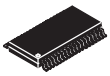


SBS v1.1-COMPLIANT GAS GAUGE FOR USE WITH THE bq29312

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 Removes Need for External Crystal with 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-A8 108.17 490.4 Tm /F6 1f (Battery)Tjy**

DESCRIPTION

The bq2084-V140 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-V140 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-V140, the host controller can manage remaining battery power to extend the system run time as much as possible.

The bq2084-V140 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-V140 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-V140 to generate the control signals necessary to implement the cell balancing and the required safety protection for Li-ion and Li-polymer battery chemistries.

APPLICATIONS

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-V140 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-V140 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-V140 from a 2-, 3-, or 4-series Li-ion cell stack, eliminating the need for an external regulator circuit.

ORDERING INFORMATION

T_A	PACKAGE(1)	
	38-PIN TSSOP (DBT)(2)	36-PIN QFN (RTT)(3)
–20°C to 85°C	bq2084DBT-V140	bq2084RTT-V140

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI Web site at www.ti.com.
(2) The bq2084DBT-V140 is available in tape and reel. Add an R suffix to the device type (e.g., bq2084DBTR-V140) to order tape and reel version.
(3) The bq2084RTT-V140 is available in tape and reel only. Add an T suffix to the device type (e.g., bq2084RTTT-V140) to order mini 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

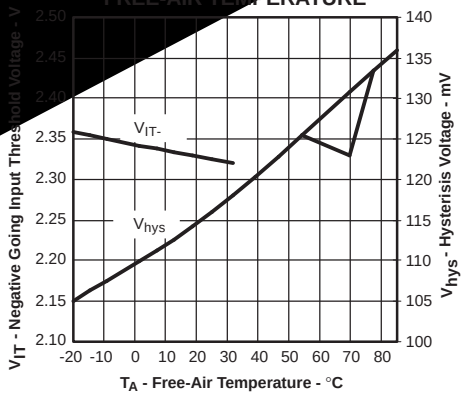
(1) Stresses beyond those listed under *absolute maximum ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *recommended operating conditions* is not implied. Exposure to 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 $V_{(SSP)}$.

ELECTRICAL CHARACTERISTICS

V_{DD} = 3 V to 3.6 V, T_A = –20°C to 85°C unless otherwise noted

PARAMETER		TEST CONDITIONS		MAX	UNIT
V_{DD}	Supply voltage	VDDA and VDDD		3.6	V
I_{DD}	Operating mode current	No flash programming or LEDs active			µA
$I_{(SLP)}$	Low-power storage mode current	Sleep mode			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, $\overline{PRES}$, $\overline{PFIN}$			0.8	V
	DISP			0.8	
V_{IH}	Input voltage high SMBC, SMBD, SDATA, SCLK, EVENT, PU, $\overline{PRES}$, $\overline{PFIN}$			6	V
	DISP			V_{DD} + 0.3	
V					

POWER ON RESET BEHAVIOR
vs
FREE-AIR TEMPERATURE



INTEGRATING ADC CHARACTERISTICS

PLL SWITCHING CHARACTERISTICS

OSCILLATOR

V_{DD} = 3 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 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 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

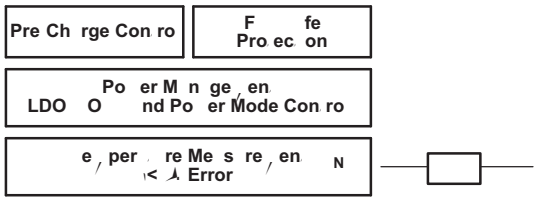
V_{DD} = 3 V to 3.6 V, T_A = -20°C to 85°C unless otherwise noted

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			µs
$t_{(SU:STA)}$	Repeated start setup time		4.7			µs
$t_{(SU:STO)}$	Stop setup time		4			µs
$t_{(HD:DAT)}$	Data hold time	Receive mode	0			ns
		Transmit mode	300			
$t_{SU:DAT)}$	Data					

(SU:STO)697.2 620 1 105.1 545 Tm /F4 -8 TLOW-8 TL (Bus)Tj 19 1 13611Tm 1 564.8 Tm /F4 611Tm 1 0 0 1 61. Tm /F4C1 287.5 492.2 Tm 27 g ET1j 1 0 0 1 406.3719 492.2 Tm /F Tf (ET1j 1 0 0 1

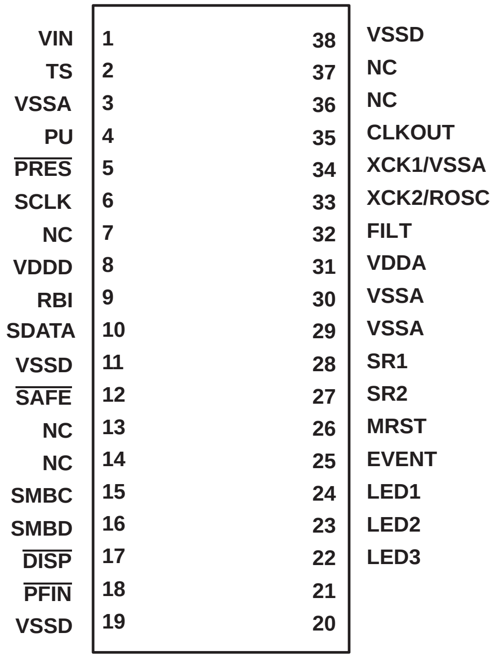
SMBus TIMING DIAGRAMS

SYSTEM DIAGRAM

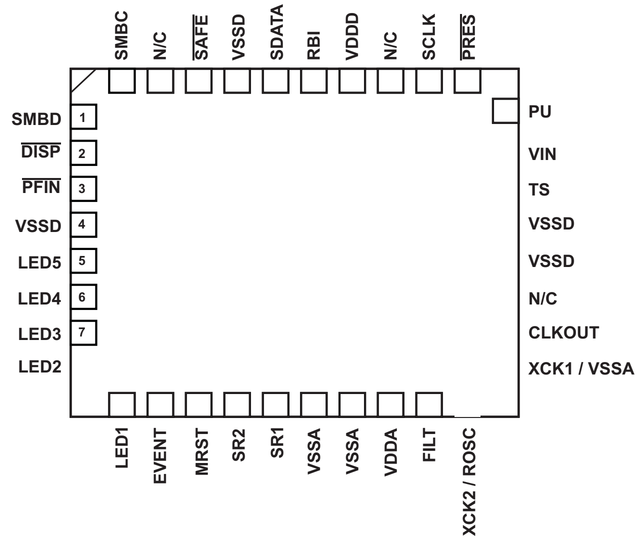


PIN ASSIGNMENTS

TSSOP (DBT)
(TOP VIEW)



QFN (RTT)
(TOP VIEW)



Terminal Functions (continued)

TERMINAL			I/O	DESCRIPTION
NAME	NO. TSSOP	NO. QFN		
SMBD	16	1	I/O	SMBus data open-drain bidirectional pin used to transfer address and data to and from the bq2084-V140
SR1	28	13	I	Connections for a small-value sense resistor to monitor the battery charge- and discharge-current flow
SR2	27	12	I	
TS	2	27	I	Thermistor voltage input connection to monitor temperature
VCCA	31	16	I	Positive supply for analog circuitry
VCCD	8	30	I	Positive supply for digital circuitry and I/O pins
VCELL	7	25	I	Single-cell voltage input from the bq29312
VSSA	29, 30	14, 15	I	Negative supply for analog circuitry
VSSD	11, 19, 38	4, 22, 23, 33	I	Negative supply for digital circuitry
XCK1/VSSA	34	19	I	32.768-kHz crystal oscillator input pin or connected to VSSA if the internal oscillator is used
XCK2/ROSC	33	18	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 oscillator of the bq2084-V140 can be set up for an internal or external operation. As the bq2084-V140 powers up it automatically attempts to start the internal oscillator, but if a 100-kΩ resistor is not connected to ROSC (pin 33), then it attempts to start the oscillator using an external

SYSTEM PRESENT OPERATION

GENERAL OPERATION

FUNCTIONAL DESCRIPTION (continued)

The bq2084-V140 interfaces with the bq29312 to perform battery protection, cell balancing, and voltage translation functions. The bq2084-V140 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-V140 uses temperature to monitor the battery pack and to compensate the self-discharge estimate.

MEASUREMENTS

The bq2084-V140 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 0.25μV. The bq2084-V140 detects charge activity when VSR = V(SR1)-V(SR2) is positive and discharge activity when VSR = V(SR1)-V(SR2) is negative. The bq2084-V140 continuously integrates the signal over time, using an internal counter. The fundamental rate of the counter is 0.65 nVh. The bq2084-V140 updates *RemainingCapacity()* with the charge or discharge accumulated in this internal counter once every second.

OFFSET CALIBRATION

The bq2084-V140 provides an auto-calibration feature to cancel the voltage offset error across SR1 and SR2 for maximum charge measurement accuracy. The bq2084-V140 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-V140 is capable of automatic offset calibration down to <1 μV.

DIGITAL FILTER

The bq2084-V140 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-V140 monitors the individual series cell voltages through the bq29312. The bq2084-V140 configures the bq29312 to present the selected cell to the CELL pin of the bq29312, which should be connected to VIN of the bq2084-V140. The internal ADC of the bq2084-V140 then measures the voltage and scales it appropriately. The bq2084-V140 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-V140 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-V140 along with an NTC thermistor measures the battery temperature as shown in the schematic. The bq2084-V140 reports temperature via the SBS command *Temperature()*.

The bq2084-V140 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.

FUNCTIONAL DESCRIPTION (continued)

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

LABEL	LOCATION	INTERNAL TEMP SENSOR SETTING	EXTERNAL TEMP SENSOR SETTING (Samsung L03AT)
	Dec (Hex)	Dec (Hex)	Dec (Hex)
Misc. Config	45 (0x2d)	Bit 7 = 1	Bit 7 = 0
TS Const1 A3	1641\2 (0xd2\8)	0 (0x0000)	−28282 (0x9E88)
TS Const1 A2	1661\7 (0xd\8)	0 (0x0000)	20804 (0x5104)
TS Const1 A1	1681\9 (0xd\a)	−11136 (0xd480)	−12717 (0xce8f)
TS Const1 A0	1701\1 (0xdd\c)	25234 (0x6222)	4015 (0x0faf)
Min Temp AD	1723\3 (0xd\e)	0 (0x0000)	0 (0x0000)
Max Temp	1741\2 (0xd\c0)	25234 (0x6222)	4015 (0x0faf)

The operational overview in Figure 1 illustrates the gas gauge operation of the pd5084-ALA0. Table 3 describes the pd5084-ALA0 registers.

Figure 1. pd5084-ALA0

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-V140 updates FCC after the battery undergoes a qualified discharge from nearly full to a low battery level. FCC is accessible through the SMBus interface.

The Discharge Count Register (DCR) is a non-accessible register that tracks discharge of the battery. The bq2084-V140 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-V140 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-V140 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-V140 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 *10 1 243.59 250.2 Tm 22.2 Tm /F2 -10 Tf (1052 Tm*

Capacity Learning (FCC Update) and Qualified Discharge

End-of-Discharge Thresholds and Capacity Correction

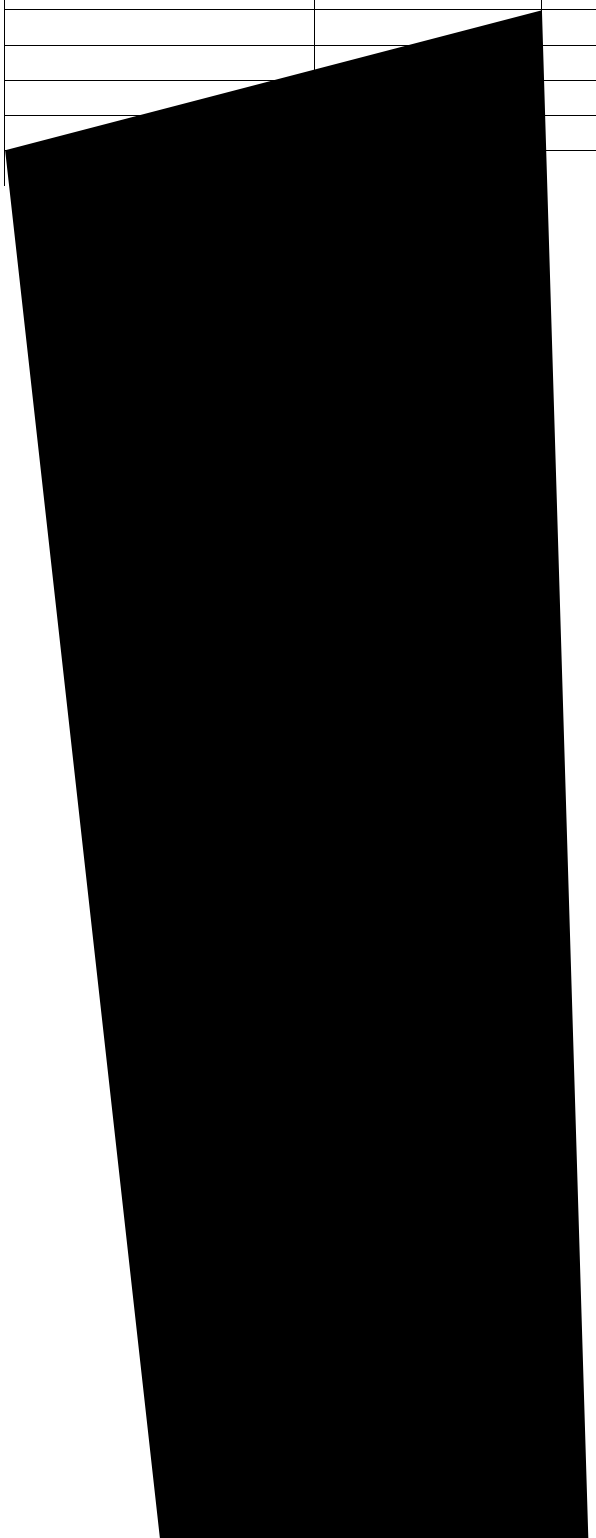
EDV Thresholds and Near-Full Programming

The bq2084-V140 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* in DF 0x30, 0x31 in mAh.

EDV Discharge Rate and Temperature Compensation Programming

If EDV compensation is enabled, the bq2084-V140 calculates battery voltage to determine EDV0, EDV1, and EDV2 thresholds as a function of battery capacity, temperature, and discharge load. The general equation for EDV0, EDV1, and EDV2 calculation is

as EDV0,1,2 = n (EMF $\times$ FBL – | ILOAD | $\times$ R0



Self-Discharge

The bq2084-V140 estimates the self-discharge of the battery to maintain an accurate measure of the battery capacity during periods of inactivity. The bq2084-V140 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	½ Y% per day
20 ≤ Temp <30	Y% per day
30 ≤ Temp <40	2Y% per day
40 ≤ Temp <50	4Y% per day
50 ≤ Temp <60	8Y% per day
60 ≤ Temp <70	16Y% per day
70 ≤ Temp	32Y% per day

The nominal self-discharge rate, %PERDAY (% per day), is programmed in an 8-bit value *Self-Discharge Rate* DF 0x2d by the following relation:

Self-Discharge Rate = %PERDAY/ 0.01

Battery Electronic Load Compensation

The bq2084-V140 can be configured to compensate for a constant load (as from battery electronics) present in the battery pack at all times. The bq2084-V140 applies the compensation continuously when the charge or discharge is below the digital filter. The bq2084-V140 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-V140 applies midrange capacity corrections when the VCOR bit is set in *Gauge Configuration* DF 0x29. The bq2084-V140 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-V140 makes midrange corrections as shown in Table 5. For a correction to occur, the bq2084-V140 must detect the need for correction twice during subsequent 20-s intervals. With the VCOR bit set, the bq2084-V140 makes midrange corrections whenever conditions permit.

If the OTVC bit in *Gauge Configuration* DF 0x29 is set and VCOR = 0, the bq2084-V140 makes two Voltage() measurements, determines the average of the two readings and sets the appropriate RM

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-V140 internal charge control is compatible with the constant current/constant voltage profile for Li-ion. The bq2084-V140 detects primary charge termination on the basis of the tapering charge current during the constant-voltage phase.

Charging Voltage Broadcasts

The bq2084-V140 supports SBS charge control by broadcasting the *ChargingCurrent()* and *ChargingVoltage()* to the Smart Charger address. The bq2084-V140 broadcasts the requests every 10 seconds. The bq2084-V140 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-V140 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* (0x42-0x43) or 0 depending on charge state and operating conditions.

When fast charge is allowed, the bq2084-V140 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-V140 sets *ChargingCurrent()* to zero and then to the *MaintenanceCharging Current* DF 40 0x41 when the termination condition ceases. The desired maintenance current is stored in mA.

When *Voltage()* is less than EDV0, the bq2084-V140 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-V140 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-V140 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.

Alarm Broadcasts to Smart Charger and Host

If any of the bits 8-15 in *BatteryStatus()* are set, the bq2084-V140 broadcasts an *AlarmWarning()* message to the Host address. If any of the bits 12-15 in *BatteryStatus()* are set, the bq2084-V140 also sends an *AlarmWarning()* message to the Smart Charger address. The bq2084-V140 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-V140 sets ChargingCurrent() to the precharge rate as programmed in *Precharge Current* DF 0x42-0x43 under the following conditions:

- Voltage: The bq2084-V140 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-V140 requests the precharge rate when Temperature() is between *Charge Inhibit Temp Low* (DF0x46) and the precharge threshold programmed in *Precharge Temp* 0x44. *Temperature( )* must be equal to or greater than the precharge threshold + 3°C to allow the fast-charge rate.

Charge Suspension

The bq2084-V140 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-V140 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-V140 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-V140 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* in DF 0x79 or *Charge Inhibit Temp Low* in DF 0x46. On detecting an undertemperature condition the bq2084-V140 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* in 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* in DF 0x63-0x64 or if *Voltage()* is greater than *Charging Voltage* in 0x3a-0x3b plus *OvervoltageMargin* in 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 condition must be cleared by *Voltage()* less than *Charging Voltage* in 0x3a-0x3b plus *OvervoltageMargin* in 0x5d-05e and all cell voltages less than *Cell Over Voltage Reset* in DF 0xe0-0xe1.
- Charging is also temporarily suspended during pulse-charging, but this is not considered a fault condition.

Pulse Charge

The bq2084-V140 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

voltage used for comparison

Primary Charge Termination

Cell Balancing

Activation

Display Modes

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-V140 with the XALERT output whenever a protection threshold is breached and its associated delay time has expired. The bq2084-V140 then determines if and when the FETs should be turned back on.

Table

Protection Configuration

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-V140 is not sealed as indicated by bit 5 of PackStatus.

–53 (AFE)Tj 1 0 0 1 16 Table 11. Overcurrent Protection) 1 0 0 1 97.05 113.6rity)Tj 1 0 0 1 122.05 513.6 Tm /F11 -10 6rity

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 discharge current > discharge detection current (DF 0x115/6)
AFE SCD 82 6rity	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

The AFE protection features can also recover automatically after *AFE Recovery Time* (DF 0x160) if the AFE Recovery Time is set to a nonzero value. When the protection feature is recovered in this manner, it does not re-trigger for *AFE Hold Off Time* (DF 0x161).

AFE Integrity Check

The bq2084-V140 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-V140 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-V140 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*

The bq2084-V140 can also activate the $\overline{\text{SAFE}}$ output and set the PF Flag based on the $\overline{\text{PFIN}}$ input. If this pin is low for *PFIN Time* seconds ±1 s, then the $\overline{\text{PFIN}}$ bit in PF Status is set.

The $\overline{\text{SAFE}}$ output can be driven low in any of the following conditions, and the bq2084-V140 sets the *PF Flag* register (DF 0x11e) to 0x66 (011001100). The activation of the $\overline{\text{SAFE}}$ 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 $\overline{\text{SAFE}}$ output and PF Flag register can only be cleared using a series of ManufacturerAccess() commands.

Table 12. $\overline{\text{SAFE}}$ 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 $\overline{\text{PFIN}}$ input has detected a low state for *PFIN Time* in consecutive seconds, as determined by DF 0x120	$\overline{\text{PFIN}}$, PF set

(1) $\overline{\text{SAFE}}$ 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 $\overline{\text{SAFE}}$ output to activate.

0 SOV fault not detected (default)

1 SOV fault detected

SOTC

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 2nd level protector has activated.

0 The PFIN input is high (default)

1 The PFIN input drive and held low by 2nd 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)

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-V140 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.

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

Low-Power Modes

The bq2084-V140 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-V140 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-V140 wakes up at a period set by *Sleep Current Multiplier* DF 0xfd multiplied by *Sleep Time* to measure current. The bq2084-V140 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-V140 is in Non-Removable mode where NR=1, then the discharge FET retains its state on entry to sleep.

Shutdown Mode

The bq2084-V140 goes into shutdown, in which all FETs are turned off and the pack electronics are powered down (including the bq2084-V140), 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-V140 can also be instructed to enter Shutdown mode via the *ManufacturerAccess()* command. When the command is sent to the bq2084-V140, the bq29312 is instructed to enter shutdown mode by the bq2084-V140. This forces the chipset into its lowest power mode. The bq2084-V140 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.

After exiting shutdown mode, the bq2084-V140 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-V140 to enter shutdown mode.

Figure 3. Shutdown Flow Chart in Normal Operation

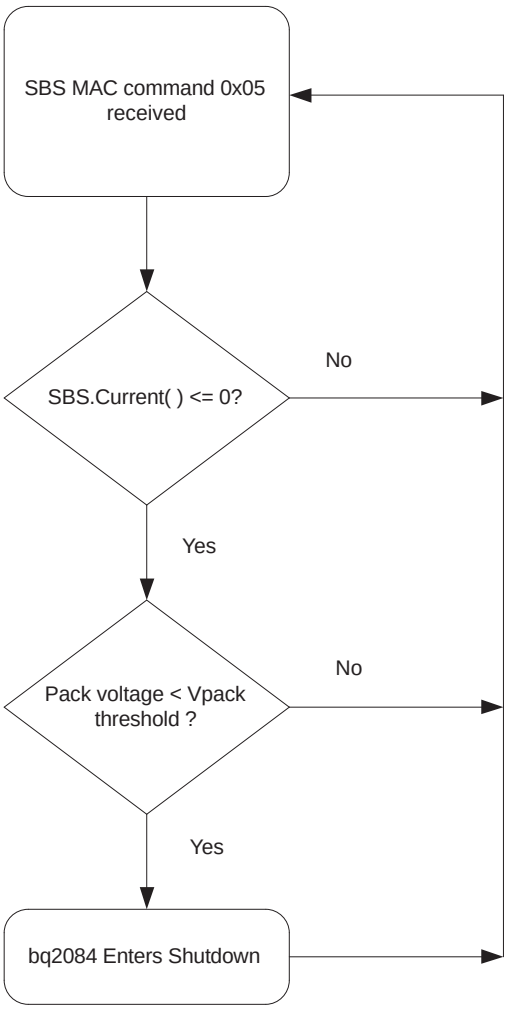


Figure 4. Shutdown Flow Chart in SBS MAC

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-V140 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-V140 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-V140. In this way a system can efficiently monitor and manage the battery.

SMBus

The SMBus interface is a command-based protocol. A processor acting as the bus master initiates communication to the bq2084-V140 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-V140 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-V140 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-V140 acts as the bus master. This occurs when the bq2084-V140 broadcasts charging requirements and alarm conditions to device addresses 0x12 (SBS Smart Charger) and 0x10 (SBS Host Controller.)

SMBus Protocol

The bq2084-V140 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-V140. The bq2084-V140 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-V140 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-V140 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-V140 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-V140 compares the value to its calculation. If the PEC is correct, the bq2084-V140 responds with an ACKNOWLEDGE (ACK). If it is not correct, the bq2084-V140 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-V140. The bq2084-V140 then sends the PEC and the host acting as a master-receiver generates a NACK and a stop condition.

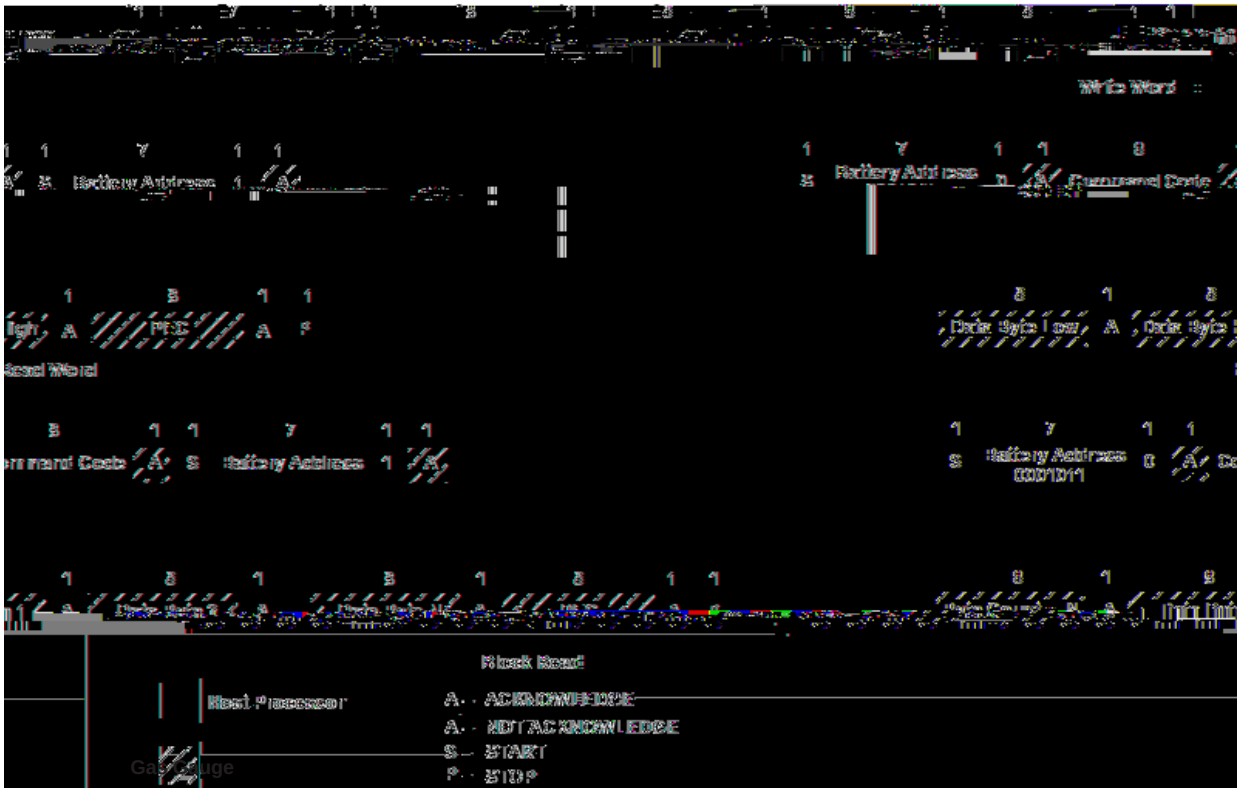


Figure 5. SMBus Communication Protocol

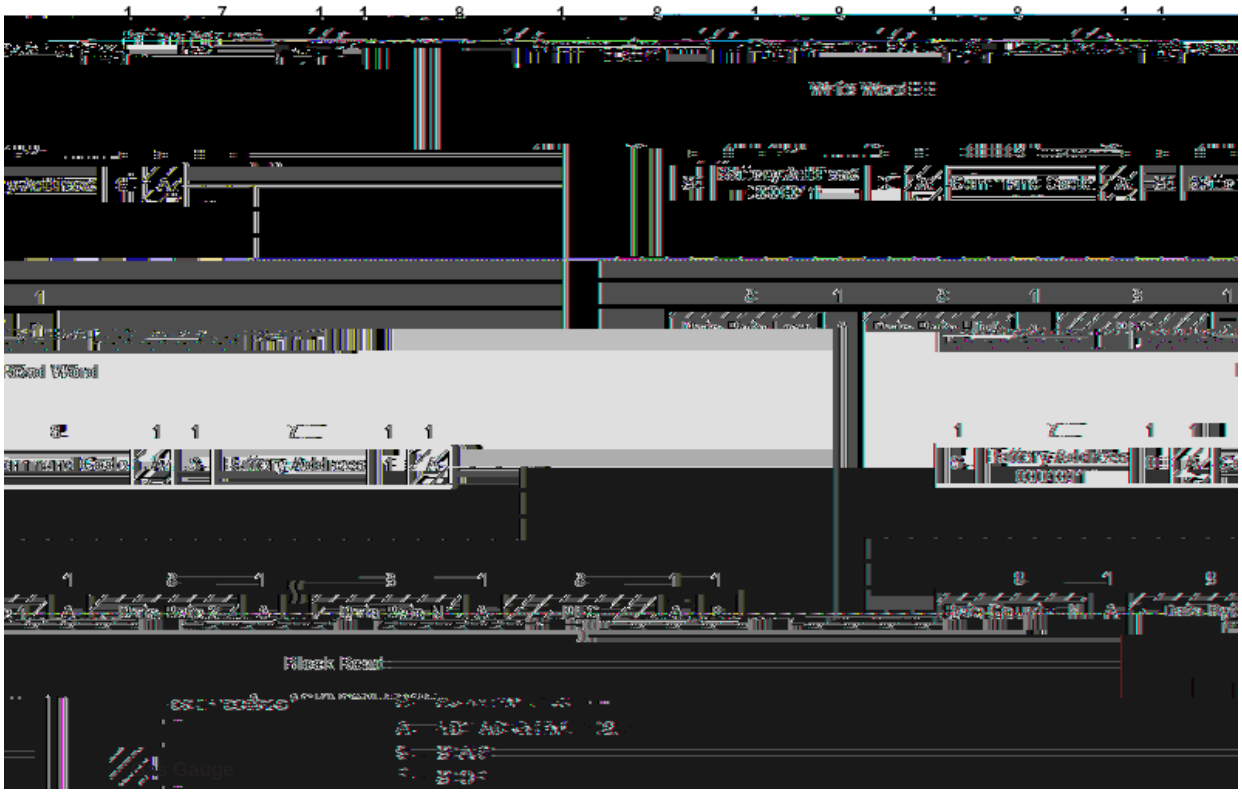


Figure 6. SMBus Communication Protocol With PEC

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-V140. This includes the host following the read word protocol. The bq2084-V140 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-V140 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-V140 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-V140 detects the Off State. When the SMBC and SMBD lines go high, the bq2084-V140 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.

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-V140 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-V140 to instruct the bq29312 to enter ship mode
0x062b	Seal	Instructs the bq2084-V140 to restrict access to those functions listed in Table 3. The bq2084-V140 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

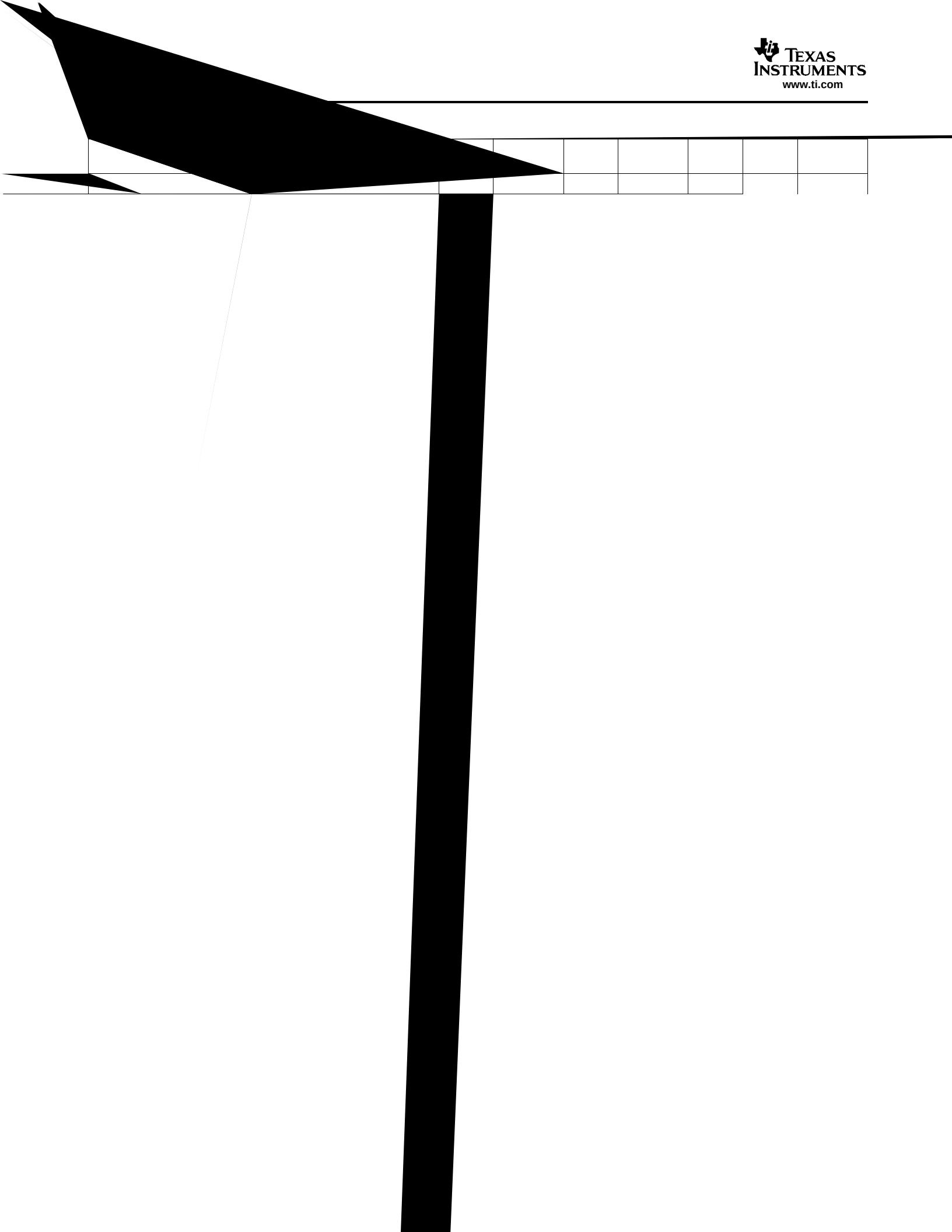
STATE3, STATE2, STATE1, STATE0

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

Purpose: The ManufacturerAccess() function provides the system host access to bq2084-V140 functions that are not defined by the SBD.

SMBus protocol: Read or write word

Input/Output: Word



RemainingTimeAlarm() (0x02)

Description: Sets or gets the *Remaining Time Alarm* value. Whenever the *AverageTimeToEmpty()* falls below the remaining time value, the bq2084-V140 sends *AlarmWarning()* messages to the SMBus host with the

BatteryMode() (0x03)

PRIMARY_BATTERY bit is not used by the bq2084-V140. The bq2084-V140 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-V140s ability to master the SMBus and send *AlarmWarning()* messages to the SMBus host and the smart battery charger. When set, the bq2084-V140 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 60s and no less than 59s. 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-V140 resets the bit and starts or restarts a 60-s (nominal) timer. After the timer expires, the bq2084-V140 automatically enables alarm broadcasts to ensure that the accidental deactivation of broadcasts does not persist. An SMBus host that does not want the bq2084-V140 to be a master on the SMBus must therefore continually set this bit at least once per 59 s to keep the bq2084-V140 from broadcasting alarms.
- The *ALARM_MODE* bit defaults to a cleared state when the bq2084-V140 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-V140's transmission of *ChargingCurrent()* and *ChargingVoltage()* messages to the smart battery charger. When set, the bq2084-V140 does *not* transmit *ChargingCurrent()* and *ChargingVoltage()* values to the smart battery charger. When cleared, the bq2084-V140 transmits the *ChargingCurrent()* and *ChargingVoltage()* values to the smart battery charger. The *CHARGER_MODE* bit defaults to a cleared state when the bq2084-V140 enters SLEEP mode.

CAPACITY_MODE bit indicates if capacity information is reported in mA/mAh or 10 mW/10 mWh. When set, the bq2084-V140 reports capacity information in 10 mW/10 mWh as appropriate. When cleared, the bq2084-V140 reports capacity information in mA/mAh as appropriate. The CAPACITY_MODE bit defaults to a cleared state when the bq2084-V140 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()*

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-V140 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-V140 (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).

AtRateTimeToFull() (0x05)

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-V140 updates *AtRateTimeToEmpty()* within 5 ms after the SMBus host sets the *AtRate()* value. The bq2084-V140 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-V140 updates *AtRateOK()* within 5 ms after the SMBus host sets the *AtRate()* value. The bq2084-V140 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-V140.

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

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

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-V140 sets *MaxError()* to 100% on a full reset. The bq2084-V140 sets *MaxError()* to 2% on completion of a learning cycle, unless the bq2084-V140 limits the learning cycle to the +512/-256 mAh maximum adjustment values. If the learning cycle is limited, the bq2084-V140 sets MaxError() to 8% unless *MaxError()* was already below 8%. In this case, *MaxError()* does not change. The bq2084-V140 increments *MaxError( )* by 1% after four fouraftercharge

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.

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.

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-V140 to dynamically control the charging profile (current/voltage) of the battery. The bq2084-V140 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.

ChargingVoltage() (0x15)

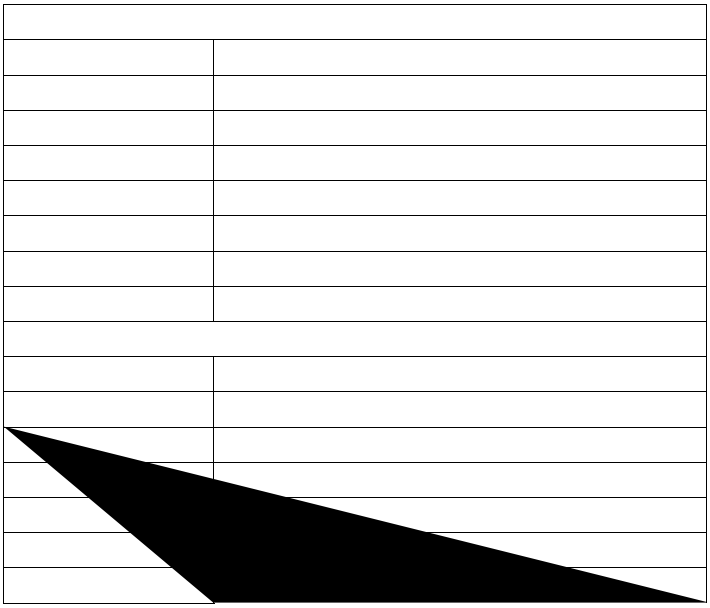
Description: Returns the desired charging voltage in mV.

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-V140 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.

BatteryStatus() (0x16)



STATUS BITS

ERROR CODES

DesignCapacity() (0x18)

DesignVoltage() (0x19)

SpecificationInfo() (0x1a)

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)

cription: This function returns the date the cell pack was manufactured in a packed integer. The date is d in the following fashion: (year-1980) * 512 + month * 32 + day. The bq2084-V140 sets *ureDate()* to the value programmed in *Manufacture Date* DF 0x08-0x09.

e *ManufactureDate()* provides the system with information that can be used to uniquely identify a y pack when used along with *SerialNumber()*.

Read word

ger-packed date of manufacture:

	BITS USED	FORMAT	ALLOWABLE VALUES
	0...4	5-bit5-1(Da0 11t)Tj	1 0 0 1 2(year-1980)

ManufacturerNam

DeviceName() (0x21)

DeviceChemistry() (0x22)

The ManufacturerData() (0x23)

Pack Status and Pack Configuration (0x2f)

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-V140.

0 The bq2084-V140 is in the unsealed state.

1 The bq2084-V140 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-V140 *PF Flag* has been set. It is cleared only when the *PF Flag* has been cleared.

0 bq2084-V140 *PF Flag* = 0x00

1 bq2084-V140 *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. If NVCELL is set in *Misc Configuration 2* then the SMBus commands are changed to 0x38-0x3b). The alternative commands are NACK'ed when not selected.

DATA FLASH

General

The bq2084-V140 accesses the internal data flash during reset and when storing historical data. The data flash stores basic configuration information for use by the bq2084-V140. The data flash must be programmed correctly for proper bq2084-V140 operation.

Memory Map

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°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

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** (2)	49701	c2	25
0xd4		*DSC Offset** (2)	38		26
0xd5		*ADC Offset** (2)	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

(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.
(2) 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.

ADDITIONAL PROGRAMMING INFORMATION

ADDITIONAL DATA FLASH PROGRAMMING

Fundamental Parameters

Sense Resistor Value

CELL AND PACK CHARACTERISTICS

Battery Pack Capacity and Voltage

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 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-V140 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

features1f6.2 Tm /F6 -8 Tf (b4)Tj 10.7399 150.3oonfiguration

CC1–CC0

The CC bits configure the bq2084-V140 for the number of series cells in the battery pack.

1-1 Configures the bq2084-V140 for four series cells

1-0 Configures the bq2084-V140 for three series cells

0-1 Configures the bq2084-V140 for two series cells

Gauge Configuration

Gauge Configuration DF 0x29 contains bit-programmable features:

b7	b6	b5	b4	b3	b2	b1	b0
FEDV0	CSYNC	SC	CEDV	EDVV	OVSEL	VCOR	OTVC

FEDV0

When this bit is set, the EDV0 voltage is fixed while the EDV1 and EDV2 are left as compensated values if
fixed CEDV is also set. When this bit is set, the compensated values of EDV1 and EDV2 are limited from going below EDV0.

0 EDV0 acted upon per CEDV bit setting

1 EDV0 fixed regardless of CEDV setting

CSYNC

In usual operation of the bq2084-V140, the CSYNC bit is set so that the coulomb counter is adjusted when a
fixed 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-V140 does not alter RM at the time of a valid charge termination.

1 The bq2084-V140 updates RM with a programmed percentage of FCC at a valid charger termination.

SC

The SC bit enable212.4 l 557.9 256 4 -10 56 Tm /F4 -10 T5 Tm /F4 -10 Tf 556 4 -10 56 Tm /F4 -11.t

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-V140 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

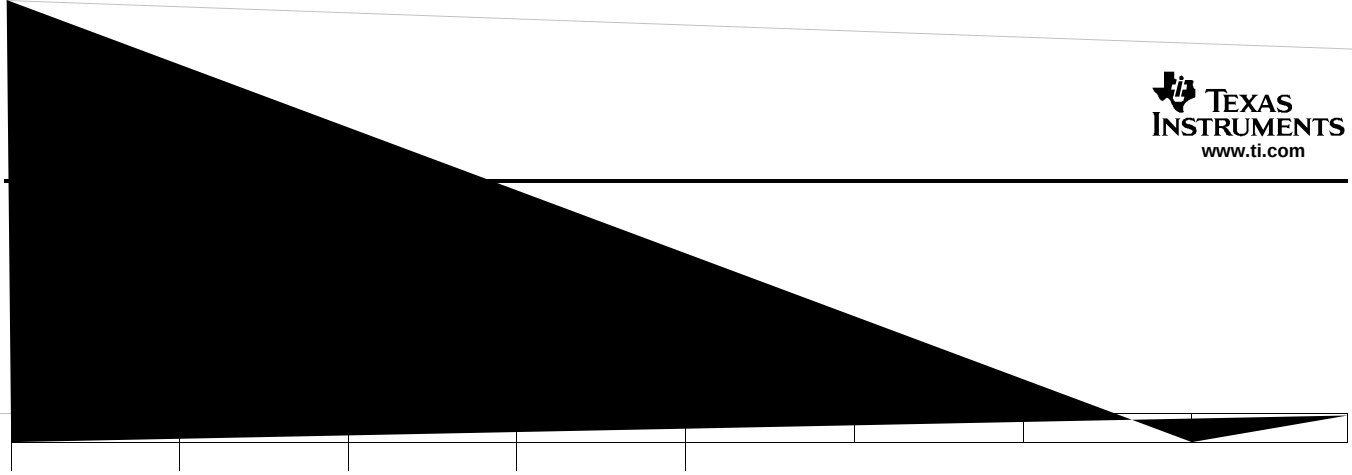
OTVC

The OTVC bit programs the bq2084-V140 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



1 ManufacturerName( ) and DeviceName( ) strings are 26 and 22 characters respectively

NVCELL

When this bit is set, it forces SBS.VCELL1..4( ) to be accessible via alternative commands.

0 SBS.VCELL1..4( ) available via 0x3c-0x3f

1 SBS.VCELL1..4( ) available via 0x38-0x3b

CCDSG

When this bit is set, it forces SBS.ChargingCurrent( ) to be reported as 0 when SBS.BatteryStatus( ))be

Constants and String Data

Specification Information

Manufacture Date

Serial Number

Manufacturer Name Data

Device Name Data

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.

Manufacturers 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.

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.

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

cross-cond 0 0 1 331.7 1

FET Fail Charge Current

FET Fail Discharge Current

FET Fail Time

Terminate Voltage

Offsets and Limits

Temperature offset

Board offset

Current Deadband

Shutdown Voltage

APPLICATION INFORMATION

Figure 7 shows a typical bq2084-V140-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-V140 operation.

APPLICATION INFORMATION (continued)

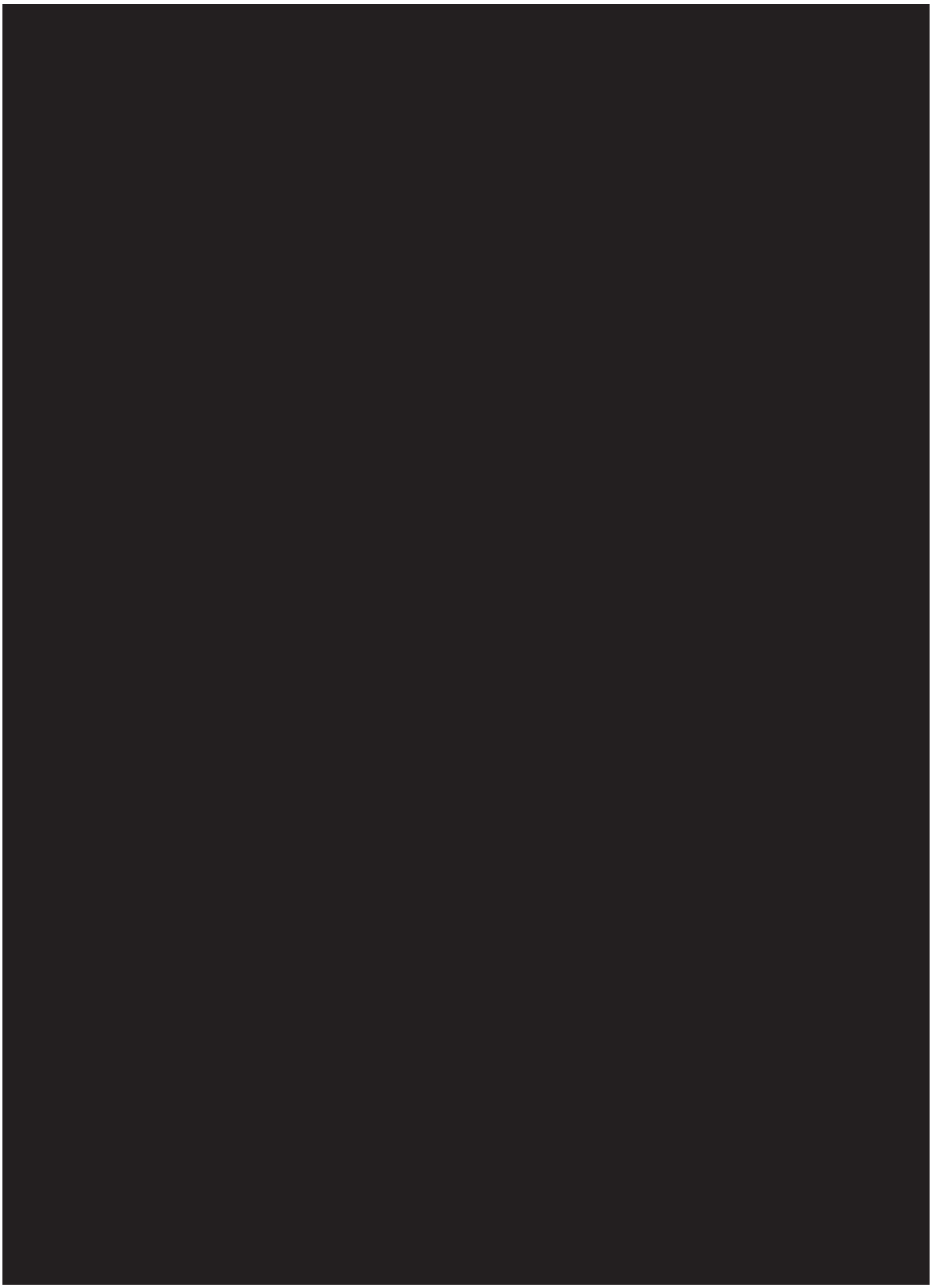


Figure 7. bq2084-V140 Based Battery Pack Schematic

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
BQ2084DBTR-V140	OBSOLETE	TSSOP	DBT	38		TBD	Call TI	Call TI	-20 to 70	2084DBT	
BQ2084DBTR-V140G4	OBSOLETE	TSSOP	DBT	38		TBD	Call TI	Call TI	-20 to 70		
BQ2084RTTR-V140	NRND	VQFN	RTT	36	3000	TBD	Call TI	Call TI	-20 to 85	BQ2084 RTT	
BQ2084RTTR-V140G4	NRND	VQFN	RTT	36	3000	TBD	Call TI	Call TI	-20 to 85	BQ2084 RTT	
BQ2084RTTT-V140	OBSOLETE	VQFN	RTT	36		TBD	Call TI	Call TI	-20 to 85	BQ2084	
BQ2084RTTT-V140G4	OBSOLETE	VQFN	RTT	36		TBD	Call TI	Call TI	-20 to 85		

(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) Only one of markings shown within the brackets will appear on the physical device.

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