Texas Instruments

Application Report
SLUA606–February 2012

bq30z50/55 Advanced Gas Gauge Circuit Design

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ABSTRACT

Components in the bq30z50/55 reference design are explained in this application report. Design analysis and suggested tradeoffs are provided, where appropriate.

Contents

List of Figures

List of Tables

1 Introduction

The bq30z50 Advanced Gas Gauge has approximately 69 components in the reference design for a four-thermistor, five-LED, four-cell application. The bq30z55 Advanced Gas Gauge has approximately 66 components—and no LEDs—for a two-thermistor, external pre-charge, four-cell application. Each device is divided into the following classifications: High-Current Path, Gas Gauge Circuit, Secondary-Current Protection and Cell-Balancing Circuit, and Secondary-Voltage Protection.

This discussion is based on the four-cell reference design for the bq30z50/55 and bq29412 chipset. Figure 18 shows the bq30z50 reference design schematic. Figure 19 shows the bq30z55 reference design schematic.

2 High-Current Path

The high-current path begins at the PACK+ terminal of the battery pack. As charge current travels through the pack, it finds its way through protection FETs, a chemical fuse, the lithium-ion cells and cell connections, and the sense resistor, and then returns to the PACK– terminal (see Section 6). In addition, some components are placed across the PACK+ and PACK– terminals to reduce effects from electrostatic discharge.

2.1 Protection FETs

The N-channel charge and discharge FETs must be selected for a given application. Most portable battery applications are a good match for the Si7114DN. The Vishay Si7114DN is an 18.3-A, 30-V device with Rds(on) of 7.5 mΩ when the gate drive voltage is 10 V.

If a precharge FET is used, R15 (in bq30z50) or R28 (in bq30z55) is calculated to limit the precharge current to the desired rate. Be sure to account for the power dissipation of the series resistor. The precharge current is limited to (Vcharger – Vbat)/R15 and maximum power dissipation is $(Vcharger – Vbat)^2/R15$.

The gates of all protection FETs are pulled to the source with a high-value resistor between the gate and source to ensure they are turned off if the gate drive is open.

Capacitors C16 and C17 help protect the FETs during an ESD event. The use of two devices ensures normal operation if one of them becomes shorted. In order to have good ESD protection, the copper trace inductance of the capacitor leads must be designed to be as short and wide as possible. Ensure that the voltage rating of both C16 and C17 are adequate to hold off the applied voltage if one of the capacitors becomes shorted.

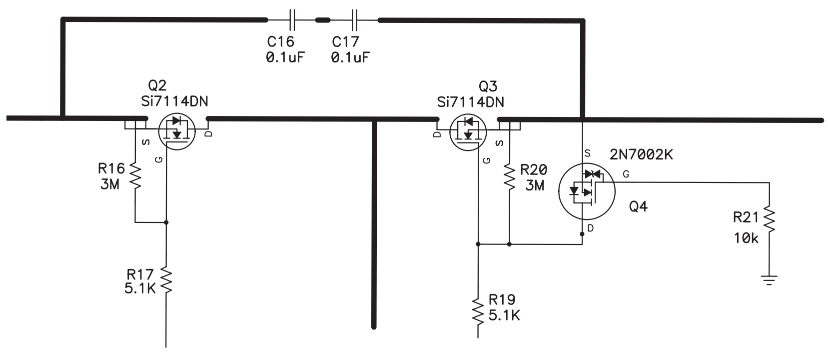

Figure 1. bq30z50 Protection FETs

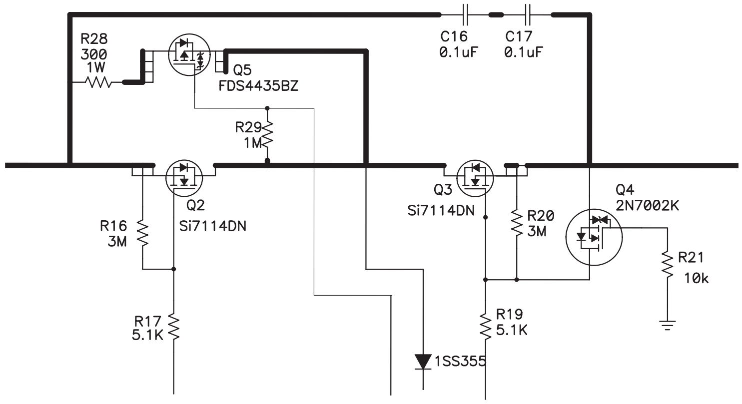

Figure 2. bq30z55 Protection FETs

2.2 Chemical Fuse

The chemical fuse (Sony Chemical, Uchihashi, etc.) is ignited under command from either the bq29412 secondary voltage protection IC or from the FUSE pin of the gas gauge. Either of these events applies a positive voltage to the gate of Q1, shown in Figure 3, which then sinks current from the third terminal of the fuse, causing it to ignite and open permanently.

It is important to carefully review the fuse specifications and match the required ignition current to that available from the N-channel FET. Ensure that the proper voltage, current, and Rds(on) ratings are used for this device. The fuse control circuit is discussed in detail in Section 3.5.

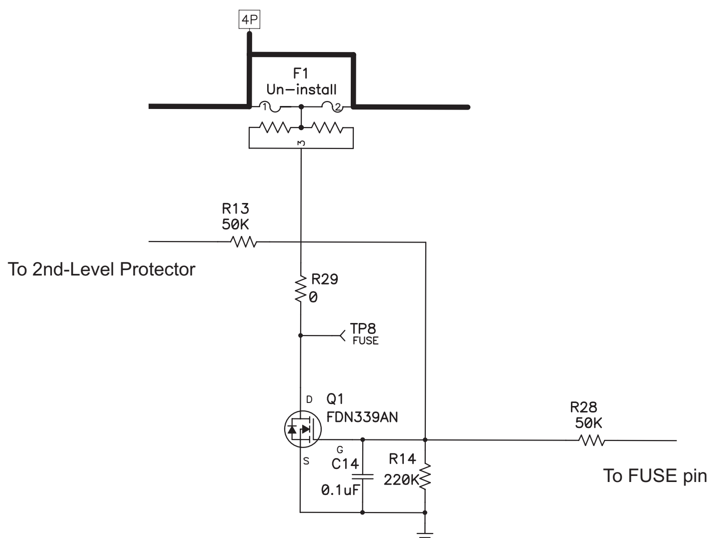

Figure 3. FUSE Circuit

2.3 Lithium-Ion Cell Connections

The important thing to remember about the cell connections is that high current flows through the top and bottom connections, and therefore the voltage sense leads at these points must be made with a Kelvin connection to avoid any errors due to a drop in the high-current copper trace. The location marked 4P in Figure 4 indicates the Kelvin connection of the most positive battery node. The connection marked 1N is equally important. The VC5 pin (a ground reference for cell voltage measurement), which is in the older generation devices, is not in the bq30z50/55 device. Hence, the single-point connection at 1N to the low-current ground is needed to avoid an undesired voltage drop through long traces while the gas gauge is measuring the bottom cell voltage.

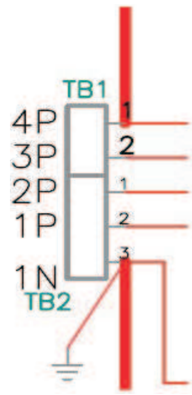

Figure 4. Lithium-Ion Cell Connections

2.4 Sense Resistor

As with the cell connections, the quality of the Kelvin connections at the sense resistor is critical. The sense resistor must have a temperature coefficient no greater than 75 ppm in order to minimize current measurement drift with temperature. Choose the value of the sense resistor to correspond to the available overcurrent and short-circuit ranges of the bq30z50/55. (See the relevant tables in SLUS996.) Select the smallest value possible in order to minimize the negative voltage generated on the bq30z50 V_{SS} node(s) during a short circuit. This pin has an absolute minimum of –0.3 V. For a pack with two parallel cylindrical cells, 10 mΩ is generally ideal. Parallel resistors can be used as long as good Kelvin sensing is ensured.

The ground scheme of bq30z50 is different from the older generation devices. In previous devices, the device ground (or low current ground) is connected to the SRN side of the Rsense resistor pad. The bq30z50, however, connects the low-current ground on the SRP side of the Rsense resistor pad, close to the battery 1N terminal (see Section 2.3). This is because the bq30z50 has one less VC pin (a ground reference pin VC5) compared to the previous devices. The pin was removed and was internally combined to SRP.

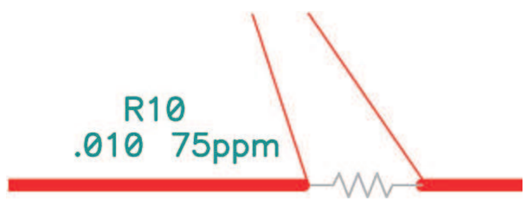

Figure 5. Sense Resistor

2.5 ESD Mitigation

A pair of series 0.1-µF ceramic capacitors is placed across the PACK+ and PACK– terminals to help in the mitigation of external electrostatic discharges. The two devices in series ensure continued operation of the pack if one of the capacitors becomes shorted.

Optionally, a tranzorb such as the SMBJ2A can be placed across the terminals to further improve ESD immunity.

3 Gas Gauge Circuit

The Gas Gauge Circuit includes the bq30z50/55 and its peripheral components. These components are divided into the following groups: Differential Low-Pass Filter, Power Supply Decoupling/RBI/, System Present, SMBus Communication, FUSE circuit, and LED.

3.1 Differential Low-Pass Filter

As shown in Figure 6, a differential filter must precede the current sense inputs of the gas gauge. This filter eliminates the effect of unwanted digital noise, which can cause offset in the measured current. Even the best differential amplifier has less common-mode rejection at high frequencies. Without a filter, the amplifier input stage may rectify a strong RF signal, which then may appear as a dc offset error.

Five percent tolerance of the components is adequate because capacitor C15 shunts C12/C13, and reduces ac common mode arising from component mismatch. It is important to locate C15 as close as possible to the gas gauge pins. The other components also must be relatively close to the IC. The ground connection of C12 and C13 must be close to the IC. It is also proven to reduce offset and noise error by maintaining a symmetrical placement pattern and adding ground shielding for the differential filter network.

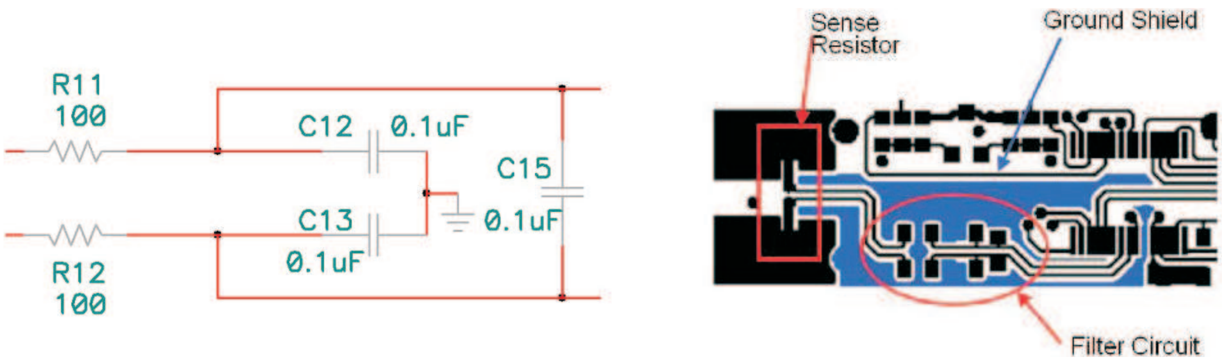

Figure 6. Differential Filter

3.2 Power Supply Decoupling and RBI

Power supply decoupling is important for optimal operation of the bq30z50/55 Advanced Gas Gauges. As shown in Figure 7, a single 1.0-μF ceramic decoupling capacitor from REG33 to V_{SS} and REG25 to V_{SS} must be placed adjacent to the IC pins.

The RBI pin is used to supply backup RAM voltage during brief transient power outages. The partial reset mechanism makes use of the RAM to restore the critical CPU registers following a temporary loss of power. A standard 0.1-μF ceramic capacitor is connected from the RBI pin to ground as shown in Figure 7.

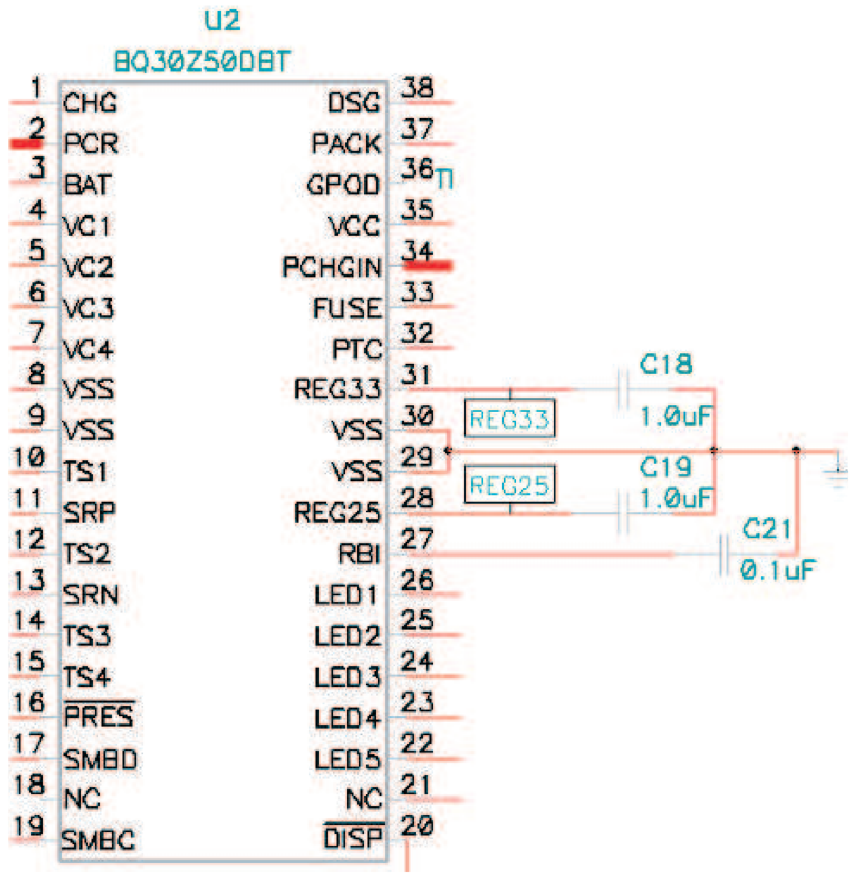

Figure 7. Power Supply Decoupling

3.3 System Present

The System Present signal is used to inform the gas gauge whether the pack is installed into or removed from the system. In the host system, this pin is grounded. The $\overline{\text{PRES}}$ pin of the bq30z50/55 is occasionally sampled to test for system present. To save power, an internal pullup is provided by the gas gauge during a brief 4-µs sampling pulse once per second.

Because the System Present signal is part of the pack connector interface to the outside world, it must be protected from external electrostatic discharge events. An integrated ESD protection on the $\overline{\text{PRES}}$ device pin reduces the external protection requirement to just R25 for an 8-kV ESD contact rating. However, if it is possible that the System Present signal may short to PACK+, then R18 and D3 must be included for high-voltage protection.

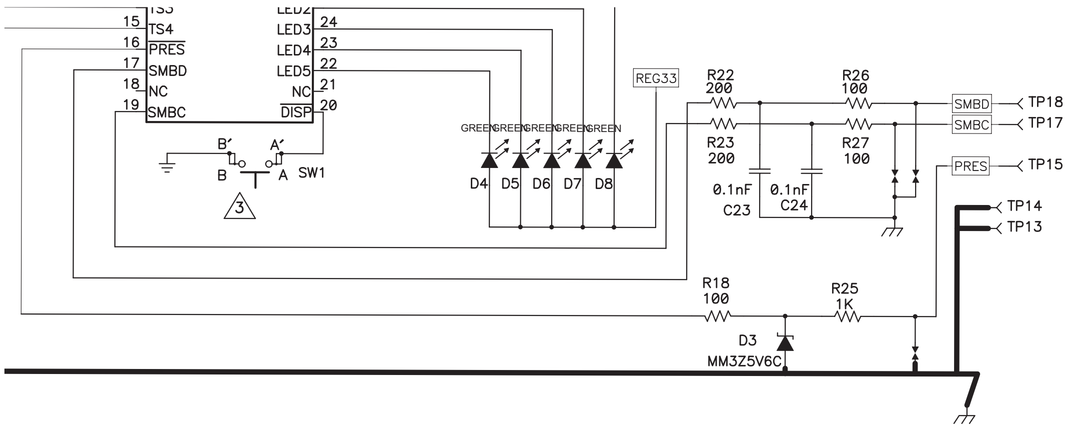

Figure 8. System Present ESD and Short Protection

3.4 SMBus Communication

Similar to the System Present pin, the SMBus clock and data pins have integrated high-voltage ESD protection circuit that reduce the need for external Zener diode protection. When using the circuit shown in Figure 9, the communication lines can withstand an 8-kV (contact) ESD strike. C23 and C24 are selected with a 100-pF value in order to meet the SMBus specifications. If it is desirable to provide increased protection with a larger input resistor and/or Zener diode, carefully investigate the signal quality of the SMBus signals under worst-case communication conditions.

The SMbus clock and data lines have internal pulldown. When the gas gauge senses that both lines are low (such as during removal of the pack), the device performs auto-offset calibration and then goes into sleep mode to conserve power.

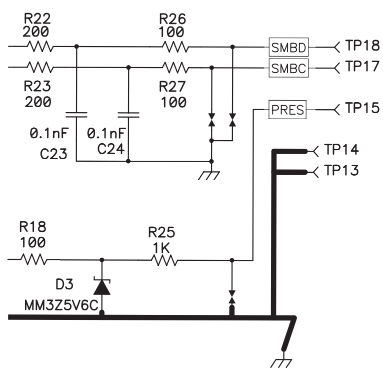

Figure 9. ESD Protection for SMB Communication

3.5 FUSE Circuitry

The FUSE pin of the bq30z50/55 is designed to ignite the chemical fuse if one of the various safety criteria is violated. The FUSE pin is also used to monitor the state of the secondary-voltage protection IC. Q3 ignites the chemical fuse when its gate is high. The 7-V output of the bq29412 is divided by R13 and R14, which provides adequate gate drive for Q1 while guarding against excessive back current into the bq29412 if the FUSE signal is high.

The use of C14 is generally good practice, especially for RFI immunity, but may be removed if desired because the chemical fuse is a comparatively slow device and is not affected by any sub-microsecond glitches that may come from the SAFE output during the cell connection process.

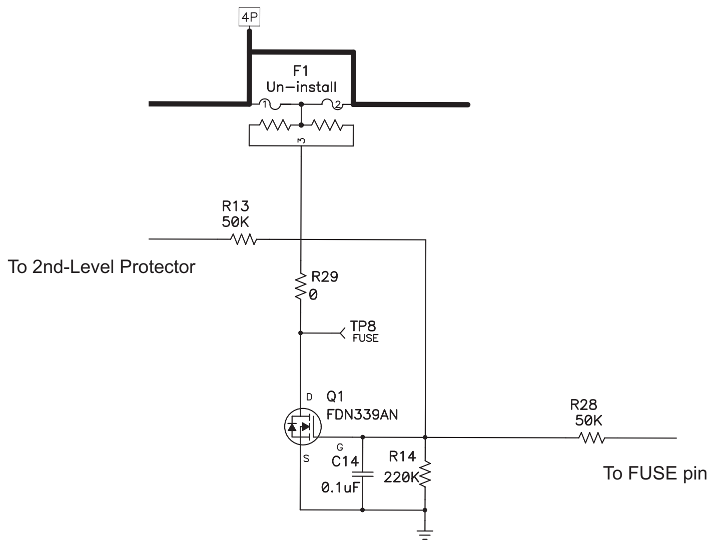

Figure 10. FUSE Circuit

When the bq30z50/55 is commanded to ignite the chemical fuse, the FUSE pin activates to give a typical 8-V output. The new design makes it possible to use a higher Vgs FET for Q1. This improves the robustness of the system, as well as widens the choices for Q1.

3.6 PFIN Detection

As previously mentioned, the FUSE pin has a dual role on this device. When bq30z50/55 is not commanded to ignite the chemical fuse, the FUSE pin defaults to sense the OUT pin status of the secondary voltage protector. When the secondary voltage protector ignites the chemical fuse, the high voltage is sensed by the FUSE pin, and the bq30z50/55 sets the PFIN flag accordingly.

4 Secondary-Current Protection

The bq30z50/55 provides secondary overcurrent and short-circuit protection, cell balancing, cell voltage multiplexing, and voltage translation. The following discussion examines Cell and Battery Inputs, Pack and FET Control, Regulator Output, Temperature Output, and Cell Balancing.

4.1 Cell and Battery Inputs

Each cell input is conditioned with a simple RC filter, which provides ESD protection during cell connect and acts to filter unwanted voltage transients. The resistor value allows some trade-off for cell balancing versus safety protection.

The internal cell balancing FETs in bq30z5x provide about typ 310 Ω (310 Ω with cell voltage ≥ 2 V. The cell balancing FETs Rds-on reduced to typ 125 Ω with cell voltage ≥ 4 V), which can be used to bypass charge current in individual cells that may be overcharged with respect to the others. The purpose of this bypass path is to reduce the current into any one cell during charging to bring the series elements to the same voltage. Series resistors placed between the input pins and the positive series element nodes control the bypass current value. The bq30z5x device is designed to take up to 10-mA cell balancing current. Series input resistors between 100 Ω and 1 kΩ are recommended for effective cell balancing.

The BAT input uses a diode (D1) and 1-μF ceramic capacitor (C9) to isolate and decouple it from the cells in the event of a transient dip in voltage caused by a short-circuit event.

Also, as described previously in Section 2, the top and bottom nodes of the cells must be sensed at the battery connections with a Kelvin connection to prevent voltage sensing errors caused by a drop in the high-current PCB copper.

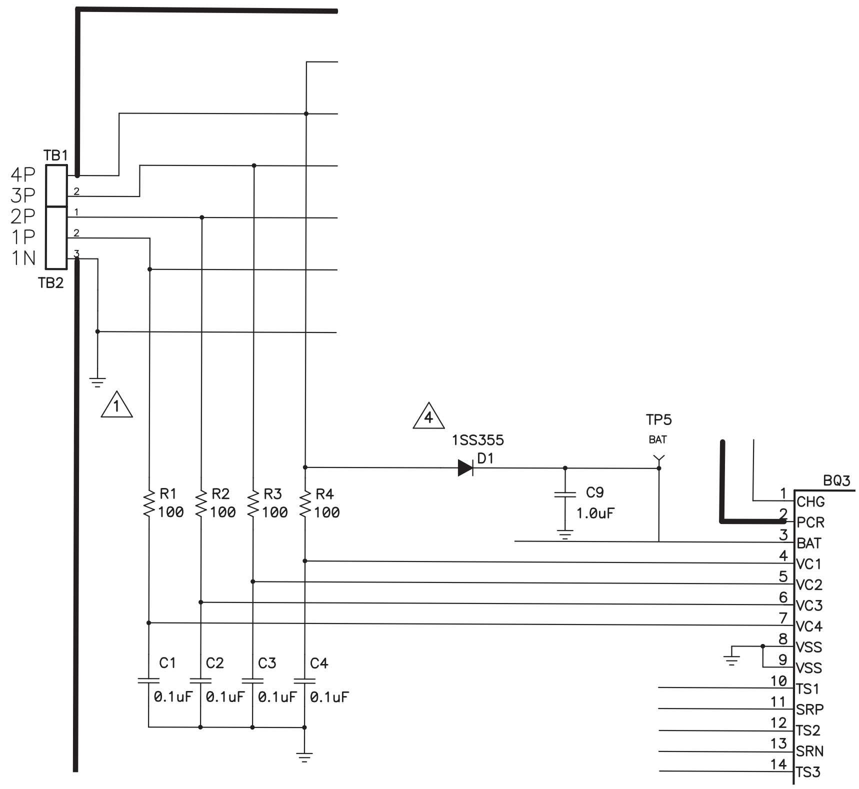

Figure 11. Cell and BAT Inputs

4.2 External Cell Balancing

Internal cell balancing can only support up to 10 mA. External cell balancing provide as another option for faster cell balancing. For details, refer to the application note, *Fast Cell Balancing Using External MOSFET* (SLUA420).

4.3 PACK and FET Control

The PACK and V_{CC} inputs provide power to the bq30z5x from the charger. The PACK input also provides a method to measure and detect the presence of a charger. The PACK input uses a 10-KΩ resistor, whereas the V_{CC} input uses a diode to guard against input transients and prevents misoperation of the date driver during short-circuit events.

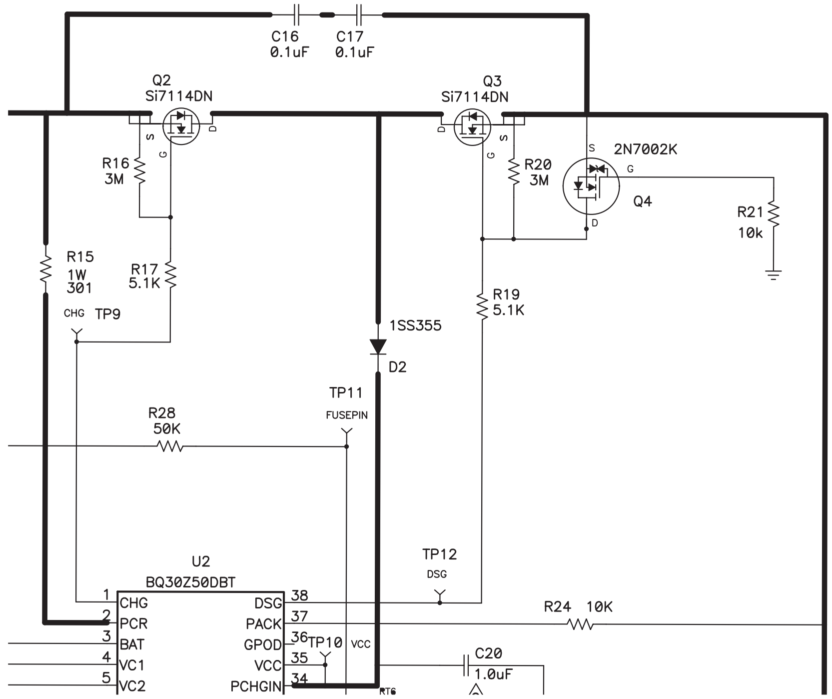

Figure 12. bq30z50 PACK and FET Control

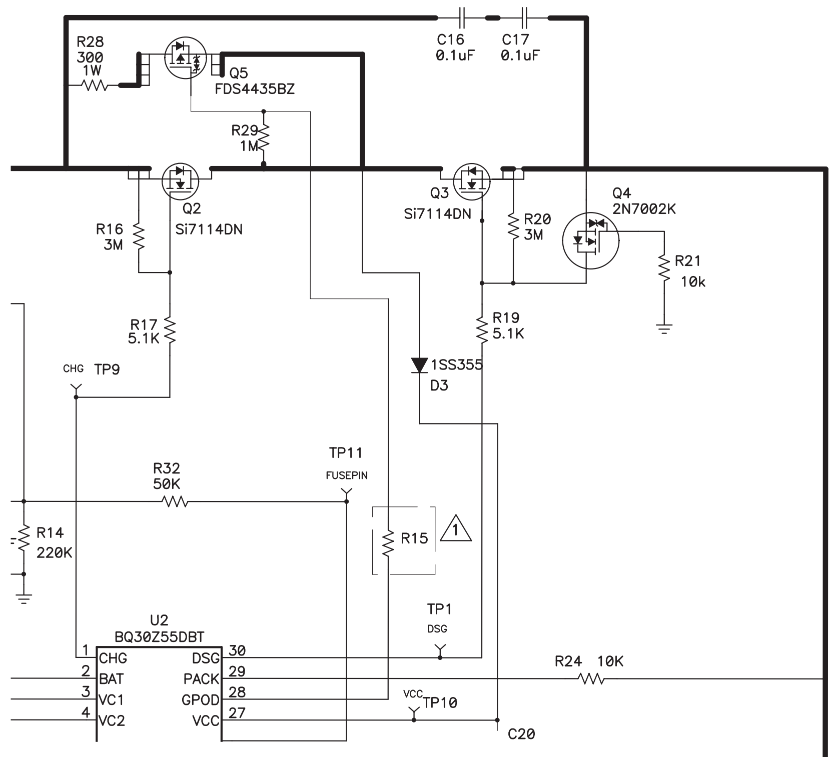

Figure 13. bq30z55 PACK and FET Control

The N-channel charge and discharge FETs are controlled with 5.1-KΩ series gate resistors, which provide a switching time constant of a few microseconds. The 3.01-MΩ resistors ensure that the FETs are off in the event of an open connection to the FET drivers. Q4 is provided to protect the discharge FET (Q3) in the event of a reverse-connected charger. Without Q4, Q3 can be driven into its linear region and suffer severe damage if the PACK+ input becomes slightly negative.

Q4 turns on in that case to protect Q3 by shorting its gate to source. To use the simple ground gate circuit, the FET must have a low gate turn-on threshold. If it is desired to use a more standard device, such as the 2N7000 as the reference schematic, the gate should be biased up to 3.3 V with a high-value resistor. The bq30z5x device has the capability to provide a current-limited charging path typically used for low battery voltage or low temperature charging. The bq30z55 device uses an external P-channel, pre-charge FET controlled by GPOD. The pre-charge FET is integrated into the bq30z50 device, allowing users to only connect an external pre-charge load resistor via the PCR pin through the PCHGIN input. The bq30z50 device supports up to 100-mA of pre-charge current. When selecting the external load resistor, user should take into account the max charger voltage and the Rdson of the internal pre-charge FET (refer to the device data sheet specification).

4.4 Regulator Output

As mentioned in Section 3.2, the two low-dropout regulators in the bq30z50/55 require capacitive compensation on the output. The outputs must have a 1-μF ceramic capacitor placed close to the IC terminal pins.

4.5 Temperature Output

For the bq30z50 device, TS1, TS2, TS3, and TS4 provide thermistor drive-under program control. Each pin can be enabled with an integrated 18-kΩ (typical) linearization pullup resistor to support the use of a 10-kΩ at 25°C (103) NTC external thermistor such as a Mitsubishi BN35-3H103. The reference design includes four 10-kΩ thermistors: RT1, RT2, RT3, and RT4. The bq30z55 device supports up to two thermistors.

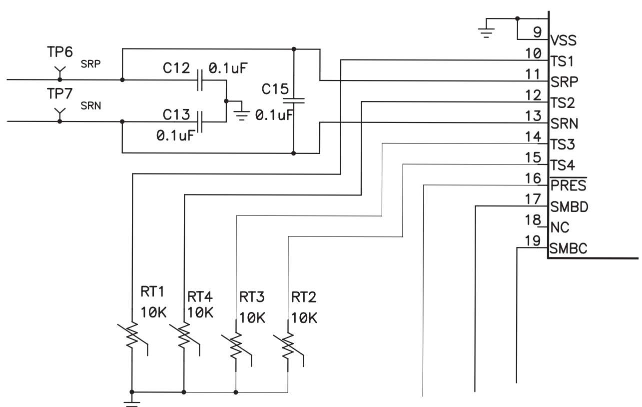

Figure 14. Thermistor Drive

4.6 LEDs

The LEDs do not need current-limiting resistors because the bq30z50 LED pins have a programmable current sink to simplify the design. The display switch pulls the bq30z50 pin 20 to ground to generate an interrupt. The REG33 output powers the LEDs.

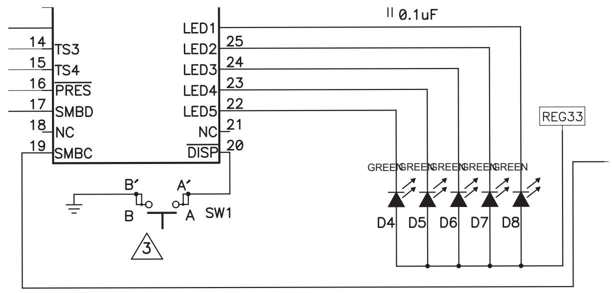

Figure 15. LEDs

4.7 Safety PTC Thermistor

The bq30z5x device provides support for a safety PTC thermistor. The PTC thermistor is connected between the PTC pin and V_{SS}. It can be placed close to the CHG/DSG FETs to monitor the temperature. The PTC pin outputs a very small current, typical ~370 nA , and the PTC fault will be triggered at ~0.7 V typical. A PTC fault is one of the permanent failure modes. It can only be cleared by a POR.

To disable this feature, connect a 10-KΩ resistor between PTC and V_{SS}.

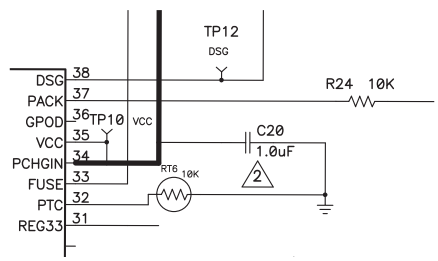

Figure 16. PTC Thermistor

5 Secondary-Overvoltage Protection

The bq29412 provides secondary-overvoltage protection and commands the chemical fuse to ignite if any cell exceeds the internally referenced threshold. The peripheral components are Cell Inputs and Time Delay Capacitor.

5.1 Cell Inputs

An input filter is provided for each cell input. This comprises the resistors R5, R6, R7, and R9 along with capacitors C5, C6, C7, and C8. This input network is completely independent of the filter network used as input to the bq30z50/55. To ensure independent safety functionality, the two devices must have separate input filters.

Because the filter capacitors are implemented differentially, a low-voltage device can be used in each case.

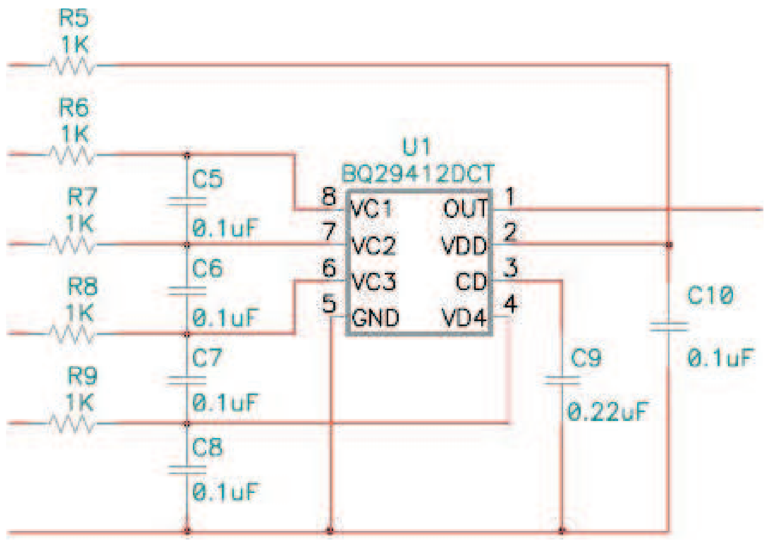

Figure 17. bq29412 Cell Inputs and Time-Delay Capacitor

5.2 Time-Delay Capacitor

C10 sets the time delay for activation of the output after any cell exceeds the threshold voltage. The time delay is calculated as td = 1.2 V × DelayCap (μF)/0.18 μA.

6 Reference Design Schematic

Figure 18 shows the bq30z50 reference design schematic. Figure 19 shows the bq30z55 reference design schematic.

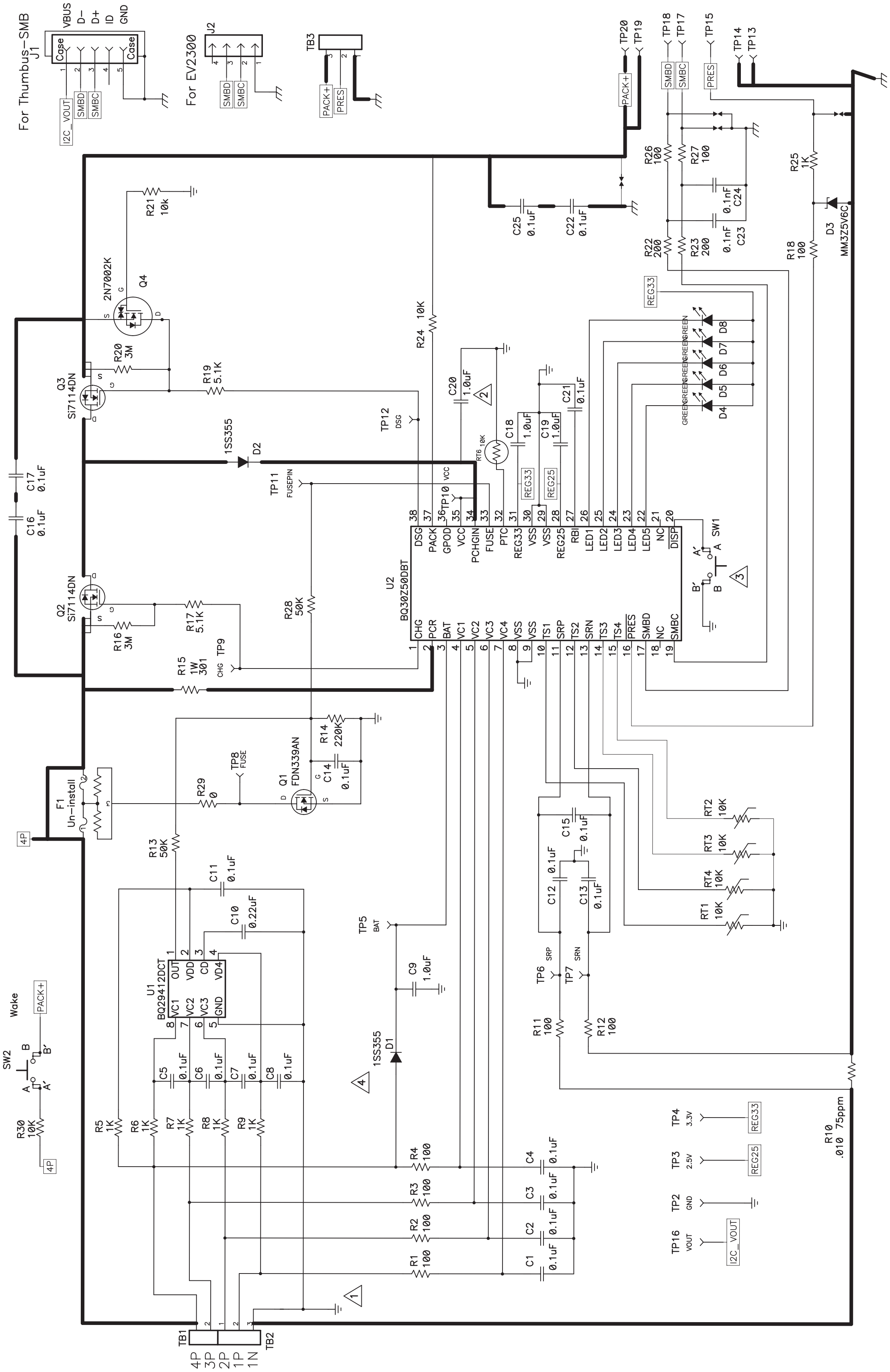

Figure 18. bq30z50 Schematic

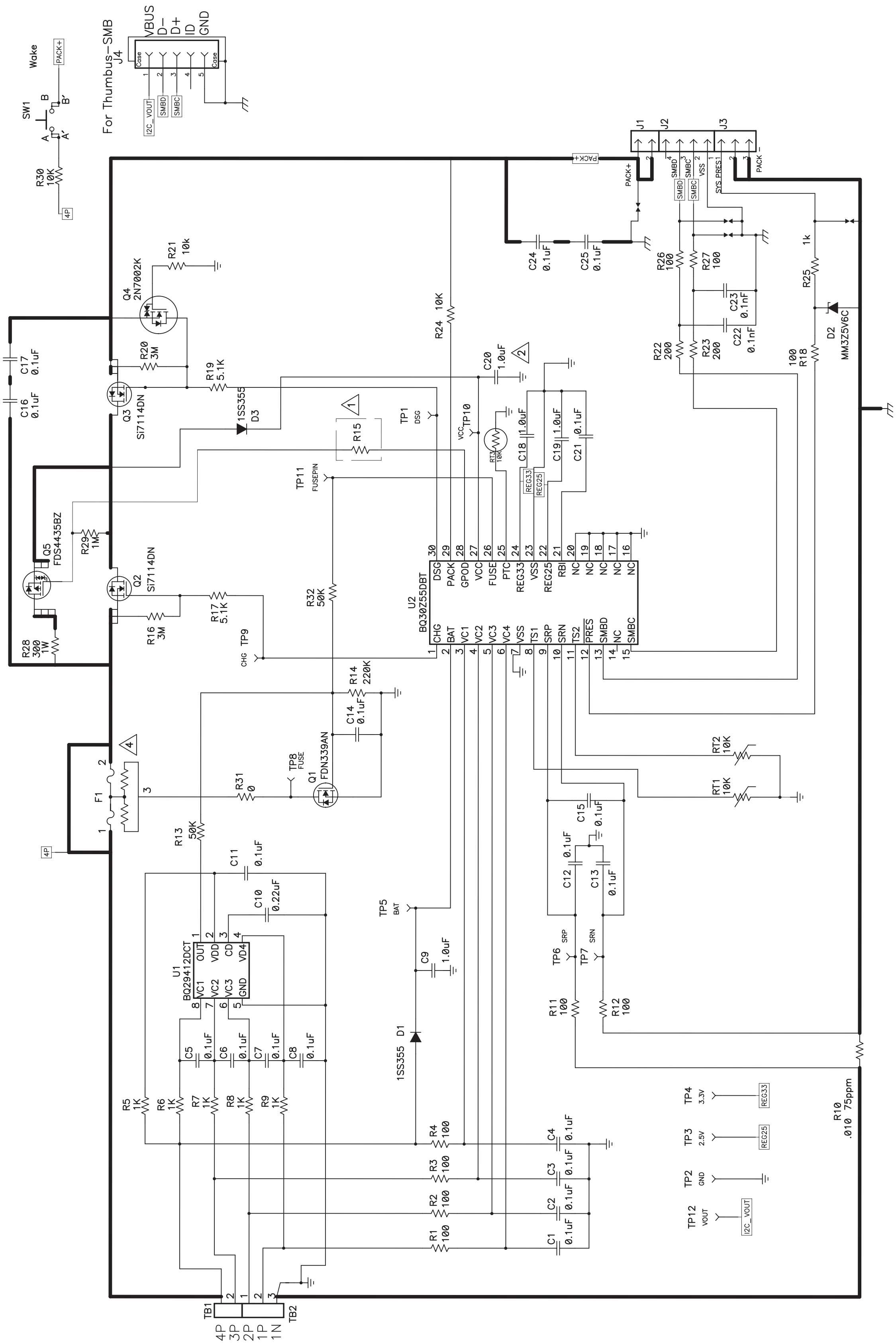

Figure 19. bq30z55 Schematic

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