bq2085−V1P3 SBS GAS GAUGE IC FOR 3- TO 5-CELL Li-Ion BATTERY PACKS

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**
- **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)**

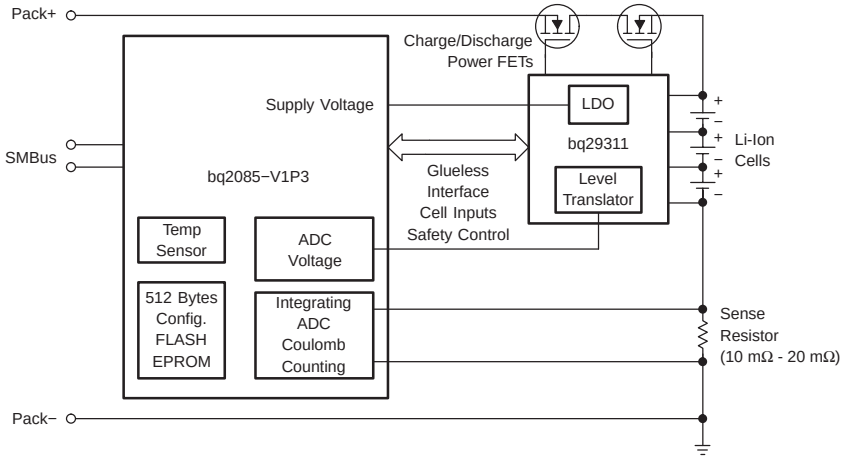
APPLICATIONS

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

DESCRIPTION

The bq2085−V1P3 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−V1P3 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−V1P3, 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)

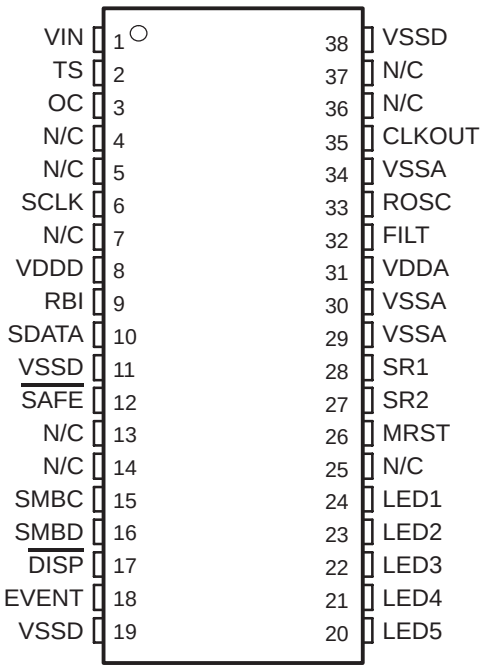
The bq2085−V1P3 uses an integrating converter with continuous sampling for the measurement of battery charge and discharge currents. Optimized for coulomb counting in portable applications, the self-calibrating integrating converter has a resolution better than 3-nVh and an offset measurement error of less than 1-μV (typical). For voltage and temperature reporting, the bq2085−V1P3 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−V1P3 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−V1P3 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−V1P3 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−V1P3 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−V1P3 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−V1P3 from a 3 or 4 series Li-ion cell stack, eliminating the need for an external regulator circuit.

TSSOP PACKAGE
(TOP VIEW)



NC − No internal connection

AVAILABLE OPTIONS

T_A	PACKAGE 38-PIN TSSOP (DBT)
−20°C to 85°C	bq2085−V1P3DBT(1)

(1) The bq2085−V1P3 is available taped and reeled. Add an R suffix to the device type (e.g., bq2085−V1P3DBTR) to order tape and reel version.

ABSOLUTE MAXIMUM RATINGS

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

		UNIT
Supply voltage range, V_{DD} relative to V_{SS}(2)		−0.3 V to 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
$I_{(SLP)}$	Sleep current			8		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

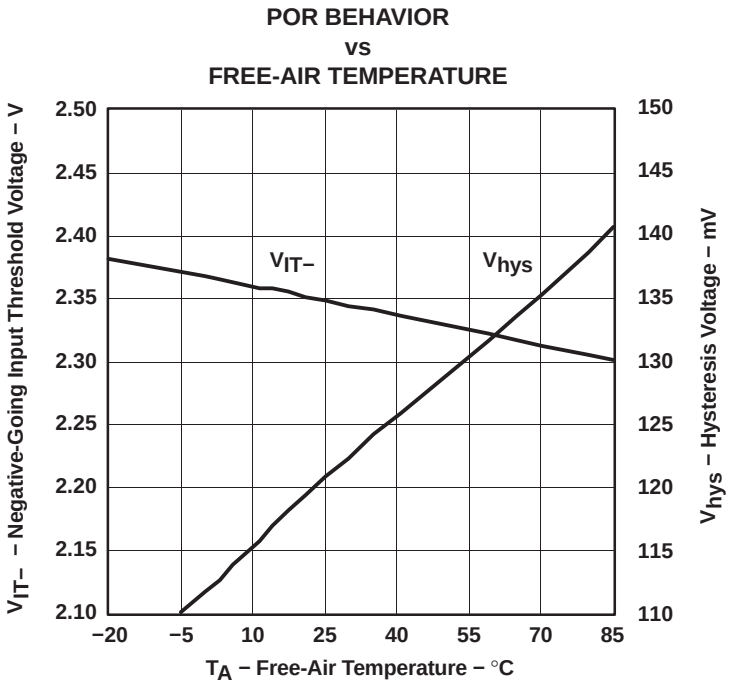


Figure 1

INTEGRATING ADC CHARACTERISTICS

V_{DD} = 3.0 V to 3.6 V, T_A = −20°C to 85°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(SR)}$	Input voltage range, $V_{(SR2)}$ and $V_{(SR1)}$	$V_{SR} = V_{(SR2)} - V_{(SR1)}$	–0.3		1.0	V
$V_{(SROS)}$	Input offset			1		

SMBUS TIMING SPECIFICATIONS

V_{DD} = 3.0 V to 3.6 V, T_A = −20°C to 85°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
F_{SMB}	SMBus operating frequency	Slave mode, SMBC 50% duty cycle	10		100	kHz
F_{MAS}	SMBus master clock frequency	Master mode, no clock low slave extend		51.2		kHz
T_{BUF}	Bus free time between start and stop		4.7			µs
$T_{HD:STA}$	Hold time after (repeated) start		4.0			µs
$T_{SU:STA}$	Repeated start setup time		4.7			µs
$T_{SU:STO}$	Stop setup time		4.0			µs
$T_{HD:DAT}$	Data hold time	Receive mode	0			ns
		Transmit mode	300			
$T_{SU:DAT}$	Data setup time		250			ns
$T_{TIMEOUT}$	Error signal/detect	See (1)	25		35	ms
T_{LOW}	Clock low period		4.7			µs
T_{HIGH}	Clock high period	See (2)	4.0		50	µs
$T_{LOW:SEXT}$	Cumulative clock low slave extend time	See (3)			25	ms
$T_{LOW:MEXT}$	Cumulative clock low master extend time	See (4)			10	ms
T_F	Clock/data fall time	See (5)			300	ns
T_R	Clock/data rise time	See (6)			1000	ns

(1) The bq2085−V1P3 times out when any clock low exceeds $T_{TIMEOUT}$
(2) T_{HIGH} Max. is minimum bus idle time. SMBC = 1 for t > 50 µs causes reset of any transaction involving bq2085−V1P3 that is in progress.
(3) $T_{LOW:SEXT}$ is the cumulative time a slave device is allowed to extend the clock cycles in one message from initial start to the stop.
(4) $T_{LOW:MEXT}$ is the cumulative time a master device is allowed to extend the clock cycles in one message from initial start to the stop.
(5) Rise time T_R = (V_{ILMAX} − 0.15 V) to (V_{IHMIN} + 0.15 V).
(6) Fall time T_F = 0.9 V_{DD} to (V_{ILMAX} − 0.15 V).

DATA FLASH MEMORY SWITCHING CHARACTERISTICS

V_{DD} = 3.0 V to 3.6 V, T_A = −20°C to 85°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{(RETENSION)}$	Data retention	See (1)	10			Years
	Flash programming write-cycles	See (1)		10^5		Cycles
$t_{(WORDPROG)}$	Word programming time	See (1)			2	ms
$I_{(DDPROG)}$	Flash-write supply current	See (1)		14	16	mA

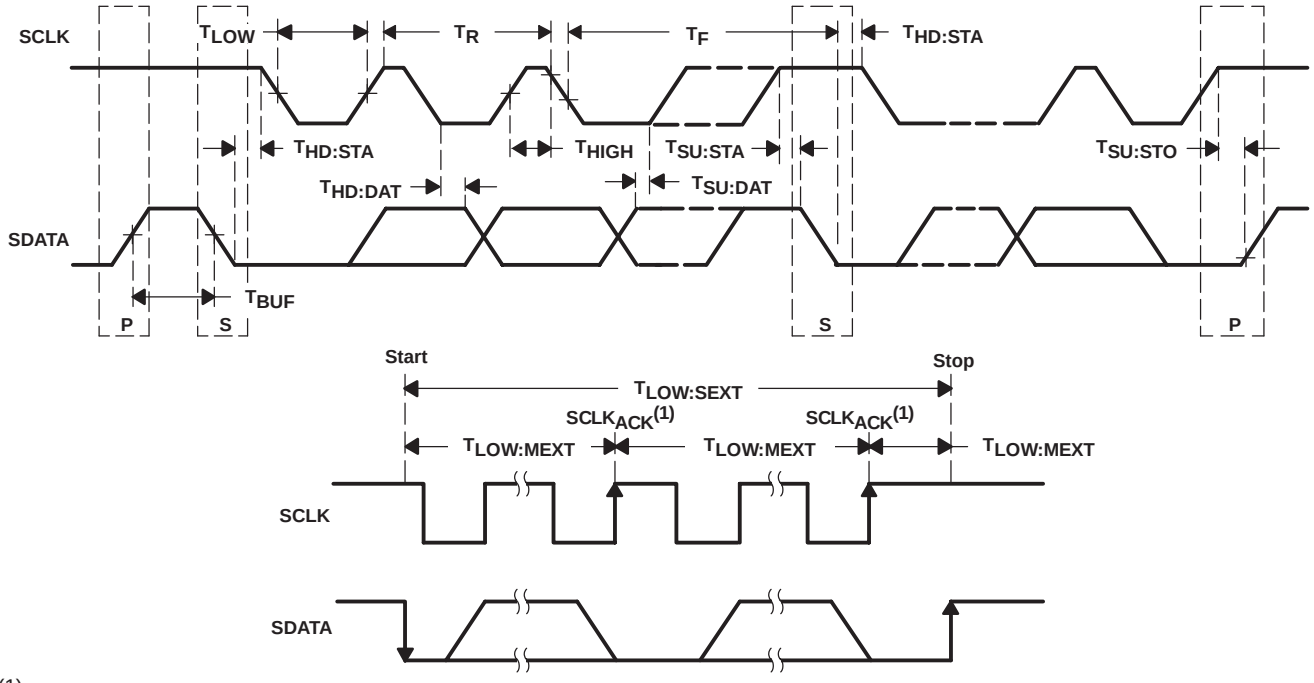
(1) Specified by design. Not production tested.

Register Backup

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$I_{(RBI)}$	RBI data-retention input current (1)	V_{RB} > 3.0 V, V_{DD} < V_{IT}		10	100	nA
$V_{(RBI)}$	RBI data-retention voltage		1.3			V

(1) Specified by design. Not production tested.

SMBUS TIMING DIAGRAMS



(1) $SCLK_{ACK}$

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−V1P3 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−V1P3 continuously integrates the signal over time, using an internal counter. The fundamental rate of the counter is 2.6 nVh. The bq2085−V1P3 updates Remaining Capacity() with the charge or discharge accumulated in this internal counter once every second.

Offset Calibration

The bq2085−V1P3 provides an autocalibration feature to cancel the voltage offset error across SR_1 and SR_2 for maximum charge measurement accuracy. The bq2085−V1P3 performs autocalibration when the SMBus lines stay low for a minimum of 20 s. The bq2085−V1P3 is capable of automatic offset calibration down to 1 μV.

Digital Filter

The bq2085−V1P3 does not measure charge or discharge counts below the digital filter threshold. The digital filter threshold is programmed in the *Digital Filter* DF 0x2b. Set it 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 bq2085−V1P3 monitors the individual series cell voltages through the bq29311. The bq2085−V1P3 configures the bq29311 to present the selected cell to the VCELL pin of the bq29311. Therefore, connect the VCELL pin to VIN of the bq2085−V1P3. The internal ADC of the bq2085−V1P3 then measures the voltage and scales it appropriately. The bq2085−V1P3 then reports the Voltage( ) and the individual cell voltages in VCELL1, VCELL2, VCELL3, and VCELL4 located in 0x3c−0x3f.

Current

The bq2085−V1P3 uses the SR1 and SR2 inputs to measure and calculate the battery charge and discharge current as represented in the data register Current().

Temperature

The TS input of the bq2085−V1P3 in conjunction with an NTC thermistor measures the battery temperature as shown in the schematic. The bq2085−V1P3 reports temperature in Temperature( ).

The bq2085−V1P3 can also be configured to use its internal temperature sensor by setting the IT bit in *Misc Configuration* DF 0x2a. Data flash locations DF 0xa4 through DF 0xad also have to be changed to prescribed values if the internal temperature sensor option is selected.

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

LABEL	LOCATION	INTERNAL TEMP SENSOR SETTING	EXTERNAL TEMP SENSOR SETTING (Semitec 103AT)
	Dec (Hex)	Dec (Hex)	Dec (Hex)
Misc. Configuration	42 (0x2a)	Bit 7 = 1	Bit 7 = 0
TS Const1 A3	164/5 (0xa4/5)	0 (0x0000)	−28285 (0x9183)
TS Const2 A2	166/7 (0xa6/7)	0 (0x0000)	20848 (0x5170)
TS Const3 A1	168/9 (0xa8/9)	−11136 (0xd480)	−7537 (0xe28f)
TS Const4 A0	170/1 (0xaa/b)	5754 (0x1666)	4012 (0x0fac)
Min Temp AD	172/3 (0xac/d)	0 (0x0000)	0 (0x0000)
Max Temp	174/5 (0xae/f)	5734 (0x1666)	4012 (0x0fac)

If AD < Min Temp AD then Temp = Max Temp

Else

Temp = ([A3 × AD × 2^ − 16 + A2] × AD × 2^ − 16 + A1) × AD 2^ −16 + A0

Gas Gauge Operation

General

RemainingCapacity( ) (RM)

RM represents the remaining capacity in the battery. The bq2085−V1P3 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−V1P3 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−V1P3 sets FCC to the value stored in *Last Measured Discharge* DF 0x35-0x36. During subsequent discharges, the bq2085−V1P3 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−V1P3 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−V1P3 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−V1P3 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−V1P3 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−V1P3 sets VDQ=1 in pack status when qualified discharge begins. The bq2085−V1P3 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−V1P3 saves the new FCC value to the data flash within 4 seconds of being updated.

Table 3. bq2085−V1P3 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

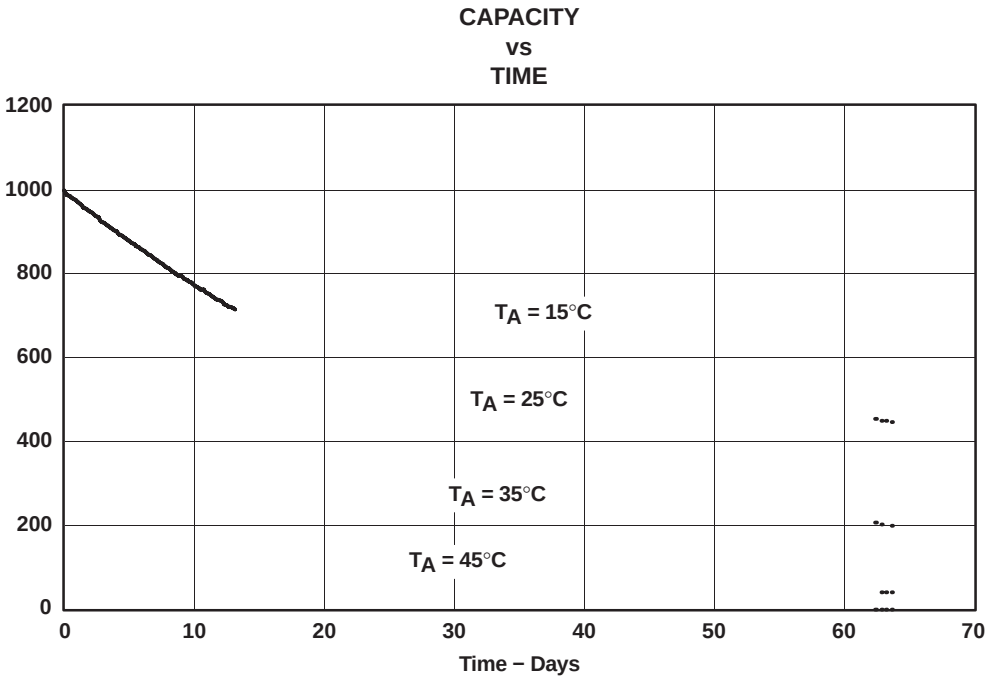
Self-Discharge

The bq2085−V1P3 estimates the self-discharge of the battery to maintain an accurate measure of the battery capacity during periods of inactivity. The bq2085−V1P3 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
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
70
Time − Days
TA = 15°C
TA = 25°C
TA = 35°C
TA = 45°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−V1P3 sets the ChargingCurrent( ) to zero and sets the OVER_CHARGED_ALARM, TERMINATE_CHARGE_ ALARM, and FULLY_CHARGED bits in BatteryStatus( ). The bq2085−V1P3 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−V1P3 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−V1P3 sets ChargingCurrent( ) to zero. The bq2085−V1P3 sets ChargingCurrent( ) to the appropriate precharge rate or fast-charge rate when Temperature( ) ≥ 0°C.

Primary Charge Termination

The bq2085−V1P3 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−V1P3 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−V1P3 detects a Primary Charge Termination, the bq2085−V1P3 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−V1P3 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−V1P3 clears the FULLY_CHARGED bit when RelativeStateOfCharge( ) is less than the programmed *Fully Charged Clear %*. The bq2085−V1P3 broadcasts the fast-charge rate when the FULLY_CHARGED bit is cleared and voltage and temperature permit. The bq2085−V1P3 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

BATTERY STATE	CONDITIONS	CC( ) CURRENT AND STATUS BITS SET	STATUS CLEAR CONDITION
Overcurrent	C( ) ≥ CC( ) + *Overcurrent Margin*	CC( ) = 0, TCA = 1	C( ) < *Overcurrent Margin*
Prolonged Overcurrent	AC( ) ≥ *Fast-Charging Current* + *Overcurrent Margin*	CVOV = 1 CC( ) = 0, TCA = 1	AC( ) < 256 mA
Overload	AC( ) ≤ −*Overload Current*	CVUV = 1	AC( ) < –256 mA
Overvoltage	V( ) ≥ CV( ) + *Over Voltage Margin* VCELL1, 2, 3, or 4 ≥ *Cell Over Voltage*	TCA = 1	DISCHARGING = 1
		CC( ) = 0, CVOV = 1	V( ) < CV( ) + *Over Voltage Margin* VCELL(all) ≤ *Cell Over Voltage Reset*
Overtemperature	T( ) ≥ *Max Temperature*	CC( ) = 0, OTA = 1, TCA = 1, CVOV = 1	T( ) ≤ *Max Temperature−Temperature Hysteresis* or T( ) ≤ 43°C
Overcharge	Capacity added after RM( ) = FCC( ) ≥ *Maximum Overcharge*	CC( ) = 0, FC = 1	RSOC( )< *Fully Charged Clear %*
		OCA = 1, TCA = 1	DISCHARGING = 1, and 2 mAh of discharge is measured
Undertemperature	T( ) < 0°C	CC( ) = 0	0°C ≤ T( )
	0°C ≤ T( ) < LTF	CC( ) = Precharge	T( ) ≥ LTF + DF 0x44 (default = 3°C)

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( ) ≥ RCA( )
Low Run Time	ATTE( ) < RTA( )	RTA = 1	ATTE( ) ≥ RTA( )

NOTE: AC( ) = AverageCurrent( ), C( ) = Current( ), CV( ) = ChargingVoltage( ), CC( ) = ChargingCurrent( ), V( ) = Voltage( ), T( ) = Temperature( ), TCA = TERMINATE_CHARGE_ALARM, OTA = OVER_TEMPERATURE_ALARM, OCA = OVER_CHARGED_ALARM, TDA = TERMINATE_DISCHARGE_ALARM, FC = FULLY_CHARGED, FD = FULLY_DISCHARGED, RSOC( ) = RelativeStateOfCharge( ). RM( ) = RemainingCapacity( ), RCA = REMAINING_CAPACITY_ALARM, RTA = REMAINING_TIME_ALARM, ATTE( ) = AverageTimeToEmpty( ), RTA( ) = RemainingTimeAlarm( ), RCA( ) = RemainingCapacityAlarm( ). LTF = Low Temperature Fault threshold

}FCC( ) = NOTE = Rem(Fu4

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 10. bq2085−V1P3 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) On if there is a discharge current ≥ 50 mA
(3) On if there is a charge current ≥50 mA.

Table 11. Stand-Alone bq29311 Protection Control

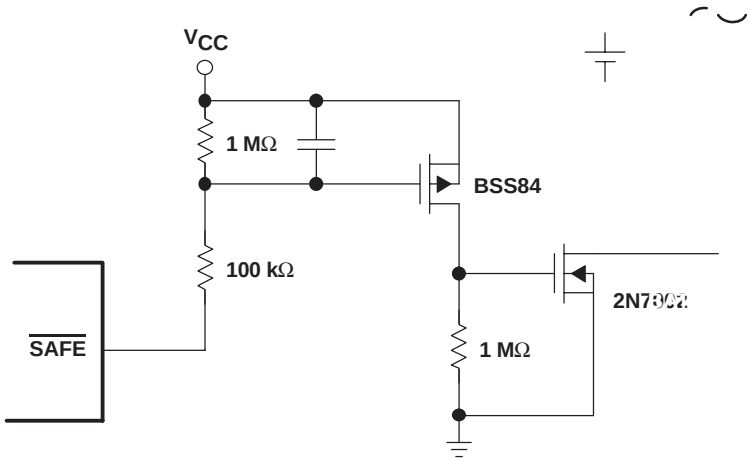
MODE	CONDITION	CLEAR(1)
Over Load	*AFE Over Curr Dsg* (DF 0xb2) is breached for *Over Curr Delay* (DF 0xb4)	AverageCurrent() = 0 mA
Over Current	*AFE Over Curr Chg* (DF 0x0b3) is breached for *Over Curr Delay* (DF 0xb4)	AverageCurrent() = 0 mA
Short Circuit, Discharge	*AFE Short Circ Thresh* (DF 0xb6) is breached for *AFE Short Circuit Delay* (DF 0xb7, lower nibble)	Normal: AverageCurrent() = 0 mA Sleep: Recovery delay of 20 s
Short Circuit, Charge	*AFE Short Circ Thresh* (DF 0xb6) is breached for *AFE Short Circuit Delay* (DF 0xb7, upper nibble)	Normal: AverageCurrent() = 0 mA Sleep: Recovery delay of 20 s

(1) Clear is detected and controlled by the bq2085−V1P3.

$\overline{\text{SAFE}}$ Output

The $\overline{\text{SAFE}}$ output of the bq2085−V1P3 provides an additional level of safety control. The active low safety output can blow a fuse or control another switch on the basis of temperature, a pack-voltage cell-voltage, or an integrity check of the AFE registers.

The $\overline{\text{SAFE}}$ output is driven low in any of the following 4 conditions if the $\overline{\text{SAFE}}$ output activates, the bq2085−V1P3 sets the SOV bit in pack status. SOV remains set until the bq2085−V1P3 is reset. The $\overline{\text{SAFE}}$


VCC
1 MΩ
BSS84
100 kΩ
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−V1P3 acts as the bus master. This occurs when the bq2085−V1P3 broadcasts charging requirements and alarm conditions to device addresses 0x12 (SBS smart charger) and 0x10 (SBS host controller.)

SMBus Protocol

The bq2085−V1P3 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−V1P3. The bq2085−V1P3 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−V1P3 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−V1P3 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−V1P3 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−V1P3 compares the value to its calculation. If the PEC is correct, the bq2085−V1P3 responds with an ACKNOWLEDGE. If it is not correct, the bq2085−V1P3 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−V1P3. The bq2085−V1P3 then sends the PEC and the host acting as a master-receiver generates a NOT ACKNOWLEDGE and a stop condition.

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−V1P3 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−V1P3. This is basically the same information broadcast to both the SMBus host and the smart battery charger by the AlarmWarning( ) function except that the AlarmWarning( ) function sets the error code bits all high before sending the data.

SMBus protocol: Read word

Output: Unsigned Integer–status register with alarm conditions bit mapped as follows:

ALARM BITS	
0x8000	OVER_CHARGED_ALARM
0x4000	TERMINATE_CHARGE_ALARM
0x2000	Reserved
0x1000	OVER_TEMP_ALARM
0x0800	TERMINATE_DISCHARGE_ALARM
0x0400	Reserved
0x0200	REMAINING_CAPACITY_ALARM
0x0100	REMAINING_TIME_ALARM
STATUS BITS	
0x0080	Initialized
0x0040	DISCHARGING
0x0020	FULLY_CHARGED
0x0010	FULLY_DISCHARGED
ERROR CODES	
0x0007	Unknown Error
0x0006	BadSize
0x0005	Overflow/Underflow
0x0004	AccessDenied
0x0003	UnsupportedCommand
0x0002	ReservedCommand
0x0001	Busy
0x0000	OK

Alarm Bits

OVER_CHARGED_ALARM bit is set whenever the bq2085−V1P3 detects that the battery is being charged beyond the maximum overcharge limit. This bit is cleared when the bq2085−V1P3 detects that the battery is no longer being charged and there are 2 mAh of continuous discharge (i.e., the bq2085−V1P3 detects discharge activity or no activity above the digital filter).

TERMINATE_CHARGE_ALARM bit is set when the bq2085−V1P3 detects that one or more of the battery charging parameters are out of range (e.g., its voltage, current, or temperature is too high) or when the bq2085−V1P3 detects a primary charge termination. This bit is cleared when the parameter falls back into the allowable range, the termination condition ceases, or when the bq2085−V1P3 detects that the battery is no longer being charged.

OVER_TEMP_ALARM bit is set when the bq2085−V1P3 detects that the internal battery temperature is greater than or equal to the *Max Temperature* threshold. This bit is cleared when the internal temperature falls back into the acceptable range.

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−V1P3 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−V1P3 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−V1P3 is has detected a valid load of data flash at full or partial reset. It is cleared when the bq2085−V1P3 detects an improper data flash load.

DISCHARGING bit is set when the bq2085−V1P3 determines that the battery is not being charged. This bit is cleared when the bq2085−V1P3 detects that the battery is being charged.

FULLY_CHARGED bit is set when the bq2085−V1P3 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−V1P3 processed the function code without detecting any errors.
Busy	The bq2085−V1P3 is unable to process the function code at this time.
Reserved	The bq2085−V1P3 detected an attempt to read or write to a function code reserved by this version of the specification. The bq2085−V1P3 detected an attempt to access an unsupported optional manufacturer function code.
Unsupported	The bq2085−V1P3 does not support this function code which is defined in this version of the specification.
AccessDenied	The bq2085−V1P3 detected an attempt to write to a read-only function code.
Over/Underflow	The bq2085−V1P3 detected a data overflow or underflow.
BadSize	The bq2085−V1P3 detected an attempt to write to a function code with an incorrect data block.
UnknownError	The bq2085−V1P3 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−V1P3 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.

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−V1P3 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−V1P3 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−V1P3 operation. The pack status register is the least significant byte of the word.

The pack configuration register reflects how the bq2085−V1P3 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−V1P3.

0 The bq2085−V1P3 is in the unsealed state.

1 The bq2085−V1P3 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

The SOV bit indicates that the safety output limits have been exceeded. Once set, the flag stays set until the bq2085−V1P3 is reset.

0 Safety limits not exceeded

1 Safety limits exceeded

CVOV

The CVOV bit indicates that a protection limit has been exceeded. It is set on a Prolonged Overcurrent, Overvoltage, or Overtemperature condition. 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. It is set on an overload or overdischarge condition. The bit is not latched and merely reflects the present fault status.

0 No secondary protection limits exceeded

1 A secondary protection limit exceeded

VCELL4-VCELL1 (0x3c-0x3f)

These functions return the calculated individual cell voltages in mV.

DATA FLASH

General

The bq2085−V1P3 accesses the internal data flash during reset and when storing historical data. The data flash stores basic configuration information for use by the bq2085−V1P3. The data flash must be programmed correctly for proper bq2085−V1P3 operation.

Memory Map

Table 13 shows the memory map for the data flash. It shows the default programming for the bq2085−V1P3. The default programming reflects example data for a 3s2p Li-Ion battery pack with a 0.02 Ω sense resistor. The data flash must be reprogrammed to meet the requirements of individual applications.

Table 13. Data Flash Memory Map (Continued)

DATA FLASH ADDRESS		NAME	LI-ION EXAMPLE	DATA	
HIGH BYTE	LOW BYTE			MSB	LSB
0x31	0x32	*Design Capacity*	3600 mAh	0e	10
0x33	0x34	Reserved	0	00	00
0x35	0x36	*Last Measured Discharge*	3600 mAh	0e	10
0x37	0x38	*Cycle Count Threshold*	2880 mAh	0b	40
					38
					40

Table 13. Data Flash Memory Map (Continued)

DATA FLASH ADDRESS		NAME	LI-ION EXAMPLE	DATA	
HIGH BYTE	LOW BYTE			MSB	LSB
0x72		Reserved			40
0x73	0x74	*VOC50*	11430 mV	2c	a6
0x75		Reserved			7f
0x76		Reserved			3d
0x77		Reserved			27
0x78	0x79	*VOC25*	11270 mV	2c	06
0x7a		Reserved			3f
0x7b		Reserved			24
0x7c		Reserved			0e
0x7c		Reserved			14

Table 13. Data Flash Memory Map (Continued)

H ADDRESS	NAME	LI-ION EXAMPLE	DATA	
LOW BYTE			MSB	LSB
0xad	TS Const 5		00	00
0xaf	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 μs (charge and discharge)		11
0xb9	*AFE Vref**	9750 mV	26	16
0xbb	*Sense Resistor Gain**	0.02 Ω	3b	d0
0xbd	*CC Delta**	0.0001298 mAh	94	08
0xbf	*CC Delta**		b1	c0
	Reserved			fa
0xc2				

EDV Discharge Rate and Temperature Compensation

If EDV compensation is enabled, the bq2085−V1P3 calculates battery voltage to determine EDV0, EDV1, and EDV2 thresholds as a function of battery capacity, temperature, and discharge load. The general equation for EDV0, EDV1, and EDV2 calculation is

EDV0,1,2 = n (EMF • FBL - | ILOAD | • R0 • FTZ)

EMF is a no-load cell voltage higher than the highest cell EDV threshold computed. EMF is programmed in mV in *EMF/EDV1* DF 0x84−0x85.

ILOAD is the current discharge load magnitude.

n = the number of series cells

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

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

C (either 0%, 3%, or *Battery Low %* for EDV0, EDV1, and EDV2, respectively) and C0 are the capacity- related EDV adjustment factors. C0 is programmed in *EDV C0 Factor/EDV1* DF 0x86−87. C1 is the desired residual battery capacity remaining at EDV0 (RM = 0). The C1 factor is stored in *EDV C1 Factor* DF 0x8f.

T is the current temperature in °

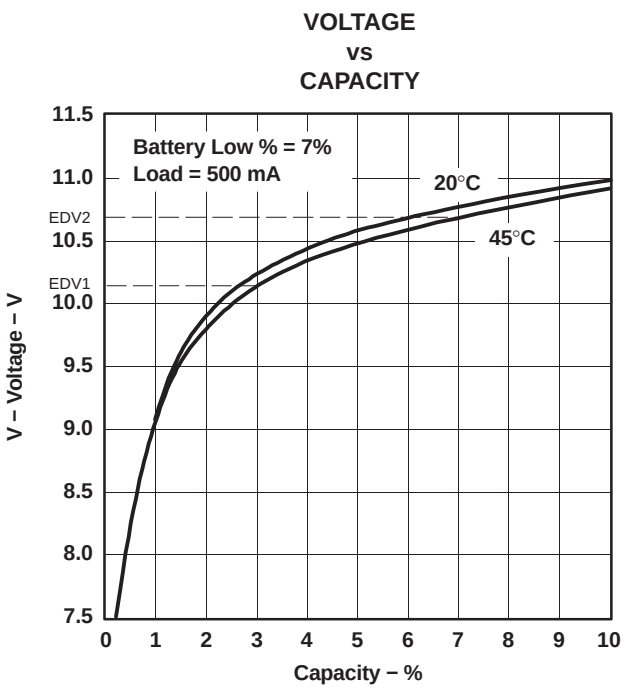


Figure 8. EDV Calculations vs Capacity for Various Temperatures

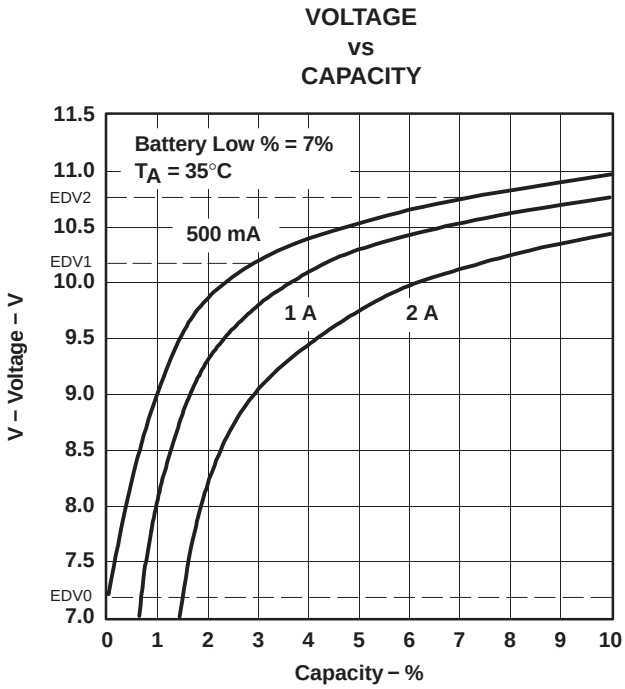


Figure 9. EDV Calculations vs Capacity for Various Loads

Overload Current Threshold

The overload protection disables discharge when the 16-bit limit programmed in DF 0x58−0x59 is breached. The threshold is stored in mA.

Midrange Capacity Corrections

Three voltage-based thresholds, *VOC25* DF 0x78−0x79, *VOC50* DF 0x73−0x74, and *VOC75* DF 0x6e−0x6f, are used to test the accuracy of the RM based on open-circuit pack voltages. These thresholds are stored in the data flash in mV. The values represent the open-circuit battery voltage at which the battery capacity should correspond to the associated state of charge for each threshold.

Self-Discharge Rate

The nominal self-discharge rate, %PERDAY (% per day), is programmed in an 8-bit value *Self-Discharge Rate* DF 0x2c by the following relation:

$$\textit{Self-Discharge Rate} = \frac{\%\text{PERDAY}}{0.01} \tag{8}$$

Charge Efficiency

The bq2085−V1P3 applies the efficiency factor, EFF%, to all charge added to the battery. EFF% is encoded in *Charge Efficiency* DF 0x51 according to equation 16:

$$\textit{Charge Efficiency} = (\text{EFF\%} \bullet 2.56 – 1) \tag{9}$$

Other Compensation

Battery Electronics Load

The amount of internal battery electronics load estimate in µA, BEL, is stored in *Electronics Load* DF 0x2d as follows:

$$\textit{Electronics Load} = \frac{\text{BEL}}{3}$$

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−V1P3 by a Level 3 smart battery charger. The bq2085−V1P3 sets the value of ChargingCurrent( ), depending on the charge requirements and charge conditions of the pack.

When fast charge is allowed, the bq2085−V1P3 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−V1P3 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−V1P3 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−V1P3 sets ChargingCurrent( ) to *PreCharge Current.* The threshold is programmed in the *Precharge Temp* DF 0x43.

$$\textit{Precharge Temp} = \frac{\text{PC (°C)}}{0.1} \tag{10}$$

The bq2085−V1P3 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−V1P3 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−V1P3 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:

$$\textit{Max Temperature} = \frac{\text{MAXTEMP}}{0.1} \tag{11}$$

The bq2085−V1P3 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−V1P3 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−V1P3 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−V1P3 sets RM to a percentage of FCC on charge termination if the CSYNC bit is set in the gauge configuration register. The percentage of FCC, FCT%, is stored in *Fast Charge Termination %* in DF 0x46. The value is stored as shown:

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

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−V1P3 for the number of series cells in the battery pack.

0 Configures the bq2085−V1P3 for four series cells

1 Configures the bq2085−V1P3 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−V1P3, 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−V1P3 does not alter RM at the time of a valid charge termination.

1 The bq2085−V1P3 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−V1P3 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−V1P3 uses the fixed values programmed in data flash for EDV0, EDV1, and EDV2. If the bit is set, the bq2085−V1P3 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−V1P3 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 bq2085−V1P3 to perform a midrange voltage one time after a device reset.

0 One-time midrange correction disabled

1 One-time midrange correction enabled

Safety Control

Secondary Protection Limits for Li-Ion

The cell undervoltage (VUV) and overvoltage (VOV) limits are programmed in *Cell Under and Cell Over Voltage* DF 0x62−0x63, DF 0x60−0x61, respectively. Both values are stored in mV. *Cell Over Voltage Reset* DF 0xef and *Cell Under Voltage Reset* 0xd1−0xd2 set the reset points in mV for these safety parameters.

$\overline{\text{SAFE}}$ Threshold

The safety voltage threshold is programmed in *Safety Over Voltage* DF 0x68−0x69. It is stored in mV.

If miscellaneous configuration bit 2 (OVSEL) = 0 then safety overvoltage is based on pack voltage, but if OVSEL = 1, then it is based on highest cell voltage.

The safety overtemperature (SOT) in °C is programmed in *Safety Over Temperature* DF 0x6a−0x6b. It is stored as

$$SafetyOvertemperature = \frac{SOT}{0.1} \quad (12)$$

AFE CONFIGURATION

The AFE protection limits are programmed as specified in the bq29311 data sheet.

AFE Brnout/Shutdn 0xb1 sets the brownout and shutdown voltage levels

AFE Over Curr Dsg DF 0xb2 sets the overcurrent threshold on discharge.

AFE Over Curr Chg DF 0xb3 sets the overcurrent threshold on charge.

AFE Over Curr Delay DF 0xb4 sets the delay timing for over current in the charge and discharge direction.

AFE Short Circ Thresh DF 0xb6 sets the short circuit threshold and

AFE Short Circuit Delay DF 0xb7 sets the short circuit delay time.

AFE INTEGRITY CHECK

AFE Check Time DF 0xe4 sets the period in seconds for the AFE integrity check.

The *AFE Fail Limit* (DF 0xd3,d4) is the number of AFE integrity check failures that occur before the AFE flag is set.

SLEEP MODE

The sleep current threshold, SLP (mA), is stored in *Sleep Current Thresh* DF 0xe5 as:

$$Sleep\ Current\ Thresh = \frac{SLP(mA)}{0.5} \quad (13)$$

The wake-up period for current measurement, WAT(s), is set in *Sleep Current Time* DF 0xe6 as:

$$Sleep\ Current\ Time = \frac{WAT(s)}{0.5} \quad (14)$$

Miscellaneous Configuration

Misc Configuration DF 0x2a contains additional bit programmable features.

b7	b6	b5	b4	b3	b2	b1	b0
IT	0	AC	DS	OT	ECLED	PHG	VOD

IT

The IT bit configures the bq2085−V1P3 to use its internal temperature sensor.

0 bq2085−V1P3 requires an external thermistor.

1 bq2085−V1P3 uses its internal temperature sensor.

AC

The AC bit enables the $\overline{\text{SAFE}}$ output to function based on the AFE integritthe SAFE 630 221.0T 10 444.72 63.44 a54.9.4

CONSTANTS AND STRING DATA

Specification Information

Specification Information DF 0x06−0x07 stores the default value for

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−V1P3 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.

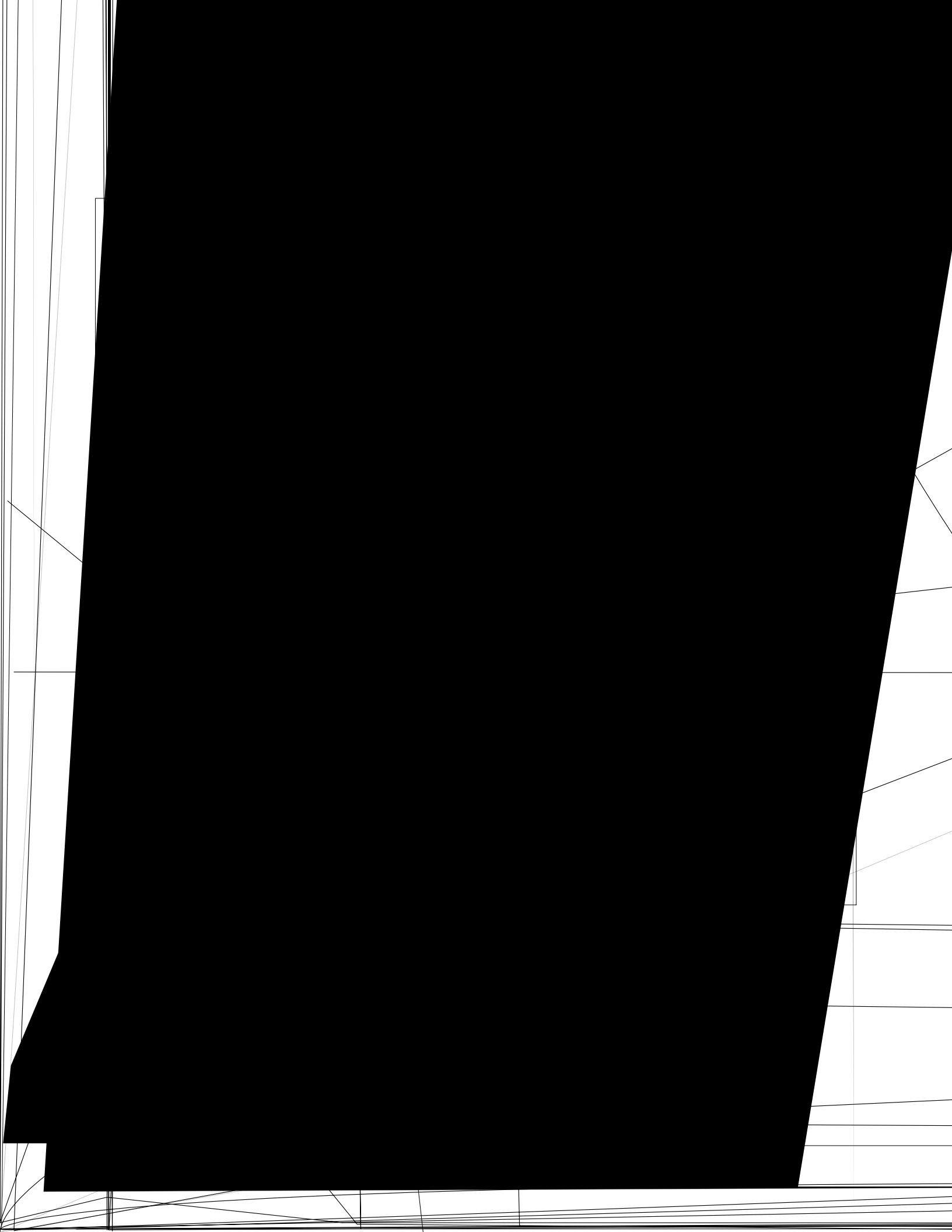
The average temperature drift error of the oscillator function over a learning charge or discharge cycle introduces an equal capacity prediction error in a learned full charge capacity (FCC).

Figure 10 shows a typical bq2085−V1P3-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−V1P3 operation. Table 13 shows the data flash memory map and outlines the programmable functions available in the bq2085−V1P3.

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]



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