# SBS v1.1-COMPLIANT GAS GAUGE FOR USE WITH THE bq29312

**Check for Samples: bq2084-V133**

## FEATURES

- **Provides Accurate Measurement of Available Charge in Li-Ion and Li-Polymer Batteries**
- **Supports the Smart Battery Specification (SBS) V1.1**
- **Integrated Time Base Eliminates Need for External Crystal**
  - **Optional Crystal input**
- **Works With the TI bq29312 Analog Front-End (AFE) Protection IC to Provide Complete Pack Electronics for 7.2-V, 10.8-V or 14.4-V Battery Packs With Few External Components**
- **Based on a Powerful Low-Power RISC CPU Core With High-Performance Peripherals**
- **Integrated Flash Memory Eliminates the Need for External Configuration EEPROM**
- **Uses 16-Bit Delta Sigma Converter for Accurate Voltage and Temperature Measurements**
- **Measures Charge Flow Using a High Resolution 16-Bit Integrating Converter**
  - **Better Than 0.65-nVh of Resolution**
  - **Self-Calibrating**
  - **Offset Error Less Than 1-µV**
- **Programmable Cell Modeling for Maximum Battery Fuel Gauge Accuracy**
- **Drives 3-, 4-, or 5-Segment LED Display for Remaining Capacity Indication**
- **Available in a 38-Pin TSSOP (DBT) Package**

## APPLICATIONS

- **Notebook PCs**
- **Medical and Test Equipment**
- **Portable Instrumentation**

## DESCRIPTION

The bq2084-V133 SBS-compliant gas gauge IC for battery pack or in-system installation maintains an accurate record of available charge in Li-ion or Li-polymer batteries. The bq2084-V133 monitors capacity and other critical parameters of the battery pack and reports the information to the system host controller over a serial communication bus. It is designed to work with the bq29312 AFE protection IC to maximize functionality and safety and minimize component count and cost in smart battery circuits. Using information from the bq2084-V133, the host controller can manage remaining battery power to extend the system run time as much as possible.

The bq2084-V133 uses an integrating converter with continuous sampling for the measurement of battery charge and discharge currents. Optimized for coulomb counting in portable applications, the self-calibrating integrating converter has a resolution better than 0.65-nVh and an offset measurement error of less than 1-µV (typical). For voltage and temperature reporting, the bq2084-V133 uses a 16-bit A-to-D converter. With the bq29312, the onboard ADC also monitors the pack and individual cell voltages in a battery pack and allows the bq2084-V133 to generate the control signals necessary to implement the cell balancing and the required safety protection for Li-ion and Li-polymer battery chemistries.

The bq2084-V133 supports the Smart Battery Data (SBData) commands and charge-control functions. It communicates data using the System Management Bus (SMBus) 2-wire protocol. The data available include the battery's remaining capacity, temperature, voltage, current, and remaining run-time predictions.

The bq2084-V133 provides LED drivers and a pushbutton input to indicate remaining battery capacity from full to empty in 20%, 25%, or 33% increments with a 3-, 4-, or 5-segment display.

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These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

## DESCRIPTION (CONTINUED)

The bq2084-V133 contains 1k bytes of internal data flash memory, which store configuration information. The information includes nominal capacity and voltage, self-discharge rate, rate compensation factors, and other programmable cell-modeling factors used to accurately adjust remaining capacity for use-conditions based on time, rate, and temperature. The bq2084-V133 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 bq29312 analog front-end (AFE) protection IC is used to maximize functionality and safety and minimize component count and cost in smart battery circuits. The bq29312 AFE protection IC provides power to the bq2084-V133 from a 2-, 3-, or 4-series Li-ion cell stack, eliminating the need for an external regulator circuit.

### ORDERING INFORMATION

| $T_A$ | PACKAGE |
|---|---|
| | 38-PIN TSSOP (DBT) |
| –20°C to 85°C | bq2084DBT-V133(1) |

(1) The bq2084-V133 is available taped and reeled. Add an R suffix to the device type (e.g., bq2084DBTR-V133) to order tape and reel version.

## ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range unless otherwise noted(1)

| | | UNIT |
|---|---|---|
| | Supply voltage range, $V_{DD}$ relative to $V_{SS}$ (2) | –0.3 V to 4.1 V |
| | Open-drain I/O pins, $V_{(IOD)}$ relative to $V_{SS}$ (2) | –0.3 V to 6 V |
| | Input voltage range to all other pins, $V_I$ relative to $V_{Ss}$ (2) | –0.3 V to $V_{DD}$ + 0.3 V |
| $T_A$ | Operating free-air temperature range | –20°C to 85°C |
| $T_{stg}$ | Storage temperature range | –65°C to 150°C |

(1) Stresses beyond those listed under *absolute maximum ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *recommended operating conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

(2) $V_{SS}$ refers to the common node of $V_{(SSA)}$, $V_{(SSD)}$, and $V_{(SSP)}$.

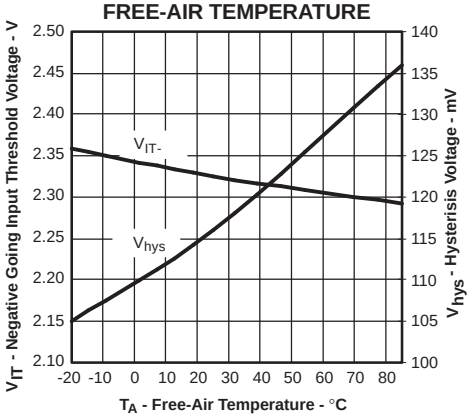

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## ELECTRICAL CHARACTERISTICS

$V_{DD}$ = 3.0 V to 3.6 V, $T_A$ = –20°C to 85°C unless otherwise noted

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| $V_{DD}$ | Supply voltage | VDDA and VDDD | 3.0 | 3.3 | 3.6 | V |
| $I_{DD}$ | Operating mode current | No flash programming or LEDs active | | 380 | | µA |
| $I_{(SLP)}$ | Low-power storage mode current | Sleep mode | | 8 | | µA |
| $V_{OL}$ | Output voltage low SMBC, SMBD, SDATA, SCLK, $\overline{SAFE}$, PU | $I_{OL}$ = 0.5 mA | | | 0.4 | V |
| | LED1-LED5 | $I_{OL}$ = 10 mA | | | 0.4 | |
| $V_{IL}$ | Input voltage low SMBC, SMBD, SDATA, SCLK, EVENT, PU, $\overline{PRES}$, $\overline{PFIN}$ | | –0.3 | | 0.8 | V |
| | DISP | | –0.3 | | 0.8 | |
| $V_{IH}$ | Input voltage high SMBC, SMBD, SDATA, SCLK, EVENT, PU, $\overline{PRES}$, $\overline{PFIN}$ | | 2 | | 6 | V |
| | DISP | | 2 | | $V_{DD}$ + 0.3 | |
| $V_{(AI1)}$ | Input voltage range VIN, TS | | $V_{SS}$ – 0.3 | | 1.0 | V |
| $V_{(AI2)}$ | Input voltage range SR1, SR2 | | $V_{SS}$ – 0.25 | | 0.25 | V |
| $Z_{(AI1)}$ | Input impedance SR1, SR2 | –0.25 V to 0.25 V | 2.5 | | | MΩ |
| $Z_{(AI2)}$ | Input impedance VIN, TS | 0 V–1.0 V | 8 | | | MΩ |
| **POWER-ON RESET** | | | | | | |
| $V_{IT+}$ | Negative-going voltage input | | 2.1 | 2.3 | 2.5 | V |
| $V_{hys}$ | Power-on reset hysteresis | | 50 | 125 | 200 | mV |

**POWER ON RESET BEHAVIOR VS FREE-AIR TEMPERATURE**




## INTEGRATING ADC CHARACTERISTICS

$V_{DD}$ = 3.0 V to 3.6 V, $T_A$ = –20°C to 85°C unless otherwise noted

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| $V_{(SR)}$ | Input voltage range, $V_{(SR2)}$ and $V_{(SR1)}$ | $V_{SR} = V_{(SR2)} – V_{(SR1)}$ | –0.25 | | 0.25 | V |
| $V_{(SROS)}$ | Input offset | | | 1 | | mV |
| INL | Integral nonlinearity error | FAST = 0, –0.1 V to 0.8 x $V_{ref}$ | | 0.004% | 0.018% | |

## PLL SWITCHING CHARACTERISTICS

$V_{DD}$ = 3.0 V to 3.6 V, $T_A$ = –20°C to 85°C unless otherwise noted

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| $t_{(SP)}$ | Start-up time (1) | ±0.5% frequency error | | 2 | 5 | ms |

(1) The frequency error is measured from the trimmed frequency of the internal system clock, which is 128 x oscillator frequency, nominally 4.194 MHz.

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## OSCILLATOR

$V_{DD}$ = 3.0 V to 3.6 V, $T_A$ = –20°C to 85°C (unless otherwise noted) (TYP: $V_{DD}$ = 3.3 V, $T_A$ = 25°C)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| $f_{(eio)}$ | Frequency error from 32.768 kHz | ROSC = 100k | –2% | 0.5% | 2% | |
| | | XCK1 = 12 pF XTAL | –0.25% | | 0.25% | |
| $f_{(dio)}$ | Frequency drift(1) | ROSC = 100k, $T_A$ = 0°C to 50°C | –1% | | 1% | |
| $f_{(sio)}$ | Start-up time(2) | ROSC = 100k | | | 200 | µs |
| $f_{(sxo)}$ | | XCK1 = 12 pF XTAL | | | 250 | ms |

(1) The frequency drift is measured from the trimmed frequency at $V_{DD}$ = 3.3 V, $T_A$ = 25°C.
(2) The start-up time is defined as the time it takes for the oscillator output frequency to be ±1%

## DATA FLASH MEMORY CHARACTERISTICS

$V_{DD}$ = 3.0 V to 3.6 V, $T_A$ = –20°C to 85°C unless otherwise noted

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| $t_{DR}$ | Data retention | See (1) | 10 | | | Years |
| | Flash programming write-cycles | See (1) | 20k | | | Cycles |
| $t_{(WORDPROG)}$ | Word programming time | See (1) | | | 2 | ms |
| $I_{(DDPROG)}$ | Flash-write supply current | See (1) | | 8 | 12 | mA |

(1) Specified by design. Not production tested.

## REGISTER BACKUP

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| $I_{(RBI)}$ | RBI data-retention input current | $V_{RBI}$ > 2.0 V, $V_{DD}$ < $V_{IT}$ | | 10 | 100 | nA |
| $V_{(RBI)}$ | RBI data-retention voltage (1) | | 1.3 | | | V |

(1) Specified by design. Not production tested.

## SMBus TIMING SPECIFICATIONS

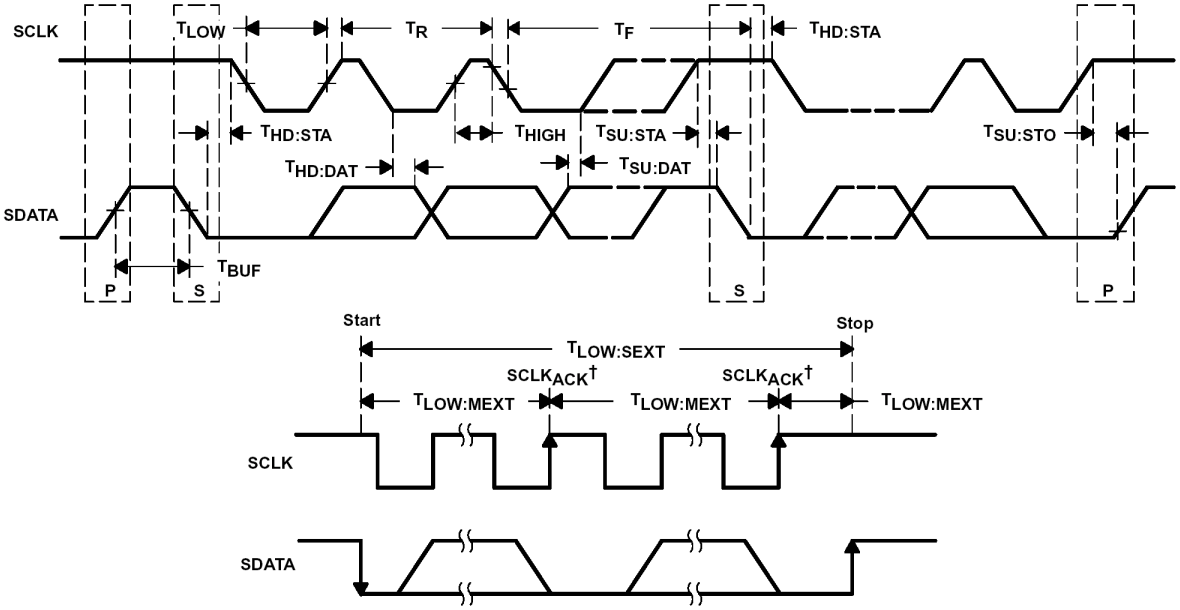
$V_{DD}$ = 3.0 V to 3.6 V, $T_A$ = -20°C to 85°C unless otherwise noted

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| $f_{(SMB)}$ | SMBus operating frequency | Slave mode, SMBC 50% duty cycle | 10 | | 100 | kHz |
| $f_{(MAS)}$ | SMBus master clock frequency | Master mode, no clock low slave extend | | 51.2 | | kHz |
| $t_{(BUF)}$ | Bus free time between start and stop | | 4.7 | | | µs |
| $T_{(HD:STA)}$ | Hold time after (repeated) start | | 4.0 | | | µs |
| $t_{(SU:STA)}$ | Repeated start setup time | | 4.7 | | | µs |
| $t_{(SU:STO)}$ | Stop setup time | | 4.0 | | | µs |
| $t_{(HD:DAT)}$ | Data hold time | Receive mode | 0 | | | ns |
| | | Transmit mode | 300 | | | |
| $t_{SU:DAT)}$ | Data setup time | | 250 | | | ns |
| $t_{(TIMEOUT)}$ | Error signal/detect | See (1) | 25 | | 35 | ms |
| $t_{(LOW)}$ | Clock low period | | 4.7 | | | µs |
| $t_{(HIGH)}$ | Clock high period | See (2) | 4.0 | | 50 | µs |
| $t_{LOW:SEXT)}$ | Cumulative clock low slave extend time | See (3) | | | 25 | ms |
| $t_{LOW:MEXT}$ | Cumulative clock low master extend time | See (4) | | | 10 | ms |
| $t_f$ | Clock/data fall time | ($V_{ILMAX}$ – 0.15 V) to ($V_{IHMIN}$ + 0.15 V) | | | 300 | ns |
| $t_r$ | Clock/data rise time | 0.9 $V_{DD}$ to ($V_{ILMAX}$ – 0.15 V) | | | 1000 | ns |

(1) The bq2084-V133 times out when any clock low exceeds $t_{(TIMEOUT)}$.
(2) $t_{(HIGH)}$ Max. is minimum bus idle time. SMBC = 1 for t > 50 ms causes reset of any transaction involving bq2084-V133 that is in progress.
(3) $t_{(LOW:SEXT)}$ is the cumulative time a slave device is allowed to extend the clock cycles in one message from initial start to the stop.
(4) $t_{(LOW:MEXT)}$ is the cumulative time a master device is allowed to extend the clock cycles in one message from initial start to the stop.

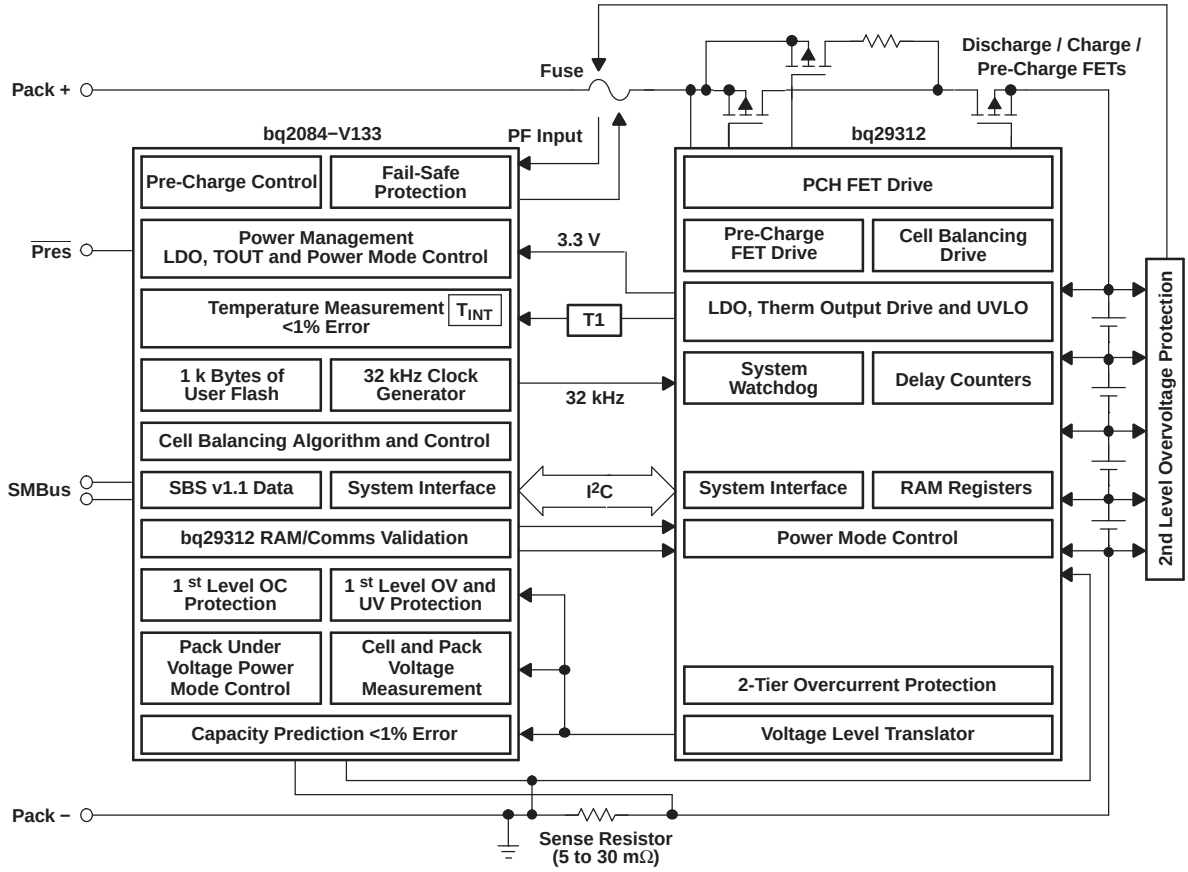

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## SMBus TIMING DIAGRAMS



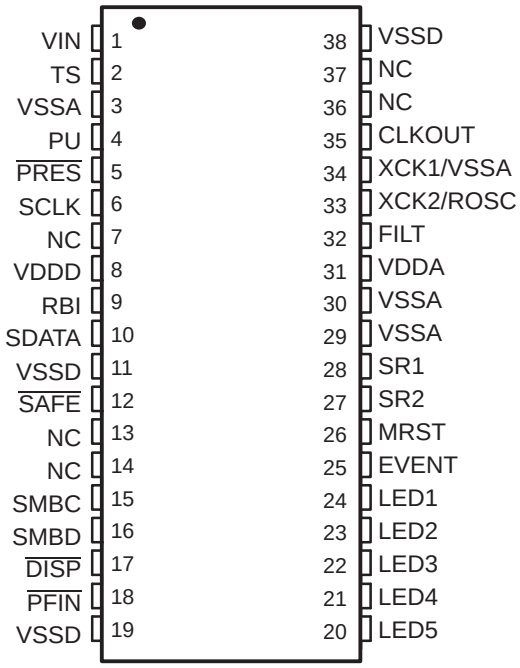

† $SCLK_{ACK}$ is the acknowledge-related clock pulse generated by the master.

## SYSTEM DIAGRAM



## PIN ASSIGNMENTS

**TSSOP (DBT)**
**(TOP VIEW)**




### Pin Functions

| PINS NAME | PINS NO. TSSOP | I/O | DESCRIPTION |
|---|---|---|---|
| CLKOUT | 35 | O | 32.768-kHz output to the bq29312 |
| $\overline{\text{DISP}}$ | 17 | I | Display control for the LED drivers LED1 through LED5 |
| FILT | 32 | I | Analog input connected to the external PLL filter |
| EVENT | 25 | I | Input from bq29312 XALERT output |
| LED1 | 24 | O | LED display segments that each may drive an external LED |
| LED2 | 23 | O | |
| LED3 | 22 | O | |
| LED4 | 21 | O | |
| LED5 | 20 | O | |
| MRST | 26 | I | Master reset input that forces the device into reset when held high |
| NC | 7, 13, 14, 36, 37 | – | No connection |
| $\overline{\text{PFIN}}$ | 18 | I | Active low input to detect secondary protector output status |
| $\overline{\text{PRES}}$ | 5 | I | Active low input to sense system insertion |
| PU | 4 | O | Output to pull up the /PRES pin for detection |
| RBI | 9 | I | Register backup that provides backup potential to the bq2084-V133 data registers during periods of low operating voltage. RBI accepts a storage capacitor or a battery input. |
| $\overline{\text{SAFE}}$ | 12 | O | Active low output for additional level of safety protection; e.g., fuse blow. |
| SCLK | 6 | O | Communication clock to the bq29312 |
| SDATA | 10 | I/O | Data transfer to and from bq29312 |
| SMBC | 15 | I/O | SMBus clock open-drain bidirectional pin used to clock the data transfer to and from the bq2084-V133 |
| SMBD | 16 | I/O | SMBus data open-drain bidirectional pin used to transfer address and data to and from the bq2084-V133 |


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**Pin Functions (continued)**

| PINS NAME | PINS NO. TSSOP | I/O | DESCRIPTION |
|---|---|---|---|
| SR1 | 28 | I | Connections for a small-value sense resistor to monitor the battery charge- and discharge-current flow |
| SR2 | 27 | I | |
| TS | 2 | I | Thermistor input to monitor temperature |
| VDDA | 31 | I | Positive supply for analog circuitry |
| VDDD | 8 | I | Positive supply for digital circuitry and I/O pins |
| VIN | 1 | I | Single-cell voltage input from the bq29312 |
| VSSA | 3, 29, 30 | I | Negative supply for analog circuitry |
| VSSD | 11, 19, 38 | I | Negative supply for digital circuitry |
| XCK1/VSSA | 34 | I | 32.768-kHz crystal oscillator input pin or connected to VSSA if the internal oscillator is used |
| XCK2/ROSC | 33 | O | 32.768-kHz crystal oscillator output pin or connected to a 100-kΩ, 50 ppm or better resistor if the internal oscillator is used |

# FUNCTIONAL DESCRIPTION

## OSCILLATOR FUNCTION

The bq2084-V133 can use an internal or an external oscillator. At powerup, the bq2084-V133 automatically attempts to start the internal oscillator. If a 100-kΩ resistor is not connected to ROSC (pin 33), then it attempts to start the oscillator using an external 32.768-kHz crystal. Install either the 100-kΩ ROSC resistor *or* the 12 pF 32.768-kHz crystal, *not* both.

The performance of the internal oscillator depends on the tolerance of the 100-kΩ resistor connected between RSOC (pin 33) and VSSA (pin 34). It is recommended that this resistor be as close to the bq2084-V133 as possible and that it has a specification of ±0.1% tolerance and ±50 ppm temperature drift or better. The 12-pF crystal, if used, should also be placed as close to the XCK1 (pin 34) and XCK2 (pin 33) pins as possible. The PCB layout around these pins and components can degrade oscillator performance if not carefully implemented.

The average oscillator temperature-drift error during a learning charge or a discharge cycle introduces an equal capacity-prediction error in the learned full-charge capacity value (FCC).

## SYSTEM PRESENT OPERATION

When the bq2084-V133 detects that the battery is inserted into the system via a low state on the $\overline{\text{PRES}}$ input, the bq2084-V133 enters normal operating mode and sets the PRES bit in *PackStatus()*. The discharge FET turns on within 250 ms of pack insertion. When the pack is removed from the system and the $\overline{\text{PRES}}$ input is high, then the bq2084-V133 enters the battery removed state and turns OFF the charge and discharge FETs, and enables the 0-V/precharging FET. If NR in Misc Config is set, then the PRES input can be left floating as it is not used.

## GENERAL OPERATION

The bq2084-V133 determines battery capacity by monitoring the amount of charge input or removed from a rechargeable battery. In addition to measuring charge and discharge, the bq2084-V133 measures individual cell voltages, pack voltage, temperature, and current, estimates battery self-discharge, and monitors the battery for low-voltage thresholds using features of the bq29312 AFE device.

The bq2084-V133 measures charge and discharge activity by monitoring the voltage across a small-value series sense resistor between the cell stack negative terminal and the negative terminal of the battery pack. The available battery charge is determined by monitoring this voltage and correcting the measurement for environmental and operating conditions.

The bq2084-V133 interfaces with the bq29312 to perform battery protection, cell balancing, and voltage translation functions. The bq2084-V133 can accept any NTC thermistor (default is Semitec 103AT) for temperature measurement or can also be configured to use its internal temperature sensor. The bq2084-V133 uses temperature to monitor the battery pack and to compensate the self-discharge estimate.

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## MEASUREMENTS

The bq2084-V133 uses an integrating sigma-delta analog-to-digital converter (ADC) for current measurement and a second sigma-delta ADC for individual cell and battery voltage and temperature measurement. The individual cell and pack voltages, *Voltage()*, *Current()*, *AverageCurrent()* and *Temperature()* are updated every 1 s during normal operation.

## CHARGE AND DISCHARGE COUNTING

The integrating ADC measures the charge and discharge flow of the battery by monitoring a small-value sense resistor between the SR1 and SR2 pins. The integrating ADC measures bipolar signals from -0.25 V to 0.25 V. The bq2084-V133 detects charge activity when VSR = $V_{(SR1)}$-$V_{(SR2)}$ is positive and discharge activity when VSR = V(SR1)-V(SR2) is negative. The bq2084-V133 continuously integrates the signal over time, using an internal counter. The fundamental rate of the counter is 0.65 nVh. The bq2084-V133 updates *RemainingCapacity()* with the charge or discharge accumulated in this internal counter once every second.

## OFFSET CALIBRATION

The bq2084-V133 provides an auto-calibration feature to cancel the voltage offset error across SR1 and SR2 for maximum charge measurement accuracy. The bq2084-V133 performs auto-calibration when the SMBus lines stay low for a minimum of 20 s when it internally connects SR1 to SR2 and measures the internal offset. With this feature the bq2084-V133 is capable of automatic offset calibration down to <1 µV.

## DIGITAL FILTER

The bq2084-V133 does not measure charge or discharge counts below the digital filter threshold. The digital filter threshold is programmed in the *Digital Filter* (DF 0x2c) and should be set sufficiently high to prevent false signal detection with no charge or discharge flowing through the sense resistor.

## VOLTAGE

While monitoring SR1 and SR2 for charge and discharge currents, the bq2084-V133 monitors the individual series cell voltages through the bq29312. The bq2084-V133 configures the bq29312 to present the selected cell to the CELL pin of the bq29312, which should be connected to VIN of the bq2084-V133. The internal ADC of the bq2084-V133 then measures the voltage and scales it appropriately. The bq2084-V133 then reports the *Voltage()* and the individual cell voltages in *VCELL1()*, *VCELL2()*, *VCELL3()*, and *VCELL4()*. An additional SMBus command (0x45) returns the measured ADC Reading of the PACK input to the AFE.

## CURRENT

The bq2084-V133 uses the SR1 and SR2 inputs to measure and calculate the battery charge and discharge current. This value is reported via the SBS command *Current()*. *AverageCurrent()* is implemented as a single-pole IIR filter with a 14.5-s time constant.

## TEMPERATURE

The TS input of the bq2084-V133 along with an NTC thermistor measures the battery temperature as shown in the schematic. The bq2084-V133 reports temperature via the SBS command *Temperature()*.

The bq2084-V133 can also be configured to use its internal temperature sensor by setting the IT bit in *Misc Configuration* (DF 0x2a-0x2b). Data flash locations DF 0xb5 through DF 0xc0 also have to be changed to prescribed values if the internal temperature sensor option is selected.

**Table 1. Data Flash Settings for Internal or External Temperature Sensor**

| LABEL | LOCATION | INTERNAL TEMP SENSOR SETTING | EXTERNAL TEMP SENSOR SETTING (Semitec 103AT) |
|---|---|---|---|
| | Dec (Hex) | Dec (Hex) | Dec (Hex) |
| Misc. Config | 42 (0x2a) | Bit 7 = 1 | Bit 7 = 0 |
| TS Const1 A3 | 164/5 (0xb5/6) | 0 (0x0000) | –28285 (0x9183) |
| TS Const2 A2 | 166/7 (0xb7/8) | 0 (0x0000) | 20848 (0x5170) |
| TS Const3 A1 | 168/9 (0xb9/a) | –11136 (0xd480) | –7537 (0xe28f) |


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**Table 1. Data Flash Settings for Internal or External Temperature Sensor (continued)**

| LABEL | LOCATION | INTERNAL TEMP SENSOR SETTING | EXTERNAL TEMP SENSOR SETTING (Semitec 103AT) |
|---|---|---|---|
| | Dec (Hex) | Dec (Hex) | Dec (Hex) |
| TS Const4 A0 | 170/1 (0xbb/c) | 5734 (0x1666) | 4012 (0x0fac) |
| Min Temp AD | 172/3 (0xbd/e) | 0 (0x0000) | 0 (0x000) |
| Max Temp | 174/5 (0xbf/c0) | 5734 (0x1666) | 4012 (0x0fac) |

## GAS GAUGE OPERATION

### General

The operational overview in Figure 1 illustrates the gas gauge operation of the bq2084-V133. Table 3 describes the bq2084-V133 registers.

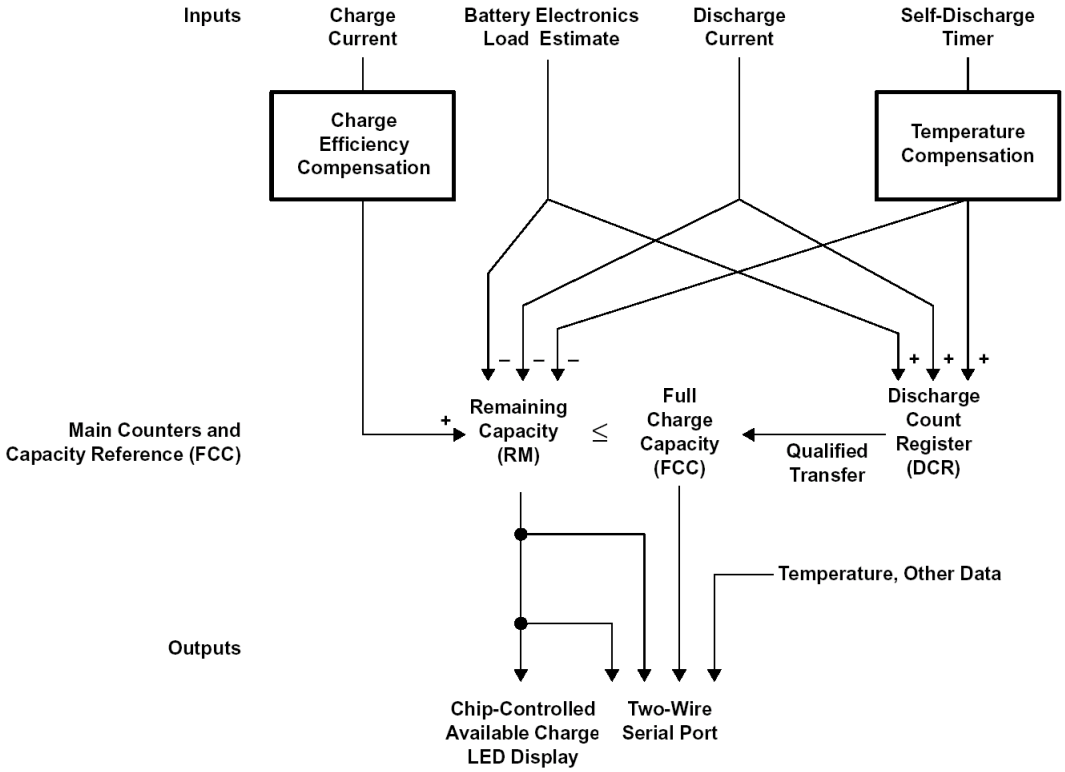



**Figure 1. bq2084-V133 Gas Gauging Operational Overview**

The bq2084-V133 accumulates a measure of charge and discharge currents and estimates self-discharge of the battery. The bq2084-V133 compensates the charge current measurement for temperature and state-of-charge of the battery. The bq2084-V133 also adjusts the self-discharge estimation based on temperature.

The main charge counter *RemainingCapacity()* (RM) represents the available capacity or energy in the battery at any given time. The bq2084-V133 adjusts RM for charge, self-discharge, and other compensation factors. The information in the RM register is accessible through the SMBus interface and is also represented through the LED display.

The *FullChargeCapacity()* (FCC) register represents the last measured learned full discharge of the battery. It is used as the battery full-charge reference for relative capacity indication. The bq2084-V133 updates FCC after the battery undergoes a qualified discharge from nearly full to a low battery level. FCC is accessible through the SMBus interface.

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The Discharge Count Register (DCR) is a non-accessible register that tracks discharge of the battery. The bq2084-V133 uses the DCR register to update the FCC register if the battery undergoes a qualified discharge from nearly full to a low battery level. In this way, the bq2084-V133 learns the true discharge capacity of the battery under system-use conditions.

### Main Gas-Gauge Registers

#### *RemainingCapacity() (RM)*

RM represents the remaining capacity in the battery. The bq2084-V133 computes RM in units of either mAh or 10 mWh depending on the selected mode. See *Battery Mode()* (0x03) for units configuration. RM counts up during charge to a maximum value of *FullChargeCapacity()* (FCC) and down during discharge and self-discharge to a minimum of 0. In addition to charge and self-discharge compensation, the bq2084-V133 calibrates RM at three low-battery-voltage thresholds, EDV2, EDV1, and EDV0 and three programmable midrange thresholds VOC25, VOC50, and VOC75. This provides a voltage-based calibration to the RM counter.

#### *DesignCapacity () (DC)*

DC is the user-specified battery full capacity. It is calculated from *Pack Capacity* (DF 0x32-0x33) and is represented in units of mAh or 10 mWh. It also represents the full-battery reference for the absolute display mode.

#### *FullChargeCapacity() (FCC)*

FCC is the last learned measured discharge capacity of the battery. It is represented in units of either mAh or 10 mWh, depending on the selected mode. On initialization, the bq2084-V133 sets FCC to the value stored in *Full Charge Capacity* (DF 0x36-0x37). During subsequent discharges, the bq2084-V133 updates FCC with the last learned measured discharge capacity of the battery. The last learned measured discharge of the battery is based on the value in the Discharge Count Register (DCR) after a qualified discharge occurs. Once updated, the bq2084-V133 writes the new FCC value to data flash in mAh to *Full Charge Capacity*. FCC represents the full-battery reference for the relative display mode, relative state of charge and *AtRate()* calculations.

#### *Discharge Count Register (DCR)*

The DCR register counts up during discharge, independent of RM. DCR counts discharge activity, battery load estimation, and self-discharge increments. The bq2084-V133 initializes DCR, at the beginning of a discharge, to FCC - RM when FCC - RM is within the programmed value in *Near Full* DF 0x30. The DCR initial value of FCC - RM is reduced by FCC/128 if SC = 1 (bit 5 in *Gauge Configuration*) and is not reduced if SC = 0. DCR stops counting when the battery voltage reaches the EDV2 threshold on discharge.

### Capacity Learning (FCC Update) and Qualified Discharge

The bq2084-V133 updates FCC with an amount based on the value in DCR if a qualified discharge occurs. The new value for FCC equals the DCR value plus the programmable nearly full and low battery levels, according to the following equation:

FCC (new) = DCR (final) = DCR (initial) + Measured Discharge to EDV2 + (FCC x *Battery Low%*)

*here Battery Low %* = (value stored in DF 0x2f) ÷ 2.56

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

- No 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 threshold programmed in *Learning Low Temp* DF 0xac during the discharge period.
- The battery voltage reaches the EDV2 threshold during the discharge period, and the voltage is ≥ EDV2 threshold – 256 mV when the bq2084-V133 detects EDV2.
- No midrange voltage correction occurs during the discharge period.
- Current remains ≥ 3C/32 when EDV2 or *Battery Low %* level is reached.
- No overload condition exists when EDV2 threshold is reached, or if *RM()* has dropped to *Battery Low%* x FCC,
- No valid charge activity occurs during the discharge period. A valid charge is defined as an uninterrupted


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charge of 10 mAh into the battery.

The bq2084-V133 sets VDQ = 1 in *PackStatus()* when qualified discharge begins. The bq2084-V133 sets VDQ = 0 if any disqualifying condition occurs. FCC cannot be reduced by more than 256 mAh or increased by more than 512 mAh during any single update cycle. The bq2084-V133 saves the new FCC value to the data flash within 4 seconds of being updated.

### End-of-Discharge Thresholds and Capacity Correction

The bq2084-V133 monitors the battery for three low-voltage thresholds, EDV0, EDV1, and EDV2. The EDV thresholds can be programmed for determination based on the overall pack voltage or an individual cell level. The EDVV bit in *Pack Configuration* DF 0x28 configures the bq2084-V133 for overall voltage or single-cell EDV thresholds. If programmed for single-cell EDV determination, the bq2084-V133 determines EDV on the basis of the lowest single-cell voltage. Fixed EDV thresholds must be programmed in *EMF/EDV0* DF 0x95-0x96, *EDV C0 Factor/EDV1* DF 0x97-0x98, and *EDV R Factor/EDV2* DF 0x99-0x9a.

If the CEDV bit in *Gauge Configuration* DF 0x29 is set, automatic compensated EDVs are enabled and the bq2084-V133 computes the EDV0, EDV1, and EDV2 voltage thresholds based on the values in DF 0x95-0xa0 and the battery's current discharge rate and temperature. The bq2084-V133 disables EDV detection if Current( ) exceeds the *Overload Current* threshold programmed in DF 0x5b-DF 0x5c. The bq2084-V133 resumes EDV threshold detection after *Current()* drops below the *Overload Current* threshold. Any EDV threshold detected is reset after charge is detected and VDQ is cleared after 10 mAh of charge.

The bq2084-V133 uses the EDV thresholds to apply voltage-based corrections to the RM register according to Table 2.

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

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

The bq2084-V133 performs EDV-based RM adjustments with *Current()* ≥ C/32. No EDV flags are set if current < C/32.

The bq2084-V133 adjusts RM as it detects each threshold. If the voltage threshold is reached before the corresponding capacity on discharge, the bq2084-V133 reduces RM to the appropriate amount as shown in Table 2.

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.

### EDV Thresholds and Near-Full Programming

The bq2084-V133 uses the values stored in data flash for the EDV0, EDV1, and EDV2 values or calculates the three thresholds from a base value and the temperature, capacity, and rate adjustment factors stored in data flash. If EDV compensation is disabled, then EDV0, EDV1, and EDV2 are stored directly in mV in DF 0x95-0x96, DF 0x97-0x98, and DF 0x99-0x9a, respectively.

For capacity correction at EDV2, *Battery Low %* DF 0x2f can be set at a desired state-of-charge, *STATEOFCHARGE%*, in the range of 3-19%. Typical values for *STATEOFCHARGE%* are 5-7%, representing 5-7% capacity.

*Battery Low %* = (*STATEOFCHARGE%* x 2.56)

The bq2084-V133 updates FCC if a qualified discharge occurs from a near-full threshold of FCC - *Near Full*, until EDV2 condition is reached. The desired near-full threshold window is programmed in *Near Full* (DF 0x30, 0x31) in mAh.

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### EDV Discharge Rate and Temperature Compensation Programming

If EDV compensation is enabled, the bq2084-V133 calculates battery voltage to determine EDV0, EDV1, and EDV2 thresholds as a function of battery capacity, temperature, and discharge load. The general equation for EDV0, EDV1, and EDV2 calculation is

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

EMF is a no-load cell voltage higher than the highest cell EDV threshold computed. EMF is programmed in mV in *EMF/EDV1* (DF 0x95-0x96).

ILOAD is the current discharge load magnitude.

n = the number of series cells

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

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

C (either 0%, 3%, or *Battery Low %* for EDV0, EDV1, and EDV2, respectively) and C0 are the capacity-related EDV adjustment factors. C0 is programmed in *EDV C0 Factor/EDV1* (DF 0x97-98). C1 is the desired residual battery capacity remaining at EDV0 (RM = 0). The C1 factor is stored in *EDV C1 Factor* (DF 0xa0).

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, T, C + C1, TC)

R0 is the first order rate dependency factor stored in *EDV R0 Factor/EDV2* DF 0x99-0x9a.

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* (DF 0x9d-0x9e).

T0 adjusts the variation of impedance with battery temperature. T0 is programmed in *EDV T0 Rate Factor* (DF 0x9b-0x9c).

TC adjusts the variation of impedance for cold temperatures (T < 23°C). TC is programmed in *EDV TC* (DF 0x9f).

Typical values for the EDV compensation factors, based on overall pack voltages for a Li-ion 3s2p 18650 pack, are:

EMF = 11550/3

T0 = 4475

C0 = 235

C1 = 0

R0 = 5350/3

R1 = 250

TC = 3


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**Table 3. bq2084-V133 Register Functions**

| FUNCTION | COMMAND CODE | ACCESS | UNITS |
|---|---|---|---|
| ManufacturerAccess | 0x00 | Read/write | NA |
| RemainingCapacityAlarm | 0x01 | Read/write | mAh, 10 mWh |
| RemainingTimeAlarm | 0x02 | Read/write | minutes |
| BatteryMode | 0x03 | Read/write | NA |
| AtRate | 0x04 | Read/write | mA, 10 mW |
| AtRateTimeToFull | 0x05 | Read | minutes |
| AtRateTimeToEmpty | 0x06 | Read | minutes |
| AtRateOK | 0x07 | Read | Boolean |
| Temperature | 0x08 | Read | 0.1°K |
| Voltage | 0x09 | Read | mV |
| Current | 0x0a | Read | mA |
| AverageCurrent | 0x0b | Read | mA |
| MaxError | 0x0c | Read | percent |
| RelativeStateOfCharge | 0x0d | Read | percent |
| AbsoluteStateOfCharge | 0x0e | Read | percent |
| RemainingCapacity | 0x0f | Read | mAh, 10 mWh |
| FullChargeCapacity | 0x10 | Read | mAh, 10 mWh |
| RunTimeToEmpty | 0x11 | Read | minutes |
| AverageTimeToEmpty | 0x12 | Read | minutes |
| AverageTimeToFull | 0x13 | Read | minutes |
| ChargingCurrent | 0x14 | Read | mA |
| ChargingVoltage | 0x15 | Read | mV |
| Battery Status | 0x16 | Read | NA |
| CycleCount | 0x17 | Read | cycles |
| DesignCapacity | 0x18 | Read | mAh, 10 mWh |
| DesignVoltage | 0x19 | Read | mV |
| SpecificationInfo | 0x1a | Read | NA |
| ManufactureDate | 0x1b | Read | NA |
| SerialNumber | 0x1c | Read | integer |
| Reserved | 0x1d-0x1f | 0 | 0 |
| ManufacturerName | 0x20 | Read | string |
| DeviceName | 0x21 | Read | string |
| DeviceChemistry | 0x22 | Read | string |
| ManufacturerData | 0x23 | Read | string |
| Pack status | 0x2f (LSB) | Read | NA |
| Pack configuration | 0x2f (MSB) | Read | NA |
| VCELL4 | 0x3c | Read | mV |
| VCELL3 | 0x3d | Read | mV |
| VCELL2 | 0x3e | Read | mV |
| VCELL1 | 0x3f | Read | mV |
| VPACK | 0x45 | Read | mV |
| AFEData | 0x46 | Read | hex |

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### Self-Discharge

The bq2084-V133 estimates the self-discharge of the battery to maintain an accurate measure of the battery capacity during periods of inactivity. The bq2084-V133 makes self-discharge adjustments to RM every 1/4 s when awake and periodically (determined by *Sleep Timer* DF 0xfe) when in sleep mode. The self-discharge estimation rate for 25°C is doubled for each 10 degrees above 25°C or halved for each 10 degrees below 25°C. Table 4 shows the relation of the self-discharge estimation at a given temperature to the rate programmed for 25°C (Y% per day programmed in DF 0x2d).

**Table 4. Self-Discharge for Rate Programmed**

| TEMPERATURE (°C) | SELF-DISCHARGE RATE |
|---|---|
| Temp < 10 | 1/4 Y% per day |
| 10 ≤ Temp <20 | 1/2 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* (DF 0x2d) by the following relation:

*Self-Discharge Rate* = %PERDAY ÷ 0.01

### Battery Electronic Load Compensation

The bq2084-V133 can be configured to compensate for a constant load (as from battery electronics) present in the battery pack at all times. The bq2084-V133 applies the compensation continuously when the charge or discharge is below the digital filter. The bq2084-V133 applies the compensation (BEL) in addition to self-discharge. The compensation occurs at a rate determined by the value stored in *Electronics Load* (DF 0x2e). The compensation range is 0 µA-765 µA in steps of approximately 3 µA. The data is stored as follows:

*Electronics Load* = BEL ÷ 3

### Midrange Capacity Corrections

The bq2084-V133 applies midrange capacity corrections when the VCOR bit is set in *Gauge Configuration* DF 0x29. The bq2084-V133 adjusts RM to the associated percentage at three different voltage levels: VOC25, VOC50, and VOC75. The VOC values represent the open-circuit battery voltage at which RM corresponds to the associated percentage for each threshold.

For the midrange corrections to occur, the temperature must be in the range of 19°C to 31°C inclusive and *Current()* and *AverageCurrent()* must both report between -64 mA and 0. The bq2084-V133 makes midrange corrections as shown in Table 5. For a correction to occur, the bq2084-V133 must detect the need for correction twice during subsequent 20-s intervals. With the VCOR bit set, the bq2084-V133 makes midrange corrections whenever conditions permit.

If the OTVC bit in *Gauge Configuration* (DF 0x29) is set and VCOR = 0, the bq2084-V133 makes two *Voltage()* measurements, determines the average of the two readings and sets the appropriate RM level. No further RSOC% vs *Voltage()* validation is performed until after the next device reset.


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**Table 5. Midrange Corrections**

| | CONDITION | RESULT |
|---|---|---|
| Voltage() | ≥ VOC75 and RelativeStateOfCharge() ≤ 63% | RelativeStateOfCharge() → 75% |
| | < VOC75 and RelativeStateOfCharge() ≥ 87% | RelativeStateOfCharge() → 75% |
| | ≥ VOC50 and RelativeStateOfCharge() <38% | RelativeStateOfCharge() → 50% |
| | <VOC50 and RelativeStateOfCharge() ≥ 62% | RelativeStateOfCharge() → 50% |
| | ≥ VOC25 and RelativeStateOfCharge() ≤ 13% | RelativeStateOfCharge() → 25% |
| | < VOC25 and RelativeStateOfCharge() ≥ 37% | RelativeStateOfCharge() → 25% |

Three voltage-based thresholds, *VOC25* (DF 0x88-0x89), *VOC50* (DF 0x83-0x84), and *VOC75* (DF 0x7e-0x7f), are stored in the data flash in mV.

### Charge Control

The bq2084-V133 internal charge control is compatible with the constant current/constant voltage profile for Li-ion. The bq2084-V133 detects primary charge termination on the basis of the tapering charge current during the constant-voltage phase.

### Charging Voltage Broadcasts

The bq2084-V133 supports SBS charge control by broadcasting the *ChargingCurrent()* and *ChargingVoltage()* to the Smart Charger address. The bq2084-V133 broadcasts the requests every 10 seconds. The bq2084-V133 updates the values used in the charging current and voltage broadcasts based on the battery's state of charge, voltage, and temperature.

The 16-bit value (mV) for charging voltage is programmed in *Charging Voltage* (DF 0x03a-0x3b) although it can be set to 0 in different operating conditions. It also sets the base value for determining overvoltage conditions during charging and voltage compliance during a constant-voltage charging methodology.

The 16-bit value, *Over Voltage Margin* (DF 0x5d-0x5e), sets the limit over *ChargingVoltage()* in mV that is to be considered as an overvoltage charge-suspension condition.

### Charging Current Broadcasts

*ChargingCurrent()* values are either broadcast to a Level 2 smart battery charger or read from the bq2084-V133 by a Level 3 smart battery charger. The *ChargingCurrent()* may take any of four different values: *Fast-Charging Current* DF (0x3e-0x3f), *Maintenance Charging Current* (DF 0x40-0x41), *Precharge Current* (DF 0x42-0x43) or 0 depending on charge state and operating conditions.

When fast charge is allowed, the bq2084-V133 sets *ChargingCurrent()* to the rate programmed in *Fast-Charging Current* DF 0x3e-0x3f. *Fast-Charging Current* is stored in mA.

When fast charge terminates, the bq2084-V133 sets *ChargingCurrent()* to zero and then to the *MaintenanceCharging Current* (DF 0x40-0x41) when the termination condition ceases. The desired maintenance current is stored in mA.

When *Voltage()* is less than EDV0, the bq2084-V133 sets *ChargingCurrent()* to *Precharge Current* (DF 0x42-0x43). 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. The desired precharge rate is stored in mA.

If temperature is between the *Charge Inhibit Temp Low* (DF0x46) and the precharge threshold PC (°C), the bq2084-V133 sets *ChargingCurrent()* to *Precharge Current.* The threshold is programmed in the *Precharge Temp* (DF 0x44). The maximal value of precharge temperature threshold setting is 12.7°C.

- *Precharge Temp* = PC (°C) / 0.1

The bq2084-V133 also sets *ChargingCurrent()* to the precharge rate if *Voltage()* is less than the value programmed in *Precharge Voltage* (DF 0x3c-0x3d). *Precharge Voltage* is programmed in mV.

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### Alarm Broadcasts to Smart Charger and Host

If any of the bits 8-15 in *BatteryStatus()* are set, the bq2084-V133 broadcasts an *AlarmWarning()* message to the Host address. If any of the bits 12-15 in *BatteryStatus()* are set, the bq2084-V133 also sends an *AlarmWarning()* message to the Smart Charger address. The bq2084-V133 repeats the *AlarmWarning()* messages every 10 seconds until the alarm bits are cleared. All broadcasts can be disabled by setting *SM* (bit 2) in *Pack Configuration* (DF 0x28).

### Precharge Qualification

The bq2084-V133 sets *ChargingCurrent()* to the precharge rate as programmed in *Precharge Current* (DF 0x42-0x43) under the following conditions:

- Voltage: The bq2084-V133 requests the precharge charge rate when any cell voltage drops below the precharge threshold or when the EDV0 threshold is detected. Once requested, a precharge rate remains until all cell voltages increase above the precharge threshold and the EDV0 condition does not exist. The precharge threshold is programmed in *Precharge Voltage* (DF 0x3c-0x3d).
- Temperature: The bq2084-V133 requests the precharge rate when *Temperature()* is between *Charge Inhibit Temp Low* (DF 0x46) and the precharge threshold programmed in *Precharge Temp* (DF 0x44). *Temperature()* must be equal to or greater than the precharge threshold + 3°C to allow the fast-charge rate.

### Charge Suspension

The bq2084-V133 may temporarily suspend charge if it detects a charging fault. A charging fault includes the following conditions.

- Overcurrent: An overcurrent condition exists when the bq2084-V133 measures the charge current to be greater than *Charge OC Threshold (*DF 0x12a-0x12b) for a time greater than *Charge OC Time* (DF 0x12c). On detecting an overcurrent condition, the bq2084-V133 turns off the Charge FET. If the Nonremovable Battery bit is not set in *Misc Configuration* (DF 0x2a), then the Discharge FET is turned off also. This condition is cleared when the pack is removed or if the Nonremovable Battery bit is set in *Misc Configuration* (DF 0x2a) and when a discharge current is detected or when *SBS AverageCurrent()* is less than the *ClearFailCurrent* (DF 0x61-0x62) for *FaultResetTime* (DF 0x130).
- Overtemperature: During charging, an overtemperature condition exists when *Temperature()* is greater than the *Charge Suspend Temp High* value programmed in DF 0x6d, 0x6e. On detecting an overtemperature condition, if enabled by the *OT* bit in *Misc Configuration* (DF 0x2a), the bq2084-V133 turns off the Charge and Discharge FETs. The overtemperature condition is cleared when *Temperature()* is equal to or below *Charge Suspend Temp High Reset* (DF 0x6f-0x70). The condition is also cleared if the pack is removed.
- Undertemperature: During charging, an undertemperature condition exists when *Temperature()* is less than the *Charge Suspend Temp Low* (DF 0x79) or *Charge Inhibit Temp Low* (DF 0x46). On detecting an undertemperature condition the bq2084-V133 turns off the Charge FET. The undertemperature condition is cleared when *Temperature()* is greater than *Charge Suspend Temp Low* DF 0x79. The condition is also cleared if the pack is removed. The maximal value of *Charge Suspend Temp Low* setting is 12.7°C.
- Charging exceeds *Maximum Charging Time* (DF 0x10f-0x110). If charging time reaches *Maximum Charge Time*, the Charge FET is turned off. This condition is cleared when the pack detects discharge current or is removed.
- Cell or Pack Overvoltage: An overvoltage condition exist when any cell is greater than *Cell Over Voltage Limit* (DF 0x63-0x64) or if *Voltage()* is greater than *Charging Voltage* (DF 0x3a-0x3b) plus *OvervoltageMargin* (DF 0x5d-05e). This condition is cleared when the pack is removed or if the *Nonremovable Battery* bit is set in *Misc Configuration* (DF 0x2a) and when a discharge current is detected or when *SBS AverageCurrent()* is less than the *ClearFailCurrent* (DF 0x61-0x62) for *FaultResetTime* (DF 0x130). Also, the overvoltage conditon must be cleared by *Voltage()* less than *Charging Voltage* (DF 0x3a-0x3b) plus *OvervoltageMargin* (DF 0x5d-05e) and all cell voltages less than *Cell Over Voltage Reset* (DF 0xe0-0xe1).
- Charging is also temporarily suspended during pulse-charging, but this is not considered a fault condition.

### Pulse Charge

The bq2084-V133 is capable of charge control using a pulse-charging algorithm, which allows for charge control in systems where the charger does not control current.

The pulse-charging algorithm uses voltage thresholds and associated time limits for control. These are stored as constants in data flash. The cell voltages are read by the a/d converter every 125 ms during charging. The


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voltage used for comparison to the thresholds is the highest cell voltage. These thesholds are set by three data flash constants: *Von Charge Voltage*, *Voff Charge Voltage*, and *Vmax Charge Voltage*. *Von* is the lowest of these, and is the threshold below which the charge FET is turned on, provided the minimum off time (*Pulse Minimum Off Time*) has been met. When the voltage crosses the *Voff* theshold, the maximum on time (*Pulse Maximum On Time*) begins to count down. When this time has expired, the charge FET is turned off. Any time *Vmax* is exceeded, the charge FET is turned off immediately.

The rules are:

1. If charge FET is on:
   (a) If voltage above *Vmax*, turn off.
   (b) Else if voltage above *Voff* and max on time expired, turn off.
   (c) Else count down max on time.
2. If charge FET is off:
   (a) If voltage below *Von* and minimum off time, turn on.
   (b) Else increment off time.

Voltage is sampled every 125 ms; therefore, the minimum off time and maximum on time are in units of 125 ms, and pulse on and off times are integral multiples of 125 ms.

The voltage thresholds can be chosen in such a way that they alter the charge mechanism. If *Voff* is set equal to *Vmax*, then every time this theshold is crossed, the charge FET turns off immediately. This effectively disables the maximum charge time, so that the *Voff* theshold has no effect. In this case, the algorithm can be described as having two voltage thresholds, rather than three. The charge FET simply turns on and off as it crosses the two thresholds.

The minimum off time can be similarly disabled by setting it to zero or one. Due to the sample interval, the charge FET always is off for at least one 125-ms cycle.

Thesholds must be chosen carefully to get the desired charging behavior. For example, if Von is set below charge voltage minus taper voltage, the pack can never detect full charge. During pulse charging, the charge FET remains off until the cells relax to below the Von voltage, which is below the qualification voltage for full charge detection.

During cycle phase of pulse charging (charge FET ON), the voltage can exceed *Voff* value for a period of 125 ms until next sample is taken and FET is switched OFF. To prevent cell overvoltage termination, or pack overvoltage termination during this period, values for cell OV should be set larger than voltage reached during this period. Reasonable value of cell OV for given charger current I can be calculated, assuming cell impedance of 0.08 Ω/cell, as $V_{(cell)}OV > Von + 0.08 \times I$.

Correspondingly, the pack overvoltage margin should be set as $V_{(margin)} > V_{(cell)}OV \times n - V_{(charge)}$

where: n = number of series cells.

When charging begins on a depleted battery pack, the voltage is below *Voff*, and may even stay below *Von* for some time. This means the pack is under constant charge, with no pulsing, for some part of the charge cycle. As the voltage on the cells rises, it crosses the *Voff* theshold (or the *Vmax* threshold if *Voff* is disabled), and the charge FET turns off. Initially, the off time is short, because the cells are only barely over the threshold and is quickly relaxed to below *Von*. As the cell voltages rises, the off times become longer and the on times shorter. This effect, in combination with the reduced current drawn by the cells, results in a gradually declining charge current. Eventually, this current falls below the taper current, and the pack detects the full charge condition and stops charging.

The pulse-charging control operates during normal charging conditions and are overridden in case of a fault condition. Charging is stopped for any fault conditions which may occur, such as overtemperature or overcurrent, without regard to the voltage thresholds or time limits.

### Primary Charge Termination

The bq2084-V133 terminates charge if it detects a charge-termination condition based on current taper. A charge-termination condition includes the following:

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The bq2084-V133 detects a current taper termination when the pack voltage is greater than *Charging Voltage* (DF 0x3a-0x3b) minus *Current Taper Qualification Voltage* (DF 0x4d-0x4e) and the *AverageCurrent()* is below the *Current Taper Threshold* (DF 0x4b-0x4c), but greater than the *Charge Detection Current* (DF 0x113-0x114), for a period of *Current Taper Window* (DF 0x4f).

Once the bq2084-V133 detects a Primary Charge Termination, the bq2084-V133 sets the *TERMINATE_CHARGE_ ALARM* and *FULLY_CHARGED* bits in *BatteryStatus()*, and turns off the charge FET via the bq29312. The charge FET is turned on when discharge current is detected and is greater than *Discharge Detection Current* (DF 0x115-0x116), to minimize IR losses. The *TERMINATE_CHARGE_ ALARM* charge current is no longer detected or the pack is removed, but returns if charging is attempted while the *FULLY_CHARGED* bit is set.

The bq2084-V133 clears the *FULLY_CHARGED* and *TERMINATE_CHARGE_ALARM* bit when *RelativeStateOfCharge()* is less than the programmed *Fully Charged Clear %*. See Table 13 for a summary of *BatteryStatus()* alarm and status bit operation.

### Cell Balancing

The bq2084-V133 balances the cells during charge by discharging those cells above the threshold set in *Cell Balance Threshold* (DF 0xe8-0xe9), if the maximum difference in cell voltages exceeds the value programmed in *Cell Balance Min* (DF 0xec). For cell balancing, the bq2084-V133 measures the cell voltages at an interval set in *Cell Balance Interval* (DF 0xed). On the basis of the cell voltages, the bq2084-V133 either selects the appropriate cell to discharge or adjusts the cell balance threshold up by the value programmed in *Cell Balance Window* (DF 0xea-0xeb) when all cells exceed the cell balance threshold or the highest cell exceeds the cell balance threshold by the cell balance window.

Cell balancing only occurs when charging current is detected and the cell balance threshold is reset to the value in *Cell Balance Threshold* at the start of every charge cycle. The threshold is only adjusted once during any balance interval.

If the cells are severely imbalanced during charging, where $VCELL_{(MAX)}$ - $VCELL_{(MIN)}$ > *Cell Imbalance Threshold* AND SBS. Current()> *Balance IMAX* for a period of *Cell Imbalance time* then the CIM bit in *PF Status* is set.

**Table 6. Cell Balancing and Cell Imbalance Programming**

| NAME | DF ADDRESS | DESCRIPTION |
|---|---|---|
| Cell Balance Threshold | 0xe8-0xe9 | Sets the maximum voltage in mV that each cell must achieve to initiate cell balancing. Programming *Cell Balance Threshold* to 65,535 disables cell balancing. |
| Cell Balance Min | 0xec | Sets in mV the cell differential that must exist to initiate cell balancing |
| Cell Balance Window | 0xea-0xeb | Sets in mV the amount that the cell balance threshold increases during cell balancing |
| Cell Balance Interval | 0xed | Sets the cell balancing time interval in seconds. |
| Cell Imbalance Threshold | 0xee-0xef | Sets the severe imbalance fault limit for cell imabalance detection |
| Balance IMAX | 0xf2-0xf3 | Sets the charge current required to allow a cell imbalance to be detected |
| Cell Imbalance Time | 0x134 | Sets the time period during which a cell imbalance must be selected for the bq2084 to enter PF mode. |

## DISPLAY PORT

### General

The display port drives a 3-, 4-, or 5-LED bar-graph display. The display is activated by a logic signal on the DISP input. The bq2084-V133 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 bq2084-V133 uses FCC as the full-battery reference; in absolute mode, it uses Design Capacity (DC). The DMODE bit in *Pack Configuration* (DF 0x28) programs the bq2084-V133 for the absolute or relative display mode. The LED bits program the 3-, 4-, or 5-LED option.


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### Activation

The display may be activated at any time by a high-to-low transition on the DISP input. This is usually accomplished with a pullup resistor and a pushbutton switch. Detection of the transition activates the display and starts a 4-s display timer. Reactivation of the display requires that the DISP input return to a logic-high state and then transition low again. The second high-to-low transition can be detected only after the display timer expires. If unused, the DISP input must be pulled up to VCC. If the EDV0 bit is set, the bq2084-V133 disables the LED display.

### Display Modes

In relative mode, each LED output represents 20%, 25%, or 33% of the *RelativeStateOfCharge()* value. In absolute mode, each LED output represents 20%, 25% or 33% of the *AbsoluteStateOfCharge()* value. Table 7 shows the display options for 5 LEDs, for 4 LEDs, Table 8 and Table 9 for 3 LEDs. In either mode, the bq2084-V133 blinks the LED display if *RemainingCapacity()* is less than *Remaining CapacityAlarm()*. The display is disabled if EDV0 = 1.

**Table 7. Display Mode for Five LEDs**

| CONDITION RELATIVE OR ABSOLUTE | FIVE-LED DISPLAY OPTION | | | | |
|---|---|---|---|---|---|
| **StateOfCharge()** | **LED1** | **LED2** | **LED3** | **LED4** | **LED5** |
| 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 8. Display Mode for Four LEDs**

| CONDITION RELATIVE OR ABSOLUTE | FOUR-LED DISPLAY OPTION | | | |
|---|---|---|---|---|
| **StateOfCharge()** | **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 |

**Table 9. Display Mode for Three LEDs**

| CONDITION RELATIVE OR ABSOLUTE | THREE-LED DISPLAY OPTION | | |
|---|---|---|---|
| **StateOfCharge()** | **LED1** | **LED2** | **LED3** |
| EDV0 = 1 | OFF | OFF | OFF |
| <34% | ON | OFF | OFF |
| ≥34%, < 67% | ON | ON | OFF |
| ≥67% | ON | ON | ON |

## LI-ION PROTECTION

The bq2084-V133 along with the bq29312 provides protection for Li-ion batteries, as shown in Table 10. The bq2084-V133 measures temperature and current and uses the bq29312 to measure individual cell voltage. The bq2084-V133 uses this information to determine protection requirements and control the safety FETs or $\overline{\text{SAFE}}$ output as necessary. It is recommended that the bq2084-V133 protection control be validated by two successive measurements by setting VOD=1 in *Misc Configuration*.

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The bq29312 can independently detect and protect the load from an overload (OL) or short circuit in charge (SCC) or discharge (SCD). The bq29312 sets the appropriate FET state and then alerts the bq2084-V133 with the XALERT output whenever a protection threshold is breached and its associated delay time has expired. The bq2084-V133 then determines if and when the FETs should be turned back on.

**Table 10. CVOV and CVUV Flags in PackStatus()**

| FLAG | SET CONDITION | DSG FET | CHG FET | CLEAR CONDITION(1) |
|---|---|---|---|---|
| CVOV | Voltage() = ChargingVoltage() + *Over Voltage Margin* | ON | OFF(2) | Voltage() < ChargingVoltage() |
| | $VCELL_{(ANY)}$ ≥ *Cell Over Voltage* | ON | OFF(2) | $VCELL_{(ALL)}$ < *Cell Over Voltage Reset* |
| CVUV | $VCELL_{(ANY)}$ ≤ *Cell Under Voltage* | | (3)ON | $VCELL_{(ALL)}$ > *Cell Under Voltage Reset* |
| | AverageCurrent() ≤ *Over Load Current* | OFF (3) | ON | AverageCurrent() ≤ *Current Fault Clear Threshold* |

(1) Clear is detected and controlled by the bq2084-V133.
(2) On if there is a discharge current ≥ *Discharge Detection Current*
(3) On if there is a charge current ≥ Charge Detection Current

## Protection Configuration

### *1st Level Cell Voltage Thresholds*

Cell under voltage is detected when any cell voltage is measured equal to or below the value programmed in *Cell Under Voltage* for a minimum of 1s and maximum of 2s and recovers when all cell voltages are above *Cell Under Voltage Reset*. Cell over voltage is detected when any cell voltage is measured equal to or above the value programmed in *Cell Over Voltage* for a minimum of 1s and maximum of 2s and recovers when all cell voltages are below *Cell Over Voltage Reset*.

The cell undervoltage (VUV) and overvoltage (VOV) limits are programmed in *Cell Under Voltage* and *Cell Over Voltage* (DF 0x65-0x66, DF 0x63-0x64, (respectively). Both values are stored in mV. *Cell Over Voltage Rese*t (DF 0xe0-0xe1) and *Cell Under Voltage Reset* (DF 0xe2-0xe3) set the reset points in mV for these safety parameters

### *Safety Overvoltage Threshold*

The safety voltage threshold is programmed in *Safety Over Voltage* (DF 0x6b-0x6c). It is stored in mV. Exceeding the Safety Voltage for a period determined by the MISC Config VOD bit causes permanent failure if enabled by PFConfig.

### *Overcurrent Thresholds*

A discharge over current fault is detected when the measured current is more negative than the value programmed in *Discharge OC Threshold* for a period equal to of greater than the time programmed into *Discharge OC Time*. When the fault is detected the DSG FET is turned OFF.

The DSG FET is turned back on when SBS.AverageCurrent( ) is less negative than the value programmed in *Current Fault Clear Threshold* (DF 0x61, 0x62).

A charge over current fault is detected when the measured current is greater than the value programmed in *Charge OC Threshold* for a period equal to of greater than the time programmed into *Charge OC Time*. When the fault is detected the CHG FET is turned OFF.

The CHG FET is turned back on when SBS.AverageCurrent( ) is less than the value programmed in *Current Fault Clear Threshold* (DF 0x61, 0x62).

Discharge current threshold is programmed in *Discharge OC Threshold* (DF 0x12d-0x12e). The discharge overcurrent must exist for time programmed in Discharge OC Time (DF 0x12f). When a discharge overcurrent condition is detected the discharge FET is turned off. Similarly, a charge overcurrent is programmed in *Charge OC Threshold* (DF 0x12a-0x12b). The charge overcurrent must exist for the time programmed in *Charge OC Time* (DF 0x12c) or Charge OC Time (DF 0x12c).

Note: See Table 10 for some special FET state conditions.


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### *Temperature Thresholds*

The Safety Over Temperature in Charge (SOTC) threshold is programmed in *Safety Over Temperature in Charge* (DF 0x75-0x76) and Safety Over Temperature in Discharge (SOTD) threshold is programmed in *Safety Over Temperature in Discharge* (DF 0x77-0x78).

SOTC is stored as *Safety Over Temperature in Charge* = SOTC ÷ 0.1 (°C) as an unsigned integer

SOTD is stored as *Safety Over Temperature in Discharge* = SOTD ÷ 0.1 (°C) as an unsigned integer. Exceeding the Safety Temperatures causes permanent failure if enabled by PFConfig.

There are also temperature thresholds to disable both charge and discharge FETs and to set the SBS Battery Status Overtemperature bit. The thresholds are set according to whether discharge or charge is detected. The *Charge Suspend Temp High* threshold is stored in DF 0x6d-0x6e with the reset threshold stored in DF 0x6f-0x70. Likewise, the *Over Temperature Discharge* threshold is stored in DF 0x71-0x72 with the reset threshold stored in DF 0x73-0x74.

The *Charge Suspend Temp Low* threshold (CSTL) is stored in *Charge Suspend Temp Low* (DF 0x79-0x7a) and is stored as *Charge Suspend Temp Low* = CSTL ÷ 0.1 (°C) as a signed integer. A *Charge Suspend Temp Low* turns off the charge FET. The maximal value of *Charge Suspend Temp Low* setting is 12.7 °C.

### *AFE Configuration*

The AFE protection limits are programmed as specified in the bq29312 data sheet.

*AFE Over Load* (DF 0xc5) sets the AFE overload protection threshold.

*AFE Over Load Delay* (DF 0xc6) sets the delay timing for overload protection.

*AFE Short Circuit in Charge* (DF 0xc7) sets the AFE short circuit in charge protection threshold and delay time.

*AFE Short Circuit in Discharge* (DF 0xc8) sets the AFE short circuit in discharge protection threshold and delay time.

SMBus command 0x46 can be used to string-read the AFE RAM with the AFE address 0x00 first, if the bq2084-V133 is not sealed as indicated by bit 5 of PackStatus.

**Table 11. Overcurrent Protection**

| FAILURE | FET STATUS | CLEAR CONDITIONS |
|---|---|---|
| **NR=1** | | |
| AFE OLV | CHG on, ZVCHG off, DSG off | Same AFE SCD |
| AFE SCC | CHG off, ZVCHG off, DSG on | Average Current ()< Clear Fail Current (DF 0x61/2) for Fault Reset Time (DF 0x130), or disharge current > discharge detection current (DF 0x115/6) |
| AFE SCD | CHG on, ZVCHG off, DSG off | Average Current () ≥ -Clear Fail Current (DF 0x61/2) for Fault Reset Time (DF 0x130), or charge current > charge detection current (DF 0x113/4) |
| GG Charge OC (set by DF 0x12a to 0x12c) | CHG off, ZVCHG off, DSG on | Same AFE SCC |
| GG Discharge OC (set by DF 0x12d to 0x12f) | CHG on, ZVCHG off, DSG off | Same AFE SCD |
| **NR=0** | | |
| **FAILURE** | **FET STATUS** | **EXIT CONDITIONS** |
| AFE OLV | All FETs off | RRES=high |
| AFE SCC | All FETs off | PRES=high |
| AFE SCD | All FETs off | PRES=high |
| GG Charge OC (set by DF 0x12a to 0x12c) | All FETs off | PRES=high |
| GG Discharge OC (set by DF 0x12d to 0x12f) | All FETs off | PRES=high |

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### *AFE Integrity Check*

The bq2084-V133 checks the programming of the AFE registers at a period determined by *AFE Check Time* (DF 0xfb). The units of the check period are seconds unless the bq2084-V133 is in sleep mode, in which case the period is *AFE Check Time* x *Sleep Current Multiplier* (DF 0xfd). If the data is not correct, the bq2084-V133 increments an internal counter until it reaches the *AFE Fail Limit* (DF 0xe4). Setting *AFE Check Time* to 0 disables this function.

When the internal AFE Fail counter reaches *AFE Fail Limit*, then the AFE bit in PF Status is set.

### *AFE Watchdog Fault and Clear*

The bq29312 has a feature where the 32-kHz output (CLKOUT, pin 35) of the bq2084-V133 is used to drive its internal clock. If this clock fails, a fault is declared in the AFE. See the bq29312 data sheet for further details.

The fault is cleared automatically on return of the 32-kHz input via the bq2084-V133 CLKOUT pin.

### *Permanent Failure Mode ($\overline{SAFE}$ Output)*

The $\overline{SAFE}$ output of the bq2084-V133 provides an additional level of safety control. The active low safety output can blow a fuse or control another switch on the basis of temperature, pack-voltage cell-voltage, CHG FET Failure, severe cell imbalance, or an integrity check of the AFE and Data Flash configuration registers.

The bq2084-V133 can also activate the $\overline{SAFE}$ output and set the PF Flag based on the $\overline{PFIN}$ input. If this pin is low for *PFIN Time* seconds ±1 s, then the $\overline{PFIN}$ bit in PF Status is set.

The $\overline{SAFE}$ output can be driven low in any of the following conditions, and the bq2084-V133 sets the *PF Flag* register (DF 0x11e) to 0x66 (011001100b). The activation of the $\overline{SAFE}$ output and the setting of the *PF Flag* can be enabled or disabled for different safety option per the *PF Config* (DF 0x11f) register settings.

The $\overline{SAFE}$ output and PF Flag register can only be cleared using a series of ManufacturerAccess() commands.

**Table 12. $\overline{SAFE}$ Activation Conditions(1)**

| CONDITION | ACTIONS |
|---|---|
| Voltage() > *Safety Over Voltage* (DF 0x6b and 0x6c), | SOV and PF set |
| Temperature() > *Safety Over Temperature in Charge* (DF 0x75 and 0x76) | SOTC and PF set |
| Temperature() > *Safety Over Temperature in Discharge* (DF 0x77 and 0x78) | SOTD and PF set |
| When Miscellaneous Configuration (0x2a) bit 13 AC is set, and the number of AFE failures has reached the *AFE Fail Limit* (DF 0xe4) | AFE and PF set |
| When $VCELL_{(MAX)}$ - $VCELL_{(MIN)}$ > *Cell Imbalance Threshold* (DF 0xee, 0xef) during charging | CIM and PF set |
| If charge FET is off, and charge current greater than FET Fail charge current stored in DF 0x125-0x126 for the time determined by FET Fail time in DF 0x129, or if discharge FET is off and discharge current greater than FET Fail discharge current stored in DF 0x127-0x128 for the time determined by FET Fail time in DF 0x129. | FETF and PF set |
| The $\overline{PFIN}$ input has detected a low state for *PFIN Time* in consecutive seconds, as determined by DF 0x120 | $\overline{PFIN}$, PF set |

(1) $\overline{SAFE}$ output activated and *PF Flag* set only if enabled by *PF Config* (DF 0x0x11f)

## Permanent Failure Status (PF Status)

*PF Status* DF 0x11d contains the flags for the cause of the permanent failure mode.

| b7 | b6 | b5 | b4 | b3 | b2 | b1 | b0 |
|---|---|---|---|---|---|---|---|
| PFF | PFIN | FETF | CIM | AFE | SOTD | SOTC | SOV |

**SOV**

The SOV bit indicates a safety overvoltage occurred which if enabled by PF Config would cause the $\overline{SAFE}$ output to activate.

0 SOV fault not detected (default)

1 SOV fault detected

**SOTC**


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The SOTC bit indicates a safety overtemperature in charge occurred which if enabled by PF Config would cause the $\overline{\text{SAFE}}$ output to activate.

0 SOTC fault not detected (default)

1 SOTC fault detected

**SOTD**

The SOTD bit indicates a safety overtemperature in discharge occurred which if enabled by PF Config would cause the $\overline{\text{SAFE}}$ output to activate.

0 SOTD fault not detected (default)

1 SOTD fault detected

**AFE**

The AFE bit indicates an AFE integrity fault state occurred which if enabled by PF Config would cause the $\overline{\text{SAFE}}$ output to activate.

0 AFE is operating correctly (default)

1 AFE Integrity check fail limit reached

**CIM**

The CIM bit indicates that a severe cell imbalance occurred during charging, which if enabled by PF Config, would cause the $\overline{\text{SAFE}}$ output to activate.

0 All cells are within the *Cell Imbalance Threshold* (default)

1 There is a severe cell imbalance

**FETF**

The FETF bit indicates a FET or FET driver failure occurred, which if enabled by PF Config would cause the $\overline{\text{SAFE}}$ output to activate.

0 The FETs are operating normally (default)

1 The FETs or FET drivers have a fault

**PFIN**

The PFIN bit is used to indicate that the output of the 2$^{nd}$ level protector has activated.

0 The PFIN input is high (default)

1 The PFIN input drive and held low by 2$^{nd}$ level protector output

**FPP**

The FPP bit is used to indicate that current has been detected when the fuse has been set to be blown.

0 Current not detected with fuse blown

1 Current detected with fuse blown

## Permanent Failure Configuration (PF Config)

*PF Config* (DF 0x11f) contains the enable/disable configuration that determines if the $\overline{\text{SAFE}}$ output is activated and the PF Flag set for each possible failure mode.

| b7 | b6 | b5 | b4 | b3 | b2 | b1 | b0 |
|---|---|---|---|---|---|---|---|
| - | XPFIN | XFETF | XCIM | XAFE | XSOTD | XSOTC | XSOV |

**XSOV**

The XSOV bit enables or disables the activation of $\overline{\text{SAFE}}$ and the setting of the PF Flag when *PF Status* SOV is set.

0 Activation disabled (default)

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1 Activation enabled

**XSOTC**

The XSOTC bit enables or disables the activation of $\overline{\text{SAFE}}$ and the setting of the PF Flag when *PF Status* SOTC is set.

0 Activation disabled (default)

1 Activation enabled

**XSOTD**

The XSOTD bit enables or disables the activation of $\overline{\text{SAFE}}$ and the setting of the PF Flag when *PF Status* SOTD is set.

0 Activation disabled (default)

1 Activation enabled

**XAFE**

The XAFE bit enables or disables the activation of $\overline{\text{SAFE}}$ and the setting of the PF Flag when *PF Status* AFE is set. Bit 13 of *Miscellaneous Config* DF 0x2a also needs to be set for activation.

0 Activation disabled (default)

1 Activation enabled

**XCIM**

The XCIM bit enables or disables the activation of $\overline{\text{SAFE}}$ and the setting of the PF Flag when *PF Status* CIM is set.

0 Activation disabled (default)

1 Activation enabled

**XFETF**

The XFETF bit enables or disables the activation of $\overline{\text{SAFE}}$ and the setting of the PF Flag when *PF Status* FETF is set.

0 Activation disabled (default)

1 Activation enabled

**XPFIN**

The XPFIN bit enables or disables the activation of $\overline{\text{SAFE}}$ and the setting of the PF Flag when *PF Status* PFIN is set.

0 Activation disabled (default)

1 Activation enabled

## Permanent Failure Flag (PF Flag)

*PF Flag* DF 0x11e contains the flag indicating if the /SAFE output has been activated.

| STATE | b7 | b6 | b5 | b4 | b3 | b2 | b1 | b0 |
|---|---|---|---|---|---|---|---|---|
| Clear | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Set | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |

**PF FLAG**

The PF Flag indicates that the $\overline{\text{SAFE}}$ output of the bq2084-V133 has been activated.

0x00 $\overline{\text{SAFE}}$ output high (default)

0x66 $\overline{\text{SAFE}}$ output activated

An example circuit using the $\overline{\text{SAFE}}$ output to blow a fuse is shown in Figure 2.


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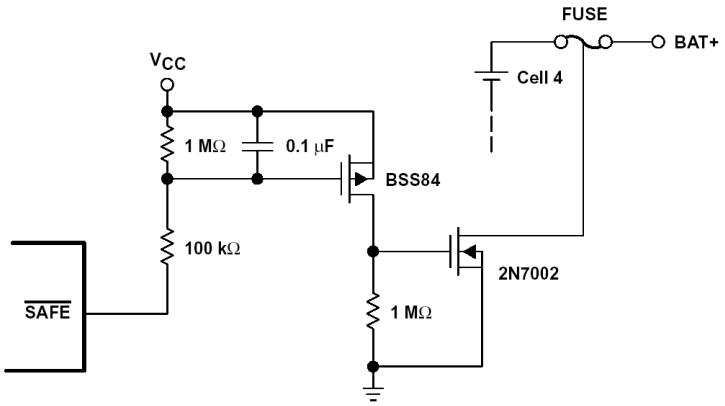



**Figure 2. Example $\overline{\text{SAFE}}$ Circuit Implementation**

### Low-Power Modes

The bq2084-V133 enters sleep mode when the charge and discharge current is less than the threshold programmed in *Sleep Current Threshold* (DF 0xfc), the SMBus lines are low for at least 2s, and bit 12 of *Misc. Configuration* DF 0x2a is set to zero. Additionally, PRES must be pulled high if the NR bit in Misc Config is set to 0. The bq2084-V133 wakes up periodically to monitor voltage and temperature and to apply self-discharge adjustment. The sleep period is set in *Sleep Timer* DF 0xfe. The bq2084-V133 wakes up at a period set by *Sleep Current Multiplier* DF 0xfd multiplied by *Sleep Time* to measure current. The bq2084-V133 comes out of sleep when either of the SMBus lines go high or when the current is measured and it is greater than the *Sleep Current Threshold*.

The sleep current threshold, SLP (mA), is stored in *Sleep Current Thresh* (DF 0xfc) as:

*Sleep Current Thresh* = SLP(mA) ÷ 0.5

The wake-up period for current measurement, WAT(s), is set using the following formula:

*Sleep Current Multiplier x Sleep Time* = WAT(s)

During sleep mode, both charge and discharge FETs are turned off if the NR bit in Misc Config is cleared. If the bq2084-V133 is in Non-Removable mode where NR=1, then the discharge FET retains its state on entry to sleep.

### Shutdown Mode

The bq2084-V133 goes into shutdown, in which all FETs are turned off and the pack electronics are powered down (including the bq2084-V133), when *SBS.Voltage()* falls below *Shutdown Voltage* (DF 0x7c-0x7d) and Voltage at the Pack pin is less than VPACK threshold (DF 0x131, 0x132) both for 2 consecutive samples (1 to 2 s).

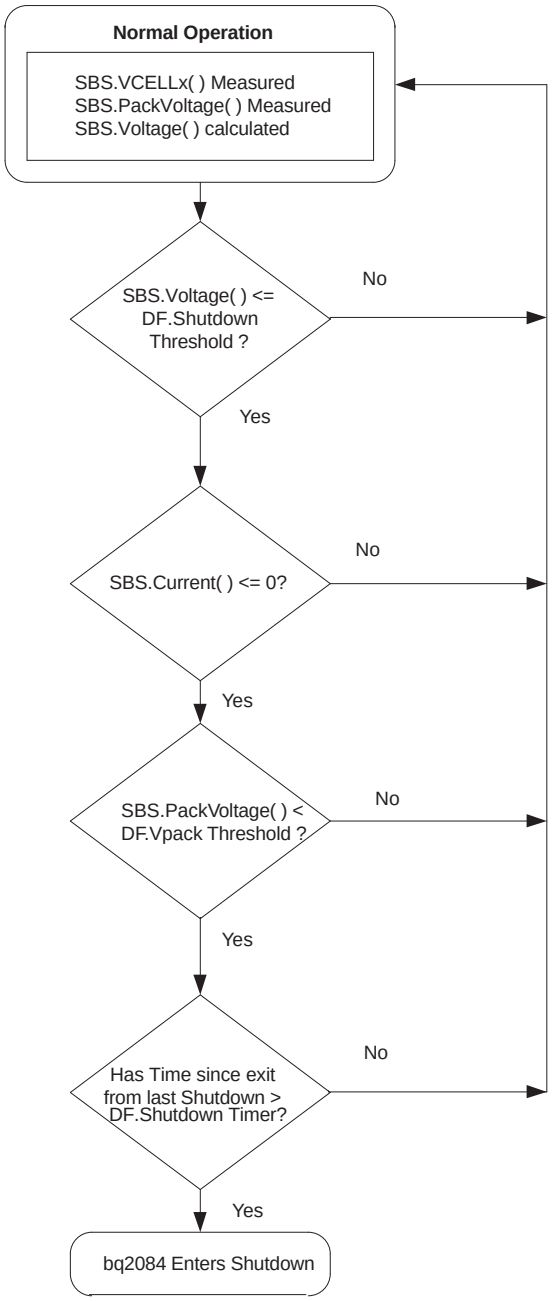
Vpack is programmed in units of 0.935 mV/count and has tolerance of ±6%. For example, to set 12 V as *Vpack Threshold*, the program value should be 12000/0.935 = 12834.

When the DSG FET is turned on, the pack voltage is close to the battery voltage even with no charger attached. Therefore, to enter shutdown, the Vpack threshold should be set higher than the shutdown threshold plus the tolerance.

The bq2084-V133 can also be instructed to enter Shutdown mode via the *ManufacturerAccess()* command. When the command is sent to the bq2084-V133, the bq29312 is instructed to enter shutdown mode by the bq2084-V133. This forces the chipset into its lowest power mode. The bq2084-V133 does not issue a shutdown command to the AFE unless the pack voltage is less than the Vpack Threshold. Program the Vpack threshold higher than the SBS.Voltage() when ship command is issued. Exit from this mode is only achieved by application of a charger.

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After exiting shutdown mode, the bq2084-V133 does not enter the shutdown mode again until the *Shutdown Timer* (DF 0x133, units are seconds) has expired even if the correct conditions are present. After the *Shutdown Timer* has expired, the SMBus command or voltage and current conditions enables the bq2084-V133 to enter shutdown mode.




DEFAULTS: *Non-Removable Pack* - DF.ShutdownVoltage = 2.8 V x Number of Series cells; DF.ShutdownTimer = 2 s

**NOTE:** VpackThreshold must be greater than Shutdown voltage + 6%.

*Removable Pack* - DF.ShutdownVoltage = 2.8 V x Number of Series cells; DF.ShutdownTimer = 20 s

**NOTE:** VpackThreshold must be greater than Shutdown voltage + 6%

**Figure 3. Shutdown Flow Chart in Normal Operation**


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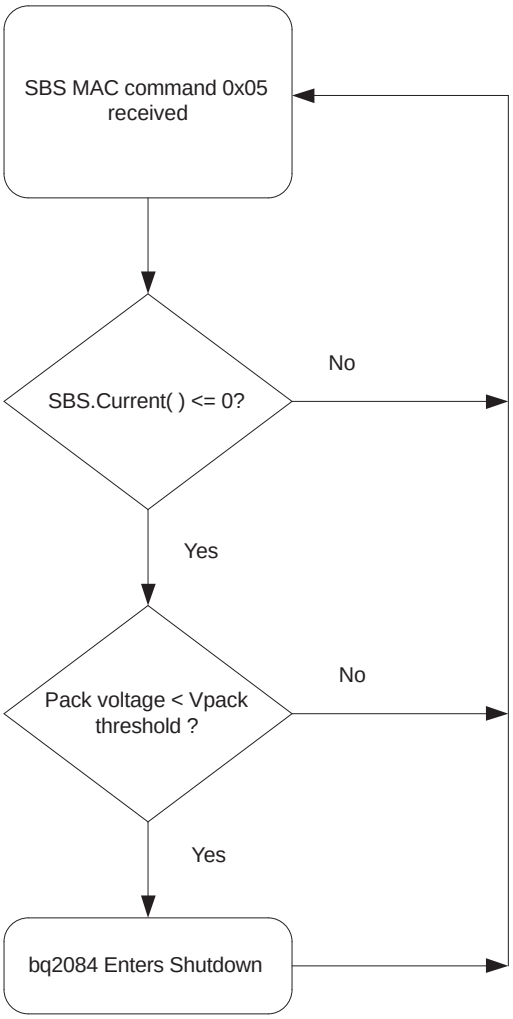



**Figure 4. Shutdown Flow Chart in SBS MAC**

### Reset Conditions

On power up, the entire IC is reset and data is loaded from Data Flash to configure the SBS Data and the battery management solution. On a partial reset (loss of VCC but RBI holds RAM valid), a limited number of locations are taken. These actions are the following:

- The AFE registers are rewritten.
- *PackStatus()* EDV2 flag is cleared.
- *BatteryStatus()* DISCHARGING flag is cleared.
- The charger and alarm broadcast period is set to 10 seconds between broadcasts.

## COMMUNICATION

The bq2084-V133 includes an SMBus communication port. The SMBus interface is a 2-wire bidirectional protocol using the SMBC (clock) and SMBD (data) pins. The communication lines are isolated from $V_{CC}$ and may be pulled up higher than VCC. Also, the bq2084-V133 does not pull these lines low if $V_{CC}$ to the part is zero. The communication ports allow a host controller, an SMBus compatible device, or other processor to access the memory registers of the bq2084-V133. In this way a system can efficiently monitor and manage the battery.

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### SMBus

The SMBus interface is a command-based protocol. A processor acting as the bus master initiates communication to the bq2084-V133 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 bq2084-V133 device address of 0001011 (bits 7-1) plus a R/W bit (bit 0) followed by an SMBus command code. The R/W bit (LSB) and the command code instruct the bq2084-V133 to either store the forthcoming data to a register specified by the SMBus command code or output the data from the specified register. The processor completes the access with a stop condition. A stop condition consists of a low-to-high transition of the SMBD line while the SMBC is high. With SMBus, the most-significant bit (MSB) of a data byte is transmitted first. In some instances, the bq2084-V133 acts as the bus master. This occurs when the bq2084-V133 broadcasts charging requirements and alarm conditions to device addresses 0x12 (SBS Smart Charger) and 0x10 (SBS Host Controller.)

### SMBus Protocol

The bq2084-V133 supports the following SMBus protocols:

- Read word
- Write word
- Block read

A processor acting as the bus master uses the three protocols to communicate with the bq2084-V133. The bq2084-V133 acting as the bus master uses the write word protocol.

The SMBD and SMBC pins are open drain and require external pullup resistors. A 1-MΩ pulldown resistor in the battery pack on SMBC and SMBD is required to ensure the detection of the SMBus off-state, the performance of automatic offset calibration, and the initiation of the low-power sleep mode when the battery pack is removed.

### SMBus Packet Error Checking

The bq2084-V133 supports packet error checking as a mechanism to confirm proper communication between it and another SMBus device. Packet error checking requires that both the transmitter and receiver calculate a packet error code (PEC) for each communication message. The device that supplies the last byte in the communication message appends the PEC to the message. The receiver compares the transmitted PEC to its PEC result to determine if there is a communication error.

### PEC Protocol

The bq2084-V133 can receive or transmit data with or without PEC. Figure 5 shows the communication protocol for the read word, write word, and read block messages without PEC. Figure 6 includes PEC.

In the read word protocol, the bq2084-V133 receives the PEC after the last byte of data from the host. If the host does not support PEC, the last byte of data is followed by a stop condition. After receipt of the PEC, the bq2084-V133 compares the value to its calculation. If the PEC is correct, the bq2084-V133 responds with an ACKNOWLEDGE (ACK). If it is not correct, the bq2084-V133 responds with a NOT ACKNOWLEDGE (NACK) and sets an error code. In the write word and block read, the host generates an ACK after the last byte of data sent by the bq2084-V133. The bq2084-V133 then sends the PEC and the host acting as a master-receiver generates a NACK and a stop condition.


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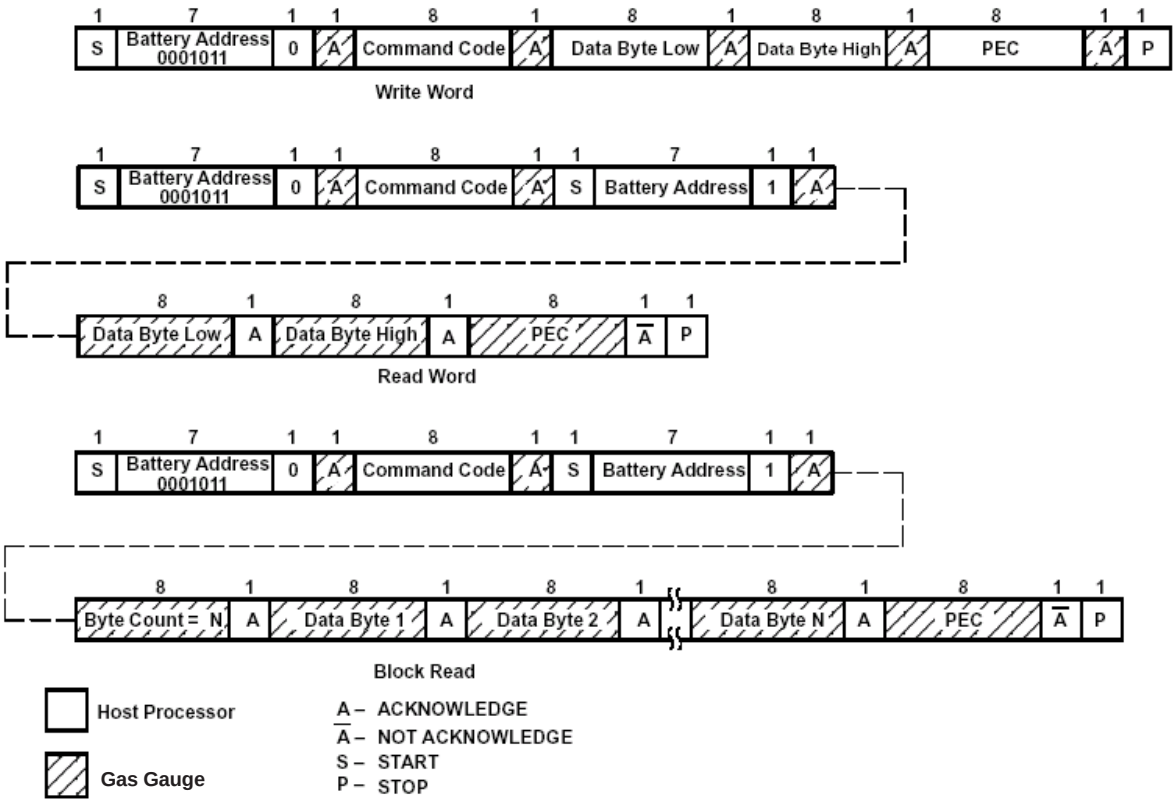



**Figure 5. SMBus Communication Protocol Without PEC**

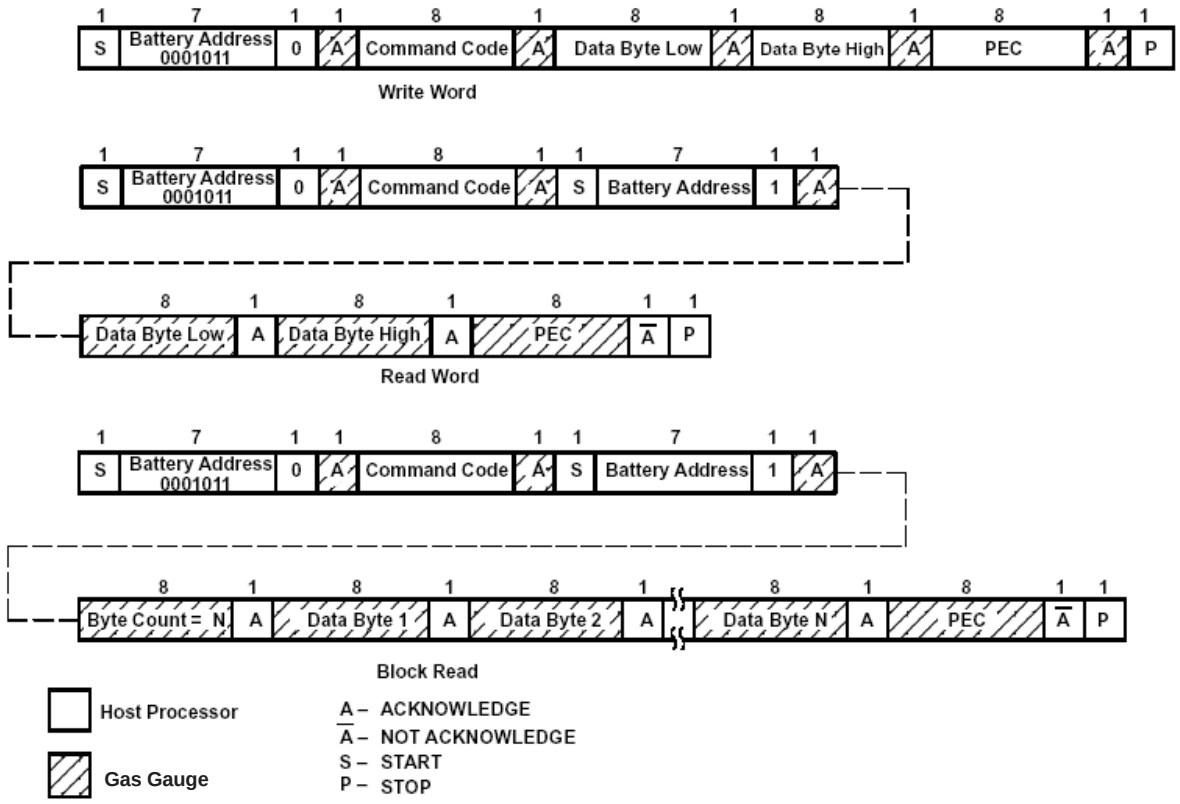



**Figure 6. SMBus Communication Protocol With PEC**

### PEC Calculation

The basis of the PEC calculation is an 8-bit cyclic redundancy check (CRC-8) based on the polynomial C(X) = X8 + X2 + X1 + 1. The PEC calculation includes all bytes in the transmission, including address, command, and data. The PEC calculation does not include ACKNOWLEDGE, NOT ACKNOWLEDGE, start, stop, and repeated start bits.

For example, the host requests RemainingCapacity() from the bq2084-V133. This includes the host following the read word protocol. The bq2084-V133 calculates the PEC based on the following 5 bytes of data, assuming the remaining capacity of the battery is 1001 mAh.

- Battery Address with R/W = 0: 0x16
- Command Code for *RemainingCapacity()*: 0x0f
- Battery Address with R/W = 1: 0x17
- *RemainingCapacity()*: 0x03e9

For 0x160f17e903, the bq2084-V133 transmits a PEC of 0xe8 to the host.

### PEC Enable in Master Mode

The PEC for master mode broadcasts to the charger, host, or both can be enabled/disabled with the combination of the bits HPE and CPE in *Pack Configuration* (DF 0x28).

### SMBus On- and Off-State

The bq2084-V133 detects whether the SMBus enters the Off State by monitoring the SMBC and SMBD lines. When both signals are continually low for at least 2.0 s, the bq2084-V133 detects the Off State. When the SMBC and SMBD lines go high, the bq2084-V133 detects the On State and can begin communication within 1 ms. One-MΩ pulldown resistors on SMBC and SMBD are recommended for reliable Off State detection.


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### Command Codes

The SMBus command codes are in (). *Temperature()*, *Voltage()*, *Current()*, and *AverageCurrent()*, performance specifications are at bq29312 regulated VCC ($V_{(REG)}$) and a temperature of -20°C to 85°C.

### Manufacturer Access() (0x00)

**Description:** This function provides writable command codes to control the bq2084-V133 during normal operation and pack manufacture. Writing the command code to SMB command 0x00 causes the following reads with the SMB command 0x00 to return the word indicated in the table. The following commands are available:

| COMMAND CODE | NAME | DESCRIPTION |
|---|---|---|
| 0x0001 | Device Type | Returns IC part number so it can be read, i.e., 2084 (0x0824) |
| 0x0002 | Firmware Rev | Returns firmware version so it can be read |
| 0x0003 | EDV Level | Returns the pending end-of-discharge voltage level so it can be read |
| 0x0004 | Manufacturer Status | Returns the battery system status so it can read |
| 0x0005 | SHIP Command | Instructs the bq2084-V133 to instruct the bq29312 to enter ship mode |
| 0x062b | Seal | Instructs the bq2084-V133 to restrict access to those functions listed in Table 3. The bq2084-V133 completes the seal function and clears ManufacturerAccess(). |

### The Manufacture Status word is defined as:

| b15 | b14 | b13 | b12 | b11 | b10 | b9 | b8 |
|---|---|---|---|---|---|---|---|
| FET1 | FET0 | PF1 | PF0 | STATE3 | STATE2 | STATE1 | STATE0 |

| b7 | b6 | b5 | b4 | b3 | b2 | b1 | b0 |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |

**FET1, FET0**

Indicated the state of the charge and discharge FETs

- 0,0 Both charge and discharge FETs are on.
- 0,1 Charge FET is off, discharge FET is on.
- 1,0 Both charge and discharge FETs are off.
- 1,1 Charge FET is on, discharge FET is off.

**PF1, PF0**

Indicates permanent failure cause when permanent failure indicated by STATE3-STATE0

- 0,0 Fuse is blown
- 0,1 Cell imbalance failure
- 1,0 Safety voltage failure
- 1,1 FET failure

**STATE3, STATE2, STATE1, STATE0**

Indicates battery state as defined in the State and Status bit Summary.

**Purpose:** The *ManufacturerAccess()* function provides the system host access to bq2084-V133 functions that are not defined by the SBD.

**SMBus protocol:** Read or write word

**Input/Output:** Word

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**Table 13. State and Status Bit Summary**

| State | MAC Mode (MSB) | CC() | CV() | CHG FET(1) | DSG FET | ZVCHG FET | FUSE | Power Mode |
|---|---|---|---|---|---|---|---|---|
| wakeup | 0x00 Wake up | 0 | 0 | off(2) | on | on(3) | ok | normal |
| precharge | 0x03 Precharge | PC | CV | of(2)f | on | on(4) | ok | normal |
| chargesusp | 0x04 Charge Suspension | FC | CV | off | on | off | ok | normal |
| terminatecharge | 0x07 Charge Terminate | MC | CV | off | on | off | ok | normal |
| normalcharge | 0x05 Charge | FC(5) | CV | on | on | off | ok | normal |
| provisionalcharge | 0x01 Normal | 0 | 0 | off | on | off | ok | normal |
| normaldischarge | | FC | CV | on | on | off | ok | normal |
| depleted | 0x0e System Present | PC | CV | off | off | off | ok | normal |
| depleted_ac | | PC | CV | off | off | off(4) | ok | normal |
| overheatdischarge | | FC | CV | off | off | off | ok | normal |
| overheatcharge | | FC | CV | off | off | off | ok | normal |
| battfail_overcharge | | 0 | 0 | off | on | off | ok | normal |
| battfail_lowtemp | | 0 | 0 | off | on | off | ok | normal |
| battfail_chargeterminate | 0x08 Fault Charge Terminate | 0 | 0 | off | on | off | ok | normal |
| battfail_afe_chg | 0x0c Battery Failure | 0 | 0 | off | of(6)f | off | ok | normal |
| battfail_afe_dsg | | FC | CV | off(6) | off | off | ok | normal |
| battfail_chg | 0x0a Over Current | 0 | 0 | off | off(6) | off | ok | normal |
| battfail_dsg | | FC | CV | off(6) | off | off | ok | normal |
| removed | 0x0f Battery Out | FC | CV | off | off | off | ok | normal |
| sleep | 0x0d Sleep | 0 | 0 | off | off(7) | off | ok | low |
| permanent_failure | 0x09 Permanent Failure | 0 | 0 | off | off | off | blow | low |

(1) CHG FET always on if discharge current greater than Discharge Detection Current (DF 0x115, 0x116)
(2) On if FET Config = 01 (Common precharge, charge FET)
(3) ZVCHG FET on, OD FET off if FET Config = 00 or 02 (ZVCHG FET or precharge FET)
(4) ZVCHG FET on, OD FET off if FET Config = 00 (ZVCHG FET), or ZVCHG FET off, OD FET on if FET Config = 02 (precharge FET)
(5) 0 if CVOV or PC is not CVOV and minimum cell voltage is less than the precharge cell voltage threshold
(6) If MiscConfig.Nonremoveable Battery is set, then FET is on.

### RemainingCapacityAlarm() (0x01)

**Description:** Sets or gets the low-capacity threshold value. Whenever the *RemainingCapacity()* falls below the low-capacity value, the bq2084-V133 sends *AlarmWarning()* messages to the SMBus host with the *REMAINING_CAPACITY_ALARM* bit set. A low-capacity value of 0 disables this alarm. The bq2084-V133 initially sets the low-capacity value to *Remaining Capacity Alarm* value programmed in DF 0x02-0x03. 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 bq2084-V133 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 | |


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| | BATTERY MODES | |
|---|---|---|
| | CAPACITY_MODE BIT = 0 | CAPACITY_MODE BIT = 1 |
| Accuracy | See RemainingCapacity() | |

**RemainingTimeAlarm() (0x02)**

**Description:** Sets or gets the *Remaining Time Alarm* value. Whenever the *AverageTimeToEmpty()* falls below the remaining time value, the bq2084-V133 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 bq2084-V133 initially sets the remaining time value to the *Remaining Time Alarm* (DF 0x00-0x01) value. 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 bq2084-V133 *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)**

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

Defined modes include

- Whether the battery capacity information is specified in units of mAh or 10 mWh (CAPACITY_MODE bit)
- Whether the *ChargingCurrent()* and *ChargingVoltage()* values are broadcast to the smart battery charger when the *CHARGER_MODE* bit is set.
- Whether all broadcasts to the smart battery charger and host are disabled

The defined request condition is the battery requesting a conditioning cycle (*RELEARN_FLAG*).

**Purpose:** The *CAPACITY_MODE* bit allows power management systems to best match their electrical characteristics with those reported by the battery. For example, a switching power supply represents a constant power load, whereas a linear supply is better represented by a constant current model. The *CHARGER_MOD*E bit allows a SMBus host or smart battery charger to override the smart battery desired charging parameters by disabling the bq2084-V133 broadcasts. The *RELEARN_FLAG* bit allows the bq2084-V133 to request a conditioning cycle.

**SMBus protocol:** Read or write word

**Input/Output:** Unsigned integer—bit mapped—see Table 14.

**Units:** Not applicable

**Range:** 0-1

**Granularity:** Not applicable

**Accuracy:** Not applicable

The *BatteryMode()* word is divided into two halves, the MSB (bits 8-15) which is read/write and the LSB (bits 0-7) which is read only. The bq2084-V133 forces bits 0-6 to zero and prohibits writes to bit 7.

Table 14 summarizes the meanings of the individual bits in the *BatteryMode()* word. Specified default values, where applicable, are noted. *INTERNAL_CHARGE_CONTROLLER* bit is not used by the bq2084-V133.

*PRIMARY_BATTERY_SUPPOR*T bit is not used by the bq2084-V133.

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*RELEARN_FLAG* bit set indicates that the bq2084-V133 is requesting a capacity relearn cycle for the battery. The bq2084-V133 sets the *RELEARN_FLAG* on a full reset and if it detects 20-cycle counts without an FCC update. The bq2084-V133 clears this flag after a learning cycle has been completed.

*CHARGE_CONTROLLER_ENABLED* bit is not used by the bq2084-V133. The bq2084-V133 forces this bit to zero.

*PRIMARY_BATTERY* bit is not used by the bq2084-V133. The bq2084-V133 forces this bit to zero.

**Table 14. Battery Mode Bits and Values**

| Battery Mode() BITS | BITS USED | FORMAT | ALLOWABLE VALUES |
|---|---|---|---|
| INTERNAL_CHARGE_CONTROLLER | 0 | Read only bit flag | 1 - always one |
| PRIMARY_BATTERY_SUPPORT | 1 | Read only bit flag | 0 - always zero |
| Reserved | 2-6 | | 0 - always zero |
| RELEARN_FLAG | 7 | Read only bit flag | 0—Battery OK1—Relearn cycle requested |
| CHARGE_CONTROLLER_ENABLED | 8 | R/W bit flag | Not used |
| PRIMARY_BATTERY | 9 | R/W bit flag | Not used |
| Reserved | 10-12 | | 0 - always zero |
| ALARM_MODE | 13 | R/W bit flag | 0—Enable alarm broadcast (default)1—Disable alarm broadcast |
| CHARGER_MODE | 14 | R/W bit flag | 0—Enable charging broadcast (default)1—Disable charging broadcast |
| CAPACITY_MODE | 15 | R/W bit flag | 0—Report in mA or mAh (default)1—Report in 10 mW or 10 mWh |

*ALARM_MODE* bit is set to disable the bq2084-V133s ability to master the SMBus and send *AlarmWarning()* messages to the SMBus host and the smart battery charger. When set, the bq2084-V133 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 60 s and no less than 59 s. 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 ALARM broadcast does not occur more often than once every 10 s. Whenever the BATTERY_MODE command is received, the bq2084-V133 resets the bit and starts or restarts a 60-s (nominal) timer. After the timer expires, the bq2084-V133 automatically enables alarm broadcasts to ensure that the accidental deactivation of broadcasts does not persist. An SMBus host that does not want the bq2084-V133 to be a master on the SMBus must therefore continually set this bit at least once per 59 s to keep the bq2084-V133 from broadcasting alarms.
- The *ALARM_MODE* bit defaults to a cleared state when the bq2084-V133 enters SLEEP mode.
- 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 bq2084-V133's transmission of *ChargingCurrent()* and *ChargingVoltage()* messages to the smart battery charger. When set, the bq2084-V133 does *not* transmit *ChargingCurrent()* and *ChargingVoltage()* values to the smart battery charger. When cleared, the bq2084-V133 transmits the *ChargingCurrent()* and *ChargingVoltage()* values to the smart battery charger. The *CHARGER_MODE* bit defaults to a cleared state when the bq2084-V133 enters SLEEP mode.

*CAPACITY_MODE* bit indicates if capacity information is reported in mA/mAh or 10 mW/10 mWh. When set, the bq2084-V133 reports capacity information in 10 mW/10 mWh as appropriate. When cleared, the bq2084-V133 reports capacity information in mA/mAh as appropriate. The CAPACITY_MODE bit defaults to a cleared state when the bq2084-V133 enters SLEEP mode.

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()*


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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()*

The bq2084-V133 updates the non-AtRate related register values immediately after changing the state of the *CAPACITY_MODE* bit. The *AtRate()* values are updated after the next *AtRate()* value is written to the bq2084-V133 (or after the next 1-s scheduled refresh calculation).

### AtRate() (0x04)

**Description:** The *AtRate()* function is the first half of a two-function call-set used to set the AtRate value used in calculations made by the *AtRateTimeToFull()*, *AtRateTimeToEmpty()*, and *AtRateOK()* functions. The *AtRate* value may be expressed in either current (mA) or power (10 mW) depending on the setting of the *BatteryMode() CAPACITY_MODE* bit.

**Purpose:** Because the *AtRate()* function is the first half of a two-function call-set, it is followed by the second function of the call-set that calculates and returns a value based on the *AtRate* value and the battery's present state.

- When the *AtRate()* value is positive, the *AtRateTimeToFull()* function returns the predicted time to full charge at the *AtRate* value of charge.
- When the *AtRate()* value is negative, the *AtRateTimeToEmpty()* function returns the predicted operating time at the *AtRate* value of discharge.
- When the *AtRate()* value is negative, the *AtRateOK()* function returns a Boolean value that predicts the battery's ability to supply the *AtRate* value of *additional* discharge energy (current or power) for 10 seconds.

The default value for *AtRate()* is zero.

**SMBus protocol:** Read or write word

**Input/Output:** Signed integer-charge or discharge; the *AtRate()* value is positive for charge, negative for discharge, and zero for neither (default).

| | BATTERY MODES | |
|---|---|---|
| | **CAPACITY_MODE BIT = 0** | **CAPACITY_MODE BIT = 1** |
| Units | mA | 10 mW |
| Charge range | 1 to 32,767 mA | 1 to 32,767 10 mW |
| Discharge range | –1 to –32,768 mA | –1 to –32,768 10 mW |
| Granularity | 1 Unit | |
| Accuracy | NA | |

### AtRateTimeToFull() (0x05)

**Description:** Returns the predicted remaining time to fully charge the battery at the *AtRate()* value (mA).

**Purpose:** The *AtRateTimeToFull()* function is part of a two-function call-set used to determine the predicted remaining charge time at the *AtRate* value in mA. The bq2084-V133 updates *AtRateTimeToFull()* within 5 ms after the SMBus host sets the *AtRate* value. The bq2084-V133 automatically updates *AtRateTimeToFull()* based on the *AtRate()* value every 1 s.

**SMBus** protocol: Read word

**Output:** Unsigned integer—predicted time in minutes to fully charge the battery.

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**Units:** Minutes

**Range:** 0 to 65,534 min

**Granularity:** 2 min or better

**Accuracy:** ± *MaxError()* × *FullChargeCapacity()* ÷ |*AtRate()*|

**Invalid Data Indication:** 65,535 indicates the *AtRate* = 0.

### AtRateTimeToEmpty() (0x06)

**Description:** Returns the predicted remaining operating time if the battery is discharged at the *AtRate()* value.

**Purpose:** The *AtRateTimeToEmpty()* function is part of a two-function call-set used to determine the remaining operating time at the *AtRate()* value. The bq2084-V133 updates *AtRateTimeToEmpty()* within 5 ms after the SMBus host sets the *AtRate()* value. The bq2084-V133 automatically updates *AtRateTimeToEmpty()* based on the *AtRate()* value every 1 s.

**SMBus protocol:** Read word

**Output:** Unsigned integer—estimated operating time left.

**Units:** Minutes

**Range:** 0 to 65,534 min

**Granularity:** 2 min or better

**Accuracy:** -0, +*MaxError()* × *FullChargeCapacity* ÷ |*AtRate()*|

**Invalid Data Indication:** 65,535 indicates *AtRate* = 0.

### AtRateOK() (0x07)

**Description:** Returns a Boolean value that indicates whether or not the battery can deliver the *AtRate()* value of *additional* energy for 10 s. If the *AtRate* value is zero or positive, the *AtRateOK()* function ALWAYS returns OK (logic 1).

**Purpose:** The *AtRateOK()* function is part of a two-function call-set used by power management systems to determine if the battery can safely supply enough energy for an additional load. The bq2084-V133 updates *AtRateOK()* within 5 ms after the SMBus host sets the *AtRate()* value. The bq2084-V133 automatically updates *AtRateOK()* based on the *At Rate()* value every 1 second.

**SMBus protocol:** Read word

**Output:** Boolean—indicates if the battery can supply the *additional* energy requested.

**Units:** Boolean

**Range:** 1, 0

**Granularity:** Not applicable

**Accuracy:** Not applicable

### Temperature() (0x08)

**Description:** Returns the temperature (K) measured by the bq2084-V133.

**Purpose:** The *Temperature()* function provides accurate cell temperatures for use by battery chargers and thermal management systems. A battery charger can use the temperature as a safety check. Thermal management systems may use the temperature because the battery is one of the largest thermal sources in a system.

**SMBus protocol:** Read word

**Output:** Unsigned integer—cell temperature in tenth-degree Kelvin increments.

**Units:** 0.1°K


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**Range:** 0 to +6553.5°K {real range}

**Granularity:** 0.1°K

**Accuracy:** ±1.5°K (from ideal Semitec 103AT thermistor performance, after calibration)

### Voltage() (0x09)

**Description:** Returns the cell-pack voltage (mV).

**Purpose:** The *Voltage()* function provides power management systems with an accurate battery terminal voltage. Power management systems can use this voltage, along with battery current information, to characterize devices they control. This ability helps enable intelligent, adaptive power-management systems.

**SMBus protocol:** Read word

**Output:** Unsigned integer—battery terminal voltage in mV.

**Units:** mV

**Range:** 0 to 20,000 mV

**Granularity:** 1 mV

**Accuracy:** ±0.25% (after calibration)

### Current() (0x0a)

**Description:** Returns the current being supplied (or accepted) by the battery (mA).

**Purpose:** The *Current()* function provides a snapshot for the power management system of the current flowing into or out of the battery. This information is of particular use in power-management systems because they can characterize individual devices and tune their operation to actual system power behavior.

**SMBus protocol:** Read word

**Output:** Signed integer—charge/discharge rate in mA increments: positive for charge, negative for discharge.

**Units:** mA

**Range:** -32,768 to 32,767 mA

**Granularity:** 1 mA

**Accuracy:** 0.25% or 5 mA, whichever is greater

### AverageCurrent() (0x0b)

**Description:** Returns a value that approximates a one-minute rolling average of the current being supplied (or accepted) through the battery terminals (mA). *AverageCurrent()* is implemented as a single pole IIR filter with a 14.5-s time constant.

**Purpose:** The *AverageCurrent()* function provides the average current flowing into or out of the battery for the power management system.

**SMBus protocol:** Read word

**Output:** Signed integer—charge/discharge rate in mA increments: positive for charge, negative for discharge.

**Units:** mA

**Range:** -32,768 to 32,767 mA

**Granularity:** 1 mA

**Accuracy:** 0.25% or 5 mA, whichever is greater

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### MaxError() (0x0c)

**Description:** Returns the expected margin of error (%) in the state of charge calculation. For example, when *MaxError()* returns 10% and *RelativeStateOfCharge()* returns 50%, the *RelativeStateOfCharge()* is more likely between 50% and 60%. The bq2084-V133 sets *MaxError()* to 100% on a full reset. The bq2084-V133 sets *MaxError()* to 2% on completion of a learning cycle, unless the bq2084-V133 limits the learning cycle to the +512/-256 mAh maximum adjustment values. If the learning cycle is limited, the bq2084-V133 sets *MaxError()* to 8% unless *MaxError()* was already below 8%. In this case, *MaxError()* does not change. The bq2084-V133 increments *MaxError()* by 1% after four increments of *CycleCount()* without a learning cycle. If voltage-based corrections are applied to the coulomb counter, *MaxError()* is set to 25%.

**Purpose:** The *MaxError()* function has real value in two ways: first, to give the user a confidence level about the state of charge and second, to give the power management system information about how aggressive it should be, particularly as the battery nears the end of its life.

**SMBus protocol:** Read word

**Output:** Unsigned integer—percent uncertainty for selected information.

**Units:** %

**Range:** 2-100%

**Granularity:** 1%

**Accuracy:** Not applicable

### RelativeStateOfCharge() (0x0d)

**Description:** Returns the predicted remaining battery capacity expressed as a percentage of *FullChargeCapacity()* (%).

**Purpose:** The *RelativeStateOfCharge()* function is used to estimate the amount of charge remaining in the battery relative to the last learned capacity.

**SMBus protocol:** Read word

**Output:** Unsigned integer-percent of remaining capacity.

**Units:** %

**Range:** 0-100%

**Granularity:** 1%

**Accuracy:** -0, +*MaxError()*

### AbsoluteStateOfCharge()(0x0e)

**Description:** Returns the predicted remaining battery capacity expressed as a percentage of *DesignCapacity()* (%). Note that *AbsoluteStateOfCharge()* can return values greater than 100%.

**Purpose:** The *AbsoluteStateOfCharge()* function is used to estimate the amount of charge remaining in the battery relative to the nominal or *DesignCapacity()*.

**SMBus protocol:** Read word

**Output:** Unsigned integer—percent of remaining capacity.

**Units:** %

**Range:** 0-100+%

**Granularity:** 1%

**Accuracy:** -0, +*MaxError()*

### RemainingCapacity() (0x0f)

**Description:** Returns the predicted charge or energy remaining in the battery. The *RemainingCapacity()* value is expressed in either charge or energy, depending on the setting of the *BatteryMode() CAPACITY_MODE* bit.


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**Purpose:** The *RemainingCapacity()* function returns the battery's remaining capacity. This information is a numeric indication of remaining charge or energy given by the *AbsoluteStateOfCharge()* or *RelativeStateOfCharge()* functions and may be in a better form for use by power management systems.

**SMBus protocol:** Read word

**Output:** Unsigned integer—remaining charge in units of mAh or 10 mWh.

| | BATTERY MODES | |
|---|---|---|
| | **CAPACITY_MODE BIT = 0** | **CAPACITY_MODE BIT = 1** |
| Units | mAh | 10 mWh |
| Range | 0-65,535 mAh | 0-65,535 10 mWh |
| Granularity | mAh | 10 mWh |
| Accuracy | -0, +MaxError() * | FullCharageCapacity() |

### FullChargeCapacity() (0x10)

**Description:** Returns the predicted pack capacity when it is fully charged. The *FullChargeCapacity()* value is expressed in either current (mAh at a C/5 discharge rate) or power (10 mWh at a P/5 discharge rate) depending on the setting of the *BatteryMode() CAPACITY_MODE* bit.

**Purpose:** The *FullChargeCapacity()* function provides a means of understanding the tank size of the battery. This information, along with information about the original capacity of the battery, indicates battery wear.

**SMBus protocol:** Read word

**Output:** Unsigned integer—estimated full-charge capacity in units of mAh or 10 mWh.

| | BATTERY MODES | |
|---|---|---|
| | **CAPACITY_MODE BIT = 0** | **CAPACITY_MODE BIT = 1** |
| Units | mAh | 10 mWh |
| Range | 0-65,535 mAh | 0-65,535 10 mWh |
| Granularity | mAh | 10 mWh |
| Accuracy | -0, +MaxError() × FullCharageCapacity() | |

### RunTimeToEmpty() (0x11)

**Description:** Returns the predicted remaining battery life at the present rate of discharge (minutes). The*RunTimeToEmpty()* value is calculated based on either current or power depending on the setting of the *BatteryMode()* CAPACITY_MODE bit.

**Purpose:** The *RunTimeToEmpty()* provides the power management system with information about the relative gain or loss in remaining battery life in response to a change in power policy. This information is **not** the same as the *AverageTimeToEmpty()*, which is not suitable to determine the effects that result from a change in power policy.

**SMBus protocol:** Read word

**Output:** Unsigned integer—minutes of operation left.

**Units:** Minutes

**Range:** 0 to 65,534 min

**Granularity:** 2 min or better

**Accuracy:** -0, +*MaxError()* × *FullChargeCapacity()* ÷ *Current()*

**Invalid Data Indication:** 65,535 indicates battery is not being discharged.

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### AverageTimeToEmpty() (0x12)

**Description:** Returns a predicted remaining battery life (minutes), based on *AverageCurrent*. The *AverageTimeToEmpty()* value is calculated based on either current or power depending on the setting of the *BatteryMode()* CAPACITY_MODE bit.

**Purpose:** The *AverageTimeToEmpty()* displays state-of-charge information in a more useful way. It averages the instantaneous estimations so that the remaining time does not appear to jump around.

**SMBus protocol:** Read word

**Output:** Unsigned integer—minutes of operation left.

**Units:** Minutes

**Range:** 0 to 65,534 min

**Granularity:** 2 min or better

**Accuracy:** -0, +*MaxError() * FullChargeCapacity()* / *AverageCurrent()*

**Invalid Data Indication:** 65,535 indicates battery is not being discharged.

### AverageTimeToFull() (0x13)

**Description:** Returns a predicted remaining time until the battery reaches full charge (minutes), based on AverageCurrent.

**Purpose:** The *AverageTimeToFull()* function can be used by the SMBus host's power management system to aid in its policy. It may also be used to find out how long the system must be left on to achieve full charge.

**SMBus protocol:** Read word

**Output:** Unsigned integer—remaining time in minutes.

**Units:** Minutes

**Range:** 0 to 65,534 minutes

**Granularity:** 2 minutes or better

**Accuracy:** -0, +*MaxError() * FullChargeCapacity() ÷AverageCurrent()*

**Invalid Data Indication:** 65,535 indicates the battery is not being charged.

### ChargingCurrent() (0x14)

**Description:** Returns the desired charging rate in mA.

**Purpose:** The *ChargingCurrent()* function sets the maximum charge current of the battery. *TheChargingCurrent()* value should be used in combination with the *ChargingVoltage()* value to set the charger's operating point. Together, these functions permit the bq2084-V133 to dynamically control the charging profile (current/voltage) of the battery. The bq2084-V133 can effectively turn off a charger by returning a value of 0 for this function. The charger may be operated as a constant-voltage source above its maximum regulated current range by returning a *ChargingCurrent()* value of 65,535.

**SMBus protocol:** Read word

**Output:** Unsigned integer—maximum charger output current in mA.

**Units:** mA

**Range:** 0 to 65,535 mA

**Granularity:** 1 mA

**Accuracy:** Not applicable

**Invalid Data Indication:** 65,535 indicates that a charger should operate as a voltage source outside its maximum regulated current range.


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### ChargingVoltage() (0x15)

**Description:** Returns the desired charging voltage in mV.

**Purpose:** The *ChargingVoltage()* function sets the maximum charge voltage of the battery. The *ChargingVoltage()* value should be used in combination with the *ChargingCurrent()* value to set the charger's operating point. Together, these functions permit the bq2084-V133 to dynamically control the charging profile (current/voltage) of the battery. The charger may be operated as a constant-current source above its maximum regulated voltage range by returning a *ChargingVoltage()* value of 65,535.

**SMBus protocol:** Read word

**Output:** Unsigned integer—charger output voltage in mV.

**Units:** mV

**Range:** 0 to 65,535 mV

**Granularity:** 1 mV

**Accuracy:** Not applicable

**Invalid Data Indication:** 65,535 indicates the charger should operate as a current source outside its maximum regulated voltage range.

### BatteryStatus() (0x16)

**Description:** Returns the bq2084-V133 status word (flags). Some of the *BatteryStatus()* flags (and *REMAINING_TIME_ALARM*) are calculated on the basis of 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 bq2084-V133. 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 | Unknown Error |
| 0x0006 | BadSize |
| 0x0005 | Overflow/Underflow |
| 0x0004 | AccessDenied |
| 0x0003 | UnsupportedCommand |

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| ALARM BITS | |
|---|---|
| 0x0002 | ReservedCommand |
| 0x0001 | Busy |
| 0x0000 | OK |

## ALARM BITS

*OVER_CHARGED_ALARM* bit is set whenever the bq2084-V133 detects that the battery is being charged beyond the maximum overcharge limit, which is full capacity plus *Maximum Overcharge* (DF 0x51-0x52). This bit is cleared when the bq2084-V133 detects that the battery is no longer being charged and there are 2 mAh of continuous discharge (i.e., the bq2084-V133 detects discharge activity or no activity above the digital filter).

*TERMINATE_CHARGE_ALARM* bit is set when the bq2084-V133 detects a primary charge termination. This bit is cleared when the bq2084-V133 detects that the battery is no longer being charged.

*OVER_TEMP_ALARM* bit is set when the bq2084-V133 detects that the internal battery temperature is greater than or equal to the *OverTemperature Charge* threshold while charging or *OverTemperature Discharge* threshold while discharging. This bit is cleared when the internal temperature falls back below the *OverTemperature Charge Reset* or *OverTemperature Discharge Reset* as appropiate..

*TERMINATE_DISCHARGE_ALARM* bit is set when RM = 0, *Voltage()* = *Terminate Voltage* (DF 0x67-0x68), the battery temperature is less than or equal to the *Charge Suspend Temp Low* (DF 0x79) 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*. The bit is cleared when Voltage() > *Terminate Voltage*, *RM()* > 0, and the *CVUV* bit is cleared.

*REMAINING_CAPACITY_ALARM* bit is set when the bq2084-V133 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 bq2084-V133 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

The initialized bit is set when the bq2084-V133 has detected a valid load of data flash at full or partial reset. It is cleared when the bq2084-V133 detects an improper data flash load.

*DISCHARGING* bit is set when the bq2084-V133 determines that the battery is not being charged. This bit is cleared when the bq2084-V133 detects that the battery is being charged.

*FULLY_CHARGED* bit is set when the bq2084-V133 detects a primary charge termination or an Overcharge condition. It is cleared when *RelativeStateOfCharge()* is less than the programmed *Fully Charged Clear %* (DF 0x4a).

*FULLY_DISCHARGED* bit is set when *Voltage()* or *VCELL* is less than the EDV2 threshold and *Current()* < *Overload Current* 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 bq2084-V133 processed the function code without detecting any errors. |
| Busy | The bq2084-V133 is unable to process the function code at this time. |
| Reserved | The bq2084-V133 detected an attempt to read or write to a function code reserved by this version of the specification.<br>The bq2084-V133 detected an attempt to access an unsupported optional manufacturer function code. |
| Unsupported | The bq2084-V133 does not support this function code which is defined in this version of the specification. |
| AccessDenied | The bq2084-V133 detected an attempt to write to a read-only function code. |
| Oveflowr/Underflow | The bq2084-V133 detected a data overflow or underflow. |


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| ERROR CODES | DESCRIPTION |
|---|---|
| BadSize | The bq2084-V133 detected an attempt to write to a function code with an incorrect data block. |
| UnknownError | The bq2084-V133 detected an unidentifiable error. |

### CycleCount()(0x17)

**Description:** Returns the number of cycles the battery has experienced. The mAh value of each count is determined by programming the *Cycle Count Threshold* value in DF 0x38-0x39. The bq2084-V133 saves the cycle count value to *Cycle Count* (DF 0x0c-0x0d) after an update to *CycleCount()*.

**Purpose:** The *CycleCount()* function provides a means to determine the battery wear. It may be used to give advance warning that the battery is nearing its end of life.

**SMBus protocol:** Read word

**Output:** Unsigned integer—count of total charge removed from the battery over its life.

**Units:** cycle

**Range:** 0 to 65,534 cycles; 65,535 indicates battery has experienced 65,535 or more cycles.

**Granularity:** 1 cycle

**Accuracy:** Absolute count

### DesignCapacity() (0x18)

**Description:** Returns the theoretical or nominal capacity of a new pack. The *DesignCapacity()* value is expressed in either current (mAh at a C/5 discharge rate) or power, (10 mWh at a P/5 discharge rate) depending on the setting of the *BatteryMode()* CAPACITY_MODE bit.

**Purpose:** The *DesignCapacity()* function is used by the SMBus host's power management along with *FullChargeCapacity()* to determine battery wear. The power management system may present this information to the user and also adjust its power policy as a result.

**SMBus protocol:** Read word

**Output:** Unsigned integer—battery capacity in units of mAh or 10 mWh.

| | BATTERY MODES | |
|---|---|---|
| | CAPACITY_MODE BIT = 0 | CAPACITY_MODE BIT = 1 |
| Units | mAh | 10 mWh |
| Range | 0-65,535 mAh | 0-65,535 10 mWh |
| Granularity | Not applicable | Not applicable |
| Accuracy | Not applicable | Not applicable |

### DesignVoltage() (0x19)

**Description:** Returns the theoretical voltage of a new pack (mV). The bq2084-V133 sets DesignVoltage() to the value programmed in *Design Voltage* DF 0x04-0x05.

**Purpose:** The *DesignVoltage()* function can be used to give additional information about a particular smart battery expected terminal voltage.

**SMBus protocol:** Read word

**Output:** Unsigned integer—the battery's designed terminal voltage in mV

**Units:** mV

**Range:** 0 to 65,535 mV

**Granularity:** Not applicable

**Accuracy:** Not applicable

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### SpecificationInfo() (0x1a)

**Description:** Returns the version number of the smart battery specification the battery pack supports, as well as voltage and current scaling information in a packed unsigned integer. Power scaling is the product of the voltage scaling times the current scaling. The *SpecificationInfo()* is packed in the following fashion:

(SpecID_H × 0x10 + SpecID_L) + (VScale + IPScale × 0x10) × 0x100.

The bq2084-V133 *VScale* (voltage scaling) and *IPScale* (current scaling) should always be set to zero. The bq2084-V133 sets *SpecificationInfo()* to the value programmed in *Specification Information* (DF 0x06-0x07).

**Purpose:** The *SpecificationInfo()* function is used by the SMBus host's power management system to determine what information the smart battery can provide.

**SMBus protocol:** Read word

**Output:** Unsigned integer—packed specification number and scaling information:

| FIELD | BITS USED | FORMAT | ALLOWABLE VALUES |
|---|---|---|---|
| SpecID_L | 0...3 | 4-bit binary value | 0–15 |
| SpecID_H | 4...7 | 4-bit binary value | 0–15 |
| VScale | 8...11 | 4-bit binary value | 0 (multiplies voltage by 10^ VScale) |
| IPScale | 12...15 | 4-bit binary value | 0 (multiplies current by 10 ^ IPScale) |

### ManufactureDate() (0x1b)

**Description:** This function returns the date the cell pack was manufactured in a packed integer. The date is packed in the following fashion: (year-1980) × 512 + month × 32 + day. The bq2084-V133 sets *ManufactureDate()* to the value programmed in *Manufacture Date* (DF 0x08-0x09).

**Purpose:** The *ManufactureDate()* provides the system with information that can be used to uniquely identify a particular battery pack when used along with *SerialNumber()*.

**SMBus protocol:** Read word

**Output:** Unsigned integer-packed date of manufacture:

| FIELD | BITS USED | FORMAT | ALLOWABLE VALUES |
|---|---|---|---|
| Day | 0...4 | 5-bit binary value | 0-31 (corresponds to date) |
| Month | 5...8 | 4-bit binary value | 1-12 (corresponds to month number) |
| Year | 9...15 | 7-bit binary value | 0-127 (corresponds to year biased by 1980) |

### SerialNumber() (0x1c)

**Description:** This function is used to return a serial number. This number, when combined with the *ManufacturerName()*, the *DeviceName()*, and the *ManufactureDate()*, uniquely identifies the battery (unsigned integer). The bq2084-V133 sets SerialNumber() to the value programmed in *Serial Number* (DF 0x0a-0x0b).

**Purpose:** The *SerialNumber()* function can be used to identify a particular battery. This may be important in systems that are powered by multiple batteries where the system can log information about each battery that it encounters.

**SMBus protocol:** Read word

**Output:** Unsigned integer

### ManufacturerName() (0x20)

**Description:** This function returns a character array containing the battery manufacturer's name. For example, MyBattCo identifies the smart battery manufacturer as MyBattCo. The bq2084-V133 sets *ManufacturerName()* to the value programmed in *Manufacturer Name* (DF 0x0e-0x19).


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**Purpose:** The *ManufacturerName()* function returns the name of the smart battery 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)

**Description:** This function returns a character string that contains the battery name. For example, a *DeviceName()* of bq2084-V133 indicates that the battery is a model bq2084-V133. The bq2084-V133 sets *DeviceName()* to the value programmed in *Device Name* (DF 0x1a-0x21).

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

**SMBus protocol:** Read block

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

### DeviceChemistry() (0x22)

**Description:** This function returns a character string that contains the battery chemistry. For example, if the *DeviceChemistry()* function returns *NiMH*, the battery pack contains nickel metal hydride cells. The bq2084-V133 sets DeviceChemistry() to the value programmed in *Device Chemistry* (DF 0x22-0x26).

**Purpose:** The *DeviceChemistry()* function gives cell chemistry information for use by charging systems. The bq2084-V133 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.

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

### The ManufacturerData() (0x23)

**Description:** This function allows access to the manufacturer data contained in the battery (data). The bq2084-V133 stores seven critical operating parameters in this data area.

**Purpose:** The *ManufacturerData()* function may be used to access the manufacturer's data area. The data fields of this command reflect the programming of eight critical data flash locations and can be used to facilitate evaluation of the bq2084-V133 under various programming sets. The *ManufacturerData()* function returns the following information in order: *Pack Configuration, Gauge Configuration, Misc Configuration (2 bytes), Digital Filter, Self Discharge Rate, Pack Load Estimate, Battery Low%, and Near Full* (2 bytes) AFE Status, and the pending EDV threshold voltage (low byte and high byte).

**SMBus protocol:** Read block

**Output:** Block data—data that reflects data flash programming as assigned by the manufacturer with maximum length of 13 characters (13 + length byte).

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## Pack Status and Pack Configuration (0x2f)

This function returns the pack status and pack configuration registers. The pack status register contains a number of status bits relating to bq2084-V133 operation. The pack status register is the least significant byte of the word. The pack configuration register reflects how the bq2084-V133 is configured as defined by the value programmed in *Pack Configuration* in DF 0x28.

The pack status register consists of the following bits:

| b7 | b6 | b5 | b4 | b3 | b2 | b1 | b0 |
|---|---|---|---|---|---|---|---|
| PRES | EDV2 | SS | VDQ | AFEFAIL | PF | CVOV | CVUV |

**PRES**

The PRES bit indicates that the bq2084-V133 has been inserted into the system.

0 bq2084-V133 is out of the system

1 bq2084-V133 is inserted into a system


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**EDV2**

The EDV2 bit indicates that pack or cell voltage (program option) is less than the EDV2 threshold.

0 Voltage > EDV2 threshold (discharging)

1 Voltage = EDV2 threshold

**SS**

The SS bit indicates the seal state of the bq2084-V133.

0 The bq2084-V133 is in the unsealed state.

1 The bq2084-V133 is in the sealed state.

**AFEFAIL**

The AFEFAIL bit indicates that AFE communications has failed.

0 AFE communications are okay.

1 AFE communications have failed.

**VDQ**

The VDQ bit indicates if the present discharge cycle is valid for an FCC update.

0 Discharge cycle not valid

1 Discharge cycle valid

**PF**

The PF bit indicates that the bq2084-V133 *PF Flag* has been set. It is cleared only when the *PF Flag* has been cleared.

0 bq2084-V133 *PF Flag* = 0x00

1 bq2084-V133 *PF Flag* = 0x66

**CVOV**

The CVOV bit indicates that a protection limit has been exceeded including Prolonged Overcurrent, Overvoltage, or Overtemperature conditions. The bit is not latched and merely reflects the present fault status.

0 No secondary protection limits exceeded

1 A secondary protection limit exceeded

**CVUV**

The CVUV bit indicates that a protection limit has been exceeded including overload or overdischarge conditions. The bit is not latched and merely reflects the present fault status.

0 No secondary protection limits exceeded

1 A secondary protection limit exceeded

### VCELL4-VCELL1 (0x3c-0x3f)

These functions return the calculated individual cell voltages in mV.

## DATA FLASH

### General

The bq2084-V133 accesses the internal data flash during reset and when storing historical data. The data flash stores basic configuration information for use by the bq2084-V133. The data flash must be programmed correctly for proper bq2084-V133 operation.

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## Memory Map

The following table shows the memory map for the data flash. It shows the default programming for the bq2084-V133. The default programming reflects example data for a 3s2p Li-ion battery pack with a 0.02-Ω sense resistor. The data flash must be reprogrammed to meet the requirements of individual applications.

| DATA FLASH ADDRESS | | NAME | LI-ION EXAMPLE | DATA | |
|---|---|---|---|---|---|
| HIGH BYTE | LOW BYTE | | | MSB | LSB |
| 0x00 | 0x01 | *Remaining Time Alarm* | 10 minutes | 00 | 0a |
| 0x02 | 0x03 | *Remaining Capacity Alarm* | 360 mAh | 01 | 68 |
| 0x04 | 0x05 | *Design Voltage* | 14400 mV | 38 | 40 |
| 0x06 | 0x07 | *Specification Information* | v1.1/PEC | 00 | 31 |
| 0x08 | 0x09 | *Manufacture Date* | 1/1/2003=11809 | 2e | 21 |
| 0x0a | 0x0b | *Serial Number* | 1 | 00 | 01 |
| 0x0c | 0x0d | *Cycle Count* | 0 | 00 | 00 |
| 0x0e | | *Manufacturer Name Length* | 11 | | 0b |
| 0x0f | | Character 1 | T | | 54 |
| 0x10 | | Character 2 | e | | 45 |
| 0x11 | | Character 3 | x | | 58 |
| 0x12 | | Character 4 | a | | 41 |
| 0x13 | | Character 5 | s | | 53 |
| 0x14 | | Character 6 | | | 20 |
| 0x15 | | Character 7 | I | | 49 |
| 0x16 | | Character 8 | n | | 4e |
| 0x17 | | Character 9 | s | | 53 |
| 0x18 | | Character 10 | t | | 54 |
| 0x19 | | Character 11 | . | | 2e |
| 0x1a | | *Device Name Length* | 6 | | 06 |
| 0x1b | | Character 1 | b | | 42 |
| 0x1c | | Character 2 | q | | 51 |
| 0x1d | | Character 3 | 2 | | 32 |
| 0x1e | | Character 4 | 0 | | 30 |
| 0x1f | | Character 5 | 8 | | 38 |
| 0x20 | | Character 6 | 4 | | 34 |
| 0x21 | | Character 7 | — | | 00 |
| 0x22 | | *Device Chemistry Length* | 4 | | 04 |
| 0x23 | | Character 1 | L | | 4c |
| 0x24 | | Character 2 | I | | 49 |
| 0x25 | | Character 3 | O | | 4f |
| 0x26 | | Character 4 | N | | 4e |
| 0x27 | | *Manufacturer Data Length* | 9 | | 09 |
| 0x28 | | *Pack Configuration* | DMODE, 4-LEDs, 4-CELL | | c3 |
| 0x29 | | *Gauge Configuration* | CSYNC, OTVC | | 41 |
| 0x2a | 0x2b | *Misc Configuration* | OT, VOD | 0b | 00 |
| 0x2c | | *Digital Filter* (Dead Band) | 9860 nV | | 22 |
| 0x2d | | *Self-Discharge Rate* | 0.2% | | 14 |
| 0x2e | | *Electronics Load* | 0 mA | | 00 |
| 0x2f | | *Battery Low % (MSB)* | 7.03% | | 12 |
| 0x30 | 0x31 | *Near Full* | 200 mAh | 00 | c8 |
| 0x32 | 0x33 | *Design Capacity* | 7200 mAh | 1c | 20 |
| 0x34 | 0x35 | Reserved | 0 | 00 | 00 |


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| DATA FLASH ADDRESS | | NAME | LI-ION EXAMPLE | DATA | |
|---|---|---|---|---|---|
| HIGH BYTE | LOW BYTE | | | MSB | LSB |
| 0x36 | 0x37 | *Full Charge Capacity* | 7200 mAh | 1c | 20 |
| 0x38 | 0x39 | *Cycle Count Threshold* | 5200 mAh | 14 | 50 |
| 0x3a | 0x3b | *Charging Voltage* | 16800 mV | 41 | a0 |
| 0x3c | 0x3d | *Precharge Voltage* | 2500 mV | 09 | c4 |
| 0x3e | 0x3f | *Fast-Charging Current* | 2500 mA | 09 | c4 |
| 0x40 | 0x41 | *Maintenance Charging Current* | 0 mA | 00 | 00 |
| 0x42 | 0x43 | *Precharge Current* | 100 mA | 00 | 64 |
| 0x44 | | *Precharge Temperature* | 9.6°C | | 60 |
| 0x45 | | *Precharge Temperature Hysteresis* | 3.0°C | | 1e |
| 0x46 | | *Charge Inhibit Temp Low* | 0.0°C | | 00 |
| 0x47 | 0x48 | *Charge Inhibit Temp High* | 50.0°C | 01 | f4 |
| 0x49 | | *Fast Charge Termination %* | 100% | | ff |
| 0x4a | | *Fully Charged Clear %* | 95% | | 5f |
| 0x4b | 0x4c | *Current Taper Threshold* | 240 mA | 00 | f0 |
| 0x4d | 0x4e | *Current Taper Qual Voltage* | 300 mV | 01 | 2c |
| 0x4f | | *Current Taper Window* | 40s | | 28 |
| 0x50 | | Reserved | | | 40 |
| 0x51 | 0x52 | *Maximum Overcharge* | 300 mAh | 01 | 2c |
| 0x53 | | Reserved | | | 02 |
| 0x54 | | *Charge Efficiency* | 100% | | ff |
| 0x55 | | Reserved | | | 64 |
| 0x56 | 0x57 | Reserved | | 02 | 22 |
| 0x58 | | Reserved | | | 32 |
| 0x59 | 0x5a | Reserved | | 01 | ae |
| 0x5b | 0x5c | *Overload Current* | 5000 mA | 13 | 88 |
| 0x5d | 0x5e | *Over Voltage Margin* | 700 mV | 02 | bc |
| 0x5f | 0x60 | Reserved | | 01 | f4 |
| 0x61 | 0x62 | *Clear Fail Current* | 256 mA | 01 | 00 |
| 0x63 | 0x64 | *Cell Over Voltage* | 4350 mV | 10 | fe |
| 0x65 | 0x66 | *Cell Under Voltage* | 2300 mV | 08 | fc |
| 0x67 | 0x68 | *Terminate Voltage* | 11300 mV | 2c | 24 |
| 0x69 | 0x6a | Reserved | | 00 | 00 |
| 0x6b | 0x6c | *Safety Over Voltage* | 20000 mV | 3a | 98 |
| 0x6d | 0x6e | *Charge Suspend Temp High* | 60°C | 02 | 58 |
| 0x6f | 0x70 | *Charge Suspend Temp High Reset* | 55°C | 02 | 26 |
| 0x71 | 0x72 | *Over Temperature Discharge* | 70°C | 02 | bc |
| 0x73 | 0x74 | *Over Temperature Discharge Reset* | 60°C | 02 | 58 |
| 0x75 | 0x76 | *Safety OverTemperature Charge* | 75°C | 02 | ee |
| 0x77 | 0x78 | *Safety OverTemperature Discharge* | 75°C | 02 | ee |
| 0x79 | | *Charge Suspend Temp Low* | 0°C | | 00 |
| 0x7a | | Reserved | | | ef |
| 0x7b | | *Current Deadband* | 3 mA | | 03 |
| 0x7c | 0x7d | *Shutdown Voltage* | 8800 mV | 22 | 60 |
| 0x7e | 0x7f | *VOC75* | 15848 mV | 3d | e8 |
| 0x80 | | Reserved | | | bf |
| 0x81 | | Reserved | | | 56 |
| 0x82 | | Reserved | | | 40 |

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| DATA FLASH ADDRESS | | NAME | LI-ION EXAMPLE | DATA | |
|---|---|---|---|---|---|
| HIGH BYTE | LOW BYTE | | | MSB | LSB |
| 0x83 | 0x84 | *VOC50* | 15240 mV | 3b | 88 |
| 0x85 | | Reserved | | | 7f |
| 0x86 | | Reserved | | | 3d |
| 0x87 | | Reserved | | | 27 |
| 0x88 | 0x89 | *VOC25* | 15024 mV | 3a | b0 |
| 0x8a | | Reserved | | | 3f |
| 0x8b | | Reserved | | | 24 |
| 0x8c | | Reserved | | | 0e |
| 0x8d | | Reserved | | | 14 |
| 0x8e | | *Voltage Average Time* | 1 s | | 01 |
| 0x8f | | *Correction Current Limit* | 64 mA | | 40 |
| 0x90 | 0x91 | Reserved | | 0b | e1 |
| 0x92 | 0x93 | Reserved | | 0b | 68 |
| 0x94 | | Reserved | | | 19 |
| 0x95 | 0x96 | *EMF/EDV0* | 3000 mV | 0b | b8 |
| 0x97 | 0x98 | *EDV C0 Factor/EDV1* | 3250 mV | 0c | b2 |
| 0x99 | 0x9a | *EDV R0 Factor/EDV2* | 3400 mV | 0d | 48 |
| 0x9b | 0x9c | *EDV T0 Factor* | 0 | 00 | 00 |
| 0x9d | 0x9e | *EDV R1 Factor* | 0 | 00 | 00 |
| 0x9f | | *EDV TC Factor* | 0 | | 00 |
| 0xa0 | | *EDV C1 Factor* | 0 | | 00 |
| 0xa1 | | Reserved | | | 08 |
| 0xa2 | | Reserved | | | 9b |
| 0xa3 | | Reserved | | | c7 |
| 0xa4 | | Reserved | | | 64 |
| 0xa5 | | Reserved | | | 14 |
| 0xa6 | 0xa7 | Reserved | | 02 | 00 |
| 0xa8 | 0xa9 | Reserved | | 01 | 00 |
| 0xaa | | Reserved | | | 08 |
| 0xab | | Reserved | | | 02 |
| 0xac | | *Learning Low Temp* | 11.9°C | | 77 |
| 0xad | | Reserved | | | 0a |
| 0xae | 0xaf | Reserved | | 01 | 80 |
| 0xb0 | 0xb1 | Reserved | | 01 | 00 |
| 0xb2 | | Reserved | | | 08 |
| 0xb3 | | Reserved | | | 18 |
| 0xb4 | | Reserved | | | 14 |
| 0xb5 | 0xb6 | TS Const 1 | | 91 | 83 |
| 0xb7 | 0xb8 | TS Const 2 | | 51 | 70 |
| 0xb9 | 0xba | TS Const 3 | | e2 | 8f |
| 0xbb | 0xbc | TS Const 4 | | 0f | ac |
| 0xbd | 0xbe | TS Const 5 | | 00 | 00 |
| 0xbf | 0xc0 | Reserved | | 0f | ac |
| 0xc1 | | Reserved | | | 02 |
| 0xc2 | | *AFE State Control* | | | 00 |
| 0xc3 | | *AFE Function Control* | | | 00 |
| 0xc4 | | *AFE Cell Select* | | | 00 |


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| DATA FLASH ADDRESS | | NAME | LI-ION EXAMPLE | DATA | |
|---|---|---|---|---|---|
| HIGH BYTE | LOW BYTE | | | MSB | LSB |
| 0xc5 | | *AFE Overload* | 140 mV | | 12 |
| 0xc6 | | *AFE Overload Delay* | 31 ms | | 0f |
| 0xc7 | | *AFE Short Circuit Charge* | | | 17 |
| 0xc8 | | *AFE Short Circuit Discharge* | | | 17 |
| 0xc9 | 0xca | *AFE Vref** (1) | 9750 mV | 26 | 16 |
| 0xcb | 0xcc | *Sense Resistor Gain** (1) | 0.02 & | 3b | d0 |
| 0xcd | 0xce | *CC Delta** (1) | 0.0000323 mAh | 92 | 0a |
| 0xcf | 0xd0 | *CC Delta** (1) | | 16 | 00 |
| 0xd1 | | Reserved | | | fa |
| 0xd2 | 0xd3 | *CC Offset** (1) | 49701 | c2 | 25 |
| 0xd4 | | *DSC Offset** (1) | 38 | | 26 |
| 0xd5 | | *ADC Offset** (1) | 38 | | 26 |
| 0xd6 | | *Temperature Offset** (1) | 0 | | 00 |
| 0xd7 | | *Board Offset** (1) | 0 | | 00 |
| 0xd8 | 0xd9 | Reserved | | 00 | 40 |
| 0xda | 0xdb | Reserved | | 01 | 00 |
| 0xdc | | Reserved | | | 05 |
| 0xdd | 0xde | Version | 1.0 | 01 | 00 |
| 0xdf | | Reserved | | 00 | 32 |
| 0xe0 | 0xe1 | *Cell Over Voltage Reset* | 4150 mV | 10 | 36 |
| 0xe2 | 0xe3 | *Cell Under Voltage Reset* | 3000 mV | 0b | b8 |
| 0xe4 | 0xe5 | *AFE Fail Limit* | 2 counts | 00 | 02 |
| 0xe6 | 0xe7 | Reserved | | ff | ff |
| 0xe8 | 0xe9 | *Cell Balance Thresh* | 3900 mV | 0f | 3c |
| 0xea | 0xeb | *Cell Balance Window* | 100 mV | 00 | 64 |
| 0xec | | *Cell Balance Min* | 40 mV | | 28 |
| 0xed | | *Cell Balance Interval* | 20 s | | 14 |
| 0xee | 0xef | *Cell Imbalance Threshold* | | 01 | f4 |
| 0xf0 | 0xf1 | *Balance Vcell Max* | | 10 | 36 |
| 0xf2 | 0xf3 | *Balance Imax* | | 00 | 9e |
| 0xf4 | 0xf5 | Reserved | | a5 | 5a |
| 0xf6 | 0xf7 | Reserved | | 7a | 43 |
| 0xf8 | 0xf9 | Reserved | | 20 | 83 |
| 0xfa | | *Battery Low (LSB)* | 7.03 % | | 12 |
| 0xfb | | *AFE Check Time* | 0 s | | 00 |
| 0xfc | | *Sleep Current Thresh* | 2 mA | | 04 |
| 0xfd | | *Sleep Current Multiplier* | 5 counts | | 05 |
| 0xfe | | Sleep Time | 20 s | | 14 |
| 0xff | 0x100 | *Manufacturer Info 1* | | 00 | 00 |
| 0x101 | 0x102 | *Manufacturer Info 2* | | 00 | 00 |
| 0x103 | 0x104 | *Manufacturer Info 3* | | 00 | 00 |
| 0x105 | 0x106 | *Vmax Charge Voltage* | 4280 mv | 10 | b8 |
| 0x107 | 0x108 | *Voff Charge Voltage* | 4280 mv | 10 | b8 |
| 0x109 | 0x10a | *Von Charge Voltage* | 4200 mv | 10 | 68 |
| 0x10b | 0x10c | *Pulse Max On Time* | 60 s | 01 | e0 |
| 0x10d | 0x10e | *Pulse Min Off Time* | 0.125 s | 00 | 01 |

(1) Reserved locations must be set as shown. Locations marked with an * are typical calibration values that can be adjusted for maximum accuracy. For these locations the table shows the appropriate default or initial setting.

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| DATA FLASH ADDRESS | | NAME | LI-ION EXAMPLE | DATA | |
|---|---|---|---|---|---|
| HIGH BYTE | LOW BYTE | | | MSB | LSB |
| 0x10f | 0x110 | *Max Charge Time* | 7200 s | 1c | 20 |
| 0x111 | 0x112 | *Precharge Detection Current* | 10 mA | 00 | 0a |
| 0x113 | 0x114 | *Charge Detection Current* | 100 mA | 00 | 64 |
| 0x115 | 0x116 | *Discharge Detection Current* | -150 mA | ff | 6a |
| 0x117 | 0x118 | Reserved | | 10 | 68 |
| 0x119 | 0x11a | Reserved | | 10 | 36 |
| 0x11b | 0x11c | Reserved | | | 00 |
| 0x11d | | *Permanent Fail Status* | 0 | | 00 |
| 0x11e | | *Permanent Fail Flag* | 0 | | 00 |
| 0x11f | | *Permanent Fail Config* | 0 | | 00 |
| 0x120 | | *Permanent Fail Input Time* | 0 | | 00 |
| 0x121 | 0x122 | Reserved | | 17 | 12 |
| 0x123 | 0x124 | Reserved | | 26 | 73 |
| 0x125 | 0x126 | *FET Fail Charge Current* | 20 mA | 00 | 20 |
| 0x127 | 0x128 | *FET Fail Discharge Current* | -20 mA | ff | ec |
| 0x129 | | *FET Fail Time* | 20 s | | 14 |
| 0x12a | 0x12b | *Charge OC Threshold* | 4000 mA | 0f | a0 |
| 0x12c | | *Charge OC Time* | 6 s | | 06 |
| 0x12d | 0x12e | *Discharge OC Threshold* | 10970 mA | 2a | da |
| 0x12f | | *Discharge OC Time* | 10 s | | 00 |
| 0x130 | | *Fault Reset Time* | 30 s | | 1e |
| 0x131 | 0x132 | *VPACK Threshold* | | 07 | d0 |
| 0x133 | | *Shutdown Timer* | 20 s | | 14 |
| 0x134 | | *Cell Imbalance Time* | 20 s | | 14 |
| 0x135 | 0x136 | Reserved | | | |

# ADDITIONAL PROGRAMMING INFORMATION

## ADDITIONAL DATA FLASH PROGRAMMING

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

### Fundamental Parameters

#### Sense Resistor Value

The 32-bit *CC Delta* (DF 0xcd-0xd0) corrects the coulomb counter for sense resistor variations. It represents the gain factor for the coulomb counter. The 16-bit *Sense Resistor Gain* (DF 0xcb-0xcc) scales each integrating converter conversion to mAh. The *Current()* related measurement *Sense Resistor Gain* is based on the resistance of the series sense resistor. The following formula computes a nominal or starting value for *Sense Resistor Gain* from the sense resistor value (in Ω).

*Sense Resistor Gain* = 306.25 ÷ Rs

| RSNS Value (mΩ) | *Sense Resistor Gain* |
|---|---|
| 5 | 61250 |
| 10 | 30625 |
| 20 | 15312 |


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### CC offset

*CC offset* (DF 0xd2-0xd3), contains the offset for the coulomb counter. It is automatically updated when the pack has met the conditions for sleep, before it enters sleep mode.

### DSC offset

*DSC offset* (DF 0xd4), contains the offset for the pack ground reference. It is automatically updated when the pack has met the conditions for sleep, before it enters sleep mode.

### ADC offset

*ADC offset* (DF 0xd5), contains the offset for the a/d converter. It is automatically updated when the pack has met the conditions for sleep, before it enters sleep mode.

### Digital Filter

The desired digital filter threshold, VDF (V), is set by the value stored in *Digital Filter* (DF 0x2c).

*Digital Filter* = VDF ÷ 290 nV

## CELL AND PACK CHARACTERISTICS

### Battery Pack Capacity and Voltage

Pack capacity in mAh units is stored in *Design Capacity* (DF 0x32-0x33). In mAh mode, the bq2084-V133 copies *Design Capacity* to *DesignCapacity()*. In mWh mode, the bq2084-V133 multiplies *Design Capacity* by *Design Voltage* (DF 0x04-0x05) to calculate *DesignCapacity()* scaled to 10 mWh. *Design Voltage* is stored in mV.

The initial value for *Full Charge Capacity*, in mAh, is stored in DF 0x36-0x37. *Full Charge Capacity* is modified over the course of pack usage to reflect cell aging under the particular use conditions. The bq2084-V133 updates *Full Charge Capacity* in mAh after a capacity learning cycle.

#### *Remaining Time Alarm and Capacity Alarm*

*Remaining Time Alarm* (DF 0x02-0x03) sets 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 units of mAh or 10 mWh, depending on the *BatteryMode()* setting.

#### *Cycle Count Initialization*

*Cycle Count* (DF 0x0c-0x0d) stores the initial value for the *CycleCount()* function. It should be programmed to 0x0000.

#### *Cycle Count Threshold*

*Cycle Count Threshold* (DF 0x37-0x38) 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 mAh.

#### *Charge Efficiency*

The bq2084-V133 applies the efficiency factor, EFF%, to all charge added to the battery. EFF% is encoded in *Charge Efficiency* (DF 0x54) according to the following equation:

*Charge Efficiency* = (EFF% w 2.56-1)

## PACK OPTIONS

### Pack Configuration

*Pack Configuration* (DF 0x28) contains bit-programmable features.

| b7 | b6 | b5 | b4 | b3 | b2 | b1 | b0 |
|---|---|---|---|---|---|---|---|
| DMODE | LED1 | LED0 | HPE | CPE | SM | CC1 | CC0 |

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**DMODE**

The DMODE bit determines whether the LED outputs indicate AbsoluteStateOfCharge() or RelativeStateOfCharge().

0 LEDs reflect AbsoluteStateOfCharge()

1 LEDs reflect RelativeStateOfCharge()

**LED1–LED0**

The LED bits set the number of LEDs for Remaining Capacity () indication.

0-0 Configures the bq2084-V133 for five LEDs

0-1 Configures the bq2084-V133 for three LEDs

1-0 Configures the bq2084-V133 for four LEDs

1-1 Configures the bq2084-V133 for five LEDs

**HPE**

The HPE bit enables/disables PEC transmissions to the smart battery host for master mode alarm messages.

0 No PEC byte on alarm warning to host

1 PEC byte on alarm warning to host

**CPE**

The CPE bit enables/disables PEC transmissions to the smart battery charger for master mode messages.

0 No PEC byte on broadcasts to charger

1 PEC byte on broadcasts to charger

**SM**

The SM bit enables/disables master mode broadcasts by the bq2084-V133.

0 Broadcasts to host and charger enabled

1 Broadcasts to host and charger disabled

If the SM bit is set, modifications to bits in BatteryMode() do not re-enable broadcasts.

**CC1–CC0**

The CC bits configure the bq2084-V133 for the number of series cells in the battery pack.

1-1 Configures the bq2084-V133 for four series cells

1-0 Configures the bq2084-V133 for three series cells

0-1 Configures the bq2084-V133 for two series cells

### Gauge Configuration

*Gauge Configuration* (DF 0x29) contains bit-programmable features:

| b7 | b6 | b5 | b4 | b3 | b2 | b1 | b0 |
|---|---|---|---|---|---|---|---|
| 0 | CSYNC | SC | CEDV | EDVV | OVSEL | VCOR | OTVC |

**CSYNC**

In usual operation of the bq2084-V133, the CSYNC bit is set so that the coulomb counter is adjusted when a fast charge termination is detected. In some applications, especially those where an externally controlled charger is used, it may be desirable *not* to adjust the coulomb counter. In these cases the CSYNC bit should be cleared.

0 The bq2084-V133 does not alter RM at the time of a valid charge termination.

1 The bq2084-V133 updates RM with a programmed percentage of FCC at a valid charger termination.


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**SC**

The SC bit enables learning cycle optimization for a Smart Charger or independent charge.

1 Learning cycle optimized for independent charger

0 Learning cycle optimized for Smart Charger

**CEDV**

The CEDV bit determines whether the bq2084-V133 implements automatic EDV compensation to calculate the EDV0, EDV1, and EDV2 thresholds base on rate, temperature, and capacity. If the bit is cleared, the bq2084-V133 uses the fixed values programmed in data flash for EDV0, EDV1, and EDV2. If the bit is set, the bq2084-V133 calculates EDV0, EDV1, and EDV2.

0 EDV compensation disabled

1 EDV compensation enabled

**EDVV**

The EDVV bit selects whether EDV termination is to be done with regard to Voltage () or the lowest single-cell voltage.

0 EDV conditions determined on the basis of the lowest single-cell voltage

1 EDV conditions determined on the basis of Voltage()

**OVSEL**

The OVSEL bit determines if Safety Over Voltage is based on Voltage () or highest cell voltages.

0 Safety overvoltage based on Voltage ()

1 Safety overvoltage based on highest cell voltage multiplied by the number of cells and then compared to the safety voltage.

**VCOR**

The VCOR bit enables the midrange voltage correction algorithm. When it is set, the bq2084-V133 compares the pack voltage to RM and may adjust RM according to the values programmed in VOC25, VOC50, and VOC75.

0 Continuous midrange corrections disabled

1 Continuous midrange corrections enabled

**OTVC**

The OTVC bit programs the bq2084-V133 to perform a midrange voltage one time after a device reset

0 One-time midrange correction disabled

1 One-time midrange correction enabled

### Miscellaneous Configuration

*Misc Configuration* (DF 0x2a, high, and 0x2b, low) contains additional bit programmable features.

*Misc Configuration* (DF 0x2a, high)

| b15 | b14 | b13 | b12 | b11 | b10 | b9 | b8 |
|---|---|---|---|---|---|---|---|
| IT | 0 | AFEDET | DS | OT | ECLED | 1 | VOD |

**IT**

The IT bit configures the bq2084-V133 to use its internal temperature sensor. The DF constants 0xb5-0xc0 need to match the required thermistor on internal temperature sensor. See the Data Flash Settings for Internal or External Temperature Sensor Table.

0 bq2084-V133 requires an external thermistor.

1 bq2084-V133 uses its internal temperature sensor.

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**AFEDET**

The AFEDET bit programs the bq2084-V133 to look for errors with $I^2C$ communications and the AFE and enables the detection of the AFE permanent failure if bit 3 of PF Config 0x11f is set.

0 Does not verify AFE communications.

1 Does verify AFE communications.

**DS**

The DS bit programs the bq2084-V133 to enter sleep mode on SMBus inactivity.

0 bq2084-V133 enters sleep mode when the SMBus is low for 2 s.

1 bq2084-V133 does not enter sleep mode.

**OT**

The OT bit programs the bq2084-V133 to turn off the discharge FET when the bq2084-V133 detects an overtemperature condition. Charge FET is always turned off in overtemperature conditions.

0 bq2084-V133 does not turn off the discharge FET on overtemperature.

1 bq2084-V133 turns off the discharge FET on overtemperature.

**ECLED**

The ECLED bit programs the LED activity during charging (DSG bit = 0).

0 The LEDs are not enabled during charging.

1 The LEDs are enabled during charging.

**VOD**

The VOD bit enables a 1-s time delay in the setting of the CVOV and CVUV bits in PackStatus.

0 No delay

1 1-s delay

*Misc Configuration* (DF 0x2b, low)

| b7 | b6 | b5 | b4 | b3 | b2 | b1 | b0 |
|---|---|---|---|---|---|---|---|
| LEDRCA | PFET1 | PFET0 | NR | CHGFET | 0 | 0 | 0 |

**LEDRCA**

The LEDRCA bit programs the LED to blink when there is a RemainingCapacityAlarm.

0 The LEDs blink when there is a RemainingCapacityAlarm.

1 The LEDs are off when there is a RemainingCapacityAlarm.

**PFET1, PFET0**

The PFETx bits define the precharge FET operation. See the bq29312 data sheet for more detail.

0,0 The bq29312 ZVCHG FET is turned on for precharge. Assumes charger has precharge function.

0,1 The charge FET is turned on for precharge. Assumes charger has precharge function.

1,0 The bq29312 OD FET is turned on for precharge. Assumes charger does not have precharge function.

1,1 Not defined, unpredictable operation


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**NR**

The NR bit defines whether the bq2084-V133 is to be used with a nonremovable system battery. If set to indicate a nonremovable system battery there are additional clear conditions for a battery failure due to overcharge, overcurrent, and overload. The additional conditions besides battery removal (defined as the loss system present pin going high) are either detection of an opposite current of that that caused the failure or when *AverageCurrent()* is less than *Clear Fail Current* DF 0x61, 0x62 for a time defined by Fault Reset Time DF 0x130. Also, for a nonremovable battery the charge FET is left on for discharge current failures and the discharge FET is left on for charge current failures.

0 Removable battery, battery fail conditions cleared by battery removal only.

1 Nonremovable system battery.

**CHGFET**

The CHGFET bit programs the charge FET to remain on even after a charge terminate condition.

0 The charge FET is turned off after a charge termination condition.

1 The charge FET is turned on after a charge termination condition.

## Constants and String Data

### Specification Information

*Specification Information* (DF 0x06-0x07) stores the default value for the *SpecificationInfo()* function. It is stored in data flash in the same format as the data returned by the *SpecificationInfo()*.

### Manufacture Date

*Manufacture Date* (DF 0x08-0x09) stores the default value for the *ManufactureDate()* function. It is stored in data flash in the same format as the data returned by the *ManufactureDate()*.

### Serial Number

*Serial Number* (DF 0x0a-0x0b) stores the default value for the *SerialNumber()* function. It is stored in data flash in the same format as the data returned by the *SerialNumber()*.

### Manufacturer Name Data

*Manufacturer Name Length* (DF 0x0e) stores the length of the desired string that is returned by the *ManufacturerName()* function. Locations DF 0x0f-0x19 store the characters for *ManufacturerName()* in ASCII code.

### Device Name Data

*Device Name Length* (DF 0x1a) stores the length of the desired string that is returned by the *DeviceName()* function. Locations DF 0x1b-0x21 store the characters for *DeviceName()* in ASCII code.

### Device Chemistry Data

*Device Chemistry Length* (DF 0x22) stores the length of the desired string that is returned by the *DeviceChemistry()* function. Locations DF 0x23-0x26 store the characters for *DeviceChemistry()* in ASCII code.

### Manufactuters Data Length

*Manufacturers Data Length* (DF 0x27) stores the length of the desired number of bytes that is returned by the *ManufacturersData()* function. It should be set to 9.

## Temperature Limits

The limits described below are extensions to those limits detailed in the safety and charging sections of this data sheet.

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### Charge Suspend Temp Low

*Charge Suspend Temp Low* (DF 0x79) sets the lowest temperature, in degrees C/10, at which normal operation is allowed. If the temperature falls below this limit, the pack goes into a temporary failure state, the charge FET is turned off, and the MAC status is set to system present. It is cleared when the pack warms, or the pack is removed.

### Charge Inhibit Temp Low

*Charge Inhibit Temp Low* (DF 0x46) inhibits charging by setting *ChargingCurrent()* and *ChargingVoltage()* to 0 and turn off the CHG FET. It is programmed in degrees C ÷ 10, and the range of -12.8°C to 12.7°C.

### Charge Inhibit Temp High

*Charge Inhibit Temp High* (DF 0x47-0x48) inhibits charging by setting *ChargingCurrent()* and *ChargingVoltage()* to 0

### Charge Suspend Temp High

*Charge Suspend Temp High* (DF 0x6d-0x6e) sets the highest temperature, in degrees C ÷ 10, at which charging will be allowed to continue. If this temperature is exceeded during charging, the pack goes into a temporary failure state, and the MAC status is set to system present. It is cleared when the pack cools below *OverTemperature Charge Reset*, or ac adapter is removed, or the pack is removed. Charging can only resume when the temperature returns to within the charge start temperature limits.

### Charge Suspend Temp High Reset

*Charge Suspend Temp High Reset* (DF 0x6f-0x70) sets the temperature, in degrees C/10, at which the pack recovers from Charge Suspend Temp High fault.

### Over Temperature Discharge

*Over Temperature Discharge* (DF 0x71-0x72) sets the highest temperature, in degrees C/10, at which discharging will be allowed. If the pack exceeds this temperature, charge and discharge FETs are turned off, and MAC status is set to system present. The pack returns to normal operation when the temperature falls below *Over Temperature Discharge Reset*, or if the pack is removed.

### Over Temperature Discharge Reset

*Over Temperature Discharge Reset* (DF 0x73-0x74) sets the temperature, in degrees C/10, at which the pack will recover from Over Temperature Discharge Over temperature will also reset when the pack is removed from the system if not in the non-removable mode.

## Failure Detection Thresholds

### Safety OverTemperature Charge

*Safety OverTemperature Charge* (DF 0x75-0x76) sets the temperature, in degrees C/10, above which, during charging, the pack enters permanent failure, if the *XSOTC* bit in *Permanent Failure Configuration* is set.

### Safety OverTemperature Discharge

*Safety OverTemperature Discharge* (DF 0x77-0x78) sets the temperature, in degrees C/10, above which, during discharging, the pack enters permanent failure, if the *XSOTD* bit in *Permanent Failure Configuration* is set.

### Charge Detection Current

*Charge Detection Current* (DF 0x113-0x114) sets the threshold in milliamperes for detecting charge current. This is a signed value and is positive. This threshold is used for detecting cross-conduction, and ensuring that charge termination is not improperly detected due to loss of charging current.


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### Discharge Detection Current

*Discharge Detection Current* (DF 0x115-0x116) sets the threshold in milliamperes for detecting discharge current. This is a signed value and is negative. This threshold is used for detecting cross-conduction and determining that the charge FET should be turned on during discharge to reduce IR losses.

### FET Fail Charge Current

*FET Fail Charge Current* (DF 0x125-0x126) sets the threshold in milliamperes for detecting current in a charge FET which is turned off. This is a signed value and is positive.

### FET Fail Discharge Current

*FET Fail Discharge Current* (DF 0x127-0x128) sets the threshold in milliamperes for detecting current in a discharge FET which is turned off. This is a signed value and is negative.

### FET Fail Time

*FET Fail Time* (DF 0x129) sets the time in seconds that current must be detected in a FET which is turned off, in order to determine that the FET has failed.

### Terminate Voltage

*Terminate Voltage* (DF 0x67-0x68) sets the threshold below which the *Terminate Discharge Alarm* bit is set. The alarm is cleared when the voltage rises above this threshold, if the *CVUV* bit in *Pack Status* is not set.

## Offsets and Limits

### Temperature offset

*Temperature offset* (DF 0xd6) contains a signed offset for the pack's temperature measurements, in degrees C/10. It is set at board test during pack calibration.

### Board offset

*Board offset* (DF 0xd7), contains a signed offset for the pack's coulomb counter measurements. If used, it is set at board design time.

### Current Deadband

*Current Deadband* (DF 0x7b), sets the threshold in mA below which a current measurement is not detected.

### Shutdown Voltage

*Shutdown Voltage* (DF 0x7c-0x7d) sets the pack voltage below which the pack's electronics, including the bq2084-V133, is shut down to conserve power. All FETs are turned off by the AFE.

# APPLICATION INFORMATION

Figure 7 shows a typical bq2084-V133-based battery pack application. The circuit consists of the bq29312 AFE IC, bq29400 second-level protection IC, LED, temperature measurement network, data flash connections, serial port, and the sense resistor. The data flash stores basic battery pack configuration information and measurement calibration values. The data flash must be programmed properly for bq2084-V133 operation.

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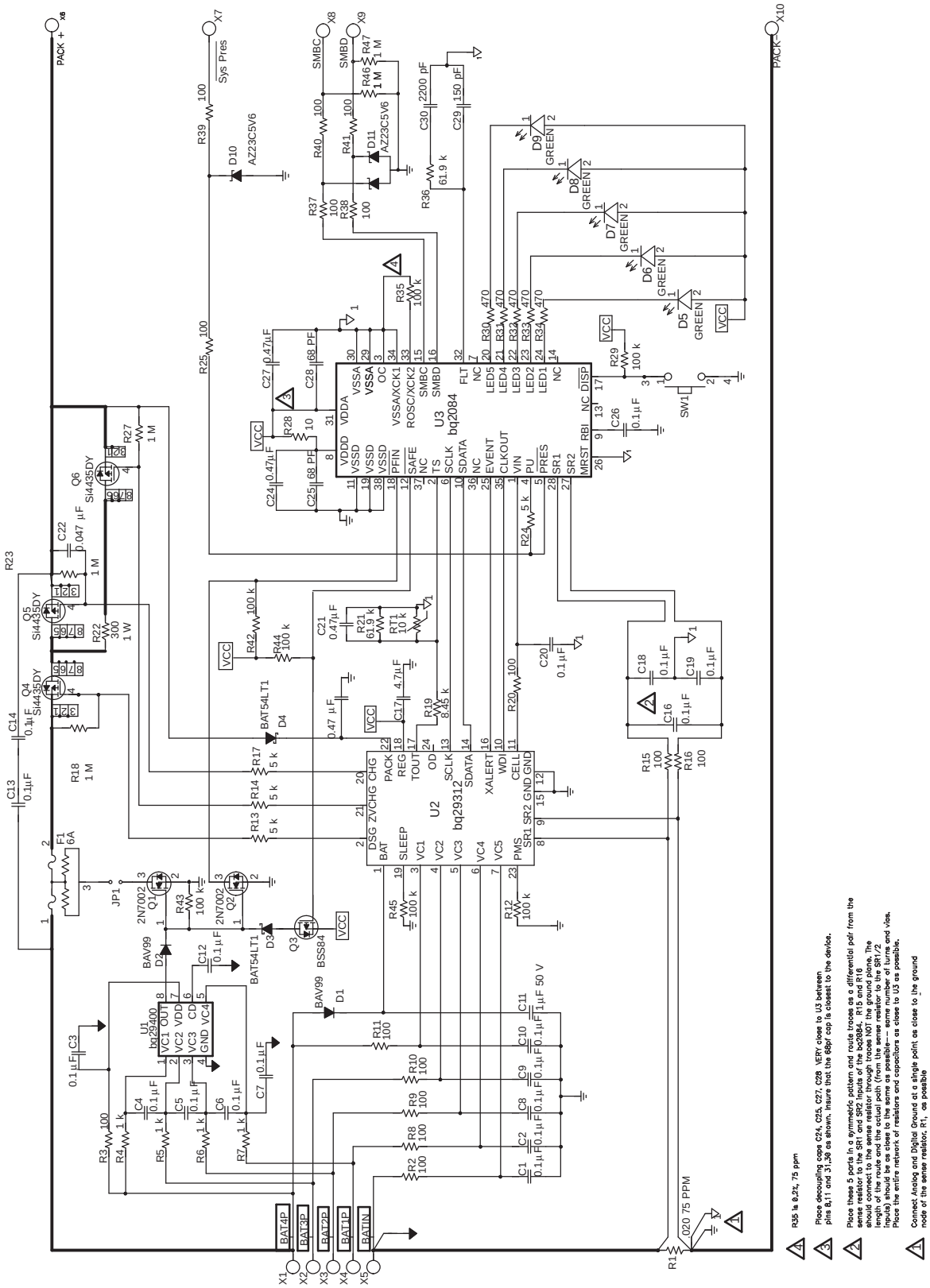



**Figure 7. bq2084-V133 Based Battery Pack Schematic**


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## REVISION HISTORY

**Changes from Revision A (June 2005) to Revision B** **Page**

- Changed Table 10 CVOV entry From: $VCELL_{(ANY)}$ = *Cell Over Voltage* To: $VCELL_{(ANY)}$ ≥ *Cell Over Voltage* ..... 20
- Changed Table 10 CVUV entry From: $VCELL_{(ANY)}$ = *Cell Under Voltage* To: $VCELL_{(ANY)}$ ≤ *Cell Under Voltage* ..... 20
- Changed Table 10 Note 2 From: On if there is a discharge current ≥ 150mA To: On if there is a discharge current ≥ Discharge Detection Current ..... 20
- Changed Table 10 Note 3 From: On if there is a charge current ≥ Charge Detection Current ≥ 50mA To: On if there is a charge current ≥ Charge Detection Current ≥ Charge Detection Current ..... 20
- Changed 1st Level Cell Voltage Thresholds section. ..... 20
- Changed Overcurrent Thresholds section ..... 20

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## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish | MSL Peak Temp (3) | Op Temp (°C) | Top-Side Markings (4) | Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BQ2084DBT-V133 | NRND | TSSOP | DBT | 38 | 50 | Green (RoHS & no Sb/Br) | Call TI | Level-2-260C-1 YEAR | -20 to 85 | 2084DBT | |
| BQ2084DBT-V133G4 | NRND | TSSOP | DBT | 38 | 50 | Green (RoHS & no Sb/Br) | Call TI | Level-2-260C-1 YEAR | -20 to 85 | 2084DBT | |
| BQ2084DBTR-V133 | NRND | TSSOP | DBT | 38 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -20 to 85 | 2084DBT | |
| BQ2084DBTR-V133G4 | NRND | TSSOP | DBT | 38 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | -20 to 85 | 2084DBT | |

(1) The marketing status values are defined as follows:
**ACTIVE:** Product device recommended for new designs.
**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.
**OBSOLETE:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
**TBD:** The Pb-Free/Green conversion plan has not been defined.
**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

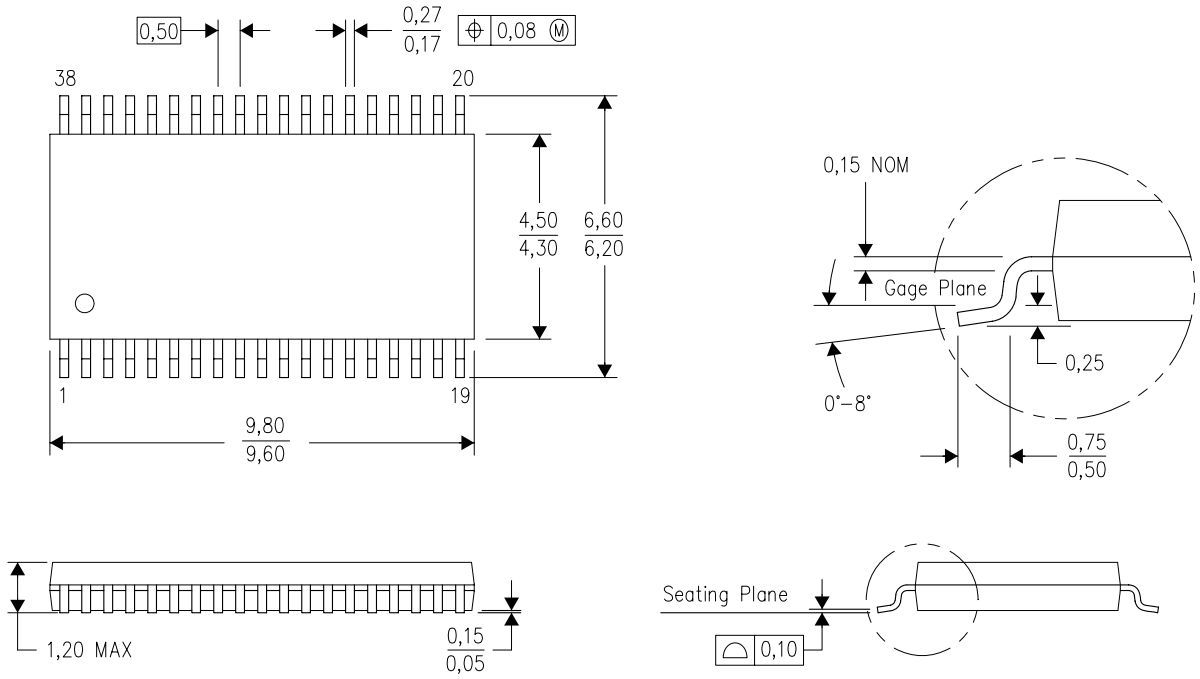
(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) Multiple Top-Side Markings will be inside parentheses. Only one Top-Side Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Top-Side Marking for that device.

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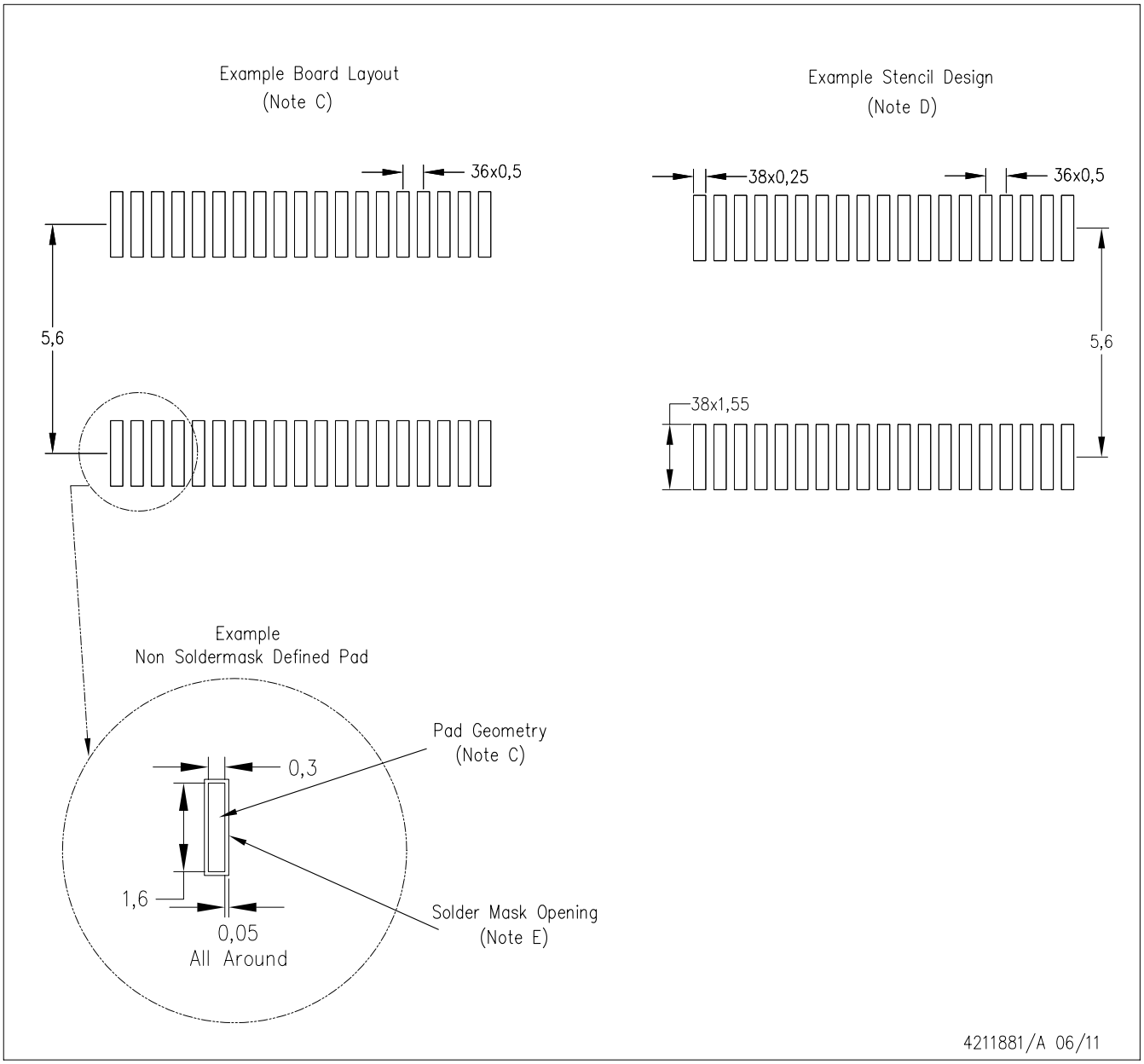
DBT (R–PDSO–G38) PLASTIC SMALL OUTLINE




4073252-6/I 03/11

NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion.
D. Falls within JEDEC MO–153.

## DBT (R–PDSO–G38) PLASTIC SMALL OUTLINE




NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC–7525.
E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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