Application Report

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Designing A Standalone Single Cell 3-A Charger with the bq25606

BCP SCS

ABSTRACT

Unlike other chargers in the bq2560x product family, the bq25606 device is a highly-integrated standalone 3-A switch-mode battery charge and system power path management device for single cell Li-Ion and Li-polymer batteries. This application report explains how to customize the charging parameters with the bq25606 device and provides answers to frequently asked application questions.

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1 Introduction

As a standalone charger, the bq25606 functions independently without any software or host control. This helps to reduce the charger system complexity. Also, the charge parameters such as charging current, charge voltage limit, and so on, are set via external components.

Referring to Figure 1, the device charges the battery in five phases: 1) battery short, 2) preconditioning (pre-charge), 3) constant current (fast charge), 4) constant voltage and 5) charge termination. Table 1 shows the key charging parameters for the bq25606 charger system.

At the beginning of a charging cycle, the device checks the battery voltage and regulates current and voltage accordingly. If the charger device is in DPM (Dynamic Power management) regulation or 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.

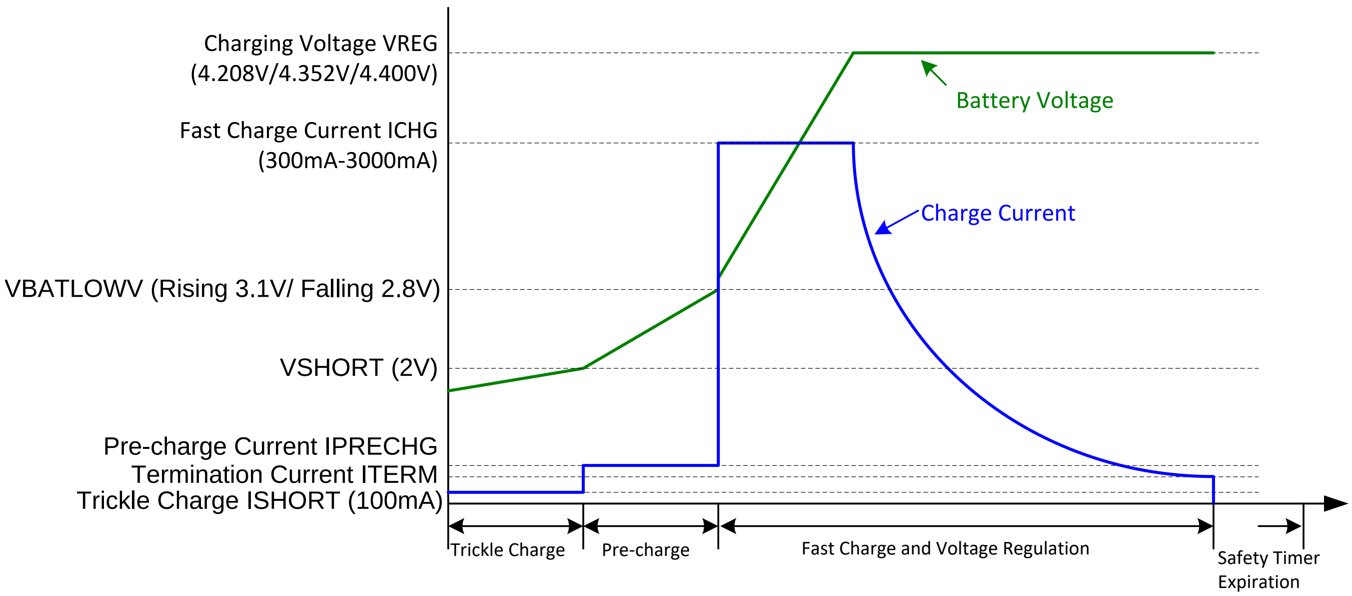

Figure 1. Battery Charging Profile

Table 1. Charging Parameter Setting

PARAMETER	PARAMETER SYMBOL	PARAMETER VALUE	PARAMETER RANGE
Trickle Charge Current (VBAT < 2 V)	ISHORT	100 mA	Fixed
Pre-charge Current (2 V < VBAT < 3 V)	IPRECHG	5% of ICHG	Depending on ICHG
Fast Charge Current (VBAT > 3 V)	ICHG	ICHG pin controlled	300 mA - 3000 mA
Termination Current	ITERM	5% of ICHG	Depending on ICHG
Charging Voltage	VREG	VSET pin controlled	4.208 V / 4.352 V / 4.400 V
Input Current Limit	ILIM	ILIM pin controlled	500 mA - 3200 mA
Temperature Profile	-	JEITA	Fixed
Safety Timer	-	10 hours	Fixed

2 Design Guidelines

2.1 Fast Charge Current (ICHG)

Fast charge current is set by a resistor (R_{ICHG}) connected from ICHG pin to ground per Equation 1.

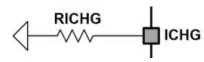

Figure 2. Fast Charge Current Setup

$$ICHG = K_{ICHG} / R_{ICHG} \quad (1)$$

$$\text{Where } K_{ICHG} = 677 \text{ A x } \Omega \text{ typically} \quad (2)$$

The acceptable range for ICHG is between 300 mA and 3000 mA. At low termination currents which is 5% of ICHG, due to the comparator offset, the actual termination current could be higher than the termination target and the termination current accuracy is not optimized. So it is not recommended to set ICHG low, especially smaller than 300 mA.

2.2 Termination Current (ITERM)

The charger device automatically terminates the charging cycle when the charging current is below termination threshold and battery voltage is above recharge threshold, and device not is in DPM (dynamic power management) mode or thermal regulation. After the charging cycle is completed, the BATFET turns off. Termination current is typically 5% of ICHG value.

2.3 Charging Voltage (VREG)

Charging voltage is the voltage that the battery is charged to when charged to full capacity. Referring to Figure 3, VSET pin sets default battery charge voltage for the charger with a resistor pull-down (R_{PD}) from VSET to GND.

The VREG can not be set on-the-fly. The charger only detects the VSET setting at POR (Power-On-Reset) and any R_{PD} changes to after POR are ignored. In order to apply new VREG setting via R_{PD}, the VBUS should be restarted.

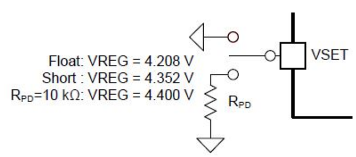

Figure 3. Charging Voltage Setup

$$R_{PD} > 50 \text{ k}\Omega \text{ (float pin)} = 4.208 \text{ V} \quad (3)$$

$$R_{PD} < 500 \ \Omega \text{ (short to GND)} = 4.352 \text{ V} \quad (4)$$

$$5 \text{ k}\Omega < R_{PD} < 25 \text{ k}\Omega = 4.400 \text{ V} \quad (5)$$

2.4 Input Current Limit (ILIM)

The input current limit should be set between 500 mA and 3200 mA. A resistor (R_{ILIM}) is connected from ILIM pin to ground to set the input current limit as in Figure 4.

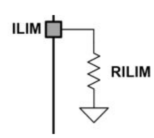

Figure 4. Input Current Limit Setup

$$IINDPM = K_{ILIM} / R_{ILIM} \quad (6)$$

$$\text{Where } K_{ILIM} = 500 \text{ A x } \Omega \text{ maximum} \quad (7)$$

The resistor based input current limit is effective only when the input adapter is detected as unknown. Otherwise, the input current limit is determined by D+/D– detection outcome.

The device has the capability to work with lower input current limits. However, the behavior and accuracy below 500 mA are not optimized. As such the ILIM is specified above 500 mA.

3 Frequently Asked Questions

If USB related functions are not used in the application, what shall the user do with the D+, D- pins?

In order to use the ILIM pin, the charger must detect D+/D- as an Unknown Adapter. Leave the D+ and D- pins floating to do so. Shorting D+ and D- detects the input as a DCP type adapter which sets the input current limit to 2.4 A automatically.

If OTG (boost function) is not used in the application, what shall the user do with the OTG pin?

Ground the OTG pin. The OTG pin cannot be floating.

If thermistor is not used in the application, what shall the user do with the TS pin?

Charge suspends when TS pin voltage is out of range. Even if a thermistor is not used, it is still necessary to connect a resistor divider from REGN to TS to GND so that the TS pin voltage is in the range, that is, between V_{T2} and V_{T3} as shown in Table 2. It is recommended to connect TS pin as in Figure 5 with two 10 kΩ resistors.

Table 2. JEITA Thermistor Comparator (Buck Mode)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX
V_{T2}	T2 (10°C) threshold, Charge back to $I_{CHG}/2$ and 4.2 V below this temperature	As percentage of V_{REGN}	67.2%	67%	69%
	Falling	As percentage of V_{REGN}	66%	66.8%	67.7%
V_{T3}	T3 (45°C) threshold, Charge back to I_{CHG} and 4.05 V above this temperature	Charger suspends charge. As percentage of V_{REGN}	43.8%	44.7%	45.8%
	Falling	As percentage of V_{REGN}	45.1%	45.7%	46.2%

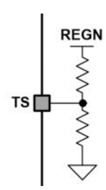

Figure 5. TS pin Connection When Thermistor Is Not In Use

What if STAT or $\overline{PG}$ functions is not used in the application?

Keep the pin floating if not used.

Are there any suggestions for key external components on the charger design?

VBUS pin: Place a 1 uF ceramic capacitor from VBUS to GND and place it as close as possible to IC. The voltage rating should be at least twice of the maximum VBUS voltage applied.

PMID pin: The actual power input for the charger. Put at least 10 µF ceramic capacitor between PMID and GND. The voltage rating should be at least twice of the maximum VBUS voltage applied. Capacitance of 22 µF is suggested for typical of 3 A charging current.

BAT pin: Connect a 10 µF (10 V rating) closely to the BAT pin.

SYS pin: Connect 10 µF to 20 µF (10 V rating) capacitor close to the SYS pin.

Output inductance: 1 μH to 2.2 μH The charger has implemented internal compensation. Strictly follow the output inductance and SYS capacitance guidelines to ensure the system stability and performance.

BTST cap: Connect a 0.047 μF (>= 10 V rating) bootstrap capacitor from SW to BTST.

REGN cap: Connect a 4.7 μF (10 V rating) ceramic capacitor from REGN to analog GND. The capacitor should be placed close to the IC.

Low ESR ceramic capacitors such as X7R or X5R are preferred for the capacitors selected.

How is VSYS regulated in buck mode with valid VBUS?

The device deploys Narrow VDC architecture (NVDC) with BATFET separating system from battery. Even with a fully depleted battery, the system is regulated above the minimum system voltage (VSYSMIN) which is 3.5 V. Table 3 shows the system regulation voltage under various conditions.

When the battery voltage (VBAT) is below VSYSMIN, the BATFET operates in linear mode (LDO mode), and the system voltage (VSYS) is typically 180 mV above VSYSMIN. As the battery voltage rises above the VSYSMIN, BATFET is fully on and the voltage difference between the system and battery is the VDS of BATFET.

When the battery charging is disabled and above VSYSMIN or charging is terminated, VSYS is always regulated at typically 50 mV above VBAT.

Table 3. VSYS Regulation with Valid VBUS in Buck Mode

	VBAT < VSYSMIN	VBAT > VSYSMIN
Charge Enable	VSYS = VSYSMIN + 180 mV	VSYS = VBAT + BATFET VOLTAGE DROP
Charge Disable	VSYS = VSYSMIN + 180 mV	VSYS = VBAT + 50 mV

When battery is not connected, that is, BAT pin is floating, why does the STAT pin blink?

The device does not have battery detection function. When battery is not connected and charge is enabled, the device tries to regulate VBAT to charging voltage (VREG) then terminate. After certain time, VBAT may drop below recharge threshold and the device charges VBAT to charging voltage again. So the charger status switches between charging in progress and charging complete and STAT pin blinks. If charge is disabled with $\overline{CE}$ pin, the device does not charge.

Can Q4 (BATFET) be turned off by users?

No. Q4 (BATFET) can not be controlled externally or be turned on/off by I^2C.

4 Summary

The bq25606 is designed to be easy-to-use and with no software is required. This application note explains the design basics for the device. More technical information is available at *http://www.ti.com/product/BQ25606/technicaldocuments*. Customers may also create bq25606 customized design with *WEBENCH® Power Designer*. Further technical inquiries can also be communicated at *TI E2E™ Community*.

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