UNITRODE

bq2004E/H

Fast-Charge IC

Features

- Fast charge and conditioning of nickel cadmium or nickel-metal hydride batteries
- Hysteretic PWM switch-mode current regulation or gated control of an external regulator
- Easily integrated into systems or used as a stand-alone charger
- Pre-charge qualification of temperature and voltage
- Configurable, direct LED outputs display battery and charge status
- Fast-charge termination by Δ temperature/Δ time, peak volume detection, -ΔV, maximum voltage, maximum temperature, and maximum time
- Optional top-off charge and pulsed current maintenance charging
- Logic-level controlled low-power mode (< 5µA standby current)

General Description

The bq2004E and bq2004H Fast Charge ICs provide comprehensive fast charge control functions together with high-speed switching power control circuitry on a monolithic CMOS device.

Integration of closed-loop current control circuitry allows the bq2004 to be the basis of a cost-effective solution for stand-alone and system-integrated chargers for batteries of one or more cells.

Switch-activated discharge-before-charge allows bq2004E/H-based chargers to support battery conditioning and capacity determination.

High-efficiency power conversion is accomplished using the bq2004E/H as a hysteretic PWM controller for switch-mode regulation of the charging current. The bq2004E/H may alternatively be used to gate an externally regulated charging current.

Fast charge may begin on application of the charging supply, replacement of the battery, or switch depression. For safety, fast charge is inhibited unless/until the battery temperature and voltage are within configured limits.

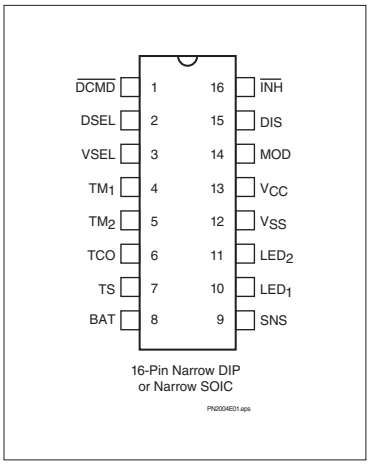
Temperature, voltage, and time are monitored throughout fast charge. Fast charge is terminated by any of the following:

- Rate of temperature rise ($\Delta T/\Delta t$)
- Peak voltage detection (PVD)
- Negative delta voltage ($-\Delta V$)
- Maximum voltage
- Maximum temperature
- Maximum time

After fast charge, optional top-off and pulsed current maintenance phases with appropriate display mode selections are available.

The bq2004H differs from the bq2004E only in that fast charge, hold-off, and top-off time units have been scaled up by a factor of two, and the bq2004H provides different display selections. Timing differences between the two ICs are illustrated in Table 1. Display differences are shown in Table 2.

Pin Connections



Pin Names

$\overline{DCMD}$	Discharge command
DSEL	Display select
VSEL	Voltage termination select
TM_1	Timer mode select 1
TM_2	Timer mode select 2
TCO	Temperature cutoff
TS	Temperature sense
BAT	Battery voltage
SNS	Sense resistor input
LED_1	Charge status output 1
LED_2	Charge status output 2
V_{SS}	System ground
V_{CC}	5.0V ±10% power
MOD	Charge current control
DIS	Discharge control output
$\overline{INH}$	Charge inhibit input

SLUS081A - APRIL 2005

Pin Description

$\overline{DCMD}$ **Input**

The $\overline{DCMD}$ input controls the conditions that enable discharge-before-charge. $\overline{DCMD}$ is pulled up internally. A negative-going pulse on $\overline{DCMD}$ initiates a discharge to end-of-discharge voltage (EDV) on the BAT pin, followed by a new charge cycle start. Tying $\overline{DCMD}$ to ground enables automatic discharge-before-charge on every new charge cycle start.

DISL **Input**

This three-state input configures the charge status display mode of the LED_1 and LED_2 outputs and can be used to disable top-off and pulsed-trickle. See Table 2.

PVL **Input**

This three-state input controls the voltage-termination technique used by the bq2004E/H. When high, PVD is active. When floating, -ΔV is used. When pulled low, both PVD and -ΔV are disabled.

TM_1–TM_2 **Input**

TM_1 and TM_2 are three-state inputs that configure the fast charge safety timer, voltage termination hold-off time, "top-off", and trickle charge control. See Table 1.

TCO **Input**

Input to set maximum allowable battery temperature. If the potential between TS and SNS is less than the voltage at the TCO input, then fast charge or top-off charge is terminated.

TS **Input**

Input, referenced to SNS, for an external thermister monitoring battery temperature.

BAT **Input**

BAT is the battery voltage sense input, referenced to SNS. This is created by a high-impedance resistor-divider network connected between the positive and the negative terminals of the battery.

SNS **Input**

SNS controls the switching of MOD based on an external sense resistor in the current path of the battery. SNS is the reference potential for both the TS and BAT pins. If SNS is connected to V_{SS}, then MOD switches high at the beginning of charge and low at the end of charge.

LED_1–LED_2 **Output**

Push-pull outputs indicating charging status. See Table 2.

V_{SS} **Ground**

V_{CC} **V_{CC} Input**

5.0V, ±10% power input.

MOD **Output**

MOD is a push-pull output that is used to control the charging current to the battery. MOD switches high to enable charging current to flow and low to inhibit charging current flow.

DSG **Output**

Push-pull output used to control an external transistor to discharge the battery before charging.

$\overline{PRES}$ **Input**

When low, the bq2004E/H suspends all charge actions, drives all outputs to high impedance, and assumes a low-power operational state. When transitioning from low to high, a new charge cycle is started.

Functional Description

Figure 2 shows a block diagram and Figure 3 shows a state diagram of the bq2004E/H.

Battery Voltage and Temperature Measurement

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

$$\frac{RB1}{RB2} = \frac{N}{2} - 1$$

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.

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

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. Both the BAT and TS inputs are referenced to SNS, so the signals used inside the IC are:

$$V_{BAT} - V_{SNS} = V_{CELL}$$

and

$$V_{TS} - V_{SNS} = V_{TEMP}$$

Discharge-Before-Charge

The $\overline{DCMD}$ input is used to command discharge-before-charge via the DIS output. Once activated, DIS becomes active (high) until V_{CELL} falls below V_{EDV}, at which time DIS goes low and a new fast charge cycle begins.

The $\overline{DCMD}$ input is internally pulled up to V_{CC} (its inactive state). Leaving the input unconnected, therefore, results in disabling discharge-before-charge. A negative going pulse on $\overline{DCMD}$ initiates discharge-before-charge at any time regardless of the current state of the bq2004. If $\overline{DCMD}$ is tied to V_{SS}, discharge-before-charge will be the first step in all newly started charge cycles.

Starting A Charge Cycle

A new charge cycle is started by:

1. Application of V_{CC} power.
2. V_{CELL} falling through the maximum cell voltage, V_{MCV} where:

$$V_{MCV} = 0.8$$

VSEL Input	Voltage Termination
Low	Disabled
Float	-ΔV
High	PVD

Voltage Sampling

Each sample is an average of voltage measurements. The IC takes 32 measurements in PVD mode and 16 measurements in -ΔV mode. The resulting sample periods (9.17ms and 18.18ms, respectively) filter out harmonics centered around 55Hz and 109Hz. This technique 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 ±16%.

Temperature and Voltage Termination Hold-off

A hold-off period occurs at the start of fast charging. During the hold-off period, -ΔV and ΔT/Δt termination are disabled. The MOD pin is enabled at a duty cycle of 260µs active for every 1820µs inactive. This modulation results in an average rate 1/8th that of the fast charge rate. This avoids premature termination on the voltage spikes sometimes produced by older batteries when fast-charge current is first applied. Maximum voltage and maximum temperature terminations are not affected by the hold-off period.

ΔT/Δt Termination

The bq2004E/H samples at the voltage at the TS pin every 34s, and compares it to the value measured two samples earlier. If V_{TEMP} has fallen 16mV ±4mV or more, fast charge is terminated. The ΔT/Δt termination test is valid only when $V_{TCO} < V_{TEMP} < V_{LTF}$.

Temperature Sampling

Each sample is an average of 16 voltage measurements. The resulting sample period (18.18ms) filters out harmonics around 55Hz. This technique 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 ±16%.

Maximum Voltage, Temperature, and Time

Anytime V_{CELL} rises above V_{MCV}, the LEDs go off and current flow into the battery ceases immediately. If V_{CELL} then falls back below V_{MCV} before t_{MCV} = 1.5s ±0.5s, the chip transitions to the Charge Complete state (maximum voltage termination). If V_{CELL} remains above V_{MCV} at the expiration of t_{MCV}, the bq2004E/H transitions to the Battery Absent state (battery removal). See Figure 3.

Maximum temperature termination occurs anytime V_{TEMP} falls below the temperature cutoff threshold V_{TCO}. Charge will also be terminated if V_{TEMP} rises above the low temperature fault threshold, V_{LTF}, after fast charge begins.

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

Corresponding Fast-Charge Rate				Typical Fast-Charge Safety Time (min)		Typical PVD, -ΔV Hold-Off Time (s)		Top-Off Rate		Pulse-Trickle Rate	Pulse-Trickle Period (Hz)	
2004E	2004H	TM1	TM2	2004E	2004H	2004E	2004H	2004E	2004H		2004E	2004H
C/4	C/8	Low	Low	325	650	137	273	Disabled		Disabled	Disabled	
C/2	C/4	Float	Low	154	325	546	546	Disabled		C/512	15	30
1C	C/2	High	Low	77	154	273	546	Disabled		C/512	7.5	15
2C	1C	Low	Float	39	77	137	273	Disabled		C/512	3.75	7.5
4C	2C	Float	Float	19	39	68	137	Disabled		C/512	1.88	3.75
C/2	C/4	High	Float	154	325	546	546	C/16	C/32	C/512	15	30
1C	C/2	Low	High	77	154	273	546	C/8	C/16	C/512	7.5	15
2C	1C	Float	High	39	77	137	273	C/4	C/18	C/512	3.75	7.5
4C	2C	High	High	19	39	68	137	C/2	C/4	C/512	1.88	3.75

Note: Typical conditions = 25°C, V_{CC} = 5.0V.

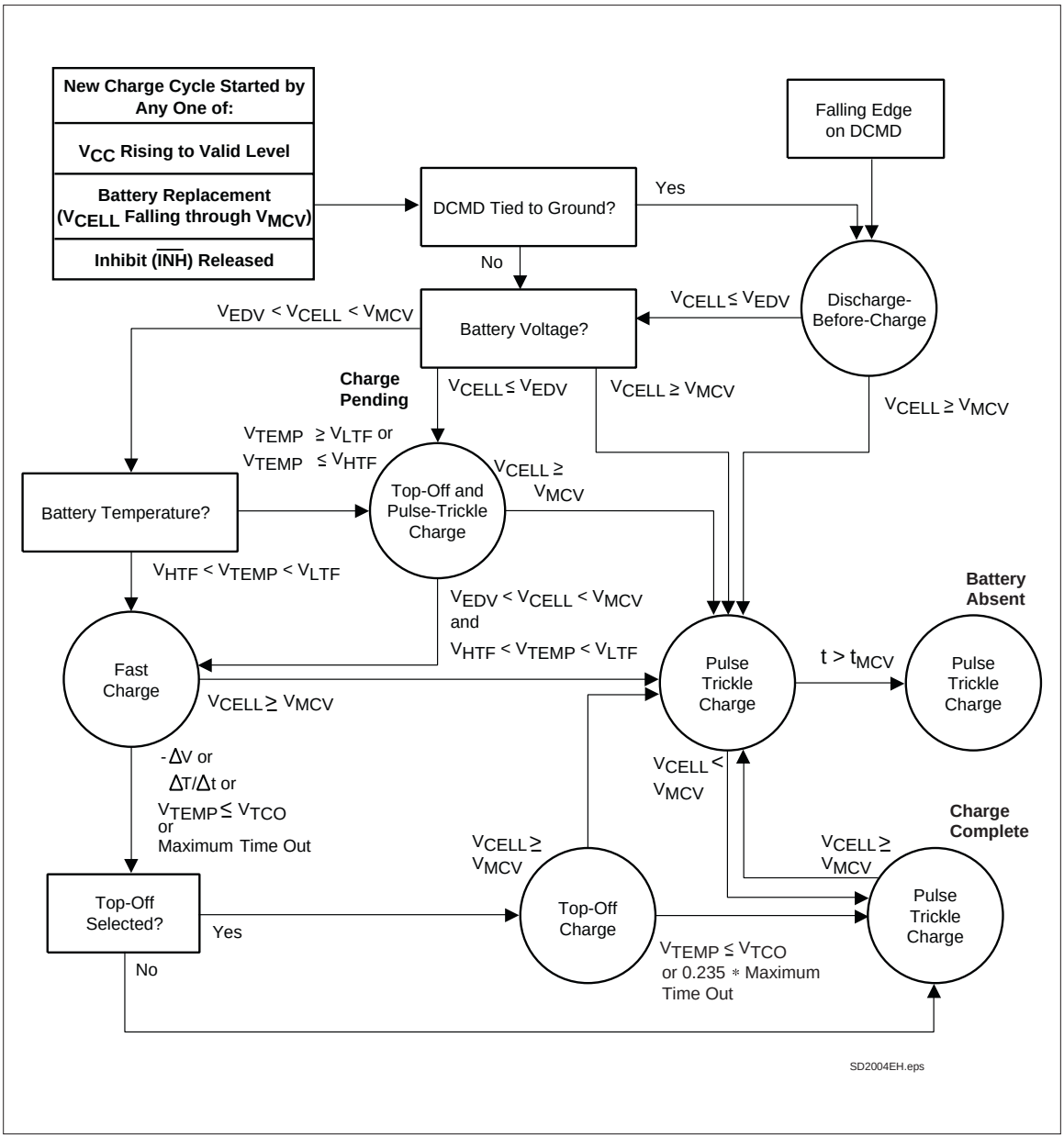


Figure 3. Charge Algorithm State Diagram

Absolute Maximum Ratings

Symbol	Parameter	Minimum	Maximum	Unit	Note
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	-55	+125	°C	
T_{SOLDER}	Soldering temperature	-	+260	°C	10 sec max.
T_{BIAS}	Temperature under bias	-40	+85	°C	

N 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 = TOPR; VCC ±10%)

Symbol	Parameter	Rating	Tolerance	Unit	Note
V_{SNSHI}	High threshold at SNS resulting in MOD = Low	$0.05 * V_{CC}$	±0.025	V	
V_{SNSLO}	Low threshold at SNS resulting in MOD = High	$0.04 * V_{CC}$	±0.025	V	
V_{LTF}	Low-temperature fault	$0.4 * V_{CC}$	±0.030	V	$V_{TEMP} \geq V_{LTF}$ inhibits/terminates charge
V_{HTF}	High-temperature fault	$(1/3 * V_{LTF}) + (2/3 * V_{TCO})$	±0.030	V	$V_{TEMP} \leq V_{HTF}$ inhibits charge
V_{EDV}	End-of-discharge voltage	$0.4 * V_{CC}$	±0.030	V	$V_{CELL} < V_{EDV}$ inhibits fast charge
V_{MCV}	Maximum cell voltage	$0.8 * V_{CC}$	±0.030	V	$V_{CELL} > V_{MCV}$ inhibits/terminates charge
V_{THERM}	TS input change for$\Delta T/\Delta t$ detection	-16	±4	mV	V_{CC} = 5V, T_A = 25°C
$-\Delta V$	BAT input change for $-\Delta V$ detection	-12	±4	mV	V_{CC} = 5V, T_A = 25°C
PVD	BAT input change for PVD detection	-6	±2	mV	V_{CC} = 5V, T_A = 25°C

Recommended DC Operating Conditions (TA = TOPR)

Symbol	Condition	Minimum	Typical	Maximum	Unit	Note
V_{CC}	Supply voltage	4.5	5.0	5.5	V	
V_{BAT}	Battery input	0	-	V_{CC}	V	
V_{CELL}	BAT voltage potential	0	-	V_{CC}	V	V_{BAT} - V_{SNS}
V_{TS}	Thermistor input	0	-	V_{CC}	V	
V_{TEMP}	TS voltage potential	0	-	V_{CC}	V	V_{TS} - V_{SNS}
V_{TCO}	Temperature cutoff	0.2 * V_{CC}	-	0.4 * V_{CC}	V	Valid $\Delta T/\Delta t$ range
V_{IH}	Logic input high	2.0	-	-	V	$\overline{DCMD}$, $\overline{INH}$
	Logic input high	V_{CC} - 0.3	-	-	V	TM_1, TM_2, DSEL, VSEL
V_{IL}	Logic input low	-	-	0.8	V	$\overline{DCMD}$, $\overline{INH}$
	Logic input low	-	-	0.3	V	TM_1, TM_2, DSEL, VSEL
V_{OH}	Logic output high	V_{CC} - 0.8	-	-	V	DIS, MOD, LED_1, LED_2, $I_{OH} \leq$ -10mA
V_{OL}	Logic output low	-	-	0.8	V	DIS, MOD, LED_1, LED_2, $I_{OL} \leq$ 10mA
I_{CC}	Supply current	-	1	3	mA	Outputs unloaded
I_{SB}	Standby current	-	-	1	µA	$\overline{INH}$ = V_{IL}
I_{OH}	DIS, LED_1, LED_2, MOD source	-10	-	-	mA	@V_{OH} = V_{CC} - 0.8V
I_{OL}	DIS, LED_1, LED_2, MOD sink	10	-	-	mA	@V_{OL} = V_{SS} + 0.8V
I_L	Input leakage	-	-	±		

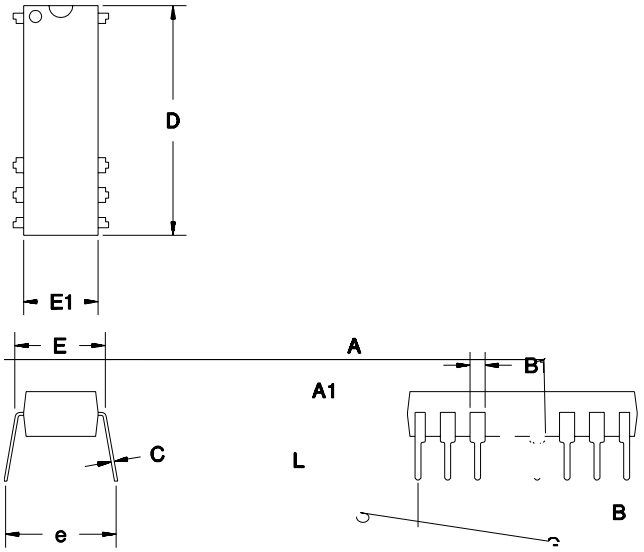
Impedance

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

Timing (T_A = 0 to +70 °C; V_{CC} ±10%)

Symbol	Parameter	Minimum	Typical	Maximum	Unit	Note
t_{PW}	Pulse width for $\overline{DCMD}$ and $\overline{INH}$ pulse command	1	-	-	µs	Pulse stari5306j26j26i06 TD87 22l charge 2l dischargeA

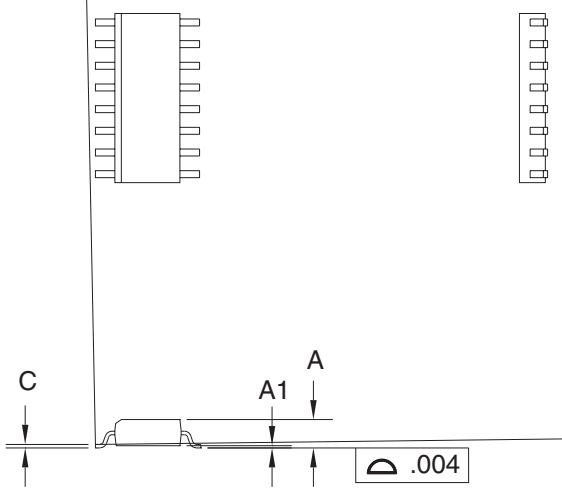
16-Pin DIP Na o J (PN)



16-Pin PN (0.300" DIP)

Dimen. ion	Inche.		Millime e .	
	Min.	Ma▬.	Min.	Ma▬.
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

16-Pin SOIC Na o⌋ (SN)

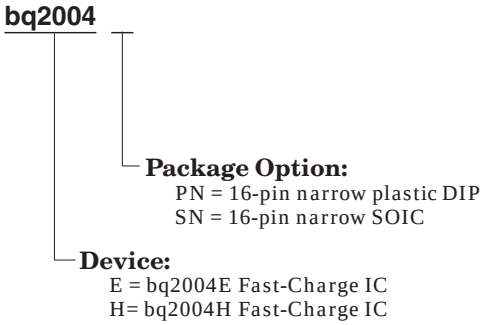


Data Sheet Revision History

Change No.	Page No.	Description	Nature of Change
1	All	Combined bq2004E and bq2004H, revised and expanded format of this data sheet	Clarification
2	7	Separated bq2004E and bq2004H in Table 2, LED Output Summary	Clarification
3	5	Description of charge-pending state	Clarification
4			
5	9	Corrected V_{SNSLO} tolerance	Was: ±0.010 Is: ±0.025

Note: Change 1 = Oct. 1997 B changes from Sept. 1996 (bq2004E), Feb. 1997 (bq2004H).
Change 2 = Feb. 1998 C changes from Oct. 1997 B.
Change 3 = Dec. 1998 D changes from Feb. 1998 C.
Change 4 = June 1999 E changes from Dec. 1998 D.
Change 5 = Apr. 2005 F changes from June 1999 E.

Ordering Information



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
BQ2004ESNTR	SOIC	D	16	2500	330.0	16.4	6.5	10.3	2.1	8.0		

8.89857 329.159 3q 40 0 1 5.q 4329.9000 2 3 5 027.346 0.5 re f Q2270 0396 339.4329.9000 5 0

*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
BQ2004ESNTR	SOIC	D	16	2500	367.0	367.0	38.0
BQ2004HSNTR	SOIC	D	16	2500	367.0	367.0	38.0

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46C and to discontinue any product or service per JESD48B. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components which meet ISO/TS16949 requirements, mainly for automotive use. Components which have not been so designated are neither designed nor intended for automotive use; and TI will not be responsible for any failure of such components to meet such requirements.

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Mobile Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2012, Texas Instruments Incorporated