# Lithium Ion Charge Management IC with Integrated Switching Controller

## Features

➤ Safe charge of Li-Ion battery packs

➤ Pulse-width modulation control for current and voltage regulation

➤ Programmable high-side/low-side current-sense

➤ Fast charge terminated by selectable minimum current; safety backup termination at maximum time

➤ Pre-charge qualification detects shorted or damaged cells and conditions battery

➤ Charging continuously qualified by temperature and voltage limits

➤ Direct LED control outputs to display charge status and fault conditions

## General Description

The bq2954 Li-Ion Charge-Management IC uses a flexible pulse-width modulation regulator to control voltage and current during charging. The regulator frequency is set by an external capacitor for design flexibility. The switch-mode design minimizes power dissipation.

For safety, the bq2954 inhibits fast charging until the battery voltage and temperature are within configured limits. If the battery voltage is less than the low-voltage threshold, the bq2954 provides low-current conditioning of the battery.

For charge qualifiction, the bq2954 uses an external thermistor to measure battery temperature. Charging begins when power is applied or the battery is inserted

The bq2954 charges a battery in two phases. First a constant-current phase replenishes approximately 70% of battery capacity. Then a voltage-regulation phase completes the battery charge.

The bq2954 provides status indications of all charger states and faults for accurate determination of the battery and charge-system conditions.

## Pin Connections



16-Pin Narrow
DIP or SOIC

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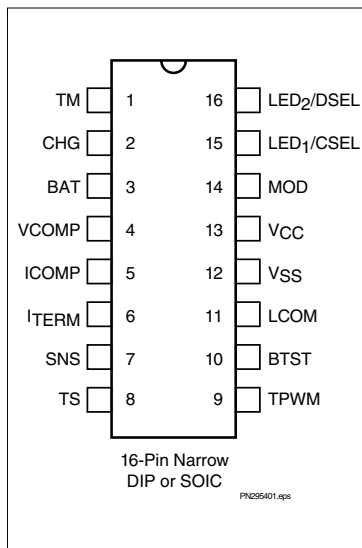
## Pin Names

| | |
|---|---|
| TM | Time-out programming input |
| CHG | Charge active output |
| BAT | Battery voltage input |
| VCOMP | Voltage loop comp input |
| ICOMP | Current loop comp input |
| $I_{TERM}$ | Minimum current termination select input |
| SNS | Sense resistor input |
| TS | Temperature sense input |
| TPWM | Regulator timebase input |
| BTST | Battery test output |
| LCOM | Common LED output |
| $V_{SS}$ | System ground |
| $V_{CC}$ | 5.0V±10% power |
| MOD | Modulation control output |
| $LED_1$/CSEL | Charge status output 1/ Charge sense select input |
| $LED_2$/DSEL | Charge status output 2/ Display select input |

## Pin Descriptions

**TM**     **Time-out programming input**

Sets the maximum charge time. The resistor and capacitor values are determined using Equation 5. Figure 10 shows the resistor/capacitor connection.

**CHG**     **Charge active output**

An open-drain output is driven low when the battery is removed, during a temperature pend, when a fault condition is present, or when charge is done. CHG can be used to disable a high-value load capacitor to detect quickly any battery removal.

**BAT**     **Battery voltage input**

Sense input. This potential is generally developed using a high-impedance resistor divider network connected between the positive and the negative terminals of the battery. See Figures 6 and 7 and Equation 1.

**VCOMP**     **Voltage loop compensation input**

Connects to an external R-C network to stabilize the regulated voltage.

**ICOMP**     **Current loop compensation input**

Connects to an external R-C network to stabilize the regulated current.

**$I_{TERM}$**     **Charge full and minimum current termination select**

Three-state input is used to set $I_{FULL}$ and $I_{MIN}$ for fast charge termination. See Table 4.

**SNS**     **Charging current sense input**

Battery current is sensed via the voltage developed on this pin by an external sense-resistor.

**TS**     **Temperature sense input**

Used to monitor battery temperature. An external resistor-divider network sets the lower and upper temperature thresholds. (See Figures 8 and 9 and Equations 3 and 4.)

**TPWM**     **Regulation timebase input**

Uses an external timing capacitor to ground to set the pulse-width modulation (PWM) frequency. See Equation 7.

**BTST**     **Battery test output**

Driven high in the absence of a battery in order to provide a potential at the battery terminal when no battery is present.

**LCOM**     **Common LED output**

Common output for $LED_{1-2}$. This output is in a high-impedance state during initialization to read programming input on DSEL and CSEL.

**$V_{SS}$**     **Ground**

**$V_{CC}$**     **$V_{CC}$ supply**

5.0V, ±10%

**MOD**     **Current-switching control output**

Pulse-width modulated push/pull output used to control the charging current to the battery. MOD switches high to enable current flow and low to inhibit current flow. (The maximum duty cycle is 80%.)

**$LED_1$– $LED_2$**     **Charger display status 1–2 outputs**

Drivers for the direct drive of the LED display. These outputs are tri-stated during initialization so that DSEL and CSEL can be read.

**DSEL**     **Display select input (shared pin with $LED_2$)**

Three-level input that controls the $LED_{1–2}$ charge display modes.

**CSEL**     **Charge sense-select input (shared pin with $LED_1$)**

Input that controls whether current is sensed on low side of battery or high side of battery. A current mirror is required for high-side sense.
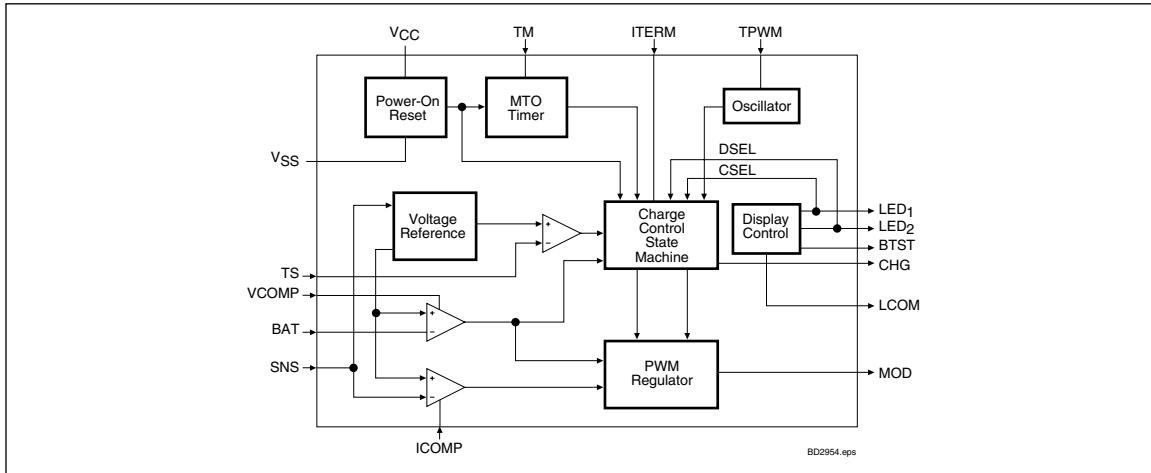
**Figure 1. Functional Block Diagram**

# Functional Description

The bq2954 functional operation is described in terms of the following (Figure 1):

- Charge algorithm

- Charge qualification

- Charge status display

- Configuring the display and termination

- Voltage and current monitoring

- Battery insertion and removal

- Temperature monitoring

- Maximum time--out

- Charge regulation

- Recharge after fast charge

## Charge Algorithm

The bq2954 uses a two-phase fast-charge algorithm. In phase 1, the bq2954 regulates constant current until the voltage on the BAT pin, $V_{BAT}$, rises to the internal threshold, $V_{REG}$. The bq2954 then transitions to phase 2 and regulates constant voltage ($V_{BAT} = V_{REG}$) until the charging current falls below the programmed $I_{MIN}$ threshold. Fast charge then terminates, and the bq2954 enters the Charge Complete state. (See Figure 2.)

## Charge Qualification

The bq2954 starts a charge cycle when power is applied while a battery is present or when a battery is inserted. Figure 2 shows the state diagram for the bq2954. The bq2954 first checks that the battery temperature is within the allowed, user-configurable range. If the temperature is out of range, the bq2954 remains in the QUALIFICATION state (S01) and waits until the battery temperature and voltage are within the allowed range.

If during any state of charge, a temperature excursion occurs HOT, the bq2954 proceeds to the DONE state (S04) and indicates this state on the LED outputs and provides no current. If this occurs, the bq2954 remains in the DONE state unless the following two conditions are met:

- Temperature falls within valid charge range

- $V_{BAT}$ falls below the internal threshold, $V_{RCHG}$

If these two conditions are met, a new charge cycle begins. During any state of charge, if a temperature excursion occurs COLD, the bq2954 terminates charge and returns to the QUALIFICATION state (S01). Charge restarts if $V_{BAT}$ and temperature are in valid range.

When the temperature and voltage are valid, the bq2954 enters the CONDITIONING state (S02) and regulates current to $I_{COND}$ (=$I_{MAX}/10$). After an initial holdoff period $t_{HO}$ (which prevents the IC from reacting to transient voltage spikes that may occur when charge current is first applied), the IC begins monitoring $V_{BAT}$. If $V_{BAT}$ does not rise to at least $V_{MIN}$ before the expiration of
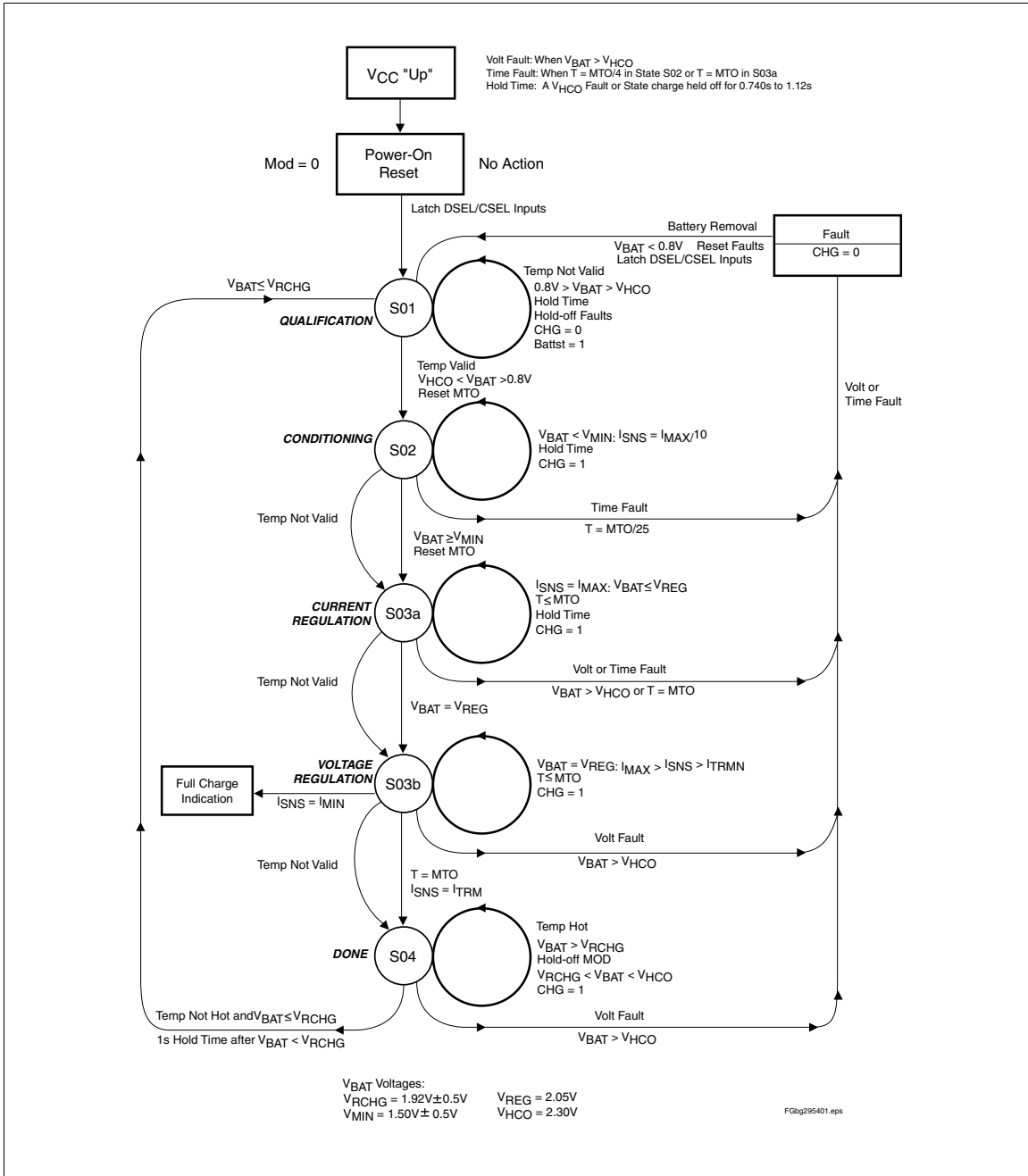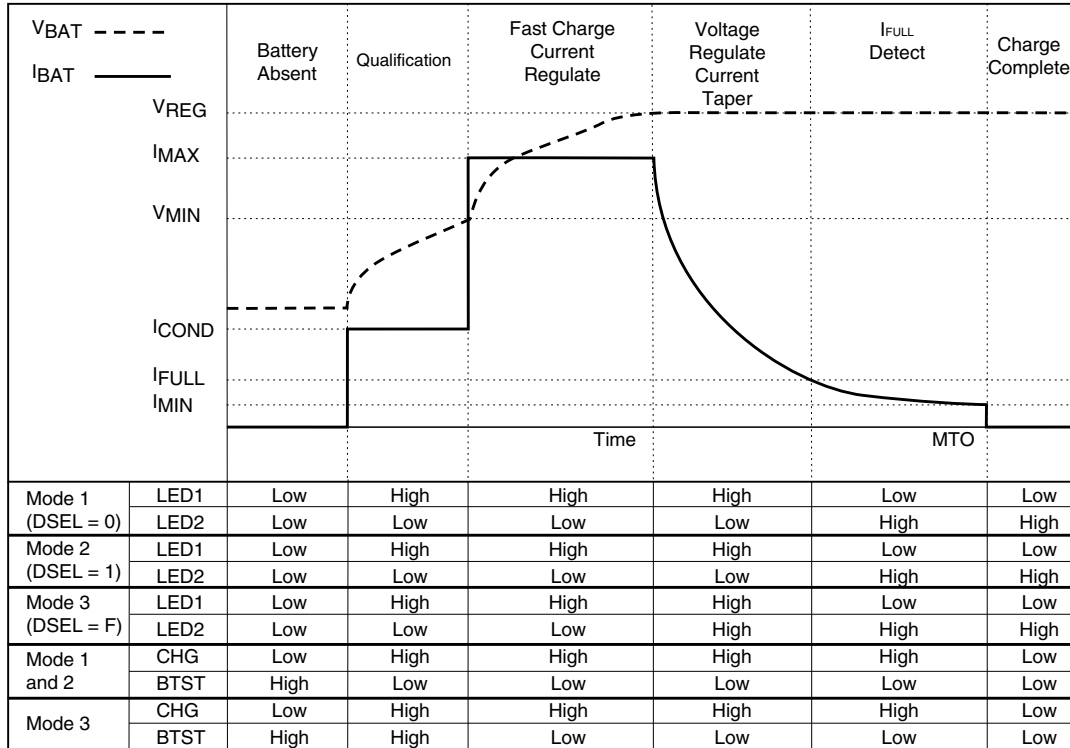
V$_{CC}$ "Up"

Volt Fault: When V$_{BAT}$ > V$_{HCO}$
Time Fault: When T = MTO/4 in State S02 or T = MTO in S03a
Hold Time: A V$_{HCO}$ Fault or State charge held off for 0.740s to 1.12s

Mod = 0 | Power-On Reset | No Action

Latch DSEL/CSEL Inputs

Battery Removal
V$_{BAT}$ < 0.8V    Reset Faults
Latch DSEL/CSEL Inputs

Fault
CHG = 0

V$_{BAT}$ ≤ V$_{RCHG}$

**S01** *QUALIFICATION*

Temp Not Valid
0.8V > V$_{BAT}$ > V$_{HCO}$
Hold Time
Hold-off Faults
CHG = 0
Battst = 1

Volt or Time Fault

Temp Valid
V$_{HCO}$ < V$_{BAT}$ >0.8V
Reset MTO

**S02** *CONDITIONING*

V$_{BAT}$ < V$_{MIN}$: I$_{SNS}$ = I$_{MAX}$/10
Hold Time
CHG = 1

Temp Not Valid

Time Fault
T = MTO/25

V$_{BAT}$ ≥V$_{MIN}$
Reset MTO

**S03a** *CURRENT REGULATION*

I$_{SNS}$ = I$_{MAX}$: V$_{BAT}$≤V$_{REG}$
T≤MTO
Hold Time
CHG = 1

Temp Not Valid

Volt or Time Fault
V$_{BAT}$ > V$_{HCO}$ or T = MTO

V$_{BAT}$ = V$_{REG}$

**S03b** *VOLTAGE REGULATION*

Full Charge Indication

I$_{SNS}$ = I$_{MIN}$

V$_{BAT}$ = V$_{REG}$: I$_{MAX}$ > I$_{SNS}$ > I$_{TRMN}$
T≤MTO
CHG = 1

Volt Fault
V$_{BAT}$ > V$_{HCO}$

Temp Not Valid

T = MTO
I$_{SNS}$ = I$_{TRM}$

**S04** *DONE*

Temp Hot
V$_{BAT}$ > V$_{RCHG}$
Hold-off MOD
V$_{RCHG}$ < V$_{BAT}$ < V$_{HCO}$
CHG = 1

Volt Fault
V$_{BAT}$ > V$_{HCO}$

Temp Not Hot andV$_{BAT}$≤V$_{RCHG}$
1s Hold Time after V$_{BAT}$ < V$_{RCHG}$

V$_{BAT}$ Voltages:
V$_{RCHG}$ = 1.92V±0.5V
V$_{MIN}$ = 1.50V± 0.5V
V$_{REG}$ = 2.05V
V$_{HCO}$ = 2.30V

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**Figure 2. bq2954 Charge Algorithm**

8-24VDC ±10%
VDC

D4
B130DI

C10
47uF
25V

Q1
FMMT3906

R4
10K

R2
4.7K

R1
1K

Q2
FMMt3904

Q5
FZT789A

L2
47uH

BAT+

D5
B130DI

C11
10uF
20V
PCS4106

U2
ZMR500

IN    G    OUT
      N
      D

5V

R5
10K

C2
1uF

D1
1N4148

L1
10 uH

R14
RB1

C3
1uF
25V

Q3
FMMT451

5V

R15
RB2

R6
10K

R9
220

R10
62K

C8
1000pF

R8
0.25 5%
0.5W

BAT-

D2
GRREN

C6
0.1 uF

C4
0.1 uF

R7
1K

5V

R13
1K

D3
RED

16  LED2/DSEL          TM   1
15  LED1/CSEL          CHG   2
14  MOD                 BAT   3
13  VCC              VCOMP   4
12  VSS              ICOMP   5
11  LCOM             ITERM   6
10  BTST               SNS   7
9   TPWM                TS   8

U1

bq2954

R11
4.32K
1%

R12
8.45K
1%

R3
10K

C9
470pF

C5
0.1uF

C7
0.01uF

C1
0.1uF

TEM+

Q4
FMMT3904

2954sch9/23/98

1. I$_{MAX}$ = 1.0A, Vreg = 4.2V ± 1% PER CELL

2. MTO = 3 HRS, I$_{FULL}$ = I$_{MAX}$/5, I$_{TERM}$ = I$_{MAX}$/10

3. TEMP = 0-45˚C,

4. Frequency = 200kHz

**Figure 3. High-Efficiency Li-Ion Charger for 1–4 Cells**

## Table 1. Normal Fast Charge Cycle

| | | Battery Absent | Qualification | Fast Charge Current Regulate | Voltage Regulate Current Taper | $I_{FULL}$ Detect | Charge Complete |
|---|---|---|---|---|---|---|---|
| Mode 1 (DSEL = 0) | LED1 | Low | High | High | High | Low | Low |
| | LED2 | Low | Low | Low | Low | High | High |
| Mode 2 (DSEL = 1) | LED1 | Low | High | High | High | Low | Low |
| | LED2 | Low | Low | Low | Low | High | High |
| Mode 3 (DSEL = F) | LED1 | Low | High | High | High | Low | Low |
| | LED2 | Low | Low | Low | High | High | High |
| Mode 1 and 2 | CHG | Low | High | High | High | High | Low |
| | BTST | High | Low | Low | Low | Low | Low |
| Mode 3 | CHG | Low | High | High | High | High | Low |
| | BTST | High | High | Low | Low | Low | Low |

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time-out limit $t_{QT}$ (i.e., the battery has failed short), the bq2954 enters the Fault state. Then $t_{QT}$ is set to 25% of $t_{MTO}$. If $V_{MIN}$ is achieved before expiration of the time limit, the bq2954 begins fast charging.

Once in the Fault state, the bq2954 waits until $V_{CC}$ is cycled or a new battery insertion is detected. It then starts a new charge cycle and begins the qualification process again.

## Charge Status Display

Charge status is indicated by the LED driver outputs $LED_1$–$LED_2$. Three display modes (Tables 1–3) are available in the bq2954 and are selected by configuring pin DSEL. Table 1 illustrates a normal fast charge cycle, Table 2 a recharge-after-fast-charge cycle, and Table 3 an abnormal condition.

## Configuring the Display Mode, $I_{FULL}/I_{MIN}$, and $I_{SENSE}$

$DSEL/LED_2$ and $CSEL/LED_1$ are bi-directional pins with two functions: as LED driver pins (output) and as programming pins (input). The selection of pull-up, pull-down, or no-resistor programs the display mode on DSEL as shown in Tables 1 through 3. A pull-down or no-resistor programs the current-sense mode on CSEL.

The bq2954 latches the programming data sensed on the DSEL and CSEL input when $V_{CC}$ rises to a valid level. The LEDs go blank for approximately 400ms (typical) while new programming data are latched.

When fast charge reaches a condition where the charging current drops below $I_{FULL}$, the LED1 and LED2 outputs indicate a full-battery condition. Fast charge terminates when the charging current drops below the

**Table 2. Recharge After Fast Charge Cycle**



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| | | Charge Complete | Fast Charge Current Regulate | Voltage Regulate Current Taper | $I_{FULL}$ Detect | Charge Complete |
|---|---|---|---|---|---|---|
| Mode 1 (DSEL = 0) | LED1 | Low | High | High | Low | Low |
| | LED2 | High | Low | Low | High | High |
| Mode 2 (DSEL = 1) | LED1 | Low | High | High | Low | Low |
| | LED2 | High | Low | Low | High | High |
| Mode 3 (DSEL = F) | LED1 | Low | High | High | Low | Low |
| | LED2 | High | Low | High | High | High |
| Mode 1 and 2 | CHG | Low | High | High | High | Low |
| | BTST | Low | Low | Low | Low | Low |
| Mode 3 | CHG | Low | High | High | High | Low |
| | BTST | Low | Low | Low | Low | Low |

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**Table 3.  Abnormal Condition**

| | | Battery Absent | Qualification | Abnormal Battery |
|---|---|---|---|---|
| Mode 1 (DSEL = 0) | LED1 | Low | High | Flash |
| | LED2 | Low | Low | Low |
| Mode 2 (DSEL = 1) | LED1 | Low | High | Low |
| | LED2 | Low | Low | Low |
| Mode 3 (DSEL = F) | LED1 | Low | High | Low |
| | LED2 | Low | Low | Low |
| CHG | | Low | High | Low |
| BTST | | High | Low | Low |
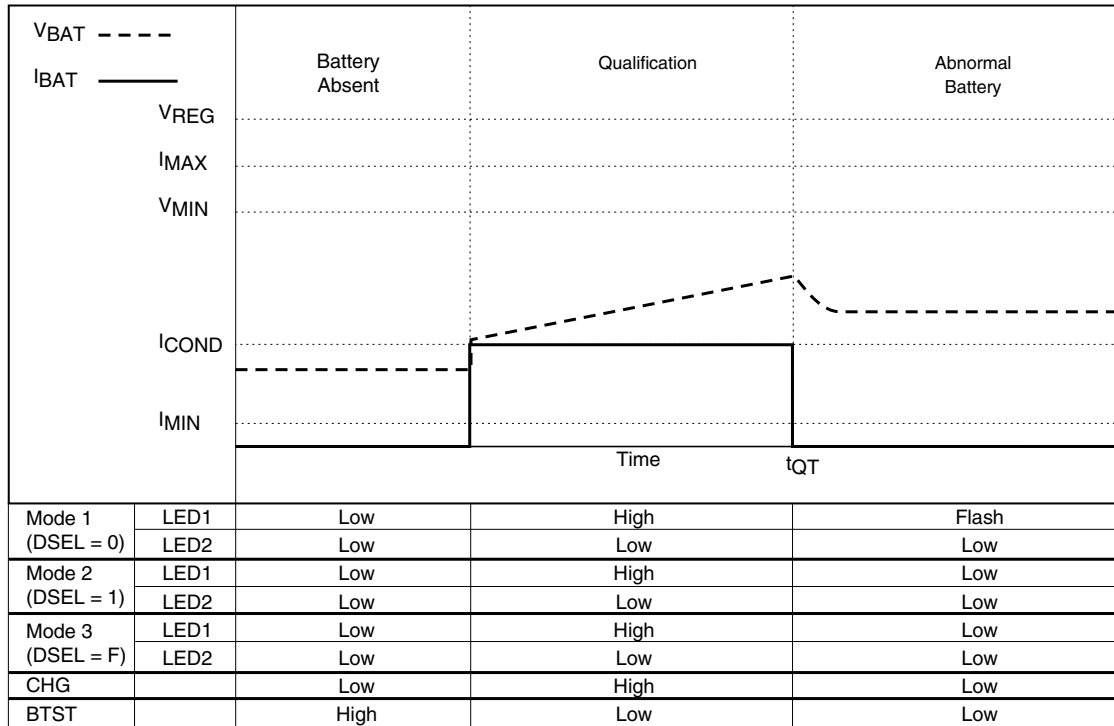
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**Table 4. $I_{FULL}$ and $I_{MIN}$ Thresholds**

| $I_{TERM}$ | $I_{FULL}$ | $I_{MIN}$ |
|---|---|---|
| 0 | $I_{MAX}/5$ | $I_{MAX}/10$ |
| 1 | $I_{MAX}/10$ | $I_{MAX}/15$ |
| Z | $I_{MAX}/15$ | $I_{MAX}/20$ |

minimum current threshold, $I_{MIN}$. The $I_{FULL}$ and $I_{MIN}$ thresholds are programmed using the $I_{TERM}$ input pin (See Table 4.)

Figures 4 and 5 show the bq2954 configured for display mode 2 and $I_{FULL} = I_{MAX}/5$ while $I_{MIN} = I_{MAX}/10$.

## Voltage and Current Monitoring

In low-side current sensing, the bq2954 monitors the battery pack voltage as a differential voltage between BAT and pins. In high-side current sensing, the bq2954 monitors the battery pack voltage as a differential voltage between BAT and $V_{SS}$ pins. This voltage is derived by scaling the battery voltage with a voltage divider. (See Figures 6 and 7.) The resistance of the voltage divider must be high enough to minimize battery drain but low enough to minimize noise susceptibility. RB1 + RB2 is typically between 150kΩ and 1MΩ. The voltage-divider resistors are calculated from the following:

$$\frac{RB1}{RB2} = \frac{N * V_{CELL}}{V_{REG}} - 1 \qquad (1)$$

where

$V_{CELL}$ = Manufacturer-specified charging cell voltage
N = Number of cells in series
$V_{REG} = 2.05V$

The current sense resistor, $R_{SNS}$ (see Figures 6 and 7), determines the fast-charge current. The value of $R_{SNS}$ is given by the following:

$$R_{SNS} = \frac{0.25V}{I_{MAX}} \qquad (2)$$

where $I_{MAX}$ is the current during the constant-current phase of the charge cycle. (See Table 1.)

## Battery Insertion and Removal

$V_{BAT}$ is interpreted by the bq2954 to detect the presence or absence of a battery. The bq2954 determines that a battery is present when $V_{BAT}$ is between the High-Voltage Cutoff ($V_{HCO} = V_{REG} + 0.25V$) and the Low-Voltage Cutoff ($V_{LCO} = 0.8V$). When $V_{BAT}$ is outside this range, the bq2954 determines that no battery is present and transitions to the battery test state, testing for valid battery voltage. The bq2954 detects battery removal when $V_{BAT}$ falls below $V_{LCO}$. The BTST pin is driven high during battery test and can activate an external battery contact pull-up. This pull-up may be used to activate an over-discharged Li-Ion battery pack. The $V_{HCO}$ limit implicitly serves as an over-voltage charge fault. The CHG output can be used to disconnect capacitors from the regulation circuitry in order to quickly detect a battery-removed condition.

Battery insertion is detected within 500ms. Transition to the fast-charge phase, however, will not occur for time $t_{HO}$ (approximately one second), even if voltage qualification $V_{MIN}$ is reached. This delay prevents a voltage spike at the BAT input from causing premature entry into the fast-charge phase. It also creates a delay in detection of battery removal if the battery is removed during this hold-off period.

## Temperature Monitoring

Temperature is measured as a *differential* voltage between TS and BAT-. This voltage is typically generated by a NTC (negative temperature coefficient) thermistor and thermistor linearization network. The bq2954 compares this voltage to its internal threshold voltages to determine if charging is allowed. These thresholds are the following:

■ High-Temperature Cutoff Voltage: $V_{TCO} = 0.4 * V_{CC}$
This voltage corresponds to the maximum temperature (TCO) at which charging is allowed.

■ High-Temperature Fault Voltage: $V_{HTF} = 0.44 * V_{CC}$
This voltage corresponds to the temperature (HTF) at which charging resumes after exceeding TCO.

■ Low-Temperature Fault Voltage: $V_{LTF} = 0.6 * V_{CC}$
This voltage corresponds to the minimum temperature (LTF) at which charging is allowed.

Charging is inhibited if the temperature is outside the LTF—TCO window. Once the temperature exceeds TCO, it must drop below HTF before charging resumes.

RT1 and RT2 for the thermistor linearization network are determined as follows:

$$0.6 * V_{CC} = \frac{V}{1 + \dfrac{RT1 * (RT2 + R_{LTF})}{(RT2 * R_{LTF})}} \qquad (3)$$

$$0.44 = \frac{1}{1 + \dfrac{RT1 * (RT2 + R_{HTF})}{(RT2 * R_{HTF})}} \qquad (4)$$

where

$R_{LTF}$ = thermistor resistance at LTF

$R_{HTF}$ = thermistor resistance at HTF

V = $V_{CC}$ - 0.250 in low-side current sensing

V = $V_{CC}$ in high-side current sensing

TCO is determined by the values of RT1 and RT2. 1% resistors are recommended.
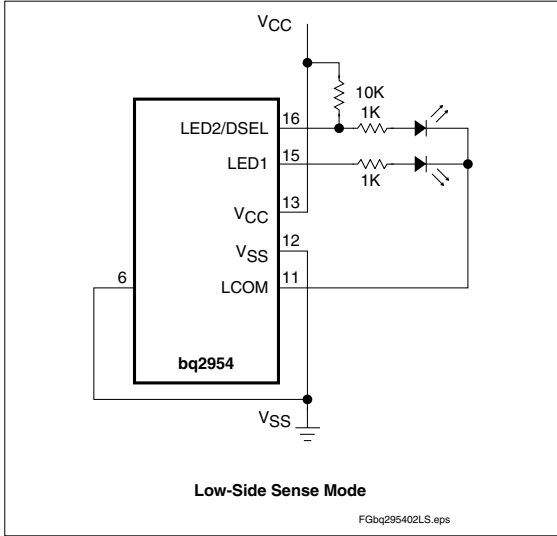
**Figure 4. Configured Display Mode
(Low-Side Sense)**
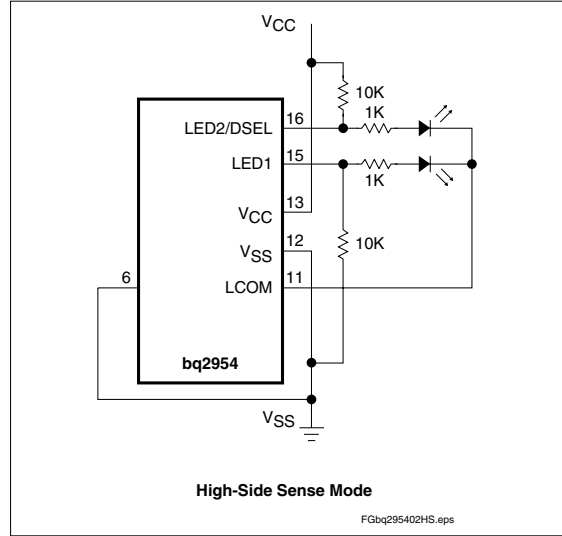


**Figure 5. Configured Display Mode
(High-Side Sense)**
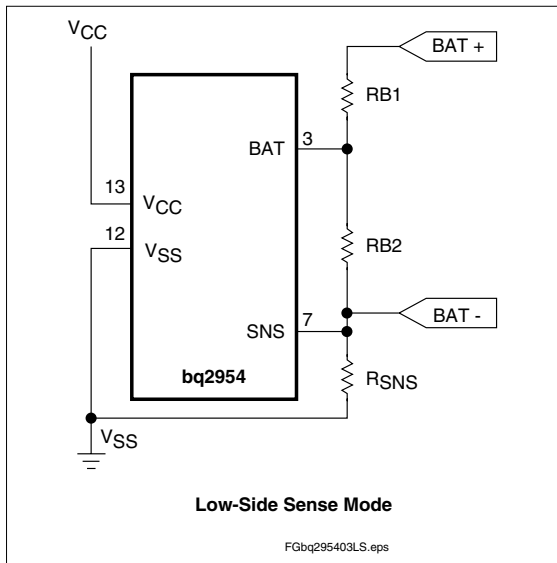


**Figure 6. Configuring the Battery Divider
(Low-Side Sense)**
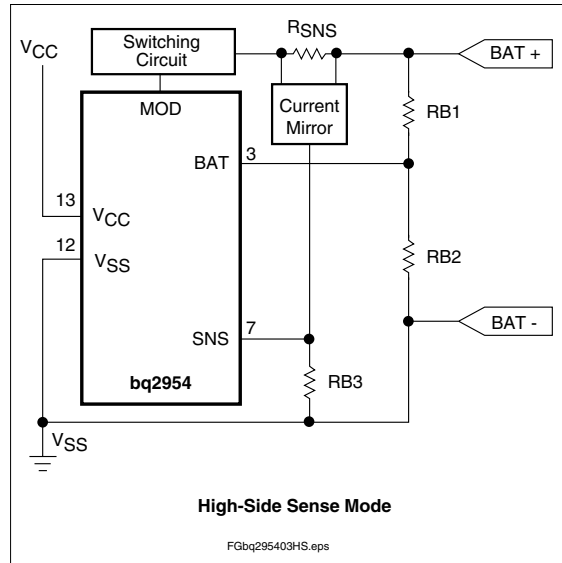


**Figure 7. Configuring the Battery Divider
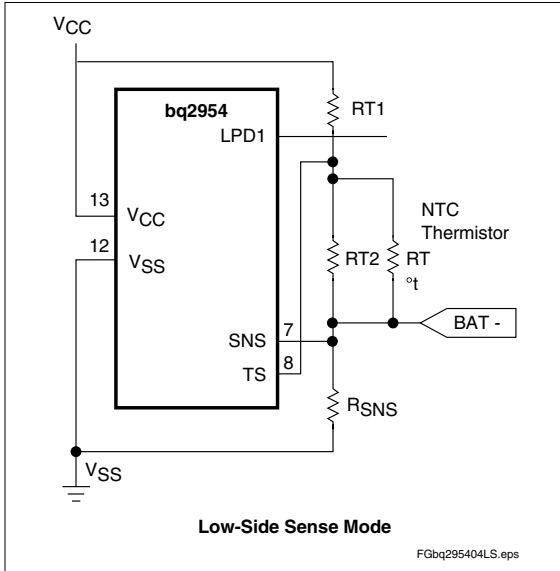(High-Side Sense)**
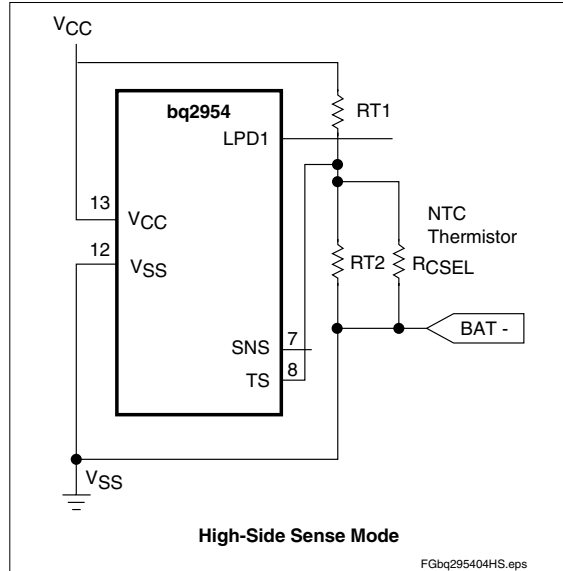
Figure 8. Low-Side Temperature Sensing



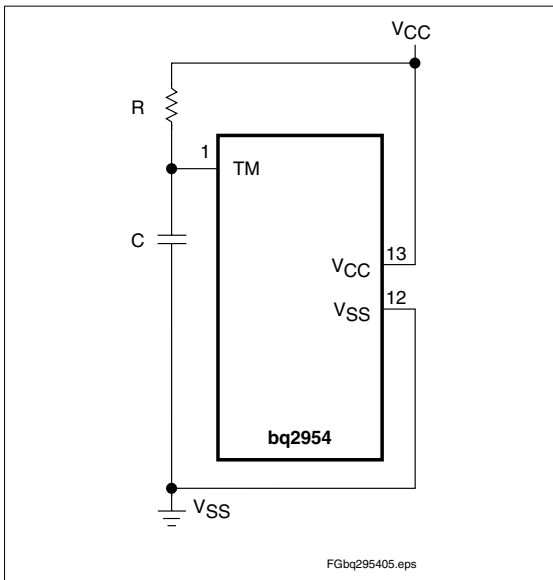Figure 9. High-Side Temperature Sensing



Figure 10. R-C Network/Setting MTO

## Disabling Temperature Sensing

Temperature sensing can be disabled by placing a 10kΩ resistor between TS and BAT- and a 10kΩ resistor between TS and $V_{CC}$. See Figures 8 and 9.

## Maximum Time-Out

Maximum Time-Out period ($t_{MTO}$) is programmed from 1 to 24 hours by an R-C network on the TM pin (see Figure 10) per the following equation:

$$t_{MTO} = 500 * R * C \qquad (5)$$

where R is in ohms, C is in Farads, and $t_{MTO}$ is in hours. The recommended value for C is 0.1μF.

The MTO timer is reset at the beginning of fast charge. If the MTO timer expires during the voltage regulation phase, fast charging terminates and the bq2954 enters the Charge Complete state. If the conditioning phase continues for time equal to $t_{QT}$ (MTO/4) and the battery potential does not reach $V_{MIN}$, the bq2954 enters the fault state and terminates charge. See Table 3. If the MTO timer expires during the current-regulation phase ($V_{BAT}$ never reaches $V_{REG}$), fast charging is terminated, and the bq2954 enters the fault state.

## Charge Regulation

The bq2954 controls charging through pulse-width modulation of the MOD output pin, supporting both constant-current and constant-voltage regulation. Charge current is monitored at the SNS pin, and charge voltage is monitored at the BAT pin. These voltages are compared to an internal reference, and the MOD output is modulated to maintain the desired value. The maximum duty cycle is 80% .

Voltage at the SNS pin is determined by the value of resistor $R_{SNS}$, so nominal regulated current is set by the following equation:

$$I_{MAX} = V_{SNS} / R_{SNS} \qquad (6)$$

The switching frequency of the MOD output is determined by an external capacitor ($C_{PWM}$) between the pin TPWM and $V_{SS}$ pins, per the following:

$$f_{PWM} = \frac{1 * 10^{-4}}{C_{PWM}} \qquad (7)$$

Where C is in Farads and the frequency is in Hz. A typical switching rate is 100kHz, implying $C_{PWM}$ = 0.001μF. MOD pulse width is modulated between 0 and 80% of the switching period.

To prevent oscillation in the voltage and current control loops, frequency compensation networks (C and R-C respectively) are typically required on the $V_{COMP}$ and $I_{COMP}$ pins .

## Recharge After Fast Charge

Once charge completion occurs, a fast charge is initiated when the battery voltage falls below $V_{RECHG}$ threshold. A delay of approximately one second passes before recharge begins so that adequate time is allowed to detect battery removal. (See Table 1.)

## Absolute Maximum Ratings

| Symbol | Parameter | Minimum | Maximum | Unit | Notes |
|---|---|---|---|---|---|
| $V_{CC}$ | $V_{CC}$ relative to $V_{SS}$ | -0.3 | +7.0 | V | |
| $V_T$ | DC voltage applied on any pin excluding $V_{CC}$ relative to $V_{SS}$ | -0.3 | +7.0 | V | |
| $T_{OPR}$ | Operating ambient temperature | -20 | +70 | °C | Commercial |
| | | -40 | +85 | °C | Industrial "N" |
| $T_{STG}$ | Storage temperature | -55 | +125 | °C | |
| $T_{SOLDER}$ | Soldering temperature | - | +260 | °C | 10s max. |

**Note:** Permanent device damage may occur if **Absolute Maximum Ratings** are exceeded. Functional operation should be limited to the Recommended DC Operating Conditions detailed in this data sheet. Exposure to conditions beyond the operational limits for extended periods of time may affect device reliability.

## DC Thresholds  ($T_A$ = $T_{OPR}$; $V_{CC}$ = 5V ±10%)

| Symbol | Parameter | Rating | Unit | Tolerance | Notes |
|---|---|---|---|---|---|
| $V_{REG}$ | Internal reference voltage | 2.05 | V | 1% | $T_A$ = 25°C |
| | Temperature coefficient | -0.5 | mV/°C | 10% | |
| $V_{LTF}$ | TS maximum threshold | $0.6 * V_{CC}$ | V | ±0.03V | Low-temperature fault |
| $V_{HTF}$ | TS hysteresis threshold | $0.44 * V_{CC}$ | V | ±0.03V | High-temperature fault |
| $V_{TCO}$ | TS minimum threshold | $0.4 * V_{CC}$ | V | ±0.03V | Temperature cutoff |
| $V_{HCO}$ | High cutoff voltage | $V_{REG}$ + 0.25V | V | ±0.03V | |
| $V_{MIN}$ | Under-voltage threshold at BAT | 1.5 | V | ±0.05V | |
| $V_{RECHG}$ | Recharge voltage threshold at BAT | 1.92 | V | ±0.05V | |
| $V_{LCO}$ | Low cutoff voltage | 0.8 | V | ±0.03V | |
| $V_{SNS}$ | Current sense at SNS | 0.250 | V | 10% | $I_{MAX}$ |
| | | 0.025 | V | 10% | $I_{COND}$ |

## Recommended DC Operating Conditions $(T_A = T_{OPR})$

| Symbol | Parameter | Minimum | Typical | Maximum | Unit | Notes |
|---|---|---|---|---|---|---|
| $V_{CC}$ | Supply voltage | 4.5 | 5.0 | 5.5 | V | |
| $V_{TEMP}$ | TS voltage potential | 0 | - | $V_{CC}$ | V | $V_{TS} - V_{SNS}$ |
| $V_{BAT}$ | BAT voltage potential | 0 | - | $V_{CC}$ | V | |
| $I_{CC}$ | Supply current | - | 2 | 4 | mA | Outputs unloaded |
| $I_{IZ}$ | DSEL tri-state open detection | -2 | - | 2 | µA | Note |
| | $I_{TERM}$ tri-state open detection | -2 | | 2 | µA | |
| $V_{IH}$ | Logic input high | $V_{CC} - 0.3$ | - | - | V | DSEL, $I_{TERM}$ |
| $V_{IL}$ | Logic input low | - | - | $V_{SS} + 0.3$ | V | DSEL, CSEL, $I_{TERM}$ |
| $V_{OH}$ | LED$_1$, LED$_2$, BTST, output high | $V_{CC} - 0.8$ | - | - | V | $I_{OH} \leq 10mA$ |
| | MOD output high | $V_{CC} - 0.8$ | - | - | V | $I_{OH} \leq 10mA$ |
| $V_{OL}$ | LED$_1$, LED$_2$, BTST, output low | - | - | $V_{SS} + 0.8$ | V | $I_{OL} \leq 10mA$ |
| | MOD output low | - | - | $V_{SS} + 0.8$ | V | $I_{OL} \leq 10mA$ |
| | CHG output low | - | - | $V_{SS} + 0.8$ | V | $I_{OL} \leq 5mA$, Note 3 |
| | LCOM output low | - | - | $V_{SS} + 0.5$ | V | $I_{OL} \leq 30mA$ |
| $I_{OH}$ | LED$_1$, LED$_2$, BTST, source | -10 | - | - | mA | $V_{OH} = V_{CC} - 0.5V$ |
| | MOD source | -5.0 | - | - | mA | $V_{OH} = V_{CC} - 0.5V$ |
| $I_{OL}$ | LED$_1$, LED$_2$, BTST, sink | 10 | - | - | mA | $V_{OL} = V_{SS} + 0.5V$ |
| | MOD sink | 5 | - | - | mA | $V_{OL} = V_{SS} + 0.8V$ |
| | CHG sink | 5 | - | - | mA | $V_{OL} = V_{SS} + 0.8V$, Note 3 |
| | LCOM sink | 30 | - | - | mA | $V_{OL} = V_{SS} + 0.5V$ |
| $I_{IL}$ | DSEL logic input low source | - | - | +30 | µA | $V = V_{SS}$ to $V_{SS} + 0.3V$, Note 2 |
| | $I_{TERM}$ logic input low source | - | - | +70 | µA | $V = V_{SS}$ to $V_{SS} + 0.3V$ |
| $I_{IH}$ | DSEL logic input high source | -30 | - | - | µA | $V = V_{CC} - 0.3V$ to $V_{CC}$ |
| | $I_{TERM}$ logic input high source | -70 | - | - | µA | $V = V_{CC} - 0.3V$ to $V_{CC}$ |

**Notes:**   1.   All voltages relative to $V_{SS}$.

2.   Conditions during initialization after $V_{CC}$ applied.

3.   SNS = 0V.

## Impedance (T$_A$ = T$_{OPR}$; V$_{CC}$ = 5V ±10%)

| Symbol | Parameter | Minimum | Typical | Maximum | Unit | Notes |
|--------|-----------|---------|---------|---------|------|-------|
| R$_{BATZ}$ | BAT pin input impedance | 50 | - | - | MΩ | |
| R$_{SNSZ}$ | SNS pin input impedance | 50 | - | - | MΩ | |
| R$_{TSZ}$ | TS pin input impedance | 50 | - | - | MΩ | |
| R$_{PROG1}$ | Soft-programmed pull-up or pull-down resistor value (for programming) | - | - | 10 | kΩ | DSEL, CSEL |
| R$_{PROG2}$ | Pull-up or pull-down resistor value | - | - | 3 | kΩ | I$_{TERM}$ |
| R$_{MTO}$ | Charge timer resistor | 20 | - | 480 | kΩ | |

## Timing  (T$_A$ = T$_{OPR}$; V$_{CC}$ = 5V ±10%)

| Symbol | Parameter | Minimum | Typical | Maximum | Unit | Notes |
|--------|-----------|---------|---------|---------|------|-------|
| t$_{MTO}$ | Charge time-out range | 1 | - | 24 | hours | See Figure 10 |
| t$_{QT}$ | Pre-charge qual test time-out period | - | 0.25 ∗ t$_{MTO}$ | - | - | |
| t$_{HO}$ | Pre-charge qual test hold-off period | 300 | 600 | 900 | ms | |
| f$_{PWM}$ | PWM regulator frequency range | - | 100 | 200 | kHz | See Equation 7 |
| d$_{PWM}$ | Duty cycle | 0 | - | 80 | % | |

## Capacitance

| Symbol | Parameter | Minimum | Typical | Maximum | Unit |
|--------|-----------|---------|---------|---------|------|
| C$_{MTO}$ | Charge timer capacitor | - | - | 0.1 | μF |
| C$_{PWM}$ | PWM capacitor | - | 0.001 | - | μF |

## 16-Pin DIP Narrow  (PN)
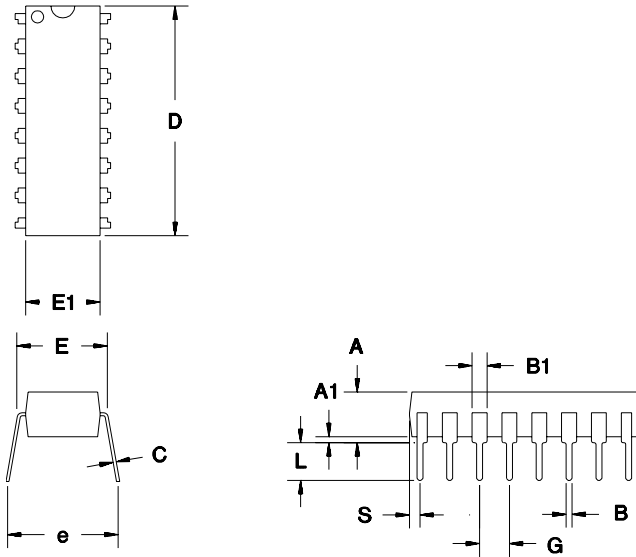
### 16-Pin PN (0.300" DIP)

| Dimension | Inches | | Millimeters | |
|:---:|:---:|:---:|:---:|:---:|
| | **Min.** | **Max.** | **Min.** | **Max.** |
| A | 0.160 | 0.180 | 4.06 | 4.57 |
| A1 | 0.015 | 0.040 | 0.38 | 1.02 |
| B | 0.015 | 0.022 | 0.38 | 0.56 |
| B1 | 0.055 | 0.065 | 1.40 | 1.65 |
| C | 0.008 | 0.013 | 0.20 | 0.33 |
| D | 0.740 | 0.770 | 18.80 | 19.56 |
| E | 0.300 | 0.325 | 7.62 | 8.26 |
| E1 | 0.230 | 0.280 | 5.84 | 7.11 |
| e | 0.300 | 0.370 | 7.62 | 9.40 |
| G | 0.090 | 0.110 | 2.29 | 2.79 |
| L | 0.115 | 0.150 | 2.92 | 3.81 |
| S | 0.020 | 0.040 | 0.51 | 1.02 |

## 16-Pin SOIC Narrow (SN)
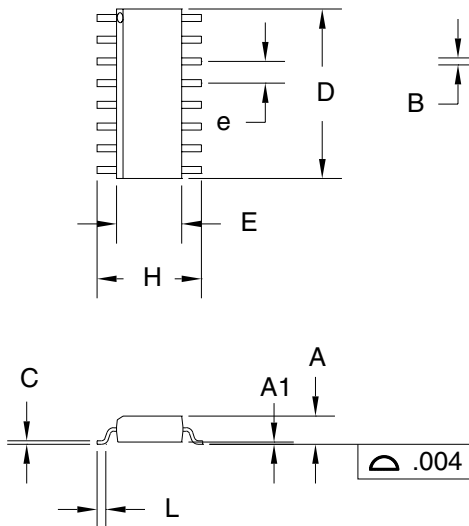
### 16-Pin SN (0.150" SOIC)

| Dimension | Inches | | Millimeters | |
|:---:|:---:|:---:|:---:|:---:|
| | **Min.** | **Max.** | **Min.** | **Max.** |
| A | 0.060 | 0.070 | 1.52 | 1.78 |
| A1 | 0.004 | 0.010 | 0.10 | 0.25 |
| B | 0.013 | 0.020 | 0.33 | 0.51 |
| C | 0.007 | 0.010 | 0.18 | 0.25 |
| D | 0.385 | 0.400 | 9.78 | 10.16 |
| E | 0.150 | 0.160 | 3.81 | 4.06 |
| e | 0.045 | 0.055 | 1.14 | 1.40 |
| H | 0.225 | 0.245 | 5.72 | 6.22 |
| L | 0.015 | 0.035 | 0.38 | 0.89 |

△ .004

## Data Sheet Revision History

| Change No. | Page No. | Description of Change |
|:---:|:---:|:---|
| 1 | All | "Final" changes from "Preliminary" version |

**Note:** Change 1 = Oct. 1998 B changes from Nov. 1997 "Preliminary."

## Ordering Information

**bq2954**

        Package Option:
           PN = 16-pin plastic DIP
           SN = 16-pin narrow SOIC

      Device:
        bq2954 Li-Ion Fast-Charge IC

## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish | MSL Peak Temp (3) | Op Temp (°C) | Top-Side Markings (4) | Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BQ2954PN | ACTIVE | PDIP | N | 16 | 25 | Pb-Free (RoHS) | CU NIPDAU | N / A for Pkg Type | 0 to 70 | 2954PN-A3 | Samples |
| BQ2954PNE4 | ACTIVE | PDIP | N | 16 | 25 | Pb-Free (RoHS) | CU NIPDAU | N / A for Pkg Type | 0 to 70 | 2954PN-A3 | Samples |
| BQ2954SN | ACTIVE | SOIC | D | 16 | 40 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | 2954 (-A3, A3) | Samples |
| BQ2954SNG4 | ACTIVE | SOIC | D | 16 | 40 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | 2954 (-A3, A3) | Samples |
| BQ2954SNTR | ACTIVE | SOIC | D | 16 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | 2954 (-A3, A3) | Samples |
| BQ2954SNTRG4 | ACTIVE | SOIC | D | 16 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | 0 to 70 | 2954 (-A3, A3) | Samples |

**(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)** Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
**TBD:** The Pb-Free/Green conversion plan has not been defined.
**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

**(4)** Only one of markings shown within the brackets will appear on the physical device.

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# PACKAGE MATERIALS INFORMATION

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

**TAPE DIMENSIONS**



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

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**



*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BQ2954SNTR | SOIC | D | 16 | 2500 | 330.0 | 16.4 | 6.5 | 10.3 | 2.1 | 8.0 | 16.0 | Q1 |

**TAPE AND REEL BOX  DIMENSIONS**



*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| BQ2954SNTR | SOIC | D | 16 | 2500 | 367.0 | 367.0 | 38.0 |

# IMPORTANT NOTICE

| Products | | Applications | |
|---|---|---|---|
| Audio | www.ti.com/audio | Automotive and Transportation | www.ti.com/automotive |
| Amplifiers | amplifier.ti.com | Communications and Telecom | www.ti.com/communications |
| Data Converters | dataconverter.ti.com | Computers and Peripherals | www.ti.com/computers |
| DLP® Products | www.dlp.com | Consumer Electronics | www.ti.com/consumer-apps |
| DSP | dsp.ti.com | Energy and Lighting | www.ti.com/energy |
| Clocks and Timers | www.ti.com/clocks | Industrial | www.ti.com/industrial |
| Interface | interface.ti.com | Medical | www.ti.com/medical |
| Logic | logic.ti.com | Security | www.ti.com/security |
| Power Mgmt | power.ti.com | Space, Avionics and Defense | www.ti.com/space-avionics-defense |
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