SINGLE-CHIP LI-ION AND LI-POL CHARGE MANAGEMENT IC
FOR CURRENT-LIMITED APPLICATIONS

FEATURES

- **Designed Specifically to Work With Current-Limited Wall Supplies**
- **Ideal for Low Dropout Charger Design for Single-Cell Li-Ion Packs With Coke or Graphite Anodes**
- **Integrated PowerFET for 500 mA**
- **Integrated Voltage Regulation With 0.5% Accuracy**
- **Battery Insertion and Removal Detection**
- **Charge Termination by Minimum Current and Time**
- **Pre-Charge Conditioning With Safety Timer**
- **Sleep Mode for Low-Power Consumption**
- **Charge Status Output for LED or Host Processor Interface Indicates Charge-in-Progress, Charge Completion, and Fault Conditions**
- **Optional Temperature Monitoring Before and During Charge**
- **Small, 8-Pin Power-Pad MSOP Package**

DESCRIPTION

The bq2420x series are simple Li-Ion linear charge management devices targeted at low-cost and space limited charger applications. The bq2420x series offer integrated powerFET, high-accuracy voltage regulation, temperature monitoring, charge status, and charge termination, in a single monolithic device.

The bq2420x is designed to work with a current-limited wall-mount transformer and therefore does not provide any current regulation. However, these devices offer a fixed internal current limit to prevent damage to the internal powerFET. A time-limited pre-conditioning phase is provided to condition deeply discharged cells. Once the battery reaches the charge voltage, the high accuracy voltage regulation loop takes over and completes the charge cycle. Charge is terminated based on minimum current. An internal charge timer provides a backup safety for charge termination.

Other standard features include an automatic sleep mode activated when V_{CC} falls below the battery voltage and a recharge feature activated when the battery voltage falls below the V_{RCH} threshold.

In addition to the standard features, the core product provides two additional enhancements: temperature monitoring and status display. The temperature-sense circuit continuously measures battery temperature using an external thermistor and inhibits charge until the battery temperature is within the user–defined thresholds. The STAT pin indicates three conditions of operation of the charger. These conditions are *charge-in-progress*, *charge complete*, and *fault*. This output can be used to drive an LED or an interface to a microcontroller.

TYPICAL APPLICATION
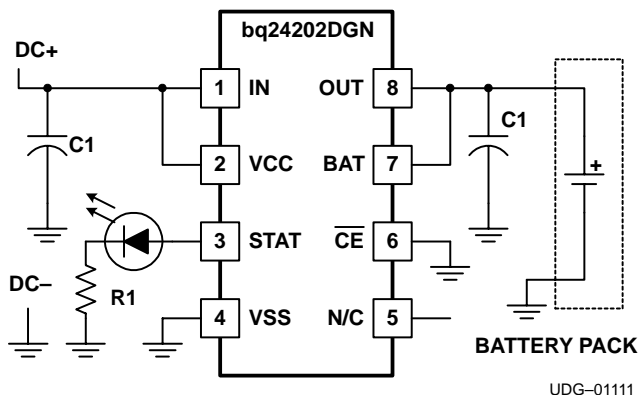
UDG–01111

bq24200, bq24201, bq24202
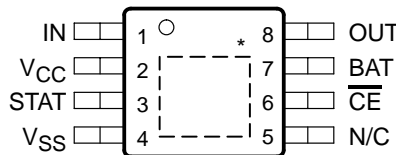# bq24203, bq24204, bq24205

AVAILABLE OPTIONS

T_J	CHARGE REGULATION VOLTAGE	OPTIONAL FUNCTIONS	MARKING	PACKAGED DEVICES (DGN)
−40°C to 125°C	4.2 V	STAT and TS	AZC	bq24200DGN
	4.1 V	STAT and TS	AZD	bq24201DGN
	4.2 V	STAT	AZE	bq24202DGN
	4.1 V	STAT	AZF	bq24203DGN
	4.2 V	–	AZG	bq24204DGN
	4.1 V	–	AZI	bq24205DGN

† The DGN package is available taped and reeled. Add TR suffix to device type (e.g. bq24200DGNTR) to order. Quantities 2500 devices per reel.
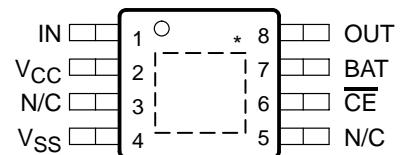
bq24200, bq24201
HTSSOP (DGN) PACKAGE
(TOP VIEW)

```
IN    [ 1 ○      * 8 ]  OUT
VCC   [ 2         7 ]  BAT
STAT  [ 3         6 ]  TS
VSS   [ 4         5 ]  N/C
```
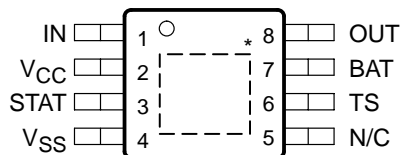
bq24202, bq24203
HTSSOP (DGN) PACKAGE
(TOP VIEW)

```
IN    [ 1 ○      * 8 ]  OUT
VCC   [ 2         7 ]  BAT
STAT  [ 3         6 ]  CE̅
VSS   [ 4         5 ]  N/C
```

bq24204, bq24205
HTSSOP (DGN) PACKAGE
(TOP VIEW)

```
IN    [ 1 ○      * 8 ]  OUT
VCC   [ 2         7 ]  BAT
N/C   [ 3         6 ]  CE̅
VSS   [ 4         5 ]  N/C
```

* Thermal pad is electrically connected to the ground of the device (V_{SS}).

Terminal Functions

NAME	bq24200 bq24201	bq24202 bq24203	bq24204 bq24205	I/O	DESCRIPTION
	TERMINAL				
	NO.				
BAT	7	7	7	I	Battery voltage sense input
CE̅	–	6	6	I	Charge enable Input (active low)
IN	1	1	1	I	Charge input voltage
N/C	5	5	3, 5	–	No connection. Must be left floating
OUT	8	8	8	O	Charge current output
STAT	3	3	–	O	Charge status output
TS	6	–	–	I	Temperature sense input
VCC	2	2	2	I	V_{CC} input
VSS	4	4	4	–	Ground input

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

Supply voltage (Vcc with respect to GND) . . . . 16.5 V

Input voltage, IN, STAT, TS (all with respect to GND) . . . . 16.5 V

Input voltage, BAT, OUT (all with respect to GND) . . . . 7 V

Output sink/source current (STAT) . . . . 15 mA

Storage temperature range, T_{stg} . . . . −65°C to 150°C

Junction temperature range, T_J . . . . −40°C to 125°C

Lead temperature (soldering, 10sec) . . . . 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.

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dissipation ratings

PACKAGE	THERMAL IMPEDANCE JUNCTION-TO-AMBIENT (θ_{JA})	THERMAL IMPEDANCE JUNCTION-TO-CASE (θ_{JC})	T_A 25°C POWER RATING	DERATING FACTOR ABOVE $T_A = 25$°C
8 Pin DGN (1)	57.20°C/W	4.4°C/W	1.75 W	0.017 W/°C

NOTE 1: This data is based on using JEDEC High-K board and topside traces, top and bottom thermal pad (2mm × 3mm), internal 1 oz. power and ground planes, four thermal via underneath the die connecting to ground plane.

recommended operating conditions

		MIN	MAX	UNIT
Supply voltage, V_{CC}		$V_{(LOWV–MIN)}$	13.5	V
Input voltage, V_{IN}		$V_{(LOWV–MIN)}$	13.5	
Operating junction temperature range, T_J		–40	125	°C

electrical characteristics over 0°C $\leq T_J \leq 125$°C and supply voltage range (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Vcc Current, $I_{CC(VCC)}$	Vcc > Vcc(min)		1.7	2.5	mA
Sleep current , $I_{CC(SLP)}$	Sum of currents into OUT and BAT pins, Vcc<$V_{(SLP)}$, 0°C $\leq$ Tj ≤ 85°C			5	µA
Sleep current , $I_{CC(SLP)}$	Sum of currents into OUT and BAT pins, Vcc<$V_{(SLP)}$			10	µA
Standby Current, $I_{CC(STDBY)}$	Sum of currents into Vcc, IN and TS pins, (Vcc–$V_{I(TS)}$) $\leq$ 300 mV			1	mA
Input Bias Current on BAT pin, $I_{IB(BAT)}$				1	µA
Input Bias Current on TS pin, $I_{IB(TS)}$	0.1*Vcc $\leq V_{I(TS)} \leq$ 0.8*Vcc			1	µA

voltage regulation, $V_{O(REG)} + V_{(DO–MAX)} \leq$ VCC, $I_{(TERM)} < I_{O(OUT)} \leq$ 500 mA, over 0°C $\leq T_J \leq 125$°C and supply voltage range (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output voltage, $V_{O(REG)}$	$V_{O(REG)} + V_{(DO–MAX)} \leq$ 10 V, $I_{(TERM)} < I_{O(OUT)} \leq$ 250 mA	4.0795	4.10	4.1205	Volts
Output voltage, $V_{O(REG)}$		4.05	4.10	4.15	Volts
Output voltage, $V_{O(REG)}$	$V_{O(REG)} + V_{(DO–MAX)} \leq$ 10 V, $I_{(TERM)} < I_{O(OUT)} \leq$ 250 mA	4.1790	4.20	4.2210	Volts
Output voltage, $V_{O(REG)}$		4.15	4.20	4.25	Volts
Dropout voltage ($V_{(IN)} – V_{(OUT)}$), $V_{(DO)}$	$V_{O(REG)} + V_{(DO–MAX)} \leq$ Vcc, $I_{O(OUT)} =$ 500 mA	200	350	500	mV

output current, over 0°C $\leq T_J \leq 125$°C and supply voltage range (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output current, $I_{O(OUT)}$	See Note 1			500	mA
Short–circuit Trip Current, $I_{(SC)}$	See Note 1	1		1.6	A

NOTE 2: Assured by design, not production tested.

pre-charge current regulation, over 0°C $\leq T_J \leq 125$°C and supply voltage range (unless otherwise noted)

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Pre–charge Current , $I_{(PRECHG)}$	$V_{I(BAT)} < V_{(LOWV)}$,	t < $t_{(30min)}$	10	13.5	17	mA
Battery Detection Current , $I_{(DETECT)}$	$V_{I(BAT)} =$ 2.5 V,	t > $t_{(30min)}$	160	210	300	µA

charge termination detection, over 0°C ≤ T$_J$ ≤ 125°C And supply voltage range (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Taper current detect threshold, I$_{(TAPER)}$	V$_{I(BAT)}$ > V$_{(RCH)}$	22	25.5	29	mA
Charge termination current detect threshold, I$_{(TERM)}$	V$_{I(BAT)}$ > V$_{(RCH)}$	0.8	1.1	1.4	mA

temperature comparator, over 0°C ≤ T$_J$ ≤ 125°C and supply voltage range (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Lower Temperature Threshold, V$_{(TS1)}$	TS pin voltage		30		%VCC
Upper Temperature Threshold, V$_{(TS2)}$	TS pin voltage		60		%VCC
Accuracy		−0.7		0.7	%VCC
Hysteresis			1		%VCC

low voltage battery threshold, over 0°C ≤ T$_J$ ≤ 125°C and supply voltage range (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
LowV Threshold, V$_{(LOWV)}$	0°C ≤ T$_J$ ≤ 85°C	2.8	2.95	3.1	Volts
LowV Threshold, V$_{(LOWV)}$		2.8	3.0	3.2	Volts

battery recharge threshold, over 0°C ≤ T$_J$ ≤ 125°C and supply voltage range (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Recharge Threshold, V$_{RCH}$		V$_{O(REG)}$ 0.115	V$_{O(REG)}$ −0.1	V$_{O(REG)}$ 0.85	Volts

STAT output, Vcc ≥ V$_{O(REG)}$, over 0°C ≤ T$_J$ ≤ 125°C and supply voltage range (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output (low) saturation voltage, V$_{OL(STAT)}$	Io = 10 mA			0.5	Volts
Output (high) saturation voltage V$_{OH(STAT)}$	Io = −5 mA	Vcc−1.5			Volts

$\overline{CE}$, over 0°C ≤ T$_J$ ≤ 125°C and supply voltage range (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input (low) voltage, V$_{IL(CE)}$	I$_{IL}$ = 5 μA	0		V$_{CC}$−1	Volts
Input (high) voltage V$_{IH(CE)}$	I$_{IH}$ = 20 μA	Vcc−0.3			Volts

timers, over 0°C ≤ T$_J$ ≤ 125°C and supply voltage range (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Pre-charge and taper timer, t$_{(PRECHG)}$		1,548	2,065	2,581	sec
Taper timer, t$_{(TAPER)}$		1,548	2,065	2,581	sec
Charge Timer, t$_{(CHG)}$		9,292	12,389	15,486	sec

sleep comparator, over 0°C ≤ T$_J$ ≤ 125°C and supply voltage range (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Sleep–mode threshold, V$_{(SLP)}$	2.3V ≤ V$_{I(BAT)}$ ≤ V$_{O(REG)}$	V(BAT)–10 mV			Volts

power-on-reset and V$_{IN}$ Ramp Rate, over 0°C ≤ T$_J$ ≤ 125°C and supply voltage range (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
POR Threshold, V$_{POR}$	See Note 1	2.3	2.4	2.5	Volts
Slew rate	See Note 1	5		5 x 10^{-5}	Volts/μs

NOTE 1. Ensured by design, not production tested.

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functional block diagram
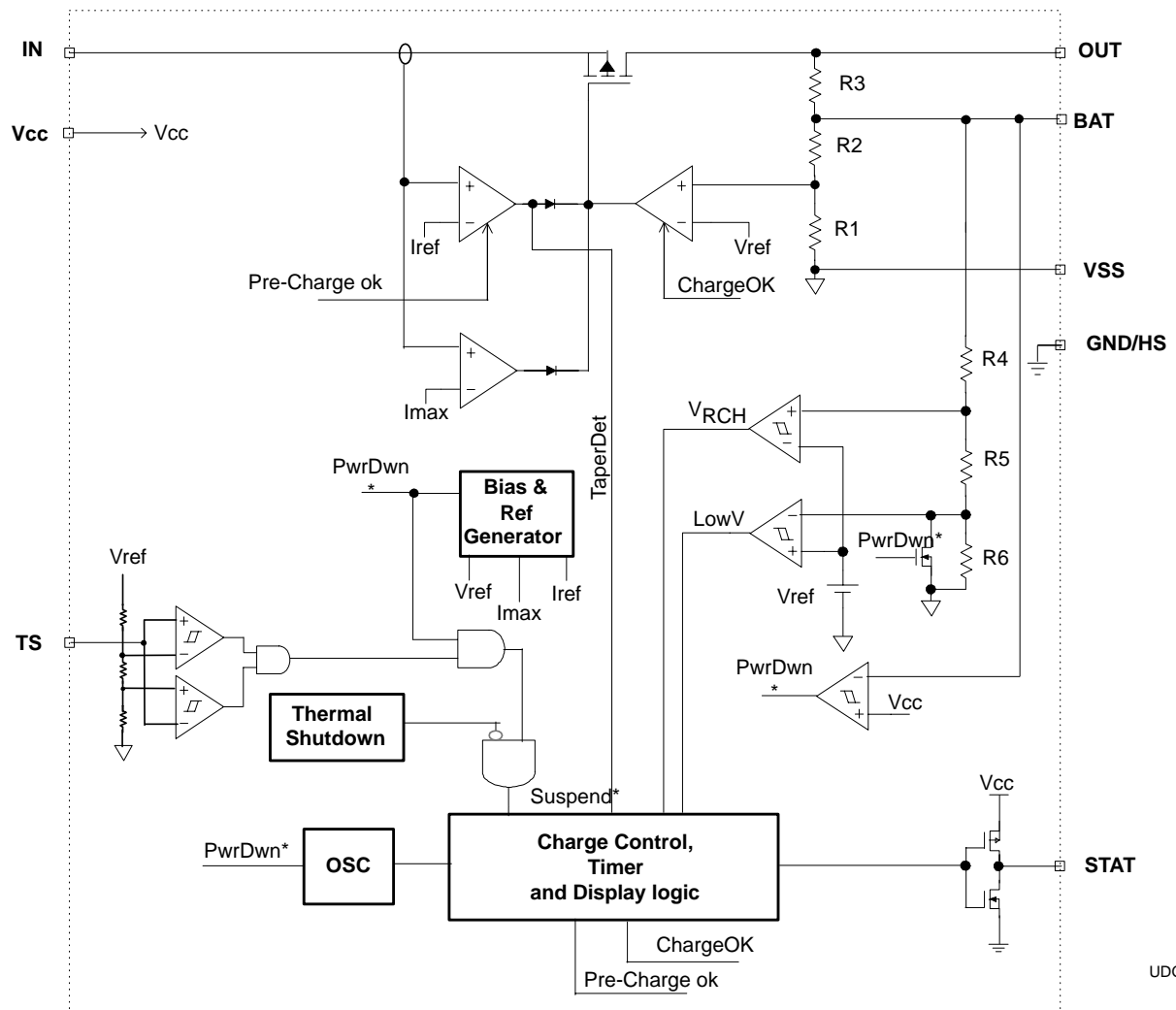
UDG–01105

detailed description

IN: This pin is connected to the source of the internal P-channel powerFET.

OUT: This pin is connected to the drain of the internal P-channel powerFET.

Battery voltage sense (BAT): Voltage sense-input tied directly to the positive side of the battery.

Temperature sense input (TS): Input for an external battery-temperature monitoring circuit.

Charge status output (STAT): High-impedance indication of various charge conditions.

Supply voltage input (VCC): Power supply input
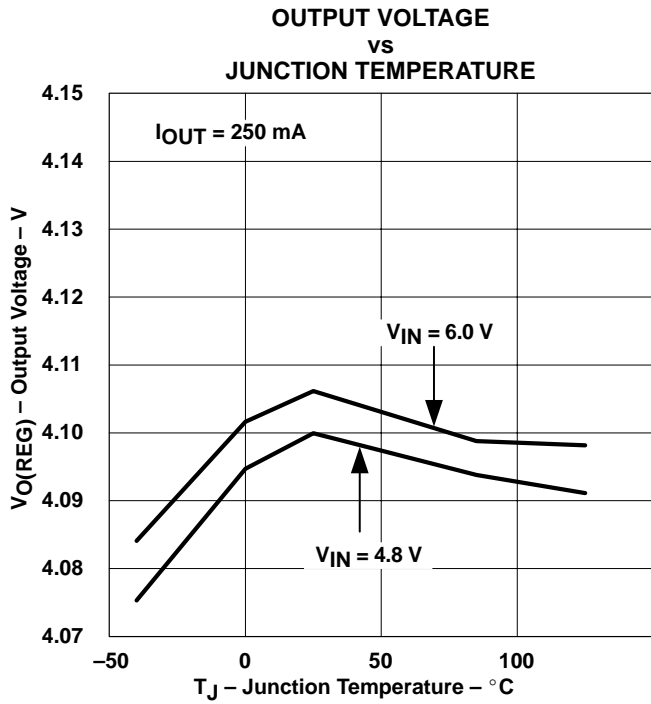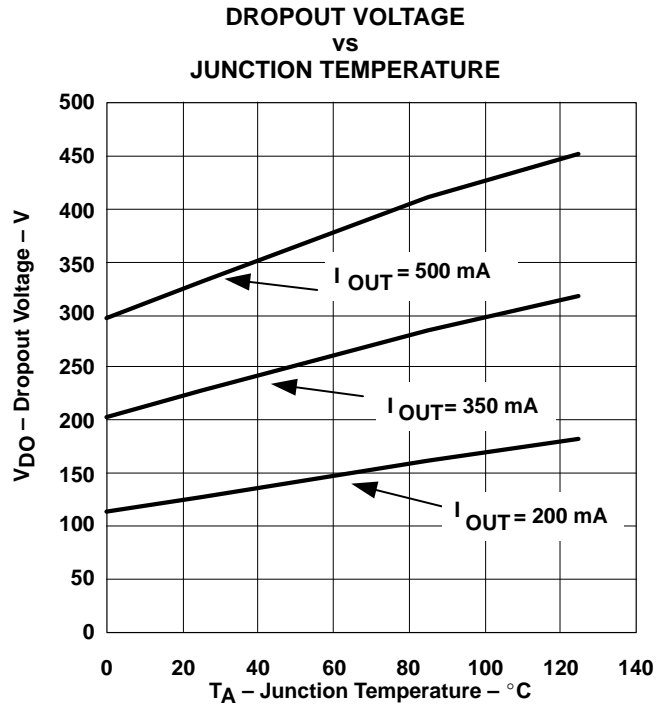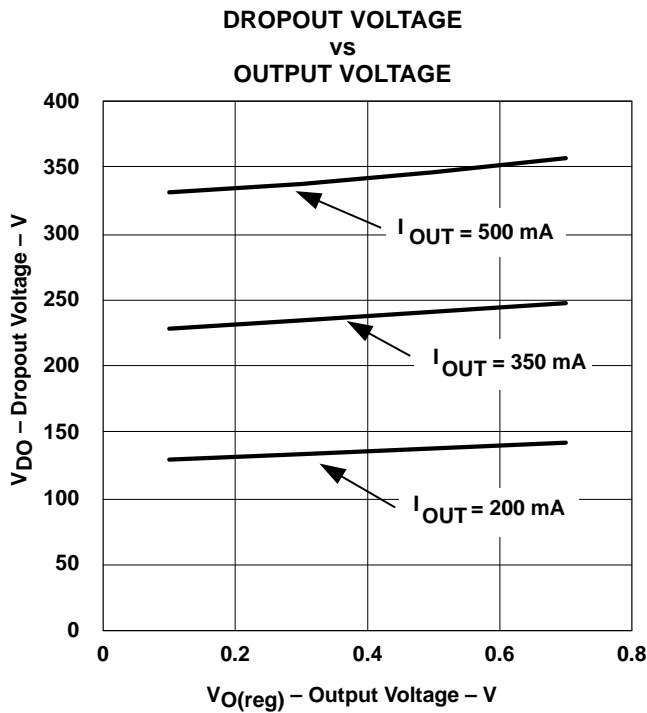
TYPICAL CHARACTERISTICS

OUTPUT VOLTAGE
vs
JUNCTION TEMPERATURE

Figure 1

DROPOUT VOLTAGE
vs
JUNCTION TEMPERATURE

Figure 2

DROPOUT VOLTAGE
vs
OUTPUT VOLTAGE

Figure 3

SUPPLY CURRENT
vs
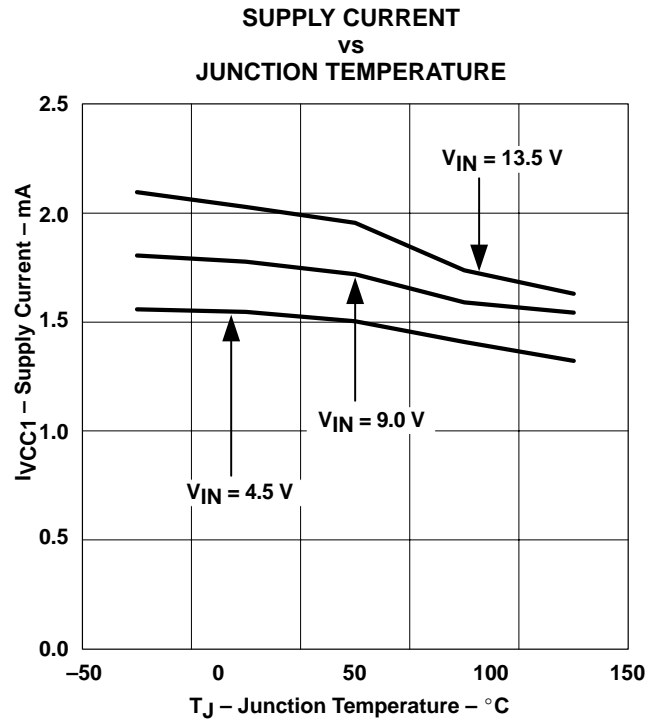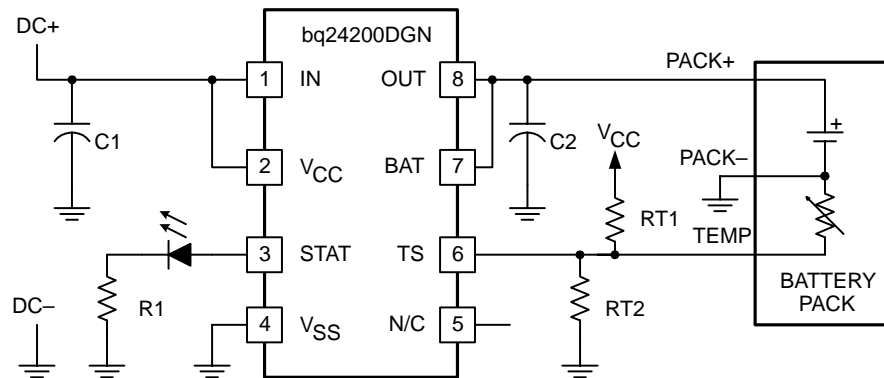**JUNCTION TEMPERATURE**

Figure 4

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APPLICATION INFORMATION

UDG–01109

Figure 5. Low Dropout Single–Cell Li–Ion/Li–Pol Charger

functional description

The bq2420x supports a precision Li-Ion or Li-Pol charging system suitable for single-cells with either coke or graphite anodes. Figure 5 shows an application schematic and Figure 6 shows the typical charge profile.

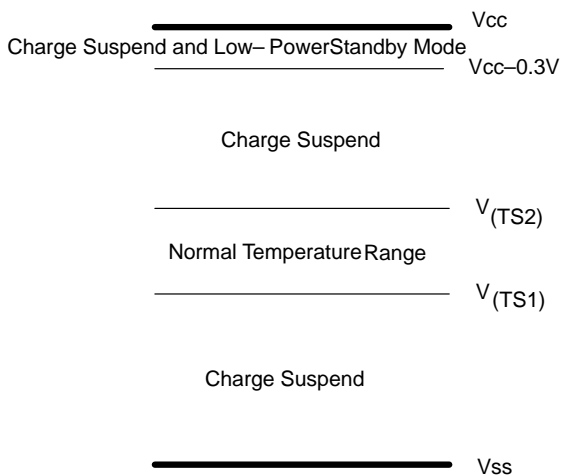## temperature qualification (bq24200 and bq24201 only)

The bq24200 and bq24201 continuously monitors battery temperature by measuring the voltage between the TS and VSS pins. A negative- or a positive-temperature coefficient thermistor (NTC, PTC) and an external voltage divider typically develop this voltage (see figure 5). The bq24200 and bq24201 compare this voltage against the internal $V_{(TS1)}$ and $V_{(TS2)}$ thresholds to determine if charging is allowed (see Figure 7). The temperature sensing circuit is immune to any fluctuation in Vcc since both the external voltage divider and the internal thresholds are referenced to Vcc.

Once a temperature outside the $V_{(TS1)}$ and $V_{(TS2)}$ thresholds is detected the bq24200 and bq24201 immediately suspend the charge. The bq24200 and bq24201 suspend the charge by turning off the powerFET and holding the timer value (i.e. timers are NOT reset). Charge is resumed when the temperature returns to the normal range.

APPLICATION INFORMATION
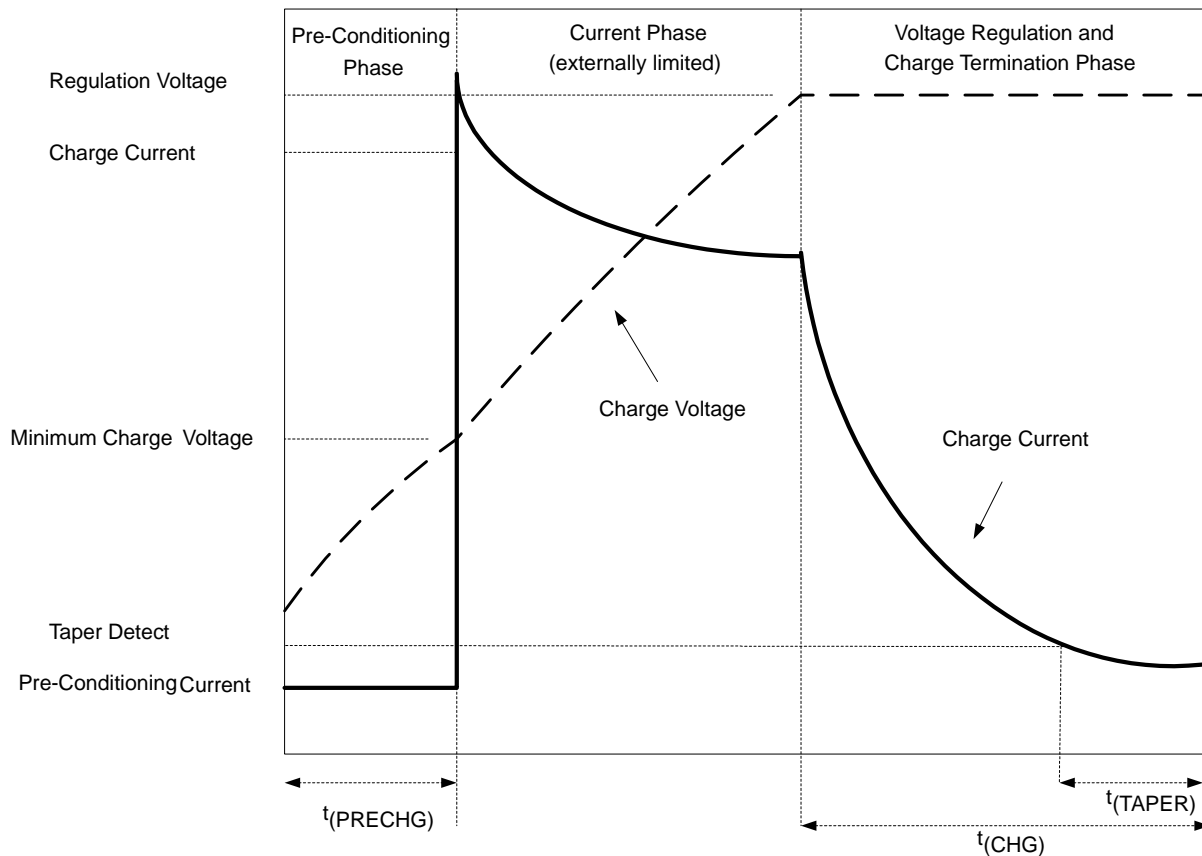
Figure 6. Typical Charge Profile

Figure 7. TS Pin Thresholds

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APPLICATION INFORMATION

operational flow diagram

POR

Vcc > V (SLP)
checked at all times

No → SLEEP MODE
Indicate SLEEP MODE
(STAT=Hi–Z)

Yes

$V_{I(BAT)} V_{(LOWV)}$ — Yes → Reset and Start $t_{(PRECHG)}$ timer → APPLY PRECHARGE, $I_{(PRECHG)}$
Indicate Charge–In–Progress

$V_{I(BAT)} V_{O(REG)}$ — Yes → Current Phase
Indicate Charge–In–Progress

$V_{I(BAT)} V_{O(REG)}$ — Yes / No

Reset all timers, Start $t_{(CHG)}$ timer

$V_{I(BAT)} V_{(LOWV)}$ — No / Yes

$t_{(PRECHG)}$ Expired? — Yes

Regulate Voltage
Indicate Charge–In–Progress

$t_{(CHG)}$ Expired? — Yes → Fault Condition
– Enable $I_{(DETECT)}$
Indicate Fault

No

$V_{I(BAT)} V_{O(REG)}$ — Yes / No

Battery replaced? — No / Yes

$I_{(TAPER)}$ detection? — Yes

$t_{(TAPER)}$ Expired? — No / Yes

$I_{(TERM)}$ detection? — No / Yes

Turn off charge
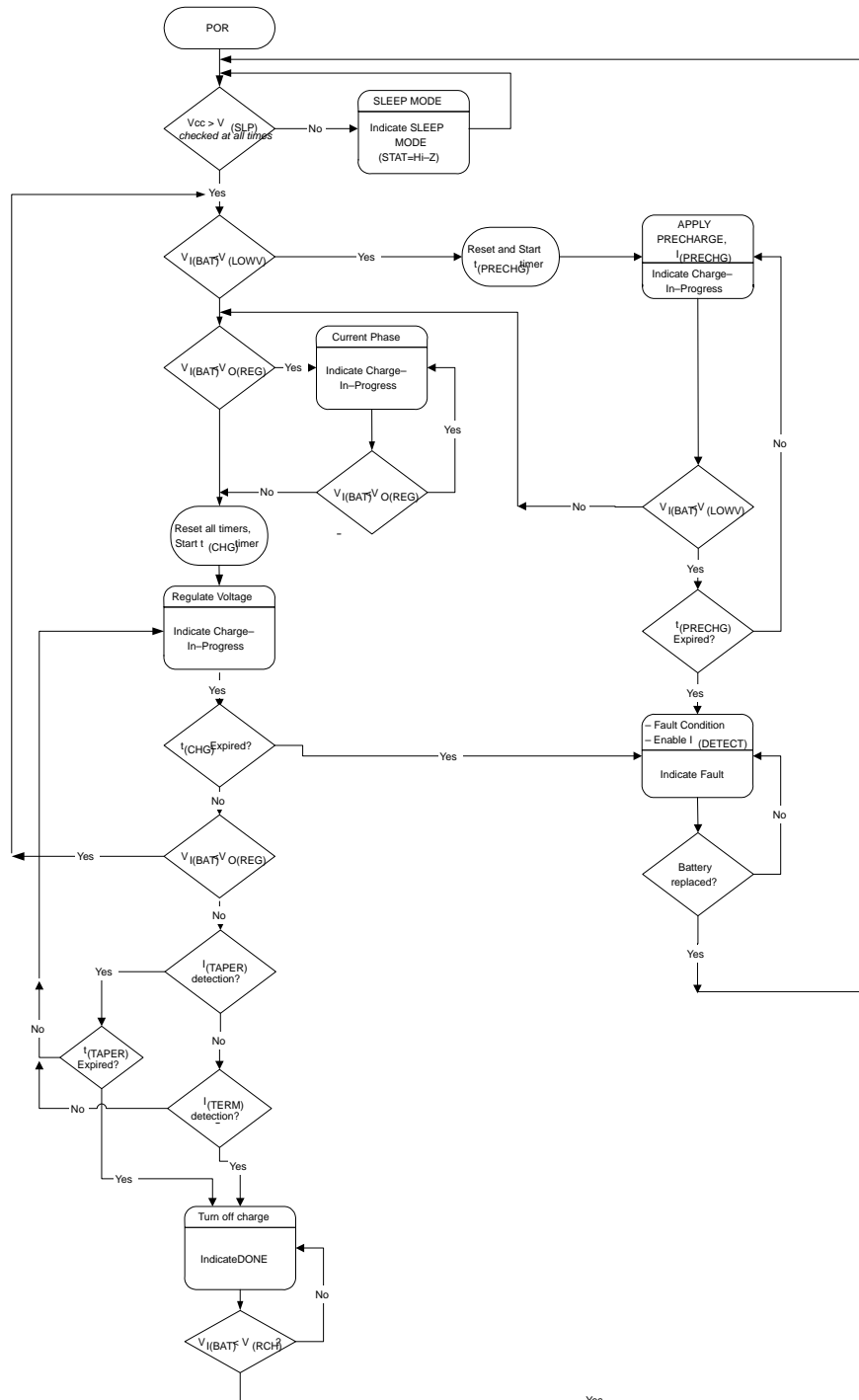Indicate DONE

$V_{I(BAT)} V_{(RCH)}$ — No / Yes

Figure 8. Operational Flow Chart

APPLICATION INFORMATION

The resistor values of R_{T1} and R_{T2} are calculated by the following equations:

For NTC Thermistors:

$$R_{T1} = \frac{\left(5 \times RT_H \times RT_C\right)}{\left(3 \times \left(RT_C - RT_H\right)\right)}$$

$$R_{T2} = \frac{\left(5 \times RT_H \times RT_C\right)}{\left(2 \times RT_C\right) - \left(7 \times RT_H\right)}$$

For PTC Thermistors:

$$R_{T1} = \frac{\left(5 \times RT_H \times RT_C\right)}{\left(3 \times \left(RT_H - RT_C\right)\right)}$$

$$R_{T2} = \frac{\left(5 \times RT_H \times RT_C\right)}{\left(2 \times RT_H\right) - \left(7 \times RT_C\right)}$$

Where RT_C is the cold temperature resistance and RT_H is the hot temperature resistance of thermistor, as specified by the thermistor manufacturer.

R_{T1} or R_{T2} can be omitted If only one temperature (hot or cold) setting is required. Applying a voltage between the V_{TS1} and V_{TS2} thresholds to pin TS disables the temperature-sensing feature. Also applying a voltage between (V_{CC} – 0.3 V) and Vcc suspends the charge and places the IC in the low-power standby mode.

battery pre-conditioning

Figure 7 shows the operational flow chart for the bq2420x.

Upon power-up, if the battery voltage is below the $V_{(LOWV)}$ threshold, the bq2420x applies a pre-charge current, $I_{(PRECHG)}$, to the battery. This feature revives deeply discharged cells. The bq2420x activates a safety timer, $t_{(PRECHG)}$, during the conditioning phase. If $V_{(LOWV)}$ threshold is not reached within the timer period, the bq2420x turns off the charger and enunciates FAULT on the STAT pin. In the case of a FAULT condition, the bq2420x reduces the current to $I_{(DETECT)}$. $I_{(DETECT)}$ is used to detect a battery replacement condition. Fault condition is cleared by POR or battery replacement.

APPLICATION INFORMATION

battery charge current

Following a successful pre-conditioning, the bq2420x relies on an external current-limited supply to limit the charge current to the cell. The bq2420x continues this phase until the battery reaches the voltage regulation phase.

During this phase (and all other phases of operation) in order to protect the integrated powerFET, the internal short circuit and thermal protection circuits are active.

battery voltage regulation

The voltage regulation feedback is through the BAT pin. This input is tied directly to the positive side of the battery pack. The bq2420x monitors the battery-pack voltage between the BAT and VSS pins. The bq2420x is offered in two fixed-voltage versions: 4.1 V and 4.2 V.

As a safety backup, the bq2420x also monitors the charge time in the voltage regulation mode. If taper current is not detected within this time period, $t_{(CHG)}$, the bq2420x turns off the charger and enunciates FAULT on the STAT pin. Fault condition is cleared by POR or battery replacement. Note that the safety timer is reset if the bq2420x is forced out of the voltage regulation mode.

charge termination and recharge

The bq2420x monitors the charging current during the voltage regulation phase. Once the taper threshold, $I_{(TAPER)}$, is detected the bq2420x initiates the taper timer, $t_{(TAPER)}$. Charge is terminated after the timer expires. The bq2420x resets the taper timer in the event that the charge current returns above the taper threshold, $I_{(TAPER)}$.

In addition to the taper current detection, the bq2420x terminates charge in the event that the charge current falls below the $I_{(TERM)}$ threshold. This feature allows for quick recognition of a battery removal condition.

After a charge termination, the bq2420x restarts the charge once the voltage on the BAT pin falls below the $V_{(RCH)}$ threshold. This feature keeps the battery at full capacity at all times.

sleep mode

The bq2420x enters the low-power sleep mode if the Vcc is removed from the circuit (i.e. the Vcc and IN pins are floating). For applications where these pins are not floating, placing a low-power 10 Ω (1/16 W) between the IN and VCC pins ensures the $V_{(SLP)}$ conditions are met (see Figure 9). This feature prevents draining the battery during the absence of V_{CC}.

APPLICATION INFORMATION
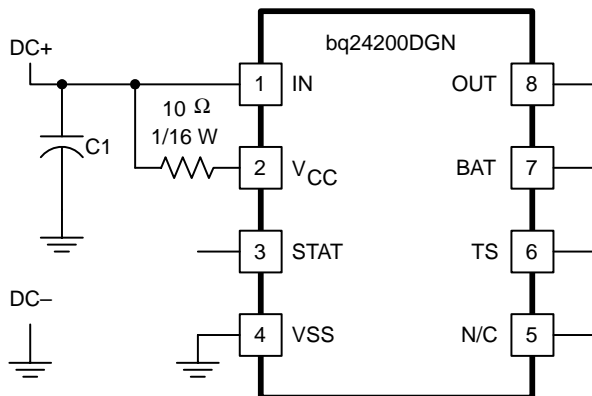
UDG–01110

Figure 9. Sleep Mode

charge enable pin

The $\overline{CE}$ pin on bq24202, bq24203, bq24204 and bq24205 can be used to enable or suspend the charge. Charge is enabled if the voltage $V_{IL(CE)}$ is applied to the pin. Applying the $V_{IH(CE)}$ suspends the charge. During a charge suspend mode, the internal powerFET is turned off and all timers are reset.

charge status output

The STAT pin on the bq2420x, indicates various conditions of operation. These conditions are summarized in Table 1.
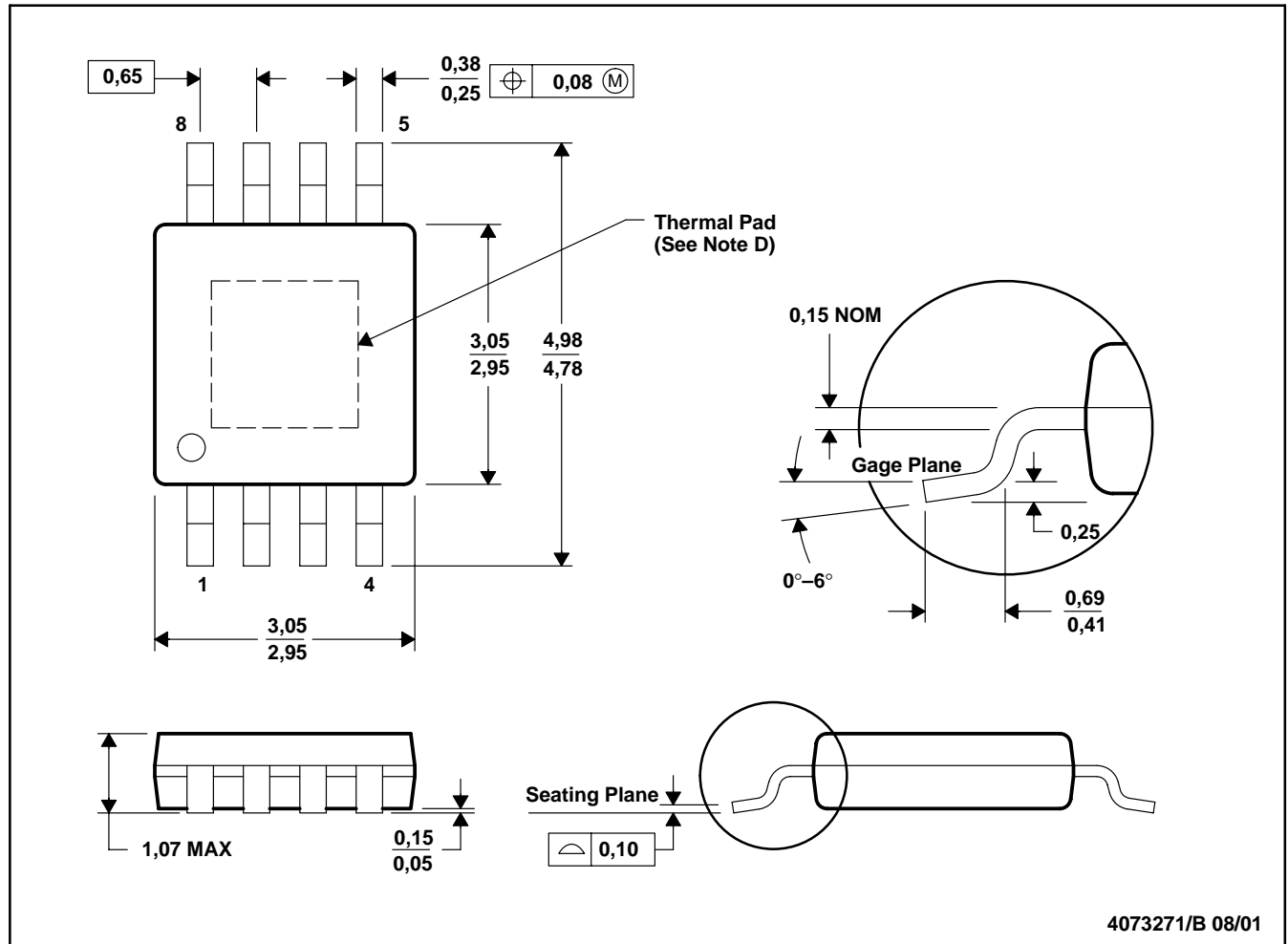
Table 1. STAT Pin

Condition	STAT
Pre-charge	High
Fast-charge	High
Charge-complete	Low
Taper timer done	Low
Charge suspend (due to temperature or $\overline{CE}$ input)	Hi–Z
Thermal shutdown	Hi–Z
Pre-charge timer fault	Hi–Z
Sleep mode	Hi–Z
Charge timer fault	Hi–Z

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PACKAGING INFORMATION

DGN (S-PDSO-G8)   **PowerPAD™ PLASTIC SMALL-OUTLINE PACKAGE**

0,65

0,38
0,25   ⊕ 0,08 Ⓜ

8   5

Thermal Pad
(See Note D)

3,05
2,95

4,98
4,78

0,15 NOM

Gage Plane

0°–6°

0,25

0,69
0,41

1   4

3,05
2,95

1,07 MAX

0,15
0,05

Seating Plane

◁ 0,10

4073271/B 08/01

NOTES: A. All linear dimensions are in millimeters.
        B. This drawing is subject to change without notice.
        C. Body dimensions include mold flash or protrusions.
        D. The package thermal performance may be enhanced by attaching an external heat sink to the thermal plane.
            This pad is electrically and thermally connected to the backside of the die and possibly selected leads.
        E. Falls within JEDEC MO-187

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