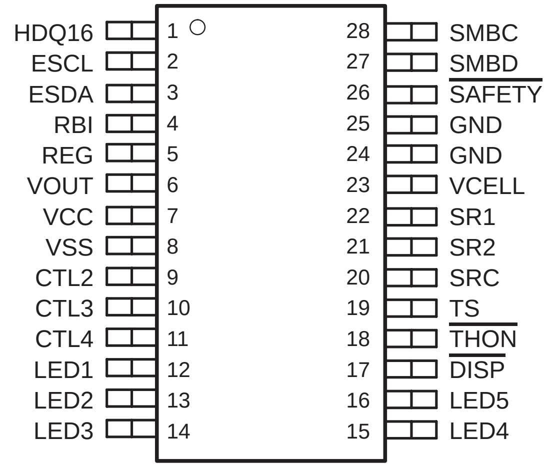
- **Provides Accurate Measurement of Available Charge in Li-Ion Batteries**
- **Supports the 2-Wire SMBus V1.1 Interface With PEC or Single-Wire HDQ16**
- **Directly Interfaces the Seiko S-8243 Protection IC for Maximum Safety Protection and Minimal Component Count**
- **Supports Internal or External Thermistor**
- **Reports Individual Cell Voltages**
- **Uses 15-Bit ADC for Accurate Voltage, Temperature, and Current Measurements**
- **Measures Charge Flow Using A V-to-F Converter With Offset of Less Than 16 μV After Calibration**
- **Consumes Less Than 0.5 mW Operating**
- **Drives 4- or 5-Segment LED Display for Remaining Capacity Indication**
- **28-Pin 150-Mil SSOP**

SSOP (DBQ) PACKAGE
(TOP VIEW)



description

The bq2063 SBS-compliant gas gauge IC for battery-pack or in-system installation maintains an accurate record of available charge in Li-Ion batteries. The bq2063 monitors capacity and other critical parameters in Li-Ion battery packs. It also directly interfaces the Seiko S-8243 protection IC to minimize component count in smart-battery circuits.

The bq2063 uses a V-to-F converter with automatic offset correction for charge and discharge counting. For voltage, temperature, and current reporting, the bq2063 uses an A-to-D converter. In conjunction with the S-8243, the onboard ADC also monitors individual cell voltages in a Li-Ion battery pack and allows the bq2063 to generate control signals to enhance pack safety.

The bq2063 supports the smart battery data (SBData) commands and charge-control functions. It communicates data using the system management bus (SMBus) 2-wire protocol or the 1-wire HDQ16 protocol. The data available include the battery's remaining capacity, temperature, voltage, current, and remaining run-time predictions. The bq2063 provides LED drivers and a push-button input to depict remaining battery capacity from full to empty in 20% or 25% increments with a 4- or 5-segment display.

The bq2063 works with an external EEPROM. The EEPROM stores the configuration information for the bq2063, such as the battery's chemistry, self-discharge rate, rate-compensation factors, measurement calibration, and design voltage and capacity. The bq2063 uses the programmable self-discharge rate and other compensation factors stored in the EEPROM to accurately adjust remaining capacity for use and standby conditions based on time, rate, and temperature. The bq2063 also automatically calibrates or *learns* the true battery capacity in the course of a discharge cycle from programmable near full to near empty levels.

The S-8243 protection IC may be used to provide power to the bq2063 from a 3- or 4-series Li-Ion cell stack.

AVAILABLE OPTIONS

T_J	PACKAGE 28-LEAD SSOP (DBQ)
−20°C to 70°C	bq2063DBQ

Figures 1−4 illustrate the diagrams for the bq2063.

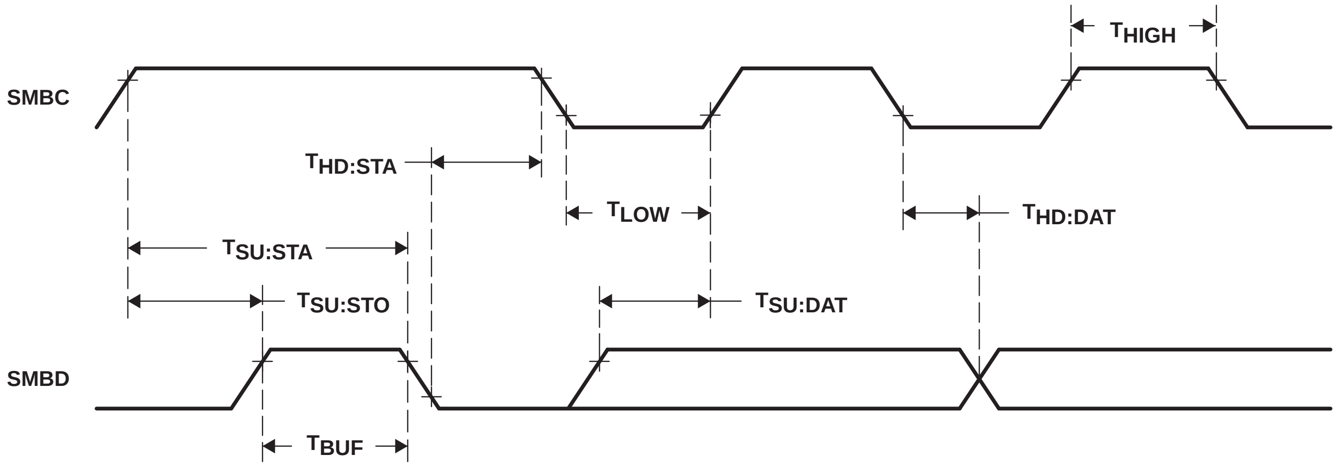


Figure 1. SMBus Timing Data

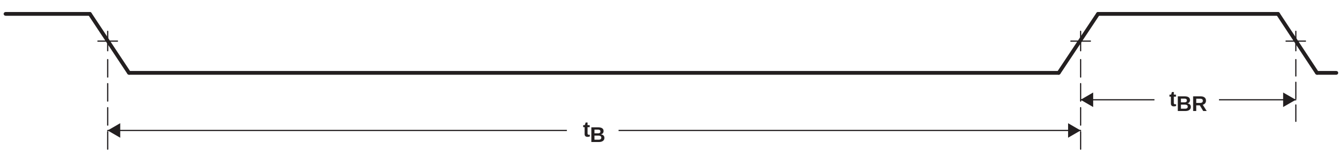


Figure 2. HDQ16 Break Timing

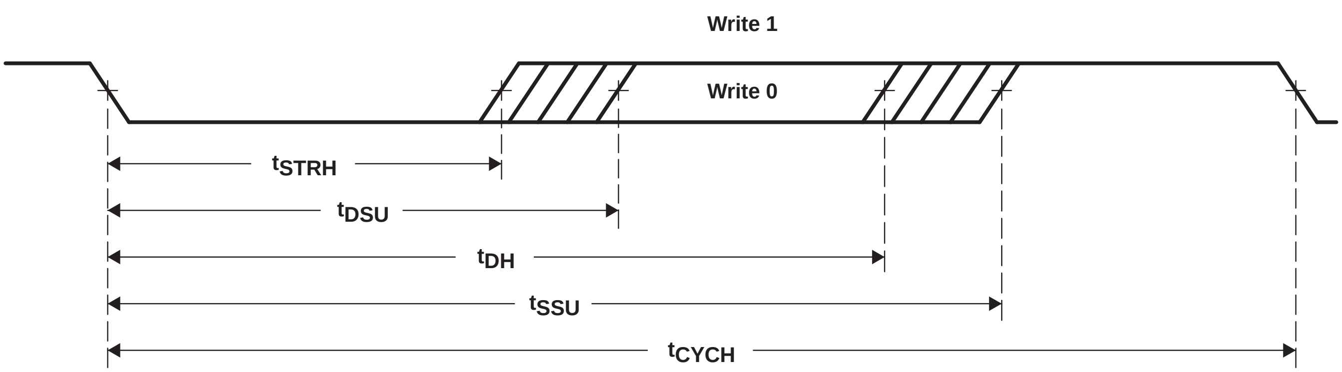


Figure 3. HDQ16 Host to bq2063

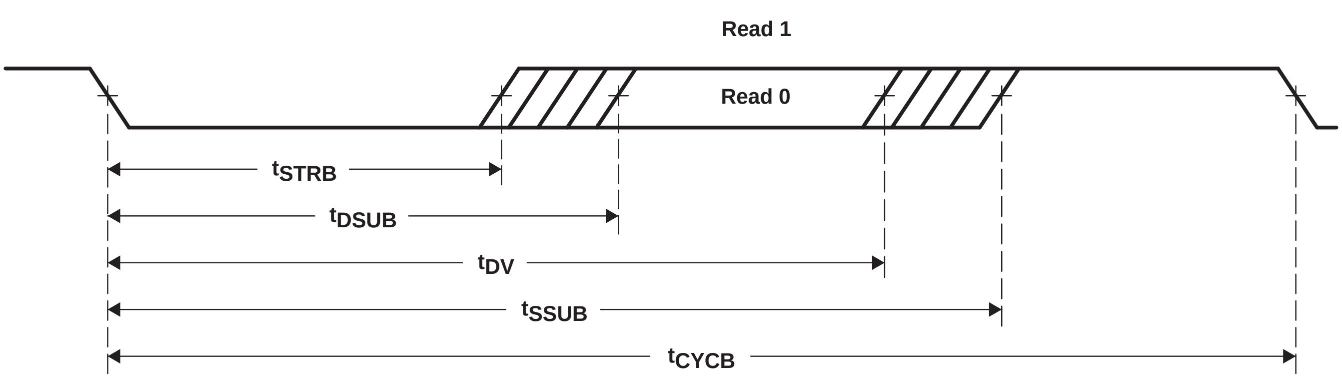


Figure 4. HDQ16 bq2063 to Host

functional description (continued)

current

The SRC input of the bq2063 measures battery charge and discharge current. The SRC ADC input converts the current signal from the series sense resistor and stores the result in Current( ). The full-scale input range to SBC is limited to ±250 mV.

temperature

The bq2063 can use its internal sensor or an external thermistor to develop the temperature reading, depending on the programming of the EXTH bit in *Pack Configuration,* EE 0x3f.

The TS input of the bq2063 in conjunction with an NTC thermistor measures the battery temperature as shown in Figure 13. The bq2063 reports temperature in Temperature( ). $\overline{\text{THON}}$ may be used to switch the bias current through the external thermistor when the bq2063 samples the TS input. $\overline{\text{THON}}$ is low impedance for 60 ms when the temperature is measured, and high impedance otherwise.

gas gauge operation

general

The operational overview in Figure 5 illustrates the gas gauge operation of the bq2063. Table 2 describes the bq2063 registers.

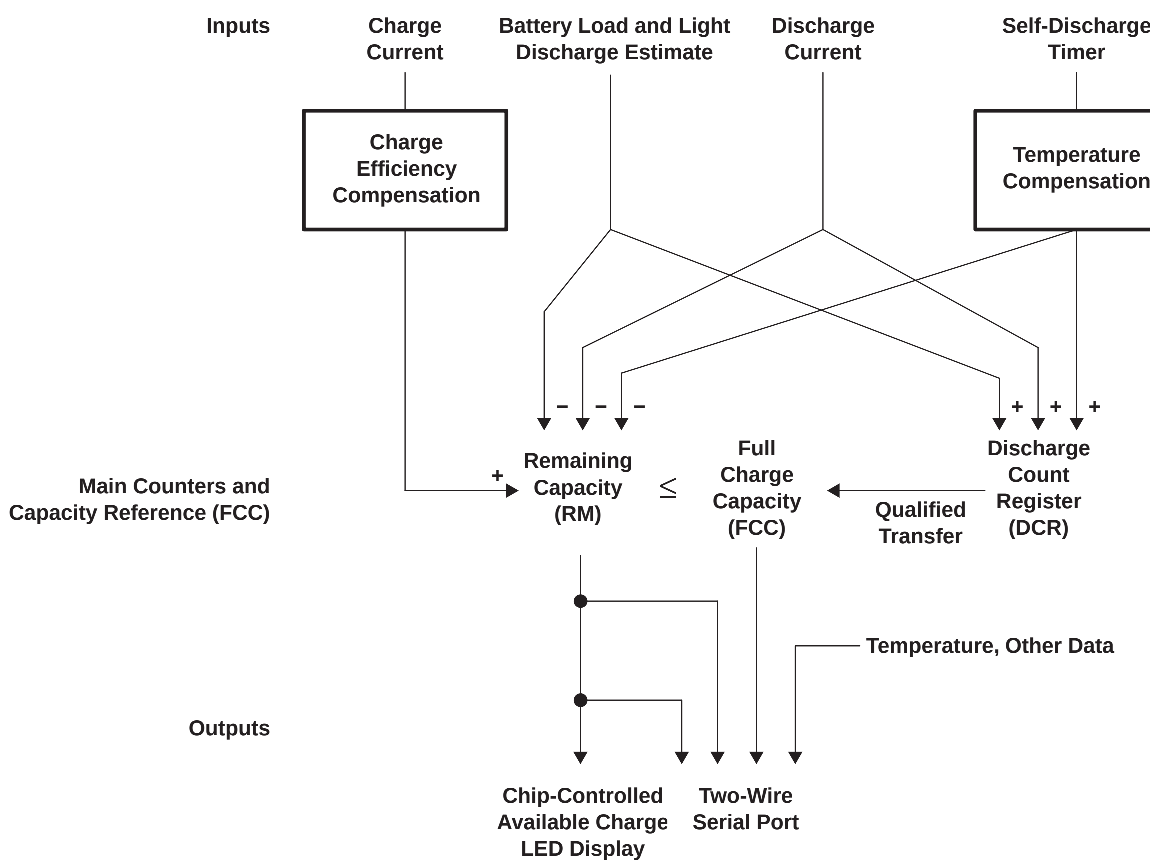


Figure 5. bq2063 Operational Overview

• DALLAS, TEXAS 75265 **self-discharge (continued)** The timer that keeps track of the self-discharge update time is halted whenever charge activity is detected. Thetimer is reset to zero if the bq2263Sreaches the RemainingCapacity( )=FullChargeCapacity( ) condition while

XA
STRUMENTS

display port

general

The display port drives a 4 or 5 LED bar-graph display. The display is activated by a logic signal on the $\overline{DISP}$ input. The bq2063 can display RM in either a relative or absolute mode with each LED representing a percentage of the full-battery reference. In relative mode, the bq2063 uses FCC as the full-battery reference; in absolute mode, it uses dc.

The DMODE bit in *Pack Configuration* programs the bq2063 for the absolute or relative display mode. The LED bit in *Control Mode* programs the 4- or 5-LED option. A fifth LED can be used with the 4-LED display option to show when the battery capacity is ≥100%.

activation

The display may be activated at any time by a high-to-low transition on the $\overline{DISP}$ input. This is usually accomplished with a pullup resistor and a pushbutton switch. Detection of the transition activates the display and starts a four second display timer. Reactivation of the display requires that the $\overline{DISP}$ input return to a logic-high state and then transition low again. The second high-to-low transition must occur after the display timer expires. The bq2063 requires the input to remain stable for a minimum of 250 ms to detect the logic state. If unused, the $\overline{DISP}$ input must be pulled up to V_{CC}.

If the EDV0 bit is set, the bq2063 disables the LED display. The display is also disabled during a VFC calibration and should be turned off before entering low-power storage mode.

display modes

In relative mode, each LED output represents 20% or 25% of the RelativeStateOfCharge( ) value. In absolute mode, each LED output represents 20% or 25% of the AbsoluteStateOfCharge( ) value. Table 6 shows the display options for 5 LEDs and Table 7 for 4 LEDs.

In either mode, the bq2063 blinks the LED display if RemainingCapacity( ) is less than Remaining CapacityAlarm( ). The display is disabled if EDV0 = 1.

Table 6. Display Mode for Five LEDs

CONDITION RELATIVE OR ABSOLUTE StateOfCharge( )	FIVE LED DISPLAY OPTION				
	LED_1	LED_2	LED_3	LED_4	LED_5
EDV0 = 1	OFF	OFF	OFF	OFF	OFF
<20%	ON	OFF	OFF	OFF	OFF
≥20%, < 40%	ON	ON	OFF	OFF	OFF
≥40%, < 60%	ON	ON	ON	OFF	OFF
≥60%, < 80%	ON	ON	ON	ON	OFF
≥80%	ON	ON	ON	ON	ON

Table 7. Display Mode for Four LEDs

CONDITION RELATIVE OR ABSOLUTE StateOfCharge( )	FOUR LED DISPLAY OPTION			
	LED1	LED2	LED3	LED4
EDV0 = 1	OFF	OFF	OFF	OFF
<25%	ON	OFF	OFF	OFF
≥25%, < 50%	ON	ON	OFF	OFF
≥50%, < 75%	ON	ON	ON	OFF
≥75%	ON	ON	ON	ON

$\overline{\text{SAFETY}}$ output (continued)

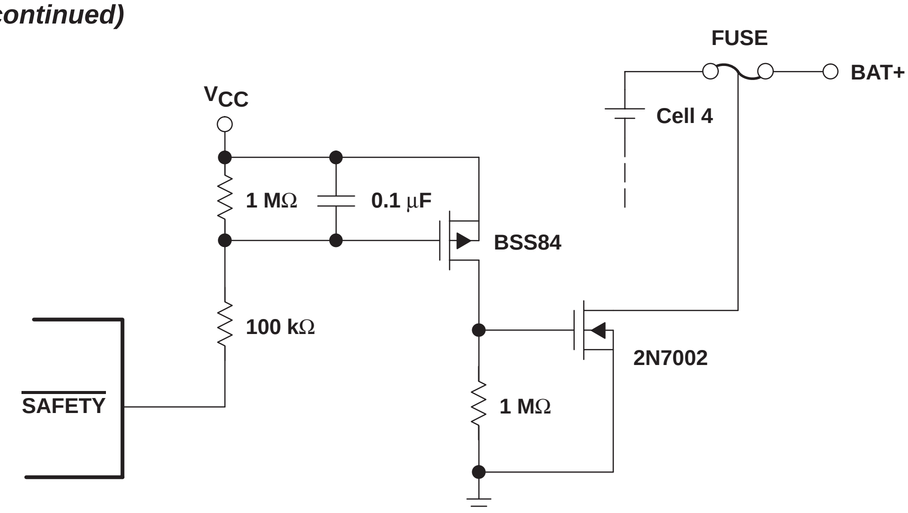


Figure 7. Example $\overline{\text{SAFETY}}$ Circuit Implementation

low-power storage mode

The bq2063 enters low-power mode 5-8 seconds after receiving the Enable Low-Power command. In this mode the bq2063 consumes less than 10 µA. A rising edge on SMBC, SMBD, or HDQ16 restores the bq2063 to the full operating mode. The bq2063 does not perform any gas-gauge functions during low-power storage mode.

device reset

The bq2063 can be reset with commands over the HDQ16 or SMBus. Upon reset, the bq2063 initializes its internal registers with the information contained in the configuration EEPROM. The following command sequence initiates a full bq2063 reset:

1. Write 0x005a to address 0x4f
2. Write 0x0000 to address 0x7d
3. Write 0x0080 to address 0x7d

A partial reset of the bq2063 occurs if step one is omitted. All initial program values are read from EEPROM for both full and partial resets. A full reset initializes MaxError( ) = 100%, sets RELEARN FLAG (bit 7) in BatteryMode, and initializes RM from EEPROM 0x2c−2d . This initial RM value should be programmed to zero for secondary (rechargeable) batteries. A partial reset leaves MaxError( ), RELEARN_FLAG, and RM unchanged.

communication

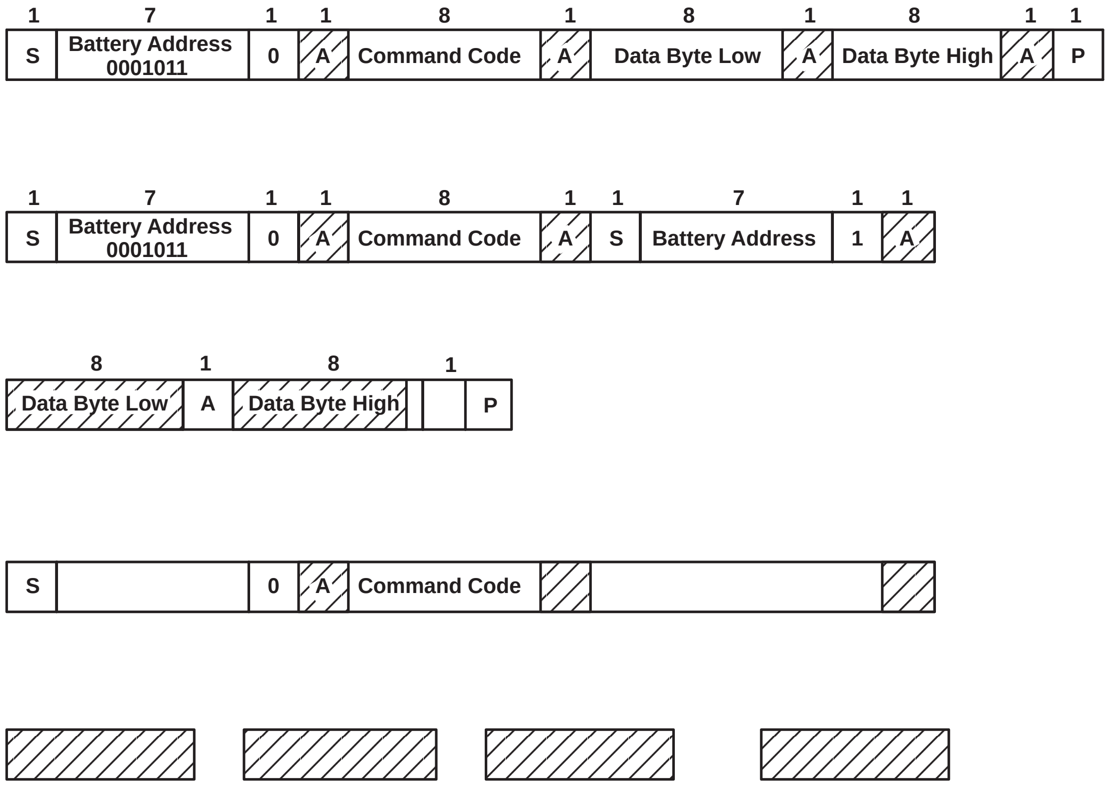
The bq2063 includes two types of communication ports: SMBus and HDQ16. The SMBus interface is a 2-wire bidirectional protocol using the SMBC (clock) and SMBD (data) pins. The HDQ16 interface is a 1-wire bidirectional protocol using the HDQ16 pin. All three communication lines are isolated from VCC and may be pulled-up higher than V_{CC}. Also, the bq2063 does not pull these lines low if V_{CC} to the part is zero . HDQ16 should be pulled down with a 100-kΩ resistor, or may be grounded, if not used.

The communication ports allow a host controller, an SMBus compatible device, or other processor to access the memory registers of the bq2063. In this way a system can efficiently monitor and manage the battery.

SMBus

The SMBus interface is a command-based protocol. A processor acting as the bus master initiates communication to the bq2063 by generating a START condition. A START condition consists of a high-to-low transition of the SMBD line while the SMBC is high. The processor then sends the bq2063 device address of

PEC protocol (continued)



0x0660 Stop VFC Calibration instructs the bq2063 to abort a VFC calibration procedure. If aborted, the bq2063 disables offset correction. The bq2063 stops calibration within 20 ms of acknowledging the command.

0x0606 Program EEPROM instructs the unsealed bq2063 to connect the SMBus to the EEPROM I2C bus. The bq2063 applies power to the EEPROM within 900 ms of acknowledging the command. After issuing the program EEPROM command, the bq2063 monitoring functions are disabled until the I2C bus is disconnected. The bq2063 disconnects the I2C bus when it detects that the Battery Address 0x16 is sent over the SMBus. The Battery Address 0x16 to disconnect the I2C bus should not be sent until 10 ms after the last write to the EEPROM.

0x07e6 Device Revision instructs the bq2063 to return the device revision level to ManufactureAccess( ) so it may be read.

Purpose: The ManufacturerAccess( ) function provides the system host access to bq2063 functions that are not defined by the SBD.

SMBus Protocol: Read or Write Word

Input/Output: Word

Example:

The following sequence of actions is an example of how to use the ManufacturerAccess( ) commands efficiently to take a battery pack that has completed all testing and calibration except for VFC calibration and to make it ready for shipment in the SEALED state and in low-power storage mode:

1. Complete testing,

RemainingCapacityAlarm( ) (0x01); [0x01]

Description: Sets or gets the low-capacity threshold value. Whenever the RemainingCapacity( ) falls below the low capacity value, the bq2063 sends AlarmWarning( ) messages to the SMBus Host with the REMAINING_CAPACITY_ALARM bit set. A low-capacity value of 0 disables this alarm. The bq2063 initially sets the low-capacity value to *Remaining Capacity Alarm* value programmed in EE 0x04−0x05. The low-capacity value remains unchanged until altered by the RemainingCapacityAlarm( ) function. The low-capacity value may be expressed in either current (mA) or power (10 mWh) depending on the setting of the BatteryMode( ) CAPACITY_MODE bit.

Purpose: The RemainingCapacityAlarm( ) function can be used by systems that know how much power they require to save their operating state. It enables those systems to more finely control the point at which they transition into suspend or hibernate state. The low-capacity value can be read to verify the value in use by the bq2063's low capacity alarm.

SMBus Protocol: Read or Write Word

Input/Output: Unsigned integer-value below which Low Capacity messages are sent.

	BATTERY MODES	
	CAPACITY_MODE BIT = 0	CAPACITY_MODE BIT = 1
Units	mAh at C/5	10 mWh at P/5
Range	0–65,535 mAh	0–65,535 10 mWh
Granularity	Not applicable	
Accuracy	See RemainingCapacity( )	

Description: Sets or gets the remaining time alarm value. Whenever the AverageTimeToEmpty( ) falls below the remaining time value, the bq2063 sends AlarmWarning( ) messages to the SMBus Host with the REMAINING_TIME_ALARM bit set. A remaining time value of 0 effectively disables this alarm. The bq2063 initially sets the remaining time value to the *Remaining Time Alarm* value programmed in EE 0x02−0x03. The remaining time value remains unchanged until altered by the RemainingTimeAlarm( ) function.

Purpose: The RemainingTimeAlarm( ) function can be used by systems that want to adjust when the remaining time alarm warning is sent. The remaining time value can be read to verify the value in use by the bq2063 RemainingTimeAlarm( ).

SMBus Protocol: Read or Write Word

Input/Output: Unsigned integer—the point below which remaining time messages are sent.

Units: minutes

Range: 0 to 65,535 minutes

Granularity: Not applicable

Accuracy: see AverageTimeToEmpty( )

BatteryMode( ) (0x03); [0x03]

Description: Selects the various battery operational modes and reports the battery's mode and requests.

Defined modes include

- Whether the battery's capacity information is specified in mAh or 10 mWh (CAPACITY_MODE bit)
- Whether the ChargingCurrent( ) and ChargingVoltage( ) values are broadcast to the Smart Battery Charger when the bq2063 detects the battery requires charging (CHARGER_MODE bit)
- Whether all broadcasts to the Smart Battery Charger and Host are disabled

command codes (continued)

ALARM_MODE bit is set to disable the bq2063's ability to master the SMBus and send AlarmWarning( ) messages to the SMBus Host and the Smart Battery Charger. When set, the bq2063 does *not* master the SMBus, and AlarmWarning( ) messages are not sent to the SMBus Host and the Smart Battery Charger for a period of no more than 65 seconds and no less than 45 seconds. When cleared (default), the Smart Battery sends the AlarmWarning( ) messages to the SMBus Host and the Smart Battery Charger any time an alarm condition is detected.

- The bq2063 polls the ALARM_MODE bit at least every 150 ms. Whenever the ALARM_MODE bit is set, the bq2063 resets the bit and starts or restarts a 55 seconds (nominal) timer. After the timer expires, the bq2063 automatically enables alarm broadcasts to ensure that the accidental deactivation of broadcasts does not persist. An SMBus host that does not want the bq2063 to be a master on the SMBus must therefore continually set this bit at least once per 50 seconds to keep the bq2063 from broadcasting alarms.
- The ALARM_MODE bit defaults to a cleared state within 130 ms after the bq2063 detects the SMBus Off-State.
- The condition of the ALARM-MODE bit does *not* affect the operation or state of the CHARGER_MODE bit which is used to prevent broadcasts of ChargingCurrent( ) and ChargingVoltage( ) to the Smart Battery Charger.

CHARGER_MODE bit enables or disables the bq2063's transmission of ChargingCurrent( ) and ChargingVoltage( ) messages to the Smart Battery Charger. When set, the bq2063 does *not* transmit ChargingCurrent( ) and ChargingVoltage( ) values to the Smart Battery Charger. When cleared, the bq2063 transmits the ChargingCurrent( ) and ChargingVoltage( ) values to the Smart Battery Charger. The CHARGER_MODE bit defaults to a cleared state within 130 ms after the bq2063 detects the SMBus Off-State.

CAPACITY_MODE bit indicates if capacity information is reported in mA/mAh or 10mW/10 mWh. When set, the bq2063 reports capacity information in 10 mW/10 mWh as appropriate. When cleared, the bq2063 reports capacity information in mA/mAh as appropriate. The CAPACITY_MODE bit defaults to a cleared state within 130 ms after the bq2063 detects the SMBus Off-State.

The following functions are changed to accept or return values in mA/mAh or 10 mW/10 mWh depending on the CAPACITY_MODE bit:

- RemainingCapacityAlarm( )
- AtRate( )
- RemainingCapacity( )
- FullChargeCapacity( )
- DesignCapacity( )

The following functions are calculated on the basis of capacity and may be calculated differently depending on the CAPACITY_MODE bit:

- AtRateOK( )
- AtRateTimeToEmpty( )
- AtRateTimeToFull( )
- RunTimeToEmpty( )
- AverageTimeToEmpty( )
- AverageTimeToFull( )
- Remaining Time Alarm( )
- BatteryStatus( )

by the secondfunction of the call-set that calculates and returns a value based on the AtRate value and the battery's presentstate. A delay of up to 1.2 seconds is required after writing AtRate( ) before the bq2063 can acknowledge the

INSTRUMENTS

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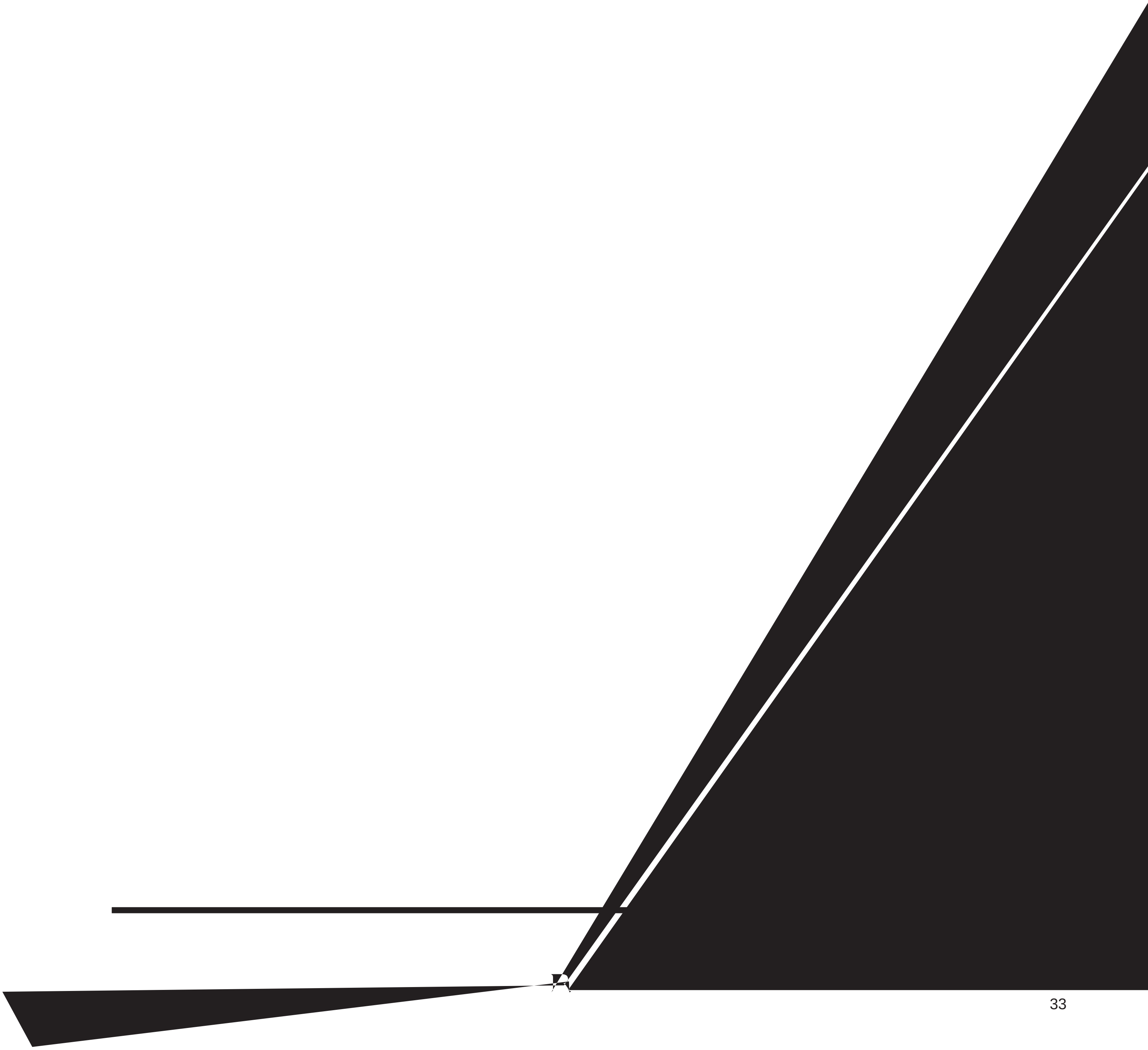
S (inte e value) **Accuracy:** ±0 .



command codes (continued)

BatteryStatus( )(0x16); [0x16]

Description: Returns the bq2063’s status word (flags). Some of the BatteryStatus( ) flags (REMAINING_CAPACITY_ALARM and REMAINING_TIME_ALARM) are calculated based on either current or power depending on the setting of the BatteryMode( ) CAPACITY_MODE bit. This is important because use of the wrong calculation mode may result in an inaccurate alarm.

Purpose: The BatteryStatus( ) function is used by the power-management system to get alarm and status bits, as well as error codes from the bq2063. This is basically the same information broadcast to both the SMBus Host and the Smart Battery Charger by the AlarmWarning( ) function except that the AlarmWarning( ) function sets the Error Code bits all high before sending the data.

SMBus Protocol: Read Word

Output: Unsigned Integer-Status Register With Alarm Conditions Bit Mapped as follows:

ALARM BITS	
0x8000	OVER_CHARGED_ALARM
0x4000	TERMINATE_CHARGE_ALARM
0x2000	Reserved
0x1000	OVER_TEMP_ALARM
0x0800	TERMINATE_DISCHARGE_ALARM
0x0400	Reserved
0x0200	REMAINING_CAPACITY_ALARM
0x0100	REMAINING_TIME_ALARM
STATUS BITS	
0x0080	INITIALIZED
0x0040	DISCHARGING
0x0020	FULLY_CHARGED
0x0010	FULLY_DISCHARGED
ERROR CODES	
0x0007	

alarm bits (continued)

OVER_TEMP_ALARM bit is set when the bq2063 detects that the internal battery temperature is greater than or equal to the *MaxT* limit. This bit is cleared when the internal temperature falls back into the acceptable range.

TERMINATE_DISCHARGE_ALARM bit is set when RM = 0, Voltage( ) ≤ EDV0, or the CVUV bit in Pack Status is set indicating that a Li-Ion cell voltage has dropped below the limit programmed in *Cell Under /Over Voltage*. The bit is cleared when Voltage( ) > EDV0, RM( ) > 0, and the CVUV bit is cleared.

REMAINING_CAPACITY_ALARM bit is set when the bq2063 detects that RemainingCapacity( ) is less than that set by the RemainingCapacityAlarm( ) function. This bit is cleared when either the value set by the RemainingCapacityAlarm( ) function is lower than the RemainingCapacity( ) or when the RemainingCapacity( ) is increased by charging.

REMAINING_TIME_ALARM bit is set when the bq2063 detects that the estimated remaining time at the present discharge rate is less than that set by the RemainingTimeAlarm( ) function. This bit is cleared when either the value set by the RemainingTimeAlarm( ) function is lower than the AverageTimeToEmpty( ) or when the AverageTimeToEmpty( ) is increased by charging.

status bits

INITIALIZED bit is set when the bq2063 is has detected a valid load of EEPROM. It is cleared when the bq2063 detects an improper EEPROM load.

DISCHARGING bit is set when the bq2063 determines that the battery is not being charged. This is determined by the detection of discharge activity or by the absence of charge activity for 22500/*DigitalFilter* (μV) seconds. This bit is cleared when the bq2063 detects that the battery is being charged.

FULLY_CHARGED bit is set when the bq2063 detects a primary charge termination or an overcharged condition. It is cleared when RelativeStateOfCharge( ) is less than or equal to the programmed *Fully Charged Clear %* in EE 0x4c.

FULLY_DISCHARGED bit is set when Voltage( ) or VCELL is less than the EDV2 threshold and Current( ) < *OverloadCurrent* or when RelativeStateOfCharge( ) < *Battery Low* %. This bit is cleared when RelativeStateOfCharge( ) is greater than or equal to 20%.

error codes

ERROR CODES	DESCRIPTION
OK	The bq2063 processed the function code without detecting any errors.
Busy	The bq2063 is unable to process the function code at this time.
Reserved	The bq2063 detected an attempt to read or write to a function code reserved by this version of the specification. The 2063 detected an attempt to access an unsupported optional manufacturer function code.
Unsupported	The bq2063 does not support this function code which is defined in this version of the specification.
AccessDenied	The bq2063 detected an attempt to write to a read-only function code.
Over/Underflow	The bq2063 detected a data overflow or underflow.
BadSize	The bq2063 detected an attempt to write to a function code with an incorrect data block.
UnknownError	The bq2063 detected an unidentifiable error.

command codes (continued)

ManufacturerName( ) (0x20); [0x20-0x25]

Description: This function returns a character array containing the battery's manufacturer's name. For example, MyBattCo identifies the Smart Battery's manufacturer as MyBattCo. The bq2063 sets ManufacturerName( ) to the value programmed in *Manufacturer Name* EE 0x20-0x2b.

Purpose: The ManufacturerName( ) function returns the name of the Smart Battery's manufacturer. The manufacturer's name can be displayed by the SMBus Host's power management system display as both an identifier and as an advertisement for the manufacturer. The name is also useful as part of the information required to uniquely identify a battery.

SMBus Protocol: Read Block

Output: String-character string with maximum length of 11 characters (11 + length byte).

DeviceName( ) (0x21); [0x28-0x2b]

Description: This function returns a character string that contains the battery's name. For example, a DeviceName( ) of bq2063A indicates that the battery is a model bq2063A. The bq2063 sets DeviceName( ) to the value programmed in *Device Name* EE 0x30-0x37.

Purpose: The DeviceName( ) function returns the battery's name for identification purposes.

SMBus Protocol: Read Block

Output: String-character string with maximum length of 7 characters (7 + length byte).

DeviceChemistry( ) (0x22); [0x30-0x32]

Description: This function returns a character string that contains the battery's chemistry. For example, if the DeviceChemistry( ) function returns *NiMH*, the battery pack contains nickel metal hydride cells. The bq2063 sets DeviceChemistry( ) to the value programmed in *Device Chemistry* EE 0x40-0x44.

Purpose: The DeviceChemistry( ) function gives cell chemistry information for use by charging systems. The bq2063 does not use DeviceChemisty( ) values for internal charge control or fuel gauging.

SMBus Protocol: Read Block

Output: String-character string with maximum length of 4 characters (4 + length byte).

The following is a partial list of chemistries and their expected abbreviations. These abbreviations are *not* case sensitive.

Lead acid	PbAc
Lithium ion	LION
Nickel cadmium	NiCd
Nickel metal hydride	NiMH
Nickel zinc	NiZn
Rechargeable alkaline-manganese	RAM
Zinc air	ZnAr

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PROGRAMMING INFORMATION

EEPROM programming

The following sections describes the function of each EEPROM location and how the data is to be stored.

fundamental parameters

sense resistor value

Two factors are used to scale the current related measurements. The 16-bit *ADC Sense Resistor Gain* value in EE 0x68-0x69 scales Current( ) to mA. Adjusting *ADC Sense Resistor Gain* from its nominal value provides a method to calibrate the current readings for system errors and the sense resistor value (Rs) . The nominal value is set by

$$ADC\ Sense\ Resistor\ Gain = \frac{625}{(Rs)}$$

The 16-bit *VFC Sense Resistor Gain* in EE 0x6a-0x6b scales each VFC interrupt to mAh. *VFC Sense Resistor Gain* is based on the resistance of the series sense resistor. The following formula computes a nominal or starting value for *VFC Sense Resistor Gain* from the sense resistor value.

$$VFC\ Capital\ Sense\ Resistor\ Gain = \frac{409.6}{(Rs)}$$

Sense resistor values are limited to the range of 0.00916 to 0.100Ω.

digital filter

The desired digital filter threshold, VDF (µV), is set by the value stored in *Digital Filter*7 -FTD -0.0007 Tc 0.0001 Tw [[lter

PROGRAMMING INFORMATION

EDV thresholds and near full percentage (continued)

The bq2063 updates FCC if a qualified discharge occurs from a near-full threshold of FCC − NFW, until EDV2 condition is reached. The desired near-full threshold window, NFW (mAh), is programmed in *Near Full* in EE 0x55.

$$\textit{Near Full} = \frac{NFW}{2} \tag{8}$$

EVD discharge rate and temperature compensation

If EDV compensation is enabled, the bq2063 calculates battery voltage to determine EDV0, EDV1, and EDV2 thresholds as a function of battery capacity, temperature, and discharge load. The general equation for EDV0, EDV1, and EDV2 calculation is

$$EDV0,1,2 = EMF \bullet FBL - |\ ILOAD\ | \bullet R0 \bullet FTZ \tag{9}$$

Where:

EMF is a no-load battery voltage higher than the highest EDV threshold computed. EMF is programmed in mV in *EMF/EDV1* EE 0x74-0x75.

ILOAD is the current discharge load magnitude.

FBL is the factor that adjusts the EDV voltage for battery capacity and temperature to match the no-load characteristics of the battery.

$$FBL = f\ (\ C0,\ C + C1,\ T\ ) \tag{10}$$

Where:

C (either 0%, 3%, or *Battery Low %* for EDV0, EDV1, and EDV2, respectively) and C0 are the capacity-related EDV adjustment factors. C0 is programmed in *EDV C0 Factor/EDV2* EE 0x78−79. C1 is the desired residual battery capacity remaining at EDV0 (RM = 0). The C1 factor is stored in *EDV C1 Factor* EE 0x06.

T is the current temperature in °K.

R0 • FTZ represents the resistance of the battery as a function of temperature and capacity.

$$FTZ = f\ (\ R1\ ,\ T0,\ T,\ C + C1,\ TC) \tag{11}$$

R0 is the first order rate dependency factor stored in *EDV R0 Factor* EE 0x7a-0x7b.

T is the current temperature; C is the battery capacity relating to EDV0, EDV1, and EDV2.

R1 adjusts the variation of impedance with battery capacity. R1 is programmed in *EDV R1 Rate Factor* EE 0x7c-0x7d.

T0 adjusts the variation of impedance with battery temperature). T0 is programmed in *EDV T0 Rate Factor* EE 0x76-0x77.

TC adjusts the variation of impedance for cold temperatures (T < 23°C). TC is programmed in *EDV TC* EE 0x07.

PROGRAMMING INFORMATION

charging current (continued)

When fast charge terminates, the bq2063 sets ChargingCurrent( ) to zero and then to the *Maintenance Charging Current* EE 0x1d when the termination condition ceases. MC is the desired rate in mA.

$$\textit{Maintenance Charging Current} = \frac{MC}{4} \tag{16}$$

When Voltage( ) is less than EDV0, the bq2063 sets ChargingCurrent( ) to *Precharge Current* EE 0x1e. Typically this rate is larger than the maintenance rate to charge a deeply depleted pack up to the point where it may be fast charged. PCC is the desired rate in mA.

$$\textit{Precharge Current} = \frac{PCC}{8} \tag{17}$$

If temperature is between 0° and the LTF threshold, the bq2063 sets ChargingCurrent( ) to *PreCharge Current.* LTF is programmed in the lower nibble (LSN) OF *MaxTLowT* EE0x45 as

$$LowT = \frac{LTF(°C)}{0.8} \tag{18}$$

charge suspension

During charge, the bq2063 compares the current to the ChargingCurrent( ) plus the value IOIM. If the pack is charged at a current above the ChargingCurrent( ) plus IOIM, the bq2063 sets ChargingCurrent( ) to zero to stop charging. IOIM is programmed in the EE 0x49 value, *Overcurrent Margin*, encoded as

$$\textit{Overcurrent Margin} = \frac{IOIM}{16} \tag{19}$$

Overcurrent Margin EE 0x49 may be used to program IOIM values of 0 to 4080mA in 16mA steps.

The desired temperature threshold for charge suspension, MAXTEMP, may be programmed between 45°C and 69°C in 1.6°C steps. *MaxT LowT* EE 0x45 (MSN) is stored in a 4-bit value as shown:

$$MaxT = \frac{69\text{–}MAXTEMP}{1.6} \tag{20}$$

The bq2063 suspends fast charge when fast charge continues past full by the amount programmed in *Maximum Overcharge* EE 0x2e-0x2f. *Maximum Overcharge* is programmed in 2s complement form of charge in mAh.

FULLY_CHARGED bit clear threshold

The bq2063 clears the FULLY_CHARGED bit in BatteryStatus( ) when RelativeStateOfCharge( ) reaches the value, *Fully Charged Clear %* EE 0x4c. *Fully Charged Clear %* is an 8-bit value and is stored as a 2s complement of percent.

fast charge termination percentage

The bq2063 sets RM to a percentage of FCC on charge termination if the CSYNC bit is set in the Pack Configuration register. The percentage of FCC, FCT%, is stored in *Fast Charge Termination %* in EE 0x4b. The value is stored as shown:

$$\textit{Fast Charge Termination\%} = (FCT\% * 2.56-1)$$

cycle count threshold

Cycle Count Threshold 0x3c-0x3d sets the number of mAh that must be removed from the battery to increment CycleCount( ). Cycle Count Threshold is a 16-bit value stored in 2s complement of charge in mAh.

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pack options (continued)

LLTF

The LLTF bit sets the temperature threshold used to disable the learning cycle (FCC update).

0 Sets the low temperature learning fault to 12C

1 Sets the low temperature learning fault to the value stored in *MaxT_LowT*

remaining time and capacity alarms

Remaining Time Alarm in EE 0x02-0x03 and *Remaining Capacity Alarm* in 0x04-0x05 set the alarm thresholds used in the SMBus command codes 0x01 and 0x02, respectively. *Remaining Time Alarm* is stored in minutes and *Remaining Capacity Alarm* in mAh or 10 mWh, depending on the Battery_Mode( ) setting.

secondary protection limits for Li-Ion

The cell undervoltage (VUV) and overvoltage (VOV) limits are programmed in *Cell Undervoltage/Overvoltage* EE 0x4a according to the equations:

$$\textit{Cell Overvoltage}\text{ (lower nibble)} = \frac{VOV–4096}{32} \quad (23)$$

$$\textit{Cell Undervoltage}\text{ (upper nibble)} = \frac{VUV - 2048}{64} \quad (24)$$

CELL UNDER/OVER VOLTAGE (UPPER NIBBLE)	VUV (mV)	CELL UNDER/OVER VOLTAGE (LOWER NIBBLE)	VOV (mV)
0	2048	0	4096
1	2112	1	4128
2	2176	2	4160
3	2240	3	4192
4	2304	4	4224
5	2368	5	4256
6	2432	6	4288
7	2496	7	4320
8	2560	8	4352
9	2624	9	4384
a	2688	a	4416
b	2752	b	4448
c	2816	c	4480
d	2880	d	4512
e	2944	e	4544
f	3008	f	4576

$\overline{\textit{SAFETY}}$ Threshold

The Safety Voltage threshold (SOV) in mV is programmed in *Safety Overvoltage* EE 0x1f. It is stored as

$$\textit{Safety Overvoltage} = \frac{SOV - 4096}{64} \quad (25)$$

The Safety Overtemperature (SOT) in °C is programmed in *Safety Overtemperature* EE 0x08. It is stored as

$$\textit{Safety Overtemperature} = (94.5 - SOT) * 10 \quad (26)$$

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measurement calibration (continued)

current

The bq2063 scales Current( ) to mA units by the 16-bit value *ADC Sense Resistor Gain* in EE 0x68-0x69. Adjusting *ADC Sense Resistor Gain* from its nominal value provides a method to calibrate the current readings for variances in the ADC gain, internal voltage reference, and sense resistor value. The bq2063 calculates Current( ) by

$$\text{Current( )} = \left[\frac{(\text{ADC Reading} + \textit{ADC Offset}) * \textit{ADC Sense Resistor Gain}}{16384}\right] \quad (30)$$

The nominal value for *ADC Sense Resistor Gain* is given by equation (4).

ADC Offset in EE 0x62 adjusts the ADC reading for bq2063 measurement offset. *ADC Offset* is a signed 8-bit value that cancels offset present in the ADC measurement. *ADC Offset* is typically between –20 and 20.

vfc

To calibrate the coulomb counting measurement for VFC gain errors and sense resistor tolerance, the value of *VFC Sense Resistor Gain* EE 0x6a-0x6b may be adjusted from its nominal value.

The nominal value of *VFC Sense Resistor Gain* is given by equation (6).

The bq2063 VFC circuit has the ability to introduce a signal opposite in sign to the inherent device and circuit offset to cancel this error. The offset calibration routine is initiated with commands to ManufacturerAccess( ).

The bq2063 calculates the offset with the calibration routine and stores the calibration value using the least 21 bits of *VFC Offset* in EE 0x5e-0x60.

The least 20 bits store the offset calibration value (OCV). The sign of the offset calibration value is positive if the 21st bit is 0.

$$\text{OCV} = \frac{0.6\ \text{V}}{\textit{VFC Offset}_{19\text{–}0}} \quad (31)$$

temperature

The bq2063 uses *Temperature Offset* in EE 0x61 to calibrate the Temperature( ) function for offset. The required offset adjustment, TOFF (°C), sets *Temperature Offset* according to the equation

$$\textit{Temperature Offset} = \text{TOFF} * 10 \quad (32)$$

Where:

$-12.8 \le \text{TOFF} \le 12.7$

constants and string data

EEPROM constants

Check Byte 1 EE 0x00-0x01 and *Check Byte 2* EE 0x7e-0x7f must be programmed to 0x3c7f and 0xa55a, respectively.

specification information

Specification Information EE 0x14-0x15 stores the default value for the SpecificationInfo( ) function. It is stored in EEPROM in the same format as the data returned by the SepcificationInfo( ).

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