Application Note

Maximizing the Full Potential of NTC Using BQ25180 Linear Charger

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ABSTRACT

The Temperature Sensing (TS) function is a vital function for providing batteries charge and to operate within a safe temperature range. The BQ25180 provides a TS design as a current source that biases a resistor network with an NTC thermistor. Although the TS is designed to work with NTC of particular characteristics, external resistors extend the NTCs which can be used with the BQ25180. The External NTC Monitoring Calculator, which is available on the TI-Charger GUI, provides an easy means to check the configured application's expected TS behavior.

Table of Contents

List of Figures

List of Tables

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1 Temperature Sensing

1.1 Temperature Sensing and JEITA Standard

Temperature sensing of the battery is a precautionary measure to maintain the battery within safe temperatures during the course of charging. Temperature sensing feature makes use of temperature sensitive resistivity to approximate and respond to battery temperatures while charging. For this purpose, many battery manufacturers incorporate a Negative Temperature Coefficient thermistor into the battery pack; for those battery packs that do not have a thermistor, we recommend including an external NTC alongside the battery pack.

The Japanese Electronics and Information Technology Industries Association (JEITA) guidelines for improving battery charging safety outline a series of battery temperature thresholds which can affect the charging parameters when crossed. These thresholds are typically defined as: cold temperatures below 0°C, cool temperatures below 10°C but above 0°C, warm temperatures above 45°C but below 60°C, and hot temperatures above 60°C. The prescribed behavior for the temperatures below the cold threshold and above the hot threshold is to cease charging until battery temperature has normalized. For battery temperatures in the cool and warm regions charge current and maximum charge voltage can be reduced. Different guidelines apply to different applications, we recommend checking the specific guidelines that apply to a given battery pack.

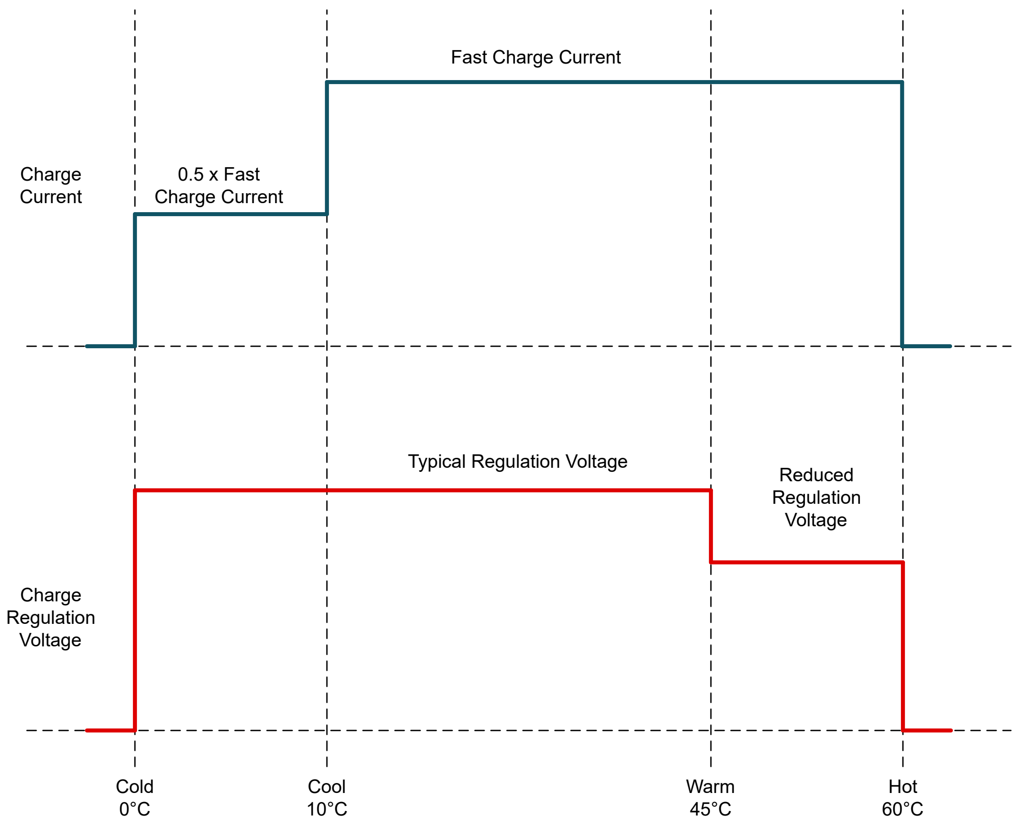

Figure 1-1. JEITA Charging Parameters

1.2 Current Driven TS Function

The operation and configurability of the TS function varies from charger to charger. The BQ25180's TS function is implemented as a current driven TS sensing. This means that a fixed current source biases an external resistor network placed at the TS pin with I_{TS_BIAS}. The NTC's temperature dependent resistance correlates the resistance, and therefore voltage, at the TS pin with the battery pack temperature. This voltage is then compared with a series of reference voltages to determine the temperature range within which the battery pack is operating. Although these reference voltages are tuned to work with NTC thermistors with a specific Beta (β) and calibrated impedance, additional resistors can be placed to allow the use of NTCs with different β values and calibrated impedance with minimal error. The TS application is described in Figure 1-2.

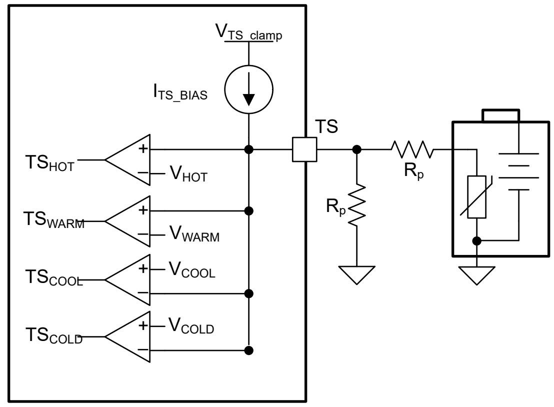

Figure 1-2. Typical Current Driven TS Application

1.3 Calculating R_S and R_P

The series resistor (R_S) and parallel resistor (R_p) can be calculated using a few formulas. The resistance of an NTC thermistor is governed by Equation 1:

$$\beta = \frac{\ln\left(\frac{R_{T1}}{R_{CAL}}\right)}{\left(\frac{1}{T_1} - \frac{1}{T_{CAL}}\right)} \tag{1}$$

R_{CAL} is the resistance of the thermistor calibrated at T_{CAL}, typically 25°C. β is given in terms of Kelvin so T_1 and T_{CAL} are expressed in Kelvin. This equation allows us to calculate the thermistor resistance at different temperatures, notably at the HOT JEITA threshold of 60°C (R_H) and at the COLD JEITA threshold 0°C (R_C). The resistor network and bias current of the TS current source produce a voltage calculated by Equation 2:

$$V_{TS} = I_{TS\_BIAS}(R_P || (R_S + R_{NTC})) \tag{2}$$

The charger data sheet provides voltage thresholds for the various JEITA temperature thresholds. These voltages, in place of V_{TS}, in Equation 2 allows the use of a system of equations to solve for the two variables needed to create our TS circuit: R_P and R_S. Because there are only have two variables to compensate the system with, only two JEITA thresholds can be met with total accuracy. Typically, HOT JEITA threshold (V_H) and COLD JEITA threshold (V_C) are prioritized.

Using known values V_H, V_C, R_H, and R_C, as well as Equation 2, we create and provide a system of equations to derive Equation 3 and Equation 4 to calculate R_S and R_P.

$$R_S = \frac{-(R_H + R_C) \pm \sqrt{\left\{(R_H + R_C)^2 - 4\left(R_H \times R_C + \frac{V_H \times V_C}{(V_H - V_C) \times I_{TS\_BIAS}} \times (R_C - R_H)\right)\right\}}}{2} \tag{3}$$

$$R_P = \frac{V_H \times (R_H + R_S)}{I_{TS\_BIAS} \times (R_H + R_S) - V_H} \tag{4}$$

2 BQ25180 and NTC Monitoring Calculator

The BQ25180 implements a 38 uA current source for biasing the resistor network. The voltage thresholds are tuned to work with a thermistor with a β of 3435 that is calibrated to 10 k Ω at 25°C. As mentioned before, external resistors can be used to allow the BQ25180 to work with other NTCs. Additionally, the BQ25180 allows for adjustable HOT and COLD voltage thresholds for applications which require different ranges. The COOL and WARM thresholds can selectively be disabled through I2C.

TI offers the *External NTC Monitoring (TS) Calculator* for the BQ25180 to facilitate configuration checking. This calculator can be accessed by selecting the calculator icon from the left menu bar on the BQ25180 TI Charger GUI page.

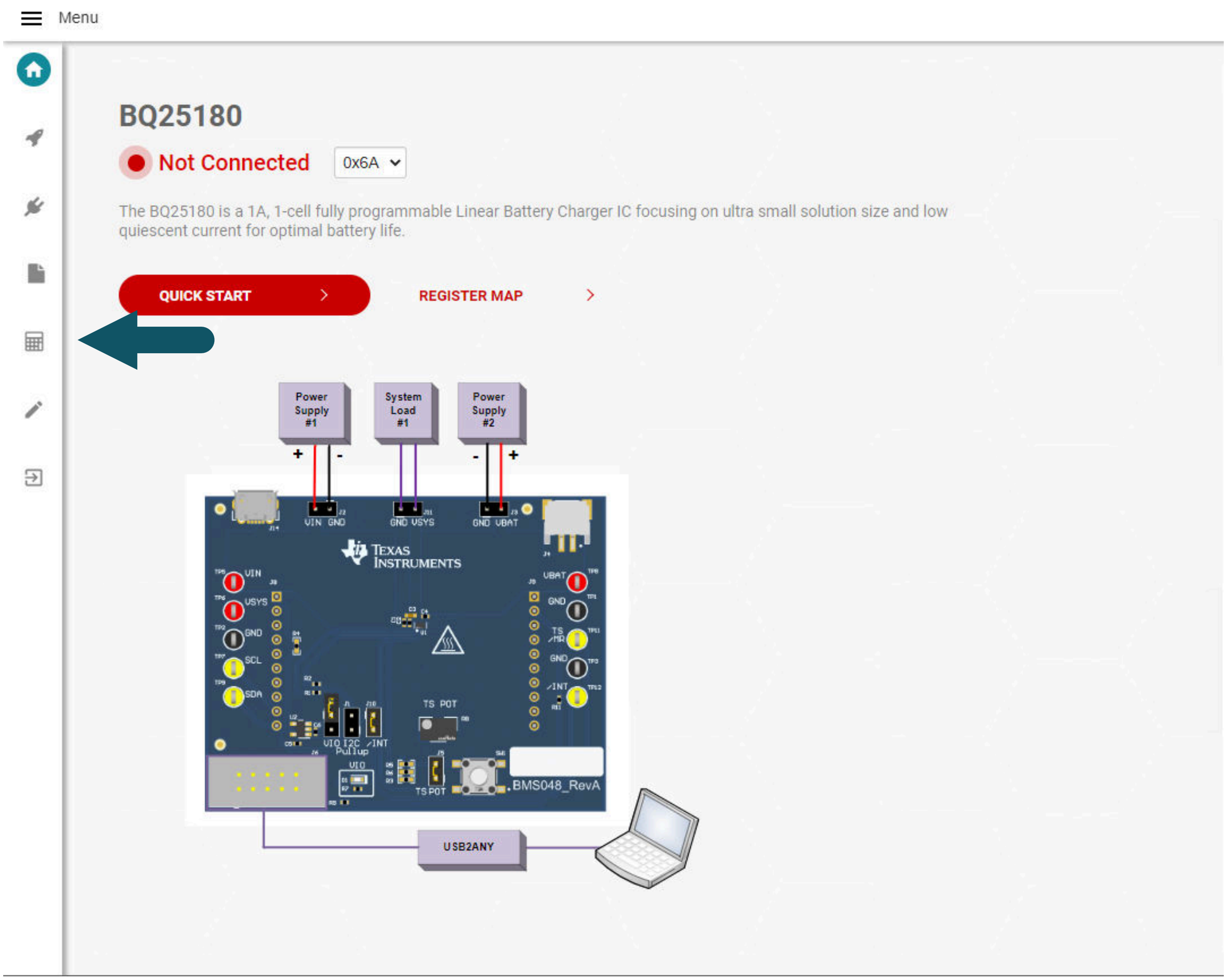

Figure 2-1. Menu Logo

The planned NTC's specifications can be entered as well as any calculated R_S values, R_P values, and register configurations. Once all configuration specifications have been entered, pressing the calculate button populates the outputs with the expected temperatures in Celsius at which the device is expected to enter and exit JEITA thresholds.

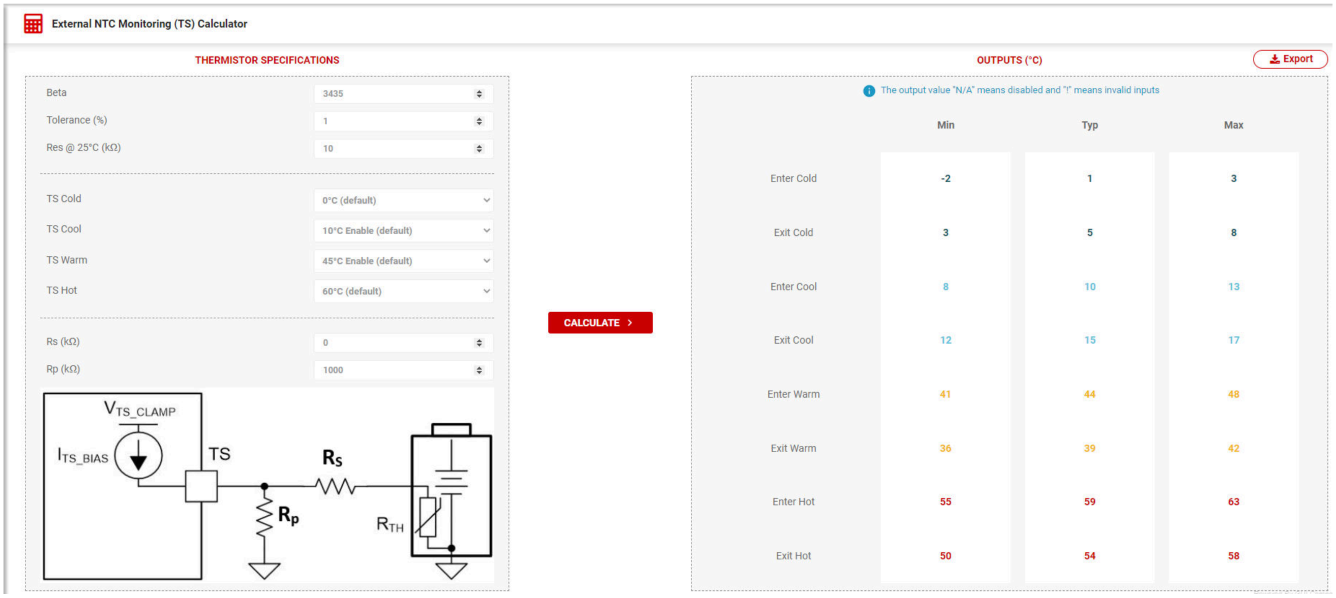

Figure 2-2. External NTC Monitoring (TS) Calculator Page View

3 Example of TS Circuit Design

If a BQ25180 used with a battery pack that includes an NTC with a calibrated resistance of 10 k Ω and a beta value of 4250, the TS circuit will need to be compensated with additional resistors. Without additional resistors, using this NTC would cause the charger to enter the cold threshold at 5°C and enter the hot threshold at 52°C, thus significantly reducing the battery temperature range within which the charger can operate normally.

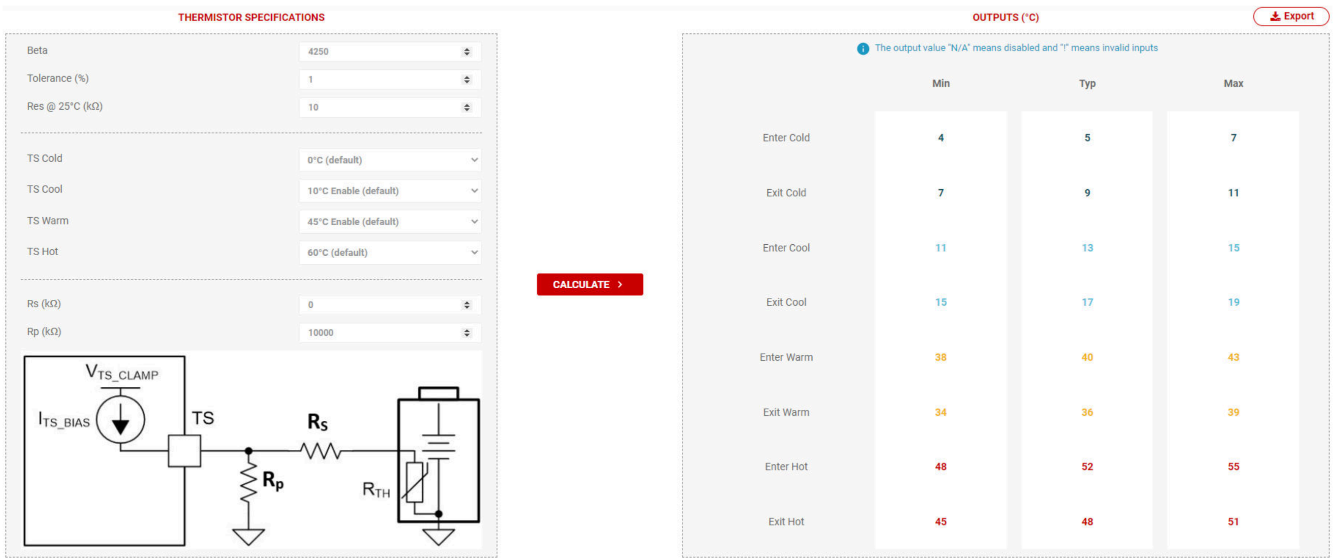

Figure 3-1. TS Thresholds Without Compensating Resistors

To calculate the necessary additional resistors, the following values are obtained from the BQ25180 data sheet or are calculated using Equation 1 and known thermistor values.

Table 3-1. Equation Constants

V_H	V_C	I_{TS_BIAS}	R_H(R_{NTC} at 60°C)	R_C(R_{NTC} at 0°C)
0.115 V	1.0075 V	38 µA	2.2 kΩ	36.8 kΩ

Using the values from the table to solve Equation 3 and Equation 4 we arrive at an R_S of 896 Ω and an R_P of 89 kΩ. With these resistors placed in the appropriate configuration, we achieve the following thresholds at the following temperature:

Table 3-2. Expected JEITA Threshold Temperatures

V_{COLD}	V_{COOL}	V_{WARM}	V_{HOT}
0°C	10°C	44°C	60°C

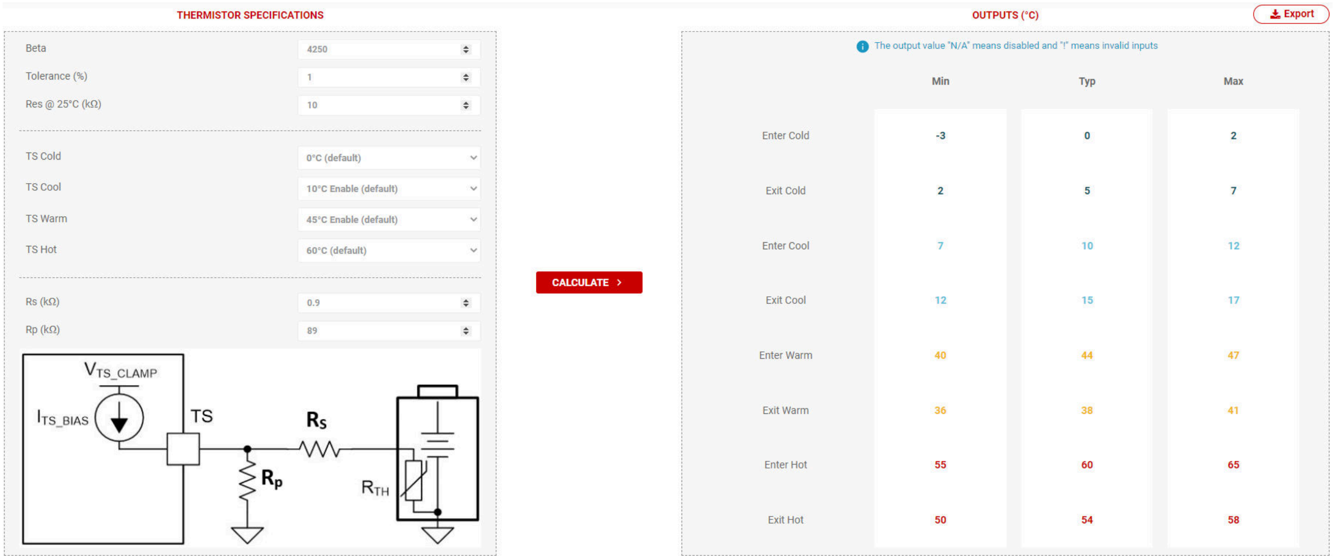

Figure 3-2. TS Threshold with Compensating Resistors

4 References

- Texas Instruments, *BQ25180 I2C Controlled, 1-Cell, 1-A Linear Battery Charger with Power Path and Ship Mode*, data sheet.
- Texas Instruments, *Li-ion Battery-Charger Solutions for JEITA Compliance*, analog applications journal.

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