bq27320

Technical Reference Manual

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Contents

Preface

This manual discusses the modules and peripherals of the bq27320 device, and how each is used to build a complete battery pack gas gauge solution. For further information, refer to the *bq27320 System-Side Fuel Gauge with Integrated LDO Data Sheet* (SLUSCG9).

Formatting conventions used in this document:

Information Type	Formatting Convention	Example
Commands	*Italics* with parentheses and no breaking spaces	*RemainingCapacity()* command
Data Flash	*Italics*, **bold**, and breaking spaces	***Design Capacity*** data
Register bits and flags	Brackets and *italics*	*[TDA]* bit
Data Flash bits	Brackets, *italics*, and **bold**	***[LED1]*** bit
Modes and states	ALL CAPITALS	UNSEALED mode

Related Documentation from Texas Instruments

To obtain a copy of any of the following TI documents, go to their TI Web links:

1. *bq27320 System-Side Gas Gauge with Integrated LDO Data Sheet* (SLUSCG9)
2. *Going to Production with the bq275xx Application Report* (SLUA449)
3. *Host System Calibration Method Application Report* (SLUA640)

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Definitions

A *Battery Glossary* is available at the Battery University on ti.com.

Glossary

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

General Description

The bq27320 gas gauge, using Compensated End-of-Discharge Voltage (CEDV) technology, accurately predicts the battery capacity and other operational characteristics of a single series, Li-based rechargeable cell. It can be interrogated by a system processor to provide cell information, such as time-to-empty (TTE), state-of-charge (SOC), and the SOC interrupt signal to the host.

Information is accessed through a series of commands, called *Standard Commands*. Further capabilities are provided by the additional *Extended Commands* set, both sets of commands, indicated by the general format *Command()*, read and write information contained within the device control and status registers, as well as its data flash locations. Commands are sent from system to gauge using the I^2C serial communications engine, and can be executed during application development, system manufacture, or end-equipment operation.

Cell information is stored in the device in non-volatile flash memory. Many of these data flash locations are accessible during application development. They cannot, in general, be accessed directly during end-equipment operation. Access to these locations is achieved by either using the companion evaluation software, through individual commands, or through a sequence of data-flash-access commands. To access a desired data flash location, the correct data flash address must be known.

The gas gauge measures charge and discharge activity by monitoring the voltage across a small-value series sense resistor (5 mΩ to 20 mΩ, typical) located between the system V_{SS} and the battery PACK– terminal. When a cell is attached to the device, information is based on cell current, cell open-circuit voltage (OCV), and cell voltage under loading conditions.

The external temperature sensing is optimized with the use of a high-accuracy negative temperature coefficient (NTC) thermistor with R25 = 10.0 kΩ ±1%. B25/85 = 3435 kΩ ± 1% (such as Semitec NTC 103AT). Alternatively, the gas gauge can also be configured to use its internal temperature sensor or receive temperature data from the host processor. When an external thermistor is used, a 18.2-kΩ pull-up resistor between BI/TOUT and TS pins is also required. The gas gauge uses temperature to monitor the battery-pack environment, which is used for gas gauging and cell protection functionality.

To minimize power consumption, the device has different power modes: NORMAL, SNOOZE, SLEEP, HIBERNATE, and BAT INSERT CHECK. The gas gauge passes automatically between these modes, depending upon the occurrence of specific events, though a system processor can initiate some of these modes directly. More details can be found in Section 4.6, *Power Modes*.

1.1 Gas Gauging

The bq27320 features the Compensated End of Discharge Voltage (CEDV) gauging algorithm, capable of gauging a maximum capacity of 32 Ah.

The operational overview in Figure 1-1 illustrates the gas gauge operation of the bq27320.

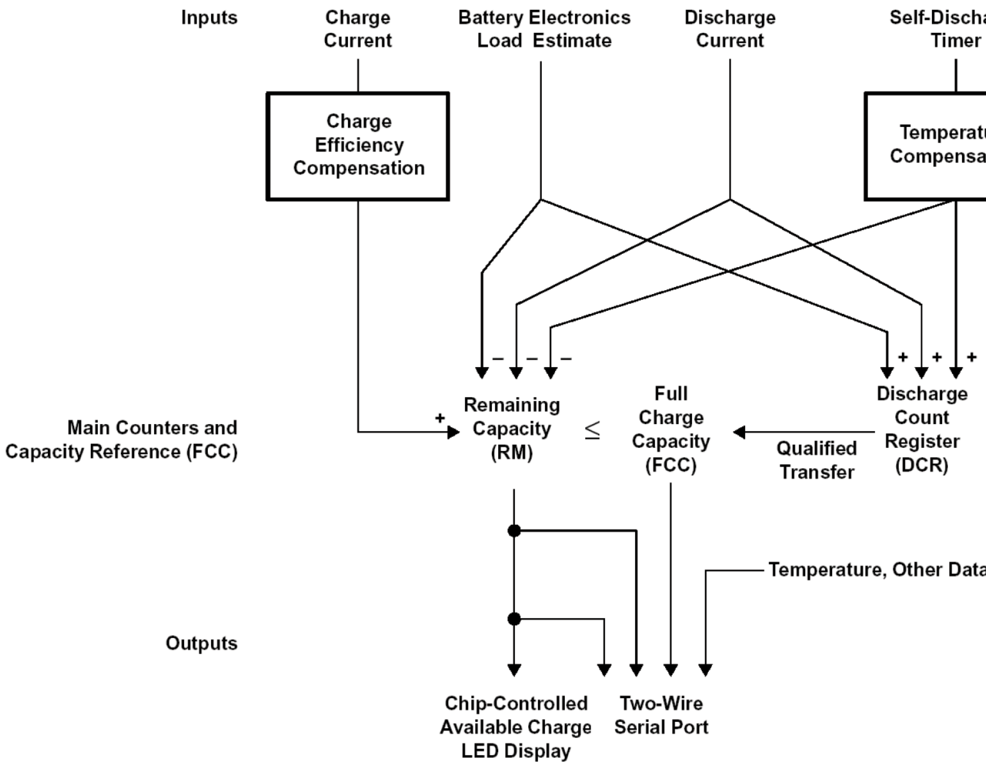


Figure 1-1. bq27320 Gas Gauging Operational Overview

1.1.1 CEDV Gas Gauging Operational Overview

The bq27320 accumulates the measured quantities of charge and discharge and estimates self-discharge of the battery. The bq27320 compensates the charge current measurement for temperature and state-of-charge of the battery. The bq27320 also adjusts the self-discharge estimation based on temperature. The initial battery state-of-charge estimation on first insertion of the battery pack in the system may display a factor of the true value; the system must go through a full charge and then a full discharge cycle before the correct FCC is estimated.

The main charge counter, *RemainingCapacity()* (RM), represents the available capacity or energy in the battery at any given time. The bq27320 adjusts RM for charge, self-discharge, and other compensation factors. The information in the RM register is accessible through the I^2C 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 bq27320 updates FCC after the battery undergoes a qualified discharge from nearly full to a low battery level. FCC is accessible through the I^2C interface.

The Discharge Count register (DCR) is an internal register that tracks discharge of the battery. The bq27320 uses the DCR to update the FCC register if the battery undergoes a qualified discharge from nearly full to a low battery level. In this way, the bq27320 learns the true discharge capacity of the battery under-system use conditions.

1.1.2 Main Gas Gauge Registers

Remaining Capacity (RM) — Remaining capacity in the battery

RM represents the remaining capacity in the battery. The bq27320 computes *RM* in units of mAh.

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 bq27320 calibrates RM at three low-battery-voltage thresholds, EDV2, EDV1, and EDV0. This provides a voltage-based calibration to the RM counter.

Design Capacity (DC) — User-specified battery full capacity

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

Full Charge Capacity (FCC) — Last measured discharge capacity of the battery

FCC is the last measured discharge capacity of the battery. It is represented in units of mAh. On initialization, the bq27320 sets *FullChargeCapacity()* to the data flash value stored in ***Learned Full Charge Capacity*** (*FCC*). During subsequent discharges, the bq27320 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 after a qualified discharge occurs. Once updated, the bq27320 writes the new *FullChargeCapacity()* value to data flash in mAh to ***Learned 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* counts up during discharge, independent of *RM*. The *DCR* counts discharge activity, battery load estimation, and self-discharge increment. The bq27320 initializes the *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 in ***CEDV Gauging Configuration*** and is not reduced if ***[SC]*** = 0. The *DCR* stops counting when the battery voltage reaches the EDV2 threshold on discharge.

1.1.3 Capacity Learning (FCC Update) and Qualified Discharge

The bq27320 updates *FCC* with an amount based on the value in the *DCR* if a qualified discharge occurs. The new value for *FCC* equals the *DCR* value plus the programmable ***Near Full*** and low battery levels, according to the following equation:

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

Where Battery_Low % = (***Battery Low %*** value in data flash) ÷ 100

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 bq27320 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 % × *FCC*.

The bq27320 sets *[VDQ]* = 1 in *OperationStatus()* when a qualified discharge begins. The bq27320 sets *[VDQ]* = 0 if any disqualifying condition occurs. One complication may arise regarding the state of *[VDQ]* if ***[CSYNC]*** is set in ***CEDV Gauging Configuration***. When ***[CSYNC]*** is enabled, *RemainingCapacity()* is written to equal *FullChargeCapacity()* on valid primary charge termination. 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. If ***[FCC_LIMIT]*** is set in ***CEDV Gauging Configuration*** then *FCC* cannot learn above the ***Design Capacity mAh***. The bq27320 saves the new *FCC* value to the data flash within 4 s of being updated.

1.1.4 End-of-Discharge Thresholds and Capacity Correction

The bq27320 monitors the battery for three low-voltage thresholds: EDV0, EDV1, and EDV2.

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

If the ***[EDV_CMP]*** bit in ***CEDV Gauging Configuration*** is set, automatic EDV compensation is enabled and the bq27320 computes the EDV0, EDV1, and EDV2 thresholds based on values stored in the selected CEDV profile in data flash and the battery's current discharge rate and temperature. If the ***[FIXED_EDV0]*** bit in ***CEDV Gauging Configuration*** is also set, then the EDV0 threshold will be set to the programmed ***Fixed EDV0,*** and the EDV1 and EDV2 compensated thresholds will not go below the programmed ***Fixed EDV0***.

The bq27320 disables EDV detection if Current exceeds the ***Overload Current*** threshold. The bq27320 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 bq27320 uses the EDV thresholds to apply voltage-based corrections to the RM register according to Table 1-1.

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

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

The bq27320 performs EDV-based RM adjustments with Current ≥ C/32. No EDVs are set if Current < C/32. The bq27320 adjusts RM as it detects each threshold. If the voltage threshold is reached before the corresponding capacity on discharge, the bq27320 reduces RM to the appropriate amount as shown in Table 1-1.

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.

1.1.5 EDV Discharge Rate and Temperature Compensation

If EDV compensation is enabled, the bq27320 calculates battery voltage to determine EDV0, EDV1, and EDV2 thresholds as a function of battery capacity, temperature, and discharge load. The general equation for EDV0, EDV1, and EDV2 calculation is as follows:

$$EDV0,1,2 = n\,(EMF \times FBL - |ILOAD| \times R0 \times FTZ) \quad (1)$$

- EMF is a no-load cell voltage higher than the highest cell EDV threshold computed. EMF is programmed in mV in the CEDV profile ***EMF***.
- I_{LOAD} is the current discharge load magnitude.
- n = the number of series cells. In the bq27320 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.

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

- 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 the CEDV profile ***C0***. C1 is the desired residual battery capacity remaining at EDV0 (RM = 0). The C1 factor is stored in the CEDV profile ***C1***.
- T is the current temperature in °K.
- R0•FTZ represents the resistance of a cell as a function of temperature and capacity.

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

- R0 is the first order rate dependency factor stored in the CEDV profile ***R0***.
- 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 the CEDV profile ***R1***.

- T0 adjusts the variation of impedance with battery temperature. T0 is programmed in the CEDV profile ***T0***.
- TC adjusts the variation of impedance for cold temperatures (T < 23°C). TC is programmed in the CEDV profile ***TC***.

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.

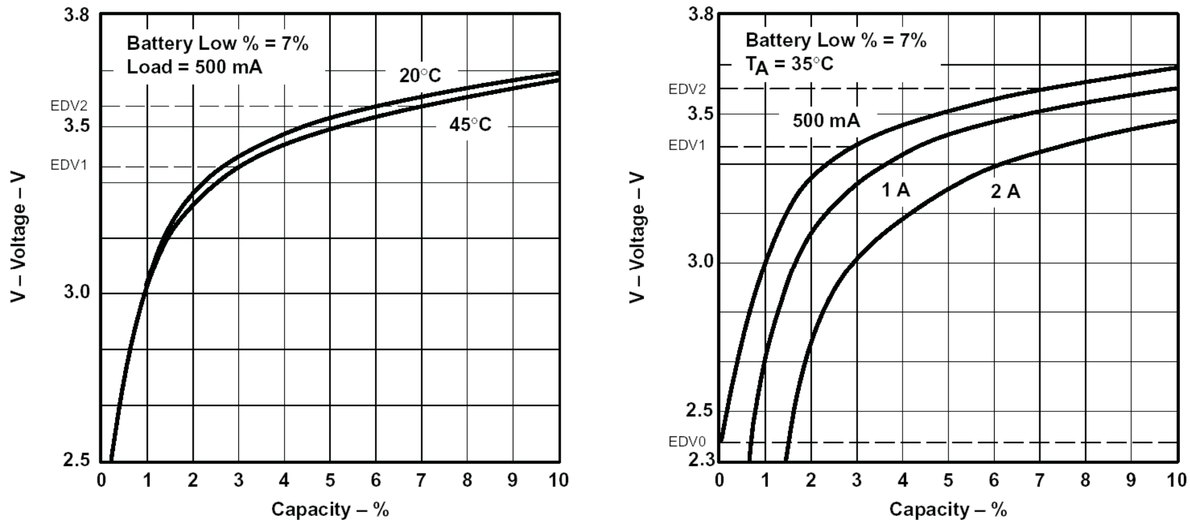


Figure 1-2. (a) EDV Calculations vs Capacity for Various Temperatures, (b) EDV Calculations vs Capacity for Various Loads

The CEDV parameters shown above can be generated using TI's online tool Gauging Parameter Calculator for CEDV gauges (GPCCEDV). In addition to seven CEDV parameters, an 11-point loaded voltage table is generated, which the gauge uses to estimate capacity at initialization. More information can be found in the *bq27320EVM-766 Evaluation Module User's Guide* (SLUUBE5).

1.1.6 EDV Age Factor

The EDV ***Age Factor*** allows the bq27320 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.

1.1.7 Self-Discharge

The bq27320 estimates the self-discharge of the battery to maintain an accurate measure of the battery capacity during periods of inactivity. The bq27320 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. *Self-Discharge* shows the relation of the self-discharge estimation at a given temperature to the rate programmed for 25°C.

Table 1-2. 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

1.1.8 Battery Electronic Load Compensation

The bq27320 can be configured to compensate for a constant load (as from battery electronics) present in the battery pack at all times. The bq27320 applies the compensation continuously when the charge or discharge is below the digital filter. The bq27320 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

1.1.9 CEDV Configuration

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

Table 1-3. CEDV Gauging Configuration Register

Feature	Description
FCC_LIMIT	The FCC_LIMIT bit selects whether FCC limit can go above ***Design Capacity mAh***. 0 = FCC can learn above ***Design Capacity mAh***. 1 = FCC is limited to ***Design Capacity mAh***.
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.
EDV_CMP	The EDV_CMP bit determines whether the bq27320 implements automatic EDV compensation to calculate the EDV0, EDV1, and EDV2 thresholds based on rate, temperature, and capacity. If the bit is cleared, the bq27320 uses the fixed values programmed in data flash for EDV0, EDV1, and EDV2. If the bit is set, the bq27320 calculates EDV0, EDV1, and EDV2. 0 = EDV compensation is disabled. 1 = EDV compensation is enabled.
FIXED_EDV0	The FIXED_EDV0 bit selects whether EDV0 is always fixed. 0 = EDV0 is determined based on the ***[EDV_CMP]*** bit. 1 = EDV0 will always use ***Fixed EDV0***. EDV1 and EDV2 compensation will not go below ***Fixed EDV0***.
CSYNC	The CSYNC bit selects whether RM is set to FCC at charge termination. 0 = RM is not changed when charge termination is reached. 1 = RM will be set to FCC when charge termination is reached.

1.1.10 Initial Battery Capacity at Device Reset

The bq27320 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 ***Learned Full Charge Capacity***. The initial RM and RSOC are estimated using the open-circuit voltage (OCV) characteristics of the programmed Li-Ion chemistry and ***DOD at EDV2***. 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, ***Learned Full Charge Capacity***, and ***DOD at EDV2*** will be learned and updated.

The data flash ***Learned Full Charge Capacity*** and ***DOD at EDV2***, as well as the CEDV profile parameters are stored separately for each of the four selectable battery profiles. However, there is only a single OCV lookup table. The OCV table should be selected based on a best fit for all cell profiles.

The data flash parameter ***Learned Full Charge Capacity*** should be initialized to the ***Design Capacity mAh***. ***DOD at EDV2*** should be initialized to (1 – Battery_Low%) × 16384, where Battery_Low% = ***Battery Low %*** ÷ 100.

1.1.11 Gas Gauge Operating Modes

Entry and exit of each mode is controlled by data flash parameters in the ***Current Thresholds*** subclass. The *[DSG]* flag referenced below is from the MAC *GaugingStatus()* subcommand and is set in both RELAX and DISCHARGING modes. The *[DSG]* flag in *BatteryStatus()* is slightly different—it sets only in DISCHARGING mode and not in RELAX mode.

CHARGE mode is exited and RELAX mode is entered when *Current()* goes below ***Quit Current*** for a period of ***Chg Relax Time***. DISCHARGE mode is entered when *Current()* goes below ***(–)Dsg Current Threshold***. DISCHARGE mode is exited and RELAX mode is entered when *Current()* goes above ***(–)Quit Current*** threshold for a period of ***Dsg Relax Time***. CHARGE mode is entered when *Current()* goes above ***Chg Current Threshold***.

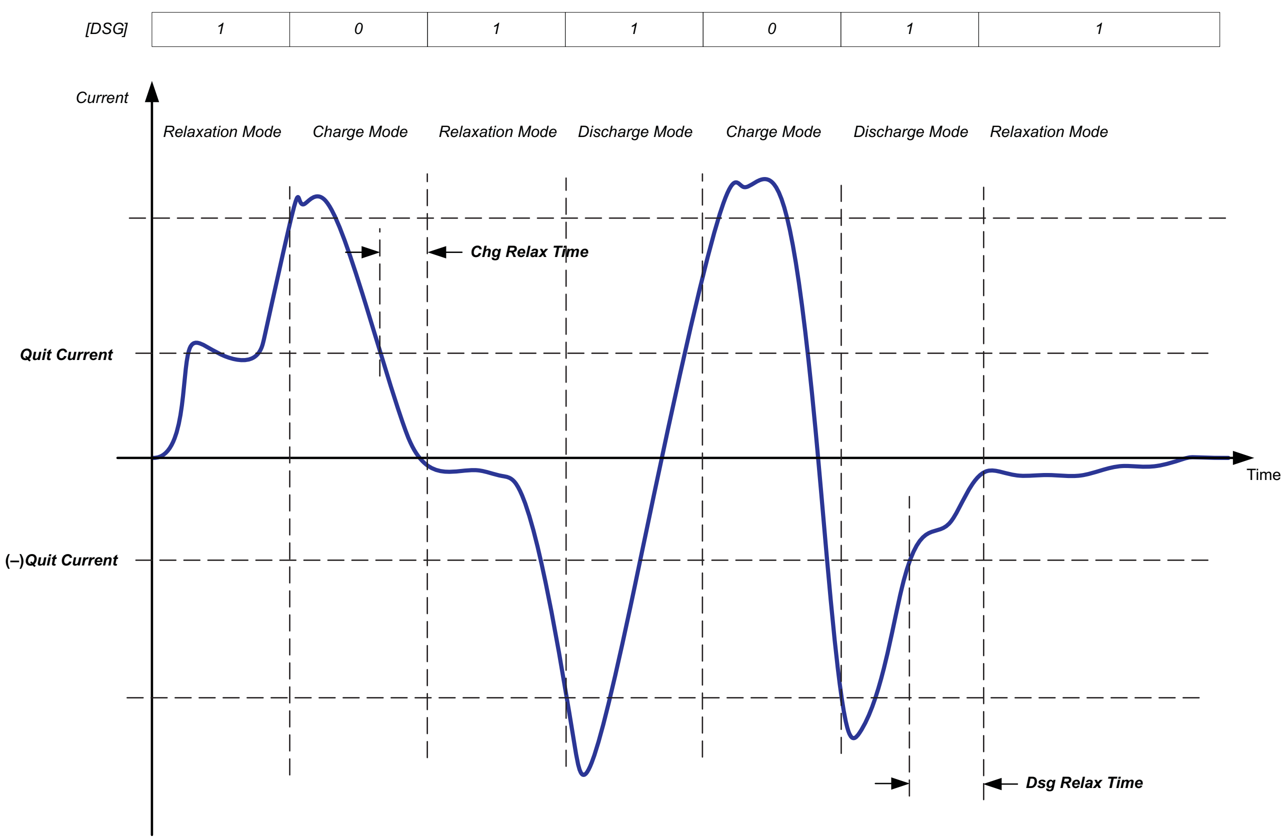


Figure 1-3. Gas Gauge Operating Mode Example

1.1.12 CEDV Smoothing

The bq27320 device has the ability to smooth the *RemainingCapacity()* during discharge in order to avoid a drop in *RelativeStateOfCharge()* when the EDV thresholds are reached. This feature is enabled by setting the ***Smoothing Config [SMEN]*** = 1 and configuring the ***Smoothing Start Voltage*** and ***Smoothing Delta Voltage***.

The smoothing will activate only when all of the following conditions are true:

- *Current()* < 0
- *Voltage()* < ***Smoothing Start Voltage***
- EDV2 has been reached (*[EDV2]* = 1) OR (*Voltage()* – present EDV2 threshold) < ***Smoothing Delta Voltage***.
- Maximum *Voltage()* during the previous one minute is less than the maximum *Voltage()* during the current minute (that is, "drop rate" is greater than 0).
- *RemainingCapacity()* is greater than the capacity at the next EDV point.

While smoothing is active, the "drop rate" is used to estimate the time to the EDV point under the assumption that the rate is constant (linear). This information is then used to estimate how much current would need to be applied in order to have *RemainingCapacity()* reach the expected capacity at the EDV point. The actual *Current()* is then scaled by the "smoothing current." This will either speed up or slow down the *RemainingCapacity()* accumulation to reach the EDV threshold at the correct time.

Whenever the *RemainingCapacity()* accumulation is actively scaled, the *OperationStatus()[SMTH]* bit will be set.

Smoothing deactivates whenever an EDV threshold is reached until the rate to the next EDV threshold can be calculated. However, smoothing past the EDV2 point only occurs if the ***Smoothing Config [SMEXT]*** is set to 1.

To improve smoothing at the end of discharge, the ***CEDV Gauging Configuration[SME0]*** bit provides additional flexibility. This is particularly useful when ***FIXED_EDV0*** is set and the calculated EDV2/EDV1 is lower than EDV0. In this scenario, the SOC smooths to EDV2, then to EDV1, and then to EDV0, leading to SOC jumps. If the ***SME0*** bit is set, then the SOC smooths directly to EDV0, leading to a smooth transition to empty.

Table 1-4 shows the available smoothing configurations.

Table 1-4. Smoothing Configurations

SMEN	SMEXT	SME0	Description
0	0	0	No Smoothing
0	0	1	No Smoothing
0	1	0	No Smoothing
0	1	1	No Smoothing
1	0	0	Smoothing to EDV2
1	0	1	Smoothing to EDV0 if calculated EDV2/EDV1 is less than EDV0.
1	1	0	Smoothing to EDV2 ≥ EDV1 ≥ EDV0
1	1	1	Smoothing to EDV0 if calculated EDV2/EDV1 is less than EDV0.

The bq27320 device can also add smoothing during charging. In situations when the FCC is not updated during a discharge cycle or on a subsequent charge cycle, if the valid charge termination is reached, RSOC is synced to 100% regardless of the true RSOC. To help in scenarios like these, the device enables the ***SMOOTHEOC_EN*** bit (default is enabled).

When enabled, the RSOC value is gradually increased to 100% instead of a sudden jump if the following is true:

a. Battery is charging.
b. Cell Voltage > Taper Voltage
c. Charge Current is decreasing AND is below the ***EOC Smooth Current*** threshold for ***EOC Smooth Current Time.***

Standard Data Commands

The bq27320 gas gauge uses a series of 2-byte standard commands to enable system reading and writing of battery information. Each standard command has an associated command-code pair, as indicated in Table 2-1. Because each command consists of two bytes of data, two consecutive I^2C transmissions must be executed both to initiate the command function and to read or write the corresponding two bytes of data. Additional options for transferring data are described in Table 2-2, *Control()* commands. Read and write permissions depend on the active access mode, SEALED or UNSEALED. For details, see Section 3.3, *Device Access Modes*. See Chapter 5, *Communications*, for I^2C details.

Table 2-1. Standard Commands

NAME		COMMAND CODE	UNIT	SEALED ACCESS
Control()/CONTROL_STATUS()	CNTL	0x00 and 0x01	NA	RW
AtRate()	AR	0x02 and 0x03	mA	RW
AtRateTimeToEmpty()	ARTTE	0x04 and 0x05	Minutes	R
Temperature()	TEMP	0x06 and 0x07	0.1°K	RW
Voltage()	VOLT	0x08 and 0x09	mV	R
BatteryStatus()	*Flags()*	0x0A and 0x0B	NA	R
Current()	*Current()*	0x0C and 0x0D	mAh	R
RemainingCapacity()	RM	0x10 and 0x11	mAh	R
FullChargeCapacity()	FCC	0x12 and 0x13	mAh	R
AverageCurrent()	AI	0x14 and 0x15	mA	R
TimeToEmpty()	TTE	0x16 and 0x17	Minutes	R
TimeToFull()	TTF	0x18 and 0x19	Minutes	R
StandbyCurrent()	SI	0x1A and 0x1B	mA	R
StandbyTimeToEmpty()	STTE	0x1C and 0x1D	Minutes	R
MaxLoadCurrent()	MLI	0x1E and 0x1F	mA	R
MaxLoadTimeToEmpty()	MLTTE	0x20 and 0x21	min	R
RawCoulombCount()	RCC	0x22 and 0x23	mAh	R
AveragePower()	AP	0x24 and 0x25	mW	R
InternalTemperature()	INTTEMP	0x28 and 0x29	0.1°K	R
CycleCount()	CC	0x2A and 0x2B	num	R
StateOfCharge()	SOC	0x2C and 0x2D	%	R
StateOfHealth()	SOH	0x2E and 0x2F	%/num	R
ChargeVoltage()	CV	0x30 and 0x31	mV	R
ChargeCurrent()	CC	0x32 and 0x33	mA	R
BTPDischargeSet()		0x34 and 0x35	mAh	R
BTPChargeSet()		0x36 and 0x37	mAh	R
OperationStatus()		0x3A and 0x3B	NA	R
DesignCapacity()	Design Cap	0x3C and 0x3D	mAh	R
ManufacturerAccessControl()	MAC	0x3E and 0x3F		
MACData()		0x40 through 0x5F		
MACDataSum()		0x60		

Table 2-1. Standard Commands (continued)

NAME		COMMAND CODE	UNIT	SEALED ACCESS
MACDataLen()		0x61		
AnalogCount()		0x79		
RawCurrent()		0x7A and 0x7B		
RawVoltage()		0x7C and 0x7D		
RawIntTemp()		0x7E and 0x7F		
RawExtTemp()		0x80 and 0x81		

2.1 Control()/CONTROL_STATUS(): 0x00 and 0x01

Issuing a *Control()* (Manufacturer Access Control or MAC) command requires a 2-byte subcommand. The subcommand specifies the particular MAC function desired. The *Control()* command allows the system to control specific features of the gas gauge during normal operation and additional features when the device is in different access modes, as described in Table 2-2. On this device, *Control()* commands may also be sent to *ManufacturerAccessControl()*. Any subcommand that has a data response will be read back on *MACData()*.

Reading the *Control()* registers will always report the *CONTROL_STATUS()* data field except after the *DEVICE_TYPE()* and *FW_VERSION()* subcommands. After these subcommands, *CONTROL_STATUS()* will report the value 0xFFA5 one time before reverting to the normal data response. This is a flag to indicate that the data response has been moved to *MACData()*. Writing a 0x0000 to *Control()* is no longer necessary to read the *CONTROL_STATUS()*; however, doing so is harmless.

When executing commands that require data (such as data flash writes), the subcommand can be written to either *Control()* or *ManufacturerAccessControl()* registers; however, it is recommended to write using the *ManufacturerAccessControl()* registers as this allows performing the full command in a single I^2C transaction.

Table 2-2. *Control()* MAC Subcommands

CNTL/MAC FUNCTION	SUBCOMMAND CODE	SEALED ACCESS?	DESCRIPTION
CONTROL_STATUS	0x0000	Yes	Ignored by gauge (in previous devices would enable *CONTROL_STATUS()* read).
DEVICE_TYPE	0x0001	Yes	Reports the device type (for example: 0x0320)
FW_VERSION	0x0002	Yes	Reports the firmware version block (device, version, build, and so on)
HW_VERSION	0x0003	Yes	Reports the hardware version of the device
IF_SUM	0x0004	Yes	Reports Instruction flash checksum
STATIC_DF_SUM	0x0005	Yes	Reports the static data flash checksum
CHEM_ID	0x0006	Yes	Reports the chemical identifier of the CEDV configuration
PREV_MACWRITE	0x0007	Yes	Returns previous *Control()* subcommand code
STATIC_CHEM_DF_SUM	0x0008	Yes	Returns the chem ID checksum
BOARD_OFFSET	0x0009	Yes	Invokes the board offset correction
CC_OFFSET	0x000A	Yes	Invokes the CC offset correction
CC_OFFSET_SAVE	0x000B	Yes	Saves the results of the offset calibration process
OCV_CMD	0x000C	Yes	Requests the gas gauge to take an OCV measurement
BAT_INSERT	0x000D	Yes	Forces *BatteryStatus()[BATTPRES]* bit set when ***Operation Config B [BIEnable]*** bit = 0
BAT_REMOVE	0x000E	Yes	Forces *BatteryStatus()[BATTPRES]* bit clear when ***Operation Config B [BIEnable]*** bit = 0
ALL_DF_SUM	0x0010	Yes	Returns the checksum of the entire data flash except for calibration data
SET_HIBERNATE	0x0011	Yes	Forces *CONTROL_STATUS()[HIBERNATE]* bit to 1

Table 2-2. *Control()* MAC Subcommands (continued)

CNTL/MAC FUNCTION	SUBCOMMAND CODE	SEALED ACCESS?	DESCRIPTION
CLEAR_HIBERNATE	0x0012	Yes	Forces *CONTROL_STATUS()[HIBERNATE]* bit to 0
SET_SNOOZE	0x0013	Yes	Forces *CONTROL_STATUS()[SNOOZE]* bit to 1
CLEAR_SNOOZE	0x0014	Yes	Forces *CONTROL_STATUS()[SNOOZE]* bit to 0
BATT_SELECT_0	0x0015	Yes	Select Battery Profile 0
BATT_SELECT_1	0x0016	Yes	Select Battery Profile 1
BATT_SELECT_2	0x0017	Yes	Select Battery Profile 2
BATT_SELECT_3	0x0018	Yes	Select Battery Profile 3
CAL_MODE	0x002D	No	Toggles *OperationStatus()[CALMD]*
SEALED	0x0030	No	Places the gas gauge in SEALED access mode
SECURITY_KEYS	0x0035	No	Read and Write Security Keys
RESET	0x0041	No	Resets device
DEVICE_NAME	0x004A	Yes	Returns the device name
OPERATION_STATUS	0x0054	Yes	This returns the same value as the *OperationStatus()* register.
GaugingStatus	0x0056	Yes	Returns the information of CEDV gauge module status register
MANU_DATA	0x0070	Yes	Returns the manufacturer info A block. This can be written directly when unsealed.
GGSTATUS1	0x0073	Yes	Returns internal gauge debug data block 1
GGSTATUS2	0x0074	Yes	Returns internal gauge debug data block 2
GGSTATUS3	0x0075	Yes	Returns internal gauge debug data block 3
GGSTATUS4	0x0076	Yes	Returns internal gauge debug data block 4
EXIT_CAL	0x0080	No	Instructs the fuel gauge to exit CALIBRATION mode
ENTER_CAL	0x0081	No	Instructs the fuel gauge to enter CALIBRATION mode
RETURN_TO_ROM	0xF00	No	Places the device in ROM mode
DF_ADDR_START	0x4000	No	Direct DF read write access boundary
DF_ADDR_END	0x43FF	No	DF read write access boundary

An example using the *DEVICE_TYPE()* subcommand:

- Write the data bytes 0x01 0x00 to device address 0xAA starting at command 0x00.
- Then read the response using an incremental read. To device address 0xAB, starting at command 0x3E, read four bytes. The result would be 0x01 0x00 0x20 0x03 with the first two bytes reflecting subcommand, and the second two bytes representing the device type in little endian order.

2.1.1 CONTROL_STATUS: 0x0000

A read on this command returns the 16-bit *CONTROL_STATUS()* data. The status word includes the following information:

Table 2-3. CONTROL_STATUS Bit Definitions

	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	HIBERNATE	RSVD	CCA	BCA	SNOOZE	RSVD	BATT_ID1	BATT_ID0

High Byte

RSVD = Reserved

Low Byte

HIBERNATE = Status bit indicating a request for entry into the HIBERNATE mode from the SLEEP mode. True when set. Default is 0.

RSVD = Reserved

CCA = Status bit indicating the gas gauge Coulomb Counter Calibration routine is active. The CCA routine takes place approximately 1 minute after the initialization and periodically as gauging conditions change. Active when set. (See Section 4.3.8, *Autocalibration*.)

BCA = Status bit indicating the gas gauge board calibration routine is active. Active when set.

SNOOZE = Status bit indicating the SNOOZE mode is enabled. True when set.

BATT_ID1 = Battery identification settings for different chemistries, using in conjunction with BATT_ID0 (to select up to four chemistry IDs)

BATT_ID0 = Battery identification settings for different chemistries, using in conjunction with BATT_ID1 (to select up to four chemistry IDs)

2.1.2 DEVICE_TYPE: 0x0001

Instructs the gas gauge to return the device type 0x0320 to *MACData()*

2.1.3 FW_VERSION: 0x0002

Instructs the gas gauge to return the firmware revision on *MACData()* in the following format:

ddDDvvVVbbBBTTzzZZRREE, where

ddDD: Device Number

vvVV: Version

bbBB: Build number

ttTT: Firmware type.

2.1.4 HW_VERSION: 0x0003

Instructs the gas gauge to return the hardware version on subsequent read of *MACData()*

2.1.5 IF_SUM: 0x0004

Instructs the gas gauge to return the instruction flash signature on subsequent read of *MACData()* after a wait of 250 ms

2.1.6 STATIC_DF_SUM: 0x0005

Instructs the gas gauge to return the data flash signature on subsequent read of *MACData()* after a wait of 250 ms. MSB is set to 1 if the calculated signature does not match ***DF Static Checksum***.

2.1.7 CHEM_ID: 0x0006

Instructs the gas gauge to return the chemical identifier value stored in data flash to address 0x40 and 0x41

2.1.8 PREV_MACWRITE: 0x0007

Instructs the gas gauge to copy the last MAC subcommand into 2-byte block *MACData()*

2.1.9 STATIC_CHEM_DF_SUM: 0x0008

Instructs the gas gauge to return the static chemistry DF on subsequent read of *MACData()* after a wait of 250 ms. MSB is set to 1 if the calculated signature does not match the signature stored in DF.

2.1.10 BOARD_OFFSET: 0x0009

Instructs the gas gauge to measure and store the board offset value

2.1.11 CC_OFFSET: 0x000A

Instructs the gas gauge to measure the internal CC offset value

2.1.12 CC_OFFSET_SAVE: 0x000B

Instructs the gas gauge to store the internal CC offset value

2.1.13 OCV_CMD: 0x000C

Requests the gas gauge to take an open-circuit voltage (OCV) reading. This command can only be issued after the *OPERATION_STATUS()[INITCOMP]* bit is set, indicating the initialization has been completed. The OCV measurement takes place at the beginning of the next repeated 1-s firmware synchronization clock. If the ***Operation Config A [INT_OCV]*** bit is set, the SOC_INT pin pulses for approximately 165 ms to indicate the measurement window. (See also Table 4-6.) See Appendix A, *Open-Circuit Voltage Measurement Background*, for more details on OCV measurements and recommended usage of this command.

NOTE: The *BatteryStatus()[OCVFAIL]* bit is set if the *OCV_CMD()* subcommand is received when the *BatteryStatus()[CHGINH]* bit is set.

2.1.14 BAT_INSERT: 0x000D

Instructs the gas gauge to force the *BatteryStatus() [BATTPRES]* bit to be set and informs the gauge of the presence of a battery when the insertion detection feature is disabled (***Operation Config B [BIEnable]*** bit = 0). Alternatively, battery presence detection can be enabled (***Operation Config B [BIEnable]*** bit = 1) to monitor the external thermistor network. (See Section 4.3.3, *Battery Presence Detection Using the BI/TOUT Pin*.)

2.1.15 BAT_REMOVE: 0x000E

Instructs the gas gauge to force the *BatteryStatus() [BATTPRES]* bit to clear when the battery insertion detection is disabled (***Operation Config B [BIEnable]*** bit = 0). Alternatively, battery presence detection can be enabled (***Operation Config B [BIEnable]*** bit = 1) to monitor the external thermistor network. (See Section 4.3.3, *Battery Presence Detection Using the BI/TOUT Pin*.)

2.1.16 ALL_DF_SUM: 0x0010

Instructs the gas gauge to return the checksum of the entire data flags area on subsequent read of *MACData()* after a wait of 250 ms. MSB is set to 1 if the calculated signature does not match ***All DF Checksum***. It is normally expected that this signature will change due to update of lifetime, gauging, and other information.

2.1.17 SET_HIBERNATE: 0x0011

Instructs the gas gauge to force the *CONTROL_STATUS [HIBERNATE]* bit to 1. This allows the gauge to enter the HIBERNATE power mode after the transition to the SLEEP power mode is detected and the required conditions are met. The *[HIBERNATE]* bit is automatically cleared upon exiting the HIBERNATE mode.

2.1.18 CLEAR_HIBERNATE: 0x0012

Instructs the gas gauge to force the *CONTROL_STATUS [HIBERNATE]* bit to 0. This prevents the gauge from entering the HIBERNATE power mode after the transition to the SLEEP power mode is detected. It can also force the gauge out of the HIBERNATE mode.

2.1.19 SET_SNOOZE: 0x0013

Instructs the gas gauge to set the *CONTROL_STATUS [SNOOZE]* bit to 1. This enables the SNOOZE power mode. The gauge enters the SNOOZE power mode after the transition conditions are met.

2.1.20 CLEAR_SNOOZE: 0x0014

Instructs the gas gauge to set the *CONTROL_STATUS [SNOOZE]* bit to 0. This disables the SNOOZE power mode. The gauge exits from the SNOOZE power mode after the *[SNOOZE]* bit is cleared.

2.1.21 BATT SELECT_0/1/2/3: 0x0015/16/17/18

Instructs the device to set the 1 of 4 different battery chemistry profiles for gas gauging

2.1.22 CAL MODE: 0x002D

Toggles the *OperationStatus()[CALMD]* flag

2.1.23 SEALED: 0x0030

Instructs the gas gauge to transition from the UNSEALED state to the SEALED state. The gas gauge must always be set to the SEALED state for use in end-equipment.

2.1.24 SECURITY KEYS: 0x0035

This is a read/write command that changes the Unseal and Full Access Keys. To read the keys, sending the *Securitykeys()* subcommand to the *Control()* or *ManufacturerAccessControl()*.

To read the keys:

1. Write 0x35 0x00 to either *Control(0x00, 0x01)* or *ManufacturerAccessControl(0x3E, 0x3F)*.

2. Read back 8 bytes at *MACData(0x40–0x47)*.

To write the keys:

1. Write 0x35 0x00 to either *Control(0x00, 0x01)* or *ManufacturerAccessControl(0x3E, 0x3F)*.

2. Write the data in big endian format to *MACData(0x40–0x47)*.

3. Write the checksum to *MACDataSum(0x60)*. The checksum is the complement of the sum of the data and command bytes.

4. Write the length of 0x08 to *MACDataLen(0x61)*. The length includes the command, data, checksum, and length bytes.

2.1.25 RESET: 0x0041

Instructs the gas gauge to perform a full reset. This subcommand is only available when the gas gauge is UNSEALED.

2.1.26 OPERATION_STATUS: 0x0054

This returns the same value as the *OperationStatus()* register.

2.1.27 GaugingStatus: 0x0056

Returns the 16-bit internal gauging status register. The most often checked flags from this register are copied to the *OperationStatus()* direct read register for easier access.

Table 2-4. Gauging Status Bit Definitions

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
High Byte	VDQ	EDV2	EDV1	RSVD	RSVD	FCCX	RSVD	RSVD
Low Byte	CF	DSG	EDV	RSVD	TC	TD	FC	FD

High Byte

VDQ = Indicates if current discharge cycle is NOT qualified or qualified for an FCC updated. Discharge cycle valid for FCC update is set.

EDV2 = Indicates if measured cell voltage is above or below EDV2 threshold. Below = True when set.

EDV1 = Indicates if measured cell voltage is above or below EDV1 threshold. Below = True when set.

RSVD = Reserved

FCCX = Indicates when FCC updates

Low Byte

CF = Indicates if battery conditioning is needed.

DSG = Set when in DISCHARGING or RELAX modes. Clear when in CHARGING mode.

EDV = Indicates if measured cell voltage is above or below EDV0 threshold. Below = True when set.

RSVD = Reserved

TC = Terminate Charge. Controlled by settings in ***SOC Flag Config A***. (This flag is identical to *BatteryStatus()[TCA].*)

TD = Terminate Discharge. Controlled by settings in ***SOC Flag Config A***. (This flag is identical to *BatteryStatus()[TDA]*.)

FC = Full Charge. Controlled by settings in ***SOC Flag Config A*** and ***SOC Flag Config B***. (This flag is identical to *BatteryStatus()[FC]*.)

FD = Full Discharge. Controlled by settings in ***SOC Flag Config B***. (This flag is identical to *BatteryStatus()[FD]*.)

2.1.28 GGStatus1: 0x0073

Returns the internal gauge debug block 1

2.1.29 GGStatus2: 0x0074

Returns the internal gauge debug block 2

2.1.30 GGStatus3: 0x0075

Returns the internal gauge debug block 3

2.1.31 GGStatus4: 0x0076

Returns the internal gauge debug block 4

2.1.32 EXIT_ CAL: 0x0080

Instructs the fuel gauge to exit CALIBRATION mode

2.1.33 ENTER_CAL: 0x0081

Instructs the fuel gauge to enter CALIBRATION mode and reset *AnalogCount()* to zero if *OperationStatus()[CALMD]* is set. *[CALMD]* is controlled by the *CAL_MODE()* command.

2.1.33.1 RETURN_ TO_ROM: 0x0F00

This commands send the device into ROM mode in preparation for re-programming. The *OperationStatus()[SEC1, SEC0]* = 0,1 AND 0xF00 to *ManufacturerAccess()*. Device goes to ROM mode ready for updates, use 0x08 to *ManufacturerAccess()* to return.

2.1.34 DF_ACCESS: 0x4000–0x43FF

Accessing data flash is only supported by the *ManufacturerAccessControl()* by addressing the physical address. See Section 3.1 Data Flash Access for examples.

The gauge supports an auto-increment on the address during a DF read. The DF address is incremented by 32 every time the *MACDataLen()* is read, which makes it possible to repeatedly read only the block from 0x3E through 0x61 without having to write a new command. This greatly reduces the time required to read out the entire DF.

2.2 AtRate(): 0x02 and 0x03

The *AtRate()* read- and write-word function is the first half of a two-function command set that sets the AtRate value used in calculations made by the *AtRateTimeToEmpty()* function. The *AtRate()* units are in mA.

The *AtRate()* value is a signed integer, with negative values interpreted as a discharge current value. The *AtRateTimeToEmpty()* function returns the predicted operating time at the AtRate value of discharge. The default value for *AtRate()* is 0 and forces *AtRateTimeToEmpty()* to return 65,535. Both the *AtRate()* and *AtRateTimeToEmpty()* commands must only be used in the NORMAL mode.

2.3 AtRateTimeToEmpty(): 0x04 and 0x05

This read-word function returns an unsigned integer value of the predicted remaining operating time if the battery is discharged at the *AtRate()* value in minutes with a range of 0 to 65,534. A value of 65,535 indicates *AtRate()* = 0. The gas gauge updates *AtRateTimeToEmpty()* within 1 s after the system sets the *AtRate()* value. The gas gauge automatically updates *AtRateTimeToEmpty()* based on the *AtRate()* value every second. Both the *AtRate()* and *AtRateTimeToEmpty()* commands must only be used in NORMAL mode.

2.4 Temperature(): 0x06 and 0x07

This read- and write-word function returns an unsigned integer value of the temperature in units of 0.1°K measured by the gas gauge. See Table 2-5, *Temperature Measurement Options,* and Section 4.4, *Temperature Measurement.*

Table 2-5. Temperature Measurement Options

Operation Config B [WRTEMP]	Operation Config A [TEMPS]	*Temperature()* Read Command	*Temperature()* Write Command
0	0	Returns internal temperature as read from an internal sensor. This data is also available using the *InternalTemperature()* function.	The data is ignored.
0	1	Returns external temperature read from an external thermistor.	
1	X	Returns the *Temperature()* value previously written.	Sets the *Temperature()* to be used for gauging calculations.

2.5 Voltage(): 0x08 and 0x09

This read-word function returns an unsigned integer value of the measured cell-pack voltage in mV with a range of 0 to 6000 mV.

2.6 BatteryStatus(): 0x0A and 0x0B

This read-word function returns the contents of the gas-gauge status register, depicting the current Battery status.

Table 2-6. Battery Status Bit Definitions

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
High Byte	FD	OCVCOMP	OCVFAIL	SLEEP	OTC	OTD	FC	CHGINH
Low Byte	RSVD	TCA	OCV_GD	AUTH_GD	BATTPRES	TDA	SYSDOWN	DSG

High Byte

FD = Full-discharge is detected. This flag is set and cleared based on the selected ***SOC Flag Config B*** options.

OCVCOMP = An OCV measurement update is complete. True when set.

OCVFAIL = Status bit indicating that the OCV reading failed due to current. This bit can only be set with the presence of a battery after receiving *OCV_CMD()*. True when set.

SLEEP = Device is operating in SLEEP mode when set. This will clear temporarily during AD measurements in SLEEP mode.

OTC = Overtemperature in charge condition is detected. If the ***Operation Config B [INT_OT]*** bit = 1, SOC_INT pin toggles once *[OTC]* bit is set.

OTD = Overtemperature in discharge condition is detected. True when set. If the ***Operation Config B [INT_OT]*** bit = 1, SOC_INT pin toggles once *[OTD]* bit is set.

FC = Full-charged is detected. This flag is set and cleared based on the selected ***SOC Flag Config A*** and ***SOC Flag Config B*** options.

CHGINH = Charge inhibit: If set, indicates that charging should not begin because *Temperature()* is outside the range ***[Charge Inhibit Temp Low, Charge Inhibit Temp High]***. True when set.

Low Byte

TCA = Terminate Charge Alarm. This flag is set and cleared based on the selected ***SOC Flag Config A*** options.

OCV_GD = Good OCV measurement taken. True when set.

AUTH_GD = Latest authentication with external bq2022A is good when set.
When BIENABLE = 0, this bit is only cleared on authentication failure.

BATTPRES = Battery Present detected. True when set.

TDA = Terminate Discharge Alarm. This flag is set and cleared based on the selected ***SOC Flag Config A*** options.

SYSDOWN = System down bit indicating the system should shut down. True when set. SOC_INT pin toggles once if set.

DSG = Device is in DISCHARGING mode when set; CHARGING or RELAX mode when clear.

2.7 Current(): 0x0C and 0x0D

This read-only function returns a signed integer value that is the instantaneous current flow through the sense resistor. It is updated every second. Units are mA.

2.8 RemainingCapacity(): 0x10 and 0x11

This read-only command pair returns the battery remaining capacity. When ***CEDV Smoothing Config [SMEN]*** is set, this will be the result of the smoothing engine. Otherwise, the unfiltered remaining capacity is returned. Units are mAh.

2.9 FullChargeCapacity(): 0x12 and 0x13

This read-only command pair returns the compensated capacity of fully charged battery Units are mAh. *FullChargeCapacity()* is updated at regular intervals, as specified by the CEDV algorithm.

2.10 TimeToEmpty(): 0x16 and 0x17

This read-only function returns an unsigned integer value of the predicted remaining battery life at the present rate of discharge, in minutes. A value of 65,535 indicates battery is not being discharged.

2.11 TimeToFull(): 0x18 and 0x19

This read-only function returns an unsigned integer value of the predicted remaining time until battery reaches full charge, in minutes, based upon *AverageCurrent()*. The computation accounts for the taper current time extension for the linear TTF computation based on a fixed *AverageCurrent()* rate of charge accumulation. A value of 65,535 indicates the battery is not being charged.

2.12 StandbyCurrent(): 0x1A and 0x1B

This read-only function returns a signed integer value of the measured standby current through the sense resistor. The *StandbyCurrent()* is an adaptive measurement. Initially, it reports the standby current programmed in ***Initial Standby***, and after spending several seconds in standby, reports the measured standby current.

The register value is updated every second when the measured current is above the ***Deadband*** and is less than or equal to 2 × ***Initial Standby***. The first and last values that meet this criteria are not included, because they may not be stable values. To approximate a 1-minute time constant, each new *StandbyCurrent()* value is computed by taking approximately 93% weight of the last standby current and approximately 7% of the current measured average current.

2.13 StandbyTimeToEmpty(): 0x1C and 0x1D

This read-only function returns an unsigned integer value of the predicted remaining battery life at the standby rate of discharge in minutes. The computation uses *NominalAvailableCapacity()* (NAC), the uncompensated remaining capacity, for this computation. A value of 65,535 indicates battery is not being discharged.

2.14 MaxLoadCurrent(): 0x1E and 0x1F

This read-only function returns a signed integer value, in units of mA, of maximum load conditions. The *MaxLoadCurrent()* is an adaptive measurement, which is initially reported as the maximum load current programmed in ***Initial Max Load Current***. If the measured current is ever greater than ***Initial Max Load Current***, then *Max Load Current ()* is reduced to the average of the previous value and ***Initial Max Load Current*** whenever the battery is charged to full after a previous discharge to an SOC is less than 50%. This prevents the reported value from maintaining an unusually high value.

2.15 MaxLoadTimeToEmpty(): 0x20 and 0x21

This read-only function returns an unsigned integer value of the predicted remaining battery life at the maximum load current discharge rate in minutes. The value of 65,535 indicates that the battery is not being discharged.

2.16 RawCoulombCount(): 0x22 and 0x23

This read-only function returns an unsigned integer value of the amount of coulombs taken out of a battery during charge/discharge. The counter increments during discharge and decrements during charge. During charge, when the FC bit is set (indicating full charge), the counter is cleared to 0. The IGNORE_SD bit provides the capability to ignore a self-discharge.

IGNORE_SD = 0 = Coulomb counter increments during regular or self-discharge.

IGNORE_SD = 1 = Coulomb counter increments only if there is a real discharge.

2.17 AveragePower(): 0x24 and 0x25

This read-only function returns a signed integer value of the average power during battery charging and discharging. It is negative during discharge and positive during charge. A value of 0 indicates that the battery is not being discharged. The value is reported in units of mW.

2.18 InternalTemperature(): 0x28 and 0x29

This read-only function returns an unsigned integer value of the internal temperature sensor in units of 0.1°K measured by the gas gauge. This function can be useful as an additional system-level temperature monitor if the main *Temperature()* function is configured for external or host-reported temperature.

2.19 CycleCount(): 0x2A and 0x2B

This read-only function returns an unsigned integer value of the number of cycles that the active cell has experienced with a range of 0 to 65535. One cycle occurs when accumulated discharge ≥ cycle threshold. The cycle threshold is calculated as ***Cycle Count Percentage*** times either *FullChargeCapacity()* (when ***CEDV Gauging Configuration [CCT]*** = 1) or *DesignCapacity()* (when ***[CCT]*** = 0).

2.20 StateOfCharge(): 0x2C and 0x2D

This read-only 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%. *StateOfCharge() = RemainingCapacity() ÷ FullChargeCapacity()* rounded up to the nearest whole percentage point.

2.21 StateOfHealth(): 0x2E and 0x2F

This read-only function returns an unsigned integer value, expressed as a percentage of the ratio of *FullChargeCapacity()* over the *DesignCapacity()*, with a range of 0 to 100%. *StateOfHealth() = FullChargeCapacity() ÷ DesignCapacity()* rounded up to the nearest whole percentage point.

2.22 ChargingVoltage(): 0x30 and 0x31

This read-only function returns an unsigned integer value of the desired charging voltage of the battery. A value of 65,535 indicates that the battery is requesting the maximum voltage from the battery charger.

2.23 ChargingCurrent(): 0x32 and 0x33

This read-only function returns an unsigned integer value of the desired charging current of the battery. A value of 65,535 indicates that the battery is requesting the maximum current from the battery charger.

2.24 BTPDischargeSet(): 0x34 and 0x35

This read/write word command updates the BTP set threshold that triggers the BTP interrupt in discharge direction, and sets the *OperationStatus()[BTPINT]* bit.

2.25 BTPChargeSet(): 0x36 and 0x37

The read/write word command updates the BTP set threshold that triggers the BTP interrupt in charge direction, and sets the *OperationStatus()[BTPINT]* bit.

2.26 OperationStatus(): 0x3A and 0x3B

This read-word function returns the contents of the internal status register.

Table 2-7. Pack Status Bit Definitions

	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	BTPINT	SMTH	INITCOMP	VDQ	EDV2	SEC1	SEC0	CALMD

High Byte

RSVD =	Reserved

Low Byte

BTPINT =	Indicates that a BTP threshold has been crossed.
SMTH =	Indicates that *RemainingCapacity()* accumulation is currently scaled by the smoothing engine.
INITCOMP =	Indicates if gas gauge initialization is complete. This bit can only be set with battery presence. True when set.
VDQ =	Indicates if Current discharge cycle is NOT qualified or qualified for an FCC updated. Discharge cycle valid for FCC update is set.
EDV2 =	Indicates if measured cell voltage is above or below EDV2 threshold. Below = True when set.
SEC1 = SEC0 =	Defines Current security status. 1,1 = Sealed Access, 1.0 = Unsealed Access, 0,1= Full Access
CALMD =	Toggles with 0x2D command to Enable/Disable CALIBRATION mode

2.27 DesignCapacity(): 0x3C and 0x3D

This read-only function returns the value stored in ***Design Capacity mAh***. This is intended to be the theoretical or nominal capacity of a new pack, and is used for the calculation of *StateOfHealth()*.

2.28 ManufacturerAccessControl(): 0x3E and 0x3F

This read-write word function returns the subcommand that is currently active for reads on *MACData()*.

Word writes to this function will set a subcommand. Commands that do not require data will execute immediately (identical to writes to *Control()*).

2.29 MACData(): 0x40 through 0x5F

This read-write block will return the result data for the currently active subcommand. It is recommended to start the read at *ManufacturerAccessControl()* to verify the active subcommand.

Writes to this block are used to provide data to a subcommand when required.

2.30 MACDataSum(): 0x60

This read-write function returns the checksum of the current subcommand and data block.

Writes to this register provide the checksum necessary in order to execute subcommands that require data. The checksum is calculated as the complement of the sum of the *ManufacturerAccessControl()* and the *MACData()* bytes. *MACDataLen()* determines the number of bytes of *MACData()* that are included in the checksum.

2.31 MACDataLen(): 0x61

This read-write function returns the number of bytes of *MACData()* that are part of the response and included in *MACDataSum()*.

Writes to this register provide the number of bytes in *MACData()* that should be processed as part of the subcommand. Subcommands that require block data are not executed until *MACDataSum()* and *MACDataLen()* are written together as a word.

2.32 AnalogCount(): 0x79

This read-only function returns the analog counter. The value is incremented every time the analog data for calibration has been updated.

2.33 RawCurrent(): 0x7A and 0x7B

This read-only function returns the raw data from the coulomb counter.

2.34 RawVoltage(): 0x7C and 0x7D

This read-only function returns the raw data from the cell voltage reading.

2.35 RawExtTemp(): 0x7E and 0x7F

This read-only function returns the raw data from the external temperature measurement.

Data Flash Interface

3.1 Accessing the Data Flash

Accessing data flash (DF) is supported by accessing the actual physical memory in the address range 0x4000–0x43FF. This provides up to 1k of directly addressable DF. In this mode, the subcommand represents the actual base address in DF to access. Reads provide a 32-byte block (except if it runs off the end of DF). The length will identify if it is at the end (less than 32 bytes). Writes can have anywhere from 1 to 32 bytes, which provide the ability to write a single DF parameter without having to read a row first.

NOTE: Changing a single bit within a data flash configuration register still requires a read-modify-write sequence to preserve the other flags.

Write to DF example:

Assume data1 is located at address 0x4000 and data2 is located at address 0x4002 and both data1 and data2 are U2 type. To update data1 and data2 to 0x1234 and 0x5678, respectively, do the following:

- Write 0x00 0x40 (DF address in little endian format) to *ManufacturerAccessControl(0x3E, 0x3F)*.
- Write 0x12 0x34 0x56 0x78 (data in big endian format) to *MACData(0x40–0x43)*. The writes to *ManufacturerAccessControl()* and *MACData()* can be performed in a single transaction.
- Write 0xAB (complement of the sum of the *ManufacturerAccessControl()* and *MACData()* bytes) to *MACDataSum(0x60)*.
- Write 0x08 (4 + length of *MACData()* bytes) to *MACDataLen(0x61)*.
- The data flash write will execute when the *MACDataSum()* and *MACDataLen()* are written in order (word write) and are verified to be correct.

Read from DF example:

- Write 0x00 0x40 (DF address in little endian format) to *ManufacturerAccessControl(0x3E, 0x3F)*.
- Read *ManufacturerAccessControl(0x3E, 0x3F)* to verify.
- Read data from *MACData(0x40–0x5F)*.
- Read checksum and length from *MACDataSum(0x60)*, *MACDataLen()*.
- Verify checksum. All data above can be read in a single transaction by reading 36 bytes starting at *ManufacturerAccessControl()*.

Auto-increment reading

To support faster data flash dumps the 0x4000–0x43FF commands will auto-increment after a successful read. This allows the host to skip the write word step which increases throughput by at least 2x. After a word read is detected of the *MACDataSum()* and *MACDataLen()* registers the gauge will add the current block size to the command (32 bytes). There is no auto-increment for the last block of DF.

3.2 Manufacturer Information Block

The gas gauge contains 32 bytes of user-programmable data flash storage called the ***Manufacturer Info Block***. This block is accessible using *MANU_DATA()* subcommand. The *MANU_DATA()* command is read/write when UNSEALED and read-only when SEALED.

To read the block in any mode, write 70 00 (*MANU_DATA()*) to *ManufacturerAccessControl()* or *Control()*, then read the *MACData()* block.

To write the block, send 70 00 to *ManufacturerAccessControl()*, write the 32 byte data block to *MACData()*, and then write the checksum and length to *MACDataSum()* and *MACDataLen()*. The write will not proceed until the checksum and length are verified.

It is also possible to write the manufacturer info block using the data flash interface by writing to the DF address where the block is stored.

NOTE: The ***Manufacturer Info Block*** is read-only when in SEALED mode.

3.3 Device Access Modes

The gas gauge provides three security modes (FULL ACCESS, UNSEALED, and SEALED) that control data flash access permissions, according to Table 3-1.

Table 3-1. Data Flash Access

Security Mode	Data Flash	Manufacturer Info Block
FULL ACCESS	RW	RW
UNSEALED	RW	RW
SEALED	None	R

Although FULL ACCESS and UNSEALED modes appear identical, only FULL ACCESS allows the gas gauge to read or write access-mode transition keys, or execute the *RETURN_TO_ROM()* subcommand.

3.4 Sealing and Unsealing Data Flash

The gas gauge implements a key-access scheme to transition between SEALED, UNSEALED, and FULL ACCESS modes. Each transition requires that a unique set of two keys be sent to the gas gauge via the *Control()* control command. The keys must be sent consecutively, with no other data being written to the *Control()* register in between. Do not set the two keys to identical values.

NOTE: To avoid conflict, the keys must be different from the codes presented in the *COMMAND CODE* column of Table 2-2, *Control() Subcommands*.

When in the SEALED mode, the *OperationStatus()[SEC1, SEC0]* bits are set to [1, 1]. When the UNSEAL keys are correctly received by the gas gauge, the bits will be set to [1, 0]. When the FULL ACCESS keys are correctly received, then the bits will change to [0, 1]. The state [0, 0] is not valid, and only indicates that the state has not yet been loaded.

The access keys are changed using the *SECURITY_KEYS()* subcommand. This command will allow read/write the 4 key words (8 bytes). Each word is in big endian order, with the first two words being the unseal code and the remaining two words being the full access codes.

When writing the codes to *Control()* or *ManufacturerAccessControl()*, they must be sent in little endian order; therefore, if 0x1234 and 0x5678 are written as the unseal codes to *SECURITY_KEYS()*, then to unseal will require writing 0x34 0x12 followed by writing 0x78 0x56. The two codes must be written within 4 s of each other to succeed.

3.5 Data Flash Summary

Summarize the data flash locations available to the user, including their default, minimum, and maximum values.

Table 3-2. Data Type Decoder

Type	Min Value	Max Value
F4	$\pm 9.8603 \times 10^{-39}$	$\pm 5.707267 \times 10^{37}$
H1	0x00	0xFF
H2	0x00	0xFFFF
H4	0x00	0xFFFF FFFF
I1	–128	127
I2	–32768	32767
I4	−2,147,483,648	2,147,483,647
Sx	1-byte string	x-byte string
U1	0	255
U2	0	65535
U4	0	4,294,967,295

NOTE: The data flash table below contains the physical addresses of all DF for firmware v0.08. These addresses may change between firmware versions.

All values in the data flash below are represented in the device native units; however, evaluation tools may display alternate units for easier editing.

Table 3-3. Data Flash Table

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Calibration	Data	0x4000	CC Gain	F4	1.00E-01	4.00E+00	.47095	—
Calibration	Data	0x4004	CC Delta	F4	2.98262E+04	1.193046E+06	5.677446e5	—
Calibration	Data	0x4008	CC Offset	I2	-32767	32767	0	mA
Calibration	Data	0x400c	Board Offset	I1	-128	127	0	µA
Calibration	Data	0x400d	Int Temp Offset	I1	-128	127	0	0.1 °C
Calibration	Data	0x400e	Ext Temp Offset	I1	-128	127	0	0.1 °C
Calibration	Data	0x400f	Pack V Offset	I1	-128	127	0	mV
Calibration	Temp Model	0x4165	Int Coeff 1	I2	-32768	32767	0	Num
Calibration	Temp Model	0x4167	Int Coeff 2	I2	-32768	32767	0	Num
Calibration	Temp Model	0x4169	Int Coeff 3	I2	-32768	32767	-12324	Num
Calibration	Temp Model	0x416b	Int Coeff 4	I2	-32768	32767	6131	0.1 °K
Calibration	Temp Model	0x416d	Int Min AD	I2	-32768	32767	0	—
Calibration	Temp Model	0x416f	Int Max Temp	I2	-32768	32767	6131	0.1 °K
Calibration	Temp Model	0x4171	Ext Coeff 1	I2	-32768	32767	-11130	Num
Calibration	Temp Model	0x4173	Ext Coeff 2	I2	-32768	32767	19142	Num
Calibration	Temp Model	0x4175	Ext Coeff 3	I2	-32768	32767	-19262	Num
Calibration	Temp Model	0x4177	Ext Coeff 4	I2	-32768	32767	28203	0.1 °K
Calibration	Temp Model	0x4179	Ext Coeff 5	I2	-32768	32767	892	0.1 °K
Calibration	Temp Model	0x417b	Ext Coeff b 1	I2	-32768	32767	328	Num
Calibration	Temp Model	0x417d	Ext Coeff b 2	I2	-32768	32767	-605	Num
Calibration	Temp Model	0x417f	Ext Coeff b 3	I2	-32768	32767	-2443	Num
Calibration	Temp Model	0x4181	Ext Coeff b 4	I2	-32768	32767	4696	0.1 °K
Calibration	Temp Model	0x4183	RC0	I2	-32768	32767	11703	Counts
Calibration	Temp Model	0x4185	ADC0	I2	-32768	32767	11338	Counts
Calibration	Temp Model	0x4187	Vcomp Coeff 1	I2	-32768	32767	0	Num

Table 3-3. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Calibration	Temp Model	0x4189	Vcomp Coeff 2	I2	-32768	32767	14902	Num
Calibration	Temp Model	0x418b	Vcomp Coeff 3	I2	-32768	32767	-623	Num
Calibration	Temp Model	0x418d	Vcomp Coeff 4	I2	-32768	32767	37	Num
Calibration	Temp Model	0x418f	Vcomp Input Multiplier	U1	0	255	48	Num
Calibration	Temp Model	0x4190	Vcomp Output Divisor	I2	-32768	32767	256	Num
Calibration	Current	0x4192	Filter	U1	0	255	239	Num
Calibration	Current	0x4193	Deadband	U1	0	255	5	mA
Calibration	Current	0x4194	CC Deadband	U1	0	255	17	294nV
Configuration	Charge Inhibit Cfg	0x40c0	Chg Inhibit Temp Low	I2	-400	1200	0	0.1 °C
Configuration	Charge Inhibit Cfg	0x40c2	Chg Inhibit Temp High	I2	-400	1200	450	0.1 °C
Configuration	Charge Inhibit Cfg	0x40c4	Temp Hys	I2	0	100	50	0.1 °C
Configuration	Charge	0x40c6	Fast Charge Current	I2	0	1000	200	mA
Configuration	Charge	0x40c8	Charging Voltage	I2	0	4600	4200	mV
Configuration	Charge Termination	0x40d2	Taper Current	I2	0	1000	100	mA
Configuration	Charge Termination	0x40d6	Taper Voltage	I2	0	1000	100	mV
Configuration	Safety	0x4105	OT Chg	I2	0	1200	550	0.1 °C
Configuration	Safety	0x4107	OT Chg Time	U1	0	60	2	s
Configuration	Safety	0x4108	OT Chg Recovery	I2	0	1200	500	0.1 °C
Configuration	Safety	0x410a	OT Dsg	I2	0	1200	600	0.1 °C
Configuration	Safety	0x410c	OT Dsg Time	U1	0	60	2	s
Configuration	Safety	0x410d	OT Dsg Recovery	I2	0	1200	550	0.1 °C
Configuration	Registers	0x4092	Battery ID	H1	0x00	0x03	0x00	Hex
Configuration	Registers	0x40d9	Operation Config A	H2	0x0000	0xffff	0x0484	Hex
Configuration	Registers	0x40db	Operation Config B	H2	0x0000	0xffff	0x8000	Hex
Configuration	Registers	0x40de	SOC Delta	U1	0	25	1	%
Configuration	Registers	0x40df	DF Wr Ind Wait	U2	0	65535	0	Num
Configuration	Registers	0x40e1	Clk Ctl Reg	H1	0x00	0x0f	0x09	Hex
Configuration	Registers	0x40e7	Device Type	H2	0x0000	0xffff	0x0320	Hex
Configuration	Power	0x40ec	Flash Update OK Voltage	I2	0	4200	2800	mV
Configuration	Power	0x40ee	Sleep Current	I2	0	100	10	mA
Configuration	Power	0x40f0	Bus Low Time	U1	0	255	5	s
Configuration	Power	0x40f1	Offset Cal Inhibit Temp Low	I2	-400	1200	50	0.1 °C
Configuration	Power	0x40f3	Offset Cal Inhibit Temp High	I2	-400	1200	450	0.1 °C
Configuration	Power	0x40f5	Sleep Voltage Time	U1	0	100	20	s
Configuration	Power	0x40f6	Sleep Current Time	U1	0	255	20	s
Configuration	Power	0x40f7	Hibernate I	U2	0	700	8	mA
Configuration	Power	0x40f9	Hibernate V	U2	2400	3000	2550	mV
Configuration	Current Thresholds	0x40fb	Discharge Detection Threshold	I2	0	2000	60	mA
Configuration	Current Thresholds	0x40fd	Charge Detection Threshold	I2	0	2000	75	mA
Configuration	Current Thresholds	0x40ff	Quit Current	I2	0	1000	40	mA
Configuration	Current Thresholds	0x4101	Discharge Relax Time	U2	0	8191	60	s
Configuration	Current Thresholds	0x4103	Charge Relax Time	U1	0	255	60	s
Configuration	Current Thresholds	0x4104	Quit Relax Time	U1	0	63	1	s
Configuration	Data	0x406a	Device Name	S9	x	x	bq27320	—
Configuration	Data	0x4073	Data Flash Version	H2	0x0000	0xffff	0xffff	—
Configuration	Data	0x410f	Initial Standby	I1	-127	0	-10	mA

Table 3-3. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Configuration	Data	0x4110	Default Temperature	I2	2732	3732	2982	0.1K
Configuration	Discharge	0x4115	SysDown Set Volt Threshold	I2	0	4200	3150	mV
Configuration	Discharge	0x4117	SysDown Set Volt Time	U1	0	60	2	s
Configuration	Discharge	0x4118	SysDown Clear Volt Threshold	I2	0	5000	3400	mV
Configuration	Integrity Data	0x4062	DF Static Checksum	H2	0x0000	0x7fff	0x0000	Hex
Configuration	Integrity Data	0x4064	All DF Checksum	H2	0x0000	0x7fff	0x0000	Hex
Configuration	Integrity Data	0x4066	IF Checksum	H4	0x00000000	0xffffffff	0xf8f8049 9	Hex
Configuration	Integrity Data	0x4090	Full Reset Counter	U1	0	255	0	Num
Configuration	Integrity Data	0x4091	Reset Counter WD	U1	0	255	0	Num
Settings	Configuration	0x40e2	IO Config	H1	0x0	0x03	0x00	Hex
Settings	Configuration	0x41b9	SOC Flag Config A	H2	0x0	0x0fff	0x0c8c	Hex
Settings	Configuration	0x41bb	SOC Flag Config B	H1	0x0	0xff	0x8c	Hex
Settings	Configuration	0x41d4	CEDV Gauging Configuration	H2	0x0	0x1fff	0x182a	Hex
Settings	BTP	0x40e3	Init Discharge Set	I2	0	32767	150	mAh
Settings	BTP	0x40e5	Init Charge Set	I2	0	32767	175	mAh
System Data	Manufacturer Data	0x4042	Manufacturer Info Block A01	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x4043	Manufacturer Info Block A02	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x4044	Manufacturer Info Block A03	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x4045	Manufacturer Info Block A04	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x4046	Manufacturer Info Block A05	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x4047	Manufacturer Info Block A06	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x4048	Manufacturer Info Block A07	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x4049	Manufacturer Info Block A08	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x404a	Manufacturer Info Block A09	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x404b	Manufacturer Info Block A10	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x404c	Manufacturer Info Block A11	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x404d	Manufacturer Info Block A12	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x404e	Manufacturer Info Block A13	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x404f	Manufacturer Info Block A14	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x4050	Manufacturer Info Block A15	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x4051	Manufacturer Info Block A16	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x4052	Manufacturer Info Block A17	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x4053	Manufacturer Info Block A18	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x4054	Manufacturer Info Block A19	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x4055	Manufacturer Info Block A20	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x4056	Manufacturer Info Block A21	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x4057	Manufacturer Info Block A22	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x4058	Manufacturer Info Block A23	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x4059	Manufacturer Info Block A24	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x405a	Manufacturer Info Block A25	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x405b	Manufacturer Info Block A26	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x405c	Manufacturer Info Block A27	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x405d	Manufacturer Info Block A28	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x405e	Manufacturer Info Block A29	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x405f	Manufacturer Info Block A30	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x4060	Manufacturer Info Block A31	H1	0x00	0xff	0x00	Hex
System Data	Manufacturer Data	0x4061	Manufacturer Info Block A32	H1	0x00	0xff	0x00	Hex
Gas Gauging	CEDV Profile 1	0x41a5	Design Capacity mAh	I2	0	32767	2200	mAh
Gas Gauging	CEDV Profile 1	0x41d6	EMF	U2	0	65535	3743	—
Gas Gauging	CEDV Profile 1	0x41d8	C0	U2	0	65535	149	—

Table 3-3. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Gas Gauging	CEDV Profile 1	0x41da	R0	U2	0	65535	867	—
Gas Gauging	CEDV Profile 1	0x41dc	T0	U2	0	65535	4030	—
Gas Gauging	CEDV Profile 1	0x41de	R1	U2	0	65535	316	—
Gas Gauging	CEDV Profile 1	0x41e0	TC	U1	0	255	9	—
Gas Gauging	CEDV Profile 1	0x41e1	C1	U1	0	255	0	—
Gas Gauging	CEDV Profile 1	0x41e2	Age Factor	U1	0	255	0	—
Gas Gauging	CEDV Profile 1	0x41e3	Fixed EDV 0	I2	0	32767	3031	—
Gas Gauging	CEDV Profile 1	0x41e5	EDV 0 Hold Time	U1	1	255	1	s
Gas Gauging	CEDV Profile 1	0x41e6	Fixed EDV 1	I2	0	32767	3385	—
Gas Gauging	CEDV Profile 1	0x41e8	EDV 1 Hold Time	U1	1	255	1	s
Gas Gauging	CEDV Profile 1	0x41e9	Fixed EDV 2	I2	0	32767	3501	—
Gas Gauging	CEDV Profile 1	0x41eb	EDV 2 Hold Time	U1	1	255	1	s
Gas Gauging	CEDV Profile 1	0x41ec	Voltage 0% DOD	I2	-32768	32767	4173	mV
Gas Gauging	CEDV Profile 1	0x41ee	Voltage 10% DOD	I2	-32768	32767	4043	mV
Gas Gauging	CEDV Profile 1	0x41f0	Voltage 20% DOD	I2	-32768	32767	3925	mV
Gas Gauging	CEDV Profile 1	0x41f2	Voltage 30% DOD	I2	-32768	32767	3821	mV
Gas Gauging	CEDV Profile 1	0x41f4	Voltage 40% DOD	I2	-32768	32767	3725	mV
Gas Gauging	CEDV Profile 1	0x41f6	Voltage 50% DOD	I2	-32768	32767	3656	mV
Gas Gauging	CEDV Profile 1	0x41f8	Voltage 60% DOD	I2	-32768	32767	3619	mV
Gas Gauging	CEDV Profile 1	0x41fa	Voltage 70% DOD	I2	-32768	32767	3582	mV
Gas Gauging	CEDV Profile 1	0x41fc	Voltage 80% DOD	I2	-32768	32767	3515	mV
Gas Gauging	CEDV Profile 1	0x41fe	Voltage 90% DOD	I2	-32768	32767	3439	mV
Gas Gauging	CEDV Profile 1	0x4200	Voltage 100% DOD	I2	-32768	32767	2713	mV
Gas Gauging	CEDV Profile 2	0x41a9	Design Capacity mAh	I2	0	32767	2200	mAh
Gas Gauging	CEDV Profile 2	0x4202	EMF	U2	0	65535	3743	—
Gas Gauging	CEDV Profile 2	0x4204	C0	U2	0	65535	149	—
Gas Gauging	CEDV Profile 2	0x4206	R0	U2	0	65535	867	—
Gas Gauging	CEDV Profile 2	0x4208	T0	U2	0	65535	4030	—
Gas Gauging	CEDV Profile 2	0x420a	R1	U2	0	65535	316	—
Gas Gauging	CEDV Profile 2	0x420c	TC	U1	0	255	9	—
Gas Gauging	CEDV Profile 2	0x420d	C1	U1	0	255	0	—
Gas Gauging	CEDV Profile 2	0x420e	Age Factor	U1	0	255	0	—
Gas Gauging	CEDV Profile 2	0x420f	Fixed EDV 0	I2	0	32767	3031	—
Gas Gauging	CEDV Profile 2	0x4211	EDV 0 Hold Time	U1	1	255	1	s
Gas Gauging	CEDV Profile 2	0x4212	Fixed EDV 1	I2	0	32767	3385	—
Gas Gauging	CEDV Profile 2	0x4214	EDV 1 Hold Time	U1	1	255	1	s
Gas Gauging	CEDV Profile 2	0x4215	Fixed EDV 2	I2	0	32767	3501	—
Gas Gauging	CEDV Profile 2	0x4217	EDV 2 Hold Time	U1	1	255	1	s
Gas Gauging	CEDV Profile 2	0x4218	Voltage 0% DOD	I2	-32768	32767	4173	mV
Gas Gauging	CEDV Profile 2	0x421a	Voltage 10% DOD	I2	-32768	32767	4043	mV
Gas Gauging	CEDV Profile 2	0x421c	Voltage 20% DOD	I2	-32768	32767	3925	mV
Gas Gauging	CEDV Profile 2	0x421e	Voltage 30% DOD	I2	-32768	32767	3821	mV
Gas Gauging	CEDV Profile 2	0x4220	Voltage 40% DOD	I2	-32768	32767	3725	mV
Gas Gauging	CEDV Profile 2	0x4222	Voltage 50% DOD	I2	-32768	32767	3656	mV
Gas Gauging	CEDV Profile 2	0x4224	Voltage 60% DOD	I2	-32768	32767	3619	mV
Gas Gauging	CEDV Profile 2	0x4226	Voltage 70% DOD	I2	-32768	32767	3582	mV
Gas Gauging	CEDV Profile 2	0x4228	Voltage 80% DOD	I2	-32768	32767	3515	mV
Gas Gauging	CEDV Profile 2	0x422a	Voltage 90% DOD	I2	-32768	32767	3439	mV
Gas Gauging	CEDV Profile 2	0x422c	Voltage 100% DOD	I2	-32768	32767	2713	mV
Gas Gauging	CEDV Profile 3	0x41ad	Design Capacity mAh	I2	0	32767	2200	mAh
Gas Gauging	CEDV Profile 3	0x422e	EMF	U2	0	65535	3743	—

Table 3-3. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Gas Gauging	CEDV Profile 3	0x4230	C0	U2	0	65535	149	—
Gas Gauging	CEDV Profile 3	0x4232	R0	U2	0	65535	867	—
Gas Gauging	CEDV Profile 3	0x4234	T0	U2	0	65535	4030	—
Gas Gauging	CEDV Profile 3	0x4236	R1	U2	0	65535	316	—
Gas Gauging	CEDV Profile 3	0x4238	TC	U1	0	255	9	—
Gas Gauging	CEDV Profile 3	0x4239	C1	U1	0	255	0	—
Gas Gauging	CEDV Profile 3	0x423a	Age Factor	U1	0	255	0	—
Gas Gauging	CEDV Profile 3	0x423b	Fixed EDV 0	I2	0	32767	3031	—
Gas Gauging	CEDV Profile 3	0x423d	EDV 0 Hold Time	U1	1	255	1	s
Gas Gauging	CEDV Profile 3	0x423e	Fixed EDV 1	I2	0	32767	3385	—
Gas Gauging	CEDV Profile 3	0x4240	EDV 1 Hold Time	U1	1	255	1	s
Gas Gauging	CEDV Profile 3	0x4241	Fixed EDV 2	I2	0	32767	3501	—
Gas Gauging	CEDV Profile 3	0x4243	EDV 2 Hold Time	U1	1	255	1	s
Gas Gauging	CEDV Profile 3	0x4244	Voltage 0% DOD	I2	-32768	32767	4173	mV
Gas Gauging	CEDV Profile 3	0x4246	Voltage 10% DOD	I2	-32768	32767	4043	mV
Gas Gauging	CEDV Profile 3	0x4248	Voltage 20% DOD	I2	-32768	32767	3925	mV
Gas Gauging	CEDV Profile 3	0x424a	Voltage 30% DOD	I2	-32768	32767	3821	mV
Gas Gauging	CEDV Profile 3	0x424c	Voltage 40% DOD	I2	-32768	32767	3725	mV
Gas Gauging	CEDV Profile 3	0x424e	Voltage 50% DOD	I2	-32768	32767	3656	mV
Gas Gauging	CEDV Profile 3	0x4250	Voltage 60% DOD	I2	-32768	32767	3619	mV
Gas Gauging	CEDV Profile 3	0x4252	Voltage 70% DOD	I2	-32768	32767	3582	mV
Gas Gauging	CEDV Profile 3	0x4254	Voltage 80% DOD	I2	-32768	32767	3515	mV
Gas Gauging	CEDV Profile 3	0x4256	Voltage 90% DOD	I2	-32768	32767	3439	mV
Gas Gauging	CEDV Profile 3	0x4258	Voltage 100% DOD	I2	-32768	32767	2713	mV
Gas Gauging	CEDV Profile 4	0x41b1	Design Capacity mAh	I2	0	32767	2200	mAh
Gas Gauging	CEDV Profile 4	0x425a	EMF	U2	0	65535	3743	—
Gas Gauging	CEDV Profile 4	0x425c	C0	U2	0	65535	149	—
Gas Gauging	CEDV Profile 4	0x425e	R0	U2	0	65535	867	—
Gas Gauging	CEDV Profile 4	0x4260	T0	U2	0	65535	4030	—
Gas Gauging	CEDV Profile 4	0x4262	R1	U2	0	65535	316	—
Gas Gauging	CEDV Profile 4	0x4264	TC	U1	0	255	9	—
Gas Gauging	CEDV Profile 4	0x4265	C1	U1	0	255	0	—
Gas Gauging	CEDV Profile 4	0x4266	Age Factor	U1	0	255	0	—
Gas Gauging	CEDV Profile 4	0x4267	Fixed EDV 0	I2	0	32767	3031	—
Gas Gauging	CEDV Profile 4	0x4269	EDV 0 Hold Time	U1	1	255	1	s
Gas Gauging	CEDV Profile 4	0x426a	Fixed EDV 1	I2	0	32767	3385	—
Gas Gauging	CEDV Profile 4	0x426c	EDV 1 Hold Time	U1	1	255	1	s
Gas Gauging	CEDV Profile 4	0x426d	Fixed EDV 2	I2	0	32767	3501	—
Gas Gauging	CEDV Profile 4	0x426f	EDV 2 Hold Time	U1	1	255	1	s
Gas Gauging	CEDV Profile 4	0x4270	Voltage 0% DOD	I2	-32768	32767	4173	mV
Gas Gauging	CEDV Profile 4	0x4272	Voltage 10% DOD	I2	-32768	32767	4043	mV
Gas Gauging	CEDV Profile 4	0x4274	Voltage 20% DOD	I2	-32768	32767	3925	mV
Gas Gauging	CEDV Profile 4	0x4276	Voltage 30% DOD	I2	-32768	32767	3821	mV
Gas Gauging	CEDV Profile 4	0x4278	Voltage 40% DOD	I2	-32768	32767	3725	mV
Gas Gauging	CEDV Profile 4	0x427a	Voltage 50% DOD	I2	-32768	32767	3656	mV
Gas Gauging	CEDV Profile 4	0x427c	Voltage 60% DOD	I2	-32768	32767	3619	mV
Gas Gauging	CEDV Profile 4	0x427e	Voltage 70% DOD	I2	-32768	32767	3582	mV
Gas Gauging	CEDV Profile 4	0x4280	Voltage 80% DOD	I2	-32768	32767	3515	mV
Gas Gauging	CEDV Profile 4	0x4282	Voltage 90% DOD	I2	-32768	32767	3439	mV
Gas Gauging	CEDV Profile 4	0x4284	Voltage 100% DOD	I2	-32768	32767	2713	mV
Gas Gauging	Design	0x41b5	Design Voltage	I2	0	32767	3700	mV

Table 3-3. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Gas Gauging	Cycle	0x41b7	Cycle Count Percentage	U1	0	100	90	%
Gas Gauging	FD	0x41bc	Set Voltage Threshold	I2	0	5000	3000	mV
Gas Gauging	FD	0x41be	Clear Voltage Threshold	I2	0	5000	3100	mV
Gas Gauging	FD	0x41c0	Set % RSOC Threshold	U1	0	100	0	%
Gas Gauging	FD	0x41c1	Clear % RSOC Threshold	U1	0	100	5	%
Gas Gauging	FC	0x41c2	Set Voltage Threshold	I2	0	5000	4200	mV
Gas Gauging	FC	0x41c4	Clear Voltage Threshold	I2	0	5000	4100	mV
Gas Gauging	FC	0x41c6	Set % RSOC Threshold	U1	0	100	100	%
Gas Gauging	FC	0x41c7	Clear % RSOC Threshold	U1	0	100	95	%
Gas Gauging	TD	0x41c8	Set Voltage Threshold	I2	0	5000	3200	mV
Gas Gauging	TD	0x41ca	Clear Voltage Threshold	I2	0	5000	3300	mV
Gas Gauging	TD	0x41cc	Set % RSOC Threshold	U1	0	100	6	%
Gas Gauging	TD	0x41cd	Clear % RSOC Threshold	U1	0	100	8	%
Gas Gauging	TC	0x41ce	Set Voltage Threshold	I2	0	5000	4200	mV
Gas Gauging	TC	0x41d0	Clear Voltage Threshold	I2	0	5000	4100	mV
Gas Gauging	TC	0x41d2	Set % RSOC Threshold	U1	0	100	100	%
Gas Gauging	TC	0x41d3	Clear % RSOC Threshold	U1	0	100	95	%
Gas Gauging	State Profile 1	0x4080	Learned Full Charge Capacity	I2	0	32767	2200	mAh
Gas Gauging	State Profile 1	0x4088	Cycle Count	U2	0	65535	0	—
Gas Gauging	State Profile 2	0x4082	Learned Full Charge Capacity	I2	0	32767	2200	mAh
Gas Gauging	State Profile 2	0x408a	Cycle Count	U2	0	65535	0	—
Gas Gauging	State Profile 3	0x4084	Learned Full Charge Capacity	I2	0	32767	2200	mAh
Gas Gauging	State Profile 3	0x408c	Cycle Count	U2	0	65535	0	—
Gas Gauging	State Profile 4	0x4086	Learned Full Charge Capacity	I2	0	32767	2200	mAh
Gas Gauging	State Profile 4	0x408e	Cycle Count	U2	0	65535	0	—
Gas Gauging	CEDV cfg	0x428a	Battery Low %	U2	0	65535	700	.01 %
Gas Gauging	CEDV cfg	0x4295	Learning Low Temp	U1	0	255	119	0.1 °C
Gas Gauging	CEDV cfg	0x429e	OverLoad Current	I2	0	32767	5000	mA
Gas Gauging	CEDV cfg	0x42a2	Self Discharge Rate	U1	0	255	20	0.01%/day
Gas Gauging	CEDV cfg	0x42a3	Electronics Load	I2	0	255	0	3µA
Gas Gauging	CEDV cfg	0x42a5	Near Full	I2	0	32767	200	mAh
Gas Gauging	CEDV cfg	0x42a7	Reserve Capacity	I2	0	32767	0	mAh
Gas Gauging	CEDV cfg	0x42a9	Chg Eff	U1	0	100	100	%
Gas Gauging	CEDV cfg	0x42aa	Dsg Eff	U1	0	100	100	%
Gas Gauging	CEDV Smoothing Config	0x42ab	Smoothing Config	H1	0x00	0xff	0x08	Hex
Gas Gauging	CEDV Smoothing Config	0x42ac	Smoothing Start Voltage	I2	0	4300	3700	mV
Gas Gauging	CEDV Smoothing Config	0x42ae	Smoothing Delta Voltage	I2	0	4200	100	mV
Gas Gauging	CEDV Smoothing Config	0x42b0	Max Smoothing Current	I2	0	32767	8000	s
Gas Gauging	CEDV Smoothing Config	0x42b5	EOC Smooth Current	U1	0	10	2	0.1%
Gas Gauging	CEDV Smoothing Config	0x42b6	EOC Smooth Current Time	U1	0	255	60	s
Authenticate	Data	0x411a	Address	H2	0x0000	0xffff	0x0000	—
Authenticate	Data	0x411c	Length	H1	0x00	0xff	0x00	—
Authenticate	Data	0x411d	Data1	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x411e	Data2	H1	0x00	0xff	0x00	Hex

Table 3-3. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Authenticate	Data	0x411f	Data3	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4120	Data4	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4121	Data5	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4122	Data6	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4123	Data7	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4124	Data8	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4125	Data9	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4126	Data10	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4127	Data11	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4128	Data12	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4129	Data13	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x412a	Data14	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x412b	Data15	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x412c	Data16	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x412d	Data17	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x412e	Data18	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x412f	Data19	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4130	Data20	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4131	Data21	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4132	Data22	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4133	Data23	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4134	Data24	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4135	Data25	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4136	Data26	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4137	Data27	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4138	Data28	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4139	Data29	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x413a	Data30	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x413b	Data31	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x413c	Data32	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x413d	Data33	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x413e	Data34	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x413f	Data35	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4140	Data36	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4141	Data37	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4142	Data38	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4143	Data39	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4144	Data40	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4145	Data41	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4146	Data42	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4147	Data43	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4148	Data44	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4149	Data45	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x414a	Data46	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x414b	Data47	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x414c	Data48	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x414d	Data49	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x414e	Data50	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x414f	Data51	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4150	Data52	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4151	Data53	H1	0x00	0xff	0x00	Hex

Table 3-3. Data Flash Table (continued)

Class	Subclass	Address	Name	Type	Min Value	Max Value	Default	Units
Authenticate	Data	0x4152	Data54	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4153	Data55	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4154	Data56	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4155	Data57	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4156	Data58	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4157	Data59	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4158	Data60	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x4159	Data61	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x415a	Data62	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x415b	Data63	H1	0x00	0xff	0x00	Hex
Authenticate	Data	0x415c	Data64	H1	0x00	0xff	0x00	Hex

Functional Description

4.1 Flash Updates

Data flash can only be updated if *Voltage()* ≥ ***Flash Update OK Voltage***. Flash programming current can cause an increase in LDO dropout. The value of ***Flash Update OK Voltage*** must be selected such that the V_{CC} voltage does not fall below its minimum of 2.4 V during flash write operations. Data flash updates can occur at any time during gauge operation. During data flash updates, the gauge may stretch the I^2C clock significantly. See Section 5.4, *I^2C Clock Stretching*, for more information.

The SOC_INT pin can be configured to generate a pulse before and during data flash updates if desired. This is disabled by default. See Section 4.3.4, *SOC_INT Pin Behavior*, for details.

4.2 Device Configuration

The configuration options are configured via the following ***Operation Configuration A*** and ***Operation Configuration B*** data flash registers. These registers are programmed and read via the methods described in Section 3.1, *Accessing the Data Flash*.

4.2.1 CEDV Smoothing Config Register

Table 4-1. CEDV Smoothing Config Register Bit Definition

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
	RSVD	RSVD	RSVD	RSVD	SMOOTHEOC_EN	SMEXT	VAVG	SMEN
Default	0	0	0	0	1	0	0	0
	0x00							

RSVD = Reserved

SMOOTHEOC_EN When enabled, the RSOC value is modified (see *CEDV Smoothing* for details).

SMEXT = When set to 1, smoothing will continue to EDV1 and EDV0 points. When set to 0, smoothing will stop at EDV2. Default is 0.

VAVG = When set to 1, smoothing uses average voltage. When set to 0, smoothing will use measured voltage. Default is 0.

SMEN = When set to 1, the smoothing result will be reported on *RemainingCapacity()*. When set to 0, the normal CEDV remaining capacity will be reported. Default is 0.

4.2.2 Battery Identification (Battery ID) Register

Table 4-2. Battery ID Register Bit Definition

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	BATT_ID1	BATT_ID0
Default	0	0	0	0	0	0	0	0
	0x00							

RSVD = Reserved

BATT_ID1, BATT_ID0 = These two bits configure up to for different battery identification options.

4.2.3 Operation Configuration A (Operation Config A) Register

Table 4-3. Operation Config A Register Bit Definition

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
High Byte	TEMPS	ID_CFG	BATG_POL	BATG_SPUEN	RSVD	SLEEP	SLPWAKECHG	WRTEMP
Default	0	0	0	0	0	1	0	0
	0x00							
Low Byte	BIEnable	BATG_OVR	GNDSEL	PFC_CFG1	PFC_CFG0	IWAKE	RSNS1	RSNS0
Default	1	0	0	0	0	1	0	0
	0x00							

High Byte

TEMPS = When set to 1, the external thermistor is selected for *Temperature()* measurements.

ID_CFG = Enables use of SDQ based authentication feature with external bq2022A

BATG_POL = BAT_GD pin polarity control. Active-low is 0. Active-high is 1.

BATG_SPUEN = Enables internal pull-up resistor to VCC (2.5 V) on BAT_GD pin. True when set.

RSVD = Reserved

SLEEP = The fuel gauge can enter SLEEP, if operating conditions allow. True when set.

SLPWAKECHG = Accumulate estimated charge on wake from sleep when *Current()* > ***Sleep Current*** but not enough to trigger wake event. Enabled when set.

WRTEMP = Enables the temperature write. The temperature is expected to be written by the host and is used for gauging. Neither the external thermistor nor the internal temperature sensor is used. True when set. (May not be fully implemented.)

Low Byte

BIEnable = When enabled, the gas gauge detects battery insertion using the TS pin. If disabled, the gas gauge relies on the host to set and clear the *BatteryStatus()[BATTPRES]* bit using *BAT_INSERT()* or *BAT_REMOVE()* subcommands. True when set.

BATG_OVR = If the gauge enters HIBERNATE only due to the cell voltage and the PFC_CFG is not set to 3, the BAT_GD pin will deassert.

GNDSEL = The ADC ground select control. The VSS (pin D1) is selected as ground reference when the bit is clear.

PFC_CFG1, PFC_CFG0 = Pin function code (PFC) mode selection: PFC 0, 1, 2, or 3 selected by 00, 01, 10, or 11, respectively (see Section 4.3.1, *Pin Function Code (PFC) Descriptions*).

IWAKE, RSNS1, RSNS0 = These bits configure the current wake function (see Section 4.3.7, *Wake-Up Comparator*).

4.2.4 Operation Configuration B (Operation Config B) Register

Table 4-4. Operation Config B Register Bit Definitions

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
High Byte	RSVD	RSVD	RSVD	RSVD	RSVD	NR	RSVD	RSVD
Default	0	0	0	0	0	0	0	0
	0x00							
Low Byte	INT_BREM	INT_BATL	INT_STATE	INT_OCV	INT_DFW	INT_OT	INT_POL	INT_FOCV
Default	0	0	0	0	0	0	0	0
	0x00							

High Byte

RSVD = Reserved

NR = Non-Removable

Low Byte

INT_BREM = The SOC_INT pulses 1 ms when the battery is removed and ***[BIEnable]*** = 1. Enabled when set.

INT_BATL = Enables toggle of SOC_INT pin upon a change in TDA.

INT_STATE = Enables SOC_INT pin function to pulse SOC_INT pin on current direction change.

INT_OCV = Enables SOC_INT pin function to generate a pulse due to OCV command

INT_DFW = Enables SOC_INT pin function to generate a pulse due to data flash write, requires ***DF Write Indication Wait*** > 0

INT_OT = Enables SOC_INT pin function to generate a pulse due to overtemperature conditions in conjunction with the assertion of *BatteryStatus()[OTC or OTD]*

INT_POL = SOC_INT pin polarity control. Active-low is 0. Active-high is 1.

INT_FOCV = The SOC_INT pulses during the first measurement if this bit is set.

4.3 External Pin Functions

4.3.1 Pin Function Code (PFC) Descriptions

This gas gauge has several pin-function configurations available for the end application. Each configuration is assigned a pin function code, or PFC, specified by the ***Operation Config A [PFC_CFG1, PFC_CFG0]*** bits (see Table 4-5). If the gas gauge is configured to measure external temperature via the ***Operation Config A [TEMPS]*** bit, a voltage bias of approximately 125 ms is applied periodically to the external thermistor network in order to make a temperature measurement.

Table 4-5. Pin Function Code Summary

<table>
<tr><th rowspan="2">PFC</th><th rowspan="2">PFC_CFG [1:0]</th><th colspan="3">External Thermistor Bias Rate ([TEMPS] = 1 only)</th><th rowspan="2">BAT_GD Pin Usage for PFC</th><th rowspan="2">Pin Function Description</th></tr>
<tr><th>Discharge</th><th>Charge</th><th>Sleep</th></tr>
<tr><td>0</td><td>00</td><td rowspan="4">1/s</td><td rowspan="2">1/s</td><td rowspan="4">1/20 s</td><td>NA</td><td>A dedicated external thermistor is used for the gas gauge to monitor battery temperature in all conditions. The BAT_GD pin is not used to interface with a charger IC.</td></tr>
<tr><td>1</td><td>01</td><td>Temperature-based Charge Inhibit</td><td>A dedicated external thermistor is used for the gas gauge to monitor battery temperature in all conditions. If battery charging temperature falls outside of the preset range defined in data flash, a charger can be disabled via the BAT_GD pin until cell temperature recovers. See Section 4.5.2, Charge Inhibit, for additional details.</td></tr>
<tr><td>2</td><td>10</td><td>None</td><td>NA</td><td>A shared external thermistor is supported between the gas gauge and a charger IC; however, the BAT_GD pin is not used to interface with the charger IC. The gas gauge biases the thermistor for battery temperature measurement and BAT INSERT CHECK mode (if Operation Config B [BIEnable] bit = 1) under discharge and relaxation conditions only so the charger IC can separately bias the thermistor during CHARGE mode. Bias networks required by the gas gauge and the charger for the thermistor must be identical.</td></tr>
<tr><td>3</td><td>11</td><td>1/s</td><td>Follows BatteryStatus()[FC] flags bit</td><td>Disables a battery charger IC when gas gauge has determined the battery is fully charged. The BAT_GD pin reflects the logical status of the BatteryStatus()[FC] bit and is typically connected directly to the charger Charge Enable/Disable (CE/CD) pin or via a network to drive the charger Temperature Sense (TS) pin.</td></tr>
</table>

4.3.2 SDQ Pin

The SDQ pin provides a single-wire communication interface to an authentication ID IC. The communication protocol is based on the standard interface timing specifications used in the bq2022A device from Texas Instruments.

4.3.3 Battery Presence Detection Using the BI/TOUT Pin

During power-up or hibernate activities or any other activity where the gas gauge needs to determine whether or not a battery is connected, the gas gauge applies a test for battery presence when the ***Operation Config B [BIEnable]*** bit is set. First, the BI/TOUT pin is put into high-Z status. The weak 1.8-MΩ pull-up resistor keeps the pin high while no battery is present. When a battery is inserted (or is already inserted) into the system device, the BI/TOUT pin is pulled low. This state is detected by the gas gauge, which polls this pin every second when the gauge has power. A battery-disconnected status is assumed when the gas gauge reads a thermistor voltage that is near 2.5 V.

When a thermistor is not used by the system for the gauge to detect battery insertion, there are two options. First, the BI/TOUT pin can be tied to V_{SS} with a resistor so the gauge always considers a battery to be present if it has power. Second, the ***Operation Config B [BIEnable]*** bit can be cleared so the host can inform the gauge of the battery status via the *BAT_INSERT()* and *BAT_REMOVE()* subcommands.

4.3.4 SOC_INT Pin Behavior

The SOC_INT pin generates a pulse of different pulse widths under various conditions as indicated by Table 4-6. After initialization, only one SOC_INT pulse is generated within any given 1-s time slot and, therefore, may indicate multiple event conditions.

Table 4-6. SOC_INT Pulse Conditions and Widths

Pulse Condition	Enable Condition	Pulse Width	Comment
Change of *StateOfCharge()*	(***SOC Delta***) ≠ 0	1 ms	During charge, when the SOC is greater than (>) the points: 100% – n × (***SOC Delta***) and 100%; During discharge, when the SOC reaches (≤) the points: 100% – n × (***SOC Delta***) and 0%; where n is an integer starting from 0 to the number generating SOC no less than 0%. Examples: For ***SOC Delta*** = 1% (default), the SOC_INT intervals are 0%, 1%, 2%, …, 99%, and 100%. For ***SOC Delta*** = 10%, the SOC_INT intervals are 0%, 10%, 20%, …, 90%, and 100%.
BatteryStatus()[SYSDOWN] set	Always	1 ms	When the *Voltage()* has reached ***SysDown Set Volt Threshold***.
Battery State Change	(***SOC Delta***) ≠ 0 and ***Operation Config B [INT_STATE]*** = 1	1 ms	Upon detection of a state change in battery charging and discharging
Battery Removal	***Operation Config A [BIEnable]*** = 1 and ***Operation Config B [INT_BREM]*** = 1	1 ms	
OCV measurement after initialization	***Operation Config B [INT_FOCV]*** = 1	Approximately 380 ms	Within 1.5 seconds after a POR event, *RESET()* subcommand, wake from hibernate, or battery insertion event (either via *BATT_INSERT()* subcommand or battery present pin), SOC_INT begins a pulse for the duration of the OCV measurement and initialization time period.
OCV measurement from *OCV_CMD()* subcommand	***Operation Config B [INT_OCV]*** = 1	Approximately 260 ms	Within 1 second after receipt of *OCV_CMD()* subcommand, SOC_INT begins a pulse for the duration of the OCV measurement execution time period.
After initialization and ***DF Wr Ind Wait*** ≠ 0	***Operation Config B [INT_DFW]*** = 1	Programmable (see comment)	SOC_INT pin indicates the data flash update. The gauge waits ***DF Wr Ind Wait*** × 5 µs after the SOC_INT signal to start the data flash update. This function is disabled if ***DF Wr Ind Wait*** = 0.
BatteryStatus()[OTC or OTD]	***Operation Config B [INT_OT]*** = 1	1 ms	Upon first assertion of *BatteryStatus()[OTC or OTD]* overtemperature conditions
BatteryStatus()[TDA]	***Operation Config B [INT_BATL]*** = 1	1 ms	On change of *BatteryStatus()[TDA]*

4.3.5 Power Path Control with the BAT_GD Pin

The gas gauge must operate in conjunction with other electronics in a system appliance, such as chargers or other ICs and application circuits that draw appreciable power. After a battery is inserted into the system, it is preferable that no charging current or discharging current higher than C/20 is present, so that an accurate OCV can be read. The OCV reading determines the initial SOC so accuracy of the OCV reading directly impacts the starting SOC. To disable these functions, the BAT_GD pin can be connected to the Charger Enable/Disable (CE/CD) pin to disable the charging function. Once an OCV reading has been made, the BAT_GD pin is asserted, thereby enabling battery charging and regular discharge of the battery. The ***Operation Config A [BATG_POL]*** bit can change the polarity of the BAT_GD pin in case the default configuration needs to be changed for the system application.

Figure 4-1 and Figure 4-2 detail how the BAT_GD pin functions in the context of battery insertion and removal, as well as NORMAL versus SLEEP modes.

In PFC 1, the BAT_GD pin also disables battery charging when the gas gauge reads battery temperatures outside the range defined by [***Charge Inhibit Temp Low***, ***Charge Inhibit Temp High***]. The BAT_GD line is asserted once temperature falls within the range [***Charge Inhibit Temp Low*** + ***Temp Hys***, ***Charge Inhibit Temp High*** – ***Temp Hys***].

4.3.6 Battery Trip Point (BTP) Interrupts

The Battery Trip Point (BTP) feature provides the function to dynamically update capacity-based interrupt thresholds using the *BTPDischargeSet()* and *BTPChargeSet()* commands. Two thresholds are supported: one for crossings in the discharge direction (*RemainingCapacity()* < *BTPDischargeSet()*), and the other used for the charge direction (*RemainingCapacity()* > *BTPChargeSet()*). When a given threshold is breached in the correct current direction, the *OperationStatus[BTPINT]* flag will set to 1 and an interrupt triggered on SOC_INT. Afterwards, writing a new threshold value to either *BTPDischargeSet()* or *BTPChargeSet()* will clear the *OperationStatus[BTPINT]* flag and de-assert the interrupt. The feature is enabled via the ***Settings:Configuration:IO Config[BTP_EN]*** bit and the polarity of the interrupt configured using ***Settings:Configuration:IO Config[BTP_POL]*** where setting to 1 selects active-high and clearing to 0 yields active-low assertion behavior on SOC_INT. It should be further noted that the logic governing trigger of BTP interrupts is dependent on both threshold crossings AND current direction. More specifically, *OperationStatus[BTPINT]* is set to 1 and a BTP pin interrupt triggered when:

- *RemainingCapacity()* < *BTPDischargeSet()* AND *Current()* ≤ 0 OR
- *RemainingCapacity()* < *BTPDischargeSet()* AND *Current()*> 0

At power-on reset, initialization values for *BTPDischargeSet()* and *BTPChargeSet()* are sourced from ***Settings:BTP:Init Discharge Set*** and ***Settings:BTP:Init Charge Set***, respectively.

Table 4-7. BTP IO Config Register Bit Definition

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
	RSVD	RSVD	RSVD	RSVD	RSVD	RSVD	BTP_POL	BTP_EN
Default	0	0	0	0	0	0	0	0
	0x00							

RSVD = Reserved

BTP_POL = BTP Polarity
1= Active High
0 = Active Low

BTP_EN = BTP Enable
1 = BTP Interrupts enabled
0 = BTP Interrupts disabled

NOTE: If BTP Interrupts is enabled, then the SOC_INT pin is dedicated solely to BTP interrupts.

4.3.7 Wake-Up Comparator

The wake-up comparator indicates a change in cell current while the gas gauge is in SLEEP mode. The ***Operation Config A [RSNS1:RSNS0]*** bits select the appropriate comparator threshold for the sense resistor value used. The ***Operation Config A [IWAKE]*** bit selects one of two possible voltage threshold ranges for the given sense resistor selection. An internal interrupt is generated when the threshold is reached in either the charge or discharge direction. Setting both ***[RSNS1]*** and ***[RSNS0]*** bits to 0 disables this feature.

Table 4-8. I_{WAKE} Threshold Settings(1)

RSNS1	RSNS0	IWAKE	Vth (SRP – SRN)
0	0	0	Disabled
0	0	1	Disabled
0	1	0	1.0 mV or –1.0 mV
0	1	1	2.2 mV or –2.2 mV
1	0	0	2.2 mV or –2.2 mV
1	0	1	4.6 mV or –4.6 mV
1	1	0	4.6 mV or –4.6 mV
1	1	1	9.8 mV or –9.8 mV

(1) The actual resistance value versus the setting of the sense resistor is not important; only the actual voltage threshold when calculating the configuration. The voltage thresholds are typical values under room temperature.

4.3.8 Autocalibration

The gas gauge provides an autocalibration feature that measures the voltage offset error across SRP and SRN as operating conditions change. It subtracts the resulting offset error from the normal sense resistor voltage, V_{SR}, for maximum measurement accuracy.

Autocalibration of the coulomb counter begins on entry to SLEEP mode, except if *Temperature()* is ≤ 5°C or *Temperature()* ≥ 45°C.

The gas gauge also performs a single offset when:

- The condition of *AverageCurrent()* ≤ 100 mA.
- {voltage change since last offset calibration ≥ 256 mV} or {temperature change since last offset calibration is greater than 8°C for ≥ 60 s}.

Capacity and current measurements continue at the last measured rate during the offset calibration when these measurements cannot be performed. If the battery voltage drops more than 32 mV during the offset calibration, the load current has likely increased; thus, the offset calibration is aborted. The *CONTROL_STATUS()[CCA]* bit is set during coulomb counter autocalibration.

4.4 Temperature Measurement

The gas gauge typically measures battery temperature via its TS input to supply battery temperature status information to the gas gauging algorithm and charger-control sections of the gauge. Alternatively, it can be configured to use an internal on-chip temperature sensor or receive temperature data from the host processor. See Section 2.4, *Temperature(): 0x06 and 0x07*, for specific information on configuration options. Regardless of which temperature configuration is used, the host processor can request the current battery temperature by reading the *Temperature()*, and for internal temperature, *InternalTemperature()*.

The external thermistor circuit requires the use of an 10K NTC 103AT-type thermistor.

4.4.1 Overtemperature Indication

4.4.1.1 Overtemperature: Charge

If during charging, *Temperature()* reaches the threshold of ***OT Chg*** for a period of ***OT Chg Time***, and *Current()* > ***Chg Current Threshold***, then the *BatteryStatus()[OTC]* bit is set. When *Temperature()* falls to ***OT Chg Recovery***, the *BatteryStatus()[OTC]* bit is cleared.

If ***OT Chg Time*** = 0, then the feature is completely disabled.

4.4.1.2 Overtemperature: Discharge

If during discharging, *Temperature()* reaches the threshold of ***OT Dsg*** for a period of ***OT Dsg Time***, and *Current()* ≤ –***Dsg Current Threshold***, then the *BatteryStatus()[OTD]* bit is set. When *Temperature()* falls to ***OT Dsg Recovery***, the *BatteryStatus()[OTD]* bit is cleared.

If ***OT Dsg Time*** = 0, then the feature is completely disabled.

4.5 Charging and Charge Termination Indication

4.5.1 Detecting Charge Termination

For proper gas gauge operation, the cell ***Charging Voltage*** must be specified by the user.

The gas gauge detects charge termination when:

- During two consecutive periods of 40 seconds, the *AverageCurrent()* < ***Taper Current***.
- During the same two periods, the accumulated change in capacity must be > 0.25 mAh.
- *Voltage()* > ***Charging Voltage – Taper Voltage***.

When this occurs, the *BatteryStatus()[FC]* and *[TCA]* bits are set depending on the ***SOC Flag Config A [FCSETVCT]*** and ***[TCSETVCT]*** options. Also, if the ***CEDV Configuration [CSYNC]*** bit is set, then *RemainingCapacity()* is set equal to *FullChargeCapacity()*.

4.5.2 Charge Inhibit

The gas gauge can indicate when battery temperature has fallen below or risen above predefined thresholds ***Charge Inhibit Temp Low*** or ***Charge Inhibit Temp High***, respectively. In this mode, the *BatteryStatus()[CHGINH]* bit is set to indicate this condition. The *[CHGINH]* bit is cleared once the battery temperature returns to the range ***[Charge Inhibit Temp Low + Temp Hys, Charge Inhibit Temp High – Temp Hys]***.

When *BatteryStatus()[CHGINH]* is set and ***[PFC_CFG]*** = 1, the BAT_GD pin is deasserted. Otherwise, when *[CHGINH]* is clear if *[OCV_GD]* is set and ***[PFC_CFG]*** ≠ 0, the BAT_GD pin is asserted.

The charging should not start when the temperature is below the ***Charge Inhibit Temp Low*** or above the ***Charge Inhibit Temp High***. The charging can continue if the charging starts inside the window [***Charge Inhibit Temp Low***, ***Charge Inhibit Temp High***].

4.6 Power Modes

The gas gauge has different power modes: NORMAL, SNOOZE, SLEEP, HIBERNATE, and BAT INSERT CHECK.

- In NORMAL mode, the gas gauge is fully powered and can execute any allowable task.
- In SNOOZE mode, low-frequency and high-frequency oscillators are active. Although the SNOOZE mode has higher current consumption than the SLEEP mode, it is also a reduced power mode.
- In SLEEP mode, the gas gauge turns off the high-frequency oscillator and exists in a reduced-power state, periodically taking measurements and performing calculations.
- In HIBERNATE mode, the gas gauge is in a low-power state, but can be woken up by communication or certain IO activity.
- BAT INSERT CHECK mode is a powered up, but low-power halted, state, where the gas gauge

resides when no battery is inserted into the system.

Figure 4-1 and Figure 4-2 show the relationship between these modes.

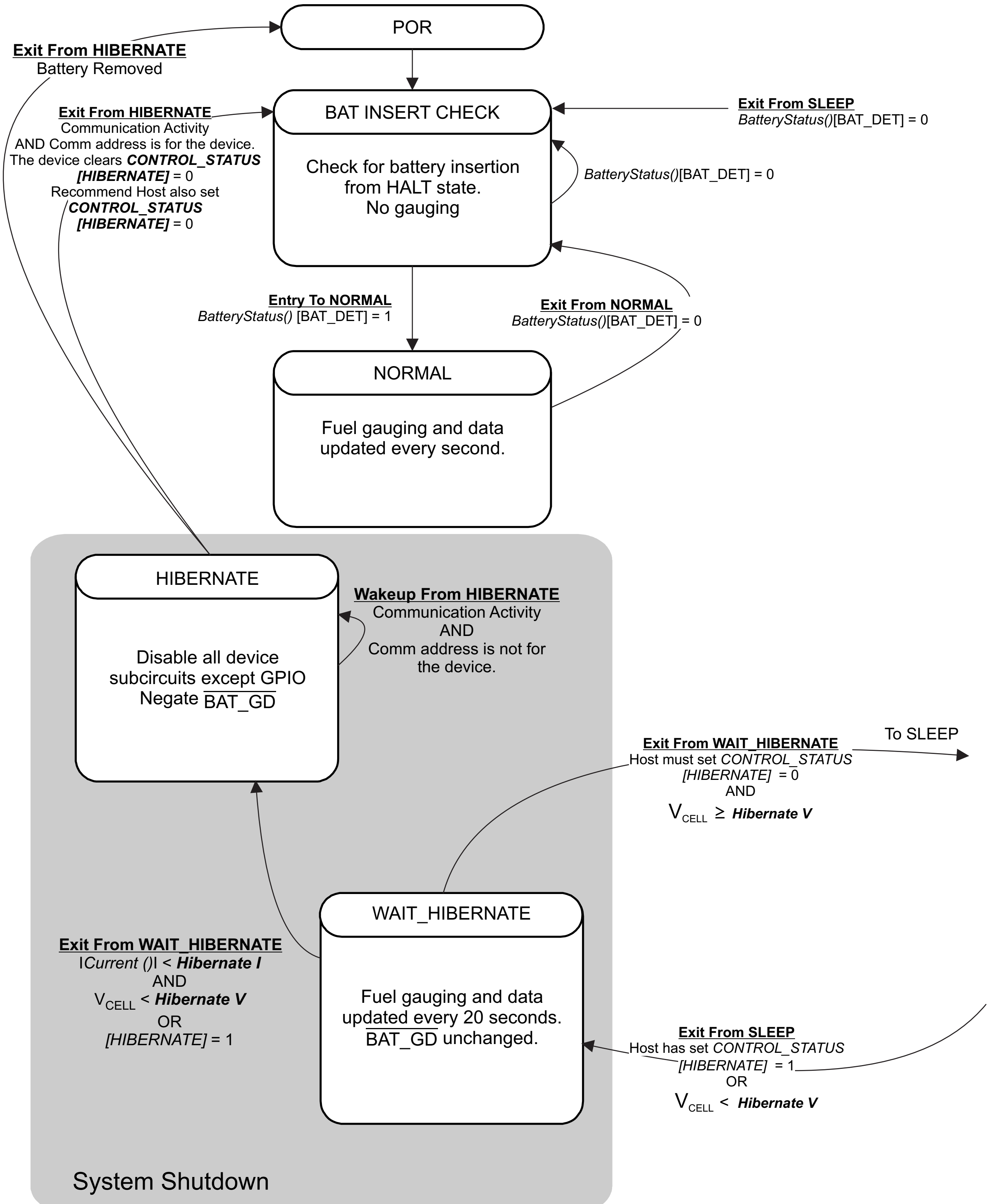


Figure 4-1. Power Mode Diagram for System Shutdown

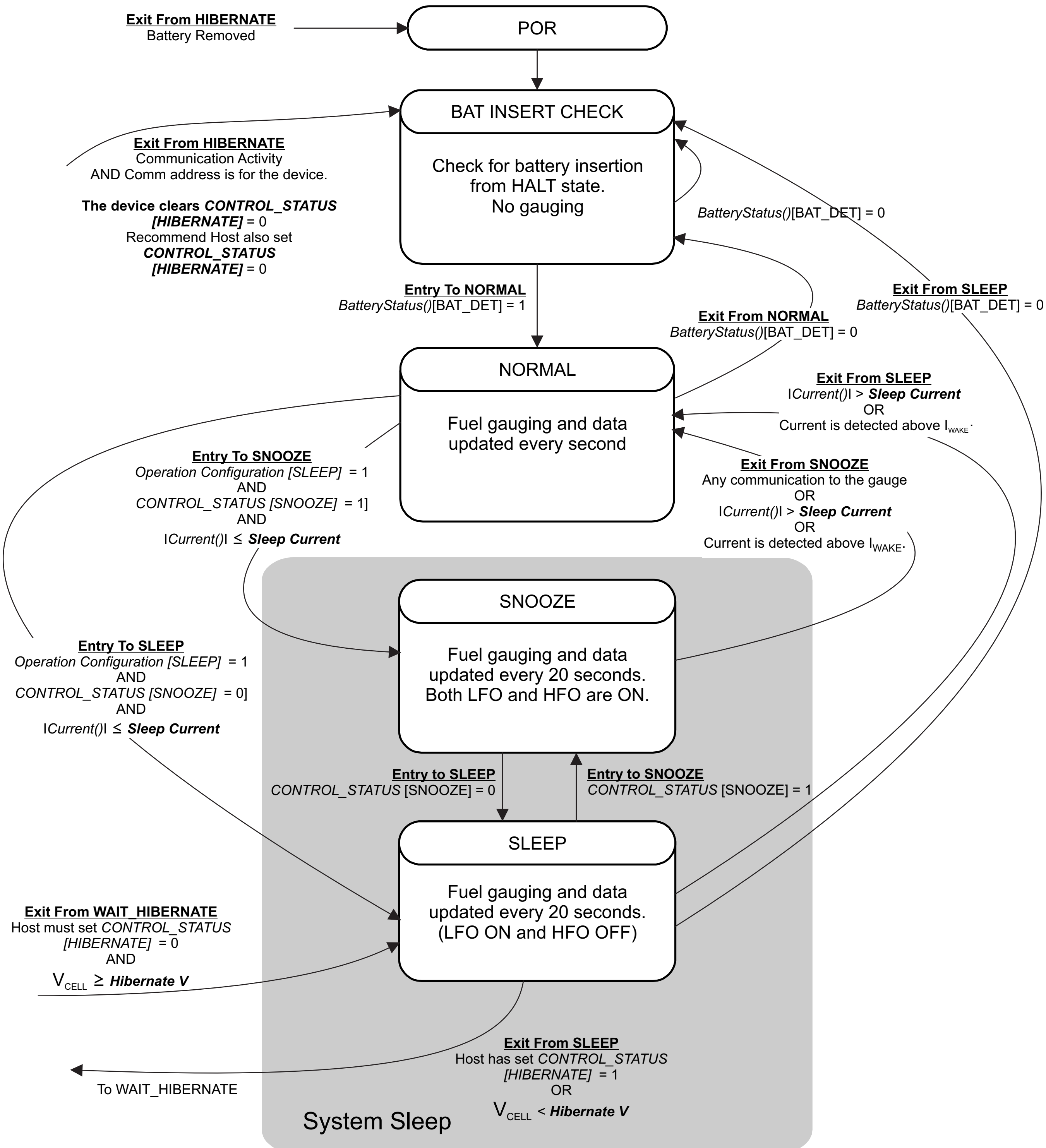


Figure 4-2. Power Mode Diagram for System Sleep

4.6.1 NORMAL Mode

The gas gauge is in NORMAL mode when not in any other power mode. During this mode, *Current()*, *Voltage()*, and *Temperature()* measurements are taken, and the interface data set is updated. Decisions to change states are also made. This mode is exited by activating a different power mode.

Because the gauge consumes the most power in the NORMAL mode, the CEDV algorithm minimizes the time the gas gauge remains in this mode.

4.6.2 SNOOZE Mode

Compared to the SLEEP mode, the SNOOZE mode has the high-frequency oscillator in operation; thus, the communication delay associated with waking up from SLEEP mode can be eliminated. The SNOOZE mode is entered automatically if the feature is enabled (*CONTROL_STATUS()[SNOOZE]* bit = 1) and *Current()* is below the programmable level ***Sleep Current***.

During SNOOZE mode, the gas gauge periodically takes data measurements and updates its data set. However, a majority of its time is spent in an idle condition.

The gas gauge exits the SNOOZE mode if any entry condition is broken, specifically when:

- Any communication activity with the gauge
- *Current()* rises above ***Sleep Current***.
- A current in excess of I_{WAKE} through R_{SENSE} is detected.

4.6.3 SLEEP Mode

SLEEP mode is entered automatically if the feature is enabled (***Operation Config A [SLEEP]*** bit = 1) and *Current()* is below the programmable level ***Sleep Current***. Once entry into SLEEP mode has been qualified, but prior to entering it, the gas gauge performs a coulomb counter autocalibration to minimize offset.

During SLEEP mode, the gas gauge periodically takes data measurements and updates its data set. However, a majority of its time is spent in an idle condition.

The gas gauge exits the SLEEP mode if any entry condition is broken, specifically when either:

- *Current()* rises above ***Sleep Current***.
- A current in excess of I_{WAKE} through R_{SENSE} is detected.

In the event that a battery is removed from the system while a charger is present (and powering the gauge), CEDV updates are not necessary. Thus, the gas gauge enters a state that checks for battery insertion and does not continue executing the CEDV algorithm.

4.6.4 HIBERNATE Mode

The HIBERNATE mode should be used when the system equipment needs to enter a low-power state, and minimal gauge power consumption is required. This mode is ideal when system equipment is set to its own HIBERNATE, SHUTDOWN, or OFF mode.

For normal entry to the HIBERNATE mode, the system must set the *CONTROL_STATUS()[HIBERNATE]* bit by issuing a *SET_HIBERNATE()* subcommand. The gauge does not enter the HIBERNATE mode until a valid OCV measurement is made and the magnitude of the average cell current has fallen below ***Hibernate I***. Regardless of the *CONTROL_STATUS()[HIBERNATE]* bit status, the gauge can also enter the HIBERNATE mode if *Voltage()* falls below ***Hibernate V*** and a valid OCV measurement has been taken. The gauge remains in the HIBERNATE mode until the system issues a direct I^2C command to the gauge or a POR occurs. I^2C communication that is not directed to the gauge does not wake the gauge.

For proper system-level coordination of the HIBERNATE mode with the use of a charger IC, see Table 4-5, *Pin Function Code Descriptions*. It is important to prevent a charger from inadvertently charging the battery before an OCV reading can be taken. It is the system’s responsibility to wake the gas gauge after it has gone into the HIBERNATE mode. After waking, the gauge can proceed with the initialization of the battery information (OCV, profile selection, and so on).

4.7 BAT INSERT CHECK Mode

This mode is a halted-CPU state that occurs when an adapter or other power source is present to power the gas gauge (and system), yet no battery has been detected. If enabled via the ***Operation Config B [BIEnable]*** bit, the gas gauge detects battery insertion either through use of the thermistor network or the BI/TOUT pin. Alternatively, the host can use the *BAT_INSERT()* and *BAT_REMOVE()* subcommands to inform the battery presence or removal status. When battery insertion is detected, a series of initialization activities begin, which include: OCV measurement, setting the BAT_GD pin, and selecting the appropriate battery profiles.

Some commands, issued by a system processor, can be processed while the gas gauge is halted in this mode. The gauge wakes up to process the command, then returns to the halted state awaiting battery insertion.

4.8 Application-Specific Information

4.8.1 Battery Profile Storage and Selection

The gas gauge supports only one type of OCV profile (chemistry). When a battery pack is inserted, the battery OCV profile is used by the CEDV algorithm to estimate initial SOC.

In addition to the chemistry, the gas gauge maintains four battery profiles based on ***Battery ID*** settings. These select one of four CEDV profiles and their associated state data. When a battery pack is removed from the host equipment, the gas gauge maintains some of the battery information in case the battery is re-inserted. Thus, the CEDV algorithm has a means of recovering battery state information to provide better state-of-charge (SOC) estimates.

When an existing pack is removed from the gas gauge and a different (or same) pack is inserted, a new set of parameters is loaded from the gas gauge to match the selected ***Battery ID***. This must be done through control commands, using BATT_SELECT_x. The gas gauge will use the selected profile information to set the required parameters for gas gauging accuracy.

4.8.2 First OCV Measurement

Upon power-up or pack insertion, an open-circuit voltage (OCV) measurement of the battery is made via the BAT pin. For best gauging results, the system load during the OCV measurement should not exceed a C/20 discharge rate of the battery. For this first critical measurement, both BAT_GD and SOC_INT pins are available for system synchronization. (See Section 4.3.5, *Power Path Control with the BAT_GD Pin*, Section 4.3.4, *SOC_INT Pin Behavior*, and Section 2.1.13, *OCV_CMD: 0x000C*.)

Upon completion of the OCV voltage measurement, the *BatteryStatus()[OCVCOMP]* is set.

4.9 Additional Data Flash Parameter Descriptions

4.9.1 Calibration

The calibration method requires a correction due to offset errors, using a number of samples to get a statistical average for the golden image. The parameters for this are listed in the following sections.

4.9.1.1 CC Gain

CC Gain sets the mA current scale factor for the coulomb counter. Use calibration routines to set this value.

4.9.1.2 CC Delta

CC Delta sets the mAh capacity scale factor for the coulomb counter. Use calibration routines to set this value.

4.9.1.3 Coulomb Counter Offset

This register value stores the coulomb counter offset compensation. It is set by automatic calibration of the device.

4.9.2 Board Offset

This register value stores the compensation for the PCB dependent coulomb counter offset. It is recommended to use characterization data of the actual PCB to set this value.

4.9.3 Int Temp Offset

This register value stores the internal temperature sensor offset compensation. Use calibration routines to set this value.

4.9.4 Ext Temp Offset

This register value stores the external temperature sensor offset compensation. Use calibration routines to set this value.

4.9.5 Pack VOffset

This register value stores the Pack voltage offset measured at the Pack pin. Use calibration routines to set this value.

4.9.6 Internal Temp Model

These values characterize the internal thermistor of the device. Do not modify these values without consulting TI.

Table 4-9. Int Coef 1..4, Int Min AD, Int Max Temp

Subclass Name	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Temp Model	Int Coef 1	Signed Integer	2	–32768	32767	0	
	Int Coef 2					0	
	Int Coef 3					–12324	
	Int Coef 4					6131	0.1K
	Int Min AD					0	
	Int Max Temp					6131	0.1K

4.9.6.1 Ext Coef 1..5, b1..b4, Ext rc0, Ext adc0

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 4-10. Ext Coef 1..5, b1..b4, Ext rc0, Ext adc0

Subclass Name	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Temp Model	Ext Coef 1	Signed Integer	2	–32768	32767	–11130	num
	Ext Coef 2					19142	
	Ext Coef 3					–19262	
	Ext Coef 4					28203	
	Ext Coef 5					892	
	Ext Coef b1					328	
	Ext Coef b2					–605	
	Ext Coef b3					–2443	
	Ext Coef b4					4696	
	Ext rc0					11703	
	Ext adc0					11338	

4.9.7 Vcomp Coeff 1..4, Internal Multiplier, Output Divisor

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 4-11. Vcomp Coef 1..4, Internal Multiplier, Output Divisor

Subclass Name	Name	Format	Size in Bytes	Min Value	Max Value	Default Value	Unit
Temp Model	Vcomp Coef 1	Signed Integer	2	–32768	32767	0	num
	Vcomp Coef 2					14902	
	Vcomp Coef 3					–623	
	Vcomp Coef 4					37	
	Vcomp Output Divisor					256	
	Vcomp Input Multiplier	Unsigned Byte	1	0	255	48	

4.9.8 External ADC0

This register value stores the characterization data for the external thermistor connected on TS pin. The default values are in referenced for Semitec 103AT NTC thermistor. Do NOT modify.

4.9.9 External RC0

This register value stores the characterization data for the external thermistor connected on TS pin. The default values are in referenced for Semitec 103AT NTC thermistor. Do NOT modify.

4.9.10 Filter

Defines the filter constant used in ± *AverageCurrent()* calculation:

AverageCurrent() = a × *AverageCurrent()* old + (1-a) × *Current()* with:

a = ***Filter***/256; time constant = 1 s/in(1/a) (default = 14.5 s)

4.9.11 Deadband

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

4.9.12 CC Deadband

This constant defines the deadband voltage for the measured voltage between the SRP and SRN pins used for capacity accumulation in units of 294 nV. Any voltages within ±***CC Deadband*** do not contribute to capacity accumulation.

4.9.13 SOC Flag Configuration A (SOC Flag Config A) Register

The settings in ***SOC Flag Config A*** configure how the *[TC]*, *[FC]*, and *[TD]* flags in *GaugingStatus()* set and clear. These flags are also used to set the *[TCA]*, *[TDA]*, and *[FC]* flags in *BatteryStatus()*.

Table 4-12. SOC Configuration Flag A Register Bit Definitions

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
High Byte	RSVD	RSVD	RSVD	RSVD	TCSETVCT	FCSETVCT	RSVD	RSVD
Default	0	0	0	0	1	1	0	0
	0x0C							
Low Byte	TCCLEAR RSOC	TCSET RSOC	TCCLEARV	TCSETV	TDCLEAR RSOC	TDSET RSOC	TDCLEARV	TDSETV
Default	1	0	0	0	1	1	0	0
	0x8C							

RSVD = Reserved

TCSETVCT= Enables *BatteryStatus()[TCA]* flag set on primary charge termination
- 0 = Disabled
- 1 = Enabled (default)

FCSETVCT= Enables *BatteryStatus()[FC]* flag set on primary charge termination
- 0 = Disabled
- 1 = Enabled (default)

TCCLEARRSOC = Enables *BatteryStatus()[TCA]* flag clear when *RelativeStateOfCharge()* ≤ ***TC:Clear % RSOC Threshold***
- 0 = Disabled
- 1 = Enabled (default)

TCSETRSOC = Enables *BatteryStatus()[TCA]* flag set when *RelativeStateOfCharge()* ≥ ***TC:Set % RSOC Threshold***
- 0 = Disabled (default)
- 1 = Enabled

TCCLEARV = Enables *BatteryStatus()[TCA]* flag clear when *Voltage()* ≤ ***TC:Clear Voltage Threshold***
- 0 = Disabled (default)
- 1 = Enabled

TCSETV = Enables *BatteryStatus()[TCA]* flag set when *Voltage()* ≥ ***TC:Set Voltage Threshold***
- 0 = Disabled (default)
- 1 = Enabled

TDCLEARRSOC = Enables *BatteryStatus()[TDA]* flag clear when *RelativeStateOfCharge()* ≥ ***TD:Clear % RSOC Threshold***
- 0 = Disabled
- 1 = Enabled (default)

TDSETRSOC = Enables *BatteryStatus()[TDA]* flag set when *RelativeStateOfCharge()* ≤ ***TD:Set % RSOC Threshold***
- 0 = Disabled
- 1 = Enabled (default)

TDCLEARV = Enables *BatteryStatus()[TDA]* flag clear when *Voltage()* ≥ ***TD:Clear Voltage Threshold***
- 0 = Disabled (default)
- 1 = Enabled

TDSETV = Enables *BatteryStatus()[TDA]* flag set when *Voltage()* ≤ ***TD:Set Voltage Threshold***
- 0 = Disabled (default)
- 1 = Enabled

4.9.14 SOC Flag Configuration B (SOC Flag Config B) Register

Table 4-13. SOC Configuration Flag B Register Bit Definitions

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
	FCCCLEAR RSOC	FCSET RSOC	FCCLEARV	FCSETV	FDCLEAR RSOC	FDSET RSOC	FDCLEARV	FDSETV
Default	1	0	0	0	1	1	0	0
	0x8C							

FCCLEARRSOC = Enables *BatteryStatus()[FC]* flag clear when *RelativeStateOfCharge()* ≤ ***FC:Clear % RSOC Threshold***
0 = Disabled
1 = Enabled (default)

FCSETRSOC = Enables *BatteryStatus()[FC]* flag set when *RelativeStateOfCharge()* ≥ ***FC:Set % RSOC Threshold***
0= Disabled (default)
1 = Enabled

FCCLEARV = Enables *BatteryStatus()[FC]* flag clear when *Voltage()* ≤ ***FC:Clear Voltage Threshold***
0 = Disabled (default)
1 = Enabled

FCSETV = Enables *BatteryStatus()[FC]* flag set when *Voltage()* ≥ ***FC:Set Voltage Threshold***
0 = Disabled (default)
1 = Enabled

FDCLEARRSOC = Enables *BatteryStatus()[FD]* flag clear when *RelativeStateOfCharge()* ≥ ***FD:Clear % RSOC Threshold***
0 = Disabled
1 = Enabled (default)

FDSETRSOC = Enables *BatteryStatus()[FD]* flag set when *RelativeStateOfCharge()* ≤ ***FD:Set % RSOC Threshold***
0 = Disabled
1 = Enabled (default)

FDCLEARV = Enables *BatteryStatus()[FD]* flag clear when *Voltage()* ≥ ***FD:Clear Voltage Threshold***
0 = Disabled (default)
1 = Enabled

FDSETV = Enables *BatteryStatus()[FD]* flag set when *Voltage()* ≤ ***FD:Set Voltage Threshold***
0 = Disabled (default)
1 = Enabled

4.9.15 CEDV Gauging Configuration (CEDV Config) Register

Table 4-14. CEDV Gauging Configuration Register Bit Definitions

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
High Byte	RSVD	RSVD	RSVD	SME0	IGNORE _SD	FC_FOR _VDQ	RSVD	FCC_LIMIT
Default	0	0	0	1	1	0	0	0
Low Byte	RSVD	RSVD	FIXED_EDV0	SC	EDV_CMP	RSVD	CSYNC	CCT
Default	0	0	1	0	1	0	1	0

SME0 = SeeTable 4-1 for usage.

IGNORE_SD = Coulomb count modification. See *RawCoulombCount()* for details.

FC_FOR_VDQ = Requires FC = 1 to set VDQ.

FCC_LIMIT = Learned FCC is not allowed to be higher than *DesignCapacity()*. Enabled when set.

FIXED_EDV0 = This bit is used when ***[EDV_CMP]*** = 1 to determine of EDV0 will use fixed threshold.

When set to 1, ***Fixed EDV0*** will be used.
When set to 0, dynamic EDV0 will be used (default).

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 Charger

EVD_CMP = Method to calculate EDV compensation
0 = Use fixed EDV values
1 = Use the EDV compensation to calculate the EDV values.

CSYNC = Sync *RemainingCapacity()* with *FullChargeCapacity()* at valid charge termination;
0 = NOT Synchronized (default)
1 = Synchronized

CCT = Cycle Count Threshold
0 = Use CC % of *DesignCapacity()*(default)
1 = Use CC % of *FullChargeCapacity()*

4.9.16 EMF

This value is the no-load cell voltage higher than the highest cell EDV threshold computed.

4.9.17 C0

This value is the no-load, capacity related EDV adjustment factor.

4.9.18 R0

This value is the first order rate dependency factor, accounting for battery impedance adjustment.

4.9.19 T0

This value adjusts the variation of impedance with battery temperature.

4.9.20 R1

This value adjusts the variation of impedance with battery capacity.

4.9.21 TC

This value adjusts the variation of impedance for cold temperatures ($T < 23°C$).

4.9.22 C1

This value is the desired reserved battery capacity remaining at EDV0.

4.9.23 Age Factor

This value allows the bq27320 to correct the EDV detection algorithm to compensate for cell aging.

4.9.24 Fixed EDV0

This value is the EDV0 threshold if ***[CEDV]*** is clear in ***CEDV Config***.

4.9.25 Fixed EDV1

This value is the EDV1 threshold if ***[CEDV]*** is clear in ***CEDV Config***.

4.9.26 Fixed EDV2

This value is the EDV2 threshold if ***[CEDV]*** is clear in ***CEDV Config***.

4.9.27 Battery Low %

The value sets should correspond to the capacity value that reflects the highest voltage point.

4.9.28 Low Temp Learning

This value specifies the minimum temperature above, which a discharge must maintain to qualify for capacity learning.

4.9.29 Overload Current

This value sets the upper current range for EDV detection, beyond which EDV detection is halted.

4.9.30 Self Discharge Rate

This value is the estimated self-discharge rate of battery.

4.9.31 Electronic Load

This value should be set to a discharge rate determined by the battery electronics current consumption.

4.9.32 Near Full

This value sets the start of discharge condition for qualified capacity learning.

4.9.33 Reserve Capacity

This value determines how much actual remaining capacity exists when the fuel gauge reports zero for *RemainingCapacity()* before reaching EDV0. This accommodates a controlled shutdown based on battery capacity rather than a specific voltage.

NOTE: If the ***Reserve Capacity*** is non-zero, then it should be added to the desired ***Near Full*** capacity as well.

4.9.34 Charge Efficiency

This is a value to compensate for efficiency loss during charging when estimating total capacity value. This is based on every coulomb counting charge period and adjusted to reflect the total charge efficiency of the battery pack.

4.9.35 Discharge Efficiency

This is a value to compensate for efficiency loss during discharging when estimating total capacity value. This is based on every coulomb counting discharge period and adjusted to reflect the total discharge efficiency of the battery pack.

4.9.36 Learned Full Charge Capacity

This value is used to set the *FullChargeCapacity()* after subtracting any ***Reserve Capacity*** setting. This represents the usable capacity from full charge down to EDV0.

4.9.37 Cycle Count

The default value of *CycleCount()* is stored in ***Cycle Count*** and copied upon bq27320 initialization. When the value changes ***Cycle Count*** is also updated.

4.9.38 Design Capacity

The *DesignCapacity()* function reports ***Design Capacity mAh***.

NOTE: There is only a single ***Design Capacity*** value for all battery profiles. When setting the battery profile in production, it may be necessary to update ***Design Capacity*** as well for accurate *StateOfHealth()* results.

4.9.39 Design Voltage

The default value of *DesignVoltage()* is stored in ***Design Voltage*** and copied upon bq27320 initialization.

4.9.40 Cycle Count %

If the *[CCT]* bit is set the cycle count function counts the accumulated discharge of (*FullChargeCapacity()* × ***CC %***) as one cycle. If (*FullChargeCapacity()* × ***CC %***) is smaller than ***CC Threshold***, ***CC Threshold*** is used for counting.

4.9.41 Charge Inhibit Temp Low

The bq27320 does not allow the battery pack to charge if *Temperature()* is below ***Charge Inhibit Temp Low***. The *[CHGINH]* bit is set in the *BatteryStatus()*. The default value is 0°C. Charging is allowed once the temperature is above ***Charge Inhibit Temp Low*** plus ***Temp Hys*** value. The *[CHGINH]* bit is reset in the *BatteryStatus()* register.

4.9.42 Charge Inhibit Temp High

The bq27320 does not allow the battery pack to charge if *Temperature()* is above ***Charge Inhibit Temp High***. The *[CHGINH]* bit is set in the *BatteryStatus()*. The default value is 45°C. Charging is allowed once the temperature is below ***Charge Inhibit Temp High*** plus ***Temp Hys*** value. The *[CHGINH]* bit is reset in the *BatteryStatus()* register.

4.9.43 Temp Hys

The bq27320 has a temperature hysteresis for both ***Charge Inhibit Temp High*** and ***Charge Inhibit Temp Low*** conditions to prevent continuous charger ON/OFF behavior. The default value is 5°C. Charging is allowed once the temperature is below ***Charge Inhibit Temp High*** plus ***Temp Hys*** or above ***Charge Inhibit Temp Low*** plus ***Temp Hys*** value.

4.9.44 Fast Charge Current

The register sets the fast charging current for the battery pack. This information can be read by the MCU using commands 0x32 and 0x33 *ChargingCurrent()*. This information may be used to communicate the information to a battery charger. This value is set based on battery capacity of the pack and recommended maximum charging current by the cell manufacturers.

4.9.45 Charging Voltage

The bq27320 sets the maximum cell charging voltage for the pack. This information can be read by the MCU using commands 0x30 and 0x31 *ChargingVoltage()*. This information may be used to communicate the information to a battery charger. This value is set based on battery capacity of the pack and recommended maximum charging voltage by the cell manufacturers.

4.9.46 Taper Current

During Primary Charge Termination detection, one of the three requirements is that the accumulated change in capacity > 0.25 mAh per *Current Taper Window* for the bq27320 to start trying to qualify a termination. It must be above this Min Taper Capacity before bq27320 starts trying to detect a primary charge termination.

The following conditions qualify for Primary Charge Termination:

1. During two consecutive periods of *Current Taper Window*, the *Current()* is < *Taper Current.*
2. During the same periods, the accumulated change in capacity > 0.25 mAh per *Current Taper Window*.

3. *Voltage()* > *Charging Voltage* – *Taper Voltage*.

Normal Setting: If the value selected is too high, then it can cause no termination or late termination detection. An example value is 0.25 mAh or C/10 to C/20 based on battery cell characteristics and charger specification. Also two Current Taper qualifications are required to prevent false current taper. False primary termination could occur with pulse charging method and with random starting and resumption of the charge current, a condition that is important at the beginning or end of the qualification period.

4.9.47 Taper Voltage

During Primary Charge Termination detection, one of the three requirements is that ***Voltage*** must be above (*Charging Voltage* – *Taper Voltage*) for the bq27320 to start trying to qualify a termination. It must be above this voltage before bq27320 starts trying to detect a primary charge termination.

Normal Setting: This value depends on charger characteristics. It must be set so that ripple voltage, noise, and charger tolerances are taken into account. A high value selected can cause early termination. If the value selected is too low, then it can cause no termination or late termination detection. An example value is 100 mV (see *Taper Current*).

4.9.48 SOC Delta

The percentage value determines when the SOC_INT intervals are registered on the SOC_INT pin. A default value of 1% means the SOC Delta intervals are 0%, 1%, 2% .....99%, and 100%. A value of 10% would provide SOC_INT pulse at intervals of 0%, 10%, 20%.... 90%, and 100%.

4.9.49 DF Write Ind Wait

This provides an option to toggle the SOC INT pin on a flash write. The Wait is a delay time between the toggle of the SOC INT pin and the flash write. This gives the host time to process the interrupt and take any required actions before the write.

4.9.50 Clock Control Register

At reset the hardware Clock Control Register is set to this value. The default setting is 09 hex, which means the XL mode is enabled and the HF oscillator is turned ON after a reset.

4.9.51 Flash Update OK Voltage

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.

4.9.52 Sleep Current

The device is allowed to go into SLEEP mode if the charge or discharge current is below ***Sleep Current***. SLEEP mode can be enabled with the ***Operation Config A [SLEEP]*** bit. If the absolute value of *Current()* is above ***Sleep Current***, the bq27320 will return to NORMAL mode.

4.9.53 Offset Calibration Inhibit Temperature Low

The bq27320 does not perform auto-calibration on entry to SLEEP mode if *Temperature()* is below ***Cal Inhibit Temp Low***. The default is 5°C.

4.9.54 Offset Calibration Inhibit Temperature High

The bq27320 does not perform auto-calibration on entry to SLEEP mode if *Temperature()* above ***Cal Inhibit Temp High***. The default value is 45°C.

4.9.55 Sleep Voltage Time

During SLEEP mode, temperature and voltage measurements will be taken in ***Sleep Voltage Time*** intervals. The default setting is 20 s.

4.9.56 Sleep Current Time

During SLEEP mode, current will be measured in ***Sleep Current Time*** intervals. The default value is 20 s.

4.9.57 Hibernate Current

When *Current()* is less than ***Hibernate I*** or greater than***(–) Hibernate I*** in mA, this device enters HIBERNATE mode if *CONTROL_STATUS()[HIBERNATE]* = 1. The setting must be below any normal application currents. The default value is 8 mA, which is sufficient for most applications.

4.9.58 Hibernate Voltage

When *Voltage()* is less than ***Hibernate V*** or greater than***(–) Hibernate V*** in mV, this device enters HIBERNATE mode if *Current()* < ***Hibernate I***. The setting must be below any normal application voltage. The default value is 2550 mV, which is sufficient for most applications.

4.9.59 Dsg Current Threshold

The bq27320 enters DISCHARGE mode from RELAXATION mode or CHARGE mode if *Current()* < (–) ***Dsg Current Threshold***. The default value setting is 60 mA.

4.9.60 Chg Current Threshold

The bq27320 enters CHARGE mode from RELAXATION mode or DISCHARGE mode if *Current()* > ***Chg Current Threshold***. The default value is 75 mA.

4.9.61 Quit Current

The bq27320 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***. The default value is 40 mA.

4.9.62 Dsg Relax Time

The bq27320 enters RELAXATION mode from DISCHARGE mode if *Current()* goes above ***(–)Quit Current*** for at least ***Dsg Relax Time.*** The default value is 60 s.

4.9.63 Chg Relax Time

The bq27320 enters RELAXATION mode from CHARGE mode if *Current()* goes below ***Quit Current*** for at least ***Chg Relax Time.*** The default value is 60 s.

4.9.64 Quit Relax Time

The *Quit Relax Time* is the delay time to exit relaxation. If current is greater than ***Chg Current Threshold*** or less than ***Dsg Current Threshold*** and this condition is maintained for *Quit Relax Time*, then exiting relaxation is permitted. This is useful in applications with low duty cycle dynamic loads. The default setting is 1 s.

4.9.65 OT Charge

The bq27320 sets the *[OTC]* flag in *BatteryStatus()* if the pack *Temperature()* is equal to or higher than the ***Over Temp Chg*** threshold. The default value setting is 55°C.

4.9.65.1 OT Charge Time

If the *[OTC]* condition exists for a time that exceeds the ***OT Chg Time*** period, the bq27320 goes into an overtemperature charge condition. This function is disabled if ***OT Chg Time*** is set to 0.

In an overtemperature charge condition, the *ChargingVoltage()* and *ChargingCurrent()* are set to 0, and the *[OTC]* bit is set in the *BatteryStatus()* register. The default setting is 2 s.

4.9.66 OT Chg Recovery

The device recovers from an overtemperature 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, and the *[OTC]* flag in *BatteryStatus()* is reset. The default value setting is 50°C.

4.9.67 OT Discharge

The bq27320 sets the *[OTD]* flag in *BatteryStatus()* if the pack *Temperature()* is equal to or higher than the ***Over Temp Dsg*** threshold. The default value setting is 60°C.

4.9.67.1 OT Discharge Time

If the *[OTD]* condition exists for a time period that exceeds the ***OT Dsg Time***, the bq27320 goes into an overtemperature discharge condition. This function is disabled if ***OT Dsg Time*** is set to 0.

In an overtemperature discharge condition the *ChargingCurrent()* is set to 0 and the *[OTD]* bit is set in the *BatteryStatus()* register.

4.9.68 OT Dsg Recovery

The bq27320 recovers from an overtemperature 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, and the *[OTD]* flag in *BatteryStatus()* is reset.

4.9.69 Initial Standby Current

This is the initial value for *StandbyCurrent()*. The default setting is –10 mA.

4.9.70 Default Temperature

This is the temperature used to initialize the *Temperature()* register until the host writes a different value if the ***Operation Config A [WRTEMP]*** bit is set.

4.9.71 Device Name

The *DeviceName()* function returns a string stored in *DeviceName()*. This is a string data with maximum text length of 7 characters. This field does not affect operation, nor is it used by the device. It is read by using the extended data command: *DeviceName()* (0x63 through 0x69).

4.9.72 System Down Set Voltage

The bq27320 goes into SYSTEM DOWN mode if the battery pack *Voltage()* is equal to or less than ***SysDown Set Voltage Threshold*** for ***SysDown Set Volt Time***.

4.9.73 System Down Set Voltage Time

The bq27320 goes into SYSTEM DOWN mode if the battery pack *Voltage()* is equal to or less than ***SysDown Set Threshold*** for ***SysDown Set Time***.

4.9.74 System Down Clear Voltage

The bq27320 goes into SYSTEM DOWN CLEAR mode if the battery pack *Voltage()* is equal to or above ***SysDown Clear Voltage Threshold***.

4.9.75 Full Reset Counter

The counter increments on a full reset event.

4.9.76 Reset Counter Watchdog

The counter increments on a watchdog reset event.

4.9.77 Static Chem DF Checksum

This is static chemistry data signature. Use *MACData()* function reports *STATIC_CHEM_DF_SUM()* (with MSB set to 0) to initialize this value.

4.9.78 DF Static Checksum

This is static data flash data signature. Use *MACData()* function reports *STATIC_DF_SUM()* (with MSB set to 0) to initialize this value.

4.9.79 All DF Checksum

This is static ALL data flash data signature. Use *MACData()* function reports *ALL_DF_SUM()* (with MSB set to 0) to initialize this value.

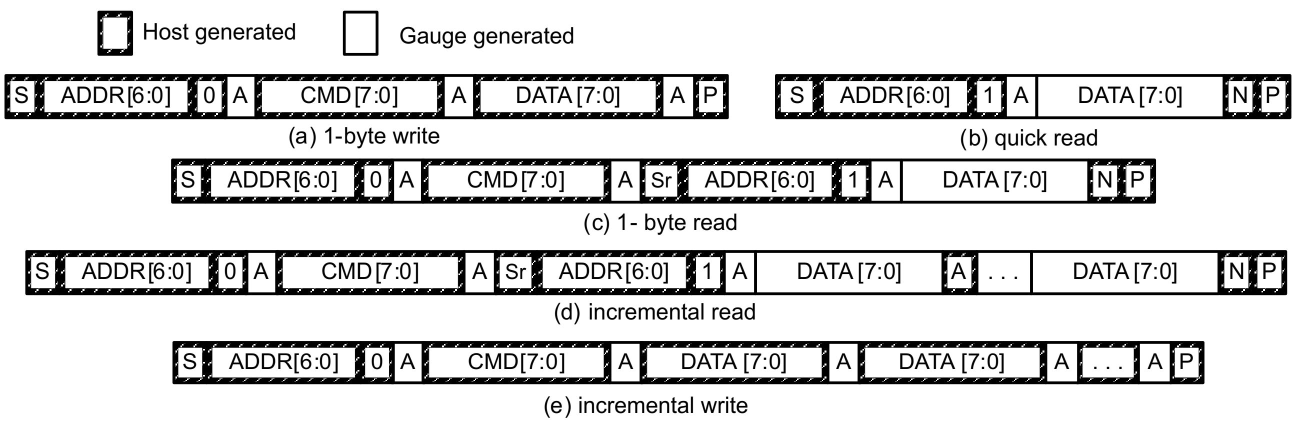
4.9.80 IF Checksum

On reset, the IF checksum is checked against this value. If it fails, the writing DF is disabled.

Communications

5.1 I²C Interface

The bq27320 gas gauge supports the standard I²C read, incremental read, quick read, one byte write, and incremental write functions. The 7-bit device address (ADDR) is the most significant 7 bits of the hex address and is fixed as 1010101. The first 8-bits of the I²C protocol is, therefore, 0xAA or 0xAB for write or read, respectively.



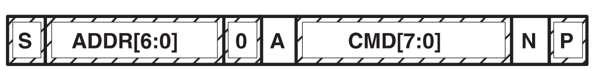
(S = Start, Sr = Repeated Start, A = Acknowledge, N = No Acknowledge, and P = Stop).

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

The following command sequences are not supported:

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

Attempt to read an address above 0x6B (NACK command):

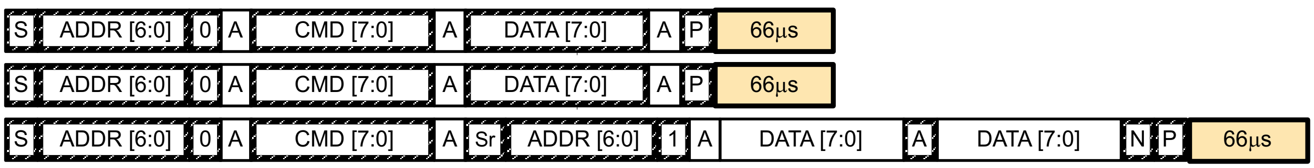


5.2 I²C Time Out

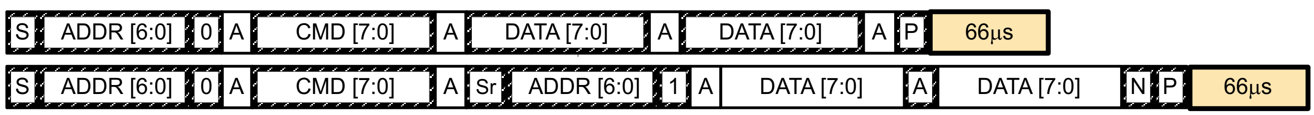
The I²C engine releases both SDA and SCL if the I²C bus is held low for 2 s. If the gas gauge was holding the lines, releasing them frees them for the master to drive the lines. If an external condition is holding either of the lines low, the I²C engine enters the low-power SLEEP mode.

5.3 I^2C Command Waiting Time

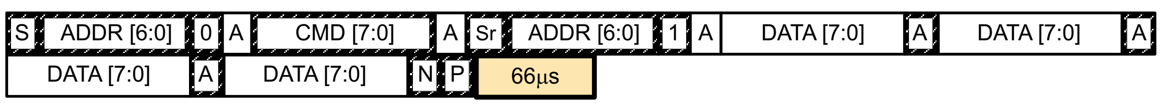
To ensure proper operation at 400 kHz, a $t_{(BUF)} \geq 66$ µs, bus-free waiting time must be inserted between all packets addressed to the gas gauge. In addition, if the SCL clock frequency (f_{SCL}) is > 100 kHz, use individual 1-byte write commands for proper data flow control. The following diagram shows the standard waiting time required between issuing the control subcommand the reading the status result. A *DF_CHECKSUM()* subcommand requires 100 ms minimum prior to reading the result. For read-write standard command, a minimum of 2 s is required to get the result updated. For read-only standard commands, there is no waiting time required, but the host should not issue all standard commands more than two times per second. Otherwise, the gas gauge could result in a reset issue due to the expiration of the watchdog timer.



Waiting time inserted between two 1-byte write packets for a subcommand and reading results
(required for 100 kHz < $f_{SCL} \leq$ 400 kHz)



Waiting time inserted between incremental 2-byte write packet for a subcommand and reading results
(acceptable for $f_{SCL} \leq$ 100 kHz)



Waiting time inserted after incremental read

5.4 I^2C Clock Stretching

A clock stretch can occur during all modes of gas gauge operation. In SLEEP and HIBERNATE modes, a short clock stretch occurs on all I^2C traffic as the device must wake-up to process the packet. In the other modes (BAT INSERT CHECK, NORMAL, SNOOZE), clock stretching only occurs for packets addressed for the gas gauge. The majority of clock stretch periods are small as the I^2C interface performs normal data flow control. However, less frequent yet more significant clock stretch periods may occur as blocks of data flash are updated. The following table summarizes the approximate clock stretch duration for various gas gauge operating conditions.

Gauging Mode	Operating Condition or Comment	Approximate Duration
SLEEP HIBERNATE	Clock stretch occurs at the beginning of all traffic as the device wakes up.	5 ms
BAT INSERT CHECK, NORMAL, SNOOZE	Clock stretch occurs within the packet for flow control (after a start bit, ACK or first data bit).	100 µs
	Data flash block writes	72 ms
	Restored data flash block write after loss of power	116 ms

Open-Circuit Voltage Measurement Background

The accuracy of the CEDV algorithm strongly depends on the accuracy and validity of the open-circuit voltage (OCV) measurement taken by gas gauges that are based on CEDV technology. This appendix describes the process of taking OCV measurements during different events.

A.1 Background

- **OCV Calculation:** OCV (open-circuit voltage) is normally a calculated value because a true measurement of OCV requires an unloaded and relaxed condition on the battery. Because such an unloaded and completely relaxed condition is not always possible in a real system, the gas gauge uses measured voltage, current, and temperature (VIT) to compute the OCV and as a result of this calculation, the state of charge (SOC) of the battery is established or reestablished.
- **OCV Qualification Time (QT):** The time in which SOC_INT is asserted during an OCV measurement is approximately 165 ms. This is the timeframe in which we test if the VIT measurement is qualified for an OCV calculation. This is not the timeframe in which the actual VIT measurement is taken. During this time, the instantaneous current (adci) is measured. If abs(adci) ≥ DesignCapacity/18, then the *[OCVFail]* bit is set. Otherwise, the VIT just measured is qualified and the gauge proceeds with OCV calculation.
- **Current Measurement Time (CMT):** The time of current is measured – 1 s.
- **Voltage Measurement Time (VMT):** The time of voltage is measured – 125 ms.
- **Temperature Measurement Time (TMT):** The time of temperature is measured – 125 ms.

A.1.1 OCV Qualification and Calculation

OCV qualification and calculation (***QC***) happens under three conditions:

- OCV_CMD is sent by the host.
- Battery Insert (***BI***) event is detected.
- Wakeup from HIBERNATE.

NOTE: POR causes an immediate BI.

A.1.2 OCV Calculation Assumption

The current, voltage, and temperature must remain stable during QT, CMT, VMT, and TMT. In every case that stable VIT is mentioned, the desired stable condition for current is < C/20. If this is not true, errors can be introduced into the OCV Calculation.

A.1.3 OCV Timing

The timing of each step in the OCV sequence is shown in Figure A-1.

1. After a POR, voltage, current, and temperature are measured before updating the gas gauge parameters.
2. Quick voltage and current measurements are taken to qualify OCV VIT conditions.
3. Voltage, current, and temperature are measured for subsequent gas gauge parameters updates.

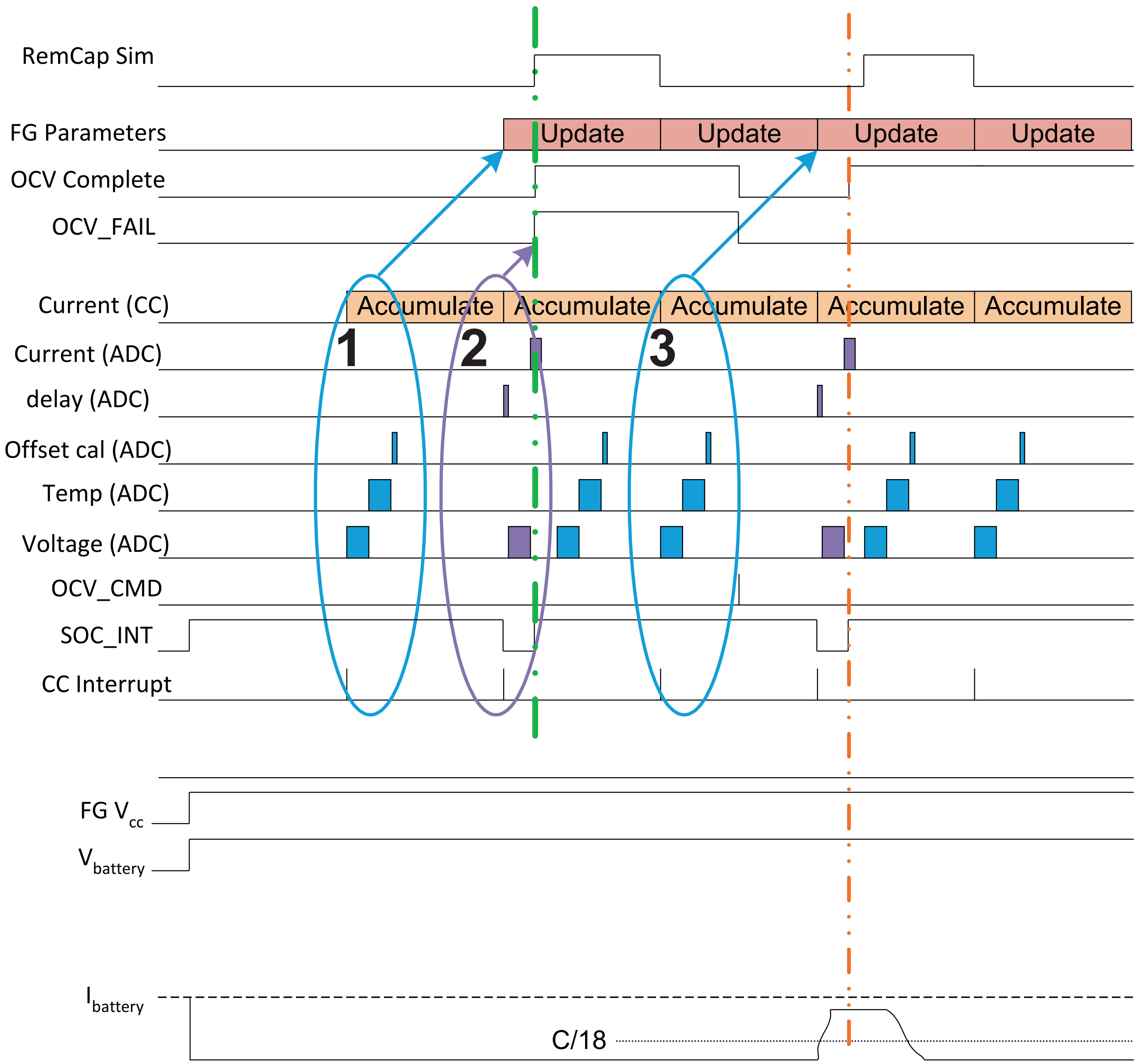


Figure A-1. OCV Timing Sequences

The green dashed lines indicate the completion of an OCV measurement that has failed due to the high load detected in current (ADC) measurement; whereas, the orange dashed lines indicate the completion of a successful OCV measurement, given that the load at the time of measurement was below C/18 rate.

The second OCV measurement (orange line) is a success by qualification standard. However, this is not the recommended-use case because the current is only lowered during the OCV_INT time (the qualification time). This makes the gas gauge respond as if this were a pass condition; however, the actual result is not good because the actual VIT measurement used for OCV was taken under high load.

A.2 OCV Timing and OCV_CMD Use Recommendations

A.2.1 ACTIVE Mode (Gas Gauge is Not in SLEEP Mode)

The VIT measurement used for the OCV calculation is the last VIT measured before the OCV_CMD was received. The VIT value used for the OCV calculation needs to be a stable, not transient value. Before sending the OCV_CMD, the current must be stable and < C/20 for at least one second. The recommendations for the OCV_CMD used for ACTIVE mode is that the VIT remains stable from two seconds before the OCV_CMD is sent until the end of SOC_INT (see Figure A-2).

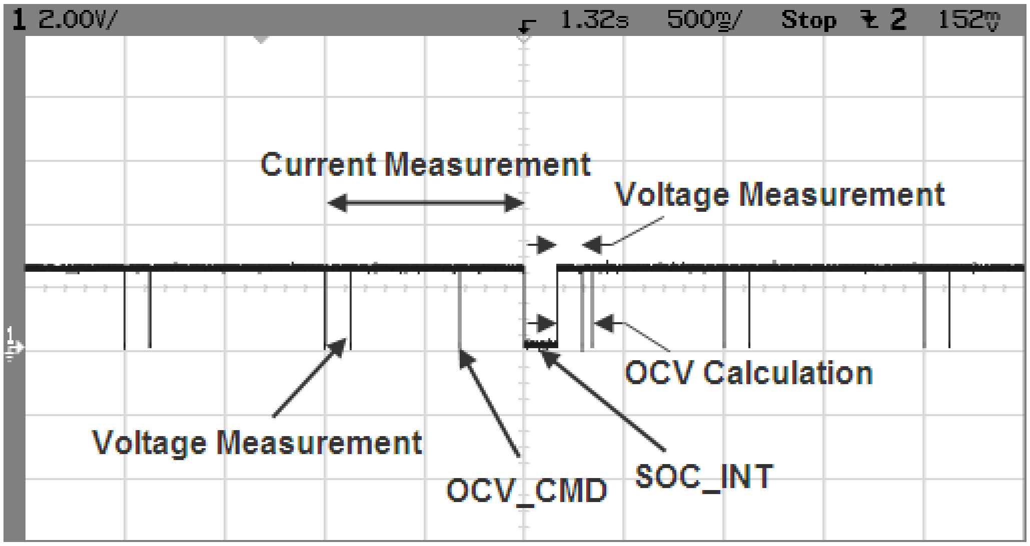


Figure A-2. OCV Calculation Based on OCV Command

A.2.2 SLEEP Mode

In SLEEP mode, the gas gauge measures VIT every 20 s, instead of 1 s. The VIT measurement used for the OCV calculation is the last VIT measured before the OCV_CMD was received. Sleep current is usually below the OCV current-fail threshold. So, the recommendations for the OCV_CMD sent during SLEEP mode is that the VIT remains stable and below the sleep threshold from the time OCV_CMD is sent until the end of SOC_INT.

A.2.3 Initial OCV – POR

During POR, the VIT measurement used for the OCV calculation and qualification takes place between about 300 ms after POR until the end of SOC_INT. To achieve a good initial OCV measurement after POR, the recommendation is to keep VIT stable from POR until the end of SOC_INT (see Figure A-3).

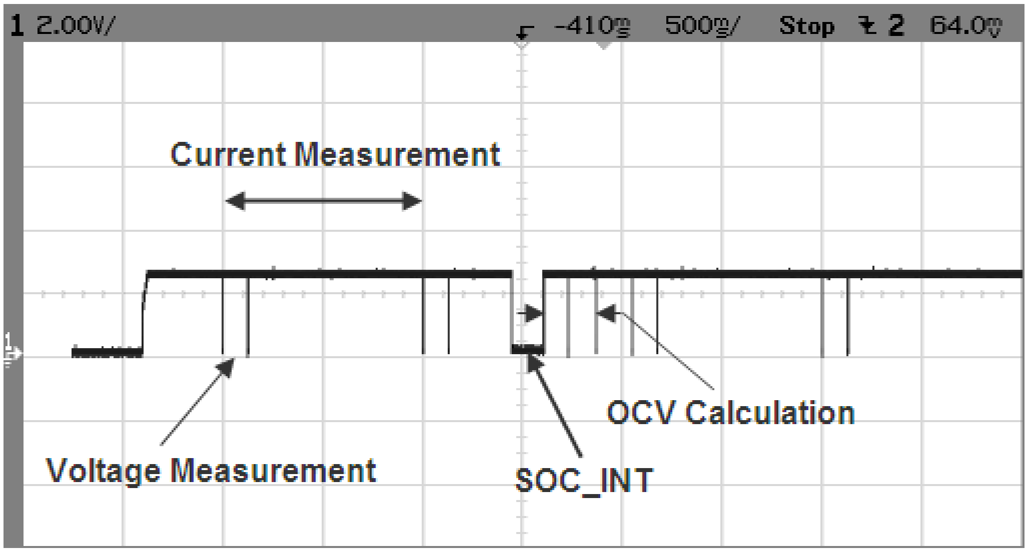


Figure A-3. Initial OCV Taken After POR

TRM-Specific Terms

ACK	Acknowledge character
ADC	Analog-to-digital converter
BCA	Board calibration
BI	Battery insert
CC	Coulomb counter
CCA	Coulomb counter calibration
CE	Chip enable
Charge Mode	Refers to a mode to where the gauge read *Current()* > ***Chg Current Threshold*** for at least 1 second.
Clear	Refers to a bit in a register becoming a logic LOW or 0. The bqEvaluation software (EVSW) represents a clear bit with the color green.
cWh	Centiwatt-hour
CMT	Current measurement time
DF	Data flash
DISCHARGE Mode	Refers to a mode where the gauge read *Current()* < (–)***Dsg Current Threshold*** for at least 1 second.
DOD	Depth of discharge in percent as related to Qmax. 100% corresponds to empty battery.
DOD0	Depth of discharge that was looked up in the DOD (OCV) table based on OCV measurement in relaxed state.
EOC	End of charge
FC	Fully charged
FCC	Full charge capacity. Total capacity of the battery compensated for present load current, temperature, and aging effects (reduction in chemical capacity and increase in internal impedance).
FIFO	First in, first out
Flag	This word usually represents a read-only status bit that indicates some action has occurred or is occurring. This bit typically cannot be modified. The flags are set and cleared automatically by the gas gauge.
FVCA	Fast voltage and current acquisition
GPIO	General-purpose input output
HDQ	High-speed data queue
IC	Integrated circuit
ID	Identification
IO	Input or output
I^2C	Inter-integrated circuit
LDO	Low dropout
LSB	Least significant bit
LT	Lifetime
MAC	Manufacturer Access Control
mAh	Milliamp-hour
MSB	Most significant bit
mWh	Milliwatt-hour
NACK	Negative acknowledge character
NTC	Negative temperature coefficient
OCV	Open-circuit voltage. Voltage measured on fully-relaxed battery with no load applied.
OTC	Overtemperature in charge
OTD	Overtemperature in discharge
PFC	Pin function code
POR	Power-on reset
Qmax	Maximum chemical capacity

QC	Qualification and calculation
QT	Qualification time
Relaxation Mode	Refers to a mode to where the gauge read *Current()* < ***Quit Current*** for at least 60 seconds.
RM	Remaining capacity
RW	Read or write
SCL	Serial clock: programmable serial clock used in the I^2C interface
SDA	Serial data: serial data bus in the I^2C interface
SE	Shutdown enable
Set	Refers to a bit in a register becoming a logic HIGH or 1. The bqEvaluation software (EVSW) represents a set bit with the color red.
SOC	State-of-charge in percent related to FCC
SOC1	State-of-charge initial
SOCF	State-of-charge final
System	The word system is sometimes used in this document. When used, it always means a host system that is consuming current from the battery pack.
TCA	Terminate charge alarm
TMT	Temperature measurement time
TS	Temperature status
TTE	Time-to-empty
TTF	Time-to-full
VIT	Voltage, current, temperature
VMT	Voltage measurement time

Revision History

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

Changes from Original (March 2016) to A Revision **Page**