UNITRODE

bq2007

Fast-Charge IC

Features

- Fast charging and conditioning of NiCd and NiMH batteries
  - Precise charging independent of battery pack number of cells
  - Discharge-before-charge on demand
  - Pulse trickle charge conditioning
  - Battery undervoltage and overvoltage protection
- Built-in 10-step voltage-based charge status monitoring
  - Charge status display options include seven-segment monotonic bargraph and fully decoded BCD digit
  - Display interface options for direct drive of LCD or LED segments
  - Charger state status indicators for pending, discharge, charge, completion, and fault
  - Audible alarm for charge completion and fault conditions
- Charge control flexibility
  - Fast or Standard speed charging
  - Top-off mode for NiMH
  - Charge rates from $\frac{1}{8}$ to 2C (30 minutes to 8 hours)
- Charge termination by:
  - Negative delta voltage (-ΔV)
  - Peak voltage detect (PVD)
  - Maximum voltage
  - Maximum time
  - Maximum temperature
- High-efficiency switch-mode design
  - Ideal for small heat-sensitive enclosures
- 24-pin, 300-mil SOIC or DIP

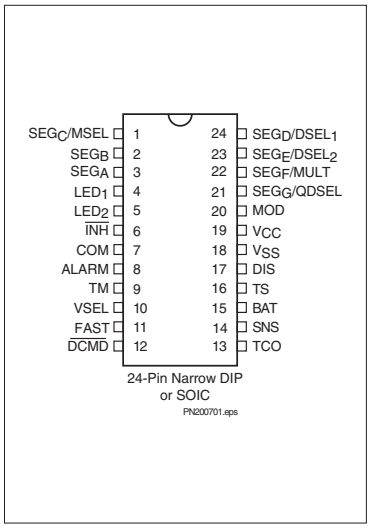
General Description

The bq2007 is a highly integrated monolithic CMOS IC designed to provide intelligent battery charging and charge status monitoring for stand-alone charge systems.

The bq2007 provides a wide variety of charge status display formats. The bq2007 internal charge status monitor supports up to a seven-segment bargraph or a single BCD digit display. The bargraph display indicates up to seven monotonic steps, whereas the BCD digit counts in ten steps of 10% increments. The bq2007 output drivers can direct-drive either an LCD or LED display.

Charge action begins either by application of the charging supply or by replacement of the battery pack. For safety, charging is inhibited until battery temperature and voltage are within configured limits.

Pin Connections



Pin Names

SEG_C/MSEL	Display output segment C/ driver mode select
SEG_B	Display output segment B
SEG_A	Display output segment A
LED_1	Charge status output 1
LED_2	Charge status output 2
$\overline{INH}$	Charge inhibit input
COM	Common LED/LCD output
ALARM	Audio alarm output
TM	Timer mode select
VSEL	Voltage termination select
FAST	Fast charge rate select
$\overline{DCMD}$	Discharge command
TCO	Temperature cutoff
SNS	Sense resistor input
BAT	Battery voltage
TS	Temperature sense
DIS	Discharge control
V_{SS}	System ground
V_{CC}	5.0V ±10% power
MOD	Modulation control
SEG_G/QDSEL	Display output segment G/ charge status display select
SEG_F/MULT	Display output segment F/ multi-cell pack select
SEG_E/$DSEL_2$	Display output segment E/ display select 2
SEG_D/$DSEL_1$	Display output segment D/ display select 1

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The acceptable battery temperature range is set by an internal low-temperature threshold and an external high-temperature cutoff threshold. The absolute temperature is monitored as a voltage on the TS pin with the external thermistor network shown in Figure 2.

The bq2007 provides for undervoltage battery protection from high-current charging if the battery voltage is less than the normal end-of-discharge value. In the case of a deeply discharged battery, the bq2007 enters the charge-pending state and attempts trickle-current conditioning of the battery until the voltage increases. Should the battery voltage fail to increase above the discharge value during the undervoltage time-out period, a fault condition is indicated.

Discharge-before-charge may be selected to automatically discharge the battery pack on battery insertion or with a push-button switch. Discharge-before-charge on demand provides conditioning services that are useful to correct or prevent the NiCd voltage depression, or "memory" effect, and also provide a zero capacity reference for accurate capacity monitoring.

After prequalification and any required discharge-before-charge operations, charge action begins until one of the full-charge termination conditions is detected. The bq2007 terminates charging by any of the following methods:

- Negative delta voltage (-ΔV)
- Peak voltage detect (PVD)
- Maximum absolute temperature
- Maximum battery voltage
- Maximum charge time-out

The bq2007 may be programmed for negative delta voltage (-ΔV) or peak voltage detect (PVD) charge termination algorithms. The VSEL input pin selects -ΔV or PVD termination to match the charge rate and battery characteristics.

To provide maximum safety for battery and system, charging terminates based on maximum temperature cutoff (TCO), maximum cutoff voltage (MCV), and maximum time-out (MTO). The TCO threshold is the maximum battery temperature limit for charging. TCO terminates charge action when the temperature sense input voltage on the TS pin drops below the TCO pin voltage threshold. MCV provides battery overvoltage protection by detecting when the battery cell voltage (V_{CELL} = V_{BAT} - V_{SNS}) exceeds the VMCV value and terminates fast charge, standard charge, or top-off charge. The maximum time-out (MTO) termination occurs when the charger safety timer has completed during the active charge state.

The bq2007 indicates charge state status with an audio alarm output option and two dedicated output pins with programmable display options. The DSEL1–2 inputs can select one of the three display modes for the LED1–2 outputs.

Charger status is indicated for:

- Charge pending
- Charge in progress
- Charge complete
- Fault condition

Pin Descriptions

$SEG_{A–G}$ Display output segments A–G

State-of-charge monitoring outputs. QDSEL input selects the bargraph or BCD digit display mode. See Table 3.

MSEL Display driver mode select

Soft-programmed input selects LED or LCD driver configuration at initialization. When MSEL is pulled up to V_{CC}, outputs $SEG_{A–G}$ are LED interface levels; when MSEL is pulled down to V_{SS}, outputs $SEG_{A–G}$ are LCD levels.

$DSEL_1$–$DSEL_2$ Display mode select 1–2

Soft-programmed inputs control the $LED_{1—2}$ charger status display modes at initialization. See Table 2.

MULT Fixed-cell pack select

Soft-programmed input is pulled up to V_{CC} when charging multi-cell packs and is pulled down to V_{SS} for charging packs with a fixed number of cells.

QDSEL State-of-charge display select

The QDSEL input controls the $SEG_{A–G}$ state-of-charge display modes. See Table 3.

LED_1–LED_2 Charger status outputs 1–2

Charger status output drivers for direct drive of LED displays. Display modes are selected by the DSEL input. See Table 2.

$\overline{INH}$ Charge inhibit input

When low, the bq2007 suspends all charge actions, drives all outputs to high impedance, and assumes a low-power operational state. When transitioning from low to high, a charge cycle is initiated. See page 10 for details.

COM **Common LCD/LED output**

Common output for LCD/LED display $SEG_{A—G}$. Output is high-impedance during initialization to allow reading of soft-programmed inputs $DSEL_1$, $DSEL_2$, MSEL, MULT, and QDSEL.

ALARM **Audio output**

Audio alarm output.

TM **Timer mode select**

TM is a three-level input that controls the settings for charge control functions. See Table 5.

VSEL **Voltage termination select**

This input switches the voltage detect sensitivity. See Table 5.

FAST **Fast charge rate select**

The FAST input switches between Fast and Standard charge rates. See Table 4.

$\overline{DCMD}$ **Discharge command**

The $\overline{DCMD}$ input controls the discharge-before-charge function. A negative-going pulse initiates a discharge action. If $\overline{DCMD}$ is connected to V_{SS}, automatic discharge-before-charge is enabled. See Figure 3.

TCO **Temperature cut-off threshold input**

Minimum allowable battery temperature-sensor voltage. If the potential between TS and SNS is less than the voltage at the TCO input, then any fast charging or top-off charging is terminated.

SNS **Sense resistor input**

SNS controls the switching of MOD output based on an external sense resistor. This provides the lower reference potential for the BAT pin and the TS pin.

BAT **Battery voltage input**

Battery voltage sense input referenced to SNS for the battery pack being charged. This resistor divider network is connected between the positive and the negative terminals of the battery. See Figure 1.

TS **Temperature sense input**

Input referenced to SNS for battery temperature monitoring negative temperature coefficient (NTC) thermistor.

DIS **Discharge control**

DIS is a push-pull output that controls an external transistor to discharge the battery before charging.

V_{SS} **Ground**

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

MOD **Current-switching control output**

Push/pull output that controls the charging current to the battery. MOD switches high to enable current flow and low to inhibit current flow.

Functional Description

Figure 1 illustrates charge control and display status during a bq2007 charge cycle. Table 1 summarizes the bq2007 operational features. The charge action states and control outputs are given for possible input conditions.

Charge Action Control

The bq2007 charge action is controlled by input pins $\overline{DCMD}$, VSEL, FAST, and TM. When charge action is initiated, the bq2007 enters the charge-pending state, checks for acceptable battery voltage and temperature, and performs any required discharge-before-charge operations. $\overline{DCMD}$ controls the discharge-before-charge function, and VSEL, FAST, and TM select the charger configuration. See Tables 4 and 5.

During charging, the bq2007 continuously tests for charge termination conditions: negative delta voltage, peak voltage detection, maximum time-out, battery over-voltage, and high-temperature cutoff. When the charge state is terminated, a trickle charge continues to compensate for self-discharge and maintain the fully charged condition.

Charge Status Indication

Table 2 summarizes the bq2007 charge status display indications. The charge status indicators include the DIS output, which can be used to indicate the discharge state, the audio ALARM output, which indicates charge completion and fault conditions, and the dedicated status outputs, LED_1 and LED_2.

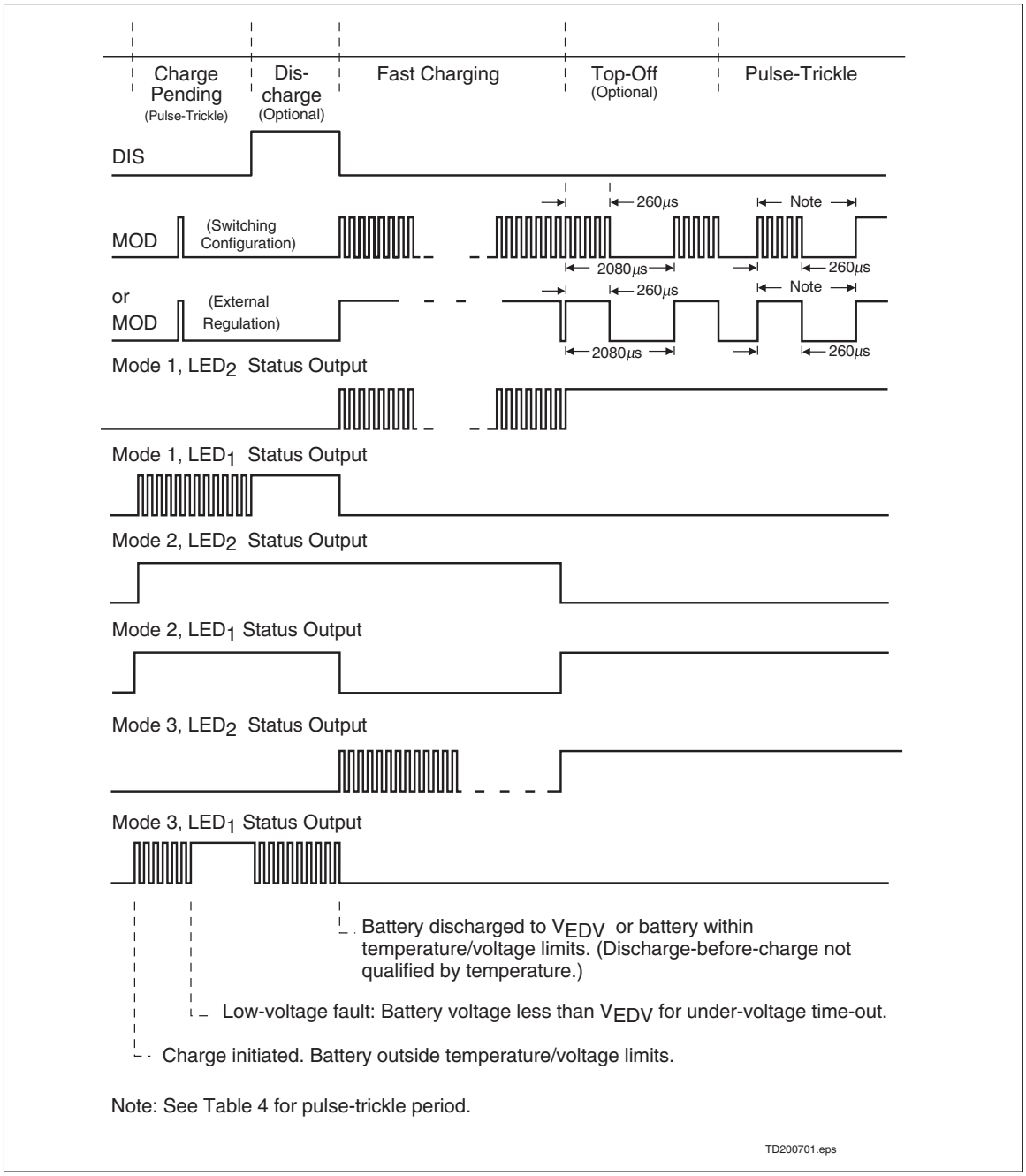


Figure 1. Example Charging Action Events

Outputs LED_{1-2} have three display modes that are selected at initialization by the input pins $DSEL_1$ and $DSEL_2$. The $DSEL_1$ and $DSEL_2$ input pins, when pulled down to V_{SS}, are intended for implementation of a simple two-LED system. LED_2 indicates the precharge status (i.e., charge pending and discharge) and LED_1 indicates the charge status (i.e., charging and completion). $DSEL_1$ pulled up to V_{CC} and $DSEL_2$ pulled down to V_{SS} mode is for implementation of a single tri-color LED such that discharge, charging, and completion each have a unique color. $DSEL_1$ pulled down to V_{SS} and $DSEL_2$ pulled up to V_{CC} allows for fault status information to be displayed.

Audio Output Alarm

The bq2007 audio alarm output generates an audio tone to indicate a charge completion or fault condition. The audio alarm output is a symmetrical duty-cycle AC signal that is compatible with standard piezoelectric alarm elements. A valid battery insertion is indicated by a single high-tone beep of ½-second typical duration. The charge completion and fault conditions are indicated by a 9.5- to 15-second high-tone sequence of ½-second typical duration at a 2-second typical repetition rate.

Charge Status Monitoring

The bq2007 charge status monitor may display the battery voltage or charge safety timer as a percentage of the full-charged condition. These options are selected with the MULT soft-programmed input pin.

When MULT is pulled down to V_{SS}, the battery charge status is displayed as a percentage of the battery voltage, and the single-cell battery voltage at the BAT pin is compared with internal charge voltage reference thresholds. When V_{BAT} is greater than the internal thresholds of V_{20}, V_{40}, V_{60}, or V_{80}, the respective 20%, 40%, 60%, or 80% display outputs are activated. The battery voltage directly indicates 20% charge increments, while the 10% charge increments use a timer that is a function of the charge safety timer.

When MULT is pulled down to V_{SS} and when V_{BAT} exceeds V_{20} during charging, the 20% charge indication is activated and the timer begins counting for a period equal to $1/64$ to $1/32$ of the charge safety time-out period. When the timer count is completed, the 30% charge indication is activated. Should V_{BAT} exceed V_{40} prior to the timer count completion, the charge status monitor activates the 30% and 40% indications. This technique

Table 1. bq2007 Operational Summary

Charge Action State	Conditions	MOD Output	DIS Output
Battery absent	V_{CC} applied and $V_{CELL} \geq V_{MCV}$	Trickle charge per Table 4	Low
Charge initiation	V_{CC} applied or V_{CELL} drops from $\geq V_{MCV}$ to $< V_{MCV}$	-	Low
Discharge-before-charge	$\overline{DCMD}$ high-to-low transition or to V_{SS} on charge initiation and $V_{EDV} < V_{CELL} < V_{MCV}$	Low	High
Charge pending	Charge initiation occurred and $V_{TEMP} \geq V_{LTF}$ or $V_{TEMP} \leq V_{TCO}$ or $V_{CELL} < V_{EDV}$	Trickle charge per Table 4	Low
Fast charging	Charge pending complete and FAST = V_{CC}	Low if $V_{SNS} > 250mV$; high if $V_{SNS} < 200mV$	Low
Standard charging	Charge pending complete and FAST = V_{SS}	Low if $V_{SNS} > 250mV$; high if $V_{SNS} < 200mV$	Low
Charge complete	$-\Delta V$ termination or $V_{TEMP} < V_{TCO}$ or PVD ≥ 0 to -3mV/cell or maximum time-out or $V_{CELL} > V_{MCV}$	-	-
Top-off pending	VSEL = V_{CC}, charge complete and $V_{TEMP} \geq V_{LTF}$ or $V_{TEMP} \leq V_{TCO}$ or $V_{CELL} < V_{EDV}$	Trickle charge per Table 4	Low
Top-off charging	VSEL = V_{CC} and charge complete and time-out not exceeded and $V_{TEMP} > V_{TCO}$ and $V_{CELL} < V_{MCV}$	Activated per V_{SNS} for 73ms of every 585ms	Low
Trickle charging	Charge complete and top-off disabled or top-off complete or pending	Trickle charge per Table 4	Low
Fault	Charge pending state and charge pending time-out (t_{PEND}) complete	Trickle charge per Table 4	Low

Definitions: $V_{CELL} = V_{BAT} - V_{SNS}$; $V_{MCV} = 0.8 * V_{CC}$; $V_{EDV} = 0.262 * V_{CC}$ or $0.4 * V_{CC}$; $V_{TEMP} = V_{TS} - V_{SNS}$; $V_{LTF} = 0.5 * V_{CC}$.

is used for all the odd percentage charge indications to assure a monotonic charge status display.

When MULT is pulled up to V_{CC}, the bq2007 charge status monitor directly displays $\frac{1}{32}$ of the charge safety timer as a percentage of full charge. This method is recommended over the voltage-based method when charging fixed-cell packs where the battery terminal voltages can vary greatly between packs. This method offers an accurate charge status indication when the battery is fully discharged. When using the timer-based method, discharge-before-charge is recommended.

During discharge with MULT pulled down to V_{SS}, the charge status monitor indicates the percentage of the battery voltage by comparing V_{BAT} to the internal discharge voltage reference thresholds. In BCD format, the discharge thresholds V_{80}, V_{60}, V_{40}, and V_{20} correspond to a battery charge state indication of 90%, 70%, 50%, and 30%, respectively. In bargraph format, the same discharge thresholds correspond to a battery charge state indication of 90%, 60%, 40%, and 30%, respectively. Differences in the battery charge state indications are due to the finer granularity of the BCD versus the bargraph format.

During discharge and when MULT is pulled up to V_{CC}, the state-of-charge monitor BCD format displays the discharge condition, letter "d," whereas the bargraph format has no indication.

The charge status display is blanked during the charge pending state and when the battery pack is removed.

Charge Status Display Modes

The bq2007 charge status monitor can be displayed in two modes summarized in Table 3. The display modes are a seven-segment monotonic bargraph or a seven-segment BCD single-digit format. When QDSEL is pulled down to V_{SS}, pins $SEG_{A–G}$ drive the decoded seven segments of a single BCD digit display, and when QDSEL is pulled up to V_{CC}, pins $SEG_{A–G}$ drive the seven segments of a bargraph display.

In the bargraph display mode, outputs $SEG_{A–G}$ allow options for a three-segment to seven-segment bargraph display. The three-segment charge status display uses outputs SEG_B, SEG_D, and SEG_F for 30%, 60%, and 90% charge indications, respectively. The four-segment charge status display uses outputs SEG_A, SEG_C, SEG_D, and SEG_E for 20%, 40%, 60%, and 80% indications, respectively. The seven-segment charge status monitor uses all segments.

The BCD display mode drives pins $SEG_{A–G}$ with the decoded seven-segment single-digit information. The display indicates in 10% increments from a BCD zero count at charge initiation to a BCD nine count indicating 90% charge capacity. Charge completion is indicated by the letter "F," a fault condition by the letter "E," and the discharge condition by the letter "d." See Table 3.

Table 2. bq2007 Charge Status Display Summary

Mode	Charge Action State	LED_1	LED_2	DIS	ALARM
$DSEL_1$ = L $DSEL_2$ = L (Mode 1)	Battery absent	0	0	0	0
	Charge pending (temp. limit, low voltage)	0	Flashing	0	0
	Discharge in progress	0	1	1	0
	Charging	Flashing	0	0	0
	Charge complete	1	0	0	High tone
	Fault (low-voltage time-out)	0	0	0	High tone
$DSEL_1$ = H $DSEL_2$ = L (Mode 2)	Battery absent	0	0	0	0
	Discharge in progress, pending	1	1	1	0
	Charging	1	0	0	0
	Charge complete	0	1	0	High tone
	Fault (low-voltage time-out)	0	0	0	High tone
$DSEL_1$ = L $DSEL_2$ = H (Mode 3)	Battery absent	0	0	0	0
	Charge pending (temp. limit, low voltage)	0	Flashing	0	0
	Discharge in progress	0	Flashing	1	0
	Charging	Flashing	0	0	0
	Charge complete	1	0	0	High tone
	Fault (low-voltage time-out)	0	1	0	High tone

Note: 1 = on; 0 = off; L = pulled down to V_{SS}; H = pulled up to V_{CC}.

Display Driver Modes

The bq2007 is designed to interface with LCD or LED type displays. The LED signal levels are driven when the MSEL soft-programmed input is pulled to V_{CC} at initialization. The output pin COM is the common anode connection for LED $SEG_{A–G}$.

The LCD interface mode is enabled when the MSEL soft-programmed input pin is pulled to V_{SS} at initialization. An internal oscillator generates all the timing signals required for the LCD interface. The output pin COM is the common connection for static direct-driving of the LCD display backplane and is driven with an AC signal at the frame period. When enabled, each of the $SEG_{A–G}$ pins is driven with the correct-phase AC signal to activate the LCD segment. In bargraph or BCD mode, output pins $SEG_{A–G}$ interface to LED or LCD segments.

Battery Voltage and Temperature Measurement

The battery voltage and temperature are monitored within set minimum and maximum limits. When MULT is pulled up to V_{CC}, battery voltage is sensed at the BAT pin by a resistive voltage divider that divides the terminal voltage between $0.262 * V_{CC}$ (V_{EDV}) and $0.8 * V_{CC}$ (V_{MCV}). The bq2007 charges multi-cell battery packs from a minimum of N cells, to a maximum of $1.5 * N$ cells. The battery voltage divider is set to the minimum cell battery pack (N) by the BAT pin voltage divider ratio equation:

$$\frac{R1}{R2} = \left(\frac{N}{1.33}\right) - 1$$

When MULT is pulled down to V_{SS}, tighter charge voltage limits and voltage-based charge status display are selected. This is recommended for charging packs with a fixed number of cells where the battery voltage divider range is between $0.4 * V_{CC}$ (V_{EDV}) and $0.8 * V_{CC}$

Table 3. bq2007 Charge Status Display Summary

Mode	Display Indication	SEG_A	SEG_B	SEG_C	SEG_D	SEG_E	SEG_F	SEG_G
QDSEL = H	20% charge	1	0	0	0	0	0	0
	30% charge	1	1	0	0	0	0	0
	40% charge	1	1	1	0	0	0	0
	60% charge	1	1	1	1	0	0	0
	80% charge	1	1	1	1	1	0	0
	90% charge	1	1	1	1	1	1	0
	Charge complete	1	1	1	1	1	1	1
QDSEL = L	0% charge—digit 0	1	1	1	1	1	1	0
	10% charge—digit 1	0	1	1	0	0	0	0
	20% charge—digit 2	1	1	0	1	1	0	1
	30% charge—digit 3	1	1	1	1	0	0	1
	40% charge—digit 4	0	1	1	0	0	1	1
	50% charge—digit 5	1	0	1	1	0	1	1
	60% charge—digit 6	1	0	1	1	1	1	1
	70% charge—digit 7	1	1	1	0	0	1	0
	80% charge—digit 8	1	1	1	1	1	1	1
	90% charge—digit 9	1	1	1	1	0	1	1
	Charge complete—letter F	1	0	0	0	1	1	1
	Fault condition—letter E	1	0	0	1	1	1	1
	Discharge—letter d	0	1	1	1	1	0	1

Note: 1 = on; 0 = off; L = pulled down to V_{SS}; H = pulled up to V_{CC}.

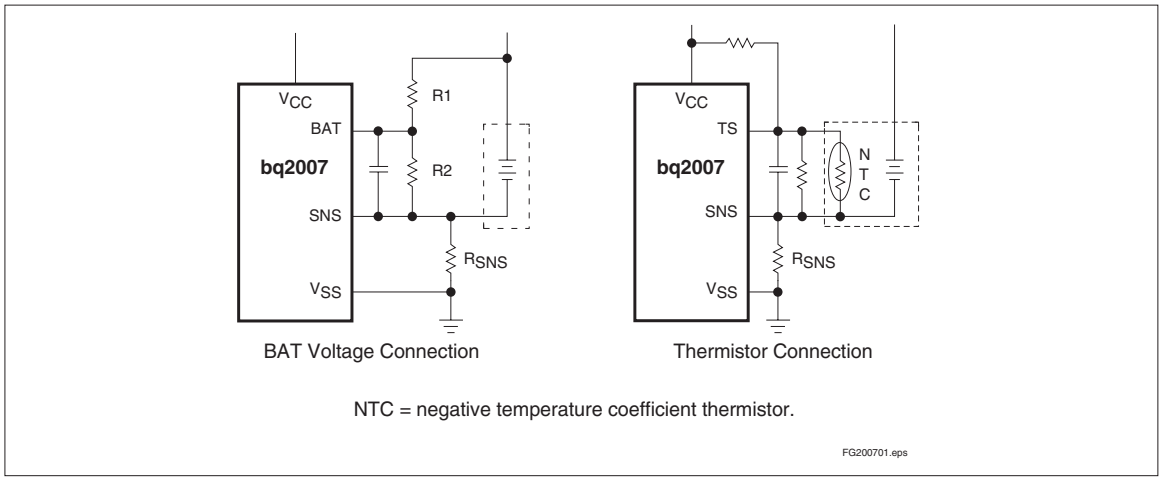


Figure 2. Voltage and Temperature Limit Measurement

(V_{MCV}). The bq2007 charges fixed-cell battery packs of N cells. The battery voltage divider is set by the divider ratio equation:

$$\frac{R1}{R2} = \left(\frac{N}{2}\right) - 1$$

Note: The resistor-divider network impedance should be above 200KΩ to protect the bq2007.

When battery temperature is monitored for maximum and minimum allowable limits, the bq2007 requires that the thermistor used for temperature measurement have a negative temperature coefficient. See Figure 2.

Temperature and Voltage Prequalifications

For charging to be initiated, the battery temperature must fall within predetermined acceptable limits. The voltage on the TS pin (V_{TS}) is compared to an internal low-temperature fault threshold (V_{LTF}) of (0.5 * V_{CC}) and the high temperature cutoff voltage (V_{TCO}) on the TCO pin. For charging to be initiated, V_{TS} must be less than V_{LTF} and greater than V_{TCO}. Since V_{TS} decreases as temperature increases, the TCO threshold should be selected to be lower than 0.5 * V_{CC} for proper operation. If the battery temperature is outside these limits, the bq2007 holds the charge-pending state with a pulse trickle current until the temperature is within limits. Temperature prequalification and termination is disabled if V_{TS} is greater than 0.8 * V_{CC}. See Figure 2.

The bq2007 provides undervoltage battery protection by trickle-current conditioning of a battery that is below the low-voltage threshold (V_{EDV}). The battery voltage (V_{CELL}) is compared to the low-voltage threshold (V_{EDV}) and charge will be inhibited if $V_{CELL} < V_{EDV}$. The condition trickle current and fault time-out are a percentage of the fast charge rate and maximum time-out (MTO).

Initiating Charge Action and Discharge-Before-Charge

A charge action is initiated under control of: (1) battery insertion or (2) power applied. Battery insertion is detected when the voltage at the BAT pin falls from above V_{MCV} to below V_{MCV}. Power applied is detected by the rising edge of V_{CC} when a battery is inserted.

Discharge-before-charge (see Figure 3) is initiated automatically on application of power or battery insertion when $\overline{DCMD}$ is connected to V_{SS}. Discharge-on-demand is initiated by a negative-going pulse on the $\overline{DCMD}$ pin

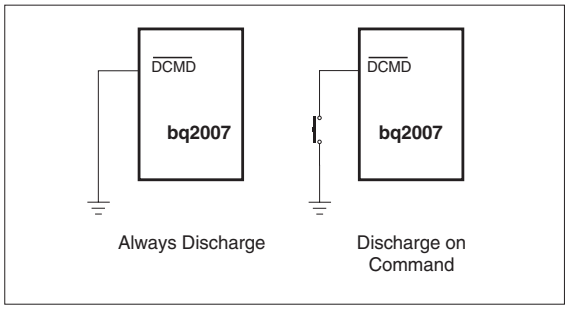


Figure 3. Discharge-Before-Charge

Table 4. bq2007 Charge Action Control Summary

FAST Input State	TM Input State	Time-out Period (min)	MOD Duty Cycle	Hold-off period (sec)	Trickle Rep Rate -ΔV $C/32$	Trickle Rep Rate PVD $C/64$
V_{SS}	Float	640 ($C/8$)	25%	2400	219Hz	109Hz
V_{SS}	V_{SS}	320 ($C/4$)	25%	1200	109Hz	55Hz
V_{SS}	V_{CC}	160 ($C/2$)	25%	600	55Hz	27Hz
V_{CC}	Float	160 ($C/2$)	100%	600	219Hz	109Hz
V_{CC}	V_{SS}	80 (C)	100%	300	109Hz	55Hz
V_{CC}	V_{CC}	40 (2C)	100%	150	55Hz	27Hz

regardless of charging activity. The $\overline{DCMD}$ pin is internally pulled up to V_{CC}; therefore, not connecting this pin results in disabling the discharge-before-charge function. When the discharge begins, the DIS output goes high to activate an external transistor that connects a load to the battery. The bq2007 terminates discharge-before-charge by detecting when the battery cell voltage is less than or equal to the end-of-discharge voltage (V_{EDV}).

Charge State Actions

Once the required discharge is completed and temperature and voltage prequalifications are met, the charge state is initiated. The charge state is configured by the VSEL, FAST, and TM input pins. The FAST input selects between Fast and Standard charge rates. The Standard charge rate is ¼ of the Fast charge rate, which is accomplished by disabling the regulator for a period of 286µs of every 1144µs (25% duty cycle). In addition to throttling back the charge current, time-out and hold-off safety time are increased accordingly. See Table 4.

The VSEL input selects the voltage termination method. The termination mode sets the top-off state and trickle charge current rates. The TM input selects the Fast charge rate, the Standard rate, and the corresponding charge times. Once charging begins at the Fast or Standard rate, it continues until terminated by any of the following conditions:

- Negative delta voltage (-ΔV)
- Peak voltage detect (PVD)
- Maximum temperature cutoff (TCO)
- Maximum time-out (MTO)
- Maximum cutoff voltage (MCV)

Voltage Termination Hold-off

To prevent early termination due to an initial false peak battery voltage, the -ΔV and PVD terminations are disabled during a short "hold-off" period at the start of charge. During the hold-off period when fast charge is selected (FAST = 1), the bq2007 will top off charge to prevent excessive overcharging of a fully charged battery. Once past the initial charge hold-off time, the termination is enabled. TCO and MCV terminations are not affected by the hold-off time.

-ΔV or PVD Termination

Table 5 summarizes the two modes for full-charge voltage termination detection. When $V_{SEL} = V_{SS}$, negative delta voltage detection occurs when the voltage seen on the BAT pin falls 12mV (typical) below the maximum sampled value. $V_{SEL} = V_{CC}$ selects peak voltage detect termination and the top-off charge state. PVD termination occurs when the BAT pin voltage falls 6mV per cell below the maximum sampled value. When charging a battery pack with a fixed number of cells, the -ΔV and PVD termination thresholds are -6mV and 0 to -3mV per cell, respectively. The valid battery voltage range on V_{BAT} for -ΔV or PVD termination is from $0.262 * V_{CC}$ to $0.8 * V_{CC}$.

Table 5. VSEL Configuration

VSEL	Detection Method	Top-Off	Pulse Trickle Rate
V_{SS}	-ΔV	Disabled	$C/32$
V_{CC}	PVD	Enabled	$C/64$

Maximum Temperature, Maximum Voltage, and Maximum Time Safety Terminations

The bq2007 also terminates charge action for maximum temperature cutoff (TCO), maximum cutoff voltage (MCV), and maximum time-out (MTO). Temperature is monitored as a voltage on the TS pin (V_{TS}), which is compared to an internal high-temperature cutoff threshold of V_{TCO}. The TCO reference level provides the maximum limit for battery temperature during charging. MCV termination occurs when $V_{CELL} > V_{MCV}$. The maximum time-out (MTO) termination is when the charger safety timer countdown has completed during the active charge state. If the MTO, MCV, or TCO limit is exceeded during Fast charge, Standard charge, or top-off states, charge action is terminated.

Top-Off and Pulse Trickle Charging

The bq2007 provides a post-detection timed charge capability called top-off to accommodate battery chemistries that may have a tendency to terminate charge prior to achieving full capacity. When $V_{SEL} = V_{CC}$, the top-off state is selected; charging continues after Fast charge termination for a period equal to the time-out value. In top-off mode, the Fast charge control cycle is modified so that MOD is activated for a pulse output of 73ms of every 585ms. This results in a rate ⅛ that of the Fast charge rate. Top-off charge is terminated by maximum temperature cutoff (TCO), maximum cutoff voltage (MCV), or maximum time-out termination.

Pulse trickle is used to compensate for self-discharge while the battery is idle and to condition a depleted low-voltage battery to a valid voltage prior to high-current charging. The battery is pulse trickle charged when Fast, Standard, or top-off charge is not active. The MOD output is active for a period of 286µs of a period specified in Table 4. This results in a trickle rate of 7/64 for PVD and 7/32 when -ΔV is enabled.

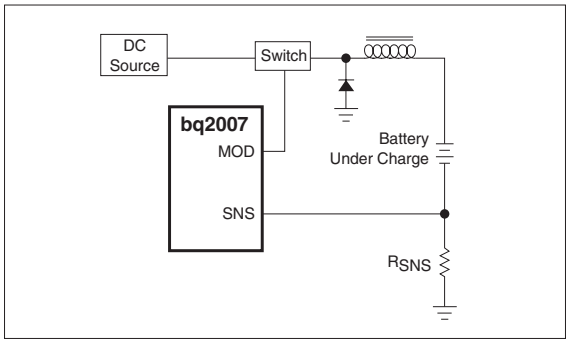


Figure 4. Constant-Current Switching Regulation

Charge Inhibit

Fast charge, top-off, and pulse trickle may be inhibited by using the $\overline{INH}$ input pin. When low, the bq2007 suspends all charge activity, drives all outputs to high impedance, and assumes a low-power operational state. When $\overline{INH}$ returns high, a fast-charge cycle is qualified and begins as soon as conditions allow.

Charge Current Control

The bq2007 controls charge current through the MOD output pin. In a frequency-modulated buck regulator configuration, the control loop senses the voltage at the SNS pin and regulates to maintain it between 0.04 ∗ V_{CC} and 0.05 ∗ V_{CC}. The nominal regulated current is $I_{REG} = 0.225V/R_{SNS}$. See Figure 4.

MOD pin is switched high or low depending on the voltage input to the SNS pin. If the voltage at the SNS pin is less than V_{SNSLO} (0.04 ∗ V_{CC} nominal), the MOD output is switched high to gate charge current through the inductor to the battery. When the SNS voltage is greater than V_{SNSHI} (0.05 ∗ V_{CC} nominal), the MOD output is switched low-shutting off charge current from the supply. The MOD pin can be used to gate an external charging current source. When an external current source is used, no sense resistor is required, and the SNS pin is connected to V_{SS}.

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
T_{STG}	Storage temperature	-40	+85	°C	
T_{SOLDER}	Soldering temperature	-	+260	°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 ($T_A = T_{OPR}$; V_{CC} = 5V ± 10%)

Symbol	Parameter	Rating	Tolerance	Unit	Notes
V_{SNSHI}	High threshold at SNS resulting in MOD = Low	$0.05 * V_{CC}$	±25	mV	
V_{SNSLO}	Low threshold at SNS resulting in MOD = High	$0.04 * V_{CC}$	±10	mV	
V_{LTF}	TS pin low-temperature threshold	$0.5 * V_{CC}$	±30	mV	SNS = 0V
V_{HTF}	TS pin high-temperature threshold	V_{TCO}	±30	mV	SNS = 0V
V_{EDV}	End-of-discharge voltage MULT is pulled up to V_{CC}	$0.262 * V_{CC}$	±30	mV	SNS = 0V
	End-of-discharge voltage MULT is pulled down to V_{SS}	$0.4 * V_{CC}$	±30	mV	SNS = 0V
V_{MCV}	BAT pin maximum cell voltage threshold	$0.8 * V_{CC}$	±30	mV	SNS = 0V
V_{20}	20% state-of-charge voltage threshold at the BAT pin	$^{187}/_{320} * V_{CC}$	±30	mV	Fast or standard charge state; MULT pulled to V_{SS}
V_{40}	40% state-of-charge voltage threshold at the BAT pin	$^{191}/_{320} * V_{CC}$	±30	mV	Fast or standard charge state; MULT pulled to V_{SS}
V_{60}	60% state-of-charge voltage threshold at the BAT pin	$^{195}/_{320} * V_{CC}$	±30	mV	Fast or standard charge state; MULT pulled to V_{SS}
V_{80}	80% state-of-charge voltage threshold at the BAT pin	$^{203}/_{320} * V_{CC}$	±30	mV	Fast or standard charge state; MULT pulled to V_{SS}
V_{20}	20% state-of-charge voltage threshold at the BAT pin	$^{158}/_{320} * V_{CC}$	±30	mV	Discharge-before-charge state; MULT pulled to V_{SS}; DIS = 1
V_{40}	40% state-of-charge voltage threshold at the BAT pin	$^{163}/_{320} * V_{CC}$	±30	mV	Discharge-before-charge state; MULT pulled to V_{SS}; DIS = 1
V_{60}	60% state-of-charge voltage threshold at the BAT pin	$^{167}/_{320} * V_{CC}$	±30	mV	Discharge-before-charge state; MULT pulled to V_{SS}; DIS = 1
V_{80}	80% state-of-charge voltage threshold at the BAT pin	$^{171}/_{320} * V_{CC}$	±30	mV	Discharge-before-charge state; MULT pulled to V_{SS}; DIS = 1

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

Symbol	Parameter	inimum	Typical	Maximum	Unit	Notes
V_{CC}	Supply voltage	4.5	5.0	5.5	V	10%
V_{BAT}	Voltage on BAT pin	0	-	V_{CC}	V	
V_{TS}	Voltage on TS pin	0	-	V_{CC}	V	Thermistor input
V_{TCO}	Temperature cutoff on TCO	0	-	0.5 * V_{CC}	V	Note 2
V_{CELL}	Battery voltage potential	0	-	V_{CC}	V	V_{BAT} - V_{SNS}
V_{TEMP}	Voltage potential on TS	0	-	V_{CC}	V	V_{TS} - V_{SNS}
V_{IH}	Logic input high	2.0	-	-	V	$\overline{DCMD}$, FAST, VSEL, $\overline{INH}$
	Tri-level input high	V_{CC} - 0.3	-	-	V	TM
V_{IL}	Logic input low	-	-	0.8	V	$\overline{DCMD}$, FAST, VSEL, $\overline{INH}$
	Tri-level input low	-	-	0.3	V	TM
V_{OH}	Logic output high	V_{CC} - 0.8	-	-	V	DIS, $LED_{1–2}$, $SEG_{A–G}$ @ I_{OH} = -10mA; MOD @ I_{OH} = -5mA
V_{OL}	Logic output low	-	-	0.8	V	DIS, $LED_{1–2}$, $SEG_{A–G}$ @ I_{OL} = 10mA; MOD @ I_{OL} = 5mA
V_{OHCOM}	COM output	V_{CC} - 0.8	-	-	V	@ I_{OHCOM} = -40mA
I_{OHCOM}	COM source	-40	-	-	mA	@ V_{OHCOM} = V_{CC} - 0.8V
I_{CC}	Supply current	-	1	2.5	mA	No output load
I_{OH}	DIS, $LED_{1–2}$, $SEG_{A–G}$ source	-10	-	-	mA	@V_{OH} = V_{CC} - 0.8V
I_{OH}	MOD	-5	-	-	mA	@V_{OH} = V_{CC} - 0.8V
I_{OL}	DIS, $LED_{1–2}$, $SEG_{A–G}$ sink	10	-	-	mA	@V_{OL} = V_{SS} + 0.8V
I_{OL}	MOD	5	-	-	mA	@V_{OL} = V_{SS} + 0.8V
I_{IZ}	Tri-state inputs floating for Z state	-2.0	-	2.0	µA	TM
I_L	Input leakage	-	-	±1	µA	$\overline{INH}$, VSEL, V = V_{SS} to V_{CC}
	Input leakage	50	-	400	µA	$\overline{DCMD}$, FAST, V = V_{SS} to V_{CC}
I_{IL}	Logic input low current	-	-	70	µA	TM, V = V_{SS} to V_{SS} + 0.3V
I_{IH}	Logic input high current	-70	-	-	µA	TM, V = V_{CC} - 0.3V to V_{CC}

Impedance

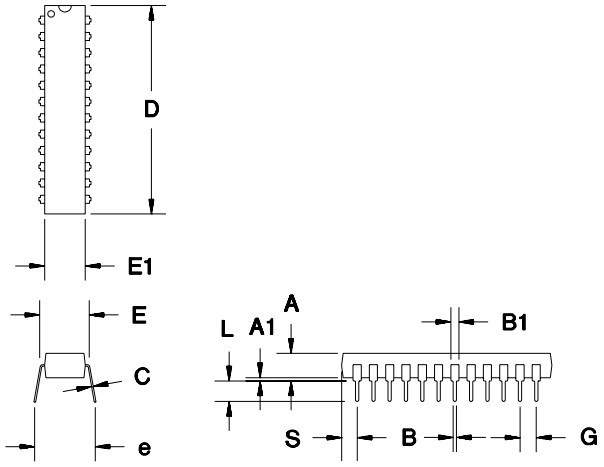
Symbol	Parameter	Minimum	Typical	Maximum	Unit	Notes
R_I	DC input impedance: pins TS, BAT, SNS, TCO	50	-	-	MΩ	
R_{PROG}	Soft-programmed pull-up resistor	150	-	200	KΩ	MSEL, $DSEL_1$, $DSEL_2$, MULT, QDSEL; resistor value ± 10% tolerance
R_{FLT}	Float state external resistor	-	5	-	MΩ	TM

Timing (TA = 0 to +70°C; VCC ± 10%)

Symbol	Parameter	Minimum	Typical	Maximum	Unit	Notes
d_{FCV}	Deviation of fast charge safety time-out	0.84	1.0	1.16	-	At V_{CC} = ±10%, T_A = 0 to 60°C; see Table 3
t_{REG}	MOD output regulation frequency	-	-	300	kHz	Typical regulation range; V_{CC} = 5.0V
t_{PEND}	Charge pending time-out	-	25	-	%	Ratio of fast charge time-out; see Table 4.
F_{COM}	Common LCD backplane frequency	-	73	-	Hz	LCD segment frame rate
F_{ALARM}	Alarm frequency output	-	3500	-	kHz	High tone
t_{PW}	Pulse width for $\overline{DCMD}$ and $\overline{INH}$ pulse command	1	-	-	µs	Signal valid time
t_{MCV}	Valid period for V_{CELL} > V_{MCV}	0.5	-	1	sec	If $V_{CELL} \geq V_{MCV}$ for t_{MCV} during charge or top-off, then a transition is recognized as a battery replacement.

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

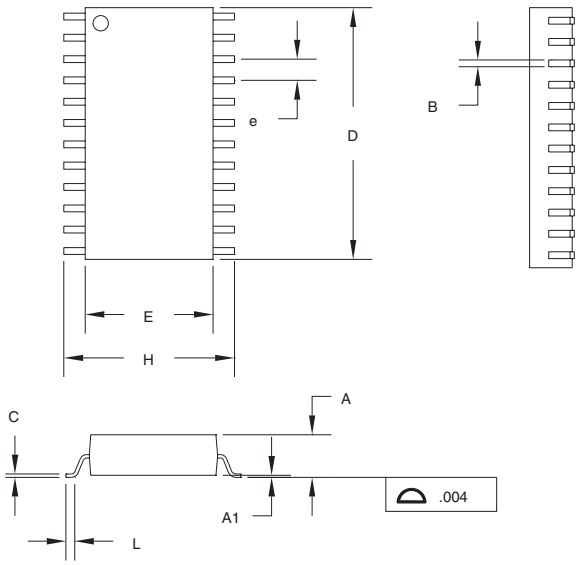
24-Pin DIP Narrow (PN)



24-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	0.045	0.055	1.14	1.40
C	0.008	0.013	0.20	0.33
D	1.240	1.280	31.50	32.51
E	0.300	0.325	7.62	8.26
E1	0.250	0.300	6.35	7.62
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	0.070	0.090	1.78	2.29

S: 24-Pin S (0.300" SOIC)



24-Pin S (0.300" SOIC)

Dimension	Inches		Millimeters	
	Min.	Max.	Min.	Max.
A	0.095	0.105	2.41	2.67
A1	0.004	0.012	0.10	0.30
B	0.013	0.020	0.33	0.51
C	0.008	0.013	0.20	0.33
D	0.600	0.615	15.24	15.62
E	0.290	0.305	7.37	7.75
e	0.045	0.055	1.14	1.40
H	0.395	0.415	10.03	10.54
L	0.020	0.040	0.51	1.02

Data Sheet Revision History

Change No.	Page No.	Description	Nature of Change
1	11	V_{SNSLO} Rating	Was V_{SNSHI} - (0.01 * V_{CC}); is 0.04 * V_{CC}

Note: Change 1 = Sept. 1996 B changes from Dec. 1995.

Ordering Information

bq2007 -

Temperature:
blank = Commercial (-20 to +70°C)
N = Industrial (-40 to +85°C)*

Package Option:
PN = 24-pin narrow plastic DIP
S = 24-pin SOIC

Device:
bq2007 Fast-Charge IC

* Contact factory for availability.

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