Application Report
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Cell Balancing Using the bq20zxx

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ABSTRACT

This application report discusses three types of cell imbalances that are observed in a battery pack with serially connected cells.

1 Types of Cell Imbalances

1. **State of Charge Imbalance**

   Charging cells to different states of charge (SOC) causes this type of imbalance. For example, given a configuration of 3 x 2200-mAh cells (QMax), if one cell is discharged by 100 mAh (Q1), the second by 100 mAh, and the third by 200 mAh from a fully charged state, the first and second cells' chemical state of charge is (Qmax-Q1)/Qmax = 95.4%, but the third cell is 91%. Therefore, cell 3 is imbalanced by 4.4%.

   This results in a different open-circuit voltage (OCV) for cell 3 compared to cells 1 and 2, because the OCV directly correlates with the chemical state of charge.

2. **Total Cell Capacity Imbalance**

   A specific cell's total chemical capacity, Qmax, initially may be different from the others in the cell package. So, even if all cells were discharged by an equal amount from a fully charged state, their chemical states of charge may be different. Indeed, if all 3 cells are discharged by 100 mAh, but cell 3 has different total capacity (e.g., 2000 mAh), the resulting chemical states of charge is 95.4% and 95%.

   This results in different OCVs. A 200-mAh difference in Qmax causes only a 0.4% difference in SOC because the SOC correlates with voltage. This indicates that the capacity imbalance causes less voltage difference than charge imbalance (cause 1).

3. **Impedance Imbalance**

   Internal impedance differences between the cells (that can be an approximate 15% range in the same production batch) do not cause differences in the OCV. However, they can cause differences in cell voltage during discharge. Indeed, cell voltage can be approximated as $V = OCV + I \times R$. If current is negative (discharge), voltage is lower for a cell with higher R. If current is positive (charge), voltage is higher for a cell with higher R.

   No balancing algorithm can help against resistance imbalance. However, it can significantly distort attempts to balance the SOC. If significant (< 200 mA) current is flowing, attempting to use voltage as a determining factor for passing more charge through a cell with higher voltage, fails to determine if the voltage differences is caused by differences in the SOC or by impedance. If it is caused by impedance imbalance, bypassing more current through this cell results in the opposite effect – increasing the SOC difference from other cells to a larger value than it would be without balancing. As a result, the OCV of this cell at the end of charge is different from the other cells, and can reach high levels, potentially causing the safety circuit to trip.

2 Cell Balancing Methods

The bq20zxx uses the unique capabilities of Impedance Track™ technology to identify the chemical SOC of each cell, which does not rely on measuring voltage during charge or discharge. This removes the distortion caused by impedance imbalance, and permits precise SOC balancing. The cell-balancing algorithm operates as follows:

(a) Determine the initial SOC for each series cell bank separately.

(b) Determine the charge needed for each cell to reach a fully charged state.

Impedance Track is a trademark of Texas Instruments.

(c) Find the cell requiring the most charge to be fully charged, and then find the differences, dQ, between all the other cells requiring charge and that of the one requiring the most charge.

(d) These differences must be bypassed for each "excessive" cell during one or multiple cycles. To achieve this, the bypass FET is turned ON during charging for the calculated duration for each cell bypass time.

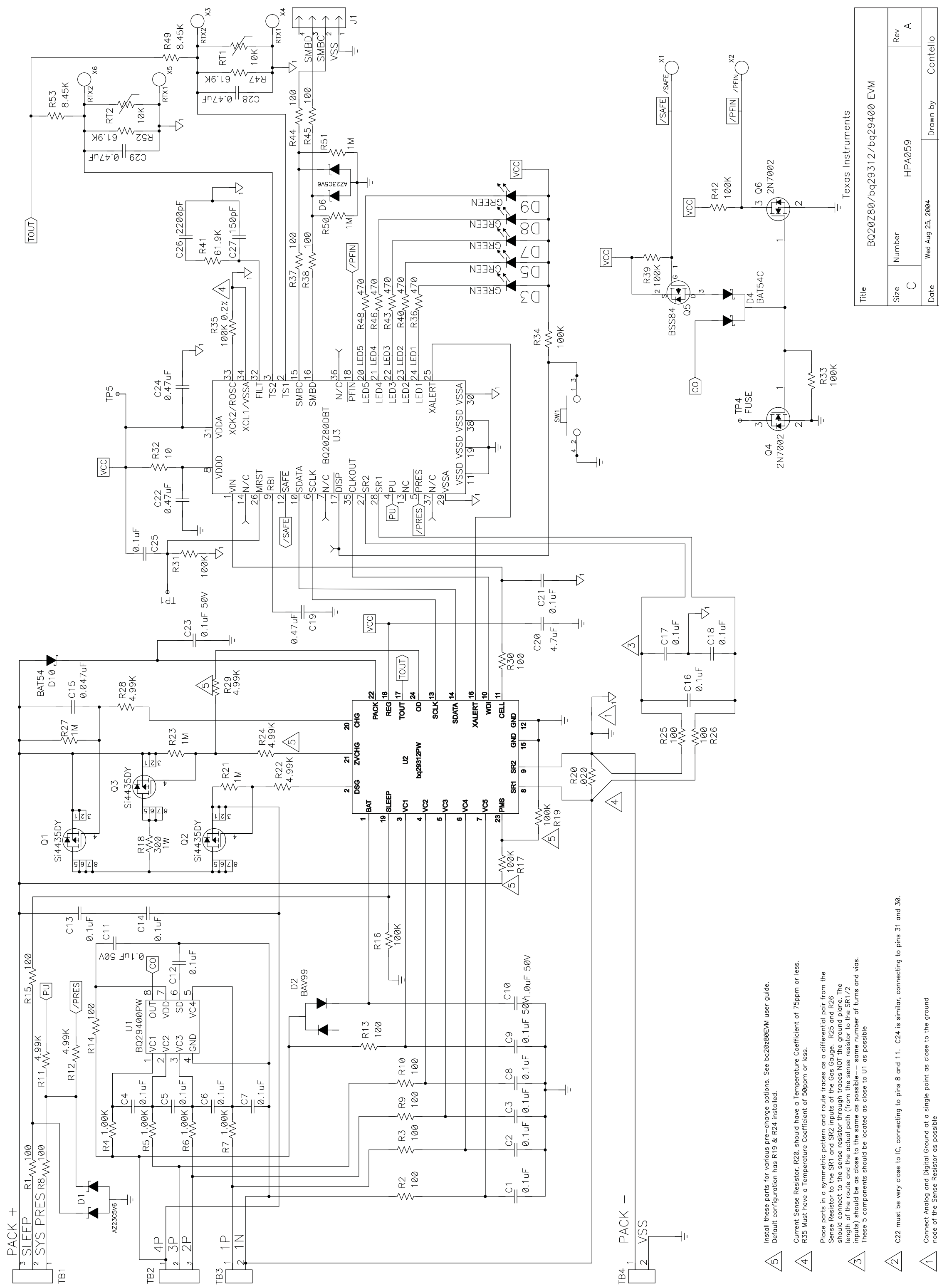
(e) The bypass time is calculated based on the value of bypass current, which in turn depends on bypass resistance values, R, as time = dQ × R / (V × duty_cycle).

(f) R is calculated as the sum of the internal bypass resistor (340 Ω, typical) and the series filter resistors (Rx) leading to the cells. R = Rx × 2 + 340. The resistors in question are R2, R3, R9, and R10. Their default value is 100 Ω, which results in R = 540.

(g) The bq20zxx stores the value of R(Ω) × 3.6 / (V × duty_cycle (ratio)) as a flash constant DF.MinCellDeviation (s/mAh). Here, 3.6 is the mAh correction factor. For default values of voltage, V = 3.6 V, R = 540 Ω and duty cycle = 40% (ratio 0.4), the value is calculated as DF.MinCellDeviation = 540 × 3.6 / (3.6 × 0.4) = 1350

This value must be changed if values of resistors R2, R3, R9, and R10 are changed from the default value.

The schematic appears on the following page.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