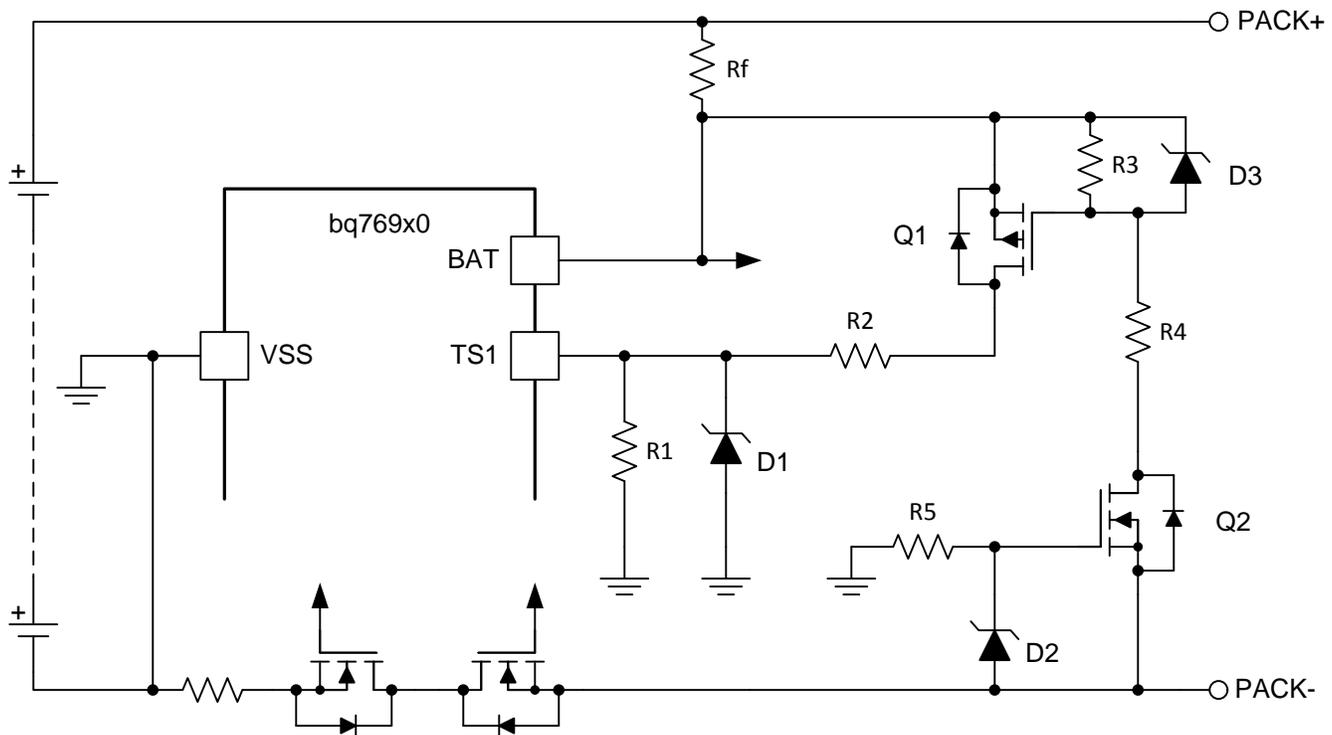


Figure 4. Pack Terminal Boot Circuit

When the charge FET is turned on, the V_{gs} of Q2 goes away, Q2 and Q1 turn off, and the voltage on TS1 returns to normal. Until this happens, the boot voltage is applied at TS1 and sums with the temperature measurement voltage. This makes the temperature appear lower than what it actually is. If this low temperature or other controller behavior prevents the charge FET from being turned on, the system could be stuck. The circuit in [Figure 5](#) provides an additional switch to turn off the boot voltage once the monitor IC power is on.

In this circuit, when Q1 is turned on, Q4 is biased as a source follower and provides a sufficient voltage to R2 to be divided for TS1. Once the monitor IC has come on and enabled REGOUT, Q3 turns on pulling down the gate of Q4 such that the boot voltage is removed from TS1. The monitor IC and controller can then measure temperature and any delay in turn on of the charge FET will not alter the measured temperature. Once the charge FET is turned on, Q2 and Q1 turn off allowing the Q4 drain to fall to ground potential. The addition of D4 will prevent R2 and R6 from becoming a parallel resistance to the thermistor R1 through Q4 and altering the measured temperature. While Q3 remains on during the operation of the pack, the circuit draws only the leakage current of the FETs.

The circuit could be powered from either PACK+, the BAT pin, or the REGSRC pin as shown in [Figure 5](#). Using a filtered signal reduces the exposure of Q1 and Q2 to power transients, but the boot circuit may pull down the filtered signal significantly during boot. For bq76930 and bq76940 implementations, REGSRC is provided through a source-follower circuit to provide a lower voltage. Using this voltage may allow use of lower voltage control transistors. When REGSRC is used, D5 should be added to prevent a PACK- at PACK+ condition from forcing current through Q2, R4, R3, and D3 raising the voltage on REGSRC.

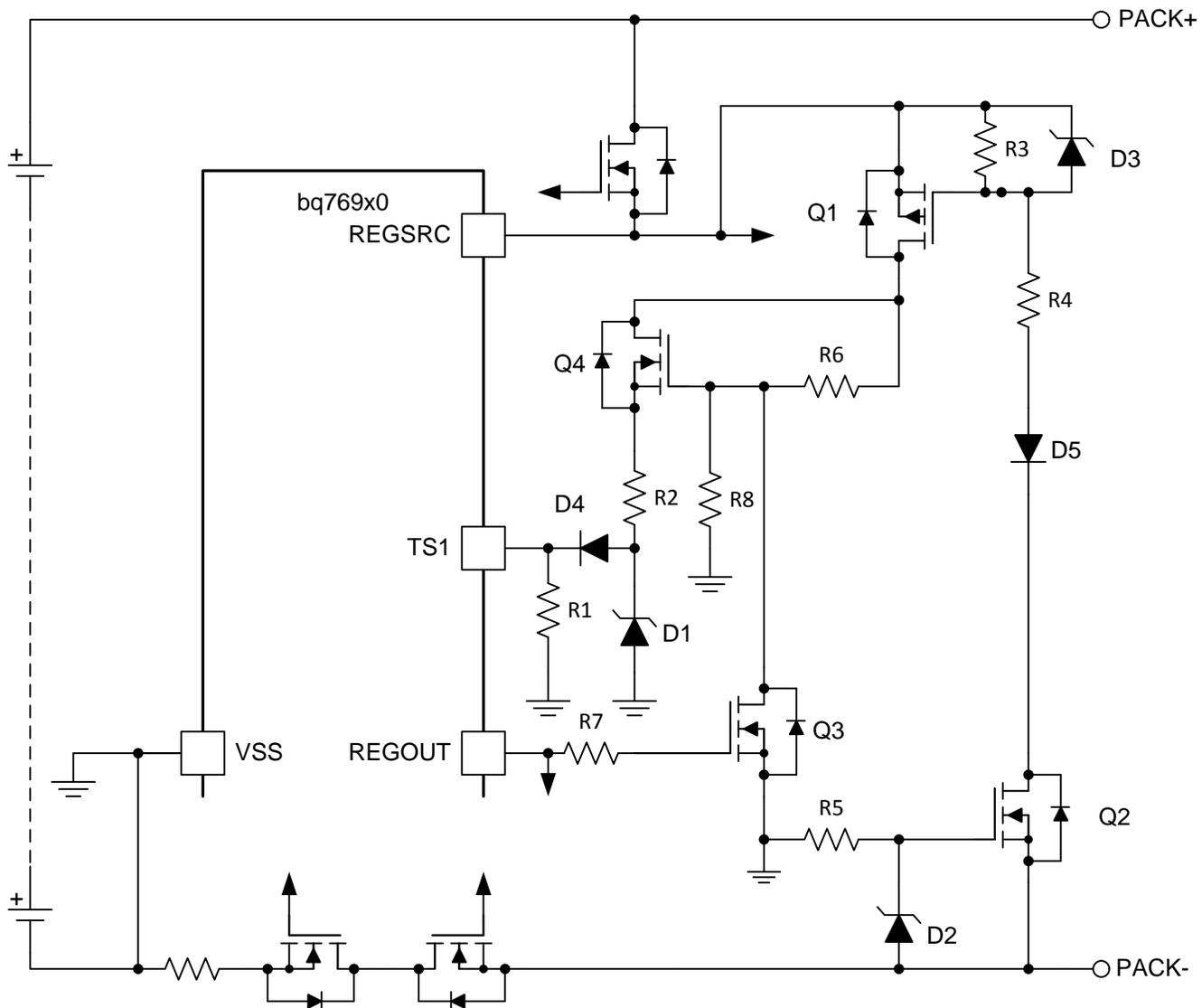


Figure 5. Pack Boot Switch From REGSRC

The circuit design must accommodate the thermistor resistance over the desired temperature range where boot is supported as well as the voltage variation of system. The circuit might be further modified for specific system needs. With high-side switching, the components around Q1 may be arranged to sense the charger to battery difference. AC coupling at R5 may be desired to trigger boot without the pack voltage exceeding the battery voltage.

5 Circuit Example

The circuit in [Figure 5](#) is built to connect to a bq76930EVM using 10 cells and is designed to have the battery boot down to a 2-V cell average and a temperature at 40°C. If the voltage applied to the pack is large compared to the battery, D2 will conduct and provide a current into the battery. When the discharge FET is off and a load is still present, R5 will provide a discharge path through D2. R5 is made large to limit these currents. A capacitor could be added across R5 to provide a operation of Q2 based on a drop in PACK- rather than a DC value. R3 and R4 are biased when the charger is attached, so their values may not matter, but these are made large as well.

The transistors Q1 to Q4 are signal transistors selected for the expected voltages. D3 and D2 are selected to limit the gate voltage of Q1 and Q2 to a safe level. Q3 operates at a low gate voltage and Q4 operates as a source follower, so these do not have gate clamp diodes.

R2 must be small enough to provide enough current at minimum voltage to provide the boot voltage on TS1. At 40°C the thermistor will be 5.8 kΩ; at least 0.172 mA must be allowed to achieve a 1-V boot voltage. For low voltage, REGSRC may be 4 V below the 5th cell, or 6 V. The drop on Q4 and D4 may also be 4 V. Only 1 V is allowed across R2 and its value should also be less than 5.8 kΩ. At high cell voltages and with lower loss in the switching the D1 diode would be conducting, the drop to REGSRC and to R2 may be lower, so the current in R2 may be $(21 - 2 - 1 - 3.9)/R2$. A 5.1-k R2 resistor may result in a 2.8-mA and 39-mW dissipation.

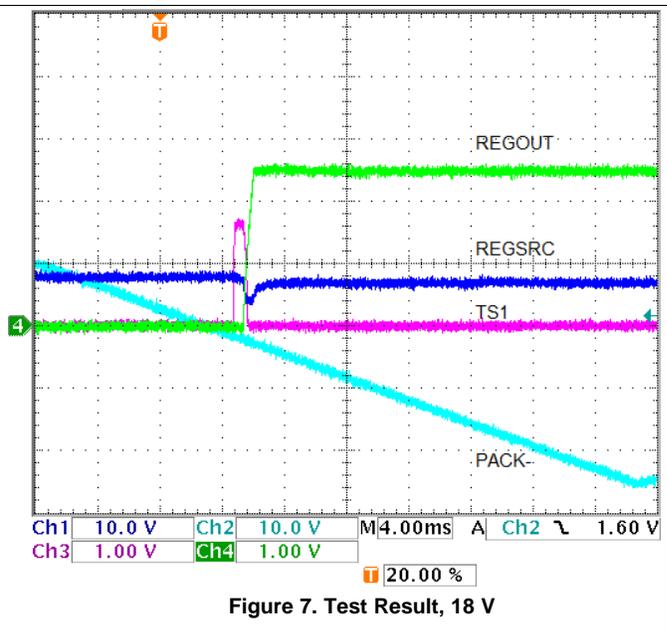
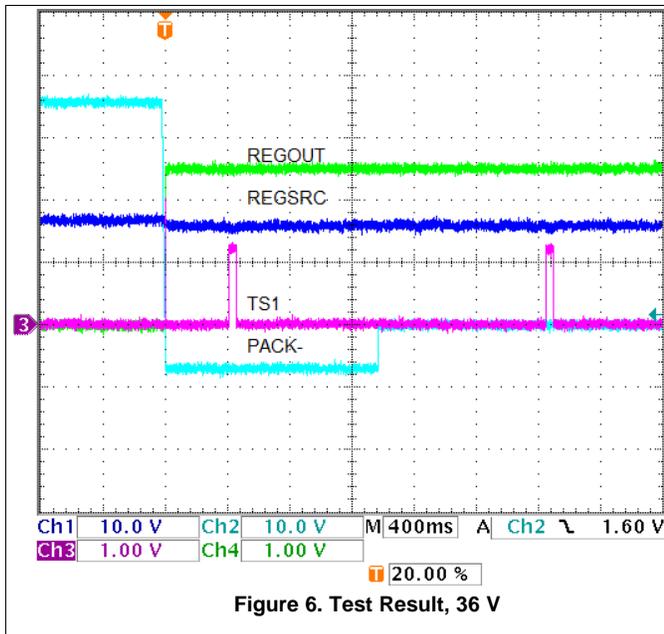
R6 is used to turn on Q4 and is pulled down to GND when Q3 turns on and Q2 has not turned off, so a large value is recommended. A 2-M value is used in this example. Because the voltage at REGSRC can be low, R8 is omitted. When PACK is used for the supply voltage R8 may be used to reduce the voltage to Q4. R7 is not critical and could use a common value such as that of R2.

Table 1 shows a summary of the component values used in the example.

Table 1. Circuit Example Components

Reference Designator	Value	Comment
R1	10 k	Thermistor, approximately 5.8 k hot
R2	5.1 k	
R3	2 M	
R4	2 M	
R5	2 M	
R6	2 M	
R7	100 k	
R8	–	Not installed
D1	1N5227B	3.6 V zener
D2	1N5245B	15 V zener
D3	MMSZ5245B	15 V zener
D4, D5	1N4148	
Q1	BSS84	50 V P-channel MOSFET
Q2, Q3, Q4	2N7000	60 V N-channel MOSFET

The circuit is connected to a bq76930 EVM set for 10 cells with the bq78350 enabled and tested for operation with simulated battery and charger voltages. A 1-MΩ load resistor is used on the PACK to pull up PACK- and provide a definite signal swing when the charger is applied. A 12-kΩ resistor is connected across the thermistor to simulate a hot condition while the boards remained at room temperature. A 43-V source is used for the charger. An example boot at 36-V battery voltage is shown in Figure 6. The monitor boots, REGOUT is on, the gauge takes a temperature sample and enables FETs pulling the PACK-voltage to the battery ground. An example boot at 18-V battery voltage is shown in Figure 7. When the circuit triggers, REGOUT starts which will load REGSRC and turn off the boot pulse. With the low voltage the gauge does not turn on the charge FET. Notice that the dip in REGSRC on REGOUT start is significant and may affect the trigger circuit at lower voltages. While the test example used REGSRC for the supply, using PACK+ or BAT may have advantages in a system design.



6 Conclusion

The boot signal is required for the bq769x0 monitor IC, but the boot switch shown in the simple circuit from the bq769x0 data sheet is not required if boot can be provided by a circuit. The availability of signals and the system configuration may determine what is suitable for a boot source. This application report has attempted to describe circuit variations which may be considered for boot signal generation. Circuit topology and component selection needs to be optimized for specific system designs.

7 References

Refer to the bq769x0 data sheet for the simplified system schematic and device specifications.

1. *bq769x0 3-Series to 15-Series Cell Battery Monitor Family for Li-Ion and Phosphate Applications*, [SLUSBK2](#)

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