bq40z50

Technical Reference

Literature Number: SLUUA43A
December 2013–Revised May 2015

Contents

Preface

Read this First

This manual discusses the modules and peripherals of the bq40z50 device, and how each is used to build a complete battery pack gas gauge and protection solution.

Notational Conventions

The following notation is used if SBS commands and data flash values are mentioned within a text block:

- SBS commands: *italics* with parentheses and no breaking spaces, for example, *RemainingCapacity()*.
- Data Flash: *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

The reference format for SBS commands is: SBS:Command Name(Command No.): Manufacturer Access(MA No.)[Flag]; for example:

SBS:Voltage(0x09), or SBS:ManufacturerAccess(0x00): Seal Device(0x0020)

Introduction

The bq40z50 device provides a feature-rich gas gauging solution for 1-series cell to 4-series cell battery-pack applications. The device has extended capabilities, including:

- Fully Integrated 1-Series, 2-Series, 3-Series, and 4-Series Li-Ion or Li-Polymer Cell Battery Pack Manager and Protection
- Next-Generation Patented Impedance Track™ Technology Accurately Measures Available Charge in Li-Ion and Li-Polymer Batteries
- High Side N-CH Protection FET Drive
- Integrated Cell Balancing While Charging or At Rest
- Low Power Modes
  - LOW POWER
  - SLEEP
- Full Array of Programmable Protection Features
  - Voltage
  - Current
  - Temperature
  - Charge Timeout
  - CHG/DSG FETs
  - Cell Imbalance
- Sophisticated Charge Algorithms
  - JEITA
  - Advanced Charging Algorithm
- Diagnostic Lifetime Data Monitor
- Black Box Event Recorder
- Supports Two-Wire SMBus v1.1 Interface
- SHA-1 Authentication
- Ultra-Compact Package: 32-Lead QFN

Protections

2.1 Introduction

The bq40z50 provides recoverable protection. When the protection is triggered, charging and/or discharging is disabled. This is indicated by the *OperationStatus()[XCHG]* = 1 when charging is disabled, and/or the *OperationStatus()[XDSG]* = 1 when discharging is disabled. Once the protection is recovered, charging and discharging resume. All protection items can be enabled or disabled under ***Settings:Enabled Protections A***, ***Settings:Enabled Protections B***, ***Settings:Enabled Protections C***, and ***Settings:Enabled Protections D***.

When the protections and permanent fails are triggered, the *BatteryStatus()[TCA][TDA][FD][OCA][OTA]* is set according to the type of safety protections. A summary of the set conditions of the various alarms flags is available in Section 4.8.

2.2 Cell Undervoltage Protection

The device can detect cell undervoltage in batteries and protect cells from damage by preventing further discharge.

Status	Condition	Action
Normal	Min cell voltage1..4 > ***CUV:Threshold***	*SafetyAlert()[CUV]* = 0 *BatteryStatus()[TDA]* = 0
Alert	Min cell voltage1..4 ≤ ***CUV:Threshold***	*SafetyAlert()[CUV]* = 1 *BatteryStatus()[TDA]* = 1
Trip	Min cell voltage1..4 ≤ ***CUV:Threshold*** for ***CUV:Delay*** duration	*SafetyAlert()[CUV]* = 0 *SafetyStatus()[CUV]* = 1 *BatteryStatus()[FD]* = 1,*[TDA]* = 0 *OperationStatus()[XDSG]* = 1
Recovery	Condition 1: *SafetyStatus()[CUV]* = 1 AND Min cell voltage1..4 ≥ ***CUV:Recovery*** AND ***Protection Configuration[CUV_RECOV_CHG]*** = 0	*SafetyStatus()[CUV]* = 0 *BatteryStatus()[FD]* = 0, *[TDA]* = 0 *OperationStatus()[XDSG]* = 0
	OR Condition 2: *SafetyStatus()[CUV]* = 1 AND Min cell voltage1..4 ≥ ***CUV:Recovery*** AND ***Protection Configuration[CUV_RECOV_CHG]*** = 1 AND Charging detected (that is, *BatteryStatus()[DSG]* = 0)	

2.3 Cell Undervoltage Compensated Protection

The device can detect cell undervoltage in batteries and protect cells from damage by preventing further discharge. The protection is compensated by the *Current()* × CellResistance1..4.

Status	Condition	Action
Normal	Min cell voltage1..4 – *Current()* × Cell Resistance > ***CUVC: Threshold***	*SafetyAlert()[CUVC]* = 0 *BatteryStatus()[TDA]* = 0
Alert	Min cell voltage1..4 – *Current()* × Cell Resistance ≤ ***CUVC: Threshold***	*SafetyAlert()[CUVC]* = 1 *BatteryStatus()[TDA]* = 1
Trip	Min cell voltage1..4 – *Current()* × Cell Resistance ≤ ***CUVC: Threshold*** for ***CUVC:Delay*** duration	*SafetyAlert()[CUVC]* = 0 *SafetyStatus()[CUVC]* = 0 *BatteryStatus()[FD]* = 1, *[TDA]* = 0 *OperationStatus()[XDSG]* = 1

Status	Condition	Action
Recovery	Condition 1: *SafetyAlert()[CUVC]* = 1 AND Min cell voltage1..4 – *Current()* × Cell Resistance > ***CUVC: Recovery*** AND ***Protection Configuration[CUV_RECOV_CHG]*** = 0	*SafetyStatus()[CUVC]* = 0 *BatteryStatus()[FD]* = 0, *[TDA]* = 0 *OperationStatus()[XDSG]* = 0
	OR Condition 2: *SafetyAlert()[CUVC]* = 1 AND Min cell voltage1..4 – *Current()* × Cell Resistance > ***CUVC: Recovery*** AND ***Protection Configuration[CUV_RECOV_CHG]*** = 1 AND Charging detected (that is, *BatteryStatus()[DSG]* = 0)	

2.4 Cell Overvoltage Protection

The device can detect cell overvoltage in batteries and protect cells from damage by preventing further charging.

> **NOTE:** The protection detection threshold may be influenced by the temperature settings of the advanced charging algorithm and the measured temperature.

Status	Condition	Action
Normal, *ChargingStatus()[UT] or [LT]* = 1	Max cell voltage1..4 < ***COV:Threshold Low Temp***	*SafetyAlert()[COV]* = 0
Normal, *ChargingStatus()[STL] or [STH]* = 1	Max cell voltage1..4 < ***COV:Threshold Standard Temp***	*SafetyAlert()[COV]* = 0
Normal, *ChargingStatus()[RT]* = 1	Max cell voltage1..4 < ***COV:Threshold Rec Temp***	*SafetyAlert()[COV]* = 0
Normal, *ChargingStatus()[HT] or [OT]* = 1	Max cell voltage1..4 < ***COV:Threshold High Temp***	*SafetyAlert()[COV]* = 0
Alert, *ChargingStatus()[UT] or [LT]* = 1	Max cell voltage1..4 ≥ ***COV:Threshold Low Temp***	*SafetyAlert()[COV]* = 1 *BatteryStatus()[TCA]* = 1
Alert, *ChargingStatus()[STL] or [STH]* = 1	Max cell voltage1..4 ≥ ***COV:Threshold Standard Temp***	*SafetyAlert()[COV]* = 1 *BatteryStatus()[TCA]* = 1
Alert, *ChargingStatus()[RT]* = 1	Max cell voltage1..4 ≥ ***COV:Threshold Rec Temp***	*SafetyAlert()[COV]* = 1 *BatteryStatus()[TCA]* = 1
Alert, *ChargingStatus()[HT] or [OT]* = 1	Max cell voltage1..4 ≥ ***COV:Threshold High Temp***	*SafetyAlert()[COV]* = 1 *BatteryStatus()[TCA]* = 1
Trip, *ChargingStatus()[UT] or [LT]* = 1	Max cell voltage1..4 ≥ ***COV:Threshold Low Temp*** for ***COV:Delay*** duration	*SafetyAlert()[COV]* = 0 *SafetyStatus()[COV]* = 1 *BatteryStatus()[TCA]* = 0 *OperationStatus()[XCHG]* = 1
Trip, *ChargingStatus()[STL] or [STH]* = 1	Max cell voltage1..4 ≥ ***COV:Threshold Standard Temp*** for ***COV:Delay*** duration	*SafetyAlert()[COV]*= 0 *SafetyStatus()[COV]* = 1 *BatteryStatus()[TCA]* = 0 *OperationStatus()[XCHG]* = 1
Trip, *ChargingStatus()[RT]* = 1	Max cell voltage1..4≥ ***COV:Threshold Rec Temp*** for ***COV:Delay*** duration	*SafetyAlert()[COV]*= 0 *SafetyStatus()[COV]* = 1 *BatteryStatus()[TCA]* = 0 *OperationStatus()[XCHG]* = 1
Trip, *ChargingStatus()[HT] or [OT]* = 1	Max cell voltage1..4 ≥ ***COV:Threshold High Temp*** for ***COV:Delay*** duration	*SafetyAlert()[COV]*= 0 *SafetyStatus()[COV]* = 1 *BatteryStatus()[TCA]* = 0 *OperationStatus()[XCHG]* = 1
Recovery, *ChargingStatus()[UT] or [LT]* = 1	*SafetyStatus()[COV]* = 1 AND Max cell voltage1..4 ≤ ***COV:Recovery Low Temp***	*SafetyStatus()[COV]* = 0 *BatteryStatus()[TCA]* = 0 *OperationStatus()[XCHG]* = 0
Recovery, *ChargingStatus()[STL] or [STH]* = 1	*SafetyStatus()[COV]* = 1 AND Max cell voltage1..4 ≤ ***COV:Recovery Standard Temp***	*SafetyStatus()[COV]* = 0 *BatteryStatus()[TCA]* = 0 *OperationStatus()[XCHG]* = 0
Recovery, *ChargingStatus()[RT]* = 1	*SafetyStatus()[COV]* = 1 AND Max cell voltage1..4 ≤ ***COV:Recovery Rec Temp***	*SafetyStatus()[COV]* = 0 *BatteryStatus()[TCA]* = 0 *OperationStatus()[XCHG]* = 0
Recovery, *ChargingStatus()[HT] or [OT]* = 1	*SafetyStatus()[COV]* = 1 AND Max cell voltage1..4 ≤ ***COV:Recovery High Temp***	*SafetyStatus()[COV]* = 0 *BatteryStatus()[TCA]* = 0 *OperationStatus()[XCHG]* = 0

2.5 Overcurrent in Charge Protection

The device has two independent overcurrent in charge protections that can be set to different current and delay thresholds to accommodate different charging behaviors.

Status	Condition	Action
Normal	*Current()* < ***OCC1:Threshold***	*SafetyAlert()[OCC1]* = 0
Normal	*Current()* < ***OCC2:Threshold***	*SafetyAlert()[OCC2]* = 0
Alert	*Current()* ≥ ***OCC1:Threshold***	*SafetyAlert()[OCC1]* = 1 *BatteryStatus()[TCA]* = 1
Alert	*Current()* ≥ ***OCC2:Threshold***	*SafetyAlert()[OCC2]* = 1 *BatteryStatus()[TCA]* = 1
Trip	*Current()* continuous ≥ ***OCC1:Threshold*** for ***OCC1:Delay*** duration	*SafetyAlert()[OCC1]* = 0 *SafetyStatus()[OCC1]* = 1 *BatteryStatus()[TCA]* = 0 Charging is not allowed. *OperationStatus()[XCHG]* = 1
Trip	*Current()* continuous ≥ ***OCC2:Threshold*** for ***OCC2:Delay*** duration	*SafetyAlert()[OCC2]* = 0 *SafetyStatus()[OCC2]* = 1 *BatteryStatus()[TCA]* = 0 *OperationStatus()[XCHG]* = 1
Recovery	*SafetyStatus()[OCC1]* = 1 AND *Current()* continuous ≤ ***OCC:Recovery Threshold*** for ***OCC:Recovery Delay*** time	*SafetyStatus()[OCC1]* = 0 *BatteryStatus()[TCA]* = 0 *OperationStatus()[XCHG]* = 0
Recovery	*SafetyStatus()[OCC2]* = 1 AND *Current()* continuous ≤ ***OCC:Recovery Threshold*** for ***OCC:Recovery Delay*** time	*SafetyStatus()[OCC2]* = 0 *BatteryStatus()[TCA]* = 0 *OperationStatus()[XCHG]* = 0

2.6 Overcurrent in Discharge Protection

The device has two independent overcurrent in discharge protections that can be set to different current and delay thresholds to accommodate different load behaviors.

Status	Condition	Action
Normal	*Current()* > ***OCD1:Threshold***	*SafetyAlert()[OCD1]* = 0
Normal	*Current()* > ***OCD2:Threshold***	*SafetyAlert()[OCD2]* = 0
Alert	*Current()* ≤ ***OCD1:Threshold***	*SafetyAlert()[OCD1]* = 1 *BatteryStatus()[TDA]* = 1
Alert	*Current()* ≤ ***OCD2:Threshold***	*SafetyAlert()[OCD2]* = 1 *BatteryStatus()[TDA]* = 1
Trip	*Current()* continuous ≤ ***OCD1:Threshold*** for ***OCD1:Delay*** duration	*SafetyAlert()[OCD1]* = 0 *SafetyStatus()[OCD1]* = 1 *BatteryStatus()[TDA]* = 0 *OperationStatus()[XDSG]* = 1
Trip	*Current()* continuous ≤ ***OCD2:Threshold*** for ***OCD2:Delay*** duration	*SafetyAlert()[OCD2]* = 0 *SafetyStatus()[OCD2]* = 1 *BatteryStatus()[TDA]* = 0 *OperationStatus()[XDSG]* = 1
Recovery	*SafetyStatus()[OCD1]* = 1 AND *Current()* continuous ≥ ***OCC:Recovery Threshold*** for ***OCC:Recovery Delay*** time	*SafetyStatus()[OCD1]* = 0 *BatteryStatus()[TDA]* = 0 *OperationStatus()[XDSG]* = 0
Recovery	*SafetyStatus()[OCD2]* = 1 AND *Current()* continuous ≥ ***OCC:Recovery Threshold*** for ***OCC:Recovery Delay*** time	*SafetyStatus()[OCD2]* = 0 *BatteryStatus()[TDA]* = 0 *OperationStatus()[XDSG]* = 0

2.7 Hardware-Based Protection

The bq40z50 device has three main hardware-based protections—AOLD, ASCC, and ASCD1,2—with adjustable current and delay time. Setting ***AFE Protection Configuration[RSNS]*** divides the threshold value in half. The ***Threshold*** settings are in mV; therefore, the actual current that triggers the protection is based on the R_{SENSE} used in the schematic design.

In addition, setting the ***AFE Protection Configuration[SCDDx2]*** bit provides an option to double all of the SCD1,2 delay times for maximum flexibility towards the application's needs.

For details on how to configure the AFE hardware protection, refer to the tables in Appendix A.

All of the hardware-based protections provide a Trip/Latch Alert/Recovery protection. The latch feature stops the FETs from toggling on and off continuously on a persistent faulty condition.

In general, when a fault is detected after the ***Delay*** time, both CHG and DSG FETs will be disabled (Trip stage), and an internal fault counter will be incremented (Alert stage). Since both FETs are off, the current will drop to 0 mA. After ***Recovery*** time, the CHG and DSG FETs will be turned on again (Recovery stage).

If the alert is caused by a current spike, the fault count will be decremented after ***Counter Dec Delay*** time. If this is a persistent faulty condition, the device will enter the Trip stage after ***Delay*** time, and repeat the Trip/Latch Alert/Recovery cycle. The internal fault counter is incremented every time the device goes through the Trip/Latch Alert/Recovery cycle. Once the internal fault counter hits the ***Latch Limit***, the protection enters a Latch stage and the fault will only be cleared through the Latch Reset condition.

The Trip/Latch Alert/Recovery/Latch stages are documented in each of the following hardware-based protection sections.

The recovery condition for removable pack (***[NR]*** = 0) is based on the transition on the $\overline{\text{PRES}}$ pin, while the recovery condition for embedded pack (***[NR]*** = 1) is based on the ***Reset*** time.

2.7.1 Overload in Discharge Protection

The device has a hardware-based overload in discharge protection with adjustable current and delay.

Status	Condition	Action
Normal	*Current()* > (***OLD Threshold[3:0]***/R_{SENSE})	*SafetyAlert()[AOLDL]* = 0, if OLDL counter = 0
Trip	*Current()* continuous ≤ (***OLD Threshold[3:0]***/R_{SENSE}) for ***OLD Threshold[7:4]*** duration	*SafetyStatus()[AOLD]* = 1 *OperationStatus()[XDSG]* = 1 Increment AOLDL counter
Recovery	*SafetyStatus()[AOLD]* = 1 for ***OLD:Recovery*** time	*SafetyStatus()[AOLD]* = 0 *OperationStatus()[XDSG]* = 0 if *SafetyStatus()[AOLDL]* = 0.
Latch Alert	AOLDL counter > 0	*SafetyAlert()[AOLDL]* = 1 Decrement AOLDL counter by one after each ***OLD:Counter Dec Delay*** period
Latch Trip	AOLDL counter ≥ ***OLD:Latch Limit***	*SafetyAlert()[AOLDL]* = 0 *SafetyStatus()[AOLDL]* = 1 *OperationStatus()[XDSG]* = 1
Latch Reset (***[NR]*** = 0)	*SafetyStatus()[AOLDL]* = 1 AND ***DA Configuration[NR]*** = 0 AND Low-high-low transition on $\overline{\text{PRES}}$ pin	*SafetyStatus()[AOLDL]* = 0 Reset AOLDL counter *OperationStatus()[XDSG]* = 0 if *SafetyStatus()[AOLD]* = 0.
Latch Reset (***[NR]*** = 1)	*SafetyStatus()[AOLDL]* = 1 AND ***DA Configuration[NR]*** = 1 for ***OLD:Reset*** time	*SafetyStatus()[AOLDL]* = 0 Reset AOLDL counter *OperationStatus()[XDSG]* = 0 if *SafetyStatus()[AOLD]* = 0.

2.7.2 Short Circuit in Charge Protection

The device has a hardware based short circuit in charge protection with adjustable current and delay.

Status	Condition	Action
Normal	*Current()* < (***SCC Threshold[2:0]***/R_{SENSE})	*SafetyAlert()[ASCCL]* = 0, if ASCCL counter = 0
Trip	*Current()* continuous ≥ (***SCC Threshold[2:0]***/R_{SENSE}) for ***SCC Threshold[7:4]*** duration	*SafetyStatus()[ASCC]* = 1 *BatteryStatus()[TCA]* = 1 *OperationStatus()[XCHG]* = 1 increment ASCCL counter
Recovery	*SafetyStatus()[ASCC]* = 1 for ***SCC:Recovery*** time	*SafetyStatus()[ASCC]* = 0 *BatteryStatus()[TCA]* = 0 *OperationStatus()[XCHG]* = 0 if *SafetyStatus()[ASCCL]* = 0.
Latch Alert	ASCCL counter > 0	*SafetyAlert()[ASCCL]* = 1 Decrement ASCCL counter by one after each ***SCC:Counter Dec Delay*** period
Latch Trip	ASCCL counter ≥ ***SCC:Latch Limit***	*SafetyAlert()[ASCCL]* = 0 *SafetyStatus()[ASCCL]* = 1 *OperationStatus()[XCHG]* = 1
Latch Reset (***[NR]*** = 0)	*SafetyStatus()[ASCCL]* = 1 AND ***DA Configuration[NR]*** = 0 AND Low-high-low transition on $\overline{\text{PRES}}$ pin	*SafetyStatus()[ASCCL]* = 0 *OperationStatus()[XCHG]* = 0 if *SafetyStatus()[ASCC]* = 0.
Latch Reset (***[NR]*** = 1)	*SafetyStatus()[ASCCL]* = 1 AND ***DA Configuration[NR]*** = 1 for ***SCC:Reset*** time	*SafetyStatus()[ASCCL]* = 0 *OperationStatus()[XCHG]* = 0 if *SafetyStatus()[ASCC]* = 0.

2.7.3 Short Circuit in Discharge Protection

The device has a hardware based short circuit in discharge protection with adjustable current and delay.

Status	Condition	Action
Normal	*Current()* > (***SCD1 Threshold[2:0]***/R_{SENSE}) AND *Current()* > (***SCD2 Threshold[2:0]***/R_{SENSE})	*SafetyAlert()[ASCDL]* = 0 if ASCDL counter = 0
Trip	*Current()* continuous ≤ (***SCD1 Threshold[2:0]***/R_{SENSE}) for ***SCD1 Threshold[7:4]*** duration OR *Current()* continuous ≤ (***SCD2 Threshold[2:0]***/R_{SENSE}) for ***SCD2 Threshold[7:4]*** duration	*SafetyStatus()[ASCD]* = 1 *OperationStatus()[XDSG]* = 0 Increment ASCDL counter
Recovery	*SafetyStatus()[ASCD]* = 1 for ***SCD:Recovery*** time	*SafetyStatus()[ASCD]* = 0 *OperationStatus()[XDSG]* = 0 if *SafetyStatus()[ASCDL]* = 0.
Latch Alert	ASCDL counter > 0	*SafetyAlert()[ASCDL]* = 1 Decrement ASCDL counter by one after each ***SCD:Counter Dec Delay*** period
Latch Trip	SCD counter ≥ ***SCD:Latch Limit***	*SafetyStatus()[ASCD]* = 0 *SafetyStatus()[ASCDL]* = 1 *OperationStatus()[XDSG]* = 1
Latch Reset (***[NR]*** = 0)	*SafetyStatus()[ASCDL]* = 1 AND ***DA Configuration[NR]*** = 0 AND Low-high-low transition on $\overline{\text{PRES}}$ pin	*SafetyStatus()[ASCDL]* = 0 *OperationStatus()[XDSG]* = 0 if *SafetyStatus()[ASCD]* = 0.
Latch Reset (***[NR]*** = 1)	*SafetyStatus()[ASCCL]* = 1 AND ***DA Configuration[NR]*** = 1 for ***SCD:Reset*** time	*SafetyStatus()[ASCDL]* = 0 *OperationStatus()[XDSG]* = 0 if *SafetyStatus()[ASCD]* = 0.

2.8 Temperature Protections

The device provides overtemperature and undertemperature protections based on Cell Temperature measurement and FET temperature measurements. The Cell Temperature based protections are further divided into a protection-in-charging direction and discharging directions. This section describes in detail each of the protection functions.

For temperature reporting, the device supports a maximum of four external thermistors and one internal temperature sensor. Unused temperature sensors must be disabled by clearing the corresponding flag in ***Settings:Temperature Enable[TS4][TS3][TS2][TS1][TSInt]***.

Each of the external thermistors and the internal temperature sensor can be set up individually as a source for Cell Temperature or FET Temperature reporting. Setting the corresponding flag to 1 in ***Settings:Temperature Mode[TS4 Mode][TS3 Mode][TS2 Mode][TS1 Mode][TSInt Mode]*** configures that temperature sensor to report for FET Temperature. Clearing the corresponding flag sets that temperature sensor to report for Cell Temperature. The ***Settings:DA Configuration[FTEMP][CTEMP]*** allows users to use the maximal (setting the corresponding flag to 0) or the average (setting the corresponding flag to 1) of the source temperature sensors for Cell Temperature and FET Temperature reporting.

The *Temperature()* command returns the Cell Temperature measurement. The MAC and extended command *DAStatus2()* also returns the temperature measurement from the internal temperature sensor, the external thermistors TS1, TS2, TS3, and TS4, and the Cell and FET Temperatures.

The Cell Temperature based overtemperature and undertemperature safety provide protections in charge and discharge conditions. The battery pack is considered in CHARGE mode when *BatteryStatus()[DSG]* = 0, where *Current()* > ***Chg Current Threshold***. The overtemperature and undertemperature in charging protections are active in this mode. The *BatteryStatus()[DSG]* is set to 1 in a NON-CHARGE mode condition, which includes RELAX and DISCHARGE modes. The overtemperature and undertemperature in discharge protections are active in these two modes. See Section 6.3 for detailed descriptions of the gas gauge modes.

2.9 Overtemperature in Charge Protection

The device has an overtemperature protection for cells under charge.

Status	Condition	Action
Normal	*Temperature()* < ***OTC:Threshold*** OR not charging	*SafetyAlert()[OTC]* = 0
Alert	*Temperature()* ≥ ***OTC:Threshold*** AND charging	*SafetyAlert()[OTC]* = 1 *BatteryStatus()[TCA]* = 1
Trip	*Temperature()* ≥ ***OTC:Threshold*** AND Charging for ***OTC:Delay*** duration	*SafetyAlert()[OTC]* = 0 *SafetyStatus()[OTC]* = 1 *BatteryStatus()[OTA]* = 1 *BatteryStatus()[TCA]* = 0 *OperationStatus()[XCHG]* = 1 if ***FET Options[OTFET]*** = 1.
Recovery	*SafetyStatus()[OTC]* AND *Temperature()* ≤ ***OTC:Recovery***	*SafetyStatus()[OTC]* = 0 *BatteryStatus()[OTA]* = 0 *BatteryStatus()[TCA]* = 0 *OperationStatus()[XCHG]* = 0

2.10 Overtemperature in Discharge Protection

The device has an overtemperature protection for cells in DISCHARGE or RELAX state (that is, non-charging state with *BatteryStatus[DSG]* = 1).

Status	Condition	Action
Normal	*Temperature()* < ***OTD:Threshold*** OR charging	*SafetyAlert()[OTD]* = 0
Alert	*Temperature()* ≥ ***OTD:Threshold*** AND Not charging (that is, *BatteryStatus[DSG]* = 1)	*SafetyAlert()[OTD]* = 1 *BatteryStatus()[TDA]* = 1
Trip	*Temperature()* ≥ ***OTD:Threshold*** AND Not charging (that is, *BatteryStatus[DSG]* = 1) for ***OTD:Delay*** duration	*SafetyAlert()[OTD]* = 0 *SafetyStatus()[OTD]* = 1 *BatteryStatus()[OTA]* = 1 *OperationStatus()[XDSG]* = 1 if ***FET Options[OTFET]*** = 1. *BatteryStatus()[TDA]* = 0
Recovery	*SafetyStatus()[OTD]* AND *Temperature()* ≤ ***OTD:Recovery***	*SafetyStatus()[OTD]* = 0 *BatteryStatus()[OTA]* = 0 *OperationStatus()[XDSG]* = 0 *BatteryStatus()[TDA]* = 0

2.11 Overtemperature FET Protection

The device has an overtemperature protection to limit the FET temperature.

Status	Condition	Action
Normal	FET Temperature in *DAStatus2()* < ***OTF:Threshold***	*SafetyAlert()[OTF]* = 0
Alert	FET Temperature in *DAStatus2()* ≥ ***OTF:Threshold***	*SafetyAlert()[OTF]* = 1 *BatteryStatus()[TDA]* = 1, *[TCA]* = 1
Trip	FET Temperature in *DAStatus()* ≥ ***OTF:Threshold*** for ***OTF:Delay*** duration	*SafetyAlert()[OTF]* = 0 *SafetyStatus()[OTF]* = 1 *BatteryStatus()[OTA]* = 1 *BatteryStatus()[TDA]* = 0, *[TCA]* = 0 *OperationStatus()[XCHG][XDSG]* = 1,1 if ***FET Options[OTFET]*** = 1
Recovery	*SafetyStatus()[OTF]* AND FET Temperature in *DAStatus2()* ≤ ***OTF:Recovery***	*SafetyStatus()[OTF* = 0 *BatteryStatus()[OTA]* = 0 *BatteryStatus()[TDA]* = 0, *[TCA]* = 0 *OperationStatus()[XCHG][XDSG]* = 0,0

2.12 Undertemperature in Charge Protection

The device has an undertemperature protection for cells in charge direction.

Status	Condition	Action
Normal	*Temperature()* > ***UTC:Threshold*** OR not charging	*SafetyAlert()[UTC]* = 0
Alert	*Temperature()* ≤ ***UTC:Threshold*** AND charging	*SafetyAlert()[UTC]* = 1
Trip	*Temperature()* ≤ ***UTC:Threshold*** AND Charging for ***UTC:Delay*** duration	*SafetyAlert()[UTC]* = 0 *SafetyStatus()[UTC]* = 1 *OperationStatus()[XCHG]* = 1
Recovery	*SafetyStatus()[UTC]* AND *Temperature()* ≥ ***UTC:Recovery***	*SafetyStatus()[UTC]* = 0 *OperationStatus()[XCHG]* = 0

2.13 Undertemperature in Discharge Protection

The device has an undertemperature protection for cells in DISCHARGE or RELAX state (that is, non-charging state with *BatteryStatus[DSG]* = 1).

Status	Condition	Action
Normal	*Temperature()* > ***UTD:Threshold*** OR charging	*SafetyAlert()[UTD]* = 0
Alert	*Temperature()* ≤ ***UTD:Threshold*** AND Not charging (that is, *BatteryStatus[DSG]* = 1)	*SafetyAlert()[UTD]* = 1
Trip	*Temperature()* ≤ ***UTD:Threshold*** AND Not charging (that is, *BatteryStatus[DSG]* = 1) for ***UTD:Delay*** duration	*SafetyAlert()[UTD]* = 0 *SafetyStatus()[UTD]* = 1 *OperationStatus()[XDSG]* = 1
Recovery	*SafetyStatus()[UTD]* AND *Temperature()* ≥ ***UTD:Recovery***	*SafetyStatus()[UTD]* = 0 *OperationStatus()[XDSG]* = 0

2.14 SBS Host Watchdog Protection

The device can check periodic communication over SBS and prevent usage of the battery pack if no valid communication is detected.

Status	Condition	Action
Trip	No valid SBS transaction for ***HWD:Delay*** duration	*SafetyStatus()[HWD]* = 1 *OperationStatus()[XCHG]* = 1
Recovery	Valid SBS transaction detected	*SafetyStatus()[HWD]* = 0 *OperationStatus()[XCHG]* = 0

2.15 Precharge Timeout Protection

The device can measure the precharge time and stop charging if it exceeds the adjustable period.

Status	Condition	Action
Enable	*Current()* > ***PTO:Charge Threshold*** AND *ChargingStatus()[PV]* = 1	Start PTO timer *SafetyAlert()[PTOS]* = 0
Suspend or Recovery	*Current()* < ***PTO:Suspend Threshold***	Stop PTO timer *SafetyAlert()[PTOS]* = 1
Trip	PTO timer > ***PTO:Delay***	Stop PTO timer *SafetyStatus()[PTO]* = 1 *BatteryStatus()[TCA]* = 1 *OperationStatus()[XCHG]* = 1
Reset	*SafetyStatus()[PTO]* = 1 AND ***DA Configuration[NR]*** = 0 AND (Discharge by an amount of ***PTO:Reset*** OR low-high-low transition on $\overline{\text{PRES}}$)	Stop and reset PTO timer *SafetyAlert()[PTOS]* = 0 *SafetyStatus()[PTO]* = 0 *BatteryStatus()[TCA]* = 0 *OperationStatus()[XCHG]* = 0
Reset	*SafetyStatus()[PTO]* = 1 AND ***DA Configuration[NR]*** = 1 AND (Discharge by an amount of ***PTO:Reset***)	Stop and reset PTO timer *SafetyAlert()[PTOS]* = 0 *SafetyStatus()[PTO]* = 0 *BatteryStatus()[TCA]* = 0 *OperationStatus()[XCHG]* = 0

2.16 Fast Charge Timeout Protection

The device can measure the charge time and stop charging if it exceeds the adjustable period.

Status	Condition	Action
Enable	*Current()* > ***CTO:Charge Threshold*** AND (*ChargingStatus()[LV]* = 1 OR *ChargingStatus()[MV]* = 1 OR *ChargingStatus()[HV]* = 1)	Start CTO timer *SafetyAlert()[CTOS]* = 0
Suspend or Recovery	*Current()* < ***CTO:Suspend Threshold***	Stop CTO timer *SafetyAlert()[CTOS]* = 1

Status	Condition	Action
Trip	CTO time > ***CTO:Delay***	Stop CTO timer *SafetyStatus()[CTO]* = 1 *BatteryStatus()[TCA]* = 1 *OperationStatus()[XCHG]* = 1
Reset	*SafetyStatus()[CTO]* = 1 AND ***DA Configuration[NR]*** = 0 AND (Discharge by an amount of ***CTO:Reset*** OR low-high-low transition on $\overline{\text{PRES}}$)	Stop and reset CTO timer *SafetyAlert()[CTOS]* = 0 *SafetyStatus()[CTO]* = 0 *BatteryStatus()[TCA]* = 0 *OperationStatus()[XCHG]* = 0
Reset	*SafetyStatus()[CTO]* = 1 AND ***DA Configuration[NR]*** = 1 AND (Discharge by an amount of ***CTO:Reset***)	Stop and reset CTO timer *SafetyAlert()[CTOS]* = 0 *SafetyStatus()[CTO]* = 0 *BatteryStatus()[TCA]* = 0 *OperationStatus()[XCHG]* = 0

2.17 Overcharge Protection

The device can prevent continuing charging if the pack is charged in excess over *FullChargeCapacity()*.

Status	Condition	Action
Normal	*RemainingCapacity()* < *FullChargeCapacity()*	*SafetyAlert()[OC]* = 0
Alert	*RemainingCapacity()* ≥ *FullChargeCapacity()* AND Internal charge counter > 0	*SafetyAlert()[OC]* = 1 *BatteryStatus()[TCA]* = 1
Trip	*RemainingCapacity()* ≥ *FullChargeCapacity()* AND Internal charge counter ≥ ***OC:Threshold***	*SafetyAlert()[OC]* = 0 *SafetyStatus()[OC]* = 1 *BatteryStatus()[TCA]* = 0, *[OCA]* = 1 if the device is in charge state (that is, *BatteryStatus[DSG]* = 0). *OperationStatus()[XCHG]* = 1
Recovery, ***[NR]*** = 0	*SafetyStatus()[OC]* = 1 AND ***DA Configuration[NR]*** = 0 AND (Low-high-low transition on $\overline{\text{PRES}}$ pin)	*SafetyStatus()[OC]* = 0 *BatteryStatus()[TCA]* = 0, *[OCA]* = 0 *OperationStatus()[XCHG]* = 0
Recovery ***[NR]*** = 1	Condition 1: *SafetyStatus()[OC]* = 1 AND ***DA Configuration[NR]*** = 1 AND continuous discharge of ***Recovery*** OR Condition 2: *SafetyStatus()[OC]* = 1 AND ***DA Configuration[NR]*** = 1 AND *RelativeStateOfCharge()* < ***OC:RSOC Recovery***	*SafetyStatus()[OC]* = 0 *BatteryStatus()[TCA]* = 0, *[OCA]* = 0 *OperationStatus()[XCHG]* = 0

2.18 OverChargingVoltage() Protection

The device can stop charging if it measures a difference between the requested *ChargingVoltage()* and the delivered voltage from the charger.

NOTE: *ChargingVoltage()* will be set to 0 mV when the protection is tripped. The *ChargingVoltage()* for the recovery is the intended or targeted Charging Voltage, not the 0 mV that was set due to the trip of protection.

Status	Condition	Action
Normal	Pack pin voltage in *DAStatus1()* < *ChargingVoltage()* + ***CHGV:Threshold***	*SafetyAlert()[CHGV]* = 0
Alert	Pack pin voltage in *DAStatus1()* ≥ *ChargingVoltage()* + ***CHGV:Threshold***	*SafetyAlert()[CHGV]* = 1 *BatteryStatus()[TCA]* = 1
Trip	Pack pin voltage in *DAStatus1()* continuous ≥ *ChargingVoltage()* + ***CHGV:Threshold*** for ***CHGV:Delay*** period	*SafetyAlert()[CHGV]* = 0 *SafetyStatus()[CHGV]* = 1 *BatteryStatus()[TCA]* = 0 *OperationStatus()[XCHG]* = 1
Recovery	SafetyStatus()[CHGV] = 1 AND Pack pin voltage in *DAStatus1()* ≤ intended *ChargingVoltage()* + ***CHGV Recovery***	*SafetyStatus()[CHGV]* = 0 *BatteryStatus()[TCA]* = 0 *OperationStatus()[XCHG]* = 0

2.19 OverChargingCurrent() Protection

The device can stop charging if it measures a difference between the requested *ChargingCurrent()* and the delivered current from the charger. This protection is designed to recover by a discharge event; therefore, ***CHGC:Recovery*** should be set to a negative value in data flash.

Status	Condition	Action
Normal	*Current()* < *ChargingCurrent()* + ***CHGC:Threshold***	*SafetyAlert()[CHGC]* = 0
Alert	*Current()* ≥ *ChargingCurrent()* + ***CHGC:Threshold***	*SafetyAlert()[CHGC]* = 1 *BatteryStatus()[TCA]* = 1
Trip	*Current()* continuous ≥ *ChargingCurrent()* + ***CHGC:Threshold*** for ***CHGC:Delay*** period	*SafetyAlert()[CHGC]* = 0 *SafetyStatus()[CHGC]* = 1 *BatteryStatus()[TCA]* = 0 *OperationStatus()[XCHG]* = 1
Recovery	*SafetyStatus()[CHGC]* = 1 AND *Current()* ≤ ***CHGC:Recovery Threshold*** for ***CHGC:Recovery Delay*** time	*SafetyStatus()[CHGC]* = 0 *BatteryStatus()[TCA]* = 0 *OperationStatus()[XCHG]* = 0

2.20 OverPreChargingCurrent() Protection

The device can stop charging if it measures a difference between the requested *ChargingCurrent()* and the delivered current from the charger during precharge. This protection is designed to recover by a discharge event; therefore, ***PCHGC:Recovery*** should be set to a negative value in data flash.

Status	Condition	Action
Normal	*Current()* < *ChargingCurrent()* + ***PCHGC:Threshold*** AND *ChargingStatus()[PV]* = 1	*SafetyAlert()[PCHGC]* = 0
Alert	*Current()* ≥ *ChargingCurrent()* + ***PCHGC:Threshold*** AND *ChargingStatus()[PV]* = 1	*SafetyAlert()[PCHGC]* = 1 *BatteryStatus()[TCA]* = 1
Trip	*Current()* continuous ≥ *ChargingCurrent()* + ***PCHGC:Threshold*** for ***PCHGC:Delay*** period AND *ChargingStatus()[PV]* = 1	*SafetyAlert()[PCHGC]* = 0 *SafetyStatus()[PCHGC]* = 1 If charging, *BatteryStatus()[TCA]* = 0 *OperationStatus()[XCHG]* = 1
Recovery	*SafetyStatus()[PCHGC]* = 1 AND *Current()* ≤ ***PCHGC:Recovery Threshold*** for ***PCHGC:Recovery Delay*** time	*SafetyStatus()[PCHGC]* = 0 *BatteryStatus()[TCA]* = 0 *OperationStatus()[XCHG]* = 0

Permanent Fail

3.1 Introduction

The device can permanently disable the use of the battery pack in case of a severe failure. The permanent failure checks, except for IFC and DFW, can be individually enabled or disabled by setting the appropriate bit in ***Settings:Enabled PF A***, ***Settings:Enabled PF B***, ***Settings:Enabled PF C***, and ***Settings:Enabled PF D***. All permanent failure checks, except for IFC and DFW, are disabled until *ManufacturingStatus()[PF]* is set. When any *PFStatus()* bit is set, the device enters PERMANENT FAIL mode and the following actions are taken in sequence:

1. Precharge, charge, and discharge FETs are turned off.
2. *OperationStatus()[PF]* = 1, *[XCHG]* = 1, *[XDSG]* = 1
3. The following SBS data is changed: *BatteryStatus()[TCA]* = 1, *BatteryStatus()[TDA]* = 1, *ChargingCurrent()* = 0, and *ChargingVoltage()* = 0.
4. A backup of the internal AFE hardware registers are written to data flash: ***AFE Interrupt Status***, ***AFE FET Status***, ***AFE RXIN***, ***AFE Latch Status***, ***AFE Interrupt Enable***, ***AFE FET Control***, ***AFE RXIEN***, ***AFE RLOUT***, ***AFE RHOUT***, ***AFE RHINT***, ***AFE Cell Balance***, ***AFE AD/CC Control***, ***AFE ADC Mux***, ***AFE LED Output***, ***AFE State Control***, ***AFE LED/Wake Control***, ***AFE Protection Control***, ***AFE OCD***, ***AFE SCC***, ***AFE SCD1***, and ***AFE SCD2***.
5. The black box data of the last three *SafetyStatus()* changes leading up to PF with the time difference is written into the black box data flash along with the 1st *PFStatus()* value.
6. The following SBS values are preserved in data flash for failure analysis:
   - *SafetyAlert()*
   - *SafetyStatus()*
   - *PFAlert()*
   - *PFStatus()*
   - *OperationStatus()*
   - *ChargingStatus()*
   - *GaugingStatus()*
   - Voltages in *DAStatus1()*
   - *Current()*
   - TSINT, TS1, TS2, TS3, and TS4 from *DAStatus2()*
   - Cell DOD0 and passed charge
7. Data flash writing is disabled (except to store subsequent *PFStatus()* flags).
8. The FUSE pin is driven high if configured for specific failures and *Voltage()* is above ***Min Blow Fuse Voltage*** or there is a CHG FET (CFETF) or DSG FET (DFETF) failure. The FUSE pin will remain asserted until the ***Fuse Blow Timeout*** expired.

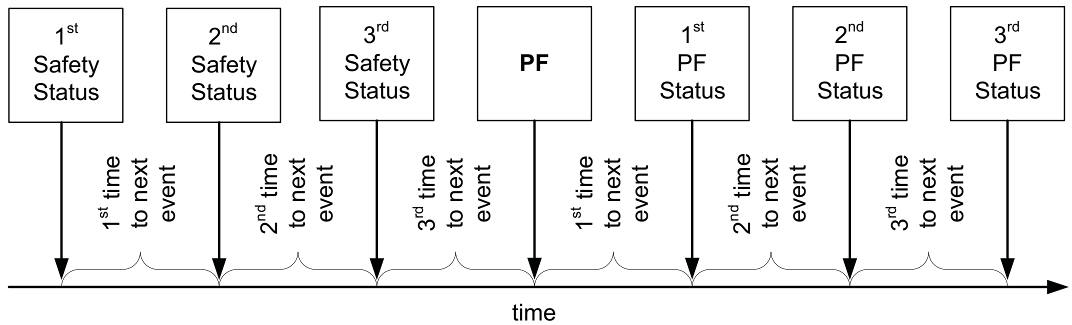
NOTE: If ***[PACK_FUSE]*** = 0, *Voltage()* is used to check for ***Min Blow Fuse Voltage***, indicating the fuse is connected to the BAT side.

If ***[PACK_FUSE]*** = 1 (that is, Fuse is connected to the PACK side and is required to have a charger connected in order to blow the fuse), then the pack voltage is used to check for ***Min Blow Fuse Voltage*** threshold.

While the device is in PERMANENT FAIL mode, any new *SafetyAlert()*, *SafetyStatus()*, *PFAlert()*, and *PFStatus()* flags that are set are added to the permanent fail log. Any new *PFStatus()* flags that occur during PERMANENT FAIL mode can trigger the FUSE pin. In addition, new *PFStatus()* flags are recorded in the Black Box Recorder 2nd and 3rd PF Status entries.

3.1.1 Black Box Recorder

The Black Box Recorder maintains the last three updates of *SafetyStatus()* in memory. When entering PERMANENT FAIL mode, this information is written to data flash together with the first three updates of *PFStatus()* after the PF event.



NOTE: This information is useful in failure analysis, and can provide a full recording of the events and conditions leading up to the permanent failure.

If there were less than three safety events before PF, then some information will be left blank.

3.2 Safety Cell Undervoltage Permanent Fail

The device can permanently disable the battery in the case of severe undervoltage in any of the cells.

Status	Condition	Action
Normal	Min cell voltage1..4 > ***SUV:Threshold***	*PFAlert()[SUV]* = 0 *BatteryStatus()[TDA]* = 0
Alert	Min cell voltage1..4 ≤ ***SUV:Threshold***	*PFAlert()[SUV]* = 1 *BatteryStatus()[TDA]* = 1
Trip	Min cell voltage1..4 continuous ≤ ***SUV:Threshold*** for ***SUV:Delay*** duration	*PFAlert()[SUV]* = 0 *PFStatus()[SUV]* = 1 *BatteryStatus()[FD]* = 1

3.2.1 SUV Check Option

When ***Protection Configuration[SUV_MODE]*** is set, the SUV PF check only applies when the gauge wakes up from shutdown. The CHG and DSG FETs are disabled for the duration of the test (***SUV:Delay***) to prevent an applied charge voltage from masking a copper deposition condition.

3.3 Safety Cell Overvoltage Permanent Fail

The device can permanently disable the battery in the case of severe overvoltage in any of the cells.

Status	Condition	Action
Normal	Max cell voltage1..4 < ***SOV:Threshold***	*PFAlert()[SOV]* = 0
Alert	Max cell voltage1..4 ≥ ***SOV:Threshold***	*PFAlert()[SOV]* = 1 *BatteryStatus()[TCA]* = 1
Trip	Max cell voltage1..4 continuous ≥ ***SOV:Threshold*** for ***SOV:Delay*** duration	*PFAlert()[SOV]* = 0 *PFStatus()[SOV]* = 1

3.4 Safety Overcurrent in Charge Permanent Fail

The device can permanently disable the battery in the case of severe overcurrent in charge state.

Status	Condition	Action
Normal	*Current()* < ***SOCC:Threshold***	*PFAlert()[SOCC]* = 0
Alert	*Current()* ≥ ***SOCC:Threshold***	*PFAlert()[SOCC]* = 1 *BatteryStatus()[TCA]* = 1 *BatteryStatus()[OCA]* = 1
Trip	*Current()* ≥ ***SOCC:Threshold*** for ***SOCC:Delay*** duration	*PFAlert()[SOCC]* = 1 *PFStatus()[SOCC]* = 1

3.5 Safety Overcurrent in Discharge Permanent Fail

The device can permanently disable the battery in the case of severe overcurrent in discharge or RELAX state.

Status	Condition	Action
Normal	*Current()* > ***SOCD:Threshold***	*PFAlert()[SOCD]* = 0
Alert	*Current()* ≤ ***SOCD:Threshold***	*PFAlert()[SOCC]* = 1 *BatteryStatus()[TDA]* = 1
Trip	*Current()* ≤ ***SOCD:Threshold*** for ***SOCD:Delay*** duration	*PFAlert()[SOCC]* = 1 *PFStatus()[SOCC]* = 1

3.6 Safety Overtemperature Cell Permanent Fail

The device can permanently disable the battery pack in case of severe overtemperature of the cells detected using the external TS1...4 temperature sensor(s), which are configured to report as cell temperature, *Temperature()*. The *Temperature()* measurement configuration is done by setting the corresponding flag in ***Temperature Mode*** and ***DA Configuration[CTEMP]***.

Status	Condition	Action
Normal	*Temperature()* < ***SOT:Threshold***	*PFAlert()[SOT]* = 0
Alert	*Temperature()* ≥ ***SOT:Threshold***	*PFAlert()[SOT]* = 1 *BatteryStatus()[OTA]* = 1
Trip	*Temperature()* continuous ≥ ***SOT:Threshold*** for ***SOT:Delay*** duration	*PFAlert()[SOT]* = 0 *PFStatus()[SOT]* = 1 *BatteryStatus()[OTA]* = 1

3.7 Safety Overtemperature FET Permanent Fail

The device can permanently disable the battery pack in case of severe overtemperature on the power FET. The temperature sensor(s) can be configured to report as FET Temperature in *DAStatus2()* by setting the corresponding flag in ***Temperature Mode*** and ***DA Configuration[FTEMP]***.

Status	Condition	Action
Normal	FET Temperature in *DAStatus2()* < ***SOTF:Threshold***	*PFAlert()[SOTF]* = 0
Alert	FET Temperature in *DAStatus2()* ≥ ***SOTF:Threshold***	*PFAlert()[SOTF]* = 1 *BatteryStatus()[OTA]* = 1
Trip	FET Temperature in *DAStatus2()* continuous ≥ ***SOTF:Threshold*** for ***SOTF:Delay*** duration	*PFAlert()[SOTF]* = 0 *PFStatus()[SOTF]* = 1 *BatteryStatus()[OTA]* = 1

3.8 QMax Imbalance Permanent Fail

The device can permanently disable the battery pack in case the capacity of one of the cells is much lower than the others.

Status	Condition	Action
Normal	*[Max(QMax Cell 1..4) – Min(QMax1..4)]/Qmax Pack* * 100 < ***QIM:Delta Threshold***	*PFAlert()[QIM]* = 0
Alert	*[Max(QMax Cell 1..4) – Min(QMax1..4)]/Qmax Pack* * 100 > ***QIM:Delta Threshold***	*PFAlert()[QIM]* = 1
Trip	*[Max(QMax Cell 1..4) – Min(QMax1..4)]/Qmax Pack* * 100 continuous ≥ ***QIM:Delta Threshold*** for number of ***QIM:Delay***[(1)] updates	*PFAlert()[QIM]* = 0 *PFStatus()[QIM]* = 1

(1) The delay for this check is counted each time ***QMax Cycle Count*** is updated.

3.9 Cell Balancing Permanent Fail

The device can permanently disable the battery pack in case one of the cells in the stack is cell-balanced much more than the others.

Status	Condition	Action
Normal	Δ(*Time Cell 1..4*) < ***CB:Delta Threshold***	*PFAlert()[CB]* = 0
Alert	Δ(*Time Cell 1..4*) ≥ ***CB:Delta Threshold***	*PFAlert()[CB]* = 1
Trip	Δ(*Time Cell 1..4*) continuous ≥ ***CB:Delta Threshold*** for ***CB:Delay***[(1)] cycles	*PFAlert()[CB]* = 0 *PFStatus()[CB]* = 1 *BatteryStatus()[TCA]* = 1 *BatteryStatus()[TDA]* = 1
Trip	Max (*Time Cell 1..4*) ≥ ***CB:Max Threshold***	*PFAlert()[CB]* = 0 *PFStatus()[CB]* = 1

(1) The delay for this check is counted each time ***QMax Cycle Count*** is updated.

3.10 Impedance Permanent Fail

The device can permanently disable the battery pack in case the impedance of one of the cells is much higher than the others.

NOTE: ***Reference Grid*** is configurable from 0 (resistance at fully charged cell) to 14 (resistance at fully discharged cell). The default setting of ***Reference Grid*** = 4 is a good typical value to use because it is close to the average in the range of 20% to 100% SOC. ***Design Resistance*** is automatically calculated and updated during the learning cycle and is part of the golden image).

This check is only performed when the gauge updates the ***Ra*** data for the ***Reference Grid*** directly. If a selected grid point is typically being scaled rather than directly updated by the gauge (for example, grid point 0 or grid point 14), this check is effectively disabled. It is recommended to use the default ***Design Resistance*** setting.

Status	Condition	Action
Normal	Δ(Cell1..4 R_a at ***IT Cfg:Reference Grid***) < (***IMP:Delta Threshold*** × ***IT Cfg:Design Resistance***)	*PFAlert()[IMP]* = 0
Alert	Δ(Cell1..4 R_a at ***IT Cfg:Reference Grid***) ≥ (***IMP:Delta Threshold*** × ***IT Cfg:Design Resistance***)	*PFAlert()[IMP]* = 1
Trip	Δ(Cell1..4 R_a at ***IT Cfg:Reference Grid***) ≥ (***IMP:Delta Threshold*** × ***IT Cfg:Design Resistance***) for ***IMP:Ra Update Counts***	*PFAlert()[IMP]* = 0 *PFStatus()[IMP]* = 1 *BatteryStatus()[TCA]* = 1 *BatteryStatus()[TDA]* = 1
Trip	Δ(Cell1..4 R_a at ***IT Cfg:Reference Grid***) ≥ (***IMP:Max Threshold*** × ***IT Cfg:Design Resistance***)	*PFAlert()[IMP]* = 0 *PFStatus()[IMP]* = 1

3.11 Capacity Degradation Permanent Fail

The device can permanently disable the battery pack in case the capacity of the battery is degraded below a threshold.

Status	Condition	Action
Normal	***QMax pack*** > ***CD:Threshold***	*PFAlert()[CD]* = 0
Alert	***QMax pack*** ≤ ***CD:Threshold***	*PFAlert()[CD]* = 1
Trip	***QMax pack*** continuous ≤ ***CD:Threshold*** for ***CD:Delay***(1) cycles	*PFAlert()[CD]* = 0 *PFStatus()[CD]* = 1

(1) The delay for this check is counted each time ***QMax Cycle Count*** is updated.

3.12 Voltage Imbalance At Rest Permanent Fail

The device can permanently disable the battery pack in case of a voltage difference between the cells in a stack while at rest.

Status	Condition	Action
Normal	Max cell voltage1..4 < ***VIMR:Check Voltage*** OR |*Current()*| > ***VIMR:Check Current*** OR Max cell voltage1..4 – Min cell voltage1..4 < ***VIMR:Delta Threshold***	*PFAlert()[VIMR]* = 0
Alert	Max cell voltage1..4 ≥ ***VIMR:Check Voltage*** AND |*Current()*| < ***VIMR:Check Current*** for ***VIMR:Duration*** AND Max cell voltage1..4 – Min cell voltage1..4 ≥ ***VIMR:Delta Threshold***	*PFAlert()[VIMR]* = 1
Trip	Max cell voltage1..4 ≥ ***VIMR:Check Voltage*** AND |*Current()*| < ***VIMR:Check Current*** for ***VIMR:Duration*** AND Max cell voltage1..4 – Min cell voltage1..4 ≥ ***VIMR:Delta Threshold*** for ***VIMR:Delta Delay***	*PFAlert()[VIMR]* = 0 *PFStatus()[VIMR]* = 1

3.13 Voltage Imbalance Active Permanent Fail

The device can permanently disable the battery pack in case of a voltage difference between the cells in a stack while active.

Status	Condition	Action
Normal	Max cell voltage1..4 < ***VIMA:Check Voltage*** OR *Current()* < ***VIMA:Check Current*** OR Max cell voltage1..4 – Min cell voltage1..4 < ***VIMA:Delta Threshold***	*PFAlert()[VIMA]* = 0
Alert	Max Cell voltage ≥ ***VIMA:Check Voltage*** AND *Current()* > ***VIMA:Check Current*** AND Max cell voltage1..4 – Min cell voltage1..4 ≥ ***VIMA:Delta Threshold***	*PFAlert()[VIMA]* = 1
Trip	Max cell voltage1..4 ≥ ***VIMA:Check Voltage*** AND *Current()* > ***VIMA:Check Current*** AND Max cell voltage1..4 – Min cell voltage1..4 ≥ ***VIMA:Delta Threshold*** for ***VIMA:Delay***	*PFAlert()[VIMA]* = 0 *PFStatus()[VIMA]* = 1

3.14 Charge FET Permanent Fail

The device can permanently disable the battery pack in case the charge FET is not working properly.

Status	Condition	Action
Normal	CHG FET off AND *Current()* < ***CFET:OFF Threshold***	*PFAlert()[CFETF]* = 0
Alert	CHG FET off AND *Current()* ≥ ***CFET:OFF Threshold***	*PFAlert()[CFETF]* = 1
Trip	CHG FET off AND *Current()* continuously ≥ ***CFET:OFF Threshold*** for ***CFET:OFF Delay*** duration	*PFAlert()[CFETF]* = 0 *PFStatus()[CFETF]* = 1

3.15 Discharge FET Permanent Fail

The device can permanently disable the battery pack in case the discharge FET is not working properly.

Status	Condition	Action
Normal	DSG FET off AND *Current()* > ***DFET:OFF Threshold***	*PFAlert()[DFETF]* = 0
Alert	DSG FET off AND *Current()* ≤ ***DFET:OFF Threshold***	*PFAlert()[DFETF]* = 1
Trip	DSG FET off AND *Current()* continuously ≤ ***DFET:OFF Threshold*** for ***DFET:OFF Delay*** duration	*PFAlert()[DFETF]* = 0 *PFStatus()[DFETF]* = 1

3.16 Chemical Fuse Permanent Fail

The device can detect a non-working fuse. It cannot disable the battery pack permanently, but can record this event for analysis.

Status	Condition	Action
Normal	FUSE pin = high AND |*Current()*| < ***FUSE:Threshold***	*PFAlert()[FUSE]* = 0
Alert	FUSE pin = high AND |*Current()*| ≥ ***FUSE:Threshold***	*PFAlert()[FUSE]* = 1
Trip	FUSE pin = high AND |*Current()*| continuous ≥ ***FUSE:Threshold*** for ***FUSE:Delay*** duration	*PFAlert()[FUSE]* = 0 *PFStatus()[FUSE]* = 1

3.17 AFE Register Permanent Fail

The device compares the AFE hardware register periodically with a RAM backup and corrects any errors. If any errors are found during the check, the device increments the AFE register fail counter. If the comparison fails too many times, the device disables the pack permanently.

Status	Condition	Action
Normal	AFE register fail counter = 0	*PFAlert()[AFER]* = 0 Compare AFE register and RAM backup every ***AFER:Compare Period***
Alert	AFE register fail counter > 0	*PFAlert()[AFER]* = 1 Decrement AFE register fail counter by one after each ***AFER:Delay Period*** Compare AFE register and RAM backup every ***AFER:Compare Period***
Trip	AFE register fail counter ≥ ***AFER:Threshold***	*PFAlert()[AFER]* = 0 *PFStatus()[AFER]* = 1

3.18 AFE Communication Permanent Fail

The device monitors the internal communication to the AFE hardware and increments the AFE read/write fail counter on any communication error. If the read or write fails exceed a limit within a configurable timeframe, the device disables the pack permanently.

Status	Condition	Action
Normal	AFE read/write fail counter = 0	*PFAlert()[AFEC]* = 0
Alert	AFE read/write fail counter > 0	*PFAlert()[AFEC]* = 1 Decrement AFE read/write fail counter by one after each ***AFEC:Delay Period***
Trip	Read and Write Fail counter ≥ ***AFEC:Threshold***	*PFAlert()[AFEC]* = 0 *PFStatus()[AFEC]* = 1

3.19 PTC Permanent Fail

The device can detect overtemperature using a positive temperature coefficient (PTC) resistor connected to the PTC pin. This protection also works in SHUTDOWN mode.

If the device detects a PTC pin high state, the CHG and DSG FETs are turned off, and the pack is disabled permanently. For manufacturer testing, the fault state can be reset by a full power cycle of the device.

This is a hardware controlled feature. To enable this feature, the PTCEN pin should be tied to BAT. To disable this feature, connect the PTCEN pin to ground.

Status	Condition	Action
Normal	Reset AFE and PTC pin = low	*PFStatus()[PTC]* = 0
Trip	PTC pin = high	*PFStatus()[PTC]* = 1 FUSE = high *BatteryStatus()[TCA]* = 1 *BatteryStatus()[TDA]* = 1

3.20 Second Level Protection Permanent Fail

The device can detect an external trigger of the chemical fuse by an external protection circuit such as a 2nd-level protector by monitoring the FUSE pin state.

If the device detects a FUSE pin high state, the CHG and DSG FETs are turned off.

Setting ***Enabled PF C[2LVL]*** = 0 will not prevent the second level protector from triggering and blowing the fuse, setting ***[2LVL]*** = 0 will only prevent the gauge from detecting the fuse state.

Status	Condition	Action
Normal	Reset AFE and FUSE pin = low AND No FUSE trigger by firmware	*PFAlert()[2LVL]* = 0
Alert	FUSE pin = high AND No FUSE trigger by firmware	*PFAlert()[2LVL]* = 1 Reset AFE FUSE bit
Trip	FUSE pin continuously high for ***2LVL:Delay*** period AND No FUSE trigger by firmware	*PFAlert()[2LVL]* = 0 *PFStatus()[2LVL]* = 1

3.21 Instruction Flash (IF) Checksum Permanent Fail

The device can permanently disable the battery if it detects a difference between the stored IF checksum and the calculated IF checksum only following a device reset.

Status	Condition	Action
Normal	Stored and calculated IF checksum match	—
Trip	Stored and calculated IF checksum after reset does not match	*PFStatus()[IFC]* = 1

3.22 Open Cell Voltage Connection Permanent Fail

The device can permanently disable the battery if it detects a difference between the BAT pin voltage and the sum of the individual cell voltages. *Recommendation*: Perform BAT pin calibration in production if this protection is enabled.

Status	Condition	Action
Normal	|*Voltage()* – BAT voltage in *DAStatus1()*|	*PFAlert()[OPNCELL]* = 0
Alert	|*Voltage()* – BAT voltage in *DAStatus1()*| ≥ ***OPNC:Threshold***	*PFAlert()[OPNCELL]* = 1
Trip	|*Voltage()* – BAT voltage in *DAStatus1()*| continuous ≥ ***OPNC:Threshold*** for ***OPNC:Delay*** Period	*PFAlert()[OPNCELL]* = 0 *PFStatus()[OPNCELL]* = 1

3.23 Data Flash (DF) Permanent Fail

The device can permanently disable the battery in case a data flash write fails.

NOTE: A DF write failure causes the gauge to disable further DF writes.

Status	Condition	Action
Normal	Data flash write OK	—
Trip	Data flash write not successful	*PFStatus()[DFW]* = 1

3.24 Open Thermistor Permanent Fail (TS1, TS2, TS3, TS4)

The device can permanently disable the battery if it detects an open thermistor on TS1, TS2, TS3, or TS4. The state of TS1..4 and the internal temperature sensor is available in *DAStatus2()*.

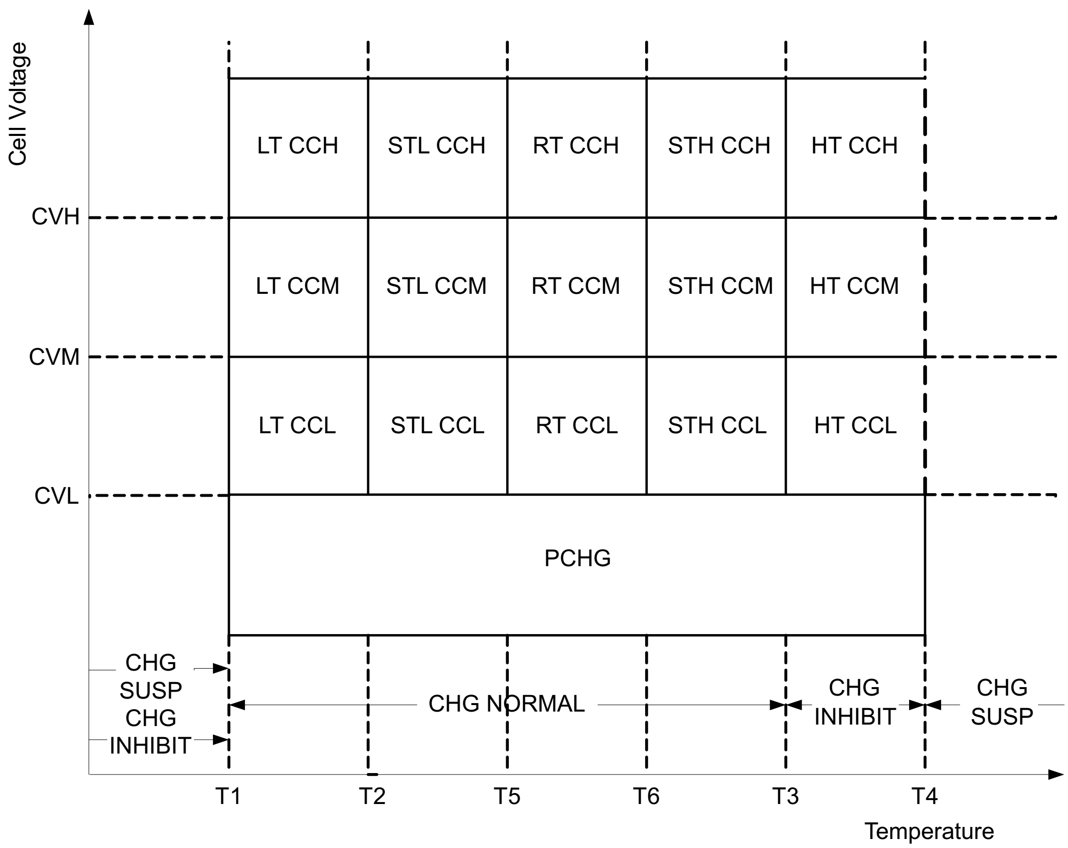
Status	Condition	Action
Normal, TS1	TS1 Temperature > ***Open Thermistor:Threshold*** OR Internal Temperature ≤ TS1 Temperature + ***Cell Delta*** if ***Temperature Mode[TS1 Mode] = 0*** OR Internal Temperature ≤ TS1 Temperature + ***FET Delta*** if ***Temperature Mode[TS1 Mode] = 1***	*PFAlert()[TS1]* = 0
Normal, TS2	TS2 Temperature > ***Open Thermistor:Threshold*** OR Internal Temperature ≤ TS2 Temperature + ***Cell Delta*** if ***Temperature Mode[TS2 Mode] = 0*** OR Internal Temperature ≤ TS2 Temperature + ***FET Delta*** if ***Temperature Mode[TS2 Mode] = 1***	*PFAlert()[TS2]* = 0
Normal, TS3	TS3 Temperature > ***Open Thermistor:Threshold*** OR Internal Temperature ≤ TS3 Temperature + ***Cell Delta*** if ***Temperature Mode[TS3 Mode] = 0*** OR Internal Temperature ≤ TS3 Temperature + ***FET Delta*** if ***Temperature Mode[TS3 Mode] = 1***	*PFAlert()[TS3]* = 0
Normal, TS4	TS4 Temperature > ***Open Thermistor:Threshold*** OR Internal Temperature ≤ TS4 Temperature + ***Cell Delta*** if ***Temperature Mode[TS4 Mode] = 0*** OR Internal Temperature ≤ TS4 Temperature + ***FET Delta*** if ***Temperature Mode[TS4 Mode] = 1***	*PFAlert()[TS4]* = 0
Alert, TS1	Condition 1: TS1 Temperature ≤ ***Open Thermistor:Threshold*** AND Internal Temperature > TS1 Temperature + ***Cell Delta*** if ***Temperature Mode[TS1 Mode] = 0***	*PFAlert()[TS1]* = 1
	OR Condition 2: TS1 Temperature ≤ ***Open Thermistor:Threshold*** AND Internal Temperature > TS1 Temperature + ***FET Delta*** if ***Temperature Mode[TS1 Mode] = 1***	
Alert, TS2	Condition 1: TS2 Temperature ≤ ***Open Thermistor:Threshold*** AND Internal Temperature > TS2 Temperature + ***Cell Delta*** if ***Temperature Mode[TS2 Mode] = 0***	*PFAlert()[TS1]* = 1
	OR Condition 2: TS2 Temperature ≤ ***Open Thermistor:Threshold*** AND Internal Temperature > TS2 Temperature + ***FET Delta*** if ***Temperature Mode[TS2 Mode] = 1***	

Status	Condition	Action
Alert, TS3	Condition 1: TS3 Temperature ≤ ***Open Thermistor:Threshold*** AND Internal Temperature > TS3 Temperature + ***Cell Delta*** if ***Temperature Mode[TS3 Mode] = 0***	*PFAlert()[TS1]* = 1
	OR Condition 2: TS3 Temperature ≤ ***Open Thermistor:Threshold*** AND Internal Temperature > TS3 Temperature + ***FET Delta*** if ***Temperature Mode[TS3 Mode] = 1***	
Alert, TS4	Condition 1: TS4 Temperature ≤ ***Open Thermistor:Threshold*** AND Internal Temperature > TS4 Temperature + ***Cell Delta*** if ***Temperature Mode[TS4 Mode] = 0***	*PFAlert()[TS1]* = 1
	OR Condition 2: TS4 Temperature ≤ ***Open Thermistor:Threshold*** AND Internal Temperature > TS4 Temperature + ***FET Delta*** if ***Temperature Mode[TS4 Mode] = 1***	
Trip, TS1	Condition 1: TS1 Temperature ≤ ***Open Thermistor:Threshold*** AND Internal Temperature > TS1 Temperature + ***Cell Delta*** for ***Open Thermistor:Delay*** duration if ***Temperature Mode[TS1 Mode] = 0***	*PFAlert()[TS1]* = 0 *PFStatus()[TS1]* = 1
	OR Condition 2: TS1 Temperature ≤ ***Open Thermistor:Threshold*** AND Internal Temperature > TS1 Temperature + ***FET Delta*** for ***OpenThermistor:Delay*** duration if ***Temperature Mode[TS1 Mode] = 1***	
Trip, TS2	Condition 1: TS2 Temperature ≤ ***Open Thermistor:Threshold*** AND Internal Temperature > TS2 Temperature + ***Cell Delta*** for ***Open Thermistor:Delay*** duration if ***Temperature Mode[TS2 Mode] = 0***	*PFAlert()[TS2]* = 0 *PFStatus()[TS2]* = 1
	OR Condition 2: TS2 Temperature ≤ ***Open Thermistor:Threshold*** AND Internal Temperature > TS2 Temperature + ***FET Delta*** for ***OpenThermistor:Delay*** duration if ***Temperature Mode[TS2 Mode] = 1***	
Trip, TS3	Condition 1: TS3 Temperature ≤ ***Open Thermistor:Threshold*** AND Internal Temperature > TS3 Temperature + ***Cell Delta*** for ***Open Thermistor:Delay*** duration if ***Temperature Mode[TS3 Mode] = 0***	*PFAlert()[TS3]* = 0 *PFStatus()[TS3]* = 1
	OR Condition 2: TS3 Temperature ≤ ***Open Thermistor:Threshold*** AND Internal Temperature > TS3 Temperature + ***FET Delta*** for ***OpenThermistor:Delay*** duration if ***Temperature Mode[TS3 Mode] = 1***	
Trip, TS4	Condition 1: TS4 Temperature ≤ ***Open Thermistor:Threshold*** AND Internal Temperature > TS4 Temperature + ***Cell Delta*** for ***Open Thermistor:Delay*** duration if ***Temperature Mode[TS4 Mode] = 0***	*PFAlert()[TS4]* = 0 *PFStatus()[TS4]* = 1
	OR Condition 2: TS4 Temperature ≤ ***Open Thermistor:Threshold*** AND Internal Temperature > TS4 Temperature + ***FET Delta*** for ***OpenThermistor:Delay*** duration if ***Temperature Mode[TS4 Mode] = 1***	

Advanced Charge Algorithm

4.1 Introduction

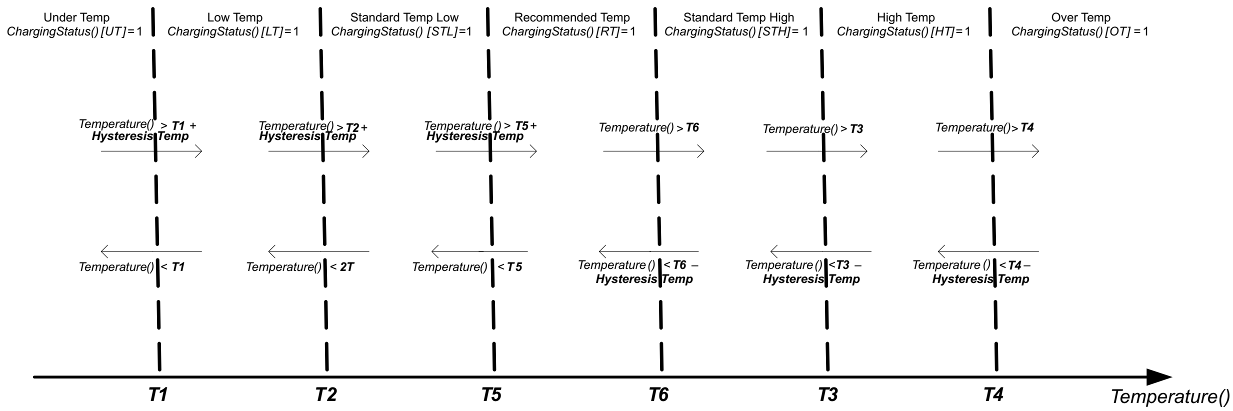
The device can change the values of *ChargingVoltage()* and *ChargingCurrent()* based on *Temperature()* and cell voltage1..4. Its flexible charging algorithm is JEITA compatible and can also meet other specific cell manufacturer charge requirements. The *ChargingStatus()* register shows the state of the charging algorithm.



4.2 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***.

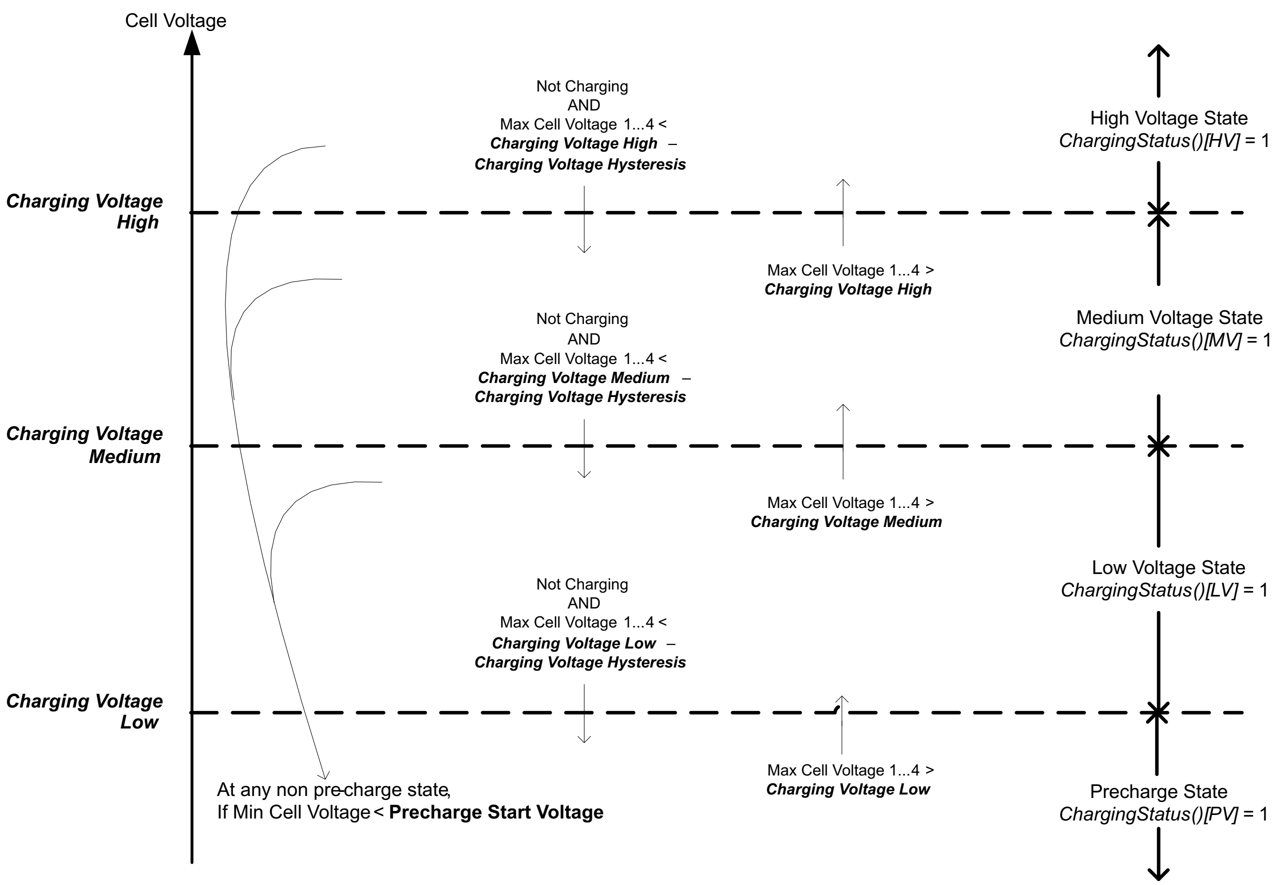


4.3 Voltage Range

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 need to adhere to the following format:

Charging Voltage Low ≤ Charging Voltage Med ≤ Charging Voltage High ≤ × Temp Charging:Voltage

where × is Standard or Rec. 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.



4.4 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 *ChargeCurrent()* = ***Rec Temp Charging: Current Med*** × 90%.

NOTE: Table priority is top to bottom.

Temp Range	Voltage Range	Condition	Action
Any	Any	*OperationStatus()[XCHG]* = 1	*ChargingCurrent()* = 0
UT or OT	Any	—	*ChargingCurrent()* = 0
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***

4.5 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
Any	*OperationStatus()[XCHG]* = 1	*ChargingVoltage()* = 0
UT or OT	—	*ChargingVoltage()* = 0
LT	—	*ChargingVoltage()* = ***Low Temp Charging:Voltage*** × (***DA Configuration[CC1:CC0]*** + 1)

Temp Range	Condition	Action
STL or STH	—	*ChargingVoltage()* = ***Standard Temp Charging:Voltage*** × (***DA Configuration[CC1:CC0]*** + 1)
RT	—	*ChargingVoltage()* = ***Rec Temp Charging:Voltage*** × (***DA Configuration[CC1:CC0]*** + 1)
HT	—	*ChargingVoltage()* = ***High Temp Charging:Voltage*** × (***DA Configuration[CC1:CC0]*** + 1)

4.6 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 ***SBS Gauging Configuration[CSYNC]*** = 1, *RemainingCapacity()* = *FullChargeCapacity()*.
- If ***SBS Gauging Configuration[RSOCL]*** = 1, *RelativeStateOfCharge()* and *RemainingCapacity()* are held at 99% until charge termination occurs. Only on entering charge termination is 100% displayed.
- If ***SBS 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()[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 Max cell voltage1..4 + ***Charge Term Voltage*** ≥ *ChargingVoltage()* / number of cells in series 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 ***SOCFlagConfig A[FCSETVCT]*** = 1 *BatteryStatus()[TCA]* = 1 and *GaugingStatus()[TCA]* = 1 if ***SOCFlagConfig B[TCASETVCT]*** = 1

4.7 Charge and Discharge Termination Flags

The *[TC]* and *[FC]* bits in *GaugingStatus()* can be set at charge termination as well as based on RSOC or cell voltages. If multiple set and clear conditions are selected, then the corresponding flag will be set whenever a valid set or clear condition is met. If both 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()[TAC][FC][TDA][FD]* flags will be set and cleared according to the *BatteryStatus()[TC][FC][TD][FD]* flags as well as the safety and permanent failure protections status. For more information, see Section 4.8.

When *GaugingStatus() [FC]* is set AND ***FET Option[CHGFET] = 1***, the CHG FET turns off.

The *[FC]* flag is identical between gauging status and battery status, but not *[TD]*. The table below summarizes the various options to set and clear the *[TC]* and *[FC]* flags in *GaugingStatus()*.

Flag	Set Criteria	Set Condition	Enable
[TC]	cell voltage	Max cell voltage1..4 ≥ ***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

Flag	Set Criteria	Set Condition	Enable
[FC]	cell voltage	Max cell voltage1..4 ≥ ***FC: Set Voltage Threshold***	***SOC Flag Config B[FCSetV]*** = 1
	RSOC	*RelativeStateOfCharge()* ≥ ***C: 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	Max cell voltage1..4 ≤ ***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	Max cell voltage1..4 ≤ ***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

[TD] and *[FD]* both have extra conditions. If gauging status *[FD]* is set then battery status is always set, but clearing depends also on some safety conditions (CUV/SUV).

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

Flag	Set Criteria	Set Condition	Enable
[TD]	cell voltage	Min cell voltage1..4 ≤ ***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	Min cell voltage1..4 ≤ ***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	Min cell voltage1..4 ≥ ***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	Min cell voltage1..4 ≥ ***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

4.8 Terminate Charge and Discharge Alarms

When the protections and permanent fails are triggered, the *BatteryStatus()[TCA][TDA][FD][OCA][OTA][FC]* will be set according to the type of safety protections. Here is a summary of the set conditions of the various alarms flags.

[TCA] = 1 if

- *SafetyAlert()[OCC1]*, *[OCC2]*, *[COV]*, *[OTC]*, *[OTF]*, *[OC]*, *[CHGC]*, *[CHGV]*, or *[PCHGC]* = 1, OR
- *PFAlert()[SOV] or [SOCC]* = 1, OR
- *Any PFStatus()* = 1, OR
- *OperationStatus()[PRES]* = 0, OR

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

[FC] = 1

- if GaugingStatus()[FC] = 1

[OCA] = 1 if

- *SafetyStatus()[OC]* = 1 AND in CHARGE mode

[TDA] = 1 if

- *SafetyAlert()[OCD1]*, *[OCD2]*, *[CUV]*, *[CUVC]*, *[OTD]*, or *[OTF]* = 1, OR
- *PFAlert()[SUV]* or *[SOCD]* = 1, OR
- Any *PFStatus()* = 1, OR
- *OperationStatus()[PRES]* = 0
- *GaugingStatus()[TD]* = 1 AND in DISCHARGE mode

[FD] = 1 if

- *SafetyStatus()[CUV]* = 1, OR
- *PFStatus()[SUV]* = 1, OR
- *GaugingStatus()[FD]*

[OTA] = 1 if

- *SafetyStatus()[OTC]*, *[OTD]*, or *[OTF]* = 1, OR
- *PFStatus()[SOT]* or *[SOTF]* = 1

4.9 Precharge

The gauge enters PRECHARGE mode if,

1. Min cell voltage1..4 < ***Precharge Start Voltage***, OR
2. Max cell voltage1..4 < ***Charging Voltage Low – Charging Voltage Hysteresis*** and not in CHARGE mode

Depending on the ***FET Options[PCHG_COMM]*** settings, the external precharge FET or CHG FET can be used in PRECHARGE mode. Setting the ***Precharge Start Voltage and Charging Voltage Low*** = 0 mV disables the precharge function.

***[PCHG_COMM]* = 0**	***[PCHG_COMM]* = 1**
FET USED: external precharge FET	FET USED: CHG FET

The device also supports 0-V charging using either an external precharge FET or CHG FET. If ***[PCHG_COMM]*** = 1, the gauge enables the hardware 0-V charging circuit automatically when the battery stack voltage is below the minimum operation voltage of the device (see the *bq40z50 1-Series to 4-Series Li-Ion Battery Pack Manager* data sheet [SLUSBS8] for bq40z50 electrical specifications).

4.10 Maintenance Charge

Maintenance charge can be configured to provide charge current after charge termination is reached.

If the Overcharge Protection is enabled, ***Enabled Protections C[OC]*** = 1, extra margin may be needed for ***OC:Threshold*** to prevent triggering the OC protection by the maintenance charging.

Status	Condition	Action
Set	*ChargingStatus()[IN]* = 0 AND *ChargingStatus()[SU]* = 0 AND *ChargingStatus()[PV]* = 0 AND *GaugingStatus()[TCA]* = 1	*ChargingStatus()[MCHG]* = 1 *ChargingVoltage()* = Charging Algorithm *ChargingCurrent()* = Charging Algorithm

Status	Condition	Action
Clear	*ChargingStatus()[IN]* = 1 OR *ChargingStatus()[SU]* = 1 OR *ChargingStatus()[PV]* = 1 OR *GaugingStatus()[TCA]* = 0	*ChargingStatus()[MCHG]* = 0 *ChargingVoltage()* = Charging Algorithm *ChargingCurrent()* = Charging Algorithm

4.11 Charge Control SMBus Broadcasts

If the ***[HPE]*** bit is enabled, MASTER mode broadcasts to the host address are PEC enabled. If the ***[CPE]*** bit is enabled, MASTER mode broadcasts to the smart-charger address are PEC enabled. The ***[BCAST]*** bit enables all broadcasts to a host or a smart charger. When the ***[BCAST]*** bit is enabled, the following broadcasts are sent:

- *ChargingVoltage()* and *ChargingCurrent()* broadcasts are sent to the smart-charger device address (0x12) every 10 to 60 s.
- If any of the *[OCA]*, *[TCA]*, *[OTA]*, *[TDA]*, *[RCA]*, *[RTA]* flags are set, the *AlarmWarning()* broadcast is sent to the host device address (0x14) every 10 seconds. Broadcasts stop when all flags above have been cleared.
- If any of the *[OCA]*, *[TCA]*, *[OTA]*, *[TDA]* flags are set, the *AlarmWarning()* broadcast is sent to a smart-charger device address every 10 seconds. Broadcasts stop when all flags above have been cleared.

4.12 Charge Disable and Discharge Disable

The device can disable charging if certain safety conditions are detected, setting the *OperationStatus()[XCHG]* = 0.

Status	Condition	Action
Normal	*ALL PFStatus()* = 0 AND *SafetyStatus()[COV]* = 0 AND *SafetyStatus()[OCC1][OCC2]* = 0,0 AND *SafetyStatus()[ASCC]* = 0 AND *SafetyStatus()[ASCCL]* = 0 AND *SafetyStatus()[CTO]* = 0 AND *SafetyStatus()[PTO]* = 0 AND *OperationStatus()[PRES]* = 1 AND *GaugingStatus()[TCA]* = 0 if ***Charging Configuration[CHGFET]*** = 1	*ChargingVoltage()* = Charging Algorithm *ChargingCurrent()* = Charging Algorithm *OperationStatus()[XCHG]* = 0
Trip	*ManufacturingStatus()[FET_EN]* = 0 OR *ANY PFStatus()[]* = 1 OR *SafetyStatus()[COV]* = 1 OR *SafetyStatus()[OCC1]* = 1 OR *SafetyStatus()[OCC2]* = 1 OR *SafetyStatus()[ASCC]* = 1 OR *SafetyStatus()[ASCCL]* = 1 OR *SafetyStatus()[CTO]* = 1 OR *SafetyStatus()[PTO]* = 1 OR *SafetyStatus()[HWDF]* = 1 OR *SafetyStatus()[OC]* = 1 OR *SafetyStatus()[CHGC]* = 1 OR *SafetyStatus()[CHGV]* = 1 OR *SafetyStatus()[PCHGC]* = 1 OR *SafetyStatus()[UTC]* = 1 OR *SafetyStatus()[OTC]* = 1 if ***[OTFET]*** = 1 OR *ChargingStatus()[IN]* = 1 if ***[CHGIN]*** = 1 OR *ChargingStatus()[SU]* = 1 if ***[CHGSU]*** = 1 OR *OperationStatus()[SLEEP]* = 1 if ***[NR]*** = 1 AND ***[SLEEPCHG]*** = 0 OR *OperationStatus()[EMSHUT]* = 1 OR *OperationStatus()[PRES]* = 0 OR *GaugingStatus()[TCA]* = 1 if ***Charging Configuration[CHGFET]*** = 1	*ChargingVoltage()* = 0 *ChargingCurrent()* = 0 *OperationStatus()[XCHG]* = 1

Similarly, the device can disable discharge if any of the following conditions are detected, setting the *OperationStatus()[XDSG]* = 1.

- *ManufacturingStatus()[FET_EN]* = 0, OR
- Any *PFStatus()* set, OR
- *SafetyStatus()[OCD1]* or *[OCD2]* or *[CUV]* or *[CUVC]* or *[AOLD]* or *[AOLDL]* or *[ASCD]* or *[ASCDL]* or *[UTD]* = 1, OR
- *SafetyStatus()[OTD]* or *[OTF]* = 1 if ***[OTFET]*** = 1, OR
- *OperationStatus()[PRES]* = 0, OR
- *OperationStatus()[EMSHUT]* = 1 ,OR
- *OperationStatus()[SDM]* = 1 AND delay time > ***FET Off Time***, OR
- *OperationStatus()[SDV]* = 1 AND low voltage time ≥ ***Shutdown Time***

4.13 Charge Inhibit

The device can inhibit the start of charging at high and low temperatures to prevent damage of the cells. This feature prevents the start of charging when the temperature is at the inhibit range; therefore, if the device is already in the charging state when the temperature reaches the inhibit range, a FET action will not take place even if ***FET Options[CHGIN]*** = 1.

Status	Condition	Action
Normal	*ChargingStatus()[LT]* = 1 OR *ChargingStatus()[STL]* = 1 OR *ChargingStatus()[RT]* = 1 OR *ChargingStatus()[STH]* = 1	*ChargingStatus()[IN]* = 0 *ChargingVoltage()* = charging algorithm *ChargingCurrent()* = charging algorithm
Trip	Not charging AND (*ChargingStatus()[HT]* = 1 OR *ChargingStatus()[OT]* = 1 OR *ChargingStatus()[UT]* = 1	*ChargingStatus()[IN]* = 1 *ChargingStatus()[SU]* = 0 *ChargingVoltage()* = 0 *ChargingCurrent()* = 0 *OperationStatus()[XCHG]* = 1 if ***FET Options[CHGIN]*** = 1.

4.14 Charge Suspend

The device can stop charging at high and low temperatures to prevent damage of the cells.

The *ChargingStatus()[SU]* condition is only active in the CHARGING mode. Once CHARGE SUSPEND is triggered, the gauge will exit CHARGING mode after ***Chg Relax Time*** and the CHARGE SUSPEND will change to CHARGE INHIBIT.

Status	Condition	Action
Normal	*ChargingStatus()[LT]* = 1 OR *ChargingStatus()[STL]* = 1 OR *ChargingStatus()[RT]* = 1 OR *ChargingStatus[STH]* = 1 OR *ChargingStatus()[HT]* = 1	*ChargingStatus()[SU]* = 0 *ChargingVoltage()* = charging algorithm *ChargingCurrent()* = charging algorithm
Trip	*ChargingStatus()[UT]* = 1 OR *ChargingStatus()[OT]* = 1	*ChargingStatus()[SU]* = 1 *ChargingVoltage()* = 0 *ChargingCurrent()* = 0 *OperationStatus()[XCHG]* = 1 if ***FET Options[CHGSU]*** = 1.

4.15 ChargingVoltage() Rate of Change

The device can slope the value changes from one range to another to avoid jumping between different voltage ranges. Setting the ***Voltage Rate*** to 1 disables this feature because the *ChargingVoltage()* changes in one step. The gauge will not apply any voltage stepping if ***Voltage Rate*** is set to 1.

NOTE: The host needs to read *ChargingVoltage()* at least once a second during charging to adjust the charger accordingly.

Status	Condition	Action
Trip	*ChargingVoltage()* Change	*ChargingStatus()[CVR]* = 1 *ChargingVoltage()* = Old + n × (New – Old)/***Voltage Rat***e, where Old = present *ChargingVoltage()* New = the target *ChargingVoltage()* that the device is going to change to n = 1..***Voltage Rate***, increment in steps of one per second.

4.16 ChargingCurrent() Rate of Change

The device can slope the value changes from one range to another to avoid jumping between different current ranges. Setting the ***Current Rate*** to 1 disables this feature because the *ChargingCurrent()* changes in one step. The gauge will not do any current stepping if ***Current Rate*** is set to 1.

NOTE: The host needs to read *ChargingCurrent()* at least once a second during charging to adjust the charger accordingly.

Status	Condition	Action
Trip	*ChargingCurrent()* Change	*ChargingStatus()[CCR]* = 1 *ChargingCurrent()* = Old + n × (New – Old)/***Current Rate***, where Old = present *ChargingCurrent()* New = the target *ChargingCurrent()* that the device will change to n = 1..***Current Rate***, increment in steps of 1 per second.

4.17 Charging Loss Compensation

The device can modify *ChargingVoltage()* and *ChargingCurrent()* to compensate losses caused by the FETs, the fuse, and the sense resistor by measuring the cell voltages directly and adjusting *ChargingCurrent()* and *ChargingVoltage()* accordingly.

In CONSTANT CURRENT mode, the device can increase the *ChargingVoltage()* value to compensate the drop losses. This feature can be enabled by setting ***Configuration[CCC]*** = 1 and configuring the ***CCC Current Threshold***.

NOTE: The host must read *ChargingVoltage()* and/or *ChargingCurrent()* at least once a second during charging to adjust the charger accordingly.

Status	Condition	Action
Normal	*Current()* > ***CCC Current Threshold*** AND *Voltage()* = Charging algorithm voltage	*ChargingStatus()[CCC]* = 0 *ChargingVoltage()* = Charging Algorithm
Active	*Current()* > ***CCC Current Threshold*** AND *Voltage()* < Charging algorithm voltage	*ChargingStatus()[CCC]* = 1 *ChargingVoltage()* = Charging Algorithm + (*PackVoltage()* – *Voltage()*)
Limit	(Pack pin voltage in *DAStatus1()* – *Voltage()*) > ***CCC Voltage Threshold***	*ChargingVoltage()* = Charging Algorithm + ***CCC Voltage Threshold***

Power Modes

5.1 Introduction

To enhance battery life, the bq40z50 supports several power modes to minimize power consumption during operation.

5.2 NORMAL Mode

In NORMAL mode, the device takes voltage, current, and temperature readings every 250 ms, performs protection and gauging calculations, updates SBS data, and makes status decisions at 1-s intervals. Between these periods of activity, the device is in a reduced power state.

If the [NR] bit is set, the $\overline{\text{PRES}}$ input can be left floating, as it is not monitored.

5.2.1 BATTERY PACK REMOVED Mode/System Present Detection

5.2.1.1 System Present

$\overline{\text{PRES}}$ is sampled four times per second, and if $\overline{\text{PRES}}$ is high for 4 samples (one second), the *OperationStatus[PRES]* flag is cleared. If $\overline{\text{PRES}}$ is low for 4 samples (one second), the *OperationStatus [PRES]* flag is set, indicating the system is present (the battery is inserted). If the ***[NR]*** bit is set, the $\overline{\text{PRES}}$ input is ignored and can be left floating.

5.2.1.2 Battery Pack Removed

The bq40z50 detects the BATTERY PACK REMOVED mode if the ***[NR]*** bit is set to 0 AND the $\overline{\text{PRES}}$ input is high (*[PRES]* = 0).

On entry to the BATTERY PACK REMOVED mode, the *[TCA]* and *[TDA]* flags are set, *ChargingCurrent()* and *ChargingVoltage()* are set to 0, the CHG and DSG FETs are turned off, and the Precharge FET is turned off (if used).

Polling of the $\overline{\text{PRES}}$ pin continues at a rate of once every 1 s.

The bq40z50 exits the BATTERY PACK REMOVED state if the ***[NR]*** flag is set to 0 AND the $\overline{\text{PRES}}$ input is low (*[PRES]* = 1). When this occurs, the *[TCA]* and *[TDA]* flags are reset.

5.3 SLEEP Mode

5.3.1 Device Sleep

When the sleep conditions are met, the device goes into SLEEP mode with periodic wake-ups for voltage, temperature, and current measurements to reduce power consumption.

OperationStatus()[SLPAD] is set when the gauge wakes to measure voltage and temperature. Similarly, the *[SLPCC]* is set when the gauge wakes for current measurement. In general, it is not possible to read these flags because an SMBus communication will wake up the gauge.

The device returns to NORMAL mode if any exit sleep condition is met.

Status	Condition	Action
Activate	SMBus low for ***Bus Timeout***[(1)] if ***[IN_SYSTEM_SLEEP]*** = 0, or no communication for ***Bus Timeout*** if ***[IN_SYSTEM_SLEEP]*** = 1 AND ***DA Config[SLEEP]*** = 1[(1)] AND |*Current()*| ≤ ***Sleep Current*** AND ***Voltage Time*** > 0 AND (*OperationStatus()[PRES]* = 0 OR ***DA Config[NR]*** = 1) AND *OperationStatus()[SDM]* = 0 AND No *PFAlert()* bits set AND[(2)] No *PFStatus()* bits set AND No *SafetyAlert()* bits set AND[(2)] No [AOLD], [AOLDL], [ASCC], [ASCCL], [ASCD], [ASCDL] set in *SafetyStatus()*	Turn off CHG FET and PCHG FET if ***DA Configuration[SLEEPCHG]*** = 0.[(3)] Device goes to sleep. Device wakes up every ***Sleep:Voltage Time*** period to measure voltage and temperature. Device wakes up every ***Sleep:Current Time*** period to measure current.
Exit	SMBus connected [(1)]OR SMBus command received [(4)] OR ***DA Config[SLEEP]*** = 1[(1)] OR |*Current()*| > ***Sleep Current*** OR Wake comparator activates[(5)] OR ***Voltage Time*** = 0 OR (*OperationStatus()[PRES]* = 1 AND ***DA Config[NR]*** = 0) OR *OperationStatus()[SDM]* = 1 OR *PFAlert()* bits set OR *PFStatus()* bits set OR *SafetyAlert()* bits set OR *[AOLD], [AOLDL], [ASCC], [ASCCL], [ASCD], [ASCDL]* set in *SafetyStatus()*	Return to NORMAL mode

(1) ***DA Config[SLEEP]*** and SMBus low are not checked if the *ManufacturerAccess()* SLEEP mode command is used to enter SLEEP mode.
(2) *SafetyAlert()[PTO]*, *[PTOS]*, *[CTO]*, *[CTOS]* or *PFAlert()[QIM]*, *[OC]*, *[IMP]*, *[CB]* will not prevent the gauge to enter SLEEP mode.
(3) For ***[NR]*** = 0, the CHG FET and PCHG FET remains on in SLEEP mode if ***[SLEEPCHG]*** = 1, but if the battery pack is removed from the system, the CHG FET is off because the system present takes higher priority than ***[SLEEPCHG]***.
(4) Wake on SMBus command is only possible when the gas gauge is put to sleep using the *ManufacturerAccess*() SLEEP mode command or ***[IN_SYSTEM_SLEEP]*** is enabled with ***Bus Timeout*** = 0. Otherwise, the gas gauge wakes on an SMBus connection (clock or data high).
(5) The wake comparator threshold is set through ***Power.WakeComparator[WK1,WK0]*** (see Section 5.3.4).

5.3.2 In System Sleep

The device provides an option for removable packs (that is, ***DA Config[NR]*** = 0) to enter SLEEP mode in-system. When the ***DA Config[IN_SYSTEM_SLEEP]*** = 1, the device will enter SLEEP mode even if the *OperationStatus()[PRES] = 1*. This option ignores the $\overline{\text{PRES}}$ pin status only. All the other sleep conditions must be met for the device to enter SLEEP mode.

In the IN SYSTEM SLEEP mode, it is possible to read the *[SLPAC]* and *[SLPCC]* flags if ***[IN_SYSTEM_SLEEP]*** = 1 and ***Bus Timeout*** = 0. This setting allows the gauge to enter SLEEP mode with active communication in progress.

NOTE: Setting the ***Bus Timeout*** = 0 with ***[IN_SYTEM_SLEEP]*** can be used for testing purposes, but it is not recommended to set the ***Bus Timeout*** = 0 in the field. If ***Bus Timeout*** = 0, the device's sleep and wake conditions are strictly controlled by current detection. If the host system performs a low load operation periodically (for example, wireless detection in a tablet application), this small load current may be missed, introducing an error into remaining capacity tracking. Having a non-zero ***Bus Timeout*** setting enables the gauge to wake up by a communication and capture the current measurement.

5.3.3 ManufacturerAccess() MAC Sleep

The SLEEP MAC command can override the requirement for bus low to enter sleep. In this case, the bq40z50 clock and data high condition is ignored for sleep to exit, though sleep will also exit if there is any further SMBus communication. The device can be sent to sleep with *ManufacturerAccess()* if specific sleep entry conditions are met.

5.3.4 Wake Function

The device can exit SLEEP mode if enabled by the presence of a voltage across SRP and SRN. The voltage threshold needed for the device to wake from SLEEP mode is programmed in ***Power:Wake Comparator***. This allows the gauge to wake up quickly in response to a higher current detection. Otherwise, the gauge only wakes up every ***Sleep Current Time*** to detect if |*Current()*| is > Sleep Current.

Reserved (Bits 7–4, 1–0): Reserved. Do not use.

WK1,0 (Bits 3–2): Wake Comparator Threshold

WK1	WK0	Voltage
0	0	±0.625 mV
0	1	±1.25 mV
1	0	±2.5 mV
1	1	±5 mV

5.4 SHUTDOWN Mode

5.4.1 Voltage Based Shutdown

To minimize power consumption and to avoid draining the battery, the device can be configured to shut down at a programmable stack voltage threshold.

Status	Condition	Action
Enable	Min cell voltage < ***Shutdown Voltage***	*OperationStatus()[SDV]* = 1
Trip	Min cell voltage continuous < ***Shutdown Voltage*** for ***Shutdown Time***	Turn DSG FET off
Shutdown	Voltage at PACK pin < ***Charger Present Threshold***	Send device into SHUTDOWN mode
Exit	Voltage at PACK pin > $V_{STARTUP}$	*OperationStatus()[SDV]* = 0 Return to NORMAL mode

NOTE: The device goes through a full reset when exiting from SHUTDOWN mode, which means the device will re-initialize. On power up, the gauge will check some special memory locations. If the memory checksum is incorrect, or if the gauge or the AFE watchdog has been triggered, the gauge will do a full reset.

The memory checksum is good; for example, in a case of a short power glitch, the gauge will do a partial reset. The initialization is faster in a partial reset, and certain memory data will not be re-initialized (for example, all SBS registers, last known FET state, last ADC and CC readings, and so on), and so a partial reset is usually transparent to the host.

5.4.2 ManufacturerAccess() MAC Shutdown

In SHUTDOWN mode, the device turns off the FETs after ***FET Off Time***, and then shuts down to minimize power consumption after ***Delay*** time. Both ***FET Off Time*** and ***Delay*** time are referenced to the time the gauge receives the command. Thus, the ***Delay*** time must be set longer than the ***FET Off Time***. The device returns to NORMAL mode when voltage at PACK pin > $V_{STARTUP}$. The device can be sent to this mode with the *ManufacturerAccess() Shutdown* command. Charger voltage must not be present for the device to enter SHIP SHUTDOWN mode.

> **NOTE:** If the gauge is unsealed and the MAC *Shutdown()* command is sent twice in a row, the gauge will execute the shutdown sequence immediately and skip the normal delay sequence.

5.4.3 Time Based Shutdown

The device can be configured to shut down after staying in SLEEP mode without communication for a preset time interval specified in the ***Auto Ship Time***. Setting the ***PowerConfig[AUTO_SHIP_EN]*** = 1 enables this feature. Any communication to the device will restart the timer. When the timer reaches the Auto Ship Time, the time based shutdown effectively triggers the MAC shutdown command to start the shutdown sequence. The device returns to NORMAL mode when voltage at PACK pin > $V_{STARTUP}$.

5.4.4 Emergency Shutdown (EMSHUT)

The EMERGENCY SHUTDOWN function provides an option to disable the battery power to the system by opening up both CHG and DSG FETs before removing an embedded battery pack. There are two ways to enter the EMERGENCY SHUTDOWN state:

(a) Use an external signal (for example, a push-button switch) to detect a low-level threshold signal on the $\overline{\text{SHUTDN}}$ pin.

(b) Send a Manual FET Control (MFC) sequence to *ManufacturerAccess()*.

When the gauge is in the EMERGENCY SHUTDOWN state, the *OperationStatus()[EMSHUT]* = 1.

5.4.4.1 Enter Emergency Shutdown Through $\overline{\text{SHUTDN}}$

When a high-to-low transition on the $\overline{\text{SHUTDN}}$ pin is detected with a debounce delay of about 1 s for the low level threshold, the gauge will turn off both CHG and DSG FETs immediately. This entry method only applies if ***[NR]*** = 1 and ***DA Configuration[EMSHUT]*** = 1. If ***[NR]*** = 0, the $\overline{\text{SHUTDN}}$ pin will restore to the regular system present detection.

5.4.4.2 Enter Emergency Shutdown Through MFC

Alternately, sending a Manual FET Control (MFC) sequence using the steps below also puts the gauge to the EMERGENCY SHUTDOWN state. This entry method applies to ***NR]*** = 0 and ***[NR]*** = 1.

(a) Send word 0x2706 to *ManufacturerAccess()* (0x00) to enable the MFC.

(b) Within 4 s, send word 0x043D to *ManufacturerAccess()* (0x00) to turn off CHG and DSG FETs.

(c) The CHG and DSG FETs will be off after ***Manual FET Control Delay***.

5.4.4.3 Exit Emergency Shutdown

Regardless of which EMSHUT entry method is used, the gauge can exit the EMSHUT mode by turning on the CHG and DSG FETs with the following conditions:

- A high-to-low transition on the $\overline{\text{SHUTDN}}$ pin is detected with a debounce delay of 1 s for the low level threshold. For example, a push button is pressed again.
- Send word 0x23A7 to *ManufacturerAccess()* (0x00).

In addition to these exit conditions, if the gauge enters EMSHUT (via a push-button, for example), it can exit the EMSHUT mode after a shutdown restore timeout defined by the ***Timeout*** parameter.

For the case of ***[NR]*** = 0, a battery insertion will also exit the EMERGENCY SHUTDOWN mode.

Gauging

6.1 Introduction

The bq40z50 measures individual cell voltages, pack voltage, temperature, and current. It determines battery state-of-charge by analyzing individual cell voltages when a certain relax time has passed since the last charge or discharge activity of the battery.

The bq40z50 measures charge and discharge activity by monitoring the voltage across a small-value series sense resistor (1 mΩ typical) between the negative terminal of the cell stack and the negative terminal of the battery pack. The battery state-of-charge is subsequently adjusted during a load or charger application using the integrated charge passed through the battery. The device is capable of supporting a maximum battery pack capacity of 32Ah. See the *Theory and Implementation of Impedance Track™ Battery Fuel-Gauging Algorithm in bq20zxx Product Family* (SLUA364B) 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. The *Gauging()* command will take effect immediately and the ***[GAUGE_EN]*** will be updated accordingly.

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

6.2 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 bq40z50 must be configured for whatever current (or power) will flow in the future. While it cannot be exactly known, the bq40z50 can use load history, such as the average current of the present discharge, to make a sufficiently accurate prediction.

The bq40z50 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 to 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. For highly variable loads, selection 7 provides the most conservative estimate and is preferable.

	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()* × average *Voltage()*
4 =	***Design Capacity***/5	***Design Energy***/5
5 =	*AtRate()* (mA)	*AtRate()* (10 mW)
6 =	***User Rate-mA***	***User Rate-mW***
7 =	***Max Avg I Last Run*** (default)	***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 bq40z50 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***.

Reserve Battery Capacity — The bq40z50 allows an amount of capacity to be reserved in either mAh (***Reserve Cap-mAh***, ***Load Mode*** = 0) or 10 mWh (***Reserve Cap-mWh***, ***Load Mode*** = 1) 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 energy, but still have enough reserve energy to perform a controlled shutdown or provide an extended sleep period for the host system.

The reserve capacity is compensated at the present discharge rate as selected by ***Load Select***.

Pack Based and Cell Based Termination — The bq40z50 forces *RemainingCapacity()* to 0 mAh when the battery stack voltage reaches the ***Term Voltage***. If ***IT Gauging Configuration[CELL_TERM]*** = 1, the battery can terminate based on cell voltage or pack voltage. When the cell based termination is used, the ***Term Min Cell V*** threshold is checked for the termination condition. The cell based termination can provide an option to enable the gauge to reach 0% before the device triggers CUV for a pack imbalance.

6.3 Gas Gauge Modes

Resistance updates take place only in DISCHARGE mode, while open circuit voltage (OCV) and QMax updates only take place in RELAX mode. If fast Qmax is enabled, the Qmax also updates at the end of discharge given a minimum of 37% delta change of charge. 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, the DSG flag in *BatteryStatus()* is set.

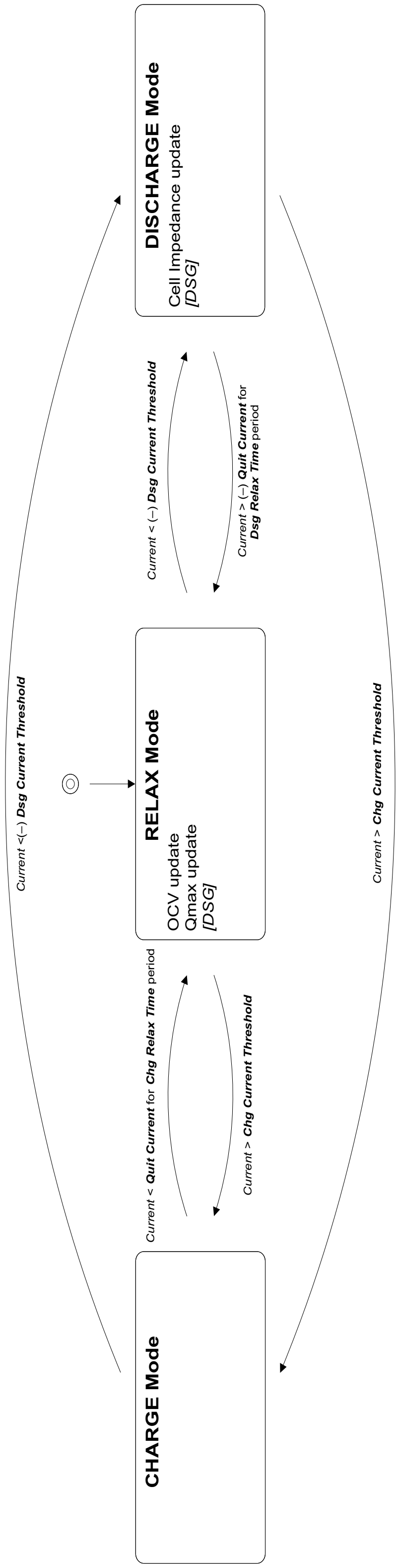


Figure 6-1. Gas Gauge Operating Modes

- 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***.

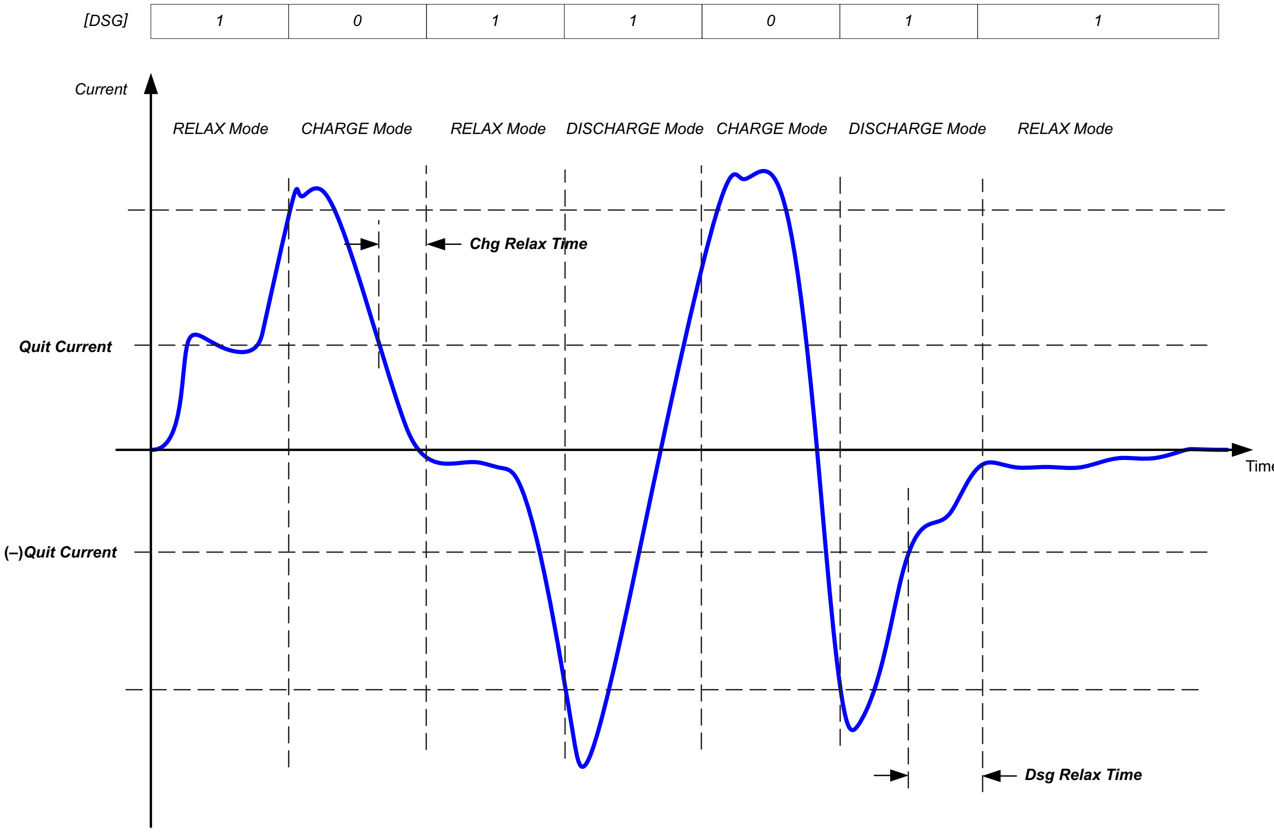


Figure 6-2. Gas Gauge Operating Mode Example

6.4 QMax and Ra

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

Measurements of OCV and charge integration determine chemical state-of-charge and Chemical Capacity (*QMax*).

The bq40z50 acquires and updates the battery-impedance profile during normal battery usage. It uses this profile, along with state-of-charge and the *QMax* values, to determine *FullChargeCapacity* and *RelativeStateOfCharge* specifically for the present load and temperature. *FullChargeCapacity* reports a capacity or energy available from a fully charged battery reduced by ***Reserve Cap-mAh*** or ***Reserve Cap-mWh*** under the present load and present temperature until *Voltage* reaches the ***Term Voltage***.

6.4.1 QMax Initial Values

The initial ***QMax Pack***, ***QMax Cell 0***, ***QMax Cell 1***, ***QMax Cell 2***, and ***QMax Cell 3*** values should be taken from the cell manufacturers' data sheet multiplied by the number of parallel cells, and are also used for the *DesignCapacity* function value in the ***Design Capacity*** data flash value.

See the *Theory and Implementation of Impedance Track Battery Fuel-Gauging Algorithm in bq20zxx Product Family Application Report* (SLUA364B) for further details.

6.4.2 QMax Update Conditions

QMax update is enabled when gauging is enabled. This is indicated by the ***GaugingStatus[QEN]*** flag. The bq40z50 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 charge or discharge activity. A relaxed state is achieved if the battery voltage has a dV/dt of < 4 µV/s. Typically it takes 2 hours in a charged state and 5 hours in a discharged state to ensure that the dV/dt condition is satisfied. If 5 hours is exceeded, a reading is taken even if the dV/dt condition was not satisfied. The *GaugingStatus()[REST]* flag is set when a valid OCV reading occurs. If a valid DOD0 (took at the previous QMax update) is available, then QMax will also be updated when a valid charge termination is detected.

The flag is cleared at the exit of a relaxed state. A QMax update is disqualified under the following conditions:

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 *CellVoltage4..1* 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 is different with different chemistry. The *GaugingStatus[OCVFR]* flag indicates if the cell voltage is inside this flat region.

Offset Error — If offset error accumulated during time passed from previous OCV reading exceeds 1% of *Design Capacity*, update is disqualified. Offset error current is calculated as ***CC Deadband*** / sense resistor value.

Several flags in *GaugingStatus()* are helpful to track for QMax update conditions. The *[REST]* flag indicates an OCV is taken in RELAX mode. The *[VOK]* flag indicates the last OCV reading is qualified for the QMax update. The *[VOK]* is set when charge or discharge starts. It clears when the QMax update occurs, when the offset error for a QMax disqualification is met, or when there is a full reset. The *[QMax]* flag will be toggled when the QMax update occurs. *ITStatus2()* and *ITStatus3()* return the QMax and DOD (depth of discharge, corresponding to the OCV reading) data.

6.4.3 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 QMax update, Fast QMax update requires only one OCV reading, AND
- The battery pack should discharge below 10% RSOC.

The differences in requirements allow the Fast QMax feature to have a QMax update at the end of discharge (given one OCV reading is already available and discharge below 10% RSOC) without a longer relax time after a discharge event. Typically, it can take up to 5 hours in a discharge state to ensure the dV/dt < 4 µV/s condition is satisfied. The Temperature, Delta Capacity, Voltage, and Offset Error requirements for 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 stage with infrequent relaxation. Setting ***IT Gauging Configuration[FAST_QMAX_LRN]*** = 1 enables Fast QMax during production learning only (that is, ***Update Status*** = 6). When setting ***IT Gauging Configuration[FAST_QMAX_FLD]*** = 1, Fast QMax is enabled when Impedance Track is enabled and ***Update Status*** ≥ 6.

6.4.4 QMax and Fast QMax Update Boundary Check

The bq40z50 implements a QMax and Fast QMax 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 ***QMaxMaxDeltaPercent***, which is the maximum allowed QMax change for each update. If the updating value is outside of this data flash

parameter, the bq40z50 caps the change to ***QMaxMaxDeltaPercent*** of the Design Capacity.

2. Bound the absolute QMax value, ***UpperBoundQMax***. This is the maximum allowed QMax value over the lifetime of the pack.
3. Ensure that QMax is greater than 0 before saving to data flash.

6.4.5 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***, ***Cell 1 R_a0...14***, ***Cell 2 R_a0...14***, ***Cell 3 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***, ***xCell 1 R_a0...14***, ***xCell 2 R_a0...14***, ***xCell 3 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***, ***Cell 1 R_a Flag***, ***Cell 2 R_a Flag***, ***Cell 3 R_a Flag*** and the ***xCell0 R_a Flag***, ***xCell 1 R_a Flag***, ***xCell 2 R_a Flag***, ***xCell 3 R_a Flag*** indicate the validity of the cell impedance table for each cell.

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

High Byte		Low Byte	
0x00	Cell impedance and QMax updated	0x00	Table not used and QMax updated
0x05	RELAX mode and QMax update in progress	0x05	RSVD
0x55	DISCHARGE mode and cell impedance updated	0x55	Table is used
0xFF	Cell impedance never updated	0xFF	A fast Qmax update without OCV read will also clear the R_DIS flag. Table never used, no QMax or cell impedance update.

6.4.6 Ra Table Update Conditions

The impedance is different across different DOD states. Each cell has 15 Ra grid points presenting 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()[R_DIS]* 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), OR
- Ra update is disabled if the charge accumulation error > 2% of Design Capacity, OR
- During a discharge, a bad Ra value is calculated:
  - A negative Ra is calculated or
  - A bad RaScale value is calculated.

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

6.5 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 at real time.

- QMax update occurs

- Ra update occurs
- At onset of charge and discharge
- At exit of discharge
- Every 5 hours in RELAX mode
- If temperature changes more than 5°C

6.6 Impedance Track Configuration Options

The bq40z50 provides several Impedance Track (IT) configuration options to fine-tune the gauging performance. These configurations can be turned on or off through the corresponding flags in ***SBS Gauging Configuration*** or ***IT Gauging Configuration***.

[LOCK0]: After a discharge event, cell voltage will usually recover to a slightly higher voltage during RELAX state. 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()* jumping back during relaxation after 0% and FD are reached during discharge.

[RSOC_HOLD]: An IT simulation will run at the onset of discharge. If charge terminates at a low temperature and a 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.

[RSOC_HOLD] should not be used when ***[SMOOTH]*** is set.

[RSOCL]: When set, RSOC will be held at 99% until charge termination is detected. See Section 4.6 for details.

[RFACTSTEP]: The gauge keeps track of an Ra factor of the (old Ra)/(new Ra) during the Ra update. This factor is used for Ra scaling. It is limited to 3 max. During an Ra update, if (old Ra)/(new Ra) is > 3, the gauge can take on two different actions based on the setting of this flag.

If this flag is set to 1 (default), the gauge allows Ra to update once using the max factor of 3, 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.

[OCVFR]: An OCV reading is taken when a dV/dt condition is met. This is not the case if charging stops within the flat voltage region.

By default, this flag is set. The device will take a 48-hour wait before taking an OCV reading if charging stops below the FlatVoltMax. A discharge will not cancel this 48-hour wait. The 48-hour wait will only be cleared if charging stops above the FlatVoltMax level. Setting this flag to 0 removes the 48-hour wait requirement, and OCV is taken when 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, etc), the temperature, and the amount of relax time at the time of the reading, and so on 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 a reduction of RSOC jumps after relaxation.

[LFP_RELAX]: This is an option for LiFePO4 chemistry. This flag can be enabled even if non-LiFePO4 chemistry is programmed. The device will check for the chemistry ID (that is, ChemID = 4xx series) before activating this function.

The LiFePF4 has a unique slow Configuration relaxation near full charge. Detailed, in-house test data suggests that the relaxation after a full charge takes a few days to settle. The slow decaying voltage causes RSOC to continue to drop every 5 hours. Depending on the full charge taper current, the fully settled voltage could be close to or even below FlatVoltMax in some cases. For the chemID 4xx (LiFePO4) series, the condition to exit the long RELAX mode is if the pack had previously charged to full or near full state, and then either a significant long relaxation or a non-trivial discharge has happened, such that when in relaxation, the OCV < ***FlatVoltMax***.

The QMax update is disabled because DOD will not be taken as long as it is in LFP_relax mode. By the time the gas gauge exits the LFP_relax mode, the OCV is already in the flat zone. Therefore, the QMax update takes an alternative approach: Once full charge occurs ([FC] bit set), DOD0=Dod_at_EOC is automatically assigned and valid for a QMax update. ***[VOK]*** is set if there is no QMax update. If QMax is updated, ***[VOK]*** is cleared. The DOD error as a result of this action is zero or negligible because in the LiFePO4 table, OCV voltage corresponding to DOD= 0 is much lower.

[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 Section 6.4.3 for more details.

[RSOC_CONV]: This function is also called fast scaling. It is an option to address the convergence of RSOC to 0% at a low temperature and a very high rate of discharge. Under such conditions, it is possible to have a drop of RSOC to 0%, especially if the termination voltage is reached at the DOD region with a higher Ra grid interval. To account for the error caused by the high granularity of the impedance grid interval, the ***[ROSC_CONV]***, when enabled, applies a scale factor to impedance, allowing more frequent impedance data updates used for RemCap simulation leading up to 0% ROSC.

If ***[ROSC_CONV]*** is enabled, it is recommended to start this function around the knee region of the discharge curve. This is usually around 10% of ROSC or around 3.3 V~3.5 V. This function will check for both cell voltage and RSOC status and start the function when either condition is met. The RSOC and cell voltage setting can be configured through ***Fast Scale Start SOC*** or ***Term Voltage Delta***.

[FF_NEAR_EDV]: Fast Filter Near EDV. If this flag is set, 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 default. When this flag is 0, the gauge uses the regular Ra filter, ***Resistance Parameter Filter***. Both of the DF filters should not be changed from the default.

[SMOOTH]: A change in temperature or current rate can cause a significant change in Remaining Capacity (RemCap) and Full Charge Capacity (FCC), resulting in a jump or drop in the Relative State-of-Charge (RSOC). This function provides an option to prevent an RSOC jump or drop during charge and discharge.

If a jump or drop of RSOC occurs, the device examines the amount of RSOC jump or drop versus the expected end point (that is, the charge termination for the charging condition or the EDV for the discharge condition) and automatically smooths the change of RSOC, and always converges with the filtered (or smoothed) value to the actual charge termination or EDV point. The actual and filtered values are always available. The ***[SMOOTH]*** flag selects either the actual or filtered values are returned by the SBS commands.

[RELAX_JUMP_OK] and ***[RELAX_SMOOTH_OK]***: When the battery enters RELAX mode from CHARGE or DISCHARGE mode, the transient voltage may change to RSOC as the battery goes into its RELAX state. Once the battery is in RELAX mode, a change in temperature or self-discharge may also cause a change in RSOC.

If ***[RELAX_JUMP_OK]*** = 1, this allows the RSOC jump to occur during RELAX mode. Otherwise, RSOC holds constant during RELAX mode and any RSOC jump will be passed into the onset of the charge or discharge phase.

If ***[RELAX_SMOOTH_OK]*** = 1, this allows the amount of the RSOC jump to be smoothed out over a period of ***Smooth Relax Time***. Otherwise, the additional RSOC jump amount will be passed into the onset of charge or discharge phase.

If both flags are set to 1, the ***[RELAX_JUMP_OK]*** = 1 takes higher priority and the RSOC jump is allowed during RELAX mode.

[TDELAV]: This flag setting defines how the ***Delta Voltage*** is calculated. By setting this flag to 1, the gauge will calculate ***Delta Voltage*** that corresponds to the power spike defined in ***Min Turbo Power***. This flag must be set to 1 if TURBO BOOST mode is used. Otherwise, leaving this flag set to 0 as default enables the gauge to calculate ***Delta Voltage*** by using the maximal difference between instantaneous and average voltage.

[CELL_TERM]: This flag provides an option to have a cell voltage based discharge termination. If the minimum cell voltage reaches ***Term Min Cell V***, *RemainingCapacity()* will be forced to 0 mAh. For more details, see the *Pack Based and Cell Based Termination* section in Section 6.2.

[CSYNC]: This flag, if set to 1, will synchronize *RemainingCapacity()* to *FullChargeCapacity()* at valid charge termination.

[CCT]: This flag provides an option to use *FullChargeCapacity()* (***[CCT]*** = 1) or *DesignCapacity()* (***[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 Design Capacity. This is to avoid any erroneous cycle count increment caused by extremely low *FullChargeCapacity()*.

[VOLTAGE_CONSIST]: Voltage Consistency Check. This function helps to prevent an RSOC jump. The flag should be set to 1 as default. The resistance toward the EDV level is not linear. The non-linearity can result in a raise in voltage in DISCHARGE mode. When this function is enabled, the gauge checks will ignore the increase of voltage from the voltage measurement. Instead, an interpolation using previous measurements is applied. The voltage consistency check will take place when the voltage is within the ***Voltage Consistency Delta*** from the ***Term Voltage***.

6.7 State-of-Health (SoH)

The bq40z50 implements a new state-of-health (SoH) function. Previously, the SoH of a battery was typically represented by the actual runtime ***FullChargeCapacity/Design Capacity*** (or FCC/DC). Using the runtime FCC, however, was not a very good representation for the state-of-health because the runtime FCC reflects the usable capacity under load. A high current load reduces the runtime FCC. If using just the FCC/DC calculation for SoH, the SoH under high load will be worse than the SoH under typical load. However, a smaller usable capacity at high load does not mean the SoH of a battery is degraded. This is the same when FCC is reduced at a lower temperature.

The bq40z50 implementation of state-of-health addresses these issues. It provides the SoH of the battery through an SBS command, *SoH()*. The *SoH()* is calculated using the FCC simulated at 25°C with current specified by ***SoH Load Rate***. The ***SoH Load Rate*** can be set to the typical current of the application, and it is specified in hour-rate (that is, ***Design Capacity/SoH Load Rate*** will be the current used for the SoH simulation). This data flash setting is used for *SOH()* calculation only. This SoH FCC is updated at the same time ASOC and RSOC are updated. Since this implementation removes the variation of current or temperature, it is a better representation of a battery's state-of-health. The SoH FCC is available on MAC *StateOfHealth()*.

6.8 TURBO BOOST Mode

A system with TURBO BOOST mode applies short high-power pulses (for example 10 ms) during the turbo boost operation. These high-power pulses may drop down battery voltage. If the battery voltage drops below the ***Shutdown Voltage***, the system will shut down. To avoid shutting down the system during turbo boost operation, the system should never apply a pulse with power that would cause the battery power to go below the system shutdown voltage.

The TURBO BOOST mode in the bq40z50 helps the system to adjust the power level by providing information about maximal power depending on the battery state-of-charge, temperature, and present battery impedance. In particular, the gauge predicts the maximum power pulse (*TURBO_POWER()*) and maximum current pulse (*TURBO_CURRENT()*) the system can draw for 10 ms without system input power delivered by the battery dropping below the termination voltage. The *TURBO_POWER()* and *TURBO_CURRENT()* are updated every 1 s in the NORMAL mode of operation.

The ***Max C Rate*** specifies the maximal discharge current. If the calculated turbo current is larger than the ***Max C Rate***, then the reported *TURBO_CURRENT()* is capped to this value. The *TURBO_POWER()* is adjusted accordingly. The ***IT Gauging Configuration[TDELTAV]*** must be set when TURBO BOOST mode is in use. This flag calls the gauge to calculate the ***Delta Voltage*** that corresponds to the power spike defined in ***Min Turbo Power***. The ***Pack Resistance*** and the ***System Resistance*** are additional resistance inputs of the overall system that should be specified to archive an accurate maximum power and current computation. The ***High Frequency Resistance*** is cell chemistry and battery pack configuration specific parameters. It is required to use the TURBO BOOST mode.

The system should always consume less power than the *TURBO_POWER()* level to avoid system shutdown. However, depending on how often the system polls the *TURBO_POWER()* data and how fast the system can switch to a lower power mode, it is possible to exceed the *TURBO_POWER()* level during the present power consumption. To avoid any system shutdown, the gauge provides a ***Reserve Energy %*** setting, which can be served as a "buffer" to ensure there is available energy at the present average discharge rate until the maximal peak power reported by *TURBO_POWER()*.

6.9 Battery Trip Point (BTP)

Required for WIN8 OS, the battery trip point (BTP) feature indicates when the RSOC of a battery pack has depleted to a certain value set in a DF register.

The BTP feature allows a host to program two capacity-based thresholds that govern the triggering of a BTP interrupt on the BTP_INT pin and the setting or clearing of the *OperationStatus()[BTP_INT]* on the basis of *RemainingCapacity()*. The interrupt is enabled or disabled via ***Settings.Configuration.IO Config[BTP_EN]***. Similarly, the polarity of the interrupt is configurable based on the value set in ***Settings.Configuration.IO Config[BTP_POL]***.

- *OperationStatus()[BTP_INT]* is set when:
  - Current > 0 and RemCap > “clear” threshold (“charge set threshold”). This threshold is initialized at reset from ***Settings.BTP.Init Charge Set***.
  - Current ≤ 0 and RemCap < “set” threshold (“discharge set threshold”). This threshold is initialized at reset from ***Settings.BTP.Init Discharge Set***.
- When *OperationStatus()[BTP_INT]* is set, if ***Settings.Configuration.IO Config[BTP_EN]*** is set, then the BTP_INT pin output is asserted.
  - If ***Settings.Configuration.IO Config[BTP_POL]*** is set, it will assert high; otherwise, it will assert low.
- When either *BTPDischargeSet()* or *BTPChargeSet()* commands are received, *OperationStatus()[BTP_INT]* will clear and the pin will be de-asserted. The new threshold is written to either *BTPDischargeSet()* or *BTPChargeSet()*.
- At reset, the pin is set to the de-asserted state.
  - If ***[BTP_POL] is changed***, one of the BTP commands must be reset or sent to “clear" the state.

Cell Balancing

7.1 Introduction

The bq40z50 can determine the chemical state-of-charge of each cell using the Impedance Track algorithm. The cell balancing algorithm used in the device decreases the differences in imbalanced cells in a fully charged state gradually, which prevents fully charged cells from becoming overcharged, causing excessive degradation. This increases overall pack energy by preventing premature charge termination.

The algorithm determines the amount of charge needed to fully charge each cell. There is a bypass FET in parallel with each cell connected to the gas gauge. The FET is enabled for each cell with a charge greater than the lowest charged cell to reduce charge current through those cells. Each FET is enabled for a precalculated time as calculated by the cell balancing algorithm. When any bypass FET is turned on, then the *OperationStatus()[CB]* operation status flag is set; otherwise, the *[CB]* flag is cleared.

The gas gauge balances the cells by balancing the SOC difference. Thus, a field updated QMax (***Update Status*** = 0E) is required prior to any attempt of Cell Balance Time calculation. This ensures the accurate SOC delta is calculated for the cell balancing operation. If the Qmax update has only occurred once (***Update Status*** = 06), then the gauge will only attempt to calculate the Cell Balance Time if a fully charged state is reached, *GaugingStatus()[FC]* = 1.

The cell balancing is enabled if ***Settings:Balancing Configuration [CB]*** = 1. The cell balancing at rest can be enabled separately by setting ***Balancing Configuration [CBR]*** = 1. If ***Settings:Balancing Configuration [CB]*** = 0, both cell balancing at charging and at rest are disabled.

The cell balancing at rest can be configured by determining the data flash ***Min Start Balance Delta***, ***Relax Balance Interval***, and ***Min RSOC for Balancing***. For the data flash setting description, see Section 13.5.12. The gas gauge balances cells by bypassing the energy. It is recommended to perform cell balancing at rest when there is capacity in the battery pack.

7.2 Cell Balancing Setup

The bq40z50 is required to be in RELAX mode before it can determine if the cells are unbalanced and how much balancing is required. The bq40z50 enters RELAX mode when:

|*Current()*|< ***Quit Current*** for at least ***Dsg Relax Time*** when coming from DISCHARGE mode or ***Chg Relax Time*** when coming for CHARGE mode.

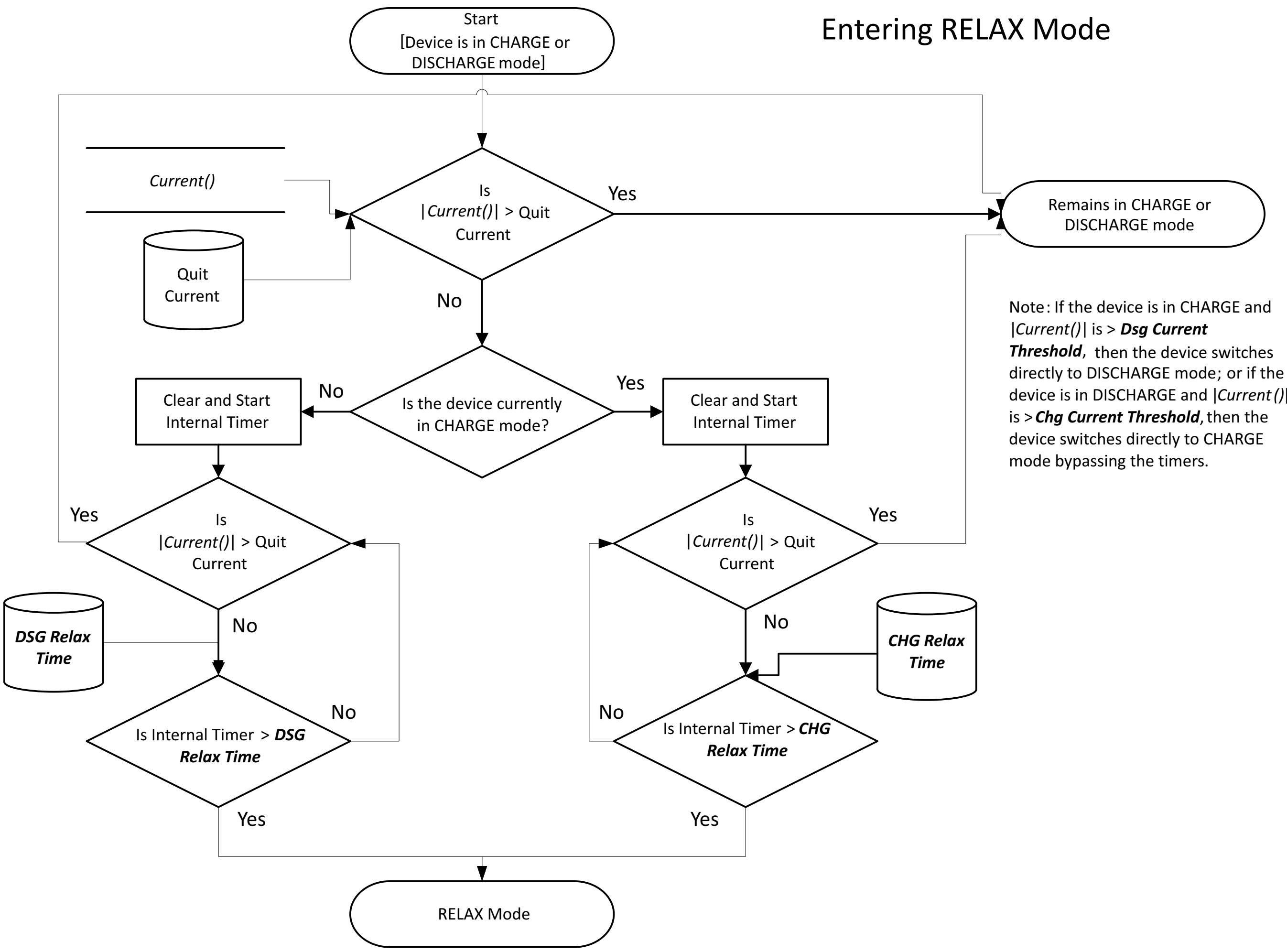


Figure 7-1. Entering CHARGE or RELAX Mode

Once in RELAX mode, the bq40z50 waits until an OCV measurement is taken, which occurs after:

1. A dV/dt condition of < 4 µV/s is satisfied,
2. Five hours from when |*Current()*| < ***Quit Current***,
3. Upon gas gauge reset,
4. An IT Enable command is issued.

The determination of when to update the OCV data is part of the normal Impedance Track algorithm and is not specific to the cell balancing algorithm.

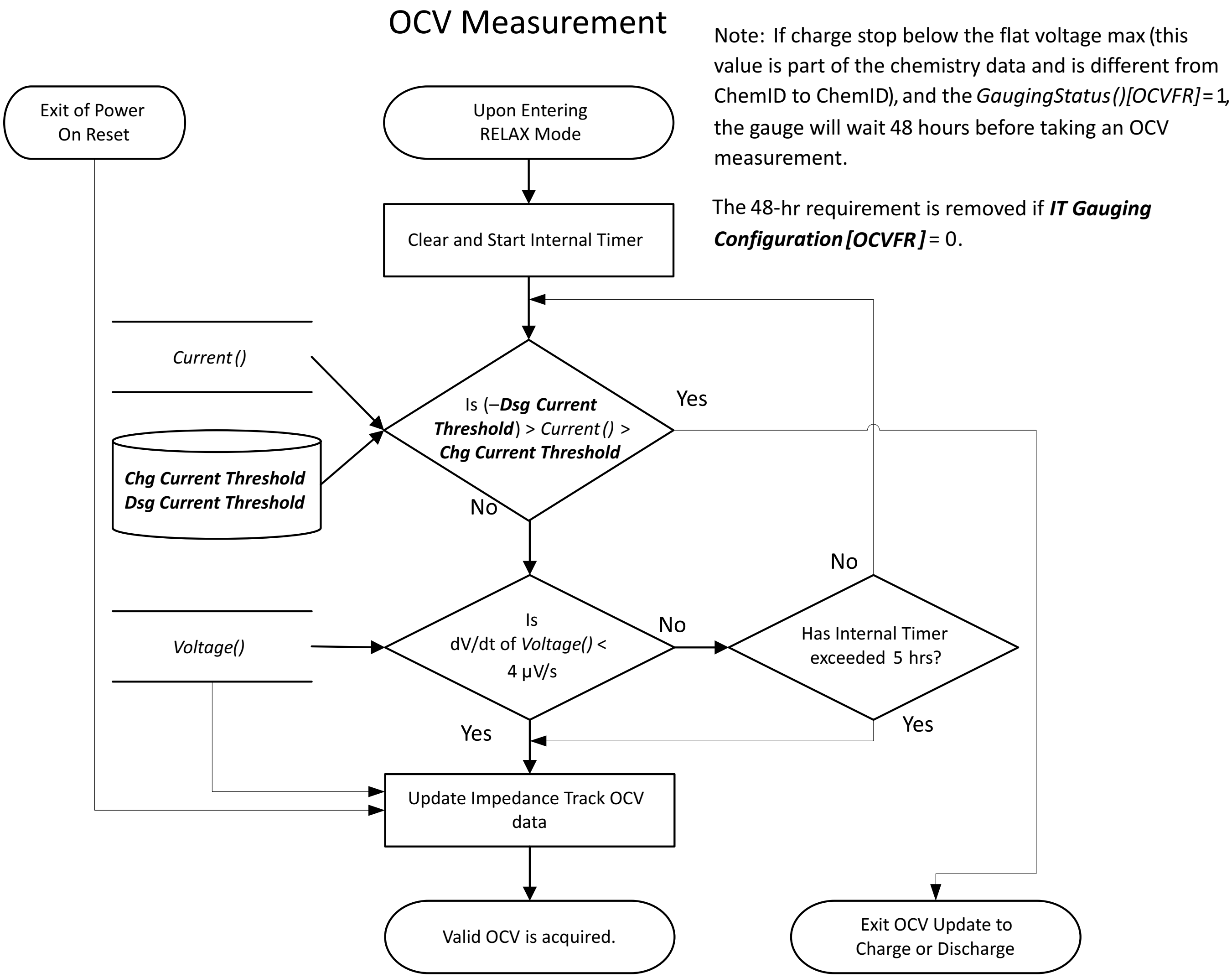


Figure 7-2. OCV Measurement

The bq40z50 then calculates the amount of charge difference between cells with a higher state-of-charge than the lowest cell SOC. The value, dQ, is determined for each cell based by converting the measured OCV to Depth-of-Discharge (DOD) percentages using a temperature-compensated DOD vs. OCV table lookup table. If the measured, OCV does not coincide with a specific table entry, then the DOD value is linearly interpolated from the two adjacent DODs of the respective table adjacent OCVs.

The delta in DOD% between each cell and the cell of lowest SOC is multiplied by the respective cells QMax to create dQ: for example, dQ = CellnDOD – CellLOWEST_SOC DOD × CellnQMax (mAh).

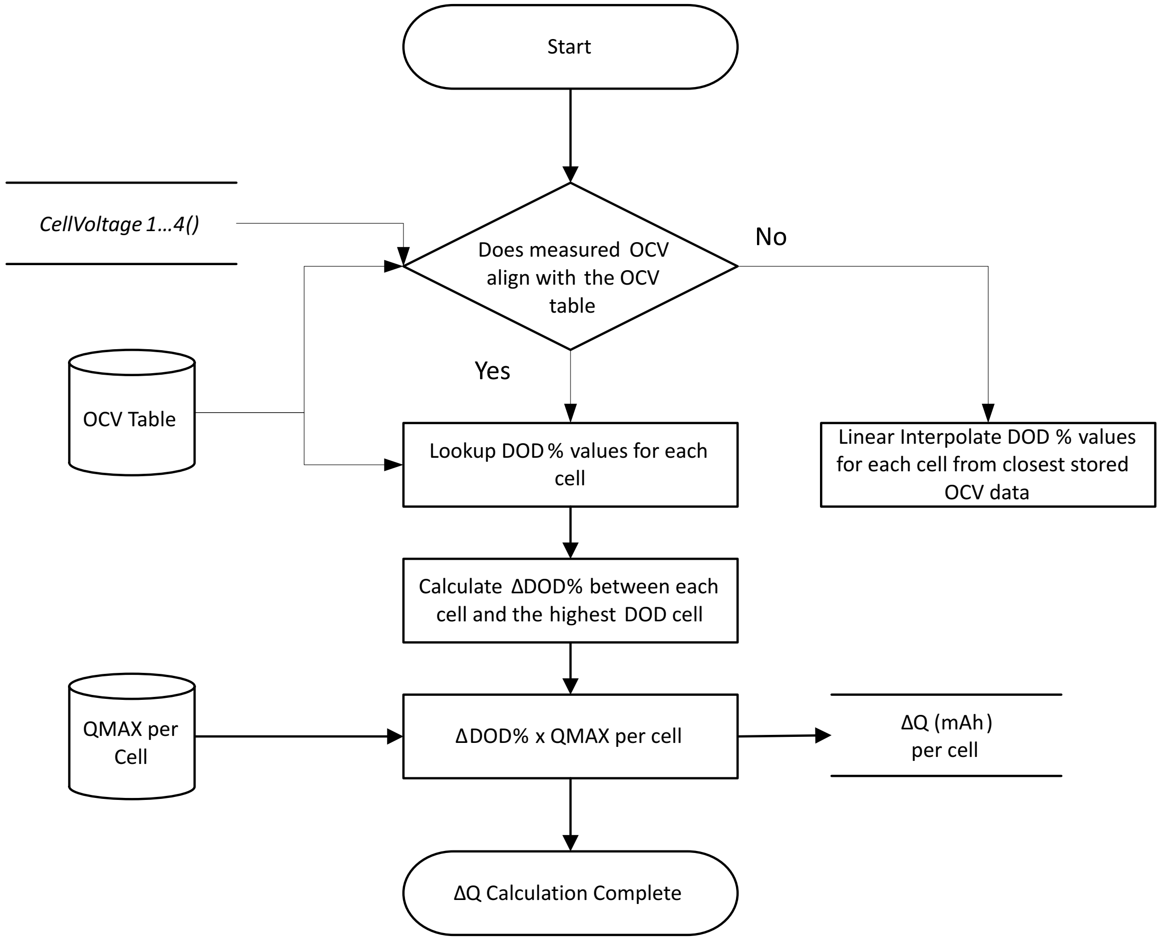


Figure 7-3. ΔQ Calculation

The bq40z50 calculates the required balancing time using dQ and ***Bal Time/mAh Cell 1*** (for Cell 1) or Bal Time/mAh Cell 2–4 (for cells 2–4). The value of ***Bal Time/mAh Cell 1*** and ***Bal Time/mAh Cell 2–4*** are fixed value determined based on key system factors and is calculated by:

Bal Time/mAh Cell 1 = 3600 mAs/(V_{CELL}/RVCx + R_{cb}) × DUTY/1000

Bal Time/mAh Cell 2–4 = 3600 mAs/(V_{CELL}/(2×RVCx + Rcb) × DUTY)/1000

Where:

V_{CELL} = average cell voltage (for example, 3.7 V for most chemistry)

RVCx = resistor value in series to VCx input (for example, 100 Ω, based on the reference schematic)

R_{cb} = cell balancing FET R_{dson}, which is 150 Ω

DUTY = cell balancing duty cycle, which is 66% typ

The cell balancing time for each cell to be balanced is calculated by: dQCelln × ***Bal Time/mAh Cell 1*** for Cell 1 or and dQCelln × ***Bal Time/mAh Cell 2–4*** for Cell 2–4. The cell balancing time is stored in the 16-bit RAM register CellnBalanceTimer, providing a maximum calculated time of 65535 s (or 18.2 hrs). This update only occurs if a valid QMax update has been made; otherwise, they are all set to 0.

7.3 Balancing Multiple Cells Simultaneously

The bq40z50 can balance multiple cells simultaneously if internal cell balancing is selected, ***Balancing Configuration[CBM]*** = 0.

If external cell balancing is selected, ***[CMB]*** = 1, the gauge will perform a rotation cell balancing with only 1 cell to be balanced at a time, starting on the cell with highest dQ first. For example, at time 0, Cell 1 has the highest dQ while Cell 2 has the 2nd highest dQ on a 3S pack. The external cell balancing will start to balance Cell 1 first. As time progresses, the dQ in cell reduces, and Cell 2 becomes the cell with the highest dQ. The gauge will then switch to balance Cell 2. The cell balancing rotation between Cell 1 and Cell 2 continues until all the cells are balanced.

7.4 Cell Balancing Operation

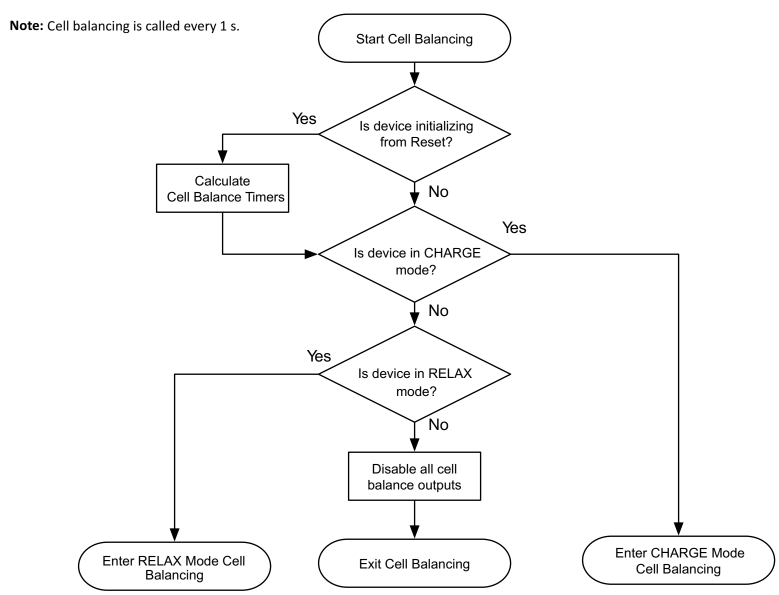


Figure 7-4. Cell Balance Mode Detection

The bq40z50 calls the cell balancing algorithm every 1 s during normal operation. Cell balancing is not called when the device is in SLEEP mode. All algorithm decisions are made on this same 1-s timer.

In RELAX mode, if cell balancing at rest is enabled, ***Balancing Configuration[CBR]*** = 1, the gauge will verify if the dv/dt condition is met at the entry of the RELAX mode. If so, then the cell balance at rest will start when all of the conditions below are met:

- Any of the pre-calculated Cell Balance Timer is non-zero, AND
- *RelativeStateofCharge()* > ***Min RSOC for Balancing***

The gauge will attempt to re-calculate the cell balancing time in RELAX mode every ***Relax Balance Interval***. The cell balancing time is updated if the conditions below are met:

- The Relax Balance Interval has passed, AND
- A OCV measurement is taken, AND
- The max cell voltage delta > ***Min Start Balance Delta***

On exit of the RELAX mode, cell balancing time is re-calculated as long as a valid OCV update is available.

NOTE: Cell balancing is paused during OCV measurement.

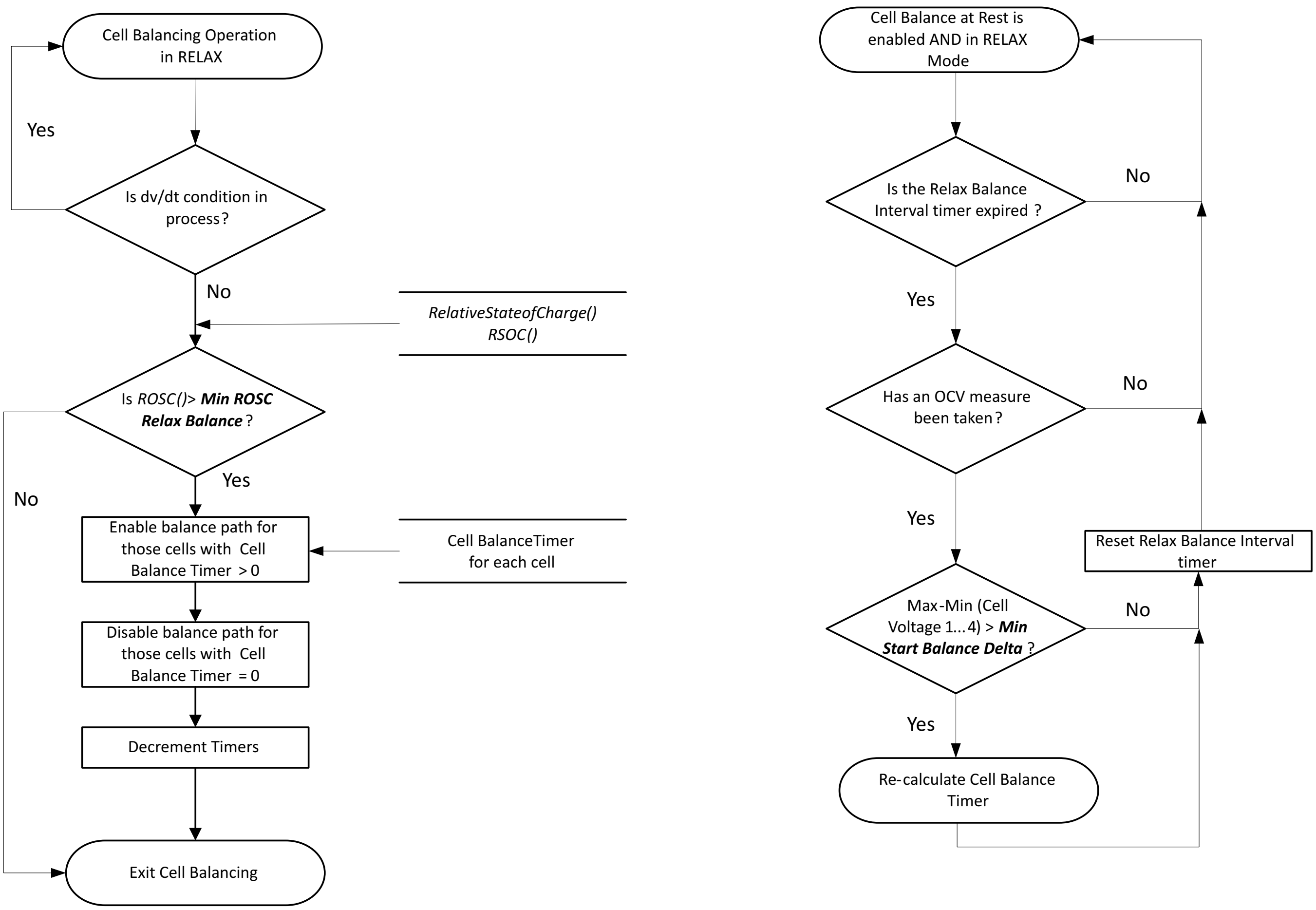


Figure 7-5. Cell Balance Operation in RELAX Mode

When the bq40z50 is in CHARGE mode, it follows these steps during cell balancing:

(a) Check if any of the pre-calculated Cell Balance Timers are > 0.

(b) The cell balance FETs are turned ON for the corresponding cell balance timers that are ≠ 0.

NOTE: There are no SOC restrictions controlling the enabling of cell balancing in CHARGE mode.

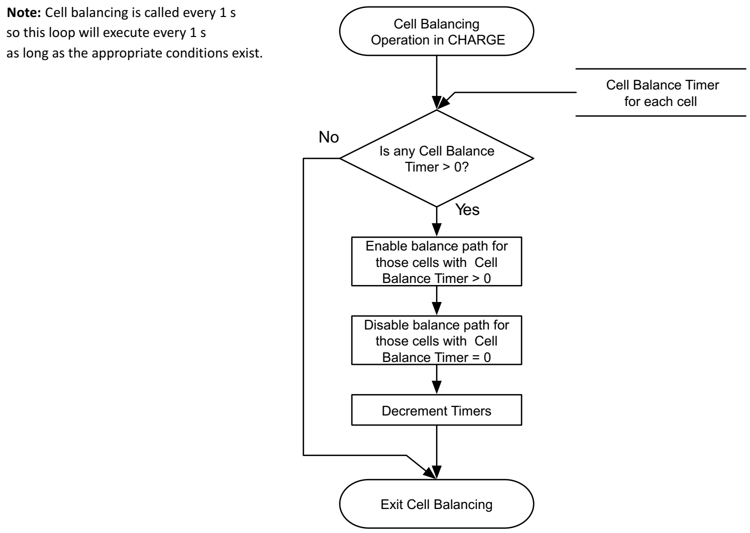


Figure 7-6. Cell Balance Operation in CHARGE Mode

LED Display

8.1 Overview

The bq40z50 device has an LED display that shows various status information when a high-to-low transition of the $\overline{DISP}$ pin is detected. The LED display is disabled if *SafetyStatus[CUV]* or *[CUVC]* = 1.

8.1.1 LED Display of State-of-Charge

When the $\overline{DISP}$ pin is pressed and a high-to-low transition of the pin is detected, the LED display shows the state-of-charge for ***LED Hold Time***. The state-of-charge can display the *RelativeStateOfCharge()* or *AbsoluteStateOfCharge()* based on the ***[LEDMODE]*** setting.

The state-of-charge threshold can be set according to the number of LEDs available. The following table shows an example for data flash setting with 5-LED display.

If ***[LEDCHG]*** = 1, the LED display will show the state-of-charge during charging when *Current()* > ***Charge Current Threshold***.

	State-of-Charge	
	Current() > 0	*Current()* ≤ 0
LED1	***CHG Thresh 1*** – 100%	***DSG Thresh 1*** – 100%
LED2	***CHG Thresh 2*** – 100%	***DSG Thresh 2*** – 100%
LED3	***CHG Thresh 3*** – 100%	***DSG Thresh 3*** – 100%
LED4	***CHG Thresh 4*** – 100%	***DSG Thresh 4*** – 100%
LED5	***CHG Thresh 5*** – 100%	***DSG Thresh 5*** – 100%

If ***[LEDRCA]*** = 1 and the BatteryStatus[RCA] change from 0 to 1, the LED display will also flash with ***LED Flash Rate*** according to the ***CHG Flash Alarm*** or ***DSG Flash Alarm*** setting as shown below.

	State-of-Charge	
	Current() > 0	*Current()* ≤ 0
Flash Alert	0 % – ***CHG Flash Alarm***	0 % – ***DSG Flash Alarm***

8.1.2 LED Display of PF Error Code

If ***[LEDPF1, LEDPF0]*** = 0,1, then the LED display shows each PF code for 2× the ***LED Hold Time*** after showing the state-of-charge information.

The following table shows each PF error code. Each code is shown with the lowest to highest priority order.

PF Flag	Priority	LED3	LED2	LED1
No PF	0	***LED Blink Rate***	off	off
SUV	0	***LED Blink Rate***	on	off
SOV	1	***LED Blink Rate***	***LED Flash Rate***	off
SOCC	2	***LED Blink Rate***	off	on
SOCD	3	***LED Blink Rate***	on	on
SOT	4	***LED Blink Rate***	***LED Flash Rate***	on
Reserved	5	***LED Blink Rate***	off	***LED Flash Rate***
SOTF	6	***LED Blink Rate***	on	***LED Flash Rate***

PF Flag	Priority	LED3	LED2	LED1
QIM	7	***LED Blink Rate***	***LED Flash Rate***	***LED Flash Rate***
CB	8	***LED Blink Rate***	off	***LED Blink Rate***
IMP	9	***LED Blink Rate***	on	***LED Blink Rate***
CD	10	***LED Flash Rate***	***LED Blink Rate***	off
VIMR	11	off	***LED Blink Rate***	off
VIMA	12	on	***LED Blink Rate***	off
Reserved	13	***LED Flash Rate***	***LED Blink Rate***	on
Reserved	14	off	***LED Blink Rate***	on
Reserved	15	on	***LED Blink Rate***	on
CFETF	16	***LED Flash Rate***	***LED Blink Rate***	***LED Flash Rate***
DFETF	17	off	***LED Blink Rate***	***LED Flash Rate***
Reserved	18	on	***LED Blink Rate***	***LED Flash Rate***
FUSE	19	***LED Flash Rate***	***LED Blink Rate***	***LED Blink Rate***
AFER	20	off	***LED Blink Rate***	***LED Blink Rate***
AFEC	21	on	off	***LED Blink Rate***
2LVL	22	***LED Flash Rate***	off	***LED Blink Rate***
PTC	23	off	off	***LED Blink Rate***
IFC	24	on	on	***LED Blink Rate***
OPNCELL	25	***LED Flash Rate***	on	***LED Blink Rate***
DF	26	off	on	***LED Blink Rate***
Reserved	27	on	***LED Flash Rate***	***LED Blink Rate***
Open Therm TS1	28	***LED Flash Rate***	***LED Flash Rate***	***LED Blink Rate***
Open Therm TS2	29	off	***LED Flash Rate***	***LED Blink Rate***
Open Therm TS3	30	on	***LED Blink Rate***	***LED Blink Rate***
Open Therm TS4	31	***LED Flash Rate***	***LED Blink Rate***	***LED Blink Rate***

8.1.3 LED Display on Exit of a Reset

If the ***[LEDR]*** = 1 and a reset occurs at the exit of the rest, the LED display shows the state-of-charge for ***LED Hold Time***. If ***[LEDPF1, LEDPF0]*** = 0,1, the LED display also shows each of the PF error code for 2 × of the ***LED Hold Time*** afterward.

8.1.4 LED Display Control Through ManufacturerAccess()

The gauge provides *ManufacturerAccess()* command (MAC) for testing purpose. The MAC *LED Toggle()* command can toggle the LED display on and off. The MAC *LED Display Press()* command can trigger the LED display and simulate 100% RSOC to demonstrate with all LEDs in actions.

Lifetime Data Collection

9.1 Description

Useful for analysis, the device has extensive capabilities for logging events over the life of the battery. The Lifetime Data Collection is enabled by setting *ManufacturingStatus()[LF_EN]* = 1. The data is collected in RAM and only written to DF under the following conditions to avoid wear out of the data flash:

- Every 10 hours if RAM content is different from flash.
- In permanent fail, before data flash updates are disabled.
- A reset counter increments. The lifetime RAM data is reset; therefore, only the reset counters are updated to data flash.
- Before scheduled shutdown
- Before low voltage shutdown and the voltage is above the ***Valid Update Voltage***.

The Lifetime Data stops collecting under following conditions:

- After permanent fail
- 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.

- *Lifetime Data Reset()* can be used to reset the Lifetime Data.
- *Lifetime Data Flush()* can be used to flush out RAM Lifetime Data to data flash.
- *Lifetime Data Speedup Mode()* can be used to increase the rate the Lifetime Data is incremented.

Total firmware Runtime starts when Lifetime Data is enabled.

- Voltage
  - Max/Min Cell Voltage Each Cell
  - Max Delta Cell Voltage at any given time (that is, the max cell imbalance voltage)
- Current
  - Max Charge/Discharge Current
  - Max Average Discharge Current
  - Max Average Discharge Power
- Safety Events that trigger the *SafetyStatus()* (The 12 most common are tracked.)
  - Number of Safety Events
  - Cycle Count at Last Safety Event(s)
- Charging Events
  - Number of Valid Charge Terminations (That is, the number of times *[VCT]* is set.)
  - Cycle Count at Last Charge Termination
- Gauging Events
  - Number of QMax updates
  - Cycle Count at Last QMax update
  - Number of RA updates and disable
  - Cycle Count at Last RA update and disable

- Power Events
  - Number of Resets, Partial Resets, and Watchdog Resets
  - Number of shutdowns
- Cell Balancing (This data is stored with a resolution of 2 hours up to a limit of 510 hours.)
  - Cell Balancing Time each Cell
- Temperature
  - Max/Min Cell Temp
  - Delta Cell Temp (max delta cell temperature across the thermistors that are used to report cell temperature)
  - Max/Min Int Temp Sensor
  - Max FET Temp
- Time (This data is stored with a resolution of 2 hours.)
  - Total runtime
  - Time spent different temperature ranges
- Discharge Temp
  - Max Discharge Temp
  - Min Discharge Temp
  - Time Max Discharge Temp
  - Time Min Discharge Temp
- Charge Temp
  - Max Charge Temp
  - Min Charge Temp
  - Time Max Charge Temp
  - Time Min Charge Temp
- Charge Voltage
  - Max Charge Voltage
  - Min Charge Voltage
  - Time Max Charge Voltage
  - Time Min Charge Voltage
- Discharge Current
  - Max Discharge Current
  - Min Discharge Current
  - Time Max Discharge Current
  - Time Min Discharge Current

Device Security

10.1 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-1 HMAC authentication with the host system.

10.2 SHA-1 Description

As of March 2012, the latest revision is FIPS 180-4. SHA-1, or secure hash algorithm, is used to compute a condensed representation of a message or data also known as hash. For messages < 2^{64}, the SHA-1 algorithm produces a 160-bit output called a digest.

In a SHA-1 one-way hash function, there is no known mathematical method of computing the input given, only the output. The specification of SHA-1, as defined by FIPS 180-4, states that the input consists of 512-bit blocks with a total input length less than 264 bits. Inputs that do not conform to integer multiples of 512-bit blocks are padded before any block is input to the hash function. The SHA-1 algorithm outputs the 160-bit digest.

The device generates a SHA-1 input block of 288 bits (total input = 160-bit message + 128-bit key). To complete the 512-bit block size requirement of the SHA-1 function, the device pads the key and message with a 1, followed by 159 0s, followed by the 64 bit value for 288 (000...00100100000), which conforms to the pad requirements specified by FIPS 180-4.

Detailed information about the SHA-1 algorithm can be found here:

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

10.3 HMAC Description

The SHA-1 engine calculates a modified HMAC value. Using a public message and a secret key, the HMAC output is considered to be a secure fingerprint that authenticates the device used to generate the HMAC.

To compute the HMAC: Let H designate the SHA-1 hash function, M designate the message transmitted to the device, and KD designate the unique 128-bit Unseal/Full Access/Authentication key of the device. HMAC(M) is defined as:

H[KD || H(KD || M)], where || symbolizes an append operation.

The message, M, is appended to the unseal/full access/authentication key, KD, and padded to become the input to the SHA-1 hash. The output of this first calculation is then appended to the unseal/full access/authentication key, KD, padded again, and cycled through the SHA-1 hash a second time. The output is the HMAC digest value.

10.4 Authentication

1. Generate 160-bit message M using a random number generator that meets approved random number generators described in FIPS PUB 140–2.
2. Generate SHA-1 input block B1 of 512 bytes (total input = 128-bit authentication key KD + 160-bit message M + 1 + 159 0s + 100100000).
3. Generate SHA-1 hash HMAC1 using B1.

4. Generate SHA-1 input block B2 of 512 bytes (total input = 128-bit authentication key KD + 160-bit hash HMAC1 + 1 + 159 0s + 100100000).
5. Generate SHA-1 hash HMAC2 using B2.
6. With no active *Authentication()* data waiting, write 160-bit message M to *Authentication()* in the format: 0xAABBCCDDEEFFGGHHIIJJKKLLMMNNOOPPQQRRSSTT, where AA is LSB.
7. Wait 250 ms, then read *Authentication()* for HMAC3.
8. Compare host HMAC2 with device HMAC3. If it matches, both host and device have the same key KD and the device is authenticated.

10.5 Security Modes

10.5.1 FULL ACCESS or UNSEALED to SEALED

The MAC *Seal Device()* command instructs the device to limit access to the SBS functions and data flash space, and sets the *[SEC1][SEC0]* flags. In SEALED mode, standard SBS functions have access (per the Smart Battery Data Specification). Most of the extended SBS functions and data flash are not accessible. Refer to Chapter 12 where each command has documented the accessibility information. Once in SEALED mode, the gauge can never permanently return to UNSEALED or FULL ACCESS modes.

10.5.2 SEALED to UNSEALED

SEALED to UNSEALED instructs the device to extend access to the SBS and data flash space and clears the *[SEC1][SEC0]* flags. In UNSEALED mode, all data, SBS, and DF have read/write access. Note that although writing to most of the SBS commands are accepted by the gauge, the written data will be immediately overwritten by the gauge and the write action is ignored. Unsealing is a two-step command performed by writing the first word of the unseal key to *ManufacturerAccess() (MAC)*, followed by the second word of the unseal key to *ManufacturerAccess()*. The two words must be sent within 4 s. The unseal key can be read and changed via the *MAC SecurityKey()* command when in the 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.

10.5.3 UNSEALED to FULL ACCESS

UNSEALED to FULL ACCESS instructs the device to allow full access to all SBS commands 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 *ManufacturerAccess()* command, by writing the first word of the Full Access Key to *ManufacturerAccess()*, followed by the second word of the Full Access Key to *ManufacturerAccess()*. The two words must be sent within 4 s. In FULL ACCESS mode, the command to go to boot ROM can be sent.

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 *ManufacturerAccess()* commands; for example, the *PCHG FET()*, *CHG FET()*, *DSG FET()*, *Lifetime Data Collection()*, *Calibration()*, and so on. Enabling only the feature under test can simplify the test flow in production by avoiding any feature interference. The *ManufacturerAccess()* commands that toggle the *ManufacturingStatus()[CAL_EN]*, *[LT_TEST]*, *[DSG_TEST]*, *[CHG_TEST]*, and *[PCHG_TEST]* will only set the RAM data, meaning the conditions set by these commands will be cleared if a reset or seal is issued to the gauge. The *ManufacturerAccess()* commands that toggle the *ManufacturingStatus()[LED_EN]*, *[FUSE_EN]*, *[BBR_EN]*, *[PF_EN]*, and *[LT_EN], [FET_EN], [GAUGE_EN]* will be updated to data flash and synchronized between *ManufacturingStatus()* and ***Mfg Status Init***. The *ManufacturingStatus()* keeps track of the status (enabled or disabled) of each feature.

The ***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 re-loaded from data flash ***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.

11.2 Calibration

Refer to the *bq40zxx Manufacture, Production, and Calibration Application Note* (SLUA734) for the detailed calibration procedure.

The device has integrated routines that support calibration of current, voltage, and temperature readings, accessible after writing 0xF081 or 0xF082 to *ManufacturerAccess()* when the *ManufacturingStatus()[CAL]* bit is ON. While the calibration is active, the raw ADC data is available on *ManufacturerData()*. The device stops reporting calibration data on *ManufacturerData()* if any other MAC commands are sent or the device is reset or sealed.

NOTE: The *ManufacturingStatus()[CAL]* bit must be turned OFF after calibration is completed. This bit is cleared at reset or after sealing.

ManufacturerAccess()	Description
0x002D	Enables/Disables *ManufacturingStatus()[CAL]*
0xF080	Disables raw ADC data output on *ManufacturerData()*
0xF081	Outputs raw ADC data of voltage, current, and temperature on *ManufacturerData()*
0xF082	Outputs raw ADC data of voltage, current, and temperature on *ManufacturerData()*. This mode enables an internal short on the coulomb counter inputs (SRP, SRN).

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

Value	Format	Description
ZZ	byte	8-bit counter, increments when raw ADC values are refreshed (every 250 ms)
YY	byte	Output status *ManufacturerAccess()* = 0xF081: 1 *ManufacturerAccess()* = 0xF082: 2
AAaa	2's comp	Current (coulomb counter)
BBbb	2's comp	Cell Voltage 1

Value	Format	Description
CCcc	2's comp	Cell Voltage 2
DDdd	2's comp	Cell Voltage 3
EEee	2's comp	Cell Voltage 4
FFff	2's comp	PACK Voltage
GGgg	2's comp	BAT Voltage
HHhh	2's comp	Cell Current 1
IIii	2's comp	Cell Current 2
JJjj	2's comp	Cell Current 3
KKkk	2's comp	Cell Current 4

SBS Commands

12.1 0x00 ManufacturerAccess() and 0x44 ManufacturerBlockAccess()

ManufacturerBlockAccess() provides a method of reading and writing data in the Manufacturer Access System (MAC). This block MAC access method is a new standard for the bq40zxy family. The MAC command is sent via *ManufacturerBlockAccess()* by the SMBus block protocol. The result is returned on *ManufacturerBlockAccess()* via an SMBus block read.

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

1. With Impedance Track disabled, send *Gauging()* (0x0021) to *ManufacturerBlockAccess()*
   (a) SMBus block write. Command = 0x44. Data = 21 00 (data must be sent in Little Endian)
2. IT is enabled, *ManufacturingStatus()[GAUGEN_EN]* = 1.

Example: Read *Chemical ID()* (0x0006) via *ManufacturerBlockAccess()*

1. Send *Chemical ID()* to *ManufacturerBlockAccess().*
   (a) SMBus block write. Command = 0x44. Data sent = 06 00 (data must be sent in Little Endian)
2. Read the result from *ManufacturerBlockAccess().*
   (a) SMBus block read. Command = 0x44. Data read = 06 00 00 01 (each data entity is returned in Little Endian).
   (b) The first 2 bytes, “06 00”, is the MAC command.
   (c) The second 2 bytes, “00 01”, is the chem ID returning in Little Endian. That is 0x0100, chem ID 100.

For backwards compatibility with the bq30zxy families, sending MAC commands via *ManufacturerAccess()* (0x00) as well as the returning data on *ManufacturerData()* are supported in bq40z50. Note that MAC commands are sent through *ManufacturerAccess()* (0x00) by an SMBus write word protocol. The result reading from *ManufacturerData()* does not include the MAC command.

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

1. With Impedance Track disabled, send *Gauging()* (0x0021) to *ManufacturerAccess()*.
   (a) SMBus word write. Command = 0x00. Data = 00 21
2. IT is enabled, *ManufacturingStatus()[GAUGEN_EN]* = 1.

Example: Read *Chemical ID()* (0x0006) via *ManufacturerAccess()*

1. Send *Chemical ID()* to *ManufacturerAccess().*
   (a) SMBus word write. Command = 0x00. Data sent = 00 06
2. Read the result from *ManufacturerData().*
   (a) SMBus block read. Command = 0x23. Data read = 00 01
   (b) That is 0x0100, chem ID 100.

The *ManufacturerAccess()* and *ManufacturerBlockAccess()*are interchangeable. The result can be read from *ManufacturerData()* or *ManufacturerBlockAccess()* regardless of how the MAC command is sent.

Table 12-1. ManufacturerAccess() Command List

Command	Function	Access	Format	Data Read on 0x44 or 0x23	Data Read on 0x2F	Available in SEALED Mode	Type	Unit
0x0001	DeviceType	R	Block	Yes	—	Yes	Hex	—
0x0002	FirmwareVersion	R	Block	Yes	—	Yes	Hex	—
0x0003	HardwareVersion	R	Block	Yes	—	Yes	Hex	—
0x0004	IFChecksum	R	Block	Yes	—	Yes	Hex	—
0x0005	StaticDFSignature	R	Block	Yes	—	Yes	Hex	—
0x0006	ChemID	R	Block	Yes	—	Yes	Hex	—
0x0008	StaticChemDFSignature	R	Block	Yes	—	Yes	Hex	—
0x0009	AllDFSignature	R	Block	Yes	—	Yes	Hex	—
0x0010	ShutdownMode	W	—	—	—	Yes	Hex	—
0x0011	SleepMode	W	—	—	—	—	Hex	—
0x0013	AutoCCOfset	W	—	—	—	—	Hex	—
0x001D	FuseToggle	W	—	—	—	—	Hex	—
0x001E	PrechargeFET	W	—	—	—	—	Hex	—
0x001F	ChargeFET	W	—	—	—	—	Hex	—
0x0020	DischargeFET	W	—	—	—	—	Hex	—
0x0021	Gauging	W	—	—	—	—	Hex	—
0x0022	FETControl	W	—	—	—	—	Hex	—
0x0023	LifetimeDataCollection	W	—	—	—	—	Hex	—
0x0024	PermanentFailure	W	—	—	—	—	Hex	—
0x0025	BlackBoxRecorder	W	—	—	—	—	Hex	—
0x0026	Fuse	W	—	—	—	—	Hex	—
0x0027	LEDDisplayEnable	W	—	—	—	—	Hex	—
0x0028	LifetimeDataReset	W	—	—	—	—	Hex	—
0x0029	PermanentFailureData Reset	W	—	—	—	—	Hex	—
0x002E	LifetimeDataFlush	W	—	—	—	—	Hex	—
0x002F	LifetimeDataSpeedUp Mode	W	—	—	—	—	Hex	—
0x002A	BlackBoxRecorderReset	W	—	—	—	—	Hex	—
0x002B	LEDToggle	W	—	—	—	—	Hex	—
0x002C	LEDDisplayPress	W	—	—	—	—	Hex	—
0x002D	CalibrationMode	W	—	—	—	—	Hex	—
0x0030	SealDevice	W	—	—	—	—	Hex	—
0x0035	SecurityKeys	R/W	Block	Yes	—	—	Hex	—
0x0037	AuthenticationKey	R/W	Block	—	Yes	—	Hex	—
0x0041	DeviceReset	W	—	—	—	—	Hex	—
0x0050	SafetyAlert	R	Block	Yes	—	Yes	Hex	—
0x0051	SafetyStatus	R	Block	Yes	—	Yes	Hex	—
0x0052	PFAlert	R	Block	Yes	—	Yes	Hex	—
0x0053	PFStatus	R	Block	Yes	—	Yes	Hex	—
0x0054	OperationStatus	R	Block	Yes	—	Yes	Hex	—
0x0055	ChargingStatus	R	Block	Yes	—	Yes	Hex	—
0x0056	GaugingStatus	R	Block	Yes	—	Yes	Hex	—
0x0057	ManufacturingStatus	R	Block	Yes	—	Yes	Hex	—
0x0058	AFERegister	R	Block	Yes	—	Yes	Hex	—
0x0060	LifetimeDataBlock1	R	Block	Yes	—	Yes	Mixed	Mixed
0x0061	LifetimeDataBlock2	R	Block	Yes	—	Yes	Mixed	Mixed
0x0062	LifetimeDataBlock3	R	Block	Yes	—	Yes	Mixed	Mixed
0x0070	ManufacturerInfo	R	Block	Yes	—	Yes	Hex	—
0x0071	DAStatus1	R	Block	Yes	—	Yes	Mixed	Mixed
0x0072	DAStatus2	R	Block	Yes	—	Yes	Mixed	Mixed
0x0073	GaugeStatus1	R	Block	Yes	—	Yes	Mixed	Mixed

Table 12-1. ManufacturerAccess() Command List (continued)

Command	Function	Access	Format	Data Read on 0x44 or 0x23	Data Read on 0x2F	Available in SEALED Mode	Type	Unit
0x0074	GaugeStatus2	R	Block	Yes	—	Yes	Mixed	Mixed
0x0075	GaugeStatus3	R	Block	Yes	—	Yes	Mixed	Mixed
0x0076	CBStatus	R	Block	Yes	—	Yes	Mixed	Mixed
0x0077	StateofHealth	R	Block	Yes	—	Yes	Mixed	Mixed
0x0078	FilteredCapacity	R	Block	Yes	—	Yes	Mixed	Mixed
0x0F00	ROMMode	W	—	—	—	—	Hex	—
0xF080	ExitCalibrationOutput	R/W	Block	Yes	—	—	Hex	—
0xF081	OutputCCandADCfor Calibration	R/W	Block	Yes	—	—	Hex	—
0xF082	OutputShortedCCand ADCforCalibration	R/W	Block	Yes	—	—	Hex	—

12.1.1 ManufacturerAccess() 0x0000

A read word on this command returns the lowest 16 bits of the *OperationStatus()* data.

12.1.2 ManufacturerAccess() 0x0001 Device Type

The device can be checked for the IC part number. The IC part number returns on a subsequent read on *ManufacturerBlockAccess()* or *ManufacturerData()* in the following format: aaAA, where:

Value	Description
AAaa	Device Type

12.1.3 ManufacturerAccess() 0x0002 Firmware Version

The device can be checked for the firmware version of the IC. The firmware revision returns on *ManufacturerBlockAccess()* or *ManufacturerData()* in the following format: ddDDvvVVbbBBTTzzZZRREE, where:

Value	Description
DDdd	Device Number
VVvv	Version
BBbb	Build Number
TT	Firmware Type
ZZzz	Impedance Track Version
RR	Reserved
EE	Reserved

12.1.4 ManufacturerAccess() 0x0003 Hardware Version

The device can be checked for the hardware version of the IC. The hardware revision returns on a subsequent read on *ManufacturerBlockAccess()* or *ManufacturerData()*.

12.1.5 ManufacturerAccess() 0x0004 Instruction Flash Signature

The device can return the instruction flash signature. The IF signature returns on a subsequent read on *ManufacturerBlockAccess()* or *ManufacturerData()*.

12.1.6 ManufacturerAccess() 0x0005 Static DF Signature

The device can return the data flash checksum. The signature of all static DF returns on a subsequent read on *ManufacturerBlockAccess()* or *ManufacturerData()*. MSB is set to 1 if the calculated signature does not match the signature stored in DF.

12.1.7 ManufacturerAccess() 0x0006 Chemical ID

This command returns the chemical ID of the OCV tables used in the gauging algorithm. The chemical ID returns on a subsequent read on *ManufacturerBlockAccess()* or *ManufacturerData()*.

12.1.8 ManufacturerAccess() 0x0008 Static Chem DF Signature

The device can return the data flash checksum. The signature of all static chemistry DF returns on subsequent read on *ManufacturerBlockAccess()* or *ManufacturerData()*. MSB is set to 1 if the calculated signature does not match the signature stored in DF.

12.1.9 ManufacturerAccess() 0x0009 All DF Signature

The device can return the data flash checksum. The signature of all DF parameters returns on a subsequent read on *ManufacturerBlockAccess()* or *ManufacturerData()*. 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.

12.1.10 ManufacturerAccess() 0x0010 SHUTDOWN Mode

To reduce power consumption, the device can be sent to SHUTDOWN mode before shipping. After sending this command, the *OperationStatus()[SDM]* = 1, an internal counter will start, the CHG and DSG FETs will be turned off when the counter reaches ***Ship FET Off Time***. When the counter reaches Ship Delay time, the device will enter SHUTDOWN mode if no charger present is detected.

If the device is SEALED, this feature requires the command to be sent twice in a row within 4 seconds (for safety purposes). If the device is in UNSEALED or FULL ACCESS mode, sending the command the second time will cancel the delay and enter shutdown immediately.

To wake up the device, a voltage > ***Charger Present Threshold*** must apply to the PACK pin. The device will power up and a full reset is applied.

12.1.11 ManufacturerAccess() 0x0011 SLEEP Mode

If the sleep conditions are met, the device can be sent to sleep with *ManufacturerAccess()*.

Status	Condition	Action
Enable	0x0011 to *ManufacturerAccess()*	*OperationStatus()[SLEEPM]* = 1
Activate	***DA Configuration[NR]*** = 0 AND *OperationStatus()[PRES]* = 0 AND |*Current()*| < ***Power:Sleep Current***	Turn off CHG FET, DSG FET, PCHG FET Device goes to sleep. Device wakes up every Power***:Sleep Voltage Time*** period to measure voltage and temperature. Device wakes up every Power***:Sleep Current Time*** period to measure current.
Activate	***DA Configuration[NR]*** = 1 AND |*Current()*| < ***Power:Sleep Current***	Turn off DSG FET, PCHG FET Turn off CHG FET if ***DA Configuration[SLEEPCHG]*** = 0 Device goes to sleep. Device wakes up every Power***:Sleep Voltage Time*** period to measure voltage and temperature. Device wakes up every Power***:Sleep Current Time*** period to measure current.
Exit	***DA Configuration[NR]*** = 0 AND *OperationStatus()[PRES]* = 1	*OperationStatus()[SLEEPM]* = 0 Return to NORMAL mode
Exit	|*Current()*| > Configuration:Sleep Current	*OperationStatus()[SLEEPM]* = 0 Return to NORMAL mode
Exit	Wake Comparator trips	*OperationStatus()[SLEEPM]* = 0 Return to NORMAL mode
Exit	*SafetyAlert()* flag or *PFAlert()* flag set	*OperationStatus()[SLEEPM]* = 0 Return to NORMAL mode

12.1.12 ManufacturerAccess() 0x0013 AutoCCOffset

This command manually starts an Auto CC Offset calibration. The calibration takes about 16 s.

This value is updated to CC Auto Offset, and is used for cell current measurement when the device is in CHARGING or DISCHARGING state. This offset is not used during RELAX mode. The cell current measurement is a current measurement taken simultaneously as the cell voltage measurement.

12.1.13 ManufacturerAccess() 0x001D Fuse Toggle

This command manually activates/deactivates the FUSE output to ease testing during manufacturing. If the *OperationStatus()[FUSE]* = 0 indicates the FUSE output is low. Sending this command toggles the FUSE output to be high and the *OperationStatus()[FUSE]* = 1.

12.1.14 ManufacturerAccess() 0x001E PCHG FET Toggle

This command turns on/off the PCHG FET drive function to ease testing during manufacturing. If the *ManufacturingStatus()[PCHG_TEST]* = 0, sending this command will turn on the PCHG FET and the *ManufacturingStatus()[PCHG_TEST]* = 1 and vice versa. This toggling command is only enabled if *ManufacturingStatus()[FET_EN]* = 0, indicating an FW FET control is not active and manual control is allowed. A reset clears the [PCHG_TEST] flag and turns off the PCHG FET.

12.1.15 ManufacturerAccess() 0x001F CHG FET Toggle

This command turns on/off the CHG FET drive function to ease testing during manufacturing. If the *ManufacturingStatus()[CHG_TEST]* = 0, sending this command turns on the CHG FET and the *ManufacturingStatus()[CHG_TEST]* = 1 and vice versa. This toggling command is only enabled if *ManufacturingStatus()[FET_EN]* = 0, indicating an FW FET control is not active and manual control is allowed. A reset clears the [CHG_TEST] flag and turns off the CHG FET.

12.1.16 ManufacturerAccess() 0x0020 DSG FET Toggle

This command turns on/off DSG FET drive function to ease testing during manufacturing. If the *ManufacturingStatus()[DSG_TEST]* = 0, sending this command turns on the DSG FET and the *ManufacturingStatus()[DSG_TEST]* = 1 and vice versa. This toggling command is only enabled if *ManufacturingStatus()[FET_EN]* = 0, indicating an FW FET control is not active and manual control is allowed. A reset clears the [DSG_TEST] flag and turns off the DSG FET.

12.1.17 ManufacturerAccess() 0x0021 Gauging

This command enables or disables the gauging function to ease testing during manufacturing. The initial setting is loaded from ***Mfg Status Init[GAUGE_EN]***. If the *ManufacturingStatus()[GAUGE_EN]* = 0, sending this command will enable gauging and the *ManufacturingStatus()[GAUGE_EN]* = 1 and vice versa. In UNSEALED mode, the *ManufacturingStatus()[GAUGE_EN]* status is copied to ***Mfg Status Init[GAUGE_EN]*** when the command is received by the gauge. The device remains on its latest gauging status prior to a reset.

12.1.18 ManufacturerAccess() 0x0022 FET Control

This command disables/enables control of the CHG, DSG, and PCHG FET by the firmware. The initial setting is loaded from ***Mfg Status Init[FET_EN]***. If the *ManufacturingStatus()[FET_EN]* = 0, sending this command allows the FW to control the PCHG, CHG, and DSG FETs and the *ManufacturingStatus()[FET_EN]* = 1 and vice versa.

In UNSEALED mode, the *ManufacturingStatus()[FET_EN]* status is copied to ***Mfg Status Init[FET_EN]*** when the command is received by the gauge. The device remains on its latest FET control status prior to a reset.

12.1.19 ManufacturerAccess() 0x0023 Lifetime Data Collection

This command disables/enables Lifetime Data Collection to help streamline production testing. The initial setting is loaded from ***Mfg Status Init[LF_EN]***. If the *ManufacturingStatus()[LF_EN]* = 0, sending this command starts the Lifetime Data Collection and the *ManufacturingStatus()[LF_EN]* = 1 and vice versa.

In UNSEALED mode, the *ManufacturingStatus()[LF_EN]* status is copied to ***Mfg Status Init[LF_EN]*** when the command is received by the gauge. The device remains on its latest Lifetime Data Collection setting prior to a reset.

12.1.20 ManufacturerAccess() 0x0024 Permanent Failure

This command disables/enables Permanent Failure to help streamline production testing.

The initial setting is loaded from ***Mfg Status Init[PF_EN]***. If the *ManufacturingStatus()[PF_EN]* = 0, sending this command enables Permanent Failure protections and the *ManufacturingStatus()[PF_EN]* = 1 and vice versa.

In UNSEALED mode, *ManufacturingStatus()[PF_EN]* status is copied to ***Mfg Status Init[PF_EN]*** when the command is received by the gauge. The device remains on its PF enable/disable setting prior to a reset.

12.1.21 ManufacturerAccess() 0x0025 Black Box Recorder

This command enables/disables Black Box Recorder function to help streamline production testing. The initial setting is loaded from ***Mfg Status Init[BBR_EN]***. If the *ManufacturingStatus()[BBR_EN]* = 0, sending this command enables the Black Box Recorder and the *ManufacturingStatus()[BBR_EN]* = 1 and vice versa.

In UNSEALED mode, the *ManufacturingStatus()[BBR_EN]* status is copied to ***Mfg Status Init[BBR_EN]*** when the command is received by the gauge. The device remains on its latest Black Box Recorder enable/disable setting prior to a reset.

12.1.22 ManufacturerAccess() 0x0026 Fuse

This command disables/enables firmware-based fuse activation to ease testing during manufacturing. The initial setting is loaded from ***Mfg Status Init[FUSE_EN]***. If the *ManufacturingStatus()[FUSE_EN]* = 0, sending this command allows the FW to control the FUSE output and the *ManufacturingStatus()[FUSE_EN]* = 1 and vice versa.

In UNSEALED mode, the *ManufacturingStatus()[FUSE_EN]* status is copied to ***Mfg Status Init[FUSE_EN]*** when the command is received by the gauge. The device remains on its latest Fuse Control setting prior to a reset.

12.1.23 ManufacturerAccess() 0x0027 LED DISPLAY Enable

This command enables or disables the LED display function to ease testing during manufacturing. The initial setting is loaded from ***Mfg Status Init[LED_EN]***. If the *ManufacturingStatus()[LED_EN]* = 0, sending this command will enable the LED display and the *ManufacturingStatus()[LED_EN]* = 1 and vice versa. In UNSEALED mode, the *ManufacturingStatus()[LED_EN]* status is copied to ***Mfg Status Init[LED_EN]*** when the command is received by the gauge. The device remains on its latest setting prior to a reset.

12.1.24 ManufacturerAccess() 0x0028 Lifetime Data Reset

Sending this command resets Lifetime Data in data flash to help streamline production testing.

12.1.25 ManufacturerAccess() 0x0029 Permanent Fail Data Reset

Sending this command resets PF data in data flash to help streamline production testing.

12.1.26 ManufacturerAccess() 0x002A Black Box Recorder Reset

Sending this command resets the Black Box Recorder data in data flash to help streamline production testing.

12.1.27 ManufacturerAccess() 0x002B LED TOGGLE

This command toggles the LED display on or off to help streamline testing during manufacturing. When the LED display is off, the *OperationStatus()[LED]* = 0. Sending this command turns on all LED displays with *OperationStatus()[LED]* set to 1, and vice versa.

12.1.28 ManufacturerAccess() 0x002C LED DISPLAY PRESS

This command simulates a low-high-low detection of the $\overline{\text{DISP}}$ pin, activating the LED display according to the LED Support data flash setting. This command forces RSOC to 100% in order to demonstrate all LEDs in use, the full speed, and the brightness.

12.1.29 ManufacturerAccess() 0x002D CALIBRATION Mode

This command disables/enables entry into CALIBRATION mode. 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 *ManufacturerAccess()*	*ManufacturingStatus()[CAL_EN]* = 0 Disable output of ADC and CC raw data on *ManufacturingData()*
Enable	*ManufacturingStatus()[CAL_EN]* = 0 AND 0x002D to *ManufacturerAccess()*	*ManufacturingStatus()[CAL_EN]* = 1 Enable output of ADC and CC raw data on *ManufacturingData()*, controllable with 0xF081 and 0xF082 on *ManufacturerAccess()*

12.1.30 ManufacturerAccess() 0x002E Lifetime Data Flush

This command flushes the RAM Lifetime Data to data flash to help streamline evaluation testing.

12.1.31 ManufacturerAccess() 0x002F Lifetime Data SPEED UP Mode

For ease of evaluation testing, this command enables a lifetime SPEED UP mode where every 1 s in real time counts as 2 hours in FW time. When the lifetime SPEED UP mode is enabled, the *ManufacturingStatus()[LT_TEST]* = 1.

The SPEED UP mode will be disabled if this command is sent again when *[LT_TEST]* = 1, the MAC *LifetimeDataReset()* command is sent, the MAC *SealDevice()* command is sent, or the device is reset.

12.1.32 ManufacturerAccess() 0x0030 Seal Device

This command seals the device for the field, disabling certain SBS commands and access to data flash. See Table 12-1 and Chapter 12 for details.

When the device is sealed, the *OperationStatus()[SEC1, SEC0]* = 1,1. All the test features in *ManufacturingStatus()* will also be disabled.

12.1.33 ManufacturerAccess() 0x0035 Security Keys

This is a read/write command for 2-word UNSEAL and FULL ACCESS keys.

When reading the keys, data can be read from *ManufacturerData()* or *ManufacturerBlockAccess()*. The keys are returned in the following format: aaAAbbBBccCCddDD, where:

Value	Description
AAaa	First word of the UNSEAL key
BBbb	Second word of the UNSEAL key
CCcc	First word of the FULL ACCESS key
DDdd	Second word of the FULL ACCESS key

The default UNSEAL key is 0x0414 and 0x3672. The default FULL ACCESS key is 0xFFFF and 0xFFFF.

It is highly recommended to change the UNSEAL and FULL ACCESS keys from default.

The keys can only be changed through the *ManufacturerBlockAccess()*.

Example: Change UNSEAL key to 0x1234, 0x5678, and leave the FULL ACCESS as default.
Send an SMBus block write with Command = 0x44.

```
Data  = MAC command + New UNSEAL key + New FULL ACCESS KEY
      = 35 00 34 12 78 56 FF FF FF FF
```

NOTE: The first word of the keys cannot be the same. That means an UNSEAL key with 0xABCD 0x1234 and FULL ACCESS key with 0xABCD 0x5678 are not valid because the first word is the same.

This is because the first word is used as a “detection” for the right command. This also means the first word cannot be the same as any existing MAC command.

12.1.34 ManufacturerAccess() 0x0037 Authentication Key

This command enables the update of the authentication key into the device. The device must be in FULL ACCESS mode for the authentication key to update.

To update a new authentication key:

- Send the *AuthenticationKey()* + the new 128-bit authentication key to *ManufacturerBlockAccess()*, OR
- Send the *AuthenticationKey()* to *ManufacturerAccess()*, then send the 128-bit authentication key to *Authentication()*.

There is no direct read access to the authentication key. After writing the new authentication to the gauge, the gauge will generate an all-zero challenge and provide the corresponding response for verification.

To verify the new authentication key:

- Read the response from *ManufacturerBlockAccess()* after updating the new authentication key, OR
- Read the response from *Authentication()* after updating the new authentication key.

12.1.35 ManufacturerAccess() 0x0041 Device Reset

This command resets the device.

NOTE: Command 0x0012 also resets the device (for backwards compatibility with the bq30zxy device).

12.1.36 ManufacturerAccess() 0x0050 SafetyAlert

This command returns the *SafetyAlert()* flags on *ManufacturerBlockAccess()* or *ManufacturerData()*.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
RSVD	RSVD	RSVD	RSVD	UTD	UTC	PCHGC	CHGV	CHGC	OC	CTOS	CTO	PTOS	PTO	RSVD	OTF
15	**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
RSVD	CUVC	OTD	OTC	ASCDL	RSVD	ASCCL	RSVD	AOLDL	RSVD	OCD2	OCD1	OCC2	OCC1	COV	CUV

RSVD (Bits 31–28): Reserved. Do not use.

UTD (Bit 27): Undertemperature During Discharge
1 = Detected
0 = Not Detected

UTC (Bit 26): Undertemperature During Charge
1 = Detected
0 = Not Detected

PCHGC (Bit 25): Over-Precharge Current
1 = Detected
0 = Not Detected

CHGV (Bit 24): Overcharging Voltage
1 = Detected
0 = Not Detected

CHGC (Bit 23): Overcharging Current
1 = Detected
0 = Not Detected

OC (Bit 22): Overcharge
1 = Detected
0 = Not Detected

CTOS (Bit 21): Charge Timeout Suspend
1 = Detected
0 = Not Detected

CTO (Bit 20): Charge Timeout
1 = Detected
0 = Not Detected

PTOS (Bit 19): Precharge Timeout Suspend
1 = Detected
0 = Not Detected

PTO (Bit 18): Precharge Timeout
1 = Detected
0 = Not Detected

RSVD (Bit 17): Reserved. Do not use.

OTF (Bit 16): Overtemperature FET
1 = Detected
0 = Not Detected

RSVD (Bit 15): Reserved. Do not use.

CUVC (Bit 14): Cell Undervoltage Compensated
1 = Detected
0 = Not Detected

OTD (Bit 13): Overtemperature During Discharge
1 = Detected
0 = Not Detected

OTC (Bit 12): Overtemperature During Charge

1 = Detected
0 = Not Detected

ASCDL (Bit 11): Short-Circuit During Discharge Latch
1 = Detected
0 = Not Detected

RSVD (Bit 10): Reserved. Do not use.

ASCCL (Bit 9): Short-Circuit During Charge Latch
1 = Detected
0 = Not Detected

RSVD (Bit 8): Reserved. Do not use.

AOLDL (Bit 7): Overload During Discharge Latch
1 = Detected
0 = Not Detected

RSVD (Bit 6): Reserved. Do not use.

OCD2 (Bit 5): Overcurrent During Discharge 2
1 = Detected
0 = Not Detected

OCD1 (Bit 4): Overcurrent During Discharge 1
1 = Detected
0 = Not Detected

OCC2 (Bit 4): Overcurrent During Charge 2
1 = Detected
0 = Not Detected

OCC1 (Bit 2): Overcurrent During Charge 1
1 = Detected
0 = Not Detected

COV (Bit 1): Cell Overvoltage
1 = Detected
0 = Not Detected

CUV (Bit 0): Cell Undervoltage
1 = Detected
0 = Not Detected

12.1.37 ManufacturerAccess() 0x0051 SafetyStatus

This command returns the *SafetyStatus()* flags on *ManufacturerBlockAccess()* or *ManufacturerData()*.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
RSVD	RSVD	RSVD	RSVD	UTD	UTC	PCHGC	CHGV	CHGC	OC	RSVD	CTO	RSVD	PTO	RSVD	OTF

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RSVD	CUVC	OTD	OTC	ASCDL	ASCD	ASCCL	ASCC	AOLDL	AOLD	OCD2	OCD1	OCC2	OCC1	COV	CUV

RSVD (Bits 31–28): Reserved. Do not use.

UTD (Bit 27): Undertemperature During Discharge
- 1 = Detected
- 0 = Not Detected

UTC (Bit 26): Undertemperature During Charge
- 1 = Detected
- 0 = Not Detected

PCHGC (Bit 25): Over-Precharge Current
- 1 = Detected
- 0 = Not Detected

CHGV (Bit 24): Overcharging Voltage
- 1 = Detected
- 0 = Not Detected

CHGC (Bit 23): Overcharging Current
- 1 = Detected
- 0 = Not Detected

OC (Bit 22): Overcharge
- 1 = Detected
- 0 = Not Detected

RSVD (Bit 21): Reserved. Do not use.

CTO (Bit 20): Charge Timeout
- 1 = Detected
- 0 = Not Detected

RSVD (Bit 19): Reserved. Do not use.

PTO (Bit 18): Precharge Timeout
- 1 = Detected
- 0 = Not Detected

RSVD (Bit 17): Reserved. Do not use.

OTF (Bit 16): Overtemperature FET
- 1 = Detected
- 0 = Not Detected

RSVD (Bit 15): Reserved. Do not use.

CUVC (Bit 14): Cell Undervoltage Compensated
- 1 = Detected
- 0 = Not Detected

OTD (Bit 13): Overtemperature During Discharge
- 1 = Detected
- 0 = Not Detected

OTC (Bit 12): Overtemperature During Charge
- 1 = Detected
- 0 = Not Detected

ASCDL (Bit 11): Short-circuit During Discharge Latch
- 1 = Detected

0 = Not Detected

ASCD (Bit 10): Short-circuit During Discharge
1 = Detected
0 = Not Detected

ASCCL (Bit 9): Short-circuit During Charge Latch
1 = Detected
0 = Not Detected

ASCC (Bit 8): Short-circuit During Charge
1 = Detected
0 = Not Detected

AOLDL (Bit 7): Overload During Discharge Latch
1 = Detected
0 = Not Detected

AOLD (Bit 6): Overload During Discharge
1 = Detected
0 = Not Detected

OCD2 (Bit 5): Overcurrent During Discharge 2
1 = Detected
0 = Not Detected

OCD1 (Bit 4): Overcurrent During Discharge 1
1 = Detected
0 = Not Detected

OCC2 (Bit 3): Overcurrent During Charge 2
1 = Detected
0 = Not Detected

OCC1 (Bit 2): Overcurrent During Charge 1
1 = Detected
0 = Not Detected

COV (Bit 1): Cell Overvoltage
1 = Detected
0 = Not Detected

CUV (Bit 0): Cell Undervoltage
1 = Detected
0 = Not Detected

12.1.38 ManufacturerAccess() 0x0052 PFAlert

This command returns the *PFAlert()* flags on *ManufacturerBlockAccess()* or *ManufacturerData()*.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
TS4	TS3	TS2	TS1	RSVD	RSVD	OPNC	RSVD	RSVD	2LVL	AFEC	AFER	FUSE	RSVD	DFETF	CFETF
15	**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
RSVD	RSVD	RSVD	VIMA	VIMR	CD	IMP	CB	QIM	SOTF	RSVD	SOT	SOCD	SOCC	SOV	SUV

TS4 (Bit 31): Open Thermistor–TS4 Failure
- 1 = Detected
- 0 = Not Detected

TS3 (Bit 30): Open Thermistor–TS3 Failure
- 1 = Detected
- 0 = Not Detected

TS2 (Bit 29): Open Thermistor–TS2 Failure
- 1 = Detected
- 0 = Not Detected

TS1 (Bit 28): Open Thermistor–TS1 Failure
- 1 = Detected
- 0 = Not Detected

RSVD (Bits 27–26): Reserved. Do not use.

OPNC (Bit 25): Open Cell Tab Connection Failure
- 1 = Detected
- 0 = Not Detected

RSVD (Bits 24–23): Reserved. Do not use.

2LVL (Bit 22): Second Level Protector Failure
- 1 = Detected
- 0 = Not Detected

AFEC (Bit 21): AFE Communication Failure
- 1 = Detected
- 0 = Not Detected

AFER (Bit 20): AFE Register Failure
- 1 = Detected
- 0 = Not Detected

FUSE (Bit 19): Chemical Fuse Failure
- 1 = Detected
- 0 = Not Detected

DFETF (Bit 17): Discharge FET Failure
- 1 = Detected
- 0 = Not Detected

CFETF (Bit 16): Charge FET Failure
- 1 = Detected
- 0 = Not Detected

RSVD (Bits 15–13): Reserved. Do not use.

VIMA (Bit 12): Voltage Imbalance While Pack Is Active Failure
- 1 = Detected
- 0 = Not Detected

VIMR (Bit 11): Voltage Imbalance While Pack Is At Rest Failure
- 1 = Detected
- 0 = Not Detected

CD (Bit 10): Capacity Degradation Failure

1 = Detected

0 = Not Detected

IMP (Bit 9): Impedance Failure

1 = Detected

0 = Not Detected

CB (Bit 8): Cell Balancing Failure

1 = Detected

0 = Not Detected

QIM (Bit 7): QMax Imbalance Failure

1 = Detected

0 = Not Detected

SOTF (Bit 6): Safety Overtemperature FET Failure

1 = Detected

0 = Not Detected

RSVD (Bit 5): Reserved. Do not use.

SOT (Bit 4): Safety Overtemperature Cell Failure

1 = Detected

0 = Not Detected

SOCD (Bit 3): Safety Overcurrent in Discharge

1 = Detected

0 = Not Detected

SOCC (Bit 2): Safety Overcurrent in Charge

1 = Detected

0 = Not Detected

SOV (Bit 1): Safety Cell Overvoltage Failure

1 = Detected

0 = Not Detected

SUV (Bit 0): Safety Cell Undervoltage Failure

1 = Detected

0 = Not Detected

12.1.39 ManufacturerAccess() 0x0053 PFStatus

This command returns the *PFStatus()* flags on *ManufacturerBlockAccess()* or *ManufacturerData()*.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
TS4	TS3	TS2	TS1	RSVD	DFW	OPN CELL	IFC	PTC	2LVL	AFEC	AFER	FUSE	RSVD	DFET F	CFET F
15	**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
RSVD	RSVD	RSVD	VIMA	VIMR	CD	IMP	CB	QIM	SOTF	RSVD	SOT	SOCD	SOCC	SOV	SUV

TS4 (Bit 31): Open Thermistor–TS4 Failure

1 = Detected

0 = Not Detected

TS3 (Bit 30): Open Thermistor–TS3 Failure

1 = Detected

0 = Not Detected

TS2 (Bit 29): Open Thermistor–TS2 Failure

1 = Detected

0 = Not Detected

TS1 (Bit 28): Open Thermistor–TS1 Failure

1 = Detected

0 = Not Detected

RSVD (Bit 27): Reserved. Do not use.

DFW (Bit 26): Data Flash Wearout Failure

1 = Detected

0 = Not Detected

OPNCELL (Bit 25): Open Cell Tab Connection Failure

1 = Detected

0 = Not Detected

IFC (Bit 24): Instruction Flash Checksum Failure

1 = Detected

0 = Not Detected

PTC (Bit 23): PTC Failure

1 = Detected

0 = Not Detected

2LVL (Bit 22): Second Level Protector Failure

1 = Detected

0 = Not Detected

AFEC (Bit 21): AFE Communication Failure

1 = Detected

0 = Not Detected

AFER (Bit 20): AFE Register Failure

1 = Detected

0 = Not Detected

FUSE (Bit 19): Chemical Fuse Failure

1 = Detected

0 = Not Detected

RSVD (Bit 18): Reserved. Do not use.

DFETF (Bit 17): Discharge FET Failure

1 = Detected

0 = Not Detected

CFETF (Bit 16): Charge FET Failure

1 = Detected

0 = Not Detected

RSVD (Bits 15–13): Reserved. Do not use.

VIMA (Bit 12): Voltage Imbalance while Pack is Active Failure

1 = Detected

0 = Not Detected

VIMR (Bit 11): Voltage Imbalance while Pack At Rest Failure
- 1 = Detected
- 0 = Not Detected

CD (Bit 10): Capacity Degradation Failure
- 1 = Detected
- 0 = Not Detected

IMP (Bit 9): Impedance Failure
- 1 = Detected
- 0 = Not Detected

CB (Bit 8): Cell Balancing Failure
- 1 = Detected
- 0 = Not Detected

QIM (Bit 7): QMax Imbalance Failure
- 1 = Detected
- 0 = Not Detected

SOTF (Bit 6): Safety Overtemperature FET Failure
- 1 = Detected
- 0 = Not Detected

RSVD (Bit 5): Reserved. Do not use.

SOT (Bit 4): Safety Overtemperature Cell Failure
- 1 = Detected
- 0 = Not Detected

SOCD (Bits 3): Safety Overcurrent in Discharge
- 1 = Detected
- 0 = Not Detected

SOCC (Bits 2): Safety Overcurrent in Charge
- 1 Detected
- 0 Not Detected

SOV (Bit 1): Safety Cell Overvoltage Failure
- 1 = Detected
- 0 = Not Detected

SUV (Bit 0): Safety Cell Undervoltage Failure
- 1 = Detected
- 0 = Not Detected

12.1.40 ManufacturerAccess() 0x0054 OperationStatus

This command returns the *OperationStatus()* flags on *ManufacturerBlockAccess()* or *ManufacturerData()*.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
RSVD	RSVD	EMSHUT	CB	SLPCC	SLPAD	SMBLCAL	INIT	SLEEPM	XL	CAL_OFFSET	CAL	AUTOCALM	AUTH	LED	SDM
15	**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
SLEEP	XCHG	XDSG	PF	SS	SDV	SEC1	SEC0	BTP_INT	RSVD	FUSE	RSVD	PCHG	CHG	DSG	PRES

RSVD (Bits 31–30): Reserved. Do not use.

EMSHUT (Bit 29): Emergency Shutdown

1 = Active

0 = Inactive

CB (Bit 28): Cell balancing status

1 = Active

0 = Inactive

SLPCC (Bit 27): CC Measurement in SLEEP mode

1 = Active

0 = Inactive

SLPAD (Bit 26): ADC Measurement in SLEEP mode

1 = Active

0 = Inactive

SMBLCAL (Bit 25): Auto CC calibration when the bus is low. This bit may not be read by the host because the FW will clear it when a communication is detected.

1 = Auto CC calibration starts

0 = When the bus is high or communication is detected for the case of ***[IN_SYSTEM_SLEEP]*** = 1.

INIT (Bit 24): Initialization after full reset

1 = Active

0 = Inactive

SLEEPM (Bit 23): SLEEP mode triggered via command

1 = Active

0 = Inactive

XL (Bit 22): 400-kHz SMBus mode

1 = Active

0 = Inactive

CAL_OFFSET (Bit 21): Calibration Output (raw CC offset data).

1 = Active when MAC *OutputShortedCCADCCal()* is sent and the raw shorted CC data for calibration is available.

0 = When the raw shorted CC data for calibration is not available.

CAL (Bit 20): 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.

AUTOCALM (Bit 19): Auto CC Offset Calibration by MAC *AutoCCOffset()*

1 = The gauge receives the MAC *AutoCCOffset()* and starts the auto CC offset calibration.

0 = Clear when the calibration is completed.

AUTH (Bit 18): Authentication in progress

1 = Active

0 = Inactive

LED (Bit 17): LED Display

1 = LED display is on.

0 = LED display is off.

SDM (Bit 16): Shutdown triggered via command
- 1 = Active
- 0 = Inactive

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

XCHG (Bit 14): Charging disabled
- 1 = Active
- 0 = Inactive

XDSG (Bit 13): Discharging disabled
- 1 = Active
- 0 = Inactive

PF (Bit 12): PERMANENT FAILURE mode status
- 1 = Active
- 0 = Inactive

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

SDV (Bit 10): Shutdown triggered via low pack voltage
- 1 = Active
- 0 = Inactive

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

BTP_INT (Bit 7): Battery Trip Point Interrupt. Setting and clearing this bit depends on various conditions. See Section 6.9 for details.

RSVD (Bit 6): Reserved. Do not use.

FUSE (Bit 5): Fuse status
- 1 = Active
- 0 = Inactive

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

PCHG (Bit 3): Precharge FET status
- 1 = Active
- 0 = Inactive

CHG (Bit 2): CHG FET status
- 1 = Active
- 0 = Inactive

DSG (Bit 1): DSG FET status
- 1 = Active
- 0 = Inactive

PRES (Bit 0): System present low

1 = Active

0 = Inactive

12.1.41 ManufacturerAccess() 0x0055 ChargingStatus

This command returns the *ChargingStatus()* flags on *ManufacturerBlockAccess()* or *ManufacturerData()*.

								23	22	21	20	19	18	17	16
								RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	CCC	CVR
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR	VCT	MCHG	IN	HV	MV	LV	PV	RSVD	OT	HT	STH	RT	STL	LT	UT

RSVD (Bits 18–23): Reserved. Do not use.

CCC (Bit 17): Charging Loss Compensation

1 = Active

0 = Inactive

CVR (Bit 16): Charging Voltage Rate of Change

1 = Active

0 = Inactive

CCR (Bit 15): Charging Current Rate of Change

1 = Active

0 = Inactive

VCT (Bit 14): Charge Termination

1 = Active

0 = Inactive

MCHG (Bit 13): Maintenance Charge

1 = Active

0 = Inactive

IN (Bit 12): Charge Inhibit

1 = Active

0 = Inactive

HV (Bit 11): High Voltage Region

1 = Active

0 = Inactive

MV (Bit 10): Mid Voltage Region

1 = Active

0 = Inactive

LV (Bit 9): Low Voltage Region

1 = Active

0 = Inactive

PV (Bit 8): Precharge Voltage Region

1 = Active

0 = Inactive

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

OT (Bit 6): Overtemperature Region
- 1 = Active
- 0 = Inactive

HT (Bit 5): High Temperature Region
- 1 = Active
- 0 = Inactive

STH (Bit 4): Standard Temperature High Region
- 1 = Active
- 0 = Inactive

RT (Bit 3): Recommended Temperature Region
- 1 = Active
- 0 = Inactive

STL (Bit 2): Standard Temperature Low Region
- 1 = Active
- 0 = Inactive

LT (Bit 1): Low Temperature Region
- 1 = Active
- 0 = Inactive

UT (Bit 0): Undertemperature Region
- 1 = Active
- 0 = Inactive

12.1.42 ManufacturerAccess() 0x0056 GaugingStatus

This command returns the *GaugingStatus()* flags on *ManufacturerBlockAccess()* or *ManufacturerData()*.

								23	22	21	20	19	18	17	16
								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	R_DIS	RSVD	REST	CF	DSG	EDV	BAL_ EN	TC	TD	FC	FD

RSVD (Bits 21 –23): 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 (opposite of the R_DIS flag)
- 1 = Detected
- 0 = Not Detected

NSFM (Bit 15): Negative Scale Factor Mode

1 = Negative Ra Scaling Factor Detected
0 = Negative Ra Scaling Factor Not Detected

RSVD (Bit 14): Reserved. Do not use.

SLPQMax (Bit 13): OCV update in SLEEP mode
1 = Active. OCV reading in process
0 = Inactive. Completed OCV reading

QEN (Bit 12): Impedance Track Gauging (Ra and QMax updates are enabled.)
1 = Enabled
0 = Disabled

VOK (Bit 11): Voltages are OK for QMax update. This flag is updated at exit of the RELAX mode.
1 = A DOD is saved for next QMax update.
0 = No DOD saved and QMax update is not possible.

R_DIS (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

CF (Bit 7): Condition Flag
1 = *MaxError()* > Max Error Limit (Condition Cycle Needed)
0 = *MaxError()* < Max Error Limit (Condition Cycle Not Needed)

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

BAL_EN (Bit 4): Cell Balancing
1 = Cell balancing is possible if enabled.
0 = Cell balancing is not allowed.

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

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

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

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

12.1.43 ManufacturerAccess() 0x0057 ManufacturingStatus

This command returns the *ManufacturingStatus()* flags on *ManufacturerBlockAccess()* or *ManufacturerData()*.

15	14	13	12	11	10	9	8
CAL_TEST	LT_TEST	RSVD	RSVD	RSVD	RSVD	LED_EN	FUSE_EN

7	6	5	4	3	2	1	0
BBR_EN	PF_EN	LF_EN	FET_EN	GAUGE_EN	DSG_EN	CHG_EN	PCHG_EN

CAL_TEST (Bit 15): CALIBRATION mode
- 1 = Enabled
- 0 = Disabled

LT_TEST (Bit 14): LIFETIME SPEED UP mode
- 1 = Enabled
- 0 = Disabled

RSVD (Bits 13–10): Reserved. Do not use.

LED_EN (Bit 9): LED Display
- 1 = LED display is on.
- 0 = LED display is off.

FUSE_EN (Bit 8): Fuse Action
- 1 = Enabled
- 0 = Disabled

BBR_EN (Bit 8): Black Box Recorder
- 1 = Enabled
- 0 = Disabled

PF_EN (Bit 6): Permanent Failure
- 1 = Enabled
- 0 = Disabled

LF_EN (Bit 5): Lifetime Data Collection
- 1 = Enabled
- 0 = Disabled

FET_EN (Bit 4): All FET Action
- 1 = Enabled
- 0 = Disabled

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

DSG_EN (Bit 2): Discharge FET Test
- 1 = Discharge FET test activated
- 0 = Disabled

CHG_EN (Bit 1): Charge FET Test
- 1 = Charge FET test activated
- 0 = Disabled

PCHG_EN (Bit 0): Precharge FET Test

1 = Precharge FET test activated

0 = Disabled

12.1.44 ManufacturerAccess() 0x0058 AFE Register

This command returns the *AFERegister()* values on *ManufacturerBlockAccess()* or *ManufacturerData()*. These are the AFE hardware registers and are intended for internal debug use only.

Status	Condition
Activate	0x0058 to *ManufacturerAccess()*

Action: Output AFE Register values on *ManufacturerBlockAccess()* or *ManufacturerData()* in the following format: AABBCCDDEEFFGGHHIIJJKKLLMMNNOOPPQQRRSSTTUU where:

Value	Description
AA	AFE Interrupt Status. AFE Hardware interrupt status (for example, wake time, push-button, and so on)
BB	AFE FET Status. AFE FET status (for example, CHG FET, DSG FET, PCHG FET, FUSE input, and so on)
CC	AFE RXIN. AFE I/O port input status
DD	AFE Latch Status. AFE protection latch status
EE	AFE Interrupt Enable. AFE interrupt control settings
FF	AFE Control. AFE FET control enable setting
GG	AFE RXIEN. AFE I/O input enable settings
HH	AFE RLOUT. AFE I/O pins output status
II	AFE RHOUT. AFE I/O pins output status
JJ	AFE RHINT. AFE I/O pins interrupt status
KK	AFE Cell Balance. AFE cell balancing enable settings and status
LL	AFE ADC/CC Control. AFE ADC/CC Control settings
MM	AFE ADC Mux Control. AFE ADC channel selections
NN	AFE LED Control
OO	AFE Control. AFE control on various HW based features
PP	AFE Timer Control. AFE comparator and timer control
QQ	AFE Protection. AFE protection delay time control
RR	AFE OCD. AFE OCD settings
SS	AFE SCC. AFE SCC settings
TT	AFE SCD1. AFE SCD1 settings
UU	AFE SCD2. AFE SCD2 settings

12.1.45 ManufacturerAccess() 0x0060 Lifetime Data Block 1

This command returns the Lifetime Data with the following format:

aaAAbbBBccCCddDDeeEEffFFggGGhhHHiiIIjjJJkkKKllLLmmMMNNOOPPQQRRSS.

Value	Description
AAaa	Cell 1 Max Voltage
BBbb	Cell 2 Max Voltage
CCcc	Cell 3 Max Voltage
DDdd	Cell 4 Max Voltage
EEee	Cell 1 Min Voltage
FFff	Cell 2 Min Voltage
GGgg	Cell 3 Min Voltage
HHhh	Cell 4 Min Voltage
IIii	Max Delta Cell Voltage
JJjj	Max Charge Current
KKkk	Max Discharge Current

Value	Description
LLll	Max Avg Dsg Current
MMmm	Max Avg Dsg Power
NN	Max Temp Cell
OO	Min Temp Cell
PP	Max Delta Cell temp
QQ	Max Temp Int Sensor
RR	Min Temp Int Sensor
SS	Max Temp Fet

12.1.46 ManufacturerAccess() 0x0061 Lifetime Data Block 2

This command returns the Lifetime Data with the following format:

AABBCCDDEEFFGGHH.

Value	Description
AA	No. of Shutdowns
BB	No. of Partial Resets
CC	No. of Full Resets
DD	No. of WDT resets
EE	CB Time Cell 1
FF	CB Time Cell 2
GG	CB Time Cell 3
HH	CB Time Cell 4

12.1.47 ManufacturerAccess() 0x0062 Lifetime Data Block 3

This command returns the Lifetime Data with the following format:

aaAAbbBBccCCddDDeeEEffFFggGGhhHH.

Value	Description
AAaa	Total FW Runtime
BBbb	Time Spent in UT
CCcc	Time Spent in LT
DDdd	Time Spent in STL
EEee	Time Spent in RT
FFff	Time Spent in STH
GGgg	Time Spent in HT
HHhh	Time Spent in OT

12.1.48 ManufacturerAccess() 0x0063 Lifetime Data Block 4

This command returns the Lifetime Data with the following format:

aaAAbbBBccCCddDDeeEEffFFggGGhhHHllLLmmMMnnNNooOOppPP.

Value	Description
AAaa	No. of COV Events
BBbb	Last COV Event
CCcc	No. of CUV Events
DDdd	Last CUV Event
EEee	No. of OCD1 Events
FFff	Last OCD1 Event
GGgg	No. of OCD2 Events

Value	Description
HHhh	Last OCD2 Event
IIii	No. of OCC1 Events
JJjj	Last OCC1 Event
KKkk	No. of OCC2 Events
LLll	Last OCC2 Event
MMmm	No. of AOLD Events
NNnn	Last AOLD Event
OOoo	No. of ASCD Events
PPpp	Last ASCD Event

12.1.49 ManufacturerAccess() 0x0064 Lifetime Data Block 5

This command returns the Lifetime Data with the following format:

aaAAbbBBccCCddDDeeEEffFFggGGhhHHllLLmmMMnnNNooOOppPP.

Value	Description
AAaa	No. of ASCC Events
BBbb	Last ASCC Event
CCcc	No. of OTC Events
DDdd	Last OTC Event
EEee	No. of OTD Events
FFff	Last OTD Event
GGgg	No. of OTF Events
HHhh	Last OTF Event
IIii	No. Valid Charge Term
JJjj	Last Valid Charge Term
KKkk	No. of Qmax Updates
LLll	Last Qmax Update
MMmm	No. of Ra Updates
NNnn	Last Ra Update
OOoo	No. of Ra Disable
PPpp	Last Ra Disable

12.1.50 ManufacturerAccess() 0x0070 ManufacturerInfo

This command returns ManufacturerInfo on *ManufacturerBlockAccess()* or *ManufacturerData()*.

Status	Condition	Action
Activate	0x0070 to *ManufacturerAccess()*	Output 32 bytes of ManufacturerInfo on *ManufacturerBlockAccess()* or *ManufacturerData()* in the following format: AABBCCDDEEFFGGHHIIJJKKLLMMNN OOPPQQRRSSTTUUVVWWXXVVZZ112233 445566

12.1.51 ManufacturerAccess() 0x0071 DAStatus1

This command returns the Cell Voltages, Pack Voltage, Bat Voltage, Cell Currents, Cell Powers, Power, and Average Power on *ManufacturerBlockAccess()* or *ManufacturerData()*.

Status	Condition
Activate	0x0071 to *ManufacturerBlockAccess()* or *ManufacturerAccess()*

Action: Output 32 bytes of data on *ManufacturerBlockAccess()* or *ManufacturerData()* in the following format: aaAAbbBBccCCddDDeeEEffFFggGGhhHHiiIIjjJJkkKKllLLmmMMnnNNooOOppPP where:

Value	Description	Unit
AAaa	Cell Voltage 1	mV
BBbb	Cell Voltage 2	mV
CCcc	Cell Voltage 3	mV
DDdd	Cell Voltage 4	mV
EEee	BAT Voltage. Voltage at the BAT pin. This is different than *Voltage()*, which is the sum of all the cell voltages.	mV
FFff	PACK Voltage	mV
GGgg	Cell Current 1. Simultaneous current measured during Cell Voltage1 measurement	mA
HHhh	Cell Current 2. Simultaneous current measured during Cell Voltage2 measurement	mA
IIii	Cell Current 3. Simultaneous current measured during Cell Voltage3 measurement	mA
JJjj	Cell Current 4. Simultaneous current measured during Cell Voltage 4 measurement	mA
KKkk	Cell Power 1. Calculated using Cell Voltage1 and Cell Current 1 data	mA
LLll	Cell Power 2. Calculated using Cell Voltage2 and Cell Current 2 data	cW
MMmm	Cell Power 3. Calculated using Cell Voltage3 and Cell Current 3 data	cW
NNnn	Cell Power 4. Calculated using Cell Voltage4 and Cell Current 4 data	cW
OOoo	Power calculated by *Voltage()* × *Current()*	cW
PPpp	Average Power	cW

12.1.52 ManufacturerAccess() 0x0072 DAStatus2

This command returns the internal temp sensor, TS1, TS2, TS3, TS4, Cell Temp, and FETTemp on *ManufacturerBlockAccess()* or *ManufacturerData()*.

Status	Condition
Activate	0x0072 to *ManufacturerBlockAccess()* or *ManufacturerAccess()*

Action: Output 14 bytes of temperature data values on *ManufacturerBlockAccess()* or *ManufacturerData()* in the following format: aaAAbbBBccCCddDDeeEEffFFggGG where:

Value	Description	Unit
AAaa	Int Temperature	0.1°K
BBbb	TS1 Temperature	0.1°K
CCcc	TS2 Temperature	0.1°K
DDdd	TS3 Temperature	0.1°K
EEee	TS4 Temperature	0.1°K
FFff	Cell Temperature	0.1°K
GGgg	FET Temperature	0.1°K

12.1.53 ManufacturerAccess() 0x0073 GaugeStatus1

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

Status	Condition
Activate	0x0073 to *ManufacturerBlockAccess()* or *ManufacturerAccess()*

Action: Output 32 bytes of IT data values on *ManufacturerBlockAccess()* or *ManufacturerData()* in the following format: aaAAbbBBccCCddDDeeEEffFFggGGhhHHiiIIjjJJkkKKllLLmmMMnnNNooOOppPPqqQQ where:

Value	Description	Unit
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.	mAh
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.	cWh

Value	Description	Unit
CCcc	Initial Q. Initial capacity calculated from IT simulation	mAh
DDdd	Initial E. Initial energy calculated from IT simulation	cWh
EEee	True FCC Q. True full charge capacity from IT simulation without the effects of any smoothing function	mAh
FFff	True FCC E. True full charge energy from IT simulation without the effects of any smoothing function	cWh
GGgg	T_sim. Temperature during the last simulation run.	0.1°K
HHhh	T_ambient. Current assumed ambient temperature used by the IT algorithm for thermal modeling	0.1°K
IIii	RaScale 0. Ra table scaling factor of Cell 1	—
JJjj	RaScale 1. Ra table scaling factor of Cell 2	—
KKkk	RaScale 2. Ra table scaling factor of Cell 3	—
LLll	RaScale 3. Ra table scaling factor of Cell 4	—
MMmm	CompRes 0. Last temperature compensated Resistance of Cell 1	2^{-10} Ω
NNnn	CompRes 1. Last temperature compensated Resistance of Cell 2	2^{-10} Ω
OOoo	CompRes 2. Last temperature compensated Resistance of Cell 3	2^{-10} Ω
PPpp	CompRes 3. Last temperature compensated Resistance of Cell 4	2^{-10} Ω

12.1.54 ManufacturerAccess() 0x0074 GaugeStatus2

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

Status	Condition
Activate	0x0074 to *ManufacturerBlockAccess()* or *ManufacturerAccess()*

Action: Output 32 bytes of IT data values on *ManufacturerBlockAccess()* or *ManufacturerData()* in the following format: AABBCCDDEEFFggGGhhHHiiIIjjJJkkKKllLLmmMMnnNNooOOppPPqqQQrrRRssSS where:

Value	Description	Unit
AA	Pack Grid. Active pack grid point (minimum of CellGrid0 to Cell Grid3). This data is only valid during DISCHARGE mode when *[R_DIS]* = 0. If *[R_DIS]* = 1 or not discharging, this value is not updated.	—
BB	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 learning cycle. 1,0 = QMax and resistance table updated in learning cycle ITEN: IT enable 0 = IT disabled 1 = IT enabled QMax: QMax update in field 0 = QMax has not been updated in the field 1= QMax updated in the field	—
CC	Cell Grid 0. Active grid point of Cell 1. This data is only valid during DISCHARGE mode when *[R_DIS]* = 0. If *[R_DIS]* = 1 or not discharging, this value is not updated.	—
DD	Cell Grid 1. Active grid point of Cell 2. This data is only valid during DISCHARGE mode when *[R_DIS]* = 0. If *[R_DIS]* = 1 or not discharging, this value is not updated.	—
EE	Cell Grid 2. Active grid point of Cell 3. This data is only valid during DISCHARGE mode when *[R_DIS]* = 0. If *[R_DIS]* = 1 or not discharging, this value is not updated.	—
FF	Cell Grid 3. Active grid point of Cell 4. This data is only valid during DISCHARGE mode when *[R_DIS]* = 0. If *[R_DIS]* = 1 or not discharging, this value is not updated.	—
GGggHHhh	State Time. Time past since last state change (DISCHARGE, CHARGE, REST)	s
IIii	DOD0_0. Depth of discharge for Cell 1	—
JJjj	DOD0_1. Depth of discharge for Cell 2	—
KKkk	DOD0_2. Depth of discharge for Cell 3	—
LLll	DOD0_3. Depth of discharge for Cell 4	—
MMmm	DOD0 Passed Q. Passed capacity since the last DOD0 update	mAh

Value	Description	Unit
NNnn	DOD0 Passed E. Passed energy since last DOD0 update	cWh
OOoo	DOD0 Time. Time passed since the last DOD0 update	hr/16
PPpp	DODEOC 0. Depth of discharge at end of charge of Cell 1	—
QQqq	DODEOC 1. Depth of discharge at end of charge of Cell 2	—
RRrr	DODEOC 2. Depth of discharge at end of charge of Cell 3	—
SSss	DODEOC 3. Depth of discharge at end of charge of Cell 4	—

12.1.55 ManufacturerAccess() 0x0075 GaugeStatus3

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

Status	Condition
Activate	0x0075 to *ManufacturerBlockAccess()* or *ManufacturerAccess()*

Action: Output 24 bytes of IT data values on *ManufacturerBlockAccess()* or *ManufacturerData()* in the following format: aaAAbbBBccCCddDDeeEEffFFggGGhhHHiiIIjjJJkkKKllLL where:

Value	Description	Unit
AAaa	QMax 0. QMax of Cell 1	mAh
BBbb	QMax 1. QMax of Cell 2	mAh
CCcc	QMax 2. QMax of Cell 3	mAh
DDdd	QMax 3. QMax of Cell 4	mAh
EEee	QMax DOD0_0. DOD0 saved to be used for next QMax update of Cell 1. The value is only valid when *[VOK]* = 1.	—
FFff	QMax DOD0_1. DOD0 saved to be used for next QMax update of Cell 2. The value is only valid when *[VOK]* = 1.	—
GGgg	QMax DOD0_2. DOD0 saved to be used for next QMax update of Cell 3 . The value is only valid when *[VOK]* = 1.	—
HHhh	QMax DOD0_3. DOD0 saved to be used for next QMax update of Cell 4. The value is only valid when *[VOK]* = 1.	—
IIii	QMax Passed Q. Pass capacity since last QMax DOD value is saved.	mAh
JJjj	QMax Time. Time passed since last QMax DOD value is saved.	hr/16
KKkk	Temp k. Thermal Model temperature factor	—
LLll	Temp a. Thermal Model temperature	—

12.1.56 ManufacturerAccess() 0x0076 CBStatus

This command instructs the device to return cell balance time information on *ManufacturerBlockAccess()* or *ManufacturerData()*.

Status	Condition
Activate	0x0076 to *ManufacturerBlockAccess()* or *ManufacturerAccess()*

Action: Output 8 bytes of IT data values on *ManufacturerBlockAccess()* or *ManufacturerData()* in the following format: aaAAbbBBccCCddDD where:

Value	Description	Unit
AAaa	Cell Balance Time 0. Calculated cell balancing time of Cell 1	s
BBbb	Cell Balance Time 1. Calculated cell balancing time of Cell 2	s
CCcc	Cell Balance Time 2. Calculated cell balancing time of Cell 3	s
DDdd	Cell Balance Time 3. Calculated cell balancing time of Cell 4	s

12.1.57 ManufacturerAccess() 0x0077 State-of-Health

This command returns the state-of-health FCC in mAh and energy in cWh with the following format: aaAAbbBB.

Value	Description	Unit
AAaa	State-of-Health FCC	mAh
BBbb	State-of-Health energy	cWh

12.1.58 ManufacturerAccess() 0x0078 FilterCapacity

This command instructs the device to return the filtered remaining capacity and full charge capacity even if ***[SMOOTH]*** = 0 on *ManufacturerBlockAccess()* or *ManufacturerData()*.

Status	Condition
Activate	0x0078 to *ManufacturerBlockAccess()* or *ManufacturerAccess()*

Action: Output 8 bytes of IT data values on *ManufacturerBlockAccess()* or *ManufacturerData()* in the following format: aaAAbbBBccCCddDD where:

Value	Description	Unit
AAaa	Filtered remaining capacity	mAh
BBbb	Filtered remaining energy	mWh
CCcc	Filtered full charge capacity	mAh
DDdd	Filtered full charge energy	mWh

12.1.59 ManufacturerAccess() 0x0F00 ROM Mode

This command sends the device into ROM mode in preparation for firmware re-programming. To enter ROM mode, the device must be in FULL ACCESS mode. To return from ROM mode to FW mode, issue the SMBus command 0x08.

NOTE: Command 0x0033 also puts the device in ROM mode (for backwards compatibility with the bq30zxy device).

12.1.60 0x4000–0x5FFF Data Flash Access()

Accessing data flash (DF) is only supported by the *ManufacturerBlockAccess()* 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 to DF. 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 an SMBus block write with command = 0x44
      block = starting address + DF data block
            = 0x00 + 0x40 + data1_LowByte + data1_HighByte + data2_LowByte + data2_HighByte
```

To read the DF, send an SMBus block write to the *ManufacturerBlockAccess(),* followed by the starting address, then send an SMBus block read to the *ManufacturerBlockAccess()*. 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 SMBus write block with command 0x44, block = 0x00 + 0x40

b. Send SMBus read block with command 0x44

The returned block = a starting address + 32 bytes of DF data

= 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 SMBus read block is sent with command 0x44, the gauge returns another 32 bytes of DF data, starting with address 0x4020.

12.1.61 ManufacturerAccess() 0xF080 Exit Calibration Output Mode

This command stops the output of calibration data to the *ManufacturerBlockAccess()* or *ManufacturerData()* command. Any other MAC command sent to the gauge will also stop the output of the calibration data.

Status	Condition	Action
Activate	*ManufacturerBlockAccess()* OR *ManufacturerData()* = 1 AND 0xF080 to *ManufacturerAccess()*	Stop output of ADC or CC data on *ManufacturerBlockAccess()* or *ManufacturerData()*

12.1.62 ManufacturerAccess() 0xF081 Output CCADC Cal

This command instructs the device to output the raw values for calibration purposes on *ManufacturerBlockAccess()* or *ManufacturerData()*. All values are updated every 250 ms and the format of each value is 2's complement, MSB first.

Status	Condition
Disable	*ManufacturingStatus()[CAL]* = 1 AND 0xF080 to *ManufacturerAccess()*

Action: *OperationStatus()[CAL]* = 0, *[CAL_OFFSET]* = 0
Stop output of ADC and CC data on *ManufacturerBlockAccess()* or *ManufacturerData()*

Status	Condition
Enable	0xF081 to *ManufacturerAccess()*

Action: *OperationStatus()[CAL]* = 1, *[CAL_OFFSET]* = 0
Outputs the raw CC and AD values on *ManufacturerBlockAccess()* or *ManufacturerData()* in the format of ZZYYaaAAbbBBccCCddDDeeEEffFFggGGhhHHiiIIjjJJkkKK:

Value	Description
ZZ	Rolling 8-bit counter, increments when values are refreshed.
YY	Status, 1 when *ManufacturerAccess()* = 0xF081, 2 when *ManufacturerAccess()* = 0xF082
AAaa	Current (coulomb counter)
BBbb	Cell Voltage 1
CCcc	Cell Voltage 2
DDdd	Cell Voltage 3
EEee	Cell Voltage 4
FFff	PACK Voltage
GGgg	BAT Voltage
HHhh	Cell Current 1
IIii	Cell Current 2
JJjj	Cell Current 3

Value	Description
KKkk	Cell Current 4

12.1.63 ManufacturerAccess() 0xF082 Output Shorted CCADC Cal

This command instructs the device to output the raw values for calibration purposes on *ManufacturerBlockAccess()* or *ManufacturerData()*. All values are updated every 250 ms and the format of each value is 2's complement, MSB first. This mode includes an internal short on the coulomb counter inputs for measuring offset.

Status	Condition
Disable	*ManufacturingStatus()[CAL]* = 1 AND 0xF080 to *ManufacturerAccess()*

Action: *OperationStatus()[CAL]* = 0, *[CAL_OFFSET]* = 0
Stop output of ADC and CC data on *ManufacturerBlockAccess()* or *ManufacturerData()*

Status	Condition
Enable	0xF081 to *ManufacturerAccess()*

Action: *OperationStatus()[CAL]* = 1, *[CAL_OFFSET]* = 1
Outputs the raw CC and AD values on *ManufacturerBlockAccess()* or *ManufacturerData()* in the format of ZZYYaaAAbbBBccCCddDDeeEEffFFggGGhhHHiiIIjjJJkkKK:

Value	Description
ZZ	Rolling 8-bit counter, increments when values are refreshed.
YY	Status, 1 when *ManufacturerAccess()* = 0xF081, 2 when *ManufacturerAccess()* = 0xF082
AAaa	Current (coulomb counter)
BBbb	Cell Voltage 1
CCcc	Cell Voltage 2
DDdd	Cell Voltage 3
EEee	Cell Voltage 4
FFff	PACK Voltage
GGgg	BAT Voltage
HHhh	Cell Current 1
IIii	Cell Current 2
JJjj	Cell Current 3
KKkk	Cell Current 4

12.2 0x01 RemainingCapacityAlarm()

This read/write word function sets a low capacity alarm threshold for the cell stack.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Default	Unit
		SE	US	FA						
0x01	*RemainingCapacityAlarm()*	R/W			Word	U2	0	700	300	mAh 10 mWh

NOTE: If *BatteryMode()[CAPM]* = 0, then the data reports in mAh.

If *BatteryMode()[CAPM]* = 1, then the data reports in 10 mWh.

12.3 0x02 RemainingTimeAlarm()

This read/write word function sets a low remaining time-to-fully discharge alarm threshold for the cell stack.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Default	Unit
		SE	US	FA						
0x02	*RemainingTimeAlarm()*	R/W			Word	U2	0	30	10	min

12.4 0x03 BatteryMode()

This read/write word function sets various battery operating mode options.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit
		SE	US	FA					
0x03	*BatteryMode()*	R/W			Word	H2	0x0000	0xFFFF	—

15	14	13	12	11	10	9	8
CAPM	CHGM	AM	RSVD	RSVD	RSVD	PB	CC

7	6	5	4	3	2	1	0
CF	RSVD	RSVD	RSVD	RSVD	RSVD	PBS	ICC

CAPM (Bit 15): CAPACITY Mode (R/W)

0 = Report in mA or mAh (default)

1 = Report in 10 mW or 10 mWh

CHGM (Bit 14): CHARGER Mode (R/W)

0 = Enable *ChargingVoltage()* and *ChargingCurrent()* broadcasts to host and smart battery charger

1 = Disable *ChargingVoltage()* and *ChargingCurrent()* broadcasts to host and smart battery charger (default)

AM (Bit 13): ALARM Mode (R/W)

0 = Enable AlarmWarning broadcasts to host and smart battery charger (default)

1 = Disable Alarm Warning broadcasts to host and smart battery charger

RSVD (Bits 12–10): Reserved. Do not use.

PB (Bit 9): Primary Battery

0 = Battery operating in its secondary role (default)

1 = Battery operating in its primary role

CC (Bit 8): Charge Controller Enabled (R/W)

0 = Internal charge controller disabled (default)

1 = Internal charge controller enabled

CF (Bit 7): Condition Flag (R)

0 = Battery OK

1 = Conditioning cycle requested

RSVD (Bits 6–2): Reserved. Do not use.

PBS (Bit 1): Primary Battery Support (R)

0 = Function not supported (default)

1 = Primary or Secondary Battery Support

ICC (Bit 0): Internal Charge Controller (R)

0 = Function not supported (default)

1 = Function supported

12.5 0x04 AtRate()

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

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x04	*AtRate()*	R/W			Word	I2	–32768	32767	0	mA 10 mW

NOTE: If *BatteryMode()[CAPM]* = 0, then the data reports in mA.

If *BatteryMode()[CAPM]* = 1, then the data reports in 10 mW.

12.6 0x05 AtRateTimeToFull()

This word read function returns the remaining time-to-fully charge the battery stack.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit
		SE	US	FA					
0x05	*AtRateTimeToFull()*	R			Word	U2	0	65535	min

NOTE: 65535 indicates not being charged.

12.7 0x06 AtRateTimeToEmpty()

This word read function returns the remaining time-to-fully discharge the battery stack.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit
		SE	US	FA					
0x06	*AtRateTimeToEmpty()*	R			Word	U2	0	65535	min

NOTE: 65535 indicates not being charged.

12.8 0x07 AtRateOK()

This read-word function returns a Boolean value that indicates whether the battery can deliver *AtRate()* for at least 10 seconds.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit
		SE	US	FA					
0x07	*AtRateOK()*	R			Word	U2	0	65535	—

NOTE: 0 = False. The gauge *cannot* deliver energy for 10 s, based on the discharge rate indicated in *AtRate()*.

> than 0 = True. The gauge *can* deliver energy for 10 s, based on the discharge rate indicated in *AtRate()*.

12.9 0x08 Temperature()

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

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit
		SE	US	FA					
0x08	*Temperature()*	R			Word	U2	0	65535	0.1°K

12.10 0x09 Voltage()

This read-word function returns the sum of the measured cell voltages.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit
		SE	US	FA					
0x09	*Voltage()*	R			Word	U2	0	65535	mV

12.11 0x0A Current()

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

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit
		SE	US	FA					
0x0A	*Current()*	R			Word	I2	–32767	32768	mA

12.12 0x0B AverageCurrent()

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit
		SE	US	FA					
0x0B	*AverageCurrent()*	R			Word	I2	–32767	32768	mA

12.13 0x0C MaxError()

This read-word function returns the expected margin of error, in %, in the state-of-charge calculation with a range of 1 to 100%.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit
		SE	US	FA					
0x0C	*MaxError()*	R			Word	U1	0	100	%

Condition	Action
Full device reset	*MaxError()* = 100%
RA-table only updated	*MaxError()* = 5%
QMax only updated	*MaxError()* = 3%
RA-table and QMax updated	*MaxError()* = 1%
Each *CycleCount()* increment after last valid QMax update	*MaxError()* increment by 0.05%

Condition	Action
The ***Configuration:Max Error Time Cycle Equivalent*** period passed since the last valid QMax update	*MaxError()* increment by 0.05%.

12.14 0x0D RelativeStateOfCharge()

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

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit
		SE	US	FA					
0x0D	*RelativeStateOfCharge()*	R			Word	U1	0	100	%

12.15 0x0E AbsoluteStateOfCharge()

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

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit
		SE	US	FA					
0x0E	*AbsoluteStateOfCharge()*	R			Word	U1	0	100	%

12.16 0x0F RemainingCapacity()

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

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit
		SE	US	FA					
0x0F	*RemainingCapacity()*	R	R	R	Word	U2	0	65535	mAh
									10 mWh

NOTE: If *BatteryMode()[CAPM]* = 0, then the data reports in mAh.

If *BatteryMode()[CAPM]* = 1, then the data reports in 10 mWh.

12.17 0x10 FullChargeCapacity()

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

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit
		SE	US	FA					
0x10	*FullChargeCapacity()*	R	R	R	Word	U2	0	65535	mAh
									10 mWh

NOTE: If *BatteryMode()[CAPM]* = 0, then the data reports in mAh.

If *BatteryMode()[CAPM]* = 1, then the data reports in 10 mWh.

12.18 0x11 RunTimeToEmpty()

This read-word function returns the predicted remaining battery capacity based on the present rate of discharge.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit
		SE	US	FA					
0x11	*RunTimeToEmpty()*	R	R	R	Word	U2	0	65535	min

NOTE: 65535 = Battery is not being discharged.

12.19 0x12 AverageTimeToEmpty()

This read-word function returns the predicted remaining battery capacity based on *AverageCurrent()*.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit
		SE	US	FA					
0x12	*AverageTimeToEmpty()*	R	R	R	Word	U2	0	65535	min

NOTE: 65535 = Battery is not being discharged.

12.20 0x13 AverageTimeToFull()

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

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit
		SE	US	FA					
0x13	*AverageTimeToFull()*	R	R	R	Word	U2	0	65535	min

NOTE: 65535 = Battery is not being discharged.

12.21 0x14 ChargingCurrent()

This read-word function returns the desired charging current.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit
		SE	US	FA					
0x14	*ChargingCurrent()*	R	R	R	Word	U2	0	65535	mA

NOTE: 65535 = Request maximum current

12.22 0x15 ChargingVoltage()

This read-word function returns the desired charging voltage.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit
		SE	US	FA					
0x15	*ChargingVoltage()*	R	R	R	Word	U2	0	65535	mV

NOTE: 65535 = Request maximum voltage

12.23 0x16 BatteryStatus()

This read-word function returns various battery status information.

SBS Cmd	Name	Access			Protocol	Type	Min	Max
		SE	US	FA				
0x16	*BatteryStatus()*	R	R	R	Word	H2	—	—

15	14	13	12	11	10	9	8
OCA	TCA	RSVD	OTA	TDA	RSVD	RCA	RTA

7	6	5	4	3	2	1	0
INIT	DSG	FC	FD	EC3	EC2	EC1	EC0

OCA (Bit 15): Overcharged Alarm
- 1 = Detected
- 0 = Not Detected

TCA (Bit 14): Terminate Charge Alarm
- 1 = Detected
- 0 = Not Detected

RSVD (Bit 13): Undefined

OTA (Bit 12): Overtemperature Alarm
- 1 = Detected
- 0 = Not Detected

TDA (Bit 11): Terminate Discharge Alarm
- 1 = Detected
- 0 = Not Detected

RSVD (Bit 10): Undefined

RCA (Bit 9): Remaining Capacity Alarm
- 1 = *RemainingCapacity()* < *RemainingCapacityAlarm()*
- 0 = *RemainingCapacity()* ≥ *RemainingCapacityAlarm()*

RTA (Bit 8): Remaining Time Alarm
- 1 = *AverageTimeToEmpty()* < *RemainingTimeAlarm()*
- 0 = *AverageTimeToEmpty()* ≥ *RemainingTimeAlarm()*

INIT (Bit 7): Initialization
- 1 = Gauge initialization is complete.
- 0 = Initialization is in progress.

DSG (Bit 6): Discharging or Relax
- 1 = Battery is in DISCHARGE or RELAX mode.
- 0 = Battery is in CHARGE mode.

FC (Bit 5): Fully Charged
- 1 = Battery fully charged when *GaugingStatus()[FC]* = 1
- 0 = Battery not fully charged

FD (Bit 4): Fully Discharged
- 1 = Battery fully depleted
- 0 = Battery not depleted

EC3,EC2,EC1,EC0 (Bits 3–0): Error Code
- 0x0 = OK
- 0x1 = Busy

0x2 = Reserved Command
0x3 = Unsupported Command
0x4 = AccessDenied
0x5 = Overflow/Underflow
0x6 = BadSize
0x7 = UnknownError

12.24 0x17 CycleCount()

This read-word function returns the number of discharge cycles the battery has experienced. The default value is stored in the data flash value ***Cycle Count***, which is updated in runtime.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit
		SE	US	FA					
0x17	*CycleCount()*	R	R/W	R/W	Word	U2	0	65535	cycles

12.25 0x18 DesignCapacity()

This read-word function returns the theoretical pack capacity. The default value is stored in the data flash value ***Design Capacity mAh*** or ***Design Capacity cWh.***

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x18	*DesignCapacity()*	R	R/W	R/W	Word	U2	0	65535	4400	mAh
									6336	10 mWh

NOTE: If *BatteryMode()[CAPM]* = 0, then the data reports in mAh.

If *BatteryMode()[CAPM]* = 1, then the data reports in 10 mWh.

12.26 0x19 DesignVoltage()

This read-word function returns the theoretical pack voltage. The default value is stored in data flash value ***Design Voltage***.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x19	*DesignVoltage()*	R	R/W	R/W	Word	U2	7000	18000	14400	mV

12.27 0x1A SpecificationInfo()

SBS Cmd	Name	Access			Protocol	Type	Min	Max
		SE	US	FA				
0x1A	*SpecificationInfo()*	R	R/W	R/W	Word	H2	0x0000	0xFFFF

15	14	13	12	11	10	9	8
IPScale	IPScale	IPScale	IPScale	VScale	VScale	VScale	VScale

7	6	5	4	3	2	1	0
Version	Version	Version	Version	Revision	Revision	Revision	Revision

IPScale (Bit 15–12): IP Scale Factor
Not supported by the gas gauge
MUST be set to 0, 0, 0, 0.

VScale (Bits 11–8): Voltage Scale Factor
Not supported by the gas gauge
MUST be set to 0, 0, 0, 0.

Version (Bits 7–4): Version
0,0,0,1 = Version 1.0
0,0,1,1 = Version 1.1
0,0,1,1 = Version 1.1 with optional PEC support

Revision (Bits 3–0): Revision
0,0,0,1 = Version 1.0 and 1.1 (default)

12.28 0x1B ManufacturerDate()

This read-word function returns the pack's manufacturer date.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default
		SE	US	FA					
0x1B	*ManufacturerDate()*	R	R/W	R/W	Word	U2		65535	0

NOTE: *ManufacturerDate()* value in the following format: Day + Month*32 + (Year–1980)*256

12.29 0x1C SerialNumber()

This read-word function returns the assigned pack serial number.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x1C	*SerialNumber()*	R	R/W	R/W	Word	H2	0x0000	0xFFFF	0x0001	

12.30 0x20 ManufacturerName()

This read-block function returns the pack manufacturer's name.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x20	*ManufacturerName()*	R	R	R	Block	S20+1	—	—	Texas Inst.	ASCII

12.31 0x21 DeviceName()

This read-block function returns the assigned pack name.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x21	*DeviceName()*	R	R	R	Block	S20+1	—	—	bq40z50	ASCII

12.32 0x22 DeviceChemistry()

This read-block function returns the battery chemistry used in the pack.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x22	*DeviceChemistry()*	R	R	R	Block	S4+1	—	—	LION	ASCII

12.33 0x23 ManufacturerData()

This read-block function returns ***ManufacturerInfo*** by default. The command also returns a response to MAC command in order to maintain compatibility of the MAC system in bq30zxy family.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit
		SE	US	FA					
0x23	*ManufacturerData()*	R	R	R	Block	Mixed	—	—	—

12.34 0x2F Authenticate()

This read/write block function provides SHA-1 authentication to send the challenge and read the response in the default mode. It is also used to input a new authentication key when the MAC *AuthenticationKey()* is used.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit
		SE	US	FA					
0x2F	*Authenticate()*	R/W	R/W	R/W	Block	H20+1	—	—	—

12.35 0x3C CellVoltage4()

This read-word function returns the Cell 4 voltage.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x3C	*CellVoltage4()*	R	R	R	Word	U2	—	65535	0	mV

12.36 0x3D CellVoltage3()

This read-word function returns the Cell 3 voltage.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x3D	*CellVoltage3()*	R	R	R	Word	U2	—	65535	0	mV

12.37 0x3E CellVoltage2()

This read-word function returns the Cell 2 voltage.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x3E	*CellVoltage2()*	R	R	R	Word	U2	—	65535	0	mV

12.38 0x3F CellVoltage1()

This read-word function returns the Cell 1 voltage.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x3F	*CellVoltage1()*	R	R	R	Word	U2	—	65535	0	mV

12.39 0x4A BTPDischargeSet()

This read/write word command updates the BTP set threshold for discharge mode for the next BTP interrupt, de-asserts the present BTP interrupt, and clears the *OperationStatus()[BTP_INT]* bit.

SBS Cmd	Name	Access			Format	Size in Bytes	Min	Max	Default	Unit
		SE	US	FA						
0x4A	*BTPDischargeSet()*	R/W	R/W	R/W	Signed Int	2	—	65535	150	mAh

12.40 0x4B BTPChargeSet()

The read/write word command updates the BTP set threshold for charge mode for the next BTP interrupt, de-asserts the present BTP interrupt, and clears the *OperationStatus()[BTP_INT]* bit.

SBS Cmd	Name	Access			Format	Size in Bytes	Min	Max	Default	Unit
		SE	US	FA						
0x4B	*BTPChargeSet()*	R/W	R/W	R/W	Signed Int	2	—	65535	175	mAh

12.41 0x4F State-of-Health (SoH)

This read word command returns the SoH information of the battery in percentage of design capacity and design energy.

12.42 0x50 SafetyAlert

This command returns the *SafetyAlert()* flags. For a description of each bit flag, see the *ManufacturerAccess()* version of the same command in Section 12.1.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x50	*SafetyAlert()*	—	R	R	Block	H4	0x00000000	0xFFFFFFFF	—	—

12.43 0x51 SafetyStatus

This command returns the *SafetyStatus()* flags. For a description of each bit flag, see the *ManufacturerAccess()* version of the same command in Section 12.1.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x51	*SafetyStatus()*	—	R	R	Block	H4	0x00000000	0xFFFFFFFF	—	—

12.44 0x52 PFAlert

This command returns the *PFAlert()* flags. For a description of each bit flag, see the *ManufacturerAccess()* version of the same command in Section 12.1.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x52	*PFAlert()*	—	R	R	Block	H4	0x00000000	0xFFFFFFFF	—	—

12.45 0x53 PFStatus

This command returns the *PFStatus()* flags. For a description of each bit flag, see the *ManufacturerAccess()* version of the same command in Section 12.1.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x53	*PFStatus()*	—	R	R	Block	H4	0x00000000	0xFFFFFFFF	—	—

12.46 0x54 OperationStatus

This command returns the *OperationStatus()* flags. For a description of each bit flag, see the *ManufacturerAccess()* version of the same command in Section 12.1.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x54	*OperationStatus()*	—	R	R	Block	H4	0x00000000	0xFFFFFFFF	—	—

12.47 0x55 ChargingStatus

This command returns the *ChargingStatus()* flags. For a description of each bit flag, see the *ManufacturerAccess()* version of the same command in Section 12.1.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x55	*ChargingStatus()*	—	R	R	Block	H4	0x00000000	0xFFFFFFFF	—	—

12.48 0x56 GaugingStatus

This command returns the *GaugingStatus()* flags. For a description of each bit flag, see the *ManufacturerAccess()* version of the same command in Section 12.1.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x56	*GaugingStatus()*	—	R	R	Block	H4	0x00000000	0xFFFFFFFF	—	—

12.49 0x57 ManufacturingStatus

This command returns the *ManufacturingStatus()* flags. For a description of each bit flag, see the *ManufacturerAccess()* version of the same command in Section 12.1.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x57	*ManufacturingStatus()*	—	R	R	Block	H4	0x00000000	0xFFFFFFFF	—	—

12.50 0x58 AFE Register

This command returns a snapshot of the AFE register settings. For a description of returned data values, see the *ManufacturerAccess()* version of the same command in Section 12.1.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x58	*AFERegister()*	—	R	R	Block	—	—	—	—	—

12.51 0x59 TURBO_POWER

TURBO_POWER reports the maximal peak power value, MAX_POWER. The gauge computes a new RAM value every second. *TURBO_POWER()* is initialized to the result of the max power calculation at reset or power up.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x59	*TURBO_POWER()*	R	R	R/W	Word					cW

NOTE: This computes and provides Turbo Power information based on the battery pack configuration.

12.52 0x5A TURBO_FINAL

TURBO_FINAL sets ***Min Turbo Power***, which represents the minimal TURBO BOOST mode power level during active operation (for example, non-SLEEP).

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x5A	*TURBO_FINAL()*	R/W	R/W	R/W	Word					cW

12.53 0x5B TURBO_PACK_R

TURBO_PACK_R sets the ***PACK Resistance*** value of the battery pack serial resistance, including resistance associated with FETs, traces, sense resistors, and so on *TURBO_PACK_R()* accesses to the data flash value ***Pack Resistance***.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x5B	*TURBO_PACK_R()*	R/W	R/W	R/W	Word					mΩ

12.54 0x5C TURBO_SYS_R

TURBO_SYS_R sets the *System Resistance* value of the system serial resistance along the path from battery to system power converter input that includes FETs, traces, sense resistors, and so on *TURBO_SYS_R()* accesses to the data flash value ***System Resistance***.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x5C	*TURBO_SYS_R()*	R/W	R/W	R/W	Word					mΩ

12.55 0x5D TURBO_EDV

TURBO_EDV sets the Minimal Voltage at the system power converter input at which the system will still operate. *TURBO_EDV()* is written to the data flash value ***Terminate Voltage***. Intended use is to write it once on first use to adjust for possible changes in system design from the time the battery pack was designed.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x5D	*MIN_SYS_V()*	R/W	R/W	R/W	Word					mV

12.56 0x5E TURBO_CURRENT

The gauge computes a maximal discharge current supported by the cell design for a C-rate discharge pulse for 10 ms. This value is updated every 1 s for the system to read.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x5D	*TURBO_CURRENT()*	R	R	R/W	Word					mAh

NOTE: This computes a maximal discharge current supported by the cell design.

12.57 0x60 Lifetime Data Block 1

This command returns the first block of Lifetime Data. For a description of returned data values, see the *ManufacturerAccess()* version of the same command in Section 12.1.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x60	*LifeTimeDataBlock1()*	—	R	R	Block	—	—	—	—	—

12.58 0x61 Lifetime Data Block 2

This command returns the second block of Lifetime Data. For a description of returned data values, see the *ManufacturerAccess()* version of the same command in Section 12.1.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x61	*LifeTimeDataBlock2()*	—	R	R	Block	—	—	—	—	—

12.59 0x62 Lifetime Data Block 3

This command returns the third block of Lifetime Data. For a description of returned data values, see the *ManufacturerAccess()* version of the same command in Section 12.1.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x62	*LifeTimeDataBlock3()*	—	R	R	Block	—	—	—	—	—

12.60 0x63 Lifetime Data Block 4

This command returns the third block of Lifetime Data. For a description of returned data values, see the *ManufacturerAccess()* version of the same command in Section 12.1.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x63	*LifeTimeDataBlock4()*	—	R	R	Block	—	—	—	—	—

12.61 0x64 Lifetime Data Block 5

This command returns the third block of Lifetime Data. For a description of returned data values, see the *ManufacturerAccess()* version of the same command in Section 12.1.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x64	*LifeTimeDataBlock5()*	—	R	R	Block	—	—	—	—	—

12.62 0x70 ManufacturerInfo

This command returns manufacturer information. For a description of returned data values, see the *ManufacturerAccess()* version of the same command in Section 12.1.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x70	*ManufacturerInfo()*	R	R/W	R/W	Block	—	—	—	—	—

12.63 0x71 DAStatus1

This command returns the Cell Voltages, Pack Voltage, Bat Voltage, Cell Currents, Cell Powers, Power, and Average Power. For a description of returned data values, see the *ManufacturerAccess()* version of the same command in Section 12.1.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x71	*DAStatus1()*	—	R	R	Block	—	—	—	—	—

12.64 0x72 DAStatus2

This command returns the internal temp sensor, TS1, TS2, TS3, TS4, Cell Temp, and FETTemp. For a description of returned data values, see the *ManufacturerAccess()* version of the same command in Section 12.1.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x72	*DAStatus2()*	—	R	R	Block	—	—	—	—	—

12.65 0x73 GaugeStatus1

This command instructs the device to return Impedance Track related gauging information. For a description of returned data values, see the *ManufacturerAccess()* version of the same command in Section 12.1.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x73	*GaugeStatus1()*	—	R	R	Block	—	—	—	—	—

12.66 0x74 GaugeStatus2

This command instructs the device to return Impedance Track related gauging information. For a description of returned data values, see the *ManufacturerAccess()* version of the same command in Section 12.1.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x74	*GaugeStatus2()*	—	R	R	Block	—	—	—	—	—

12.67 0x75 GaugeStatus3

This command instructs the device to return Impedance Track related gauging information. For a description of returned data values, see the *ManufacturerAccess()* version of the same command in Section 12.1.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x75	*GaugeStatus3()*	—	R	R	Block	—	—	—	—	—

12.68 0x76 CBStatus

This command instructs the device to return cell balance time information. For a description of returned data values, see the *ManufacturerAccess()* version of the same command in Section 12.1.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x75	*CBStatus()*	—	R	R	Block	—	—	—	—	—

12.69 0x77 State-of-Health

This command instructs the device to return the state-of-health full charge capacity and energy. For a description of returned data values, see the *ManufacturerAccess()* version of the same command in Section 12.1.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x75	*StateOfHealth()*	—	R	R	Block	—	—	—	—	—

12.70 0x78 FilteredCapacity

This command instructs the device to return the filtered capacity and energy even if ***[SMOOTH]*** = 0. For a description of returned data values, see the *ManufacturerAccess()* version of the same command in Section 12.1.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x75	*FilteredCapacity()*	—	R	R	Block	—	—	—	—	—

Data Flash Values

13.1 Data Formats

13.1.1 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

13.1.2 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

13.1.3 Floating Point

Floating point values are stored using the IEEE754 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 unique meanings.

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

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

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

13.1.4 Hex

Bit register definitions are stored in unsigned integer format.

13.1.5 String

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

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

13.2 Calibration

13.2.1 Voltage

Class	Subclass	Name	Start	Type	Min	Max	Default	Unit	Description
Calibration	Voltage	Cell Gain	0x4000	I2	–32767	32767	12101	—	VC[n]–VC[n–1] gain
Calibration	Voltage	PACK Gain	0x4002	U2	0	65535	49669	—	PACK–VSS gain
Calibration	Voltage	BAT Gain	0x4004	U2	0	65535	48936	—	BAT–VSS gain

13.2.2 Current

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Description
Calibration	Current	CC Gain	0x4006	F4	1.00E–001	4.00E+000	3.58422	Coulomb Counter Gain
Calibration	Current	Capacity Gain	0x400A	F4	2.98E+004	1.19E+006	1069035.256	Capacity Gain

13.2.3 Current Offset

13.2.3.1 CC Offset

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Current Offset	CC Offset	0x400E	I2	–32767	32767	0	—

Description: Coulomb Counter Offset. This offset is used for *Current()* and *AverageCurrent()* measurement.

13.2.3.2 Coulomb Counter Offset Samples

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Current Offset	Coulomb Counter Offset Samples	0x4010	U2	0	65535	64	—

Description: Coulomb Counter Offset Samples is used for averaging.

13.2.3.3 Board Offset

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Current Offset	Board Offset	0x4012	I2	–32768	32767	0	—

Description: PCB board offset

13.2.4 CC Auto Config

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
Calibration	Current Offset	CC Auto Config	0x40C0	H1	0x00	0x07	0x03	Hex

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	RSVD	RSVD	OFFSET_TAKEN	AUTO_NESTON	AUTO_CAL_EN

SpecificationInformation() values

RSVD (Bits 7–3): Reserved. Do not use.

OFFSET_TAKEN (Bit 2): CC Auto offset is taken.

1 = CC Auto Offset has been measured.

0 = CC Auto Offset has not been measured.

AUTO_NESTON (Bit 1): NEST Circuit ON

1 = When ***[OFFSET_TAKEN]*** = 1, FW automatically controls the HW NEST circuit for best current and cell current measurements.

0 = HW NEST circuit is always on. Individual cell current measurement may have error relative to *Current()*, but the *Current()* accuracy is not impacted.

AUTO_CAL_EN (Bit 0): Auto CC offset calibration enable

1 = FW will perform auto CC calibration on entry into SLEEP mode. A min auto CC calibration interval is set to 10hr to prevent flash wear out. The result is saved to CC Auto Offset.

0 = Auto CC offset calibration is disabled.

13.2.5 CC Auto Offset

Class	Subclass	Name	Start Address	Type	Min	Max	Default
Calibration	Current Offset	CC Auto Offset	0x40C1	I2	–10000	10000	0

Description: CC offset collected via CC Auto Calibration. This offset is used for cell current measurement and is different than CC Offset.

13.2.6 Temperature

13.2.6.1 Internal Temp Offset

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Temperature	Internal Temp Offset	0x4014	I1	–128	127	0	0.1 °C

Description: Internal temperature sensor reading offset

13.2.6.2 External 1 Temp Offset

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Temperature	External 1 Temp Offset	0x4015	I1	–128	127	0	0.1 °C

Description: TS1 temperature sensor reading offset

13.2.6.3 External 2 Temp Offset

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Temperature	External 2 Temp Offset	0x4016	I1	–128	127	0	0.1 °C

Description: TS2 temperature sensor reading offset

13.2.6.4 External 3 Temp Offset

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Temperature	External 3 Temp Offset	0x4017	I1	–128	127	0	0.1 °C

Description: TS3 temperature sensor reading offset

13.2.6.5 External 4 Temp Offset

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Temperature	External 4 Temp Offset	0x4018	I1	–128	127	0	0.1 °C

Description: TS4 temperature sensor reading offset

13.2.7 Internal Temp Model

13.2.7.1 Int Gain

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Internal Temp Model	Int Gain	0x45C0	I2	–32768	32767	–12143	—

Description: Internal temperature gain

13.2.7.2 Int Base Offset

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Internal Temp Model	Int Base Offset	0x45C2	I2	–32768	32767	6232	—

Description: Internal temperature base offset

13.2.7.3 Int Minimum AD

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Internal Temp Model	Int Minimum AD	0x45C4	I2	–32768	32767	0	—

Description: Minimum AD count used for calculation

13.2.7.4 Int Maximum Temp

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Internal Temp Model	Int Maximum Temp	0x45C6	I2	–32768	32767	6232	0.1 °K

Description: Maximum Temperature boundary

13.2.8 Cell Temp Model

13.2.8.1 Coefficient a1

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Cell Temp Model	Coefficient a1	0x45C8	I2	–32768	32767	–11130	—

Description: Cell Temperature calculation polynomial a1

13.2.8.2 Coefficient a2

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Cell Temp Model	Coefficient a2	0x45CA	I2	–32768	32767	19142	—

Description: Cell Temperature calculation polynomial a2

13.2.8.3 Coefficient a3

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Cell Temp Model	Coefficient a3	0x45CC	I2	–32768	32767	–19262	—

Description: Cell Temperature calculation polynomial a3

13.2.8.4 Coefficient a4

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Cell Temp Model	Coefficient a4	0x45CE	I2	–32768	32767	28203	—

Description: Cell Temperature calculation polynomial a4

13.2.8.5 Coefficient a5

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Cell Temp Model	Coefficient a5	0x45D0	I2	–32768	32767	892	—

Description: Cell Temperature calculation polynomial a5

13.2.8.6 Coefficient b1

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Cell Temp Model	Coefficient b1	0x45D2	I2	–32768	32767	328	—

Description: Cell Temperature calculation polynomial b1

13.2.8.7 Coefficient b2

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Cell Temp Model	Coefficient b2	0x45D4	I2	–32768	32767	–605	—

Description: Cell Temperature calculation polynomial b2

13.2.8.8 Coefficient b3

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Cell Temp Model	Coefficient b3	0x45D6	I2	–32768	32767	–2443	—

Description: Cell Temperature calculation polynomial b3

13.2.8.9 Coefficient b4

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Cell Temp Model	Coefficient b4	0x41D8	I2	–32768	32767	4969	—

Description: Cell Temperature calculation polynomial b4

13.2.8.10 Rc0

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Cell Temp Model	Rc0	0x41DA	I2	–32768	32767	11703	Ω

Description: Resistance at 25°C

13.2.8.11 Adc0

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Cell Temp Model	Adc0	0x41DC	I2	–32768	32767	11703	—

Description: ADC reading at 25°C

13.2.8.12 Rpad

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Cell Temp Model	Rpad	0x41DE	I2	–32768	32767	0	Ω

Description: Pad Resistance (0 to use factory calibration)

13.2.8.13 Rint

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Cell Temp Model	Rint	0x41E0	I2	–32768	32767	0	Ω

Description: Pull up resistor resistance (0 to use factory calibration)

13.2.9 FET Temp Model

13.2.9.1 Coefficient a1

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	FET Temp Model	Coefficient a1	0x41E2	I2	–32768	32767	–11130	—

Description: FET Temperature calculation polynomial a1

13.2.9.2 Coefficient a2

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	FET Temp Model	Coefficient a2	0x41E4	I2	–32768	32767	19142	—

Description: FET Temperature calculation polynomial a2

13.2.9.3 Coefficient a3

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	FET Temp Model	Coefficient a3	0x41E6	I2	–32768	32767	–19262	—

Description: FET Temperature calculation polynomial a3

13.2.9.4 Coefficient a4

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	FET Temp Model	Coefficient a4	0x41E8	I2	–32768	32767	28203	—

Description: FET Temperature calculation polynomial a4

13.2.9.5 Coefficient a5

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	FET Temp Model	Coefficient a5	0x41EA	I2	–32768	32767	892	—

Description: FET Temperature calculation polynomial a5

13.2.9.6 Coefficient b1

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	FET Temp Model	Coefficient b1	0x41EC	I2	–32768	32767	328	—

Description: FET Temperature calculation polynomial b1

13.2.9.7 Coefficient b2

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	FET Temp Model	Coefficient b2	0x41EE	I2	–32768	32767	–605	—

Description: FET Temperature calculation polynomial b2

13.2.9.8 Coefficient b3

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	FET Temp Model	Coefficient b3	0x41F0	I2	–32768	32767	–2443	—

Description: FET Temperature calculation polynomial b3

13.2.9.9 Coefficient b4

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	FET Temp Model	Coefficient b4	0x41F2	I2	–32768	32767	4969	—

Description: FET Temperature calculation polynomial b4

13.2.9.10 Rc0

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	FET Temp Model	Rc0	0x41F4	I2	–32768	32767	11703	Ω

Description: Resistance at 25°C

13.2.9.11 Adc0

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	FET Temp Model	Adc0	0x41F6	I2	–32768	32767	11703	—

Description: ADC reading at 25°C

13.2.9.12 Rpad

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	FET Temp Model	Rpad	0x41F8	I2	–32768	32767	0 [(1)]	Ω

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

Description: Pad Resistance (0 to use factory calibration)

13.2.9.13 Rint

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	FET Temp Model	Rint	0x41FA	I2	–32768	32767	0 [(1)]	Ω

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

Description: Pull up resistor resistance (0 to use factory calibration)

13.2.10 Current Deadband

13.2.10.1 Deadband

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Current Deadband	Deadband	0x4606	U1	0	255	3	mA

Description: Pack-based Deadband to report 0 mA

13.2.10.2 Coulomb Counter Deadband

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Calibration	Current Deadband	Coulomb Counter Deadband	0x4607	U1	0	255	9	116 nV

Description: Coulomb counter deadband to report 0 charge (This setting should not be modified.)

13.3 Settings

13.3.1 Configuration

13.3.1.1 FET Options

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Configuration	FET Options	0x47C7	H1	0x00	0xFF	0x20	Hex

7	6	5	4	3	2	1	0
PACK_FUSE	SLEEPCHG	CHGFET	CHGIN	CHGSU	OTFET	RSVD	PCHG_COMM

PACK_FUSE (Bit 7): Source of voltage to check for ***Min Blow Fuse Voltage***

1 = Pack+ voltage

0 = Battery stack voltage

SLEEPCHG (Bit 6): CHG FET enabled during sleep

1 = CHG FET remains on during sleep

0 = CHG FET off during sleep (default)

CHGFET (Bit 5): FET action on setting of *BatteryStatus() [FC]*

1 = Charging and Precharging disabled, FET off

0 = FET active (default)

CHGIN (Bit 4): FET action in CHARGE INHIBIT mode

1 = Charging and Precharging disabled, FETs off

0 = FET active (default)

CHGSU (Bit 3): FET action in CHARGE SUSPEND mode

1 = Charging and Precharging disabled, FETs off

0 = FET active (default)

OTFET (Bit 2): FET action in OVERTEMPERATURE mode

1 = CHG and DSG FETs will be turned off for overtemperature conditions

0 = No FET action for overtemperature condition (default)

RSVD (Bit 1): Reserved. Do not use.

PCHG_COMM (Bit 0): Precharge FET selection

1 = CHG FET

0 = PCHG FET (default)

13.3.1.2 SBS Gauging Configuration

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Configuration	SBS Gauging Configuration	0x47C8	H1	0x00	0xFF	0x04	Hex

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	RSVD	RSVD	LOCK0	RSOC_HOLD	RSOCL

RSVD (Bit 7–3): Reserved. Do not use.

LOCK0 (Bit 2): Keep *RemainingCapacity()* and *RelativeStateOfCharge()* jumping back during relaxation after 0 was reached during discharge.

1 = Enabled (default)

0 = Disabled

RSOC_HOLD (Bit 1): Prevent RSOC from increasing during discharge

1 = RSOC not allowed to increase during discharge

0 = RSOC not limited (default)

RSOCL (Bit 0): *RelativeStateOfCharge()* and *RemainingCapacity()* behavior at end of charge

1 = Held at 99% until valid charge termination. On entering valid charge termination update to 100%

0 = Actual value shown (default)

13.3.1.3 SBS Configuration

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Configuration	SBS Configuration	0x47C9	H1	0x7F	0xFF	0x20	Hex

7	6	5	4	3	2	1	0
RSVD	RSVD	BLT1	BLT0	XL	HPE	CPE	BCAST

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

RSVD (Bit 6): Reserved. Do not use.

BLT1 (Bit 5): Bus low timeout

0,0 = No SBS bus low timeout

0,1 = 1-s SBS bus low timeout

1,0 = 2-s SBS bus low timeout (default)

1,1 = 3-s SBS bus low timeout

BLT0 (Bit 4): Bus low timeout

0,0 = No SBS bus low timeout

0,1 = 1-s SBS bus low timeout

1,0 = 2-s SBS bus low timeout (default)

1,1 = 3-s SBS bus low timeout

XL (Bit 3): Enable 400-kHz COM mode

1 = 400-kHz bus speed

0 = Normal SBS bus speed (default)

HPE (Bit 2): PEC on host communication

1 = Enabled

0 = Disabled (default)

CPE (Bit 1): PEC on charger broadcast

1 = Enabled

0 = Disabled (default)

BCAST (Bit 0): Enable alert and charging broadcast from device to host

1 = Enabled

0 = Disabled (default)

13.3.1.4 Power Config

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Configuration	Power Config	0x47CA	H1	0x00	0x01	0x00	Hex

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	AUTO_SHIP_EN

RSVD (Bit 7–1): Reserved. Do not use.

AUTO_SHIP_EN (Bit 0): *Automatically Shutdown for Shipment*

1 = Enable auto shutdown after the device is in SLEEP mode without communication for a set period of time.

0 = Disable auto shutdown feature

13.3.1.5 IO Config

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Configuration	IO Config	0x47CB	H1	0x0	0x03	0x00	Hex

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	BTP_POL	BTP_EN

RSVD (Bit 7–2): Reserved. Do not use.

BTP_POL (Bit 1): *Control polarity of BTP pin*

1 = BTP pin is asserted high when BTP is triggered.

0 = BTP pin is asserted low when BTP is triggered (default).

BTP_EN (Bit 0): *Enable assertion of BTP pin*

1 = Enable assertion of BTP pin when BTP is triggered.

0 = Disable assertion of BTP pin when BTP is triggered (default).

13.3.1.6 LED Configuration

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Configuration	LED Configuration	0x47E8	H1	0x0	0xFF	0x0D0	Hex

7	6	5	4	3	2	1	0
LEDC1	LEDC0	LEDPF1	LEDPF0	LEDMODE	LEDCHG	LEDRCA	LEDR

LEDC1, LEDC0 (Bit 7–Bit 6): LED Current sink

0,0 = 0.94 mA average LED current (default)

0, 1 = 1.87 mA average LED current

1, 0 = 2.81 mA average LED current

1, 1 = 3.75 mA average LED current

LEDPF1, LEDPF0 (Bit 5–Bit 4): LED Display PF Error Code

0,0 = PF Error Code not available

0, 1 = PF Error Code shown after SOC if DISP is held low for LED Hold Time (default)

1, 0 = PF Error Code not available

1, 1 = PF Error Code shown after SOC

LEDMODE (Bit 3): LED Display Capacity Selector

1 = Display ASOC/DC

0 = Display RSOC (default)

LEDCHG (Bit 2): LED Display During Charging

1 = Enabled
0 = Disabled

LEDRCA (Bit 1): Flashing of LED Display when [RCA] is set

1 = Enabled
0 = Disabled

LEDR (Bit 0): LED Display activation at Exit of Device Reset

1 = Enabled
0 = Disabled

13.3.1.7 SOC Flag Config A

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Configuration	SOC Flag Config A	0x480E	H2	0x0	0xFFF	0xC8C	Hex

15	14	13	12	11	10	9	8
RSVD	RSVD	RSVD	RSVD	TCSETVCT	FCSETVCT	RSVD	RSVD

7	6	5	4	3	2	1	0
TCCLEAR RSOC	TCSETRSOC	TCCLEARV	TCSETV	TDCLEAR RSOC	TDSETRSOC	TDCLEARV	TDSETV

RSVD (Bit 15–12): Reserved. Do not use.

TCSETVCT (Bit 11): Enable TC flag set by primary charge termination

1 = Enabled (default)
0 = Disabled

FCSETVCT (Bit 10): Enable FC flag set by primary charge termination

1 = Enabled (default)
0 = Disabled

RSVD (Bit 9–8): Reserved. Do not use.

TCCLEARRSOC (Bit 7): Enable TC flag clear by RSOC threshold

1 = Enabled (default)
0 = Disabled

TCSETRSOC (Bit 6): Enable TC flag set by RSOC threshold

1 = Enabled
0 = Disabled (default)

TCCLEARV (Bit 5): Enable TC flag clear by cell voltage threshold

1 = Enabled
0 = Disabled (default)

TCSETV (Bit 4): Enable TC flag set by cell voltage threshold

1 = Enabled
0 = Disabled (default)

TDCLEARRSOC (Bit 3): Enable TD flag clear by RSOC threshold

1 = Enabled (default)
0 = Disabled

TDSETRSOC (Bit 2): Enable TD flag set by RSOC threshold

1 = Enabled (default)
0 = Disabled

TDCLEARV (Bit 1): Enable TD flag clear by cell voltage threshold
1 = Enabled
0 = Disabled (default)

TDSETV (Bit 0): Enable TD flag set by cell voltage threshold
1 = Enabled
0 = Disabled (default)

13.3.1.8 SOC Flag Config B

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Configuration	SOC Flag Config B	0x4810	H1	0x00	0xFF	0x8C	Hex

7	6	5	4	3	2	1	0
FCCLEAR RSOC	FCSETRSOC	FCCLEARV	FCSETV	FDCLEAR RSOC	FDSETRSOC	FDCLEARV	FDSETV

FCCLEARRSOC (Bit 7): Enable FC flag clear by RSOC threshold
1 = Enabled (default)
0 = Disabled

FCSETRSOC (Bit 6): Enable FC flag set by RSOC threshold
1 = Enabled
0 = Disabled (default)

FCCLEARV (Bit 5): Enable FC flag clear by cell voltage threshold
1 = Enabled
0 = Disabled (default)

FCSETV (Bit 4): Enable FC flag set by cell voltage threshold
1 = Enabled
0 = Disabled (default)

FDCLEARRSOC (Bit 3): Enable FD flag clear by RSOC threshold
1 = Enabled (default)
0 = Disabled

FDSETRSOC Bit 2: Enable FD flag set by RSOC threshold
1 = Enabled (default)
0 = Disabled

FDCLEARV (Bit 1): Enable FD flag clear by cell voltage threshold
1 = Enabled
0 = Disabled (default)

FDSETV (Bit 0): Enable FD flag set by cell voltage threshold
1 = Enabled
0 = Disabled (default)

13.3.1.9 IT Gauging Configuration

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Configuration	IT Gauging Configuration	0x4829	H2	0x0	0xFFFF	0x5FE	Hex

15	14	13	12	11	10	9	8
VOLT_CONSIST	RELAX_SMOOTH_OK	TDELTAV	SMOOTH	RELAX_JUMP_OK	FF_NEAR_EDV	CELL_TERM	FAST_QMAX_FLD

7	6	5	4	3	2	1	0
FAST_QMAX_LRN	RSOC_CONV	LFP_RELAX	DOD0EW	OCVFR	RFACTSTEP	CSYNC	CCT

VOLT_CONSIST (Bit 15): Voltage Consistency Check

1 = Enabled (default)

0 = Disabled

RELAX_SMOOTH_OK (Bit 14): Smooth RSOC during RELAX mode

1 = Enabled (default)

0 = Disabled

TDELTAV (Bit 13): TURBO Mode Delta Voltage

1 = Calculate ***DeltaVoltage*** that corresponds to the power spike defined in ***Min Turbo Power***. Must set this flag to 1 to support TURBO mode.

0 = Use of ***DeltaVoltage*** learned as the maximal difference between instantaneous and average voltage (default).

SMOOTH (Bit 12): Smooth RSOC

1 = Smoothed *FullChargeCapacity()* and *RemainingCapacity()* is used (default).

0 = True *FullChargeCapacity()* and *RemainingCapacity()* is used.

RELAX_JUMP_OK (Bit 11): Allows RSOC jump during RELAX mode

1 = Enabled

0 = Disabled (default)

FF_NEAR_EDV (Bit 10): Fast Filter Near EDV

1 = ***Near EDV Ra Param Filter*** is used for Ra update in the ***[RSOC_CONV]*** region (fast scaling region starts around 10% RSOC) (default).

0 = Regular ***Resistance Parameter Filter*** is used for Ra update.

CELL_TERM (Bit 9): Cell Based Termination

1 = Cell based termination

0 = Stack voltage based termination (default)

FAST_QMAX_FLD (Bit 8): Fast Qmax Update in Field

1 = Enabled

0 = Disabled (default)

FAST_QMAX_LRN (Bit 7): Fast Qmax Update in Learning

1 = Enabled (default)

0 = Disabled

RSOC_CONV (Bit 6): RSOC Convergence (Fast Scaling)

1 = Enabled (default)

0 = Disabled

LFP_RELAX (Bit 5): Lithium Iron Phosphate Relax

1 = Enabled

0 = Disabled

DOD0EW (Bit 4): DOD0 error weighting

1 = Enabled

0 = Disabled

OCVFR (Bit 3): Open Circuit Voltage Flat Region

1 = Enabled

0 = Disabled

RFACTSTEP (Bit 2): Ra Factor Step

1 = Enabled (default).

0 = Disabled

CSYNC (Bit 1): Sync *RemainingCapacity()* with *FullChargeCapacity()* at valid charge termination

1 = Synchronized (default)

0 = Not synchronized

CCT (Bit 0): Cycle count threshold

1 = Use CC % of *FullChargeCapacity()*

0 = Use CC % of *DesignCapacity()* (default)

13.3.1.10 Charging Configuration

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Configuration	Charging Configuration	0x490C	H1	0x0	0x3F	0x0	Hex

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	CCC	CRATE

RSVD (Bits 7–2): Reserved. Do not use.

CCC (Bit 1)

1 = Enable Charging Loss Compensation feature

0 = Charging Loss Compensation disabled (default)

CRATE (Bit 0): ChargeCurrent rate

1 = *ChargingCurrent()* adjusted based on *FullChargeCapacity()* / *DesignCapacity()*

0 = No adjustment to *ChargingCurrent()* (default)

13.3.1.11 Temperature Enable

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Configuration	Temperature Enable	0x494E	H1	0x0	0x1F	0x6	Hex

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	TS4	TS3	TS2	TS1	Internal TS

RSVD (Bit 7–5): Reserved. Do not use.

TS4 (Bit 4): Enable TS4

1 = Enable TS4 (default)

0 = Disable TS4

TS3 (Bit 3): Enable TS3

1 = Enable TS3 (default)

0 = Disable TS3

TS2 (Bit 2): Enable TS2

1 = Enable TS2 (default)

0 = Disable TS2

TS1 (Bit 1): Enable TS1

1 = Enable TS1 (default)

0 = Disable TS1

Internal TS (Bit 0): Enable internal TS

1 = Enable internal TS

0 = Disable internal TS (default)

13.3.1.12 Temperature Mode

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Configuration	Temperature Mode	0x494F	H1	0x0	0x1F	0x4	Hex

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	TS4 Mode	TS3 Mode	TS2 Mode	TS1 Mode	TSInt Mode

RSVD (Bit 7–5): Reserved. Do not use.

TS4 Mode (Bit 4): Cell temp or FET temp

1 = FET temp (default)

0 = Cell temp

TS3 Mode (Bit 3): Cell temp or FET temp

1 = FET temp (default)

0 = Cell temp

TS2 Mode (Bit 2): Cell temp or FET temp

1 = FET temp (default)

0 = Cell temp

TS1 Mode (Bit 1): Cell temp or FET temp

1 = FET temp

0 = Cell temp (default)

TSInt Mode (Bit 0): Cell temp or FET temp

1 = FET temp

0 = Cell temp (default)

13.3.1.13 DA Configuration

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Configuration	DA Configuration	0x4950	H1	0x0	0xFF	0x12	Hex

7	6	5	4	3	2	1	0
FTEMP	CTEMP	EMSHUT_EN	SLEEP	IN_SYSTEM_ SLEEP	NR	CC1	CC0

FTEMP (Bit 7): FET Temperature protection source
- 1 = Average
- 0 = MAX (default)

CTEMP (Bit 6): Cell Temperature protection source
- 1 = Average
- 0 = MAX (default)

EMSHUT_EN (Bit 5): Emergency Shutdown Enable
- 1 = Enable
- 0 = Disable

SLEEP (Bit 4): SLEEP mode
- 1 = Enable SLEEP mode (default)
- 0 = Disable SLEEP mode

IN_SYSTEM_SLEEP (Bit 3): In-system SLEEP mode
- 1 = Enable
- 0 = Disable (default)

NR (Bit 2): Use $\overline{\text{PRES}}$ in system detection
- 1 = NON-REMOVABLE mode
- 0 = Use $\overline{\text{PRES}}$, REMOVABLE mode (default)

CC1, CC0 (Bit 1,0): Cell Count
- 1,1 = 4 cell
- 1,0 = 3 cell (default)
- 0,1 = 2 cell
- 0,0 = 1 cell

13.3.1.14 Balancing Configuration

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Configuration	Balancing Configuration	0x4C40	H1	0x0	0xFF	0x1	Hex

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	RSVD	RSVD	CBR	CBM	CB

RSVD (Bits 7–3): Reserved. Do not use.

CBR (Bit 2): Cell balancing at rest
- 1 = Enable cell balancing at rest
- 0 = Disable cell balancing at rest (default)

CBM (Bit 1): Cell balancing method
- 1 = External cell balancing
- 0 = Internal cell balancing (default)

CB (Bit 0): Cell balancing

1 = Cell balancing enabled (default)
0 = Cell balancing disabled

13.3.2 Fuse

13.3.2.1 Permanent Fail Fuse A

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Fuse	Permanent Fail Fuse A	0x47C0	H1	0x0	0xFF	0x0	—

7	6	5	4	3	2	1	0
QIM	SOTF	RSVD	SOT	SOCD	SOCC	SOV	SUV

Fuse blow action for *PFStatus()* bits:

QIM (Bit 7): QMax Imbalance
1 = Enabled
0 = Disabled (default)

SOTF (Bit 6): Safety Overtemperature FET
1 = Enabled
0 = Disabled (default)

RSVD (Bit 5): Reserved. Do not use.

SOT (Bit 4): Safety Overtemperature
1 = Enabled
0 = Disabled (default)

SOCD (Bit 3): Safety Overcurrent in Discharge
1= Enabled
0 = Disabled (default)

SOCC (Bit 2): Safety Overcurrent in Charge
1= Enabled
0 = Disabled (default)

SOV (Bit 1): Safety Cell Overvoltage
1 = Enabled
0 = Disabled (default)

SUV (Bit 0): Safety Cell Undervoltage
1 = Enabled
0 = Disabled (default)

13.3.2.2 Permanent Fail Fuse B

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Fuse	Permanent Fail Fuse B	0x47C1	H1	0x0	0xFF	0	Hex

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	VIMA	VIMR	CD	IMP	CB

Fuse blow action for *PFStatus()* bits:

RSVD (Bit 7–5): Reserved. Do not use.

VIMA (Bit 4): Voltage Imbalance At Rest

1 = Enabled

0 = Disabled (default)

VIMR (Bit 3): Voltage Imbalance At Rest

1 = Enabled

0 = Disabled (default)

CD (Bit 2): Capacity Degradation

1 = Enabled

0 = Disabled (default)

IMP (Bit 1): Cell impedance

1 = Enabled

0 = Disabled (default)

CB (Bit 0): Cell balancing

1 = Enabled

0 = Disabled (default)

13.3.2.3 Permanent Fail Fuse C

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Fuse	Permanent Fail Fuse C	0x47C2	H1	0x0	0xFF	0	Hex

7	6	5	4	3	2	1	0
PTC	2LVL	AFEC	AFER	FUSE	RSVD	DFETF	CFETF

Fuse blow action for *PFStatus()* bits:

PTC (Bit 7): Permanent Fail flag Display

1 = Allow ***PFStatus[PTC]*** = 1 when PTC fault is triggered. Function should be enabled/disabled by the PTCEN pin connection.

0 = Disable the ***PFStatus[PTC]*** = 1 when PTC fault is triggered. Function should be enabled/disabled by the PTCEN pin connection.

2LVL (Bit 6): FUSE input indicating fuse trigger by external 2nd level protection

1 = Enabled

0 = Disabled (default)

AFEC (Bit 5): AFE Communication

1 = Enabled

0 = Disabled (default)

AFER (Bit 4): AFE Register

1 = Enabled

0 = Disabled (default)

FUSE (Bit 3): Fuse

1 = Enabled

0 = Disabled (default)

RSVD (Bit 2): Reserved. Do not use.

DFETF (Bit 1): Discharge FET

1 = Enabled

0 = Disabled (default)

CFETF (Bit 0): Charge FET

1 = Enabled

0 = Disabled (default)

13.3.2.4 Permanent Fail Fuse D

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Fuse	Permanent Fail Fuse D	0x47C3	H1	0x0	0xFF	0x0	Hex

15	14	13	12	11	10	9	8
TS4	TS3	TS2	TS1	RSVD	DFW	OPNCELL	IFC

Fuse blow action for *PFStatus()* bits:

TS4 (Bit 15)

1 = Enabled

0 = Disabled (default)

TS3 (Bit 14)

1 = Enabled

0 = Disabled (default)

TS2 (Bit 13)

1 = Enabled

0 = Disabled (default)

TS1 (Bit 12)

1 = Enabled

0 = Disabled (default)

RSVD (Bit 11): Reserved. Do not use.

DFW (Bit 10): DF wearout

1 = Enabled

0 = Disabled (default)

OPNCELL (Bit 9): Open Cell tab (tab to PCB)

1 = Enabled

0 = Disabled (default)

IFC (Bit 8)

1 = Enabled

0 = Disabled (default)

13.3.2.5 Min Blow Fuse Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default
Settings	Fuse	Min Blow Fuse Voltage	0x47C4	I2	0	65535	3500

Description: Minimum voltage required to attempt fuse blow, pack based, FET failures bypass this requirement to blow the fuse.

13.3.2.6 Fuse Blow Timeout

Class	Subclass	Name	Start Address	Type	Min	Max	Default
Settings	Fuse	Min Blow Fuse Voltage	0x47C6	U1	0	255	30

Description: Minimum time to keep the fuse blow voltage high

13.3.3 BTP

13.3.3.1 Init Discharge Set

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	BTP	Init Discharge Set	0x47CC	I2	0	32767	150	mAH

Description: Initial value for *BTPDischargeSet()*

13.3.3.2 Init Charge Set

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	BTP	Init Discharge Set	0x47C2	I2	0	32767	175	mAH

Description: Initial value for *BTPChargeSet()*

13.3.4 Protection

13.3.4.1 Protection Configuration

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Protection	Protection Configuration	0x4840	H1	0x00	0x03	0x00	Hex

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	CUV_RECOV_CHG	SUV_MODE

RSVD (Bits 7–2): Reserved. Do not use.

CUV_RECOV_CHG (Bit 1): Require charge to recover *SafetyStatus()[CUV]*

1 = Enabled (default)

0 = Disabled

SUV_MODE (Bit 0): Copper Deposition check for *PFStatus()[CUV]*

1 = Enabled (default)

0 = Disabled

13.3.4.2 Enabled Protections A

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Protection	Enabled Protections A	0x4841	H1	0x00	0xFF	0xFF	Hex

7	6	5	4	3	2	1	0
AOLDL	AOLD	OCD2	OCD1	OCC2	OCC1	COV	CUV

AOLDL (Bit 7): Overload in Discharge latch
- 1 = Enabled (default)
- 0 = Disabled

AOLD (Bit 6): Overload in Discharge
- 1 = Enabled (default)
- 0 = Disabled

OCD2 (Bit 5): Overcurrent in Discharge 2nd Tier
- 1 = Enabled (default)
- 0 = Disabled

OCD1 (Bit 4): Overcurrent in Discharge 1st Tier
- 1 = Enabled (default)
- 0 = Disabled

OCC2 (Bit 3): Overcurrent in Charge 2nd Tier
- 1 = Enabled (default)
- 0 = Disabled

OCC1 (Bit 2): Overcurrent in Charge 1st Tier
- 1 = Enabled (default)
- 0 = Disabled

COV (Bit 1): Cell Overvoltage
- 1 = Enabled (default)
- 0 = Disabled

CUV (Bit 0): Cell Undervoltage
- 1 = Enabled (default)
- 0 = Disabled

13.3.4.3 Enabled Protections B

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Protection	Enabled Protections B	0x4842	H1	0x00	0xFF	0xFF	—

7	6	5	4	3	2	1	0
RSVD	CUVC	OTD	OTC	ASCDL	ASCD	ASCCL	ASCC

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

CUVC (Bit 6): I*R compensated CUV
- 1 = Enabled (default)
- 0 = Disabled

OTD (Bit 5): Overtemperature in discharge
- 1 = Enabled (default)
- 0 = Disabled

OTC (Bit 4): Overtemperature in charge

1 = Enabled (default)
0 = Disabled

ASCDL (Bit 3): Short circuit in discharge latch
1 = Enabled (default)
0 = Disabled

ASCD (Bit 2): Short circuit in discharge
1 = Enabled (default)
0 = Disabled

ASCCL (Bit 1): Short circuit in charge latch
1 = Enabled (default)
0 = Disabled

ASCC (Bit 0): Short circuit in charge
1 = Enabled (default)
0 = Disabled

13.3.4.4 Enabled Protections C

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Protection	Enabled Protections C	0x4843	H1	0x00	0xFF	0xFF	Hex

7	6	5	4	3	2	1	0
CHGC	OC	RSVD	CTO	RSVD	PTO	HWDF	OTF

CHGC (Bit 7): *ChargingCurrent()* higher than requested
1 = Enabled (default)
0 = Disabled

OC (Bit 6): Overcharge
1 = Enabled (default)
0 = Disabled

RSVD (Bit 5): Reserved. Do not use.

CTO (Bit 4): Charging timeout
1 = Enabled (default)
0 = Disabled

RSVD (Bit 3): Reserved. Do not use.

PTO (Bit 2): Pre-charging timeout
1 = Enabled (default)
0 = Disabled

HWDF (Bit 1): SBS Host watchdog timeout
1 = Enabled (default)
0 = Disabled

OTF (Bit 0): FET overtemperature
1 = Enabled (default)
0 = Disabled

13.3.4.5 Enabled Protections D

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Protection	Enabled Protections D	0x4844	H1	0x00	0xFF	0xFF	Hex

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	RSVD	UTD	UTC	PCHGV	CHGV

RSVD (Bits 7–4): Reserved. Do not use.

UTD (Bit 3): Under temperature while not charging
1 = Enabled (default)
0 = Disabled

UTC (Bit 2): Under temperature while charging
1 = Enabled (default)
0 = Disabled

PCHGV (Bit 1): *ChargingVoltage()* higher than requested in precharge
1 = Enabled (default)
0 = Disabled

CHGV (Bit 0): *ChargingVoltage()* higher than requested
1 = Enabled (default)
0 = Disabled

13.3.5 Permanent Failure

13.3.5.1 Enabled PF A

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Permanent Failure	Enabled PF A	0x48BE	H1	0x00	0xFF	0x00	Hex

7	6	5	4	3	2	1	0
QIM	SOTF	RSVD	SOT	SOCD	SOCC	SOV	SUV

QIM (Bit 7): QMax Imbalance
1 = Enabled (default)
0 = Disabled

OTF (Bit 6): Overtemperature FET
1 = Enabled (default)
0 = Disabled

RSVD (Bit 5): Reserved. Do not use.

PF_OTCE (Bit 4): Overtemperature
1 = Enabled (default)
0 = Disabled

RSVD (Bits 3–2): Reserved. Do not use.

SOT (Bit 4): Safety Overtemperature

1 = Enabled
0 = Disabled (default)

SOCD (Bit 3): Safety Overcurrent in Discharge
1= Enabled
0 = Disabled (default)

SOCC (Bit 2): Safety Overcurrent in Charge
1= Enabled
0 = Disabled (default)

SOV (Bit 1): Safety Cell Overvoltage
1 = Enabled
0 = Disabled (default)

SUV (Bit 0): Safety Cell Undervoltage
1 = Enabled
0 = Disabled (default)

13.3.5.2 Enabled PF B

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Permanent Failure	Enabled PF B	0x48BF	H1	0x00	0xFF	0x00	—

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	VIMA	VIMR	CD	IMP	CB

RSVD (Bits 7–5): Reserved. Do not use.

VIMA (Bit 4): Voltage imbalance At Rest
1 = Enabled (default)
0 = Disabled

VIMR (Bit 3): Voltage imbalance At Rest
1 = Enabled (default)
0 = Disabled

CD (Bit 2): Capacity Degradation
1 = Enabled (default)
0 = Disabled

IMP (Bit 1): Cell impedance
1 = Enabled (default)
0 = Disabled

CB (Bit 0): Cell balancing
1 = Enabled (default)
0 = Disabled

13.3.5.3 Enabled PF C

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Permanent Failure	Enabled PF C	0x48C0	H1	0x00	0xFF	0x00	Hex

7	6	5	4	3	2	1	0
PTC	2LVL	AFEC	AFER	FUSE	RSVD	DFET	CFETF

PTC (Bit 7): Permanent Fail Flag Display

1 = Allow ***PFStatus[PTC]*** = 1 when PTC fault is triggered. Function should be enabled/disabled by the PTCEN pin connection.

0 = Disable the ***PFStatus[PTC]*** = 1 when PTC fault is triggered. Function should be enabled/disabled by the PTCEN pin connection.

2LVL (Bit 6): FUSE input indicating fuse trigger by external 2nd level protection

1 = Enabled (default)

0 = Disabled

AFEC (Bit 5): AFE Communication

1 = Enabled (default)

0 = Disabled

AFER (Bit 4): AFE Register

1 = Enabled (default)

0 = n/a

FUSE (Bit 3): Fuse

1 = Enabled (default)

0 = Disabled

RSVD (Bit 2): Reserved. Do not use.

DFET (Bit 1): Discharge FET

1 = Enabled (default)

0 = Disabled

CFETF (Bit 0): Charge FET

1 = Enabled (default)

0 = Disabled

13.3.5.4 Enabled PF D

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Permanent Failure	Enabled PF D	0x48C1	H1	0x00	0xFF	0x00	Hex

7	6	5	4	3	2	1	0
TS4	TS3	TS2	TS1	RSVD	RSVD	OPNCELL	RSVD

TS4 (Bit 7)

1 = Enabled (default)

0 = Disabled

TS3 (Bit 6)

1 = Enabled (default)

0 = Disabled

TS2 (Bit 5)

1 = Enabled (default)

0 = Disabled

TS1 (Bit 4)

1 = Enabled (default)

0 = Disabled

RSVD (Bits 3–2): Reserved. Do not use.

OPNCELL (Bit 1): Open Cell tab (tab to PCB)

1 = Enabled (default)

0 = Disabled

RSVD (Bit 0): Reserved. Do not use.

13.3.6 AFE

13.3.6.1 AFE Protection Control

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Configuration	AFE	AFE Protection Control	0x4952	H1	0x00	0xFF	0x70	Hex

7	6	5	4	3	2	1	0
RSTRIM	RSTRIM	RSTRIM	RSTRIM	RSVD	RSVD	SCDDx2	RSNS

RSTRIM (Bits 7–4): *Unsupport* function. Should leave the default setting 0x7. Changing this setting may cause an error to the AFE current protection accuracy.

RSVD (Bits 3–2): Reserved. Do not use.

SCDDx2 (Bit 1): Double SCD Delay Times

1 = 2 × SCD delay times

0 = Normal SCD delay times (default)

RSNS (Bit 0): AOLD, ASCC, ASCD1, ASCD2 Thresholds

1 = Normal AFE Protection Thresholds

0 = 0.5 × AFE Protection Thresholds (default)

13.3.7 ZVCHG Exit Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Configuration	AFE	ZVCHG Exit Threshold	0x4958	I2	0x0	0xFFFF	0x0000	mV

Description: *Voltage()* threshold where the gauge will exit ZVCHG mode when CFET is used for precharging.

13.4 Manufacturing

13.4.1 Manufacturing Status Init

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Settings	Manufacturing	Manufacturing Status Init	0x4580	H2	0x0	0xFFFF	0x0000	Hex

15	14	13	12	11	10	9	8
RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	LED_EN	FUSE_EN

7	6	5	4	3	2	1	0
BBR_EN	PF_EN	LF_EN	FET_EN	GAUGE_EN	RSVD	RSVD	RSVD

RSVD (Bits 15–10): Reserved. Do not use.

LED_EN (Bit 9): LED Display

1 = Enabled

0 = Disabled

FUSE_EN (Bit 8): FUSE action

1 = Enabled

0 = Disabled (default)

BBR_EN (Bit 7): Black Box Recorder

1 = Enabled

0 = Disabled (default)

PF_EN (Bit 6): Permanent Fail

1 = Enabled

0 = Disabled (default)

LF_EN (Bit 5): Lifetime Data Collection

1 = Enabled

0 = Disabled

FET_EN (Bit 4): FET action

1 = Enabled

0 = Disabled (default)

GAUGE_EN (Bit 3): Gauging

1 = Enabled

0 = Disabled (default)

RSVD (Bits 2–0): Reserved. Do not use.

13.5 Advanced Charging Algorithm

13.5.1 Temperature Ranges

13.5.1.1 T1 Temp

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Temperature Ranges	T1 Temp	0x490D	I1	–128	127	0	°C

Description: T1 low temperature range lower limit

13.5.1.2 T2 Temp

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Temperature Ranges	T2 Temp	0x490E	I1	–128	127	12	°C

Description: T2 low temperature range to standard temperature range

13.5.1.3 T5 Temp

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Temperature Ranges	T5 Temp	0x490F	I1	–128	127	20	°C

Description: T5 recommended temperature range lower limit

13.5.1.4 T6 Temp

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Temperature Ranges	T6 Temp	0x4910	I1	–128	127	25	°C

Description: T6 recommended temperature range upper limit

13.5.1.5 T3 Temp

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Temperature Ranges	T3 Temp	0x4911	I1	–128	127	30	°C

Description: T3 standard temperature range to high temperature range

13.5.1.6 T4 Temp

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Temperature Ranges	T4 Temp	0x4912	I1	–128	127	55	°C

Description: T4 high temperature range upper limit

13.5.1.7 Hysteresis

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Temperature Ranges	Hysteresis Temp	0x4913	I1	–128	127	1	°C

Description: Temperature Hysteresis, applied when temperature is decreasing.

13.5.2 Low Temp Charging

13.5.2.1 Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Low Temp Charging	Voltage	0x4914	I2	0	32767	4000	mV

Description: Low temperature range *ChargingVoltage()*

13.5.2.2 Current Low

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Low Temp Charging	Current Low	0x4916	I2	0	32767	132	mA

Description: Low temperature range low voltage range *ChargingCurrent()*

13.5.2.3 Current Med

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Low Temp Charging	Current Med	0x4918	I2	0	32767	352	mA

Description: Low temperature range medium voltage range *ChargingCurrent()*

13.5.2.4 Current High

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Low Temp Charging	Current High	0x491A	I2	0	32767	264	mA

Description: Low temperature range high voltage range *ChargingCurrent()*

13.5.3 Standard Temp Charging

13.5.3.1 Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Standard Temp Charging	Voltage	0x491C	I2	0	32767	4200	mV

Description: Standard temperature range *ChargingVoltage()*

13.5.3.2 Current Low

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Standard Temp Charging	Current Low	0x491E	I2	0	32767	1980	mA

Description: Standard temperature range low voltage range *ChargingCurrent()*

13.5.3.3 Current Med

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Standard Temp Charging	Current Med	0x4920	I2	0	32767	4004	mA

Description: Standard temperature range medium voltage range *ChargingCurrent()*

13.5.3.4 Current High

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Standard Temp Charging	Current High	0x4922	I2	0	32767	2992	mA

Description: Standard temperature range high voltage range *ChargingCurrent()*

13.5.4 High Temp Charging

13.5.4.1 Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	High Temp Charging	Voltage	0x4924	I2	0	32767	4000	mV

Description: High temperature range *ChargingVoltage()*

13.5.4.2 Current Low

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	High Temp Charging	Current Low	0x4926	I2	0	32767	1012	mA

Description: High temperature range low voltage range *ChargingCurrent()*

13.5.4.3 Current Med

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	High Temp Charging	Current Med	0x4928	I2	0	32767	1980	mA

Description: High temperature range medium voltage range *ChargingCurrent()*

13.5.4.4 Current High

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	High Temp Charging	Current High	0x492A	I2	0	32767	1496	mA

Description: High temperature range high voltage range *ChargingCurrent()*

13.5.5 Rec Temp Charging

13.5.5.1 Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Rec Temp Charging	Voltage	0x492C	I2	0	32767	4100	mV

Description: Recommended temperature range *ChargingVoltage()*

13.5.5.2 Current Low

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Rec Temp Charging	Current Low	0x492E	I2	0	32767	2508	mA

Description: Recommended temperature range low voltage range *ChargingCurrent()*

13.5.5.3 Current Med

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Rec Temp Charging	Current Med	0x4930	I2	0	32767	4488	mA

Description: Recommended temperature range medium voltage range *ChargingCurrent()*

13.5.5.4 Current High

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Rec Temp Charging	Current High	0x4932	I2	0	32767	3520	mA

Description: Recommended temperature range high voltage range *ChargingCurrent()*

13.5.6 Pre-Charging

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	PCHG	Current	0x4934	I2	0	32767	88	mA

Description: Precharge *ChargingCurrent()*

13.5.7 Maintenance Charging

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	MCHG	Current	0x4936	I2	0	32767	44	mA

Description: Maintenance *ChargingCurrent()*

13.5.8 Voltage Range

13.5.8.1 Precharge Start Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Voltage Range	Precharge Start Voltage	0x4938	I2	0	32767	2500	mV

Description: Min cell voltage to enter PRECHARGE mode

13.5.8.2 Charging Voltage Low

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Voltage Range	Charging Voltage Low	0x493A	I2	0	32767	2900	mV

Description: Precharge Voltage range to Charging Voltage Low range

13.5.8.3 Charging Voltage Med

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Voltage Range	Charging Voltage Med	0x493C	I2	0	32767	3600	mV

Description: Charging Voltage Low range to Charging Voltage Med range

13.5.8.4 Charging Voltage High

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Voltage Range	Charging Voltage High	0x493E	I2	0	32767	4000	mV

Description: Charging Voltage Med to Charging Voltage High range

13.5.8.5 Charging Voltage Hysteresis

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Voltage Range	Charging Voltage Hysteresis	0x4940	U1	0	255	0	mV

Description: Charging Voltage Hysteresis applied when voltage is decreasing

13.5.9 Termination Config

13.5.9.1 Charge Term Taper Current

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Termination Config	Charge Term Taper Current	0x4941	I2	0	32767	250	mA

Description: Valid Charge Termination taper current qualifier threshold

13.5.9.2 Charge Term Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Termination Config	Charge Term Voltage	0x4945	I2	0	32767	75	mV

Description: Valid Charge Termination delta voltage qualifier, max cell-based

13.5.10 Charging Rate of Change

13.5.10.1 Current Rate

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Charging Rate of Change	Current Rate	0x4948	U1	1	255	1	steps/s

Description: Number of steps to add between any two *ChargingCurrent()* settings

13.5.10.2 Voltage Rate

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Charging Rate of Change	Voltage Rate	0x4949	U1	1	255	1	steps/s

Description: Number of steps to add between any two *ChargingVoltage()* settings

13.5.11 Charge Loss Compensation

13.5.11.1 CCC Current Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Charge Loss Compensation	CCC Current Threshold	0x494A	I2	0	32767	3520	mA

Description: CONSTANT CURRENT CHARGE mode *ChargingCurrent()* threshold to activate Charge Loss Compensation

13.5.11.2 CCC Voltage Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Charge Loss Compensation	CCC Voltage Threshold	0x494C	I2	0	32767	4200	mV

Description: CONSTANT CURRENT CHARGE mode max *ChargingVoltage()* increase limit

13.5.12 Cell Balancing Config

13.5.12.1 Balance Time per mAh Cell 1

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Cell Balancing Config	Balance Time per mAh Cell 1	0x4C41	U2	0	65535	367	s/mAh

Description: Required balance time per mAh for Cell 1. For information on how to calculate balancing time, see Section 7.1.

13.5.12.2 Balance Time per mAh Cell 2–4

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Cell Balancing Config	Balance Time per mAh Cell 2–4	0x4C43	U2	0	65535	514	s/mAh

Description: Required balance time per mAh for cells 2 to 4. For information on how to calculate balancing time, see Section 7.1.

13.5.12.3 Min Start Balance Delta

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Cell Balancing Config	Min Start Balance Delta	0x4C45	U1	0	255	3	mV

Description: Minimum cell voltage delta to start cell balancing during ***Relax Balance Interval*** checks. This condition is checked in RELAX mode and so it only applies if cell balancing at rest is enabled.

13.5.12.4 Relax Balance Interval

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Cell Balancing Config	Relax Balance Interval	0x4C46	U4	0	4294967295	18000	s

Description: Interval during RELAX mode to check for cell imbalance. This parameter applies to cell balancing at rest only.

13.5.12.5 Min RSOC for Balancing

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Advanced Charging Algorithms	Cell Balancing Config	Min RSOC for Balancing	0x4C4A	U1	0	100	80	%

Description: Minimum *RelativeStateOfCharge()* threshold for cell balancing. This condition is checked during relaxation and so it only applies if cell balancing at rest is enabled.

13.6 Power

13.6.1 Power

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Power	Power	Valid Update Voltage	0x47D0	I2	0	32767	3500	mV

Description: Min stack voltage threshold for Flash update

13.6.2 Shutdown

13.6.2.1 Shutdown Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Power	Shutdown	Shutdown Voltage	0x47D2	I2	0	32767	1750	mV

Description: Cell-based shutdown voltage trip threshold

13.6.2.2 Shutdown Time

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Power	Shutdown	Shutdown Time	0x47D4	U2	0	255	10	s

Description: Cell-based shutdown voltage trip delay

13.6.2.3 Charger Present Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Power	Shutdown	Charger Present Threshold	0x47D5	I2	0	32767	3000	mV

Description: Pack pin charger present detect threshold

13.6.3 Sleep

13.6.3.1 Sleep Current

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Power	Sleep	Sleep Current	0x47D7	I2	0	32767	10	mA

Description: |*Current()*| threshold to enter SLEEP mode. If this parameter is set to 0, then the ***deadband*** will effectively become the Sleep Current setting because any current blow the ***deadband*** will set the *Current()* = 0 mA.

13.6.3.2 Bus Timeout

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Power	Sleep	Bus Timeout	0x47D9	U1	0	255	5	s

Description: Bus low or no communication time to enter SLEEP mode

13.6.3.3 Voltage Time

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Power	Sleep	Voltage Time	0x47DE	U1	0	255	5	s

Description: *Voltage()* sampling period in SLEEP mode

13.6.3.4 Current Time

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Power	Sleep	Current Time	0x47DF	U1	0	255	20	s

Description: *Current()* sampling period in SLEEP mode

13.6.3.5 Wake Comparator

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Power	Sleep	Wake Comparator	0x47E0	H1	0x00	0xFF	0x00	—

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	RSVD	WK1	WK0	RSVD	RSVD

RSVD (Bits 7–4): Reserved. Do not use.

WK1, WK0 (Bits 3–2): Wake Comparator Threshold

1,1 = ±5 mV

1,0 = ±2.5 mV

0,1 = ±1.25 mV

0,0 = ±0.625 mV

RSVD (Bits 1–0): Reserved. Do not use.

13.6.4 Ship

13.6.4.1 FET Off Time

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Power	Ship	FET Off Time	0x47E1	U1	0	127	10	s

Description: Delay time to turn off FETs prior to entering SHUTDOWN mode. This setting should not be longer than the ***Ship Delay*** setting.

13.6.4.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Power	Ship	Delay	0x47E2	U1	0	254	20	s

Description: Delay time to enter SHUTDOWN mode after FETs are turned off.

13.6.4.3 Auto Ship Time

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Power	Ship	Auto Ship time	0x47E3	U2	0	65535	1440	min

Description: The device will automatically enter SHUTDOWN mode after staying in SLEEP mode without communication for this amount of time when ***Power Config[AUTO_SHIP_EN]*** = 1.

13.6.5 Power Off

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Power	Power Off	Timeout	0x47E5	U2	0	65535	30	min

Description: Timeout to exit the Emergency Shutdown condition

13.6.6 Manual FET Control

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Power	Manual FET Control	MFC Delay	0x47E7	U1	0	255	60	min

Description: Delay time to turn off FETs through MFC

13.7 LED Support

13.7.1 LED Config

13.7.1.1 LED Flash Period

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
LED Support	LED Config	LED Flash Period	0x47E9	U2	32	65535	512	488 µs

Description: LED Flashing period for alarm display

13.7.1.2 LED Blink Period

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
LED Support	LED Config	LED Blink Period	0x47EB	U2	32	65535	1024	488 µs

Description: LED Blinking period for state-of-charge display

13.7.1.3 LED Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
LED Support	LED Config	LED Delay	0x47ED	U2	16	65535	100	488 µs

Description: Delay time from LED to LED for state-of-charge display

13.7.1.4 LED Hold Time

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
LED Support	LED Config	LED Hold Time	0x47EF	U1	1	63	16	0.25 s

Description: LED display active time

13.7.1.5 CHG Flash Alarm

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
LED Support	LED Config	CHG Flash Alarm	0x4046	I1	0	100	10	%

Description: *RelativeStateOfCharge()* alarm threshold during charging

13.7.1.6 CHG Thresh 1

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
LED Support	LED Config	CHG Thresh 1	0x47F0	I1	0	100	0	%

Description: *RelativeStateOfCharge()* threshold for LED1 during charging

13.7.1.7 CHG Thresh 2

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
LED Support	LED Config	CHG Thresh 2	0x47F1	I1	0	100	20	%

Description: *RelativeStateOfCharge()* threshold for LED2 during charging

13.7.1.8 CHG Thresh 3

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
LED Support	LED Config	CHG Thresh 3	0x47F2	I1	0	100	40	%

Description: *RelativeStateOfCharge()* threshold for LED3 during charging

13.7.1.9 CHG Thresh 4

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
LED Support	LED Config	CHG Thresh 4	0x47F3	I1	0	100	60	%

Description: *RelativeStateOfCharge()* threshold for LED4 during charging

13.7.1.10 CHG Thresh 5

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
LED Support	LED Config	CHG Thresh 5	0x47F4	I1	0	100	80	%

Description: *RelativeStateOfCharge()* threshold for LED5 during charging

13.7.1.11 DSG Flash Alarm

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
LED Support	LED Config	DSG Flash Alarm	0x47F5	I1	0	100	10	%

Description: *RelativeStateOfCharge()* alarm threshold during discharging

13.7.1.12 DSG Thresh 1

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
LED Support	LED Config	DSG Thresh 1	0x47F6	I1	0	100	0	%

Description: *RelativeStateOfCharge()* threshold for LED1 during discharging

13.7.1.13 DSG Thresh 2

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
LED Support	LED Config	DSG Thresh 2	0x47F7	I1	0	100	20	%

Description: *RelativeStateOfCharge()* threshold for LED2 during discharging

13.7.1.14 DSG Thresh 3

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
LED Support	LED Config	DSG Thresh 3	0x47F8	I1	0	100	40	%

Description: *RelativeStateOfCharge()* threshold for LED3 during discharging

13.7.1.15 DSG Thresh 4

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
LED Support	LED Config	DSG Thresh 4	0x47F9	I1	0	100	60	%

Description: *RelativeStateOfCharge()* threshold for LED4 during discharging

13.7.1.16 DSG Thresh 5

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
LED Support	LED Config	DSG Thresh 5	0x47FA	I1	0	100	80	%

Description: *RelativeStateOfCharge()* threshold for LED5 during discharging

13.8 System Data

13.8.1 Manufacturer Info

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
System Data	Manufacturer Data	ManufacturerInfo	0x4040	S33	—	—	abcdefghijklmnopqr stuvwzxy012345	—

Description: *ManufacturerInfo()* value

13.8.2 Static DF Signature

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
System Data	Integrity	Static DF Signature	0x4061	H2	0x0	0x7FFF	0x0	Hex

Description: Static data flash signature. Use MAC *StaticDFSignature()* (with MSB set to 0) to initialize this value.

13.8.3 Static Chem DF

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
System Data	Integrity	Static Chem DF Signature	0x4063	H2	0x0	0x7FFF	0x0	Hex

Description: Static chemistry data signature. Use MAC *StaticChemDFSignature()* (with MSB set to 0) to initialize this value.

13.8.4 All DF Signature

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
System Data	Integrity	All DF Signature	0x4065	H2	0x0	0x7FFF	0x0	Hex

Description: Static data flash signature. Use MAC *AllDFSignature()* (with MSB set to 0) to initialize this value.

13.9 Lifetimes

13.9.1 Voltage

13.9.1.1 Cell 1 Max Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Voltage	Cell 1 Max Voltage	0x4380	I2	0	32767	0	mV

Description: Maximum reported cell voltage 1

13.9.1.2 Cell 2 Max Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Voltage	Cell 2 Max Voltage	0x4382	I2	0	32767	0	mV

Description: Maximum reported cell voltage 2

13.9.1.3 Cell 3 Max Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Voltage	Cell 3 Max Voltage	0x4384	I2	0	32767	0	mV

Description: Maximum reported cell voltage 3

13.9.1.4 Cell 4 Max Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Voltage	Cell 4 Max Voltage	0x4386	I2	0	32767	0	mV

Description: Maximum reported cell voltage 4

13.9.1.5 Cell 1 Min Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Voltage	Cell 1 Min Voltage	0x4388	I2	0	32767	32767	mV

Description: Minimum reported cell voltage 1

13.9.1.6 Cell 2 Min Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Voltage	Cell 2 Min Voltage	0x438A	I2	0	32767	32767	mV

Description: Minimum reported cell voltage 2

13.9.1.7 Cell 3 Min Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Voltage	Cell 3 Min Voltage	0x438C	I2	0	32767	32767	mV

Description: Minimum reported cell voltage 3

13.9.1.8 Cell 4 Min Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Voltage	Cell 4 Min Voltage	0x438E	I2	0	32767	32767	mV

Description: Minimum reported cell voltage 4

13.9.1.9 Max Delta Cell Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Voltage	Max Delta Cell Voltage	0x4390	I2	0	32767	0	mV

Description: Maximum reported delta between cell voltages 1..4

13.9.2 Current

13.9.2.1 Max Charge Current

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Current	Max Charge Current	0x4392	I2	0	32767	0	mA

Description: Maximum reported *Current()* in charge direction

13.9.2.2 Max Discharge Current

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Current	Max Discharge Current	0x4394	I2	–32768	0	0	mA

Description: Maximum reported *Current()* in discharge direction

13.9.2.3 Max Avg Dsg Current

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Current	Max Avg Dsg Current	0x4396	I2	–32768	0	0	mA

Description: Maximum reported *AverageCurrent()* in discharge direction

13.9.2.4 Max Avg Dsg Power

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Current	Max Avg Dsg Power	0x4398	I2	–32768	0	0	cW

Description: Maximum reported Power in discharge direction

13.9.3 Temperature

13.9.3.1 Max Temp Cell

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Temperature	Max Temp Cell	0x439A	I1	–128	127	–128	°C

Description: Maximum reported cell temperature

13.9.3.2 Min Temp Cell

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Temperature	Min Temp Cell	0x439B	I1	–128	127	127	°C

Description: Minimum reported cell temperature

13.9.3.3 Max Delta Cell Temp

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Temperature	Max Delta Cell Temp	0x439C	I1	–128	127	0	°C

Description: Maximum reported temperature delta for TSx inputs configured as cell temperature

13.9.3.4 Max Temp Int Sensor

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Temperature	Max Temp Int Sensor	0x439D	I1	–128	127	–128	°C

Description: Maximum reported internal temperature sensor temperature

13.9.3.5 Min Temp Int Sensor

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Temperature	Min Temp Int Sensor	0x439E	I1	–128	127	127	°C

Description: Minimum reported internal temperature sensor temperature

13.9.3.6 Max Temp Fet

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Temperature	Max Temp Fet	0x439F	I1	–128	127	–128	°C

Description: Maximum reported FET temperature

13.9.4 Safety Events

13.9.4.1 No Of COV Events

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Safety Events	No Of COV Events	0x43A0	U2	0	32767	0	events

Description: Total number of *SafetyStatus()[COV]* events

13.9.4.2 Last COV Event

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Safety Events	Last COV Event	0x43A2	U2	0	32767	0	cycles

Description: Last *SafetyStatus()[COV]* event in *CycleCount()* cycles

13.9.4.3 No Of CUV Events

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Safety Events	No Of CUV Events	0x43A4	U2	0	32767	0	events

Description: Total number of *SafetyStatus()[CUV]* events

13.9.4.4 Last CUV Event

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Safety Events	Last CUV Event	0x43A6	U2	0	32767	0	cycles

Description: Last *SafetyStatus()[CUV]* event in *CycleCount()* cycles

13.9.4.5 No Of OCD1 Events

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Safety Events	No Of OCD1 Events	0x43A8	U2	0	32767	0	events

Description: Total number of *SafetyStatus()[OCD1]* events

13.9.4.6 Last OCD1 Event

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Safety Events	Last OCD1 Event	0x43AA	U2	0	32767	0	cycles

Description: Last *SafetyStatus()[OCD1]* event in *CycleCount()* cycles

13.9.4.7 No Of OCD2 Events

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Safety Events	No Of OCD2 Events	0x43AC	U2	0	32767	0	events

Description: Total number of *SafetyStatus()[OCD2]* events

13.9.4.8 Last OCD2 Event

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Safety Events	Last OCD2 Event	0x43AE	U2	0	32767	0	cycles

Description: Last *SafetyStatus()[OCD2]* event in *CycleCount()* cycles

13.9.4.9 No Of OCC1 Events

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Safety Events	No Of OCC1 Events	0x43B0	U2	0	32767	0	events

Description: Total number of *SafetyStatus()[OCC1]* events

13.9.4.10 Last OCC1 Event

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Safety Events	Last OCC1 Event	0x43B2	U2	0	32767	0	cycles

Description: Last *SafetyStatus()[OCC1]* event in *CycleCount()* cycles

13.9.4.11 No Of OCC2 Events

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Safety Events	No Of OCC2 Events	0x43B4	U2	0	32767	0	events

Description: Total number of *SafetyStatus()[OCC2]* events

13.9.4.12 Last OCC2 Event

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Safety Events	Last OCC2 Event	0x43B6	U2	0	32767	0	cycles

Description: Last *SafetyStatus()[OCC2]* event in *CycleCount()* cycles

13.9.4.13 No Of AOLD Events

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Safety Events	No Of AOLD Events	0x43B8	U2	0	32767	0	events

Description: Total number of *SafetyStatus()[OLD]* events

13.9.4.14 Last AOLD Event

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Safety Events	Last AOLD Event	0x43BA	U2	0	32767	0	cycles

Description: Last *SafetyStatus()[OLD]* event in *CycleCount()* cycles

13.9.4.15 No Of ASCD Events

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Safety Events	No Of ASCD Events	0x43BC	U2	0	32767	0	events

Description: Total number of *SafetyStatus()[SCD]* events

13.9.4.16 Last ASCD Event

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Safety Events	Last ASCD Event	0x43BE	U2	0	32767	0	cycles

Description: Last *SafetyStatus()[SCD]* event in *CycleCount()* cycles

13.9.4.17 No Of ASCC Events

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Safety Events	No Of ASCC Events	0x43C0	U2	0	32767	0	events

Description: Total number of *SafetyStatus()[SCC]* events

13.9.4.18 Last ASCC Event

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Safety Events	Last ASCC Event	0x43C2	U2	0	32767	0	cycles

Description: Last *SafetyStatus()[SCC]* event in *CycleCount()* cycles

13.9.4.19 No Of OTC Events

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Safety Events	No Of OTC Events	0x43C4	U2	0	32767	0	events

Description: Total number of *SafetyStatus()[OTC]* events

13.9.4.20 Last OTC Event

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Safety Events	Last OTC Event	0x43C6	U2	0	32767	0	cycles

Description: Last *SafetyStatus()[OTC]* event in *CycleCount()* cycles

13.9.4.21 No Of OTD Events

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Safety Events	No Of OTD Events	0x43C8	U2	0	32767	0	events

Description: Total number of *SafetyStatus()[OTD]* events

13.9.4.22 Last OTD Event

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Safety Events	Last OTD Event	0x43CA	U2	0	32767	0	cycles

Description: Last *SafetyStatus()[OTD]* event in *CycleCount()* cycles

13.9.4.23 No Of OTF Events

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Safety Events	No Of OTF Events	0x43CC	U2	0	32767	0	events

Description: Total number of *SafetyStatus()[OTF]* events

13.9.4.24 Last OTF Event

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Safety Events	Last OTF Event	0x43CE	U2	0	32767	0	cycles

Description: *Last SafetyStatus()[OTF]* event in *CycleCount()* cycles

13.9.5 Charging Events

13.9.5.1 No Valid Charge Term

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Charging Events	No Valid Charge Term	0x43D0	U2	0	32767	0	events

Description: Total number of valid charge termination events

13.9.5.2 Last Valid Charge Term

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Charging Events	Last Valid Charge Term	0x43D2	U2	0	32767	0	cycles

Description: Last valid charge termination in *CycleCount()* cycles

13.9.6 Gauging Events

13.9.6.1 No Of Qmax Updates

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Gauging Events	No Of Qmax Updates	0x43D4	U2	0	32767	0	events

Description: Total number of *GaugingStatus()[QMax]* toggles

13.9.6.2 Last Qmax Update

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Gauging Events	Last Qmax Update	0x43D6	U2	0	32767	0	cycles

Description: The *CycleCount()* cycles made at the last event of *GaugingStatus()[QMax]* update

13.9.6.3 No Of Ra Updates

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Gauging Events	No Of Ra Updates	0x43D8	U2	0	32767	0	events

Description: Total number of *GaugingStatus()[RX]* toggles

13.9.6.4 Last Ra Update

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Gauging Events	Last Ra Update	0x43DA	U2	0	32767	0	cycles

Description: Last *GaugingStatus()[RX]* toggle in *CycleCount()* cycles

13.9.6.5 No Of Ra Disable

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Gauging Events	No Of Ra Disable	0x43DC	U2	0	32767	0	events

Description: Total number of *GaugingStatus()[R_DIS]* = 1 event

13.9.6.6 Last Ra Disable

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Gauging Events	Last Ra Disable	0x43DE	U2	0	32767	0	cycles

Description: The *CycleCount()* cycles of the last update event of *GaugingStatus()[R_DIS]* = 1

13.9.7 Power Events

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Power Events	No of Shutdowns	0x43E0	U1	0	255	0	events

Description: Total number of shutdown events

13.9.8 Cell Balancing

13.9.8.1 CB Time Cell 1

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Cell Balancing	CB Time Cell 1	0x43E4	U1	0	255	0	2 h

Description: Total performed cell balancing bypass time Cell 0

13.9.8.2 CB Time Cell 2

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Cell Balancing	CB Time Cell 2	0x43E5	U1	0	255	0	2 h

Description: Total performed cell balancing bypass time Cell 1

13.9.8.3 CB Time Cell 3

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Cell Balancing	CB Time Cell 3	0x43E6	U1	0	255	0	2 h

Description: Total performed cell balancing bypass time Cell 2

13.9.8.4 CB Time Cell 4

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Cell Balancing	CB Time Cell 4	0x43E7	U1	0	255	0	2 h

Description: Total performed cell balancing bypass time Cell 3

13.9.9 Time

13.9.9.1 Total Firmware Runtime

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Time	Total Firmware Runtime	0x43E8	U2	0	65535	0	2 h

Description: Total firmware runtime between resets

13.9.9.2 Time Spent in UT

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Time	Time Spent in UT	0x43EA	U2	0	65535	0	2 h

Description: Total firmware runtime spent below T1

13.9.9.3 Time Spent in LT

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Time	Time Spent in LT	0x43EC	U2	0	65535	0	2 h

Description: Total firmware runtime spent between T1 and T2

13.9.9.4 Time Spent in STL

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Time	Time Spent in STL	0x43EE	U2	0	65535	0	2 h

Description: Total firmware runtime spent between T2 and T5

13.9.9.5 Time Spent in RT

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Time	Time Spent in RT	0x43F0	U2	0	65535	0	2 h

Description: Total firmware runtime spent between T5 and T6

13.9.9.6 Time Spent in STH

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Time	Time Spent in STH	0x43F2	U2	0	65535	0	2 h

Description: Total firmware runtime spent between T6 and T3

13.9.9.7 Time Spent in HT

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Time	Time Spent in HT	0x43F4	U2	0	65535	0	2 h

Description: Total firmware runtime spent between T3 and T4

13.9.9.8 Time Spent in OT

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Lifetimes	Time	Time Spent in OT	0x43F6	U2	0	65535	0	2 h

Description: Total firmware runtime spent above T6

13.10 Protections

13.10.1 CUV—Cell Undervoltage

13.10.1.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	CUV	Threshold	0x4845	I2	0	32767	2500	mV

Description: Cell undervoltage trip threshold

13.10.1.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	CUV	Delay	0x4847	U1	0	255	2	s

Description: Cell undervoltage trip delay

13.10.1.3 Recovery

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	CUV	Recovery	0x4848	I2	0	32767	3000	mV

Description: Cell undervoltage recovery threshold

13.10.2 CUVC—Cell Undervoltage

13.10.2.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	CUVC	Threshold	0x484A	I2	0	32767	2400	mV

Description: Cell undervoltage trip threshold

13.10.2.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	CUVC	Delay	0x484C	U1	0	255	2	s

Description: Cell undervoltage trip delay

13.10.2.3 Recovery

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	CUVC	Recovery	0x484D	I2	0	32767	3000	mV

Description: Cell undervoltage recovery threshold

13.10.3 COV—Cell Overvoltage

13.10.3.1 Threshold Low Temp

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	COV	Threshold Low Temp	0x484F	I2	0	32767	4300	mV

Description: Cell overvoltage low temperature range trip threshold

13.10.3.2 Threshold Standard Tem

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	COV	Threshold Standard Temp	0x4851	I2	0	32767	4300	mV

Description: Cell overvoltage standard temperature range trip threshold

13.10.3.3 Threshold High Temp

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	COV	Threshold High Temp	0x4853	I2	0	32767	4300	mV

Description: Cell overvoltage high temperature range trip threshold

13.10.3.4 Threshold Rec Temp

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	COV	Threshold Rec Temp	0x4855	I2	0	32767	4300	mV

Description: Cell overvoltage recommended temperature range trip threshold

13.10.3.5 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	COV	Delay	0x4857	U1	0	255	2	s

Description: Cell overvoltage trip delay

13.10.3.6 Recovery Low Temp

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	COV	Recovery Low Temp	0x4858	I2	0	32767	3900	mV

Description: Cell overvoltage low temperature range recovery threshold

13.10.3.7 Recovery Standard Temp

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	COV	Recovery Standard Temp	0x485A	I2	0	32767	3900	mV

Description: Cell overvoltage standard temperature recovery range threshold

13.10.3.8 Recovery High Temp

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	COV	Recovery High Temp	0x485C	I2	0	32767	3900	mV

Description: Cell overvoltage high temperature range recovery threshold

13.10.3.9 Recovery Rec Temp

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	COV	Recovery Rec Temp	0x485E	I2	0	32767	3900	mV

Description: Cell overvoltage recommended temperature range recovery threshold

13.10.4 OCC1—Overcurrent In Charge 1

13.10.4.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	OCC1	Threshold	0x4860	I2	–32768	32767	6000	mA

Description: Overcurrent in Charge 1 trip threshold

13.10.4.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	OCC1	Delay	0x4862	U1	0	255	6	s

Description: Overcurrent in Charge 1 trip delay

13.10.5 OCC2—Overcurrent In Charge 2

13.10.5.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	OCC2	Threshold	0x4863	I2	–32768	32767	8000	mA

Description: Overcurrent in Charge 2 trip threshold

13.10.5.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	OCC2	Delay	0x4865	U1	0	255	3	s

Description: Overcurrent in Charge 2 trip delay

13.10.6 OCC—Overcurrent In Charge Recovery

13.10.6.1 Recovery Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	OCC	Recovery Threshold	0x4866	I2	–32768	32767	–200	mA

Description: Overcurrent in Charge 1 and 2 recovery threshold

13.10.6.2 Recovery Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	OCC	Recovery Delay	0x4868	U1	0	255	5	s

Description: Overcurrent in Charge 1 and 2 recovery delay

13.10.7 OCD1—Overcurrent In Discharge 1

13.10.7.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	OCD1	Threshold	0x4869	I2	–32768	32767	–6000	mA

Description: Overcurrent in Discharge 1 trip threshold

13.10.7.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	OCD1	Delay	0x486B	U1	0	255	6	s

Description: Overcurrent in Discharge 1 trip delay

13.10.8 OCD2—Overcurrent In Discharge 2

13.10.8.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	OCD2	Threshold	0x486C	I2	–32768	32767	–8000	mA

Description: Overcurrent in Discharge 2 trip threshold

13.10.8.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	OCD2	Delay	0x486E	U1	0	255	3	s

Description: Overcurrent in Discharge 2 trip delay

13.10.9 OCD—Overcurrent In Discharge Recovery

13.10.9.1 Recovery Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	OCD	Recovery Threshold	0x486F	I2	–32768	32767	200	mA

Description: Overcurrent in Discharge 1 and 2 recovery threshold

13.10.9.2 Recovery Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	OCD	Recovery Delay	0x4871	U1	0	255	5	s

Description: Overcurrent in Discharge 1 and 2 recovery delay

13.10.10 AOLD—Overload in Discharge

13.10.10.1 Latch Limit

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	AOLD	Latch Limit	0x4872	U1	0	255	0	counts

Description: Overload latch counter trip threshold

13.10.10.2 Counter Dec Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	AOLD	Counter Dec Delay	0x4873	U1	0	255	10	s

Description: Overload latch counter decrement delay

13.10.10.3 Recovery

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	AOLD	Recovery	0x4874	U1	0	255	5	s

Description: Overload recovery time

13.10.10.4 Reset

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	AOLD	Reset	0x4875	U1	0	255	15	s

Description: Overload latch reset time

13.10.10.5 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	AOLD	Threshold	0x4953	H1	0x0	0xFF	0xF4	Hex

Description: ***AOLD:Threshold*** Setting

Bits 7–4: OLDD: AOLD delay time

Bits 3–0: OLDV: AOLD threshold

13.10.11 ASCC—Short Circuit In Charge

13.10.11.1 Latch Limit

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	ASCC	Latch Limit	0x4876	U1	0	255	0	—

Description: Short Circuit in Charge Latch counter trip threshold

13.10.11.2 Counter Dec Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	ASCC	Counter Dec Delay	0x4877	U1	0	255	10	s

Description: Short Circuit in Charge counter decrement delay

13.10.11.3 Recovery

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	ASCC	Recovery	0x4878	U1	0	255	5	s

Description: Short Circuit in Charge recovery time

13.10.11.4 Reset

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	ASCC	Reset	0x4879	U1	0	255	15	s

Description: Short Circuit in Charge latch reset time

13.10.11.5 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	ASCC	Threshold	0x4954	H1	0x0	0xFF	0x77	Hex

Description: ***ASCC:Threshold*** Setting

Bits 7–4: SCCD: SCC delay time
Bit 3: Reserved
Bits 2–0: SCCV: SCC threshold

13.10.12 ASCD—Short Circuit in Discharge

13.10.12.1 Latch Limit

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	ASCD	Latch Limit	0x487A	U1	0	255	0	—

Description: Short Circuit in Discharge Latch counter trip threshold

13.10.12.2 Counter Dec Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	ASCD	Counter Dec Delay	0x487B	U1	0	255	10	s

Description: Short Circuit in Discharge counter decrement delay

13.10.12.3 Recovery

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	ASCD	Recovery	0x487C	U1	0	255	5	s

Description: Short Circuit in Discharge recovery time

13.10.12.4 Reset

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	ASCD	Reset	0x487D	U1	0	255	15	s

Description: Short Circuit in Discharge latch reset time

13.10.12.5 Thresholds 1 and 2

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	ASCD	Threshold 1	0x4955	H1	0x0	0xFF	0x77	Hex
Protections	ASCD	Threshold 2	0x4956	H1	0x0	0xFF	0xE7	Hex

Threshold 1 Description: ***ASCD:Threshold 1*** Setting

Bits 7–4: SCD1D–SCD1 delay time

Bit 3: Reserved

Bits 2–0: SCD1V: SCD1 threshold

Threshold 2 Description: ***ASCD:Threshold 2*** Setting

Bits 7–4: SCD2D–SCD2 delay time

Bit 3: Reserved

Bits 2–0: SCD2V: SCD2 threshold

13.10.13 OTC—Overtemperature in Charge

13.10.13.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	OTC	Threshold	0x487E	I2	–400	1500	550	0.1°C

Description: Overtemperature in Charge trip threshold

13.10.13.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	OTC	Delay	0x4880	U1	0	255	2	s

Description: Overtemperature in Charge Cell trip delay

13.10.13.3 Recovery

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	OTC	Recovery	0x4881	I2	–400	1500	500	0.1°C

Description: Overtemperature in Charge Cell recovery threshold

13.10.14 OTD—Overtemperature in Discharge

13.10.14.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	OTD	Threshold	0x4883	I2	–400	1500	600	0.1°C

Description: Overtemperature in Discharge trip threshold

13.10.14.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	OTD	Delay	0x4885	U1	0	255	2	s

Description: Overtemperature in Discharge trip delay

13.10.14.3 Recovery

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	OTD	Recovery	0x4886	I2	–400	1500	550	0.1°C

Description: Overtemperature in Discharge recovery threshold

13.10.15 OTF—Overtemperature FET

13.10.15.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	OTF	Threshold	0x4888	I2	–400	1500	800	0.1°C

Description: Overtemperature FET trip threshold

13.10.15.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	OTF	Delay	0x488A	U1	0	255	2	s

Description: Overtemperature FET trip delay

13.10.15.3 Recovery

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	OTF	Recovery	0x488B	I2	–400	1500	650	0.1°C

Description: Overtemperature FET recovery threshold

13.10.16 UTC—Under Temperature in Charge

13.10.16.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	UTC	Threshold	0x488D	I2	–400	1500	0	0.1°C

Description: Undertemperature in Charge trip threshold

13.10.16.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	UTC	Delay	0x488F	U1	0	255	2	s

Description: Undertemperature in Charge Cell trip delay

13.10.16.3 Recovery

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	UTC	Recovery	0x4890	I2	–400	1500	50	0.1°C

Description: Undertemperature in Charge Cell recovery threshold

13.10.17 UTD—Under Temperature in Discharge

13.10.17.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	UTD	Threshold	0x4892	I2	–400	1500	0	0.1°C

Description: Under Temperature in Discharge trip threshold

13.10.17.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	UTD	Delay	0x4894	U1	0	255	2	s

Description: Under Temperature in Discharge trip delay

13.10.17.3 Recovery

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	UTD	Recovery	0x4895	I2	–400	1500	50	0.1°C

Description: Under Temperature in Discharge recovery threshold

13.10.18 HWD—Host Watchdog

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	HWD	Delay	0x4897	U1	0	255	10	s

Description: SBS Host watchdog trip delay

13.10.19 PTO—Precharge mode Time Out

13.10.19.1 Charge Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	PTO	Charge Threshold	0x4898	I2	–32768	32767	2000	mA

Description: Precharge Timeout Current Threshold

13.10.19.2 Suspend Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	PTO	Suspend Threshold	0x489A	I2	–32768	32767	1800	mA

Description: Precharge Timeout Suspend Threshold

13.10.19.3 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	PTO	Delay	0x489C	U2	0	65535	1800	s

Description: Precharge Timeout trip delay

13.10.19.4 Reset

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	PTO	Reset	0x489E	I2	–32768	32767	2	mA

Description: Precharge Timeout Reset Threshold

13.10.20 CTO—Fast Charge Mode Time Out

13.10.20.1 Charge Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	CTO	Charge Threshold	0x48A0	I2	–32768	32767	2500	mA

Description: Fast-Charge Timeout Current Threshold

13.10.20.2 Suspend Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	CTO	Suspend Threshold	0x48A2	I2	–32768	32767	2000	mA

Description: Fast-Charge Timeout Suspend Threshold

13.10.20.3 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	CTO	Delay	0x48A4	U2	0	65535	54000	s

Description: Fast-Charge Timeout trip delay

13.10.20.4 Reset

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	CTO	Reset	0x48A6	I2	0	32767	2	mA

Description: Fast-Charge Timeout Reset Threshold

13.10.21 OC—Overcharge

13.10.21.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	OC	Threshold	0x48A8	I2	–32768	32767	300	mAh

Description: Overcharge trip threshold

13.10.21.2 Recovery

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	OC	Recovery	0x48AA	I2	–32768	32767	2	mAh

Description: Overcharge recovery threshold

13.10.21.3 RSOC Recovery

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	OC	RSOC Recovery	0x48AC	U1	0	100	90	%

Description: Overcharge *RelativeStateOfCharge()* recovery threshold

13.10.22 CHGV—ChargingVoltage

13.10.22.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	CHGV	Threshold	0x48AD	I2	–32768	32767	500	mV

Description: *ChargingVoltage()* delta trip threshold

13.10.22.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	CHGV	Delay	0x48AF	U1	0	255	30	s

Description: *ChargingVoltage()* delta trip delay

13.10.22.3 Recovery

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	CHGV	Recovery	0x48B0	I2	–32768	32767	–500	mV

Description: *ChargingVoltage()* delta recovery threshold

13.10.23 CHGC—ChargingCurrent

13.10.23.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	CHGC	Threshold	0x48B2	I2	–32768	32767	500	mA

Description: *ChargingCurrent()* delta trip threshold

13.10.23.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	CHGC	Delay	0x48B4	U1	0	255	2	s

Description: *ChargingCurrent()* delta trip delay

13.10.23.3 Recovery Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	CHGC	Recovery Threshold	0x48B5	I2	–32768	32767	100	mA

Description: *ChargingCurrent()* delta recovery threshold

13.10.23.4 Recovery Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	CHGC	Recovery Delay	0x48B7	U1	0	255	2	s

Description: *ChargingCurrent()* delta recovery delay

13.10.24 PCHGC—Pre-ChargingCurrent

13.10.24.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	PCHGC	Threshold	0x48B8	I2	–32768	32767	50	mA

Description: *Pre-ChargingCurrent()* trip threshold

13.10.24.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	PCHGC	Delay	0x48BA	U1	0	255	2	s

Description: *Pre-ChargingCurrent()* trip delay

13.10.24.3 Recovery Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	PCHGC	Recovery Threshold	0x48BB	I2	–32768	32767	10	mA

Description: *Pre-ChargingCurrent()* recovery threshold

13.10.24.4 Recovery Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Protections	PCHGC	Recovery Delay	0x48BD	U1	0	255	2	s

Description: *Pre-ChargingCurrent()* recovery delay

13.11 Permanent Fail

13.11.1 SUV—Safety Cell Undervoltage

13.11.1.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	SUV	Threshold	0x48C2	I2	0	32767	2200	mV

Description: Safety Cell Undervoltage trip threshold

13.11.1.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	SUV	Delay	0x48C4	U1	0	255	5	s

Description: Safety Cell Undervoltage trip delay

13.11.2 SOV—Safety Cell Overvoltage

13.11.2.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	SOV	Threshold	0x48C5	I2	0	32767	4500	mV

Description: Safety Cell Overvoltage trip threshold

13.11.2.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	SOV	Delay	0x48C7	U1	0	255	5	s

Description: Safety Cell Overvoltage trip delay

13.11.3 SOCC—Safety Overcurrent in Charge

13.11.3.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	SOCC	Threshold	0x48C8	I2	–32768	32767	10000	mA

Description: Safety Overcurrent in Charge trip threshold

13.11.3.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	SOCC	Delay	0x48CA	U1	0	255	5	s

Description: Safety Overcurrent in Charge trip delay

13.11.4 SOCD—Safety Overcurrent in Discharge

13.11.4.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	SOCD	Threshold	0x48CB	I2	–32768	32767	–10000	mA

Description: Safety Overcurrent in Discharge trip threshold

13.11.4.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	SOCD	Delay	0x48CD	U1	0	255	5	s

Description: Safety Overcurrent in Discharge trip delay

13.11.5 SOT—Overtemperature Cell

13.11.5.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	SOT	Threshold	0x48CE	I2	–400	1500	650	0.1°C

Description: Overtemperature Cell trip threshold

13.11.5.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	SOT	Delay	0x48D0	U1	0	255	5	s

Description: Overtemperature Cell trip delay

13.11.6 SOTF—Overtemperature FET

13.11.6.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	SOTF	Threshold	0x48D1	I2	–400	1500	1000	0.1°C

Description: Overtemperature FET trip threshold

13.11.6.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	SOTF	Delay	0x48D3	U1	0	255	5	s

Description: Overtemperature FET trip delay

13.11.7 Open Thermistor—NTC Thermistor Failure

13.11.7.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	Open Thermistor	Threshold	0x48D4	I2	0	32767	2232	0.1 °K

Description: Temperature threshold for open thermistor

13.11.7.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	Open Thermistor	Delay	0x48D6	U1	0	255	5	s

Description: Trip delay for open thermistor

13.11.7.3 FET Delta

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	Open Thermistor	FET Delta	0x48D7	I2	0	–400	1500	0.1 °K

Description: Delta from internal temperature to enable Open Thermistor check for FET thermistors

13.11.7.4 Cell Delta

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	Open Thermistor	Cell Delta	0x48D9	I2	0	–400	1500	0.1 °K

Description: Delta from internal temperature to enable Open Thermistor check for cell thermistors

13.11.8 QIM—QMax Imbalance

13.11.8.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	QIM	Threshold	0x48DB	I2	0	32767	100	0.10%

Description: QMax Imbalance trip threshold

13.11.8.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	QIM	Delay	0x48DD	U1	0	255	2	updates

Description: QMax Imbalance trip delay

13.11.9 CB—Cell Balance

13.11.9.1 Max Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	CB	Max Threshold	0x48DE	I2	0	32767	120	2 h

Description: Cell Balance max trip threshold

13.11.9.2 Delta Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	CB	Delta Threshold	0x48E0	U1	0	255	20	2 h

Description: Cell Balance cell delta trip threshold

13.11.9.3 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	CB	Delay	0x48E1	U1	0	255	2	cycles

Description: Cell Balance trip delay

13.11.10 VIMR—Voltage Imbalance At Rest

13.11.10.1 Check Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	VIMR	Check Voltage	0x48E2	I2	0	5000	3500	mV

Description: Voltage Imbalance At Rest Check Voltage

13.11.10.2 Check Current

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	VIMR	Check Current	0x48E4	I2	0	32767	10	mA

Description: Voltage Imbalance At Rest Check Current

13.11.10.3 Delta Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	VIMR	Delta Threshold	0x48E6	I2	0	5000	200	mV

Description: Voltage Imbalance At Rest trip threshold

13.11.10.4 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	VIMR	Delay	0x48E8	U1	0	255	5	s

Description: Voltage Imbalance At Rest Check trip delay

13.11.10.5 Duration

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	VIMR	Duration	0x48E9	U2	0	65535	100	s

Description: Voltage Imbalance At Rest Check Duration

13.11.11 VIMA—Voltage Imbalance Active

13.11.11.1 Check Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	VIMA	Check Voltage	0x48EB	I2	0	5000	3700	mV

Description: Voltage Imbalance active Check Voltage

13.11.11.2 Check Current

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	VIMA	Check Current	0x48ED	I2	0	32767	50	mA

Description: Voltage Imbalance active Check Current

13.11.11.3 Delta Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	VIMA	Delta Threshold	0x48EF	I2	0	5000	300	mV

Description: Voltage Imbalance active trip threshold

13.11.11.4 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	VIMA	Delay	0x48F1	U1	0	255	5	s

Description: Voltage Imbalance active check trip Delay

13.11.12 IMP—Impedance Imbalance

13.11.12.1 Delta Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	IMP	Delta Threshold	0x48F2	I2	0	32767	300	%

Description: Impedance Imbalance delta threshold

13.11.12.2 Max Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	IMP	Max Threshold	0x48F4	I2	0	32767	400	%

Description: Impedance Imbalance max threshold

13.11.12.3 Ra Update Counts

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	IMP	Ra Update Counts	0x48F6	U1	0	255	2	counts

Description: Impedance Imbalance trip delay

13.11.13 CD—Capacity Degradation

13.11.13.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	CD	Threshold	0x48F7	I2	0	32767	4200	mAh

Description: Capacity Degradation threshold

13.11.13.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	CD	Delay	0x48F9	U1	0	255	2	cycles

Description: Capacity Degradation trip delay

13.11.14 CFET—CHG FET Failure

13.11.14.1 OFF Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	CFET	OFF Threshold	0x48FA	I2	0	500	5	mA

Description: CHG FET OFF current trip threshold

13.11.14.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	CFET	Delay	0x48FC	U1	0	255	5	s

Description: CHG FET OFF trip delay

13.11.15 DFET—DFET Failure

13.11.15.1 OFF Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	DFET	OFF Threshold	0x48FD	I2	–500	0	–5	mA

Description: DSG FET OFF current trip threshold

13.11.15.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	DFET	Delay	0x48FF	U1	0	255	5	s

Description: DSG FET OFF trip delay

13.11.16 FUSE—FUSE Failure

13.11.16.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	FUSE	Threshold	0x4900	I2	0	255	5	mA

Description: FUSE activation fail trip threshold

13.11.16.2 Delay

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	FUSE	Delay	0x4902	U1	0	255	5	s

Description: FUSE activation fail trip delay

13.11.17 AFER—AFE Register

13.11.17.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	AFER	Threshold	0x4903	U1	0	255	100	—

Description: AFE Register comparison fail trip threshold

13.11.17.2 Delay Period

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	AFER	Delay Period	0x4904	U1	0	255	5	s

Description: AFE Register comparison counter decrement period

13.11.17.3 Compare Period

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	AFER	Compare Period	0x4905	U1	0	255	5	s

Description: AFE Register comparison compare period

13.11.18 AFEC—AFE Communication

13.11.18.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	AFEC	Threshold	0x4906	U1	0	255	100	—

Description: AFE Communication fail trip threshold

13.11.18.2 Delay Period

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	AFEC	Delay Period	0x4907	U1	0	255	5	s

Description: AFE Communication counter decrement period

13.11.19 2LVL—2nd Level OV

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	2LVL	Threshold	0x4908	U1	0	255	5	s

Description: 2nd Level Protector trip detection delay

13.11.20 OPNCELL—Open Cell Connection

13.11.20.1 Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	OPNCELL	Threshold	0x4909	I2	0	32767	5000	mV

Description: Open Cell Tab Connection trip threshold

13.11.20.2 Delay Period

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Permanent Fail	OPNCELL	Delay Period	0x490B	U1	0	255	5	s

Description: Open Cell Tab Connection trip delay

13.12 PF Status

The data in this class is saved at the time of the PF event.

13.12.1 Device Status Data

13.12.1.1 Safety Alert A

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
PF Status	Device Status Data	Safety Alert A	0x4440	H1	0x0	0xFF	0x0	Hex

Description: Accumulated safety flags since PF event

13.12.1.2 Safety Status A

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
PF Status	Device Status Data	Safety Status A	0x4441	H1	0x0	0xFF	0x0	Hex

Description: Accumulated safety flags since PF event

13.12.1.3 Safety Alert B

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
PF Status	Device Status Data	Safety Alert B	0x4442	H1	0x0	0xFF	0x0	Hex

Description: Accumulated safety flags since PF event

13.12.1.4 Safety Status B

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
PF Status	Device Status Data	Safety Status B	0x4443	H1	0x0	0xFF	0x0	Hex

Description: Accumulated safety flags since PF event

13.12.1.5 Safety Alert C

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
PF Status	Device Status Data	Safety Alert C	0x4444	H1	0x0	0xFF	0x0	Hex

Description: Accumulated safety flags since PF event

13.12.1.6 Safety Status C

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
PF Status	Device Status Data	Safety Status C	0x4445	H1	0x0	0xFF	0x0	Hex

Description: Accumulated safety flags since PF event

13.12.1.7 Safety Alert D

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
PF Status	Device Status Data	Safety Alert D	0x4446	H1	0x0	0xFF	0x0	Hex

Description: Accumulated safety flags since PF event

13.12.1.8 Safety Status D

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
PF Status	Device Status Data	Safety Status D	0x4447	H1	0x0	0xFF	0x0	Hex

Description: Accumulated safety flags since PF event

13.12.1.9 PF Alert A

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
PF Status	Device Status Data	PF Alert A	0x4448	H1	0x0	0xFF	0x0	Hex

Description: Accumulated PF flags since PF event

13.12.1.10 PF Status A

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
PF Status	Device Status Data	PF Status A	0x4449	H1	0x0	0xFF	0x0	Hex

Description: Accumulated PF flags since PF event

13.12.1.11 PF Alert B

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
PF Status	Device Status Data	PF Alert B	0x444A	H1	0x0	0xFF	0x0	Hex

Description: Accumulated PF flags since PF event

13.12.1.12 PF Status B

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
PF Status	Device Status Data	PF Status B	0x444B	H1	0x0	0xFF	0x0	Hex

Description: Accumulated PF flags since PF event

13.12.1.13 PF Alert C

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
PF Status	Device Status Data	PF Alert C	0x444C	H1	0x0	0xFF	0x0	Hex

Description: Accumulated PF flags since PF event

13.12.1.14 PF Status C

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
PF Status	Device Status Data	PF Status C	0x444D	H1	0x0	0xFF	0x0	Hex

Description: Accumulated PF flags since PF event

13.12.1.15 PF Alert D

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
PF Status	Device Status Data	PF Alert D	0x444E	H1	0x0	0xFF	0x0	Hex

Description: Accumulated PF flags since PF event

13.12.1.16 PF Status D

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
PF Status	Device Status Data	PF Status D	0x444F	H1	0x0	0xFF	0x0	Hex

Description: Accumulated PF flags since PF event

13.12.1.17 Fuse Flag

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
PF Status	Device Status Data	Fuse Flag	0x4450	H2	0x0	0xFFff	0x0	Hex

Description: Flag set to indicate fuse blow

13.12.1.18 Operation Status A

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
PF Status	Device Status Data	Operation Status A	0x4452	H2	0x0	0xFFff	0x0	Hex

Description: *OperationStatus()* data at the time of the PF event

13.12.1.19 Operation Status B

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
PF Status	Device Status Data	Operation Status B	0x4454	H2	0x0	0xFFff	0x0	Hex

Description: *OperationStatus()* data at the time of the PF event

13.12.1.20 Temp Range

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
PF Status	Device Status Data	Temp Range	0x4456	H1	0x0	0xFF	0x0	Hex

Description: Temperature range status at the time of the PF event. The temperature range information returned by *ChargingStatus()*

13.12.1.21 Charging Status A

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
PF Status	Device Status Data	Charging Status A	0x4457	H1	0x0	0xFF	0x0	Hex

Description: The charging status at the time of the PF event. See Section 12.48 for the bit definitions.

7	6	5	4	3	2	1	0
VCT	MCHG	SU	IN	HV	MV	LV	PV

13.12.1.22 Charging Status B

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
PF Status	Device Status Data	Charging Status B	0x4458	H1	0x0	0xFF	0x0	Hex

Description: The charging status at the time of the PF event. See Section 12.48 for the bit definitions.

7	6	5	4	3	2	1	0
VCT	RSVD	RSVD	RSVD	RSVD	CCC	CVR	CCR

13.12.1.23 Gauging Status

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
PF Status	Device Status Data	Gauging Status	0x4459	H1	0x0	0xFF	0x0	Hex

Description: The gauging status at the time of the PF event.

7	6	5	4	3	2	1	0
CF	DSG	EDV	BAL_EN	TCA	TDA	FC	FD

13.12.1.24 IT Status

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Units
PF Status	Device Status Data	IT Status	0x445A	H2	0x0	0xFFff	0x0	Hex

Description: The Impedance Track status at the time of the PF event. See Section 12.48 for the bit definitions.

15	14	13	12	11	10	9	8
RSVD	RSVD	SLPQ MAX	QEN	VOK	RDIS	RSVD	

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	OCVFR	LDMD	RX	QMAX	VDQ

13.12.2 Device Voltage Data

13.12.2.1 Cell 1 Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	Device Voltage Data	Cell 1 Voltage	0x445C	I2	–32768	32767	0	mV

Description: Cell 1 voltage

13.12.2.2 Cell 2 Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	Device Voltage Data	Cell 2 Voltage	0x445E	I2	–32768	32767	0	mV

Description: Cell 2 voltage

13.12.2.3 Cell 3 Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	Device Voltage Data	Cell 3 Voltage	0x4460	I2	–32768	32767	0	mV

Description: Cell 3 voltage

13.12.2.4 Cell 4 Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	Device Voltage Data	Cell 4 Voltage	0x4462	I2	–32768	32767	0	mV

Description: Cell 4 voltage

13.12.2.5 Battery Direct Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	Device Voltage Data	Battery Direct Voltage	0x4464	I2	–32768	32767	0	mV

Description: Battery voltage

13.12.2.6 Pack Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	Device Voltage Data	Pack Voltage	0x4466	I2	–32768	32767	0	mV

Description: Pack pin voltage

13.12.3 Device Current Data

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	Device Current Data	Current	0x4468	I2	–32768	32767	0	mV

Description: *Current()*

13.12.4 Device Temperature Data

13.12.4.1 Internal Temperature

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	Device Temperature Data	Internal Temperature	0x446A	I2	–32768	32767	0	0.1°K

Description: Internal temperature sensor temperature

13.12.4.2 External 1 Temperature

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	Device Temperature Data	External 1 Temperature	0x446C	I2	–32768	32767	0	0.1°K

Description: External TS1 temperature

13.12.4.3 External 2 Temperature

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	Device Temperature Data	External 2 Temperature	0x446E	I2	–32768	32767	0	0.1°K

Description: External TS2 temperature

13.12.4.4 External 3 Temperature

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	Device Temperature Data	External 3 Temperature	0x4470	I2	–32768	32767	0	0.1°K

Description: External TS3 temperature

13.12.4.5 External 4 Temperature

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	Device Temperature Data	External 4 Temperature	0x4472	I2	–32768	32767	0	0.1°K

Description: External TS4 temperature

13.12.5 Device Gauging Data

13.12.5.1 Cell 1DOD0

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	Device Gauging Data	Cell 1DOD0	0x4474	I2	–32768	32767	0	—

Description: Cell 1 depth of discharge

13.12.5.2 Cell 2 DOD0

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	Device Gauging Data	Cell 2 DOD0	0x4476	I2	–32768	32767	0	—

Description: Cell 2 depth of discharge

13.12.5.3 Cell 3 DOD0

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	Device Gauging Data	Cell 3 DOD0	0x4478	I2	–32768	32767	0	—

Description: Cell 3 depth of discharge

13.12.5.4 Cell 4 DOD0

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	Device Gauging Data	Cell 4 DOD0	0x447A	I2	–32768	32767	0	—

Description: Cell 4 depth of discharge

13.12.5.5 Passed Charge

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	Device Gauging Data	Passed Charge	0x447C	I2	–32768	32767	0	mAh

Description: Passed charge since last QMax update

13.12.6 AFE Regs

13.12.6.1 AFE Interrupt Status

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	AFE Regs	AFE Interrupt Status	0x447E	H1	0x00	0xFF	0x00	Hex

Description: AFE Interrupt Status Register Contents

13.12.6.2 AFE FET Status

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	AFE Regs	AFE FET Status	0x447F	H1	0x00	0xFF	0x00	Hex

Description: AFE FET Status Register Contents

13.12.6.3 AFE RXIN

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	AFE Regs	AFE RXIN	0x4480	H1	0x00	0xFF	0x00	Hex

Description: AFE Rxin Register Contents

13.12.6.4 AFE Latch Status

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	AFE Regs	AFE Latch Status	0x4481	H1	0x00	0xFF	0x00	Hex

Description: AFE Latch Status Register Contents

13.12.6.5 AFE Interrupt Enable

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	AFE Regs	AFE Interrupt Enable	0x4482	H1	0x00	0xFF	0x00	Hex

Description: AFE Interrupt Enable Register Contents

13.12.6.6 AFE FET Control

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	AFE Regs	AFE FET Control	0x4483	H1	0x00	0xFF	0x00	Hex

Description: AFE FET Control Register Contents

13.12.6.7 AFE RXIEN

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	AFE Regs	AFE RXIEN	0x4484	H1	0x00	0xFF	0x00	Hex

Description: AFE RXIEN Register Contents

13.12.6.8 AFE RLOUT

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	AFE Regs	AFE RLOUT	0x4485	H1	0x00	0xFF	0x00	Hex

Description: AFE RLOUT Register Contents

13.12.6.9 AFE RHOUT

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	AFE Regs	AFE RHOUT	0x4486	H1	0x00	0xFF	0x00	Hex

Description: AFE RHOUT Register Contents

13.12.6.10 AFE RHINT

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	AFE Regs	AFE RHINT	0x4487	H1	0x00	0xFF	0x00	Hex

Description: AFE RHINT Register Contents

13.12.6.11 AFE Cell Balance

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	AFE Regs	AFE Cell Balance	0x4488	H1	0x00	0xFF	0x00	Hex

Description: AFE Cell Balance Register Contents

13.12.6.12 AFE AD/CC Control

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	AFE Regs	AFE AD/CC Control	0x4489	H1	0x00	0xFF	0x00	Hex

Description: AFE AD/CC Control Register Contents

13.12.6.13 AFE ADC Mux

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	AFE Regs	AFE ADC Mux	0x448A	H1	0x00	0xFF	0x00	Hex

Description: AFE ADC Mux Register Contents

13.12.6.14 AFE LED Output

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	AFE Regs	AFE LED Output	0x448B	H1	0x00	0xFF	0x00	Hex

Description: AFE LED Output Register Contents

13.12.6.15 AFE State Control

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	AFE Regs	AFE State Control	0x448C	H1	0x00	0xFF	0x00	Hex

Description: AFE State Control Register Contents

13.12.6.16 AFE LED/Wake Control

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	AFE Regs	AFE LED/Wake Control	0x448D	H1	0x00	0xFF	0x00	Hex

Description: AFE LED/Wake Control Register Contents

13.12.6.17 AFE Protection Control

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	AFE Regs	AFE Protection Control	0x448E	H1	0x00	0xFF	0x00	Hex

Description: AFE Protection Control Register Contents

13.12.6.18 AFE OCD

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	AFE Regs	AFE OCD	0x448F	H1	0x00	0xFF	0x00	Hex

Description: AFE OCD Register Contents

13.12.6.19 AFE SCC

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	AFE Regs	AFE SCC	0x4490	H1	0x00	0xFF	0x00	Hex

Description: AFE SCC Register Contents

13.12.6.20 AFE SCD1

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	AFE Regs	AFE SCD1	0x4491	H1	0x00	0xFF	0x00	Hex

Description: AFE SCD1 Register Contents

13.12.6.21 AFE SCD2

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
PF Status	AFE Regs	AFE SCD2	0x4492	H1	0x00	0xFF	0x00	Hex

Description: AFE SCD2 Register Contents

13.13 Black Box

13.13.1 Safety Status

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit	Description
Black Box	Safety Status	1st Status Status A	0x4400	H1	0x0	0xFF	0x0	Hex	*SafetyStatus()* data
Black Box	Safety Status	1st Status Status B	0x4401	H1	0x0	0xFF	0x0	Hex	*SafetyStatus()* data
Black Box	Safety Status	1st Safety Status C	0x4402	H1	0x0	0xFF	0x0	Hex	*SafetyStatus()* data
Black Box	Safety Status	1st Safety Status D	0x4403	H1	0x0	0xFF	0x0	Hex	*SafetyStatus()* data
Black Box	Safety Status	1st Time to Next Event	0x4404	U1	0	255	0	s	Time from 1st event to 2nd event
Black Box	Safety Status	2nd Status Status A	0x4405	H1	0x0	0xFF	0x0	Hex	*SafetyStatus()* data
Black Box	Safety Status	2nd Status Status B	0x4406	H1	0x0	0xFF	0x0	Hex	*SafetyStatus()* data
Black Box	Safety Status	2nd Safety Status C	0x4407	H1	0x0	0xFF	0x0	Hex	*SafetyStatus()* data
Black Box	Safety Status	2nd Safety Status D	0x4408	H1	0x0	0xFF	0x0	Hex	*SafetyStatus()* data
Black Box	Safety Status	2nd Time to Next Event	0x4409	U1	0	255	0	s	Time from 2nd event to 3rd event
Black Box	Safety Status	3rd Status Status A	0x440A	H1	0x0	0xFF	0x0	Hex	*SafetyStatus()* data
Black Box	Safety Status	3rd Status Status B	0x440B	H1	0x0	0xFF	0x0	Hex	*SafetyStatus()* data
Black Box	Safety Status	3rd Safety Status C	0x440C	H1	0x0	0xFF	0x0	Hex	*SafetyStatus()* data
Black Box	Safety Status	3rd Safety Status D	0x440D	H1	0x0	0xFF	0x0	Hex	*SafetyStatus()* data
Black Box	Safety Status	3rd Time to Next Event	0x440E	U1	0	255	0	s	Time since 3rd event

13.13.2 PF Status

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit	Description
Black Box	PF Status	1st PF Status A	0x440F	H1	0x0	0xFF	0x0	Hex	*PFStatus()* data
Black Box	PF Status	1st PF Status B	0x4410	H1	0x0	0xFF	0x0	Hex	*PFStatus()* data
Black Box	PF Status	1st PF Status C	0x4411	H1	0x0	0xFF	0x0	Hex	*PFStatus()* data
Black Box	PF Status	1st PF Status D	0x4412	H1	0x0	0xFF	0x0	Hex	*PFStatus()* data

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit	Description
Black Box	PF Status	1st Time to Next Event	0x4413	U1	0	255	0	s	Time from 1st event to 2nd event
Black Box	PF Status	2nd PF Status A	0x4414	H1	0x0	0xFF	0x0	Hex	*PFStatus()* data
Black Box	PF Status	2nd PF Status B	0x4415	H1	0x0	0xFF	0x0	Hex	*PFStatus()* data
Black Box	PF Status	2nd PF Status C	0x4416	H1	0x0	0xFF	0x0	Hex	*PFStatus()* data
Black Box	PF Status	2nd PF Status D	0x4417	H1	0x0	0xFF	0x0	Hex	*PFStatus()* data
Black Box	PF Status	2nd Time to Next Event	0x4418	U1	0	255	0	s	Time from 2nd event to 3rd event
Black Box	PF Status	3rd PF Status A	0x4419	H1	0x0	0xFF	0x0	Hex	*PFStatus()* data
Black Box	PF Status	3rd PF Status B	0x441A	H1	0x0	0xFF	0x0	Hex	*PFStatus()* data
Black Box	PF Status	3rd PF Status C	0x441B	H1	0x0	0xFF	0x0	Hex	*PFStatus()* data
Black Box	PF Status	3rd PF Status D	0x441C	H1	0x0	0xFF	0x0	Hex	*PFStatus()* data
Black Box	PF Status	3rd Time to Next Event	0x441D	U1	0	255	0	s	Time since 3rd event

13.14 Gas Gauging

13.14.1 Current Thresholds

13.14.1.1 Dsg Current Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	Current Thresholds	Dsg Current Threshold	0x495B	I2	–32768	32767	100	mA

Description: DISCHARGE mode *Current()* threshold

13.14.1.2 Chg Current Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	Current Thresholds	Chg Current Threshold	0x495D	I2	–32768	32767	50	mA

Description: CHARGE mode *Current()* threshold

13.14.1.3 Quit Current

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	Current Thresholds	Quit Current	0x495F	I2	0	32767	10	mA

Description: |*Current()*| threshold to enter rest mode

13.14.1.4 Dsg Relax Time

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	Current Thresholds	Dsg Relax Time	0x4961	U1	0	255	1	mA

Description: Discharge to relax timeout. When discharge is stopped, the device will exit the DISCHARGE mode after this time is passed.

13.14.1.5 Chg Relax Time

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	Current Thresholds	Chg Relax Time	0x4962	U1	0	255	60	mA

Description: Charge to relax timeout. When charging is stopped, the device will exit the CHARGE mode after this time is passed.

13.14.2 Design

13.14.2.1 Design Capacity mAh

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	Design	Design Capacity mAh	0x4806	I2	0	32767	4400	mAh

Description: Design Capacity in mAh. This is reported by *DesignCapacity()* if ***[CAPM]*** = 0.

13.14.2.2 Design Capacity in cWh

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	Design	Design Capacity cWh	0x4808	I2	0	32767	6336	cWh

Description: Design Capacity in cWh. This is reported by *DesignCapacity()* if ***[CAPM]*** = 1.

13.14.2.3 Design Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	Design	Design Voltage	0x480A	I2	0	32767	14400	mV

Description: Design Voltage. This is reported by *DesignVoltage()*.

13.14.3 Cycle

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	Cycle	Cycle Count Percentage	0x480C	U1	0	100	90	%

Description: This is a threshold to increment the ***Cycle Count*** if the accumulated discharge is more than this set percentage of *FullChargeCapacity()* (if ***[CCT]*** = 1) or *DesignCapacity()* (if ***[CCT]*** = 0). Note that a minimum of 10% of *DesignCapacity()* change of the accumulated discharge is required for cycle count increment. This is to prevent an erroneous cycle count increment due to extremely low *FullChargeCapacity()*.

13.14.4 FD

13.14.4.1 Set Voltage Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	FD	Set Voltage Threshold	0x4811	I2	0	5000	3000	mV

Description: *GaugingStatus()[FD]* and *BatteryStatus()[FD]* cell voltage set threshold

13.14.4.2 Clear Voltage Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	FD	Clear Voltage Threshold	0x4813	I2	0	5000	3100	mV

Description: *GaugingStatus()[FD]* and *BatteryStatus()[FD]* cell voltage clear threshold

13.14.4.3 Set RSOC % Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	FD	Set RSOC % Threshold	0x4815	U1	0	100	0	%

Description: *GaugingStatus()[FD]* and *BatteryStatus()[FD] RelativeStateOfCharge()* set threshold

13.14.4.4 Clear RSOC % Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	FD	Clear RSOC % Threshold	0x4816	U1	0	100	5	%

Description: *GaugingStatus()[FD]* and *BatteryStatus()[FD] RelativeStateOfCharge()* clear threshold

13.14.5 FC

13.14.5.1 Set Voltage Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	FC	Set Voltage Threshold	0x4817	I2	0	5000	4200	mV

Description: *GaugingStatus()[FC]* and *BatteryStatus()[FC]* cell voltage set threshold

13.14.5.2 Clear Voltage Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	FC	Clear Voltage Threshold	0x4819	I2	0	5000	4100	mV

Description: *GaugingStatus()[FC]* and *BatteryStatus()[FC]* cell voltage clear threshold

13.14.5.3 Set RSOC % Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	FC	Set RSOC % Threshold	0x481B	U1	0	100	100	%

Description: *GaugingStatus()[FC]* and *BatteryStatus()[FC] RelativeStateOfCharge()* set threshold

13.14.5.4 Clear RSOC % Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	FC	Clear RSOC % Threshold	0x481C	U1	0	100	95	%

Description: *GaugingStatus()[FC]* and *BatteryStatus()[FC] RelativeStateOfCharge()* clear threshold

13.14.6 TD

GaugingStatus()[TD] is used to set *BatteryStatus()[TDA]* when in DISCHARGE mode.

13.14.6.1 Set Voltage Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	TD	Set Voltage Threshold	0x481D	I2	0	5000	3200	mV

Description: *GaugingStatus()[TD]* cell voltage set threshold

13.14.6.2 Clear Voltage Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	TD	Clear Voltage Threshold	0x481F	I2	0	5000	3300	mV

Description: *GaugingStatus()[TD]* cell voltage clear threshold

13.14.6.3 Set RSOC % Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	TD	Set RSOC % Threshold	0x4821	U1	0	100	6	%

Description: *GaugingStatus()[TD] RelativeStateOfCharge()* set threshold

13.14.6.4 Clear RSOC % Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	TD	Clear RSOC % Threshold	0x4822	U1	0	100	8	%

Description: *GaugingStatus()[TD] RelativeStateOfCharge()* clear threshold

13.14.7 TC

GaugingStatus()[TC] is used to set *BatteryStatus()[TCA]* when in CHARGE mode

13.14.7.1 Set Voltage Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	TC	Set Voltage Threshold	0x4823	I2	0	5000	4200	mV

Description: *GaugingStatus()[TC]* cell voltage set threshold

13.14.7.2 Clear Voltage Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	TC	Clear Voltage Threshold	0x4825	I2	0	5000	4100	mV

Description: *GaugingStatus()[TC]* cell voltage clear threshold

13.14.7.3 Set RSOC % Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	TC	Set RSOC % Threshold	0x4827	U1	0	100	100	%

Description: *GaugingStatus()[TC] RelativeStateOfCharge()* set threshold

13.14.7.4 Clear RSOC % Threshold

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	TC	Clear RSOC % Threshold	0x4828	U1	0	100	95	%

Description: *GaugingStatus()[TC] RelativeStateOfCharge()* clear threshold

13.14.8 State

13.14.8.1 QMax

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit	Description
Gas Gauging	State	QMax Cell 1	0x4304	I2	0	32767	4400	mAh	QMax Cell 1
Gas Gauging	State	QMax Cell 2	0x4306	I2	0	32767	4400	mAh	QMax Cell 2
Gas Gauging	State	QMax Cell 3	0x4308	I2	0	32767	4400	mAh	QMax Cell 3
Gas Gauging	State	QMax Cell 4	0x430A	I2	0	32767	4400	mAh	QMax Cell 4
Gas Gauging	State	QMax Pack	0x430C	I2	0	32767	4400	mAh	QMax of the whole stack
Gas Gauging	State	Qmax Cycle Count	0x430E	U2	0	65535	0	—	The *CycleCount()* when Qmax updated

13.14.8.2 Update Status

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	State	Update Status	0x4310	H1	0x00	0x0E	0x00	—

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	RSVD	QMax	Enable	Update1	Update0

RSVD (Bits 7–4): Reserved. Do not use.

QMax update in the field (Bit 3)

1 = Updated

0 = Not updated

Enable (Bit 2): Impedance Track gauging and lifetime updating enable

1 = Enabled

0 = Disabled

Update1, Update0 (Bits 1–0): Update Status

0,0 = Impedance Track gauging and lifetime updating is disabled.
0,1 = QMax updated
1,0 = QMax and Ra table have been updated.

13.14.8.3 Cell 1–4 Chg Voltage at EoC

13.14.8.3.1 Cell 1Chg Voltage at EoC

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	State	Cell 1Chg Voltage at EoC	0x4311	I2	0	32767	4200	mV

Description: Cell 1 voltage value at end of charge

13.14.8.3.2 Cell 2 Chg Voltage at EoC

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	State	Cell 2 Chg Voltage at EoC	0x4313	I2	0	32767	4200	mV

Description: Cell 2 voltage value at end of charge

13.14.8.3.3 Cell 3 Chg Voltage at EoC

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	State	Cell 3 Chg Voltage at EoC	0x4315	I2	0	32767	4200	mV

Description: Cell 3 voltage value at end of charge

13.14.8.3.4 Cell 4 Chg Voltage at EoC

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	State	Cell 4 Chg Voltage at EoC	0x4317	I2	0	32767	4200	mV

Description: Cell 4 voltage value at end of charge

13.14.8.4 Current at EoC

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	State	Current at EoC	0x4319	I2	0	32767	250	mA

Description: Current at end of charge

13.14.8.5 Average Last Run

13.14.8.5.1 Avg I Last Run

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	State	Avg I Last Run	0x431B	I2	–32768	32767	–2000	mA

Description: Average current last discharge cycle

13.14.8.5.2 Avg P Last Run

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	State	Avg P Last Run	0x431D	I2	–32768	32767	–3022	10 mW

Description: Average power last discharge cycle

13.14.8.6 Delta Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	State	Delta Voltage	0x431F	I2	–32768	32767	0	mV

Description: *Voltage()* delta between normal and short load spikes to optimize run time calculation

13.14.8.7 Temp

13.14.8.7.1 Temp k

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	State	Temp k	0x4321	I2	0	32767	100	0.1°C/ 2560 mW

Description: Initial Thermal model temperature factor

13.14.8.7.2 Temp a

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	State	Temp a	0x4323	I2	0	32767	1000	—

Description: Initial Thermal model temperature

13.14.8.8 Max Avg Last Run

13.14.8.8.1 Max Avg I Last Run

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	State	Max Avg I Last Run	0x4325	I2	–32768	32767	–2000	mA

Description: Max current last discharge cycle

13.14.8.8.2 Max Avg P Last Run

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	State	Max Avg P Last Run	0x4327	I2	–32768	32767	–3022	cW

Description: Max power last discharge cycle

13.14.9 Cycle Count

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit	Description
Gas Gauging	State	Cycle Count	0x4340	U2	0	65535	0	—	Cycle Count

Description: Value reported by *CycleCount()*. Updated by the gauge automatically based on ***Cycle Count Percentage***.

13.14.10 IT Config

13.14.10.1 Load Select

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	IT Cfg	Load Select	0x4300	U1	0	7	7	—

Description: Defines Load compensation mode used by gauging algorithm

13.14.10.2 Load Mode

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	IT Cfg	Load Mode	0x4302	U1	0	1	0	—

Description: Defines unit used by gauging algorithm:

0 = Constant Current
1 = Constant Power

13.14.10.3 Design Resistance

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	IT Cfg	Design Resistance	0x482E	I2	1	32767	42	mΩ

Description: Averaged cell resistance at ***Reference Grid*** point. Automatically updated when Update Status is set to 0x6 by the gauge. To automatically update again, set Update Status to 0x4 or manually set when Update Status is set to 0x6.

13.14.10.4 User Rate-mA

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	IT Cfg	User Rate-mA	0x4830	I2	–9000	0	0	mA

Description: Discharge rate used for capacity calculation selected by ***Load Select*** = 6

13.14.10.5 User Rate-cW

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	IT Cfg	User Rate-cW	0x4832	I2	–32768	0	0	cW

Description: Discharge rate used for capacity calculation selected by ***Load Select*** = 6

13.14.10.6 Reserve Cap-mAh

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	IT Cfg	Reserve Cap-mAh	0x4834	I2	0	9000	0	mAh

Description: Capacity reserved available when the gauging algorithm reports 0% *RelativeStateOfCharge()*

13.14.10.7 Reserve Cap-cWh

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	IT Cfg	Reserve Cap-cWh	0x4836	I2	0	32000	0	cWh

Description: Capacity reserved available when the gauging algorithm reports 0% *RelativeStateOfCharge()*

13.14.10.8 Ra Filter

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	IT Cfg	Ra Filter	0x474E	U2	0	999	500	%

Description: Filter value used in Ra Updates and specifies what percentage or Ra update is from the new value (100% setting) vs. old value (setting). The recommended setting is 80% if the ***[RSOC_CONV]*** feature is enabled. Otherwise, the setting should be 50% as default.

13.14.10.9 Ra Max Delta

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	IT Cfg	Ra Max Delta	0x4751	U1	0	255	15	%

Description: Maximum value of allowed Ra change

13.14.10.10 Reference Grid

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	IT Cfg	Reference Grid	0x4753	U1	0	14	4	—

Description: ***Reference Grid*** point used by Design Resistance. The default setting should be used if the ***[RSOC_CONV]*** feature is enabled. Otherwise, grid point 11 should be used to ensure resistance updates fast enough at the grid where discharge termination occurs.

13.14.10.11 Resistance Parameter Filter

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	IT Cfg	Resistance Parameter Filter	0x4754	U2	1	65535	65142	—

Description: This is one of the filters used for resistance update. Reducing this filter setting can improve low temperature performance at high rates. The default setting is 41 s. It is recommended to keep this filter within the range of 4 s (that is, DF setting = 61680) up to the default 41 s (that is, DF setting = 65142). Examining the Term Voltage Delta setting and Fast Scale Start SOC should be done prior to twisting 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 = [0.25 / (1 – (DF_Value / 65536))] – 0.25.

13.14.10.12 Near EDV Ra Param Filter

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	IT Cfg	Near EDV Ra Param Filter	0x4756	U2	1	65535	59220	—

Description: Ra filter used in the fast scaling region if [FF_NEAR_EDV] = 1. Default value should be used.

13.14.10.13 Qmax Delta

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	IT Cfg	Qmax Delta	0x477C	U1	3	100	5	%

Description: 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.

13.14.10.14 Qmax Upper Bound

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	IT Cfg	Qmax Upper Bound	0x477D	U1	100	255	130	%

Description: 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.

13.14.10.15 Term Voltage

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	IT Cfg	Term Voltage	0x477E	I2	0	32767	9000	mV

Description: Min stack voltage to be used for capacity calculation

13.14.10.16 Term Voltage Delta

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	IT Cfg	Term Voltage Delta	0x4780	I2	0	32767	300	mV

Description: Controls when the ***[RSOC_CONV]*** feature becomes active. The recommended setting is 3.3 – ***Term Voltage***/Number Cells.

The default setting is 300 mV, which is assuming a typical 3-V termination voltage per cell. If a different termination voltage is used, this parameter should be adjusted accordingly.

13.14.10.17 Term Min Cell V

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	IT Cfg	Term Min Cell V	0x4782	I2	0	32767	2800	mV

Description: Minimum cell termination voltage when used when ***[CELL_TERM]*** = 1. This is intended to allow the IT algorithm to reach 0% before CUV is triggered; therefore, this value should be set at or above ***CUV:Threshold***.

13.14.10.18 Voltage Consistency Delta

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	IT Cfg	Voltage Consistency Delta	0x4787	I2	0	32767	300	mV

Description: Use in voltage consistency check. See ***[VOLTAGE_CONSIST]*** in the Section 6.6 for details.

13.14.10.19 Fast Scale Start SOC

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	IT Cfg	Fast Scale Start SOC	0x479A	U1	0	100	10	%

Description: Control the start of convergence when ***[RSOC_CONV]*** = 1 based on RSOC %. Raising this setting can improve RSOC drop at the end of discharge. However, the RSOC % chosen for this setting must keep after the sharp drop of the discharge curve (the keen of the discharge curve).

13.14.10.20 Pack Resistance

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	IT Cfg	Pack Resistance	0x4300	I2	0	32767	30	mΩ

Description: Pack side resistance value accessed using *TURBO_PACK_R()*

13.14.10.21 System Resistance

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	IT Cfg	System Resistance	0x4302	I2	0	32767	0	mΩ

Description: System side resistance value accessed using *TURBO_SYS_R()*

13.14.11 Smoothing

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	Smoothing	Smooth Relax Time	0x4838	I2	1	32767	1000	s

Description: If ***[RELAX_SMOOTH_OK]*** = 1, the delta Remaining Capacity and Full Charge Capacity is smoothed over this set period of time. It is recommended to use the default setting.

13.14.12 Condition Flag

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	Condition Flag	Max Error Limit	0x483A	U1	0	100	100	%

Description: Max Error Limit Percentage

13.14.13 Max Error

13.14.13.1 Time Cycle Equivalent

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	Max Error	Time Cycle Equivalent	0x483E	U1	1	255	12	2 h

Description: After valid QMax update, each passed time period of ***Time Cycle Equivalent*** will increment of *MaxError()* by ***Cycle Delta***.

13.14.13.2 Cycle Delta

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	Max Error	Cycle Delta	0x483F	U1	0	255	5	0.01%

Description: Each increment of *CycleCount()* after valid QMax update will increment of *MaxError()* by ***Cycle Delta***. Setting this parameter to 0 disables the *MaxError()* increment by time or cycle increment.

13.14.14 SoH

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	SoH	SoH Load Rate	0x47A3	U1	1	255	50	0.1 h rate

Description: Current rate used in SoH simulation specified in hour-rate (that is, current = C/***SoH Load Rate***)

13.14.15 TURBO Cfg

13.14.15.1 Min Turbo Power

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	Turbo Cfg	Min Turbo Power	0x44C0	I2	–32768	32767	–1000	cW

Description: This is the minimal Turbo Power for the TURBO BOOST mode used by the system toward the end of discharge. This value is used when ***[TDELATV]*** = 1 to calculate the ***Delta Voltage***. Using the lowest turbo level instead of the regular learned ***Delta Voltage*** for IT simulation can avoid unnecessary SOC jumps when the system is switching from higher to lower turbo mode levels, reducing its power approaching the end of discharge.

13.14.15.2 Max Current C Rate

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	Turbo Cfg	Max Current C Rate	0x44C2	I1	–127	00	-4	C

Description: This value specifies the maximal discharge current. If *TURBO_CURRENT()* > ***Max Current C Rate***, the *TURBO_CURRENT()* will be capped to this setting and the *TURBO_POWER()* will be adjusted accordingly.

13.14.15.3 High Frequency Resistance

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	Turbo Cfg	High Frequency Resistance	0x44C3	I2	0	32767	20	mΩ

Description: This is the high frequency resistance related the specific cell chemistry and pack configuration.

13.14.15.4 Reserve Energy %

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
Gas Gauging	Turbo Cfg	Reserve Energy %	0x44C9	I1	0	100	2	%

Description: Remaining energy at present average discharge rate (as defined in ***Load Select***) until the maximal peak power will reach the value reported by *MAX_POWER()*.

13.15 RA Table

13.15.1 R_a0

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
RA Table	R_a0	Cell 0 R_A Flag	0x4100	H2	0x0000	0xFFFF	0xFF55	2^{-10} Ω

Description:
This value indicates the validity of the cell impedance table for Cell1. It is recommended not to change this value manually.

High Byte		Low Byte	
0x00	Cell impedance and QMax updated	0x00	Table not used and QMax updated
0x05	RELAX mode and QMax update in progress	0x55	Table being used
0x55	DISCHARGE mode and cell impedance updated	0xFF	Table never used, no QMax or cell impedance update
0xFF	Cell impedance never updated		

The gauge stores and updates the impedance profile for Cell1 as shown in the following table.

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit	Description
RA Table	R_a0	Cell 0 R_A 0	0x4102	I2	0	32767	38	2^{-10} Ω	Cell 0 resistance at grid point 0
RA Table	R_a0	Cell 0 R_A 1	0x4104	I2	0	32767	41	2^{-10} Ω	Cell 0 resistance at grid point 1
RA Table	R_a0	Cell 0 R_A 2	0x4106	I2	0	32767	43	2^{-10} Ω	Cell 0 resistance at grid point 2
RA Table	R_a0	Cell 0 R_A 3	0x4108	I2	0	32767	44	2^{-10} Ω	Cell 0 resistance at grid point 3
RA Table	R_a0	Cell 0 R_A 4	0x410A	I2	0	32767	42	2^{-10} Ω	Cell 0 resistance at grid point 4
RA Table	R_a0	Cell 0 R_A 5	0x410C	I2	0	32767	42	2^{-10} Ω	Cell 0 resistance at grid point 5
RA Table	R_a0	Cell 0 R_A 6	0x410E	I2	0	32767	45	2^{-10} Ω	Cell 0 resistance at grid point 6
RA Table	R_a0	Cell 0 R_A 7	0x4110	I2	0	32767	48	2^{-10} Ω	Cell 0 resistance at grid point 7
RA Table	R_a0	Cell 0 R_A 8	0x4112	I2	0	32767	49	2^{-10} Ω	Cell 0 resistance at grid point 8
RA Table	R_a0	Cell 0 R_A 9	0x4114	I2	0	32767	52	2^{-10} Ω	Cell 0 resistance at grid point 9
RA Table	R_a0	Cell 0 R_A 10	0x4116	I2	0	32767	56	2^{-10} Ω	Cell 0 resistance at grid point 10
RA Table	R_a0	Cell 0 R_A 11	0x4118	I2	0	32767	64	2^{-10} Ω	Cell 0 resistance at grid point 11
RA Table	R_a0	Cell 0 R_A 12	0x411A	I2	0	32767	74	2^{-10} Ω	Cell 0 resistance at grid point 12
RA Table	R_a0	Cell 0 R_A 13	0x411C	I2	0	32767	128	2^{-10} Ω	Cell 0 resistance at grid point 13
RA Table	R_a0	Cell 0 R_A 14	0x411E	I2	0	32767	378	2^{-10} Ω	Cell 0 resistance at grid point 14

13.15.2 R_a1

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
RA Table	R_a1	Cell 1 R_A Flag	0x4140	H2	0x0000	0xFFFF	0xFF55	—

Description:
This value indicates the validity of the cell impedance table for Cell2. It is recommended not to change this value manually.

High Byte		Low Byte	
0x00	Cell impedance and QMax updated	0x00	Table not used and QMax updated
0x05	RELAX mode and QMax update in progress	0x55	Table being used
0x55	DISCHARGE mode and cell impedance updated	0xFF	Table never used, no QMax or cell impedance update
0xFF	Cell impedance never updated		

The gauge stores and updates the impedance profile for Cell2, as shown in the following table.

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit	Description
RA Table	R_a1	Cell 1 R_A 0	0x4142	I2	–32768	32768	38	2^{-10} Ω	Cell 1 resistance at grid point 0
RA Table	R_a1	Cell 1 R_A 1	0x4144	I2	–32768	32768	41	2^{-10} Ω	Cell 1 resistance at grid point 1
RA Table	R_a1	Cell 1 R_A 2	0x4146	I2	–32768	32768	43	2^{-10} Ω	Cell 1 resistance at grid point 2
RA Table	R_a1	Cell 1 R_A 3	0x4148	I2	–32768	32768	44	2^{-10} Ω	Cell 1 resistance at grid point 3
RA Table	R_a1	Cell 1 R_A 4	0x414A	I2	–32768	32768	42	2^{-10} Ω	Cell 1 resistance at grid point 4
RA Table	R_a1	Cell 1 R_A 5	0x414C	I2	–32768	32768	42	2^{-10} Ω	Cell 1 resistance at grid point 5
RA Table	R_a1	Cell 1 R_A 6	0x414E	I2	–32768	32768	45	2^{-10} Ω	Cell 1 resistance at grid point 6
RA Table	R_a1	Cell 1 R_A 7	0x4150	I2	–32768	32768	48	2^{-10} Ω	Cell 1 resistance at grid point 7
RA Table	R_a1	Cell 1 R_A 8	0x4152	I2	–32768	32768	49	2^{-10} Ω	Cell 1 resistance at grid point 8
RA Table	R_a1	Cell 1 R_A 9	0x4154	I2	–32768	32768	52	2^{-10} Ω	Cell 1 resistance at grid point 9
RA Table	R_a1	Cell 1 R_A 10	0x4156	I2	–32768	32768	56	2^{-10} Ω	Cell 1 resistance at grid point 10
RA Table	R_a1	Cell 1 R_A 11	0x4158	I2	–32768	32768	64	2^{-10} Ω	Cell 1 resistance at grid point 11
RA Table	R_a1	Cell 1 R_A 12	0x415A	I2	–32768	32768	74	2^{-10} Ω	Cell 1 resistance at grid point 12
RA Table	R_a1	Cell 1 R_A 13	0x415C	I2	–32768	32768	128	2^{-10} Ω	Cell 1 resistance at grid point 13
RA Table	R_a1	Cell 1 R_A 14	0x415E	I2	–32768	32768	378	2^{-10} Ω	Cell 1 resistance at grid point 14

13.15.3 R_a2

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
RA Table	R_a2	Cell 2 R_A Flag	0x4180	H2	0x0000	0xFFFF	0xFF55	—

Description:
This value indicates the validity of the cell impedance table for Cell3. It is recommended not to change this value manually.

High Byte		Low Byte	
0x00	Cell impedance and QMax updated	0x00	Table not used and QMax updated
0x05	RELAX mode and QMax update in progress	0x55	Table being used
0x55	DISCHARGE mode and cell impedance updated	0xFF	Table never used, no QMax or cell impedance update
0xFF	Cell impedance never updated		

The gauge stores and updates the impedance profile for Cell3 as shown in the following table.

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit	Description
RA Table	R_a2	Cell 2 R_A 0	0x4182	I2	–32768	32768	38	2^{-10} Ω	Cell 2 resistance at grid point 0
RA Table	R_a2	Cell 2 R_A 1	0x4184	I2	–32768	32768	41	2^{-10} Ω	Cell 2 resistance at grid point 1
RA Table	R_a2	Cell 2 R_A 2	0x4186	I2	–32768	32768	43	2^{-10} Ω	Cell 2 resistance at grid point 2
RA Table	R_a2	Cell 2 R_A 3	0x4188	I2	–32768	32768	44	2^{-10} Ω	Cell 2 resistance at grid point 3
RA Table	R_a2	Cell 2 R_A 4	0x418A	I2	–32768	32768	42	2^{-10} Ω	Cell 2 resistance at grid point 4
RA Table	R_a2	Cell 2 R_A 5	0x418C	I2	–32768	32768	42	2^{-10} Ω	Cell 2 resistance at grid point 5
RA Table	R_a2	Cell 2 R_A 6	0x418E	I2	–32768	32768	45	2^{-10} Ω	Cell 2 resistance at grid point 6
RA Table	R_a2	Cell 2 R_A 7	0x4190	I2	–32768	32768	48	2^{-10} Ω	Cell 2 resistance at grid point 7
RA Table	R_a2	Cell 2 R_A 8	0x4192	I2	–32768	32768	49	2^{-10} Ω	Cell 2 resistance at grid point 8
RA Table	R_a2	Cell 2 R_A 9	0x4194	I2	–32768	32768	52	2^{-10} Ω	Cell 2 resistance at grid point 9
RA Table	R_a2	Cell 2 R_A 10	0x4196	I2	–32768	32768	56	2^{-10} Ω	Cell 2 resistance at grid point 10
RA Table	R_a2	Cell 2 R_A 11	0x4198	I2	–32768	32768	64	2^{-10} Ω	Cell 2 resistance at grid point 11
RA Table	R_a2	Cell 2 R_A 12	0x419A	I2	–32768	32768	74	2^{-10} Ω	Cell 2 resistance at grid point 12
RA Table	R_a2	Cell 2 R_A 13	0x419C	I2	–32768	32768	128	2^{-10} Ω	Cell 2 resistance at grid point 13
RA Table	R_a2	Cell 2 R_A 14	0x419E	I2	–32768	32768	378	2^{-10} Ω	Cell 2 resistance at grid point 14

13.15.4 R_a3

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
RA Table	R_a3	Cell 3 R_A Flag	0x41C0	H2	0x0000	0xFFFF	0xFF55	—

Description:
This value indicates the validity of the cell impedance table for Cell4. It is recommended not to change this value manually.

High Byte		Low Byte	
0x00	Cell impedance and QMax updated	0x00	Table not used and QMax updated
0x05	RELAX mode and QMax update in progress	0x55	Table being used
0x55	DISCHARGE mode and cell impedance updated	0xFF	Table never used, no QMax or cell impedance update
0xFF	Cell impedance never updated		

The gauge stores and updates the impedance profile for Cell4 as shown in the following table.

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit	Description
RA Table	R_a3	Cell 3 R_A 0	0x41C2	I2	–32768	32768	38	2^{-10} Ω	Cell 3 resistance at grid point 0
RA Table	R_a3	Cell 3 R_A 1	0x41C4	I2	–32768	32768	41	2^{-10} Ω	Cell 3 resistance at grid point 1
RA Table	R_a3	Cell 3 R_A 2	0x41C6	I2	–32768	32768	43	2^{-10} Ω	Cell 3 resistance at grid point 2
RA Table	R_a3	Cell 3 R_A 3	0x41C8	I2	–32768	32768	44	2^{-10} Ω	Cell 3 resistance at grid point 3
RA Table	R_a3	Cell 3 R_A 4	0x41CA	I2	–32768	32768	42	2^{-10} Ω	Cell 3 resistance at grid point 4
RA Table	R_a3	Cell 3 R_A 5	0x41CC	I2	–32768	32768	42	2^{-10} Ω	Cell 3 resistance at grid point 5
RA Table	R_a3	Cell 3 R_A 6	0x41CE	I2	–32768	32768	45	2^{-10} Ω	Cell 3 resistance at grid point 6
RA Table	R_a3	Cell 3 R_A 7	0x41D0	I2	–32768	32768	48	2^{-10} Ω	Cell 3 resistance at grid point 7
RA Table	R_a3	Cell 3 R_A 8	0x41D2	I2	–32768	32768	49	2^{-10} Ω	Cell 3 resistance at grid point 8
RA Table	R_a3	Cell 3 R_A 9	0x41D4	I2	–32768	32768	52	2^{-10} Ω	Cell 3 resistance at grid point 9

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit	Description
RA Table	R_a3	Cell 3 R_A 10	0x41D6	I2	–32768	32768	56	2^{-10} Ω	Cell 3 resistance at grid point 10
RA Table	R_a3	Cell 3 R_A 11	0x41D8	I2	–32768	32768	64	2^{-10} Ω	Cell 3 resistance at grid point 11
RA Table	R_a3	Cell 3 R_A 12	0x41DA	I2	–32768	32768	74	2^{-10} Ω	Cell 3 resistance at grid point 12
RA Table	R_a3	Cell 3 R_A 13	0x41DC	I2	–32768	32768	128	2^{-10} Ω	Cell 3 resistance at grid point 13
RA Table	R_a3	Cell 3 R_A 14	0x41DE	I2	–32768	32768	378	2^{-10} Ω	Cell 3 resistance at grid point 14

13.15.5 R_a0x

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
RA Table	R_a0x	xCell 0 R_A Flag	0x4200	H2	0x0000	0xFFFF	0xFFFF	—

Description:
This value indicates the validity of the cell impedance table for Cell1. It is recommended not to change this value manually.

High Byte		Low Byte	
0x00	Cell impedance and QMax updated	0x00	Table not used and QMax updated
0x05	RELAX mode and QMax update in progress	0x55	Table being used
0x55	DISCHARGE mode and cell impedance updated	0xFF	Table never used, no QMax or cell impedance update
0xFF	Cell impedance never updated		

The gauge stores and updates the impedance profile for Cell1 as shown in the following table.

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit	Description
RA Table	R_a0x	xCell 0 R_A 0	0x4202	I2	–32768	32768	38	2^{-10} Ω	Cell 0 resistance at grid point 0
RA Table	R_a0x	xCell 0 R_A 1	0x4204	I2	–32768	32768	41	2^{-10} Ω	Cell 0 resistance at grid point 1
RA Table	R_a0x	xCell 0 R_A 2	0x4206	I2	–32768	32768	43	2^{-10} Ω	Cell 0 resistance at grid point 2
RA Table	R_a0x	xCell 0 R_A 3	0x4208	I2	–32768	32768	44	2^{-10} Ω	Cell 0 resistance at grid point 3
RA Table	R_a0x	xCell 0 R_A 4	0x420A	I2	–32768	32768	42	2^{-10} Ω	Cell 0 resistance at grid point 4
RA Table	R_a0x	xCell 0 R_A 5	0x420C	I2	–32768	32768	42	2^{-10} Ω	Cell 0 resistance at grid point 5
RA Table	R_a0x	xCell 0 R_A 6	0x420E	I2	–32768	32768	45	2^{-10} Ω	Cell 0 resistance at grid point 6
RA Table	R_a0x	xCell 0 R_A 7	0x4210	I2	–32768	32768	48	2^{-10} Ω	Cell 0 resistance at grid point 7
RA Table	R_a0x	xCell 0 R_A 8	0x4212	I2	–32768	32768	49	2^{-10} Ω	Cell 0 resistance at grid point 8
RA Table	R_a0x	xCell 0 R_A 9	0x4214	I2	–32768	32768	52	2^{-10} Ω	Cell 0 resistance at grid point 9
RA Table	R_a0x	xCell 0 R_A 10	0x4216	I2	–32768	32768	56	2^{-10} Ω	Cell 0 resistance at grid point 10
RA Table	R_a0x	xCell 0 R_A 11	0x4218	I2	–32768	32768	64	2^{-10} Ω	Cell 0 resistance at grid point 11
RA Table	R_a0x	xCell 0 R_A 12	0x421A	I2	–32768	32768	74	2^{-10} Ω	Cell 0 resistance at grid point 12
RA Table	R_a0x	xCell 0 R_A 13	0x421C	I2	–32768	32768	128	2^{-10} Ω	Cell 0 resistance at grid point 13
RA Table	R_a0x	xCell 0 R_A 14	0x421E	I2	–32768	32768	378	2^{-10} Ω	Cell 0 resistance at grid point 14

13.15.6 R_a1x

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
RA Table	R_a1x	xCell 1 R_A Flag	0x4240	H2	0x0000	0xFFFF	0xFFFF	—

Description:
This value indicates the validity of the cell impedance table for Cell2. It is recommended not to change this value manually.

High Byte		Low Byte	
0x00	Cell impedance and QMax updated	0x00	Table not used and QMax updated
0x05	RELAX mode and QMax update in progress	0x55	Table being used
0x55	DISCHARGE mode and cell impedance updated	0xFF	Table never used, no QMax or cell impedance update
0xFF	Cell impedance never updated		

The gauge stores and updates the impedance profile for Cell2 as shown in the following table.

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit	Description
RA Table	R_a1x	xCell 1 R_A 0	0x4242	I2	–32768	32768	38	2^{-10} Ω	Cell 1 resistance at grid point 0
RA Table	R_a1x	xCell 1 R_A 1	0x4244	I2	–32768	32768	41	2^{-10} Ω	Cell 1 resistance at grid point 1
RA Table	R_a1x	xCell 1 R_A 2	0x4246	I2	–32768	32768	43	2^{-10} Ω	Cell 1 resistance at grid point 2
RA Table	R_a1x	xCell 1 R_A 3	0x4248	I2	–32768	32768	44	2^{-10} Ω	Cell 1 resistance at grid point 3
RA Table	R_a1x	xCell 1 R_A 4	0x424A	I2	–32768	32768	42	2^{-10} Ω	Cell 1 resistance at grid point 4
RA Table	R_a1x	xCell 1 R_A 5	0x424C	I2	–32768	32768	42	2^{-10} Ω	Cell 1 resistance at grid point 5
RA Table	R_a1x	xCell 1 R_A 6	0x424E	I2	–32768	32768	45	2^{-10} Ω	Cell 1 resistance at grid point 6
RA Table	R_a1x	xCell 1 R_A 7	0x4250	I2	–32768	32768	48	2^{-10} Ω	Cell 1 resistance at grid point 7
RA Table	R_a1x	xCell 1 R_A 8	0x4252	I2	–32768	32768	49	2^{-10} Ω	Cell 1 resistance at grid point 8
RA Table	R_a1x	xCell 1 R_A 9	0x4254	I2	–32768	32768	52	2^{-10} Ω	Cell 1 resistance at grid point 9
RA Table	R_a1x	xCell 1 R_A 10	0x4256	I2	–32768	32768	56	2^{-10} Ω	Cell 1 resistance at grid point 10
RA Table	R_a1x	xCell 1 R_A 11	0x4258	I2	–32768	32768	64	2^{-10} Ω	Cell 1 resistance at grid point 11
RA Table	R_a1x	xCell 1 R_A 12	0x425A	I2	–32768	32768	74	2^{-10} Ω	Cell 1 resistance at grid point 12
RA Table	R_a1x	xCell 1 R_A 13	0x425C	I2	–32768	32768	128	2^{-10} Ω	Cell 1 resistance at grid point 13
RA Table	R_a1x	xCell 1 R_A 14	0x425E	I2	–32768	32768	378	2^{-10} Ω	Cell 1 resistance at grid point 14

13.15.7 R_a2x

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
RA Table	R_a2x	xCell 2 R_A Flag	0x4280	H2	0x0000	0xFFFF	0xFFFF	—

Description:
This value indicates the validity of the cell impedance table for Cell3. It is recommended not to change this value manually.

High Byte		Low Byte	
0x00	Cell impedance and QMax updated	0x00	Table not used and QMax updated
0x05	RELAX mode and QMax update in progress	0x55	Table being used

High Byte		Low Byte	
0x55	DISCHARGE mode and cell impedance updated	0xFF	Table never used, no QMax or cell impedance update
0xFF	Cell impedance never updated		

The gauge stores and updates the impedance profile for Cell3 as shown in the following table.

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit	Description
RA Table	R_a2x	xCell 2 R_A 0	0x4282	I2	–32768	32768	38	2^{-10} Ω	Cell 2 resistance at grid point 0
RA Table	R_a2x	xCell 2 R_A 1	0x4284	I2	–32768	32768	41	2^{-10} Ω	Cell 2 resistance at grid point 1
RA Table	R_a2x	xCell 2 R_A 2	0x4286	I2	–32768	32768	43	2^{-10} Ω	Cell 2 resistance at grid point 2
RA Table	R_a2x	xCell 2 R_A 3	0x4288	I2	–32768	32768	44	2^{-10} Ω	Cell 2 resistance at grid point 3
RA Table	R_a2x	xCell 2 R_A 4	0x428A	I2	–32768	32768	42	2^{-10} Ω	Cell 2 resistance at grid point 4
RA Table	R_a2x	xCell 2 R_A 5	0x428C	I2	–32768	32768	42	2^{-10} Ω	Cell 2 resistance at grid point 5
RA Table	R_a2x	xCell 2 R_A 6	0x428E	I2	–32768	32768	45	2^{-10} Ω	Cell 2 resistance at grid point 6
RA Table	R_a2x	xCell 2 R_A 7	0x4290	I2	–32768	32768	48	2^{-10} Ω	Cell 2 resistance at grid point 7
RA Table	R_a2x	xCell 2 R_A 8	0x4292	I2	–32768	32768	49	2^{-10} Ω	Cell 2 resistance at grid point 8
RA Table	R_a2x	xCell 2 R_A 9	0x4294	I2	–32768	32768	52	2^{-10} Ω	Cell 2 resistance at grid point 9
RA Table	R_a2x	xCell 2 R_A 10	0x4296	I2	–32768	32768	56	2^{-10} Ω	Cell 2 resistance at grid point 10
RA Table	R_a2x	xCell 2 R_A 11	0x4298	I2	–32768	32768	64	2^{-10} Ω	Cell 2 resistance at grid point 11
RA Table	R_a2x	xCell 2 R_A 12	0x429A	I2	–32768	32768	74	2^{-10} Ω	Cell 2 resistance at grid point 12
RA Table	R_a2x	xCell 2 R_A 13	0x429C	I2	–32768	32768	128	2^{-10} Ω	Cell 2 resistance at grid point 13
RA Table	R_a2x	xCell 2 R_A 14	0x429E	I2	–32768	32768	378	2^{-10} Ω	Cell 2 resistance at grid point 14

13.15.8 R_a3x

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
RA Table	R_a3x	xCell 3 R_A Flag	0x42C0	H2	0x0000	0xFFFF	0xFFFF	—

Description:
This value indicates the validity of the cell impedance table for Cell4. It is recommended not to change this value manually.

High Byte		Low Byte	
0x00	Cell impedance and QMax updated	0x00	Table not used and QMax updated
0x05	RELAX mode and QMax update in progress	0x55	Table being used
0x55	DISCHARGE mode and cell impedance updated	0xFF	Table never used, no QMax or cell impedance update
0xFF	Cell impedance never updated		

The gauge stores and updates the impedance profile for Cell4 as shown in the following table.

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit	Description
RA Table	R_a3x	xCell 3 R_A 0	0x42C2	I2	–32768	32768	38	2^{-10} Ω	Cell 3 resistance at grid point 0
RA Table	R_a3x	xCell 3 R_A 1	0x42C4	I2	–32768	32768	41	2^{-10} Ω	Cell 3 resistance at grid point 1
RA Table	R_a3x	xCell 3 R_A 2	0x42C6	I2	–32768	32768	43	2^{-10} Ω	Cell 3 resistance at grid point 2

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit	Description
RA Table	R_a3x	xCell 3 R_A 3	0x42C8	I2	–32768	32768	44	2^{-10} Ω	Cell 3 resistance at grid point 3
RA Table	R_a3x	xCell 3 R_A 4	0x42CA	I2	–32768	32768	42	2^{-10} Ω	Cell 3 resistance at grid point 4
RA Table	R_a3x	xCell 3 R_A 5	0x42CC	I2	–32768	32768	42	2^{-10} Ω	Cell 3 resistance at grid point 5
RA Table	R_a3x	xCell 3 R_A 6	0x42CE	I2	–32768	32768	45	2^{-10} Ω	Cell 3 resistance at grid point 6
RA Table	R_a3x	xCell 3 R_A 7	0x42D0	I2	–32768	32768	48	2^{-10} Ω	Cell 3 resistance at grid point 7
RA Table	R_a3x	xCell 3 R_A 8	0x42D2	I2	–32768	32768	49	2^{-10} Ω	Cell 3 resistance at grid point 8
RA Table	R_a3x	xCell 3 R_A 9	0x42D4	I2	–32768	32768	52	2^{-10} Ω	Cell 3 resistance at grid point 9
RA Table	R_a3x	xCell 3 R_A 10	0x42D6	I2	–32768	32768	56	2^{-10} Ω	Cell 3 resistance at grid point 10
RA Table	R_a3x	xCell 3 R_A 11	0x42D8	I2	–32768	32768	64	2^{-10} Ω	Cell 3 resistance at grid point 11
RA Table	R_a3x	xCell 3 R_A 12	0x42DA	I2	–32768	32768	74	2^{-10} Ω	Cell 3 resistance at grid point 12
RA Table	R_a3x	xCell 3 R_A 13	0x42DC	I2	–32768	32768	128	2^{-10} Ω	Cell 3 resistance at grid point 13
RA Table	R_a3x	xCell 3 R_A 14	0x42DE	I2	–32768	32768	378	2^{-10} Ω	Cell 3 resistance at grid point 14

13.16 SBS Configuration

13.16.1 Data

13.16.1.1 Remaining Capacity Alarm

13.16.1.1.1 Remaining Ah Capacity Alarm

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
SBS Configuration	Data	Remaining Ah Capacity Alarm	0x47FC	U2	0	700	300	mAh

Description: *RemainingCapacityAlarm()* value in mAh

13.16.1.1.2 Remaining Wh Capacity Alarm

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
SBS Configuration	Data	Remaining Wh Capacity Alarm	0x47FE	U2	0	1000	432	cWh

Description: *RemainingCapacityAlarm()* value in 10 mWh

13.16.1.2 RemainingTimeAlarm

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
SBS Configuration	Data	Remaining Time Alarm	0x4800	U2	0	30	10	min

Description: *RemainingTimeAlarm()* value

13.16.1.3 Initial Battery Mode

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
SBS Configuration	Data	Initial Battery Mode	0x4802	H2	0x0000	0xFFFF	0x0081	—

15	14	13	12	11	10	9	8
CAPM	CHGM	AM	RSVD	RSVD	RSVD	PB	CC

7	6	5	4	3	2	1	0
CF	RSVD	RSVD	RSVD	RSVD	RSVD	PBS	ICC

CAPM (Bit 15): Capacity_Mode (R/W)
- 1 = Report in 10 mW or 10 mWh
- 0 = Report in mA or mAh (default)

CHGM (Bit 14): Charger_Mode (R/W)
- 1 = Disable *ChargingVoltage()* and *ChargingCurrent()* broadcasts to host and smart battery charger (default)
- 0 = Enable *ChargingVoltage()* and *ChargingCurrent()* broadcasts to host and smart battery charger

AM (Bit 13): ALARM Mode (R/W)
- 1 = Disable AlarmWarning broadcasts to host and smart battery charger
- 0 = Enable AlarmWarning broadcasts to host and smart battery charger (default)

RSVD (Bits 12–10): Reserved. Do not use.

PB (Bit 9): Primary_Battery (R/W)
- 1 = Battery operating in its primary role
- 0 = Battery operating in its secondary role (default)

CC (Bit 8): Charge_Controller_Enabled (R/W)
- 1 = Internal charge control enabled
- 0 = Internal charge control disabled (default)

CF (Bit 7): Condition_Flag (R)
- 1 = Conditioning cycle requested
- 0 = Battery OK

RSVD (Bits 6–2): Reserved. Do not use.

PBS (Bit 1): Primary_Battery_Support (R)
- 1 = Primary or secondary battery support
- 0 = Function not supported (default)

ICC (Bit 0): Internal_Charge_Controller (R)
- 1 = Function supported
- 0 = Function not supported (default)

13.16.1.4 Specification Information

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
SBS Configuration	Data	Specification Information	0x4804	H2	0x0000	0xFFFF	0x0031	—

15	14	13	12	11	10	9	8
IPScale	IPScale	IPScale	IPScale	VScale	VScale	VScale	VScale

7	6	5	4	3	2	1	0
Version	Version	Version	Version	Revision	Revision	Revision	Revision

SpecificationInformation() values

IPScale (Bits 15–12): IP Scale Factor

0,0,0,0 = Reported currents and capacities scaled by 10E0 except *ChargingVoltage()* and *ChargingCurrent()*

0,0,0,1 = Reported currents and capacities scaled by 10E1 except *ChargingVoltage()* and *ChargingCurrent()*

0,0,1,0 = Reported currents and capacities scaled by 10E2 except *ChargingVoltage()* and *ChargingCurrent()*

0,0,1,1 = Reported currents and capacities scaled by 10E3 except *ChargingVoltage()* and *ChargingCurrent()*

VScale (Bits 11–8): Voltage Scale Factor

0,0,0,0 = Reported voltages scaled by 10E0

0,0,0,1 = Reported voltages scaled by 10E1

0,0,1,0 = Reported voltages scaled by 10E2

0,0,1,1 = Reported voltages scaled by 10E3

Version (Bits 7–4): Version

0,0,0,1 = Version 1.0

0,0,1,1 = Version 1.1

0,0,1,1 = Version 1.1 with optional PEC support

Revision (Bits 3–0): Revision

0,0,0,1 = Version 1.0 and 1.1 (default)

13.16.1.5 Manufacturer Date

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
SBS Configuration	Data	Manufacturer Date	0x4067	U2	0	65535	01/01/80	—

Description: *ManufacturerDate()* value in the following format: Day + Month*32 + (Year–1980) * 512

13.16.1.6 Serial Number

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
SBS Configuration	Data	Serial Number	0x4069	H2	0x0000	0xFFFF	0x0001	—

Description: *SerialNumber()* value

13.16.1.7 Manufacturer Name

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
SBS Configuration	Data	Manufacturer Name	0x406B	S20+1	—	—	Texas Instruments	ASCII

Description: *ManufacturerName()* value

13.16.1.8 Device Name

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
SBS Configuration	Data	Device Name	0x4080	S20+1	—	—	bq40z50	ASCII

Description: *DeviceName()* value

13.16.1.9 Device Chemistry

Class	Subclass	Name	Start Address	Type	Min	Max	Default	Unit
SBS Configuration	Data	Device Chemistry	0x4095	S4+1	—	—	LION	ASCII

Description: *DeviceChemistry()* value

AFE Threshold and Delay Settings

A.1 Overload in Discharge Protection (AOLD)

Table A-1. Overload in Discharge Protection Threshold (Settings:AFE:AFE Protection Control [RSNS] = 0)(1)

OLD Threshold ([RSNS] = 0)			
Setting	**Threshold**	**Setting**	**Threshold**
0x00	–8.30 mV	0x08	–30.54 mV
0x01	–11.08 mV	0x09	–33.32 mV
0x02	–13.86 mV	0x0A	–36.10 mV
0x03	–16.64 mV	0x0B	–38.88 mV
0x04	–19.42 mV	0x0C	–41.66 mV
0x05	–22.20 mV	0x0D	–44.44 mV
0x06	–24.98 mV	0x0E	–47.22 mV
0x07	–27.76 mV	0x0F	–50.00 mV

(1) Data flash setting ***Protection:AFE Thresholds:OLD Threshold[3:0]*** sets the voltage threshold.

Table A-2. Overload in Discharge Protection Threshold (Settings:AFE:AFE Protection Control [RSNS] = 1)(1)

OLD Threshold ([RSNS] = 1)			
Setting	**Threshold**	**Setting**	**Threshold**
0x00	–16.60 mV	0x08	–61.08 mV
0x01	–22.16 mV	0x09	–66.64 mV
0x02	–27.72 mV	0x0A	–72.20 mV
0x03	–33.28 mV	0x0B	–77.76 mV
0x04	–38.84 mV	0x0C	–83.32 mV
0x05	–44.40 mV	0x0D	–88.88 mV
0x06	–49.96 mV	0x0E	–94.44 mV
0x07	–55.52 mV	0x0F	–100.00 mV

(1) Data flash setting ***Protection:AFE Thresholds:OLD Threshold[3:0]*** sets the voltage threshold.

Table A-3. Overload in Discharge Protection Delay(1)

Setting	Time	Setting	Time	Setting	Time	Setting	Time
0x00	1 ms	0x04	9 ms	0x08	17 ms	0x0C	25 ms
0x01	3 ms	0x05	11 ms	0x09	19 ms	0x0D	27 ms
0x02	5 ms	0x06	13 ms	0x0A	21 ms	0x0E	29 ms
0x03	7 ms	0x07	15 ms	0x0B	23 ms	0x0F	31 ms

(1) Data flash setting ***Protection:AFE Thresholds:OLD Threshold[7:4]*** sets the delay time.

A.2 Short Circuit in Charge (ASCC)

Table A-4. Short Circuit in Charge Threshold (Settings:AFE:AFE Protection Control [RSNS] = 0)(1)

Setting	Threshold	Setting	Threshold
0x00	22.2 mV	0x04	66.65 mV
0x01	33.3 mV	0x05	77.75 mV
0x02	44.4 mV	0x06	88.85 mV
0x03	55.5 mV	0x07	100 mV

(1) Data flash setting ***Protection:AFE Thresholds:SCC Threshold[2:0]*** sets the voltage threshold.

Table A-5. Short Circuit in Charge Threshold (Settings:AFE:AFE Protection Control [RSNS] = 1)(1)

Setting	Threshold	Setting	Threshold
0x00	44.4 mV	0x04	133.3 mV
0x01	66.6 mV	0x05	155.5 mV
0x02	88.8 mV	0x06	177.7 mV
0x03	111.1 mV	0x07	200 mV

(1) Data flash setting ***Protection:AFE Thresholds:SCC Threshold[2:0]*** sets the voltage threshold.

Table A-6. Short Circuit in Charge Delay(1)

Setting	Time	Setting	Time	Setting	Time	Setting	Time
0x00	0 µs	0x04	244 µs	0x08	488 µs	0x0C	732 µs
0x01	61 µs	0x05	305 µs	0x09	549 µs	0x0D	793 µs
0x02	122 µs	0x06	366 µs	0x0A	610 µs	0x0E	854 µs
0x03	183 µs	0x07	427 µs	0x0B	671 µs	0x0F	915 µs

(1) Data flash setting ***Protection:AFE Thresholds:SCC Threshold[7:4]*** sets the delay time.

A.3 Short Circuit in Discharge (ASCD1 and ASCD2)

Table A-7. Short Circuit in Discharge Threshold (Settings:AFE:AFE Protection Control [RSNS] = 0)(1)

Setting	Threshold	Setting	Threshold
0x00	–22.2 mV	0x04	–66.65 mV
0x01	–33.3 mV	0x05	–77.75 mV
0x02	–44.4 mV	0x06	–88.85 mV
0x03	–55.5 mV	0x07	–100 mV

(1) Data flash setting ***Protection:AFE Thresholds:SCD1 Threshold[2:0]*** and ***Protection:AFE Thresholds:SCD2 Threshold[2:0]*** sets the voltage thresholds.

Table A-8. Short Circuit in Discharge Threshold (Settings:AFE:AFE Protection Control [RSNS] = 1)(1)

Setting	Threshold	Setting	Threshold
0x00	–44.4 mV	0x04	–133.3 mV
0x01	–66.6 mV	0x05	–155.5 mV
0x02	–88.8 mV	0x06	–177.7 mV
0x03	–111.1 mV	0x07	–200 mV

(1) Data flash setting ***Protection:AFE Thresholds:SCD1 Threshold[2:0]*** and ***Protection:AFE Thresholds:SCD2 Threshold[2:0]*** sets the voltage thresholds.

Table A-9. Short Circuit in Discharge 1 Delay (Settings:AFE:AFE Protection Control [SCDDx2] = 0)[(1)]

Setting	Time	Setting	Time	Setting	Time	Setting	Time
0x00	0 µs	0x04	244 µs	0x08	488 µs	0x0C	732 µs
0x01	61 µs	0x05	305 µs	0x09	549 µs	0x0D	793 µs
0x02	122 µs	0x06	366 µs	0x0A	610 µs	0x0E	854 µs
0x03	183 µs	0x07	427 µs	0x0B	671 µs	0x0F	915 µs

(1) Data flash setting ***Protection:AFE Thresholds:SCD1Threshold[7:4]*** sets the delay time.

Table A-10. Short Circuit in Discharge 1 Delay (Settings:AFE:AFE Protection Control [SCDDx2] = 1)[(1)]

Setting	Time	Setting	Time	Setting	Time	Setting	Time
0x00	0 µs	0x04	488 µs	0x08	976 µs	0x0C	1464 µs
0x01	122 µs	0x05	610 µs	0x09	1098 µs	0x0D	1586 µs
0x02	244 µs	0x06	732 µs	0x0A	1220 µs	0x0E	1708 µs
0x03	366 µs	0x07	854 µs	0x0B	1342 µs	0x0F	1830 µs

(1) Data flash setting ***Protection:AFE Thresholds:SCD1 Threshold[7:4]*** sets the delay time.

Table A-11. Short Circuit in Discharge 2 Delay (Settings:AFE:AFE Protection Control [SCDDx2] = 0)[(1)]

Setting	Time	Setting	Time	Setting	Time	Setting	Time
0x00	0 µs	0x04	122 µs	0x08	244 µs	0x0C	366 µs
0x01	31 µs	0x05	153 µs	0x09	275 µs	0x0D	396 µs
0x02	61 µs	0x06	183 µs	0x0A	305 µs	0x0E	427 µs
0x03	92 µs	0x07	214 µs	0x0B	335 µs	0x0F	458 µs

(1) Data flash setting ***Protection:AFE Thresholds:SCD2 Threshold[7:4]*** sets the delay time.

Table A-12. Short Circuit in Discharge 2 Delay (Settings:AFE:AFE Protection Control [SCDDx2] = 1)[(1)]

Setting	Time	Setting	Time	Setting	Time	Setting	Time
0x00	0 µs	0x04	244 µs	0x08	488 µs	0x0C	732 µs
0x01	62 µs	0x05	306 µs	0x09	550 µs	0x0D	792 µs
0x02	122 µs	0x06	366 µs	0x0A	610 µs	0x0E	854 µs
0x03	184 µs	0x07	428 µs	0x0B	670 µs	0x0F	916 µs

(1) Data flash setting ***Protection:AFE Thresholds:SCD2 Threshold[7:4]*** sets the delay time.

Sample Filter Settings

Table B-1. Sample V/I/P Filter Settings and Associated Low-Pass Filter Time Constants(1)

Average V/I/P Filter	Effective Low-Pass Time Constant
10	0.25 seconds
50	0.5 seconds
145	1 second
200	3 seconds

(1) Data flash setting ***Calibration:Filter:Average V/I/P*** sets this threshold.

Revision History

Changes from Original (December 2013) to A Revision **Page**

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