bq78350

Technical Reference

Texas Instruments

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Contents

Preface

Read this First

This manual discusses the modules and peripherals of the bq78350 device, and how each is used to build a complete battery pack gas gauge and protection solution.

Notational Conventions

The following notational conventions are 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)

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Introduction

The bq78350 device provides a feature-rich battery management solution for 3-series cell to 15-series cell battery pack applications. The device has extended capabilities, including:

- Companion Protection Controller to the bq76920, bq76930, and bq76940 AFE Devices for Li-Ion or Li-FePO4 Battery Packs
- Compensated End-of-Discharge Voltage (CEDV) Gas Gauging Algorithm Accurately Measures Available Charge and State-of-Health
- Voltage Based Cell Balancing Control
- Normal and Lower Power Modes
  - NORMAL
  - SLEEP
  - SHUTDOWN
- Full Array of Programmable Protection Features
  - Voltage
  - Current
  - Temperature
  - Charge Timeout
  - CHG/DSG FETs
- Precharge and Fast Charge Algorithm
- Diagnostic Lifetime Data Monitor
- Black Box Event Recorder
- Supports Two-Wire SMBus v1.1 Interface
- SHA-1 Authentication
- Package: 30-Lead TSSOP

The bq78350 is intended to be used with the bq769x0 with a 2.5-V REGOUT configuration and I^2C Address 0x08. However, the bq78350 can use a bq769x0 with or without the communications CRC enabled (the bq78350 automatically detects if CRC is enabled).

Basic Measurement System

2.1 Introduction

NOTE: For this section, refer to the *bq769x0 3-Series to 15-Series Cell Battery Monitor Family for Li-Ion and Phosphate Applications Data Manual* (SLUSBK2) for further details.

The bq78350 reads the bq769x0 companion AFE registers that contain recent values from the integrating analog-to-digital converter (ADC) for current measurement, and a second delta-sigma ADC for individual cell and temperature measurements. The bq78350 also has the capability to measure the battery voltage through an externally translated voltage.

2.2 Current and Coulomb Counting

The integrating delta-sigma ADC in the companion bq769x0 AFE measures the charge/discharge flow of the battery by measuring the voltage drop across a small-value sense resistor between the SRP and SRN pins. The 15-bit integrating ADC measures bipolar signals from –0.20 V to 0.20 V with 15-µV resolution. The AFE reports charge activity when VSR = $V_{(SRP)} - V_{(SRN)}$ is positive, and discharge activity when VSR = $V_{(SRP)} - V_{(SRN)}$ is negative. The bq78350 continuously monitors the measured current and integrates the digital signal from the AFE over time using an internal counter.

To support large battery configurations, the current data can be scaled to ensure accurate reporting through the SMBus. The data reported is scaled based on the setting of the *SpecificationInfo()* command.

The data reported through the *Current()* can also have a deadband applied to it. This removes any noise or offset that has not been calibrated out from being reported as real current. This value is programmed in ***Deadband*** with a default configured for mA scaling in *SpecificationInfo()*. If the *SpecificationInfo()* IPSCALE is set to 10 mA or 100 mA, then it is strongly recommended to set ***Deadband*** to 1.

2.3 Voltage

The bq78350 updates the individual series cell voltages through the bq769x0 at 1-s intervals. The bq78350 configures the bq769x0 to connect to the selected cells in sequence and uses this information for cell balancing and individual cell fault functions. The internal 14-bit ADC of the bq769x0 measures each cell voltage value, which is then communicated digitally to the bq78350 where it is scaled and translated into unit millivolts. The maximum supported input range of the ADC is 6.075 V.

The bq78350 also separately measures the average cell voltage through an external translation circuit at the BAT pin. This value is specifically used for the gas gauge algorithm. The external translation circuit is controlled via the VEN pin so that the translation circuit is only enabled when required to reduce overall power consumption. VEN requires an external pullup to VCC, typically 100 k, to operate correctly.

In addition to the voltage measurements used by the bq78350 algorithms, there is an optional auxiliary voltage measurement capability via the VAUX pin. This feature measures the input on a 1-s update rate and provides the programmable scaled value through the *VAUXVoltage()* SMBus command. The data can be enabled to influence selected fault recovery features. See General Protections Configuration, ***[VAUXR]***, for further details.

The VEN pin will go high 2 ms prior to the BAT being measured if ***DA Configuration [ExtAveEN]*** = 1, and then return low unless ***DA Configuration [VAUXEN]*** = 1, which will cause VEN to remain high for a further 2 ms prior to making the VAUX measurement. This results in VEN possibly being high for up to 40 ms per second in NORMAL mode.

To support large battery configurations where the battery voltage can exceed 32768 mV, the data can be scaled to ensure accurate reporting through the SMBus. The data reported is scaled based on the setting of the *SpecificationInfo()* command. The cell voltages are not scaled.

2.4 Temperature

The bq78350 receives temperature information from external or internal temperature sensors in the bq769x0 AFE. Depending on the number of series cells supported, the AFE will provide one, two, or three external thermistor measurements. The value of temperature is reported through *Temperature()* and can be configured in DA Configuration.

2.4.1 Temperature Enable

This register enables/disables the available temperature sensor options.

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Settings	Configuration	Temperature Enable	hex	1	0x00	0xFF	0x09	—

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Low Byte	RSVD	RSVD	RSVD	RSVD	SOURCE	TS3	TS2	TS1

RSVD (Bits 7–4): Reserved

SOURCE (Bit 3): Configure the use of Internal or External temperature sensor for all AFE ports

0 = Use internal temperature sensor(s)

1 = Use external temperature sensor(s)

TS3 (Bit 2): Enable/disable companion AFE temperature sensor TS3, if available

0 = Disable TS3 temperature sensor

1 = Enable TS3 temperature sensor

TS2 (Bit 1): Enable/disable companion AFE temperature sensor TS2, if available

0 = Disable TS2 temperature sensor

1 = Enable TS2 temperature sensor

TS1 (Bit 0): Enable/disable companion AFE temperature sensor TS1

0 = Disable TS1 temperature sensor

1 = Enable TS1 temperature sensor

2.5 Temperature Ranges

The measured temperature is segmented into several temperature ranges. The bq78350 uses these as indication, and, for Lifetime Data Logging, the time spent in each range. The temperature ranges set in data flash should adhere to the following format:

T1 ≤ T2 ≤ T3 ≤ T4

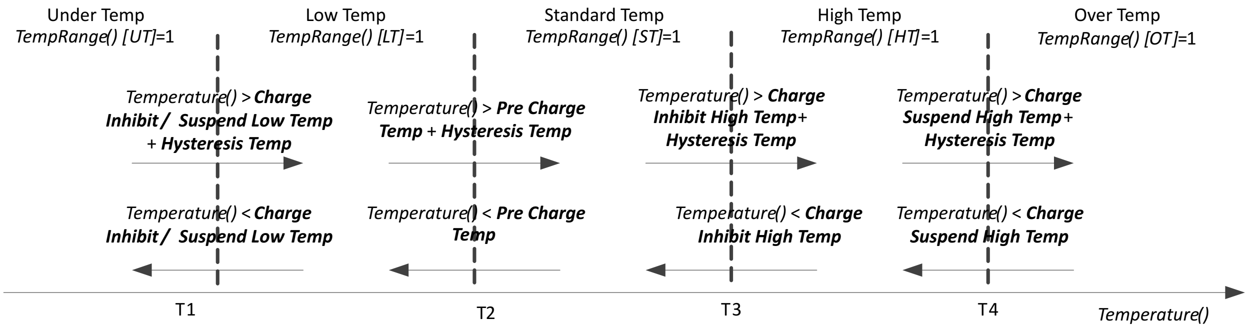


Figure 2-1. Data Flash Temperature Range Format

See the Temperature Ranges data flash subclass for details on the specific data flash variables.

2.6 Basic Configuration Options

There are a variety of options available in the bq78350 and the companion AFE that influence the startup conditions, system configuration, and the data measurement system.

2.6.1 DA Configuration

This register is used to configure the setup of various measurement features of the bq78350.

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Settings	Configuration	DA Configuration	hex	1	0x00	0xFF	0x11	—

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Low Byte	RSVD	RSVD	RSVD	ExtAveEN	VAUXEN	VAUX_SCALE	CTEMP	SLEEP

RSVD (Bits 7–5): Reserved

ExtAveEN (Bit 4): Enables the bq78350 to measure the BAT input

0 = BAT input is not measured.

1 = BAT input is measured and made available via *ExternalAverageVoltage()* (default).

VAUXEN (Bit 3): Enables the bq78350 to measure the VAUX input

0 = VAUX input is not measured (default).

1 = VAUX input is measured and made available via *VAUX().*

VAUX_SCALE (Bit 2): Enables the bq78350 to scale the *VAUX()* data by 10. For example: Units are 10 mV rather than 1 mV.

0 = *VAUX()* is not scaled (resolution is 1 mV) (default).

1 = *VAUX()* is scaled (resolution is 10 mV).

CTEMP (Bit 1): Cell Temperature Protection Source

0 = Maximum of external available sources (default)

1 = Average of external available sources

SLEEP (Bit 0): Enables the bq78350 to enter SLEEP mode.

0 = The bq78350 never enters SLEEP mode.

1 = The bq78350 enters SLEEP mode under normal sleep entry criteria (default).

2.6.2 FET Options

This register configures the various FET control options.

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Settings	Configuration	FET Options	hex	2	0x0000	0xFFFF	0x0021	—

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
High Byte	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	KEY_POL	PCHG_POL
Low Byte	RSVD	SLEEPCHG	CHGFET	CHGIN	CHGSU	OTFET	KEY_EN	PCHG_EN

RSVD (Bits 7–2): Reserved

KEY_POL: This bit configures the KEYIN input detection polarity.

0 = KEYIN detection is active low (default).
1 = KEYIN detection is active high.

PCHG_POL: Configures the bq78350 $\overline{\text{PRECHG}}$ pin output polarity. If PCHG_EN = 0, then this bit has no influence.

0 = The bq78350 configures the $\overline{\text{PRECHG}}$ as active low (default).
1 = The bq78350 configures the $\overline{\text{PRECHG}}$ as active high, requiring an external pull up.

SLEEPCHG: CHG FET is enabled during SLEEP.

0 = CHG FET off during SLEEP (default).
1 = CHG FET remains on during SLEEP.

CHGFET: FET action on valid charge termination

0 = FET active
1 = Charging and Precharging disabled, FET off (default)

CHGIN: FET action in CHARGE INHIBIT mode

0 = FET active (default)
1 = Charging and Precharging disabled, FETs off

CHGSU: FET action in CHARGE SUSPEND mode

0 = FET active (default)
1 = Charging and Precharging disabled, FETs off

OTFET: FET action in OVERTEMPERATURE mode

0 = No FET action for overtemperature condition (default)
1 = CHG and DSG FETs will be turned off for overtemperature conditions.

KEY_EN: Enables the bq78350 to use the KEYIN pin function.

0 = The bq78350 never uses KEYIN (default).
1 = The bq78350 KEYIN is used to control the DSG FET.

PCHG_EN: Enables the bq78350 to use the $\overline{\text{PRECHG}}$ pin during PRECHARGE mode.

0 = The bq78350 never uses $\overline{\text{PRECHG}}$.
1 = The bq78350 controls $\overline{\text{PRECHG}}$ under normal charge control algorithm (default).

2.6.3 AFE Cell Map

This register maps the cells connected to the companion AFE so that the bq78350 knows cells are present at the indicated VCx channel.

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Configuration	AFE	AFE Cell Map	hex	2	0x0000	0xFFFF	0x0013	—

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
High Byte	RSVD	VC15	VC14	VC13	VC12	VC11	VC10	VC9
Low Byte	VC8	VC7	VC6	VC5	VC4	VC3	VC2	VC1

RSVD (Bit 7): Reserved

VCx (Bits 14–0): Cell connected to this node

1 = A cell is connected to this node and valid measurements are expected.

0 = A cell is NOT connected to this node.

The bq78350 determines which companion AFE is connected by the total number of cells connected.

- When Series Cells = 3 to 5, the bq76920 companion AFE is used.
- When Series Cells = 6 to 10, the bq76930 companion AFE is used.
- When Series Cells = 9 to 15, the bq76940 companion AFE is used.

Protections

3.1 Introduction

The bq78350 supports a wide range of battery and system protection features that are easily configured or enabled via the integrated data flash. All of the protection items can be enabled or disabled under ***Settings:Enable Protections A***, ***Settings:Enable Protections B***, and ***Settings:Enable Protections C***.

3.1.1 General Protections Configuration

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Settings	Protection	Protection Configuration	Hex	1	0x00	0xFF	0x00	—

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	RSVD	LPEN	VAUXR	CUV_RECOV_CHG	RSVD

RSVD (Bits 7–4): Reserved

LPEN (Bit 3): Protection recovery uses the LOAD_PRESENT flag in the AFE to determine discharge fault recovery. LOAD_PRESENT should only be used in a low-side protection FET configuration.

0 = Disabled (default)

1 = Enabled

VAUXR (Bit 2): Protection recovery uses the VAUX input as charger present detection.

0 = Disabled (default)

1 = Enabled

CUV_RECOV_CHG (Bit 1): Requires charge to recover *SafetyStatus()[CUV]*

0 = Disabled (default)

1 = Enabled

RSVD (Bit 0): Reserved

3.1.2 Enabled Protections

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Settings	Protection	Enabled Protections A	Hex	1	0x00	0xFF	0xFF	—

7	6	5	4	3	2	1	0
ASCDL	ASCD	AOLDL	AOLD	OCD	OCC	COV	CUV

ASCDL (Bit 7): Short Circuit in Discharge Latch
- 0 = Disabled
- 1 = Enabled

ASCD (Bit 6): Short Circuit in Discharge recovery. Detection of an ASCD fault cannot be disabled.
- 0 = Bypassed, auto recovers within 250 ms
- 1 = Enabled

AOLDL (Bit 5): Overload in Discharge Latch
- 0 = Disabled
- 1 = Enabled

AOLD (Bit 4): Overload in Discharge recovery. Detection of an AOLD fault cannot be disabled.
- 0 = Bypassed, auto recovers within 250 ms
- 1 = Enabled

OCD (Bit 3): Overcurrent in Discharge
- 0 = Disabled
- 1 = Enabled

OCC (Bit 2): Overcurrent in Charge
- 0 = Disabled
- 1 = Enabled

COV (Bit 1): Cell Overvoltage
- 0 = Disabled
- 1 = Enabled

CUV (Bit 0): Cell Undervoltage
- 0 = Disabled
- 1 = Enabled

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Settings	Protection	Enabled Protections B	Hex	1	0x00	0xFF	0x0F	—

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	RSVD	UTD	UTC	OTD	OTC

RSVD (Bits 7–4): Reserved

UTD (Bit 3): Undertemperature in Discharge
- 0 = Disabled
- 1 = Enabled

UTC (Bit 2): Undertemperature in Charge
- 0 = Disabled
- 1 = Enabled

OTD (Bit 1): Overtemperature in Discharge
- 0 = Disabled
- 1 = Enabled

OTC (Bit 0): Overtemperature in Charge
0 = Disabled
1 = Enabled

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Settings	Protection	Enabled Protections C	Hex	1	0x00	0xFF	0x15	—

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	OC	CTOS	CTO	PTOS	PTO

RSVD (Bits 7–5): Reserved

OC (Bit 4): Overcharge
0 = Disabled
1 = Enabled

CTOS (Bit 3): Charging Timeout Suspended
0 = Disabled
1 = Enabled

CTO (Bit 2): Charging Timeout
0 = Disabled
1 = Enabled

PTOS (Bit 1): Precharging Timeout Suspend
0 = Disabled
1 = Enabled

PTO (Bit 0): Precharging Timeout
0 = Disabled
1 = Enabled

3.2 Cell Undervoltage Protection

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

Upon CUV detection, a snapshot of the measured cell voltages are made available in *CUVSnapshot()*. This snapshot is available until the next instance of a CUV fault, as this causes the data to be updated to the latest set of measurements.

Status	Condition	Action
Normal	All Cell voltages in *Voltages()* > ***CUV:Threshold***	*SafetyAlert()[CUV]* = 0 *BatteryStatus()[TDA]* = 0
Alert	Any Cell voltages in *Voltages()* ≤ ***CUV:Threshold***	*SafetyAlert()[CUV]* = 1 *BatteryStatus()[TDA]* = 1
Trip	Any Cell voltages in *Voltages()* ≤ ***CUV:Threshold*** for ***CUV:Delay*** duration	*SafetyAlert()[CUV]* = 0 *SafetyStatus()[CUV]* = 1 *BatteryStatus()[FD]* = 1 *OperationStatus()[XCHG]* = 1 Discharging is not allowed.

Status	Condition	Action
Recovery	*SafetyStatus()[CUV]* = 1 AND All Cell voltages in *Voltages()* ≥ ***CUV:Recovery*** AND ***Protection Configuration[CUV_RECOV_CHG]*** = 0 OR ***[CUV_RECOV_CHG]*** = 1 AND Charging detected (that is, *BatteryStatus[DSG]* = 0)	*SafetyStatus()[CUV]* = 0 *BatteryStatus()[FD]* = 0, *[TDA]* = 0 *OperationStatus()[XCHG]* = 0 Discharging is allowed.

Class	Subclass	Name	Type	Min	Max	Default	Unit
Protections	CUV	Threshold	I2	0	5000	2500	mV
Protections	CUV	Delay	U1	0	255	2	s
Protections	CUV	Recovery	I2	0	5000	3000	mV

3.3 Cell Overvoltage Protection

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

Upon COV detection, a snapshot of the measured cell voltages are made available in *COVSnapshot()*. This snapshot is available until the next instance of a COV fault, as this causes the data to be updated to the latest set of measurements.

Status	Condition	Action
Normal	All voltages in *CellVoltages1..15()* < ***COV:Threshold***	*SafetyAlert()[COV]* = 0
Alert	Any voltage in *CellVoltages1..15()* ≥ ***COV:Threshold***	*SafetyAlert()[COV]* = 1 *BatteryStatus()[TCA]* = 1
Trip	Any voltage in *CellVoltages1..15()* ≥ ***COV:Threshold*** continuous ≥ ***COV:Threshold*** for ***COV:Delay*** duration	*SafetyAlert()[COV]* = 0 *SafetyAlert()[COV]* = 1 *BatteryStatus()[TCA]* = 0
Recovery	*SafetyStatus()[COV]* = 1 AND ***Protection Configuration:VAUXR*** = 0 all voltages in *CellVoltages1..15()* ≤ ***COV:Recovery***	*SafetyStatus()[COV]* = 0 *BatteryStatus()[TCA]* = 0
Recovery	*SafetyStatus()[COV]* = 1 AND ***Protection Configuration:VAUXR*** = 1 all voltages in *CellVoltages1..15()* ≤ ***COV:Recovery*** AND *VAUX()* < ***Power:Charger Present Threshold***	*SafetyStatus()[COV]* = 0 *BatteryStatus()[TCA]* = 0

Class	Subclass	Name	Type	Min	Max	Default	Unit
Protections	COV	Threshold	I2	0	32767	4300	mV
Protections	COV	Delay	U1	0	255	2	s
Protections	COV	Recovery	I2	0	32767	4100	mV

3.4 Overcurrent in Charge Protection

The device has overcurrent in charge protection that can be configured to specific current and delay thresholds to accommodate charging behaviors.

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

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Protections	OCC	Threshold	I2	–32768	32767	6000	mA	Overcurrent in Charge trip threshold
Protections	OCC	Delay	U1	0	255	6	s	Overcurrent in Charge trip delay
Protections	OCC	Recovery Threshold	I2	–32768	32767	–200	mA	Overcurrent in Charge 1 and 2 recovery threshold
Protections	OCC	Recovery Delay	U1	0	255	5	s	Overcurrent in Charge 1 and 2 recovery delay

3.5 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()* > ***OCD:Threshold***	*SafetyAlert()[OCD]* = 0
Alert	*Current()* ≤ ***OCD:Threshold***	*SafetyAlert()[OCD]* = 1
Trip	*Current()* continuous ≤ ***OCD:Threshold*** for ***OCD:Delay*** duration	*SafetyAlert()[OCD]* = 0 *SafetyStatus()[OCD]* = 1 *OperationStatus()[XCHG]* = 1 Discharging is not allowed.
Recovery	*[SafetyStatus()[OCD]* = 1 AND ***Protection Configuration:VAUXR*** = 0 *Current()* continuous ≥ ***OCD:Recovery Threshold*** for ***OCD:Recovery Delay*** time	*SafetyStatus()[OCD]* = 0 *OperationStatus()[XCHG]* = 0 Discharging is allowed.
Recovery	*[SafetyStatus()[OCD]* = 1 AND ***Protection Configuration:VAUXR*** = 1 *Current()* continuous ≥ ***OCD:Recovery Threshold*** for ***OCD:Recovery Delay*** time OR *VAUX()* ≥ ***Power:Charger Present Threshold***	*SafetyStatus()[OCD]* = 0 *OperationStatus()[XCHG]* = 0 Discharging is allowed.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Protections	OCD	Threshold	I2	–32768	32767	–6000	mA	Overcurrent in Discharge trip threshold
Protections	OCD	Delay	U1	0	255	6	s	Overcurrent in Discharge trip delay
Protections	OCD	Recovery	I2	–32768	32767	200	mA	Overcurrent in Discharge 1 and 2 recovery threshold
Protections	OCD	Recovery Delay	U1	0	255	5	s	Overcurrent in Discharge 1 and 2 recovery delay

3.6 Hardware-Based Protection

The bq78350 device has two main hardware-based protections, AOLD and ASCD, with adjustable current and delay time. Setting ***ASCD Threshold and Delay [RSNS]*** doubles the threshold value. It is located in bit 8 of the ***ASCD Threshold Delay*** register. 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.

For details on how to configure the AFE hardware protection, refer to the tables in the companion data manual, *bq769x0 3-Series to 15-Series Cell Battery Monitor Family for Li-Ion and Phosphate Applications* (SLUSBK2).

All of the hardware-based protections provide a short term Trip/Alert/Recovery protection to account for a current spike as well as a Trip/Alert/Latch protection for persistent faulty condition. The latch feature also stops the FETs from toggling on and off continuously, preventing damage to the FETs.

In general, when a fault is detected after the ***Delay*** time, the DSG FET will be disabled. However, if ***Protection Configuration [LPEN]*** is set, then both FETs are turned off (Trip stage), and an internal fault counter will be incremented (Alert stage). As the DSG FET is turned off, the current will drop to 0 mA. After ***Recovery*** time, the CHG and DSG FETs will be turned on again (Recovery stage) unless additional recovery conditions are enabled.

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/Alert/Recovery cycle. The internal fault counter is incremented every time the device goes through the Trip/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. If Latch Limit is set to 0, it will latch after the first detection.

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

3.6.1 Overload in Discharge Protection

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

Status	Condition	Action
Normal	*Current()* > (***AOLD Threshold and Delay[3:0]***/R_{SENSE})	*SafetyAlert()[AOLDL]* = 0, if AOLDL counter = 0
Alert	AOLDL counter > 0	*SafetyAlert()[AOLDL]* = 1 Decrement AOLDL counter by one after each ***AOLD:Counter Dec Delay*** period
Trip	*Current()* continuous ≤ (***AOLD Threshold and Delay[3:0]***/R_{SENSE}) for ***AOLD Threshold and Delay[6:4]*** duration	*SafetyStatus()[AOLD]* = 1 *OperationStatus()[XCHG]* = 1 DSG FET is disabled. Increment AOLDL counter
Latch	AOLDL counter ≥ ***AOLD:Latch Limit***	*SafetyAlert()[AOLDL]* = 0 *SafetyStatus()[AOLDL]* = 1 *OperationStatus()[XCHG]* = 1 DSG FET is disabled.
Recovery	*SafetyStatus()[AOLD]* = 1 for ***AOLD:Recovery*** time OR If ***Protection Configuration [LPEN]*** = 1 AND *AFEStatus()[LOAD_PRESENT]*= 0	*SafetyStatus()[AOLD]* = 0 *OperationStatus()[XCHG]* = 0 DSG FET returns to normal if *SafetyStatus[AOLDL]* = 0.
Latch Reset	*SafetyStatus()[AOLDL]* = 1 for A***OLD:Reset*** time	*SafetyStatus()[AOLDL]* = 0 Reset AOLDL counter *OperationStatus()[XCHG]* = 0 DSG FET returns to normal if *SafetyStatus()[AOLD]* = 0.

Class	Subclass	Name	Type	Min	Max	Default	Unit
Protections	AOLD	Threshold and Delay	H1	0x00	0xFF	0x00	—
Protections	AOLD	Latch Limit	U1	0	255	0	counts
Protections	AOLD	Counter Dec Delay	U1	0	255	10	s
Protections	AOLD	Recovery	U1	0	255	5	s
Protections	AOLD	Reset	U1	0	255	15	s

This register is representative of the bq769x0 PROTECT 2 register.

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Settings	AOLD	Threshold and Delay	Hex	1	0x00	0xFF	0x00	—

7	6	5	4	3	2	1	0
RSVD	OCD_D2	OCD_D1	OCD_D0	OCD_T3	OCD_T2	OCD_T1	OCD_T0

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

OCD_D2:0 (Bits 6–4): OCD Thresholds Delay Time

000 = 8 ms
001 = 20 ms
010 = 40 ms
011 = 80 ms
100 = 160 ms
101 = 320 ms
110 = 640 ms
111 = 1280 ms

OCD_T3:0 (Bits 3–0): OCD Thresholds with RSNS = 1

0000 = 17 mv
0001 = 22 mv
0010 = 28 mv
0011 = 33 mv
0100 = 39 mv
0101 = 44 mv
0110 = 50 mv
0111 = 56 mv
1000 = 61 mv
1001 = 67 mv
1010 = 72 mv
1011 = 78 mv
1100 = 83 mv
1101 = 89 mv
1110 = 94 mv
1111 = 100 mv

OCD_T3:0 (Bits 3–0): OCD Thresholds with RSNS = 0

0000 = 8 mv
0001 = 11 mv
0010 = 14 mv
0011 = 17 mv
0100 = 19 mv
0101 = 25 mv
0110 = 28 mv
0111 = 31 mv
1000 = 31 mv
1001 = 33 mv
1010 = 36 mv
1011 = 39 mv
1100 = 42 mv
1101 = 44 mv
1110 = 47 mv
1111 = 50 mv

3.6.2 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()* > (***ASCD Threshold and Delay[2:0]***/R_{SENSE})	*SafetyAlert()[ASCDL]* = 0, if ASCDL counter = 0
Alert	ASCDL counter > 0	*SafetyAlert()[ASCDL]* = 1 Decrement ASCDL counter by one after each ***SCD:Counter Dec Delay*** period
Trip	*Current()* continuous ≤ (***ASCD Threshold and Delay[2:0]***/R_{SENSE}) for ***ASCD Threshold and Delay[7:4]*** duration	*SafetyStatus()[ASCD]* = 1 *OperationStatus()[XCHG]* = 1 DSG FET is disabled. Increment ASCDL counter
Latch	ASCD counter ≥ ***ASCD:Latch Limit***	*SafetyStatus()[ASCD]* = 0 *SafetyStatus()[ASCDL]* = 1 *OperationStatus()[XCHG]* = 1 DSG FET is disabled.
Recovery	*SafetyStatus()[ASCD]* = 1 for ***ASCD:Recovery*** time OR If ***Protection Configuration [LPEN]*** = 1 AND *AFEStatus()[LOAD_PRESENT]*= 0	*SafetyStatus()[ASCD]* = 0 *OperationStatus()[XCHG]* = 0 DSG FET returns to normal if *SafetyStatus()[ASCDL]* = 0.
Latch Reset	*SafetyStatus()[ASCDL]* = 1 for ***ASCD:Reset*** time	*SafetyStatus()[ASCDL]* = 0 *OperationStatus()[XCHG]* = 0 DSG FET returns to normal if *SafetyStatus()[ASCD]* = 0.

Class	Subclass	Name	Type	Min	Max	Default	Unit
Protections	ASCD	Threshold and Delay	H1	0x00	0xFF	0x00	—
Protections	ASCD	Latch Limit	U1	0	255	0	counts
Protections	ASCD	Counter Dec Delay	U1	0	255	10	s
Protections	ASCD	Recovery	U1	0	255	5	s
Protections	ASCD	Reset	U1	0	255	15	s

This register is representative of the bq769x0 PROTECT 1 register.

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Settings	ASCD	Threshold and Delay	Hex	1	0x00	0xFF	0x00	—

7	6	5	4	3	2	1	0
RSNS	RSVD	RSVD	SCD_D1	SCD_D0	SCD_T2	SCD_T1	SCD_T0

LEGEND: RSVD = Reserved Location

RSNS (Bit 7): AOLD and ASCD Thresholds Divisor

0 = 0.5 × AFE Protection Thresholds (default)

1 = Normal AFE Protection Thresholds

RSVD (Bits 6–5): Reserved. Do not use.

SCD_D1:0 (Bit 4–3): ASCD Thresholds Delay Time

00 = 70 µs

01 = 100 µs

10 = 200 µs

11 = 400 µs

SCD_T2:0 (Bit 2–0): ASCD Thresholds Delay Time with RSNS = 1

000 = 44 mv

001 = 67 mv

010 = 89 mv
011 = 111 mv
100 = 133 mv
101 = 155 mv
110 = 178 mv
111 = 200 mv

SCD_T2:0 (Bit 2–0): ASCD Thresholds Delay Time with RSNS = 0

000 = 22 mv
001 = 33 mv
010 = 44 mv
011 = 56 mv
100 = 67 mv
101 = 78 mv
110 = 89 mv
111 = 100 mv

3.7 Temperature Protections

The device provides overtemperature and undertemperature protections based on Cell 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 either three external thermistors or three internal temperature sensors. The selection of Internal or External temperature sensors is set by ***Settings:Temperature Enable[SOURCE]***. Unused temperature sensors should be disabled by clearing the corresponding flag in ***Settings:Temperature Enable[TS3][TS2][TS1]***.

The *Temperature()* command returns the Cell Temperature measurement. The MAC and extended command *DAStatus2()* also returns the temperature measurement from the enabled temperature sensors and the Cell Temperature.

The Cell Temperature based overtemperature and undertemperature safety provide protections in charge and discharge conditions. The battery pack is considered in CHARGE mode when *Battery[DSG]* = 0, where *Current()* > ***Chg Current Threshold***. The overtemperature and undertemperature in charging protections are active in this mode. The *Battery[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.

3.7.1 Overtemperature in Charge Protection

The device has an overtemperature protection for cells under charge.

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

Class	Subclass	Name	Type	Min	Max	Default	Unit
Protections	OTC	Threshold	I2	–400	1500	550	0.1°C
Protections	OTC	Delay	U1	0	255	2	s
Protections	OTC	Recovery	I2	–400	1500	500	0.1°C

3.7.2 Overtemperature in Discharge Protection

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

Status	Condition	Action
Normal	Cell Temperature in *Temperatures()* < ***OTD:Threshold*** OR charging	*SafetyAlert()[OTD]* = 0
Alert	Cell Temperature in *Temperatures()* ≥ ***OTD:Threshold*** AND not charging (that is, *BatteryStatus[DSG]* = 1)	*SafetyAlert()[OTD]* = 1
Trip	Cell Temperature in *Temperatures()* ≥ ***OTD:Threshold*** AND not charging (that is, *BatteryStatus[DSG]* = 1) for ***OTD:Delay*** duration	*SafetyAlert()[OTD]* = 0 *SafetyStatus()[OTD]* = 1 *BatteryStatus()[OTA]* = 1 Discharging is disabled AND *OperationStatus()[XCHG]* = 1 if ***FET Options[OTFET]*** = 1.
Recovery	*SafetyStatus()[OTD]* AND Cell Temperature in *Temperatures()* ≤ ***OTD:Recovery***	*SafetyStatus()[OTD]* = 0 *BatteryStatus()[OTA]* = 0 Discharging is allowed AND *OperationStatus()[XCHG]* = 0 if FET Options[OTFET] = 1.

Class	Subclass	Name	Type	Min	Max	Default	Unit
Protections	OTD	Threshold	I2	–400	1500	600	0.1°C
Protections	OTD	Delay	U1	0	255	2	s
Protections	OTD	Recovery	I2	–400	1500	550	0.1°C

3.7.3 Undertemperature in Charge Protection

The device has an undertemperature protection for cells in charge direction (that is, with *BatteryStatus[DSG]* = 0).

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

Class	Subclass	Name	Type	Min	Max	Default	Unit
Protections	UTC	Threshold	I2	–400	1500	0	0.1°C
Protections	UTC	Delay	U1	0	255	2	s
Protections	UTC	Recovery	I2	–400	1500	50	0.1°C

3.7.4 Undertemperature in Discharge Protection

The device has an undertemperature protection for cells in DISCHARGE 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

Class	Subclass	Name	Type	Min	Max	Default	Unit
Protections	UTD	Threshold	I2	–400	1500	0	0.1°C
Protections	UTD	Delay	U1	0	255	2	s
Protections	UTD	Recovery	I2	–400	1500	50	0.1°C

3.8 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()[PCHG]* = 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 Charging is not allowed.
Reset	*SafetyStatus()[PTO]* = 1 AND (Discharge by an amount of ***PTO:Reset***)	Stop and reset PTO timer *SafetyAlert()[PTOS]* = 0 *SafetyStatus()[PTO]* = 0 *BatteryStatus()[TCA]* = 0 Charging is allowed.

Class	Subclass	Name	Type	Min	Max	Default	Unit
Protections	PTO	Charge Threshold	I2	–32768	32767	2000	mA
Protections	PTO	Suspend Threshold	I2	–32768	32767	1800	mA
Protections	PTO	Delay	U2	0	65535	1800	s
Protections	PTO	Reset	I2	–32768	32767	2	mA

3.9 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	Start CTO timer *SafetyAlert()[CTOS]* = 0
Suspend or Recovery	*Current()* < CTO:Suspend Threshold	Stop CTO timer *SafetyAlert()[CTOS]* = 1
Trip	CTO time > CTO:Delay	Stop CTO timer *SafetyStatus()[CTO]* = 1 *BatteryStatus()[TCA]* = 1 Charging is not allowed.

Status	Condition	Action
Reset	*SafetyStatus()[CTO]* = 1 AND (Discharge by an amount of ***CTO:Reset***)	Stop and reset CTO timer *SafetyAlert()[CTOS]* = 0 *SafetyStatus()[CTO]* = 0 *BatteryStatus()[TCA]* = 0 Charging is allowed.

Class	Subclass	Name	Type	Min	Max	Default	Unit
Protections	CTO	Charge Threshold	I2	–32768	32767	2500	mA
Protections	CTO	Suspend Threshold	I2	–32768	32767	2000	mA
Protections	CTO	Delay	U2	0	65535	54000	s
Protections	CTO	Reset	I2	–32768	32767	2	mA

3.10 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()*	*SafetyAlert()[OC]* = 1
Trip	*RemainingCapacity()* ≥ *FullChargeCapacity()* + ***OC:Threshold***	*SafetyAlert()[OC]* = 0 *SafetyStatus()[OC]* = 1 *BatteryStatus()[TCA]* = 1, *[OCA]* = 1 if the device is in CHARGE state (that is, *BatteryStatus[DSG]* = 0). Charging is not allowed.
Recovery	*SafetyStatus()[OC]* = 1 AND continuous discharge of ***Recovery*** OR *RemainingStateOfCharge()* < ***OC:RSOC Recovery***	*SafetyStatus()[OC]* = 0 *BatteryStatus()[TCA]* = 0, *[OCA]* = 0 Charging is allowed.

Class	Subclass	Name	Type	Min	Max	Default	Unit
Protections	OC	Threshold	I2	–32768	32767	300	mAh
Protections	OC	Recovery	I2	–32768	32767	2	mAh
Protections	OC	RSOC Recovery	U1	0%	100%	90%	

Permanent Fail

4.1 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
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 Status***, ***AFE Config***, ***AFE VCx***, and ***AFE Data***.
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()*
   - TS1, TS2, and TS3 from *DAStatus2()*
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 SAFE Voltage*** or there is a CHG FET (CFETF) or DSG FET (DFETF) failure. The SAFE pin will remain asserted until the ***SAFE Blow Timeout*** expired.

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 SAFE pin. In addition, new *PFStatus()* flags are recorded in the Black Box Recorder 2nd and 3rd PF Status entries.

4.2 Permanent Failure Configuration

The following configuration registers allow the various permanent failure detection features to be enabled or disabled. If disabled (default), the feature takes no action including setting flags in *PFAlert()* or *PFStatus()*.

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Settings	Permanent Failure	Enabled PF A	Hex	1	0x00	0xFF	0x00	—

7	6	5	4	3	2	1	0
DFETF	CFETF	VIMR	SOT	SOCD	SOCC	SOV	SUV

DFETF (Bit 7): Discharge FET
- 1 = Enabled
- 0 = Disabled (default)

CFETF (Bit 6): Charge FET
- 1 = Enabled
- 0 = Disabled (default)

VIMR (Bit 5): Voltage imbalance at rest
- 1 = Enabled
- 0 = Disabled (default)

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 overvoltage
- 1 = Enabled
- 0 = Disabled (default). This feature cannot be stopped from turning the appropriate FETs OFF as this is a hardware feature of the companion AFE.

SUV (Bit 0): Safety undervoltage
- 1 = Enabled
- 0 = Disabled (default). This feature cannot be stopped from turning the appropriate FETs OFF as this is a hardware feature of the companion AFE.

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Settings	Permanent Failure	Enabled PF B	Hex	1	0x00	0xFF	0x00	—

7	6	5	4	3	2	1	0
RSVD	TS3	TS2	TS1	AFE_XRDY	AFE_OVRD	AFEC	AFER

RSVD (Bit 7): Reserved

TS3 (Bit 6): Temperature sensor 3
- 1 = Enabled
- 0 = Disabled (default)

TS2 (Bit 5): Temperature sensor 2
- 1 = Enabled
- 0 = Disabled (default)

TS1 (Bit 4): Temperature sensor 1
- 1 = Enabled
- 0 = Disabled (default)

AFE_XRDY (Bit 3): Companion AFE XREADY
- 1 = Enabled
- 0 = Disabled (default)

AFE_OVRD (Bit 2): Companion AFE OVERRIDE
- 1 = Enabled
- 0 = Disabled (default)

AFEC (Bit 1): AFE Communication
- 1 = Enabled
- 0 = Disabled (default)

AFER (Bit 0): AFE Register
- 1 = Enabled
- 0 = Disabled (default)

4.3 Enabling Use of the SAFE Pin

The AFE pin can be enabled or disabled for use for any of the enabled protections through the settings in the following:

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Settings	Fuse	PF SAFE A	Hex	1	0x00	0xFF	0x00	—

7	6	5	4	3	2	1	0
DFETF	CFETF	VIMR	SOT	SOCD	SOCC	SOV	SUV

DFETF (Bit 7): Discharge FET
- 1 = Enabled
- 0 = Disabled (default)

CFETF (Bit 6): Charge FET
- 1 = Enabled
- 0 = Disabled (default)

VIMR (Bit 5): Voltage Imbalance at Rest
- 1 = Enabled
- 0 = Disabled (default)

SOT(Bit 4): Safety over temperature

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 Overvoltage

1 = Enabled

0 = Disabled (default)

SUV (Bit 0): Safety Undervoltage

1 = Enabled

0 = Disabled (default)

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Settings	Fuse	PF SAFE B	Hex	1	0x00	0xFF	0x00	—

7	6	5	4	3	2	1	0
RSVD	TS3	TS2	TS1	AFE_XRDY	AFE_OVRD	AFEC	AFER

RSVD (Bit 7): Reserved

TS3 (Bit 6): TS3

1 = Enabled

0 = Disabled (default)

TS2 (Bit 5): TS2

1 = Enabled

0 = Disabled (default)

TS1 (Bit 4): TS1

1 = Enabled

0 = Disabled (default)

AFE_XRDY (Bit 3): AFE XREADY

1 = Enabled

0 = Disabled (default)

AFE_OVRD (Bit 2): AFE Override

1 = Enabled

0 = Disabled (default)

AFEC (Bit 1): AFE Communication

1 = Enabled

0 = Disabled (default)

AFER (Bit 0): AFE Register

1 = Enabled
0 = Disabled (default)

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Settings	Fuse	PF SAFE C	Hex	1	0x00	0xFF	0x00	—

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	DFW	IFC

RSVD (Bits 7–2): Reserved

DFW (Bit 1): Data flash write

1 = Enabled
0 = Disabled (default)

IFC (Bit 0): Instruction flash checksum

1 = Enabled
0 = Disabled (default)

The bq78350 has a minimum voltage required to attempt to blow a fuse through SAFE activation. This is a pack-based value of 3500 mV. This value is automatically internally adjusted for any VSCALE setting. FET failures bypass this requirement to activate SAFE.

4.4 Safety Cell Undervoltage Permanent Fail

The bq78350 uses the UV Protection function of the companion AFE for this feature and can be configured to permanently disable the battery in the case of severe undervoltage in any of the cells. This feature cannot be disabled.

The voltage threshold setting is set in ***AFE SUV:Threshold***, which the device will map to the available settings in the companion AFE with the maximum setting of 3131 mV and the minimum of 1568 mV.

The delay timing configuration for this feature is combined in the same register with the delay time of the Safety Overvoltage feature.

Status	Condition	Action
Normal	*AFEStatus() [UV]* = 0	*PFStatus()[SUV]* = 0
Trip	*AFEStatus() [UV]* = 1	*PFStatus()[SUV]* = 1 *BatteryStatus()[FD]* = 1 *BatteryStatus()[TDA]* = 1 *BatteryStatus()[TCA]* = 1

Class	Subclass	Name	Type	Min	Max	Default	Unit
Permanent Fail	AFE SUV	Threshold	I2	0	32767	1750	mV
Permanent Fail	AFE SOV/AFE SUV	SOV and SUV Delay	U1	0	255	2	s

This register is representative of the bq769x0 PROTECT 3 register.

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Settings	AFE SOV/AFE SUV	SOV and SUV Delay	Hex	1	0x00	0xF0	0x50	—

7	6	5	4	3	2	1	0
SUV_D1	SUV_D0	SOV_D1	SOV_D0	RSVD	RSVD	RSVD	RSVD

LEGEND: R/W = Read/Write; R = Read only; -*n* = value after reset

SUV_D1:0 (Bit 7–6): Safety Undervoltage Delay Time

00 = 1 s
01 = 4 s
10 = 8 s
11 = 16 s

SOV_D1:0 (Bit 7–6): Safety Overvoltage Delay Time

00 = 1 s
01 = 4 s
10 = 8 s
11 = 16 s

011 = 111 mv
100 = 133 mv
101 = 155 mv
110 = 178 mv
111 = 200 mv

SCD_T2:0 (Bit 4–3): ASCD Thresholds Delay Time with RSNS = 0

000 = 22 mv
001 = 33 mv
010 = 44 mv
011 = 56 mv
100 = 67 mv
101 = 78 mv
110 = 89 mv
111 = 100 mv

RSVD: (Bits 2–0): Reserved

4.5 Safety Cell Overvoltage Permanent Fail

The bq78350 uses the OV Protection function of the companion AFE for this feature and can be configured to permanently disable the battery in the case of severe overvoltage in any of the cells. This feature cannot be disabled.

The voltage threshold setting is set in ***AFE SOV:Threshold***, which the device will map to the available settings in the companion AFE with the maximum setting of 4703 mV and the minimum of 3140 mV.

The delay timing configuration for this feature is combined in the same register with the delay time of the Safety Undervoltage feature.

Status	Condition	Action
Normal	*AFEStatus() [OV]* = 0	*PFStatus()[SOV]* = 0
Trip	*AFEStatus() [OV]* = 1	*PFStatus()[SOV]* = 1 *BatteryStatus()[TDA]* = 1 *BatteryStatus()[TCA]* = 1

Class	Subclass	Name	Type	Min	Max	Default	Unit
Permanent Fail	AFE SOV	Threshold	I2	0	32767	4350	mV

4.6 Safety Overcurrent in Charge Permanent Fail

The device can permanently disable the battery in the case of a 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]* = 0 *PFStatus()[SOCC]* = 1 *BatteryStatus()[TCA]* = 1 *BatteryStatus()[TDA]* =1 *BatteryStatus()[OCA]* = 1

4.7 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()[SOCD]* = 1 *BatteryStatus()[TDA]* = 1
Trip	*Current()* ≤ ***SOCD:Threshold*** for ***SOCD:Delay*** duration	*PFAlert()[SOCD]* = 0 *PFStatus()[SOCD]* = 1 *BatteryStatus()[TCA]* = 1 *BatteryStatus()[TDA]* =1

4.8 Safety Overtemperature Permanent Fail

The device can permanently disable the battery pack in case of severe overtemperature of the cells detected using the external TS1...3 temperature sensor(s), which are configured to report *Temperature()*. The *Temperature()* measurement configuration is controlled by setting the corresponding flag in ***DA Configuration***.

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

Class	Subclass	Name	Type	Min	Max	Default	Unit
Permanent Fail	SOT	Threshold	I2	–400	1500	650	0.1°C
Permanent Fail	SOT	Delay	U1	0	255	5	s

4.9 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	*CellVoltage1..15()* < ***VIMR:Check Voltage*** OR |*Current()*| > ***VIMR:Check Current*** OR Δ(*CellVoltage1..15()*) < ***VIMR:Delta Threshold***	*PFAlert()[VIMR]* = 0
Alert	Any(*CellVoltage1..15()*) ≥ ***VIMR:Check Voltage*** AND |*Current()*| < ***VIMR:Check Current*** for ***VIMR:Duration*** AND Δ(*CellVoltage1..15()*) ≥ ***VIMR:Delta Threshold***	*PFAlert()[VIMR]* = 1
Trip	Any(*CellVoltage1..15()*) ≥ ***VIMR:Check Voltage*** AND |*Current()*| < ***VIMR:Check Current*** for ***VIMR:Duration*** AND Δ(*CellVoltage1..15()*) ≥ ***VIMR:Delta Threshold*** for ***VIMR:Delta Delay***	*PFAlert()[VIMR]* = 0 *PFStatus()[VIMR]* = 1 *BatteryStatus()[TCA]* = 1 *BatteryStatus()[TDA]* = 1

Class	Subclass	Name	Type	Min	Max	Default	Unit
Permanent Fail	VIMR	Check Voltage	I2	0	5000	5000	mV
Permanent Fail	VIMR	Check Current	I2	0	32767	10	mA
Permanent Fail	VIMR	Delta Threshold	I2	0	5000	500	mV
Permanent Fail	VIMR	Delta Delay	U1	0	255	5	s
Permanent Fail	VIMR	Duration	U2	0	65535	100	s

4.10 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 *BatteryStatus()[TCA]* = 1 *BatteryStatus()[TDA]* = 1

Class	Subclass	Name	Type	Min	Max	Default	Unit
Permanent Fail	CFETF	OFF Threshold	I2	0	500	5	mA
Permanent Fail	CFETF	Delay	U1	0	255	5	s

4.11 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 *BatteryStatus()[TCA]* = 1 *BatteryStatus()[TDA]* = 1

Class	Subclass	Name	Type	Min	Max	Default	Unit
Permanent Fail	DFET	OFF Threshold	I2	–500	0	–5	mA
Permanent Fail	DFET	Delay	U1	0	255	5	s

4.12 External Override Permanent Fail

The device can detect an external override signal sent to the companion bq769x0 AFE, which can cause permanent failure of the battery. This can be used to indicate to the bq78350 that an external circuit, such as an independent voltage protection circuit, has disabled the battery permanently.

Status	Condition	Action
Normal	*AFESysStat() [OVRD_ALERT]* = 0	*PFAlert()[AFE_OVRD]* = 0
Alert	*AFESysStat() [OVRD_ALERT]* = 1	*PFAlert()[AFE_OVRD]* = 1
Trip	*AFESysStat() [OVRD_ALERT]* = 1 continuously for ***AFE External Override: Delay*** duration	*PFAlert()[AFE_OVRD]* = 0 *PFStatus()[AFE_OVRD]* = 1

Class	Subclass	Name	Type	Min	Max	Default	Unit
Permanent Fail	AFE External Override	Delay	U1	0	255	5	s

4.13 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 *BatteryStatus()[TCA]* = 1 *BatteryStatus()[TDA]* = 1

Class	Subclass	Name	Type	Min	Max	Default	Unit
Permanent Fail	AFER	Threshold	U1	0	255	100	counts
Permanent Fail	AFER	Delay Period	U1	0	255	2	s
Permanent Fail	AFER	Compare Period	U1	0	255	5	s

4.14 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***

Status	Condition	Action
Trip	Read and Write Fail counter ≥ ***AFEC:Threshold***	*PFAlert()[AFEC]* = 0 *PFStatus()[AFEC]* = 1

Class	Subclass	Name	Type	Min	Max	Default	Unit
Permanent Fail	AFEC	Threshold	U1	0	255	100	counts
Permanent Fail	AFEC	Delay Period	U1	0	255	5	s

4.15 AFE XREADY Permanent Fail

The companion bq769x0 AFE includes an internal self check, and if this check fails, then the XREADY bit is set. Each time the bq78350 reads the AFE it checks this bit, and if it is set, then increments an internal counter. If this counter reaches a configurable limit, then the device disables the pack permanently.

Status	Condition	Action
Normal	XREADY counter = 0	*PFAlert()[AFE_XRDY]* = 0
Alert	XREADY counter > 0	*PFAlert()[AFE_XRDY]* = 1 Decrement AFE_XRDY counter by one after each ***AFE XREADY:Delay*** period
Trip	XREADY counter ≥ ***XREADY: Threshold***	*PFAlert()[AFE_XRDY]* = 0 *PFStatus()[AFE_XRDY]* = 1

Class	Subclass	Name	Type	Min	Max	Default	Unit
Permanent Fail	AFE XREADY	Threshold	U1	0	255	100	counts
Permanent Fail	AFE XREADY	Delay Period	U1	0	255	5	s

4.16 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 *BatteryStatus()[TCA]* = 1 *BatteryStatus()[TDA]* = 1

4.17 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 *BatteryStatus()[TCA]* = 1 *BatteryStatus()[TDA]* = 1

4.18 Open Thermistor Permanent Fail (TS1, TS2, TS3)

The device can permanently disable the battery if it detects an open thermistor on TS1, TS2, or TS3.. This feature is only available when the bq78350 is used in conjunction with the bq76930 or the bq76940.

Status	Condition	Action
Normal	TS1 Temperature > ***Open Thermistor:Threshold***	*PFAlert()[TS1]* = 0
Normal	TS2 Temperature > ***Open Thermistor:Threshold***	*PFAlert()[TS2]* = 0
Normal	TS3 Temperature > ***Open Thermistor:Threshold***	*PFAlert()[TS3]* = 0
Alert	TS1 Temperature ≤ ***Open Thermistor:Threshold***	*PFAlert()[TS1]* = 1
Alert	TS2 Temperature ≤ ***Open Thermistor:Threshold***	*PFAlert()[TS2]* = 1
Alert	TS3 Temperature ≤ ***Open Thermistor:Threshold***	*PFAlert()[TS3]* = 1
Trip	TS1 Temperature ≤ ***Open Thermistor:Threshold*** for ***Open Thermistor:Delay*** duration	*PFAlert()[TS1]* = 0 *PFStatus()[TS1]* = 1 *BatteryStatus()[TCA]* = 1 *BatteryStatus()[TDA]* = 1
Trip	TS2 Temperature ≤ ***Open Thermistor:Threshold*** for ***Open Thermistor:Delay*** duration	*PFAlert()[TS2]* = 0 *PFStatus()[TS2]* = 1 *BatteryStatus()[TCA]* = 1 *BatteryStatus()[TDA]* = 1
Trip	TS3 Temperature ≤ ***Open Thermistor:Threshold*** for ***Open Thermistor:Delay*** duration	*PFAlert()[TS3]* = 0 *PFStatus()[TS3]* = 1 *BatteryStatus()[TCA]* = 1 *BatteryStatus()[TDA]* = 1

Class	Subclass	Name	Type	Min	Max	Default	Unit
Permanent Fail	Open Thermistor	Threshold	I2	0	32767	2232	0.1°K
Permanent Fail	Open Thermistor	Delay	U1	0	255	5	s

4.19 PF Status Snapshot Data Flash

4.19.1 Device Status Data

Class	Subclass	Name	Type	Min	Max	Default	Description
PF Status	Device Status Data	Safety Alert A	H1	0x00	0xFF	0	Accumulated safety flags since PF event
PF Status	Device Status Data	Safety Status A	H1	0x00	0xFF	0	Accumulated safety flags since PF event
PF Status	Device Status Data	Safety Alert B	H1	0x00	0xFF	0	Accumulated safety flags since PF event
PF Status	Device Status Data	Safety Status B	H1	0x00	0xFF	0	Accumulated safety flags since PF event
PF Status	Device Status Data	Safety Alert C	H1	0x00	0xFF	0	Accumulated safety flags since PF event
PF Status	Device Status Data	Safety Status C	H1	0x00	0xFF	0	Accumulated safety flags since PF event
PF Status	Device Status Data	Safety Alert D	H1	0x00	0xFF	0	Accumulated safety flags since PF event
PF Status	Device Status Data	Safety Status D	H1	0x00	0xFF	0	Accumulated safety flags since PF event
PF Status	Device Status Data	PF Alert A	H1	0x00	0xFF	0	Accumulated PF flags since PF event
PF Status	Device Status Data	PF Status A	H1	0x00	0xFF	0	Accumulated PF flags since PF event
PF Status	Device Status Data	PF Alert B	H1	0x00	0xFF	0	Accumulated PF flags since PF event
PF Status	Device Status Data	PF Status B	H1	0x00	0xFF	0	Accumulated PF flags since PF event
PF Status	Device Status Data	PF Alert C	H1	0x00	0xFF	0	Accumulated PF flags since PF event
PF Status	Device Status Data	PF Status C	H1	0x00	0xFF	0	Accumulated PF flags since PF event
PF Status	Device Status Data	PF Alert D	H1	0x00	0xFF	0	Accumulated PF flags since PF event

Class	Subclass	Name	Type	Min	Max	Default	Description
PF Status	Device Status Data	PF Status D	H1	0x00	0xFF	0	Accumulated PF flags since PF event
PF Status	Device Status Data	SAFE Flag	H2	0x0000	0xFFFF	0	Flag set to indicate SAFE activation
PF Status	Device Status Data	Operation Status A	H2	0x0000	0xFFFF	0	*OperationStatus()* data at the time of the PF event
PF Status	Device Status Data	Operation Status B	H2	0x0000	0xFFFF	0	*OperationStatus()* data at the time of the PF event
PF Status	Device Status Data	Charging Status A	H1	0x00	0xFF	0	*ChargingStatus()* data at the time of the PF event
PF Status	Device Status Data	Charging Status B	H1	0x00	0xFF	0	*ChargingStatus()* data at the time of the PF event
PF Status	Device Status Data	Gauging Status A	H1	0x00	0xFF	0	*ChargingStatus()* data at the time of the PF event
PF Status	Device Status Data	Gauging Status B	H2	0x0000	0xFFFF	0	*ChargingStatus()* data at the time of the PF event

4.19.2 Device Voltage Data

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
PF Status	Device Voltage Data	Cell Voltage 1	I2	0	32767	0	mV	Cell 1 voltage
PF Status	Device Voltage Data	Cell Voltage 2	I2	0	32767	0	mV	Cell 2 voltage
PF Status	Device Voltage Data	Cell Voltage 3	I2	0	32767	0	mV	Cell 3 voltage
PF Status	Device Voltage Data	Cell Voltage 4	I2	0	32767	0	mV	Cell 4 voltage
PF Status	Device Voltage Data	Cell Voltage 5	I2	0	32767	0	mV	Cell 5 voltage
PF Status	Device Voltage Data	Cell Voltage 6	I2	0	32767	0	mV	Cell 6 voltage
PF Status	Device Voltage Data	Cell Voltage 7	I2	0	32767	0	mV	Cell 7 voltage
PF Status	Device Voltage Data	Cell Voltage 8	I2	0	32767	0	mV	Cell 8 voltage
PF Status	Device Voltage Data	Cell Voltage 9	I2	0	32767	0	mV	Cell 9 voltage
PF Status	Device Voltage Data	Cell Voltage 10	I2	0	32767	0	mV	Cell 10 voltage
PF Status	Device Voltage Data	Cell Voltage 11	I2	0	32767	0	mV	Cell 11 voltage
PF Status	Device Voltage Data	Cell Voltage 12	I2	0	32767	0	mV	Cell 12 voltage
PF Status	Device Voltage Data	Cell Voltage 13	I2	0	32767	0	mV	Cell 13 voltage
PF Status	Device Voltage Data	Cell Voltage 14	I2	0	32767	0	mV	Cell 14 voltage
PF Status	Device Voltage Data	Cell Voltage 15	I2	0	32767	0	mV	Cell 15 voltage
PF Status	Device Voltage Data	Bat Direct Voltage	I2	0	32767	0	mV	Cell stack voltage

4.19.3 Device Current Data

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
PF Status	Device Current Data	Current	I2	–32768	32767	0	mA	*Current()*

4.19.4 Device Temperature Data

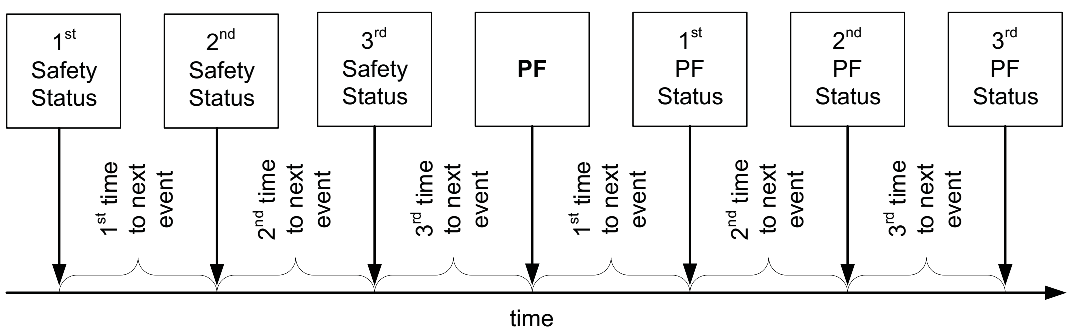
Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
PF Status	Device Temperature Data	TS1 Temperature	I2	0	9999	0	0.1°K	TS1 temperature
PF Status	Device Temperature Data	TS2 Temperature	I2	0	9999	0	0.1°K	TS2 temperature
PF Status	Device Temperature Data	TS3 Temperature	I2	0	9999	0	0.1°K	TS3 temperature

4.19.5 AFE Regs

Class	Subclass	Name	Type	Length in Bytes	Min	Max	Default
PF Status	AFE Regs	AFE Sys Stat	H1	1	0x00	0xFF	0x00
PF Status	AFE Regs	AFE Cell Balance 1	H1	1	0x00	0xFF	0x00
PF Status	AFE Regs	AFE Cell Balance 2	H1	1	0x00	0xFF	0x00
PF Status	AFE Regs	AFE Cell Balance 3	H1	1	0x00	0xFF	0x00
PF Status	AFE Regs	AFE Sys Control 1	H1	1	0x00	0xFF	0x00
PF Status	AFE Regs	AFE Sys Control 2	H1	1	0x00	0xFF	0x00
PF Status	AFE Regs	AFE Protection 1	H1	1	0x00	0xFF	0x00
PF Status	AFE Regs	AFE Protection 2	H1	1	0x00	0xFF	0x00
PF Status	AFE Regs	AFE Protection 3	H1	1	0x00	0xFF	0x00
PF Status	AFE Regs	AFE OV Trip	H1	1	0x00	0xFF	0x00
PF Status	AFE Regs	AFE UV Trip	H1	1	0x00	0xFF	0x00

4.20 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 in addition to 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.

4.20.1 Black Box Recorded Data

4.20.1.1 Safety Status

Class	Subclass	Name	Type	Min	Max	Default
Black Box	Safety Status	1st Safety Status 0–7	H1	0x00	0xFF	0
Black Box	Safety Status	1st Safety Status 8–15	H1	0x00	0xFF	0
Black Box	Safety Status	1st Safety Status 16–23	H1	0x00	0xFF	0
Black Box	Safety Status	1st Safety Status 24–31	H1	0x00	0xFF	0
Black Box	Safety Status	1st Time to Next Event	U1	0	255	0
Black Box	Safety Status	2nd Safety Status 0–7	H1	0x00	0xFF	0
Black Box	Safety Status	2nd Safety Status 8–15	H1	0x00	0xFF	0
Black Box	Safety Status	2nd Safety Status 16–23	H1	0x00	0xFF	0
Black Box	Safety Status	2nd Safety Status 24–31	H1	0x00	0xFF	0
Black Box	Safety Status	2nd Time to Next Event	U1	0	255	0
Black Box	Safety Status	3rd Safety Status 0–7	H1	0x00	0xFF	0
Black Box	Safety Status	3rd Safety Status 8–15	H1	0x00	0xFF	0
Black Box	Safety Status	3rd Safety Status 16–23	H1	0x00	0xFF	0
Black Box	Safety Status	3rd Safety Status 24–31	H1	0x00	0xFF	0
Black Box	Safety Status	3rd Time to Next Event	U1	0	255	0

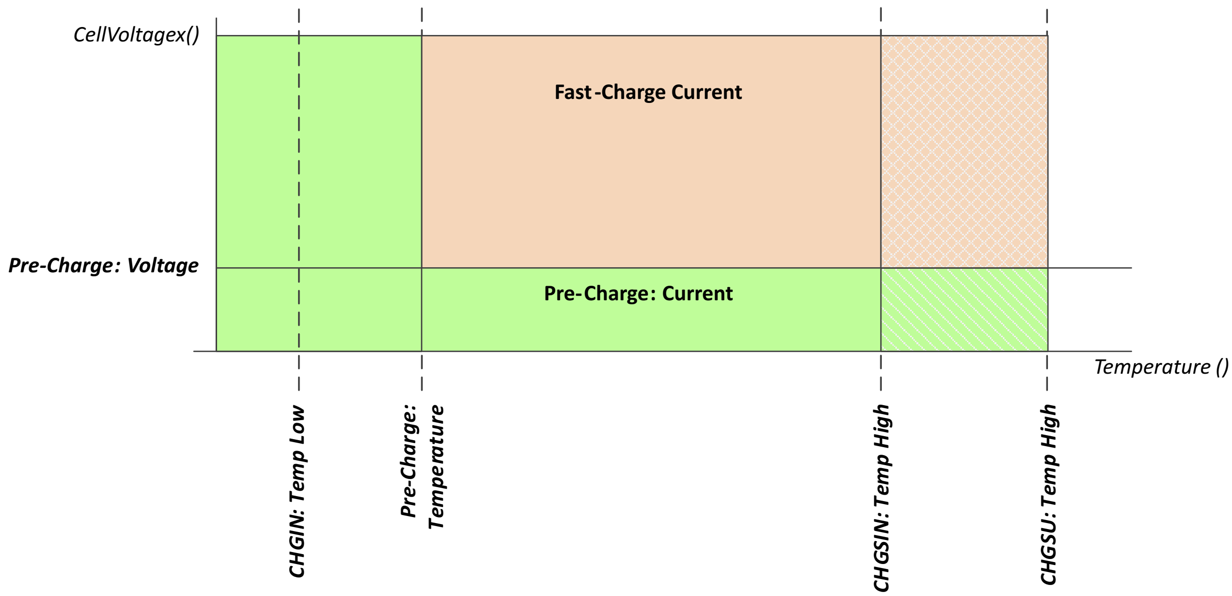
4.20.1.2 PF Status

Class	Subclass	Name	Type	Min	Max	Default
Black Box	PF Status	1st PF Status 0–7	H2	0x0000	0xFFFF	0
Black Box	PF Status	1st PF Status 8–15	H2	0x0000	0xFFFF	0
Black Box	PF Status	1st PF Status 16–23	H2	0x0000	0xFFFF	0
Black Box	PF Status	1st PF Status 24–31	H2	0x0000	0xFFFF	0
Black Box	PF Status	1st Time to Next Event	U1	0	255	0
Black Box	PF Status	2nd PF Status 0–8	H2	0x0000	0xFFFF	0
Black Box	PF Status	2nd PF Status 9–15	H2	0x0000	0xFFFF	0
Black Box	PF Status	2nd PF Status 16–23	H2	0x0000	0xFFFF	0
Black Box	PF Status	2nd PF Status 24–32	H2	0x0000	0xFFFF	0
Black Box	PF Status	2nd Time to Next Event	U1	0	255	0
Black Box	PF Status	3rd PF Status 0–8	H2	0x0000	0xFFFF	0
Black Box	PF Status	3rd PF Status 9–15	H2	0x0000	0xFFFF	0
Black Box	PF Status	3rd PF Status 16–23	H2	0x0000	0xFFFF	0
Black Box	PF Status	3rd PF Status 24–32	H2	0x0000	0xFFFF	0
Black Box	PF Status	3rd Time to Next Event	U1	0	255	0

Charge Algorithm

5.1 Introduction

The device can change the values of *ChargingVoltage()* and *ChargingCurrent()* based on *Temperature()*, *Cell Voltage1..15()* and system fault conditions. The *ChargingStatus()* register shows the state of the charging algorithm.



5.2 Fast and Pre-Charging

The charging algorithm adjusts *ChargingCurrent()* and *ChargingVoltage()* to allow the appropriate charging conditions to be read.

Current State	Condition	Action
Fast Charging	*Temperature()* > ***Precharge Temp*** + ***Hysteresis Temp*** AND ALL *CellVoltages1..15()* > Pre-Charging: Recovery Voltage AND *GaugingStatus() [EDV0]* = 0	*ChargingStatus()[FCHG]* = 1 *ChargingStatus()[PCHG]* = 0 *ChargingVoltage()* = ***Fast Charging: Voltage*** *ChargingCurrent()* = ***Fast Charging: Current***
Pre-Charging	*Temperature()* ≤ Pre-Charging: ***Precharge Temp*** + ***Hysteresis Temp*** OR ANY *CellVoltages1..15()* ≤ Pre-Charging: Start Voltage OR *GaugingStatus() [EDV0]* = 1	*ChargingStatus()[FCHG]* = 0 *ChargingStatus()[PCHG]* = 1 *ChargingVoltage()* = ***Fast Charging: Voltage*** *ChargingCurrent()* = ***Pre-Charging: Current***

Depending on the ***FET Options[PCHG_EN]*** settings, the external precharge FET or CHG FET can be used in PRE-CHARGE mode. Setting the ***Pre-Charging Current*** = 0 mA disables the precharge function by requesting 0 mA charging current from the charger.

FET Options[PCHG_EN]	FET Used
0	PCHG
1	CHG

Class	Subclass	Name	Type	Min	Max	Default	Unit
Charge Algorithm	Fast Charging	Voltage	I2	0	5000	4200	mV
Charge Algorithm	Fast Charging	Current	I2	0	32767	3000	mA
Charge Algorithm	Pre-Charging	Current	I2	0	32767	100	mA
Charge Algorithm	Pre-Charging	Start Voltage	I2	0	32767	2500	mV
Charge Algorithm	Pre-Charging	Recovery Voltage	I2	0	32767	2900	mV

5.3 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 ***FETOption[CHGFET] = 1***, CHG FET turns off.
- If ***CEDV 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()[REST]* = 0 AND *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 (*CellVoltage1..15()*) + ***Charge Term Voltage*** ≥ *ChargingVoltage()*/number of cells in series AND The accumulated change in capacity > 0.25 mAh since current and voltage termination conditions where first detected.	*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

Class	Subclass	Name	Type	Min	Max	Default	Unit
Charging Algorithms	Termination Config	Charge Term Taper Current	I2	0	32767	250	mA
Charging Algorithms	Termination Config	Charge Term Voltage	I2	0	32767	75	mV

5.4 Charge and Discharge Alarms

The *[TCA]* and *[FC]* bits in *BatteryStatus()* can be set at charge termination as well as based on RSOC when the device is in CHARGE state (that is, *BatteryStatus[DSG]* = 0). If more than one set and clear conditions are selected, then the corresponding flag will be set whenever a valid set or clear condition is met. The same functionality is applied to the *[TDA]* and *[FD]* bits in *BatteryStatus()*.

Per the *Smart Battery Data Specification v1.1*, TDA is only active while discharging and TCA is only active while charging but the bq78350 will only follow this particular requirement if ***SOC Flag Config [SBS_COMP]*** = 1. By default, the TCA and TDA flags will not change based on current magnitude or direction.

NOTE: In *BatteryStatus()*, the *[TCA]* and *[FC]* bits, as well as the *[TDA]* and *[FD]* bits, are also set and cleared based on safety and permanent fail protections. In *GaugingStatus()*, however, these bits do not react on the safety protections.

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***.

The *GaugingStatus[TC][TD]* flags are not the same as the *BatteryStatus[TCA][TDA]* flags. The *[TCA]* and *[TDA]* flags can be set or cleared by the gauging event or by the safety or PF events. These flags also clear if charging current is not present. The *[TC]* and *[TD]* flags, however, only set and clear by a gauging event.

GaugingStatus[FC][FD] has the same behavior as *BatteryStatus[FC][FD]*.

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]	RSOC	*RelativeStateOfCharge()* > = ***TC: Set % RSOC Threshold***	***SOC Flag Config [TCSetRSOC]*** = 1
	Valid Charge Termination (enable by default)	When *ChargingStatus[VCT]* = 1	***SOC Flag Config [TCSetVCT]*** = 1
[FC]	RSOC	*RelativeStateOfCharge()* > = ***FC: Set % RSOC Threshold***	***SOC Flag Config [FCSetRSOC]*** = 1
	Valid Charge Termination (enable by default)	When *ChargingStatus[VCT]* = 1	***SOC Flag Config [FCSetVCT]*** = 1

Flag	Clear Criteria	Clear Condition	Enable
[TC]	RSOC (enable by default)	*RelativeStateOfCharge()* ≤ ***TC: Clear % RSOC Threshold***	***SOC Flag Config [TCClearRSOC]*** = 1
[FC]	RSOC (enable by default)	*RelativeStateOfCharge()* ≤ ***FC: Clear % RSOC Threshold***	***SOC Flag Config [FCClearRSOC]*** = 1

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

Flag	Set Criteria	Set Condition	Enable
[TD]	RSOC (enable by default)	*RelativeStateOfCharge()* < = ***TD: Set % RSOC Threshold***	***SOC Flag Config [TDSetRSOC]*** = 1
[FD]	RSOC (enable by default)	*RelativeStateOfCharge()* < = ***FD: Set % RSOC Threshold***	***SOC Flag Config [FDSetRSOC]*** = 1

Flag	Clear Criteria	Clear Condition	Enable
[TD]	RSOC (enable by default)	*RelativeStateOfCharge()* ≥ ***TD: Clear % RSOC Threshold***	***SOC Flag Config [TDClearRSOC]*** = 1
[FD]	RSOC (enable by default)	*RelativeStateOfCharge()* ≥ ***FD: Clear % RSOC Threshold***	***SOC Flag Config [FDClearRSOC]*** = 1

The SOC configuration is stored in the following data flash.

Table 5-1. SOC FLAG Config

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Settings	Configuration	SOC Flag Config	Hex	2	0x0000	0xFFFF	0x02FB	

15	14	13	12	11	10	9	8
RSVD	RSVD	RSVD	SBS_COMP	RSVD	RSVD	FCCLEARRSOC	FCSETRSOC
7	6	5	4	3	2	1	0
FDCLEARRSOC	FDSETRSOC	TCSETVCT	FCSETVCT	TCCLEARRSOC	TCSETRSOC	TDCLEARRSOC	TDSETRSOC

RSVD (Bits 11–10): Reserved

SMB_COMP (Bit 12): Enable SOC FLAG Smart Battery Standard specification compliance

1 = Enabled

0 = Disabled (default)

RSVD (Bits 11–10): Reserved

FCCLEARRSOC (Bit 9): Enable FC flag clear by RSOC threshold

1 = Enabled (default)

0 = Disabled

FCSETRSOC (Bit 8): Enable FC flag set by RSOC threshold

1 = Enabled

0 = Disabled (default)

FDCLEARRSOC (Bit 7): Enable TC flag set by primary charge

1 = Enabled (default)

0 = Disabled

FDSETRSOC (Bit 6): Enable FD flag set by RSOC threshold

1 = Enabled (default)

0 = Disabled

TCSETVCT (Bit 5): Enable TC flag set by primary charge

1 = Enabled (default)

0 = Disabled

FCSETVCT (Bit 4): Enable FC flag set by primary charge

1 = Enabled (default)

0 = Disabled

TCCLEARRSOC (Bit 3): Enable TC flag clear by RSOC threshold

1 = Enabled (default)

0 = Disabled

TCSETRSOC (Bit 2): Enable TC flag set by RSOC threshold

1 = Enabled

0 = Disabled (default)

TDCLEARRSOC (Bit 1): TDCLEARRSOC—Enable TD flag clear by RSOC threshold

1 = Enabled (default)

0 = Disabled

TDSETRSOC (Bit 0): TDSETRSOC—Enable TD flag set by RSOC threshold

1 = Enabled (default)

0 = Disabled

Class	Subclass	Name	Type	Min	Max	Default
Fuel Gauging	FD	Set RSOC % Threshold	U1	0%	100%	0%
Fuel Gauging	FD	Clear RSOC % Threshold	U1	0%	100%	5%
Fuel Gauging	FC	Set RSOC % Threshold	U1	0%	100%	100%
Fuel Gauging	FC	Clear RSOC % Threshold	U1	0%	100%	95%
Fuel Gauging	TD		U1	0%	100%	6%
Fuel Gauging	TD	Clear RSOC % Threshold	U1	0%	100%	8%
Fuel Gauging	TC	Set RSOC % Threshold	U1	0%	100%	100%
Fuel Gauging	TC	Clear RSOC % Threshold	U1	0%	100%	95%

5.5 Charge Disable

The device can disable charging if certain safety conditions are detected setting the *OperationStatus()[XCHG]* = 1.

Status	Condition	Action
Normal	*ALL PFStatus()* = 0 AND *SafetyStatus()[COV]* = 0 AND *SafetyStatus()[OTC]* = 0 AND *SafetyStatus()[UTC]* = 0 AND *SafetyStatus()[OCC]* = 0 AND *SafetyStatus()[CTO]* = 0 AND *SafetyStatus()[PTO]* = 0 AND *GaugingStatus()[TCA]* = 0 if ***Charging Configuration[CHGFET]*** = 1	*ChargingVoltage()* = Charging Algorithm *ChargingCurrent()* = Charging Algorithm
Trip	*ANY PFStatus()* = 1 OR *SafetyStatus()[COV]* = 1 OR *SafetyStatus()[OTC]* = 1 OR *SafetyStatus()[UTC]* = 1 OR *SafetyStatus()[OCC]* = 1 OR *SafetyStatus()[CTO]* = 1 OR *SafetyStatus()[PTO]* = 1 OR *GaugingStatus()[TCA]* = 1 if ***Charging Configuration[CHGFET]*** = 1	*ChargingVoltage()* = 0 *ChargingCurrent()* = 0

5.6 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	*BatteryStatus()[DSG]* = 0 ***Charge Inhibit/Charge Suspend Low Temp*** + ***Hysteresis Temp*** < *Temperature()* < ***Charge Inhibit High Temp*** – ***Hysteresis Temp***	*ChargingStatus()[IN]* = 0 *ChargingVoltage()* = charging algorithm *ChargingCurrent()* = charging algorithm
Trip	*BatteryStatus()[DSG]* = 0 ***Charge Inhibit/Suspend Low Temp*** > *Temperature()* > ***Charge Inhibit Temp High***	*ChargingStatus()[IN]* = 1 *ChargingVoltage()* = 0 *ChargingCurrent()* = 0 No charging is allowed if ***FET Options[CHGIN]*** = 1.

Class	Subclass	Name	Type	Min	Max	Default	Unit
Charge Algorithm	Temperature Ranges	Charge Inhibit/Suspend Low Temp	I1	–127	128	0	°C
Charge Algorithm	Temperature Ranges	Pre-Charge Temp	I1	–127	128	12	°C
Charge Algorithm	Temperature Ranges	Charge Inhibit High Temp	I1	–127	128	45	°C
Charge Algorithm	Temperature Ranges	Hysteresis Temp	I1	–127	128	3	°C

5.7 Charge Suspend

The device can suspend charging at high and low temperatures to prevent damage of the cells. Care should be taken to ensure Charge Inhibit and Charge Suspend features are configured correctly as upon Charge Suspend detection [CHGSU=1], then Charge Inhibit detection criteria will have to be passed prior to restarting charge.

Status	Condition	Action
Normal	*BatteryStatus()[DSG]* = 0 ***Charge Inhibit/Suspend Low Temp*** < *Temperature()* < ***Charge Suspend High Temp***	*ChargingStatus()[SU]* = 0 *ChargingVoltage()* = charging algorithm *ChargingCurrent()* = charging algorithm
Trip	*BatteryStatus()[DSG]* = 0 ***Charge Inhibit/Suspend Low Temp*** > *Temperature()* > ***Charge Suspend High Temp***	*ChargingStatus()[SU]* = 1 *ChargingVoltage()* = 0 *ChargingCurrent()* = 0 No charging is allowed if ***FET Options[CHGSU]*** = 1.

Class	Subclass	Name	Type	Min	Max	Default	Unit
Charge Algorithm	Temperature Ranges	Charge Suspend High Temp	I1	–127	128	55	°C

System Present

6.1 Introduction

The bq78350 has the capability to detect the presence of a system and/or a charger through the state of the $\overline{PRES}$ pin. This can be used to disable the battery output when the bq78350 detects the battery has been removed from the system or charger.

6.2 System Present Detection and Action

The $\overline{PRES}$ pin is polled every 250 ms and if it is detected High for four consecutive 250-ms samples, then the CHG, DSG, and PCHG FETs are turned off. If $\overline{PRES}$ is detected Low, then the FETs are allowed to be turned on depending on other safety and charging related algorithms. If this feature is not required, then the $\overline{PRES}$ pin should be tied to VSS.

Cell Balancing

7.1 Introduction

Cell balancing in bq78350 is accomplished by connecting an external parallel bypass load to each cell of the associated AFE, and enabling the bypass load depending on each cell's charge state. The bypass load is typically formed by a P-CH MOSFET and a resistor connected in series across each battery cell. The filter resistors that connect the cell tabs to VC1~VC15 pins of the associated AFE are required to be 1 kΩ.

Using this circuit, the bq78350 balances the cells during charge by enabling the bypass around those cells above the threshold set in ***Cell Balance Threshold*** if the maximum difference in cell voltages exceeds the value programmed in ***Cell Balance Min***. During cell balancing, the bq78350 measures the cell voltages at an interval set in ***Cell Balance Interval***.

The cell(s) to be balanced are prioritized by highest cell voltage but the bq78350 will not try to balance adjacent cells. If adjacent cells are needing to be balanced the bq78350 will alternate between the highest and next-highest adjacent cells until they are balanced.

On the basis of the cell voltages, the bq78350 either selects the appropriate cell to discharge or adjusts the cell balance threshold up by the value programmed in ***Cell Balance Window*** when all cells exceed the cell balance threshold or the highest cell exceeds the cell balance threshold by the cell balance window.

More in-depth details and data on this cell balancing algorithm can be found in: http://www.ti.com/lit/slva155.

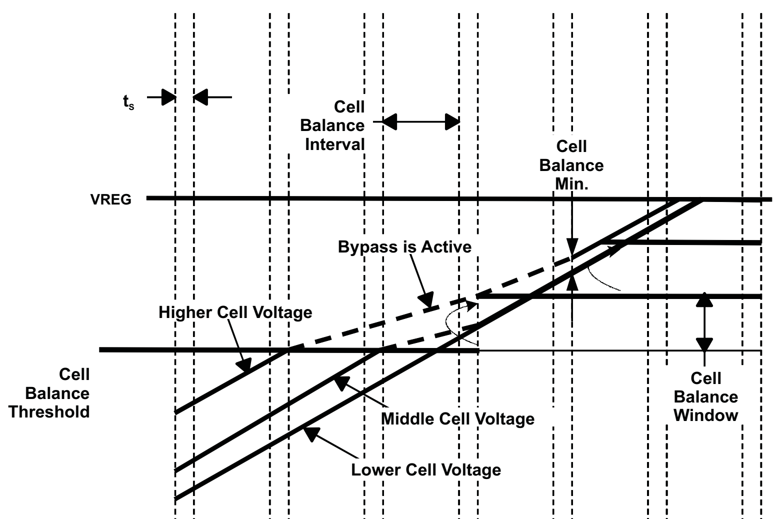


Figure 7-1. Cell Balancing

Cell balancing only occurs when charging current is detected, and on non-adjacent cells at the same time. The cell balance threshold is reset to the value in Cell Balance Threshold at the start of every charge cycle. The threshold is only adjusted once during any balance interval.

The configuration data flash is stored in ***Advanced Charging Algorithms: Cell Balancing Config.***

7.1.1 Cell Balancing Configuration

Class	Subclass	Name	Type	Min	Max	Default	Unit
Charge Algorithm	Cell Balancing Config	Cell Balance Threshold	I2	0	5000	3900	mV
Charge Algorithm	Cell Balancing Config	Cell Balance Window	I2	0	5000	100	mV
Charge Algorithm	Cell Balancing Config	Cell Balance Min	U1	0	255	40	mV
Charge Algorithm	Cell Balancing Config	Cell Balance Interval	U1	0	255	20	s

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Settings	Configuration	Balancing Configuration	Hex	1	0x00	0xFF	0x01	—

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	CB

RSVD (Bits 7–1): Reserved

CB (Bit 0): Cell balancing

1 = Enabled (default)

0 = Disabled

Power Modes

8.1 Introduction

To enhance battery life, the bq78350 supports several power modes to minimize power consumption during operation.

8.2 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 readings at 1-s intervals. Between these periods of activity, the device is in a reduced power state.

8.3 SLEEP Mode

8.3.1 Device Sleep

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

Status	Condition	Action
Activate	SMBus low for ***SBS Low Time***[1] AND ***DA Config[SLEEP]*** = 1[1] AND |*Current()*| ≤ ***Sleep Current*** AND ***Voltage Time*** > 0 AND *OperationStatus()[SDM]* = 0 AND No *PFAlert()* bits set AND No *PFStatus()* bits set AND No *SafetyAlert()* bits set AND No [AOLD], [AOLDL], [ASCD], [ASCDL] set in *SafetyStatus()*	Turn off CHG FET and PCHG FET if ***DA Configuration[SLEEPCHG]*** = 0 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 [2] OR ***DA Config[SLEEP]*** = 1[1] OR |*Current()*| > ***Sleep Current*** OR ***Voltage Time*** = 0 OR *OperationStatus()[SDM]* = 1 OR *PFAlert()* bits set OR *PFStatus()* bits set OR *SafetyAlert()* bits set OR *[AOLD], [AOLDL], [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) A wake on SMBus command is only possible when the gas gauge is put to sleep using the *ManufacturerAccess()* SLEEP mode command. Otherwise, the gas gauge wakes on an SMBus connection (clock or data high).

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

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Power	Sleep	Sleep Current	I2	0	32767	10	mA	|*Current()*| threshold to enter SLEEP mode
Power	Sleep	Voltage Time	U1	0	255	5	s	Voltage sampling period in SLEEP mode
Power	Sleep	Current Time	U1	0	255	20	s	Current sampling period in SLEEP mode

8.3.2 ManufacturerAccess() MAC Sleep

The Sleep MAC command can override the requirement for bus low to enter SLEEP. In this case, the clock and data high condition are 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.

8.4 SHUTDOWN Mode

8.4.1 Voltage Based Shutdown

To minimize power consumption and avoid draining the battery, the device can be configured to shutdown at a programmable voltage threshold. 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***. When the device is in PERMANENT FAILURE mode, the parameters ***PF Shutdown Voltage*** and ***PF Shutdown Time*** configure the voltage-based shutdown.

Status	Condition	Action
Enable	Min(Cell Voltage in *DAStatus1()*) < ***Shutdown Voltage***	*OperationStatus()[SDV]*= 1
Trip	Min(Cell Voltage in *Voltages()*) continuous < ***Shutdown Voltage*** for ***Shutdown Time***	Turn DSG FET off for ***Shutdown Time***
Shutdown	***Protection Configuration:VAUXR*** = 0	Send device into SHUTDOWN mode
Shutdown	***Protection Configuration:VAUXR*** = 1 AND *VAUX()* < ***Charger Present Threshold***	Send device into SHUTDOWN mode
Exit	Voltage at TS1 pin > V_{BOOT}	*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. The RAM data is re-loaded with a data flash setting. This is different than a partial reset, which could occur during a short power glitch. The device will check for the RAM integrity at partial reset, and if the data checksum is correct, RAM data will not be re-initialized.

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

Class	Subclass	Name	Type	Min	Max	Default	Unit
Power	Shutdown	Shutdown Voltage	I2	0	32767	1750	mV
Power	Shutdown	PF Shutdown Voltage	I2	0	32767	1750	mV
Power	Shutdown	Shutdown Time	U2	0	255	10	s
Power	Shutdown	PF Shutdown Time	U2	0	255	10	s
Power	Shutdown	Charger Present Threshold	I2	0	32767	3000	mV
Power	Ship	FET Off Time	U1	0	127	20	s
Power	Ship	Delay	U1	0	254	20	s

8.4.2 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 TS1 pin > V_{BOOT}. The device can be sent to this mode with the *ManufacturerAccess() Shutdown* command if *OperationStatus() [DSG]* = 1.

8.5 Power Mode Indication (PWRM)

The PWRM pin can be used to indicate the power mode of the bq78350. The PWRM has the following conditions:

- PWRM is high:
  - bq78350 is in NORMAL mode.
  - bq78350 is in SLEEP mode AND ***GaugeConfiguration[PWRMSleep]*** = 1.
- PWRM is High-Z:
  - bq78350 is in SLEEP mode AND ***GaugeConfiguration[PWRMSleep]*** = 0.
  - bq78350 is in SHUTDOWN mode.

This pin can be used to control other external circuit elements based on the power mode state of the bq78350.

CEDV Gas Gauging

9.1 Introduction

The bq78350 features the Compensated End-of-Discharge Voltage (CEDV) gauging algorithm, capable of gauging a Li-Ion or LiFEPO4 battery. The data from the gas gauge is in either mAh or mWh units based on the 0 or 1 setting of *[CapM]* in *GaugingStatus()*, and can be scaled per the *[IPScale]* setting in *SpecInfo()*.

The operational overview in Figure 9-1 illustrates the gas gauge operation of the bq78350.

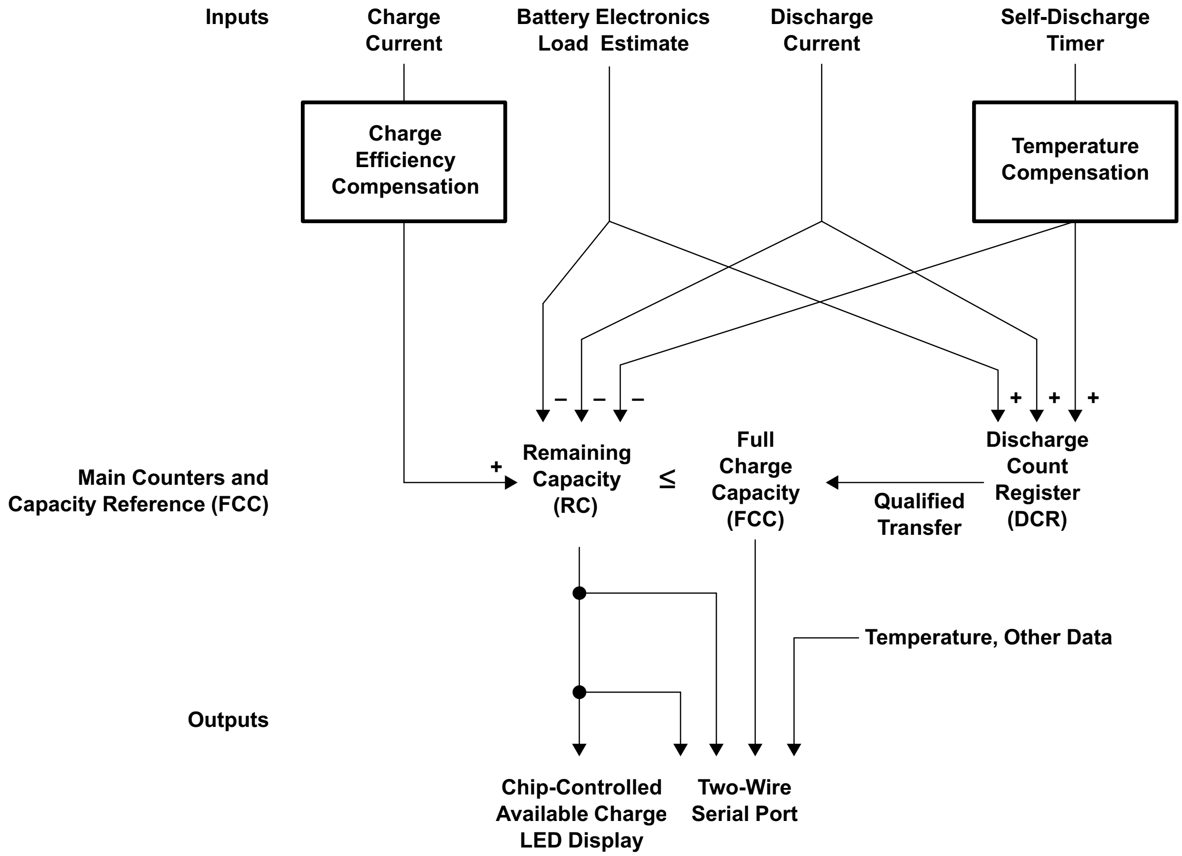


Figure 9-1. CEDV Operational Overview

The bq78350 accumulates the measured quantities of charge and discharge and estimates self-discharge of the battery. The bq78350 compensates the charge current measurement for temperature and state-of-charge of the battery. The bq78350 also adjusts the self-discharge estimation based on temperature.

9.1.1 Main Fuel Gauge Registers

The main charge counter, *RemainingCapacity()* (RC), represents the available capacity or energy in the battery at any given time. The bq78350 adjusts RC for charge, self-discharge, and other compensation factors. The information in the RC register is accessible through the SMBus.

The bq78350 computes RC in units based of the settings of two configuration bits, ***CapM*** and *SpecificationInfo()*. RC counts up during charge to a maximum value of FCC and down during discharge and self-discharge to a minimum of 0. In addition to charge and self-discharge compensation, the bq78350 calibrates RC at three low-battery-voltage thresholds, EDV2, EDV1, and EDV0. This provides a voltage-based calibration to the RC counter and is based on the lowest voltage measured at the BAT pin.

The Design Capacity (DC) register is the user-specified battery full capacity. It is calculated from ***Design Capacity*** and is represented in units set by ***CapM***. It also represents the full-battery reference for the absolute display mode and *AbsoluteStateOfCharge()*. In programming ***Design Capacity***, the value should not include the value programmed in ***Reserve Capacity***.

The *FullChargeCapacity()* (FCC) register represents the initial or last measured full discharge of the battery. It is used as the battery full-charge reference for relative capacity indication. The bq78350 updates FCC after the battery undergoes a qualified discharge from nearly full to a low battery level. FCC is accessible through the SMBus.

The bq78350 computes FCC in units based of the settings of two configuration bits, ***CapM*** and ***IPScale***. On initialization, the bq78350 sets FCC to the value stored in ***Full Charge Capacity***. During subsequent discharges, the bq78350 updates FCC with the last measured discharge capacity of the battery. The last measured discharge of the battery is based on the value in the DCR register after a qualified discharge occurs. Once updated, the bq78350 writes the new FCC value to data flash in mAh, scaled per the setting of ***IPScale***, to ***Full Charge Capacity***.

NOTE: Care should be taken to ensure that the correct scaling is used to ensure that the ***Full Charge Capacity*** does not exceed 65535 of the units configured by the scaling. If ***Full Charge Capacity*** is calculated to be above 65535, then it will roll over creating potentially uncorrectable error in the gauging algorithm.

9.1.2 Fuel Gauge Operating Modes

During a gauging operation, different features and functions occur based on whether the battery is discharging, charging, or in a rest state.

Entry and exit of each mode is controlled by data flash parameters in the subclass *Fuel Gauging: Current Thresholds* section.

- In RELAX mode or DISCHARGE mode, the *[DSG]* flag in *CEDVStatus()* is set.
- CHARGE mode is entered when *Current* goes above ***Chg Current Threshold***.
- 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***.

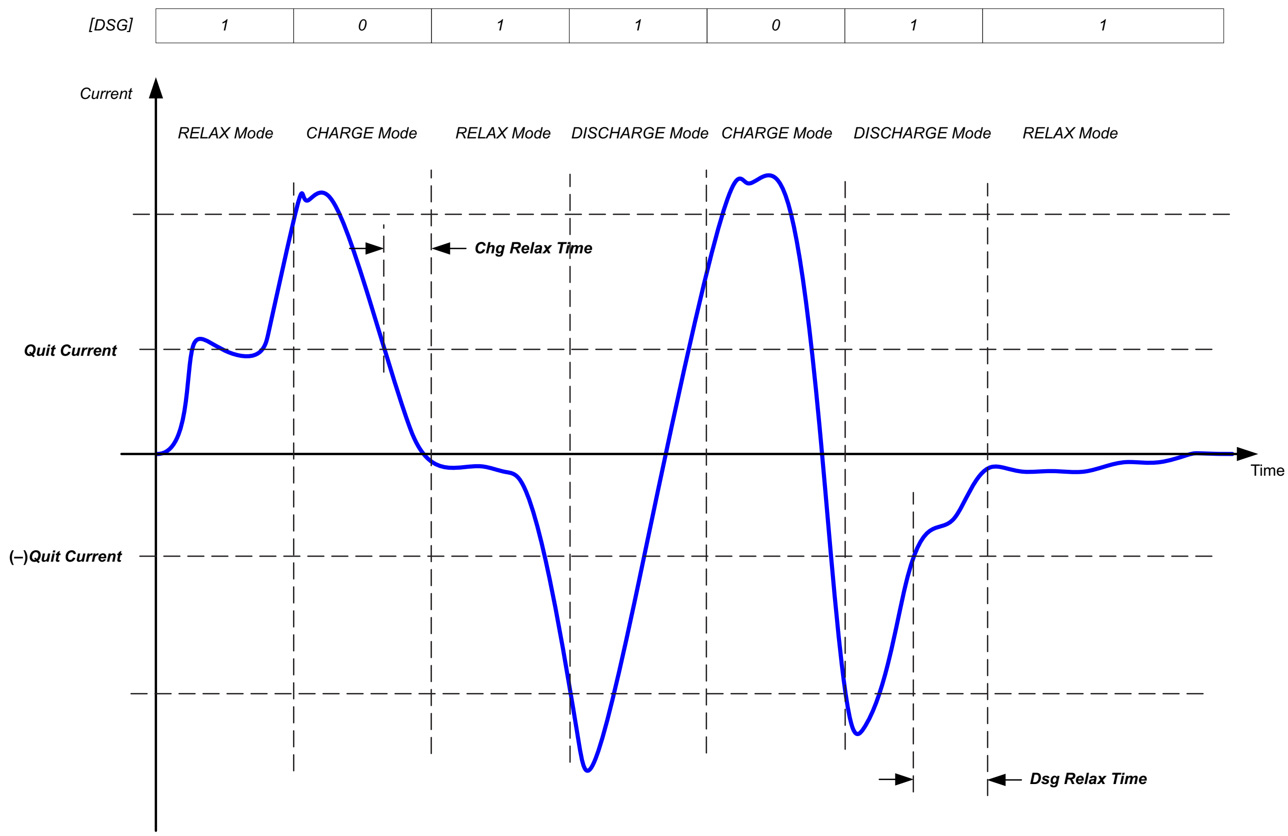


Figure 9-2. Fuel Gauge Operating Mode Example

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Fuel Gauging	Current Thresholds	Dsg Current Threshold	Unsigned Integer	2	0	2000	100	mA
Fuel Gauging	Current Thresholds	Dsg Relax Time	Unsigned Integer	1	0	255	1	s
Fuel Gauging	Current Thresholds	Chg Current Threshold	Unsigned Integer	2	0	2000	50	mA
Fuel Gauging	Current Thresholds	Chg Relax Time	Unsigned Integer	1	0	255	60	s
Fuel Gauging	Current Thresholds	Quit Current	Unsigned Integer	2	0	1000	10	mA

9.1.3 Qmax

The Qmax Pack value is used for initial capacity (RC and RSOC) estimated in conjunction with the cell voltages and programmed chemistry information when the device resets. The ***Qmax Pack*** value should be taken from the cell manufacturers' data sheet multiplied by the number of parallel cells.

Typically, set this value to a room temperature, low-rate (0.2°C ~ 0.5°C) discharge capacity (usually available from the battery cell data sheet). If the data is not available, set this to ***Full Charge Capacity***.

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Fuel Gauging	State	Qmax Pack	Integer	2	0	32767	4400	mAh

9.1.4 Full Charge Capacity

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Fuel Gauging	State	Learned Full Charge Capacity	Unsigned Integer	2	0	65535	4400	mAh or 10 mWh

FCC also represents the full battery reference for the relative display mode and *RelativeStateOfCharge()* calculations.

The *DischargeCountRegister()* (DCR) register that tracks discharge of the battery. The bq78350 uses the DCR register to update the FCC register if the battery undergoes a qualified discharge from nearly full to a low battery level. In this way, the bq78350 learns the true discharge capacity of the battery under system-use conditions.

The DCR counts up during discharge, independent of RC. DCR counts discharge activity, battery load estimation, and self-discharge increments. The bq78350 initializes DCR at the beginning of a discharge to FCC – RC when RC is within the programmed value in ***Near Full***. The DCR initial value of FCC – RC is reduced by FCC/128 if ***SC*** = 1, and is not reduced if ***SC*** = 0. The DCR stops counting when the battery voltage reaches the EDV2 threshold on discharge.

9.1.5 Initial Battery Capacity at Device Reset

The bq78350 estimates the initial capacity of a battery pack at device reset, which is the case when battery cell(s) are first attached to the application circuit. The initial FCC is a direct copy of ***Full Charge Capacity***. The initial RC and RSOC are estimated using the open-circuit voltage (OCV) characteristics of the programmed Li-Ion chemistry (default ID1210), ***DOD at EDV2***, and ***Qmax Pack***. When assessing the RC vs. OCV correlation, the bq78350 uses the applicable *CellVoltage1..15()* data even if *ExtAveCellVoltage()* data is available. Upon the update of RC and RSOC based on the OCV data, then *BatteryMode() [CF]* flag will be cleared. This gives a reasonably accurate and RSOC; however, battery capacity learning is required in order to determine the most accurate FCC, RC, and RSOC.

During battery capacity learning, ***Full Charge Capacity*** and ***DOD at EDV2*** will be learned and updated. ***Full Charge Capacity*** should be initialized to the ***Design Capacity***. DOD at EDV2 should be initialized to (1 – Battery Low%) × 16384, where Battery Low% = ***Battery_Low%*** ÷ 2.56.

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Fuel Gauging	State	DOD at EDV2	Integer	2	0	16384	15232	—

9.1.6 Capacity Learning (FCC Update)

The bq78350 updates FCC with an amount based on the value in DCR if a qualified discharge occurs. The new value for FCC equals the DCR value plus the value of nearly full and low battery levels, as shown in the following equation:

FCC (new) = DCR (final) = DCR (initial) + Measured Discharge to EDV2 + (FCC × ***Battery_Low%***)

Where ***Battery_Low%*** = (Battery Low%) ÷ 2.56

The new value of FCC can be limited to not go above the ***Design Capacity*** value if ***FCC_LIMIT*** in ***CEDV Gauging Configuration*** is set.

NOTE: ***Learned Full Charge Capacity*** limits an update to a minimum of 100.

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Fuel Gauging	CEDV Cfg	Battery Low%	Unsigned Integer	2	0	65535	700	0.01%
Fuel Gauging	State	Learned Full Charge Capacity	Integer	2	0	32767	4400	mAh

Battery_Low% should be set to match a capacity value that corresponds to the first or highest voltage point, EDV2. It should be chosen where the capacity sensitivity to voltage is easily detectable. It is a non-measured portion of the overall ***Learned Full Charge Capacity***. If the target ***Battery_Low%*** is changed in the design, ensure that the initial value of ***DOD at EDV2*** is also adjusted accordingly.

9.1.7 Qualified Discharge

A qualified discharge occurs if the battery discharges from RC ≥ FCC – ***Near Full*** to the EDV2 voltage threshold with the following conditions:

- No valid charge activity occurs during the discharge period. A valid charge is defined as a charge of 10 mAh into the battery.
- No more than 256 mAh of self-discharge or battery load estimation occurs during the discharge period.
- The temperature does not drop below the low temperature thresholds programmed in ***Low Temp*** during the discharge period.
- The battery voltage reaches the EDV2 threshold during the discharge period and the voltage is greater than or equal to the EDV2 threshold minus 256 mV when the bq78350 detected EDV2.
  - When ***CEDV Gauging Configuration [VFLT_EN]*** is set, a filter is added to the EDV detection that is set by ***CEDV Min Delta V*** to improve false triggering under pulsed load activity. If the latest compensated EDV2 voltage changes by more than CEDV Min Delta V from the previously calculated value, then the previous one is not updated.
- *Current()* remains ≥ ***Overload Current*** when EDV2 is reached.
- No overload condition exists when EDV2 threshold is reached, or if RC has dropped to ***Battery_Low %*** × FCC.

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Fuel Gauging	CEDV Cfg	Near Full	Integer	2	0	65535	200	mAh or 10 mWh
Fuel Gauging	CEDV Cfg	Learning Low Temp	Integer	2	–100	255	119	0.1°C
Fuel Gauging	CEDV Cfg	Min Delta V Filter	Integer	2	0	32767	10	mV

The bq78350 sets [VDQ] = 1 in *CEDVStatus()* when a qualified discharge begins. The bq78350 sets *[VDQ]* = 0 if any disqualifying condition occurs. One complication may arise regarding the state of [VDQ] if ***[CSYNC]*** is set in ***CEDV Gauging Configuration***. When ***[CSYNC]*** is enabled, RC is written to equal FCC on valid primary charge termination. This capacity synchronization is done even if the condition RC ≥ FCC – ***Near Full*** is NOT satisfied at charge termination.

FCC cannot be reduced by more than ***FCC Learn Down*** or increased by more than ***FCC Learn Up*** during any single update cycle. The bq78350 saves the new FCC value to the data flash within 4 s of being updated.

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Fuel Gauging	CEDV Cfg	FCC Learn Down	Integer	2	0	65535	256	mAh or 10 mWh
Fuel Gauging	CEDV Cfg	FCC Learn Up	Integer	2	0	65535	512	mAh or 10 mWh

9.1.8 End-of-Discharge Thresholds and Capacity Correction

The bq78350 monitors the battery for three low-voltage thresholds, EDV0, EDV1, and EDV2. The bq78350 uses the lowest, single-cell value from individual cell voltage measurements for EDV threshold comparison when ***CEDV Gauging Configuration [EDV_EXT_CELL]*** = 0. However, if this bit = 1, then the *ExternalCellVoltage()* is used.

With either Compensated or Fixed EDV configurations, the configured voltage to be used must be equal to or below the appropriate voltage for the corresponding ***EDV2,1,0 Hold Time*** to ensure correct detection under all load types. EDV1 Detection and its associated hold time do not begin until EDV2 has been detected and the EDV2 flag is set. Similarly, EDV0 detection does not begin before the EDV1 flag is set.

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Fuel Gauging	CEDV Cfg	Fixed EDV0	Integer	2	0	32767	3031	mV
Fuel Gauging	CEDV Cfg	Fixed EDV1	Integer	2	0	32767	3385	mV
Fuel Gauging	CEDV Cfg	Fixed EDV2	Integer	2	0	32767	3501	mV
Fuel Gauging	CEDV Cfg	EDV0 Hold Time	Unsigned Integer	1	1	255	1	s
Fuel Gauging	CEDV Cfg	EDV1 Hold Time	Unsigned Integer	1	1	255	1	s
Fuel Gauging	CEDV Cfg	EDV2 Hold Time	Unsigned Integer	1	1	255	1	s

If the ***[EDV_CMP]*** bit in ***CEDV Gauging Configuration*** is set, automatic EDV compensation is enabled and the bq78350 computes the EDV0, EDV1, and EDV2 thresholds based on values stored in ***CEDV Cfg*** subclass of data flash and the battery's current discharge rate and temperature. However, if ***[FIXED_EDV0]*** bit in ***CEDV Gauging Configuration*** is set, then even if [EDV_CMP] = 1, then EDV0 is a fixed voltage value and is not compensated.

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Fuel Gauging	CEDV Cfg	EMF	Unsigned Integer	2	0	65535	3743	mV
Fuel Gauging	CEDV Cfg	EDV C0 Factor	Unsigned Integer	2	0	65535	149	—
Fuel Gauging	CEDV Cfg	EDV R0 Factor	Unsigned Integer	2	0	65535	867	—
Fuel Gauging	CEDV Cfg	EDV T0 Rate Factor	Unsigned Integer	2	0	65535	4030	—
Fuel Gauging	CEDV Cfg	EDV R1 Rate Factor	Unsigned Integer	2	0	65535	316	—
Fuel Gauging	CEDV Cfg	EDV TC Factor	Unsigned Integer	1	0	255	9	—
Fuel Gauging	CEDV Cfg	EDV a0 Age Factor	Unsigned Integer	1	0	255	0	

The bq78350 disables EDV detection if the measured battery discharge current (*Current()*) exceeds the ***Overload Current*** threshold, which is scaled by IPSCALE. The bq78350 resumes EDV threshold detection after C drops below the ***Overload Current*** threshold. Any EDV threshold detected is reset after charge is applied and *[VDQ]* is then cleared after RC has increased by a value of 10, which is scaled by IPSCALE.

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Fuel Gauging	CEDV Cfg	Overload Current	Integer	2	0	32767	5000	mA

The bq78350 uses the EDV thresholds to apply voltage-based corrections to the RC register according to the content in Table 9-1.

Table 9-1. State-of-Charge Based on Low Battery Voltage

Threshold	Relative State-of-Charge (RSOC)
EDV0	0%
EDV1	3%
EDV2	Battery Low%

The bq78350 performs EDV-based RC adjustments with *Current()* ≥ C/32. No EDVs are set if *Current()* < C/32. The bq78350 adjusts RC as it detects each threshold. If the voltage threshold is reached before the corresponding capacity on discharge, the bq78350 reduces RC to the appropriate amount, as shown in Table 9-1.

If an RC % level is reached on discharge before the voltage reaches the corresponding threshold, then RC is held at that % level until the threshold is reached. RC is only held if [VDQ] = 1, indicating a valid learning cycle is in progress. If ***Battery_Low%*** is set to zero, EDV1 and EDV0 corrections are disabled. If ***Battery_Low%*** is set to 0, EDV1 and EDV0 corrections are disabled.

9.1.9 Reserve Capacity

The bq78350 can provide an additional programmable quantity of capacity in "reserve"; that is, when RC = 0, then there is still ***Reserve Capacity*** left. This value is required to be entered and scaled to match the settings of IPSCALE and CapM settings.

The value of ***Reserve Capacity*** is subtracted from the learn capacity when determining the value of the reported FCC. This means when RSOC = 0% (EDV0), then there is still some capacity left for critical system actions. It is strongly recommended that when determining the value for Reserve Capacity that the setting of ***Battery_Low%*** is still considered to ensure the appropriate setting of the EDV2 voltage on the discharge curve. For example: If Reserve Capacity ~1% of ***Design Capacity***, then the typical value for ***Battery_Low%*** would be 6%.

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Fuel Gauging	CEDV Cfg	Reserve Capacity	Integer	2	0	32767	0	mAh

9.1.10 EDV Discharge Rate and Temperature Compensation

If EDV compensation is enabled, ***CEDV*** = 1, the bq78350 calculates battery voltage to determine EDV0, EDV1, and EDV2 thresholds as a function of battery capacity, temperature, and discharge load.

The general equation for EDV0, EDV1, and EDV2 calculation is as follows:

EDV0,1,2 = n (EMF × FBL – |ILOAD| × R0 × FTZ)

- EMF is a no-load cell voltage higher than the highest cell EDV threshold computed. EMF is programmed in mV in ***EMF***.
- ILOAD is the current discharge load magnitude.
- n = the number of series cells. In the bq78350 case n = 1.
- FBL is the factor that adjusts the EDV voltage for battery capacity and temperature to match the no-load characteristics of the battery.

FBL = f (C0, C + C1, T)

- C (either 0%, 3%, or Battery Low% for EDV0, EDV1, and EDV2, respectively) and C0 are the capacity related EDV adjustment factors. C0 is programmed in ***EDV C0 Factor***. C1 is the desired residual battery capacity remaining at EDV0 (RC = 0). The C1 factor is stored in ***EDV C1 Factor***.
- T is the current temperature in °K.
- R0•FTZ represents the resistance of a cell as a function of temperature and capacity.

FTZ = f (R1, T0, C + C1, TC)

- R0 is the first order rate dependency factor stored in ***EDV R0 Factor*** (DF).
- T is the current temperature. C is the battery capacity relating to EDV0, EDV1, and EDV2.
- R1 adjusts the variation of impedance with battery capacity. R1 is programmed in ***EDV R1 Rate Factor***.
- T0 adjusts the variation of impedance with battery temperature. T0 is programmed in ***EDV T0 Rate Factor***.
- TC adjusts the variation of impedance for cold temperatures T < TC is programmed in ***EDV TC Factor***.
- Typical values for the EDV compensation factors, based on overall pack voltages for a 3s2p Li-Ion 18650 pack, are
  - EMF = 11550/3
  - T0 = 4475
  - C0 = 235
  - C1 = 0
  - R0 = 5350/3
  - R1 = 250
  - TC = 3

The graphs below show the calculated EDV0, EDV1, and EDV2 thresholds versus capacity using the typical compensation values for different temperatures and loads for a Li-Ion 18650 cell. The compensation values vary widely for different cell types and manufacturers and must be matched exactly to the unique characteristics for optimal performance.

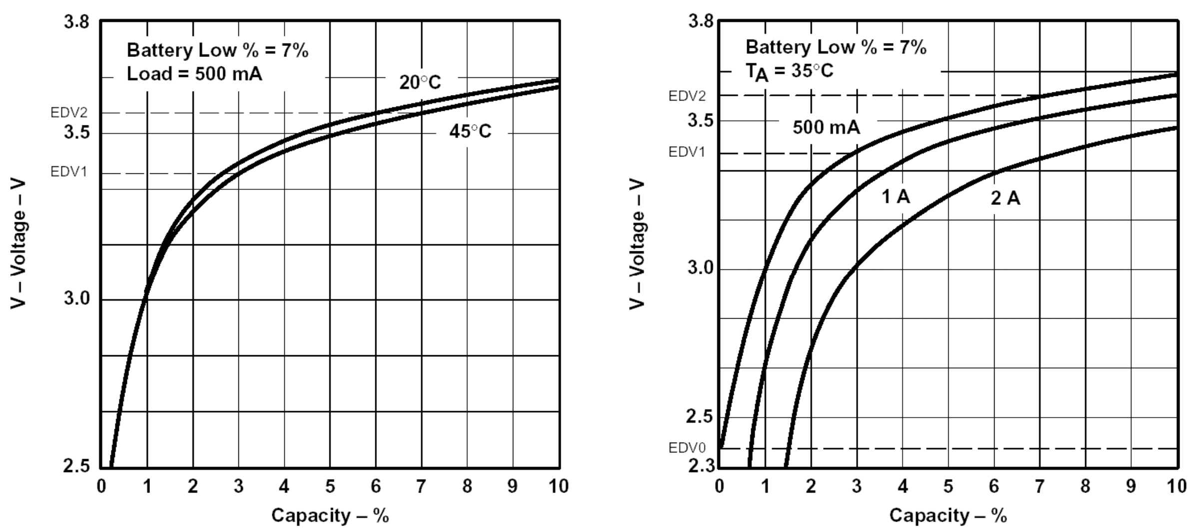


Figure 9-3. (a) EDV Calculations vs Various Temperatures, (b) EDV Calculations vs Capacity for Various Loads

9.1.11 EDV Age Factor

EDV Age factor allows the bq78350 to correct the EDV detection algorithm to compensate for cell aging. This parameter scales cell impedances as the cycle count increases. This factor is used to accommodate for much higher impedances observed in larger capacity and/or aged cells.

For most Li-Ion and Li-Polymer applications, the default value of zero is sufficient. However, for Lithium Iron Phosphate, a value of 18 is recommended.

9.1.12 Self Discharge

The bq78350 estimates the self-discharge of the battery to maintain an accurate measurement of the battery capacity during periods of inactivity. The bq78350 makes self-discharge adjustments to RC every ¼ second when awake and periodically when in SLEEP mode. The period is determined by ***Sleep Current Time***.

The self-discharge estimation rate for 25°C is doubled for each 10 degrees above 25°C or halved for each 10 degrees below 25°C. The table below shows the relation of the self-discharge estimation at a given temperature to the rate programmed for 25°C.

Temperature (°C)	Self-Discharge Rate
Temp < 10	¼ Y% per day
10 ≤ Temp < 20	½ Y% per day
20 ≤ Temp < 30	½ Y% per day
30 ≤ Temp < 40	2 Y% per day
40 ≤ Temp < 50	4 Y% per day
50 ≤ Temp < 60	8 Y% per day
60 ≤ Temp < 70	16 Y% per day
70 ≤ Temp	32 Y% per day

The nominal self-discharge rate, %PERDAY (% per day), is programmed in an 8-bit value ***Self-Discharge Rate*** by the following relation:

Self-Discharge Rate = %PERDAY/ 0.01

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Fuel Gauging	CEDV Cfg	Self Discharge Rate	Unsigned Integer	1	0%	255%	20%	0.01/day

9.1.13 Battery Electronic Load Compensation

The bq78350 can be configured to compensate for a constant load (as from battery electronics) present in the battery pack at all times. The bq78350 applies the compensation continuously when the charge or discharge is below the digital filter. The bq78350 applies the compensation in addition to self-discharge.

The compensation occurs at a rate determined by the value stored in ***Electronics Load***. The compensation range is 0 µA – 765 µA in steps of approximately 3 µA.

The amount of internal battery electronics load estimate in µA, BEL, is stored as follows: ***Electronics Load*** = BEL/3.

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Fuel Gauging	CEDV Cfg	Electronics Load	Integer	2	0	255	0	3 µA

9.2 Gauging Configuration Options

The bq78350 has a variety of configurable options that can be configured, enabled, or disabled through the following data flash options.

Class	Subclass	Name	Type	Min	Max	Default	Unit
Gas Gauging	Design	Design Capacity mAh	I2	0	32767	4400	mAh
Gas Gauging	Design	Design Capacity cWh	I2	0	32767	6336	cWh
Gas Gauging	Design	Design Voltage	I2	0	5000	3600	mV
Gas Gauging	Cycle	Cycle Count Percentage	U1	0%	100%	90%	

Table 9-2. SBS Gauging Configuration

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Settings	Configuration	SBS Gauging Configuration	Hex	1	0x00	0xFF	0x00	—

7	6	5	4	3	2	1	0
PWRMSleep	RSVD	RSVD	RSVD	RSVD	RSVD	RSOC_HOLD	RSOCL

RSOCL (Bit 0): *RelativeStateOfCharge()* and *RemainingCapacity()* behaviors 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)

RSOC_HOLD (Bit 1): Prevent RSOC from increasing during discharge

1 = RSOC not allowed to increase during discharge

0 = RSOC not limited (default)

PWRMSleep (Bit 7): Power mode indication pin control during sleep

1 = PWRM is high during sleep

0 = PWRM is low during sleep (default)

Table 9-3. CEDV Gauging Configuration

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Settings	Configuration	CEDV Gauging Configuration	Hex	2	0x0000	0xFFFF	0x0002	—

15	14	13	12	11	10	9	8
RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	FCC_LIMIT
7	6	5	4	3	2	1	0
VFLT_EN	RSVD	FIXED_EDV0	SC	EDV_CMP	EDV_EXT_CELL	CSYNC	CCT

CCT (Bit 0): Cycle count threshold

1 = Use CC % of *FullChargeCapacity()*

0 = Use CC % of DesignCapacity (default)

CSYNC (Bit 1): Sync *RemainingCapacity()* with *FullChargeCapacity()* at valid charge termination

1 = Synchronized (default)

0 = Not synchronized

EDV_EXT_CELL (Bit 2): External average cell voltage used for EDV detection

1 = External average cell voltage used as EDV detection reference

0 = Minimum individual cell voltage used as EDV detection reference (default)

EDV_CMP (Bit 3): This bit enables EDV Compensation for EDV2, EDV1, and EDV0.

1 = Enabled

0 = Disabled (default)

SC (Bit 4): This bit enables learning cycle optimization for a Smart Charger or independent charge.

1 = Learning cycle optimized for independent charger

0 = Learning cycle optimized for Smart Charger (default)

FIXED_EDV0 (Bit 5): This bit determines whether the bq78350 implements automatic EDV compensation to calculate the EDV0 threshold based on rate, temperature, and capacity, or uses a fixed voltage value. If EDV_CMP = 0, then this bit has no effect.

1 = EDV Compensation Not Used. For example: Fixed EDV gauge enabled

0 = EDV Compensation Used (default)

VFLT_EN (Bit 7): Enable voltage filtering to prevent sudden termination due to pulse loading

1 = Enabled

0 = Disabled (default)

FCC_LIMIT (Bit 8): Prevent FCC from learning higher than Design Capacity

1 = Enabled

0 = Disabled (default)

Lifetime Data Collection

10.1 Description

The device has extensive capabilities for logging events over the life of the battery useful for analysis. 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.
- Before scheduled shutdown
- Before low voltage shutdown

The lifetime data stops collecting under following conditions:

- After permanent fail
- Lifetime Data Collection is disabled by setting ***ManufacturingStatus[LF_EN]*** = 0.

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
  - Cycle Count at Last FCC update
- Power Events
  - Number of shutdowns
- Cell Balancing (This data is updated every two 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)
- Time (this data is updated every 2 hours)
  - Total runtime
  - Time spent different temperature ranges (See Charge Algorithm for ranges.)

10.2 Lifetimes

10.2.1 Max Cell Voltage

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

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Lifetimes	Voltage	Max Voltage Cell 1	U1	0	255	0	20 mV	Maximum reported cell voltage 1
Lifetimes	Voltage	Max Voltage Cell 2	U1	0	255	0	20 mV	Maximum reported cell voltage 2
Lifetimes	Voltage	Max Voltage Cell 3	U1	0	255	0	20 mV	Maximum reported cell voltage 3
Lifetimes	Voltage	Max Voltage Cell 4	U1	0	255	0	20 mV	Maximum reported cell voltage 4
Lifetimes	Voltage	Max Voltage Cell 5	U1	0	255	0	20 mV	Maximum reported cell voltage 5
Lifetimes	Voltage	Max Voltage Cell 6	U1	0	255	0	20 mV	Maximum reported cell voltage 6
Lifetimes	Voltage	Max Voltage Cell 7	U1	0	255	0	20 mV	Maximum reported cell voltage 7
Lifetimes	Voltage	Max Voltage Cell 8	U1	0	255	0	20 mV	Maximum reported cell voltage 8
Lifetimes	Voltage	Max Voltage Cell 9	U1	0	255	0	20 mV	Maximum reported cell voltage 9
Lifetimes	Voltage	Max Voltage Cell 10	U1	0	255	0	20 mV	Maximum reported cell voltage 10
Lifetimes	Voltage	Max Voltage Cell 11	U1	0	255	0	20 mV	Maximum reported cell voltage 11
Lifetimes	Voltage	Max Voltage Cell 12	U1	0	255	0	20 mV	Maximum reported cell voltage 12
Lifetimes	Voltage	Max Voltage Cell 13	U1	0	255	0	20 mV	Maximum reported cell voltage 13
Lifetimes	Voltage	Max Voltage Cell 14	U1	0	255	0	20 mV	Maximum reported cell voltage 14
Lifetimes	Voltage	Max Voltage Cell 15	U1	0	255	0	20 mV	Maximum reported cell voltage 15

10.2.2 Min Cell Voltage

Lifetime voltage data is available through Lifetime Data Block 2 via *ManufacturerAccess()*.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Lifetimes	Voltage	Min Voltage Cell 1	U1	0	255	255	20 mV	Minimum reported cell voltage 1
Lifetimes	Voltage	Min Voltage Cell 2	U1	0	255	255	20 mV	Minimum reported cell voltage 2
Lifetimes	Voltage	Min Voltage Cell 3	U1	0	255	255	20 mV	Minimum reported cell voltage 3
Lifetimes	Voltage	Min Voltage Cell 4	U1	0	255	255	20 mV	Minimum reported cell voltage 4
Lifetimes	Voltage	Min Voltage Cell 5	U1	0	255	255	20 mV	Minimum reported cell voltage 5
Lifetimes	Voltage	Min Voltage Cell 6	U1	0	255	255	20 mV	Minimum reported cell voltage 6
Lifetimes	Voltage	Min Voltage Cell 7	U1	0	255	255	20 mV	Minimum reported cell voltage 7
Lifetimes	Voltage	Min Voltage Cell 8	U1	0	255	255	20 mV	Minimum reported cell voltage 8
Lifetimes	Voltage	Min Voltage Cell 9	U1	0	255	255	20 mV	Minimum reported cell voltage 9
Lifetimes	Voltage	Min Voltage Cell 10	U1	0	255	255	20 mV	Minimum reported cell voltage 10
Lifetimes	Voltage	Min Voltage Cell 11	U1	0	255	255	20 mV	Minimum reported cell voltage 11
Lifetimes	Voltage	Min Voltage Cell 12	U1	0	255	255	20 mV	Minimum reported cell voltage 12
Lifetimes	Voltage	Min Voltage Cell 13	U1	0	255	255	20 mV	Minimum reported cell voltage 13
Lifetimes	Voltage	Min Voltage Cell 14	U1	0	255	255	20 mV	Minimum reported cell voltage 14
Lifetimes	Voltage	Min Voltage Cell 15	U1	0	255	255	20 mV	Minimum reported cell voltage 15

10.2.3 Current

Lifetime current data is available through Lifetime Data Block 3 via *ManufacturerAccess()*.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Lifetimes	Voltage	Max Delta Cell Voltage	U1	0	255	0	20 mV	Maximum reported delta between cell voltages 1 to 15
Lifetimes	Current	Max Chg Current	U1	0	255	0	200 mA	Maximum reported *Current()* in charge direction
Lifetimes	Current	Max Dsg Current	U1	0	255	0	200 mA	Maximum reported *Current()* in discharge direction
Lifetimes	Current	Max Avg Dsg Current	U1	0	255	0	200 mA	Maximum reported *AverageCurrent()* in discharge direction
Lifetimes	Current	Max Avg Dsg Power	U1	0	255	0	W	Maximum reported Power in discharge direction

10.2.4 Temperature

Lifetime temperature data is available through Lifetime Data Block 3 via *ManufacturerAccess().*

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Lifetimes	Temperature	Max Temp Cell	I1	–128	127	–128	°C	Maximum reported cell temperature
Lifetimes	Temperature	Min Temp Cell	I1	–128	127	127	°C	Minimum reported cell temperature
Lifetimes	Temperature	Max Delta Temp Cell	I1	–128	127	0	°C	Maximum reported temperature delta for TSx inputs configured as cell temperature
Lifetimes	Temperature	Max Temp Int Sensor	I1	–128	127	–128	°C	Maximum reported internal temperature sensor temperature
Lifetimes	Temperature	Min Temp Int Sensor	I1	–128	127	127	°C	Minimum reported internal temperature sensor temperature

10.2.5 Power Events

Lifetime power events data is available through Lifetime Data Block 4 via *ManufacturerAccess()*.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Lifetimes	Power Events	No of Shutdowns	U1	0	255	0	events	Total number of Shutdown events

10.2.6 Cell Balancing

Lifetime cell balancing data is available through Lifetime Data Block 4 via *ManufacturerAccess()*.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Lifetimes	Cell Balancing	CB Time Cell 1	U1	0	255	0	2 h	Total performed cell balancing bypass time cell 1
Lifetimes	Cell Balancing	CB Time Cell 2	U1	0	255	0	2 h	Total performed cell balancing bypass time cell 2
Lifetimes	Cell Balancing	CB Time Cell 3	U1	0	255	0	2 h	Total performed cell balancing bypass time cell 3
Lifetimes	Cell Balancing	CB Time Cell 4	U1	0	255	0	2 h	Total performed cell balancing bypass time cell 4
Lifetimes	Cell Balancing	CB Time Cell 5	U1	0	255	0	2 h	Total performed cell balancing bypass time cell 5
Lifetimes	Cell Balancing	CB Time Cell 6	U1	0	255	0	2 h	Total performed cell balancing bypass time cell 6
Lifetimes	Cell Balancing	CB Time Cell 7	U1	0	255	0	2 h	Total performed cell balancing bypass time cell 7
Lifetimes	Cell Balancing	CB Time Cell 8	U1	0	255	0	2 h	Total performed cell balancing bypass time cell 8

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Lifetimes	Cell Balancing	CB Time Cell 9	U1	0	255	0	2 h	Total performed cell balancing bypass time cell 9
Lifetimes	Cell Balancing	CB Time Cell 10	U1	0	255	0	2 h	Total performed cell balancing bypass time cell 10
Lifetimes	Cell Balancing	CB Time Cell 11	U1	0	255	0	2 h	Total performed cell balancing bypass time cell 11
Lifetimes	Cell Balancing	CB Time Cell 12	U1	0	255	0	2 h	Total performed cell balancing bypass time cell 12
Lifetimes	Cell Balancing	CB Time Cell 13	U1	0	255	0	2 h	Total performed cell balancing bypass time cell 13
Lifetimes	Cell Balancing	CB Time Cell 14	U1	0	255	0	2 h	Total performed cell balancing bypass time cell 14
Lifetimes	Cell Balancing	CB Time Cell 15	U1	0	255	0	2 h	Total performed cell balancing bypass time cell 15

10.2.7 Time

Lifetime time data is available through Lifetime Data Block 5 via *ManufacturerAccess().*

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Lifetimes	Time	Total firmware Runtime	U2	0	65535	0	2 h	Total firmware runtime between resets
Lifetimes	Time	Time Spent in UT	U2	0	65535	0	2 h	Total firmware runtime spent below T1
Lifetimes	Time	Time Spent in LT	U2	0	65535	0	2 h	Total firmware runtime spent between T1 and T2
Lifetimes	Time	Time Spent in STL	U2	0	65535	0	2 h	Total firmware runtime spent between T2 and T5
Lifetimes	Time	Time Spent in RT	U2	0	65535	0	2 h	Total firmware runtime spent between T5 and T6
Lifetimes	Time	Time Spent in STH	U2	0	65535	0	2 h	Total firmware runtime spent between T6 and T3
Lifetimes	Time	Time Spent in HT	U2	0	65535	0	2 h	Total firmware runtime spent between T3 and T4
Lifetimes	Time	Time Spent in OT	U2	0	65535	0	2 h	Total firmware runtime spent above T6

10.2.8 Safety Events

Lifetime safety events data is available through Lifetime Data Block 6 via *ManufacturerAccess()*.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Lifetimes	Safety Events	No of COV Events	U1	0	255	0	8 events	Total number of *SafetyStatus()[COV]* events
Lifetimes	Safety Events	Last COV Event	U1	0	255	0	4 cycles	Last *SafetyStatus()[COV]* event in *CycleCount()* cycles
Lifetimes	Safety Events	No of CUV Events	U1	0	255	0	8 events	Total number of *SafetyStatus()[CUV]* events
Lifetimes	Safety Events	Last CUV Event	U1	0	255	0	4 cycles	Last *SafetyStatus()[CUV]* event in *CycleCount()* cycles
Lifetimes	Safety Events	No of OCD Events	U1	0	255	0	8 events	Total number of *SafetyStatus()[OCD]* events
Lifetimes	Safety Events	Last OCD Event	U1	0	255	0	4 cycles	Last *SafetyStatus()[OCD]* event in *CycleCount()* cycles
Lifetimes	Safety Events	No of OCC Events	U1	0	255	0	8 events	Total number of *SafetyStatus()[OCC]* events
Lifetimes	Safety Events	Last OCC Event	U1	0	255	0	4 cycles	Last *SafetyStatus()[OCC]* event in *CycleCount()* cycles
Lifetimes	Safety Events	No of AOLD Events	U1	0	255	0	8 events	Total number of *SafetyStatus()[OLD]* events

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Lifetimes	Safety Events	Last AOLD Event	U1	0	255	0	4 cycles	Last *SafetyStatus()[OLD]* event in *CycleCount()* cycles
Lifetimes	Safety Events	No of ASCD Events	U1	0	255	0	8 events	Total number of *SafetyStatus()[SCD]* events
Lifetimes	Safety Events	Last ASCD Event	U1	0	255	0	4 cycles	Last *SafetyStatus()[SCD]* event in *CycleCount()*cycles
Lifetimes	Safety Events	No of OTC Events	U1	0	255	0	8 events	Total number of *SafetyStatus()[OTC]* events
Lifetimes	Safety Events	Last OTC Event	U1	0	255	0	4 cycles	Last *SafetyStatus()[OTC]* event in *CycleCount()* cycles
Lifetimes	Safety Events	No of OTD Events	U1	0	255	0	8 events	Total number of *SafetyStatus()[OTD]* events
Lifetimes	Safety Events	Last OTD Event	U1	0	255	0	4 cycles	Last *SafetyStatus()[OTD]* event in *CycleCount()* cycles

10.2.9 Charging Events

Lifetime charging events data is available through Lifetime Data Block 7 via *ManufacturerAccess()*.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Lifetimes	Safety Events	No of Valid Charge Terminations	U1	0	255	0	8 events	Total number of valid charge termination events
Lifetimes	Safety Events	Last Valid Charge Termination	U1	0	255	0	4 cycles	Last valid charge termination in *CycleCount()* cycles

Device Security

11.1 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 (SE), UNSEALED (UN), and FULL ACCESS (FA). The device also supports SHA-1 HMAC authentication with the host system.

11.2 SHA-1 Description

The SHA-1 is known as a one-way hash function, which means there is no known mathematical method of computing the input given only the output. The specification of the SHA-1, as defined by FIPS 180–2, states that the input consists of 512-bit blocks with a total input length less than 2^{64} 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 160 bits, commonly referred to as the digest.

(As of April 23, 2004 the latest revision is FIPS 180–2.) 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 produces 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, 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 180–2.

Detailed information about the SHA-1 algorithm can be found in the following locations:

1. http://www.itl.nist.gov/fipspubs/fip180–1.htm
2. http://csrc.nist.gov/publications/fips
3. www.faqs.org/rfcs/rfc3174.html

11.3 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.

11.4 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 *ManufacturerInput()* data waiting, write 160-bit message M to *ManufacturerInput()* in the format 0xAABBCCDDEEFFGGHHIIJJKKLLMMNNOOPPQQRRSSTT, where AA is LSB.
7. Wait 250 ms, then read *ManufacturerInput()* for HMAC3.
8. Compare host HMAC2 with device HMAC3, and if it matches, both host and device have the same key KD and the device is authenticated.

11.5 Security Modes

11.5.1 FULL ACCESS or UNSEALED to SEALED

The *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. Extended SBS functions and data flash are not accessible. Once in SEALED mode, the part can never permanently return to UNSEALED or FULL ACCESS modes although there is a capability to temporarily switch from SEALED to UNSEALED and then to FULL ACCESS.

11.5.2 SEALED to UNSEALED

SEALED to UNSEALED instructs the device to temporarily 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. 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 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.

11.5.3 UNSEALED to FULL ACCESS

UNSEALED to FULL ACCESS instructs the device to temporarily 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()*. In FULL ACCESS mode, the command to go to boot ROM can be sent.

Manufacture Production

12.1 Manufacture Testing

To improve the manufacture testing flow, the bq78350 allows certain features to be toggled on or off through *ManufacturerAccess()* commands: for example, the *PRE-CHG 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. These toggling commands will only set the RAM data, which means the conditions set by the these commands will be cleared if a reset or seal is issued to the gauge. The *ManufacturingStatus()* keeps track of the status (enabled or disabled) of each feature.

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

12.1.1 Manufacturing Status Configuration

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Settings	Manufacturing	Mfg Status Init	Hex	2	0x0000	0xFFFF	0x00	—

15	14	13	12	11	10	9	8
RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	LED_EN	SAFE_EN

7	6	5	4	3	2	1	0
BBR_EN	PF_EN	LF_EN	FET_EN	RSVD	RSVD	RSVD	RSVD

RSVD (Bits 15–10): Reserved

LED_EN (Bit 9): Enables $\overline{\text{DISP}}$ pin triggered activation of the display

1 = Enabled

0 = Disabled (default)

SAFE_EN (Bit 8): Voltage imbalance At Rest

1 = Enabled

0 = Disabled (default)

BBR_EN (Bit 7): Black Box Recorder

1 = Enabled

0 = Disabled (default)

PF_EN (Bit 6): Permanent Fail. The [DFW], [IFC], [SOV], and [SUV] permanent failure features are always enabled regardless of the setting of this bit.

1 = Enabled

0 = Disabled (default)

LF_EN (Bit 5): Lifetime Data Collection

1 = Enabled

0 = Disabled (default)

FET_EN (Bit 4): FET action

1 = Enabled

0 = Disabled (default)

RSVD (Bits 3–0): Reserved

12.2 Calibration

The bq78350 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 factory calibrated 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 factory calibrated ADC data of the first 10-series cell voltages on *ManufacturerData()*
0xF082	Outputs factory calibrated ADC data of the 11- to 15-series cell voltages, external average voltage, VAUX voltage, current, and temperatures on *ManufacturerData()*

For 0xF081, the *ManufacturerData()* output format is: ZZaaAAbbBBccCCddDDeeEEffFFggGGhhHHiiIIjjJJkkKK, 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	*AFE CELL Map*
BBbb	2's comp	Cell Voltage 1
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	Cell Voltage 5
GGgg	2's comp	Cell Voltage 6
HHhh	2's comp	Cell Voltage 7
IIii	2's comp	Cell Voltage 8
JJjj	2's comp	Cell Voltage 9
KKkk	2's comp	Cell Voltage 10

For 0xF082, the *ManufacturerData()* output format is: ZZaaAAbbBBccCCddDDeeEEffFFggGGhhHHiiIIjjJJkkKKllLLmmMM, 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	AFE CELL Map
BBbb	2's comp	Cell Voltage 11
CCcc	2's comp	Cell Voltage 12
DDdd	2's comp	Cell Voltage 13
EEee	2's comp	Cell Voltage 14
FFff	2's comp	Cell Voltage 15
GGgg	—	Reserved
HHhh	2's comp	Ext Ave Cell Voltage
IIiiJJjj	2's comp	VAUX Voltage
KKkk	2's comp	Current Coulomb Counter
LLll	2's comp	TS1 Temperature
MMmm	2's comp	TS2 Temperature
NNnn	2's comp	TS3 Temperature

12.2.1 Cell Voltage Calibration

1. Apply known voltages in mV to the cell voltage inputs. See the companion AFE data manual, *bq769x0 3-Series to 15-Series Cell Battery Monitor Family for Li-Ion and Phosphate Applications* (SLUSBK2), for the actual physical pin connections:
   - V_{CELL1} is the lowest physical cell in the stack.
   - V_{CELL2} is the next (second) cell in the stack.
   - V_{CELLn} is the top cell in the stack.
2. If *ManufacturerStatus()[CAL]* = 0, send 0x002D to *ManufacturerAccess()* to enable the *[CAL]* flag.
3. Send 0xF081 or 0xF082 to *ManufacturerAccess()* to enable cell voltage output on *ManufacturerData(),* depending on which cells are being calibrated.
4. Poll *ManufacturerData()* until the 8-bit counter value increments by 2 before reading data.
5. See the readings of factory calibrated cell voltages from *ManufacturerData()* beginning with Cell 1 and ending in the number of configured cell, n, with the maximum being 15. Depending on the number of cells, the data is available through two separate read-blocks (0xF081 or 0xF082):
   - $FCAL_{CELL1}$ = BBbb of *ManufacturerData()*
   - $FCAL_{CELL10}$= KKkk of *ManufacturerData()*.
   - $FCAL_{CELL11}$= BBbb of *ManufacturerData()*.
   - $FCAL_{CELL15}$= FFff of *ManufacturerData()*.
6. Average several readings for higher accuracy. Poll *ManufacturerData()* until ZZ increments, to indicate that updated values are available:
   - $FCAL_{CELLx}$ = [$FCAL_{CELLx}$(reading n) + ...+ $FCAL_{CELLx}$(reading 1)]/n

7. Calculate Cell n Offset value: where N = number of cells.
   - $FCAL_{CELLn}$ – Reference Cell Voltage = ***Cell n Offset***
8. Write the new ***Cell n Offset*** value to data flash.
9. Re-check the voltage reading and if it is not accurate, repeat Steps 5 through 8.
10. Send 0x002D to *ManufacturerAccess()* to clear the *[CAL]* flag if all calibration is complete.

12.2.2 External Average Voltage Calibration

The bq78350 can be configured with an external resistor divider to measure the battery stack voltage directly. This measurement has its own calibration procedure.

1. Apply a known voltage in mV to the battery terminals on which the resistor divider is connected.
2. Divide the known battery voltage by the number of cells configured in ***AFE Cell Map***. This would be Actual Avg Cell Voltage.
3. Read *ExtAveCellVoltage()*.
4. Calculate the Ext Cell Divider Gain.
   - New ***Ext Cell Divider Gain*** = (Old ***Ext Cell Divider Gain*** × Actual Avg Cell Voltage)/Measured Avg Cell Voltage
5. Update ***Ext Cell Divider Gain*** in data flash.

12.2.3 VAUX Voltage Calibration

The bq78350 can be configured with an auxiliary voltage measurement input. This measurement has its own calibration procedure, as follows:

1. Apply a known voltage in mV to the VAUX input.
2. Read *VAUXVoltage()*.
3. Calculate the VAUX Gain.
   - New ***VAUX Gain*** = (Old ***VAUX Gain***/VAUX Voltage)
4. Update ***VAUX Gain*** in data flash.

12.2.4 Voltage Calibration Data Flash

Class	Subclass	Name	Type	Length in Bytes	Min	Max	Default	Unit
Calibration	Voltage	Cell1 Offset to Cell15 Offset	Integer	1	–128	127	0 (1)	—
Calibration	VAUX Voltage	VAUX Gain	Integer	4	0	10000	5000	—
Calibration	Ext Cell Voltage	Ext Ave Divider Gain	Integer	2	0	32767	5000	—

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

12.2.5 Current Calibration

12.2.5.1 CC Offset Calibration

1. Apply a known current of 0 mA, and ensure no current is flowing through the sense resistor connected between the SRP and SRN pins.
2. If *ManufacturerStatus()[CAL]* = 0, send 0x002D to *ManufacturerAccess()* to enable the [CAL] flag.
3. Send 0xF082 to *ManufacturerAccess()* to enable factory calibrated CC output on *ManufacturerData()*.
4. Poll *ManufacturerData()* until ZZ increments by 2 before reading data.
5. Obtain the factory calibrated conversion readings of current from *ManufacturerData()*:
   - $FCAL_{CC}$ = HHhh of *ManufacturerData()*

   Is $FCAL_{CC}$ < 0x8000? If yes, use $FCAL_{CC}$; otherwise, $FCAL_{CC}$ = –(0xFFFF – AAaa + 0x0001).
6. Average several readings for higher accuracy. Poll *ManufacturerData()* until ZZ increments to indicate that updated values are available:
   - $FCAL_{CC}$ = [$FCAL_{CC}$(reading n) + … + $FCAL_{CC}$(reading 1)]/n
7. Read *Coulomb Counter Offset Samples* from data flash.
8. Calculate offset value:
   - CC offset = $FCAL_{CC}$ × (Coulomb Counter Offset Samples)

9. Write the new *CC Offset* value to data flash.
10. Re-check the current reading and if it is not accurate, repeat the steps.
11. Send 0x002D to *ManufacturerAccess()* to clear the *[CAL]* flag if all calibration is complete.

12.2.5.2 CC Gain/Capacity Gain Calibration

1. Apply a known current, which is the nominal discharge current of the battery and can be up to 100 A.
2. If *ManufacturerStatus()[CAL]* = 0, send 0x002D to *ManufacturerAccess()* to enable the *[CAL]* flag.
3. Send 0xF082 to *ManufacturerAccess()* to enable factory calibrated CC output on *ManufacturerData()*.
4. Poll *ManufacturerData()* until ZZ increments by 2 before reading data.
5. Using the *ManufacturerAccess()* Commands 0x001F and 0x0020, turn ON the CHG and DSG FETs.
6. Read the factory calibrated conversion readings of current from *ManufacturerData()*:
   - $FCAL_{CC}$ = HHhh of *ManufacturerData()*

   Is $FCAL_{CC}$ < 0x8000? If yes, use $FCAL_{CC}$; otherwise, $FCAL_{CC}$ = –(0xFFFF – AAaa + 0x0001).
7. Average several readings for higher accuracy. Poll *ManufacturerData()* until ZZ increments to indicate that updated values are available:
   - $FCAL_{CC}$ = [$FCAL_{CC}$(reading n) + … + $FCAL_{CC}$(reading 1)]/n
8. Using the *ManufacturerAccess()* Commands 0x001F and 0x0020, turn OFF the CHG and DSG. FETs
9. Read ***Coulomb Counter Offset Samples*** from data flash.
10. Calculate gain values:

$$CC\ Gain = \frac{I_{CC}}{ADC_{CC} - \dfrac{CC\ Offset}{Coulomb\ Counter\ Offset\ Samples}}$$

$$Capacity\ Gain = CC\ Gain \times 298261.6178$$

11. Write the new ***CC Gain*** and ***Capacity Gain*** values to data flash.
12. Re-check the current reading. If the reading is not accurate, repeat the steps.
13. Send 0x002D to *ManufacturerAccess()* to clear the *[CAL]* flag if all calibration is complete.

12.2.6 Deadbands

The bq78350 can be configured to ignore current and coulomb measurements below individually programmable levels.

12.2.6.1 Current Deadband

When *Current()* measures a value less than the value programmed in ***Current Deadband,*** *Current()* will report 0. This has no effect on the coulomb counting for the gas gauging functionality.

The value of ***Current Deadband*** should be selected based on the characterization of the battery electronics design combined with the environment in which the battery will be used. If the PCB senses noise causing a real no-current condition to report a non-zero value, then ***Current Deadband*** could be adjusted accordingly.

12.2.7 Coulomb Counter Deadband

During normal operation, there could be noise generated in the battery electronics environment that could cause the bq78350 to accumulate incorrectly (positively or negatively). To filter out this noise, the ***Coulomb Counter Deadband*** setting is used. Any input below this threshold is not accumulated.

12.2.8 Current Calibration Data Flash

Class	Subclass	Name	Format	Length in Bytes	Min	Max	Default	Unit
Calibration	Current	CC Gain	Float	4	1.00E–001	9.00E+000	8.4381	mΩ
Calibration	Current	Capacity Gain	Float	4	2.98E+004	2.69E+07	2516761.36	—
Calibration	Current Offset	CC Offset	Integer	2	–32768	32767	0	—
Calibration	Current Offset	Coulomb Counter Offset Samples	Unsigned Integer	2	0	65535	64	—
Calibration	Current Deadband	Deadband	Unsigned Integer	1	0	255	3	mA
Calibration	Current Deadband	Coulomb Counter Deadband	Unsigned Integer	1	0	255	38	264 nV

12.2.9 Temperature Calibration

12.2.9.1 TS1–TS2–TS3 Calibration

1. Apply a known temperature in 0.1°C, and ensure that temperature $TEMP_{TSx}$ is applied to the thermistor connected to the TSx pin. "TSx" refers to TS1, TS2, or TS3, whichever is applicable.
2. Send 0xF082 to *ManufacturerAccess()* to enable factory calibrated Temperature output on *ManufacturerData()*.
3. Poll *ManufacturerData()* until ZZ increments by 2 before reading data.
4. Read the factory calibrated conversion readings of Temperature from *ManufacturerData()*:
   - $FCAL_{TS1}$ = LLll of *ManufacturerData()*
   - $FCAL_{TS2}$ = MMmm of *ManufacturerData()*
   - $FCAL_{TS3}$ = NNnn of *ManufacturerData()*
5. Read the TSx $offset_{old}$ from ***External × Temp Offset***, where × is 1, 2 , or 3.
6. Re-check the temperature reading. If the reading is not accurate, repeat the steps.
7. Calculate the temperature offset:
   $$TSx\ offset = TEMP_{TSx} - TSx + TSx\ offset_{old}$$
   where × is 1, 2, or 3.
8. Write the new ***External × Temp Offset*** (where × is 1, 2, or 3) value to data flash.
9. Re-check the temperature reading. If the reading is not accurate, repeat the steps.

12.2.10 Temperature Calibration Data Flash

Class	Subclass	Name	Type	Length in Bytes	Min	Max	Default	Unit
Calibration	Temperature	External 1 Temp Offset	Integer	1	–128	127	0	0.1 °C
Calibration	Temperature	External 2 Temp Offset	Integer	1	–128	127	0	0.1 °C
Calibration	Temperature	External 3 Temp Offset	Integer	1	–128	127	0	0.1 °C

12.2.11 External Temp Model

Class	Subclass	Name	Type	Length in Bytes	Min	Max	Default	Unit
Calibration	Cell Temp Model	Coefficient a1	Integer	2	–32768	32768	–11130	—
Calibration	Cell Temp Model	Coefficient a2	Integer	2	–32768	32768	19142	—

Class	Subclass	Name	Type	Length in Bytes	Min	Max	Default	Unit
Calibration	Cell Temp Model	Coefficient a3	Integer	2	–32768	32768	–19262	—
Calibration	Cell Temp Model	Coefficient a4	Integer	2	–32768	32768	28203	—
Calibration	Cell Temp Model	Coefficient a5	Integer	2	–32768	32768	892	—
Calibration	Cell Temp Model	Coefficient b1	Integer	2	–32768	32768	328	—
Calibration	Cell Temp Model	Coefficient b2	Integer	2	–32768	32768	–605	—
Calibration	Cell Temp Model	Coefficient b3	Integer	2	–32768	32768	–2443	—
Calibration	Cell Temp Model	Coefficient b4	Integer	2	–32768	32768	4969	—
Calibration	Cell Temp Model	Rc0	Integer	2	–32768	32768	11703	Ω
Calibration	Cell Temp Model	Adc0	Integer	2	–32768	32768	11703	—

Display Port

13.1 Introduction

The Display Port feature can provide a visual display of *RelativeStateofCharge()* or *AbsoluteStateOfCharge()*, and can be activated in several ways. This feature can use LEDs or a 5-bar LCD and has a variety of configuration options to enable a wide range of indications.

The bq78350 display type is set in ***LED Configuration [LCDEN]***. When ***[LCDEN]*** = 0, the display type is LED; when ***[LCDEN]*** = 1, the display type is LCD.

13.1.1 Light Emitting Diode (LED) Display Operation

The LED display is the default display type for the bq78350. When the LED display is activated, the device turns on the appropriate LEDs through the LED1..5 pins when a push button is pressed or a command is sent to the device.

13.1.2 Liquid Crystal Display (LCD) Operation

The LCD controller supports 3- to 5-segment static bar graph liquid crystal displays (LCDs). The LCD is operational at all times except when the bq78350 is in the SHUTDOWN power mode.

A static LCD generally has one large electrode on one side of the liquid crystal material called a "common," and a number of smaller electrodes on the other side called "segments." Segments are made visible (black) by applying a differential voltage between the back plane signal of the LCD and the corresponding segment pin. Segments are turned off when there is no voltage difference between the back plane signal and a segment signal. The display signals must be periodically reversed to ensure zero average DC voltage and to refresh the display.

Liquid crystal displays having an operating voltage range of 2.5 V to 6 V and a refresh frequency between 30 Hz and 200 Hz are supported. The display refresh must be implemented such that the device current consumption requirements during sleep and active modes are not violated. The display refresh frequency must always be set as low as the LCD specification allows in order to minimize current consumption.

Static LCD drive procedure is as follows:

- Step 1. Drive back plane to ground, drive "on" segments high, "off" segments to ground.
- Step 2. Wait for time 1/refresh frequency.
- Step 3. Drive back plane high, drive "on" segments to ground, "off" segments high.
- Step 4. Wait for time 1/refresh frequency.
- Step 5. Go to Step 1.

13.2 Display Activation

13.2.1 LED Display Activation

The LED display is activated for a period of ***LED Hold Time***:

- If the $\overline{\text{DISP}}$ pin is low for < ***LED Hold Time***.
- If ***[LEDR]*** = 1 AND the device is Reset.
- If ***[LEDCHG]*** = 1 AND *Current()* > 0.
- If *ManufacturerStatus()* = 0x002C.

If *SafetyStatus()* [CUV] flag is set, the display is disabled.

If ***[LEDRCA]*** = 1 and the *BatteryStatus() [RCA]* change from 0 to 1, the LED display will also flash at the ***LED Flash Rate*** according to the ***LED Flash Alarm***.

13.2.2 LCD Display Activation

The LCD is activated all the time during operation except:

- If *SafetyStatus()* [CUV] flag is set.
- If the device is in the SHUTDOWN power mode.

13.3 State-Of-Charge Display

The state-of-charge can display *RelativeStateOfCharge()* or (*AbsoluteStateOfCharge()*/*DesignCapacity()*) , selectable with ***LED Configuration [LEDMODE]***.

LED/LCD Segment Output ON	State-Of-Charge
LED1/LCD1	LED Thresh 1
LED2/LCD2	LED Thresh 2
LED3/LCD3	LED Thresh 3
LED4/LCD4	LED Thresh 4
LED5/LCD5	LED Thresh 5

Table 13-1. Display Thresholds

Class	Subclass	Name	Format	Length in Bytes	Min Value	Max Value	Default Value
LED Support	LED Config	LED Flash Alarm	Integer	1	0%	100%	10%
LED Support	LED Config	LED Thresh 1	Integer	1	0%	100%	0%
LED Support	LED Config	LED Thresh 2	Integer	1	0%	100%	20%
LED Support	LED Config	LED Thresh 3	Integer	1	0%	100%	40%
LED Support	LED Config	LED Thresh 4	Integer	1	0%	100%	60%
LED Support	LED Config	LED Thresh 5	Integer	1	0%	100%	80%

The default settings are for a 5-LED/LCD segment display; however, if fewer LEDs/LCD segments are required, that is, when extra Host Controlled GPIOs are required, then less LEDs/LCD segments can be used. In this case, the lower LEDs/LCD segments should be used with the unused LEDs/LCD segments being set to 100%. For example, in a 3-LED case, LED1, LED2, and LED3 should be used and can be configured for 0, 33%, and 66%, respectively, with LED4 and LED5 set to 100%.

NOTE: Unused LED settings must be set to 100% even if the pin is not used.

13.4 LED and LCD Display Configuration

All data flash settings are available through the ***LED Support***:***LED Config*** subclass. When the display is enabled for LEDs, the following configuration options are available:

- ***LED Blink Period***—During charging, the top LED segment flashes with the LED Blink Period time period, and lower LEDs will be fully ON. For example, if battery charge is 36% and the display uses five LEDs, LED 1 will be ON and LED 2 will blink. ***[LEDRCA]*** will override this setting if active.
- ***LED Flash Period***—During discharge alarm, the remaining LED segments flash with the ***LED Flash Period*** time period: for example, if battery charge is 36% and the display uses five LEDs, LED 1 and LED 2 will blink.
- ***LED Delay***—An activation delay from one LED to another LED can be set with this value. For LCD, this configuration is not used because the display is always active.
- ***LED Hold Time***—After display activation, the display will stay on for the ***LED Hold Time*** period. For LCD, this configuration is not used because the display is always active.

Table 13-2. LED Configuration Values

Class	Subclass	Name	Format	Length in Bytes	Min Value	Max Value	Default Value	Unit
LED Support	LED Config	LED Flash Period	Unsigned Integer	2	32	65535	512	488 µs
LED Support	LED Config	LED Blink Period	Unsigned Integer	2	32	65535	1024	488 µs
LED Support	LED Config	LED Delay	Unsigned Integer	2	32	65535	100	488 µs
LED Support	LED Config	LED Hold Time	Unsigned IntegerU1	1	0	63	16	0.25 s

13.5 LCD Specific Display Configuration

When the display is enabled for a 5-bar LCD, then the following configuration options are available.

The ***LCD Refresh*** parameter is the LCD refresh frequency setting register. If the LCD display "blinks," or is not constantly on, then this value should be reduced.

Table 13-3. LCD Configuration Values

Class	Subclass	Name	Format	Length in Bytes	Min Value	Max Value	Default Value	Unit
LED Support	LED Config	LCD Refresh	Unsigned Integer	1	20	100	35	Hz

13.6 LED Configuration Register

This register contains a variety of display enable/display settings.

Table 13-4. Display Configuration Enable/Disable Options

Class	Subclass	Name	Format	Min Value	Max Value	Default Value	Unit
Settings	Configuration	LED Configuration	Hex	0x00	0xFF	0x00	—

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	LCDEN	LEDMODE	LEDCHG	LEDRCA	LEDR

RSVD (Bit 7–5): Reserved, do not use.

LCDEN (Bit 4): LCD Display Type Enable

1 = LCD display type is selected.

0 = LED display type is selected (default).

LEDMODE (Bit 3): Determines if *RelativeStateOfCharge()* or *AbsoluteStateOfCharge()* is used for the display.

1 = *AbsoluteStateOfCharge()* is used.

0 = *RelativeStateOfCharge()* is used (default).

LEDCHG (Bit 2): Enables LED during charging. For LCD, the display is always active so this setting has no effect.

1 = Activates display due to charging current

0 = Does not activate display due to charging current (default)

LEDRCA (Bit 1): Enables flashing of the LED display when the *[RCA]* flag in *BatteryStatus()* BatteryStatus is set.

1 = If the LED display is activated when *[RCA]* is set, the display flashes with ***LED Flash Period***.

0 = The LED display is not activated due to *[RCA]* being set. (default)

LEDR (Bit 0): Enables activation of the LED display on device-reset exit. For LCD, the display is activated on device-reset exit; same as setting ***LEDR*** = 1.

1 = LED display is not activated on exit from device reset.

0 = LED display is activated (simulates a $\overline{\text{DISP}}$ transition) on exit from device reset (default).

Host Controlled GPIO

14.1 Introduction

The bq78350 can have the SMBus host read or drive GPIO. Two of the available seven GPIO are dedicated GPIO (GPIO A and GPIO B), and the other five are default configured as the LED display (LED1...5). However, each LED pin can be individually selected to be read or driven by the host SMBus as a GPIO.

14.2 Configuring the GPIO

Each pin chosen as a host controlled GPIO pin must be selected as a GPIO, even the dedicated ones, in ***GPIO Config***. Once selected, the Input or Output selection is set in ***GPIO Output Enable***. If the corresponding bit in ***GPIO Config*** is not set then the bit in ***GPIO Output Enable*** is ignored. If configured as an output the defualt state upon reset of the device can be set through ***GPIO Output Default***. Additionally each pin can be configured as either Open Drain (OD) or as a 3-mA Current Sink (CS) through the ***GPIO Type*** settings.

Table 14-1. Host Controlled GPIO Enable Options

Class	Subclass	Name	Format	Min Value	Max Value	Default Value	Unit
GPIO	GPIO Config	GPIO Config	Hex	0x00	0xFE	0x00	—

7	6	5	4	3	2	1	0
GPIO B	GPIO A	LED5	LED4	LED3	LED2	LED1	RSVD

GPIO B (Bit 7): GPIO B
- 1 = Active as GPIO
- 0 = Inactive

GPIO A (Bit 6): GPIO A
- 1 = Active as GPIO
- 0 = Inactive

LED5 (Bit 5): GPIO 5
- 1 = Active as GPIO
- 0 = Inactive (used as LED5)

LED4 (Bit 4): GPIO 4
- 1 = Active as GPIO
- 0 = Inactive (used as LED4)

LED3 (Bit 3): GPIO 3
- 1 = Active as GPIO
- 0 = Inactive (used as LED3)

LED2 (Bit 2): GPIO 2
- 1 = Active as GPIO
- 0 = Inactive (used as LED2)

LED1 (Bit 1): GPIO 1
- 1 = Active as GPIO
- 0 = Inactive (used as LED1)

RSVD (Bit 0): Reserved

Table 14-2. Host Controlled GPIO Output Enable Configuration

Class	Subclass	Name	Format	Min Value	Max Value	Default Value	Unit
GPIO	GPIO Config	GPIO Output Enable	Hex	0x00	0xFE	0x00	—

7	6	5	4	3	2	1	0
GPIO B	GPIO A	LED5	LED4	LED3	LED2	LED1	RSVD

GPIO B (Bit 7): GPIO B
- 1 = Output
- 0 = Input

GPIO A (Bit 6): GPIO A
- 1 = Output
- 0 = Input

LED5 (Bit 5): GPIO 5
- 1 = Output
- 0 = Input

LED4 (Bit 4): GPIO 4
- 1 = Output
- 0 = Input

LED3 (Bit 3): GPIO 3
- 1 = Output
- 0 = Input

LED2 (Bit 2): GPIO 2
- 1 = Output
- 0 = Input

LED1 (Bit 1): GPIO 1
- 1 = Output
- 0 = Input

RSVD (Bit 0): Reserved

Table 14-3. Host Controlled GPIO Output Default Configuration

Class	Subclass	Name	Format	Min Value	Max Value	Default Value	Unit
GPIO	GPIO Config	GPIO Output Default	Hex	0x00	0xFE	0x00	—

7	6	5	4	3	2	1	0
GPIO B	GPIO A	LED5	LED4	LED3	LED2	LED1	RSVD

GPIO B (Bit 7): GPIO B
- 1 = If enabled as Output, High
- 0 = If enabled as Output, Low

GPIO A (Bit 6): GPIO A
- 1 = If enabled as Output, High
- 0 = If enabled as Output, Low

LED5 (Bit 5): GPIO 5
- 1 = If enabled as Output, High
- 0 = If enabled as Output, Low

LED4 (Bit 4): GPIO 4
- 1 = If enabled as Output, High
- 0 = If enabled as Output, Low

LED3 (Bit 3): GPIO 3
- 1 = If enabled as Output, High
- 0 = If enabled as Output, Low

LED2 (Bit 2): GPIO 2
- 1 = If enabled as Output, High
- 0 = If enabled as Output, Low

LED1 (Bit 1): GPIO 1
- 1 = If enabled as Output, High
- 0 = If enabled as Output, Low

RSVD (Bit 0): Reserved

Table 14-4. Host Controlled GPIO Type Configuration

Class	Subclass	Name	Format	Min Value	Max Value	Default Value	Unit
GPIO	GPIO Config	GPIO Type	Hex	0x00	0xFE	0xC0	—

7	6	5	4	3	2	1	0
GPIO B	GPIO A	LED5	LED4	LED3	LED2	LED1	RSVD

GPIO B (Bit 7): GPIO B
- 1 = Open Drain
- 0 = 3-mA Current Sink

GPIO A (Bit 6): GPIO A
- 1 = Open Drain
- 0 = 3-mA Current Sink

LED5 (Bit 5): GPIO 5
- 1 = Open Drain
- 0 = 3-mA Current Sink

LED4 (Bit 4): GPIO 4
- 1 = Open Drain
- 0 = 3-mA Current Sink

LED3 (Bit 3): GPIO 3

1 = Open Drain
0 = 3-mA Current Sink

LED2 (Bit 2): GPIO 2

1 = Open Drain
0 = 3-mA Current Sink

LED1 (Bit 1): GPIO 1

1 = Open Drain
0 = 3-mA Current Sink

RSVD (Bit 0): Reserved

14.3 Using the GPIO

The status of all enabled GPIO can be read through *GPIOStatus()*, and the enabled outputs can be driven to a specific state through *GPIOControl()*. When enabling a mix of the LED and GPIO pins to be used as host controlled GPIO, care should be taken to ensure they are configured correctly for appropriate desired operation.

Key Input

15.1 Introduction

The bq78350 uses the KEYIN input to enable or disable the DSG FET if safety conditions allow.

15.2 Input Configuration

The polarity of KEYIN detection can be set to active high or active low. If the KEYIN driver does not drive to both high and low states then the KEYIN pin will require an external pull-up, typ 100 k, to VCC. If ***FET Options [KEY_POL]*** = 0, then the KEYIN input is active low; if ***[KEY_POL]*** = 1, then the KEYIN input is active high. To enable this feature, ***FET Options [KEYEN]*** must be set.

15.3 Operation

When ***[KEY_POL]*** = 0 (active low) and the KEYIN input is low, then the bq78350 operates normally. However, if KEYIN were to transition to a high state and remain in that state for KEYIN Time, then the bq78350 would control the companion AFE to turn off the DSG FET. If the KEYIN input transitions back to low before ***KEYIN Time*** expires, then the bq78350 continues to operate normally and the bq78350 is not influenced by the KEYIN pin.

If the KEYIN input transitions back to a low state and remains in that state for ***KEYIN Time,*** then the bq78350 would control the companion AFE to turn off the DSG FET only if all other safety conditions allow.

If ***KEYEN*** = 1 and if the bq78350 experiences a full power-on reset, then DSG FET will be turned OFF and the KEYIN transition is again required to turn on the DSG FET.

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Power	Keyin	Time	Integer	1	0	10	2	s

Communications

16.1 Introduction

The bq78350 uses SMBus v1.1 with MASTER mode and packet error checking (PEC) options per the SBS specification.

16.2 SMBus On and Off State

The bq78350 detects an SMBus off state when SMBC and SMBD are logic-low for ≥ 2 seconds. Clearing this state requires either SMBC or SMBD to transition high. Within 1 ms, the communication bus is available.

16.3 Packet Error Checking

The bq78350 can receive or transmit data with or without packet error checking (PEC).

In the write-word protocol, if the host does not support PEC, the last byte of data is followed by a stop condition and the ***[HPE]*** bit should be set to 0 (default).

In the write-word protocol, the bq78350 receives the PEC after the last byte of data from the host. If the host does not support PEC, the last byte of data is followed by a stop condition. After receipt of the PEC, the bq78350 compares the value to its calculation. If the PEC is correct, the bq78350 responds with an ACKNOWLEDGE. If it is not correct, the bq78350 responds with a NOT ACKNOWLEDGE and sets an error code. If the host supports PEC, the ***[HPE]*** bit should be set to 1.

In the read-word and block-read in MASTER mode, the host generates an ACKNOWLEDGE after the last byte of data sent by the bq78350. The bq78350 then sends the PEC, and the host, acting as a master-receiver, generates a NOT ACKNOWLEDGE and a stop condition.

16.4 Slave Address

The bq78350 has a configurable addressing scheme that can be enabled or this feature can be disabled resulting in the slave address being fixed as 0x16/0x17.

When ***[FIXED_ADDR]*** in ***SMB Configuration*** is clear (0), then the slave address is determined by the voltage measured at the SMBA pin. The voltage on the SMBA pin is created via either being tied to VCC, VSS, or through an external resistor divider. The external divider can be enabled and disabled via the ADREN (pin 29) and an external FET. The upper resistor should be connected between VCC and SMBA with the lower resistor of the divider connected between SMBA and VSS. Both of these resistors are recommended to be 1% tolerance or better.

Upon exit from Power On Reset (POR) or when *OperationStatus() [PRES]* transitions from 0 to 1, the bq78350 drives ADREN high, takes a number of sequential voltage measurements (set by ***Addr Reads***) of the SMBA pin taking approximately 32 ms each. The corresponding address, set by ***SMBTAR_ADDR0…7***, is determined for each measurement with the most common address selection being the one used. If all are different, then the average voltage value is used to determine the address. Upon completion of the address selection, ADREN is set low to turn off the resistor divider to conserve power.

Care should be taken in the setting of ***Addr Reads*** as the bq78350 will only respond to address 0x16/0x17 until at least ***Addr Read*** × 32 ms after POR.

The actual address corresponding to the SMBA voltage is configurable per the following table.

SMBA Pin Voltage			
Channel	VSMBAMIN Voltage (V)	VSMBAMAX Voltage (V)	Address Data Flash
0	0.070	0.130	SMBTAR_ADDR0
1	0.170	0.230	SMBTAR_ADDR1
2	0.270	0.330	SMBTAR_ADDR2
3	0.370	0.430	SMBTAR_ADDR3
4	0.470	0.530	SMBTAR_ADDR4
5	0.570	0.630	SMBTAR_ADDR5
6	0.670	0.730	SMBTAR_ADDR6
7	0.770	0.830	SMBTAR_ADDR7
0	All other values		0x16

If ***SMB Configuration [FIXED_ADDR]*** is set (1), then the slave address is 0x16/0x17 and the ADREN and SMBA pins are ignored and not used.

NOTE: When determining the values for SMBTAR_ADDR0...7, take into account the R/W bit by programming all addresses to even numbers.

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Settings	Configuration	Addr Reads	Integer	1	0	10	3	—
Settings	Configuration	SMBTAR_ADDR0	Integer	1	0x00	0xFE	0x20	—
Settings	Configuration	SMBTAR_ADDR1	Integer	1	0x00	0xFE	0x22	—
Settings	Configuration	SMBTAR_ADDR2	Integer	1	0x00	0xFE	0x24	—
Settings	Configuration	SMBTAR_ADDR3	Integer	1	0x00	0xFE	0x25	—
Settings	Configuration	SMBTAR_ADDR4	Integer	1	0x00	0xFE	0x26	—
Settings	Configuration	SMBTAR_ADDR5	Integer	1	0x00	0xFE	0x28	—
Settings	Configuration	SMBTAR_ADDR6	Integer	1	0x00	0xFE	0x2A	—
Settings	Configuration	SMBTAR_ADDR7	Integer	1	0x00	0xFE	0x2C	—

16.5 Broadcasts to Smart Charger and Smart Battery Host

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 (***Charger Address***) periodically. The default period is set in Alarm Timer.
- If any of the [OCA], [TCA], [OTA], [TDA], [RCA], [RTA] flags are set, the *AlarmWarning()* broadcast is sent to the host device address (***Host Address***) at the period set in***SMB BCAST Time***. 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 at the period set in ***Charger Request Time***. Broadcasts stop when all flags above have been cleared.

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Settings	SMB Master Mode	Host Address	Integer	1	0x00	0xFE	10	—
Settings	SMB Master Mode	Charger Address	Integer	1	0x00	0xFE	12	—
Settings	SMB Master Mode	Alarm Timer	Integer	1	0	255	10	s

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Settings	SMB Master Mode	Charger Request Timer	Integer	1	0	255	50	s

16.6 SMB Configuration Options

This register configures various SMBus related features.

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Settings	Configuration	SBS Configuration	hex	1	0x00	0xFF	0x01	—

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Low Byte	FIXED_ADDR	RSVD	BLT1	BLT0	RSVD	HPE	CPE	BCAST

FIXED_ADDR (Bit 7): This bit enables the bq78350 to determine its slave address via measurement of the SMBA pin or to use a fixed address of 0x16.

0 = The SMBus slave address is selected via SMBA (default).

1 = The SMBus address is 0x16.

RSVD (Bit 6): Reserved

BLT1:0 (Bits 5–4): 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

RSVD (Bit 3): Reserved

HPE (Bit 2): PEC on host communication

0 = Disabled (default)

1 = Enabled

CPE (Bit 1): PEC on charger communication

0 = Disabled (default)

1 = Enabled

BCAST (Bit 0): Enable alert and charging broadcast from device to host

0 = Disabled (default)

1 = Enabled

SBS Commands

17.1 Summary

Table 17-1. SBS Commands Summary

SBS Cmd	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x00	R/W	ManufacturerAccess	hex	2	0x0000	0xFFFF	—	
0x01	R/W	RemainingCapacityAlarm	unsigned int	2	0	65535	300	mAh or 10 mWh
0x02	R/W	RemainingTimeAlarm	unsigned int	2	0	65535	10	min
0x03	R/W	BatteryMode	hex	2	0x0000	0xFFFF	—	
0x04	R/W	AtRate	integer	2	–32768	32767	—	mAh or 10 mWh
0x05	R	AtRateTimeToFull	unsigned int	2	0	65534	—	min
0x06	R	AtRateTimeToEmpty	unsigned int	2	0	65534	—	min
0x07	R	AtRateOK	unsigned int	2	0	65535	—	
0x08	R	Temperature	unsigned int	2	0	65535	—	0.1°K
0x09	R	Voltage	unsigned int	2	0	65535	—	mV
0x0A	R	Current	integer	2	–32768	32767	—	mA
0x0B	R	AverageCurrent	integer	2	–32768	32767	—	mA
0x0C	R	MaxError	unsigned int	1	0%	100%	—	
0x0D	R	RelativeStateOfCharge	unsigned int	1	0%	100%	—	
0x0E	R	AbsoluteStateOfCharge	unsigned int	1	0%	100+%	—	
0x0F	R/W	RemainingCapacity	unsigned int	2	0	65535	—	mAh or 10 mWh
0x10	R	FullChargeCapacity	unsigned int	2	0	65535	—	mAh or 10 mWh
0x11	R	RunTimeToEmpty	unsigned int	2	0	65534	—	min
0x12	R	AverageTimeToEmpty	unsigned int	2	0	65534	—	min
0x13	R	AverageTimeToFull	unsigned int	2	0	65534	—	min
0x14	R	ChargingCurrent	unsigned int	2	0	65534	—	mA
0x15	R	ChargingVoltage	unsigned int	2	0	65534	—	mV
0x16	R	BatteryStatus	unsigned int	2	0x0000	0xdbff	—	
0x17	R	CycleCount	unsigned int	2	0	65535	—	
0x18	R	DesignCapacity	unsigned int	2	0	65535	—	mAh or 10 mWh
0x19	R	DesignVoltage	unsigned int	2	0	65535	—	mV
0x1A	R	SpecificationInfo	hex	2	0x0000	0xFFFF	0x0031	
0x1B	R	ManufacturerDate	unsigned int	2	0	65535	—	
0x1C	R	SerialNumber	hex	2	0x0000	0xFFFF	0x0001	
0x20	R	ManufacturerName	string	11+1	—	—	Texas Inst.	ASCII
0x21	R	DeviceName	string	7+1	—	—	bq78350	ASCII
0x22	R	DeviceChemistry	string	4+1	—	—	LION	ASCII
0x23	R	ManufacturerData	String	14+1	—	—	—	ASCII
0x2B	R/W	HostFETControl	hex	2	0	65535	—	
0x2C	R	GPIOStatus	hex	2	0	65535	—	
0x2D	R/W	GPIOControl	hex	2	0	65535	—	
0x2E	R	VAUXVoltage	unsigned int	2	0	65535	1	

Table 17-1. SBS Commands Summary (continued)

SBS Cmd	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x2F	R/W	Authenticate	hex	20+1	—	—	—	
0x30	R	Reserved	—	—	—	—	—	—
0x31	R	CellVoltage15	unsigned int	2	0	65535	—	mV
0x32	R	CellVoltage14	unsigned int	2	0	65535	—	mV
0x33	R	CellVoltage13	unsigned int	2	0	65535	—	mV
0x34	R	CellVoltage12	unsigned int	2	0	65535	—	mV
0x35	R	CellVoltage11	unsigned int	2	0	65535	—	mV
0x36	R	CellVoltage10	unsigned int	2	0	65535	—	mV
0x37	R	CellVoltage9	unsigned int	2	0	65535	—	mV
0x38	R	CellVoltage8	unsigned int	2	0	65535	—	mV
0x39	R	CellVoltage7	unsigned int	2	0	65535	—	mV
0x3A	R	CellVoltage6	unsigned int	2	0	65535	—	mV
0x3B	R	CellVoltage5	unsigned int	2	0	65535	—	mV
0x3C	R	CellVoltage4	unsigned int	2	0	65535	—	mV
0x3D	R	CellVoltage3	unsigned int	2	0	65535	—	mV
0x3E	R	CellVoltage2	unsigned int	2	0	65535	—	mV
0x3F	R	CellVoltage1	unsigned int	2	0	65535	—	mV
0x4D	R	ExtAveCellVoltage	unsigned int	2	0	65535	—	mV
0x4E	R	PendingEDV	unsigned int	2	0	65535	—	mV
0x4F	R	StateOfHealth	unsigned int	1	0%	100%	—	
0x50	R	SafetyAlert	hex	4+1	0x00000000	0xFFFFffff	—	—
0x51	R	SafetyStatus	hex	4+1	0x00000000	0xFFFFffff	—	—
0x52	R	PFAlert	hex	2+1	0x0000	0x9fff	—	—
0x53	R	PFStatus	hex	2+1	0x0000	0x9fff	—	—
0x54	R	OperationStatus	hex	2+1	0x0000	0xf7F7	—	—
0x55	R	ChargingStatus	hex	2+1	0x0000	0xFFFF	—	—
0x56	R	GaugingStatus	Hex	2+1	0x0000	0xFFFF	—	—
0x57	R	ManufacturingStatus	Hex	2+1	0x0000	0xFFFF	—	—
0x58	R	AFEStatus	hex	2+1	0x00	0xFF	—	—
0x59	R	AFEConfig	String	10+1	—	—	—	ASCII
0x5A	R	AFEVCx	String	30+1	—	—	—	ASCII
0x5B	R	AFEData	String	13+1	—	—	—	ASCII
0x60	R	Lifetime Data Block 1	String	32+1	—	—	—	
0x61	R	Lifetime Data Block 2	String	32+1	—	—	—	
0x62	R	Lifetime Data Block 3	String	32+1	—	—	—	
0x63	R	Lifetime Data Block 4	String	32+1	—	—	—	
0x64	R	Lifetime Data Block 5	String	32+1	—	—	—	
0x65	R	Lifetime Data Block 6	String	32+1	—	—	—	
0x66	R	Lifetime Data Block 7	String	32+1	—	—	—	
0x70	R	ManufacturerInfo	String	32+1	—	—	—	
0x71	R	DAStatus 1	String	32+1	—	—	—	
0x72	R	DAStatus 2	String	32+1	—	—	—	
0x80	R	CUV Snapshot	String	32+1	—	—	—	
0x81	R	COV Snapshot	String	32+1	—	—	—	

17.2 0x00 ManufacturerAccess() and 0x44 ManufacturerBlockAccess()

The *ManufacturerAccess()* and *ManufacturerBlockAccess()* commands make available a variety of data:

- *ManufacturerAccess()* provides access to the data through the Smart Battery Data Set standard, including when in SEALED mode, using a sequence of a *ManufacturerAccess()* write word and a *ManufacturerData()* block read.
- The *ManufacturerBlockAccess()* is an extended command that enables access to the same data, but through a simpler block write/read sequence to the same command.

ManufacturerAccess() example to read *LifetimeDataBlock1()*:

(a) Send *LifetimeDataBlock1()* command through the *ManufacturerAccess()*: SMBus Write Word of 0x0060 to command 0x00.

(b) SMBus Read Block of command 0x26: The first two bytes of the return block will be the data length and the next bytes will be the data of the command.

ManufacturerBlockAccess() example to read *LifetimeDataBlock1()*:

(a) Send *LifetimeDataBlock1()* command through the *ManufacturerBlockAccess()*: SMBus Write Block of 0x60 + 0x00 to command 0x44. (Data must be sent in Little Endian.)

(b) SMBus Read Block of command 0x44: The first two bytes of the return block will be the Manufacturer Access command, followed by return data of the command.

Each data entity read/write through *ManufacturerBlockAccess()* is in Little Endian. For example, a 2-byte data 0x1234 should be read/write as 0x34 + 0x12; a 4-byte 0x12345678 data should be read/write as 0x78+ 0x56+ 0x34 + 0x12.

There are two exceptions:

1. 0x0035 *SecurityKeys()*: This Manufacturer Access command allows the user to read or change the Unseal/Full Access keys. The above description is applied when reading the security keys. However, only the *ManufacturerBlockAccess()* can be used to change the security keys.

   To write data through *ManufacturerBlockAccess()*, follow the SMBus write block protocol with the first two bytes being the *SecurityKeys()*, followed by the desired new keys' values. See ManufacturerAccess() 0x0035 Security Keys for details.
2. 0x0037 *AuthenticationKey()*: This Manufacturer Access command allows users to change the authentication key. Sending the new authentication key through *ManufacturerBlockAccess()* is supported. Additionally, the gauge also supports the approach of updating the authentication keys by sending the new keys to *ManufacturerInput()*. See Section 17.2.32 for details.

Table 17-2. ManufacturerAccess() Command List

Command	Function	Access	Format	Data Read on 0x44 and 0x23	DATA READ on 0x2F	Not Available in SEALED Mode	Type	Unit
0x0001	DeviceType	R	Block	√	—	—	Hex	—
0x0002	FirmwareVersion	R	Block	√	—	—	Hex	—
0x0003	HardwareVersion	R	Block	√	—	—	Hex	—
0x0004	IFChecksum	R	Block	√	—	—	Hex	—
0x0005	StaticDFSignature	R	Block	√	—	—	Hex	—
0x0006	ChemID	R	Block	√	—	—	Hex	—
0x0008	StaticChemDFSignature	R	Block	√	—	—	Hex	—
0x0009	AllDFSignature	R	Block	√	—	—	Hex	—
0x0010	ShutdownMode	W	—	—	—	—	Hex	—
0x0011	SleepMode	W	—	—	—	√	Hex	—
0x0012	DeviceReset	W	—	—	—	√	Hex	—
0x001B	CellBalanceToggle	W	—	—	—	√	Hex	—
0x001C	AFEDelayDisable	W	—	—	—	√	Hex	—
0x001D	SAFEToggle	W	—	—	—	√	Hex	—
0x001E	PrechargeFET	W	—	—	—	√	Hex	—
0x001F	ChargeFET	W	—	—	—	√	Hex	—
0x0020	DischargeFET	W	—	—	—	√	Hex	—
0x0021	Gauging	W	—	—	—	√	Hex	—

Table 17-2. ManufacturerAccess() Command List (continued)

Command	Function	Access	Format	Data Read on 0x44 and 0x23	DATA READ on 0x2F	Not Available in SEALED Mode	Type	Unit
0x0022	FETControl	W	—	—	—	√	Hex	—
0x0023	LifetimeDataCollection	W	—	—	—	√	Hex	—
0x0024	PermanentFailure	W	—	—	—	√	Hex	—
0x0025	BlackBoxRecorder	W	—	—	—	√	Hex	—
0x0026	SAFE	W	—	—	—	√	Hex	—
0x0027	LEDDisplayEnable	W	—	—	—	√	Hex	—
0x0028	LifetimeDataReset	W	—	—	—	√	Hex	—
0x0029	PermanentFailureDataReset	W	—	—	—	√	Hex	—
0x002A	BlackBoxRecorderReset	W	—	—	—	√	Hex	—
0x002C	LEDDisplayPress	W	—	—	—	√	Hex	—
0x002D	CalibrationMode	W	—	—	—	√	Hex	—
0x0030	SealDevice	W	—	—	—	—	Hex	—
0x0035	SecurityKeys	R/W	Block	√	—	—	Hex	—
0x0037	AuthenticationKey	R/W	Block	—	√	—	Hex	—
0x0041	DeviceReset	W	—	—	—	√	Hex	—
0x004F	StateOfHealth	R	Block	√	—	—	Hex	—
0x0050	SafetyAlert	R	Block	√	—	—	Hex	—
0x0051	SafetyStatus	R	Block	√	—	—	Hex	—
0x0052	PFAlert	R	Block	√	—	—	Hex	—
0x0053	PFStatus	R	Block	√	—	—	Hex	—
0x0054	OperationStatus	R	Block	√	—	—	Hex	—
0x0055	ChargingStatus	R	Block	√	—	—	Hex	—
0x0056	GaugingStatus	R	Block	√	—	—	Hex	—
0x0057	ManufacturingStatus	R	Block	√	—	—	Hex	—
0x0058	AFEStatus	R	Block	√	—	—	Hex	—
0x0059	AFEConfig	R	String	√	—	—		—
0x005A	AFEVCx	R	String	√	—	—		—
0x005B	AFEData	R/W	String	√	—	—		—
0x0060	LifetimeDataBlock1	R	Block	√	—	—	Mixed	Mixed
0x0061	LifetimeDataBlock2	R	Block	√	—	—	Mixed	Mixed
0x0062	LifetimeDataBlock3	R	Block	√	—	—	Mixed	Mixed
0x0063	LifetimeDataBlock4	R	Block	√	—	—	Mixed	Mixed
0x0064	LifetimeDataBlock5	R	Block	√	—	—	Mixed	Mixed
0x0065	LifetimeDataBlock6	R	Block	√	—	—	Mixed	Mixed
0x0066	LifetimeDataBlock7	R	Block	√	—	—	Mixed	Mixed
0x0070	ManufacturerInfo	R	Block	√	—	—	Hex	—
0x0071	DAStatus1	R	Block	√	—	—	Mixed	Mixed
0x0072	DAStatus2	R	Block	√	—	—	Mixed	Mixed
0x0080	CUVSnapshot	R	Block	√	—	—	Hex	—
0x0081	COVSnapshot	R	Block	√	—	—	Hex	—
0x01yy	DFAccessRowAddress	R/W	Block	—	√	√	Hex	—
0x0F00	ROMMode	W	—	—	—	√	Hex	—
0xF080	ExitCalibrationOutput	R/W	Block	√	—	√	Hex	—
0xF081	OutputCellVoltageforCalibration	R/W	Block	√	—	√	Hex	—
0xF082	OutputCellVoltageCCandTempforCalibration	R/w	Block	√	—	√	Hex	—

17.2.1 ManufacturerAccess() 0x0000 ManufacturerBlockAccess() or ManufacturerData()

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

17.2.2 ManufacturerAccess() 0x0001 Device Type

The device can be checked for the IC part number. When 0x0001 is written to *ManufacturerAccess()*, the bq78350 returns the IC part number on a subsequent read on *ManufacturerBlockAccess()* or *ManufacturerData()* in the following format: aaAA, where:

Value	Description
aaAA	Device type

17.2.3 ManufacturerAccess() 0x0002 Firmware Version

The device can be checked for the firmware version of the IC. When 0x0002 is written to *ManufacturerAccess()*, the bq78350 returns the firmware revision on *ManufacturerBlockAccess()* or *ManufacturerData()* in the following format: ddDDvvVVbbBBTTzzZZRREE, where:

Value	Description
ddDD	Device Number
vvVV	Version
ttTT	Firmware Type
zzZZ	CEDV Version
RREE	Reserved

17.2.4 ManufacturerAccess() 0x0003 Hardware Version

The device can be checked for the hardware version of the IC. When 0x0003 is written to *ManufacturerAccess()*, the bq78350 returns the hardware revision on a subsequent read on *ManufacturerBlockAccess()* or *ManufacturerData()*.

Value	Description
aaAA	Hardware Version

17.2.5 ManufacturerAccess() 0x0004 Instruction Flash Signature

The device can return the instruction flash signature. When 0x0004 is written to *ManufacturerAccess()*, the bq78350 returns the IF signature on a subsequent read on *ManufacturerBlockAccess()* or *ManufacturerData()* after a wait time of 250 ms.

17.2.6 ManufacturerAccess() 0x0005 Static DF Signature

The device can return the data flash checksum. When 0x0005 is written to *ManufacturerAccess()* the bq78350 returns the signature of all static DF on a subsequent read on *ManufacturerBlockAccess()* or *ManufacturerData()* after a wait time of 250 ms. The MSB is set to 1 if the calculated signature does not match the signature stored in DF.

17.2.7 ManufacturerAccess() 0x0006 Chemical ID

This command returns the chemical ID of the OCV tables used in the gauging algorithm. When 0x0006 is written to *ManufacturerAccess()*, the bq78350 returns the chemical ID on a subsequent read on *ManufacturerBlockAccess()* or *ManufacturerData()*.

17.2.8 ManufacturerAccess() 0x0008 Static Chem DF Signature

The device can return the data flash checksum. When 0x0008 is written to *ManufacturerAccess()*, the bq78350 returns the signature of all static chemistry DF on a subsequent read on *ManufacturerBlockAccess()* or *ManufacturerData()* after a wait time of 250 ms. The MSB is set to 1 if the calculated signature does not match the signature stored in DF.

17.2.9 ManufacturerAccess() 0x0009 All DF Signature

The device can return the data flash checksum. When 0x0009 is written to *ManufacturerAccess()*, the bq78350 returns the signature of all DF parameters on a subsequent read on *ManufacturerBlockAccess()* or *ManufacturerData()* after a wait time of 250 ms. The MSB is set to 1 if the calculated signature does not match the signature stored in DF. It is normally expected that this signature will change due to updates of lifetime, gauging, and other information.

17.2.10 ManufacturerAccess() 0x0010 SHUTDOWN Mode

The device can be sent to SHUTDOWN mode before shipping to reduce power consumption to a minimum. The device will wake up when a voltage is applied to companion AFE bq769x0. When the pack is sealed, this feature requires the command be sent twice, one after the other, for safety. Once SHUTDOWN mode is enabled, it is not possible to clear it without entering SHUTDOWN mode.

Status	Condition	Action
Normal	*OperationStatus()[SDM]* = 0	Shutdown feature is armed internally.
Arm	*OperationStatus()[SEC1,SEC0]* = [1, 1] 0x0010 sent to *ManufacturerAccess()*	Shutdown feature is armed internally.
Enable	0x0010 to *ManufacturerAccess()* when *OperationStatus[SEC1,SEC0]* = [1, 1] OR 0x0010 to *ManufacturerAccess()* when shutdown feature is armed.	*OperationStatus()[SDM]* = 1
Trip	*Current()* = 0 AND *OperationStatus()[SDM]* = 1	No charging or discharging allowed. Device shutdown.
Recovery	Voltage on companion AFE bq769x0 TS1 pin > V_{BOOT}	Device powers up (reset)

17.2.11 ManufacturerAccess() 0x0011 SLEEP Mode

The device can be send to SLEEP mode with *ManufacturerAccess()* if the sleep conditions are met.

Status	Condition	Action
Enable	0x0011 to *ManufacturerAccess()*	*OperationStatus()[SLEEPM]* = 1
Activate	|*Current()*| < ***Power:Sleep Current***	Turn off 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	|*Current()*| > Configuration:Sleep Current	*OperationStatus()[SLEEPM]* = 0 Returns to NORMAL mode.
Exit	*SafetyAlert()* flag or *PFAlert()* flag set	*OperationStatus()[SLEEPM]* = 0 Returns to NORMAL mode

17.2.12 ManufacturerAccess() 0x001B Cell Balance Toggle

This command activates/deactivates the internal cell balance FETs to ease testing during manufacturing. When 0x001B is written to *ManufacturerAccess()* when *ManufacturingStatus()[CB_TEST]* = 1, then cell balance FETs for ODD cells as determined by ***AFE Cell Map*** (Cell 1, Cell 3, Cell 5, and so on) are turned ON. If 0x001B is written to *ManufacturerAccess()* once again, then the cell balance FETs for EVEN cells (Cell 2, Cell 4, Cell 6, and so on) are turned ON. If 0x001B is written to *ManufacturerAccess()* once again, then the cell balance FETs are turned OFF and *ManufacturingStatus()[CB_TEST]* is cleared to 0.

CAUTION

This feature should not be used with cells connected to the bq769x0.

17.2.13 ManufacturerAccess() 0x001C AFE Delay Disable

This command deactivates the companion AFE bq769x0 output to ease testing during manufacturing. When 0x001C is written to *ManufacturerAccess()* when *ManufacturingStatus()[AFE_DD_TEST]* = 0, then the companion AFE protection delays are reduced to ~250 ms if they are longer than this in NORMAL mode and *ManufacturingStatus()[AFE_DD_TEST]* is set to 1. If 0x001C is written to *ManufacturerAccess()* once again, then the companion AFE protection delays are returned to their normal settings and *ManufacturingStatus()[AFE_DD_TEST]* is cleared to 0.

17.2.14 ManufacturerAccess() 0x001D SAFE Toggle

This command activates/deactivates the SAFE output to ease testing during manufacturing. When 0x001D is written to *ManufacturerAccess()* when *ManufacturingStatus()[SAFE_EN]* = 0, then the SAFE pin is driven high and *ManufacturingStatus()[SAFE_EN]* is set to 1. If 0x001D is written to *ManufacturerAccess()* once again, then the SAFE pin returns low and *ManufacturingStatus()[SAFE_EN]* is cleared to 0.

17.2.15 ManufacturerAccess() 0x001E PRE-CHG FET

This command turns on/off Pre-CHG FET drive function to ease testing during manufacturing. When 0x001E is written to *ManufacturerAccess()* when *ManufacturingStatus()[FET_EN,PCHG_TEST]* = 0, 0, then PCHG turns ON and *ManufacturingStatus()[PCHG_TEST]* is set to 1. If 0x001E is written to *ManufacturerAccess()* once again, then PCHG turns OFF and *ManufacturingStatus()[PCHG_TEST]* is cleared to 0.

17.2.16 ManufacturerAccess() 0x001F CHG FET

This command turns on/off CHG FET drive function to ease testing during manufacturing. When 0x001F is written to *ManufacturerAccess()* when *ManufacturingStatus()[FET_EN,CHG_TEST]* = 0, 0, then CHG turns ON and *ManufacturingStatus()[CHG_TEST]* is set to 1. If 0x001F is written to *ManufacturerAccess()* once again, then CHG turns OFF and *ManufacturingStatus()[CHG_TEST]* is cleared to 0.

17.2.17 ManufacturerAccess() 0x0020 DSG FET

This command turns on/off DSG FET drive function to ease testing during manufacturing. When 0x0020 is written to *ManufacturerAccess()* when *ManufacturingStatus()[FET_EN, DSG_TEST]* = 0, 0, then DSG turns ON and *ManufacturingStatus()[DSG_TEST]* is set to 1. If 0x0020 is written to *ManufacturerAccess()* once again, then DSG turns OFF and *ManufacturingStatus()[DSG_TEST]* is cleared to 0.

17.2.18 ManufacturerAccess() 0x0022 FET Control

This command disables/enables control of the CHG, DSG, and PCHG FET by the firmware. When 0x0022 is written to *ManufacturerAccess()* when *ManufacturingStatus()[FET_EN]* = 0, then FETs are controlled by the firmware and*ManufacturingStatus()[FET_EN]* is set to 1. If 0x0022 is written to *ManufacturerAccess()* once again, then CHG, DSG and PCHG turn OFF and *ManufacturingStatus()[FET_EN]* is cleared to 0.

17.2.19 ManufacturerAccess() 0x0023 Lifetime Data Collection

This command disables/enables Lifetime Data Collection for ease of manufacturing. When 0x0023 is written to *ManufacturerAccess()* when *ManufacturingStatus()[LF_EN]* = 0, then the Lifetime Data Collection feature is enabled and *ManufacturingStatus()[LF_EN]* is set to 1. If 0x0023 is written to *ManufacturerAccess()* once again, then the Lifetime Data Collection feature is disabled and *ManufacturingStatus()[LF_EN]* is cleared to 0.

17.2.20 ManufacturerAccess() 0x0024 Permanent Failure

This command disables/enables Permanent Failure for ease of manufacturing. When 0x0024 is written to *ManufacturerAccess()* when *ManufacturingStatus()[PF_EN]* = 0, then the Permanent Failure feature is enabled and *ManufacturingStatus()[PF_EN]* is set to 1. If 0x0024 is written to *ManufacturerAccess()* once again, then the Permanent Failure feature is disabled and *ManufacturingStatus()[PF_EN]* is cleared to 0.

17.2.21 ManufacturerAccess() 0x0025 Black Box Recorder

This command enables/disables Black Box Recorder function for ease of manufacturing. When 0x0025 is written to *ManufacturerAccess()* when *ManufacturingStatus()[BBR_EN]* = 0, then the Black Box Recorder feature is enabled and *ManufacturingStatus()[BBR_EN]* is set to 1. If 0x0025 is written to *ManufacturerAccess()* once again, then the Black Box Recorder feature is disabled and *ManufacturingStatus()[BBR_EN]* is cleared to 0.

17.2.22 ManufacturerAccess() 0x0026 SAFE

This command disables/enables firmware-based SAFE pin activation to ease testing during manufacturing. When 0x0026 is written to *ManufacturerAccess()* when *ManufacturingStatus()[SAFE_EN]* = 0, then the SAFE pin is enabled and *ManufacturingStatus()[SAFE_EN]* is set to 1. If 0x0026 is written to *ManufacturerAccess()* once again, then the SAFE pin is disabled and *ManufacturingStatus()[SAFE_EN]* is cleared to 0.

17.2.23 ManufacturerAccess() 0x0027 LED Display Enable

This command enables or disables the LED display function from being triggered by the $\overline{\text{DISP}}$ pin 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.

17.2.24 ManufacturerAccess() 0x0028 Lifetime Data Reset

This command resets Lifetime data in data flash for ease of manufacturing. When 0x0028 is written to *ManufacturerAccess(),* the Lifetime data stored in data flash is cleared.

Status	Condition	Action
Reset	0x0028 to *ManufacturerAccess()*	Clear Lifetime Data in DF

17.2.25 ManufacturerAccess() 0x0029 Permanent Fail Data Reset

This command resets PF data in data flash for ease of manufacturing. When 0x0029 is written to *ManufacturerAccess()*, the Permanent Failure data stored in data flash is cleared.

Status	Condition	Action
Reset	0x0029 to *ManufacturerAccess()*	Clear PF Data in DF

17.2.26 ManufacturerAccess() 0x002A Black Box Recorder Reset

This command resets the Black Box Recorder data in data flash for ease of manufacturing. When 0x002A is written to *ManufacturerAccess()*, the Black Box Recorder data stored in data flash is cleared.

Status	Condition	Action
Reset	0x002A to *ManufacturerAccess()*	Clear Black Box Recorder data in DF

17.2.27 ManufacturerAccess() 0x002B LED TOGGLE

This command toggles the LED display from off to on and from on to off to help streamline testing during manufacturing. The status of the display is indicated through *OperationStatus()[LED]*.

17.2.28 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.

17.2.29 ManufacturerAccess() 0x002D CALIBRATION Mode

This command disables/enables entry into CALIBRATION mode. When 0x002D is written to *ManufacturerAccess()* when *ManufacturingStatus()[CAL_EN]* = 0, then *ManufacturingData()* is enabled to output ADC and CC raw data, is controllable with 0xF081 and 0xF082 on *ManufacturerAccess()*, and *ManufacturingStatus()[CAL_EN]* is set to 1. If 0x002D is written to *ManufacturerAccess()* once again, then *ManufacturingData()* returns default data and *ManufacturingStatus()[CAL_EN]* is cleared to 0.

17.2.30 ManufacturerAccess() 0x0030 Seal Device

This command seals the device for the field, disabling certain SBS commands and access to DF. When 0x0030 is written to *ManufacturerAccess()* when *OperationStatus()[SEC1, SEC0]* = 0, 1 or 0,1, then the bq78350 device enters SEALED mode and *OperationStatus()[SEC1, SEC0]* is set to 1,1.

17.2.31 ManufacturerAccess() 0x0035 Security Keys

This is a read/write command that changes the Unseal and Full Access keys. To read the keys, sending the *SecurityKeys()* command to either the *ManufacturerAccess()* 0x00 or the *ManufacturerBlockAccess()* 0x44 returns the keys on *ManufacturerBlockAccess()* or *ManufacturerData()*.

To change the keys, the write operations must send through *ManufacturerBlockAccess()* 0x44 with *SecurityKeys()* followed by the keys. Each parameter entry must be sent in Little Endian.

Example:

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

SMBus write block: command = 0x44, block = 0x35 + 0x00 + 0x23 + 0x12 + 0x67 + 0x45 + 0xAB + 0x89 + 0xEF + 0xCD

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

17.2.32 ManufacturerAccess() 0x0037 Authentication Key

This command enters a new authentication key into the device.

Status	Condition	Action
Initiate	*OperationStatus()[SEC1,SEC0]* = 0,1 AND 0x0037 to *ManufacturerAccess()*	*OperationStatus()[AUTH]* = 1 160-bit random number available at *ManufacturerInput()*
Enter Key	Correct 128-bit Key written to *ManufacturerInput()* in the format 0xAABBCCDDEEFFGGHHIIJJKKLLMMNNOOPP, where AA is LSB.	Wait time 250 ms *OperationStatus()[AUTH]* = 0 Device returns 160-bit HMAC digest at *ManufacturerInput()* in the format 0xAABBCCDDEEFFGGHHIIJJKKLLMMNNOOPPQQRRSSTTT, where AA is LSB. The HMAC digest was calculated using the random number + key. Compare with own calculations, check the validity of the key.

17.2.33 ManufacturerAccess() 0x0041 Device Reset

This command resets the device. When 0x0012 or 0x0041 is written to *ManufacturerAccess()*, the bq78350 is reset.

17.2.34 ManufacturerAccess() 0x0050 SafetyAlert

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

Status	Condition	Action
Activate	0x0050 to *ManufacturerAccess()*	Outputs *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	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	OC	CTOS	RSVD	PTOS	RSVD
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	RSVD	UTD	UTC	OTD	OTC	ASCDL	ASCD	AOLDL	AOLD	OCD	OCC	COV	CUV

RSVD (Bit 31–21): Reserved

OC (Bit 20): Overcharge

1 = Detected

0 = Not Detected

CTOS (Bit 19): Charge Timeout Suspend

1 = Detected

0 = Not Detected

RSVD (Bit 18): Reserved

PTOS (Bit 17): Precharge Timeout Suspend

1 = Detected

0 = Not Detected

RSVD (Bit 16–12): Reserved

UTD (Bit 11): Undertemperature During Discharge

1 = Detected

0 = Not Detected

UTC (Bit 10): Undertemperature During Charge

1 = Detected

0 = Not Detected

OTD (Bit 9): Overtemperature During Discharge

1 = Detected

0 = Not Detected

OTC (Bit 8): Overtemperature During Charge

1 = Detected

0 = Not Detected

ASCDL (Bit 7): Short Circuit During Discharge Latch

1 = Detected

0 = Not Detected

ASCD (Bit 6): Short Circuit During Discharge

1 = Detected

0 = Not Detected

AOLDL (Bit 5): Overload During Discharge Latch

1 = Detected

0 = Not Detected

AOLD (Bit 4): Overload During Discharge

1 = Detected

0 = Not Detected

OCD (Bit 3): Overcurrent During Discharge

1 = Detected

0 = Not Detected

OCC (Bit 2): Overcurrent During Charge

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

17.2.35 ManufacturerAccess() 0x0051 SafetyStatus

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

Status	Condition	Action
Activate	0x0051 to *ManufacturerAccess()*	Outputs *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	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	OC	RSVD	CTO	RSVD	PTO
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	RSVD	UTD	UTC	OTD	OTC	ASCDL	ASCD	AOLDL	AOLD	OCD	OCC	COV	CUV

RSVD (Bits 31–21): Reserved

OC (Bit 20): Overcharge

1 = Detected

0 = Not Detected

RSVD (Bit 19): Reserved

CTO (Bit 18): Charge Timeout

1 = Detected

0 = Not Detected

RSVD (Bit 17): Reserved

PTO (Bit 16): Precharge Timeout

1 = Detected

0 = Not Detected

RSVD (Bits 15–12): Reserved

UTD (Bit 11): Undertemperature During Discharge

1 = Detected

0 = Not Detected

UTC (Bit 10): Undertemperature During Charge

1 = Detected

0 = Not Detected

OTD (Bit 9): Overtemperature During Discharge

1 = Detected

0 = Not Detected

OTC (Bit 8): Overtemperature During Charge

1 = Detected

0 = Not Detected

ASCDL (Bit 7): Short Circuit During Discharge Latch

1 = Detected

0 = Not Detected

ASCD (Bit 6): Short Circuit During Discharge

1 = Detected

0 = Not Detected

AOLDL (Bit 5): Overload During Discharge Latch

1 = Detected

0 = Not Detected

AOLD (Bit 4): Overload During Discharge

1 = Detected

0 = Not Detected

OCD (Bit 3): Overcurrent During Discharge

1 = Detected

0 = Not Detected

OCC (Bit 2): Overcurrent During Charge

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

17.2.36 ManufacturerAccess() 0x0052 PFAlert

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

Status	Condition	Action
Activate	0x0052 to *ManufacturerAccess()*	Outputs *PFAlert()* flags on *ManufacturerBlockAccess()* or *ManufacturerData()*

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RSVD	TS3	TS2	TS1	AFE_XRDY	AFE_OVRD	AFEC	AFER	DFETF	CFETF	VIMR	SOT	SOCD	SOCC	SOV	SUV

RSVD (Bit 15): Reserved, do not use.

TS3 (Bit 14): Open Thermistor – TS3 Failure
- 1 = Detected
- 0 = Not Detected

TS2 (Bit 13): Open Thermistor – TS2 Failure
- 1 = Detected
- 0 = Not Detected

TS1 (Bit 12): Open Thermistor – TS1 Failure
- 1 = Detected
- 0 = Not Detected

AFE_XRDY (Bit 11): Companion bq769x0 AFE XREADY Failure
- 1 = Detected
- 0 = Not Detected

AFE_OVRD (Bit 10): Companion bq769x0 AFE Override Failure
- 1 = Detected
- 0 = Not Detected

AFEC (Bit 9): AFE Communication Failure
- 1 = Detected
- 0 = Not Detected

AFER (Bit 8): AFE Register Failure
- 1 = Detected
- 0 = Not Detected

DFETF (Bit 7): Discharge FET Failure
- 1 = Detected
- 0 = Not Detected

CFETF (Bit 6): Charge FET Failure
- 1 = Detected
- 0 = Not Detected

VIMR (Bit 5): Voltage Imbalance While Pack Is at Rest Failure
- 1 = Detected
- 0 = Not Detected

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

17.2.37 ManufacturerAccess() 0x0053 PFStatus

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

Status	Condition	Action
Activate	0x0053 to *ManufacturerAccess()*	Outputs *PFStatus()* 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	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	DFW	IFC
15	**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
RSVD	TS3	TS2	TS1	AFE_XRDY	AFE_OVRD	AFEC	AFER	DFETF	CFETF	VIMR	SOT	SOCD	SOCC	SOV	SUV

RSVD (Bit 31–18): Reserved. Do not use.

DFW (Bit 17): Data Flash Wearout Failure

1 = Detected

0 = Not Detected

IFC (Bit 16): Instruction Flash Checksum Failure

1 = Detected

0 = Not Detected

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

TS3 (Bit 14): Open Thermistor – TS3 Failure

1 = Detected

0 = Not Detected

TS2 (Bit 13): Open Thermistor – TS2 Failure

1 = Detected

0 = Not Detected

TS1 (Bit 12): Open Thermistor – TS1 Failure

1 = Detected

0 = Not Detected

AFE_XRDY (Bit 11): Companion bq769x0 AFE XREADY Failure

1 = Detected

0 = Not Detected

AFE_OVRD (Bit 10): Companion bq769x0 AFE Override Failure

1 = Detected

0 = Not Detected

AFEC (Bit 9): AFE Communication Failure

1 = Detected

0 = Not Detected

AFER (Bit 8): AFE Register Failure

1 = Detected

0 = Not Detected

DFETF (Bit 7): Discharge FET Failure

1 = Detected

0 = Not Detected

CFETF (Bit 6): Charge FET Failure

1 = Detected

0 = Not Detected

VIMR (Bit 5): Voltage Imbalance while pack is at rest failure

1 = Detected

0 = Not Detected

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

17.2.38 ManufacturerAccess() 0x0054 OperationStatus

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

SBS Cmd	Mode	Name	Format	Size in Bytes	Min	Max	Default	Unit
0x0054	R	OperationStatus	Hex	2	0x0000	0x00FF	—	—

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
KEY_IN	RSVD	RSVD	CB	RSVD	RSVD	RSVD	INIT	SLEEPM	RSVD	RSVD	CAL	RSVD	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	RSVD	RSVD	SAFE	RSVD	PCHG	DSG	CHG	PRES

KEYIN (Bit 31): Indicates the state of the KEYIN input detection and is independent of the [KEY_POL] setting.

1 = KEYIN has been detected.

0 = KEYIN not been detected.

RSVD (Bit 30–29): Reserved. Do not use.

CB (Bit 28): Cell balancing status

1 = Active
0 = Inactive

RSVD (Bits 27–25): Reserved. Do not use.

INIT (Bit 24): Initialization after full reset

1 = Active
0 = Inactive

SLEEPM (Bit 23): SLEEP mode

1 = Active
0 = Inactive

RSVD (Bits 22–21): Reserved. Do not use.

CAL (Bit 20): Calibration Output (raw ADC and CC)

1 = Active
0 = Inactive

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

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 (Bit 9,8): SECURITY mode
- 0, 0 = Reserved
- 0, 1 = Unsealed
- 1, 0 = Full Access
- 1, 1 = Sealed

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

SAFE (Bit 5): SAFE pin status
- 1 = Active
- 0 = Inactive

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

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

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

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

PRES (Bit 0): System present low
- 1 = Active
- 0 = Inactive

17.2.39 ManufacturerAccess() 0x0055 ChargingStatus

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

Status	Condition	Action
Activate	0x0055 to *ManufacturerAccess()*	Outputs *ChargingStatus()* flags (LSB) AND *TempRange()* flags (MSB) on *ManufacturerBlockAccess()* or *ManufacturerData()*

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	OT	HT	ST	LT	UT	VCT	RSVD	SU	IN	RSVD	RSVD	FCHG	PCHG

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

OT (Bit 12): Overtemperature Region
- 1 = Active
- 0 = Inactive

HT (Bit 11): High Temperature Region
- 1 = Active
- 0 = Inactive

ST (Bit 10): Standard Temperature Region
- 1 = Active
- 0 = Inactive

LT (Bit 9): Low Temperature Region

1 = Active

0 = Inactive

UT (Bit 8): Undertemperature Region

1 = Active

0 = Inactive

VCT (Bit 7): Charge Termination

1 = Active

0 = Inactive

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

SU (Bit 5): Charge Suspend

1 = Active

0 = Inactive

IN (Bit 4): Charge Inhibit

1 = Active

0 = Inactive

RSVD (Bit 3–2): Reserved. Do not use.

FCHG (Bit 1): FAST-CHARGE mode

1 = Active

0 = Inactive

PCHG (Bit 0): PRE-CHARGE mode

1 = Active

0 = Inactive

17.2.40 ManufacturerAccess() 0x0056 GaugingStatus

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

Status	Condition	Action
Activate	0x0056 to *ManufacturerAccess()*	Outputs *GaugingStatus()* flags on *ManufacturerBlockAccess()* or *ManufacturerData()*.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
VDQ	EDV2	EDV1	RSVD	RSVD	FCCX	OCVFR	REST	CF	DSG	EDV0	BAL_OK	TC	TD	FC	FD

VDQ (Bit 15): Discharge Qualified for Learning (based on the RU flag)

1 = Detected

0 = Not Detected

EDV2 (Bit 14): End-of-Discharge Voltage Level 2

1 = EDV2 voltage is reached during discharge.

0 = EDV2 voltage is not reached, or not in DISCHARGE mode.

EDV1 (Bit 13): End-of-Discharge Voltage Level 1

1 = EDV1 voltage is reached during discharge.

0 = EDV1 voltage is not reached, or not in DISCHARGE mode.

RSVD (Bit 12–11): Reserved. Do not use.

FCCX (Bit 10): *FullChargeCapacity()* has been updated. This bit changes state each time *FullChargeCapacity()* updates.

OCVFR (Bit 9): Reserved and not used.

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

EDV0 (Bit 5): End-of-Discharge Voltage Level 0 (Termination)

1 = Termination voltage is reached during discharge.

0 = Termination voltage is not reached, or not in DISCHARGE mode.

BAL_OK (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

17.2.41 ManufacturerAccess() 0x0057 ManufacturingStatus

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

Status	Condition	Action
Activate	0x0057 to *ManufacturerAccess()*	Outputs *ManufacturingStatus()* flags on *ManufacturerBlockAccess()* or *ManufacturerData().*

15	14	13	12	11	10	9	8
CAL_EN	LT_TEST	CB_TEST	AFE_DD_TEST	RSVD	RSVD	LED_EN	SAFE_EN

7	6	5	4	3	2	1	0
BBR_EN	PF_EN	LF_EN	FET_EN	RSVD	DSG_TEST	CHG_TEST	PCHG_TEST

LEGEND: R/W = Read/Write; R = Read only; -*n* = value after reset

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

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

CB_TEST (Bit 13): Cell Balancing Test
1 = Enabled
0 = Disabled

AFE_DD_TEST (Bit 12): AFE Delay Disable Test
1 = Enabled
0 = Disabled

RSVD (Bit 11–10): Reserved. Do not use.

LED_EN (Bit 9): LED Display
1 = Enabled
0 = Disabled

SAFE_EN (Bit 8): SAFE Action
1 = Enabled
0 = Disabled

BBR_EN (Bit 7): 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

RSVD (Bit 3): Reserved. Do not use.

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

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

PCHG_TEST (Bit 0): Precharge FET Test
1 = Precharge FET test activated
0 = Disabled

17.2.42 ManufacturerAccess() 0x0058 AFEStatus

This command returns the configuration of the companion AFE (address 0x00). See the AFE *bq769x0 3-Series to 15-Series Cell Battery Monitor Family for Li-Ion and Phosphate Applications Data Manual* (SLUSBK2) for further details.

SBS Cmd	Mode	Name	Format	Size in Bytes	Min	Max	Default	Unit
0x0058	R	AFEStatus	Hex	2	0x0000	0x00FF	—	—

17.2.43 ManufacturerAccess() 0x0059 AFEConfig

This command returns the configuration of the companion AFE (address 0x01 to 0x0B). See the AFE *bq769x0 3-Series to 15-Series Cell Battery Monitor Family for Li-Ion and Phosphate Applications Data Manual* (SLUSBK2).

SBS Cmd	Mode	Name	Format	Size in Bytes	Min	Max	Default	Unit
0x0059	R	AFEConfig	String	11+1	—	—	—	—

17.2.44 ManufacturerAccess() 0x005A AFEVCx

This command returns the cell voltage measurement data of the companion AFE (address 0x0C to 0x29) on *ManufacturerBlockAccess()* or *ManufacturerData()*. See the AFE *bq769x0 3-Series to 15-Series Cell Battery Monitor Family for Li-Ion and Phosphate Applications Data Manual* (SLUSBK2).

SBS Cmd	Mode	Name	Format	Size in Bytes	Min	Max	Default	Unit
0x005A	R	AFEVCx	String	30+1	—	—	—	—

17.2.45 ManufacturerAccess() 0x005B AFEData

This command returns the system voltage, temperature, and current measurement data of the companion AFE (address 0x2A to 0x33, 0x50, 0x51, and 0x59) on *ManufacturerBlockAccess()* or *ManufacturerData()*. See the AFE *bq769x0 3-Series to 15-Series Cell Battery Monitor Family for Li-Ion and Phosphate Applications Data Manual* (SLUSBK2).

SBS Cmd	Mode	Name	Format	Size in Bytes	Min	Max	Default	Unit
0x005B	R	AFEData	String	13+1	—	—	—	—

17.2.46 ManufacturerAccess() 0x0060 Lifetime Data Block 1

This command returns the Lifetime data on *ManufacturerBlockAccess()* or *ManufacturerData()*. See Lifetimes for details.

Status	Condition	Action
Activate	0x0060 to *ManufacturerAccess()*	Outputs lifetime data values of Max Cell Voltage on *ManufacturerBlockAccess()* or *ManufacturerData()*

17.2.47 ManufacturerAccess() 0x0061 Lifetime Data Block 2

This command returns the Lifetime data on *ManufacturerBlockAccess()* or *ManufacturerData()*. See Lifetimes for details.

Status	Condition	Action
Activate	0x0060 to *ManufacturerAccess()*	Outputs lifetime data values of Min Cell Voltage on *ManufacturerBlockAccess()* or *ManufacturerData()*

17.2.48 ManufacturerAccess() 0x0062 Lifetime Data Block 3

This command returns the Lifetime data on *ManufacturerBlockAccess()* or *ManufacturerData()*. See Lifetimes for details.

Status	Condition	Action
Activate	0x0061 to *ManufacturerAccess()*	Outputs lifetime data values of Delta Voltage, Currents, Power and Temperatures on *ManufacturerBlockAccess()* or *ManufacturerData()*

17.2.49 ManufacturerAccess() 0x0063 Lifetime Data Block 4

This command returns the Lifetime data on *ManufacturerBlockAccess()* or *ManufacturerData()*. See Lifetimes for details.

Status	Condition	Action
Activate	0x0064 to *ManufacturerAccess()*	Outputs lifetime data of the Power events and Cell Balancing Times data on *ManufacturerBlockAccess()* or *ManufacturerData()*. (OLD, SCD, OTC, OTD)

17.2.50 ManufacturerAccess() 0x0064 Lifetime Data Block 5

This command returns the Lifetime data on *ManufacturerBlockAccess()* or *ManufacturerData()*. See Lifetimes for details.

Status	Condition	Action
Activate	0x0062 to *ManufacturerAccess()*	Outputs lifetime data of the Time values on *ManufacturerBlockAccess()* or *ManufacturerData()*

17.2.51 ManufacturerAccess() 0x0065 Lifetime Data Block 6

This command returns the Lifetime data on *ManufacturerBlockAccess()* or *ManufacturerData()*. See Lifetimes for details.

Status	Condition	Action
Activate	0x0063 to *ManufacturerAccess()*	Outputs lifetime data of the safety events data on *ManufacturerBlockAccess()* or *ManufacturerData()* (COV, CUV, OCD, OCC)

17.2.52 ManufacturerAccess() 0x0066 Lifetime Data Block 7

This command returns the Lifetime data on *ManufacturerBlockAccess()* or *ManufacturerData()*. See Lifetimes for details.

Status	Condition	Action
Activate	0x0065 to *ManufacturerAccess()*	Outputs lifetime data of the charger termination and FC update events data on *ManufacturerBlockAccess()* or *ManufacturerData()*. (OLD, SCD, OTC, OTD)

17.2.53 ManufacturerAccess() 0x0070 ManufacturerInfo

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

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

17.2.54 ManufacturerAccess() 0x0071 DAStatus1

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

Status	Condition	Action
Activate	0x0071 to *ManufacturerAccess()*	Outputs 32 bytes of data on *ManufacturerBlockAccess()* or *ManufacturerData()* in the following format: aaAAbbBBccCCddDDeeEEffFFggGGhhHHiiIIjjJJkkKKllLL mmMMnnNNooOOppPP where: AAaa: Cell Voltage 1 BBbb: Cell Voltage 2 CCcc: Cell Voltage 3 DDdd: Cell Voltage 4 EEee: Cell Voltage 5 FFff: Cell Voltage 6 GGgg: Cell Voltage 7 HHhh: Cell Voltage 8 IIii: Cell Voltage 9 JJjj: Cell Voltage 10 KKkk: Cell Voltage 11 LLll: Cell Voltage 12 MMmm: Cell Voltage 13 NNnn: Cell Voltage 14 OOoo: Cell Voltage 15 PPpp: Reserved

17.2.55 ManufacturerAccess() 0x0072 DAStatus2

This command returns the TS1, TS2, TS3, and Cell Temperature data on *ManufacturerBlockAccess()* or *ManufacturerData().*

Status	Condition	Action
Activate	0x0072 to *ManufacturerAccess()*	Outputs 14 bytes of temperature data values on *ManufacturerBlockAccess()* or *ManufacturerData()* in the following format: aaAAbbBBccCCddDD where: AAaa: ExtAveCellVoltage BBbb: VAUX Voltage CCcc: TS1 Temperature DDdd: TS2 Temperature EEee: TS3 Temperature FFff: Cell Temperature

17.2.56 ManufacturerAccess() 0x0080 CUV Snapshot

This command returns the CellVoltages on *ManufacturerBlockAccess()* or *ManufacturerData()* at the time *SafetyStatus() [CUV]* is set. It is refreshed each time *[CUV]* becomes set.

Status	Condition	Action
Activate	0x0080 to *ManufacturerAccess()*	Outputs 32 bytes of data on *ManufacturerBlockAccess()* or *ManufacturerData()* in the following format: aaAAbbBBccCCddDDeeEEffFFggGGhhHHiiIIjjJJkkKKllLL mmMMnnNNooOOppPP where: AAaa: Cell Voltage 1 BBbb: Cell Voltage 2 CCcc: Cell Voltage 3 DDdd: Cell Voltage 4 EEee: Cell Voltage 5 FFff: Cell Voltage 6 GGgg: Cell Voltage 7 HHhh: Cell Voltage 8 IIii: Cell Voltage 9 JJjj: Cell Voltage 10 KKkk: Cell Voltage 11 LLll: Cell Voltage 12 MMmm: Cell Voltage 13 NNnn: Cell Voltage 14 OOoo: Cell Voltage 15 PPpp: Reserved

17.2.57 ManufacturerAccess() 0x0081 COV Snapshot

This command returns the CellVoltages on *ManufacturerBlockAccess()* or *ManufacturerData()* at the time *SafetyStatus() [COV]* is set. It is refreshed each time *[COV]* becomes set.

Status	Condition	Action
Activate	0x0081 to *ManufacturerAccess()*	Outputs 32 bytes of data on *ManufacturerBlockAccess()* or *ManufacturerData()* in the following format: aaAAbbBBccCCddDDeeEEffFFggGGhhHHiiIIjjJJkkKKllLL mmMMnnNNooOOppPP where: AAaa: Cell Voltage 1 BBbb: Cell Voltage 2 CCcc: Cell Voltage 3 DDdd: Cell Voltage 4 EEee: Cell Voltage 5 FFff: Cell Voltage 6 GGgg: Cell Voltage 7 HHhh: Cell Voltage 8 IIii: Cell Voltage 9 JJjj: Cell Voltage 10 KKkk: Cell Voltage 11 LLll: Cell Voltage 12 MMmm: Cell Voltage 13 NNnn: Cell Voltage 14 OOoo: Cell Voltage 15 PPpp: Reserved

17.2.58 ManufacturerAccess() 0x0F00 ROM Mode

This command sends the device into ROM mode in preparation for re-programming.

Status	Condition	Action
ROM Mode	*OperationStatus()[SEC1,SEC0]* = 0,1 AND 0x0F00 to *ManufacturerAccess()*	Device goes to ROM mode ready for update, use 0x08 to *ManufacturerAccess()* to return

17.2.59 Data Flash Access() 0x4000–0x5FFF

Accessing data flash 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 a 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 dat
= 0x00 + 0x40 + data1_LowByte + data1_HighByte + data2_LowByte + data2_HighByte.... data32_LowByte + data32_HighByte

The gauge supports an auto-increment on the address during a DF read. This greatly reduces the time required to read out the entire DF. Continue with the read from the DF example. If another SMBus read block is sent with command 0x44, the gauge returns another 32 bytes of DF data, starting with address 0x4020.

17.2.60 ManufacturerAccess() 0xF080 Exit Calibration Output Mode

This command stops the output of calibration data to the *ManufacturerBlockAccess()* or *ManufacturerData()* command.

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

17.2.61 ManufacturerAccess() 0xF081 OutputCellVoltageforCalibration

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	Action
Disable	*ManufacturingStatus()[CAL]* = 1 AND 0xF080 to *ManufacturerAccess()*	*ManufacturingStatus()[CAL]* = 0 Stops output of ADC and CC data on *ManufacturerBlockAccess()* or *ManufacturerData()*
Enable	0xF081 to *ManufacturerAccess()*	*ManufacturingStatus()[CAL]* = 1 Outputs the raw CC and AD values *ManufacturerBlockAccess()* or *ManufacturerData()* in the format of ZZaaAAbbBBccCCddDDeeEEffFF ggGGhhHHiiIIjjJJkkKK: ZZ: rolling 8-bit counter, increments when values are refreshed. YY: Status: 1 when *ManufacturerAccess()* = 0xF081; 2 when *ManufacturerAccess()* = 0xF082 AAaa: AFE Cell Map BBaa: Cell Voltage 1 CCaa: Cell Voltage 2 DDaa: Cell Voltage 3 EEee: Cell Voltage 4 FFff: Cell Voltage 5 GGgg: Cell Voltage 6 HHhh: Cell Voltage 7 IIii: Cell Voltage 8 JJjj: Cell Voltage 9 KKkk: Cell Voltage 10

17.2.62 ManufacturerAccess() 0xF082 OutputCellVoltageCCandTempforCalibration

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	Action
Disable	*ManufacturingStatus()[CAL]* = 1 AND 0xF080 to *ManufacturerAccess()*	*ManufacturingStatus()[CAL]* = 0 Stop output of ADC and CC data on *ManufacturerBlockAccess()* or *ManufacturerData()*
Enable	0xF081 to *ManufacturerAccess()*	*ManufacturingStatus()[CAL]* = 1 Outputs the raw CC and AD values on *ManufacturerBlockAccess()* or *ManufacturerData()* in the format of ZZYYaaAAbbBBccCCddDDeeEEffFF ggGGhhHHiiIIjjJJkkKK: ZZ: rolling 8-bit counter, increments when values are refreshed. YY: Status: 1 when *ManufacturerAccess()* = 0xF081; 2 when *ManufacturerAccess()* = 0xF082 AAaa: AFE Cell Map BBaa: Cell Voltage 11 CCaa: Cell Voltage 12 DDaa: Cell Voltage 13 EEee: Cell Voltage 14 FFff: Cell Voltage 15 GGgg: Reserved HHhh: ExtAveCellVoltage IIii: Current (Coulomb Counter) IIiiJJjj VAUX Voltage KKkk: TS1 Temperature LLll: TS2 Temperature Mmm: TS3 Temperature

17.3 0x01 RemainingCapacityAlarm()

This read- or write-word function sets or gets a low-capacity alarm threshold value. The default value for *RemainingCapacityAlarm* is stored in ***Rem Cap Alarm***. If *RemainingCapacityAlarm()* is set to 0, the alarm is disabled. If *RemainingCapacity()* < *RemainingCapacityAlarm()*, the *[RCA]* flag is set and the bq78350 sends an *AlarmWarning()* message to the SMBUS host. If *RemainingCapacity()* ≥ *RemainingCapacityAlarm()* and *[DSG]* is set, the *[RCA]* flag is cleared. 0 = remaining capacity alarm is disabled. 1..700 = the remaining capacity limit for *[RCA]* flag.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Default	Unit	Note
		SE	US	FA							
0x01	*RemainingCapacityAlarm()*	R/W			Word	U2	0	700	300	10 mAh	*GaugingStatus()[CAPM]* = 0
										100 mWh	*GaugingStatus()[CAPM]* = 1

The threshold value is stored in the following data flash location.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
SBS Configuration	Data	Remaining Capacity Alarm	U2	0	700	300	mAh	*RemainingCapacityAlarm()* value in mAh
SBS Configuration	Data	Remaining Capacity Alarm	U2	0	1000	432	cWh	*RemainingCapacityAlarm()* value in 10 mWh

17.4 0x02 RemainingTimeAlarm()

This read- or write-word function sets or gets the *RemainingTimeAlarm()* value. The default value of *RemainingTimeAlarm()* is stored in ***Rem Time Alarm***. If *RemainingTimeAlarm()* = 0, this alarm is disabled. If *AverageTimeToEmpty()* < *RemainingTimeAlarm()*, the *[RTA]* flag is set and the bq78350 sends an *AlarmWarning()* message to the SMBus host. If *AverageTimeToEmpty()* ≥ *RemainingTimeAlarm()*, the *[RTA]* flag is reset.

0 = remaining time alarm is disabled. 1..30 = the remaining time limit for the *[RTA]* flag.

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

The threshold value is stored in the following data flash location.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
SBS Configuration	Data	Remaining Time Alarm	U2	0	30	10	min	*RemainingTimeAlarm()* value

17.5 0x03 BatteryMode()

This read- or write-word function selects the various battery operational modes, reports the battery's capabilities and modes, and flags minor conditions that require attention.

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	7	6	5	4	3	2	1	0
CAPM	CHGM	AM	RSVD	RSVD	RSVD	PB	CC	CF	RSVD	RSVD	RSVD	RSVD	RSVD	PBS	ICC

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

1 = Reports specific data in 10 mW or 10 mWh

0 = Reports specific data 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 12): ALARM Mode (R/W)

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

0 = Enable AlarmWarning broadcasts to host and smart battery charger

PB (Bit 9): Primary Battery. This bit does not affect the operation of the bq78350 device and is for information only.

1 = Battery is operating in its secondary role.

0 = Battery is operating in its primary role (default).

CC (Bit 8): Charge Controller Enabled (R/W). This bit does not affect the operation of the bq78350 device and is for information only.

1 = Internal charge control enabled

0 = Internal charge controller disabled (default)

CF (Bit 7): Condition Flag (R). This bit a the same as *GaugingStatus() [CF*]

1 = Conditioning cycle requested

0 = Battery OK

PBS (Bit 1): Primary Battery Support (R). This bit does not affect the operation of the bq78350 device and is for information only.

1 = Primary or Secondary Battery Support

0 = Function not supported (default)

ICC (Bit 0): Internal Charge Controller (R). This bit does not affect the operation of the bq78350 device and is for information only.

1 = Function supported (default)

0 = Function not supported

Class	Subclass	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
SBS Configuration	Data	Initial Battery Mode	Hex	2	0x0000	0xFFFF	0x81	—

17.6 0x04 AtRate()

This read- or write-word function is the first half of a two-function call set used to set the *AtRate* value, which is used in calculations made by the *AtRateTimeToFull()*, *AtRateTimeToEmpty()*, and *AtRateOK()* functions.

The *AtRate()* units are in either mA (*[CapM]* = 0) or 10 mW (*[CapM]* = 1). When the *AtRate()* value is positive, the *AtRateTimeToFull()* function returns the predicted time to full charge at the *AtRate()* value of charge. When the *AtRate()* value is negative, the *AtRateTimeToEmpty()* function returns the predicted operating time at the *AtRate()* value of discharge. When the *AtRate()* value is negative, the *AtRateOK()* function returns a Boolean value that predicts the battery's ability to supply the *AtRate()* value of additional discharge energy (current or power) for 10 s.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Default	Unit	Note
		SE	US	FA							
0x04	*AtRate()*	R/W			Word	I2	–32768	32767	0	10 mAh	*GaugingStatus()[CAPM]* = 0
										100 mWh	*GaugingStatus()[CAPM]*= 1

17.7 0x05 AtRateTimeToFull()

This read-word function returns an unsigned integer value of the predicted remaining time to fully charge the battery using a CC-CV method at the *AtRate()* value in minutes with a range of 0 to 65,534. A value of 65,535 indicates that the *AtRate()* = 0.

AtRateTimeToFull() can report time based on constant current (*[CapM]* = 0) or constant power (*[CapM]* = 1), and is updated within 1 s after the SMBus host sets the *AtRate()* value. The bq78350 automatically updates *AtRateTimeToFull()* based on the *AtRate()* function at 1-s intervals. 0..65,534 = predicted time to full charge, based on *AtRate()*. 65,535 = no charge or discharge (*AtRate()* is 0).

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit	Note
		SE	US	FA						
0x05	*AtRateTimeToFull()*	R			Word	U2	0	65535	min	65535 indicates not being charged.

17.8 0x06 AtRateTimeToEmpty()

This read-word function returns an unsigned integer value of the predicted remaining operating time in minutes with a range of 0 to 65,534 if the battery is discharged at the *AtRate()* value. A value of 65,535 indicates that *AtRate()* = 0.

AtRateTimeToEmpty() can report time based on constant current (*[LDMD]* = 0) or constant power (*[LDMD]* = 1), and is updated within 1 s after the SMBus host sets the *AtRate()* value. The bq78350 updates *AtRateTimeToEmpty()* at 1-s intervals.

0..65,534 = predicted remaining operating time, based on *AtRate()*. 65,535 = no charge or discharge (*AtRate()* is 0).

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit	Note
		SE	US	FA						
0x06	*AtRateTimeToEmpty()*	R			Word	U2	0	65535	min	65535 indicates not being charged.

17.9 0x07 AtRateOK()

This read-word function returns a boolean value that indicates whether or not the battery can deliver the *AtRate()* value of energy for 10 seconds. The bq78350 updates this value within 1 s after the SMBus host sets the *AtRate()* function value. The bq78350 updates *AtRateOK()* at 1-s intervals.

If the *AtRate()* function returns ≥ 0, *AtRateOK()* always returns TRUE. Based on the discharge rate indicated in *AtRate()*, if it returns 0, 0 = FALSE and bq78350 ***cannot*** deliver energy for 10 seconds. 1..65,535 = TRUE and bq78350 ***can*** deliver energy for 10 seconds.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit	Note
		SE	US	FA						
0x07	*AtRateOK()*	R			Word	U2	0	65535	—	0 = No 1 = Yes

17.10 0x08 Temperature()

This read-word function returns the temperature in units of 0.1 K, as measured by the bq769x0 AFE. The source of the measured temperature is configured in ***Settings: Temperature Enable***. The selection of Max or Average, if multiple temp sensors are enabled, is configured by ***DA Configuration[CTEMP]***.

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

17.11 0x09 Voltage()

This read-word function returns the sum of the measured cell voltages and is scaled per *SpecificationInfo()*.

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

17.12 0x0A Current()

This read-word function returns an integer value of the measured current being supplied (or accepted) by the battery in mA, with a range of –32,768 to 32,767. A positive value indicates charge current and a negative value indicates discharge. Any current value within ***Deadband*** is reported as 0 mA by the *Current()* function.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x0A	*Current()*	R			Word	I2	–32767	32768	10 mA

The value reported is an average of four readings of the CC_HI and CC_LO registers of the companion AFE taken at 250-ms intervals.

17.13 0x0B AverageCurrent()

This read-word function returns a signed integer value that approximates a one-minute rolling average of the current being supplied (or accepted) through the battery terminals in mA, with a range of –32,768 to 32,767.

AverageCurrent() is calculated by a rolling IIR filtered average of *Current()* function data with a period of 14.5 s. During the time after a reset or when switching between charge and discharge currents and before 14.5 s has elapsed, the reported *AverageCurrent()* = *Current()* function value.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x0B	*AverageCurrent()*	R			Word	I2	–32767	32768	10 mA

17.14 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
		SE	US	FA				
0x0C	*MaxError()*	R			Word	U1	0%	100%

Status Condition	Action
Full device reset	*MaxError()* = 100%
FCC updated	*MaxError()* = 2%
FCC Updated but capped by FCC Learn Up or FCC Learn Down	*MaxError()* = 2%

Status Condition	Action
Each *CycleCount()* increment after last valid FCC update	*MaxError()* increment by 0.25% to a maximum of 100%
After ***Requested Learning Cycle Count*** increments of *CycleCount()* since the last FCC update	*CEDV GaugingStatus() [CF]* = 1

Class	Subclass	Name	Type	Min	Max	Default	Unit
Fuel Gauging	CEDV Cfg	Requested Learning Cycle Count	U1	1	255	20	Cycles

17.15 0x0D RelativeStateOfCharge()

This read-word function returns the predicted remaining battery capacity as a percentage of *FullChargeCapacity()* and is an output of the CEDV gas gauging feature.

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

17.16 0x0E AbsoluteStateOfCharge()

This read-word function returns the predicted remaining battery capacity as a percentage of *Design Capacity*, and is an output of the CEDV gas gauging feature.

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

17.17 0x0F RemainingCapacity()

This read-word function returns the predicted remaining battery capacity and is an output of the CEDV gas gauging feature. It is scaled per *SpecificationInfo()*.

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

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

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

17.18 0x10 FullChargeCapacity()

This read-word function returns the predicted battery capacity when fully charged and scaled per *SpecificationInfo()*.

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

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

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

17.19 0x11 RunTimeToEmpty()

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

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

NOTE: 65535 = Battery is not being discharged.

17.20 0x12 AverageTimeToEmpty()

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

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

NOTE: 65535 = Battery is not being discharged.

17.21 0x13 AverageTimeToFull()

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

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

NOTE: 65535 = Battery is not being discharged.

17.22 0x14 ChargingCurrent()

This read-word function returns the desired charging current.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x14	*ChargingCurrent()*	R	R	R	Word	U2	0	65535	10 mAh or 100 mWh

NOTE: 65535 = Request maximum current

Scaled per *SpecificationInfo()*

17.23 0x15 ChargingVoltage()

This read-word function returns the desired charging voltage.

SBS Cmd	Name	Access			Proto-col	Type	Min	Max	Unit	Note
		SE	US	FA						
0x15	*ChargingVoltage()*	R	R	R	Word	U2	0	65535	mV	65535 = request maximum voltage

NOTE: 65535 = Request maximum voltage

Scaled per *SpecificationInfo()*

17.24 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	0x0000	0xFFFF

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OCA	TCA	RSVD	OTA	TDA	RSVD	RCA	RTA	INIT	DSG	FC	FD	EC3	EC2	EC1	EC0

OCA (Bit 15): Overcharged Alarm
- 1 = Active
- 0 = Inactive

TCA (Bit 14): Terminate Charge Alarm
- 1 = Active
- 0 = Inactive

RSVD (Bit 13): Reserved

OTA (Bit 12): Overtemperature Alarm
- 1 = Active
- 0 = Inactive

TDA (Bit 11): Terminate Discharge Alarm
- 1 = Active
- 0 = Inactive

RSVD (Bit 10): Reserved

RCA (Bit 9): Remaining Capacity Alarm
- 1 = Active
- 0 = Inactive

RTA (Bit 8): Remaining Time Alarm
- 1 = Active
- 0 = Inactive

INIT (Bit 7): Initialization
- 1 = Active
- 0 = Inactive

DSG (Bit 6): Charge FET Test
- 1 = Battery is discharging or at rest.
- 0 = Battery is charging.

FC (Bit 5): Fully Charged
1 = Battery is fully charged.
0 = Battery is not fully charged.

FD (Bit 4): Fully Discharged
1 = Battery is fully discharged.
0 = Battery is ok.

EC3:0 (Bit 3–0): Error Code
0x0 = OK
0x1 = Busy
0x2 = Reserved Command
0x3 = Unsupported Command
0x4 = AccessDenied
0x5 = Overflow/Underflow
0x6 = BadSize
0x7 = UnknownError

17.25 0x17 CycleCount()

This read-word function returns the number of discharge cycles the battery has experienced. The value of *CycleCount()* increments when an accumulated discharge is more than Cycle Count Percentage of *FullChargeCapacity()* (if ***[CCT]*** = 1) or ***Design Capacity*** (if ***[CCT]*** = 0).

NOTE: A minimum of 10% of ***Design Capacity*** change of the accumulated discharge is required for cycle count increment. This prevents an erroneous cycle count increment due to extremely low *FullChargeCapacity()*.

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

Class	Subclass	Name	Format	Min	Max	Default	Unit	Description
Fuel Gauging	Cycle	Cycle Count Percentage	Unsigned Integer	0	100	90	%	Cycle Count Percentage

17.26 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.*** The data should be entered in the same units as configured by *SpecificationInfo() [IPSCALE]*.

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

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

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

Class	Subclass	Name	Format	Length in Bytes	Min	Max	Default	Unit
Fuel Gauging	Design	Design Capacity mAh	Integer	2	0	32767	4400	mAh
Fuel Gauging	Design	Design Capacity 10 mWh	Integer	2	0	32767	6336	10 mWh

17.27 0x19 DesignVoltage()

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

SBS Cmd	Name	Access			Protocol	Type	Length in Bytes	Min	Max	Unit
		SE	US	FA						
0x18	*DesignVoltage()*	R	R/W	R/W	Word	Unsigned Integer	2	0	65535	mV

Class	Subclass	Name	Format	Length in Bytes	Min	Max	Default	Unit
Fuel Gauging	Design	Design Capacity mAh	Integer	2	0	32767	5000	mV

17.28 0x1A SpecificationInfo()

This read-word function returns, as an unsigned integer value, the version number of the Smart Battery Specification that the battery pack supports, as well as voltage- and current-scaling information.

Power-scaling is the product of the voltage-scaling × the current-scaling. The data is packed, as follows:

IPScale × 0x1000 + VScale × 0x0100 + SpecID_H × 0x0010 + SpecID_L

VScale (voltage scaling) should be selected based on the total battery pack maximum voltage. The default for this is 1, which causes the battery level voltage data to be reported in 10-mV units rather than 1-mV units. The IPScale (current scaling) should be selected based on the battery size and current magnitudes expected. The default for this is 1, which causes all mA and mAh units to change to 10 mA and 10 mAh, respectively. The default setting is stored in ***Data: Specification Information***, and if the data flash value is changed, a reset (POR or via *ManufacturerAccess()[RESET]*) of the device is required for full correct operation.

The default value is stored in the following data flash.

Class	Subclass	Name	Format	Length in Bytes	Min	Max	Default	Unit
SBS Configuration	Data	Specification Information	Hex	2	0x0000	0xFFFF	0x0031	—

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
IPSCALE				VSCALE				VERSION				REVISION			

IPSCALE (Bit 15:12): Current Scale Factor

0x0 = Noted reported current and capacities are scaled by 10E0

0x1 = Noted reported current and capacities are scaled by 10E1

0x2 = Noted reported current and capacities are scaled by 10E2

0x3 = Noted reported current and capacities are scaled by 10E2

VSCALE (Bit 11:8): Voltage Scale Factor

0x0 = *Voltage()* and *ChargingVoltage()* are scaled by 10E0

0x1 = *Voltage()* and *ChargingVoltage()* are scaled by 10E1

0x2 = *Voltage()* and *ChargingVoltage()* are scaled by 10E1

0x3 = *Voltage()* and *ChargingVoltage()* are scaled by 10E1

VER (Bit 7:4): Version

0x1 = Version 1.0

0x2 = Version 1.1

0x3 = Version 1.1 with optional PEC support

REV3:0 (Bit 3:0): Revision

0x1 = Version 1.0 and 1.1 (default)

All others reserved

17.29 0x1B ManufacturerDate()

This read-word function returns the pack's manufacture date. The *ManufacturerDate()* value is in the following format: Day + Month×32 + (Year–1980)×256 and is stored in ***Manufacturer Date***.

SBS Cmd	Name	Access			Protocol	Type	Length in Bytes	Min	Max	Unit
		SE	US	FA						
0x1B	*ManufacturerDate()*	R	R/W	R/W	Word	Unsigned Integer	2	0	65535	—

Class	Subclass	Name	Format	Length in Bytes	Min	Max	Default	Unit
SBS Configuration	Data	Manufacturer Date	Unsigned Integer	2	0	65535	01/01/80	

17.30 0x1C SerialNumber()

This read-word function returns the assigned pack serial number stored in ***Serial Number***.

SBS Cmd	Name	Access			Protocol	Type	Length in Bytes	Min	Max	Unit
		SE	US	FA						
0x1C	*SerialNumber()*	R	R/W	R/W	Word	Unsigned Integer	2	0	65535	—

Class	Subclass	Name	Format	Length in Bytes	Min	Max	Default	Unit
SBS Configuration	Data	Serial Number	Hex	2	0x0000	0xFFFF	0x0001	

17.31 0x20 ManufacturerName()

This read block function returns the pack manufacturer's name stored in ***Manufacturer Name***.

SBS Cmd	Name	Access			Protocol	Type	Length in Bytes	Min	Max	Unit
		SE	US	FA						
0x20	*ManufacturerName()*	R	R	R	Block	String	11+1	—	—	—

Class	Subclass	Name	Format	Length in Bytes	Min	Max	Default	Unit
SBS Configuration	Data	Manufacturer Name	String	20	—	—	Texas Instruments	ASCII

17.32 0x21 DeviceName()

This read block function returns the assigned pack name stored in ***Device Name***.

SBS Cmd	Name	Access			Protocol	Type	Length in Bytes	Min	Max	Unit
		SE	US	FA						
0x21	*DeviceName()*	R	R	R	Block	String	7+1	—	—	ASCII

Class	Subclass	Name	Format	Length in Bytes	Min	Max	Default	Unit
SBS Configuration	Data	Device Name	String	8	—	—	bq78350	ASCII

17.33 0x22 DeviceChemistry()

This read block function returns the battery chemistry used in the pack stored in ***Device Chemistry***.

SBS Cmd	Name	Access			Protocol	Type	Length in Bytes	Min	Max	Unit
		SE	US	FA						
0x22	*DeviceChemistry()*	R	R	R	Block	String	4+1	—	—	ASCII

Class	Subclass	Name	Format	Length in Bytes	Min	Max	Default	Unit
SBS Configuration	Data	Device Chemistry	String	5	—	—	LION	ASCII

17.34 0x23 ManufacturerData()/CalibrationData()

This read block function returns several elements of manufacturing-related pack information in the default mode. It is also used to return a variety of other data and can provide measured voltage, current, and temperature data for calibration purposes in CALIBRATION mode. See Section 17.2, *ManufacturerAccess()*, for more details on these options.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit	Note
		SE	US	FA						
0x23	*ManufacturerData()*	R	R	R	Block	S32+1				

Status	Condition	Action
ManufacturerData	Valid command sent	Returns pack information on *ManufacturerData()*

The default data returned by *ManufacturerData()* is stored in the following data flash.

Class	Subclass	Name	Format	Length in Bytes	Min	Max	Default	Unit
SBS Configuration	Data	Manufacturer Info	String	33	—	—	—	ASCII

When the bq78350 is in CALIBRATION mode, this command changes the data it returns. See the Manufacture Production in Calibration for more details on the data and format.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit	Note
		SE	US	FA						
0x23	*CalibrationData()*	R	R	R	Block	H2+S24				

Status	Condition	Action
CalibrationData	0x002D to *ManufacturerAccess()* to enable CALIBRATION mode 0xF081 or 0xF082 to *ManufacturerAccess()* to enable calibration data acquisition Valid command sent	Return measured voltage, current, and temperature on *ManufacturerData()*

17.35 0x2B HostFETControl

This read/write-word function allows the host to control the PCHG, DSG, and CHG FETs during normal operation (if protection features allow). The following two-step procedure enables the host to control the FETs via SMBus commands:

1. Send FET Control Access Code [0x1197] to *HostFETControl()*.
2. Send data to turn on or off the required FET to *HostFETControl()* within 4 s of sending the FET Control Access Code.

The sequence must be repeated for each write to control the FETs. If there are any SMBus commands received by the bq78350 in between receiving the FET Control Access Code and the FET control data, then the FET control data is ignored. The two-step sequence enables control of the FETs in SEALED mode.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit	Note
		SE	US	FA						
0x2B	*HostFETControl()*	R/W	R/W	R/W	Word	Hex	0x0000	0x003	—	

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	RSVD	RSVD	PCHG	DSG	CHG

RSVD (Bits 7–3): Reserved

PCHG (Bit 2): Pre-Charge FET Control

1 = ON, if protection features allow, see [XCHG]

0 = OFF

DSG (Bit 1): Discharge FET Control

1 = ON, if protection features allow, see [XDSG]

0 = OFF

CHG (Bit 0): Charge FET Control

1 = ON, if protection features allow, see [XCHG]

0 = OFF

17.36 0x2C GPIOStatus

This read-word function returns the bit-wise status of all the GPIO enabled in ***GPIO Config***.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit	Note
		SE	US	FA						
0x2C	*GPIOStatus()*	R	R	R	Word	Hex	0x0000	0x00EF	—	

7	6	5	4	3	2	1	0
GPIO B	GPIO A	LED5	LED4	LED3	LED2	LED1	RSVD

GPIO B (Bit 7): GPIO B

1 = High

0 = Low

GPIO A (Bit 6): GPIO A

1 = High

0 = Low

LED5 (Bit 5): GPIO 5
1 = High
0 = Low

LED4 (Bit 4): GPIO 4
1 = High
0 = Low

LED3 (Bit 3): GPIO 3
1 = High
0 = Low

LED2 (Bit 2): GPIO 2
1 = High
0 = Low

LED1 (Bit 1): GPIO 1
1 = High
0 = Low

RSVD (Bit 0): Reserved

17.37 0x2D GPIOControl

This read/write-word function allows the host to program GPIO Outputs enabled in ***GPIO Type*** to a High or Low state. A Read of this command returns what was written to the command. To read the actual status of the GPIO pins, the *GPIOStatus()* command should be used.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit	Note
		SE	US	FA						
0x2D	*GPIOControl()*	R/W	R/W	R/W	Word	Hex	0x0000	0x00EF	—	

7	6	5	4	3	2	1	0
GPIO B	GPIO A	LED5	LED4	LED3	LED2	LED1	RSVD

GPIO B (Bit 7): GPIO B
1 = High
0 = Low

GPIO A (Bit 6): GPIO A
1 = High
0 = Low

LED5 (Bit 5): GPIO 5
1 = High
0 = Low

LED4 (Bit 4): GPIO 4
1 = High
0 = Low

LED3 (Bit 3): GPIO 3
1 = High
0 = Low

LED2 (Bit 2): GPIO 2

1 = High

0 = Low

LED1 (Bit 1): GPIO 1

1 = High

0 = Low

RSVD (Bit 0): Reserved

17.38 0x2E VAUXVoltage()

This read-word function returns an unsigned integer value representing the scaled measured voltage from the VAUX pin, in units of mV if ***[VAUX_SCALE]*** = 0, and 10 mV if ***[VAUX_SCALE]*** = 1 with a range of 0 to 65535. The returned value = VAUX × ***VAUX Divider Gain***.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit	Note
		SE	US	FA						
0x2E	*VAUXVoltage()*	R	R	R	Word	U2	—	—	—	

The value of ***VAUX Scaler*** is stored in the following data flash.

Class	Subclass	Name	Type	Min	Max	Default	Unit
Calibration	Voltage	VAUX Gain	U4	0	65535	5000	—

17.39 0x2F Authenticate()/ManufacturerInput()

This read/write block function provides SHA-1 authentication in the default mode. It is also used to perform data flash read/writes in DATA FLASH ACCESS mode.

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

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Unit	Note
		SE	US	FA						
0x2F	*ManufacturerInput()*	R/W	R/W	R/W	Block	H32	—	—	—	

17.40 0x30..0x3E CellVoltage1..15()

These read-word functions return an unsigned value of the calculated individual cell voltages, in mV, with a range of 0 to 65535. *CellVoltage1()* corresponds to the bottom-most series cell element, while *CellVoltage15()* corresponds to the top-most series cell element.

SBS Cmd	Mode	Name	Format	Size in Bytes	Min	Max	Default	Unit
0x30	R	Reserved	Unsigned Integer	2	0	65535	—	mV
0x31		CellVoltage15						
0x32		CellVoltage14						
0x33		CellVoltage13						
0x34		CellVoltage12						
0x35		CellVoltage11						
0x36		CellVoltage10						
0x37		CellVoltage9						
0x38		CellVoltage8						
0x39		CellVoltage7						
0x3A		CellVoltage6						
0x3B		CellVoltage5						
0x3C		CellVoltage4						
0x3D		CellVoltage3						
0x3E		CellVoltage2						
0x3F		CellVoltage1						

17.41 0x4D ExtAveCellVoltage()

This read-word function returns the external average cell voltage measurement, if enabled, which can be used within the gas gauging algorithm for EDV2, EDV1, and EDV0 detection.

SBS Cmd	Mode	Name	Format	Size in Bytes	Min	Max	Default	Unit
0x4D	R	ExtAveCellVoltage	Unsigned Integer	2	0	65535	—	mV

17.42 0x4E PendingEDV()

This read-word function returns the predicted EDV2 until EDV2 is reached, then the predicted EDV1 until EDV1 is reached, and then the predicted EDV0. The format is Little Endian.

SBS Cmd	Mode	Name	Format	Size in Bytes	Min	Max	Default	Unit
0x4E	R	PendingEDV	Unsigned Integer	2	0	65535	—	mV

17.43 0x4F StateOfHealth (SOH)

This command returns the state-of-health (SOH) information of the battery. *StateOfHealth()* is calculated as a percentage of *FullChargeCapacity()* Design Capacity or Design Energy. It is a read-only command.

Byte 0: LSB of SOH in capacity
Byte 1: MSB of SOH in capacity
Byte 2: LSB of SOH in energy
Byte 3: MSB of SOH in energy

17.44 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 17.2.

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

17.45 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 17.2.

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

17.46 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 17.2.

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

17.47 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 17.2.

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

17.48 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 17.2.

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

17.49 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 17.2.

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

17.50 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 17.2.

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

17.51 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 17.2.

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

17.52 0x58 AFEStatus

This command sets or gets the configuration of the companion AFE (address 0x00).

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit	Note
		SE	US	FA							
0x58	*AFEStatus()*	—	R	R	Block	H1	0x00	0xFF	—	—	

17.53 0x59 AFEConfig

This read/write-block function sets or gets the configuration of the companion AFE (address 0x01 to 0x0B).

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit	Note
		SE	US	FA							
0x59	*AFEConfig()*	—	R	R	String	H4	—	—	—	—	

17.54 0x5A AFEVCx

This command returns the cell voltage measurement data of the companion AFE (address 0x0C to 0x29) on *ManufacturerBlockAccess()* or *ManufacturerData()*.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit	Note
		SE	US	FA							
0x5A	*AFEVCx()*	—	R	R	String	H4	—	—	—	—	

17.55 0x5B AFEData

This command returns the system voltage, temperature, and current measurement data of the companion AFE (address 0x2A to 0x33, 0x50, 0x51, and 0x59) on *ManufacturerBlockAccess()* or *ManufacturerData()*.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit	Note
		SE	US	FA							
0x5B	*AFEData()*	—	R	R	String	H4	—	—	—	—	

17.56 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 17.2.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit	Note
		SE	US	FA							
0x60	*LifeTimeDataBlock1()*	—	R	R	Block	—	—	—	—	—	

17.57 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 17.2.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit	Note
		SE	US	FA							
0x61	*LifeTimeDataBlock2()*	—	R	R	Block	—	—	—	—	—	

17.58 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 17.2.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit	Note
		SE	US	FA							
0x62	*LifeTimeDataBlock3()*	—	R	R	Block	—	—	—	—	—	

17.59 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 17.2.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit	Note
		SE	US	FA							
0x63	*LifeTimeDataBlock4()*	—	R	R	Block	—	—	—	—	—	

17.60 0x63 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 17.2.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit	Note
		SE	US	FA							
0x64	*LifeTimeDataBlock5()*	—	R	R	Block	—	—	—	—	—	

17.61 0x63 Lifetime Data Block 6

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 17.2.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit	Note
		SE	US	FA							
0x65	*LifeTimeDataBlock6()*	—	R	R	Block	—	—	—	—	—	

17.62 0x63 Lifetime Data Block 7

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 17.2.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit	Note
		SE	US	FA							
0x66	*LifeTimeDataBlock7()*	—	R	R	Block	—	—	—	—	—	

17.63 0x70 ManufacturerInfo

This command returns manufacturer information. For a description of returned data values, see the *ManufacturerAccess()* version of the same command in Section 17.2.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit	Note
		SE	US	FA							
0x70	*ManufacturerInfo()*	R	R	R	Block	—	—	—	—	—	

17.64 0x71 DAStatus1

This command returns the CellVoltages. For a description of returned data values, see the *ManufacturerAccess()* version of the same command in Section 17.2.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit	Note
		SE	US	FA							
0x71	*DAStatus1()*	—	R	R	Block	—	—	—	—	—	

17.65 0x72 DAStatus2

This command returns the TS1, TS2, TS3, and Cell Temp Temperatures. For a description of returned data values, see the *ManufacturerAccess()* version of the same command in Section 17.2.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit	Note
		SE	US	FA							
0x72	*DAStatus2()*	—	R	R	Block	—	—	—	—	—	

17.66 0x80 CUV Snapshot

This command returns the CUV snapshot data. For a description of returned data values, see the *ManufacturerAccess()* version of the same command in Section 17.2.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit	Note
		SE	US	FA							
0x64	*LifeTimeDataBlock5()*	—	R	R	Block	—	—	—	—	—	

17.67 0x81 COV Snapshot

This command returns the COV snapshot data. For a description of returned data values, see the *ManufacturerAccess()* version of the same command in Section 17.2.

SBS Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit	Note
		SE	US	FA							
0x64	*LifeTimeDataBlock5()*	—	R	R	Block	—	—	—	—	—	

Data Flash Access and Format

18.1 Data Flash Access

18.1.1 Minimum Voltage

Data flash can only be updated when the sum of the cell voltages connected between the VC0 and VC5 pins of the companion AFE is above the ***Valid Update Voltage***.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Power	Power	Valid Update Voltage	I2	0	32767	6500	mV	Min voltage threshold for Flash update

NOTE:

- VC1 to VC5 voltages may not be represented directly by *CellVoltage1...5()* when the number of cells in series is > 5. The VCx to *CellVoltagex()* decode is through the DF:AFE Cell Map.
- It is not recommended to change this value.

18.2 Data Formats

18.2.1 Unsigned Integer (U)

Unsigned integer is 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

18.2.2 Integer (I)

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

18.2.3 Floating Point (F)

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 special meaning.

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

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

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

18.2.4 Hex (H)

Bit register definitions are stored in unsigned integer format.

18.2.5 String (S)

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

Chapter 19

SLUUAN7B–July 2014–Revised June 2015

Data Flash Summary

19.1 Data Flash Summary Table

Class	Subclass	Address	Type	Name	Min	Max	Default	Unit
Calibration	Current	0x4000	F4	CC Gain	1.00E–01	9.00E+00	8.4381	—
Calibration	Current	0x4004	F4	Capacity Gain	2.98E+04	2.69E+07	2516761.36	—
Calibration	Voltage	0x4008	I1	Cell1 Offset	–128	127	0	mV
Calibration	Voltage	0x4009	I1	Cell2 Offset	–128	127	0	mV
Calibration	Voltage	0x400A	I1	Cell3 Offset	–128	127	0	mV
Calibration	Voltage	0x400B	I1	Cell4 Offset	–128	127	0	mV
Calibration	Voltage	0x400C	I1	Cell5 Offset	–128	127	0	mV
Calibration	Voltage	0x400D	I1	Cell6 Offset	–128	127	0	mV
Calibration	Voltage	0x400E	I1	Cell7 Offset	–128	127	0	mV
Calibration	Voltage	0x400F	I1	Cell8 Offset	–128	127	0	mV
Calibration	Voltage	0x4010	I1	Cell9 Offset	–128	127	0	mV
Calibration	Voltage	0x4011	I1	Cell10 Offset	–128	127	0	mV
Calibration	Voltage	0x4012	I1	Cell11 Offset	–128	127	0	mV
Calibration	Voltage	0x4013	I1	Cell12 Offset	–128	127	0	mV
Calibration	Voltage	0x4014	I1	Cell13 Offset	–128	127	0	mV
Calibration	Voltage	0x4015	I1	Cell14 Offset	–128	127	0	mV
Calibration	Voltage	0x4016	I1	Cell15 Offset	–128	127	0	mV
Calibration	Current Offset	0x4018	I2	CC Offset	–32767	32767	0	—
Calibration	Current Offset	0x401A	U2	Coulomb Counter Offset Samples	0	65535	64	—
Calibration	Temperature	0x401E	I1	T1 Temp Offset	–128	127	0	0.1°C
Calibration	Temperature	0x401F	I1	T2 Temp Offset	–128	127	0	0.1°C
Calibration	Temperature	0x4020	I1	T3 Temp Offset	–128	127	0	0.1°C
Calibration	Ext Cell Voltage	0x4021	I2	Ext Cell Divider Gain	0	32767	5000	—
Calibration	VAux Voltage	0x4023	I4	VAux Gain	0	100000	5000	—
Calibration	Internal Temp Model	0x44F4	I2	Int Gain	0	32767	44	—
Calibration	Internal Temp Model	0x44F6	I2	Int base offset	–32768	32767	6232	—
Calibration	Internal Temp Model	0x44F8	I2	Int Minimum AD	–32768	32767	0	—
Calibration	Internal Temp Model	0x44FA	I2	Int Maximum Temp	–32768	32767	6232	0.1°K
Calibration	Cell Temperature Model	0x44FC	I2	Coeff a1	–32768	32767	–11130	—
Calibration	Cell Temperature Model	0x44FE	I2	Coeff a2	–32768	32767	19142	—
Calibration	Cell Temperature Model	0x4500	I2	Coeff a3	–32768	32767	–19262	—
Calibration	Cell Temperature Model	0x4502	I2	Coeff a4	–32768	32767	28203	—
Calibration	Cell Temperature Model	0x4504	I2	Coeff a5	–32768	32767	892	—
Calibration	Cell Temperature Model	0x4506	I2	Coeff b1	–32768	32767	328	—

Class	Subclass	Address	Type	Name	Min	Max	Default	Unit
Calibration	Cell Temperature Model	0x4508	I2	Coeff b2	–32768	32767	–605	—
Calibration	Cell Temperature Model	0x450A	I2	Coeff b3	–32768	32767	–2443	—
Calibration	Cell Temperature Model	0x450C	I2	Coeff b4	–32768	32767	4696	—
Calibration	Cell Temperature Model	0x450E	I2	Rc0	–32768	32767	11703	—
Calibration	Cell Temperature Model	0x4510	I2	Adc0	–32768	32767	11703	—
Calibration	Current Deadband	0x42D8	U1	Deadband	0	255	3	mA
Calibration	Current Deadband	0x42D9	U1	Coulomb Counter Deadband	0	255	38	264 nV
Settings	Configuration	0x441F	H2	FET Options	0x0	0x03ff	0x0121	hex
Settings	Configuration	0x4421	H1	Sbs Gauging Configuration	0x0	0x83	0x0	hex
Settings	Configuration	0x4422	H1	Smb Configuration	0x0	0xb7	0xa0	hex
Settings	Configuration	0x4449	H1	LED Configuration	0x0	0xFF	0x00	hex
Settings	Configuration	0x4466	H1	Temperature Enable	0x0	0x1F	0x09	hex
Settings	Configuration	0x4468	H1	DA Configuration	0x0	0x1F	0x11	hex
Settings	Configuration	0x4469	H2	AFE Cell Map	0x0	0x7Fff	0x0013	hex
Settings	Configuration	0x4516	H2	CEDV Gauging Configuration	0x0	0x3ff	0x0002	hex
Settings	Configuration	0x455E	H2	SOC Flag Config	0x0	0x13ff	0x2Fb	hex
Settings	Configuration	0x4596	H1	Balancing Configuration	0x0	0xFF	0x01	hex
Settings	Fuse	0x4418	H1	PF SAFE A	0x0	0xFF	0x0	hex
Settings	Fuse	0x4419	H1	PF SAFE B	0x0	0x7F	0x0	hex
Settings	Fuse	0x441A	H1	PF SAFE C	0x0	0x03	0x0	hex
Settings	Fuse	0x441E	U1	Fuse Blow Timeout	0	255	30	s
Settings	Aux SMB Address	0x4423	U1	Addr Reads	0	10	3	—
Settings	Aux SMB Address	0x4424	H1	SMBTAR_ADDR0	0x0	0xFF	0x20	hex
Settings	Aux SMB Address	0x4425	H1	SMBTAR_ADDR1	0x0	0xFF	0x22	hex
Settings	Aux SMB Address	0x4426	H1	SMBTAR_ADDR2	0x0	0xFF	0x24	hex
Settings	Aux SMB Address	0x4427	H1	SMBTAR_ADDR3	0x0	0xFF	0x25	hex
Settings	Aux SMB Address	0x4428	H1	SMBTAR_ADDR4	0x0	0xFF	0x26	hex
Settings	Aux SMB Address	0x4429	H1	SMBTAR_ADDR5	0x0	0xFF	0x28	hex
Settings	Aux SMB Address	0x442A	H1	SMBTAR_ADDR6	0x0	0xFF	0x2A	hex
Settings	Aux SMB Address	0x442B	H1	SMBTAR_ADDR7	0x0	0xFF	0x2C	hex
Settings	SMB Master Mode	0x442E	H1	Host Address	0x0	0xFF	0x10	hex
Settings	SMB Master Mode	0x442F	H1	Charger Address	0x0	0xFF	0x12	hex
Settings	SMB Master Mode	0x4430	U1	Alarm Timer	10	255	10	s
Settings	SMB Master Mode	0x4431	U1	Charger Request Timer	10	255	50	s
Settings	Protection	0x4481	H1	Protection Configuration	0x0	0x0E	0x00	hex
Settings	Protection	0x4482	H1	Enabled Protections A	0x0	0xFF	0xFF	hex
Settings	Protection	0x4483	H1	Enabled Protections B	0x0	0x0F	0x0F	hex
Settings	Protection	0x4484	H1	Enabled Protections C	0x0	0x1F	0x15	hex
Settings	Permanent Failure	0x44CD	H1	Enabled PF A	0x0	0xFF	0x0	hex
Settings	Permanent Failure	0x44CE	H1	Enabled PF B	0x0	0x7F	0x0	hex
Settings	Manufacturing	0x4288	H2	Mfg Status init	0x0	0xFFFF	0x0000	hex
Charge Algorithm	Temperature Ranges	0x4569	I1	Charge Inhibit/Suspend Low Temp	–128	127	0	°C
Charge Algorithm	Temperature Ranges	0x456A	I1	Precharge Temp	–128	127	12	°C
Charge Algorithm	Temperature Ranges	0x456B	I1	Charge Inhibit High Temp	–128	127	45	°C

Class	Subclass	Address	Type	Name	Min	Max	Default	Unit
Charge Algorithm	Temperature Ranges	0x456C	I1	Charge Suspend High Temp	–128	127	55	°C
Charge Algorithm	Temperature Ranges	0x456D	I1	Hysteresis Temp	–128	127	3	°C
Charge Algorithm	Fast Charging	0x456E	I2	Voltage	0	32767	4200	mV
Charge Algorithm	Fast Charging	0x4570	I2	Current	0	32767	3000	mA
Charge Algorithm	Pre-Charging	0x4572	I2	Current	0	32767	100	mA
Charge Algorithm	Pre-Charging	0x4574	I2	Start Voltage	0	32767	2500	mV
Charge Algorithm	Pre-Charging	0x4576	I2	Recovery Voltage	0	32767	2900	mV
Charge Algorithm	Termination Config	0x4578	I2	Charge Term Taper Current	0	32767	250	mA
Charge Algorithm	Termination Config	0x457C	I2	Charge Term Voltage	0	32767	75	mV
Charge Algorithm	Cell Balancing Config	0x4597	I2	Cell Balance Threshold	0	5000	3900	mV
Charge Algorithm	Cell Balancing Config	0x4599	I2	Cell Balance Window	0	5000	100	mV
Charge Algorithm	Cell Balancing Config	0x459B	U1	Cell Balance Min	0	255	40	mV
Charge Algorithm	Cell Balancing Config	0x459C	U1	Cell Balance Interval	0	255	20	s
Power	Power	0x4432	I2	Valid Update Voltage	0	32767	3500	mV
Power	Shutdown	0x4434	I2	Shutdown Voltage	0	32767	1750	mV
Power	Shutdown	0x4436	U1	Shutdown Time	0	255	10	s
Power	Shutdown	0x4437	I2	PF Shutdown Voltage	0	32767	1750	mV
Power	Shutdown	0x4439	U1	PF Shutdown Time	0	255	10	s
Power	Shutdown	0x443A	I2	Charger Present Threshold	0	32767	3000	mV
Power	Sleep	0x443C	I2	Sleep Current	0	32767	10	mA
Power	Sleep	0x443E	U1	Bus Timeout	0	255	5	s
Power	Sleep	0x4443	U1	Voltage Time	0	255	5	s
Power	Sleep	0x4444	U1	Current Time	0	255	20	s
Power	Ship	0x4446	U1	FET Off Time	0	127	10	s
Power	Ship	0x4447	U1	Delay	0	254	20	s
Power	KEYIN	0x4448	U1	Time	0	10	2	s
LED Support	LED Config	0x444A	U2	LED Flash Period	32	65535	512	488 µs
LED Support	LED Config	0x444C	U2	LED Blink Period	32	65535	1024	488 µs
LED Support	LED Config	0x444E	U2	LED Delay	16	65535	100	488 µs
LED Support	LED Config	0x4450	U1	LED Hold Time	1	63	16	0.25 s
LED Support	LED Config	0x4451	I1	LED Flash Alarm	0	100	10	%
LED Support	LED Config	0x4452	I1	LED Thresh 1	0	100	0	%
LED Support	LED Config	0x4453	I1	LED Thresh 2	0	100	20	%
LED Support	LED Config	0x4454	I1	LED Thresh 3	0	100	40	%
LED Support	LED Config	0x4455	I1	LED Thresh 4	0	100	60	%
LED Support	LED Config	0x4456	I1	LED Thresh 5	0	100	80	%
LED Support	LED Config	0x4457	U1	LCD Refresh Rate	20	100	35	Hz
GPIO	GPIO Config	0x4458	H1	GPIO Configuration	0x0	0xFF	0x00	hex
GPIO	GPIO Config	0x4459	H1	GPIO Output Enable	0x0	0xFF	0x00	hex
GPIO	GPIO Config	0x445A	H1	GPIO Default Output Enable	0x0	0xFF	0x00	hex
GPIO	GPIO Config	0x445B	H1	GPIO Type	0x0	0xFF	0xc0	hex
System Data	Manufacturer Data	0x4040	U1	Manufacturer Info A Length	1	32	32	—

Class	Subclass	Address	Type	Name	Min	Max	Default	Unit
System Data	Manufacturer Data	0x4041	H1	Manufacturer Info Block A01	0x0	0xFF	0x61	Hex
System Data	Manufacturer Data	0x4042	H1	Manufacturer Info Block A02	0x0	0xFF	0x62	Hex
System Data	Manufacturer Data	0x4043	H1	Manufacturer Info Block A03	0x0	0xFF	0x63	Hex
System Data	Manufacturer Data	0x4044	H1	Manufacturer Info Block A04	0x0	0xFF	0x64	Hex
System Data	Manufacturer Data	0x4045	H1	Manufacturer Info Block A05	0x0	0xFF	0x65	Hex
System Data	Manufacturer Data	0x4046	H1	Manufacturer Info Block A06	0x0	0xFF	0x66	Hex
System Data	Manufacturer Data	0x4047	H1	Manufacturer Info Block A07	0x0	0xFF	0x67	Hex
System Data	Manufacturer Data	0x4048	H1	Manufacturer Info Block A08	0x0	0xFF	0x68	Hex
System Data	Manufacturer Data	0x4049	H1	Manufacturer Info Block A09	0x0	0xFF	0x69	Hex
System Data	Manufacturer Data	0x404A	H1	Manufacturer Info Block A10	0x0	0xFF	0x6A	Hex
System Data	Manufacturer Data	0x404B	H1	Manufacturer Info Block A11	0x0	0xFF	0x6B	Hex
System Data	Manufacturer Data	0x404C	H1	Manufacturer Info Block A12	0x0	0xFF	0x6C	Hex
System Data	Manufacturer Data	0x404D	H1	Manufacturer Info Block A13	0x0	0xFF	0x6D	Hex
System Data	Manufacturer Data	0x404E	H1	Manufacturer Info Block A14	0x0	0xFF	0x6E	Hex
System Data	Manufacturer Data	0x404F	H1	Manufacturer Info Block A15	0x0	0xFF	0x6F	Hex
System Data	Manufacturer Data	0x4050	H1	Manufacturer Info Block A16	0x0	0xFF	0x70	Hex
System Data	Manufacturer Data	0x4051	H1	Manufacturer Info Block A17	0x0	0xFF	0x71	Hex
System Data	Manufacturer Data	0x4052	H1	Manufacturer Info Block A18	0x0	0xFF	0x72	Hex
System Data	Manufacturer Data	0x4053	H1	Manufacturer Info Block A19	0x0	0xFF	0x73	Hex
System Data	Manufacturer Data	0x4054	H1	Manufacturer Info Block A20	0x0	0xFF	0x74	Hex
System Data	Manufacturer Data	0x4055	H1	Manufacturer Info Block A21	0x0	0xFF	0x75	Hex
System Data	Manufacturer Data	0x4056	H1	Manufacturer Info Block A22	0x0	0xFF	0x76	Hex
System Data	Manufacturer Data	0x4057	H1	Manufacturer Info Block A23	0x0	0xFF	0x77	Hex
System Data	Manufacturer Data	0x4058	H1	Manufacturer Info Block A24	0x0	0xFF	0x7A	Hex
System Data	Manufacturer Data	0x4059	H1	Manufacturer Info Block A25	0x0	0xFF	0x78	Hex
System Data	Manufacturer Data	0x405A	H1	Manufacturer Info Block A26	0x0	0xFF	0x79	Hex
System Data	Manufacturer Data	0x405B	H1	Manufacturer Info Block A27	0x0	0xFF	0x30	Hex
System Data	Manufacturer Data	0x405C	H1	Manufacturer Info Block A28	0x0	0xFF	0x31	Hex
System Data	Manufacturer Data	0x405D	H1	Manufacturer Info Block A29	0x0	0xFF	0x32	Hex
System Data	Manufacturer Data	0x405E	H1	Manufacturer Info Block A30	0x0	0xFF	0x33	Hex
System Data	Manufacturer Data	0x405F	H1	Manufacturer Info Block A31	0x0	0xFF	0x34	Hex
System Data	Manufacturer Data	0x4060	H1	Manufacturer Info Block A32	0x0	0xFF	0x35	Hex

Class	Subclass	Address	Type	Name	Min	Max	Default	Unit
SBS Configuration	Data	0x406B	U2	Manufacture Date	0	65535	0	date
SBS Configuration	Data	0x406D	H2	Serial Number	0x0	0xFFFF	0x1	hex
SBS Configuration	Data	0x406F	S21	Manufacturer Name	x	x	Texas Instruments	—
SBS Configuration	Data	0x4084	S21	Device Name	x	x	bq78350	—
SBS Configuration	Data	0x4099	S5	Device Chemistry	x	x	LION	—
SBS Configuration	Data	0x445C	I2	Remaining AH Cap. Alarm	0	32767	300	mAh
SBS Configuration	Data	0x445E	I2	Remaining WH Cap. Alarm	0	32767	432	cWh
SBS Configuration	Data	0x4460	U2	Remaining Time Alarm	0	65535	10	min
SBS Configuration	Data	0x4462	H2	Initial Battery Mode	0x0	0xFFFF	0x81	hex
SBS Configuration	Data	0x4464	H2	Specification Information	0x0	0xFFFF	0x0031	hex
Lifetimes	Voltage	0x40C0	U1	Cell 1 Max Voltage	0	255	0	20 mV
Lifetimes	Voltage	0x40C1	U1	Cell 2 Max Voltage	0	255	0	20 mV
Lifetimes	Voltage	0x40C2	U1	Cell 3 Max Voltage	0	255	0	20 mV
Lifetimes	Voltage	0x40C3	U1	Cell 4 Max Voltage	0	255	0	20 mV
Lifetimes	Voltage	0x40C4	U1	Cell 5 Max Voltage	0	255	0	20 mV
Lifetimes	Voltage	0x40C5	U1	Cell 6 Max Voltage	0	255	0	20 mV
Lifetimes	Voltage	0x40C6	U1	Cell 7 Max Voltage	0	255	0	20 mV
Lifetimes	Voltage	0x40C7	U1	Cell 8 Max Voltage	0	255	0	20 mV
Lifetimes	Voltage	0x40C8	U1	Cell 9 Max Voltage	0	255	0	20 mV
Lifetimes	Voltage	0x40C9	U1	Cell 10 Max Voltage	0	255	0	20 mV
Lifetimes	Voltage	0x40CA	U1	Cell 11 Max Voltage	0	255	0	20 mV
Lifetimes	Voltage	0x40CB	U1	Cell 12 Max Voltage	0	255	0	20 mV
Lifetimes	Voltage	0x40CC	U1	Cell 13 Max Voltage	0	255	0	20 mV
Lifetimes	Voltage	0x40CD	U1	Cell 14 Max Voltage	0	255	0	20 mV
Lifetimes	Voltage	0x40CE	U1	Cell 15 Max Voltage	0	255	0	20 mV
Lifetimes	Voltage	0x40D0	U1	Cell 1 Min Voltage	0	255	255	20 mV
Lifetimes	Voltage	0x40D1	U1	Cell 2 Min Voltage	0	255	255	20 mV
Lifetimes	Voltage	0x40D2	U1	Cell 3 Min Voltage	0	255	255	20 mV
Lifetimes	Voltage	0x40D3	U1	Cell 4 Min Voltage	0	255	255	20 mV
Lifetimes	Voltage	0x40D4	U1	Cell 5 Min Voltage	0	255	255	20 mV
Lifetimes	Voltage	0x40D5	U1	Cell 6 Min Voltage	0	255	255	20 mV
Lifetimes	Voltage	0x40D6	U1	Cell 7 Min Voltage	0	255	255	20 mV
Lifetimes	Voltage	0x40D7	U1	Cell 8 Min Voltage	0	255	255	20 mV
Lifetimes	Voltage	0x40D8	U1	Cell 9 Min Voltage	0	255	255	20 mV
Lifetimes	Voltage	0x40D9	U1	Cell 10 Min Voltage	0	255	255	20 mV
Lifetimes	Voltage	0x40DA	U1	Cell 11 Min Voltage	0	255	255	20 mV
Lifetimes	Voltage	0x40DB	U1	Cell 12 Min Voltage	0	255	255	20 mV
Lifetimes	Voltage	0x40DC	U1	Cell 13 Min Voltage	0	255	255	20 mV
Lifetimes	Voltage	0x40DD	U1	Cell 14 Min Voltage	0	255	255	20 mV
Lifetimes	Voltage	0x40DE	U1	Cell 15 Min Voltage	0	255	255	20 mV
Lifetimes	Voltage	0x40E0	U1	Max Delta Cell Voltage	0	255	0	20 mV
Lifetimes	Current	0x40E1	I2	Max Charge Current	0	32767	0	mA
Lifetimes	Current	0x40E3	I2	Max Discharge Current	–32768	0	0	mA
Lifetimes	Current	0x40E5	I2	Max Avg Dsg Current	–32768	0	0	mA
Lifetimes	Current	0x40E7	I2	Max Avg Dsg Power	–32768	0	0	cW
Lifetimes	Temperature	0x40E9	I1	Max Temp Cell	–128	127	–128	°C
Lifetimes	Temperature	0x40EA	I1	Min Temp Cell	–128	127	127	°C

Class	Subclass	Address	Type	Name	Min	Max	Default	Unit
Lifetimes	Temperature	0x40EB	I1	Max Delta Cell Temp	–128	127	0	°C
Lifetimes	Safety Events	0x40EC	U2	No Of COV Events	0	32767	0	events
Lifetimes	Safety Events	0x40EE	U2	Last COV Event	0	32767	0	cycles
Lifetimes	Safety Events	0x40F0	U2	No Of CUV Events	0	32767	0	events
Lifetimes	Safety Events	0x40F2	U2	Last CUV Event	0	32767	0	cycles
Lifetimes	Safety Events	0x40F4	U2	No Of OCD Events	0	32767	0	events
Lifetimes	Safety Events	0x40F6	U2	Last OCD Event	0	32767	0	cycles
Lifetimes	Safety Events	0x40F8	U2	No Of OCC Events	0	32767	0	events
Lifetimes	Safety Events	0x40FA	U2	Last OCC Event	0	32767	0	cycles
Lifetimes	Safety Events	0x40FC	U2	No Of AOLD Events	0	32767	0	events
Lifetimes	Safety Events	0x40FE	U2	Last AOLD Event	0	32767	0	cycles
Lifetimes	Safety Events	0x4100	U2	No Of ASCD Events	0	32767	0	events
Lifetimes	Safety Events	0x4102	U2	Last ASCD Event	0	32767	0	cycles
Lifetimes	Safety Events	0x4104	U2	No Of OTC Events	0	32767	0	events
Lifetimes	Safety Events	0x4106	U2	Last OTC Event	0	32767	0	cycles
Lifetimes	Safety Events	0x4108	U2	No Of OTD Events	0	32767	0	events
Lifetimes	Safety Events	0x410A	U2	Last OTD Event	0	32767	0	cycles
Lifetimes	Charging Events	0x410C	U2	No Valid Charge Term	0	32767	0	events
Lifetimes	Charging Events	0x410E	U2	Last Valid Charge Term	0	32767	0	cycles
Lifetimes	Gauging Events	0x4110	U2	No of FCC Updates	0	32767	0	events
Lifetimes	Gauging Events	0x4112	U2	Last FCC Update	0	32767	0	cycles
Lifetimes	Power Events	0x4114	U1	No Of Shutdowns	0	255	0	events
Lifetimes	Cell Balancing	0x4118	U1	Cb Time Cell 1	0	255	0	2 h
Lifetimes	Cell Balancing	0x4119	U1	Cb Time Cell 2	0	255	0	2 h
Lifetimes	Cell Balancing	0x411A	U1	Cb Time Cell 3	0	255	0	2 h
Lifetimes	Cell Balancing	0x411B	U1	Cb Time Cell 4	0	255	0	2 h
Lifetimes	Cell Balancing	0x411C	U1	Cb Time Cell 5	0	255	0	2 h
Lifetimes	Cell Balancing	0x411D	U1	Cb Time Cell 6	0	255	0	2 h
Lifetimes	Cell Balancing	0x411E	U1	Cb Time Cell 7	0	255	0	2 h
Lifetimes	Cell Balancing	0x411F	U1	Cb Time Cell 8	0	255	0	2 h
Lifetimes	Cell Balancing	0x4120	U1	Cb Time Cell 9	0	255	0	2 h
Lifetimes	Cell Balancing	0x4121	U1	Cb Time Cell 10	0	255	0	2 h
Lifetimes	Cell Balancing	0x4122	U1	Cb Time Cell 11	0	255	0	2 h
Lifetimes	Cell Balancing	0x4123	U1	Cb Time Cell 12	0	255	0	2 h
Lifetimes	Cell Balancing	0x4124	U1	Cb Time Cell 13	0	255	0	2 h
Lifetimes	Cell Balancing	0x4125	U1	Cb Time Cell 14	0	255	0	2 h
Lifetimes	Cell Balancing	0x4126	U1	Cb Time Cell 15	0	255	0	2 h
Lifetimes	Time	0x4128	U2	Total Fw Runtime	0	65535	0	2 h
Lifetimes	Time	0x412A	U2	Time Spent In UT	0	65535	0	2 h
Lifetimes	Time	0x412C	U2	Time Spent In LT	0	65535	0	2 h
Lifetimes	Time	0x412E	U2	Time Spent In ST	0	65535	0	2 h
Lifetimes	Time	0x4130	U2	Time Spent In HT	0	65535	0	2 h
Lifetimes	Time	0x4132	U2	Time Spent In OT	0	65535	0	2 h
Lifetimes	Time	0x4134	U2	Time Since Last Charge	0	65535	0	2 h
Protections	CUV	0x4486	I2	Threshold	0	32767	2500	mV
Protections	CUV	0x4488	U1	Delay	0	255	2	s
Protections	CUV	0x4489	I2	Recovery	0	32767	3000	mV
Protections	COV	0x448B	I2	Threshold	0	32767	4300	mV
Protections	COV	0x448D	U1	Delay	0	255	2	s
Protections	COV	0x448E	I2	Recovery	0	32767	4100	mV
Protections	OCC	0x4490	I2	Threshold	–32768	32767	6000	mA
Protections	OCC	0x4492	U1	Delay	0	255	6	s

Class	Subclass	Address	Type	Name	Min	Max	Default	Unit
Protections	OCC	0x4493	I2	Recovery Threshold	–32768	32767	–200	mA
Protections	OCC	0x4495	U1	Recovery Delay	0	255	5	s
Protections	OCD	0x4496	I2	Threshold	–32768	32767	–6000	mA
Protections	OCD	0x4498	U1	Delay	0	255	6	s
Protections	OCD	0x4499	I2	Recovery Threshold	–32768	32767	200	mA
Protections	OCD	0x449B	U1	Recovery Delay	0	255	5	s
Protections	AOLD	0x446E	H1	Threshold and Delay	0x0	0xFF	0x00	hex
Protections	AOLD	0x449C	U1	Latch Limit	0	255	0	—
Protections	AOLD	0x449D	U1	Counter Dec Delay	0	255	10	s
Protections	AOLD	0x449E	U1	Recovery	0	255	5	s
Protections	AOLD	0x449F	U1	Reset	0	255	15	s
Protections	ASCD	0x446D	H1	Threshold and Delay	0x0	0xFF	0x00	hex
Protections	ASCD	0x44A0	U1	Latch Limit	0	255	0	—
Protections	ASCD	0x44A1	U1	Counter Dec Delay	0	255	10	s
Protections	ASCD	0x44A2	U1	Recovery	0	255	5	s
Protections	ASCD	0x44A3	U1	Reset	0	255	15	s
Protections	OTC	0x44A4	I2	Threshold	–400	1500	550	0.1°C
Protections	OTC	0x44A6	U1	Delay	0	255	2	s
Protections	OTC	0x44A7	I2	Recovery	–400	1500	500	0.1°C
Protections	OTD	0x44A9	I2	Threshold	–400	1500	600	0.1°C
Protections	OTD	0x44AB	U1	Delay	0	255	2	s
Protections	OTD	0x44AC	I2	Recovery	–400	1500	550	0.1°C
Protections	UTC	0x44AE	I2	Threshold	–400	1500	0	0.1°C
Protections	UTC	0x44B0	U1	Delay	0	255	2	s
Protections	UTC	0x44B1	I2	Recovery	–400	1500	50	0.1°C
Protections	UTD	0x44B3	I2	Threshold	–400	1500	0	0.1°C
Protections	UTD	0x44B5	U1	Delay	0	255	2	s
Protections	UTD	0x44B6	I2	Recovery	–400	1500	50	0.1°C
Protections	PTO	0x44B8	I2	Charge Threshold	–32768	32767	2000	mA
Protections	PTO	0x44BA	I2	Suspend Threshold	–32768	32767	1800	mA
Protections	PTO	0x44BC	U2	Delay	0	65535	1800	s
Protections	PTO	0x44BE	I2	Reset	0	32767	2	mAh
Protections	CTO	0x44C0	I2	Charge Threshold	–32768	32767	2500	mA
Protections	CTO	0x44C2	I2	Suspend Threshold	–32768	32767	2000	mA
Protections	CTO	0x44C4	U2	Delay	0	65535	54000	s
Protections	CTO	0x44C6	I2	Reset	0	32767	2	mAh
Protections	OC	0x44C8	I2	Threshold	–32768	32767	300	mAh
Protections	OC	0x44CA	I2	Recovery	–32768	32767	2	mAh
Protections	OC	0x44CC	U1	RSOC Recovery	0%	100%	90%	
Permanent Fail	SOCC	0x44D1	I2	Threshold	–32768	32767	10000	mA
Permanent Fail	SOCC	0x44D3	U1	Delay	0	255	5	s
Permanent Fail	SOCD	0x44D4	I2	Threshold	–32768	32767	–10000	mA
Permanent Fail	SOCD	0x44D6	U1	Delay	0	255	5	s
Permanent Fail	SOT	0x44D7	I2	Threshold	–400	1500	650	0.1°C
Permanent Fail	SOT	0x44D9	U1	Delay	0	255	5	s
Permanent Fail	Open Thermistor	0x44DA	I2	Threshold	0	32767	2232	0.1°K
Permanent Fail	Open Thermistor	0x44DC	U1	Delay	0	255	5	s

Class	Subclass	Address	Type	Name	Min	Max	Default	Unit
Permanent Fail	VIMR	0x44DD	I2	Check Voltage	0	5000	3500	mV
Permanent Fail	VIMR	0x44DF	I2	Check Current	0	32767	10	mA
Permanent Fail	VIMR	0x44E1	I2	Delta Threshold	0	5000	500	mV
Permanent Fail	VIMR	0x44E3	U1	Delta Delay	0	255	5	s
Permanent Fail	VIMR	0x44E4	U2	Duration	0	65535	100	s
Permanent Fail	CFET	0x44E6	I2	OFF Threshold	0	500	5	mA
Permanent Fail	CFET	0x44E8	U1	OFF Delay	0	255	5	s
Permanent Fail	DFET	0x44E9	I2	OFF Threshold	–500	0	–5	mA
Permanent Fail	DFET	0x44EB	U1	OFF Delay	0	255	5	s
Permanent Fail	AFER	0x44EC	U1	Threshold	0	255	100	—
Permanent Fail	AFER	0x44ED	U1	Delay Period	0	255	2	s
Permanent Fail	AFER	0x44EE	U1	Compare Period	0	255	5	s
Permanent Fail	AFEC	0x44EF	U1	Threshold	0	255	100	—
Permanent Fail	AFEC	0x44F0	U1	Delay Period	0	255	5	s
Permanent Fail	AFE XREADY	0x44F1	U1	Threshold	0	255	100	—
Permanent Fail	AFE XREADY	0x44F2	U1	Delay Period	0	255	5	s
Permanent Fail	AFE External Override	0x44F3	U1	Delay	0	255	5	s
Permanent Fail	AFE SOV/AFE SUV	0x446F	H1	SOV and SUV Delay	0x0	0xFF	0x50	hex
Permanent Fail	AFE SOV	0x4474	I2	Threshold	3150	4700	4350	mV
Permanent Fail	AFE SUV	0x4476	I2	Threshold	1580	3100	1750	mV
PF Status	Device Status Data	0x4180	H1	Safety Alert A	0x0	0xFF	0x0	hex
PF Status	Device Status Data	0x4181	H1	Safety Status A	0x0	0xFF	0x0	hex
PF Status	Device Status Data	0x4182	H1	Safety Alert B	0x0	0xFF	0x0	hex
PF Status	Device Status Data	0x4183	H1	Safety Status B	0x0	0xFF	0x0	hex
PF Status	Device Status Data	0x4184	H1	Safety Alert C	0x0	0xFF	0x0	hex
PF Status	Device Status Data	0x4185	H1	Safety Status C	0x0	0xFF	0x0	hex
PF Status	Device Status Data	0x4188	H1	PF Alert A	0x0	0xFF	0x0	hex
PF Status	Device Status Data	0x4189	H1	PF Status A	0x0	0xFF	0x0	hex
PF Status	Device Status Data	0x418A	H1	PF Alert B	0x0	0xFF	0x0	hex
PF Status	Device Status Data	0x418B	H1	PF Status B	0x0	0xFF	0x0	hex
PF Status	Device Status Data	0x418C	H1	PF Alert C	0x0	0xFF	0x0	hex
PF Status	Device Status Data	0x418D	H1	PF Status C	0x0	0xFF	0x0	hex

Class	Subclass	Address	Type	Name	Min	Max	Default	Unit
PF Status	Device Status Data	0x4190	H2	Fuse Flag	0x0	0xFFFF	0x0	hex
PF Status	Device Status Data	0x4192	H2	Operation Status A	0x0	0xFFFF	0x0	hex
PF Status	Device Status Data	0x4194	H2	Operation Status B	0x0	0xFFFF	0x0	hex
PF Status	Device Status Data	0x4196	H1	Temp Range	0x0	0xFF	0x0	hex
PF Status	Device Status Data	0x4197	H1	Charging Status	0x0	0xFF	0x0	hex
PF Status	Device Status Data	0x4198	H1	Gauging Status	0x0	0xFF	0x0	hex
PF Status	Device Status Data	0x4199	H1	CEDV Status	0x0	0xFF	0x0	hex
PF Status	Device Voltage Data	0x419A	I2	Cell 1 Voltage	–32768	32767	0	mV
PF Status	Device Voltage Data	0x419C	I2	Cell 2 Voltage	–32768	32767	0	mV
PF Status	Device Voltage Data	0x419E	I2	Cell 3 Voltage	–32768	32767	0	mV
PF Status	Device Voltage Data	0x41A0	I2	Cell 4 Voltage	–32768	32767	0	mV
PF Status	Device Voltage Data	0x41A2	I2	Cell 5 Voltage	–32768	32767	0	mV
PF Status	Device Voltage Data	0x41A4	I2	Cell 6 Voltage	–32768	32767	0	mV
PF Status	Device Voltage Data	0x41A6	I2	Cell 7 Voltage	–32768	32767	0	mV
PF Status	Device Voltage Data	0x41A8	I2	Cell 8 Voltage	–32768	32767	0	mV
PF Status	Device Voltage Data	0x41AA	I2	Cell 9 Voltage	–32768	32767	0	mV
PF Status	Device Voltage Data	0x41AC	I2	Cell 10 Voltage	–32768	32767	0	mV
PF Status	Device Voltage Data	0x41AE	I2	Cell 11 Voltage	–32768	32767	0	mV
PF Status	Device Voltage Data	0x41B0	I2	Cell 12 Voltage	–32768	32767	0	mV
PF Status	Device Voltage Data	0x41B2	I2	Cell 13 Voltage	–32768	32767	0	mV
PF Status	Device Voltage Data	0x41B4	I2	Cell 14 Voltage	–32768	32767	0	mV
PF Status	Device Voltage Data	0x41B6	I2	Cell 15 Voltage	–32768	32767	0	mV
PF Status	Device Voltage Data	0x41BA	I2	Battery Direct Voltage	–32768	32767	0	mV
PF Status	Device Current Data	0x41BE	I2	Current	–32768	32767	0	mA
PF Status	Device Temperature Data	0x41C0	I2	TS1 Temperature	–32768	32767	0	0.1°K
PF Status	Device Temperature Data	0x41C2	I2	TS2 Temperature	–32768	32767	0	0.1°K
PF Status	Device Temperature Data	0x41C4	I2	TS3 Temperature	–32768	32767	0	0.1°K
PF Status	AFE Regs	0x41C6	H1	AFE SYS Stat	0x0	0xFF	0x0	hex
PF Status	AFE Regs	0x41C7	H1	AFE Cell Balance1	0x0	0xFF	0x0	hex
PF Status	AFE Regs	0x41C8	H1	AFE Cell Balance2	0x0	0xFF	0x0	hex
PF Status	AFE Regs	0x41C9	H1	AFE Cell Balance3	0x0	0xFF	0x0	hex
PF Status	AFE Regs	0x41CA	H1	AFE Sys Control1	0x0	0xFF	0x0	hex
PF Status	AFE Regs	0x41CB	H1	AFE Sys Control2	0x0	0xFF	0x0	hex
PF Status	AFE Regs	0x41CC	H1	AFE Protection1	0x0	0xFF	0x0	hex
PF Status	AFE Regs	0x41CD	H1	AFE Protection2	0x0	0xFF	0x0	hex

Class	Subclass	Address	Type	Name	Min	Max	Default	Unit
PF Status	AFE Regs	0x41CE	H1	AFE Protection3	0x0	0xFF	0x0	hex
PF Status	AFE Regs	0x41CF	H1	AFE OV Trip	0x0	0xFF	0x0	hex
PF Status	AFE Regs	0x41D0	H1	AFE UV Trip	0x0	0xFF	0x0	hex
Black Box	Safety Status	0x4140	H1	1st Status Status A	0x0	0xFF	0x0	hex
Black Box	Safety Status	0x4141	H1	1st Status Status B	0x0	0xFF	0x0	hex
Black Box	Safety Status	0x4142	H1	1st Safety Status C	0x0	0xFF	0x0	hex
Black Box	Safety Status	0x4144	U1	1st Time to Next Event	0	255	0	s
Black Box	Safety Status	0x4145	H1	2nd Status Status A	0x0	0xFF	0x0	hex
Black Box	Safety Status	0x4146	H1	2nd Status Status B	0x0	0xFF	0x0	hex
Black Box	Safety Status	0x4147	H1	2nd Safety Status C	0x0	0xFF	0x0	hex
Black Box	Safety Status	0x4149	U1	2nd Time to Next Event	0	255	0	s
Black Box	Safety Status	0x414A	H1	3rd Status Status A	0x0	0xFF	0x0	hex
Black Box	Safety Status	0x414B	H1	3rd Status Status B	0x0	0xFF	0x0	hex
Black Box	Safety Status	0x414C	H1	3rd Safety Status C	0x0	0xFF	0x0	hex
Black Box	Safety Status	0x414E	U1	3rd Time to Next Event	0	255	0	s
Black Box	PF Status	0x414F	H1	1st PF Status A	0x0	0xFF	0x0	hex
Black Box	PF Status	0x4150	H1	1st PF Status B	0x0	0xFF	0x0	hex
Black Box	PF Status	0x4151	H1	1st PF Status C	0x0	0xFF	0x0	hex
Black Box	PF Status	0x4153	U1	1st Time to Next Event	0	255	0	s
Black Box	PF Status	0x4154	H1	2nd PF Status A	0x0	0xFF	0x0	hex
Black Box	PF Status	0x4155	H1	2nd PF Status B	0x0	0xFF	0x0	hex
Black Box	PF Status	0x4156	H1	2nd PF Status C	0x0	0xFF	0x0	hex
Black Box	PF Status	0x4158	U1	2nd Time to Next Event	0	255	0	s
Black Box	PF Status	0x4159	H1	3rd PF Status A	0x0	0xFF	0x0	hex
Black Box	PF Status	0x415A	H1	3rd PF Status B	0x0	0xFF	0x0	hex
Black Box	PF Status	0x415B	H1	3rd PF Status C	0x0	0xFF	0x0	hex
Black Box	PF Status	0x415D	U1	3rd Time to Next Event	0	255	0	s
Fuel Gauging	CEDV cfg	0x4518	U2	EMF	0	65535	3743	—
Fuel Gauging	CEDV cfg	0x451A	U2	C0	0	65535	149	—
Fuel Gauging	CEDV cfg	0x451C	U2	R0	0	65535	867	—
Fuel Gauging	CEDV cfg	0x451E	U2	T0	0	65535	4030	—
Fuel Gauging	CEDV cfg	0x4520	U2	R1	0	65535	316	—
Fuel Gauging	CEDV cfg	0x4522	U1	TC	0	255	9	—
Fuel Gauging	CEDV cfg	0x4523	U1	C1	0	255	0	—
Fuel Gauging	CEDV cfg	0x4524	U1	Age Factor	0	255	0	—
Fuel Gauging	CEDV cfg	0x4525	I2	Fixed EDV 0	0	32767	3031	—
Fuel Gauging	CEDV cfg	0x4527	U1	EDV 0 Hold Time	1	255	1	s
Fuel Gauging	CEDV cfg	0x4528	I2	Fixed EDV 1	0	32767	3385	—
Fuel Gauging	CEDV cfg	0x452A	U1	EDV 1 Hold Time	1	255	1	s
Fuel Gauging	CEDV cfg	0x452B	I2	Fixed EDV 2	0	32767	3501	—
Fuel Gauging	CEDV cfg	0x452D	U1	EDV 2 Hold Time	1	255	1	s
Fuel Gauging	CEDV cfg	0x4532	U2	Battery Low %	0%	65535%	700%	0.01
Fuel Gauging	CEDV cfg	0x4536	I2	Min Delta V Filter	0	32767	10	mV
Fuel Gauging	CEDV cfg	0x4538	I2	FCC Learn Up	0	32767	512	mAh
Fuel Gauging	CEDV cfg	0x453A	I2	FCC Learn Down	0	32767	256	mAh
Fuel Gauging	CEDV cfg	0x453f	I2	Learning Low Temp	–100	32767	119	0.1°C
Fuel Gauging	CEDV cfg	0x4548	U1	Requested Learning cycle count	0	255	20	num
Fuel Gauging	CEDV cfg	0x4549	I2	OverLoad Current	0	32767	5000	mA
Fuel Gauging	CEDV cfg	0x454D	U1	Self Discharge Rate	0%	255%	20%	0.01/day
Fuel Gauging	CEDV cfg	0x454E	I2	Electronics Load	0	255	0	3 µA
Fuel Gauging	CEDV cfg	0x4550	I2	Near Full	0	32767	200	mAh
Fuel Gauging	CEDV cfg	0x4552	I2	Reserve Capacity	0	32767	0	mAh

Class	Subclass	Address	Type	Name	Min	Max	Default	Unit
Fuel Gauging	State	0x4280	I2	Qmax Pack	0	32767	4400	mAh
Fuel Gauging	State	0x4282	I2	Learned Full Charge Capacity	0	32767	4400	mAh
Fuel Gauging	State	0x4284	I2	Dod at EDV2	0	16384	15232	—
Fuel Gauging	State	0x4286	U2	Cycle Count	0	65535	0	—
Fuel Gauging	Current Thresholds	0x4479	I2	Dsg Current Threshold	–32768	32767	100	mA
Fuel Gauging	Current Thresholds	0x447B	I2	Chg Current Threshold	–32768	32767	50	mA
Fuel Gauging	Current Thresholds	0x447D	I2	Quit Current	0	32767	10	mA
Fuel Gauging	Current Thresholds	0x447F	U1	Dsg Relax Time	0	255	1	s
Fuel Gauging	Current Thresholds	0x4480	U1	Chg Relax Time	0	255	60	s
Fuel Gauging	Design	0x4556	I2	Design Capacity mAh	0	32767	4400	mAh
Fuel Gauging	Design	0x4558	I2	Design Capacity cWh	0	32767	6336	cWh
Fuel Gauging	Design	0x455A	I2	Design Voltage	0	5000	3600	mV
Fuel Gauging	Cycle	0x455C	U1	Cycle Count Percentage	0%	100%	90%	
Fuel Gauging	FD	0x4560	U1	Set % RSOC Threshold	0%	100%	0%	
Fuel Gauging	FD	0x4561	U1	Clear % RSOC Threshold	0%	100%	5%	
Fuel Gauging	FC	0x4562	U1	Set % RSOC Threshold	0%	100%	100%	
Fuel Gauging	FC	0x4563	U1	Clear % RSOC Threshold	0%	100%	95%	
Fuel Gauging	TD	0x4564	U1	Set % RSOC Threshold	0%	100%	6%	
Fuel Gauging	TD	0x4565	U1	Clear % RSOC Threshold	0%	100%	8%	
Fuel Gauging	TC	0x4566	U1	Set % RSOC Threshold	0%	100%	100%	
Fuel Gauging	TC	0x4567	U1	Clear % RSOC Threshold	0%	100%	95%	

Revision History

Changes from A Revision (September 2014) to B Revision **Page**

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