bq2002

Fast Charge IC

Features

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

General Description

The bq2002 Fast Charge IC is a low-cost CMOS battery charge controller providing reliable charge termination for both NiCd and NiMH battery applications. Controlling a current-limited or constant-current supply allows the bq2002 to be the basis for a cost-effective stand-alone or system-integrated charger. The bq2002 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.

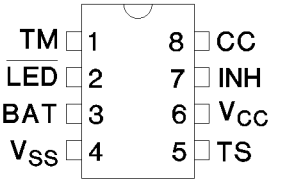
Fast charge is initiated on application of the charging supply or battery replacement. For safety, fast charge is inhibited if the battery temperature and voltage are outside configured limits.

Fast charge is terminated by any of the following:

- Peak voltage detection (PVD)
- Negative delta voltage (-ΔV)
- Maximum temperature
- Maximum time

After fast charge, the bq2002 optionally tops-off and pulse-trickles the battery per the pre-configured limits. Fast charge may be inhibited using the INH pin. The bq2002 may also be placed in low-standby-power mode to reduce system power consumption.

Pin Connections



8-Pin DIP or
Narrow SOIC

PN-55

Pin Names

TM	Timer mode select input	TS	Temperature sense input
$\overline{LED}$	Charging status output	V_{CC}	5.0V ±20% power
BAT	Battery voltage input	INH	Charge inhibit input
V_{SS}	System ground	CC	Charge control output

Pin Descriptions

TM **Timer mode input**

TM is 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**

This open-drain output indicates the charging status.

BAT **Battery input voltage**

BAT is the battery voltage sense input. This potential is generally developed 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**

This input is for an external battery temperature monitoring thermistor.

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

5.0V ±20% power input.

INH **Charge inhibit input**

When high, the bq2002 suspends the fast charge in progress. When returned low, the bq2002 resumes operation at the point where initially suspended.

CC **Charge control output**

CC is an open-drain output that is 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

Figure 1 illustrates the charge control status during a bq2002 charge cycle. Figure 2 outlines the various bq2002 operational states and their associated conditions, which are described in detail in the following sections.

Charge Action Control

The bq2002 initiates a charge action by the application of power on V_{CC} or by battery replacement. Control of the charge action is then determined by inputs from TM, TS, and BAT.

Following charge initiation, the bq2002 checks for acceptable battery voltage and temperature. If the battery voltage or temperature is outside of the fast charge limits, pulse-trickle initiates at a rate determined by the TM pin. If the battery temperature and voltage are valid at charge initiation, fast charge begins.

The bq2002 then tests for the full-charge conditions: -ΔV, PVD, maximum temperature, or maximum time.

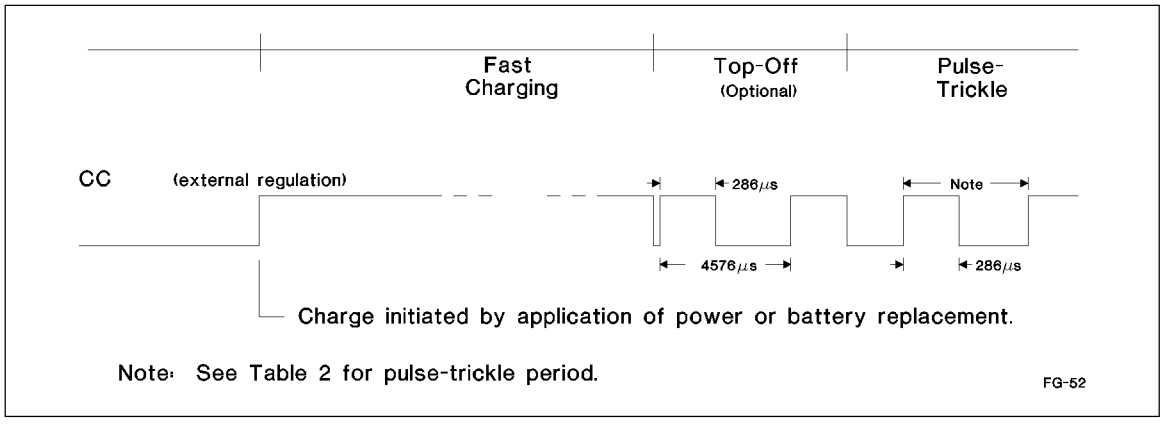


Figure 1. Example Charging Action Events

Charge Status Indication

A fast charge in progress is uniquely indicated when the $\overline{LED}$ pin goes low. The $\overline{LED}$ pin is driven to the high-Z state for all conditions other than fast charge. Figure 2 outlines the state of the $\overline{LED}$ pin during charge.

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:

$$\frac{R1}{R2} = N - 1$$

is recommended to maintain the battery voltage within the valid range, where N is the number of cells, R1 is the resistor connected to the positive battery terminal, and R2 is the resistor connected to the negative battery terminal. See Figure 3.

Note: This resistor-divider network input impedance to BAT should be above 200KΩ to protect the bq2002.

A ground-referenced negative temperature coefficient thermistor placed in close 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 3.

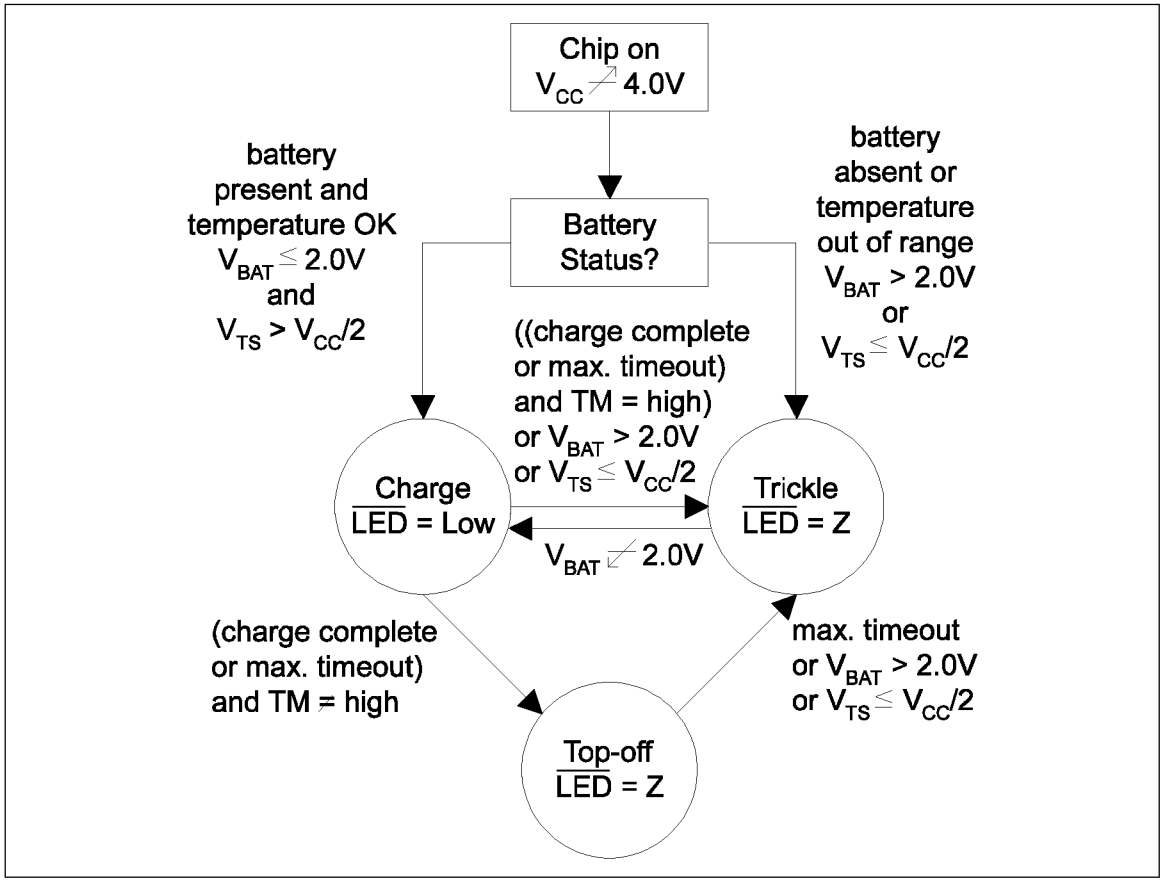


Figure 2. Operational Summary

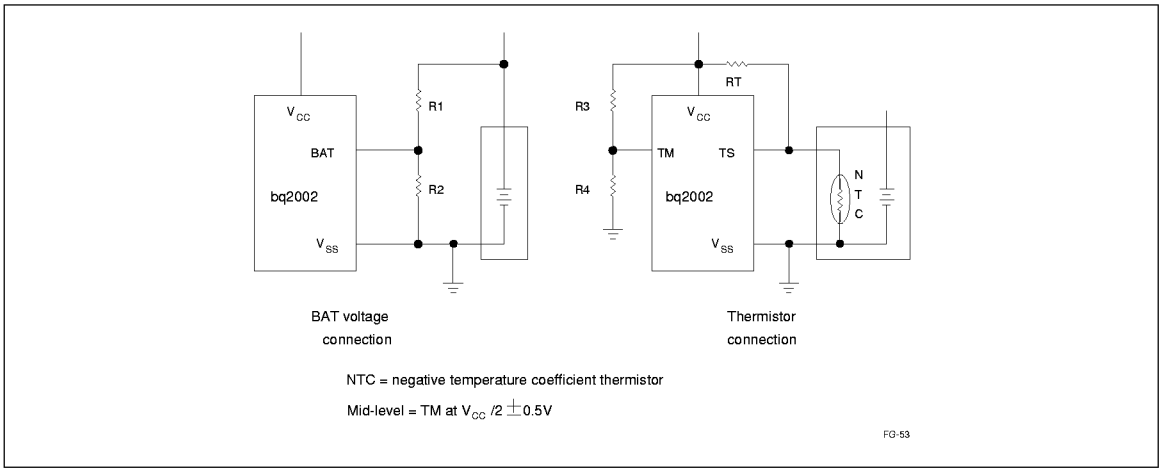


Figure 3. Voltage and Temperature Limit Measurement

TM Pin

The TM pin is a three-level pin used to select the various charge timer, top-off, voltage termination mode, trickle rates, and voltage hold-off periods. Table 1 describes the various states selected by the TM pin. The mid-level selection input is developed by a resistor divider between V_{CC} and ground. See Figure 3.

Charge Initiation

Application of power or battery voltage falling from above 2V initiates a charge action. If the battery is within the configured temperature and voltage limits, the bq2002 begins fast charge. The valid battery voltage range is BAT < 2V. The valid temperature range is TS > 0.5 * V_{CC}. If the battery voltage or temperature is outside of these limits, the bq2002 pulse-trickle charges until the next valid charge initiation.

The bq2002 continues to fast charge the battery until termination by one or more of the four possible termination conditions:

- Peak voltage detection (PVD)
- Negative delta voltage (-ΔV)
- Maximum time
- Maximum temperature (TCO)

V_{BAT} > V_{MCV} stops fast charge or top-off.

Voltage Termination Hold-off

A hold-off time occurs at the start of fast charging. During the hold-off time, the PVD and -ΔV terminations are disabled (see Table 1). Once past the initial fast charge hold-off time, the PVD and -ΔV terminations are re-enabled. Maximum temperature is not affected by the hold-off period.

PVD and -ΔV Termination

The bq2002 has two modes for voltage termination depending on the state of TM. For standard -ΔV (TM = high), if V_{BAT} is lower than any previously measured value by 12mV typical, the fast charge phase of the charge action is terminated. For PVD termination (TM = low or mid), a threshold of 0 to 5mV typical is used. The PVD and -ΔV tests are valid for: 1V < BAT < 2V.

Maximum Time and Temperature

The bq2002 also terminates fast charge for maximum temperature (TCO) and maximum time. TCO reference levels provide the maximum limits for battery temperature during fast charge. If this limit is exceeded, then fast charge or optional top-off charge is terminated.

Maximum time selection is programmed using the TM pin. Time settings are available for corresponding charge rates of C/2, 1C, and 2C.

Top-off Charge

An optional top-off charge phase is selected to follow fast charge termination for 1C and C/2 rates. This may be necessary to accommodate battery chemistries that have a tendency to terminate charge prior to achieving full capacity. With top-off enabled, charging continues 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 results in an average rate 1/16th that of the fast charge rate. Maximum time and temperature (TCO) terminations are the only methods enabled during top-off.

Pulse-Trickle Charge

Pulse-trickle is used to compensate for self-discharge while the battery is idle in the charger. The battery is pulse-trickle charged after fast charge or top off by driving the CC pin active for a period of 286µs for every 18.0ms of inactivity for 1C and 2C selections, and 286µs for every 8.86ms of inactivity for C/2 selection. This results in a trickle rate of C/64 for the top-off enabled mode and C/32 otherwise.

Charge Inhibit

Fast charge and top-off may be inhibited by using the INH pin of the bq2002. When high, the bq2002 suspends all fast charge and top-off activity and the internal charge timer control. INH freezes the current state of $\overline{\text{LED}}$ until inhibit is removed. Temperature detection is not affected by the INH pin. During charge inhibit, the bq2002 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 went active.

Low-Power Mode

When BAT is driven above V_{PD}, the bq2002 assumes a low-power operational state. Both the CC pin and the $\overline{\text{LED}}$ pin are driven to the high-Z state. The operating current of the bq2002 is reduced to less than 1µA in this mode. Subsequently, when BAT returns to a value below V_{PFD}, trickle charge is initiated.

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

Corresponding Fast Charge Rate	TM	Termination	Fast Charge Top-off and Safety Time (minutes)	PVD and -ΔV Hold-Off Time (seconds)	Top-Off Rate	Pulse-Trickle Rate	Pulsed Trickle Period (ms)
			Typical	Typical			
C/2	Mid	PVD	160	600	C/32	C/64	9.14
1C	Low	PVD	80	300	C/16	C/64	18.3
2C	High	-ΔV	40	150	Disabled	C/32	18.3

Notes: $T_A = 25°C$, $V_{CC} = 5.0V$.

Mid = $0.5 * V_{CC}$.

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 (T_A = 0 to 70°C; V_{CC} ±20%)

Symbol	Parameter	Rating	Tolerance	Unit	Notes
V_{TCO}	Temperature cutoff	0.5 * V_{CC}	±5%	V	$V_{TS} \le V_{TCO}$ inhibits charge
V_{MCV}	Maximum cell voltage	2	±5%	V	$V_{BAT} > V_{MCV}$ inhibits/terminates 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_{DET}	-ΔV, PVD detect voltage	1	-	2	V	
V_{BAT}	Battery input	0	-	V_{CC}	V	
V_{TS}	Thermistor input	0.5	-	V_{CC}	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	$\frac{V_{CC}}{2} - 500mV$	-	$\frac{V_{CC}}{2} + 500mV$	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 bq2002; $V_{BAT} < V_{PD}$ min. = normal operation.
I_{CC}	Supply current	-	-	250	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 (TA = 0 to +70°C; VCC ±10%)

Symbol	Parameter	Minimum	Typical	Maximum	Unit	Notes
d_{FCV}	Fast charge safety time variation	0.80	1.0	1.20	-	

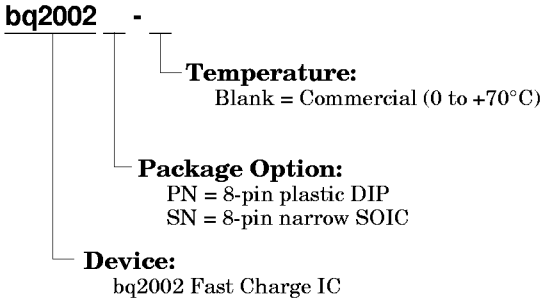
Note: Typical is at T_A = 25°C, V_{CC} = 5.0V.

Data Sheet Revision History

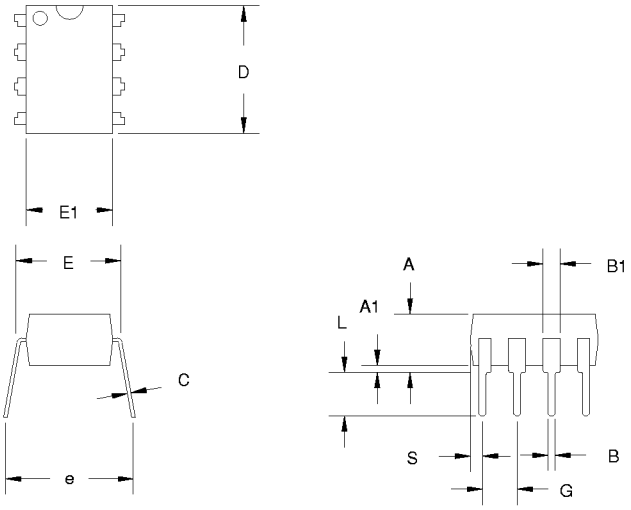
Change No.	Page No.	Description	Nature of Change
1	3	Was: Table 1 gave the bq2002 Operational Summary. Is: Figure 2 gives the bq2002 Operational Summary.	Changed table to figure.
1	5	Added Termination column to table and Top-off values.	Added column and values.

Note: Change 1 = Sept. 1996 B changes from July 1994.

Ordering Information



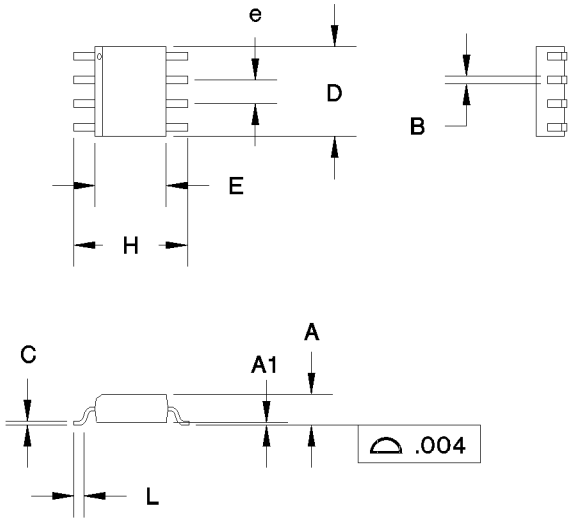
8-Pin DIP (PN)



8-Pin PN (0.300" DIP)

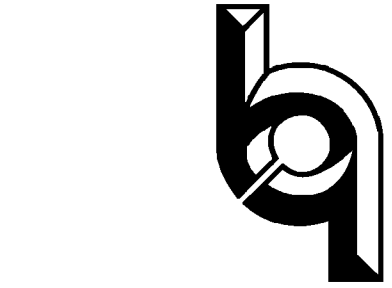
Dimension	Inches		Millimeters	
	Min.	Max.	Min.	Max.
A	0.160	0.180	4.06	4.57
A1	0.015	0.040	0.38	1.02
B	0.015	0.022	0.38	0.56
B1	0.055	0.065	1.40	1.65
C	0.008	0.013	0.20	0.33
D	0.350	0.380	8.89	9.65
E	0.300	0.325	7.62	8.26
E1	0.230	0.280	5.84	7.11
e	0.300	0.370	7.62	9.40
G	0.090	0.110	2.29	2.79
L	0.115	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



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