Overvoltage and Overcurrent Protection IC and Li+ Charger Front-End Protection IC With LDO Mode

FEATURES

- **Input Overvoltage Protection**
- **Accurate Battery Overvoltage Protection**
- **Output Short-Circuit Protection**
- **Soft-Start to Prevent Inrush Currents**
- **Soft-Stop to Prevent Voltage Spikes**
- **30-V Maximum Input Voltage**
- **Supports up to 1.7-A Load Current**
- **Thermal Shutdown**
- **Enable Function**
- **Fault Status Indication**
- **Small 2 mm × 2 mm 8-Pin SON Package**

APPLICATIONS

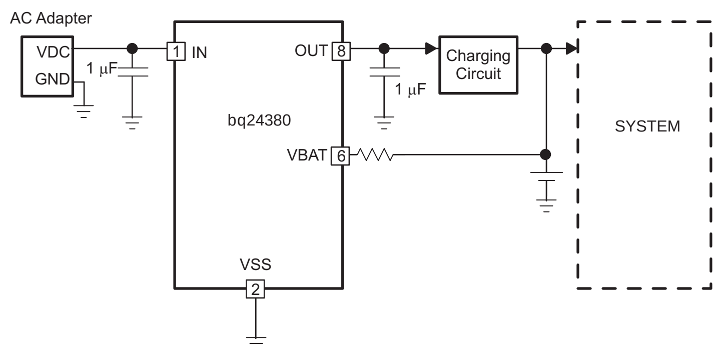
- **Smart Phones, Mobile Phones**
- **PDAs**
- **MP3 Players**
- **Low-Power Handheld Devices**

DESCRIPTION

The bq2438x family are charger front-end integrated circuits designed to provide protection to Li-ion batteries from failures of the charging circuitry. The IC continuously monitors the input voltage and the battery voltage. The device operates like a linear regulator, maintaining a 5.5-V (bq24380) or 5-V (bq24381, bq24382) output with input voltages up to the Input overvoltage threshold. During input overvoltage conditions, the IC immediately turns off the internal pass FET disconnecting the charging circuitry from the damaging input source. Additionally, if the battery voltage rises to unsafe levels while charging, power is removed from the system. The IC checks for short-circuit or overload conditions at its output when turning the pass FET on, and if it finds unsafe conditions, it switches off, and then rechecks the conditions. Additionally, the IC also monitors its die temperature and switches off if it exceeds 140°C.

When the IC is controlled by a processor, the IC provides status information about fault conditions to the host.

APPLICATION SCHEMATIC



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

DEVICE	V_{OVP}	$V_{O(REG)}$	PACKAGE(1)	MARKING
bq24380	6.3 V	5.5 V	2mm x 2mm SON	CFE
bq24381	7.1 V	5 V	2mm x 2mm SON	CFW
bq24382	10.5 V	5 V	2mm x 2mm SON	OBE

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI Web site at www.ti.com.

ABSOLUTE MAXIMUM RATINGS(1)

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

			VALUE	UNIT
V_I	Input voltage	IN (with respect to VSS)	–0.3 to 30	V
		OUT (with respect to VSS)	–0.3 to 12	V
		$\overline{\text{FAULT}}$, $\overline{\text{CE}}$, VBAT (with respect to VSS)	–0.3 to 7	V
I_{OUT}max	Output source current	OUT	2	A
	Output sink current	$\overline{\text{FAULT}}$	15	mA
T_J	Junction temperature		–40 to 150	°C
T_{stg}	Storage temperature		–65 to 150	°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. All voltage values are with respect to the network ground terminal unless otherwise noted.

DISSIPATION RATINGS

PACKAGE	$R_{\theta JC}$	$R_{\theta JA}$
DSG	5°C/W	75°C/W

RECOMMENDED OPERATING CONDITIONS

		MIN	MAX	UNIT
V_I	IN voltage range	3.3	30	V
I_O	Current, OUT pin		1.7	A
T_J	Junction temperature	-40	125	°C

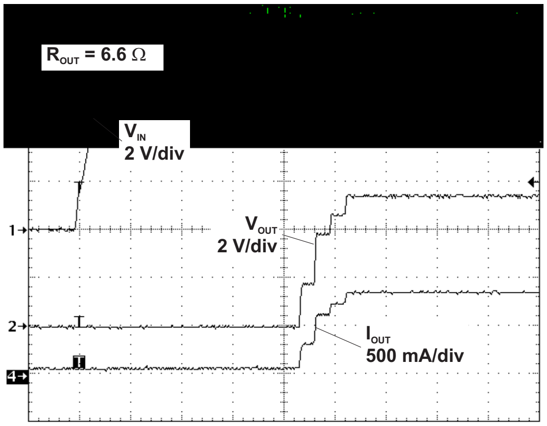
[redacted] CHARACTERISTICS

[redacted]

[redacted]

TYPICAL CHARACTERISTICS

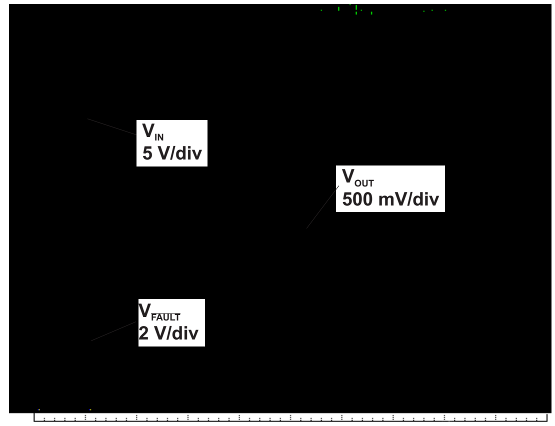
NORMAL POWER-ON SHOWING SOFT-START (bq24380)



t - Time - 2 ms/div

Figure 1.

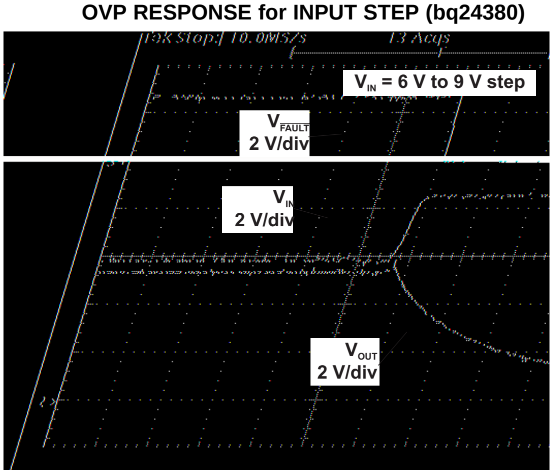
OVP at POWER-ON



t - Time - 2 ms/div

Figure 2.

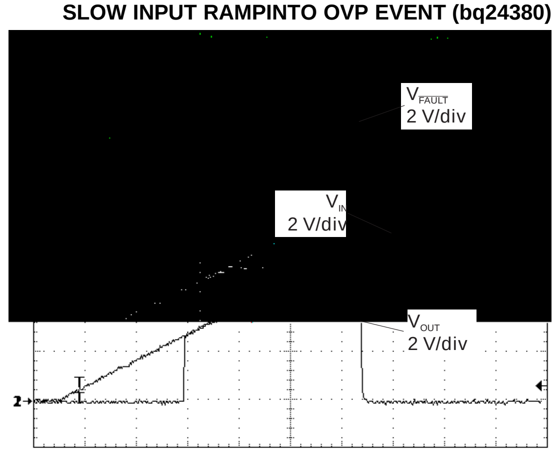
OVP RESPONSE for INPUT STEP (bq24380)



t - Time - 5 μs/div

Figure 3.

SLOW INPUT RAMPINTO OVP EVENT (bq24380)



t - Time - 200 ms/div

Figure 4.

RECOVERY FROM OVP (bq24380)

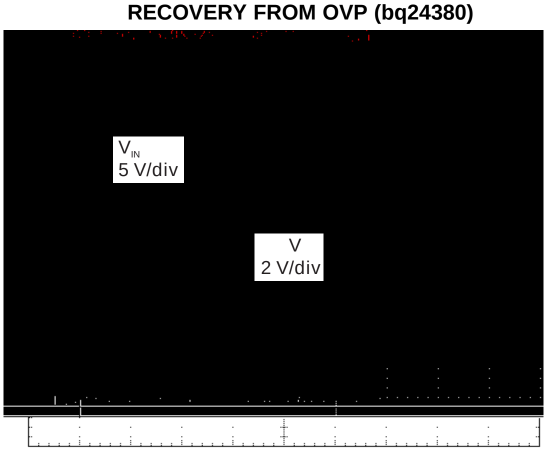


Figure 5.

POWER UP INTO SHORT CIRCUIT

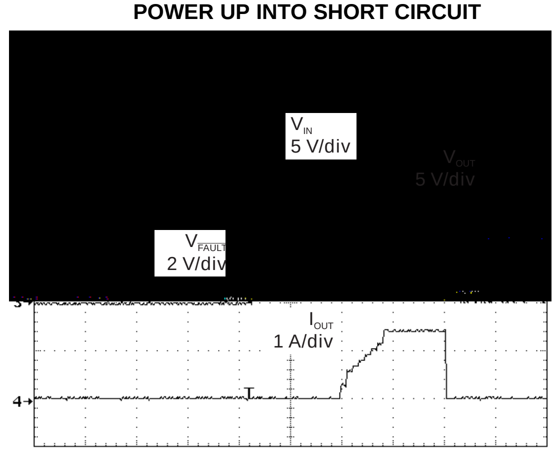


Figure 6.

TYPICAL CHARACTERISTICS (continued)

SOFT-STOP DURING OCP EVENT (bq24380)

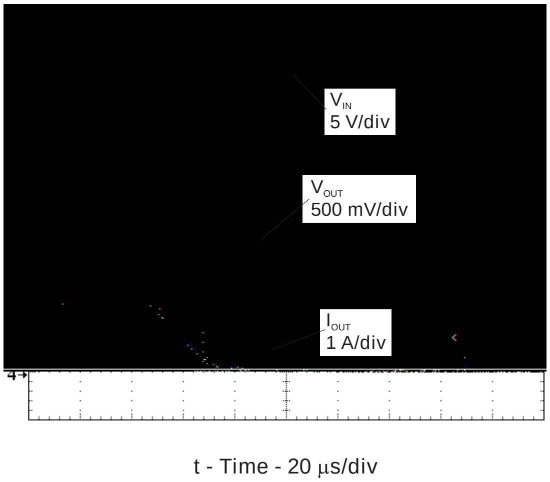


Figure 7.

BATTERY OVP EVENT (bq24380)

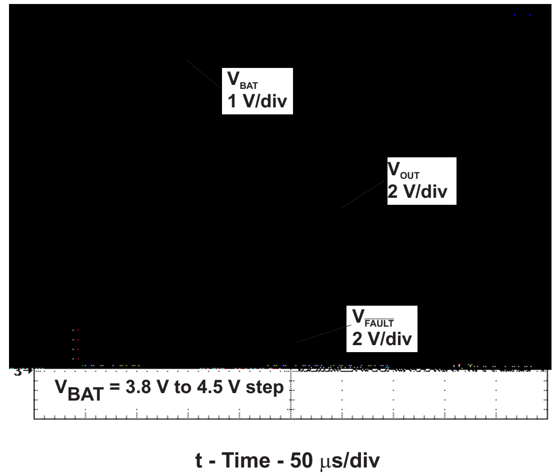


Figure 8.

UVLO vs FREE-AIR TEMPERATURE

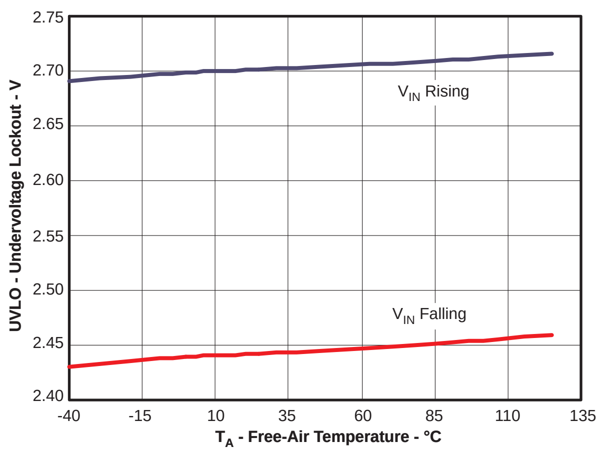


Figure 9.

DROPOUT VOLTAGE vs FREE-AIR TEMPERATURE

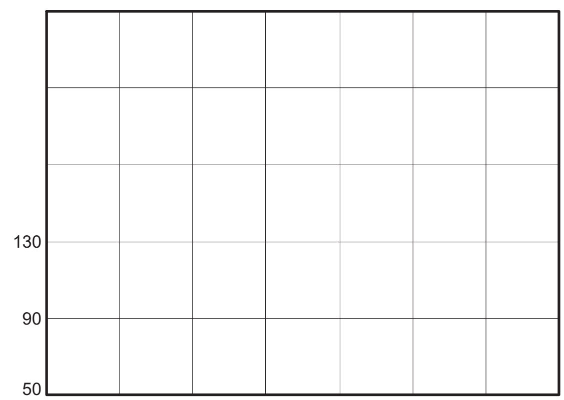


Figure 10.

OUTPUT VOLTAGE REGULATION, $V_{O(REG)}$ vs FREE-AIR TEMPERATURE

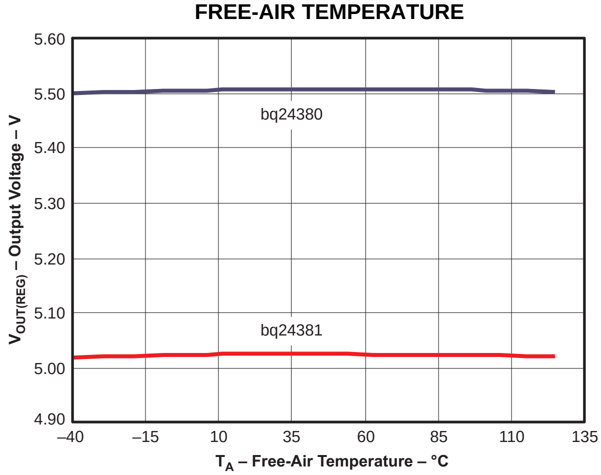


Figure 11.

OVP THRESHOLD vs FREE-AIR TEMPERATURE

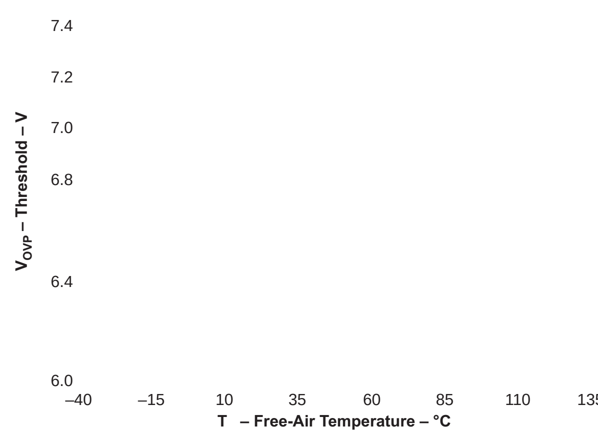


Figure 12.

TYPICAL CHARACTERISTICS (continued)

**OVP THRESHOLD, V_{BOVP}
vs
FREE-AIR TEMPERATURE**

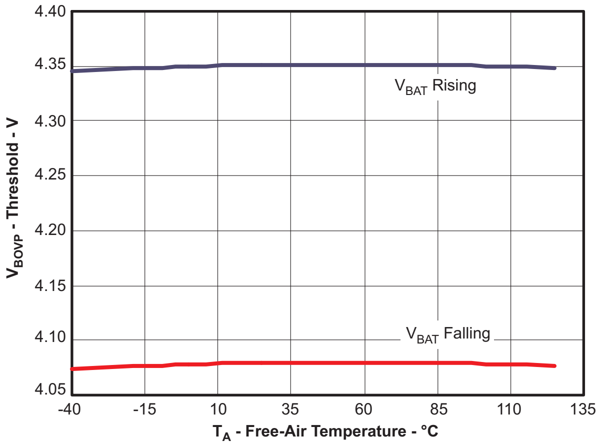


Figure 13.

**LEAKAGE CURRENT (VBAT PIN)
vs
FREE-AIR TEMPERATURE**

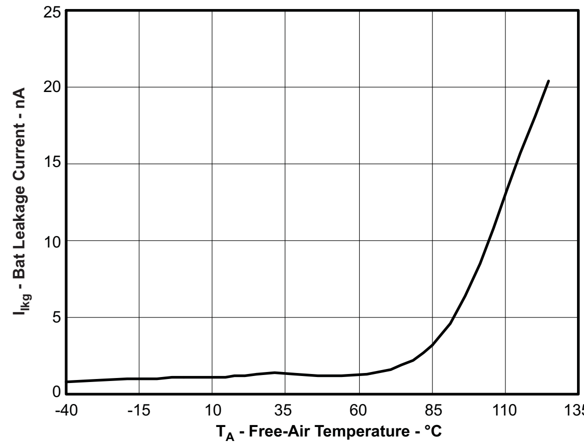


Figure 14.

**SUPPLY CURRENT
vs
INPUT VOLTAGE (bq24380)**

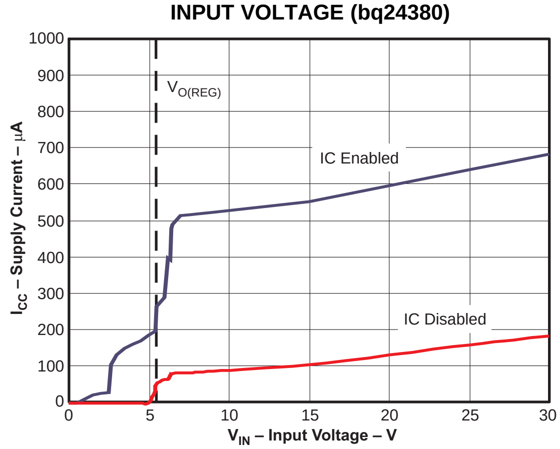


Figure 15.

**SUPPLY CURRENT
vs
INPUT VOLTAGE (bq24381)**

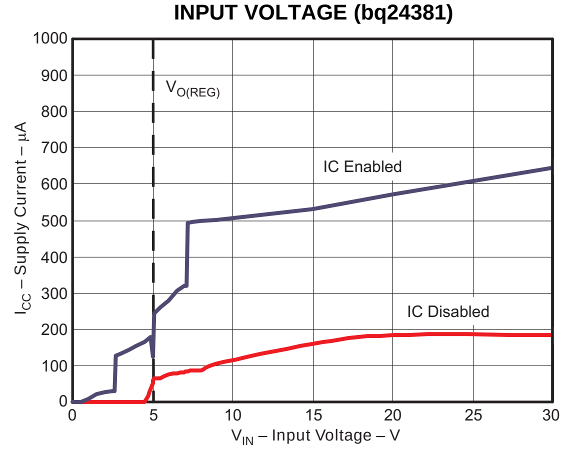


Figure 16.

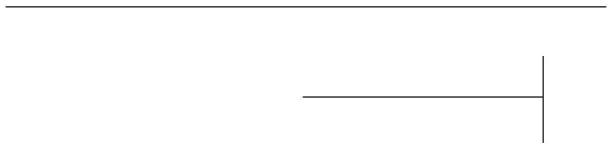


Figure 17. Typical Application Circuit

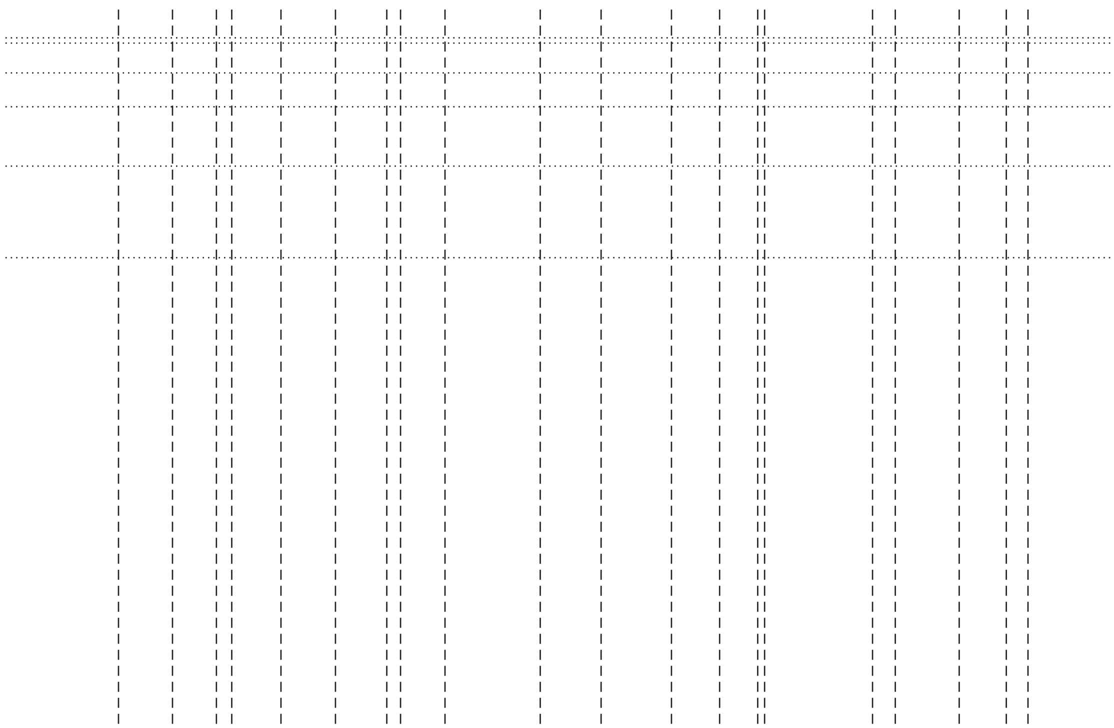


Figure 18. Timing Diagram

DETAILED FUNCTIONAL DESCRIPTION

The bq2438x is a highly integrated circuit designed to provide protection to Li-ion batteries from failures of the charging circuit and the input source. The IC continuously monitors the input voltage and the battery voltage. The device operates like a linear regulator, maintaining a 5.5-V (bq24380) or 5-V (bq24381, bq24382) output with input voltages up to the input overvoltage threshold (V_{OVP}). If the input voltage exceeds V_{OVP}, the IC shuts off the pass FET and disconnects the system from input power. Additionally, if the battery voltage rises above 4.35 V, the IC switches off the pass FET, removing the power from the system until the battery voltage falls to safe levels. The IC also monitors its die temperature and switches the pass FET off if it exceeds 140°C.

The IC can be controlled by a processor, and also provides status information about fault conditions to the host.

POWER DOWN

The device remains in power-down mode when the input voltage at the IN pin is below the undervoltage threshold (UVLO) of 2.8 V. The FET connected between the IN and OUT pins is off, and the status output, $\overline{\text{FAULT}}$, is set to HI-Z.

POWER ON RESET

The device resets when the input voltage at the IN pin exceeds the UVLO threshold. During power-on reset, the IC waits for duration $t_{DGL(PGOOD)}$ for the input voltage to stabilize. If, after $t_{DGL(PGOOD)}$, the input voltage and battery voltage are within operation limits, the pass FET is turned ON. The IC has a soft-start feature to control the inrush current. The soft-start minimizes the ringing at the input due to the resonant circuit formed by the parasitic inductance of the adapter cable and the input bypass capacitor. During the soft-start time, t_{SStart}, the current limit is stepped up in 8 equal steps every 625µs. Each step is 1/8 of the $I_{O(SC)}$. After the soft-start sequence is over, the IC samples the load current. If the load current exceeds $I_{O(SC)}$, the IC initiates short circuit protection. See the Startup Short-Circuit Protection section for details. If no overcurrent event is measured, the current monitoring circuitry is disabled for normal operation.

In the event a short-circuit is detected at power-on, to prevent the input voltage from spiking up when the pass FET is switched off (due to the inductance of the input cable), The pass FET is turned off by gradually reducing its gate-drive, resulting in a *soft-stop* (t_{SStop}).

DETAILED FUNCTIONAL DESCRIPTION

The device continuously monitors the input voltage and the battery voltage as described in detail below:

Input Overvoltage Protection

The OUT output of the bq2438x operates similar to a linear regulator. While the input voltage is less than $V_{O(REG)}$, and above the UVLO, the output voltage tracks the input voltage (less the drop caused by $R_{DS(on)}$ of the pass FET). When the input voltage is greater than $V_{O(REG)}$ (plus the $R_{DS(on)}$ drop) and less than V_{OVP}, the output voltage is regulated to $V_{O(REG)}$. $V_{O(REG)}$ is 5.5 V for the bq24380, and 5 V for the bq24381 and bq24382. If the input voltage is increased above V_{OVP}, the internal pass FET is turned off, removing power from the charging circuitry connected to OUT. The $\overline{\text{FAULT}}$ output is then asserted low. When the input voltage drops below V_{OVP} – $V_{hys(OVP)}$ (but is still above UVLO), the pass FET is turned on after a deglitch time of $t_{REC(OVP)}$. The deglitch time ensures that the input supply has stabilized. The *condition 5* in Figure 18 illustrates an input overvoltage event.

Battery Overvoltage Protection

The battery overvoltage threshold BV_{OVP} is internally set to 4.35 V for the bq2438x. *Condition 3* in Figure 18 illustrates a battery overvoltage event. If the battery voltage exceeds the BV_{OVP} threshold for longer than $t_{DGL(BVovp)}$, the pass FET is turned off (using soft-stop), and $\overline{\text{FAULT}}$ is asserted low. The pass FET is turned on (using the soft-start sequence) once the battery voltage drops to BV_{OVP} – $V_{hys(BVovp)}$.

Thermal Protection

If the junction temperature of the device exceeds $T_{J(OFF)}$, the pass FET is turned off, and the $\overline{\text{FAULT}}$ output is asserted low. The FET is turned on when the junction temperature falls below $T_{J(OFF)}$ – $T_{J(OFF-HYS)}$.

Start-Up Short-Circuit Protection

Enable Function

Fault Indication

APPLICATION INFORMATION

Selection of $R_{(BAT)}$

It is recommended that the battery not be tied directly to the VBAT pin of the device, as under some failure modes of the IC, the voltage at the IN pin may appear on the VBAT pin. This voltage can be as high as 30 V, and applying 30 V to the battery may cause failure of the device and can be hazardous. Connecting the VBAT pin through $R_{(BAT)}$ prevents a large current from flowing into the battery in the event of failure. For safety, $R_{(BAT)}$ must have a high value. The problem with a large $R_{(BAT)}$ is that the voltage drops across the resistor because of the VBAT bias current, $I_{(VBAT)}$, which causes an error in the BV_{OVP} threshold. This error is over and above the tolerance on the nominal 4.35-V BV_{OVP} threshold.

Choosing $R_{(BAT)}$ in the range of 100 k to 470 k is a good compromise. If the IC fails with $R_{(BAT)}$ equal to 100 k , the maximum current flowing into the battery would be (30 V – 3 V) ÷ 100 k = 246 µA, which is low enough to be absorbed by the bias currents of the system components. $R_{(BAT)}$ equal to 100 k results in a worst-case voltage drop of $R_{(BAT)} \times I_{(VBAT)} \approx 1$ mV. This is negligible compared to the internal tolerance of 50 mV on the BV_{OVP} threshold.

If the Bat-OVP function is not required, the VBAT pin must be connected to VSS.

Selection of $R_{(CE)}$

The $\overline{CE}$ pin can be used to enable and disable the IC. If host control is not required, the $\overline{CE}$ pin can be tied to ground or left unconnected, permanently enabling the device.

In applications where external control is required, the $\overline{CE}$ pin can be controlled by a host processor. As with the VBAT pin (see previous discussion), the $\overline{CE}$ pin must be connected to the host GPIO pin through as large a resistor as possible. The limitation on the resistor value is that the minimum V_{OH} of the host GPIO pin less the drop across the resistor must be greater than V_{IH} of the bq2430x $\overline{CE}$ pin. The drop across the resistor is given by $R_{(CE)} \times I_{IH}$.

Selection of Input and Output Bypass Capacitors

The input capacitor C_{IN} in Figure 17 is for decoupling and serves an important purpose. Whenever a step change downwards in the system load current occurs, the inductance of the input cable causes the input voltage to spike up. C_{IN} prevents the input voltage from overshooting to dangerous levels. It is recommended that a ceramic capacitor of at least 1 µF be used at the input of the device. It must be located in close proximity to the IN pin.

C_{OUT} in Figure 17 is also important. During an overvoltage transient, this capacitance limits the output overshoot until the power FET is turned off by the overvoltage protection circuitry. C_{OUT} must be a ceramic capacitor of at least 1 µF, located close to the OUT pin. C_{OUT} also serves as the input decoupling capacitor for the charging circuit downstream of the protection IC.

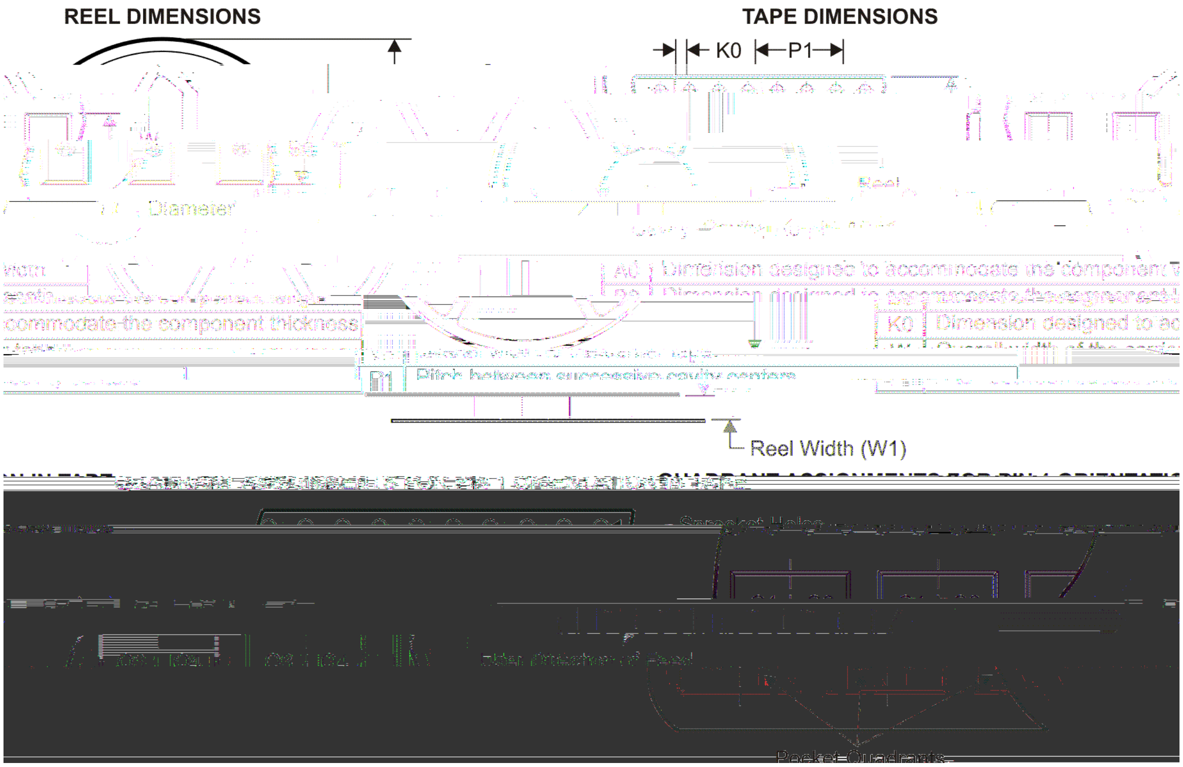
PCB Layout Guidelines

1. This device is a protection device and is meant to protect down-stream circuitry from hazardous voltages. Potentially, high voltages may be applied to this IC. It has to be ensured that the edge-to-edge clearances of PCB traces satisfy the design rules for the maximum voltages expected to be seen in the system.
2. The device uses SON packages with a PowerPAD™. For good thermal performance, the PowerPAD must be thermally coupled with the PCB ground plane. In most applications, this requires a copper pad directly under the IC. This copper pad should be connected to the ground plane with an array of thermal vias.
3. C_{IN} and C_{OUT} should be located close to the IC. Other components like $R_{(BAT)}$ should also be located close to the IC.

PACKAGING INFORMATION

Orderable Device	Status

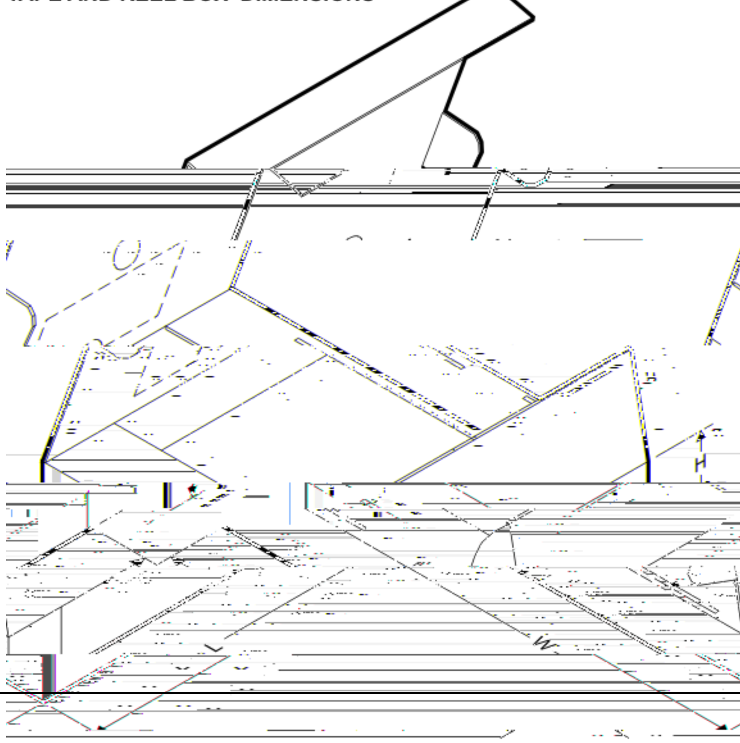
TAPE AND REEL INFORMATION



*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
BQ24380DSGR	WSON	DSG	8	3000	179.0	8.4	2.2	2.2	1.2	4.0	8.0	Q2
BQ24380DSGT	WSON	DSG	8	250	179.0	8.4	2.2	2.2	1.2	4.0	8.0	Q2
BQ24381DSGR	WSON	DSG										

TAPE AND REEL BOX DIMENSIONS

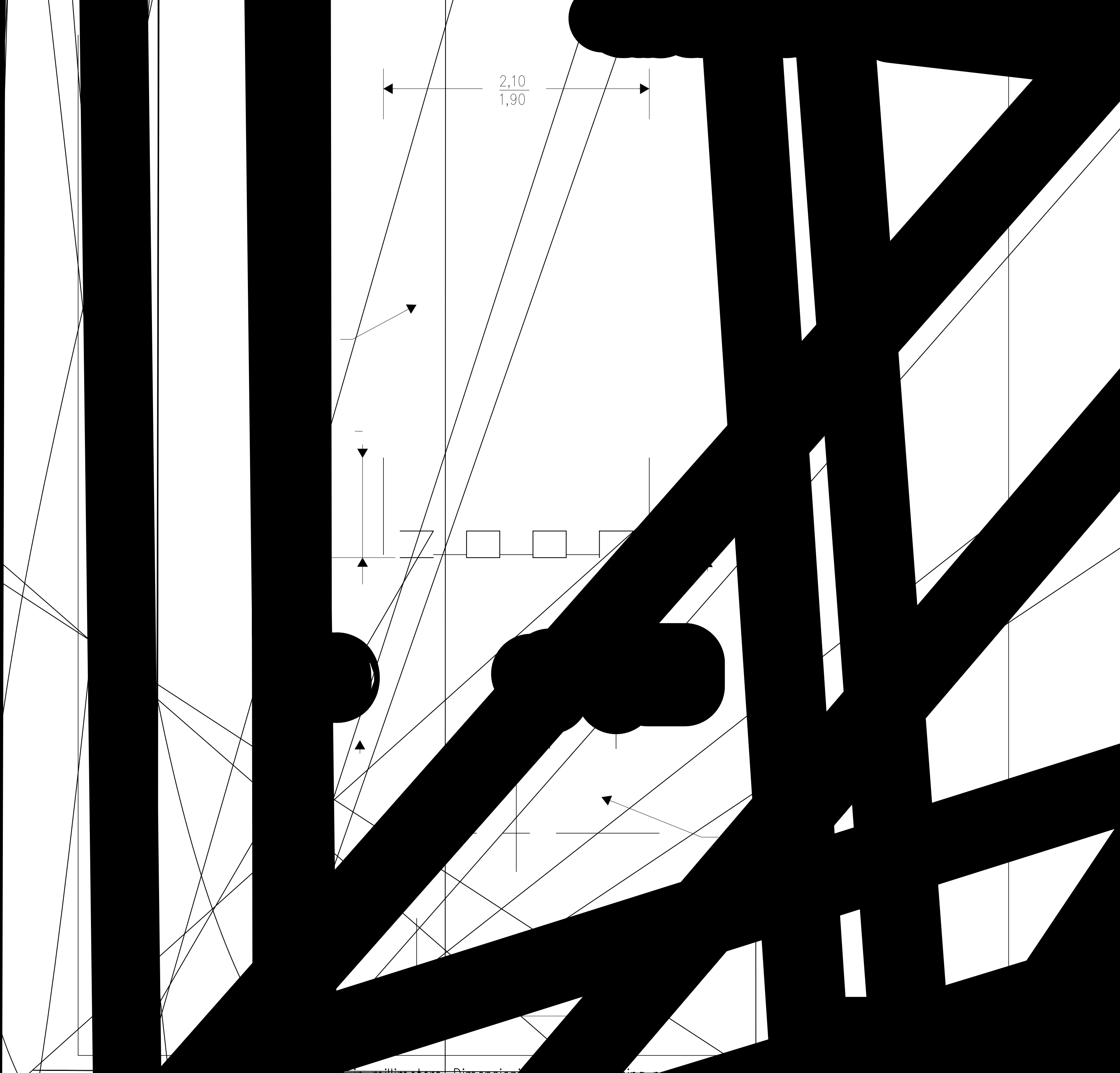


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
BQ24380DSGR	WSON	DSG	8	3000	195.0	200.0	45.0
BQ24380DSGT	WSON	DSG	8	250	195.0		

[redacted]ANICAL DATA

[redacted]



[redacted] in millimeters. Dimensioni[redacted]
[redacted] to change without notic[redacted]

[redacted] packa[redacted]
[redacted]al pad dimensions.