bq28400

Technical Reference

Literature Number: SLUU431
June 2011

Contents

Preface

Read this First

This manual discusses the modules and peripherals of the bq28400 device, and how the bq28400 is used to build a complete battery pack gas gauge and protection solution.

Notational Conventions

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

- SBS commands are set in italic; for example, *Voltage*.
- SBS bits and flags are capitalized, set in italic and enclosed with square brackets; for example, *[TCA]*.
- Data flash values are set in bold italic; for example, ***CUV Threshold***.
- All data flash bits and flags are capitalized, set in bold italic and enclosed with square brackets, for example, ***[NR]***.

All SBS commands, data flash values, and flags mentioned in a chapter are listed at the end of each chapter for reference.

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

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

The reference format for data flash values is: DF:Class Name:Subclass Name(Subclass ID):Value Name(Offset)[Flag], for example:

DF:1st Level Safety:Voltage(0):CUV Threshold(13), or

DF:Configuration:Registers(64):Operation A Cfg(0)[SLEEP].

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Calibration

1.1 Overview

The bq28400 has integrated routines that support calibration of current, voltage, and temperature readings, accessible after writing 0xF081 or 0xF082 to ManufacturerAccess( ). When the calibration routines are activated, the raw ADC data is available through the ManufacturerData( ) command, which returns a 26-byte data block.

ManufacturerAccess( )	Description
0xF02d	Enable/Disable Calibration Mode
0xF080	
0xF081	Output raw ADC data of voltage, current, and temperature on ManufacturerData( )
0xF082	Output raw ADC data of voltage, current, and temperature on ManufacturerData( ). This mode includes a shunt of the coulomb counter input.

The ManufacturerData( ) output format is: ZZYYaaAAbbBBccCCddDDeeEEffFFggGGhhHHiiIIjjJJkkKKllLL, where:

VALUE	FORMAT	DESCRIPTION
ZZ	byte	8-bit counter, increments when raw ADC values are refreshed, typically every 250 ms
YY	byte	Output status
		ManufacturerAccess( ) = 0xF081: 1
		ManufacturerAccess( ) = 0xF082: 2
AAaa	2's comp	ManufacturerAccess( ) = 0xF081: coulomb counter
		ManufacturerAccess( ) = 0xF082, internal shorted coulomb counter
BBbb	2's comp	Cell Voltage 1
CCcc	2's comp	Cell Voltage 2
FFff	2's comp	Internal temperature sensor
GGgg	2's comp	Temperature Sensor 1
IIii		RSVD
JJjj		RSVD
KKkk		RSVD
LLll		RSVD

1.2 Combining Calibrations

Table 1-1. Combining Calibrations

TIME (S)	ZZ in ManufacturerData( )	ACTION
0	N	• Read DF values • Apply 0 mA current • Apply cell voltages • Apply known temperature • ManufacturerAccess() = 0xf082 • Poll ManufacturerData() for ZZ increment
0.25	N + 1	• Poll ManufacturerData() for ZZ increment
0.5	N + 2	• Store ManufacturerData ( ) block 1 • Poll ManufacturerData() for ZZ increment
0.75	N + 3	• Store ManufacturerData() block 2 • Poll ManufacturerData() for ZZ increment
1	N + 4	• Store ManufacturerData() block 3 • Poll ManufacturerData() for ZZ increment
1.25	N + 5	• Store ManufacturerData() block 4 apply Pack Voltage • ManufacturerAccess() = 0xf081 • Poll ManufacturerData() for ZZ increment
1.5	N + 6	• Poll ManufacturerData() for ZZ increment
1.75	N + 7	• Store ManufacturerData() block 5 • Poll ManufacturerData() for ZZ increment
2	N + 8	• Store ManufacturerData() block 6 • Poll ManufacturerData() for ZZ increment
2.25	N + 9	• Store ManufacturerData() block 7 • Poll ManufacturerData() for ZZ increment
2.5	N + 10	• Store ManufacturerData() block 8 • Apply calibration current • Poll ManufacturerData() for ZZ increment
2.75	N + 11	• Poll ManufacturerData() for ZZ increment
3	N + 12	• Store ManufacturerData() block 9 • Poll ManufacturerData() for ZZ increment
3.25	N + 13	• Store ManufacturerData() block 10 • Poll ManufacturerData() for ZZ increment
3.5	N + 14	• Store ManufacturerData() block 11 • Poll ManufacturerData() for ZZ increment
3.75	N + 15	• Store ManufacturerData() block 12 • Calculate CC Offset using blocks 1 to 4 • Calculate board Offset using blocks 5 to 8 • Calculate current gain using blocks 9 to 12 • Calculate Cell Voltage 1 – 4 using blocks 1 to 4 • Calculate Pack Voltage using blocks 5 to 8 • Calculate Temperatures using blocks 5 to 8 write values to data flash

1.3 Cell Voltage Calibration

1. Apply known voltages in mV to the cell voltage inputs:
   - V_{CELL1} between VC2 pin and VSS pin
   - V_{CELL2} between VC1 pin and VC2 pin

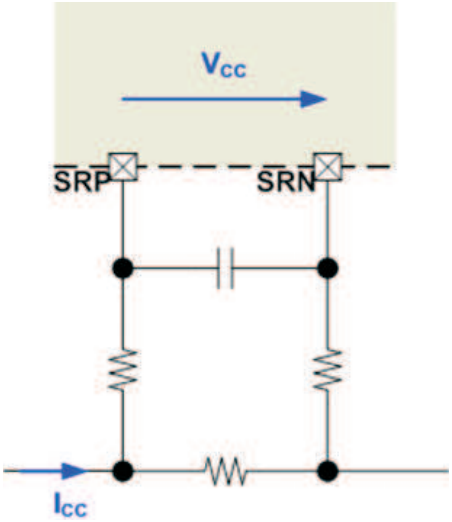
2. Send 0xF081 or 0xF082 to ManufacturerAccess( ) to enable raw cell voltage output on ManufacturerData( ).
3. Poll ManufacturerData( ) until ZZ increments by 2 before reading data.
4. Grab the ADC conversion readings of cell voltages from ManufacturerData( ):
   - ADC_{CELL1} = AAaa of ManufacturerData( ), is ADCCELL1 < 0x8000? If yes, use ADC_{CELL1}; otherwise, ADCCELL1 = AAaa – 0xFFFF + 0x0001
   - ADC_{CELL2} = BBbb of ManufacturerData( ), is ADC_{CELL2} < 0x8000? If yes, use ADC_{CELL2}; otherwise, ADC_{CELL2} = BBbb – 0xFFFF + 0x0001
5. Average several readings for higher accuracy. Poll ManufacturerData( ) until ZZ increments, which indicates updated values.
6. Calculate gain values:

$$Alt\ Cell\ Scale1 = \frac{V_{CELL1}}{ADC_{CELL1}} * 2^{16}$$

$$Alt\ Cell\ Scale2 = \frac{V_{CELL1} + V_{CELL2}}{ADC_{CELL1} + ADC_{CELL2}} * 2^{16}$$

7. Update the data flash with Cell Scale 1 and Cell Scale 2.
8. Re-check the voltage reading. Repeat the steps if the reading is not accurate.

1.4 Current Calibration



1.4.1 Offset Calibration

1. Apply a known current of 0 mA:
   - Make sure no current is flowing through the sense resistor connected between the SRP and SRN pins.
2. Send 0xF082 to ManufacturerAccess( ) to enable raw CC output on ManufacturerData( ) with CC shunt.
3. Read *Coulomb Counter Offset Samples* from data flash.
4. Poll ManufacturerData( ) until ZZ increments by 2 before reading data.
5. Grab the ADC conversion readings of current from ManufacturerData( ):
   - ADC_{CC} = AAaa of ManufacturerData( ), is ADC_{CC} < 0x8000? If yes, use ADC_{CC}; otherwise, ADC_{CC} = AAaa – 0xFFFF + 0x0001.
6. Average several readings for higher accuracy. Poll ManufacturerData( ) until ZZ increments, which indicates updated values.
   - ADC_{CC} = [ADC_{CC}(reading n) + … + ADC_{CC}(reading 1)]/n
7. Calculate offset value:

$$CC\,offset = ADC_{CC} * (Coulomb\ Counter\ Offset\ Samples)$$

8. Update the data flash with *CC Offset*.
9. Re-check the current reading. Repeat the steps if the reading is not accurate.

1.4.2 Board Offset Calibration

1. Apply a known current of 0 mA:
   - Make sure no current is flowing through the sense resistor connected between SRP pin and SRN pin.
2. Send 0xF081 to ManufacturerAccess( ) to enable raw CC output on ManufacturerData( ).
3. Read *Coulomb Counter Offset Samples* from data flash.
4. Poll ManufacturerData( ) until ZZ increments by 2 before reading data.
5. Grab the ADC conversion readings of current from ManufacturerData( ):
   - ADCCC = AAaa of ManufacturerData( ), is ADC_{CC} < 0x8000? If yes, use ADC_{CC}; otherwise, ADC_{CC} = AAaa – 0xFFFF + 0x0001.
6. Average several readings for higher accuracy. Poll ManufacturerData( ) until ZZ increments, which indicates updated values.
   - ADC_{CC} = [ADC_{CC}(reading n) + … + ADC_{CC}(reading 1)]/n
7. Calculate offset value:
   $Board\ offset = (ADC_{CC} - CC\ Offset / (Coulomb\ Counter\ Offset\ Samples)) * (Coulomb\ Counter\ Offset\ Samples)$
8. Update the data flash with *Board Offset*.
9. Re-check the current reading. Repeat the steps if the reading is not accurate.

1.4.3 Gain Calibration

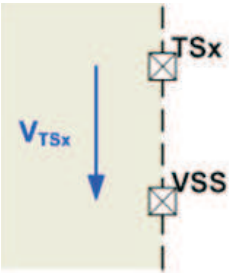
1. Apply a known current in mA to the current input.
   - Make sure current I_{CC} is flowing through the sense resistor connected between SRP pin and SRN pin.
2. Send 0xF081 to ManufacturerAccess( ) to enable raw CC output on ManufacturerData( ).
3. Read *Coulomb Counter Offset Samples* from data flash.
4. Poll ManufacturerData( ) until ZZ increments by 2 before reading data.
5. Grab the ADC conversion readings of current from ManufacturerData( ):
   - ADC_{CC} = AAaa of ManufacturerData( ), is ADC_{CC} < 0x8000? If yes, use ADC_{CC}; otherwise, ADC_{CC} = AAaa – 0xFFFF + 0x0001.
6. Average several readings for higher accuracy. Poll ManufacturerData( ) until ZZ increments, which indicates updated values.
   - ADC_{CC} = [ADC_{CC}(reading n) + … + ADC_{CC}(reading 1)]/n
7. Calculate gain values:

$$CC\ Gain = \frac{I_{CC}}{ADC_{CC} - \frac{(Board\ Offset) + (CC\ Offset)}{(Coulomb\ Counter\ Offset\ Samples)}}$$

$$Capacity\ Gain = CC\ Gain * 298261.6178$$

8. Update the data flash with CC Gain, CC Delta (*Capacity Gain*).
9. Re-check the current reading. Repeat the steps if the reading is not accurate.

1.5 Temperature Calibration



1.5.1 Internal Temperature Sensor Calibration (OPTION 1)

1. Apply a known temperature in 0.1ºC.
   - Make sure temperature $Temp_{TINT}$ is applied to the device.
2. Enable TINT as the SBS temperature source by setting the Misc Configuration bit 7 to 1.
3. Grab the reported temperature from the SBS temperature.
4. Calculate temperature offset:
   $$TINT\ offset = TEMP_{TINT} - TINT$$
5. Update the data flash with the calculated value.
6. Re-check the current reading. Repeat the steps if the reading is not accurate.

1.5.2 Internal Temperature Sensor Calibration (OPTION 2)

1. Apply a known temperature in 0.1ºC.
   - Make sure temperature $Temp_{TINT}$ is applied to the device.
2. Read *Int Coeff 1*, *Int Coeff 2*, *Int Coeff 3*, *Int Coeff 4* from data flash.
3. Send 0xF081 or 0xF082 to ManufacturerAccess( ) to enable raw cell voltage output on ManufacturerData( ).
4. Poll ManufacturerData( ) until ZZ increments by 2 before reading data.
5. Grab the ADC conversion readings of temperature from Temperature( ):
   - ADCTINT = FFff of ManufacturerData( ), is ADC_{INT} < 0x8000? If yes, use ADC_{TINT}; otherwise, ADC_{TINT} = FFff – 0xFFFF + 0x0001.
6. Average several readings for higher accuracy. Poll ManufacturerData( ) until ZZ increments, which indicates updated values.
   - ADC_{TINT} = [ADC_{TINT}(reading n) + … + ADC_{TINT}(reading 1)]/n
7. Calculate temperature offset:
   $$A = ADC_{TINT} / 2^{16}$$
   $$T_{TINT} = ((INTCoeff\,1) * A^3 + (INTCoeff\,2) * A^2 + (INTCoeff\,3) * A + (INTCoeff\,4)) * 0.1 - 273.15$$
   $$Internal\ Temperature\ Offset = TEMP_{TINT} - T_{TINT}$$
8. Update the data flash with the *Internal Temperature Offset*.
9. Re-check the temperature reading. Repeat the steps if the reading is not accurate.

1.5.3 TS1 Calibration (OPTION 1)

1. Apply a known temperature in 0.1ºC.
   - Make sure temperature $Temp_{TS1}$ is applied to the thermistor connected to the TS1 pin.
2. Enable TS1 as the SBS temperature source by setting the Misc Configuration bit 7 to 0.
3. Grab the reported temperature from the SBS temperature.
4. Calculate the temperature offset:
   $$TS1\ offset = TEMP_{TS1} - TS1$$
5. Update the data flash with the calculated value.

6. Re-check the current reading. Repeat the steps if the reading is not accurate.

1.5.4 TS1 Calibration (OPTION 2)

1. Apply a known temperature in 0.1ºC.
   - Make sure temperature $Temp_{TS1}$ is applied to the thermistor connected to the TS1 pin.
2. Read Coeff a1, Coeff a2, Coeff a3, Coeff a4, Coeff b1, Coeff b2, Coeff b3, Coeff b4 from data flash.
3. Send 0xF081 or 0xF082 to ManufacturerAccess( ) to enable raw cell voltage output on ManufacturerData( ).
4. Poll ManufacturerData( ) until ZZ increments by 2 before reading data.
5. Grab the ADC conversion readings of temperature from ManufacturerData( ):
   - ADC_{TS1}= GGgg of ManufacturerData( ), is ADC_{TS1} < 0x8000? If yes, use ADC_{TS1}; otherwise, ADC_{TS1} = GGgg – 0xFFFF + 0x0001.
6. Average several readings for higher accuracy. Poll ManufacturerData( ) until ZZ increments, which indicates updated values.
   - ADC_{TS1} = [ADC_{TS1}(reading n) + … + ADC_{TS1}(reading 1)]/n
7. Calculate temperature offset:

$$A = \frac{ADC_{TS1}}{2^{15}}$$

$$B = \frac{A}{(CoeffA1)*A^{4} + (CoeffA2)*A^{3} + (CoeffA3)*A^{2} + (CoeffA4)*A + (CoeffA5)} * 2^{14}$$

$$T_{TS1} = ((CoeffB1)*B^{3} + (CoeffB2)*B^{2} + (CoeffB3)*B^{1} + (CoeffB4))*0.1 - 273.15$$

$$External\,1\,Temperature\,Offset = TEMP_{TS1} - T_{TS1}$$

8. Update the data flash with the calculated *External 1 Temperature Offset*.
9. Re-check the temperature reading. Repeat the steps if the reading is not accurate.

Detailed Description

2.1 JEITA Temperature Ranges

The bq28400 follows the JEITA guidelines, which specify that charging voltage and charging current depend on the temperature. Temperature ranges are used for specifying both what the charging voltage and charging current should be.

There are three temperature ranges in which charging is allowed and they are defined as:

- T1 – T2: Low charging temperature range (T1 ≤ Temperature < T2)
- T2 – T3: Standard charging temperature range (T2 ≤ Temperature < T3)
- T3 – T4: High charging temperature range (T3 ≤ Temperature < T4)

For added flexibility the standard temperature range is divided into 2 sub-ranges: standard range 1 and standard range 2. An additional temperature value (T2a) is needed to specify these two ranges. These temperature ranges will be configurable in the gas gauge through the following data flash constants.

- ***JT1:*** Lower bound of low charging temperature range, in °C.
- ***JT2:*** Upper bound of low charging temperature range and lower bound of standard charging temperature range 1, in °C.
- ***JT2a:*** Upper bound of standard charging temperature range 1 and lower bound of standard charging temperature range 2, in °C
- ***JT3:*** Upper bound of standard charging temperature range 2 and lower bound of high charging temperature range, in °C.
- ***JT4:*** Upper bound of high charging temperature range, in °C.

The bq28400 implements hysteresis for the temperature ranges above using the DF variable (***Temp Hys***). This variable specifies the number of degrees of hysteresis that should be used before switching charging temperature ranges.

The active temperature range is indicated using a set of flags. Since hysteresis is implemented for the temperature ranges, determining the active temperature range depends on the previous state, in addition to the actual temperature. These flags reside in a status register called *TempRange*.

Table 2-1. Temperature Ranges in bq28400

Flag	JEITA Temperature Range	Charging Mode
TR1	Temp < ***JT1***	Charge Suspend or Charge Inhibit
TR2	***JT1*** < Temp < ***JT2***	Low Temp Charge
TR2A	***JT2*** < Temp < ***JT2a***	Standard Temp Charge 1
TR3	***JT2a*** < Temp < ***JT3***	Standard Temp Charge 2
TR4	***JT3*** < Temp < ***JT4***	High Temp Charge or Charge Inhibit
TR5	***JT4*** < Temp	Charge Suspend or Charge Inhibit

2.2 1st Level Protection Features

The bq28400 supports a wide range of battery and system protection features that are easily configured or enabled via the integrated data flash.

2.2.1 Cell Overvoltage (COV) and Cell Undervoltage (CUV)

The bq28400 can detect cell overvoltage/undervoltage and protect battery cells from damage from battery

cell overvoltage/undervoltage. If the over/undervoltage remains over a period of 2 s, the bq28400 goes into overvoltage/undervoltage condition and switches off the CHG/DSG FET. The bq28400 recovers from a cell overvoltage condition if all the cell voltages drop below the cell overvoltage recovery threshold. The bq28400 recovers from cell undervoltage condition if all the cell voltages rise above the cell undervoltage recovery threshold.

Per JEITA guidelines, the cell overvoltage threshold changes depending on the temperature. A separate cell overvoltage threshold is specified for each operating temperature range.

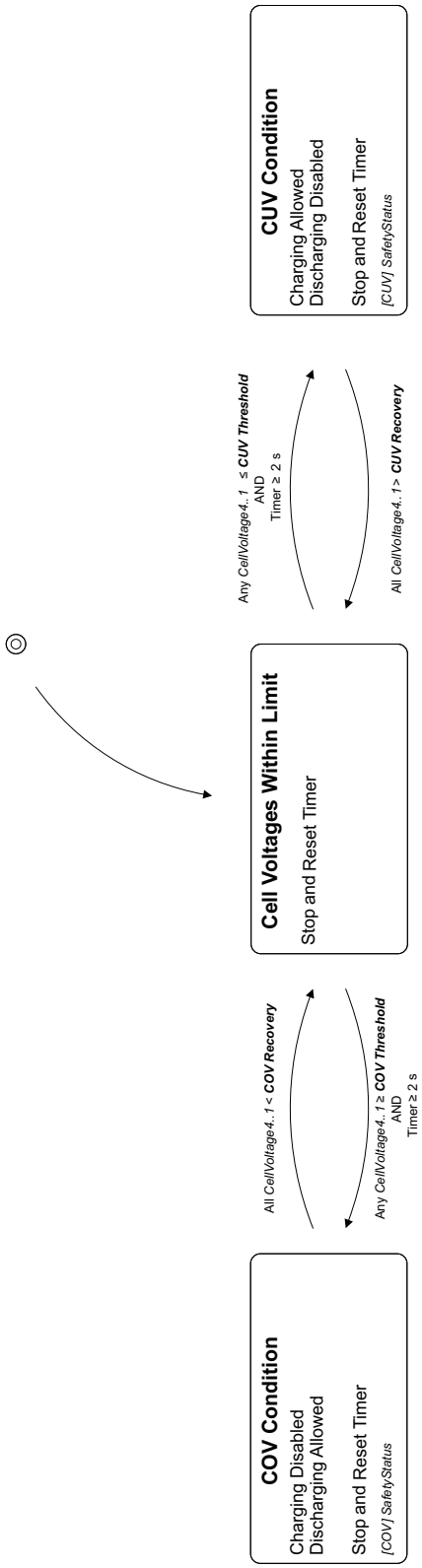


Figure 2-1. COV and CUV

Table 2-2. COV and CUV

Condition:		COV Condition	Normal	CUV Condition
Flags:	*BatteryStatus*	*[TCA]*		*[TDA], [FD]*
	SafetyStatus	*[COV]*		*[CUV]*
	OperationStatus			*[XDSG]*
FET:		CHG FET disabled, enabled during discharge	Normal	DSG FET disabled, enabled during charge
SBS Command:	*ChargingCurrent*	0	Charging algorithm	Charging algorithm
	ChargingVoltage	0	Charging algorithm	Charging algorithm

The bq28400 indicates cell overvoltage condition by setting the *[COV]* flag in *SafetyStatus* if any *CellVoltage2..1* reaches or surpasses the cell overvoltage limit (***LT COV Threshold, ST COV Threshold***, or ***HT COV Threshold***, depending on the current temperature range) and stays above the threshold for period of 2 s.

In cell overvoltage condition charging is disabled and CHG FET and ZVCHG FET (if used) are turned off, *ChargingCurrent* and *ChargingVoltage* are set to zero, *[TCA]* flag in *BatteryStatus* and *[COV]* flag in *SafetyStatus* are set.

The bq28400 recovers from a cell overvoltage condition if all *CellVoltages4..1* are equal to or lower than the appropriate COV Recovery limit (***LT COV Recovery***, ***ST COV Recovery***, or ***HT COV Recovery***) . On recovery the *[COV]* and *[TCA]* flags are reset, and *ChargingCurrent* and *ChargingVoltage* are set back to appropriate values per the charging algorithm.

In a cell overvoltage condition, the CHG FET is turned on during discharging to prevent overheating of the CHG FET body diode.

The bq28400 indicates cell undervoltage by setting the *[CUV]* flag in *SafetyStatus* if any *CellVoltage2..1* reaches or drops below the ***CUV Threshold*** limit during discharging and stays below the threshold for a period of 2 s.

In a cell undervoltage condition, discharging is disabled and DSG FET is turned off, the *[TDA]* and *[FD]* flags in *BatteryStatus* and the *[CUV]* flag in *SafetyStatus* are set.

The bq28400 recovers from cell undervoltage condition if all *CellVoltages4..1* are equal to or higher than ***CUV Recovery*** limit. On recovery, the *[CUV]* flag in *SafetyStatus* is reset, *[XDSG]* flag is reset, the *[TDA]* and *[FD]* flags are reset, and *ChargingCurrent* and *ChargingVoltage* are set back to appropriate values per the charging algorithm.

In cell undervoltage condition, the DSG FET is turned on during charging to prevent overheating of the DSG FET body diode.

2.2.2 Charge and Discharge Overcurrent

The bq28400 has two independent levels of recoverable overcurrent protection, the tier-1 (firmware overcurrent protection, charge and discharge directions) and AFE (hardware overcurrent protection, for discharge only) overcurrent protection. Both levels require the *Current* value to be greater than or equal to a programmed OC Threshold in either charge or discharge current for a period greater than OC Time Limit. In tier-1 only however, if the OC Time Limit is set to 0, that specific feature is disabled.

Table 2-3. Recoverable Charge and Discharge Overcurrent

Protection	OC Threshold	OC Time Limit	OC Recovery Threshold	*SafetyAlert* Flag	*SafetyStatus* Flag
Tier-1 Charge	***OC (1st Tier)Chg***	***OC(1st Tier) Chg Time***	***OC Chg Recovery*** for ***Current Recovery Time***	*[OCC]*	*[OCC]*
Tier-1 Discharge	***OC (1st Tier) Dsg***	***OC (1st Tier) Dsg Time***	***OC Dsg Recovery*** for ***Current Recovery Time***	*[OCD]*	*[OCD]*
AFE Hardware Discharge	***AFE OC Dsg***	***AFE OC Dsg Time***	***AFE OC Dsg Recovery*** for ***Current Recovery Time***	—	*[AOCD]*

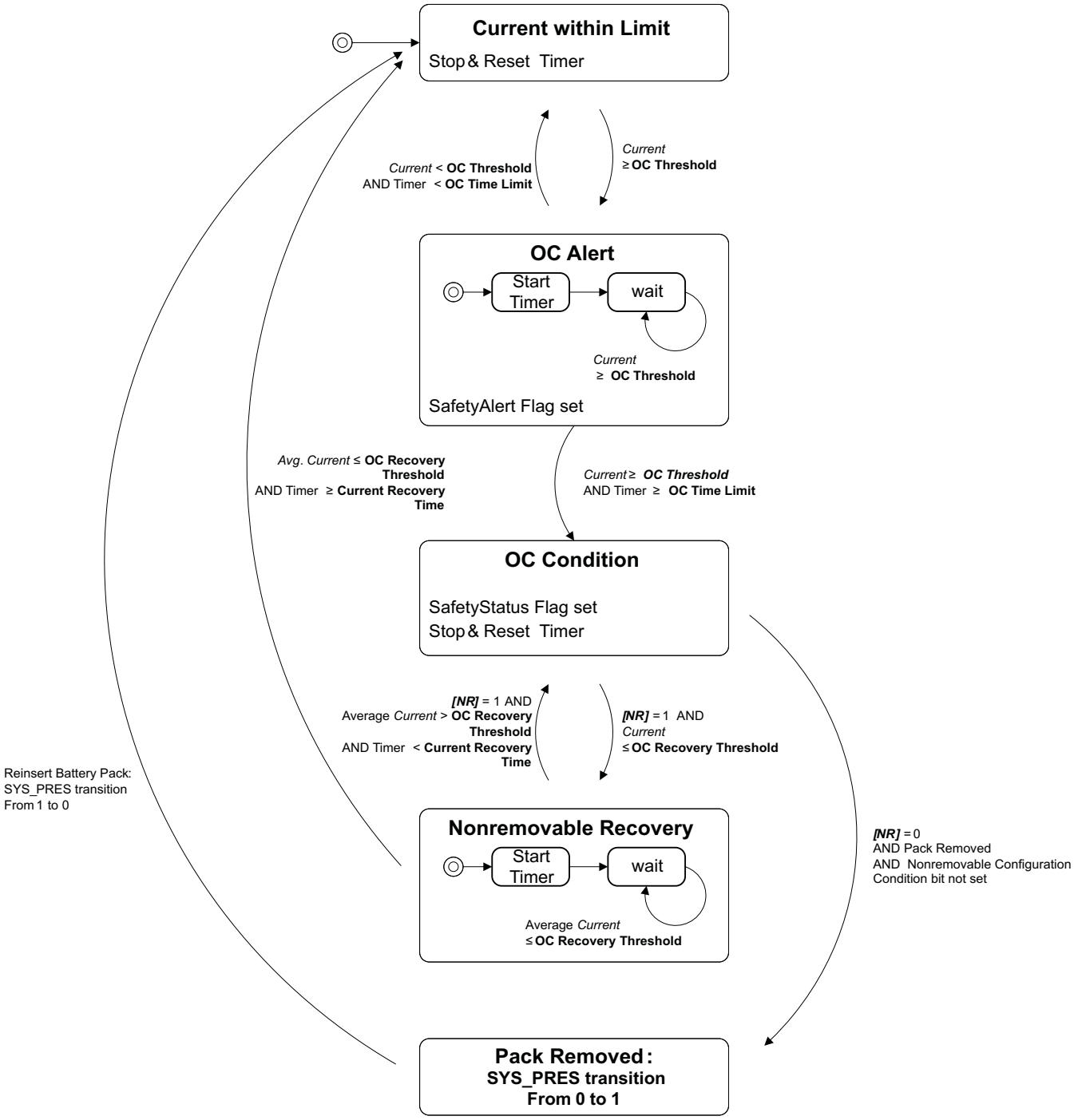


Figure 2-2. Recoverable OC Protection

For the tier-1 overcurrent protection, the specific flag in *SafetyAlert* is set if *Current* exceeds the OC Threshold. The bq28400 changes the specific flag in *SafetyAlert* to the specific flag in *SafetyStatus* if the *Current* stays above the OC Threshold limit for at least OC Time Limit period. This function is disabled if the OC Time Limit is set to zero. The *SafetyStatus* flag is reset if the *Current* falls below the OC Recovery Threshold.

If the tier-1 timer expires during charging, the CHG FET is turned off. When this occurs, the internal current fault timer is reset, *ChargingCurrent* and *ChargingVoltage* are set to 0, *[TCA]* flag is set and the *[OCC]* flag is set in *SafetyStatus*.

However, when the bq28400 has the *[OCC]* flag in *SafetyStatus* set, the CHG FET is turned on again during discharge (*Current* ≤ (–) ***Dsg Current Threshold***). This prevents overheating of the CHG FET body diode during discharge. No other flags change state until full recovery is reached. This action is not affected by the setting of ***[NR]*** bit.

If the tier-1 timer expires during discharging, the DSG FET is turned off and the ZVCHG FET is turned on if used. When this occurs the internal current fault timer is reset, *ChargingCurrent* is set to ***Pre-chg Current***, *[PCHG]*, *[XDSG]*, *[XDSGI]*, and *[TDA]* flag are set, and the *[OCD]* flag is set in *SafetyStatus*.

When the current measured by the AFE exceeds the ***AFE OC Dsg*** for longer than ***AFE OC Dsg Time***, the integrated AFE detects a discharge-overcurrent fault, the CHG and DSG FETs are turned off, the internal XALERT signal triggers an interrogation by the bq28400. When the bq28400 identifies the overcurrent condition, the CHG FET is re-enabled, *[TDA]* flag is set, *ChargingCurrent* is set to 0, and *[AOCD]* is set.

However, when either *[OCD]* or *[AOCD]* is set, the discharge-FET is turned on again during charging (*Current* ≥ `Chg Current Threshold`). This prevents overheating of the discharge-FET body diode during charge. No other flags change state until full recovery is reached.

Table 2-4. Overcurrent Conditions

Protection	Condition	Flags					FET	Charging Current	Charging Voltage
		Safety Alert	*Safety Status*	*Battery Status*	*Operation Status*	*Charging Status*			
Tier-1 Charge	OC Alert	*[OCC]*					normal	charging algorithm	charging algorithm
	OC Condition		*[OCC]*	*[TCA]*			CHG FET disabled, enabled during discharge	0	0
Tier-1 Discharge	OC Alert	*[OCD]*					normal	charging algorithm	charging algorithm
	OC Condition		*[OCD]*	*[TDA]*	*[XDSG],[XDSGI]*	*[PCHG]*	DSG FET disabled, enabled during charge	***Pre-chg Current***	charging algorithm
AFE Discharge	OC Condition		*[AOCD]*	*[TDA]*	*[XDSGI]*		CHG FET and DSG FET disabled; CHG FET will be re-enabled	0	charging algorithm

The bq28400 can individually configure each recoverable overcurrent-protection to recover via two different methods based on ***[NR]*** bit.

Standard Recovery where ***[NR]*** = 0 and the overcurrent tier is not selected in ***Non-Removable Cfg*** register. When the pack is removed and reinserted the condition is cleared. Pack removal and reinsertion is detected by a low-to-high-to-low transition on the $\overline{\text{PRES}}$ input. When the overcurrent tier is selected in ***Non-Removable Cfg***, that particular feature uses the Non-Removable Battery Mode recovery.

Non-removable Battery Mode Recovery where ***[NR]*** = 1. The state of ***Non-Removable Cfg*** has no consequence. This recovery requires *AverageCurrent* to be ≤ the respective recovery threshold, and for the *Current_Fault* timer ≥ ***Current Recovery Time***.

When a charging-fault recovery condition is detected, then the CHG FET is allowed to be turned on, if other safety and configuration states permit, *[TCA]* is reset, *ChargingCurrent* and *ChargingVoltage* are set to the appropriate value per the charging algorithm, and the appropriate *SafetyStatus* flag is reset.

When a discharging-fault recovery condition is detected, the DSG FET is allowed to be turned on if other safety and configuration states permit, *[TDA]* flag is reset, *ChargingCurrent* and *ChargingVoltage* are set to the appropriate value per the charging algorithm, and the *[PCHG]*,*[XDSG]*, *[XDSGI]*, and the appropriate *SafetyStatus* flag are reset.

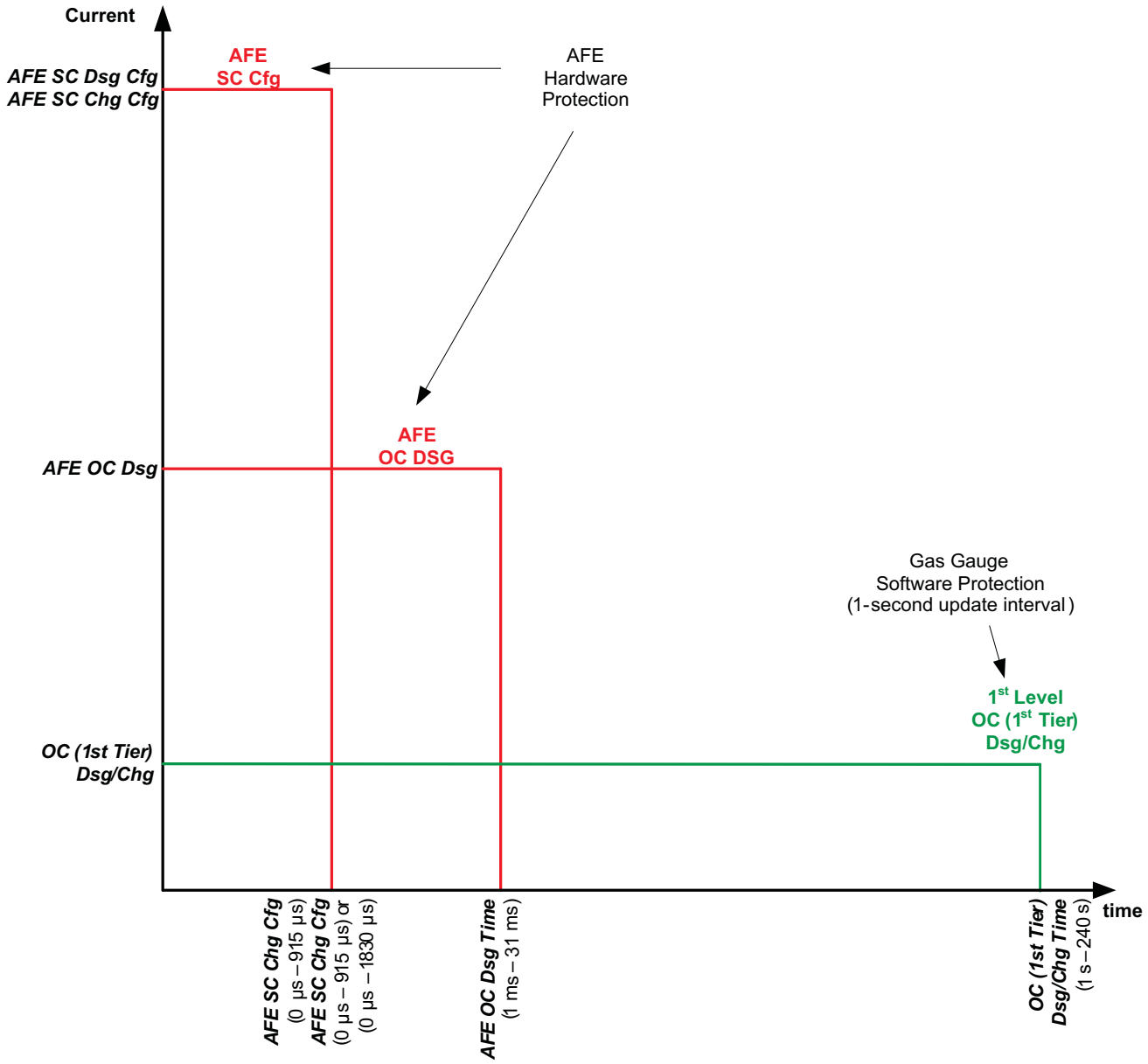


Figure 2-3. Overcurrent Protection Levels

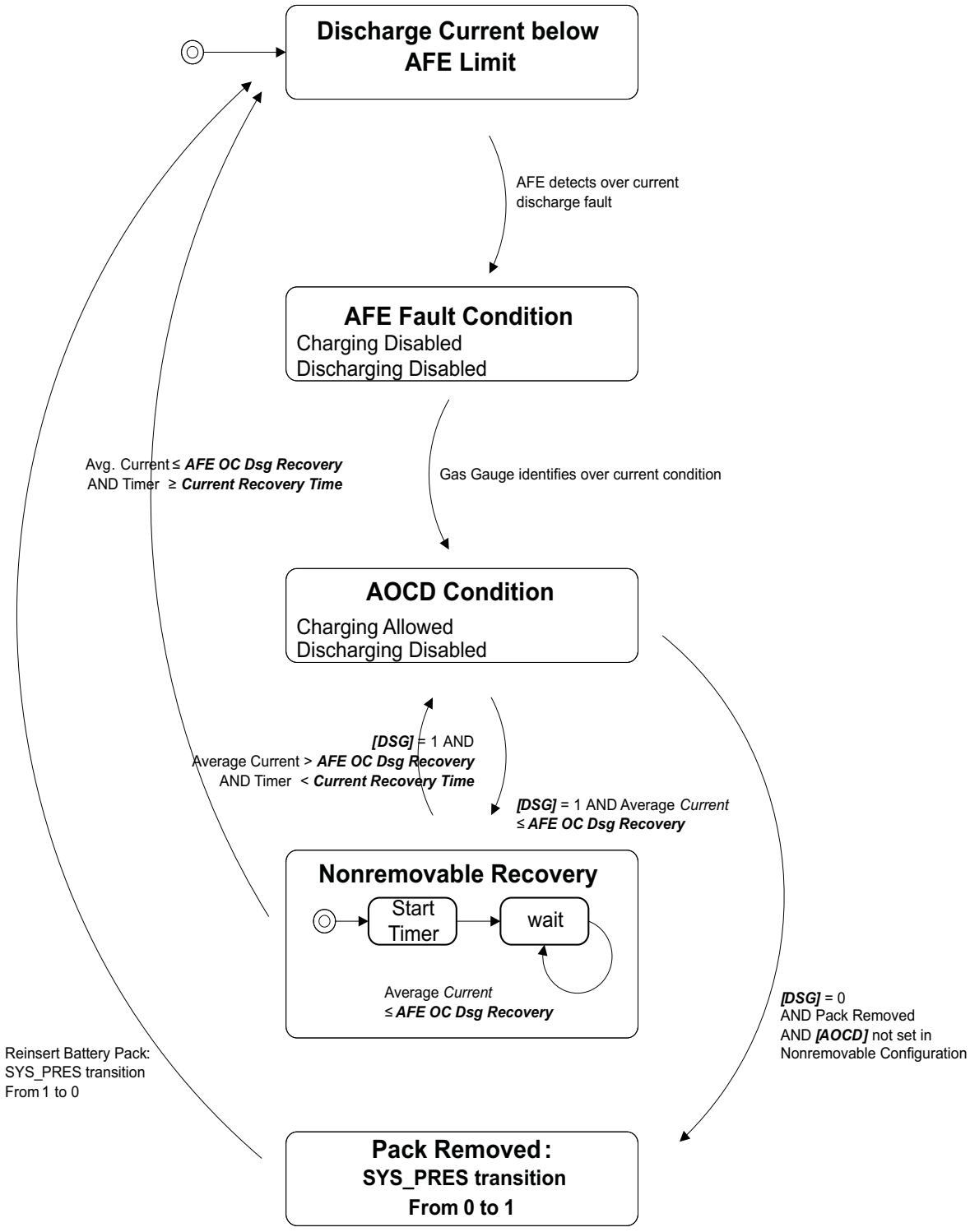


Figure 2-4. AFE Discharge Overcurrent Protection

2.2.3 Short-Circuit Protection

The bq28400 short-circuit protection is executed by the integrated AFE, but is recovered by the bq28400. This allows different recovery methods to accommodate various applications.

The integrated AFE charge short-circuit and discharge short-circuit protection are configured by the bq28400 data flash ***AFE SC Chg Cfg*** and ***AFE SC Dsg Cfg*** registers, respectively.

When the integrated AFE detects a short circuit in charge (in discharge) fault, the charge (discharge) FET is turned off, the internal XALERT signal is driven low by the integrated AFE and the bq28400 starts interrogation of the AFE. When the bq28400 identifies the short-circuit in charge (discharge) condition, discharge-FET (charge-FET) is re-enabled, the internal AFE current fault timer is reset, *[TCA]* (*[TDA]*) in battery status is set, *ChargingCurrent* and *ChargingVoltage* is set to 0 and *[SCC]* (*[SCD]*) is set. If the short-circuit condition is in discharge, then *[XDSG]* flag is also set.

Each bq28400 short-circuit protection feature can be individually configured to recover via two different methods, based on ***[NR]*** bit.

Standard Recovery is where ***[NR]*** = 0 and the overcurrent tier is not selected in ***Non-Removable Cfg***. When the pack is removed and re-inserted, the condition is cleared. Pack removal and re-insertion is detected by transition on the $\overline{\text{PRES}}$ input from low to high to low. When the overcurrent tier is selected in ***Non-Removable Cfg***, that particular feature uses the Non-removable Battery Mode recovery.

Non-removable Battery Mode Recovery is where ***[NR]*** = 1. The state of ***Non-Removable Cfg*** has no consequence when ***[NR]*** bit is set to 1. This recovery requires that *AverageCurrent* be ≤ ***AFE SC Recovery*** threshold and that the internal AFE current recovery timer ≥ ***Current Recovery Time***.

When the recovery condition for a charging fault is detected, the CHG FET is allowed to be turned on if other safety and configuration states permit. The ZVCHG FET also returns to previous state. When this occurs, *[TCA]* is reset, *ChargingCurrent* and *ChargingVoltage* are set to the appropriate values per the charging algorithm, and the appropriate *SafetyStatus* flag is reset.

When the recovery condition for a discharging fault is detected, the DSG FET is allowed to be turned on if other safety and configuration states permit. The ZVCHG FET also returns to previous state. When this occurs *[TDA]* is reset, *ChargingCurrent* and *ChargingVoltage* are set to the appropriate value per the charging algorithm, and *[XDSG]* and the appropriate *SafetyStatus* flags are reset.

Table 2-5. Short Circuit Protection

Short Circuit	Condition	Flags set	FET	Charging Current	Charging Voltage	Clear Threshold
Charge	***AFE SC Chg Cfg***	*[SCC] SafetyStatus*, *[TCA]*	CHG FET disabled, enabled during discharge	0	0	***AFE SC Recovery***
Discharge	***AFE SC Dsg Cfg***	*[SCD] SafetyStatus*, *[TDA]*, *[XDSG]*	DSG FET disabled, enabled during charge	0	0	

2.2.4 Overtemperature Protection

The bq28400 has overtemperature protection for both charge and discharge conditions.

The bq28400 sets the over temperature charging *[OTC] SafetyAlert* flag, if pack temperature reaches or surpasses ***Over Temp Chg*** limit during charging. The bq28400 changes *[OTC]SafetyAlert* to over temperature condition, if pack temperature stays above ***Over Temp Chg*** limit for a time period of ***OT Chg Time***. This function is disabled if ***OT Chg Time*** is set to zero.

When bq28400 is in *[OTC]* condition, charging is disabled and CHG FET is turned off, ZVCHG FET is turned off if configured for use, *ChargingCurrent* and *ChargingVoltage* are set to zero, the *[OTC]* flag in *SafetyAlert* is reset, *[TCA]* and *[OTC]* in *SafetyStatus* are set.

The bq28400 recovers from an *[OTC]* condition if *Temperature* is equal to or below ***OTC Chg Recovery*** limit. On recovery the *[OTC]* flag in *SafetyStatus* is reset, *[TCA]* is reset, *ChargingCurrent* and *ChargingVoltage* are set back to their appropriate value per the charging algorithm, and the CHG FET returns to previous state.

In an *[OTC]* condition, the CHG FET is turned on during discharging to prevent overheating of the CHG FET body diode.

The bq28400 sets the over temperature discharging *[OTD]SafetyAlert* flag, if pack temperature reaches or surpasses ***Over Temp Dsg*** limit during discharging. The bq28400 changes *[OTD]SafetyAlert* to over temperature condition, if pack temperature stays above ***Over Temp Dsg*** limit for a time period of ***OT Dsg Time***. This function is disabled if ***OT Dsg Time*** is set to zero.

When bq28400 is in *[OTD]* condition, discharging is disabled and DSG FET is turned off, *ChargingCurrent* is set to zero, the *[OTD] SafetyAlert* flag is reset, *[TDA]* is set, *[XDSG]* flag is set and the *[OTD]* flag in *SafetyStatus* is set.

The bq28400 recovers from an *[OTD]* condition if pack temperature is equal to or below ***OTD Chg Recovery*** limit. On recovery *[OTD]* in *SafetyStatus* is reset, *[TDA]* is reset, *ChargingCurrent* is set back to the appropriate value per the charging algorithm, and the DSG FET is allowed to switch on again.

In an *[OTD]* condition, the DSG FET is turned on during charging to prevent overheating of the DSG FET body diode.

Table 2-6. Overtemperature Protection

	Alert Threshold	Alert Time Limit	*SafetyAlert* Flags Set	Overtemp Condition	Recovery Threshold
Charge	***Over Temp Chg***	***OT Chg Time***	*[OTC]*	*[OTC] SafetyStatus* Flag, *[TCA]* set, ChargingCurrent =0, ChargingVoltage = 0, (CHG FET off	***OT Chg Recovery***
Discharge	***Over Temp Dsg***	***OT Dsg Time***	*[OTD]*	*[OTD] SafetyStatus* Flag, *[TDA]* Set, ChargingCurrent =0, (*[XDSG]* set and DSG FET off	***OT Dsg Recovery***

2.2.5 AFE Watchdog

The integrated AFE automatically turns off the CHG FET, DSG FET and ZVCHG FET (if used), if the integrated AFE does not receive the appropriate frequency on the internal watchdog input (WDI) signal from bq28400. The bq28400 has no warning that this is about to happen, but it can report the occurrence once the bq28400 is able to interrogate the integrated AFE.

When the internal XALERT input of the bq28400 is triggered by the integrated AFE, the bq28400 reads the STATUS register of the integrated AFE. If *[WDF]* is set, the bq28400 also sets *[WDF]* in *SafetyStatus* and periodic verification of the integrated AFE RAM is undertaken. If verification of the integrated AFE RAM fails then the FETs will turn off. Verification of the integrated AFE RAM will continue once every second. If the periodic verification passes, then *[WDF]* in *SafetyStatus* is cleared and the FETs return to normal operation.

2.3 2nd Level Protection Features

The bq28400 provides features that can be used to indicate a more serious fault via the FUSE output. These outputs can be used to blow an in-line fuse to permanently disable the battery pack from charge or discharge activity.

If any PF Threshold condition is met, the appropriate flag is set in *PFAlert*. If the PF Threshold condition is cleared within the PF time limit, the appropriate PFAlert flag is cleared in *PFAlert*. But if the PF Threshold condition continues over the PF Time Limit or Alert Limit, then the bq28400 goes into permanent failure condition and the appropriate flag is set in *PFStatus* and reset in *PFAlert*.

When any NEW cause of a permanent failure is set in *PFStatus* function, the NEW cause is added to ***PF Flags 1*** register. This allows ***PF Flags 1*** register to show ALL permanent failure conditions that have occurred.

On the first occasion of a permanent failure indicated by *PFStatus* change from 0x00, the *PFStatus* value is stored in ***PF Flags 2***.

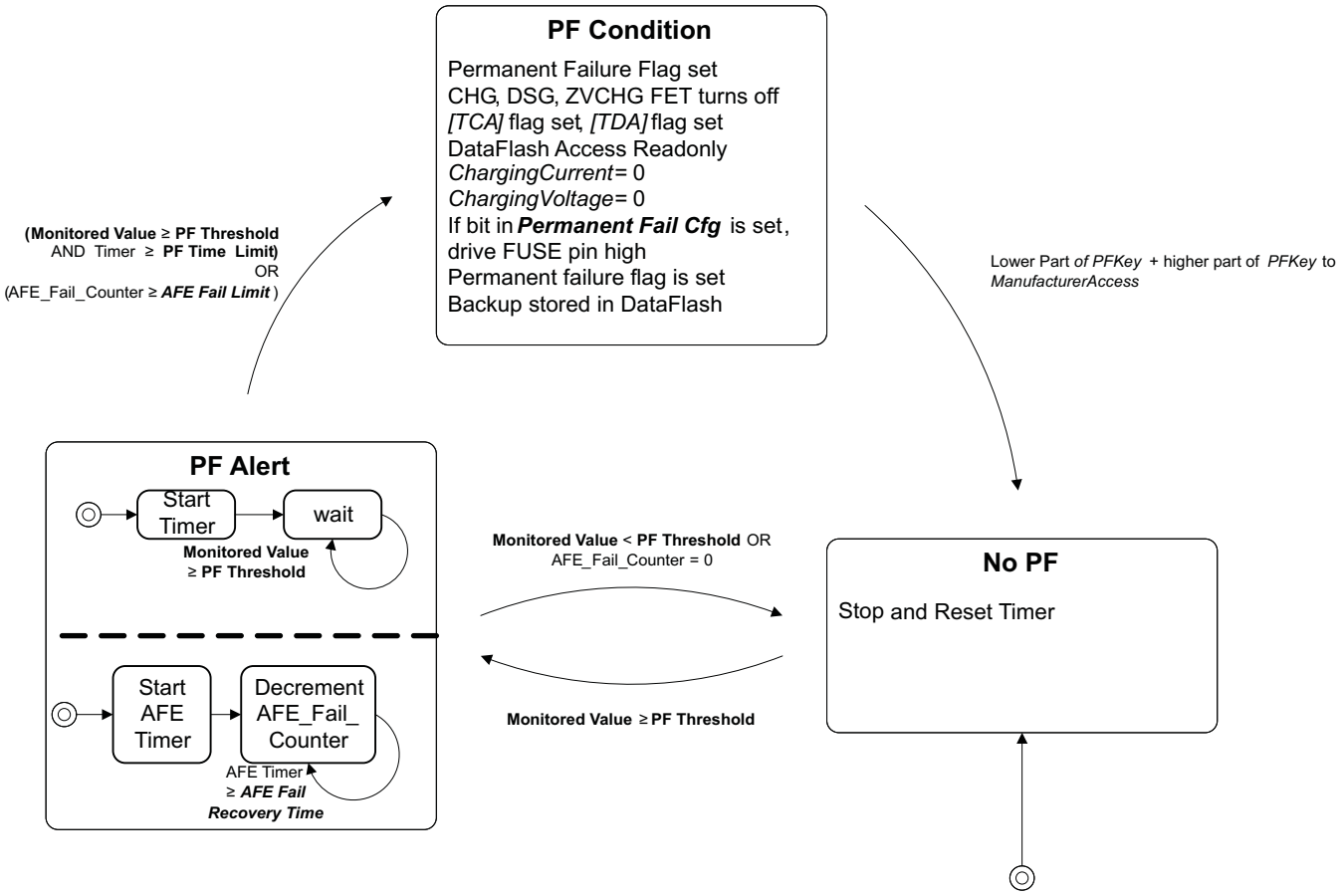


Figure 2-5. 2nd Level Protection

2.3.1 2nd Level (Permanent) Failure Actions

When the *PFStatus* register changes from 0x00 to indicate a permanent failure then the following actions are taken in sequence.

- CHG, DSG, and ZVCHG FETs are turned OFF.
- *[TCA], [TDA]* flags in *BatteryStatus* are set.
- A backup of SBS data and the complete memory map of the integrated AFE is stored to data flash (if *[LTPF]* is set in *OperationStatus*).
- Data flash write access is disabled, but the data flash can be read (if *[LTPF]* is set in *OperationStatus*).
- *ChargingCurrent* and *ChargingVoltage* are set to 0.
- The appropriate bit in *PF Flags 1* is set (if *[LTPF]* is set in *OperationStatus*).
- If the appropriate bit in ***Permanent Fail Cfg*** is set, then 0x3672 is programmed to ***Fuse Flag***, and the FUSE pin is driven and latched high. The*[PF]* flag in *SafetyStatus* is also set (if *[LTPF]* is set in *OperationStatus*).

For the convenience of production test, If *[LTPF]* is cleared in *OperationStatus* , when permanent failures occur, data flash write is still allowed, there is no PF data logging in DF:PF Status, and the PF can be cleared by resetting the bq28400. *[LTPF]* is set by the *LTPF Enable* ManufacturerAccess command. If *[LTPF]* in *OperationStatus* is already set, to clear this bit and disable PF data logging, clear the DF:Configuration:Registers(64):Operation Cfg C(4)[PROD_LTPF_EN], and then reset the bq28400.

Table 2-7. Permanent Fail Backup

SBS Value	Data Flash Backup
SBS:Voltage(0x09)	DF:PF Status:Device Status Data(96):PF Voltage(4)
SBS:CellVoltage2(0x3e)	DF:PF Status:Device Status Data(96):PF C2 Voltage(10)
SBS:CellVoltage1(0x3f)	DF:PF Status:Device Status Data(96):PF C1 Voltage(12)
SBS:Current(0x0a)	DF:PF Status:Device Status Data(96):PF Current(14)
SBS:Temperature(0x08)	DF:PF Status:Device Status Data(96):PF Temperature(16)
SBS:BatteryStatus(0x16)	DF:PF Status:Device Status Data(96):PF Batt Stat(18)
SBS:RemainingCapacity(0x0f)	DF:PF Status:Device Status Data(96):PF RC-mAh(20)
SBS:FullChargeCapacity(0x10)	DF:PF Status:Device Status Data(96):PF FCC(22)
DOD at EDV2	DF:PF Status:Device Status Data(96):PF DOD(28)
Integrated AFE Memory Map	
	DF:PF Status:AFE Regs(97):AFE Status(0)
	DF:PF Status:AFE Regs(97):AFE State(1)
	DF:PF Status:AFE Regs(97):AFE Output(2)
	DF:PF Status:AFE Regs(97):AFE Output Status(3)
	DF:PF Status:AFE Regs(97):AFE Cell Select(5)
	DF:PF Status:AFE Regs(97):AFE OLV(6)
	DF:PF Status:AFE Regs(97):AFE OLT(7)
	DF:PF Status:AFE Regs(97):AFE SCC(8)
	DF:PF Status:AFE Regs(97):AFE SCD(9)
	DF:PF Status:AFE Regs(97):AFE Function(10)

2.3.2 Time Limit-Based Protection

The bq28400 device reports a protection alert by setting the appropriate flag in the *PFAlert* function if the monitored value reaches or rises above the Protection Threshold. If the monitored value stays above the Protection Threshold over the Max Alert duration, the bq28400 reports a permanent failure, clears the appropriate *PFAlert* flag, and sets the appropriate *PFStatus* flag. See Table 2-8 for all Protection Thresholds and Max Alert durations.

Safety Overvoltage Protection — The bq28400 monitors the individual cell voltages for extreme values. Depending on the temperature range the battery is operating in, either LT, ST, or HT Safety Overvoltage is activated when cells go above these thresholds.

Cell Imbalance Fault — The bq28400 starts cell imbalance fault detection when *Current* is lesser or equal to ***Cell Imbalance Current*** for ***Battery Rest Time*** period AND All (*CellVoltage2..1*) > ***Min CIM-check voltage***. The difference between highest cell voltage and lowest cell voltage is monitored. If ***Battery Rest Time*** is set to zero or ***Cell Imbalance Time*** is set to zero, this function is disabled.

2nd Level Protection IC Input — The FUSE pin of the bq28400 can be used to determine the output state of an external protection device such as the bq294xx or bq29200. The bq28400 watches for FUSE pin level when the 2nd level voltage protection IC outputs high.

Safety Overcurrent Protection — The bq28400 monitors the current during charging and discharging. The overcurrent thresholds and time limits can be set independently for charging and discharging.

Safety Overtemperature Protection — The bq28400 monitors the pack temperature during charging and discharging. The overtemperature thresholds and time limits can be set independently for charging and discharging.

Open Thermistor — The bq28400 can detect an open thermistor condition if the temperature function reports extreme temperature values.

CHG and ZVCHG FET Fault Protection — The bq28400 monitors if there is, at any time, an attempt to turn off the CHG FET or ZVCHG FET, or the CHG bit in the *FETStatus* register is clear and the current continues to flow.

Discharge FET Fault Protection — The bq28400 monitors if there is, at any time, an attempt to turn off the DSG FET, or the DSG bit in the *FETStatus* register is clear and the current continues to flow.

Table 2-8. Time Limit-Based Protection

Protection	Monitored Value	Requirement	PF Threshold	PF Time Limit (set to 0 to disable Protection)	*PFAlert* and *PFStatus* Flag,	*Permanent Fail Cfg* Flag
Safety Cell Overvoltage	Cell voltage	—	***LT SOV Threshold***, ST SOV Threshold, or HT SOV Threshold	***SOV Time***	*[SOV]*	*[XSOV]*
Cell Imbalance Fault	Difference of highest and lowest of *CellVoltage2..1*	*Current* ≤ ***Cell Imbalance Current*** for ***Battery Rest Time*** AND All (*CellVoltage2..1*) > ***Min CIM-check voltage***	***Cell Imbalance Fail Voltage***	***Cell Imbalance Time***	*[CIM]*	*[XCIM]*
2nd Level Protection IC Input	FUSE pin voltage	—	FUSE pin voltage > 2V(typical)	***PFIN Detect Time***	*[PFIN]*	*[XPFIN]*
Safety Overcurrent Charge	*Current*	*Current* > 0	***SOC Chg***	***SOC Chg Time***	*[SOCC]*	*[XSOCC]*
Safety Overcurrent Discharge	(–)*Current*	*Current* < 0	***SOC Dsg***	***SOC Dsg Time***	*[SOCD]*	*[XSOCD]*
Safety Overtemperature Chg	*Temperature*	*Current* > 0	***SOT Chg***	***SOT Chg Time***	*[SOTC]*	*[XSOTC]*
Safety Overtemperature Dsg	*Temperature*	*Current* < 0	***SOT Dsg***	***SOT Dsg Time***	*[SOTD]*	*[XSOTD]*
Open Thermistor	*Temperature*	—	***Open Thermistor***	***Open Time***	*[OTS]*	*[XOTS]*
Charge and ZVCHG FET Fault	*Current*	(CHG FET or ZVCHG FET turn off attempt or CHG Flag in *FETStatus* clear) and *Current* >0	***FET Fail Limit***	***FET Fail Time***	*[CFETF]*	*[XCFETF]*
Discharge FET Fault	(–)*Current*	(DSG FET turn off attempt or DSG Flag in *FETStatus* clear) and *Current* < 0	***FET Fail Limit***	***FET Fail Time***	*[DFETF]*	*[XDFETF]*

2.3.3 Limit-Based Protection

The bq28400 reports a permanent failure and sets the appropriate *PFStatus* flag if the internal error counter reaches the max error limit. The internal error counter is incremented by one if the error happens and decremented by one each fail recovery period.

Integrated AFE Communication Fault Protection — The bq28400 periodically validates its read and write communications with the integrated AFE. If either a read or write verify fails, an internal AFE_Fail_Counter is incremented. If the AFE_Fail_Counter reaches ***AFE Fail Limit***, the bq28400 reports a *[AFE_C]* permanent failure. If the ***AFE Fail Limit*** is set to 0, this feature is disabled. An *[AFE_C]* fault can also be declared if, after a full reset, the initial gain and offset values read from the AFE cannot be verified. These values are A/D readings of the integrated AFE VCELL output. The integrated AFE offset values are verified by reading the values twice and confirming that the readings are within acceptable limits. The max difference between 2 readings is set with ***AFE Init Limit***. The maximum number of read retries, if offset and gain value verification fails and *[AFE_C]* fault is declared, is set in ***AFE Fail Limit***.

Periodic AFE Verification — The bq28400 periodically (***AFE Check Time***) compares certain RAM content of the integrated AFE with that of the bq28400 data flash and the expected control-bit states. This function is disabled if ***AFE Check Time*** is set to 0. If an error is detected, the internal AFE_Fail_Counter is incremented. If the internal AFE_Fail_Counter reaches the ***AFE Fail Limit***, the bq28400 reports a permanent failure.

Integrated AFE Init Verification — After a full reset the bq28400 and the AFE offset and gain values are read twice and compared. The ***AFE Init Limit*** sets the maximum difference in A/D counts of two successful readings of offset and gain, which the bq28400 still considers as the same value. If the gain and offset values are still not considered the same after ***AFE Init Retry Limit*** comparison retries, the bq28400 reports a permanent failure error.

Data Flash Failure — The bq28400 can detect if the data flash is not operating correctly. A permanent failure is reported when either: (I) After a full reset the instruction flash checksum does not verify; (ii) if any data flash write does not verify; or (iii) if any data flash erase does not verify.

Table 2-9. Limit-Based Protection

Protection	Monitored Value	Fail Recovery	Max Error Limit (set to 0 to disable Protection)	*PFAlert* **Flag,** *PFStatus* **Flag,**	*Permanent Fail Cfg* **Flag**
AFE Communication Fault	Periodic Communication with integrated AFE	Decrement of internal AFE_Fail_Counter by one per ***AFE Fail Recovery Time*** period	***AFE Fail Limit***	*[AFE_C]*	***[XAFE_C]***
Periodic AFE Verification	Check RAM of integrated AFE with ***AFE Check Time*** period	Decrement of internal AFE_Fail_Counter by one per ***AFE Fail Recovery Time*** period	***AFE Fail Limit***	*[AFE_P]*	***[XAFE_P]***
AFE Initialization	Initial gain and offset values from integrated AFE after full reset	—	***AFE Init Retry Limit***	*[AFE_C]*	***[XAFE_C]***
Data Flash Failure	Data Flash	—	False flash checksum after reset, data flash write not verified, data flash erase not verified	*[DFF]*	***[XDFF]***

2.3.4 Clearing Permanent Failure

The bq28400 permanent failure can be cleared by sending two *ManufacturerAccess* commands in sequence: the first word of the *PFKey* followed by the second word of the *PFKey*. After sending these two commands in sequence, *PFStatus* flags are cleared. Refer to Permanent Fail Clear (*PFKey*) Manufacturer access for further details.

2.4 Gas Gauging

The bq28400 features Compensated End of Discharge Voltage(CEDV) gauging algorithm, capable of gauging a maximum capacity of 32 Ah.

The operational overview in Figure 2-6 illustrates the gas gauge operation of the bq28400.

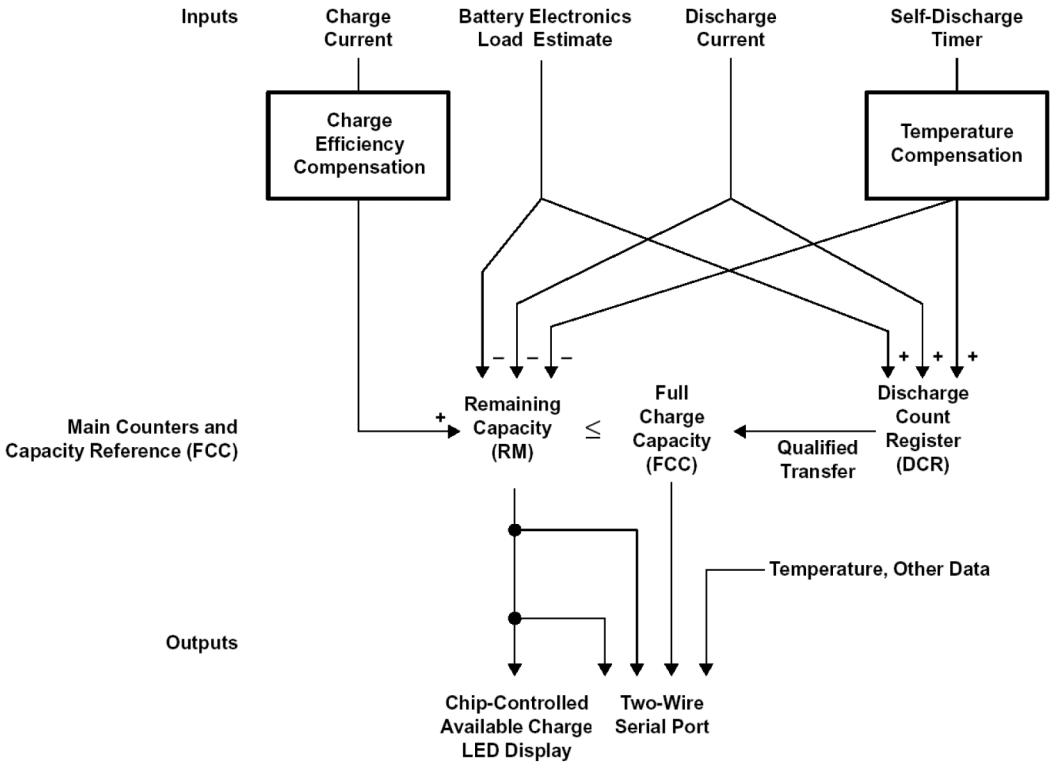


Figure 2-6. bq28400 Gas Gauging Operational Overview

2.4.1 CEDV Gas Gauging Operational Overview

The bq28400 accumulates the measured quantities of charge and discharge and estimates self-discharge of the battery. The bq28400 compensates the charge current measurement for temperature and state-of-charge of the battery. The bq28400 also adjusts the self-discharge estimation based on temperature.

The main charge counter *RemainingCapacity* (RM) represents the available capacity or energy in the battery at any given time. The bq28400 adjusts RM for charge, self-discharge, and other compensation factors. The information in the RM register is accessible through the SMBus interface. The *FullChargeCapacity* (FCC) register represents the initial or last measured full discharge of the battery. It is used as the battery full-charge reference for relative capacity indication. The bq28400 updates FCC after the battery undergoes a qualified discharge from nearly full to a low battery level. FCC is accessible through the SMBus interface.

The Discharge Count Register (DCR) is a non-accessible register that tracks discharge of the battery. The bq28400 uses the DCR register to update the FCC register if the battery undergoes a qualified discharge from nearly full to a low battery level. In this way, the bq28400 learns the true discharge capacity of the battery under system use conditions.

2.4.2 Main Gas Gauge Registers

RemainingCapacity (RM) — Remaining capacity in the battery.

RM represents the remaining capacity in the battery. The bq28400 computes RM in units of either mAh or 10 mWh depending on the selected capacity mode. See *BatteryMode* (0x03) for unit configuration.

RM counts up during charge to a maximum value of *FCC* and down during discharge and self-discharge to a minimum of 0. In addition to charge and self-discharge compensation, the bq28400 calibrates RM at three low-battery-voltage thresholds, EDV2, EDV1, and EDV0. This provides a voltage-based calibration to the RM counter.

DesignCapacity (DC) — User-specified battery full capacity

DC is the user-specified battery full capacity. It is calculated from ***Design Capacity*** and is represented in units of mAh or 10 mWh. It also represents the full-battery reference for the absolute display mode.

FullChargeCapacity (FCC) — Last measured discharge capacity of the battery

FCC is the last measured discharge capacity of the battery. It is represented in units of either mAh or 10 mWh, depending on the selected capacity mode. On initialization, the bq28400 sets *FullChargeCapacity* to the data flash value stored in ***Full Charge Capacity*** (*FCC*). During subsequent discharges, the bq28400 updates *FullChargeCapacity* with the last measured discharge capacity of the battery. The last measured discharge of the battery is based on the value in the DCR register after a qualified discharge occurs. Once updated, the bq28400 writes the new *FullChargeCapacity* value to data flash in mAh to ***Full Charge Capacity***. *FullChargeCapacity* represents the full battery reference for the relative display mode and relative state of charge calculations.

Discharge Count Register (DCR) —

The DCR register counts up during discharge, independent of RM. DCR counts discharge activity, battery load estimation, and self-discharge increment. The bq28400 initializes DCR, at the beginning of a discharge, to FCC – RM when RM is within the programmed value in ***Near Full***. The DCR initial value of *FCC* – RM is reduced by *FCC*/128 if SC = 1 (bit 5 in ***CEDV Config***) and is not reduced if SC = 0. DCR stops counting when the battery voltage reaches the EDV2 threshold on discharge.

2.4.3 Capacity Learning (FCC Update) and Qualified Discharge

The bq28400 updates *FCC* with an amount based on the value in DCR if a qualified discharge occurs. The new value for *FCC* equals the DCR value plus the programmable nearly full and low battery levels, according to the following equation:

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

Where Battery_Low % = (***Battery Low %*** value in data flash) ÷2.56

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

- No valid charge activity occurs during the discharge period. A valid charge is defined as a charge of 10 mAh into the battery.
- No more than 256 mAh of self-discharge or battery load estimation occurs during the discharge period.
- The temperature does not drop below the low temperature thresholds programmed in ***Low Temp*** during the discharge period.
- The battery voltage reaches the EDV2 threshold during the discharge period and the voltage is greater than or equal to the EDV2 threshold minus 256 mV when the bq28400 detected EDV2.
- Current remains ≥3C/32 when EDV2 is reached.
- No overload condition exists when EDV2 threshold is reached, or if RM has dropped to Battery_Low % x *FCC*.

The bq28400 sets *[VDQ]* = 1 in ***Operation Status*** when a qualified discharge begins. The bq28400 sets *[VDQ]* = 0 if any disqualifying condition occurs. One complication may arise regarding the state of *[VDQ]* if ***[CSYNC]*** is set in ***Operation Cfg B***. When ***[CSYNC]*** is enabled, *RemainingCapacity* is written to equal *FullChargeCapacity* on valid primary charge termination and the charge deficit (difference between FCC and RM) is stored; and when discharge begins, the charge deficit is subtracted from RM. This capacity synchronization is done even if the condition *RM* ≥ *FCC* - ***Near Full*** is NOT satisfied at charge termination.

FCC cannot be reduced by more than 256 mAh or increased by more than 512 mAh during any single update cycle. The bq28400 saves the new *FCC* value to the data flash within 4 seconds of being updated.

2.4.4 End-of-Discharge Thresholds and Capacity Correction

The bq28400 monitors the battery for three low-voltage thresholds, EDV0, EDV1, and EDV2. The ***[EDVV]*** bit in ***CEDV Config*** configures the bq28400 for single-cell EDV thresholds.

If the ***[CEDV]*** bit in ***CEDV Config*** is clear, fixed EDV thresholds may be programmed in ***Fixed EDV0***, ***Fixed EDV1***, and ***Fixed EDV2*** in mV.

If the ***[CEDV]*** bit in ***CEDV Config*** is set, automatic EDV compensation is enabled and the bq28400 computes the EDV0, EDV1, and EDV2 thresholds based on values stored in the CEDV subclass data-flash from address offsets of 1 through 13 and the battery's current discharge rate and temperature.

The bq28400 disables EDV detection if Current exceeds the ***Overload Current*** threshold. The bq28400 resumes EDV threshold detection after Current drops below the ***Overload Current*** threshold. Any EDV threshold detected is reset after charge is applied and *[VDQ]* is cleared after 10 mAh of charge.

The bq28400 uses the EDV thresholds to apply voltage-based corrections to the RM register according to Table 2-10.

Table 2-10. State of Charge Based on Low Battery Voltage

THRESHOLD	RELATIVE STATE OF CHARGE
EDV0	0%
EDV1	3%
EDV2	*Battery Low %*

The bq28400 performs EDV-based RM adjustments with Current ≥C/32. No EDVs are set if Current <C/32. The bq28400 adjusts RM as it detects each threshold. If the voltage threshold is reached before the corresponding capacity on discharge, the bq28400 reduces RM to the appropriate amount as shown in Table 2-10.

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

2.4.5 EDV Discharge Rate and Temperature Compensation

If EDV compensation is enabled, the bq28400 calculates battery voltage to determine EDV0, EDV1, and EDV2 thresholds as a function of battery capacity, temperature, and discharge load. The general equation for EDV0, EDV1, and EDV2 calculation is

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

- EMF is a no-load cell voltage higher than the highest cell EDV threshold computed. EMF is programmed in mV in ***EMF***.
- ILOAD is the current discharge load magnitude.
- n = the number of series cells. In the bq28400 case n = 1.
- FBL is the factor that adjusts the EDV voltage for battery capacity and temperature to match the no-load characteristics of the battery.

FBL = f (C0, C + C1, T) (2)

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

FTZ = f (R1, T0, C + C1, TC) (3)

- R0 is the first order rate dependency factor stored in ***EDV R0 Factor*** (DF).
- T is the current temperature; C is the battery capacity relating to EDV0, EDV1, and EDV2.
- R1 adjusts the variation of impedance with battery capacity. R1 is programmed in ***EDV R1 Rate Factor***.
- T0 adjusts the variation of impedance with battery temperature. T0 is programmed in ***EDV T0 Rate***

Factor.

- TC adjusts the variation of impedance for cold temperatures (T < 23°C). TC is programmed in ***EDV TC Factor*** .
- Typical values for the EDV compensation factors, based on overall pack voltages for a 3s2p Li-Ion 18650 pack, are
  - EMF = 11550/3
  - T0 = 4475
  - C0 = 235
  - C1 = 0
  - R0 = 5350/3
  - R1 = 250
  - TC = 3

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

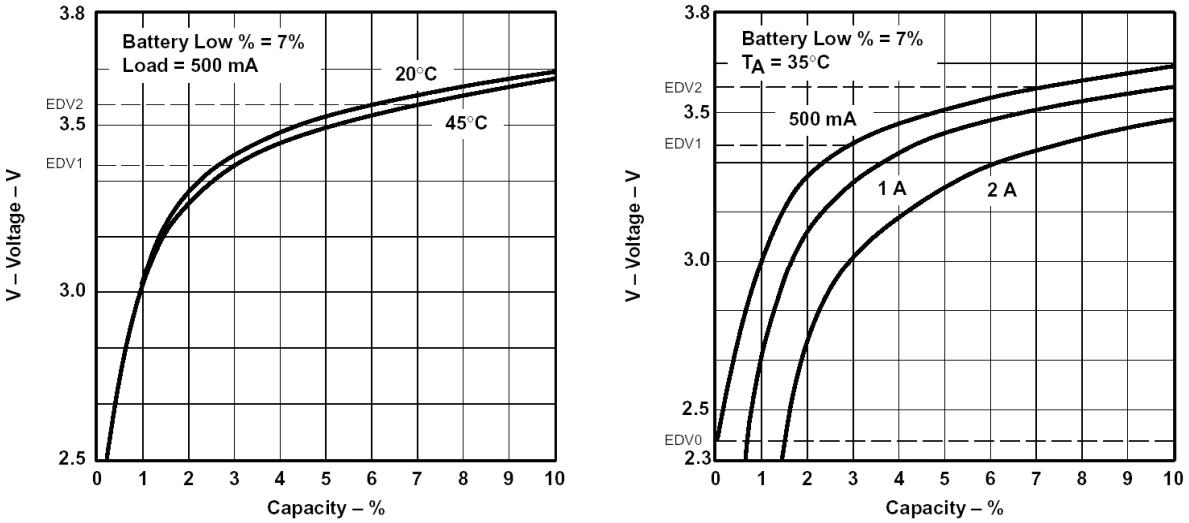


Figure 2-7. (a) EDV Calculations vs Capacity for Various Temperatures, (b) EDV Calculations vs Capacity for Various Loads

2.4.6 EDV Age Factor

EDV Age factor allows the bq28400 to correct the EDV detection algorithm to compensate for cell aging. This parameter scales cell impedances as the cycle count increases. This new factor is used to accommodate for much higher impedances observed in larger capacity and/or aged cells. For most applications the default value of zero is sufficient. However, for some very specific applications, this new aging factor may be required. In those cases, experimental data must be taken at the 0, 100, 200, and 300 cycle read points using a typical discharge rate while at ambient temperature. Entering this data into a TI provided MathCAD™ program will yield the appropriate ***EDV Age factor*** value. Contact TI Applications Support @ http://www-k.ext.ti.com/sc/technical-support/email-tech-support.asp?AAP for more detailed information.

2.4.7 Self-Discharge

The bq28400 estimates the self-discharge of the battery to maintain an accurate measure of the battery capacity during periods of inactivity. The bq28400 makes self-discharge adjustments to RM every 1/4 second when awake and periodically when in sleep mode. The period is determined by ***Sleep Time***.

The self-discharge estimation rate for 25°C is doubled for each 10 degrees above 25°C or halved for each 10 degrees below 25°C. Table 2-11 shows the relation of the self-discharge estimation at a given temperature to the rate programmed for 25°C.

Table 2-11. Self Discharge for Rate Programmed

TEMPERATURE (°C)	SELF-DISCHARGE RATE
Temp < 10	1/4 Y% per day
10 ≤ Temp <20	½ Y% per day
20≤Temp <30	Y% per day
30≤Temp <40	2Y% per day
40≤Temp <50	4Y% per day
50≤Temp <60	8Y% per day
60≤Temp <70	16Y% per day
70≤Temp	32Y% per day

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

Self-Discharge Rate = %PERDAY/ 0.01

2.4.8 Battery Electronic Load Compensation

The bq28400 can be configured to compensate for a constant load (as from battery electronics) present in the battery pack at all times. The bq28400 applies the compensation continuously when the charge or discharge is below the digital filter. The bq28400 applies the compensation in addition to self-discharge. The compensation occurs at a rate determined by the value stored in *Electronics Load*. The compensation range is 0 µA–765 µA in steps of approximately 3 µA.

The amount of internal battery electronics load estimate in µA, BEL, is stored as follows:

Electronics Load = BEL / 3

2.4.9 CEDV Configuration

Various gas gauging features can be configured by the ***CEDV Config*** register.

Table 2-12. CEDV Config Register

Feature	Description
SC	The SC bit enables learning cycle optimization for a Smart Charger or independent charge. 0 = Learning cycle is optimized for Smart Charger. 1 = Learning cycle is optimized for independent charger.
CEDV	The CEDV bit determines whether the bq28400 implements automatic EDV compensation to calculate the EDV0, EDV1, and EDV2 thresholds base on rate, temperature, and capacity. If the bit is cleared, the bq28400 uses the fixed values programmed in data flash for EDV0, EDV1, and EDV2. If the bit is set, the bq28400 calculates EDV0, EDV1, and EDV2. 0 = EDV compensation is disabled. 1 = EDV compensation is enabled.
EDVV	The EDVV bit selects whether EDV termination is to be done with regard to voltage or the lowest single-cell voltage. 0 = EDV conditions are determined on the basis of the lowest single-cell voltage. 1 = EDV conditions are determined on the basis of *Voltage*.

2.4.10 Initial Battery Capacity at Device Reset

The bq28400 estimates the initial capacity of a battery pack at device reset, which is the case when battery cells are first attached to the application circuit. The initial *FullChargeCapacity* (FCC) is a direct copy of the data flash parameter ***Full Charge Capacity***. The initial RM and RSOC are estimated using the open-circuit voltage (OCV) characteristics of the programmed Li-ion chemistry (default ID0100), ***DOD at EDV2***, and ***Qmax Pack***. This gives a reasonably accurate RM and RSOC, however, battery capacity learning is required in order to find the accurate FCC, RM and RSOC. During battery capacity learning, ***Full Charge Capacity*** and ***DOD at EDV2*** will be learned and updated.

The data flash parameter *Full Charge Capacity* should be initialized to the ***DesignCapacity***. ***DOD at EDV2*** should be initialized to (1 – Battery_Low%) x 16384, where Battery_Low% = ***Battery Low %*** ÷2.56.

2.4.11 Gas Gauge Operating Modes

Entry and exit of each mode is controlled by data flash parameters in the subclass 'Gas Gauging: Current Thresholds' section. In Relaxation Mode or Discharge Mode, the DSG flag in *BatteryStatus* is set.

Charge mode is exited and Relaxation 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 Relaxation 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***.

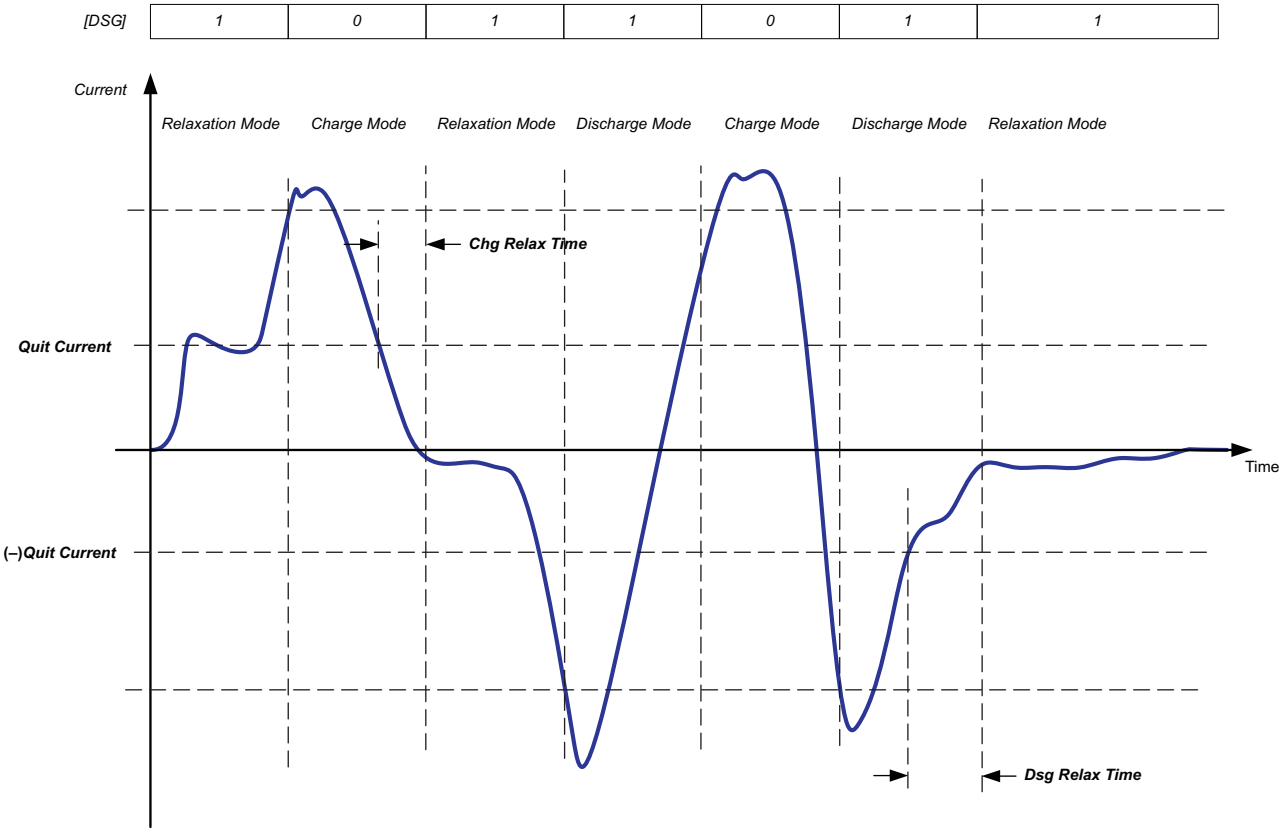


Figure 2-8. Gas Gauge Operating Mode Example

2.4.12 Qmax

Qmax is used for initial capacity (RM and RSOC) estimate in conjunction with the cell voltages and programmed chemistry information when device resets. The ***Qmax Pack***, ***Qmax Cell 0***, and ***Qmax Cell 1*** values should be taken from the cell manufacturers' data sheet multiplied by the number of parallel cells. This is also used for the *DesignCapacity* function and the ***Design Capacity*** data flash value.

2.5 Charge Control

The bq28400 can report the appropriate charging current needed for the constant charging current and the charging voltage needed for constant voltage charging per charging algorithm to a smart charger using the *ChargingCurrent* and the *ChargingVoltage* functions. The actual charging status of bq28400 is indicated with flags and can be read out with the *ChargingStatus* function.

- SBS:ChargingCurrent(0x14)
- SBS:ChargingVoltage(0x15)

2.5.1 Charge Control SMBus Broadcasts

All broadcasts to a host or a smart charger are enabled by the ***[BCAST]*** bit. If the ***[HPE]*** bit is enabled, Master-Mode broadcasts to the Host address are PEC enabled. If the ***[CPE]*** bit is enabled, Master-Mode broadcasts to the Smart-Charger address are PEC enabled. When broadcast is enabled, the following broadcasts are sent:

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

2.5.2 Charging and Temperature Ranges

The bq28400 requests different charging current and charging voltage for each of the temperature ranges defined in Section 2.1, through the *ChargingVoltage* and *ChargingCurrent* commands.

Additionally, the charging current can be set differently depending on the cell voltage. Three ranges of cell voltage are defined using two cell voltage thresholds: ***Cell Voltage Threshold 1*** and ***Cell Voltage Threshold 2*** (see Table 2-13). During charging, as cell voltage increases *ChargingCurrent* is set to the appropriate value when cell voltage crosses one of the cell voltage thresholds. However, if cell voltage decreases below the threshold *ChargingCurrent* is not set back to the previous value unless discharge or relax state is detected. This is done to avoid the situation where charging current being changed back and forth due to the voltage drop that results form changing the charging current value. In addition, ***Cell Voltage Thresh Hys*** is used to make sure that transitions between cell voltage ranges are not affected by small transients.

Table 2-13. Cell Voltage Ranges

Condition	Cell Voltage Range
max(*CellVoltage2..1*) < ***Cell Voltage Threshold 1***	CVR1
Cell Voltage Threshold 1 < max(*CellVoltage2..1*) < ***Cell Voltage Threshold 2***	CVR2
Cell Voltage Threshold 2 < max(*CellVoltage2..1*)	CVR3

The dependency of the *Charging Voltage* and *Charging Current* on temperature range and cell voltage range is summarized in Table 2-14 and illustrated in Figure 2-9 and Figure 2-10.

Table 2-14. Charging Voltage and Charging Current Dependency on Temperature Range and Cell Voltage Range

Temp Range	Cell Voltage	Charging Voltage	Charging Current
TR1	—	0	0
TR2	CVR1	***LT Chg Voltage***	***LT Chg Current 1***
	CVR2		***LT Chg Current 2***
	CVR3		***LT Chg Current 3***

Table 2-14. Charging Voltage and Charging Current Dependency on Temperature Range and Cell Voltage Range (continued)

Temp Range	Cell Voltage	Charging Voltage	Charging Current
TR2A	CVR1	***ST1 Chg Voltage***	***ST1 Chg Current 1***
	CVR2		***ST1 Chg Current 2***
	CVR3		***ST1 Chg Current 3***
TR3	CVR1	***ST2 Chg Voltage***	***ST2 Chg Current 1***
	CVR2		***ST2 Chg Current 2***
	CVR3		***ST2 Chg Current 3***
TR4	CVR1	***HT Chg Voltage***	***HT Chg Current 1***
	CVR2		***HT Chg Current 2***
	CVR3		***HT Chg Current 3***
TR5	—	0	0

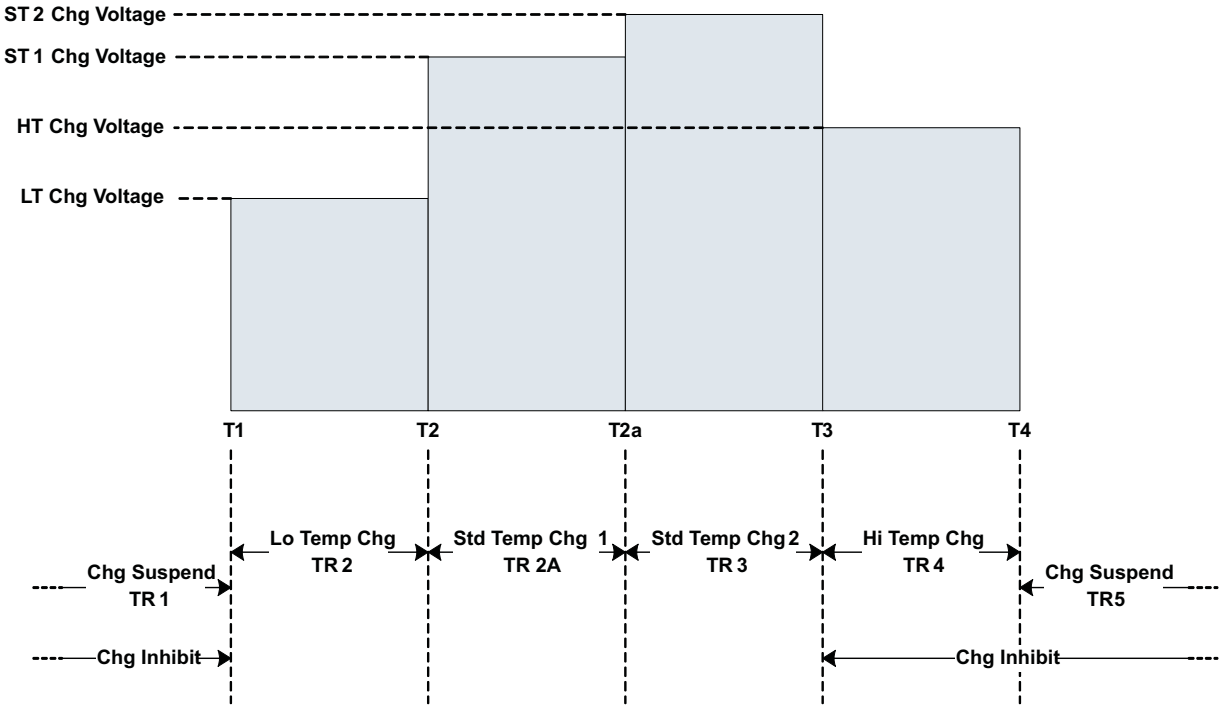


Figure 2-9. Temp Ranges and Charge Voltage for JEITA With Enhancements for More Complex Charging Profiles

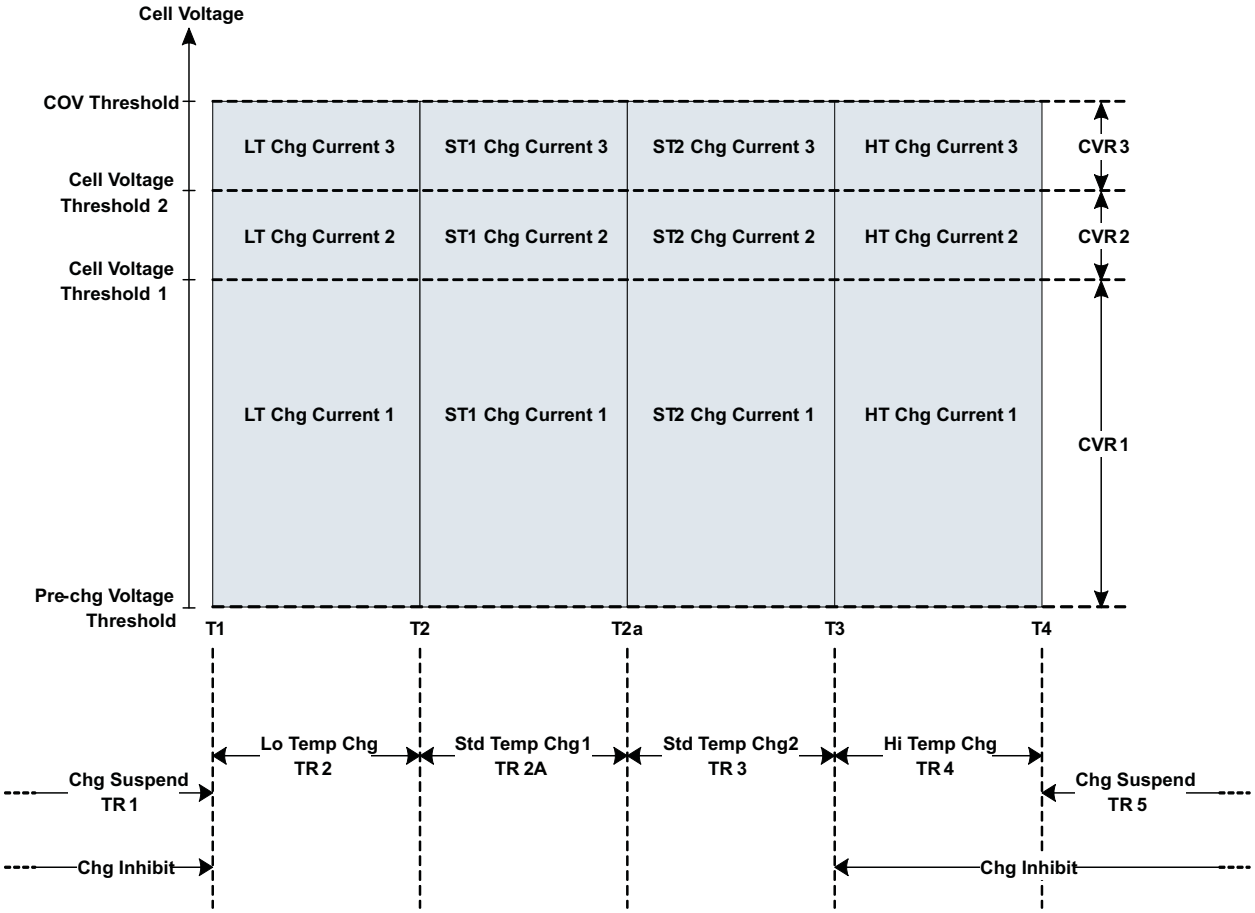


Figure 2-10. Temp Ranges and Charge Current for JEITA With Enhancements for More Complex Charging Profiles

2.5.2.1 Low Temperature Charging

The bq28400 enters this mode when the *Temperature* function reports a temperature in the TR2 range (***JT1*** < *Temperature* < ***JT2***). In this mode [*LTCHG*] flag in *ChargingStatus* is set, the *ChargingVoltage* is set to *LT Chg Voltage*, and the *ChargingCurrent* is set to ***LT Chg Current 1***, ***LT Chg Current 2***, or ***LT Chg Current 3***, depending on the active cell voltage range. The charging current data flash values for low temp charging should be set to low current values similar to precharge mode. The bq28400 leaves this mode and clears the *[LTCHG]* flag if the *Temperature* goes below ***JT1*** or above ***JT2*** + *Temp Hys*.

2.5.2.2 Standard Temperature Charging 1

The bq28400 enters this mode when the *Temperature* function reports a temperature in the TR2A range (***JT2*** < *Temperature* < ***JT2a***). In this mode the *[ST1CHG]* flag in *ChargingStatus* is set, *ChargingVoltage* is set to ***ST1 Chg Voltage***, and the *ChargingCurrent* is set to ***ST1 Chg Current***, ***ST1 Chg Current 2***, or ***ST1 Chg Current 3*** depending on the active cell voltage range. The bq28400 leaves this mode and clears the *[ST1CHG]* flag if the *Temperature* goes below ***JT2*** or above ***JT2a***.

2.5.2.3 Standard Temperature Charging 2

The bq28400 enters this mode when the *Temperature* function reports a temperature in the TR3 range (***JT2a*** < Temperature < ***JT3***). In this mode the *[ST2CHG]* flag in *ChargingStatus* is set, *ChargingVoltage* is set to ***ST2 Chg Voltage***, and the *ChargingCurrent* is set to ***ST2 Chg Current 1*** or ***ST2 Chg Current 2*** or ***ST2 Chg Current 3*** depending on the active cell voltage. The bq28400 leaves this mode and clears the *[ST2CHG]* flag if the *Temperature* goes below ***JT2a*** – ***Temp Hys*** or above ***JT3***.

2.5.2.4 High Temperature Charging

The bq28400 enters this mode when the *Temperature* function reports a temperature in the TR4 range (***JT3*** < *Temperature* < ***JT4***). In this mode the *[HTCHG]* flag in *ChargingStatus* is set, ChargingVoltage is set to ***HT Chg Voltage***, and the *ChargingCurrent* is set to ***HT Chg Current 1***, ***HT Chg Current 2***, or ***HT Chg Current 3*** depending on the active cell voltage. The bq28400 leaves this mode and clears the *[HTCHG]* flag if the *Temperature* goes below ***JT3*** – ***Temp Hys*** or above ***JT4***.

2.5.3 Charge-Inhibit Mode

If the bq28400 is in discharge mode or relaxation mode (*[DSG]* = 1), the bq28400 goes into charge-inhibit mode and sets the *ChargingCurrent* and *ChargingVoltage* values to 0 to inhibit charging if:

- *Temperature* < ***JT1*** limit OR
- *Temperature* > ***JT3*** limit

In charge-inhibit mode, the *[XCHG]* flag in *ChargingStatus* is set. If the ***[CHGIN]*** bit in ***Operation Cfg B*** is set, the CHG FET and ZVCHG FET (if used) are also turned off when the bq28400 is in charge-inhibit mode.

The bq28400 allows charging to resume when:

- *Temperature* ≥ ***JT1*** + ***Temp Hys*** AND
- *Temperature* ≤ ***JT3*** – ***Temp Hys***

The FETs also return to their previous states at that time. The *[XCHG]* flag is cleared when the foregoing conditions are met, when a charge fault condition is detected, or when the battery is removed if in removable mode (***[NR]*** = 0).

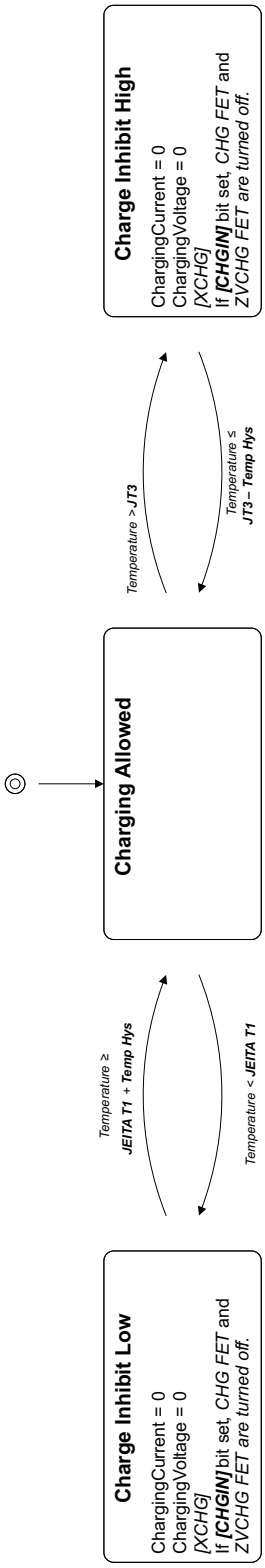


Figure 2-11. Charge Inhibit

2.5.4 Charge-Suspend Mode

The bq28400 suspends charging when:

- *Temperature* < ***JT1***, OR
- *Temperature* > ***JT4***

In charge-suspend mode, the *[CHGSUSP]* flag in *ChargingStatus* is set and *ChargingCurrent* is set to 0. The CHG FET and ZVCHG FET (if used) are also turned off if the ***[CHGSUSP]*** bit in the ***Operation Cfg B*** register is set.

The bq28400 resumes charging if:

- *Temperature* ≥ ***JT1*** + ***Temp Hys***, AND
- *Temperature* ≤ ***JT3*** – ***Temp Hys***.

On resuming, the bq28400 clears the *[CHGSUSP]* status flag and sets *ChargingCurrent* according to the appropriate charging mode entered, and the CHG and ZVCHG FETs (if used) return to their previous state.

The bq28400 also leaves the charge-suspend mode and clears the *[CHGSUSP]* flag when a protection condition is detected or when the battery is removed in removable battery mode (***[NR]*** = 0).

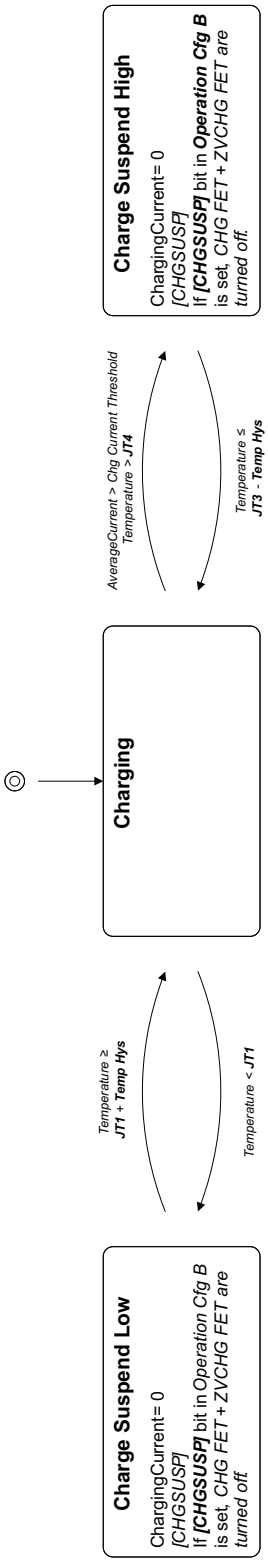


Figure 2-12. Charge Suspend

2.5.5 Pre-Charge Cfg

The bq28400 enters precharge mode during charging if any cell voltage goes below ***Pre-chg Voltage*** limit or if any of the *SafetyStatus* flags, *[CUV]* or *[OCD]*, is set.

In precharge mode the *[PCHG]* flag is set and *ChargingCurrent* is set to ***Pre-chg Current***.

The bq28400 leaves Pre-charge mode and clears the *[PCHG]* flag if all cell voltages reach or rise above ***Recovery Voltage***. Pre-charge mode is also exited if charge suspend mode is entered, any charge fault condition is detected, or the pack is removed in removable mode.

2.5.6 Primary Charge Termination

The bq28400 determines charge termination if:

- Average Charge Current < ***Taper Current*** during two consecutive ***Current Taper Window*** time periods, AND
- The accumulated change in capacity must be > 0.25 mAh per period during two consecutive ***Current Taper Window*** time periods, AND
- *Voltage* + ***Taper Voltage*** ≥ ***Charging Voltage***

NOTE: To make sure that the charge terminates properly, it is recommend that ***Taper Current*** be set to a value greater than ***Quit Current***.

The following parameters change the behavior of bq28400 on charge termination:

Table 2-15. Primary Charge Termination

Parameter	Behavior on Primary Charge Termination
TCA Set % = –1	*[TCA]* flag set, *ChargingCurrent* = 0
FC Set % = –1	*[FC]* flag set
[CHGFET] set	CHG FET turned off
[CSYNC] set	*RemainingCapacity* = *FullChargeCapacity* regardless of ***TCA Set %*** value
[RSOCL] set	If the ***[RSOCL]*** bit in ***Operation Cfg C*** is set then *RelativeStateofCharge* and *RemainingCapacity* are held at 99% until primary charge termination occurs and only displays 100% upon entering primary charge termination.
[RSOCL] clear	If the ***[RSOCL]*** bit in ***Operation Cfg C*** is cleared then *RelativeStateofCharge* and *RemainingCapacity* are **not** held at 99% until primary charge termination occurs. Fractions of % greater than 99% are rounded up to display 100%.

2.5.7 Charge Alarms

The bq28400 enables *[TCA], [FD] and [FC]* flags in *BatteryStatus* to be cleared or set on the following thresholds based on *RelativeStateOfCharge*. The flags are set on primary charge termination or faults related to safety or permanent failures. The following thresholds are used for this device.

Table 2-16. Charge Alarms

	Threshold	*BatteryStatus* Flag
RelativeStateOfCharge	≤ ***95 %***	*[TCA]* is cleared
	≤ ***98 %***	*[FC]* is cleared
	0% or over discharge is detected	*[FD]* is set
	≥ 20% (default)	*[FD]* is cleared

The *[TCA]* and *[FC]* flags in *BatteryStatus* can also be set or cleared based on *Voltage*.

2.5.8 Cell Balancing

Cell balancing in bq28400 is accomplished by connecting an external parallel bypass load to each cell, and enable the bypass load depending on each individual cell's charge state. The bypass load is typically formed by a P-ch MOSFET and a resistor connected in series across each battery cell. The filter resistors

that connect the cell tabs to VC1~VC2 pins of the bq28400 are required to be 1k ohms. Using this circuit, the bq28400 balances the cells during charge by discharging those cells above the threshold set in *Cell Balance Threshold*, if the maximum difference in cell voltages exceeds the value programmed in *Cell Balance Min*. During cell balancing, the bq28400 measures the cell voltages at an interval set in *Cell Balance Interval*. On the basis of the cell voltages, the bq28400 either selects the appropriate cell to discharge or adjusts the cell balance threshold up by the value programmed in *Cell Balance Window* when all cells exceed the cell balance threshold or the highest cell exceeds the cell balance threshold by the cell balance window.

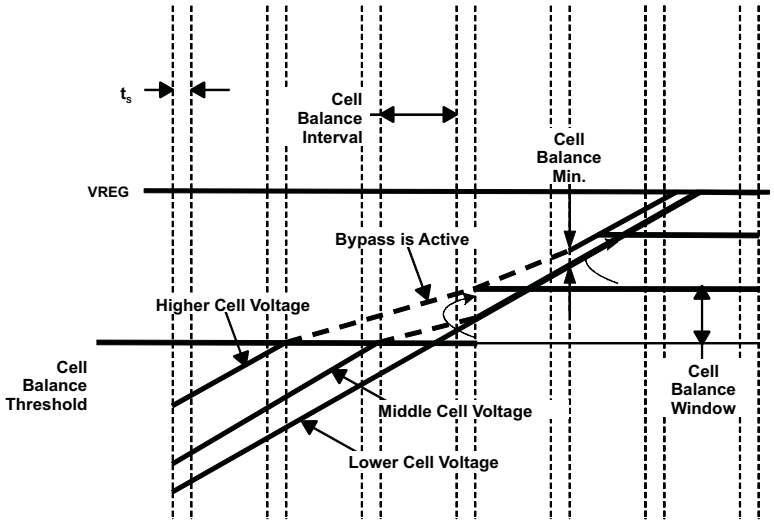


Figure 2-13. Cell Balancing

Cell balancing only occurs when charging current is detected. The cell balance threshold is reset to the value in *Cell Balance Threshold* at the start of every charge cycle. The threshold is only adjusted once during any balance interval. Refer to the application report *bq28400 Gas Gauge Circuit Design* (SLUA507) for more details.

Cell balancing can also be implemented using CB_EN output from the bq28400. This output will control the bq29200 (EXT_CB_EN pin) auto cell balancing feature of the product. When the bq28400 detects cell imbalance a low pulse is set from CB_EN to the companion IC (bq29200) to activate the feature (active low). This feature can be disabled by setting the CB_EN output high.

2.5.9 External Cell Balancing

Cell balancing can also be implemented using CB_EN output from the bq28400. This output will control the bq29200 (EXT_CB_EN pin) auto cell balancing feature of the product. When the bq28400 detects cell imbalance a low pulse is set from CB_EN to the companion IC (bq29200) to activate the feature. This feature can be disabled by set the CB_EN output high, the setting for external cell balancing is in Operation Configuration C register.

2.5.10 Charging Faults

The bq28400 can report charging faults in the *ChargingStatus* register.

On occurrence of an FCMTO, PCMTO, or both, and an OC charging fault, the bq28400 sets:

- The appropriate *ChargingStatus* flag
- If the flags in ***Charge Fault Cfg*** and *ChargingStatus* match, the CHG FET (or the ZVCHG FET if in precharge) is turned off.
- *ChargingCurrent* = 0, *ChargingVoltage* = 0.
- *[TCA]* flag in *BatteryStatus*
- *[OC]* flag in *BatteryStatus* if it is an Overcharge fault

On Recovery the bq28400:

- Resets the appropriate *ChargingStatus* flags
- CHG FET and ZVCHG FET (if used) return to previous states. In PCMTO, if the bq28400 recovers by discharge current and the discharge current sustains, the CHG FET is turned on even if the device is still in precharge mode.
- Sets *ChargingCurrent* and *ChargingVoltage* back to previous state according to charging algorithm.
- Resets *[TCA]* flag in *BatteryStatus*

Precharge Mode Timeout

When *Current* is ≥ ***Chg Current Threshold*** the bq28400 starts the Precharge Timer. The Precharge Timer is suspended when precharge mode is not active (*[PCHG]* = 0), or when *[DSG]* = 1. The precharge Timer is reset when an amount of discharge greater than ***Over Charge Recovery*** is detected or the pack is removed and reinserted when NR =0. Set ***PC-MTO*** to zero to disable this feature.

The bq28400 goes into precharge mode charging timeout if:

- Precharge timer ≥ ***PC-MTO***

The bq28400 suspends the precharge timer if:

- *Current* ≤ ***(–)Dsg Current Threshold***

The bq28400 recovers (i.e. timer resets) if:

- ***PC-MTO*** is set, OR
- An amount of discharge greater than ***Over Charge Recovery*** is detected, OR
- Pack is removed and reinserted, if ***[NR]*** = 0

Fast Charge Mode Timeout

When *Current* is ≥ ***Chg Current Threshold***, the bq28400 starts the Fast Charge timer. The Fast Charge Timer is suspended when fast charge is not active (*[FCHG]* = 0), or when *[DSG]* = 1. The Fast Charge Timer is reset when an amount of discharge greater than ***Over Charge Recovery*** is detected or the pack is removed and reinserted when NR = 0. Set ***FC-MTO*** to 0 to disable this feature.

The bq28400 goes into fast charge mode charging timeout if:

- Fast charge timer ≥ ***FC-MTO***

The bq28400 suspends the fast charge timer if:

- *Current* ≤ ***(–)Dsg Current Threshold***

The bq28400 recovers (i.e. timer resets) if:

- ***FC-MTO*** is set, OR
- An amount of discharge greater than ***Over Charge Recovery*** is detected, OR
- Pack is removed and reinserted if ***[NR]*** = 0

Overcharge

The bq28400 goes into overcharge mode if the battery pack is charged in excess of *FullChargeCapacity* by ***Over Charge Capacity***:

The bq28400 recovers if any of the following conditions are met:

- Pack removed and reinserted (***[NR]*** = 0)
- Continuous amount of discharge over ***Over Charge Recovery*** and *AverageCurrent* < 0, when ***[NR]*** = 1
- *RemainingCapacity* ≤ ***FC Clear %***

Table 2-17. Charging Faults

Charge Fault	Fault Condition	Recovery Condition	*ChargingStatus* **Flag,** *Charge Fault Configuration* **Flag**
Precharge Timeout	Precharge Timer ≥ ***PC-MTO***	*Current* ≤ ***(–)Dsg Current Threshold***, OR Pack removed and reinserted if ***[NR]*** = 0	*[PCMTO]*
Fast charge Timeout	Fast charge Timer ≥ ***FC-MTO***		*[FCMTO]*

Table 2-17. Charging Faults (continued)

Charge Fault	Fault Condition	Recovery Condition	*ChargingStatus* **Flag,** *Charge Fault Configuration* **Flag**
Overcharge	*RemainingCapacity* – *FullChargeCapacity* ≥ ***Over Charge Capacity***	Pack removed and reinserted if ***[NR]*** = 0, OR continuous amount of discharge of ***Over Charge Recovery*** if ***[NR]*** = 1, OR *RemainingCapacity*	*[OC]*

2.6 Device Operating Mode

The bq28400 has several device power modes. During these modes, the bq28400 modifies its operation to minimize power consumption from the battery.

2.6.1 Normal Mode

During normal operation, the bq28400 takes *Current*, *Voltage*, and *Temperature* measurements, performs calculations, updates SBS data, and makes protection and status decisions at one-second intervals. Between these periods of activity, the bq28400 is in a reduced power state.

$\overline{\text{PRES}}$ is sampled once per second and if $\overline{\text{PRES}}$ is high, the *OperationStatus [PRES]* flag is cleared. If $\overline{\text{PRES}}$ is low, the *OperationStatus [PRES]* flag is set indicating the system is present (the battery is inserted).

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

2.6.2 Battery Pack Removed Mode/System Present Detection

2.6.2.1 Battery Pack Removed

The bq28400 detects the Battery Pack Removed state if ***[NR]*** bit is set to 0 AND the $\overline{\text{PRES}}$ input is high (*[PRES]* = 0).

On entry to the Battery Pack Removed state, *[TCA]* and *[TDA]* flags are set, *ChargingCurrent* and *ChargingVoltage* are set to 0, the CHG and DSG FETs are turned off, and the ZVCHG FET is turned off (if used).

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

The bq28400 exits the Battery Pack Removed state if ***[NR]*** flag is set to 0, AND the $\overline{\text{PRES}}$ input is low (*[PRES]* = 1). When this occurs, *[TCA]* and *[TDA]* flags are reset.

2.6.2.2 System Present

$\overline{\text{PRES}}$ is sampled once per second and if $\overline{\text{PRES}}$ is high, the *OperationStatus [PRES]* flag is cleared. If $\overline{\text{PRES}}$ is low, the *OperationStatus [PRES]* flag is set indicating the system is present (the battery is inserted). If the ***[NR]*** bit is set, the PRES input is ignored and can be left floating. The bq28400 turns on both CHG and DSG FET when the *OperationStatus [PRES]* flag is set and the device is operating in the normal mode with no safety conditions.

2.6.3 Sleep Mode

In Sleep mode the bq28400 measures Voltage and Temperature in ***Sleep Voltage Time*** intervals and *Current* at ***Sleep Current Time*** intervals. At each interval the bq28400 performs calculations, updates SBS data, and makes protection and status decisions. Between these periods of activity, the bq28400 is in a reduced-power state.

The bq28400 enters Sleep mode when the following conditions exist:

- If ***[NR]*** bit is set to 0, *[PRES]* must also be cleared for the bq28400 to enter sleep.

  AND one of the following conditions:
- (|*Current*| ≤ ***Sleep Current***) AND (SMBus is low for ***Bus Low Time, fixed at 5 s)*** AND (***[SLEEP]*** bit is set).

OR

- (|*Current*| ≤ ***Sleep Current***) AND *(ManufacturerAccess* Sleep command is received) AND (***[SLEEP]*** is set).

Entry to Sleep mode is blocked if any of the *PFStatus* flags are set. If ***Sleep Voltage Time*** = 0 or ***Sleep Current Time*** = 0, sleep mode is not entered, and the bq28400 remains in Normal mode.

On entry to sleep, if ***[NR]*** = 0, the CHG and DSG FETs are turned off, and the ZVCHG FET is turned off (if used) regardless of ***[NRCHG]*** setting. If ***[NR]*** = 1, the CHG FET is turned off, and the ZVCHG FET is turned off (if used). However, if ***[NRCHG]*** is set then the CHG FET remains on.

Typically, on entry to Sleep mode, the auto calibration of the A/DC begins. However, if *Temperature* is ≤ ***5°C*** or *Temperature* ≥ ***Cal Inhibit Temp High*** (fixed at 45°C), or if the Sleep is caused by the *ManufacturerAccess* Sleep command, Auto Calibration is not started on entry to sleep mode. The activation of auto calibration is not affected by the state of ***[SLEEP]***, ***Sleep Voltage Time***, ***Sleep Current Time***, or *Current*.

The bq28400 exits Sleep mode when one or more of the following conditions exist:

- If the ***[NR]*** bit is set to 0 and *[PRES]* is set to 1.
- (|*Current*| > ***Sleep Current***
- SMBC or SMBD inputs transition high
- *OperationStatus*, *ChargingStatus* or *SafetyStatus* are set.
- Wake function enabled by setting ***Wake Current Reg*** and a voltage across SRP and SRN is detected.

The bq28400 exits Sleep mode if absolute value of *Current* is greater than ***Sleep Current***, OR the SMBC or SMBD inputs transition high, OR any *OperationStatus*, *ChargingStatus*, or *SafetyStatus* flags change state.

In addition, if ***[NR]*** is cleared, the bq28400 exits Sleep mode when *[PRES]* = 1.

2.6.4 Wake Function

The bq28400 can exit sleep mode, if enabled, by the presence of a voltage across SRP and SRN. The level of the current signal needed is programmed in ***Wake Current Reg***.

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Low Byte	RSVD	RSVD	RSVD	RSVD	RSVD	IWAKE	RSNS1	RSNS0

LEGEND: RSVD = Reserved and **must** be programmed to 0.

Figure 2-14. Wake Current Reg

IWAKE — This bit sets the current threshold for the Wake function.

0 = 0.5A (or if RSNS0=RSNS1=0 then this function is disabled)
1 = 1.0A (or if RSNS0=RSNS1=0 then this function is disabled)

Table 2-18. Wake Current Reg

RSNS1	RSNS0	Resistance
0	0	Disabled (default)
0	1	2.5 mΩ
1	0	5 mΩ
1	1	10 mΩ

2.6.5 Shutdown Mode

The bq28400 enters Shutdown mode if the following conditions are met:

- ***[SHUTV]*** in ***Operation Cfg C*** is set to 0 AND*Voltage* ≤ ***Shutdown Voltage*** AND *Current* ≤ 0 for a period of ***Cell Shutdown Time***AND *PackVoltage* < ***3000 mV*** threshold.
  OR

- ***[SHUTV]*** in ***Operation Cfg C*** is set to 1 AND Min (*CellVoltage2..1*) ≤ ***Cell Shutdown Voltage*** AND *Current* ≤ 0 for a period of ***Shutdown Time***AND *PackVoltage* < ***3000 mV*** threshold.
  OR
- (*ManufacturerAccess* shutdown command received AND *Current* = 0) AND *PackVoltage* < ***3000 mV*** threshold.

When the bq28400 meets these conditions, the CHG, DSG, and ZVCHG FETs are turned off, and the integrated AFE is commanded to shut down. In Shutdown mode, the bq28400 is completely powered down because its supply is removed.

To exit Shutdown mode the voltage at the PACK pin must be greater than the startup voltage specified in bq28400 datasheet. When this happens, the integrated AFE returns power to the bq28400 , the *[WAKE]* flag is set, and the integrated AFE is configured by the AGG. The *[WAKE]* flag is cleared and the *[INIT]* flag is set after approximately 1 s when all SBS parameters have been measured and updated.

2.7 Security (Enables and Disables Features)

There are two levels of secured operation within the bq28400. To switch between the levels, different commands are required. The two levels are sealed and full access.

1. Full Access to Sealed — To enter Sealed mode from Full Access in MAC CMD (0x00), enter 0x0020. Using the *Seal Device* command instructs the bq28400 to limit access to the SBS functions and data flash space, and sets the *[SS]* flag. In Sealed mode, standard SBS functions have access per the Smart Battery Data Specification - Appendix A. Extended SBS Functions and data flash are not accessible. Once in Sealed mode, the part can never permanently return to Full Access modes.

2. Sealed to Full Access — To enter Full Access mode from Sealed mode in CMD (0x61), enter the 1st and 2nd bytes of the words as 0xffff and 0xffff. This instructs the bq28400 to allow Full Access to all SBS commands and data flash. The bq28400 is shipped from TI in this mode. The key for Full Access can be read and changed via the extended SBS block command *FullAccessKey* when in Full Access mode. *Use the ManufacturerAccess* command to change from Sealed to Full Access by writing the 1st word of the *FullAccessKey* to *ManufacturerAccess* followed by the second word of the *FullAccessKey* to *ManufacturerAccess*. The full access key can be read and changed via the extended SBS block command *FullAccessKey* when in Full Access mode. In Full Access mode, the command to go to Boot ROM can be sent.

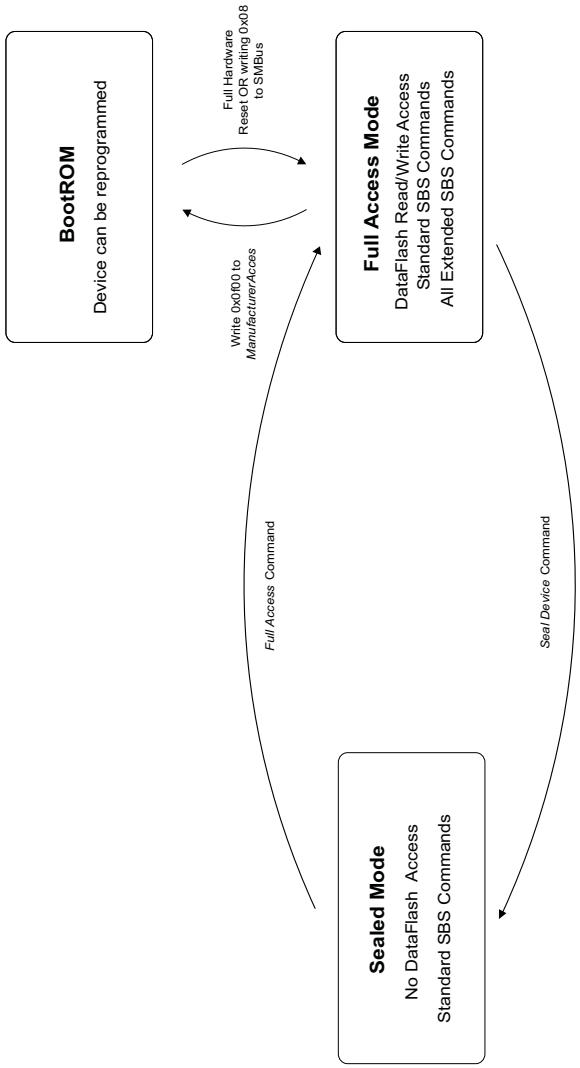


Figure 2-15. Security

2.8 Calibration

2.8.1 Coulomb Counter Deadband

The bq28400 does not accumulate charge or discharge for gas gauging when the current input is below the dead-band current threshold. The threshold is programmed in ***CC Deadband*** (Coulomb Counter Deadband) and should be set sufficiently high to prevent false signal detection with no charge or discharge flowing through the sense resistor.

2.8.2 Auto Calibration

The bq28400 provides an auto-calibration feature to cancel the voltage offset error across SRP and SRN for maximum charge measurement accuracy. The bq28400 performs auto-calibration when the SMBus lines stay low continuously for a minimum of 5 s and *Temperature* is within bounds of ***Cal Inhibit Temp Low*** (fixed at 5C) and ***Cal Inhibit Temp High*** (fixed at 45C). If the Sleep is caused by the *ManufacturerAccess* Sleep command, Auto Calibration is not started on entry to sleep mode.

2.9 Communications

The bq28400 uses SMBus v1.1 with Master Mode and packet error checking (PEC) options per the SBS specification.

2.9.1 SMBus On and Off State

The bq28400 detects an SMBus off state when SMBC and SMBD are logic-low for ≥ 2 seconds. Clearing this state requires either SMBC or SMBD to transition high. Within 1 ms, the communication bus is available.

2.9.2 Packet Error Checking

The bq28400 can receive or transmit data with or without PEC.

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

In the write-word protocol, the bq28400 receives the PEC after the last byte of data from the host. If the host does not support PEC, the last byte of data is followed by a stop condition. After receipt of the PEC, the bq28400 compares the value to its calculation. If the PEC is correct, the bq28400 responds with an ACKNOWLEDGE. If it is not correct, the bq28400 responds with a NOT ACKNOWLEDGE and sets an error code. If the host supports PEC, the ***[HPE]*** bit should be set to 1.

In the read-word and block-read in master mode, the host generates an ACKNOWLEDGE after the last byte of data sent by the bq28400. The bq28400 then sends the PEC, and the host, acting as a master-receiver, generates a NOT ACKNOWLEDGE and a stop condition.

2.9.3 bq28400 Slave Address

The bq28400 uses the address 0x16 on SMB for communication.

2.9.4 Broadcasts to Smart Charger and Smart Battery Host

The bq28400 can broadcast messages to the smart battery charger and smart battery host. This can be enabled with the ***[BCAST]*** bit.

PEC byte for alarm transmissions in master-mode to charger can be enabled with the ***[CPE]*** bit.

PEC byte for alarm transmissions in master-mode to smart battery host and the PEC byte for receiving communications from all sources in slave-mode can be enabled with the ***[HPE]*** bit.

Standard SBS Commands

The bq28400 SBS command set meets the SBS v1.1 specification. All SBS Values are updated in 1-second intervals.

A.1 ManufacturerAccess (0x00)

This read- or write-word function provides battery-system level data, access to test controls, and security features.

Table A-1. ManufacturerAccess

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x00	R/W	ManufacturerAccess	hex	2	0x0000	0xffff	—	

A.1.1 System Data

The results of these commands need to be read from *ManufacturerAccess* after a write with the command word to *ManufacturerAccess*.

A.1.1.1 Device Type (0x0001)

Device Type returns the IC part number.

Table A-2. Device Type

Manufacturer Access	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x0001	R	Device Type	hex	2	—	—	0x0900	

A.1.1.2 Firmware Version (0x0002)

Returns the firmware version. The format is most-significant byte (MSB) = Decimal integer, and the least-significant byte (LSB) = sub-decimal integer; for example, 0x0120 = version 01.20.

Table A-3. Firmware Version

Manufacturer Access	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x0002	R	Firmware Version	hex	2	—	—	0x0102	

A.1.1.3 Hardware Version (0x0003)

Hardware Version returns the hardware version stored in a single byte of reserved data flash; for example, 0x00a7 = Version A7.

Table A-4. Hardware Version

Manufacturer Access	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x0003	R	Hardware Version	hex	2	—	—	0x00a7	

A.1.1.4 DF Checksum (0x0004)

This function is only available when the bq28400 is in Sealed mode, indicated by the *[SS]* and *[FAS]* flag. A write to this command forces the bq28400 to generate a checksum of the full data flash (DF) array. The generated checksum is then returned within 45 ms.

NOTE: If another SMBus command is received while the checksum is being generated, the DF Checksum is generated but the response may be time out (<25 ms).

Table A-5. DF Checksum

Manufacturer Access	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x0004	R	DF Checksum	hex	2	—	—	—	

A.1.1.5 Pending EDV Threshold Voltage (0x0005)

The read-word function returns the predicted EDV2 until EDV2 is reached, then the predicted EDV1 until EDV1 is reached, and then the predicted EDV0. Format is Big Endian.

Table A-6. Pending EDV Threshold Voltage

Manufacturer Access	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x0005	R	Pending EDV Threshold Voltage	hex	2	—	—	—	mV

A.1.1.6 Manufacturer Status (0x0006)

This function is available while the bq28400 is in normal operation. This 16-bit word reports the battery status.

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
High Byte	FET1	FET0	PF1	PF0	STATE3	STATE2	STATE1	STATE0
Low Byte	0	0	0	0	1	0	1	0

LEGEND: All bits are read-only.

Figure A-1. Manufacturer Status

FET1, FET0 — Indicates the state of the charge and discharge FETs

0,0 = Both charge and discharge FETs are on.
0,1 = CHG FET is off, DSG FET is on.
1,0 = Both charge and discharge FETs are off.
1,1 = CHG FET is on, DSG FET is off.

PF1, PF0 — Indicates permanent failure cause when permanent failure is indicated by STATE3..STATE0

0,0 = Fuse is blown if enabled via DF:Configuration:Register(64):Permanent Fail Cfg.
0,1 = Cell imbalance failure
1,0 = Safety voltage failure
1,1 = FET failure

STATE3, STATE2, STATE1, STATE0 — Indicates the battery state.

0,0,0,0 = Wake Up
0,0,0,1 = Normal Discharge
0,0,1,1 = Pre-Charge
0,1,0,1 = Charge
0,1,1,1 = Charge Termination
1,0,0,0 = Fault Charge Terminate
1,0,0,1 = Permanent Failure
1,0,1,0 = Overcurrent
1,0,1,1 = Overtemperature
1,1,0,0 = Battery Failure
1,1,0,1 = Sleep
1,1,1,0 = Discharge Prohibited
1,1,1,1 = Battery Removed

A.1.1.7 Chemistry ID (0x0008)

Returns the OCV table chemistry ID of the battery. The default table ID is 0x0100. For a list of OCV chemistry IDs, refer to the application note*Support of Multiple Li-Ion Chemistries w/Impedance Track™ Gas Gauges* (SLUA372).

Table A-7. Chemistry ID

Manufacturer Access	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x0008	R	Chemistry ID	hex	2	0x0000	0xffff	0x0100	

A.1.2 System Control

The commands in this section cause the bq28400 to take actions when written. No data is returned.

A.1.2.1 Shutdown (0x0010)

Instructs the bq28400 to verify and enter shutdown mode. This command is only available when the bq28400 is in Full Access mode. Shutdown will not be entered unless the *PackVoltage* < ***Charger Present*** and *Current* ≤ 0.

A.1.2.2 Sleep (0x0011)

Instructs the bq28400 to verify and enter sleep mode if no other command is sent after the *Sleep* command. Any SMB transition will wake up the bq28400. It takes about 1 minute before the device will go to sleep. This command is only available when the bq28400 is in Full Access mode.

A.1.2.3 Seal Device (0x0020)

Instructs the bq28400 to limit access to the extended SBS functions and data flash space, sets the *[SS]* flag, and clears the *[FAS]* flag.

This command is only available when the bq28400 is in Full Access mode.

See Section 2.7 in this document for detailed information.

A.1.2.4 LTPF Enable (0x0021)

This command clears any existing PF flags, enables Lifetime Data and PF and sets the *[LTPF]* flag in *Operation Status* and the ***[PROD_LTPF_EN]*** bit in ***Operation Cfg C***. See the description in *Operation Cfg C*.

This command is only available when the bq28400 is in Full Access mode.

A.1.2.5 FUSE Activation (0x0030)

This command drives the FUSE pin high.

This command is only available when the bq28400 is in Full Access mode.

A.1.2.6 FUSE Clear (0x0031)

This command sets the FUSE pin back to low.

This command is only available when the bq28400 is in Full Access mode.

A.1.2.7 Reset (0x0041)

The bq28400 undergoes a full reset. The bq28400 holds the clock line down for a few milliseconds to complete the reset.

This command is only available when the bq28400 is in Full Access mode.

A.1.2.8 BootRom (0x0f00)

The bq28400 goes into BootRom mode.

This command is only available when the bq28400 is in Full Access mode.

A.1.2.9 Permanent Fail Clear (*PFKey*)

This two-step command needs to be written to *ManufacturerAccess* in following order: 1st word of the *PFKey* first followed by the 2nd word of the *PFKey*. If the command fails 4 seconds must pass before the command can be reissued.

It instructs the bq28400 to clear the *PFStatus*, clear the *[PF]* flag, clear the ***Fuse Flag***, reset the FUSE pin, and unlock the data flash for writes.

This command is only available when the bq28400 is in Full Access mode.

NOTE: Higher word must be immediately followed by lower word. If clear command fails, command can only be repeated 4 seconds after previous attempt. If communication other than the lower word occurs after the first word is sent, the ***Permanent Fail Clear*** command fails.

A.1.2.10 Full Access Device (*FullAccessKey*)

Instructs the bq28400 to enable full access to all SBS functions and data flash space and set the *[FAS]* flag. This 2 step command needs to be written to *ManufacturerAccess* in the following order: 1st word of the *FullAccessKey* first followed by the 2nd word of the *FullAccessKey*.

See Section 2.7 in this document for detailed information.

A.2 BatteryMode (0x03)

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

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
High Byte	CapM	ChgM	AM	RSVD	RSVD	RSVD	PB	CC
Low Byte	CF	RSVD	RSVD	RSVD	RSVD	RSVD	PBS	ICC

LEGEND: High Byte is Read/Write, Low Byte is Read Only; RSVD = Reserved and **must** be programmed to 0.

Figure A-2. BatteryMode

CapM — Sets the units used for capacity information and internal calculation

0 = Reports in mA or mAh (default)

1 = Reports in 10 mW or 10 mWh

Following functions are instantaneously updated after *[CapM]* change:

SBS:RemainingCapacity(0x0f)

SBS:FullChargeCapacity(0x10)

SBS:DesignCapacity(0x18)

The following functions are recalculated within 1 second after *[CapM]* change:

SBS:BatteryStatus(0x16)

ChgM — Enables or disables the bq28400 device's transmission of *ChargingCurrent* and *ChargingVoltage* messages to the Smart Battery Charger

0 = Enable *ChargingVoltage* and *ChargingCurrent* broadcasts to the Smart Battery Charger by setting the ***[BCAST]*** bit in ***Operation Cfg B*** when charging is desired.

1 = Disable *ChargingVoltage* and *ChargingCurrent* broadcasts to the Smart Battery Charger (default)

AM — Enables or disables *AlarmWarning* broadcasts to the host and Smart Battery Charger

0 = Enable *AlarmWarning* broadcast to host and Smart Battery Charger by setting the ***[BCAST]*** bit in ***Operation Cfg B*** (default). The bq28400 sends the *AlarmWarning* messages to the SMBus Host and the Smart Battery Charger any time an alarm condition is detected.

1 = Disable *AlarmWarning* broadcast to host and Smart Battery Charger. The bq28400 does not master the SMBus, and *AlarmWarning* messages are not sent to the SMBus Host and the Smart Battery Charger for a period of no more than 65 seconds and no less than 45 seconds. *[AM]* is automatically cleared by the bq28400 60 seconds after being set to 1, independent of the ***[BCAST]*** bit.

NOTE: The system, as a minimum, is required to poll the Smart Battery Charger every 10 seconds if the *[AM]* flag is set.

PB — Sets the role of the battery pack. This flag is not used by bq28400 and should be set to 0.

CC — Enable or disable internal charge controller. This flag is not used by bq28400 and should be set to 0.

CF — This flag is set if *MaxError* > ***CF MaxError Limit***

0 = Battery OK

1 = Condition cycle requested

PBS — Primary battery support is not supported by bq28400 and is fixed to 0.

ICC — This flag indicates if internal charge controller function is supported or not. This value is fixed to 1.

A.3 Temperature (0x08)

This read-word function returns an unsigned integer value of the temperature in units of 0.1°K, as measured by the bq28400. It has a range of 0 to 6553.5°K.

The source of the measured temperature is configured by the Temp bit in the ***Operation*** register.

Table A-8. Temperature

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x08	R	Temperature	Unsigned Integer	2	0	65535	—	0.1°K

A.4 Voltage (0x09)

This read-word function returns an unsigned integer value of the sum of the individual cell voltage measurements in mV with a range of 0 to 20000 mV.

Table A-9. Voltage

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x09	R	Voltage	Unsigned Integer	2	0	20000	—	mV

A.5 Current (0x0a)

This read-word function returns a signed integer value of the measured current being supplied (or accepted) by the battery in mA, with a range of –32,768 to 32,767. A positive value indicates charge current and a negative value indicates discharge.

Any current value within the ***Deadband*** will be reported as 0 mA by the *Current* function.

Table A-10. Current

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x0a	R	Current	Signed Integer	2	–32768	32767	—	mA

NOTE: *Current* function is the average of four internal current measurements over a one-second period.

A.6 AverageCurrent (0x0b)

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

AverageCurrent is calculated by a rolling IIR filtered average of *Current* function data with a period of 14.5 s. During the time after a reset and before 14.5 s have elapsed the reported *AverageCurrent* = *Current* function value.

Table A-11. AverageCurrent

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x0b	R	AverageCurrent	Signed Integer	2	–32768	32767	—	mA

A.7 MaxError (0x0c)

This gives the expected margin of error (%) in the state of charge calculations. For example, if the max error is 10% and the Relative State of Charge is 50%, the value of Relative State of Charge is between 50% and 60%.

Table A-12. MaxError

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x0c	R	MaxError	Unsigned Integer	1	0	100	1	%

A.8 RelativeStateOfCharge (0x0d)

This read-word function returns an unsigned integer value of the predicted remaining battery capacity expressed as a percentage of *FullChargeCapacity* with a range of 0 to 100%, with fractions of % rounded up.

If the ***[RSOCL]*** bit in ***Operation Cfg C*** is set then *RelativeStateofCharge* and *RemainingCapacity* are held at 99% until primary charge termination occurs and only displays 100% upon entering primary charge termination.

If the ***[RSOCL]*** bit in ***Operation Cfg C*** is cleared then *RelativeStateofCharge* and *RemainingCapacity* are **not** held at 99% until primary charge termination occurs. Fractions of % greater than 99% are rounded up to display 100%.

Table A-13. RelativeStateOfCharge

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x0d	R	RelativeStateOfCharge	Unsigned Integer	1	0	100	—	%

A.9 RemainingCapacity (0x0f)

This read- or write-word function returns an unsigned integer value, with a range of 0 to 65535, of the predicted charge or energy remaining in the battery. This value is expressed in either charge (mAh) or energy (10 mWh), depending on the setting of the *[CapM]* flag.

Table A-14. RemainingCapacity

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x0f	R/W	RemainingCapacity	Unsigned Integer	2	0	65535	—	mAh or 10 mWh

A.10 FullChargeCapacity (0x10)

This read-word function returns an unsigned integer value, with a range of 0 to 65535, of the predicted pack capacity when it is fully charged. This value is expressed in either charge (mAh) or power (10 mWh) depending on setting of *[CapM]* flag.

Table A-15. FullChargeCapacity

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x10	R	FullChargeCapacity	Unsigned Integer	2	0	65535	—	mAh or 10 mWh

A.11 ChargingCurrent (0x14)

This read-word function returns an unsigned integer value of the desired charging current, in mA, with a range of 0 to 65534. A value of 65535 indicates that a charger should operate as a voltage source outside its maximum regulated current range.

0..65534 = Desired charging current in mA
65535 = Charger should operate as voltage source outside its maximum regulated current range.

Table A-16. ChargingCurrent

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x14	R	ChargingCurrent	Unsigned Integer	2	0	65535	—	mA

A.12 ChargingVoltage (0x15)

This read-word function returns an unsigned integer value of the desired charging voltage, in mV, where the range is 0 to 6553. A value of 65535 indicates that the charger should operate as a current source outside its maximum regulated voltage range.

0..65534 = Desired charging voltage in mV
65535 = Charger should operate as current source outside its maximum regulated voltage range.

Table A-17. ChargingVoltage

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x15	R	ChargingVoltage	Unsigned Integer	2	0	65535	—	mV

A.13 BatteryStatus (0x16)

This read-word function returns the status of the battery.

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
High Byte	OCA	TCA	RSVD	OTA	TDA	RSVD	RSVD	RSVD
Low Byte	INIT	DSG	FC	FD	EC3	EC2	EC1	EC0

LEGEND: All Values Read Only; RSVD = Reserved

Figure A-3. BatteryStatus

OCA — 1 = Over Charged Alarm

TCA — 1 = Terminate Charge Alarm

OTA — 1 = Over Temperature Alarm

TDA — 1 = Terminate Discharge Alarm

INIT — 1 = Initialization. This flag is cleared approx. 1 second after device reset, after all SBS parameters have been measured and updated.

DSG — Discharging

0 = bq28400 is in charging mode.
1 = bq28400 is in discharging mode, relaxation mode, or valid charge termination has occurred. See: Section C.9.

FC — 1 = Fully Charged

FD — 1 = Fully Discharged

EC3, EC2, EC1, EC0 — Error Code, returns status of processed SBS function

0,0,0,0 =	OK	bq28400 processed the function code with no errors detected.
0,0,0,1 =	BUSY	bq28400 is unable to process the function code at this time.
0,0,1,0 =	Reserved	bq28400 detected an attempt to read or write to a function code reserved by this version of the specification or bq28400 detected an attempt to access an unsupported optional manufacturer function code.
0,0,1,1 =	Unsupported	bq28400 does not support this function code as defined in this version of the specification.
0,1,0,0 =	AccessDenied	bq28400 detected an attempt to write to a read-only function code.
0,1,0,1 =	Over/Underflow	bq28400 detected a data overflow or underflow.

0,1,1,0 =	BadSize	bq28400 detected an attempt to write to a function code with an incorrect data block.
0,1,1,1 =	UnknownError	bq28400 detected an unidentifiable error.

A.14 CycleCount (0x17)

This read-word function returns, as an unsigned integer value, the number of cycles the battery has experienced, with a range of 0 to 65535. The default value is stored in the data flash value ***Cycle Count***, which is updated each time this variable is incremented. One cycle count is the accumulated discharge of ***CC Threshold***.

When the bq28400 is in Full Access mode, this block is R/W.

CCT	Cycle Count Calculation
0 =	One cycle count is the accumulated discharge of ***CC Threshold***.

Table A-18. CycleCount

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x17	R/W	CycleCount	Unsigned Integer	2	0	65535	0	

A.15 DesignCapacity (0x18)

This read-word function returns, as an unsigned integer value, the theoretical or nominal capacity of a new pack, stored in ***Design Capacity*** or in ***Design Energy***.

The *DesignCapacity* value is expressed in either current (mAh at a C/5 discharge rate) or power (10 mWh at a P/5 discharge rate) depending on the setting of the *[CapM]* bit.

When the bq28400 is in Full Access mode, this block is R/W.

Table A-19. DesignCapacity

SBS Cmd.	Mode	Name	CapM	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x18	R/W	DesignCapacity	0	Unsigned Integer	2	0	65535	4400	mAh
			1	Unsigned Integer	2	0	65535	6336	10 mWh

A.16 DesignVoltage (0x19)

This read-word function returns an unsigned integer value of the theoretical voltage of a new pack, in mV, with a range of 0 to 65535. The default value is stored in ***Design Voltage***.

When the bq28400 is in Full Access mode, this block is R/W.

Table A-20. DesignVoltage

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x19	R/W	DesignVoltage	Unsigned Integer	2	3000	18000	7200	mV

A.17 SpecificationInfo (0x1a)

This read-word function returns, as an unsigned integer value, the version number of the Smart Battery Specification the battery pack supports, as well as voltage- and current-scaling information.

Power-scaling is the product of the voltage-scaling times the current-scaling. The data is packed in the following fashion:

IPScale x 0x1000 + VScale x 0x0100 + SpecID_H x 0x0010 + SpecID_L

VScale (voltage scaling) and IPScale (current scaling) should always be set to zero. The default setting is stored in ***Spec Info***.

When the bq28400 is in Full Access mode, this block is R/W.

Table A-21. SpecificationInfo

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x1a	R/W	SpecificationInfo	hex	2	0x0000	0xffff	0x0031	

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
IPScale (0) (multiplies current by $10^{IPScale}$)				VScale (0) (multiplies voltage by 10^{VScale})				SpecI D_H (0..15)				SpecID _L (0..15)			

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

Figure A-4. SpecificationInfo

A.18 ManufactureDate (0x1b)

This read-word function returns the date the pack was manufactured in a packed integer. The date is packed in the following fashion:

(year–1980) x 512 + month x 32 + day

The default value for this function is stored in ***Manuf Date***.

When the bq28400 is in Full Access mode, this block is R/W.

Table A-22. ManufactureDate

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x1b	R/W	ManufactureDate	Unsigned Integer	2	0	65535	0	

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Year biased by 1980 (0..127)							Month (1..12)				Date (0..31)				
MSB						LSB	MSB			LSB	MSB				LSB

Figure A-5. ManufactureDate

A.19 SerialNumber (0x1c)

This read-word function is used to return an unsigned integer serial number. The default value of this function is stored in ***Ser. Num.***.

When the bq28400 is in Full Access mode, this block is R/W.

Table A-23. SerialNumber

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x1c	R/W	SerialNumber	hex	2	0x0000	0xffff	0x0001	

A.20 ManufacturerName (0x20)

This read-block function returns a character string containing the battery manufacturer's name with a maximum length of 11 characters (11 data + length byte).

The default setting of this function is stored in data flash ***Manuf Name***.

When the bq28400 is in Full Access mode, this block is R/W.

Table A-24. ManufacturerName

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x20	R/W	ManufacturerName	String	11+1	—	—	Texas Inst.	ASCII

A.21 DeviceName (0x21)

This read-block function returns a character string that contains the battery name with a maximum length of 7 characters (7 data + length byte).

The default setting of this function is stored in data flash ***Device Name***.

When the bq28400 is in Full Access mode, this block is R/W.

Table A-25. DeviceName

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x21	R/W	DeviceName	String	7+1	—	—	bq28400	ASCII

A.22 DeviceChemistry (0x22)

This read-block function returns a character string that the manufacturer uses to identify the battery chemistry with a maximum length of 4 characters (4 data + length byte).

The default setting of this function is stored in data flash ***Device Chemistry***, although it has no use for internal charge control or fuel gauging.

When the bq28400 is in Full Access mode, this block is R/W.

Table A-26. DeviceChemistry

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x22	R/W	DeviceChemistry	String	4+1	—	—	LION	ASCII

A.23 ManufacturerData (0x23)

This read-block function returns several configuration data flash elements with an absolute maximum length of 14 Data + 1 length byte (stored in Manufacturer Data Length). The Manufacturing data elements shown below are stored in the Manufacturer Data subclass.

When the bq28400 is in Full Access mode, this block is R/W.

Table A-27. ManufacturerData

Data	Byte	Name	Format
Manufacturer Data	1	Firmware Version	Hex
	2		
	3	Hardware Revision	
	4		
bq28400 Counter	5	Partial Reset Counter	
	6	Full Reset Counter	
	7	Watchdog Reset Counter	
	8	Check Sum	

A.24 Authenticate (0x2f)

This read- or write-block function allows the host to authenticate the bq28400 -based battery using a SHA-1 authentication transform with a length of 20 data bytes + 1 length byte. See *SHA-1 Authentication* chapter and *Using SHA-1 in bq20zxx Family of Gas Gauges* application report (SLUA359) for detailed information.

Table A-28. Authenticate

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x2f	R/W	Authenticate	String	20+1	—	—	—	

A.25 CellVoltage2..1 (0x3e..0x3f)

These read-word functions return an unsigned value of the calculated individual cell voltages, in mV, with a range of 0 to 65535. *CellVoltage1* corresponds to the bottom most series cell element, while *CellVoltage2* corresponds to the top most series cell element.

Table A-29. CellVoltage2..1

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x3c		CellVoltage2					—	
0x3d		CellVoltage1					—	

A.26 SBS Command Table

Table A-30. SBS Commands

SBS CMD	NAME	ACCESS		PROTOCOL	TYPE	MIN	MAX	UNIT	NOTE
		SE	FA						
0x00	ManufacturerAccess()	R/W	R/W	Word	H2	0x0000	0xFFFF		
0x03	BatteryMode().3.	R/W	R/W	Word	H2	0x0000	0xFFFF		**Bit 0: ICC** Internal_Charge_Controller ®) 0 = Function not supported **Bit 1: PBC** Primary_Battery_Support ®) 1 = Primary or Secondary Battery Support **Bit 2:—Bit 6: Reserved** **Bit 7: CF** Condition_Flag ®) 0 = Battery OK 1 = Conditioning cycle requested **Bit 8: CCE** Charge_Controller_Enabled (R/W) 0 = Internal charge controller disabled **Bit 9: PB** Primary_Battery (R/W) 0 = Battery operating in its secondary role (default) 1 = Battery operating in its primary role **Bit 10:—Bit 12: Reserved** **Bit 13: AM** Alarm Mode (R/W) 0 = Enable *AlarmWarning* broadcasts to host and smart battery charger 1 = Disable *AlarmWarning* broadcasts to host and smart battery charger **Bit 14: CHGM** Charger_Mode (R/W) 0 = Enable ChargingVoltage() and ChargingCurrent() broadcasts to host and smart battery charger 1 = Disable ChargingVoltage() and ChargingCurrent() broadcasts to host and smart battery charger **Bit 15: CAPM** Capacity_Mode (R/W) 0 = Report in mA or mAh (default) 1 = Report in 10 mW or 10 mWh
0x08	Temperature() HT	R	R	Word	U2		65535	0.1°K	
0x09	Voltage()	R	R	Word	I2		65535	mV	
0x0a	Current()	R	R	Word	I2	–32767	32768	mA	
0x0b	AverageCurrent()	R	R	Word	U2	–32767	32768	mA	
0x0c	MaxError()	R	R	Word	U2		100	%	
0x0d	RelativeStateOfCharge()	R	R	Word	U2		100	%	
0x0f	RemainingCapacity()	R	R	Word	U2		65535	mAh or 10 mWh	
0x10	FullChargeCapacity()	R	R	Word	U2		65535	mAh or 10 mWh	
0x14	ChargingCurrent()	R	R	Word	U2		65534	mA	
0x15	ChargingVoltage()	R	R	Word	U2		65534	mV	
0x16	BatteryStatus()	R	R	Word	H2				**Bit 0:3: EC3,EC2,EC1,EC0** Error Code 0x0 = OK 0x1 = Busy 0x2 = ReservedCommand 0x3 = UnsupportedCommand 0x4 = AccessDenied 0x5 = Overflow/Underflow 0x6 = BadSize 0x7 = UnknownError **Bit 4: FD** Fully Discharged 0 = Battery ok 1 = Battery fully depleted **Bit 5: FC** Fully Charged 0 = Battery not fully charged 1 = Battery fully charged **Bit 6: DSG** Discharging 0 = Battery is charging 1 = Battery is discharging **Bit 7:** INIT Initialization 0 = inactive 1 = active **Bit 10: Reserved** Undefined **Bit 11: TDA** Terminate Discharge Alarm 0 = inactive 1 = active **Bit 12: OTA** Over Temperature Alarm 0 = inactive 1 = active **Bit 13: Reserved** Undefined **Bit 14: TCA** Terminate Charge Alarm 0 = inactive 1 = active **Bit 15: OCA** Over Charged Alarm 0 = inactive 1 = active
0x17	CycleCount()	R	R	Word	U2	0	65535	cycles	latch at 65535

Table A-30. SBS Commands (continued)

SBS CMD	NAME	ACCESS		PROTOCOL	TYPE	MIN	MAX	UNIT	NOTE
		SE	FA						
0x18	DesignCapacity()	R	R	Word	U2	0	65535	mAh or 10 mWh	
0x19	DesignVoltage()	R	R	Word	U2	0	65535	mV	
0x1a	SpecificationInfo()	R	R	Word		0x0000	0xFFFF		
0x1b	ManufactureDate()	R	R	Word					
0x1c	SerialNumber()	R	R	Word					
0x20	ManufacturerName()	R	R	Word					
0x21	DeviceName()	R	R	Block					
0x22	DeviceChemistry()	R	R	Block	S4		LION		
0x23	ManufacturerData()	R	R	Block					
0x2f	Validate	—	R/W	Block					
0x3e	CellVoltage2()	R	R	Word					
0x3f	CellVoltage1()	R	R	Word					

Extended SBS Commands

The extended SBS commands are only available when the bq28400 device is in Full access mode.

B.1 FET Control (0x46)

This function is only available when the bq28400 is in the Full-Access mode, indicated by a cleared *[FAS]* flag.

This is a read-or write function, allowing direct control of the FETs for test purposes only. If this command is used to alter the current state of the FETs, the gauge can overwrite the FET state, depending on the gauging and safety conditions. If the FUSE pin is NOT used in the application circuit, it should be connected to ground directly or the FETs will NOT turn ON.

Table B-1. FET Control

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
FETControl	RSVD	RSVD	RSVD	RSVD	ZVCHG	CHG	DSG	RSVD

RSVD = Reserved and **Must** be programmed to 0.

ZVCHG—Pre Charge FET Control: 0 = Turn OFF Pre Charge FET, 1 = Turn ON Pre Charge FET.

CHG—Charge FET Control: 0 = Turn OFF Charge FET. The Charge FET does NOT turn OFF in Discharge mode to protect the FET body diode. 1 = Turn ON Charge FET.

DSG—Discharge FET Control: 0 = Turn OFF Discharge FET. The Discharge FET does NOT turn OFF in Charge Mode to protect the FET body diode. 1 = Turn ON Discharge FET.

B.2 Safety Alert (0x50)

This is a read-word function returns indications of pending safety issues, such as running safety timers, or fail counters that are nonzero but have not reached the required time or value to trigger a **SafetyStatus** failure.

Table B-2. Safety Alert

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
High Byte	OTD	OTC	OCD	OCC	RSVD	RSVD	RSVD	RSVD
Low Byte	CUV	COV	PF	RSVD	WDF	AOCD	SCC	SCD

All Values are Read Only, RSVD = Reserved

OTD = 1 = Discharge overtemperature alert

OTC = 1 = Charge overtemperature alert

OCD = 1 = Discharge overcurrent alert

OCC = 1 = Charge overcurrent alert

WDF = 1 = AFE watch dog alert

AOCD = 1 = AFE discharge overcurrent alert

SCC = 1 = Charge short-circuit alert

SCD = 1 = Discharge short-circuit alert

B.3 Safety Status (0x51)

This is a read-word which returns the status of the safety features.

Table B-3. Safety Status

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
High Byte	OTD	OTC	OCD	OCC	RSVD	RSVD	RSVD	RSVD
Low Byte	CUV	COV	PF	RSVD	WDF	AOCD	SCC	SCD

All Values are Read Only, RSVD = Reserved

OTD = 1 = Discharge overtemperature alert

OTC = 1 = Charge overtemperature alert

OCD = 1 = Discharge overcurrent alert

OCC = 1 = Charge overcurrent alert

PF = 1 = Permanent failure and FUSE pin has been driven high

WDF = 1 = AFE watch dog alert

AOCD = 1 = AFE discharge overcurrent alert

SCC = 1 = Charge short-circuit alert

SCD = 1 = Discharge short-circuit alert

B.4 PF Alert (0x52)

This is a read-word that returns the status of the safety features, indicating pending safety issues, such as running safety timers that have not reached the required time to trigger a **PFAlert failure**.

Table B-4. PF Alert

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
High Byte	RSVD	VSHUT	RSVD	SOPT	SOCD	SOCC	AFE_P	AFE_C
Low Byte	DFF	DFETF	CFETF	CIM	SOTD	SOTC	SOV	PFIN

All Values are Read Only, RSVD = Reserved

VSHUT = 1 = A permanent failure has occurred AND the device went into shutdown after that event

SOPT = 1 = Open Thermistor permanent failure alert

SOCD = 1 = Discharge Safety Overcurrent permanent failure alert

SOCC = 1 = Charge Safety Overcurrent permanent failure alert

AFE_P = 1 = Periodic AFE communications permanent failure alert

AFE_C = 1 = Permanent AFE communications permanent failure alert

AOCD = 1 = AFE discharge overcurrent alert

DFF = 1 = Data flash permanent failure alert

DFETF = 1 = Discharge FET- Failure permanent failure alert

CFETF = 1 = Charge FET- Failure permanent failure alert

CIM = 1 = Cell-imbalance permanent failure alert

SOTD = 1= Discharge FET safety overtemperature permanent failure alert

SOTC = 1= Charge FET safety overtemperature permanent failure alert

SOV = 1= Safety- Overvoltage permanent failure alert

PFIN = 1= External Input Indication of permanent failure alert

B.5 PF Status (0x53)

This permanent failure status register indicates the source of the permanent failure condition. Any new permanent failure is added to the PF flags 1 register to show all permanent failures that have occurred.

Table B-5. PF Status

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
High Byte	RSVD	VSHUT	RSVD	SOPT	SOCD	SOCC	AFE_P	AFE_C
Low Byte	DFF	DFETF	CFETF	CIM	SOTD	SOTC	SOV	PFIN

All Values are Read Only, RSVD = Reserved

VSHUT = 1 = A permanent failure has occurred AND the device went into shutdown after that event

SOPT = 1 = Open Thermistor permanent failure

SOCD = 1 = Discharge Safety Overcurrent permanent failure

SOCC = 1 = Charge Safety Overcurrent permanent failure

AFE_P = 1 = Periodic AFE communications permanent failure

AFE_C = 1 = Permanent AFE communications permanent failure

AOCD = 1 = AFE discharge overcurrent

DFF = 1 = Data flash permanent failure

DFETF = 1 = Discharge FET- Failure permanent failure

CFETF = 1 = Charge FET- Failure permanent failure

CIM = 1 = Cell-imbalance permanent failure

SOTD = 1= Discharge FET safety overtemperature permanent failure

SOTC = 1= Charge FET safety overtemperature permanent failure

SOV = 1= Safety- Overvoltage permanent failure

PFIN = 1= External Input Indication of permanent failure

B.6 OperationStatus (0x54)

This read-word function returns the current operation status of the bq28400.

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
High Byte	PRES	FAS	SS	CSV	LTPF	RSVD	RSVD	RSVD
Low Byte	WAKE	DSG	XDSG	XDSGI	EDV2	VDQ	RSVD	RSVD

LEGEND: All Values Read-Only; RSVD = Reserved

Figure B-1. OperationStatus

PRES — 1 = $\overline{\text{PRES}}$ is low, indicating that the system is present (battery inserted).

FAS — 0 = Full access security mode

SS — 1 = Sealed security mode

CSV — 1 = Data flash checksum value has been generated.

LTPF — The LTPF flag indicates if Lifetime Data and PF are enabled.

0 = Lifetime Data and PF are not enabled (default).

1 = Lifetime Data and PF are enabled.

WAKE — 1 = bq28400 WAKE mode

DSG — Replica of the SBS:BatteryStatus(0x16)[DSG] flag.

XDSG — 1 = Discharge fault

XDSGI — 1 = Discharge disabled due to a current issue.

EDV2 — Indicates that cell voltage is less than the EDV2 threshold.
0 = Voltage > EDV2 threshold (discharging)
1 = Voltage < EDV2 threshold

VDQ — Indicates if the present discharge cycle is valid for an FCC update.
0 = Discharge cycle not valid
1 = Discharge cycle valid

B.7 ChargingStatus (0x55)

This read-word function returns the current status of the charging functions.

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
High Byte	XCHG	CHGSUSP	PCHG	RSVD	LTCHG	ST1CHG	ST2CHG	HTCHG
Low Byte	RSVD	CB	PCMTO	FCMTO	OCHGV	OCHGI	OC	XCHGLV

LEGEND: All Values Read-Only

Figure B-2. ChargingStatus

XCHG — 1 = Charging disabled

CHGSUSP — 1 = Charging suspended

PCHG — 1 = Precharging conditions exist

LTCHG — 1 = Low temperature charging

ST1CHG — 1 = Standard temperature charging 1

ST2CHG — 1 = Standard temperature charging 2

HTCHG — 1 = Low temperature charging

CB — 1 = Cell balancing in progress

PCMTO — 1 = Precharge timeout fault

FCMTO — 1 = Fast-charge timeout fault

OCHGV — 1 = Overcharge voltage fault

OCHGI — 1 = Overcharge current fault

OC — 1 = Overcharge fault

XCHGLV — 1 = Battery is depleted .

B.8 FET Status (0x56)

This read-word function allows display of the FET status in Sealed mode.

Table B-6. FET Status

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
FETControl	RSVD	RSVD	RSVD	RSVD	ZVCHG	CHG	DSG	RSVD

RSVD — Reserved and **Must** be programmed to 0.

ZVCHG — Pre Charge FET Control: 0 = Pre Charge FET is OFF, 1 = Pre Charge FET is ON.

CHG — Charge FET Control: 0 = Charge FET is OFF. 1 = Charge FET is ON.

DSG— Discharge FET Control: 0 = Discharge FET is OFF.1 = Discharge FET is ON.

B.9 Pack Voltage (0x5a)

This is a read-word function that returns the integer value representing the measured voltage on the PACK pin in mV within a range of 0 to 65535. **Pack Gain** is the scale factor for the *PackVoltage*.

Table B-7. Pack Voltage

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x5a	R	PackVoltage	Unsigned Integer	2	0	65535	—	mV

B.10 TS0 Temperature (0x5e)

This is a read-word function that returns the TS0 temperature.

Table B-8. TS0 Temperature

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x5e	R	TS0 temperature	Integer	2	–400	1200	—	0.1C

B.11 FullAccessKey (0x61)

This function is only available when the bq28400 is in the Full-Access mode, indicated by a cleared *[FAS]* flag.

The order of the bytes, when entered in *ManufacturerAccess*, is the reverse of what is written to or read from the part. For example, if the 1st and 2nd word of the *FullAccessKey* block read returns 0x1234 and 0x5678, then in *ManufacturerAccess*, 0x3412 and 0x7856 should be entered to put the part in full access mode.

Table B-9. FullAccessKey

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x61	R/W	FullAccessKey	hex	4	0x00000000	0xffffffff	—	

B.12 PFKey (0x62)

This read- or write-block command allows the user to change the Permanent-Failure-Clear key. This function is only available when the bq28400 is in the Full Access mode, indicated by a cleared *[FAS]* flag.

The order of the bytes, when entered in *ManufacturerAccess*, is the reverse of what is written to or read from the part. For example, if the 1st and 2nd word of the *PFKey* block read returns 0x1234 and 0x5678, then in *ManufacturerAccess*, 0x3412 and 0x7856 should be entered to clear a permanent failure.

Table B-10. PFKey

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x62	R/W	PFKey	hex	4	0x00000000	0xffffffff	—	

B.13 AuthenKey3 (0x63)

This read- or write-block command stores Byte 12–Byte 15 of the 16 Byte long authentication key. This function is only available when the bq28400 is in the Full Access mode, indicated by a cleared *[FAS]* flag.

Table B-11. AuthenKey3

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x63	R/W	AuthenKey3	hex	4	0x00000000	0xffffffff	0x10325476	

B.14 AuthenKey2 (0x64)

This read- or write-block command stores Byte 8–Byte 11 of the 16 Byte long authentication key. This function is only available when the bq28400 is in the Full Access mode, indicated by a cleared *[FAS]* flag.

Table B-12. AuthenKey2

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x64	R/W	AuthenKey2	hex	4	0x00000000	0xffffffff	0x98abdcfe	

B.15 AuthenKey1 (0x65)

This read- or write-block command stores Byte 4–Byte 7 of the 16 Byte long authentication key. This function is only available when the bq28400 is in the Full Access mode, indicated by a cleared *[FAS]* flag.

Table B-13. AuthenKey1

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x65	R/W	AuthenKey1	hex	4	0x00000000	0xffffffff	0xdfceab89	

B.16 AuthenKey0 (0x66)

This read- or write-block command stores Byte 0–Byte 3 of the 16 Byte long authentication key. This function is only available when the bq28400 is in the Full Access mode, indicated by a cleared *[FAS]* flag.

Table B-14. AuthenKey0

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x66	R/W	AuthenKey0	hex	4	0x00000000	0xffffffff	0x67452301	

B.17 ManufacturerInfo (0x70)

This read/write block function returns the data stored in ***Manuf. Info*** where byte 0 is the MSB with a maximum length of 31 data + 1 length byte. When the bq28400 is in Full Access mode, this block is read/write. When the bq28400 is in Sealed mode, this block is read only.

Table B-15. ManfacturerInfo

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x70	R/W	ManufacturerInfo	String	31+1	—	—	—	

B.18 SenseResistor (0x71)

This read- or write-word command allows the user to change the sense resistor value used in µΩ. The bq28400 automatically updates the respective calibration data on receipt of a new sense resistor value.

Table B-16. SenseResistor

SBS Cmd.	Mode	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0x71	R/W	SenseResistor	unsigned integer	2	0	65535	10000	µΩ

B.19 TempRange (0x72)

This read-word function returns the present temperature range in effect.

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
High Byte	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD
Low Byte	RSVD	RSVD	TR5	TR4	TR3	TR2A	TR2	TR1

LEGEND: All values read-only. RSVD = Reserved

Figure B-3. TempRange

- **TR1** – 1 = temperature range 1: *Temperature* < ***JT1***
- **TR2** – 1 = temperature range 2: ***JT1*** < *Temperature* < ***JT2***
- **TR2A** – 1 = temperature range 3: ***JT2*** < *Temperature* < ***JT2a***
- **TR3** – 1 = temperature range 4: ***JT2a*** < *Temperature* < ***JT3***
- **TR4** – 1 = temperature range 5: ***JT3*** < *Temperature* < ***JT4***
- **TR5** – 1 = temperature range 6: ***JT4*** < *Temperature*

B.20 Manufacturing Status (0xB1)

This allows the device to be calibrated

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
High Byte	CAL_EN	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD
Low Byte	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD

RSVD = Reserved

Figure B-4. ManufacturingStatus

CAL_EN = 1 = Calibration enabled

B.21 Extended SBS Command Values

Table B-17. Extended SBS Commands

SBS CMD	NAME	ACCESS		PROTOCOL	TYPE	MIN	MAX	UNIT	NOTE
		SE	FA						
0x46	FETCONTROL	R/W	R/W	Word		0x00	0x1e	—	**Bit 0: RSVD (Reserved)** **Bit 1: DSG** 0 = Turn OFF DSG FET, DSG FET does NOT turn off in Charge mode to protect the FET body diode 1 = Turn ON DSG FET **Bit 2: CHG** 0 = Turn OFF CHG FET, CHG FET does NOT turn off in Discharge mode to protect the FET body diode 1 = Turn ON CHG FET **Bit 3: ZVCHG** 0 = Turn OFF pre-charge FET 1 = Turn ON pre charge FET **Bit 4, 7: Reserved**

Table B-17. Extended SBS Commands (continued)

SBS CMD	NAME	ACCESS		PROTOCOL	TYPE	MIN	MAX	UNIT	NOTE
		SE	FA						
0x50	SAFETY_ALERT	—	R	Word		0x0000	0xffff	—	**Bit 0: SCD** 1 = Discharge short-circuit alert **Bit 1: SCC** 1 = Charge short-circuit alert **Bit 2: AOCD** 1 = AFE Discharge Overcurrent alert **Bit 3: WDF** 1 = AFE Watchdog alert **Bit 4: Reserved** **Bit 5: DFF data flash error** 1 = Permanent failure alert **Bit 6: COV** 1 = Cell Over voltage alert **Bit 7: CUV** 1 = Cell Under voltage alert **Bit 8: 11 Reserved** **Bit 12: OCC** 1 = Charge Overcurrent alert **Bit 13: OCD** 1 = Discharge Overcurrent alert **Bit 14: OTC** 1 = Charge Over-temperature alert **Bit 15: OTD** 1 = Discharge Over-temperature alert
0x51	SAFETY_STATUS	—	R	Word		0x0000	0xffff	—	**Bit 0: SCD** 1 = Discharge short-circuit condition **Bit 1: SCC** 1 = Charge short-circuit condition **Bit 2: AOCD** 1 = AFE Discharge Overcurrent condition **Bit 3: WDF** 1 = AFE Watchdog condition **Bit 4: Reserved** **Bit 5: PF** 1 = Permanent failure condition **Bit 6: COV** 1 = Cell Over voltage Condition **Bit 7: CUV** 1 = Cell Under voltage Condition **Bit 8: 11 Reserved** **Bit 12: OCC** 1 = Charge Overcurrent condition **Bit 13: OCD** 1 = Discharge Overcurrent condition **Bit 14: OTC** 1 = Charge Over-temperature condition **Bit 15: OTD** 1 = Discharge Over-temperature condition

Table B-17. Extended SBS Commands (continued)

SBS CMD	NAME	ACCESS		PROTOCOL	TYPE	MIN	MAX	UNIT	NOTE
		SE	FA						
0x52	PERMANENTFAILURE_ALERT	—	R	Word		0x0000	0x9ffff	—	**Bit 0: PFIN** 1 = External indication of permanent failure alert **Bit 1: SOV** 1 = Safety Over-voltage permanent failure alert **Bit 2: SOTC** 1 = Charge Safety Over-temperature permanent failure alert **Bit 3: SOTD** 1 = Discharge Safety Over-temperature permanent failure alert **Bit 4: CIM** 1 = Cell-imbalance permanent failure alert **Bit 5: CFETF** 1 = Charge FET failure, permanent failure alert **Bit 6: DFETF** 1 = Discharge FET failure, permanent failure alert **Bit 7: DFF** 1 = Data flash fault, permanent failure alert **Bit 8: AFE_C** 1 = AFE Communications, permanent failure alert **Bit 9: AFE_P** 1 = Periodic AFE Communications, permanent failure alert **Bit 10: SOCC** 1 = Charge safety Overcurrent, permanent failure alert **Bit 11: SOCD** 1 = Discharge safety Overcurrent, permanent failure alert **Bit 12: SOPT** 1 = Open Thermistor, permanent failure alert **Bit 13: Reserved** **Bit 14: VSHUT** 1 = A permanent failure occurred and the device went into shutdown mode due to this failure **Bit 15: Reserved**

Table B-17. Extended SBS Commands (continued)

SBS CMD	NAME	ACCESS		PROTOCOL	TYPE	MIN	MAX	UNIT	NOTE
		SE	FA						
0x53	PERMANENTFAILURE_STATUS	—	R	Word					**Bit 0: PFIN** 1 = External indication of permanent failure **Bit 1: SOV** 1 = Safety Over-voltage permanent failure **Bit 2: SOTC** 1 = Charge Safety Over-temperature permanent failure **Bit 3: SOTD** 1 = Discharge Safety Over-temperature permanent failure **Bit 4: CIM** 1 = Cell-imbalance permanent failure **Bit 5: CFETF** 1 = Charge FET failure, permanent failure **Bit 6: DFETF** 1 = Discharge FET failure, permanent failure **Bit 7: DFF** 1 = Data flash fault, permanent failure **Bit 8: AFE_C** 1 = AFE Communications, permanent failure **Bit 9: AFE_P** 1 = Periodic AFE Communications, permanent failure **Bit 10: SOCC** 1 = Charge safety Overcurrent, permanent failure **Bit 11: SOCD** 1 = Discharge safety Overcurrent, permanent failure **Bit 12: SOPT** 1 = Open Thermistor, permanent failure **Bit 13: Reserved** **Bit 14: VSHUT** 1 = A permanent failure occurred and the device went into shutdown mode due to this failure **Bit 15: Reserved**

Table B-17. Extended SBS Commands (continued)

SBS CMD	NAME	ACCESS		PROTOCOL	TYPE	MIN	MAX	UNIT	NOTE
		SE	FA						
0x54	OPERATIONSTATUS	—	R	Word					**Bit 0:1 : Reserved** **Bit 2: VDQ** Indicates if the present discharge cycle is valid for an FCC update 0 = Discharge cycle NOT valid 1 = Discharge cycle valid **Bit 3: EDV2** Indicates that the cell voltage is less than the EDV2 threshold 0 = Voltage > EDV2 threshold (discharging) 1 = Voltage < EDV2 threshold **Bit 4: XDSGI** 1 = Discharged disabled due to a current issue **Bit 5: XDSG** 1 = Discharge fault **Bit 6: DSG** 0 = Battery is charging 1 = Battery is discharging **Bit 7: WAKE** 1 = Device in wake mode **Bit 8: Calibration Mode** **Bit 9: Shutdown** **Bit 10: RSVD** **Bit 11: LTPF** Indicates if Lifetime data and PF are enabled 0 = Lifetime Data and PF are NOT enabled (default) 1 = Lifetime and PF enabled **Bit 12: CSV** Data flash checksum value is generated 1 = Data flash checksum value is generated **Bit 13: SS** Sealed security mode 1 = Sealed security mode **Bit 14: FAS** Full access security mode 0 = Full access security mode **Bit 15: PRES** (active low) 1 = PRES input is low, indicating Battery is discharging

Table B-17. Extended SBS Commands (continued)

SBS CMD	NAME	ACCESS		PROTOCOL	TYPE	MIN	MAX	UNIT	NOTE
		SE	FA						
0x55	CHARGINGSTATUS	—	R	Word					**Bit 0: XCHGLV** 1 = Battery is depleted **Bit 1: OC** 1 = Over-charge fault **Bit 2: OCHGI** 1 = Overcharge current fault **Bit 3: OCHGV** 1 = Overcharge voltage fault **Bit 4: FCMTO** 1 = Fast-charge timeout fault **Bit 5: PCMTO** 1 = Pre-charge timeout fault **Bit 6: CB** 1 = Cell balancing in progress **Bit 7: Reserved** 1 = Device in wake mode **Bit 8:HTCHG** 1 = Low temperature charging **Bit 9: ST2CHG** 1 = Standard temperature charging 2 **Bit 10: ST1CHG** 1 = Standard temperature charging 1 **Bit 11: LTCHG** 1 = Low temperature charging **Bit 12: Reserved** **Bit 13: PCHG** 1 = Precharge condition exists **Bit 14: CHGSUP** 1 = Charging suspended **Bit 15: XCHG** 1 = Charging disabled
0x56	FET_STATUS	—		Byte					**Bit 0: RSVD (Reserved)** **Bit 1: DSG** 0 = DSG FET is OFF 1 = DSG FET is ON **Bit 2: CHG** 0 = CHG FET is OFF 1 = CHG FET is IN **Bit 3: ZVCHG** 0 = Pre-charge FET is OFF 1 = Pre charge FET is ON **Bit 4, 7: Reserved**
0x5a	PACKVOLTAGE	R	R	Word	U2	0	65535	mV	
0x5e	EXT_TS0	—	R	Word	I2	–400	1200	0.1C	
0x61	FULL_ACCESS_KEY	R/W	R/W	Block		0x0000	0xFFFF		
0x62	PF_CLEAR_KEY	—	R/W	Block	hex	0x00000000	0xFFFFFFFF		
0x63	AUTH_KEY_0	R/W	R/W	Block	hex	0x0000	0xFFFF		
0x64	AUTH_KEY_1	R/W	R/W	Block	hex	0x0000	0xFFFF		
0x65	AUTH_KEY_2	R/W	R/W	Block	hex	0x0000	0xFFFF		
0x66	AUTH_KEY_3	R/W	R/W	Block	hex	0x0000	0xFFFF		
0x70	MFGINFO	—	R/W	Block	hex	0x00000000	0xFFFFFFFF		
0x71	SET_SENSE_RESISTOR	—	R/W	Word	U2	0	65535	µΩ	

Table B-17. Extended SBS Commands (continued)

SBS CMD	NAME	ACCESS		PROTOCOL	TYPE	MIN	MAX	UNIT	NOTE
		SE	FA						
0x72	TEMPRANGE	—	R	Word					**Bit 0: TR1** 1 = Temperature Range 1: Temperature < ***JT1*** **Bit 1: TR2** 1 = Temperature Range 2: JT1 < Temperature < JT2 **Bit 2: TR2A** 1 = Temperature Range 3: JT2 < Temperature < JT2a **Bit 3: TR3** 1 = Temperature Range 4: JT2a < Temperature < JT3 **Bit 4: TR4** 1 = Temperature Range 5: JT3 < Temperature < JT4 **Bit 5: TR5** 1 = Temperature Range 6: JT4 < Temperature **Bit 6: 8 Reserved**
0xB1	MANUFACTURINGSTATUS	—	R						**Bit 0: 14 Reserved** **Bit 15: CAL_EN** ADC or CC output on ManufacturerData 0 = Disabled 1 = Enabled (default)

Data Flash

CAUTION

Care should be taken when mass programming the data flash space using previous versions of data flash memory map files (such as *.gg files) to make sure that all public locations are updated correctly.

Data flash can only be updated if *Voltage* ≥ ***Flash Update OK Voltage*** .

NOTE: Data flash updates are disabled when the *[DFF] SafetyStatus* flag is set.

C.1 Accessing Data Flash

In different security modes, the data flash access conditions change. See *ManufacturerAccess* and Section 2.7 for further details.

SECURITY MODE	NORMAL DATA FLASH ACCESS
BootROM	N/A
Full Access	R/W
Sealed	N/A

C.1.1 Data Flash Interface

The bq28400 data flash is organized into subclasses where each data flash variable is assigned an offset within its numbered subclass. For example: the ***Pre-chg Current*** location is defined as:

- Class = Charge Control
- SubClass = Pre-Charge Cfg = 486
- Pre-charge Current Offset = 0

NOTE: Data flash commands are NACKed if the bq28400 is in Sealed mode (*[SS]* flag is set).

Reading and writing subclass data are block operations that are each 32 bytes long. Data can be written in shorter block sizes, however. The final block in one subclass can be shorter than 32 bytes, so care must be taken not to write over the subclass boundary. None of the values written are bounded by the bq28400 and the values are not rejected by the gas gauge. Writing an incorrect value may result in a hardware failure due to firmware program interpretation of the invalid data. The data written is persistent, so a Power On Reset does resolve the fault.

C.1.2 Data Flash Access

The following method shows commands used to read/write to data flash:

Command Type	SBS Command	SBS Data	Description
Write word	0x00	0x1YY	ManufacturerAccess() command to set up the dataflash (DF) address in order to write a row (32 bytes) of data. yy = the row number where the target DF address is located.
Read/Write Block	0x2F	32-byte of data	ManufacturerInput() command. Issue this command after setting up the DF address to read/write the 32-byte data to the data flash.

To update a parameter in data flash:

1. Identify the physical byte location of the target parameter using the class and subclass ID information. This is typically the subclass ID + Offset.
2. Identify the target row number by truncating the division of the byte location and the row length; for example, a byte location 27 would be in row: 27 divided by 32 = row number 0.
3. The byte location within the target row is determined by:
   Byte Index = physical location – (row number * row length)
   Byte Index = 27 – (0 *32) = 27. The target byte is in row 0, byte 27.
4. Using MAC command 0x1yy, where yy = row number. In this example, the SMBus write command would be 0x100.
5. Read the original target row first through a block read command 0x2F before updating.
6. Store original data in memory array so the appropriate byte(s) can be updated.
   SMBus block read cmd = 0x2F, length = 32 byte.
7. Store the read data into a memory array (for example, yRowDataArray).
8. Update the target byte (yRowDataArray(27)).
9. Repeat Step 4 to write the updated yRowDataArray() array back to the device data flash.
10. Issue SMBus block write cmd = 0x27, length 32.
11. A read verify is recommended to ensure the data flash has been re-programmed correctly. Repeat Steps 4 and 5 to do a read verify.

C.1.3 Example

To change a Cell Undervoltage Threshold (CUV Threshold) from 2200 mV to 2300 mV, the following sequence is used:

Locate the register required to change this value using subclassID + Offset:

This is indicated in the DF section as Subclass ID (576) + Offset (13).

This gives the location of the target information at 589.

There are 32 bytes per row, therefore:

Row number is 589/32 ≈ 18 (the nearest complete row)

byte Index = 589 – (18 * 32) = 13

Change byte 13 on row 18:

- MAC Access
- SBS CMD; Write 0x00
- SBS Data; 0x112 Data for row 18
- SBS CMD; Read 0x2F
- Store data into memory array.
- Update the 18th row, byte 13 from 0898 (hex) to 08FC (hex). This changes the threshold from 2200 mV to 2300 mV.
- Write the updated information back to the device data flash.
- SBS CMD; Write 0x00

- SBS Data; 0x112
- Verify the change by reading the appropriate row in data flash.
- SBS CMD; Write 0x00
- SBS Data; 0x112 Data for row 18
- SBS CMD; Read 0x2F

C.2 1st Level Safety Class

C.2.1 Voltage (Subclass 653)

C.2.1.1 LT COV Threshold (Offset 0)

When the bq28400 is operating in the low temperature range (see Section 2.1), it sets the *[COV]* flag in *SafetyStatus* if any *CellVoltage2..1* is equal to or higher than the ***LT COV Threshold*** for a period of 2 s.

Table C-1. LT COV Threshold

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
653	Voltage	0	LT COV Threshold	Integer	2	3700	5000	4300	mV

C.2.1.2 LT COV Recovery (Offset 2)

When the bq28400 is operating in the low temperature range it recovers from a cell overvoltage condition if all cell voltages are lower than the ***LT COV Recovery*** threshold level.

Table C-2. LT COV Recovery

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
653	Voltage	2	LT COV Recovery	Integer	2	0	4400	4100	mV

C.2.1.3 ST COV Threshold (Offset 4)

When the bq28400 is operating in the standard temperature range 1 or 2 (see Section 2.1), it sets the *[COV]* flag in *SafetyStatus* if any *CellVoltage2..1* is equal to or higher than the ***ST COV Threshold*** for a period of 2 s.

Table C-3. ST COV Threshold

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
653	Voltage	4	ST COV Threshold	Integer	2	3700	5000	4500	mV

C.2.1.4 ST COV Recovery (Offset 6)

When the bq28400 is operating in the standard temperature range 1 or 2, it recovers from a cell overvoltage condition if all cell voltages are lower than the ***ST COV Recovery*** threshold level.

Table C-4. ST COV Recovery

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
653	Voltage	6	ST COV Recovery	Unsigned integer	2	0	4400	4300	mV

C.2.1.5 HT COV Threshold (Offset 8)

When the bq28400 is operating in the high temperature range (see Section 2.1), it sets the *[COV]* flag in *SafefyStatus* if any *CellVoltage2..1* is equal to or higher than the ***HT COV Threshold*** for a period of 2 s.

Table C-5. HT COV Threshold

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
653	Voltage	8	HT COV Threshold	Integer	2	3700	5000	4200	mV

C.2.1.6 HT COV Recovery (Offset 10)

When the bq28400 is operating in the high temperature range, it recovers from a cell overvoltage condition if all cell voltages are lower than the ***HT COV Recovery*** threshold level.

Table C-6. HT COV Recovery

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
653	Voltage	10	HT COV Recovery	Integer	2	0	4400	4100	mV

C.2.1.7 CUV Threshold (Offset 13)

The bq28400 sets the *[CUV]* *SafetyAlert* if *Cell* is equal to or lower than the ***CUV Threshold*** for a period of 2 s.

Table C-7. CUV Threshold

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
653	Voltage	13	CUV Threshold	Unsigned Integer	2	0	3500	2300	mV

C.2.1.8 CUV Recovery (Offset 16)

The bq28400 recovers from a cell undervoltage condition, if all *CellVoltage2..1* are higher than the ***CUV Recovery*** threshold. On recovery, the *ChargingCurrent* and *ChargingVoltage* are set to their appropriates value per the charging algorithm, the *[TDA]* and *[FD]* flags are reset, the *[CUV]* in *SafetyStatus* is reset, and the *[XDSG]* flag in *OperationStatus* is reset.

Table C-8. CUV Recovery

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
653	Voltage	16	CUV Recovery	Unsigned Integer	2	0	3600	3000	mV

C.2.2 Current (Subclass 671)

C.2.2.1 OC (1st Tier) Chg (Offset 0)

The bq28400 sets the *[OCC]SafetyAlert* if charge *Current* is equal to or higher than the ***OC (1st Tier) Chg*** threshold.

Table C-9. OC (1st Tier) Chg

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
671	Current	0	OC (1st Tier) Chg	Unsigned Integer	2	0	20000	6000	mA

C.2.2.2 OC (1st Tier) Chg Time (Offset 2)

If the *[OCC]* in *SafetyAlert* time period exceeds the ***OC (1st Tier) Chg Time*** time, the bq28400 goes into an overcurrent charge condition. This function is disabled if ***OC (1st Tier) Chg Time*** is set to 0.

In an overcurrent while charging condition the CHG FET is turned off, the *ChargeCurrent* and *ChargeVoltage* are set to 0, the *[TCA]* flag is set, the *[OCC]* flag in *SafetyAlert* is cleared, and the *[OCC]* flag in *SafetyStatus* is set.

Table C-10. OC (1st Tier) Chg Time

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
671	Current	2	OC (1st Tier) Chg Time	Unsigned Integer	1	0	240	2	s

C.2.2.3 OC Chg Recovery (Offset 3)

The bq28400 recovers from an overcurrent charge condition in non-removable battery mode if the *AverageCurrent* is equal to or lower than the ***OC Chg Recovery*** threshold for a length of ***Current Recovery Time***. The bq28400 recovers in removable battery mode by removing and reinserting the battery pack. On recovery, the *ChargingCurrent* and *ChargingVoltage* are set to appropriate their values per the charging algorithm, *[TCA]* is reset, and the *[OCC]* flag in *SafetyStatus* is reset.

Table C-11. OC Chg Recovery

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
671	Current	3	OC Chg Recovery	Signed Integer	2	–1000	1000	200	mA

C.2.2.4 OC (1st Tier) Dsg (Offset 5)

The bq28400 sets the *[OCD]SafetyAlert* if the discharge *Current* is equal to or higher than the ***OC (1st Tier) Dsg*** threshold.

Table C-12. OC (1st Tier) Dsg

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
671	Current	5	OC (1st Tier) Dsg	Unsigned Integer	2	0	20000	6000	mA

C.2.2.5 OC (1st Tier) Dsg Time (Offset 7)

If the *[OCD]* in *SafetyAlert* time period exceeds the ***OC (1st Tier) Dsg Time*** bq28400 goes into an overcurrent discharge condition. This function is disabled if ***OC (1st Tier) Dsg Time*** is set to 0.

In an overcurrent discharge condition the DSG FET is turned off, the *ChargeCurrent* is set to ***Pre-chg Current***, the *[TDA]* flag is set, the *[OCD]* flag in *SafetyAlert* is reset, the *[OCD]* flag in *SafetyStatus* is set, and the *[XDSG]* flag is set.

Table C-13. OC (1st Tier) Dsg Time

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
671	Current	7	OC (1st Tier) Dsg Time	Unsigned Integer	1	0	240	2	sec

C.2.2.6 OC Dsg Recovery (Offset 8)

The bq28400 recovers from an overcurrent discharge condition in non-removable battery mode if the *AverageCurrent* is equal to or lower than the ***OC Dsg Recovery*** current level for a length of ***Current Recovery Time***. On recovery, the *ChargingCurrent* and *ChargingVoltage* are set to their appropriate values per the charging algorithm, *[TDA]* is reset, the *[OCD]SafetyStatus* flag is reset, and the *[XDSG]* flag is reset.

Table C-14. OC Dsg Recovery

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
671	Current	8	OC Dsg Recovery	Signed Integer	2	0	1000	200	mA

C.2.2.7 AFE OC Dsg (Offset 11)

The ***AFE OC Dsg*** threshold sets the OCDV register of the integrated AFE device. Changes to this data flash value requires a software full reset or a power reset of the bq28400 to take effect.

Table C-15. AFE OC Dsg

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
671	Current	11	AFE OC Dsg	hex	1	0x00	0x0f	0x07	

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
AFE OCDV Register	RSVD	RSVD	RSVD	RSVD	OCDV3	OCDV2	OCDV1	OCDV0

LEGEND: RSVD = Reserved and **must** be programmed to 0.

Figure C-1. OCDV Register

OCDV3, OCDV2, OCDV1, OCDV0 — Sets the overload voltage threshold

[RSNS] = 0, 0x00–0x0f = Sets the voltage threshold between 50 mV and 200 mV in 10-mV steps
[RSNS] = 1, 0x00–0x0f = Sets the voltage threshold between 20 mV and 100 mV in 5-mV steps

Table C-16. OCDV (b3–b0) Configuration Bits with Corresponding Voltage Threshold When STATE_CTL[RSNS] = 0

OCDV (b3-b0) configuration bits with corresponding voltage threshold			
0x00	0.050 V	0x08	0.130 V
0x01	0.060 V	0x09	0.140 V
0x02	0.070 V	0x0a	0.150 V
0x03	0.080 V	0x0b	0.160 V
0x04	0.090 V	0x0c	0.170 V
0x05	0.100 V	0x0d	0.180 V
0x06	0.110 V	0x0e	0.190 V
0x07	0.120 V	0x0f	0.200 V

Table C-17. OCDV (b3–b0) Configuration Bits with Corresponding Voltage Threshold When STATE_CTL[RSNS] = 1

OCDV (b3-b0) configuration bits with corresponding voltage threshold(1)			
0x00	0.025 V	0x08	0.065 V
0x01	0.030 V	0x09	0.070 V
0x02	0.035 V	0x0a	0.075 V
0x03	0.040 V	0x0b	0.080 V

Table C-17. OCDV (b3–b0) Configuration Bits with Corresponding Voltage Threshold When STATE_CTL[RSNS] = 1 (continued)

OCDV (b3-b0) configuration bits with corresponding voltage threshold(1)			
0x04	0.045 V	0x0c	0.085 V
0x05	0.050 V	0x0d	0.090 V
0x06	0.055 V	0x0e	0.095 V
0x07	0.060 V	0x0f	0.100 V

C.2.2.8 AFE OC Dsg Time (Offset 12)

The ***AFE OC Discharge Time*** is programmed into the OCDD register of the integrated AFE device. If an overcurrent discharge condition is detected, *ChargingCurrent* is set to 0, *[TDA]* in ***BatteryStatus*** is set, and *[AOCD]* in *SafetyStatus* is set. Changes to this data flash value requires a software full reset or a power reset of the bq28400 to take effect.

Table C-18. AFE OC Time

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
671	Current	12	AFE OC Dsg Time	hex	1	0x00	0x0f	0x07	

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
AFE OCDD Register	RSVD	RSVD	RSVD	RSVD	OCDD3	OCDD2	OCDD1	OCDD0

LEGEND: RSVD = Reserved and **must** be programmed to 0.

Figure C-2. OCDD Register

OCDD3, OCDD2, OCDD1, OCDD0 — Sets the overload voltage delay

0x00–0x0f = Sets the overvoltage trip delay between 1 ms–31 ms in 2-ms steps

Table C-19. OCDD (b3–b0) Configuration Bits with Corresponding OC Dsg Delay Time

Setting	Time	Setting	Time	Setting	Time	Setting	Time
0x00	1 ms	0x04	9 ms	0x08	17 ms	0x0c	25 ms
0x01	3 ms	0x05	11 ms	0x09	19 ms	0x0d	27 ms
0x02	5 ms	0x06	13 ms	0x0a	21 ms	0x0e	29 ms
0x03	7 ms	0x07	15 ms	0x0b	23 ms	0x0f	31 ms

C.2.2.9 AFE OC Dsg Recovery (Offset 13)

The bq28400 recovers from an overcurrent discharge condition in non-removable battery mode if the *AverageCurrent* is equal to or lower than the ***(–)AFE OC Dsg Recovery*** current level for the length of ***Current Recovery Time***. On recovery, the *ChargingCurrent* and *ChargingVoltage* are set to their appropriate values per the charging algorithm, *[TDA]* is reset, the *[AOCD]* flag in *SafetyStatus* is reset, and *[XDSG]* is reset.

Table C-20. AFE OC Dsg Recovery

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
671	Current	13	AFE OC Dsg Recovery	Signed Integer	2	10	1000	5	mA

C.2.2.10 AFE SC Chg Cfg (Offset 15)

The ***AFE SC Charge Cfg*** is programmed into the SCC register of the integrated AFE device. ***AFE SC Charge Cfg*** sets the short circuit in charging voltage threshold and the short circuit in charging delay of the integrated AFE. Changes to this data flash value requires a software full reset or a power reset of the bq28400 to take effect.

If the bq28400 identifies a charge in short circuit situation, *ChargingCurrent* and *ChargingVoltage* are set to 0, *[TCA]* in *BatteryStatus* is set, and *[SCC]* in *SafetyStatus* is set.

Table C-21. AFE SC Chg Cfg

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
671	Current	15	AFE SC Chg Cfg	hex	1	0x00	0xf7	0x73	

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
AFE SCC Register	SCCD3	SCCD2	SCCD1	SCCD0	—	SCCV2	SCCV1	SCCV0

Figure C-3. SCC Register

SCCD3, SCCD2, SCCD1, SCCD0 — Sets the short circuit delay in charging

0x0–0xf = Sets the short circuit delay in charging between 0 µs–915 µs in 61-µs steps. Exceeding the short circuit in charge voltage threshold for longer than this period turns off the CHG and DSG outputs. 0000 is the AFE power on reset default.

SCCV2, SCCV1, SCCV0 — Sets the short circuit voltage threshold in charging

[RSNS] = 0, 0x0–0x4 = Sets the short circuit voltage threshold between 100 mV and 300 mV in 50-mV steps. Note: settings for 0x05 to 0x07 are not supported.

[RSNS] = 1, 0x0–0x7 = Sets the short circuit voltage threshold between 50 mV and 225 mV in 25-mV steps

SCC (b3) — Not used.

Table C-22. SCCV (b2–b0) Configuration Bits with Corresponding Voltage Threshold When STATE_CTL[RSNS] = 0

Setting	Threshold	Setting	Threshold
0x00	–0.100 V	0x04	–0.300 V
0x01	–0.150 V	0x05	N/A
0x02	–0.200 V	0x06	N/A
0x03	–0.250 V	0x07	N/A

Table C-23. SCCV (b2–b0) Configuration Bits with Corresponding Voltage Threshold When STATE_CTL[RSNS] = 1

Setting	Threshold	Setting	Threshold
0x00	–0.050 V	0x04	–0.150 V
0x01	–0.075 V	0x05	–0.175 V
0x02	–0.100 V	0x06	–0.200 V
0x03	–0.125 V	0x07	–0.225 V

Table C-24. SCCD (b7–b4) Configuration Bits with Corresponding SC Chg Delay Time

Setting	Time	Setting	Time	Setting	Time	Setting	Time
0x00	0 µs	0x04	244 µs	0x08	488 µs	0x0c	732 µs
0x01	61 µs	0x05	305 µs	0x09	549 µs	0x0d	793 µs
0x02	122 µs	0x06	366 µs	0x0a	610 µs	0x0e	854 µs
0x03	183 µs	0x07	427 µs	0x0b	671 µs	0x0f	915 µs

C.2.2.11 AFE SC Dsg Cfg (Offset 16)

The ***AFE SC Dsg Cfg*** is programmed into the SCD register of the integrated AFE device. The ***AFE SC Dsg Cfg*** sets the short circuit in discharging voltage threshold and the short circuit in discharging delay of the integrated AFE. Changes to this data flash value requires a software full reset or a power reset of the bq28400 to take effect.

If the bq28400 identifies a discharge in short circuit situation from the integrated AFE *ChargingCurrent* and *ChargingVoltage* are set to 0, *[TDA]* in *BatteryStatus* is set, *[SCD]* in *SafetyStatus* is set, and *[XDSG]* in *OperationStatus* is set.

Table C-25. AFE SC Dsg Cfg

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
671	Current	16	AFE SC Dsg Cfg	hex	1	0x00	0xff	0x73	

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
AFE SCD Register	SCDD3	SCDD2	SCDD1	SCDD0	—	SCDV2	SCDV1	SCDV0

Figure C-4. SCD Register

SCDD3, SCDD2, SCDD1, SCDD0 — Sets the short circuit delay in discharging of the integrated AFE

0x0–0xf = Sets the short circuit in discharging delay between 0 µs–915 µs in 61-µs steps. Exceeding the short circuit in discharge voltage threshold for longer than this period turns off the CHG and DSG outputs. 0000 is the AFE power on reset default. If STATE_CTL[SCDDx2] is set, the delay time is double of that programmed in this register.

SCDV2, SCDV1, SCDV0 — Sets the short circuit voltage threshold in discharging of the integrated AFE

[RSNS] = 0, 0x0–0x7 = Sets the short circuit voltage threshold between 100 mV and 450 mV in 50-mV steps

[RSNS] = 1, 0x0–0x7 = Sets the short circuit voltage threshold between 50 mV and 475 mV in 25-mV steps

SCD (b3) — Not used.

Table C-26. SCDV (b2–b0) Configuration Bits with Corresponding Voltage Threshold When STATE_CTL[RSNS] = 0

Setting	Threshold	Setting	Threshold
0x00	0.100 V	0x04	0.300 V
0x01	0.150 V	0x05	0.350 V
0x02	0.200 V	0x06	0.400 V
0x03	0.250 V	0x07	0.450 V

Table C-27. SCDV (b2–b0) Configuration Bits with Corresponding Voltage Threshold When STATE_CTL[RSNS] = 1

Setting	Threshold	Setting	Threshold
0x00	0.050 V	0x04	0.150 V
0x01	0.075 V	0x05	0.175 V
0x02	0.100 V	0x06	0.200 V
0x03	0.125 V	0x07	0.225 V

Table C-28. SCDD (b7–b4) Configuration Bits with Corresponding SC Dsg Delay Time

Setting	Time	Setting	Time	Setting	Time	Setting	Time
0x00	0 µs	0x04	244 µs	0x08	488 µs	0x0c	732 µs
0x01	61 µs	0x05	305 µs	0x09	549 µs	0x0d	793 µs
0x02	122 µs	0x06	366 µs	0x0a	610 µs	0x0e	854 µs
0x03	183 µs	0x07	427 µs	0x0b	671 µs	0x0f	915 µs

C.2.2.12 AFE SC Recovery (Offset 17)

The bq28400 recovers from a short circuit in charging or discharging condition in non-removable battery mode if the absolute value of *AverageCurrent* is equal to or lower than the ***AFE SC Recovery*** current level for the length of ***Current Recovery Time***. On recovery, the *ChargingCurrent* and *ChargingVoltage* are set to their appropriate values per the charging algorithm, *[TDA]* and *[TCA]* in *BatteryStatus* are reset, *[SCC]* and *[SCD]* in *SafetyStatus* are reset, and *[XDSG]* is reset.

Table C-29. AFE SC Recovery

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
671	Current	17	AFE SC Recovery	Unsigned Integer	2	0	200	1	mA

C.2.3 Temperature (Subclass 690)

C.2.3.1 Over Temp Chg (Offset 0)

The bq28400 sets the *[OTC]* flag in *SafetyAlert* if the pack *Temperature* is equal to or higher than the ***Over Temp Chg*** threshold.

Table C-30. Over Temp Chg

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
690	Temperature	0	Over Temp Chg	Unsigned Integer	2	0	1200	550	0.1°C

C.2.3.2 OT Chg Time (Offset 2)

If the *[OTC]* in *SafetyAlert* time period exceeds the ***OT Chg Time*** period the bq28400 goes into an over temperature charge condition. This function is disabled if ***OT Chg Time*** is set to 0.

In and over temperature charge condition the *ChargingVoltage* and *ChargingCurrent* are set to 0, the *[OTA]* flag in *BatteryStatus* is set, *[TCA]* is set, the *[OTC]* flag in *SafetyAlert* is reset, and the *[OTC]* flag in *SafetyStatus* is set and CHG FET is turned off.

Table C-31. OT Chg Time

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
690	Temperature	2	OT Chg Time	Unsigned Integer	1	0	240	2	sec

C.2.3.3 OT Chg Recovery (Offset 3)

The bq28400 recovers from an over temperature charge condition if the *Temperature* is equal to or lower than the ***OT Chg Recovery*** level. On recovery, the CHG FET returns to its normal operating state, the *ChargingCurrent* and *ChargingVoltage* are set to their appropriate values per the charging algorithm, the *[OTA]* flag is reset, and the *[OTC]* flag in *SafetyStatus* is reset.

Table C-32. OT Chg Recovery

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
690	Temperature	3	OT Chg Recovery	Unsigned Integer	2	0	1200	500	0.1°C

C.2.3.4 Over Temp Dsg (Offset 5)

The bq28400 sets the *[OTD]* in *SafetyAlert* if the pack *Temperature* is equal to or higher than the ***Over Temp Dsg*** threshold.

Table C-33. Over Temp Dsg

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
690	Temperature	5	Over Temp Dsg	Unsigned Integer	2	0	1200	600	0.1°C

C.2.3.5 OT Dsg Time (Offset 7)

If the *[OTD]* in *SafetyAlert* time period exceeds the ***OT Dsg Time*** the bq28400 goes into an over temperature discharge condition. This function is disabled if ***OT Dsg Time*** is set to 0.

In an over temperature discharge condition the *ChargingCurrent* is set to 0, *[OTA]* is set, the *[OTD]* flag in *SafetyAlert* is reset, and the *[OTD] SafetyStatus* flag is set. the DSG FET is turned off and *[XDSG]* in *OperationStatus* is set.

Table C-34. OT Dsg Time

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
690	Temperature	7	OT Dsg Time	Unsigned Integer	1	0	240	2	s

C.2.3.6 OT Dsg Recovery (Offset 8)

The bq28400 recovers from an over temperature discharge condition if the *Temperature* is equal to or lower than the ***OT Dsg Recovery*** level. On recovery, the DSG FET returns to its normal operating state, the *ChargingCurrent* and *ChargingVoltage* are set to their appropriate values per the charging algorithm, the *[OTA]* flag is reset, the *[OTD] SafetyStatus* flag is reset, and the *[XDSG]* flag in *OperationStatus* is reset.

Table C-35. OT Dsg Recovery

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
690	Temperature	8	OT Dsg Recovery	Unsigned Integer	2	0	1200	550	0.1°C

C.3 2nd Level Safety

C.3.1 Voltage (Subclass 700)

C.3.1.1 LT SOV Threshold (Offset 0)

When the bq28400 is operating in the low temperature charging range (*[TR2]* = 1), it sets the *[SOV]* flag in *PFStatus* if any *CellVoltage2..1* is equal to or higher than the ***LT SOV Threshold*** for a period of ***SOV Time***.

Table C-36. LT SOV Threshold

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
700	Voltage	0	LT SOV Threshold	Integer	2	0	20000	4400	mV

C.3.1.2 ST SOV Threshold (Offset 2)

When the bq28400 is operating in the standard temperature charging range 1 or 2(*[TR2A] = 1*, or *[TR3]* = 1), it sets the *[SOV]* flag in *PFStatus* if any *CellVoltage2..1* is equal to or higher than the ***ST SOV Threshold*** for a period of ***SOV Time***.

Table C-37. ST SOV Threshold

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
700	Voltage	2	ST SOV Threshold	Integer	2	0	20000	4600	mV

C.3.1.3 HT SOV Threshold (Offset 4)

When the bq28400 is operating in the high temperature charging range (*[TR4]* = 1), it sets the *[SOV]* flag in *PFStatus* if any *CellVoltage2..1* is equal to or higher than the ***HT SOV Threshold*** for a period of ***SOV Time***.

Table C-38. HT SOV Threshold

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
700	Voltage	4	HT SOV Threshold	Integer	2	0	20000	4500	mV

C.3.1.4 SOV Time (Offset 6)

The bq28400 sets the *[SOV]* flag in *PFStatus* and goes into a safety overvoltage condition if any *CellVoltage2..1* is equal to or higher than the appropriate SOV threshold (depending on temperature range) for a period of ***SOV Time***. If the ***[XSOV]*** bit in ***Permanent Fail Cfg 1*** is set, the SAFE pin is driven high. This function is disabled if ***SOV Time*** is set to 0.

Table C-39. SOV Time

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
700	Voltage	6	SOV Time	Unsigned integer	1	0	240	0	s

C.3.1.5 PF SOV Fuse Blow Delay(Offset 7)

In case of a safety overvoltage permanent failure condition, the assertion of the FUSE output (to blow a fuse) can be delayed to allow the battery to discharge to a safe level before blowing the fuse. A PF timer is started once an SOV PF event occurs (i.e. ***when SOV Time*** has passed and the *[SOV]* flag has been set). The FUSE output will be driven high (thus blowing the fuse) once this timer reaches ***PF SOV Fuse Blow Delay***, or as soon as all cell voltages go below the ***COV Recovery threshold*** for the current temperature range, whichever comes first.

Table C-40. PF SOV Fuse Blow Delay

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
700	Voltage	7	PF SOV Fuse Blow Delay	Unsigned integer	2	0	65,535	0	s

C.3.1.6 Cell Imbalance Current (Offset 9)

The battery pack *Current* must be below the ***Cell Imbalance Current*** limit for ***Cell Imbalance Time*** before the bq28400 starts detecting cell imbalance.

Table C-41. Cell Imbalance Current

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
700	Voltage	9	Cell Imbalance Current	Unsigned Integer	1	0	200	5	mA

C.3.1.7 Cell Imbalance Fail Voltage (Offset 10)

If the *Current* goes below ***Cell Imbalance Current*** for ***Battery Rest Time*** the bq28400 starts cell imbalance measurements. The bq28400 sets the *[CIM]* flag in *PFAlert* if the bq28400 measures a difference between any *CellVoltage2..1* equal to or higher than the ***Cell Imbalance Fail Voltage*** threshold.

Table C-42. Cell Imbalance Fail Voltage

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
700	Voltage	10	Cell Imbalance Fail Voltage	Unsigned Integer	2	0	5000	1000	mV

C.3.1.8 Cell Imbalance Time (Offset 12)

If the *[CIM] PFAlert* time period exceeds the ***Cell Imbalance Time*** limit the bq28400 goes into a cell imbalance condition, *[CIM]* in *PFAlert* is cleared, *[CIM]* in *PFStatus* is set and, if ***[XCIM]*** in ***Permanent Fail Cfg*** is set, the FUSE pin is also driven high. This function is disabled if ***Cell Imbalance Time*** is set to 0.

Table C-43. Cell Imbalance Time

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
700	Voltage	12	Cell Imbalance Time	Unsigned Integer	1	0	240	0	s

C.3.1.9 Battery Rest Time(Offset 13)

The battery *Current* must be below ***Cell Imbalance Current*** limit for at least ***Battery Rest Time*** period before this device starts detecting cell imbalance. Cell imbalance feature is disabled if *Battery Rest Time* is set to 0.

Table C-44. Battery Rest Time

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
700	Voltage	15	Battery Rest time	Unsigned Integer	2	0	65535	1800	sec

C.3.1.10 Min CIM-check Voltage (Offset 15)

The battery *Current* must be below ***Cell Imbalance Current*** limit for at least ***Battery Rest Time*** period AND All (*CellVoltage2..1*) must be greater than ***Min CIM-check voltage*** before the bq28400 starts detecting cell imbalance.

Table C-45. Min CIM-check voltage

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
700	Voltage	15	Min CIM-check voltage	Unsigned Integer	2	0	65535	3000	mV

C.3.1.11 PFIN Detect Time (Offset 17)

If the FUSE pin is driven logic high externally then *[PFIN]* in *PFAlert* is set. If the *[PFIN]* PF alert time period exceeds ***PFIN Detect Time*** *[PFIN]* in *PFAlert* is reset, *[PFIN]* in *PFStatus* is set, and both DSG- and CHG-FET are turned OFF. If ***[XPFIN]*** in ***Permanent Fail Cfg*** is set, the FUSE pin is also driven high by the bq28400. This function is disabled if ***PFIN Detect Time*** is set to 0.

Regardless of PFIN being disabled or not, however, when the FUSE pin is driven high externally, both DSG- and CHG-FET are turned OFF by the AFE hardware.

Table C-46. PFIN Detect Time

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
700	Voltage	17	PFIN Detect Time	Unsigned Integer	1	0	240	0	sec

C.3.2 Current (Subclass 718)

C.3.2.1 SOC Chg (Offset 0)

The bq28400 sets the *[SOCC]* in *PFAlert* if *Current* is equal to or higher than the ***SOC Chg*** threshold.

Table C-47. SOC Chg

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
718	Current	0	SOC Chg	Unsigned Integer	2	0	30000	10000	mA

C.3.2.2 SOC Chg Time (Offset 2)

If the *[SOCC]* in *PFAlert* time period exceeds the ***SOC Chg Time*** the bq28400 goes into a SOCC condition *[SOCC]* in *PFAlert* is cleared, *[SOCC]* in *PFStatus* is set and, if ***[XSOCC]*** in ***Permanent Fail Cfg*** is set, the FUSE pin is driven high. This function is disabled if ***SOC Chg Time*** is set to 0.

Table C-48. SOC Chg Time

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
718	Current	2	SOC Chg Time	Unsigned Integer	1	0	240	0	sec

C.3.2.3 SOC Dsg (Offset 3)

The bq28400 sets the *[SOCD] PFAlert* if discharge *Current* is equal to or higher than the ***(–)SOC Dsg*** threshold.

Table C-49. SOC Dsg

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
718	Current	3	SOC Dsg	Unsigned Integer	2	0	30000	10000	mA

C.3.2.4 SOC Dsg Time (Offset 5)

If the *[SOCD] PFAlert* time period exceeds the safety overcurrent charge time the bq28400 goes into a SOCD condition, *[SOCD]* in *PFAlert* is cleared, *[SOCD]* in *PFStatus* is set and, if the ***[XSOCD]*** bit in ***Permanent Fail Cfg*** is set, the FUSE pin is driven high. This function is disabled if ***SOCD Dsg Time*** is set to 0.

Table C-50. SOC Dsg Time

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
718	Current	5	SOC Dsg Time	Unsigned Integer	1	0	240	0	sec

C.3.3 Temperature (Subclass 724)

C.3.3.1 SOT Chg (Offset 0)

The bq28400 sets the *[SOTC] PFAlert* if *Temperature* is equal to or higher than the ***SOT Chg*** threshold during charging (*[DSG]* = 0).

Table C-51. SOT Chg

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
724	Temperature	0	SOT Chg	Unsigned Integer	2	0	1200	650	0.1°C

C.3.3.2 SOT Chg Time (Offset 2)

If the *[SOT]* flag in *PFAlert* time period exceeds ***SOT Chg Time*** the bq28400 goes into a SOTC condition, *[SOTC]* in *PFAlert* is cleared, *[SOTC]* in *PFStatus* is set and, if ***[XSOTC]*** in ***Permanent Fail Cfg*** is set, the FUSE pin is driven high. This function is disabled if ***SOT Chg Time*** is set to 0.

Table C-52. SOT Chg Time

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
724	Temperature	2	SOT Chg Time	Unsigned Integer	1	0	240	0	sec

C.3.3.3 SOT Dsg (Offset 3)

The bq28400 sets the *[SOTD] PFAlert* if *Temperature* is equal to or higher than the *SOT Dsg* threshold during discharging (*[DSG]* = 1).

Table C-53. SOT Dsg

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
724	Temperature	3	SOT Dsg	Unsigned Integer	2	0	1200	750	0.1°C

C.3.3.4 SOT Dsg Time (Offset 5)

If the *[SOTD]* in *PFAlert* time period exceeds ***SOT Dsg Time*** the bq28400 goes into a *SOTD* condition, *[SOTD]* in *PFAlert* is reset, *[SOTD]* in *PFStatus* is set and, if ***[XSOTD]*** in ***Permanent Fail Cfg*** is set, the FUSE pin is driven high. This function is disabled if ***SOT Dsg Time*** is set to 0.

Table C-54. SOT Dsg Time

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
724	Temperature	5	SOT Dsg Time	Unsigned Integer	1	0	240	0	s

C.3.3.5 Open Thermistor (Offset 6)

The bq28400 sets the *[SOPT]* flag in *PFAlert* if the thermistor *Temperature* is equal to or lower than the ***Open Thermistor*** threshold.

Table C-55. Open Thermistor

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
724	Temperature	6	Open Thermistor	Signed Integer	2	–1000	1200	–333	0.1°C

C.3.3.6 Open Time (Offset 8)

If the *[SOPT] PFAlert* time period exceeds ***Open Time*** period the bq28400 goes into a safety open thermistor condition, *[SOPT]* in *PFAlert* is reset, *[SOPT]* in *PFStatus* is set and, if ***[XSOPT]*** in ***Permanent Fail Cfg*** is set, the FUSE pin is driven high. This function is disabled if ***Open Time*** is set to 0.

Table C-56. Open Time

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
724	Temperature	8	Open Time	Unsigned Integer	1	0	240	0	s

C.3.4 FET Verification (Subclass 733)

C.3.4.1 FET Fail Limit (Offset 0)

The bq28400 sets the *[CFETF] PFAlert* if the bq28400 detects charge *Current* equal to or higher than the ***FET Fail Limit*** threshold when the CHG FET is supposed to be off.

The bq28400 sets the *[DFETF] PFAlert* if the bq28400 detects discharge *Current* equal to or lower than the ***(–)FET Fail Limit*** threshold when the DSG FET is supposed to be off.

Table C-57. FET Fail Limit

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
733	FET Verification	0	FET Fail Limit	Unsigned Integer	2	0	500	20	mA

C.3.4.2 FET Fail Time (Offset 2)

If the *[CFETF]* alert time period exceeds ***FET Fail Time*** the bq28400 goes into a CHG FET failure condition, *[CFETF]* in *PFAlert* is reset, *[CFETF]* in *PFStatus* is set and, if ***[XCFETF]*** in ***Permanent Fail Cfg*** is set, the FUSE pin is driven high. This function is disabled if ***FET Fail Time*** is set to 0.

If the *[DFETF]* alert time period exceeds ***FET Fail Time*** the bq28400 goes into a DSG FET failure condition, *[DFETF]* in *PFAlert* is reset, *[DFETF]* in *PFStatus* is set and, if ***[XDFETF]*** in ***Permanent Fail Cfg*** is set, the FUSE pin is driven high. This function is disabled if ***FET Fail Time*** is set to 0.

Table C-58. FET Fail Time

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
733	FET Verification	2	FET Fail Time	Unsigned Integer	1	0	240	0	s

C.3.5 AFE Verification (Subclass 736)

C.3.5.1 AFE Check Time (Offset 0)

The bq28400 compares periodically, with a period of ***AFE Check Time***, certain RAM content and expected control bit states of the integrated AFE with the values stored in data flash. If an error is detected, the internal AFE fail counter is incremented. Set to 0 to disable *[AFE_P]* faults.

Table C-59. AFE Check Time

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
736	AFE Verification	0	AFE Check Time	Unsigned Integer	1	0	255	0	s

C.3.5.2 AFE Fail Limit (Offset 1)

If the internal AFE fail counter reaches the ***AFE Fail Limit*** the bq28400 reports a *[AFE_C]* permanent failure and, if *[XAFE_C]* in ***Permanent Fail Cfg*** is set, the FUSE pin is driven high. This function is disabled if ***AFE Fail Limit*** is set to zero.

Table C-60. AFE Fail Limit

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
736	AFE Verification	1	AFE Fail Limit	Unsigned Integer	1	0	255	10	

C.3.5.3 AFE Fail Recovery Time (Offset 2)

The bq28400 decrements the internal AFE fail counter by one each ***AFE Fail Recovery Time*** period to a minimum of zero.

Table C-61. AFE Fail Recovery Time

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
736	AFE Verification	2	AFE Fail Recovery Time	Unsigned Integer	1	0	255	20	sec

C.3.5.4 AFE Init Retry Limit (Offset 3)

After a full reset the AFE offset and gain values are read twice and then compared. ***AFE Init Retry Limit*** is the maximum number of times that the initial AFE offset and gain values will be read, if they are not considered the same, until the *[AFE_C]* permanent failure occurs.

Table C-62. AFE Init Retry Limit

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
736	AFE Verification	3	AFE Init Retry Limit	Unsigned Integer	1	0	255	6	number

C.3.5.5 AFE Init Limit (Offset 4)

AFE Init Limit is the difference in A/D counts that two successive readings of AFE offset and gain can be and still considered the be same value, after a full reset.

Table C-63. AFE Init Limit

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
736	AFE Verification	4	AFE Init Limit	Unsigned Integer	1	0	255	20	count

C.4 Charge Control

C.4.1 Charge Control SMBus Broadcasts

All broadcasts to a host or a smart charger are enabled by the ***[BCAST]*** bit. If the ***[HPE]*** bit is enabled, master-mode broadcasts to the host address are PEC enabled. If the ***[CPE]*** bit is enabled, master-mode broadcasts to the Smart-Charger address are PEC enabled. When broadcast is enabled, the following broadcasts are sent:

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

C.4.2 Charge Temperature Cfg (Subclass 474)

C.4.2.1 JT1 (Offset 0)

JT1 is the lower bound of the low temperature charging range. If *Temperature* is below the ***JT1*** threshold, then *[TR1]* flag in *TempRange* is set and charging is inhibited from starting. If bq28400 is in charge mode (*[DSG]* = 0), then charging is suspended, *[CHGSUSP]* flag in *ChargingStatus* is set, and *ChargingCurrent* and *ChargingVoltage* are set to 0.

Table C-64. JT1

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
474	Charge Temperature Cfg	0	JT1	Integer	2	–400	1200	0	0.1°C

C.4.2.2 JT2 (Offset 2)

JT2 is the upper bound of the low temperature charging range and the lower bound of standard temperature charging range 1. If *Temperature* is between ***JT1*** and ***JT2***, then *[TR2]* flag in *TempRange* is set, *Charging Voltage* is set to ***LT Chg Voltage*** and *ChargingCurrent* is set to ***LT Chg Current 1***, ***LT Chg Current 2***, or ***LT Chg Current 3***, depending on cell voltage (see Section 2.5.2).

Table C-65. JT2

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
474	Charge Temperature Cfg	2	JT2	Integer	2	–400	1200	120	0.1°C

C.4.2.3 JT2a (Offset 4)

JT2a is the upper bound of the standard temperature charging range1 and the lower bound of standard temperature charging range 2. If *Temperature* is between ***JT2*** and ***JT2a***, then *[TR2A]* flag in *TempRange* is set, *Charging Voltage* is set to ***ST1 Chg Voltage*** and *ChargingCurrent* is set to ***ST1 Chg Current 1***, ***ST1 Chg Current 2***, or ***ST1 Chg Current 3***, depending on cell voltage (see Section 2.5.2).

Table C-66. JT2a

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
474	Charge Temperature Cfg	4	JT2a	Integer	2	–400	1200	300	0.1°C

C.4.2.4 JT3 (Offset 6)

JT3 is the upper bound of the standard temperature charging range 2, and the lower bound of high temperature charging range. If *Temperature* is between ***JT2a*** and ***JT3***, then *[TR3]* flag in *TempRange* is set, *Charging Voltage* is set to ***ST2 Chg Voltage*** and *ChargingCurrent* is set to ***ST2 Chg Current 1***, ***ST2 Chg Current 2***, or ***ST2 Chg Current 3***, depending on cell voltage (see Section 2.5.2).

If *Temperature* is greater than ***JT3*** and charging did not start ([DSG] = 1), then charging is inhibited from starting.

Table C-67. JT3

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
474	Charge Temperature Cfg	6	JT3	Integer	2	–400	1200	450	0.1°C

C.4.2.5 JT4 (Offset 8)

JT4 is the upper bound of the high temperature charging range. If *Temperature* is between ***JT3*** and ***JT4***, then *[TR4]* flag in *TempRange* is set, *Charging Voltage* is set to ***HT Chg Voltage*** and *Charging Current* is set to ***HT Chg Current 1, HT Chg Current 2***, or ***HTChg Current 3***, depending on cell voltage (see Section 2.5.2).

If *Temperature* is greater than ***JT4*** then [*[TR5]*] flag in *TempRange* is set. If bq28400 is in charge mode (*[DSG]* = 0), then charging is suspended, *[CHGSUSP]* flag in *ChargingStatus* is set, and *ChargingCurrent* and *ChargingVoltage* are set to 0.

Table C-68. JT4

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
474	Charge Temperature Cfg	8	JT4	Integer	2	–400	1200	550	0.1°C

C.4.2.6 Temp Hys (Offset 4)

If, in charge inhibit mode, the *Temperature* rises above ***JT1*** + ***Temp Hys*** or falls below ***JT3*** – ***Temp Hys*** charging is allowed to be resumed and *[XCHG]* in *ChargingStatus* is cleared. If the ***[NR]*** flag is cleared the fault condition can be cleared by removing and reinserting the battery pack.

Table C-69. Temp Hys

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
474	Charge Temperature Cfg	10	Temp Hys	Signed Integer	2	0	100	10	0.1°C

C.4.3 Pre-Charge Cfg (Subclass 486)

C.4.3.1 Pre-chg Current (Offset 0)

The bq28400 sets the *ChargingCurrent* to the ***Pre-chg Current*** value when in pre-charge mode.

Table C-70. Pre-Chg Current

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
486	Pre-Charge Cfg	0	Pre-chg Current	Unsigned Integer	2	0	2000	250	mA

C.4.3.2 Pre-chg Voltage (Offset 2)

The bq28400 enters pre-charge mode and sets the *[PCHG]* flag in *ChargingStatus* if any *CellVoltage2..1* drops below the ***Pre-chg Voltage*** threshold. In this mode, *Charging Voltage* is set to ***LT Chg Voltage***, and *Charging Current* is set to ***Pre-chg Current***.

Table C-71. Pre-Chg Voltage

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
486	Pre-Charge Cfg	2	Pre-chg Voltage	Unsigned Integer	2	0	20000	3000	mV

C.4.3.3 Recovery Voltage (Offset 4)

The bq28400 enters fast charge mode from pre-charge mode and sets either the *[LTCHG], [ST1CHG], [ST2CHG], or [HTCHG]* flag in *ChargingStatus* if all *CellVoltage2..1* are equal to or higher than the ***Recovery Voltage***.

Table C-72. Recovery Voltage

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
486	Pre-Charge Cfg	4	Recovery Voltage	Unsigned Integer	2	0	20000	3100	mV

C.4.4 Charge Cfg (Subclass 492)

C.4.4.1 LT Chg Voltage (Offset 0)

The bq28400 sets *ChargingVoltage* to the ***LT Chg Voltage*** value when *Temperature* in is the low temperature charging range (*[TR2]* = 1).

Table C-73. LT Chg Voltage

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
492	Charge Cfg	0	LT Chg Voltage	Integer	2	0	20,000	6000	mV

C.4.4.2 LT Chg Current 1 (Offset 2)

The bq28400 sets *ChargingCurrent* to the ***LT Chg Current 1*** value when *Temperature* is in the low temperature charging range (*[TR2]* = 1) and max (*CellVoltage2..1*) is in the CVR1 range.

Table C-74. LT Chg Current 1

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
492	Charge Cfg	2	LT Chg Current 1	Integer	2	0	20,000	250	mA

C.4.4.3 LT Chg Current 2 (Offset 4)

The bq28400 sets *ChargingCurrent* to the ***LT Chg Current 2*** value when *Temperature* in the low temperature charging range (*[TR2]* = 1) and max (*CellVoltage2..1*) is in the CVR2 range.

Table C-75. LT Chg Current 2

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
492	Charge Cfg	4	LT Chg Current 2	Integer	2	0	20,000	250	mA

C.4.4.4 LT Chg Current 3 (Offset 6)

The bq28400 sets *ChargingCurrent* to the ***LT Chg Current 3*** value when *Temperature* in the low temperature charging range (*[TR2]* = 1) and max (*CellVoltage2..1*) is in the CVR3 range.

Table C-76. LT Chg Current 3

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
492	Charge Cfg	6	LT Chg Current 3	Integer	2	0	20,000	250	mA

C.4.4.5 ST1 Chg Voltage (Offset 8)

The bq28400 sets *ChargingVoltage* to the ***ST1 Chg Voltage*** value when *Temperature* is in the standard temperature charging range 1 (*[TR2A]* = 1).

Table C-77. ST1 Chg Voltage

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
492	Charge Cfg	8	ST1 Chg Voltage	Integer	2	0	20,000	8400	mV

C.4.4.6 ST1 Chg Current 1 (Offset 10)

The bq28400 sets *ChargingCurrent* to the ***ST1 Chg Current 1*** value when *Temperature* is in the standard temperature charging range 1 (*[TR2A]* = 1) and max (*CellVoltage2..1*) is in the CVR1 range.

Table C-78. ST1 Chg Current 1

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
492	Charge Cfg	10	ST1 Chg Current 1	Integer	2	0	20,000	4,000	mA

C.4.4.7 ST1 Chg Current 2 (Offset 12)

The bq28400 sets *ChargingCurrent* to the ***ST1 Chg Current 2*** value when *Temperature* is in the standard temperature charging range 1 (*[TR2A]* = 1) and max (*CellVoltage2..1*) is in the CVR2 range.

Table C-79. ST1 Chg Current 2

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
492	Charge Cfg	12	ST1 Chg Current 2	Integer	2	0	20,000	4,000	mA

C.4.4.8 ST1 Chg Current 3 (Offset 14)

The bq28400 sets *ChargingCurrent* to the ***ST1 Chg Current 3*** value when *Temperature* is in the standard temperature charging range 1 (*[TR2A]* = 1) and max (*CellVoltage2..1*) is in the CVR3 range.

Table C-80. ST1 Chg Current 3

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
492	Charge Cfg	14	ST1 Chg Current 3	Integer	2	0	20,000	4,000	mA

C.4.4.9 ST2 Chg Voltage (Offset 16)

The bq28400 sets *ChargingVoltage* to the ***ST2 Chg Voltage*** value when *Temperature* is in the standard temperature charging range 2 (*[TR3]* = 1).

Table C-81. ST2 Chg Voltage

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
492	Charge Cfg	16	ST2 Chg Voltage	Integer	2	0	20,000	8400	mV

C.4.4.10 ST2 Chg Current 1 (Offset 18)

The bq28400 sets *ChargingCurrent* to the ***ST2 Chg Current 1*** value when *Temperature* is in the standard temperature charging range 2 (*[TR3]* = 1) and max (*CellVoltage2..1*) is in the CVR1 range.

Table C-82. ST2 Chg Current 1

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
492	Charge Cfg	18	ST2 Chg Current 1	Integer	2	0	20,000	4,000	mA

C.4.4.11 ST2 Chg Current 2 (Offset 20)

The bq28400 sets *ChargingCurrent* to the ***ST2 Chg Current 2*** value when *Temperature* is in the standard temperature charging range 2 (*[TR3]* = 1) and max (*CellVoltage2..1*) is in the CVR2 range.

Table C-83. ST2 Chg Current 2

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
492	Charge Cfg	20	ST2 Chg Current 2	Integer	2	0	20,000	4,000	mA

C.4.4.12 ST2 Chg Current 3 (Offset 22)

The bq28400 sets *ChargingCurrent* to the ***ST2 Chg Current 3*** value when *Temperature* is in the standard temperature charging range 2 (*[TR3]* = 1) and max (*CellVoltage2..1*) is in the CVR3 range.

Table C-84. ST2 Chg Current 3

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
492	Charge Cfg	22	ST2 Chg Current 3	Integer	2	0	20,000	4,000	mA

C.4.4.13 HT Chg Voltage (Offset 24)

The bq28400 sets *ChargingVoltage* to the ***HT Chg Voltage*** value when *Temperature* is in the high temperature charging range (*[TR4]* = 1).

Table C-85. HT Chg Voltage

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
492	Charge Cfg	24	HT Chg Voltage	Integer	2	0	20,000	8380	mV

C.4.4.14 HT Chg Current 1 (Offset 26)

The bq28400 sets *ChargingCurrent* to the ***HT Chg Current 1*** value when *Temperature* is in the high temperature charging range (*[TR4]* = 1) and max (*CellVoltage2..1*) is in the CVR1 range.

Table C-86. HT Chg Current 1

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
492	Charge Cfg	26	HT Chg Current 1	Integer	2	0	20,000	3,800	mA

C.4.4.15 HT Chg Current 2 (Offset 28)

The bq28400 sets *ChargingCurrent* to the ***HT Chg Current 2*** value when *Temperature* is in the high temperature charging range (*[TR4]* = 1) and max (*CellVoltage2..1*) is in the CVR2 range.

Table C-87. HT Chg Current 2

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
492	Charge Cfg	28	HT Chg Current 2	Integer	2	0	20,000	3,800	mA

C.4.4.16 HT Chg Current 3 (Offset 30)

The bq28400 sets *ChargingCurrent* to the ***HT Chg Current 3*** value when *Temperature* is in the high temperature charging range (*[TR4]* = 1) and max (*CellVoltage2..1*) is in the CVR3 range.

Table C-88. HT Chg Current 3

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
492	Charge Cfg	30	HT Chg Current 3	Integer	2	0	20,000	3,800	mA

C.4.4.17 Cell Voltage Threshold 1 (Offset 32)

The bq28400 is in cell voltage range 1 (CVR1) when max(*CellVoltage2..1*) < ***Cell Voltage Threshold 1***.

Table C-89. Cell Voltage Threshold 1

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
492	Charge Cfg	32	Cell Voltage Threshold 1	Integer	2	0	5,000	3,900	mV

C.4.4.18 Cell Voltage Threshold 2 (Offset 34)

The bq28400 enters cell voltage range 2 (CVR2) when ***Cell Voltage Threshold 1*** < max(*CellVoltage2..1*) < ***Cell Voltage Threshold 2***. The bq28400 enters cell voltage range 3 (CVR3) when max(*CellVoltage2..1*) > ***Cell Voltage Threshold 2***.

Table C-90. Cell Voltage Threshold 2

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
492	Charge Cfg	34	Cell Voltage Threshold 2	Integer	2	0	5,000	4,000	mV

C.4.4.19 Cell Voltage Thresh Hys (Offset 36)

Cell Voltage Thresh Hys is used to make sure that transitions between cell voltage ranges are not affected by small transients. For example, if the current cell voltage range is CVR2 and cell voltage goes above ***Cell Voltage Threshold 2*** then CVR3 is entered. Cell voltage has to fall below ***Cell Voltage Threshold 2*** – ***Cell Voltage Thresh Hys*** for the bq28400 to go back to CVR2 range.

Table C-91. Cell Voltage Thresh Hys

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
492	Charge Cfg	36	Cell Voltage Thresh Hys	Integer	2	0	1,000	10	mV

C.4.5 Termination Cfg. (Subclass 530)

C.4.5.1 Taper Current (Offset 0)

If battery *Current* falls below ***Taper Current*** for two consecutive ***Current Taper Window*** time periods during charging and *Voltage* is equal to or higher than ***Charging Voltage*** – ***Taper Voltage*** the bq28400 recognizes valid primary charge termination.

Table C-92. Taper Current

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
530	Termination Cfg.	0	Taper Current	Unsigned Integer	2	0	1000	250	mA

C.4.5.2 Taper Voltage (Offset 4)

For valid primary charge termination, pack *Voltage* must be equal to or higher than ***Charging Voltage*** – ***Taper Voltage***.

Table C-93. Taper Voltage

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
530	Termination Cfg.	4	Taper Voltage	Unsigned Integer	2	0	1000	300	mV

C.4.5.3 Current Taper Window (Offset 6)

For a valid primary charge termination, *Current* must fall below ***Taper Current*** threshold for two consecutive ***Current Taper Window*** time periods.

Table C-94. Current Taper Window

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
530	Termination Cfg.	6	Current Taper Window	Unsigned Integer	1	0	240	40	s

C.4.6 Cell Balancing Cfg (Subclass 541)

C.4.6.1 Cell Balance Threshold (Offset 0)

This value sets the minimum voltage in mV that each cell must achieve to initiate cell balancing.

Table C-95. Cell Balance Threshold

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
541	Cell Balancing Cfg	0	Cell Balance Threshold	Integer	2	0	5000	3900	mV

C.4.6.2 Cell Balance Window (Offset 2)

This value sets in mV the amount that the cell balance threshold increases during cell balancing.

Table C-96. Cell Balance Window

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
541	Cell Balancing Cfg	2	Cell Balance Window	Integer	2	0	5000	100	mV

C.4.6.3 Cell Balance Min (Offset 4)

This value sets in mV the cell differential that must exist to initiate cell balancing.

Table C-97. Cell Balance Min

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
541	Cell Balancing Cfg	4	Cell Balance Min	Unsigned Integer	1	0	5000	40	mV

C.4.6.4 Cell Balance Interval (Offset 5)

This value sets the cell balancing time interval in seconds.

Table C-98. Cell Balance Interval

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
541	Cell Balancing Cfg	5	Cell Balance Interval	Unsigned Integer	1	0	240	20	s

C.4.7 Charging Faults (Subclass 547)

C.4.7.1 Over Charge Capacity (Offset 0)

The bq28400 goes into an overcharge fault and sets the *[OC]* flag in *ChargingStatus* if the internal counted remaining capacity exceeds *FullChargeCapacity* + ***Over Charge Capacity***. The CHG FET and ZVCHG FET (if used) are also turned of if the ***[OC]*** bit is set in ***Charge Fault Cfg***.

Table C-99. Over Charge Capacity

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
547	Charging Faults	0	Over Charge Capacity	unsigned integer	2	0	4000	300	mAh

C.4.7.2 Over Charge Recovery (Offset 2)

The bq28400 recovers from an overcharge in non-removable battery mode (***[NR]*** = 1) if it is continuously discharged by an amount of ***Over Charge Recovery*** charge.

Table C-100. Over Charge Recovery

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
547	Charging Faults	2	Over Charge Recovery	Unsigned Integer	2	0	100	2	mAh

C.4.7.3 FC-MTO (Offset 4)

If charge *Current* is equal to or greater than ***Chg Current Threshold*** for ***FC-MTO*** time period the bq28400 generates a fast charge mode time out fault and sets the *[FCMTO]* flag. The CHG FET and ZVCHG FET (if used) are also turned of if ***[FCMTO]*** is set in ***Charge Fault Cfg***. Set to 0 to disable ***FC-MTO***.

Table C-101. FC-MTO

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
547	Charging Faults	4	FC-MTO	Unsigned Integer	2	0	65535	10800	sec

C.4.7.4 PC-MTO (Offset 6)

If charge *Current* is equal to or greater than ***Chg Current Threshold*** for ***PC-MTO*** time period the bq28400 generates a precharge mode-time out error and sets the *[PCMTO]* flag. The CHG FET and ZVCHG FET (if used) are also turned of if ***[PCMTO]*** is set in ***Charge Fault Cfg***. Set to 0 to disable ***PC-MTO***.

Table C-102. PC-MTO

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
547	Charging Faults	6	PC-MTO	Unsigned Integer	2	0	65535	3600	s

C.4.7.5 Charge Fault Cfg (Offset 8)

This register sets the behavior of the charge, discharge, and precharge FETs in fault conditions.

Table C-103. Charge Fault Cfg

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
547	Charging Faults	8	Charge Fault Cfg	hex	1	0	0x3f	0x00	

7	6	5	4	3	2	1	0
RSVD	RSVD	PCMTO	FCMTO	RSVD	RSVD	OC	RSVD
R	R	R/W	R/W	R/W	R/W	R/W	R/W

LEGEND: R/W = Read/Write; R = Read only; – *n* = value after reset; RSVD = Reserved and **must** be programmed to 0.

Figure C-5. Charge Fault Cfg Register

PCMTO — If set, CHG FET and ZVCHG FET (if used as the precharge FET) are turned off when pre-charge time out fault occurs.

FCMTO — If set, CHG FET and ZVCHG FET (if used as the precharge FET) are turned off when fast charge time out fault occurs.

OC — If set, CHG FET and ZVCHG FET (if used as the precharge FET) are turned off when over charge fault occurs.

C.5 SBS Configuration

C.5.1 Data (Subclass 91)

C.5.1.1 Initial Battery Mode (Offset 0)

The default value of *DesignVoltage* is stored in ***Design Voltage*** and copied to the SBS value upon bq28400 initialization.

Table C-104. Initial Battery Mode

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
91	Data	0	Init Battery Mode	hex	2	0	0xffff	81	hex

C.5.1.2 Design Voltage (Offset 2)

The default value of *DesignVoltage* is stored in ***Design Voltage*** and copied to the SBS value upon bq28400 initialization.

Table C-105. Design Voltage

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
91	Data	2	Design Voltage	Unsigned Integer	2	7000	18000	7200	mV

C.5.1.3 Spec Info (Offset 4)

The default value of *SpecificationInfo* is stored in ***Spec Info*** and copied to the SBS value upon bq28400 initialization.

Table C-106. Spec Info

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
91	Data	4	Spec Info	hex	2	0x0000	0xffff	0x0031	hex

C.5.1.4 Manuf Date (Offset 6)

The default value of *ManufactureDate* is stored in ***Manuf Date*** and copied to the SBS value upon bq28400 initialization.

Table C-107. Manuf Date

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
91	Data	6	Manuf Date	Unsigned Integer	2	0	65535	0	Day + Mo*32 + (Yr –1980)*512

C.5.1.5 Ser. Num. (Offset 8)

The default value of *SerialNumber* is stored in ***Ser. Num.*** and copied to the SBS value upon bq28400 initialization.

Table C-108. Ser. Num.

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
91	Data	8	Ser. Num.	hex	2	0x0000	0xffff	0x0001	hex

C.5.1.6 Cycle Count (Offset 10)

The default value of *CycleCount* is stored in ***Cycle Count*** and copied to the SBS value upon bq28400 initialization. When the SBS value changes ***Cycle Count*** is also updated.

Table C-109. Cycle Count

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
91	Data	10	Cycle Count	Unsigned Integer	2	0	65535	0	Count

C.5.1.7 CC Threshold (Offset 12)

If the *[CCT]* bit is cleared the cycle count function counts the accumulated discharge of the ***CC Threshold*** value as one cycle.

Table C-110. CC Threshold

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
91	Data	12	CC Threshold	Signed Integer	2	100	32767	4400	mAh

C.5.1.8 Design Capacity (Offset 16)

If *[CapM]* in *BatteryMode* is set to 0, the *DesignCapacity* function reports ***Design Capacity***.

Table C-111. Design Capacity

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
91	Data	16	Design Energy	Unsigned Integer	2	0	65535	4400	mAh

C.5.1.9 Design Energy (Offset 18)

If *[CapM]* in *BatteryMode* is set to 1, the *DesignCapacity* function reports ***Design Energy***.

Table C-112. Design Energy

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
91	Data	18	Design Energy	Unsigned Integer	2	0	65535	4752	0.1 Wh

C.5.1.10 Full Charge Capacity(Offset 20)

This value is used as the *Full Charge Capacity* at device reset. This value is updated by the CEDV gauging algorithm when battery voltage reaches EDV2. Initialize this value to Design Capacity.

Table C-113. Full Charge Capacity

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
91	Data	20	Full Charge Capacity	Unsigned Integer	2	0	65535	4400	mAh

C.5.1.11 Manuf Name (Offset 24)

The *ManufacturerName* function returns a string stored in ***Manuf Name***. The maximum text length is 11 characters.

Table C-114. Manuf Name

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
91	Data	24	Manuf Name	String	11 + 1	—	—	Texas Inst.	ASCII

C.5.1.12 Device Name (Offset 36)

The *DeviceName* function returns a string stored in ***Device Name***. The maximum text length is seven characters.

Table C-115. Device Name

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
91	Data	36	Device Name	String	7 + 1	—	—	bq28400	ASCII

C.5.1.13 Device Chemistry (Offset 44)

The *DeviceChemistry* function returns a string stored in ***Device Chemistry***. The maximum text length is four characters.

Table C-116. Device Chemistry

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
91	Data	44	Device Chemistry	String	4+1	—	—	LION	ASCII

C.5.2 Configuration (Subclass 146)

C.5.2.1 Full Discharge Set % (Offset 2)

The FD Set % sets the FD flag in *BatteryStatus* if the ***RelativeStateOfCharge*** reaches or falls below the FD Set %. Set to –1 to disable this function.

Table C-117. FD Set %

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
146	Configuration	2	FD Set %	String	1	-1	100	0	%

C.5.3 Full Discharge Clear % (Offset 3)

This clears FD flag in *BatteryStatus* if the ***RelativeStateOfCharge*** reaches or rises above the FD Clear %. Set to –1 to disable this function.

Table C-118. FD Clear %

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
146	Configuration	3	FD Clear %	String	1	-1	100	20	%

C.6 System Data

C.6.1 Manufacturer Data (Subclass 76)

C.6.1.1 Firmware Revision (Offset 1)

The *ManufacturerData* function reports ***Hardware Version*** as part of its return value.

Table C-119. Firmware Revision

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
76	Manufacturer Data	1	Firmware Revision	hex	2	0x0000	0xffff	0x0000	

C.6.1.2 Hardware Revision (Offset 6)

The *ManufacturerData* function reports ***Hardware Version*** as part of its return value.

Table C-120. Hardware Revision

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
76	Manufacturer Data	3	Hardware Revision	hex	2	0x0000	0xffff	0x0000	

C.6.2 Manufacturer Info (Subclass 154)

C.6.2.1 Manuf. Info (Offset 0)

The *ManufacturerInfo* function returns the string stored in ***Manuf. Info***. The maximum text length is 31 characters.

Table C-121. Manuf. Info

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
154	Manufacturer Info	0	Manuf. Info	String	31 + 1	—	—	0123456789abcdef0123456789abcde	

C.6.3 Lifetime Data (Subclass 768)

C.6.3.1 Lifetime Max Temp (Offset 0)

If the *[LTPF]* flag is set ***Lifetime Max Temp*** value is updated if one of the following conditions are met:

- internal measurement temperature – ***Lifetime Max Temp*** > 1 °C.
- internal measurement temperature > ***Lifetime Max Temp*** for a period > 60 seconds
- internal measurement temperature > ***Lifetime Max Temp*** AND any other lifetime value is updated.

Table C-122. Lifetime Max Temp

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
768	Lifetime Data	0	Lifetime Max Temp	Signed Integer	2	0	1400	300	0.1°C

C.7 Configuration

C.7.1 Registers (Subclass 556)

C.7.1.1 Operation Cfg A (Offset 0)

This register enables, disables, or configures various features of the bq28400.

Table C-123. Operation Cfg A

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
556	Configuration	0	Operation Cfg A	hex	2	0x0000	0xffff	0x0128	

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
High Byte	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD
Low Byte	RSVD	RSVD	SLEEP	RSVD	TEMP0	RSVD	RSVD	RSVD

LEGEND: RSVD = Reserved and **must** be programmed to 0.

Figure C-6. Operation Cfg A

SLEEP — Enables the bq28400 to enter Sleep mode if the SMBus lines are low.

0 = The bq28400 never enters Sleep mode.
1 = The bq28400 enters Sleep mode under normal Sleep entry criteria (default).

TEMP0 — This bit configure the source of the *Temperature* function.

0 = Internal Temperature Sensor
1 = External TS Input (default)

C.7.1.2 Operation Cfg B(Offset 2)

This register enables, disables, or configures various features of the bq28400.

Table C-124. Operation Cfg B

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
556	Configuration	2	Operation Cfg B	hex	2	0x0000	0xffff	0x0040	

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
High Byte	RSVD	RSVD	RSVD	RSVD	NRCHG	RSVD	CHGTERM	RSVD
Low Byte	CHGSUSP	RSVD	CHGFET	CHGIN	NR	CPE	HPE	BCAST

LEGEND: RSVD = Reserved and **must** be programmed to 0.

Figure C-7. Operation Cfg B

NRCHG— This bit configures the CHG FET during sleep mode when used in non-removable battery mode.

0 (default) = CHG FET turns OFF in Sleep Mode if the [NR] bit is set.
1 = CHG FET remains ON in Sleep Mode if the [NR] bit is set.

CHGTERM — This bit configures the [TCA] and [FC] flags in BatteryStatus to be cleared after charge termination is detected.

0 (default) = [TCA] and [FC] are not cleared by primary charge termination confirmation, but are cleared by other means.
1 = [TCA] and [FC] are cleared by valid primary charge termination confirmation, but are cleared by other means. Note this does not disable clearing the flags by **TCA clear % and FC Clear %.**

CHGSUSP — This bit enables the device to turn off the CHG FET (and ZVCHG FET) when in charge suspend mode.

0 (default) = NO FET's change in Charge Suspend Mode.
1 = CHG and ZVCHG FET (if used) turn off in Charge Suspend Mode

CHGFET— This bit controls the CHG FET from reacting to a valid Charge termination.

0 (default) = CHG FET stays on at charge termination ([TCA] is set).
1 = CHG FET turns off at charge termination.

CHGIN— This bit configures the CHG FET and ZVCHG FET (if used) in charge inhibit mode.

0 (default) = No FET change in charge-inhibit mode
1 = CHG and ZVCHG FET (if used) turn off in charge-inhibit mode.

CPE— This bit enables or disables PEC transmission to smart-battery charger for master-mode alarm messages.

0 (default) = No PEC byte alarm warning to charger
1 = PEC byte on alarm warning to charger

HPE— This bit enables or disables PEC transmission to smart-battery host for master-mode alarm messages and prevents receiving communications from all sources in slave mode. If the host uses PEC this bit should be set.

0 (default) = No PEC byte alarm warning to host and receiving communications from all sources in slave mode
1 = PEC byte alarm warning to host and receiving communications from all sources in slave mode. If host uses PEC, this bit should be set

BCAST — This bit enables or disables SBS broadcasts to the smart-battery charger and host .

0 (default) = Broadcasts to host and charger disabled
1 = Broadcasts to host and charger enabled

C.7.1.3 Operation Cfg C (Offset 4)

This register enables, disables, or configures various features of the bq28400.

Table C-125. Operation Cfg C

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
556	Configuration	4	Operation Cfg C	hex	2	0x0000	0xffff	0x0040	

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
High Byte	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD
Low Byte	SMBError Reset	CUV_RECOV_CHG	RSVD	RSVD	EXT_CB_EN	SHUTV	PROD_LTPF_EN	RSOCL

LEGEND: RSVD = Reserved and **must** be programmed to 0.

Figure C-8. Operation Cfg C

SMBErrorReset — This bit resets the gas gauge.

0 (default) = Does NOT reset gas gauge.
1 = Resets gas gauge after 5 consecutive resets if SMBus does NOT respond.

CUV_RECOV_CHG — This bit configures the cell undervoltage recovery condition.

0 (default) = CUV recovery uses voltage criteria only.
1 = In addition to the voltage criteria, gas gauge must also be in charge mode for CUV recovery; see Section 2.4.11 for more information on gas gauge operating modes.

EX_CB_EN — This bit configures External Cell Balance Control.

0 = External Cell Balance Circuit Enabled (Active Low)
1 = Disable External Cell Balance circuit

SHUTV — This bit configures the voltage threshold used when entering Shutdown mode.

0 = Shutdown occurs when *Voltage* ≤ ***Shutdown Voltage*** AND *Current* ≤ 0 for a period greater than ***Shutdown Time***.
1 (default) = Shutdown occurs when Min (*CellVoltage2..1*) ≤ to ***Cell Shutdown Voltage*** and *Current* ≤ 0 for a period greater than ***Cell Shutdown Time***.

PROD_LTPF_EN — Production Lifetime Data and PF enable bit; this bit enables or disables Lifetime Data and permanent failures from occurring. This bit can be directly set by the LTPF Enable command (see MAC command 0x0021).

0 (default) = All Lifetime Data logging and PFs (except DFF) are prevented from occurring.
NOTE: If this bit is set to 0, and a Permanent Failure occurs, *PFStatus* reports that the failure has occurred. Also, if the FETs have been turned on, they will turn off if a failure occurs. However, data flash write access is still granted and the Permanent Failure is NOT logged in the PF Status section of data flash. The *PFStatus* indicator will clear and the FETs will turn back on once *ManufacturerAccess*(0x00) has received the *LTPF Enable* (0x0021) command or the *Reset* (0x0041) command, assuming the Permanent Failure condition no longer exists.
1 = All Lifetime Data logging and PFs are allowed.

RSOCL — This bit determines the method in which *RelativeStateOfCharge* and *RemainingCapacity* are updated to 100% when charging is complete.

0 (default) = If the ***[RSOCL]*** bit in ***Operation Cfg C*** is cleared then *RelativeStateofCharge* and *RemainingCapacity* are **not** held at 99% until primary charge termination occurs. Fractions of % greater than 99% are rounded up to display 100%.
1 = If the ***[RSOCL]*** bit in ***Operation Cfg C*** is set then *RelativeStateofCharge* and *RemainingCapacity* are held at 99% until primary charge termination occurs and only displays 100% upon entering primary charge termination.

C.7.1.4 Permanent Fail Cfg (Offset 6)

The ***Permanent Fail Cfg*** register enables or disables the use of the FUSE pin when the corresponding permanent fail error occurs. If the FUSE pin is driven high ***Fuse Flag*** is set to 0x3672.

Table C-126. Permanent Fail Cfg

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
556	Configuration	6	Permanent Fail Cfg	hex	2	0x0000	0xffff	0x0000	

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
High Byte	RSVD	XPFVSHUT	RSVD	XSOPT	XSOCD	XSOCC	XAFE_P	XAFE_C
Low Byte	XDFF	XDFETF	XCFETF	XCIM	XSOTD	XSOTC	XSOV	XPFIN

LEGEND: RSVD = Reserved and **must** be programmed to 0.

Figure C-9. Permanent Fail Cfg

XPFVSHUT — If this bit is set AND any permanent failure happens AND the bq28400 goes into shutdown the FUSE pin is driven high.

XSOPT — If this bit is set AND an open thermistor permanent failure occurs the FUSE pin is driven high.

XSOCD — If this bit is set AND a discharge safety overcurrent permanent failure occurs the FUSE pin is driven high.

XSOCC — If this bit is set AND a charge safety overcurrent failure occurs the FUSE pin is driven high.

XAFE_P — If this bit is set AND a periodic AFE-communications permanent failure occurs the FUSE pin is driven high.

XAFE_C — If this bit is set AND an AFE-communications permanent failure occurs the FUSE pin is driven high.

XDFF — If this bit is set AND a data flash fault permanent failure occurs the FUSE pin is driven high.

XDFETF — If this bit is set AND a DSG FET permanent failure occurs the FUSE pin is driven high.

XCFETF — If this bit is set AND a CHG FET permanent failure occurs the FUSE pin is driven high.

XCIM — If this bit is set AND a cell imbalance permanent failure occurs the FUSE pin is driven high.

XSOTD — If this bit is set AND a discharge overtemperature permanent failure occurs the FUSE pin is driven high.

XSOTC — If this bit is set AND a charge overtemperature permanent failure occurs the FUSE pin is driven high.

XSOV — If this bit is set AND a safety cell overvoltage permanent failure occurs the FUSE pin is driven high.

XPFIN — If this bit is set AND an external input indication permanent failure occurs the FUSE pin is driven high.

C.7.2 Manufacturing Status Flags (Offset 10)

This register enables, disables, or configures various features of the bq28400.

Table C-127. Manufacturing Status Flag

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
556	Configuration	10	Manufacturing Status	hex	2	0x0000	0xffff	8000	

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
High Byte	CAL_EN	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD
Low Byte	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD

LEGEND: RSVD = Reserved and **must** be programmed to 0.

Figure C-10. Manufacturing Status Flag

CAL_EN — Enables or Disables Calibration of the device

0 = Disables calibration
1 = Enables Calibration (default)

C.7.3 AFE (Subclass 65)

C.7.3.1 AFE State_Ctl (Offset 1)

This register adjusts the AFE hardware overcurrent and short circuit protection thresholds and delay.

Table C-128. AFE State_Ctl

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
65	AFE	1	AFE State_Ctl	hex	1	0x00	0xff	0x00	

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Low Byte	RSVD	RSVD	SDCDX2	RSNS	RSVD	RSVD	RSVD	RSVD

LEGEND: RSVD = Reserved and **must** be programmed to 0.

Figure C-11. AFE State_Ctl

SCDDX2 — Set this bit to double the SCD delay periods.

0 (default) = Short Circuit current protection delay is as programmed.
1 = Short Circuit current protection delay is twice that programmed.

RSNS — This bit, if set, configures the OCD, SCC, and SCD thresholds into a range suitable for a low sense resistor value by dividing the OCDV, SCCV, and SCDV selected voltage thresholds by 2.

0 (default) = Current protection voltage thresholds are as programmed.
1 = Current protection voltage thresholds are divided by 2 as programmed.

C.8 Power

C.8.1 Power (Subclass 577)

C.8.1.1 Flash Update OK Voltage (Offset 0)

This value sets the minimum allowed battery pack voltage for a flash update. If the battery pack *Voltage* is below this threshold no flash update will be made. However, if *PackVoltage* ≥ ***Flash Update OK Voltage*** then the flash can be updated.

Table C-129. Flash Update OK Voltage

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
577	Power	0	Flash Update OK Voltage	Unsigned Integer	2	6000	20000	3000	mV

C.8.1.2 Shutdown Voltage (Offset 2)

The bq28400 goes into shutdown mode if the battery pack *Voltage* is equal to or less than ***Shutdown Voltage*** for ***Shutdown Time*** and has been out of shutdown mode for at least ***Shutdown Time***.

Table C-130. Shutdown Voltage

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
577	Power	2	Shutdown Voltage	Unsigned Integer	2	5000	20000	4400	mV

C.8.1.3 Shutdown Time (Offset 4)

The bq28400 goes into shutdown mode if the battery pack *Voltage* is equal to or less than ***Shutdown Voltage*** for ***Shutdown Time*** and has been out of shutdown mode for at ***Shutdown Time***.

Table C-131. Shutdown Time

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
577	Power	4	Shutdown Time	Unsigned Integer	1	0	240	10	sec

C.8.1.4 Cell Shutdown Voltage (Offset 5)

The bq28400 goes into shutdown mode if Min (*CellVoltage2..1*) is equal to or less than ***Cell Shutdown Voltage*** for 10 s and has been out of shutdown mode for at least ***Cell Shutdown Time***.

Table C-132. Shutdown Voltage

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
577	Power	5	Cell Shutdown Voltage	Unsigned Integer	2	0	5000	2200	mV

C.8.1.5 Cell Shutdown Time (Offset 7)

The bq28400 goes into shutdown mode if Min (*CellVoltage2..1*) is equal to or less than ***Cell Shutdown Voltage*** for 10 s and has been out of shutdown mode for at least ***Cell Shutdown Time***.

Table C-133. Shutdown Time

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
577	Power	7	Cell Shutdown Time	Unsigned Integer	1	0	240	10	sec

C.8.1.6 Sleep Current Threshold (Offset 10)

The bq28400 is allowed to go into sleep mode if the charge or discharge current is below ***Sleep Current***. Sleep mode can be enabled with the ***[SLEEP]*** bit. If the absolute value of *Current* is above ***Sleep Current*** the bq28400 will return to normal mode.

Table C-134. Sleep Current

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
577	Power	10	Sleep Current	Unsigned Integer	2	0	100	10	mA

C.8.1.7 Sleep Voltage Time (Offset 17)

In sleep mode the Voltage and Temperature measurements will be taken at Sleep Voltage Time.

Table C-135. Sleep Voltage Time

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
577	Power	17	Sleep Current	Unsigned Integer	1	1	240	5	sec

C.8.1.8 Sleep Current Time (Offset 16)

In sleep mode the Current measurements will be taken at Sleep Current Time.

Table C-136. Sleep Current Time

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
577	Power	18	Sleep Current	Unsigned Integer	1	1	255	20	sec

C.8.1.9 Wake Current Reg (Offset 19)

Wake Current Reg configures the current threshold required to wake the bq28400 from sleep mode by detecting voltage across SRP and SRN.

Table C-137. Wake Current Reg

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
577	Power	19	Wake Current Reg	hex	1	0x00	0xff	0x00	hex

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Low Byte	RSVD	RSVD	RSVD	RSVD	RSVD	IWAKE	RSNS1	RSNS0

LEGEND: RSVD = Reserved and **must** be programmed to 0

Figure C-12. Wake Current Reg

IWAKE — This bit sets the current threshold for the Wake function.

0 = 0.5A (or if RSNS0=RSNS1=0 then this function is disabled)
1 = 1.0A (or if RSNS0=RSNS1=0 then this function is disabled)

Table C-138. Wake Current Reg

RSNS1	RSNS0	Resistance
0	0	Disabled (default)
0	1	2.5 mΩ
1	0	5 mΩ
1	1	10mΩ

C.9 Gas Gauging

C.9.1 CEDV Cfg (Subclass 426)

C.9.1.1 CEDV Config (Offset 0)

This register configures various features of the CEDV gauging.

Table C-139. CEDV Config

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
426	Gas Gauging	0	CEDV Config	hex	1	0x00	0x70	0x00	

	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
CEDV Config	0	RSVD	SC	CEDV	EDVV	RSVD	RSVD	RSVD

LEGEND: RSVD = Reserved and **must** be programmed to 0.

Figure C-13. CEDV Config

SC — This bit enables learning cycle optimization for a Smart Charger or independent charge.

0 (default) = Learning cycle is optimized for Smart Charger.
1 = Learning cycle is optimized for independent charger.

CEDV — This bit determines whether the bq28400 implements automatic EDV compensation to calculate the EDV0, EDV1, and EDV2 thresholds base on rate, temperature, and capacity. If the bit is cleared, the bq28400 uses the fixed values programmed in data flash for EDV0, EDV1, and EDV2. If the bit is set, the bq28400 calculates EDV0, EDV1, and EDV2.

0 (default) = EDV compensation is disabled.
1 = EDV compensation is enabled.

EDVV — This bit selects whether EDV termination is to be done with regard to voltage or the lowest single-cell voltage.

0 (default) = EDV conditions are determined on the basis of the lowest single-cell voltage.
1 = EDV conditions are determined on the basis of voltage.

C.9.1.2 EMF (Offset 1)

This value is the no-load cell voltage higher than the highest cell EDV threshold computed.

Table C-140. EMF

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
426	CEDV Cfg	1	EMF	Unsigned Integer	2	0	65535	3743	mV

C.9.1.3 EDV C0 Factor (Offset 3)

This value is the no-load, capacity related EDV adjustment factor.

Table C-141. C0

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
426	CEDV Cfg	3	C0	Unsigned Integer	2	0	65535	149	

C.9.1.4 EDV R0 Factor (Offset 5)

This value is the first order rate dependency factor, accounting for battery impedance adjustment.

Table C-142. R0

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
426	CEDV Cfg	5	R0	Unsigned Integer	2	0	65535	867	

C.9.1.5 EDV T0 Rate Factor (Offset 7)

This value adjusts the variation of impedance with battery temperature.

Table C-143. T0

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
426	CEDV Cfg	7	T0	Unsigned Integer	2	0	65535	4030	

C.9.1.6 EDV R1 Rate Factor (Offset 9)

This value adjusts the variation of impedance with battery capacity.

Table C-144. R1

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
426	CEDV Cfg	9	R1	Unsigned Integer	2	0	65535	316	

C.9.1.7 EDV TC Factor (Offset 11)

This value adjusts the variation of impedance for cold temperatures (T<23°C).

Table C-145. TC

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
426	CEDV Cfg	11	TC	Unsigned Integer	1	0	255	9	

C.9.1.8 EDV C1 Factor (Offset 12)

This value is the desired reserved battery capacity remaining at EDV0.

Table C-146. C1

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
426	CEDV Cfg	12	C1	Unsigned Integer	1	0	255	0	

C.9.1.9 EDV Age Factor (Offset 13)

This value allows the bq28400 to correct the EDV detection algorithm to compensate for cell aging.

Table C-147. Age Factor

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
426	CEDV Cfg	13	Age Factor	Unsigned Integer	1	0	255	0	

C.9.1.10 Fixed EDV0 (Offset 14)

This value is the EDV0 threshold if ***[CEDV]*** is clear in ***CEDV Config***.

Table C-148. Fixed EDV0

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
426	CEDV Cfg	14	Fixed EDV0	Unsigned Integer	2	0	65535	3031	mV

C.9.1.11 Fixed EDV1 (Offset 16)

This value is the EDV1 threshold if ***[CEDV]*** is clear in ***CEDV Config***.

Table C-149. Fixed EDV1

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
426	CEDV Cfg	16	Fixed EDV1	Unsigned Integer	2	0	65535	3385	mV

C.9.1.12 Fixed EDV2 (Offset 18)

This value is the EDV2 threshold if ***[CEDV]*** is clear in ***CEDV Config***.

Table C-150. Fixed EDV2

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
426	CEDV Cfg	18	Fixed EDV2	Unsigned Integer	2	0	65535	3501	mV

C.9.1.13 Low Temp (Offset 29)

This value specifies the minimum temperature above which a discharge must maintain to qualify for capacity learning.

Table C-151. Low Temp

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
426	CEDV Cfg	29	Low Temp	Unsigned Integer	1	0	255	119	0.1C

C.9.1.14 Overload Current (Offset 38)

This value sets the upper current range for EDV detection, beyond which EDV detection is halted.

Table C-152. Overload Current

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
426	CEDV Cfg	38	Overload Current	Unsigned Integer	2	0	65535	5000	mA

C.9.1.15 Self Discharge Rate (Offset 42)

This value is the estimated self-discharge rate of battery.

Table C-153. Self Discharge Rate

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
426	CEDV Cfg	42	Self Discharge Rate	Unsigned Integer	1	0	255	20	0.01%/day

C.9.1.16 Electronic Load (Offset 43)

This value should be set to a discharge rate determined by the battery electronics current consumption.

Table C-154. Electronic Load

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
426	CEDV Cfg	43	Overload Current	Unsigned Integer	1	0	255	0	3 µA

C.9.1.17 Battery Low % (Offset 44)

The value sets should correspond to the capacity value that reflects the highest voltage point.

Table C-155. Battery Low %

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
426	CEDV Cfg	44	Overload Current	Unsigned Integer	2	0	65535	4608	%/2.56

C.9.1.18 Near Full (Offset 46)

This value sets the start of discharge condition for qualified capacity learning.

Table C-156. Near Full

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
426	CEDV Cfg	46	Overload Current	Unsigned Integer	2	0	65535	200	mAh

C.9.2 Current Thresholds (Subclass 597)

C.9.2.1 Discharge Detection Threshold (Offset 0)

This device enters discharge mode from relaxation mode or charge mode if Current < (–) DSG Current Threshold.

Table C-157. Discharge Detection Threshold

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
597	Current Thresholds	0	Dsg Current Threshold	Integer	2	0	2000	200	mA

C.9.2.2 Charge Detection Threshold (Offset 2)

This device enters charge mode from relaxation mode or discharge mode if Current > Chg Current Threshold.

Table C-158. Charge Detection Threshold

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
597	Current Thresholds	2	Chg Current Threshold	Integer	2	0	2000	50	mA

C.9.2.3 Quit Current (Offset 4)

This device enters relaxation mode from charge mode if Current goes below Quit Current for Chg Relax Time. the device enters relaxation mode from discharge mode if Current goes above (–) Quit Current for Dsg Relax Time.

Table C-159. Quit Current

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
597	Current Thresholds	4	Quit Current	Integer	2	0	1000	10	mA

C.9.2.4 Discharge Relax Time (Offset 6)

This device enters relaxation mode from discharge mode if Current goes above (–) Quit Current for at least Dsg Relax Time.

Table C-160. Discharge Relax Time

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
597	Current Thresholds	6	Dsg Relax Time	Unsigned Integer	1	1	240	1	sec

C.9.2.5 Charge Relax Time

This device enters relaxation mode from charge mode if Current goes below Quit Current for at least Chg Relax Time.

Table C-161. Charge Relax Time

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
597	Current Thresholds	8	Chg Relax Time	Unsigned Integer	1	1	240	60	sec

C.9.3 State (Subclass 229)

C.9.3.1 Qmax Cell 0..1

These are the maximum values used for the capacity calculations for the chemical capacity.

Table C-162. Qmax State

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
229	State	0	Qmax Cell 0	Integer	2	0	4400	32767	mAh
229	State	2	Qmax Cell 1	Integer	2	0	4400	32767	mAh

C.9.4 Qmax Pack

This is maximum chemical capacity of the battery pack. Set the value to the smallest value of Qmax Cell 0 ...1. This information is used to calculate the initial remaining capacity of the pack upon a full reset.

Table C-163. Qmax Pack

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
229	State	4	Qmax Pack	Integer	2	0	4400	32767	mAh

C.10 PF Status

C.10.1 Device Status Data (Subclass 186)

C.10.1.1 PF Flags 1 (Offset 0)

The flags in the ***PF Flags 1*** register indicate the reason that the bq28400 has entered permanent failure. If the failure flag in ***PF Flags 1*** matches the bit in ***Permanent Fail Cfg*** the FUSE pin is driven high and the ***Fuse Flags*** is set to 0x3672. The FUSE pin can be used to blow an optional fuse in a severe failure condition to prevent more damage of the system.

All permanent failure flags in the failure sequence are stored in ***PF Flags 1***. Only the first permanent failure flag in a failure sequence is stored in ***PF Flags 2*** to indicate the cause of the permanent failure.

Table C-164. PF Flags 1

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
186	Device Status Data	0	PF Flags 1	hex	2	0x0000	0x8000	0x0000	

C.10.1.2 Fuse Flag (Offset 2)

The ***Fuse Flag*** is set to 0x3672 when a 2nd level protection failure occurs and the matching bit is set in the ***Permanent Fail Cfg*** register. The FUSE pin is driven high.

0x0000 = No Failure(default)
0x3672 = ***Permanent Fail Cfg*** flag matches ***PF Flags 1*** flag and FUSE pin is driven low.

Table C-165. Fuse Flag

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
186	Device Status Data	2	Fuse Flag	hex	2	0x0000	0xffff	0x0000	

C.10.1.3 PF Voltage (Offset 4)

When a permanent failure is detected *Voltage* is captured and stored into in ***PF Voltage***.

Table C-166. PF Voltage

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
186	Device Status Data	4	PF Voltage	Unsigned Integer	2	0	32767	0	mV

C.10.1.4 PF C1 Voltage (Offset 6)

When a permanent failure is detected *CellVoltage1* is captured and stored in ***PF C1 Voltage***.

Table C-167. PF C1 Voltage

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
186	Device Status Data	6	PF C1 Voltage	Unsigned Integer	2	0	9999	0	mV

C.10.1.5 PF C2 Voltage (Offset 8)

When a permanent failure is detected *CellVoltage2* is captured and stored in ***PF C2 Voltage***.

Table C-168. PF C2 Voltage

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
186	Device Status Data	8	PF C1 Voltage	Unsigned Integer	2	0	9999	0	mV

C.10.1.6 PF Current (Offset 10

When a permanent failure is detected the pack *Current* is captured and stored in ***PF Current***.

Table C-169. PF Current

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
186	Device Status Data	10	PF Current	Signed Integer	2	–32768	32767	0	mA

C.10.1.7 PF Temperature (Offset 12)

When a permanent failure is detected the pack *Temperature* is captured and stored in ***PF Temperature***.

Table C-170. PF Temperature

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
186	Device Status Data	12	PF Temperature	Signed Integer	2	–9999	9999	0	0.1 K

C.10.1.8 PF Batt Stat (Offset 14)

When a permanent failure is detected the *BatteryStatus* flags are captured and stored in ***PF Batt Stat***.

Table C-171. PF Batt Stat

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
186	Device Status Data	14	PF Batt Stat	Unsigned Integer	2	0x0000	0xffff	0x0000	

C.10.1.9 PF RC-mAh (Offset 16)

When a permanent failure is detected *RemainingCapacity,* in mAh, is captured and stored into in ***PF RC-mAh***.

Table C-172. PF RC-mAh

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
186	Device Status Data	16	PF RC-mAh	Unsigned Integer	2	0	32767	0	mAh

C.10.1.10 PF FCC(Offset 18)

When a permanent failure is detected FullChargeCapacity, in mAh, is captured and stored in ***PF FCC***.

Table C-173. PF FCC

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
186	Device Status Data	18	PF FCC	Unsigned Integer	2	0	32767	0	mAh

C.10.1.11 PF Chg Status (Offset 20)

When a permanent failure is detected the *ChargingStatus* flags are captured and stored in ***PF Chg Status***.

Table C-174. PF Chg Status

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
186	Device Status Data	20	PF Chg Status	hex	2	0x0000	0xffff	0x0000	

C.10.1.12 PF Safety Status (Offset 22)

When a permanent failure is detected, the *SafetyStatus* flags are captured and stored in ***PF Safety Status***.

Table C-175. PF Safety Status

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
186	Device Status Data	22	PF Safety Status	hex	2	0x0000	0xffff	0x0000	

C.10.1.13 PF Flags 2 (Offset 26)

On the first occurrence of a permanent failure, when PFStatus changes from 0x0000, the *PFStatus* flags will be captured and stored in this value. Only the first permanent failure flag in a failure sequence is stored in ***PF Flags 2*** to indicate the cause of the permanent failure. All permanent failure flags in the failure sequence are stored in ***PF Flags 1***.

Table C-176. PF Flags 2

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
186	Device Status Data	26	PF Flags 2	hex	2	0x0000	0x8000	0x0000	

C.10.2 AFE Regs (Subclass 218)

When the bq28400 detects a permanent failure a complete copy of the integrated AFE register values is stored ***AFE Regs***.

Table C-177. AFE Regs

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
218	AFE Regs	5	AFE Cell Select	hex	1	0x00	0xff	0x00	
		6	AFE OLV						
		7	AFE OLT						
		8	AFE SCC						
		9	AFE SCD						
		10	AFE Function						

C.11 Calibration

C.11.1 Voltage (Subclass 0)

C.11.1.1 Cell Scale 0 (Offset 0)

This register value stores the ADC voltage translation factor for the bottom cell (Cell 1), which is connected between the VC4 and VSS pins. By default, this value is not used and the factory calibration are ineffective. This value overrides the factory calibration when ***Delta Cell Scale 0*** is set to 0x9669 by the software voltage calibration process.

Table C-178. Cell Scale 0

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0	Voltage	0	Cell Scale 0	Signed Integer	2	0	32767	20500	

C.11.1.2 Cell Scale 1(Offset 2)

This register value stores the ADC voltage translation factor for Cell 2, which is connected between the VC3 and VC4 pins. By default, this value is not used and the factory calibration are ineffective. This value overrides the factory calibration when ***Delta Cell Scale 1*** is set to 0x9669 by the software voltage calibration process.

Table C-179. Cell Scale 1

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0	Voltage	2	Cell Scale 1	Signed Integer	2	0	32767	20500	

C.11.1.3 Pack Gain (Offset 8)

This register value stores the scale factor for the PackVoltage measured at the Pack pin.

Table C-180. Pack Gain

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0	Voltage	8	Pack Gain	Unsigned Integer	2	0	65535	44100	

C.11.1.4 BAT Gain (Offset 10)

This register value stores the scale factor for the BAT Voltage measured at the BAT pin.

Table C-181. BAT Gain

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
0	Voltage	10	BAT Gain	Unsigned Integer	2	0	65535	44100	

C.11.1.5 Current (Subclass 12)

C.11.1.5.1 CC Gain (Offset 0)

CC Gain sets the mA current scale factor for the coulomb counter. Use calibration routines to set this value.

Table C-182. CC Gain

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
12	Current	0	CC Gain	Floating	4	0.1	4	0.9419	

C.11.1.5.2 CC Delta (Offset 4)

CC Delta sets the mAh capacity scale factor for the coulomb counter. Use calibration routines to set this value.

Table C-183. CC Delta

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
12	Current	4	CC Delta	Floating	4	29826	1193046	280932	

C.11.1.6 Current Offset (Subclass 20)

C.11.1.6.1 Coulomb Counter Offset (Offset 0)

This register value stores the coulomb counter offset compensation. It is set by automatic calibration of the device. It is not recommended to change this value.

Table C-184. Coulomb Counter Offset

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
20	Current Offset	0	CC Offset	Signed Integer	2	–32767	32767	–7744	

C.11.1.7 Coulomb Counter Offset Samples (Offset 2)

This register value stores the AFE reference voltage in units of 50 µV.

Table C-185. Coulomb Counter Offset Samples

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
20	Current Offset	2	Coulomb Counter Offset Samples	Unsigned Integer	2	0	65535	64	

C.11.1.8 Board Offset (Offset 4)

This register value stores the compensation for the PCB dependant coulomb counter offset. It is recommended to use characterization data of the actual PCB to set this value.

Table C-186. Board Offset

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
20	Current Offset	4	Board Offset	Signed Integer	2	–32767	32767	0	

C.11.1.9 Temperature (Subclass 26)

C.11.1.9.1 Int Temp Offset (Offset 0)

This register value stores the internal temperature sensor offset compensation. Use calibration routines to set this value.

Table C-187. Int Temp Offset

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
26	Temperature	0	Int Temp Offset	Signed Integer	1	–128	127	0	0.1C

C.11.2 Ext Temp Offset (Offset 1)

This register value stores the external temperature sensor offset compensation. Use calibration routines to set this value.

Table C-188. Ext Temp Offset

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
26	Temperature	1	Ext Temp Offset	Signed Integer	1	–128	127	0	0.1C

C.11.3 Internal Temp Model (Subclass 31)

These values characterize the internal thermistor of the device. Do not modify these values without consulting TI.

Table C-189. Int Coef 1..4, Int Min AD, Int Max Temp

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
31	Temp Model	0	Int Coef 1	Signed Integer	2	–32768	32767	0	
		2	Int Coef 2					0	
		4	Int Coef 3					–11136	
		6	Int Coef 4					5754	
		8	Int Min AD					0	
		10	Int Max Temp					5754	0.1C

C.11.3.1 Ext Coef a1..a5, b1..b4, Ext rc0, Ext adc0 (Offset 0..20)

These values characterize the external thermistor connected to the TS pin of the device. The default values characterize the Semitec 103AT NTC thermistor. Do not modify these values without consulting TI.

Table C-190. Ext Coef a1..a5, b1..b4, Ext rc0, Ext adc0

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
43	Temp Model	0	Ext Coef a1	Signed Integer	2	–32768	32767	–11130	num
		2	Ext Coef a2					19142	
		4	Ext Coef a3					–19262	
		6	Ext Coef a4					28203	
		8	Ext Coef a5					892	
		10	Ext Coef b1					328	
		12	Ext Coef b2					–605	
		14	Ext Coef b3					–2443	
		16	Ext Coef b4					4696	
		18	Ext rc0					87	
		20	Ext adc0					17740	

C.11.3.2 Rpad, Rint (Offset 22, 24)

These values characterize the pad and the internal resistance of the bq28400. Do not modify these values without consulting TI.

Table C-191. Pad Resistance and Int Resistance

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
106	Temp Model	22	Rpad	Signed Integer	2	–32768	32767	87	num
		24	Rint					17740	

C.11.4 Current Deadband (Subclass 69)

C.11.4.1 Deadband (Offset 0)

Any current within ± ***Deadband*** will be reported as 0 mA by the *Current* function.

Table C-192. Deadband

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
69	Current Deadband	0	Deadband	Unsigned Integer	1	0	255	3	mA

C.11.4.2 CC Deadband (Offset 1)

This constant defines the deadband voltage for the measured voltage between the SR1 and SR2 pins used for capacity accumulation in units of 294 nV. Any voltages within ±***CC Deadband*** do not contribute to capacity accumulation.

Table C-193. CC Deadband

Subclass ID	Subclass Name	Offset	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
69	Current Deadband	1	CC Deadband	Unsigned Integer	1	0	255	34	294 nV

C.12 Data Flash Values

Table C-194. Data Flash Table

Class/Subclass	Name	Offset	Data Type	Min	Max	Default	Unit	Comments
1st Level Safety								
Subclass 653: Voltage	COV Threshold Low Temp	0	I2	3700	5000	4300	mV	
	COV Recovery Low Temp	2	I2	0	4400	4100	mV	
	COV Threshold Standard Temp	4	I2	3700	5000	4500	mV	
	COV Recovery Standard Temp	6	I2	0	4400	4300	mV	
	COV Threshold High Temp	8	I2	3700	5000	4200	mV	
	COV Recovery High Temp	10	I2	0	4400	4000	mV	
	CUV Threshold	13	I2	0	3500	2300	mV	
	CUV Recovery	16	I2	0	3600	3000	mV	
Subclass 671: Current	OC (1st Tier) Chg	0	I2	0	20000	6000	mA	
	OC (1st Tier) Chg Time	2	U1	0	240	2	sec	
	OC Chg Recovery	3	I2	–1000	1000	200	mA	
	OC (1st Tier) Dsg	5	I2	0	20000	6000	mA	
	OC (1st Tier) Dsg Time	7	U1	0	240	2	sec	
	OC Dsg Recovery	8	I2	0	1000	200	mA	
	Current Recovery Timer	10	U1	0	240	8	sec	
	AFE OC Dsg	11	H1	0	f	7	hex	
	AFE OC Dsg Time	12	H1	0	f	7	hex	
	AFE OC Dsg Recovery	13	I2	5	1000	5	mA	
	AFE SC Chg Cfg	15	H1	0	f7	73	hex	
	AFE SC Dsg Cfg	16	H1	0	f7	73	hex	
	AFE SC Recovery	17	I2	0	200	1	mA	
Subclass 690: Temp	OT Chg Threshold	0	I2	0	1200	550	0.1°C	
	OT Chg Delay	2	U1	0	240	2	sec	
	OT Chg Recovery	3	I2	0	1500	500	0.1°C	
	OT Dsg Threshold	5	I2	0	1200	600	0.1°C	
	OT Dsg Delay	7	U1	0	240	2	sec	
	OT Dsg Recovery	8	I2	0	1500	550	0.1°C	
2nd Level Safety								
SubClass 700: Voltage	LT SOV Threshold	0	I2	0	20000	4400	mV	
	ST SOV Threshold	2	I2	0	20000	4600	mV	
	HT SOV Threshold	4	I2	0	20000	4500	mV	
	SOV Time	6	U	0	240	0	sec	
	PF SOV Fuse Blow Delay	7	U	0	240	0	sec	
	Cell Imbalance Current	9	I1	0	200	5	mA	
	Cell Imbalance Fail Voltage	10	I2	0	5000	1000	mV	
	Cell Imbalance Time	12	U1	0	240	0	sec	
	Battery Rest Time	13	U2	0	65353	1800	sec	
	Min CIM-check Voltage	15	U2	0	65535	3000	mV	
	PFIN Detect Time	17	U1	0	240	0	sec	
Subclass 718: Current	SOT Charge	0	I2	0	30000	10000	mA	
	SOT Charge Time	2	U1	0	240	0	sec	
	SOT Discharge	3	I2	0	30000	10000	mA	
	SOT Charge Time	5	U1	0	240	0	sec	
Subclass 733: FET Verification	FET Fail Limit	0	I2	0	500	20	mA	
	FET Fail Time	2	U1	0	240	0	sec	
Subclass 733: AFE Verification	AFE Check Time	0	U1	0	255	0	sec	
	AFE Fail Limit	1	U1	0	255	10	number	
	AFE Fail Recovery Time	2	U1	0	255	20	sec	
	AFE Init Retry Limit	3	U1	0	255	6	number	
	AFE Init Limit	4	U1	0	255	20	counts	
Charge Control								

Table C-194. Data Flash Table (continued)

Class/Subclass	Name	Offset	Data Type	Min	Max	Default	Unit	Comments
Subclass 474: Chg Temp Cfg	JT1	0	I2	–400	1200	0	°C	
	JT2	2	I2	–400	1200	120	°C	
	JT2a	4	I2	–400	1200	300	°C	
	JT3	6	I2	–400	1200	450	°C	
	JT4	8	I2	–400	1200	550	°C	
	Temp Hys	10	I2	0	100	10	°C	
Subclass 486: Pre-Chg Cfg	Pre-Charge Current	0	I2	0	2000	250	mA	
	Pre-Charge Voltage	2	I2	0	20000	3000	mV	
	Recovery Voltage	4	I2	0	20000	3100	mV	
Subclass 492: Charge Cfg	LT Charge Voltage	0	I2	0	20000	6000	mV	
	LT Charge Current1	2	I2	0	20000	250	mA	
	LT Charge Current2	4	I2	0	20000	250	mA	
	LT Charge Current3	6	I2	0	20000	250	mA	
	ST1 Charge Voltage	8	I2	0	20000	8400	mV	
	ST1 Charge Current1	10	I2	0	20000	4000	mA	
	ST1 Charge Current2	12	I2	0	20000	4000	mA	
	ST1 Charge Current3	14	I2	0	20000	4000	mA	
	ST2 Charge Voltage	16	I2	0	20000	8400	mV	
	ST2 Charge Current1	18	I2	0	20000	4000	mA	
	ST2 Charge Current2	20	I2	0	20000	4000	mA	
	ST2 Charge Current3	22	I2	0	20000	4000	mA	
	HT Charge Voltage	24	I2	0	20000	8380	mV	
	HT Charge Current1	26	I2	0	20000	3800	mA	
	HT Charge Current2	28	I2	0	20000	3800	mA	
	HT Charge Current3	30	I2	0	20000	3800	mA	
	Cell Voltage Threshold1	32	I2	0	5000	3900	mV	
	Cell Voltage Threshold2	34	I2	0	5000	4000	mV	
	Cell Voltage Threshold Hys	36	I2	0	1000	10	mV	
Subclass 530: Termination Cfg	Taper Current	0	I2	0	1000	250	mA	
	Taper Voltage	4	I2	0	1000	300	mV	
	Current Taper Window	6	U1	0	240	40	sec	
Subclass 541: cell Balancing Cfg	Cell Balancing Threshold	0	I2	0	5000	3900	mV	
	Cell Balancing Window	2	I2	0	5000	100	mV	
	Cell Balancing Min	4	U1	0	5000	40	mV	
	Cell Balancing Interval	5	U1	0	240	20	s	
Subclass 547: Charging Faults	Maximum Over Charge Capacity	0	I2	0	4000	300	mAh	
	Over Charge Recovery	2	I2	0	100	2	mAh	
	FC-MTO (Fast Charge Mode Timeout)	4	U2	0	65535	10800	s	
	PC-MTO (Pre Charge Mode Timeout)	6	U2	0	65535	3600	s	
	Charge Fault Cfg	8	H1	0	FFFF	0	flags	**Bit 0: RSVD (Reserved)** **Bit 1: OC** If this bit is set the CHG FET and ZVCHG (if used as a precharge FET) are turned OFF when over charge fault occurs. **Bit 2, 3: RSVD (Reserved)** **Bit 4: FCMTO** If this bit is set the CHG FET and ZVCHG (if used as a precharge FET) are turned OFF when fast charge time out fault occurs. **Bit 5: PCMTO** If this bit is set the CHG FET and ZVCHG (if used as a precharge FET) are turned OFF when pre charge time out fault occurs. **Bit 7, 6: RSVD (Reserved)**
SBS Configuration								

Table C-194. Data Flash Table (continued)

Class/Subclass	Name	Offset	Data Type	Min	Max	Default	Unit	Comments
Subclass 91: Data	Init Battery Mode	0	H2	0	FFFF	81	Hex	
	Design Voltage	2	I2	7000	18000	10800	mV	
	Spec Info	4	H2	0	FFFF	31	Hex	
	Manufacture Date	6	U2	0	65535	0	Day + Mo*32 + (Yr–1980)*256	
	Ser. Num	8	H2	0	FFFF	1	Hex	
	Cycle Count	10	U2	0	65535	0	count	
	CC Threshold	12	I2	100	32767	4400	mAh	
	Design Capacity	16	I2	0	65535	4400	mAh	
	Design Energy	18	I2	0	65535	4752	0.1 Wh	
	Full Charge Capacity Value Used After Device Reset	20	I2	0	65535	4400	mAh	
	Manuf Name	24	S12			Texas Inst	ASCII	
	Device Name	36	S8			bq28400	ASCII	
	Device Chemistry	44	S5			LION	ASCII	
Subclass 146: Configuration	FD Set %	2	I1	-1	100	0	%	
	FD Clear %	3	I1	-1	100	20	%	
System Data								
Subclass 76: Manufacturer Data	Firmware Version	1	H2	0	FFFF	0		
	Hardware Version	3	H2	0	FFFF	0		
Subclass: Manufacturer Info	Manuf. Info		S32	0	FFFF	0123456789abcdef0123456789abcde		
Subclass: Lifetime Data	Lifetime Max Temp	0	I2	0	1400	300	0.1°C	
Configuration								
Subclass 556: Registers	Operation Cfg A	0	H2	0	FFFF	128		**Bit 0, 1, 2: RSVD (Reserved)** **Bit 3: TEMP0** Configuration for Temperature sensor function 1 = TS1 Temperature sensor input enabled **Bit 4: RSVD (Reserved)** **Bit 5: SLEEP** Sleep mode configuration based on SMBus activity 0 =Device never enters sleep mode 1 = Enters sleep mode under specified conditions (default) **Bit 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 : RSVD (Reserved)**

Table C-194. Data Flash Table (continued)

Class/Subclass	Name	Offset	Data Type	Min	Max	Default	Unit	Comments
	Operation Cfg B	2	H2	0	FFFF	0		**Bit 0: BCAST** Smart Charger Broadcast 0 =Broadcast to Host and Charger Disabled (default) 1 =Broadcast to Host and Charger Enabled **Bit 1: HPE** PEC Transmission to Smart Battery Host 0 = NO PEC byte on alarm to host and receiving communications from all sources in slave mode (default) 1 = PEC byte on alarm to host and receiving communications from all sources in slave mode. If host uses PEC this bit should be set. **Bit 2: CPE** Enable or Disable PEC Transmission to Smart Battery Host 0 = NO PEC byte on *AlarmWarning* to charger (default) 1 = PEC byte on *AlarmWarning* to charger **Bit 3: NR** Removable or Non-Removable Battery Mode 0 = Removable Battery Mode (default) 1 = Non-Removable Battery Mode **Bit 4: CGHIN** Enable or Disable CHG and ZVCHG FET in charge-inhibit mode 0 = No FET change in charge-inhibit mode (default) 1 = CHG and ZVCHG if used turns OFF in charge-inhibit mode **Bit 5: CHGFET** Enable or Disable CHG from reacting to a valid charge termination 0 = CHG FET stays ON at charge termination ([TCS] is set) (default) 1 = Charge FET turns OFF at charge termination **Bit 6: RSVD (Reserved)** **Bit 7: CHGSUSP** The bit enables the turn OFF the CHG FET (and ZVCHG FET) when in charge suspend mode 0 = No FETs change in Charge Suspend Mode (default) 1 = CHG FET and ZVCHG FET (if used) turn OFF in Charge Suspend Mode **Bit 8 RSVD (Reserved)** **Bit 9: CHGTERM** This bit Enables or Disables the [TCA] and [FC] flags in BatteryStatus to be cleared after charge termination is confirmed 0 = [TCA] and [FC] are NOT cleared by primary charge termination (default) 1 = [TCA] and [FC] are cleared by valid primary charge termination. This does NOT disable clearing the flags by TCA Clear % and FC Clear % **Bit 10: RSVD (Reserved)** **Bit 11: NRCHG** CHG FET status during sleep mode and in non-removable battery mode 0 = CHG FET turns OFF in sleep mode if [NR] bit is set (default). **Bit 12, 13, 14, 15: RSVD (Reserved)**

Table C-194. Data Flash Table (continued)

Class/Subclass	Name	Offset	Data Type	Min	Max	Default	Unit	Comments
	Operation Cfg C	4	H2	0	FFFF	40		**Bit 0: RSOCL** Relative State Of Charge and Remaining Capacity Updates 0 =Relative State Of Charge and Remaining Capacity are NOT held at 99% until primary charge termination occurs (default). 1=Relative State Of Charge and Remaining Capacity are held at 99% until primary charge termination occurs and only displays 100% upon entering primary charge termination. **Bit 1: PROD_LTPF_EN** Production Lifetime Data and PF enable bit 0 = All lifetime data logging and PFs are prevented from occurring (default). Note: If PF does occur, PF status will still report that the failure occurred. Also, if the FETs are turned ON, they will turn OFF if a failure occurs. However, data flash write access is still granted and the Permanent Failure is NOT logged in the PF Status selection of data flash. The PF Status indicator will clear and the FETs will turn on once Manufacturer Access (0x00) has received the LTPF Enable (0x00210 command or the Reset (0x0041) command if the Permanent Failure condition no longer exists. 1 = All lifetime data logging and PFs are allowed. **Bit 2: SHUTV** Voltage Threshold for entering shutdown mode 0 = Shutdown occurs when Voltage ≤ **Shutdown Voltage** AND Current ≤ 0 for a period greater than **Shutdown Time**. 1 = Shutdown occurs when Min cell voltage for 2 cell in series Voltage ≤ **Shutdown Voltage** AND Current ≤ 0 for a period greater than **Shutdown Time** (default). **Bit 3: EX_CB_EN** External Cell Balance Control 0 = External Cell Balance Circuit Enabled (Active low) 1 = Disable External Cell Balance circuit **Bit 4, 5: RSVD (Reserved)** **Bit 6: CUV_RECOV_CHG** Cell Under Voltage Recovery Condition 0 = CUV recovery uses voltage criteria only (default) 1 = In addition to the voltage mode criteria, gas gauge must also be in charge mode for CUV recovery. **Bit 7: SMBErrorReset** SMBus error, resets gas gauge 0 = Does NOT reset gas gauge (default) 1 = Resets gas gauge after 5 consecutive resets if SMBus does NOT respond **Bit 7, 8, 9, 10, 11, 12, 13, 14, 15: RSVD (Reserved)**

Table C-194. Data Flash Table (continued)

Class/Subclass	Name	Offset	Data Type	Min	Max	Default	Unit	Comments
	Permanent Failure Cfg		H2	0	FFFF	0		**Bit 0: XPFIN** External input indication of permanent failure if this bit is set AND an external indication of permanent failure occurs the FUSE pin is driven high. **Bit 1: XSCOV** Safety Cell Over Voltage Configuration if this bit is set AND a safety Over Voltage permanent failure occurs the FUSE pin is driven high. **Bit 2: XSOTC** Safety Charge Over Temperature Configuration if this bit is set AND a Charge Over Temperature permanent failure occurs the FUSE pin is driven high. **Bit 3: XSOTD** Safety Discharge Over Temperature Configuration if this bit is set AND a Discharge Over Temperature permanent failure occurs the FUSE pin is driven high. **Bit 4: XCIM** Cell Imbalance failure Configuration If this bit is set AND external indication of cell imbalance occurs the FUSE pin is driven high. **Bit 5: XCFETF** Charge FET failure Configuration If this bit is set AND a CHG FET permanent failure occurs causing the FUSE pin is driven high. **Bit 6: XDFETF** Discharge FET failure Configuration If this bit is set AND a DSG FET permanent failure occurs causing the FUSE pin is driven high. **Bit 7: XDFF** Data Flash failure Configuration If this bit is set AND a data flash permanent failure occurs causing the FUSE pin is driven high. **Bit 8: XAFE_C** AFE Communications failure Configuration If this bit is set AND an AFE Communications permanent failure occurs causing the FUSE pin is driven high. **Bit 9: XAFE_P** AFE Communications periodic failure Configuration If this bit is set AND a periodic AFE Communications permanent failure occurs causing the FUSE pin is driven high. **Bit 10: XSOCC** Charge State Over Current failure Configuration If this bit is set AND a Charge State Over Current permanent failure occurs the FUSE pin is driven high. **Bit 11: XSOCD** Discharge State Over Current failure Configuration If this bit is set AND a Discharge State Over Current permanent failure occurs the FUSE pin is driven high. **Bit 12: XSOPT** Open Thermistor failure Configuration If this bit is set AND an Open Thermistor permanent failure occurs the FUSE pin is driven high. **Bit 13: RSVD (Reserved)** **Bit 14: XPFVSHUT** Permanent Failure Indication and Configuration If this bit is set AND any permanent failure occurs AND a the device goes into shutdown the FUSE pin is driven high. **Bit 15: RSVD (Reserved)**
	Manufacturing Status Flags	10	H2	0	FFFF	1		**Bit 0 to 14: RSVD (Reserved)** **Bit 15: CAL_EN** If set allows calibration of the device

Table C-194. Data Flash Table (continued)

Class/Subclass	Name	Offset	Data Type	Min	Max	Default	Unit	Comments
Subclass 568: AFE	AFE State_CTL	1	H1	0	FFFF	0		**Bit 0, 1, 2, 3: RSVD (Reserved)** **Bit 4: RSNS** This bit if set configures the OCD, SCC and SCD thresholds into a range suitable for a low sense resistor value by dividing the OCDV, SCCV and SCDV selected voltage thresholds by 2. 0 = Current protection voltage thresholds as programmed (default) 1 = Current protection voltage thresholds divided by 2 as programmed **Bit 5: SDCDX2** This bit if set doubles the SCD delay periods 0 = Short Circuit Current protection delay is as programmed (default) 1 = Short Circuit Current protection delay is twice that programmed **Bit 6, 7: RSVD (Reserved)**
Power								
Subclass 577: Power	Flash Update OK Voltage	0	I2	6000	20000	7500	mV	
	Shutdown Voltage	2	I2	5000	20000	5250	mV	
	Shutdown Time	4	U1	0	240	10	s	
	Cell Shutdown Voltage	5	I2	0	5000	1750	mV	
	Cell Shutdown Time	7	U1	0	240	10	s	
	Sleep Current	10	I2	0	100	10	mA	
	Sleep Voltage Time for Temperature and Voltage Measurements	17	U1	1	240	5	s	
	Sleep Current Time Current Measurements	18	U1	1	255	20	s	
	Wake Current Register (Wake up from Sleep Mode)	19	H1	0	FF	0	number	
Gas Gauging								
Subclass 426: CEDV Cfg	CEDV Config	0	H1	0	FF	0		**Bit 0, 2: RSVD (Reserved)** **Bit 3: EDVV** This bit selects weather EDV termination is to be done with regard to voltage or the lowest single-cell voltage. 0 = EDV conditions determined on the basis of the lowest single-cell voltage (default) 1 = EDV conditions determined on the basis of Voltage **Bit 4: CEDV** This bit determines whether automatic EDV compensation to calculate EDV0, EDV1 and EDV2 thresholds based on rate, temperature and capacity. 0 = if this bit is cleared (0) the device uses fixed values programmed in data flash for EDV0, EDV1, EDV2 (default- EDV Compensation disabled). 1 = If bit is set (1) EDV Compensation is enabled. This bit if set doubles the SCD delay periods. 0 = Short Circuit Current protection delay is as programmed (default). **Bit 5: SC** This is a selection for learning cycle optimization for a Smart Charger or Independent Charger. 0 =Learning cycle optimized for Smart Charger(default) 1 = Learning cycle optimized for Independent Charge **Bit 6, 7: RSVD (Reserved)**
	EMF - No load Cell Voltage	1	U2	0	65535	3743	mV	
	EDV - C0	3	U2	0	65535	149		
	EDV - R0	5	U2	0	65535	867		
	EDV - T0	7	U2	0	65535	4030		
	EDV - R1	9	U2	0	65535	316		
	EDV - TC	11	U1	0	255	9		
	EDV - C1	12	U1	0	255	0		
	EDV - Age Factor	13	U1	0	255	0		
	Fixed EDV0	14	U2	0	65535	3031		
	Fixed EDV1	16	U2	0	65535	3385		

Table C-194. Data Flash Table (continued)

Class/Subclass	Name	Offset	Data Type	Min	Max	Default	Unit	Comments
	Fixed EDV2	18	U2	0	65535	3501		
	Low Temp	29	U1	0	255	119	0.1C	
	Overload Current	38	U2	0	65535	5000	mA	
	Self Discharge Rate	42	U1	0	255	20	0.01%/day	
	Electronics Load	43	U1	0	255	0	3 µA	
	Battery Low %	44	U2	0	65535	4608	%/2.56	
	Near Full	46	U2	0	65535	200	mAh	
Subclass: 597 Current Thresholds	Discharge Detection Threshold	0	I2	0	2000	100	mA	
	Charge Detection Threshold	2	I2	0	2000	50	mA	
	Quit Current	4	I2	0	1000	10	mA	
	Discharge Relax Time	6	U1	0	240	1	sec	
	Charge Relax Time	7	U1	0	240	60	sec	
Subclass: State	Qmax Cell 0	0	I2	0	32767	4400	mAh	
	Qmax Cell 1	2	I2	0	32767	4400	mAh	
	Qmax Pack	4	I2	0	32767	4400	mAh	
PF Status								
Subclass 186: Device State Data	PF Flags 1	0	H2	0	FFFF	0		**Bit 0: PFIN** 1 = External indication of permanent failure alert **Bit 1: SCOV** 1 = Safety Over-voltage permanent failure alert **Bit 2: SOTC** 1 = Charge Safety Over-temperature permanent failure alert **Bit 3: SOTD** 1 = Discharge Safety Over-temperature permanent failure alert **Bit 4: CIM** 1 = Cell-imbalance permanent failure alert **Bit 5: CFETF** 1 = Charge FET failure, permanent failure alert **Bit 6: DFETF** 1 = Discharge FET failure, permanent failure alert **Bit 7: DFF** 1 = Data flash fault, permanent failure alert **Bit 8: AFE_C** 1 = AFE Communications, permanent failure alert **Bit 9: AFE_P** 1 = Periodic AFE Communications, permanent failure alert **Bit 10: SOCC** 1 = Charge safety Overcurrent, permanent failure alert **Bit 11: SOCD** 1 = Discharge safety Overcurrent, permanent failure alert **Bit 12: SOPT** 1 = Open Thermistor, permanent failure alert **Bit 13: Reserved** **Bit 14: PFVSHUT** 1 = A permanent failure occurred and the device went into shutdown mode due to this failure **Bit 15: Reserved**
	Fuse Flag	2	H2	0	FFFF	0		
	PF Voltage	4	I2	0	32767	0	mV	
	PF C1 Voltage	6	I2	0	9999	0	mV	
	PF C2 Voltage	8	I2	0	9999	0	mV	
	PF Current	10	I2	–32768	32767	0	mA	
	PF Temperature	12	I2	–9999	9999	0	C	
	PF Batt Stat	14	H2	0	FFFF	0		
	PF RC-mAh	16	I2	0	32767	0	mAh	
	PF FCC	18	I2	0	65535	0	mAh	

Table C-194. Data Flash Table (continued)

Class/Subclass	Name	Offset	Data Type	Min	Max	Default	Unit	Comments
	PF Chg Status	20	H2	0	FFFF	0		**Bit 0: RSVD** **Bit 1: OC** 1 = Over-charge fault **Bit 2, 3: RSVD** **Bit 4: FCMTO** 1 = Fast-charge timeout fault **Bit 5: PCMTO** 1 = Pre-charge timeout fault **Bit 6: CB** 1 = Cell balancing in progress **Bit 7, 8: Reserved** **Bit 9: FCHG** 1 = Standard temperature charging 2 **Bit 10, 11, 12: RSVD** **Bit 13: PCHG** 1 = Precharge condition exists **Bit 14: CHGSUP** 1 = Charging suspended **Bit 15: XCHG** 1 = Charging disabled
	PF Safety Status	22	H2	0	FFFF	0		**Bit 0: SCD** 1 = Discharge short-circuit alert **Bit 1: SCC** 1 = Charge short-circuit alert **Bit 2: AOCD** 1 = AFE Discharge Overcurrent alert **Bit 3: WDF** 1 = AFE Watchdog alert **Bit 4: Reserved** **Bit 5: DFF data flash error** 1 = Permanent failure alert **Bit 6: COV** 1 = Cell Over voltage alert **Bit 7: CUV** 1 = Cell Under voltage alert **Bit 8: 11 Reserved** **Bit 12: OCC** 1 = Charge Overcurrent alert **Bit 13: OCD** 1 = Discharge Overcurrent alert **Bit 14: OTC** 1 = Charge Over-temperature alert **Bit 15: OTD** 1 = Discharge Over-temperature alert
	PF Flags 2	26	H2	0	FFFF	0		**Bit 0: PFIN** 1 = External indication of permanent failure **Bit 1: SCOV** 1 = Safety Over-voltage permanent failure **Bit 2: SOTC** 1 = Charge Safety Over-temperature permanent failure **Bit 3: SOTD** 1 = Discharge Safety Over-temperature permanent failure **Bit 4: CIM** 1 = Cell-imbalance permanent failure **Bit 5: CFETF** 1 = Charge FET failure, permanent failure **Bit 6: DFETF** 1 = Discharge FET failure, permanent failure **Bit 7: DFF** 1 = Data flash fault, permanent failure **Bit 8: AFE_C** 1 = AFE Communications, permanent failure **Bit 9: AFE_P** 1 = Periodic AFE Communications, permanent failure **Bit 10: SOCC** 1 = Charge safety Overcurrent, permanent failure **Bit 11: SOCD** 1 = Discharge safety Overcurrent, permanent failure **Bit 12: SOPT** 1 = Open Thermistor, permanent failure **Bit 13, 14, 15: Reserved**
Subclass 218: AFE Regs	AFE Cell Select 0	5	H1	0	FFFF	0		
	AFE Overload Threshold	6	H1	0	FFFF	0		
	AFE Overload Delay	7	H1	0	FFFF	0		
	AFE Short Circuit Charging	8	H1	0	FFFF	0		
	AFE Short Circuit Discharging	9	H1	0	FFFF	0		
	AFE Function Register	10	H1	0	FFFF	0		

Table C-194. Data Flash Table (continued)

Class/Subclass	Name	Offset	Data Type	Min	Max	Default	Unit	Comments
Calibration								
Subclass 0 Voltage	Cell 0 Scale (K-Factor)	0	I2	0	32767	20500		
	Cell 1 Scale (K-Factor)	2	I2	0	32767	20500		
	Pack Gain	8	U2	0	65535	44100		
	BAT Gain	10	U2	0	65535	44100		
Subclass 12:Current	CC Gain	0	F4	0.1	4	0.9419		Sets the mA current scale factor for the coulomb counter. Use calibration routine to set this up.
	CC Delta (Capacity Gain)	4	F4	29626	1193046	280932.6		Sets the mAh capacity scale factor for the coulomb counter. Use calibration routine to set this up.
Subclass 20: Current Offset	Coulomb Counter Offset	0	I2	–32768	32768	–7744		Stores the Coulomb Counter Offset compensation. Set during CC Offset calibration or by automatic calibration before device enters sleep mode.
	Coulomb Counter Offset Samples	2	U2	0	65535	64		
	Board Offset	4	I2	–32768	32768	0		Stores the compensation for the PCB dependent Coulomb Counter Offset. Use characterization data of the actual PCB used to set this value.
Subclass 26: Temperature	Internal Temperature Offset	0	I1	–128	127	0	0.1°C	Sets the internal temperature sensor offset compensation. Use calibration routine to set this value.
	External Temperature Offset	2	I1	–128	127	0	0.1°C	Sets the external temperature sensor offset compensation of TS1 input. Use calibration routine to set this value.
Subclass 31: Internal Temp Model	Internal Coefficient 1	0	I2	–32768	32767	0		These values characterize the internal thermistor of the device. Do NOT modify.
	Internal Coefficient 2	2	I2	–32768	32767	0		These values characterize the internal thermistor of the device. Do NOT modify.
	Internal Coefficient 3	4	I2	–32768	32767	–11136		These values characterize the internal thermistor of the device. Do NOT modify.
	Internal Coefficient 4	6	I2	–32768	32767	5754		These values characterize the internal thermistor of the device. Do NOT modify.
	Internal Minimum AD	8	I2	–32768	32767	0		
	Internal Maximum Temperature	10	I2	–32768	32767	5754	0.1°K	

Table C-194. Data Flash Table (continued)

Class/Subclass	Name	Offset	Data Type	Min	Max	Default	Unit	Comments
Subclass 43: External Temp Model	External Coefficient a1	0	I2	–32768	32767	–14520		These values characterize the external thermistor connected on TS1 pin of the device. Do NOT modify.
	External Coefficient a2	2	I2	–32768	32767	23696		These values characterize the external thermistor connected on TS1 pin of the device. Do NOT modify: These default values characterize Semitec 103AT NTC thermistor.
	External Coefficient a3	4	I2	–32768	32767	–20298		These values characterize the external thermistor connected on TS1 pin of the device. Do NOT modify: These default values characterize Semitec 103AT NTC thermistor.
	External Coefficient a4	6	I2	–32768	32767	28073		These values characterize the external thermistor connected on TS1 pin of the device. Do NOT modify.
	External Coefficient a5	8	I2	–32768	32767	865		These values characterize the external thermistor connected on TS1 pin of the device. Do NOT modify: These default values characterize Semitec 103AT NTC thermistor.
	External Coefficient b1	10	I2	–32768	32767	–694		These values characterize the external thermistor connected on TS1 pin of the device. Do NOT modify: These default values characterize Semitec 103AT NTC thermistor.
	External Coefficient b2	12	I2	–32768	32767	1326		These values characterize the external thermistor connected on TS1 pin of the device. Do NOT modify: These default values characterize Semitec 103AT NTC thermistor.
	External Coefficient b3	14	I2	–32768	32767	–3880		These values characterize the external thermistor connected on TS1 pin of the device. Do NOT modify: These default values characterize Semitec 103AT NTC thermistor.
	External Coefficient b4	16	I2	–32768	32767	5127		These values characterize the external thermistor connected on TS1 pin of the device. Do NOT modify: These default values characterize Semitec 103AT NTC thermistor.
	External rc0	18	I2	–32768	32767	11703		These values characterize the external thermistor connected on TS1 pin of the device. Do NOT modify: These default values characterize Semitec 103AT NTC thermistor.
	External adc0	20	I2	–32768	32767	11703		These values characterize the external thermistor connected on TS1 pin of the device. Do NOT modify these default values characterize Semitec 103AT NTC thermistor.
	Pad Resistance-Rpad	22	I2	–32768	32767	0		These values characterize the external thermistor connected on TS1 pin of the device. Do NOT modify: These default values characterize Semitec 103AT NTC thermistor.
	Internal Resistance-Rint	24	I2	–32768	32767	0		These values characterize the external thermistor connected on TS1 pin of the device. Do NOT modify: These default values characterize Semitec 103AT NTC thermistor.
Subclass 69: Current Deadband	Deadband	0	U1	0	255	3	mA	Any current within in the ± Deadband will be reported as 0 mA by the current function.
	Coulomb Counter Deadband	1	U1	0	255	34	294 nV	This represents the deadband voltage for the measured value between SRP and SRN pins used for capacity accumulation in units of 294 nV. Any voltage within ± CC deadband will NOT be considered for capacity accumulation.
	Filter	5	U1	0	255	239	mA	Defines the filter constant in Average Current Calculation

Glossary

ADC	Analog to Digital Converter
AFE	Analog Front End
alert	A warning set by the bq28400
bit	A single bit in a SBS command or data flash value that the user can change
CC	Coulomb Counter
CHG FET	Charge FET, connected to the CHG pin of the integrated AFE; used by the integrated AFE to enable or disable charging
COV	Cell Over Voltage
CPU	Central Processing Unit
CUV	Cell Under Voltage
DF	Data Flash
DSG	Flag set by the bq28400 to indicate charge (DSG = 0) or discharge (DSG = 1)
DSG FET	Discharge FET, connected to the DSG pin of the integrated AFE; used by the integrated AFE to enable or disable discharging.
FAS	Full Access Security
FC	Fully Charged
FCHG	Fast Charge
FCMTO	Fast Charge Timeout
FD	Fully Discharged
flag	A single bit in a SBS command or data flash value which is set by the bq28400 or the integrated AFE and indicates a status change.
IC	Integrated Circuit
Li-Ion	Lithium-Ion
NR	Non-Removable
OC	Overcurrent
OCA	Over Charge Alarm
OCV	Open Circuit Voltage
OTC	Over Temperature Charging
OTD	Over Temperature Discharging
PCHG	Pre-Charge
PCMTO	Pre-Charge Timeout
PEC	Packet Error Checking
PF	Permanent Fail
PRES	System Present Flag
Qmax	Maximum Chemical Capacity
RCA	Remaining Capacity Alarm
RSOC	Relative State of Charge
SBS	Smart Battery System
SCC	Short Circuit Charge

SCD	Short Circuit Discharge
SMBus	System Management Bus
SOC	Safety overcurrent
SOT	Safety Over Temperature
SS	Sealed mode flag
SYS_PRES	System present terminal
TCA	Terminate Charge Alarm
TDA	Terminate Discharge Alarm
Zero-volt charge	The action of charging a totally depleted battery, i.e. the battery cell's voltage is 0 V.
ZVCHG FET	Precharge FET, connected to the ZVCHG pin; it is used for pre-charging only in bq28400.
XDSG	Discharge Fault flag

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