Application Note

Design Flexibility for Reverse Charge Protection Using BQ27Z746

Justin Kim

ABSTRACT

This application note introduces design option for RCP (Reverse Charge Protection) feature that is offered with the BQ27Z746. The RCP feature will be required by cell manufacturers to prohibit reverse charging of battery packs in the system and make sure safety. Most BMS (Battery Management System) IC requires a parallel FET to implement RCP feature. However, this can be a design limitation for some applications with limited PCB sizes such as smart phones and wearables. The BQ27Z746 Impedance Track™ battery gauge design is a highly integrated, accurate 1-series cell gas gauge and protection design with integrated RCP feature. Using a parallel FET for RCP is no longer required if BQ27Z746 is used in the system and it can be determined by system needs. Therefore it can help save PCB size and BOM cost. This document describes how RCP feature can be implemented without parallel FET and with it for both cases.

Table of Contents

List of Figures

Trademarks

Impedance Track™ is a trademark of Texas Instruments.
All trademarks are the property of their respective owners.

1 Introduction

The BQ27Z746 EVM schematic is shown in Figure 1-1. The BQ27Z746 EVM includes a reverse charge circuit as *Optional RCP* consisting of Q2 FET and R4 gate resistor. The purpose of this circuit is to hold the gate of the discharge FET at the source potential to keep it off when the PACK+ terminal is pulled below VSS. This circuit will be important if an IC does not have internal RCP feature when a system uses a common connector such as a coaxial power connector for the charger. Since adapters with both polarities are available in the market, the incorrect charger could be attached and experience a reverse voltage condition.

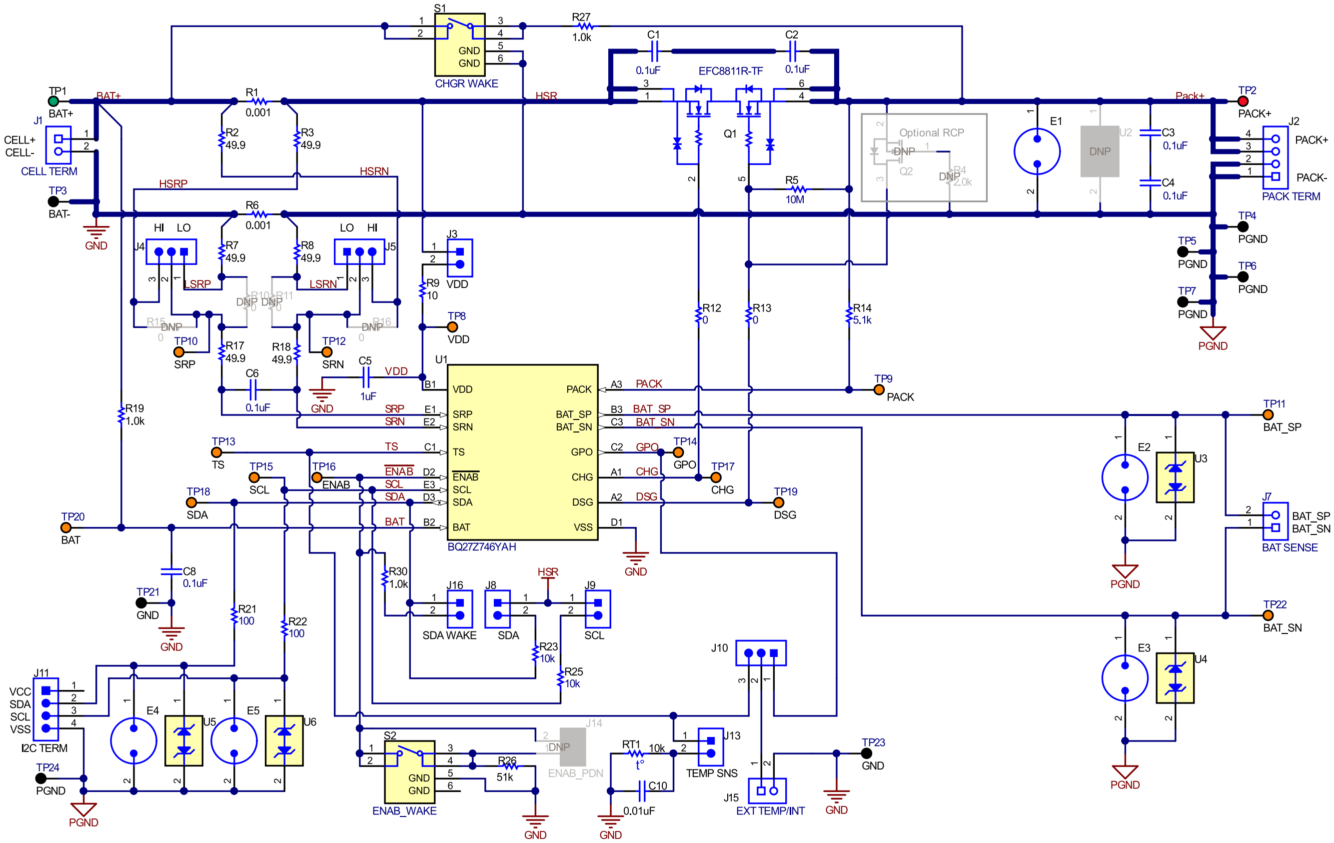

Figure 1-1. BQ27Z746 EVM Schematic

With a reversed charger, both the battery and charger will push current to flow in the same direction. The result can be a short circuit, or discharge to undervoltage with a protection event in battery. Therefore, most cell manufacturers specify that the battery pack must be protected from reverse charging connection. Figure 1-2 shows an example of specification from usual cell manufacturer as part.

- The Battery Pack must be designed to prevent reverse charge.

Figure 1-2. Example of Specification for RCP

When the protector attempts to turn off, it drives DSG to 0 V. If the charger has survived the event, the voltage goes negative. As the PACK+ terminal and source of discharge FET are forced to a negative voltage by the reversed charger, the DSG pin remains at approximately 0 V. The discharge FET is then conducted as a source follower since there is a positive voltage across gate to source of discharge FET. It operates in the ohmic region which can cause heating of the FET and failure, thus causing a short circuit event, draining the battery. Discharge FET can be damaged and burned out if the current is too high which is not safe. Figure 1-3 shows an example of current flow with a reversed charger when there is no RCP feature. BQ27Z746 has an internal RCP feature, so it depends on system needs to use optional RCP circuit or not. See Section 2 and Section 3 for more details about both cases.

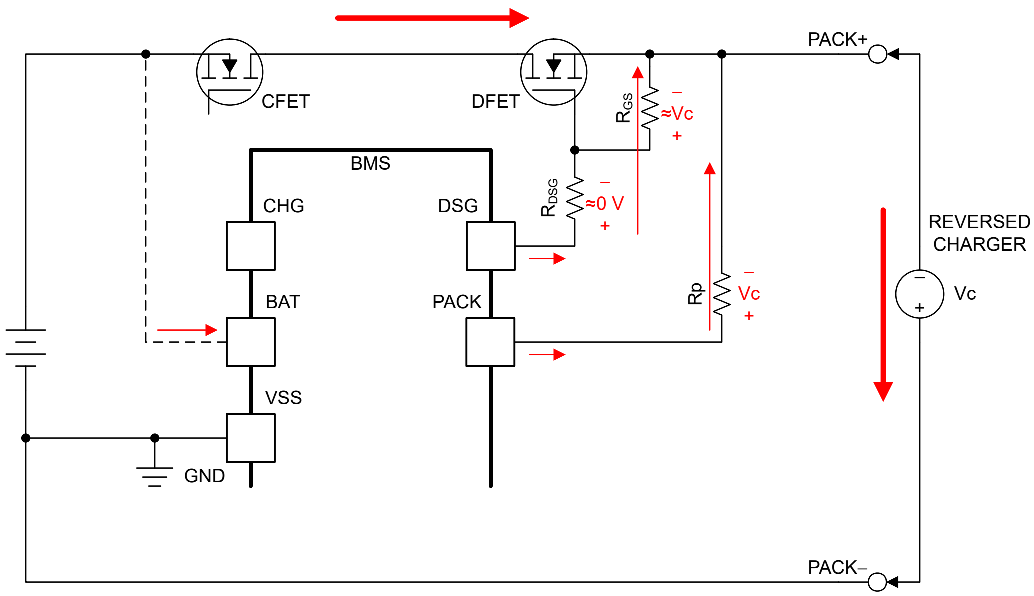

Figure 1-3. Currents with Reversed Charger Connection

2 Reverse Charger Protection with Optional RCP Circuit

A typical implementation of a reverse charge protection circuit is shown in Figure 2-1. The gate of discharge FET (DFET) is pulled to the source by a high value resistor between the gate and source to ensure it is turned off if the gate drive is open. The resistor value is 10 MΩ in the BQ27Z746 EVM schematic which is described in Figure 1-1. The 10 MΩ resistor ensures that the discharge FET is off in the event of an open connection to the FET driver. The RCP FET, which is an N-channel enhancement MOSFET, is added across RGS (10 MΩ) of the discharge FET with the gate connected to ground as RCP circuit. To use the simple ground gate circuit, the RCP FET must have a low gate turn-on threshold. If it is desired to use a more standard device, such as the 2N7002 as the reference schematic, the gate needs to be biased up to 3.3 V with a high value resistor.

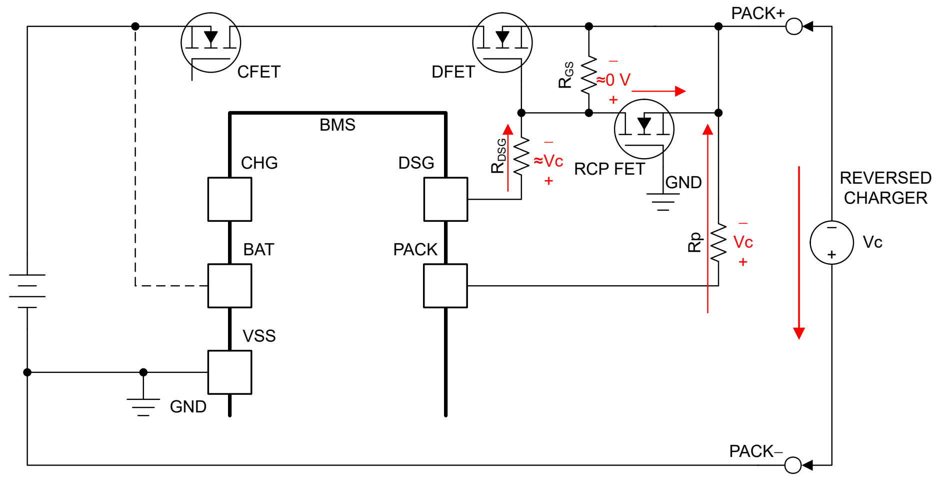

Figure 2-1. Reverse Cgarge Protection Circuit

When PACK+ is pulled below VSS, the source of RCP FET is pulled below its gate turning on the FET. Once RCP FET is turned on, it pulls the gate of discharge FET to its source keeping it off, thus preventing current flow. Figure 2-2 shows the waveform once RCP is properly occurred with optional RCP circuit. With the negative voltage on PACK+, the discharge FET sees the sum of the battery and charger voltages. So it must be able to withstand the battery voltage plus the reversed charger voltage considering a suitable VDS voltage. In most cases, this will be at least twice the maximum battery voltage. Any component placed across the discharge FET needs to have a similar rating. The circuit works while the battery and reverse voltages are within the absolute maximum VGS limit of the RCP FET.

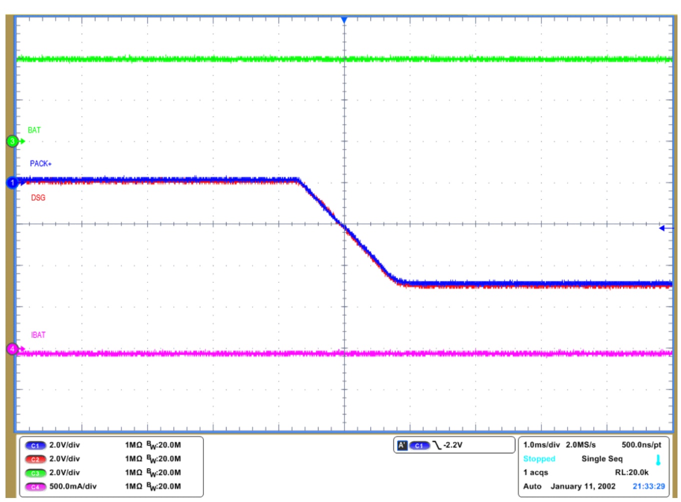

Figure 2-2. Negative Pack+ With optional RCP Circuit

3 Reverse Charge Protection Without Optional RCP Circuit

The DSG pin should be able to transition to negative voltage when reverse charging connection has occurred. It will drive any voltage across the RCP resistor to 0, turning off the DFET, and protecting the battery from discharging. Figure 3-1 shows a system diagram of BQ27Z746 for reverse charge protection. It shows that BQ27Z746 has an internal P channel MOSFET. The PFET blocks the negative voltage from reaching inside the IC with an ESD diode. The ESD diode prevents the pin voltage from going negative. The internal PFET allows the DSG pin voltage transition to negative below ground. If RCP has occurred, PFET will be very slightly turned on with extremely low leakage current. Thus, most reverse voltage is applied across the PFET, and the voltage drop across RGS resistor will be almost 0 V.

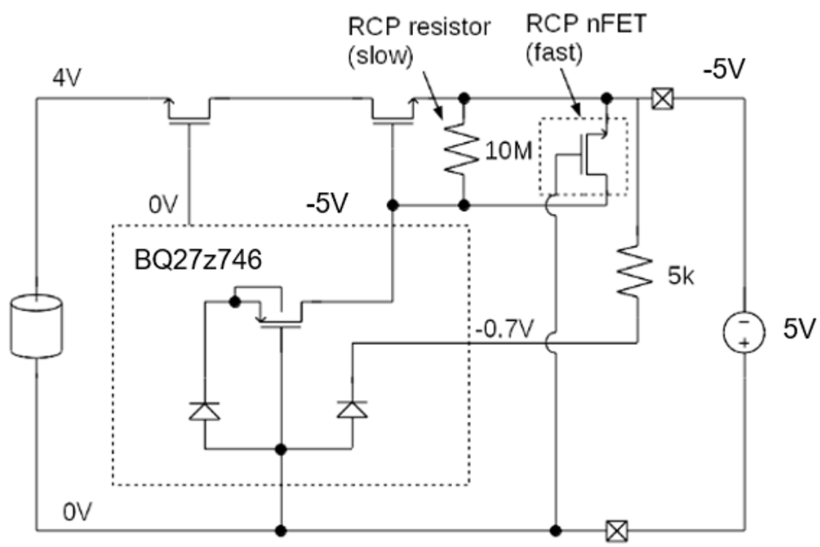

Figure 3-1. Reverse Charger Protection System Diagram

Transition from 0 V to reverse charger voltage (for example, -5 V) occurs via RCP resistor. Equalization time is determined by the resistance value and gate to source capacitance of discharging FET. With 10 MΩ resistance and 2 nF capacitance, the equalization time is approximately 50 ms. Figure 3-2 shows the simulation model for this operation with TINA. Figure 3-3 and Figure 3-4 shows the simulation results based on the resistance value. With 5 MΩ resistance value, the transition to negative of DSG pin is 2x faster than 10 MΩ resistance value. However, lowering the resistance value will increase the current consumption of the device in normal operation by increasing the output current load on the charge pump. Demand for fast equalization time can be determined by the current of the reverse charger voltage source.

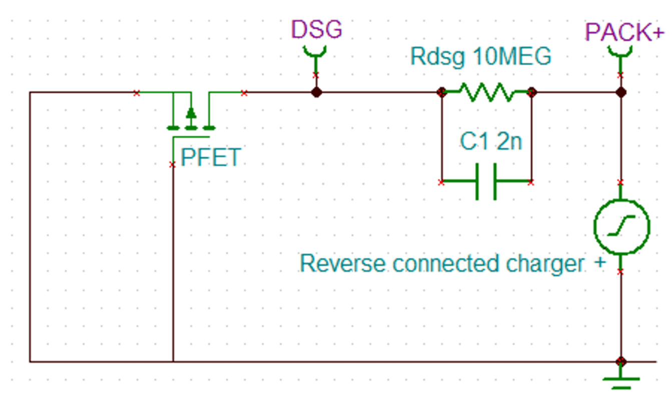

Figure 3-2. Simulation Model for Internal RCP Circuit of BQ27Z746

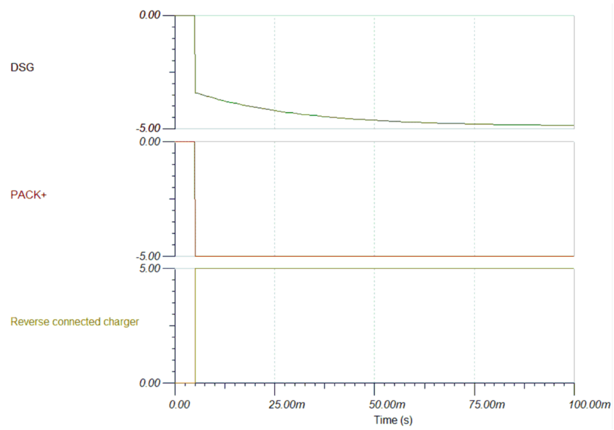

Figure 3-3. Simulation Result When R_{GS} = 10 MΩ

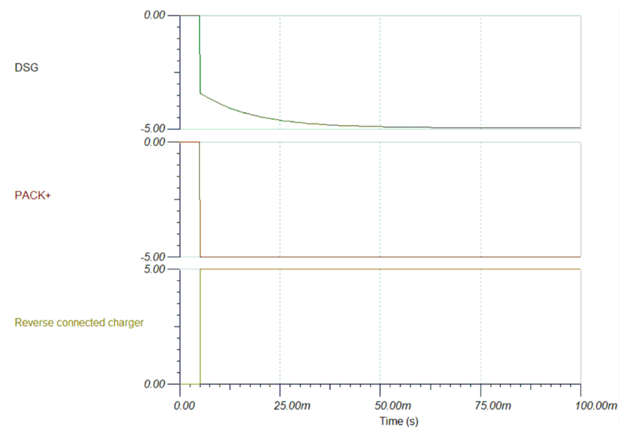

Figure 3-4. Simulation Result When R_{GS} = 5 MΩ

Figure 3-5 shows the waveform when reverse charger connection has occurred using a gauge which does not have an internal RCP circuit. The battery charger source has limited charging current to 200 mA as reference. Therefore, the battery discharging current is 200 mA in the waveform. The battery discharging current will get as high as the reverse connected source's current limit. Figure 3-6 shows the waveform when reverse charge connection is occurred with BQ27Z746 without optional RCP circuit. The power source limited charging current to 3 A. As a result, BQ27Z746 successfully protects discharging current from battery. At this measurement, DSG pin was not connected to oscilloscope. Since a probe can connect the RCP resistor to ground on DSG, the DSG pin cannot transition negative if there is a 10 MΩ from DSG to ground through the scope connection.

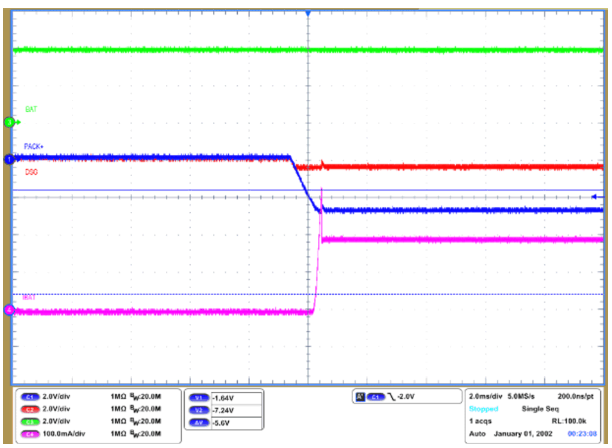

Figure 3-5. Reverse Charge Connection With the Gauge Which Does Not Have Internal RCP

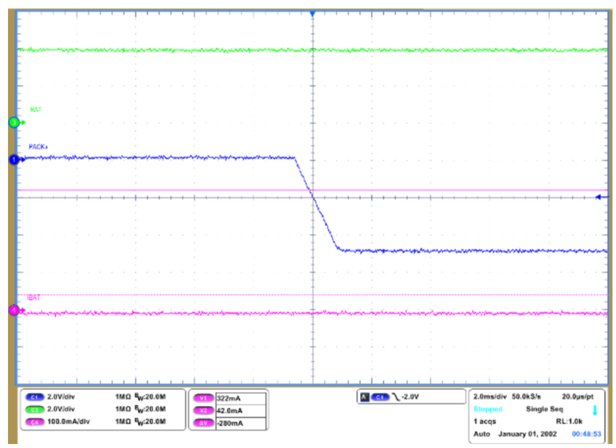

Figure 3-6. Reverse Charge Connection with BQ27Z746 which has internal RCP

Figure 3-7 shows the placement of optional RCP circuit in PCB from BQ27Z746 reference schematic. With BQ27Z746, User can save 27 mm^2 of PCB size and BOM cost by removing the components of optional RCP circuit.

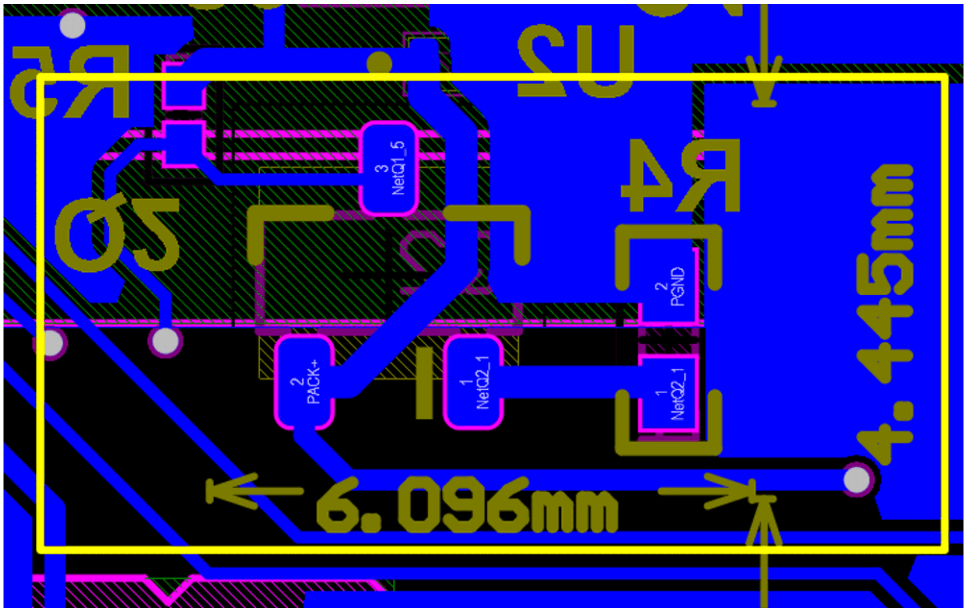

Figure 3-7. Optional RCP Circuit in PCB

4 Summary

Design flexibility for RCP feature with BQ27Z746 is described in this application note. The BQ27Z746 has an internal RCP circuit. The Internal RCP feature can help a designer reduce BOM cost and PCB size. Thus BQ27Z746 will be the best option for gauge selection from applications which require small form factor such as mobile phones and wearables. This application note describes the RCP feature and how a designer can leverage the design flexibility using the BQ27Z746.

5 References

- Texas Instruments, *BQ27Z746 Impedance Track™ Technology Battery Gas Gauge and Protection Solution for 1-Series Cell Li-Ion Battery Packs*, data sheet.
- Texas Instruments, *BQ27Z746 EVM Impedance Track™ Battery Gas Gauge and Protection Solution for 1-Series Cell Li-ion Battery Packs*, user's guide
- Texas Instruments, *BQ40Z50 1-Series, 2-Series, 3-Series, and 4-Series Li-Ion Battery Pack Manager*, data sheet.
- Texas Instruments, *Multiple FETs with the BQ769x2 Battery Monitors*, application note.
- Texas Instruments, *bq76200 Reverse Voltage Considerations*, application note.