BQ27Z746

Technical Reference Manual

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Table of Contents

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About This Manual

This manual discusses the modules and peripherals of the BQ27Z746 device, and how each is used to build a complete battery pack gas gauge and protection solution. For electrical specifications, refer to the *BQ27Z746 Single-Cell Battery Fuel Gauge with Integrated Protector* (SLUSDW2).

Notational Conventions

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

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

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

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

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Glossary

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

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The BQ27Z746 device provides a feature-rich gas gauging solution for single-cell battery pack applications. The device has extended capabilities, including:

- Fully integrated single-cell Li-ion or Li-polymer cell battery gauge solution and protection
- Next-generation patented Impedance Track® technology accurately measures available charge in Li-ion and Li-polymer batteries
- High side N-CH protection FET drive
- Power modes:
  - NORMAL mode
  - SLEEP mode
  - SHIP mode
  - SHELF mode
  - SHUTDOWN mode
- Full array of programmable protection features
  - Voltage
  - Current
  - Temperature
  - CHG/DSG FETs
- Information available to external smart charger
  - JEITA
  - Charging current
  - Charging voltage
- Diagnostic lifetime data monitor
- Supports two-wire I^{2}C interface
- Supports one-wire HDQ interface
- SHA-256 authentication
- Ultra-compact package: 16-ball DSBGA

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2.1 Configuration of the GPO Pin

The GPO pin can be optionally configured to read a second thermistor (using *Temperature Enable*) or it can be used as a digital output as a host interrupt signal. The pin can be used for either purpose, but not both.

Class	Subclass	Name	Type	Min	Max	Default	Unit
Settings	Configuration	GPO Pin Config	H1	0x00	0x01	0x00	Hex

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

RSVD (Bits 7–1): Reserved. Do not use.

HOSTINT_EN (Bit 0): Use the pin for output of a host interrupt signal

      1 = Enabled

      0 = Disabled (default)

Note

By default, neither option is selected.

If one of the options is selected, see the appropriate chapter for either temperature measurement or host interrupts.

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3.1 Introduction

The BQ27Z746 gauge contains an integrating analog-to-digital converter (ADC) for current measurement and a second order delta-sigma ADC for cell voltage and temperature measurements.

3.2 Current and Coulomb Counting

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

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

3.3 Voltage

3.3.1 Cell Voltage

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

3.3.2 Pack Voltage

The second order delta-sigma ADC in the gauge measures the pack voltage (at the PACK pin) at 1-s intervals in NORMAL mode, and **Voltage Time**-second intervals in SLEEP mode. This data is scaled and translated into mV using **Pack Gain** and reported through PACK pin voltage in *DAStatus1()*. The gauge uses this information for entry to SHUTDOWN mode, zero-volt charging, and BUFFER mode for the battery sensing output.

3.4 Temperature

3.4.1 Internal Temperature

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

3.4.2 Cell Temperature

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

1. The cell temperature can be used for gauging and lifetime data logging functions if ***Temperature Enable[TS1]*** = 1.

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

3.4.3 Optional Second Temperature Sensor

The GPO pin can be configured to provide an additional temperature sensor. The default for the sensor is Semitec 103AT NTC thermistor. The thermistor is connected between Vss and the GPO when this configuration is used. This additional sensor can be configured as either a FET temperature sensor or an additional cell temperature sensor.

3.4.4 Temperature Configuration

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

Class	Subclass	Name	Type	Min	Max	Default	Description
Settings	Configuration	Temperature Enable	H1	0x00	0x0F	0x02	Determines whether the internal temperature (TSInt) or the external temperature (TS1 on TS pin) is reported with *Temperature()*. Bit 0: TSInt—Enables internal TS Bit 1: TS1—Enables external TS pin 0, 0: Neither enabled, *Temperature()* reports –273.2K. 0, 1: Enables internal TS, *Temperature()* reports the internal temperature. 1, 0: Enables TS1, *Temperature()* reports the value determined by the thermistor on the TS pin. 1, 1: TSInt and TS1 are enabled, *Temperature()* reports the higher of the two values. Bit 2: TS2—Selected for a second thermistor on the GPO pin for temperature measurement reported as TS2 Temperature. This should only be enabled if ***GPO Pin Config[HOSTINT_EN]*** = 0. Additionally, when Bit 3:TS2FET is set, the gauge uses the second thermistor as a FET temperature measurement reported as FET Temperature. Otherwise, the second thermistor is used for *Temperature()*, where the highest value of all enabled sources is reported and FET Temperature reports –273.2 K.

4.1 Introduction

The BQ27z746 provides two levels of protection. The first level of protection is firmware based and is backed up by a second hardware based level of protection. The hardware protections have precedence over the firmware protections.

4.2 Hardware-Based Protection

The device has five hardware-based protections—HCUV, HCOV, HOCC, HOCD, and HSCD—with adjustable threshold and delay time. The threshold settings are in mV; therefore, for current-based protections, the actual current that triggers the protection is based on the R_{SENSE} used in the schematic design.

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

4.2.1 Cell Undervoltage Protection

The device has a hardware-based cell undervoltage protection with adjustable threshold and delay time.

Status	Condition	Action
Normal	*Voltage()* > Protector UVP Threshold	*SafetyStatus()[HCUV]* = 0
Trip	*Voltage()* ≤ Protector UVP Threshold for Protector UVP Delay Time	*SafetyStatus()[HCUV]* = 1 *OperationStatus()[XDSG]* = 1 Turn off DSG FET
Recovery	*SafetyStatus()[HCUV]* = 1 AND (*Voltage()* ≥**HCUV:Recovery** for **HCUV:Recovery Delay** in RELAX or DISCHARGE mode) OR (*Voltage()* ≥ **HCUV:Recovery Chg** for **HCUV:Recovery Delay** in CHARGE mode)	*SafetyStatus()[HCUV]* = 0 *OperationStatus()[XDSG]* = 0

4.2.2 Cell Overvoltage Protection

The device has a hardware-based cell overvoltage protection with adjustable threshold and delay time.

Status	Condition	Action
Normal	*Voltage()* < Protector OVP Threshold	*SafetyStatus()[HCOV]* = 0
Trip	*Voltage()* ≥ Protector OVP Threshold for Protector OVP Delay Time	*SafetyStatus()[HCOV]* = 1 *OperationStatus()[XDSG]* = 1 Turn off CHG FET
Recovery	*SafetyStatus()[HCOV]* = 1 AND *Voltage()* ≤ **HCOV:Recovery** for **HCOV:Recovery Delay**	*SafetyStatus()[HCOV]* = 0 *OperationStatus()[XDSG]* = 0

4.2.3 Overcurrent in Discharge Protection

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

Status	Condition	Action
Normal	*Current()* > Protector OCD Threshold	*SafetyStatus()[HOCD]* = 0
Trip	*Current()* ≤ Protector OCD Threshold for Protector OCD Delay Time	*SafetyStatus()[HOCD]* = 1 *OperationStatus()[XDSG]* = 1 Turn off DSG FET

Status	Condition	Action
Recovery	*SafetyStatus()[HOCD]* = 1 AND *Current()* ≥ **HOCD:Recovery Threshold** for **HOCD:Recovery Delay** time	*SafetyStatus()[HOCD]* = 0 *OperationStatus()[XDSG]* = 0

4.2.4 Overcurrent in Charge Protection

The device has a hardware-based overcurrent in charge protection with adjustable current and delay time.

Status	Condition	Action
Normal	*Current()* < Protector OCC Threshold	*SafetyStatus()[HOCC]* = 0
Trip	*Current()* ≥ Protector OCC Threshold for Protector OCC Delay Time	*SafetyStatus()[HOCC]* = 1 *OperationStatus()[XCHG]* = 1 Turn off CHG FET
Recovery	*SafetyStatus()[HOCC]* = 1 AND *Current()* ≤ **HOCC:Recovery Threshold** for **HOCC:Recovery Delay** time	*SafetyStatus()[HOCC]* = 0 *OperationStatus()[XCHG]* = 0

4.2.5 Short Circuit in Discharge Protection

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

Status	Condition	Action
Normal	*Current()* > Protector SCD Threshold	*SafetyStatus()[HSCD]* = 0
Trip	*Current()* ≤ Protector SCD Threshold for Protector SCD Delay Time	*SafetyStatus()[HSCD]* = 1 *OperationStatus()[XDSG]* = 1 Turn off DSG FET
Recovery	*SafetyStatus()[HSCD]* = 1 AND *Current()* ≥ **HSCD:Recovery Threshold** for **HSCD:Recovery** time	*SafetyStatus()[HSCD]* = 0 *OperationStatus()[XDSG]* = 0

4.2.6 Threshold Targets

An area of data flash at memory address 0x4020 is reserved for storing the threshold targets for the hardware-based protections. Updates to these data flash parameters must be done manually and do not impact operation of the hardware-based protections. Instead, these parameters provide a record of any changes made from the factory settings and provide an easy to read format of the threshold targets. **Field Config** can be used as an identifier for a specific combination of threshold targets to differentiate certain pack configurations.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Protections	HW Threshold Targets	OVP	U2	2000	5000	4525	mV	Threshold target for cell voltage for hardware-based OVP
Protections	HW Threshold Targets	UVP	U2	2000	4000	2300	mV	Threshold target for cell voltage for hardware-based UVP
Protections	HW Threshold Targets	OCC	I2	0	1000	140	0.1 mV	Threshold target for voltage across the sense resistor for hardware-based OCC
Protections	HW Threshold Targets	OCD	I2	−1000	0	−160	0.1 mV	Threshold target for voltage across the sense resistor for hardware-based OCD
Protections	HW Threshold Targets	SCD	I2	−1000	0	−200	0.1 mV	Threshold target for voltage across the sense resistor for hardware-based SCD
Protections	HW Threshold Targets	I-Wake	I2	−1000	0	−20	0.1 mV	Threshold target for voltage across the sense resistor for hardware-based I-Wake
Protections	HW Threshold Targets	BDP	I2	−1000	0	−200	mV	Threshold target for voltage between BAT and BAT_SP for hardware-based BDP
Protections	HW Threshold Targets	BCP	I2	0	1000	200	mV	Threshold target for voltage between BAT and BAT_SP for hardware-based BCP

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Protections	HW Threshold Targets	BDN	I2	−1000	0	−200	mV	Threshold target for voltage between VSS and BAT_SN for hardware-based BDN
Protections	HW Threshold Targets	BCN	I2	0	1000	200	mV	Threshold target for voltage between VSS and BAT_SN for hardware-based BCN
Protections	HW Threshold Targets	Field Cal	U2	0x0000	0xFFFF	0x0000	Hex	Flags to indicate which target thresholds have been modified from factory settings
Protections	HW Threshold Targets	Field Config	U1	0x00	0xFF	0x00	Hex	Numeric identifier for a set of target thresholds for hardware-based protections

4.3 Firmware Based Protections

Firmware cannot override any hardware based protection. The firmware protections are used to signal impending hardware protection. This can allow a host system to respond to conditions before hardware protection opens a FET. Some of the firmware protection can be programmed to open a FET. Every firmware protection has two associated signals. When a threshold violation is detected the associated status bit is set. Each threshold has an associated timer. If the timer expires an associated status bit is set. If the status bit has an active associated FET control action, that action will be taken when the status bit is set. All firmware based protections have an associated recovery threshold.

When the protection is triggered, charging and/or discharging is disabled. This is indicated by the *OperationStatus()[XCHG]* = 1 when charging is disabled (the CHG FET is turned OFF), and/or the *OperationStatus()[XDSG]* = 1 when discharging is disabled (DSG FET is turned OFF). Once the protection is recovered, charging and discharging resume. All firmware-based protections can be enabled or disabled under **Settings:Enabled Protections A**, **Settings:Enabled Protections B**, **Settings:Enabled Protections C**, and **Settings:Enabled Protections D**. All hardware-based protections are either enabled or disabled, which is based on the configuration image stored in secure memory.

To protect the DSG FET body diode, the DSG FET will always be closed when *Current()* ≥ **Chg Current Threshold**, including when *OperationStatus()[XDSG]* = 1. Likewise, to protect the CHG FET body diode, the CHG FET will always be closed when *Current()* ≤ **(−)Dsg Current Threshold**, including when *OperationStatus()[XCHG]* = 1. Setting **FET Options[IWAKE_FET]** = 1 configures the device to protect the body diode of the CHG FET during low power modes such as SLEEP and SHIP when the hardware-based IWAKE threshold is surpassed. This is because the IWAKE threshold can only be configured to detect discharge current.

When the protections are triggered, *BatteryStatus()[TCA][TDA][FD][OCA][OTA]* is set according to the type of safety protections. Section 11.10 provides a summary of the various alarms flags' set conditions.

Note

Delay settings with 1-s granularity can have an average trigger delay equal to the delay setting plus 1.8 s.

4.3.1 Cell Undervoltage Protection

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

Status	Condition	Action
Normal	*Voltage()* > **CUV:Threshold**	*SafetyAlert()[CUV]* = 0 *BatteryStatus()[TDA]* = 0
Alert	*Voltage()* ≤ **CUV:Threshold**	*SafetyAlert()[CUV]* = 1 *BatteryStatus()[TDA]* = 1
Trip	*Voltage()* ≤ **CUV:Threshold** for **CUV:Delay** duration	*SafetyAlert()[CUV]* = 0 *SafetyStatus()[CUV]* = 1 *BatteryStatus()[FD]* = 1, *[TDA]* = 0 *OperationStatus()[XDSG]* = 1

Status	Condition	Action
Recovery	Condition 1: *SafetyStatus()[CUV]* = 1 AND *Voltage()* ≥ **CUV:Recovery** for **CUV:Recovery Delay** AND **Protection Configuration[CUV_RECOV_CHG]** = 0	*SafetyStatus()[CUV]* = 0 *BatteryStatus()[FD]* = 0, *[TDA]* = 0 *OperationStatus()[XDSG]* = 0
	OR Condition 2: *SafetyStatus()[CUV]* = 1 AND *Voltage()* ≥ **CUV:Recovery** for **CUV:Recovery Delay** AND **Protection Configuration[CUV_RECOV_CHG]** = 1 AND Charging detected (that is, *BatteryStatus()[DSG]* = 0)	

4.3.2 Cell Overvoltage Protection

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

Note

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

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

4.3.3 Overcurrent in Charge Protection

To protect cells from damage due to unsafe charge currents, the device can detect overcurrent events and disable the CHG FET.

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

4.3.4 Overcurrent in Discharge Protection

To protect cells from damage due to unsafe load currents, the device can detect overcurrent events and disable the DSG FET.

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

4.3.5 Temperature Protections

The device provides overtemperature and undertemperature protections based on cell temperature measurement. The cell temperature-based protections are further divided into CHARGE and DISCHARGE conditions. This section describes in detail each of the protection functions.

The device supports up to two external thermistors and one internal temperature sensor for measuring temperature. Unused temperature sensors must be disabled by clearing the corresponding flag in *Settings:Temperature Enable[TS2][TS1][TSInt]*.

The *Temperature()* command returns the cell temperature measurement, which is the maximum of the enabled temperature sensors.

AltManufacturerBlockAccess() command *DAStatus2()* returns all the temperature measurements.

The cell-based overtemperature and undertemperature safety provide protections in CHARGE and DISCHARGE conditions. The battery pack is in CHARGE mode when *BatteryStatus()[DSG]* = 0, where *Current() > Chg Current Threshold*. The overtemperature and undertemperature in charging protections are active in this mode. The *BatteryStatus()[DSG]* is set to 1 in a NON-CHARGE mode condition, which includes RELAX and DISCHARGE modes. The overtemperature and undertemperature in discharge protections are active in these two modes. See Section 7.6 for detailed descriptions of the gas gauge modes.

4.3.6 Overtemperature in Charge Protection

The device has an overtemperature protection for cells in CHARGE state (that is, charging state with *BatteryStatus[DSG]* = 0).

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

4.3.7 Overtemperature in Discharge Protection

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

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

4.3.8 Undertemperature in Charge Protection

The device has an undertemperature protection for cells in CHARGE state (that is, charging state 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*

4.3.9 Undertemperature in Discharge Protection

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

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

Status	Condition	Action
Recovery	*SafetyStatus()[UTD]* AND *Temperature()* ≥ **UTD:Recovery**	*SafetyStatus()[UTD]* = 0 *BatteryStatus()[OTA]* = 0 *OperationStatus()[XDSG]* = 0

4.3.10 Precharge Timeout Protection

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

Status	Condition	Action
Enable	*Current()* > **PTO:Charge Threshold** AND *ChargingStatus()[PV]* = 1	Start PTO timer *SafetyAlert()[PTOS]* = 0
Suspend or Recovery	*Current()* < **PTO:Suspend Threshold**	Stop PTO timer *SafetyAlert()[PTOS]* = 1
Trip	PTO timer > **PTO:Delay**	Stop PTO timer *SafetyStatus()[PTO]* = 1 *OperationStatus()[XCHG]* = 1
Reset	(*SafetyAlert()[PTOS]* = 1 OR *SafetyStatus()[PTO]* = 1) AND Discharge by an amount of **PTO:Reset**	Stop and reset PTO timer *SafetyAlert()[PTOS]* = 0 *SafetyStatus()[PTO]* = 0 *OperationStatus()[XCHG]* = 0

4.3.11 Fast Charge Timeout Protection

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

Status	Condition	Action
Enable	*Current()* > **CTO:Charge Threshold** AND (*ChargingStatus()[LV]* = 1 OR *ChargingStatus()[MV]* = 1 OR *ChargingStatus()[HV]* = 1)	Start CTO timer *SafetyAlert()[CTOS]* = 0
Suspend or Recovery	*Current()* < **CTO:Suspend Threshold**	Stop CTO timer *SafetyAlert()[CTOS]* = 1
Trip	CTO time > **CTO:Delay**	Stop CTO timer *SafetyStatus()[CTO]* = 1 *OperationStatus()[XCHG]* = 1
Reset	(*SafetyAlert()[CTOS]* = 1 OR *SafetyStatus()[CTO]* = 1) AND Discharge by an amount of **CTO:Reset**	Stop and reset CTO timer *SafetyAlert()[CTOS]* = 0 *SafetyStatus()[CTO]* = 0 *OperationStatus()[XCHG]* = 0

4.3.12 Protections Configuration

Class	Subclass	Name	Type	Min	Max	Default	Unit
Settings	Configuration	Protection Configuration	H2	0x00	0x02	0x00	Hex

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

RSVD (Bits 7–2): Reserved. Do not use.

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

    1 = Enabled

    0 = Disabled (default)

RSVD (Bit 0): Reserved. Do not use.

Class	Subclass	Name	Type	Min	Max	Default	Unit
Settings	Configuration	Enabled Protections A	H2	0x00	0xFF	0x57	Hex

7	6	5	4	3	2	1	0
RSVD	RSVD_1	RSVD	OCD	RSVD	OCC	COV	CUV

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

RSVD_1 (Bit 6): Reserved and programmed to 1 for proper operation. Do not use.

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

OCD (Bit 4): Overcurrent in Discharge

    1 = Enabled (default)

    0 = Disabled

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

OCC (Bit 2): Overcurrent in Charge

    1 = Enabled (default)

    0 = Disabled

COV (Bit 1): Cell Overvoltage

    1 = Enabled (default)

    0 = Disabled

CUV (Bit 0): Cell Undervoltage

    1 = Enabled (default)

    0 = Disabled

Class	Subclass	Name	Type	Min	Max	Default	Unit
Settings	Configuration	Enabled Protections B	H2	0x00	0xFF	0x35	Hex

7	6	5	4	3	2	1	0
RSVD	RSVD	OTD	OTC	RSVD	RSVD_1	RSVD	RSVD_1

RSVD (Bits 7–6): Reserved. Do not use.

OTD (Bit 5): Overtemperature in discharge

    1 = Enabled (default)

    0 = Disabled

OTC (Bit 4): Overtemperature in charge

    1 = Enabled (default)

    0 = Disabled

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

RSVD_1 (Bit 2): Reserved and programmed to 1 for proper operation. Do not use.

RSVD (Bit 1): Reserved. Do not use.

RSVD_1 (Bit 0): Reserved and programmed to 1 for proper operation. Do not use.

Class	Subclass	Name	Type	Min	Max	Default	Unit
Settings	Protection	Enabled Protections C	H1	0x00	0xFF	0x14	Hex

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	CTO	RSVD	PTO	RSVD	RSVD

RSVD (Bits 7–5): Reserved. Do not use.

CTO (Bit 4): Charging timeout

      1 = Enabled (default)

      0 = Disabled

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

PTO (Bit 2): Precharging timeout

      1 = Enabled (default)

      0 = Disabled

RSVD (Bits 1–0): Reserved. Do not use.

Class	Subclass	Name	Type	Min	Max	Default	Unit
Settings	Protection	Enabled Protections D	H1	0x00	0xFF	0xCC	Hex

7	6	5	4	3	2	1	0
RSVD_1	RSVD_1	RSVD	RSVD	UTD	UTC	RSVD	RSVD

RSVD_1 (Bit 7): Reserved and programmed to 1 for proper operation. Do not use.

RSVD_1 (Bit 6): Reserved and programmed to 1 for proper operation. Do not use.

RSVD (Bits 5–4): Reserved. Do not use.

UTD (Bit 3): Undertemperature While Not Charging

      1 = Enabled (default)

      0 = Disabled

UTC (Bit 2): Undertemperature While Charging

      1 = Enabled (default)

      0 = Disabled

RSVD (Bits 1–0): Reserved. Do not use.

4.3.13 FET Options

Class	Subclass	Name	Type	Min	Max	Default	Unit
Settings	Configuration	FET Options	H2	0x0000	0x01FF	0x0142	Hex

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

7	6	5	4	3	2	1	0
RSVD	SLEEPCHG	CHGFET	CHGIN	CHGSU	OTFET	UTFET	RSVD

RSVD (Bits 15–9): Reserved. Do not use.

IWAKE_FET (Bit 8): CHG FET body diode protection for IWAKE

  1 = CHG FET turns on for IWAKE (default)

  0 = CHG FET unchanged for IWAKE

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

SLEEPCHG (Bit 6): CHG FET enabled during SLEEP

  1 = CHG FET remains on during SLEEP (default)

  0 = CHG FET off during SLEEP

CHGFET (Bit 5): FET action on setting of *GaugeStatus()[TC]*

  1 = Charging disabled, FET off

  0 = No FET action for terminate charge condition (default)

CHGIN (Bit 4): FET action in CHARGE INHIBIT mode

  1 = Charging disabled, FET off

  0 = No FET action for charge inhibit condition (default)

CHGSU (Bit 3): FET action in CHARGE SUSPEND mode

  1 = Charging disabled, FET off

  0 = No FET action for charge suspend condition (default)

OTFET (Bit 2): FET action in OVERTEMPERATURE mode. Bit is ignored when there is no FET temperature sensor configured.

  1 = CHG and DSG FETs will be turned off for overtemperature conditions

  0 = No FET action for overtemperature condition (default)

UTFET (Bit 1): FET action in UNDERTEMPERATURE mode. Bit is ignored when there is no FET temperature sensor configured.

  1 = CHG and DSG FETs will be turned off for undertemperature conditions (default)

  0 = No FET action for undertemperature condition

RSVD (Bit 0): Reserved. Do not use.

4.3.14 Protections Data Flash Values
4.3.14.1 CUV—Cell Undervoltage

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Protections	CUV	Threshold	I2	0	32767	2500	mV	Cell undervoltage trip threshold
Protections	CUV	Delay	U1	0	255	1	s	Cell undervoltage trip delay
Protections	CUV	Recovery	I2	0	32767	2900	mV	Cell undervoltage recovery threshold
Protections	CUV	Recovery Delay	U1	0	255	1	s	Cell undervoltage recovery delay

4.3.14.2 HCUV—Hardware Cell Undervoltage

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Protections	HCUV	Recovery	I2	0	32767	2900	mV	Hardware Cell Undervoltage recovery threshold in RELAX or DISCHARGE mode
Protections	HCUV	Recovery Chg	I2	0	32767	2520	mV	Hardware Cell Undervoltage recovery threshold in CHARGE mode
Protections	HCUV	Recovery Delay	U1	0	255	1	s	Hardware Cell Undervoltage recovery delay

4.3.14.3 COV—Cell Overvoltage

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Protections	COV	Threshold Low Temp	I2	0	32767	4490	mV	Cell overvoltage low temperature range threshold

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Protections	COV	Threshold Standard Temp Low	I2	0	32767	4490	mV	Cell overvoltage standard low temperature range threshold
Protections	COV	Threshold Standard Temp High	I2	0	32767	4490	mV	Cell overvoltage standard high temperature range threshold
Protections	COV	Threshold High Temp	I2	0	32767	4490	mV	Cell overvoltage high temperature range threshold
Protections	COV	Threshold Rec Temp	I2	0	32767	4490	mV	Cell overvoltage recommended temperature range threshold
Protections	COV	Delay	U1	0	255	1	s	Cell overvoltage trip delay
Protections	COV	Recovery Low Temp	I2	0	32767	4290	mV	Cell overvoltage low temperature range recovery threshold
Protections	COV	Recovery Standard Temp Low	I2	0	32767	4290	mV	Cell overvoltage standard low temperature recovery range threshold
Protections	COV	Recovery Standard Temp High	I2	0	32767	4290	mV	Cell overvoltage standard high temperature recovery range threshold
Protections	COV	Recovery High Temp	I2	0	32767	4290	mV	Cell overvoltage high temperature range recovery threshold
Protections	COV	Recovery Rec Temp	I2	0	32767	4290	mV	Cell overvoltage recommended temperature range recovery threshold
Protections	COV	Recovery Delay	U1	0	255	1	s	Cell overvoltage recovery delay

4.3.14.4 HCOV—Hardware Cell Overvoltage

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Protections	HCOV	Recovery	I2	0	32767	4290	mV	Hardware Cell Overvoltage recovery threshold
Protections	HCOV	Recovery Delay	U1	0	255	1	s	Hardware Cell Overvoltage recovery delay

4.3.14.5 OCC—Overcurrent In Charge

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Protections	OCC	Threshold	I2	−32768	32767	12000	mA	Overcurrent in Charge trip threshold
Protections	OCC	Delay	U1	0	255	1	s	Overcurrent in Charge trip delay
Protections	OCC	Recovery Threshold	I2	−32768	32767	200	mA	Overcurrent in Charge recovery threshold
Protections	OCC	Recovery Delay	U1	0	255	10	s	Overcurrent in Charge recovery delay

4.3.14.6 HOCC—Hardware Overcurrent in Charge

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Protections	HOCC	Recovery Threshold	I2	-32768	32767	200	mA	Hardware Overcurrent in Charge recovery threshold
Protections	HOCC	Recovery Delay	U1	0	255	70	s	Hardware Overcurrent in Charge recovery delay

4.3.14.7 OCD—Overcurrent in Discharge

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Protections	OCD	Threshold	I2	−32768	32767	−7000	mA	Overcurrent in Discharge trip threshold
Protections	OCD	Delay	U1	0	255	3	s	Overcurrent in Discharge trip delay
Protections	OCD	Recovery Threshold	I2	−32768	32767	-200	mA	Overcurrent in Discharge recovery threshold
Protections	OCD	Recovery Delay	U1	0	255	10	s	Overcurrent in Discharge recovery delay

4.3.14.8 HOCD—Hardware Overcurrent in Discharge

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Protections	HOCD	Recovery Threshold	I2	-32768	32767	-200	mA	Hardware Overcurrent in Discharge recovery threshold
Protections	HOCD	Recovery Delay	U1	0	255	70	s	Hardware Overcurrent in Discharge recovery delay

4.3.14.9 HSCD—Hardware Short Circuit in Discharge

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Protections	HSCD	Recovery Threshold	I2	−32768	32767	−200	mA	Short Circuit in Discharge recovery threshold
Protections	HSCD	Recovery Delay	U1	0	255	7	s	Short Circuit in Discharge recovery delay

4.3.14.10 OTC—Overtemperature in Charge

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Protections	OTC	Threshold	I2	−400	1500	550	0.1°C	Overtemperature in Charge trip threshold
Protections	OTC	Delay	U1	0	255	2	s	Overtemperature in Charge Cell trip delay
Protections	OTC	Recovery	I2	−400	1500	500	0.1°C	Overtemperature in Charge Cell recovery threshold

4.3.14.11 OTD—Overtemperature in Discharge

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Protections	OTD	Threshold	I2	−400	1500	600	0.1°C	Overtemperature in Discharge trip threshold
Protections	OTD	Delay	U1	0	255	2	s	Overtemperature in Discharge trip delay
Protections	OTD	Recovery	I2	−400	1500	550	0.1°C	Overtemperature in Discharge recovery threshold

4.3.14.12 UTC—Undertemperature in Charge

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Protections	UTC	Threshold	I2	−400	1500	0	0.1°C	Undertemperature in Charge trip threshold
Protections	UTC	Delay	U1	0	255	2	s	Undertemperature in Charge Cell trip delay
Protections	UTC	Recovery	I2	−400	1500	50	0.1°C	Undertemperature in Charge Cell recovery threshold

4.3.14.13 UTD—Undertemperature in Discharge

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Protections	UTD	Threshold	I2	−400	1500	0	0.1°C	Undertemperature in Discharge trip threshold
Protections	UTD	Delay	U1	0	255	2	s	Undertemperature in Discharge trip delay
Protections	UTD	Recovery	I2	−400	1500	50	0.1°C	Undertemperature in Discharge recovery threshold

5.1 Introduction

The cell voltage is buffered and output on the BAT_SP and BAT_SN pins with a configurable offset during a low voltage condition. This mode is known as buffer mode and it typically coincides with cell undervoltage protection (CUV), but is separate for added flexibility. The default voltage offset is 400 mV, but can be changed through *Batt Sense Config[BUF_REF_1][BUF_REF_0]*. In all other conditions, which include the buffer mode while the CHG FET is turned off, BAT_SN is connected to VSS and BAT_SP is connected to BAT through separate low resistors that are 510 OΩ or 200 Ω. The default resistance for these low resistors (RLO) is 510 Ω, but it can be changed through *Batt Sense Config[RLO_SEL]*.

Class	Subclass	Name	Type	Min	Max	Default	Unit
Settings	Batt Sense	Batt Sense Config	H1	0x00	0xFF	0x02	Hex

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	RLO_SEL	RSVD	RSVD	BUF_REF_1	BUF_REF_0

RSVD (Bits 7–5): Reserved. Do not use.

RLO_SEL (Bit 4): Resistance of low resistors (RLO)

      1 = 200 Ω

      0 = 510 Ω (default)

RSVD (Bits 3–2): Reserved. Do not use.

BUF_REF_1, BUF_REF_0 (Bits 1–0): Voltage offset of buffers

      1, 1 = 600 mV

      1, 0 = 400 mV (default)

      0, 1 = 200 mV

      0, 0 = 0 mV

Class	Subclass	Name	Type	Min	Max	Default	Unit
Settings	Batt Sense	Batt Sense Options	H1	0x00	0x01	0x00	Hex

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

RSVD (Bits 7–1): Reserved. Do not use.

XCHG_RLO (Bit 0): Use RLO Mode when *OperationStatusA()[XCHG]* = 1

      1 = Use RLO Mode when *OperationStatusA()[XCHG]* = 1

      0 = Use HIZ Mode when *OperationStatusA()[XCHG]* = 1 (default)

5.2 Automatic Mode

In AUTOMATIC mode (*BattSenseOutput()[MANUAL]* = 0), the device controls the output on BAT_SP and BAT_SN based on discrete states, as defined below.

Table 5-1. Battery Sensing Output States in AUTOMATIC Mode

Value	State	BAT_SP	BAT_SN
0	HIZ Mode	BAT_SP connected to BAT through a 1- MΩ resistor	BAT_SN connected to VSS through a 1-MΩ resistor
1	RLO Mode	BAT_SP connected to BAT through RLO	BAT_SN connected to VSS through RLO
2	RLO Charge Mode	BAT_SP connected to BAT through RLO with option to include buffer with 0-mV offset	BAT_SN connected to VSS through RLO with option to include buffer with 0-mV offset
3	Buffer Mode	BAT_SP connected to BAT through buffer with configured offset	BAT_SN connected to VSS through buffer with configured offset

The configuration of BAT_SP and BAT_SN during initialization (before initial measurements complete and the CHG and DSG FETs are turned on) is either HIZ mode or BUFFER mode. The initial state is BUFFER mode when ZVCHG must be enabled, otherwise it is HIZ mode. After the initial set of measurements complete, the next state is determined by the entry or exit conditions of each state.

5.2.1 RLO Mode

RLO mode is the standard state for automatic mode when not in a low voltage condition or charging at high current. In this mode, BAT_SN is connected to VSS and BAT_SP is connected to BAT through separate low resistors.

Status	Condition	Action
Activate	(*OperationStatusA()[XCHG]* = 1 AND **Batt Sense Options[XCHG_RLO]** = 1) OR (*OperationStatusA()[XCHG]* = 0 AND *Current()* < **RLO Charge Threshold** AND Not in Buffer Mode)	Enter RLO mode
Exit	(*OperationStatusA()[XCHG]* = 1 AND **Batt Sense Options[XCHG_RLO]** = 0) OR (*OperationStatusA()[XCHG]* = 0 AND (*Current()* ≥ **RLO Charge Threshold** OR Enter Buffer Mode))	Exit RLO mode

5.2.2 RLO Charge Mode

RLO Charge mode is similar to RLO mode, except it includes the option to individually enable the buffer with 0-mV offset on BAT_SP and BAT_SN using **RLO Charge Config**. Enabling the buffer in RLO Charge mode is intended to reduce battery sensing error due to high charge currents through the $R_{DS(on)}$ of the CHG and DSG FETs and the parasitic resistance on the high and low sides of the battery.

Status	Condition	Action
Activate	*OperationStatusA()[XCHG]* = 0 AND *Current()* ≥ **RLO Charge Threshold**	Enter RLO Charge Mode
Exit	*OperationStatusA()[XCHG]* = 1 OR *Current()* < **RLO Charge Threshold**	Exit RLO Charge Mode

Class	Subclass	Name	Type	Min	Max	Default	Unit
Settings	Batt Sense	RLO Charge Threshold	I2	0	32767	75	mA
Settings	Batt Sense	RLO Charge Config	H1	0x00	0x0C	0x0C	Hex

7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	RSVD	BUF_P_EN	BUF_N_EN	RSVD	RSVD

RSVD (Bits 7–4): Reserved. Do not use.

BUF_P_EN (Bit 3): Buffer enable on BAT_SP during RLO Charge Mode

    1 = Enable buffer with 0-mV offset between BAT and BAT_SP (default)

    0 = Disable buffer with 0-mV offset between BAT and BAT_SP

BUF_N_EN (Bit 2): Buffer enable on BAT_SN during RLO Charge Mode

    1 = Enable buffer with 0-mV offset between VSS and BAT_SN (default)

    0 = Disable buffer with 0-mV offset between VSS and BAT_SN

RSVD (Bits 1–0): Reserved. Do not use.

5.2.3 BUFFER Mode

During BUFFER mode, the cell voltage is buffered and output on the BAT_SP and BAT_SN pins with a configurable offset. However, to produce an offset on BAT_SP, there must be sufficient voltage headroom on the PACK pin above the cell voltage, which is enforced by **Buffer Mode PACK Margin**. BUFFER mode typically coincides with cell undervoltage protection (CUV) but is separate for added flexibility.

Status	Condition	Action
Activate	*OperationStatusA()[XCHG]* = 0 AND *Current()* < **RLO Charge Threshold** AND *Voltage()* ≤ **Buffer Mode Threshold** for **Buffer Mode Delay** AND PACK pin voltage ≥ *Voltage()* + **Buffer Mode PACK Margin**	Enter BUFFER mode
Exit	*OperationStatusA()[XCHG]* = 1 OR *Current()* ≥ **RLO Charge Threshold** OR *Voltage()* ≥ **Buffer Mode Recovery** OR PACK pin voltage < *Voltage()* + **Buffer Mode PACK Margin**	Exit BUFFER mode

When transitioning from BUFFER mode to RLO Mode or RLO HARGE Mode, the battery sensing output is configured to **Transition Config** for **Transition Delay** to perform a make-before-break switch between the low resistors and buffers.

Class	Subclass	Name	Type	Min	Max	Default	Unit
Settings	Batt Sense	Transition Config	H1	0x00	0x6C	0x44	Hex

7	6	5	4	3	2	1	0
RSVD	RLO_P_EN	RLO_N_EN	RSVD	BUF_P_EN	BUF_N_EN	RSVD	RSVD

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

RLO_P_EN (Bit 6): Low resistor (RLO) enable on BAT_SP during transition

    1 = Enable low resistor between BAT and BAT_SP (default)

    0 = Disable low resistor between BAT and BAT_SP

RLO_N_EN (Bit 5): Low resistor (RLO) enable on BAT_SN during transition

    1 = Enable low resistor between VSS and BAT_SN

    0 = Disable low resistor between VSS and BAT_SN (default)

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

BUF_P_EN (Bit 3): Buffer enable on BAT_SP during transition

    1 = Enable buffer between BAT and BAT_SP

    0 = Disable buffer between BAT and BAT_SP (default)

BUF_N_EN (Bit 2): Buffer enable on BAT_SN during transition

        1 = Enable buffer between VSS and BAT_SN (default)

        0 = Disable buffer between VSS and BAT_SN

RSVD (Bits 1–0): Reserved. Do not use.

Class	Subclass	Name	Type	Min	Max	Default	Unit
Settings	Batt Sense	Buffer Mode Threshold	I2	0	32767	2500	mV
Settings	Batt Sense	Buffer Mode Delay	U1	0	255	1	s
Settings	Batt Sense	Buffer Mode Recovery	I2	0	32767	2900	mV
Settings	Batt Sense	Buffer Mode PACK Margin	I2	-1000	1000	100	mV
Settings	Batt Sense	Transition Delay	U2	0	1000	250	2 µs

5.3 Hardware-Based Protections

As reported in *BattSenseOutput()*, the device detects short-circuits from BAT_SP or BAT_SN to PACK+ or PACK- while the low resistors or buffers are enabled. For example, BCP and BDP indicate a short-circuit on BAT_SP, whereas BCN and BDN indicate a short-circuit on BAT_SN. The detection of these short-circuits is to prevent discharging or charging the battery through alternate paths which avoid the CHG and DSG FETs. When enabling the low resistor or buffer on either BAT_SP or BAT_SN, the device waits for **Protection Enable Delay** to allow the voltage on the pins to settle before enabling these hardware-based protections: BCP, BDP, BCN, and BDN. **Protection Enable Delay** should only be increased if **Transition Delay** is increased above 500, which corresponds to 1000 µs. In this case, **Protection Enable Delay** should be increased to 4 ms to avoid BCP or BCN from being detected when transitioning from Buffer Mode.

The voltage threshold and detection time for each of these hardware-based protections is configured separately through the *ProtectorCalibration()* or *ProtectorImage1()/ProtectorImage2()* commands.

If BCP, BDP, BCN, or BDN is detected, the device switches the battery sensing output to HIZ Mode, as described in Table 5-1, to limit the current flow on BAT_SP and BAT_SN. After waiting for **Protection Recovery Delay**, the device configures the battery sensing output to the state based on the present conditions. During this recovery period, the battery sensing output cannot be changed from HIZ Mode.

Class	Subclass	Name	Type	Min	Max	Default	Unit
Settings	Batt Sense	Protection Enable Delay	U1	0	255	3	ms
Settings	Batt Sense	Protection Recovery Delay	U1	0	255	5	s

6.1 Introduction

To enhance battery life, the BQ27Z746 supports several power modes to minimize power consumption during operation.

6.2 NORMAL Mode

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

6.3 SLEEP Mode

6.3.1 Device Sleep

When the sleep conditions are met, the device goes into SLEEP mode with periodic wakeups to reduce power consumption. The device returns to NORMAL mode if any exit sleep condition is met, but waits until the 4-second current measurement completes to avoid losing passed charge.

By setting **DA Configuration[WAKE_SLP_1SEC]** = 1, the device can be configured to exit to NORMAL on the next 1-second boundary and stop the present current measurement. However, this configuration is not recommended, especially if SLEEP mode is frequently entered and exited. The device always exits SLEEP to NORMAL on the next 1-second boundary for *OperationStatus()[SDM]* and *OperationStatus()[CAL]*, which are used to enter SHUTDOWN and calibration mode.

Firmware processing is minimized by reducing the number of calculations. Some calculations are performed less frequently: only after voltage and temperature are measured. These less frequent calculations include updating lifetime data, the voltage and temperature range of the advanced charge algorithm, and averaged values such as *AveragePower()*.

Status	Condition	Action
Activate	**DA Config[SLEEP]** = 1 AND |*Current()*| ≤ **Sleep Current** AND **Voltage Time** > 0 AND Device in RELAX mode	The device goes to SLEEP mode. The device wakes up every **Voltage Time** to measure voltage and temperature.[1] The device continues to coulomb count and update current every 4 s. Tip: Synchronize these two times to save power.
Exit	**DA Config[SLEEP]** = 0 OR |*Current()*| > **Sleep Current** OR **Voltage Time** = 0 OR (Hardware-based IWAKE threshold surpassed AND **DA Configuration[IWAKE_EXIT]** = 1) OR *OperationStatus()[SDM]* = 1 OR *OperationStatus()[CAL]* = 1 OR *SafetyAlert()* ≠ 0	Return to NORMAL mode

(1)   The device wakes up every 1 second to measure voltage and temperature for best performance when an OCV is in progress (*GaugingStatus()[SLPQMAX]* = 1) or a safety alert is present (*SafetyAlert()* ≠ 0) prior to exiting SLEEP.

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

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

6.4 SHIP Mode

In SHIP mode, the device measures voltage and temperature very infrequently and at shorter ADC conversion times, and current is not measured or coulomb counted. Current is assumed to be and reported as 0 mA. Therefore, the device tracks the battery's state-of-charge from OCVs. The measurements performed at each interval are:

1. Cell voltage
2. Temperature (rotating between TSInt, TS1, and TS2 if enabled)
3. PACK voltage (every fourth interval)

Note

The ADC conversion time for temperature measurements is short enough that added capacitance on the TS and GPO (for TS2 if enabled) pins can cause temperature error due to longer voltage settling time.

Firmware processing is minimized by reducing the number of calculations. Some calculations are performed less frequently: only after voltage and temperature are measured. These less frequent calculations include updating firmware-based protections, lifetime data, and the voltage and temperature range of the advanced charge algorithm. Other calculations, such as updating *RemainingCapacity()* and *FullChargeCapacity*, are not performed at all with the assumption the system is off and will not communicate with the gauge.

SHIP mode is entered based on voltage through SLEEP or by command through NORMAL or SLEEP. Exit from this mode is through a current level or command.

Status	Condition	Action
Activate	(*OperationStatusA()[SLEEP]* = 1 AND *Voltage()* < **Shipmode Voltage Threshold** for **Shipmode Voltage Delay**) OR (*OperationStatusB()[SHIPM]* = 1 for **Shipmode Command Delay** AND |*Current()*| ≤ **Sleep Current**)	*OperationStatusA()[SHIP]* = 1 The device enters RELAX mode. *Current()* = 0 mA, *AverageCurrent()* = 0 mA The device wakes up every **Shipmode Measure Time** to measure voltage and temperature.[1] The device does NOT coulomb count or measure current.
Exit	(Hardware-based IWAKE threshold surpassed AND **DA Configuration[IWAKE_EXIT]** = 1) OR (*Voltage()* ≥ **Shipmode Voltage Threshold** AND *OperationStatusB()[SHIPM]* = 0) OR (*OperationStatusB()[SHIPM]* = 1 AND MAC *ShipmodeDisable()* received)	*OperationStatusA()[SHIP]* = 0 *OperationStatusB()[SHIPM]* = 0 Return to NORMAL mode

(1) For best performance, the device wakes up every 1 second to measure voltage and temperature when an OCV is in progress (*GaugingStatus()[SLPQMAX]* = 1) or a firmware-based protection entered the alert state (that is, *SafetyAlert()* ≠ 0).

Note

If the gauge is UNSEALED and the MAC *ShipmodeEnable()* command is sent twice in a row, the gauge enters SHIP mode immediately and skips the normal delay sequence.

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

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Power	Shipmode	Shipmode Voltage Threshold	I2	0	32767	2300	mV	Cell based SHIP voltage trip threshold
Power	Shipmode	Shipmode Voltage Delay	U2	0	255	10	s	Cell based SHIP voltage trip delay

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Power	Shipmode	Shipmode Measure Time	U1	1	30	30	s	Determines the wake interval to measure voltage and temperature in SHIP mode
Power	Shipmode	Shipmode Command Delay	U1	0	255	0	s	Delay time to enter SHIP mode after MAC *ShipmodeEnable()* is received. The device takes an additional 1-2 seconds to enter SHIP mode for command processing

6.5 SHELF Mode

SHELF mode operates the same as SHIP mode with a minimized amount of measurements and firmware processing. However, device power consumption in SHELF mode is reduced from SHIP mode by turning off the CHG and DSG FETs and hardware protector (all hardware-based protections and IWAKE). Due to the FETs being off in SHELF mode, the system is not powered without a charger attached, so the exit conditions are different from SHIP mode and the FET control logic is not performed.

In SHELF mode, the device measures voltage and temperature very infrequently and at shorter ADC conversion times, and current is not measured or coulomb counted. Current is assumed to be and reported as 0 mA. Therefore, the device tracks the battery's state-of-charge from OCVs. The measurements performed each interval are:

1. Cell voltage
2. Temperature (rotating between TSInt, TS1, and TS2 if enabled)
3. PACK voltage (every fourth interval)

Note

The ADC conversion time for temperature measurements is short enough that added capacitance on the TS and GPO (for TS2 if enabled) pins can cause temperature error due to longer voltage settling time.

Firmware processing is minimized by reducing the number of calculations. Some calculations are performed less frequently: only after voltage and temperature are measured. These less frequent calculations include updating firmware-based protections, lifetime data, and the voltage and temperature range of the advanced charge algorithm. Other calculations, such as updating *RemainingCapacity()* and *FullChargeCapacity*, are not performed at all with the assumption the system is off and will not communicate with the gauge.

SHELF mode is entered based on voltage through SLEEP or SHIP or by command through NORMAL or SLEEP. Exit from this mode is through command, voltage at the PACK terminal > $V_{Startup-}$, or the ENAB pin being pulled low. The latter two conditions are shared with SHUTDOWN and only checked **Shelf Exit Holdoff** seconds after entering SHELF mode to allow pin voltages to settle once the DSG and CHG FETs turn off.

Status	Condition	Action
Activate	(*OperationStatusA()[SLEEP]* = 1 AND *Voltage()* < **Shelf Voltage Threshold** for **Shelf Voltage Delay**) OR (*OperationStatusB()[SHELFM]* = 1 for **Shelf Command Delay** AND |*Current()*| ≤ **Sleep Current**)	*OperationStatusA()[SHELF]* = 1 The device enters RELAX mode. *Current()* = 0 mA, *AverageCurrent()* = 0 mA The device wakes up every **Shelf Measure Time** to measure voltage and temperature.[1] The device does NOT coulomb count or measure current. Turn off the CHG and DSG FETs. Turn off the protector (all hardware-based protections and IWAKE).
Exit	(*Voltage()* ≥ **Shelf Voltage Threshold** AND *OperationStatusB()[SHELFM]* = 0) OR (*OperationStatusB()[SHELFM]* = 1 AND MAC *ShelfDisable()* received) OR (Time in SHELF mode ≥ **Shelf Exit Holdoff** AND (Voltage at PACK terminal > $V_{Startup-}$ OR ENAB pin pulled low))	*OperationStatusA()[SHELF]* = 0 *OperationStatusB()[SHELFM]* = 0 Return to NORMAL mode

(1) For best performance, the device wakes up every 1 second to measure voltage and temperature when an OCV is in progress (*GaugingStatus()[SLPQMAX]* = 1) or a firmware-based protection entered the alert state (that is, *SafetyAlert()* ≠ 0).

Note

If the gauge is UNSEALED and the MAC *ShelfEnable()* command is sent twice in a row, the gauge enters SHELF immediately and skips the normal delay sequence.

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

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Power	Shelf	Shelf Voltage Threshold	I2	0	32767	2200	mV	Cell based SHELF voltage trip threshold
Power	Shelf	Shelf Voltage Delay	U2	0	255	10	s	Cell based SHELF voltage trip delay
Power	Shelf	Shelf Measure Time	U1	1	30	30	s	Determines the wake interval to measure voltage and temperature in SHELF mode
Power	Shelf	Shelf Command Delay	U1	0	255	10	s	Delay time to enter SHELF mode after MAC *ShelfEnable()* is received. The device takes an additional 1-2 seconds to enter SHELF mode for command processing
Power	Shelf	Shelf Exit Holdoff	U1	1	255	10	s	Holdoff time after entering SHELF mode to check the PACK and ENAB pin exit conditions

6.6 SHUTDOWN Mode

6.6.1 Voltage-Based Shutdown

To minimize power consumption and avoid draining the battery, the device can be configured to shut down at a programmable cell voltage threshold, **Shutdown Voltage**. If **Shutdown Voltage** is configured above the cell undervoltage thresholds, the delay to enter SHUTDOWN may be longer than **Shutdown Time**, because the voltage on the PACK terminal takes time to drain (assuming a charger is not attached) once the DSG FET turns off. The time to drain the PACK terminal depends on the load attached.

Note

In a test environment, it is possible to quickly drop the cell voltage below **Shutdown Voltage**. Even if **Shutdown Voltage** is configured below the cell undervoltage thresholds, the PACK terminal may take extra time to drain, especially if PACK+ is floating. However, this should not be a concern with a system load attached with sufficient voltage margin between the **Shutdown Voltage** and the DSG FET turning off.

Status	Condition	Action
Enable	Cell voltage < **Shutdown Voltage**	*OperationStatus()[SDV]* = 1
Trip	Cell voltage continuous < **Shutdown Voltage** for **Shutdown Time**	Turn DSG FET off
Shutdown	Voltage at PACK terminal < **Charger Present Threshold** AND *Current()* ≤ 0 AND ENAB pin is high	Send device into SHUTDOWN mode
Exit	Voltage at PACK terminal > $V_{STARTUP}$ OR ENAB pin pulled low OR Cell voltage > **Shutdown Voltage** if not in SHUTDOWN mode	*OperationStatus()[SDV]* = 0 Return to NORMAL mode

Note

The device goes through a full reset when exiting from SHUTDOWN mode, which means the device reinitializes. On power up, the gauge checks certain special memory locations. If the memory checksum is incorrect, or if the watchdog was triggered, the gauge does a full reset.

If the memory checksum is good (for example, in the case of a short power glitch), the gauge does a partial reset. The initialization is faster in a partial reset, and certain memory data is not reinitialized (for example, all SBS registers, last ADC and CC readings, safety alerts, and statuses, and so on) and so a partial reset is usually transparent to the host. After a partial reset, the FETs remain off until the hardware-based cell undervoltage protection, HCUV, is able to complete detection. Once HCUV detection finishes, the FETs turn on or remain off based on this result and the other restored safety statuses.

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

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Power	Shutdown	Shutdown Voltage	I2	0	32767	2150	mV	Cell based shutdown voltage trip threshold
Power	Shutdown	Shutdown Time	U2	0	255	10	s	Cell based shutdown voltage trip delay
Power	Shutdown	Charger Present Threshold	I2	0	32767	100	mV	PACK terminal voltage threshold

6.6.2 AltManufacturerAccess() MAC Shutdown

In SHUTDOWN mode, the device turns off the CHG and DSG 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 received the command. Thus, the *Delay* time must be set longer than the *FET Off Time*. The device returns to NORMAL mode when the voltage at PACK terminal > $V_{Startup-}$ or the ENAB pin is pulled low. The device can be sent to this mode with the *AltManufacturerAccess() Shutdown* command, which sets *OperationStatus()[SDM]*. Charger voltage must not be present and the ENAB pin must be high for the device to enter SHUTDOWN mode. If there is charger voltage present or charge current is flowing, the device waits until the charger is removed to enter the SHUTDOWN state. This is to prevent the device from an unintended, immediate wakeup. The *Shutdown()* command cannot be canceled.

Note

If the gauge is unsealed and the MAC *Shutdown()* command is sent twice in a row, the gauge executes the shutdown sequence immediately and skips the normal delay sequence.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Power	Ship	FET Off Time	U1	0	127	10	s	Delay time to turn OFF FETs prior to entering SHUTDOWN mode. This setting should not be longer than the *Delay* setting.
Power	Ship	Delay	U1	0	254	20	s	Delay time to enter SHUTDOWN mode
Power	Ship	Auto Ship Time	U2	0	65535	4320	min	Time without communication in SLEEP to automatically enter SHUTDOWN when *Power Config[AUTO_SHIP_EN]* = 1

6.6.3 Time-Based Shutdown

The device can be configured to enter SHUTDOWN after staying in SLEEP mode without communication for a preset time interval specified in *Auto Ship Time*. Setting *Power Config[AUTO_SHIP_EN]* = 1 enables this feature. Any communication to the device restarts the timer. When the timer reaches *Auto Ship Time*, the time-based shutdown effectively triggers the MAC shutdown command to start the shutdown sequence. The device returns to NORMAL mode when voltage at the PACK terminal > $V_{Startup-}$ or the ENAB pin is pulled low.

6.7 Power Modes Configuration

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Settings	Configuration	Power Config	H2	0x0000	0xFFFF	0x0011	—	Bit 0: AUTO_SHIP_EN 0 = Disable time-based entry into SHUTDOWN 1 = Enable time-based entry into SHUTDOWN (default) Bits 3:1 Reserved Bit 4: SLP_ACCUM 0 = Disables CC accumulation during SLEEP mode 1 = Enables CC accumulation during SLEEP mode Bits 15:5: Reserved
Settings	Configuration	DA Configuration	H2	0x0000	0x0010	0x0010	—	Bits 3:0: Reserved Bit 4: SLEEP—SLEEP mode 0 = Disables SLEEP mode 1 = Enables SLEEP mode (default) Bits 9:5: Reserved Bit 10: IWAKE_EXIT—Exit from SLEEP, SHIP due to IWAKE 0 = Disables IWAKE exit 1 = Enable IWAKE exit (default WAKE_SLP_1SEC—Wake from SLEEP within 1 second 0 = Disables wake within 1 second (default) 1 = Enables wake within 1 second Bits 15:12: Reserved

7.1 Impedance Track (IT) Model

Predicting available energy from lithium-ion cells requires a number of measurable parameters. The Impedance Track (IT) model measures, records, and predicts available capacity or energy from these parameters. The model provides the means to accurately determine available energy over the life of a cell by accounting for aging and present environmental conditions. Aging can be accounted for by measuring QMax and cell impedances as the cell is cycled. QMax is the amount of charge available in a fully charged cell. The present conditions include consideration of cell and ambient temperature as well as the present or predicted power requirements. There are three major components of Impedance Track.

- One is measurement of QMax.
- Two is measurement of cell impedance.
- Three is the calculation of capacities.

All three components rely on the relationship of the open circuit voltage (OCV) versus depth of discharge (DOD). DOD is the percent of QMax removed from a cell during a no load discharge and goes to 100% when the cell is fully discharged. The OCV versus DOD relationship is fixed for each particular cell chemistry. QMax is determined by measuring the charge passed between two DOD points; the DOD points being determined from OCV measurements during Relax mode. Cell impedance is measured during constant load times during discharge from the difference of measured voltage to the OCV voltage based on the known DOD. The DOD determined from the most recent OCV reading and adjusted by the passed charge during the discharge. In general, capacities are recalculated based on changes in temperature, load or impedance. Capacity calculations use the known DOD, load, temperature, end-of-discharge voltage, *TermV*, and *QMax*.

7.2 Thermal Model

Because temperature changes significantly during the course of a discharge, the algorithm needs to be able to predict the future temperature. This is required for temperature correction of battery impedance during voltage simulation near the end of discharge. To achieve this, the algorithm collects temperature-time dependence data during discharge. This data is used to update parameters of a simple thermal model, including a heat exchange coefficient, *temp k*, and a thermal time constant, *temp k*. These parameters are updated at the same time as resistances. The algorithm also records the outside temperature during relaxation periods. These parameters are used to define a temperature function T(t, T_start) that calculates a temperature profile starting from the present temperature, T_start, and continuing until the end of discharge in the simulation calculation.

7.3 Gauging Capacities

The BQ27Z746 measures individual cell voltages, pack voltage, temperature, and current. When at rest and *GaugingStatus[REST]* is set or when cell impedance is updated, the Impedance Track capacity calculation determines battery state-of-charge from DOD and temperature. The BQ27Z746 measures charge and discharge activity by integrating the voltage across a small-value series sense resistor (1 mΩ typ.) between the negative terminal of the cell stack and the negative terminal of the battery pack. The battery state-of-charge is subsequently adjusted during load or charger application, using the integrated charge passed through the battery.

The device is capable of supporting a maximum battery pack capacity of 32 Ah. See the *Theory and Implementation of Impedance Track™ Battery Fuel-Gauging Algorithm in the bq20zxx Product Family Application Report* (SLUA364) for further details of the Impedance Track calculations.

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

The *ITStatus1()*, *ITStatus2()*, and *ITStatus3()* commands return various gauging related information, which is useful to verify learned cell data was updated correctly, as well as problem analyses.

7.4 Learning Cycles

As described in Section 7.3, IT is not enabled by default. When the BQ27Z746 gauge receives an enable request , the gauge is then in its learning cycle mode. It is not necessary to use the gauge in this mode for all gauges during manufacture.

This mode helps to determine the golden image, which can be programmed into all gauges during the manufacture process. Learning cycles are generally run under lab conditions. When the golden image is learned by a gauge, the gauge is left in the IT learned mode of operation. Thus, when its data flash image is transferred to another gauge during manufacture, that gauge is then in learned mode; the gauge with this update will still need to receive an IT enable request. Requiring this request prevents the gauge from any unintended updates that could result from pack activity during manufacture. It would be one of the last commands to the pack before it is prepared for shipment. For more details, see the application note *Impedance Track™ Gas Gauge for Novices – bq20z70/z90* (SLUA397), which is can be downloaded from TI.com.

7.5 Impedance Track Configuration

Load Mode

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

Load Select

To compensate for the I × R drop near the end of discharge, the BQ27Z746 must be configured for whatever current (or power) will flow in the future. While it cannot be exactly known, the BQ27Z746 can use load history, such as the average current of the present discharge to make a sufficiently accurate prediction.

The BQ27Z746 can be configured to use several methods of this prediction by setting the **Load Select** value. Because this estimate has only a second-order effect on remaining capacity accuracy, different measurement-based methods (methods 0–3, and method 7) result in only minor differences in accuracy. However, methods 4–6, where an estimate is arbitrarily assigned by the user, can result in a significant error if a fixed estimate is far from the actual load.

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

Pulsed Load Compensation

To take into account pulsed loads while calculating remaining capacity until **Term Voltage** threshold is reached, the BQ27Z746 monitors not only average load, but also short load

and Termination Voltage	spikes. The maximum voltage deviation during a load spike is continuously updated during discharge and stored in **Delta Voltage**, with the minimum value allowed set in **Min Delta Voltage**. **Delta Voltage** is added to **Term Voltage** to determine end-of-discharge voltage (EDV).
Reserve Battery Capacity	The BQ27Z746 allows an amount of capacity to be reserved in both mAh (**Reserve Cap-mAh**) and cWh (**Reserve Cap-cWh**) units between the point where the *RemainingCapacity()* function reports zero capacity and the absolute minimum pack voltage, **Term Voltage**. This enables a system to report zero capacity/energy, but still have enough reserve capacity/energy to perform a controlled shutdown or provide an extended sleep period for the host system.
Pack Based Termination Voltage	The BQ27Z746 forces *RemainingCapacity()* to 0 mAh when the battery voltage discharges to **Term Voltage** for a period of **Term V Hold Time**.

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

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

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

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

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

7.6 Gas Gauge Modes

Resistance updates take place only in DISCHARGE mode, while OCV and QMax updates only take place in RELAX mode. Fast QMax will update at the end of discharge (see Section 7.7.2 for details). Entry and exit of each mode is controlled by data flash parameters in the subclass **Gas Gauging: Current Thresholds** section. When the device is determined to be in RELAX mode and OCV is taken, the *GaugingStatus()[REST]* flag is set. In RELAX mode or DISCHARGE mode, *BatteryStatus()[DSG]* is set. Figure 7-1 shows the flow.
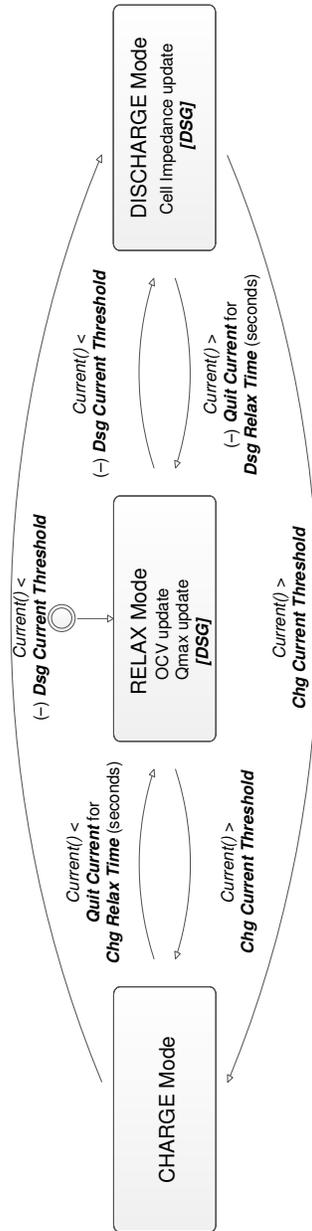
Figure 7-1. Gas Gauge Operating Modes

CHARGE mode is exited and RELAX mode is entered when *Current* goes below **Quit Current** for a period of **Chg Relax Time**. DISCHARGE mode is entered when *Current* goes below **(–)Dsg Current Threshold**. DISCHARGE mode is exited and RELAX mode is entered when *Current* goes above **(–)Quit Current** threshold for a period of **Dsg Relax Time**. CHARGE mode is entered when *Current* goes above **Chg Current Threshold**. Figure 7-2 shows an example of the operating modes.
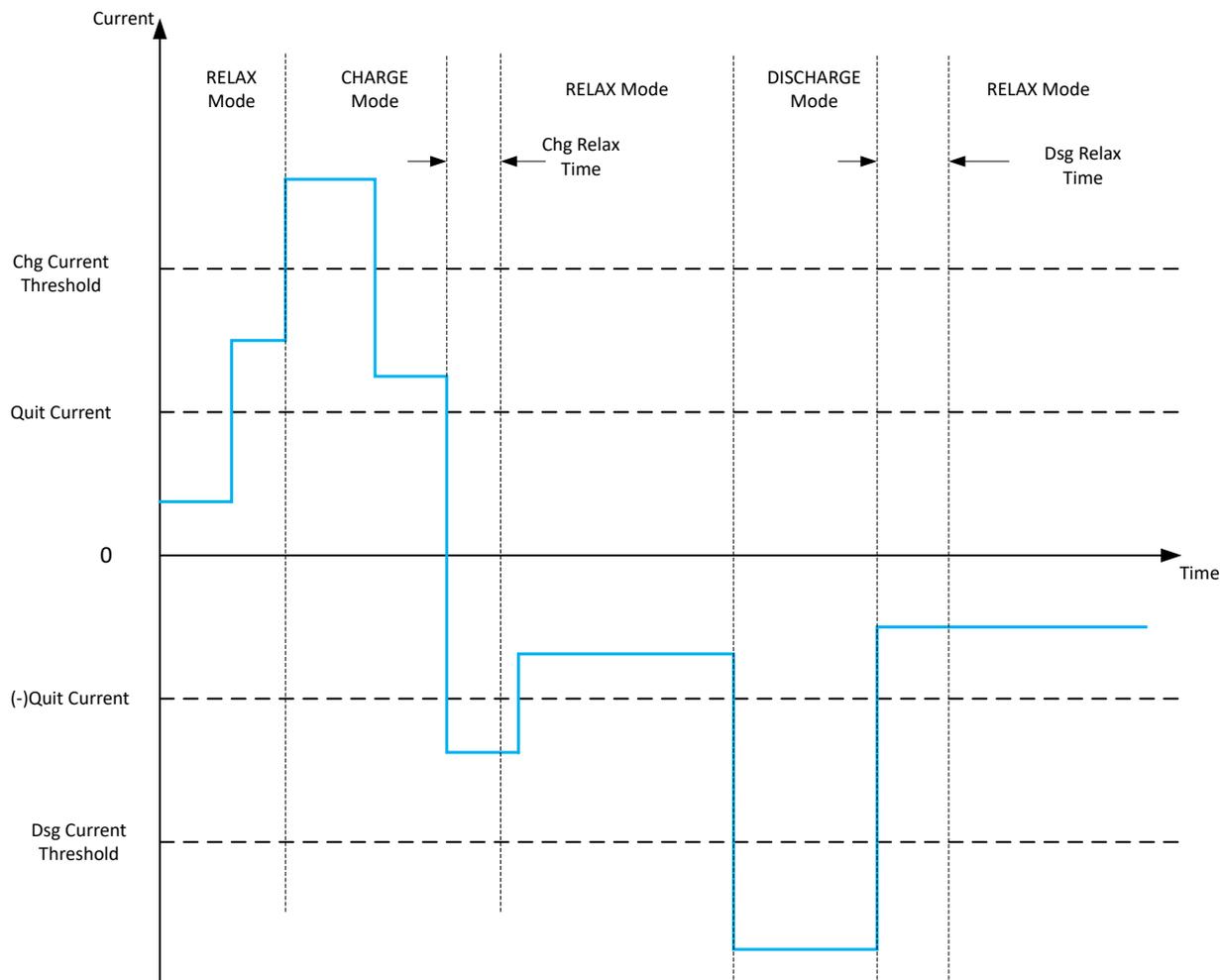
Figure 7-2. Gas Gauge Operating Mode Example

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

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

7.7 QMax and Ra

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

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

The BQ27Z746 acquires and updates the battery-impedance profile during normal battery usage. It uses this profile, along with the state-of-charge and QMax value, to determine *FullChargeCapacity()* and *RelativeStateOfCharge()* specifically for the configured load and present temperature. *FullChargeCapacity()* reports a capacity or energy available from a fully charged battery reduced by **Reserve Cap-mAh** or **Reserve Cap-cWh** under the configured load and present temperature until *Voltage()* reaches end-of-discharge voltage (EDV).

7.7.1 QMax Initial Values

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

See the "Theory and Implementation of Impedance Track Battery Fuel-Gauging Algorithm" section in the *BQ20zxx Product Family Application Report* (SLUA364) for further details.

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

7.7.2 QMax Update Conditions

7.7.2.1 Base Required Conditions

QMax learning/updates do not occur until the *GaugingStatus()[QEN]* flag is set by sending the *Gauging()* (0x0021) command to *AltManufacturerAccess()*.

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

Temperature	If *Temperature()* is outside of the range 10°C to 40°C
Delta Capacity	If the capacity change between suitable battery rest periods is less than 37%
Voltage	If *Voltage()* is inside a flat voltage region. (See the *Support of Multiple Li-Ion Chemistries with Impedance Track Gas Gauges Application Report* (SLUA372) for the voltage ranges of other chemistries.) This flat region varies with different chemistries. The *GaugingStatus()[OCVFR]* flag indicates if the cell voltage is inside this flat region when *GaugingStatus()[REST]* is set. Prior to an exit from CHARGE or DISCHARGE mode, the *GaugingStatus()[QMAXDODOK]* flag can be checked to determine if the cell is in the flat zone.
CC Error	If the estimated coulomb counter (CC) error accumulated during the time passed from the previous OCV reading exceeds 1.5% of **Design Capacity mAh**, the update is disqualified. CC error current is calculated as a function of **Coulomb Counter Deadband** and the sense resistor value. For applications with small battery capacities, CC error of 1.5% of **Design Capacity mAh** can be reached in a short period of time, especially with a small sense resistor. Therefore, a minimum time of 11 hours from the last qualified OCV is enforced before disqualification, which facilitates QMax updates in such applications. Enforcing this minimum time can increase CC error to as high as 5.5% of **Design Capacity mAh**.

7.7.2.2 Tracking QMax Updates

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

7.7.2.3 Relaxed Cell OCV

The BQ27Z746 updates the no-load full capacity (QMax) when two open circuit voltage (OCV) readings are taken. These OCV readings are taken when the battery is in RELAX mode before and after a minimum charge or discharge activity. A relaxed state is achieved if the battery voltage has a dV/dt of < 1 µV/s. Typically, it can take up to two hours after charging and five hours after discharging to ensure that the dV/dt condition is satisfied. If five hours are exceeded, a reading is taken even if the dV/dt condition was not satisfied. This relaxed cell state is indicated when the *[REST]* flag is set.

7.7.2.4 OCV Prediction

Another method available in the BQ27Z746 gauge is to estimate an accurate OCV reading. After a set wait time (**OCV Pred Transient T**) in RELAX mode, the gauge begins to accumulate voltage readings. Once **OCV Pred Measure Time** has passed, the gauge uses a fast OCV algorithm to predict the final OCV value. This fast OCV method is enabled by setting **IT Gauging Ext[FOCV_EN]** = 1. This method provides the benefit of reduced relaxation requirements for QMax updates. If at any time the requirements for the conventional OCV method are achieved (dV/dt of < 1 µV/s requirement) after a fast OCV estimation, the device updates the OCV measurement accordingly. For a fast OCV estimate, entry into RELAX mode must be preceded by at least **OCV Pred Active T Limit** of a charge or discharge current large enough for the BQ27Z746 to exit RELAX mode.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Gas Gauging	IT Cfg	OCV Pred Active T Limit	U2	100	65535	200	s	This is the minimum time the gauge must be in CHARGE or DISCHARGE mode before entering into RELAX mode for a fast OCV estimate.
Gas Gauging	IT Cfg	OCV Pred Transient T	U2	100	65535	300	s	This is the minimum time the gauge must be in RELAX mode before fast OCV voltage readings start to accumulate.
Gas Gauging	IT Cfg	OCV Pred Measure Time	U2	0	65535	200	s	This is the time in RELAX mode when fast OCV voltage readings are accumulated and fast OCV is predicted.

7.7.2.5 Cycle Count Based QMax Degradation

For a gauging situation that never or rarely meets the condition for any of the previously described QMax updates, QMax will update and diminish based on a cycle count. The gauge tracks full discharge cycles since the last QMax update was determined via one of the above methods. When this cycle count reaches **Cycle Adjust Threshold**, QMax updates as QMax = QMax × (1 – (**Cycle Adj Incr** × **Cycle Adjust Threshold** / 10000)).

7.7.2.6

Note

When there is a QMax update, the discharge cycle count since the last QMax update is set to 0. The discharge cycle count since the last QMax update is incremented each time *CycleCount()* is incremented.

7.7.2.7 Fast QMax Update Conditions

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

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

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

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

The DOD is taken for QMax at a high state-of-charge, then during discharge when at the steep portion of the voltage curve (92–96% DOD). This enables a good estimation of DOD. This DOD estimation during discharge is used to update QMax immediately instead of first needing a rest period. The actual update to QMax occurs when the discharge stops after verifying that no conditions are present to cause the QMax update to fail. The BQ27Z746 devoce has an option to qualify DODEOC for QMax updates, which means it is possible to update QMax with no rest periods (by having a charge termination followed by a full discharge). Fast QMax can be enabled in either LEARN mode (*[FAST_QMAX_LRN]*) or FIELD mode (*[FAST_QMAX_FLD]*). The LEARN mode flag means Fast QMax is only enabled with *Update Status* = 06, and will be disabled when the status = 0x0E. FIELD mode means Fast QMax is enabled with *Update Status* = 06 and 0E.

7.7.2.8 QMax and Fast QMax Update Boundary Check

The BQ27Z746 implements a QMax and Fast QMax boundary check prior to saving the value to data flash. This improves the robustness of the QMax update in case of potential QMax corruption during the update process.

The verifications are as follows:

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

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

7.7.3 Ra Table Initial Values

The Ra table is part of the impedance profile that updates during discharge when gauging is enabled. The initial *Cell0 R_a0...14* values should be programmed by selecting the correct chemistry data during data flash configuration. A chemistry database is constantly updating, and can be downloaded from the Gas Gauge

Chemistry Updater product web page (http://www.ti.com/tool/gasgaugechem-sw). The initial **xCell0 R_a0...14** values are a copy of the non-x data set. Two sets of Ra tables are used alternatively when gauging is enabled to prevent wearing out the data flash.

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

Note

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

7.7.3.1 R_a0 Table

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

7.7.3.2 R_a0x Table

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

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Ra Table	R_a0x	xCell0 R_a 14	I2	0	32767	282	2^{-10} Ω	Cell 0 resistance at grid point 14

7.7.4 Ra Table Update Conditions

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

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

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

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

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Gas Gauging	IT Cfg	Resistance Parameter Filter	U2	1	65535	65142	—	This is the filter coefficient on voltage, current, and temperature for resistance updates. Reducing this filter setting can improve low temperature performance at high rates. Examining the **Term Voltage Delta** setting and **Fast Scale Start SOC** should be done prior to adjusting this parameter when trying to improve the RSOC performance. The following is the formula to convert the DF setting into actual filter time constant: Filter time constant = [1/(1 – (DF_Value /65536))] – 1.
Gas Gauging	IT Cfg	Max Charge Current %	U1	0	100	10	%	If *AverageCurrent()* changes by more than this threshold from the previous resistance measurement to the present, the present resistance measurement and Ra scale update are not used. This protects resistance measurements from voltage transients after step changes in current, especially transitions to relaxation.
Gas Gauging	IT Cfg	Resistance Update Voltage	I2	0	32767	50	mV	The difference between the open circuit voltage based on DOD and the measured voltage is estimated as the IR drop. If this IR drop is greater than **Resistance Update Voltage**, then the resistance calculation is allowed. This can be helpful in applications with small battery packs and large resistances that do not meet the C/10 minimum current requirement for resistance updates.
Gas Gauging	IT Cfg	Ra Filter	U2	0	999	800	0.1%	Filter value used in Ra updates that specifies what percentage of the Ra update is from the new value (100%—setting) versus the old value (setting). The recommended setting is 80% if fast resistance scaling is enabled. Otherwise, the setting should be 50% as the default.
Gas Gauging	IT Cfg	Ra Max Delta	U1	0	255	15	% of Design Resistance	Maximum value of allowed Ra change
Gas Gauging	IT Cfg	Design Resistance	I2	1	32767	90	mΩ	Cell resistance at grid point 4. Automatically updated during learning when **Update Status** is set by the gauge to 06 and 0E. To automatically update again, set **Update Status** to 04. **Design Resistance** could be set manually when **Update Status** = 0E.

7.7.5 Fast Resistance Scaling

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

improves RSOC convergence to 0% by scaling cell resistance values from Ra table interpolation to reflect the most recent measured resistance.

The following terms are defined to understand the operation of fast resistance scaling:
- True RSOC: The true relative state-of-charge of the battery pack, as determined by the gauge. It is computed as True Rem Q / True Full Chg Q.
- Resistance voltage: A filtered cell voltage used for resistance measurements with a time constant defined by **Near EDV Ra Param Filter** (or **Resistance parameter filter** if **IT Gauging Configuration[FF_NEAR_EDV]** = 0).
- Average voltage: A filtered pack voltage with the same time constant as *AverageCurrent()*.

7.7.5.1 Calculation of Resistance Scale

When enabled with **IT Gauging Configuration[RSOC_CONV]** = 1, fast resistance scaling becomes active once one of the following is true:
- True RSOC ≤ **Fast Scale Start SOC** OR
- Resistance voltage < **Term Voltage** + **Term Voltage Delta**.

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

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

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

7.7.5.2 Negative Resistance Scale

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

7.7.5.3 Reset of Resistance Scale

Cell 1 RaScale resets to 1000 under the following conditions:
- Initialization of the device
- IT is enabled (*GaugingStatus()[QEN]* changes to 1).
- In CHARGE mode when average voltage > **Term Voltage** + **Term V Delta** AND True RSOC > **Fast Scale Start SOC**.
- In RELAX mode when an OCV reading occurs with *Temperature()* > 15.0°C.
- In DISCHARGE mode when a negative resistance scale is calculated.

7.7.5.4 Application of Resistance Scale

The scale can be applied in two ways:

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

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

7.7.5.5 Fast Resistance Scaling Configuration

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

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

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

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

7.8.1 Smoothing Engine

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

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

7.8.1.1 Smoothing to 0% in DISCHARGE Mode

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

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

Note

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

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Gas Gauging	Smoothing	Term Smooth Start Cell V Delta	I2	0	32767	150	mV	If **[DSG_0_SMOOTH_OK]** = 1, then during DISCHARGE mode and once *Voltage()* is less than or equal to **Term Voltage** + **Term Smooth Start Cell V Delta**, time-based smoothing to 0% is initiated. This will smooth *RemainingCapacity()* to 0 mAh over the next **Term Smooth Time** seconds.
Gas Gauging	Smoothing	Term Smooth Final Cell V Delta	I2	0	32767	100	mV	If **[DSG_0_SMOOTH_OK]** = 1, then during DISCHARGE mode and once *Voltage()* is less than or equal to **Term Voltage** + **Term Smooth Final Cell V Delta**, *RemainingCapacity()* is forced to 0 mAh.
Gas Gauging	Smoothing	Term Smooth Time	U1	1	32767	20	s	If **[DSG_0_SMOOTH_OK]** = 1, then during DISCHARGE mode and once *Voltage()* is less than or equal to **Term Voltage** + **Term Smooth Start Cell V Delta**, time-based smoothing to 0% is initiated. This will smooth *RemainingCapacity()* to 0 mAh over the next **Term Smooth Time** seconds.

7.8.1.2 Smoothing to 100% in CHARGE Mode

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

7.8.1.3 Smoothing in RELAX Mode

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

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

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

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

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

7.9 Impedance Track (IT) Configuration Options

The BQ27Z746 provides several Impedance Track configuration options to fine-tune the gauging performance. These configurations can be turned on or off through the corresponding flags in **Settings**: **IT Gauging Configuration** and **I2C Gauging Configuration**.

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

[1PERCENT_HOLD]: When enabled, holds the RSOC value at 1% until ***Term Voltage*** has been reached during discharge.

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

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

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

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

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

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

[LFP_RELAX]: When enabled, this bit activates an additional functionality only if the chemistry ID programmed indicates a LiFePO$_4$ chemistry (ID 0x4xxx or 0x04xx). Having this bit enabled with a non-LiFePO$_4$ cell type does not introduce any behavioral modifications.

LiFePO$_4$ has a unique, slow configuration relaxation near full charge. The slow decaying voltage causes RSOC to continue to drop every 5 hours. Depending on the full charge taper current, the fully settled voltage could be close to or even below ***FlatVoltMax*** in some cases. If ***[LFP_RELAX]*** is enabled and the LiFePO$_4$ chemID is selected, ***[OCVFR]*** will be set on exit from CHARGE mode regardless of voltage or state of charge. For ***[OCVFR]*** to clear, a relaxation of 48 hours or non-trivial discharge must occur. A non-trivial discharge is indicated when the cell voltage in relaxation falls below ***FlatVoltMin***. The QMax update is unlikely disabled because DOD will not update due to ***[OCVFR]*** forcing the 48-hour timeout, and voltage likely relaxing into the flat zone. Therefore, the QMax update takes an alternative approach: Once full charge occurs (***[FC]*** bit set), DOD0 = Dod_at_EOC is automatically assigned and valid for a QMax update. ***[VOK]*** is set if there is no QMax update. If QMax is updated, ***[VOK]*** is cleared. The DOD error, as a result of this action, is zero or negligible because in the LiFePO$_4$ table, the OCV voltage corresponding to DOD = 0 is much lower. ***[RSOC_CONV]***: This function is also called fast resistance scaling. It is an option to address the convergence of RSOC to 0% at a low temperature and a very high rate of discharge. See *Fast Resistance Scaling* for more details.

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

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

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

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

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

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

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

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

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

[FOCV_EN]: If this bit is set to 1, the gauge enables a fast OCV algorithm to predict the final OCV value, which reduces relaxation requirements for QMax updates.

Class	Subclass	Name	Type	Min	Max	Default	Description
Settings	Configuration	I2C Gauging Configuration	H1	0x00	0x3F	0x20	Bit 0: RSOCL—*RelativeStateOfCharge()* and *RemainingCapacity()* behavior at end of charge 0 = Actual value shown (default) 1 = Held at 99% until valid charge termination. On entering valid charge termination, updates to 100% Bit 1: RSOC_HOLD—Prevents RSOC from increasing during discharge 0 = RSOC is not limited. 1 = RSOC is not allowed to increase during discharge. Bit 2: LOCK0—Keeps *RemainingCapacity()* and *RelativeStateOfCharge()* from jumping back during relaxation after 0 was reached during discharge 0 = Disabled (default) 1 = Enabled Bit 3:RSVD BIT 4: 1PERCENT_HOLD 0 = Disabled 1= Enabled Bit 5: TAMB_SYNC_SIM—Ambient Temperature Synchronization Simulation 0 = Disabled 1 = Enabled (default) Bit 7:6: Reserved

Class	Subclass	Name	Type	Min	Max	Default	Description
Settings	Configuration	IT Gauging Configuration	H2	0x0000	0xFFFF	0xD5FE	Bit 0: CCT—Cycle count threshold 0 = Use *DesignCapacity()* for cycle count threshold (default) 1 = Use *FullChargeCapacity()* for cycle count threshold Bit 1: CSYNC—Syncs *RemainingCapacity()* with *FullChargeCapacity()* at valid charge termination 0 = Not synchronized 1 = Synchronized (default) Bit 2: RFACTSTEP—Ra factor step 0 = Disabled 1 = Enabled (default) Bit 3: OCVFR—Open circuit voltage flat region 0 = Disabled 1 = Enabled (default) Bit 4: DOD0EW—DOD0 error weighting 0 = Disabled 1 = Enabled (default) Bit 5: RSVD— Do not use. Bit 6: RSOC_CONV—RSOC convergence (fast resistance scaling) 0 = Disabled 1 = Enabled (default) Bit 7: FAST_QMAX_LRN—Fast QMax LEARN mode 0 = Disabled 1 = Enabled (default) Bit 8: FAST_QMAX_FLD—Fast QMax FIELD mode 0 = Disabled 1 = Enabled (default) Bit 9: RSVD Bit 10: FF_NEAR_EDV—Fast filter near EDV 0 = Disabled 1 = Enabled (default) Bit 11: RELAX_JUMP_OK—Enables RSOC Jumps in RELAX mode 0 = Disabled (default) 1 = Enabled Bit 12: SMOOTH—Smoothing engine 0 = Disabled 1 = Enabled (default) Bit 13: LFP_RELAX—Lithium iron phosphate relax 0 = Disabled 1 = Enabled Bit 14: RELAX_SMOOTH_OK—Smoothing in RELAX 0 = Disabled 1 = Enabled (default) Bit 15: DOD_RSCALE_EN—Configures which DOD the new RaScale is to be applied. 0 = The RaScale is applied to all DODs during IT simulations. 1 = The RaScale is only applied to DODs higher than the DOD where the RaScale is calculated. (default)
Settings	Configuration	IT Gauging Ext	H2	0x0000	0x003F	0x003B	Bit 0: DSG_0_SMOOTH_OK—Smoothing to 0% 0 = Disabled 1 = Enabled (default) Bit 1: CHG_100_SMOOTH_OK—Smoothing to 100% 0 = Disabled 1 = Enabled (default) Bit 2: AMB_PRED—Ambient temperature prediction 0 = Disabled (default) 1 = Enabled Bit 3: THERM_IV—Thermal model IV heat 0 = Disabled 1 = Enabled (default) Bit 4: THERM_SAT—Thermal model saturation 0 = Disabled 1 = Enabled (default) Bit 5: FOCV_EN—Enables fast OCV feature 0 = Disabled 1 = Enabled (default) Bits 15:6: RSVD

7.10 State-Of-Health (SOH)

The BQ27Z746 device implements an updated version of the battery state-of-health (SOH), which is reported by the *StateOfHealth()* command. In the previous version (in the BQ27Z746 device), the *StateOfHealth()* was calculated using a special 25°C version of *FullChargeCapacity()* as a fraction of **Design Capacity**. However, this calculation still included some parameters that were updated during operation based on the loading and use of the battery, separate from the battery status itself. This could lead to varying calculations of state-of-health for the same battery, depending on how the battery was used in the system. The updated version of *StateOfHealth()* addresses this by calculating a special *FCC_SOH()*, with the initial ambient temperature fixed at 25°C, using a current load specified by **SOH Load Rate**, and using the thermal model parameters, **SOH Temp a** and **SOH Temp k**.

The **SOH Load Rate** can be set to the typical current of the application, and it is specified in units of hour-rate (that is, **Design Capacity** / **SOH Load Rate** will be the current used for the SOH simulation). The **SOH Temp a** and **SOH Temp k** can be set to expected values for the system during operation. These data flash settings are used only for the *StateOfHealth()* calculation. The SOH full charge capacity is updated whenever QMax or the impedance table is updated. Because this implementation removes the variation of load current, temperature, and learned parameters, it is a better representation of the battery's state-of-health. The SOH full charge capacity is available on the MAC command *FCC_SOH()*.

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

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Gas Gauging	SoH	SOH Load Rate	U1	1	255	50	0.1 Hr rate	Rate used in SOH simulation
Advanced Charge Algorithm	Rec Temp Charging	Voltage	I2	0	32767	4400	mV	Constant value for charge terminate voltage for the SOH calculation only
Gas Gauging	State	SOH Temp k	I2	0	32767	1	0.1°C/ 256 cW	Thermal model temperature factor for SOH
Gas Gauging	State	SOH Temp a	I2	0	32767	1000	s	Thermal model temperature factor for SOH
Gas Gauging	It Cfg	Min Delta Voltage	I2	–32768	32767	0	mV	Constant added to terminate voltage for the SOH simulation

7.11 Battery Trip Point (BTP)

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

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

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

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Settings	BTP	Init Discharge Set	I2	0	32767	150	mAh	Initial value for *BTPDischargeSet()*, for **Settings.Configuration.IO Config[BTP_SRC]** = 0
Settings	BTP	Init Charge Set	I2	0	32767	175	mAh	Initial value for *BTPChargeSet()*, for **Settings.Configuration.IO Config[BTP_SRC]** = 0
Settings	BTP	Init Discharge Set RSOC	U1	0	255	10	%	Initial value for *BTPDischargeSet()*, for **Settings.Configuration.IO Config[BTP_SRC]** = 1

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Settings	BTP	Init Charge Set RSOC	U1	0	255	15	mAh	Initial value for *BTPChargeSet()*, for **Settings.Configuration.IO Config[BTP_SRC]** = 1

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8.1 Description

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

- Every 10 hours if RAM content is different from data flash.
- A reset counter increments. The lifetime RAM data is reset; therefore, only the reset counters are updated to data flash.
- Before scheduled shutdown.
- Before low voltage shutdown and the voltage is above *Valid Update Voltage*.
- A safety event counter increments and *Lifetimes Configuration[SAFETY_SAVE]* = 1.

The lifetime data stops collecting under the following conditions:

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

When the gauge is unsealed, the following *ManufacturingStatus()* can be used for testing lifetime data.
- *LifetimeDataReset()* can reset the lifetime data (RAM and data flash) to the default values.
- *LifetimeDataFlush()* can force an update of the RAM lifetime data to data flash.
- *LifetimeDataSpeedupMode()* can increase the rate the lifetime data is incremented.

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

- Voltage
  - Maximum or minimum cell voltage
- Current
  - Maximum charge/discharge current
  - Maximum average discharge current
  - Maximum average discharge power
- Safety events that trigger *SafetyStatus()*
  - 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 Valid Charge Termination
- Discharging events
  - Number of full discharges (That is, the number of times *[FD]* is set.)
  - *Cycle Count* at last Full Discharge
- Gauging events
  - Number of QMax updates
  - *Cycle Count* at Last QMax update
  - Number of RA updates and disable
  - *Cycle Count* at Last RA update and disable
- Power events
  - Number of full resets, partial resets, and watchdog resets
  - Number of shutdowns

- Temperature
  - Max/Min Cell Temperature
  - Max/Min Int Temperature Sensor
- Time (This data is stored with a resolution of 1 second up to over 100 years.)
  - Total runtime
  - Total time spent charging
  - Total time spent discharging
  - Time spent in different *RelativeStateOfCharge() – Temperature()* ranges
    - Eight *RelativeStateOfCharge()* ranges for each of the seven charge temperature ranges
    - 56 *RelativeStateOfCharge() – Temperature()* runtime values

Table 8-1. Time Spent in *RelativeStateOfCharge() – Temperature()* Ranges

	RSOC ≥ 95% [default]	RSOC ≥ 90%	RSOC ≥ 80%	RSOC ≥ 60%	RSOC ≥ 40%	RSOC ≥ 20%	RSOC ≥ 10%	RSOC ≥ 0%
Under Temperature								
Low Temperature								
Standard Temperature Low								
Recommended Temperature								
Standard Temperature High								
High Temperature								
Over Temperature								

8.2 Reset

In addition to the *ManufacturerAccess() 0x0028 Lifetime Data Reset*, **Lifetime Data Collection** can also be reset when **[SEALED_RESET]** is set using a two-word MAC sequence available in SEALED and UNSEALED modes. The two-word key is programmable using *ManufacturerAccess() 0x0035 Security Keys*. Both keys must be sent within 4 seconds of each other for **LIfetimes** data to reset.

9.1 Description

The device can be enabled to generate an interrupt to the host processor on the INT pin under various voltage, temperature, and RSOC conditions. The **GPO Pin Config[HOSTINT_EN]** bit is used to enable or disable the interrupt function, and its polarity can be set to active high (**Host Intr Config[ACTIVEHI_EN]** = 1) or active low (**Host Intr Config[ACTIVEHI_EN]** = 0). The **Host Intr Config[INT_TYPE]** bit is used to select if interrupt is a pulse on the INT pin with an approximate width of 1 ms (**Host Intr Config[INT_TYPE]** = 1) or level-based interrupt (**Host Intr Config[INT_TYPE]** = 0). The **Host Intr Config[PUSHPULL_EN]** bit is to select if INT output is open-drain (**Host Intr Config[PUSHPULL_EN]** = 0) or push-pull (**Host Intr Config[PUSHPULL_EN]** = 1).

9.2 Voltage and Temperature Interrupts

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

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

The interrupts are indicated in *InterruptStatus()*.

Table 9-1 summarizes the interrupt flags, which are *[VOLT_HI]*, *[VOLT_LO]*, *[TEMP_HI]*, and *[TEMP_LO]*.

Table 9-1. Interrupt Flags (Interrupt Status)

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

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

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

9.3 RSOC Interrupts

The device can be enabled to generate an interrupt on the INT pin at configurable RSOC intervals. The threshold setting is configurable through **SOC Delta** for the initial value, and later by writing to the standard command *SOCSetDeltaThreshold()*. Setting **SOC Delta** to 0 disables RSOC interrupts; otherwise, interrupts will be generated at the following RSOC points:

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

The RSOC interrupt is indicated in *InterruptStatus()* by *[SOC_DELTA]* flag.

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

9.4 Host Interrupts Configuration

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Settings	Configuration	Host Intr Config	H1	0x00	0x38	0x00	—	Bit 0: BTP_EN 0 = Disables assertion of the INT pin when BTP is triggered 1 = Enables assertion of the INT pin when BTP is triggered Bit 1: = BTP_SRC 0 = BTP interrupts use capacity-based thresholds 1 = BTP interrupts use RSOC-based thresholds Bit 2: RSVD Bit 3: ACTVLO_EN 0 = Interrupt (INT) is active HIGH. 1 = Interrupt (INT) is active LOW. Bit 4: PUSHPULL_EN 0 = Interrupts on the INT pin are open-drain type (pull up required), 1 = Interrupts on the INT pin are push-pull type (internal pull up used), Bit 5: INT_TYPE 0 = Interrupts enabled on INT pin as level-type 1 = Interrupts enabled on INT pin as pulse-type Bits 7-6: RSVD

10.1 Description

There are three levels of secured operation within the device: SEALED, UNSEALED, and FULL ACCESS. To switch between the levels, different operations are needed with different access keys. The device also supports SHA-256 HMAC authentication with the host system. Additionally, lifetime data is protected by an access key.

10.2 SHA-256 Authentication

The BQ27Z746 uses SHA-256 for authentication.

- SHA-256 preprocessing is described in the *SHA-1 Preprocessing* section in FIPS 180-4.
- The hash computation is described in the *SHA-1 Hash Computation* section in FIPS 180-4.
- The HMAC implementation is described in FIPS 198-1.

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

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

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

10.2.1 Secure Key

The secure key is stored in the secured memory of the BQ27Z746 device. It is located in secure memory, which can store up to three secure keys.

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

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Settings	Configuration	Auth Config	H1	0x0	0x02	0x00	—	Bit 0: KEY_SEL0 Bit 1: KEY_SEL1 00 = Enables KEY 1 01 = Enables KEY 2 10 = Enables KEY 3 11 = Reserved. Do not use.

10.2.2 Authentication Flow

The authentication procedure is described in the following steps:

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

10.3 Security Modes

As shipped, the device is in FULL ACCESS mode. For device security after manufacture, the device should be set to the SEALED access operational mode. To do this, send the MAC seal 0x0030 to the gauge. After the device is set to the SEALED mode, any device resets will cause the device to enter the SEALED mode. See the following sections for instructions on how to return to the other access modes.

For security mode access keys, the device ships with factory defaults. The manufacturer should change the keys to their proprietary keys using the MAC 0x0035. See Section 15.2.27.

10.3.1 SEALING and UNSEALING Data Flash

The gas gauge has a key access scheme to transition between SEALED, UNSEALED, and FULL ACCESS modes. Each transition requires that a unique set of two keys be sent to the gas gauge via the *AltManufacturerAccess()* command. The keys must be sent consecutively, with no other data being written to the *AltManufacturerAccess()* register. The *Seal Device* command instructs the device to limit access to the registers, functions, and data flash space, and sets the *[SEC1][SEC0]* flags. In SEALED mode, standard register information is accessible. Extended MAC Command functions and data flash are not accessible. Once in SEALED mode, the device can never permanently return to UNSEALED or FULL ACCESS modes. Section 15.2.35, the *OperationStatusB()* register, shows the status of the device using the *[SEC1][SEC0]* bits.

10.3.2 SEALED to UNSEALED

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

10.3.3 UNSEALED to FULL ACCESS

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

TEXAS INSTRUMENTS

11.1 Introduction

The BQ27Z746 device does not control the charge directly. It can interact with a smart charger to enhance its performance. The device can change the values of *ChargingVoltage()* and *ChargingCurrent()* based on *Temperature()* and *Voltage()*. Its flexible charging algorithm is JEITA-compatible and can also meet other specific cell manufacturer charge requirements. The *ChargingStatus()* register shows the state of the charging algorithm.
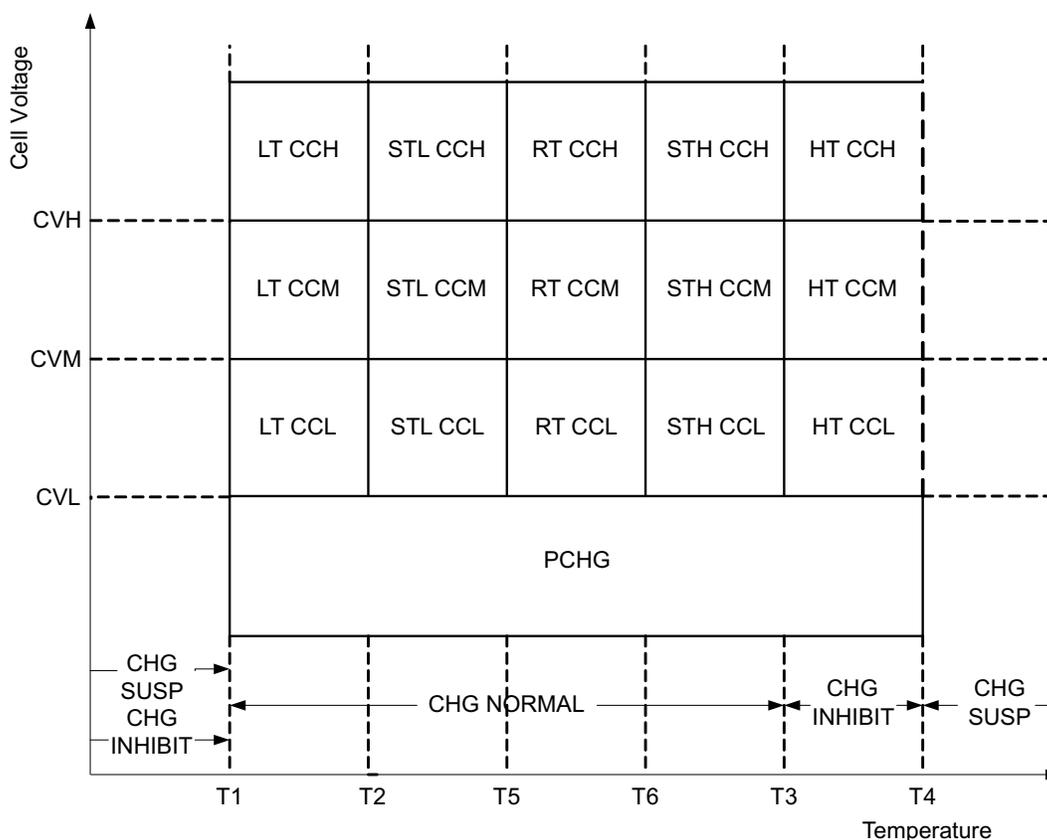
Figure 11-1. Charging Matrix

11.2 Charge Temperature Ranges

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

T1 ≤ T2 ≤ T5 ≤ T6 ≤ T3 ≤ T4

Temp Range bit definitions can be found in *ChargingStatus()*.
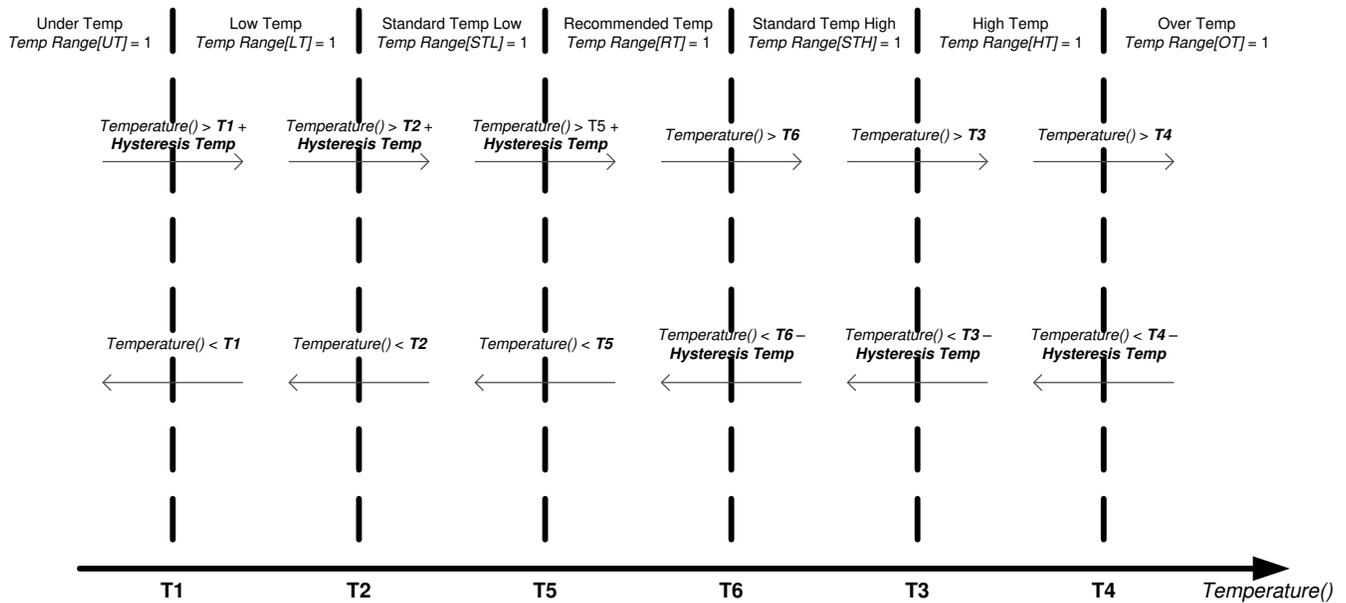
Figure 11-2. Charging Across Temperature

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

11.3 Voltage Range

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

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

Depending on the specific charging profile, the ***Low Temp Charging:Voltage*** and ***High Temp Charging:Voltage*** settings do not necessarily have the highest setting values.
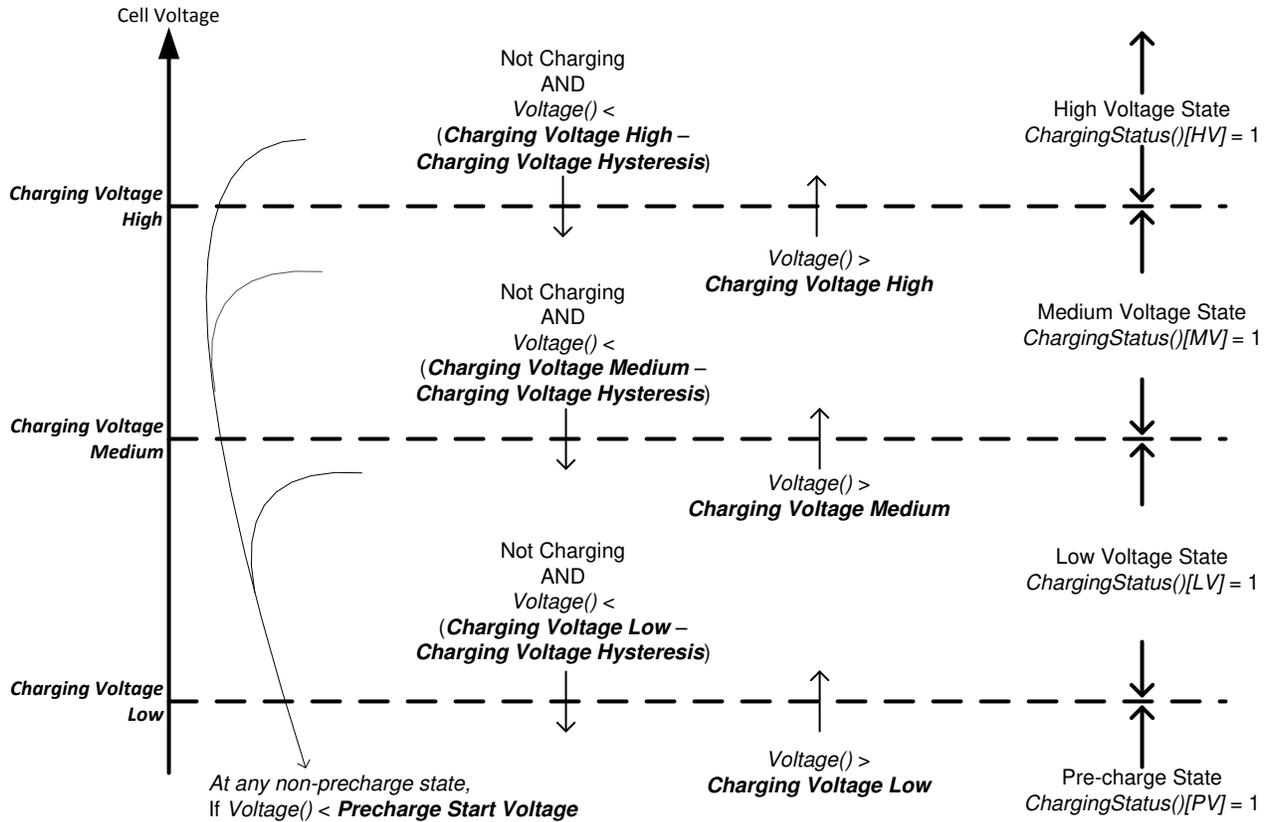
Figure 11-3. Charging Voltage Ranges

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

11.3.1 RelativeStateofCharge() Range

If **[SOC_CHARGE]** in **Charging Configuration** is set, then the voltage-based threshold control, as described in Section 11.3, is replaced with *RelativeStateOfCharge()* control.

With this method, the following changes in the control transitions occur:

1. [LV] state and *RelativeStateOfCharge()* > **Charging SOC Mid**; move to [MV].
2. [MV] state and *RelativeStateOfCharge()* > **Charging SOC High**; move to [HV].
3. [MV] state [DSG] = 1, and *RelativeStateOfCharge()* < **Charging SOC Mid – SOC Hysteresis**; move to [LV].

4. [HV] state [DSG] = 1, and *RelativeStateOfCharge()* < **Charging SOC High – Charging SOC Hysteresis**; move to [MV].

Table 11-1. *RelativeStateofCharge()* Range

Class	Subclass	Name	Type	Min Value	Max Value	Default Value	Unit
Advanced Charge Algorithm	SOC Range	Charging SOC Mid	U1	0	100	50	%
Advanced Charge Algorithm	SOC Range	Charging SOC High	U1	0	100	75	%
Advanced Charge Algorithm	SOC Range	Charging SOC Hysteresis	U1	0	100	1	%

11.4 Charging Current

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

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

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

Note

Table priority is top to bottom.

Temp Range	Voltage Range	Condition	Action
UT or OT	Any	—	*ChargingCurrent()* = 0
Any	PV	—	*ChargingCurrent()* = **Pre-Charging:Current**
LT	LV	—	*ChargingCurrent()* = **Low Temp Charging:Current Low**
	MV	—	*ChargingCurrent()* = **Low Temp Charging:Current Med**
	HV	—	*ChargingCurrent()* = **Low Temp Charging:Current High**
STL	LV	—	*ChargingCurrent()* = **Standard Temp Low Charging:Current Low**
	MV	—	*ChargingCurrent()* = **Standard Temp Low Charging:Current Med**
	HV	—	*ChargingCurrent()* = **Standard Temp Low Charging:Current High**
STH	LV	—	*ChargingCurrent()* = **Standard Temp High Charging:Current Low**
	MV	—	*ChargingCurrent()* = **Standard Temp High Charging:Current Med**
	HV	—	*ChargingCurrent()* = **Standard Temp High Charging:Current High**
RT	LV	—	*ChargingCurrent()* = **Rec Temp Charging:Current Low**
	MV	—	*ChargingCurrent()* = **Rec Temp Charging:Current Med**
	HV	—	*ChargingCurrent()* = **Rec Temp Charging:Current High**
HT	LV	—	*ChargingCurrent()* = **High Temp Charging:Current Low**
	MV	—	*ChargingCurrent()* = **High Temp Charging:Current Med**
	HV	—	*ChargingCurrent()* = **High Temp Charging:Current High**

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

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Settings	Configuration	Charging Configuration	H2	0x00	0x3F85	0x00	—	Bit 0: CRATE—*ChargingCurrent()* rate 0 = No adjustment to *ChargingCurrent()* (default) 1 = *ChargingCurrent()* adjusted based on *FullChargeCapacity()*/*DesignCapacity()* Bit 1: Reserved Bit 2: SOC_CHARGE 0 = Uses voltage thresholds (CVL, CVM, and CVH) in **Advanced Charging Algorithms** 1 = Enables the SOC threshold to replace voltage thresholds (CVL, CVM, and CVH) in **Advanced Charging Algorithms** Bits 6:3: Reserved Bit 7: CS_CV 0 = Cell swelling voltage degradation disabled 1 = Cell swelling voltage degradation enabled Bit 8: COMP_IR 0 = Disables voltage compensation for system resistance 1 = Enables voltage compensation for system resistance Bit 9: DEGRADE_CC 0 = Disables *ChargingCurrent()* degradation based on the charging degradation mode 1 = Enables *ChargingCurrent()* degradation based on the charging degradation mode Bit 10: CHGV_DEGRADE 0 = Disables *ChargingVoltage()* degradation based on the charging degradation mode 1 = Enables *Charging Voltage()* degradation based on the charging degradation mode Bit 11: HIBAT_CHG 0 = Disables the high battery voltage feature = Enables the high battery voltage feature Bit 12: SLEEPCHG 0 = *ChargingCurrent()* and *ChargingVoltage()* are 0 in SLEEP mode 1 = *ChargingCurrent()* and *ChargingVoltage()* are determined by **Advanced Charging Algorithms** in SLEEP mode. Bit 13: TAPER_VOLT 0 = Uses *ChargingVoltage()* for charge termination detection 1 = Uses fixed **Charge Term Charging Voltage** for charge termination Bits 15:14: Reserved
Advanced Charging Algorithms	Pre-Charging	Current	I2	0	32767	88	mA	Precharge *ChargingCurrent()*
Advanced Charging Algorithms	Maintenance Charging	Current	I2	0	32767	44	mA	Maintenance *ChargingCurrent()*
Advanced Charging Algorithms	Low Temp Charging	Current Low	I2	0	32767	132	mA	Low temperature range low voltage range *ChargingCurrent()*
Advanced Charging Algorithms	Low Temp Charging	Current Med	I2	0	32767	352	mA	Low temperature range medium voltage range *ChargingCurrent()*
Advanced Charging Algorithms	Low Temp Charging	Current High	I2	0	32767	264	mA	Low temperature range high voltage range *ChargingCurrent()*
Advanced Charging Algorithms	Standard Temp Low Charging	Current Low	I2	0	32767	1980	mA	Standard temperature low range low voltage range *ChargingCurrent()*
Advanced Charging Algorithms	Standard Temp Low Charging	Current Med	I2	0	32767	4004	mA	Standard temperature low range medium voltage range *ChargingCurrent()*
Advanced Charging Algorithms	Standard Temp Low Charging	Current High	I2	0	32767	2992	mA	Standard temperature low range high voltage range *ChargingCurrent()*
Advanced Charging Algorithms	Standard Temp High Charging	Current Low	I2	0	32767	1980	mA	Standard temperature high range low voltage range *ChargingCurrent()*

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Advanced Charging Algorithms	Standard Temp High Charging	Current Med	I2	0	32767	4004	mA	Standard temperature high range medium voltage range *ChargingCurrent()*
Advanced Charging Algorithms	Standard Temp High Charging	Current High	I2	0	32767	2992	mA	Standard temperature high range high voltage range *ChargingCurrent()*
Advanced Charging Algorithms	High Temp Charging	Current Low	I2	0	32767	1012	mA	High temperature range low voltage range *ChargingCurrent()*
Advanced Charging Algorithms	High Temp Charging	Current Med	I2	0	32767	1980	mA	High temperature range medium voltage range *ChargingCurrent()*
Advanced Charging Algorithms	High Temp Charging	Current High	I2	0	32767	1496	mA	High temperature range high voltage range *ChargingCurrent()*
Advanced Charging Algorithms	Rec Temp Charging	Current Low	I2	0	32767	2508	mA	Recommended temperature range low voltage range *ChargingCurrent()*
Advanced Charging Algorithms	Rec Temp Charging	Current Med	I2	0	32767	4488	mA	Recommended temperature range medium voltage range *ChargingCurrent()*
Advanced Charging Algorithms	Rec Temp Charging	Current High	I2	0	32767	3520	mA	Recommended temperature range high voltage range *ChargingCurrent()*

11.5 Charging Voltage

The *ChargingVoltage()* changes depending on the detected temperature per the charge algorithm. If cell temperature reduces *ChargingVoltage()* below the cell voltage, setting **[HIBAT_CHG]** can hold it unchanged while *ChargingCurrent()* is held at 0. This action continues until the desired *ChargingVoltage()* is above the cell voltage.

Note

Table priority is top to bottom.

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

Table 11-2 shows the configurations for the charging voltages. They can be changed with the *ChargingVoltageOverride* MAC.

Table 11-2. JEITA Charging Voltages

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

Table 11-2. JEITA Charging Voltages (continued)

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

11.5.1 Charge Voltage Compensation for System Impedance

The design of some battery charging systems may have a not insignificant impedance between the charger and battery terminals. In this case, a voltage compensation feature handles system level IR drops to ensure the correct charging voltage is supplied at the battery terminals. Program the **System Resistance** register with the measured resistance in milliohms (mΩ) between the battery terminals and charger terminals. To enable this feature, set the configuration bit **[COMP_IR]** in (default 0) the **Charging Configuration** register.

This feature works as follows:

ChargingVoltage() = charging_voltage + *ChargingCurrent()* × **System Resistance**

where charging_voltage was computed as a result of a selected configuration; from the JEITA table and any applied degradations.

11.6 Charging Degradation Modes

This optional feature can be used to reduce charging voltages and/or currents based on measured parameters that reflect the aging of cells.

Here is an example of charging degradation using **Cycle Count** (although it is the same for the other aging parameters as itemized below):

In NORMAL mode (there is no reduction of *ChargingCurrent()* or *ChargingVoltage()*), *ChargingCurrent()* is reduced by CC Degradation Mode 1 (assuming the Cycle Count 1 entry conditions are met), then moving to Cycle Count Mode 2, *ChargingCurrent()* is further reduced by CC Degradation Mode 2 (assuming Cycle Count 2 entry conditions are met). This is similar for Cycle Count Mode 3.

Care should be taken to set the degradation mode thresholds such that each threshold is increased for each mode. The fact that any of the other measured aging parameters have not passed a degradation mode threshold would not cause the lower mode to be used.

This charging current degradation scheme (if enabled) works in conjunction with any other existing degradation/increments (such as charge loss compensation).

The following table shows the default values for how charging voltage and charging current are degraded for each degradation mode:

[CHGV_DEGRADE] is set.)	**Charging Voltage (CV)** **(CV degradation is available if enabled.)**	**Charging Current (CC)** **(CC degradation is available if enabled [DEGRADE_CC]).**[1]
Normal	*No CV Degradation*	*No CC Degradation*
Mode 1	*CV Degradation* (default 10 mV / cell)	*CC Degradation* (default 10%)
Mode 2	*CV Degradation* (default 40 mV / cell)	*CC Degradation* (default 20%)
Mode 3	*CV Degradation* (default 70 mV / cell)	*CC Degradation* (default 40%)

(1)   Only **[DEGRADE_CC]** or **[CRATE]** can be used at a time. Both must not be enabled together.

A degrade mode is entered when any measured parameter exceeds the thresholds set in data flash. The following thresholds are defined for each mode (see *Data Flash Summary* for threshold value settings and addresses).

- **Cycle Threshold** checked against *CycleCount()*
- **SOH Threshold** checked against *StateOfHealth()*

- *Runtime Threshold* checked against *Runtime Degrade*
- *High SOC Threshold* checked against the sum of all the high SOC times recorded in *Lifetimes* : *Time Spent In UT RSOC A*, *Time Spent In LT RSOC A*, *Time Spent In STL RSOC A*, *Time Spent In RT RSOC A*, *Time Spent In STH RSOC A*, *Time Spent In HT RSOC A*, and *Time Spent In OT RSOC A*
- *High Temp Threshold* checked against the sum of all the high temperature times recorded in *Lifetimes* : *Time Spent In HT RSOC A*, *Time Spent In HT RSOC B*, *Time Spent In HT RSOC C*, *Time Spent In HT RSOC D*, *Time Spent In HT RSOC E*, *Time Spent In HT RSOC F*, *Time Spent In HT RSOC G*, and *Time Spent In HT RSOC H*
- *High Temp SOC Threshold* checked against *Time Spent in HT RSOC A*

CycleCount() must be greater than *Cycle Count Start Runtime* before *Runtime Degrade* starts to increment and any degradation modes are detected.

The current degradation mode can be determined from the value of *[CV_DGRD]*.

Runtime Degrade is updated to data flash every *Runtime Update Interval* and tracks the runtime after *CycleCount()* ≥ *Cycle Count Start Runtime* .

Note

A threshold can be set to an unobtainable value for a particular aging parameter to be disabled.

11.7 Cell Swelling Control (via Charging Voltage Degradation)

Cell swelling can occur when the cell temperature and cell voltage are above certain thresholds. In these situations, the charging voltage can be stepped down gradually until the cell temperature moves back down.

This scheme works (as shown in Figure 11-4) when enabled by setting *[CS_CV]* (default is cleared) in the *Charging Configuration* register. When the max cell voltage1..4 and cell temperature are above the *Voltage Threshold* and *Temperature Threshold*, respectively, for the period defined by *Time Interval*, then the charging voltage is stepped down by *Delta Voltage*. This step down continues until either the max cell voltage1..4 and cell temperature conditions go away (that is, cell swelling reduces) or the step down reaches *Min CV*.

The charging voltage reduction/degradation resulting from this feature is reset when exiting CHARGE mode.

Note

This degradation works in conjunction with other degradation features; therefore, use with care.
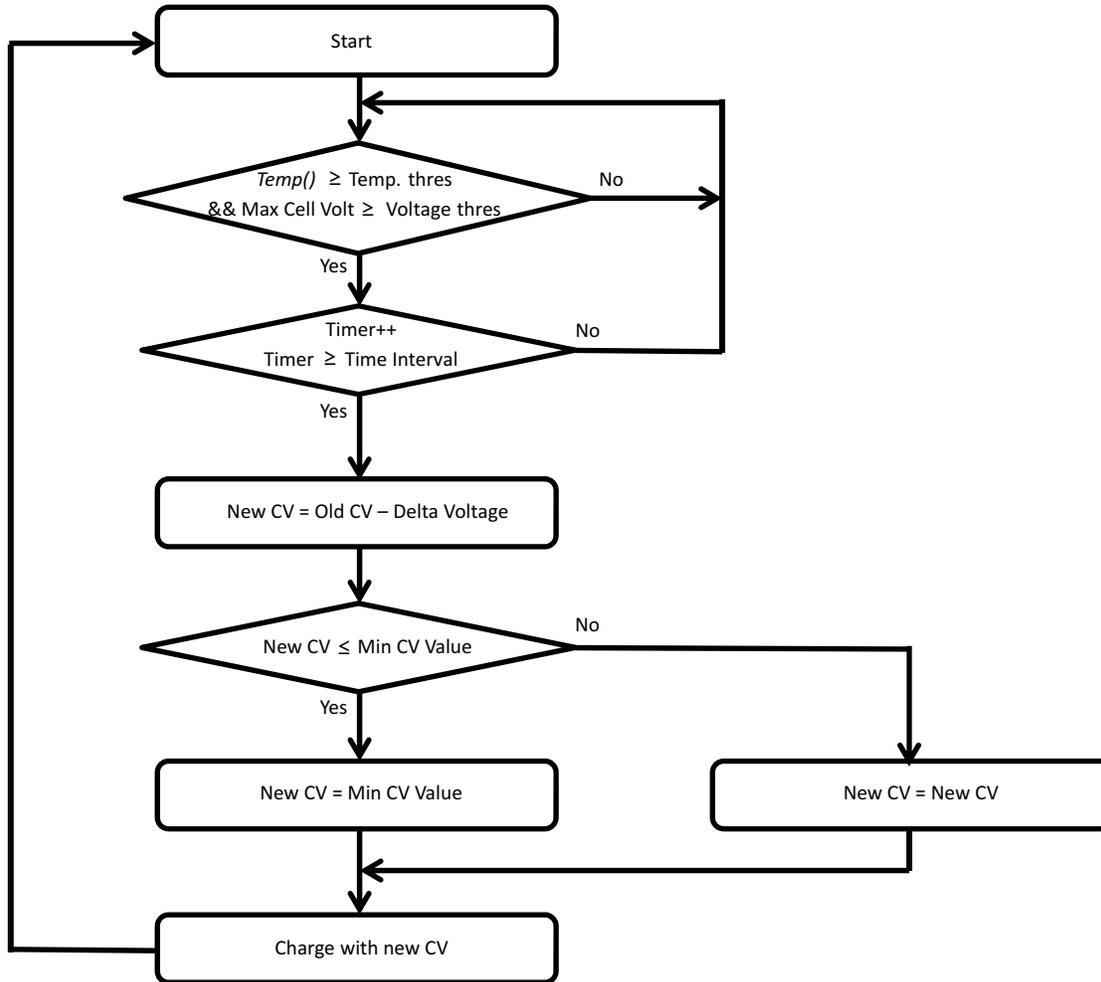
Figure 11-4. Cell Swelling Control

11.8 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 bits settings:

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

Status	Condition	Action
Charging	*GaugingStatus()[REST]* = 0 AND *BatteryStatus()[DSG]* = 0	Charge Algorithm active

Status	Condition	Action
Valid Taper Charge Termination	*SOC Flag Config A[TCSETVCT]* = 1 selects termination detection based on the taper conditions. All of the following conditions must occur for two consecutive 40-s periods: Charging (that is, *BatteryStatus()[DSG]* = 0) AND *AverageCurrent()* < **Charge Term Taper Current** AND *Voltage()* + **Charge Term Voltage** ≥ *ChargingVoltage()* AND **[TAPER_VOLT]** = 0 AND The accumulated change in capacity > 0.25 mAh,	*ChargingStatus()[VCT]* = 1 *ChargingVoltage()* = Charging Algorithm *ChargingCurrent()* = Charging Algorithm *BatteryStatus()[FC]* = 1 and *GaugingStatus()[FC]* = 1 if **SOC Flag Config A[FCSETVCT]** = 1 *BatteryStatus()[TCA]* = 1 and *GaugingStatus()[TC]* = 1 if **SOC Flag Config A[TCSETVCT]** = 1 **Cell 1 Chg Voltage at EoC** = *Voltage()* **Current at EoC** = *Current()* Calculate Cell 1 DODEOC Trigger IT simulation
Valid Charge Termination from SOC or Voltage Thresholds	**SOC Flag Config A[TCSETRSOC]** = 1 and *Relative State of Charge()* >= **TC.Set % RSOC Threshold** or **SOC Flag Config A[TCSETV]** = 1 and *Voltage()* >= **TC.Set Voltage Threshold**	*ChargingStatus()[VCT]* = 1 *ChargingVoltage()* = Charging Algorithm *ChargingCurrent()* = Charging Algorithm *BatteryStatus()[FC]* = 1 and *GaugingStatus()[FC]* = 1 *BatteryStatus()[TCA]* = 1 and *GaugingStatus()[TC]* = 1 **Cell 1 Chg Voltage at EoC** = *Voltage()* **Current at EoC** = *Current()* Calculate Cell 1 DODEOC Trigger IT simulation

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Note

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

Note

Setting **[TAPER_VOLT]** causes **Charge Term Charging Voltage** to be used in place of *ChargingVoltage()*.

Note

It is recommended to choose the Taper Charge Termination method. However, some applications may have difficulty achieving all the conditions. In that case the other method could be selected. It is not recommended to select both methods.

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

11.9 Charge and Discharge Alarms

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

Note

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

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

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

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

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

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

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

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

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

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

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

11.10 Terminate Charge and Discharge Alarms

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

[TCA] = 1

- *SafetyAlert()[OCC], [COV], [OTC] , [UTC]* = 1 OR
- *GaugingStatus()[TC]* = 1 AND in CHARGE mode

[FC] = 1

- *GaugingStatus()[FC]* = 1

[TDA] = 1 if

- *SafetyAlert()[OCD], [CUV], [OTD] , [UTD]* = 1 OR
- *GaugingStatus()[TD]* = 1 AND in DISCHARGE mode

[FD] = 1 if

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

[OTA] = 1 if

- *SafetyStatus()[OTC], [OTD]* = 1

11.11 Precharge

The device enters PRECHARGE mode if the cell voltage falls below **Precharge Start Voltage**.

11.12 Charge Disable and Discharge Disable

The BQ27Z746 device can disable charging if certain safety conditions are detected, setting the *OperationStatus()[XCHG]* = 0.

Status	Condition	Action
Normal	*GaugingStatus()[TCA]* = 0 if **Charging Configuration[CHGFET]** = 1	*ChargingVoltage()* = Charging Algorithm *ChargingCurrent()* = Charging Algorithm *OperationStatus()[XCHG]* = 0

Status	Condition	Action
Trip	*ManufacturingStatus()[FET_EN]* = 0 OR *ChargingStatus()[IN]* = 1 if **[CHGIN]** = 1 OR *ChargingStatus()[SU]* = 1 if **[CHGSU]** = 1 OR *OperationStatus()[SLEEP]* = 1 if AND **[SLEEPCHG]** = 0 OR *GaugingStatus()[TCA]* = 1 if **Charging Configuration[CHGFET]** = 1	*ChargingVoltage()* = 0 *ChargingCurrent()* = 0 *OperationStatus()[XCHG]* = 1

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

- *ManufacturingStatus()[FET_EN]* = 0 OR
- Any *PFStatus()* set OR
- *OperationStatus()[SDM]* = 1 AND delay time > **FET Off Time** OR
- *OperationStatus()[SDV]* = 1 AND low voltage time ≥ **Shutdown Time**.

11.13 Charge Inhibit

The BQ27Z746 device can provide information to the smart charger to enable it to inhibit the start of charging at high and low temperatures to prevent damage of the cells. This feature is intended to enable the charger to prevent the start of charging when the temperature is at the inhibit range; therefore, if charging is in progress, the charger must determine its actions. *Temp Range* bit definitions can be found in *ChargingStatus()*.

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

11.14 Charge Suspend

The device can stop charging at high and low temperatures to prevent damage of the cells. The charge suspend feature is mutually exclusive with the charge inhibit, so if charge inhibit is set after the device exits charging, then the charge suspend status will be cleared.

Status	Condition	Action
Normal	*ChargingStatus()[LT]* = 1 OR *ChargingStatus()[STL]* = 1 OR *ChargingStatus()[RT]* = 1 OR *ChargingStatus[STH]* = 1 OR *ChargingStatus()[HT]* = 1 OR *ChargingStatus[IN]* = 1	*ChargingStatus()[SU]* = 0 *ChargingVoltage()* = charging algorithm *ChargingCurrent()* = charging algorithm
Trip	*ChargingStatus()[UT]* = 1 OR *ChargingStatus()[OT]* = 1	*ChargingStatus()[SU]* = 1 *ChargingVoltage()* = 0 *ChargingCurrent()* = 0

11.15 Zero Volt Charging (ZVCHG)

The device supports trickle charging a cell at very low voltages. This is known as zero volt charging (ZVCHG). When ZVCHG is enabled, the device connects the gate of the CHG FET to the PACK pin to turn it on when the cell voltage is otherwise too low. ZVCHG is only enabled in the presence of a charger as determined by the PACK pin voltage. While ZVCHG is enabled, the FET driver to the gate of the CHG FET is disabled (reflected by *OperationStatus()[CHG]*). ZVCHG is disabled for the same charge disable conditions as described above, as well as for any protections that disable the CHG FET.

When the device boots up, the DSG FET is off and the CHG FET is on due to ZVCHG. The device performs very fast ADC measurements of cell and PACK voltage to determine if ZVCHG should remain enabled to prevent the

device from possibly experiencing a power-on reset due to a low cell voltage. If the conditions to enable ZVCHG are not present, the CHG FET is turned off by disabling ZVCHG to ensure no current flows during the initial measurements for open-circuit voltage (OCV).

Status	Condition	Action
Activate	*Voltage() < ZVCHG Exit Threshold* AND Pack Pin Voltage ≥ *ZVCHG PACK Threshold*	*OperationStatus()[ZVCHG]* = 1 *OperationStatus()[CHG]* = 0
Exit	*Voltage() ≥ ZVCHG Exit Threshold* OR Pack Pin Voltage < *ZVCHG PACK Threshold*	*OperationStatus()[ZVCHG]* = 0 *OperationStatus()[CHG]* = 1

Class	Subclass	Name	Type	Min	Max	Default	Unit
Settings	AFE	ZVCHG Exit Threshold	I2	0	2000	2000	mV
Settings	AFE	ZVCHG PACK Threshold	I2	0	2000	1500	mV

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TEXAS INSTRUMENTS

12.1 HDQ Single-Pin Serial Interface

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

Note

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

The 8-bit command code consists of two fields: the 7-bit HDQ command code (bits 0:6) and the 1-bit RW field (MSB bit 7). The RW field directs the fuel gauge either to:
- Store the next 8 or 16 bits of data to the specified register or
- Output 8 bits of data from the specified register.

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

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

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

The BQ27Z746 gauge is shipped in I^{2}C mode, but TI provides a method to switch to HDQ mode via *SwitchToHDQ()* (see *AltManufacturerAccess() 0x7C40* for details).

12.2 I^{2}C Interface

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

The 7-bit device address can be configured by setting *Alt I2C Address* to the desired address and *Alt I2C Addr Chk* to the 2's complement of *Alt I2C Address*. If *Alt I2C Address* and *Alt I2C Addr Chk* are updated, a reset is required for the gauge to use the new device address. However, the gauge defaults to 0x55 if *Alt I2C Address* is 0x00 or 0xFF or *Alt I2C Addr Chk* is not set correctly.

☐ Host Generated   ☐ Fuel Gauge Generated

| S | ADDR[6:0] | 0 | A | CMD[7:0] | A | DATA[7:0] | A | P | | S | ADDR[6:0] | 1 | A | DATA[7:0] | N | P |

(a)   (b)

| S | ADDR[6:0] | 0 | A | CMD[7:0] | A | Sr | ADDR[6:0] | 1 | A | DATA[7:0] | N | P |

(c)

| S | ADDR[6:0] | 0 | A | CMD[7:0] | A | Sr | ADDR[6:0] | 1 | A | DATA[7:0] | A | . . . | DATA[7:0] | N | P |

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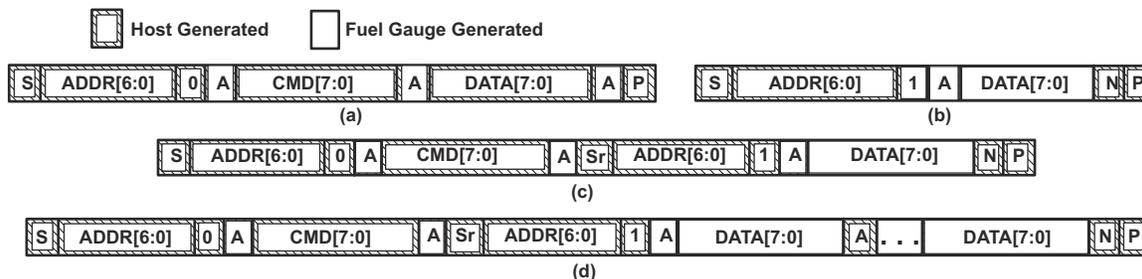
a. 1-byte write
b. Quick read
c. 1-byte read
d. Incremental read

Figure 12-1. Supported I^{2}C Formats

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

The quick read returns data at the address indicated by the address pointer. The address pointer, a register internal to the I^{2}C communication engine, increments when data is acknowledged by the fuel gauge or the I^{2}C master. Quick writes function in the same way and are a convenient means of sending multiple bytes to consecutive command locations (such as two-byte commands that require two bytes of data).

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

| S | ADDR[6:0] | 0 | A | CMD[7:0] | A | DATA[7:0] | A | P |

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

| S | ADDR[6:0] | 0 | A | CMD[7:0] | N | P |

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

| S | ADDR[6:0] | 0 | A | CMD[7:0] | A | DATA[7:0] | A | DATA[7:0] | N | . . . | N | P |
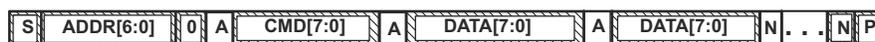
Incremental read at the maximum allowed read address:

| S | ADDR[6:0] | 0 | A | CMD[7:0] | A | Sr | ADDR[6:0] | 1 | A | DATA[7:0] | A | . . . | DATA[7:0] | N | P |

Address 0x7F   Data From addr 0x7F   Data From addr 0x00
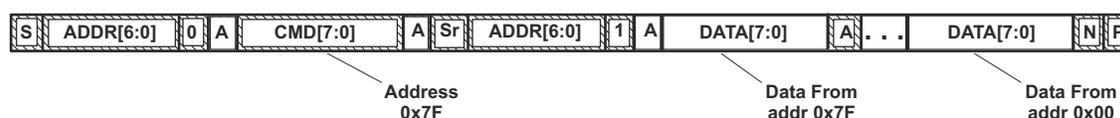
12.2.1 I^{2}C Clock Frequency

The gauge supports different maximum clock frequencies for the I^{2}C engine. The desired maximum clock frequency can be configured via *Settings.Configuration.I2C Configuration*.

12.2.2 I^{2}C Time Out

The I^{2}C engine releases SDA and SCL if the I^{2}C bus is held low for about two seconds. If the fuel gauge were holding the lines, releasing them frees the master to drive the lines.

12.2.3 I^{2}C Command Waiting Time

To ensure the correct results of a command with the 400-kHz I^{2}C operation, there must be a proper waiting time between issuing the command and reading the results. For *AltManufacturerAccess()* commands, the following diagram shows the waiting time required between issuing the *AltManufacturerAccess()* command and reading the status. For read-only standard commands, there is no waiting time required, but the host must not issue all standard commands more than two times per second. If thousands of I^{2}C transactions are sent to the gauge in one second, then it could adversely impact the CPU and cause a watchdog reset.

| S | ADDR[6:0] | 0 | A | CMD[7:0] | A | DATA [7:0] | A | DATA [7:0] | A | P | t_{BUF} |

| S | ADDR[6:0] | 0 | A | CMD[7:0] | A | Sr | ADDR[6:0] | 1 | A | DATA [7:0] | A | DATA [7:0] | N | P | 66 ☐s |

Waiting time between control subcommand and reading results

| S | ADDR[6:0] | 0 | A | CMD[7:0] | A | Sr | ADDR[6:0] | 1 | A | DATA [7:0] | A | DATA [7:0] | A |

| DATA [7:0] | A | DATA [7:0] | N | P | 66 ☐s |

Waiting time between continuous reading results

Table 12-1. Command Waiting Times

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

12.2.4 I^{2}C Clock Stretching

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

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

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13.1 Manufacture Testing

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

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

13.1.1 Manufacturing Status Configuration

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

13.2 I²C Configuration

The following table describes the bit settings for I²C communication options.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Settings	Configuration	I2C Configuration	H1	0x0000	0x08FF	0x0028	—	Bit 2:0: Reserved Bit 3: XL—Enables 400-kHz I^{2}C max clock frequency 0 = 100-kHz max clock frequency 1 = 400-kHz max clock frequency (default) Bits 5:4:Bus Low Timeout 0,0 = No timeout 0,1 = 1 second 1,0 = 2 seconds 1,1 = 3 seconds Bit 6: Reserved Bit 7: FLASH_BUSY_WAIT—Set this bit to avoid NACKs on legal commands. Note there will be long clock stretches if the gauge is updating data flash. Bit 10:8: Reserved Bit 11: NO_CLOCK—HFO Clock Disabled for Target Address 0 = HFO clock enabled receiving target address (default) 1 = HFO clock disabled receiving target address. Requires strict timing compliance Bit 15:12: Reserved

13.3 Manufacturer Information Blocks

There are three 32-byte manufacturer information blocks in data flash that record details related to the manufacture of a battery pack. The gauge does not use this data; it is available for the manufacturer to use and interpret the data. No formatting of data written in these blocks is imposed by the gauge firmware. These blocks can be accessed by either the regular data flash access methods or by using *ManufacturerAccess()* commands. See the entries for **Manufacturer Data**, **Manufacturer Info B**, and **Manufacturer Info C** in the Section 17.1 to *AltManufacturerAccess() 0x007A ManufacturerInfoB* access by Section 15.2.63.

The manufacturer information blocks can also be read or written when the gauge is in the UNSEALED mode, using the associated MACs *AltManufacturerAccess() 0x0070 ManufacturerInfo*, *AltManufacturerAccess() 0x007A ManufacturerInfoB*, and *AltManufacturerAccess() 0x007B ManufacturerInfoC*. *AltManufacturerAccess() 0x007B ManufacturerInfoC* can be used to write to manufacturer information block c when the gauge is SEALED if *[MFG_C_SEALED]* is set in **Settings.Configuration.I^{2}C Configuration**.

13.4 Verification of Data Flash

During manufacture, the configuration of the gauge in data flash will be updated. Typically, a known good data flash image is loaded to the device. To avoid the time needed to read back to verify the data flash, a number of data flash signature Manufacturer Access commands are available (see Section 15.2). The BQ27Z746 has both static and non-static sections in the data flash memory. The static memory areas are only changed by host writes to data flash commands. Non-static memory may be modified by the gauge firmware.

13.5 Calibration

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

Note

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

Table 13-1. AltManufacturerAccess() Descriptions

AltManufacturerAccess()	Description
0x002D	Enables/disables *ManufacturingStatus()[CAL_EN]*

Table 13-1. AltManufacturerAccess() Descriptions (continued)

AltManufacturerAccess()	Description
0xF080	Disables raw ADC data output on *MACData()*
0xF081	Outputs raw ADC data of voltage and current *MACData()*

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

where:

Table 13-2. MACData() Format Descriptions

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

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Note

All calibration steps that require accessing data on *MACData()* must begin read operations starting at *AltManufacturerAccess()* to ensure the data portion of the block is properly refreshed per the intended *AltManufacturerAccess()* subcommand (in this case 0xF081). The first two bytes returned are the *AltManufacturerAccess()* subcommand followed by the counter, status, and raw ADC values, as shown in Table 13-1.

14.1 Voltage Calibration

14.1.1 Cell (BAT) Voltage Calibration
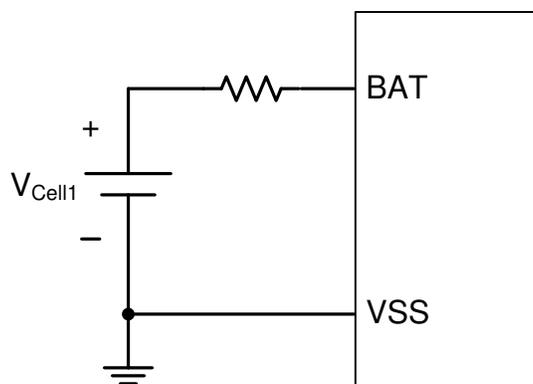
Figure 14-1. Cell Voltage Calibration

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

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

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

14.1.2 Pack (PACK) Voltage Calibration
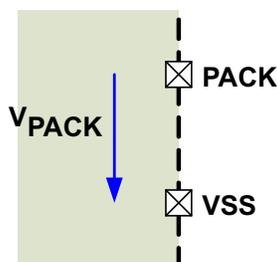
1. Apply known voltages in mV to the voltage input:
   • V_{PACK} between PACK terminal and VSS terminal
2. If *ManufacturerStatus()[CAL_EN]* = 0, send 0x002D to *AltManufacturerAccess()* to enable the *[CAL_EN]* flag.
3. Send 0xF081 to *AltManufacturerAccess()* to enable raw pack voltage output on *MACData()*.
4. Poll *MACData()* until the 8-bit counter value increments by 2 before reading data.
5. Read ADC conversion readings of pack voltage from *MACData()*:
   • ADC_{PACK} = FFff of *MACData()*
6. Average several readings for higher accuracy. Poll *MACData()* until ZZ increments to indicate that updated values are available:
   • ADC_{PACK} = [ADC_{PACK}(reading n) + … + ADC_{PACK}(reading 1)]/n
7. Calculate gain value:

$$PACK\ Gain = \frac{V_{PACK}}{ADC_{PACK}} \times 2^{16}$$

8. Write the new **Pack Gain** value to data flash.
9. Recheck voltage readings and if they are not accurate, repeat Steps 4 through 6.
10. Send 0x002D to *AltManufacturerAccess()* to clear the *[CAL_EN]* flag if all calibration is complete.

14.1.3 Voltage Calibration Data Flash

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Calibration	Voltage	Cell Gain	I2	–32768	32767	12101[1]	—	BAT – VSS gain
Calibration	Voltage	Pack Gain	U2	0	65536	24835[1]	—	Pack – VSS gain

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

14.2 Current Calibration
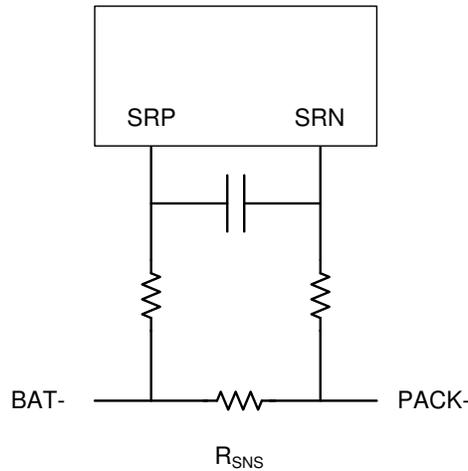
Figure 14-2. Current Calibration (Charge Current Flow Is BAT– to PACK–)

Note

CC offset and board offset are no longer calibrations required by the BQ27Z746 due to hardware improvements.

14.2.1 CC Gain/Capacity Gain Calibration

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

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

   $$CC\ Gain = I_{CC} / ADC_{CC}$$

   $$Capacity\ Gain = CC\ Gain \times 1193046.4712$$
8. Write the new **CC Gain** and **Capacity Gain** values to data flash.
9. Recheck the current reading. If the reading is not accurate, repeat the steps.
10. Send 0x002D to *AltManufacturerAccess()* to clear the *[CAL_EN]* flag if all calibration is complete.

14.2.2 Deadbands

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

14.2.2.1 Current Deadband

When current measures to a value less than the value programmed in **Deadband**, *Current()* will report 0. This has no effect on the coulomb counting for the gas gauging functionality. The value of **Deadband** should be selected based on the characterization of the battery electronics design combined with the environment in which

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the battery will be used. If the PCB senses noise causing a real no-current condition to report a non-zero value, then ***Deadband*** could be adjusted accordingly.

14.2.2.2 Coulomb Counter Deadband

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

14.2.3 Current Calibration Data Flash

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

14.3 Temperature Calibration

Note

For temperature calibration, only an offset is determined and then applied to the gauge's measured temperatures.
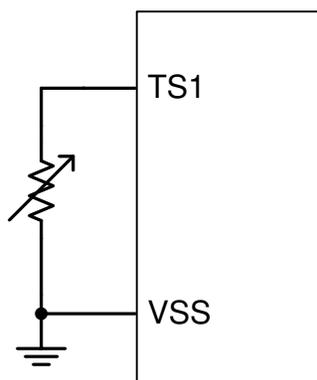
Figure 14-3. Temperature Calibration

14.3.1 Internal Temperature Sensor Calibration

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

   Is TINT > 0? If yes, TINT = AAaa – 2732.
4. Calculate temperature offset:

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

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

14.3.2 TS Calibration

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

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

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

Note

Follow the same steps when calibrating the temperature measurement on the GPO pin (referred to as TS2 Temperature in *DAStatus2()*, which can be used for cell or FET temperature), except use **External2 Temp Offset**.

14.3.3 Temperature Calibration Data Flash

It is not necessary to adjust these offsets. These offsets can be used to improve temperature accuracy at temperatures away from the calibration temperature of the models below; however, they can reduce accuracy across the range of temperatures.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Calibration	Temperature	Internal Temp Offset	I1	−128	127	0	0.1 °C	Internal temperature sensor reading offset
Calibration	Temperature	External1 Temp Offset	I1	−128	127	0	0.1 °C	TS pin temperature sensor reading offset
Calibration	Temperature	External2 Temp Offset	I1	−128	127	0	0.1 °C	GPO pin (used for TS2) temperature sensor reading offset

14.3.4 Cell Temp Model

The parameters in the following table are used for the Semitec 103AT-2 thermistor; default for the TS pin. These parameters will only need to be updated if a different thermistor is used. See the application report to calculate coefficients for other thermistors.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Calibration	Cell Temp Model	Coefficient a1	I2	−32768	32767	−17447	—	Cell Temperature calculation polynomial a1
Calibration	Cell Temp Model	Coefficient a2	I2	−32768	32767	29332	—	Cell Temperature calculation polynomial a2
Calibration	Cell Temp Model	Coefficient a3	I2	−32768	32767	−25430	—	Cell Temperature calculation polynomial a3
Calibration	Cell Temp Model	Coefficient a4	I2	−32768	32767	29836	—	Cell Temperature calculation polynomial a4
Calibration	Cell Temp Model	Coefficient a5	I2	−32768	32767	1200	—	Cell Temperature calculation polynomial a5
Calibration	Cell Temp Model	Coefficient b1	I2	−32768	32767	−293	—	Cell Temperature calculation polynomial b1
Calibration	Cell Temp Model	Coefficient b2	I2	−32768	32767	552	—	Cell Temperature calculation polynomial b2
Calibration	Cell Temp Model	Coefficient b3	I2	−32768	32767	−2887	—	Cell Temperature calculation polynomial b3
Calibration	Cell Temp Model	Coefficient b4	I2	−32768	32767	4591	—	Cell Temperature calculation polynomial b4
Calibration	Cell Temp Model	Rc0	I2	−32768	32767	11703	—	Resistance at 25°C
Calibration	Cell Temp Model	Adc0	I2	−32768	32767	11703	—	ADC reading at 25°C
Calibration	Cell Temp Model	Rpad	I2	−32768	32767	1[1]	Ω	Pad Resistance (0 to use factory calibration)
Calibration	Cell Temp Model	Rint	I2	−32768	32767	18000[1]	Ω	Pullup resistor resistance (0 to use factory calibration)

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

14.3.5 Internal Temp Model

Values in this table should not be modified, as the voltage-based sensor in the device was factory trimmed for these model parameters.

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

14.3.6 2nd Temperature Model

The parameters in the following table are used for the Semitec 103AT-2 thermistor; default for the GPO pin for either cell or FET temperature. These parameters only need to be updated if a different thermistor is used. If a different thermistor is desired, guidance on selection and coefficient calculation can be found at *Thermistor Selection Guide for Texas Instruments Advanced Fuel Gauges*.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Calibration	2nd Temperature Model	Coefficient a1	I2	–32768	32767	–17447	—	Cell Temperature calculation polynomial a1
Calibration	2nd Temperature Model	Coefficient a2	I2	–32768	32767	29332	—	Cell Temperature calculation polynomial a2
Calibration	2nd Temperature Model	Coefficient a3	I2	–32768	32767	–25430	—	Cell Temperature calculation polynomial a3
Calibration	2nd Temperature Model	Coefficient a4	I2	–32768	32767	29836	—	Cell Temperature calculation polynomial a4
Calibration	2nd Temperature Model	Coefficient a5	I2	–32768	32767	1200	—	Cell Temperature calculation polynomial a5
Calibration	2nd Temperature Model	Coefficient b1	I2	–32768	32767	–293	—	Cell Temperature calculation polynomial b1
Calibration	2nd Temperature Model	Coefficient b2	I2	–32768	32767	552	—	Cell Temperature calculation polynomial b2
Calibration	2nd Temperature Model	Coefficient b3	I2	–32768	32767	–2887	—	Cell Temperature calculation polynomial b3
Calibration	2nd Temperature Model	Coefficient b4	I2	–32768	32767	4591	—	Cell Temperature calculation polynomial b4
Calibration	2nd Temperature Model	Rc0	I2	–32768	32767	11703	—	Resistance at 25°C
Calibration	2nd Temperature Model	Adc0	I2	–32768	32767	11703	—	ADC reading at 25°C
Calibration	2nd Temperature Model	Rpad	I2	–32768	32767	1[1]	Ω	Pad Resistance (0 to use factory calibration)
Calibration	2nd Temperature Model	Rint	I2	–32768	32767	18000[1]	Ω	Pullup resistor resistance (0 to use factory calibration)

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

15.1 Standard Data Commands

The BQ27Z746 device uses a series of 2-byte standard commands to enable system reading and writing of battery information. Each standard command has an associated command code pair, as indicated in Table 15-1, *Standard Commands*. The LSB of the command code corresponds to the LSB register data. The LSB should be read first to keep the register data synchronized. For some host systems, the host should change the byte order so that the order corresponds to the host's native endianness. Both the I^{2}C and HDQ protocols have methods to access the data for each command code. The gauge updates and/or reads the standard command registers once per second.

Table 15-1. Standard Commands

Name		Register Code (LSB/MSB)	Description
ManufacturerAccess/ControlStatus()	CNTL	0x00/0x01	Control Register (See Section 15.1.1.)
AtRate()	AR	0x02/0x03	Read/write. The value is a signed integer with the negative value indicating a discharge current value. The default value is 0 and forces *AtRateTimeToEmpty()* to return 65,535.
AtRateTimeToEmpty()	ARTTE	0x04/0x05	This read-only function returns an unsigned integer value to predict remaining operating time based on battery discharge at the *AtRate()* value in minutes with a range of 0 to 65,534. A value of 65,535 indicates *AtRate()* = 0. The gas gauge updates the *AtRateTimeToEmpty()* within 1 s after the system sets the *AtRate()* value. The gas gauge updates these parameters every 1 s. The commands are used in NORMAL mode.
Temperature()	TEMP	0x06/0x07	This read-only function returns an unsigned integer value of temperature measured by the gas gauge and is used for the gauging algorithm. Values are reported in units 0.1 K. It reports either internal temperature or external thermistor temperature, depending on the setting of the *[TS1]* and *[TSInt]* bits in **Temperature Enable**.
Voltage()	VOLT	0x08/0x09	This read-only function returns an unsigned integer value of the measured cell pack in mV with a range of 0 to 6000 mV.
BatteryStatus()	FLAGS	0x0A/0x0B	This read-only function returns various battery status information.
Current()	INSTCURR	0x0C/0x0D	This read-only function returns a signed integer value that is the instantaneous current flow through the sense resistor. The value is updated every 1 s. Units are mA.
RemainingCapacity()	RM	0x10/0x11	This read-only command returns the predicted remaining capacity, based on rate (per configured **Load Select**), temperature, present depth-of-discharge, and stored impedance. Values are reported in mAh.
FullChargeCapacity()	FCC	0x12/0x13	This read-only command returns the predicted capacity of the battery at full charge, based on rate (per configured **Load Select**), temperature, present depth-of-discharge, and stored impedance. Values are reported in mAh.
AverageCurrent()	AI	0x14/0x15	This read-only function returns a signed integer value that is the average current flow through the sense resistor. The value is updated every 1 s. Units are mA.
AverageTimeToEmpty()	TTE	0x16/0x17	Uses average current value with a time constant of 15 s for this method. A value of 65,535 means the battery is not being discharged.
AverageTimeToFull()	TTF	0x18/0x19	This read-only function returns a unsigned integer value, predicting time to reach full charge for the battery in units of minutes based on *AverageCurrent()*. The computation accounts for the taper current time extension from a linear TTF computation based on a fixed *AverageCurrent()* rate of charge accumulation. A value of 65,535 indicates the battery is not being charged.
MaxLoadCurrent()	MLI	0x1E/0x1F	This read-only function returns a signed integer value in units of mA of the maximum load current. The *MaxLoadCurrent()* is an adaptive measurement which is initially reported as the maximum load current programmed in **Max Load Current**. If the measured current is ever greater than **Max Load Current**, then the *MaxLoadCurrent()* updates to the new current. *MaxLoadCurrent()* is reduced to the average of the previous value and **Max Load Current** whenever the battery is charged to full after a previous discharge to an RSOC of less than **Max Load Rsoc**. This will prevent the reported value from maintaining an unusually high value.
MaxLoadTimeToEmpty()	MLTTE	0x20/0x21	This read-only function returns a unsigned integer value, predicting remaining battery life at the maximum discharge load current rate in units of minutes. A value of 65,535 indicates that the battery is not being discharged.
AveragePower()	AP	0x22/0x23	This read-only function returns a signed integer value of average power during battery charging and discharging. It is negative during discharge and positive during charge. A value of 0 indicates that the battery is not being discharged. The value is reported in units of mW.
BTPDischargeSet()	BTP	0x24/0x25	This read-/write-word command updates the BTP set threshold for DISCHARGE mode for the next BTP interrupt, deasserts the present BTP interrupt, and clears the *OperationStatus()[BTP_INT]* bit.
BTPChargeSet()	BTP	0x26/0x27	The read-/write-word command updates the BTP set threshold for CHARGE mode for the next BTP interrupt, deasserts the present BTP interrupt, and clears the *OperationStatus()[BTP_INT]* bit.

Table 15-1. Standard Commands (continued)

Name		Register Code (LSB/MSB)	Description
InternalTemperature()	INT_TEMP	0x28/0x29	This read-only function returns an unsigned integer value of the measured internal temperature of the device in 0.1 K units measured by the gas gauge.
CycleCount()	CC	0x2A/0x2B	This read-only function returns an unsigned integer value of the number of cycles the battery has experienced a discharge (range 0 to 65,535). One cycle occurs when accumulated discharge greater than or equal to the cycle count threshold.
RelativeStateOfCharge()	RSOC	0x2C/0x2D	This read-only function returns an unsigned integer value of the predicted remaining battery capacity expressed as percentage of *FullChargeCapacity()* with a range of 0% to 100%.
StateOfHealth()	SOH	0x2E/0x2F	This read-only function returns an unsigned integer value of the battery state-of-health expressed as a percentage of the ratio of predicted FCC (simulated with **SOH Load Rate** at 25°C) over the *DesignCapacity()*. The range is 0% to 100%.
ChargingVoltage()	CV	0x30/0x31	Returns the desired charging voltage in mV to the charger
ChargingCurrent()	CC	0x32/0x33	Returns the desired charging current in mA to the charger
TerminateVoltage()		0x34/0x35	Returns or updates the value of **Terminate Voltage**
TimeStampUpper()		0x36/0x37	Returns or updates the upper 16 bits of the time stamp in seconds
TimeStampLower()		0x38/0x39	Returns or updates the lower 16 bits of the time stamp in seconds
QmaxCycles()		0x3A/0x3B	Returns cycle count at the last QMax update
DesignCapacity()		0x3C/0x3D	In SEALED and UNSEALED access: This command returns the value stored in **Design Capacity mAh**. This is intended to be a theoretical or nominal capacity of a new pack, but should have no bearing on the operation of the gas gauge functionality.
AltManufacturerAccess()		0x3E/0x3F	MAC data block command
MACData()		0x40/0x5F	MAC data block
MACDataSum()		0x60	MAC data block checksum
MACDataLen()		0x61	MAC data block length
VoltHiSetThreshold()		0x62/0x63	This read/write function is a signed integer in units of mV for the high voltage level threshold, which sets *InterruptStatus()[VOLT_HI]*.
VoltHiClearThreshold()		0x64/0x65	This read/write function is a signed integer in units of mV for the high voltage level threshold, which clears *InterruptStatus()[VOLT_HI]*.
VoltLoSetThreshold()		0x66/0x67	This read/write function is a signed integer in units of mV for the low voltage level threshold, which sets *InterruptStatus()[VOLT_LO]*.
VoltLoClearThreshold()		0x68/0x69	This read/write function is a signed integer in units of mV for the low voltage level threshold, which clears *InterruptStatus()[VOLT_LO]*.
TempHiSetThreshold()		0x6A	This read/write function is a signed integer in units of °C for the high temperature level threshold, which sets *InterruptStatus()[TEMP_HI]*.
TempHiClearThreshold()		0x6B	This read/write function is a signed integer in units of °C for the high temperature level threshold, which clears *InterruptStatus()[TEMP_HI]*.
TempLoSetThreshold()		0x6C	This read/write function is a signed integer in units of °C for the low temperature level threshold, which sets *InterruptStatus()[TEMP_LO]*.
TempLoClearThreshold()		0x6D	This read/write function is a signed integer in units of °C for the low temperature level threshold, which clears *InterruptStatus()[TEMP_LO]*.
InterruptStatus()		0x6E	This read-only function returns the status of the interrupt including cause of interrupt.
SOCDeltaSetThreshold()		0x6F	This read/write function is an unsigned char in units of % for the SOC delta level threshold, which clears *InterruptStatus()SOC_DELTA*.

15.1.1 0x00/01 ManufacturerAccess()/ControlStatus()

This read/write word function returns the control bits when read and is an interface to the manufacturer access system (MAC) when written. This command is provided for backward compatibility/ease of use, as all of the control bits except *ControlStatus()[CheckSumValid]* are available in *OperationStatusA()* and *OperationStatusB()* in addition to *AltManufacturerAccess()* being the recommended interface for MAC (as discussed in Section 15.2).

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

RSVD (Bit 15): Reserved

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

        0, 0 = Full Access

        0, 1 = Reserved

<center>1, 0 = Unsealed</center>

<center>1, 1 = Sealed</center>

RSVD (Bit 12): Reserved

RSVD (Bits 11–10): Reserved

CheckSumValid (Bit 9): Checksum valid

<center>1 = Flash Writes are enabled.</center>

<center>0 = Flash Writes are disabled due to low voltage or PF condition.</center>

RSVD (Bits 8–4): Reserved

LDMD (Bit 3): LOAD mode

<center>1 = Constant power</center>

<center>0 = Constant current</center>

RDIS (Bit 2): Resistance updates

<center>1 = Disabled</center>

<center>0 = Enabled</center>

VOK (Bit 1): Voltage OK for QMax update

<center>1 = Detected</center>

<center>0 = Not detected</center>

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

15.1.2 0x02/03 AtRate()

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Default	Unit
		SE	US	FA						
0x02/03	*AtRate()*		R/W		Word	I2	–32768	32767	0	mA

15.1.3 0x04/05 AtRateTimeToEmpty()

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit	Note
		SE	US	FA						
0x04/05	*AtRateTimeToEmpty()*		R		Word	U2	0	65535	min	65535 indicates not being charged

15.1.4 0x06/07 Temperature()

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x06/07	*Temperature()*		R		Word	I2	0	32767	0.1 K

15.1.5 0x08/09 Voltage()

This read-word function returns the measured cell voltage.

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x08/09	*Voltage()*		R		Word	I2	0	32767	mV

15.1.6 0x0A/0B BatteryStatus()

This read-word function returns various battery status information.

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

RSVD (Bit 15): Reserved

TCA (Bit 14): Terminate Charge Alarm

>>> 0 = Inactive

>>> 1 = Active

RSVD (Bits 13–12): Reserved

TDA (Bit 11): Terminate Discharge Alarm

>>> 0 = Inactive

>>> 1 = Active

RSVD (Bit 10): Reserved

RCA (Bit 9): Remaining Capacity Alarm

>>> 0 = Inactive

>>> 1 = Active

RSVD (Bit 8): Reserved

INIT (Bit 7): Initialization

>>> 0 = Complete

>>> 1 = Active

DSG (Bit 6): Discharging

>>> 0 = The battery is charging.

>>> 1 = The battery is discharging.

FC (Bit 5): Fully Charged

>>> 0 = The battery is not fully charged.

>>> 1 = The battery is fully charged.

FD (Bit 4): Fully Discharged

>>> 0 = The battery is okay.

>>> 1 = The battery is fully depleted.

RSVD (Bits 3–0): Reserved

15.1.7 0x0C/0D Current()

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x0C/0D	*Current()*		R		Word	I2	–32768	32767	mA

15.1.8 0x10/11 RemainingCapacity()

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x10/11	*RemainingCapacity()*		R		Word	U2	0	32767	mAh

15.1.9 0x12/13 FullChargeCapacity()

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x12/13	FullChargeCapacity()	R			Word	I2	0	32767	mAh

15.1.10 0x14/15 AverageCurrent()

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x14/15	AverageCurrent()	R			Word	I2	–32767	32768	mA

15.1.11 0x16/17 AverageTimeToEmpty()

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit	Note
		SE	US	FA						
0x16/17	AverageTimeToEmpty()	R			Word	U2	0	65535	min	65535 = The battery is not being discharged.

15.1.12 0x18/19 AverageTimeToFull()

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit	Note
		SE	US	FA						
0x18/19	AverageTimeToFull()	R			Word	U2	0	65535	min	

15.1.13 0x1E/1F MaxLoadCurrent()

This read-word function returns the maximum load current.

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x1E/1F	MaxLoadCurrent()	R			Word	I2	0	65535	mA

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

15.1.14 0x20/21 MaxLoadTimeToEmpty()

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x20/21	MaxLoadTimeToEmpty()	R			Word	I2	0	65535	min

15.1.15 0x22/23 AveragePower()

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x22/23	*AveragePower()*		R		Word	I2	–32768	32767	mW

15.1.16 0x28/29 InternalTemperature()

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x28/29	*InternalTemperature()*		R		Word	I2	0	32767	0.1 K

15.1.17 0x2A/2B CycleCount()

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x2A/2B	*CycleCount()*	R	R		Word	U2	0	65535	cycles

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

15.1.18 0x2C/2D RelativeStateOfCharge()—RSOC

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x2C/2D	*RelativeStateOfCharge()*		R		Word	U1	0	100	%

15.1.19 0x2E/2F StateOfHealth()

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x2E/2F	*StateOfHealth()*		R		Word	U1	0	100	%

15.1.20 0x30/31 ChargingVoltage()

This read-word function returns the desired charging voltage.

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit	Note
		SE	US	FA						
0x30/31	*ChargingVoltage()*	R	R	R	Word	I2	0	32767	mV	32767 = Request maximum voltage

15.1.21 0x32/33 ChargingCurrent()

This read-word function returns the desired charging current.

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit	Note
		SE	US	FA						
0x32/33	ChargingCurrent()	R	R	R	Word	I2	0	32767	mA	32767 = Request maximum current

15.1.22 0x34/35 TerminateVoltage()

This reads or writes the voltage level at which the state-of-charge goes to 0. See **Term Voltage** in Section 7.5.

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit	Note
		SE	US	FA						
0x34/35	TerminateVoltage()	RW	RW	RW	Word	I2	0	32767	mV	

15.1.23 0x36/0x37/0x38/0x39 Timestamp()

This 4-byte value, which is the system runtime in seconds, can be read or written. Always begin the read operation at 0x36 (the LSB) to keep the bytes synchronized during the read by copying the gauge clock to the time stamp registers. The host should read bytes into its 32-byte unsigned integer format in the appropriate endianness. When written by the host, the gauge will update its internal clock on the write to register 0x39.

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit	Note
		SE	US	FA						
0x36/37	TimeStampUpper()	R	RW	RW	Word	U2	0	65535	s	

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit	Note
		SE	US	FA						
0x38/39	TimeStampLower()	R	RW	RW	Word	U2	0	65535	s	

15.1.24 QMax Cycles() 0x3A/3B

This returns the cycle count when QMax was last updated. It is helpful for a host system to compare this to the present *CycleCount()*.

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit	Note
		SE	US	FA						
0x3A/3B	QmaxCycles()	R	R	R	Word	U2	0	65535	—	

15.1.25 0x3C/3D DesignCapacity()

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Default	Unit
		SE	US	FA						
0x3C/3D	DesignCapacity()	R	R/W	R/W	Word	I2	0	32767	5300	mAh
									2040	cWh

15.1.26 0x3E/3F AltManufacturerAccess()

Writes to this command are interchangeable with *AltManufacturerAccess()*. This command is provided to enable an easy way to verify the active MAC command while reading the *MACData()* returned by the MAC. The host may simply read from *AltManufacturerAccess()* to *MACDataLength()* with one block read. For a description of returned data values, see the *AltManufacturerAccess()* version of same command in Section 15.2.

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Default	Unit
		SE	US	FA						
0x3E/3F	AltManufacturerAccess()	R	R	R	Word	—	—	—	—	—

15.1.27 0x40/0x5F MACData()

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Default	Unit
		SE	US	FA						
0x40/5F	*MACData ()*	R	R	R	Block	—	—	—	—	—

15.1.28 0x60 MACDataChecksum()

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

I²C Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x60	*MACDataChecksum()*	R	R	R	Byte	—	—	—	—	—

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

15.1.29 0x61 MACDataLength()

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

I²C Cmd	Name	Access			Protocol	Type	Min	Max	Default	Unit
		SE	US	FA						
0x61	*MACDataLength()*	R	R	R	Byte	—	—	—	—	—

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

15.1.30 0x62/63 VoltHiSetThreshold

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x62/63	*VoltHiSetThreshold()*	R/W	R/W	R/W	Word	I2	0	5000	mV

15.1.31 0x64/65 VoltHiClearThreshold

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x64/65	*VoltHiClearThreshold()*	R/W	R/W	R/W	Word	I2	0	5000	mV

15.1.32 0x66/67 VoltLoSetThreshold

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x66/67	*VoltLoSetThreshold()*	R/W	R/W	R/W	Word	I2	0	5000	mV

15.1.33 0x68/69 VoltLoClearThreshold

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x68/69	*VoltLoClearThreshold()*	R/W	R/W	R/W	Word	I2	0	5000	mV

15.1.34 0x6A TempHiSetThreshold

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x6A	*TempHiSetThreshold()*	R/W	R/W	R/W	Byte	I1	−128	127	°C

15.1.35 0x6B TempHiClearThreshold

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x6B	*TempHiClearThreshold()*	R/W	R/W	R/W	Byte	I1	−128	127	°C

15.1.36 0X6C TempLoSetThreshold

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x6C	*TempLoSetThreshold()*	R/W	R/W	R/W	Byte	I1	−128	127	°C

15.1.37 0x6D TempLoClearThreshold

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

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x6D	*TempLoClearThreshold()*	R/W	R/W	R/W	Byte	I1	−128	127	°C

15.1.38 0x6E InterruptStatus()

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

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

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

RSVD (Bits 7–5): Reserved

SOC_DELTA (Bit 4): RSOC interrupt

      1 = RSOC interrupt set

      0 = RSOC interrupt cleared

TEMP_LO (Bit 3): Low temperature interrupt

      1 = Low temperature interrupt set

      0 = Low temperature interrupt cleared

TEMP_HI (Bit 2): High temperature interrupt

      1 = High temperature interrupt set

      0 = High temperature interrupt cleared

VOLT_LO (Bit 1): Low voltage interrupt

      1 = Low voltage interrupt set

      0 = Low voltage interrupt cleared

VOLT_HI (Bit 0): High voltage interrupt

1 = High voltage interrupt set

0 = High voltage interrupt cleared

15.1.39 0x6F SOCSetDeltaThreshold

This read/write-byte function returns the desired interrupt set threshold for battery RSOC delta.

I²C Cmd	Name	Access			Proto-col	Type	Min	Max	Unit
		SE	US	FA					
0x6F	*SOCSetDeltaThreshold()*	R/W	R/W	R/W	Byte	U1	0	100	%

15.2 0x00, 0x01 ManufacturerAccess() and 0x3E, 0x3F AltManufacturerAccess()

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

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

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

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

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

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

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

Table 15-2. AltManufacturerAccess() Command List

Command	Function	Access	Format	Data Read on MACData()	Available in SEALED Mode	Type	Units
0x0001	DeviceType	R	Block	√	R	hex	—
0x0002	FirmwareVersion	R	Block	√	R	hex	—
0x0003	HardwareVersion	R	Block	√	R	hex	—
0x0004	IFChecksum	R	Block	√	R	hex	—
0x0005	StaticDFSignature	R	Block	√	R	hex	—
0x0006	ChemID	R	Block	√	R	hex	—
0x0007	Prev_MacWrite	R	Block	√	R	hex	—
0x0008	StaticChemDFSignature	R	Block	√	R	hex	—

Table 15-2. AltManufacturerAccess() Command List (continued)

Command	Function	Access	Format	Data Read on MACData()	Available in SEALED Mode	Type	Units
0x0009	AllDFSignature	R	Block	√	R	hex	—
0x000b	ShelfEnable	W	—	—	W	hex	—
0x000c	ShelfDisable	W	—	—	W	hex	—
0x0010	ShutdownMode	W	—	—	W	hex	—
0x0012	Reset	W	—	—	—	hex	—
0x0015	ShipmodeEnable	W	—	—	W	hex	—
0x0016	ShipmodeDisable	W	—	—	W	hex	—
0x0017	QMax Day	R	Block	√	R	U2	days
0x001F	ChargeFETToggle	W	—	—	W	hex	—
0x0020	DischargeFETToggle	W	—	—	W	hex	—
0x0021	Gauging (IT Enable)	W	—	—	—	hex	—
0x0022	FET Enable	W	—	—	—	hex	—
0x0023	LifetimeDataCollection	W	—	—	—	hex	—
0x0028	LifetimeDataReset	W	—	—	—	hex	—
0x002D	CalibrationMode	W	—	—	—	hex	—
0x002E	LifetimeDataFlush	W	—	—	—	hex	—
0x002F	LifetimeDataSpeedUp Mode	W	—	—	—	hex	—
0x0030	SealDevice	W	—	—	—	hex	—
0x0035	SecurityKeys	R/W	Block	√	—	hex	—
0x0041	Reset	W	—	—	—	hex	—
0x0047	TambientSync	W	—	—	W	hex	—
0x004A	Device Name	R	Block	√	R	hex	—
0x004B	Device Chem	R	Block	√	R	hex	—
0x004C	Manufacturer Name	R	Block	√	R	hex	—
0x004D	Manufacture Date	R/W	Block	√	R	hex	—
0x004E	Serial Number	R/W	Word	√	R	hex	—
0x0050	SafetyAlert	R	Block	√	R	hex	—
0x0051	SafetyStatus	R	Block	√	R	hex	—
0x0054	OperationStatus	R	Block	√	R	hex	—
0x0055	ChargingStatus	R	Block	√	R	hex	—
0x0056	GaugingStatus	R	Block	√	R	hex	—
0x0057	ManufacturingStatus	R	Block	√	R	hex	—
0x0060	LifetimeDataBlock1	R	Block	√	R	Mixed	Mixed
0x0061	LifetimeDataBlock2	R	Block	√	R	Mixed	Mixed
0x0062	LifetimeDataBlock3	R	Block	√	R	U4	s
0x0063	LifetimeDataBlock4	R	Block	√	R	Mixed	Mixed
0x0065	LifetimeDataBlock6	R	Block	√	R	Mixed	Mixed
0x0065	LifetimeDataBlock7	R	Block	√	R	Mixed	Mixed
0x0067	LifetimeDataBlock8	R	Block	√	R	Mixed	Mixed
0x0068	LifetimeDataBlock9	R	Block	√	R	Mixed	Mixed
0x0069	LifetimeDataBlock10	R	Block	√	R	Mixed	Mixed
0x006A	LifetimeDataBlock11	R	Block	√	R	Mixed	Mixed
0x006B	LifetimeDataBlock12	R	Block	√	R	Mixed	Mixed
0x0070	ManufacturerInfo	R/W	Block	√	R	hex	—
0x0071	DAStatus1	R	Block	√	R	Mixed	Mixed
0x0072	DAStatus2	R	Block	√	R	Mixed	Mixed
0x0073	ITStatus1	R	Block	√	R	Mixed	Mixed
0x0074	ITStatus2	R	Block	√	R	Mixed	Mixed
0x0075	ITStatus3	R	Block	√	R	Mixed	Mixed
0x0077	FCC_SOH	R	Block	√	R	hex	—
0x0078	Filtered Capacity	R	Block	√	R	hex	Mixed
0x007A	ManufacturerInfoB	R/W	Block	√	R	hex	—
0x007B	ManufacturerInfoC	R/W	Block	√	R/W	hex	—
0x0097	FET Control Override	W	Word	—	W	hex	—

Table 15-2. AltManufacturerAccess() Command List (continued)

Command	Function	Access	Format	Data Read on MACData()	Available in SEALED Mode	Type	Units
0x00A3	System Reset Enable	W	—	—	W	—	—
0x00A4	System Reset	W	—	—	W	—	—
0x00B1	BattSenseOutput	R/W	Block	√	R	hex	—
0x00E0	RaTableCell0	R	Block	√	R	I2	2^{-10} Ω
0x0F00	ROMMode	W	—	—	—	hex	—
0x4000 - 0x5FFF	DataFlashAccess	R/W	Block	√	—	hex	Mixed
0x7C40	SwitchToHDQ	W	—	—	—	hex	—
0xF080	ExitCalibrationOutput	R/W	Block	√	—	hex	—
0xF081	OutputCCandADCforCalibration	R/W	Block	√	—	hex	—
0xF083	OutputTemperatureCal	R/W	Block	√	—	hex	—
0xF0A0	ProtectorCalibration	R/W	Block	√	—	hex	—
0xF0A1	ProtectorImage1	R/W	Block	√	—	hex	—
0xF0A2	ProtectorImage2	R/W	Block	√	—	hex	—
0xF0A3	ProtectorImageSave	R/W	Block	√	—	hex	—
0xF0A4	ProtectorImageLock	R/W	Block	√	—	hex	—
0xF0A5	ProtectorFactoryConfig	R	Block	√	—	hex	—

15.2.1 AltManufacturerAccess() 0x0001 Device Type

The device can be checked for its part number.

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

15.2.2 AltManufacturerAccess() 0x0002 Firmware Version

The device can be checked for its firmware version.

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

15.2.3 AltManufacturerAccess() 0x0003 Hardware Version

The device can be checked for its hardware version.

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

15.2.4 AltManufacturerAccess() 0x0004 Instruction Flash Signature

The device can return the instruction flash signature.

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

15.2.5 AltManufacturerAccess() 0x0005 Static DF Signature

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

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

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

15.2.6 AltManufacturerAccess() 0x0006 Chemical ID

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

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

15.2.7 AltManufacturerAccess() 0x0007 Pre_MACWrite

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

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

15.2.8 AltManufacturerAccess() 0x0008 Static Chem DF Signature

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

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

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

15.2.9 AltManufacturerAccess() 0x0009 All DF Signature

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

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

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

15.2.10 AltManufacturerAccess() 0x000B SHELF Enable

To reduce power consumption further without entering SHUTDOWN mode, the device can be sent to SHELF mode. After receiving *ShelfEnable()*, *OperationStatusB()[SHELFM]* = 1 and an internal counter starts. When

the counter reaches **Shelf Command Delay** seconds, the device enters SHELF mode if |*Current()*| ≤ **Sleep Current**.

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

15.2.11 AltManufacturerAccess() 0x000C SHELF Disable

After receiving *ShelfDisable()*, *OperationStatusB()[SHELFM]* = 0 and the device exits SHELF mode within 1 second. The command has no effect if the device is not in SHELF mode.

15.2.12 AltManufacturerAccess() 0x0010 SHUTDOWN Mode

To reduce power consumption to a minimum, the device can be sent to SHUTDOWN mode. After sending this command, the *OperationStatus()[SDM]* = 1, an internal counter starts and the CHG and DSG FETs turn off when the counter reaches **FET Off Time**. When the counter reaches **Delay** time, the device enters SHUTDOWN mode if no charger present is detected and the ENAB pin is high.

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

To wake up the device, a voltage > $V_{Startup-}$ must apply to the PACK pin or the ENAB pin pulled low. The device powers up and a full reset is applied.

15.2.13 AltManufacturerAccess() 0x0012 Device Reset

This command resets the device.

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

Note

Command 0x0041 also resets the device.

15.2.14 AltManufacturerAccess() 0x0015 SHIP Mode Enable

To reduce power consumption further without entering SHUTDOWN, the device can be sent into SHIP mode. After receiving *ShipmodeEnable()*, *OperationStatusB()[SHIPM]* = 1 and an internal counter starts. When the counter reaches **Shipmode Command Delay** seconds, the device enters SHIP mode if |*Current()*| ≤ **Sleep Current**.

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

15.2.15 AltManufacturerAccess() 0x0016 SHIP Mode Disable

After receiving *ShipmodeDisable()*, *OperationStatusB()[SHIPM]* = 0 and the device exits SHIP mode within 1 second. The command has no effect if the device is not in SHIP mode.

15.2.16 AltManufacturerAccess() 0x0017 QMax Day

Instructs the fuel gauge to return the last day QMax was updated. The value is updated with the *Elapsed Time Count()* converted to days whenever QMax is updated.

15.2.17 AltManufacturerAccess() 0x001F CHG FET Toggle

This command turns on/off the CHG FET drive function to ease testing during manufacturing. If the *ManufacturingStatus()[CHG_TEST]* = 0, sending this command turns on the CHG FET and the *ManufacturingStatus()[CHG_TEST]* = 1 and vice versa. This toggling command is only enabled if

ManufacturingStatus()[FET_EN] = 0 or *ManufacturingStatus()[FET_OVRD]* = 1 when SEALED, indicating FW FET control is not active and manual control is allowed. A reset clears the *[CHG_TEST]* flag and turns off the CHG FET if *ManufacturingStatus()[FET_EN]* = 0.

15.2.18 AltManufacturerAccess() 0x0020 DSG FET Toggle

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

15.2.19 AltManufacturerAccess() 0x0021 Gauging

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

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

15.2.20 AltManufacturerAccess() 0x0022 FET Control

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

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

Note

The firmware FET control state can only be changed while the gauge is in the UNSEALED mode. FETs are closed only if there are no safety violations. When *ManufacturingStatus()[FET_EN]* = 0, the FETs are open and no current flows in or out of the cell.

15.2.21 AltManufacturerAccess() 0x0023 Lifetime Data Collection

This command disables/enables lifetime data collection for manufacturing.

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

15.2.22 AltManufacturerAccess() 0x0028 Lifetime Data Reset

This command resets lifetime data in data flash for manufacturing.

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

15.2.23 AltManufacturerAccess() 0x002D CALIBRATION Mode

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

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

15.2.24 AltManufacturerAccess() 0x002E Lifetime Data Flush

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

15.2.25 AltManufacturerAccess() 0x002F Lifetime Data SPEED UP Mode

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

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

15.2.26 AltManufacturerAccess() 0x0030 Seal Device

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

Status	Condition	Action
Sealed	*OperationStatusA()[SEC1,SEC0]* = 0,1 or 1,0 AND 0x0030 to *AltManufacturerAccess()*	*OperationStatusA()[SEC1,SEC0]* = 1,1 Certain commands are not available. See Table 15-1 for details.

15.2.27 AltManufacturerAccess() 0x0035 Security Keys

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

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

Note

Create each access key to be unique; otherwise, the copy key will not execute the intended function.

Example of changing the Unseal key to 0x0123, 0x4567; the Full Access key to 0x89AB, 0xCDEF; and the Lifetime reset key to 0x2244, 0x2131:

Byte 0: Unseal Key LSW
Byte 1: Unseal Key MSW
Byte 2: Full Access Key LSW
Byte 3: Full Access Key MSW
Byte 4: Lifetime Reset Key LSW
Byte 5: Lifetime Reset Key MSW

Write block: command through *AltManufacturerAccess()* starting address 0x3E:

data block (hex) = [35 00 23 01 67 45 AB 89 EF CD 44 22 31 21].

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

Checksum = 0x52 = ~(0x35 + 0x00 + 0x23 + 0x01 + 0x67 + 0x45 + 0xAB + 0x89 + 0xEF + 0xCD + 0x44 + 0x22 + 0x31 + 0x21). The checksum is the 8-bit sum of the MSB and LSB of the command plus the (command length) bytes in the buffer. The final sum is the bitwise inversion of the result.

15.2.28 AltManufacturerAccess() 0x0041 Device Reset

This command resets the device hardware and firmware. The command causes the FETs to open until initial safety checks are completed by the firmware.

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

Note

Command 0x0012 also resets the device.

15.2.29 AltManufacturerAccess() 0x0047 Tambient Sync

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

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

15.2.30 AltManufacturerAccess() 0x004A Device Name

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

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

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
I2C Configuration	Data	Device Name	S21	—	—	BQ27Z746	ASCII	Assigned pack name

15.2.31 AltManufacturerAccess() 0x004B Device Chem

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

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

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

15.2.32 AltManufacturerAccess() 0x004C Manufacturer Name

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

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

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

15.2.33 AltManufacturerAccess() 0x004D Manufacture Date

This command returns the manufacture date of the pack, as programmed in data flash. This command can be written to update data flash in UNSEALED mode.

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

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

15.2.34 AltManufacturerAccess() 0x004E Serial Number

This command returns the serial number of the pack, as programmed in data flash. This command can be written to update data flash in UNSEALED mode.

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

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

15.2.35 AltManufacturerAccess() 0x0054 OperationStatus

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

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

15.2.35.1 Operation Status A

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SLEEP	XCHG	XDSG	RSVD	SS	SDV	SEC1	SEC0	BTP–INT	SHELF	RSVD	SHIP	ZVCHG	CHG	DSG	SHIPV

SLEEP (Bit 15): SLEEP mode conditions met

    1 = Active

    0 = Inactive

XCHG (Bit 14): Charging disabled

    0 = Inactive

    1 = Active

XDSG (Bit 13): Discharging disabled

    1 = Active

    0 = Inactive

RSVD (Bit 12): Reserved

SS (Bit 11): SAFETY status. This is the ORd value of all the Safety Status bits.

    1 = Active

    0 = Inactive

SDV (Bit 10): SHUTDOWN mode triggered from a low cell voltage

    1 = Active

    0 = Inactive

SEC1, SEC0 (Bits 9, 8): SECURITY mode

> 0, 0 = Reserved

> 0, 1 = Full Access

> 1, 0 = Unsealed

> 1, 1 = Sealed

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

> See Section 7.11 for details.

SHELF (Bit 6): SHELF mode

> 1 = Active

> 0 = Inactive

RSVD (Bit 5): Reserved

SHIP (Bit 4): SHIP mode

> 1 = Active

> 0 = Inactive

ZVCHG (Bit 3): Zero-volt (low voltage) charging status

> 1 = Active

> 0 = Inactive

CHG (Bit 2): CHG FET status

> 1 = Active

> 0 = Inactive

DSG (Bit 1): DSG FET status

> 1 = Active

> 0 = Inactive

SHIPV (Bit 0): SHIP mode triggered via low cell voltage

> 1 = Active

> 0 = Inactive

15.2.35.2 Operation Status B

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

SHELFV (Bit 15): SHELF mode triggered through low cell voltage

> 1 = Active

> 0 = Inactive

SHIPM (Bit 14): SHIP mode triggered through command

> 1 = Active

> 0 = Inactive

RSVD (Bits 13–11): Reserved

SLPAD (Bit 10): ADC measurement in SLEEP, SHIP, or SHELF mode

> 1 = Active

> 0 = Inactive

RSVD (Bit 9): Reserved

INIT (Bit 8): Initialization after full reset

1 = Active

0 = Inactive

SHELFM (Bit 7): SHELF mode triggered through command

1 = Active

0 = Inactive

XL (Bit 6): 400-kHz mode

1 = Active

0 = Inactive

RSVD (Bit 5): Reserved

CAL (Bit 4): Calibration output (raw ADC and CC data)

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

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

RSVD (Bit 3): Reserved

AUTH (Bit 2): Authentication in progress

1 = Active

0 = Inactive

RSVD (Bit 1): Reserved

SDM (Bit 0): SHUTDOWN mode triggered through command

1 = Active

0 = Inactive

15.2.36 AltManufacturerAccess() 0x0055 ChargingStatus

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

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

15.2.36.1 Temp Range

Temp Range status bits indicate the current operating temperature range.

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

RSVD (Bit 7): Reserved

OT (Bit 6): Overtemperature range

1 = Temperature > T4

0 = Inactive

HT (Bit 5): High temperature range

1 = T3 < Temperature < T4

0 = Inactive

STH (Bit 4): Standard temperature high range

1 = T6 < Temperature < T3

0 = Inactive

RT (Bit 3): Recommended temperature range

        1 = T5 < Temperature < T6

        0 = Inactive

STL (Bit 2): Standard temperature low range

        1 = T2 < Temperature < T5

        0 = Inactive

LT (Bit 1): Low temperature range

        1 = T1 < Temperature < T2

        0 = Inactive

UT (Bit 0): Undertemperature range

        1 = Temperature < T1

        0 = Inactive

15.2.36.2 Charging Status

Charging Status bits indicate various status bits related to charging.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RSVD	RSVD	RSVD	RSVD	NCT	RSVD	CV_D GRD1	CV_D GRD0	VCT	RSVD	SU	IN	HV	MV	LV	PV

RSVD (Bits 15–12): Reserved

NCT (Bit 11): NCT

        1 = Active

        0 = Inactive

RSVD (Bit 10): Reserved

CV_DGRD (Bits 9–8): Charge degradation

        0,0 = No degradation

        0,1 = Mode 1

        1,0 = Mode 2

        1,1 = Mode 3

VCT (Bit 7): Charge termination

        1 = Active

        0 = Inactive

RSVD (Bit 6): Reserved

SU (Bit 5): Charge suspend

        1 = Active

        0 = Inactive

IN (Bit 4): Charge inhibit

        1 = Active

        0 = Inactive

HV (Bit 3): High voltage region

        1 = Active

        0 = Inactive

MV (Bit 2): Mid voltage region

        1 = Active

0 = Inactive

LV (Bit 1): Low voltage region

1 = Active

0 = Inactive

PV (Bit 0): Precharge voltage region

1 = Active

0 = Inactive

15.2.37 AltManufacturerAccess() 0x0056 GaugingStatus

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

Note

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

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

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	QMA XDOD OK	OCV FR	LDMD	RX	QMax	VDQ

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
NSFM	OCVP RED	SLP QMax	QEN	VOK	RDIS	RSVD	REST	RSVD	DSG	EDV	RSVD	TC	TD	FC	FD

RSVD (Bits 31–22): Reserved. Do not use.

QMAXDODOK (Bit 21): Indicates whether the DOD is outside the cell chemistry's voltage flat zone. QMax updates do not happen if DOD is in the flat zone.

1 = Outside the flat zone

0 = In the flat zone

OCVFR (Bit 20): Open circuit voltage in flat region (during RELAX)

1 = Detected

0 = Not detected

LDMD (Bit 19): LOAD mode

1 = Constant power

0 = Constant current

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

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

VDQ (Bit 16): Discharge qualified for learning (based on RU flag)

NSFM (Bit 15): Negative scale factor mode

1 = Negative Ra scaling factor detected

0 = Negative Ra scaling factor not detected

OCVPRED (Bit 14): Open-circuit-voltage predicted

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1 = Fast OCV prediction is performed in RELAX mode.

0 = Fast OCV prediction is not performed or not in RELAX mode.

SLPQMax (Bit 13): QMax update during sleep

1 = Active

0 = Inactive

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

1 = Enabled

0 = Disabled

VOK (Bit 11): Voltage OK for QMax update

1 = Detected

0 = Not detected

RDIS (Bit 10): Resistance updates

1 = Disabled

0 = Enabled

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

REST (Bit 8): Rest

1 = The OCV reading is taken.

0 = The OCV reading is not taken or is not in RELAX mode.

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

DSG (Bit 6): Discharge/relax

1 = Charging not detected

0 = Charging detected

EDV (Bit 5): End-of-discharge termination voltage

1 = Termination voltage reached during discharge

0 = Termination voltage not reached or not in DISCHARGE mode

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

TC (Bit 3): Terminate charge

1 = Detected

0 = Not detected

TD (Bit 2): Terminate discharge

1 = Detected

0 = Not detected

FC (Bit 1): Fully charged

1 = Detected

0 = Not detected

FD (Bit 0): Fully discharged

1 = Detected

0 = Not detected

15.2.38 AltManufacturerAccess() 0x0057 ManufacturingStatus

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

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

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

7	6	5	4	3	2	1	0
RSVD	RSVD	LF_EN	FET_EN	GAUGE_EN	DSG_TEST	CHG_TEST	RSVD

CAL_EN (Bit 15): CALIBRATION mode

    1 = Enabled

    0 = Disabled

LT_TEST (Bit 14): LIFETIME SPEED UP mode

    1 = Enabled

    0 = Disabled

RSVD (Bits 13–6): Reserved

LF_EN (Bit 5): Lifetime data collection

    1 = Enabled

    0 = Disabled

RSVD (Bit 4): Reserved

GAUGE_EN (Bit 3): Gas gauging

    1 = Enabled

    0 = Disabled

RSVD (Bits 2–0): Reserved

15.2.39 AltManufacturerAccess() 0x0060 Lifetime Data Block 1

This command returns the lifetime data in RAM on *MACData()* with the following format:

aaAAbbBBccCCddDDeeEEffFFGGHHIIJJ.

Value	Description
AAaa	Cell 1 Max Voltage
BBbb	Cell 1 Min Voltage
CCcc	Max Charge Current
DDdd	Max Discharge Current
EEee	Max Avg Dsg Current
FFff	Max Avg Dsg Power
GG	Max Temp Cell
HH	Min Temp Cell
II	Max Temp Int Sensor
JJ	Min Temp Int Sensor

15.2.40 AltManufacturerAccess() 0x0061 Lifetime Data Block 2

This command returns the lifetime data in RAM on *MACData()* with the following format:

AABBCCDD.

Value	Description
AA	No Of Shutdowns
BB	No Of Partial Resets
CC	No Of Full Resets
DD	No Of Wdt Reset

15.2.41 AltManufacturerAccess() 0x0062 Lifetime Data Block 3

This command returns the lifetime data in RAM on *MACData()* with the following format:

aaAAbbBBccCCddDDeeEEffFF

Value	Description
BBbbAAaa	Total Fw Runtime
DDddCCcc	Total Charge time
FFffEEee	Total Discharge time

15.2.42 ManufacturerAccess() 0x0063 Lifetime Data Block 4

This command returns the lifetime data in RAM with the following format:

aaAAbbBBccCCddDDeeEEffFFggGGhhHHiiIIjjJJkkKKllLLmmMMnnNNooOOppPP.

Value	Description
AAaa	No Of COV Events
BBbb	Last COV Event
CCcc	No Of CUV Events
DDdd	Last CUV Event
EEee	No Of OCD Events
FFff	Last OCD Event
GGgg	No Of OCC Events
HHhh	Last OCC Event
IIii	No Of UTC Events
JJjj	Last UTC Event
KKkk	No Of HSCD Events
LLll	Last HSCD Event
MMmm	No Of UTD Events
NNnn	Last UTD Event
OOoo	No Of OTC Events
PPpp	Last OTC Event

15.2.43 ManufacturerAccess() 0x0064 Lifetime Data Block 5

This command returns the lifetime data in RAM with the following format:

aaAAbbBBccCCddDDeeEEffFFggGGhhHHiiIIjjJJkkKKllLLmmMMnnNNooOOppPP.

Value	Description
AAaa	No Of OTD Events
BBbb	Last OTD Event
CCcc	No Of OTF Events
DDdd	Last OTF Event
EEee	No Valid Charge Term
FFff	Last Valid Charge Term
GGgg	No Of Qmax Updates
HHhh	Last Qmax Update

Value	Description
IIii	No Of Ra Updates
JJjj	Last Ra Update
KKkk	No Of Ra Disable
LLll	Last Ra Disable
MMmm	No Of PTO Events
NNnn	Last PTO Event
OOoo	No Of CTO Events
PPpp	Last CTO Event

15.2.44 AltManufacturerAccess() 0x0065–0x006B Lifetime SOC Range Table Data Blocks

These commands return the lifetime data in RAM on *MACData()*. See Table 8-1 for more information on the collected time based data.

Each block access returns data, as indicated below, where MAC 0x0065 returns SOC range one, MAC 0x0066 returns SOC range two, and so on:

aaAAbbBBCCccDDddEEeeFFffGGggHHhhIIiiJJjjKKkkLLllMMmmNNnnOOooPPpp.

Value	Description
BBbbAAaa	Seconds at temperature range 1 at SOC range = (MAC number – 0x0064)
DDddCCcc	Seconds at temperature range 2 at SOC range = (MAC number – 0x0064)
FFffEEee	Seconds at temperature range 3 at SOC range = (MAC number – 0x0064)
HHhhGGgg	Seconds at temperature range 4 at SOC range = (MAC number – 0x0064)
JJjjIIii	Seconds at temperature range 5 at SOC range = (MAC number – 0x0064)
LLllKKkk	Seconds at temperature range 6 at SOC range = (MAC number – 0x0064)
NNnnMMmm	Seconds at temperature range 7 at SOC range = (MAC number – 0x0064)
PPppOOoo	Seconds at temperature range 8 at SOC range = (MAC number – 0x0064)

15.2.45 AltManufacturerAccess() 0x006C Lifetime Data Block 13

This command returns the lifetime data in RAM with the following format:

aaAAbbBBccCCddDDeeEEffFFggGGhhHHiiIIjjJJkkKKllLL.

Value	Description
AAaa	Unused
BBbb	Unused
CCcc	No Full Discharge
DDdd	Last Full Discharge
EEee	No Of HCOV Events
FFff	Last HCOV Event
GGgg	No Of HCUV Events
HHhh	Last HCUV Event
IIii	No Of HOCC Events
JJjj	Last HOCC Event
KKkk	No Of HOCD Events
LLll	Last HOCD Event

15.2.46 AltManufacturerAccess() 0x0070 ManufacturerInfo

This command reads or writes the data flash values of *Manufacturer Info Block A01* through *Manufacturer Info Block A32* on *MACData()*. Writes are only available in UNSEALED mode.

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

Class	Subclass	Name	Type	Min	Max	Default	Unit
System Data	Manufacturer Data	Manufacturer Info Block A01	H1	0x00	0xFF	0x61	—
System Data	Manufacturer Data	Manufacturer Info Block A02	H1	0x00	0xFF	0x62	—
System Data	Manufacturer Data	Manufacturer Info Block A03	H1	0x00	0xFF	0x63	—
System Data	Manufacturer Data	Manufacturer Info Block A04	H1	0x00	0xFF	0x64	—
System Data	Manufacturer Data	Manufacturer Info Block A05	H1	0x00	0xFF	0x65	—
System Data	Manufacturer Data	Manufacturer Info Block A06	H1	0x00	0xFF	0x66	—
System Data	Manufacturer Data	Manufacturer Info Block A07	H1	0x00	0xFF	0x67	—
System Data	Manufacturer Data	Manufacturer Info Block A08	H1	0x00	0xFF	0x68	—
System Data	Manufacturer Data	Manufacturer Info Block A09	H1	0x00	0xFF	0x69	—
System Data	Manufacturer Data	Manufacturer Info Block A10	H1	0x00	0xFF	0x6A	—
System Data	Manufacturer Data	Manufacturer Info Block A11	H1	0x00	0xFF	0x6B	—
System Data	Manufacturer Data	Manufacturer Info Block A12	H1	0x00	0xFF	0x6C	—
System Data	Manufacturer Data	Manufacturer Info Block A13	H1	0x00	0xFF	0x6D	—
System Data	Manufacturer Data	Manufacturer Info Block A14	H1	0x00	0xFF	0x6E	—
System Data	Manufacturer Data	Manufacturer Info Block A15	H1	0x00	0xFF	0x6F	—
System Data	Manufacturer Data	Manufacturer Info Block A16	H1	0x00	0xFF	0x70	—
System Data	Manufacturer Data	Manufacturer Info Block A17	H1	0x00	0xFF	0x71	—
System Data	Manufacturer Data	Manufacturer Info Block A18	H1	0x00	0xFF	0x72	—
System Data	Manufacturer Data	Manufacturer Info Block A19	H1	0x00	0xFF	0x73	—
System Data	Manufacturer Data	Manufacturer Info Block A20	H1	0x00	0xFF	0x74	—
System Data	Manufacturer Data	Manufacturer Info Block A21	H1	0x00	0xFF	0x75	—
System Data	Manufacturer Data	Manufacturer Info Block A22	H1	0x00	0xFF	0x76	—
System Data	Manufacturer Data	Manufacturer Info Block A23	H1	0x00	0xFF	0x77	—
System Data	Manufacturer Data	Manufacturer Info Block A24	H1	0x00	0xFF	0x7A	—
System Data	Manufacturer Data	Manufacturer Info Block A25	H1	0x00	0xFF	0x78	—
System Data	Manufacturer Data	Manufacturer Info Block A26	H1	0x00	0xFF	0x79	—
System Data	Manufacturer Data	Manufacturer Info Block A27	H1	0x00	0xFF	0x30	—
System Data	Manufacturer Data	Manufacturer Info Block A28	H1	0x00	0xFF	0x31	—
System Data	Manufacturer Data	Manufacturer Info Block A29	H1	0x00	0xFF	0x32	—
System Data	Manufacturer Data	Manufacturer Info Block A30	H1	0x00	0xFF	0x33	—
System Data	Manufacturer Data	Manufacturer Info Block A31	H1	0x00	0xFF	0x34	—
System Data	Manufacturer Data	Manufacturer Info Block A32	H1	0x00	0xFF	0x35	—

15.2.47 AltManufacturerAccess() 0x0071 DAStatus1

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

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

15.2.48 AltManufacturerAccess() 0x0072 DAStatus2

This command returns the internal temperature sensor, TS1 temperature, TS2 temperature, cell temperature, FET temperature, and raw cell voltage and current on *MACData()*.

Status	Condition	Action
Activate	0x0072 to *AltManufacturerAccess()*	Outputs 20 bytes of temperature data values on *MacData()* in the following format: aaAAbbBBccCCddDDeeEEffFFggGGhhHHiiIIjjJJ where: AAaa: Int Temperature BBbb: TS1 Temperature CCcc: TS2 Temperature DDdd: EEee: FFff: Cell Temperature GGgg: FET Temperature HHhh: Cell Raw Voltage IIii: Cell Raw Current JJjj:

15.2.49 AltManufacturerAccess() 0x0073 ITStatus1

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

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

15.2.50 AltManufacturerAccess() 0x0074 ITStatus2

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

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

15.2.51 AltManufacturerAccess() 0x0075 ITStatus3

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

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

15.2.52 AltManufacturerAccess() 0x0077 FCC_SOH

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

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

15.2.53 AltManufacturerAccess() 0x0078 Filtered Capacity

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

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

15.2.54 AltManufacturerAccess() 0x007A ManufacturerInfoB

This command reads or writes the data flash values of **Manufacturer Info Block B01** through **Manufacturer Info Block B32** on *MACData()*. Writes are only available in UNSEALED mode.

Status	Condition	Action
Activate	0x007A to *AltManufacturerAccess()*	Outputs 32 bytes of Manufacturer Info on *MACData()* in the following format: AABBCCDDEEFFGGHHIIJJKKLLMMNN OOPPQQRRSSTTUUVVWWXXVVZZ112233445566

Class	Subclass	Name	Type	Min	Max	Default	Unit
System Data	Manufacturer Info B	Manufacturer Info Block B01	H1	0x00	0xFF	0x61	—
System Data	Manufacturer Info B	Manufacturer Info Block B02	H1	0x00	0xFF	0x62	—
System Data	Manufacturer Info B	Manufacturer Info Block B03	H1	0x00	0xFF	0x63	—
System Data	Manufacturer Info B	Manufacturer Info Block B04	H1	0x00	0xFF	0x64	—
System Data	Manufacturer Info B	Manufacturer Info Block B05	H1	0x00	0xFF	0x65	—
System Data	Manufacturer Info B	Manufacturer Info Block B06	H1	0x00	0xFF	0x66	—
System Data	Manufacturer Info B	Manufacturer Info Block B07	H1	0x00	0xFF	0x67	—
System Data	Manufacturer Info B	Manufacturer Info Block B08	H1	0x00	0xFF	0x68	—
System Data	Manufacturer Info B	Manufacturer Info Block B09	H1	0x00	0xFF	0x69	—
System Data	Manufacturer Info B	Manufacturer Info Block B10	H1	0x00	0xFF	0x6A	—
System Data	Manufacturer Info B	Manufacturer Info Block B11	H1	0x00	0xFF	0x6B	—
System Data	Manufacturer Info B	Manufacturer Info Block B12	H1	0x00	0xFF	0x6C	—
System Data	Manufacturer Info B	Manufacturer Info Block B13	H1	0x00	0xFF	0x6D	—
System Data	Manufacturer Info B	Manufacturer Info Block B14	H1	0x00	0xFF	0x6E	—

Class	Subclass	Name	Type	Min	Max	Default	Unit
System Data	Manufacturer Info B	Manufacturer Info Block B15	H1	0x00	0xFF	0x6F	—
System Data	Manufacturer Info B	Manufacturer Info Block B16	H1	0x00	0xFF	0x70	—
System Data	Manufacturer Info B	Manufacturer Info Block B17	H1	0x00	0xFF	0x71	—
System Data	Manufacturer Info B	Manufacturer Info Block B18	H1	0x00	0xFF	0x72	—
System Data	Manufacturer Info B	Manufacturer Info Block B19	H1	0x00	0xFF	0x73	—
System Data	Manufacturer Info B	Manufacturer Info Block B20	H1	0x00	0xFF	0x74	—
System Data	Manufacturer Info B	Manufacturer Info Block B21	H1	0x00	0xFF	0x75	—
System Data	Manufacturer Info B	Manufacturer Info Block B22	H1	0x00	0xFF	0x76	—
System Data	Manufacturer Info B	Manufacturer Info Block B23	H1	0x00	0xFF	0x77	—
System Data	Manufacturer Info B	Manufacturer Info Block B24	H1	0x00	0xFF	0x7A	—
System Data	Manufacturer Info B	Manufacturer Info Block B25	H1	0x00	0xFF	0x78	—
System Data	Manufacturer Info B	Manufacturer Info Block B26	H1	0x00	0xFF	0x79	—
System Data	Manufacturer Info B	Manufacturer Info Block B27	H1	0x00	0xFF	0x30	—
System Data	Manufacturer Info B	Manufacturer Info Block B28	H1	0x00	0xFF	0x31	—
System Data	Manufacturer Info B	Manufacturer Info Block B29	H1	0x00	0xFF	0x32	—
System Data	Manufacturer Info B	Manufacturer Info Block B30	H1	0x00	0xFF	0x33	—
System Data	Manufacturer Info B	Manufacturer Info Block B31	H1	0x00	0xFF	0x34	—
System Data	Manufacturer Info B	Manufacturer Info Block B32	H1	0x00	0xFF	0x35	—

15.2.55 AltManufacturerAccess() 0x007B ManufacturerInfoC

This command reads or writes the data flash values of *Manufacturer Info Block C01* through *Manufacturer Info Block C32* on *MACData()*. Data is organized with default values such as, for example, Info Block B in its table. Writes are available in SEALED mode when *I2C Configuration[MFG_C_SEALED]* = 1.

15.2.56 AltManufacturerAccess() 0x0097 FET Control Override

Use this command to temporarily allow the host system to toggle FETs on a SEALED gauge where the *[FET_EN]* bit was set. A FET cannot be closed if a safety limit is violated. The FETs are toggled using the *AltManufacturerAccess() 0x001F/0x0020* FET toggle commands. This word write command is protected by requiring the correct code word to be sent to command 0x40 first (writing to *0x60 MACDataChecksum()* and *0x61 MACDataLength()* is not required) and then to 0x3E. That code word is 0xb25c. Both the code word and command must be sent as little endian.

Note

After enabling FET Control Override using this command, the FETs open and remain open until the *AltManufacturerAccess() 0x001F/0x0020* FET toggle commands are received due to *ManufacturingStatus()[CHG_TEST]* and *ManufacturingStatus()[DSG_TEST]* initially being clear.

This command has an associated timer, *FET OVRD Time*. While the timer is counting down, the FETs can be toggled and *ManufacturingStatus()[FET_OVRD]* is set. When the timer expires, *ManufacturingStatus() [FET_OVRD]*, *ManufacturingStatus()[CHG_TEST]*, and *ManufacturingStatus()[DSG_TEST]* all clear.

15.2.57 AltManufacturerAccess() 0x00A3 System Reset Enable

Signals the device to prepare to open the discharge FET. The signal is only held for two seconds. This signal must be asserted for the device to open the FET with *AltManufacturerAccess()* System Reset.

15.2.58 AltManufacturerAccess() 0x00A4 System Reset

The BQ27Z746 device opens the discharge FET when no charging is present and the enable signal timer has not expired. The FET remains open until *Dsg FET Off Time* expires. The feature is disabled by setting *Dsg FET Off Time* to zero.

15.2.59 AltManufacturerAccess() 0x00B0 ChargingVoltageOverride

This command enables writing the five advanced charge algorithm charging voltage values in SEALED mode to data flash in the following format: aaAAbbBBccCCddDDeeEE where:

Value	Description	Unit
AAaa	Low Temperature Charging Voltage	mV
BBbb	Standard Temperature Low Charging Voltage	mV
CCcc	Standard Temperature High Charging Voltage	mV
DDdd	High Temperature Charging Voltage	mV
EEee	Recommended Temperature Charging Voltage	mV

15.2.60 AltManufacturerAccess() 0x00B1 BattSenseOutput

This read-write command reports the configuration and status of the battery sensing output (BAT_SP and BAT_SN pins) in UNSEALED and SEALED modes.

The lower byte contains the real-time configuration of the battery sensing output. The upper byte contains the status of protection events on BAT_SP (BCP, BDP) and BAT_SN (BCN, BDN), which detect short-circuits to either PACK+ or PACK-.

While *BattSenseOutput()[MANUAL]* = 0, the configuration of the battery sensing output updates automatically and is reflected in *BattSenseOutput()*.

While *BattSenseOutput()[MANUAL]* = 1, the configuration of the battery sensing output updates based on writes to *BattSenseOutput()*. The exception to *BattSenseOutput()[MANUAL]* = 1 is that the device automatically updates the configuration to a high impedance state during protection events. When *BattSenseOutput()[MANUAL]* changes from 1 to 0, the remaining bits in *BattSenseOutput()* are ignored and the battery sensing output returns to HIZ mode, as described in Table 5-1.

The lower byte of *BattSenseOutput()* is only writeable in UNSEALED mode.

15	14	13	12	11	10	9	8
RSVD	RSVD	RSVD	RSVD	BCP	BDP	BCN	BDN

7	6	5	4	3	2	1	0
MANUAL	RLO_P_EN	RLO_N_EN	RLO_SEL	BUF_P_EN	BUF_N_EN	BUF_REF_1	BUF_REF_0

RSVD (Bits 15–12): Reserved. Do not use.

BCP (Bit 11): BAT_SP to PACK+ short detection

    1 = Short between BAT_SP and PACK+ detected

    0 = Short between BAT_SP and PACK+ not detected

BDP (Bit 10): BAT_SP to PACK– short detection

    1 = Short between BAT_SN and PACK– detected

    0 = Short between BAT_SN and PACK– not detected

BCN (Bit 9): BAT_SN to PACK+ short detection

    1 = Short between BAT_SN and PACK+ detected

    0 = Short between BAT_SN and PACK+ not detected

BDN (Bit 8): BAT_SN to PACK– short detection

    1 = Short between BAT_SN and PACK– detected

    0 = Short between BAT_SN and PACK– not detected

MANUAL (Bit 7): Battery sensing output manual mode

1 = Enable manual mode

0 = Disable manual mode (automatic mode)

RLO_P_EN (Bit 6): Low resistor (RLO) enable on BAT_SP

1 = Enable low resistor between BAT and BAT_SP

0 = Disable low resistor between BAT and BAT_SP

RLO_N_EN (Bit 5): Low resistor (RLO) enable on BAT_SN

1 = Enable low resistor between VSS and BAT_SN

0 = Disable low resistor between VSS and BAT_SN

RLO_SEL (Bit 4): Resistance of low resistors (RLO)

1 = 200 Ω

0 = 510 Ω

BUF_P_EN (Bit 3): Buffer enable on BAT_SP

1 = Enable buffer between BAT and BAT_SP

0 = Disable buffer between BAT and BAT_SP

BUF_N_EN (Bit 2): Buffer enable on BAT_SN

1 = Enable buffer between VSS and BAT_SN

0 = Disable buffer between VSS and BAT_SN

BUF_REF_1, BUF_REF_0 (Bits 1–0): Voltage offset of buffers

1, 1 = 600 mV

1, 0 = 400 mV

0, 1 = 200 mV

0, 0 = 0 mV

15.2.61 AltManufacturerAccess() 0x00E0 Ra Table Cell0

This read-only command returns the data flash values of **Cell0 R_a 0...14** or **xCell0 R_a 0...14** on *MACData()*, depending which Ra table is presently being used. Reads are available in all security modes, including SEALED.

Status	Condition	Action
Activate	0x00E0 to *AltManufacturerAccess()*	Outputs 30 bytes of the presently used Ra table in data flash on *MACData()* in the following format: aaAAbbBBccCCddDDeeEEffFFggGGhhHHiiIIjjJJkkKKllLLmmMMnnNN ooOO AAaa: **Cell0 R_a 0** or **xCell0 R_a 0** BBbb: **Cell0 R_a 1** or **xCell0 R_a 1** CCcc: **Cell0 R_a 2** or **xCell0 R_a 2** DDdd: **Cell0 R_a 3** or **xCell0 R_a 3** EEee: **Cell0 R_a 4** or **xCell0 R_a 4** FFff: **Cell0 R_a 5** or **xCell0 R_a 5** GGgg: **Cell0 R_a 6** or **xCell0 R_a 6** HHhh: **Cell0 R_a 7** or **xCell0 R_a 7** IIii: **Cell0 R_a 8** or **xCell0 R_a 8** JJjj: **Cell0 R_a 9** or **xCell0 R_a 9** KKkk: **Cell0 R_a 10** or **xCell0 R_a 10** LLll: **Cell0 R_a 11** or **xCell0 R_a 11** MMmm: **Cell0 R_a 12** or **xCell0 R_a 12** NNnn: **Cell0 R_a 13** or **xCell0 R_a 13** OOoo: **Cell0 R_a 14** or **xCell0 R_a 14**

15.2.62 AltManufacturerAccess() 0x0F00 ROM Mode

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

Status	Condition	Action
ROM Mode	*OperationStatusA()[SEC1,SEC0]* = 0,1 AND 0x0F00 to *AltManufacturerAccess()*	The device goes into ROM mode to prepare for updates. The ROM command 0x08 returns it to FIRMWARE mode. (Note: ROM commands are sent to address 0x16 using the I²C protocol.)

15.2.63 Data Flash Access() 0x4000–0x5FFF

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

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

Write to DF example:

Assuming: data1 locates at address 0x4000 and data2 locates at address 0x4002.

Both data1 and data2 are U2 type.

To update data1 and data2, send a block write with command = 0x3E

block = starting address + DF data block

= 0x00 + 0x40 + data1_LowByte + data1_HighByte + data2_LowByte + data2_HighByte

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

Read from DF example:

Taking the same assuming from the read DF example, to read DF:

a. Send the write block with command 0x3E, block = 0x00 + 0x40

b. Send the read block with command 0x3E

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

= 0x00 + 0x40 + data1_LowByte + data1_HighByte + data2_LowByte + data2_HighByte.... data32_LowByte + data32_HighByte

The gauge supports an auto-increment on the address during a DF read. This greatly reduces the time required to read out the entire DF. To trigger auto-increment on the address during DF reads, follow the example above, but read from *AltManufacturerAccess()* through *MACDataLength()* for a total of 36 bytes. If another read block is performed starting from *AltManufacturerAccess()*, the gauge returns another 32 bytes of DF data, starting with address 0x4020.

15.2.64 AltManufacturerAccess() 0x7C40 Switch to HDQ

This command PERMANENTLY switches the device's communication protocol from I²C to HDQ.

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

Note

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

15.2.65 AltManufacturerAccess() 0xF080 Exit Calibration Output Mode

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

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

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

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

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

15.2.67 AltManufacturerAccess() 0xF083 OutputTemperatureCal

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

Status	Condition
Disable	*ManufacturingStatus()[CAL_EN]* = 1 AND 0xF080 to *AltManufacturerAccess()*

Action: *OperationStatus()[CAL]* = 0, *[CAL_OFFSET]* = 0
Stops output of raw temperature values on *MACData()*

Status	Condition
Enable	0xF083 to *AltManufacturerAccess()*

Action: *OperationStatus()[CAL]* = 1, *[CAL_OFFSET]* = 0
Outputs the raw temperature values on *MACData()* in the format of ZZaaAAbbBBccCCddDDeeEE:

Value	Description
ZZ	Rolling 8-bit counter, increments when values are refreshed
AAaa	Internal Temperature
BBbb	TS1 External Temperature
CCcc	TS2 External Temperature
DDdd	Reserved
EEee	Reserved

15.2.68 AltManufacturerAccess() 0xF0A0 ProtectorCalibration

When written, this command calibrates the threshold of a protector channel to the presently applied voltage if *ManufacturingStatus()[CAL_EN]* = 1 and the device is in UNSEALED or FULL ACCESS mode. In addition to the command, a three byte payload is required: Channel Value + Fault Count LSB + Fault Count MSB.

Channel Name	Channel Value	Fault Count Min	Fault Count Max	Description
I-WAKE	0	0x0000	0x0007	Current Wake-Up in Discharge
OCD	1	0x0000	0x00FF	Overcurrent in Discharge
SCD	2	0x0000	0x0007	Short-Circuit Current in Discharge
OCC	3	0x0000	0x001F	Overcurrent in Charge
UVP	4	0x0000	0x007F	Undervoltage Protection
OVP	5	0x0000	0x0FFF	Overvoltage Protection
BDP	6	0x0000	0x003F	BAT_SP Overcurrent in Discharge
BCP	7	0x0000	0x003F	BAT_SP Overcurrent in Charge
BDN	8	0x0000	0x003F	BAT_SN Overcurrent in Discharge
BCN	9	0x0000	0x003F	BAT_SN Overcurrent in Charge

After the command is written to and executed by the device, a status byte can be read from *MACData()* to indicate success or failure.

Status Byte	Description
0x00	Success
0x01	Invalid channel value
0x02	Fault count out of range
0x03	Protector hardware registers locked
0x04	Failed to calibrate protector threshold

15.2.69 AltManufacturerAccess() 0xF0A1 ProtectorImage1

This read-write command is only accessible if *ManufacturingStatus()[CAL_EN]* = 1 and the device is in UNSEALED or FULL ACCESS mode. When read, the command returns the first block of protector hardware registers to *MACData()*. This register block is the first part of the protector configuration image. When written, the command directly updates the first block of protector hardware registers to immediately affect device operation.

Offset	Name	Description
0-9	RSVD	Reserved
10	CNT_SCD	Fault count for SCD
11	CNT_OCD	Fault count for OCD
12	CNT_OCC	Fault count for OCD
13	CNT_OVP_LSB	Fault count for OVP (LSB)
14	CNT_OVP_MSB	Fault count for OVP (MSB)
15	CNT_UVP	Fault count for UVP
16	CNT_IWAKE	Fault count for I-WAKE
17	CNT_BATS	Fault count for BDP, BCP, BDN, BCN

15.2.70 AltManufacturerAccess() 0xF0A2 ProtectorImage2

This read-write command is only accessible if *ManufacturingStatus()[CAL_EN]* = 1 and the device is in UNSEALED or FULL ACCESS mode. When read, the command returns the second block of protector hardware registers to *MACData()*. This register block is the second part of the protector configuration image. When written, the command directly updates the second block of protector hardware registers to immediately affect device operation.

Offset	Name	Description
0–9	RSVD	Reserved
10	CREF_SCD	Trim for SCD
11	CREF_OCD	Trim for OCD
12	CREF_OCC	Trim for OCC
13	CREF_OVP	Trim for OVP
14	CREF_UVP	Trim for UVP
15	CREF_IWAKE	Trim for I-WAKE
16	CREF_BDP	Trim for BDP
17	CREF_BCP	Trim for BCP
18	CREF_BDN	Trim for BDN
19	CREF_BCN	Trim for BCN
20–29	RSVD	Reserved

15.2.71 AltManufacturerAccess() 0xF0A3 ProtectorImageSave

This read-write command is only accessible if *ManufacturingStatus()[CAL_EN]* = 1 and the device is in UNSEALED or FULL ACCESS mode. When written, the command saves the present state of the protector hardware registers to the configuration image in secure memory. In addition to the command, a one byte payload is required to indicate whether to lock the protector hardware registers after loading the configuration image from secure memory. If the byte is zero, the protector hardware registers are not locked. If the byte is non-zero, the protection hardware registers are locked to prevent modifications.

After the command is written to and executed by the device, a status byte can be read from *MACData()* to indicate success or failure.

Status Byte	Description
0x00	Success
0x01	Failed to erase configuration image in secure memory
0x02	Failed to save configuration image to secure memory
0x05	Failed because configuration image in secure memory is locked

15.2.72 AltManufacturerAccess() 0xF0A4 ProtectorImageLock

This command is only accessible if *ManufacturingStatus()[CAL_EN]* = 1 and the device is in UNSEALED or FULL ACCESS mode. When written, the command permanently locks the configuration image in secure memory from modification. A two byte key, 0x83de, must be sent with the command for a successful write. The key must be sent in little endian order: 0xde + 0x83.

After the command is written to and executed by the device, a status byte can be read from *MACData()* to indicate success or failure.

Status Byte	Description
0x00	Success
0x01	Failed because the configuration image in secure memory is already locked
0x02	Failed because the key is invalid

15.2.73 AltManufacturerAccess() 0xF0A5 ProtectorFactoryConfig

This command returns one byte that is the profile number of the factory programmed protector configuration. This profile number is only relevant if more than one protector configuration is programmed at the factory. A profile number is assigned to each set of protector threshold targets that is programmed in the factory for identification purposes.

This command is only available in UNSEALED or FULL ACCESS modes.

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16.1 Data Flash Access

16.1.1 Minimum Voltage

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

Note

ManufacturingStatus()[CAL_EN] = 1 overrides this voltage requirement so data flash can be updated prior to or during calibration of cell voltage. However, the voltage applied must exceed *Valid Update Voltage* for proper data flash update operation.

Class	Subclass	Name	Type	Min	Max	Default	Unit	Description
Power	Power	Valid Update Voltage	I2	0	32767	2100	mV	Min cell voltage threshold for the flash update

16.2 Data Formats

16.2.1 Unsigned Integer

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

0

U1 MSB

0   1

U2 LSB	U2 MSB

0   1   2   3

U4 L LSB	U4 L MSB	U4 H LSB	U4 H MSB

16.2.2 Integer

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

0

I1 MSB

0   1

I2 LSB	I2 MSB

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

16.2.3 Floating Point

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

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

Where:

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

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

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

16.2.4 Hex

Bit register definitions are stored in unsigned integer format.

16.2.5 String

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

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

17.1 Data Flash Summary

Table 17-1. Data Flash Table

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Calibration	Voltage	0x4000	Cell Gain	I2	–32767	32767	12101	—
Calibration	Voltage	0x4002	Pack Gain	U2	0	65535	24835	—
Calibration	Current	0x4006	CC Gain	F4	1.00E–01	4.00E+00	3.68	—
Calibration	Current	0x400A	Capacity Gain	F4	2.98262E+02	1.193046E+08	4390411.01	—
Calibration	Temperature	0x4014	Internal Temp Offset	I1	–128	127	0	0.1°C
Calibration	Temperature	0x4015	External1 Temp Offset	I1	–128	127	0	0.1°C
Calibration	Temperature	0x4016	External2 Temp Offset	I1	–128	127	0	0.1°C
Calibration	Internal Temp Model	0x43C0	Int Gain	I2	–32768	32767	–13908	—
Calibration	Internal Temp Model	0x43C2	Int base offset	I2	–32768	32767	6959	—
Calibration	Internal Temp Model	0x43C4	Int Minimum AD	I2	–32768	32767	0	—
Calibration	Internal Temp Model	0x43C6	Int Maximum Temp	I2	–32768	32767	6959	0.1 K
Calibration	Cell Temperature Model	0x43C8	Coeff a1	I2	–32768	32767	–17447	—
Calibration	Cell Temperature Model	0x43CA	Coeff a2	I2	–32768	32767	29322	—
Calibration	Cell Temperature Model	0x43CC	Coeff a3	I2	–32768	32767	–25430	—
Calibration	Cell Temperature Model	0x43CE	Coeff a4	I2	–32768	32767	29836	—
Calibration	Cell Temperature Model	0x43D0	Coeff a5	I2	–32768	32767	1200	—
Calibration	Cell Temperature Model	0x43D2	Coeff b1	I2	–32768	32767	–293	—
Calibration	Cell Temperature Model	0x43D4	Coeff b2	I2	–32768	32767	552	—
Calibration	Cell Temperature Model	0x43D6	Coeff b3	I2	–32768	32767	–2887	—
Calibration	Cell Temperature Model	0x43D8	Coeff b4	I2	–32768	32767	4591	—
Calibration	Cell Temperature Model	0x43DA	Rc0	I2	–32768	32767	11703	—
Calibration	Cell Temperature Model	0x43DC	Adc0	I2	–32768	32767	11703	—
Calibration	Cell Temperature Model	0x43DE	Rpad	I2	–32768	32767	1	—
Calibration	Cell Temperature Model	0x43E0	Rint	I2	–32768	32767	18000	—
Calibration	2nd Temperature Model	0x43E2	Coeff a1	I2	–32768	32767	–17447	—

Table 17-1. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Calibration	2nd Temperature Model	0x43E4	Coeff a2	I2	–32768	32767	29322	—
Calibration	2nd Temperature Model	0x43E6	Coeff a3	I2	–32768	32767	–25430	—
Calibration	2nd Temperature Model	0x43E8	Coeff a4	I2	–32768	32767	29836	—
Calibration	2nd Temperature Model	0x43EA	Coeff a5	I2	–32768	32767	1200	—
Calibration	2nd Temperature Model	0x43EC	Coeff b1	I2	–32768	32767	–293	—
Calibration	2nd Temperature Model	0x43EE	Coeff b2	I2	–32768	32767	552	—
Calibration	2nd Temperature Model	0x43F0	Coeff b3	I2	–32768	32767	–2887	—
Calibration	2nd Temperature Model	0x43F2	Coeff b4	I2	–32768	32767	4591	—
Calibration	2nd Temperature Model	0x43F4	Rc0	I2	–32768	32767	11703	—
Calibration	2nd Temperature Model	0x43F6	Adc0	I2	–32768	32767	11703	—
Calibration	2nd Temperature Model	0x43F8	Rpad	I2	–32768	32767	1	—
Calibration	2nd Temperature Model	0x43FA	Rint	I2	–32768	32767	18000	—
Calibration	Current Deadband	0x4401	Deadband	U1	0	255	3	mA
Calibration	Current Deadband	0x4402	Coulomb Counter Deadband	U1	0	255	9	116 nV
Protections	HW Threshold Targets	0x4020	OVP	U2	2000	5000	4525	mV
Protections	HW Threshold Targets	0x4022	UVP	U2	2000	4000	2300	mV
Protections	HW Threshold Targets	0x4024	OCC	I2	0	1000	140	0.1 mV
Protections	HW Threshold Targets	0x4026	OCD	I2	–1000	0	–160	0.1 mV
Protections	HW Threshold Targets	0x4028	SCD	I2	–1000	0	–200	0.1 mV
Protections	HW Threshold Targets	0x402A	I-Wake	I2	–1000	0	–20	0.1 mV
Protections	HW Threshold Targets	0x402C	BDP	I2	–1000	0	–200	mV
Protections	HW Threshold Targets	0x402E	BCP	I2	0	1000	200	mV
Protections	HW Threshold Targets	0x4030	BDN	I2	–1000	0	–200	mV
Protections	HW Threshold Targets	0x4032	BCN	I2	0	1000	200	mV
Protections	HW Threshold Targets	0x4034	Field Cal	H2	0x0	0xFFFF	0x0	Hex
Protections	HW Threshold Targets	0x4036	Field Config	H1	0x0	0xFF	0x00	Hex
Protections	CUV	0x46D8	Threshold	I2	0	32767	2500	mV
Protections	CUV	0x46DA	Delay	U1	0	255	1	s
Protections	CUV	0x46DB	Recovery	I2	0	32767	2900	mV
Protections	CUV	0x46DD	Recovery Delay	U1	0	255	1	s
Protections	HCUV	0x46DE	Recovery	I2	0	32767	2900	mV
Protections	HCUV	0x46E0	Recovery Chg	I2	0	32767	2520	mV
Protections	HCUV	0x46E2	Recovery Delay	U1	0	255	1	s
Protections	COV	0x46E3	Threshold Low Temp	I2	0	32767	4490	mV

Table 17-1. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Protections	COV	0x46E5	Threshold Standard Temp Low	I2	0	32767	4490	mV
Protections	COV	0x46E7	Threshold Standard Temp High	I2	0	32767	4490	mV
Protections	COV	0x46E9	Threshold High Temp	I2	0	32767	4490	mV
Protections	COV	0x46EB	Threshold Rec Temp	I2	0	32767	4490	mV
Protections	COV	0x46ED	Delay	U1	0	255	1	s
Protections	COV	0x46EE	Recovery Low Temp	I2	0	32767	4290	mV
Protections	COV	0x46F0	Recovery Standard Temp Low	I2	0	32767	4290	mV
Protections	COV	0x46F2	Recovery Standard Temp High	I2	0	32767	4290	mV
Protections	COV	0x46F4	Recovery High Temp	I2	0	32767	4290	mV
Protections	COV	0x46F6	Recovery Rec Temp	I2	0	32767	4290	mV
Protections	COV	0x46F8	Recovery Delay	U1	0	255	1	s
Protections	HCOV	0x46F9	Recovery	I2	0	32767	4290	mV
Protections	HCOV	0x46FB	Recovery Delay	U1	0	255	1	s
Protections	OCC	0x46FC	Threshold	I2	–32768	32767	12000	mA
Protections	OCC	0x46FE	Delay	U1	0	255	1	s
Protections	OCC	0x46FF	Recovery Threshold	I2	–32768	32767	200	mA
Protections	OCC	0x4701	Recovery Delay	U1	0	255	10	s
Protections	HOCC	0x4702	Recovery Threshold	I2	–32768	32767	200	mA
Protections	HOCC	0x4704	Recovery Delay	U1	0	255	70	s
Protections	OCD	0x4705	Threshold	I2	–32768	32767	–7000	mA
Protections	OCD	0x4707	Delay	U1	0	255	3	s
Protections	OCD	0x4708	Recovery Threshold	I2	–32768	32767	–200	mA
Protections	OCD	0x470A	Recovery Delay	U1	0	255	10	s
Protections	HOCD	0x470B	Recovery Threshold	I2	–32768	32767	–200	mA
Protections	HOCD	0x470D	Recovery Delay	U1	0	255	70	s
Protections	HSCD	0x470E	Recovery Threshold	I2	–32768	32767	–200	mA
Protections	HSCD	0x4710	Recovery Delay	U1	0	255	70	s
Protections	OTC	0x4711	Threshold	I2	2332	3932	3282	0.1 K
Protections	OTC	0x4713	Delay	U1	0	255	2	s
Protections	OTC	0x4714	Recovery	I2	2332	3932	3232	0.1 K
Protections	OTD	0x4716	Threshold	I2	2332	3932	3332	0.1 K
Protections	OTD	0x4718	Delay	U1	0	255	2	s
Protections	OTD	0x4719	Recovery	I2	2332	3932	3282	0.1 K
Protections	OTF	0x471B	Threshold	I2	2332	3932	3532	0.1 K
Protections	OTF	0x471D	Delay	U1	0	255	2	s
Protections	OTF	0x471E	Recovery	I2	2332	3932	3382	0.1 K
Protections	UTC	0x4720	Threshold	I2	2332	3932	2732	0.1 K
Protections	UTC	0x4722	Delay	U1	0	255	2	s
Protections	UTC	0x4723	Recovery	I2	2332	3932	2782	0.1 K
Protections	UTD	0x4725	Threshold	I2	2332	3932	2732	0.1 K
Protections	UTD	0x4727	Delay	U1	0	255	2	s
Protections	UTD	0x4728	Recovery	I2	2332	3932	2782	0.1 K
Protections	PTO	0x472A	Charge Threshold	I2	–32768	32767	2000	mA
Protections	PTO	0x472C	Suspend Threshold	I2	–32768	32767	1800	mA
Protections	PTO	0x472E	Delay	U2	0	65535	1800	s
Protections	PTO	0x4730	Reset	I2	0	32767	2	mAh
Protections	CTO	0x4732	Charge Threshold	I2	–32768	32767	2500	mA
Protections	CTO	0x4734	Suspend Threshold	I2	–32768	32767	2000	mA
Protections	CTO	0x4736	Delay	U2	0	65535	54000	s
Protections	CTO	0x4738	Reset	I2	0	32767	2	mAh

Table 17-1. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Settings	Protection	0x46D3	Protection Configuration	H1	0x0	0x02	0x0	Hex
Settings	Protection	0x46D4	Enabled Protections A	H1	0x0	0xFF	0x57	Hex
Settings	Protection	0x46D5	Enabled Protections B	H1	0x0	0xFF	0x35	Hex
Settings	Protection	0x46D6	Enabled Protections C	H1	0x0	0xFF	0x14	Hex
Settings	Protection	0x46D7	Enabled Protections D	H1	0x0	0xFF	0xCC	Hex
Settings	Batt Sense	0x46C2	Batt Sense Options	H1	0x0	0x01	0x00	Hex
Settings	Batt Sense	0x46C3	Batt Sense Config	H1	0x0	0xFF	0x00	Hex
Settings	Batt Sense	0x46C4	RLO Charge Config	H1	0x0	0x0C	0x0C	Hex
Settings	Batt Sense	0x46C5	RLO Charge Threshold	I2	0	32767	75	mA
Settings	Batt Sense	0x46C7	Buffer Mode Threshold	I2	0	32767	2500	mV
Settings	Batt Sense	0x46C9	Buffer Mode Delay	U1	0	255	1	s
Settings	Batt Sense	0x46CA	Buffer Mode Recovery	I2	0	32767	2900	mV
Settings	Batt Sense	0x46CC	Buffer Mode PACK Margin	I2	−1000	1000	100	mV
Settings	Batt Sense	0x46CE	Transition Config	H1	0x0	0x6C	0x44	Hex
Settings	Batt Sense	0x46CF	Transition Delay	U2	0	1000	250	2 µs
Settings	Batt Sense	0x46D1	Protection Enable Delay	U1	1	255	3	ms
Settings	Batt Sense	0x46D2	Protection Recovery Delay	U1	0	255	5	s
Settings	Configuration	0x45C0	FET Options	H2	0x0	0x01FF	0x0142	Hex
Settings	Configuration	0x45C2	FET OVRD Time	U2	30	1800	60	s
Settings	Configuration	0x45C4	I2C Gauging Configuration	H1	0x0	0x3F	0x20	Hex
Settings	Configuration	0x45C5	I2C Configuration	H2	0x0	0x08FF	0x0028	Hex
Settings	Configuration	0x45C7	Alt I2C Address	H1	0x0	0xFF	0x0	Hex
Settings	Configuration	0x45C8	Alt I2C Addr Chk	H1	0x0	0xFF	0x0	Hex
Settings	Configuration	0x45C9	Auth Config	H1	0x0	0x03	0x00	Hex
Settings	Configuration	0x45CA	Power Config	H2	0x0	0xFFFF	0x0010	Hex
Settings	Configuration	0x45CE	GPO Pin Config	H1	0x0	0x01	0x00	Hex
Settings	Configuration	0x45CF	Host Intr Config	H1	0x0	0x3B	0x00	Hex
Settings	Configuration	0x45D6	Init Voltage High Set	I2	0	5000	4500	mV
Settings	Configuration	0x45D8	Init Voltage High Clear	I2	0	5000	4400	mV
Settings	Configuration	0x45DA	Init Voltage Low Set	I2	0	5000	2500	mV
Settings	Configuration	0x45DC	Init Voltage Low Clear	I2	0	5000	2600	mV
Settings	Configuration	0x45DE	Init Temperature High Set	I1	−128	127	60	°C
Settings	Configuration	0x45DF	Init Temperature High Clear	I1	−128	127	55	°C
Settings	Configuration	0x45E0	Init Temperature Low Set	I1	−128	127	0	°C
Settings	Configuration	0x45E1	Init Temperature Low Clear	I1	−128	127	5	°C
Settings	Configuration	0x45E2	SOC Delta	U1	0	100	1	%
Settings	Configuration	0x4608	SOC Flag Config A	H2	0x0	0x0FFF	0x0C8C	Hex
Settings	Configuration	0x460A	SOC Flag Config B	H1	0x0	0xFF	0x8C	Hex
Settings	Configuration	0x4623	IT Gauging Configuration	H2	0x0	0xFFFF	0xF5DE	Hex
Settings	Configuration	0x4627	IT Gauging Ext	H2	0x0000	0x003F	0x003B	Hex
Settings	Configuration	0x463C	Charging Configuration	H2	0x0	0x3F87	0x0000	Hex
Settings	Configuration	0x46B1	Temperature Enable	H1	0x0	0x0F	0x02	Hex
Settings	Configuration	0x46B2	DA Configuration	H2	0x0	0x0C10	0x0410	Hex
Settings	AFE	0x46B5	ZVCHG Exit Threshold	I2	0	2000	2000	mV
Settings	AFE	0x46B7	ZVCHG PACK Threshold	I2	0	2000	1500	mV
Settings	BTP	0x45D0	Init Discharge Set	I2	0	32767	150	mAh
Settings	BTP	0x45D2	Init Charge Set	I2	0	32767	175	mAh
Settings	BTP	0x45D4	Init Discharge Set RSOC	U1	0	100	10	%
Settings	BTP	0x45D5	Init Charge Set RSOC	U1	0	100	15	%
Settings	Lifetimes	0x473A	Lifetimes Configuration	H2	0x0	0x00FF	0x0000	Hex

Table 17-1. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Settings	Lifetimes	0x473D	Time RSOC Threshold A	U1	0	100	95	%
Settings	Lifetimes	0x473E	Time RSOC Threshold B	U1	0	100	90	%
Settings	Lifetimes	0x473F	Time RSOC Threshold C	U1	0	100	80	%
Settings	Lifetimes	0x4740	Time RSOC Threshold D	U1	0	100	50	%
Settings	Lifetimes	0x4741	Time RSOC Threshold E	U1	0	100	20	%
Settings	Lifetimes	0x4742	Time RSOC Threshold F	U1	0	100	10	%
Settings	Lifetimes	0x4743	Time RSOC Threshold G	U1	0	100	5	%
Settings	Manufacturing	0x438C	Mfg Status init	H2	0x0	0xFFFF	0x0000	Hex
Advanced Charge Algorithm	Temperature Ranges	0x463E	T1 Temp	I1	−128	127	0	°C
Advanced Charge Algorithm	Temperature Ranges	0x463F	T2 Temp	I1	−128	127	10	°C
Advanced Charge Algorithm	Temperature Ranges	0x4640	T5 Temp	I1	−128	127	20	°C
Advanced Charge Algorithm	Temperature Ranges	0x4641	T6 Temp	I1	−128	127	25	°C
Advanced Charge Algorithm	Temperature Ranges	0x4642	T3 Temp	I1	−128	127	45	°C
Advanced Charge Algorithm	Temperature Ranges	0x4643	T4 Temp	I1	−128	127	55	°C
Advanced Charge Algorithm	Temperature Ranges	0x4644	Hysteresis Temp	I1	0	127	1	°C
Advanced Charge Algorithm	Low Temp Charging	0x4382	Voltage	I2	0	32767	4400	mV
Advanced Charge Algorithm	Low Temp Charging	0x4645	Current Low	I2	0	32767	132	mA
Advanced Charge Algorithm	Low Temp Charging	0x4647	Current Med	I2	0	32767	352	mA
Advanced Charge Algorithm	Low Temp Charging	0x4649	Current High	I2	0	32767	264	mA
Advanced Charge Algorithm	Standard Temp Low Charging	0x4384	Voltage	I2	0	32767	4400	mV
Advanced Charge Algorithm	Standard Temp Low Charging	0x464B	Current Low	I2	0	32767	1980	mA
Advanced Charge Algorithm	Standard Temp Low Charging	0x464D	Current Med	I2	0	32767	4004	mA
Advanced Charge Algorithm	Standard Temp Low Charging	0x464F	Current High	I2	0	32767	2992	mA
Advanced Charge Algorithm	Standard Temp High Charging	0x4386	Voltage	I2	0	32767	4400	mV
Advanced Charge Algorithm	Standard Temp High Charging	0x4651	Current Low	I2	0	32767	1980	mA
Advanced Charge Algorithm	Standard Temp High Charging	0x4653	Current Med	I2	0	32767	4004	mA
Advanced Charge Algorithm	Standard Temp High Charging	0x4655	Current High	I2	0	32767	2992	mA
Advanced Charge Algorithm	High Temp Charging	0x4388	Voltage	I2	0	32767	4100	mV
Advanced Charge Algorithm	High Temp Charging	0x4657	Current Low	I2	0	32767	1012	mA
Advanced Charge Algorithm	High Temp Charging	0x4659	Current Med	I2	0	32767	1980	mA
Advanced Charge Algorithm	High Temp Charging	0x465B	Current High	I2	0	32767	1496	mA
Advanced Charge Algorithm	Rec Temp Charging	0x438A	Voltage	I2	0	32767	4400	mV
Advanced Charge Algorithm	Rec Temp Charging	0x465D	Current Low	I2	0	32767	2508	mA

Table 17-1. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Advanced Charge Algorithm	Rec Temp Charging	0x465F	Current Med	I2	0	32767	4488	mA
Advanced Charge Algorithm	Rec Temp Charging	0x4661	Current High	I2	0	32767	3520	mA
Advanced Charge Algorithm	Pre-Charging	0x4663	Current	I2	0	32767	88	mA
Advanced Charge Algorithm	Voltage Range	0x4665	Precharge Start Voltage	I2	0	32767	2500	mV
Advanced Charge Algorithm	Voltage Range	0x4667	Charging Voltage Low	I2	0	32767	2900	mV
Advanced Charge Algorithm	Voltage Range	0x4669	Charging Voltage Med	I2	0	32767	3600	mV
Advanced Charge Algorithm	Voltage Range	0x466B	Charging Voltage High	I2	0	32767	4000	mV
Advanced Charge Algorithm	Voltage Range	0x466D	Charging Voltage Hysteresis	U1	0	255	0	mV
Advanced Charge Algorithm	SoC Range	0x466E	Charging SoC Med	U1	0	100	50	%
Advanced Charge Algorithm	SoC Range	0x466F	Charging SoC High	U1	0	100	75	%
Advanced Charge Algorithm	SoC Range	0x4670	Charging SoC Hysteresis	U1	0	100	1	%
Advanced Charge Algorithm	Degrade Mode 1	0x4671	Cycle Threshold	U2	0	65535	50	—
Advanced Charge Algorithm	Degrade Mode 1	0x4673	SOH Threshold	U1	0	100	95	%
Advanced Charge Algorithm	Degrade Mode 1	0x4674	Runtime Threshold	U2	0	65535	8760	h
Advanced Charge Algorithm	Degrade Mode 1	0x4676	High SOC Threshold	U2	0	65535	8760	h
Advanced Charge Algorithm	Degrade Mode 1	0x4678	High Temp Threshold	U2	0	65535	8760	h
Advanced Charge Algorithm	Degrade Mode 1	0x467A	High Temp at SOC Threshold	U2	0	65535	8760	h
Advanced Charge Algorithm	Degrade Mode 1	0x467C	Voltage Degradation	I2	0	32767	10	mV
Advanced Charge Algorithm	Degrade Mode 1	0x467E	Current Degradation	U1	0	100	10	%
Advanced Charge Algorithm	Degrade Mode 2	0x467F	Cycle Threshold	U2	0	65535	150	—
Advanced Charge Algorithm	Degrade Mode 2	0x4681	SOH Threshold	U1	0	100	80	%
Advanced Charge Algorithm	Degrade Mode 2	0x4682	Runtime Threshold	U2	0	65535	17520	h
Advanced Charge Algorithm	Degrade Mode 2	0x4684	High SOC Threshold	U2	0	65535	17520	h
Advanced Charge Algorithm	Degrade Mode 2	0x4686	High Temp Threshold	U2	0	65535	17520	h
Advanced Charge Algorithm	Degrade Mode 2	0x4688	High Temp at SOC Threshold	U2	0	65535	17520	h
Advanced Charge Algorithm	Degrade Mode 2	0x468A	Voltage Degradation	U2	0	65535	40	mV
Advanced Charge Algorithm	Degrade Mode 2	0x468C	Current Degradation	U1	0	100	20	%
Advanced Charge Algorithm	Degrade Mode 3	0x468D	Cycle Threshold	U2	0	65535	350	—
Advanced Charge Algorithm	Degrade Mode 3	0x468F	SOH Threshold	U1	0	100	60	%
Advanced Charge Algorithm	Degrade Mode 3	0x4690	Runtime Threshold	U2	0	65535	26280	h

Table 17-1. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Advanced Charge Algorithm	Degrade Mode 3	0x4692	High SOC Threshold	U2	0	65535	26280	h
Advanced Charge Algorithm	Degrade Mode 3	0x4694	High Temp Threshold	U2	0	65535	26280	h
Advanced Charge Algorithm	Degrade Mode 3	0x4696	High Temp at SOC Threshold	U2	0	65535	26280	h
Advanced Charge Algorithm	Degrade Mode 3	0x4698	Voltage Degradation	U2	0	65535	70	mV
Advanced Charge Algorithm	Degrade Mode 3	0x469A	Current Degradation	U1	0	100	40	%
Advanced Charge Algorithm	Degrade Mode	0x4200	Runtime Degrade	U2	0	65535	0	h
Advanced Charge Algorithm	Degrade Mode	0x469B	Cycle Count Start Runtime	U1	0	255	1	—
Advanced Charge Algorithm	Degrade Mode	0x469C	Runtime Update Interval	U1	0	18	10	h
Advanced Charge Algorithm	CS Degrade	0x469D	Temperature Threshold	I2	0	32767	3232	0.1 K
Advanced Charge Algorithm	CS Degrade	0x469F	Voltage Threshold	I2	0	32767	4200	mV
Advanced Charge Algorithm	CS Degrade	0x46A1	Time Interval	U2	0	14400	300	s
Advanced Charge Algorithm	CS Degrade	0x46A3	Delta Voltage	I2	0	32767	25	mV
Advanced Charge Algorithm	CS Degrade	0x46A5	Min CV	I2	0	32767	3000	mV
Advanced Charge Algorithm	Termination Config	0x46A7	Charge Term Taper Current	I2	0	32767	100	mA
Advanced Charge Algorithm	Termination Config	0x46AB	Charge Term Voltage Offset	I2	0	32767	100	mV
Advanced Charge Algorithm	Termination Config	0x46AD	Charge Term Charging Voltage	I2	0	32767	4400	mV
Advanced Charge Algorithm	IR Correction	0x46B0	Averaging Interval	U1	1	255	12	s
Gas Gauging	Current Thresholds	0x46BA	Dsg Current Threshold	I2	−32768	32767	60	mA
Gas Gauging	Current Thresholds	0x46BC	Chg Current Threshold	I2	−32768	32767	75	mA
Gas Gauging	Current Thresholds	0x46BE	Quit Current	I2	0	32767	40	mA
Gas Gauging	Current Thresholds	0x46C0	Dsg Relax Time	U1	0	255	60	s
Gas Gauging	Current Thresholds	0x46C1	Chg Relax Time	U1	0	255	60	s
Gas Gauging	Max Load	0x45FB	Max Load Current	I2	−32768	0	−500	mA
Gas Gauging	Max Load	0x45FD	Max Load Rsoc	U1	0	100	50	%
Gas Gauging	Design	0x4600	Design Capacity mAh	I2	0	32767	5300	mAh
Gas Gauging	Design	0x4602	Design Capacity cWh	I2	0	32767	2040	cWh
Gas Gauging	Design	0x4604	Design Voltage	I2	0	32767	3850	mV
Gas Gauging	Cycle	0x4606	Cycle Count Percentage	U1	0	100	90	%
Gas Gauging	FD	0x460B	Set Voltage Threshold	I2	0	5000	3000	mV
Gas Gauging	FD	0x460D	Clear Voltage Threshold	I2	0	5000	3100	mV
Gas Gauging	FD	0x460F	Set % RSOC Threshold	U1	0	100	0	%
Gas Gauging	FD	0x4610	Clear % RSOC Threshold	U1	0	100	5	%
Gas Gauging	FC	0x4611	Set Voltage Threshold	I2	0	5000	4400	mV
Gas Gauging	FC	0x4613	Clear Voltage Threshold	I2	0	5000	4300	mV
Gas Gauging	FC	0x4615	Set % RSOC Threshold	U1	0	100	100	%
Gas Gauging	FC	0x4616	Clear % RSOC Threshold	U1	0	100	95	%
Gas Gauging	TD	0x4617	Set Voltage Threshold	I2	0	5000	3200	mV
Gas Gauging	TD	0x4619	Clear Voltage Threshold	I2	0	5000	3300	mV

Table 17-1. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Gas Gauging	TD	0x461B	Set % RSOC Threshold	U1	0	100	6	%
Gas Gauging	TD	0x461C	Clear % RSOC Threshold	U1	0	100	8	%
Gas Gauging	TC	0x461D	Set Voltage Threshold	I2	0	5000	4400	mV
Gas Gauging	TC	0x461F	Clear Voltage Threshold	I2	0	5000	4300	mV
Gas Gauging	TC	0x4621	Set % RSOC Threshold	U1	0	100	100	%
Gas Gauging	TC	0x4622	Clear % RSOC Threshold	U1	0	100	95	%
Gas Gauging	State	0x4186	Qmax Cell 1	I2	0	32767	5359	mAh
Gas Gauging	State	0x4188	Qmax Day	U2	0	65535	0	—
Gas Gauging	State	0x418A	Qmax Cycle Count	U2	0	65535	0	—
Gas Gauging	State	0x418C	Update Status	H1	0x0	0x0E	0x0	—
Gas Gauging	State	0x418D	Cell 1 Chg Voltage at EoC	I2	0	32767	4375	mV
Gas Gauging	State	0x418F	Current at EoC	I2	0	32767	100	mA
Gas Gauging	State	0x4191	Avg I Last Run	I2	−32768	32767	−500	mA
Gas Gauging	State	0x4193	Avg P Last Run	I2	−32768	32767	−192	cW
Gas Gauging	State	0x4195	Delta Voltage	I2	−32768	32767	0	mV
Gas Gauging	State	0x4197	Temp k	I2	0	32767	200	0.1°C/256 cW
Gas Gauging	State	0x4199	Temp a	I2	0	32767	1000	s
Gas Gauging	State	0x419B	Max Avg I Last Run	I2	−32768	32767	−500	mA
Gas Gauging	State	0x419D	Max Avg P Last Run	I2	−32768	32767	−192	cW
Gas Gauging	State	0x41C0	Cycle Count	U2	0	65535	0	—
Gas Gauging	State	0x45B8	SOH Temp k	I2	0	32767	100	0.1°C/256 cW
Gas Gauging	State	0x45BA	SOH Temp a	I2	0	32767	1000	s
Gas Gauging	IT Cfg	0x4180	Design Resistance	I2	1	32767	90	mΩ
Gas Gauging	IT Cfg	0x4182	Pack Resistance	I2	0	32767	0	mΩ
Gas Gauging	IT Cfg	0x4184	System Resistance	I2	0	32767	0	mΩ
Gas Gauging	IT Cfg	0x454E	Ra Filter	U2	0	999	800	0.1%
Gas Gauging	IT Cfg	0x4551	Ra Max Delta	U1	0	255	15	%
Gas Gauging	IT Cfg	0x4554	Resistance Parameter Filter	U2	1	65535	65142	—
Gas Gauging	IT Cfg	0x4556	Near EDV Ra Param Filter	U2	1	65535	62184	—
Gas Gauging	IT Cfg	0x4558	Cell 1 Interconnect Resistance	I2	0	32767	0	2^{-10} Ω
Gas Gauging	IT Cfg	0x455A	Max Current Change %	U1	0	100	10	%
Gas Gauging	IT Cfg	0x455B	Resistance Update Voltage	I2	0	32767	50	mV
Gas Gauging	IT Cfg	0x457F	Qmax Delta	U1	3	100	5	%
Gas Gauging	IT Cfg	0x4580	Qmax Upper Bound	U1	100	255	130	%
Gas Gauging	IT Cfg	0x4581	Cycle Adjust Threshold	U1	0	255	20	—
Gas Gauging	IT Cfg	0x4582	Cycle Adj Incr	U1	0	255	5	0.01%
Gas Gauging	IT Cfg	0x4583	OCV Pred Active T Limit	U2	100	65535	200	s
Gas Gauging	IT Cfg	0x4585	OCV Pred Transient T	U2	100	65535	300	s
Gas Gauging	IT Cfg	0x4587	OCV Pred Measure Time	U2	0	65535	200	s
Gas Gauging	IT Cfg	0x4589	Term Voltage	I2	0	32767	3000	mV
Gas Gauging	IT Cfg	0x458B	Term V Hold Time	U1	0	255	2	s
Gas Gauging	IT Cfg	0x458C	Term Voltage Delta	I2	0	32767	200	mV
Gas Gauging	IT Cfg	0x4597	Max Simulation Iterations	U1	20	50	50	—
Gas Gauging	IT Cfg	0x4598	Simulation Near Term Delta	I2	0	32767	250	mV
Gas Gauging	IT Cfg	0x45AA	Fast Scale Start SOC	U1	0	100	10	%
Gas Gauging	IT Cfg	0x45B3	Min Delta Voltage	I2	−32768	32767	0	mV
Gas Gauging	IT Cfg	0x4629	Load Select	U1	0	7	1	—
Gas Gauging	IT Cfg	0x462A	Load Mode	U1	0	1	1	—

Table 17-1. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Gas Gauging	IT Cfg	0x462B	User Rate-mA	I2	−9000	0	0	mA
Gas Gauging	IT Cfg	0x462D	User Rate-cW	I2	−32768	0	0	cW
Gas Gauging	IT Cfg	0x462F	Reserve Cap-mAh	I2	0	9000	0	mAh
Gas Gauging	IT Cfg	0x4631	Reserve Cap-cWh	I2	0	32000	0	cWh
Gas Gauging	IT Cfg	0x463A	Predict Ambient Time	U2	0	65535	2000	s
Gas Gauging	Smoothing	0x4633	Smooth Relax Time	U2	1	32767	1000	s
Gas Gauging	Smoothing	0x4635	Term Smooth Start Cell V Delta	I2	0	32767	150	mV
Gas Gauging	Smoothing	0x4637	Term Smooth Final Cell V Delta	I2	0	32767	100	mV
Gas Gauging	Smoothing	0x4639	Term Smooth Time	U1	1	32767	20	s
Gas Gauging	SoH	0x45B7	SoH Load Rate	U1	0	255	50	0.1 Hr rate
Power	Power	0x45E3	Valid Update Voltage	I2	0	32767	2100	mV
Power	Shutdown	0x45E5	Shutdown Voltage	I2	0	32767	2150	mV
Power	Shutdown	0x45E7	Shutdown Time	U1	0	255	10	s
Power	Shutdown	0x45E8	Charger Present Threshold	I2	0	32767	100	mV
Power	Sleep	0x45EA	Sleep Current	I2	0	32767	15	mA
Power	Sleep	0x45EC	Voltage Time	U1	1	20	5	s
Power	Ship	0x45ED	FET Off Time	U1	0	127	10	s
Power	Ship	0x45EE	Delay	U1	0	254	20	s
Power	Ship	0x45FE	Auto Ship Time	U2	0	65535	4320	min
Power	Shipmode	0x45EF	Shipmode Voltage Threshold	I2	0	32767	2300	mV
Power	Shipmode	0x45F1	Shipmode Voltage Delay	U1	0	255	10	s
Power	Shipmode	0x45F2	Shipmode Command Delay	U1	0	255	0	s
Power	Shipmode	0x45F3	Shipmode Measure Time	U1	1	30	30	s
Power	Shelf	0x45F4	Shelf Voltage Threshold	I2	0	32767	2200	mV
Power	Shelf	0x45F6	Shelf Voltage Delay	U1	0	255	10	s
Power	Shelf	0x45F7	Shelf Command Delay	U1	0	255	10	s
Power	Shelf	0x45F8	Shelf Measure Time	U1	1	30	30	s
Power	Shelf	0x45F9	Shelf Exit Holdoff	U1	1	255	10	s
Power	SysReset	0x45FA	Dsg FET Off Time	U1	0	30	0	s
System Data	Manufacturer Data	0x4041	Manufacturer Info Block A01	H1	0x0	0xFF	0x61	Hex
System Data	Manufacturer Data	0x4042	Manufacturer Info Block A02	H1	0x0	0xFF	0x62	Hex
System Data	Manufacturer Data	0x4043	Manufacturer Info Block A03	H1	0x0	0xFF	0x63	Hex
System Data	Manufacturer Data	0x4044	Manufacturer Info Block A04	H1	0x0	0xFF	0x64	Hex
System Data	Manufacturer Data	0x4045	Manufacturer Info Block A05	H1	0x0	0xFF	0x65	Hex
System Data	Manufacturer Data	0x4046	Manufacturer Info Block A06	H1	0x0	0xFF	0x66	Hex
System Data	Manufacturer Data	0x4047	Manufacturer Info Block A07	H1	0x0	0xFF	0x67	Hex
System Data	Manufacturer Data	0x4048	Manufacturer Info Block A08	H1	0x0	0xFF	0x68	Hex
System Data	Manufacturer Data	0x4049	Manufacturer Info Block A09	H1	0x0	0xFF	0x69	Hex
System Data	Manufacturer Data	0x404A	Manufacturer Info Block A10	H1	0x0	0xFF	0x6A	Hex
System Data	Manufacturer Data	0x404B	Manufacturer Info Block A11	H1	0x0	0xFF	0x6B	Hex
System Data	Manufacturer Data	0x404C	Manufacturer Info Block A12	H1	0x0	0xFF	0x6C	Hex
System Data	Manufacturer Data	0x404D	Manufacturer Info Block A13	H1	0x0	0xFF	0x6D	Hex
System Data	Manufacturer Data	0x404E	Manufacturer Info Block A14	H1	0x0	0xFF	0x6E	Hex
System Data	Manufacturer Data	0x404F	Manufacturer Info Block A15	H1	0x0	0xFF	0x6F	Hex
System Data	Manufacturer Data	0x4050	Manufacturer Info Block A16	H1	0x0	0xFF	0x70	Hex
System Data	Manufacturer Data	0x4051	Manufacturer Info Block A17	H1	0x0	0xFF	0x71	Hex
System Data	Manufacturer Data	0x4052	Manufacturer Info Block A18	H1	0x0	0xFF	0x72	Hex
System Data	Manufacturer Data	0x4053	Manufacturer Info Block A19	H1	0x0	0xFF	0x73	Hex
System Data	Manufacturer Data	0x4054	Manufacturer Info Block A20	H1	0x0	0xFF	0x74	Hex
System Data	Manufacturer Data	0x4055	Manufacturer Info Block A21	H1	0x0	0xFF	0x75	Hex

Table 17-1. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
System Data	Manufacturer Data	0x4056	Manufacturer Info Block A22	H1	0x0	0xFF	0x76	Hex
System Data	Manufacturer Data	0x4057	Manufacturer Info Block A23	H1	0x0	0xFF	0x77	Hex
System Data	Manufacturer Data	0x4058	Manufacturer Info Block A24	H1	0x0	0xFF	0x7A	Hex
System Data	Manufacturer Data	0x4059	Manufacturer Info Block A25	H1	0x0	0xFF	0x78	Hex
System Data	Manufacturer Data	0x405A	Manufacturer Info Block A26	H1	0x0	0xFF	0x79	Hex
System Data	Manufacturer Data	0x405B	Manufacturer Info Block A27	H1	0x0	0xFF	0x30	Hex
System Data	Manufacturer Data	0x405C	Manufacturer Info Block A28	H1	0x0	0xFF	0x31	Hex
System Data	Manufacturer Data	0x405D	Manufacturer Info Block A29	H1	0x0	0xFF	0x32	Hex
System Data	Manufacturer Data	0x405E	Manufacturer Info Block A30	H1	0x0	0xFF	0x33	Hex
System Data	Manufacturer Data	0x405F	Manufacturer Info Block A31	H1	0x0	0xFF	0x34	Hex
System Data	Manufacturer Data	0x4060	Manufacturer Info Block A32	H1	0x0	0xFF	0x35	Hex
System Data	Manufacturer Info B	0x4062	Manufacturer Info Block B01	H1	0x0	0xFF	0x61	Hex
System Data	Manufacturer Info B	0x4063	Manufacturer Info Block B02	H1	0x0	0xFF	0x62	Hex
System Data	Manufacturer Info B	0x4064	Manufacturer Info Block B03	H1	0x0	0xFF	0x63	Hex
System Data	Manufacturer Info B	0x4065	Manufacturer Info Block B04	H1	0x0	0xFF	0x64	Hex
System Data	Manufacturer Info B	0x4066	Manufacturer Info Block B05	H1	0x0	0xFF	0x65	Hex
System Data	Manufacturer Info B	0x4067	Manufacturer Info Block B06	H1	0x0	0xFF	0x66	Hex
System Data	Manufacturer Info B	0x4068	Manufacturer Info Block B07	H1	0x0	0xFF	0x67	Hex
System Data	Manufacturer Info B	0x4069	Manufacturer Info Block B08	H1	0x0	0xFF	0x68	Hex
System Data	Manufacturer Info B	0x406A	Manufacturer Info Block B09	H1	0x0	0xFF	0x69	Hex
System Data	Manufacturer Info B	0x406B	Manufacturer Info Block B10	H1	0x0	0xFF	0x6A	Hex
System Data	Manufacturer Info B	0x406C	Manufacturer Info Block B11	H1	0x0	0xFF	0x6B	Hex
System Data	Manufacturer Info B	0x406D	Manufacturer Info Block B12	H1	0x0	0xFF	0x6C	Hex
System Data	Manufacturer Info B	0x406E	Manufacturer Info Block B13	H1	0x0	0xFF	0x6D	Hex
System Data	Manufacturer Info B	0x406F	Manufacturer Info Block B14	H1	0x0	0xFF	0x6E	Hex
System Data	Manufacturer Info B	0x4070	Manufacturer Info Block B15	H1	0x0	0xFF	0x6F	Hex
System Data	Manufacturer Info B	0x4071	Manufacturer Info Block B16	H1	0x0	0xFF	0x70	Hex
System Data	Manufacturer Info B	0x4072	Manufacturer Info Block B17	H1	0x0	0xFF	0x71	Hex
System Data	Manufacturer Info B	0x4073	Manufacturer Info Block B18	H1	0x0	0xFF	0x72	Hex
System Data	Manufacturer Info B	0x4074	Manufacturer Info Block B19	H1	0x0	0xFF	0x73	Hex
System Data	Manufacturer Info B	0x4075	Manufacturer Info Block B20	H1	0x0	0xFF	0x74	Hex
System Data	Manufacturer Info B	0x4076	Manufacturer Info Block B21	H1	0x0	0xFF	0x75	Hex
System Data	Manufacturer Info B	0x4077	Manufacturer Info Block B22	H1	0x0	0xFF	0x76	Hex
System Data	Manufacturer Info B	0x4078	Manufacturer Info Block B23	H1	0x0	0xFF	0x77	Hex
System Data	Manufacturer Info B	0x4079	Manufacturer Info Block B24	H1	0x0	0xFF	0x7A	Hex
System Data	Manufacturer Info B	0x407A	Manufacturer Info Block B25	H1	0x0	0xFF	0x78	Hex
System Data	Manufacturer Info B	0x407B	Manufacturer Info Block B26	H1	0x0	0xFF	0x79	Hex
System Data	Manufacturer Info B	0x407C	Manufacturer Info Block B27	H1	0x0	0xFF	0x30	Hex
System Data	Manufacturer Info B	0x407D	Manufacturer Info Block B28	H1	0x0	0xFF	0x31	Hex
System Data	Manufacturer Info B	0x407E	Manufacturer Info Block B29	H1	0x0	0xFF	0x32	Hex
System Data	Manufacturer Info B	0x407F	Manufacturer Info Block B30	H1	0x0	0xFF	0x33	Hex
System Data	Manufacturer Info B	0x4080	Manufacturer Info Block B31	H1	0x0	0xFF	0x34	Hex
System Data	Manufacturer Info B	0x4081	Manufacturer Info Block B32	H1	0x0	0xFF	0x35	Hex
System Data	Manufacturer Info C	0x4083	Manufacturer Info Block C01	H1	0x0	0xFF	0x61	Hex
System Data	Manufacturer Info C	0x4084	Manufacturer Info Block C02	H1	0x0	0xFF	0x62	Hex
System Data	Manufacturer Info C	0x4085	Manufacturer Info Block C03	H1	0x0	0xFF	0x63	Hex
System Data	Manufacturer Info C	0x4086	Manufacturer Info Block C04	H1	0x0	0xFF	0x64	Hex
System Data	Manufacturer Info C	0x4087	Manufacturer Info Block C05	H1	0x0	0xFF	0x65	Hex
System Data	Manufacturer Info C	0x4088	Manufacturer Info Block C06	H1	0x0	0xFF	0x66	Hex
System Data	Manufacturer Info C	0x4089	Manufacturer Info Block C07	H1	0x0	0xFF	0x67	Hex

Table 17-1. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
System Data	Manufacturer Info C	0x408A	Manufacturer Info Block C08	H1	0x0	0xFF	0x68	Hex
System Data	Manufacturer Info C	0x408B	Manufacturer Info Block C09	H1	0x0	0xFF	0x69	Hex
System Data	Manufacturer Info C	0x408C	Manufacturer Info Block C10	H1	0x0	0xFF	0x6A	Hex
System Data	Manufacturer Info C	0x408D	Manufacturer Info Block C11	H1	0x0	0xFF	0x6B	Hex
System Data	Manufacturer Info C	0x408E	Manufacturer Info Block C12	H1	0x0	0xFF	0x6C	Hex
System Data	Manufacturer Info C	0x408F	Manufacturer Info Block C13	H1	0x0	0xFF	0x6D	Hex
System Data	Manufacturer Info C	0x4090	Manufacturer Info Block C14	H1	0x0	0xFF	0x6E	Hex
System Data	Manufacturer Info C	0x4091	Manufacturer Info Block C15	H1	0x0	0xFF	0x6F	Hex
System Data	Manufacturer Info C	0x4092	Manufacturer Info Block C16	H1	0x0	0xFF	0x70	Hex
System Data	Manufacturer Info C	0x4093	Manufacturer Info Block C17	H1	0x0	0xFF	0x71	Hex
System Data	Manufacturer Info C	0x4094	Manufacturer Info Block C18	H1	0x0	0xFF	0x72	Hex
System Data	Manufacturer Info C	0x4095	Manufacturer Info Block C19	H1	0x0	0xFF	0x73	Hex
System Data	Manufacturer Info C	0x4096	Manufacturer Info Block C20	H1	0x0	0xFF	0x74	Hex
System Data	Manufacturer Info C	0x4097	Manufacturer Info Block C21	H1	0x0	0xFF	0x75	Hex
System Data	Manufacturer Info C	0x4098	Manufacturer Info Block C22	H1	0x0	0xFF	0x76	Hex
System Data	Manufacturer Info C	0x4099	Manufacturer Info Block C23	H1	0x0	0xFF	0x77	Hex
System Data	Manufacturer Info C	0x409A	Manufacturer Info Block C24	H1	0x0	0xFF	0x7A	Hex
System Data	Manufacturer Info C	0x409B	Manufacturer Info Block C25	H1	0x0	0xFF	0x78	Hex
System Data	Manufacturer Info C	0x409C	Manufacturer Info Block C26	H1	0x0	0xFF	0x79	Hex
System Data	Manufacturer Info C	0x409D	Manufacturer Info Block C27	H1	0x0	0xFF	0x30	Hex
System Data	Manufacturer Info C	0x409E	Manufacturer Info Block C28	H1	0x0	0xFF	0x31	Hex
System Data	Manufacturer Info C	0x409F	Manufacturer Info Block C29	H1	0x0	0xFF	0x32	Hex
System Data	Manufacturer Info C	0x40A0	Manufacturer Info Block C30	H1	0x0	0xFF	0x33	Hex
System Data	Manufacturer Info C	0x40A1	Manufacturer Info Block C31	H1	0x0	0xFF	0x34	Hex
System Data	Manufacturer Info C	0x40A2	Manufacturer Info Block C32	H1	0x0	0xFF	0x35	Hex
System Data	Integrity	0x40A3	Static DF Signature	H2	0x0	0x7FFF	0x0	Hex
System Data	Integrity	0x40A5	Static Chem DF Signature	H2	0x0	0x7FFF	0x3A4C	Hex
System Data	Integrity	0x40A7	All DF Signature	H2	0x0	0x7FFF	0x0	Hex
I2C Configuration	Data	0x40A9	Manufacture Date	U2	0	65535	0	date
I2C Configuration	Data	0x40AB	Serial Number	H2	0x0	0xFFFF	0x0001	Hex
I2C Configuration	Data	0x40AD	Manufacturer Name	S21	x	x	Texas Instruments	—
I2C Configuration	Data	0x40C2	Device Name	S21	x	x	BQ27Z746	—
I2C Configuration	Data	0x40D7	Device Chemistry	S5	x	x	LION	—
Lifetimes	Voltage	0x4202	Cell 1 Max Voltage	I2	0	32767	0	mV
Lifetimes	Voltage	0x4204	Cell 1 Min Voltage	I2	0	32767	32767	mV
Lifetimes	Current	0x4206	Max Charge Current	I2	0	32767	0	mA
Lifetimes	Current	0x4208	Max Discharge Current	I2	−32768	0	0	mA
Lifetimes	Current	0x420A	Max Avg Dsg Current	I2	−32768	0	0	mA
Lifetimes	Current	0x420C	Max Avg Dsg Power	I2	−32768	0	0	cW
Lifetimes	Temperature	0x420E	Max Temp Cell	I1	−128	127	−128	°C
Lifetimes	Temperature	0x420F	Min Temp Cell	I1	−128	127	127	°C
Lifetimes	Temperature	0x4210	Max Temp Int Sensor	I1	−128	127	−128	°C
Lifetimes	Temperature	0x4211	Min Temp Int Sensor	I1	−128	127	127	°C
Lifetimes	Safety Events	0x4212	No Of COV Events	U2	0	32767	0	events
Lifetimes	Safety Events	0x4214	Last COV Event	U2	0	32767	0	cycles
Lifetimes	Safety Events	0x4216	No Of CUV Events	U2	0	32767	0	events
Lifetimes	Safety Events	0x4218	Last CUV Event	U2	0	32767	0	cycles
Lifetimes	Safety Events	0x421A	No Of OCD Events	U2	0	32767	0	events
Lifetimes	Safety Events	0x421C	Last OCD Event	U2	0	32767	0	cycles

Table 17-1. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Lifetimes	Safety Events	0x421E	No Of OCC Events	U2	0	32767	0	events
Lifetimes	Safety Events	0x4220	Last OCC Event	U2	0	32767	0	cycles
Lifetimes	Safety Events	0x4222	No Of UTC Events	U2	0	32767	0	events
Lifetimes	Safety Events	0x4224	Last UTC Event	U2	0	32767	0	cycles
Lifetimes	Safety Events	0x4226	No Of HSCD Events	U2	0	32767	0	events
Lifetimes	Safety Events	0x4228	Last HSCD Event	U2	0	32767	0	cycles
Lifetimes	Safety Events	0x422A	No Of UTD Events	U2	0	32767	0	events
Lifetimes	Safety Events	0x422C	Last UTD Event	U2	0	32767	0	cycles
Lifetimes	Safety Events	0x422E	No Of OTC Events	U2	0	32767	0	events
Lifetimes	Safety Events	0x4230	Last OTC Event	U2	0	32767	0	cycles
Lifetimes	Safety Events	0x4232	No Of OTD Events	U2	0	32767	0	events
Lifetimes	Safety Events	0x4234	Last OTD Event	U2	0	32767	0	cycles
Lifetimes	Safety Events	0x4236	No Of OTF Events	U2	0	32767	0	events
Lifetimes	Safety Events	0x4238	Last OTF Event	U2	0	32767	0	cycles
Lifetimes	Safety Events	0x424A	No Of PTO Events	U2	0	32767	0	events
Lifetimes	Safety Events	0x424C	Last PTO Event	U2	0	32767	0	cycles
Lifetimes	Safety Events	0x424E	No Of CTO Events	U2	0	32767	0	events
Lifetimes	Safety Events	0x4250	Last CTO Event	U2	0	32767	0	cycles
Lifetimes	Safety Events	0x425A	No Of HCOV Events	U2	0	32767	0	events
Lifetimes	Safety Events	0x425C	Last HCOV Event	U2	0	32767	0	cycles
Lifetimes	Safety Events	0x425E	No Of HCUV Events	U2	0	32767	0	events
Lifetimes	Safety Events	0x4260	Last HCUV Event	U2	0	32767	0	cycles
Lifetimes	Safety Events	0x4262	No Of HOCC Events	U2	0	32767	0	events
Lifetimes	Safety Events	0x4264	Last HOCC Event	U2	0	32767	0	cycles
Lifetimes	Safety Events	0x4266	No Of HOCD Events	U2	0	32767	0	events
Lifetimes	Safety Events	0x4268	Last HOCD Event	U2	0	32767	0	cycles
Lifetimes	Charging Events	0x423A	No Valid Charge Term	U2	0	32767	0	events
Lifetimes	Charging Events	0x423C	Last Valid Charge Term	U2	0	32767	0	cycles
Lifetimes	Gauging Events	0x423E	No Of Qmax Updates	U2	0	32767	0	events
Lifetimes	Gauging Events	0x4240	Last Qmax Update	U2	0	32767	0	cycles
Lifetimes	Gauging Events	0x4242	No Of Ra Updates	U2	0	32767	0	events
Lifetimes	Gauging Events	0x4244	Last Ra Update	U2	0	32767	0	cycles
Lifetimes	Gauging Events	0x4246	No Of Ra Disable	U2	0	32767	0	events
Lifetimes	Gauging Events	0x4248	Last Ra Disable	U2	0	32767	0	cycles
Lifetimes	Discharging Events	0x4256	No Full Discharge	U2	0	32767	0	events
Lifetimes	Discharging Events	0x4258	Last Full Discharge	U2	0	32767	0	cycles
Lifetimes	Power Events	0x426A	No Of Shutdowns	U1	0	255	0	events
Lifetimes	Time	0x426E	Total Fw Runtime	U4	0	4294967295	0	s
Lifetimes	Time	0x4272	Total Charge Time	U4	0	4294967295	0	s
Lifetimes	Time	0x4276	Total Discharge Time	U4	0	4294967295	0	s
Lifetimes	Time	0x427A	Time Spent In UT RSOC A	U4	0	4294967295	0	s
Lifetimes	Time	0x427E	Time Spent In UT RSOC B	U4	0	4294967295	0	s
Lifetimes	Time	0x4282	Time Spent In UT RSOC C	U4	0	4294967295	0	s
Lifetimes	Time	0x4286	Time Spent In UT RSOC D	U4	0	4294967295	0	s
Lifetimes	Time	0x428A	Time Spent In UT RSOC E	U4	0	4294967295	0	s
Lifetimes	Time	0x428E	Time Spent In UT RSOC F	U4	0	4294967295	0	s
Lifetimes	Time	0x4292	Time Spent In UT RSOC G	U4	0	4294967295	0	s
Lifetimes	Time	0x4296	Time Spent In UT RSOC H	U4	0	4294967295	0	s
Lifetimes	Time	0x429A	Time Spent In LT RSOC A	U4	0	4294967295	0	s
Lifetimes	Time	0x429E	Time Spent In LT RSOC B	U4	0	4294967295	0	s

Table 17-1. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Lifetimes	Time	0x42A2	Time Spent In LT RSOC C	U4	0	4294967295	0	s
Lifetimes	Time	0x42A6	Time Spent In LT RSOC D	U4	0	4294967295	0	s
Lifetimes	Time	0x42AA	Time Spent In LT RSOC E	U4	0	4294967295	0	s
Lifetimes	Time	0x42AE	Time Spent In LT RSOC F	U4	0	4294967295	0	s
Lifetimes	Time	0x42B2	Time Spent In LT RSOC G	U4	0	4294967295	0	s
Lifetimes	Time	0x42B6	Time Spent In LT RSOC H	U4	0	4294967295	0	s
Lifetimes	Time	0x42BA	Time Spent In STL RSOC A	U4	0	4294967295	0	s
Lifetimes	Time	0x42BE	Time Spent In STL RSOC B	U4	0	4294967295	0	s
Lifetimes	Time	0x42C2	Time Spent In STL RSOC C	U4	0	4294967295	0	s
Lifetimes	Time	0x42C6	Time Spent In STL RSOC D	U4	0	4294967295	0	s
Lifetimes	Time	0x42CA	Time Spent In STL RSOC E	U4	0	4294967295	0	s
Lifetimes	Time	0x42CE	Time Spent In STL RSOC F	U4	0	4294967295	0	s
Lifetimes	Time	0x42D2	Time Spent In STL RSOC G	U4	0	4294967295	0	s
Lifetimes	Time	0x42D6	Time Spent In STL RSOC H	U4	0	4294967295	0	s
Lifetimes	Time	0x42DA	Time Spent In RT RSOC A	U4	0	4294967295	0	s
Lifetimes	Time	0x42DE	Time Spent In RT RSOC B	U4	0	4294967295	0	s
Lifetimes	Time	0x42E2	Time Spent In RT RSOC C	U4	0	4294967295	0	s
Lifetimes	Time	0x42E6	Time Spent In RT RSOC D	U4	0	4294967295	0	s
Lifetimes	Time	0x42EA	Time Spent In RT RSOC E	U4	0	4294967295	0	s
Lifetimes	Time	0x42EE	Time Spent In RT RSOC F	U4	0	4294967295	0	s
Lifetimes	Time	0x42F2	Time Spent In RT RSOC G	U4	0	4294967295	0	s
Lifetimes	Time	0x42F6	Time Spent In RT RSOC H	U4	0	4294967295	0	s
Lifetimes	Time	0x42FA	Time Spent In STH RSOC A	U4	0	4294967295	0	s
Lifetimes	Time	0x42FE	Time Spent In STH RSOC B	U4	0	4294967295	0	s
Lifetimes	Time	0x4302	Time Spent In STH RSOC C	U4	0	4294967295	0	s
Lifetimes	Time	0x4306	Time Spent In STH RSOC D	U4	0	4294967295	0	s
Lifetimes	Time	0x430A	Time Spent In STH RSOC E	U4	0	4294967295	0	s
Lifetimes	Time	0x430E	Time Spent In STH RSOC F	U4	0	4294967295	0	s
Lifetimes	Time	0x4312	Time Spent In STH RSOC G	U4	0	4294967295	0	s
Lifetimes	Time	0x4316	Time Spent In STH RSOC H	U4	0	4294967295	0	s
Lifetimes	Time	0x431A	Time Spent In HT RSOC A	U4	0	4294967295	0	s
Lifetimes	Time	0x431E	Time Spent In HT RSOC B	U4	0	4294967295	0	s
Lifetimes	Time	0x4322	Time Spent In HT RSOC C	U4	0	4294967295	0	s
Lifetimes	Time	0x4326	Time Spent In HT RSOC D	U4	0	4294967295	0	s
Lifetimes	Time	0x432A	Time Spent In HT RSOC E	U4	0	4294967295	0	s
Lifetimes	Time	0x432E	Time Spent In HT RSOC F	U4	0	4294967295	0	s
Lifetimes	Time	0x4332	Time Spent In HT RSOC G	U4	0	4294967295	0	s
Lifetimes	Time	0x4336	Time Spent In HT RSOC H	U4	0	4294967295	0	s
Lifetimes	Time	0x433A	Time Spent In OT RSOC A	U4	0	4294967295	0	s
Lifetimes	Time	0x433E	Time Spent In OT RSOC B	U4	0	4294967295	0	s
Lifetimes	Time	0x4342	Time Spent In OT RSOC C	U4	0	4294967295	0	s
Lifetimes	Time	0x4346	Time Spent In OT RSOC D	U4	0	4294967295	0	s
Lifetimes	Time	0x434A	Time Spent In OT RSOC E	U4	0	4294967295	0	s
Lifetimes	Time	0x434E	Time Spent In OT RSOC F	U4	0	4294967295	0	s
Lifetimes	Time	0x4352	Time Spent In OT RSOC G	U4	0	4294967295	0	s
Lifetimes	Time	0x4356	Time Spent In OT RSOC H	U4	0	4294967295	0	s
Ra Table	R_a0	0x4100	Cell0 R_a flag	H2	0x0	0xFFFF	0xFF55	—
Ra Table	R_a0	0x4102	Cell0 R_a 0	I2	0	32767	159	2^{-10} Ω
Ra Table	R_a0	0x4104	Cell0 R_a 1	I2	0	32767	58	2^{-10} Ω
Ra Table	R_a0	0x4106	Cell0 R_a 2	I2	0	32767	65	2^{-10} Ω

Table 17-1. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Ra Table	R_a0	0x4108	Cell0 R_a 3	I2	0	32767	79	2^{-10} Ω
Ra Table	R_a0	0x410A	Cell0 R_a 4	I2	0	32767	90	2^{-10} Ω
Ra Table	R_a0	0x410C	Cell0 R_a 5	I2	0	32767	63	2^{-10} Ω
Ra Table	R_a0	0x410E	Cell0 R_a 6	I2	0	32767	76	2^{-10} Ω
Ra Table	R_a0	0x4110	Cell0 R_a 7	I2	0	32767	82	2^{-10} Ω
Ra Table	R_a0	0x4112	Cell0 R_a 8	I2	0	32767	82	2^{-10} Ω
Ra Table	R_a0	0x4114	Cell0 R_a 9	I2	0	32767	87	2^{-10} Ω
Ra Table	R_a0	0x4116	Cell0 R_a 10	I2	0	32767	87	2^{-10} Ω
Ra Table	R_a0	0x4118	Cell0 R_a 11	I2	0	32767	101	2^{-10} Ω
Ra Table	R_a0	0x411A	Cell0 R_a 12	I2	0	32767	118	2^{-10} Ω
Ra Table	R_a0	0x411C	Cell0 R_a 13	I2	0	32767	191	2^{-10} Ω
Ra Table	R_a0	0x411E	Cell0 R_a 14	I2	0	32767	282	2^{-10} Ω
Ra Table	R_a0x	0x4140	xCell0 R_a flag	H2	0x0	0xFFFF	0xFFFF	—
Ra Table	R_a0x	0x4142	xCell0 R_a 0	I2	0	32767	159	2^{-10} Ω
Ra Table	R_a0x	0x4144	xCell0 R_a 1	I2	0	32767	58	2^{-10} Ω
Ra Table	R_a0x	0x4146	xCell0 R_a 2	I2	0	32767	65	2^{-10} Ω
Ra Table	R_a0x	0x4148	xCell0 R_a 3	I2	0	32767	79	2^{-10} Ω
Ra Table	R_a0x	0x414A	xCell0 R_a 4	I2	0	32767	90	2^{-10} Ω
Ra Table	R_a0x	0x414C	xCell0 R_a 5	I2	0	32767	63	2^{-10} Ω
Ra Table	R_a0x	0x414E	xCell0 R_a 6	I2	0	32767	76	2^{-10} Ω
Ra Table	R_a0x	0x4150	xCell0 R_a 7	I2	0	32767	82	2^{-10} Ω
Ra Table	R_a0x	0x4152	xCell0 R_a 8	I2	0	32767	82	2^{-10} Ω
Ra Table	R_a0x	0x4154	xCell0 R_a 9	I2	0	32767	87	2^{-10} Ω
Ra Table	R_a0x	0x4156	xCell0 R_a 10	I2	0	32767	87	2^{-10} Ω
Ra Table	R_a0x	0x4158	xCell0 R_a 11	I2	0	32767	101	2^{-10} Ω
Ra Table	R_a0x	0x415A	xCell0 R_a 12	I2	0	32767	118	2^{-10} Ω
Ra Table	R_a0x	0x415C	xCell0 R_a 13	I2	0	32767	191	2^{-10} Ω
Ra Table	R_a0x	0x415E	xCell0 R_a 14	I2	0	32767	282	2^{-10} Ω

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

Date	Revision	Notes
October 2021	*	Initial Release

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