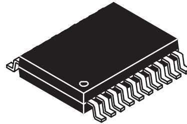

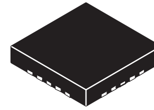

SINGLE-CELL Li-ION CHARGE MANAGEMENT IC FOR PDAs AND INTERNET APPLIANCES

FEATURES

- **Highly Integrated Solution With FET Pass Transistor and Reverse-Blocking Schottky and Thermal Protection**
- **Integrated Voltage and Current Regulation With Programmable Charge Current**
- **High-Accuracy Voltage Regulation (±1%)**
- **Ideal for Low-Dropout Linear Charger Designs for Single-Cell Li-Ion Packs With Coke or Graphite Anodes**
- **Up to 1.2-A Continuous Charge Current**
- **Safety-Charge Timer During Preconditioning and Fast Charge**
- **Integrated Cell Conditioning for Reviving Deeply Discharged Cells and Minimizing Heat Dissipation During Initial Stage of Charge**
- **Optional Temperature or Input-Power Monitoring Before and During Charge**
- **Various Charge-Status Output Options for Driving Single, Double, or Bicolor LEDs or Host-Processor Interface**
- **Charge Termination by Minimum Current and Time**
- **Low-Power Sleep Mode**
- **Packaging: 5 mm × 5 mm MLP or 20-Lead TSSOP PowerPAD™**

APPLICATIONS

- **PDAs**
- **Internet Appliances**
- **MP3 Players**
- **Digital Cameras**

DESCRIPTION

The bq2400x series ICs are advanced Li-Ion linear charge management devices for highly integrated and space-limited applications. They combine high-accuracy current and voltage regulation; FET pass-transistor and reverse-blocking Schottky; battery conditioning, temperature, or input-power monitoring; charge termination; charge-status indication; and charge timer in a small package.

The bq2400x measures battery temperature using an external thermistor. For safety reasons, the bq2400x inhibits charge until the battery temperature is within the user-defined thresholds. Alternatively, the user can monitor the input voltage to qualify charge. The bq2400x series then charge the battery in three phases: preconditioning, constant current, and constant voltage. If the battery voltage is below the internal low-voltage threshold, the bq2400x uses low-current precharge to condition the battery. A preconditioning timer is provided for additional safety. Following pre-conditioning, the bq2400x applies a constant-charge current to the battery. An external sense-resistor sets the magnitude of the current. The constant-current phase is maintained until the battery reaches the charge-regulation voltage. The bq2400x then transitions to the constant voltage phase. The user can configure the device for cells with either coke or graphite anodes. The accuracy of the voltage regulation is better than ±1% over the operating junction temperature and supply voltage range.

Charge is terminated by maximum time or minimum taper current detection

The bq2400x automatically restarts the charge if the battery voltage falls below an internal recharge threshold.

Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

PowerPAD is a trademark of Texas Instruments.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

ORDERING INFORMATION

T_J	PACKAGE		CHARGE STATUS CONFIGURATION
	20-LEAD HTTSOP PowerPAD™ (PWP)(1)	20-LEAD 5 mm × 5 mm MLP (RGW)(2)	
−40°C to 125°C	bq24001PWP	bq24001RGW	Single LED
	bq24002PWP	bq24002RGW	2 LEDs
	bq24003PWP	bq24003RGW	Single bicolor LED

(1) The PWP package is available taped and reeled. Add R suffix to device type (e.g. bq24001PWPR) to order. Quantities 2500 devices per reel.
(2) The RGW package is available taped and reeled. Add R suffix to device type (e.g. bq24001RGWR) to order. Quantities 3000 devices per reel.

PACKAGE DISSIPATION RATINGS

PACKAGE	Θ_{JA}	Θ_{JC}	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$
PWP(1)	30.88°C/W	1.19°C/W	3.238 W	0.0324W/°C
RGW(2)	31.41°C/W	1.25°C/W	3.183 W	0.0318W/°C

(1) This data is based on using the JEDEC high-K board and topside traces, top and bottom thermal pad (6.5 × 3.4 mm), internal 1 oz power and ground planes, 8 thermal via underneath the die connecting to ground plane.
(2) This data is based on using the JEDEC high-K board and topside traces, top and bottom thermal pad (3.25 × 3.25 mm), internal 1 oz power and ground planes, 9 thermal via underneath the die connecting to ground plane.

ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range unless otherwise noted(1)

	bq24001 bq24002 bq24003
Supply voltage (Vcc with respect to GND)	13.5 V
Input voltage (IN, ISNS, EN, APG/THERM/CR/STAT1/STAT2, VSENSE, TMR SEL, VSEL) (all with respect to GND)	13.5 V
Output current (OUT pins)	2 A
Output sink/source current (STAT1 and STAT2)	10 mA
Operating free-air temperature range, T_A	−40°C to 70°C
Storage temperature range, T_{stg}	−65°C to 150°C
Junction temperature range, T_J	−40°C to 125°C
Lead temperature (Soldering, 10 sec)	300°C

(1) Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

RECOMMENDED OPERATING CONDITIONS

	MIN	MAX	UNIT
Supply voltage, V_{CC}	4.5	10	V
Input voltage, VIN	4.5	10	V
Continuous output current		1.2	A
Operating junction temperature range, T_J	−40	125	°C

ELECTRICAL CHARACTERISTICS

over recommended operating junction temperature supply and input voltages, and V_I (V_{CC}) ≥ V_I (IN) (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{CC} current	V_{CC} > $V_{CC_}$UVLO, EN ≤ $V_{IH(EN)}$			1	mA

ELECTRICAL CHARACTERISTICS CONTINUED

over recommended operating junction temperature supply and input voltages, and V_I (V_{CC}) ≥ V_I (IN) (unless otherwise noted)

HIGHV (RECHARGE) COMPARATOR, 0°C ≤ T_J ≤ 125°C

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Start threshold		3.80	3.90	4.00	V

OVERV COMPARATOR, 0°C ≤ T_J ≤ 125°C

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Start threshold		4.35	4.45	4.55	V
Stop threshold		4.25	4.30	4.35	V
Hysteresis		50			mV

TAPERDET COMPARATOR, 0°C ≤ T_J ≤ 125°C

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Trip threshold		12	18.5	25	mV

EN LOGIC INPUT, 0°C ≤ T_J ≤ 125°C

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
High-level input voltage		2.25			V
Low-level input voltage				0.8	V
Input pulldown resistance		100		200	kΩ

VSEL LOGIC INPUT, 0°C ≤ T_J ≤ 125°C

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
High-level input voltage		2.25			V
Low-level input voltage				0.8	V
Input pulldown resistance		100		200	kΩ

TMR SEL INPUT 0°C ≤ T_J ≤ 125°C

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
High-level input voltage		2.7			V
Low-level input voltage				0.6	V
Input bias current	$V_{I(TMR SEL)}$ ≤ 5V			15	µA

STAT1, STAT2 (bq24001, bq24003), 0°C ≤ T_J ≤ 125°C

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output (low) saturation voltage	I_O = 10 mA			1.5	V
Output (low) saturation voltage	I_O = 4 mA			0.6	V
Output (high) saturation voltage	I_O = –10 mA	V_{CC}–1.5			V
Output (high) saturation voltage	I_O = –4 mA	V_{CC}–0.5			V
Output turn on/off time	I_O = ± 10 mA, C = 100 p(1)			100	µs

(1) Assured by design, not production tested.

POWER-ON RESET (POR), 0°C ≤ T_J ≤ 125°C

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
POR delay	See Note 1	1.2		3	ms
POR falling-edge deglitch	See Note 1	25		75	µs

(1) Assured by design, not production tested.

ELECTRICAL CHARACTERISTICS CONTINUED

over recommended operating junction temperature supply and input voltages, and V_I (V_{CC}) ≥ V_I (IN) (unless otherwise noted)

APG/THERM DELAY, 0°C ≤ T_J ≤ 125°C

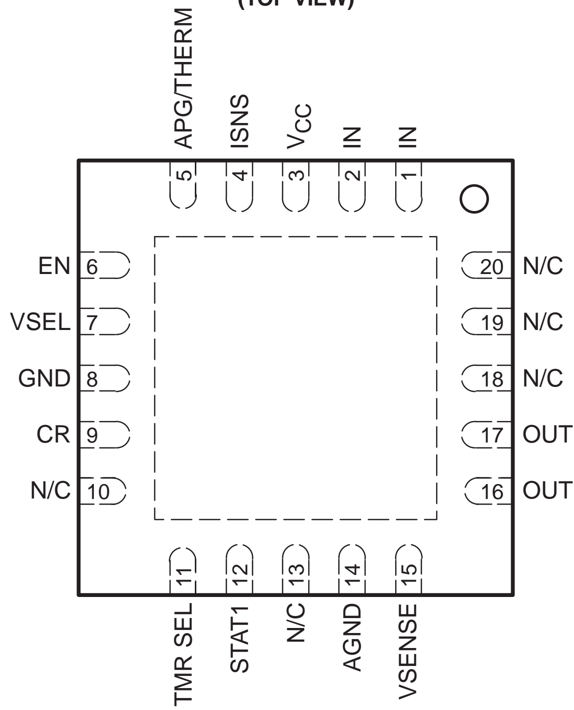
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
APG/THERM falling-edge deglitch	See Note 1	25		75	µs

(1) Assured by design, not production tested.

TIMERS, 0°C ≤ T_J ≤ 125°C

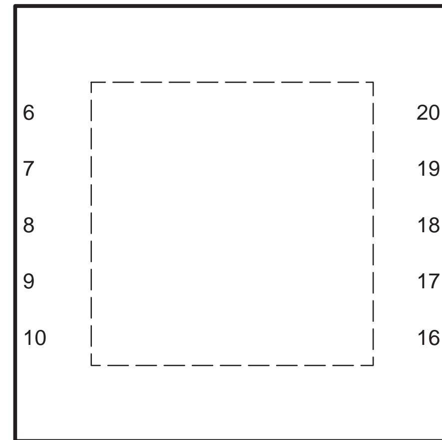
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
User selectable timer accuracy					

bq24001
RGW PACKAGE
(TOP VIEW)



N/C – Do Not Connect

bq24002, bq24003
RGW PACKAGE
(TOP VIEW)



01
02
03
004

TYPICAL CHARACTERISTICS

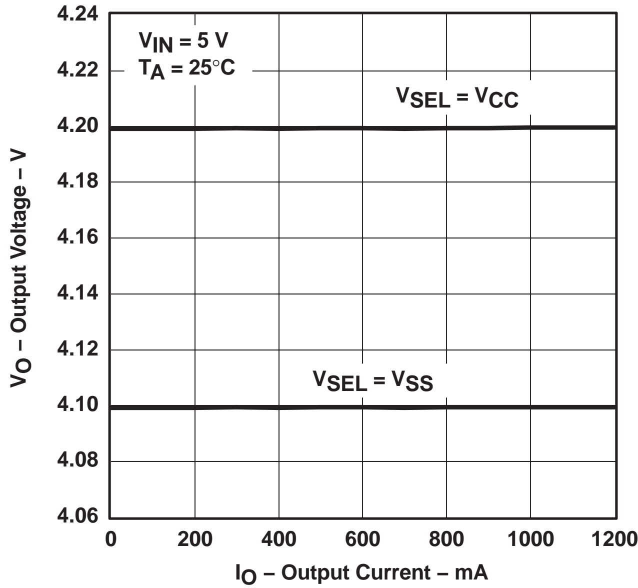


Figure 1

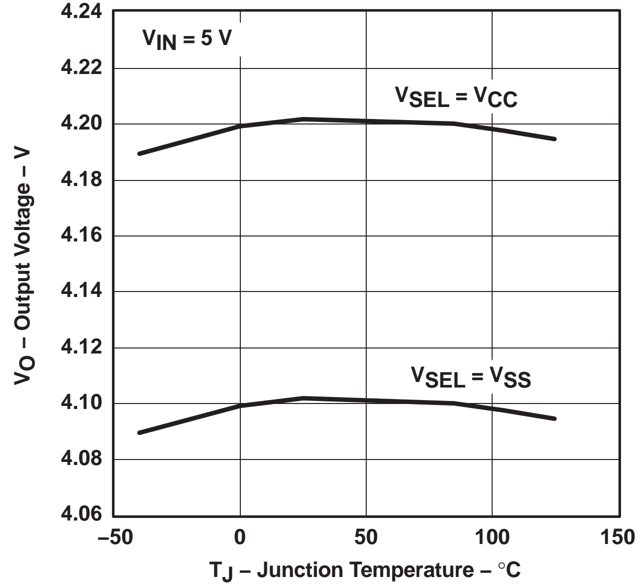


Figure 2

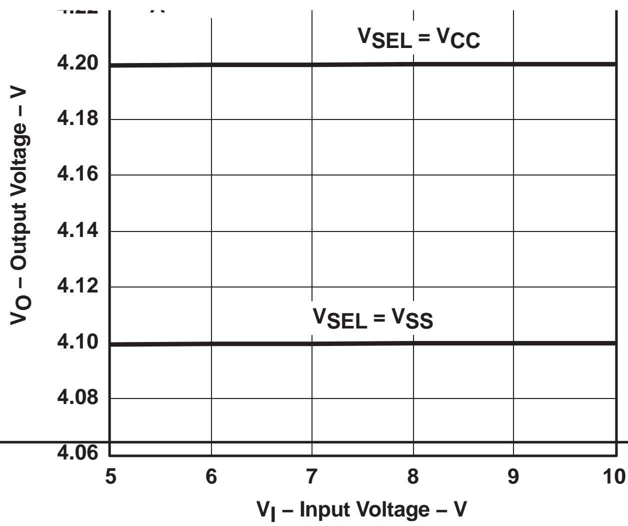


Figure 3

V_I – Input Voltage – V

Figure 4

TYPICAL CHARACTERISTICS

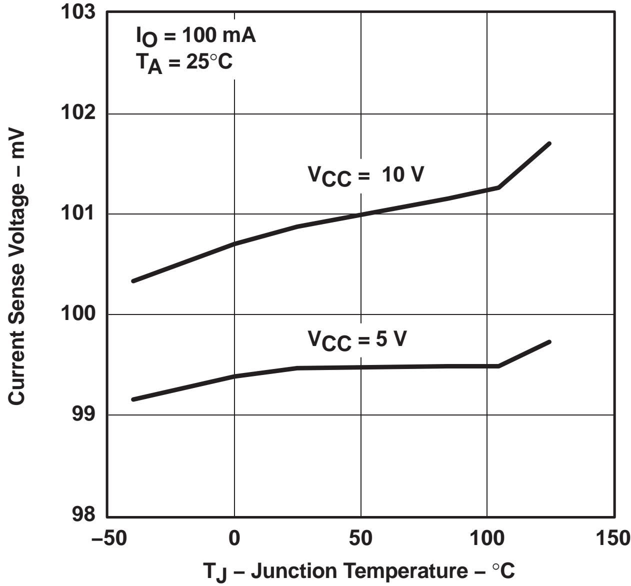


Figure 5

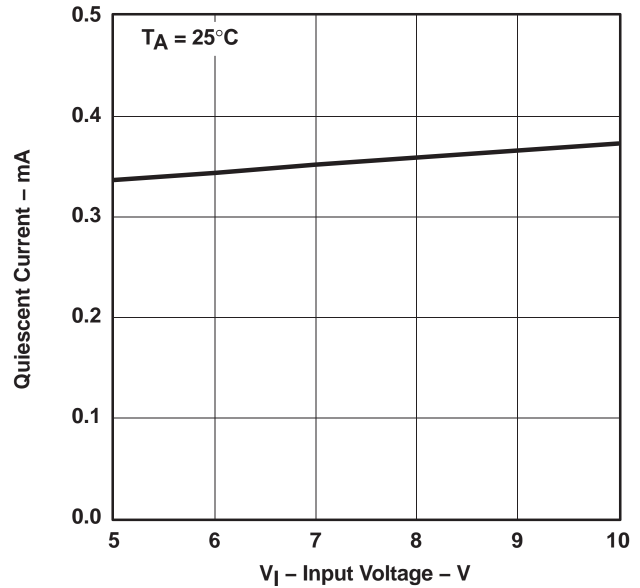


Figure 6

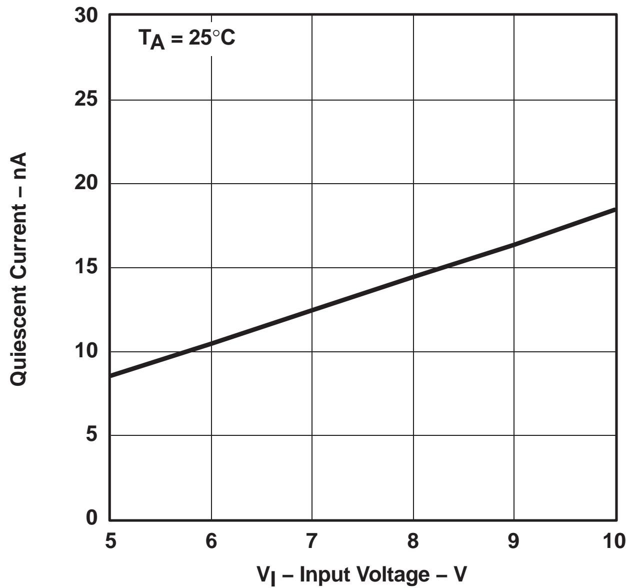


Figure 7

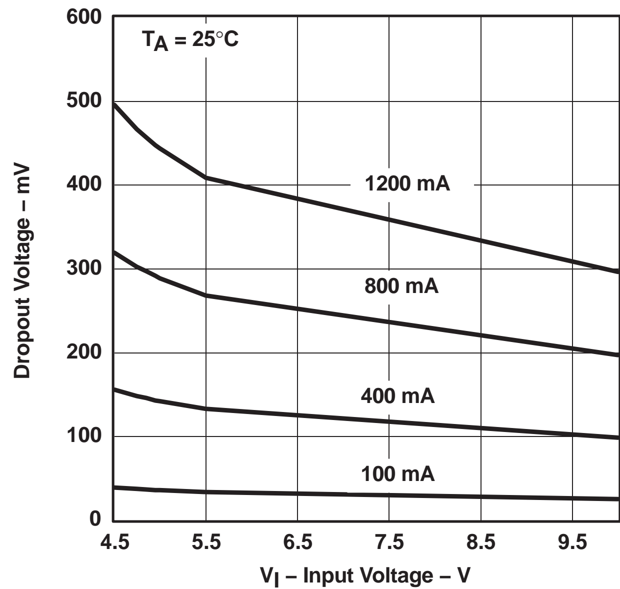


Figure 8

TYPICAL CHARACTERISTICS

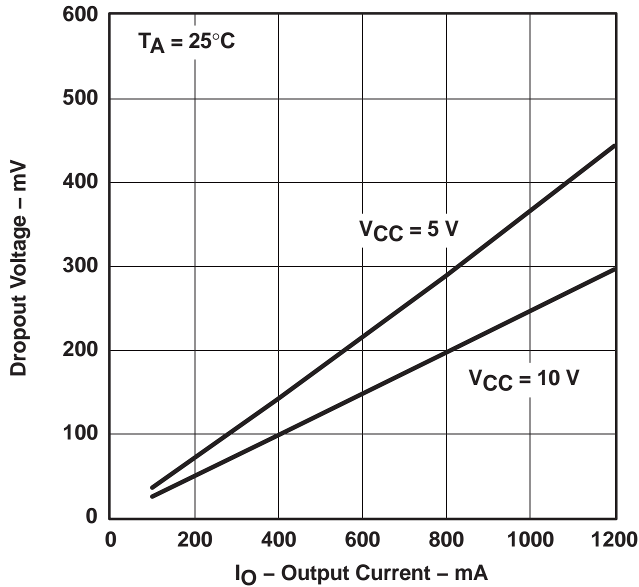


Figure 9

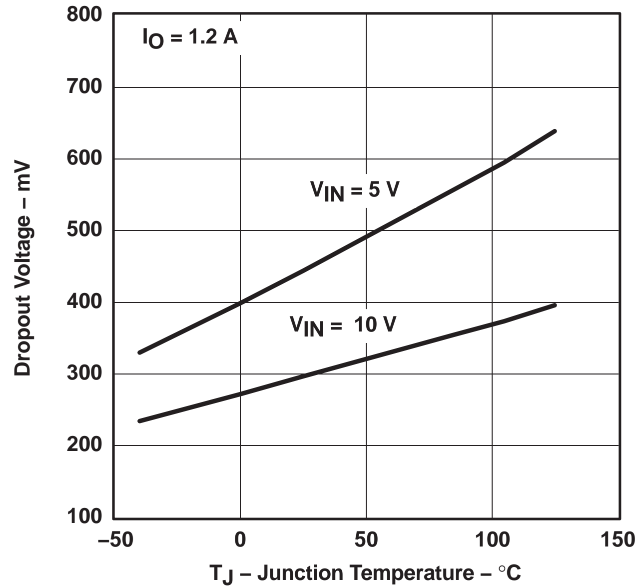


Figure 10

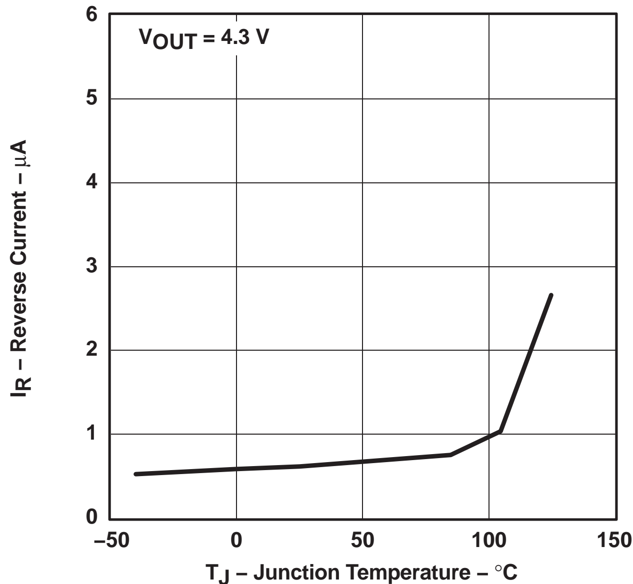


Figure 11

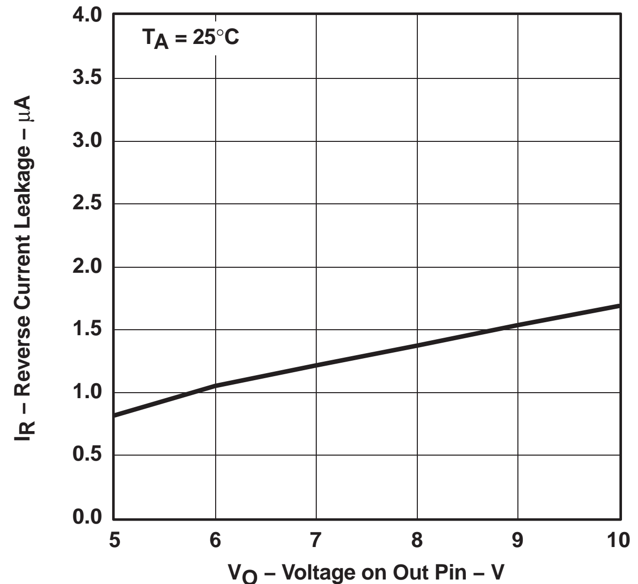
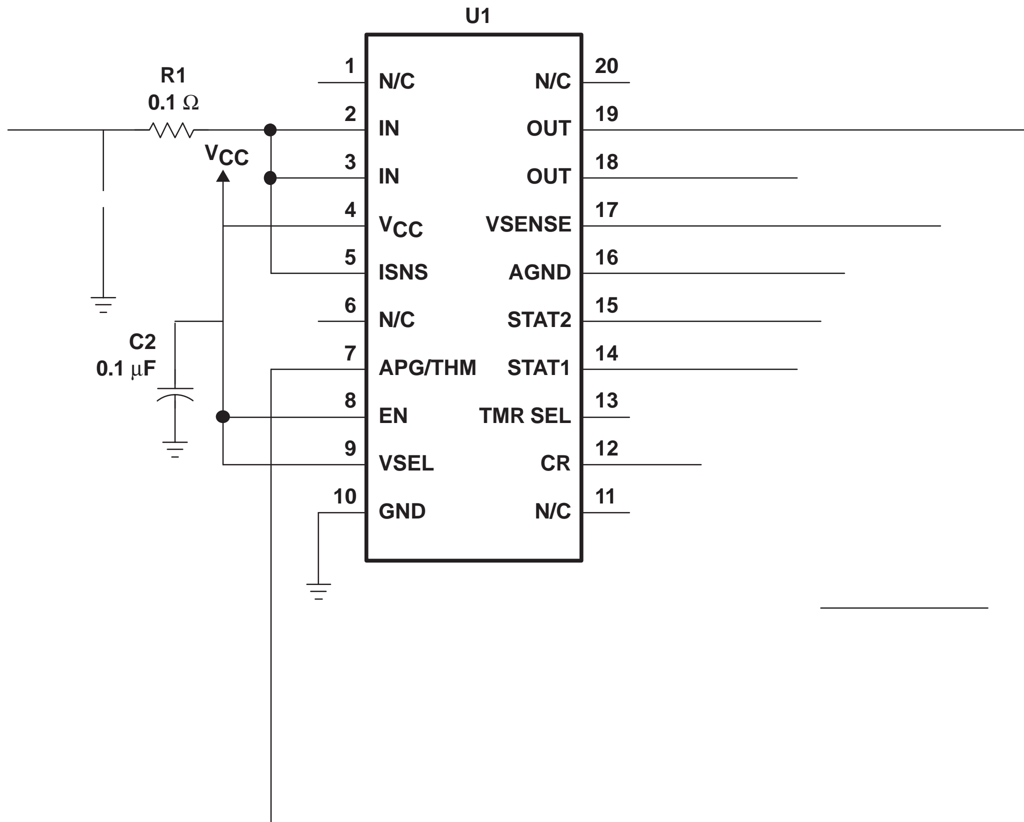


Figure 12

APPLICATION INFORMATION



APPLICATION INFORMATION

FUNCTIONAL DESCRIPTION

The bq2400x supports a precision current- and voltage-regulated Li-Ion charging system suitable for cells with either coke or graphite anodes. See Figure 14 for a typical charge profile and Figure 15 for an operational flowchart.

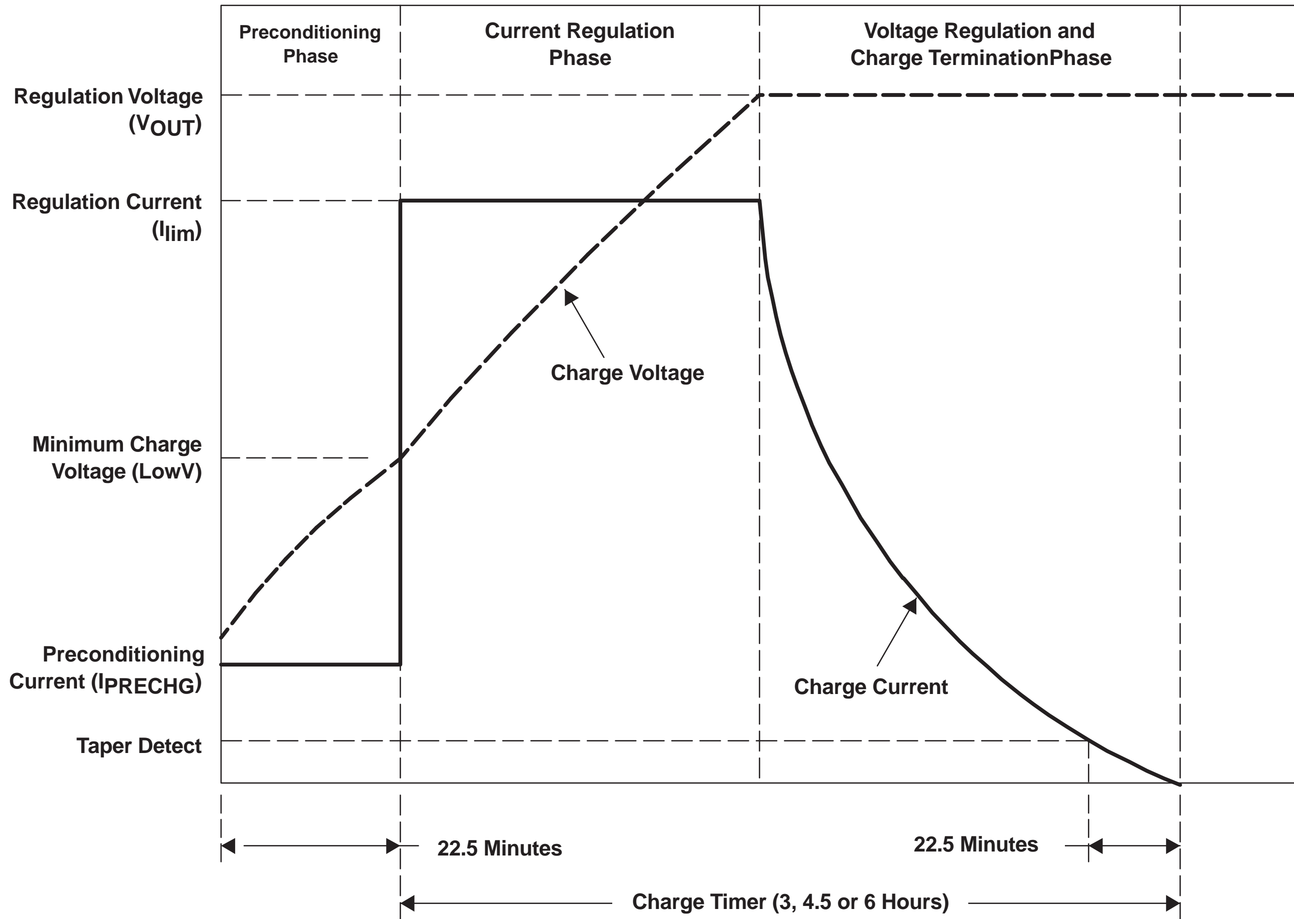
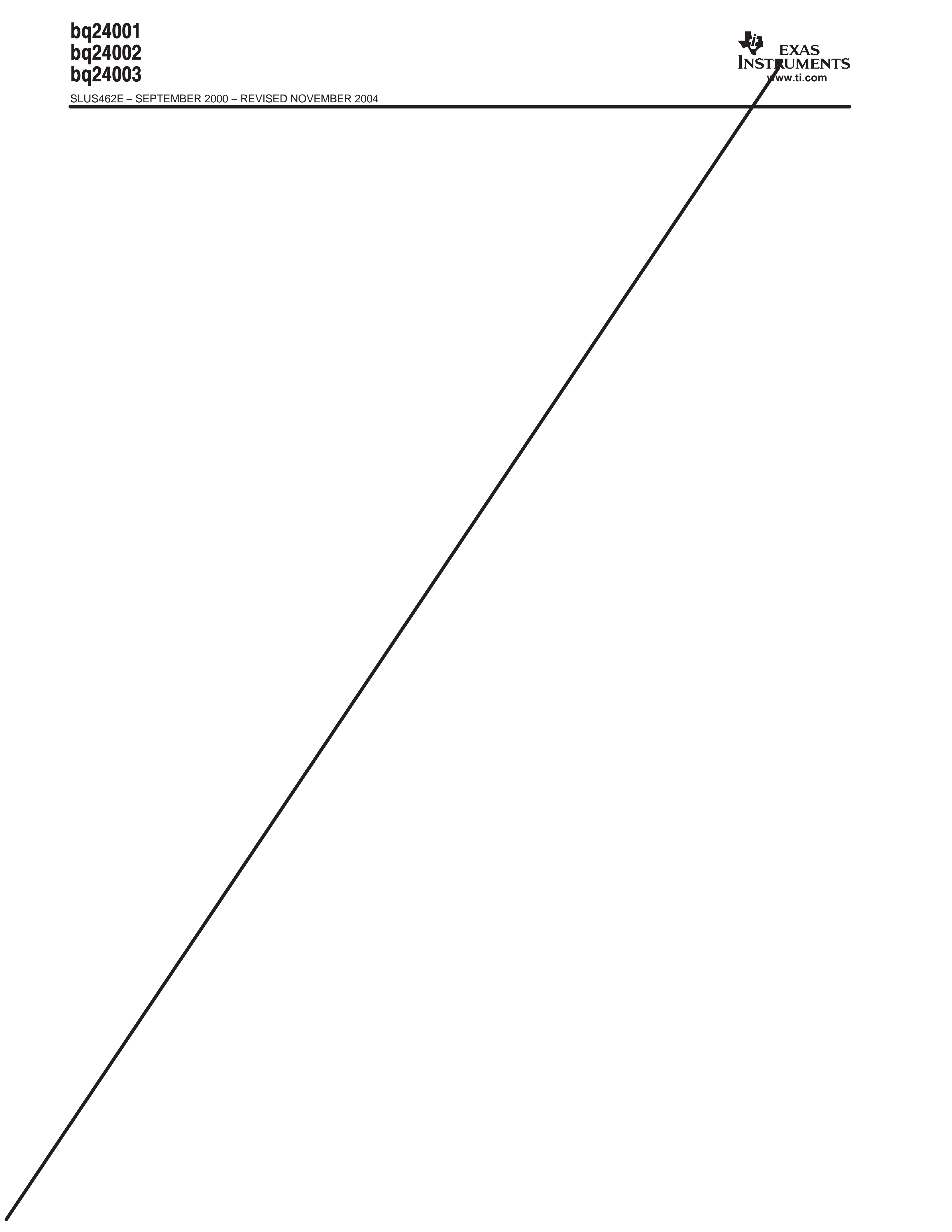


Figure 14. Typical Charge Profile



If the charger designs incorporate a thermistor, the resistor divider RT1 and RT2 is calculated by using the following two equations.

First, calculate RT2.

$$RT2 = \frac{V_B\,R_H\,R_C\left[\frac{1}{V_C} - \frac{1}{V_H}\right]}{R_H\left(\frac{V_B}{V_H} - 1\right) - R_C\left(\frac{V_B}{V_C} - 1\right)}$$

then use the resistor value to find RT1.

$$RT1 = \frac{\frac{V_B}{V_C} - 1}{\frac{1}{RT2} + \frac{1}{R_C}}$$

Where:

$V_B = V_{CR}$ (bias voltage)

R_H = Resistance of the thermistor at the desired hot trip

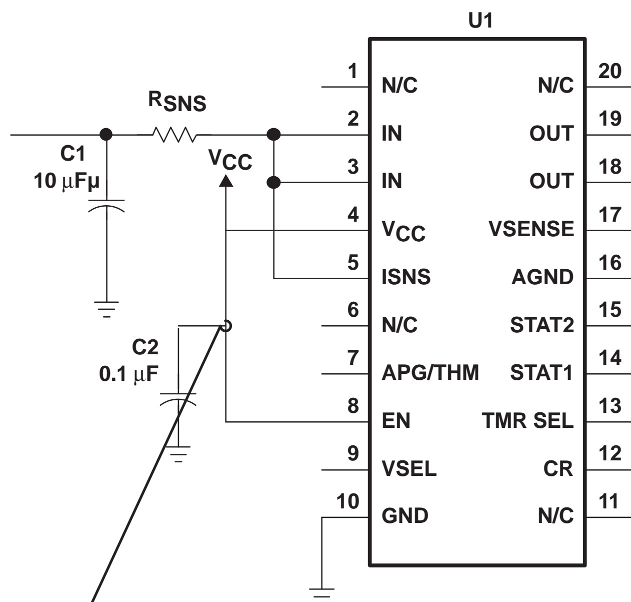

U1
RSNS
C1
10 μFμ
VCC
C2
0.1 μF
1 N/C
2 IN
3 IN
4 VCC
5 ISNS
6 N/C
7 APG/THM
8 EN
9 VSEL
10 GND
20 N/C
19 OUT
18 OUT
17 VSENSE
16 AGND
15 STAT2
14 STAT1
13 TMR SEL
12 CR
11 N/C

Table 2. bq24002 (2 Individual LEDs)

CHARGE STATE	STAT1 (RED)	STAT2 (GREEN)
Precharge	ON (LOW)	OFF
Fast charge	ON (LOW)	OFF
FAULT	Flashing (1 Hz, 50% duty cycle)	OFF
Done (>90%)	OFF	ON (LOW)
Sleep-mode	OFF	OFF
APG/Therm invalid	OFF	OFF
Thermal shutdown	OFF	OFF
Battery absent	OFF	OFF(1)

(1) If thermistor is used, then the Green LED is off.

Table 3. bq24003 (Single Bicolor LED)

CHARGE STATE	LED1 (RED)	LED2 (GREEN)	APPARENT COLOR
Precharge	ON (LOW)	OFF (HIGH)	RED
Fast charge	ON (LOW)	OFF (HIGH)	RED
FAULT	ON (LOW)	ON (LOW)	YELLOW
Done (>90%)	OFF (HIGH)	ON (LOW)	GREEN
Sleep-mode	OFF (HIGH)	OFF (HIGH)	OFF
APG/Therm invalid	OFF (HIGH)	OFF (HIGH)	OFF
Thermal shutdown	OFF (HIGH)	OFF (HIGH)	OFF
Battery absent	OFF (HIGH)	OFF (HIGH)(1)	OFF(1)

(1) If thermistor is used, then the Green LED is off.

Thermal Shutdown

The bq2400x monitors the junction temperature T_J of the DIE and suspends charging if T_J exceeds 165°C. Charging resumes when T_J falls below 155°C.

DETAILED DESCRIPTION

POWER FET

The integrated transistor is a P-channel MOSFET. The power FET features a reverse-blocking Schottky diode, which prevents current flow from OUT to IN.

An internal thermal-sense circuit shuts off the power FET when the junction temperature rises to approximately 165°C. Hysteresis is built into the thermal sense circuit. After the device has cooled approximately 10°C, the power FET turns back on. The power FET continues to cycle off and on until the fault is removed.

CURRENT SENSE

The bq2400x regulates current by sensing, on the ISNS pin, the voltage drop developed across an external sense resistor. The sense resistor must be placed between the supply voltage (Vcc) and the input of the IC (IN pins).

VOLTAGE SENSE

To achieve maximum voltage regulation accuracy, the bq2400x uses the feedback on the VSENSE pin. Externally, this pin should be connected as close to the battery cell terminals as possible. For additional safety, a 10kΩ internal pullup resistor is connected between the VSENSE and OUT pins.

ENABLE (EN)

The logic EN input is used to enable or disable the IC. A high-level signal on this pin enables the bq2400x. A low-level signal disables the IC and places the device in a low-power standby mode.

THERMAL INFORMATION

THERMALLY ENHANCED TSSOP-20

The thermally enhanced PWP package is based on the 20-pin TSSOP, but includes a thermal pad (see Figure 20) to provide an effective thermal contact between the IC and the PWB.

Traditionally, surface mount and power have been mutually exclusive terms. A variety of scaled-down TO220-type packages have leads formed as gull wings to make them applicable for surface-mount applications. These packages, however, suffer from several shortcomings: they do not address the very low profile requirements (<2 mm) of many of today's advanced systems, and they do not offer a pin-count high enough to accommodate increasing integration. On the other hand, traditional low-power surface-mount packages require power-dissipation derating that severely limits the usable range of many high-performance analog circuits.

The PWP package (thermally enhanced TSSOP) combines fine-pitch surface-mount technology with thermal performance comparable to much larger power packages.

The PWP package is designed to optimize the heat transfer to the PWB. Because of the very small size and limited mass of a TSSOP package, thermal enhancement is achieved by improving the thermal conduction paths that remove heat from the component. The thermal pad is formed using a lead-frame design (patent pending) and manufacturing technique to provide the user with direct connection to the heat-generating IC. When this pad is soldered or otherwise coupled to an external heat dissipator, high power dissipation in the ultrathin, fine-pitch, surface-mount package can be reliably achieved.

THERMAL INFORMATION

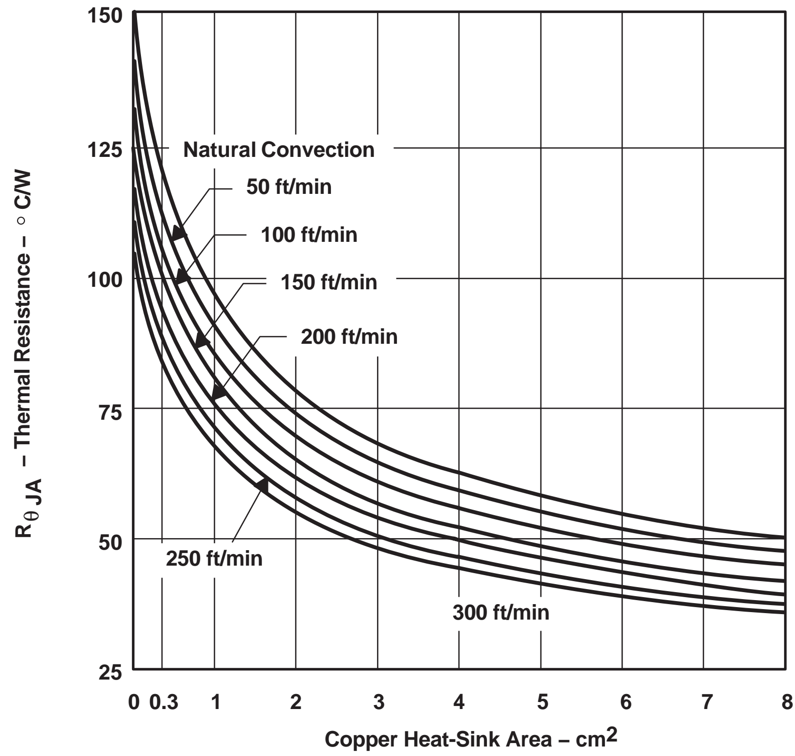
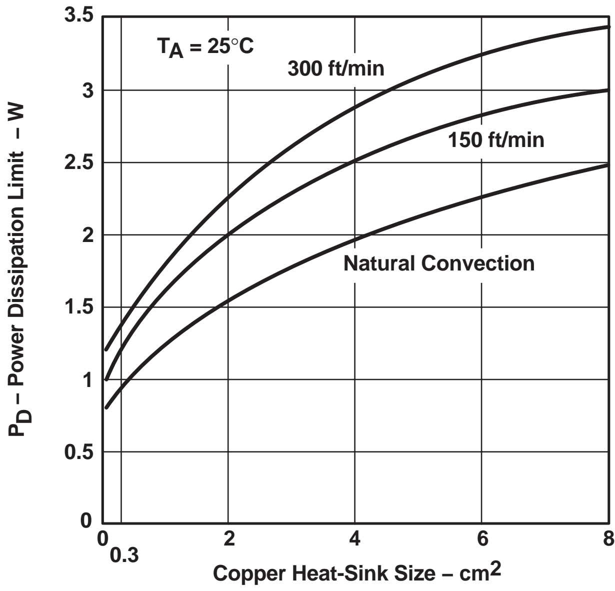
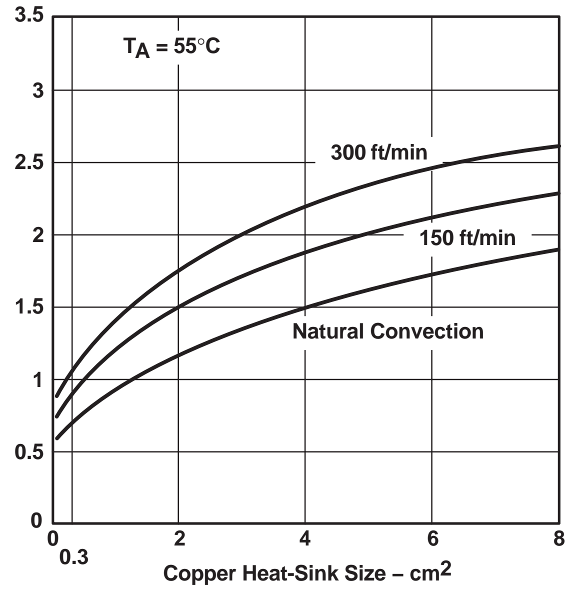


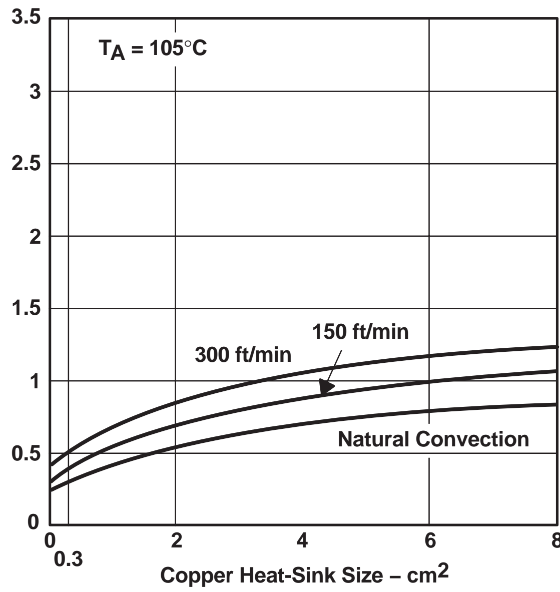
Figure 21

THERMAL INFORMATION





(b)



(c)

PACKAGING INFORMATION

Orderable Device	Status [1]	Package Type	Package Drawing	Pins	Package Qty	Eco Plan [2]	Lead/Ball Finish	MSL Peak Temp [3]
BQ24001PWP	ACTIVE	HTSSOP	PWP	20	70	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24001PWPG4	ACTIVE	HTSSOP	PWP	20	70	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24001PWPR	ACTIVE	HTSSOP	PWP	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24001PWPRG4	ACTIVE	HTSSOP	PWP	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24001RGWR	ACTIVE	VQFN	RGW	20	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24001RGWRG4	ACTIVE	VQFN	RGW	20	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24002PWP	ACTIVE	HTSSOP	PWP	20	70	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24002PWPG4	ACTIVE	HTSSOP	PWP	20	70	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24002PWPR	ACTIVE	HTSSOP	PWP	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24002PWPRG4	ACTIVE	HTSSOP	PWP	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24002RGWR	ACTIVE	VQFN	RGW	20	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24002RGWRG4	ACTIVE	VQFN	RGW	20	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24003PWP	ACTIVE	HTSSOP	PWP	20	70	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24003PWPG4	ACTIVE	HTSSOP	PWP	20	70	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24003PWPR	ACTIVE	HTSSOP	PWP	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24003PWPRG4	ACTIVE	HTSSOP	PWP	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24003RGWR	ACTIVE	VQFN	RGW	20	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24003RGWRG4	ACTIVE	VQFN	RGW	20	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR

[1] The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

[2] Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and

package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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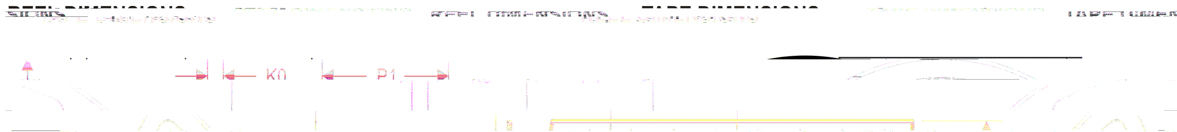
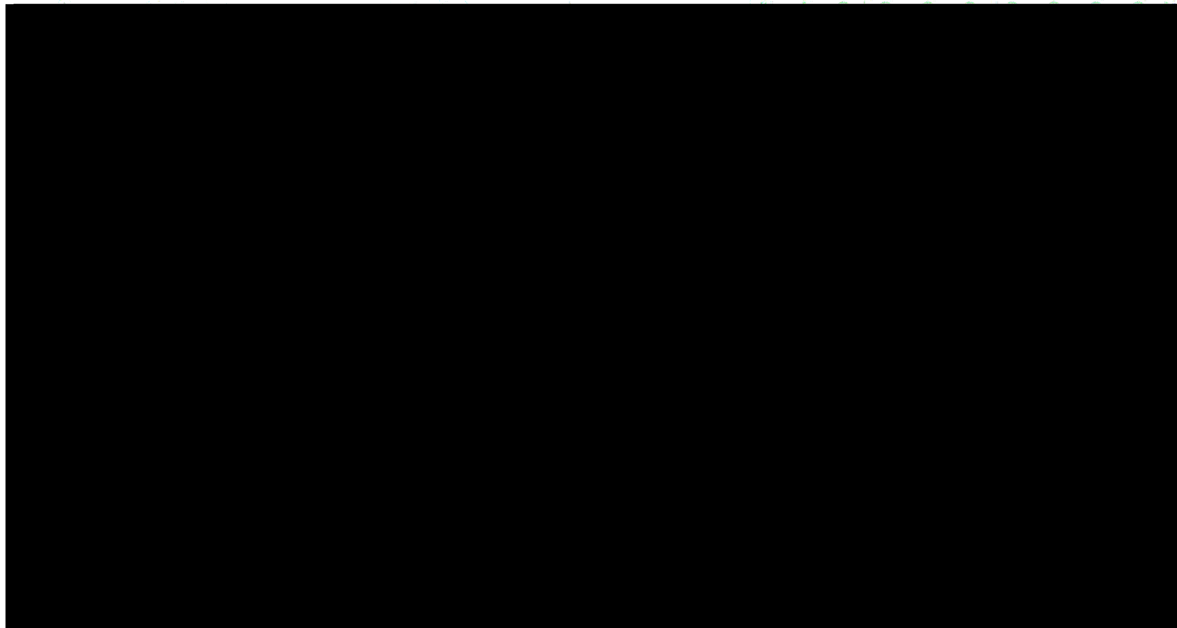
TAPE AND REEL INFORMATION

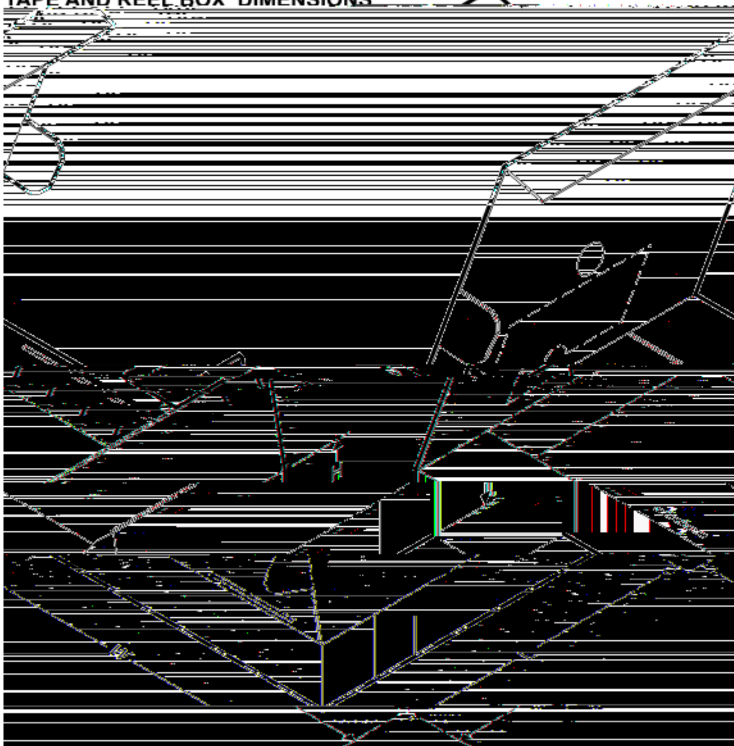




*All dimensions are nominal

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
BQ24001PWPR	HTSSOP	PWP	20	2000	330.0	16.4	6.95	7.1	1.6	8.0	16.0	Q1
BQ24001RGWR	VQFN	RGW	20	3000	330.0	12.4	5.3	5.3	1.5	8.0	12.0	Q2
BQ24002PWPR	HTSSOP	PWP	20	2000	330.0	16.4	6.95	7.1	1.6	8.0	16.0	Q1
BQ24002RGWR	VQFN	RGW	20	3000	330.0	12.4	5.3	5.3	1.5	8.0	12.0	Q2
BQ24003PWPR	HTSSOP	PWP	20	2000	330.0	16.4	6.95	7.1	1.6	8.0	16.0	Q1
BQ24003RGWR	VQFN	RGW	20	3000	330.0	12.4	5.3	5.3	1.5	8.0	12.0	Q2

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
BQ24001PWPR	HTSSOP	PWP	20	2000	367.0	367.0	38.0
BQ24001RGWR	VQFN	RGW	20	3000	367.0	367.0	35.0
BQ24002PWPR	HTSSOP	PWP	20	2000	367.0	367.0	38.0
BQ24002RGWR	VQFN	RGW	20	3000	367.0	367.0	35.0
BQ24003PWPR	HTSSOP	PWP	20	2000	367.0	367.0	38.0
BQ24003RGWR	VQFN	RGW	20	3000	367.0	367.0	35.0

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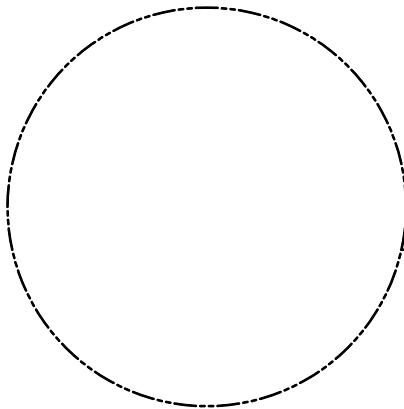

C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined

-o Technical Brief, PowerPad

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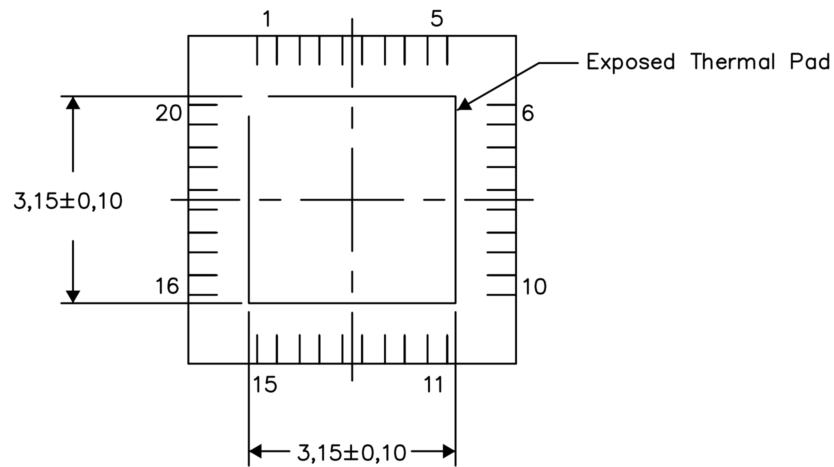
F. Customers should contact their board fal

r paste release. Custo

PLASTIC QUAD FLATPACK NO-LEAD



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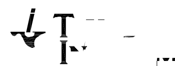
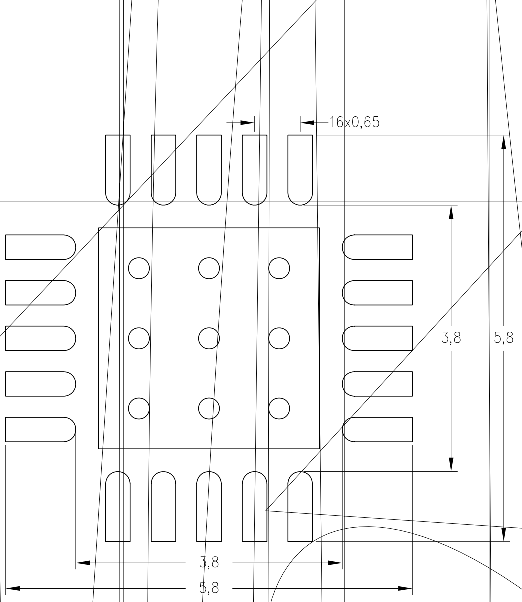
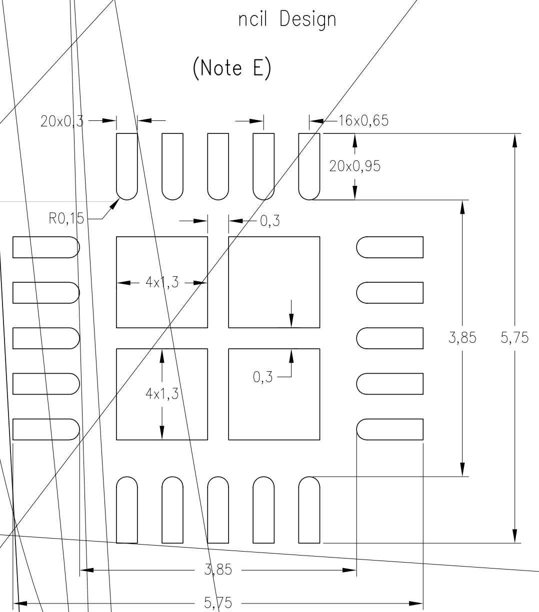
NOTE: All linear dimensions are in millimeters



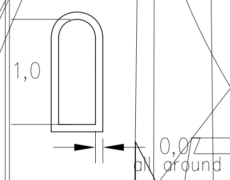
ncil Design

(Note E)

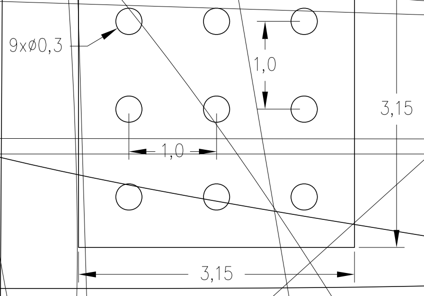




Non Solder Mask Defined Pad



(Note C)



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NOTES:

ommended for alternate designs.

oe soldered to a thermal pad on the board. Refer to Application Note, QFN Packages, Texas Instruments Litera for specific thermal information, via requirements, and recommended board layout. These documents are available at

E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design co

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