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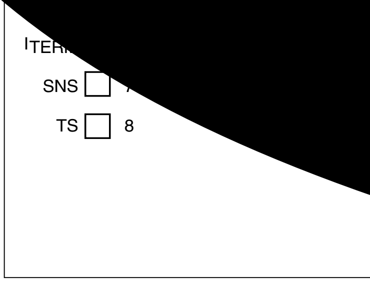


Pin Descriptions

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 $LED_{1\text{-}2}$. 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.

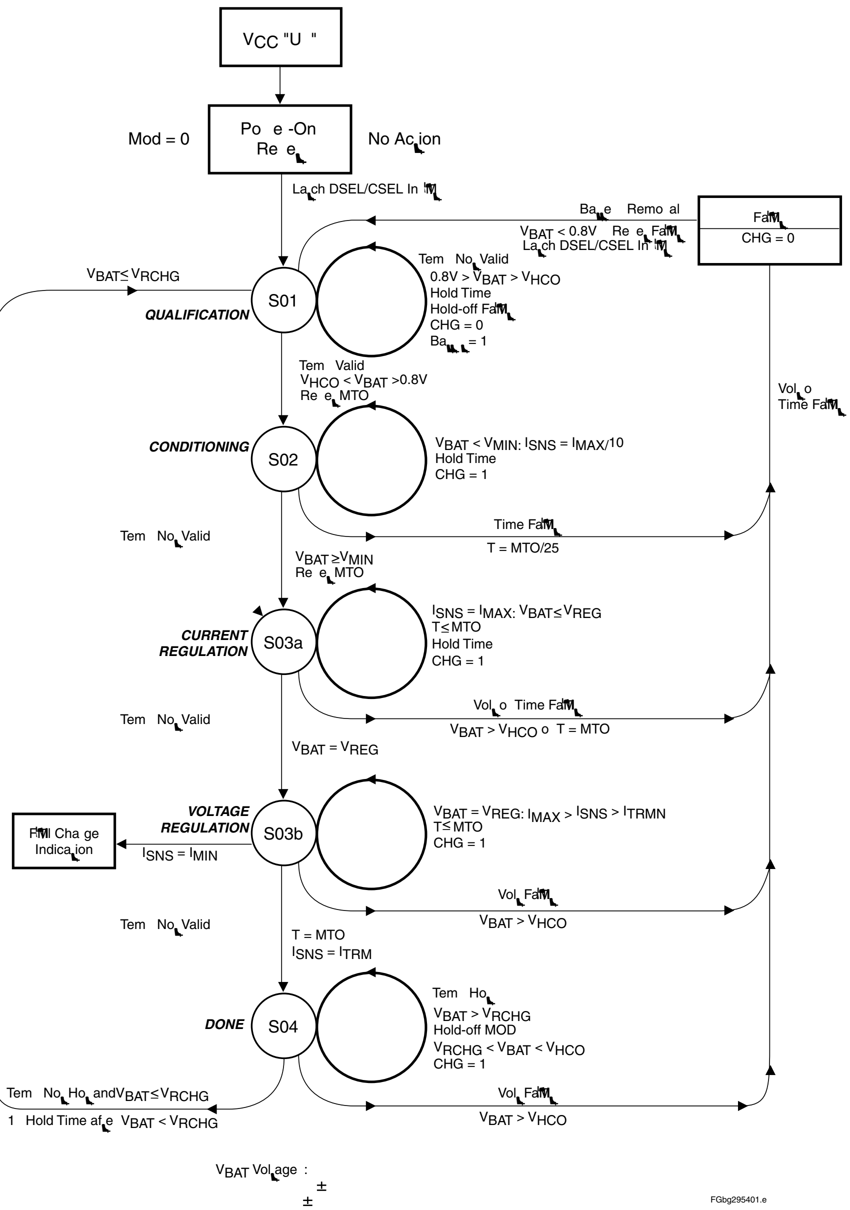
Functional Description

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


Power-On Reset
Mod = 0
No Action
S01
QUALIFICATION
S02
CONDITIONING
S03a
CURRENT REGULATION
S03b
VOLTAGE REGULATION
S04
DONE
CHG = 0
Hold Time
Hold-off MOD
T = MTO/25
T = MTO
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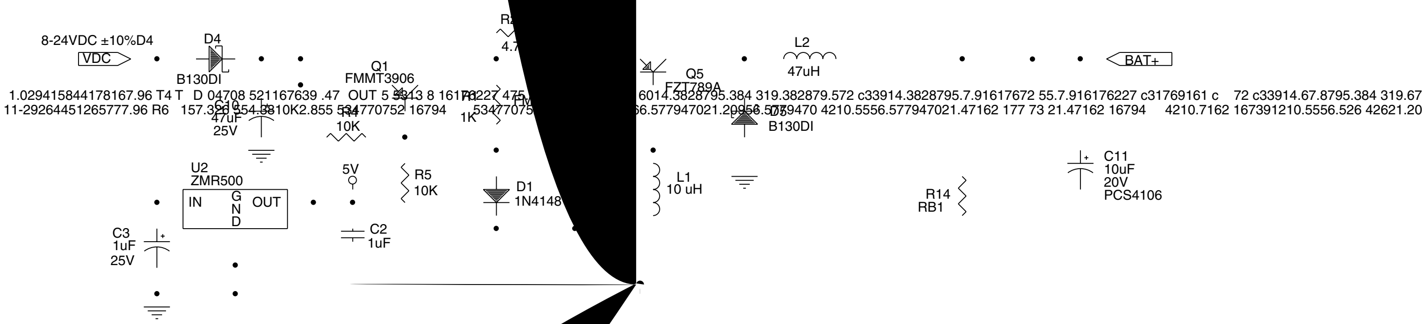
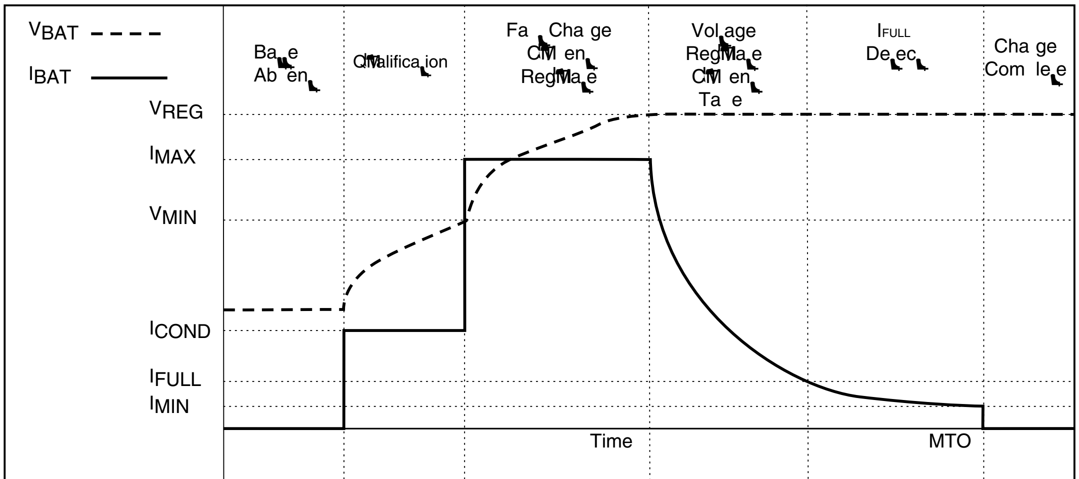

8-24VDC ±10%
VDC
D4
B130DI
C10
47uF
25V
U2
ZMR500
IN
G
N
D
OUT
C3
1uF
25V
Q1
FMMT3906
R4
10K
5V
R5
10K
C2
1uF
1K
D1
1N4148
Q5
FZT789A
B130DI
L1
10 uH
L2
47uH
R14
RB1
C11
10uF
20V
PCS4106
BAT+

Table 1. Normal Fast Charge Cycle



Mode 1 (DSEL = 0)	LED1	Lo	High	High	High	Lo	Lo
	LED2	Lo	Lo	Lo	Lo	High	High
Mode 2 (DSEL = 1)	LED1	Lo	High	High	High	Lo	Lo
	LED2	Lo	Lo	Lo	Lo	High	High
Mode 3 (DSEL = F)	LED1	Lo	High	High	High	Lo	Lo
	LED2	Lo	Lo	Lo	High	High	High
Mode 1 and 2	CHG	Lo	High	High	High	High	Lo
	BTST	High	Lo	Lo	Lo	Lo	Lo
Mode 3	CHG	Lo	High	High	High	High	Lo
	BTST	High	High	Lo	Lo	Lo	Lo

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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.

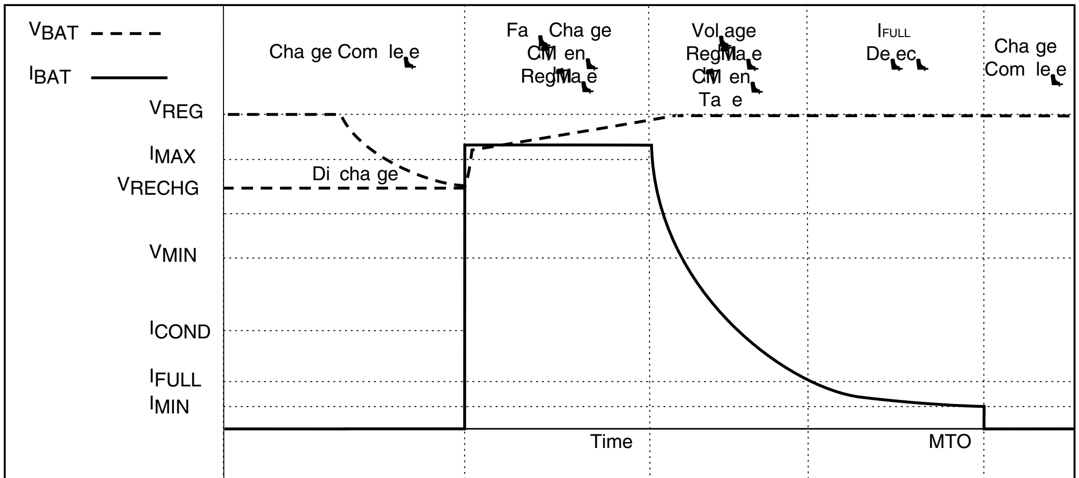
Configuring the Display Mode, I_{FULL}/I_{MIN}, and I_{SENSE}

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.

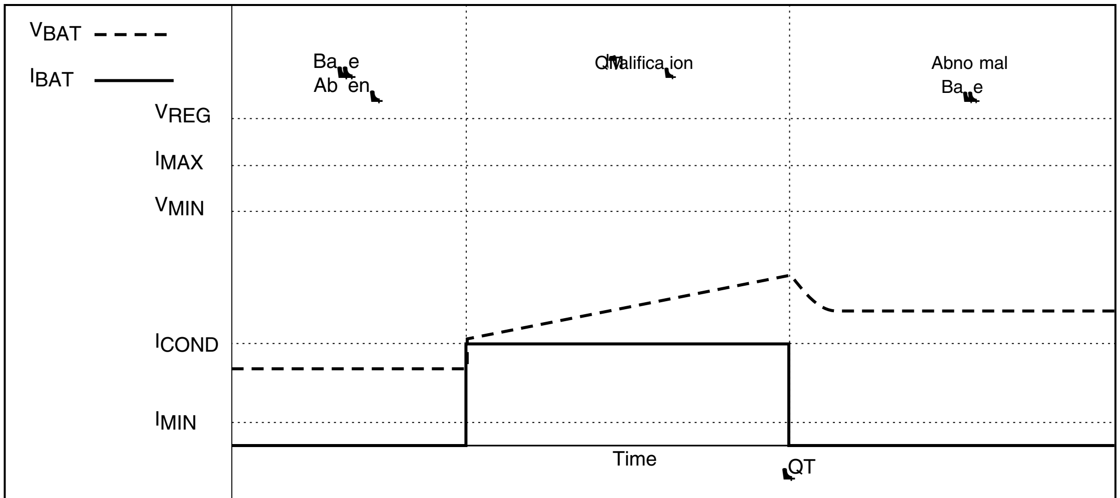
When fast charge reaches a condition where the charging current drops below I_{FULL}, the LED1 and LED2 outputs indicate a full-battery condition. Fast charge terminates when the charging current drops below the

Table 2. Recharge After Fast Charge Cycle



Mode 1 (DSEL = 0)	LED1	Lo	High	High	Lo	Lo
	LED2	High	Lo	Lo	High	High
Mode 2 (DSEL = 1)	LED1	Lo	High	High	Lo	Lo
	LED2	High	Lo	Lo	High	High
Mode 3 (DSEL = F)	LED1	Lo	High	High	Lo	Lo
	LED2	High	Lo	High	High	High
Mode 1 and 2	CHG	Lo	High	High	High	Lo
	BTST	Lo	Lo	Lo	Lo	Lo
Mode 3	CHG	Lo	High	High	High	Lo
	BTST	Lo	Lo	Lo	Lo	Lo

Table 3. Abnormal Condition



Mode 1 (DSEL = 0)	LED1	Lo	High	Fla h
	LED2	Lo	Lo	Lo
Mode 2 (DSEL = 1)	LED1	Lo	High	Lo
	LED2	Lo	Lo	Lo
Mode 3 (DSEL = F)	LED1	Lo	High	Lo
	LED2	Lo	Lo	Lo
CHG		Lo	High	Lo
BTST		High	Lo	Lo

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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

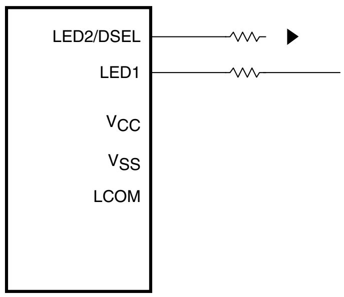
The current sense resistor, R_{SNS} (see Figures 6 and 7), determines the fast-charge current. The value of R_{SNS} is given by the following:

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

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 exter-



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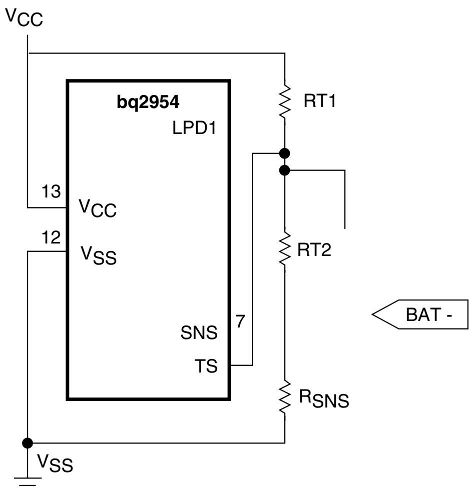

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Disabling Temperature Sensing

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:

$$I_{MAX} = V_{SNS} / R_{SNS} \tag{6}$$

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

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

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.

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_{SSTERM}

Impedance ($T_A = T_{OPR}$; $V_{CC} = 5V \pm 10\%$)

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	

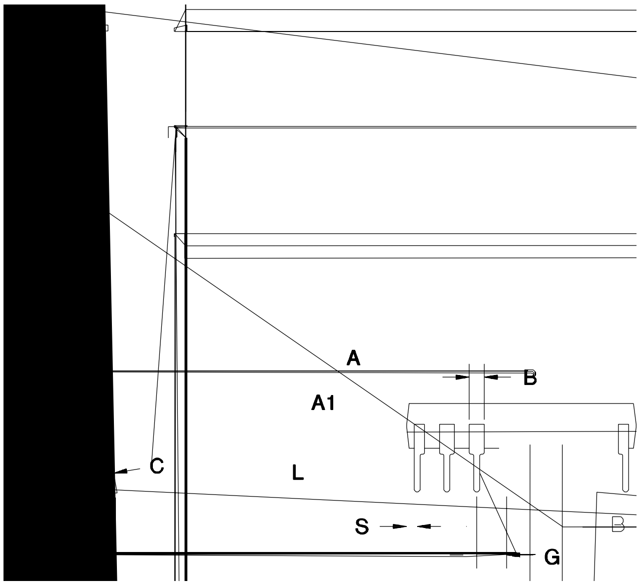
Timing ($T_A = T_{OPR}$; $V_{CC} = 5V \pm 10\%$)

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

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

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CERTAIN APPLICATIONS USING SEMICONDUCTOR PRODUCTS MAY INVOLVE POTENTIAL RISKS OF DEATH,

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 et172.54a/F3 8 Tf 1 0 0 -1 0 6.844 Tm [(LIFEBUi7ill) 2 23.612999 m 62.36ir23 8 Tf 1 0 0 -1 36.888 6.844 Tm [( ) (TI Q q 22.677 23.6

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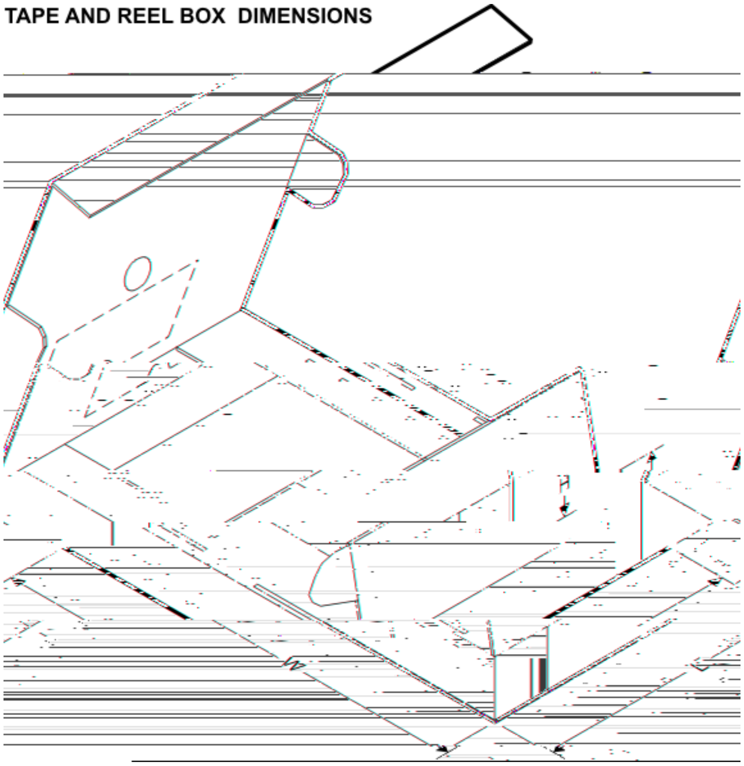
TAPE AND REEL INFORMATION

*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