

## Single-Chip, Li-Ion Charge Management IC for Handheld Applications ( bqTINY™ )

Check for Samples: [bq24010](#), [bq24012](#), [bq24013](#), [bq24014](#), [bq24018](#)

### FEATURES

- Small 3-mm × 3-mm MLP (QFN) Package
- Ideal for Low-Dropout Designs for Single-Cell Li-Ion or Li-Pol Packs in Space Limited Applications
- Integrated Power FET and Current Sensor for Up to 1-A Charge Applications
- Reverse Leakage Protection Prevents Battery Drainage
- Integrated Current and Voltage Regulation
- ±0.5% Voltage Regulation Accuracy
- Charge Termination by Minimum Current and Time
- Pre-Charge Conditioning With Safety Timer
- Status Outputs for LED or System Interface Indicates Charge and Fault Conditions
- Battery Insertion and Removal Detection
- Works With Regulated and Unregulated Supplies
- Short-Circuit Protection
- Charge Voltage Options: 4.2 V and 4.36 V

### APPLICATIONS

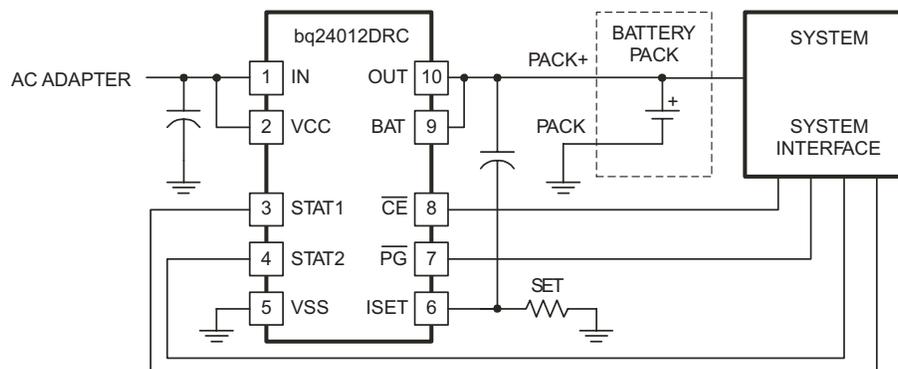
- Cellular Phones
- PDAs
- MP3 Players
- Digital Cameras
- Internet Appliances

### DESCRIPTION

The bqTINY™ series are highly integrated Li-Ion and Li-Pol linear charge management devices targeted at space limited portable applications. The bqTINY™ series offer integrated powerFET and current sensor, reverse blocking protection, high accuracy current and voltage regulation, charge status, and charge termination, in a small package.

The bqTINY™ charges the battery in three phases: conditioning, constant current, and constant voltage. Charge is terminated based on minimum current. An internal charge timer provides a backup safety feature for charge termination. The bqTINY™ automatically restarts the charge if the battery voltage falls below an internal threshold. The bqTINY™ automatically enters sleep mode when  $V_{CC}$  supply is removed.

In addition to the standard features, different versions of the bqTINY™ offer a multitude of additional features. These include temperature sensing input for detecting hot or cold battery packs; power good ( $\overline{PG}$ ) output indicating the presence of valid input power; a TTL-level charge-enable input (CE) used to disable or enable the charge process; and a TTL-level timer and termination enable (TTE) input used to disable or enable the fast-charge timer and charge termination.



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

bqTINY is a trademark of Texas Instruments.



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

## ABSOLUTE MAXIMUM RATINGS<sup>(1)</sup>

|   |  | VALUE            | UNIT |
|---|--|------------------|------|
| Supply voltage range, ( $V_{CC}$ all with respect to $V_{SS}$ )     |  | -0.3 to 18       | V    |
| Input voltage range <sup>(2)</sup>                                  | IN, STAT1, STAT2, TS, $\overline{PG}$ , $\overline{CE}$ , $\overline{TTE}$ | -0.3 to $V_{CC}$ | V    |
|   | BAT, OUT, ISET   | -0.3 to 7        | VDC  |
| Voltage difference between $V_{CC}$ and IN inputs $V_{CC} - V_{IN}$ |  | $\pm 0.5$        | V    |
| Output sink/source current  | STAT1, STAT2, $\overline{PG}$  | 15               |      |
| Output current  | IN, OUT  | 1.5              |      |
| $T_A$   | Operating free-air temperature range                                       | -40 to 125       | °C   |
| $T_J$   | Junction temperature range   |                  |      |
| $T_{stg}$   | Storage temperature  | -65 to 150       | °C   |

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

## DISSIPATION RATINGS

| PACKAGE            | $\theta_{JA}$ | $T_A < 40^\circ\text{C}$<br>POWER RATING | DERATING FACTOR<br>ABOVE $T_A = 40^\circ\text{C}$ |
|--------------------|---------------|--|---|
| DRC <sup>(1)</sup> | 47°C/W        | 1.5 W                                    | 0.021 W/°C1                                       |

- (1) This data is based on using the JEDEC High-K board and the exposed die pad is connected to a copper pad on the board. This is connected to the ground plane by a 2x3 via matrix.

## RECOMMENDED OPERATING CONDITIONS

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

|          |                                      | MIN | NOM | MAX  | UNIT |
|----------|--------------------------------------|-----|-----|------|------|
| $V_{CC}$ | Supply voltage <sup>(1) (2)</sup>    | 3   |     | 16.5 | V    |
| $V_{IN}$ | Input voltage <sup>(1) (2)</sup>     | 3   |     | 16.5 | V    |
| $T_J$    | Operating junction temperature range | -40 |     | 125  | °C   |

- (1) Pins  $V_{CC}$  and IN must be tied together.
- (2) If  $V_{in}$  is between UVLO and 4.35V, and above the battery voltage, then the IC is active (can deliver some charge to the battery), but the IC will have limited or degraded performance (some functions may not meet data sheet specifications). The battery may be undercharged ( $V_{O(Reg)}$  less than in the specification), but will not be overcharged ( $V_{O(Reg)}$  will not exceed specification).

## ELECTRICAL CHARACTERISTICS

over  $0^\circ\text{C} \leq T_J \leq 125^\circ\text{C}$  and recommended supply voltage, (unless otherwise noted)

| PARAMETER   |  | TEST CONDITIONS   |  |  | MIN  | TYP | MAX | UNIT          |
|---|--|---|--|--|------|-----|-----|---------------|
| <b>INPUT CURRENT</b>  |  |   |  |  |      |     |     |               |
| $I_{CC(VCC)}$   | VCC current                                | $V_{CC} > V_{CC(min)}$ , STATx pins in OFF state            |  |  | 0    | 3.5 | 5   | mA            |
| $I_{CC(SLP)}$   | Sleep current                              | Sum of currents into OUT and BAT pins, $V_{CC} < V_{(SLP)}$ |  |  |      |     | 5   | $\mu\text{A}$ |
| $I_{IB(BAT)}$   | Input bias current on BAT pin              |   |  |  |      |     | 500 | nA            |
| $I_{IB(TS)}$  | Input current on TS pin                    | $V_{I(TS)} \leq 10\text{ V}$                                |  |  |      |     | 1   | $\mu\text{A}$ |
| $I_{IB(CE)}$  | Input current on $\overline{CE}$ pin       |   |  |  |      |     | 1   |               |
| $I_{IB(TTE)}$   | Input bias current on $\overline{TTE}$ pin |   |  |  |      |     | 1   |               |
| <b>VOLTAGE REGULATION <math>V_{O(Reg)} + V_{(DO-MAX)} \leq V_{CC}</math>, <math>I_{(TERM)} &lt; I_{O(OUT)} \leq 1\text{ A}</math></b> |  |   |  |  |      |     |     |               |
| Output voltage, $V_{O(Reg)}$  | bq24010, bq24012, bq24013, bq24014         |   |  |  | 4.2  |     | V   |               |
|   | bq24018                                    |   |  |  | 4.36 |     |     |               |

**ELECTRICAL CHARACTERISTICS (continued)**

 over  $0^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$  and recommended supply voltage, (unless otherwise noted)

| PARAMETER  | TEST CONDITIONS  | MIN   | TYP                | MAX       | UNIT          |
|--|--|-------|--------------------|-----------|---------------|
| Voltage regulation accuracy  | $T_A = 25^{\circ}\text{C}$   | -0.5% |                    | 0.5%      |               |
| $V_{(\text{DO})}$ Dropout voltage ( $V_{(\text{IN})} - V_{(\text{OUT})}$ ) | $V_{(\text{O(REG)}} + V_{(\text{DO-MAX})} \leq V_{\text{CC}}, I_{\text{O(OUT)}} = 1\text{A}$   |       | -1%                | 1%        |               |
|  |  |       | 650                | 790       | mV            |
| <b>CURRENT REGULATION</b>  |  |       |                    |           |               |
| $I_{\text{O(OUT)}}^{(1)}$ Output current range                             | $V_{\text{CC}} \geq 4.5\text{V}, V_{\text{IN}} \geq 4.5\text{V}, V_{(\text{BAT})} > V_{(\text{LOWV})},$<br>$V_{\text{IN}} - V_{(\text{BAT})} > V_{(\text{DO-MAX})}$  | 100   |                    | 1000      | mA            |
|  | See note <sup>(2)</sup>  | 25    |                    | 100       |               |
| $V_{(\text{SET})}$ Output current set voltage                              | Voltage on ISET pin, $V_{\text{CC}} \geq 4.5\text{V},$<br>$V_{\text{IN}} \geq 4.5\text{V}, V_{(\text{BAT})} > V_{(\text{LOWV})},$<br>$V_{\text{IN}} - V_{(\text{BAT})} > V_{(\text{DO-MAX})}, V_{\text{O(REG)}} = 4.2\text{V}$ |       | 2.45               | 2.50 2.55 | V             |
|  |  |       | 2.548              | 2.6 2.652 | V             |
| $K_{(\text{SET})}$ Output current ISET factor                              | $50\text{mA} \leq I_{\text{O(OUT)}} \leq 1000\text{mA}, V_{(\text{LOWV})} < V_{(\text{OUT})} < V_{(\text{RCH})}$   | 315   | 335                | 355       |               |
|  | $25\text{mA} \leq I_{\text{O(OUT)}} < 50\text{mA}, V_{(\text{LOWV})} < V_{(\text{OUT})} < V_{(\text{RCH})}$  | 315   | 372                | 430       |               |
|  | $10\text{mA} \leq I_{\text{O(OUT)}} < 100\text{mA}, V_{(\text{OUT})} < V_{(\text{LOWV})}$  | 350   |                    | 1000      |               |
|  | $2.5\text{mA} \leq I_{\text{O(OUT)}} < 10\text{mA}, V_{(\text{OUT})} < V_{(\text{LOWV})}$  |       | 450                |           |               |
|  | $2.5\text{mA} \leq I_{\text{O(OUT)}} < I_{(\text{PGM})}, V_{(\text{OUT})} < V_{(\text{RCH})}$  |       | 355 <sup>(3)</sup> |           |               |
| <b>PRE-CHARGE AND SHORT-CIRCUIT CURRENT REGULATION</b>                     |  |       |                    |           |               |
| $V_{(\text{LOWV})}$ Pre-charge to fast-charge transition threshold         | Voltage on BAT pin   | 2.80  | 2.95               | 3.10      | V             |
| $V_{(\text{SC})}$ Pre-charge to short-charge transition threshold          | Voltage on BAT pin   | 1     | 1.4                | 1.8       | V             |
| $I_{\text{O(PRECHG)}}^{(4)}$ Pre-charge range                              | $V_{(\text{SC})} < V_{(\text{BAT})} < V_{(\text{LOWV})}, t < t_{(\text{PRECHG})}$  | 10    |                    | 100       | mV            |
| $V_{(\text{PRECHG})}$ Pre-charge set voltage                               | Voltage on ISET pin, $V_{(\text{SC})} < V_{(\text{BAT})} < V_{(\text{LOWV})}$  | 225   | 250                | 280       | mV            |
| $I_{\text{SC}}$ Short circuit current                                      | $V_{(\text{SC})} > V_{(\text{BAT})}$   | 660   | 900                | 1200      | $\mu\text{A}$ |

$$I_{\text{O(OUT)}} = \frac{(K_{(\text{SET})} \times V_{(\text{SET})})}{R_{(\text{SET})}}$$

(1)

(2) Specified by design. Not production tested.

(3) The ISET pin may be used as a current monitor during voltage regulation by applying the following equation:

$$I_{\text{O(OUT)}} = K_{(\text{ISET})} \times \left( \frac{V_{(\text{ISET})}}{R_{(\text{ISET})}} + 10\mu\text{A} \right)$$

This equation is also used for calculating the termination point.

$$I_{\text{O(PRECHG)}} = \frac{(K_{(\text{SET})} \times V_{(\text{PRECHG})})}{R_{(\text{SET})}}$$

(4)

## ELECTRICAL CHARACTERISTICS (Continued)

over  $0^{\circ}\text{C} \leq T_j \leq 125^{\circ}\text{C}$  and recommended supply voltage, (unless otherwise noted)

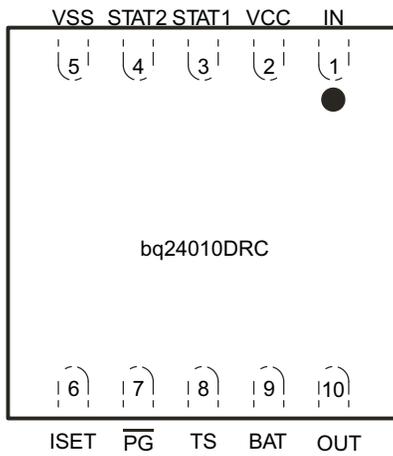
| PARAMETER   | TEST CONDITIONS                          | MIN  | TYP          | MAX                                     | UNIT                                    |      |               |
|---|--|--|--------------|---|---|------|---------------|
| <b>CHARGE TAPER AND TERMINATION DETECTION</b>   |  |  |              |   |   |      |               |
| $I_{(TAPER)}$ <sup>(1)</sup>  | Charge taper detection range             | $V_{(BAT)} > V_{(RCH)}, t < t_{(TAPER)}$   |              | 10                                      | 100                                     | mA   |               |
| $V_{(TAPER)}$   | Charge taper detection set voltage       | Voltage on ISET pin, $V_{(BAT)} > V_{(RCH)}, t < t_{(TAPER)}, V_{(BAT)} = V_{O(REG)}$                                      |              | 225                                     | 250                                     | 275  | mV            |
| $V_{(TERM)}$  | Charge termination detection set voltage | Voltage on ISET pin, $V_{(BAT)} = V_{O(REG)}, V_{(BAT)} > V_{(RCH)}, I_{(TERM)} = K_{(SET)} \times V_{(TERM)} / R_{(SET)}$ |              | 5                                       | 17.5                                    | 50   | mV            |
| <b>TEMPERATURE COMPARATOR</b>   |  |  |              |   |   |      |               |
| $V_{(TS1)}$   | Lower threshold                          | Voltage on TS pin  |              | 29                                      | 30                                      | 31   | %VCC          |
| $V_{(TS2)}$   | Upper threshold                          | Voltage on TS pin  |              | 60                                      | 61                                      | 62   |               |
|   | Hysteresis                               |  |              |   | 1                                       |      |               |
| <b>BATTERY RECHARGE THRESHOLD</b>   |  |  |              |   |   |      |               |
| $V_{(RCH)}$   | Recharge threshold                       |  | $V_{O(REG)}$ | $V_{O(REG)}$                            | $V_{O(REG)}$                            | V    |               |
|   |  |  | -0.135       | -0.1                                    | -0.075                                  |      |               |
| <b>STAT1, STAT2, AND PG OUTPUTS</b>   |  |  |              |   |   |      |               |
| $V_{OL}$  | Output (low) saturation voltage          | $I_O = 10 \text{ mA}$  |              |   | 0.5                                     | V    |               |
| <b>CHARGE ENABLE (<math>\overline{CE}</math>) AND TIMER AND TERMINATION ENABLE (<math>\overline{TTE}</math>) INPUTS</b> |  |  |              |   |   |      |               |
| $V_{IL}$  | Low-level input voltage                  | $I_{IL} = 1 \mu\text{A}$   |              | 0                                       | 0.8                                     | V    |               |
| $V_{IH}$  | High-level input voltage                 | $I_{IL} = 1 \mu\text{A}$   |              | 2.0                                     |   |      |               |
| <b>TIMERS</b>   |  |  |              |   |   |      |               |
| $t_{(PRECHG)}$  | Pre-charge time                          |  | 1 548        | 2,065                                   | 2,581                                   | s    |               |
| $t_{(TAPER)}$   | Taper time                               |  | 1 548        | 2,065                                   | 2,581                                   |      |               |
| $t_{(CHG)}$   | Charge time                              |  | 15 480       | 20,650                                  | 25,810                                  |      |               |
| <b>SLEEP COMPARATOR</b>   |  |  |              |   |   |      |               |
| $V_{SLP}$   | Sleep mode entry threshold voltage       | $V_{POR} \leq V_{(BAT)} \leq V_{O(REG)}$   |              |   | $V_{CC} \leq V_{(BAT)} + 30 \text{ mV}$ | V    |               |
|   | Sleep mode exit threshold voltage        | $V_{POR} \leq V_{(BAT)} \leq V_{O(REG)}$   |              | $V_{CC} \geq V_{(BAT)} + 22 \text{ mV}$ |   |      |               |
|   | Sleep mode deglitch time                 | VCC decreasing below threshold, 100-ns fall time, 10-mV overdrive  |              | 250                                     | 650                                     | ms   |               |
| <b>BATTERY DETECTION THRESHOLDS</b>   |  |  |              |   |   |      |               |
| $I_{(DETECT)}$  | Battery detection current                | $2 \text{ V} \leq V_{(BAT)} \leq V_{(RCH)}$  |              | -3.1                                    | -4.6                                    | -6.1 | mA            |
| $t_{(DETECT)}$  | battery detection time                   | $2 \text{ V} \leq V_{(BAT)} \leq V_{(RCH)}$  |              | 100                                     | 125                                     | 150  | ms            |
| $I_{(FAULT)}$   | Fault current                            | $V_{(BAT)} < V_{(RCH)}$ and/or $t > t_{(PRECHG)}$  |              | 660                                     | 900                                     | 1200 | $\mu\text{A}$ |
| <b>POWER-ON RESET AND INPUT VOLTAGE RAMP RATE</b>   |  |  |              |   |   |      |               |
| $V_{POR}$ <sup>(2)</sup>  | Power-on reset threshold voltage         |  | 225          | 2.5                                     | 2.75                                    | V    |               |

$$I_{O(TAPER)} = \frac{(K_{(SET)} \times V_{(TAPER)})}{R_{(SET)}}$$

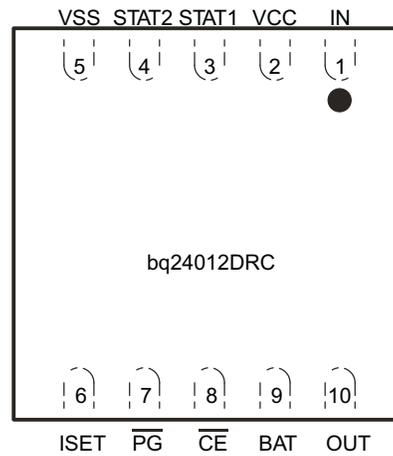
- (1) Specified by design. Not production tested.  
(2) Specified by design. Not production tested.

**DEVICE INFORMATION**

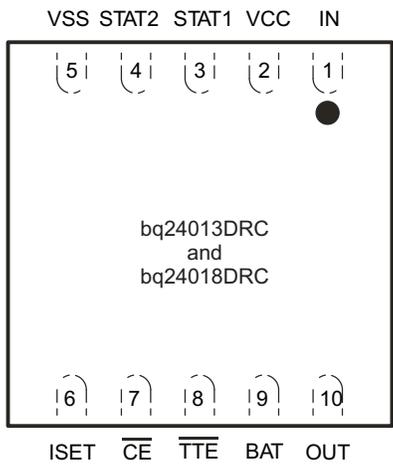
**DRC PACKAGE**  
**(TOP VIEW)**



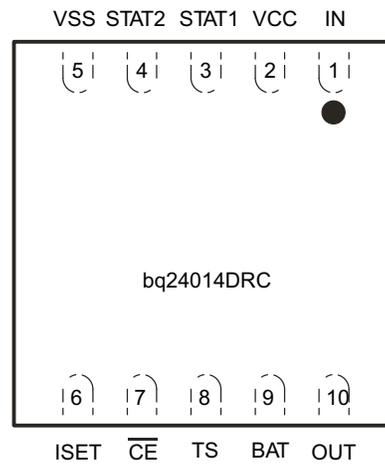
**DRC PACKAGE**  
**(TOP VIEW)**



**DRC PACKAGE**  
**(TOP VIEW)**



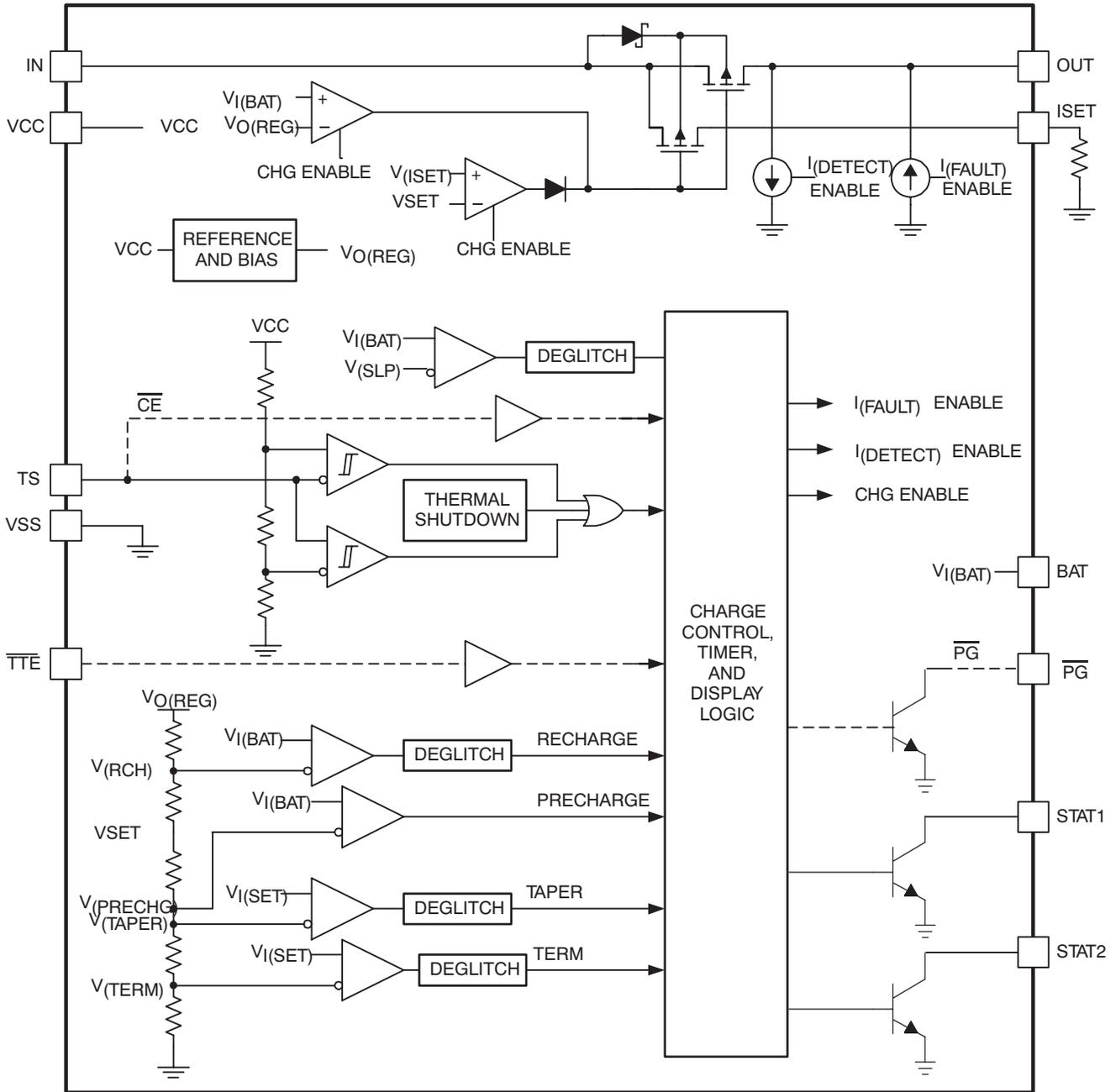
**DRC PACKAGE**  
**(TOP VIEW)**



**Table 1. TERMINAL FUNCTIONS**

| NAME                    | TERMINAL |         |                     |         | I/O | DESCRIPTION   |
|-------------------------|----------|---------|---------------------|---------|-----|---|
|                         | bq24010  | bq24012 | bq24013 and bq24018 | bq24014 |     |   |
| BAT                     | 9        | 9       | 9                   | 9       | I   | Battery voltage sense input   |
| $\overline{\text{CE}}$  | –        | 8       | 7                   | 7       | I   | Charge enable input (active low)  |
| IN                      | 1        | 1       | 1                   | 1       | I   | Charge input voltage. This input must be tied to the VCC pin.   |
| ISET                    | 6        | 6       | 6                   | 6       | O   | Charge current set point  |
| OUT                     | 10       | 10      | 10                  | 10      | O   | Charge current output   |
| $\overline{\text{PG}}$  | 7        | 7       | –                   | –       | O   | Power good status output (open collector)   |
| STAT1                   | 3        | 3       | 3                   | 3       | O   | Charge status output 1 (open collector)   |
| STAT2                   | 4        | 4       | 4                   | 4       | O   | Charge status output 2 (open collector)   |
| $\overline{\text{TTE}}$ | –        | –       | 8                   | –       | I   | Timer and termination enable input (active low)   |
| TS                      | 8        | –       | –                   | 8       | I   | Temperature sense input   |
| VCC                     | 2        | 2       | 2                   | 2       | I   | VCC supply input  |
| VSS                     | 5        | 5       | 5                   | 5       | –   | Ground input  |
| Exposed Thermal PAD     | Pad      | Pad     | Pad                 | Pad     | –   | There is an internal electrical connection between the exposed thermal pad and V <sub>SS</sub> pin of the device. The exposed thermal pad must be connected to the same potential as the V <sub>SS</sub> pin on the printed circuit board. Do not use the thermal pad as the primary ground input for the device. V <sub>SS</sub> pin must be connected to ground at all times. |

FUNCTIONAL BLOCK DIAGRAM



Dotted lines represent optional features

TYPICAL CHARACTERISTICS

## FUNCTIONAL DESCRIPTION

The bqTINY™ supports a precision Li-Ion, Li-Pol charging system suitable for single-cells. Figure 2 shows a typical charge profile, application circuit, and Figure 5 shows an operational flow chart.

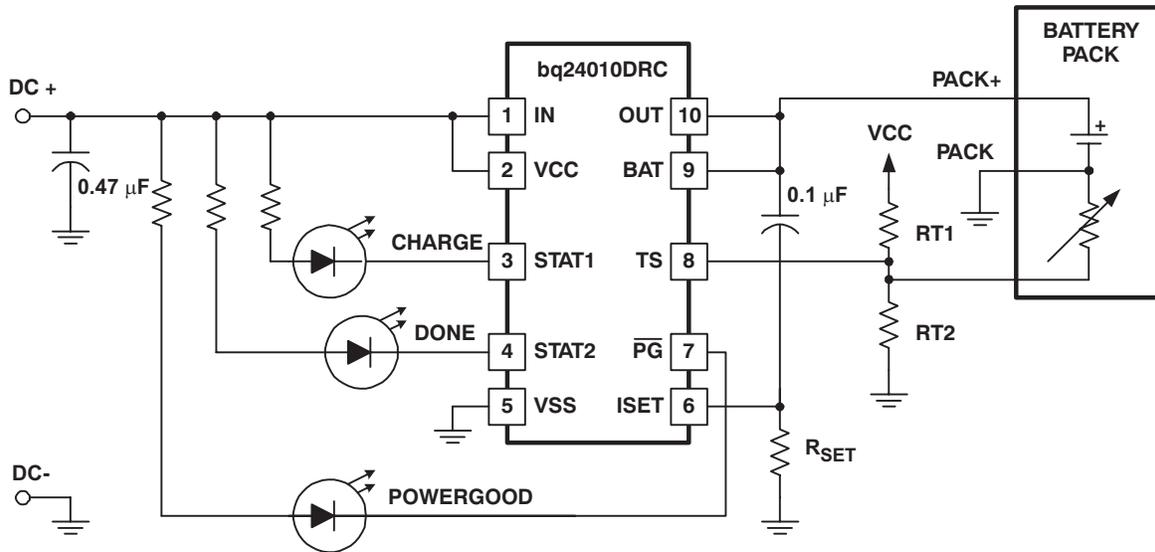


Figure 3. Typical Application Circuit

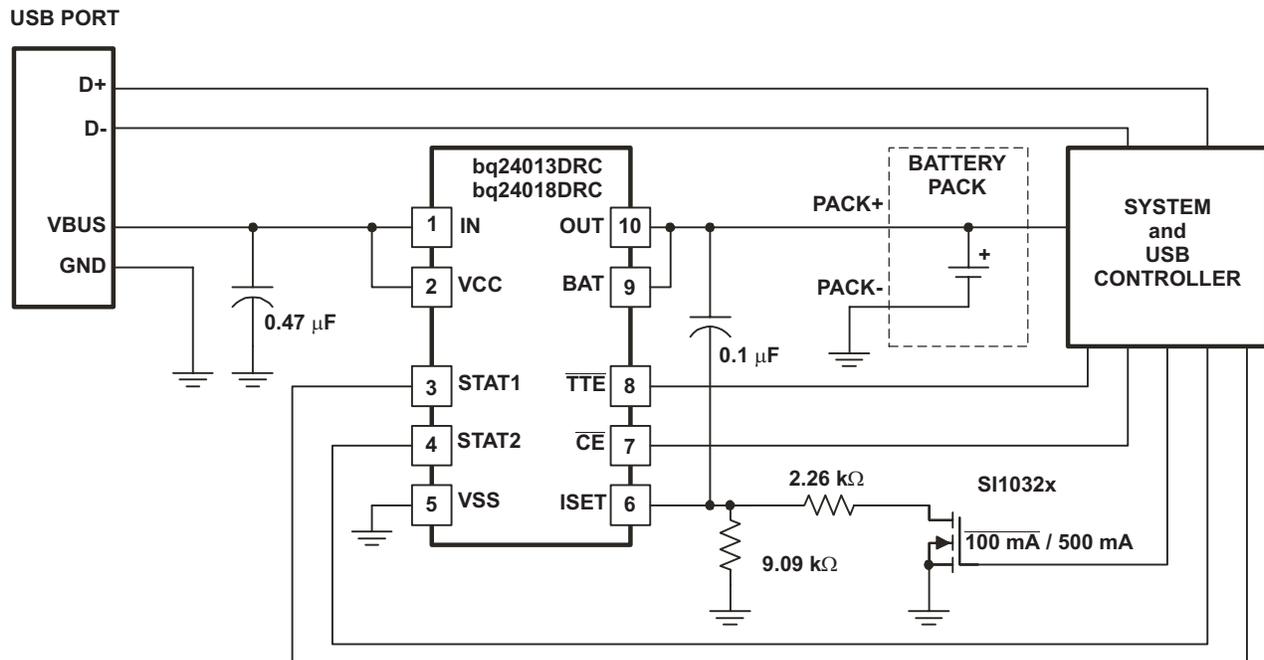


Figure 4. USB Charger Circuit

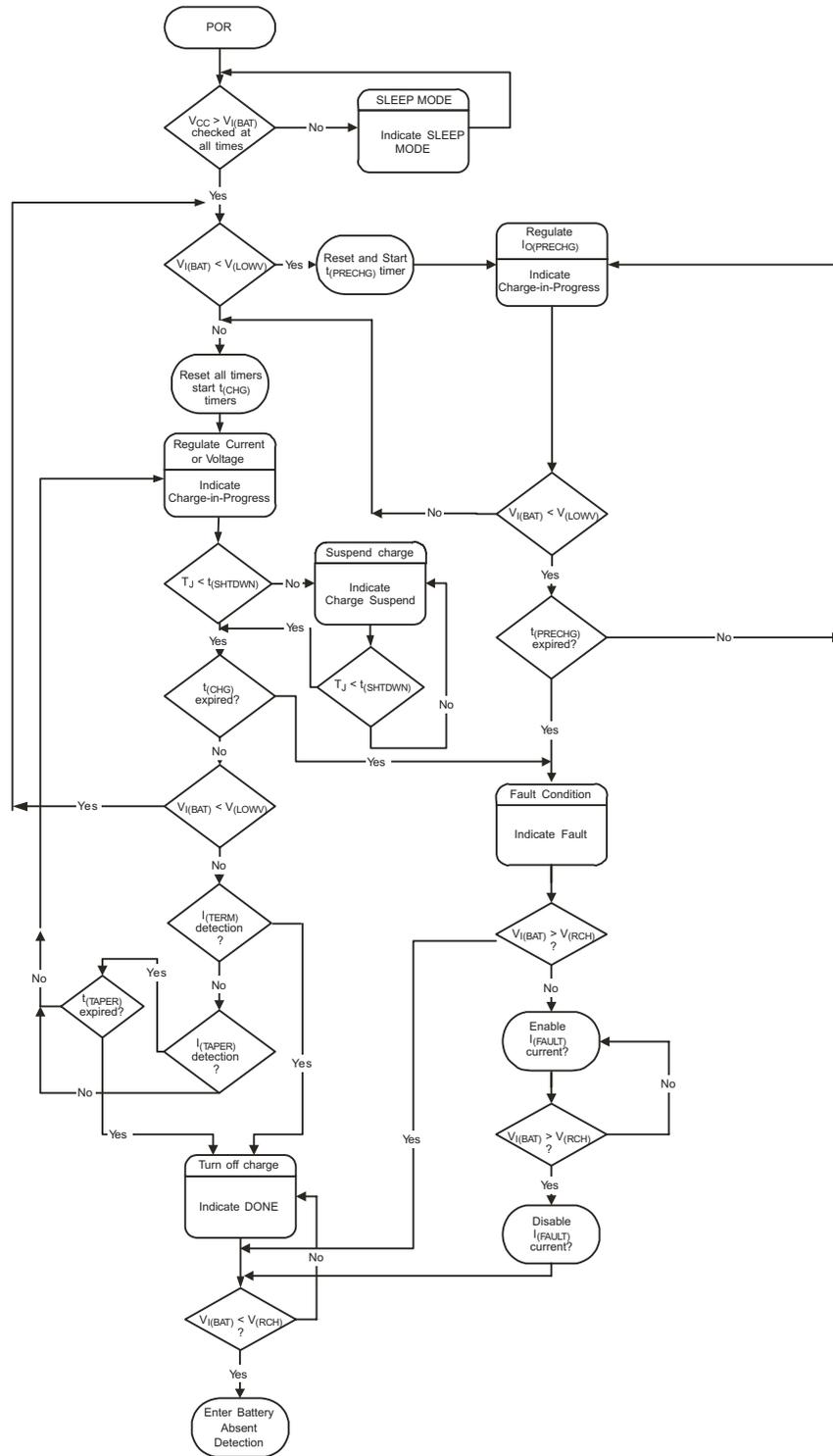


Figure 5. Operational Flow Chart

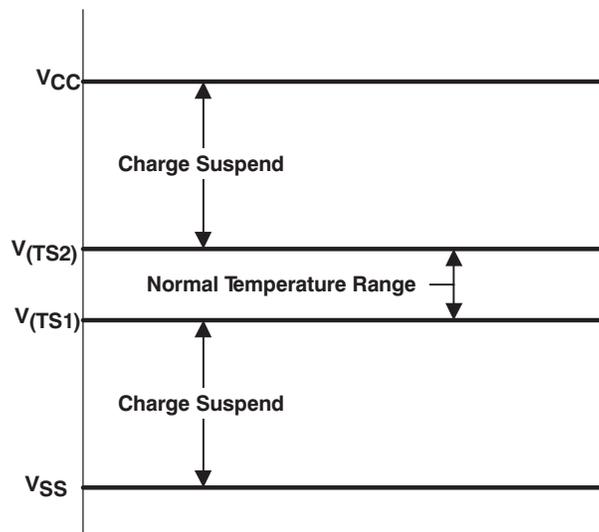
## TEMPERATURE QUALIFICATION

### NOTE

The temperature qualifications apply only to versions with temperature sense input (TS) pin option (bq24020 and bq24014).

Versions of the bqTINY with the TS pin option, continuously monitor battery temperature by measuring the voltage between the TS and VSS pins. A negative temperature coefficient thermistor (NTC) and an external voltage divider typically develops this voltage (see [Figure 3](#)). The bqTINY compare this voltage against the internal  $V_{(TS1)}$  and  $V_{(TS2)}$  thresholds to determine if charging is allowed (see [Figure 6](#)). The temperature sensing circuit is immune to any fluctuation in  $V_{CC}$  since both the external voltage divider and the internal thresholds are ratiometric to  $V_{CC}$ .

Once a temperature outside the  $V_{(TS1)}$  and  $V_{(TS2)}$  thresholds is detected the bqTINY immediately suspend the charge. The bqTINY suspends charge by turning off the power FET and holding the timer value (i.e. timers are NOT reset). Charge resumes when the temperature returns to the typical range.



**Figure 6. TS Pin Thresholds**

The resistor values of  $R_{T1}$  and  $R_{T2}$  are calculated by [Equation 1](#) and [Equation 2](#) (for NTC Thermistors).

$$R_{T1} = \frac{(5 \times R_{TH} \times R_{TC})}{(3 \times (R_{TC} - R_{TH}))} \quad (1)$$

$$R_{T2} = \frac{(5 \times R_{TH} \times R_{TC})}{(2 \times R_{TC}) - (7 \times R_{TH})} \quad (2)$$

Where  $R_{TC}$  is the cold temperature resistance and  $R_{TH}$  is the hot temperature resistance of thermistor, as specified by the thermistor manufacturer.

$R_{T1}$  or  $R_{T2}$  can be omitted if only one temperature (hot or cold) setting is required. Applying a constant voltage between the  $V_{TS1}$  and  $V_{TS2}$  thresholds to pin TS disables the temperature-sensing feature.

## BATTERY PRE-CONDITIONING

During a charge cycle, if the battery voltage is below the  $V_{(LOWV)}$  threshold, the bqTINY applies a pre-charge current,  $I_{O(PRECHG)}$ , to the battery. This feature revives deeply discharged cells. The resistor connected between the ISET and  $V_{SS}$ ,  $R_{SET}$ , determines the pre-charge rate. The  $V_{(PRECHG)}$  and  $K_{(SET)}$  parameters are specified in the specifications table.

$$I_{O(PRECHG)} = \frac{(V_{(PRECHG)} \times K_{(SET)})}{R_{(SET)}} \quad (3)$$

The bqTINY activates a safety timer,  $t_{(PRECHG)}$ , during the conditioning phase. If  $V_{(LOWV)}$  threshold is not reached within the timer period, the bqTINY turns off the charger and enunciates FAULT on the STAT1 and STAT2 pins. Refer to *Timer Fault Recovery* section for additional details.

## BATTERY CHARGE CURRENT

The bqTINY offers on-chip current regulation with programmable set point. The resistor connected between the ISET and  $V_{SS}$ ,  $R_{SET}$ , determines the charge rate. The  $V_{(SET)}$  and  $K_{(SET)}$  parameters are specified in the specifications table.

$$I_{O(OUT)} = \frac{(K_{(SET)} \times V_{(SET)})}{R_{(SET)}} \quad (4)$$

## BATTERY VOLTAGE REGULATION

Voltage regulation feedback is accomplished through the BAT pin. This input is tied directly and close to the positive side of the battery pack. The bqTINY monitors the battery-pack voltage between the BAT and  $V_{SS}$  pins. When the battery voltage rises to  $V_{O(REG)}$  threshold, the voltage regulation phase begins and the charging current begins to taper down.

As a safety backup, the bqTINY also monitors the charge time in the charge mode. If termination does not occur within this time period,  $t_{(CHG)}$ , the bqTINY turns off the charger and enunciates FAULT on the STAT1 and STAT1 pins. Refer to the *Timer Fault Recovery* section for additional details.

## CHARGE TAPER DETECTION, TERMINATION AND RECHARGE

The bqTINY monitors the charging current during the voltage regulation phase. Once the taper threshold,  $I_{(TAPER)}$ , is detected the bqTINY initiates the taper timer,  $t_{(TAPER)}$ . Charge terminates after the timer expires. The resistor connected between the ISET and  $V_{SS}$ ,  $R_{SET}$ , determines the taper detection level. The  $V_{(TAPER)}$  and  $K_{(SET)}$  parameters are specified in the specifications table.

$$I_{(TAPER)} = \frac{(V_{(TAPER)} \times K_{(SET)})}{R_{(SET)}} \quad (5)$$

The bqTINY resets the taper timer in the event that the charge current returns above the taper threshold,  $I_{(TAPER)}$ .

In addition to the taper current detection, the bqTINY terminates charge in the event that the charge current falls below the  $I_{(TERM)}$  threshold. This feature allows for quick recognition of a battery removal condition or insertion of a fully charged battery. Note that taper timer is not used for  $I_{(TERM)}$  detection. The resistor connected between the ISET and  $V_{SS}$ ,  $R_{SET}$ , determines the taper detection level. The  $V_{(TERM)}$  and  $K_{(SET)}$  parameters are specified in the specifications table.

$$I_{(TERM)} = \frac{(V_{(TERM)} \times K_{(SET)})}{R_{(SET)}} \quad (6)$$

After charge termination, the bqTINY restarts the charge once the voltage on the BAT pin falls below the V(RCH) threshold. This feature keeps the battery at full capacity at all times. See the *Battery Absent Detection* section for additional details.

## SLEEP MODE

The bqTINY enters the low-power sleep mode if the  $V_{CC}$  is removed from the circuit ( $\overline{PG}$  pin is high impedance). This feature prevents draining the battery during the absence of  $V_{CC}$ . The status pins do not function when in sleep mode or when  $V_{CC} < V_{POR}$  and default to the OFF state.

## CHARGE STATUS OUTPUTS

The open-collector STAT1 and STAT2 outputs indicate various charger operations as shown in the following table. These status pins can be used to drive LEDs or communicate to the host processor. Note that OFF indicates the open-collector transistor is turned off. When  $V_{CC} < V_{POR}$  or  $V_{CC} < V_{BAT}$  (Sleep Mode – PG OFF) the STAT pins default to their OFF state. Note that this STAT1 or STAT2 OFF/OFF state is shared by several operating conditions. Decode the actual fault condition by monitoring IN, BAT,  $\overline{PG}$ , and TS.

**Table 2. Status Pins Summary**

| CHARGE STATE  | STAT1              | STAT2 |
|---|--------------------|-------|
| Charge-in-progress  | ON                 | OFF   |
| Charge done   | OFF <sup>(1)</sup> | ON    |
| Battery absent<br>Charge suspend (temperature)<br>Timer fault<br>Sleep mode | OFF                | OFF   |

(1) OFF means the open-collector output transistor on the STAT1 or STAT2 pins is in an off state.

## $\overline{PG}$ OUTPUT

The open-collector  $\overline{PG}$  (power good) indicates when the AC adapter (i.e.,  $V_{CC}$ ) is present. The  $\overline{PG}$  bipolar transistor turns ON when a valid  $V_{CC}$  is detected. This output is turned off in the sleep mode. The PG pin can be used to drive an LED or communicate to the host processor.

## $\overline{CE}$ INPUT (CHARGE ENABLE)

The  $\overline{CE}$  digital input is used to disable or enable the charge process. A low-level signal on this pin enables the charge and a high-level signal disables the charge. A high-to-low transition on this pin also resets all timers and fault conditions and starts a new charge cycle.

## $\overline{TTE}$ INPUT (TIMER AND TERMINATION ENABLE)

The  $\overline{TTE}$  digital input is used to disable or enable the fast-charge timer and charge termination. A low-level signal on this pin enables the fast-charge timer and termination and a high-level signal disables this feature. A high-to-low transition on this pin also resets all timers.

## THERMAL SHUTDOWN AND PROTECTION

The bqTINY monitors the junction temperature,  $T_J$ , of the die and suspends charging if  $T_J$  exceeds 155°C. Charging resumes when  $T_J$  falls below approximately 130°C.

## BATTERY ABSENT DETECTION

For applications with removable battery packs, bqTINY provides a battery absent detection scheme to reliably detect insertion or removal of battery packs, or both.

The voltage at the BAT pin is held above the battery recharge threshold,  $V_{(RCH)}$ , by the charged battery following fast charging. When the voltage at the BAT pin falls to the recharge threshold, either by a load on the battery or due to battery removal, the bqTINY begins a battery absent detection test. This test involves enabling a detection current,  $I_{(DETECT)}$ , for a period of  $t_{(DETECT)}$  and checking to see if the battery voltage is below the pre-charge threshold,  $V_{(LOWV)}$ . Following this, the pre-charge current,  $I_{O(PRECHG)}$  is applied for a period of  $t_{(DETECT)}$  and the battery voltage checked again to be above the recharge threshold. The purpose is to attempt to close a battery pack with an open protector, if one is connected to the bqTINY. Passing both of the discharge and charging tests indicates a battery absent fault at the STAT pins. Failure of either test starts a new charge cycle. For the absent battery condition the voltage on the BAT pin rises and falls between the  $V_{(LOWV)}$  and  $V_{O(REG)}$  thresholds indefinitely. See Figure 7.

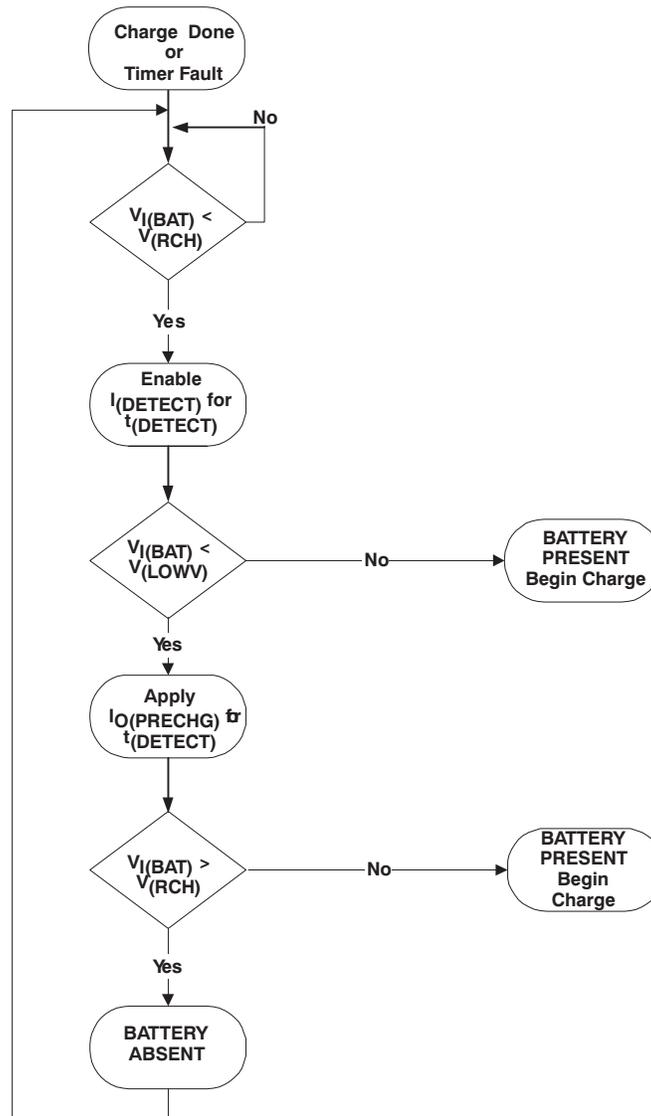


Figure 7. Battery Absent Detection

## **TIMER FAULT RECOVERY**

As shown in [Figure 5](#), bqTINY provides a recovery method to deal with timer fault conditions. The following conditions summarize this method.

Condition 1: Charge voltage above recharge threshold ( $V_{(RCH)}$ ) and timeout fault occurs

Recovery method: bqTINY waits for the battery voltage to fall below the recharge threshold. This could happen as a result of a load on the battery, self-discharge, or battery removal. Once the battery falls below the recharge threshold, the bqTINY clears the fault and enters the battery absent detection routine. A POR or CE toggle also clears the fault.

Condition 2: Charge voltage below recharge threshold ( $V_{(RCH)}$ ) and timeout fault occurs.

Recovery method: Under this scenario, the bqTINY applies the  $I_{(FAULT)}$  current. This small current is used to detect a battery removal condition and remains on as long as the battery voltage stays below the recharge threshold. If the battery voltage goes above the recharge threshold, then the bqTINY disables the  $I_{(FAULT)}$  current and executes the recovery method described for condition #1. Once the battery falls below the recharge threshold, the bqTINY clears the fault and enters the battery absent detection routine. A POR or CE toggle also clears the fault.

## APPLICATION INFORMATION

### SELECTING INPUT CAPACITOR

In most applications, all that is needed is a high-frequency decoupling capacitor. A 0.47- $\mu\text{F}$  ceramic, placed in close proximity to  $V_{\text{CC}}$  and  $V_{\text{SS}}$  pins, works well. The bqTINY is designed to work with both regulated and unregulated external DC supplies. If a non-regulated supply is chosen, the supply unit should have enough capacitance to hold up the supply voltage to the minimum required input voltage at maximum load. If not, more capacitance has to be added to the input of the charger.

### SELECTING OUTPUT CAPACITOR

The bqTINY requires only a small output capacitor for loop stability. A 0.1- $\mu\text{F}$  ceramic capacitor placed between the BAT and ISET pins is typically sufficient for embedded applications (for example non-removable battery packs). For application with removable battery packs a 1- $\mu\text{F}$  ceramic capacitor ensure proper operation of the battery detection circuitry. Note that the output capacitor can also be placed between BAT and VSS pins.

### THERMAL CONSIDERATIONS

The bqTINY is packaged in a thermally enhanced MLP (also referred to as QFN) package. The package includes a thermal pad to provide an effective thermal contact between the device and the printed circuit board (PCB). Full PCB design guidelines for this package are provided in the application note entitled, *QFN/SON PCB Attachment* application note (SLUA271).

The most common measure of package thermal performance is thermal impedance ( $\theta_{\text{JA}}$ ) measured (or modeled) from the device junction to the air surrounding the package surface (ambient). The mathematical expression for  $\theta_{\text{JA}}$  is:

$$\theta_{\text{JA}} = \frac{T_{\text{J}} \times T_{\text{A}}}{\text{P}} \quad (7)$$

Where:

$T_{\text{J}}$  = device junction temperature

$T_{\text{A}}$  = ambient temperature

P = device power dissipation

Factors that can greatly influence the measurement and calculation of  $\theta_{\text{JA}}$  include:

- Whether or not the device is board mounted
- Trace size, composition, thickness, and geometry
- Orientation of the device (horizontal or vertical)
- Volume of the ambient air surrounding the device under test and airflow
- Whether other surfaces are in close proximity to the device being tested

The device power dissipation, P, is a function of the charge rate and the voltage drop across the internal PowerFET. It can be calculated from the following equation:

$$\text{P} = (\text{V}_{\text{IN}} - \text{V}_{\text{I(BAT)}}) \times \text{I}_{\text{O(OUT)}} \quad (8)$$

Due to the charge profile of Li-xx batteries, the maximum power dissipation is typically seen at the beginning of the charge cycle when the battery voltage is at its lowest. See [Figure 2](#).

## PCB LAYOUT CONSIDERATIONS

It is important to pay special attention to the PCB layout. The following list provides some guidelines:

- To obtain optimal performance, the decoupling capacitor from  $V_{CC}$  to  $V_{SS}$  and the output filter capacitors from BAT to ISET should be placed as close as possible to the bqTINY, with short trace runs to both signal and  $V_{SS}$  pins.
- All low-current  $V_{SS}$  connections should be kept separate from the high-current charge or discharge paths from the battery. Use a single-point ground technique incorporating both the small signal ground path and the power ground path.
- The BAT pin is the voltage feedback to the device and should be connected with its trace as close to the battery pack as possible.
- The high current charge paths into IN and from the OUT pins must be sized appropriately for the maximum charge current in order to avoid voltage drops in these traces.
- The bqTINY is packaged in a thermally enhanced MLP package. The package includes a thermal pad to provide an effective thermal contact between the device and the printed circuit board (PCB). Full PCB design guidelines for this package are provided in the application note entitled: *QFN/SON PCB Attachment Application Note (SLUA271)*.
- There is an internal electrical connection between the exposed thermal pad and  $V_{SS}$  pin of the device. The exposed thermal pad must be connected to the same potential as the  $V_{SS}$  pin on the printed circuit board. Do not use the thermal pad as the primary ground input for the device.  $V_{SS}$  pin must be connected to ground at all times.

## REVISION HISTORY

| Changes from Revision J (December 2008) to Revision K | Page |
|---|------|
| • Updated $I_{O(OUT)}$ equation .....                 | 3    |

**PACKAGING INFORMATION**

| Orderable Device | Status<br>(1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan<br>(2)         | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|-----------------|------|-------------|-------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| BQ24010DRCCR     | ACTIVE        | VSON         | DRC             | 10   | 3000        | Green (RoHS & no Sb/Br) | NIPDAU                  | Level-2-260C-1 YEAR  | -40 to 85    | AZN                     | <a href="#">Samples</a> |
| BQ24010DRCRG4    | ACTIVE        | VSON         | DRC             | 10   | 3000        | Green (RoHS & no Sb/Br) | NIPDAU                  | Level-2-260C-1 YEAR  | -40 to 85    | AZN                     | <a href="#">Samples</a> |
| BQ24012DRCCR     | ACTIVE        | VSON         | DRC             | 10   | 3000        | Green (RoHS & no Sb/Br) | NIPDAU                  | Level-2-260C-1 YEAR  | -40 to 85    | AZP                     | <a href="#">Samples</a> |
| BQ24013DRCCR     | ACTIVE        | VSON         | DRC             | 10   | 3000        | Green (RoHS & no Sb/Br) | NIPDAU                  | Level-2-260C-1 YEAR  | -40 to 85    | AZQ                     | <a href="#">Samples</a> |
| BQ24013DRCRG4    | ACTIVE        | VSON         | DRC             | 10   | 3000        | Green (RoHS & no Sb/Br) | NIPDAU                  | Level-2-260C-1 YEAR  | -40 to 85    | AZQ                     | <a href="#">Samples</a> |
| BQ24014DRCCR     | ACTIVE        | VSON         | DRC             | 10   | 3000        | Green (RoHS & no Sb/Br) | NIPDAU                  | Level-2-260C-1 YEAR  | -40 to 85    | AZR                     | <a href="#">Samples</a> |
| BQ24014DRCRG4    | ACTIVE        | VSON         | DRC             | 10   | 3000        | Green (RoHS & no Sb/Br) | NIPDAU                  | Level-2-260C-1 YEAR  | -40 to 85    | AZR                     | <a href="#">Samples</a> |
| BQ24018DRCCR     | ACTIVE        | VSON         | DRC             | 10   | 3000        | Green (RoHS & no Sb/Br) | NIPDAU                  | Level-2-260C-1 YEAR  | -40 to 125   | BZH                     | <a href="#">Samples</a> |
| BQ24018DRCT      | ACTIVE        | VSON         | DRC             | 10   | 250         | Green (RoHS & no Sb/Br) | NIPDAU                  | Level-2-260C-1 YEAR  | -40 to 125   | BZH                     | <a href="#">Samples</a> |

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

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

**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.

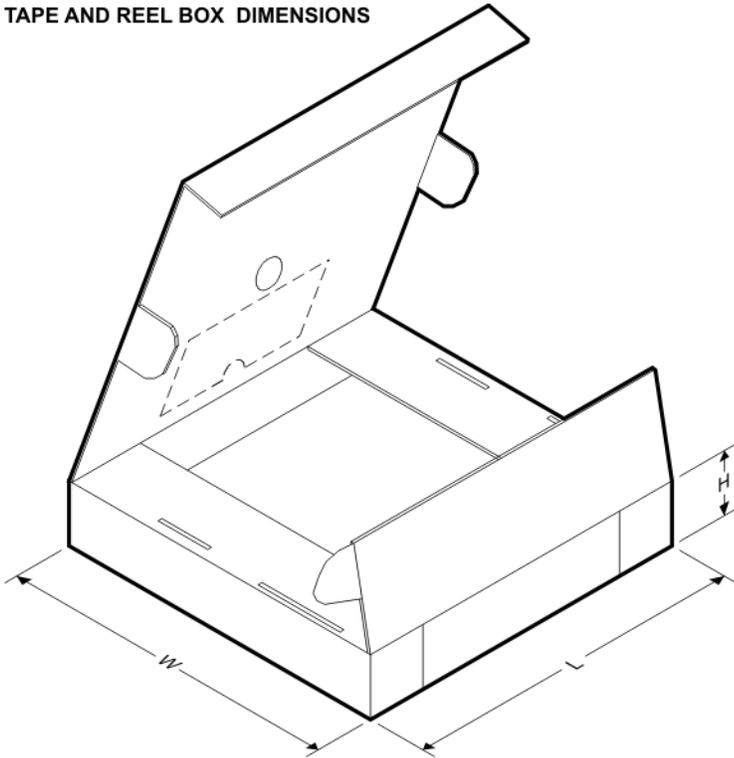
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

**TAPE AND REEL INFORMATION**

**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 |
|-------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| BQ24010DRCR | VSON         | DRC             | 10   | 3000 | 330.0              | 12.4               | 3.3     | 3.3     | 1.1     | 8.0     | 12.0   | Q2            |
| BQ24010DRCR | VSON         | DRC             | 10   | 3000 | 330.0              | 12.4               | 3.3     | 3.3     | 1.1     | 8.0     | 12.0   | Q2            |
| BQ24012DRCR | VSON         | DRC             | 10   | 3000 | 330.0              | 12.4               | 3.3     | 3.3     | 1.1     | 8.0     | 12.0   | Q2            |
| BQ24012DRCR | VSON         | DRC             | 10   | 3000 | 330.0              | 12.4               | 3.3     | 3.3     | 1.1     | 8.0     | 12.0   | Q2            |
| BQ24013DRCR | VSON         | DRC             | 10   | 3000 | 330.0              | 12.4               | 3.3     | 3.3     | 1.1     | 8.0     | 12.0   | Q2            |
| BQ24013DRCR | VSON         | DRC             | 10   | 3000 | 330.0              | 12.4               | 3.3     | 3.3     | 1.1     | 8.0     | 12.0   | Q2            |
| BQ24014DRCR | VSON         | DRC             | 10   | 3000 | 330.0              | 12.4               | 3.3     | 3.3     | 1.1     | 8.0     | 12.0   | Q2            |
| BQ24014DRCR | VSON         | DRC             | 10   | 3000 | 330.0              | 12.4               | 3.3     | 3.3     | 1.1     | 8.0     | 12.0   | Q2            |
| BQ24018DRCR | VSON         | DRC             | 10   | 3000 | 330.0              | 12.4               | 3.3     | 3.3     | 1.1     | 8.0     | 12.0   | Q2            |
| BQ24018DRCT | VSON         | DRC             | 10   | 250  | 180.0              | 12.4               | 3.3     | 3.3     | 1.1     | 8.0     | 12.0   | Q2            |

**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

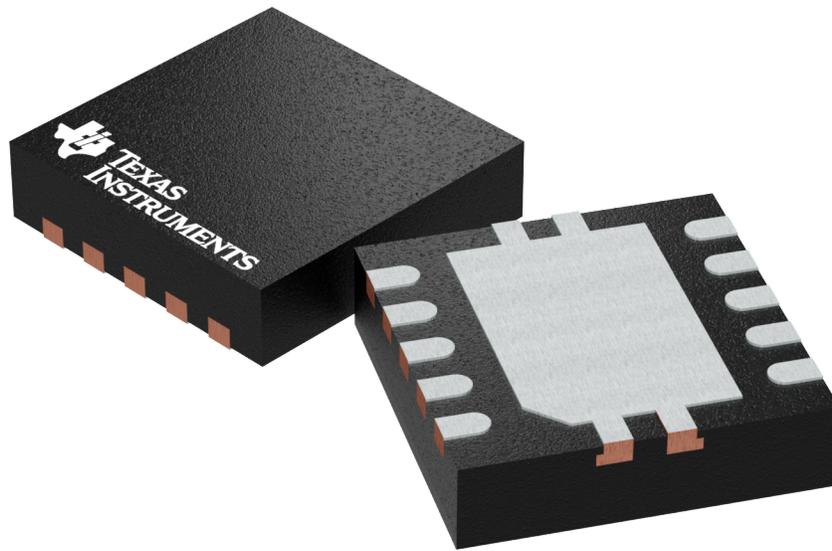
| Device      | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|-------------|--------------|-----------------|------|------|-------------|------------|-------------|
| BQ24010DRCR | VSON         | DRC             | 10   | 3000 | 367.0       | 367.0      | 35.0        |
| BQ24010DRCR | VSON         | DRC             | 10   | 3000 | 338.0       | 355.0      | 50.0        |
| BQ24012DRCR | VSON         | DRC             | 10   | 3000 | 367.0       | 367.0      | 35.0        |
| BQ24012DRCR | VSON         | DRC             | 10   | 3000 | 338.0       | 355.0      | 50.0        |
| BQ24013DRCR | VSON         | DRC             | 10   | 3000 | 367.0       | 367.0      | 35.0        |
| BQ24013DRCR | VSON         | DRC             | 10   | 3000 | 338.0       | 355.0      | 50.0        |
| BQ24014DRCR | VSON         | DRC             | 10   | 3000 | 367.0       | 367.0      | 35.0        |
| BQ24014DRCR | VSON         | DRC             | 10   | 3000 | 338.0       | 355.0      | 50.0        |
| BQ24018DRCR | VSON         | DRC             | 10   | 3000 | 367.0       | 367.0      | 35.0        |
| BQ24018DRCT | VSON         | DRC             | 10   | 250  | 210.0       | 185.0      | 35.0        |

## GENERIC PACKAGE VIEW

DRC 10

VSON - 1 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



Images above are just a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.

4204102-3/M

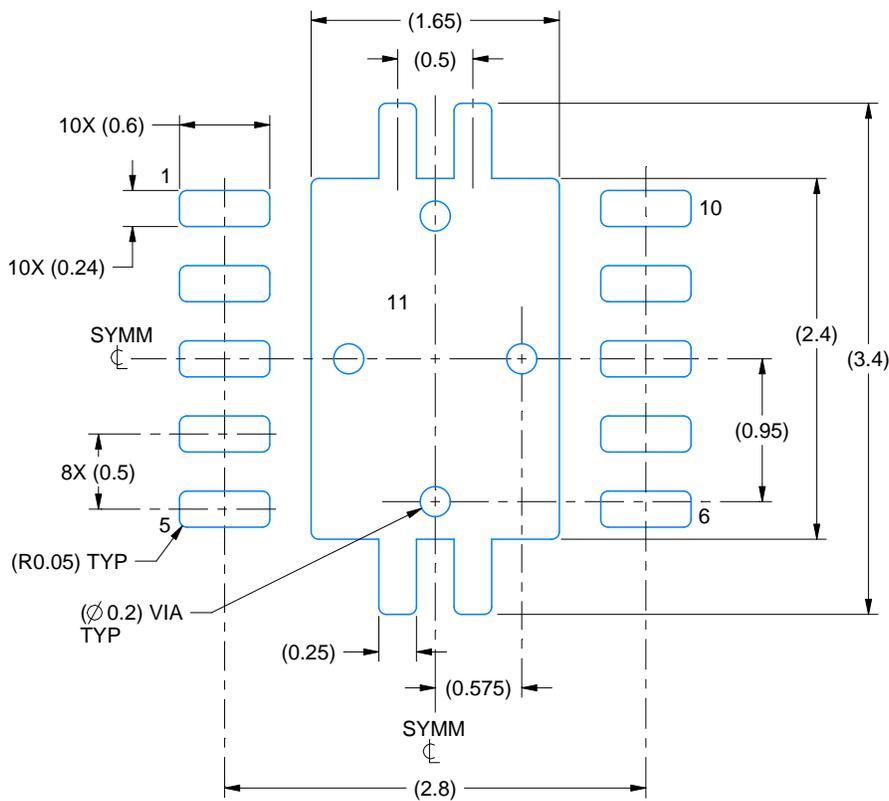


# EXAMPLE BOARD LAYOUT

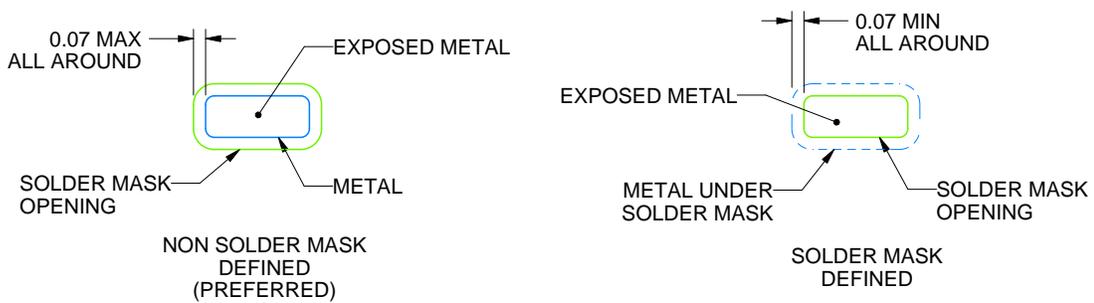
DRC0010J

VSON - 1 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:20X



SOLDER MASK DETAILS

4218878/B 07/2018

NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/sluea271](http://www.ti.com/lit/sluea271)).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.



## IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to TI's Terms of Sale ([www.ti.com/legal/termsofsale.html](http://www.ti.com/legal/termsofsale.html)) or other applicable terms available either on [ti.com](http://ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2020, Texas Instruments Incorporated