SBS 1.1-COMPLIANT GAS GAUGE ENABLED WITH ImpedanceTrack™ TECHNOLOGY FOR USE WITH THE bq29312

FEATURES

- **Patented ImpedanceTrack Technology Accurately Measures Available Charge in Li-Ion and Li-Polymer Batteries**
- **Better than 1% Error Over Lifetime of the Battery**
- **Instant Accuracy – No Learning Cycle Required**
- **Supports the Smart Battery Specification SBS V1.1**
- **Works With the TI bq29312 Analog Front End (AFE) Protection IC to Provide Complete Pack Electronics Solution**
- **Full Array of Programmable Voltage, Current, and Temperature Protection Features**
- **Integrated Time Base Removes Need for External Crystal with Optional Crystal Input**
- **Electronics for 7.2-V, 10.8-V or 14.4-V Battery Packs With Few External Components**
- **Based on a Powerful Low-Power RISC CPU Core With High-Performance Peripherals**
- **Integrated Field Programmable FLASH Memory Eliminates the Need for External Configuration Memory**
- **Measures Charge Flow Using a High-Resolution, 16-Bit Integrating Converter**
  - **Better Than 0.65-nVh of Resolution**
  - **Self-Calibrating**
  - **Offset Error Less Than 1-μV**
- **Uses 16-Bit Delta Sigma Converter for Accurate Voltage and Temperature Measurements**
- **Extensive Data Reporting Options For Improved System Interaction**
- **Optional Pulse Charging Feature for Improved Charge Times**

- **Drives 3-, 4- or 5- Segment LED Display for Remaining Capacity Indication**
- **38L TSSOP (DBT)**

APPLICATIONS

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

DESCRIPTION

The bq20z80 SBS-compliant gas gauge IC, incorporating patented ImpedanceTrack technology, is designed for battery-pack or in-system installation. The bq20z80 measures and maintains an accurate record of available charge in Li-ion or Li-polymer batteries using its integrated high-performance analog peripherals. The bq20z80 monitors capacity change, battery impedance, open circuit voltage, and other critical parameters of the battery pack, and reports the information to the system host controller over a serial-communication bus. It is designed to work with the bq29312 analog front-end (AFE) protection IC to maximize functionality and safety, and minimize component count and cost in smart battery circuits.

The ImpedanceTrack technology continuously analyzes the battery impedance, resulting in superior gas-gauging accuracy. This enables remaining capacity to be calculated with discharge rate, temperature, and cell aging all accounted for during each stage of every cycle.

AVAILABLE OPTIONS

T_A	PACKAGE
	38-PIN TSSOP (DBT)
−40°C to 85°C	bq20z80DBT[1]

(1) The bq20z80 is available taped and reeled. Add an R suffix to the device type (e.g., bq20z80DBTR) to order tape and reel version.
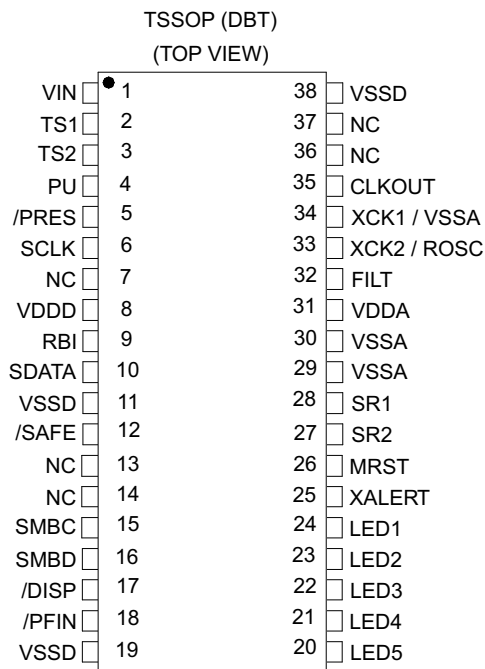
These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

TSSOP (DBT)

(TOP VIEW)

VIN	1		38	VSSD
TS1	2		37	NC
TS2	3		36	NC
PU	4		35	CLKOUT
/PRES	5		34	XCK1 / VSSA
SCLK	6		33	XCK2 / ROSC
NC	7		32	FILT
VDDD	8		31	VDDA
RBI	9		30	VSSA
SDATA	10		29	VSSA
VSSD	11		28	SR1
/SAFE	12		27	SR2
NC	13		26	MRST
NC	14		25	XALERT
SMBC	15		24	LED1
SMBD	16		23	LED2
/DISP	17		22	LED3
/PFIN	18		21	LED4
VSSD	19		20	LED5

NC - No internal connection

TERMINAL FUNCTIONS

TERMINAL		I/O[1]	DESCRIPTION[2]
NO.	NAME		
1	VIN	I	Voltage Measurement input from the AFE
2	TS1	I	1st Thermistor voltage input connection to monitor temperature
3	TS2	I	2nd Thermistor voltage input connection to monitor temperature
4	PU	O	Output to pull up the $\overline{PRES}$ pin for system detection
5	$\overline{PRES}$	I	Active low input to sense system insertion and typically requires additional ESD protection
6	SCLK	I/OD	Communication clock to the AFE
7	NC	–	Not used and should be left floating
8	VDDD	P	Positive supply for digital circuitry and I/O pins
9	RBI	P	Backup power to the bq20z80 data registers during periods of low operating voltage. RBI accepts a storage capacitor or a battery input.
10	SDATA	I/O	Data transfer to and from the AFE
12	SAFE	O	Active high output for additional level of safety protection; e.g., fuse blow.
13	NC	–	Not used— leave floating
14	NC	–	Not used— leave floating
15	SMBC	I/OD	SMBus clock open-drain bidirectional pin used to clock the data transfer to and from the bq20z80
16	SMBD	I/OD	SMBus data open-drain bidirectional pin used to transfer address and data to and from the bq20z80
17	$\overline{DISP}$	I	Display control for the LEDs. This pin is typically connected to VCC via a 100k resistor and a push-button switch to VSS.
18	$\overline{PFIN}$	I	Active low input to detect secondary protector output status and allows the bq20z80 to report the status of the 2nd level protection output
20	LED5	O	LED5 display segment that drives an external LED depending on the firmware configuration

(1) I = Input, IA = Analog input, I/O = Input/output, I/OD = Input/Open-drain output, O = Output, OA = Analog output, P = power
(2) VSS refers to the common mode of VSSA and VSSD.

TERMINAL FUNCTIONS (continued)

TERMINAL		I/O[1]	DESCRIPTION[2]
NO.	NAME		
21	LED4	O	LED4 display segment that drives an external LED depending on the firmware configuration
22	LED3	O	LED3 display segment that drives an external LED depending on the firmware configuration
23	LED2	O	LED2 display segment that drives an external LED depending on the firmware configuration
24	LED1	O	LED1 display segment that drives an external LED depending on the firmware configuration
25	XALERT	I	Input from bq29312 XALERT output.
26	MRST	I	Master reset input that forces the device into reset when held high
27	SR2	IA	Connections for a small-value sense resistor to monitor the battery charge- and discharge-current flow
28	SR1	IA	Connections for a small-value sense resistor to monitor the battery charge- and discharge-current flow
31	VDDA	P	Positive supply for analog circuitry
32	FILT	IA	Analog input connected to the external PLL filter components which are a 150-pF capacitor to V_{SS}, in parallel with a 61.9-kΩ resistor and a 1200-pF capacitor in series. Place these components as close as possible to the bq20z80 to ensure optimal performance.
33	XCK2/ROSC	O	32.768 kHz crystal oscillator output pin or connected to a 100k, 50ppm or better resistor if the internal oscillator is used
34	XCK1/VSSA	I	32.768 kHz crystal oscillator input pin or connected to VSSA if the internal oscillator is used
35	CLKOUT	O	32.768-kHz output for the bq29312. This pin should be directly connected to the AFE.
36	NC	-	Not used— leave floating
37	NC	-	Not used— leave floating
11, 29	VSSD	P	Negative supply for digital circuitry
19, 38	VSSD	P	Negative supply for output circuitry
29, 30	VSSA	P	Negative supply for analog circuitry.

ABSOLUTE MAXIMUM RATINGS

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

		RANGE
V_{DD} relative to V_{SS}[2]	Supply voltage range	−0.3 V to 4.1 V
$V_{(IOD)}$ relative to V_{SS}[2]	Open-drain I/O pins	−0.3 V to 6 V
V_I relative to V_{SS}[2]	Input voltage range to all other pins	−0.3 V to VDD + 0.3 V
T_A	Operating free-air temperature range	−40°C to 85°C
T_{stg}	Storage temperature range	− 65°C to 150°C

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

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

ELECTRICAL CHARACTERISTICS

V_{DD} = 3.0 V to 3.6 V, T_A = −40°C to 85°C (unless otherwise noted)

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{DD}	Supply voltage	VDDA and VDDD	3.0	3.3	3.6	V
I_{DD}	Operating mode current	No flash programming		350[1]		µA
$I_{(SLP)}$	Low-power storage mode current	Sleep mode		8[1]		µA
V_{OL}	Output voltage low SMBC, SMBD, SDATA, SCLK, $\overline{SAFE}$, PU	I_{OL} = 0.5 mA			0.4	
	LED1 − LED5	I_{OL} = 10 mA			0.4	
V_{OH}	Output high voltage, SMBC, SMBD, SDATA, SCLK, $\overline{SAFE}$, PU	I_{OH} = −1 mA	V_{DD}− 0.5			
V_{IL}	Input voltage low SMBC, SMBD, SDATA, SCLK, EVENT, $\overline{PRES}$, $\overline{PFIN}$		−0.3		0.8	V
	DISP		−0.3		0.8	
V_{IH}	Input voltage high SMBC, SMBD, SDATA, SCLK, EVENT, $\overline{PRES}$, $\overline{PFIN}$		2		6	
	DISP		2		V_{CC} + 0.3	
C_{IN}	Input Capacitance			5		pF
$V_{(AI1)}$	Input voltage range VIN, TS1, TS2		V_{SS}− 0.3		1.0	V
$V_{(AI2)}$	Input voltage range SR1, SR2		V_{SS}− 0.25		0.25	
$Z_{(AI1)}$	Input impedance SR1, SR2	0 V−1.0 V			2.5	MΩ
$Z_{(AI2)}$	Input impedance VIN, TS1, TS2	0 V−1.0 V			8	MΩ

(1)   This value does not include the bq29312

POWER-ON RESET

V_{DD} = 3.0 V to 3.6 V, T_A = −40°C to 85°C (unless otherwise noted)

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{IT-}	Negative-going voltage input		2.1	2.3	2.5	V
V_{HYS}	Power-on reset hysteresis		50	150	200	mV

POWER ON RESET BEHAVIOR
vs
FREE-AIR TEMPERATURE
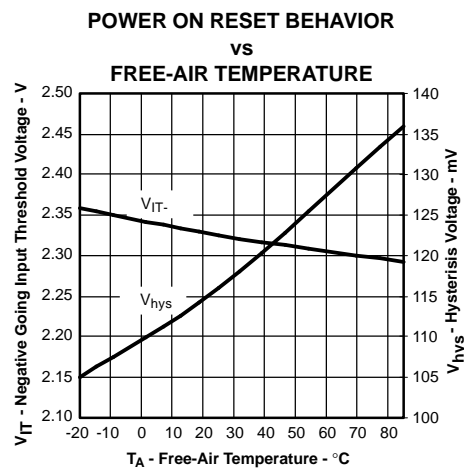
INTEGRATING ADC (Coulomb Counter) CHARACTERISTICS

V_{DD} = 3.0 V to 3.6 V, T_A = −40°C to 85°C (unless otherwise noted)

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(SR)}$	Input voltage range, $V_{(SR2)}$ and $V_{(SR1)}$	VSR = V(SR2) − V(SR1)	−0.25		0.25	V
$V_{(SROS)}$	Input offset				1	µV
INL	Integral nonlinearity error			0.004%	0.019%	

PLL SWITCHING CHARACTERISTICS

V_{DD} = 3.0 V to 3.6 V, T_A = −40°C to 85°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{(SP)}$	Start-up time [1]	0.5% frequency error				

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

OSCILLATOR

V_{DD} = 3.0 V to 3.6 V, T_A = −40°C to 85°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$f_{(exo)}$	Frequency error from 32.768kHz	ROSC = 100 kΩ	−2%	0.25%	2%	
		ROSC = 100 kΩ, V_{DD} = 3.3 V	−1%	0.25%	1%	
		XCK1 = 12-pF XTAL	−0.25%		0.25%	
$f_{(sxo)}$	Start-up time [1]	ROSC = 100 kΩ			250	µs
		XCK1 = 12-pF XTAL			200	ms

(1) The start-up time is defined as the time it takes for the oscillator output frequency to be within 1% of the specified frequency.

DATA FLASH MEMORY CHARACTERISTICS

V_{DD} = 3.0 V to 3.6 V, T_A = −40°C to 85°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{DR}	Data retention		[1]10			Years
	Flash programming write-cycles	[1]		20,000		Cycles
$t_{(WORDPROG)}$	Word programming time	[1]			2	ms
$I_{(DDPROG)}$	Flash-write supply current	[1]		8	15	mA

(1) Assured by design. Not production tested

REGISTER BACKUP

V_{DD} = 3.0 V to 3.6 V, T_A = −40°C to 85°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$I_{(RBI)}$	RBI data-retention input current [1]	VRB_I > 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.

TEXAS INSTRUMENTS
www.ti.com

SMBus TIMING SPECIFICATIONS

V_{DD} = 3.0 V to 3.6 V, T_A = −40°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		
t_{BUF}	Bus free time between start and stop		4.7			μs
$t_{HD:STA}$	Hold time after (repeated) start		4.0			
$t_{SU:STA}$	Repeated start setup time		4.7			
$t_{SU:STO}$	Stop setup time		4.0			
$t_{HD:DAT}$	Data hold time	Receive mode	0			ns
		Transmit mode	300			
$t_{SU:DAT}$	Data setup time		250			
$t_{TIMEOUT}$	Error signal/detect		[1]25		35	ms
t_{LOW}	Clock low period		4.7			μs
tHIGH	Clock high period		[2]4.0		50	
$t_{LOW:SEXT}$	Cumulative clock low slave extend time				[3]25	ms
$t_{LOW:MEXT}$	Cumulative clock low master extend time				[4]10	
t_F	Clock/data fall time	(V_{ILMAX}− 0.15 V) to (V_{IHMIN} + 0.15 V)			300	ns
t_R	Clock/data rise time	0.9 VDD to (VILMAX – 0.15 V)			1000	

(1) The bq20z80 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 The bq20z80 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.

SMBus TIMING DIAGRAM
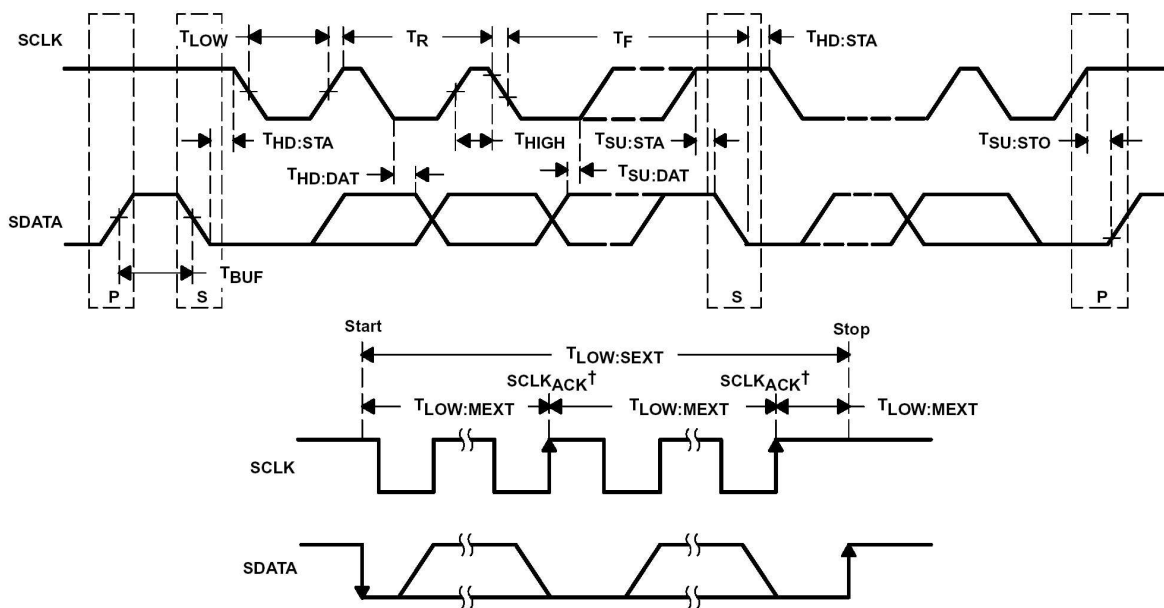
. SCLK$_{ACK}$ is the acknowledge-related clock pulse generated by the master.

FUNCTIONAL DESCRIPTION

OSCILLATOR FUNCTION

The oscillator of the bq20z80 can be set up for internal or external operation. On powerup, the bq20z80 automatically attempts to start the internal oscillator. If a 100-kΩ resistor is not connected to ROSC (pin 33), then it attempts to start the oscillator using an external 32.768-kHz crystal.

NOTE:

> Install either the 100-kΩ ROSC resistor *or* the 12-pF, 32.768-kHz crystal. Do not install both.

The performance of the internal oscillator depends on the tolerance of the 100-kΩ resistor between RSOC (pin 33) and VSSA (pin 34). Choose a resistor with a tolerance of ±0.1%, and 50-ppm or better temperature drift. Place this resistor as close as possible to the bq20z80. If a 12-pF crystal, is used, place it as close as possible to the XCK1 (pin 34) and XCK2 (pin 33) pins. If not properly implemented, the PCB layout in this area can degrade oscillator performance. 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), so the error cancels out.

SYSTEM PRESENT OPERATION

The bq20z80 periodically (<1 s) pulls the PU output high. Connect this pin to the $\overline{\text{PRES}}$ pin of the bq20z80 via a resistor of approximately 5 kΩ. The bq20z80 measures the $\overline{\text{PRES}}$ input during the PU-active period to determine its state.

The bq20z80 detects that the battery is present in the system via a low state on the $\overline{\text{PRES}}$ input. When this occurs, the bq20z80 enters normal operating mode and sets the PRES bit in *SBS.OperationStatus( )*. When the pack is removed from the system and the $\overline{\text{PRES}}$ input is high, the bq20z80 enters the battery-removed state, disabling the charge and discharge FETs, and enabling the 0-V/precharging FET. If *DF.OperationConfiguration,NR* is set, the $\overline{\text{PRES}}$ input is ignored and can be left floating.

GENERAL OPERATION

The bq20z80 determines battery capacity by monitoring individual cell impedance, and the amount of charge input or removed from a rechargeable battery. In addition to measuring impedance, charge, and discharge, the bq20z80 measures individual cell voltages, pack voltage, temperature, and current using features of the bq29312 AFE device.

The bq20z80 measures charge/discharge activity by monitoring the voltage across a small-value series sense resistor between the cell stack negative terminal and the negative terminal of the battery pack. The individual cell impedance is measured using the open-circuit voltage (OCV), and the change of voltage vs change of coulombs measured under load.

The bq20z80 interfaces with the bq29312 to perform battery protection, cell balancing, and voltage translation functions. The bq20z80 can accept inputs of up to two identical NTC thermistors (default is Semitec 103AT) for temperature measurement, or can also be configured to use its internal temperature sensor. The bq20z80 uses temperature to monitor the battery-pack environment.

BATTERY PARAMETER MEASUREMENTS

The bq20z80 uses an integrating sigma-delta analog-to-digital converter (ADC) for current measurement, and a second sigma-delta ADC for individual cell and battery voltage, and temperature measurement. The individual cell and pack voltages, *SBS.VCELLx( ), SBS.Voltage( ), SBS.Current( ), SBS.AverageCurrent( )*, and *SBS.Temperature( )* are updated at 1-second intervals during normal operation.

FUNCTIONAL DESCRIPTION (continued)

Charge and Discharge Counting

The integrating ADC measures the charge/discharge flow of the battery by measuring the voltage drop across a small-value sense resistor between the SR1 and SR2 pins. The integrating ADC measures bipolar signals from -0.25 V to 0.25 V. The bq20z80 detects charge activity when VSR = $V_{(SR1)}$-$V_{(SR2)}$ is positive and discharge activity when V_{SR} = $V_{(SR1)}$-$V_{(SR2)}$ is negative. The bq20z80 continuously integrates the signal over time, using an internal counter. The fundamental rate of the counter is 0.65 nVh.

Coulomb Counter Dead Band

The bq20z80 does not accumulate charge or discharge for gas gauging when the current input is below the dead-band current threshold. The threshold is programmed in *DF.CCDeadBand* and should be set sufficiently high to prevent false signal detection with no charge or discharge flowing through the sense resistor.

Voltage

The bq20z80 monitors the individual series cell voltages through the bq29312 at one-second intervals. The bq20z80 configures the bq29312 to connect the selected cell to the CELL pin of the bq29312, typically connected to VIN of the bq20z80. The internal ADC of the bq20z80 measures the voltage and scales it appropriately, then reports the *SBS.Voltage( )* and the individual cell voltages in *SBS.VCELL1( )*, *SBS.VCELL2( )*, *SBS.VCELL3( )*, and *SBS.VCELL4( )*. This data is also used to calculate the impedance of the cell for the ImpedanceTrack gas-gauging when *SBS.Current( )* is below 200 mA and dV/dt is <1 μV/sec.

Current

The bq20z80 uses the SR1 and SR2 inputs to measure and calculate the battery charge and discharge current. This value is reported via *SBS.Current( )* and is updated at one-second intervals in normal mode, and at intervals defined by *DF.SleepTime* in sleep mode. *SBS.AverageCurrent( )* is implemented as a single-pole infinite-impulse response (IIR) filter with a 14.5-s time constant using *SBS.Current( )* data.

Auto Calibration

The bq20z80 provides an auto-calibration feature to cancel the voltage offset error across SR1 and SR2 for maximum charge measurement accuracy. The bq20z80 performs auto-calibration when the SMBus lines stay low continuoesly for a minimum of 20 s. The bq20z80 is capable of automatic offset calibration down to 1μV.

Temperature

The bq20z80 TS1 and TS2 inputs, in conjunction with two identical NTC thermistors, measure the battery environmental temperature. The bq20z80 can also be configured to use its internal temperature sensor. The bq20z80 reports temperature via *SBS.Temperature( )* depending on the state of bits *TEMP0* and *TEMP1* in *DF.OperationConfiguration*.

Table 1. Temperature Sensor Selection

TEMP1	TEMP0	SBS TEMPERATURE () SOURCE
0	0	Internal Temperature Sensor
0	1	TS1 Input (default)
1	0	Most extreme of TS1 or TS2 Inputs
1	1	Average of TS1 and TS2 Inputs

Gas Gauging

The bq20z80 ImpedanceTrack feature gas-gauges a 2-, 3-, or 4-series-cell Li-Ion battery by using open-circuit voltage (OCV) when the system is in a relaxed state, and charge integration (coulomb counting) when the system is under load. These measurements determine *Chemical State of Charge* (*SOC*) and *Chemical Capacity* (*Qmax*). The initial *DF.Qmax Pack*, *DF.Qmax Cell 1*, *DF.Qmax Cell2*, *DF.Qmax Cell3*, and *DF.Qmax Cell4* values are taken from the cell data sheet, and are also used for the *SBS.DesignCapacity( )* value. The bq20z80 acquires and updates the battery-impedance profile during normal battery usage. It uses this profile, along with *SOC* and the *Qmax* values, to determine *SBS.FullChargeCapacity( )* (*FCC*) and *SBS.RelativeStateOfCharge* (*RSOC*) specifically for the present load and temperature. *SBS.FCC( )* is reported as capacity or energy available from a fully charged battery under the present load and temperature until *SBS.Voltage( )* reaches the *DF.Terminate Voltage*.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
QMax Pack	Maximum Chemical Pack Capacity	Integer	0 to 60000	2	mAh	4400
Qmax Cell 1	Maximum Chemical Cell 1 capacity	Integer	0 to 60000	2	mAh	4400
Qmax Cell 2	Maximum Chemical Cell 2 capacity	Integer	0 to 60000	2	mAh	4400
Qmax Cell 3	Maximum Chemical Cell 3 capacity	Integer	0 to 60000	2	mAh	4400
Qmax Cell 4	Maximum Chemical Cell 4 capacity	Integer	0 to 60000	2	mAh	4400

SBS.FullChargeCapacity( ) Updating

The bq20z80 updates *SBS.FCC( )* each time the resistance data is updated—up to 15 times through a full discharge.

SBS.RemainingCapacity( ) and SBS.RemainingStateOfCharge( ) Updating

The bq20z80 updates *SBS.RemainingCapacity( )* at one-second intervals as coulomb transfers are measured, and updates *SBS.RemainingStateOfCharge( )* each time *SBS.FullChargeCapacity( )* or *SBS. RemainingCapacity( )* is updated. *SBS.FullChargeCapacity( )* and *SBS.RemainingCapacity( )* are smoothed to prevent *SBS.RemainingCapacity( )* from increasing during discharge, or from decreasing during charge. *SBS.RemainingCapacity( )* is also prevented from changing more than 1% over a period of *DF.RSOC_STEP* seconds in either direction.

If *DF.RSOC_STEP* = 0, *SBS.FullChargeCapacity( )* and *SBS.RemainingCapacity( )* are not smoothed, and *SBS.RemainingCapacity( )* steps are not capped.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
RSOCSTEP	RSOC Step Limit	Integer	0 to 256	1	Seconds	0

ImpedanceTrack Load Model

During normal operation, the battery-impedance profile compensation of the ImpedanceTrack algorithm can provide more accurate full-charge and remaining state-of-charge information if the typical load type is known. There are two selectable options; constant-current, and constant-power. These are selected by the *DF.ITConfiguration, LoadMode1, 2* bits.

DF.ITConfiguration		COMPENSATION
LoadMode2	**LoadMode1**	
0	0	Constant current
0	1	Constant power
1	0	Reserved
1	1	Reserved

bq20z80

ImpedanceTrack Load Compensation

The bq20z80 can be configured to use a variety of load-compensation factors. These are selected, as shown in Table 2, by setting the *DF.LoadSelect* value.

Table 2. ImpedanceTrack Load-Compensation Settings

LoadSelect (hex)	LoadMode	Load Compensation
00	Constant Current	Previous Discharge Average Current
	Constant Power	Previous Discharge Average Power
01	Constant Current	Present Discharge Average Current
	Constant Power	Present Discharge Average Power
02	Constant Current	SBS.Current( )
	Constant Power	SBS.InstantPower( ) = SBS.Current( ) x SBS.Voltage( )
03	Constant Current	SBS.AverageCurrent( )
	Constant Power	SBS.AveragePower( ) = SBS.AverageCurrent( ) x SBS.Voltage( )
04	Constant Current	SBS.DesignCapacity( ) / 5
	Constant Power	SBS.DesignEnergy( ) / 5
05	Constant Current	SBS.AtRate( ) (mAh)
	Constant Power	SBS.AtRate( ) (10mWh)
06	Constant Current	DF.UserDefinedCurrent
	Constant Power	DF.UserDefinedCurrent x SBS.DesignVoltage( )

Reserve Battery Capacity

The bq20z80 allows a fixed amount of capacity to be reserved between the point where *SBS.RemainingCapacity( )* is reported as 0%, and the absolute minimum voltage, *DF.TerminateVoltage threshold (TV)*. This enables a system to report zero energy, but still have enough reserve energy to perform a controlled shutdown, or to provide an extended sleep period for the host system.

The *DF.TerminateVoltage* threshold is a battery voltage based on, and compared to *SBS.Voltage( )*.

Also, if *DF.OperationConfiguration, ResCap* = 0, the reserve capacity is compensated at a light-load level (C/20). However, if *DF.OperationConfiguration, ResCap* = 1, then the reserve capacity is compensated for the present discharge rate.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
TVT	Terminate Voltage Cell Threshold	Integer	0 to 20000	2	mV	3000
ResCap	Reserve Capacity	Integer	0 to 2000	2	mAh	250

Discharge and Charge Alarms

The bq20z80 enables the *SBS.BatteryStatus( )Terminate_Discharge_Alarm*, *Fully_Discharged*, *Terminate_Charge_Alarm* and *Fully_Charged* flags based on the following thresholds based on *SBS.RelativeStateOfCharge( )* or *SBS.AbsoluteStateOfCharge( )* depending on the *DMODE* setting of *DF.Operation Configuration*.

- When *SBS.RSOC( )* or *SBS.ASOC( )*≤*DF.TDASet*, *Terminate_Discharge_Alarm* is set.
- When *SBS.RSOC( )* or *SBS.ASOC( )*≥*DF.TDAClear*, *Fully_Discharged* is cleared.
- When *SBS.RSOC( )* or *SBS.ASOC( )*≤*DF.FDSet*, *Terminate_Discharge_Alarm* is set.
- When *SBS.RSOC( )* or *SBS.ASOC( )*≥*DF.FDClear*, *Fully_Discharged* is cleared.
- When *SBS.RSOC( )* or *SBS.ASOC( )*≥*DF.TCASet*, *Terminate_Charge_Alarm* is set.
- When *SBS.RSOC( )* or *SBS.ASOC( )*≤*DF.TCAClear*, *Terminate_Charge_Alarm* is cleared.
- When *SBS.RSOC( )* or *SBS.ASOC( )*≥*DF.FCSet*, *Fully_Charged* is set.
- When *SBS.RSOC( )* or *SBS.ASOC( )*≤*DF.FCClear*, *Fully_Charged* is cleared.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
TDASet	*TDA* Set Threshold[1]	Unsigned Char	0 to 101	1	%	6
TDAClear	*TDA* Clear Threshold[1]					8
FDSet	*FD* Set Threshold[1]					2
FDClear	*FD* Clear Threshold[1]					5
TCASet	*TCA* Set Threshold[2]					100
TCAClear	*TCA* Clear Threshold[2]					95
FCSet	*FC* Set Threshold[2]					100
FCClear	*FC* Clear Threshold[2]					98

(1) Setting to 101% prevents the *TDA* or *FD* flag from being set or cleared based on *SBS.RelativeStateOfCharge( )*.
(2) Setting to 0% prevents the *TCA* or *FC* flag from being set or cleared based on *SBS.RelativeStateOfCharge( )*.
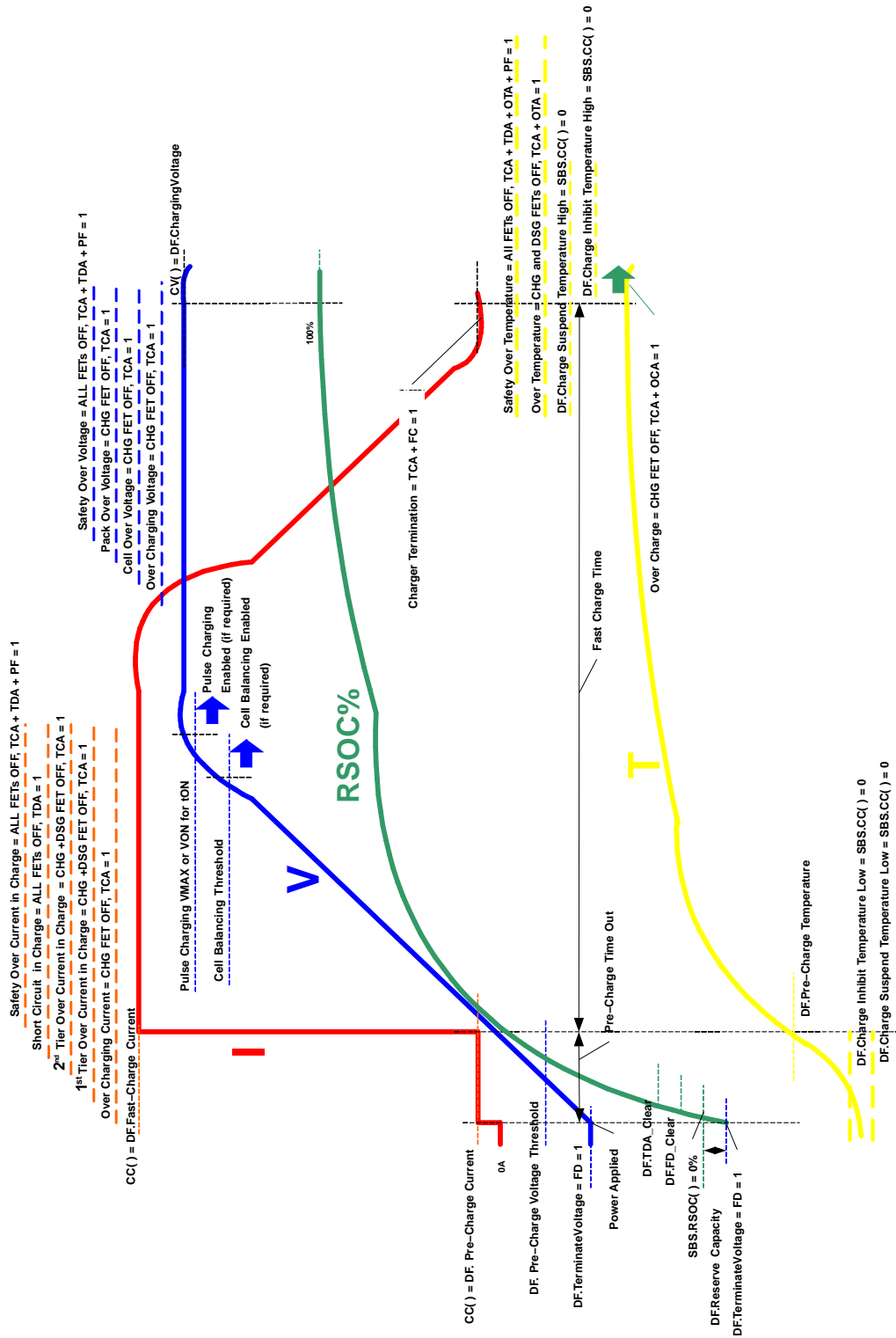
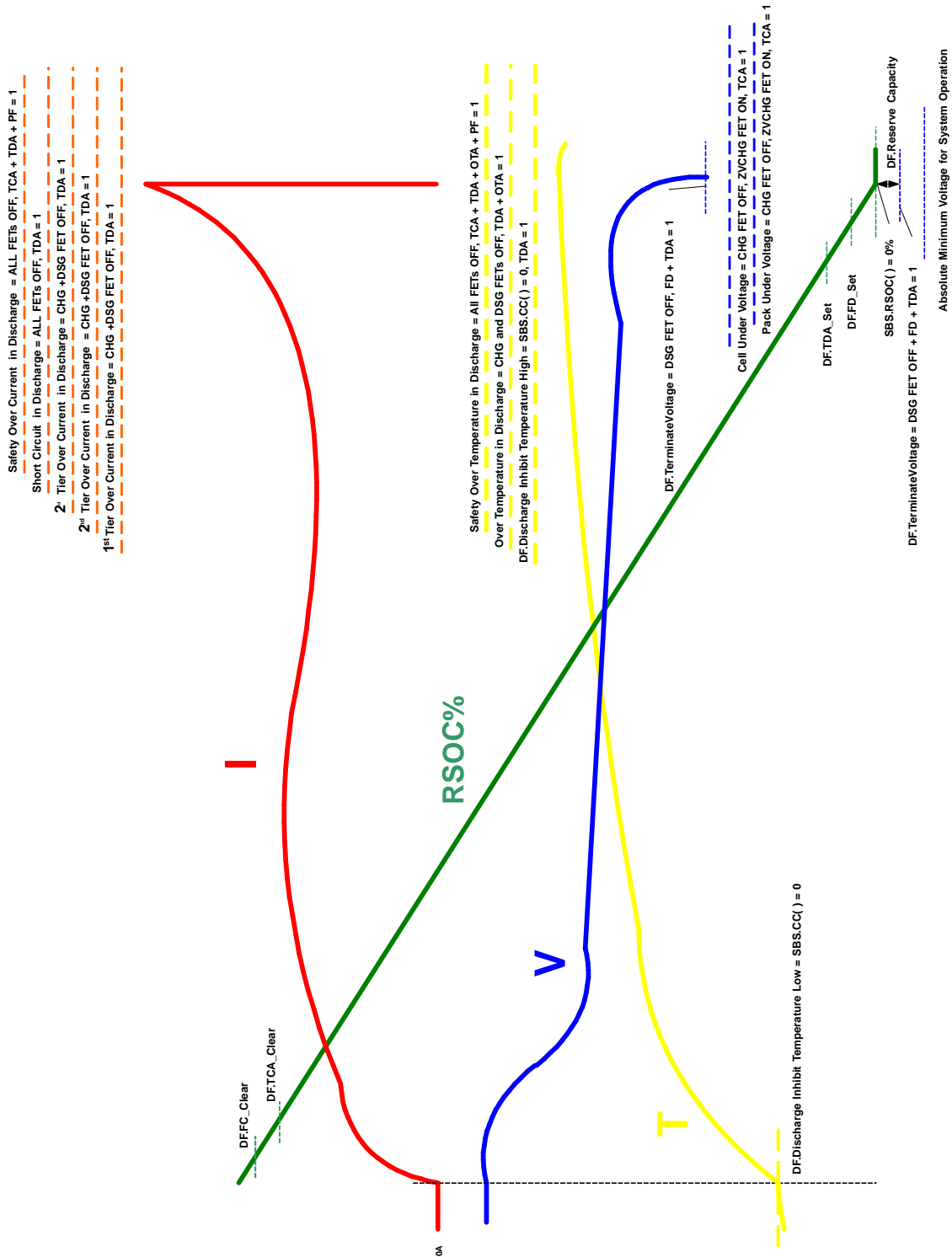**Figure 1. Typical Charge Profile of Measured Parameters and the Associated FET and Flag States**

Figure 2. Typical Discharge Profile of Measured Parameters and the Associated FET and Flag States

PRIMARY SAFETY FEATURES

The bq20z80 supports a wide range of battery- and system-protection features that are easily configured via the integrated data flash.

Cell Overvoltage

The bq20z80 can disable charging by turning off the charge FET if any cell voltage is equal to or greater than the *DF.CellOverVoltage* (*COV*) threshold for a period equal to or greater than *DF.CellOverVoltageTime* (*COVT*). This feature is disabled if *COVT* = 0,.

During the time between when an excessive voltage is first detected and the expiration of *COVT*, the *COV* bit in *SBS.SafetyAlert( )* is set. If, during this period, the voltage falls below the *COV* threshold, this flag is cleared.

If *COVT* expires, the charge FET is turned off. The ZVCHG FET is also turned off if the *DF.OperationConfiguration, ZVCHGx* bits are set appropriately. Also, when *COVT* expires, *SBS.ChargingCurrent( )* is set to 0, *SBS.ChargingVoltage( )* is cleared, *SBS.BatteryStatus( ) Terminate_Charge_Alarm* is set, and the *COV* bit in *SBS.SafetyStatus( )* is set.

For the bq20z80 to fully recover from a cell overvoltage condition, all *SBS.VCELLx( )* reports must be equal to or less than the *DF.CellOverVoltageRecovery* (*COVR*) threshold. When this occurs, the charge FET is allowed to be turned on only if other safety and configuration states permit. On recovery from an overvoltage condition, *SBS.BatteryStatus( ) Terminate_Charge_Alarm* is reset, *SBS.ChargingCurrent( )* and *SBS.ChargingVoltage( )* are set to the appropriate value per the charging algorithm, and the *COV* bit in *SBS.SafetyStatus( )* is reset.

However, when the bq20z80 has the *COV* bit set, the charge FET will be turned on again while *SBS.Current( )* is reported to be less than or equal to the *DF.DischargeDetectionThreshold (IDSG)*. No other flags change state until full recovery is reached. This prevents overheating the charge-FET body diode during discharge from an overvoltage condition.

Cell Overvoltage Threshold Compensation

If the bq20z80 is detects charging (*SBS.BatteryStatus( ) DISCHARGING* = 0), the actual threshold for cell-overvoltage detection is reduced, based on the reported *SBS.Temperature( )*.

If *SBS.Temperature( )* is greater than *DF.OverTemperatureInCharge–DF.TemperatureHysteresis* (*THYS*), the actual cell-overvoltage threshold used is *DF.CellOverVoltage*–COV_{DELTA}. However, if COV_{DELTA} = 0 then the compensation of the cell-overvoltage threshold is disabled.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
COV	Cell Overvoltage Threshold	Integer	3700 to 5000	2	mV	4300
COVR	Cell Overvoltage Recovery Threshold	Integer	0 to 5000	2	mV	4150
COVT	Cell Overvoltage Time	Integer	0 to 60	1	s	2
COV_{DELTA}	Cell Overvoltage Delta	Integer	0 to 200	1	mV	20
THYS	Cell Overvoltage Temperature Hysteresis	Integer	0 to 200	1	0.1oC	150

Pack Overvoltage

The bq20z80 can disable charging by turning off the charge FET if the pack voltage is equal to or greater than the *DF.PackOverVoltage* (*POV*) threshold for a period equal to or greater than *DF.PackOverVoltageTime* (*POVT*). However, if *POVT* = 0, this feature is disabled.

During the period between when an excessive voltage is detected and the expiration of *POVT*, the *POV* bit in *SBS.SafetyAlert( )*. If, during this period, the voltage falls below the *POV* threshold, this flag is cleared.

If *POVT* expires, the charge FET is turned off. The ZVCHG FET is also turned off if the *DF.OperationConfiguration, ZVCHGx* bits are set appropriately. Also, when *POVT* expires, *SBS.ChargingCurrent( )* is set to 0, *SBS.ChargingVoltage( )* is cleared, *SBS.BatteryStatus( ) Terminate_Charge_Alarm* is set, and the *POV* bit in *SBS.SafetyStatus( )* is set.

For the bq20z80 to fully recover from a pack overvoltage condition, *SBS.Voltage( )* must be equal to or less than the *DF.PackOverVoltageRecovery* (*POVR*) threshold. When this occurs, the charge FET is allowed to be turned on only if other safety and configuration states permit. On recovery from a pack overvoltage condition, *SBS.BatteryStatus( ) Terminate_Charge_Alarm* is reset, *SBS.ChargingCurrent( )* and *SBS.ChargingVoltage( )* are set to the appropriate value per the charging algorithm, and the *POV* bit in *SBS.SafetyStatus( )* is reset.

However, when the bq20z80 has the *POV* bit set, the charge FET is turned on again while *SBS.Current( )* is reported to be less than or equal to the *DF.DischargeDetectionThreshold* (*IDSG*). No other flags change state until the full recovery is reached. This prevents overheating the charge-FET body diode during discharge from an overvoltage condition.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
POV	Pack Overvoltage Threshold	Integer	0 to 30000	2	mV	17500
POVR	Pack Overvoltage Recovery Threshold	Integer	0 to 30000	2		16000
POVT	Pack Overvoltage Time	Integer	0 to 60	1	s	2

Cell Undervoltage

The bq20z80 can disable discharging by turning off the discharge FET if any cell voltage is equal to or less than the *DF.CellUnderVoltage (CUV)* threshold for a period equal to or greater than *DF.CellUnderVoltageTime (CUVT)*. This feature is disabled if *CUVT* = 0.

During the period between the time when a low voltage is first detected and the expiration of *CUVT*, the *CUV* bit in *SBS.SafetyAlert( )* is set. If, during this period, the voltage falls below the *CUV* threshold, this flag is cleared.

If *CUVT* expires, the discharge FET is turned off and the ZVCHG FET is turned on if *DF.OperationConfiguration, ZVCHGx* bits are set appropriately. Also, when *CUVT* expires *SBS.ChargingCurrent( )* is cleared, *SBS.ChargingVoltage( )* is cleared, *SBS.BatteryStatus( ) Terminate_Discharge_Alarm* is set, and the *CUV* bit in *SBS.SafetyStatus( )* is set.

For the bq20z80 to fully recover from a cell undervoltage condition all *SBS.VCELLx( )* reports should be equal to or greater than the *DF.CellUnderVoltageRecovery* (*CUVR*) threshold. When this occurs, the discharge FET is allowed to be turned on only if other safety and configuration states permit. On recovery from an undervoltage condition, *SBS.BatteryStatus( ) Terminate_Discharge_Alarm* is reset, *SBS.BatteryStatus( ) Fully_Discharged* is set, *SBS.ChargingCurrent( )* and *SBS.ChargingVoltage( )* are set to the appropriate value per the charging algorithm, and the *CUV* bit in *SBS.SafetyStatus( )* is reset.

However, when the bq20z80 has the *CUV* bit set, the discharge FET is turned on again as long as *SBS.Current( )* is reported to be greater than or equal to the *DF.ChargeDetectionThreshold (ICHG)*. No other flags change state until full recovery is reached. This prevents overheating the discharge-FET body diode during charging from an undervoltage condition.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
CUV	Cell Under Voltage Threshold	Integer	0 to 3500	2	mV	2800
CUVR	Cell Under Voltage Recovery Threshold	Integer	0 to 3600	2		3000
CUVT	Cell Under Voltage Time	Integer	0 to 60	1	s	2
ICHG	Charge Detection Current	Integer	0 to 2000	2	mA	60

Pack Undervoltage

The bq20z80 can disable discharging by turning off the discharge FET if *SBS.Voltage( )* is equal to or less than the *DF.PackUnderVoltage* (*PUV*) threshold for a time period equal to or greater than *DF.PackUnderVoltageTime* (*PUVT*). This feature is disabled if *PUVT* = 0.

During the period between the time when a low voltage is first detected and the expiration of *PUVT*, the *PUV* bit in *SBS.SafetyAlert( )* is set. If, during this period, the voltage falls below the *PUV* threshold, this flag is cleared.

If *PUVT* expires, the discharge FET is turned off and the ZVCHG FET is turned on if *DF.OperationConfiguration, ZVCHGx* bits are set appropriately. Also when *PUVT* expires, *SBS.ChargingCurrent( )* is cleared, *SBS.ChargingVoltage( )* is cleared, *SBS.BatteryStatus( ) Terminate_Discharge_Alarm* is set, and the *PUV* bit in *SBS.SafetyStatus( )* is set.

For the bq20z80 to fully recover from a pack undervoltage condition, *SBS.Voltage( )* should be equal to or greater than the *DF.PackUnderVoltageRecovery* (*PUVR*) threshold. When this occurs, the discharge FET is allowed to be turned on only if other safety and configuration states permit. On recovery from a pack undervoltage condition,*SBS.BatteryStatus( ) Terminate_Discharge_Alarm* is reset, *SBS.BatteryStatus( ) Fully_Discharged* is set, *SBS.ChargingCurrent( )* and *SBS.ChargingVoltage( )* are set to the appropriate value per the charging algorithm, and the *PUV* bit in *SBS.SafetyStatus( )* is reset.

However, when the bq20z80 has the *PUV* bit set, the discharge FET is turned on again, as long as *SBS.Current( )* is reported to be greater than or equal to the *DF.ChargeDetectionThreshold* (*ICHG*). No other flags change state until full recovery is reached. This prevents overheating the discharge-FET body diode during charging from an undervoltage condition.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
PUV	Pack Under Voltage	Integer	0 to 16000	2	mV	11000
PUVR	Pack Under Voltage Recovery	Integer	0 to 16000	2		12000
PUVT	Pack Under Voltage Time	Integer	0 to 60	1	s	2

Charge and Discharge Overcurrent

The bq20z80 has two independent tiers of overcurrent protection for discharge and charge. These two tiers require the *SBS.Current( )* to be equal to or greater than a programmed threshold in either charge or discharge current for a period equal to or greater than a programmable time. If the programmable time for any of the current-protection levels is set to 0, that specific feature is disabled.

The bq29312 provides a third level of discharge overcurrent protection that reacts according to the bq29312 internal settings. The bq29312 discharge overcurrent (overload) is configured by the bq20z80, where *DF.AFEOverCurrent* (*AOCD*) and *DF.AFEOverCurrentTime* (*AOCT*) are used to provide the current threshold and delay timing. See the bq29312 data sheet for the appropriate values to use.

For the first two tiers of overcurrent protection, during the period between when excessive current is detected and the expiration of the timer, the respective *SBS.SafetyAlert( )* bit is set. If the timer expires, or *SBS.Current( )* returns within normal operating parameters, the *SBS.SafetyAlert( )* bit is cleared.

	DF THRESHOLD	DF TIME	FET	SBS.SAFETYALERT( ), SBS.SAFETYSTATUS( ) AND DF.NRCONFIG	DF CLEAR THRESHOLD
Tier-1 Charge	Overcurrent,Charge (OCC)	Overcurrent, Charge Time (OCCT)	CHG	OCC	Overcurrent, Charge Recovery (OCC)
Tier-2 Charge	Overcurrent, Charge 2 (OCC2)	Overcurrent, Charge Time 2 (OCC2T)	CHG	OCC2	
Tier-1 Discharge	Overcurrent, Discharge (OCD)	Overcurrent, Discharge Time (OCDT)	DSG	OCD	Overcurrent, Dis-charge Recovery (OCD)
Tier-2 Discharge	Overcurrent, Discharge 2 (OCD2)	Overcurrent, Discharge Time 2 (OCD2T)	DSG	OCD2	
Tier-3 Discharge	AFE Overcurrent, Dis-charge (AOCD)	AFE Overcurrent, Discharge Time (AOCDT)	CHG, DSG	AOCD[1]	

(1) No SBS.SafetyAlert( ) flag

If the timer of any tier expires during charge, the charge FET is turned off and the ZVCHG FET is turned off if the *DF.OperationConfiguration, ZVCHGx* bits are set appropriately. When this occurs, the *AFE_Current_Fault* timer is started from 0, *SBS. ChargingCurrent( )* is cleared, *SBS.ChargingVoltage( )* is cleared, *SBS.BatteryStatus( ) Terminate_Charge_Alarm* is set, and the correct tier flag is set in *SBS.SafetyStatus( )*.

However, when the bq20z80 has either *SBS.SafetyStatus( )OCC* or *OCC2* set, the charge FET is turned on again, as long as *SBS.Current( )* is reported to be less than or equal to the *DF.DischargeDetectionThreshold* (*IDSG*). No other flags change state until full recovery is reached. This prevents overheating the charge-FET body diode during discharge. This action is not affected by the state of the *NR* bit in *DF.OperationConfiguration*.

If the timer of either of the first two tiers expires during discharge, the discharge FET is turned off and the ZVCHG FET is turned on if the *DF.OperationConfiguration, ZVCHGx* bits are set appropriately. When this occurs the *AFE_Current_Fault* timer is started from 0, *SBS.ChargingCurrent( )* is cleared, *SBS.BatteryStatus( )Terminate_Discharge_Alarm* is set, and the correct tier flag is set in *SBS.SafetyStatus( )*.

When the bq29312 detects a discharge-overcurrent fault, the charge and discharge FETs are turned off, the EVENT pin of the bq20z80 is driven low, and the bq29312 is interrogated. When the bq20z80 identifies the overcurrent condition, the *AFE_Current_Fault* timer is started from 0, *SBS.BatteryStatus( ) Terminate_Discharge_Alarm* is set, *SBS.ChargingCurrent( )* is cleared, and the *AOCD* bit in *SBS.SafetyStatus( )* is set.

However, when the bq20z80 has *SBS.SafetyStatus( )OCD*, *OCD2* or *AOCD* set, the FETs are turned on again, as long as *SBS.Current( )* is reported to be less than or equal to the *DF.DischargeDetectionThreshold* (*IDSG*). No other flags change state until full recovery is reached. This prevents overheating the charge-FET body diode during discharge. This action is not affected by the state of the *NR* bit in *DF.OperationConfiguration*.

The bq20z80 can individually configure each overcurrent-protection feature to recover via two different methods based on the *NR* bit in *DF.OperationConfiguration*.

Standard Recovery, where *DF.OperationConfiguration.NR* = 0, and the overcurrent tier is selected in *DF.NRConfig*. When the pack is removed and re-inserted the condition is cleared. Pack removal and re-insertion is detected by a high-to-low transition on the $\overline{\text{PRES}}$ input. When the tier is not selected in *DF.NRConfig*, that particular feature uses the Non-Removable Battery Mode recovery.

Non-Removable Battery Mode Recovery where *DF.OperationConfiguration.NR* = 1. The state of *DF.NRConfig* has no consequence when *DF.OperationConfiguration.NR* = 1. This recovery requires *SBS.AverageCurrent( )* to be less than or equal to the respective recovery threshold, and for the *AFE_Current_Fault* timer to be equal to or greater than *DF.Current Recovery Time*.

When a charge-fault recovery condition is detected, then the charge FET is allowed to be turned on, if other safety and configuration states permit. , the ZVCHG FET is turned off if the *DF.OperationConfiguration, ZVCHGx* bits are set appropriately, *SBS.BatteryStatus( ) Terminate_Charge_Alarm* is reset, *SBS.ChargingCurrent( )* and *SBS.ChargingVoltage( )* are set to the appropriate value per the charging algorithm, and the appropriate *SBS.SafetyStatus( )* flag is reset.

When a discharge-fault recovery condition is detected, the discharge FET is allowed to be turned on if other safety and configuration states permit. The ZVCHG FET is turned off if the *DF.OperationConfiguration, ZVCHGx* bits are set appropriately, *SBS.BatteryStatus( ) Terminate_Discharge_Alarm* is reset, *SBS.ChargingCurrent( )* and *SBS.ChargingVoltage( )* are set to the appropriate value per the charging algorithm, and the appropriate *SBS.SafetyStatus( )* flag is reset.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
OCC	Overcurrent, Charge Threshold	Integer	0 to 20000	2	mA	4000
OCCR	Overcurrent, Charge Recovery		0 to 2000	2	mA	200
OCCT	Overcurrent, Charge Time		0 to 60	1	s	5
CRT	Current Recovery Time		0 to 60	1	s	10
OCD	Overcurrent, Discharge Threshold		0 to 20000	2	mA	4000
OCDR	Overcurrent, Discharge Recovery		0 to 20000	2	mA	200
OCDT	Overcurrent, Discharge Time		0 to 60	1	s	5
OCC2	Tier-2 Overcurrent, Charge Threshold		0 to 20000	2	mA	6000
OCC2T	Tier-2 Overcurrent, Charge Time		0 to 60	1	s	2
OCD2	Tier-2 Overcurrent, Discharge Threshold		0 to 20000	2	mA	6000
OCD2T	Tier-2 Overcurrent, Discharge Time		0 to 60	1	s	2
AOCD	AFE Overcurrent, Discharge Setting	Hex	00 to 1f	1	–	–
AOCDR	AFE Overcurrent, Discharge Recovery	Integer	0 to 500	2	mA	100
AOCDT	AFE Overcurrent, Discharge Time Setting	Hex	00 to 0f	1	–	–

Short Circuit Protection

The bq20z80 short-circuit protection is controlled by the bq29312, but is recovered by the bq20z80. This allows different recovery methods to accomodate various applications.

The bq29312 charge short-circuit and discharge short-circuit protection are configured by the bq20z80 in *DF.AFEShortCircuitInCharge* and *DF.AFEShortCircuitInDischarge*, respectively. See the bq29312 data sheet for the appropriate values to use.

Short Circuit	DF THRESHOLD & DF.Time	FET	SBS.SAFETYSTATUS( ) AND DF.NRCONFIG	DF CLEAR THRESHOLD
Charge	Short Circuit in Charge (ASCC)	CHG	ASCC	Short Circuit Recovery
Discharge	Short Circuit in Discharge (ASCD)	DSG	ASCD	

When the bq29312 detects a short circuit in charge (*ASCC*) or short circuit in discharge (*ASCD*) fault, the charge and discharge FETs are turned off, the EVENT pin of the bq20z80 is driven low and the bq29312 is interrogated. When the bq20z80 identifies the short-circuit condition, the *AFE_Current_Fault* timer is started from 0, *SBS.BatteryStatus( ) Terminate_Discharge_Alarm* is set, *SBS.ChargingCurrent( )* is cleared, and the *ASCC* or *ASCD* bit in *SBS.SafetyStatus( )* is set.

However, when the bq20z80 has *SBS.SafetyStatus( ) SCC* set, the CHG FET is turned on again, as long as *SBS.Current( )* is reported to be less than or equal to the *DF.DischargeDetectionThreshold* (*IDSG*). Also, when the bq20z80 has *SBS.SafetyStatus( ) SCD* set, the DSG FET is turned on again, as long as SBS.Current( ) is reported to be greater than or equal to *DF.ChargeDetectionThreshold* (*ICHG*). No other flags change state until full recovery is reached. This prevents overheating of charge- or discharge-FET body diode during operation. This action is not affected by the state of the *NR* bit in *DF.OperationConfiguration*.

Each bq20z80 short-circuit protection feature can be individually configured to recover via two different methods, based on the *NR* bit in *DF.OperationConfiguration*.

Standard Recovery is where *DF.OperationConfiguration.NR* = 0 and the overcurrent tier is selected in *DF.NRConfig*. When the pack is removed and re-inserted, the condition is cleared. Pack removal and re-insertion is detected by transition on the $\overline{PRES}$ input from low to high to low. When the tier is not selected in *DF.NRConfig*, that particular feature uses the Non-Removable Battery Mode recovery.

Non-Removable Battery Mode Recovery is where *DF.OperationConfiguration.NR* = 1. The state of *DF.NRConfig* has no consequence when *NR* = 1. This recovery requires *SBS.AverageCurrent( )* to be less than or equal to the *DF.ShortCircuitRecovery* threshold and for the *AFE_Current_Fault* timer to be equal to or greater than *DF.Current Recovery Time*.

When the recovery condition for a charge fault is detected, the charge FET is allowed to be turned on if other safety and configuration states permit. The ZVCHG FET is turned off if the *DF.OperationConfiguration, ZVCHGx* bits are set appropriately. When this occurs, *SBS.BatteryStatus( ) Terminate_Charge_Alarm* is reset, *SBS.ChargingCurrent( )* and *SBS.ChargingVoltage( )* are set to the appropriate values per the charging algorithm, and the appropriate *SBS.SafetyStatus( )* flag is reset.

When the recovery condition for a discharge fault is detected, the discharge FET is allowed to be turned on if other safety and configuration states permit, and the ZVCHG FET is turned on if the *DF.OperationConfiguration, ZVCHGx* bits are set appropriately, *SBS.BatteryStatus( ) Terminate_Discharge_Alarm* is reset, *SBS.ChargingCurrent( )* and *SBS.ChargingVoltage( )* are set to the appropriate value per the charging algorithm, and the appropriate *SBS.SafetyStatus( )* flag is reset.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
SCC	Low Nibble = AFE Short Circuit, Charge Setting	Hex	x0 to xf			00
SCCT	High Nibble = AFE Short Circuit, Charge Time Setting	Hex	0x to fx		−	
SCD	Low Nibble = AFE Short Circuit, Discharge Setting	Hex	x0 to xf	1		x0
SCDT	High Nibble = AFE Short Circuit, Discharge Time Setting	Hex	0x to fx			0x
SCR	Short Circuit Recovery Threshold	Integer	v		mA	1

Over-Temperature Protection

The bq20z80 has over-temperature protection for both charge and discharge conditions. In either case, if *SBS.Temperature( )* is greater than or equal to the protection threshold for a period greater than or equal to the protection delay time then action is taken. However, if the delay time is set to 0 then the feature is disabled.

	DF THRESHOLD	DF TIME	FET	SBS.SAFETYALERT( ) SBS.SAFETYSTATUS( )	DF CLEAR THRESHOLD
Charge	Over Temperature, Charge (OTC)	Over Temperature, Charge Time (OTCT)	CHG	OTC	Over Temperature, Charge Recovery (OTCR)
Dis-charge	Over Temperature, Discharge (OTD)	Over Temperature, Discharge Time (OTDT)	DSG	OTD	Over Temperature, Discharge Recovery (OTDR)

During the period between detection of excessive temperature and the expiration of the timer, the respective *SBS.SafetyAlert( )* bit is set. If the timer expires or *SBS.Temperature( )* returns within the normal operation range, the *SBS.SafetyAlert( )* bit is cleared.

If OTC becomes set and if *DF.OperationConfiguration.OTFET* is set, the CHG FET is turned off and the ZVCHG FET turned off, if the *DF.OperationConfiguration, ZVCHGx* bits are set appropriatly. If *OTD* becomes set and if *DF.OperationConfiguration, OTFET* is set, the DSG FET turns off. If the *OTFET* bit is cleared, no FET action is taken. Also, *SBS.BatteryStatus( ) Over_Temperature_Alarm* is set, *SBS.ChargingCurrent( )* is cleared, *SBS.ChargingVoltage( )* is cleared, *SBS.BatteryStatus( ) Terminate_Charge_Alarm* or *SBS.BatteryStatus( ) Terminate_Discharge_Alarm* is set, and the corresponding flag in *SBS.SafetyStatus( )* is set.

However, when the bq20z80 has either *SBS.SafetyStatus( ) OTC* bit set, the CHG FET is turned on again, as long as *SBS.Current( )* is reported to be less than or equal to the *DF.DischargeDetectionThreshold* (*IDSG*). Also, when the bq20z80 has *SBS.SafetyStatus( ) OTD* set, the DSG FET is turned on again, as long as *SBS.Current( )* is reported to be less than or equal to the *DF.ChargeDetectionThreshold* (*ICHG*). No other flags change state until full recovery is reached. This prevents overheating the respective FET's body diode during operation. This action is not affected by the state of the *NR* bit in *DF.OperationConfiguration*.

For normal recovery to be achieved, *SBS.Temperature( )* must be less than or equal to the respective *DF.OverTemperature Recovery* in *Charge* or *DF.OverTemperature Recovery* in *Discharge*. When this occurs, the FETs are returned to the normal operating state if applicable, *SBS.BatteryStatus( ) Over_Temperature_Alarm* is cleared, *SBS.BatteryStatus( ) Terminate_Charge_Alarm* or *SBS.BatteryStatus( ) Terminate_Discharge_Alarm* is cleared, *SBS.ChargingCurrent( )* and *SBS.ChargingVoltage( )* are set to the appropriate values per the charging algorithm, and the appropriate *SBS.SafetyStatus( )* flag is reset.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
OTC	Over Temperature in Charge Threshold	Integer	0 to 1200	2	0.1°C	550
OTCR	Over Temperature in Charge Recovery		0 to 1200	2	0.1°C	450
OTCT	Over Temperature in Charge Time		0 to 60	1	s	2
ICHG	Charging Detection Current Threshold		0 to 2000	2	mA	50
OTD	Over Temperature in Discharge Threshold		0 to 1200	2	0.1°C	600
OTDT	Over Temperature in Discharge Delay		0 to 30	1	s	2
OTDR	Over Temperature Discharge Recovery		0 to 1200	2	0.1°C	500
IDSG	Discharging Detection Current Threshold		0 to 2000	2	mA	50

AFE Watchdog

The bq29312 incorporates a watchdog feature that automatically turns off the FETs if the bq29312 does not receive the appropriate frequency input on the WDI pin. The bq20z80 has no warning that this is about to happen, but can report that it occurred, once the bq20z80 can next interrogate the bq29312.

When the EVENT input of the bq20z80 is triggered by the XALERT pin of the bq29312, the bq20z80 reads *AFE.STATUS* and records the status to RAM for use by *SBS.AFEData( )* and other data management functions. If the *WDF* bit is set, the *WDF* bit in *SBS.Safety Status( )* is set, and periodic verification of the bq29312 RAM is undertaken. If 3 attempts of the periodic verification fail, the bq20z80 sets *AFE_P of DF.PF_Status* and enters permanent failure. See *Periodic AFE Verification* for further details.

If the periodic verification passes, the *WDF* flag in *SBS.SafetyStatus* is cleared and the FETs returned to normal operation.

Host Watchdog

The bq20z80 can be configured to require the host system to communicate with the battery periodically, else the battery disables charging and discharging. The Host Watchdog function is only active in Normal Power Mode and is disabled if the timeout period is set to 0.

If the bq20z80 does not receive any valid SMBus communications for a period of time equal to or greater than *DF.Host Watchdog Timeout*, the FETs are turned off, *SBS.ChargingVoltage( )* = 0, *SBS.ChargingCurrent( )* = 0, *SBS.BatteryStatus( )*, *TCA* and *TDA* are set, and *SBS.SafetyStatus( ) HWDG* is set.

For normal recovery to be achieved, normal SMBus communications must be resumed. When this occurs, the FETs are returned to the normal operating state, *SBS.BatteryStatus( ) Terminate_Charge_Alarm* and *SBS.BatteryStatus( ) Terminate_Discharge_Alarm* are cleared, *SBS.ChargingCurrent( )* and *SBS.ChargingVoltage( )* are set to the appropriate value per the charging algorithm, and the *HWDG SBS.SafetyStatus( ) flag* is reset.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
HWTO	Host Watchdog Timeout Period	Integer	0 to 240	1	s	10

SECONDARY PROTECTION FEATURES

The bq20z80 provides features that can be used to indicate a more serious fault via the $\overline{\text{SAFE}}$ output. This output can be used to blow an in-line fuse to permanently disable the battery pack from charge or discharge activity.

Actions on Detection of Secondary or Permanent Failure

When the bq20z80 *SBS.PFStatus( )* changes from 0x00 to indicate a permanent failure then the following actions are taken in sequence.

- CHG, DSG and ZVCHG FETs are turned OFF
- *SBS.BatteryStatus( ) Terminate_Charge_Alarm* and *Terminate_Discharge_Alarm* are set
- A backup of SBS data is stored to data flash including *SBS.Voltage( )*, *SBS.VCELL1( )*, *SBS.VCELL2( )*, *SBS.VCELL3( )*, *SBS.VCELL4( )*, *SBS.Current( )*, *SBS.Temperature( )*, *SBS.BatteryStatus( )*, *SBS.RemaingCapacity( )* , *SBS.SafetyStatus( )*, *SBS.ChargingStatus( )*, *AFE.Data* (Complete memory map)
- Data Flash write access is then disabled, but the data flash can be read.
- *SBS.ChargingCurrent( )* and *SBS.ChargingVoltage( )* are set to 0
- The appropriate bit in *DF.PFStatus* is set
- If the appropriate bit in *DF.PFConfig* is set then 0x3672 is programmed to *DF.PF_Flag* and the $\overline{\text{SAFE}}$ pin is driven and latched low
- *PF* in *SBS.SafetyStatus( )* is set

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
PF_FLAG	Permanent Failure Flag	Hex	0000 or 3672	2	–	0000

Clearing Permanent Failure

The bq20z80 permanent failure mode can be cleared by sending 2 *SBS.ManufacturerAccess( )* commands in sequence. See *SBS.ManufacturerAccess( )* for more details.

2nd Level Protection IC Input (PFIN)

The $\overline{\text{PFIN}}$ input of the bq20z80 can be used to determine the state of an external protection device such as the bq29400. If this pin is logic low for a period of time greater than or equal to *DF.PFINTime* (*PFINT*), the Permananet Failure Mode is entered. During the period of time between when $\overline{\text{PFIN}}$ is detected low and the expiration of *PFINT*, the *PFIN* bit in *SBS.PFAlert( )* is set.

If *DF.PFConfig XPFIN* is set, the $\overline{\text{SAFE}}$ pin is driven low. Also, if *PFINT* is set to 0, this feature is disabled.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
PFINT	PFIN Input Detection Time	Integer	0 to 30	1	s	0 (4 typ)

Safety Overvoltage Protection (SOV)

The bq20z80 reports a safety-overvoltage condition when *SBS.Voltage( )* is greater than or equal to the *DF.SafetyOverVoltage* (*SOV*) threshold for a period greater than or equal to the *DF.SafetyOverVoltageTime* (*SOVT*). During the period of time between when the excessive voltage is first detected and the expiration of *SOVT* the *SOV* bit in *SBS.PFAlert( )* is set.

If *DF.PFConfig XSOV* is set, the $\overline{\text{SAFE}}$ pin is driven low. If *SOVT* is set to 0, this feature is disabled.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
SOV	Safety Overvoltage Threshold	Integer	0 to 20000	2	mV	18000
SOVT	Safety Overvoltage Time	Integer	0 to 30	1	s	0 (4 typ)

Safety Overcurrent Protection (SOCC, SOCD)

The bq20z80 reports a safety-overcurrent condition for either charge (*SBS.Current( )* = positive) or discharge (*SBS.Current( )* = negative). A fault is reported when *SBS.Current( )* is greater than or equal to the *DF.SafetyOverCurrentInCharge* (*SOCC*) or *DF.SafetyOverCurrentInDischarge* (*SOCD*) threshold for a period greater than or equal to the *DF.SafetyOverCurrentTime* (*SOCT*). During the period between the time when excessive current is first detected and the expiration of *SOCT*, the *SOCC* or *SOCD* (depending on direction of current flow) bit in *SBS.PFAlert( )* is set.

Either the protection in discharge and charge can be independently configured or disabled, where if *DF.PFConfig XSOCC* or *XSOCD* is set, the $\overline{\text{SAFE}}$ pin is driven low for the respective fault. Also, if *SOCC* or *SOCD* is set to 0, this feature is disabled for the respective current direction.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
SOCC	Safety Overcurrent in Charge Threshold	Integer	0 to 30000	2	mA	0 (10000 typ)
SOCD	Safety Overcurrent in Discharge Threshold		0 to 30000			0 (10000 typ)
SOCT	Safety Overcurrent Time		0 to 30	1	s	4

Safety Over Temperature Protection (SOTC, SOTD)

The bq20z80 reports a safety over-temperature condition for either charge (*SBS.Current( )* = positive) or discharge (*SBS.Current( )* = negative). A fault will be reported when *SBS.Temperature( )* is greater than or equal to the *DF.SafetyOverTemperatureInCharge* (*SOTC*) or *DF.SafetyOverTemperatureInDischarge* (*SOTD*) threshold for a period greater than or equal to the *DF.SafetyOverTemperatureInChargeTime* (*SOTCT*) or *DF.SafetyOverTemperatureInDischargeTime* (*SOTDT*). During the period between the time when excessive temperature is first detected and the expiration of *SOTT*, the *SOTC* or *SOTD* bit (depending on direction of current flow) in *SBS.PFAlert( )* is set.

Either discharge or charge protection can be independently configured or disabled, where if *DF.PFConfig XSOTC* or *XSOTD* is set, the $\overline{\text{SAFE}}$ pin is driven low for the respective fault. If *SOTCT* or *SOTDT* is set to 0, this feature is disabled for the respective current direction.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
SOTC	Safety Over Temperature in Charge Threshold	Integer	0 to 1200	2	0.1°C	650
SOTCT	Safety Over Temperature in Charge Time		0 to 30	1	s	0 (4 typ)
SOTD	Safety Over Temperature in Discharge Threshold		0 to 1200	2	0.1°C	750
SOTDT	Safety Over Temperature in Discharge Time		0 to 30	1	s	0 (4 typ)

Cell Imbalance Fault Protection (CIM)

The bq20z80 reports a cell imbalance condition when *SBS.Current( )* is less than or equal to *DF.MinimumCellImbalanceCurrent* (*I_CIM*) for a period of *DF.BatteryRestTime* (*BRT*), and the difference between the highest measured cell voltage (*VCELL(MAX)*)) and lowest measured cell voltage (*VCELL(MIN)*)) is greater than or equal to *DF.CellImbalanceThreshold* (*CIM*) for a period greater than or equal to *Cell Imbalance Time* (*CIMT*).

During the period between the time when excessive cell-voltage variance is first detected and the expiration of *CIMT*, the *CIM* bit in *SBS.PFAlert( )* is set.

If *DF.PFConfig XCIM* is set, the $\overline{\text{SAFE}}$ pin is driven low. If *CIMT* is set to 0, this feature is disabled.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
CIM	Cell Imbalance Threshold		0 to 5000	2	mV	1000
CIMT	Cell Imbalance Time	Integer	0 to 30	1	s	2
I_CIM	Minimum Cell Imbalance Current		0 to 200	1	mA	5
BRT	Battery Rest Time		0 to 240	1	s	0 (60 typ)

Charge and Zero-Volt Charge FET Fault Protection (CFETF)

If the bq20z80 has at any time attempted to turn off the CHG or ZVCHG FETs, or the *AFE.OUTPUT_CTL, CHG* bit is set, and a charge current continues to flow that is greater than or equal to *DF.FET Fault Threshold* (*FETF*) for a period of *DF.FETFailTime*, then a CHG FET Fault is reported.

When the first occurrence of excessive charge current is detected, the *CFETF* bit in *SBS.PFAlert( )* is set, and the bq20z80 attempts to turn off the CHG and ZVCHG FET again. The *CFETF* bit in *SBS.PFAlert( )* is cleared if at any time before the *FETFT* is equaled or exceeded, the current is measured below the *FETF* threshold.

If *DF.PFConfig XCFETF* is set, the $\overline{\text{SAFE}}$ pin is driven low. If *FETF* is set to 0, this feature is disabled.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
FETF	FET Failure Threshold	Integer	0 to 5000	2	mA	200
FETFT	FET Failure Time		0 to 30	1	s	0 (2 typ)

Discharge FET Fault Protection (DFETF)

If the bq20z80 has at any time attempted to turn off the DSG FET, or the *AFE.OUTPUT_CTL, DSG* bit is set, and discharge current continues to flow greater than or equal to *DF.FETFaultThreshold* (*FETF*) for a period of *DF.FETFailTime*, then a DSG FET Fault is reported. If *FEFT* is set to 0, the feature is completely disabled.

When the first occurrence of excessive charge current is detected, the *DFETF* bit in *SBS.PFAlert( )* is set, and the bq20z80 attempts to turn off the DSG FET again. The *DFETF* bit in *SBS.PFAlert( )* is cleared if at any time before the *FETFT* times out, the current is measured below the *FETF* threshold.

If *DF.PFConfig XDFETF* is set, the $\overline{\text{SAFE}}$ pin is driven low. If *FETF* is set to 0, this feature is disabled.

AFE Communication Fault Protection (AFE_C)

The bq20z80 continuously validates its read and write communications with the bq29312. If either a read or write verify fails, an internal *AFE_Fail_Counter* is incremented. If the *AFE_Fail_Counter* exceeds the *DF.AFE_Fail_Limit* value, the bq20z80 reports a permanent failure. If the *DF.AFE_Fail_Limit* is set to 0, this feature is *not* disabled, but reports a permanent failure after only 1 AFE communication fault.

The internal *AFE_Fail_Counter* is decremented by one count each *DF.Fail_Counter_Recovery_Time* (*FCRT*). If the *AFE_Fail_Counter* is greater than one, the *AFE_C* bit in *SBS.PFAlert( )* is set, and is only cleared when *AFE_Fail_Counter* is returned to 0, or the *AFE_C* bit in *SBS.PFStatus( )* is set.

If *DF.PFConfig XAFE_C* is set, the $\overline{\text{SAFE}}$ pin is driven low.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
AFL	AFE Fail Limit	Integer	0 to 255	1	counts	0 (2 typ)
FCRT	AFE Fail Counter Recovery Time		0 to 255	1	s	20

Periodic AFE Verification (AFE_P)

The bq20z80 periodically (*DF.AFE_Check_Time, (ACT)*) compares the entire RAM in the bq29312 with that of the bq20z80 data flash and the expected control-bit states. If an error is detected, the *AFE_Periodic_Fail_Counter* is incremented. If the *AFE_Periodic_Fail_Counter* reaches the *DF.Periodic_Fail_Limit*, the bq20z80 reports a permanent failure. If the *DF.Periodic_Fail_Limit* is set to 0, this feature is *not* disabled, but reports a permanent failure after only 1 AFE verification fault.

The internal *AFE_Periodic_Fail_Counter* is decremented by one count each *DF.Periodic_Fail_Counter_Recovery_Time* (*PFCRT*). If the *AFE_Periodic_Fail_Counter* is greater than one, the *AFE_P* bit in *SBS.PFAlert( )* is set, and is only cleared when *AFE_Periodic_Fail_Counter* is returned to 0, or the *AFE_P* bit in *SBS.PFStatus( )* is set.

However, if *DF.PFConfig XAFE_P* is set, the $\overline{SAFE}$ pin is not driven low, and if *DF.AFE_Check_Time* is set to 0, this feature is disabled.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
ACT	AFE Check Time	Integer	0 to 255	1	s	0 (10 typ)
PFCRT	Periodic Fail Counter Recovery Time			1	s	100

Fuse State Detection (FBF)

The bq20z80 can detect if an attempt has been made to blow the fuse, but this has failed. If the bq20z80 *DF.PF_Flag* is set and *SBS.Current( )* is greater than or equal to *DF.Fuse_Fail_Limit* (*FFL*) in either charge or discharge directions for a period greater than or equal to the *DF.Fuse_Failure_Time* (*FFT*), the bq20z80 sets the FBF bit in *SBS.PFStatus( )*.

When the *FFT* timer begins, the *FBF* bit in *SBS.PFAlert( )* is set. When the *FFT* timer expires or is cleared, the *FBF* bit in *SBS.PFAlert( )* is cleared.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
FFT	Fuse Failure Time	Integer	0 to 30	1	s	0 (10 typ)
FFL	Fuse Failure Limit		0 to 20	1	mA	2

Data Flash Verification

The bq20z80 generates the checksum of the static data flash upon receiving the appropriate *SBS.ManufacturerAccess( )* command. Once the first checksum has been created, the *CSV* bit in *SBS.OperationStatus( )* is set. The checksum can only be manually verified by reading the *ChecksumSBS.ManufcturerAccess( )* command.

The data flash locations NOT included in the checksum are:
- Cycle Count
- Full Charge Capacity
- Impedance Track RA Table

During normal opertion of the bq20z80 the device will verify all writes to Data Flash via a read and re-write verifcation loop. If this verification fails then the SBS.SafetyStatus( ) DFF bit is set.

If *DF.PFConfig XDFF* is set, the $\overline{SAFE}$ pin is not driven low.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
DFCKS	DF Checksum	Integer	00000000 to ffffffff	4		00

COMMUNICATIONS

The bq20z80 uses SMBus 1.1 with Master Mode and PEC options per the SBS specification.

SMBus On and Off State

The bq20z80 detects an SMBus off state when SMBC and SMBD are logic-low for equal to or greater than 2 seconds. Clearing this state requires either SMBC or SMBD to transition high, and within 1 ms, the communication bus is available.

Packet Error Checking

The bq20z80 can receive or transmit data with or without PEC.

In the read-word protocol, the bq20z80 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 bq20z80 compares the value to its calculation. If the PEC is correct, the bq20z80 responds with an ACKNOWLEDGE. If it is not correct, the bq20z80 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 bq20z80. The bq20z80 then sends the PEC, and the host, acting as a master-receiver, generates a NOT ACKNOWLEDGE and a stop condition.
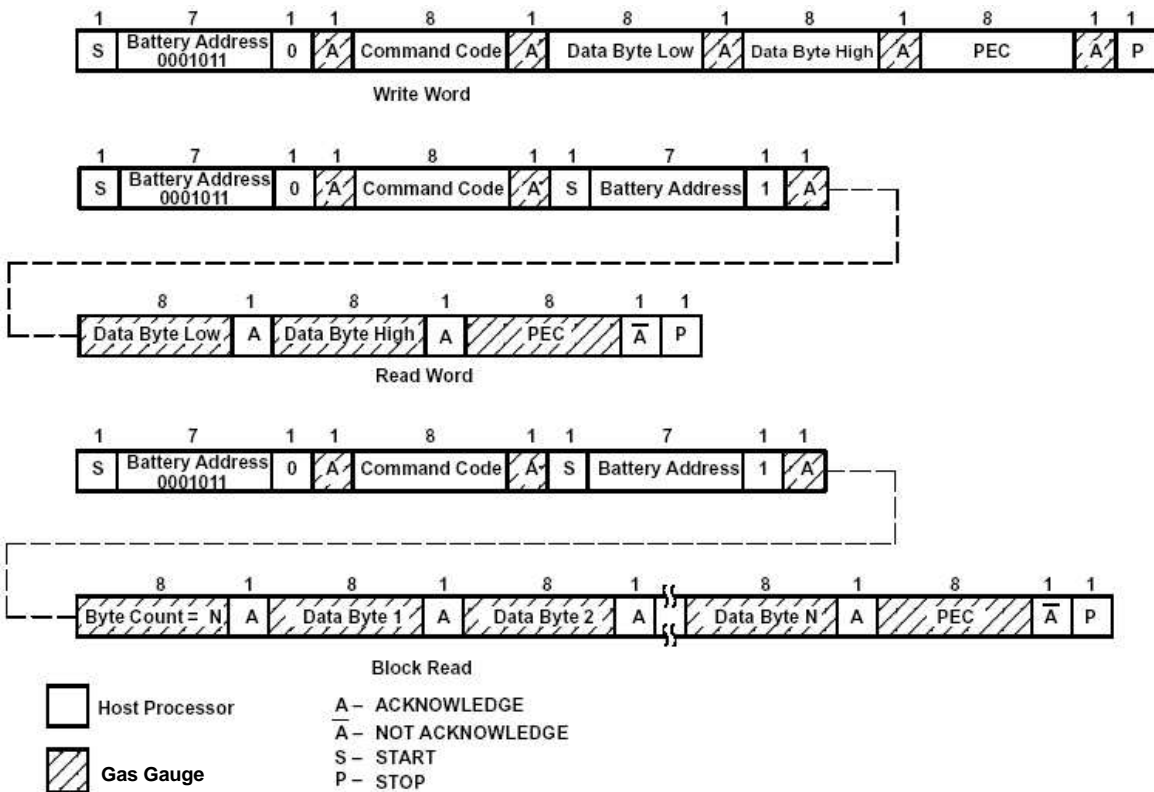

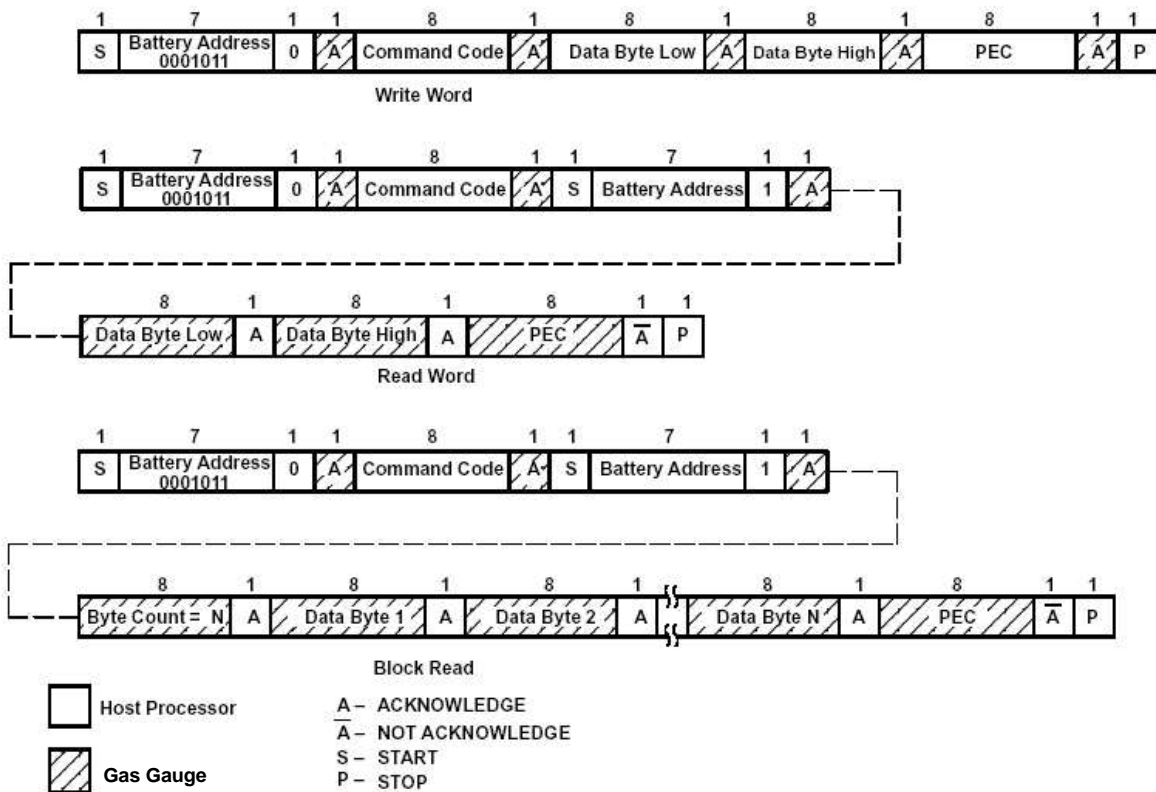**Figure 3. SMBus Communication Protocol Without PEC**

Figure 4. SMBus Communication Protocol With PEC

PEC Calculation

PEC calculation is an 8-bit cyclic redundancy check (CRC-8) based on the polynomial $C(X) = X8 + X2 + X1 + 1$

All bytes in the transmission are used in the calculation, including: Address, Command, and Data.

Not included: ACKNOWLEDGE, NOT ACKNOWLEDGE, start, stop, and repeated start.

STANDARD SBS COMMANDS

The bq20z80 SBS commands meet the SBD v1.1 specification.

ManufacturerAccess( ) (0x00)

This Read- or Write-Word function provides battery-system level data, access to test controls and security features.

System Data (Returns Data)

Device Type: 0x0001, Returns IC part number. 0x0800 - The number is not stored in data flash, but is part of the instruction flash.

Firmware Version: 0x0002, Returns the firmware version. This is not stored in data flash, but is part of the instruction flash. Its format is most-significant byte (MSB) = Decimal integer, and the least-significant byte (LSB) = sub-decimal integer, e.g., 0x0120 = version 01.20.

Hardware Version: 0x0003, Returns the hardware version stored in reserved data flash with a format of MSB = Major Rev and LSB = Minor Rev, E.G.: 0xa2 = Version A2.

DF Checksum: 0x0004, This function is only available when the bq20z80 is 'Unsealed', where *SBS.OperationStatus( ) SS* = 0. A write to this command forces the bq20z80 to generate a checksum of the static elements of the Data Flash (DF) array, write it to DF, and return the generated checksum on a read. A Read returns the DF Checksum which is stored in DF.

NOTE:

If another *SBS.ManufacturersAcces( )* command is received, the DF Checksum is not returned, and can only be read from DF directly.

Manufacturer Status 0x0006, This function is compatible with the equivilant command in the bq2084, and is available while the bq20z80 is in normal operation.

This 16-bit word reports the battery status. It is formatted differently in the bq20z80, based on the DF.OperationConfiguration, MAC1 and MAC2 bits. The bq2084 format is the same as bq20z80 DF.OperationConfiguration, MAC1 = MAC2 = 0, and is detailed below.

Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8
FET1	FET0	PF1	PF0	STATE3	STATE2	STATE1	STATE0

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0	0	0	0	1	0

FET1, FET0 Indicated the state of the charge and discharge FETs

0,0 Both charge and discharge FETs are on

0,1 Charge FET is off, discharge FET is on

1,0 Both charge and discharge FETs are off

1,1 Charge FET is on, discharge FET is off

PF1, PF0 Indicates permanent failure cause when permanent failure indicated by STATE3-STATE0

0,0 Fuse is blown

0,1 Cell imbalance failure

1,0 Safety voltage failure

1,1 FET failure

STATE3, STATE2, STATE1, STATE0 Indicates battery state as defined in the State and Status bit Summary

Table 3. STATE Code for Manufacture Status

bq2084 STATE	STATE CODE (hex)	CORRESPONDING bq20z80 FLAG
Wakeup	0	SBS.OperationStatus( ) WAKE
Precharge	3	SBS.ChargingStatus( ) PCHG
Chargesusp	4	SBS.ChargingStatus( ) CHGSUSP
Terminatecharge	7	
Normalcharge	5	SBS.ChargingStatus( ) FCHG
Provisionalcharge	1	SBS.ChargignStatus( ) XCHG
Normaldischarge	1	SBS.OperationStatus( ) DSG

**Table 3. STATE Code for Manufacture
Status (continued)**

bq2084 STATE	STATE CODE (hex)	CORRESPONDING bq20z80 FLAG
Depleted	e	SBS.OperationStatus( ) XDSG or XDSGV or XDSGI or XDSGT
Depleted_ac		
Overheatdischarge		
Overheatcharge		
Battfail_overcharge		
Battfail_lowtemp		
Battfail_chargeterminate	8	SBS.ChargingStatus( ) OCHGI or OCHGV
Battfail_afe_chg	c	SBS.SafetyStatus( ) SCC
Battfail_afe_dsg	c	SBS.SafetyStatus( ) AOCD or SCD
Battfail_chg	a	SBS.SafetyStatus( ) OCC or OCC2
Battfail_dsg	a	SBS.SafetyStatus( ) OCD or OCD2
Removed	f	SBS.OperationStatus( ) PRES
Sleep	d	Communication causes exit of Sleep
Permanent_failure	g	SBS.SafetyStatus( ) PF

System Control (Triggers Actions)

Ship Command: 0x0010 Instructs the bq20z80 to verify and enter Shutdown. See 'Shutdown' in Power Modes.

Sleep Command: 0x0011 Instructs the bq20z80 to enter Sleep. See 'Sleep' in Power Modes.

IT Enable: 0x0021 This function is only available when the bq20z80 is 'Unsealed'. A Write forces the bq20z80 to begin the ImpedanceTrack algorithm and sets the *ITEN* bit in *DF.OperationConfiguration*. This also sets the *ZEN* and *QEN* bits in *SBSOperationStatus( )*. *ZEN* is cleared after a discharge, where resistance is updated and *QMAX* is not updated. When *QMAX* updates *ZEN* is set.

Permanent Fail Clear: (1) 0x2673 then (2) 0x1712, This function is only available when the bq20z80 is 'Unsealed', and instructs the bq20z80 to clear the Permanent Failure Status, clear the Permanent Failure Flag, clear the $\overline{SAFE}$ pin and unlock the Data flash for writes.

NOTE:

(1) must be followed by (2). If the clear fails then (1) can only be re-sent after 4s since the last communication in the failed attempt. If communication, other than the second code, occurs after the first code is sent, the clear fails.

SAFE Activation: 0x0030 This function is only available when the bq20z80 is *Unsealed*, and drives the $\overline{SAFE}$ pin high.

SAFE Clear: SAFE Clear 0x0031 This function is only available when the bq20z80 is *Unsealed*, and drives the $\overline{SAFE}$ pin low, only if protection functions allow. This does not clear *PF* Mode.

LEDs ON: 0x0032 This function is only available when the bq20z80 is*Unsealed*, and activates all configured LEDs and will stay ON.

LED's OFF: 0x0033 This function is only available when the bq20z80 is *Unsealed*, and deactivates all configured LEDs.

Display ON: 0x0034 This function is only available when the bq20z80 is *Unsealed*, and activates the configured LED display per the level of *SBS.RemainingStateOfCharge( )*. The display turns off per the normal display conditions.

Calibration Mode: 0x0040 This function is only available when the bq20z80 is *Unsealed*, and places the bq20z80 into calibration mode. See the Calibration and Test section of this specification for further details.

bq20z80 Reset: 0x00041 This function is only available when the bq20z80 is *Unsealed*, and when written to the bq20z80 undergoes a full reset.

Security (Enables and Disables Features)

There are three levels of secured operation within the bq20z80. To switch between the levels, different operations are needed with different codes. The 3 levels are Sealed, Unsealed and Full Access.

1. Full Access or Unsealed to Sealed: 0x0020 Instructs the bq20z80 to limit access to the SBS Functions and Data Flash space. In sealed mode, standard SBS functions have access per the standard SBS-function summary table. Extended SBS Functions and data flash are not accessible.

2. Sealed to Unsealed Instructs the bq20z80 to extend access to the SBS and Data Flash space. In unsealed mode, standard SBS functions have Read/Write access, extended SBS functions have access per the extended SBS function summary table, and Data Flash have Read/Write access.

To return to the Sealed mode, either a hardware reset is needed, or a command to transition from Full Access or Unsealed to Sealed.

3. Unsealed to Full Access Instructs the bq20z80 to allow Full Access to SBS and DF. The bq20z80 is shipped from TI in this mode. In Full Access mode, the command to go to BootROM can be sent, and the security keys for Unsealed to Full Access can be changed via *SBS.SecurtiyKey1( )* and *SBS.SecurityKey2( ).*

RemainingCapacityAlarm( ) (0x01)

This read or write function sets or gets the Low Capacity alarm threshold unsigned integer value.

When the *SBS.RemainingCapacity( )* is less than *SBS.RemainingCapacityAlarm( )*, the bq20z80 sends *SBS.AlarmWarning( )* messages to the SMBus Host address with the *REMAINING_CAPACITY_ALARM* (*RCA*) bit set. *RCA* is cleared when *SBS.RemainingCapacityAlarm( )* is less than *SBS.RemainingCapacity( )*, or when the *SBS.RemainingCapacity( )* is increased by charging.

The default value of *RemainingCapacityAlarm( )* is set in *DF.Remaining Capacity Alarm*. If *RemainingCapacityAlarm( )* = 0, this alarm is disabled.

If the *ALARM_MODE* bit is set in *SBS.BatteryMode( )*, the *SBS.AlarmWarning( )* message is disabled for a set period of time. See the *SBS.BatteryMode( )* function for further information.

SBS.RemainingCapacityAlarm( ) may be expressed in terms of capacity (mAh) or power (10mWh), depending on the setting of the *CAPACITY_MODE* bit in *SBS.BatteryMode( )* (see *SBS.BatteryMode( )*).

	BATTERY MODE	
	CAPACITY_MODE bit = 0	CAPACITY_MODE bit = 1
Units:	mAh at C/5	10mWh at P/5
Range:	0 to 65,535 mAh	0 to 65,535 10mWh
Granularity	not applicable	
Accuracy	see RemainingCapacity( )	

RemainingTimeAlarm( ) (0x02)

This read or write-word function sets or gets the Remaining Time Alarm unsigned integer value in minutes and with a range of 0 to 65,535.

When the *SBS.AverageTimeToEmpty( )* is less than *SBS.RemainingTimeAlarm( )*, the bq20z80 sends *SBS.AlarmWarning( )* messages to the SMBus Host with the *REMAINING_TIME_ALARM* (*RTA*) bit set. *RTA* is cleared when *SBS.RemainingTimeAlarm( )* is less than *SBS.AverageTimeToEmpty( )*, or when the *SBS.AverageTimeToEmpty( )* is increased by charging.

The default value of *SBS.RemainingTimeAlarm( )* is set in *DF.Remaining Time Alarm*. If *SBS.RemainingTimeAlarm( )* is set to 0, the alarm is disabled. If the *ALARM_MODE* bit is set in *SBS.BatteryMode( )* then the *SBS.AlarmWarning( )* message is disabled for a set period of time. See the *SBS.BatteryMode( )* function for further information.

BatteryMode( ) (0x03)

This read- or write-word function selects the various battery operational modes and reports the battery's capabilities, modes, and flags minor conditions requiring attention.

BatteryMode( )	bit7	bit6	bit5	bit4	bit3	bit2	bi1	bit0
High Byte	CapM	ChgM	AM	RSVD	RSVD	RSVD	PB	CC
Low Byte	CF	RSVD	RSVD	RSVD	RSVD	RSVD	PBS	ICC

The *SBS.BatteryMode( )* word is divided into two halves, the MSB (bits 8-15) which is read/write and the LSB (bits 0-7) which is read only. The default state of *SBS.BatteryMode( )* is stored in *DF.Initial Battery Mode.*

FIELD	FORMAT	ALLOWABLE VALUES
ICC = INTERNAL_CHARGE_CONTROLLER	Read Only	Fixed to 1
PBS = PRIMARY_BATTERY_SUPPORT	Read Only	Fixed to 0
CF = CONDITION_FLAG	Read Only	0 – Battery OK
		1 – Conditioning Cycle Requested
CC = CHARGE_CONTROLLER_ENABLED	Read/Write	Not used, Fixed to 0
PB = PRIMARY_BATTERY	Read/Write	Not use, Fixed to 0
AM = ALARM_MODE	Read/Write	0 – Enable AlarmWarning( ) broadcasts to Host and Smart Battery Charger (default)
		1 – Disable AlarmWarning( ) broadcast to Host and Smart Battery Charger
ChgM = CHARGER_MODE	Read/Write	0 – Enable ChargingVoltage( ) and ChargingCurrent( ) broadcasts to Smart Battery Charger (default)
		1 – Disable broadcasts of ChargingVoltage( ) and ChargingCurrent( ) to Smart Battery Charger
CapM = CAPACITY_MODE	Read/Write	0 – Report in mA or mAh (default)
		1 – Report in 10mW or 10mWh

NOTE:

Because only *CF*, *AM*, *ChgM* and *CapM* are active; the remaining bits are not described here. See the SBD specification for details on those bits.

CONDITION_FLAG: Indicates that the battery is requesting a conditioning cycle. Set by an increment of 20 counts in *SBS.CycleCount( )* and cleared when *SBS.FullChargeCapacity( )* has been updated.

ALARM_MODE: Disables the bq20z80's ability to master the SMBus and send *SBS.AlarmWarning( )* messages to the SMBus Host and the Smart Battery Charger.

When *ALARM_MODE* = 1, the bq20z80 does not master the SMBus, and *SBS.AlarmWarning( )* messages are not sent to the SMBus Host and the Smart Battery Charger for a period of no more than 65 seconds and no less than 45 seconds. The ALARM_MODE bit is automatically cleared by the bq20z80 60 seconds after being set to 1.

When ALARM_MODE = 0 (default), the bq20z80 sends the *SBS.AlarmWarning( )* messages to the SMBus Host and the Smart Battery Charger any time an alarm condition is detected.

NOTE:

The system **must** poll the Smart Battery every 10 seconds, even when the system is suspended, or while it is powered by AC if the *ALARM_MODE* bit is set.

CHARGER_MODE: Enables or disables the bq20z80's transmission of *SBS.ChargingCurrent( )* and *SBS.ChargingVoltage( )* messages to the Smart Battery Charger.

When *CHARGER_MODE* = 1, the bq20z80 will NOT transmit SBS.ChargingCurrent( ) and SBS.ChargingVoltage( ) values to the Smart Battery Charger.

When *CHARGER_MODE* = 0 (default), the bq20z80 transmits the *SBS.ChargingCurrent( )* and *SBS.ChargingVoltage( )* values to the Smart Battery Charger when charging is desired.

CAPACITY_MODE: Indicates if capacity information is reported in mA/mAh or 10mW/10mWh.

When CAPCITY_MODE = 1 (default), the capacity information is reported in mA/mAh as appropriate. After changing the CAPACITY_MODE bit, the following functions are updated:

- *SBS.RemainingCapacityAlarm( )*– Within 1s
- *SBS.AtRate( )* - Within 1s
- *SBS.RemainingCapacity( )*– Within 1s
- *SBS.FullChargeCapacity( )*– Within 1s
- *SBS.DesignCapacity( )*– Within 1s, SBS.DesignCapacity( ) will change between DF.Design Capacity or DF.Design Power depending on the CM bit transition.

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

- *SBS.AtRateOK( )*– Within 1s
- *SBS.AtRateTimeToEmpty( )*– Within 1s
- *SBS.RunTimeToEmpty( )*– Within 1s
- *SBS.AverageTimeToEmpty( )*– Within 1s
- *SBS.RemainingTimeAlarm( )*– Within 1s
- *SBS.BatteryStatus( )*– Within 1s

AtRate( ) (0x04)

This read- or write-word function is the first half of a two-function call set used to set the *AtRate* value used in calculations made by the *SBS.AtRateTimeToFull( )*, *SBS.AtRateTimeToEmpty( )*, and *SBS.AtRateOK( )* functions. The *AtRate* units are in either current (mA) or power (10mW) depending on the setting of the *SBS.BatteryMode( ) CAPACITY_MODE* bit.

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

The default value for *SBS.AtRate( )* is zero. It is a signed integer where the *SBS.AtRate( )* value is positive for charge, negative for discharge.

	BATTERY MODE()	
	CAPACITY_MODE	
	BIT = 0	**BIT = 1**
Units:	mA	10 mW
Charge Range:	1 to 32,767 mA	1 to 32,767 10 mW
Discharge Range:	−1 to −32,768 mA	−1 to −32,768 10 mW
Granularity	1 Unit	
Accuracy	NA	

AtRateTimeToFull( ) (0x05)

This read-word function returns an unsigned integer value of the predicted remaining time to fully charge the battery at the AtRate( ) value in minutes, with a range of 0 to 65534. A value of 65,535 indicates that the *SBS.AtRate( )* = 0.

SBS.AtRateTimeToFull( ) can report time based on constant current (*SBS.BatteryMode( ) CAPACITY* = 0) or constant power (*SBS.BatteryMode( ) CAPACITY* = 1), and updates within one second after the SMBus host sets the *AtRate* value. The bq20z80 automatically updates *SBS.AtRateTimeToFull( )* based on the *SBS.AtRate( )* at one-second intervals.

AtRateTimeToEmpty( ) (0x06)

This read-word function returns an unsigned integer value of the predicted remaining operating time in minutes with a range of 0 to 65534, if the battery is discharged at the *SBS.AtRate( )* value. A value of 65,535 indicates that *SBS.AtRate( )* = 0.

SBS.AtRateTimeToEmpty( ) can report time based on constant current (*SBS.BatteryMode( ) CAPACITY* = 0), or constant power (*SBS.BatteryMode( ) CAPACITY* = 1), and is updated within one second after the SMBus host sets the *SBS.AtRate( )* value. The bq20z80 automatically updates *SBS.AtRateTimeToEmpty( )* based on the *SBS.AtRate( )* at one-second intervals.

AtRateOK( ) (0x07)

This read-word function returns a Boolean value that indicates whether or not the battery can deliver the *SBS.AtRate( )*-value of additional energy for 10 seconds.

If *SBS.AtRate( )* is greater than or equal to 0, the *SBS.AtRateOK( )* function *always* returns OK (logic 1).

The bq20z80 updates *SBS.AtRateOK( )* within one second after the SMBus host sets the *SBS.AtRate( )* value. The bq20z80 automatically updates *SBS.AtRateOK( )* based on the *SBS.AtRate( )* at one-second intervals.

Temperature( ) (0x08)

This read-word function returns an unsigned integer value of the temperature in units of 0.1°K, as measured by the bq20z80. It has a range of 0 to 6553.5°K.

The source of the measured temperature is configured by the *TEMP0* and *TEMP1* bits in *DF.OperationConfiguration*.

TEMP1	TEMP0	TEMPERATURE() SOURCE[1]
0	0	Internal Temperature Sensor
0	1	TS1 Input (default)
1	0	Most extreme of TS1 or TS2 Inputs
1	1	Average of TS1 and TS2 Inputs

(1) Both external temperature sensors, if used, MUST be the same type.

Voltage( ) (0x09)

This read-word function returns an unsigned integer value of the sum of the individual cell voltage measurements in mV with a range of 0 to 20000mV.

Current( ) (0x0a)

This read-word function returns a signed integer value of the measured current being supplied (or accepted) by the battery in mA, with a range of −32,768 to 32,767. A positive value indicates charge current and negative indicates discharge.

NOTE:

SBS.Current( ) is the average of 4 local current measurements over a one-second period.

AverageCurrent( ) (0x0b)

This read-word function returns a signed integer value that approximates a one-minute rolling average of the current being supplied (or accepted) through the battery terminals in mA, with a range of -32,768 to 32,767.

SBS.AverageCurrent( ) is calculated by a rolling average of *SBS.Current( )* data with a period of *DF.AveragingTime*. During the time after a reset and before *DF.AveragingTime* has expired the reported *SBS.AverageCurrent( )* = *SBS.Current( ).*

MaxError( ) (0x0c)

This read-word function returns an unsigned integer value of the expected margin of error, in %, in the state-of-charge calculation with a range of 1 to 100%.

SBS.MaxError( ) is set to 100% on a full reset, and is updated by the following mechanism.

On *SBS.FullChargeCapacity( )* and/or QMAX update, the *SBS.MaxError( )* is set to 1%.

On ResistanceFactor update,

1. If *MaxError( )* <= 7% then MaxError = 2% + *MaxError_Adder*
2. Else *MaxError( )* = 10% + *MaxError_Adder*

Where the Internal counter *MaxError_Adder* is Incremented by 0.1% every cycle.

RelativeStateOfCharge( ) (0x0d)

This read-word function returns an unsigned integer value of the predicted remaining battery capacity expressed as a percentage of *SBS.FullChargeCapacity( )*, in %, with a range of 0 to 100%.

AbsoluteStateOfCharge( )(0x0e)

This read-word function returns an unsigned integer value of the predicted remaining battery capacity expressed as a percentage of *SBS.DesignCapacity( )*, in %, with a range of 0 to 100%. If SBS.BatteryMode( ) CAPACITY bit is set then the predicted remaing capacity is a percentage of *SBS.RemainingCapacity( )* / (*SBS.DesignCapacity( )* x SBS.DesignVoltage( )).

Note that AbsoluteStateOfCharge( ) can return values greater than 100%.

RemainingCapacity( ) (0x0f)

This read-word function returns an unsigned integer value of the predicted charge or energy remaining in the battery. The *SBS.RemainingCapacity( )* value is expressed in either charge or energy, depending on the setting of the *BatteryMode( ) CAPACITY_MODE* bit.

	BATTERY MODE()	
	CAPACITY_MODE	CAPACITY_MODE
	BIT = 0	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)

This read-word function returns an unsigned integer value of the predicted pack capacity when it is fully charged. *SBS.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.

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

RunTimeToEmpty( ) (0x11)

This read-word function returns an unsigned integer value of the predicted remaining battery life at the present rate of discharge, in minutes, with a range of 0 to 65,534 min. A value of 65,535 indicates battery is not being discharged.

SBS.RunTimeToEmpty( ) is calculated and updated based on current or power, depending on the setting of the *SBS.BatteryMode( ) CAPACITY_MODE* bit.

AverageTimeToEmpty( ) (0x12)

This read-word function returns an unsigned integer value of predicted remaining battery life, in minutes, based upon *SBS.AverageCurrent( )* with a range of 0 to 65534. A value of 65,535 indicates that the battery is not being discharged.

AverageTimeToEmpty( ) is calculated based on current or power, depending on the setting of the *BatteryMode( ) CAPACITY_MODE* bit.

AverageTimeToFull( ) (0x13)

This read-word function returns an unsigned integer value of predicted remaining time until the battery reaches full charge, in minutes, based on *SBS.AverageCurrent( )* with a range of 0 to 65,535. A value of 65,534 indicates that the battery is not being charged.

ChargingCurrent( ) (0x14)

This read-word function returns an unsigned integer value of the desired charging rate, in mA, with a range of 0 to 65,535. A value of 65,535 indicates that a charger should operate as a voltage source outside its maximum regulated current range.

See Section 12, Section 5, and Section 6 sections of this data sheet for further details.

ChargingVoltage( ) (0x15)

This read-word function returns an unsigned integer value of the desired charging voltage, in mV, where the range is 0 to 65,534. A value of 65,535 indicates that the charger should operate as a current source outside its maximum regulated voltage range.

Please review the charging and safety features of the bq20z80 for further information on this command..

BatteryStatus( ) (0x16)

This read-word function returns the status of the bq20z80-based battery.

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 *SBS.BatteryMode( ) CAPACITY_MODE* bit.

BatteryMode( )	bit7	bit6	bit5	bit4	bit3	bit2	bi1	bit0
High Byte	OCA	TCA	RSVD	OTA	TDA	RSVD	RCA	RTA
Low Byte	INIT	DSB	FC	FD	Error Codes			

ALARM AND STATUS BITS	ERROR CODES	
OCA = Over_Charge_Alarm	0x7	Unknown Error
TCA = Terminate_Charge_Alarm	0x6	Bad Size
OTA = Over_Temperature_Alarm	0x5	Overflow/Underflow
TDA = Terminate_Discharge_Alarm	0x4	Access Denied
RCA = Remaining_Capacity_Alarm	0x3	Unsupported Command
RTA = Remaining_Time_Alarm	0x2	Reserved Command
INIT = Initialized	0x1	Busy
DSG = Discharging	0x0	OK
FC = Fully_Charged		
FD = Fully_Discharged		

Alarm Bits

OVER_CHARGED_ALARM: See *Overcharge* in the *Primary Protection* section of this data sheet.

TERMINATE_CHARGE_ALARM: See 'Primary Charge Termination' in the 'Charging', 'Primary Protection Features' and 'Secondary Protection Features' sections of this data sheet

OVER_TEMP_ALARM: See 'Over Temperature' functions in the 'Primary Protection Features' and 'Secondary Protection Features' of this data sheet.

TERMINATE_DISCHARGE_ALARM: See the 'Primary Protection Features' and 'Secondary Protection Features' sections of this data sheet.

REMAINING_CAPACITY_ALARM: See *SBS.RemainingCapacityAlarm( )* section of the datasheet.

REMAINING_TIME_ALARM: See *SBS.RemainigTimeAlarm( )* section of the datasheet.

Status Bits

INITIALIZED: Set when a valid load of data flash at full or partial reset has occurred. It is cleared when an improper data flash load is detected.

DISCHARGING: Set when *SBS.Current( )* > 0 and is reset when *SBS.Current( )* = 0.

FULLY_CHARGED: See 'Primary Charge Termination' and 'Over Charge' functions in the 'Charging' and 'Primary Protection Features' and 'Secondary Protection Features' sections of this data sheet respectively.

FULLY_DISCHARGED: Is set when *(SBS.Voltage( )* = *DF.Terminate Voltage* AND *SBS.Current( )* < *DF.Over Current in Discharge* (*OCD*) threshold), OR when *SBS.RelativeStateOfCharge( )* < *FD_Set %*.

This bit is cleared when *SBS.RelativeStateOfCharge( )* is greater than or equal to *FD_Clear%*.

ERRORS CODES	DESCRIPTION
OK	The bq20z80 processed the function code with no errors detected.
Busy	The bq20z80 is unable to process the function code at this time.
Reserved	The bq20z80 detected an attempt to read or write to a function code reserved by this version of the specification.
	The bq20z80 detected an attempt to access an unsupported optional manufacturer function code.
Unsupported	The bq20z80 does not support this function code as defined in this version of the specification.
AccessDenied	The bq20z80 detected an attempt to write to a read-only function code.
Over/Underflow	The bq20z80 detected a data overflow or underflow.
BadSize	The bq20z80 detected an attempt to write to a function code with an incorrect data block.
UnknownError	The bq2084 detected an unidentifiable error.

CycleCount( )(0x17)

This read-word function returns, as an unsigned integer value, the number of cycles the battery has experienced, with a range of 0 to 65,534. The default value of *SBS.CycleCount( )* is stored in DF.Cycle Count (CCNT) which is updated each time *SBS.CycleCount( )* increments.

If *DF.Operation Configuration CCT* = 0, one cycle = accumulated discharge = *DF.Cycle Count Threshold*.

If *DF.Operation Configuration CCT* = 1, one cycle = accumulated discharge = *DF.Cycle Count %*×*SBS.FullChargeCapacity( )*.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
CCT	Cycle Count Threshold	Unsigned Int	0 to 65534	2	mAh	3800
CCnt	Cycle Count	Unsigned Int	0 to 65534	2	Counts	0
CC%	Cycle Count Percentage	Unsigned Int	0 to 100	1	%	90

DesignCapacity( ) (0x18)

This read-word function returns, as an unsigned integer value, the theoretical or nominal capacity of a new pack, stored in *DF.Design Capacity* or *DF.Design Power*.

The *SBS.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.

	BATTERY MODE()	
	CAPACITY_MODE	CAPACITY_MODE
	BIT = 0	BIT = 1
Units	mAh	10 mWh
Range	0–65,535mAh	0–65,535 10 mWh
Granularity	Not applicable	Not applicable
Accuracy	Not applicable	Not applicable
Default	Design Capacity	Design Power

DesignVoltage( ) (0x19)

This read-word function returns an unsigned integer value of the theoretical voltage of a new pack, in mV, with a range of 0 to 65,534. The default value of *SBS.DesignVoltage( )* is in *DF.Design Voltage*.

SpecificationInfo( ) (0x1a)

This read-word function returns, as an unsigned integer value, the version number of the Smart Battery Specification the battery pack supports, as well as voltage- and current-scaling information.

Power scaling is the product of the voltage scaling times the current scaling. The *SBS.SpecificationInfo( )* is packed in the following fashion:

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

VScale (voltage scaling) and IPScale (current scaling) should always be set to zero. The default setting of *SBS.SpecificationInfo( )* is in *DF.Specification Information*.

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

ManufactureDate( ) (0x1b)

This read-word function returns the date the pack was manufactured in a packed integer. The date is packed in the following fashion:

(year-1980) $\times$ 512 + month $\times$ 32 + day

The default *SBS.ManufactureDate( )* is in Data Flash Manufacture Date.

FIELD	BITS USED	FORMAT	ALLOWABLE VALUES
Daty	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)

This read-word function is used to return an unsigned integer serial number. The default value of *SBS.SerialNumber( )* is in *DF.Serial Number*.

ManufacturerName( ) (0x20)

This read-block function returns a character string containing the battery manufacturer's name with a maximum length of 11 characters (11 Data + length byte).

The default setting of *SBS.ManufacturerName( )* is in *DF.Manufacturer Name*. When the bq20z80 is in Unsealed or higher security mode, this block is R/W.

DeviceName( ) (0x21)

This read-block function returns a character string that contains the battery name with a maximum length of 7 characters (7 Data + length byte).

The default setting of *SBS.DeviceName( )* is in *DF.Device Name*. When the bq20z80 is in Unsealed or higher security mode, this block is R/W.

DeviceChemistry( ) (0x22)

This read-block function returns a character string that contains the battery chemistry with a maximum length of 4 characters (4 Data + length byte).

The default setting of *SBS.DeviceChemistry( )* is in *DF.Device Chemistry* although it has no use for internal charge control or fuel gauging. When the bq20z80 is in Unsealed or higher security mode, this block is R/W.

ManufacturerData( ) (0x23)

This read-block function returns several configuration data flash elements with a maximum length of 31 Data + 1 length byte (stored in Manufacturer Data Length) where the total bytes, including length byte, cannot exceed 32 bytes. When the bq20z80 is in Unsealed or higher security mode, this block is R/W.

The data available is:

MANUFACTURING DATA		
Lot Code of Pack	Data stored in DF as raw data	2-bytes
Lot Code of PCB	Data stored in DF as raw data	2-bytes
Firmware Version	Data stored in DF as raw data	1-byte
Hardware Revision	Data stored in DF as raw data	1-byte
Cell Revision	Data stored in DF as raw data	2-bytes
SYSTEM DATA		
Reset Counter Partial	Count	1-byte
Reset Counter Full	Count	1-byte
Reset Counter Watch Dog	Count	1-byte
Check Sum	Number	1-byte

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

These read-word functions return an unsigned value of the calculated individual cell voltages, in mV, with a range of 0 to 65,534. *SBS.VCELL1( )* corresponds to the bottom series element.

EXTENDED SBS COMMANDS

These commands are only available when the device is unsealed (*DF.Operational Configuration, SS* = 0). The standard set of commands is also available when unsealed.

GetRAMDataBlock( ) (0x43)

This read-word function returns the contents of a 32-byte block of bq20z80 RAM specified by *SBS.SetRAMBlockNumber( )*.

SetRAMBlockNumber( ) (0x44)

This write-word function sets the 32-byte block number for bq20z80 RAM to be read by *SBS.GetRAMDataBlock( )*.

AFEData( ) (0x45)

This read-block function returns the AFE memory map, beginning with AFE.0x00 as the MSB returned with a maximum length of 9 data bytes + 1 length byte.

FETControl( ) (0x46)

This write/read-word function allows direct control of the FETs for test purposes using SMBus commands.

1. Bit 0, 5 & 6 = Reserved
2. Bit 1 = DSG, Discharge FET
3. Bit 2 = CHG, Charge FET
4. Bit 3 = ZVCHG, Zero-Volt Charge (Precharge) FET
5. Bit 4 = OD, General Purpose Open Drain output
6. Bit 7 = CNTL, Control bit for allowing FET override control by normal operation

When the bit is set, the FET is turned on. When the bit is cleared, the FET is turned off.

When *CNTL* = 1, all gas-gauge-based FET operations are overridden when an *SBS.FETControl( )* command is received. When *CNTL* = 0, if normal gas-gauge operation requires a FET to change state, it is allowed.

NOTE:

> If an AFE condition requires a FET to turn off, the settings in this command are ignored regardless of the state of CNTL.

SafetyAlert( ) (0x50)

This read-word function returns indications of pending safety issues, such as when safety timers have started, or fail counters are non-zero but have not reached the required time or value to trigger an *SBS.SafetyStatus( )* change. The bit arrangement follows that of *SBS.SafetyStatus( )*. See the *SBS.SafetyStatus( )* and Primary Protection Features sections of the data sheet for further details.

SafetyStatus( ) (0x51)

This read-word function returns the current status of the safety functions.

BatteryMode( )	bit7	bit6	bit5	bit4	bit3	bit2	bi1	bit0
High Byte	OTD	OTC	OCD	OCC	OCD2	OCC2	PUV	POV
Low Byte	CUV	COV	PF	HWDG	-	AOCD	SCC	SCD

SCD	1 = Discharge short-circuit fault	**PUV**	1 = Pack Undervoltage fault
SCC	1 = Charge short-circuit fault	**OCC2**	1 = Tier-2 Charge Overcurrent fault
AOCD	1 = Discharge Overcurrent fault	**OCD2**	1 = Tier-2 Discharge Overcurrent fault
HWDG	1 = Host Watchdog fault	**OCC**	1 = Charge Overcurrent fault
PF	1 = Permanent Failure flag has been set	**OCD**	1 = Discharge Overcurrent fault
COV	1 = Cell Overvoltage faultt	**OTC**	1 = Charge Over Temperature fault
CUV	1 = Cell Undervoltage fault	**OTD**	1 = Discharge Over Temperature fault
POV	1 = Pack Overvoltage fault		

PFAlert( ) (0x52)

This read-word function returns indications of pending permanent failure issues, such as when safety timers have started, or fail counters are non-zero, but have not reached the required time or value to trigger a *DF.Permanent Failure Status* change. The bit arrangement follows that of *SBS.PFStatus( )*. See the *SBS.PFStatus( )* and Secondary Protection Features sections of the data sheet for further details.

PFStatus( ) (0x53)

The permanent failure status register indicates the source of the bq20z80 permanent-failure condition. The bit arrangement follows that of *DF.PFStatus*. See the *DF.PFStatus* and Secondary Protection Features sections of the data sheet for further details.

When any NEW cause of PF is detected in *SBS.PFStatus( )*, the NEW cause is added to *DF.PLFlag1*. This allows *DF.PFlag1* to show ALL of the different PF conditions that have occurred. On the first occasion of *SBS.PFStatus( )* changing from 0x00 the value is stored to *DF.PFFlag2*.

OperationStatus( ) (0x54)

This read-word function returns the current status of the operation status of the bq20z80.

BatteryMode( )	bit7	bit6	bit5	bit4	bit3	bit2	bi1	bit0
High Byte	PRES	FA	SS	-	-	Load Mode	-	-
Low Byte	WAKE	DSG	XDSG	XDSGI	XDSGT	XDSGV	VOK	QEN

QEN 1 = QMAX updates are enabled

VOK 1 = Voltages are OK for a QMAX update

XDSGV 1 = Discharge disabled due to a voltage issue

XDSGI 1 = Discharge disabled due to a current issue

XDSGT 1 = Discharge disabled due to a temperature issue

XDSG 1 = Discharge fault

DSG Replica of the *SBS.BatteryStatus( ) DISCHARGING* bit.

WAKE 1 = bq20z80 WAKE mode

LoadMode Load mode for ImpedanceTrack modeling. 0 = constant current, 1 = constant power

CSV 1 = Data Flash checksum value has been generated

SS 1 = Sealed mode

FA 1 = Full access security mode

PRES 1 = $\overline{PRES}$ is low, indicating that the system is present (battery inserted).

ChargingStatus( ) (0x55)

This read-word function returns the current status of the charging functions.

ChargingStatus( )	bit7	bit6	bit5	bit4	bit3	bit2	bi1	bit0
High Byte	XCHG	CHGSUSP	PCHG	MCHG	TCHG2	TCHG1	FCHG	PULSE
Low Byte	PULSEOFF	CB	PCMTO	FCMTO	OCHGV	OCHGI	OC	XCHGLV

PCMTO 1 = Pre-charge timeout fault

FCMTO 1 = Fast-charge timeout fault

XCHGLV 1 = Battery is depleted

OC 1 = Overcharge fault

OCHGI 1 = Overcharge current fault

OCHGV 1 = Overcharge voltage fault

CB 1 = Cell balancing in progress

MCHG 1 = Maintenance-charging in progress

TCHG 1 = Temperature-based throttling of *SBS.ChargingCurrent( )* in progress

Pulse   1 = Pulse charging in progress

CHGSUSP   1 = Charging suspended

FCHG   1 = Fast charging in progress

PCHG   1 = Pre-charging in progress

XCHG   1 = Charging disabled

ResetData( ) (0x57)

This read-word function returns the data stored in *DF.Reset Counter - Partial* in the low byte and *DF.Reset Counter - Full* in the high byte.

ResetData( ) (0x58)

This read-word function returns the data stored in *DF.Reset Counter - Watchdog* in the low byte.

FlashWriteData( ) (0x59)

This read-word function returns the number of data flash writes than have occured in the lifetime of the device.

PackVoltage( ) (0x5a)

This read-word function returns an unsigned integer representing the measured voltage from the AFE Pack pin, in mV, with a range of 0 to 65,534.

UnSealKey( ) (0x60)

This read/write block (2-words) command allows to the user to change the Unseal key for the Sealed-to-Unsealed security-state transition. This function is only available when the bq20z80 is in the Full-Access Mode.

FullAccessKey( ) (0x61)

This read/write block (2-words) command allows the user to change the Full-Access security key for the Unsealed-to-Full-Access security-state transition. This function is only available when the bq20z80 is in the Full-Access Mode.

PFKey( ) (0x62)

This read/write block (2-words) command allows to the user to change the Permanent-Failure-Clear key. This function is only available when the bq20z80 is in the Full Access Mode.

ManufacturerInfo( ) (0x70)

This read-block function returns the data stored in *DF.Manufacturer Info 1…8*, where *Manufacturer Info 1* is the MSB with a maximum length of 8 data + 1 length byte. When the bq20z80 is in Unsealed or higher security mode, this block is R/W.

DataFlashClass( ) (0x77)

This write word command sets the bq20z80 data flash Class that is to be accessed by the *SBS.DataFlashSubClass( )* commands that follow. These commands only allow access to the data flash locations that are not reserved (or private) within the respective labeled class. See 'Data Flash Access' for further details.

A NACK is returned to the *SBS.DataFlashClass( )* command if the value of the class is outside of the allowed range. The classes are defined in the 'Data Flash' section of this data sheet.

DataFlashSubClass( ) Commands

These commands are used to access the consecutive 32-byte subclasses of each class.

NOTE:

Any DF location deemed Reserved or Private responds with a NACK unless the bq20z80 is in the correct security state to allow access.

DataFlashClassSubClass1( ) (0x78)

DataFlashClassSubClass2( ) (0x79)

DataFlashClassSubClass3( ) (0x7a)

DataFlashClassSubClass4( ) (0x7b)

DataFlashClassSubClass5( ) (0x7c)

DataFlashClassSubClass6( ) (0x7d)

DataFlashClassSubClass7( ) (0x7e)

DataFlashClassSubClass8( ) (0x7f)

DATA FLASH

Data Flash can only be updated if *SBS.Voltage( ) = DF.Valid Update Voltage*. In this case, the flash update is cancelled. Data flash reads and writes are verified according to the method detailed in the 'Primary Protection Features' section of this data sheet.

Access

In different security modes, the data flash access conditions change, based on the Public or Private (reserved) status of that location. See *SBS.ManufacturerAccess( )* for further details.

SECURITY MODE	DF – PUBLIC ACCESS	DF – PRIVATE ACCESS
BootROM	N/A	N/A
Full Access	R/W	R/W
Unsealed	R/W	R
Sealed	R	N/A

Operation Configuration A (OPCFGA)

OPERATION CONFIGURATION	bit7	bit6	bit5	bit4	bit3	bit2	bi1	bit0
High Byte	LEDR	LEDRCA	CHGLED	DMODE	LED1	LED0	CC1	CC0
Low Byte	MAC2	MAC1	SLEEP	TEMP1	TEMP0	-	ZVCHG1	ZVCHG0

The Operation Configuration bits enable, disable and configure various features of the bq20z80.

ZVCHG0, ZVCHG1 These bits enable or disable the use of ZVCHG or CHG FET for Zero-Volt/Pre-charge modes.

ZVCHG1	ZVCHG0	FET USED
0	0	ZVCHG
0	1	CHG
1	0	OD
1	1	No Action

TEMP0, TEMP1 These bits select the measurement source used for *SBS.Temperature( )*.

TEMP1	TEMP0	TEMPERATURE() SOURCE
0	0	Internal Temperature Sensor
0	1	TS1 Input (default)
1	0	Most extreme of TS1 or TS2 Inputs
1	1	Average of TS1 and TS2 Inputs

SLEEP   Enables the bq20z80 to enter Sleep mode.

0 =   bq20z80 enters Sleep Mode under normal Sleep entry requirements

1 =   bq20z80 never enters Sleep

CC0, CC1

These bits configure the bq20z80 for the number of series cells in the battery stack.

MAC1, MAC2 These bits configure the *SBS.ManufacturerAccess( )* function for multiple data options, but only 00 options exist today and should not be changed. Other combinations are reserved for future use.

CC1	CC0	# OF SERIES CELLS
0	0	Reserved
0	1	2
1	0	3
1	1	4

LED0, LED1

These bits configure the number of LEDs used in the LED Display.

LED1	LED0	# OF LED'S USED
0	0	0
0	1	3
1	0	4
1	1	5

DMODE   This bit sets the display as Relative or Absolute mode

0 = Display reflects *SBS.RelativeStateOfCharge( )*

1 = Display reflects *SBSAbsoluteStateOfCharge( )*

CHGLED   Enables display while charging

0 = Display not activated by charging, requires push-button event or SMBus command

1 = Display active during charging

LEDR   Enables activation of the LED display on device-reset exit.

0 = LED display is not activated on exit from device reset

1 = LED display is activated (simulates a $\overline{DISP}$ transition) on exit from device reset

Operation Configuration B (OPCFGB)

OPERATION CONFIGURATION	bit7	bit6	bit5	bit4	bit3	bit2	bi1	bit0
High Byte	–	–	RESCAP	–	–	–	CHGTERM	CCT
Low Byte	CHGSUSP	DSGOT	CHGFET	CHGIN	NR	CPE	HPE	BCAST

BCAST   This bit enables or disables SBS broadcasts to smart charger and host.

0 = Broadcast to host and charger enabled

1 = Broadcast to host and charger disabled

HPE   This bit enables or 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   This bit enables or disables PEC transmissions to the smart-battery charger for master-mode alarm messages.

   0 = No PEC byte on alarm warning to charger

   1 = PEC byte on alarm warning to charger

NR   This bit can set the bq20z80 in non-removable battery mode.

   0 = Removable battery mode

   1 = Non-removable battery mode

CHGIN   This bit can set enable the CHG FET (and ZVCHG FET if used) to turn off when the bq20z80 is in charge-inhibit mode.

   0 = No FET change in charge-inhibit mode

   1 = Charge and ZVCHG, if used, turn off in charge-inhibit mode

CHGFET   This bit enables or disables the CHG FET from reacting to a valid charge termination.

   0 = CHG FET stays on at charge termination

   1 = CHG FET turns off at charge termination

OTFET   This bit enables or disables FET actions from reacting to an Over Temperature Fault.

   0 = There is NO opposite FET action when an Over Temperature condition is detected

   1 = There is opposite FET action when an Over Temperature condition is detected

CHGSUSP This bit can enable the CHG FET (and ZVCHG FET if used) to turn off when the bq20z80 is in Charge Suspend mode.

   0 = No FET change in Charge Suspend mode

   1 = Charge and ZVCHG, if used, turns off in Charge Suspend mode

CCT   This bit sets the format of the Cycle Count Threshold.

   0 = *DF.CycleCount* is in % of *SBS.FullChargeCapacity( )*

   1 = *DF.CycleCount* is a fixed mAh value

CHGTERM This bit enables or disables *TCA* and *FC* to be cleared after charger termination confirmed.

   0 = *SBS.BatteryStatus( ) TCA* and *FC* bits are not cleared by charge termination confirmation, but are cleared by other means.

   1 = *SBS.BatteryStatus( ) TCA* and *FC* bits are cleared by charge termination confirmation, or by other means.

RESCAP   This bit configures the compensation model for the *DF.ReserveCapacity*

   0 = Light Load (C/20) Compensation

   1 = SBS.AverageLoad( ) Compensation

Non-Removable Configuration (NRConfig)

NON-REMOVABLE CONFIGURATION	bit7	bit6	bit5	bit4	bit3	bit2	bi1	bit0
High Byte	–	–	OCD	OCC	OCD2	OCC2	–	–
Low Byte	–	–	OC	–	–	AOCD	SCC	SCD

The NR_Config bits enable the current and charge protection recovery features to be treated differently based on the DF.Operation Configuration, NR bit. The individual features indicate the recovery options available.

SCD   Short Circuit, Discharge can be configured to have additional recovery mechanisms depending on *DF.Operation Configuration, NR*.

SCC   Short Circuit, Charge can be configured to have additional recovery mechanisms depending on *DF.Operation Configuration, NR*.

AOCD   AFE Overcurrent, Discharge can be configured to have additional recovery mechanisms depending on *DF.Operation Configuration, NR*.

OC   Overcharge can be configured to have additional recovery mechanisms depending on *DF.Operation Configuration, NR*.

OCC2   Tier-2 Overcurrent, Charge can be configured to have additional recovery mechanisms depending on *DF.Operation Configuration*.

OCD2   Tier-2 Overcurrent, Discharge can be configured to have additional recovery mechanisms depending on *DF.Operation Configuration, NR*.

OCC   Overcurrent, Charge can be configured to have additional recovery mechanisms depending on *DF.Operation Configuration, NR*.

OCD   Overcurrent, Discharge can be configured to have additional recovery mechanisms depending on *DF.Operation Configuration*.

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Permanent Failure Status (PFSTATUS)

The permanent failure status register indicates that reason the bq20z80 has entered permanent failure.

PERMANENT FAILURE STATUS	bit7	bit6	bit5	bit4	bit3	bit2	bi1	bit0
High Byte	FBF	–	–	–	SOCD	SOCC	AFE_P	AFE_C
Low Byte	DFF	DFETF	CFETF	CIM	SOTD	SOTC	SOV	PFIN

PFIN   Set on External Input Indication of permanent failure

SOV   Set on a Safety-Overvoltage permanent failure

SOTC   Set on a Charge Safety Over-Temperature permanent failure

SOTD   Set on a Discharge Safety Over-Temperature permanent failure

CIM   Set on a Cell-Imbalance permanent failure

CFETF   Set on a Charge-FET-Failure permanent failure

DFETF   Set on a Discharge-FET-Failure permanent failure

DFF   Set on a Data-Flash Verification permanent failure

AFE_C   Set on an AFE-Communications permanent failure

AFE_P   Set on a Periodic-AFE-Communications permanent failure

SOCC   Set on a Charge Safety-Overcurrent permanent failure

SOCD   Set on a Discharge Safety Overcurrent in permanent failure

FBF   Set when the fuse has not cut off current, even though the output has been driven low

Permanent Failure Configuration (PFCFG)

The Permanent Failure Configuration register enables or disables the use of the pin when the corresponding DF.Permanent Failure Status flag is set.

PERMANENT FAILURE CONFIGURATION	bit7	bit6	bit5	bit4	bit3	bit2	bi1	bit0
High Byte	–	–	–	–	XSOCD	XSOCC	XAFE_P	XAFE_C
Low Byte	XDFF	XDFETF	XCFETF	XCIM	XSOTD	XSOTC	XSOV	XPFIN

If corresponding *DF.PF_Status* AND *DF.PermanentFailureConfiguration* bits are set (1), the output is driven and latched low. This does not include the *FBF* bit of *DF.PermanentFailure Status*.

Lifetime Data

Lifetime Maximum Temperature: This data flash value is updated if the current *SBS.Temperature( )* is > the current *Lifetime Maximum Temperature* value for a time greater than *Lifetime Update Time* (*LTUT*), OR an increment greater than *Lifetime Temperature Delta* (*LTTD*).

Lifetime Minimum Temperature: This data flash value is updated if the current *SBS.Temperature( )* is < the current *Lifetime Minimum Temperature* value for a time greater than *LTUT*, OR an increment greater than *Lifetime Temperature Delta* (*LTTD*).

Lifetime Average Temperature: If *SBS.Temperature( )*NEW + LTTD = *SBS.Temperature( )*OLD = *SBS.Temperature( )*NEW - LTTD. Then, the *Lifetime Average Temperature* is updated. The average is calculated as a simple average of all the valid temperature readings.

Lifetime Maximum Discharge Current: This data flash value is updated if the current *SBS.AverageCurrent ( )* is greater than the current *Lifetime Maximum Discharge Current* value, and *SBS.AverageCurrent( )* is negative (discharge) for a time greater than *LTUT*, OR an increment greater than *Lifetime Current Delta* (*LTCD*).

Lifetime Maximum Charge Current: This data flash value is updated if the current *SBS.AverageCurrent( )* is greater than the current *Lifetime Maximum Charge Current* value, and *SBS.AverageCurrent( )* is positive (charge) for a time greater than *LTUT*, OR an increment greater than *LTCD*.

Lifetime Maximum Battery Voltage: This data flash value is updated if the current *SBS.Voltage( )* is greater than the current *Lifetime Maximum Battery Voltage* value for a time greater than *LTUT*, OR an increment greater than *Lifetime Battery Voltage Delta* (*LTBVD*).

Lifetime Minimum Battery Voltage: This data flash value is updated if the current *SBS.Voltage( )* is less than the current *Lifetime Minimum Battery Voltage* value for a time greater than *LTUT*, OR an increment greater than *LTBVD*.

Lifetime Maximum Cell Voltage: This data flash value is updated if any *SBS.VCELLx( )* is greater than the current *Lifetime Maximum Cell Voltage* value for a time greater than *LTUT*, OR an increment greater than *Lifetime Cell Voltage Delta* (*LTCVD*).

Lifetime Minimum Cell Voltage: This data flash value is updated if the current *SBS.VCELLx( )* is less than the current *Lifetime Minimum Cell Voltage* value for a time greater than *LTUT*, OR an increment greater than *LTCVD*.

Lifetime Maximum Power: This data flash value is updated when *DF.SBSAveragePower( )* is greater than the current *Lifetime Maximum Power* value for a time greater than *LTUT*, OR an increment greater than *Lifetime Max Power Delta* (*LTMPD*).

When the Life Time Update Time expires then **ALL** Life Time data is updated to data flash.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
LTMaxT	Lifetime Maximum Temperature	Unsigned Int	0 to 1400			
LTMinT	Lifetime Minimum Temperature	Signed Int	-600 to 1400		0.1°C	
LTAveT	Lifetime Average Temperature		-600 to 1400			
LTMaxDSG	Lifetime Maximum Discharge Current		0 to 65345		mA	
LTMaxCHG	Lifetime Maximum Charge Current		0 to 65345	2		0
LTMaxV	Lifetime Maximum Pack Voltage		0 to 65345			
LTMinV	Lifetime Minimum Pack Voltage		0 to 65345		mV	
LTMaxCV	Lifetime Maximum Cell Voltage		0 to 65345			
LTMinCV	Lifetime Minimum Cell Voltage		0 to 65345			
LTMP	Lifetime Maximum Power	Unsigned Int	0 to 65345		10mWh	
LTUT	Lifetime Update Time		0 to 60	1	s	10
LTTD	Lifetime Temperature Delta		0 to 200	1	0.1°C	50
LTCD	Lifetime Current Delta		0 to 200	1	mA	50
LTBVD	Lifetime Battery Voltage Delta		0 to 2000	2	mv	200
LTCVD	Lifetime Cell Voltage Delta		0 to 200	1	mV	50
LTMPD	Lifetime Maximum Power Delta		0 to 256	1	10mWh	200

CHARGE CONTROL

Figure 5 shows the charge algorithm by mode.

Notes:

1) If ANY safety function activation is detected then charging mode is exited regardless of state.

2) If ANY power mode activation is detected then charging mode is exited regardless of state.

3) If DF.OperationConfiguration, NR = 0 AND /PRES is detected high then charging mode is exited regardless of state

4) If a charging source is no longer detected then charging mode is exited regardless of state.
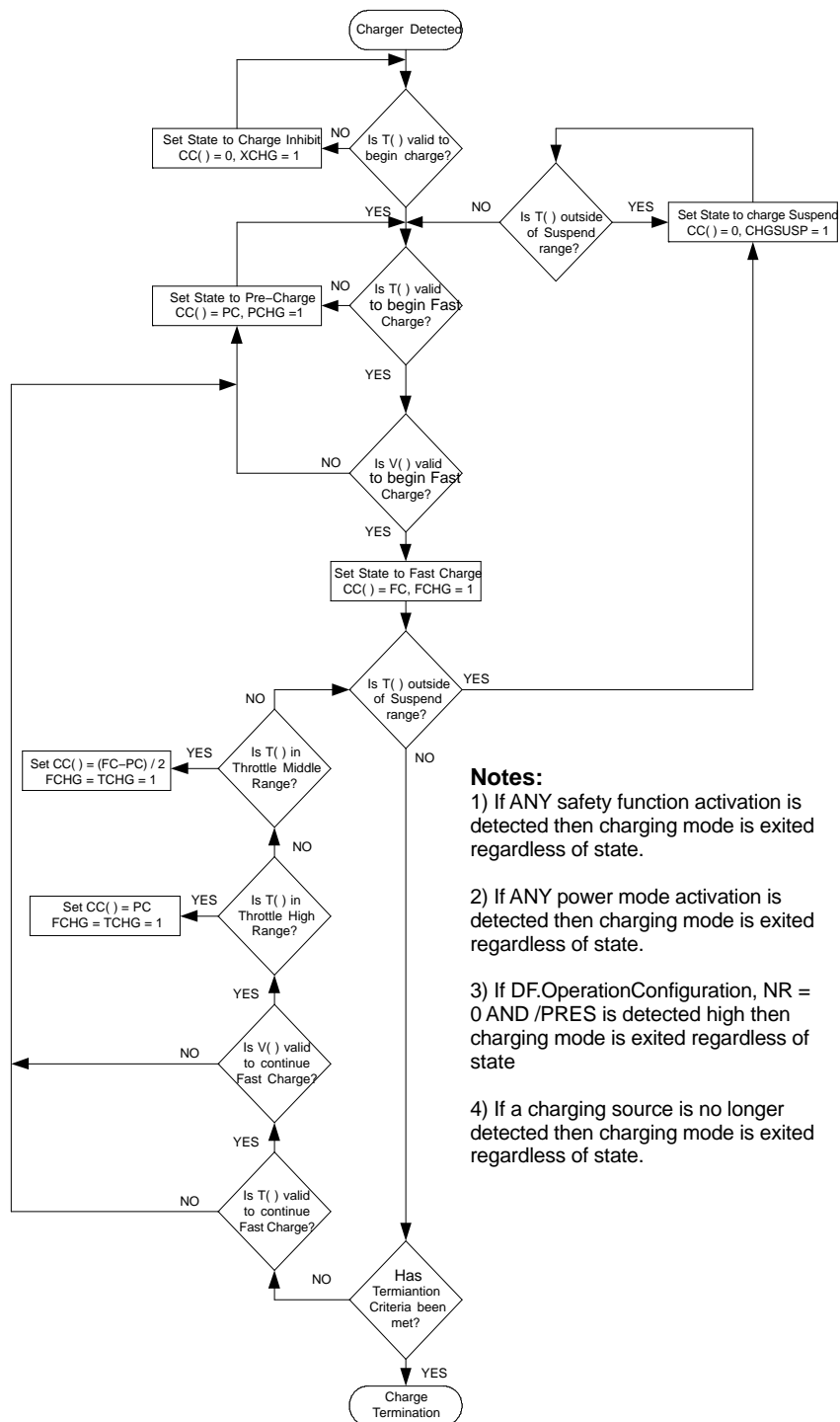
Figure 5. bq20z80 Charge Modes

CC-CV Charging

SBS.ChargingCurrent( ) (0x14) Read only, 16-bit unsigned integer word, units in mA. Reports the appropriate charging current per the charging algorithm in this section. The default value is set in *DF.Fast Charge Current* (*FCHGI*), and altered per the algorithm or safety conditions.

SBS.ChargingVoltage( ) (0x15) Read only, 16-bit unsigned integer word, units in mV. Reports the appropriate charging voltage per the charging algorithm in this section. The default value is set in *DF.Fast Charge Voltage* (*FCHGV*), and altered per the algorithm or safety condition.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
FCHGI	Fast Charge Current	Integer	0 to 10000	2	mA	3000
FCHGV	Fast Charge Voltage	Integer	0 to 20000	2	mV	16800

Charge Inhibit Mode

The bq20z80 sets the *SBS.ChargingCurrent( )* and *SBS.ChargingVoltage( )* values to 0 to inhibit charging when *DF.Charge Inhibit Temperature Low* (*XCHGTL*) is greater than *SBS.Temperature( )*, which is greater than *DF.Charge Inhibit Temperature High* (*XCHGTH*). When charging is inhibited, *XCHG* in *SBS.ChargingStatus( )* is set.

If *CHGIN* in *DF.OperationConfiguration* is set the CHG FET and ZVCHG FET (if used) are turned off when the bq20z80 is in charge-inhibit mode.

The bq20z80 allows charging to resume when *DF.Charge Inhibit Temperature Low* (*XCHGTL*) + *Temperature Hysteresis* (*THYS*) is less than or equal to *SBS.Temperature( )*, which is less than or equal to *Charge Inhibit Temperature High* (*XCHGTH*) −*THYS*. The FETs also return to their previous states at this time.

XCHG in *SBS.ChargingStatus( )* will be cleared when these conditions are met or when a fault condition is detected or when the battery is removed if *DF.OperationConfiguration, NR,* is cleared.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
XCHGTL	Charge Inhibit Temperature Low	Integer	-400 to 1200	2	0.1°C	0
XCHGTH	Charge Inhibit Temperature High		-400 to 1200	2		450
THYS	Temperature Hysteresis		0 to 100	1		30

Pre-Charge Mode

The bq20z80 sets *SBS.ChargingCurrent( )* to DF.Pre-Charge Current (PCHGI) when *DF.Charge Inhibit Temperature* is less than *SBS.Temperature( ),* which is less than or equal to *DF.Pre-Charge Temperature* (*PCHGT*), OR if *SBS.VCELL(ANY)( )* is less than *DF.Pre-Charge Voltage* (*PCHGV*). Depending on the setting of *DF.OperationConfigurationZVCHG0, ZVCHG1*, FET action may be taken.

ZVCHG1	ZVCHG0	FET USED
0	0	ZVCHG
0	1	CHG
1	0	OD Pin
1	1	No Action

During precharge, *PCHG* in *SBS.Charging Status( )* is set, and is cleared when *SBS.Temperature( )* is greater than or equal to *DF.Pre-Charge Temperature* (*PCHGT*) + *THYS*, AND *SBS.VCELL(ALL)( )* is greater than or equal to *DF.Pre-Charge Voltage Recovery* (*PCHGVR*), OR Charge Suspend is entered, a fault condition detected, or the battery removed if *DF.OperationConfiguration*, *NR*, is cleared.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
PCHGT	Pre-Charge Temperature	Integer	-400 to 1200	2	0.1°C	120
PCHGV	Pre-Charge Voltage		0 to 20000		mV	13000
PCHGVR	Pre-Charge Voltage Recovery		0 to 20000		mV	14000
PCHGI	Pre-Charge Current		0 to 2000		mA	250

Fast Charge

The bq20z80 sets *SBS.ChargingCurrent( )* to *DF.Fast Charge Current* (*FCHGI*) when if *DF.Pre-Charge Temperature + THYS* is less than *SBS.Temperature( )*, which is less than or equal to *DF.Over Temperature in Charge*, AND if *DF.Pre-Charge Voltage* is less than or equal to *SBS.Voltage( )*, which is less than *SBS.ChargingVoltage( ) + DF.Over Charging Voltage* (*OCHG*). See Over Charging Voltage section for further details. During fast charge, *FCHG* in *SBS.ChargingStatus( )* is set, and the CHG FET is turned on if no protection conditions are detected.

Fast Charge Temperature Throttling

The bq20z80 alters *SBS.ChargingCurrent( )* and sets the *TCHGx* bits in *SBS.ChargingStatus( )* during fast charge in response to changing temperature conditions. If *DF.Charge Suspend Temperature High* (*CHGSUSPH*) is greater than *SBS.Temperature( ),* which is greater than or equal to *CHGSUSPH - Delta Temperature* (*dT*), *SBS.ChargingCurrent( )* is set to *DF.Pre-Charge Current* and *SBS.ChargingStatus( ) TCHG1* .

If *CHGSUSPH - dT* is greater than *SBS.Temperature( )* which is greater than or equal to *CHGSUSPH– 2 ×dT*, *SBS.ChargingCurrent( )* is set to (*DF.Fast Charge Current–DF.Pre-Charge Current*) ÷ 2 and *SBS.ChargingStatus( ) TCHG2* is set.

If *CHGSUSPH - 2 ×dT* is greater than *SBS.Temperature( )* which is greater than or equal to *DF.Pre-Charge Temperature*, *SBS.ChargingCurrent( )* is set to *DF.Fast Charge Current*, and *SBS.ChargingStatus( ) TCHG* is cleared.

SBS.ChargingStatus( ) TCHGx are also cleared when another charging mode is entered, a protection condition is detected, or the battery is removed while the *DFOperationConfiguration, NR* bit is set.

However, if *DF.dT* is set to 0, no throttling change in *SBS.ChargingCurrent( )* from *DF.Fast Charge Current* occurs.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
OCHG	Over Charging Voltage		0 to 2000		mV	500
dT	Delta Temperature	Integer	0 to 500	2	0.1°C	50
CHGSUSH	Charge Suspend Temperature High		−400 to 1200		0.1°C	550

Charge Suspend Mode

The bq20z80 suspends charging when *SBS.AverageCurrent( )* is greater than the *DF.Charge Current Detection* (*ICHG*) threshold {Charging has begun}, AND *DF.Charge Suspend Temperature Low* (*CHGSUSPL*) is greater than *SBS.Temperature( )* which is greater than *DF.Charge Suspend Temperature High* (*CHGSUSPH*).

If *CHGSUSP* in *DF.OperationConfiguration* is set, the CHG FET and ZVCHG FET (if used), are turned off when the bq20z80 is in charge-suspend mode.

When charging is suspended, *SBS.ChargingCurrent( )* is set to 0, and the *CHGSUSP* bit in *SBS.ChargingStatus( )* is set.

To return to normal charging, *SBS.Temperature( )* must be greater than or equal to *DF.Charge Inhibit Temperature Low* (*XCHGTL*) + *Temperature Hysteresis* (*THYS*), AND greater then or equal to *DF.Charge Inhibit Temperature High* (*XCHGTH*) −*THYS*. The bq20z80 clears the *CHGSUSP* bit of *SBS.ChargingStatus( )* when this condition is met, and sets *SBS.ChargingCurrent( )* according to the appropriate charging mode entered. The FETs are also returned to their previous state at this time.

The *CHGSUSP* bit of *SBS.ChargingStatus( )* is also cleared when a protection condition is detected, or when the battery is removed while *DF.OperationConfiguration*, *NR*, is cleared.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
CHGSUSPL	Charge Suspend Temperature Low	Integer	−400 to 1200	2	0.1°C	−50
CHGSUSH	Charge Suspend Temperature High		−400 to 1200			550

Pulse Charging

Pulse charging is part of the fast-charging mode and is a loop. During the loop, the measured cell voltages are calculated every 250ms. This data is not reported via the *SBS.VCELLx( )* commands.

The pulse-charging loop is entered when the maximum cell voltage is greater than or equal to *DF.Max Charge Voltage* (*VMAX*), OR maximum cell voltage is greater than or equal to *DF.Charge ON Voltage* (*VON*) for *DF.Maximum ON Pulse* (*tON*). When these conditions are met, the CHG FET is turned off, and the *SBS.ChargingStatus( )PULSE* and *PULSE_OFF* bits are set.

If the maximum cell voltage is less than *DF.Charge OFF Voltage* (*VOFF*), AND the CHG FET is off for *DF.Minimum OFF Pulse* (*tOFF*), the CHG FET is turned on and the *SBS.ChargingStatus( )PULSE_OFF* bit cleared.
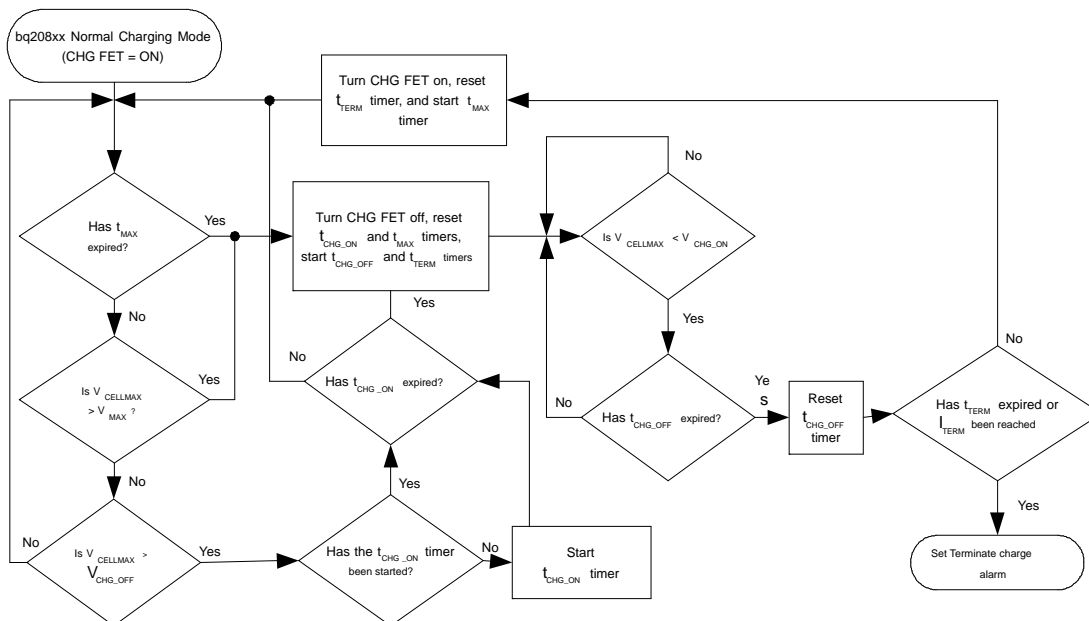

Figure 6. Pulse Charging

The pulse-charging loop is exited and *SBS.ChargingStatus( )*, *PULSE*, is cleared if another charging mode is entered, a protection condition detected, or the battery is removed when *DF.OperationConfiguration*, *NR*, is cleared.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
VON	Cell CHG FET Turn ON Voltage	Integer	0 to 5000	2	mV	4200
VOFF	Cell CHG FET Turn OFF Voltage		0 to 5000			4200
tON	Maximum ON Pulse Time		0 to 240	1	s/8	480
tOFF	Minimum OFF Pulse Time		0 to 240			0
VMAX	Maximum Cell ON Pulse Voltage		0 to 5000	2	mV	4270

Primary Charge Termination

The bq20z80 sets *Fully_Charged and Terminate_Charge* in *SBS.BatteryStatus( )* when *SBS.Current( )* is less than *DF.Charging Taper Current* (*CHGTI*), AND *SBS.Voltage( )* is greater than *SBS.ChargingVoltage( )−DF.Charge Termination Voltage* (*CHGTV*) threshold for 2 consecutive periods of *DF.Current Taper Window* (*CTW*). If *DF.OperationConfiguration,CHGFET*, bit is set, the CHG is also turned off.

When charge termination is detected, *SBS.ChargingStatus( )* is cleared, and *SBS.ChargingCurrent( )* is set to *DF.Maintenance Charge Current* (*MCHGI*).

SBS.BatteryStatus( ) Fully_Charged is cleared and *SBS.ChargingCurrent( )* is set to the appropriate value for battery conditions when *SBS.RelativeStateOfCharge( )* is less than *DF.Fully Charged Clear %*.

SBS.BatteryStatus( ) Terminate_Charge_Alarm is also cleared, and *SBS.ChargingCurrent( )* is set to the appropriate value for battery conditions when *DF.OperationConfiguration*, *CHGTERM* is set, AND *SBS.Current( )* is less than *DF.Charge Detection Threshold* (*ICHG*) for a period of 2 consecutive periods of *Current Taper Window* (*CTW*).

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
MCHGI	Maintenance Charge Current	Integer	0 to 255	1	mA	0
CHGTI	Charge Termination Taper Current		0 to 1000	2		250
CHGTV	Charge Termination Voltage		0 to 1000	2	mV	300
FCT	Fast Charge Termination %		0 to 100	1	%	100
CTW	Current Taper Window		0 to 60	1	s	40

Charge Control SMBus Broadcasts

All broadcasts are enabled by setting the *BCAST* bit in *DF.Operation Configuration*. If *DF.Operation ConfigurationHPE* is set, the Master-Mode broadcasts to the Host address have PEC enabled, and if *Operation Configuration CPE* is set, the Master-Mode broadcasts to the Smart-Charger address have PEC enabled.

If enabled, *SBS.ChargingVoltage( )* and *SBS.ChargingCurrent( )* is broadcast to the Smart-Charger Address every 10 seconds.

If enabled, *SBS.AlarmWarning( )* is broadcast to the Host Address every 10 seconds, only while any of the *SBS.BatteryStatus( )*, bits 8 -15, are set. Broadcasting stops when *SBS.BatteryStatus( )*, 8-15, are clear.

If enabled *SBS.AlarmWarning( )* is broadcast to the Smart Charge Address every 10s only when any of *SBS.BatteryStatus( )*, bits 12 -15. Broadcasting stops when *SBS.BatteryStatus( )*, 12-15, are clear.

Charging Faults

Battery Depleted

The bq20z80 sets the XCHGLV bit in *SBS.ChargingStatus( )* when the charger is present AND *SBS.Voltage( )* is less than or equal to *DF.Terminate Voltage* (*TV*).

When this fault is detected, *SBS.ChargingCurrent( )* is set to 0, *SBS.BatteryStatus( )* Terminate_Discharge_Alarm is set, DSG and CHG FETs are turned off, and the ZVCHG FET is turned off, if the *ZVCHG0,1* bits in *DF.Operation Configuration* are set appropriately.

To recover from this mode, *SBS.Current( )* must be greater than or equal to *DF.Charge Detection Current*, OR *SBS.Voltage( )* becomes greater than *DF.Terminate Voltage*. When the bq20z80 recovers from a Battery Depleted state, the DSG, CHG and ZVCHG FET's are returned to the previous state in accordance with the charging algorithm and the *DF.OperationConfigurationZVCHG0,1* bits, *SBS.BatteryStatus( )* Terminate_Charge_Alarm is reset, and the *XCHGLV* bit in *SBS.ChargingStatus( )* is reset.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
TV	Terminate Voltage	Integer	0 to 20000	2	mV	8000

Overcharging Voltage

The bq20z80 sets the *OCHGV* bit in *SBS.ChargingStatus( )* when *SBS.Voltage( )* is greater than or equal to *SBS.ChargingVoltage( )* + *DF.Over Charging Voltage* (*OCHGV*) for a time greater than or equal to *DF.Pack Overvoltage Time* (*POVT*). If *OCHGV* = 0, this feature is completely disabled.

When *OCHGV* is set, the CHG FET is turned off and the ZVCHG FET is turned off if the *ZVCHG0,1* bits in *DF.Operation Configuration* are set appropriately. Also, *SBS.ChargingCurrent( )* is set to 0, *SBS.ChargingVoltage( )* is set to 0, and *SBS.BatteryStatus( )Terminate_Charge_Alarm* is set.

To recover from this mode, *SBS.Current( )* must be greater than or equal to *DF.Dicharge Detection Current*. When the bq20z80 recovers from an Over Charging Voltage state, the CHG and ZVCHG FET's are returned to the previous state in accordance with the charging algorithm, and *SBS.BatteryStatus( )Terminate_Charge_Alarm* is reset. The *OCHGV* flag, *SBS.ChargingCurrent( )*, *SBS.ChargingVoltage( )* are *not* reset via this recovery.

If *SBS.Voltage( )* is less than or equal to *SBS.ChargingVoltage( )*, *SBS.ChargingCurrent( )*, *SBS.ChargingVoltage( )* and the CHG and ZVCHG FET's are returned to the previous state in accordance with the charging algorithm, and the *DF.OperationConfiguration*, *ZVCHG0,1* bits and *SBS.BatteryStatus( )Terminate_Charge_Alarm* are reset.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
OCHGV	Over Charging Voltage Threshold	Integer	0 to 3000	2	mV	500

Overcharging Current

The bq20z80 sets the OCHGI bit in *SBS.ChargingStatus( )* is set when *SBS.Current( )* is greater than or equal to *SBS.ChargingCurrent( )* + DF.Over Charging Current (OCHGI) threshold for DF.Over Current in Charge time (tOCC). If OCHGI = 0 then feature is completely disabled.

When OCHGI is set then the CHG will to be turned OFF and ZVCHG FET is turned OFF if the ZVCHG0,1 bits in *DF.Operation Configuration* are set appropriately. Also, *SBS.ChargingCurrent( )* is set to 0, *SBS.ChargingVoltage( )* is set to 0, and *SBS.BatteryStatus( )* Terminate_Charge_Alarm is set.

To recover from this mode then *SBS.AverageCurrent( )* must be less than or equal to DF.OverCurrent in Charge Recovery. When the bq20z80 recovers from an Over Charging Current state then *SBS.ChargingCurrent( )*, *SBS.ChargingVoltage( )* and the CHG and ZVCHG FET's are returned to previous state in accordance with the charging algorithm and the *DF.OperationConfiguration* ZVCHG0,1 bits. *SBS.BatteryStatus( )* Terminate_Charge_Alarm and *SBS.ChargingStatus( )* OCHGI are cleared.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
OCHGI	Over Charging Current Threshold	Integer	0 to 2000	2	mA	500

Overcharge

The bq20z80 sets the *OC* bit in *SBS.ChargingStatus( )* when the amount of capacity added after the point where *SBS.RemainingCapacity( )* is equal to or greater than *SBS.FullChargeCapacity( )* + *DF.Maximum Over Charge* (*OCHG*). If *OCHG* is set to 0, this feature is completely disabled.

When *OC* is set, the CHG FET and ZVCHG FET are turned off if the *ZVCHG0,1* bits in *DF.Operation Configuration* are set appropriately. Also, *SBS.ChargingCurrent( )* is set to 0, *SBS.ChargingVoltage( )* is set to 0, and *SBS.BatteryStatus( )* Terminate_Charge_Alarm, Fully_Charged and Over_Charged_Alarm are set.

If *DF.Operation Configuration* CHGFET is set, the CHG FET is *not* turned off.

There are 3 recovery methods from this fault state:

 1. If *DF.NR_Config, OC* = 1 AND *DF.Operational Configuration, NR* bit = 0, AND a transition of bit0 input from low to high to low (pack removal and re-insertion) occurs, the bq20z80 recovers from this fault mode.
 2. If *DF.Operational Configuration*, *NR* bit = 1 AND *SBS.Current( )* is less than or equal to 0mA, AND there has been *DF.Maximum Over Charger Recovery* (*OCHGR*) amount of continuous discharge, the bq20z80 recovers from this fault mode.
 3. If *SBS.RemainingStateOfCharge%( )* becomes less than or equal to *DF.FC_Clear%*, the bq20z80 recovers from this fault mode.

On recovery, the CHG and ZVCHG FETs are returned to the previous state in accordance with the charging algorithm, and the *DF.OperationConfiguration*, *ZVCHG0,1* bits are returned to the previous state. *SBS.BatteryStatus( )Terminate_Charge_Alarm, Fully_Charged* and *Over_Charged_Alarm*, and *SBS.ChargingStatus( )* OC are cleared.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
OCHG	Maximum Overcharge Threshold		0 to 4000	2	mAh	300
OCHGR	Maximum Overcharge Recovery	Integer	0 to 100	1		2
FC_CLR	Full Charge Flag Clear %				%	95

bq20z80

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Fast Charge Mode Charging Timeout

When *SBS.Current( )* is greater than or equal to *DF.Fast Charge detection* (*FCCHG*), the bq20z80 starts the Fast Charge timer.

The Fast Charge Timer is suspended when Pulse Charging is active (*SBS.ChargingStatus( )PC* = 1), or Temperature-based Charge Current Throttling is active (*SBS.ChargingStatus( )TCHG* = 1), or when the FCMTO expires.

The Fast Charge Timer is reset when *DF.Over Charge Recovery* (*OCR*) amount of discharge is detected, OR if *DF.OperationConfiguration*, *NR* = 1, AND CCT transitions from low to high to low.

The bq20z80 sets *FCMTO* bit is *SBS.ChargingStatus( )* if the Fast Charge Timer becomes equal to exceeds the *DF.Fast Charge Mode Charger Timeout* (*FCMTO*) then the CHG FET is turned off, and the ZVCHG FET is turned OFF if the *ZVCHG0,1* bits in *DF.Operation Configuration* are set appropriately. Also, *SBS.ChargingCurrent( )* is set to 0, *SBS.ChargingVoltage( )* is set to 0, and *SBS.BatteryStatus( )Terminate_Charge_Alarm* is set. If *FCMTO* is programmed to 0, this feature is completely disabled.

To recover from this mode,*SBS.Current( )* must be greater than or equal to *DF.Discharge Detection Current* (*IDSG*), or if *DF.Operation Configuration*, *NR* = 0 AND BCAST transitions from low to high back to low. On recovery, the *SBS.ChargingCurrent( ), SBS.ChargingVoltage( )* and the CHG and ZVCHG FET's are returned to the previous state in accordance with the charging algorithm, and the *DF.OperationConfigurationZVCHG0,1* bits. *SBS.BatteryStatus( )Terminate_Charge_Alarm* and *SBS.ChargingStatus( )FCMTO* are cleared.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
IFCCHG	Fast Charge Detection Current Threshold	Integer	0 to 2000	2	mA	800
FCMTO	Fast Charge Mode Charge Timeout		0 to 14400		s	10800

Precharge Mode Charging Timeout

When *SBS.Current( )*is greater than or equal to *DF.Pre-Charge detection threshold* (*IPCCHG*), the bq20z80 starts the Pre-Charge Timer.

The Pre-Charge Timer is suspended when pulse charging is active (*SBS.ChargingStatus( )PC* = 1), and when Temperature-based Charge Current Throttling is Active (*SBS.ChargingStatus( )TCHG* = 1) or when the PCMTO timer expires.

The Pre-Charge Timer is reset when a *DF.Over Charge Recovery* (*OCR*) amount of discharge is detected, OR if *DF.Operation Configuration*, *NR* = 1 AND PRES transitions from low to high back to low.

The bq20z80 sets the *PCMTO* bit in *SBS.ChargingStatus( )* if the Pre-Charge Timer becomes equal to exceeds the *DF.Pre-Charge Mode Charger Timeout* (*PCMTO*), the CHG FET is turned off, and the ZVCHG FET is turned off if the *ZVCHG0,1* bits in *DF.Operation Configuration* are set appropriately. Also, *SBS.ChargingCurrent( )* is set to 0, *SBS.ChargingVoltage( )* is set to 0, and *SBS.BatteryStatus( )Terminate_Charge_Alarm* is set. If *PCMTO* is programmed to 0, this feature is completely disabled.

To recover from this mode, *SBS.Current( )* must be greater than or equal to *DF.Discharge Detection Current* (*IDSG*), or if *DF.Operation Configuration*, *NR* = 0 AND PRES transitions from low to high back to low. On recovery, the *SBS.ChargingCurrent( ), SBS.ChargingVoltage( )* and the CHG and ZVCHG FET's are returned to the previous state in accordance with the charging algorithm, *SBS.BatteryStatus( )* Terminate_Charge_Alarm and *SBS.ChargingStatus( )* PCMTO are cleared.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
IPCCHG	Pre-Charge Detection Current Threshold	Integer	0 to 2000	2	mA	50
PCMTO	Pre-charge Mode Timeout		0 to 14400		s	3600

POWER MODE

The bq20z80 has several power modes. During these modes, the bq20z80 modifies its operation to minimize power consumption from the battery.

During normal operation, the bq20z80 takes *ADC.Current*, *ADC.Voltage* and *ADC.Temperature* measurements, performs calculations, updates SBS data, and makes protection and status decisions at one-second intervals. Between these periods of activity, the bq20z80 is in a reduced power state.

During this measurement period, the PU pin is pulled high, the $\overline{PRES}$ input state is read, and PU is released. If $\overline{PRES}$ is high, the *PRES* bit in *SBS.OperationStatus( )* is cleared. If $\overline{PRES}$ is low, the *PRES* bit *SBS.OperationStatus( )* is set indicating the system is present (the battery is inserted).

If *DF.Operation Configuration*, *NR* is cleared, the $\overline{PRES}$ input must also be low (*DF.Operation Status*, *PRES* = 1) for the bq20z80 to enter Normal Mode.

Normal Mode Discharge Fault – Current

The bq20z80 reports a Normal Mode Discharge Fault due to Current by setting *SBS.OperationStatus( )XDSGI* when *SBS.BatteryStatus( )*, *DISCHARGING* is set {battery not charging}, AND *SBS.SafetyStatus( )*, *OCD* is set. When this occurs, the CHG and DSG FETs are turned off, and ZVCHG FET is turned OFF if the *ZVCHG0,1* bits in *DF.Operation Configuration* are set appropriately. Also, *SBS.ChargingCurrent( )* is set to 0, and *SBS.BatteryStatus( )Terminate_Discharge_Alarm* is set.

When *SBS.SafetyStatus( )*, *OCD* clears, the *SBS.ChargingCurrent( )* and the CHG, DSG and ZVCHG FET's are returned to previous state in accordance with the charging algorithm, and the *DF.OperationConfigurationZVCHG0,1* bits are **TBD**. *SBS.BatteryStatus( )Terminate_Discharge_Alarm* and *SBS.OperationStatus( )XDSGI* are also cleared.

Normal Mode Discharge Fault - Temperature

The bq20z80 will report a Normal Mode Discharge Fault due to Temperature by setting *SBS.OperationStatus( )XDSGT* when *SBS.BatteryStatus( )*, *DISCHARGING* is set {battery not charging}, AND either *SBS.SafetyStatus( )*, *OTD* is set, OR *SBS.Temperature( )* is less than or equal to *DF.Discharge Inhibit Temperature Low* (*XDSGTL*), and greater than or equal to *DF.Discharge Inhibit Temperature High* (*XDSGTH*). When this occurs, the CHG and DSG FETs are turned off, and the ZVCHG FET is turned off if the *ZVCHG0,1* bits in *DF.Operation Configuration* are set appropriately. Also, *SBS.ChargingCurrent( )* is set to 0, and *SBS.BatteryStatus( )Terminate_Discharge_Alarm* is set.

When *SBS.SafetyStatus( )*, *OTD* clears, and *SBS.Temperature( )* is greater than or equal to *DF.Discharge Inhibit Temperature Low* (*XDSGTL*) + *THYS* and less than or equal to *DF.Discharge Inhibit Temperature High* (*XDSGTH*) + *THYS*, the *SBS.ChargingCurrent( )* and the CHG, DSG and ZVCHG FET's are returned to the previous state in accordance with the charging algorithm, and the *DF.OperationConfiguration* ZVCHG0,1 bits are **TBD**. *SBS.BatteryStatus( )Terminate_Discharge_Alarm*, and *SBS.OperationStatus( )XDSGT* are also cleared.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
XDSGTL	Inhibit Discharge Low	Integer	−40 to 120	2	0.1°C	−50
XDSGTH	Inhibit Discharge High					600

Normal Mode Discharge Fault - Low Voltage (Battery Depleted)

The bq20z80 reports a Normal Mode Discharge Fault due to Low Voltage by setting *SBS.OperationStatus( )XDSGLV* when *SBS.BatteryStatus( )*, *DSICHARGING* = 1 {battery not charging}, AND *SBS.Voltage( )* is less than or equal to *DF.Terminate Voltage*. When this occurs, the CHG and DSG FETs are turned off, and the ZVCHG FET is turned off if the *ZVCHG0,1* bits in *DF.Operation Configuration* are set appropriately. Also, *SBS.ChargingCurrent( )* is set to 0, and *SBS.BatteryStatus( )Terminate_Discharge_Alarm* is set.

When *SBS.Voltage( )* is greater than or equal to *DF.Terminate Voltage*, the *SBS.ChargingCurrent( )* and the CHG, DSG and ZVCHG FET's are returned to the previous state in accordance with the charging algorithm. *SBS.BatteryStatus( )* Terminate_Discharge_Alarm and *SBS.OperationStatus( )* XDSGLV are also cleared.

Sleep Mode

In Sleep mode, the bq20z80 measures *ADC.Voltage* and *ADC.Temperature* every *DF.tSLEEP* time period, and *ADC.Current* is measured at intervals equal to *DF.tSLEEP*×*DF.Sleep Current Multiplier* (*tSLEEPX*). At each interval, the bq20z80 performs calculations, updates SBS data and makes protection and status decisions. Between these periods of activity the bq20z80 is in a reduced-power state.

The bq20z80 enters sleep mode when the following conditions exist.

- *SBS.Current( )* in charge or discharge is less than or equal to *DF.Sleep Threshold* (*ISLEEP*), AND SMBus is Low for a Bus Low period (*tBUSLOW*), AND *DF.Operation Configuration*, *SLEEP* bit is set
    OR
- *SBS.Current( )* is less than or equal to *DF.Sleep Threshold* in discharge, AND *SBS.ManufacturerAccess( )* Sleep command is received, AND *DF.Operation Configuration*, *SLEEP* bit is set.
    AND
- If *DF.Operation Configuration*, *NR* is cleared, the $\overline{PRES}$ input must also be high, *SBS.OperationStatus( )*, *PRES* = 0, for the bq20z80 to enter sleep.

Entry to Sleep mode is held off if any flag in *SBS.PFAlert( )* or *SBS.SafetyAlert( )* is set, or if any protection-feature recovery timers are active and have not expired, sleep mode is not entered and the bq20z80 remains in Normal mode.

On entry to sleep, and if *DF.Operation Configuration*, *NR* is cleared, the CHG and DSG FETs are turned off, and the ZVCHG FET is turned off if the *ZVCHG0,1* bits in *DF.Operation Configuration* are set appropriately. If *DF.Operation Configuration*, *NR* is set, the CHG FET is turned off, and the ZVCHG FET is turned off if the *ZVCHG0,1* bits in *DF.Operation Configuration* are set appropriately.

Also, on entry to sleep, the auto calibration of the ADC begins. However, if *SBS.Temperature( )* is less than or equal to 5ºC and greater than or equal to 45ºC, Auto Calibration of the ADC is not started on entry to sleep mode.

The bq20z80 exits sleep if |*SBS.Current( )*| is non-zero, OR the SMBC or the SMBD input transitions high, OR {any *SBS.OperationStatus( )*, *SBS.ChargingStatus( )* or *SBS.SafetyStatus( )* flag changes state}.

If *DF.Operation ConfigurationNR* is cleared, the bq20z80 to exits sleep mode when $\overline{PRES}$ is pulled low (*SBS.OperationSatatu( ) PRES* = 1).

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
tSLEEP	Sleep Time	Integer	0 to 200	1	s	6
ISLEEP	Sleep Current Threshold				mA	2
tBUSLOW	SMBus Low Detection Time		0 to 60		s	
tSLEEPX	Sleep Current Multiplier					10

Battery Removed Mode

The bq20z80 detects the Battery-Removed state when *DF.Operation Configuration*, *NR* is cleared AND the $\overline{PRES}$ input is high (*SBS.Operation Status( )*, PRES = 0).

On entry to Battery-Removed state, *SBS.BatteryStatus( )*, *Terminate_Charge_Alarm* and *Terminate_Discharge_Alarm* are set, *SBS.ChargingCurrent( )* and *SBS.ChargingVoltage( )* are set to 0, and the CHG and DSG FETs are turned off, and the ZVCHG FET is turned off if the *ZVCHG0,1* bits in *DF.Operation Configuration* are set appropriately.

Polling of the $\overline{PRES}$ pin continues at a rate of less than every 250ms.

The bq20z80 exits the Battery-Removed state if *DF.Operation Configuration*, *NR* is cleared, AND the $\overline{PRES}$ input is low (*SBS.Operation Status( )*, *PRES* = 1). When this occurs, *SBS.BatteryStatus( )*, *Terminate_Charge_Alarm* and *Terminate_Discharge_Alarm* are reset.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
VSHUT	Shutdown Voltage Threshold		0 to 20000	2	mV	9000
tSHUT	Shutdown Time	Integer	0 to 2	1	s	2
CHGPRES	Charger Present Threshold		0 to 21000	2	mV	17000

Shutdown Mode

The bq20z80 enters shutdown mode if the following conditions are met:

- *SBS.Voltage( )* is less than or equal to the *DF.Shutdown Voltage* (*VSHUT*) threshold,
  OR
- *SBS.ManufacturerAccess( )* shutdown command} AND Voltage at the bq29312 Pack pin is less than the *DF.Charger Present* (*CHGPRES*) threshold for a period of *DF.Shutdown Time* (*tSHUT*) AND *SBS.Current( )* is zero.

If *DF.Operation Configuration*, *NR* is set, *CHGPRES* must be greater than *VSHUT* + 6% for correct operation. It is also recommended that the value of *CHGPRES* be greater than 4.3V × the number of series cells for any setting on *NR*.

When the bq20z80 meets these conditions, the CHG, DSG and ZVCHG FETs are turned off, and the bq29312 is commanded to shut down. In shutdown mode, the bq20z80 is completely powered down because its supply is removed.

To exit shutdown mode, the voltage at the PACK pin of the bq29312 must be greater than its minimum operating voltage. When this occurs, the bq29312 returns power to the bq20z80, *SBS.OperationStatus( )WAKE* is set, and data flash configuration is loaded into the RAM of the bq20z80 and the bq29312. If the data-flash load was valid, the *SBS.BatteryMode( ), INIT* bit is set. When the DF load is completed, the *SBS.OperationStatus( )WAKE* bit is cleared.

If the data-flash load was bad, *SBS.BatteryMode( ), INIT* = 0, and the bq20z80 will attempt one reload. If the bq20z80 has attempted load 2 times without success, the bq20z80 enters the Data Flash Verification Failure state.

See Data Flash Verification for more details.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
VSHUT	Shutdown Voltage Threshold		0 to 20000	2	mV	9000
tSHUT	Shutdown Time	Integer	0 to 60	1	s	2
CHGPRES	Charger Present Threshold		0 to 21000	2	mV	17000

Display

Configuration

Number of LEDs Supported

Operation Configuration, LED0 and LED1 determine the number of LEDs supported.

LED1	LED0	LED's SUPPORTED
0	0	User
0	1	3
1	0	4
1	1	5

NOTE:

At powerup, the *LEDs Supported* bit is read and the associated LEDxON and LEDxOFF thresholds are loaded into data flash.

Display Mode

The mode of the display is set in *DF.Operation Configuration*, DMODE.

DMODE	LEDs SUPPORTED	% DATA	FULL REFERENCE
0	Relative Mode (default)	SBS.RSOC( )	*SBS.DesignCapacity( )*
1	Absolute Mode	SBS.ASOC( )	*SBS.FullChargeCapacity( )*

Display Format - Discharge

This mode is available when *SBS.BatteryStatus( )* DSG = 1

LED	THRESHOLD	3-LEDs	4-LEDs	5-LEDs	USER
ALARM	LED ALARM	10%	10%	10%	LED_ALARM%
1	LED1OFF	0 to 32%	0 to 24%	0 to 19%	LED1OFF%
2	LED2OFF	33 to 65%	25 to 49%	20 to 39%	LED2OFF%
3	LED3OFF	66 to 100%	50 to 74%	40 to 59%	LED3OFF%
4	LED4OFF	–	75 to 100%	60 to 79%	LED4OFF%
5	LED5OFF	–	–	80 to 100%	LED5OFF%

The LEDxOFF threshold is the % of *SBS.RSOC( )* or *SBS.ASOC( )* to enable the respective LED.

The LED_ALARM threshold is the % of *SBS.RSOC( )* or *SBS.ASOC( )* at which the remaining active LEDs will Flash at a 50% duty cycle rate of LED_Flash.

If *LEDRCA* in *DF.Operational Configuration* is set, AND If *SBS.BatteryStatus( )* RCA is set, the display flashes at the *DF.LED_Flash* rate with a 50% duty cycle.

If *LED0, LED1* = User, the User data flash percentages are used.

When *LEDRCA* =1, the LED_ALARM is ignored.

When *LEDRCA* = 0, the *SBS.BatteryStatus( )* is ignored.

Display Format - Charge

This mode is available when *SBS.BatteryStatus( )* DSG = 0

LED	THRESHOLD	3-LEDs	4-LEDs	5-LEDs	USER
ALARM	LED ALARM	10%	10%	10%	LED_ALARM%
1	LED1ON	0 to 32%	0 to 24%	0 to 19%	LED1ON%
2	LED2ON	33 to 65%	25 to 49%	20 to 39%	LED2ON%
3	LED3ON	66 to 100%	50 to 74%	40 to 59%	LED3ON%
4	LED4ON	–	75 to 100%	60 to 79%	LED4ON%
5	LED5ON	–	–	80 to 100%	LED5ON%

The LEDxON threshold is the % of SBS.RSOC( ) or SBS.ASOC( ) to enable the respective LED.

The LED_ALARM threshold is the % of SBS.RSOC( ) or SBS.ASOC( ) at which the remaining active LEDs flash at the rate of DF.LED_Flash, with a 50% duty cycle.

If LEDRCA in *DF.OperationConfiguration* is set AND if *SBS.BatteryStatus( )* RCA is set, the display flashes at the DF.LED_Flash rate with a 50% duty cycle.

If LED0, LED1 = User, the User data flash percentages are used.

If DF.LED_Blink is greater than 0, the top active LED blinks at the *DF.LED_Blink* rate with a 50% duty cycle.

Display Format - Permanent Failure

This mode is available when *SBS.SafetyStatus( )PF* = 1. The LEDs indicate the permanent failure cause as indicated by the flag in *SBS.PFStatus( )*.

PF MODE	LED5	LED4	LED3	LED2	LED1
-	0	0	0	0	Flash
PFIN	0	0	0	1	Flash
SOV	0	0	1	0	Flash
SOTC	0	0	1	1	Flash
SOTD	0	1	0	0	Flash
CIM	0	1	0	1	Flash
CFETF	0	1	1	0	Flash
DFETF	0	1	1	1	Flash
DFF	1	0	0	0	Flash
AFE_C	1	0	0	1	Flash
AFE_P	1	0	1	0	Flash

Display Timing

When the display is activated, between each active LED illumination there is a delay time of *DF.LED_Delay*.

When all active LEDs are illuminated, the display remains active for *DF.LED_Hold* time. When this time expires, all LEDs turn off at the same time.

LABEL	DESCRIPTION	FORMAT	VALID RANGE	SIZE (BYTES)	UNITS	DEFAULT VALUE
LED_Flash	LED Flash Time	Unsigned Integer	0 to 1000	2	ms	50
LED_Blink	LED Blink Time					750
LED_Delay	LED Delay Time					50
LED_Hold	LED Hold Time	Byte	0 to 10	1	s	4
LED1ON	LED1 Threshold in Charge		0 to 100		%	0
LED2ON	LED2 Threshold in Charge					19
LED3ON	LED3 Threshold in Charge					39
LED4ON	LED4 Threshold in Charge					59
LED5ON	LED5 Threshold in Charge					79
LED1OFF	LED1 Threshold in Discharge					0
LED2OFF	LED2 Threshold in Discharge					20
LED3OFF	LED3 Threshold in Discharge					40
LED4OFF	LED4 Threshold in Discharge					60
LED5OFF	LED5 Threshold in Discharge					80

Display Activation

There are 4 methods of display activation.

1. *ManufacturerAcces( )* commands – See ManufacturerAccess( ) section for details.
2. If Operation configuration *LEDR* is set, the display is activated on exit from reset.
3. Charge activity detected. If *CHGLED* in Operation Configuration is set, while *SBS.Current( )* is greater than *Charge Detection Current* (*ICHG*), the display remains active.
4. High-to-Low logic transition on the $\overline{DISP}$ pin. The next high-to-low transition of $\overline{DISP}$ is not recognized until *DF.LED_Hold* expires.

If a high-to-low logic transition on the $\overline{DISP}$ pin occurs, and the low-state held for *DF.tLED_HOLD*, the permanent-failure display is activated after the capacity display. The next high-to-low transition of $\overline{DISP}$ is not recognized until *DF.LED_Hold* expires.

If *SBS.Voltage( )* is less than or equal to *DF.Terminate Voltage*, the display is disabled.

If *DF.OperationConfiguration*, PFD0 is set, then the PF display can be activated for a further period of 2 x LED_Hold in two possible ways depending on the *DF.OperationConfiguration*, PFD1. The PF display is shown after the normal SOC display.
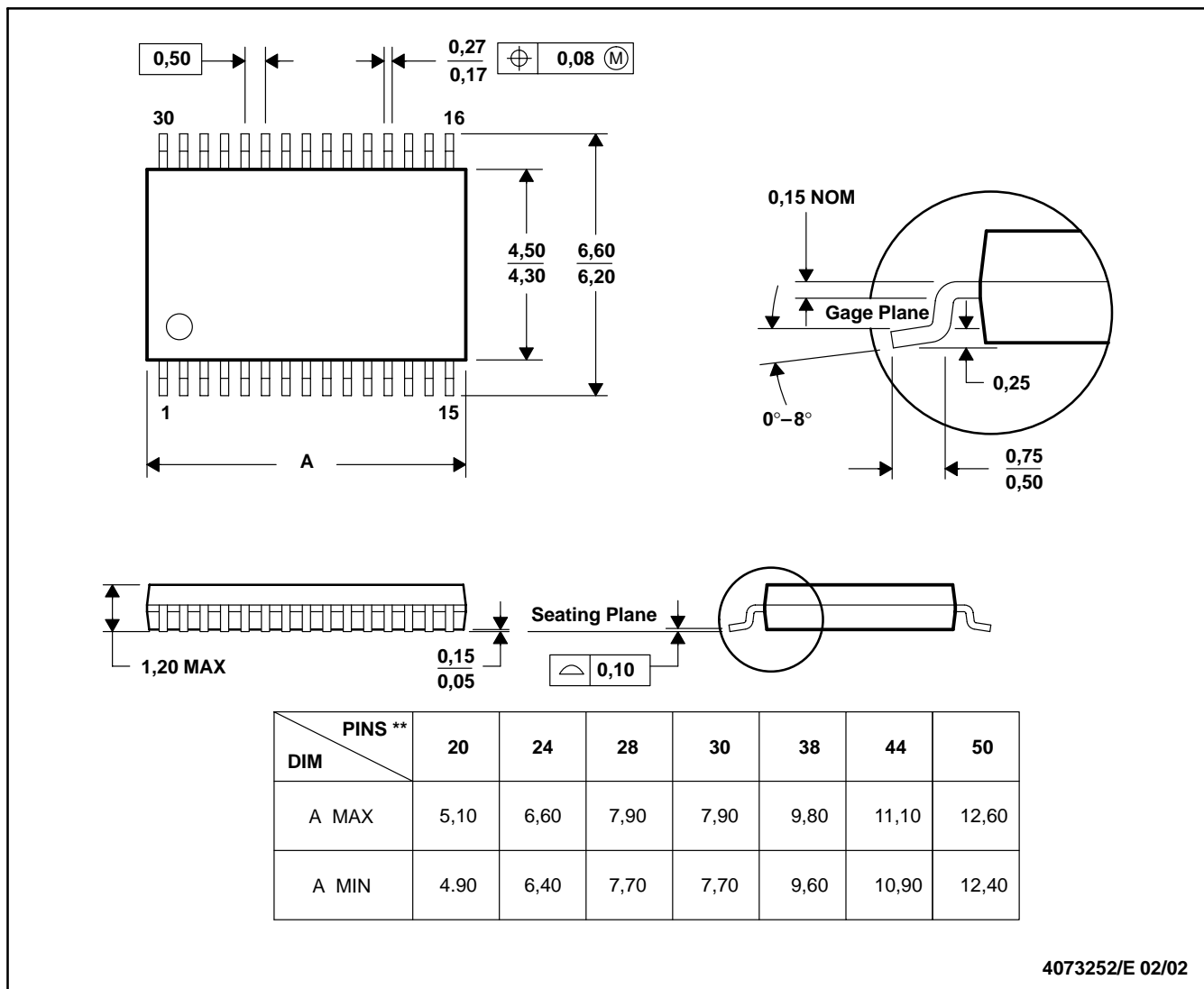
1. If a high-to-low logic transition on the $\overline{\text{DISP}}$ pin occurs, AND the low-state is held for t_{LED_HOLD}, AND *DF.OperationConfiguration*, PFD1 = 0

2. If a high-to-low logic transition on the $\overline{\text{DISP}}$ pin occurs, AND *DF.OperationConfiguration*, PFD1 = 1.

   The next high-to-low transition of $\overline{\text{DISP}}$ is not recognized until LED_Hold expires.

DBT (R-PDSO-G**)   **PLASTIC SMALL-OUTLINE PACKAGE**

30 PINS SHOWN

PINS ** DIM	20	24	28	30	38	44	50
A MAX	5,10	6,60	7,90	7,90	9,80	11,10	12,60
A MIN	4.90	6,40	7,70	7,70	9,60	10,90	12,40

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NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion.
D. Falls within JEDEC MO-153

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