TEXAS INSTRUMENTS

Application Report
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Using the bqSWITCHER™ bq24115 as a Nickel Charger

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ABSTRACT

This application report describes the combination of the bqSWITCHER™ bq24115 charge management device and the bq2002 battery charge controller to provide a high-efficiency-switching charging solution for nickel battery packs.

The bqSWITCHER™ was designed to properly charge 1-to-3 Li-ion cells; it does not have the features to properly terminate a charge on a nickel chemistry pack. This corresponds to ~3-to-10 nickel cells. The bq2002 is designed as a control chip to monitor the voltage on a nickel pack and provide a signal to enable or disable the charge. This charge-control (CC) signal typically interfaces with a current source that has an enable input, which turns on or off according to the bq2002's enable signal. This application report describes the combination of the bq24115 and the bq2002 ICs to provide a high-efficiency-switching charging solution for a nickel battery pack.

Figure 1 is the schematic for a completed 5-nickel-cell design. The top portion of the schematic is the bq24115 design which is operated in the constant-current mode for fast charge. The lower portion of the schematic is the bq2002 circuit which is the controller IC and determines whether to charge or terminate. The two circuits interface via Q1 between the CC and $\overline{CE}$ pins. When the CC pin is high impedance, Q1 turns on and pulls $\overline{CE}$ low and enables the charge. A low on the CC pin, turns off Q1 and pulls $\overline{CE}$ high, disabling the charge.

Design Example:

System Design Specification:

• Vin:	10±1 VDC
• Vbat:	5 nickel cell
• Cell capacity:	3000 mAHr
• Fast-charge:	C/2 or 1.5 A
• Precharge:	0.3 A
• Safety timer:	80 minutes per C-rate or 160 minutes for a C/2-rate
• Inductor ripple current:	<30% of fast-charge
• Temperature charge window:	0°– 45°C

1. Determine the inductor value, L_{OUT} for the specified current ripple:

$$\Delta I_L = I_{CHARGE} \times I_{CHARGE}\text{Ripple}$$

$$L_{OUT} = \frac{V_{BAT} \times \left(V_{INMAX} - V_{BAT}\right)}{V_{INMAX} \times f \times \Delta I_L} \quad (1)$$

ΔI_L = 1.5 A × 0.3 = 0.45 A

L_{OUT}= 5 × 1.3 V × (11 V – 5 × 1.3 V)/(11 V × 1.1 MHz × 0.45 A) > 5.4 µH

Choose between 5 µH and 10 µH (10 µH works well with the desired compensation).

bqSWITCHER is a trademark of Texas Instruments.

Calculate the peak inductor current.
Using a 10-µH value, the estimated ripple current is a ratio of the two inductances:
5.4/10 × 0.45 A = 0.24 App.

The peak current is fast-charge current plus one-half the ripple current or 1.62 A.

Choose a 10-µH inductor with a saturation current over 1.62 A, e.g., Sumida CDRH74-100.

2. Pick the output capacitor.
The internal compensation for the bqSWITCHER is optimized for an LC break frequency of 16 kHz. The break frequency is given by the f_o equation and is solved for C_{OUT}.

$$f_O = \frac{1}{2\pi\sqrt{L_{OUT} \times C_{OUT}}}$$

$$C_{OUT} = \frac{1}{4\pi^2 \times f_O{}^2 \times L_{OUT}}$$

$$C_{OUT} = \frac{1}{4\pi^2 \times (16 \times 10^3)^2 \times (10 \times 10^{-8})}$$

$$C_{OUT} = 9.89\ \mu F \tag{2}$$

3. Choose a current sense resistor: Calculate the current sense resistor by the following equation, and then select a standard value that is equal to or greater than the calculated value.

$$R_{SNS} = \frac{V_{RSNS}}{I_{CHARGE}} \tag{3}$$

V_{RSNS} should be between 100 mV and 200 mV, and a lower value results in better efficiency.
R_{SNS} = 100 mV/1.5 A = 66.7 mΩ

A standard value is 68 mΩ.

Estimate the power dissipation during fast charge: P = I^2R = $1.5^2(0.068)$ = 153 mW.

Choose a Panasonic 1206 (250 mW, 1%).

4. Calculate the ISET1 resistor:

$$R_{ISET1} = \frac{K_{ISET1} \times V_{ISET1}}{R_{SNS} \times I_{CHARGE}} \tag{4}$$

R_{ISET1} = 1000 × 1 V/(0.068 × 1.5 A) = 9804 Ω. Choose the closest standard 1% value which is 9.76 kΩ.

5. Calculate the ISET2 resistor which sets the precharge current level.

$$R_{ISET2} = \frac{K_{ISET2} \times V_{ISET2}}{R_{SNS} \times I_{PRECHARGE}} \tag{5}$$

R_{ISET1} = 1000 × 0.1 V/(0.068 × 0.3 A) = 4902 Ω. Choose the closest standard 1% value which is 4.87 kΩ.

The bq24115 charge is controlled by the $\overline{CE}$ and CMODE pins.

CMODE sets the charger in precharge or fast-charge mode. Tying this pin high puts the part in fast-charge mode when enabled with the CE pin. The bq2002 controls when and how long the charge lasts. To use the precharge feature, a control signal is needed to determine when the cells are depleted and to set the CMODE low.

6. Set the TS to 50% of the VTSB pin value to disable this feature. The bq2002 monitors the pack temperature.

Designing the bq2002:

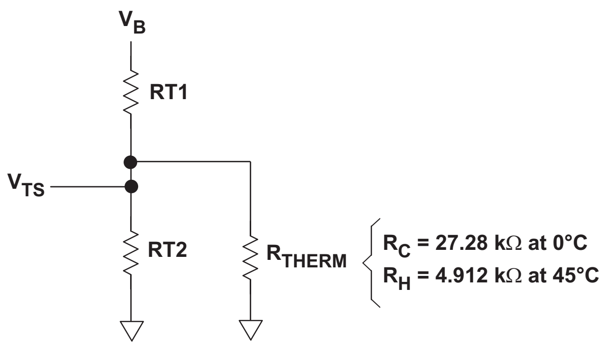
See the bq2002 data sheet (SLUS131) to assist in designing the bq2002 portion of this circuit.

The TM pin is set high to select the 160-minute safety time for charging at the C/2-level (half the capacity of the battery).

The nickel battery is charged in constant-current mode, and if the voltage ever reaches the maximum cell voltage (Vmcv), the charging should terminate. New cells typically terminate around 1.45 V/cell. As the battery ages, the cell impedance goes up, and this termination voltage increases slightly. Usually, one wants to end the charge if the cell voltage is between 1.7 V and 1.8 V per cell because this indicates a bad cell. To calculate the BAT feedback divider, the MCV of the battery should be calculated and divided down to the BAT pin reference voltage of 2 V.

The MCV is 5 cells × 1.75 V/cell = 8.75 V. Let RB2 equal 100 kΩ, which will have 2 V across it when it reaches MCV. The remaining voltage, 8.75 V – 2 = 6.75 V, will be across RB1. The same current goes through each resistor, so RB1 has to be the same ratio of ohms to volts or 6.75 V/2 V × 100 kΩ = 337.5 kΩ. The closest standard value is 340 kΩ.

The TS divider was set up for use of the D- or T-version of the bq2002. The following equation calculates the RT1 and RT2 values for the valid temperature window. The hot and cold TS voltage trip limits and the thermistor value at these hot and cold thresholds are needed to calculate RT1 and RT2. The product folder has TS solver software to do this calculation automatically.



Solve for RT2 first:

$$RT2 = \frac{1.944\ R_C\ R_H}{1.5\ R_C - 3.444\ R_H} = \frac{1.944\ (27.28\ k)(4.912\ k)}{1.5\ (27.28\ k) - 3.444\ (4.912\ k)} = 10.85\ k \tag{6}$$

$$RT1 = \frac{1.4\ R_C\ RT2}{RT2 + R_C} = \frac{1.5\ (27.28\ k)\ 10.85\ k}{10.85\ k + 27.28\ k} = 11.64\ k \tag{7}$$

Use the closet values RT1 = 11.5 kΩ and RT2 = 10.7 kΩ.

These calculations are done for the bq2002D IC but are also valid for the *T* version, where the cold threshold is disabled.

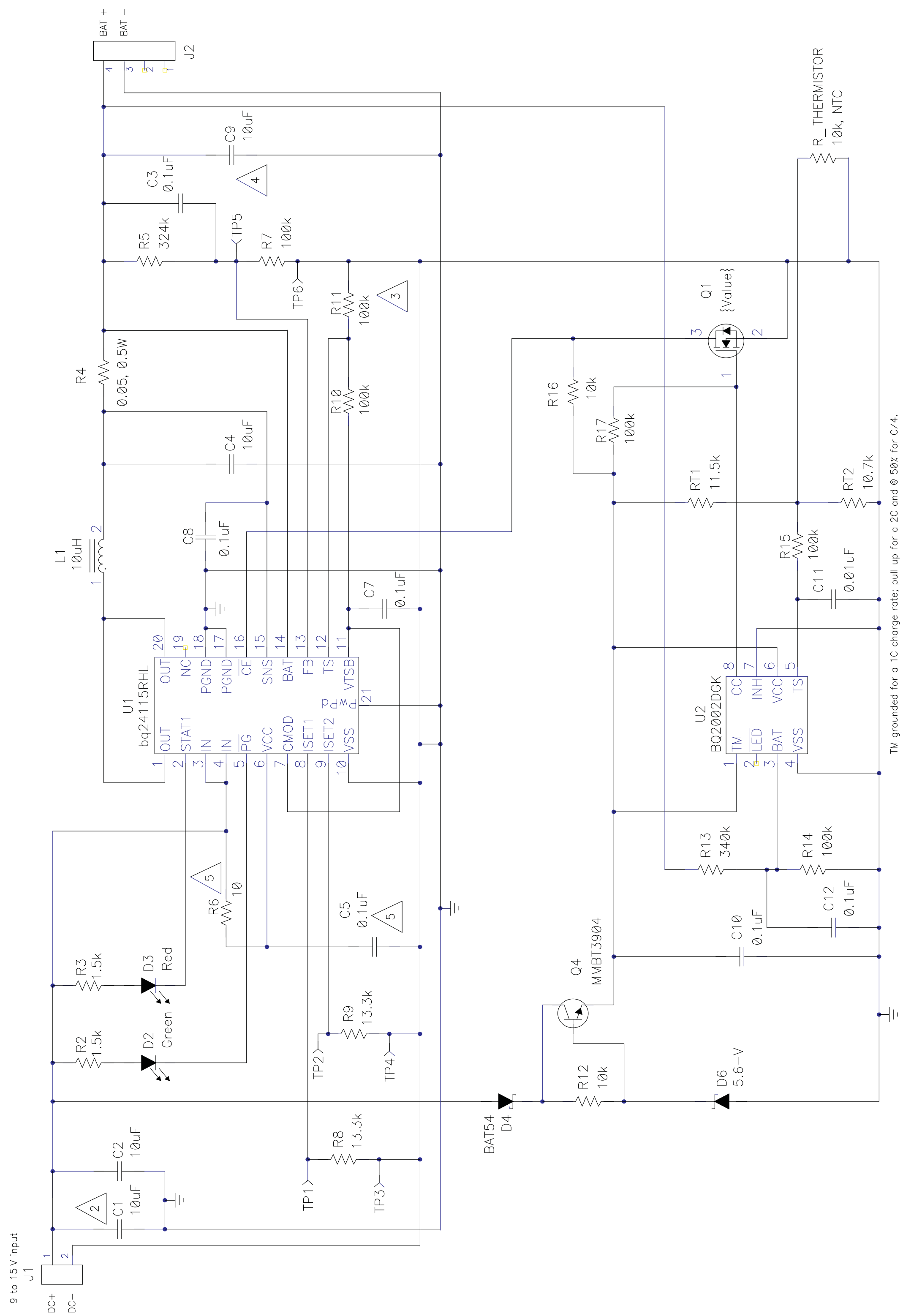


Figure 1. Five-Nickel-Cell Schematic

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