Application Report
SLUA792–October 2016

Enhanced Resolution Gauging for Low Current Applications Using Scaling

Battery Management Solutions/Battery Gauges

ABSTRACT

This application report aims to address key concerns and design limitations associated with using large (> 20 mΩ) current sense resistors to achieve greater current resolution on Texas Instruments battery gauge products. Using this method, it is possible to achieve < 1 mA current resolution and improve accuracy for systems with small battery capacities which experience very low charge and discharge currents. This document details the enhanced resolution process and highlights primary concerns associated with large sense resistors in battery gauging applications. An implementation example with a bq27426 Impedance Track gauge is included.

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1 Introduction

Enhancing current resolution relies on increasing the input to the coulomb counter and adjusting the device configuration to accommodate this change. The coulomb counter determines the amount of passed charge by measuring the voltage across the sense resistor. Using a larger sense resistor results in a larger voltage for the coulomb counter to measure. By scaling the current during calibration, it is possible to decrease the least significant bit value to less than 1 mA. This process allows the gauge to measure currents less than 1 mA and enables gauging functionality for systems with < 1 mA discharge current.

2 Choosing A Calibration Ratio

The calibration ratio refers to the factor by which the reported gauge current will be scaled. This ratio is chosen by the user in order to meet their application's necessary resolution. The default resolution is 1 mA per LSB. The equation below is used to calculate the calibration ratio, *K*, where LSB_{value} is the user's desired resolution. For example, if the desired resolution is 100 µA, a calibration ratio of 10x should be used.

$$K = \frac{1\,mA}{LSB_{value}} \quad (1)$$

3 Hardware Considerations

In order to improve resolution below 1 mA, it is recommended to use a larger sense resistor in order to create a larger voltage for the coulomb counter to measure. A general rule is to increase the resistance by the same factor as the calibration ratio. For example, if the default sense resistor value is 10 mΩ and a calibration ratio of 10x is needed, a 100 mΩ sense resistor is recommended.

3.1 Maximum Charge and Discharge Rate

A larger sense resistor will limit the maximum charge/discharge current rate that the fuel gauge can measure without saturating the coulomb counter. For proper operation, the maximum voltage range of the gauge coulomb counter, which is described in the device data sheet, must not be exceeded. This limit can be calculated using the equation shown in Equation 2.

$$I_{max} = \frac{V_{range}}{R_{sense}} \quad (2)$$

For example, if a 200 mΩ current sense resistor is used and the voltage range of the gauge coulomb counter is ±125 mV, the maximum measurable charge/discharge rate is 625 mA.

3.2 System Headroom Reduction

Using a large sense resistor will result in a larger I x R drop across the sense resistor for a given current. The headroom available to the system would ultimately be less due to this increased voltage drop.

4 Current Calibration

The gain and offset of the gauge coulomb counter must be adjusted appropriately in order to measure the desired current range and achieve greater resolution. This is accomplished through current calibration using evaluation software such as bqStudio or bqEVSW. When calibrating, the reported current in the evaluation software should be equal to K x I_{rate} where I_{rate} is the applied current and K is the user's chosen calibration ratio. For example, if calibration is performed at an actual current of 100 mA and the reported calibration current is 1000 mA, the calibration ratio is 10x and all current values will be reported as I_{actual} multiplied by the calibration ratio. The least significant bit is equal to 100 µA in this example.

$$I_{GAUGE} = K * I_{rate} \quad (3)$$

5 Gauge Configuration Considerations

The gauge uses several parameters including FCC, Qstart and Passed Charge to calculate the current state of charge for the battery. If the current is multiplied by some scaling factor, these other parameters must also be multiplied by the same ratio. As such, all current and capacity related data flash parameters need to be multiplied by the calibration ratio to maintain proper operation and accuracy of the gauge. As an example, if a 200 mAh battery with a nominal voltage of 3.7 V is used with a calibration ratio of 10x, the user should set design energy to 2000 mAh and design energy to 7400 mWh. This does present a limitation on the maximum allowable calibration ratio in order to maintain all data flash parameters within their respective limits.

6 Enhanced Resolution Example

In this example, a bq27426 gauge is used with a 400 mAh battery with nominal voltage of 3.7 V. The desired resolution is 50 µA. The maximum current the battery is expected to deliver is 400 mA with a termination voltage of 3.3 V. A CCCV charger is used with a charging current of 400 mA and charging voltage of 4.05 V.

Table 1. System Design Parameters

DESIGN PARAMETER	VALUE
Capacity	400 mAh
Nominal Voltage	3.7 V
Resolution	50 µA
Maximum System Current	± 400 mA
Charging Voltage	4.05 V
Charging Current	400 mA
Termination Voltage	3.30 V

6.1 Equipment

Table 2 summarizes the equipment used in this example to perform current scaling.

Table 2. Equipment List

MODEL NUMBER	DESCRIPTION
Description	Evaluation module for bq27426 Impedance Track gas gauge
bq27GDK000EVM	TI Gauge Development Kit
Keithley 2400	TI Gauge Development Kit
bqStudio 1.3.52	Gauge development software

6.2 Sense Resistor Selection

To achieve the desired 50 µA resolution, a calibration ratio of 20x is needed. As the default value of the sense resistor is 10 mΩ, a 200 mΩ, 1% resistor is installed at R1 on the EVM. The maximum measurable current is 400 mA.

6.3 Calibration and Configuration

The gauge development kit was connected to Load+ and Load- on the EVM in order to perform the calibration. Using bqStudio, a board offset calibration is performed while there is no current flowing in the system. Once the offset calibration is completed, a charging current of 200 mA is applied to the EVM. On the calibration tab In bqStudio, type in the calibration current as 4000 mA. This sets the calibration ratio to 20x.

Table 3 summarizes the necessary configuration changes to implement the design parameters in Table 1 and to properly scale capacity and current parameters on the bq27426. Parameters with units of mA, mW or mAh should be multiplied by the calibration ratio accordingly. Parameters defer from gas gauge to gas gauge so great care must be taken when making adjustments. The technical reference manual should always be referenced. For the bq27426 gas gauge, current thresholds are in units of 0.1 Hr rate, meaning a value of 100 is equivalent to C/10, 200 is equivalent to C/20, and so on. As the design capacity is already scaled, the threshold rates should not be scaled.

Table 3. bq27426 Parameter Settings

PARAMETER	CLASS	SUBCLASS	STANDARD VALUE	SCALED VALUE
Taper Capacity (mAh)	Configuration	Charge Termination	50	1000
Taper Rate (0.1 Hr Rate)	Gas Gauging	State	100	100
Chg Current Threshold (0.1 Hr Rate)	Gas Gauging	Current Thresholds	167	167
Dsg Current Threshold (0.1 Hr Rate)	Gas Gauging	Current Thresholds	100	100
Quit Current Threshold (0,1 Hr Rate	Gas Gauging	Current Thresholds	250	250
Design Capacity (mAh)	Gas Gauging	State	400	8000
Design Energy (mWh)	Gas Gauging	State	1480	29600
V at Chg Term (mV)	Chemistry Info	Chem Data	4050	4050
Taper Voltage (mV)	Chemistry Info	Chem Data	3950	3950

6.4 Results and Discussion

To verify the resolution, the Keithley source meter was connected to Load+ and Load- on the EVM. Using the source meter, current ranging from -1 mA (discharging) to 1 mA (charging) were applied to the EVM while reading the gauge Current() output.

As shown in Figure 1, the gauge reports the measured current with the expected 20X scale factor. The data readings obtained for current in the range -200 µA to +200 µA is expected to be zero from the gauge Deadband setting of 200 µA, which limits the gauge from reporting any current below this level.

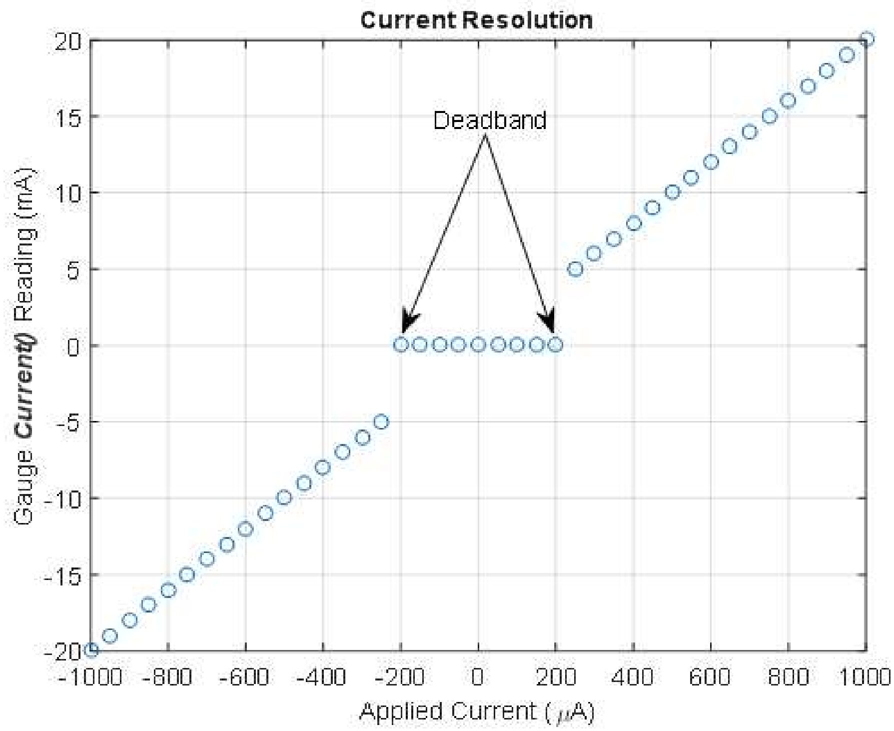

Figure 1. Gauge Reported Current vs Applied Current

Figure 2 shows the charging profile for the implemented gauge configuration. The current and voltage waveforms are consistent with a constant current, constant voltage profile (CCCV). The GDK charges the battery at a constant current of 400 mA until the battery voltage is greater than the taper voltage threshold set in data memory. The charger then provides a constant voltage until the charge current has fallen below 50 mA.

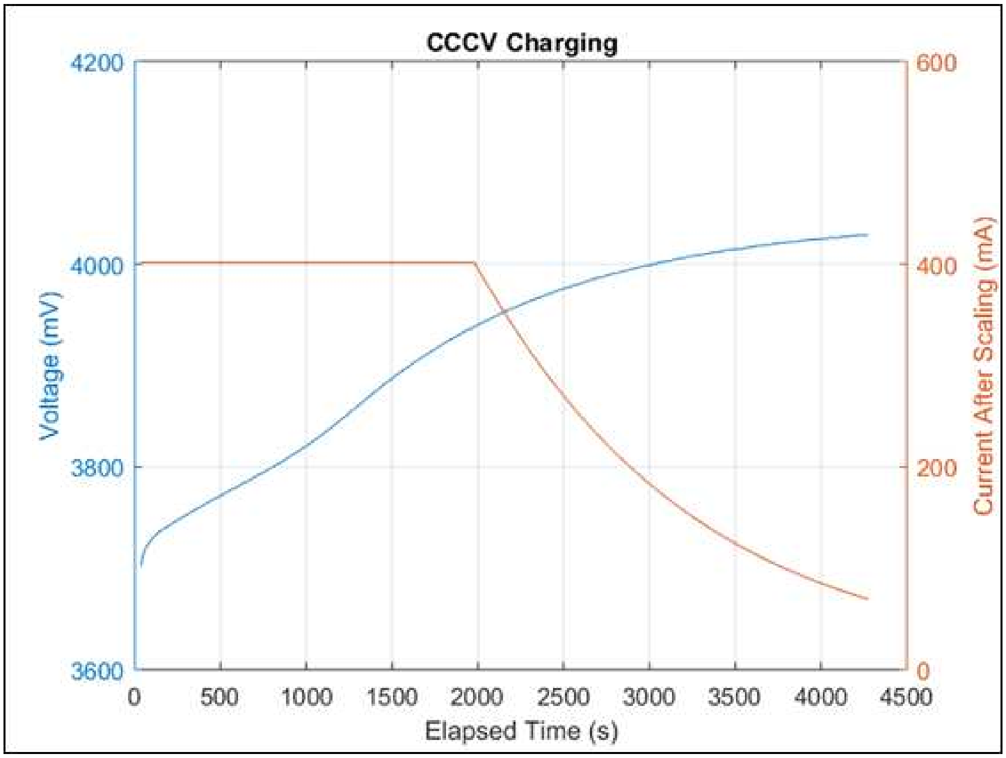

Figure 2. Charging Profile

7 References

bq34z100-G1 High Cell Count and High Capacity Applications (SLUA760)

bq27426 System-Side Impedance Track™ Fuel Gauge, data sheet (SLUSC91)

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