SBS-COMPLIANT GAS GAUGE IC FOR USE WITH THE bq29311

- **Supports the Smart Battery Specification (SBS) V1.1**
- **Integrated Time Base Removes Need for External Crystal**
- **Works With the TI bq29311 Analog Front End (AFE) Protection IC to Provide Complete Pack Electronics for 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**
- **Measures Charge Flow Using a High Resolution 16-Bit Integrating Converter**
  - **Better Than 3-nVh of Resolution**
  - **Self-Calibrating**
  - **Offset Error Less Than 1-μV**
- **Uses 16-Bit Delta Sigma Converter for Accurate Voltage and Temperature Measurements**
- **Programmable Cell Modeling for Maximum Battery Fuel Gauge Accuracy**
- **Drives 3-, 4-, or 5-Segment LED Display for Remaining Capacity Indication**
- **38-Pin TSSOP (DBT)**

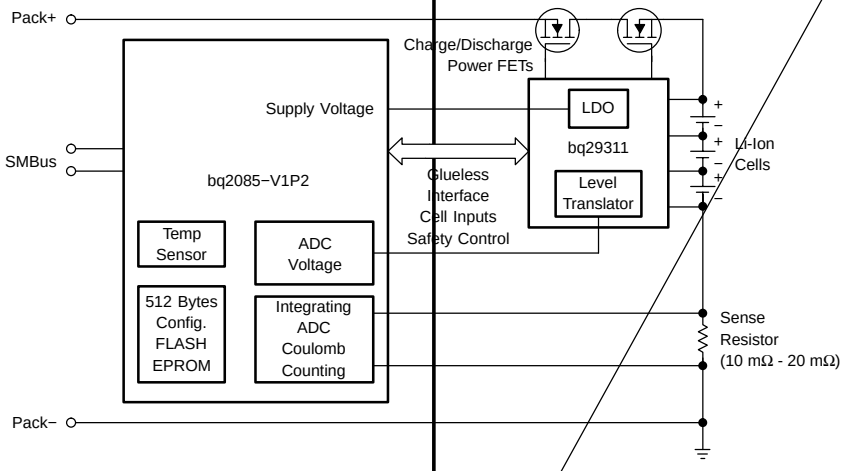
APPLICATIONS

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

DESCRIPTION

The bq2085−V1P2 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 bq2085−V1P2 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 bq29311 analog front-end (AFE) protection IC to maximize functionality and safety and minimize component count and cost in smart battery circuits. Using information from the bq2085−V1P2, the host controller can manage remaining battery power to extend the system run time as much as possible.

BLOCK DIAGRAM



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DESCRIPTION (CONTINUED)

The bq2085−V1P2 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 3-nVh and an offset measurement error of less than 1-μV (typical). For voltage and temperature reporting, the bq2085−V1P2 uses a 16-bit A-to-D converter. In conjunction with the bq29311, the onboard ADC also monitors individual cell voltages in a battery pack and allows the bq2085−V1P2 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 bq2085−V1P2 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 bq2085−V1P2 provides LED drivers and a push-button input to depict remaining battery capacity from full to empty in 20%, 25%, or 33% increments with a 3-, 4-, or 5-segment display.

The bq2085−V1P2 contains 512 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 bq2085−V1P2 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 bq29311 AFE protection IC provides power to the bq2085−V1P2 from a 3 or 4 series Li-ion cell stack, eliminating the need for an external regulator circuit.

1	38
2	37
3	36
4	35
5	34
6	33
7	32
8	31
9	30
10	29
11	28
12	27
13	26
14	453 he 2
15	4641(45)Tj(N/CTj0 -1.5mar7TD-0N/CTj0
16	
17	
18	30
19	

Terminal Functions

TERMINAL		

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 6 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} + 0.3V
Operating free-air temperature range, T_A		−20°C to 85°C
Storage temperature range, T_{stg}		−65°C to 150°C
ESD rating	HBM	1.5 kV
	CDM	1.5 kV
	MM	50 V

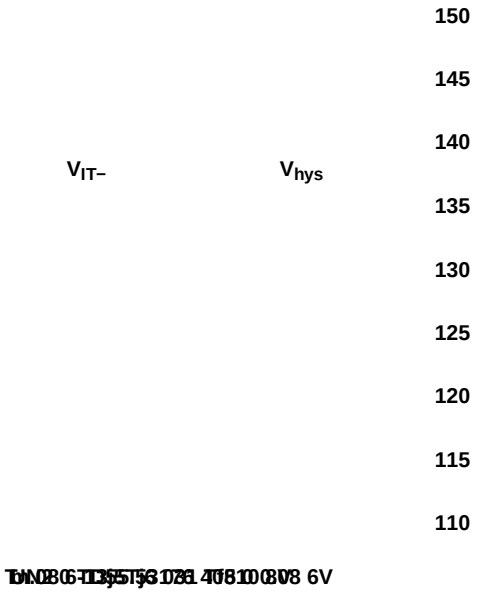
(1) Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to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

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

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	V_{DDA} and V_{DDD}	3.0	3.3	3.6	V
I_{DD}	Operating current	No flash programming		450		µA
$I_{(SLP)}$	Low-power storage mode current	Hibernate mode		1		µA
$V_{(OLS)}$	Output voltage low: (LED1−LED5)	$I_{(OLS)}$ = 10 mA			0.4	V
V_{IL}	Input voltage low $\overline{DISP}$		−0.3		0.8	V
V_{IH}	Input voltage high $\overline{DISP}$		2		V_{CC} + 0.3	V
V_{OL}	Output voltage low SMBC, SMBD, SDATA, SCLK, EVENT, $\overline{SAFE}$	I_{OL} = 0.5 mA			0.4	V
$V_{(ILS)}$	Input voltage low SMBC, SMBD, SDATA, SCLK, EVENT, $\overline{SAFE}$		−0.3		0.8	V
$V_{(IHS)}$	Input voltage high SMBC, SMBD, SDATA, SCLK, EVENT, $\overline{SAFE}$		1.7		6	V
$V_{(AI)}$	Input voltage range VIN, TS, OC		V_{SS} − 0.3		1.0	V
$Z_{(AI1)}$	Input impedance SR1, SR2	0 V–1.0 V	10			MΩ
$Z_{(AI2)}$	Input impedance VIN, TS, OC	0 V–1.0 V	8			MΩ
POWER-ON RESET (see FIGURE 1)						
V_{IT-}	Negative-going voltage input		2.1	2.3	2.5	V
V_{hys}	Power-on reset hysteresis		50	125	210	mV


150
145
140
135
130
125
120
115
110
V_{IT-}
V_{hys}

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					

PSTHD:S TATHD:DATTHISSATHD:S HASSTOSAPSCLKSDASTCLKACK)(1LO

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 as shown in the schematic. The integrating ADC measures bipolar signals from −0.3 to 1.0 V. The bq2085−V1P2 detects charge activity when $V_{SR} = V_{(SR1)}–V_{(SR2)}$ is positive and discharge activity when $V_{SR} = V_{(SR1)}–V_{(SR2)}$ is negative. The bq2085−V1P2 continuously integrates the signal over

s the gas gauge operation of the bq2085−V1P2. Table 3

▼

aining
acity
M)

●

RemainingCapacity( ) (RM)

RM represents the remaining capacity in the battery. The bq2085−V1P2 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 FCC and down during discharge and self-discharge to a minimum of 0. In addition to charge and self-discharge compensation, the bq2085−V1P2 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 0x31-0x32 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 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 bq2085−V1P2 sets FCC to the value stored in *Last Measured Discharge* DF 0x35-0x36. During subsequent discharges, the bq2085−V1P2 updates FCC with the last measured discharge capacity of the battery. The last measured discharge of the battery is based on the value in the DCR register after a qualified discharge occurs. Once updated, the bq2085−V1P2 writes the new FCC value to data flash in mAh to *Last Measured Discharge*. FCC represents the full battery reference for the relative display mode and relative state of charge calculations.

Discharge Count Register (DCR)

The DCR register counts up during discharge, independent of RM. DCR counts discharge activity, battery load estimation, and self-discharge increment. The bq2085−V1P2 initializes DCR, at the beginning of a discharge, to FCC − RM when RM is within the programmed value in *Near Full* DF 0x2f. 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 bq2085−V1P2 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:

$$\text{FCC (new)} = \text{DCR (final)} = \text{DCR (initial)} + \text{Measured Discharge to EDV2} + (\text{FCC} \times \textit{Battery Low\%}) \quad (1)$$

Battery Low % = (value stored in DF 0x2e) ÷ 2.56

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

- No valid charge activity occurs during the discharge period. A valid charge is defined as a charge of 10 mAh into the battery.
- No more than 256 mAh of self-discharge or battery load estimation occurs during the discharge period.
- The temperature does not drop below the low temperature thresholds programmed in *Learning Low Temp* DF 0x9b during the discharge period.
- The battery voltage reaches the EDV2 threshold during the discharge period and the voltage is greater than or equal to the EDV2 threshold minus 256 mV when the bq2085−V1P2 detected 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%* *FCC.

The bq2085−V1P2 sets VDQ=1 in pack status when qualified discharge begins. The bq2085−V1P2 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 bq2085−V1P2 saves the new FCC value to the data flash within 4 seconds of being updated.

Table 3. bq2085−V1P2 Register Functions (Continued)

FUNCTION	COMMAND CODE	ACCESS	UNITS
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

Self-Discharge

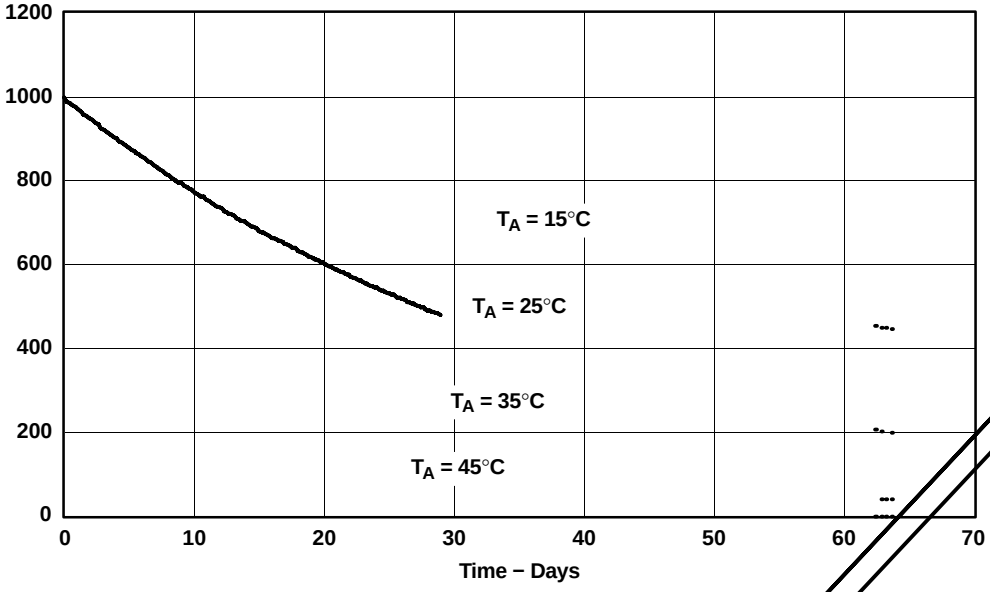
The bq2085−V1P2 estimates the self-discharge of the battery to maintain an accurate measure of the battery capacity during periods of inactivity. The bq2085−V1P2 makes self-discharge adjustments to RM( ) every 1/4 seconds when awake and periodically when in sleep mode. The period is determined by *Sleep Timer* DF 0xe7.

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. The following table 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 0x2c).

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

CAPACITY
vs
TIME



Charge Control

Charging Voltage and Current Broadcasts

The bq2085−V1P2 supports SBS charge control by broadcasting the ChargingCurrent( ) and ChargingVoltage( ) to the Smart Charger address. The bq2085−V1P2 broadcasts the requests every 10 seconds. The bq2085−V1P2 updates the values used in the charging current and voltage broadcasts based on the battery's state of charge, voltage, and temperature. The charge voltage is programmed in *Charging Voltage* DF 0x039-0x3a. The charge current may take any of four different values: Fast Charging Current DF (0x3d–0x3c), Maintenance Charging Current (DF 0x3f), Precharge Current (0x41), or 0. The charge current depends on charge state and operating conditions.

The bq2085−V1P2 internal charge control is compatible with the constant current/constant voltage profile for Li-Ion. The bq2085−V1P2 detects primary charge termination on the basis of the tapering charge current during the constant-voltage phase.

Alarm Broadcasts to Smart Charger and Host

If any of the bits 8−15 in BatteryStatus( ) are set, the bq2085−V1P2 broadcasts an AlarmWarning( ) message to the Host address. If any of the bits 12−15 in BatteryStatus( ) are set, the bq2085−V1P2 also sends an AlarmWarning( ) message to the Smart Charger address. The bq2085−V1P2 repeats the AlarmWarning( ) messages every 10 seconds until the alarm bits are cleared.

Precharge Qualification

The bq2085−V1P2 sets ChargingCurrent( ) to the precharge rate as programmed in *Precharge Current* DF 0x41 under the following conditions:

- Voltage: The bq2085−V1P2 requests the precharge charge rate when Voltage( ) drops below the precharge threshold or when the EDV0 threshold is detected. Once requested, a precharge rate remains until Voltage( ) increases above the precharge threshold and the EDV0 condition does not exist. The precharge threshold is programmed in *Precharge Voltage* DF 0x3b−0x3c.
- Temperature: The bq2085−V1P2 requests the precharge rate when Temperature( ) is between 0°C and the precharge threshold programmed in *Precharge Temp* 0x43. Temperature( ) must be equal to or greater than the precharge threshold to allow the fast-charge rate.

Charge Suspension

The bq2085−V1P2 may temporarily suspend charge if it detects a charging fault. A charging fault includes the following conditions.

- Overcurrent: An overcurrent condition exists when the bq2085−V1P2 measures the charge current to be equal to or greater than *Overcurrent Margin* plus ChargingCurrent( ). *Overcurrent Margin* is programmed in DF 0x5c−0x5d. On detecting an overcurrent condition, the bq2085−V1P2 sets the ChargingCurrent( ) to zero and sets the TERMINATE_CHARGE_ALARM bit in Battery Status( ). The overcurrent condition and TERMINATE_ CHARGE_ALARM are cleared when the measured current drops below *Overcurrent Margin*.
- Overvoltage: An overvoltage condition exists when the bq2085−V1P2 measures the battery voltage to be more than *Over Voltage Margin* plus ChargingVoltage( ), or when a cell voltage has exceeded the overvoltage limit programmed in *Cell Over Voltage*. *Over Voltage Margin* is programmed in DF 0x5a−0x5b and *Cell Over Voltage* in DF 0x60. On detecting an overvoltage condition, the bq2085−V1P2 sets the ChargingCurrent( ) to zero and sets the TERMINATE_CHARGE_ALARM bit in BatteryStatus( ). The bq2085−V1P2 clears the TERMINATE_ CHARGE_ALARM bit when it detects that the battery is no longer being charged (DISCHARGING bit set in BatteryStatus( )). The bq2085−V1P2 continues to broadcast zero charging current until the overvoltage condition is cleared. The overvoltage condition is cleared when the measured battery voltage drops below the ChargingVoltage( ) plus the *Over Voltage Margin* and all cell voltages are less than the *Cell Over Voltage* Reset threshold in DF 0xcf, 0xd0.
- Overtemperature: An overtemperature condition exists when Temperature( ) is greater than or equal to the *Max Temperature* value programmed in DF 0x53, 0x54. On detecting an overtemperature condition, the bq2085−V1P2 sets the ChargingCurrent( ) to zero and sets the OVER_TEMP_ALARM and TERMINATE_CHARGE_ ALARM bit in BatteryStatus( ) and the CVOV bit in pack status. The overtemperature condition is cleared when Temperature( ) is equal to or below (*Max Temperature − Temperature Hysteresis* DF 0x55, 0x56) or 43°C.

- Overcharge: An overcharge condition exists if the battery is charged more than the *Maximum Overcharge* value after RM = FCC. *Maximum Overcharge* is programmed in DF 0x4e-0x4f. On detecting an overcharge condition, the bq2085−V1P2 sets the ChargingCurrent( ) to zero and sets the OVER_CHARGED_ALARM, TERMINATE_CHARGE_ ALARM, and FULLY_CHARGED bits in BatteryStatus( ). The bq2085−V1P2 clears the TERMINATE_CHARGE_ ALARM when it detects that the battery is no longer being charged and clears the OVER_CHARGED_ALARM when 2mAh of discharge are measured. The FULLY_CHARGED bit remains set and the bq2085−V1P2 continues to broadcast zero charging current until RelativeStateOfCharge( ) is less than *Fully Charged Clear*% programmed in DF 0x47. The counter used to track overcharge capacity is reset with 2 mAh of discharge.
- Undertemperature: An undertemperature condition exists if Temperature( ) < 0°C. On detecting an under temperature condition, the bq2085−V1P2 sets ChargingCurrent( ) to zero. The bq2085−V1P2 sets ChargingCurrent( ) to the appropriate precharge rate or fast-charge rate when Temperature( ) ≥ 0°C.

Primary Charge Termination

The bq2085−V1P2 terminates charge if it detects a charge-termination condition based on current taper. A charge-termination condition includes the following:

For current taper, ChargingVoltage( ) must be set to the pack voltage desired during the constant-voltage phase of charging. The bq2085−V1P2 detects a current taper termination when the pack voltage is greater than or equal to ChargingVoltage( ) minus *Current Taper Qual Voltage* in DF 0x4a and the charging current is below a threshold determined by *Current Taper Threshold* in DF 0x48−0x49 and above 22.5 mA for two consecutive 40-second intervals.

Once the bq2085−V1P2 detects a Primary Charge Termination, the bq2085−V1P2 sets the TERMINATE_CHARGE_ALARM and FULLY_CHARGED bits in BatteryStatus( ), and sets the ChargingCurrent( ) to the maintenance charge rate as programmed in *Maintenance Charging Current* DF 0x3f, 0x40. On termination, the bq2085−V1P2 also sets RM to a programmed percentage of FCC, provided that RelativeStateOfCharge( ) is below the desired percentage of FCC and the CSYNC bit in *Gauge Configuration* DF 0x29 is set. The programmed percentage of FCC, *Fast Charge Termination %*, is set in DF 0x46. The bq2085−V1P2 clears the FULLY_CHARGED bit when RelativeStateOfCharge( ) is less than the programmed *Fully Charged Clear %*. The bq2085−V1P2 broadcasts the fast-charge rate when the FULLY_CHARGED bit is cleared and voltage and temperature permit. The bq2085−V1P2 clears the TERMINATE_CHARGE_ALARM when it no longer detects that the battery is being charged or it no longer detects the termination condition. See Table 6 for a summary of BatteryStatus( ) alarm and status bit operation.

Table 6. Alarm and Status Bit Summary (Continued)

BATTERY STATE	CONDITIONS	CC( ) CURRENT AND STATUS BITS SET	STATUS CLEAR CONDITION
Primary Charge Termination	Current taper	FC = 1, TCA = 1 *CC( ) = Maintenance Charging Current*	RSOC( ) < *Fully Charged Clear%*
Fully Discharged	RM( ) < *Battery Low %* and DISCHARGING = 1	FD = 1	RSOC( ) ≥ 20%
Overdischarged	RM( ) = 0 V( ) ≤ *Terminate Voltage*	TDA = 1	V( ) > *Terminate Voltage* and RM( ) > 0
	VCELL1, 2, 3 or 4 ≤ *Cell Under Voltage*	TDA = 1, CVUV = 1	V( ) > *Terminate Voltage* VCELL(all) ≥ *Cell Under Voltage Reset*
Low Capacity	RM( ) < RCA( )	RCA = 1	RM( )

Table 7. Display Mode for Five LEDs

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

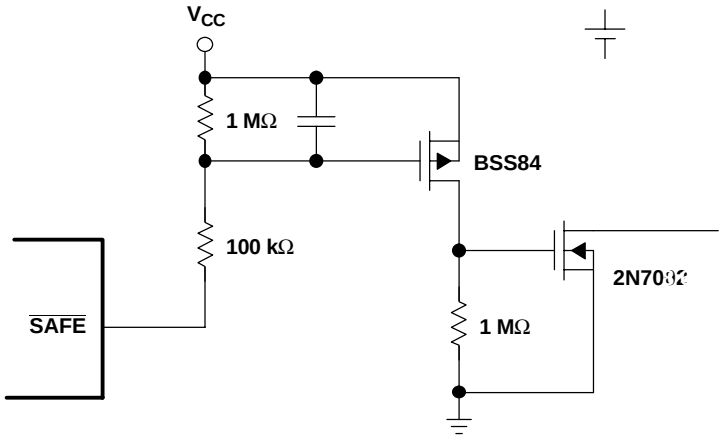
Table 9. Display Mode for Three LEDs

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

Table 10. bq2085−V1P2 to bq29311 Interface (FET Protection Control)

Battery State (Table 6)	DISCHARGING FET	CHARGING FET
CVOV = 1: Prolonged Overcurrent, Overvoltage, Overtemperature	Normal (1)	Off (2)
CVOV = CVUV = 0	Normal (1)	Normal (1)
CVUV = 1: Overload, Overdischarged	Off(3)	Normal (1)

(1) State determined by bq29311
(2)


V_{CC}
1 MΩ
BSS84
100 kΩ
2N7002
SAFE
1 MΩ

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 bq2085−V1P2 acts as the bus master. This occurs when the bq2085−V1P2 broadcasts charging requirements and alarm conditions to device addresses 0x12 (SBS smart charger) and 0x10 (SBS host controller.)

SMBus Protocol

The bq2085−V1P2 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 bq2085−V1P2. The bq2085−V1P2 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 assure the detection of the SMBus offstate, 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 bq2085−V1P2 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 bq2085−V1P2 can receive or transmit data with or without PEC. Figure 6 shows the communication protocol for the read word, write word, and read block messages without PEC. Figure 7 includes PEC.

In the read word protocol, the bq2085−V1P2 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 bq2085−V1P2 compares the value to its calculation. If the PEC is correct, the bq2085−V1P2 responds with an ACKNOWLEDGE. If it is not correct, the bq2085−V1P2 responds with a NOT ACKNOWLEDGE and sets an error code.

In the write word and block read, the host generates an ACKNOWLEDGE after the last byte of data sent by the bq2085−V1P2. The bq2085−V1P2 then sends the PEC and the host acting as a master-receiver generates a NOT ACKNOWLEDGE and a stop condition.

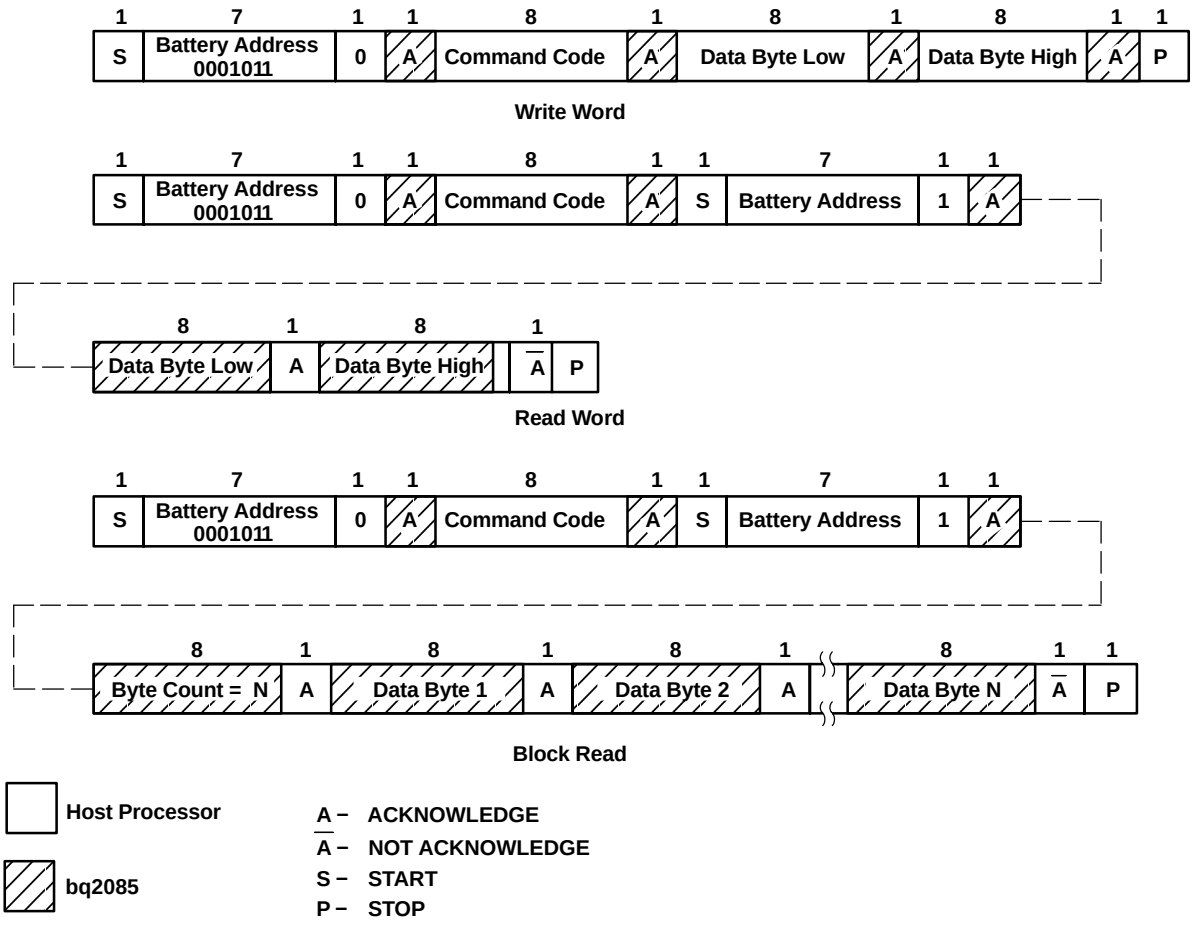


Figure 6. SMBus Communication Protocol Without PEC

COMMAND CODES

The SMBus command codes are in ( ). Temperature( ), Voltage( ), Current( ), and AverageCurrent( ), performance specifications are at bq29311 regulated V_{CC} ($V_{(REG)}$) and a temperature of 0-70°C.

ManufacturerAccess( ) (0x00)

Description: This function provides writable command codes to control the bq2085−V1P2 during normal operation and pack manufacture. The following commands are available:

0x0001 Device Type instructs the bq2085−V1P2 to return the IC part number; i.e., 2083 (0823h) to Manufacture Access( ) so it can be read.

0x0002 Firmware Revision instructs the bq2085−V1P2 to return the firmware revision.

0x0003 EDV Level instructs the bq2085−V1P2 to return the pending end-of-discharge voltage level so it can be read.

0x062b SEAL instructs the bq2085−V1P2 to restrict access to those functions listed in Table 3. The bq2085−V1P2 completes the seal function and clears ManufacturerAccess( ).

Purpose: The ManufacturerAccess( ) function provides the system host access to bq2085−V1P2 functions that are not defined by the SBD.

SMBus protocol: Read or write word

Input/Output: Word

RemainingCapacityAlarm( ) (0x01)

Description: Sets or gets the low-capacity threshold value. Whenever the RemainingCapacity( ) falls below the low capacity value, the bq2085−V1P2 sends AlarmWarning( ) messages to the SMBus host with the REMAINING_CAPACITY_ALARM bit set. A low-capacity value of 0 disables this alarm. The bq2085−V1P2 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 bq2085−V1P2 low-capacity alarm.

SMBus protocol: Read or write word

Input/Output: Unsigned integer-value below which low capacity messages are sent.

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

SMBus protocol: Read or write word

Input/Output: Unsigned integer—

Table 12. Battery Mode Bits and Values

Battery Mode( ) BITS	BITS USED	FORMAT	ALLOWABLE VALUES
INTERNAL_CHARGE_CONTROLLER	0	Read only bit flag	
PRIMARY_BATTERY_SUPPORT	1	Read only bit flag	
Reserved	2–6		
RELEARN_FLAG	7	Read only bit flag	0—Battery OK 1—Relearn cycle requested
CHARGE_CONTROLLER_ENABLED	8	R/W bit flag	
PRIMARY_BATTERY	9	R/W bit flag	
Reserved	10–12		
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 10mW or 10 mWh

ALARM_MODE bit is set to disable the bq2085−V1P2's ability to master the SMBus and send AlarmWarning( ) messages to the SMBus host and the smart battery charger. When set, the bq2085−V1P2 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 seconds and no less than 59 seconds. When cleared (default), the smart battery sends the AlarmWarning( ) messages to the SMBus host and the smart battery charger any time an alarm condition is detected.

- The ALARM broadcast does not occur more often than once every 10 s. Whenever the BATTERY_MODE command is received, the bq2085−V1P2 resets the bit and starts or restarts a 60-seconds (nominal) timer. After the timer expires, the bq2085−V1P2 automatically enables alarm broadcasts to ensure that the accidental deactivation of broadcasts does not persist. An SMBus host that does not want the bq2085−V1P2 to be a master on the SMBus must therefore continually set this bit at least once per 59 seconds to keep the bq2085−V1P2 from broadcasting alarms.
- The ALARM_MODE bit defaults to a cleared state when the bq2085−V1P2 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 bq2085−V1P2's transmission of ChargingCurrent( ) and ChargingVoltage( ) messages to the smart battery charger. When set, the bq2085−V1P2 does *not* transmit ChargingCurrent( ) and ChargingVoltage( ) values to the smart battery charger. When cleared, the bq2085−V1P2 transmits the ChargingCurrent( ) and ChargingVoltage( ) values to the smart battery charger. The CHARGER_MODE bit defaults to a cleared state when the bq2085−V1P2 enters SLEEP mode.

CAPACITY_MODE bit indicates if capacity information is reported in mA/mAh or 10mW/10 mWh. When set, the bq2085−V1P2 reports capacity information in 10 mW/10 mWh as appropriate. When cleared, the bq2085−V1P2 reports capacity information in mA/mAh as appropriate. The CAPACITY_MODE bit defaults to a cleared state when the bq2085−V1P2 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:

- RemainingC. ca 1 Tf5.254F2 1 TARca 1 Tf2e(

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 bq2085−V1P2 updates the non-AtRate related register values within 1 s of changing the state of the CAPACITY_MODE bit. The AtRate( ) values are updated after the next AtRate value is written to the bq2085−V1P2 (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 oFull(hmade by0001 Tcexp(inTDmARasf-p

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

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 bq2085−V1P2 updates AtRateTimeToEmpty( ) within 5 ms after the SMBus host sets the AtRate( ) value. The bq2085−V1P2 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 seconds. 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 bq2085−V1P2 updates AtRateOK( ) within 5 ms after the SMBus host sets the AtRate( ) value. The bq2085−V1P2 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 bq2085−V1P2.

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 T .0TJ0.10nagement 0 TD0 Tw0.25s739 vo0499.44 753.36haracterize d8 -1.728 TI voltage. Pow ofs739 vo0499.4flow753voltage, along igent1telligen1 Tf-7.y to or volta3ent1twer migenej/F13 Tf-7.

sets MaxError( ) to 2% on completion of a learning cycle, unless the bq2085−V1P2 limits the learning cycle to the +512/-256 mAh maximum adjustment values. If the learning cycle is limited, the bq2085−V1P2 sets MaxError( ) to 8% unless MaxError( ) was already below 8%. In this case MaxError( ) does not change. The bq2085−V1P2 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: Absolut6 TD0 Tw(Descript6matej/F1e 1 Tf5.88 0 TDTD-0.( )-6.5(Returns)-6.5(the)-6.5(

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	0–65,535mAh	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 one-minute rolling average of the predicted remaining battery life (minutes). 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 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 one-minute rolling average of the predicted remaining time until the battery reaches full charge (minutes).

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. The ChargingCurrent( ) value should be used in combination with the ChargingVoltage( ) value to set the charger's operating point. Together, these functions permit the bq2085−V1P2 to dynamically control the charging profile (current/voltage) of the battery. The bq2085−V1P2 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 bq2085−V1P2 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: 1mV

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 bq2085−V1P2 status word (flags). Some of the BatteryStatus( ) flags (REMAINING_CAPACITY_ALARM 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 bq2085−V1P2. This is basically the same information broadcast to both the

TERMINATE_DISCHARGE_ALARM bit is set when RM = 0, Voltage( ) ≤ *Terminate Voltage*, 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 bq2085−V1P2 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 bq2085−V1P2 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 bq2085−V1P2 is has detected a valid load of data flash at full or partial reset. It is cleared when the bq2085−V1P2 detects an improper data flash load.

DISCHARGING bit is set when the bq2085−V1P2 determines that the battery is not being charged. This bit is cleared when the bq2085−V1P2 detects that the battery is being charged.

FULLY_CHARGED bit is set when the bq2085−V1P2 detects a primary charge termination or an Overcharge condition. It is cleared when RelativeStateOfCharge( ) is less than the programmed *Fully Charged Clear %* in DF 0x47.

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 bq2085−V1P2 processed the function code without detecting any errors.
Busy	The bq2085−V1P2 is unable to process the function code at this time.
Reserved	The bq2085−V1P2 detected an attempt to read or write to a function code reserved by this version of the specification. The bq2085−V1P2 detected an attempt to access an unsupported optional manufacturer function code.
Unsupported	The bq2085−V1P2 does not support this function code which is defined in this version of the specification.
AccessDenied	The bq2085−V1P2 detected an attempt to write to a read-only function code.
Over/Underflow	The bq2085−V1P2 detected a data overflow or underflow.
BadSize	The bq2085−V1P2 detected an attempt to write to a function code with an incorrect data block.
UnknownError	The bq2085−V1P2 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 0x37-0x38. The bq2085−V1P2 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 in conjunction 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 bq2085−V1P2 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

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 bq2085−V1P2 VScale (voltage scaling) and IPScale (current scaling) should always be set to zero. The bq2085−V1P2 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

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 bq2085−V1P2 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 bq2085−V1P2 sets ManufacturerName( ) to the value programmed in *Manufacturer Name Length* DF 0x0e−0x19.

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 bq2085−V1P2 indicates that the battery is a model bq2085−V1P2. The bq2085−V1P2 sets DeviceName( ) to the value programmed in *Device Name Length* 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 bq2085−V1P2 sets DeviceChemistry( ) to the value programmed in *Device Chemistry Length* DF 0x22−0x26.

Purpose: The DeviceChemistry( ) function gives cell chemistry information for use by charging systems. The bq2085−V1P2 does not use DeviceChemisty( ) values for internal charge control or fuel gauging.

SMBus protocol: Read block

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

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

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

The ManufacturerData( ) (0x23)

Description: This function allows access to the manufacturer data contained in the battery (data). The bq2085−V1P2 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 bq2085−V1P2 under various programming sets. The ManufacturerData( ) function returns the following information in order: *Pack Configuration, Gauge Configuration, Misc Configuration, 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 (12 + length byte).

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 bq2085−V1P2 operation. The pack status register is the least significant byte of the word.

The pack configuration register reflects how the bq2085−V1P2 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
AFE	EDV2	SS	VDQ	0	SOV	CVOV	CVUV

AFE

The AFE bit indicates whether the bq29311 RAM integrity check has failed.

0 bq29311 integrity check passed
1 bq29311 integrity check failed

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 bq2085−V1P2.

0 The bq2085−V1P2 is in the unsealed state.
1 The bq2085−V1P2 is in the sealed state.

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

SOV

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Table 13. Data Flash Memory Map

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*	10800 mV	2a	30
0x06	0x07	*Specification Information*	v1.1/PEC	00	31
0x08	0x09	*Manufacture Date*	2/15/02=11343	2c	4f
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	5		35
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*	12		09
0x28		*Pack Configuration*	DMODE, LED1, CC1		c2
0x29		*Gauge Configuration*	CSYNC		40
0x2a		*Misc Configuration*	VOD		01
0x2b		*Digital Filter*	9860 nV		22
0x2c		*Self-Discharge Rate*	0.2%		14
0x2d		*Electronics Load*	0 mA		00
0x2e		*Battery Low %*	7.03%		12
0x2f	0x30	*Near Full*	200 mAh	00	c8

NOTE: 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.

Table 13. Data Flash Memory Map (Continued)

DATA FLASH ADDRESS			DATA
39			

Table 13. Data Flash Memory Map (Continued)

NAME	LI-ION EXAMPLE	DATA	
		MSB	LSB
TS Const 5		00	00
Reserved		0f	ac
Reserved			32
AFE Brnout Shutdn	Shutdown = 6.475, Brownout = 7.975 V		00
AFE Over Curr Dsg	140 mV		12
AFE Over Curr Chg	70 mV		04
AFE Over Curr Delay	Charge = 31 ms, Discharge = 31 ms		ff
Reserved			00
AFE Short Circ Thrsh	275 mV		07
AFE Short Circuit Delay	61 us (charge and discharge)		11

PROGRAMMING INFORMATION

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 0xbc−0xbf corrects the coulomb counter for sense resistor variations. It represents the gain factor for the coulomb counter.

The 16-bit *Sense Resistor Gain* in DF 0xba-0xbb 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.

$$\textit{Sense Resistor Gain} = \frac{306.25}{Rs} \quad (2)$$

Digital Filter

The desired digital filter threshold, VDF (V), is set by the value stored in *Digital Filter* DF 0x2b.

$$\textit{Digital Filter} = \frac{VDF}{290\ nV} \quad (3)$$

Cell and Pack Characteristics

Battery Pack Capacity and Voltage

Pack capacity in mAh units is stored in *Design Capacity*, DF 0x31−0x32. In mAh mode, the bq2085−V1P2 copies *Design Capacity* to DesignCapacity( ). In mWh mode, the bq2085−V1P2 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 *Last Measured Discharge*, in mAh, is stored in DF 0x35−0x36. *Last Measured Discharge* is modified over the course of pack usage to reflect cell aging under the particular use conditions. The bq2085−V1P2 updates *Last Measured Discharge* in mAh after a capacity learning cycle. The bq2085−V1P2 uses the *Last Measured Discharge* value to calculate FullChargeCapacity( ) in units of mAh or 10 mWh.

Remaining Time and Capacity Alarms

Remaining Time Alarm in DF 0x00-0x01 and *Remaining Capacity Alarm* in 0x02-0x03 set the alarm thresholds used in the SMBus command codes 0x01 and 0x02, respectively. *Remaining Time Alarm* is stored in minutes and *Remaining Capacity Alarm* in units of mAh or 10 mWh, depending on the BatteryMode( ) setting.

EDV Thresholds and Near Full Percentage

The bq2085−V1P2 uses three pack-voltage thresholds to provide voltage-based warnings of low battery capacity. The bq2085−V1P2 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 0x84−0x85, DF 0x86−0x87, and DF 0x88−0x89, respectively.

For capacity correction at EDV2, *Battery Low %* DF 0x2e 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.

$$\textit{Battery Low \%} = (\text{STATEOFCHARGE\%} \bullet 2.56) \quad (4)$$

The bq2085−V1P2 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 0x2f, 0x30 in mAh.

Change Control

Charging Voltage

The 16-bit value, *Charging Voltage* DF 0x39−0x3a programs the ChargingVoltage( ) value broadcast to a smart charger. It also sets the base value for determining overvoltage conditions during charging and voltage compliance during a constant-voltage charging methodology. It is stored in mV.

Over Voltage

The 16-bit value, *Over Voltage Margin* DF 0x5a−0x5b, sets the limit over ChargingVoltage( ) in mV that is to be considered as an overvoltage charge-suspension condition.

Charging Current

ChargingCurrent( ) values are either broadcast to a Level 2 smart battery charger or read from the bq2085−V1P2 by a Level 3 smart battery charger. The bq2085−V1P2 sets the value of ChargingCurrent( ), depending on the charge requirements and charge conditions of the pack.

When fast charge is allowed, the bq2085−V1P2 sets ChargingCurrent( ) to the rate programmed in *Fast-Charging Current* DF 0x3d−0x3e. *Fast-Charging Current* is stored in mA.

When fast charge terminates, the bq2085−V1P2 sets ChargingCurrent( ) to zero and then to the *Maintenance Charging Current* DF 0x3f, 0x40 when the termination condition ceases. The desired maintenance current is stored in mA.

When Voltage( ) is less than EDV0, the bq2085−V1P2 sets ChargingCurrent( ) to *Precharge Current* DF 0x41, 0x42. 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 0° and the precharge threshold PC (°C), the bq2085−V1P2 sets ChargingCurrent( ) to *PreCharge Current.* The threshold is programmed in the *Precharge Temp* DF 0x43.

$$\textit{Precharge Temp} = \frac{\text{PC (°C)}}{0.1}$$

The bq2085−V1P2 also sets ChargingCurrent( ) to the precharge rate if Voltage( ) is less than the value programmed in *Precharge Voltage* DF 0x3b−0x3c. *Precharge Voltage* is programmed in mV.

Charge Suspension

During charge, the bq2085−V1P2 compares the current to the ChargingCurrent( ) plus the value in *OverCurrent Margin* DF 0x5c−0x5d. If the pack is charged at a current above or equal to the ChargingCurrent( ) plus the programmed value, the bq2085−V1P2 sets ChargingCurrent( ) to zero to stop charging.

The desired *Overcurrent Margin* is programmed in mA.

The desired temperature threshold for charge suspension, MAXTEMP (°C), is programmed in *Max Temperature* DF 0x53, 0x54 and is stored as shown:

$$\textit{Max Temperature} = \frac{\text{MAXTEMP}}{0.1}$$

The bq2085−V1P2 clears the maximum temperature condition when Temperature( ) drops by the amount programmed in *Temperature Hysteresis* DF 0x55 from MAXTEMP or when the temperature is less than or equal to 43.0°C. *Temperature Hysteresis* is stored in °C.

The bq2085−V1P2 suspends fast charge when fast charge continues past full by the amount programmed in *Maximum Overcharge* DF 0x4e-0x4f. *Maximum Overcharge* is programmed in mAh.

FULLY_CHARGED Bit Clear Threshold

The bq2085−V1P2 clears the FULLY_CHARGED bit in BatteryStatus( ) when RelativeStateOfCharge( ) reaches the value, *Fully Charged Clear %* DF 0x47. *Fully Charged Clear %* is an 8-bit value and is stored in percent.

Fast Charge Termination Percentage

The bq2085−V1P2 sets RM to a percentage of FCC on charge termination if the CSYNC bit is set in the gauge

Fast Charge Termination% = (FCT% * 2.56−1)

Cycle Count Initialization

Cycle Count DF 0x0c-0x0d stores the initial value for the CycleCount( ) function. Program it 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.

Current Taper Termination Characteristics

Two factors in the data flash set the current taper termination for Li-Ion battery packs. The two locations are *Current Taper Qual Voltage* DF 0x4a and *Current Taper Threshold* DF 0x48−0x49. Current taper termination occurs during charging when the pack voltage is above or equal to the charging voltage minus the qualification voltage, and the charging current is below the taper threshold for at least 40 seconds. *Current Taper Qual Voltage* DF 0x4a is stored in mV and *Current Taper Threshold* DF 0x48−0x49 in mA.

Cell Balancing

Four constants set the cell balancing parameters. *Cell Balance Threshold* DF 0xd9−0xda sets the maximum voltage in mV that each cell must achieve to initiate cell balancing. *Cell Balance Window* DF 0xd9−0xda sets in mV the amount that the cell balance threshold can increase. *Cell Balance Min* DF 0xdb sets in mV the cell differential that must exist to initiate cell balancing and *Cell Balance Interval* DF 0xdc sets the cell balancing time interval in seconds. Programming *Cell Balance Threshold* to 65,535 disables cell balancing.

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

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.

0−1 Configures the bq2085−V1P2 for three LEDs

1−0 Configures the bq2085−V1P2 for four LEDs

1−1 or 0−0 Configures the bq2085−V1P2 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 bq2085−V1P2.

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 bq2085−V1P2 for the number of series cells in the battery pack.

0 Configures the bq2085−V1P2 for four series cells

1 Configures the bq2085−V1P2 for three 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 bq2085−V1P2, 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 clear the CSYNC bit.

0 The bq2085−V1P2 does not alter RM at the time of a valid charge termination.

1 The bq2085−V1P2 updates RM with a programmed percentage of FCC at a valid charger termination.

SC

The SC bit enables learning cycle optimization for a smart charger or independent charge.

0 Learning cycle optimized for independent charger

1 Learning cycle optimized for smart charger

CEDV

The CEDV bit determines whether the bq2085−V1P2 implements automatic EDV compensation to calculate the EDV0, EDV1, and EDV2 thresholds base on rate, temperature, and capacity. If the bit is cleared, the bq2085−V1P2 uses the fixed values programmed in data flash for EDV0, EDV1, and EDV2. If the bit is set, the bq2085−V1P2 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 overvoltage is based on pack or highest cell voltages.

0 Safety over voltage based on pack voltage

1 Safety over voltage 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 bq2085−V1P2 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

Miscellaneous Configuration

Misc Configuration DF 0x2a contains additional bit programmable features.

b7	b6	b5	b4

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 SepcificationInfo( ).

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.

Manufacturers Data Length

Manufacturers Data Length DF 0x27 stores the length of the desired number of bytes that is returned by the ManufacturersData( ) function. Set it to 9.

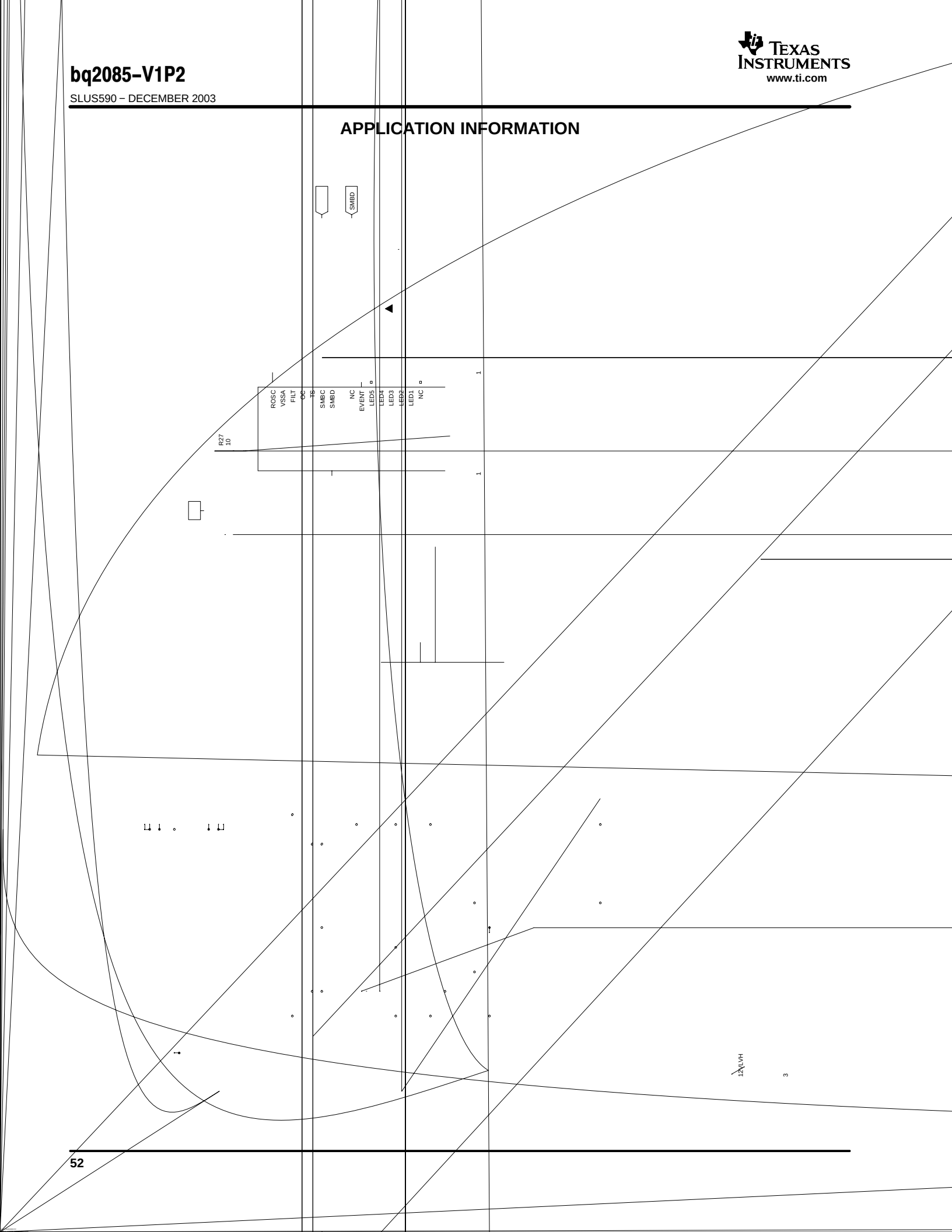
APPLICATION INFORMATION

The internal oscillator performance also depends on the tolerance of the 113k resistor connected between RSOC (pin 33) and VSSA (pin 34). It is recommended that this resistor be placed as close to the bq2085−V1P2 as possible and that it have a specification of ±0.1% tolerance and ±50 ppm temperature drift or better. The layout of the PCBA is also an additional contributing factor to performance degradation.

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

Figure 10 shows a typical bq2085−V1P2-based battery pack application. The circuit consists of the bq29311 analog front end (AFE) IC, LED display, 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 bq2085−V1P2 operation. Table 13 shows the data flash memory map and outlines the programmable functions available in the bq2085−V1P2.

APPLICATION INFORMATION



PACKAGING INFORMATION

Orderable Device	Status [1]	Package Type	Package Drawing	Pins	Package Qty	Eco Plan [2]	Lead/ Ball Finish	MSL Peak Temp [3]	Samples (Requires Login)
BQ2085DBT-V1P2	NRND	TSSOP	DBT	38	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	
BQ2085DBT-V1P2G4	NRND	TSSOP	DBT	38	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	

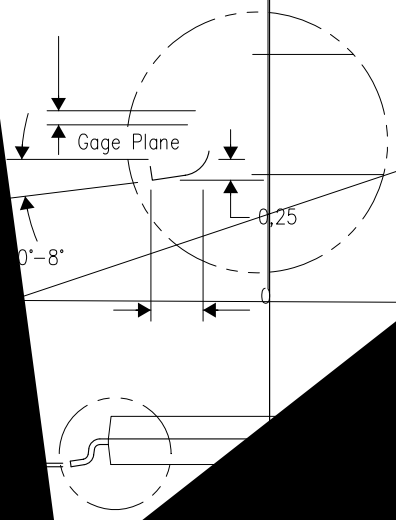
[1] The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, 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.

MECHANICAL DATA

PLASTIC SMALL OUTLINE



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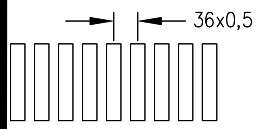
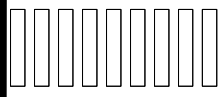


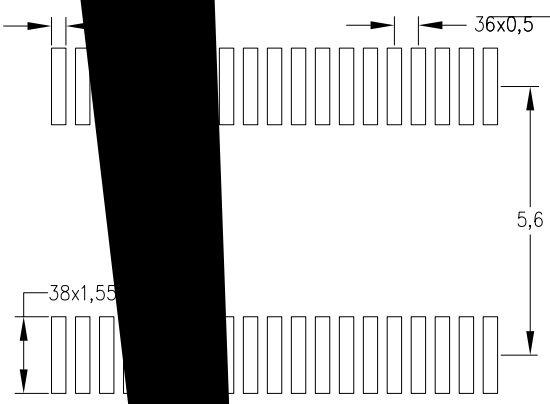


ed Pad

Pad Geometry
(Note C)

Solder Mask Opening

ample Stencil Design



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board assembly site for stencil design recommendations. Refer to PD 7525

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