

具有运行时间显示功能的 **bq78412** 铅酸电池充电状态指示器

查询样品: **bq78412**

特性

- 专为与消费型 **UPS** 系统中的 **12V** 铅酸电池一起使用而设计
- 可编程电池模型用于提升铅酸电池的电量监测性能
- 可提供电池剩余运行时间（放电期间）和%容量（充电期间）显示的 **10-LED** 条形图
- 可以容易地集成到电池盖之中
- 可与容量高达 **327 Ah** 的铅酸电池配合使用
- 在内部记录累积使用数据，用于担保退货分析
- 片上温度传感器
- 用于检索担保信息的数据接口
- 通过 **UART** 串行接口实现了完全可编程的特性和阈值
- 寿命状态 (**State-of-Health, SoH**) 判定及状态报告
- 包括用于提供低容量、低电压及过压声音告警的可配置信号
- 适合在多电池系统中使用的可寻址命令
- 任选的红外通信接口

应用

- 独立型不间断电源
- **12V** 铅酸电池监视器
- 电池担保数据记录设备

说明

具有运行时间显示功能的 **bq78412** 铅酸电池充电状态 (SoC) 指示器是一款完整的独立型电池电量监测解决方案，专为单 **12V** 铅酸电池而设计。 **bq78412** 利用一个 **10-LED**（发光二极管）条形图来显示电池的剩余运行时间（放电期间）和百分比 (%) 容量（充电期间）。

bq78412 可监视电池电压、电流和环境温度，以计算充电状态并推定电池的剩余运行时间。测量值可以记录和追踪，以便日后为担保用途提供检索。

可编程电池模型 (cell model) 使得 **bq78412** 能够针对多种铅酸电池化学组成和容量进行定制设计。

此外，用于电量监测的电流测量及库仑计数也可由 **bq78412** 自动完成。电流测量采用一个置于负电源通路中的小阻值电阻器来实现，并实施电路内部校准。这提供了电池容量和剩余运行时间值的精确、连续和实时计算。

温度检测采用一种固件算法扩充了电量监测及电池容量信息，以补偿温度对于电池容量的影响。

该器件提供了一个串行端口，用于配置各种可编程参数，包括电池模型、校准值、序列号及生产日期。该串行端口能够操作一个红外 (IR) 接口，以实现无连接器的数据采集。 **bq78412** 可轻松配置、全面编程且无需进行算法或固件开发。



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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 | | UNITS |
|--|--------------------------------------|-------|-----------------|-------|
| | | MIN | MAX | |
| 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.

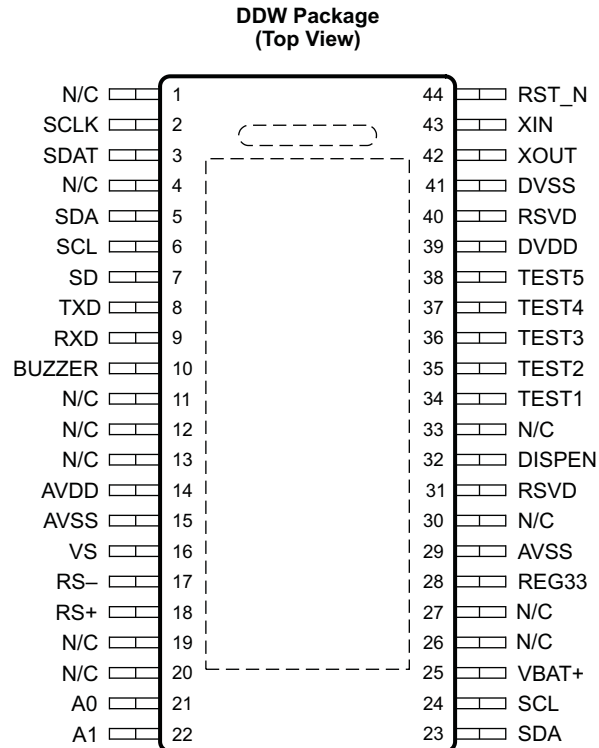
CURRENT CONSUMPTION

| 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 | $100\ \mu\text{A} \leq I_{\text{LOAD}} \leq 100\ \text{mA}$, $T_J = 25^\circ\text{C}$ | | 0.04% | 0.20% | |
| | $100\ \mu\text{A} \leq I_{\text{LOAD}} \leq 100\ \text{mA}$, $-40^\circ\text{C} \leq T_J \leq 85^\circ\text{C}$ | | | 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 | | m Ω |

Package Outline

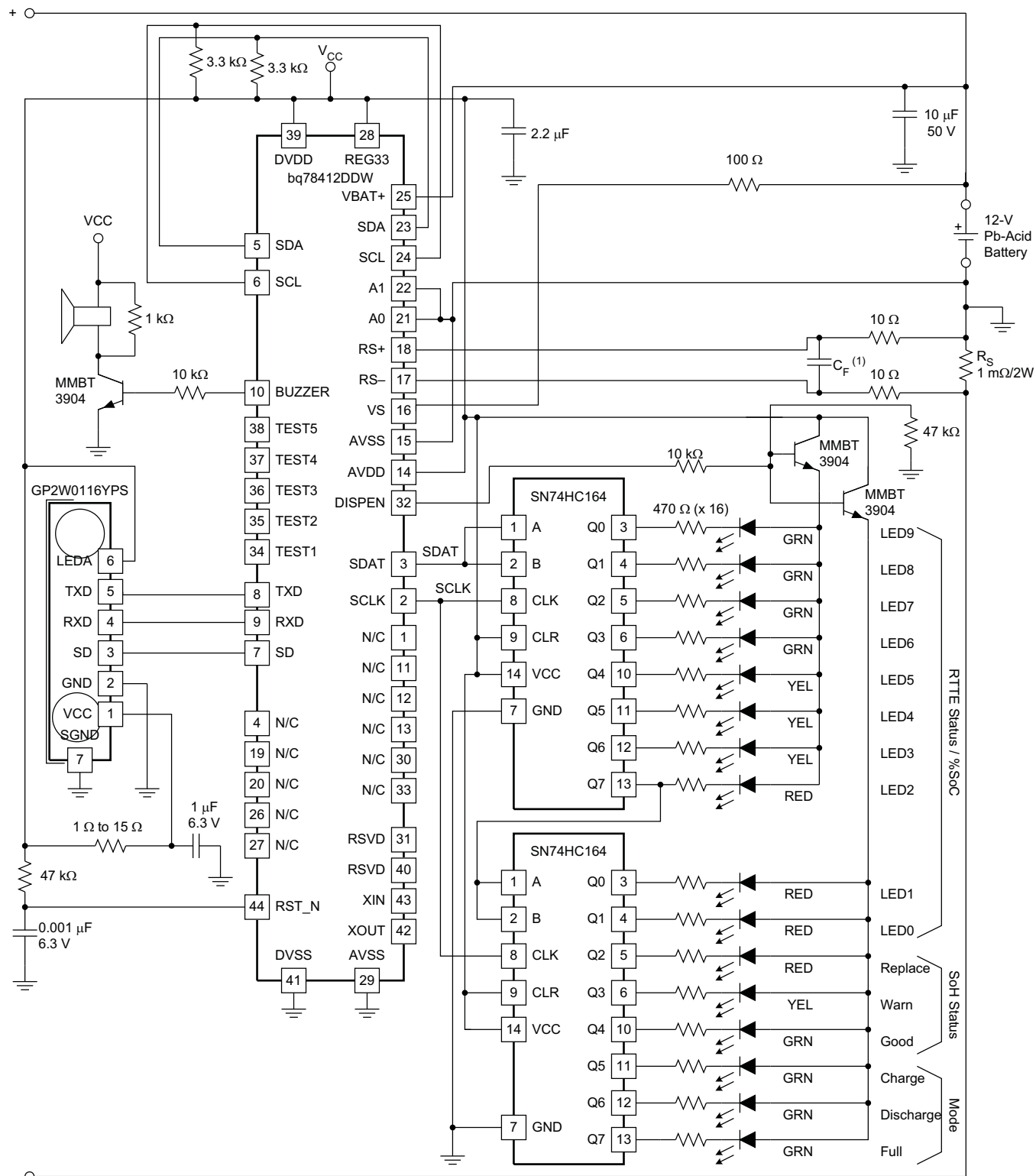


- A. Thermal pad is on the bottom side of the package
- B. N/C = no connect

PIN DESCRIPTIONS

| bq78412 | | I/O/P | DESCRIPTION |
|---------|-----|-------|--|
| NAME | No. | | |
| 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- μ F 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 ² C clock output |
| | 24 | I | I ² C 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 ² C data |
| | 23 | I/O | I ² C 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



UDG-10084

(1) $C_F = 0.1 \mu F$ to $1 \mu F$

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 m Ω) 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 [公式 1](#).

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

where

- Derating is the capacity derating fraction as a function of load current (1)

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

Finally, 3 years is 365 days x 3 = 1095 days

So $CapDerateH = 9$

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 interval (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: $(100Ah - 90.9Ah) / 100Ah = 9.1\% / 3 \text{ years} = 3.033\%/year$

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

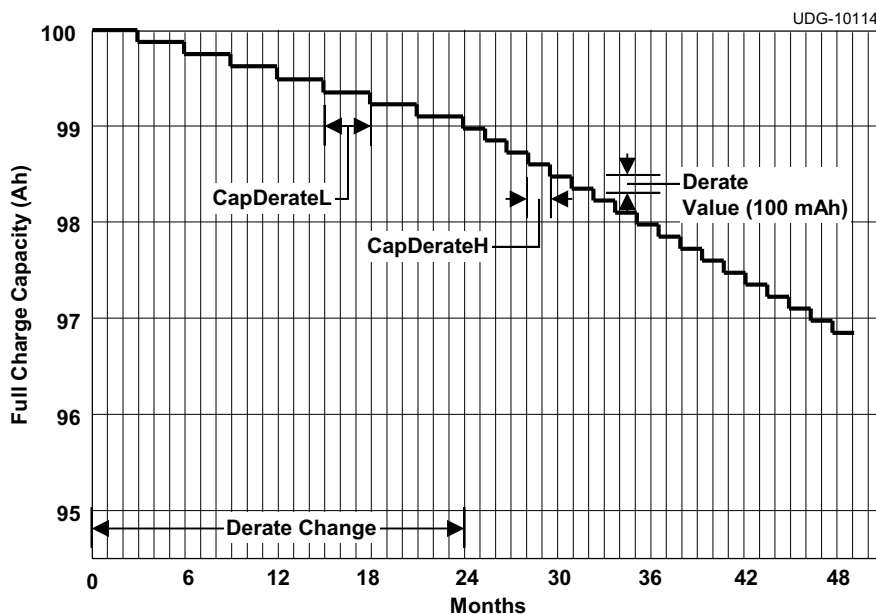


图 1. Age Based Capacity Method

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.

表 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 |

表 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.

表 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 表 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.

表 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 <i>LifeCycles</i> parameter or when full charge capacity(FCC) drops below the value in <i>EolCap</i> parameter |
| WARN | | Turned on when cycle count reaches the value of <i>LifeCycleWarn</i> parameter or when full charge capacity(FCC) has dropped below the <i>EolCapWarn</i> 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. |

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

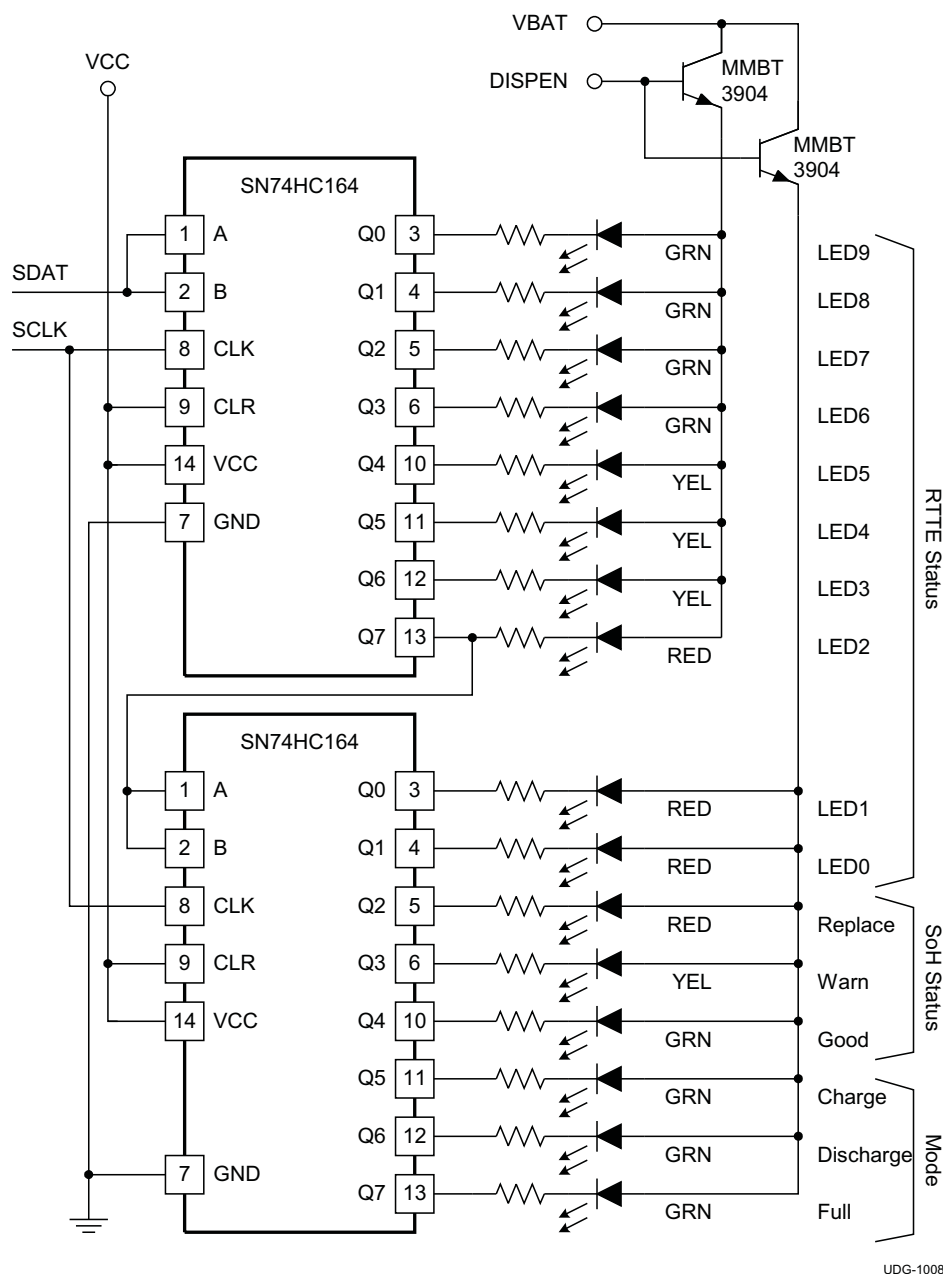


图 2. 10-Bar LED Bar Graph Display and Status LED Connections

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.

表 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 = <i>time in LED0</i> , during discharge | |
| [5:4] | LED1 turns off | RTTE = <i>time in LED0</i> + <i>time in LED1</i> , during discharge | |
| [7:6] | LED2 turns off | RTTE = <i>time in LED0</i> + <i>time in LED1</i> + <i>time in LED2</i> , during discharge | |
| [10:8] | Overvoltage | Battery voltage > <i>OvThresh</i> | 0 to 7 |
| [13:11] | Undervoltage | Battery voltage < <i>UvThresh</i> | |

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 $\geq TransToActive$), 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.

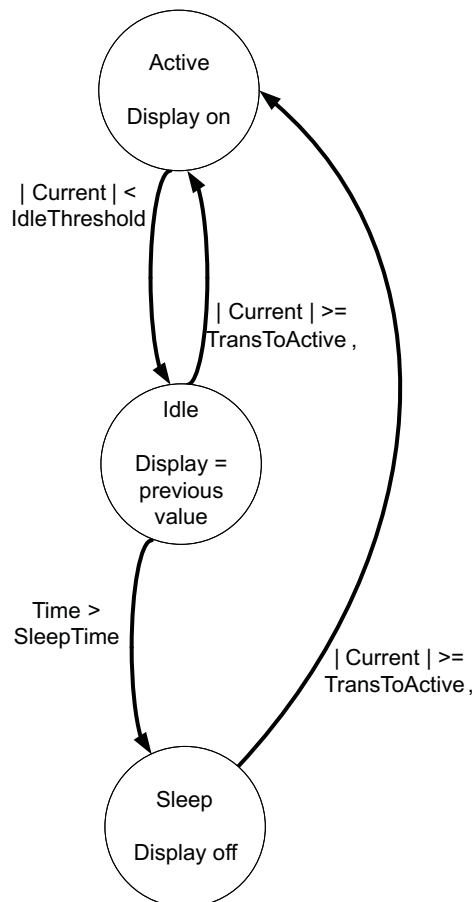


图 3. Operational States

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

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

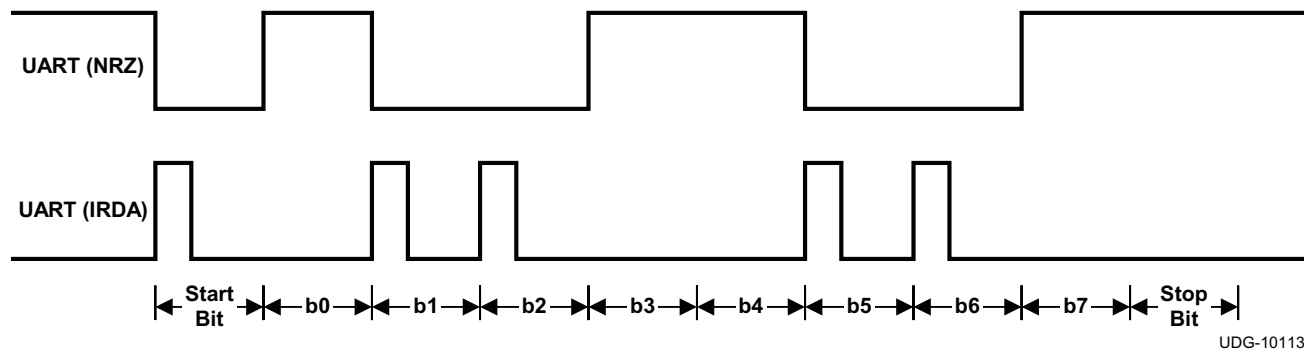


图 4. UART Encoding

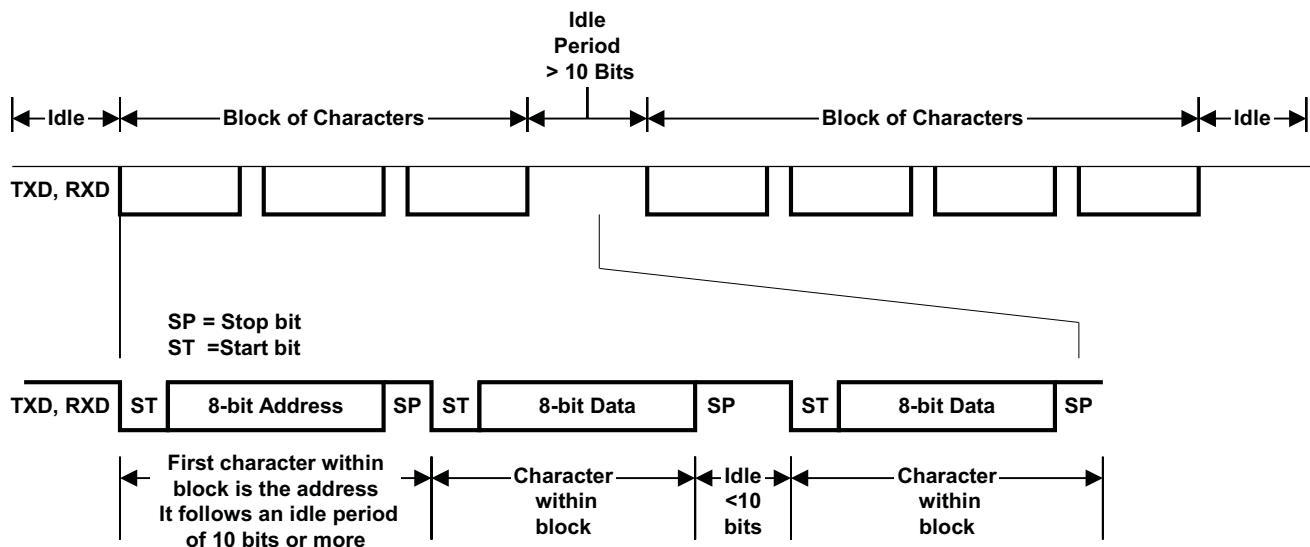


图 5. Multi-Drop Operation

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 Param0XOR 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 byte1XOR 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. 表 6 lists the broadcast status message block words in the order that they are transmitted.

表 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 <i>CurrentAvgTime</i> 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 1XOR 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.

表 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 > <i>OccThresh</i> |
| OverDschgCurrent | 7 | 1 = overcurrent on discharge, discharge current > <i>OcdThresh</i> |
| OverVoltage | 8 | 1 = overcharge, battery voltage above <i>OvThresh</i> |
| OverTemp | 9 | 1 = over temperature, battery temperature above <i>OtThresh</i> |
| UnderVoltage | 10 | 1 = over discharge, battery voltage below <i>UvThresh</i> |
| UnderTemp | 11 | 1 = under temperature, battery temperature below <i>UtThresh</i> |
| UnderCharged | 12 | 1 = undercharged battery as defined by configuration of <i>MissChgLim</i> parameter. Indicates that the battery must be charged. |
| EOD | 13 | 1 = end-of-discharge condition detected. Cleared when charge detected. |
| SealStatus[1,0] | 14 | [0,0] = Sealed level 0 |
| | 15 | [0,1] = Sealed Level 1 [1,0] = Sealed Level 2 |

(1) See description in 表 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.

表 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 <i>CurrentAvgTime</i> 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.

表 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*

图 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 ($\text{DoD} = 100\% - \text{SoC}$) 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 $100\% \geq \text{DoD} > 80\%$
- *DoD60Count* : Counts events where $80\% \geq \text{DoD} > 60\%$
- *DoD30Count* : Counts events where $60\% \geq \text{DoD} > 30\%$
- *DoD10Count* : Counts events where $30\% \geq \text{DoD} > 10\%$
- *DoD0Count* : Counts events where $10\% \geq \text{DoD} > 0\%$

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

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

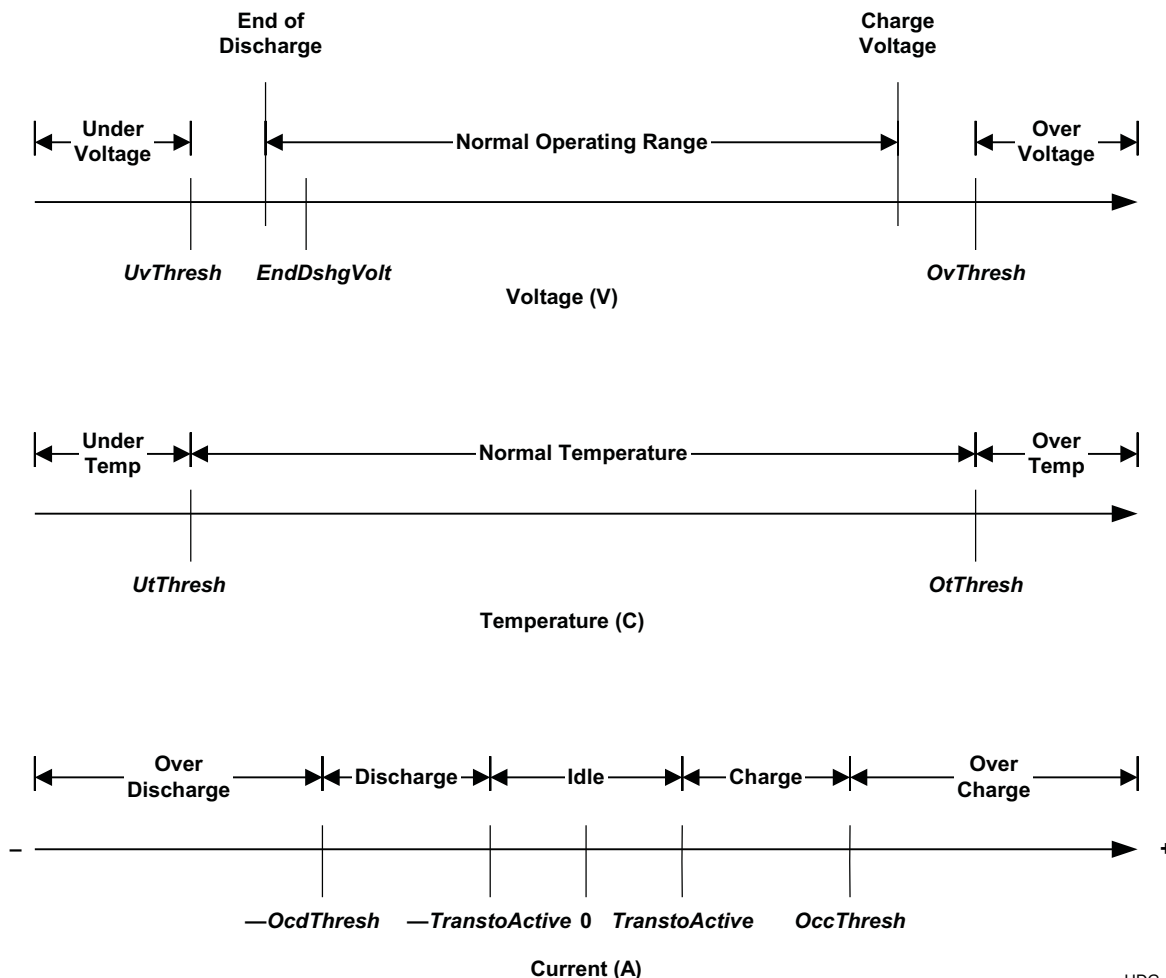
These counters calculate the cumulative charge in and out of the battery. These data are stored in 2 bytes in steps of 16 Ah. Thus the maximum value stored is $65535 \times 16 \text{ Ah}$ or 1,048,560 Ah, which is equivalent to >3495 full discharge cycles of a 300-Ah battery.

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.



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图 6. Operating Ranges and Thresholds

表 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 <i>OtThresh</i> | 6 minutes |
| UtCount | 0x1A | | | Time temperature was below <i>UtThresh</i> | 6 minutes |
| OvCount | 0x1C | | | Time battery voltage exceeded <i>OvThresh</i> | 6 minutes |
| UvCount | 0x1E | | | Time battery voltage was below <i>UvThresh</i> | 6 minutes |
| OccCount | 0x20 | | | Time charge current was above <i>OccThresh</i> | 6 minutes |
| OcdCount | 0x22 | | | Time discharge current was above <i>OcdThresh</i> | 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 |
| DischargeAHCCount | 0x2E | | | Cumulative AH out from battery | 16 Ah |
| ChargeAHCCount | 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.

表 10 summarizes the sealed access levels.

表 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

表 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.

表 11. bq78412 Parameter Set and Access Rights

| PARAMETER | ADDRESS OFFSET | BYTES | DATA TYPE ⁽¹⁾ | ACCESS RIGHTS | | | | DESCRIPTION | DEFAULT VALUE | UNITS |
|---------------------|----------------|-------|--------------------------|---------------|---|--------|---|--|--------------------------|---------------------|
| | | | | LEVEL1 | | LEVEL2 | | | | |
| | | | | R | W | R | W | | | |
| 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. $V_{\text{CAL}} = V_{\text{RAW}} \times \frac{\text{Voltage Gain}}{32768}$ | 32768 | |
| TempOffset | 0x12 | 2 | S | Y | N | Y | N | Temperature calibration offset. $T_{\text{CAL}} = T_{\text{RAW}} + \text{TempOffset}$ | 0 | °C |
| MeasScale | 0x14 | 2 | U | Y | N | Y | N | Scale factor to calibrate Gain Error on current measurement. $I_{\text{CAL}} = \left(\frac{I_{\text{RAW}} \times \text{MeasScale}}{4096} \right) + \text{CurrentOffset}$ | 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 | °C |
| UtThresh | 0x1B | 1 | S | Y | N | Y | N | Minimum recommended battery temperature | 0 | °C |
| 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

表 11. bq78412 Parameter Set and Access Rights (接下页)

| 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 <i>DerateChange</i> . | 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 <i>DerateChange</i> . | 10 | days |
| DerateChange | 0x30 | 2 | U | N | N | N | N | Number of days after which the aging algorithm changes slope from <i>CapDerateL</i> to <i>CapDerateH</i> . | 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 | |

表 11. bq78412 Parameter Set and Access Rights (接下页)

| PARAMETER | ADDRESS OFFSET | BYTES | DATA TYPE ⁽¹⁾ | ACCESS RIGHTS | | | | DESCRIPTION | DEFAULT VALUE | UNITS |
|---------------------------|-------------------|-------|-----------------------------|---------------|---|--------|---|--|----------------------|---------|
| | | | | LEVEL1 | | LEVEL2 | | | | |
| | | | | R | W | R | W | | | |
| 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]: <i>CapLearnEnable</i> 1 = bq78412 learns the battery capacity opportunistically at end of discharge. 0 = No opportunistic capacity learning (default) Bit[15]: <i>CapAgeEnable</i> 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 表 1 for more information.

表 11. bq78412 Parameter Set and Access Rights (接下页)

| PARAMETER | ADDRESS OFFSET | BYTES | DATA TYPE ⁽¹⁾ | ACCESS RIGHTS | | | | DESCRIPTION | DEFAULT VALUE | UNITS |
|----------------|-------------------|-------|-----------------------------|---------------|---|--------|---|--|------------------|---------|
| | | | | LEVEL1 | | LEVEL2 | | | | |
| | | | | R | W | R | W | | | |
| 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: $Pscale = 4827 \times (\text{rated current})^{0.4}$ | 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 <i>SealedLevel0</i> access. | 0xFFFF FFFF | Hex |
| Level1Password | 0x58 | 4 | | Y | Y | N | N | Four byte password for <i>SealedLevel1</i> 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 |
| 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.

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GENERIC PACKAGE VIEW

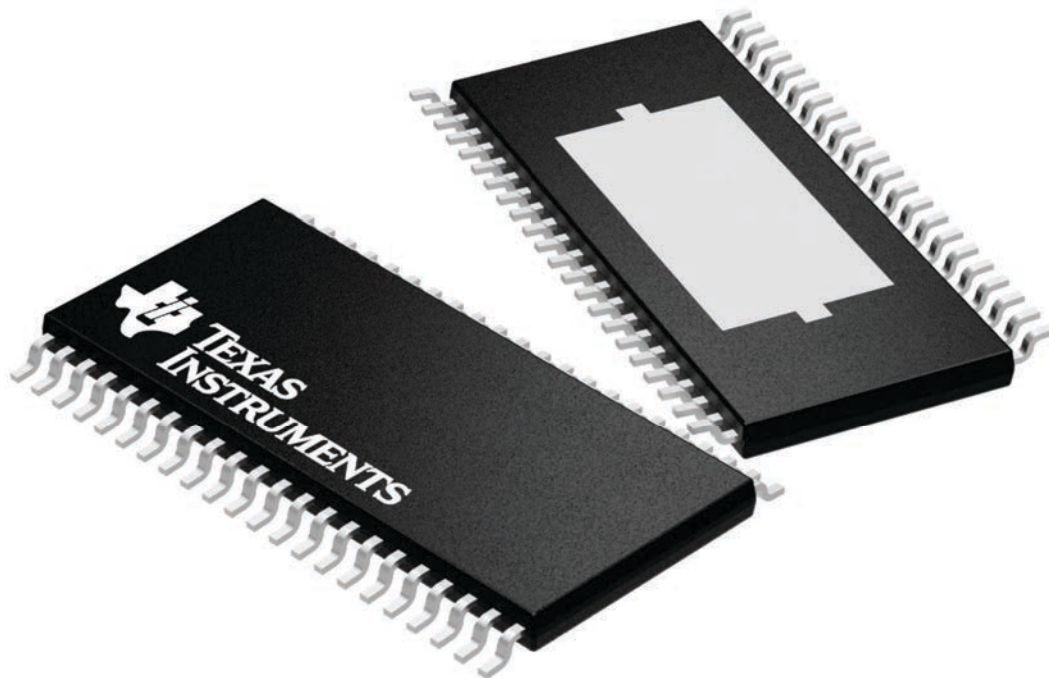
DDW 44

PowerPAD TSSOP - 1.2 mm max height

6.1 x 14, 0.635 mm pitch

PLASTIC SMALL OUTLINE

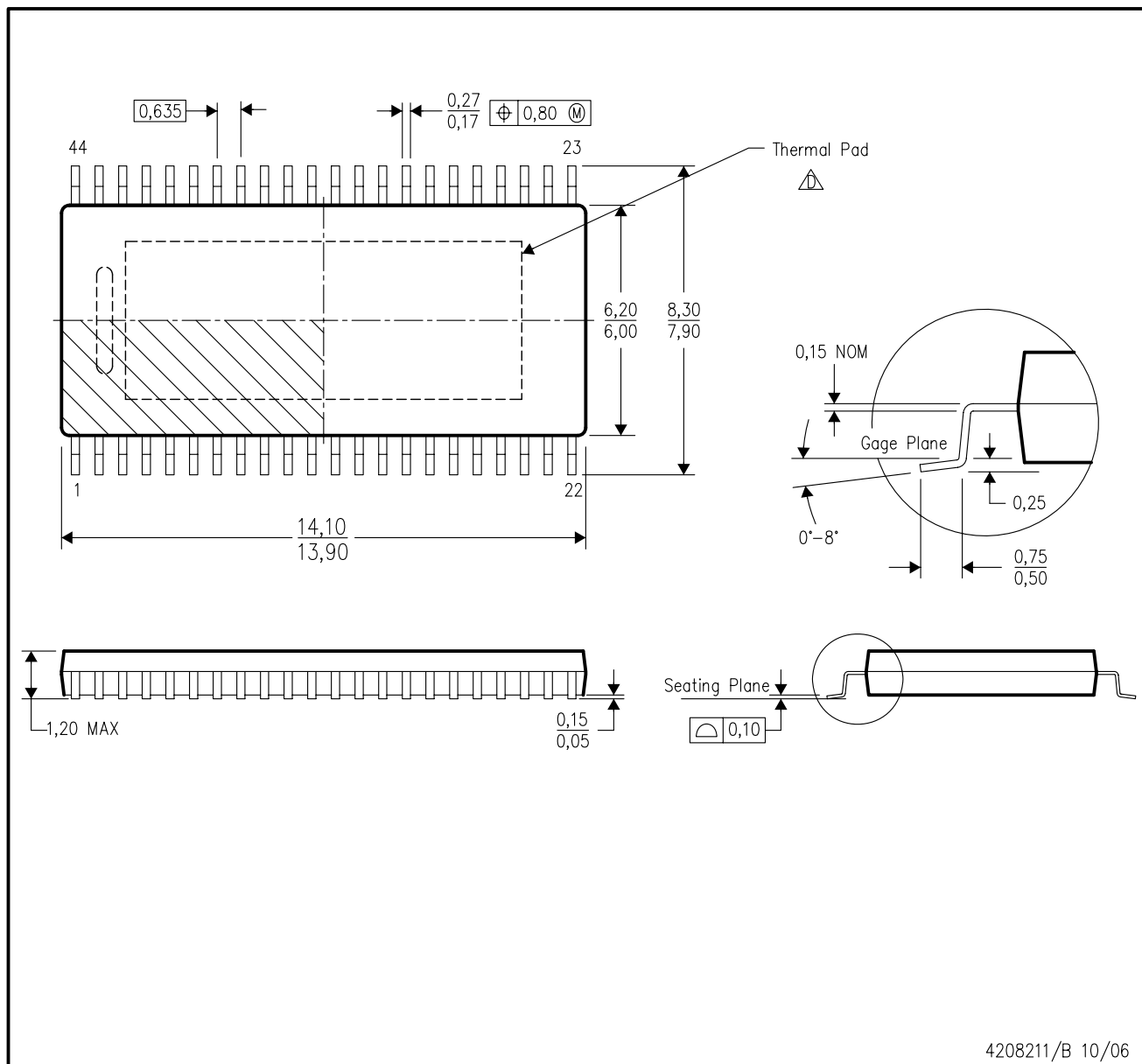
This image is a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.



4224876/A

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.
 - △ 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.

THERMAL PAD MECHANICAL DATA

DDW (R-PDSO-G44)

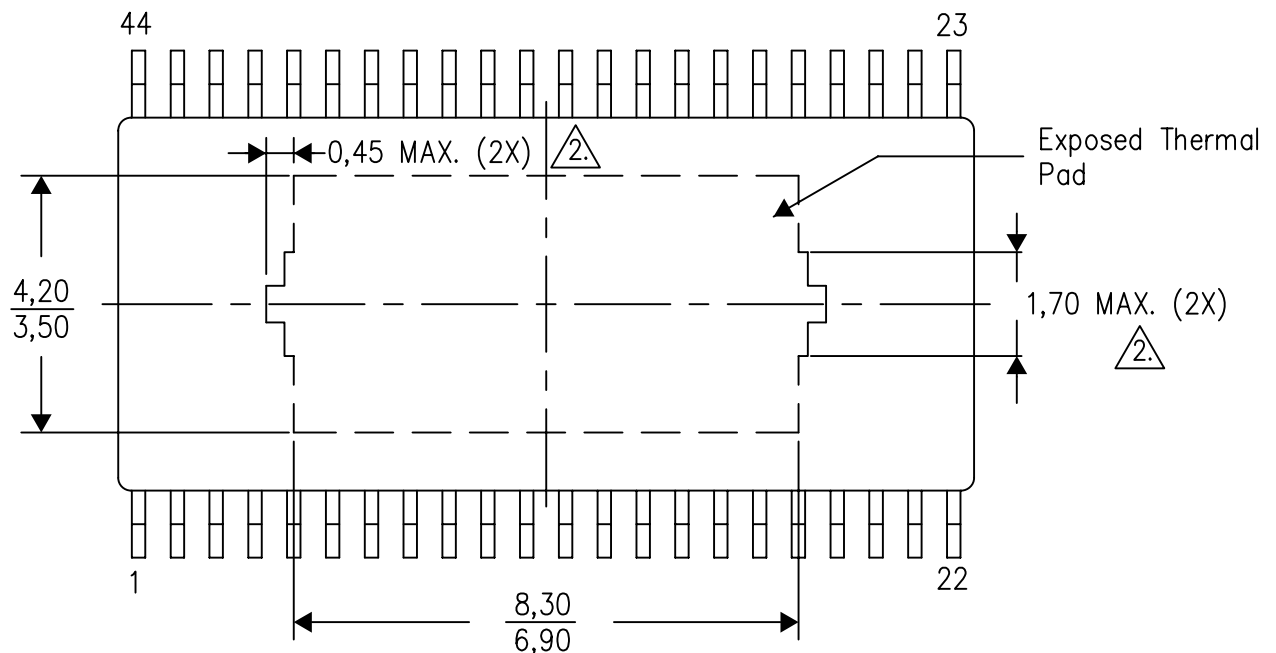
PowerPAD™ SMALL OUTLINE PACKAGE

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

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