

bq77905 Separate Current Paths

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BMS: Monitoring and Protection

ABSTRACT

The basic implementation of the bq77905 3-5S Low Power Protector for lithium-ion batteries uses a single series current path for charge and discharge. In some system designs it is desirable to have separate current paths for charge and discharge. This document shows circuit implementation examples of separate charge and discharge paths when using the bq77905. The schematic examples and test results will help the battery electronics designer when selecting a circuit topology with separate charge and discharge paths.

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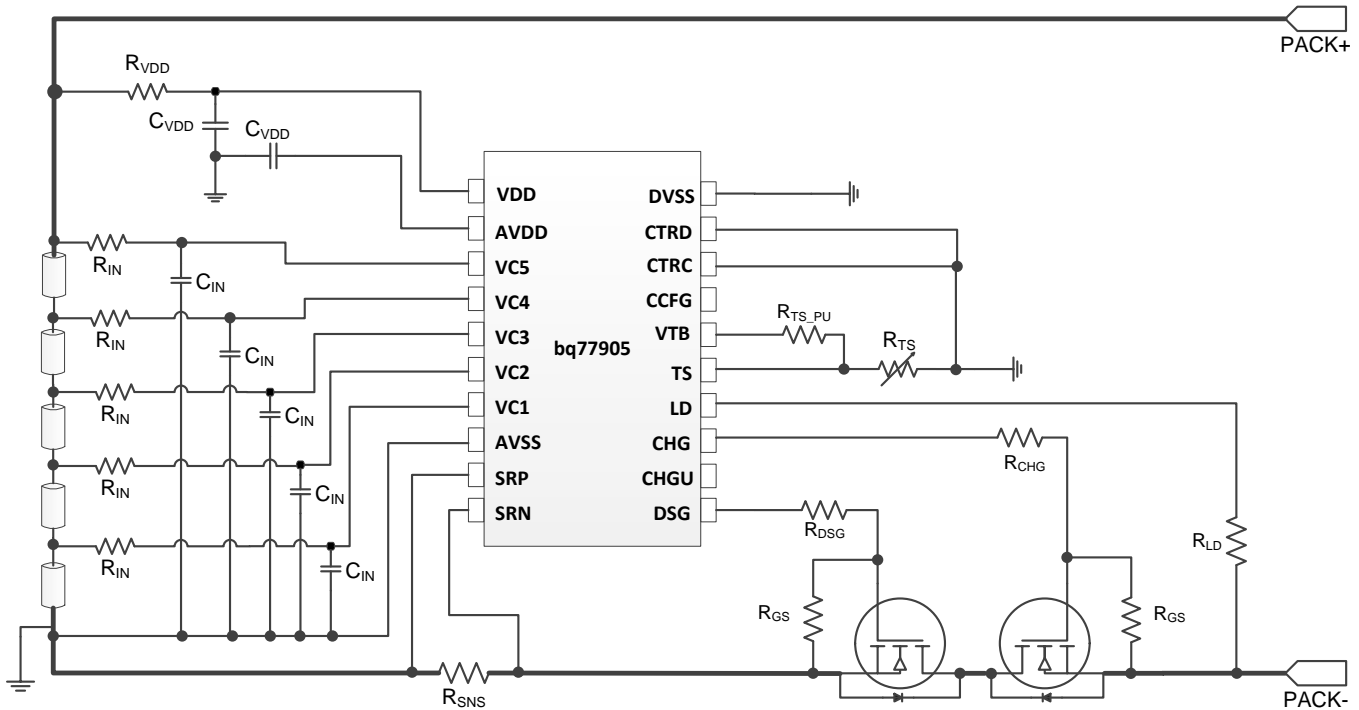
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1 Introduction

The bq77905 3-5S low-power protector is an easy-to-use component for lithium-ion battery circuits. The common schematic uses series FETs where the current for both charge and discharge flows through both the charge and discharge FETs. This provides a simple 2-terminal battery but requires both FETs to handle the same current. In some battery designs the charge and load currents are much different and the system accommodates multiple terminals. By splitting the charge and discharge paths, the FETs can be sized appropriately for the current in the path providing a lower cost solution.

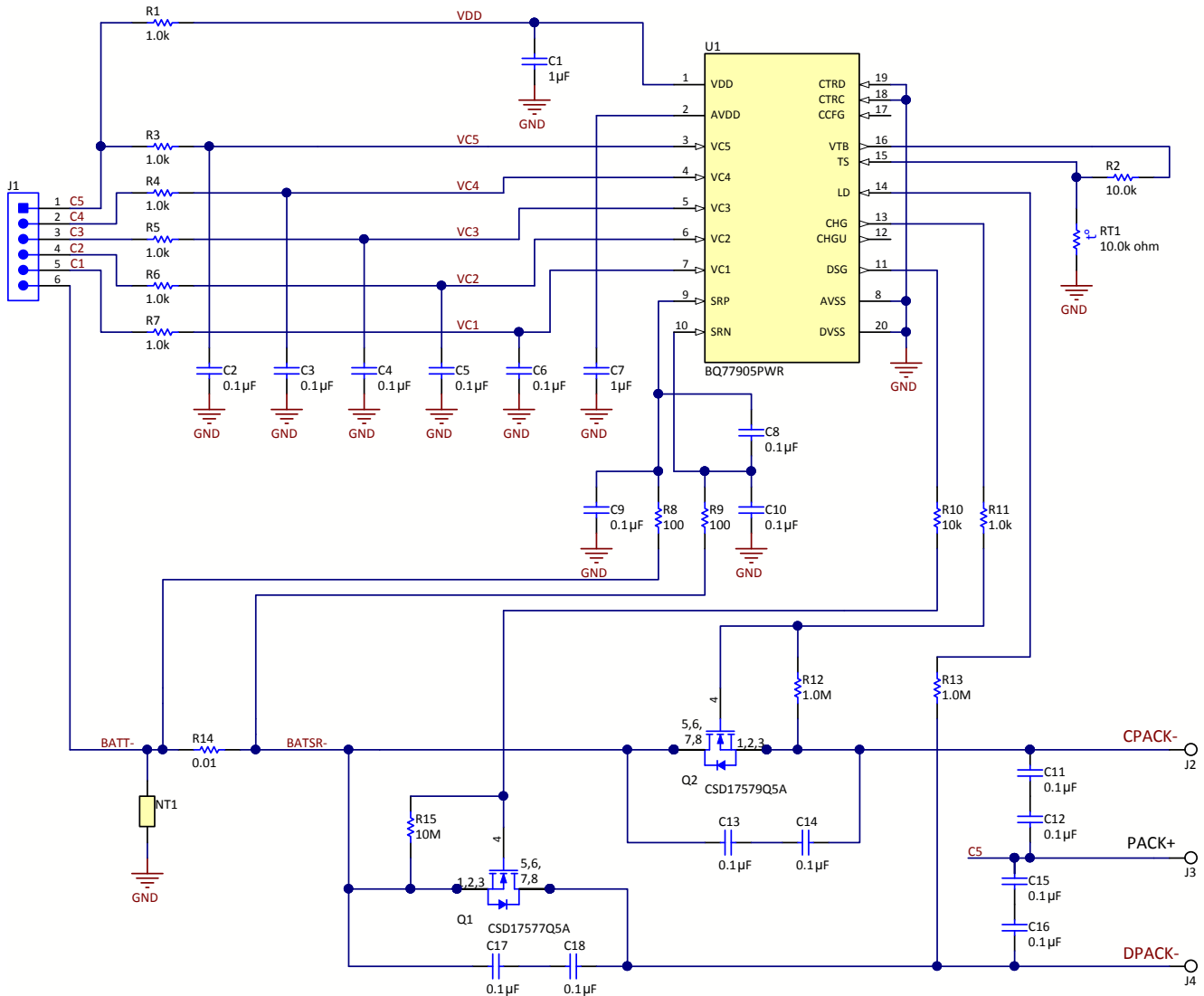


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Figure 1. Common Circuit Implementation

2 Separate Paths

The charge and discharge paths can be separated to provide different pack negative terminals for charge and discharge. An example connecting both the charge and discharge FETs at the sense resistor is shown in Figure 2. The LD pin must reference the DPACK- terminal for proper load detection. DPACK- can go significantly above BATSr- but only the body diode voltage of Q1 below. CPACK- can only go above the BATSr- potential by the body diode voltage of Q2 but can go significantly below. With the limited positive range and since CHG cannot drive the LD pin, the connection of CHG to the charge FET gate can be simple. CPACK- should not be allowed to move below the CHG range of the bq77905, and in designs where CHG - CPACK- can be large, protection for the FET gate may be needed. The body diodes of the FETs will allow discharge to occur through the charge path and charge to occur through the discharge path, so the circuit should only be used where appropriate.



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Figure 2. Schematic With Separate Paths

When the bq77905 detects an overcurrent discharge fault, it turns off both CHG and DSG. Figure 3 shows example waveforms when PACK+ is shorted to DPACK- in Figure 2. The CPACK- reference waveform is saved from a previous capture. The DSG pin goes low, but due to the R_{DSG} resistor R10, the discharge FET gate drops more slowly to increase the turn off time of the discharge FET. The current drops from the short circuit level to zero in about 15 μ s. DPACK- is clamped to PACK+ by the short and there is an inductive response from the cells and interconnect to the drop in current causing an overshoot, this shows in the DPACK- voltage. With CHG low, the charge FET is off and the CPACK-, CHG, and the charge gate are free to be pushed low by the ESD capacitors when PACK+ falls.

NOTE: Waveform captures in this document show charge current as positive.

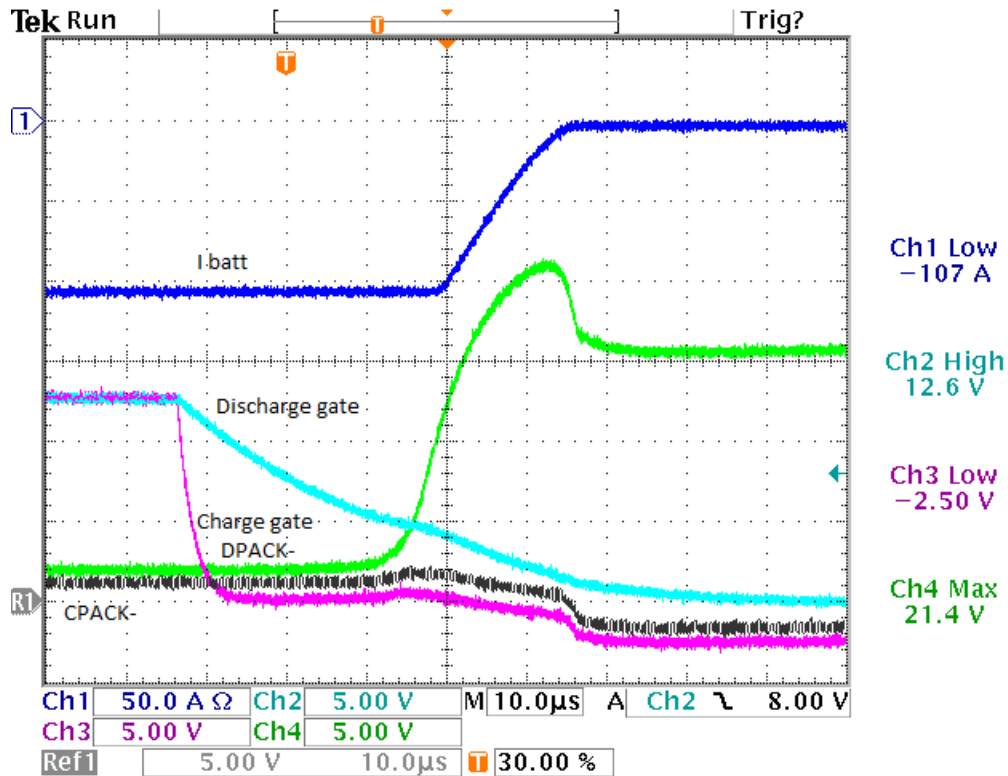


Figure 3. Short Circuit With Separate Paths

When the part goes to undervoltage, only DSG is switched off, the charge FET remains on. In Figure 4 the discharge FET gate changes slowly again due to the gate series resistance. The current is modest and the DPACK- voltage changes slowly, dependent on the characteristic of the test load.

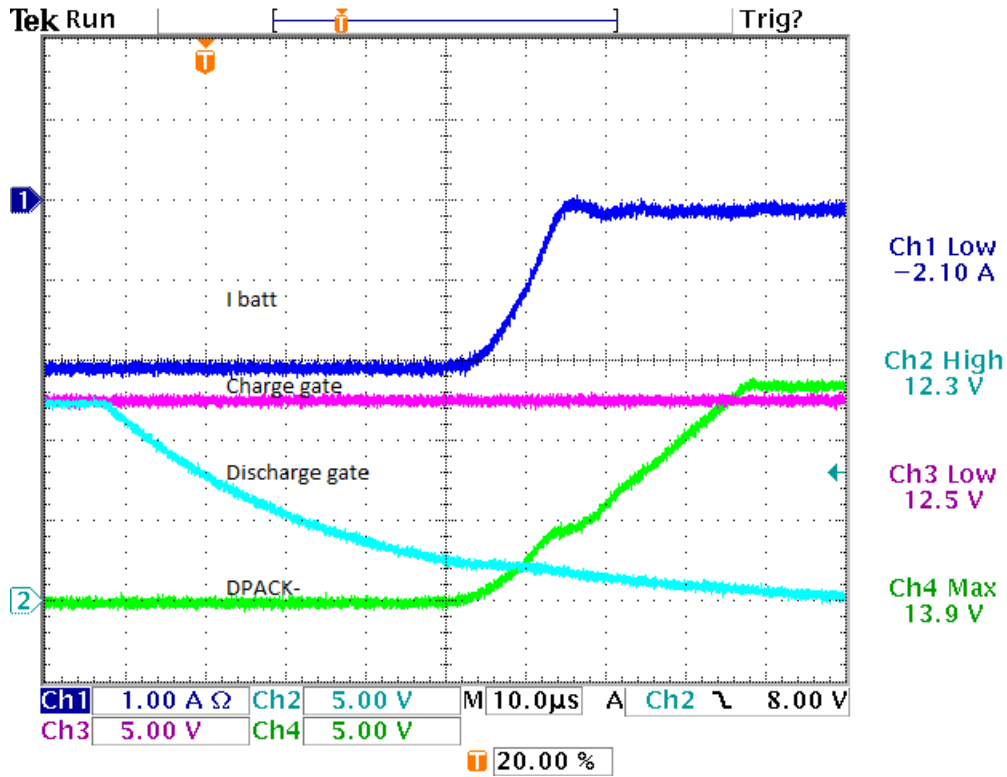


Figure 4. Undervoltage With Separate Paths

When the part goes to overvoltage or overtemperature state, only the charge FET is turned off. Figure 5 shows an overtemperature event while charging. When CHG falls to 0 the charge FET turns off, current drops, and CPACK- drops below BATT- by the threshold voltage of the FET. The CPACK- continues to fall depending on the charger characteristic and the gate falls with it, pulled down by the gate-source resistor R12.

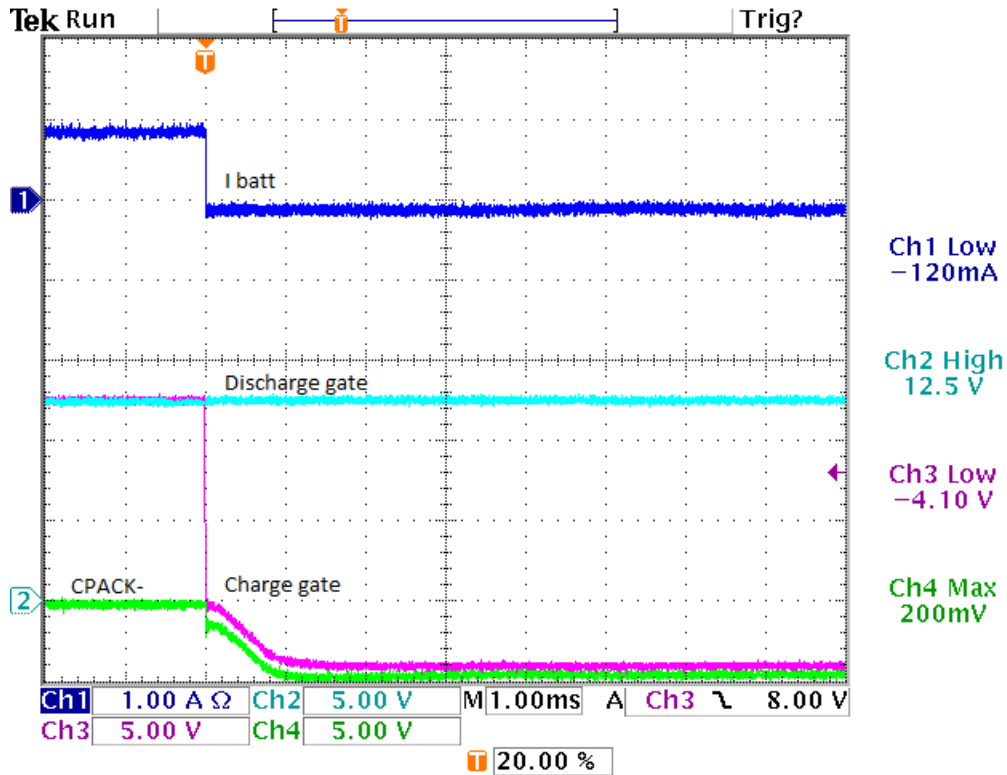


Figure 5. Charge Overtemperature With Separate Paths

With the typical series FET implementation only a charger or load would be connected or the sense resistor will experience only the difference of the charge and discharge currents. Separating the current paths will allow the FETs to be sized appropriately for the system currents but does not add a power path control function to the part. Since the bq77905 expects a series FET configuration and has a body diode protection function, simultaneous connection of a charger and load with this circuit can cause a FET turned off by a fault to turn on again. Figure 6 shows an example of the discharge FET cycling when the part is in the undervoltage state with a load still applied but a charge current is also applied. If the charge current is sufficient to trigger the body diode protection feature, the discharge FET will be turned on and discharge will occur. The discharge current will release the body diode protection and DSG will turn off again. The process will repeat and the discharge FET will cycle. Moving the charge FET drain to the battery side of the sense resistor would prevent charge current from overriding a discharge protection. A similar toggling effect can occur when a load is applied in the overvoltage or overtemperature charge states. The charge FET will be cycled by the body diode protection. Whether the battery charges or discharges in these conditions will depend on the magnitude of the charge and discharge currents, but the cycling of the FETs may be undesirable. The circuit configuration should only be used when it is appropriate in the battery system design.

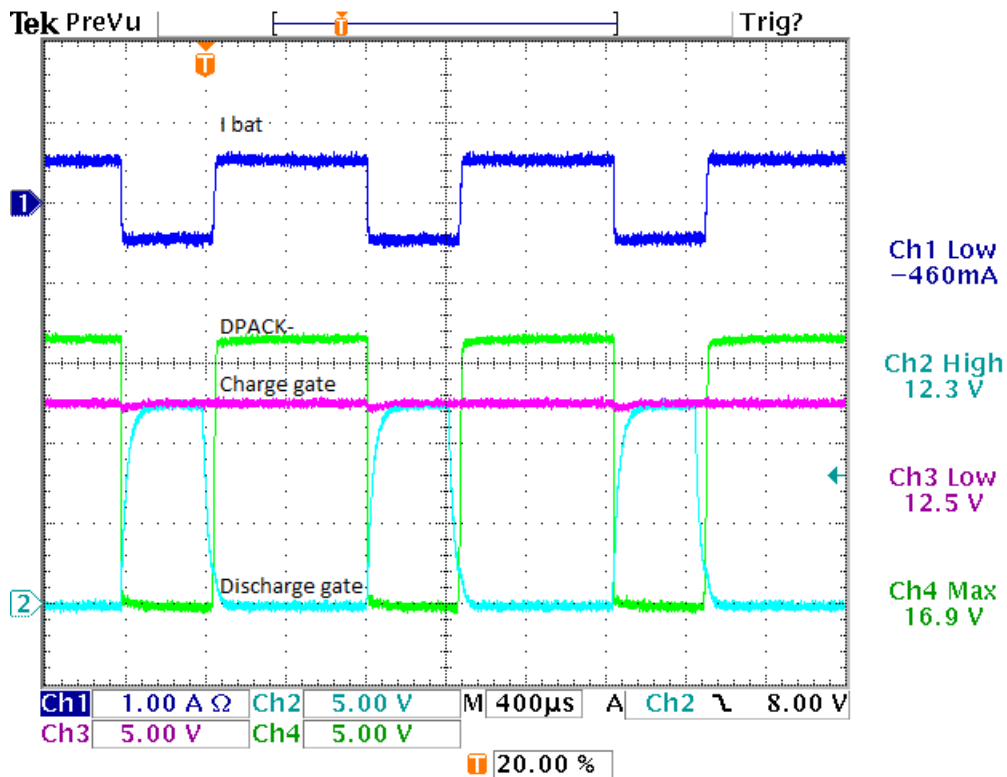
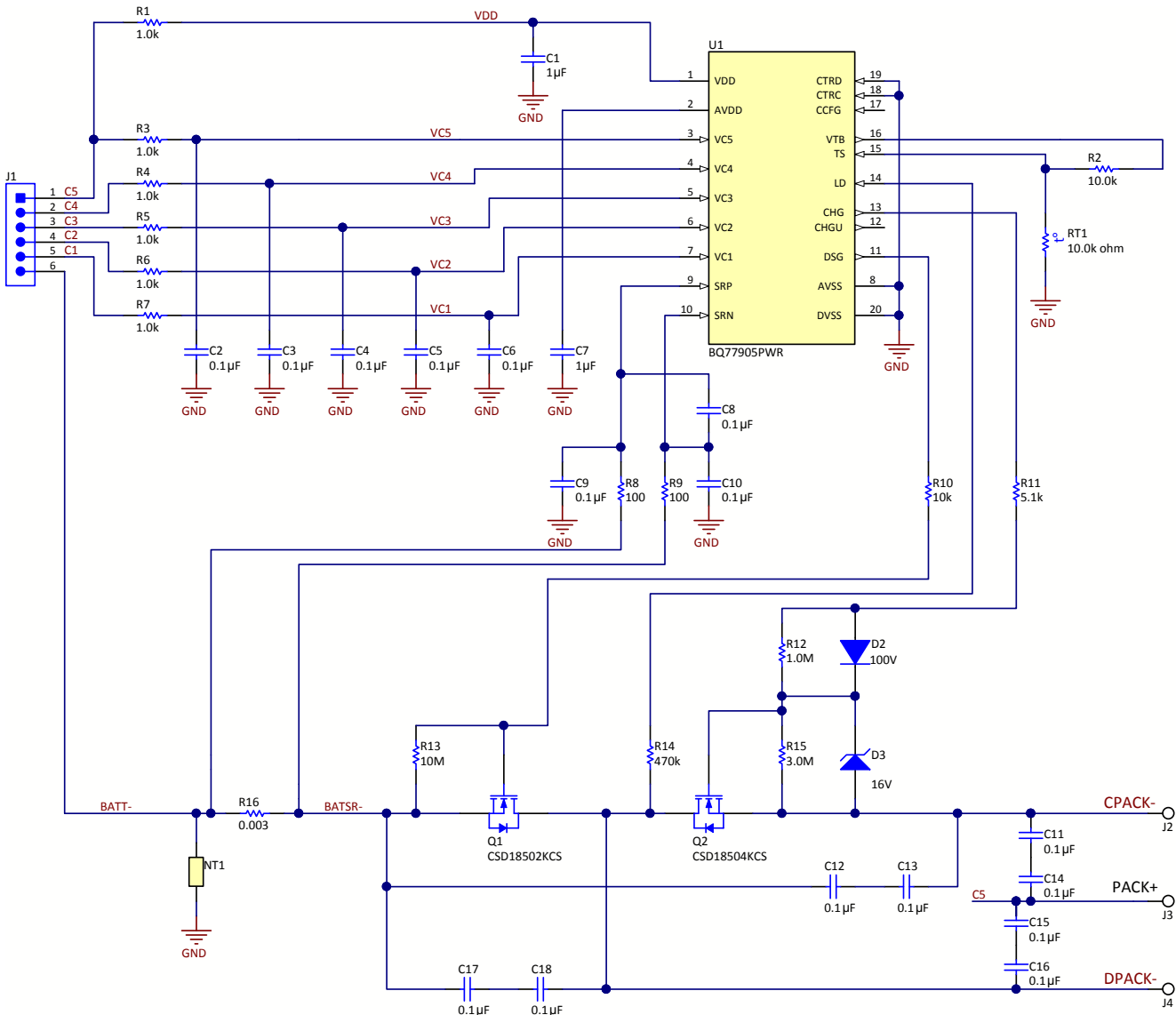


Figure 6. Undervoltage With Charge, Separate Paths

3 Discharge-Protected Charge Path

The circuit illustrated in Figure 7 is a variation of the typical circuit which takes the discharge path from the common drain of the series FETs. This type circuit may be appropriate where the system load cannot provide current to charge the battery but the charger might provide a path to discharge it. Discharge current bypasses the charge FET while charge current passes through both FETs to provide a discharge-protected charge path. This allows the discharge FETs to be sized for large current while the charge FET can be sized for lower current and reduced cost. Since the CPACK- can swing above or below BATT- or the bq77905 VSS, the blocking circuit from the data sheet is used to protect the charge FET gate. The LD pin must again be referenced to the DPACK- terminal of the circuit.



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Figure 7. Schematic With Discharge-Protected Charge Path

When PACK+ is shorted to DPACK- in this system, again the bq77905 drives both DSG and CHG low (see Figure 8). DSG turns off the discharge FET through the R_{DSG} resistor R10 and an overshoot occurs on the cells and DPACK- which is shorted to PACK+. Although CHG goes low, the gate of the charge FET rises with CPACK- due to the gate capacitance, and in the short term the FET remains on. As R12 and R15 pull down the gate, the FET will turn off and CPACK- will fall.

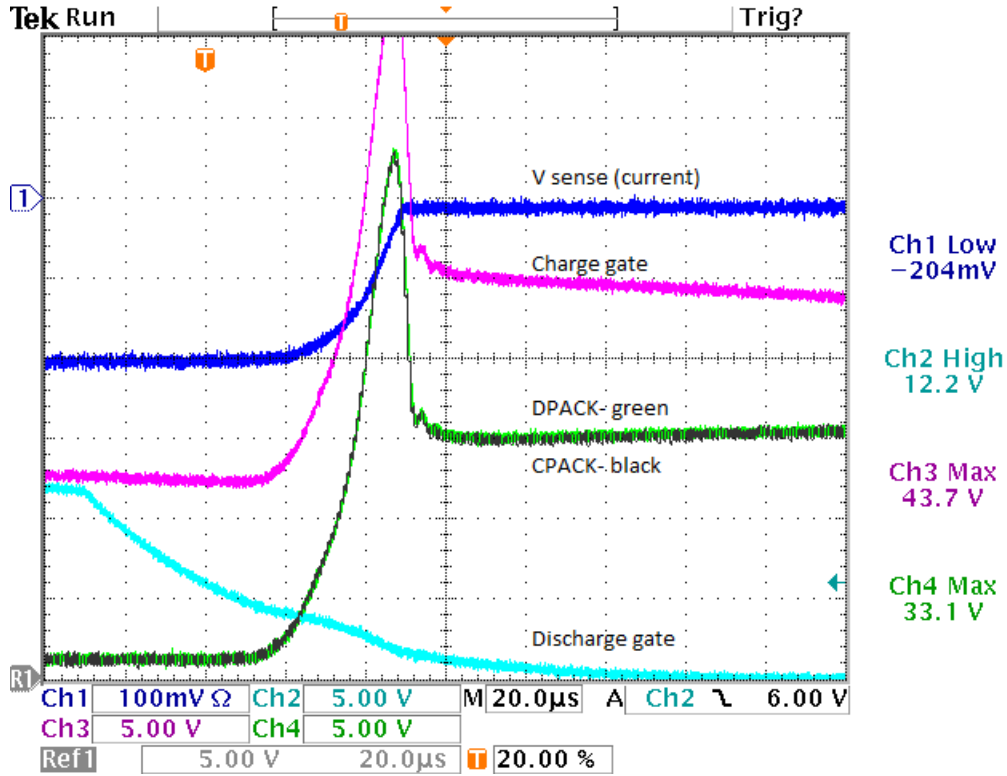


Figure 8. Short Circuit With Protected Charge Path

When the part goes to the undervoltage state, only DSG is turned off. DPACK- and CPACK- will rise and the charge FET gate will again be pushed up by its gate capacitance. In Figure 9 the CPACK- voltage is greater than the CHG voltage, so while CHG remains high the charge gate voltage drops and the FET turns off. Connection of a charger would pull down CPACK- and turn the FET back on. If the charger current is sufficient to overcome an applied load it can pull down DPACK- and force load removal detection.

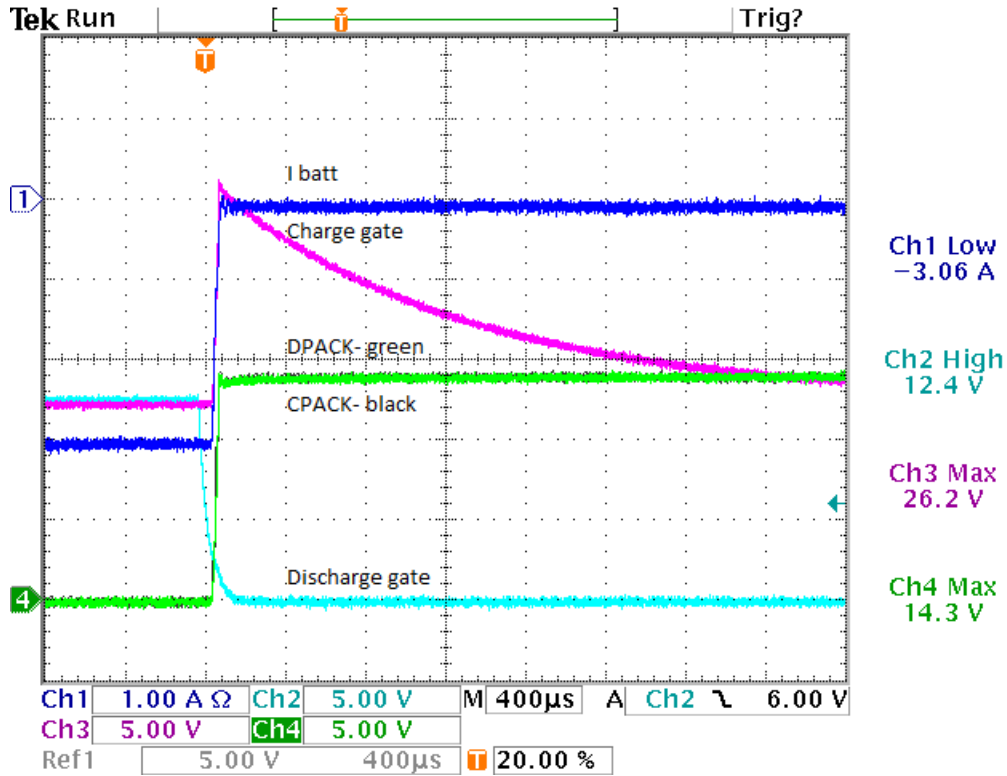


Figure 9. Undervoltage With Protected Charge Path

Only the charge outputs are turned off during overvoltage or overtemperature charge states. Figure 10 shows overtemperature charge turn off with charge current. With the blocking circuit to protect the charge FET gate and large values to prevent CHG from preventing load recovery, turn off is slower than the previous circuit.

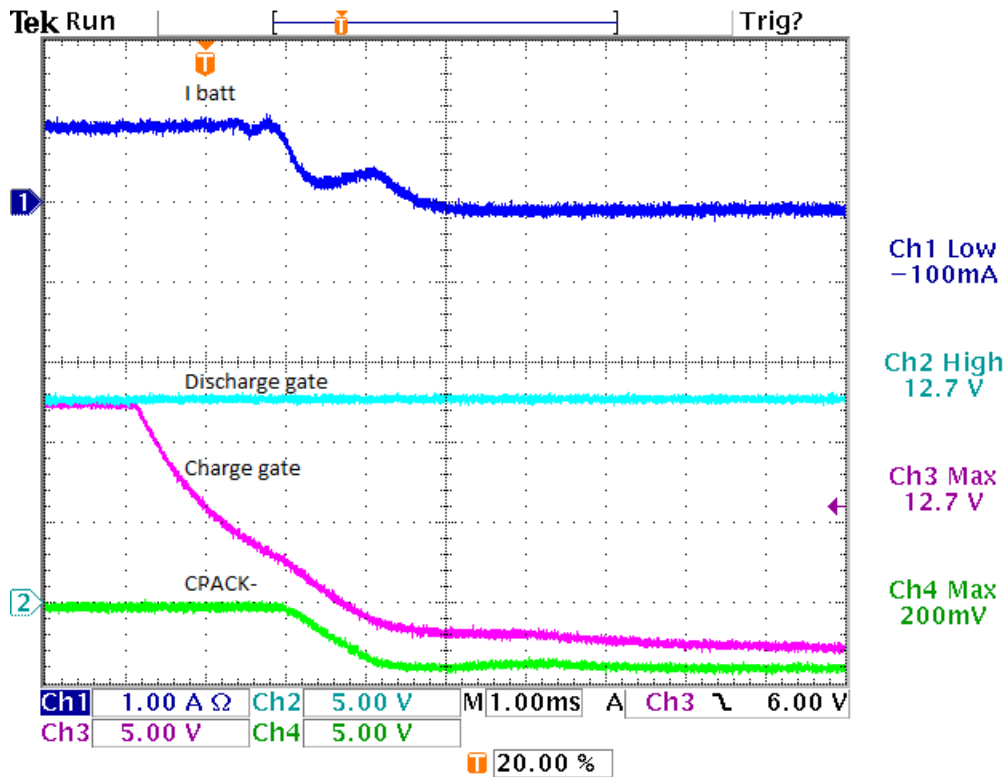


Figure 10. Overtemperature Charge With Protected Charge Path

When using the typical series FET and 2-terminal configuration, simultaneous charge and discharge connection allows current to flow from the charger to load without passing through the battery FETs. With this discharge-protected charge path circuit, charge current will be provided to the discharge path through the charge FET. The net current into the battery will be the difference between the charger and the load. In the case of the discharge FET being off with load and charger attached, the discharge FET will not come on until the charge current exceeds the load current enough to trigger the body diode protection. For steady currents FET cycling is not expected, but if the load holds the charger voltage low so that the charge FET V_{gs} is low, the charge FET overheats and damage could occur. If the load or charger current varies, the discharge FET could cycle. Figure 11 shows an example of a simultaneous charge and load with approximately the same currents. When an overtemperature charge fault occurs and the charge FET turns off, the discharge current triggers the body diode protection of the charge FET and it turns on again. In this example there is a current surge from the charger. The battery current falls, the charge FET turns off again and cycling continues. So while the conditions where FETs can cycle when both the charger and load are connected to the battery are reduced from the separate FET circuit, the circuit should still be used only in systems where it is appropriate.

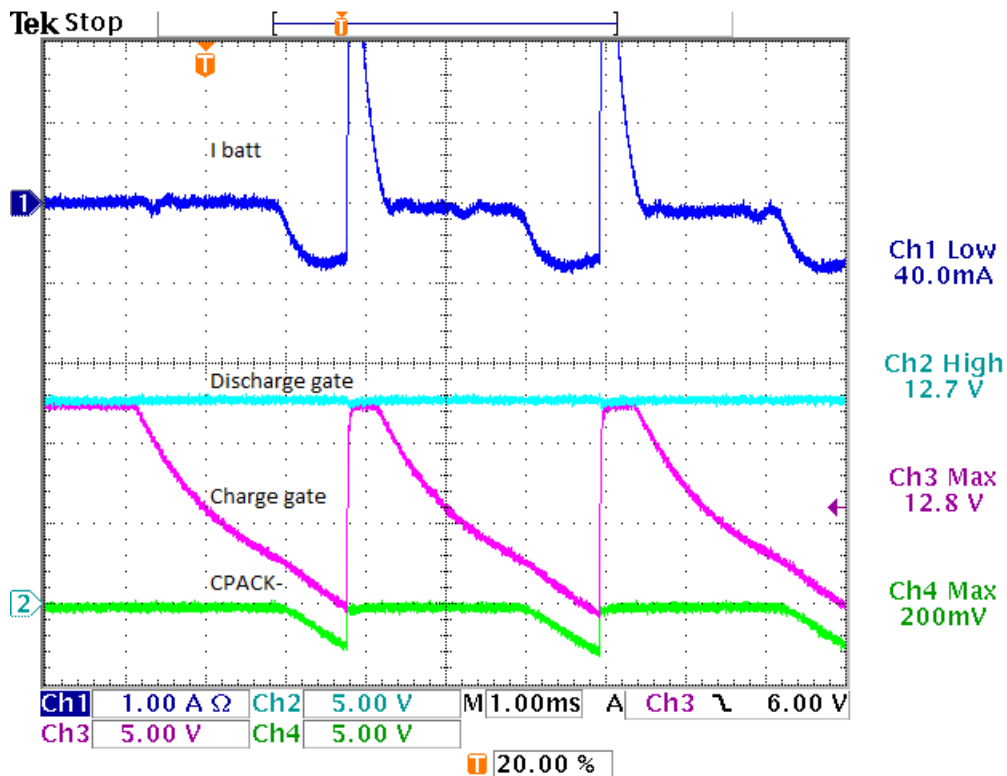


Figure 11. Overtemperature Charge and Discharge With Protected Charge Path

4 References

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

- [bq77904 / bq77905: 3-5S Low Power Protector data sheet \(SLUSCM3\)](#)
- [bq77905 EVM User's Guide \(SLVUAN2\)](#)

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (June 2016) to A Revision	Page
• Changed the data sheet literature number From: SLUSBZ7 To: SLUSCM3 in Section 4	12

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