Application Note

Selection of Single-Cell Buck Narrow VDC Switching Battery Chargers

Ning Tang

ABSTRACT

This application report provides a general single-cell charge selection guidance and comparison among BQ2419x, BQ2429x, BQ2589x, BQ25898x, BQ2560x, BQ2561x, and BQ2562x single-cell switching battery charge devices with Narrow Voltage DC (NVDC) Power Path Management. The document presents the main differences and describes the key features of each part. The summary also includes the comparison across various charger product families. This information provided hereby can assist design engineers with making good choices for their single-cell switching battery charging applications.

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1 Introduction

Besides the common charger parameters such as the input voltage range, the battery charge voltage limit, the maximum charging current, the package size and so on, a single-cell charger designer needs to consider system-level architecture including but not limit to the input current limit detection scheme, the system control methodology, the system monitoring and protection scheme and boost mode operation.

1.1 Input Current Limit Detection

If the application requires USB D+/D- input current limit detection capability, the user needs to check the related specs of a charger IC. Please visit USB D+ D- Input Current Limit Detection for BQ2419x, BQ2429x, BQ2589x, BQ25898x, BQ2560x, and BQ2561x (*USB D+ D- Input Current Limit Detection for BQ2419x, BQ2429x, BQ2589x, BQ25898x, BQ2560x, and BQ2561x* application note) for the details.

If the application does not require USB D+/D- input current limit, the user can either leave the D+/D- pins open or short the D+/D- pins together. Below are the general guidelines. Please refer to the corresponding data sheet for the specific input current limit settings

1. When D+/D- pins are open, the input source is usually detected as Unknown Adapter.
2. When D+/D- pins are short, the input source is usually detected as USB DCP.

1.2 Control Methodology Host Controlled vs Stand-Alone

As a battery charger designer, one of the most important questions to consider is the control method for the charging system. Shall a microprocessor-controlled charger or a stand-alone charger be used?

The two most popular control methodologies are:

- Inter-Integrated Circuit (I2C) controlled: The I2C bus is a very popular and powerful bus used for communication between a host device (or multiple host devices) and a single auxiliary device (or multiple auxiliary devices). A microcontroller, known as the host device, is necessary to communicate with auxiliary devices, including the charger. It's possible for the host device to modify tens of charger system parameters via I2C on the fly. Charger status as well as fault conditions can be reported back to the host device.
- Stand-alone: The charger functions independently without any software or host control. Fixed resistors on the board determine adjustable settings like charge current and voltage limit.

Table 1-1 lists what can be considered when determining the control method for a charger system.

Table 1-1. I2C Control vs. Stand-Alone

	I2C-controlled	Stand-alone
Need real-time control over the charger?	√	X
Need the flexibility of charging parameters?	√	X
Need to monitor charging parameter values?	√	X
Require a host?	Yes	No
Require software code?	Yes	No

1.3 Battery Monitoring and Protection

To improve battery safety, battery monitoring and protection are important in a charger system. The main job of a charger is to charge the battery. The chargers are essentially power supplies with complex state machines and analog feedback loops. In general, chargers do not offer battery monitoring function and only implement basic battery protection functions such as under-voltage protection, over-voltage protection and over-current protection.

The gauges are micro-controllers using ADCs and digital logic. Although a few chargers offer battery monitoring as an extra feature in addition to regular charger, a gauge makes more accurate voltage, current and temperature measurements compared to that of a charger. For accurate ADC measurements and full-featured battery monitoring function, a gauge is recommended.

1.4 Boost Mode On-The-Go (OTG) Output

For the single-cell switching battery charge devices discussed hereby, most of them support boost mode operations while some chargers provide the boost output at both VBUS and PMID pins (Q1 RBFET is on in boost mode) and some chargers provide the boost output at the PMID pin only (Q1 RBFET is off in boost mode). If an application uses the boost mode operations, the charger designer needs to check which pin needs the boost output in their system.

2 Stand-Alone Single-Cell Switching Battery Chargers

Table 2-1 shows available stand-alone single-cell switching battery chargers.

Table 2-1. Device Comparison for Stand-alone Single-Cell Switching Battery Chargers

	BQ25606	BQ25616	BQ25616J
Quiescent battery current (BAT, SYS, SW)	58 µA	9.5 µA	9.5 µA
VBUS OVP Reaction-time	200 ns	130 ns	130 ns
Input voltage regulation accuracy	±3%	±2%	±2%
TS profile	JEITA	Hot/Cold	JEITA
Charge safety timer accuracy	10 hr	20 hr	20 hr
Charge Voltage Limit	4.2 V/4.35 V/4.4 V	4.1 V/4.2 V/4.35 V	4.1 V/4.2 V/4.35 V
Battery voltage regulation	±0.5%	±0.4%	±0.4%
ACDRV	No	Yes	Yes

3 I2C-Controlled 3.9 V – 14 V Single-Cell Switching Battery Chargers With Battery Monitoring (BQ2589x and BQ25898x)

Both BQ2589x in QFN package and BQ25898x WCSP package are full-featured chargers with battery monitoring function.

Table 3-1 shows device comparison for BQ2589x product family in 4 mm × 4 mm QFN package.

Table 3-1. BQ2589x Device Comparison

Features	BQ25890	BQ25892	BQ25896	BQ25890H	BQ25895	BQ25895M
Max Charge Current	5 A	5 A	3 A	5 A	5 A	5 A
Boost Mode Output Current	2.4 A	2.4 A	2 A	2.4 A	3.1 A	3.1 A
USB Detection	D+/D-	PSEL	PSEL	D+/D-	D+/D-	D+/D-
HVDCP Support	Yes Default Enable	Yes Default Enable	No BC1.2 Only	Yes Default Enable	Yes Default Enable	Yes Default Disable
Default Battery Voltage	4.2 V	4.2 V	4.2 V	4.2 V	4.2 V	4.35 V
IR Compensation	Yes	Yes	Yes	Yes	Yes	Yes
Direct BATSENSE	No	No	No	No	No	No
Input Control Optimization (ICO)	Yes	Yes	Yes	Yes	Yes	Yes
I2C Default Input Current Limit	3.25 A	3.25 A	3.25 A	3.25 A	3.25 A	3.25 A
ILIM Pin	Yes	Yes	Yes	Yes	Yes	Yes
Default Charge Current	2 A	2 A	2 A	2 A	2 A	2 A
ADC Battery Monitoring	Yes	Yes	Yes	Yes	Yes	Yes
QON Full System Reset (QON Pin)	Yes	Yes	Yes	Yes	Yes	Yes
D+/D- Driver	No	No	No	Yes	No	No
VOK Driver	No	No	No	No	No	No
Status Output	STAT	STAT/PG	STAT/PG	STAT	STAT	STAT
Temperature Profile (TS Pin)	JEITA	JEITA	JEITA	JEITA	JEITA	JEITA
Package	QFN	QFN	QFN	QFN	QFN	QFN
I2C Address	6AH	6BH	6BH	6AH	6AH	6AH

Table 3-2 shows device comparison for BQ25898x product family in 2.8 mm × 2.5 mm WCSP package

Table 3-2. BQ25898x Device Comparison

Features	BQ25898D	BQ25898	BQ25898C
Max Charge Current	4 A	4 A	3 A
Boost Mode Output Current	2.4 A	2.4 A	Not Supported
USB Detection	D+/D-	PSEL	PSEL
HVDCP Support	Yes Default Enable	Yes Default Enable	No BC1.2 Only
MTK-PE+ Support (Autonomous / Software)	Yes (Auto)	Yes (Auto)	Not Supported
Default Battery Voltage	4.2 V	4.2 V	4.2 V
IR Compensation	Yes	Yes	No
Direct BATSENSE	Yes	Yes	Yes
Input Control Optimization (ICO)	Yes	Yes	No
I2C Default Input Current Limit	3.25 A	3.25 A	1.5 A
ILIM Pin	Yes	Yes	No
Default Charge Current	2 A	2 A	Charge Disabled
ADC	Yes	Yes	Yes
QON Full System Reset (QON Pin)	Yes	Yes	No
D+/D- Driver	Yes	No	No
VOK Driver	No	Yes	No
Status Output	STAT	STAT/PG	STAT/PG
Temperature Profile (TS Pin)	JEITA	JEITA	Not Supported
Package	WCSP	WCSP	WCSP
I2C Address	6AH	6BH	6BH

4 I2C-Controlled 3.9 V – 17 V VBUS Single-Cell Switching Battery Chargers (BQ2419x)

The BQ2419x product family including BQ24292I was initially released around year 2012. BQ2419x, BQ2419x, and BQ2589x are basically pin-compatible.

Table 4-1. BQ2419x Device Comparison

Features	BQ24190	BQ24192	BQ24192I/ BQ24292I	BQ24193	BQ24196	BQ24195	BQ24195L
Temperature Profile	Cold/Hot	Cold/Hot	Cold/Hot	JEITA	Cold/Hot	Cold/Hot	Cold/Hot
Maximum Charge Current	4.5 A	4.5 A	4.5 A	4.5 A	2.5 A	4.5 A	2.5 A
Boost Mode Output Current	1.3 A	1.3 A	1.3 A	1.3 A	1.3 A	2.1 A	1.0 A
USB Detection	D+/D-	PSEL	PSEL	PSEL	PSEL	D+/D-	D+/D-
Default Battery Regulation Voltage	4.208 V	4.208 V	4.112 V	4.208 V	4.208 V	4.208 V	4.208 V
IR Compensation	Yes	Yes	Yes	Yes	No	No	No
Input OVP	18 V	18 V	18 V	18 V	18 V	18 V	18 V
VINDPM Default	4.36 V	4.36 V	4.44V	4.36 V	4.36 V	4.36 V	4.36 V
REGN Voltage	6 V	6 V	6 V	6 V	6 V	6 V	6 V
Default Adapter Input Current Limit	1.5 A	3 A	1.5 A	3 A	3 A	1.5 A	1.5 A
Default Charging Current	2.048 A	2.048 A	1.024A	2.048 A	2.048 A	2.048 A	2.048 A
Default Precharging Current	256 mA	256 mA	256 mA	256 mA	256 mA	256 mA	256 mA
Maximum Precharging Current	2.048 A	2.048 A	640 mA	2.048 A	2.048 A	2.048 A	2.048 A
Status Output	STAT	STAT/PG	STAT/PG	STAT/PG	STAT/PG	STAT	STAT
STAT pin during fault	Blinking	Blinking	10k pull down	Blinking	Blinking	Blinking	Blinking

5 I2C-Controlled 3.9 V – 6.2 V VBUS Single-Cell Switching Battery Chargers (BQ2429x)

The BQ2429x product family is a low voltage version of the BQ2419x product family.

Table 5-1. BQ2429x Device Comparison

Features	BQ24295	BQ24296	BQ24297	BQ24296M	BQ24298
Maximum Charge Current	3 A	3 A	3 A	3 A	3 A
Boost Mode Output Current	1.5 A	1.5 A	1.5 A	1.5 A	1.5 A
USB Detection	D+/D-	PSEL	D+/D-	PSEL	PSEL
Default Battery Regulation Voltage	4.208 V	4.208 V	4.208 V	4.208 V	4.208 V
Input Current Limits	100 mA, 150 mA, 500 mA, 900 mA, 1 A, 1.5 A, 2 A, 3 A	100 mA, 150 mA, 500 mA, 900 mA, 1 A, 1.5 A, 2 A, 3 A	100 mA, 150 mA, 500 mA, 900 mA, 1 A, 1.5 A, 2 A, 3 A	100 mA, 150 mA, 500 mA, 900 mA, 1 A, 1.5 A, 2 A, 3 A	100 mA, 150 mA, 500 mA, 900 mA, 1 A, 1.5 A, 2 A, 3 A
BATFET Overcurrent Latch off	Yes	Yes	Yes	No	No
VINDPM Default	4.76 V	4.36 V	4.36 V	4.36 V	4.36 V
Max. V_{SYS} Regulation Voltage	V_{BAT} + 150 mV	V_{BAT} + 150 mV	V_{BAT} + 150 mV	V_{BAT}+ 70 mV	V_{BAT}+ 70 mV
Default Adapter Input Current Limit	3 A	3 A	3 A	3 A	3 A
Default Precharging Current	256 mA	256 mA	256 mA	128 mA	128 mA
Default Charging Current	1.012 A	2.048 A	2.048 A	2.048 A	2.048 A
Termination Current Range	128 mA about 2048 mA	128 mA about 2048 mA	128 mA about 2048 mA	128 mA about 1024 mA	128 mA about 1024 mA
Status Output	STAT	STAT/PG	STAT	STAT/PG	STAT/PG
QON	Low to Hi Transition Exit Ship Mode	Low to Hi Transition Exit Ship Mode	Low to Hi Transition Exit Ship Mode	Low to Hi Transition Exit Ship Mode	Hi to Low Transition Exit Ship Mode, System reset
Force BATFET Off Control (I2C)	Y(Instant-off)	Y(Instant-off)	Y(Instant-off)	Y(Instant-off)	Y (5s-10s delay)
Package	RGE-24	RGE-24	RGE-24	RGE-24	RTW-24

6 I2C-Controlled 3.9 V – 13.5 V VBUS Single-Cell Switching Battery Chargers (BQ2560x and BQ2561x)

The BQ2560x and BQ2561x product families are the newer generation of the BQ2419x product family.

Table 6-1. BQ2560x/61x Device Comparison

Features	BQ25600(D)	BQ25601(D)	BQ25611D	BQ25618/619
Control interface	I2C	I2C	I2C	I2C
Input voltage range/ abs max	3.9 V to 13.5 V / 22 V	3.9 V to 13.5 V / 22 V	4 V to 13.5 V / 22 V	4 V to 13.5 V / 22 V
OVP /Reaction time	5.5 V, **6.5 V**, 10.5 V, 14 V/ 200 ns	5.5 V, **6.5 V**, 10.5 V, 14 V/ 200 ns	5.9 V, 6.4 V, 11 V, **14.2 V** / 130 ns	5.9 V, 6.4 V, 11 V, **14.2 V** / 130 ns
Battery only Quiescent Current in Ship mode (typical)	17 uA with BATFET off	17 uA with BATFET off	7 uA with BATFET off	7 uA with BATFET off
Battery Only Quiescent Current (typical)	58 uA with BATFET on	58 uA with BATFET on	9.5 uA with BATFET on	9.5 uA with BATFET on
USB detection	D+D- / BC1.2	D+D- / BC1.2	D+D- / BC1.2	PSEL
Charging current max /default	3 A / 2.04 A	3 A / 2.04 A	3 A / 1.02 A	1.5 A/ 340 mA
Battery Regulation Voltage	3.856 V - 4.624 V	3.847 V - 4.615 V	3.494 V to 4.510 V	3.504 V to 4.520V
Direct BATSENSE	Yes	No	Yes	Yes
TS JEITA Profile	Fixed JEITA	Fixed JEITA	JEITA with adjustable T2, T3, ICHG%	JEITA with adjustable T2, T3, ICHG%
TS ignore bit	No	No	Yes	Yes
Top-off timer	0(default), 15, 30, 45min	0(default), 15, 30, 45min	0(default), 15, 30, 45min	0(default), 15, 30, 45min
Safety Timer	5hr, 10 hr (default)	5hr, 10 hr (default)	10 hr (default), 20hr	10 hr (default), 20hr
Min Termination current	60 mA	60 mA	60 mA	20 mA
Boost Voltage/ Boost Current	4.85 V/5 V/5.15 V/5.3 V	4.85 V/5 V/5.15 V/5.3 V	4.6 V/4.75 V/5 V/5.15 V	4.6 V/4.75 V/5 V/5.15 V
	1.2 A	1.2 A	0.5 A/1.2 A	0.5 A/1.2 A
/QON SYS reset with adapter	No	No	Yes	Yes
Package Type (mm)	2 mm × 2.4 mm WCSP	QFN-24 4 mm × 4 mm p2p w/ BQ2419x/ BQ2429x/BQ2589x	QFN-24 4 mm × 4 mm p2p w/ BQ2419x/ BQ2429x/BQ2589x	QFN-24 4 mm ×4 mm (BQ25619) WCSP 2 mm × 2.4 mm (BQ25618)

7 I2C-Controlled 3.9 V – 18 V VBUS Single-Cell Switching Battery Chargers (BQ2562x)

BQ2562x is a newly released product family with enhanced design. Table 7-1 highlighted the difference between the selected BQ2560x/BQ2561x/BQ2562x.

Table 7-1. BQ2560x/61x/62x Device Comparison

	BQ25601D	BQ25611D	BQ25620/622
Input current limit	3.2 A	3.2 A	3.2 A
Input voltage max/abs max	13.5 V/22 V	13.5 V/22 V	18 V/26 V
ADC Battery Monitoring	No	No	Yes
USB Detection	BC1.2	BC1.2	620: BC1.2; 622: ILIM
Max charge current	3 A	3 A	3.5 A
Battery only quiescent current with BATFET on (typ)	58 µA	9.5 µA	1.5 µA
Battery only quiescent current in ship mode with BATFET off (typ)	17 µA	7 µA	0.15 µA
Battery Voltage	3.847 V to 4.615 V	3.494 V to 4.510 V	3.5 V - 4.8 V (10mV/step)
Boost mode voltage range	4.85 V/5 V/5.15 V/5.3 V	4.6 V/4.75 V/5 V/5.15 V	3.84 V – 9.6 V
Boost mode max output current	1.2 A	1.2 A	3.2 A
Minimum battery voltage to keep BATFET on	2.2 V	2.2 V	1.8 V
Minimum termination current	60 mA	60 mA	10 mA
Safety Timer	5 hr, 10 hr (default)	10 hr (default), 20hr	10 hr (default), 20hr
JEITA Profile	Fixed JEITA	Flexible JEITA	Flexible JEITA with VSET selections
Package	4 mm × 4 mm QFN-24	4mm × 4 mm QFN-24	2.5 mm × 3 mm QFN-18

8 Summary

The single cell switching battery charger devices including BQ2419x, BQ2429x, BQ2589x, BQ25898x, BQ2560x, BQ2561x, and BQ2562x are I2C Controlled except BQ25606/616/616J as standalone chargers. Table 8-1 shows the key features for each product family. Please refer to the corresponding data sheets for the details.

Table 8-1. Single Cell NVDC Charger Device Comparison

Features	BQ2419x	BQ2429x	BQ2589x	BQ25898x	BQ2560x/61x	BQ2562x
Charger architecture (1)	NVDC	NVDC	NVDC	NVDC	NVDC	NVDC
Charger Topology	Step-Down	Step-Down	Step-Down	Step-Down	Step-Down	Step-Down
Input Voltage Range	3.9 V – 17 V	3.9 V – 6.2 V	3.9 V – 14 V	3.9 V – 14 V	3.9 V – 13.5V	3.9 V – 18 V
Max Charge Current Range	4.5A except BQ24196 & BQ24195L	3 A	5 A except BQ25896 3 A	4 A except BQ25898C 3 A	3 A except BQ25618x/619x 1.5 A	3.5 A
Boost Mode	Yes	Yes	Yes	Yes	Yes, except BQ25618E/ 25619E	Yes
USB Detection	BC1.2	BC1.2	BC1.2 + HVDCP	BC1.2 + HVDCP	BC1.2	BC1.2 + HVDCP
D+/D- Driver	No	No	Yes	Yes	No	No
IR Compensation	No	No	Yes	Yes	No	No
Direct BATSENSE	No	No	No	Yes	Yes for BQ25600/2560 0D and BQ2561x	No
Input Control Optimization (ICO)	No	No	Yes	Yes	No	Yes
ADC Battery Monitoring	No	No	Yes	Yes	No	Yes
QON Full System Reset (QON Pin)	No	Yes	Yes	Yes	Yes	Yes
VOK Driver	No	No	Yes	Yes	No	No
Status Output	STAT	STAT/PG	STAT/PG	STAT	STAT	STAT
Temperature Profile (TS Pin)	JEITA	JEITA	JEITA	JEITA	JEITA	JEITA
Package	QFN	QFN	QFN	WCSP	QFN&WCSP	QFN

1. Note : NVDC refers to Narrow VDC architecture (NVDC) with BATFET separating system from battery.

9 References

1. Texas Instruments, *USB D+ D- Input Current Limit Detection for BQ2419x, BQ2429x, BQ2589x, BQ25898x, BQ2560x, and BQ2561x* application note

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