Benchmarq Products
from Texas Instruments

bq2002D/T

NiCd/NiMH Fast-Charge Management ICs

Features

- ➤ Fast charge of nickel cadmium or nickel-metal hydride batteries
- ➤ Direct LED output displays charge status
- ➤ Fast-charge termination by rate of rise of temperature, maximum voltage, maximum temperature, and maximum time
- ➤ Internal band-gap voltage reference
- ➤ Optional top-off charge (bq2002T only)
- ➤ Selectable pulse-trickle charge rates (bq2002T only)
- ➤ Low-power mode
- ➤ 8-pin 300-mil DIP or 150-mil SOIC

General Description

The bq2002D/T Fast-Charge IC are low-cost CMOS battery-charge controllers able to provide reliable charge termination for both NiCd and NiMH battery applications. Controlling a current-limited or constant-current supply allows the bq2002D/T to be the basis for a cost-effective stand-alone or system-integrated charger. The bq2002D/T integrates fast charge with optional top-off and pulsed-trickle control in a single IC for charging one or more NiCd or NiMH battery cells.

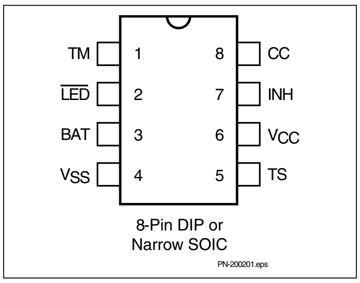
Fast charge is initiated on application of the charging supply or battery replacement. For safety, fast charge is inhibited if the battery temperature and voltage are outside configured limits.

Fast charge is terminated by any of the following:

- Rate of temperature rise
- Maximum voltage
- Maximum temperature
- Maximum time

After fast charge, the bq2002T optionally tops-off and pulse-trickles the battery per the pre-configured limits. Fast charge may be inhibited using the INH pin. The bq2002D/T may be placed in low-standby-power mode to reduce system power consumption.

Pin Connections



Pin Names

TM	Timer mode select input	TS	Temperature sense input
$\overline{LED}$	Charging status output	V_{CC}	Supply voltage input
BAT	Battery voltage input	INH	Charge inhibit input
V_{SS}	System ground	CC	Charge control output

bq2002D/T Selection Guide

Part No.	TCO	HTF	LTF	Fast Charge	Time-Out	Top-Off	Maintenance
bq2002D	$0.225 * V_{CC}$	$0.25 * V_{CC}$	$0.4 * V_{CC}$	C/4	320 min	C/64	C/256
				1C	80 min	C/16	C/256
				2C	40 min	None	C/128
bq2002T	$0.225 * V_{CC}$	$0.25 * V_{CC}$	None	C/4	440 min	None	None
				1C	110 min	None	None
				2C	55 min	None	None

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Pin Descriptions

TM **Timer mode input**

A three-level input that controls the settings for the fast charge safety timer, voltage termination mode, top-off, pulse-trickle, and voltage hold-off time.

$\overline{\text{LED}}$ **Charging output status**

Open-drain output that indicates the charging status.

BAT **Battery input voltage**

The battery voltage sense input. The input to this pin is created by a high-impedance resistor divider network connected between the positive and negative terminals of the battery.

V_{SS} **System ground**

TS **Temperature sense input**

Input for an external battery temperature monitoring thermistor.

V_{CC} **Supply voltage input**

5.0V ±20% power input.

INH **Charge inhibit input**

When high, INH suspends the fast charge in progress. When returned low, the IC resumes operation at the point where initially suspended.

CC **Charge control output**

An open-drain output used to control the charging current to the battery. CC switching to high impedance (Z) enables charging current to flow, and low to inhibit charging current. CC is modulated to provide top-off, if enabled, and pulse trickle.

Functional Description

Figures 2 and 3 show state diagrams of bq2002D/T and Figure 4 shows the block diagram of the bq2002D/T

Battery Voltage and Temperature Measurements

Battery voltage and temperature are monitored for maximum allowable values. The voltage presented on the battery sense input, BAT, should represent a single-cell potential for the battery under charge. A resistor-divider ratio of:

$$\frac{RB1}{RB2} = N - 1$$

is recommended to maintain the battery voltage within the valid range, where N is the number of cells, RB1 is the resistor connected to the positive battery terminal, and RB2 is the resistor connected to the negative battery terminal. See Figure 1.

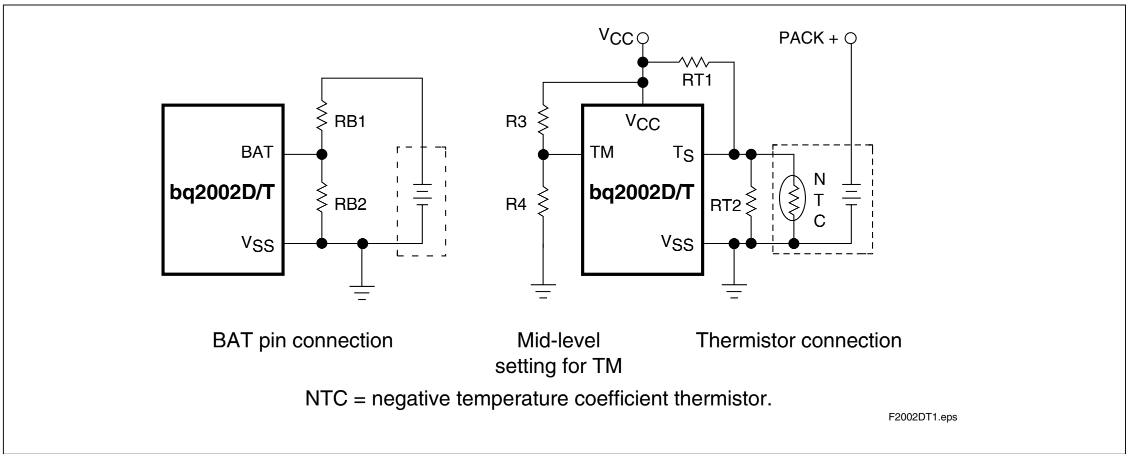


Figure 1. Voltage and Temperature Monitoring and TM Pin Configuration

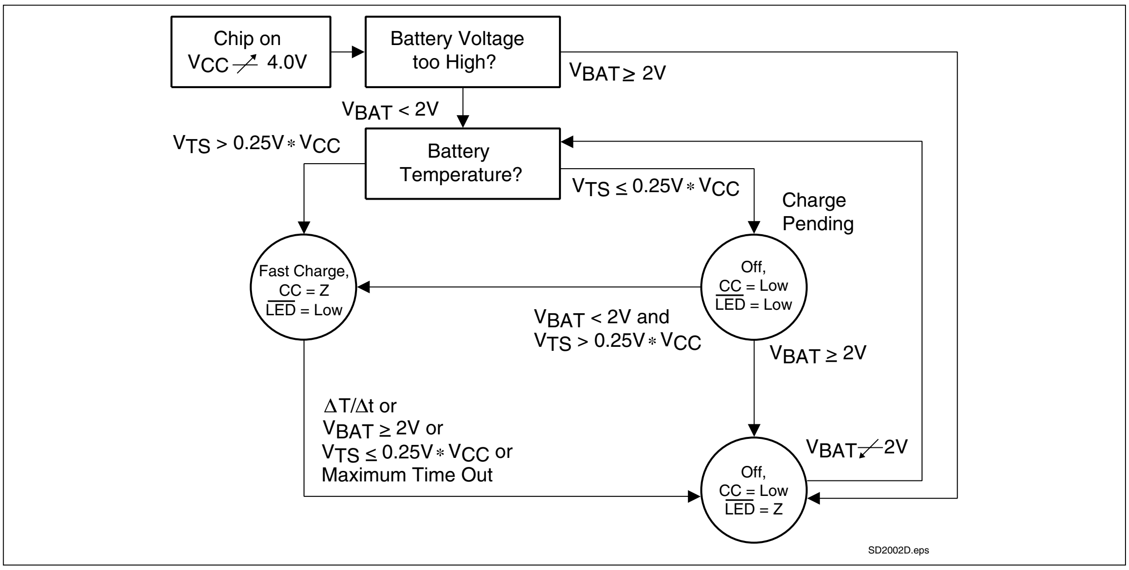


Figure 2. bq2002D State Diagram

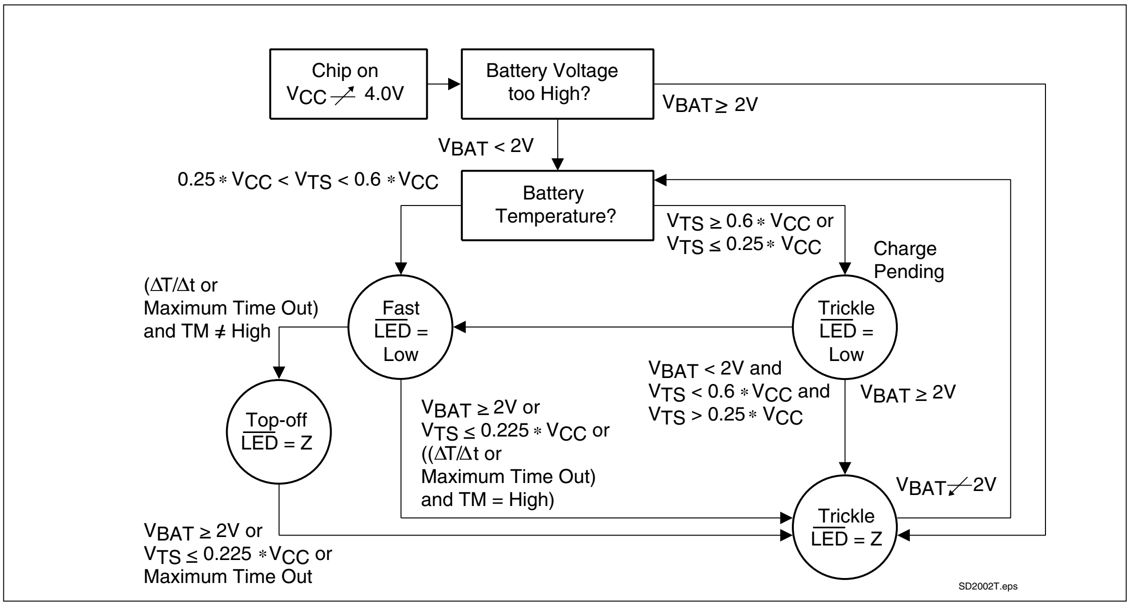


Figure 3. bq2002T State Diagram

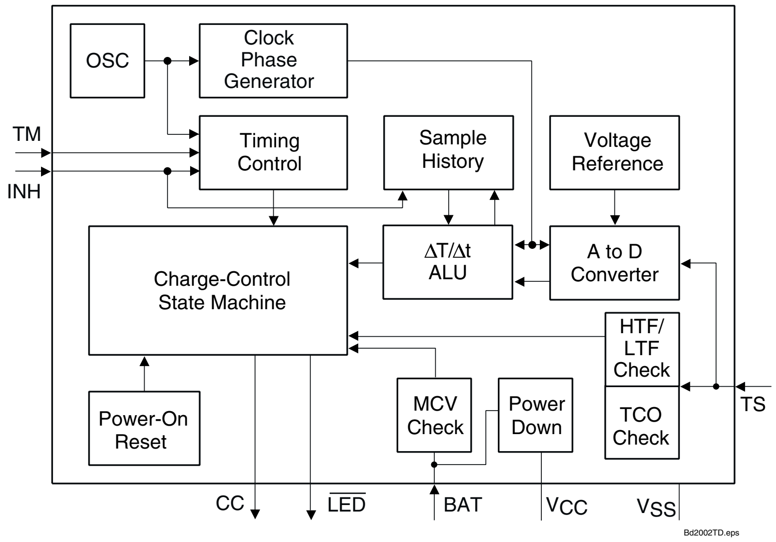


Figure 4. Block Diagram

Note: This resistor-divider network input impedance to end-to-end should be at least 200kΩ and less than 1 MΩ.

A ground-referenced negative temperature coefficient thermistor placed in proximity to the battery may be used as a low-cost temperature-to-voltage transducer. The temperature sense voltage input at TS is developed using a resistor-thermistor network between V_{CC} and V_{SS}. See Figure 1.

Starting A Charge Cycle

Either of two events starts a charge cycle (see Figure 5):

1. Application of power to V_{CC} or

2. Voltage at the BAT pin falling through the maximum cell voltage where:

$$V_{MCV} = 2V \pm 5\%.$$

If the battery is within the configured temperature and voltage limits, the IC begins fast charge. The valid battery voltage range is $V_{BAT} < V_{MCV}$. The valid temperature range is $V_{HTF} < V_{TS} < V_{LTF}$ for the bq2002T and $V_{HTF} < V_{TS}$ for the bq2002D where:

$$V_{LTF} = 0.4 * V_{CC} \pm 5\%.$$

$$V_{HTF} = 0.25 * V_{CC} \pm 5\% \text{ (bq2002T only)}.$$

If the battery voltage or temperature is outside of these limits, the IC pulse-trickle charges until the temperature falls within the allowed fast charge range or a new charge cycle is started.

Fast charge continues until termination by one or more of the four possible termination conditions:

- Rate of temperature rise
- Maximum voltage
- Maximum temperature
- Maximum time

ΔT/Δt Termination

The bq2002D/T samples at the voltage at the TS pin every 19s and compares it to the value measured three samples earlier. If the voltage has fallen 25.6mV or more, fast charge is terminated. The ΔT/Δt termination test is valid only when $V_{TCO} < V_{TS} < V_{LTF}$ for the bq2002T and $V_{TCO} < V_{TS}$ for the bq2002D.

Temperature Sampling

A sample is taken by averaging together 16 measurements taken 57µs apart. The resulting sample period (18.18ms) filters out harmonics around 55Hz. This tech-

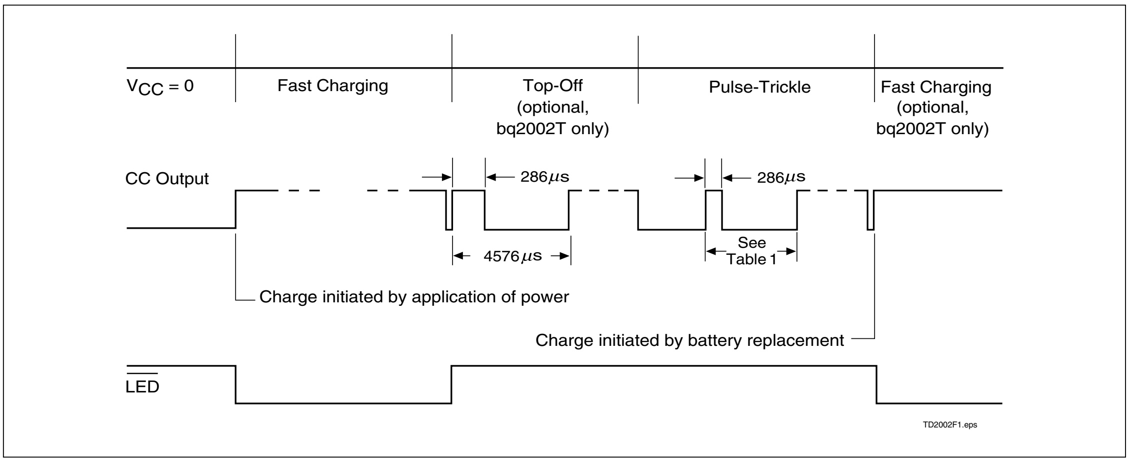


Figure 5. Charge Cycle Phases

nique minimizes the effect of any AC line ripple that may feed through the power supply from either 50Hz or 60Hz AC sources. Tolerance on all timing is ±20%.

Maximum Voltage, Temperature, and Time

Any time the voltage on the BAT pin exceeds the maximum cell voltage, V_{MCV}, fast charge or optional top-off charge is terminated.

Maximum temperature termination occurs anytime the voltage on the TS pin falls below the temperature cut-off threshold V_{TCO} where:

$$V_{TCO} = 0.225 * V_{CC} \pm 5\%$$

Maximum charge time is configured using the TM pin. Time settings are available for corresponding charge rates of C/4, 1C, and 2C. Maximum time-out termination is enforced on the fast-charge phase, then reset, and

Table 1. Fast-Charge Safety Time/Top-Off Table

	Corresponding Fast-Charge Rate	TM	Typical Fast-Charge and Top-Off Time Limits (minutes)	Top-Off Rate	Pulse-Trickle Rate	Pulse-Trickle Period (ms)
bq2002D	C/4	Mid	440	NA	NA	NA
	1C	Low	110	NA	NA	NA
	2C	High	55	NA	NA	NA
bq2002T	C/4	Mid	320	C/64	C/256	18.3
	1C	Low	80	C/16	C/256	73.1
	2C	High	40	Disabled	C/128	73.1

Notes: Typical conditions = 25°C, V_{CC} = 5.0V.
Mid = $0.5 * V_{CC} \pm 0.5V$
Tolerance on all timing is ±20%

enforced again on the top-off phase, if selected (bq2002T only). There is no time limit on the trickle-charge phase.

Top-off Charge—bq2002T Only

An optional top-off charge phase may be selected to follow fast charge termination for 1C and C/4 rates. This phase may be necessary on NiMH or other battery chemistries that have a tendency to terminate charge prior to reaching full capacity. With top-off enabled, charging continues at a reduced rate after fast-charge termination for a period of time selected by the TM pin. (See Table 1.) During top-off, the CC pin is modulated at a duty cycle of 286µs active for every 4290µs inactive. This modulation results in an average rate 1/16th that of the fast charge rate. Maximum voltage, time, and temperature are the only termination methods enabled during top-off.

Pulse-Trickle Charge—bq2002T Only

Pulse-trickle is used to compensate for self-discharge while the battery is idle in the charger. The battery is pulse-trickle charged by driving the CC pin active for a period of 286µs for every 72.9ms of inactivity for 1C and 2C selections, and 286µs for every 17.9ms of inactivity for C/4 selection. This results in a trickle rate of C/256 for the top-off enabled mode and C/128 otherwise.

TM Pin

The TM pin is a three-level pin used to select the charge timer, top-off, voltage termination mode, trickle rate, and voltage hold-off period options. Table 1 describes the states selected by the TM pin. The mid-level selection input is developed by a resistor divider between V_{CC} and ground that fixes the voltage on TM at $V_{CC}/2 \pm 0.5V$. See Figure 5.

Charge Status Indication

In the fast charge and charge pending states, and whenever the inhibit pin is active, the $\overline{LED}$ pin goes low. The $\overline{LED}$ pin is driven to the high-Z state for all other conditions. Figure 3 outlines the state of the $\overline{LED}$ pin during charge.

Charge Inhibit

Fast charge and top-off may be inhibited by using the INH pin. When high, INH suspends all fast charge and top-off activity and the internal charge timer. INH freezes the current state of $\overline{LED}$ until inhibit is removed. Temperature monitoring is not affected by the INH pin. During charge inhibit, the bq2002D/T continues to pulse-trickle charge the battery per the TM selection. When INH returns low, charge control and the charge timer resume from the point where INH became active. The V_{TS} sample history is cleared by INH.

Low-Power Mode

The IC enters a low-power state when V_{BAT} is driven above the power-down threshold (V_{PD}) where:

$$V_{PD} = V_{CC} - (1V \pm 0.5V)$$

Both the CC pin and the $\overline{LED}$ pin are driven to the high-Z state. The operating current is reduced to less than 1µA in this mode. When V_{BAT} returns to a value below V_{PD}, the IC pulse-trickle charges until the next new charge cycle begins.

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	0	+70	°C	Commercial
T_{STG}	Storage temperature	-40	+85	°C	
T_{SOLDER}	Soldering temperature	-	+260	°C	10 sec max.
T_{BIAS}	Temperature under bias	-40	+85	°C	

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 (TA = 0 to 70°C; VCC ±20%)

Symbol	Parameter	Rating	Tolerance	Unit	Notes
V_{TCO}	Temperature cutoff	$0.225 * V_{CC}$	±5%	V	$V_{TS} \leq V_{TCO}$ terminates fast charge and top-off
V_{HTF}	High-temperature fault	$0.25 * V_{CC}$	±5%	V	$V_{TS} \leq V_{HTF}$ inhibits fast charge start
V_{LTF}	Low-temperature fault	$0.4 * V_{CC}$	±5%	V	$V_{TS} \geq V_{LTF}$ inhibits fast charge start (bq2002T only)
V_{MCV}	Maximum cell voltage	2	±5%	V	$V_{BAT} \geq V_{MCV}$ inhibits/terminates fast charge

Recommended DC Operating Conditions (T_A = 0 to 70°C)

Symbol	Condition	Minimum	Typical	Maximum	Unit	Notes
V_{CC}	Supply voltage	4.0	5.0	6.0	V	
V_{BAT}	Battery input	0	-	V_{CC}	V	
V_{TS}	Thermistor input	0.5	-	V_{CC}	V	$V_{TS} < 0.5V$ prohibited
V_{IH}	Logic input high	0.5	-	-	V	INH
	Logic input high	V_{CC} - 0.5	-	-	V	TM
V_{IM}	Logic input mid	$\frac{V_{CC}}{2} - 0.5$	-	$\frac{V_{CC}}{2} + 0.5$	V	TM
V_{IL}	Logic input low	-	-	0.1	V	INH
	Logic input low	-	-	0.5	V	TM
V_{OL}	Logic output low	-	-	0.8	V	$\overline{LED}$, CC, I_{OL} = 10mA
V_{PD}	Power down	V_{CC} - 1.5	-	V_{CC} - 0.5	V	$V_{BAT} \geq V_{PD}$ max. powers down bq2002D/T; $V_{BAT} < V_{PD}$ min. = normal operation.
I_{CC}	Supply current	-	-	500	µA	Outputs unloaded, V_{CC} = 5.1V
I_{SB}	Standby current	-	-	1	µA	V_{CC} = 5.1V, $V_{BAT} = V_{PD}$
I_{OL}	$\overline{LED}$, CC sink	10	-	-	mA	@$V_{OL} = V_{SS}$ + 0.8V
I_L	Input leakage	-	-	±1	µA	INH, CC, V = V_{SS} to V_{CC}
I_{OZ}	Output leakage in high-Z state	-5	-	-	µA	$\overline{LED}$, CC

Note: All voltages relative to V_{SS}.

Impedance

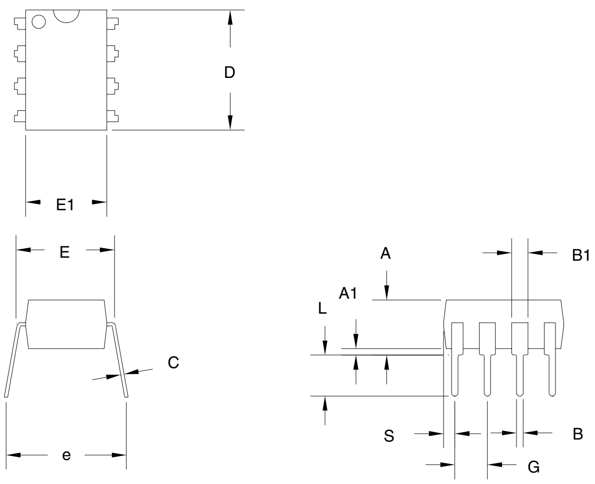
Symbol	Parameter	Minimum	Typical	Maximum	Unit
R_{BAT}	Battery input impedance	50	-	-	MΩ
R_{TS}	TS input impedance	50	-	-	MΩ

Timing (T$_A$ = 0 to +70°C; V$_{CC}$ ±10%)

Symbol	Parameter	Minimum	Typical	Maximum	Unit	Notes
d_{FCV}	Time-base variation	-20	-	20	%	

Note: Typical is at T_A = 25°C, V_{CC} = 5.0V.

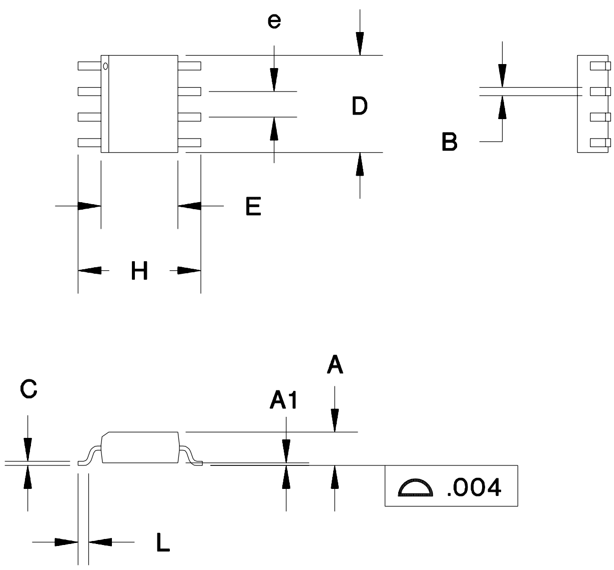
8-Pin DIP (PN)



8-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	0.350	0.380	8.89	9.65
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

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

Data Sheet Revision History

Change No.	Page No.	Description	Nature of Change
1	3	Was: Table 1 gave the bq2002D/T Operational Summary. Is: Figure 2 gives the bq2002D/T Operational Summary.	Changed table to figure.
1	5	Added top-off values.	Added column and values.
2	All	Revised and expanded this data sheet	
3	All	Revised and included bq2002D	Addition of device
4		Specified package information for the bq2002D	

Notes: Change 1 = Sept. 1996 B changes from Aug. 1994.

Change 2 = Aug. 1997 C changes from Sept. 1996 B.

Change 3 = Jan. 1999 D changes from Aug. 1997 C.

Change 4 = Jan. 2000 E changes from Jan. 1999 D.

Ordering Information

bq2002 ___ ___

Package Option:
PN = 8-pin plastic DIP
SN = 8-pin narrow SOIC*

Device:
D = bq2002D Fast-Charge IC
T = bq2002T Fast-Charge IC

* bq2002D is only available in the 8-pin narrow SOIC package