Benchmarq Products
from Texas Instruments

bq2057

Advanced Li-Ion Linear Charge Management IC

Features

- ➤ Ideal for single- and dual-cell Li-Ion packs with coke or graphite anodes
- ➤ Dropout voltage as low as 0.3V
- ➤ AutoComp™ dynamic compensation of battery pack's internal impedance
- ➤ Optional temperature-monitoring before and during charge
- ➤ Integrated voltage and current regulation with programmable charge-current and high- or low-side current sensing
- ➤ Integrated cell conditioning for reviving deeply discharged cells and minimizing heat dissipation during initial stage of charge
- ➤ Better than ±1% voltage regulation accuracy
- ➤ Charge status output for LED or host processor interface
- ➤ Automatic battery-recharge feature
- ➤ Charge termination by minimum current
- ➤ Low-power sleep mode
- ➤ Packaging: 8-pin SOIC, 8-pin TSSOP

General Description

The BENCHMARQ bq2057 series advanced Li-Ion linear charge-management ICs are designed for cost-sensitive and compact portable electronics. They combine high-accuracy current and voltage regulation, battery conditioning, temperature monitoring, charge termination, charge-status indication, and AutoComp charge-rate compensation in a single 8-pin IC.

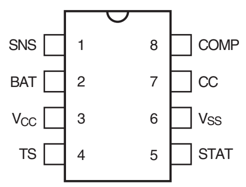
The bq2057 continuously measures battery temperature using an external thermistor. For safety reasons, the bq2057 inhibits charge until the battery temperature is within user-defined thresholds. The bq2057 then charges the battery in three phases: conditioning, constant current, and constant voltage. If the battery voltage is below the low-voltage threshold V_{MIN}, the bq2057 trickle-charges to condition the battery. The conditioning charge rate is set at 10% of the regulation current. The conditioning current also minimizes heat dissipation in the external pass-element during the initial stage of charge.

After conditioning, the bq2057 applies a constant current to the battery. An external sense-resistor sets the magnitude of the current. The sense-resistor can be on either the low or the high side of the battery without additional components. The constant-current phase continues until the battery reaches the charge-regulation voltage.

The bq2057 then begins the constant-voltage phase. The accuracy of the voltage regulation is better than ±1% over the operating-temperature and supply-voltage ranges. For single and dual cells with either coke or graphite anodes, the bq2057 is offered in four fixed-voltage versions: 4.1V, 4.2V, 8.2V, and 8.4V. Charge stops when the current tapers to the charge termination threshold, V_{TERM}. The bq2057 automatically restarts the charge if the battery voltage falls below the V_{RCH} threshold.

The designer also may use the AutoComp feature to reduce charging time. This proprietary technique allows safe and dynamic compensation for the internal impedance of the battery pack during charge.

Pin Connections



8-Pin PDIP, Narrow SOIC, or TSSOP

PN-205701.eps

Pin Names

SNS	Current-sense input	STAT	Charge status output
BAT	Battery-voltage input	V_{SS}	Ground input
V_{CC}	Supply voltage	CC	Charge control output
TS	Temperature sense input	COMP	Charge-rate compensation input

SLUS025A – JANUARY 2000 - REVISED MAY 2000

Pin Descriptions

SNS **Current-sense input**

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

BAT **Battery voltage input**

Voltage sense-input tied directly to the positive side of the battery.

V_{CC} **V_{CC} supply input**

TS **Temperature sense input**

Input for an external battery-temperature monitoring circuit. Connecting this input to Vcc/2 disables this feature.

STAT **Charge status output**

Tri-state indication of charge-in-progress, charge-complete, and temperature fault.

V_{SS} **Ground input**

CC **Charge-control output**

Source-follower output that drives an external pass-transistor for current and voltage regulation.

COMP **Charge-rate compensation input**

Sets the charge-rate compensation level. The voltage-regulation output may be programmed to vary as a function of the charge current delivered to the battery.

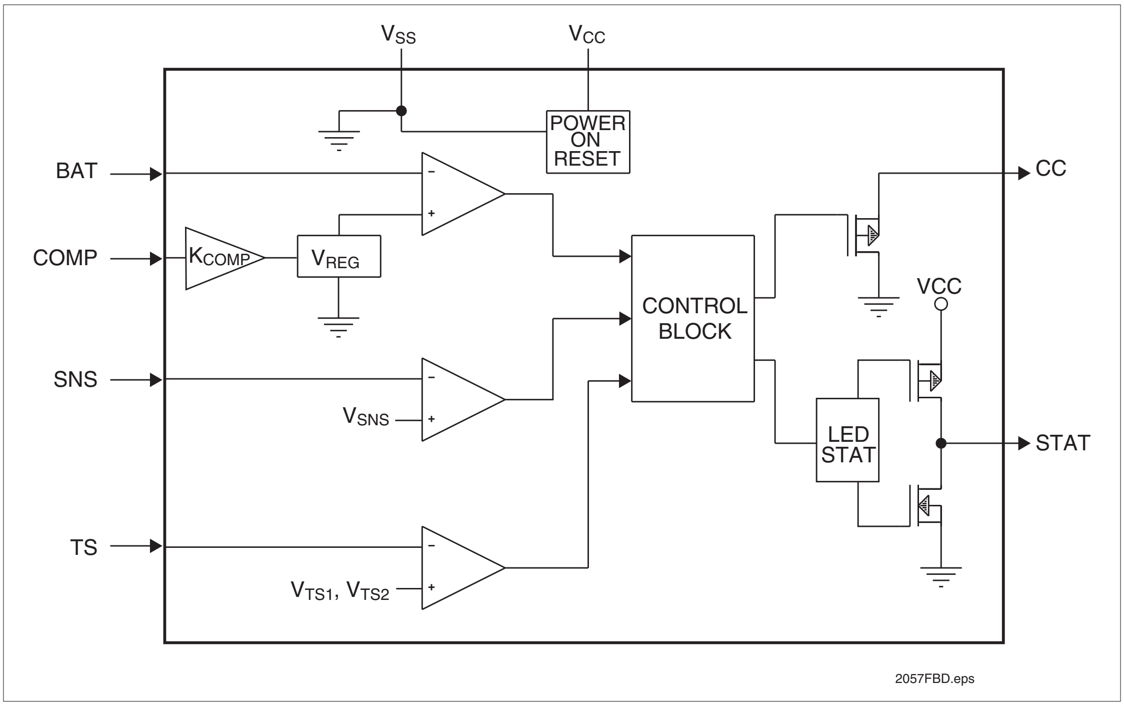


Figure 1. Functional Block Diagram

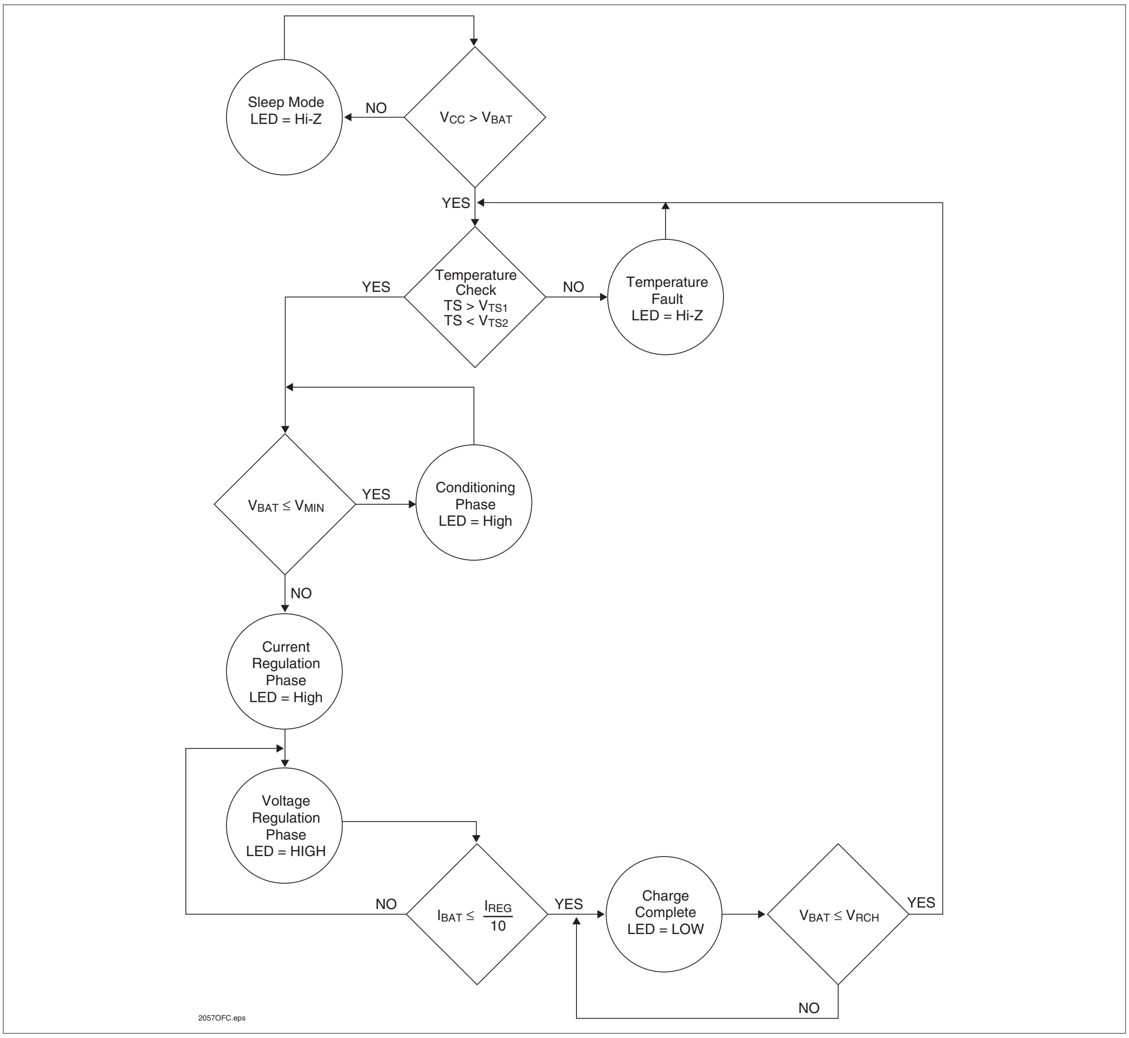


Figure 2. bq2057 Operational Flow Chart

Functional Description

Figure 1 is a functional block diagram, Figure 2 an operational flow chart, and Figure 3 a typical charger schematic for the bq2057.

Charge Qualification and Conditioning

When power is applied, the bq2057 starts a charge-cycle if a battery is already present or when a battery is inserted. Charge qualification is based on battery temperature and voltage. The bq2057 suspends charge if the battery temperature is outside the V_{TS1} to V_{TS2} range and suspends charge until the battery temperature is within the allowed range. The bq2057 also checks the battery voltage. If the battery voltage is below the low-voltage threshold V_{MIN}, the bq2057 uses trickle-charge to condition the battery. The conditioning charge rate I_{COND} is set at 10% of the regulation current. The conditioning current also minimizes heat dis-

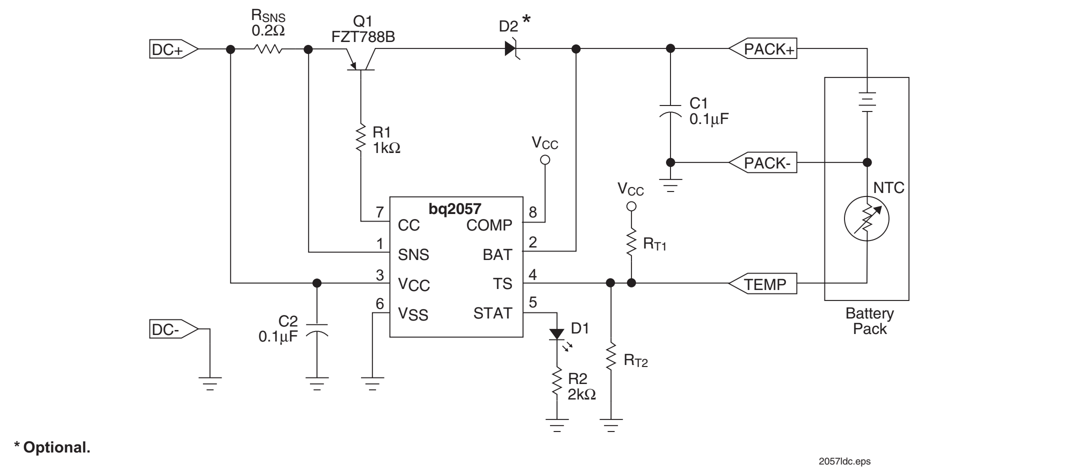


Figure 3. Low-Dropout Single- or Dual-Cell Li-Ion Charger

sipation in the external pass-element during the initial stage of charge. See Figure 4 for a typical charge-algorithm.

Current Regulation

The bq2057 regulates current while the battery-pack voltage is less than the regulation voltage, V_{REG}. The bq2057 monitors charge current at the SNS input by the voltage drop across a sense-resistor, R_{SNS}, in series with the battery pack. In high-side current sensing configuration (Figure 5), R_{SNS} is placed between the Vcc and SNS pins, and in low-side sensing (Figure 6) the R_{SNS} is placed between Vss (battery negative) and SNS (charger ground) pins.

Charge-current feedback, applied through pin SNS, maintains regulation around a threshold of V_{SNS}. The following formula calculates the value of the sense resistor:

$$R_{SNS} = \frac{V_{SNS}}{I_{REG}}$$

where I_{REG} is the desired charging current.

Voltage Monitoring and Regulation

Voltage regulation feedback is through pin BAT. This input is tied directly to the positive side of the battery pack. The bq2057 monitors the battery-pack voltage between the BAT and V_{SS} pins. The bq2057 is offered in four fixed-voltage versions for single- and dual-cells with either coke or graphite anodes: 4.1V, 4.2V, 8.2V, and 8.4V.

Other regulation voltages can be achieved by adding a voltage divider between the positive and negative terminals of the battery pack. The voltage divider presents a scaled battery pack voltage to BAT input. (See Figures 7 and 8.) The resistor values R_{B1} and R_{B2} for the voltage divider are calculated by the following equation:

$$\frac{R_{B1}}{R_{B2}} = \left(N * \frac{V_{CELL}}{V_{REG}}\right) - 1$$

where

N = Number of cells in series

V_{CELL} = Desired regulation voltage per cell

Charge Termination and Re-Charge

The bq2057 monitors the charging current during the voltage-regulation phase. The bq2057 declares a "battery-complete" condition and terminates charge when the current tapers off to the charge termination threshold, V_{TERM}. A new charge cycle begins when the battery voltage falls below the V_{RCH} threshold.

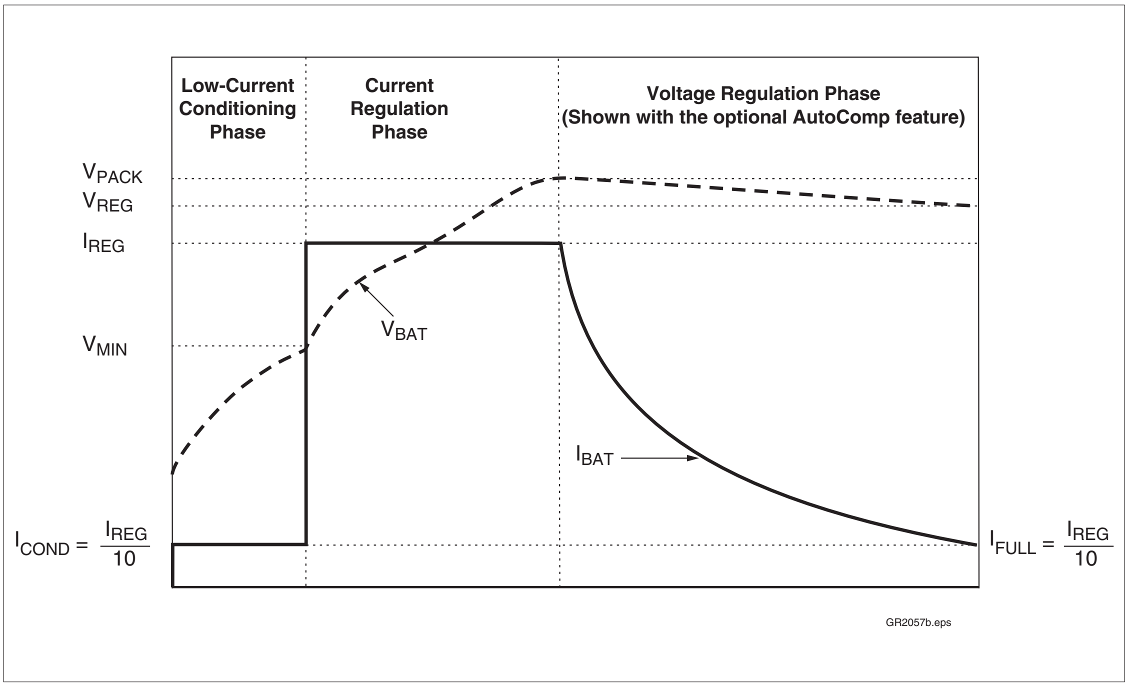


Figure 4. bq2057 Typical Charge Algorithm

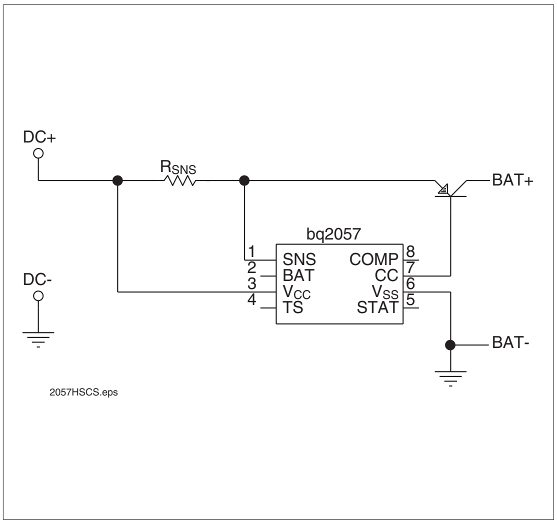


Figure 5. High-Side Current Sensing

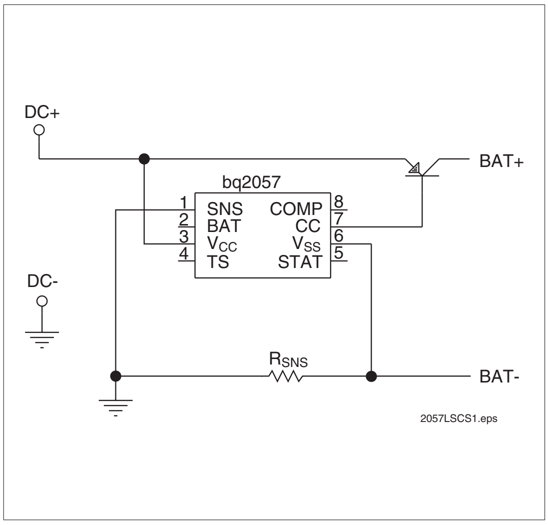


Figure 6. Low-Side Current Sensing

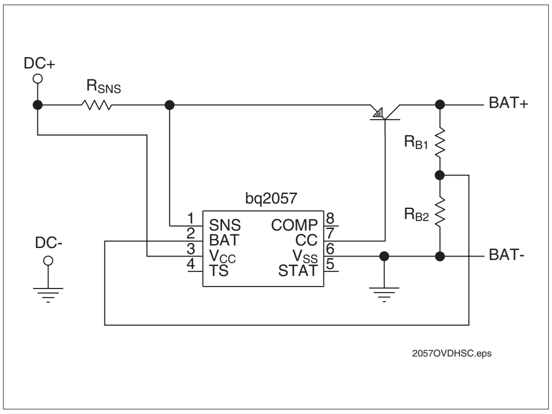


Figure 7. Optional Voltage Divider for Non-Standard Regulation Voltage, (High-Side Current Sensing)

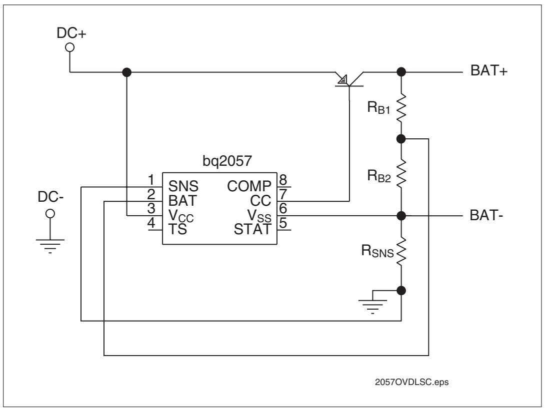


Figure 8. Optional Voltage Divider for Non-Standard Regulation Voltage, (Low-Side Current Sensing)

Temperature Monitoring

The bq2057 continuously monitors temperature by measuring the voltage between the TS and V_{SS} pins. A negative- or a positive-temperature coefficient thermistor (NTC, PTC) and an external voltage-divider typically develop this voltage. (See Figure 9.) The bq2057 compares this voltage against its internal V_{TS1} and V_{TS2} thresholds to determine if charging is allowed. (See Figure 10.) The temperature sensing circuit is immune to any fluctuation in the V_{CC}, since both the external voltage divider and the internal thresholds (V_{TS1} and V_{TS2}) are referenced to V_{CC}.

The resistor values of R_{T1} and R_{T2} are calculated by the following equations:

For NTC thermistors

$$R_{T1} = \frac{(5 * R_{TH} * R_{TC})}{(3 * (R_{TC} - R_{TH}))}$$

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

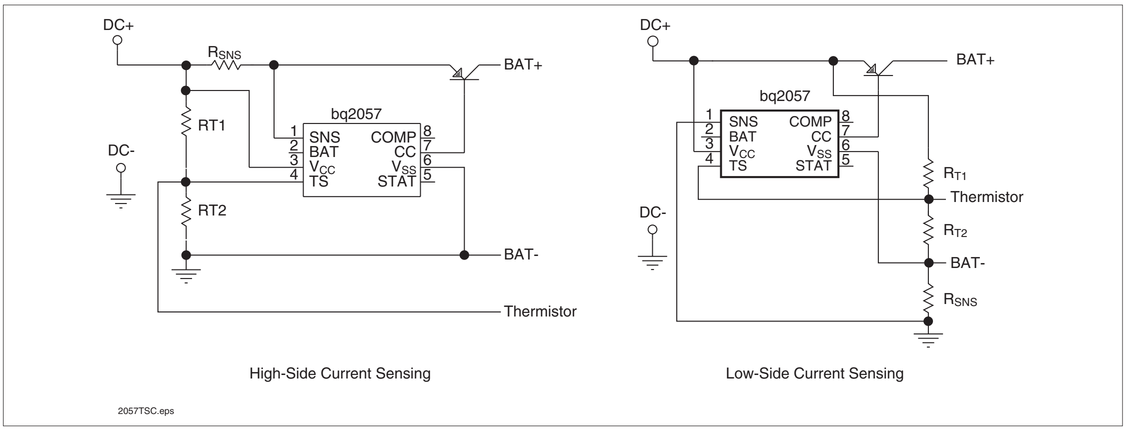


Figure 9. Temperature Sensing Circuits

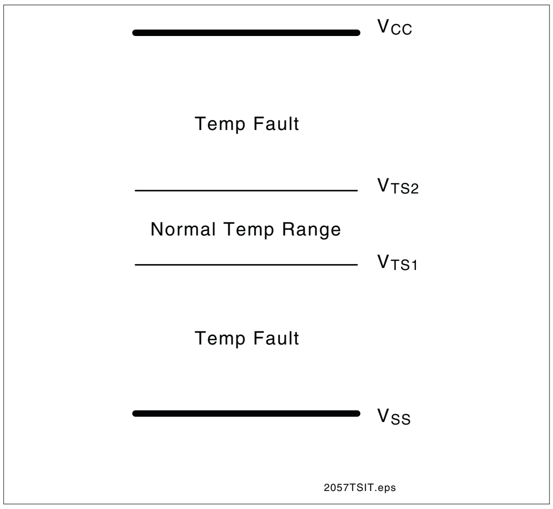


Figure 10. bq2057 TS Input Thresholds

For PTC thermistors

$$R_{T1} = \left(\frac{5 * R_{TH} * R_{TC}}{(3 * (R_{TH} - R_{TC}))} \right)$$

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

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

R_{T1} or R_{T2} can be omitted if only one temperature setting (Hot or Cold) is required.

Applying a voltage between the V_{TS1} and V_{TS2} thresholds to pin TS disables the temperature-sensing feature.

Low-Power Mode

The bq2057 enters the sleep mode if the V_{CC} falls below the voltage at the BAT input. This feature prevents draining the battery pack during the absence of V_{CC}.

Charge Status Display

The bq2057 reports the status of the charger on the tri-state STAT pin. The three states include "charge in progress, charge complete, and temperature fault.

Condition	STAT Pin
Battery conditioning and charging	High
Charge complete	Low
Temperature fault or sleep mode	High-Z

Automatic Charge-Rate Compensation

To reduce charging time, the bq2057 uses the proprietary AutoComp technique to compensate safely for internal impedance of the battery pack.

Figure 11 outlines the major components of a single-cell Li-Ion battery pack. The Li-Ion battery pack consists of a cell, protection circuit, fuse, connector, current sense-resistors, and some wiring. Each of these components contains some resistance. Total impedance of the battery pack is the sum of the minimum resistances of all battery-pack components. Using the minimum resistance values reduces the odds for overcompensating. Overcompensating may activate the safety circuit of the battery pack.

Compensation is through input pin COMP (Figure 12). A portion of the current-sense voltage, presented through this pin, is scaled by a factor of K_{COMP} and summed with the regulation threshold, V_{REG}. This process increases the output voltage to compensate for the battery pack's internal impedance and for undesired voltage drops in the circuit.

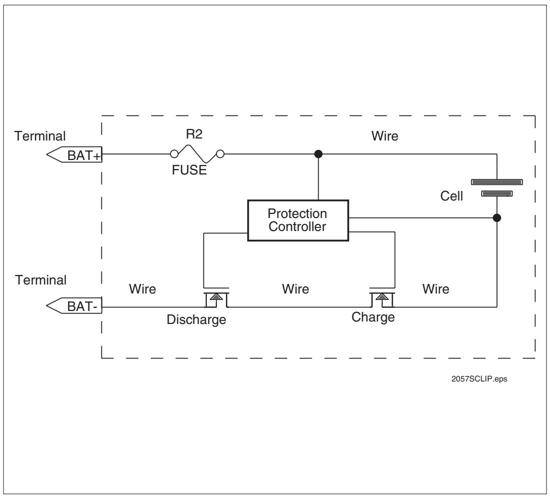


Figure 11. Typical Components of a Single-Cell Li-Ion Pack

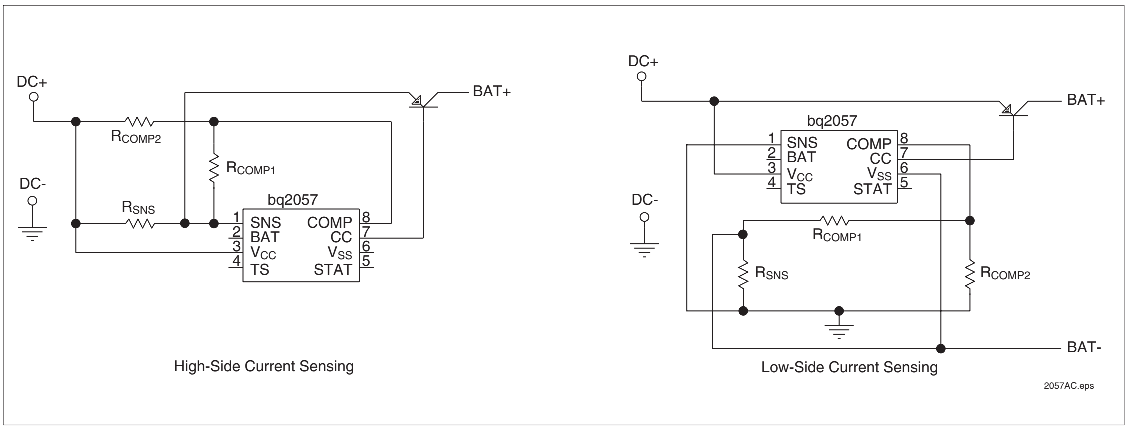


Figure 12. AutoComp Circuits

AutoComp setup requires the following information:

- Total impedance of battery pack (Z_{PACK})
- Maximum charging current (I_{REG})

The voltage drop VZ across the internal impedance of the battery pack can then be calculated by

$$V_Z = Z_{PACK} * I_{REG}$$

The required compensation is then calculated using the following equations:

$$V_{COMP} = \frac{V_Z}{K_{COMP}}$$

$$V_{PACK} = V_{REG} + (K_{COMP} * V_{COMP})$$

where V_{COMP} is the voltage on COMP pin. This voltage is referenced to Vcc in high-side current-sensing configuration and to Vss for low-side sensing. V_{PACK} is the voltage across the battery pack.

The values of R_{COMP1} and R_{COMP2} can be calculated using the following equation:

$$\frac{V_{COMP}}{V_{SNS}} = \frac{R_{COMP2}}{R_{COMP1} + R_{COMP2}}$$

Absolute Maximum Ratings

Symbol	Parameter	Min.	Max.	Units	Notes
V_{CC}	V_{CC} relative to V_{SS}	-0.3	+18	V	
V_T	V_{CC} relative to V_{SS}	-0.3	V_{CC} + 0.3	V	DC voltage applied on any pin (excluding V_{CC})
T_{OPR}	Operating ambient temperature	-20	70	°C	
T_{STG}	Storage temperature	-40	125	°C	
P_D	Power dissipation		300	mW	

DC Thresholds (T_A=T_{OPR} and V_{CC} = 4.5–15V unless otherwise specified)

Symbol	Parameter	Rating	Tolerance	Unit	Notes
V_{REG}	Voltage regulation reference	4.10	±1%	V	For bq2057 only; See Note 1,2,3
		4.20	±1%	V	For bq2057C only; See Note 1,2,3
		8.20	±1%	V	For bq2057T only; See Note 1,2,3
		8.40	±1%	V	For bq2057W only; See Note 1,2,3
V_{SNS}	Current regulation reference	-110	±10%	mV	V_{CC} = 5V, See Note 4
		-115	±10%	mV	V_{CC} = 9V, See Note 4
		-115	±15%	mV	All other V_{CC}, See Note 4
V_{MIN}	Conditioning voltage reference	3.0	±2%	V	For bq2057 only
		3.1	±2%	V	For bq2057C only
		6.0	±2%	V	For bq2057T only
		6.2	±2%	V	For bq2057W only
K_{COMP}	AutoComp gain	2.2	±15%	V/V	See Note 1
V_{TS1}	Lower temperature threshold	0.3 * V_{CC}	±3% of V_{CC}	V	Voltage at pin TS, relative to V_{SS}
V_{TS2}	Upper temperature threshold	0.6 * V_{CC}	±3% of V_{CC}	V	Voltage at pin TS, relative to V_{SS}
V_{RCH}	Recharge threshold	V_{REG} - 0.1	±2%	V	Voltage on BAT pin, bq2057 and bq2057C only
V_{RCH}	Recharge threshold	V_{REG} - 0.2	±2%	V	Voltage on BAT pin, bq2057T and bq2057W only
V_{TERM}	Charge termination reference	-14	±10mV	mV	See Note 4

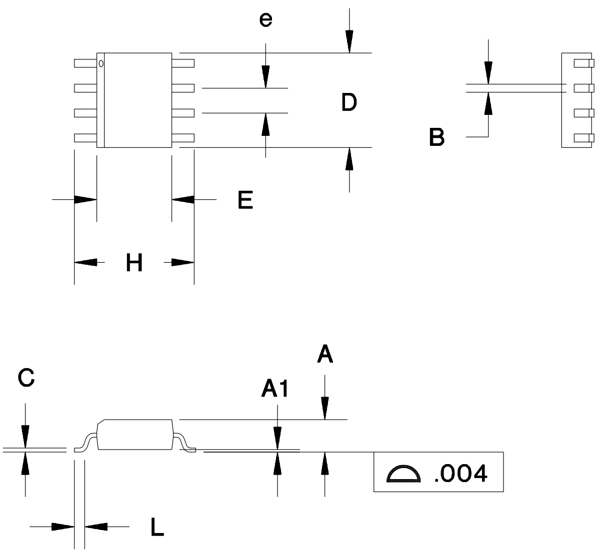
Notes:
1. V_{CC} = V_{BAT} + 0.3V to 15V.
2. For high-side current-sensing configuration.
3. For low-side current-sensing, the tolerance is ±1% for T_A = 25°C and ±1.2% for T_A = T_{ORR}.
4. Voltage at pin SNS, relative to V_{CC} for high-side sensing, and to V_{SS} for low-side sensing, 0°C <= T_A <= 50°C

DC Electrical Characteristics ($T_A = T_{OPR}$, and V_{CC} = 4.5 - 15V unless otherwise specified))

Symbol	Parameter	Min	Typical	Max	Units	Notes
V_{CC}	Supply voltage	4.5	-	15	V	
I_{CC}	Operating current	-	2	4	mA	Excluding external loads
I_{CCS}	Sleep current	-	3	6	µA	For bq2057 and bq2057C, See note
		-	-	10	µA	For bq2057T and bq2057W, See note
V_{OL}	Output-low voltage	-	0.4	0.6	V	I_{OL} = 10mA; STAT pin
V_{OH}	Output-high voltage	V_{CC} - 0.5	-	-	V	I_{OH} = 5mA; STAT pin
I_{IH}	Input leakage current	-	-	1	µA	BAT input, $V_{BAT} = V_{REG}$
		-	-	5	µA	SNS, COMP, and TS inputs, $V_{SNS} = V_{COMP} = V_{TS} = 5V$
I_{SNK}	Sink current	5	-	40	mA	CC pin, not to exceed P_D specification
V_{OLCC}	CC pin output-low voltage	-	-	1.5	V	At I_{SNK} (minimum)

Note: $V_{BAT} \geq V_{MIN}$, $V_{BAT} - V_{CC} \geq 0.8V$, $+20°C \leq T_A \leq 70°C$.

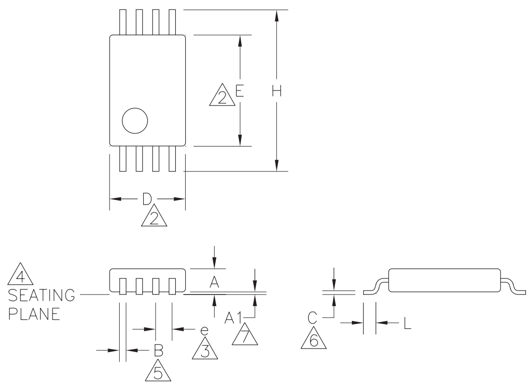
8-Pin SOIC Narrow (SN)



8-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	0.185	0.200	4.70	5.08
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

TS: 8-Pin TSSOP



Dimension	Inches		Millimeters	
	Min.	**Max.**	**Min.**	**Max.**
A	-	0.043	-	1.10
A1	0.002	0.006	0.05	0.15
B	0.007	0.012	0.18	0.30
C	0.004	0.007	0.09	0.18
D	0.114	0.122	2.90	3.10
E	0.169	0.176	4.30	4.48
e	0.0256BSC		0.65BSC	
H	0.246	0.256	6.25	6.50

Notes:

1. Controlling dimension: millimeters. Inches shown for reference only.

2. 'D' and 'E' do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15mm per side

3. Each lead centerline shall be located within ±0.10mm of its exact true position.

4. Leads shall be coplanar within 0.08mm at the seating plane.

5. Dimension 'B' does not include dambar protrusion. The dambar protrusion(s) shall not cause the lead width to exceed 'B' maximum by more than 0.08mm.

6. Dimension applies to the flat section of the lead between 0.10mm and 0.25mm from the lead tip.

7. 'A1' is defined as the distance from the seating plane to the lowest point of the package body (base plane).

Ordering Information

bq2057 _

Package Option:
SN = 8-pin narrow SOIC
TS = 8-pin TSSOP

Device:
bq2057 Advanced Li-Ion Linear Charger for One Cell (4.1V)
bq2057C Advanced Li-Ion Linear Charger for One Cell (4.2V)
bq2057T Advanced Li-Ion Linear Charger for Two Cells (8.2V)
bq2057W Advanced Li-Ion Linear Charger for Two Cells (8.4V)

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