TEXAS INSTRUMENTS

BQ25176J
JAJSRW9 – OCTOBER 2023

BQ25176J：1 セル リチウムイオンおよび LiFePO$_4$ 向け 800mA JEITA 準拠リニア バッテリ チャージャ、VINDPM 搭載

1 特長

- 最大 30V の入力電圧に対応
- 入力電圧のダイナミック・パワー・マネージメント (VINDPM)
- 自動スリープ・モードによる消費電力の低減
  - バッテリ・リーク電流：350nA
  - 充電ディセーブル時の入力リーク電流 80µA
- 1 セルのリチウムイオン、リチウムポリマ、LiFePO$_4$ をサポート
- 外付け抵抗によりプログラム可能な動作
  - VSET によりバッテリ・レギュレーション電圧を設定：
    - リチウムイオン：4.05V、4.15V、4.2V、4.35V、4.4V
    - LiFePO$_4$：3.5V、3.6V、3.7V
  - ISET により充電電流を 10mA～800mA に設定
- 高精度
  - ±0.5% の充電電圧精度
  - ±10% の充電電流精度
- 充電機能
  - プリチャージ電流：ISET の 20%
  - 終端電流：ISET の 10%
  - NTC サーミスタ入力によるバッテリ温度監視
  - JEITA 範囲全体にわたる充電動作を TS ピンで制御
  - ステータスおよびフォルト表示用のオープン・ドレイン出力
- フォルト保護機能内蔵
  - 26V の IN 過電圧保護
  - VSET による OUT 過電圧保護
  - 1000mA の過電流保護機能
  - 125℃のサーマル・レギュレーション、150℃のサーマル・シャットダウン保護
  - OUT の短絡保護
  - VSET、ISET ピンの短絡 / 開放保護

2 アプリケーション

- 完全ワイヤレス ヘッドセット
- ウェアラブル・アクセサリ、スマート・バンド
- 美容および理容
- 電動歯ブラシ
- フリート管理、アセット追跡

3 概要

BQ25176J は、スペースに制約のあるポータブル アプリケーションを対象とした、1 セルのリチウムイオン、リチウムポリマ、LiFePO$_4$ バッテリ用の統合型 800mA リニア チャージャです。このデバイスには、バッテリを充電する電源出力が 1 つあります。平均的なシステム負荷において安全タイマの継続時間内にバッテリがフル充電されるならば、システム負荷をバッテリと並列に配置できます。システム負荷をバッテリと並列に配置した場合、充電電流がシステムとバッテリの間で共有されます。

このデバイスは、リチウムイオン / リチウムポリマ バッテリ充電用の次の 4 つのフェーズを備えています。これらは、バッテリ電圧を V$_{BAT\_SHORT}$ まで引き上げるトリクル充電、完全に放電されたバッテリを回復するプリチャージ、大量の電荷を供給する定電流の高速充電、最大容量に達するための電圧レギュレーションです。
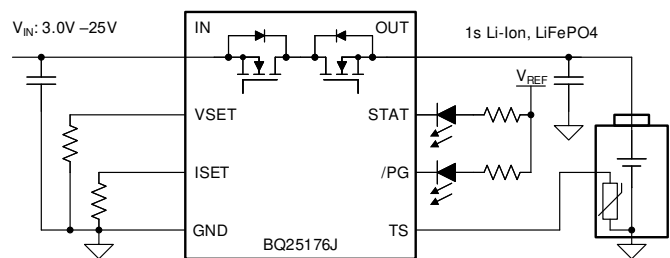
すべての充電フェーズで、内部の制御ループが IC の接合部温度を監視し、内部温度スレッショルド T$_{REG}$ を超えた場合には充電電流を減少させます。

充電器の電力段と充電電流センス機能は完全に統合されています。充電器には、高精度の電流および電圧レギュレーション ループ、充電ステータスの表示、および充電の自動終了の機能があります。充電電圧と高速充電電流は、外付け抵抗によりプログラム可能です。プリチャージおよび終端電流スレッショルドは、高速充電電流の設定に応じて設定されます。

パッケージ情報

部品番号[1]	パッケージ	パッケージ・サイズ[2]	本体サイズ (公称)
BQ25176J	DSG (WSON、8)	2.0mm × 2.0mm	2.0mm × 2.0mm

(1) 利用可能なすべてのパッケージについては、データシートの末尾にある注文情報を参照してください。
(2) パッケージ・サイズ (長さ × 幅) は公称値であり、該当する場合はピンも含まれます。

V$_{IN}$: 3.0V –25V   IN   OUT   1s Li-Ion, LiFePO4   V$_{REF}$ VSET   STAT   ISET   /PG   GND   BQ25176J   TS

概略回路図

Table of Contents

4 Revision History

資料番号末尾の英字は改訂を表しています。その改訂履歴は英語版に準じています。

DATE	REVISION	NOTES
October 2023	*	Initial Release

       Copyright © 2023 Texas Instruments Incorporated

5 Pin Configuration and Functions
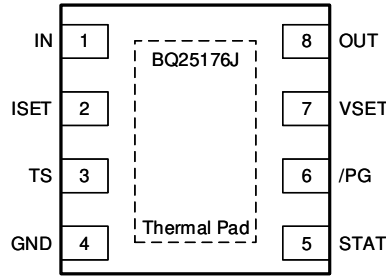
図 5-1. DSG Package 8-Pin WSON Top View

表 5-1. Pin Functions

PIN		I/O	DESCRIPTION
NAME	NUMBER		
IN	1	P	Input power, connected to external DC supply. Bypass IN with at least 1-µF capacitor to GND, placed close to the IC.
ISET	2	I	Programs the device fast-charge current. External resistor from ISET to GND defines fast charge current value. Expected range is 30 kΩ (10 mA) to 375 Ω (800 mA). ICHG = K_{ISET} / R_{ISET}. Precharge current is defined as 20% of ICHG. Termination current is defined as 10% of ICHG.
TS	3	I	Temperature qualification voltage input. Connect a negative temperature coefficient (NTC) thermistor directly from TS to GND (AT103-2 recommended). Charge suspends when the TS pin voltage is out of range. If TS function is not needed, connect an external 10-kΩ resistor from this pin to GND. Pulling TS < V_{TS_ENZ} will disable the charger.
GND	4	–	Ground pin
STAT	5	O	Open drain charger status indication output. Connect to pull-up rail via 10-kΩ resistor. LOW indicates charge in progress. HIGH indicates charge complete or charge disabled. When a fault condition is detected STAT pin blinks at 1 Hz.
$\overline{PG}$	6	O	Open drain charge power good indication output. Connect to pull-up rail via 10-kΩ resistor. $\overline{PG}$ pulls low when V_{IN} > V_{IN_LOWV} and VOUT + V_{SLEEPZ} < V_{IN} < V_{IN_OV}.
VSET	7	I	Programs the regulation voltage for OUT pin with a pull-down resistor. Valid resistor range is 18.2 kΩ to 100 kΩ, values outside this range will suspend charge. Refer to セクション 7.3.1.2 for voltage level details. Recommend using ±1% tolerance resistor with <200 ppm/ºC temperature coefficient.
OUT	8	P	Battery connection. System Load may be connected in parallel to battery. Bypass OUT with at least 1-µF capacitor to GND, placed close to the IC.
Thermal Pad	—	—	Exposed pad beneath the IC for heat dissipation. Solder thermal pad to the board with vias connecting to solid GND plane.

6 Specifications

6.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
Voltage	IN	−0.3	30	V
Voltage	OUT	−0.3	13	V
Voltage	ISET, $\overline{PG}$, STAT, TS, VSET	−0.3	5.5	V
Output Sink Current	$\overline{PG}$, STAT		5	mA
Junction temperature	T_J	−40	150	°C
Storage temperature	T_{stg}	−65	150	°C

(1) Operation outside the *Absolute Maximum Ratings* may cause permanent device damage. *Absolute maximum ratings* do not imply functional operation of the device at these or any other conditions beyond those listed under *Recommended Operating Conditions*. If briefly operating outside the *Recommended Operating Conditions* but within the *Absolute Maximum Ratings*, the device may not sustain damage, but it may not be fully functional. Operating the device in this manner may affect device reliability, functionality, performance, and shorten the device lifetime.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001[1]	±2500	V
		Charged device model (CDM), per ANSI/ESDA/JEDEC JS-002[2]	±1500	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

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

		MIN	NOM	MAX	UNIT
V_{IN}	Input voltage	3.0		25	V
V_{OUT}	Output voltage			4.4	V
I_{OUT}	Output current			0.8	A
T_J	Junction temperature	−40		125	°C
C_{IN}	IN capacitor	1			µF
C_{OUT}	OUT capacitor	1			µF
R_{VSET}	VSET resistor	18.2		100	kΩ
R_{VSET_TOL}	Tolerance for VSET resistor	-1		1	%
R_{VSET_TEMPCO}	Temperature coefficient for VSET resistor			200	ppm/°C
R_{ISET}	ISET resistor	0.375		30	kΩ
R_{TS}	TS thermistor resistor (recommend 103AT-2)		10		kΩ

Product Folder Links: *BQ25176J*

6.4 Thermal Information

THERMAL METRIC[1]		BQ25176J	UNIT
		DSG	
		8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance (JEDEC[1])	75.2	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	93.4	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	41.8	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	3.8	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	41.7	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	17.0	°C/W

(1) For more information about traditional and new thermal metrics, see the Semiconductor and IC Package Thermal Metrics application report.

6.5 Electrical Characteristics

$3.0V < V_{IN} < 18V$ and $V_{IN} > V_{OUT} + V_{SLEEP}$, $T_J = -40°C$ to $+125°C$, and $T_J = 25°C$ for typical values (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
QUIESCENT CURRENTS						
I_{Q_OUT}	Quiescent output current (OUT)	OUT= 4.2V, IN floating or IN = 0V - 5V, Charge Disabled, $T_J = 25°C$		0.35	0.6	µA
		OUT= 4.2V, IN floating or IN = 0V - 5V, Charge Disabled, $T_J < 105°C$		0.35	0.8	µA
$I_{SD\_IN\_TS}$	Shutdown input current (IN) with charge disabled via TS pin	IN = 5V, Charge Disabled ($V_{TS} < V_{TS\_ENZ}$), no battery		80	110	µA
$I_{STANDBY\_IN}$	Standby input current (IN) with charge terminated	IN = 5V, Charge Enabled, charge terminated		190		µA
I_{Q_IN}	Quiescent input current (IN)	IN = 5V, OUT = 3.8V, Charge Enabled, ICHG = 0A		0.45	0.6	mA
INPUT						
V_{IN_OP}	IN operating range		3.0		25	V
V_{IN_LOWV}	IN voltage to start charging	IN rising	3.05	3.09	3.15	V
V_{IN_LOWV}	IN voltage to stop charging	IN falling	2.80	2.95	3.10	V
V_{SLEEPZ}	Exit SLEEP mode threshold	IN rising, $V_{IN} - V_{OUT}$, OUT = 4V	30	55	80	mV
V_{SLEEP}	Enter SLEEP mode threshold	IN falling, $V_{IN} - V_{OUT}$, OUT = 4V	5	30	50	mV
V_{IN_OV}	VIN overvoltage rising threshold	IN rising	26.0	26.5	27.0	V
V_{IN_OVZ}	VIN overvoltage falling threshold	IN falling	25.0	25.5	26.0	V
V_{IN_DPM}	Input voltage DPM threshold	VOUT = 2.9V, VSET = 4.35V, measured at IN pin	3.15	3.25	3.35	V
CONFIGURATION PINS SHORT/OPEN PROTECTION						
R_{ISET_SHORT}	Highest resistor value considered short	R_{ISET} below this at startup, charger does not initiate charge, power cycle or TS toggle to reset			350	Ω
R_{VSET_SHORT}	Highest resistor value considered short	R_{VSET} below this at startup, charger does not initiate charge, power cycle or TS toggle to reset			2.8	kΩ
R_{VSET_OPEN}	Lowest resistor value considered open	R_{VSET} below this at startup, charger does not initiate charge, power cycle or TS toggle to reset		200		kΩ
BATTERY CHARGER						
V_{DO}	Dropout voltage ($V_{IN} - V_{OUT}$)	VIN falling, VOUT = 4.35V, IOUT = 500mA		425		mV
V_{REG_ACC}	OUT charge voltage regulation accuracy	$T_J = 25°C$, all VSET settings	–0.5		0.5	%
		$T_J = -40°C$ to $125°C$, all VSET settings	–0.8		0.8	%
I_{CHG_RANGE}	Typical charge current regulation range	$V_{OUT} > V_{BAT\_LOWV}$	10		800	mA
K_{ISET}	Charge current setting factor, $I_{CHG} = K_{ISET} / R_{ISET}$	10mA < ICHG < 800mA	270	300	330	AΩ
I_{CHG_ACC}	Charge current accuracy	$R_{ISET} = 375Ω$, OUT = 3.8V	720	800	880	mA
		$R_{ISET} = 600Ω$, OUT = 3.8V	450	500	550	mA
		$R_{ISET} = 3.0kΩ$, OUT = 3.8V	90	100	110	mA
		$R_{ISET} = 30kΩ$, OUT = 3.8V	9	10	11	mA
I_{PRECHG}	Typical pre-charge current, as percentage of ICHG	$V_{OUT} < V_{BAT\_LOWV}$		20		%

Product Folder Links: *BQ25176J*

English Data Sheet: SLUSF72

6.5 Electrical Characteristics (続き)

$3.0V < V_{IN} < 18V$ and $V_{IN} > V_{OUT} + V_{SLEEP}$, T_J = -40°C to +125°C, and T_J = 25°C for typical values (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{PRECHG_ACC}	Precharge current accuracy	R_{ISET} = 375Ω, OUT = 2.5V	144	160	176	mA
		R_{ISET} = 600Ω, OUT = 2.5V	85	100	110	mA
		R_{ISET} = 3.0kΩ, OUT = 2.5V	18	20	22	mA
		R_{ISET} = 30kΩ, OUT = 2.5V	1.4	2	2.6	mA
I_{TERM}	Typical termination current, as percentage of ICHG	$V_{OUT} = V_{REG}$		10		%
I_{TERM_ACC}	Termination current accuracy	R_{ISET} = 600Ω, OUT = VREG = 4.2V	45	50	55	mA
		R_{ISET} = 3.0kΩ, OUT = VREG = 4.2V	8.5	10	11.5	mA
		R_{ISET} = 30kΩ, OUT = VREG = 4.2V	0.4	1	1.6	mA
V_{BAT_SHORT}	Output (OUT) short circuit voltage rising threshold for Li-Ion chemistry	OUT rising	2.1	2.2	2.3	V
V_{BAT_SHORT}	Output (OUT) short circuit voltage rising threshold for LiFePO$_4$ chemistry	OUT rising, VSET configured for LiFePO$_4$	1.1	1.2	1.3	V
$V_{BAT\_SHORT\_HYS}$	Output (OUT) short circuit voltage hysteresis	OUT falling		200		mV
I_{BAT_SHORT}	OUT short circuit charging current	$V_{OUT} < V_{BAT\_SHORT}$	12	16	20	mA
V_{BAT_LOWV}	Pre-charge to fast-charge transition threshold for Li-Ion chemistry	OUT rising	2.7	2.8	3.0	V
V_{BAT_LOWV}	Pre-charge to fast-charge transition threshold for Li-FePO$_4$ chemistry	OUT rising, VSET configured for LiFePO$_4$	1.9	2.0	2.1	V
$V_{BAT\_LOWV\_HYS}$	Battery LOWV hysteresis	OUT falling		100		mV
V_{RECHG}	Battery recharge threshold for Li-Ion chemistry	OUT falling, V_{REG_ACC} - V_{OUT}	75	100	125	mV
V_{RECHG}	Battery recharge threshold for LiFePO$_4$ chemistry	OUT falling, VSET configured for LiFePO$_4$, V_{REG_ACC} - V_{OUT}	175	200	225	mV
R_{ON}	Charging path FET on-resistance	IOUT = 400mA, T_J = 25°C		845	1000	mΩ
		IOUT = 400mA, T_J = -40 - 125°C		845	1450	mΩ
BATTERY CHARGER PROTECTION						
V_{OUT_OVP}	OUT overvoltage rising threshold	VOUT rising, as percentage of VREG	103	104	105	%
V_{OUT_OVP}	OUT overvoltage falling threshold	VOUT falling, as percentage of VREG	101	102	103	%
I_{OUT_OCP}	Output current limit threshold	IOUT rising	0.9	1	1.1	A
TEMPERATURE REGULATION AND TEMPERATURE SHUTDOWN						
T_{REG}	Typical junction temperature regulation			125		°C
T_{SHUT}	Thermal shutdown rising threshold	Temperature increasing		150		°C
	Thermal shutdown falling threshold	Temperature decreasing		135		°C
BATTERY-PACK NTC MONITOR						
I_{TS_BIAS}	TS nominal bias current		36.5	38	39.5	µA
V_{COLD}	Cold temperature threshold; Charge disabled	TS pin voltage rising (approx. 0°C)	0.99	1.04	1.09	V
	Cold temperature exit threshold; Charge current target increased to 20% × ISET	TS pin voltage falling (approx. 4°C)	0.83	0.88	0.93	V
V_{COOL}	Normal to low temperature charge; Charge current target reduced to 20% x ISET	TS pin voltage rising (approx. 10°C)	650	680	710	mV
	Low temperature to normal charge; Charge current target returns to ISET	TS pin voltage falling (approx. 13°C)	580	610	640	mV

6.5 Electrical Characteristics (続き)

3.0V < V_{IN} < 18V and V_{IN} > V_{OUT} + V_{SLEEP}, T_J = -40°C to +125°C, and T_J = 25°C for typical values (unless otherwise noted)
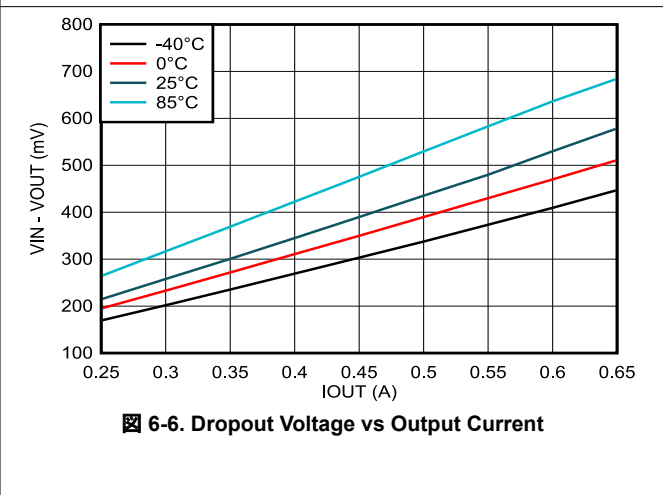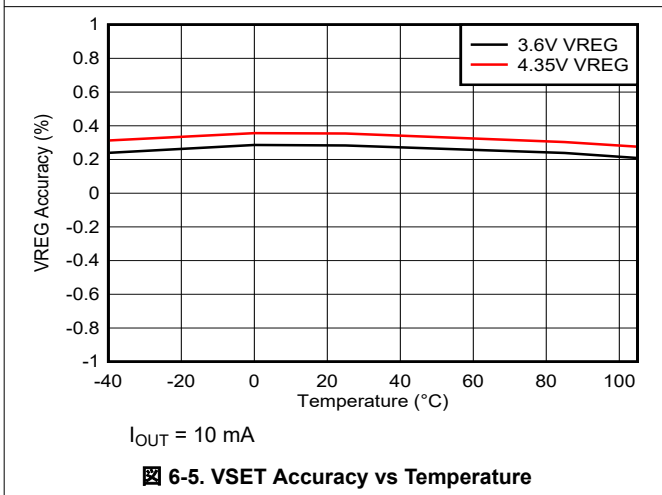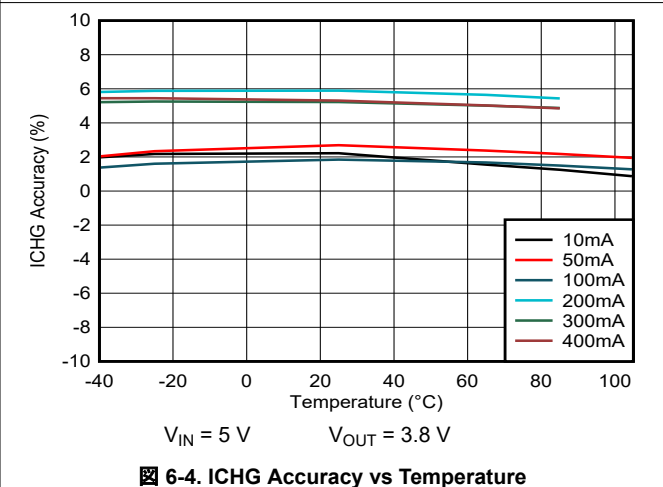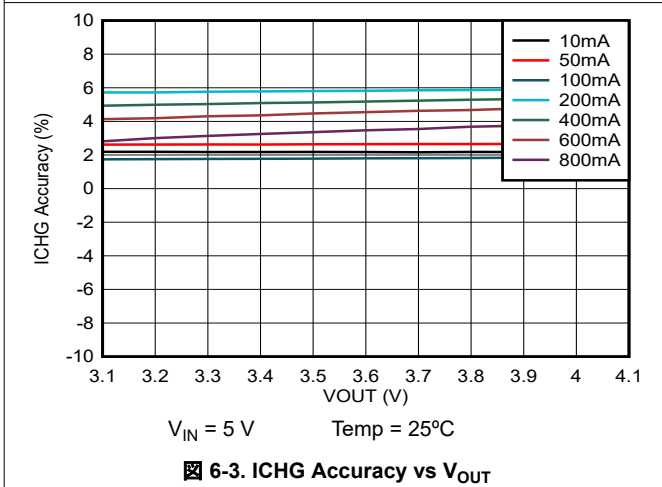
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{WARM}	Normal to warm temperature threshold; Charge current target reduced to 50% x ISET; VREG reduced to 4.1V for VSET = 4.15V, 4.2 V, 4.35 V, 4.4 V	TS pin voltage falling (approx. 45°C)	176	188	200	mV
	Warm to normal temperature threshold; Charge current target increased to ISET; VREG increased to VSET for VSET = 4.15V, 4.2 V, 4.35 V, 4.4 V	TS pin voltage rising (approx. 40°C)	208	220	232	mV
V_{HOT}	Warm to hot temperature threshold; charge disabled	TS pin voltage falling (approx. 55°C)	125	135	145	mV
	Hot to warm temperature threshold; Charge current target increased to 50% x ISET; VREG set to 4.1V for VSET = 4.15V, 4.2 V, 4.35 V, 4.4 V	TS pin voltage rising (approx. 51°C)	148	158	168	mV
V_{TS_ENZ}	Charge Disable threshold. Crossing this threshold shall shutdown IC	TS pin voltage falling	40	50	60	mV
V_{TS_EN}	Charge Enable threshold. Crossing this threshold shall restart IC operation	TS pin voltage rising	65	75	85	mV
V_{TS_CLAMP}	TS maximum voltage clamp	TS pin open-circuit (float)	2.3	2.6	2.9	V
LOGIC OUTPUT PIN (STAT, $\overline{PG}$)						
V_{OL}	Output low threshold level	Sink current = 5mA			0.4	V
I_{OUT_BIAS}	High-level leakage current	Pull up rail 3.3V			1	µA

6.6 Timing Requirements

		MIN	NOM	MAX	UNIT
BATTERY CHARGER					
$t_{TS\_DUTY\_OFF}$	TS turn-off time during TS duty cycle mode		2		s
$t_{OUT\_OCP\_DGL}$	Deglitch time for I_{OUT_OCP}, IOUT rising		100		µs
t_{PRECHG}	Pre-charge safety timer accuracy	28.5	30	31.5	min
t_{SAFETY}	Fast-charge safety timer accuracy	9.5	10	10.5	hr

Product Folder Links: *BQ25176J*

English Data Sheet: *SLUSF72*

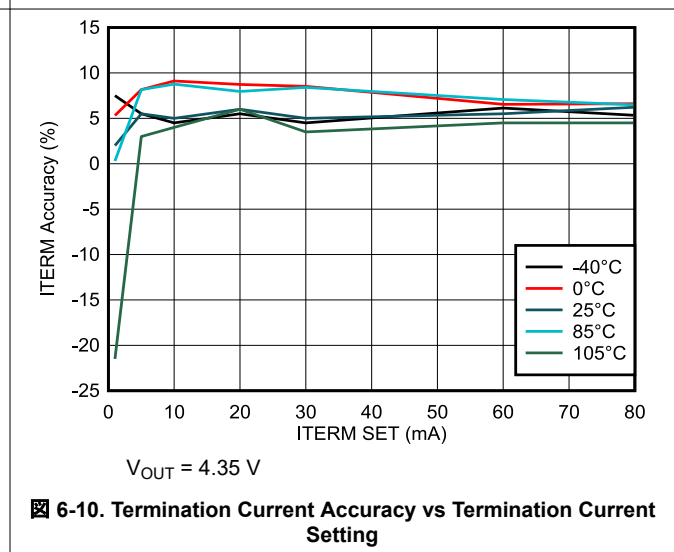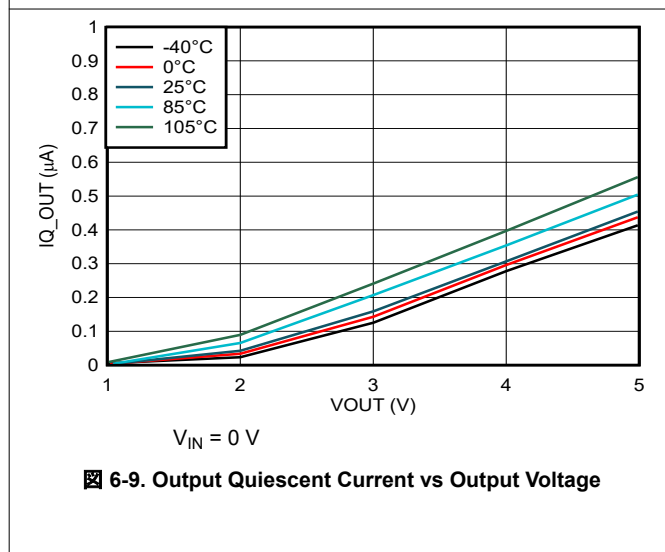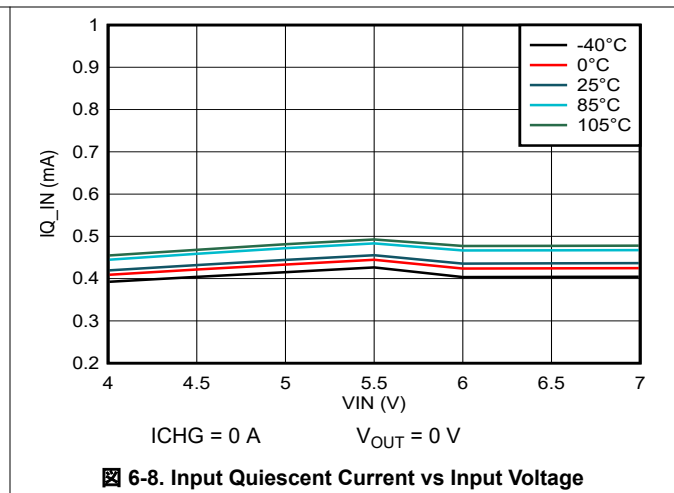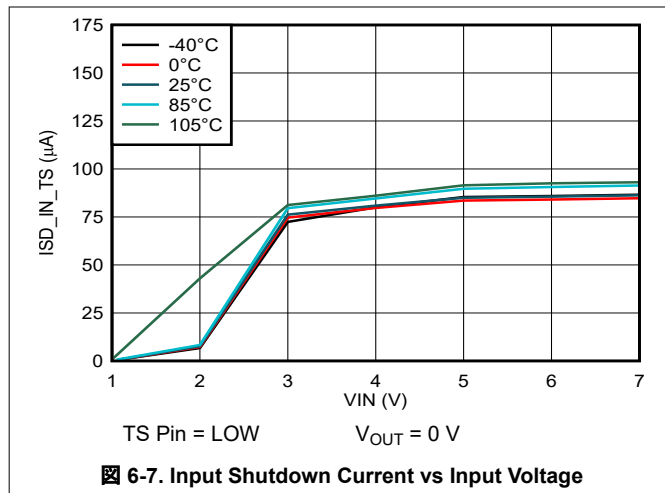## 6.7 Typical Characteristics

C_{IN} = 1 μF, C_{OUT} = 1 μF, V_{IN} = 5 V, V_{OUT} = 3.8 V (unless otherwise specified)

I_{OUT} = 10 mA V_{OUT} = 4.2 V

図 **6-1. Line Regulation**

V_{IN} = 5 V V_{OUT} = 4.2 V

図 **6-2. Load Regulation**

V_{IN} = 5 V   Temp = 25ºC

図 **6-3. ICHG Accuracy vs V_OUT**

V_{IN} = 5 V V_{OUT} = 3.8 V

図 **6-4. ICHG Accuracy vs Temperature**

I_{OUT} = 10 mA

図 **6-5. VSET Accuracy vs Temperature**

図 **6-6. Dropout Voltage vs Output Current**

資料に関するフィードバック (ご意見やお問い合わせ) を送信   9

Product Folder Links: *BQ25176J*

English Data Sheet: *SLUSF72*
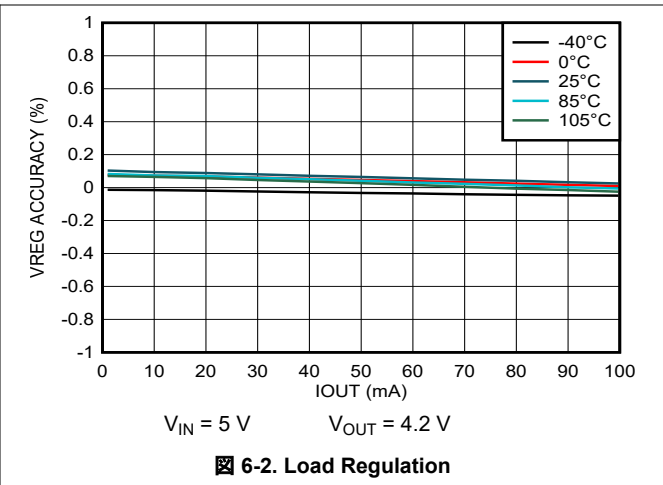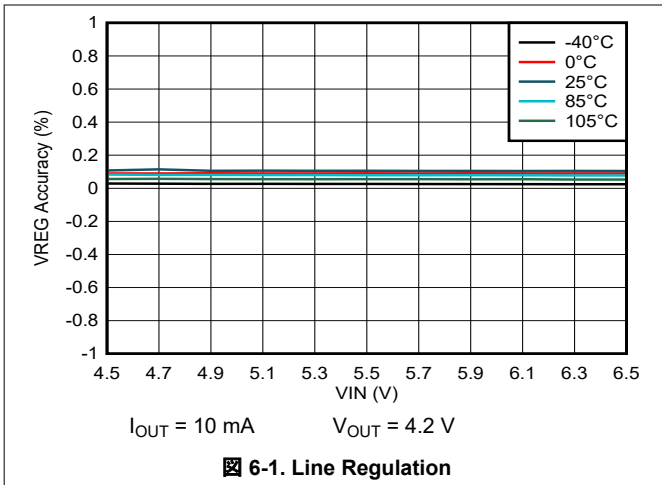
6.7 Typical Characteristics (continued)

C_{IN} = 1 µF, C_{OUT} = 1 µF, V_{IN} = 5 V, V_{OUT} = 3.8 V (unless otherwise specified)

TS Pin = LOW V_{OUT} = 0 V

図 6-7. Input Shutdown Current vs Input Voltage

ICHG = 0 A V_{OUT} = 0 V

図 6-8. Input Quiescent Current vs Input Voltage

V_{IN} = 0 V

図 6-9. Output Quiescent Current vs Output Voltage

V_{OUT} = 4.35 V

図 6-10. Termination Current Accuracy vs Termination Current Setting

Product Folder Links: *BQ25176J*

English Data Sheet: *SLUSF72*

7 Detailed Description

7.1 Overview

The BQ25176J is an integrated 800-mA linear charger for 1-cell Li-Ion, Li-Polymer, and LiFePO$_4$ batteries. The device has a single power output that charges the battery. The system load can be placed in parallel with the battery, as long as the average system load does not prevent the battery from charging fully within the safety timer duration. When the system load is placed in parallel with the battery, the output current is shared between the system and the battery.

The device has four phases for charging a Li-Ion/Li-Poly battery: trickle charge to bring the battery voltage up to V_{BAT_SHORT}, precharge to recover a fully discharged battery, fast-charge constant current to supply the bulk of the charge, and voltage regulation to reach full capacity.

The charger includes flexibility in programming of the fast-charge currentand regulation voltage.This charger is designed to work with a standard USB connection or dedicated charging adapter (DC output).

The charger also comes with a full set of safety features: battery temperature monitoring, overvoltage protection, charge safety timers, and configuration pin (VSET, ISET) short and open protection. All of these features and more are described in detail below.

The charger is designed for a single path from the input to the output to charge the battery. Upon application of a valid input power source, the configuration pins are checked for short/open circuit.

If the battery voltage is below the V_{BAT_LOWV} threshold, the battery is considered discharged and a preconditioning cycle begins. If the battery voltage is below V_{BAT_SHORT}, the charge current is I_{BAT_SHORT}. If the battery voltage is higher than V_{BAT_SHORT} but lower than V_{BAT_LOWV}, the amount of precharge current is 20% of the programmed fast-charge current via the ISET pin. The t_{PRECHG} safety timer is active, and stops charging after expiration if battery voltage fails to rise above V_{BAT_LOWV}.

Once the battery has charged to the V_{BAT_LOWV} threshold, Fast Charge Mode is initiated, applying the fast charge current and starting the t_{SAFETY} timer. The fast charge constant current is programmed using the ISET pin. The constant current phase provides the bulk of the charge. Power dissipation in the IC is greatest in fast charge with a lower battery voltage. If the IC temperature reaches T_{REG}, the IC enters thermal regulation, slows the timer clock by half, and reduces the charge current as needed to keep the temperature from rising any further. 図 7-1 shows the typical lithium battery charging profile with thermal regulation. Under normal operating conditions, the IC junction temperature is less than T_{REG} and thermal regulation is not entered.

Once the battery has charged to the regulation voltage, the voltage loop takes control and holds the battery at the regulation voltage until the current tapers to the termination threshold. The termination threshold is 10% of the programmed fast-charge current.

Further details are described in セクション 7.3.
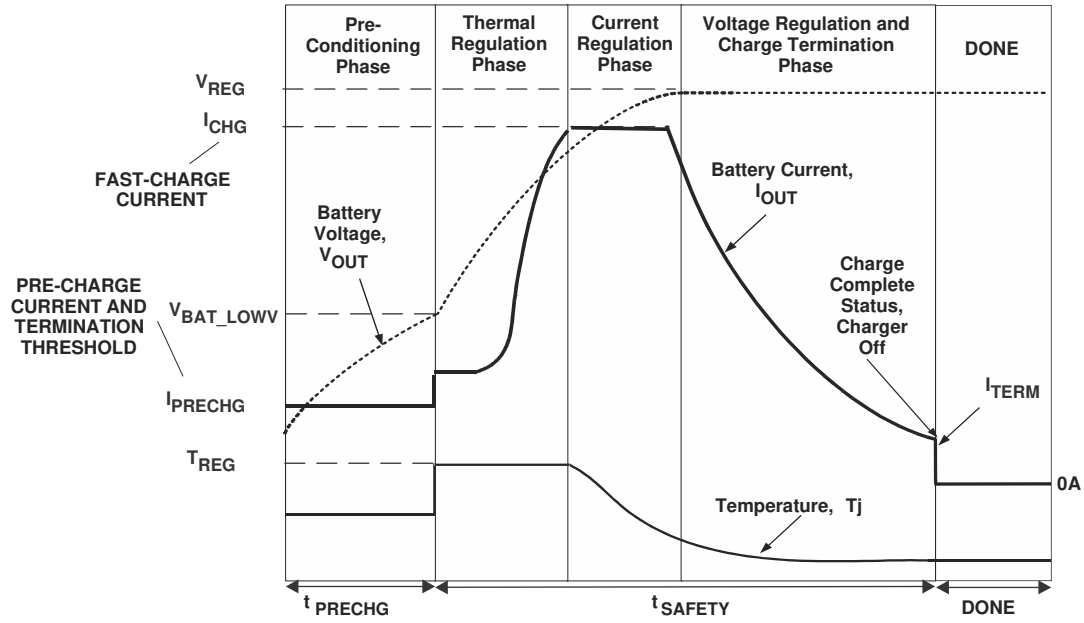
図 7-1. Lithium-Ion Battery Charging Profile with Thermal Regulation

7.2 Functional Block Diagram
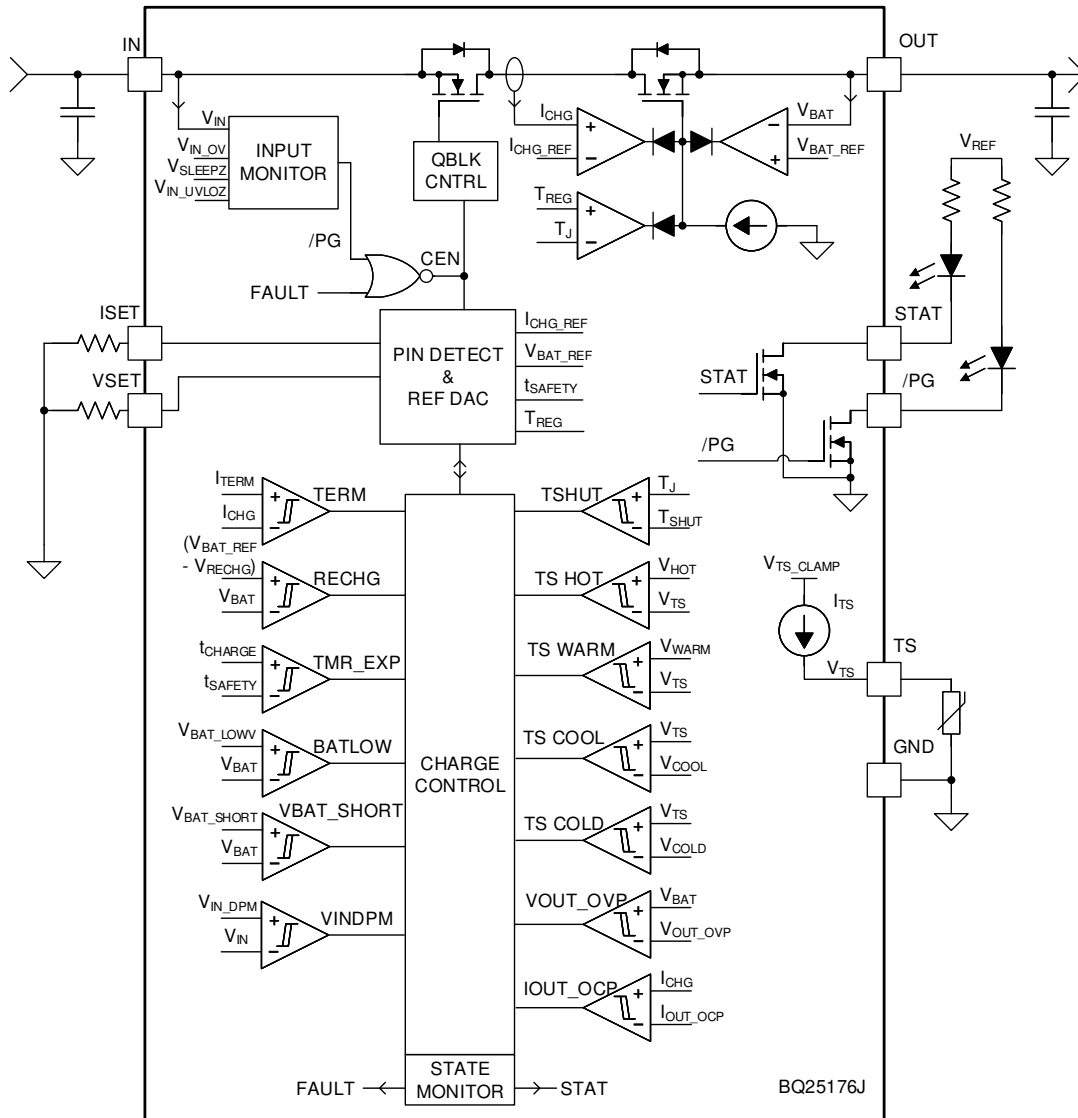
7.3 Feature Description

7.3.1 Device Power Up from Input Source

When an input source is plugged in and charge is enabled, the device checks the input source voltage to turn on all the bias circuits. It detects and sets the charge current and charge voltage limits before the linear regulator is started. The power up sequence from input source is as listed:

1. ISET pin detection
2. VSET pin detection to select charge voltage
3. Charger power up

7.3.1.1 ISET Pin Detection

After a valid VIN is plugged in, the device checks the resistor on the ISET pin for a short circuit (R_{ISET} < R_{ISET_SHORT}). If a short condition is detected, the charger remains in the FAULT state until the input or TS pin is toggled. If the ISET pin is open-circuit, the charger proceeds through pin detection and starts the charger with no charge current. This pin is monitored while charging and changes in R_{ISET} while the charger is operating will immediately translate to changes in charge current.

An external pulldown resistor (±1% or better is recommended to minimize charge current error) from the ISET pin to GND sets the charge current as:

$$I_{CHG} = \frac{K_{ISET}}{R_{ISET}}$$

(1)

where:

- I_{CHG} is the desired fast-charge current
- K_{ISET} is a gain factor found in the electrical specifications
- R_{ISET} is the pulldown resistor from the ISET pin to GND

For charge currents below 50 mA, an extra RC circuit is recommended on ISET to achieve a more stable current signal. For greater accuracy at lower currents, part of the current-sensing FET is disabled to give better resolution.

7.3.1.2 VSET Pin Detection

VSET pin is used to program the device regulation voltage at end-of-charge using a ±1% pulldown resistor. The available pulldown resistor and corresponding charging levels are listed in the following table.

表 7-1. VSET Pin Resistor Value Table

RESISTOR	CHARGE VOLTAGE (V)
> 150 kΩ	No charge (open-circuit)
100 kΩ	1-cell LiFePO$_4$: 3.50 V
82.5 kΩ	1-cell LiFePO$_4$: 3.60 V
61.9 kΩ	1-cell LiFePO$_4$: 3.70 V
47.5 kΩ	1-cell Li-Ion: 4.05 V
35.7 kΩ	1-cell Li-Ion: 4.15 V
27.4 kΩ	1-cell Li-Ion: 4.20 V
24.3 kΩ	1-cell Li-Ion: 4.35 V
18.2 kΩ	1-cell Li-Ion: 4.40 V
< 3.0 kΩ	No charge (short-circuit)

Product Folder Links: *BQ25176J*

English Data Sheet: SLUSF72

If either a short- or open-circuit condition is detected, charger stops operation and remains in the FAULT state until the input or TS pin is toggled.

Once a valid resistor value has been detected, the corresponding charge voltage is latched in and the pin is not continuously monitored during operation. A change in this pin will not be acknowledged by the IC until the input supply or TS pin is toggled.

7.3.1.3 Charger Power Up

After VSET, ISET pin resistor values have been validated, the device proceeds to enable the charger. The device automatically begins operation at the correct stage of battery charging depending on the OUT voltage.

7.3.2 Battery Charging Features

When charge is enabled, the device automatically completes a charging cycle according to the settings on the VSET, ISET pins without any intervention. The lithium-based charging cycle is automatically terminated when the charging current is below termination threshold, charge voltage is above recharge threshold, and device is not in VINDPM or in thermal regulation (TREG). When a full battery is discharged below the recharge threshold (V_{RECHG}), the device automatically starts a new charging cycle. After charge is done, toggling the input supply or the TS pin can initiate a new charging cycle.

7.3.2.1 Lithium-Ion Battery Charging Profile

The device charges a lithium based battery in four phases: trickle charge, precharge, constant current, and constant voltage. At the beginning of a charging cycle, the device checks the battery voltage and regulates current and voltage accordingly.

If the charger is in thermal regulation during charging, the actual charging current is less than the programmed value. In this case, termination is temporarily disabled and the charging safety timer is counted at half the clock rate. For more information, refer to セクション 7.3.2.4.

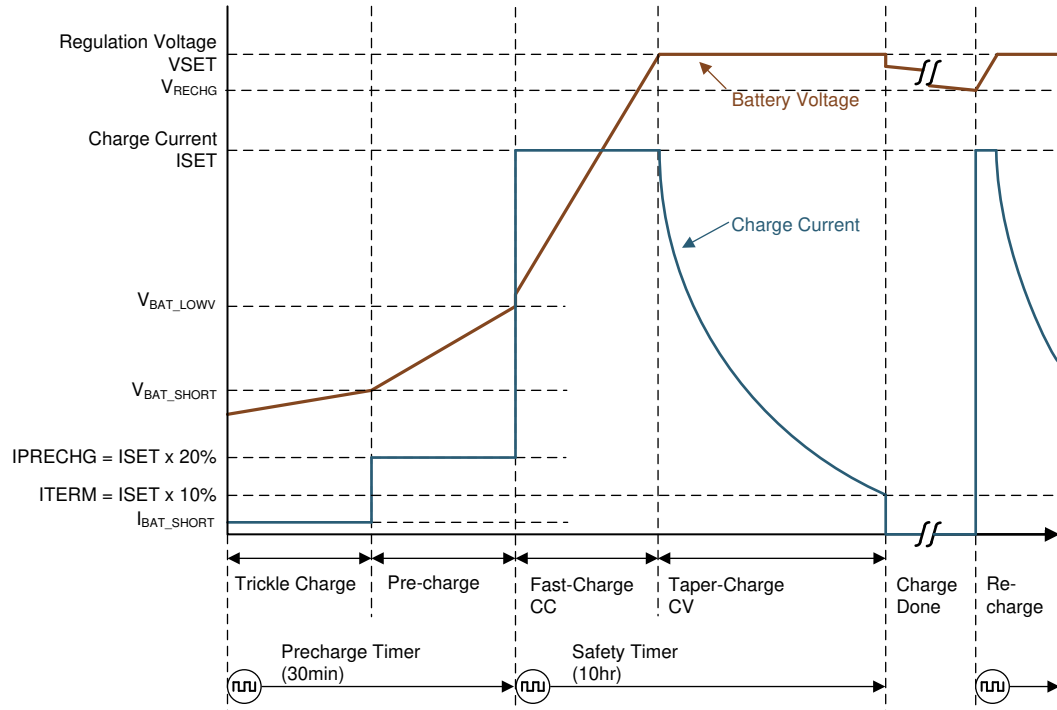**図 7-2. Battery Charging Profile**

7.3.2.2 Input Voltage Based Dynamic Power Management (VINDPM)

The VINDPM feature is used to detect an input source voltage that is reaching its current limit due to excessive load and causing the voltage to reduce. When the input voltage drops to the VINDPM threshold (V_{IN_DPM}), the internal pass FET reduces the current until there is no further drop in voltage at the input. This prevents a source with voltage less than the V_{IN_DPM} to power the OUT pin. This unique feature makes the IC work well with current limited (for example, high impedance) power sources, such as solar panels or inductive charging pads. This is also an added safety feature that helps protect the source from excessive loads.

7.3.2.3 Charge Termination and Battery Recharge

The device terminates a charge cycle when the OUT pin voltage is above the recharge threshold (V_{RECHG}) and the current is below the termination threshold (I_{TERM}). Termination is temporarily disabled when the charger device is in thermal regulation or VINDPM. After charge termination is detected, the linear regulator turns off and the device enters the Standby state. Once the OUT pin drops below the V_{RECHG} threshold, a new charge cycle is automatically initiated.

7.3.2.4 Charging Safety Timers

The device has built-in safety timers to prevent an extended charging cycle due to abnormal battery conditions. The precharge timer is fixed at 30 minutes. The fast-charge safety timer is fixed at 10 hours. When the safety timer expires, the charge cycle ends. A toggle on the input supply or TS pin is required to restart a charge cycle after the safety timer has expired.

During thermal regulation or VINDPM, the safety timer counts at half the clock rate as the actual charge current is likely to be below the ISET setting. For example, if the charger is in thermal regulation throughout the whole charging cycle and the safety timer is 10 hours, then the timer will expire in 20 hours.

During faults which disable charging, such as VIN_OV, VOUT_OVP, TSHUT, or TS faults, the timer is suspended. Once the fault goes away, charging and the safety timer resume. If the charging cycle is stopped and started again, the timer gets reset (toggle of the TS pin restarts the timer).

The safety timer restarts counting for the following events:
1. Charging cycle stop and restart (toggle TS pin, charged battery falls below recharge threshold, or toggle input supply)
2. OUT pin voltage crosses the V_{BAT_LOWV} threshold in either direction

The precharge safety timer (fixed counter that runs when $V_{OUT} < V_{BAT\_LOWV}$), follows the same rules as the fast-charge safety timer in terms of getting suspended, reset, and counting at half-rate.

7.3.2.5 Battery Temperature Qualification (TS Pin)

While charging, the device continuously monitors battery temperature by sensing the voltage at the TS pin. A negative temperature coefficient (NTC) thermistor should be connected between the TS and GND pins (recommend: 103AT-2). If temperature sensing is not required in the application, connect a fixed 10-kΩ resistor from TS to GND to allow normal operation.

The TS function for BQ25176J is designed to follow the JEITA temperature standard for Li-Ion and Li-Poly batteries; charge current (ISET) and regulation voltage (V_{REG}) are reduced based on battery temp (TS). There are four thresholds, Hot-55C, Warm-45C, Cool-10C and Cold-0C.

Normal operation occurs between 10C and 45C, charge current and voltage will be the normal values. When battery is in the Cool temperature range, between 0C and 10C, the charger current level is 20% of ISET value and regulation voltage is not changed. When the battery is in the Warm temperature range, between 45C and 55C, ISET is reduced by 50% and regulation voltage is reduced to 4.1V for VSET settings greater than 4.1V. Regulation voltage is not reduced during the Warm region for VSET settings less than 4.1V. Charge is suspended below Cold temp of 0C and above Hot temp of 55C. When charge is suspended device enters the STANDBY state, and blinks the STAT pin. Once battery temperature returns to normal conditions, charging resumes automatically. See 図 7-3.

When charge current is reduced during Cool or Warm temp the safety timer runs at half the clock rate.
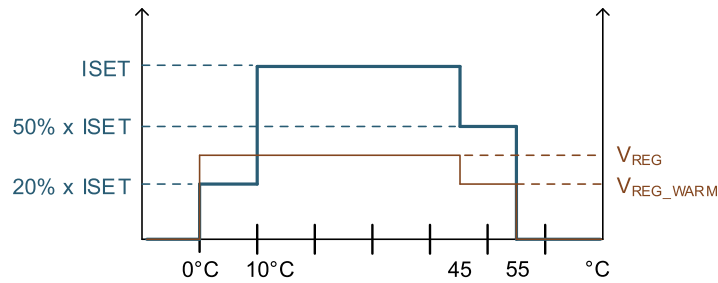

図 7-3. Standard JEITA Profile figure

In addition to battery temperature sensing, the TS pin can be used to disable the charger at any time by pulling TS voltage below V_{TS_ENZ}. The device disables the charger and consumes $I_{SD\_IN\_TS}$ from the input supply. After the TS pin pull-down is released, the device may take up to $t_{TS\_DUTY\_OFF}$ to turn the I_{TS_BIAS} back on. After the source is turned on, the TS pin voltage will go above V_{TS_EN}, and re-enable the charger operation. The device treats this TS pin toggle as an input supply toggle, triggering Device Power Up From Input Source (セクション 7.3.1).

7.3.3 Status Outputs ($\overline{PG}$, STAT)

7.3.3.1 Power Good Indicator ($\overline{PG}$ Pin)

This open-drain pin pulls LOW to indicate a good input source when:
1. VIN above V_{IN_LOWV}
2. VIN above V_{OUT} + V_{SLEEPZ} (not in SLEEP)
3. VIN below V_{IN_OV}

7.3.3.2 Charging Status Indicator (STAT)

The device indicates the charging state on the open-drain STAT pin. This pin can drive an LED.

表 7-2. STAT Pin State

CHARGING STATE	STAT PIN STATE
Charge completed, charger in Sleep mode or charge disabled (V_{TS} < V_{TS_ENZ})	HIGH
Charge in progress (including automatic recharge)	LOW
Fault (VIN_OV, VOUT_OVP, IOUT_OCP, TS HOT, TS COLD, TSHUT, TMR_EXP, VSET pin short/open, or ISET pin short)	BLINK at 1Hz

7.3.4 Protection Features

The device closely monitors input and output voltages, as well as internal FET current and temperature for safe linear regulator operation.

7.3.4.1 Input Overvoltage Protection (VIN_OV)

If the voltage at the IN pin exceeds V_{IN_OV}, the device turns off after a deglitch , $t_{VIN\_OV\_DGL}$. The safety timer suspends counting and the device enters Standby mode. Once the IN voltage recovers to a normal level, the charge cycle and the safety timer automatically resume operation.

7.3.4.2 Output Overvoltage Protection (VOUT_OVP)

If the voltage at the OUT pin exceeds V_{OUT_OVP}, the device immediately stops charging.The safety timer suspends counting and the device enters Standby mode. Once the OUT voltage recovers to a normal level, the charge cycle and the safety timer automatically resume operation.

7.3.4.3 Output Overcurrent Protection (IOUT_OCP)

During normal operation, the OUT current should be regulated to the ISET programmed value. However, if a short circuit occurs on the ISET pin, the OUT current may rise to an unintended level. If the current at the OUT pin exceeds I_{OUT_OCP}, the device turns off after a deglitch, $t_{OUT\_OCP\_DGL}$. The safety timer resets the count, and the device remains latched off. An input supply or TS pin toggle is required to restart operation.
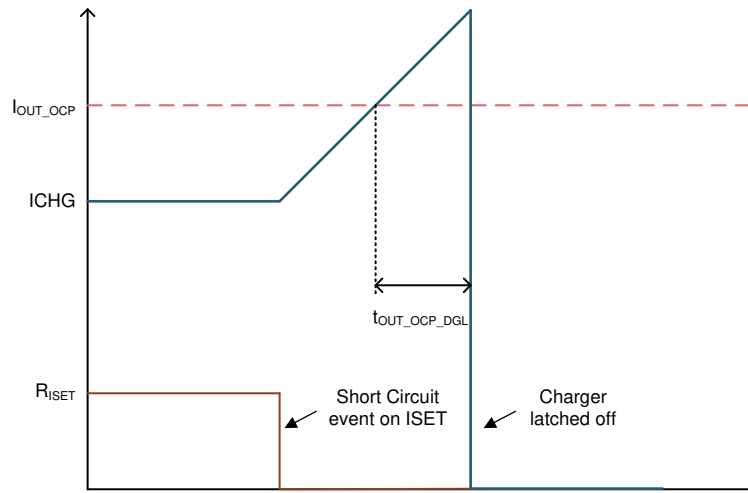

図 7-4. Overcurrent Protection

7.3.4.4 Thermal Regulation and Thermal Shutdown (TREG and TSHUT)

The device monitors its internal junction temperature (T_J) to avoid overheating and to limit the IC surface temperature. When the internal junction temperature exceeds the thermal regulation limit, the device automatically reduces the charge current to maintain the junction temperature at the thermal regulation limit (TREG). During thermal regulation, the actual charging current is usually below the programmed value on the ISET pin. Therefore, the termination comparator for the Lithium-Ion battery is disabled, and the safety timer runs at half the clock rate.

Additionally, the device has thermal shutdown to turn off the linear regulator when the IC junction temperature exceeds the TSHUT threshold. The charger resumes operation when the IC die temperature decreases below the TSHUT falling threshold.

7.4 Device Functional Modes

7.4.1 Shutdown or Undervoltage Lockout (UVLO)

The device is in the shutdown state if the IN pin voltage is less than V_{IN_LOWV} or the TS pin is below V_{TS_ENZ}. The internal circuitry is powered down, all the pins are high impedance, and the device draws $I_{SD\_IN\_TS}$ from the input supply. Once the IN voltage rises above the V_{IN_LOW} threshold and the TS pin is above V_{TS_EN}, the IC enters Sleep mode or Active mode depending on the OUT pin voltage.

7.4.2 Sleep Mode

The device is in Sleep mode when $V_{IN\_LOWV} < V_{IN} < V_{OUT} + V_{SLEEPZ}$. The device waits for the input voltage to rise above $V_{OUT} + V_{SLEEPZ}$ to start operation.

7.4.3 Active Mode

The device is powered up and charges the battery when the TS pin is above V_{TS_ENZ} and the IN voltage ramps above both V_{IN_LOWV} and V_{OUT} + V_{SLEEPZ}. The device draws I_{Q_IN} from the supply to bias the internal circuitry. For details on the device power-up sequence, refer to セクション 7.3.1.

7.4.3.1 Standby Mode

The device is in Standby mode if a valid input supply is present and charge is terminated or if a recoverable fault is detected. The internal circuitry is partially biased, and the device continues to monitor for either VOUT to drop below V_{RECHG} or the recoverable fault to be removed.

7.4.4 Fault Mode

The fault conditions are categorized into recoverable and nonrecoverable as follows:

- Recoverable, from which the device should automatically recover once the fault condition is removed:
    - VIN_OV
    - VOUT_OVP
    - TS HOT
    - TS COLD
    - TSHUT
- Nonrecoverable, requiring TS pin or input supply toggle to resume operation:
    - IOUT_OCP
    - ISET pin short detected
    - VSET pin short/open detected

8 Application and Implementation

8.1 Application Information

A typical application consists of the device configured as a standalone battery charger for single-cell Lithium-Ion, Li-Polymer, or LiFePO$_4$ chemistries. The charge voltage and number of cells is configured using a pull-down resistor on the VSET pin. The charge current is configured using a pull-down resistor on the ISET pin. A battery thermistor may be connected to the TS pin to allow the device to monitor battery temperature and control charging. Pulling the TS pin below V_{TS_ENZ} disables the charging function. The charger and input supply status is reported via the STAT and PG pins.

8.2 Typical Applications

8.2.1 Li-Ion Charger Design Example
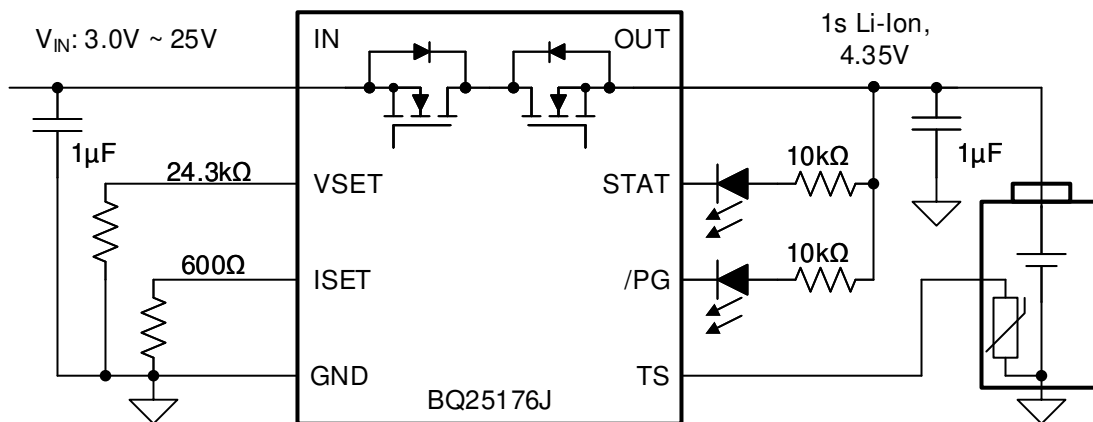
図 8-1. BQ25176J Typical Application for Li-Ion Charging at 500 mA

8.2.1.1 Design Requirements

- Supply voltage = 5 V
- Battery is single-cell Li-Ion
- Fast charge current: I_{CHG} = 500 mA
- Charge voltage: V_{REG} = 4.35 V
- Termination current: I_{TERM} = 10% of I_{CHG} or 50 mA
- Precharge current: I_{PRECHG} = 20% of I_{CHG} or 100 mA
- TS – Battery Temperature Sense = 10-kΩ NTC (103AT)
- TS pin can be pulled down to disable charging

8.2.1.2 Detailed Design Procedure

The regulation voltage is set via the VSET pin to 4.35 V, the input voltage is 5 V and the charge current is programmed via the ISET pin to 500 mA.

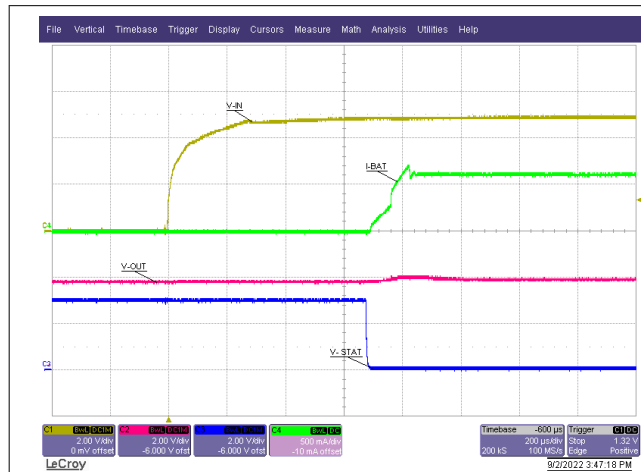R_{ISET} = [K_{ISET} / I_{CHG}]
from electrical characteristics table. . . K_{ISET} = 300 AΩ
R_{ISET} = [300 AΩ/0.5 A] = 600 Ω

Product Folder Links: *BQ25176J*

English Data Sheet: SLUSF72

Selecting the closest 1% resistor standard value, use a 604-Ω resistor between ISET and GND, for an expected I_{CHG} 497 mA.

8.2.1.3 Application Curves

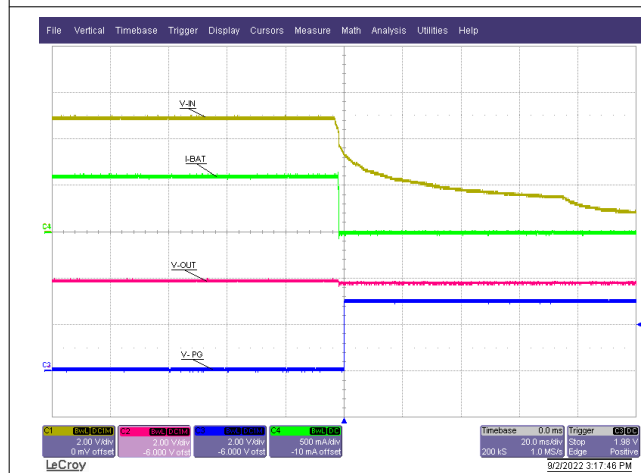C_{IN} = 1 µF, C_{OUT} = 1 µF, V_{IN} = 5 V, V_{OUT} = 3.8 V, I_{CHG} = 600 mA (unless otherwise specified)
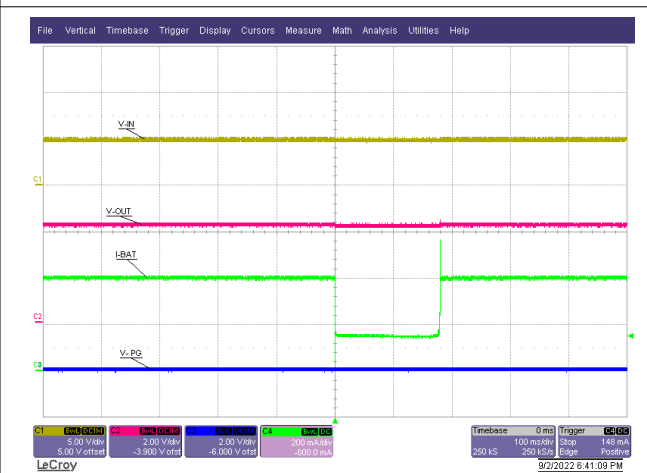

R_{ISET} = 500 Ω

図 8-2. Power Up With Battery

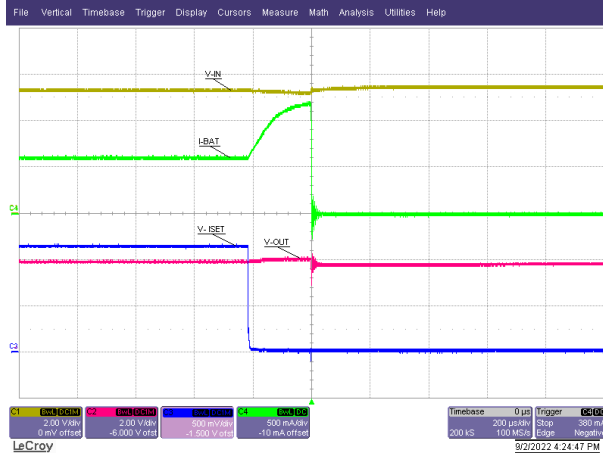R_{ISET} = 500 Ω   OUT = open-circuit

図 8-3. Power Up Without Battery

VIN = 5 V → 0 V

図 8-4. Power Down

V_{OUT} = V_{SET} = 4.2 V R_{ISET} = 0.5 kΩ I_{SYS} = 0 mA → 250 mA

図 8-5. OUT Transient Response

Product Folder Links: *BQ25176J*

English Data Sheet: *SLUSF72*

R_{ISET} = 500 Ω → 0 Ω

図 8-6. ISET Short-Circuit Response

9 Power Supply Recommendations

The device is designed to operate from an input voltage supply range between 3.0 V and 25 V (up to 30 V tolerant) and current capability of at least the maximum designed charge current. If located more than a few inches from the IN and GND pins, a larger capacitor is recommended.

10 Layout

10.1 Layout Guidelines

To obtain optimal performance, the decoupling capacitor from the IN pin to the GND pin and the output filter capacitor from the OUT pin to the GND pin should be placed as close as possible to the device, with short trace runs to both IN, OUT, and GND.

- All low-current GND 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 high current charge paths into the IN pin and from the OUT pin must be sized appropriately for the maximum charge current in order to avoid voltage drops in these traces.

To achieve correct pin detection, the ISET pin and VSET pin resistors should be placed as close as possible to the device, with short trace runs to both ISET, VSET, and GND.
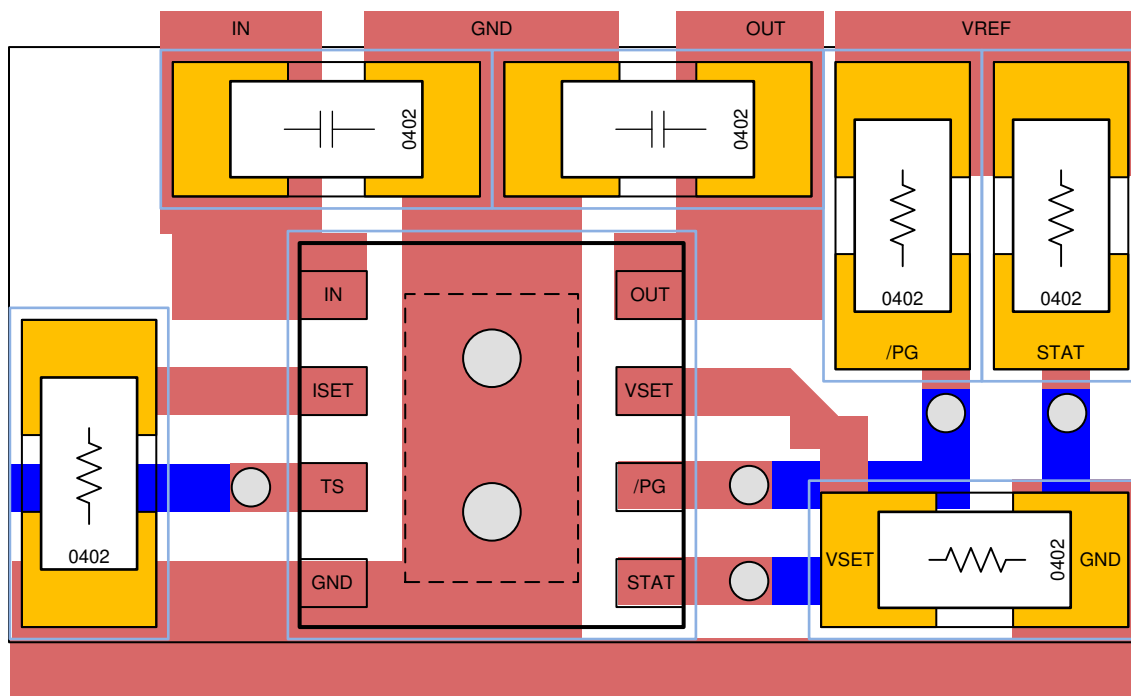
10.2 Layout Example

図 10-1. Board Layout Example

Product Folder Links: *BQ25176J*

English Data Sheet: *SLUSF72*

11 Device and Documentation Support

11.1 Device Support

11.1.1 サード・パーティ製品に関する免責事項

サード・パーティ製品またはサービスに関するテキサス・インスツルメンツの出版物は、単独またはテキサス・インスツルメンツの製品、サービスと一緒に提供される場合に関係なく、サード・パーティ製品またはサービスの適合性に関する是認、サード・パーティ製品またはサービスの是認の表明を意味するものではありません。

11.2 ドキュメントの更新通知を受け取る方法

ドキュメントの更新についての通知を受け取るには、www.tij.co.jp のデバイス製品フォルダを開いてください。[通知] をクリックして登録すると、変更されたすべての製品情報に関するダイジェストを毎週受け取ることができます。変更の詳細については、改訂されたドキュメントに含まれている改訂履歴をご覧ください。

11.3 サポート・リソース

テキサス・インスツルメンツ E2E™ サポート・フォーラムは、エンジニアが検証済みの回答と設計に関するヒントをエキスパートから迅速かつ直接得ることができる場所です。既存の回答を検索したり、独自の質問をしたりすることで、設計で必要な支援を迅速に得ることができます。

リンクされているコンテンツは、各寄稿者により「現状のまま」提供されるものです。これらはテキサス・インスツルメンツの仕様を構成するものではなく、必ずしもテキサス・インスツルメンツの見解を反映したものではありません。テキサス・インスツルメンツの使用条件を参照してください。

11.4 Trademarks

テキサス・インスツルメンツ E2E™ is a trademark of Texas Instruments.

すべての商標は、それぞれの所有者に帰属します。

11.5 静電気放電に関する注意事項

この IC は、ESD によって破損する可能性があります。テキサス・インスツルメンツは、IC を取り扱う際には常に適切な注意を払うことを推奨します。正しい取り扱いおよび設置手順に従わない場合、デバイスを破損するおそれがあります。

ESD による破損は、わずかな性能低下からデバイスの完全な故障まで多岐にわたります。精密な IC の場合、パラメータがわずかに変化するだけで公表されている仕様から外れる可能性があるため、破損が発生しやすくなっています。

11.6 用語集

テキサス・インスツルメンツ用語集　　　この用語集には、用語や略語の一覧および定義が記載されています。

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

Product Folder Links: *BQ25176J*

English Data Sheet: SLUSF72

PACKAGE OPTION ADDENDUM

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
BQ25176JDSGR	ACTIVE	WSON	DSG	8	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	176J	Samples

(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) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.
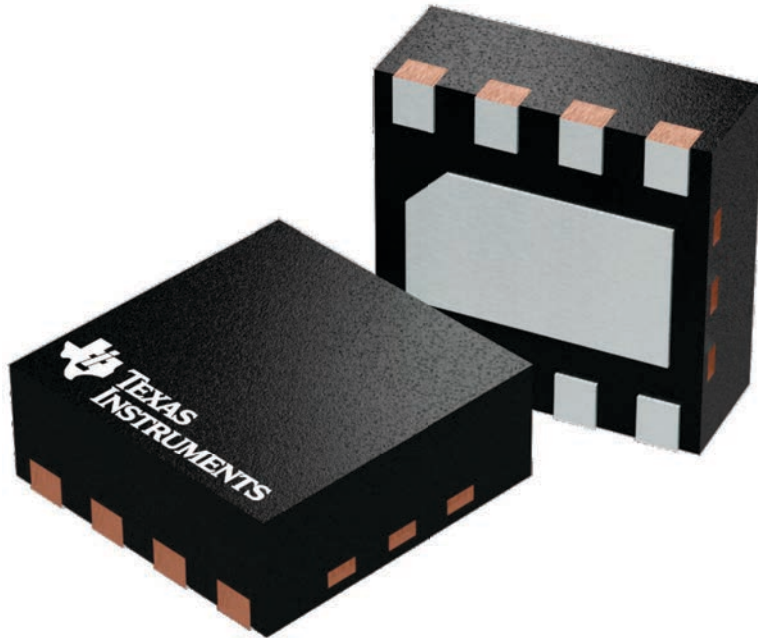
This image is a representation of the package family, actual package may vary.
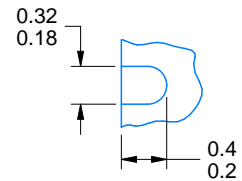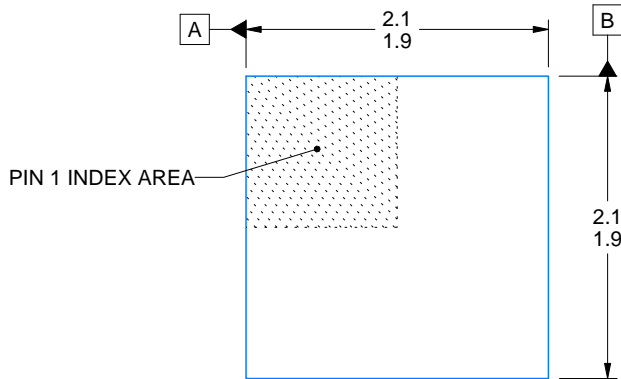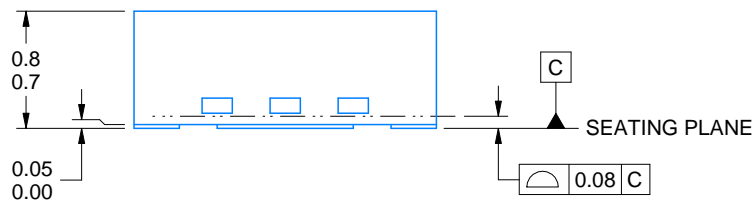Refer to the product data sheet for package details.

4224783/A

A | 2.1 / 1.9 | B

PIN 1 INDEX AREA

2.1 / 1.9

0.32 / 0.18

0.4 / 0.2

ALTERNATIVE TERMINAL SHAPE
TYPICAL

0.8 / 0.7

0.05 / 0.00

C

SEATING PLANE

⌓ | 0.08 | C

SIDE WALL METAL THICKNESS DIM A	
OPTION 1	OPTION 2
0.1	0.2

EXPOSED THERMAL PAD

0.9 ± 0.1

(DIM A) TYP

4

6X | 0.5

2X | 1.5

5

9

1.6 ± 0.1

1

8

PIN 1 ID (45° X 0.25)

8X | 0.4 / 0.2

8X | 0.32 / 0.18

⊕	0.1 Ⓜ	C	A	B
	0.05 Ⓜ	C		
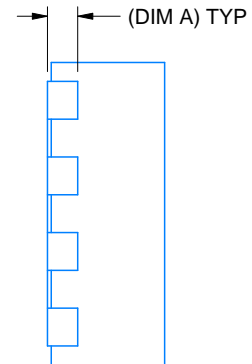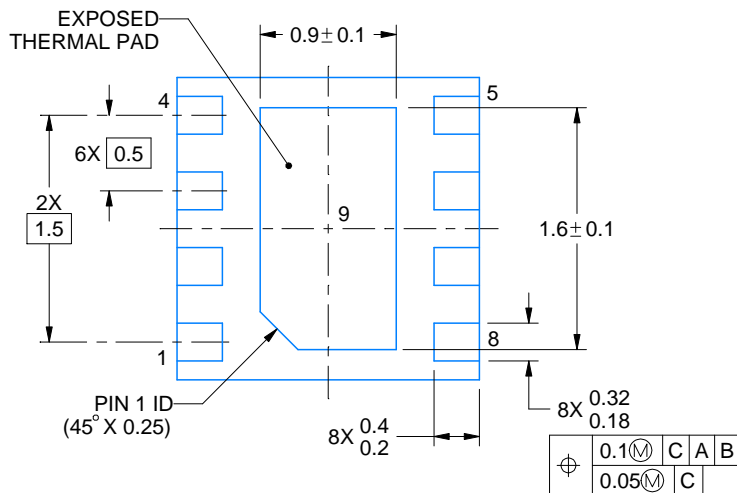
4218900/E   08/2022

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

LAND PATTERN EXAMPLE
SCALE:20X

SOLDER MASK OPENING

METAL

NON SOLDER MASK
DEFINED
(PREFERRED)

METAL UNDER
SOLDER MASK

SOLDER MASK
OPENING

SOLDER MASK
DEFINED

SOLDER MASK DETAILS

4218900/E   08/2022

NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.

8X (0.5)

1

8X (0.25)

SYMM
℄

6X (0.5)

4

(R0.05) TYP

SYMM
℄

METAL

8

9

(0.45)

(0.7)

5

(0.9)

(1.9)

SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD 9:
87% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE
SCALE:25X

4218900/E   08/2022

NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

重要なお知らせと免責事項