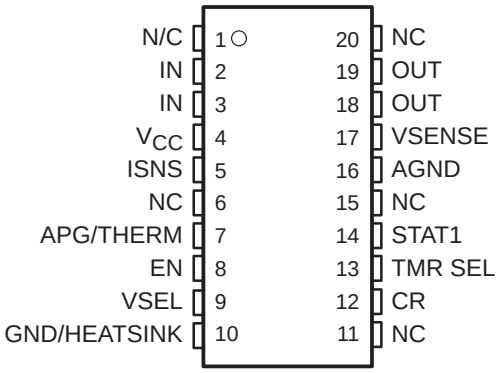
bq24001, bq24002, bq24003
SINGLE-CELL ADVANCED LINEAR Li-ION CHARGE MANAGEMENT IC WITH INTEGRATED POWER FET

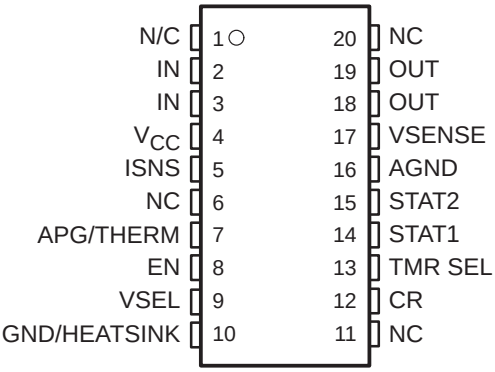
SLUS462 – SEPTEMBER 2000

- **Highly Integrated Solution With FET Pass Transistor and Reverse-Blocking Schottky and thermal Protection**
- **Integrated Voltage and Current Regulation with Programmable Charge Current**
- **Ideal for Linear Charger Designs for Single-Cell Li-Ion Packs With Coke or Graphite Anodes**
- **Up to 1.2-A Continuous Charge Current With Low Dropout Voltage (Maximum of 0.7 V)**
- **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**
- **Soft-Start Circuit for Limiting the Current Ramp Rate to Maintain Compliance With the USB 1.1 Standard**
- **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: 20-Lead TSSOP PowerPAD™**

bq24001
PWP PACKAGE
(TOP VIEW)



bq24002, bq24003
PWP PACKAGE
(TOP VIEW)



PRODUCT PREVIEW

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, 20-lead TSSOP PowerPAD™ package.

The bq2400x continuously 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 trickle-charge to condition the battery. A preconditioning timer is provided for additional safety. Following preconditioning, 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 ±1.2% over the operating junction temperature and supply voltage range.

description (continued)

Charge is terminated by either of the following methods:

- Maximum time
- Minimum current detection

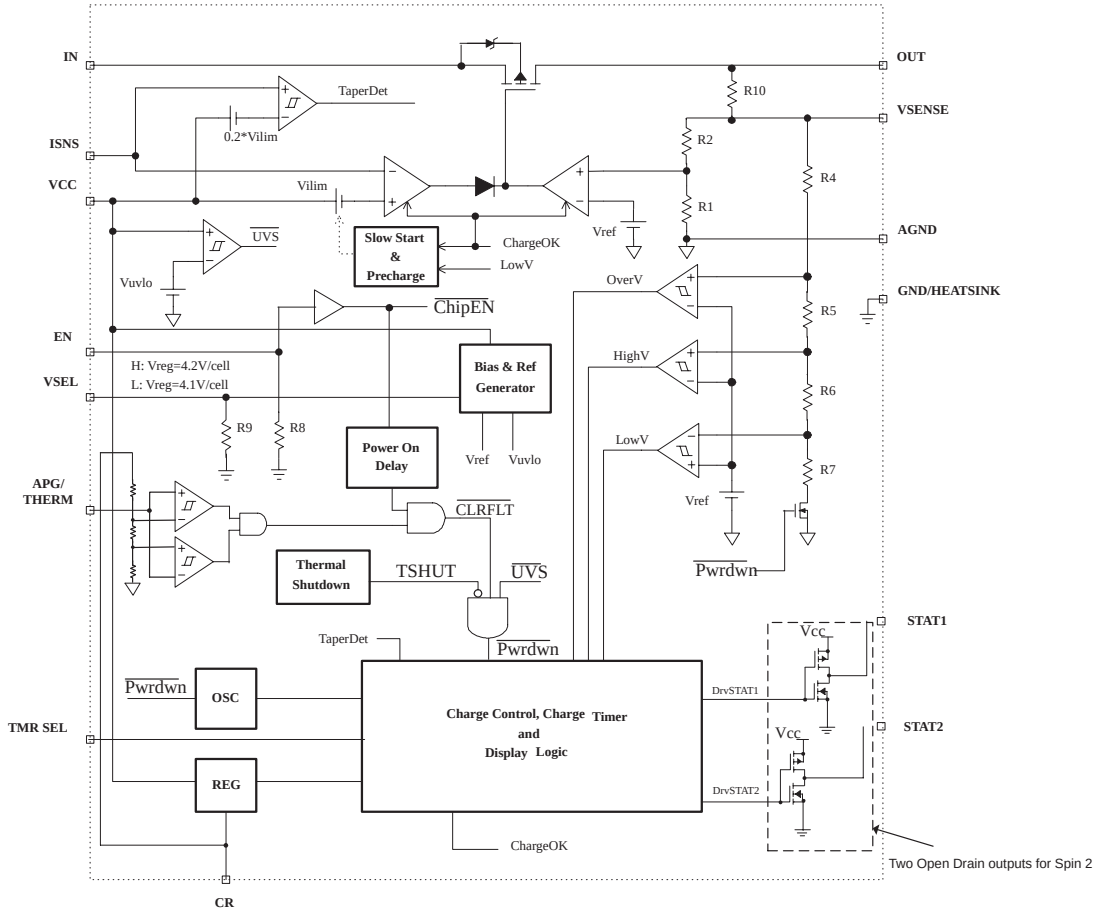
The bq2400x automatically restarts the charge if the battery voltage falls below an internal recharge threshold.

As shown in the following table, the bq2400x series ICs are available in 3 charge-status configuration options.

AVAILABLE OPTIONS

T_J	PACKAGE	Charge Status Configuration
	20-Pin HTTSOP PowerPAD™ (PWP)	
–40°C to 125°C	bq24001	Single LED
	bq24002	2 LEDs
	bq24003	Bicolor LED

functional block diagram



Terminal Functions

TERMINAL		I/O	DESCRIPTION
NAME	No.		
AGND	16		Ground pin; connect close to the battery terminal for remote sensing.
APG/THERM	7	I	Adapter power good input/Thermistor sense
CR	12	I	Internal regulator bypass capacitor
EN	8	I	Active-high enable input with internal pull down. Low-Iq stand-by mode active when EN is low.
GND/HEATSINK	10		Ground pin, connect to PowerPAD™ heat-sink layout pattern
IN	2,3	I	Input voltage
ISNS	5	I	Current sense input
NC	1,6,11 15,20		No connect
OUT	18,19	O	Charge current output
STAT1	14	O	Display output 1
STAT2	15	O	Display output 2 (for bq24002 and bq24003 only)
TMR SEL	13	I	User selectable total charge timer
V_{CC}	4	I	Supply voltage
VSEL	9	I	Voltage regulation options
VSENSE	17	I	Remote voltage sense input regulation

PRODUCT PREVIEW

PRODUCT PREVIEW

absolute maximum ratings over operating free–air temperature range (unless otherwise noted)†

Supply voltage (Vcc with respect to GND) 13.5V
Input voltage (IN, ISNS, EN, APG/THERM/CR/STAT1/STAT2, VSENSE, TMR SEL, VSEL) (all with respect to GND) 13.5V
Output current (OUT pins) 2A
Output sink/source current (STAT1 and STAT2) 10mA
Operating free-air temperature range, T_A . . . . . –20°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

† 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.

DISSIPATION RATING TABLE 1 – FREE-AIR TEMPERATURE (SEE FIGURE 1)‡

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 70°C$ POWER RATING	$T_A = 125°C$ POWER RATING
PWP§	700 mW	5.6 mW/°C	448 mW	140 mW

DISSIPATION RATING TABLE 2 – CASE TEMPERATURE (SEE FIGURE 2)‡

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 70°C$ POWER RATING	$T_A = 125°C$ POWER RATING
PWP§	25 W	285.7 mW/°C	22.9 W	7.1 W

‡ Dissipation rating tables and figures are provided for maintenance of junction temperature at or below absolute maximum temperature of 1505C. For guidelines on maintaining junctions temperature within recommended operating rage, see the *thermal information* section.

§ Refer to the *thermal information* section for detailed power dissipation considerations when using the TSSOP packages.

DISSIPATION DERATING CURVE¶ vs FREE-AIR TEMPERATURE

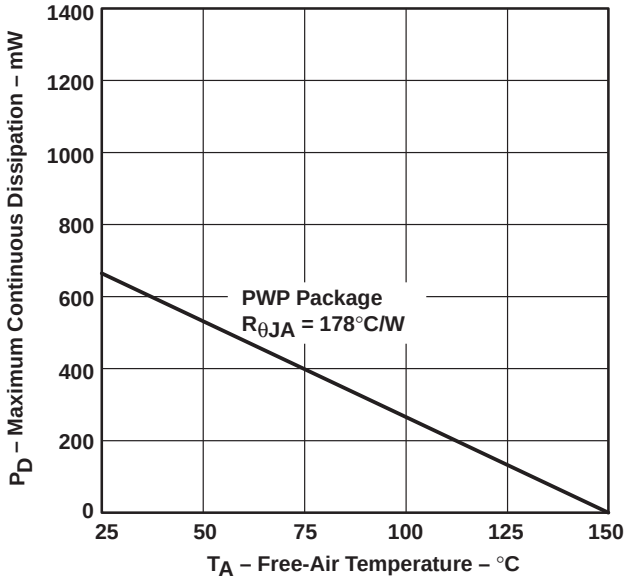


Figure 1

MAXIMUM CONTINUOUS DISSIPATION¶ vs CASE TEMPERATURE

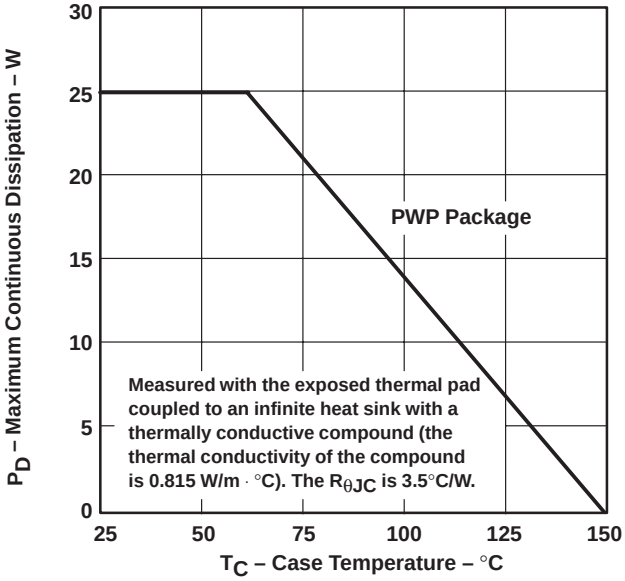


Figure 2

¶ Dissipation rating tables and figures are provided for maintenance of junction temperature at or below absolute maximum temperature of 150°C. It is recommended not to exceed a junction temperature of 125°C.

recommended operating conditions

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

electrical characteristicsover 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
V_{CC} current, standby-mode	EN ≤ $V_{IL(EN)}$			1	µA
IN current, standby mode	EN ≤ $V_{IL(EN)}$			10	µA
Standby current (sum of currents into OUT and VSENSE pins)	V_{CC} < V_{CC_UVLO}, V_{OUT} =4.3 V, VSENSE =4.3V		2	4	µA
	EN <= Vil_{EN}, V_{OUT} =4.3 V, VSENSE =4.3 V		2	4	
Standby current (sum of currents into OUT and VSENSE pins)	V_{CC} < V_{CC_UVLO}, V_{OUT} = 8.6 V, VSENSE =8.6 V		4	8	µA
	EN ≤ $V_{IL(EN)}$, V_{OUT} = 8.6 V, VSENSE =8.6 V		4	8	
Input bias current, VSENSE (1 cell)	VSENSE = 4.3 V, EN > $V_{IH(EN)}$			4	µA
Input bias current, ISNS	V_{CC} = 10 V, ISNS = 10 V, EN > $V_{IH(EN)}$			1	µA

voltage regulation , 0°C ≤ T_J ≤ 125°C

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output voltage	VSEL = V_{SS}, $V_{OUT(VSEL-LOW)}$ 0 < I_O ≤ 1.2 A	4.05	4.10	4.15	V
Output voltage	VSEL = Vcc, $V_{O(VSEL-HIGH)}$ 0 < I_O <= 1.2 A	4.15	4.20	4.25	V
Load regulation	1 mA ≤ I_O ≤ 1.2 A, $V_{I(IN)}$= 5 V, V_{CC} =5 V, T_J = 25°C		3		mV
Line regulation	V_{OUT}+V_{DO}+$V_{ilim(MAX)}$ < $V_{I(VCC)}$ < 10 V, T_J = 25°C		0.01		%/V
Dropout voltage = VI(IN)-Vout	V_{OUT}+V_{DO}+$V_{ilimMAX}$ <$V_{I(VCC)}$< 10 V, I_O = 1.2 A			0.7	V

current regulation

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Current regulation threshold	VSENSE < $V_{O(VSEL-LOW/HIGH)}$	0.095	0.1	0.105	V
Delay time	VSENSE pulsed above VVLOWV to I_O = 10% of regulated value			1	ms
Rise time	I_O increasing from 10% to 90% of regulated value. Rilim ≥ 0.2 ?	0.1		1	ms

current sense resistor

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Current sense resistor range	100 mA ≤ Ilim ≤ 1.2A	0.083		1	Ω

PRODUCT PREVIEW

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

precharge current regulation

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Precharge current regulation	V_{SENSE}<V_{LOWV} , 0.083 ≤ Rilim ≤ 1.00 ?	45	65	85	mA

V_{CC} UVLO comparator

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Start threshold		4.40	4.45	4.50	V
Stop threshold		4.30	4.35	4.40	V
Hysteresis		50			mV

APG/THERM comparator

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Upper trip threshold		1.490	1.500	1.510	V
Lower trip threshold		0.550	0.560	0.570	V
Input bias current				1	μA

lowv comparator (per cell values)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Start threshold		2.80	2.90	3.00	V
Stop threshold		3.00	3.10	3.20	V
Hysteresis		100			mV

highv comparator (per cell values)

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

overv comparator (per cell values)

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

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Trip threshold		0.015	0.020	0.025	V

EN logic input (TTL logic)

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 (CMOS logic)

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

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

TMR SEL input (CMOS logic)

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

STAT1, STAT2 (spin 1 and 3)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output (low) saturation voltage	I_O = 10mA			1.5	V
Output (low) saturation voltage	I_O = 4 mA			0.4	V
Output (high) saturation voltage	I_O = –10mA			V_{CC}–1.5	V
Output (high) saturation voltage	I_O = –4 mA			V_{CC}–0.4	V
Output turn on/off time	I_O = ± 10mA, C = 100 pF			100	µs
Output saturation voltage	I_O = 10mA			1.5	V
Output saturation voltage	I_O = 4 mA			0.4	V

power-on reset (POR)

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

APG/THERM delay

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

oscillator/timers

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Oscillaotr frequency, MCLK		89.5	99.4	109.3	kHz
User-select 3-hour charge timer		9,720	10,800	11,880	s
User-select 4.5-hour charge timer		14,580	16,200	17,820	s
User-select 6-hour charge timer		19,440	21,600	23,760	s

thermal shutdown

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Thermal trip			165		°C
Thermal hysteresis			10		°C

PRODUCT PREVIEW

detailed description

power FET

The integrated transistor is a P-channel MOSFET with a maximum on-resistance of 58 mΩ. The power FET also 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 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.

IMPORTANT NOTICE

Texas Instruments and its subsidiaries (TI) reserve the right to make changes to their products or to discontinue any product or service without notice, and advise customers to obtain the latest version of relevant information to verify, before placing orders, that information being relied on is current and complete. All products are sold subject to the terms and conditions of sale supplied at the time of order acknowledgment, including those pertaining to warranty, patent infringement, and limitation of liability.

TI warrants performance of its semiconductor products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are utilized to the extent TI deems necessary to support this warranty. Specific testing of all parameters of each device is not necessarily performed, except those mandated by government requirements.

Customers are responsible for their applications using TI components.

In order to minimize risks associated with the customer's applications, adequate design and operating safeguards must be provided by the customer to minimize inherent or procedural hazards.

TI assumes no liability for applications assistance or customer product design. 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 of TI covering or relating to any combination, machine, or process in which such semiconductor products or services might be or are used. TI's publication of information regarding any third party's products or services does not constitute TI's approval, warranty or endorsement thereof.