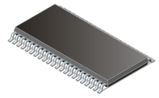


bq78412 Pb-Acid Battery State-of-Charge Indicator With Run-Time Display

Check for Samples: bq78412

FEATURES

- **Designed for Use with 12-V Lead-Acid Batteries in Consumer UPS Systems**
- **Programmable Cell Models for Enhanced Pb-Acid Gas Gauging Performance**
- **Provides 10-LED Bar Graph of Run-Time Remaining During Discharge and % Capacity During Charge**
- **Can Be Easily Integrated Into Battery Cover**
- **Works with Pb-Acid Batteries Up to 327 Ah**
- **Records Cumulative Usage Data Internally for Warranty Return Analysis**
- **On-Chip Temperature Sensor**
- **Data Interface for Retrieving Warranty Information**
- **Fully Programmable Features and Thresholds via UART Serial Interface**
- **State-of-Health (SoH) Determination and Status Reporting**
- **Includes Configurable Signal for Audible Low-Capacity, Low-Voltage, and Overvoltage Warnings**
- **Addressable Commands for Use in Multi-Battery Systems**
- **Optional Infra-Red Communications Interface**

APPLICATIONS

- **Stand-Alone Uninterruptible Power Supplies**
- **12-V Pb-Acid Battery Monitors**
- **Battery Warranty Data Logging Equipment**

DESCRIPTION

The bq78412 Pb-Acid Battery State-of-Charge (SoC) Indicator with Run-Time Display is a complete stand-alone battery gas-gauge solution designed for single 12V Pb-Acid batteries. The bq78412 displays remaining Run-Time-To-Empty during discharge and Percent (%) capacity during charge using a 10-LED (light-emitting diode) bar graph.

The bq78412 monitors battery voltage, current, and ambient temperature to calculate state-of-charge and determine remaining runtime-to-empty. Measured values can be recorded and tracked for later retrieval for warranty purposes.

Programmable cell models allow the bq78412 to be customized to a variety of Pb-Acid formulations and capacities.

Current measurements and Coulomb-counting for gas-gauging are also automatically performed by the bq78412. Current measurements use a small value sense resistor placed in the negative power path and calibrated in-circuit. This allows the precise, continuous, real-time calculation of battery capacity and run-time-to-empty values.

Temperature sensing augments gas-gauge and capacity information using a firmware algorithm to compensate for the temperature effects on capacity.

A serial port is available for configuring various programmable parameters including cell models, calibration values, serial number and date of manufacture. The serial port can operate an infra-red (IR) interface to allow connector-less data acquisition. The bq78412 is easily configurable, is fully programmed and requires no algorithm or firmware development

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.

ABSOLUTE MAXIMUM RATINGS(1)

PARAMETER		VALUE MIN	VALUE MAX	UNITS
Voltage applied to VBAT+		–0.3	30	V
Voltage applied to VS		–0.3	26	V
Voltage applied to RS+, RS–	Differential (V_{RS+}– $V_{RS–}$)	–26	26	V
	Common mode (V_{RS+}, $V_{RS–}$)	–0.3	26	V
Voltage applied to AVDD and DVDD		–0.3	4.1	V
Voltage applied to other pins(2)		–0.3	V_{VDD}+0.3	V
Diode current at any device terminal		–2	2	mA

(1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not implied.
(2) VDD refers to voltage on DVDD and AVDD pins.

RECOMMENDED OPERATING CONDITIONS

		MIN	TYP	MAX	UNITS
Supply voltage	VBAT+	4	12	26	V
Operating temperature		–40		85	°C
Battery capacity			150	327	Ahr
Current measurement, average		–100		100	A
Current measurement, peak		–320		300	A

MEASUREMENT ACCURACY (12-V Battery)

PARAMETER	MIN	TYP	MAX	UNIT
Battery voltage measurement(1)		±0.5%	±1%	
Shunt voltage measurement(2)		±0.5%	±1%	
Temperature measurement(3)		±1		°C
Timing accuracy of internal clock(4)	–2.5%		2.5%	
Run-time-to-empty (RTTE)(5)		±15		min

(1) Specified at 12 V.
(2) Specified at full scale.
(3) Offset calibration of the temperature takes place prior to this measurement
(4) Calibrated clock frequency, tolerance over temperature 0°C to +85°C
(5) Capacity learning is done prior to this.

UART COMMUNICATIONS PORT TIMING

	MIN	TYP	MAX	UNITS
Data rate		9600 or 1200		Baud
Command response time(1)			100	ms
Transmit intercharacter interval(2)			4	ms

(1) Maximum time from host transmission of last command byte to first response by the device.
(2) Maximum time interval between start bits for data or response being transmitted from the device.

CURRENT CONSUMPTION

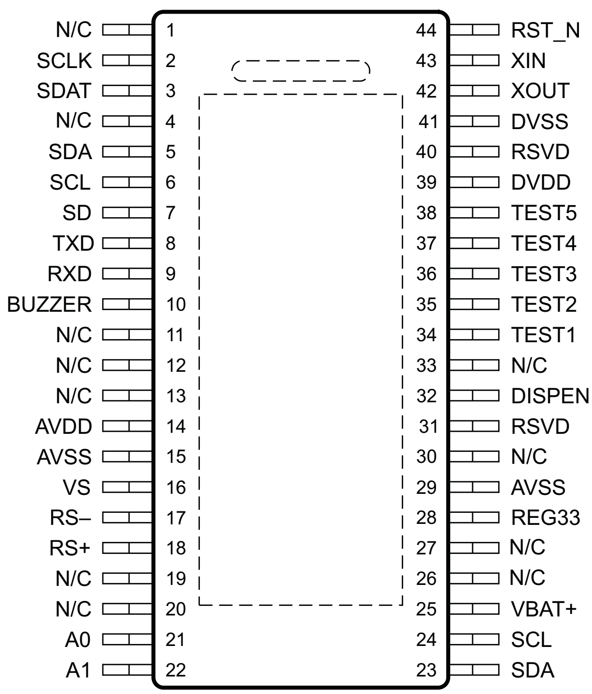
OPERATING MODE	TYPICAL (mA)	NOTES
Active	3.2	Connected to UPS and gas gauging active. Display is active and not included.
Idle	3.2	Not connected to UPS. Display is active and not included.
Sleep	3.2	Not connected. Display off.

ELECTRICAL CHARACTERISTICS

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
REG33 load regulation	100 µA ≤ I_{LOAD} ≤ 100 mA, T_J = 25°C		0.04%	0.20%	
	100 µA ≤ I_{LOAD} ≤ 100 mA, –40°C ≤ T_J ≤ 85°C			0.30%	
ADC basic resolution			12		bits
Sense voltage measurement step size			4		mV
Shunt current measurement step size			0.1		A
Full scale current sense voltage range			±160		mV
Sense resistor			1		mΩ

Package Outline

DDW Package
(Top View)



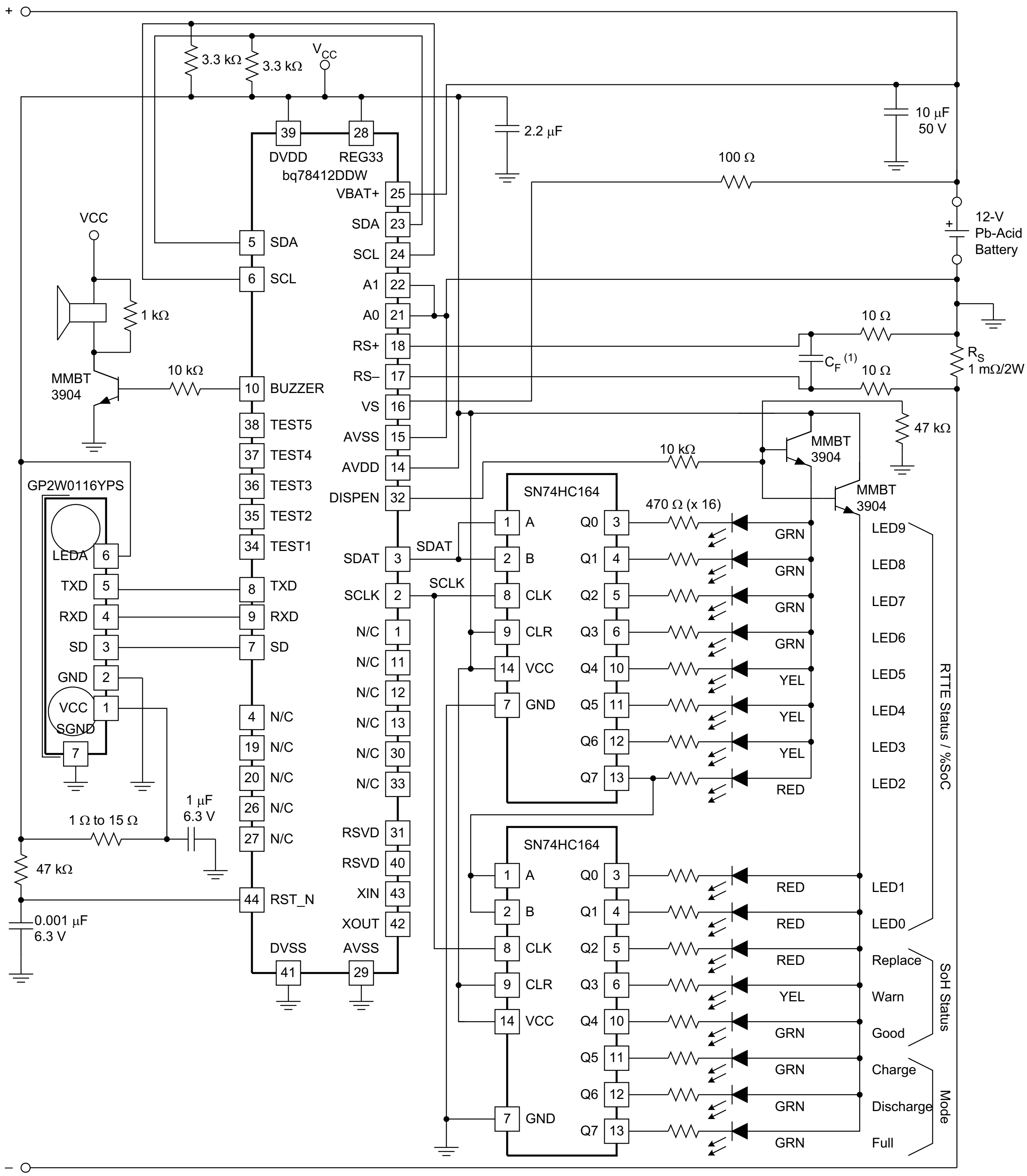
A. Thermal pad is on the bottom side of the package

B. N/C = no connect

PIN DESCRIPTIONS

bq78412 NAME	No.	I/O/P	DESCRIPTION
A0	21	I	Configuration input. Connect to ground.
A1	22	I	Configuration input. Connect to ground.
AVDD	14	P	3.3-V power to the analog logic. Typically connected to REG33.
AVSS	15	P	Connect to ground.
	29		
BUZZER	10	O	Buzzer output. Active high when alarm condition is detected.
DISPEN	32	O	Active high output, turns on display enable transistor. Not required in all applications. Blanks display during updates.
DVDD	39	P	3.3-V supply to the digital logic. Connect a 2.2- µF capacitor to VSS. Typically connected to REG33.
DVSS	41	P	Connect to ground
REG33	28	P	Regulated 3.3-V power output.
RST_N	44	I	Connect to external RC network for power-up reset.
RSVD	31	–	Reserved, no connection required.
	40		
RS–	17	I	Current sense negative
RS+	18	I	Current sense positive
RXD	9	I	UART RX data
SCL	6	O	I^2C clock output
	24	I	I^2C clock for internal use. Connect to SCL pin 6.
SCLK	2	O	Low-to-high transition clocks data into external serial in, parallel out shift register.
SD	7	O	IR XCVR Shutdown; HIGH=XCVR in shutdown, LOW=XCVR Active
SDA	5	I/O	I^2C data
	23	I/O	I^2C data for internal use. Connect to SDA pin 5.
SDAT	3	O	Serial display data to serial in, parallel out shift register. A low bit turns on an LED.
TEST1	34	I/O	Test pin, no connection
TEST2	35	I/O	Test pin, no connection
TEST3	36	I/O	Test pin, no connection
TEST4	37	I/O	Test pin, no connection
TEST5	38	I/O	Test pin, no connection
TXD	8	O	UART TX data
VBAT+	25	P	Input to internal regulator.
VS	16	I	Sense voltage. Connect to battery positive.
XIN	43	I	Input terminal of 8-MHz crystal oscillator or crystal pin. (Optional: Can be left unconnected to use internal oscillator)
XOUT	42	O	Output terminal of 8-MHz crystal oscillator or crystal pin. (Optional: Can be left unconnected to use internal oscillator)
N/C	1	–	No connection
	4		
	11		
	12		
	13		
	19		
	20		
	26		
	27		
	33		

TYPICAL APPLICATION



(1) C_F = 0.1 µF to 1 µF

APPLICATION INFORMATION

Overview

The bq78412 is a complete Pb-Acid gas-gauge with a run-time display and warranty information storage. It supports large batteries up to a maximum capacity of 327 Ahr when measured at the 20 hour rate.

Measurement inputs include the 12-V nominal battery voltage and the battery current. Coulomb counting on discharge and charge allows a state-of-charge calculation and run-time-to-empty on discharge estimation.

Cumulative usage information is periodically and permanently stored internally and may be retrieved only by a special sequencing operation performed by the manufacturer.

Operation of the bq78412 requires no user interaction. During charge and discharge, the LED display is automatically activated when charge or discharge current is detected above a configurable threshold.

Current Sense, Battery Voltage, Temperature, and Time Measurements

The bq78412 measures charge and discharge current using a low-value (between 1 and 3 mΩ) sense resistor placed in the negative power path of the circuit. This sense resistor may be as simple as a piece of thermally stable metal or the lead power post on the battery itself. Calibration of this sense resistor is required in circuit (in module). The printed circuit board (PCB) designer must consider the impact of drift and/or variation in the sense resistor value over time and temperature, including self-heating temperature effects. The bq78412 does not compensate for such changes.

The voltage measured between the RS+ and RS– pins is scaled by the sense resistor value (set in *MeasScale* parameter) to calculate the current value. The maximum differential voltage allowed between the RS+ pin and the RS– pin is 160 mV.

Alternatively, a voltage proportional to the current (derived using means other than a sense resistor, but within range of the allowable differential) could be applied to the terminals to provide the current measurement.

The bq78412 measures the battery voltage between the VS and AVSS pins

The bq78412 has an on-chip temperature sensor. The battery temperature is assumed to be equal to the on-chip measurement.

Time measurement is referenced to an internal oscillator. However, for more accuracy, an external 8-MHz crystal oscillator or crystal can be used. This is enabled by setting *DevConfig2*[15] = 1. The switch-over happens only after a hardware or software reset.

State-of-Charge (SoC) Gas-Gauging

The bq78412 provides capacity and run-time-to-empty estimates for Pb-Acid batteries using a rate and temperature compensated coulomb counting algorithm.

The gas-gauging information is used to drive the local LED display with run-time-to-empty information.

Capacity correction is supported based on the discharge current. A 64-byte battery characterization table contains battery performance data that is used to adjust the remaining capacity and run-time-to-empty as a function of discharge rate and temperature. This information is unique to each battery model and is programmed at the battery manufacturing facility based on battery performance data provided by the manufacturer.

Charge Efficiency Compensation

The bq78412 provides a parameter, *ChgEff* that allows for correction of accumulated charge in the battery due to charge efficiency. During charge, the passed charge is multiplied by the charge efficiency and the result is added to the remaining capacity.

For example, if *ChgEff* is set to 85 (representing 85%), when 100 Ah have been measured, only 85 Ah are recorded as actually being accumulated. With the default setting for the *ChgEff* = 100, all charge current is accumulated.

Gas Gauging After a Reset

During normal operation, the last learned full charge capacity (FCC), elapsed time and other important variables are stored in permanent memory. If, for some reason the battery discharges to the point where there is no longer sufficient voltage for the bq78412 to operate, it shuts down. Under such conditions, when the device powers up, these variables are restored and battery is assumed to be at 50% relative SoC. If a charge current is present, the device begins to measure the accumulated charge and time. Charging proceeds as normal with the appropriate end-of-charge detection criteria. If the bq78412 powers up and there is no current, the device goes into idle state followed by sleep state until a current is detected.

Battery Capacity Update

The bq78412 has two mechanisms for updating the battery capacity as the battery ages. (Note that the initial capacity programmed into the bq78412 could be in error due to manufacturing tolerances or formation procedures. This translates to a gas gauging error until the battery capacity is accurately learned.)

Both the *Learned Capacity* method and *Age-Based Capacity* method operate independently and both may be enabled or disabled separately in order to maintain the correct measure of capacity of the battery over a variety of operating conditions, but it is suggested that both be enabled for optimal performance.

Learned Capacity Method

When *DevConfig1[14]* is set to "1", the bq78412 opportunistically learns the full charge capacity (FCC) of the battery based on a *qualified* discharge. A complete discharge from fully charged to fully discharged with no charging events raising the remaining state of charge (SoC) above 80% is considered *qualified*. An internal state variable qualified discharge (QD) is used for maintaining the status of discharge qualification. QD is initially disabled. When the battery has reached the fully charged state, QD is set to enabled and discharge learn accumulator is cleared to zero. When a discharge begins, QD is set to active. While QD is active, all passed charge (positive or negative) is accumulated in the discharge learn accumulator. If at any time (while QD is in an active state) a charging event raises SoC above 80%, QD is set to disabled and the discharge learn accumulator is ignored. If the battery reaches the fully discharged state and QD is still active, the algorithm learns FCC based on the discharge learn accumulator and the current load de-rating using Equation 1.

$$\text{FCC} = \frac{\text{Discharge Learn Accumulator}}{\text{Derating}} \tag{1}$$

where

- Derating is the capacity derating fraction as a function of load current

Age-Based Capacity Method

The counter for the elapsed time starts when the device is activated.

When *DevConfig1[15]* is set to "1" (non-default), the bq78412 updates the FCC based on elapsed time and an aging algorithm with manufacturer defined parameters. The bq78412 decrements the FCC by 0.100 Ah every *CapDerateL* days until *DerateChange* days have elapsed, after which the FCC decrements by the same amount every *CapDerateH* days.

In this way the FCC is regularly de-rated (decremented) at regular intervals independently of the *learned capacity method*.

The values for *CapDerateL*, *DerateChange*, and *CapDerateH* must be carefully chosen to implement an appropriate age-based capacity decrease formula.

For example: Assuming a 100Ah battery (when new) and a 3%/year capacity fade for the first 3 years and a 4%/year fade afterwards, the parameters might be set as follows:

3% of 100Ah = 3Ah decrease in one year

3Ah decrease in 0.1 Ah steps = 30 separate steps over 365 days

365 days / 30 decrement steps = one decrement step every 12.1 days So *CapDerateL* = 12

4% of 100Ah = 4Ah decrease in one year

4Ah decrease in 0.1 Ah steps = 40 separate steps over 365 days

365 days / 40 decrement steps = one decrement step every 9.1 days So *CapDerateH* = 9

Finally, 3 years is 365 days x 3 = 1095 days So *DerateChange* = 1095

Note that due to slight rounding errors (12 days instead of 12.1 days, etc.) the actual capacity represented at the end of any time internal (one year, two years, etc.) may be off by a small fraction.

In the example above, the actual implementation calculates to be as listed below (assuming no changes to FCC from the *learned capacity method* occur):

Initial capacity = 100Ah and full charge capacity (FCC) decremented 0.1 Ah every 12 days:

End of year 1 capacity (at day 360) = 100Ah – 3.0Ah = 97Ah and (3.0Ah / 100Ah) = 3%

End of year 2 capacity (at day 732) = 97Ah – 3.1 Ah = 93.9Ah and (3.1 Ah / 93.9Ah) = 3.3%

End of year 3 capacity (at day 1095) = 93.9Ah – 3.0Ah = 90.9Ah and (3.0Ah / 90.9Ah) = 3.3%

Total from time 0 to Year 3: (100Ah – 90.9Ah) / 100Ah = 9.1% / 3 years = 3.033%/year

Figure 1 shows how the FCC decreases with time and how the parameters control this. Note that the parameter values used in Figure 1 are different from the values used in the previous example.

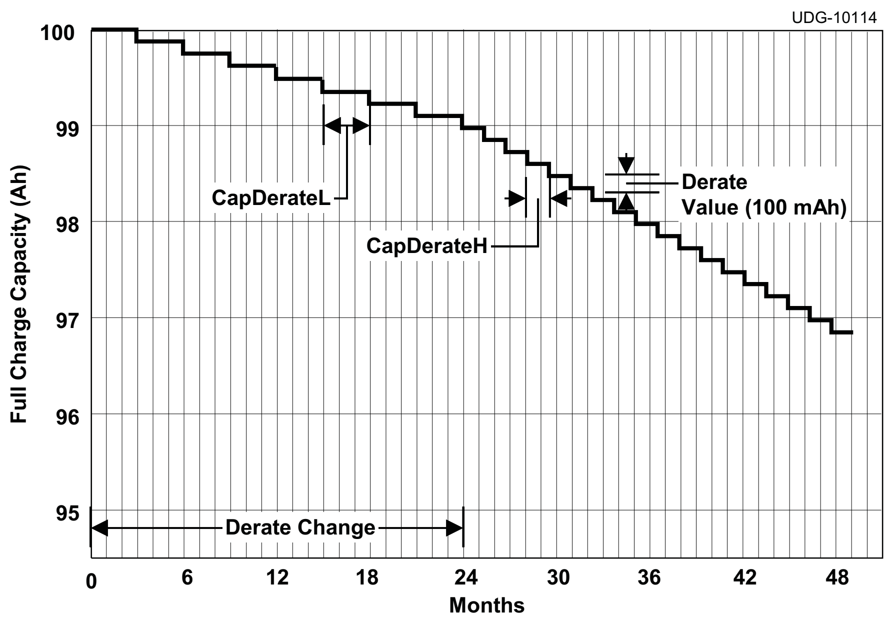


Figure 1. Age Based Capacity Method

State of Health (SoH) Detection

The state of health indication can be configured either on the number of charge/discharge cycles that have occurred or a reduced full charge capacity. Discharge and charge by an amount equal to the design capacity of the battery constitutes one cycle. A reduced full charge capacity (FCC) could be obtained by either of the two capacity learning methods.

The number of cycles or the FCC at which the WARN and REPLACE indications are provided, are configurable. The parameters used for state of health include

- *EOLCap*
- *EOLCapWarn*
- *LifeCycles*
- *LifeCycleWarn*

The **REPLACE** or **WARN** LED is turned on when the one or the other of the two state of health conditions occur. See the Status LEDs section for details on status indicator LED operation. Gas gauging and device operation are not affected when a state-of-health indication has been detected.

Display

The bq78412 supports up to a 10-segment LED display in bar graph format. During a discharge, it shows run time to empty at the current discharge rate and during charge, this shows %SoC.

The bq78412 also supports battery status indicators:

- **REPLACE**
- **WARN**
- **GOOD**
- **CHARGE**
- **DISCHARGE**
- **FULL**

Display data are transmitted serially to external shift registers which are used to latch and turn on the external LEDs. The shift registers are updated when a status change is detected.

Display use is not required. Instead, an external device may query the bq78412 for status via the universal asynchronous receiver/transmitter (UART) port. The bq78412 can also be configured to automatically broadcast the status through the UART TXD pin. See the Status Broadcast section.

Bar Graph Display

The bq78412 supports up to a 10-segment LED display in bar graph format. The size of the bar graph display is defined in *DevConfig1[5:2]* with a default value of 10.

During discharge, the bar graph shows run time to empty at the current discharge rate. Each bar represents a run time to empty up to a maximum number as defined by the *DsplyConf1* through *DsplyConf5* parameters. Each byte indicates how much run time (in minutes) is allocated to the respective LED. The total time represented by the display is the sum of the time in each parameter. For example, when each parameter is set to 30 minutes, the total display time is 300 minutes or five hours. When the calculated discharge run time to empty is greater than the maximum time for the display, all LEDs are turned on. In the default mode, each LED represents ½ hour or 30 minutes remaining run time. When one LED is on, there is at least ½ hour of remaining run time.

During charge, the LEDs represent the %SoC based on capacity in amp-hours and the number of LEDs defined in *DevConfig1[5:2]*. When the display size in *DevConfig1[5:2]* is set to 10, each LED represents 10% of capacity. When the display size in *DevConfig1[5:2]* is set to 5, each LED represents 20% of capacity.

Table 1. DsplyConf Parameter Description

PARAMETER	BITS[15:8] ALLOCATION	BITS[7:0] ALLOCATION	BITS[15:8] ALLOCATION DEFAULT (MINUTES)	BITS[7:0] ALLOCATION DEFAULT (MINUTES)
DsplyConf1	Time in LED1	Time in LED0	30	30
DsplyConf2	Time in LED3	Time in LED2	30	30
DsplyConf3	Time in LED5	Time in LED4	30	30
DsplyConf4	Time in LED7	Time in LED6	30	30
DsplyConf5	Time in LED9	Time in LED8	30	30

Table 2. Bar Graph Display Operation During Discharge – Five LED Example, Default DsplyConf Setting (1)

RTTE (min)	LED0	LED1	LED2	LED3	LED4	CHARGE LED	DIS CHARGE LED	FULL LED	GOOD LED	WARN LED	REPLAC E LED
≥150	On	On	On	On	On	Off	On	Off	On	Off	Off
120-149	On	On	On	On	Off	Off	On	Off	On	Off	Off
90-119	On	On	On	Off	Off	Off	On	Off	On	Off	Off
60-89	On	On	Off	Off	Off	Off	On	Off	On	Off	Off
30-59	On	Off	Off	Off	Off	Off	On	Off	On	Off	Off
0-29	Off	Off	Off	Off	Off	Off	On	Off	On	Off	Off

(1) Example assumes battery state of health is good.

Table 3. Bargraph Display Operation During Charge – 5 LED Example (1)

PERCENT SoC	LED0	LED1	LED2	LED3	LED4	CHARGE LED	DIS CHARGE LED	FULL LED	GOOD LED	WARN LED	REPLACE LED
0-19	Off	Off	Off	Off	Off	On	Off	Off	On	Off	Off
20-39	On	Off	Off	Off	Off	On	Off	Off	On	Off	Off
40-59	On	On	Off	Off	Off	On	Off	Off	On	Off	Off
60-79	On	On	On	Off	Off	On	Off	Off	On	Off	Off
80-99	On	On	On	On	Off	On	Off	Off	On	Off	Off
100	On	On	On	On	On	On	Off	Off	On	Off	Off
100 and Full Charge Detected	On	On	On	On	On	On	Off	On	On	Off	Off

(1) Example assumes battery state of health is good.

Status LEDs

Status indicators described in Table 4 may be populated as desired. The output signals could also be used to drive multi-color LEDs where the status is indicated by the color.

Table 4. Status Indicator LEDs

STATUS LED	INDICATION	DESCRIPTION
REPLACE	Battery state of health	Turned on when battery end-of-life condition is detected either when cycle count reaches the value of *LifeCycles* parameter or when full charge capacity(FCC) drops below the value in *EolCap* parameter
WARN		Turned on when cycle count reaches the value of *LifeCycleWarn* parameter or when full charge capacity(FCC) has dropped below the *EolCapWarn* level.
GOOD		On when no state of health condition detected.
CHARGE	Mode of operation	On when battery is charging.
DISCHARGE		On when battery is discharging.
FULL		On when qualified full charge condition is detected.

Figure 2 shows the application schematic showing the 10-bar LED bar graph display and status LED connections.

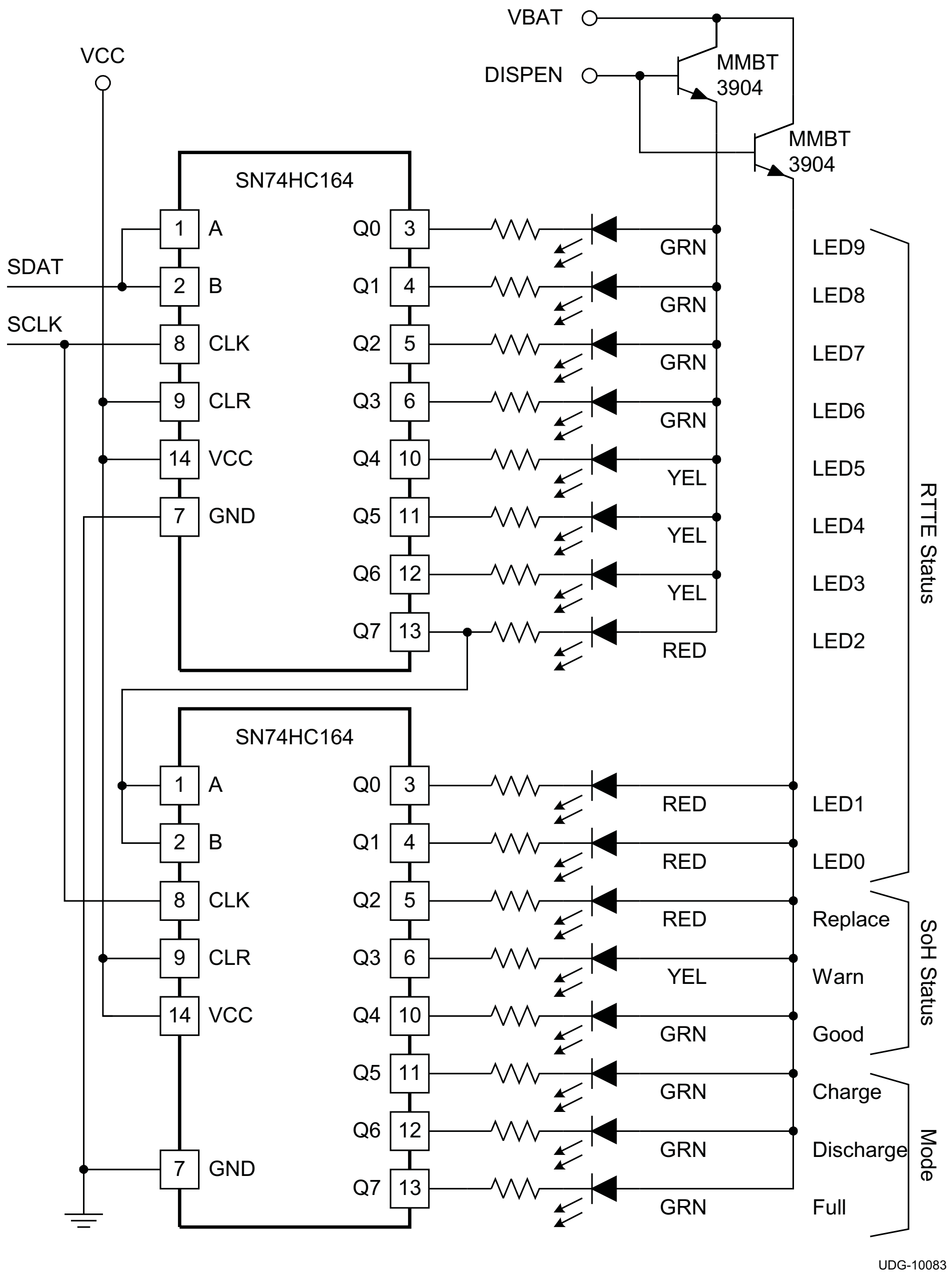


Figure 2. 10-Bar LED Bar Graph Display and Status LED Connections

Buzzer Operation

A buzzer can be set to beep on various conditions. Bits in the *DevConfig2* register control the number of beeps sounded on each condition. Each beep is sounded for 1 second and gaps (that is, silence period) between beeps (if set for multiple beeps) are also of 1 second duration. Setting the number of beeps to 0 for a condition is equivalent to disabling the buzzer operation for that condition.

One hour after an overvoltage or undervoltage condition is detected (and the buzzer sounds) the device checks for this condition again. The buzzer again sounds (the same number of beeps) if the condition persists. From then on, this condition is not checked for until the battery voltage returns to the normal range.

Table 5. *DevConfig2* Parameter Description

BITS	CONDITION	DESCRIPTION	NUMBER OF BEEPS
`[1:0]`	Empty	RTTE = 0 minutes, during discharge	0 to 3
`[3:2]`	LED0 turns off	RTTE = *time in LED0*, during discharge	
`[5:4]`	LED1 turns off	RTTE = *time in LED0* + *time in LED1*, during discharge	
`[7:6]`	LED2 turns off	RTTE = *time in LED0* + *time in LED1* + *time in LED2*, during discharge	
`[10:8]`	Overvoltage	Battery voltage > *OvThresh*	0 to 7
`[13:11]`	Undervoltage	Battery voltage < *UvThresh*	

Operational States

The bq78412 supports three operational states.

- Active
- Idle
- Sleep

Active State

When the bq78412 detects that the battery is being charged or discharged (Current magnitude ≥*TransToActive*), it enters the active state. Upon entry to the active state, the display is activated and run-time-to-empty or %SoC is displayed.

Idle State

When the bq78412 detects that the observed current magnitude is less than or equal to *IdleThresh*, it enters the Idle state. In Idle state, the display is active and remains at the last displayed value when in the active state.

Sleep State

If the bq78412 is in the idle state for more than the number of seconds specified in *SleepTime*, it enters the sleep state. In sleep state, the display is turned off.

In each of the states, the bq78412 periodically measures current, voltage, temperature, records elapsed time, and updates the warranty record. Also, the UART interface remains active in all states (including broadcasts, if enabled). Coulomb counting is disabled in the idle and sleep states.

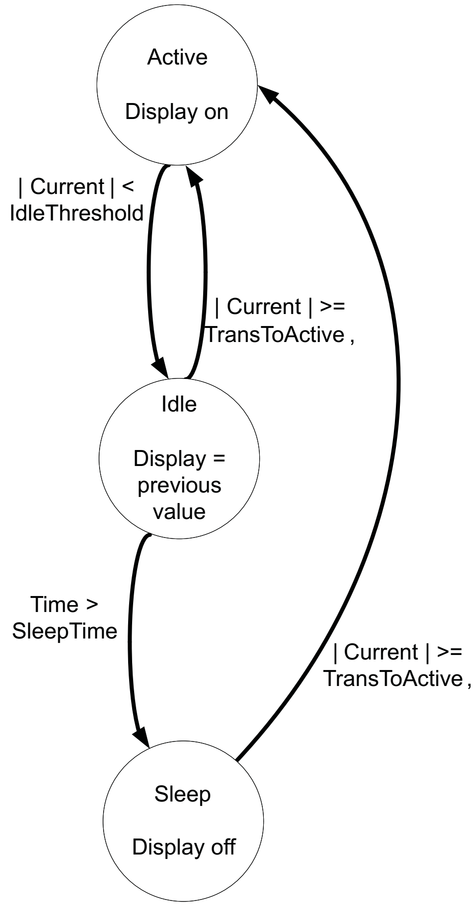


Figure 3. Operational States

COMMUNICATION AND CONTROL

Communications Interface

The bq78412 provides a UART communications interface for parameter initialization during system configuration and test. This interface also provides real-time measurement capability and access to stored battery performance data. This interface can be used with RS-232, IrDA, RS-485, or any other transceiver that is compatible with NRZ- or IrDA-formatted data streams.

The serial interface always operates in multi-drop mode. The default address is 0xFF. The address can be changed in parameter flash parameter, *MultiDropAdr*. This design allows multiple batteries to be supported in a system and accessed from a single point.

Communications to the bq78412 is via messages. The first byte transmitted to the bq78412 is the address byte. Subsequent bytes are the message. Bytes within a message must be separated by less than 10 bit times. Messages must be separated by more than 10 bit times.

The bq78412 is configurable for either NRZ- or IrDA-compatible bit encoding.

- *DevConfig1[13:12]* = [0,0]: Multi-drop mode with NRZ encoding. RS-232, RS-485, or wireless transceivers can be used. (default)
- *DevConfig1[13:12]* = [0,1]: Multi-drop mode with IrDA encoding. IrDA transceivers can be used.

When real-time data are being accessed and/or when the communications mode is active for configuration, power consumption may increase.

The communications interface has the following fixed data rate configuration:

- 9600 or 1200 baud rate (set by *DevConfig1*[11])
- 8 bits
- No parity
- 1 stop bit
- No flow control

Figure 4 shows UART Encoding waveforms. Figure 5 shows the multi-drop operation data structure.

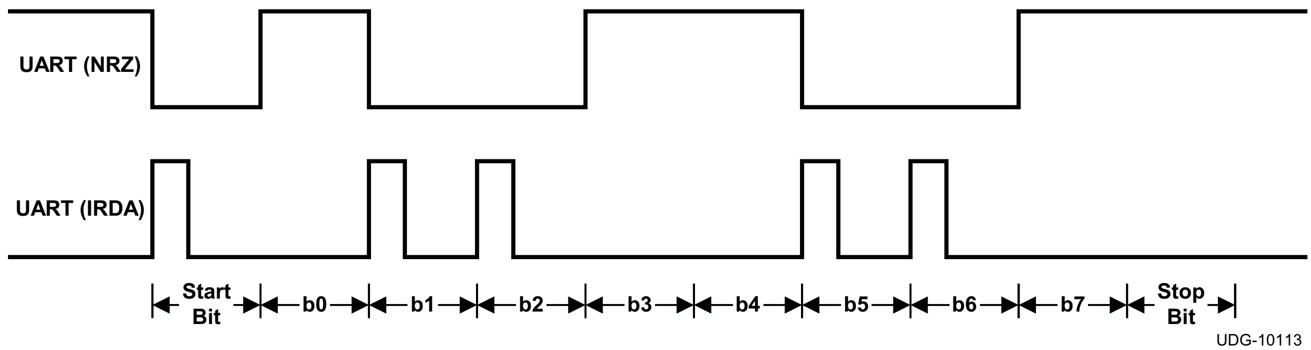


Figure 4. UART Encoding

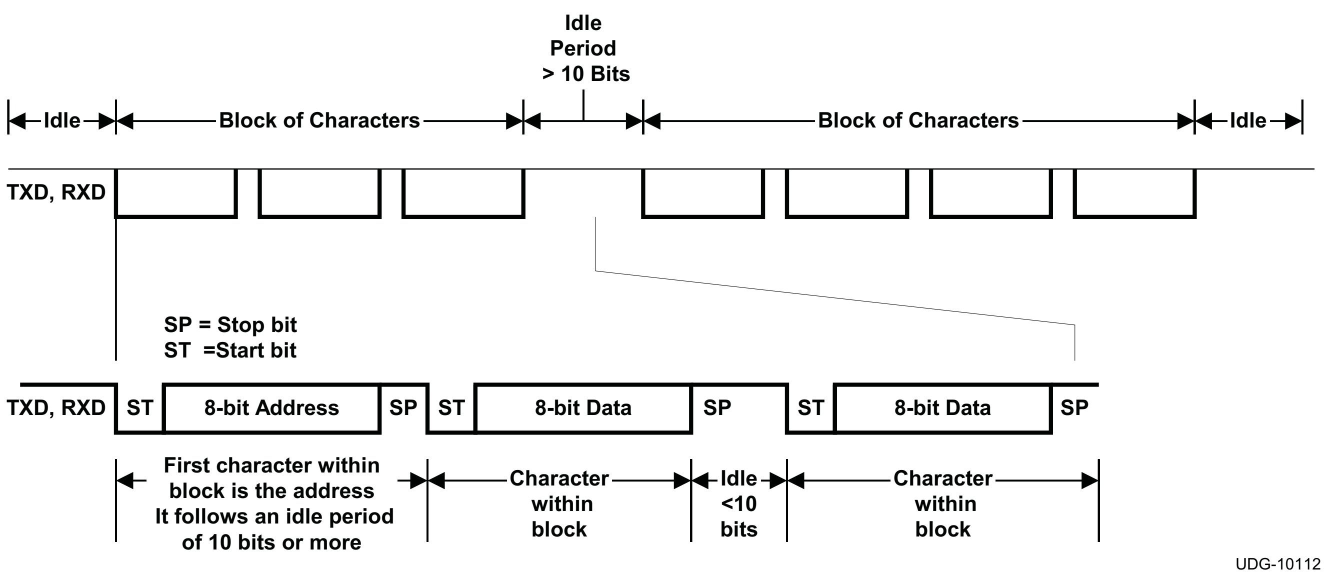


Figure 5. Multi-Drop Operation

Command Set and Status Reporting

This section describes the bq78412 communications, command set, and status reporting.

Command Syntax

Communications between the bq78412 and external host device consists of message commands.

The host to bq78412 commands are always seven (7) bytes long with the general format shown below.

General Command Format Host to bq78412

Address	ID	Param0	Param1	Param2	Param3	Checksum

- The address is a hexadecimal number that distinguishes between target bq78412 devices. The default address is 0xFF.
- The header ID is a hexadecimal number that distinguishes between individual commands.
- Checksum is XOR of all bytes (excluding checksum) including header ID = 0xFF XOR Address XOR ID XOR Param0 …..XOR Param3
- The bq78412 sends a response with its address, ACK requested data if any, and checksum upon successful reception of a command that is addressed to it.
- The bq78412 sends a response with its address, NACK, and checksum if a command packet addressed to it has been correctly received but the command is not implemented or not allowed to be used due to the security level.
- The bq78412 does not respond to packets that have a different address or when the checksum is invalid.
- The transmission of any requested data follows the transmitted ACK character.
- Addresses are in Little Endian format (least significant bit first).
- Read or write data are in Little Endian format.

General Response Code from ***bq78412*** to host

Address	Response Code	Byte0	Byte1	...	Byte n-2	Byte n-1	Checksum

ACK Response from bq78412 to host, no response data

Address	ACK = "!"	Checksum

ACK Response Code from bq78412 to host with data.

Address	ACK = "!"	Byte0	Byte1	...	Byte n-2	Byte n-1	Checksum

NACK Response from bq78412 to host

Address	NACK = 0x15	Checksum

Broadcast Message from bq78412

Address	ACK = "!"	Byte0	Byte1	...	Byte24	Byte25	Checksum

- Checksum is XOR of all bytes (excluding checksum) including address byte and ACK byte. = 0xFF XOR Address XOR ACK/NACK XOR byte0 XOR byte1 …..XOR byte n-2 XOR byte n-1

  When data are not requested only the Address, ACK, and checksum are transmitted.

  The bq78412 uses the "!" character as the ACK response code. Its value is 0x21.

  The bq78412 uses 0x15 as NACK response code.

Single Word Write

Host request to bq78412

Address	0x17	Address LSB	Address MSB	Data LSB	Data MSB	Checksum

Note: The memory address is a byte address and must be an even number.

Response from to host to bq78412.

Address	ACK	Checksum

Command Permissions

SealedLevel0	SealedLevel1	SealedLevel2
Enabled	Enabled	Enabled

Note: Data access is a function of sealed level. If access to a memory location is prohibited due to seal level then there is a NACK response from the bq78412.

Single/Multiple Word Read

Host request to ***bq78412***

Address	0x16	Address LSB	Address MSB	Number of Words (1-16)	0x00	Checksum

Note: The memory address is a byte address and must be an even number.

Response from bq78412 to host

Address	ACK	Data LSB 0	Data MSB 0	…	Data LSB n-1	Data MSB n-1	Checksum

Command Permissions

SealedLevel0	SealedLevel1	SealedLevel2
Enabled	Enabled	Enabled

Note: Data access is a function of sealed level. If access to a memory location is prohibited due to seal level then there is a NACK response from the bq78412.

Read Device Type and Version

Host request to bq78412

Address	0x12	0x01	0x00	0x00	0x00	Checksum

Response from bq78412 to host

Address	ACK	'b'	'q'	'7'	'8'	'4'	'1'	'2'	Ver	Rev	Build	Checksum

Note: Firmware version, revision, and build are reported as hexadecimal numbers.

Command Permissions

SealedLevel0	SealedLevel1	SealedLevel2
Enabled	Enabled	Enabled

Set SealedLevel0

Host request to bq78412

Address	0x15	Byte3 (MSB)	Byte2	Byte1	Byte0 (LSB)	Checksum

Response from bq78412 to host

Address	ACK	Checksum

Command Permissions

SealedLevel0	SealedLevel1	SealedLevel2
NACK	Enabled	Enabled

Set SealedLevel1 from SealedLevel2

Host request to ***bq78412***

Address	0x14	Byte3 (MSB)	Byte2	Byte1	Byte0 (LSB)	Checksum

Response from bq78412 to host

Address	ACK	Checksum

Command Permissions

SealedLevel0	SealedLevel1	SealedLevel2
NACK	NACK	Enabled

Reset bq78412

Host request to bq78412

Address	0x13	0x01	0x00	0x00	0x00	Checksum

Response from bq78412 to host

Address	ACK	Checksum

Note: This response is sent when the bq78412 is reset. When the device receives a valid reset command the device is reset, then sends the reset ACK message.

Command Permissions

SealedLevel0	SealedLevel1	SealedLevel2
Enabled	NACK	NACK

Reset Cumulative Data

Host request to bq78412

Address	0x13	0x02	0x00	0x00	0x00	Checksum

Response from bq78412 to host

Address	ACK	Checksum

Command Permissions

SealedLevel0	SealedLevel1	SealedLevel2
Enabled	NACK	NACK

Set SealedLevel1 from SealedLevel0

Host request to bq78412

Address	0x13	0x03	0x00	0x00	0x00	Checksum

Response from bq78412 to host

Address	ACK	Checksum

Command Permissions

SealedLevel0	SealedLevel1	SealedLevel2
Enabled	NACK	NACK

Set SealedLevel2

Host request to bq78412

Address	0x13	0x04	0x00	0x00	0x00	Checksum

Response from bq78412 to host

Address	ACK	Checksum

Command Permissions

SealedLevel0	SealedLevel1	SealedLevel2
Enabled	Enabled	NACK

Initialize State-of-Charge (SoC)

This command initializes the SoC reported by the bq78412 to the SoC% parameter, forces the FCC to the value in the *DesignCapacity* parameter, clears *CycleCount*, sets the last discharge to DesignCapacity/20, and initializes all gas gauging variables to correspond to the written SoC level.

Host request to bq78412

Address	0x13	0x05	0x00	0x00	SoC%	Checksum

Response from bq78412 to host

Address	ACK	Checksum

Command Permissions

SealedLevel0	SealedLevel1	SealedLevel2
Enabled	Enabled	NACK

Status Broadcast

The bq78412 can be configured to automatically broadcast a status message block when *DevConfig1[0]* = 1. This option allows the output of the UART to be connected to a wireless transmitter so battery status can be remotely received and displayed.

Automatic transmission of the broadcast status message block is suspended for 60 seconds when a command is received, after transmission of the current frame is completed. Automatic status transmission restarts a minimum of 60 seconds after completion of the response to the received command. The address is included in the status block since it may be desired to have one receiver unit monitor several batteries. Table 6 lists the broadcast status message block words in the order that they are transmitted.

Table 6. bq78412 Broadcast Status Message Block

STATUS	BYTE OFFSET(1)	BYTES	DESCRIPTION(2)	UNITS
Device Address	0	1	Address of bq78412	
"!"	1	1	Indicates ACK	
BatteryStatusWord	2	2	Battery status. See description in BatteryStatusWord section.	-
Temperature	4	2	Battery temperature	°C
BatteryVoltage	6	2	Battery voltage.	mV
Current	8	2	Battery current. Positive value = charge current, negative value = discharge current.	100 mA
RemCapDerated	10	2	Remaining battery capacity derated as function of discharge current.	100 mAh
FullChargeCapacity	12	2	Learned battery capacity at full charge, rated load.	100 mAh
RunTimetoEmpty	14	2	Run time to empty derated as a function of discharge current. Only valid during discharge.	Minutes
CycleCount	16	2	Number of full discharge cycles or equivalents.	
AverageCurrent	18	2	Battery current averaged based on *CurrentAvgTime* parameter.	100 mA
DeratedFCC	20	2	Derated Available Capacity	100 mAh
AccumulatedMissedCharge	22	2	Accumulated missed charge due to multiple discharges occurring before a full charge has occurred.	%
RelativeStateOfCharge	24	2	Battery relative state of charge.	%
Checksum	26	1	= 0xFF XOR byte 0 XOR byte 1 …..XOR byte24 XOR byte25	

(1) Byte offsets are counted from the start of the broadcast message block.
(2) Data words are transmitted in Little Endian format (least significant byte first)

While the broadcast message is being generated and transmitted, reception of commands is suspended, therefore, the response to the command sent may arrive after a broadcast message. Any external device should verify that the response it receives to a command does not appear to be a broadcast.

BatteryStatusWord

The bq78412 maintains a 16-bit master battery status word. This word can be accessed at any time and is also transmitted in the broadcast status message block.

Table 7. bq78412 Battery Status Word

STATUS BIT	BIT POSITION	DESCRIPTION
Full	0	1 = full(1)
Discharge	1	1 = discharging(1)
Charge	2	1= charging(1)
Good	3	1 = battery good(1)
Warn	4	1 = battery warning(1)
Replace	5	1 = replace battery(1)
OverChgCurrent	6	1 = overcurrent on charge, charge current > *OccThresh*
OverDschgCurrent	7	1 = overcurrent on discharge, discharge current > *OcdThresh*
OverVoltage	8	1 = overcharge, battery voltage above *OvThresh*
OverTemp	9	1 = over temperature, battery temperature above *OtThresh*
UnderVoltage	10	1 = over discharge, battery voltage below *UvThresh*
UnderTemp	11	1 = under temperature, battery temperature below *UtThresh*
UnderCharged	12	1 = undercharged battery as defined by configuration of *MissChgLim* parameter. Indicates that the battery must be charged.
EOD	13	1 = end-of-discharge condition detected. Cleared when charge detected.
SealStatus[1,0]	14 15	[0,0] = Sealed level 0 [0,1] = Sealed Level 1 [1,0] = Sealed Level 2

(1) See description in Table 4. Status Indicator LEDs

bq78412 Registers and Memory

The bq78412 maintains the status of numerous battery performance variables in its on-chip registers. The device registers are also used to retrieve the battery operational limits. No password is required to access these registers. The registers are read-only.

Battery information is retrieved by issuing message commands over the serial interface to access the specific registers. Registers can be read individually or as a sequential block of registers. All registers are 16-bit registers or multiples of 16 bits.

Table 8. bq78412 Registers (Stored in Volatile Memory)(1)

ITEM	ADDRESS	BYTES	DATA TYPE	DESCRIPTION	UNITS
BatteryStatusWord	0x0000	2		Battery status. See description in BatteryStatusWord	–
Temperature	0x0002		S	Battery temperature	°C
BatteryVoltage	0x0004		U	Battery voltage	mV
Current	0x0006		S	Battery current. Positive value = charge current, Negative value = discharge current.	100 mA
RemCapDerated	0x0008		U	Remaining battery capacity derated as function of discharge current.	100 mAh
FullChargeCapacity(FCC)	0x000A		U	Learned battery capacity at full charge, rated load.	100 mAh
RunTimetoEmpty	0x000C		U	Run time to empty derated as a function of discharge current. Only valid during discharge.	minute
CycleCount	0x000E		U	Number of full discharge cycles or equivalents	
AverageCurrent	0x0010		S	Battery current averaged based on *CurrentAvgTime* parameter	100 mA
DeratedFCC	0x0012		U	Derated available capacity	100 mAh
AccumulatedMissedCharge	0x0014		U	Accumulated missed charge due to multiple discharges occurring before a full charge has occurred	%
RelativeStateOfCharge	0x0016		U	Battery relative state of charge	%

(1) Data words are returned in Little Endian format (least significant bit first).

Cumulative Usage Data

The bq78412 provides internal storage for cumulative usage data during normal operation. The stored data can be retrieved over the communications interface for analysis by an external reader and used for warranty analysis purposes. These data are stored in volatile memory. However, the stored data are backed up once a day to the non-volatile memory and are written back to the volatile memory on a subsequent power-up. This retrieval only happens if the device has been activated. Activation also provides a start point for usage logging.

Activation is done by setting *DevConfig1[10]* = 1

None of the counters roll-over, and are saturated to the maximum value in case of overflow.

Table 9 gives the memory locations of the stored data.

The following is the information that is stored.

Abuse Counters

These count the amount of time that the battery has spent outside recommended operating conditions.

Once every 6 minutes, the battery is checked for abuse. The appropriate counter increments if abuse is detected. Each counter is of 2 bytes and can store values from 0 to 65535. This permits a maximum time of 273 days to be recorded.

The abuse counters are:

- *OtCount* : Time temperature was above *OtThresh*
- *UtCount* : Time temperature was below *UtThresh*
- *OvCount* : Time battery voltage was above *OvThresh*
- *UvCount* : Time battery voltage was below *UvThresh*
- *OccCount* : Time charging current was above *OccThresh*
- *OcdCount* : Time discharging current was above *OcdThresh*

Figure 6 shows operating ranges and thresholds for voltage, temperature and current.

Depth of Discharge (DoD) Counters

These counters are used to generate a histogram of the depth of discharge reached at the end of discharge. On each transition from discharge to charge, the appropriate counter is incremented based on the Depth-of-Discharge (DoD = 100% – SoC) if the drain is significant (see description of *DoDThresh* parameter below). Note that the increment happens even if the previous cycle did not return to 100% full. Each counter is of 2 bytes and can store values from 0 to 65535.

- *DoD80Count* : Counts events where 100% ≥ DoD > 80%
- *DoD60Count* : Counts events where 80% ≥ DoD > 60%
- *DoD30Count* : Counts events where 60% ≥ DoD > 30%
- *DoD10Count* : Counts events where 30% ≥ DoD > 10%
- *DoD0Count* : Counts events where 10% ≥ DoD > 0%

The *DoD10Count* and *DoD0Count* increment every 16 counts so that the range is 65535 x 16 = 1,048,560.

The *DoDThresh* parameter sets the threshold (in 0.1 Ah steps) for the capacity drain during a discharge below which the event does not cause an increment. The capacity drain is calculated as the difference between the capacity at the beginning of discharge and that at the end of discharge.

Charge Counters

These counters calculate the cumulative charge in and out of the battery. These data are stored in 2 bytes in steps of 16 Ah. Thus the maximum value stored is 65535×16 Ah or 1,048,560 Ah, which is equivalent to >3495 full discharge cycles of a 300-Ah battery.

ChargeAH: Cumulative amp-hours in to the battery (includes charge efficiency compensation using the *ChgEff* parameter)

DischargeAH : Cumulative amp-hours out from the battery.

Discharge Time Counter

This counter records the cumulative time in discharge mode. As with the abuse counters, this counter increments every 6 minutes This counter is of 2 bytes and can store values from 0 to 65535. This range permits a maximum time of 273 days to be recorded.

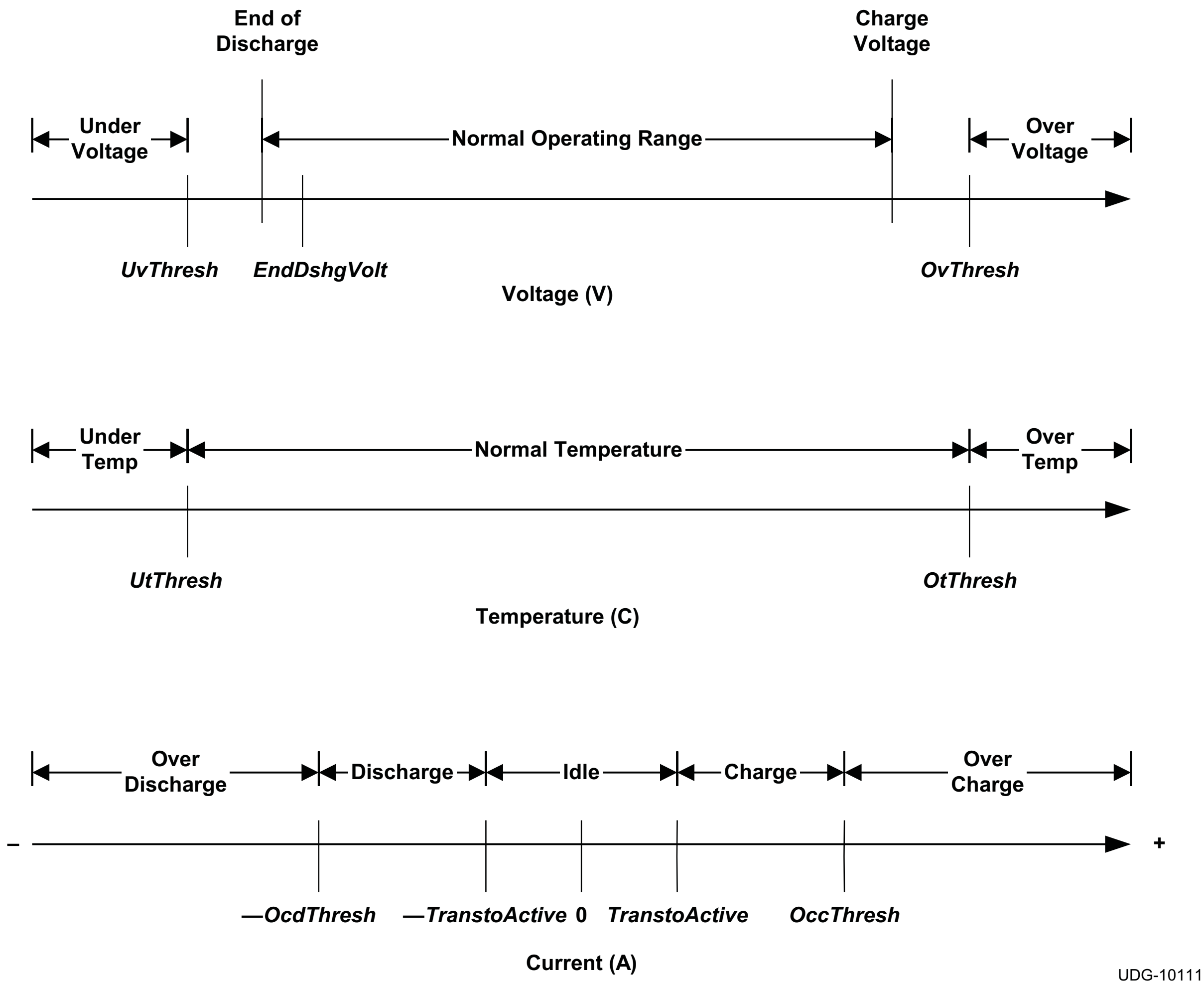


Figure 6. Operating Ranges and Thresholds

Table 9. bq78412 Cumulative Usage Data (Stored in Volatile Memory)

CUMULATIVE DATA	ADDRESS	BYTES	DATA TYPE(1)	DESCRIPTION	UNITS
OtCount	0x18	2	U	Time temperature was above *OtThresh*	6 minutes
UtCount	0x1A			Time temperature was below *UtThresh*	6 minutes
OvCount	0x1C			Time battery voltage exceeded *OvThresh*	6 minutes
UvCount	0x1E			Time battery voltage was below *UvThresh*	6 minutes
OccCount	0x20			Time charge current was above *OccThresh*	6 minutes
OcdCount	0x22			Time discharge current was above *OcdThresh*	6 minutes
DoD80Count	0x24			Instances DoD exceeded 80% at end of discharge	
DoD60Count	0x26			Instances DoD was between 61% and 80% at end of discharge	
DoD30Count	0x28			Instances DoD was between 31% and 60% at end of discharge	
DoD10Count	0x2A			Instances DoD was between 11% and 30% at end of discharge	16 counts
DoD0Count	0x2C			Instances DoD was between 1% and 10% at end of discharge	16 counts
DischargeAHCount	0x2E			Cumulative AH out from battery	16 Ah
ChargeAHCount	0x30			Cumulative AH in to battery	16 Ah
DischargeTime	0x32			Total time in discharge	6 minutes

(1) S=signed integer, U=unsigned integer

Manufacturer Data

Manufacturer-specific data can be stored in the flash memory. The 14-byte space provided can be used as the manufacturer wishes. For example:

- *InstallationDate* parameter can store the installation date of the battery, packed in 2-bytes as: (Year-2010) x 512 + Month x 32 + Day
- *ActivationDate* parameter can store the activation date of the battery, packed in 2-bytes as: (Year-2010) x 512 + Month x 32 + Day.
- *ActivationIndicator* parameter can store activation details such as batch number, packed in 2-bytes.
- *MFGCodeSN* parameter can store other details such as model number, serial number, etc, packed in 8-bytes.

Data Security

The bq78412 has three levels of data security: Levels 0, 1, and 2.

- **SealedLevel0** is the fully unsealed mode where parameters are accessible and programmable under user control. Upon initial power up, the bq78412 defaults to Level 0, so that all parameters can be set and the device can be calibrated.
- **SealedLevel1** is the partially sealed mode where the only parameters that can be modified are *MultiDropAdr*, *InstallDate*, *ActivationDate*, *ActivationIndicator* and *MFGCodeSN*, *Level1Password*. Several parameters can be read in this mode.
- **SealedLevel2** is fully sealed mode where none of the parameters can be modified.

Table 10 summarizes the sealed access levels.

Table 10. Sealed Access Levels

LEVEL	BatteryStatusWord [15,14]	OPERATION
SealedLevel0	`[0,0]`	Device unsealed and full access to parameters, warranty data memory, and calibration data are permitted.
SealedLevel1	`[0,1]`	Device partially sealed. Read access to many parameters.
SealedLevel2	`[1,0]`	Device fully sealed, Only read access to some parameters.

Configuring Security Levels

The seal level can be increased by sending any of the following commands to the bq78412 over the serial interface.

- "*Set SealedLevel1 from SealedLevel0*": Sets the bq78412 to SealedLevel1 from SealedLevel0.
- "*Set SealedLevel2*": Sets the bq78412 to *SealedLevel2* from SealedLevel0 or SealedLevel1.

Unsealing the bq78412

The seal level can be decreased by sending any of the following commands to the bq78412 via the serial interface, along with the appropriate password:

- *"Set SealedLevel0"*: Sets the bq78412 to *SealedLevel0* from *SealedLevel1* or *SealedLevel2* when the received password matches the value in the parameter *Level0Password.*
- *"Set SealedLevel1 from SealedLevel2"*: Sets the bq78412 to SealedLevel1 from SealedLevel2 when the received password matches the value in the parameter *Level1Password.*

After it is unsealed from *SealedLevel1* or *SealedLevel2*, the bq78412 remains unsealed until no activity has been detected on the UART for 60 seconds. After this interval, it reverts to the previous sealed state. Hence, the bq78412 can be maintained in an unsealed state as long as valid commands are being sent to the device at intervals of less than 60 seconds.

The bq78412 does not implement any special algorithm for evaluating the unseal password. It is highly recommended that the password be set immediately prior to sealing the device. For highest security, a secret algorithm should be used to generate the passwords based on a secret key and the battery serial number.

Flash Parameters

Table 11 lists the bq78412 parameter set and the access control rules for each parameter. The address offset starts from a base value of 0x4000 (i.e. address = 0x4000 + Address Offset).

These parameter values are stored in the internal flash memory (non-volatile) and retain the respective values even when the chip is not powered.

In *SealedLevel0* all parameters can be read or written.

Values can only be read or written on 2-byte (even) address boundaries. For example, *NumberCells* at address 0x27h can only be read or written as part of a read/write of the address 0x26h, *ChemID* value.

Table 11. bq78412 Parameter Set and Access Rights

PARAMETER	ADDRESS OFFSET	BYTES	DATA TYPE(1)	ACCESS RIGHTS LEVEL1 R	LEVEL1 W	LEVEL2 R	LEVEL2 W	DESCRIPTION	DEFAULT VALUE	UNITS
MultiDropAdr	0x00	2	U	Y	Y	Y	N	Upper byte = reserved Lower byte = Address of device when configured for multi-drop mode.	0xFF	Hex
MANUFACTURER										
InstallDate	0x02	2	U	Y	Y	Y	N	Installation date can be packed as (year-2010) x 512 + month x 32 + day	0xFFFF	
ActivationDate	0x04	2	U	Y	Y	Y	N	Activation date can be packed as (year-2010) x 512 + month x 32 + day	0xFFFF	
ActivationIndicator	0x06	2		Y	Y	Y	N	2 bytes indicating activation status, used as required by manufacturer.	0xFFFF	Packed Alphanumeric
MFGCodeSN	0x08	8		Y	Y	Y	N	Manufacturer code, serial number. etc, used as required by manufacturer.	0xFFFF FFFF FFFF FFFF	Packed Alphanumeric
CALIBRATION										
VoltageGain	0x10	2	U	Y	N	Y	N	Scale factor to calibrate gain error on voltage measurement. $V_{CAL} = V_{RAW} \times \frac{\text{Voltage Gain}}{32768}$	32768	
TempOffset	0x12	2	S	Y	N	Y	N	Temperature calibration offset. $T_{CAL} = T_{RAW} + \textit{TempOffset}$	0	ºC
MeasScale	0x14	2	U	Y	N	Y	N	Scale factor to calibrate Gain Error on current measurement. $I_{CAL} = \left(\frac{I_{RAW} \times \text{MeasScale}}{4096}\right) + \text{CurrentOffset}$	4096	
CurrentOffset	0x16	2	S	Y	N	Y	N	Calibration offset for zero current	0	100 mA
MeasConfig	0x18	2	U	Y	N	Y	N	Current measurement configuration	13515	
WARRANTY CHECKS										
OtThresh	0x1A	1	S	Y	N	Y	N	Maximum recommended battery temperature	60	ºC
UtThresh	0x1B	1	S	Y	N	Y	N	Minimum recommended battery temperature	0	ºC
OvThresh	0x1C	2	U	Y	N	Y	N	Maximum recommended battery voltage	14800	mV
UvThresh	0x1E	2	U	Y	N	Y	N	Minimum recommended battery voltage	10000	mV
OccThresh	0x20	1	U	Y	N	Y	N	Maximum recommended charge current	4	10 A
OcdThresh	0x21	1	U	Y	N	Y	N	Maximum recommended discharge current	10	10 A
DoDThresh	0x22	1	U	Y	N	Y	N	Threshold of capacity reduction in discharge below which DoD counters are not incremented.	50	0.1 Ah

(1) S=signed integer, U=unsigned integer

Table 11. bq78412 Parameter Set and Access Rights (continued)

PARAMETER	ADDRESS OFFSET	BYTES	DATA TYPE(1)	ACCESS RIGHTS				DESCRIPTION	DEFAULT VALUE	UNITS
				LEVEL1		LEVEL2				
				R	W	R	W			
BATTERY AND INVERTER										
DesignCapacity	0x24	2	U	Y	N	Y	N	Battery design capacity.	1500	100 mAhr
Chem ID	0x26	1	U	Y	N	Y	N	Battery chemistry ID. Indicates the chemistry file in use.	0	
NumberCells	0x27	1	U	Y	N	Y	N	Number of nominal 2-V cells in battery	6	
ChgTaperTime	0x28	2	U	Y	N	Y	N	Time after start of charge taper current detection that battery is fully charged. Sets FULL flag on this event.	600	minutes
ChargeTime	0x2A	2	U	Y	N	Y	N	Time after start of charge that battery is considered fully charged. Sets FULL flag on this event.	1200	minutes
EndDschgVolt	0x2C	2	U	Y	N	Y	N	Voltage below which battery is considered at end of discharge.	10800	mV
AGING ALGORITHM										
CapDerateL	0x2E	1	U	N	N	N	N	Number of days after which FCC is decremented by 0.1 Ah in the capacity aging algorithm, before *DerateChange*.	20	days
CapDerateH	0x2F	1	U	N	N	N	N	Number of days after which FCC is decremented by 0.1 Ah in the capacity aging algorithm, after *DerateChange*.	10	days
DerateChange	0x30	2	U	N	N	N	N	Number of days after which the aging algorithm changes slope from *CapDerateL* to *CapDerateH*.	730	days
SoH CALCULATION										
EolCAP	0x32	2	U	N	N	N	N	End-of-life battery capacity. When full charge capacity falls below the value in this parameter the REPLACE LED is turned on.	1200	100 mAhr
LifeCycles	0x34	2	U	N	N	N	N	Number of full charge/discharge cycles, or equivalent, after which the battery is considered to need replacing. When this cycle count is reached the REPLACE LED is turned on.	1000	
EOLCapWarn	0x36	2	U	N	N	N	N	Battery capacity at which WARN LED is turned on to indicate battery is approaching end of life.	1300	100 mAhr
LifeCycleWarn	0x38	2	U	N	N	N	N	Number of charge/discharge cycles at which WARN LED is turned on to indicate battery is approaching end of life.	800	

Table 11. bq78412 Parameter Set and Access Rights (continued)

PARAMETER	ADDRESS OFFSET	BYTES	DATA TYPE(1)	ACCESS RIGHTS LEVEL1 R	W	LEVEL2 R	W	DESCRIPTION	DEFAULT VALUE	UNITS
HARDWARE										
DevConfig1	0x3A	2	U	N	N	N	N	**Bit[0]:** 1= Enable broadcast, 0 = disable broadcast (default) **Bit[1]:** Reserved **Bit[5:2]:** Number of segments in bar graph display, default = 10. **Bit[9:6]:** Battery Status Broadcast Interval in seconds, 20+ n*20s, n = 0-15, Default = 20 seconds **Bit[10]:** 1 = Activated, 0 = Not Activated (default) **Bit[11]:** UART baud rate 0 = 9600 (default) 1 = 1200 **Bit[13:12]:** 0,0 = NRZ encoding (default) 0,1 = IrDA encoding 1,0 = Reserved 1,1 = Reserved **Bit [14]:** *CapLearnEnable* 1 = bq78412 learns the battery capacity opportunistically at end of discharge. 0 = No opportunistic capacity learning (default) **Bit[15]:** *CapAgeEnable* 1 = The bq78412 derates the capacity based on aging rates specified. 0 = No age based capacity derating (default)	0x0028	Hex
DevConfig2	0x3C	2	U	N	N	N	N	**Bit[1:0]:** Number of beeps on empty. **Bit[3:2]:** Number of beeps when LED0 turns off **Bit[5:4]:** Number of beeps when LED1 turns off **Bit[7:6]:** Number of beeps when LED2 turns of **Bit[10:8]:** Number of beeps on overvoltage **Bit[13:11]:** Number of beeps on undervoltage **Bit[14]:** Reserved **Bit[15]:** Enable external XTAL	0x0000	Hex
LEDs										
DsplyConf1 (2)	0x3E	2	U	N	N	N	N	LED bar graph discharge transition point configuration 1	0x1E1E or {30,30}	minutes
DsplyConf2 (2)	0x40	2	U	N	N	N	N	LED bar graph discharge transition point configuration 2		
DsplyConf3 (2)	0x42	2	U	N	N	N	N	LED bar graph discharge transition point configuration 3		
DsplyConf4 (2)	0x44	2	U	N	N	N	N	LED bar graph discharge transition point configuration 4		
DsplyConf5 (2)	0x46	2	U	N	N	N	N	LED bar graph discharge transition point configuration 5		
MissChgLim	0x48	1	U	N	N	N	N	Total missed charge due to discharges starting before battery has reached full charge. This number can be set above 100%. Full charge clears this condition.	100%	

(2) Refer to Table 1 for more information.

Table 11. bq78412 Parameter Set and Access Rights (continued)

PARAMETER	ADDRESS OFFSET	BYTES	DATA TYPE(1)	ACCESS RIGHTS LEVEL1 R	ACCESS RIGHTS LEVEL1 W	ACCESS RIGHTS LEVEL2 R	ACCESS RIGHTS LEVEL2 W	DESCRIPTION	DEFAULT VALUE	UNITS
ALGORITHMS										
ChgEff	0x49	1	U	N	N	N	N	Percentage of charge current actually stored by battery. Any charge current is derated by this parameter. See Charge Efficiency Compensation section for details.	100%	
P-Scale	0x4A	2		N	N	N	N	Peukart Scaling Factor. Unique for each battery and generated along with the battery characterization table. When using the pre-programmed default table, calculate this using: $\text{Pscale} = 4827 \times (\text{rated current})^{0.4}$	0x2A37	Hex
CurrentAvgTime	0x4C	2	U	N	N	N	N	Current averaging time	120	seconds
IdleThresh	0x4E	2	U	N	N	N	N	Current level below which the part is considered to be in idle state.	3	100 mA
TransToActive	0x50	2	U	N	N	N	N	Current at which battery transitions to charge or discharge mode from idle or sleep modes.	10	100 mA
SleepTime	0x52	2	U	N	N	N	N	Time in idle mode after which the bq78412 transitions to low-power sleep state with the display off.	30	seconds
PASSWORDS										
Level0Password	0x54	4		N	N	N	N	Four byte password for *SealedLevel0* access.	0xFFFF FFFF	Hex
Level1Password	0x58	4		Y	Y	N	N	Four byte password for *SealedLevel1* access.	0xFFFF FFFF	Hex

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
BQ78412DDWR	Active	Production	HTSSOP (DDW) | 44	2000 | LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 85	BQ78412
BQ78412DDWR.A	Active	Production	HTSSOP (DDW) | 44	2000 | LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 85	BQ78412
BQ78412DDWR.B	Active	Production	HTSSOP (DDW) | 44	2000 | LARGE T&R	-	Call TI	Call TI	-40 to 85	
BQ78412DDWT	Active	Production	HTSSOP (DDW) | 44	250 | SMALL T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 85	BQ78412
BQ78412DDWT.A	Active	Production	HTSSOP (DDW) | 44	250 | SMALL T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 85	BQ78412

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

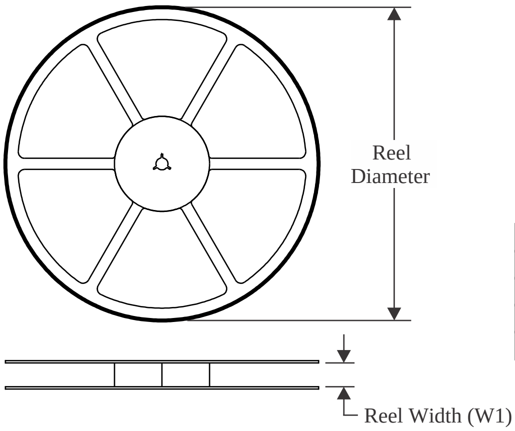
Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

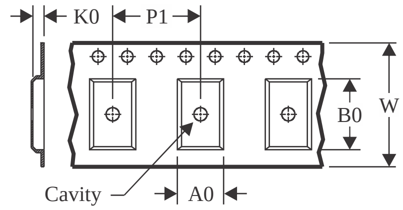
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

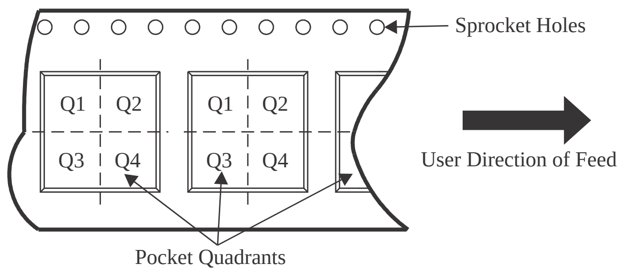


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

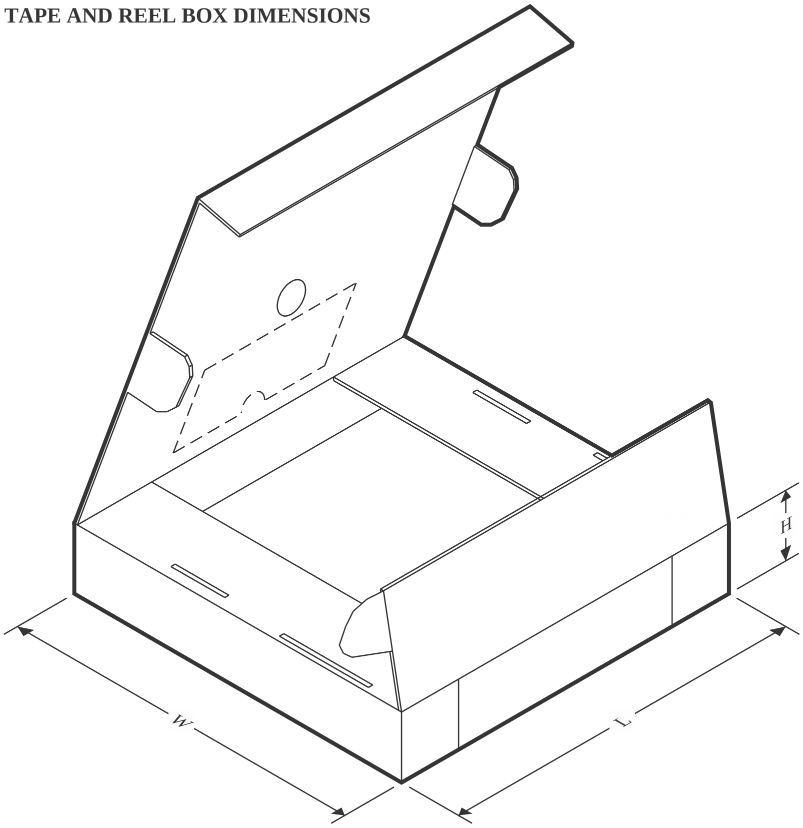
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
BQ78412DDWR	HTSSOP	DDW	44	2000	330.0	24.4	8.6	15.6	1.8	12.0	24.0	Q1
BQ78412DDWT	HTSSOP	DDW	44	250	180.0	24.4	8.6	15.6	1.8	12.0	24.0	Q1

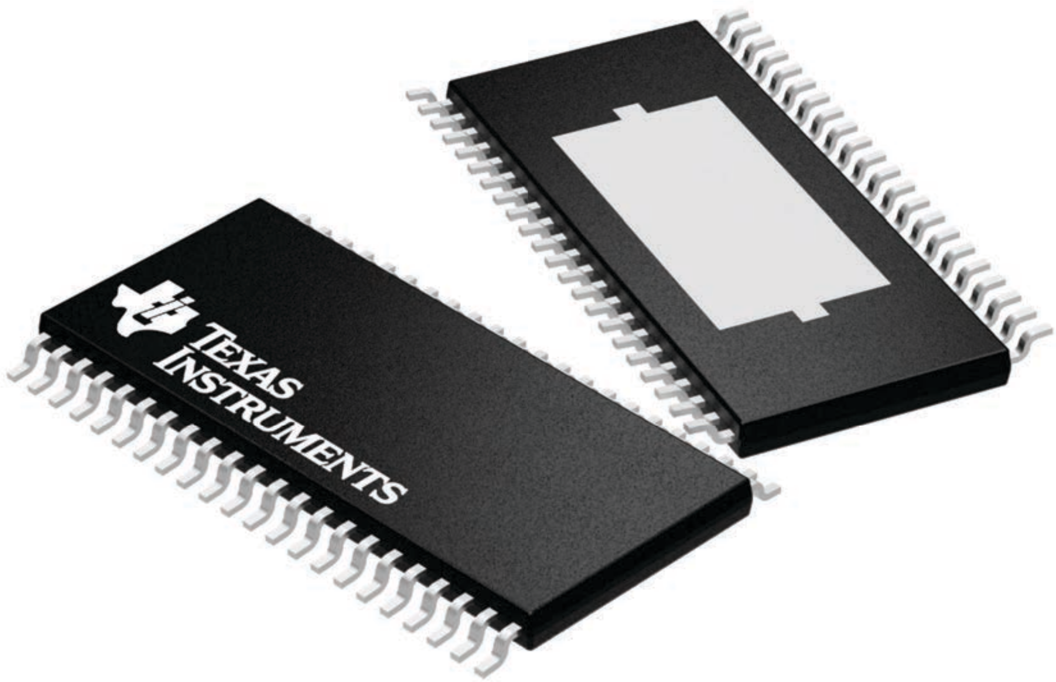
TAPE AND REEL BOX DIMENSIONS



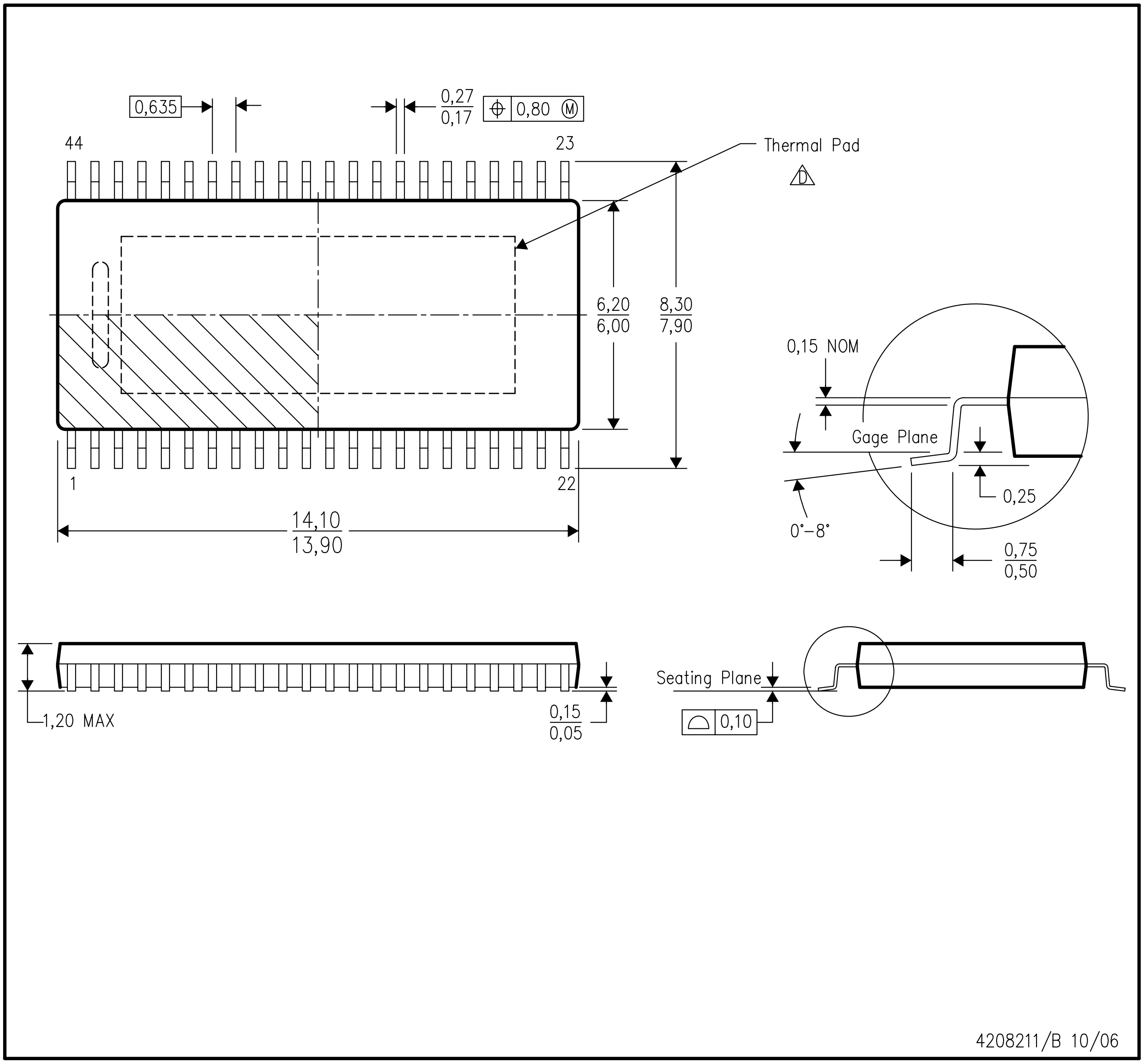
*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
BQ78412DDWR	HTSSOP	DDW	44	2000	350.0	350.0	43.0
BQ78412DDWT	HTSSOP	DDW	44	250	213.0	191.0	55.0

This image is a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.



DDW (R-PDSO-G44) PowerPAD ™ PLASTIC SMALL-OUTLINE PACKAGE (PAD DOWN)



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 not to exceed 0,15.
D. This package thermal performance is optimized for conductive cooling with attachment to an external heat sink. See the product data sheet for details regarding the exposed thermal pad dimensions.

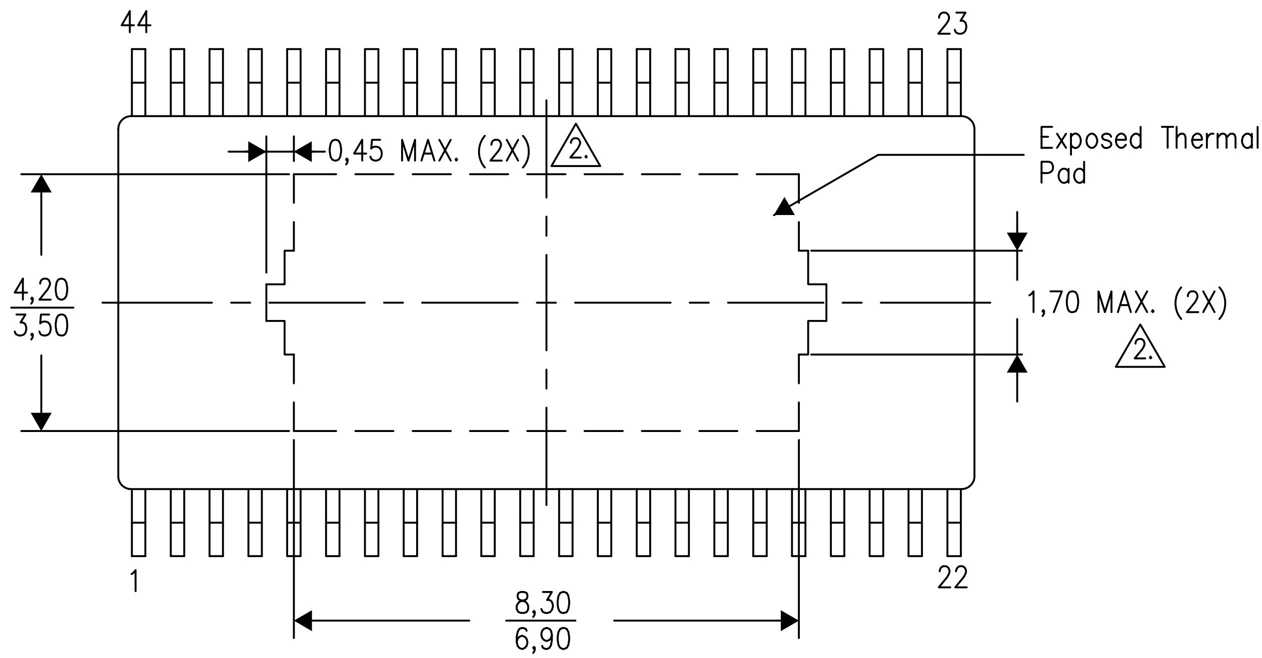
PowerPAD is a trademark of Texas Instruments.

THERMAL INFORMATION

This PowerPAD™ package incorporates an exposed thermal pad that is designed to be attached to a printed circuit board (PCB). The thermal pad must be soldered directly to the PCB. After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For additional information on the PowerPAD package and how to take advantage of its heat dissipating abilities, refer to Technical Brief, PowerPAD Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 and Application Brief, PowerPAD Made Easy, Texas Instruments Literature No. SLMA004. Both documents are available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.



Top View

1. All linear dimensions are in millimeters
2. These features may not be present.

Exposed Thermal Pad Dimensions