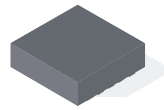


bq24010, bq24012
bq24013, bq24014, bq24018

SLUS530J–SEPTEMBER 2002–REVISED DECEMBER 2008

SINGLE-CHIP, LI-ION CHARGE MANAGEMENT IC FOR HANDHELD APPLICATIONS (bqTINY™)

FEATURES

- Small 3 mm × 3 mm MLP (QFN) Package
- Ideal for Low-Dropout Designs for Single-Cell Li-Ion or Li-Pol Packs in Space Limited Applications
- Integrated Power FET and Current Sensor for Up to 1-A Charge Applications
- Reverse Leakage Protection Prevents Battery Drainage
- Integrated Current and Voltage Regulation
- ±0.5% Voltage Regulation Accuracy
- Charge Termination by Minimum Current and Time
- Precharge Conditioning With Safety Timer
- Status Outputs for LED or System Interface Indicates Charge and Fault Conditions
- Battery Insertion and Removal Detection
- Works With Regulated and Unregulated Supplies
- Short-Circuit Protection
- Charge Voltage Options 4.2 V and 4.36 V

APPLICATIONS

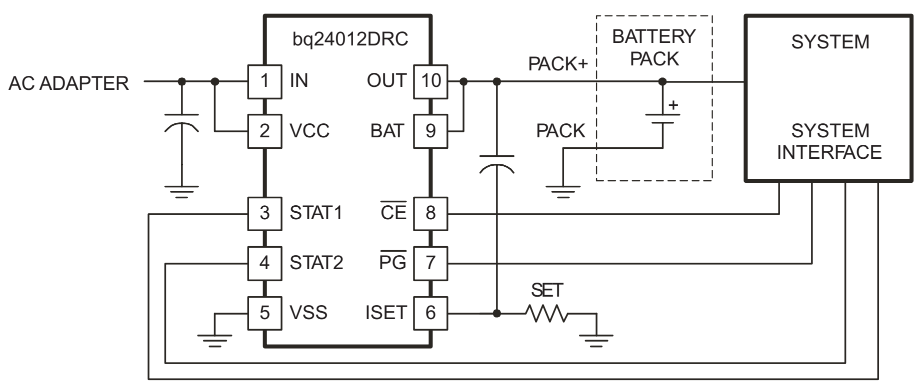
- Cellular Phones
- PDAs, MP3 Players
- Digital Cameras
- Internet Appliances

DESCRIPTION

The bqTINY™ series are highly integrated Li-Ion and Li-Pol linear charge management devices targeted at space limited portable applications. The bqTINY™ series offer integrated powerFET and current sensor, reverse blocking protection, high accuracy current and voltage regulation, charge status, and charge termination, in a small package.

The bqTINY™ charges the battery in three phases: conditioning, constant current, and constant voltage. Charge is terminated based on minimum current. An internal charge timer provides a backup safety feature for charge termination. The bqTINY™ automatically re-starts the charge if the battery voltage falls below an internal threshold. The bqTINY™ automatically enters sleep mode when V_{CC} supply is removed.

In addition to the standard features, different versions of the bqTINY™ offer a multitude of additional features. These include temperature sensing input for detecting hot or cold battery packs; power good ($\overline{PG}$) output indicating the presence of valid input power; a TTL-level charge-enable input (CE) used to disable or enable the charge process; and a TTL-level timer and termination enable (TTE) input used to disable or enable the fast-charge timer and charge termination.



ABSOLUTE MAXIMUM RATINGS[(1)]

ELECTRICAL CHARACTERISTICS

over 0°C ≤ T_J ≤ 125°C and recommended supply voltage, (unless otherwit5

(1) $$I_{O(OUT)} = \frac{\left(K_{(SET)} \times V_{(SET)}\right)}{R_{(SET)}}$$

$$I_{O(OUT)} = K_{(ISET)} \times \left(\frac{V_{(ISET)}}{R_{(ISET)} + 10\mu A}\right)$$

(4) $$I_{O(PRECHG)} = \frac{\left(K_{(SET)} \times V_{(PRECHG)}\right)}{R_{(SET)}}$$

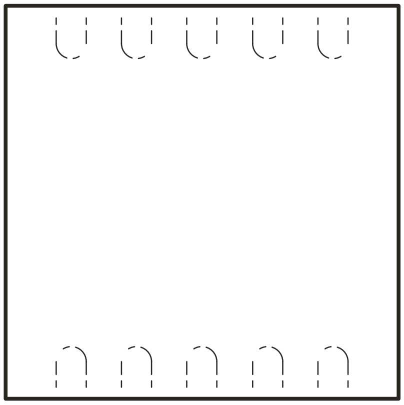
ELECTRICAL CHARACTERISTICS (Continued)

over 0°C ≤ T_J ≤ 125°C and recommended supply voltage, (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
CHARGE TAPER AND TERMINATION DETECTION						
$I_{(TAPER)}$ [(1)]	Charge taper detection range	$V_{I(BAT)} > V_{(RCH)}$, $t < t_{(TAPER)}$	10		100	mA
$V_{(TAPER)}$	Charge taper detection set voltage	Voltage on ISET pin, $V_{I(BAT)} > V_{(RCH)}$, $t < t_{(TAPER)}$, $V_{I(BAT)} = V_{O(REG)}$	225	250	275	mV
$V_{(TERM)}$	Charge termination detection set voltage	Voltage on ISET pin, $V_{I(BAT)} = V_{O(REG)}$, $V_{I(BAT)} > V_{(RCH)}, I_{(TERM)} = K_{(SET)} \times V_{(TERM)} / R_{(SET)}$	5	17.5	50	mV
TEMPERATURE COMPARATOR						
$V_{(TS1)}$	Lower threshold	Voltage on TS pin	29	30	31	%VCC
$V_{(TS2)}$	Upper threshold	Voltage on TS pin	60	61	62	%VCC
	Hysteresis			1		%VCC
BATTERY RECHARGE THRESHOLD						
$V_{(RCH)}$	Recharge threshold		$V_{O(REG)}$ –0.135	$V_{O(REG)}$ –0.1	$V_{O(REG)}$ –0.075	V
STAT1, STAT2, AND $\overline{PG}$ OUTPUTS						
V_{OL}	Output (low) saturation voltage	I_O = 10 mA			0.5	V
CHARGE ENABLE ($\overline{CE}$) AND TIMER AND TERMINATION ENABLE ($\overline{TTE}$) INPUTS						
V_{IL}	Low-level input voltage	I_{IL} = 1 µA	0		0.8	V
V_{IH}	High-level input voltage	I_{IL} = 1 µA	2.0			V
TIMERS						
$t_{(PRECHG)}$	Precharge time		1, 548	2,065	2,581	s
$t_{(TAPER)}$	Taper time		1, 548	2,065	2,581	s
$t_{(CHG)}$	Charge time		15, 480	20,650	25,810	s
SLEEP COMPARATOR						
V_{SLP}	Sleep mode entry threshold voltage	$V_{POR} \le V_{(IBAT)} \le V_{O(REG)}$			$V_{CC} \le V_{I(BAT)}$ + 30 mV	V
	Sleep mode exit threshold voltage	$V_{POR} \le V_{(IBAT)} \le V_{O(REG)}$	$V_{CC} \ge V_{I(BAT)}$ + 22 mV			V
	Sleep mode deglitch time	VCC decreasing below threshold, 100 ns fall time, 10 mV overdrive	250		650	ms
BATTERY DETECTION						

$$I_{O(TAPER)} = \frac{\left(K_{(SET)} \times V_{(TAPER)}\right)}{R_{(SET)}}$$

DEVICE INFORMATION



[redacted]

TERMINAL FUNCTIONS

TERMINAL					I/O	DESCRIPTION
NAME	bq24010	bq24012	bq24013 and bq24018 [1]	bq24014		
BAT	9	9	9	9	I	Battery voltage sense input
$\overline{CE}$	–	8	7	7	I	Charge enable input (active low)
IN	1	1	1	1	I	Charge input voltage. This input must be tied to the VCC pin.
ISET	6	6	6	6	O	Charge current set point
OUT	10	10	10	10	O	Charge current output
$\overline{PG}$	7	7	–	–	O	Power good status output (open collector)
STAT1	3	3	3	3	O	Charge status output 1 (open collector)
STAT2	4	4	4	4	O	Charge status output 2 (open collector)
$\overline{TTE}$	–	–	8	–	I	Timer and termination enable input (active low)
TS	8	–	–	8	I	Temperature sense input
VCC	2	2	2	2	I	VCC supply input
VSS	5	5	5	5	–	Ground input
Exposed Thermal PAD	Pad	Pad	Pad	Pad	–	There is an internal electrical connection between the exposed thermal pad and V_{SS} pin of the device. The exposed thermal pad must be connected to the same potential as the Vss pin on the printed circuit board. Do not use the thermal pad as the primary ground input for the device. VSS pin must be connected to ground at all times.

(1)

FUNCTIONAL BLOCK DIAGRAM

$V_{I(BAT)}$
$V_{O(REG)}$

$I_{(DETECT)}$ ENABLE
$I_{(FAULT)}$ ENABLE

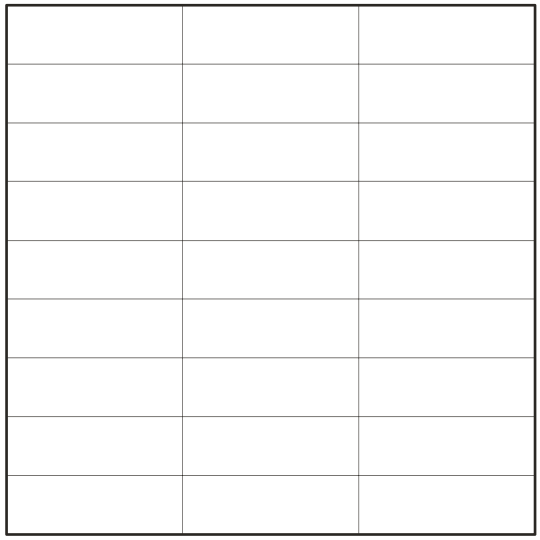
$V_{I(BAT)}$
$V_{(SLP)}$

$I_{(FAULT)}$ ENABLE

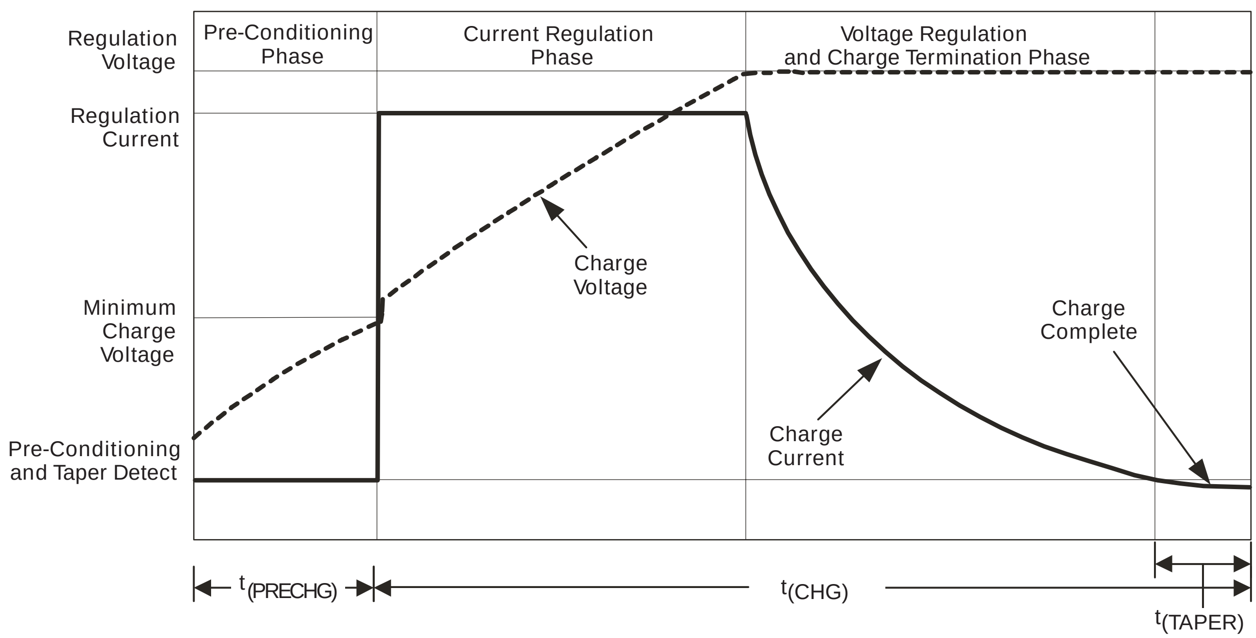
$I_{(DETECT)}$ ENABLE

TYPICAL CHARACTERISTICS

DROPOUT VOLTAGE
vs
JUNCTION TEMPERATURE



Figur 1. e



Figur 2. Ty pe ical Char Pr ging ofile

FUNCTIONAL DESCRIPTION

The bqTINY™ supports a precision Li-Ion, Li-Pol charging system suitable for single-cells. Figure 2 shows a typical charge profile, application circuit and Figure 5 shows an operational flow chart.

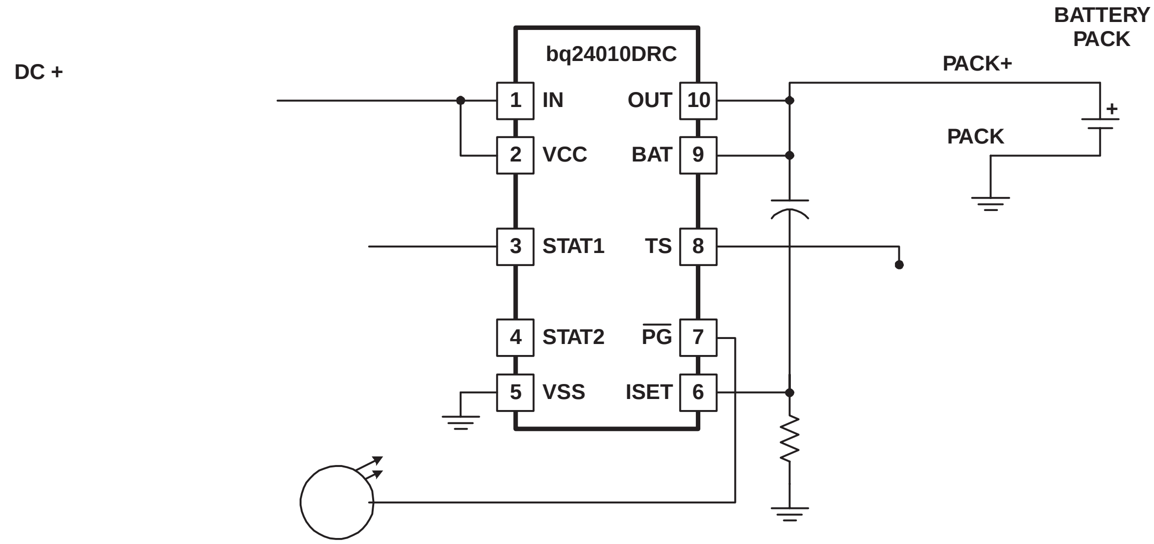


Figure 3. Typical Application Circuit

Figure 4. USB Charger Circuit

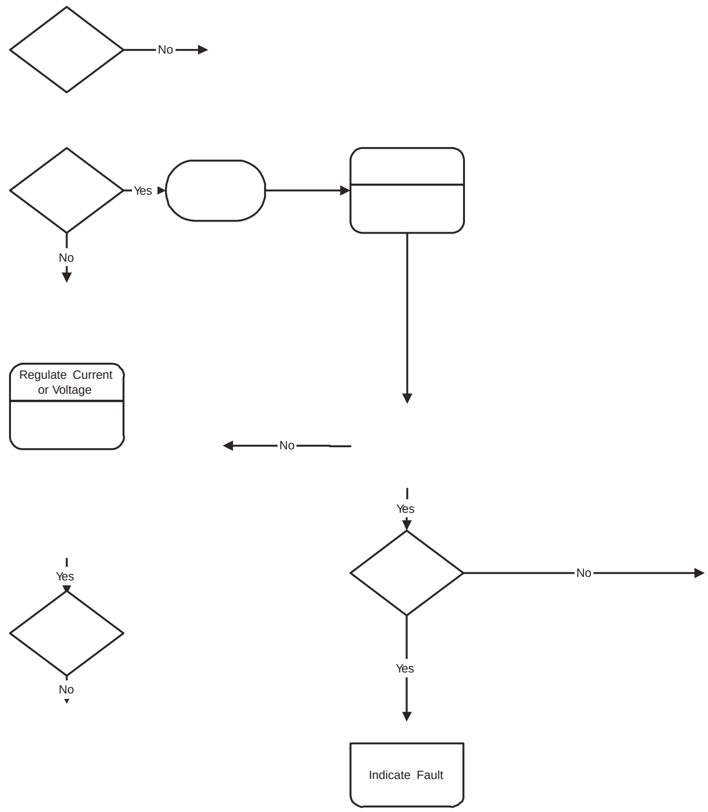
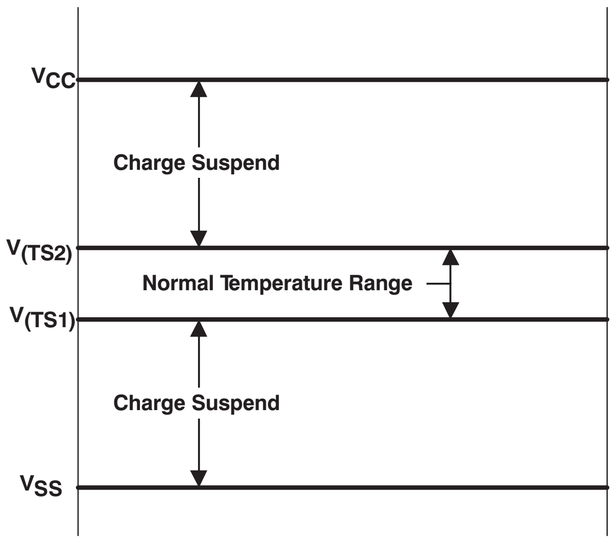


Figure 5. Operational Flow Chart

TEMPERATURE QUALIFICATION



$$R_{T1} = \frac{5 \times R_{TH} \times R_{TC}}{3 \times R_{TC} - R_{TH}} \quad (1)$$

BATTERY PRE-CONDITIONING

During a charge cycle if the battery voltage is below the $V_{(LOWV)}$ threshold, the bqTINY applies a precharge current, $I_{O(PRECHG)}$, to the battery. This feature revives deeply discharged cells. The resistor connected between the ISET and V_{SS}, R_{SET}, determines the precharge rate. The $V_{(PRECHG)}$ and $K_{(SET)}$ parameters are specified in the specifications table.

$$I_{O(PRECHG)} = \frac{\left(V_{(PRECHG)} \times K_{(SET)}\right)}{R_{(SET)}} \tag{3}$$

The bqTINY activates a safety timer, $t_{(PRECHG)}$, during the conditioning phase. If $V_{(LOWV)}$ threshold is not reached within the timer period, the bqTINY turns off the charger and enunciates FAULT on the STAT1 and STAT2 pins. Refer to *Timer Fault Recovery* section for additional details.

BATTERY CHARGE CURRENT

The bqTINY offers on-chip current regulation with programmable set point. The resistor connected between the ISET and V_{SS}, R_{SET}, determines the charge rate. The $V_{(SET)}$ and $K_{(SET)}$ parameters are specified in the specifications table.

$$I_{O(OUT)} = \frac{\left(K_{(SET)} \times V_{(SET)}\right)}{R_{(SET)}} \tag{4}$$

BATTERY VOLTAGE REGULATION

Voltage regulation feedback is accomplished through the BAT pin. This input is tied directly and close to the positive side of the battery pack. The bqTINY monitors the battery-pack voltage between the BAT and VSS pins. When the battery voltage rises to $V_{O(REG)}$ threshold, the voltage regulation phase begins and the charging current begins to taper down.

As a safety backup, the bqTINY also monitors the charge time in the charge mode. If termination does not occur within this time period, $t_{(CHG)}$, the bqTINY turns off the charger and enunciates FAULT on the STAT1 and STAT1 pins. Refer to the *Timer Fault Recovery* section for additional details.

CHARGE TAPER DETECTION, TERMINATION AND RECHARGE

The bqTINY monitors the charging current during the voltage regulation phase. Once the taper threshold, $I_{(TAPER)}$, is detected the bqTINY initiates the taper timer, $t_{(TAPER)}$. Charge is terminated after the timer expires. The resistor connected between the ISET and V_{SS}, R_{SET}, determines the taper detection level. The $V_{(TAPER)}$ and $K_{(SET)}$ parameters are specified in the specifications table.

$$I_{(TAPER)} = \frac{\left(V_{(TAPER)} \times K_{(SET)}\right)}{R_{(SET)}} \tag{5}$$

The bqTINY 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 bqTINY 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 or insertion of a fully charged battery. Note that taper timer is not used for $I_{(TERM)}$ detection. The resistor connected between the ISET and V_{SS}, R_{SET}, determines the taper detection level. The $V_{(TERM)}$ and $K_{(SET)}$ parameters are specified in the specifications table.

$$I_{(TERM)} = \frac{\left(V_{(TERM)} \times K_{(SET)}\right)}{R_{(SET)}} \tag{6}$$

After charge termination, the bqTINY 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. See the *Battery Absent Detection section* for additional details.

SLEEP MODE

The bqTINY enters the low-power sleep mode if the V_{CC} is

CHARGE STATUS OUTPUTS

PG OUTPUT

CE INPUT (CHARGE ENABLE)

TTE INPUT (TIMER AND TERMINATION ENABLE)

THERMAL SHUTDOWN AND PROTECTION

BATTERY ABSENT DETECTION

For applications with removable battery packs, bqTINY provides a battery absent detection scheme to reliably detect insertion and/or removal of battery packs.

The voltage at the BAT pin is held above the battery recharge threshold, $V_{(RCH)}$, by the charged battery following fast charging. When the voltage at the BAT pin falls to the recharge threshold, either by a load on the battery or due to battery removal, the bqTINY begins a battery absent detection test. This test involves enabling a detection current, $I_{(DETECT)}$, for a period of $t_{(DETECT)}$ and checking to see if the battery voltage is below the pre-charge threshold, $V_{(LOWV)}$. Following this, the precharge current, $I_{O(PRECHG)}$ is applied for a period of $t_{(DETECT)}$ and the battery voltage checked again to be above the recharge threshold. The purpose is to attempt to close a battery pack with an open protector, if one is connected to the bqTINY. Passing both of the discharge and charging tests indicates a battery absent fault at the STAT pins. Failure of either test starts a new charge cycle. For the absent battery condition the voltage on the BAT pin rises and falls between the $V_{(LOWV)}$ and $V_{O(REG)}$ thresholds indefinitely. See Figure 7.

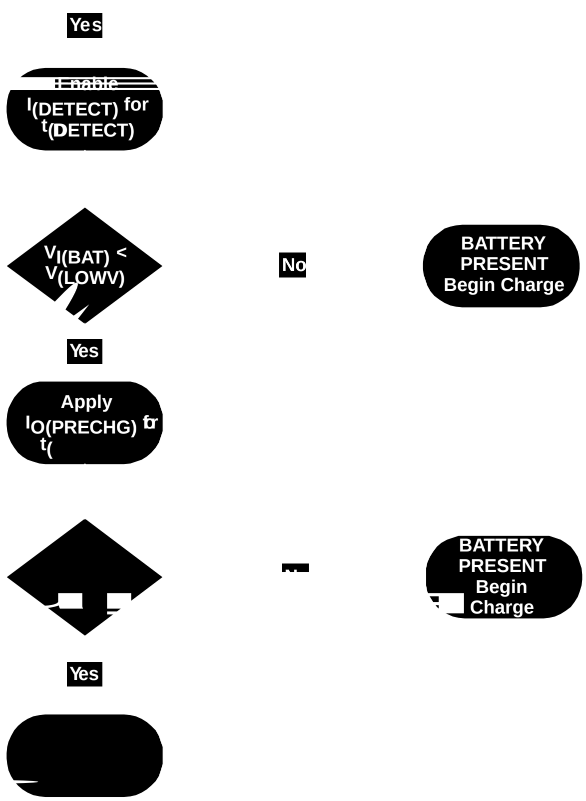


Figure 7. Battery Absent Detection

TIMER FAULT RECOVERY

As shown in Figure 5, bqTINY provides a recovery method to deal with timer fault conditions. The following conditions summarize this method.

Condition #1: Charge voltage above recharge threshold ($V_{(RCH)}$) and timeout fault occurs

Recovery method: bqTINY waits for the battery voltage to fall below the recharge threshold. This could happen as a result of a load on the battery, self-discharge or battery removal. Once the battery falls below the recharge threshold, the bqTINY clears the fault and enters the battery absent detection routine. A POR or CE toggle also clears the fault.

Condition #2: Charge voltage below recharge threshold ($V_{(RCH)}$) and timeout fault occurs.

Recovery method: Under this scenario, the bqTINY applies the $I_{(FAULT)}$ current. This small current is used to detect a battery removal condition and remains on as long as the battery voltage stays below the recharge threshold. If the battery voltage goes above the recharge threshold, then the bqTINY disables the $I_{(FAULT)}$ current and executes the recovery method described for condition #1. Once the battery falls below the recharge threshold, the bqTINY clears the fault and enters the battery absent detection routine. A POR or CE toggle also clears the fault.

APPLICATION INFORMATION

SELECTING INPUT CAPACITOR

In most applications, all that is needed is a high-frequency decoupling capacitor. A 0.47-µF ceramic, placed in close proximity to V_{CC} and V_{SS} pins, works well. The bqTINY is

SELECTING OUTPUT CAPACITOR

THERMAL CONSIDERATIONS

$$JA = \frac{T_J \times T_A}{P} \qquad (7)$$

$$P = V_{IN} - V_{I(BAT)} \times I_{O(OUT)} \qquad (8)$$

PCB LAYOUT CONSIDERATIONS

It is important to pay special attention to the PCB layout. The following provides some guidelines:

- To obtain optimal performance, the decoupling capacitor from V_{CC} to V_{SS} and the output filter capacitors from BAT to ISET should be placed as close as possible to the bqTINY, with short trace runs to both signal and V_{SS} pins.
- All low-current V_{SS} connections should be kept separate from the high-current charge or discharge paths from the battery. Use a single-point ground technique incorporating both the small signal ground path and the power ground path.
- The BAT pin is the voltage feedback to the device and should be connected with its trace as close to the battery pack as possible.
- The high current charge paths into IN and from the OUT pins must be sized appropriately for the maximum charge current in order to avoid voltage drops in these traces.
- The bqTINY is packaged in a thermally enhanced MLP package. The package includes a thermal pad to provide an effective thermal contact between the device and the printed circuit board (PCB). Full PCB design guidelines for this package are provided in the application note entitled: *QFN/SON PCB Attachment Application Note* (SLUA271).
- There is an internal electrical connection between the exposed thermal pad and V_{SS} pin of the device. The exposed thermal pad must be connected to the same potential as the VSS pin on the printed circuit board. Do not use the thermal pad as the primary ground input for the device. V_{SS} pin must be connected to ground at all times.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)
BQ24010DRCR	ACTIVE	SON	DRC	10	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24010DRCRG4	ACTIVE	SON	DRC	10	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24012DRCR	ACTIVE	SON	DRC	10	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24012DRCRG4	ACTIVE	SON	DRC	10	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24013DRCR	ACTIVE	SON	DRC	10	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24013DRCRG4	ACTIVE	SON	DRC	10	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24014DRCR	ACTIVE	SON	DRC	10	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24014DRCRG4	ACTIVE	SON	DRC	10	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24018DRCR	ACTIVE	SON	DRC	10	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24018DRCRG4	ACTIVE	SON	DRC	10	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24018DRCT	ACTIVE	SON	DRC	10	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
BQ24018DRCTG4	ACTIVE	SON	DRC	10	250	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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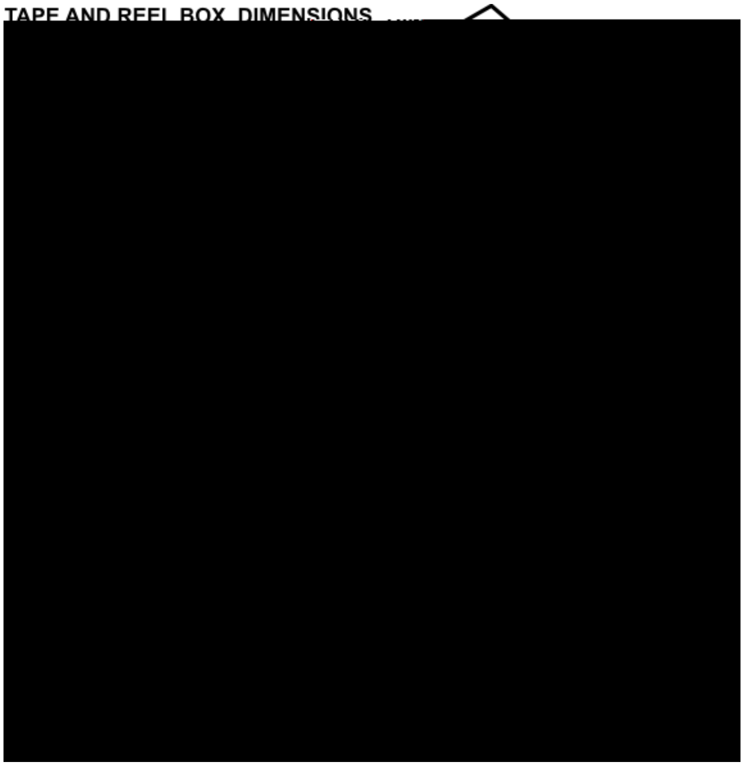
TAPE AND REEL INFORMATION

REEL DIMENSIONS **TAPE DIMENSIONS**

*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
BQ24010DRCR	SON	DRC	10	3000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2
BQ24012DRCR	SON	DRC	10	3000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2
BQ24013DRCR	SON	DRC	10	3000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2
BQ24014DRCR	SON	DRC	10	3000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2
BQ24018DRCR	SON	DRC	10	3000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2
BQ24018DRCT	SON	DRC	10	250	180.0	12.4	3.3	3.3	1.1	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)
BQ24010DRCR	SON	DRC	10	3000	367.0	367.0	35.0
BQ24012DRCR	SON	DRC	10	3000	367.0	367.0	35.0
BQ24013DRCR	SON	DRC	10	3000	367.0	367.0	35.0
BQ24014DRCR	SON	DRC	10	3000	367.0	367.0	35.0
BQ24018DRCR	SON	DRC	10	3000	367.0	367.0	35.0
BQ24018DRCT	SON	DRC	10	250	210.0	185.0	35.0

...ata Sheet for details regarding the exposed thermal pad features

IMPORTANT NOTICE

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