bq27z561

Technical Reference

Literature Number: SLUUBO7
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Contents

Preface

Read this First

This manual discusses the modules and peripherals of the bq27z561 device, and how each is used to build a complete battery pack gas gauge solution. For electrical specifications, see the *bq27z561 Impedance Track™ Battery Gas Gauge Solution for 1-Series Cell Li-Ion Battery Packs Data Sheet* (SLUSCY0).

Notational Conventions

The following notation is used if Standard commands and data flash (DF) values are mentioned within a text block:

- Standard commands: *italics* with parentheses and no breaking spaces; for example, *RemainingCapacity()*
- Data flash (DF): *italics*, **bold**, and breaking spaces; for example, ***Design Capacity***
- Register bits and flags: *italics* and brackets; for example, *[TDA]*
- Data flash bits: *italics* and **bold**; for example, ***[LED1]***
- Modes and states: ALL CAPITALS; for example, UNSEALED

Trademarks

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Glossary

TI Glossary **—** This glossary lists and explains terms, acronyms, and definitions.

Introduction

The bq27z561 device provides a feature-rich gas gauging solution for single-cell battery pack applications. The device has extended capabilities, including:

- Fully Integrated Single-Cell Li-Ion or Li-Polymer Cell Battery Gauge Solution
- Next-Generation Patented Impedance Track™ Technology Accurately Measures Available Charge in Li-Ion and Li-Polymer Batteries
- Power Modes
  - NORMAL Mode
  - SLEEP Mode
  - DEEP SLEEP Mode
  - OFF Mode (CE ≤ V_{IL})
- Information Available to External Smart Charger
  - JEITA
  - Charging Current
  - Charging Voltage
- Diagnostic Lifetime Data Monitor
- Supports Two-Wire I^2C Interface
- Supports One-Wire HDQ Interface
- SHA-256 Authentication
- Ultra-Compact Package: 12-Ball DSBGA

Basic Measurement System

2.1 Introduction

The bq27z561 gauge contains an integrating analog-to-digital converter (ADC) for current measurement and a second order delta-sigma ADC for cell voltage and temperature measurements.

2.2 Current and Coulomb Counting

The integrating delta-sigma ADC in the gauge measures the charge/discharge flow of the battery by measuring the voltage drop across a small-value sense resistor between the SRP and SRN pins. The 16-bit integrating ADC measures bipolar signals from –0.10 V to 0.10 V with 3.74-µV resolution. The gauge reports charge activity when VSR = $V_{(SRP)} - V_{(SRN)}$ is positive, and discharge activity when VSR = $V_{(SRP)} - V_{(SRN)}$ is negative. This data is scaled and translated into mA using ***CC Gain*** and reported through *Current()*. The gauge uses this information for gauging and lifetime data logging functions. In NORMAL and SLEEP modes, the gauge continuously monitors the measured current and integrates the digital signal over time using an internal coulomb counter, which is also used for gauging.

In addition, the integrating ADC is sampled during voltage measurements and converted to mA in the same manner. This data is used for gauging (but not coulomb counting) and reported through Cell 1 Current in *DAStatus1()*.

The data reported through *Current()* can also have a deadband applied to it. This removes any noise or offset that has not been calibrated out from being reported as real current or from being accumulated by the coulomb counter in DOD0 Passed Q. This deadband value is programmed in ***Deadband***.

2.3 Voltage

The second order delta-sigma ADC in the gauge measures the cell voltage at 1-s intervals in NORMAL mode, and ***Voltage Time***-second intervals in SLEEP mode. This data is scaled and translated into mV using ***Cell Gain*** and reported through *Voltage()*. The gauge uses this information for gauging and lifetime data logging functions.

2.4 Temperature

2.4.1 Internal Temperature

The second order delta-sigma ADC in the gauge measures internal temperature at 1-s intervals in NORMAL mode and ***Voltage Time***-second intervals in SLEEP mode. This data is translated into 0.1K using the parameters in ***Internal Temp Model*** and reported through *InternalTemperature()*. The internal temperature can be used for gauging and lifetime data logging functions, and reported through *Temperature()* if ***Temperature Enable[TSInt]*** = 1.

2.4.2 Cell Temperature

The second order delta-sigma ADC in the gauge measures cell temperature via an external thermistor at 1-s intervals in NORMAL mode and ***Voltage Time***-second intervals in SLEEP mode. This data is translated into 0.1K using the parameters in ***Cell Temp Model*** and reported through *Temperature()* if ***Temperature Enable[TS1]*** = 1. The cell temperature can be used for gauging and lifetime data logging functions if ***Temperature Enable[TS1]*** = 1.

The cell temperature measurement requires an external 10-kΩ negative temperature coefficient (NTC) thermistor, such as the Semitec 103AT-2, connected between VSS and the TS pin.

2.4.3 Temperature Configuration

The following data flash parameter enables/disables the available temperature sensor options.

Class	Subclass	Name	Type	Min	Max	Default	Description
Settings	Configuration	Temperature Enable	H1	0x00	0x03	0x02	Determines whether the internal temperature (TSInt) or the external temperature (TS1 on TS pin) is reported with *Temperature()*. Bit 0: TSInt—Enables internal TS Bit 1: TS1—Enables external TS pin 0, 0: Neither enabled, *Temperature()* reports –273.2K. 0, 1: Enables internal TS, *Temperature()* reports the internal temperature. 1, 0: Enables TS1, *Temperature()* reports the value determined by thermistor on the TS pin. 1, 1: Both TSInt and TS1 are enabled, *Temperature()* reports the higher of the two values. Bits 7:2: Reserved

Power Modes

3.1 Introduction

To enhance battery life, the bq27z561 supports several power modes to minimize power consumption during operation.

3.2 NORMAL Mode

In NORMAL mode (also referred to as ACTIVE mode), the device takes voltage, current, and temperature readings every 1 s, performs gauging calculations, updates data, and makes status selections at 1-s intervals. Between these periods of activity, the device is in a reduced power state.

3.3 SLEEP Mode

3.3.1 Device Sleep

When the sleep conditions are met, the device goes into SLEEP mode with periodic wake-ups to reduce power consumption. The device returns to NORMAL mode if any exit sleep condition is met.

Status	Condition	Action
Activate	***DA Config[SLEEP]*** = 1 AND |*Current()*| ≤ ***Sleep Current*** AND ***Voltage Time*** > 0 AND *OperationStatusB()[DPSLEEPM]* = 0	The device goes to SLEEP mode. The device wakes up every ***Voltage Time*** to measure voltage and temperature. The device continues to coulomb count and update current every 4 s. Tip: Synchronize these two times to save power.
Exit	***DA Config[SLEEP]*** = 0 OR |*Current()*| > ***Sleep Current*** OR ***Voltage Time*** = 0 OR *OperationStatusB()[DPSLEEPM]* = 1	Return to NORMAL mode

The configuration options for SLEEP are in the following data flash.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Power	Sleep	Sleep Current	I2	0	32767	15	mA	|*Current()*| threshold to enter SLEEP mode
Power	Sleep	Voltage Time	U1	1	20	5	s	Voltage sampling period in SLEEP mode

3.4 DEEP SLEEP Mode

In DEEP SLEEP mode, the device takes data similar to SLEEP mode with the exception of the current consumption reduced by measuring current periodically, instead of continuously, with the low-power coulomb counter. DEEP SLEEP mode lowers power consumption and is entered through SLEEP mode. Exit from this mode is through a current level or a command.

Status	Condition	Action
Activate	(***Power Config[AUTO_DP_SLP_EN]*** = 1 OR *OperationStatusB()[DPSLEEPM]* = 1) AND |Wake Comparator Current| ≤ ***Deep Sleep Current***	The device goes to DEEP SLEEP mode. The device wakes up every ***Deep Sleep Voltage Time*** to measure voltage, current, and temperature. The device coulomb counts every 1 s, based on the last measured current. The device performs a low resolution measurement of current and updates Wake Comparator Current every ***Wake Check Time***. Wake Comparator Current is overwritten by the value of *Current()* when it updates (true for all modes).
Exit	(***Power Config[AUTO_DP_SLP_EN]*** = 0 AND *OperationStatusB()[DPSLEEPM]* = 0) OR |Wake Comparator Current| > ***Deep Sleep Current***	Return to SLEEP mode

The configuration options for DEEP SLEEP are in the following data flash.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Power	Sleep	Deep Sleep Voltage Time	U1	1	20	20	s	Determines the wake interval to measure voltage, current, and temperature in DEEP SLEEP mode
Power	Sleep	Wake Check Time	U1	0	20	1	s	Determines the wake interval to determine if required to return to SLEEP mode
Power	Sleep	Deep Sleep Current	I2	0	32767	10	mA	|Wake Comparator Current| must be lower than this value to allow DEEP SLEEP mode entry.

3.5 Power Modes Configuration

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Settings	Configuration	Power Configuration	H1	0x00	0xFF	0x10	—	Bit 4: SLP_ACCUM 0 = Disables CC accumulation during SLEEP mode 1 = Enables CC accumulation during SLEEP mode Bit 6: AUTO_DP_SLP_EN 0 = Automatic entry into DEEP SLEEP mode disabled 1 = Automatic entry into DEEP SLEEP mode enabled
Settings	Configuration	DA Configuration	H2	0x0000	0x0010	0x0010	—	Bits 3:0: Reserved Bit 4: SLEEP—SLEEP mode 0 = Disables SLEEP mode 1 = Enables SLEEP mode (default) Bits 15:5: Reserved

Gauging

4.1 Introduction

The bq27z561 measures cell voltage, temperature, and current.

The bq27z561 measures charge and discharge activity by monitoring the stable voltage across a small-value series sense resistor (1 mΩ typical) between the negative terminal of the cell and the negative terminal of the battery pack. The battery state-of-charge is subsequently adjusted during load or charger application, using the integrated charge passed through the battery. See the "Theory and Implementation of Impedance Track Battery Fuel-Gauging Algorithm" section in the *bq20zxx Product Family Application Report* (SLUA364) for further details.

The default for Impedance Track gauging is *off*. To enable the gauging function, set ***Manufacturing Status[GAUGE_EN]*** = 1. The gauging function will be enabled after a reset or a seal command is set. Alternatively, the MAC command *Gauging()* can be used to turn on and off the gauging function. *Gauging()* takes an immediate effect and [GAUGE_EN] is also updated accordingly.

The *ITStatus1()*, *ITStatus2()*, and *ITStatus3()* commands return various gauging-related information, which is useful for problem analysis.

4.2 Impedance Track Configuration

Load Mode — During normal operation, the battery-impedance profile compensation of the Impedance Track algorithm can provide more accurate full-charge and remaining state-of-charge information if the typical load type is known. The two selectable options are constant current (***Load Mode*** = 0) and constant power (***Load Mode*** = 1).

Load Select — To compensate for the I × R drop near the end of discharge, the bq27z561 must be configured for whatever current (or power) will flow in the future. While it cannot be exactly known, the bq27z561 can use load history, such as the average current of the present discharge to make a sufficiently accurate prediction.

The bq27z561 can be configured to use several methods of this prediction by setting the ***Load Select*** value. Because this estimate has only a second-order effect on remaining capacity accuracy, different measurement-based methods (methods 0–3, and method 7) result in only minor differences in accuracy. However, methods 4–6, where an estimate is arbitrarily assigned by the user, can result in a significant error if a fixed estimate is far from the actual load.

	Constant Current (***Load Mode*** = 0)	**Constant Power** (***Load Mode*** = 1)
0 =	***Avg I Last Run***	***Avg P Last Run***
1 =	Present average discharge current	Present average discharge power
2 =	*Current()*	*Current()* × *Voltage()*
3 =	*AverageCurrent()*	*AverageCurrent()* ×*Voltage()*
4 =	***Design Capacity mAh***/5	***Design Capacity cWh***/5
5 =	*AtRate()* (mA)	N/A
6 =	***User Rate-mA***	***User Rate-cW***
7 =	***Max Avg I Last Run***	***Max Avg P Last Run***

Pulsed Load Compensation and Termination Voltage — To take into account pulsed loads while calculating remaining capacity until ***Term Voltage*** threshold is reached, the bq27z561 monitors not only average load, but also short load spikes. The maximum voltage deviation during a load spike is continuously updated during discharge and stored in ***Delta Voltage***, with the minimum value allowed set in ***Min Delta Voltage***. ***Delta Voltage*** is added to ***Term Voltage*** to determine end-of-discharge voltage (EDV).

Reserve Battery Capacity — The bq27z561 allows an amount of capacity to be reserved in both mAh (***Reserve Cap-mAh***) and cWh (***Reserve Cap-cWh***) units between the point where the *RemainingCapacity()* function reports zero capacity and the absolute minimum pack voltage, ***Term Voltage***. This enables a system to report zero capacity/energy, but still have enough reserve capacity/energy to perform a controlled shutdown or provide an extended sleep period for the host system.

The same capacity is reserved when calculating *Imax()* if ***IT Gauging Configuration[IMAXRESRVEN]*** = 1; however, only ***Reserve Cap-mAh*** is considered.

Pack Based Termination Voltage — The bq27z561 forces *RemainingCapacity()* to 0 mAh when the battery voltage discharges to ***Term Voltage*** for a period of ***Term V Hold Time***.

A portion of the configuration options for Impedance Track are in the following data flash. Additional configuration options are located in the sections in which they are discussed.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Gas Gauging	IT Cfg	Pack Resistance	I2	0	32767	0	mΩ	Value of the battery pack serial resistance that is NOT along the cell voltage measurement path of the gauge. This can include the resistance associated with FETs, traces, sense resistors, and any additional resistance in the path.
Gas Gauging	IT Cfg	System Resistance	I2	0	32767	0	mΩ	Value of the system serial resistance that is along the path from the battery pack to the system power converter input. This can include FETs, traces, sense resistors and any additional resistance in the path.
Gas Gauging	IT Cfg	Cell 1 Interconnect Resistance	I2	0	32767	0	2^{-10} Ω	Value of the battery pack serial resistance that is along the cell voltage measurement path of the gauge; that is, the negative rail to the bottom of the cell and the top of the cell to the gauge. This can include the resistance associated with FETs, traces, sense resistors, and any additional resistance in the path. The gauge will offset the measured resistance with this value to improve Ra accuracy.
Gas Gauging	IT Cfg	Term Voltage	I2	0	32767	3000	mV	Minimum pack voltage used in IT simulations. ***Term Voltage*** should be set to the minimum allowable voltage at the system power converter input. If it is desired to report 0% *RelativeStateOfCharge()* before the pack voltage reaches ***Term Voltage***, it is recommended to increase ***Reserve Cap-mAh*** and ***Reserve Cap-cWh***.
Gas Gauging	IT Cfg	Term V Hold Time	U1	0	255	2	s	When ***Term Voltage*** is met for ***Term V Hold Time***, the *RemainingCapacity()* is set to 0 mAh.
Gas Gauging	IT Cfg	Max Simulation Iterations	U1	20	50	50	—	Enables the user to set the max number of simulation iterations IT is allowed to do. If the user finds that the watchdog is tripping, this number can be lowered.
Gas Gauging	IT Cfg	Simulation Near Term Delta	I2	0	32767	250	mV	Voltage delta from ***Term Voltage***, which defines "near EDV" for IT simulations. If ***Term Voltage*** is increased, ***Simulation Near Term Delta*** should be decreased to keep ***Term Voltage*** + ***Simulation Near Term Delta*** around 3.2 V–3.5 V, the knee of the discharge curve.
Gas Gauging	IT Cfg	Min Delta Voltage	I2	–32768	32767	0	mV	The minimum ***Delta Voltage*** that is saved during discharge cycles
Gas Gauging	IT Cfg	Load Select	U1	0	7	1	—	Defines load compensation mode used by the gauging algorithm

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Gas Gauging	IT Cfg	Load Mode	U1	0	1	1	—	Defines unit used by the gauging algorithm: 0 = Constant Current 1 = Constant Power
Gas Gauging	IT Cfg	User Rate-mA	I2	–9000	0	0	mA	Discharge rate used for capacity calculation selected by ***Load Select*** = 6
Gas Gauging	IT Cfg	User Rate-cW	I2	–32768	0	0	cW	Discharge rate used for capacity calculation selected by ***Load Select*** = 6
Gas Gauging	IT Cfg	Reserve Cap-mAh	I2	0	9000	0	mAh	Capacity reserved available when the gauging algorithm reports 0% *RelativeStateOfCharge()*
Gas Gauging	IT Cfg	Reserve Cap-cWh	I2	0	32000	0	cWh	Capacity reserved available when the gauging algorithm reports 0% *RelativeStateOfCharge()*
Gas Gauging	IT Cfg	Predict Ambient Time	U2	0	65535	2000	s	Wait time before the gauging algorithm starts to predict the ambient temperature during CHARGE and DISCHARGE modes (if ***[AMB_PRED]*** = 1). It is recommended to be set to 2× the value of ***Temp a*** to represent system thermal equilibrium.

The parameters updated by AND used for Impedance Track are in the following data flash.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Gas Gauging	State	Update Status	H1	0x00	0x0E	0x00	—	Bit 1:0: UPDATE1, UPDATE0 Update Status 0,0 = QMax NOT updated, Ra NOT updated 0,1 = QMax updated, Ra NOT updated 1,0 = QMax updated, Ra updated 1,1 = Unused Bit 2: Enable—Impedance Track gauging is enabled. This bit can only be changed via the *Gauging()* command. 0 = Disabled 1 = Enabled Bit 3: is_Qmax_Field_Updated—QMax has updated in the field. 0 = Not updated 1 = Updated Bit 7:4: Reserved
Gas Gauging	State	Avg I Last Run	I2	–32768	32767	–500	mA	Average current last discharge cycle
Gas Gauging	State	Avg P Last Run	I2	–32768	32767	–192	cW	Average power last discharge cycle
Gas Gauging	State	Delta Voltage	I2	–32768	32767	0	mV	*Voltage()* delta between normal and short load spikes to optimize runtime calculation
Gas Gauging	State	Temp k	I2	0	32767	200	0.1°C/ 256 cW	Thermal Model temperature factor
Gas Gauging	State	Temp a	I2	0	32767	1000	s	Thermal Model temperature time constant
Gas Gauging	State	Max I Last Run	I2	–32768	32767	–500	mA	Max current last discharge cycle
Gas Gauging	State	Max P Last Run	I2	–32768	32767	–192	cW	Max power last discharge cycle

4.3 Gas Gauge Modes

Resistance updates take place only in DISCHARGE mode, while OCV and QMax updates only take place in RELAX mode. Fast QMax will update at the end of discharge (see Section 4.4.2 for details). Entry and exit of each mode is controlled by data flash parameters in the subclass ***Gas Gauging: Current Thresholds*** section. When the device is determined to be in RELAX mode and OCV is taken, the *GaugingStatus()[REST]* flag is set. In RELAX mode or DISCHARGE mode, *BatteryStatus()[DSG]* is set. Figure 4-1 shows the flow.

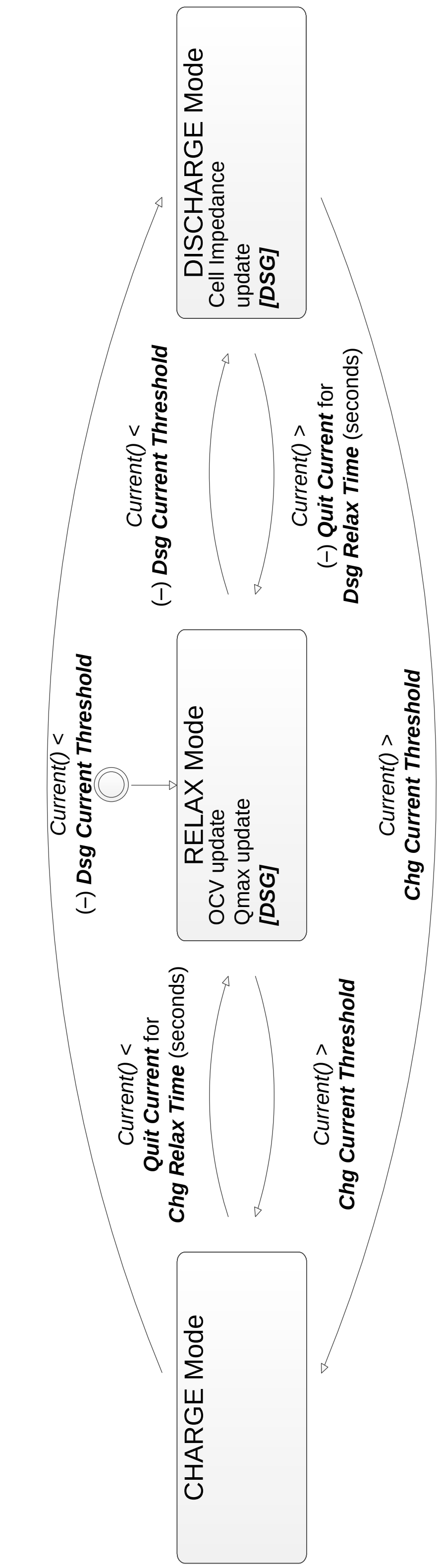


Figure 4-1. Gas Gauge Operating Modes

CHARGE mode is exited and RELAX mode is entered when *Current* goes below ***Quit Current*** for a period of ***Chg Relax Time***. DISCHARGE mode is entered when *Current* goes below ***(–)Dsg Current Threshold***. DISCHARGE mode is exited and RELAX mode is entered when *Current* goes above ***(–)Quit Current*** threshold for a period of ***Dsg Relax Time***. CHARGE mode is entered when *Current* goes above ***Chg Current Threshold***. Figure 4-2 shows an example of the operating modes.

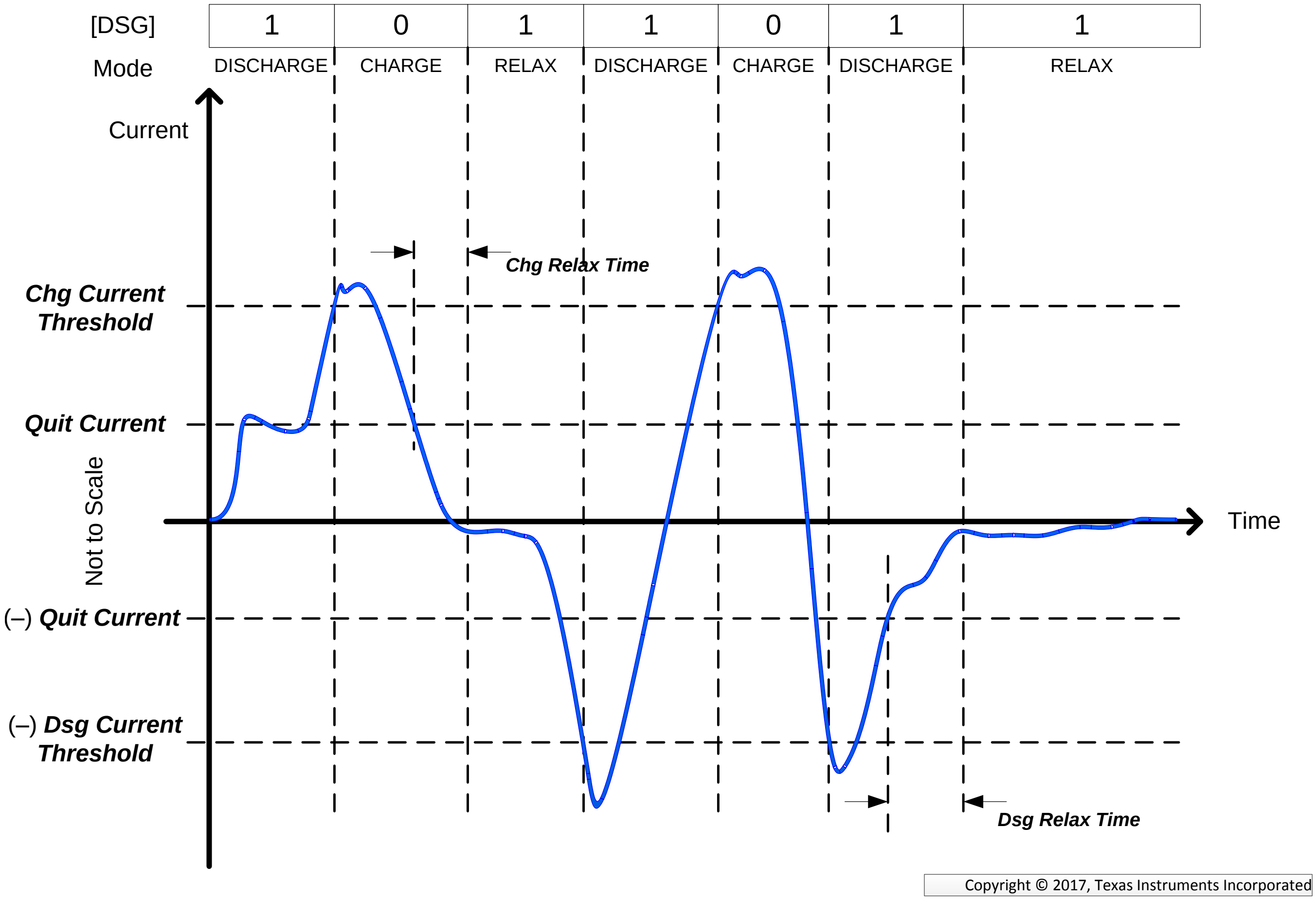


Figure 4-2. Gas Gauge Operating Mode Example

The configuration options for the gas gauge modes are in the following data flash.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Gas Gauging	Current Thresholds	Dsg Current Threshold	I2	–32768	32767	60	mA	DISCHARGE mode *Current()* threshold
Gas Gauging	Current Thresholds	Chg Current Threshold	I2	–32768	32767	75	mA	CHARGE mode *Current()* threshold
Gas Gauging	Current Thresholds	Quit Current	I2	0	32767	40	mA	|*Current()*| threshold to enter RELAX mode
Gas Gauging	Current Thresholds	Dsg Relax Time	U1	0	255	60	s	DISCHARGE to RELAX timeout
Gas Gauging	Current Thresholds	Chg Relax Time	U1	0	255	60	s	CHARGE to RELAX timeout

4.4 QMax and Ra

The total battery capacity is found by comparing states-of-charge before and after applying the load with the amount of charge passed. When an applications load is applied, the impedance of the cell is measured by comparing the open circuit voltage (OCV) obtained from a predefined function for the present state-of-charge with the measured voltage under load.

Measurements of OCV and charge integration determine the chemical state-of-charge (SOC) and chemical capacity (QMax). Ra is the impedance of the cell at 25°C at various states-of-charge.

The bq27z561 acquires and updates the battery-impedance profile during normal battery usage. It uses this profile, along with the state-of-charge and QMax value, to determine *FullChargeCapacity()* and *RelativeStateOfCharge()* specifically for the configured load and present temperature. *FullChargeCapacity()* reports a capacity or energy available from a fully charged battery reduced by ***Reserve Cap-mAh*** or ***Reserve Cap-cWh*** under the configured load and present temperature until *Voltage()* reaches end-of-discharge voltage (EDV).

4.4.1 QMax Initial Values

The initial ***Qmax Cell 1*** value should be taken from the cell manufacturers' data sheet multiplied by the number of parallel cells, and are also used for the ***Design Capacity mAh*** data flash value.

See the "Theory and Implementation of Impedance Track Battery Fuel-Gauging Algorithm" section in the *bq20zxx Product Family Application Report* (SLUA364) for further details.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Gas Gauging	State	Qmax Cell 1	I2	0	32767	5359	mAh	QMax Cell 1
Gas Gauging	Design	Design Capacity mAh	I2	0	32767	5300	mAh	Design Capacity in mAh
Gas Gauging	Design	Design Capacity cWh	I2	0	32767	2040	cWh	Design Capacity in cWh
Gas Gauging	Design	Design Voltage	I2	0	32767	3850	mV	Design Voltage

4.4.2 QMax Update Conditions

QMax update is enabled when gauging is enabled. This is indicated by the *GaugingStatus()[QEN]* flag. The bq27z561 updates the no-load full capacity (QMax) when two open circuit voltage (OCV) readings are taken. These OCV readings are taken when the battery is in a RELAXED state before and after a minimum charge or discharge activity. A RELAXED state is achieved if the battery voltage has a dV/dt of < 1 µV/s. Typically, it can take up to two hours in a CHARGED state and five hours in a DISCHARGED state to ensure that the dV/dt condition is satisfied. If five hours are exceeded, a reading is taken even if the dV/dt condition was not satisfied.

The following conditions will prevent a QMax update when an OCV is taken.

Temperature — If *Temperature()* is outside of the range 10°C to 40°C

Delta Capacity — If the capacity change between suitable battery rest periods is less than 37%

Voltage — If *Voltage()* is inside a flat voltage region. (See the *Support of Multiple Li-Ion Chemistries with Impedance Track Gas Gauges Application Report* (SLUA372) for the voltage ranges of other chemistries.) This flat region varies with different chemistries. The *GaugingStatus()[OCVFR]* flag indicates if the cell voltage is inside this flat region.

Offset Error — If offset error accumulated during the time passed from the previous OCV reading exceeds 1.5% of ***Design Capacity mAh***, the update is disqualified. Offset error current is calculated as a function of ***Coulomb Counter Deadband*** and the sense resistor value. For applications with small battery capacities, an offset error of 1.5% of ***Design Capacity mAh*** can be reached in a short period of time, especially with a small sense resistor. Therefore, a minimum time of 11 hours from the last qualified OCV is enforced before disqualification, which facilitates QMax updates in such applications. Enforcing this minimum time can increase an offset error to as high as 5.5% of ***Design Capacity mAh***.

Several flags in *GaugingStatus()* are helpful to track QMax update conditions. The *[REST]* flag indicates an OCV is taken in RELAX mode. *[REST]* sets when the OCV is taken and clears when exiting RELAX mode. The *[VOK]* flag indicates the last OCV reading is qualified for the QMax update. *[VOK]* sets when exiting RELAX mode after an OCV that qualifies for QMax updates (including those that update QMax). *[VOK]* clears when a QMax update occurs, when a QMax update is disqualified based on an offset error (as described above), or upon a full reset. The *[QMAX]* flag toggles when a QMax update occurs. *ITStatus2()* and *ITStatus3()* return the QMax and DOD (the depth of discharge that corresponds to the OCV reading) data.

4.4.3 Fast QMax Update Conditions

The Fast QMax update conditions are very similar to the QMax update conditions with the following differences:

- Instead of taking two OCV readings for a QMax update, a Fast QMax update requires only one OCV reading AND
- The battery pack should discharge below 10% RSOC.

The differences in requirements enable the Fast QMax feature to have a QMax update at the end of discharge (given one OCV reading is already available and discharge < 10% RSOC) without a longer relax time after a discharge event. The temperature, delta capacity, voltage, and offset error requirements for a QMax update are still required for the Fast QMax update.

This feature is particularly useful for reducing production QMax learning cycle time or for an application that is mostly in CHARGE or DISCHARGE state with infrequent relaxation. Setting ***IT Gauging Configuration[FAST_QMAX_LRN]*** = 1 enables Fast QMax during production learning only (that is, ***Update Status*** = 06). When setting ***IT Gauging Configuration[FAST_QMAX_FLD]*** = 1, Fast QMax is enabled when Impedance Track is enabled and ***Update Status*** = 06 or 0E.

The DOD is taken for QMax at a high state-of-charge, then during discharge when at the steep portion of the voltage curve (92–96% DOD). This enables a good estimation of DOD. This DOD estimation during discharge is used to update QMax immediately instead of first needing a rest period. The actual update to QMax occurs when the discharge stops after verifying that no conditions are present to cause the QMax update to fail. The bq27z561 has an option to qualify DODEOC for QMax updates, which means it is possible to update QMax with no rest periods (by having a charge termination followed by a full discharge); however, this is only recommended for certain new chemistries. Fast QMax can be enabled in either LEARN mode (***[FAST_QMAX_LRN]***) or FIELD mode (***[FAST_QMAX_FLD]***). The LEARN mode flag means Fast QMax is only enabled with ***Update Status*** = 06, and will be disabled once 0E is reached. FIELD mode means Fast QMax is enabled with ***Update Status*** = 06 and 0E.

4.4.4 QMax and Fast QMax Update Boundary Check

The bq27z561 implements a QMax and Fast QMax boundary check prior to saving the value to data flash. This improves the robustness of the QMax update in case of potential QMax corruption during the update process.

The verifications are as follows:

1. Verify that the updating QMax or Fast QMax value is within ***Qmax Delta*** of the present QMax (above or below). ***Qmax Delta*** is the maximum allowed QMax change for each update, expressed as a percentage of ***Design Capacity mAh***. If the updating value is outside of this range, the QMax change is capped to (***Qmax Delta*** × ***Design Capacity mAh***) / 100.
2. Bound the QMax value to a maximum of ***Qmax Upper Bound***. ***Qmax Upper Bound*** is expressed as a percentage of ***Design Capacity mAh***. If the updating value is above this maximum, the QMax update is capped to (***Qmax Upper Bound*** × ***Design Capacity mAh***) / 100.
3. Ensure that QMax is greater than 0 mAh.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Gas Gauging	IT Cfg	Qmax Delta	U1	3	100	5	%	Maximum allowed QMax change from its previous value. The QMax change will be capped by this setting if the delta from the previous QMax is larger than ***Qmax Delta. Qmax Delta*** is a percentage of ***Design Capacity mAh***.
Gas Gauging	IT Cfg	Qmax Upper Bound	U1	100	255	130	%	Maximum QMax value over the lifetime of the pack. If the updated QMax value is larger than this setting, the updated QMax will be capped to ***Qmax Upper Bound. Qmax Upper Bound*** is a percentage of ***Design Capacity mAh***.

4.4.5 Ra Table Initial Values

The Ra table is part of the impedance profile that updates during discharge when gauging is enabled. The initial ***Cell0 R_a0...14*** values should be programmed by selecting the correct chemistry data during data flash configuration. A chemistry database is constantly updating, and can be downloaded from the Gas Gauge Chemistry Updater product web page (http://www.ti.com/tool/gasgaugechem-sw). The initial ***xCell0 R_a0...14*** values are a copy of the non-x data set. Two sets of Ra tables are used alternatively when gauging is enabled to prevent wearing out the data flash.

The ***Cell0 R_a flag*** and the ***xCell0 R_a flag*** indicate the validity of the cell impedance table for the cell.

NOTE: Firmware updates these values: It is not recommended to change them manually.

4.4.5.1 R_a0 Table

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Ra Table	R_a0	Cell0 R_a flag	H2	0x0000	0xFFFF	0xFF55	—	High Byte: 0x00: Cell Impedance and QMax updated 0x05: RELAX mode and QMax update in progress 0x55: DISCHARGE mode and cell updated 0xFF: Cell impedance never updated Low-Byte: 0x00: Table not used and QMax updated 0x55: Table being used 0xFF: Table never used, no QMax or cell impedance update
Ra Table	R_a0	Cell0 R_a 0	I2	0	32767	159	$2^{-10}\ \Omega$	Cell 0 resistance at grid point 0
Ra Table	R_a0	Cell0 R_a 1	I2	0	32767	58	$2^{-10}\ \Omega$	Cell 0 resistance at grid point 1
Ra Table	R_a0	Cell0 R_a 2	I2	0	32767	65	$2^{-10}\ \Omega$	Cell 0 resistance at grid point 2
Ra Table	R_a0	Cell0 R_a 3	I2	0	32767	79	$2^{-10}\ \Omega$	Cell 0 resistance at grid point 3
Ra Table	R_a0	Cell0 R_a 4	I2	0	32767	90	$2^{-10}\ \Omega$	Cell 0 resistance at grid point 4
Ra Table	R_a0	Cell0 R_a 5	I2	0	32767	63	$2^{-10}\ \Omega$	Cell 0 resistance at grid point 5
Ra Table	R_a0	Cell0 R_a 6	I2	0	32767	76	$2^{-10}\ \Omega$	Cell 0 resistance at grid point 6
Ra Table	R_a0	Cell0 R_a 7	I2	0	32767	82	$2^{-10}\ \Omega$	Cell 0 resistance at grid point 7
Ra Table	R_a0	Cell0 R_a 8	I2	0	32767	82	$2^{-10}\ \Omega$	Cell 0 resistance at grid point 8
Ra Table	R_a0	Cell0 R_a 9	I2	0	32767	87	$2^{-10}\ \Omega$	Cell 0 resistance at grid point 9
Ra Table	R_a0	Cell0 R_a 10	I2	0	32767	87	$2^{-10}\ \Omega$	Cell 0 resistance at grid point 10
Ra Table	R_a0	Cell0 R_a 11	I2	0	32767	101	$2^{-10}\ \Omega$	Cell 0 resistance at grid point 11
Ra Table	R_a0	Cell0 R_a 12	I2	0	32767	118	$2^{-10}\ \Omega$	Cell 0 resistance at grid point 12
Ra Table	R_a0	Cell0 R_a 13	I2	0	32767	191	$2^{-10}\ \Omega$	Cell 0 resistance at grid point 13
Ra Table	R_a0	Cell0 R_a 14	I2	0	32767	282	$2^{-10}\ \Omega$	Cell 0 resistance at grid point 14

4.4.5.2 R_a0x Table

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Ra Table	R_a0x	xCell0 R_a flag	H2	0x0000	0xFFFF	0xFFFF	—	High-Byte: 0x00: Cell Impedance and QMax updated 0x05: RELAX mode and QMax update in progress 0x55: DISCHARGE mode and cell updated 0xFF: Cell impedance never updated. Low-Byte: 0x00: Table is not used and QMax updated. 0x55: Table is being used. 0xFF: Table was never used and no QMax or cell impedance was updated.
Ra Table	R_a0x	xCell0 R_a 0	I2	0	32767	159	2^{-10} Ω	Cell 0 resistance at grid point 0
Ra Table	R_a0x	xCell0 R_a 1	I2	0	32767	58	2^{-10} Ω	Cell 0 resistance at grid point 1
Ra Table	R_a0x	xCell0 R_a 2	I2	0	32767	65	2^{-10} Ω	Cell 0 resistance at grid point 2
Ra Table	R_a0x	xCell0 R_a 3	I2	0	32767	79	2^{-10} Ω	Cell 0 resistance at grid point 3
Ra Table	R_a0x	xCell0 R_a 4	I2	0	32767	90	2^{-10} Ω	Cell 0 resistance at grid point 4
Ra Table	R_a0x	xCell0 R_a 5	I2	0	32767	63	2^{-10} Ω	Cell 0 resistance at grid point 5
Ra Table	R_a0x	xCell0 R_a 6	I2	0	32767	76	2^{-10} Ω	Cell 0 resistance at grid point 6
Ra Table	R_a0x	xCell0 R_a 7	I2	0	32767	82	2^{-10} Ω	Cell 0 resistance at grid point 7
Ra Table	R_a0x	xCell0 R_a 8	I2	0	32767	82	2^{-10} Ω	Cell 0 resistance at grid point 8
Ra Table	R_a0x	xCell0 R_a 9	I2	0	32767	87	2^{-10} Ω	Cell 0 resistance at grid point 9
Ra Table	R_a0x	xCell0 R_a 10	I2	0	32767	87	2^{-10} Ω	Cell 0 resistance at grid point 10
Ra Table	R_a0x	xCell0 R_a 11	I2	0	32767	101	2^{-10} Ω	Cell 0 resistance at grid point 11
Ra Table	R_a0x	xCell0 R_a 12	I2	0	32767	118	2^{-10} Ω	Cell 0 resistance at grid point 12
Ra Table	R_a0x	xCell0 R_a 13	I2	0	32767	191	2^{-10} Ω	Cell 0 resistance at grid point 13
Ra Table	R_a0x	xCell0 R_a 14	I2	0	32767	282	2^{-10} Ω	Cell 0 resistance at grid point 14

4.4.6 Ra Table Update Conditions

The impedance is different across different DOD states. The cell has 15 Ra grid points representing the impedance from 0%–100% DOD. In general, the Ra table is updated during discharge. The *GaugingStatus()[RX]* flag will toggle when the Ra grid point is updated. The Ra update is disabled if any of the following conditions are met. The *GaugingStatus()[RDIS]* is set to indicate the Ra update is disabled.

- During the optimization cycle, the Ra update is disabled until QMax is updated (that is, Ra will not be updated if ***Update Status*** = 4).
- Ra update is disabled if the charge accumulation error > 5% of ***Design Capacity mAh***.
- During a discharge a negative resistance is measured.

A valid OCV reading during RELAX mode or a fast QMax update without an OCV read will clear the *[RDIS]* flag.

The configuration options related to Ra table updates are in the following data flash.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Gas Gauging	IT Cfg	Resistance Parameter Filter	U2	1	65535	65142	—	This is the filter coefficient on voltage, current, and temperature for resistance updates. Reducing this filter setting can improve low temperature performance at high rates. Examining the ***Term Voltage Delta*** setting and ***Fast Scale Start SOC*** should be done prior to adjusting this parameter when trying to improve the RSOC performance. The following is the formula to convert the DF setting into actual filter time constant: Filter time constant = [1/(1 – (DF_Value /65536))] – 1.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Gas Gauging	IT Cfg	Max Charge Current %	U1	0	100	10	%	If *AverageCurrent()* changes by more than this threshold from the previous resistance measurement to the present, the present resistance measurement and Ra scale update are not used. This protects resistance measurements from voltage transients after step changes in current, especially transitions to relaxation.
Gas Gauging	IT Cfg	Resistance Update Voltage	I2	0	32767	50	mV	The difference between the open circuit voltage based on DOD and the measured voltage is estimated as the IR drop. If this IR drop is greater than ***Resistance Update Voltage***, then the resistance calculation is allowed. This can be helpful in applications with small battery packs and large resistances that do not meet the C/10 minimum current requirement for resistance updates.
Gas Gauging	IT Cfg	Ra Filter	U2	0	999	800	0.1%	Filter value used in Ra updates that specifies what percentage of the Ra update is from the new value (100%—setting) versus the old value (setting). The recommended setting is 80% if Fast Resistance Scaling is enabled. Otherwise, the setting should be 50% as the default.
Gas Gauging	IT Cfg	Ra Max Delta	U1	0	255	15	% of Design Resistance	Maximum value of allowed Ra change
Gas Gauging	IT Cfg	Design Resistance	I2	1	32767	90	mΩ	Cell resistance at grid point 4. Automatically updated during learning when ***Update Status*** is set by the gauge to 06 and 0E. To automatically update again, set ***Update Status*** to 04. ***Design Resistance*** could be set manually when ***Update Status*** = 0E.

4.4.7 Fast Resistance Scaling

At low temperatures and very high discharge rates, using cell resistance directly from interpolating Ra table grids can lead to higher errors in RSOC. This is especially true near the end of discharge when cell resistance is changing quickly, which could cause undesirable drops to 0% RSOC. Fast Resistance Scaling is an algorithm that improves RSOC convergence to 0% by scaling cell resistance values from Ra table interpolation to reflect the most recent measured resistance.

The following terms are defined to understand the operation of Fast Resistance Scaling:

- True RSOC: The true relative state-of-charge of the battery pack, as determined by the gauge. Computed as True Rem Q / True Full Chg Q.
- Resistance Voltage: A filtered cell voltage used for resistance measurements with a time constant defined by ***Near EDV Ra Param Filter*** (or ***Resistance Parameter Filter*** if ***IT Gauging Configuration[FF_NEAR_EDV]*** = 0).
- Average Voltage: A filtered pack voltage with the same time constant as *AverageCurrent()*.

4.4.7.1 Calculation of Resistance Scale

When enabled with ***IT Gauging Configuration[RSOC_CONV]*** = 1, Fast Resistance Scaling becomes active once one of the following is true:

- True RSOC ≤ ***Fast Scale Start SOC*** OR
- Resistance Voltage < ***Term Voltage*** + ***Term Voltage Delta***.

For most applications, the default values of ***Term Voltage Delta*** and ***Fast Scale Start SOC*** are recommended. It is typically best to keep ***Term Voltage*** + ***Term Voltage Delta*** around 3.2 V–3.5 V, the knee of the discharge curve, for most battery applications.

Once active, every 30 seconds the algorithm calculates a new cell resistance scale as (R_{new} / R_{old}) × 1000, where R_{new} is the most recent measured cell resistance and R_{old} is the interpolated cell resistance at the present DOD. The raw scale is reported on Cell 1 RaScale. After a scale is calculated, an IT simulation is triggered to utilize the new resistance information. In addition, the scale is used for ambient temperature prediction (if enabled) and calculating *Imax()*.

As a safeguard, the scale is limited to a minimum of 200 and a maximum of 5000 when applied, but Cell 1 RaScale maintains the raw scale. For clarity, a scale of 200 corresponds to 0.2 (reducing cell resistance) and 5000 corresponds to 5.0 (increasing cell resistance).

4.4.7.2 Negative Resistance Scale

If a negative scale is calculated, it usually indicates significant error in QMax or an incorrect DOD0, which could be from system loading during initialization. When this occurs, Cell 1 RaScale resets to 1000 and *GaugingStatus()[NSFM]* sets to 1. The gauge attempts to correct the error in DOD by adjusting DOD0 such that DOD0 + (DOD0 Passed Q / QMax) equals the DOD computed from voltage, current, and temperature used for resistance.

4.4.7.3 Reset of Resistance Scale

Cell 1 RaScale resets to 1000 under the following conditions:

- Initialization of the device
- IT is enabled (*GaugingStatus()[QEN]* changes to 1).
- In CHARGE mode when Average Voltage > ***Term Voltage*** + ***Term V Delta*** AND True RSOC > ***Fast Scale Start SOC***.
- In RELAX mode when an OCV reading occurs with *Temperature()* > 15.0°C.
- In DISCHARGE mode when a negative resistance scale is calculated.

4.4.7.4 Application of Resistance Scale

The scale can be applied in two ways:

- If ***IT Gauging Configuration[DOD_RSCALE_EN]*** = 0, the resistance scale is applied across all DODs.
- If ***IT Gauging Configuration[DOD_RSCALE_EN]*** = 1, the resistance scale is only applied to DODs greater than or equal to the DOD at which it was calculated.

Setting ***IT Gauging Configuration[DOD_RSCALE_EN]*** = 1 is recommended because it reduces the sensitivity of FCC to large changes in the resistance scale.

4.4.7.5 Fast Resistance Scaling Configuration

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Gas Gauging	IT Cfg	Term Voltage Delta	I2	0	32767	200	mV	Controls when Fast Resistance Scaling becomes active when ***[RSOC_CONV]*** = 1. If ***Term Voltage*** is increased, ***Term Voltage Delta*** should be decreased to keep ***Term Voltage*** + ***Term Voltage Delta*** around 3.2 V–3.5 V, the knee of the discharge curve.
Gas Gauging	IT Cfg	Fast Scale Start SOC	U1	0	100	10	%	Controls the RSOC % that Fast Resistance Scaling becomes active when ***[RSOC_CONV]*** = 1. The default value is recommended, however, it may be appropriate to adjust this value in certain applications to be around the knee of the discharge curve.
Gas Gauging	IT Cfg	Near EDV Ra Param Filter	U2	1	65535	62184	—	Ra filter used in the Fast Resistance Scaling region if ***[FF_NEAR_EDV]*** = 1. The default value should be used.

4.5 FullChargeCapacity (FCC), RemainingCapacity (RemCap), and RelativeStateOfCharge (RSOC)

The Impedance Track algorithm applies QMax, impedance, temperature, voltage, and current data to predict the runtime *FullChargeCapacity()*, *RemainingCapacity()*, and *RelativeStateOfCharge()*. These values are updated if any of the following conditions are met, reflecting the battery capacity in real time:

- QMax update occurs
- Ra update occurs
- At onset of charge and discharge
- Valid charge termination
- Every 1 hour in RELAX mode after an OCV has been taken
- If temperature changes more than 5°C
- Every second when current is measured and passed charge is accumulated

4.5.1 Smoothing Engine

The gauge provides an engine that ensures *FullChargeCapacity()*, *RemainingCapacity()*, and *RelativeStateOfCharge()* change smoothly, which can be desirable in certain system applications. This smoothing engine is enabled when ***IT Gauging Configuration[SMOOTH]*** = 1. The true and smooth versions of FCC, RemCap, and RSOC are always available, but ***IT Gauging Configuration[SMOOTH]*** selects which version is reported on the standard commands.

When the smoothing engine is enabled, there are specific cases that can be handled differently based on user preference.

4.5.1.1 Smoothing to 0% in DISCHARGE Mode

When ***IT Gauging Configuration[DSG_0_SMOOTH_OK]*** = 1, smoothing to 0% in DISCHARGE mode is enabled. For preventing jumps to 0% in DISCHARGE mode, two data flash parameters are used: ***Term Smooth Start Cell V Delta*** and ***Term Smooth Time***. If *Voltage()* is less than or equal to ***Term Voltage*** + ***Term Smooth Start Cell V Delta*** while in DISCHARGE mode, time-based smoothing to 0% is initiated. *RemainingCapacity()* smoothly converges to 0 mAh over the next ***Term Smooth Time*** seconds. Time-based smoothing to 0% will continue unless CHARGE mode is entered.

Term Smooth Final Cell V Delta ensures that the gauge reports 0% before voltage drops too low. If *Voltage()* is less than or equal to ***Term Voltage*** – ***Term Smooth Final Cell V Delta*** while in DISCHARGE mode, *RemainingCapacity()* will be forced to 0 mAh, even if time-based smoothing to 0% was active.

NOTE: ***Term Smooth Final Cell V Delta*** can be disabled by setting equal to ***Term Voltage***, but is typically expected to be low enough to enable the system to shut down properly (without brownout).

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Gas Gauging	Smoothing	Term Smooth Start Cell V Delta	I2	0	32767	150	mV	If ***[DSG_0_SMOOTH_OK]*** = 1, then during DISCHARGE mode and once *Voltage()* is less than or equal to ***Term Voltage*** + ***Term Smooth Start Cell V Delta***, time-based smoothing to 0% is initiated. This will smooth *RemainingCapacity()* to 0 mAh over the next ***Term Smooth Time*** seconds.
Gas Gauging	Smoothing	Term Smooth Final Cell V Delta	I2	0	32767	100	mV	If ***[DSG_0_SMOOTH_OK]*** = 1, then during DISCHARGE mode and once *Voltage()* is less than or equal to ***Term Voltage*** + ***Term Smooth Final Cell V Delta***, *RemainingCapacity()* is forced to 0 mAh.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Gas Gauging	Smoothing	Term Smooth Time	U1	1	32767	20	s	If ***[DSG_0_SMOOTH_OK]*** = 1, then during DISCHARGE mode and once *Voltage()* is less than or equal to ***Term Voltage*** + ***Term Smooth Start Cell V Delta***, time-based smoothing to 0% is initiated. This will smooth *RemainingCapacity()* to 0 mAh over the next ***Term Smooth Time*** seconds.

4.5.1.2 Smoothing to 100% in CHARGE Mode

When ***IT Gauging Configuration[CHG_100_SMOOTH_OK]*** = 1, smoothing to 100% in CHARGE mode is enabled. For preventing jumps to 100% in CHARGE mode, this feature uses the valid charge termination logic to predict when charging will complete. Refer to Valid Charge Termination for the full set of details. The valid charge termination logic requires two consecutive 40-s windows that meet all taper conditions. After the first 40-s window is satisfied, time-based smoothing to 100% will be initiated. *RemainingCapacity()* smoothly converges to *FullChargeCapacity()* over the next 40-s window.

4.5.1.3 Smoothing in RELAX Mode

IT Gauging Configuration[RELAX_JUMP_OK] and ***IT Gauging Configuration[RELAX_SMOOTH_OK]*** determine the behavior of *RelativeStateOfCharge()* during RELAX mode.

When ***IT Gauging Configuration[RELAX_JUMP_OK]*** = 1, *RelativeStateOfCharge()* is allowed to jump during RELAX mode. When ***IT Gauging Configuration[RELAX_JUMP_OK]*** = 0, *RelativeStateOfCharge()* holds constant during RELAX mode and any RSOC jump will be passed onto CHARGE and DISCHARGE mode.

When ***IT Gauging Configuration[RELAX_SMOOTH_OK]*** = 1, *RelativeStateOfCharge()* is NOT allowed to jump during RELAX mode. Any RSOC jumps during RELAX mode are smoothed out over a period of ***Smooth Relax Time***. If ***Smooth Relax Time*** is not reached, the remaining portion of the RSOC jump will be passed onto CHARGE and DISCHARGE mode.

If both flags are set to 1, ***IT Gauging Configuration[RELAX_JUMP_OK]*** takes higher priority and *RelativeStateOfCharge()* is allowed to jump during RELAX mode.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Gas Gauging	Smoothing	Smooth Relax Time	I2	1	32767	1000	s	If ***[RELAX_SMOOTH_OK]*** = 1, the delta remaining capacity and full charge capacity are smoothed over this set period of time. It is recommended to use the default setting.

4.6 Impedance Track (IT) Configuration Options

The bq27z561 provides several Impedance Track configuration options to fine-tune the gauging performance. These configurations can be turned on or off through the corresponding flags in ***Settings***: ***IT Gauging Configuration*** and ***I2C Gauging Configuration***.

[LOCK0]: After a discharge event, cell voltage will usually recover to a slightly higher voltage during RELAX mode. A new OCV reading during this time can result in a slightly higher state-of-charge. This flag provides an option to keep *RemainingCapacity()* and *RelativeStateOfCharge()* locked during relaxation after 0% and *GaugingStatus()[FD]* are reached during discharge. The lock is removed once CHARGE mode is entered.

[RSOC_HOLD]: An IT simulation will run at the onset of discharge. If charge terminates at a low temperature and discharge occurs at a higher temperature, the difference in temperature could cause a small rise of RSOC for a short period of time at the beginning of discharge. This flag option prevents RSOC rises during discharge. RSOC will be held until the calculated value falls below the actual state.

[RSOCL]: When set, RSOC will be held to 99% until charge termination is detected.

[RFACTSTEP]: The gauge keeps track of the change in Ra over 15 updates. It is limited to 1.5 max. During an Ra update, if (new Ra)/(old Ra) > 1.5 or < 0.5, the gauge will take different actions based on the setting of this flag.

If the flag is set to 1 (default), the gauge allows Ra to update once using the max factor of 1.5 or min factor of 0.5, then disables the Ra update. If this flag is set to 0, the gauge will not update Ra and also disables the Ra update. It is recommended to keep the default setting. In both cases, *GaugingStatus()[RDIS]* becomes set.

[OCVFR]: An OCV reading is taken when a dV/dt condition is met. This is not the case if charging stops within or below the flat voltage region, which varies with ChemID. The change of cell voltage in this region is very small; therefore, a same voltage error can correspond to a larger DOD error. By default, this flag is set. The device will take a 48-hour wait before taking an OCV reading if charging stops prematurely. A short discharge will not cancel this 48-hour wait. OCV will be taken whenever the dV/dt condition is met. Removing the 48-hour requirement can be useful sometimes to reduce test time during evaluation.

[DOD0EW]: DOD0 readings have an associated error based on the elapsed time since the reading, the conditions at the time of the reading (reset, charge termination, and so on), the temperature, and the amount of relax time at the time of the reading, among others. This flag provides an option to take into account both the previous and new calculated DOD0, which are weighted according to their respective accuracies. This can result in improved accuracy and in reduction of RSOC jumps after relaxation.

[RSOC_CONV]: This function is also called Fast Resistance Scaling. It is an option to address the convergence of RSOC to 0% at a low temperature and a very high rate of discharge. See *Fast Resistance Scaling* for more details.

[FAST_QMAX_LRN] and ***[FAST_QMAX_FLD]***: The first flag enables fast QMax during the learning cycle when ***Update Status*** = 06. The second flag enables fast QMax in the field when ***Update Status*** ≥ 06. See *Fast QMax Update Conditions* for more details on Fast QMax.

[FF_NEAR_EDV]: Fast Filter Near EDV. If this flag is set to 1, the gauge applies an alternative filter, ***Near EDV Ra Param Filter***, for an Ra update in the fast scaling region (starting around 10% RSOC). This flag should be kept to 1 as a default. If this flag is set to 0, the gauge uses the regular Ra filter, ***Resistance Parameter Filter***. Both DF filters should not be changed from the default value.

[SMOOTH]: If this flag is set to 1, the smoothing engine is enabled. For more details, see *Smoothing Engine*, which covers ***[RELAX_JUMP_OK]***, ***[RELAX_SMOOTH_OK]***, ***[CHG_100_SMOOTH_OK]***, and ***[DSG_0_SMOOTH_OK]*** as further configuration to the smoothing engine.

[CSYNC]: If this flag is set to 1, the gauge synchronizes *RemainingCapacity()* to *FullChargeCapacity()* at valid charge termination.

[CCT]: This flag provides an option to use *FullChargeCapacity()* (when ***[CCT]*** = 1) or *DesignCapacity()* (when ***[CCT]*** = 0) for cycle count threshold calculation. If *FullChargeCapacity()* is selected for cycle count threshold calculation, the minimum cycle count threshold is always 10% of *DesignCapacity()*. This helps to avoid any erroneous cycle count increment caused by an extremely low *FullChargeCapacity()*.

[IMAXRESRVEN]: If this flag is set to 1, the reserve battery capacity is factored into the calculation of *Imax()*. See *Imax Calculation* for more details.

[TAMB_SYNC_SIM]: If this flag is set to 1, the gauge performs an IT simulation after the *TambientSync()* command is received to use the newly recorded ambient temperature. This IT simulation could produce a change in *RelativeStateOfCharge()* if ***[SMOOTH]*** = 0. If ***[SMOOTH]*** = 1, *RelativeStateOfCharge()* behaves according to the configuration of the smoothing engine.

[AMB_PRED]: If this flag is set to 1, ambient temperature can be predicted during DISCHARGE and CHARGE modes. This can be useful in system applications that experience large increases in ambient temperature during discharges and/or charges without entry to RELAX mode. Ambient temperature prediction is triggered after being in DISCHARGE/CHARGE for ***Predict Ambient Time***, when the system is assumed to be at thermal equilibrium.

[THERM_IV]: If this flag is set to 1, battery heat is held constant near the end of an IT simulation. This helps prevent overestimation of temperature towards the end of discharge, and applies to SOH simulations.

[THERM_SAT]: If this flag is set to 1, IT simulations occurring near termination in a sustained discharge (when thermal saturation is reached) assume simulated temperature to be equal to measured cell temperature. This behavior does NOT apply to SOH simulations.

Class	Subclass	Name	Type	Min	Max	Default	Description
Settings	Configuration	I2C Gauging Configuration	H1	0x00	0x0F	0x08	Bit 0: RSOCL—*RelativeStateOfCharge()* and *RemainingCapacity()* behavior at end of charge 0 = Actual value shown (default) 1 = Held at 99% until valid charge termination. On entering valid charge termination, updates to 100% Bit 1: RSOC_HOLD—Prevents RSOC from increasing during discharge 0 = RSOC not limited 1 = RSOC not allowed to increase during discharge Bit 2: LOCK0—Keeps *RemainingCapacity()* and *RelativeStateOfCharge()* from jumping back during relaxation after 0 was reached during discharge 0 = Disabled (default) 1 = Enabled Bit 3: TAMB_SYNC_SIM—Ambient Temperature Synchronization Simulation 0 = Disabled 1 = Enabled (default) Bit 7:4: Reserved
Settings	Configuration	IT Gauging Configuration	H2	0x0000	0xFFFF	0xD5FE	Bit 0: CCT—Cycle Count Threshold 0 = Use *DesignCapacity()* for cycle count threshold (default) 1 = Use *FullChargeCapacity()* for cycle count threshold Bit 1: CSYNC—Syncs *RemainingCapacity()* with *FullChargeCapacity()* at valid charge termination 0 = Not synchronized 1 = Synchronized (default) Bit 2: RFACTSTEP—Ra Factor Step 0 = Disabled 1 = Enabled (default) Bit 3: OCVFR—Open Circuit Voltage Flat Region 0 = Disabled 1 = Enabled (default) Bit 4: DOD0EW—DOD0 error weighting 0 = Disabled 1 = Enabled (enable) Bit 5: IMAXRESRVEN—Imax Reserve Capacity 0 = Disabled 1 = Enabled (default) Bit 6: RSOC_CONV —RSOC Convergence (Fast Resistance Scaling) 0 = Disabled 1 = Enabled (default) Bit 7: FAST_QMAX_LRN—Fast QMax Learn Mode 0 = Disabled 1 = Enabled (default) Bit 8: FAST_QMAX_FLD—Fast QMax Field Mode 0 = Disabled 1 = Enabled (default) Bit 9: RSVD Bit 10: FF_NEAR_EDV—Fast Filter Near EDV 0 = Disabled 1 = Enabled (default) Bit 11: RELAX_JUMP_OK—Enables RSOC Jumps in RELAX Mode 0 = Disabled (default) 1 = Enabled Bit 12: SMOOTH—Smoothing Engine 0 = Disabled 1 = Enabled (default) Bit 13: RSVD Bit 14: RELAX_SMOOTH_OK—Smoothing in RELAX 0 = Disabled 1 = Enabled (default) Bit 15: DOD_RSCALE_EN—Configures which DOD the new RaScale is to be applied. 0 = The RaScale is applied to all DODs during IT simulations. 1 = The RaScale is only applied to DODs higher than the DOD where the RaScale is calculated. (default)
Settings	Configuration	IT Gauging Ext	H2	0x0000	0x001F	0x001B	Bit 0: DSG_0_SMOOTH_OK—Smoothing to 0% 0 = Disabled 1 = Enabled (default) Bit 1: CHG_100_SMOOTH_OK—Smoothing to 100% 0 = Disabled 1 = Enabled (default) Bit 2: AMB_PRED—Ambient Temperature Prediction 0 = Disabled (default) 1 = Enabled Bit 3: THERM_IV—Thermal Model IV Heat 0 = Disabled 1 = Enabled (default) Bit 4: THERM_SAT—Thermal Model Saturation 0 = Disabled 1 = Enabled (default) Bits 15:5: RSVD

4.7 State-of-Health (SOH)

The state-of-health (SOH) of the battery is provided through the standard command, *StateOfHealth()*. *StateOfHealth()* is the ratio of an IT simulation at 25°C and load specified by ***SOH Load Rate*** to ***Design Capacity mAh***. The ***SOH Load Rate*** can be set to the typical load of the application, and it is specified in hour-rate. In other words, ***Design Capacity mAh*** / ***SOH Load Rate*** will be the current used for the SOH simulation when ***Load Mode*** = 0, and ***Design Capacity cWh*** / ***SOH Load Rate*** will be the power used when ***Load Mode*** = 1. *StateOfHealth()* is updated on initialization, Ra updates, and QMax updates. The capacity and energy result of the SOH simulation is available on *FCC_SOH()*.

The configuration options for state-of-health (SOH) are in the following data flash.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Gas Gauging	SOH	SOH Load Rate	U1	1	255	50	0.1 Hr rate	Rate used in SOH simulation

4.8 Imax Calculation

The Imax feature enables a system to determine how much load can be applied for ***Max Current Pulse Duration*** without causing an instant drop to ***Term Voltage***. It is useful for systems that require intelligent load throttling under different conditions at various points of operation. The fuel gauge computes the *Imax()* current every second, based on the programmed ***Max Allowed Current*** and ***Max Current Pulse Duration***. ***Reserve Cap-mAh*** is factored into the *Imax()* calculation if ***IT Gauging Configuration[IMAXRESRVEN]*** = 1.

The configuration options for Imax are in the following data flash.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Gas Gauging	Imax	Max Allowed Current	I2	0	32767	8500	mA	The worst-case current pulse that the system expects to impose on the battery for ***Max Current Pulse Duration***. It is used to compute the reported *Imax()*.
Gas Gauging	Imax	Max Current Pulse Duration	U1	0	255	10	s	This DF specifies the longest time the ***Max Allowed Current*** is expected to be applied in a given system and is used to compute *Imax()*.

Lifetime Data Collection

5.1 Description

The device has the capability to log events over the life of the battery, which is useful for analysis. Lifetime data collection is enabled by setting ***ManufacturingStatus[LF_EN]*** = 1. The data is collected in RAM and only written to data flash under the following conditions to avoid wear out of the data flash:

- Every 10 hours if RAM content is different from data flash.
- A reset counter increments. The lifetime RAM data is reset; therefore, only the reset counters are updated to data flash.

The lifetime data stops collecting under the following condition:

- Lifetime data collection is disabled by setting ***ManufacturingStatus[LF_EN]*** = 0.

When the gauge is unsealed, the following *ManufacturingStatus()* can be used for testing lifetime data.

- *LifetimeDataReset()* can be used to reset the lifetime data (RAM and data flash) to default values.
- *LifetimeDataFlush()* can be used to force an update of RAM lifetime data to data flash.

The following lifetime data is collected when ***ManufacturingStatus[LF_EN]*** = 1.

- Voltage
  - Max Cell Voltage of the Cell
- Current
  - Max Charge/Discharge Current
- Temperature
  - Max/Min Cell Temp

5.2 Lifetimes

5.2.1 Voltage

Lifetime voltage data is available through Lifetime Data Block 1 via *AltManufacturerAccess()*.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Lifetimes	Voltage	Cell 1 Max Voltage	I2	0	32767	0	mV	Maximum reported voltage for cell 1

5.2.2 Current

Lifetime current data is available through Lifetime Data Block 1 via *AltManufacturerAccess()*.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Lifetimes	Current	Max Chg Current	I2	0	32767	0	mA	Maximum reported *Current()* in charge direction
Lifetimes	Current	Max Dsg Current	I2	–32768	0	0	mA	Maximum reported *Current()* in discharge direction

5.2.3 Temperature

Lifetime temperature data is available through Lifetime Data Block 1 via *AltManufacturerAccess()*.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Lifetimes	Temperature	Max Temp Cell	I1	–128	127	–128	°C	Maximum reported cell temperature
Lifetimes	Temperature	Min Temp Cell	I1	–128	127	127	°C	Minimum reported cell temperature

Host Interrupts

6.1 Description

The device can be enabled to generate an interrupt to the host processor on the INT pin under various voltage, temperature, and RSOC conditions. The ***IO Config[INT_EN]*** bit is used to enable or disable the interrupt function, and its polarity can be set to active high (***IO Config[INT_POL]*** = 1) or active low (***IO Config[INT_POL]*** = 0). The interrupt is a pulse on the INT pin with an approximate width of 1 ms.

6.2 Voltage and Temperature Interrupts

The device can be enabled to generate an interrupt on the INT pin to indicate an overvoltage, undervoltage, overtemperature, or undertemperature condition. The thresholds to set and clear each event are configurable through data flash for the initial values, and later by writing to the standard commands referenced below:

- The voltage for the overvoltage set interrupt threshold is *VoltHiSetThreshold()*.
- The voltage for the overvoltage clear interrupt threshold is *VoltHiClearThreshold()*.
- The voltage for the undervoltage set interrupt threshold is *VoltLoSetThreshold()*.
- The voltage for the undervoltage clear interrupt threshold is *VoltLoClearThreshold()*.
- The temperature for the overtemperature set interrupt threshold is *TempHiSetThreshold()*.
- The temperature for the overtemperature clear interrupt threshold is *TempHiClearThreshold()*.
- The temperature for the undertemperature set interrupt threshold is *TempLoSetThreshold()*.
- The temperature for the undertemperature clear interrupt threshold is *TempLoClearThreshold()*.

The interrupts are indicated in *InterruptStatus()*.

The interrupt flags are *[VOLT_HI]*, *[VOLT_LO]*, *[TEMP_HI]*, and *[TEMP_LO]*, and are summarized by the table below.

Table 6-1. Interrupt Flags (Interrupt Status)

Flag	Set Criteria	Clear Criteria
[VOLT_HI]	*Voltage() > VoltHiSetThreshold()*	*Voltage() < VoltHiClearThreshold()*
[VOLT_LO]	*Voltage() < VoltLoSetThreshold()*	*Voltage() > VoltLoClearThreshold()*
[TEMP_HI]	*Temperature() > TempHiSetThreshold()*	*Temperature() < TempHiClearThreshold()*
[TEMP_LO]	*Temperature() < TempLoSetThreshold()*	*Temperature() > TempLoClearThreshold()*

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Settings	Configuration	Init Voltage High Set	I2	0	5000	4500	mV	Initial value for *VoltHiSetThreshold()*, the high cell voltage set threshold
Settings	Configuration	Init Voltage High Clear	I2	0	5000	4400	mV	Initial value for *VoltHiClearThreshold()*, the high cell voltage clear threshold
Settings	Configuration	Init Voltage Low Set	I2	0	5000	2500	mV	Initial value for *VoltLoSetThreshold()*, the low cell voltage set threshold
Settings	Configuration	Init Voltage Low Clear	I2	0	5000	2600	mV	Initial value for *VoltLoClearThreshold()*, the low cell voltage clear threshold
Settings	Configuration	Init Temperature High Set	I1	–128	127	60	°C	Initial value for *TempHiSetThreshold()*, the high temperature set threshold

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Settings	Configuration	Init Temperature High Clear	I1	–128	127	55	°C	Initial value for *TempHiClearThreshold()*, the high temperature clear threshold
Settings	Configuration	Init Temperature Low Set	I1	–128	127	0	°C	Initial value for *TempLoSetThreshold()*, the low temperature set threshold
Settings	Configuration	Init Temperature Low Clear	I1	–128	127	5	°C	Initial value for *TempLoClearThreshold()*, the low temperature clear threshold

6.3 RSOC Interrupts

The device can be enabled to generate an interrupt on the INT pin at configurable RSOC intervals. Setting ***SOC Delta*** to 0 disables RSOC interrupts; otherwise, interrupts will be generated at the following RSOC points:

- 100%
- 100% – n × ***SOC Delta***, where n is an integer from 1 to INT(100 / ***SOC Delta***)
- 0%

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Settings	Configuration	SOC Delta	U1	0	100	1	%	Interval for generating RSOC-based interrupts on the INT pin. Set to 0 to disable these RSOC-based interrupts. Otherwise, interrupts are generated at the following RSOC points: 0%, 100%, 100% – n × ***SOC Delta***, where n is an integer from 1 to INT(100 / ***SOC Delta***).

6.4 Host Interrupts Configuration

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Settings	Configuration	IO Config	H1	0x00	0x3C	0x00	—	Bit 2: INT_EN 0 = Disables interrupt function on pin INT 1 = Enables interrupt function on pin INT Bit 3: INT_POL 0 = Interrupt (INT) is active LOW. 1 = Interrupt (INT) is active HIGH. Bit 4: GPIO_POL 0 = Pulse (PULS) is active LOW. 1 = Pulse (PULS) is active HIGH. Bit 5: GPIO_LEVEL_EN 0 = Pulse (PULS) is pulse only. 1 = Pulse (PULS) is level set.

Programmable Pulse Width

7.1 Description

The device can be enabled to generate a single pulse on the PULS pin with a programmable width. The polarity can also be set for active high or active low with ***IO Config[GPIO_POL]***. The PULS pin can be used to signal other system components, via a command to the gauge, without a connection to the host processor.

The PULS pin is open-drain so a resistor must be tied to a pullup voltage. The pulse width can be set in ***GPIO Pulse Width*** in steps of 25 ms. Setting the width to 0 effectively disables the pulse. A single pulse is generated each time the *PulseGPIO()* command is sent.

Additionally, the PULS pin can be programmed to a level (high or low) with the ***IO Config[GPIO_LEVEL_EN]*** bit. When ***IO Config[GPIO_LEVEL_EN]*** is set, the *PulseGPIO()* command will change the state of the PULS pin.

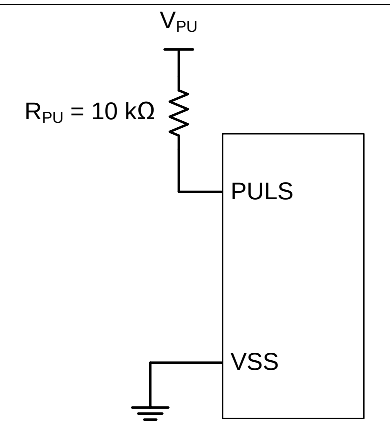


Figure 1. PULS Open-Drain Configuration

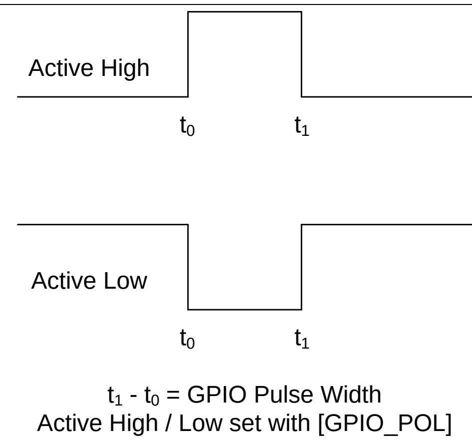


Figure 2. Pulse Width and Polarity

7.2 Programmable Pulse Width Configuration

Class	Subclass	Name	Type	Min	Max	Default	Description
Settings	Configuration	IO Config	H1	0x0	0x3C	0x00	Bits 1:0: Reserved Bit 2: INT_EN 0 = Disables interrupt function on pin INT 1 = Enables interrupt function on pin INT Bit 3: INT_POL 0 = Interrupt (INT) is active LOW. 1 = Interrupt (INT) is active HIGH. Bit 4: GPIO_POL 0 = Pulse (PULS) is active LOW. 1 = Pulse (PULS) is active HIGH. Bit 5: GPIO_LEVEL_EN 0 = Pulse (PULS) is pulse only. 1 = Pulse (PULS) is level set. Bits 7:6: Reserved
Settings	Configuration	GPIO Pulse Width	U1	—	255	7	Pulse width of PULS (7 indicates 7 × 25 ms = 175 ms)

Device Security

8.1 Description

There are three levels of secured operation within the device. To switch between the levels, different operations are needed with different keys. The three levels are SEALED, UNSEALED, and FULL ACCESS. The device also supports SHA-256 HMAC authentication with the host system.

8.2 SHA-256 Authentication

The bq27z561 uses SHA-256 for authentication.

- SHA-256 preprocessing is described in Section 6.2.1, *SHA-1 Preprocessing*, in FIPS 180-4.
- The Hash Computation is described in Section 6.2.2, *SHA-1 Hash Computation*, in FIPS 180-4.
- The HMAC implementation is described in FIPS 198-1.

Detailed information about the SHA-256 algorithm can be found here:

- http://www.nist.gov/itl/
- http://csrc.nist.gov/publications/fips
- www.faqs.org/rfcs/rfc3174.html

The random number should be a 32-byte random number generated from the host processor system. Once this number is generated, it is used to generate the HMAC value using the random number as the message and the secure key as the secret key for SHA-256.

8.2.1 Secure Key

The secure key is stored in the secured memory of the bq27z561 device. It is located in secure memory, which can store up to four secure keys.

Auth Config selects which of the four keys to be used with KEY_SEL0 and KEY_SEL1.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Settings	Configuration	Auth Config	H1	0x0	0x03	0x00	—	Bit 0: KEY_SEL0 Bit 1: KEY_SEL1 00 = Enables KEY 1 01 = Enables KEY 2 10 = Enables KEY 3 11 = Enables KEY 4

8.2.2 Authentication Flow

The authentication procedure is described in the following steps:

1. The host writes 0x00 to 0x3E.
2. The host writes 0x00 to 0x3F.
3. Write the random challenge should be written in a 32-byte block to address 0x40-0x5F.
4. Write the checksum (2's complement sum of (1), (2), and (3)) to address 0x60.
5. Write the length 0x24 to address 0x61.
6. The gauge will compute the HMAC using SHA-256 after step (5). Wait 200 ms. (60 ms is how long authentication takes, but extra margin is added).
7. The *MACData()* command will contain the computed HMAC result using SHA-256.

8. *[AUTH]* = 1 in *OperationStatusB()*.

8.3 Security Modes

Changing the security keys requires using the change MAC command; the code to unseal the device can be sent to 0x3E, 0x3F. The order of the data is in Little Endian. To change the keys, the write operations must be sent through *AltManufacturerAccess()* 0x3E, 0x3F with the *SecurityKey()* followed by the key information. Each parameter entry must be sent in Little Endian. The 0x3E write block should end after the "0xCD". The checksum and length are a second command starting at 0x60.

Example:

Changing the Unseal key to 0x0123, 0x4567 and the Full Access key to 0x89AB, 0xCDEF:

Write block: command = 0x3E, block = 0x35 + 0x00 + 0x23 + 0x01 + 0x67 + 0x45 + 0xAB + 0x89 + 0xEF + 0xCD + 1 byte for checksum + 1 byte for data length. Note: The checksum and length are a second command starting at 0x60.

Starting address 0x3E, data block (hex) is [35 00 23 01 67 45 ab 89 EF CD], then starting address 0x60, data block (hex) is [0A 0C] (checksum followed by length) Checksum = 0x0A = ~(0x35 + 0x00 + 0x23 + 0x01 + 0x67 + 0x45 + 0xAB + 0x89 + 0xEF + 0xCD). The final checksum is the bitwise inversion of the result.

Byte0: Unseal Key LSB
Byte1: Unseal Key MSB
Byte2: Full Access Key LSB
Byte3: Full Access Key MSB

For this activity, the second key must be sent within 4 s of sending the first key; otherwise, the request will not be accepted.

8.3.1 SEALING and UNSEALING Data Flash

The gas gauge has a key access scheme to transition between SEALED, UNSEALED, and FULL ACCESS modes. Each transition requires that a unique set of two keys be sent to the gas gauge via the *AltManufacturerAccess()* command. The keys must be sent consecutively, with no other data being written to the *AltManufacturerAccess()* register. The *Seal Device* command instructs the device to limit access to the registers, functions, and data flash space, and sets the *[SEC1][SEC0]* flags. In SEALED mode, standard register information is accessible. Extended MAC Command functions and data flash are not accessible. Once in SEALED mode, the device can never permanently return to UNSEALED or FULL ACCESS modes. Section 13.2.28, the *OperationStatusB()* register, shows the status of the device using the *[SEC1][SEC0]* bits.

8.3.2 SEALED to UNSEALED

SEALED to UNSEALED instructs the device to extend access to the standard and extended registers and data flash space and clears the *[SEC1][SEC0]* flags. In UNSEALED mode, all data, standard and extended registers and DF have read/write access. Unsealing is a two-step command performed by writing the first word of the unseal key to *AltManufacturerAccess() (MAC)*, followed by the second word of the unseal key to *AltManufacturerAccess()*. The unseal key can be read and changed via the *MAC SecurityKey()* command when in FULL ACCESS mode. To return to the SEALED mode, either a hardware reset is needed, or the *MAC Seal Device()* command is needed to transit from FULL ACCESS or UNSEALED to SEALED.

8.3.3 UNSEALED to FULL ACCESS

UNSEALED to FULL ACCESS instructs the device to allow full access to all standard and extended registers and data flash. The device is shipped from TI in this mode. The keys for UNSEALED to FULL ACCESS can be read and changed via the MAC command *SecurityKey()* when in FULL ACCESS mode. Changing from UNSEALED to FULL ACCESS is performed by using the *AltManufacturerAccess()* command, by writing the first word of the Full Access Key to *AltManufacturerAccess()*, followed by the second word of the Full Access Key to *AltManufacturerAccess()*. In FULL ACCESS mode, the command to go to boot ROM can be sent.

Advanced Charge Algorithm

9.1 Introduction

The bq27z561 device does not control the charge directly. It can interact with a smart charger to enhance its performance. The device can change the values of *ChargingVoltage()* and *ChargingCurrent()* based on *Temperature()* and *Voltage()*. Its flexible charging algorithm is JEITA-compatible and can also meet other specific cell manufacturer charge requirements. The *ChargingStatus()* register shows the state of the charging algorithm.

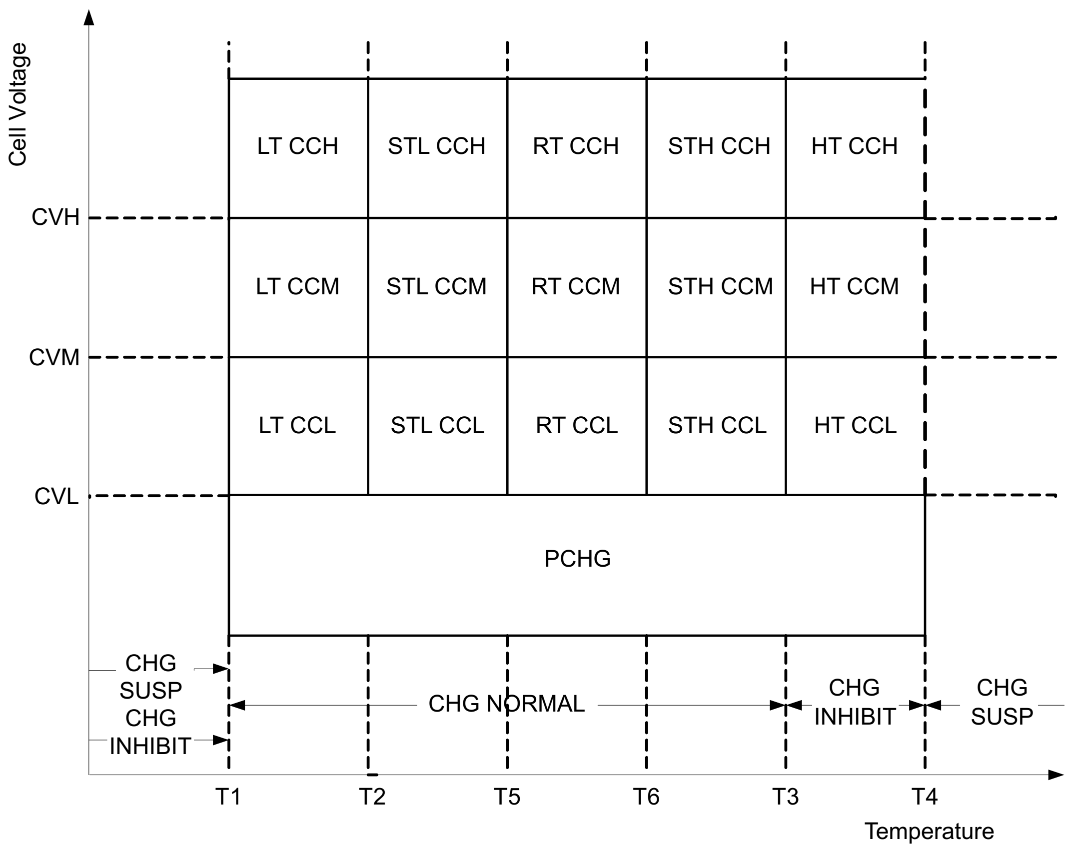


Figure 9-1. Charging Matrix

9.2 Charge Temperature Ranges

The measured temperature is segmented into several temperature ranges. The charging algorithm adjusts *ChargingCurrent()* and *ChargingVoltage()* according to the temperature range. The temperature ranges set in data flash should adhere to the following format:

T1* ≤ *T2* ≤ *T5* ≤ *T6* ≤ *T3* ≤ *T4

Temp Range bit definitions can be found in *ChargingStatus()*.

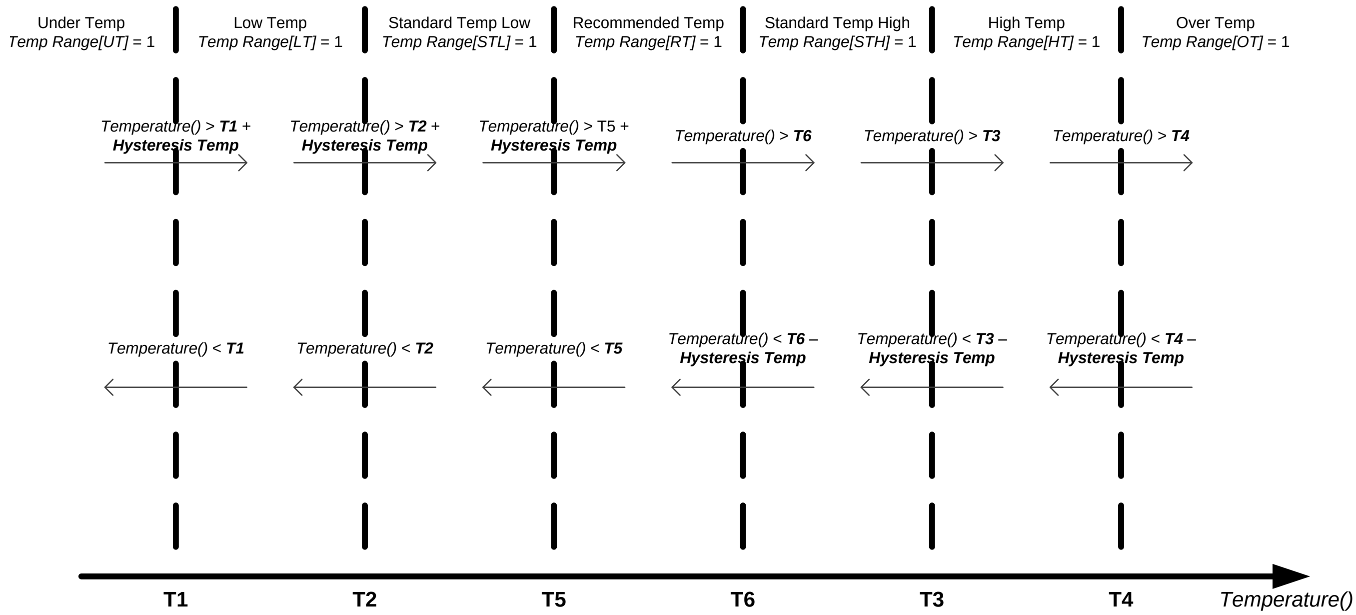


Figure 9-2. Charging Across Temperature

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Advanced Charging Algorithms	Temperature Ranges	T1	I1	–128	127	0	°C	T1 low temperature range lower limit
Advanced Charging Algorithms	Temperature Ranges	T2	I1	–128	127	10	°C	T2 low temperature range to standard temperature range
Advanced Charging Algorithms	Temperature Ranges	T5	I1	–128	127	20	°C	T5 recommended temperature range lower limit
Advanced Charging Algorithms	Temperature Ranges	T6	I1	–128	127	25	°C	T6 recommended temperature range upper limit
Advanced Charging Algorithms	Temperature Ranges	T3	I1	–128	127	45	°C	T3 standard temperature range to high temperature range
Advanced Charging Algorithms	Temperature Ranges	T4	I1	–128	127	55	°C	T4 high temperature range upper limit
Advanced Charging Algorithms	Temperature Ranges	Hysteresis	I1	–128	127	1	°C	Temperature hysteresis, applied when temperature is decreasing.

9.3 Voltage Range

The measured cell voltage is segmented into several voltage ranges. The charging algorithm adjusts *ChargingCurrent()* according to the temperature range and voltage range. The voltage ranges set in data flash should adhere to the following format:

Charging Voltage Low ≤ Charging Voltage Med ≤ Charging Voltage High ≤ [Standard or Rec] Temp Charging:Voltage

Depending on the specific charging profile, the ***Low Temp Charging:Voltage*** and ***High Temp Charging:Voltage*** settings do not necessarily have the highest setting values.

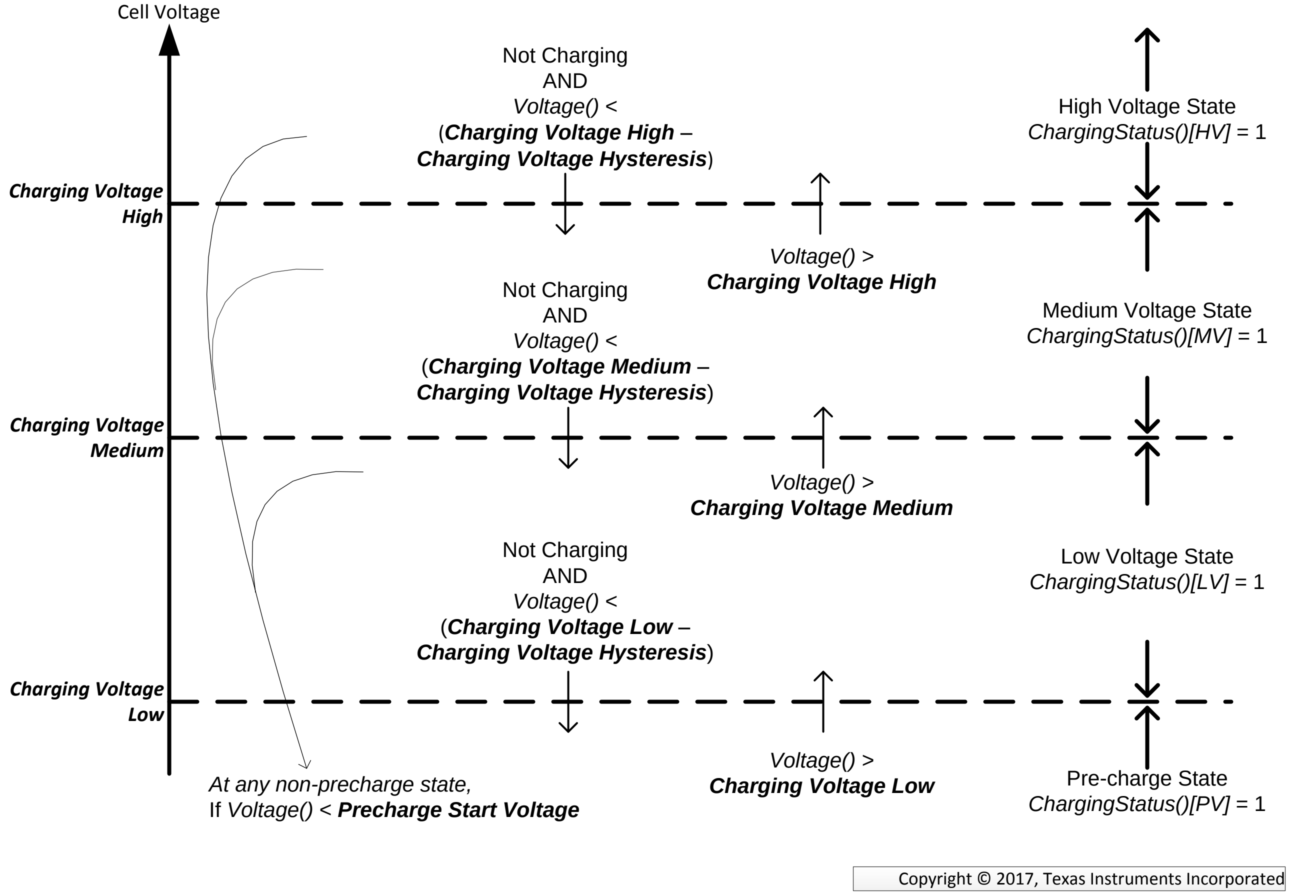


Figure 9-3. Charging Voltage Ranges

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Advanced Charging Algorithms	Voltage Range	Precharge Start Voltage	I2	0	32767	2500	mV	Minimum cell voltage to enter PRECHARGE mode
Advanced Charging Algorithms	Voltage Range	Charging Voltage Low	I2	0	32767	2900	mV	***Precharge Start Voltage*** range to ***Charging Voltage Low*** range
Advanced Charging Algorithms	Voltage Range	Charging Voltage Med	I2	0	32767	3600	mV	***Charging Voltage Low*** range to ***Charging Voltage Med*** range
Advanced Charging Algorithms	Voltage Range	Charging Voltage High	I2	0	32767	4000	mV	***Charging Voltage Med*** to ***Charging Voltage High*** range
Advanced Charging Algorithms	Voltage Range	Charging Voltage Hysteresis	U1	0	255	0	mV	***Charging Voltage Hysteresis*** is applied when voltage is decreasing.

9.4 Charging Current

The *ChargingCurrent()* value changes depending on the detected temperature and voltage per the charging algorithm.

The ***Charging Configuration[CRATE]*** flag provides an option to adjust the *ChargingCurrent()* based on *FullChargeCapacity()/DesignCapacity()*.

For example, with ***[CRATE]*** = 1, if *FullChargeCapacity()*/*DesignCapacity()* = 90% and ***Rec Temp Charging: Current Med*** is active per the charging algorithm, the *ChargingCurrent()* = ***Rec Temp Charging: Current Med*** × 90%.

NOTE: Table priority is top to bottom.

Temp Range	Voltage Range	Condition	Action
Any	PV	—	*ChargingCurrent()* = ***Pre-Charging:Current***
Any	LV, MV, or HV	*ChargingStatus()[MCHG]* = 1	*ChargingCurrent()* = ***Maintenance Charging:Current***
LT	LV	—	*ChargingCurrent()* = ***Low Temp Charging:Current Low***
	MV	—	*ChargingCurrent()* = ***Low Temp Charging:Current Med***
	HV	—	*ChargingCurrent()* = ***Low Temp Charging:Current High***
STL or STH	LV	—	*ChargingCurrent()* = ***Standard Temp Charging:Current Low***
	MV	—	*ChargingCurrent()* = ***Standard Temp Charging:Current Med***
	HV	—	*ChargingCurrent()* = ***Standard Temp Charging:Current High***
RT	LV	—	*ChargingCurrent()* = ***Rec Temp Charging:Current Low***
	MV	—	*ChargingCurrent()* = ***Rec Temp Charging:Current Med***
	HV	—	*ChargingCurrent()* = ***Rec Temp Charging:Current High***
HT	LV	—	*ChargingCurrent()* = ***High Temp Charging:Current Low***
	MV	—	*ChargingCurrent()* = ***High Temp Charging:Current Med***
	HV	—	*ChargingCurrent()* = ***High Temp Charging:Current High***

The configuration options for charging current are in the following data flash.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Settings	Configuration	Charging Configuration	H1	0x00	0x3F	0x00	—	Bit 0: CRATE—*ChargingCurrent()* rate 0 = No adjustment to *ChargingCurrent()* (default) 1 = *ChargingCurrent()* adjusted based on *FullChargeCapacity()*/*DesignCapacity()* Bits 7:1: Reserved
Advanced Charging Algorithms	Pre-Charging	Current	I2	0	32767	88	mA	Precharge *ChargingCurrent()*
Advanced Charging Algorithms	Maintenance Charging	Current	I2	0	32767	44	mA	Maintenance *ChargingCurrent()*
Advanced Charging Algorithms	Low Temp Charging	Current Low	I2	0	32767	132	mA	Low temperature range low voltage range *ChargingCurrent()*
Advanced Charging Algorithms	Low Temp Charging	Current Med	I2	0	32767	352	mA	Low temperature range medium voltage range *ChargingCurrent()*
Advanced Charging Algorithms	Low Temp Charging	Current High	I2	0	32767	264	mA	Low temperature range high voltage range *ChargingCurrent()*
Advanced Charging Algorithms	Standard Temp Charging	Current Low	I2	0	32767	1980	mA	Standard temperature range low voltage range *ChargingCurrent()*
Advanced Charging Algorithms	Standard Temp Charging	Current Med	I2	0	32767	4004	mA	Standard temperature range medium voltage range *ChargingCurrent()*
Advanced Charging Algorithms	Standard Temp Charging	Current High	I2	0	32767	2992	mA	Standard temperature range high voltage range *ChargingCurrent()*
Advanced Charging Algorithms	High Temp Charging	Current Low	I2	0	32767	1012	mA	High temperature range low voltage range *ChargingCurrent()*

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Advanced Charging Algorithms	High Temp Charging	Current Med	I2	0	32767	1980	mA	High temperature range medium voltage range *ChargingCurrent()*
Advanced Charging Algorithms	High Temp Charging	Current High	I2	0	32767	1496	mA	High temperature range high voltage range *ChargingCurrent()*
Advanced Charging Algorithms	Rec Temp Charging	Current Low	I2	0	32767	2508	mA	Recommended temperature range low voltage range *ChargingCurrent()*
Advanced Charging Algorithms	Rec Temp Charging	Current Med	I2	0	32767	4488	mA	Recommended temperature range medium voltage range *ChargingCurrent()*
Advanced Charging Algorithms	Rec Temp Charging	Current High	I2	0	32767	3520	mA	Recommended temperature range high voltage range *ChargingCurrent()*

9.5 Charging Voltage

The *ChargingVoltage()* changes depending on the detected temperature per the charge algorithm.

NOTE: Table priority is top to bottom.

Temp Range	Condition	Action
LT	—	*ChargingVoltage()* = ***Low Temp Charging:Voltage***
STL or STH	—	*ChargingVoltage()* = ***Standard Temp Charging:Voltage***
RT	—	*ChargingVoltage()* = ***Rec Temp Charging:Voltage***
HT	—	*ChargingVoltage()* = ***High Temp Charging:Voltage***

The configuration options for charging voltage are in the following data flash.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Advanced Charging Algorithms	Low Temp Charging	Voltage	I2	0	32767	4400	mV	Low temperature range *ChargingVoltage()*
Advanced Charging Algorithms	Standard Temp Charging	Voltage	I2	0	32767	4400	mV	Standard temperature range *ChargingVoltage()*
Advanced Charging Algorithms	High Temp Charging	Voltage	I2	0	32767	4100	mV	High temperature range *ChargingVoltage()*
Advanced Charging Algorithms	Rec Temp Charging	Voltage	I2	0	32767	4400	mV	Recommended temperature range *ChargingVoltage()*

9.6 Valid Charge Termination

The charge termination condition must be met to enable valid charge termination. The device has the following actions at charge termination, based on the flags settings:

- If ***IT Gauging Configuration[CSYNC]*** = 1, *RemainingCapacity()* = *FullChargeCapacity()*.
- If ***I2C Gauging Configuration[RSOCL]*** = 1, *RelativeStateOfCharge()* and *RemainingCapacity()* are held at 99% until charge termination occurs. Only on entering charge termination is 100% displayed.
- If ***I2C Gauging Configuration[RSOCL]*** = 0, *RelativeStateOfCharge()* and *RemainingCapacity()* are not held at 99% until charge termination occurs. Fractions of % greater than 99% are rounded up to display 100%.

Status	Condition	Action
Charging	*GaugingStatus()[REST]* = 0 AND *BatteryStatus()[DSG]* = 0	Charge Algorithm active
Valid Charge Termination	All of the following conditions must occur for two consecutive 40-s periods: Charging (that is, *BatteryStatus()[DSG]* = 0) AND *AverageCurrent()* < ***Charge Term Taper Current*** AND *Voltage()* + ***Charge Term Voltage*** ≥ *ChargingVoltage()* AND The accumulated change in capacity > 0.25 mAh	*ChargingStatus()[VCT]* = 1 *ChargingStatus()[MCHG]* = 1 *ChargingVoltage()* = Charging Algorithm *ChargingCurrent()* = Charging Algorithm *BatteryStatus()[FC]* = 1 and *GaugingStatus()[FC]* = 1 if ***SOC Flag Config A[FCSETVCT]*** = 1 *BatteryStatus()[TCA]* = 1 and *GaugingStatus()[TC]* = 1 if ***SOC Flag Config A[TCSETVCT]*** = 1 ***Cell 1 Chg Voltage at EoC*** = *Voltage()* ***Current at EoC*** = *Current()* Calculate Cell 1 DODEOC Trigger IT simulation

NOTE: After valid charge termination, *RemainingCapacity()* and *FullChargeCapacity()* will reflect any change in capacity due to any difference in *ChargingVoltage()* from the previous valid charge termination.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Advanced Charging Algorithms	Termination Config	Charge Term Taper Current	I2	0	32767	100	mA	Valid charge termination taper current qualifier threshold
Advanced Charging Algorithms	Termination Config	Charge Term Voltage	I2	0	32767	100	mV	Valid charge termination delta voltage qualifier, max cell based
Gas Gauging	State	Cell 1 Chg Voltage at EoC	I2	0	32767	4375	mV	Cell 1 Voltage value at end of charge
Gas Gauging	State	Current at EoC	I2	—	32767	100	mA	Current at end of charge

9.7 Charge and Discharge Alarms

The *[TC]* and *[FC]* bits in *GaugingStatus()* can be set at charge termination and based on RSOC or cell voltage. If multiple set and clear conditions are selected, then the corresponding flag is set whenever a valid set or clear condition is met. If the set and clear conditions are true at the same time, the flag will clear. The same functionality is applied to the *[TD]* and *[FD]* bits in *GaugingStatus()*.

NOTE: *GaugingStatus()[TC][TD][FC][FD]* are the status flags based on the gauging conditions only. These flags are set and cleared based on ***SOC Flag Config A*** and ***SOC Flag Config B***.

The *BatteryStatus()[TCA][TDA][FC][FD]* flags are set and cleared according to the *GaugingStatus()[TC][TD][FC][FD]* flags.

The table below summarizes the options to set and clear the *[TC]* and *[FC]* flags in *GaugingStatus()*.

Flag	Set Criteria	Set Condition	Enable
[TC]	Cell Voltage	*Voltage()* > ***TC: Set Voltage Threshold***	***SOC Flag Config A[TCSETV]*** = 1
	RSOC	*RelativeStateOfCharge()* > ***TC: Set % RSOC Threshold***	***SOC Flag Config A[TCSETRSOC]*** = 1
	Valid Charge Termination (enable by default)	When *ChargingStatus[VCT]* = 1	***SOC Flag Config A[TCSETVCT]*** = 1
[FC]	Cell Voltage	*Voltage()* > ***FC: Set Voltage Threshold***	***SOC Flag Config B[FCSETV]*** = 1
	RSOC	*RelativeStateOfCharge()* > ***FC: Set % RSOC Threshold***	***SOC Flag Config B[FCSETRSOC]*** = 1
	Valid Charge Termination (enable by default)	When *ChargingStatus[VCT]* = 1	***SOC Flag Config A[FCSETVCT]*** = 1

Flag	Clear Criteria	Clear Condition	Enable
[TC]	Cell Voltage	*Voltage()* ≤ ***TC: Clear Voltage Threshold***	***SOC Flag Config A[TCCLEARV]*** = 1
	RSOC (enable by default)	*RelativeStateOfCharge()* ≤ ***TC: Clear % RSOC Threshold***	***SOC Flag Config A[TCCLEARRSOC]*** = 1
[FC]	Cell Voltage	*Voltage()* ≤ ***FC: Clear Voltage Threshold***	***SOC Flag Config B[FCCLEARV]*** = 1
	RSOC (enable by default)	*RelativeStateOfCharge()* ≤ ***FC: Clear % RSOC Threshold***	***SOC Flag Config B[FCCLEARRSOC]*** = 1

The tables below summarize the various options to set and clear the *[TD]* and *[FD]* flags in *GaugingStatus()*.

Flag	Set Criteria	Set Condition	Enable
[TD]	Cell Voltage	*Voltage()* < ***TD: Set Voltage Threshold***	***SOC Flag Config A[TDSETV]*** = 1
	RSOC (enable by default)	*RelativeStateOfCharge()* < ***TD: Set % RSOC Threshold***	***SOC Flag Config A[TDSETRSOC]*** = 1
[FD]	Cell Voltage	*Voltage()* < ***FD: Set Voltage Threshold***	***SOC Flag Config B[FDSETV]*** = 1
	RSOC (enable by default)	*RelativeStateOfCharge()* <***FD: Set % RSOC Threshold***	***SOC Flag Config B[FDSETRSOC]*** = 1

Flag	Clear Criteria	Clear Condition	Enable
[TD]	Cell Voltage	*Voltage()* ≥ ***TD: Clear Voltage Threshold***	***SOC Flag Config A[TDCLEARV]*** = 1
	RSOC (enable by default)	*RelativeStateOfCharge()* ≥ ***TD: Clear % RSOC Threshold***	***SOC Flag Config A[TDCLEARRSOC]*** = 1
[FD]	Cell Voltage	*Voltage()* ≥ ***FD: Clear Voltage Threshold***	***SOC Flag Config B[FDCLEARV]*** = 1
	RSOC (enable by default)	*RelativeStateOfCharge()* ≥ ***FD: Clear % RSOC Threshold***	***SOC Flag Config B[FDCLEARRSOC]*** = 1

The configuration options for the charge and discharge alarms are in the following data flash.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Settings	Configuration	SOC Flag Config A	H2	0x0000	0x0FFF	0x0C8C	—	Bit 0: TDSETV—Enables the TD flag set by cell voltage threshold 0 = Disabled (default) 1 = Enabled Bit 1: TDCLEARV—Enables the TD flag cleared by the cell voltage threshold 0 = Disabled (default) 1 = Enabled Bit 2: TDSETRSOC—Enables the TD flag set by the RSOC threshold 0 = Disabled 1 = Enabled (default) Bit 3: TDCLEARRSOC—Enables the TD flag cleared by the RSOC threshold 0 = Disabled 1 = Enabled (default) Bit 4: TCSETV—Enables the TC flag set by the cell voltage threshold 0 = Disabled (default) 1 = Enabled Bit 5: TCCLEARV—Enables the TC flag cleared by the cell voltage threshold 0 = Disabled (default) 1 = Enabled Bit 6: TCSETRSOC—Enables the TC flag set by the RSOC threshold 0 = Disabled (default) 1 = Enabled Bit 7: TCCLEARRSOC—Enables the TC flag cleared by the RSOC threshold 0 = Disabled 1 = Enabled (default) Bit 8: Reserved Bit 9: Reserved Bit 10: FCSETVCT—Enables the FC flag set by valid charge termination 0 = Disabled 1 = Enabled (default) Bit 11: TCSETVCT—Enables the TC flag set by valid charge termination 0 = Disabled 1 = Enabled (default) Bit 15: 12: Reserved
Settings	Configuration	SOC Flag Config B	H1	0x00	0xFF	0x8C	—	Bit 0: FDSETV—Enables the FD flag set by the cell voltage threshold 0 = Disabled (default) 1 = Enabled Bit 1: FDCLEARV—Enables the FD flag cleared by the cell voltage threshold 0 = Disabled (default) 1 = Enabled Bit 2: FDSETRSOC—Enables the FD flag set by the RSOC threshold 0 = Disabled 1 = Enabled (default) Bit 3: FDCLEARRSOC—Enables the FD flag cleared by the RSOC threshold 0 = Disabled 1 = Enabled (default) Bit 4: FCSETV—Enables the FC flag set by the cell voltage threshold 0 = Disabled (default) 1 = Enabled Bit 5: FCCLEARV—Enables the FC flag cleared by the cell voltage threshold 0 = Disabled (default) 1 = Enabled Bit 6: FCSETRSOC—Enables the FC flag set by the RSOC threshold 0 = Disabled (default) 1 = Enabled Bit 7: FCCLEARRSOC—Enables the FC flag cleared by the RSOC threshold 0 = Disabled 1 = Enabled (default)
Gas Gauging	FD	Set Voltage Threshold	I2	0	5000	3000	mV	*GaugingStatus()[FD]* and *BatteryStatus()[FD]* cell voltage set threshold
Gas Gauging	FD	Clear Voltage Threshold	I2	0	5000	3100	mV	*GaugingStatus()[FD]* and *BatteryStatus()[FD]* cell voltage clear threshold
Gas Gauging	FD	Set RSOC % Threshold	U1	0	100	0	%	*GaugingStatus()[FD]* and *BatteryStatus()[FD]* *RelativeStateOfCharge()* set threshold
Gas Gauging	FD	Clear RSOC % Threshold	U1	0	100	5	%	*GaugingStatus()[FD]* and *BatteryStatus()[FD]* *RelativeStateOfCharge()* clear threshold
Gas Gauging	FC	Set Voltage Threshold	I2	0	5000	4400	mV	*GaugingStatus()[FC]* and *BatteryStatus()[FC]* cell voltage set threshold

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Gas Gauging	FC	Clear Voltage Threshold	I2	0	5000	4300	mV	*GaugingStatus()[FC]* and *BatteryStatus()[FC]* cell voltage clear threshold
Gas Gauging	FC	Set RSOC % Threshold	U1	0	100	100	%	*GaugingStatus()[FC]* and *BatteryStatus()[FC] RelativeStateOfCharge()* set threshold
Gas Gauging	FC	Clear RSOC % Threshold	U1	0	100	95	%	*GaugingStatus()[FC]* and *BatteryStatus()[FC] RelativeStateOfCharge()* clear threshold
Gas Gauging	TD	Set Voltage Threshold	I2	0	5000	3200	mV	*GaugingStatus()[TD]* cell voltage set threshold
Gas Gauging	TD	Clear Voltage Threshold	I2	0	5000	3300	mV	*GaugingStatus()[TD]* cell voltage clear threshold
Gas Gauging	TD	Set RSOC % Threshold	U1	0	100	6	%	*GaugingStatus[()TD] RelativeStateOfCharge()* set threshold
Gas Gauging	TD	Clear RSOC % Threshold	U1	0	100	8	%	*GaugingStatus()[TD] RelativeStateOfCharge()* clear threshold
Gas Gauging	TC	Set Voltage Threshold	I2	0	5000	4400	mV	*GaugingStatus()[TC]* cell voltage set threshold
Gas Gauging	TC	Clear Voltage Threshold	I2	0	5000	4300	mV	*GaugingStatus()[TC]* cell voltage clear threshold
Gas Gauging	TC	Set RSOC % Threshold	U1	0	100	100	%	*GaugingStatus()[TC] RelativeStateOfCharge()* set threshold
Gas Gauging	TC	Clear RSOC % Threshold	U1	0	100	95	%	*GaugingStatus()[TC] RelativeStateOfCharge()* clear threshold

9.8 Terminate Charge and Discharge Alarms

The *BatteryStatus()[TCA][TDA][[FC]FD]* flags are set according to *GaugingStatus()*. The following is a summary of the set conditions and their various alarm flags:

[TCA] = 1

- *GaugingStatus()[TC]* = 1 AND in CHARGE mode

[FC] = 1

- *GaugingStatus()[FC]* = 1

[TDA] = 1 if

- *GaugingStatus()[TD]* = 1 AND in DISCHARGE mode

[FD] = 1 if

- *GaugingStatus()[FD]* = 1

9.9 Charge Inhibit

The bq27z561 device can provide information to the smart charger to enable it to inhibit the start of charging at high and low temperatures to prevent damage of the cells. This feature is intended to enable the charger to prevent the start of charging when the temperature is at the inhibit range; therefore, if charging is in progress, the charger must determine its actions. *Temp Range* bit definitions can be found in *ChargingStatus()*.

Status	Condition	Action
Normal	*Temp Range[LT]* = 1 OR *Temp Range[STL]* = 1 OR *Temp Range[RT]* = 1 OR *Temp Range[STH]* = 1	*ChargingStatus()[IN]* = 0 *ChargingVoltage()* = charging algorithm *ChargingCurrent()* = charging algorithm
Trip	Not charging AND *Temp Range[HT]* = 1	*ChargingStatus()[IN]* = 1 *ChargingStatus()[SU]* = 0 *ChargingVoltage()* = 0 *ChargingCurrent()* = 0

Communications

10.1 HDQ Single-Pin Serial Interface

The HDQ interface is an asynchronous return-to-one protocol where a processor sends the command code to the fuel gauge. With HDQ, the least significant bit (LSB) of a data byte (command) or word (data) is transmitted first.

NOTE: The HDQ pin (A3) is open-drain and requires an external pullup resistor.

The 8-bit command code consists of two fields: the 7-bit HDQ command code (bits 0:6) and the 1-bit RW field (MSB bit 7). The RW field directs the fuel gauge either to:

- Store the next 8 or 16 bits of data to the specified register or
- Output 8 bits of data from the specified register.

The HDQ peripheral can transmit and receive data as either an HDQ master or slave.

The host processor initiates HDQ serial communication by sending a break command to the fuel gauge. A break is detected when the DATA pin is driven to a logic-low state for a time $t_{(B)}$ or greater. The DATA pin should then be returned to its normal ready high logic state for a time $t_{(BR)}$. The fuel gauge is now ready to receive information from the host processor.

The *HDQ Communication Basics Application Report* (SLUA408) provides details of HDQ communication basics, including an alternative method to use a standard two-wire UART for single-wire HDQ communication.

The bq27z561 gauge is shipped in I^2C mode, but TI provides a method to switch to HDQ mode via *SwitchToHDQ()* (see Section 13.2.43 for details).

10.2 I^2C Interface

The gauge supports the standard I^2C read, incremental read, one-byte write, quick read, and functions. The 7-bit device address (ADDR) is the most significant 7 bits of the hex address and is fixed as 1010101, or 0x55. The 8-bit device address is therefore 0xAA or 0xAB for write or read, respectively.

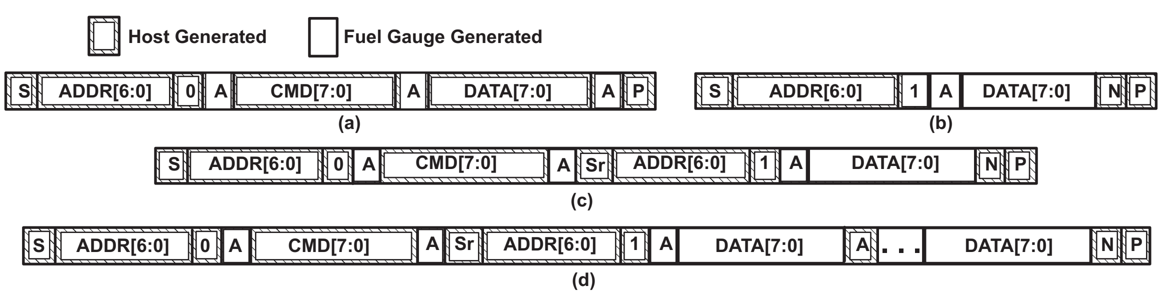


Figure 10-1. Supported I^2C Formats

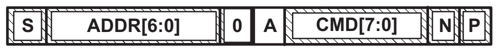
(a) 1-byte write
(b) Quick read
(c) 1-byte read
(d) Incremental read

(S = Start, Sr = Repeated Start, A = Acknowledge, N = No Acknowledge, and P = Stop)

The quick read returns data at the address indicated by the address pointer. The address pointer, a register internal to the I²C communication engine, increments when data is acknowledged by the fuel gauge or the I²C master. Quick writes function in the same way and are a convenient means of sending multiple bytes to consecutive command locations (such as two-byte commands that require two bytes of data).

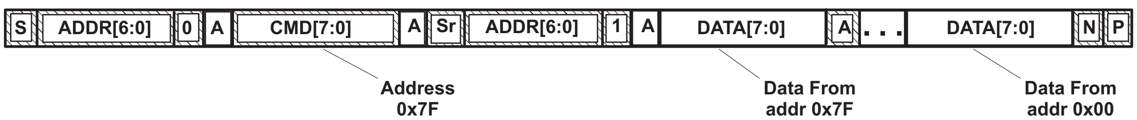
Attempt to write a read-only address (NACK after data sent by master):

Attempt to read an address above 0x7F (NACK command):



Attempt at incremental writes (NACK all extra data bytes sent):

Incremental read at the maximum allowed read address:



10.2.1 I²C Clock Frequency

The gauge supports different maximum clock frequencies for the I²C engine. The desired maximum clock frequency can be configured via ***I2C Configuration***.

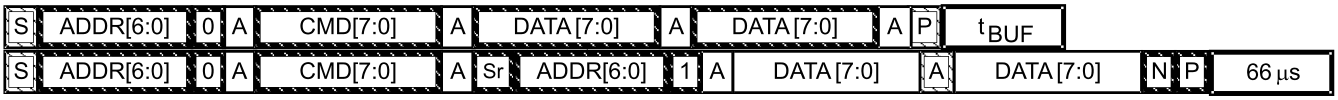
Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Settings	Configuration	I2C Configuration	H1	0x00	0xFF	0x08	—	Bit 0:2: Reserved Bit 3: XL—Enables 400-kHz I²C max clock frequency 0 = 100-kHz max clock frequency 1 = 400-kHz max clock frequency (default) Bit 7:4: Reserved

10.2.2 I²C Time Out

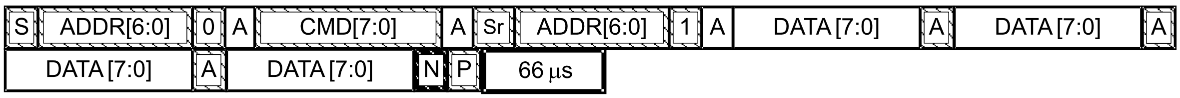
The I²C engine releases SDA and SCL if the I²C bus is held low for about two seconds. If the fuel gauge were holding the lines, releasing them frees the master to drive the lines.

10.2.3 I²C Command Waiting Time

To ensure the correct results of a command with the 400-kHz I²C operation, there must be a proper waiting time between issuing the command and reading the results. For *AltManufacturerAccess()* commands, the following diagram shows the waiting time required between issuing the *AltManufacturerAccess()* command and reading the status. For read-only standard commands, there is no waiting time required, but the host must not issue all standard commands more than two times per second. If thousands of I²C transactions are sent to the gauge in one second, then it could adversely impact the CPU and cause a watchdog reset.



Waiting time between control subcommand and reading results



Waiting time between continuous reading results

Table 10-1. Command Waiting Times

Command	t_{BUF}
Data flash signature commands: *StaticDFSignature()*, *StaticChemDFSignature()*, or *AllDFSignature()*	250 ms
All other writes to *AltManufacturerAccess()*	66 µs

10.2.4 I^2C Clock Stretching

I^2C clock stretches can occur during all modes of fuel gauge operation. In SLEEP mode, a short clock stretch occurs on all I^2C traffic, as the device must wake up to process the packet. In NORMAL and SLEEP modes, clock stretching only occurs for packets addressed for the fuel gauge. The timing of stretches varies as interactions between the communicating host and the gauge are asynchronous. The I^2C clock stretches may occur after start bits, the ACK/NACK bit, and first data bit transmit on a host read cycle. The majority of clock stretch periods are small (≤ 4 ms), as the I^2C interface peripheral and CPU firmware perform normal data flow control. However, less frequent but more significant clock stretch periods may occur when data flash is written by the CPU to update the Ra tables and other data flash parameters, such as QMax. Due to the organization of data flash, updates need to be written in data blocks consisting of multiple data bytes.

For example, an Ra table update requires erasing a single page of data flash and programming the updated Ra table. The potential I^2C clock stretching time is 40.08 ms maximum. This includes a 40-ms page erase and 40-µs row programming time (×2 rows). The Ra table updates occur during the discharge cycle and at up to 15 resistance grid points that occur during the discharge cycle.

Manufacture Production

11.1 Manufacture Testing

To improve the manufacture testing flow, the gas gauge device allows certain features to be toggled on or off through *AltManufacturerAccess()* commands (for example, *LifetimeDataCollection()*, *CalibrationMode()*, and *Gauging()*). Enabling only the feature under test can simplify the test flow in production by avoiding any feature interference. The *AltManufacturerAccess()* command that toggles *ManufacturingStatus()[CAL_EN]* will only set the RAM data, meaning the conditions set by this command will be cleared if a reset or seal is issued to the gauge. The *AltManufacturerAccess()* commands that toggle *ManufacturingStatus()[LF_EN], [GAUGE_EN]* will be updated to data flash and synchronized between *ManufacturingStatus()* and ***Mfg Status Init***. *ManufacturingStatus()* keeps track of the status (enabled or disabled) of each feature.

Mfg Status Init provides the option to enable or disable individual features for normal operation. Upon a reset or a seal command, *ManufacturingStatus()* will be reloaded from ***Mfg Status Init***. This means if an update is made to *Mfg Status Init* to enable or disable a feature, the gauge will only take the new setting if a reset or seal command is sent.

11.1.1 Manufacturing Status Configuration

Class	Subclass	Name	Type	Min	Max	Default	Description
Settings	Manufacturing	Mfg Status Init	H2	0x0000	0xFFFF	0x0000	Bit 0: Reserved Bit 1: Reserved Bit 2: Reserved Bit 3: GAUGE_EN—Gauging 0 = Disabled (default) 1 = Enabled Bit 4: Reserved Bit 5: LF_EN—Lifetime data collection 0 = Disabled (default) 1 = Enabled Bit 15:6: Reserved

11.2 Calibration

The device has integrated routines that support calibration of current and voltage readings, accessible after writing 0xF081 to *AltManufacturerAccess()* when the *ManufacturingStatus()[CAL_EN]* bit is ON. While the calibration is active, the raw ADC data is available on *MACData()*. The device stops reporting calibration data on *MACData()* if any other MAC commands are sent or the device is reset or sealed.

NOTE: The *ManufacturingStatus()[CAL_EN]* bit must be turned OFF after calibration is completed. The *ManufacturingStatus()[CAL_EN]* bit is set by default when ***Mfg Status Init*** is set to 0. This bit is cleared at reset or after sealing.

Table 11-1. AltManufacturerAccess() Descriptions

AltManufacturerAccess()	Description
0x002D	Enables/Disables *ManufacturingStatus()[CAL_EN]*
0xF080	Disables raw ADC data output on *MACData()*
0xF081	Outputs raw ADC data of voltage and current *MACData()*

The *MACData()* output format is: ZZYYaaAAbbBBccCCddDDeeEEffFFggGGhhHHiiIIjjJJkkKK, where:

Table 11-2. MACData() Format Descriptions

Value	Format	Description
ZZ	byte	8-bit counter, increments when raw ADC values are refreshed (every 1000 ms).
YY	byte	Output status *AltManufacturerAccess()* = 0xF081: 1
AAaa	2's comp	Current (coulomb counter)
BBbb	2's comp	Cell Voltage
CCcc	2's comp	Reserved
DDdd	2's comp	Reserved
EEee	2's comp	Reserved
FFff	2's comp	Reserved
GGgg	2's comp	Reserved
HHhh	2's comp	Cell Current
IIii	2's comp	Reserved
JJjj	2's comp	Reserved
KKkk	2's comp	Reserved

Calibration

NOTE: All calibration steps that require accessing data on *MACData()* must begin read operations starting at *AltManufacturerAccess()* to ensure the data portion of the block is properly refreshed per the intended *AltManufacturerAccess()* subcommand (in this case 0xF081). The first two bytes returned are the *AltManufacturerAccess()* subcommand followed by the counter, status, and raw ADC values, as shown in Table 11-1.

12.1 Cell (BAT) Voltage Calibration

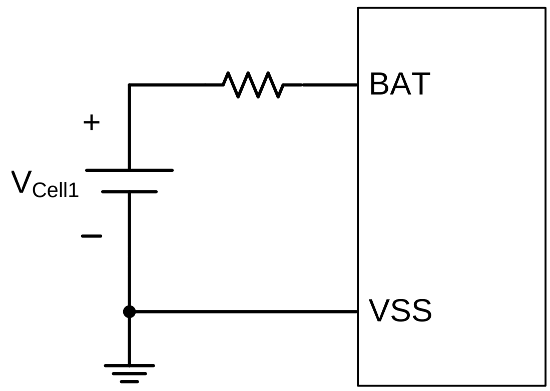


Figure 12-1. Cell Voltage Calibration

1. Apply known voltage in mV to the cell voltage inputs:
   - V_{CELL1} between BAT terminal and VSS terminal
2. If *ManufacturingStatus()[CAL_EN]* = 0, send 0x002D to *AltManufacturerAccess()* to enable the *[CAL_EN]* flag.
3. Send 0xF081 to *AltManufacturerAccess()* to enable raw cell voltage output on *MACData()*.
4. Poll *MACData()* until the 8-bit counter value increments by 2 before reading data.
5. Read the ADC conversion readings of cell voltages from *MACData()*:
   - ADC_{CELL1} = BBbb of *MACData()*
6. Average several readings for higher accuracy. Poll *MACData()* until ZZ increments, to indicate that updated values are available:
   - ADC_{CELL1} = [ADC_{CELL1}(reading n) + ...+ ADC_{CELL1}(reading 1)]/n

7. Calculate gain value:

$$Cell\ Gain = \frac{V_{Cell1}}{ADC_{Cell1}}\ x\ 2^{16}$$

8. Write the new ***Cell Gain*** value to data flash.
9. Recheck the voltage reading and if it is not accurate, repeat Steps 5 and 6.
10. Send 0x002D to *AltManufacturerAccess()* to clear the *[CAL_EN]* flag if all calibration is complete.

12.1.1 Voltage Calibration Data Flash

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Calibration	Voltage	Cell Gain	I2	–32768	32767	12101	—	BAT – VSS gain

12.2 Current Calibration

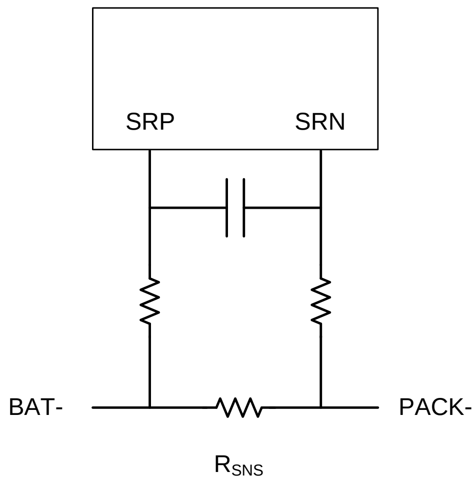


Figure 12-2. Current Calibration (Charge Current Flow Is BAT– to PACK–)

12.2.1 CC Gain/Capacity Gain Calibration

1. Apply a known current (typically 1 A to 2 A), and ensure I_{CC} is flowing through the sense resistor connected between the SRP and SRN pins.
2. If *ManufacturingStatus()[CAL_EN]* = 0, send 0x002D to *AltManufacturerAccess()* to enable the *[CAL_EN]* flag.
3. Send 0xF081 to *AltManufacturerAccess()* to enable raw CC output on *MACData()*.
4. Poll *MACData()* until ZZ increments by 2 before reading data.
5. Check the ADC conversion current output from *MACData()*:
   - ADC_{CC} = AAaa of *MACData()*

   Is ADC_{CC} < 0x8000? If yes, use ADC_{CC}; otherwise, ADC_{CC} = –(0xFFFF – AAaa + 0x0001).
6. Average several readings for higher accuracy. Poll *MACData()* until ZZ increments to indicate that updated values are available:
   - ADC_{CC} = [ADC_{CC}(reading n) + … + ADC_{CC}(reading 1)]/n
7. Calculate gain values:

$$CC\ Gain = I_{CC}\ /\ ADC_{CC}$$
$$Capacity\ Gain = CC\ Gain \times 1193046.4712$$

8. Write the new ***CC Gain*** and ***Capacity Gain*** values to data flash.
9. Recheck the current reading. If the reading is not accurate, repeat the steps.
10. Send 0x002D to *AltManufacturerAccess()* to clear the *[CAL_EN]* flag if all calibration is complete.

12.2.2 Deadbands

The gauge can be configured to ignore current and coulomb measurements below individually programmable levels.

12.2.2.1 Current Deadband

When current measures to a value less than the value programmed in ***Current Deadband***, *Current()* will report 0. This has no effect on the coulomb counting for the gas gauging functionality. The value of ***Current Deadband*** should be selected based on the characterization of the battery electronics design combined with the environment in which the battery will be used. If the PCB senses noise causing a real no-current condition to report a non-zero value, then ***Current Deadband*** could be adjusted accordingly.

12.2.2.2 Coulomb Counter Deadband

During normal operation, there could be noise generated in the battery electronics environment that could cause the gauge to accumulate incorrectly (positively or negatively). To filter out this noise, the ***Coulomb Counter Deadband*** setting is used. Any input below this threshold is not accumulated.

12.2.3 Current Calibration Data Flash

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Calibration	Current	CC Gain	F4	1.00E–001	4.00E+000	3.68	—	Coulomb Counter Gain
Calibration	Current	Capacity Gain	F4	2.98262E+004	1.193046E+006	4390411.01	—	Capacity Gain
Calibration	Current Deadband	Deadband	U1	0	255	3	mA	Cell-based deadband to report 0 mA
Calibration	Current Deadband	Coulomb Counter Deadband	U1	0	255	9	116 nV	Coulomb counter deadband to report 0 charge (This setting should not be modified.)

12.3 Temperature Calibration

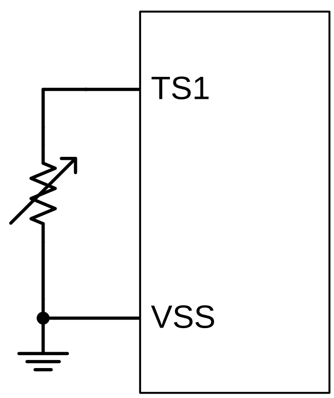


Figure 12-3. Temperature Calibration

12.3.1 Internal Temperature Sensor Calibration

1. Apply a known temperature in 0.1°C, and ensure that temperature $Temp_{TINT}$ is applied to the device.
2. Read the TINT $offset_{old}$ from ***Internal Temp Offset***.
3. Read the reported temperature from *DAStatus2()*:
   - TINT = AAaa of *DAStatus2()*

Is TINT > 0? If yes, TINT = AAaa – 2732.

4. Calculate temperature offset:

$$TINT\ offset = TEMP_{TINT} - TINT + TINT\ offset_{old}$$

5. Write the new ***Internal Temp Offset*** value to data flash.
6. Recheck the *DAStatus2()* reading. If the reading is not accurate, repeat the steps.

12.3.2 TS Calibration

1. Apply a known temperature in 0.1°C, and ensure that temperature $TEMP_{TS}$ is applied to the thermistor connected to the TS terminal.
2. Read the TS $offset_{old}$ from ***External1 Temp Offset***.
3. Read the appropriate temperature from the *DAStatus2()* block as TS.
4. Calculate the temperature offset:

$$TS\ offset = TEMP_{TS} - TS + TS\ offs$$

5. Write the new ***External1 Temp Offset*** value to data flash.
6. Recheck the *DAStatus2()* reading. If the reading is not accurate, repeat the steps.

12.3.3 Temperature Calibration Data Flash

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Calibration	Temperature	Internal Temp Offset	I1	–128	127	0	0.1 °C	Internal temperature sensor reading offset
Calibration	Temperature	External1 Temp Offset	I1	–128	127	0	0.1 °C	TS pin temperature sensor reading offset

12.3.4 Cell Temp Model

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Calibration	Cell Temp Model	Coefficient a1	I2	–32768	32767	–17447	—	Cell Temperature calculation polynomial a1
Calibration	Cell Temp Model	Coefficient a2	I2	–32768	32767	29332	—	Cell Temperature calculation polynomial a2
Calibration	Cell Temp Model	Coefficient a3	I2	–32768	32767	–25430	—	Cell Temperature calculation polynomial a3
Calibration	Cell Temp Model	Coefficient a4	I2	–32768	32767	29836	—	Cell Temperature calculation polynomial a4
Calibration	Cell Temp Model	Coefficient a5	I2	–32768	32767	1200	—	Cell Temperature calculation polynomial a5
Calibration	Cell Temp Model	Coefficient b1	I2	–32768	32767	–293	—	Cell Temperature calculation polynomial b1
Calibration	Cell Temp Model	Coefficient b2	I2	–32768	32767	552	—	Cell Temperature calculation polynomial b2
Calibration	Cell Temp Model	Coefficient b3	I2	–32768	32767	–2887	—	Cell Temperature calculation polynomial b3
Calibration	Cell Temp Model	Coefficient b4	I2	–32768	32767	4591	—	Cell Temperature calculation polynomial b4
Calibration	Cell Temp Model	Rc0	I2	–32768	32767	11703	—	Resistance at 25°C
Calibration	Cell Temp Model	Adc0	I2	–32768	32767	11703	—	ADC reading at 25°C
Calibration	Cell Temp Model	Rpad	I2	–32768	32767	0(1)	Ω	Pad Resistance (0 to use factory calibration)
Calibration	Cell Temp Model	Rint	I2	–32768	32767	0(1)	Ω	Pullup resistor resistance (0 to use factory calibration)

(1) Setting this value to 0 causes the gauge to use the internal factory calibration default.

12.3.5 Internal Temp Model

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Calibration	Internal Temp Model	Int Gain	I2	–32768	32767	–13908	—	Internal temperature gain
Calibration	Internal Temp Model	Int Base Offset	I2	–32768	32767	6959	—	Internal temperature base offset
Calibration	Internal Temp Model	Int Minimum AD	I2	–32768	32767	0	—	Minimum AD count used for calculation
Calibration	Internal Temp Model	Int Maximum Temp	I2	–32768	32767	6959	0.1°K	Maximum Temperature boundary

Data Commands

13.1 Standard Data Commands

To enable the system to read and write battery information, the bq27z561 uses a series of 2-byte standard commands to enable system reading and writing of battery information. Each standard command has an associated command code pair, as indicated in Table 13-1, *Standard Commands*. Each protocol has specific means to access the data at each command code. Data RAM is updated and read by the gauge once per second.

Table 13-1. Standard Commands

Name		Register Code (LSB/MSB)	Description
ManufacturerAccess/ControlStatus()	CNTL	0x00/0x01	Control Register (See Section 13.1.1.)
AtRate()	AR	0x02/0x03	Read/write. The value is a signed integer with the negative value indicating a discharge current value. The default value is 0 and forces *AtRateTimeToEmpty()* to return 65,535.
AtRateTimeToEmpty()	ARTTE	0x04/0x05	This read-only function returns an unsigned integer value to predict remaining operating time based on battery discharge at the *AtRate()* value in minutes with a range of 0 to 65,534. A value of 65,535 indicates *AtRate()* = 0. The gas gauge updates the *AtRateTimeToEmpty()* within 1 s after the system sets the *AtRate()* value. The gas gauge updates these parameters every 1 s. The commands are used in NORMAL mode.
Temperature()	TEMP	0x06/0x07	This read-only function returns an unsigned integer value of temperature measured by the gas gauge and is used for the gauging algorithm. Values are reported in units 0.1K. It reports either internal temperature or external thermistor temperature, depending on the setting of the ***[TS1]*** and ***[TSInt]*** bits in ***Temperature Enable***.
Voltage()	VOLT	0x08/0x09	This read-only function returns an unsigned integer value of the measured cell pack in mV with a range of 0 to 6000 mV.
BatteryStatus()	FLAGS	0x0A/0x0B	This read-only function returns various battery status information.
Current()	INSTCURR	0x0C/0x0D	This read-only function returns a signed integer value that is the instantaneous current flow through the sense resistor. The value is updated every 1 s. Units are mA.
Imax()		0x0E/0x0F	This read-only function returns the maximum discharge current that the battery can support for ***Max Current Pulse Duration*** time without prematurely dropping to empty (that is, 0%). It is useful for systems that need to dynamically scale applied load for extended runtime at low states of charge.
RemainingCapacity()	RM	0x10/0x11	This read-only command returns the predicted remaining capacity, based on rate (per configured ***Load Select***), temperature, present depth-of-discharge, and stored impedance. Values are reported in mAh.
FullChargeCapacity()	FCC	0x12/0x13	This read-only command returns the predicted capacity of the battery at full charge, based on rate (per configured ***Load Select***), temperature, present depth-of-discharge, and stored impedance. Values are reported in mAh.
AverageCurrent()	AI	0x14/0x15	This read-only function returns a signed integer value that is the average current flow through the sense resistor. The value is updated every 1 s. Units are mA.
AverageTimeToEmpty()	TTE	0x16/0x17	Uses average current value with a time constant of 15 s for this method. A value of 65,535 means the battery is not being discharged.
AverageTimeToFull()	TTF	0x18/0x19	This read-only function returns a unsigned integer value, predicting time to reach full charge for the battery in units of minutes based on *AverageCurrent()*. The computation accounts for the taper current time extension from a linear TTF computation based on a fixed *AverageCurrent()* rate of charge accumulation. A value of 65,535 indicates the battery is not being charged.
MaxLoadCurrent()	MLI	0x1E/0x1F	This read-only function returns a signed integer value in units of mA of the maximum load current. The *MaxLoadCurrent()* is an adaptive measurement which is initially reported as the maximum load current programmed in ***Max Load Current***. If the measured current is ever greater than ***Max Load Current***, then the *MaxLoadCurrent()* updates to the new current. *MaxLoadCurrent()* is reduced to the average of the previous value and ***Max Load Current*** whenever the battery is charged to full after a previous discharge to an RSOC of less than ***Max Load Rsoc***. This will prevent the reported value from maintaining an unusually high value.
MaxLoadTimeToEmpty()	MLTTE	0x20/0x21	This read-only function returns a unsigned integer value, predicting remaining battery life at the maximum discharge load current rate in units of minutes. A value of 65,535 indicates that the battery is not being discharged.
AveragePower()	AP	0x22/0x23	This read-only function returns a signed integer value of average power during battery charging and discharging. It is negative during discharge and positive during charge. A value of 0 indicates that the battery is not being discharged. The value is reported in units of mW.
InternalTemperature()	INT_TEMP	0x28/0x29	This read-only function returns an unsigned integer value of the measured internal temperature of the device in 0.1K units measured by the gas gauge.
CycleCount()	CC	0x2A/0x2B	This read-only function returns an unsigned integer value of the number of cycles the battery has experienced a discharge (range 0 to 65,535). One cycle occurs when accumulated discharge greater than or equal to the cycle count threshold.

Table 13-1. Standard Commands (continued)

Name		Register Code (LSB/MSB)	Description
RelativeStateOfCharge()	RSOC	0x2C/0x2D	This read-only function returns an unsigned integer value of the predicted remaining battery capacity expressed as percentage of *FullChargeCapacity()* with a range of 0% to 100%.
StateOfHealth()	SOH	0x2E/0x2F	This read-only function returns an unsigned integer value of the battery state-of-health expressed as a percentage of the ratio of predicted FCC (simulated with ***SOH Load Rate*** at 25°C) over the *DesignCapacity()*. The range is 0% to 100%.
ChargingVoltage()	CV	0x30/0x31	Returns the desired charging voltage in mV to the charger
ChargingCurrent()	CC	0x32/0x33	Returns the desired charging current in mA to the charger
DesignCapacity()		0x3C/0x3D	In SEALED and UNSEALED access: This command returns the value stored in ***Design Capacity mAh***. This is intended to be a theoretical or nominal capacity of a new pack, but should have no bearing on the operation of the gas gauge functionality.
AltManufacturerAccess()		0x3E/0x3F	MAC Data block command
MACData()		0x40/0x5F	MAC Data block
MACDataSum()		0x60	MAC Data block checksum
MACDataLen()		0x61	MAC Data block length
VoltHiSetThreshold()		0x62/0x63	This read/write function is a signed integer in units of mV for the high voltage level threshold, which sets *InterruptStatus()[VOLT_HI]*.
VoltHiClearThreshold()		0x64/0x65	This read/write function is a signed integer in units of mV for the high voltage level threshold, which clears *InterruptStatus()[VOLT_HI]*.
VoltLoSetThreshold()		0x66/0x67	This read/write function is a signed integer in units of mV for the low voltage level threshold, which sets *InterruptStatus()[VOLT_LO]*.
VoltLoClearThreshold()		0x68/0x69	This read/write function is a signed integer in units of mV for the low voltage level threshold, which clears *InterruptStatus()[VOLT_LO]*.
TempHiSetThreshold()		0x6A	This read/write function is a signed integer in units of °C for the high temperature level threshold, which sets *InterruptStatus()[TEMP_HI]*.
TempHiClearThreshold()		0x6B	This read/write function is a signed integer in units of °C for the high temperature level threshold, which clears *InterruptStatus()[TEMP_HI]*.
TempLoSetThreshold()		0x6C	This read/write function is a signed integer in units of °C for the low temperature level threshold, which sets *InterruptStatus()[TEMP_LO]*.
TempLoClearThreshold()		0x6D	This read/write function is a signed integer in units of °C for the low temperature level threshold, which clears *InterruptStatus()[TEMP_LO*.
InterruptStatus()		0x6E	This read-only function returns the status of the interrupt including cause of interrupt.

13.1.1 0x00/01 ManufacturerAccess()/ControlStatus()

This read/write word function returns the control bits when read and is an interface to the Manufacturer Access System (MAC) when written. This command is provided for backward compatibility/ease of use, as all of the control bits except *ControlStatus()[CheckSumValid]* are available in *OperationStatusA()* and *OperationStatusB()* in addition to *AltManufacturerAccess()* being the recommended interface for MAC (as discussed in Section 13.2).

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RSVD	FAS	SS	RSVD	RSVD	RSVD	Check Sum Valid	RSVD	RSVD	RSVD	RSVD	RSVD	LDMD	RDIS	VOK	QEN

RSVD (Bit 15): Reserved

FAS, SS (Bits 14–13): Legacy SECURITY Mode

0, 0 = Full Access
0, 1 = Reserved
1, 0 = Unsealed
1, 1 = Sealed

RSVD (Bit 12): Reserved

RSVD (Bits 11–10): Reserved

CheckSumValid (Bit 9): Checksum Valid

1 = Flash Writes are enabled.
0 = Flash Writes are disabled due to low voltage or PF condition.

RSVD (Bits 8–4): Reserved

LDMD (Bit 3): LOAD Mode

1 = Constant Power

0 = Constant Current

RDIS (Bit 2): Resistance Updates

1 = Disabled

0 = Enabled

VOK (Bit 1): Voltage OK for QMax Update

1 = Detected

0 = Not Detected

QEN (Bit 0): Impedance Track Gauging (Ra and QMax updates are enabled.)

13.1.2 0x02/03 AtRate()

This read/write word function sets the value used in calculating *AtRateTimeToEmpty()*.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Default	Unit
		SE	US	FA						
0x02/03	*AtRate()*	R/W			Word	I2	–32768	32767	0	mA

13.1.3 0x04/05 AtRateTimeToEmpty()

This read-word function returns the remaining time to fully discharge the battery based on *AtRate()*.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit	Note
		SE	US	FA						
0x04/05	*AtRateTimeToEmpty()*	R			Word	U2	0	65535	min	65535 indicates not being charged

13.1.4 0x06/07 Temperature()

This read-word function returns the temperature in units 0.1K.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x06/07	*Temperature()*	R			Word	I2	0	32767	0.1K

13.1.5 0x08/09 Voltage()

This read-word function returns the measured cell voltage.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x08/09	*Voltage()*	R			Word	I2	0	32767	mV

13.1.6 0x0A/0B BatteryStatus()

This read-word function returns various battery status information.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RSVD	TCA	RSVD	RSVD	TDA	RSVD	RCA	RSVD	INIT	DSG	FC	FD	RSVD	RSVD	RSVD	RSVD

RSVD (Bit 15): Reserved

TCA (Bit 14): Terminate Charge Alarm

0 = Inactive
1 = Active

RSVD (Bits 13–12): Reserved

TDA (Bit 11): Terminate Discharge Alarm

0 = Inactive
1 = Active

RSVD (Bit 10): Reserved

RCA (Bit 9): Remaining Capacity Alarm

0 = Inactive
1 = Active

RSVD (Bit 8): Reserved

INIT (Bit 7): Initialization

0 = Complete
1 = Active

DSG (Bit 6): Discharging

0 = Battery is charging
1 = Battery is discharging

FC (Bit 5): Fully Charged

0 = Battery not fully charged
1 = Battery fully charged

FD (Bit 4): Fully Discharged

0 = Battery okay
1 = Battery fully depleted

RSVD (Bits 3–0): Reserved

13.1.7 0x0C/0D Current()

This read-word function returns the measured current from the coulomb counter.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x0C/0D	*Current()*	R			Word	I2	–32768	32767	mA

13.1.8 0x10/11 RemainingCapacity()

This read-word function returns the predicted remaining battery capacity.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x10/11	*RemainingCapacity()*	R			Word	U2	0	32767	mAh

13.1.9 0x12/13 FullChargeCapacity()

This read-word function returns the predicted battery capacity when fully charged.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x12/13	*FullChargeCapacity()*	R			Word	I2	0	32767	mAh

13.1.10 0x14/15 AverageCurrent()

This read-word function provides the filtered / average current.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x14/15	*AverageCurrent()*	R			Word	I2	–32767	32768	mA

13.1.11 0x16/17 AverageTimeToEmpty()

This read-word function returns the predicted remaining time to fully discharge the battery based on *AverageCurrent()*.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit	Note
		SE	US	FA						
0x16/17	*AverageTimeToEmpty()*	R			Word	U2	0	65535	min	65535 = Battery is not being discharged.

13.1.12 0x18/19 AverageTimeToFull()

This read-word function returns the predicted remaining time to achieve full charge based on *AverageCurrent()*.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit	Note
		SE	US	FA						
0x18/19	*AverageTimeToFulll()*	R			Word	U2	0	65535	min	

13.1.13 0x1E/1F MaxLoadCurrent()

This read-word function returns the maximum load current.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x1E/1F	*MaxLoadCurrent()*	R			Word	I2	0	65535	mA

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Gas Gauging	Max Load	Max Load Current	I2	–32768	0	–500	mA	Initial value reported on *MaxLoadCurrent()*
Gas Gauging	Max Load	Max Load Rsoc	U1	0	100	50	%	Threshold that RSOC must fall below to average *MaxLoadCurrent()* with ***Max Load Current*** on the next valid charge termination

13.1.14 0x20/21 MaxLoadTimeToEmpty()

This read-word function returns the remaining time to fully discharge the battery based on *MaxLoadCurrent()*.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x20/21	*MaxLoadTimeToEmpty()*	R			Word	I2	0	65535	min

13.1.15 0x22/23 AveragePower()

This read-word function returns the average power [*Voltage()* × *AverageCurrent()*] during battery charging or discharging. It is negative due to discharge and positive due to charge. A 0 value indicates the battery is not being discharged.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x22/23	*AveragePower()*	R			Word	I2	–32768	32767	mW

13.1.16 0x28/29 InternalTemperature()

This read-word function returns the internal die temperature in units 0.1K.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x28/29	*InternalTemperature()*	R			Word	I2	0	32767	0.1K

13.1.17 0x2A/2B CycleCount()

This read-word function returns the number of discharge cycles the battery has experienced.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x2A/2B	*CycleCount()*	R	R/W	R/W	Word	U2	0	65535	cycles

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Gas Gauging	Cycle	Cycle Count Percentage	U1	0	100	90	%	Percentage of *DesignCapacity()* or *FullChargeCapacity()* (determined by ***IT Gauging Configuration[CCT]***) to be used for the cycle count threshold
Gas Gauging	State	Cycle Count	U2	0	65535	0	—	Value reported by *CycleCount()*. Updated by the gauge automatically based on ***Cycle Count Percentage***
Gas Gauging	State	Qmax Cycle Count	U2	0	65535	0	—	The *CycleCount()* when QMax last updated

13.1.18 0x2C/2D RelativeStateOfCharge()—RSOC

This read-word function returns the predicted remaining battery capacity as a percentage of *FullChargeCapacity()*.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x2C/2D	*RelativeStateOfCharge()*	R			Word	U1	0	100	%

13.1.19 0x2E/2F StateOfHealth()

This command returns the state-of-health (SOH) information of the battery in percentage of ***Design Capacity mAh***. It is a read-only command.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x2E/2F	*StateOfHealth()*	R			Word	U1	0	100	%

13.1.20 0x30/31 ChargingVoltage()

This read-word function returns the desired charging voltage.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit	Note
		SE	US	FA						
0x30/31	*ChargingVoltage()*	R	R	R	Word	I2	0	32767	mV	32767 = Request maximum voltage

13.1.21 0x32/33 ChargingCurrent()

This read-word function returns the desired charging current.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit	Note
		SE	US	FA						
0x32/33	*ChargingCurrent()*	R	R	R	Word	I2	0	32767	mA	32767 = Request maximum current

13.1.22 0x3C/3D DesignCapacity()

This read-word function returns the theoretical or nominal maximum pack capacity.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Default	Unit
		SE	US	FA						
0x3C/3D	*DesignCapacity()*	R	R/W	R/W	Word	I2	0	32767	5300	mAh
									2040	cWh

13.1.23 0x3E/3F AltManufacturerAccess()

Writes to this command are interchangeable with *AltManufacturerAccess()*. This command is provided to enable an easy way to verify the active MAC command while reading the *MACData()* returned by the MAC. The host may simply read from *AltManufacturerAccess()* to *MACDataLength()* with one block read. For a description of returned data values, see the *AltManufacturerAccess()* version of same command in Section 13.2.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Default	Unit
		SE	US	FA						
0x3E/3F	*MACBlockDataCommand()*	R	R	R	Word	—	—	—	—	—

13.1.24 0x40/0x5F MACData()

This is the data block for *AltManufacturerAccess()* or *AltManufacturerAccess()* commands.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Default	Unit
		SE	US	FA						
0x40/5F	*MACData ()*	R	R	R	Block	—	—	—	—	—

13.1.25 0x60 MACDataChecksum()

This is the checksum of the *AltManufacturerAccess()* and *MACData()* bytes.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x60	*MACDataChecksum()*	R	R	R	Byte	—	—	—	—	—

The checksum is the 8-bit sum of the MSB and LSB of the command + the (command length) bytes in the buffer. The final sum is the bitwise inversion of the result. Because the length is part of the checksum, the verification cannot take place until the length is written. The checksum and length must be written together as a word to be valid.

13.1.26 0x61 MACDataLength()

This is the length for *AltManufacturerAccess()* and *MACData()*.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x61	*MACDataLength()*	R	R	R	Byte	—	—	—	—	—

The length byte for all MAC commands includes the 2-byte command, the 1-byte checksum, the 1-byte length, and 1 to 32 bytes of data. This means the minimum length value is 5 for a valid block (no length or checksum is used for command only writes, so a block of 0 size is not necessary). For proper write command validation, the checksum and length must be written in order (word access triggered).

13.1.27 0x62/63 VoltHiSetThreshold

This read/write-word function returns the desired interrupt set threshold for a high battery voltage.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x62/63	*VoltHiSetThreshold()*	R/W	R/W	R/W	Word	I2	0	5000	mV

13.1.28 0x64/65 VoltHiClearThreshold

This read/write-word function returns the desired interrupt clear threshold for a high battery voltage.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x64/65	*VoltHiClearThreshold()*	R/W	R/W	R/W	Word	I2	0	5000	mV

13.1.29 0x66/67 VoltLoSetThreshold

This read/write-word function returns the desired interrupt set threshold for a low battery voltage.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x66/67	*VoltLoSetThreshold()*	R/W	R/W	R/W	Word	I2	0	5000	mV

13.1.30 0x68/69 VoltLoClearThreshold

This read/write-word function returns the desired interrupt clear threshold for a low battery voltage.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x68/69	*VoltLoClearThreshold()*	R/W	R/W	R/W	Word	I2	0	5000	mV

13.1.31 0x6A TempHiSetThreshold

This read/write-byte function returns the desired interrupt set threshold for a high battery temperature.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x6A	*TempHiSetThreshold()*	R/W	R/W	R/W	Byte	I1	–128	127	°C

13.1.32 0x6B TempHiClearThreshold

This read/write-byte function returns the desired interrupt clear threshold for a high battery temperature.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x6B	*TempHiClearThreshold()*	R/W	R/W	R/W	Byte	I1	–128	127	°C

13.1.33 0X6C TempLoSetThreshold

This read/write-byte function returns the desired interrupt set threshold for a low battery temperature.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x6C	*TempLoSetThreshold()*	R/W	R/W	R/W	Byte	I1	–128	127	°C

13.1.34 0x6D TempLoClearThreshold

This read/write-byte function returns the desired interrupt clear threshold for a low battery temperature.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x6D	*TempLoClearThreshold()*	R/W	R/W	R/W	Byte	I1	–128	127	°C

13.1.35 0x6E InterruptStatus()

This read-byte function returns the status of the interrupt bits for high/low voltage and temperature.

Status	Condition	Action
Activate	0x0057 to *AltManufacturerAccess()*	Outputs *ManufacturingStatus()* flags on *MACData()*

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	RSVD	TEMP_LO	TEMP_HI	VOLT_LO	VOLT_HI

RSVD (Bits 7–4): Reserved

TEMP_LO (Bit 3): Low temperature interrupt
- 1 = Low temperature interrupt set
- 0 = Low temperature interrupt cleared

TEMP_HI (Bit 2): High temperature interrupt
- 1 = High temperature interrupt set
- 0 = High temperature interrupt cleared

VOLT_LO (Bit 1): Low voltage interrupt
- 1 = Low voltage interrupt set
- 0 = Low voltage interrupt cleared

VOLT_HI (Bit 0): High voltage interrupt
- 1 = High voltage interrupt set
- 0 = High voltage interrupt cleared

13.2 0x00, 0x01 ManufacturerAccess() and 0x3E, 0x3F AltManufacturerAccess()

AltManufacturerAccess() provides a method of reading and writing data in the Manufacturer Access System (MAC). The MAC command is sent via *AltManufacturerAccess()* by a block protocol. The result is returned on *AltManufacturerAccess()* via a block read.

Commands are sent by writing to registers 0x00/0x01 or 0x3E/0x3F. 0x3E and 0x3F work the same as 0x00 and 0x01, but are primarily intended for block writes and reads.

Example: Send a MAC *Gauging()* to enable IT via *AltManufacturerAccess().*

1. With Impedance Track disabled, send *Gauging()* (0x0021) to *AltManufacturerAccess()*
   a. Command Write, start address = 0x3E (or 0x00). Data = 21 00 (data must be sent in Little Endian).
2. IT is enabled, *ManufacturingStatus()[GAUGE_EN]* = 1.

Example: Read *Chemical ID()* (0x0006) via *AltManufacturerAccess().*

1. Send *Chemical ID()* to *AltManufacturerAccess().*
   a. Command Write, start address = 0x3E (or 0x00). Data sent = 06 00 (data must be sent in Little Endian).
2. Read the result from *AltManufacturerAccess()* and *MACData()*.
   a. Command Read, start address = 0x3E length = 36 bytes. The first 4 bytes of the response will be 06 00 10 12.
   b. The first two bytes "06 00" is the MAC command (for verification).
   c. The second two bytes "10 12" are the Chem ID in Little Endian. That is, 0x1210 for ChemID 1210.
   d. The last two bytes of the 36-byte block will be the checksum and length. The length in this case will be 6. The checksum is 0xFF – (sum of the first length – 2 bytes). The length and checksum are used to validate the block response.

It is recommended to send “command only” operations to 0x00 and 0x01, and to set the command for a read back in the same way. The reason for this is that it can always reset any legacy support options that may be in effect; whereas, some legacy support options use 0x3E and 0x3F for other purposes. However, 0x3E and 0x3F can always safely be used for block reads. For backward compatibility, a request of the device number or version reports a value for a read on 0x00/0x01. The response word for the MAC commands DEV and VERSION (0x0001 and 0x0002) should report 0xFFA5 as the legacy response. This is meant as a token to indicate to the host that the real response is on the extended block. “Command only” operations take place immediately after the word write.

Table 13-2. AltManufacturerAccess() Command List

Command	Function	Access	Format	Data Read on MACData()	Not Available in SEALED Mode	Type	Units
0x0001	DeviceType	R	Block	√	—	hex	—
0x0002	FirmwareVersion	R	Block	√	—	hex	—
0x0003	HardwareVersion	R	Block	√	—	hex	—
0x0004	IFChecksum	R	Block	√	—	hex	—
0x0005	StaticDFSignature	R	Block	√	—	hex	—
0x0006	ChemID	R	Block	√	—	hex	—
0x0007	Prev_MacWrite	R	Block	√	—	hex	—
0x0008	StaticChemDFSignature	R	Block	√	—	hex	—
0x0009	AllDFSignature	R	Block	√	—	hex	—
0x012	Reset	W	—	—	—	hex	—
0x0021	Gauging (IT Enable)	W	—	—	√	hex	—
0x0023	LifetimeDataCollection	W	—	—	√	hex	—
0x0028	LifetimeDataReset	W	—	—	√	hex	—
0x002D	CalibrationMode	W	—	—	√	hex	—
0x002E	LifetimeDataFlush	W	—	—	√	hex	—
0x0030	SealDevice	W	—	—	—	hex	—
0x0035	SecurityKeys	R/W	Block	√	√	hex	—
0x0041	Reset	W	—	—	—	hex	—
0x0044	SetDeepSleep	W	—	—	—	hex	—

Table 13-2. AltManufacturerAccess() Command List (continued)

Command	Function	Access	Format	Data Read on MACData()	Not Available in SEALED Mode	Type	Units
0x0045	ClearDeepSleep	W	—	—	—	hex	—
0x0046	PulseGPIO	W	—	—	—	hex	—
0x0047	TambientSync	W	—	—	—	hex	—
0x004A	Device Name	R/W	Block	√	—	hex	—
0x004B	Device Chem	R/W	Block	√	—	hex	—
0x004C	Manufacturer Name	R/W	Block	√	—	hex	—
0x004D	Manufacture Date	R/W	Block	√	—	hex	—
0x004E	Serial Number	R/W	—	√	—	hex	—
0x0054	OperationStatus	R	Block	√	—	hex	—
0x0055	ChargingStatus	R	Block	√	—	hex	—
0x0056	GaugingStatus	R	Block	√	—	hex	—
0x0057	ManufacturingStatus	R	Block	√	—	hex	—
0x0060	LifetimeDataBlock1	R	Block	√	—	Mixed	Mixed
0x0070	ManufacturerData	R	Block	√	—	hex	—
0x0071	DAStatus1	R	Block	√	—	Mixed	Mixed
0x0072	DAStatus2	R	Block	√	—	Mixed	Mixed
0x0073	ITStatus1	R	Block	√	—	Mixed	Mixed
0x0074	ITStatus2	R	Block	√	—	Mixed	Mixed
0x0075	ITStatus3	R	Block	√	—	Mixed	Mixed
0x0077	FCC_SOH	R	Block	√	—	hex	—
0x0078	Filtered Capacity	R	Block	√	—	Hex	Mixed
0x01yy	DFAccessRowAddress	R/W	Block	—	√	hex	—
0x0F00	ROMMode	W	—	—	√	hex	—
0x7C40	SwitchToHDQ	W	—	—	√	hex	—
0xF080	ExitCalibrationOutput	R/W	Block	√	√	hex	—
0xF081	OutputCCandADCforCalibration	R/W	Block	√	√	hex	—

13.2.1 AltManufacturerAccess() 0x0001 Device Type

The device can be checked for its part number.

Status	Condition	Action
Enable	0x0001 to *AltManufacturerAccess()*	Returns the device part number on a subsequent read on *MACData()* in the following format: aaAA, where: aaAA: Device type

13.2.2 AltManufacturerAccess() 0x0002 Firmware Version

The device can be checked for its firmware version.

Status	Condition	Action
Enable	0x0002 to *AltManufacturerAccess()*	Returns the firmware revision on *MACData()* in the following format: ddDDvvVVbbBBTTzzZZRREE, where: ddDD: Device Number vvVV: Version bbBB: build number TT: Firmware type zzZZ: Impedance Track Version RR: Reserved EE: Reserved

13.2.3 AltManufacturerAccess() 0x0003 Hardware Version

The device can be checked for its hardware version.

Status	Condition	Action
Enable	0x0003 to *AltManufacturerAccess()*	Returns the hardware version on a subsequent read on *MACData()*

13.2.4 AltManufacturerAccess() 0x0004 Instruction Flash Signature

The device can return the instruction flash signature.

Status	Condition	Action
Enable	0x0004 to *AltManufacturerAccess()*	Returns the IF signature on a subsequent read on *MACData()* after a wait time of 250 ms

13.2.5 AltManufacturerAccess() 0x0005 Static DF Signature

This command returns the signature of all static data flash parameters. The command does not update ***Static DF Signature***.

Status	Condition	Action
Enable	0x0005 to *AltManufacturerAccess()*	Returns the signature of all static DF on a subsequent read on *MACData()* after a wait time of 250 ms. The MSB is set to 1 if the calculated signature does not match the signature stored in DF.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
System Data	Integrity	Static DF Signature	H2	0	0x7FFF	0x0000	—	Static data flash signature. Use the MAC *StaticDFSignature()* (with MSB set to 0) to manually initialize this value.

13.2.6 AltManufacturerAccess() 0x0006 Chemical ID

This command returns the chemical ID of the OCV tables used in the gauging algorithm.

Status	Condition	Action
Enable	0x0006 to *AltManufacturerAccess()*	Returns the chemical ID on subsequent read on *MACData()*

13.2.7 AltManufacturerAccess() 0x0007 Pre_MACWrite

This command enables copying the last MAC into a 2-byte block.

Status	Condition	Action
Enable	0x0007 to *AltManufacturerAccess()*	Copies the last MAC information into a 2-byte block *MACData()*

13.2.8 AltManufacturerAccess() 0x0008 Static Chem DF Signature

This command returns the signature of all static, chemistry-related data flash parameters. The command does not update ***Static Chem DF Signature***.

Status	Condition	Action
Enable	0x0008 to *AltManufacturerAccess()*	Returns the signature of all static chemistry DF on a subsequent read on *MACData()* after a wait time of 250 ms. The MSB is set to 1 if the calculated signature does not match the signature stored in DF.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
System Data	Integrity	Static Chem DF Signature	H2	0	0x7FFF	0x3A4C	—	Static chemistry data signature. Use the MAC *StaticChemDFSignature()* (with MSB set to 0) to manually initialize this value.

13.2.9 AltManufacturerAccess() 0x0009 All DF Signature

This command returns the signature of all data flash parameters. The command does not update ***All DF Signature***.

Status	Condition	Action
Enable	0x0009 to *AltManufacturerAccess()*	Returns the signature of all DF parameters on a subsequent read on *MACData()* after a wait time of 250 ms. The MSB is set to 1 if the calculated signature does not match the signature stored in DF. It is normally expected that this signature will change due to updates of lifetime, gauging, and other information.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
System Data	Integrity	All DF Signature	H2	0	0x7FFF	0x0000	—	All data flash signature. Use the MAC *AllDFSignature()* (with MSB set to 0) to manually initialize this value.

13.2.10 AltManufacturerAccess() 0x0012 Device Reset

This command resets the device.

Status	Condition	Action
Enable	0x0012 to *AltManufacturerAccess()*	Resets the device

NOTE: Command 0x0041 also resets the device.

13.2.11 AltManufacturerAccess() 0x0021 Gauging

This command enables or disables the gauging function to ease testing during manufacturing.

Status	Condition	Action
Disable	*ManufacturingStatus()[GAUGE_EN]* = 1 AND 0x0021 to *AltManufacturerAccess()*	*ManufacturingStatus()[GAUGE_EN]* = 0 Disables the gauging feature
Enable	*ManufacturingStatus()[GAUGE_EN]* = 0 AND 0x0021 to *AltManufacturerAccess()*	*ManufacturingStatus()[GAUGE_EN]* = 1 Enables the gauging feature

13.2.12 AltManufacturerAccess() 0x0023 Lifetime Data Collection

This command disables/enables lifetime data collection for manufacturing.

Status	Condition	Action
Disable	*ManufacturingStatus()[LF_EN]* = 1 AND 0x0023 to *AltManufacturerAccess()*	*ManufacturingStatus()[LF_EN]* = 0 The lifetime data collection feature is disabled.
Enable	*ManufacturingStatus()[LF_EN]* = 0 AND 0x0023 to *AltManufacturerAccess()*	*ManufacturingStatus()[LF_EN]* = 1 The lifetime data collection feature is enabled.

13.2.13 AltManufacturerAccess() 0x0028 Lifetime Data Reset

This command resets lifetime data in data flash for manufacturing.

Status	Condition	Action
Reset	0x0028 to *AltManufacturerAccess()*	Clears lifetime data in DF

13.2.14 AltManufacturerAccess() 0x002D CALIBRATION Mode

This command disables/enables entry into CALIBRATION mode. The status is indicated by the *ManufacturingStatus()[CAL_EN]* flag. CALIBRATION mode is disabled upon a reset.

Status	Condition	Action
Disable	*ManufacturingStatus()[CAL_EN]* = 1 AND 0x002D to *AltManufacturerAccess()*	*ManufacturingStatus()[CAL_EN]* = 0 Disables output of ADC and CC raw data on *MACData()*
Enable	*ManufacturingStatus()[CAL_EN]* = 0 AND 0x002D to *AltManufacturerAccess()*	*ManufacturingStatus()[CAL_EN]* = 1 Enables output of ADC and CC raw data on *MACData()*, controllable with 0xF081 on *AltManufacturerAccess()*

13.2.15 AltManufacturerAccess() 0x0030 Seal Device

This command seals the device for the field, disabling certain commands and access to DF.

Status	Condition	Action
Sealed	*OperationStatusA()[SEC1,SEC0]* = 0,1 or 1,0 AND 0x0030 to *AltManufacturerAccess()*	*OperationStatusA()[SEC1,SEC0]* = 1,1 Certain commands are not available. See Table 13-1 for details.

13.2.16 AltManufacturerAccess() 0x0035 Security Keys

This is a read/write command that changes the Unseal and Full Access keys. To read the keys, send the *SecurityKeys()* command to either the *AltManufacturerAccess()* 0x00 or 0x3E, followed by a read from *AltManufacturerAccess()*.

To change the keys, the write operations must be sent through *AltManufacturerAccess()* 0x3E with the *SecurityKeys()* followed by the keys. Each parameter entry must be sent in Little Endian.

Example:

Changing the Unseal key to 0x0123, 0x4567 and the Full Access key to 0x89AB, 0xCDEF:

Byte 0: Unseal Key LSB
Byte 1: Unseal Key MSB
Byte 2: Full Access Key LSB
Byte 3: Full Access Key MSB

Write block: command through *AltManufacturerAccess()* starting address 0x3E, data block (hex) = [35 00 23 01 67 45 AB 89 EF CD].

Starting address 0x60, data block(hex) = [0A 0C] (checksum followed by length)

Checksum = 0x0A = ~(0x35 + 0x00 + 0x23 + 0x01 + 0x67 + 0x45 + 0xAB + 0x89 + 0xEF + 0xCD). The checksum is the 8-bit sum of the MSB and LSB of the command plus the (command length) bytes in the buffer. The final sum is the bitwise inversion of the result.

13.2.17 AltManufacturerAccess() 0x0037 Authentication Key

This command enters a new authentication key into the device.

Status	Condition	Action
Initiate	*OperationStatusA()[SEC1,SEC0]* = 0,1 AND 0x0037 to *AltManufacturerAccess()*	*OperationStatusB()[AUTH]* = 1 160-bit random number available at *MACData()*
Enter Key	Correct 128-bit key written to *MACData()* in the format 0xAABBCCDDEEFFGGHHIIJJKKLLMMNNOOPP, where AA is LSB. In addition to this information, the checksum + length data block is required.	Wait time 250 ms *OperationStatusB()[AUTH]* = 0 The device returns a 160-bit HMAC digest at *MACData()* in the format: 0xAABBCCDDEEFFGGHHIIJJKKLLMMNNOOPPQQRRSSTTT, where AA is LSB. The HMAC digest was calculated using a challenge of all 0s + key. The result can be used to verify the key without allowing a plain text read back.

13.2.18 AltManufacturerAccess() 0x0041 Device Reset

This command resets the device.

Status	Condition	Action
Enable	0x0041 to *AltManufacturerAccess()*	Resets the device

NOTE: Command 0x0012 also resets the device.

13.2.19 AltManufacturerAccess() 0x0044 Set Deep Sleep

This command instructs the gauge to enter DEEP SLEEP mode when available.

Status	Condition	Action
Enable	0x0044 to *AltManufacturerAccess()*	*OperationStatusB()[DPSLEEPM]* = 1

13.2.20 AltManufacturerAccess() 0x0045 Clear Deep Sleep

This command instructs the gauge to exit DEEP SLEEP mode.

Status	Condition	Action
Enable	0x0045 to *AltManufacturerAccess()*	*OperationStatusB()[DPSLEEPM]* = 0

13.2.21 AltManufacturerAccess() 0x0046 Pulse GPIO

This command generates a single pulse or state change on the PULS pin.

Status	Condition	Action
Enable	0x0046 to *AltManufacturerAccess()*	If ***IO Config[GPIO_LEVEL_EN]*** = 0, it generates a single pulse on the PULS pin with a polarity of ***IO Config[GPIO_POL]*** and a width of ***GPIO Pulse Width***. If ***IO Config[GPIO_LEVEL_EN]*** = 1, it changes the state of the PULS pin.

13.2.22 AltManufacturerAccess() 0x0047 Tambient Sync

This command synchronizes the ambient temperature in Impedance Track, T_ambient, to the presently measured cell temperature, *Temperature()*.

Status	Condition	Action
Enable	0x0047 to *AltManufacturerAccess()*	Synchronize T_ambient to *Temperature()* and trigger an IT simulation if ***I2C Gauging Configuration[TAMB_SYNC_SIM]*** = 1

13.2.23 AltManufacturerAccess() 0x004A Device Name

This command returns the assigned pack name, as programmed in data flash.

Status	Condition	Action
Enable	0x004A to *AltManufacturerAccess()*	Returns the value stored in ***Device Name***

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
I2C Configuration	Data	Device Name	S21	—	—	bq27z561	ASCII	Assigned pack name

13.2.24 AltManufacturerAccess() 0x004B Device Chem

This command returns the battery chemistry used in the pack, as programmed in data flash.

Status	Condition	Action
Enable	0x004B to *AltManufacturerAccess()*	Returns the value stored in ***Device Chemistry***

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
I2C Configuration	Data	Device Chemistry	S5	—	—	LION	ASCII	Battery chemistry used in the pack. This parameter does not change with chemistry programming and must be manually updated.

13.2.25 AltManufacturerAccess() 0x004C Manufacturer Name

This command returns the pack manufacturer name, as programmed in data flash.

Status	Condition	Action
Enable	0x004C to *AltManufacturerAccess()*	Returns the value stored in ***Manufacturer Name***

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
I2C Configuration	Data	Manufacturer Name	S21	—	—	Texas Instruments	ASCII	Pack manufacturer name

13.2.26 AltManufacturerAccess() 0x004D Manufacture Date

This command returns the manufacture date of the pack, as programmed in data flash.

Status	Condition	Action
Enable	0x004D to *AltManufacturerAccess()*	Returns the value stored in ***Manufacture Date***

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
I2C Configuration	Data	Manufacture Date	U2	0	65535	1980-1-1	date	Manufacture date of the pack, which follows the format: Day + Month×32 + (Year–1980) × 512 Example: 10/27/2017 = 19291 (or 0x4B5B, binary split: 100101, 1010, 11011)

13.2.27 AltManufacturerAccess() 0x004E Serial Number

This command returns the serial number of the pack, as programmed in data flash.

Status	Condition	Action
Enable	0x004E to *AltManufacturerAccess()*	Returns the value stored in ***Serial Number***

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
I2C Configuration	Data	Serial Number	H2	0x0000	0xFFFF	0x0001	—	Serial number of the pack

13.2.28 AltManufacturerAccess() 0x0054 OperationStatus

This command returns the *OperationStatusA()* and *OperationStatusB()* flags on *MACData()*.

Status	Condition	Action
Activate	0x0054 to *AltManufacturerAccess()*	Outputs *OperationStatusA()* and *OperationStatusB()* flags on *MACData()* in the format AAaaBBbb where AAaa is ***Operation Status A*** and BBbb is ***Operation Status B***

13.2.28.1 Operation Status A

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SLEEP	RSVD	RSVD	RSVD	SS	RSVD	SEC1	SEC0	RSVD	DP_SLP	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD

SLEEP (Bit 15): SLEEP mode conditions met
- 1 = Active
- 0 = Inactive

RSVD (Bits 14–12): Reserved

SS (Bit 11): SAFETY mode status
- 1 = Active
- 0 = Inactive

RSVD (Bit 10): Reserved

SEC1, SEC0 (Bits 9, 8): SECURITY Mode
- 0, 0 = Reserved
- 0, 1 = Full Access
- 1, 0 = Unsealed
- 1, 1 = Sealed

RSVD (Bit 7): Reserved

DP_SLP (Bit 6): DEEP SLEEP mode status
- 1 = Active
- 0 = Inactive

RSVD (Bits 5–0): Reserved

13.2.28.2 Operation Status B

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	RSVD	RSVD	SLPAD	RSVD	INIT	DPSLEEPM	XL	RSVD	CAL	RSVD	AUTH	RSVD	RSVD

RSVD (Bits 15–11): Reserved

SLPAD (Bit 10): SLPAD
- 1 = Active
- 0 = Inactive

RSVD (Bit 9): Reserved
- 1 = Active
- 0 = Inactive

INIT (Bit 8): Initialization after full reset
- 1 = Active
- 0 = Inactive

DPSLEEPM (Bit 7): DEEP SLEEP command received
- 1 = Active
- 0 = Inactive

XL (Bit 6): 400-kHz mode
- 1 = Active
- 0 = Inactive

RSVD (Bit 5): Reserved

CAL (Bit 4): Calibration Output (raw ADC and CC data)
- 1 = Active when either the MAC *OutputCCADCCal()* or *OutputShortedCCADCCal()* is sent and the raw CC and ADC data for calibration is available.
- 0 = When the raw CC and ADC data for calibration is not available.

RSVD (Bit 3): Reserved

AUTH (Bit 2): Authentication in progress
- 1 = Active
- 0 = Inactive

RSVD (Bits 1–0): Reserved

13.2.29 AltManufacturerAccess() 0x0055 ChargingStatus

This command returns the *Temp Range* and *Charging Status* flags on *MACData()*.

Status	Condition	Action
Activate	0x0055 to *AltManufacturerAccess()*	Outputs three bytes of charging related data in the format AABBbb, where AA is *Temp Range* and BBbb is *Charging Status* flags on *MACData()*

13.2.29.1 Temp Range

Temp Range status bits indicate the current operating temperature range.

7	6	5	4	3	2	1	0
RSVD	OT	HT	STH	RT	STL	LT	UT

RSVD (Bit 7): Reserved

OT (Bit 6): Overtemperature Range
- 1 = Temperature > T4
- 0 = Inactive

HT (Bit 5): High Temperature Range
- 1 = T3 < Temperature < T4
- 0 = Inactive

STH (Bit 4): Standard Temperature High Range
- 1 = T6 < Temperature < T3
- 0 = Inactive

RT (Bit 3): Recommended Temperature Range

1 = T5 < Temperature < T6
0 = Inactive

STL (Bit 2): Standard Temperature Low Range
1 = T2 < Temperature < T5
0 = Inactive

LT (Bit 1): Low Temperature Range
1 = T1 < Temperature < T2
0 = Inactive

UT (Bit 0): Undertemperature Range
1 = Temperature < T1
0 = Inactive

13.2.29.2 Charging Status

Charging Status bits indicate various status bits related to charging.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	RSVD	NCT	RSVD	RSVD	RSVD	VCT	MCHG	SU	IN	HV	MV	LV	PV

RSVD (Bits 15–12): Reserved

NCT (Bit 11): NCT
1 = Active
0 = Inactive

RSVD (Bits 10–8): Reserved

VCT (Bit 7): Charge Termination
1 = Active
0 = Inactive

MCHG (Bit 6): Maintenance Charge
1 = Active
0 = Inactive

SU (Bit 5): Charge Suspend
1 = Active
0 = Inactive

IN (Bit 4): Charge Inhibit
1 = Active
0 = Inactive

HV (Bit 3): High Voltage Region
1 = Active
0 = Inactive

MV (Bit 2): Mid Voltage Region
1 = Active
0 = Inactive

LV (Bit 1): Low Voltage Region
1 = Active

0 = Inactive

PV (Bit 0): Precharge Voltage Region

1 = Active

0 = Inactive

13.2.30 AltManufacturerAccess() 0x0056 GaugingStatus

This command returns the *GaugingStatus()* flags on *MACData()*.

NOTE: The Battery Management Studio (bqStudio) tool splits the returned value of *GaugingStatus()* into two separate registers: Gauging Status = lowest byte, and IT Status = 2nd and 3rd bytes, with the 4th byte reserved.

Status	Condition	Action
Activate	0x0056 to *AltManufacturerAccess()*	Outputs *GaugingStatus()* flags on *MACData()*

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	OCV FR	LDMD	RX	QMax	VDQ
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
NSFM	RSVD	SLP QMax	QEN	VOK	RDIS	RSVD	REST	RSVD	DSG	EDV	RSVD	TC	TD	FC	FD

RSVD (Bits 31–21): Reserved. Do not use.

OCVFR (Bit 20): Open Circuit Voltage in Flat Region (During RELAX)

1 = Detected

0 = Not Detected

LDMD (Bit 19): LOAD mode

1 = Constant Power

0 = Constant Current

RX (Bit 18): Resistance update (toggles after every resistance update)

QMax (Bit 17): QMax update (toggles after every QMax update)

VDQ (Bit 16): Discharge Qualified for Learning (based on RU flag)

NSFM (Bit 15): Negative Scale Factor Mode

1 = Negative Ra Scaling Factor Detected

0 = Negative Ra Scaling Factor Not Detected

SLPQMax (Bit 13): QMax Update During Sleep

1 = Active

0 = Inactive

QEN (Bit 12): Impedance Track Gauging (Ra and QMax updates are enabled.)

1 = Enabled

0 = Disabled

VOK (Bit 11): Voltage OK for QMax Update

1 = Detected

0 = Not Detected

RDIS (Bit 10): Resistance Updates

1 = Disabled
0 = Enabled

RSVD (Bit 9): Reserved. Do not use.

REST (Bit 8): Rest
1 = OCV reading taken
0 = OCV reading not taken or not in relax

RSVD (Bit 7): Reserved. Do not use.

DSG (Bit 6): Discharge/Relax
1 = Charging not detected
0 = Charging detected

EDV (Bit 5): End-of-Discharge Termination Voltage
1 = Termination voltage reached during discharge
0 = Termination voltage not reached or not in DISCHARGE mode

RSVD (Bit 4): Reserved. Do not use.

TC (Bit 3): Terminate Charge
1 = Detected
0 = Not Detected

TD (Bit 2): Terminate Discharge
1 = Detected
0 = Not Detected

FC (Bit 1): Fully Charged
1 = Detected
0 = Not Detected

FD (Bit 0): Fully Discharged
1 = Detected
0 = Not Detected

13.2.31 AltManufacturerAccess() 0x0057 ManufacturingStatus

This command returns the *ManufacturingStatus()* flags on *MACData()*.

Status	Condition	Action
Activate	0x0057 to *AltManufacturerAccess()*	Outputs *ManufacturingStatus()* flags on *MACData()*

15	14	13	12	11	10	9	8
CAL_EN	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD

7	6	5	4	3	2	1	0
RSVD	RSVD	LF_EN	RSVD	GAUGE_EN	RSVD	RSVD	RSVD

CAL_EN (Bit 15): CALIBRATION Mode
1 = Enabled
0 = Disabled

RSVD (Bits 14–6): Reserved

LF_EN (Bit 5): Lifetime data collection

1 = Enabled
0 = Disabled

RSVD (Bit 4): Reserved

GAUGE_EN (Bit 3): Gas Gauging
1 = Enabled
0 = Disabled

RSVD (Bits 2–0): Reserved

13.2.32 AltManufacturerAccess() 0x0060 Lifetime Data Block 1

This command returns the lifetime data on *MACData()*.

Status	Condition	Action
Activate	0x0060 to *AltManufacturerAccess()*	Outputs lifetime data values of voltage, current, power, and temperature on *MACData()*

13.2.33 AltManufacturerAccess() 0x0070 ManufacturerInfo

This command returns ***Manufacturer Info Block A01*** through ***Manufacturer Info Block A32*** on *MACData()*.

Status	Condition	Action
Activate	0x0070 to *AltManufacturerAccess()*	Outputs 32 bytes of Manufacturer Info on *MACData()* in the following format: AABBCCDDEEFFGGHHIIJJKKLLMMNN OOPPQQRRSSTTUUVVWWXXVVZZ112233445566

Class	Subclass	Name	Type	Min	Max	Default	Unit
System Data	Manufacturer Data	Manufacturer Info Block A01	H1	0x00	0xFF	0x61	—
System Data	Manufacturer Data	Manufacturer Info Block A02	H1	0x00	0xFF	0x62	—
System Data	Manufacturer Data	Manufacturer Info Block A03	H1	0x00	0xFF	0x63	—
System Data	Manufacturer Data	Manufacturer Info Block A04	H1	0x00	0xFF	0x64	—
System Data	Manufacturer Data	Manufacturer Info Block A05	H1	0x00	0xFF	0x65	—
System Data	Manufacturer Data	Manufacturer Info Block A06	H1	0x00	0xFF	0x66	—
System Data	Manufacturer Data	Manufacturer Info Block A07	H1	0x00	0xFF	0x67	—
System Data	Manufacturer Data	Manufacturer Info Block A08	H1	0x00	0xFF	0x68	—
System Data	Manufacturer Data	Manufacturer Info Block A09	H1	0x00	0xFF	0x69	—
System Data	Manufacturer Data	Manufacturer Info Block A10	H1	0x00	0xFF	0x6A	—
System Data	Manufacturer Data	Manufacturer Info Block A11	H1	0x00	0xFF	0x6B	—
System Data	Manufacturer Data	Manufacturer Info Block A12	H1	0x00	0xFF	0x6C	—
System Data	Manufacturer Data	Manufacturer Info Block A13	H1	0x00	0xFF	0x6D	—
System Data	Manufacturer Data	Manufacturer Info Block A14	H1	0x00	0xFF	0x6E	—
System Data	Manufacturer Data	Manufacturer Info Block A15	H1	0x00	0xFF	0x6F	—
System Data	Manufacturer Data	Manufacturer Info Block A16	H1	0x00	0xFF	0x70	—
System Data	Manufacturer Data	Manufacturer Info Block A17	H1	0x00	0xFF	0x71	—
System Data	Manufacturer Data	Manufacturer Info Block A18	H1	0x00	0xFF	0x72	—
System Data	Manufacturer Data	Manufacturer Info Block A19	H1	0x00	0xFF	0x73	—
System Data	Manufacturer Data	Manufacturer Info Block A20	H1	0x00	0xFF	0x74	—
System Data	Manufacturer Data	Manufacturer Info Block A21	H1	0x00	0xFF	0x75	—
System Data	Manufacturer Data	Manufacturer Info Block A22	H1	0x00	0xFF	0x76	—
System Data	Manufacturer Data	Manufacturer Info Block A23	H1	0x00	0xFF	0x77	—

Class	Subclass	Name	Type	Min	Max	Default	Unit
System Data	Manufacturer Data	Manufacturer Info Block A24	H1	0x00	0xFF	0x7A	—
System Data	Manufacturer Data	Manufacturer Info Block A25	H1	0x00	0xFF	0x78	—
System Data	Manufacturer Data	Manufacturer Info Block A26	H1	0x00	0xFF	0x79	—
System Data	Manufacturer Data	Manufacturer Info Block A27	H1	0x00	0xFF	0x30	—
System Data	Manufacturer Data	Manufacturer Info Block A28	H1	0x00	0xFF	0x31	—
System Data	Manufacturer Data	Manufacturer Info Block A29	H1	0x00	0xFF	0x32	—
System Data	Manufacturer Data	Manufacturer Info Block A30	H1	0x00	0xFF	0x33	—
System Data	Manufacturer Data	Manufacturer Info Block A31	H1	0x00	0xFF	0x34	—
System Data	Manufacturer Data	Manufacturer Info Block A32	H1	0x00	0xFF	0x35	—

13.2.34 AltManufacturerAccess() 0x0071 DAStatus1

This command returns the cell voltage, cell current, cell power, power, and average power on *MACData()*.

Status	Condition	Action
Activate	0x0071 to *AltManufacturerAccess()*	Outputs 32 bytes of data on *MACData()* in the following format: aaAAbbBBccCCddDDeeEEffFFggGGhhHHiiIIjjJJkkKKllLLmmMMnnNNooOOppPP where: AAaa: Cell 1 Voltage BBbb: CCcc: DDdd: EEee: FFff: GGgg: Cell 1 Current. Simultaneous current measured during Cell 1 Voltage measurement HHhh: IIii: JJjj: KKkk: Cell 1 Power. Calculated using Cell 1 Voltage and Cell 1 Current data LLll: MMmm: NNnn: OOoo: Power calculated by *Voltage()* × *Current()* PPpp: Average Power. Calculated by *Voltage()* × *AverageCurrent()*

13.2.35 AltManufacturerAccess() 0x0072 DAStatus2

This command returns the internal temp sensor, TS1*MACData()*.

Status	Condition	Action
Activate	0x0072 to *AltManufacturerAccess()*	Outputs 20 bytes of temperature data values on *MacData()* in the following format: aaAAbbBBccCCddDDeeEEffFFggGGhhHHiiIIjjJJ where: AAaa: Int Temperature BBbb: TS1 Temperature CCcc: DDdd: EEee: FFff: Cell Temperature GGgg: HHhh: Cell 1 Raw Voltage IIii: Cell 1 Raw Current JJjj: Wake Comparator Current

13.2.36 AltManufacturerAccess() 0x0073 ITStatus1

This command instructs the device to return Impedance Track related gauging information on *MACData()*.

Status	Condition	Action
Activate	0x0073 to *AltManufacturerAccess()*	Outputs 20 bytes of IT data values on *MACData()* in the following format: aaAAbbBBccCCddDDeeEEffFFggGGhhHHiiIIjjJJ where: AAaa: True Rem Q. True remaining capacity in mAh from IT simulation before any filtering or smoothing function. This value can be negative or higher than FCC. BBbb: True Rem E. True remaining energy in cWh from IT simulation before any filtering or smoothing function. This value can be negative or higher than FCC. CCcc: Initial Q. Initial capacity calculated from IT simulation DDdd: Initial E. Initial energy calculated from IT simulation EEee: True Full Chg Q. True full charge capacity from IT simulation without the effects of any smoothing function FFff: True Full Chg E. True full charge energy from IT simulation without the effects of any smoothing function GGgg: T_sim. Temperature during the last simulation run HHhh: T_ambient. Current assumed ambient temperature used by the IT algorithm for thermal modeling IIii: Cell 1 RaScale. Ra table scaling factor of Cell 1 JJjj: Cell 1 CompRes. Last temperature compensated resistance of Cell 1

13.2.37 AltManufacturerAccess() 0x0074 ITStatus2

This command instructs the device to return Impedance Track related gauging information on *MACData()*.

Status	Condition	Action
Activate	0x0074 to *AltManufacturerAccess()*	Outputs 20 bytes of IT data values on *MACData()* in the following format: AABBCCDDEEFFggGGhhHHiiIIjjJJkkKKllLLmmMM where: AA: BB: LStatus—Learned status of resistance table Bit 3 | Bit 2 | Bit 1| Bit 0 QMax | ITEN | CF1 | CF0 CF1, CF0: QMax Status 0,0 = Battery OK 0,1 = QMax is first updated in the learning cycle. 1,0 = QMax and resistance table updated in the learning cycle ITEN: IT enable 0 = IT disabled 1 = IT enabled QMax: QMax field updates 0 = QMax is not updated in the field. 1= QMax is updated in the field. CC: Cell Grid 0. Active grid point of Cell 1 DD: EE: FF: GGggHHhh: State Time. Time passed since last state change (DISCHARGE, CHARGE, RELAX) IIii: DOD0_0. Depth of discharge for Cell 1 JJjj: DOD0 Passed Q. Passed capacity since the last DOD0 update KKkk: DOD0 Passed E. Passed energy since last DOD0 update LLll: DOD0 Time. Time passed since the last DOD0 update MMmm: Cell 1 DODEOC. Depth of discharge at valid charge termination for Cell 1

13.2.38 AltManufacturerAccess() 0x0075 ITStatus3

This command instructs the device to return Impedance Track related gauging information on *MACData()*.

Status	Condition	Action
Activate	0x0075 to *AltManufacturerAccess()*	Outputs 14 bytes of IT data values on *MACData()* in the following format: aaAAbbBBccCCddDDeeEEffFFggGG where: AAaa: QMax 0. QMax of Cell 1 BBbb: QMax DOD0 0. DOD0 at last QMax update of Cell 1 CCcc: QMax Passed Q. Pass capacity since last QMax update DDdd: QMax Time. Time passed since last QMax update EEee: Temp k. Thermal Model temperature factor FFff: Temp a. Thermal Model temperature time constant GGgg: Raw DOD0 1. Raw DOD0 of Cell 1

13.2.39 AltManufacturerAccess() 0x0077 FCC_SOH

This command returns the capacity and energy results of the IT simulation for state-of-health.

Status	Condition	Action
Enable	0x0077 to *AltManufacturerAccess()*	Returns the state-of-health capacities (4 bytes) on a subsequent read on *MACData()* in the following format: aaAAbbBB where: AAaa: SoH FC@25C Q. State-of-health simulated at 25°C in mAh BBbb: SoH FC@25C E. State-of-health simulated at 25°C in cWh

13.2.40 AltManufacturerAccess() 0x0078 Filtered Capacity

This command instructs the device to return Impedance Track related gauging information on *MACData()*.

Status	Condition	Action
Activate	0x0078 to *AltManufacturerAccess()*	Outputs 8 bytes of IT data values on *MACData()* in the following format: AAaaBBbbCCccDDdd where: AAaa: Flt Rem Q. Filtered remaining capacity (mAh) BBbb: Flt Rem E. Filtered remaining capacity (cWh) CCcc: Flt FCC Q. Filtered full charge capacity (mAh) DDdd: Flt FCC E. Filtered full charge capacity (cWh)

13.2.41 AltManufacturerAccess() 0x0F00 ROM Mode

This command sends the device into ROM mode in preparation for reprogramming.

Status	Condition	Action
ROM Mode	*OperationStatusA()[SEC1,SEC0]* = 0,1 AND 0x0F00 to *AltManufacturerAccess()*	The device goes into ROM mode to prepare for updates. The ROM command 0x08 returns it to FIRMWARE mode. (Note: ROM commands are sent to address 0x16 using the I^2C protocol.)

13.2.42 Data Flash Access() 0x4000–0x5FFF

Accessing data flash (DF) is only supported by the *AltManufacturerAccess()* by addressing the physical address.

To write to the DF, send the starting address, followed by the DF data block. The DF data block is the intended revised DF data to be updated. The size of the DF data block ranges from 1 byte to 32 bytes. All individual data must be sent in Little Endian.

Write to DF example:

Assuming: data1 locates at address 0x4000 and data2 locates at address 0x4002.
Both data1 and data2 are U2 type.

To update data1 and data2, send a block write with command = 0x3E
block = starting address + DF data block
= 0x00 + 0x40 + data1_LowByte + data1_HighByte + data2_LowByte + data2_HighByte

To read the DF, send a block write to the *AltManufacturerAccess()* followed by the starting address, then send a block read to the *AltManufacturerAccess()*. The return data contains the starting address followed by 32 bytes of DF data in Little Endian.

Read from DF example:
Taking the same assuming from the read DF example, to read DF:
a. Send the write block with command 0x3E, block = 0x00 + 0x40
b. Send the read block with command 0x3E
The returned block = a starting address + 32 bytes of DF dat
= 0x00 + 0x40 + data1_LowByte + data1_HighByte + data2_LowByte + data2_HighByte.... data32_LowByte + data32_HighByte

The gauge supports an auto-increment on the address during a DF read. This greatly reduces the time required to read out the entire DF. Continue with the read from the DF example. If another read block is sent with command 0x3E, the gauge returns another 32 bytes of DF data, starting with address 0x4020.

13.2.43 AltManufacturerAccess() 0x7C40 Switch to HDQ

This command PERMANENTLY switches the device's communication protocol from I^2C to HDQ.

Status	Condition	Action
Activate	*OperationStatusA()[SEC1,SEC0]* = 0,1 or 1,0 AND 0x7C40 to *AltManufacturerAccess()*	The device permanently switches the communication protocol to HDQ (includes ROM mode).

NOTE: After switching to HDQ, ***I2C Configuration[XL]*** has no effect on gauge operation.

13.2.44 AltManufacturerAccess() 0xF080 Exit Calibration Output Mode

This command stops the output of calibration data to the *MACData()* command.

Status	Condition	Action
Activate	*MACData()* = 1 AND 0xF080 to *AltManufacturerAccess()*	Stops output of ADC or CC data on *MACData()*

13.2.45 AltManufacturerAccess() 0xF081 Output CC and ADC for Calibration

This command instructs the device to output the raw values for calibration purposes on *MACData()*. All values are updated every 1000 ms and the format of each value is 2's complement, MSB first.

Status	Condition	Action
Disable	*OperationStatusB()[CAL]* = 1 AND 0xF080 to *AltManufacturerAccess()*	*OperationStatusB()[CAL]* = 0 Stops output of ADC and CC data on *MACData()*
Enable	0xF081 to *AltManufacturerAccess()*	*OperationStatusB()[CAL]* = 1 Outputs the raw CC and AD values on *MACData()* in the format of ZZYYaaAAbbBBccCCddDDeeEEffFF ggGGhhHHiiIIjjJJkkKK: ZZ: Rolling 8-bit counter, increments when values are refreshed. YY: Status, 1 when *AltManufacturerAccess()* = 0xF081 AAaa: Current (coulomb counter) BBaa: Cell 1 Voltage CCaa: DDaa: EEee: FFff: GGgg: HHhh: Cell 1 Current IIii: JJjj: KKkk:

Data Flash Access and Format

14.1 Data Flash Access

14.1.1 Minimum Voltage

Data flash can only be updated when the cell voltage is above the ***Valid Update Voltage***.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Power	Power	Valid Update Voltage	I2	0	32767	2800	mV	Min cell voltage threshold for the flash update

14.2 Data Formats

14.2.1 Unsigned Integer

Unsigned integers are stored without changes as 1-byte, 2-byte, or 4-byte values in Little Endian byte order.

0
U1 MSB

0	1
U2 LSB	U2 MSB

0	1	2	3
U4 L LSB	U4 L MSB	U4 H LSB	U4 H MSB

14.2.2 Integer

Integer values are stored in 2's-complement format in 1-byte, 2-byte, or 4-byte values in Little Endian byte order.

0
I1 MSB

0	1
I2 LSB	I2 MSB

0	1	2	3
I4 L LSB	I4 L MSB	I4 H LSB	I4 H MSB

14.2.3 Floating Point

Floating point values are stored using the IEEE 754 single-precision, 4-byte format in Little Endian byte order.

0	1	2	3
Fract [0–7]	Fract [8–15]	Exp[0] + Fract[16–22]	Sign + Exp[1–7]

Where:

Exp: 8-bit exponent stored with an offset bias of 127. The values 00 and FF have special meaning.

Fract: 23-bit fraction. If the exponent is > 0, then the mantissa is 1.fract. If the exponent is 0, then the mantissa is 0.fract.

The floating point value depends on the special cases of the exponent:

- If the exponent is FF and the fraction is 0, this represents ± infinity.
- If the exponent is FF and the fraction is non-0, this represents "not a number" (NaN).
- If the exponent is 00, then the value is a subnormal number represented by $(–1)^{sign} \times 2^{–126} \times$ 0.fraction.
- Otherwise, the value is a normalized number represented by $(–1)^{sign} \times 2^{(exponent\ –\ 127)} \times$ 1.fraction.

14.2.4 Hex

Bit register definitions are stored in unsigned integer format.

14.2.5 String

String values are stored with the length byte first, followed by a number of data bytes defined with the length byte.

0	1	. . .	N
Length	Data0	. . .	DataN

Data Flash Summary

15.1 Data Flash Table

Table 15-1. Data Flash Table

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Calibration	Voltage	0x4000	Cell Gain	I2	–32767	32767	12101	—
Calibration	Current	0x4006	CC Gain	F4	1.00E–01	4.00E+00	3.68	—
Calibration	Current	0x400A	Capacity Gain	F4	2.98262E+02	1.193046E+08	4390411.01	—
Calibration	Current Offset	0x400E	CC Offset	I2	–32767	32767	0	—
Calibration	Current Offset	0x4010	Coulomb Counter Offset Samples	U2	0	65535	64	—
Calibration	Current Offset	0x4012	Board Offset	I2	–32768	32767	0	—
Calibration	Temperature	0x4014	Internal Temp Offset	I1	–128	127	0	0.1°C
Calibration	Temperature	0x4015	External1 Temp Offset	I1	–128	127	0	0.1°C
Calibration	Internal Temp Model	0x42C0	Int Gain	I2	–32768	32767	–13908	—
Calibration	Internal Temp Model	0x42C2	Int base offset	I2	–32768	32767	6959	—
Calibration	Internal Temp Model	0x42C4	Int Minimum AD	I2	–32768	32767	0	—
Calibration	Internal Temp Model	0x42C6	Int Maximum Temp	I2	–32768	32767	6959	0.1°K
Calibration	Cell Temperature Model	0x42C8	Coeff a1	I2	–32768	32767	–17447	—
Calibration	Cell Temperature Model	0x42CA	Coeff a2	I2	–32768	32767	29322	—
Calibration	Cell Temperature Model	0x42CC	Coeff a3	I2	–32768	32767	–25430	—
Calibration	Cell Temperature Model	0x42CE	Coeff a4	I2	–32768	32767	29836	—
Calibration	Cell Temperature Model	0x42D0	Coeff a5	I2	–32768	32767	1200	—
Calibration	Cell Temperature Model	0x42D2	Coeff b1	I2	–32768	32767	–293	—
Calibration	Cell Temperature Model	0x42D4	Coeff b2	I2	–32768	32767	552	—
Calibration	Cell Temperature Model	0x42D6	Coeff b3	I2	–32768	32767	–2887	—
Calibration	Cell Temperature Model	0x42D8	Coeff b4	I2	–32768	32767	4591	—
Calibration	Cell Temperature Model	0x42DA	Rc0	I2	–32768	32767	11703	—
Calibration	Cell Temperature Model	0x42DC	Adc0	I2	–32768	32767	11703	—
Calibration	Cell Temperature Model	0x42DE	Rpad	I2	–32768	32767	0	—
Calibration	Cell Temperature Model	0x42E0	Rint	I2	–32768	32767	0	—
Calibration	Current Deadband	0x42E5	Deadband	U1	0	255	3	mA
Calibration	Current Deadband	0x42E6	Coulomb Counter Deadband	U1	0	255	9	116 nV

Table 15-1. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Settings	Configuration	0x4480	I2C Gauging Configuration	H1	0x0	0x0F	0x08	Hex
Settings	Configuration	0x4481	I2C Configuration	H1	0x0	0xFF	0x08	Hex
Settings	Configuration	0x4482	Auth Config	H1	0x0	0x03	0x00	Hex
Settings	Configuration	0x4483	Power Config	H1	0x0	0xFF	0x10	Hex
Settings	Configuration	0x4484	IO Config	H1	0x0	0x3C	0x00	Hex
Settings	Configuration	0x4485	Init Voltage High Set	I2	0	5000	4500	mV
Settings	Configuration	0x4487	Init Voltage High Clear	I2	0	5000	4400	mV
Settings	Configuration	0x4489	Init Voltage Low Set	I2	0	5000	2500	mV
Settings	Configuration	0x448B	Init Voltage Low Clear	I2	0	5000	2600	mV
Settings	Configuration	0x448D	Init Temperature High Set	I1	–128	127	60	°C
Settings	Configuration	0x448E	Init Temperature High Clear	I1	–128	127	55	°C
Settings	Configuration	0x448F	Init Temperature Low Set	I1	–128	127	0	°C
Settings	Configuration	0x4490	Init Temperature Low Clear	I1	–128	127	5	°C
Settings	Configuration	0x4491	SOC Delta	U1	0	100	1	%
Settings	Configuration	0x4492	GPIO Pulse Width	U1	0	255	7	25 ms
Settings	Configuration	0x44A7	SOC Flag Config A	H2	0x0	0x0FFF	0x0C8C	Hex
Settings	Configuration	0x44A9	SOC Flag Config B	H1	0x0	0xFF	0x8C	Hex
Settings	Configuration	0x44C2	IT Gauging Configuration	H2	0x0	0xFFFF	0x55FE	Hex
Settings	Configuration	0x44C6	IT Gauging Ext	H2	0x0000	0x001F	0x001B	Hex
Settings	Configuration	0x44DF	Charging Configuration	H1	0x0	0x3F	0x0	Hex
Settings	Configuration	0x451B	Temperature Enable	H1	0x0	0x03	0x02	Hex
Settings	Configuration	0x451C	DA Configuration	H2	0x0	0x0010	0x0010	Hex
Settings	Manufacturing	0x4280	Mfg Status init	H2	0x0	0xFFFF	0x0000	Hex
Advanced Charge Algorithm	Temperature Ranges	0x44E0	T1 Temp	I1	–128	127	0	°C
Advanced Charge Algorithm	Temperature Ranges	0x44E1	T2 Temp	I1	–128	127	10	°C
Advanced Charge Algorithm	Temperature Ranges	0x44E2	T5 Temp	I1	–128	127	20	°C
Advanced Charge Algorithm	Temperature Ranges	0x44E3	T6 Temp	I1	–128	127	25	°C
Advanced Charge Algorithm	Temperature Ranges	0x44E4	T3 Temp	I1	–128	127	45	°C
Advanced Charge Algorithm	Temperature Ranges	0x44E5	T4 Temp	I1	–128	127	55	°C
Advanced Charge Algorithm	Temperature Ranges	0x44E6	Hysteresis Temp	I1	0	127	1	°C
Advanced Charge Algorithm	Low Temp Charging	0x44E7	Voltage	I2	0	32767	4400	mV
Advanced Charge Algorithm	Low Temp Charging	0x44E9	Current Low	I2	0	32767	132	mA
Advanced Charge Algorithm	Low Temp Charging	0x44EB	Current Med	I2	0	32767	352	mA
Advanced Charge Algorithm	Low Temp Charging	0x44ED	Current High	I2	0	32767	264	mA
Advanced Charge Algorithm	Standard Temp Charging	0x44EF	Voltage	I2	0	32767	4400	mV
Advanced Charge Algorithm	Standard Temp Charging	0x44F1	Current Low	I2	0	32767	1980	mA
Advanced Charge Algorithm	Standard Temp Charging	0x44F3	Current Med	I2	0	32767	4004	mA
Advanced Charge Algorithm	Standard Temp Charging	0x44F5	Current High	I2	0	32767	2992	mA
Advanced Charge Algorithm	High Temp Charging	0x44F7	Voltage	I2	0	32767	4100	mV
Advanced Charge Algorithm	High Temp Charging	0x44F9	Current Low	I2	0	32767	1012	mA

Table 15-1. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Advanced Charge Algorithm	High Temp Charging	0x44FB	Current Med	I2	0	32767	1980	mA
Advanced Charge Algorithm	High Temp Charging	0x44FD	Current High	I2	0	32767	1496	mA
Advanced Charge Algorithm	Rec Temp Charging	0x44FF	Voltage	I2	0	32767	4400	mV
Advanced Charge Algorithm	Rec Temp Charging	0x4501	Current Low	I2	0	32767	2508	mA
Advanced Charge Algorithm	Rec Temp Charging	0x4503	Current Med	I2	0	32767	4488	mA
Advanced Charge Algorithm	Rec Temp Charging	0x4505	Current High	I2	0	32767	3520	mA
Advanced Charge Algorithm	Pre-Charging	0x4507	Current	I2	0	32767	88	mA
Advanced Charge Algorithm	Maintenance Charging	0x4509	Current	I2	0	32767	44	mA
Advanced Charge Algorithm	Voltage Range	0x450B	Precharge Start Voltage	I2	0	32767	2500	mV
Advanced Charge Algorithm	Voltage Range	0x450D	Charging Voltage Low	I2	0	32767	2900	mV
Advanced Charge Algorithm	Voltage Range	0x450F	Charging Voltage Med	I2	0	32767	3600	mV
Advanced Charge Algorithm	Voltage Range	0x4511	Charging Voltage High	I2	0	32767	4000	mV
Advanced Charge Algorithm	Voltage Range	0x4513	Charging Voltage Hysteresis	U1	0	255	0	mV
Advanced Charge Algorithm	Termination Config	0x4514	Charge Term Taper Current	I2	0	32767	100	mA
Advanced Charge Algorithm	Termination Config	0x4518	Charge Term Voltage	I2	0	32767	100	mV
Gas Gauging	Current Thresholds	0x451F	Dsg Current Threshold	I2	–32768	32767	60	mA
Gas Gauging	Current Thresholds	0x4521	Chg Current Threshold	I2	–32768	32767	75	mA
Gas Gauging	Current Thresholds	0x4523	Quit Current	I2	0	32767	40	mA
Gas Gauging	Current Thresholds	0x4525	Dsg Relax Time	U1	0	255	60	s
Gas Gauging	Current Thresholds	0x4526	Chg Relax Time	U1	0	255	60	s
Gas Gauging	Max Load	0x449C	Max Load Current	I2	–32768	0	–500	mA
Gas Gauging	Max Load	0x449E	Max Load Rsoc	U1	0	100	50	%
Gas Gauging	Design	0x449F	Design Capacity mAh	I2	0	32767	5300	mAh
Gas Gauging	Design	0x44A1	Design Capacity cWh	I2	0	32767	2040	cWh
Gas Gauging	Design	0x44A3	Design Voltage	I2	0	32767	3850	mV
Gas Gauging	Cycle	0x44A5	Cycle Count Percentage	U1	0	100	90	%
Gas Gauging	FD	0x44AA	Set Voltage Threshold	I2	0	5000	3000	mV
Gas Gauging	FD	0x44AC	Clear Voltage Threshold	I2	0	5000	3100	mV
Gas Gauging	FD	0x44AE	Set % RSOC Threshold	U1	0	100	0	%
Gas Gauging	FD	0x44AF	Clear % RSOC Threshold	U1	0	100	5	%
Gas Gauging	FC	0x44B0	Set Voltage Threshold	I2	0	5000	4400	mV
Gas Gauging	FC	0x44B2	Clear Voltage Threshold	I2	0	5000	4300	mV
Gas Gauging	FC	0x44B4	Set % RSOC Threshold	U1	0	100	100	%
Gas Gauging	FC	0x44B5	Clear % RSOC Threshold	U1	0	100	95	%
Gas Gauging	TD	0x44B6	Set Voltage Threshold	I2	0	5000	3200	mV
Gas Gauging	TD	0x44B8	Clear Voltage Threshold	I2	0	5000	3300	mV
Gas Gauging	TD	0x44BA	Set % RSOC Threshold	U1	0	100	6	%
Gas Gauging	TD	0x44BB	Clear % RSOC Threshold	U1	0	100	8	%

Table 15-1. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Gas Gauging	TC	0x44BC	Set Voltage Threshold	I2	0	5000	4400	mV
Gas Gauging	TC	0x44BE	Clear Voltage Threshold	I2	0	5000	4300	mV
Gas Gauging	TC	0x44C0	Set % RSOC Threshold	U1	0	100	100	%
Gas Gauging	TC	0x44C1	Clear % RSOC Threshold	U1	0	100	95	%
Gas Gauging	State	0x4146	Qmax Cell 1	I2	0	32767	5359	mAh
Gas Gauging	State	0x4148	Qmax Cycle Count	U2	0	65535	0	—
Gas Gauging	State	0x414A	Update Status	H1	0x0	0x0E	0x0	—
Gas Gauging	State	0x414B	Cell 1 Chg Voltage at EoC	I2	0	32767	4375	mV
Gas Gauging	State	0x414D	Current at EoC	I2	0	32767	100	mA
Gas Gauging	State	0x414F	Avg I Last Run	I2	–32768	32767	–500	mA
Gas Gauging	State	0x4151	Avg P Last Run	I2	–32768	32767	–192	cW
Gas Gauging	State	0x4153	Delta Voltage	I2	–32768	32767	0	mV
Gas Gauging	State	0x4155	Temp k	I2	0	32767	200	0.1°C/ 256 cW
Gas Gauging	State	0x4157	Temp a	I2	0	32767	1000	s
Gas Gauging	State	0x4159	Max Avg I Last Run	I2	–32768	32767	–500	mA
Gas Gauging	State	0x415B	Max Avg P Last Run	I2	–32768	32767	–192	cW
Gas Gauging	State	0x4180	Cycle Count	U2	0	65535	0	—
Gas Gauging	IT Cfg	0x4140	Design Resistance	I2	1	32767	90	mΩ
Gas Gauging	IT Cfg	0x4142	Pack Resistance	I2	0	32767	0	mΩ
Gas Gauging	IT Cfg	0x4144	System Resistance	I2	0	32767	0	mΩ
Gas Gauging	IT Cfg	0x440E	Ra Filter	U2	0	999	800	0.1%
Gas Gauging	IT Cfg	0x4411	Ra Max Delta	U1	0	255	15	%
Gas Gauging	IT Cfg	0x4414	Resistance Parameter Filter	U2	1	65535	65142	—
Gas Gauging	IT Cfg	0x4416	Near EDV Ra Param Filter	U2	1	65535	62184	—
Gas Gauging	IT Cfg	0x4418	Cell 1 Interconnect Resistance	I2	0	32767	0	2^{-10} Ω
Gas Gauging	IT Cfg	0x441A	Max Current Change %	U1	0	100	10	%
Gas Gauging	IT Cfg	0x441B	Resistance Update Voltage	I2	0	32767	50	mV
Gas Gauging	IT Cfg	0x4441	Qmax Delta	U1	3	100	5	%
Gas Gauging	IT Cfg	0x4442	Qmax Upper Bound	U1	100	255	130	%
Gas Gauging	IT Cfg	0x4443	Term Voltage	I2	0	32767	3000	mV
Gas Gauging	IT Cfg	0x4445	Term V Hold Time	U1	0	255	2	s
Gas Gauging	IT Cfg	0x4446	Term Voltage Delta	I2	0	32767	200	mV
Gas Gauging	IT Cfg	0x4448	Term Min Cell V	I2	0	32767	2800	mV
Gas Gauging	IT Cfg	0x4451	Max Simulation Iterations	U1	20	50	50	—
Gas Gauging	IT Cfg	0x4452	Simulation Near Term Delta	I2	0	32767	250	mV
Gas Gauging	IT Cfg	0x4464	Fast Scale Start SOC	U1	0	100	10	%
Gas Gauging	IT Cfg	0x446D	Min Delta Voltage	I2	–32768	32767	0	mV
Gas Gauging	IT Cfg	0x44C8	Load Select	U1	0	7	1	—
Gas Gauging	IT Cfg	0x44C9	Load Mode	U1	0	1	1	—
Gas Gauging	IT Cfg	0x44CA	User Rate-mA	I2	–9000	0	0	mA
Gas Gauging	IT Cfg	0x44CC	User Rate-cW	I2	–32768	0	0	cW
Gas Gauging	IT Cfg	0x44CE	Reserve Cap-mAh	I2	0	9000	0	mAh
Gas Gauging	IT Cfg	0x44D0	Reserve Cap-cWh	I2	0	32000	0	cWh
Gas Gauging	IT Cfg	0x44DD	Predict Ambient Time	U2	0	65535	2000	s
Gas Gauging	Smoothing	0x44D2	Smooth Relax Time	I2	1	32767	1000	s
Gas Gauging	Smoothing	0x44D4	Term Smooth Start Cell V Delta	I2	0	32767	150	mV
Gas Gauging	Smoothing	0x44D6	Term Smooth Final Cell V Delta	I2	0	32767	100	mV
Gas Gauging	Smoothing	0x44D8	Term Smooth Time	U1	1	32767	20	s
Gas Gauging	Imax	0x44DA	Max Allowed Current	I2	0	32767	8500	mA

Table 15-1. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Gas Gauging	Imax	0x44DC	Max Current Pulse Duration	U1	0	255	10	s
Gas Gauging	SoH	0x446F	SoH Load Rate	U1	0	255	50	0.1 Hr rate
Power	Power	0x4493	Valid Update Voltage	I2	0	32767	2800	mV
Power	Sleep	0x4495	Sleep Current	I2	0	32767	15	mA
Power	Sleep	0x4497	Voltage Time	U1	1	20	5	s
Power	Sleep	0x4498	Deep Sleep Voltage Time	U1	1	20	20	s
Power	Sleep	0x4499	Wake Check Time	U1	0	20	1	s
Power	Sleep	0x449A	Deep Sleep Current	I2	0	32767	10	mA
System Data	Manufacturer Data	0x4041	Manufacturer Info Block A01	H1	0x0	0xFF	0x61	Hex
System Data	Manufacturer Data	0x4042	Manufacturer Info Block A02	H1	0x0	0xFF	0x62	Hex
System Data	Manufacturer Data	0x4043	Manufacturer Info Block A03	H1	0x0	0xFF	0x63	Hex
System Data	Manufacturer Data	0x4044	Manufacturer Info Block A04	H1	0x0	0xFF	0x64	Hex
System Data	Manufacturer Data	0x4045	Manufacturer Info Block A05	H1	0x0	0xFF	0x65	Hex
System Data	Manufacturer Data	0x4046	Manufacturer Info Block A06	H1	0x0	0xFF	0x66	Hex
System Data	Manufacturer Data	0x4047	Manufacturer Info Block A07	H1	0x0	0xFF	0x67	Hex
System Data	Manufacturer Data	0x4048	Manufacturer Info Block A08	H1	0x0	0xFF	0x68	Hex
System Data	Manufacturer Data	0x4049	Manufacturer Info Block A09	H1	0x0	0xFF	0x69	Hex
System Data	Manufacturer Data	0x404A	Manufacturer Info Block A10	H1	0x0	0xFF	0x6A	Hex
System Data	Manufacturer Data	0x404B	Manufacturer Info Block A11	H1	0x0	0xFF	0x6B	Hex
System Data	Manufacturer Data	0x404C	Manufacturer Info Block A12	H1	0x0	0xFF	0x6C	Hex
System Data	Manufacturer Data	0x404D	Manufacturer Info Block A13	H1	0x0	0xFF	0x6D	Hex
System Data	Manufacturer Data	0x404E	Manufacturer Info Block A14	H1	0x0	0xFF	0x6E	Hex
System Data	Manufacturer Data	0x404F	Manufacturer Info Block A15	H1	0x0	0xFF	0x6F	Hex
System Data	Manufacturer Data	0x4050	Manufacturer Info Block A16	H1	0x0	0xFF	0x70	Hex
System Data	Manufacturer Data	0x4051	Manufacturer Info Block A17	H1	0x0	0xFF	0x71	Hex
System Data	Manufacturer Data	0x4052	Manufacturer Info Block A18	H1	0x0	0xFF	0x72	Hex
System Data	Manufacturer Data	0x4053	Manufacturer Info Block A19	H1	0x0	0xFF	0x73	Hex
System Data	Manufacturer Data	0x4054	Manufacturer Info Block A20	H1	0x0	0xFF	0x74	Hex
System Data	Manufacturer Data	0x4055	Manufacturer Info Block A21	H1	0x0	0xFF	0x75	Hex
System Data	Manufacturer Data	0x4056	Manufacturer Info Block A22	H1	0x0	0xFF	0x76	Hex
System Data	Manufacturer Data	0x4057	Manufacturer Info Block A23	H1	0x0	0xFF	0x77	Hex
System Data	Manufacturer Data	0x4058	Manufacturer Info Block A24	H1	0x0	0xFF	0x7A	Hex
System Data	Manufacturer Data	0x4059	Manufacturer Info Block A25	H1	0x0	0xFF	0x78	Hex
System Data	Manufacturer Data	0x405A	Manufacturer Info Block A26	H1	0x0	0xFF	0x79	Hex

Table 15-1. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
System Data	Manufacturer Data	0x405B	Manufacturer Info Block A27	H1	0x0	0xFF	0x30	Hex
System Data	Manufacturer Data	0x405C	Manufacturer Info Block A28	H1	0x0	0xFF	0x31	Hex
System Data	Manufacturer Data	0x405D	Manufacturer Info Block A29	H1	0x0	0xFF	0x32	Hex
System Data	Manufacturer Data	0x405E	Manufacturer Info Block A30	H1	0x0	0xFF	0x33	Hex
System Data	Manufacturer Data	0x405F	Manufacturer Info Block A31	H1	0x0	0xFF	0x34	Hex
System Data	Manufacturer Data	0x4060	Manufacturer Info Block A32	H1	0x0	0xFF	0x35	Hex
System Data	Integrity	0x4061	Static DF Signature	H2	0x0	0x7FFF	0x0	Hex
System Data	Integrity	0x4063	Static Chem DF Signature	H2	0x0	0x7FFF	0x3A4C	Hex
System Data	Integrity	0x4065	All DF Signature	H2	0x0	0x7FFF	0x0	Hex
I2C Configuration	Data	0x4067	Manufacture Date	U2	0	65535	0	date
I2C Configuration	Data	0x4069	Serial Number	H2	0x0	0xFFFF	0x0001	Hex
I2C Configuration	Data	0x406B	Manufacturer Name	S21	x	x	Texas Instruments	—
I2C Configuration	Data	0x4080	Device Name	S21	x	x	bq27z561	—
I2C Configuration	Data	0x4095	Device Chemistry	S5	x	x	LION	—
Lifetimes	Voltage	0x41C0	Cell 1 Max Voltage	I2	0	32767	0	mV
Lifetimes	Current	0x41C2	Max Charge Current	I2	0	32767	0	mA
Lifetimes	Current	0x41C4	Max Discharge Current	I2	–32768	0	0	mA
Lifetimes	Temperature	0x41C6	Max Temp Cell	I1	–128	127	–128	°C
Lifetimes	Temperature	0x41C7	Min Temp Cell	I1	–128	127	127	°C
Ra Table	R_a0	0x40C0	Cell0 R_a flag	H2	0x0	0xFFFF	0xFF55	—
Ra Table	R_a0	0x40C2	Cell0 R_a 0	I2	0	32767	159	$2^{-10}\,\Omega$
Ra Table	R_a0	0x40C4	Cell0 R_a 1	I2	0	32767	58	$2^{-10}\,\Omega$
Ra Table	R_a0	0x40C6	Cell0 R_a 2	I2	0	32767	65	$2^{-10}\,\Omega$
Ra Table	R_a0	0x40C8	Cell0 R_a 3	I2	0	32767	79	$2^{-10}\,\Omega$
Ra Table	R_a0	0x40CA	Cell0 R_a 4	I2	0	32767	90	$2^{-10}\,\Omega$
Ra Table	R_a0	0x40CC	Cell0 R_a 5	I2	0	32767	63	$2^{-10}\,\Omega$
Ra Table	R_a0	0x40CE	Cell0 R_a 6	I2	0	32767	76	$2^{-10}\,\Omega$
Ra Table	R_a0	0x40D0	Cell0 R_a 7	I2	0	32767	82	$2^{-10}\,\Omega$
Ra Table	R_a0	0x40D2	Cell0 R_a 8	I2	0	32767	82	$2^{-10}\,\Omega$
Ra Table	R_a0	0x40D4	Cell0 R_a 9	I2	0	32767	87	$2^{-10}\,\Omega$
Ra Table	R_a0	0x40D6	Cell0 R_a 10	I2	0	32767	87	$2^{-10}\,\Omega$
Ra Table	R_a0	0x40D8	Cell0 R_a 11	I2	0	32767	101	$2^{-10}\,\Omega$
Ra Table	R_a0	0x40DA	Cell0 R_a 12	I2	0	32767	118	$2^{-10}\,\Omega$
Ra Table	R_a0	0x40DC	Cell0 R_a 13	I2	0	32767	191	$2^{-10}\,\Omega$
Ra Table	R_a0	0x40DE	Cell0 R_a 14	I2	0	32767	282	$2^{-10}\,\Omega$
Ra Table	R_a0x	0x4100	xCell0 R_a flag	H2	0x0	0xFFFF	0xFFFF	—
Ra Table	R_a0x	0x4102	xCell0 R_a 0	I2	0	32767	159	$2^{-10}\,\Omega$
Ra Table	R_a0x	0x4104	xCell0 R_a 1	I2	0	32767	58	$2^{-10}\,\Omega$
Ra Table	R_a0x	0x4106	xCell0 R_a 2	I2	0	32767	65	$2^{-10}\,\Omega$
Ra Table	R_a0x	0x4108	xCell0 R_a 3	I2	0	32767	79	$2^{-10}\,\Omega$
Ra Table	R_a0x	0x410A	xCell0 R_a 4	I2	0	32767	90	$2^{-10}\,\Omega$
Ra Table	R_a0x	0x410C	xCell0 R_a 5	I2	0	32767	63	$2^{-10}\,\Omega$
Ra Table	R_a0x	0x410E	xCell0 R_a 6	I2	0	32767	76	$2^{-10}\,\Omega$
Ra Table	R_a0x	0x4110	xCell0 R_a 7	I2	0	32767	82	$2^{-10}\,\Omega$
Ra Table	R_a0x	0x4112	xCell0 R_a 8	I2	0	32767	82	$2^{-10}\,\Omega$

Table 15-1. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Ra Table	R_a0x	0x4114	xCell0 R_a 9	I2	0	32767	87	2^{-10} Ω
Ra Table	R_a0x	0x4116	xCell0 R_a 10	I2	0	32767	87	2^{-10} Ω
Ra Table	R_a0x	0x4118	xCell0 R_a 11	I2	0	32767	101	2^{-10} Ω
Ra Table	R_a0x	0x411A	xCell0 R_a 12	I2	0	32767	118	2^{-10} Ω
Ra Table	R_a0x	0x411C	xCell0 R_a 13	I2	0	32767	191	2^{-10} Ω
Ra Table	R_a0x	0x411E	xCell0 R_a 14	I2	0	32767	282	2^{-10} Ω

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Date	Revision	Notes
June 2018	*	Initial Release

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