

# BQ25606 Standalone 1-Cell 3.0-A Buck Battery Charger

## 1 Features

- High-efficiency, 1.5-MHz, synchronous switch-mode buck charger
  - 92% charge efficiency at 2-A from 5-V input
  - Optimized for USB voltage input (5 V)
- Supports USB On-The-Go (OTG)
  - Boost converter with up to 1.2-A output
  - 92% boost efficiency at 1-A output
  - Accurate constant current (CC) limit
  - Soft-start up to 500- $\mu$ F capacitive load
  - Output short circuit protection
- Single input to support USB input and high voltage adapters
  - Support 3.9-V to 13.5-V input voltage range with 22-V absolute maximum input voltage rating
  - Maximum power tracking by input voltage limit up to 4.6 V (VINDPM)
  - VINDPM threshold automatically tracks battery voltage
  - Auto detect USB SDP, DCP and non-standard adapters
- High battery discharge efficiency with 19.5-m $\Omega$  battery discharge MOSFET
- Narrow VDC (NVDC) power path management
  - Instant-on works with no battery or deeply discharged battery
  - Ideal diode operation in battery supplement mode
- High integration includes all MOSFETs, current sensing and loop compensation
- 58- $\mu$ A low battery leakage current with system voltage standby
- High accuracy
  - $\pm 0.5\%$  charge voltage regulation
  - $\pm 6\%$  at 1.2-A and 1.8-A charge current regulation

- $\pm 5\%$  at 0.5-A, 1.2-A and 1.8-A input current regulation

- Safety-Related Certification:
  - IEC 62368-1 CB Certification

## 2 Applications

- EPOS, Portable speakers
- Mobile phone accessory
- Medical equipment

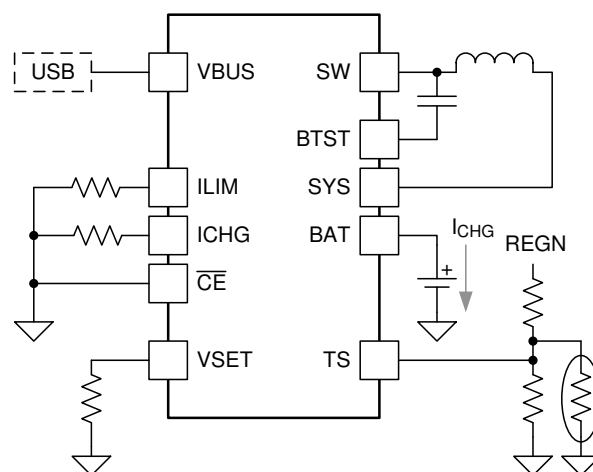
## 3 Description

The BQ25606 is a highly-integrated standalone 3.0-A switch-mode battery charge management and system power path management device for single cell Li-ion and Li-polymer batteries. The solution is highly integrated with input reverse-blocking FET (RBFET, Q1), high-side switching FET (HSFET, Q2), low-side switching FET (LSFET, Q3), and battery FET (BATFET, Q4) between system and battery. The low impedance power path optimizes switch-mode operation efficiency, reduces battery charging time, and extends battery life during discharging phase.

### Device Information<sup>(1)</sup>

| PART NUMBER | PACKAGE   | BODY SIZE (NOM)          |
|-------------|-----------|--------------------------|
| BQ25606     | VQFN (24) | 4.00 mm $\times$ 4.00 mm |

- (1) For all available packages, see the orderable addendum at the end of the data sheet.



**Simplified Application**



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## 4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

| <b>Changes from Revision B (November 2019) to Revision C (September 2021)</b>               | <b>Page</b> |
|---|-------------|
| • Added IEC 62368-1 CB Feature.....   | 1           |
| • Deleted WEBENCH throughout data sheet.....  | 1           |
| • Deleted "to zero" from third paragraph in <a href="#">Section 5</a> .....                 | 4           |
| • Added <a href="#">Section 6</a> .....   | 5           |
| • Added <a href="#">Section 9.3.4.1</a> .....   | 20          |
| • Added <a href="#">Section 9.3.4.2</a> .....   | 20          |
| • Added <a href="#">Section 9.3.4.3</a> .....   | 20          |
| • Added sentence to third paragraph in <a href="#">Section 9.3.5.4</a> .....                | 21          |
| • Changed "fault" to "the timer" in last paragraph of <a href="#">Section 9.3.5.6</a> ..... | 23          |
| • Added <a href="#">Section 9.3.6</a> .....   | 23          |
| • Added <a href="#">Section 9.3.6.1</a> .....   | 23          |
| • Added <a href="#">Section 9.3.6.2</a> .....   | 23          |
| • Added <a href="#">Table 10-1</a> .....  | 26          |
| • Changed > to ≤ in last paragraph in <a href="#">Section 10.2.2.3</a> .....                | 27          |

| <b>Changes from Revision A (August 2017) to Revision B (November 2019)</b> | <b>Page</b> |
|--|-------------|
| • Changed Application section .....  | 1           |

| <b>Changes from Revision * (May 2017) to Revision A (August 2017)</b>            | <b>Page</b> |
|--|-------------|
| • Changed data sheet title .....   | 1           |
| • Deleted 200 ns Fast Turn-Off in <a href="#">Section 1</a> .....                | 1           |
| • Changed Simplified Application schematic.....                                  | 1           |
| • Changed ACDRV pin references to "NC" in <a href="#">Section 7</a> section..... | 6           |
| • Deleted ACDRV pin references from Pin Functions table.....                     | 6           |
| • Changed VAC pin description in Pin Functions table.....                        | 6           |
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| • Changed <a href="#">Section 9.2</a> .....                                      | 17          |
| • Changed Power Up from Input Source section.....                                | 18          |

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|--|----|
| • Deleted Power Up OVPFET section.....                     | 18 |
| • Deleted OVPFET Startup Control timing illustration ..... | 18 |
| • Added subsection explaining D+/D– detection .....        | 18 |
| • Changed Input Overvoltage (ACOV) section.....            | 24 |
| • Changed BQ25606 Application Diagram schematic.....       | 26 |

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## 5 Description (continued)

The BQ25606 features fast charging with high input voltage support for a wide range of standalone chargers and portable devices. Its input voltage and current regulation deliver maximum charging power to the battery. It also integrates a bootstrap diode for the high-side gate drive for simplified system design.

The device supports a wide range of input sources, including standard USB host port, USB charging port, and USB compliant high voltage adapter. The device sets the default input current limit based on the built-in USB interface. The device is compliant with the USB 2.0 and USB 3.0 power specs with input current and voltage regulation. When the built-in USB interface identifies the input adaptor is unknown, the input current limit of the device is determined by the ILIM pin setting resistor value. The device also meets the USB On-the-Go (OTG) operation power rating specification by supplying 5.15 V on VBUS with a constant current limit up to 1.2 A.

The power path management regulates the system slightly above battery voltage but does not drop below the 3.5-V minimum system voltage. With this feature, the system maintains operation even when the battery is completely depleted or removed. When the input current limit or voltage limit is reached, the power path management automatically reduces the charge current. As the system load continues to increase, the power path discharges the battery until the system power requirement is met. This Supplement mode prevents overloading the input source.

The device initiates and completes a charging cycle without software control. It senses battery voltage and charges the battery in three phases: pre-conditioning, constant current, and constant voltage. At the end of the charging cycle, the charger automatically terminates when the charge current is below a preset limit and the battery voltage is higher than the recharge threshold. If the fully charged battery falls below the recharge threshold, the charger automatically starts another charging cycle.

The charger provides various safety features for battery charging and system operations including: battery negative temperature coefficient thermistor monitoring, charging safety timer, and overvoltage and overcurrent protections. The thermal regulation reduces charge current when the junction temperature exceeds 110°C. The STAT output reports charging status and any fault conditions. Other safety features include battery temperature sensing for charge and boost mode, thermal regulation and thermal shutdown, and input UVLO and overvoltage protection.

The device is available in a 24-pin, 4 mm x 4 mm QFN package.

## 6 Device Comparison Table

|  | <b>BQ25606</b>     | <b>BQ25616</b>     | <b>BQ25616J</b>    |
|--|--------------------|--------------------|--------------------|
| Quiescent battery current (BAT,SYS,SW) | 58 $\mu$ A         | 9.5 $\mu$ A        | 9.5 $\mu$ A        |
| VBUS OVP reaction-time                 | 200 ns             | 130 ns             | 130 ns             |
| Input voltage regulation accuracy      | $\pm 3\%$          | $\pm 2\%$          | $\pm 2\%$          |
| 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             | $\pm 0.5\%$        | $\pm 0.4\%$        | $\pm 0.4\%$        |
| ACDRV                                  | No                 | Yes                | Yes                |

## 7 Pin Configuration and Functions

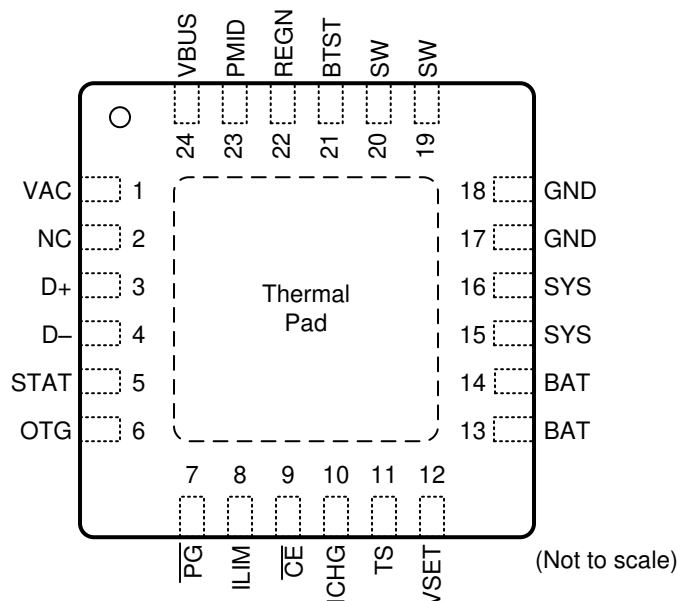


Figure 7-1. BQ25606 RGE Package 24-Pin VQFN Top View

Table 7-1. Pin Functions

| PIN  |     | I/O | DESCRIPTION   |
|------|-----|-----|---|
| NAME | NO. |     |   |
| NC   | 2   |     | No connection. This pin must be floating.   |
| BAT  | 13  | P   | Battery connection point to the positive terminal of the battery pack. The internal current sensing resistor is connected between SYS and BAT. Connect a 10-μF capacitor closely to the BAT pin.  |
|      | 14  |     |   |
| BTST | 21  | P   | PWM high side driver positive supply. Internally, the BTST is connected to the cathode of the boost-strap diode. Connect a 0.047-μF bootstrap capacitor from SW to BTST.  |
| CE   | 9   | DI  | Charge enable pin. When this pin is driven low, battery charging is enabled.  |
| D+   | 3   | AIO | Positive line of the USB data line pair. D+/D– based USB host/charging port detection. The detection includes data contact detection (DCD), primary and secondary detection in BC1.2 and nonstandard adaptors.  |
| D–   | 4   | AIO | Negative line of the USB data line pair. D+/D– based USB host/charging port detection. The detection includes data contact detection (DCD), primary and secondary detection in BC1.2 and nonstandard adaptors.  |
| GND  | 17  | P   | Power ground and signal ground.   |
|      | 18  |     |   |
| ICHG | 10  | AI  | I <sub>CHG</sub> pin sets the charge current limit. A resistor is connected from I <sub>CHG</sub> pin to ground to set charge current limit as $I_{CHG} = K_{ICHG}/R_{ICHG}$ . The acceptable range for charge current is 300 mA to 3000 mA.  |
| ILIM | 8   | AI  | ILIM sets the input current limit. A resistor is connected from ILIM pin to ground to set the input current limit as $I_{INDPM} = K_{ILIM}/R_{ILIM}$ . The acceptable range for ILIM current is 500 mA to 3200 mA. 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. |
| OTG  | 6   | DI  | Boost mode enable pin. When this pin is pulled HIGH, OTG is enabled. OTG cannot be floating.  |
| PG   | 7   | DO  | Open drain active low power good indicator. Connect to the pull up rail through a 10-kΩ resistor. LOW indicates a good input if the input voltage is between UVLO and ACOV, above SLEEP mode threshold, and input current limit is above 30 mA.   |
| PMID | 23  | P   | Connected to the drain of the reverse blocking MOSFET (RBFET) and the drain of HSFET. Connect a 10-μF ceramic capacitor between PMID and GND.   |
| REGN | 22  | P   | PWM low side driver positive supply output. Internally, REGN is connected to the anode of the boost-strap diode. Connect a 4.7-μF (10-V rating) ceramic capacitor from REGN to analog GND. The capacitor should be placed close to the IC.  |

**Table 7-1. Pin Functions (continued)**

| PIN         |     | I/O | DESCRIPTION   |
|-------------|-----|-----|---|
| NAME        | NO. |     |   |
| STAT        | 5   | DO  | Open-drain interrupt output. Connect the STAT pin to a logic rail via 10-k $\Omega$ resistor. The STAT pin indicates charger status.<br>Charge in progress: LOW<br>Charge complete or charger in SLEEP mode: HIGH<br>Charge suspend (fault response): Blink at 1 Hz.  |
| SW          | 19  | P   | Switching node connecting to output inductor. Internally SW is connected to the source of the n-channel HSFET and the drain of the n-channel LSFET. Connect a 0.047- $\mu$ F bootstrap capacitor from SW to BTST.   |
|             | 20  |     |   |
| SYS         | 15  | P   | Converter output connection point. The internal current sensing resistor is connected between SYS and BAT. Connect a 20- $\mu$ F capacitor close to the SYS pin.  |
|             | 16  |     |   |
| TS          | 11  | AI  | Temperature qualification voltage input to support JEITA profile. Connect a negative temperature coefficient thermistor. Program temperature window with a resistor divider from REGN to TS to GND. Charge suspends when TS pin voltage is out of range. Recommend 103AT-2 thermistor.  |
| VAC         | 1   | AI  | Input voltage sensing. This pin must be shorted to the VBUS pin.  |
| VBUS        | 24  | P   | Charger input voltage. The internal n-channel reverse block MOSFET (RBFET) is connected between VBUS and PMID with VBUS on source. Place a 1- $\mu$ F ceramic capacitor from VBUS to GND and place it as close as possible to the IC.   |
| VSET        | 12  | AI  | VSET pin sets default battery charge voltage in the BQ25606. Program battery regulation voltage with a resistor pull-down from VSET to GND.<br>$R_{PD} > 50 \text{ k}\Omega$ (float pin) = 4.208 V<br>$R_{PD} < 500 \Omega$ (short to GND) = 4.352 V<br>$5 \text{ k}\Omega < R_{PD} < 25 \text{ k}\Omega$ = 4.400 V   |
| Thermal Pad |     | P   | Ground reference for the device that is also the thermal pad used to conduct heat from the device. This connection serves two purposes. The first purpose is to provide an electrical ground connection for the device. The second purpose is to provide a low thermal-impedance path from the device die to the PCB. This pad should be tied externally to a ground plane. |

## 8 Specifications

### 8.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

|                                       |  | MIN  | MAX | UNIT |
|---------------------------------------|--|------|-----|------|
| Voltage Range (with respect to GND)   | VAC  | –2   | 22  | V    |
| Voltage Range (with respect to GND)   | VBUS (converter not switching) <sup>(2)</sup>                                    | –2   | 22  | V    |
| Voltage Range (with respect to GND)   | BTST, PMID (converter not switching) <sup>(2)</sup>                              | –0.3 | 22  | V    |
| Voltage Range (with respect to GND)   | SW   | –2   | 16  | V    |
| Voltage Range (with respect to GND)   | BTST to SW   | –0.3 | 7   | V    |
| Voltage Range (with respect to GND)   | D+, D–   | –0.3 | 7   | V    |
| Voltage Range (with respect to GND)   | REGN, TS, $\overline{CE}$ , $\overline{PG}$ , BAT, SYS (converter not switching) | –0.3 | 7   | V    |
| Output Sink Current                   | STAT   |      | 6   | mA   |
| Voltage Range (with respect to GND)   | VSET, ILIM, ICHG, OTG  | –0.3 | 7   | V    |
| Voltage Range (with respect to GND)   | PGND to GND (QFN package only)   | –0.3 | 0.3 | V    |
| Operating junction temperature, $T_J$ |  | –40  | 150 | °C   |
| Storage temperature, $T_{stg}$        |  | –65  | 150 | °C   |

- (1) Stresses beyond those listed under Absolute maximum Ratings may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions. 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.
- (2) VBUS is specified up to 22 V for a maximum of one hour at room temperature

### 8.2 ESD Ratings

|             |                         |  | VALUE | UNIT |
|-------------|-------------------------|--|-------|------|
| $V_{(ESD)}$ | Electrostatic discharge | Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins <sup>(1)</sup>              | ±2000 | V    |
|             |                         | Charged device model (CDM), per JEDEC specification JESD22-C101, all pins <sup>(2)</sup> | ±250  |      |

- (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.

### 8.3 Recommended Operating Conditions

|             |                                  | MIN | NOM | MAX                 | UNIT |
|-------------|----------------------------------|-----|-----|---------------------|------|
| $V_{BUS}$   | Input voltage                    | 3.9 |     | 13.5 <sup>(1)</sup> | V    |
| $I_{in}$    | Input current (VBUS)             |     |     | 3.25                | A    |
| $I_{SYSOP}$ | Output current (SW)              |     |     | 3.0                 | A    |
| $V_{BATOP}$ | Battery voltage                  |     |     | 4.4                 | V    |
| $I_{BATOP}$ | Fast charging current            |     |     | 3.0                 | A    |
| $I_{BATOP}$ | Discharging current (continuous) |     |     | 6                   | A    |



### 8.3 Recommended Operating Conditions (continued)

|                |                               | MIN | NOM | MAX | UNIT |
|----------------|-------------------------------|-----|-----|-----|------|
| T <sub>A</sub> | Operating ambient temperature | –40 |     | 85  | °C   |

- (1) The inherent switching noise voltage spikes should not exceed the absolute maximum voltage rating on either the BTST or SW pins. A tight layout minimizes switching noise.

### 8.4 Thermal Information

| THERMAL METRIC <sup>(1)</sup> |  | BQ25606    | UNIT |
|-------------------------------|--|------------|------|
|                               |  | RGE (VQFN) |      |
|                               |  | 24 PINS    |      |
| R <sub>θJA</sub>              | Junction-to-ambient thermal resistance       | 31.9       | °C/W |
| R <sub>θJC(top)</sub>         | Junction-to-case (top) thermal resistance    | 27         | °C/W |
| R <sub>θJB</sub>              | Junction-to-board thermal resistance         | 9.2        | °C/W |
| Ψ <sub>JT</sub>               | Junction-to-top characterization parameter   | 0.4        | °C/W |
| Ψ <sub>JB</sub>               | Junction-to-board characterization parameter | 9.2        | °C/W |
| R <sub>θJC(bot)</sub>         | Junction-to-case (bottom) thermal resistance | 2.8        | °C/W |

- (1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics Application Report](#).

### 8.5 Electrical Characteristics

$V_{VAC\_PRESENT} < V_{VAC} < V_{VAC\_OV}$  and  $V_{VAC} > V_{BAT} + V_{SLEEP}$ , T<sub>J</sub> = –40°C to 125°C and T<sub>J</sub> = 25°C for typical values (unless otherwise noted)

| PARAMETER                             | TEST CONDITIONS   | MIN  | TYP   | MAX   | UNIT |
|---------------------------------------|---|------|-------|-------|------|
| <b>QUIESCENT CURRENTS</b>             |   |      |       |       |      |
| I <sub>BAT</sub>                      | Battery discharge current (BAT, SW, SYS) in buck mode<br>V <sub>BAT</sub> = 4.5 V, V <sub>BUS</sub> < V <sub>AC-UVLOZ</sub> , leakage between BAT and VBUS, T <sub>J</sub> < 85°C               |      |       | 5     | μA   |
| I <sub>BAT</sub>                      | Battery discharge current (BAT, SW, SYS)<br>V <sub>BAT</sub> = 4.5 V, No VBUS, T <sub>J</sub> < 85°C  |      | 58    | 85    | μA   |
| I <sub>VBUS</sub>                     | Input supply current (VBUS) in buck mode<br>V <sub>VBUS</sub> = 12 V, V <sub>VBUS</sub> > V <sub>VBAT</sub> , converter not switching   |      | 1.5   | 3     | mA   |
| I <sub>VBUS</sub>                     | Input supply current (VBUS) in buck mode<br>V <sub>VBUS</sub> > V <sub>UVLO</sub> , V <sub>VBUS</sub> > V <sub>VBAT</sub> , converter switching, V <sub>BAT</sub> = 3.8V, I <sub>SYS</sub> = 0A |      | 3     |       | mA   |
| I <sub>BOOST</sub>                    | Battery discharge current in boost mode<br>V <sub>BAT</sub> = 4.2 V, boost mode, I <sub>VBUS</sub> = 0 A, converter switching   |      | 3     |       | mA   |
| <b>VBUS, VAC AND BAT PIN POWER UP</b> |   |      |       |       |      |
| V <sub>BUS_OP</sub>                   | VBUS operating range<br>V <sub>VBUS</sub> rising  | 3.9  |       | 13.5  | V    |
| V <sub>VAC_PRESENT</sub>              | REGN turn-on threshold<br>V <sub>VAC</sub> rising   | 3.36 | 3.65  | 3.97  | V    |
| V <sub>VAC_PRESENT_HYS</sub>          | V <sub>VAC</sub> falling  |      | 300   |       | mV   |
| V <sub>SLEEP</sub>                    | Sleep mode falling threshold<br>(V <sub>VAC</sub> –V <sub>VBAT</sub> ), V <sub>BUSMIN_FALL</sub> ≤ V <sub>BAT</sub> ≤ V <sub>REG</sub> , V <sub>VAC</sub> falling                               | 37   | 76    | 126   | mV   |
| V <sub>SLEEPZ</sub>                   | Sleep mode rising threshold<br>(V <sub>VAC</sub> –V <sub>VBAT</sub> ), V <sub>BUSMIN_FALL</sub> ≤ V <sub>BAT</sub> ≤ V <sub>REG</sub> , V <sub>VAC</sub> rising                                 | 130  | 220   | 350   | mV   |
| V <sub>VAC_OV_RISE</sub>              | VAC Overvoltage rising threshold<br>V <sub>VAC</sub> rising   | 13.5 | 14.28 | 14.91 | V    |
| V <sub>VAC_OV_HYS</sub>               | VAC Overvoltage hysteresis<br>V <sub>VAC</sub> falling  |      | 520   |       | mV   |
| V <sub>BAT_DPL_FALL</sub>             | Battery depletion falling threshold (Q4 turn-off threshold)<br>V <sub>BAT</sub> falling   | 2.15 |       | 2.6   | V    |
| V <sub>BAT_DPL_RISE</sub>             | Battery Depletion rising threshold (Q4 turn-on threshold)<br>V <sub>BAT</sub> rising  | 2.35 |       | 2.82  | V    |
| V <sub>BAT_DPL_HYST</sub>             | Battery Depletion rising hysteresis<br>V <sub>BAT</sub> rising  |      | 180   |       | mV   |

## 8.5 Electrical Characteristics (continued)

$V_{VAC\_PRESENT} < V_{VAC} < V_{VAC\_OV}$  and  $V_{VAC} > V_{BAT} + V_{SLEEP}$ ,  $T_J = -40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  and  $T_J = 25^{\circ}\text{C}$  for typical values (unless otherwise noted)

| PARAMETER              |   | TEST CONDITIONS  | MIN   | TYP                      | MAX   | UNIT |
|------------------------|---|--|-------|--------------------------|-------|------|
| $V_{BUSMIN\_FALL}$     | Bad adapter detection falling threshold                                     | $V_{BUS}$ falling  | 3.65  | 3.8                      | 3.93  | V    |
| $V_{BUSMIN\_HYST}$     | Bad adapter detection hysteresis  |  |       | 200                      |       | mV   |
| $I_{BADSRC}$           | Bad adapter detection current source  | Sink current from $V_{BUS}$ to GND   |       | 30                       |       | mA   |
| <b>POWER PATH</b>      |   |  |       |                          |       |      |
| $V_{SYS\_MIN}$         | System regulation voltage   | $V_{VBAT} < V_{SYS\_MIN} = 3.5\text{V}$ , charge enabled or disabled   | 3.5   | 3.68                     |       | V    |
| $V_{SYS}$              | System regulation voltage   | $I_{SYS} = 0\text{ A}$ , $V_{VBAT} > V_{SYSMIN}$ , charge disabled   |       | $V_{BAT} + 50\text{ mV}$ |       | V    |
| $R_{ON(RBFET)}$        | Top reverse blocking MOSFET on-resistance between $V_{BUS}$ and $PMID$ - Q1 | $-40^{\circ}\text{C} \leq T_A \leq 125^{\circ}\text{C}$  |       | 45                       |       | mΩ   |
| $R_{ON(HSFET)}$        | Top switching MOSFET on-resistance between $PMID$ and $SW$ - Q2             | $V_{REGN} = 5\text{ V}$ , $-40^{\circ}\text{C} \leq T_A \leq 125^{\circ}\text{C}$                            |       | 62                       |       | mΩ   |
| $R_{ON(LSFET)}$        | Bottom switching MOSFET on-resistance between $SW$ and GND - Q3             | $V_{REGN} = 5\text{ V}$ , $-40^{\circ}\text{C} \leq T_A \leq 125^{\circ}\text{C}$                            |       | 70                       |       | mΩ   |
| $V_{FWD}$              | BATFET forward voltage in supplement mode                                   |  |       | 30                       |       | mV   |
| $R_{ON(BAT-SYS)}$      | SYS-BAT MOSFET on-resistance  | QFN package, Measured from BAT to SYS, $V_{BAT} = 4.2\text{V}$ , $T_J = 25^{\circ}\text{C}$                  |       | 19.5                     | 24    | mΩ   |
| $R_{ON(BAT-SYS)}$      | SYS-BAT MOSFET on-resistance  | QFN package, Measured from BAT to SYS, $V_{BAT} = 4.2\text{V}$ , $T_J = -40 - 125^{\circ}\text{C}$           |       | 19.5                     | 30    | mΩ   |
| <b>BATTERY CHARGER</b> |   |  |       |                          |       |      |
| $V_{BATREG}$           | Charge voltage  | $R_{VSET} > 50\text{ k}\Omega$ , $-40 \leq T_J \leq 85^{\circ}\text{C}$                                      | 4.187 | 4.208                    | 4.229 | V    |
|                        |   | $R_{VSET} < 500\text{ }\Omega$ , $-40 \leq T_J \leq 85^{\circ}\text{C}$                                      | 4.330 | 4.352                    | 4.374 | V    |
|                        |   | $R_{VSET} = 10\text{ k}\Omega$ , $-40 \leq T_J \leq 85^{\circ}\text{C}$                                      | 4.378 | 4.4                      | 4.422 | V    |
| $V_{BATREG\_ACC}$      | Charge voltage setting accuracy   | $V_{BAT} = 4.208\text{ V}$ or $V_{BAT} = 4.352\text{ V}$ , $-40 \leq T_J \leq 85^{\circ}\text{C}$            | -0.5% |                          | 0.5%  |      |
| $I_{CHG\_REG\_RANGE}$  | Charge current regulation range   |  | 0     |                          | 3000  | mA   |
| $I_{CHG\_REG}$         | Charge current regulation   | $R_{ICHG} = 1100\text{ }\Omega$ , $V_{VBAT} = 3.1\text{ V}$ or $V_{VBAT} = 3.8\text{ V}$                     | 516   | 615                      | 715   | mA   |
| $I_{CHG\_REG\_ACC}$    | Charge current regulation accuracy  | $R_{ICHG} = 1100\text{ }\Omega$ , $V_{VBAT} = 3.1\text{ V}$ or $V_{VBAT} = 3.8\text{ V}$                     | -16%  |                          | 16%   |      |
| $I_{CHG\_REG}$         | Charge current regulation   | $R_{ICHG} = 562\text{ }\Omega$ , $V_{VBAT} = 3.1\text{ V}$ or $V_{VBAT} = 3.8\text{ V}$                      | 1.14  | 1.218                    | 1.28  | A    |
| $I_{CHG\_REG}$         | Charge current regulation accuracy  | $R_{ICHG} = 562\text{ }\Omega$ , $V_{BAT} = 3.1\text{ V}$ or $V_{BAT} = 3.8\text{ V}$                        | -6%   |                          | 6%    |      |
| $I_{CHG\_REG}$         | Charge current regulation   | $R_{ICHG} = 372\text{ }\Omega$ , $V_{VBAT} = 3.1\text{ V}$ or $V_{VBAT} = 3.8\text{ V}$                      | 1.715 | 1.813                    | 1.89  | A    |
| $I_{CHG\_REG\_ACC}$    | Charge current regulation accuracy  | $R_{ICHG} = 372\text{ }\Omega$ , $V_{VBAT} = 3.1\text{ V}$ or $V_{VBAT} = 3.8\text{ V}$                      | -5%   |                          | 5%    |      |
| $K_{ICHG}$             | Charge current regulation setting ratio                                     | $R_{ICHG} = 372\text{ }\Omega$ , $562\text{ }\Omega$ $V_{VBAT} = 3.1\text{ V}$ or $V_{VBAT} = 3.8\text{ V}$  | 639   | 677                      | 715   | A×Ω  |
| $K_{ICHG\_ACC}$        | Charge current regulation setting ratio accuracy                            | $R_{ICHG} = 372\text{ }\Omega$ , $562\text{ }\Omega$ $V_{VBAT} = 3.1\text{ V}$ or $V_{VBAT} = 3.8\text{ V}$  | -6%   |                          | 6%    |      |
| $V_{BATLOWV\_FALL}$    | Battery LOWV falling threshold  | Fast charge to precharge   | 2.67  | 2.8                      | 2.87  | V    |
| $V_{BATLOWV\_RISE}$    | Battery LOWV rising threshold   | Pre-charge to fast charge  | 3.0   | 3.1                      | 3.24  | V    |
| $I_{PRECHG}$           | Precharge current regulation  | $R_{ICHG} = 1100\text{ }\Omega$ , $V_{VBAT} = 2.6\text{ V}$ , $I_{PRECHG} = 5\%$ of $I_{CHG} = 615\text{mA}$ | 21    |                          | 38    | mA   |

## 8.5 Electrical Characteristics (continued)

$V_{VAC\_PRESENT} < V_{VAC} < V_{VAC\_OV}$  and  $V_{VAC} > V_{BAT} + V_{SLEEP}$ ,  $T_J = -40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  and  $T_J = 25^{\circ}\text{C}$  for typical values (unless otherwise noted)

| PARAMETER                                   |  | TEST CONDITIONS   | MIN   | TYP  | MAX   | UNIT                     |
|---|--|---|-------|------|-------|--------------------------|
| $I_{PRECHG\_ACC}$                           | Precharge current regulation accuracy                        | Percentage of $I_{CHG}$ , $R_{ICHG} = 1100\ \Omega$ , $V_{VBAT} = 2.6\ \text{V}$ , $I_{CHG} = 615\text{mA}$                         | 3.4%  |      | 6.2%  |                          |
| $I_{PRECHG}$                                | Precharge current regulation                                 | $R_{ICHG} = 562\ \Omega$ , $V_{VBAT} = 2.6\ \text{V}$ , $I_{PRECHG} = 5\%$ of $I_{CHG} = 1.218\text{A}$                             | 48    |      | 67    | mA                       |
| $I_{PRECHG\_ACC}$                           | Precharge current regulation accuracy                        | Percentage of $I_{CHG}$ , $R_{ICHG} = 562\ \Omega$ , $V_{1330} = 2.6\ \text{V}$ , $I_{CHG} = 1.218\text{A}$                         | 3.9%  |      | 5.5%  |                          |
| $I_{PRECHG}$                                | Precharge current regulation                                 | $R_{ICHG} = 372\ \Omega$ , $V_{VBAT} = 2.6\ \text{V}$ , $I_{PRECHG} = 5\%$ of $I_{CHG} = 1.813\text{A}$                             | 76    |      | 97    | mA                       |
| $I_{PRECHG\_ACC}$                           | Precharge current regulation accuracy                        | Percentage of $I_{CHG}$ , $R_{ICHG} = 372\ \Omega$ , $V_{VBAT} = 2.6\ \text{V}$ , $I_{CHG} = 1.813\text{A}$                         | 4.1%  |      | 5.4%  |                          |
| $I_{TERM}$                                  | Termination current regulation                               | $R_{ICHG} = 562\ \Omega$ , $V_{VBAT} = 4.35\text{V}$ , $I_{CHG} = 1.218\text{A}$  | 26    |      | 100   | mA                       |
| $I_{TERM\_ACC}$                             | Termination current regulation accuracy                      | Percentage of $I_{CHG}$ , $R_{ICHG} = 562\ \Omega$ , $V_{VBAT} = 4.35\ \text{V}$ , $I_{CHG} = 1.218\ \text{A}$                      | 2.1%  |      | 8.3%  |                          |
| $I_{TERM}$                                  | Termination current regulation                               | $R_{ICHG} = 372\ \Omega$ , $V_{VBAT} = 4.35\ \text{V}$ , $I_{CHG} = 1.813\ \text{A}$  | 56    | 100  | 126   | mA                       |
| $I_{TERM\_ACC}$                             | Termination current regulation accuracy                      | Percentage of $I_{CHG}$ , $R_{ICHG} = 372\ \Omega$ , $V_{VBAT} = 4.35\ \text{V}$ , $I_{CHG} = 1.813\ \text{A}$                      | 3.0%  |      | 7.0%  |                          |
| $V_{SHORT}$                                 | Battery short voltage  | $V_{VBAT}$ falling  | 1.85  | 2    | 2.15  | V                        |
| $V_{SHORTZ}$                                | Battery short voltage  | $V_{VBAT}$ rising   | 2.05  | 2.25 | 2.35  | V                        |
| $I_{SHORT}$                                 | Battery short current  | $V_{VBAT} < V_{SHORTZ}$   | 70    | 90   | 110   | mA                       |
| $V_{RECHG}$                                 | Recharge Threshold below $V_{BAT\_REG}$                      | $V_{BAT}$ falling   | 87    | 121  | 156   | mV                       |
| $I_{SYSLOAD}$                               | System discharge load current                                | $V_{SYS} = 4.2\ \text{V}$   |       | 30   |       | mA                       |
| <b>INPUT VOLTAGE AND CURRENT REGULATION</b> |  |   |       |      |       |                          |
| $V_{DPM\_VBAT}$                             | Input voltage regulation limit                               | $V_{VBAT} < 4.1\ \text{V}$ ( $V_{VBAT} = 3.6\ \text{V}$ )   | 4.171 | 4.3  | 4.429 | V                        |
| $V_{DPM\_VBAT\_ACC}$                        | Input voltage regulation accuracy                            | $V_{VBAT} < 4.1\ \text{V}$ ( $V_{VBAT} = 3.6\ \text{V}$ )   | –3%   |      | 3%    |                          |
| $I_{INDPM}$                                 | USB input current regulation limit                           | $V_{BUS} = 5\ \text{V}$ , USB500 charge port detected by DPDM, $-40 \leq T_J \leq 85^{\circ}\text{C}$                               | 448   |      | 500   | mA                       |
| $I_{INDPM}$                                 | Input current regulation limit                               | $R_{ILIM} = 910\ \Omega$ , unknown adaptor detected by DPDM, $-40 \leq T_J \leq 85^{\circ}\text{C}$                                 | 505   | 526  | 550   | mA                       |
| $I_{INDPM}$                                 | Input current regulation limit accuracy                      | $R_{ILIM} = 374\ \Omega$ , unknown adaptor detected by DPDM, $-40 \leq T_J \leq 85^{\circ}\text{C}$                                 | 1220  | 1276 | 1330  | mA                       |
| $I_{INDPM}$                                 | Input current regulation limit                               | $R_{ILIM} = 265\ \Omega$ , unknown adaptor detected by DPDM, $-40 \leq T_J \leq 85^{\circ}\text{C}$                                 | 1.73  | 1.8  | 1.871 | A                        |
| $I_{INDPM\_ACC}$                            | Input current regulation limit accuracy                      | $R_{ILIM} = 265\ \Omega$ , $374\ \Omega$ , $910\ \Omega$ , unknown adaptor detected by DPDM, $-40 \leq T_J \leq 85^{\circ}\text{C}$ | –5%   |      | 5%    |                          |
| $K_{ILIM}$                                  | Input current setting ratio, $I_{LIM} = K_{ILIM} / R_{ILIM}$ | $R_{ILIM} = 910\ \Omega$ , $374\ \Omega$ , $265\ \Omega$ , unknown adaptor detected by DPDM, $-40 \leq T_J \leq 85^{\circ}\text{C}$ | 459   | 478  | 500   | $\text{A} \times \Omega$ |
| $K_{ILIM\_ACC}$                             | Input current setting ratio, $I_{LIM} = K_{ILIM} / R_{ILIM}$ | $R_{ILIM} = 910\ \Omega$ , $374\ \Omega$ , $265\ \Omega$ , unknown adaptor detected by DPDM, $-40 \leq T_J \leq 85^{\circ}\text{C}$ | –5%   |      | 5%    |                          |
| $I_{IN\_START}$                             | Input current limit during system start-up sequence          |   |       | 200  |       | mA                       |
| <b>BAT PIN OVERVOLTAGE PROTECTION</b>       |  |   |       |      |       |                          |

## 8.5 Electrical Characteristics (continued)

$V_{VAC\_PRESENT} < V_{VAC} < V_{VAC\_OV}$  and  $V_{VAC} > V_{BAT} + V_{SLEEP}$ ,  $T_J = -40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  and  $T_J = 25^{\circ}\text{C}$  for typical values (unless otherwise noted)

| PARAMETER   |  | TEST CONDITIONS   | MIN   | TYP   | MAX   | UNIT               |
|---|--|---|-------|-------|-------|--------------------|
| $V_{BATOVP\_RISE}$                                    | Battery overvoltage threshold  | $V_{BAT}$ rising, as percentage of $V_{BAT\_REG}$   | 103%  | 104%  | 105%  |                    |
| $V_{BATOVP\_FALL}$                                    | Battery overvoltage threshold  | $V_{BAT}$ falling, as percentage of $V_{BAT\_REG}$  | 101%  | 102%  | 103%  |                    |
| <b>THERMAL REGULATION AND THERMAL SHUTDOWN</b>        |  |   |       |       |       |                    |
| $T_{JUNCTION\_REG}$                                   | Junction Temperature Regulation Threshold  |   |       | 110   |       | $^{\circ}\text{C}$ |
| $T_{SHUT}$  | Thermal Shutdown Rising Temperature  | Temperature Increasing  |       | 160   |       | $^{\circ}\text{C}$ |
| $T_{SHUT\_HYST}$                                      | Thermal Shutdown Hysteresis  |   |       | 30    |       | $^{\circ}\text{C}$ |
| <b>JEITA THERMISTOR COMPARATOR (BUCK MODE)</b>        |  |   |       |       |       |                    |
| $V_{T1}$  | T1 ( $0^{\circ}\text{C}$ ) threshold, Charge suspended T1 below this temperature.                  | Charger suspends charge. As Percentage to $V_{REGN}$  | 72.4% | 73.3% | 74.2% |                    |
| $V_{T1}$  | Falling  | As Percentage to $V_{REGN}$   | 69%   | 71.5% | 74%   |                    |
| $V_{T2}$  | T2 ( $10^{\circ}\text{C}$ ) threshold, Charge back to $I_{CHG}/2$ and 4.2 V below this temperature | As percentage of $V_{REGN}$   | 67.2% | 68%   | 69%   |                    |
| $V_{T2}$  | Falling  | As Percentage to $V_{REGN}$   | 66%   | 66.8% | 67.7% |                    |
| $V_{T3}$  | T3 ( $45^{\circ}\text{C}$ ) threshold, charge back to $I_{CHG}$ and 4.05V above this temperature.  | Charger suspends charge. As Percentage to $V_{REGN}$  | 43.8% | 44.7% | 45.8% |                    |
| $V_{T3}$  | Falling  | As Percentage to $V_{REGN}$   | 45.1% | 45.7% | 46.2% |                    |
| $V_{T5}$  | T5 ( $60^{\circ}\text{C}$ ) threshold, charge suspended above this temperature.                    | As Percentage to $V_{REGN}$   | 33.7% | 34.2% | 35.1% |                    |
| $V_{T5}$  | Falling  | As Percentage to $V_{REGN}$   | 34.5% | 35.3% | 36.2% |                    |
| <b>COLD OR HOT THERMISTOR COMPARATOR (BOOST MODE)</b> |  |   |       |       |       |                    |
| $V_{BCOLD}$   | Cold Temperature Threshold, TS pin Voltage Rising Threshold  | As Percentage to $V_{REGN}$ (Approx. $-20^{\circ}\text{C}$ w/ 103AT), $-20^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$ | 79.5% | 80%   | 80.5% |                    |
| $V_{BCOLD}$   | Falling  | $-20^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$   | 78.5% | 79%   | 79.5% |                    |
| $V_{BHOT}$  | Hot Temperature Threshold, TS pin Voltage falling Threshold  | As Percentage to $V_{REGN}$ (Approx. $60^{\circ}\text{C}$ w/ 103AT), $-20^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$  | 30.2% | 31.2% | 32.2% |                    |
| $V_{BHOT}$  | Rising   | $-20^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$   | 33.8% | 34.4% | 34.9% |                    |
| <b>CHARGE OVERCURRENT COMPARATOR (CYCLE-BY-CYCLE)</b> |  |   |       |       |       |                    |
| $I_{HSFET\_OCP}$                                      | HSFET cycle-by-cycle over-current threshold  |   | 5.2   |       | 8.0   | A                  |
| $I_{BATFET\_OCP}$                                     | System over load threshold   |   | 6.0   |       |       | A                  |
| <b>PWM</b>  |  |   |       |       |       |                    |
| $f_{SW}$  | PWM switching frequency  | Oscillator frequency, buck mode   | 1320  | 1500  | 1680  | kHz                |
|   |  | Oscillator frequency, boost mode  | 1170  | 1412  | 1500  | kHz                |
| $D_{MAX}$   | Maximum PWM duty cycle <sup>(1)</sup>  |   |       | 97%   |       |                    |
| <b>BOOST MODE OPERATION</b>                           |  |   |       |       |       |                    |
| $V_{OTG\_REG}$  | Boost mode regulation voltage  | $V_{VBAT} = 3.8\text{ V}$ , $I_{(PMID)} = 0\text{ A}$   | 4.972 | 5.126 | 5.280 | V                  |
| $V_{OTG\_REG\_ACC}$                                   | Boost mode regulation voltage accuracy   | $V_{VBAT} = 3.8\text{ V}$ , $I_{(PMID)} = 0\text{ A}$   | -3    |       | 3     | %                  |
| $V_{BATLOWV\_OTG}$                                    | Battery voltage exiting boost mode   | $V_{VBAT}$ falling  | 2.6   | 2.8   | 2.9   | V                  |
|   | Battery voltage entering boost mode  | $V_{VBAT}$ rising   | 2.9   | 3.0   | 3.15  | V                  |
| $I_{OTG}$   | OTG mode output current limit  |   | 1.2   | 1.4   | 1.6   | A                  |
| $V_{OTG\_OVP}$  | OTG overvoltage threshold  | Rising threshold  | 5.55  | 5.8   | 6.15  | V                  |
| <b>REGN LDO</b>                                       |  |   |       |       |       |                    |

## 8.5 Electrical Characteristics (continued)

$V_{VAC\_PRESENT} < V_{VAC} < V_{VAC\_OV}$  and  $V_{VAC} > V_{BAT} + V_{SLEEP}$ ,  $T_J = -40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  and  $T_J = 25^{\circ}\text{C}$  for typical values (unless otherwise noted)

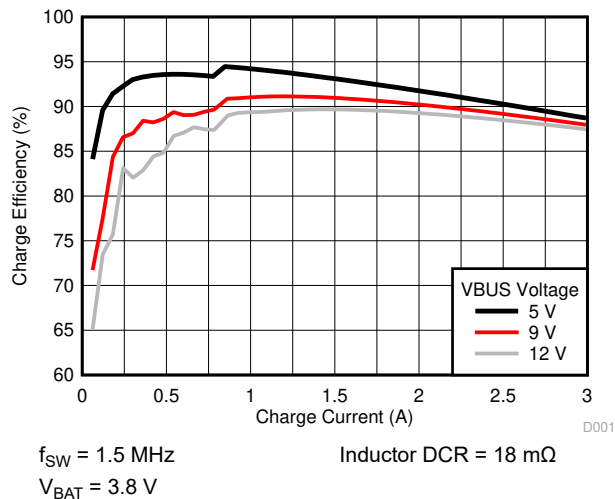
| PARAMETER  |   | TEST CONDITIONS                                     | MIN   | TYP | MAX  | UNIT          |
|--|---|---|-------|-----|------|---------------|
| $V_{REGN}$   | REGN LDO output voltage   | $V_{VBUS} = 9\text{ V}$ , $I_{REGN} = 40\text{ mA}$ | 5.6   | 6   | 6.65 | V             |
| $V_{REGN}$   | REGN LDO output voltage   | $V_{VBUS} = 5\text{ V}$ , $I_{REGN} = 20\text{ mA}$ | 4.6   | 4.7 | 4.9  | V             |
| <b>LOGIC I/O PIN CHARACTERISTICS (<math>\overline{CE}</math>, PSEL, SCL, SDA, INT)</b> |   |   |       |     |      |               |
| $V_{ILO}$  | Input low threshold $\overline{CE}$   |   |       |     | 0.4  | V             |
| $V_{IH}$   | Input high threshold $\overline{CE}$  |   | 1.3   |     |      | V             |
| $I_{BIAS}$   | High-level leakage current $\overline{CE}$  | Pull up rail 1.8 V                                  |       |     | 1    | $\mu\text{A}$ |
| $V_{ILO}$  | Input low threshold OTG   |   |       |     | 0.4  | V             |
| $V_{IH}$   | Input high threshold OTG  |   | 1.3   |     |      | V             |
| $I_{BIAS}$   | High-level leakage current OTG  | Pull up rail 1.8 V                                  |       |     | 1    | $\mu\text{A}$ |
| <b>LOGIC I/O PIN CHARACTERISTICS (<math>\overline{PG}</math>, STAT)</b>                |   |   |       |     |      |               |
| $V_{OL}$   | Low-level output voltage  |   |       |     | 0.4  | V             |
| <b>D+/D- DETECTION</b>   |   |   |       |     |      |               |
| $V_{D+_1P2}$   | D+ Threshold for Non-standard adapter (combined $V_{1P2\_VTH\_LO}$ and $V_{1P2\_VTH\_HI}$ ) |   | 1.05  |     | 1.35 | V             |
| $I_{D+_LKG}$   | Leakage current into D+   | HiZ   | -1    |     | 1    | $\mu\text{A}$ |
| $V_{D-\_600MVSRC}$   | Voltage source (600 mV)   |   | 500   | 600 | 700  | mV            |
| $I_{D-\_100UAISNK}$  | D- current sink (100 $\mu\text{A}$ )  | $V_{D-} = 500\text{ mV}$ ,                          | 50    | 100 | 150  | $\mu\text{A}$ |
| $R_{D-\_19K}$  | D- resistor to ground (19 k $\Omega$ )  | $V_{D-} = 500\text{ mV}$ ,                          | 14.25 |     | 24.8 | k $\Omega$    |
| $V_{D-\_0P325}$  | D- comparator threshold for primary detection   | D- pin Rising                                       | 250   |     | 400  | mV            |
| $V_{D-\_2P8}$  | D- Threshold for non-standard adapter (combined $V_{2P8\_VTH\_LO}$ and $V_{2P8\_VTH\_HI}$ ) |   | 2.55  |     | 2.85 | V             |
| $V_{D-\_2P0}$  | D- Comparator threshold for non-standard adapter (For non-standard – same as BQ2589x)       |   | 1.85  |     | 2.15 | V             |
| $V_{D-\_1P2}$  | D- Threshold for non-standard adapter (combined $V_{1P2\_VTH\_LO}$ and $V_{1P2\_VTH\_HI}$ ) |   | 1.05  |     | 1.35 | V             |
| $I_{D-\_LKG}$  | Leakage current into D-   | HiZ   | -1    |     | 1    | $\mu\text{A}$ |

(1) Specified by design. Not production tested.

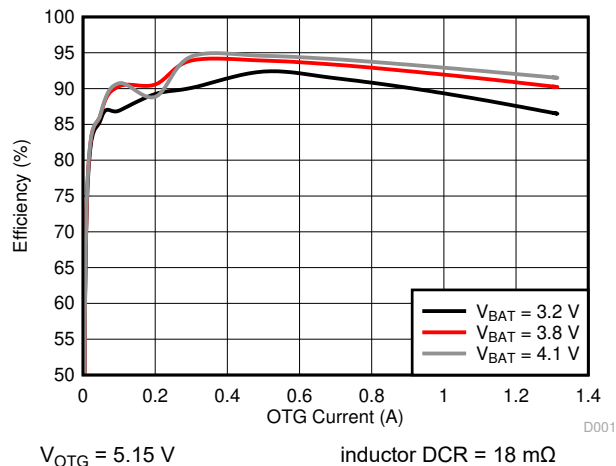
## 8.6 Timing Requirements

| PARAMETER                |  |  | MIN | NOM | MAX | UNIT          |
|--------------------------|--|--|-----|-----|-----|---------------|
| <b>VBUS/BAT POWER UP</b> |  |  |     |     |     |               |
| $t_{ACOV}$               | VBUS OVP reaction time                               | VAC rising above ACOV threshold to turn off Q2 |     | 200 |     | ns            |
| $t_{BADSRC}$             | Bad adapter detection duration                       |  |     | 30  |     | ms            |
| $t_{TERM\_DGL}$          | Deglintch time for charge termination                |  |     | 250 |     | ms            |
| $t_{RECHG\_DGL}$         | Deglintch time for recharge                          |  |     | 250 |     | ms            |
| $t_{SYSOVLD\_DGL}$       | System over-current deglintch time to turn off Q4    |  |     | 100 |     | $\mu\text{s}$ |
| $t_{BATOV}$              | Battery overvoltage deglintch time to disable charge |  |     | 1   |     | $\mu\text{s}$ |
| $t_{SAFETY}$             | Typical Charge Safety Timer Range                    |  | 8   | 10  | 12  | hr            |

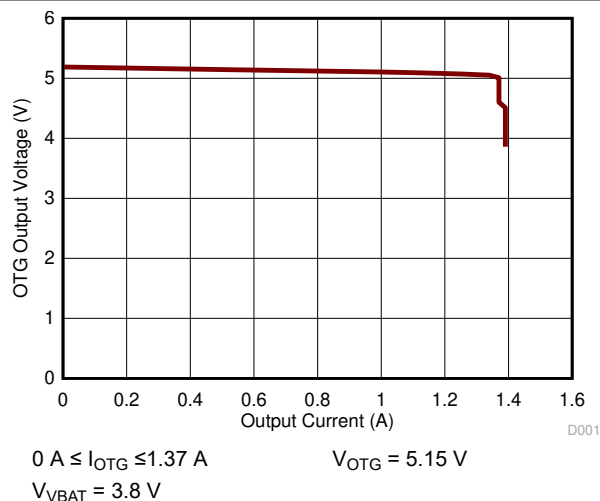
## 8.7 Typical Characteristics



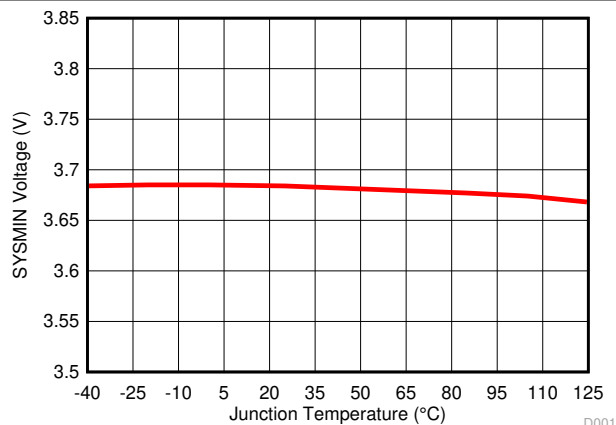
**Figure 8-1. Charge Efficiency vs. Charge Current**



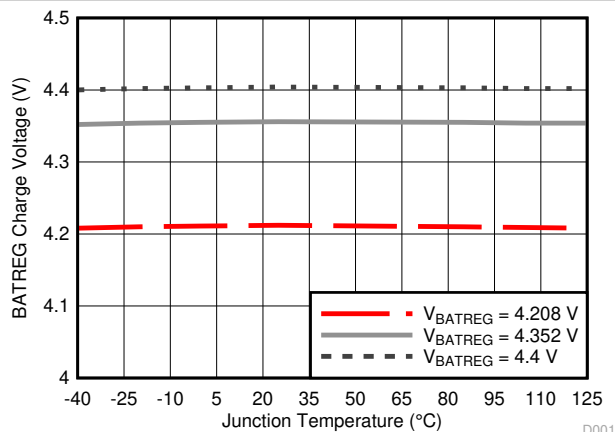
**Figure 8-2. Efficiency vs. OTG Current**



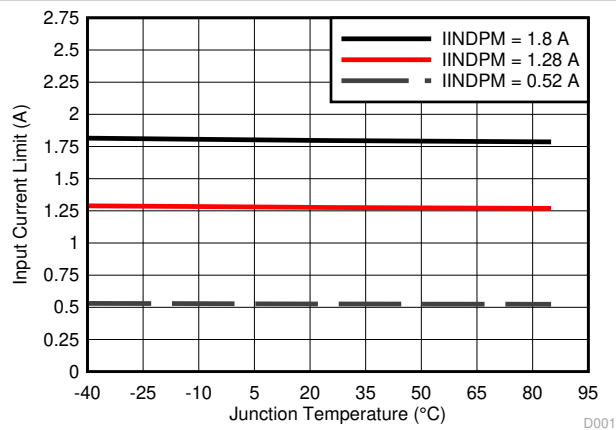
**Figure 8-3. OTG Output Voltage vs. Output Current**



**Figure 8-4. SYSMIN Voltage vs. Junction Temperature**

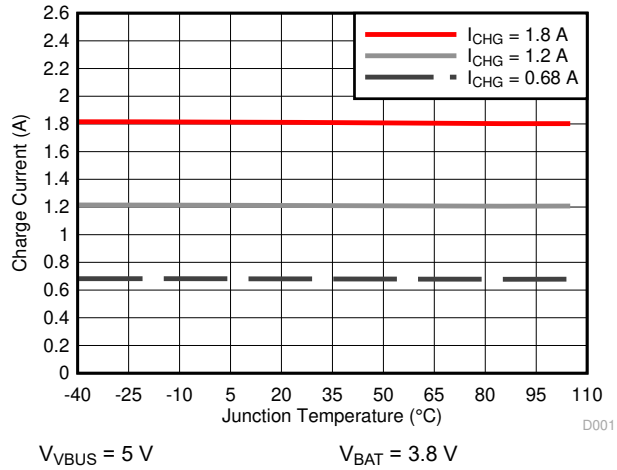


**Figure 8-5. BATREG Charge Voltage vs. Junction Temperature**

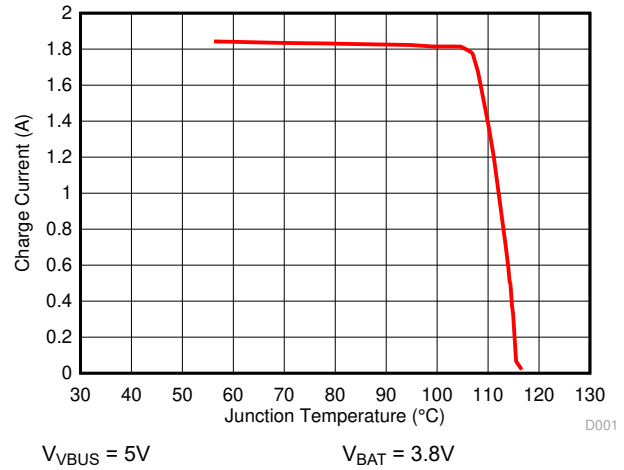


**Figure 8-6. Input Current Limit vs. Junction Temperature**

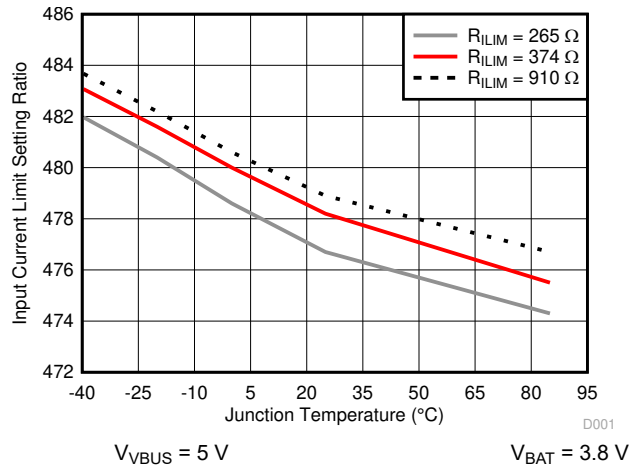
## 8.7 Typical Characteristics (continued)



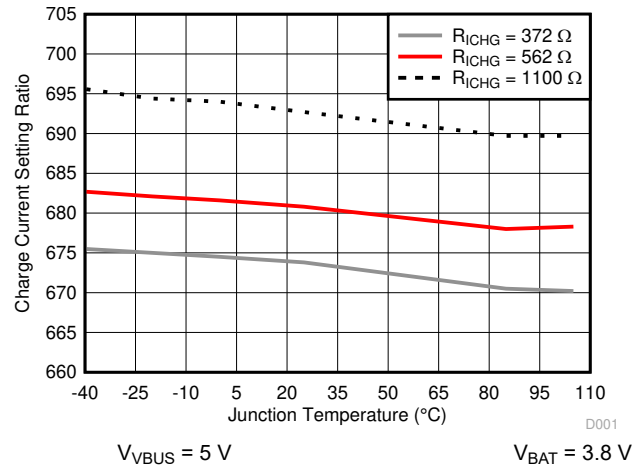
**Figure 8-7. Charge Current vs. Junction Temperature**



**Figure 8-8. Charge Current vs. Junction Temperature Under Thermal Regulation**



**Figure 8-9. Input Current Limit Setting Ratio vs. Junction Temperature**



**Figure 8-10. Charge Current Setting Ratio vs. Junction Temperature**

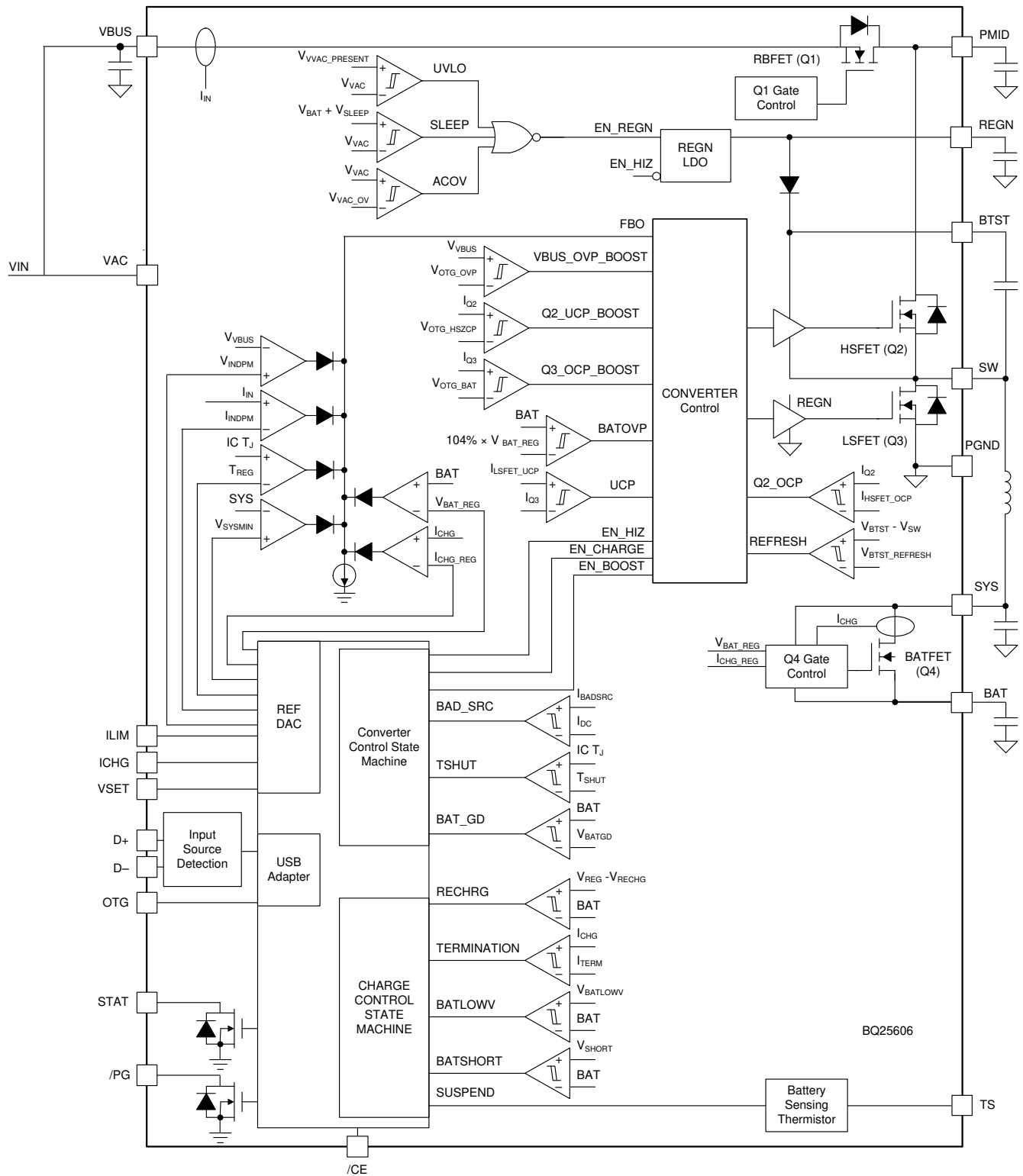
## 9 Detailed Description

### 9.1 Overview

The BQ25606 is a highly integrated 3.0-A switch-mode battery charger for single cell Li-ion and Li-polymer batteries. It includes an input reverse-blocking FET (RBFET, Q1), high-side switching FET (HSFET, Q2), low-side switching FET (LSFET, Q3), and battery FET (BATFET, Q4), and bootstrap diode for the high-side gate drive.



## 9.2 Functional Block Diagram



## 9.3 Feature Description

### 9.3.1 Device Power Up from Battery without Input Source

If only battery is present and the voltage is above depletion threshold ( $V_{BAT\_DPL\_RISE}$ ), the BATFET turns on and connects battery to system. The REGN stays off to minimize the quiescent current. The low  $R_{DS(on)}$  of BATFET and the low quiescent current on BAT minimize the conduction loss and maximize the battery run time.

The device always monitors the discharge current through BATFET (Supplement Mode). When the system is overloaded or shorted ( $I_{BAT} > I_{BATFET\_OCP}$ ), the device turns off BATFET immediately until the input source plugs in again.

### 9.3.2 Power Up from Input Source

When an input source is plugged in, the device checks the input source voltage to turn on REGN LDO and all the bias circuits. It detects and sets the input current limit before the buck converter is started. The power-up sequence from input source is as listed:

1. Power up REGN LDO
2. Poor source qualification
3. Input source type detection is based on D+/D– to set input current limit (IINDPM) .
4. Input voltage limit threshold setting (VINDPM threshold)
5. Converter power up

#### 9.3.2.1 Power Up REGN Regulation

The REGN LDO supplies internal bias circuits as well as the HSFET and LSFET gate drive. The REGN also provides bias rail to TS external resistors. The pull-up rail of STAT can be connected to REGN as well. The REGN is enabled when all the below conditions are valid:

- $V_{VAC}$  above  $V_{VAC\_PRESENT}$
- $V_{VAC}$  above  $V_{BAT} + V_{SLEEPZ}$  in buck mode or  $V_{BUS}$  below  $V_{BAT} + V_{SLEEP}$  in boost mode
- After 220-ms delay is completed

If any one of the above conditions is not valid, the device is in high impedance mode (HIZ) with REGN LDO off. The device draws less than  $I_{VBUS\_HIZ}$  from  $V_{BUS}$  during HIZ state. The battery powers up the system when the device is in HIZ.

#### 9.3.2.2 Poor Source Qualification

After REGN LDO powers up, the device confirms the current capability of the input source. The input source must meet both of the following requirements in order to start the buck converter.

- VAC voltage below  $V_{VAC\_OV}$
- $V_{BUS}$  voltage above  $V_{VBUSMIN}$  when pulling  $I_{BADSRC}$  (typical 30 mA)

If the device fails the poor source detection, it repeats poor source qualification every 2 seconds.

#### 9.3.2.3 Input Source Type Detection

After the REGN LDO is powered, the device runs input source detection through D+/D– lines. The BQ25606 follows the USB Battery Charging Specification 1.2 (BC1.2) to detect input source (SDP/ DCP) and nonstandard adapter through USB D+/D– lines. The BQ25606 sets input current limit through D+/D– detection and ILIM pins.

##### 9.3.2.3.1 D+/D– Detection Sets Input Current Limit in BQ25606

The BQ25606 contains a D+/D– based input source detection to set the input current limit at  $V_{BUS}$  plug-in. The D+/D– detection includes standard USB BC1.2 and nonstandard adapter. When input source is plugged in, the device starts standard USB BC1.2 detections. The USB BC1.2 is capable to identify Standard Downstream Port (SDP) and Dedicated Charging Port (DCP). When the Data Contact Detection (DCD) timer expires, the nonstandard adapter detection is applied to set the input current limit. The nonstandard detection is used to distinguish vendor specific adapters (Apple and Samsung) based on their unique dividers on the D+/D– pins. If an adapter is detected as DCP, the input current limit is set at 2.4 A. If an adapter is detected as unknown, the input current limit is set at 500 mA by ILIM pin.

**Table 9-1. Nonstandard Adapter Detection**

| NONSTANDARD ADAPTER | D+ THRESHOLD                  | D- THRESHOLD                  | INPUT CURRENT LIMIT (A) |
|---------------------|-------------------------------|-------------------------------|-------------------------|
| Divider 1           | $V_{D+}$ within $V_{D+\_2p8}$ | $V_{D-}$ within $V_{D-\_2p0}$ | 2.1                     |
| Divider 2           | $V_{D+}$ within $V_{D+\_1p2}$ | $V_{D-}$ within $V_{D-\_1p2}$ | 2                       |
| Divider 3           | $V_{D+}$ within $V_{D+\_2p0}$ | $V_{D-}$ within $V_{D-\_2p8}$ | 1                       |
| Divider 4           | $V_{D+}$ within $V_{D+\_2p8}$ | $V_{D-}$ within $V_{D-\_2p8}$ | 2.4                     |

**Table 9-2. Input Current Limit Setting from D+/D- Detection**

| D+/D- DETECTION     | INPUT CURRENT LIMIT (IILIM) |
|---------------------|-----------------------------|
| USB SDP (USB500)    | 500 mA                      |
| USB DCP             | 2.4 A                       |
| Divider 3           | 1 A                         |
| Divider 1           | 2.1 A                       |
| Divider 4           | 2.4 A                       |
| Divider 2           | 2 A                         |
| Unknown 5-V adapter | Set by ILIM pin             |

#### 9.3.2.4 Input Voltage Limit Threshold Setting (VINDPM Threshold)

The device VINDPM is set at 4.3 V. The device supports dynamic VINDPM tracking which tracks the battery voltage. The device VINDPM tracks battery voltage with 200 mV offset such that when  $V_{BAT} + 200 \text{ mV}$  is greater than 4.3 V, the VINDPM value is automatically adjusted to  $V_{BAT} + 200 \text{ mV}$ .

#### 9.3.2.5 Converter Power Up

After the input current limit is set, the converter is enabled and the HSFET and LSFET start switching. If battery charging is disabled, BATFET turns off. Otherwise, BATFET stays on to charge the battery.

The device provides soft start when system rail is ramped up. When the system rail is below 2.2 V, the input current is limited to 200 mA. After the system rises above 2.2 V, the device limits input current to the value set by ILIM pin.

As a battery charger, the device deploys a highly efficient 1.5 MHz step-down switching regulator. The fixed frequency oscillator keeps tight control of the switching frequency under all conditions of input voltage, battery voltage, charge current and temperature, simplifying output filter design.

The device switches to PFM control at light load or when battery is below minimum system voltage setting or charging is disabled.

#### 9.3.3 Boost Mode Operation From Battery

The device supports boost converter operation to deliver power from the battery to other portable devices through USB port. The maximum output current is up to 1.2 A. The boost operation can be enabled if the conditions are valid:

1. BAT above  $V_{OTG\_BAT}$
2. VBUS less than  $BAT + V_{SLEEP}$  (in sleep mode)
3. Boost mode operation is enabled (OTG pin HIGH)
4. Voltage at TS (thermistor) pin as a percentage of  $V_{REGN}$  is within acceptable range ( $V_{BHOT} < V_{TS} < V_{BCOLD}$ )
5. After 30-ms delay from boost mode enable

During boost mode, the VBUS output is 5.15 V and the output current can reach up to 1.2 A. The boost output is maintained when BAT is above  $V_{OTG\_BAT}$  threshold.

When OTG is enabled, the device starts up with PFM and later transits to PWM to minimize the overshoot.

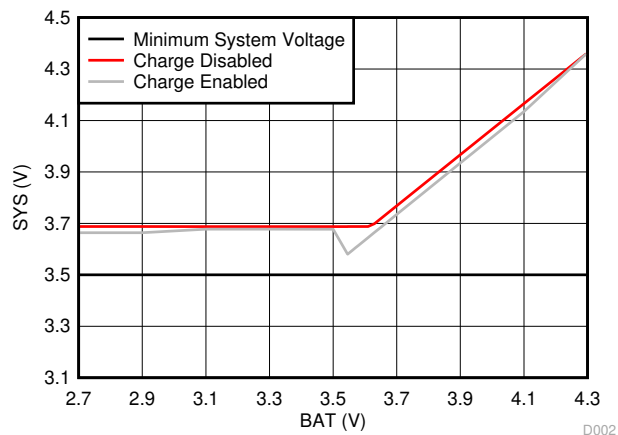
### 9.3.4 Power Path Management

The device accommodates a wide range of input sources from USB, wall adapter, to car charger. The device provides automatic power path selection to supply the system (SYS) from input source (VBUS), battery (BAT), or both.

#### 9.3.4.1 Narrow VDC Architecture

When the battery is below the minimum system voltage setting, the BATFET operates in linear mode (LDO mode), and the system is typically 180 mV above the minimum system voltage setting. As the battery voltage rises above the minimum system voltage, the BATFET is fully on and the voltage difference between the system and battery is the  $V_{DS}$  of the BATFET.

When battery charging is disabled and above the minimum system voltage setting or charging is terminated, the system is always regulated at typically 50 mV above the battery voltage.



**Figure 9-1. System Voltage vs Battery Voltage**

#### 9.3.4.2 Dynamic Power Management

To meet maximum current limit in the USB specification and avoid over loading the adapter, the device features Dynamic Power management (DPM), which continuously monitors the input current and input voltage. When input source is overloaded, either the current exceeds the input current limit (IINDPM) or the voltage falls below the input voltage limit (VINDPM). The device then reduces the charge current until the input current falls below the input current limit or the input voltage rises above the input voltage limit.

When the charge current is reduced to zero, but the input source is still overloaded, the system voltage starts to drop. Once the system voltage falls below the battery voltage, the device automatically enters the supplement mode where the BATFET turns on and the battery starts discharging so that the system is supported from both the input source and battery.

#### 9.3.4.3 Supplement Mode

When the system voltage falls below the battery voltage, the BATFET turns on and the BATFET gate is regulated so that the minimum BATFET  $V_{DS}$  stays at 30 mV when the current is low. This prevents oscillation from entering and exiting the supplement mode.

As the discharge current increases, the BATFET gate is regulated with a higher voltage to reduce  $R_{DS(on)}$  until the BATFET is in full conduction. At this point onwards, the BATFET  $V_{DS}$  linearly increases with discharge current. shows the V-I curve of the BATFET gate regulation operation. The BATFET turns off to exit supplement mode when the battery is below battery depletion threshold.

### 9.3.5 Battery Charging Management

The device charges 1-cell Li-Ion battery with up to 3.0-A charge current for high capacity tablet battery. The 19.5-m $\Omega$  BATFET improves charging efficiency and minimize the voltage drop during discharging.

### 9.3.5.1 Autonomous Charging Cycle

With battery charging enabled ( $\overline{\text{CE}}$  pin is LOW), the device autonomously completes a charging cycle. The device default charging parameters are listed in [Table 9-3](#).

**Table 9-3. Charging Parameter Default Setting**

| DEFAULT MODE        | BQ25606                     |
|---------------------|-----------------------------|
| Charging voltage    | VSET controlled             |
| Charging current    | I <sub>CHG</sub> controlled |
| Precharge current   | 5% of I <sub>CHG</sub>      |
| Termination current | 5% of I <sub>CHG</sub>      |
| Temperature profile | JEITA                       |
| Safety timer        | 10 hours                    |

A new charge cycle starts when the following conditions are valid:

- Converter starts
- Battery charging is enabled ( $\overline{\text{CE}}$  is low)
- No thermistor fault on TS
- No safety timer fault

The charger device automatically terminates the charging cycle when the charging current is below termination threshold, battery voltage is above recharge threshold, and device not is in DPM mode or thermal regulation. When a fully charged battery is discharged below recharge threshold, the device automatically starts a new charging cycle. After the charge is done, toggle  $\overline{\text{CE}}$  pin can initiate a new charging cycle.

The STAT output indicates the charging status: charging (LOW), charging complete or charge disable (HIGH) or charging fault (blinking).

### 9.3.5.2 Charging Termination

The device terminates a charge cycle when the battery voltage is above recharge threshold, and the current is below termination current. After the charging cycle is completed, the BATFET turns off. The converter keeps running to power the system, and BATFET can turn on again to engage Supplement Mode.

### 9.3.5.3 Thermistor Qualification

The charger device provides a single thermistor input for battery temperature monitor.

### 9.3.5.4 JEITA Guideline Compliance During Charging Mode

To improve the safety of charging Li-ion batteries, JEITA guideline was released on April 20, 2007. The guideline emphasized the importance of avoiding a high charge current and high charge voltage at certain low and high temperature ranges.

To initiate a charge cycle, the voltage on TS pin must be within the VT1 to VT5 thresholds. If TS voltage exceeds the T1-T5 range, the controller suspends charging and waits until the battery temperature is within the T1 to T5 range.

At cool temperature (T1-T2), the charge current is reduced to 20% of programmed fast charge current. At warm temperature (T3-T5), the charge voltage is reduced to 4.1 V. Charge termination is disabled for cool and warm conditions.

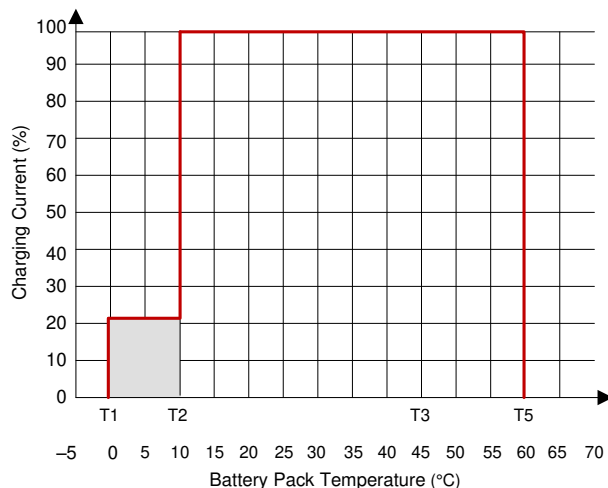


Figure 9-2. JEITA Profile: Charging Current

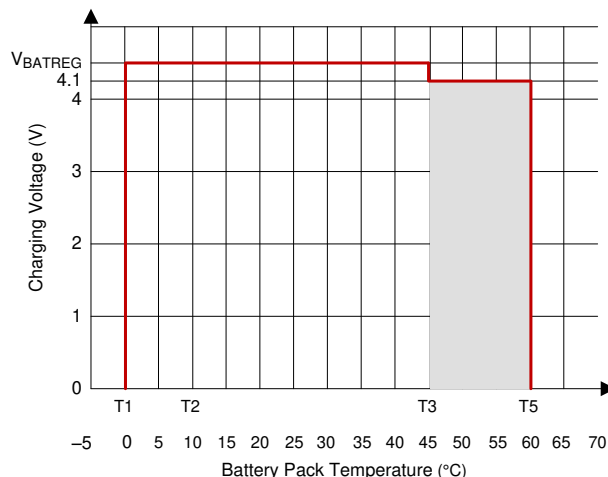


Figure 9-3. JEITA Profile: Charging Voltage

Equation 1 through Equation 2 describe updates to the resistor bias network.

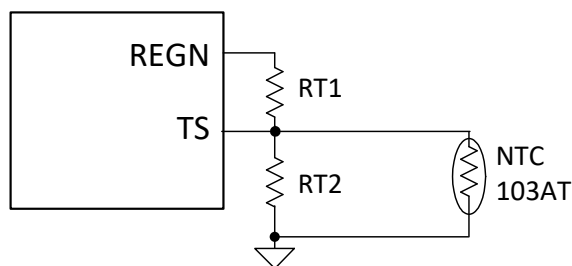


Figure 9-4. TS Pin Resistor Network

$$RT2 = \frac{R_{NTC,T1} \times R_{NTC,T5} \times \left( \frac{1}{V_{T5}\%} - \frac{1}{V_{T1}\%} \right)}{R_{NTC,T1} \times \left( \frac{1}{V_{T1}\%} - 1 \right) - R_{NTC,T5} \times \left( \frac{1}{V_{T5}\%} - 1 \right)} \quad (1)$$

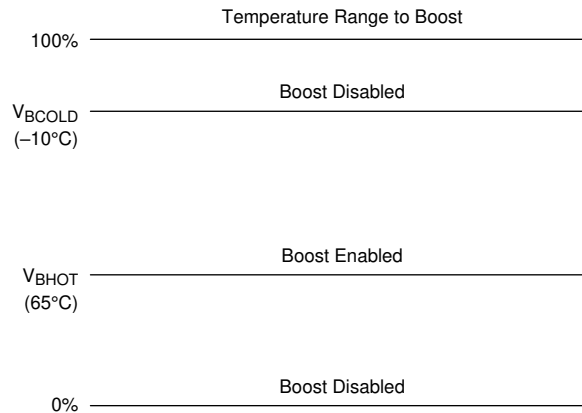
$$RT1 = \frac{\frac{1}{V_{T1}\%} - 1}{\frac{1}{RT2} + \frac{1}{R_{NTC,T1}}} \quad (2)$$

Select 0°C to 60°C range for Li-ion or Li-polymer battery:

- $R_{TH\_COLD} = 27.28 \text{ k}\Omega$
- $R_{TH\_HOT} = 3.02 \text{ k}\Omega$
- $RT1 = 5.23 \text{ k}\Omega$
- $RT2 = 30.9 \text{ k}\Omega$

### 9.3.5.5 Boost Mode Thermistor Monitor during Battery Discharge Mode

For battery protection during boost mode, the device monitors the battery temperature to be within the  $V_{BCOLD}$  to  $V_{BHOT}$  thresholds. When temperature is outside of the temperature thresholds, the boost mode is suspended.



**Figure 9-5. TS Pin Thermistor Sense Threshold in Boost Mode**

### 9.3.5.6 Charging Safety Timer

The device has built-in safety timer to prevent extended charging cycle due to abnormal battery conditions. The safety timer is two hours when the battery is below  $V_{BATLOWV}$  threshold and 10 hours when the battery is higher than  $V_{BATLOWV}$  threshold.

During input voltage, current, JEITA cool or thermal regulation, the safety timer counts at half clock rate as the actual charge current is likely to be below the register setting. For example, if the charger is in input current regulation throughout the whole charging cycle, the safety timer will expire in 20 hours.

During the fault, timer is suspended. Once the fault goes away, the timer resumes. If user stops the current charging cycle, and start again, timer gets reset.

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

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

The  $\overline{PG}$  pin goes LOW to indicate a good input source when:

- $V_{BUS}$  above  $V_{VBUS\_UVLO}$
- $V_{BUS}$  above battery (not in sleep)
- $V_{BUS}$  below  $V_{ACOV}$  threshold
- $V_{BUS}$  above  $V_{POOSRC}$  (typical 3.8 V) when  $I_{BADSRC}$  (typical 30 mA) current is applied (not a poor source)
- Completed [Section 9.3.2.3](#)

#### 9.3.6.2 Charging Status Indicator (STAT)

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

**Table 9-4. STAT Pin State**

| CHARGING STATE   | STAT INDICATOR   |
|--|------------------|
| Charging in progress (including recharge)  | LOW              |
| Charging termination (top off timer may be running)                                    | HIGH             |
| Sleep mode, charge disable, boost mode   | HIGH             |
| Charge suspend (input overvoltage, TS fault, safety timer fault or system overvoltage) | Blinking at 1 Hz |

### 9.3.7 Protections

#### 9.3.7.1 Input Current Limit

The device's ILIM pin is to program maximum input current when D+/D- detection identifies an unknown adaptor plugged in. The maximum input current is set by a resistor from ILIM pin to ground as:

$$I_{INMAX} = \frac{K_{ILIM}}{R_{ILIM}} \quad (3)$$

### 9.3.7.2 Voltage and Current Monitoring in Converter Operation

The device closely monitors the input and system voltage, as well as internal FET currents for safe buck and boost mode operation.

#### 9.3.7.2.1 Voltage and Current Monitoring in Buck Mode

##### 9.3.7.2.1.1 Input Overvoltage (ACOV)

If VAC exceeds V<sub>VAC\_OV</sub>, HSFET stops switching immediately.

##### 9.3.7.2.1.2 System Overvoltage Protection (SYSOVP)

The charger device clamps the system voltage during load transient so that the components connect to system would not be damaged due to high voltage. SYSOVP threshold is 350 mV above minimum system regulation voltage when the system is regulate at V<sub>SYS\_MIN</sub>. Upon SYSOVP, converter stops switching immediately to clamp the overshoot. The charger provides 30-mA discharge current (I<sub>SYSLOAD</sub>) to bring down the system voltage.

### 9.3.7.3 Voltage and Current Monitoring in Boost Mode

The device closely monitors the VBUS voltage, as well as RBFET and LSFET current to ensure safe boost mode operation.

#### 9.3.7.3.1 VBUS Soft Start

When the boost function is enabled, the device soft-starts boost mode to avoid inrush current.

#### 9.3.7.3.2 VBUS Output Protection

The device monitors boost output voltage and other conditions to provide output short circuit and overvoltage protection. The boost build in accurate constant current regulation to allow OTG to adapt to various types of load. If a short circuit is detected on VBUS, boost turns off and retries 7 times. If retries are not successful, OTG is disabled.

#### 9.3.7.3.3 Boost Mode Overvoltage Protection

When the VBUS voltage rises above regulation target and exceeds VOTG\_OVP, the device stop switching.

### 9.3.7.4 Thermal Regulation and Thermal Shutdown

#### 9.3.7.4.1 Thermal Protection in Buck Mode

The BQ25606 monitors the internal junction temperature T<sub>J</sub> to avoid overheat of the chip and limits the IC surface temperature in buck mode. When the internal junction temperature exceeds thermal regulation limit (110°C), the device lowers down the charge current. During thermal regulation, the actual charging current is usually below the programmed battery charging current. Therefore, termination is disabled, the safety timer runs at half the clock rate.

#### 9.3.7.4.2 Thermal Protection in Boost Mode

The device monitors the internal junction temperature to provide thermal shutdown during boost mode. When IC junction temperature exceeds T<sub>SHUT</sub> (160°C), the boost mode is disabled and BATFET is turned off. When IC junction temperature is below T<sub>SHUT</sub>(160°C) - T<sub>SHUT\_HYS</sub> (30°C), the BATFET is enabled automatically to allow system to restore.

### 9.3.7.5 Battery Protection

#### 9.3.7.5.1 Battery Overvoltage Protection (BATOVP)

The battery overvoltage limit is clamped at 4% above the battery regulation voltage. When battery over voltage occurs, the charger device immediately disables charging.



#### 9.3.7.5.2 Battery Overdischarge Protection

When battery is discharged below  $V_{BAT\_DPL\_FALL}$ , the BATFET is turned off to protect battery from overdischarge. To recover from overdischarge latch-off, an input source plug-in is required at VBUS. The battery is charged with  $I_{SHORT}$  (typically 100 mA) current when the  $V_{BAT} < V_{SHORT}$ , or precharge current as set by 5% of ICHG when the battery voltage is between  $V_{SHORTZ}$  and  $V_{BAT\_LOWV}$ .

#### 9.3.7.5.3 System Overcurrent Protection

When the system is shorted or significantly overloaded ( $I_{BAT} > I_{BATOP}$ ) and the current exceeds BATFET overcurrent limit, the BATFET latches off. The BATFET latch can be reset with VBUS plug-in.

## 10 Application and Implementation

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### Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

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### 10.1 Application Information

A typical application consists of the device configured as a stand-alone power path management device and a single cell battery charger for Li-Ion and Li-polymer batteries used in a wide range of Smartphone and other portable devices. It integrates an input reverse-block FET (RBFET, Q1), high-side switching FET (HSFET, Q2), low-side switching FET (LSFET, Q3), and battery FET (BATFET Q4) between the system and battery. The device also integrates a bootstrap diode for the high-side gate drive.

## 10.2 Typical Application

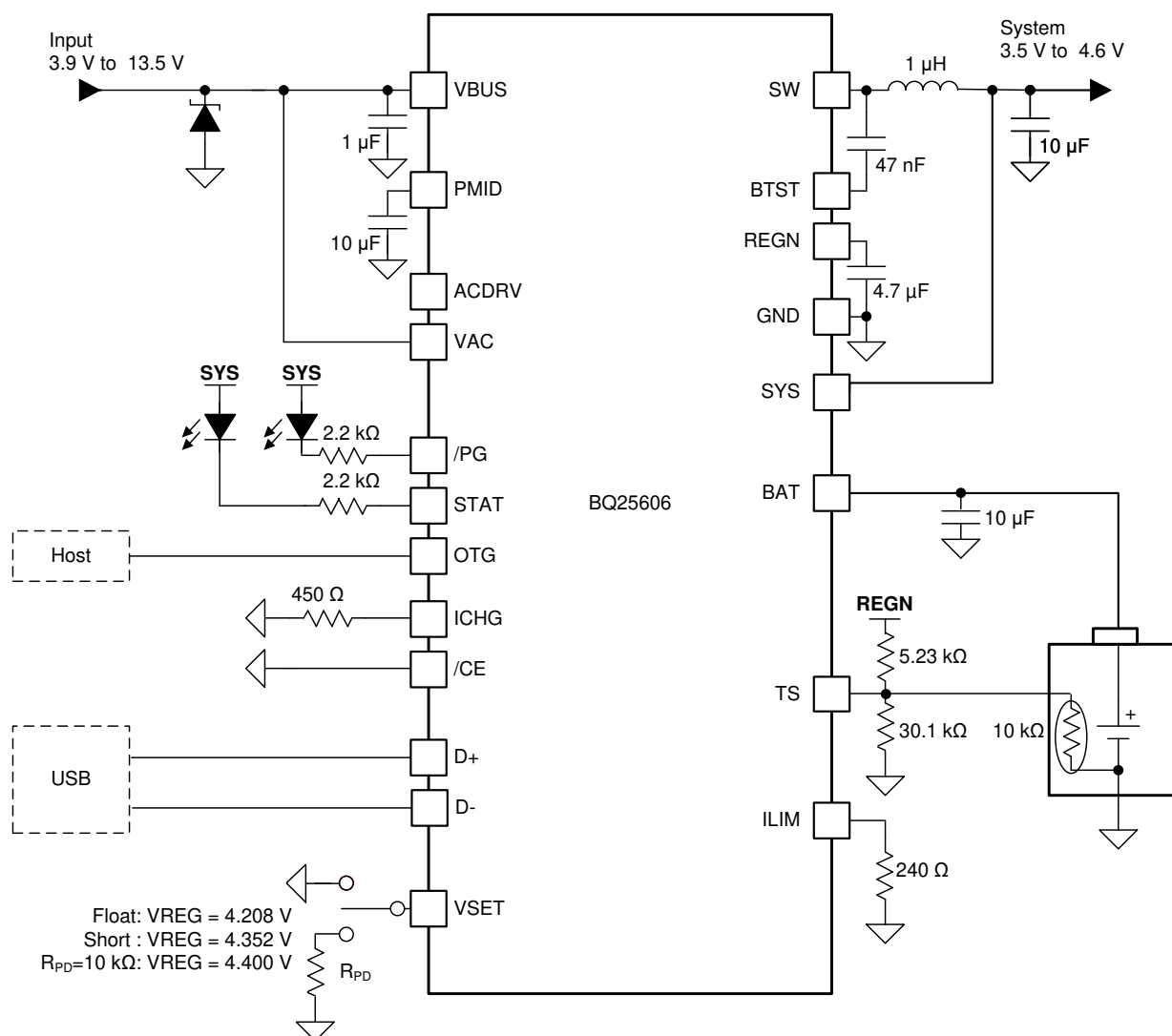


Figure 10-1. BQ25606 Application Diagram

### 10.2.1 Design Requirements

Table 10-1. Design Parameters

| PARAMETER                             | VALUE         |
|---------------------------------------|---------------|
| V <sub>BUS</sub> voltage range        | 4 V to 13.5 V |
| Input current limit (D+/D– detection) | 2.4 A         |
| Fast charge current limit (ICHG pin)  | ICHG pin      |
| Minimum system voltage                | 3.5 V         |
| Battery regulation voltage (VSET pin) | 4.2 V         |

### 10.2.2 Detailed Design Procedure

#### 10.2.2.1 Inductor Selection

The 1.5-MHz switching frequency allows the use of small inductor and capacitor values to maintain an inductor saturation current higher than the charging current (I<sub>CHG</sub>) plus half the ripple current (I<sub>RIPPLE</sub>):

$$I_{SAT} \geq I_{CHG} + (1/2) I_{RIPPLE} \quad (4)$$

The inductor ripple current depends on the input voltage ( $V_{VBUS}$ ), the duty cycle ( $D = V_{BAT}/V_{VBUS}$ ), the switching frequency ( $f_s$ ) and the inductance ( $L$ ).

$$I_{RIPPLE} = \frac{V_{IN} \times D \times (1 - D)}{f_s \times L} \quad (5)$$

The maximum inductor ripple current occurs when the duty cycle ( $D$ ) is 0.5 or approximately 0.5. Usually inductor ripple is designed in the range between 20% and 40% maximum charging current as a trade-off between inductor size and efficiency for a practical design.

#### 10.2.2.2 Input Capacitor

Design input capacitance to provide enough ripple current rating to absorb input switching ripple current. The worst case RMS ripple current is half of the charging current when duty cycle is 0.5. If the converter does not operate at 50% duty cycle, then the worst case capacitor RMS current  $I_{CIN}$  occurs where the duty cycle is closest to 50% and can be estimated using [Equation 6](#).

$$I_{CIN} = I_{CHG} \times \sqrt{D \times (1 - D)} \quad (6)$$

Low ESR ceramic capacitor such as X7R or X5R is preferred for input decoupling capacitor and should be placed to the drain of the high-side MOSFET and source of the low-side MOSFET as close as possible. Voltage rating of the capacitor must be higher than normal input voltage level. A rating of 25 V or higher capacitor is preferred for 15-V input voltage. Capacitance of 22  $\mu$ F is suggested for typical of 3-A charging current.

#### 10.2.2.3 Output Capacitor

Ensure that the output capacitance has enough ripple current rating to absorb the output switching ripple current. [Equation 7](#) shows the output capacitor RMS current  $I_{COUT}$  calculation.

$$I_{COUT} = \frac{I_{RIPPLE}}{2 \times \sqrt{3}} \approx 0.29 \times I_{RIPPLE} \quad (7)$$

The output capacitor voltage ripple can be calculated as follows:

$$\Delta V_O = \frac{V_{OUT}}{8LCf_s^2} \left( 1 - \frac{V_{OUT}}{V_{IN}} \right) \quad (8)$$

At certain input and output voltage and switching frequency, the voltage ripple can be reduced by increasing the output filter LC.

The charger device has internal loop compensation optimized for  $\leq 20$ - $\mu$ F ceramic output capacitance. The preferred ceramic capacitor is 10-V rating, X7R or X5R.

## 10.2.3 Application Curves

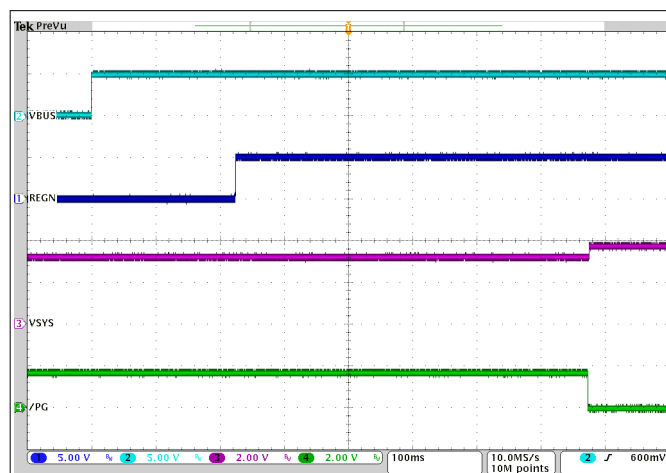
 $V_{\text{VBUS}} = 5 \text{ V}$  $V_{\text{VBAT}} = 3.2 \text{ V}$ 

Figure 10-2. Power Up with Charge Disabled

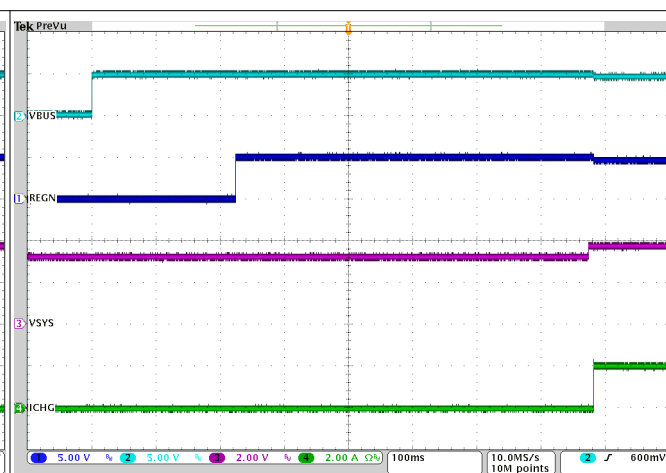
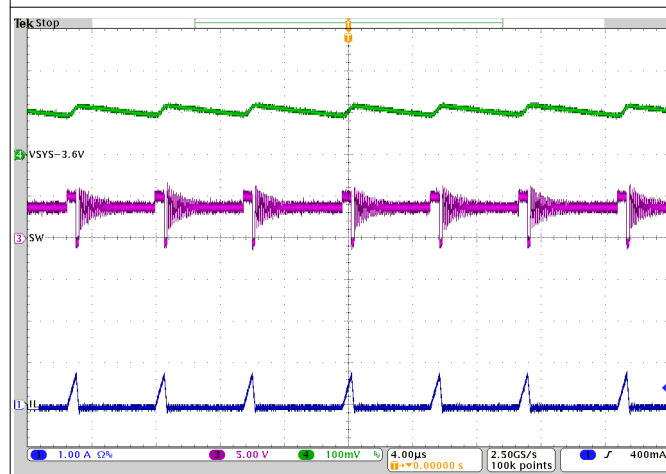
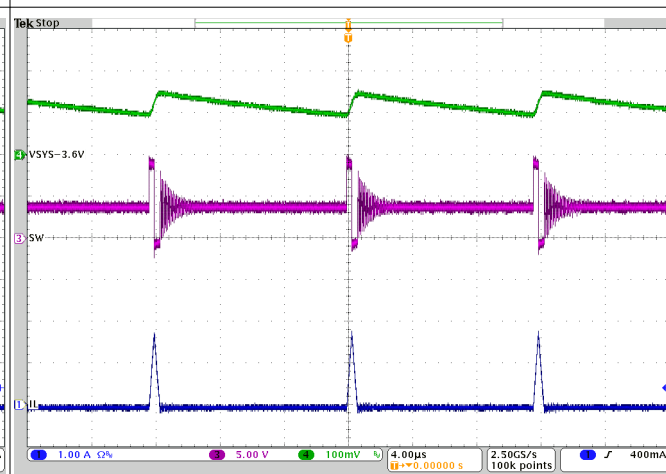
 $V_{\text{VBUS}} = 5 \text{ V}$  $V_{\text{VBAT}} = 3.2 \text{ V}$  $I_{\text{CHG}} = 2 \text{ A}$ 

Figure 10-3. Power Up with Charge Enabled

 $V_{\text{VBUS}} = 5 \text{ V}$  $I_{\text{SYS}} = 50 \text{ mA}$ 

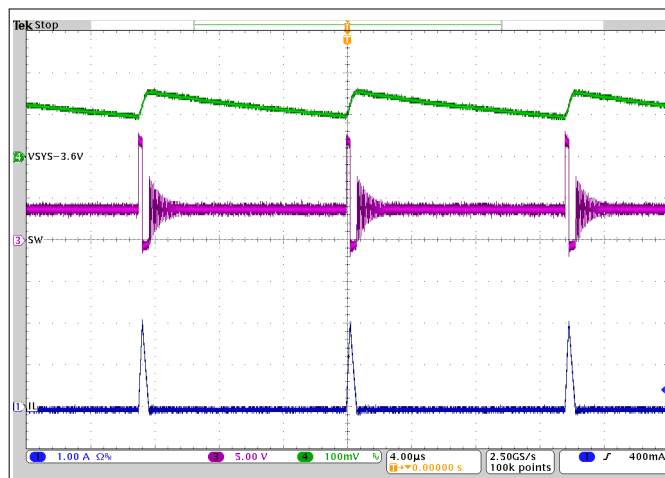
Charge Disabled

Figure 10-4. PFM Switching in Buck Mode

 $V_{\text{VBUS}} = 9 \text{ V}$  $I_{\text{SYS}} = 50 \text{ mA}$ 

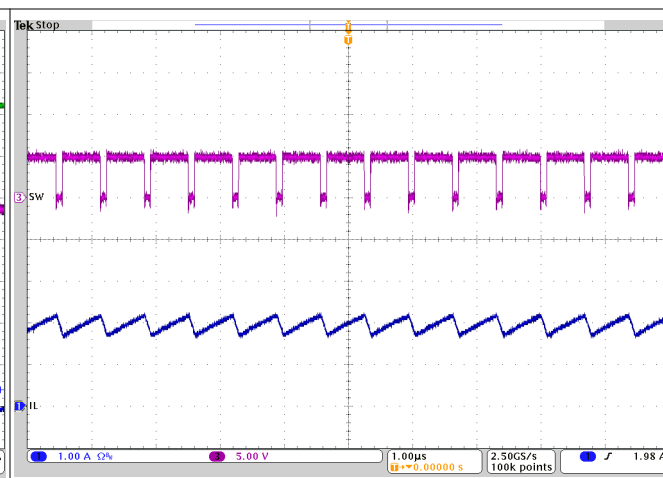
Charge Disabled

Figure 10-5. PFM Switching in Buck Mode



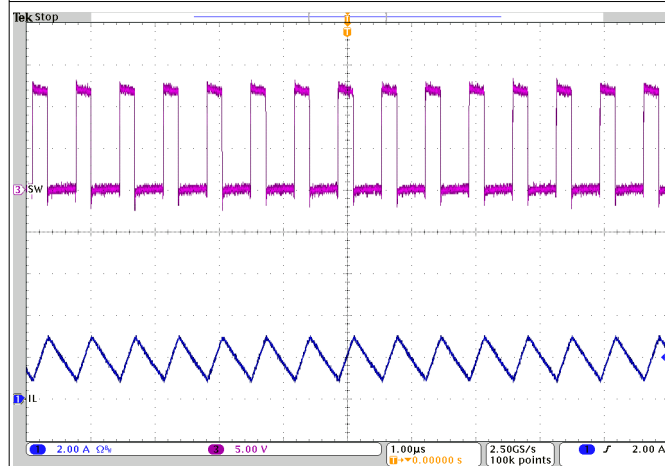
$V_{VBUS} = 12\text{ V}$   
 $I_{SYS} = 50\text{ mA}$  Charge Disabled

**Figure 10-6. PFM Switching in Buck Mode**



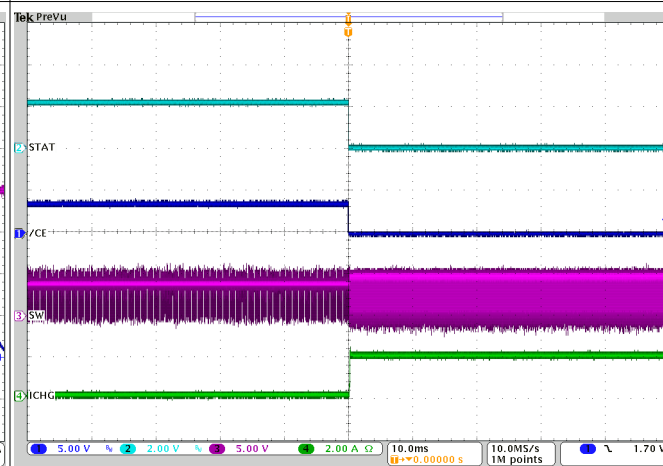
$V_{VBUS} = 5\text{ V}$   $V_{VBAT} = 3.8\text{ V}$   
 $I_{CHG} = 2\text{ A}$

**Figure 10-7. PWM Switching in Buck Mode**



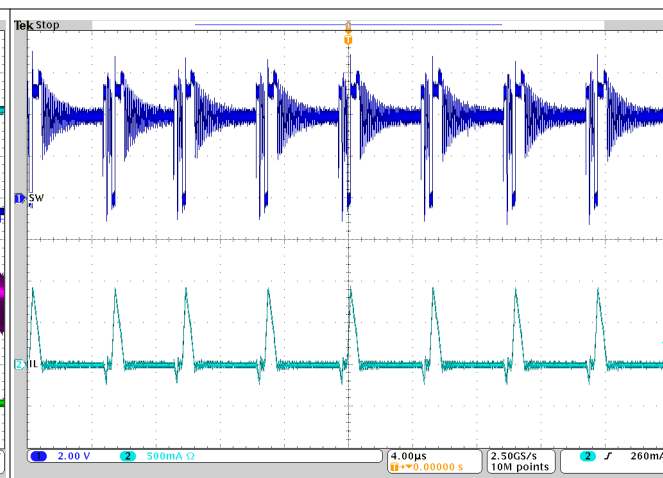
$V_{VBUS} = 12\text{ V}$   $V_{VBAT} = 3.8\text{ V}$   
 $I_{CHG} = 2\text{ A}$

**Figure 10-8. PWM Switching in Buck mode**

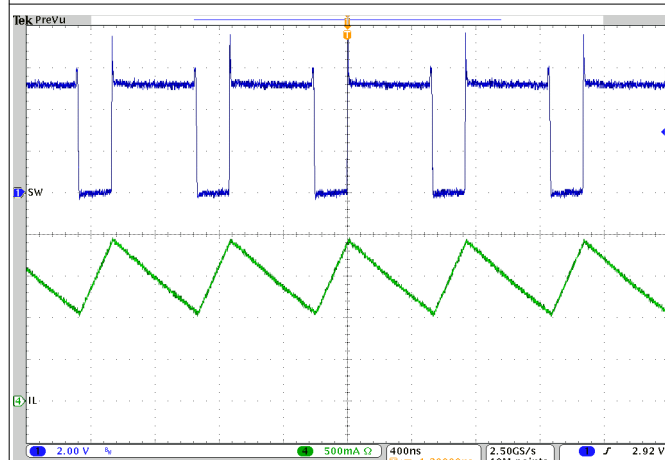


$V_{VBUS} = 5\text{ V}$   $V_{VBAT} = 3.2\text{ V}$   
 $I_{CHG} = 2\text{ A}$

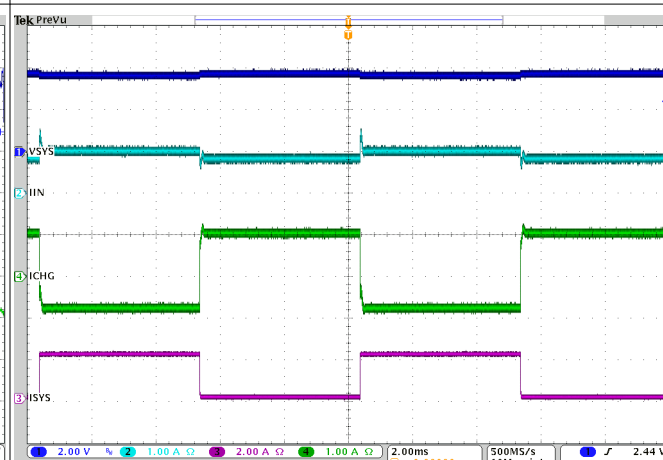
**Figure 10-9. Charge Enable**

 $V_{VBUS} = 5\text{ V}$  $V_{VBAT} = 3.2\text{ V}$  $I_{CHG} = 2\text{ A}$ **Figure 10-10. Charge Disable** $V_{VBAT} = 4\text{ V}$  $I_{LOAD} = 50\text{ mA}$ 

PFM Enabled

**Figure 10-11. OTG Switching** $V_{VBAT} = 4\text{ V}$  $I_{LOAD} = 1\text{ A}$ 

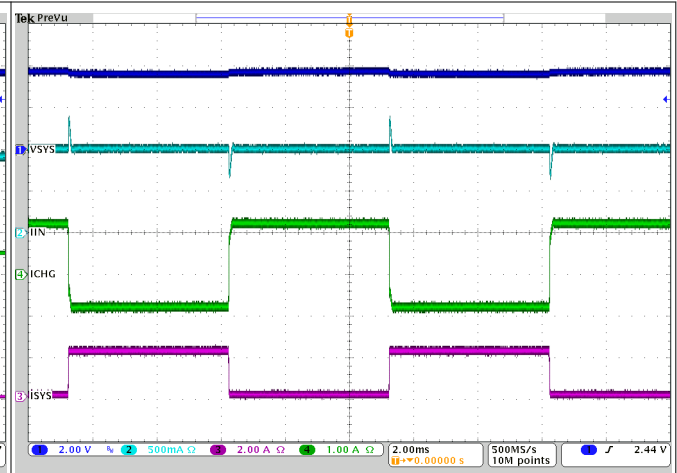
PFM Enabled

**Figure 10-12. OTG Switching** $V_{VBUS} = 5\text{ V}$  $I_{SYS}$  from 0 A to 2 A $V_{BAT} = 3.7\text{ V}$  $I_{INDPM} = 1\text{ A}$  $I_{CHG} = 1\text{ A}$ **Figure 10-13. System Load Transient**



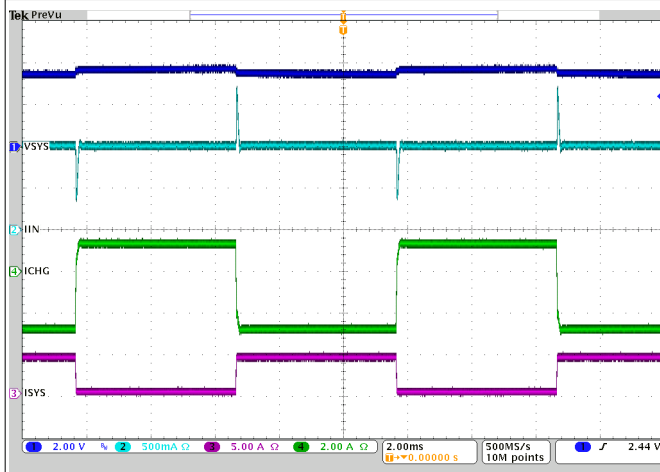
$V_{BUS} = 5\text{ V}$   
 $I_{SYS}$  from 0 A to 4 A  
 $V_{BAT} = 3.7\text{ V}$   
 $I_{INDPM} = 2\text{ A}$   
 $I_{CHG} = 1\text{ A}$

**Figure 10-14. System Load Transient**



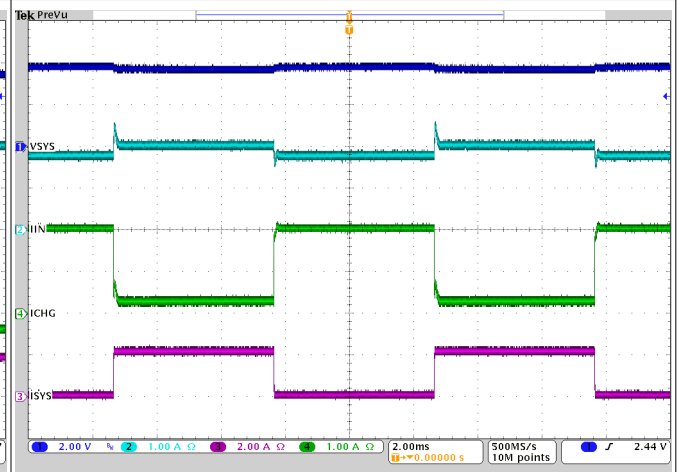
$V_{BUS} = 5\text{ V}$   
 $I_{SYS}$  from 0 A to 2 A  
 $V_{BAT} = 3.7\text{ V}$   
 $I_{INDPM} = 1\text{ A}$   
 $I_{CHG} = 2\text{ A}$

**Figure 10-15. System Load Transient**



$V_{BUS} = 5\text{ V}$   
 $I_{SYS}$  from 0 A to 4 A  
 $V_{BAT} = 3.7\text{ V}$   
 $I_{INDPM} = 1\text{ A}$   
 $I_{CHG} = 2\text{ A}$

**Figure 10-16. System Load Transient**

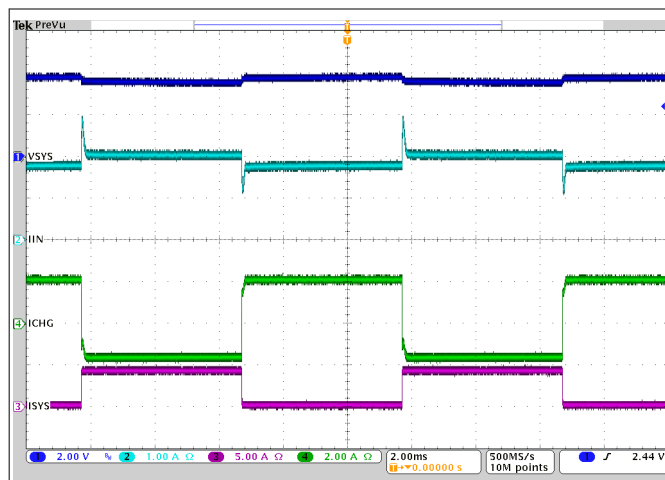


$V_{BUS} = 5\text{ V}$   
 $I_{SYS}$  from 0 A to 2 A  
 $V_{BAT} = 3.7\text{ V}$   
 $I_{INDPM} = 2\text{ A}$   
 $I_{CHG} = 2\text{ A}$

**Figure 10-17. System Load Transient**

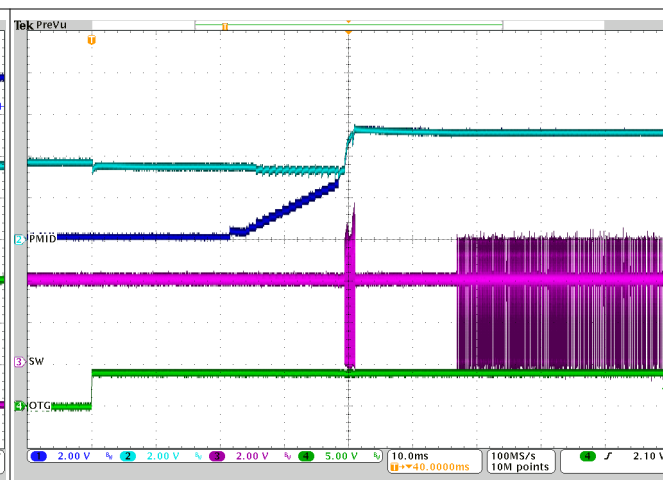
# BQ25606

SLUSCK6C – MAY 2017 – REVISED SEPTEMBER 2021



$V_{VBUS} = 5\text{ V}$   
 $I_{SYS}$  from 0 A to 4 A  
 $V_{BAT} = 3.7\text{ V}$   
 $I_{INDPM} = 2\text{ A}$   
 $I_{CHG} = 2\text{ A}$

**Figure 10-18. System Load Transient**



$V_{BAT} = 3.8\text{ V}$   
 $C_{LOAD} = 470\text{ }\mu\text{F}$

**Figure 10-19. OTG Start Up**



## 11 Power Supply Recommendations

In order to provide an output voltage on SYS, the BQ25606 device requires a power supply between 3.9-V and 13.5-V input with at least 100-mA current rating connected to VBUS and a single-cell Li-Ion battery with voltage  $> V_{BATUVLO}$  connected to BAT. The source current rating needs to be at least 3 A in order for the buck converter of the charger to provide maximum output power to SYS.

## 12 Layout

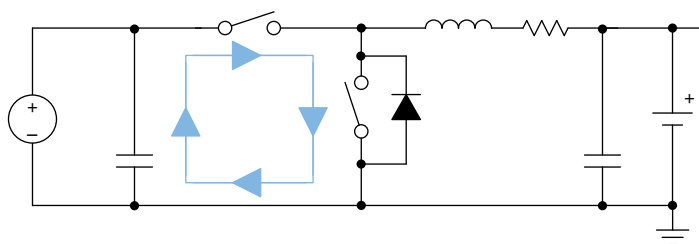
### 12.1 Layout Guidelines

The switching node rise and fall times should be minimized for minimum switching loss. Proper layout of the components to minimize high frequency current path loop (see [Figure 12-1](#)) is important to prevent electrical and magnetic field radiation and high frequency resonant problems. Follow this specific order carefully to achieve the proper layout.

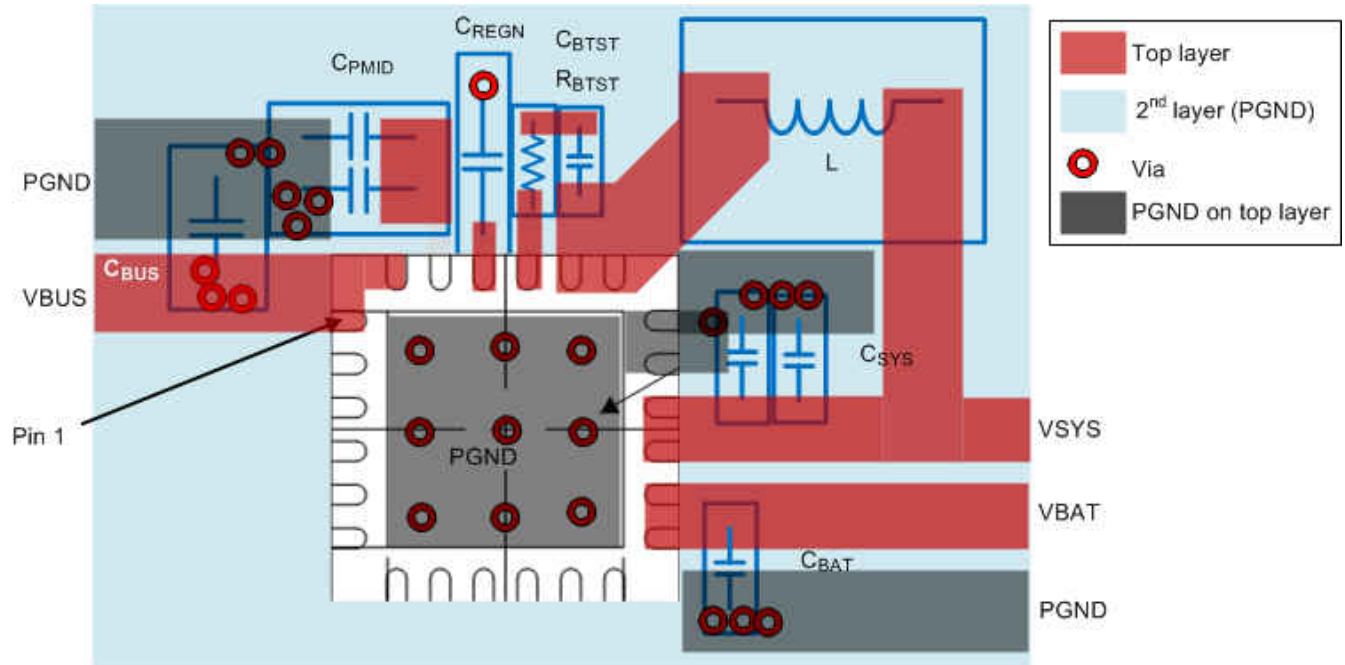
1. Place input capacitor as close as possible to PMID pin and GND pin connections and use shortest copper trace connection or GND plane.
2. Place inductor input pin to SW pin as close as possible. Minimize the copper area of this trace to lower electrical and magnetic field radiation but make the trace wide enough to carry the charging current. Do not use multiple layers in parallel for this connection. Minimize parasitic capacitance from this area to any other trace or plane.
3. Put output capacitor near to the inductor and the device. Ground connections need to be tied to the IC ground with a short copper trace connection or GND plane.
4. Route analog ground separately from power ground. Connect analog ground and connect power ground separately. Connect analog ground and power ground together using thermal pad as the single ground connection point. Or using a 0-Ω resistor to tie analog ground to power ground.
5. Use single ground connection to tie charger power ground to charger analog ground. Just beneath the device. Use ground copper pour but avoid power pins to reduce inductive and capacitive noise coupling.
6. Place decoupling capacitors next to the IC pins and make trace connection as short as possible.
7. It is critical that the exposed thermal pad on the backside of the device package be soldered to the PCB ground. Ensure that there are sufficient thermal vias directly under the IC, connecting to the ground plane on the other layers.
8. Ensure that the number and sizes of vias allow enough copper for a given current path.

Refer to the [BQ25601 and BQ25601D \(PWR877\) Evaluation Module User's Guide](#) for the recommended component placement with trace and via locations. For the VQFN information, refer to the [Quad Flatpack No-Lead Logic Packages Application Report](#) and [QFN and SON PCB Attachment Application Report](#).

### 12.2 Layout Example



**Figure 12-1. High Frequency Current Path**



**Figure 12-2. Layout Example**

## 13 Device and Documentation Support

### 13.1 Device Support

#### 13.1.1 Third-Party Products Disclaimer

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#### 13.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on [ti.com](http://ti.com). Click on *Subscribe to updates* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

#### 13.3 Support Resources

[TI E2E™ support forums](#) are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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#### 13.5 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

#### 13.6 Glossary

[TI Glossary](#) This glossary lists and explains terms, acronyms, and definitions.

## 14 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.

## PACKAGING INFORMATION

| Orderable part number       | Status<br>(1) | Material type<br>(2) | Package   Pins  | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|-----------------------------|---------------|----------------------|-----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">BQ25606RGER</a> | Active        | Production           | VQFN (RGE)   24 | 3000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 85    | BQ25606             |
| <a href="#">BQ25606RGET</a> | Active        | Production           | VQFN (RGE)   24 | 250   SMALL T&R       | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 85    | BQ25606             |

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **Lead finish/Ball material:** Parts 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.

<sup>(5)</sup> **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

**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.

## 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 |
|-------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| BQ25606RGER | VQFN         | RGE             | 24   | 3000 | 330.0              | 12.4               | 4.25    | 4.25    | 1.15    | 8.0     | 12.0   | Q2            |
| BQ25606RGET | VQFN         | RGE             | 24   | 250  | 180.0              | 12.4               | 4.25    | 4.25    | 1.15    | 8.0     | 12.0   | Q2            |

## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

| Device      | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|-------------|--------------|-----------------|------|------|-------------|------------|-------------|
| BQ25606RGER | VQFN         | RGE             | 24   | 3000 | 367.0       | 367.0      | 35.0        |
| BQ25606RGET | VQFN         | RGE             | 24   | 250  | 210.0       | 185.0      | 35.0        |



**RGE 24**

**GENERIC PACKAGE VIEW**

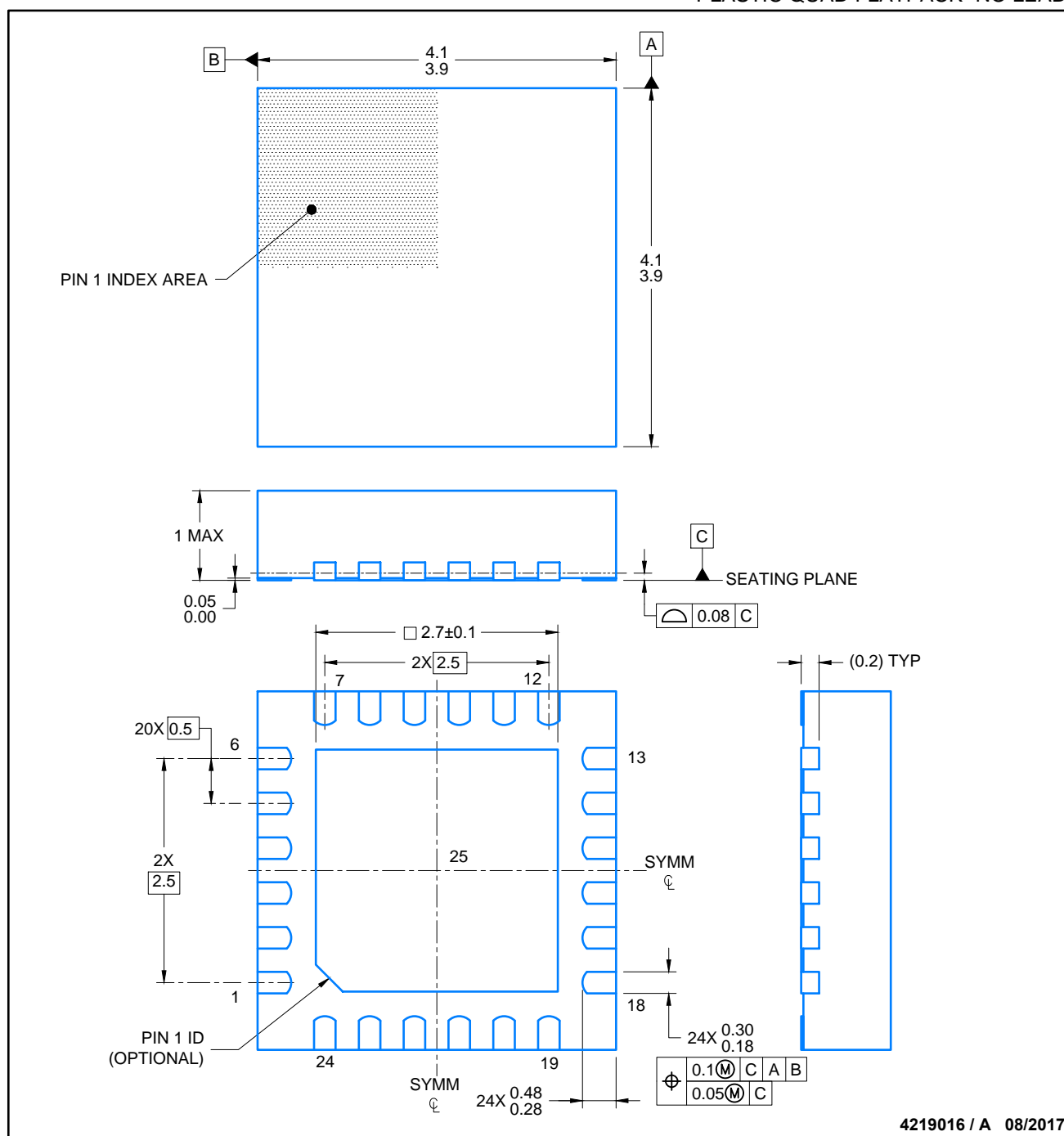
**VQFN - 1 mm max height**

PLASTIC QUAD FLATPACK - NO LEAD



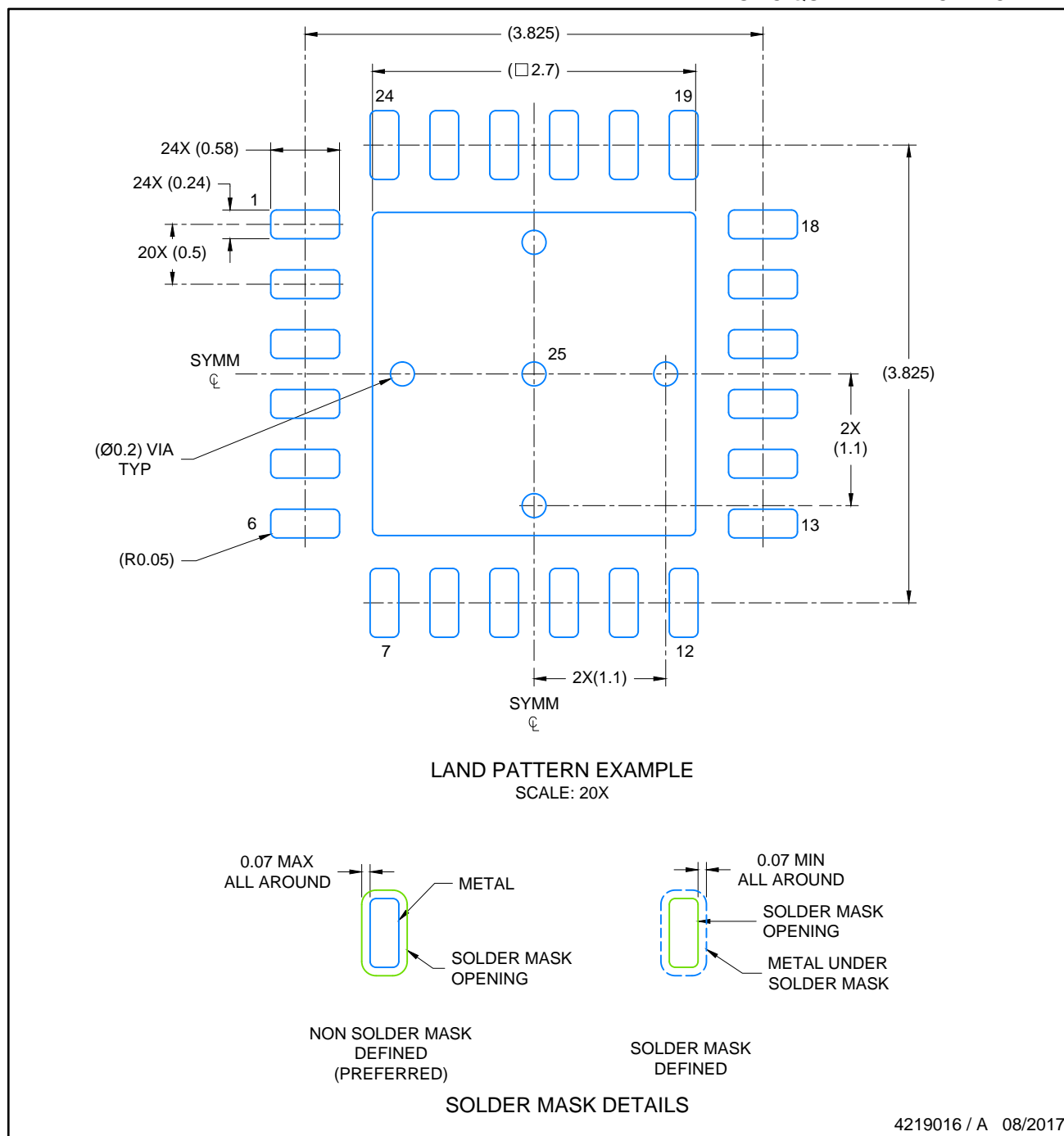
Images above are just a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.

4204104/H



## NOTES:

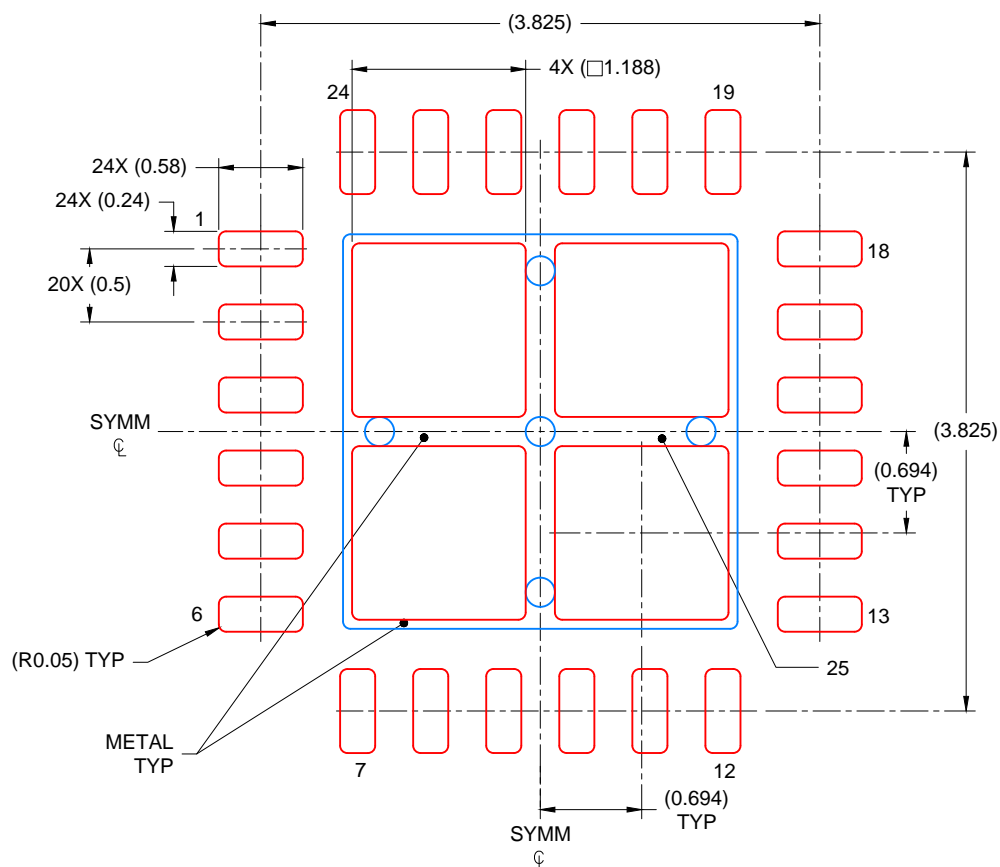
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.



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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/sluea271](http://www.ti.com/lit/sluea271)).
5. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD  
78% PRINTED COVERAGE BY AREA  
SCALE: 20X

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NOTES: (continued)

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

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