1A, Single-Input, Single Cell Li-Ion Battery Charger with 50-mA LDO, External Power Path Control, and Single Input Interface

Check for Samples: bq25050

FEATURES
• 30V input Rating, With 10.5V Over-Voltage Protection (OVP)
• FET Controller for External Battery FET for External Power Path Control (BGATE)
• Input Voltage Dynamic Power Management
• 50mA integrated Low Dropout Linear Regulator (LDO)
• Programmable Charge Current Through Single Input Interface (CTRL)
• 0.5% Battery Voltage Regulation Accuracy
• 7% Charge Current Regulation Accuracy
• Thermal Regulation and Protection
• Battery NTC Monitoring During Charge and Discharge
• Status Indication – Charging/Done and Temperature Faults
• Available in small 2mm × 3mm 10 Pin SON Package

APPLICATIONS
• Smart Phones
• Mobile Phones
• Portable Media Players
• Low Power Handheld Devices

DESCRIPTION
The bq25050 is a highly integrated Li-Ion linear battery charger targeted at space-limited portable applications. It operates from either a USB port or AC Adapter and charges a single-cell Li-Ion battery with up to 1A of charge current. The 30V input voltage range with input over-voltage protections supports low-cost unregulated adapters.

The bq25050 has a single power output that charges the battery. The system load is connected to OUT. The low-battery system startup circuitry maintains OUT greater than 3.4V whenever an input source is connected. This allows the system to start-up and run whenever an input source is connected regardless of the battery voltage. The charge current is programmable up to 1A using the CTRL input. Additionally, a 4.9V 50mA LDO is integrated into the IC for supplying low power external circuitry.

The battery is charged in three phases: conditioning, constant current and constant voltage. In all charge phases, an internal control loop monitors the IC junction temperature and reduces the charge current if an internal temperature threshold is exceeded. The charger power stage and charge current sense functions are fully integrated. The charger function has high accuracy current and voltage regulation loops, charge status display, and charge termination.

Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.
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.

### ORDERING INFORMATION

<table>
<thead>
<tr>
<th>PART NO.</th>
<th>MARKING</th>
<th>MEDIUM</th>
<th>QUANTITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>bq25050DQCR</td>
<td>DAM</td>
<td>Tape and Reel</td>
<td>3000</td>
</tr>
<tr>
<td>bq25050DQCT</td>
<td>DAM</td>
<td>Tape and Reel</td>
<td>250</td>
</tr>
</tbody>
</table>

### PACKAGE DISSIPATION RATINGS TABLE

<table>
<thead>
<tr>
<th>PACKAGE</th>
<th>$R_{JA}$</th>
<th>$R_{JC}$</th>
<th>$T_A &lt; 25^\circ C$ POWER RATING</th>
<th>DERATING FACTOR ABOVE $T_A = 25^\circ C$</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 Pin 2mm × 3mm SON&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>58.7°C/W</td>
<td>3.9°C/W</td>
<td>1.70W</td>
<td>0.017W/°C</td>
</tr>
</tbody>
</table>

<sup>(1)</sup> Maximum power dissipation is a function of $T_{J(max)}$, $R_{JA}$, and $T_A$. The maximum allowable power dissipation at any allowable ambient temperature is $PD = [T_{J(max)} - T_A]/R_{JA}$.

<sup>(2)</sup> This data is based on using the JEDEC High-K board and the exposed die pad is connected to a Cu pad on the board. The pad is connected to the ground plane by a 2 x 3 via matrix.

### ABSOLUTE MAXIMUM RATINGS<sup>(1)</sup>

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

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Voltage</td>
<td>IN (with respect to VSS)</td>
<td>3.55</td>
<td>28</td>
<td>V</td>
</tr>
<tr>
<td>Control, TS, CHG, BGATE (with respect to VSS)</td>
<td>4.4</td>
<td>10.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Voltage</td>
<td>BAT, OUT, LDO, CHG, BGATE, IMON (with respect to VSS)</td>
<td>1.2</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>Input Current (Continuous)</td>
<td>IN</td>
<td>100 mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Current (Continuous)</td>
<td>BAT</td>
<td>5 mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Sink Current</td>
<td>CHG</td>
<td>1 A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Junction temperature, $T_J$</td>
<td>0</td>
<td>125</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Storage temperature, $T_{STG}$</td>
<td>−65°C to 150°C</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>(1)</sup> Stresses beyond those listed under absolute maximum ratings may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under recommended operating conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability. All voltage values are with respect to the network ground terminal unless otherwise noted.

### RECOMMENDED OPERATING CONDITIONS

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

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>MIN</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{IN}$</td>
<td>3.55</td>
<td>28</td>
<td>V</td>
</tr>
<tr>
<td>$I_{IN}$</td>
<td>4.4</td>
<td>10.2</td>
<td></td>
</tr>
<tr>
<td>$I_{OUT}$</td>
<td>1</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>$T_J$</td>
<td>0</td>
<td>125</td>
<td>°C</td>
</tr>
</tbody>
</table>

### ELECTRICAL CHARACTERISTICS

Over junction temperature range $0^\circ C \leq T_J \leq 125^\circ C$ and VIN = 5V (unless otherwise noted)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{UVLO}$</td>
<td>Under-voltage lock-out</td>
<td>$V_{AC} 0V \rightarrow 4V$</td>
<td>3.25</td>
<td>3.30</td>
<td>3.55</td>
</tr>
<tr>
<td>$V_{HYS-UVLO}$</td>
<td>Hysteresis on UVLO</td>
<td>$V_{AC} 4V \rightarrow 0V$</td>
<td>250</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### ELECTRICAL CHARACTERISTICS (continued)

Over junction temperature range 0°C ≤ $T_J$ ≤ 125°C and VIN = 5V (unless otherwise noted)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{BAT\text{UVLO}}$</td>
<td>Battery UVLO</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{VBS-BAT\text{UVLO}}$</td>
<td>Hysteresis on BAT UVLO</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{\text{IN-SLP}}$</td>
<td>Valid input source threshold $V_{\text{IN-SLP}}$ above $V_{\text{BAT}}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_{\text{OGL(NO-IN)}}$</td>
<td>Deglitch time, input power loss to charger turn-off</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{\text{DVP}}$</td>
<td>Input over-voltage protection threshold</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{\text{IN-SLP}}$</td>
<td>Valid input source threshold $V_{\text{IN-SLP}}$ above $V_{\text{BAT}}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_{\text{REC(OVP)}}$</td>
<td>Input over-voltage deglitch time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{\text{IN} (PDWN)}$</td>
<td>Battery current into BAT, No input connected</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_{\text{BAT(DONE)}}$</td>
<td>BAT current, charging terminated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_{\text{CC}}$</td>
<td>Active supply current, IN pin</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### QUIESCENT CURRENT

- $I_{\text{BAT(PDWN)}}$: Battery current into BAT, No input connected
- $I_{\text{BAT(DONE)}}$: BAT current, charging terminated
- $I_{\text{CC}}$: Active supply current, IN pin

#### BATTERY CHARGER FAST-CHARGE

- $V_{\text{BAT(REG)}}$: Battery charge regulation voltage

#### PRE-CHARGE AND CHARGE DONE

- $V_{\text{LOWV}}$: Pre-charge to fast-charge transition threshold
- $I_{\text{OGL1,LOWV}}$: Deglitch time on pre-charge to fast-charge transition
- $I_{\text{OGL2,LOWV}}$: Deglitch time on fast-charge to pre-charge transition
- $I_{\text{PRECHARGE}}$: Precharge current to BAT during precharge mode
- $I_{\text{TERM}}$: Default termination current threshold

#### RECHARGE OR REFRESH

- $V_{\text{RCH}}$: Recharge detection threshold

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Product Folder Link(s): bq25050
**ELECTRICAL CHARACTERISTICS (continued)**

Over junction temperature range 0 °C ≤ T<sub>J</sub> ≤ 125 °C and VIN = 5V (unless otherwise noted)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>t&lt;sub&gt;DGL(RCH)&lt;/sub&gt;</td>
<td>Deglitch time, recharge threshold detected</td>
<td>25</td>
<td>ms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V&lt;sub&gt;OUT(REG)&lt;/sub&gt;</td>
<td>Output regulation voltage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V&lt;sub&gt;BAT&lt;/sub&gt; ≤ 2.9 V</td>
<td></td>
<td>3.4</td>
<td>3.5</td>
<td>3.6</td>
<td>V</td>
</tr>
<tr>
<td>V&lt;sub&gt;BAT&lt;/sub&gt; &gt; 2.9 V</td>
<td></td>
<td>3.44</td>
<td>3.59</td>
<td>3.75</td>
<td>V</td>
</tr>
<tr>
<td>V&lt;sub&gt;BAT&lt;/sub&gt; + V&lt;sub&gt;AVG(BAT)&lt;/sub&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V&lt;sub&gt;supp1&lt;/sub&gt;</td>
<td>Enter supplement mode threshold</td>
<td>V&lt;sub&gt;BAT&lt;/sub&gt; = 3.4 V, V&lt;sub&gt;OUT&lt;/sub&gt; Falling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V&lt;sub&gt;supp2&lt;/sub&gt;</td>
<td>Exit supplement mode threshold</td>
<td>V&lt;sub&gt;BAT&lt;/sub&gt; = 3.4 V, V&lt;sub&gt;OUT&lt;/sub&gt; Rising</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDO</td>
<td>LDO Output Voltage</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt; = 5.5V, I&lt;sub&gt;LDO&lt;/sub&gt; = 0mA to 50mA</td>
<td>4.1</td>
<td>4.9</td>
<td>5.1</td>
</tr>
<tr>
<td>I&lt;sub&gt;LDO&lt;/sub&gt;</td>
<td>Maximum LDO Output Current</td>
<td></td>
<td>60</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>V&lt;sub&gt;DO&lt;/sub&gt;</td>
<td>Dropout Voltage</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt; = 4.5V, I&lt;sub&gt;DO&lt;/sub&gt; = 50mA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTRL INTERFACE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>t&lt;sub&gt;CTRL-DGL&lt;/sub&gt;</td>
<td>CTRL Deglitch timer</td>
<td>5</td>
<td>ms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>t&lt;sub&gt;CTRL-LATCH&lt;/sub&gt;</td>
<td>CTRL Latch timer</td>
<td>2</td>
<td>ms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>t&lt;sub&gt;CTRL-HIGH&lt;/sub&gt;</td>
<td>High Duration on CTRL</td>
<td>50</td>
<td>1000</td>
<td>µs</td>
<td></td>
</tr>
<tr>
<td>t&lt;sub&gt;CTRL-LOW&lt;/sub&gt;</td>
<td>Low Time Duration on CTRL</td>
<td>50</td>
<td>1000</td>
<td>µs</td>
<td></td>
</tr>
<tr>
<td>R&lt;sub&gt;PULLDOWN&lt;/sub&gt;</td>
<td>CTRL Pulldown Resistor</td>
<td>260</td>
<td>kΩ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOGIC LEVELS ON CTRL, CHG, BGATE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V&lt;sub&gt;L&lt;/sub&gt;</td>
<td>Logic LOW input voltage</td>
<td></td>
<td></td>
<td>0.4</td>
<td>V</td>
</tr>
<tr>
<td>V&lt;sub&gt;H&lt;/sub&gt;</td>
<td>Logic HIGH input voltage</td>
<td></td>
<td></td>
<td>1.4</td>
<td>V</td>
</tr>
<tr>
<td>BATTERY-PACK NTC MONITOR (TS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V&lt;sub&gt;TS_CLAMP&lt;/sub&gt;</td>
<td>Maximum TS Voltage</td>
<td></td>
<td></td>
<td>1.5</td>
<td>V</td>
</tr>
<tr>
<td>I&lt;sub&gt;TS-0C&lt;/sub&gt;</td>
<td>Current source for 0 °C TS sensing</td>
<td>3.75</td>
<td>4</td>
<td>4.25</td>
<td>µA</td>
</tr>
<tr>
<td>I&lt;sub&gt;TS&lt;/sub&gt;</td>
<td>Current source for 45 °C and 60 °C TS sensing</td>
<td>19</td>
<td>20</td>
<td>21</td>
<td>µA</td>
</tr>
<tr>
<td>V&lt;sub&gt;COLD&lt;/sub&gt;</td>
<td>TS Cold Threshold, when BGATE is disabled</td>
<td>V&lt;sub&gt;TS&lt;/sub&gt; &lt; V&lt;sub&gt;COLD&lt;/sub&gt; to begin charge</td>
<td>0.55</td>
<td>0.575</td>
<td>0.600</td>
</tr>
<tr>
<td>V&lt;sub&gt;CUTOFF_0&lt;/sub&gt;</td>
<td>TS Cold Cutoff Threshold</td>
<td>Temp falling (Corresponds to –1 °C, 1 °C, 3 °C)</td>
<td>0.575</td>
<td>0.600</td>
<td>0.625</td>
</tr>
<tr>
<td>V&lt;sub&gt;HOT_45&lt;/sub&gt;</td>
<td>TS Hot Threshold (0 °C to 45 °C), when BGATE is disabled</td>
<td>V&lt;sub&gt;TS&lt;/sub&gt; &gt; V&lt;sub&gt;HOT_45&lt;/sub&gt; to begin charge, 0 °C to 45 °C thresholds selected. (Corresponds to 40 °C, 45 °C, 44 °C)</td>
<td>0.44</td>
<td>0.45</td>
<td>0.46</td>
</tr>
<tr>
<td>V&lt;sub&gt;CUTOFF_45&lt;/sub&gt;</td>
<td>TS Hot Cutoff Threshold (0 °C to 45 °C)</td>
<td>Temp rising (Corresponds to 45 °C, 47 °C, 49 °C)</td>
<td>0.365</td>
<td>0.375</td>
<td>0.385</td>
</tr>
<tr>
<td>V&lt;sub&gt;HOT_60&lt;/sub&gt;</td>
<td>TS Hot Threshold (0 °C to 60 °C), when BGATE is disabled</td>
<td>V&lt;sub&gt;TS&lt;/sub&gt; &gt; V&lt;sub&gt;HOT_60&lt;/sub&gt; to begin charge, 0 °C to 60 °C thresholds selected, Temp rising (Corresponds to 54.5 °C, 57 °C, 60 °C)</td>
<td>0.240</td>
<td>0.250</td>
<td>0.258</td>
</tr>
<tr>
<td>V&lt;sub&gt;CUTOFF_60&lt;/sub&gt;</td>
<td>TS Hot Cutoff Threshold (0 °C to 60 °C)</td>
<td>Temp rising, (Corresponds to 58.5 °C, 61.5 °C, 64 °C)</td>
<td>0.204</td>
<td>0.213</td>
<td>0.223</td>
</tr>
<tr>
<td>V&lt;sub&gt;20&lt;/sub&gt;</td>
<td>–20 °C TS Voltage</td>
<td>See (1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V&lt;sub&gt;60&lt;/sub&gt;</td>
<td>+80 °C TS Voltage</td>
<td>See (1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>t&lt;sub&gt;dgl(TS)&lt;/sub&gt;</td>
<td>Deglitch for TS Fault</td>
<td>Fault detected on TS to stop charge</td>
<td>25</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td>CRG OUTPUT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V&lt;sub&gt;OL&lt;/sub&gt;</td>
<td>Output LOW voltage</td>
<td>I&lt;sub&gt;SINK&lt;/sub&gt; = 5 mA</td>
<td>0.45</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>I&lt;sub&gt;L&lt;/sub&gt;</td>
<td>Leakage current</td>
<td>V&lt;sub&gt;CHG&lt;/sub&gt; = 5 V</td>
<td>1</td>
<td>µA</td>
<td></td>
</tr>
<tr>
<td>t&lt;sub&gt;FLSH(TS)&lt;/sub&gt;</td>
<td>TS fault flash period</td>
<td>50% Duty Cycle, TS out of valid range</td>
<td>100</td>
<td>ms</td>
<td></td>
</tr>
<tr>
<td>THERMAL REGULATION</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T&lt;sub&gt;REG&lt;/sub&gt;</td>
<td>Temperature Regulation Limit</td>
<td>T&lt;sub&gt;J&lt;/sub&gt; rising</td>
<td>125</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>T&lt;sub&gt;OFF&lt;/sub&gt;</td>
<td>Thermal shutdown temperature</td>
<td>T&lt;sub&gt;J&lt;/sub&gt; rising</td>
<td>155</td>
<td>°C</td>
<td></td>
</tr>
</tbody>
</table>

(1) Information is based on using the NCP15WB473F NTC thermistor.
(2) Temperature references give design guidance only, actual absolute temperatures are not guaranteed.
ELECTRICAL CHARACTERISTICS (continued)
Over junction temperature range 0°C ≤ \( T_J \) ≤ 125°C and VIN = 5V (unless otherwise noted)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T_{J(OFF-HYS)} )</td>
<td>Thermal shutdown hysteresis</td>
<td>( T_J ) falling</td>
<td>20</td>
<td></td>
<td>°C</td>
</tr>
</tbody>
</table>

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PIN CONFIGURATION

<table>
<thead>
<tr>
<th>PIN</th>
<th>I/O</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>IN</td>
<td>1</td>
<td>I Input power supply. IN is connected to the external DC supply (AC adapter or USB port). Bypass IN to VSS with at least a 0.1µF ceramic capacitor.</td>
</tr>
<tr>
<td>IMON</td>
<td>2</td>
<td>O Current monitoring output. Connect a 1kΩ resistor from IMON to VSS to monitor the input current. The voltage at IMON ranges from 0V to 1V which corresponds to an input current from 0A to 1A.</td>
</tr>
<tr>
<td>VSS</td>
<td>3</td>
<td>– Ground terminal. Connect to the thermal pad and the ground plane of the circuit.</td>
</tr>
<tr>
<td>LDO</td>
<td>4</td>
<td>O LDO output. LDO is regulated to 4.9V and drives up to 50mA. Bypass LDO to VSS with a 0.1µF ceramic capacitor. LDO is enabled when $V_{UVLO} &lt; V_{IN} &lt; V_{OVP}$.</td>
</tr>
<tr>
<td>TS</td>
<td>5</td>
<td>I Battery pack NTC monitoring input. Connect the battery pack 47-kΩ NTC from TS to VSS to monitor battery pack temperature. The default pack temperature range is 0°C to 45°C thresholds.</td>
</tr>
<tr>
<td>CTRL</td>
<td>7</td>
<td>I Single-input interface input. Drive CTRL with pulses to enable/disable the device, enable/disable $V_{IN}$ DPM, select battery temperature range and select current limits. See the interface section for details on using the CTRL interface.</td>
</tr>
<tr>
<td>CHG</td>
<td>8</td>
<td>I/O Charge status indicator open-drain output. CHG is pulled low while the device is charging the battery. CHG goes high impedance when the battery is fully charged and does not indicate subsequent recharge cycles. CHG pulses to indicate TS faults.</td>
</tr>
<tr>
<td>BAT</td>
<td>6</td>
<td>O Battery connection output. BAT is the sense input for the battery as well as the precharge current output. Connect BAT to the battery and bypass BAT to VSS with a 0.1µF ceramic capacitor.</td>
</tr>
<tr>
<td>BGATE</td>
<td>9</td>
<td>I/O Battery P-Channel FET gate drive output. Connect BGATE to the gate of the external P-Channel FET that connects the battery to OUT. Connect BGATE to VSS if the external FET is not used. No external capacitor is recommended from BGATE to GND.</td>
</tr>
<tr>
<td>OUT</td>
<td>10</td>
<td>O System output connection. OUT supplies the system with a minimum voltage of 3.4V (min.) to ensure system operation whenever an input adapter is connected regardless of the battery voltage. Bypass OUT to VSS with a 1µF ceramic capacitor.</td>
</tr>
<tr>
<td>Thermal PAD</td>
<td>Pad</td>
<td>– There is an internal electrical connection between the exposed thermal pad and the VSS pin of the device. The thermal pad must be connected to the same potential as the VSS pin on the printed circuit board. Do not use the thermal pad as the primary ground input for the device. VSS pin must be connected to ground at all times.</td>
</tr>
</tbody>
</table>
APPLICATION CIRCUITS

Figure 1. Typical Application Circuit Using the External Power Path Control Feature

Figure 2. Typical Application Circuit Disabling the External Power Path Control Feature
TYPICAL CHARACTERISTICS

Using circuit in Figure 1, $T_A = 25^\circ C$, unless otherwise specified

**ADAPTER INSERTION**
- $V_{IN} = 0 \text{ V} - 5 \text{ V}, V_{BAT} = 3.3 \text{ V}, I_{CHG} = 280 \text{ mA}$
- $V_{IN} = 5 \text{ V/div}$
- $BGATE = 2 \text{ V/div}$
- $LDO = 2 \text{ V/div}$
- $I = 0.5 \text{ A/div}$

**ENABLE USING CTRL**
- $V_{IN} = 5 \text{ V}, V_{BAT} = 3 \text{ V}, I_{CHG} = 280 \text{ mA}$
- $CTRL = 2 \text{ V/div}$
- $CHG = 2 \text{ V/div}$
- $BGATE = 2 \text{ V/div}$
- $I_{IN} = 100 \text{ mA/div}$

**DISABLE USING CTRL**
- $V_{IN} = 5 \text{ V}, V_{BAT} = 3.4 \text{ V}, I_{CHG} = 280 \text{ mA}$
- $CTRL = 2 \text{ V/div}$
- $LDO = 2 \text{ V/div}$
- $BGATE = 2 \text{ V/div}$
- $I_{IN} = 2 \text{ mA/div}$

**CONTROL CURRENT LIMIT - STEP UP**
- $V_{IN} = 5 \text{ V}, V_{BAT} = 3.4 \text{ V}, I_{CHG} = 93 \text{ mA to 935 mA}$
- $CTRL = 2 \text{ V/div}$
- $BGATE = 2 \text{ V/div}$
- $IMON = 500 \text{ mV/div}$
- $I_{BAT} = 0.5 \text{ A/div}$

**CONTROL CURRENT LIMIT - STEP DOWN**
- $V_{IN} = 5 \text{ V}, V_{BAT} = 3.4 \text{ V}, I_{CHG} = 935 \text{ mA to 93 mA}$
- $CTRL = 2 \text{ V/div}$
- $BGATE = 2 \text{ V/div}$
- $IMON = 500 \text{ mV/div}$
- $I_{BAT} = 500 \text{ mA/div}$

**BGATE FORCED ON**
- $V_{IN} = 5 \text{ V}, V_{BAT} = 4.18 \text{ V}, V_{BAT(REG)} = 4.2 \text{ V}$
- $CTRL = 2 \text{ V/div}$
- $VBAT = 2 \text{ V/div}$
- $Offset = 4.1 \text{ V}$
- $V_{OUT} = 2 \text{ V/div}$
- $Offset = 4.1 \text{ V}$
- $BGATE = 2 \text{ V/div}$

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TYPICAL CHARACTERISTICS (continued)

Using circuit in Figure 1, $T_A = 25^\circ C$, unless otherwise specified.

**CANCEL BGATE FORCED ON**

![Graph showing CTRL, VBAT, VOUT, and BGATE voltages with specified divisions and offsets.]

**INPUT OVP**

![Graph showing VIN, VBAT, LDO, and IBAT voltages with specified divisions and offsets.]

**PRE-CHARGE MODE TO MINIMUM OUTPUT REGULATION MODE**

![Graph showing VBAT, IMON, BGATE, and IBAT voltages with specified divisions and offsets.]

**MINIMUM OUTPUT REGULATION MODE TO CONSTANT CURRENT (CC) MODE**

![Graph showing VBAT, IMON, BGATE, and IBAT voltages with specified divisions and offsets.]

**PRE-CHARGE TO CONSTANT VOLTAGE (CV) MODE**

![Graph showing VBAT, IMON, BGATE, and IBAT voltages with specified divisions and offsets.]

**VIN-DPM**

![Graph showing VIN, IIN, IMON, and BGATE voltages with specified divisions and offsets.]

---

VIN$ = 5$ V, VBAT$ = 4.18$ V, VBAT(REG)$ = 4.2$ V

CTRL
2 V/div

VBAT
2 V/div
Offset 4.1 V

VOUT
2 V/div
Offset 4.1 V

BGATE
2 V/div

1 ms/div

VIN$ = 5$ V, VBAT$ = 4.18$ V, VBAT(REG)$ = 4.2$ V

CTRL
2 V/div

VBAT
2 V/div
Offset 4.1 V

VOUT
2 V/div
Offset 4.1 V

BGATE
2 V/div
1 ms/div

VIN$ = 5$ V to 29 V, VBAT $= 3.8$ V

CTRL
2 V/div

VBAT
2 V/div
Offset 4.1 V

VOUT
2 V/div
Offset 4.1 V

BGATE
2 V/div
1 ms/div

V = 5 V to 29 V, VBAT$ = 3.8$ V

CTRL
2 V/div

VBAT
2 V/div
Offset 4.1 V

VOUT
2 V/div
Offset 4.1 V

BGATE
2 V/div
1 ms/div

VIN$ = 5$ V, VBAT$ = 1.8$ V to 3.45 V, ICHG$ = 467$ mA

VBAT
500 mV/div

IMON
500 mV/div

BGATE
2 V/div

IBAT
500 mA/div
20 ms/div

VIN$ = 5$ V, VBAT$ = 1.8$ V to 3.45 V, ICHG$ = 467$ mA

VBAT
500 mV/div

IMON
500 mV/div

BGATE
2 V/div

IBAT
500 mA/div
20 ms/div

VIN = 5 V, VBAT = 1.8 to 3.45 V, ICHG = 467 mA

VBAT
500 mV/div

IMON
500 mV/div

BGATE
2 V/div

IBAT
500 mA/div
20 ms/div

VIN = 5 V, VBAT = 1.8 to 3.45 V, ICHG = 467 mA

VIN = 5 V, VBAT = 2.4 V to 3.6 V, ICHG = 467 mA
**TYPICAL CHARACTERISTICS (continued)**

Using circuit in Figure 1, $T_A = 25^\circ C$, unless otherwise specified.

**SUPPLEMENT MODE**

<table>
<thead>
<tr>
<th>IMON</th>
<th>1 V/div</th>
</tr>
</thead>
<tbody>
<tr>
<td>BGATE</td>
<td>1 V/div</td>
</tr>
<tr>
<td>VOUT</td>
<td>2 V/div</td>
</tr>
<tr>
<td>IOUT</td>
<td>2 A/div</td>
</tr>
</tbody>
</table>

$V_{IN} = 5\, V$, $V_{BAT} = 3.2\, V$, $I_{CHG} = 935\, mA$, $I_{OUT} = 0\, A$ to $2\, A$

**CHARGE CYCLE DEMO**

<table>
<thead>
<tr>
<th>VOUT</th>
<th>2 V/div</th>
</tr>
</thead>
<tbody>
<tr>
<td>VBAT</td>
<td>2 V/div</td>
</tr>
<tr>
<td>IIN</td>
<td>100 mA/div</td>
</tr>
<tr>
<td>BGATE</td>
<td>2 V/div</td>
</tr>
</tbody>
</table>

$V_{IN} = 5\, V$, $I_{CHG} = 280\, mA$, $BGATE = Enabled$, $CBAT = 2000\, \mu F$, No battery connected, $R_{DSON}$ from IN to OUT

**Figure 15.**

**BATTERY VOLTAGE VS CHARGE CURRENT**

<table>
<thead>
<tr>
<th>$I_{CHRG}$ - Charge Current - mA</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

**Figure 17.**

**$R_{DSON}$ (From IN to OUT) VS JUNCTION TEMPERATURE**

<table>
<thead>
<tr>
<th>$T_J$ - Junction Temperature - °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>-50</td>
</tr>
<tr>
<td>0.00</td>
</tr>
</tbody>
</table>

**Figure 18.**

---

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DETAILED FUNCTIONAL DESCRIPTION

The bq25050 is a highly integrated Li-Ion linear battery charger targeted at space-limited portable applications. It operates from either a USB port or AC Adapter and charges a single-cell Li-Ion battery with up to 1A of charge current. The 30V input voltage range with input over-voltage protections supports low-cost unregulated adapters.

The bq25050 has a single power output that charges the battery. The system load is connected to OUT. The low-battery system startup circuitry maintains OUT pin voltage at \( V_{OUT(REG)} \) whenever an input source is connected. This allows the system to start-up and run whenever an input source is connected regardless of the battery voltage. The charge current is programmable up to 1A using the CTRL input. Additionally, a 4.9V 50mA LDO is integrated into the IC for supplying low power external circuitry.

External FET Controller (BGATE)

The External Power Path Control feature is implemented using the BGATE output. BGATE is also used to enable/ disable the External Power Path Control feature. When power is first applied to either \( V_{BAT} \) or \( V_{IN} \) on the bq25050, the BGATE output is tested. If the BGATE pin is connected to VSS, the External Power Path Control feature is disabled. In order to enable the External Power Path Control feature after it has been disabled, the battery and the input source must be removed and reconnected and BGATE must NOT be connected to VSS.

With External Power Path Control enabled, BGATE is used to drive an external P-channel MOSFET that connects the battery to the system output. This state of this MOSFET is dependant on the battery voltage and the IC status. In discharge mode, BGATE is pulled to GND to turn the MOSFET on fully. During discharge mode, the output is connected directly to the battery. Discharge mode is entered under the following conditions:

1. IC disabled or no input power
2. Supplement mode
3. "Force On" – enabled through CTRL

When not in one of these conditions, the BGATE output is controlled by the bq25050 and changes depending on which mode is required. See the Charging Operation section for more details.
Enable/ Disable External Power Path Control

When power is first applied to the bq25050, either at the IN or BAT input, the bq25050 checks the BGATE output. The device sources a small current out of BGATE for 32ms and monitors the voltage. If VBGATE is connected to ground and the voltage does not rise above logic High, the External Power Path Control feature is disabled and VLOWV is set to 2.5V. If the BGATE voltage rises above logic High, the External Power Path Control feature is enabled and VLOWV is set to 2.9V. The bq25050 only does this check when power is initially applied. Power must removed from IN and BAT and then reapplied to initiate another check. Figure 21 illustrates the startup check procedure.

![BGATE Monitor Sequence Diagram]

Figure 21. BGATE Monitor Sequence

Charging Operation

The bq25050 charges a battery in 3 stages while maintaining a minimum system output. When the bq25050 is enabled by CTRL, the battery voltage is monitored to verify which stage of charging must be used. The bq25050 charges in precharge mode, minimum output regulation mode, or normal CC/CV mode based on the battery voltage.
Charger Operation with External Power Path Control Mode Enabled

**Precharge Mode** ($V_{BAT} \leq V_{LOWV}$)

The bq25050 enters precharge mode when $V_{BAT} \leq V_{LOWV}$. Upon entering precharge mode, the battery is charged with a 40mA current source and /CHG goes low. During precharge mode, $V_{OUT}$ is regulated to 3.5V and the battery is charged from the internal fixed 40mA current source connected to the BAT output. With BGATE connected to GND, the system output is connected to the battery and therefore the system voltage is equal to the battery voltage.

**Minimum Output Regulation Mode** ($2.9V < V_{BAT} < 3.6V$)

Once $V_{BAT}$ exceeds 2.9V, the bq25050 enters Minimum Output Regulation Mode. While $2.9V < V_{BAT} < 3.6V$, $V_{OUT}$ is regulated to $V_{OUT(REG)}$ by the external FET (QBAT) while the internal FETs between IN and OUT is used to regulate the fast charge current. The total current is shared between the output load and the battery. As the system current increases, the battery charge current decreases. In order to maintain the minimum output regulation voltage $V_{OUT(REG)}$, the system load must be less than the input current limit.

**Normal CC/CV Mode**

Once $V_{BAT} > 3.6V$, QBAT is fully turned on and $V_{OUT} = V_{BAT} + V_{drop(Q1)}$. At this point, the bq25050 is in constant current (CC) mode where charge current is regulated using the internal FETs between IN and OUT. The $V_{OUT}$ voltage is not regulated. The total current is shared between the output load and the battery. Once the battery voltage charges up to $V_{BAT(REG)}$, the bq25050 enters constant voltage (CV) mode where $V_{BAT}$ is regulated to $V_{BAT(REG)}$ and the current is reduced. Once the input current falls below the termination threshold ($I_{TERM}$), BGATE is turned off and CHG goes high impedance. The system output is regulated to 4.2V and the battery is disconnected from OUT, however supplement mode is still available.
Charger Operation With External Power Path Control Mode Disabled (BGATE = VSS)

**Precharge Mode (V\_BAT ≤ V\_LOWV)**

The bq25050 enters precharge mode when \( V_{\text{BAT}} \leq V_{\text{LOWV}} \). Upon entering precharge mode, \( \overline{\text{CHG}} \) goes low and the input current limit is set to \( I_{\text{PRECHARGE}} \). With BGATE connected to GND, the system output is connected to the battery and therefore the system voltage is equal to the battery voltage. During precharge mode, the input current is regulated to 50mA and as such, only loads up to 50mA are supported.

**Normal CC/CV Mode**

Once \( V_{\text{BAT}} > V_{\text{LOWV}} \), the bq25050 enters constant current (CC) mode where charge current is regulated using the internal MOSFETs between IN and OUT. The total current is shared between the output load and the battery. Once the battery voltage charges up to VBAT(REG), the bq25050 enters constant voltage (CV) mode where \( V_{\text{BAT}} \) is regulated to VBAT(REG) and the current is reduced. Once the input current falls below the termination threshold \( (I_{\text{TERM}}) \), \( \overline{\text{CHG}} \) goes high impedance but the system remains charging and regulates the output to \( V_{\text{BAT(REG)}} \).

**Charge Current Translator (IMON)**

When the charger is enabled, internal circuits generate a current proportional to the charge current at the IMON input. The current out of IMON is 1/1000 (±10%) of the charge current. This current, when applied to the external charge current programming resistor, R1 (see **Figure 1**), generates an analog voltage that can be monitored by an external host to calculate the current sourced from BAT. Connect a 1kΩ resistor from IMON to VSS. The voltage at IMON is calculated as:

\[
V_{\text{IMON}} = 1_{\text{IN}} \times 1 \text{ V/A}
\]

Using this output allows for the host to calculate the actual charging current and therefore perform more accurate termination. The input current to the system must be monitored and subtracted from the current into the bq25050 which is show by \( V_{\text{IMON}} \).

**Input Over Voltage Protection**

The bq25050 contains an input over voltage protection circuit that disables the LDO output and charging when the input voltage rises above \( V_{\text{OVP}} \). This prevents damage from faulty adapters. The OVP circuitry contains an de-glitch that prevents ringing on the input from line transients from tripping the OVP circuitry falsely. If an adapter with an output greater than \( V_{\text{OVP}} \) is plugged in, the IC completes power up and then shuts down if the voltage remains above \( V_{\text{OVP}} \) after the de-glitch. The LDO remains off and charging remains disabled until the input voltage falls below \( V_{\text{OVP}} \).
Under-Voltage Lockout (UVLO)

The bq25050 remains in power down mode when the input voltage is below the under-voltage lockout threshold (VUVLO). During this mode, the control input (CTRL) is ignored. The LDO, the charge FET connected between IN and OUT are off and the status output (CHG) is high impedance. Once the input voltage rises above VUVLO, the internal circuitry is turned on and the normal operating procedures are followed.

Input DPM Mode (VIN-DPM)

The input current into the bq25050 includes all load currents, i.e. the system load, LDO load, and battery charge current. The total input current is regulated by the input current limit of the bq25050. The bq25050 utilizes the VIN-DPM mode for operation from current-limited input sources. VIN-DPM is enabled at startup and active until disabled by the CTRL interface. See the Single Input Interface (CTRL) section for more details.

When VIN-DPM is enabled, the input voltage is monitored. If VIN falls to VIN-DPM, the input current limit is reduced to prevent the input voltage from falling further. This prevents the bq25050 from crashing poorly designed or incorrectly configured USB sources. Figure 24 shows the VIN-DPM behavior to a current limited source. In this figure the input source has a 200mA current limit and the device has started up with the 285mA current limit.

![Figure 24. bq25050 VIN-DPM](image)

External NTC Monitoring (TS)

The bq25050 provides a TS input for monitoring an external 47kΩ NTC thermistor. There are 2 temperature thresholds that are monitored; the cold battery threshold (T_COLD) and the hot battery threshold (T_HOT). The TS input is monitored at all times and disables charge if the temperature of the NTC falls outside of the operating range. The operating range by default is 0°C to 45°C. An extended range of 0°C to 60°C is selectable using the CTRL input. VTST is also used to monitor the battery temperature. The temperature range is based on the NTC thermistor #NCP15WB473F.

The TS function remains on during battery discharge to enable the host to monitor the battery temperature. The VTS reflects the battery temperature the same as when the battery is charged. The bq25050 does not monitor this voltage, only the current source is active. Table 1 shows important temperatures and the corresponding voltage. This table can be used by the host to determine proper operation limits. The TS function is disabled if the CHG voltage falls below logic low while in battery discharge mode.
Table 1. $V_{TS}$ vs Temperature
(47kΩ Thermistor, $\beta=4050$, NCP15WB473F)

<table>
<thead>
<tr>
<th>TEMPERATURE</th>
<th>$V_{TS}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>–20°C</td>
<td>0.968 V</td>
</tr>
<tr>
<td>0°C</td>
<td>0.600 V</td>
</tr>
<tr>
<td>45°C</td>
<td>0.450 V</td>
</tr>
<tr>
<td>60°C</td>
<td>0.250 V</td>
</tr>
<tr>
<td>80°C</td>
<td>0.110 V</td>
</tr>
</tbody>
</table>

50mA LDO (LDO)

The LDO output of the bq25050 is a low dropout linear regulator (LDO) that supplies up to 50mA while regulating to $V_{LDO}$. The LDO is active whenever the input voltage is above $V_{UVLO}$ and below $V_{OVP}$. It is not affected by the CTRL input. The LDO output is used to power circuitry such as USB transceivers in dead battery conditions. This allows the user to operate the product immediately after plugging the adapter in, instead of waiting for the battery to charge to useable levels.

Charge Status Indicator (CHG)

The bq25050 contains an open drain CHG output that indicates when charge cycles and faults. When charging a battery in precharge, fastcharge or CV mode, the CHG output is pulled to VSS. Once the BAT output reaches regulation and the charge current falls below the termination threshold, CHG goes high impedance to signal the battery is fully charged. The CHG output goes low during battery recharge cycles to signal the host to monitor for termination.

Additionally, CHG notifies the host if a NTC temperature fault has occurred. CHG pulses with a period of 100ms and a 50% duty cycle if a TS faults occurs. Connect CHG to the required logic level voltage through a resistor to use the signal with a microprocessor. The sink current $I_{CHG}$ must be below 5mA.

The IC monitors the CHG pin when no input is connected to verify if the phone circuitry is active. If the voltage at CHG is logic low when no driven low, the TS current source is turned off for a low quiescent current state. Once the voltage at CHG increases above logic high, the current source is turned on to allow the host to sense battery temperature.

Single Input Interface (CTRL)

CTRL is used to enable/disable the device as well as select the input current limit, enable/disable charge, extend the TS operation range and disable $V_{IN}$-DPM mode. CTRL is pulled low to enable the device. After the deglitch $t_{CTRL,DGL}$ expires, the IC enters the 32ms WAIT state. CTRL may be used to program the bq25050 during this time. Once $t_{WAIT}$ expires, the IC starts up. If no command is sent to CTRL during $t_{WAIT}$, the IC starts up with a default 285mA current limit, termination enabled and $V_{IN}$-DPM enabled.

Programming the different modes is done by pulsing the CTRL input. See Table 2 for a map of the different modes. The width of the CTRL pulses is unimportant as long as they are between 50µs and 1000µs long. The time between pulses must be between 50µs and 1000µs to be properly read. Once CTRL is held low for 2ms, the number of pulses is passed to the control logic and decoded and then the mode changes. To ensure proper operation, more than 16 pulses are not recommended. See Figure 26 for a flow diagram of the CTRL interface.

Table 2. Pulse Counting Map for CTRL Interface

<table>
<thead>
<tr>
<th># OF PULSES</th>
<th>BGATE CONTROL</th>
<th>CURRENT LIMIT</th>
<th>TS RANGE</th>
<th>$V_{IN}$-DPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Force Termination</td>
<td>No Change</td>
<td>No Change</td>
<td>No Change</td>
</tr>
<tr>
<td>2</td>
<td>Force On Disable</td>
<td>No Change</td>
<td>No Change</td>
<td>No Change</td>
</tr>
<tr>
<td>3</td>
<td>Force On Enable</td>
<td>No Change</td>
<td>No Change</td>
<td>No Change</td>
</tr>
<tr>
<td>4</td>
<td>No Change</td>
<td>93 mA</td>
<td>No Change</td>
<td>No Change</td>
</tr>
<tr>
<td>5</td>
<td>No Change</td>
<td>187 mA</td>
<td>No Change</td>
<td>No Change</td>
</tr>
<tr>
<td>6</td>
<td>No Change</td>
<td>280 mA</td>
<td>No Change</td>
<td>No Change</td>
</tr>
<tr>
<td>7</td>
<td>No Change</td>
<td>374 mA</td>
<td>No Change</td>
<td>No Change</td>
</tr>
<tr>
<td>8</td>
<td>No Change</td>
<td>467 mA</td>
<td>No Change</td>
<td>No Change</td>
</tr>
</tbody>
</table>
If, at any time, the CTRL input is held high for more than 2ms, the IC is disabled. When disabled, charging is suspended and the bq25050 input quiescent current is reduced.

**Table 2. Pulse Counting Map for CTRL Interface (continued)**

<table>
<thead>
<tr>
<th># OF PULSES</th>
<th>BGATE CONTROL</th>
<th>CURRENT LIMIT</th>
<th>TS RANGE</th>
<th>V_in-DPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>No Change</td>
<td>654 mA</td>
<td>No Change</td>
<td>No Change</td>
</tr>
<tr>
<td>10</td>
<td>No Change</td>
<td>794 mA</td>
<td>No Change</td>
<td>No Change</td>
</tr>
<tr>
<td>11</td>
<td>No Change</td>
<td>935 mA</td>
<td>No Change</td>
<td>No Change</td>
</tr>
<tr>
<td>12</td>
<td>No Change</td>
<td>No Change</td>
<td>0°C to 60°C</td>
<td>No Change</td>
</tr>
<tr>
<td>13-16</td>
<td>No Change</td>
<td>No Change</td>
<td>No Change</td>
<td>Disabled</td>
</tr>
</tbody>
</table>

**Figure 25. CTRL Timing Diagram**
Figure 26. CTRL Flow Diagram
Thermal Regulation and Thermal Shutdown

The bq25050 contains a thermal regulation loop that monitors the die temperature continuously. If the temperature exceeds $T_{J(REG)}$, the device automatically reduces the charging current to prevent the die temperature from increasing further. In some cases, the die temperature continues to rise despite the operation of the thermal loop, particularly under high $V_{IN}$ conditions. If the die temperature increases to $T_{J(OFF)}$, the IC is turned off. Once the device die temperature cools by $T_{J(OFF-HYS)}$, the device turns on and returns to thermal regulation. Continuous over-temperature conditions result in the pulsing of the load current. If the junction temperature of the device exceeds $T_{J(OFF)}$, the charge FET is turned off. The FET is turned back on when the junction temperature falls below $T_{J(OFF)} - T_{J(OFF-HYS)}$.

Note that these features monitor the die temperature of the bq25050. This is not synonymous with ambient temperature. Self heating exists due to the power dissipated in the IC because of the linear nature of the battery charging algorithm.
APPLICATION INFORMATION

Selection of Input/Output Capacitors

In most applications, all that is needed is a high-frequency decoupling capacitor on the input power pin. For normal charging applications, a 0.1µF ceramic capacitor, placed in close proximity to the IN pin and GND pad works best. In some applications, depending on the power supply characteristics and cable length, it may be necessary to increase the input filter capacitor to avoid exceeding the OVP voltage threshold during adapter hot plug events where the ringing exceeds the deglitch time.

The charger in the bq25050 requires a capacitor from OUT to GND for loop stability. Connect a 1µF ceramic capacitor from OUT to GND close to the pins for best results. More output capacitance may be required to minimize the output droop during large load transients. Connect a 0.1µF ceramic capacitor from BAT to GND to eliminate the potential ESD strike.

The LDO also requires an output capacitor for loop stability. Connect a 0.1µF ceramic capacitor from LDO to GND close to the pins. For improved transient response, this capacitor may be increased.

bq25050 Charger Design Example

The following sections provide an example for determining the component values for use with the bq25050.

Requirements
Refer to Figure 1 and Figure 2 for Schematics of the Design Example

- Supply voltage = 4.35~10.2V
- Fast charge current is set by CTRL - pin 7
- Input current monitoring output - pin 2
- Set 0°C~45°C operating range

Calculations

Program the Fast Charge Current (CTRL): Programming the different input currents, BGATE option, temperature operating range, and VIN-DPM is done by pulsing the CTRL input. See table 2 for details. If, at any time, the CTRL input is held high for more than 2ms, the IC is disabled. After CTRL is pulled low for more than 2ms, the charger resumes. See Figure 26 for details.

Program the input current monitoring output (IMON): Connect a resistor from IMON to VSS to monitor the input current. The voltage of IMON pin is determined by:

\[ V_{IMON} = K_{IMON} \times R_{IMON} \times I_{CHG} \]

The maximum IMON pin voltage is typically 1.2V. If the \( V_{IMON} \) is programmed to be higher than \( V_{IMON(MAX)} \), the \( V_{IMON} \) will be clamped on \( V_{IMON(MAX)} \). But, \( I_{CHG} \) is controlled by the CTRL pin separately and is not affected by \( V_{IMON} \).

Set charger operating temperature range (TS): The operating range is 0°C to 45°C by a default NTC thermistor NCP15WB473F (47kΩ Thermistor, \( \beta=4050 \)). 12 qualified CTRL pulses can set \( V_{HOT_60} \) as TS hot threshold and set 0°C to 60°C as the operating range. The following conditions will reset temperature operating range back to 0°C to 45°C.

- Input voltage is lower than UVLO
- The CTRL input is held high for more than 2ms

In battery discharge mode, the TS function is disabled if the CHG voltage falls below logic low.

External FET Controller (BGATE): On Figure 1, BGATE drives an external P-channel FET that connects the battery to the system output. When power is first applied to either \( V_{BAT} \) or \( V_{IN} \), the device sources a typical 50µA small current out of BGATE and monitors the voltage. If BGATE voltage is higher than logic high in first 1ms and stays high for at least 2ms, the external power path control feature is enabled and \( V_{LOWV} \) is set to 2.9V. The OUT pin maintains voltage at \( V_{OUT(REG)} \).

In Figure 2, BGATE is connected to Vss. The external power path control feature is disabled and \( V_{LOWV} \) is set to 2.5V. The OUT pin shorts to BAT.

Status Indicators (CHG): The CHG pin is open drain output. If used, CHG pin should be pulled up via a resistor and possibly a LED to a power source. If monitored by a host, the host pull-up power source should be used.
Thermal Considerations

The bq25050 is packaged in a thermally enhanced QFN package. The package includes a thermal pad to provide an effective thermal contact between the IC and the printed circuit board (PCB). Full PCB design guidelines for this package are provided in the application note entitled: QFN/SON PCB Attachment Application Note (SLUA271).

The most common measure of package thermal performance is thermal impedance ($\theta_{JA}$) measured (or modeled) from the chip junction to the air surrounding the package surface (ambient). The mathematical expression for $\theta_{JA}$ is:

$$\theta_{JA} = \frac{T_J - T_A}{P_D}$$

Where:
- $T_J$ = chip junction temperature
- $T_A$ = ambient temperature
- $P_D$ = device power dissipation

Factors that can greatly influence the measurement and calculation of $\theta_{JA}$ include:
- Whether or not the device is board mounted
- Trace size, composition, thickness, and geometry
- Orientation of the device (horizontal or vertical)
- Volume of the ambient air surrounding the device under test and airflow
- Whether other surfaces are in close proximity to the device being tested

The device power dissipation, $P_D$, is a function of the charge rate and the voltage drop across the internal PowerFET. It can be calculated from the following equation when a battery pack is being charged:

$$P_D = (V_{IN} - V_{OUT}) \times I_{OUT}$$

Due to the charge profile of Li-Ion batteries the maximum power dissipation is typically seen at the beginning of the charge cycle when the battery voltage is at its lowest. See the charging profile, Figure 22. If the board thermal design is not adequate the programmed fast charge rate current may not be achieved under maximum input voltage and minimum battery voltage, as the thermal loop can be active, effectively reducing the charge current to avoid excessive IC junction temperature.

PCB Layout Considerations

It is important to pay special attention to the PCB layout. The following provides some guidelines:
- To obtain optimal performance, the decoupling capacitor from IN to GND (thermal pad) and the output filter capacitors from OUT to GND (thermal pad) should be placed as close as possible to the bq25050, with short trace runs to both IN, OUT and GND (thermal pad).
- All low-current GND connections should be kept separate from the high-current charge or discharge paths from the battery. Use a single-point ground technique incorporating both the small signal ground path and the power ground path.
- The high current charge paths into IN pin and from the OUT pin must be sized appropriately for the maximum charge current in order to avoid voltage drops in these traces.
- The bq25050 is packaged in a thermally enhanced SON package. The package includes a thermal pad to provide an effective thermal contact between the IC and the printed circuit board (PCB); this thermal pad is also the main ground connection for the device. Connect the thermal pad to the PCB ground connection. Full PCB design guidelines for this package are provided in the application note entitled: QFN/SON PCB Attachment Application Note (SLUA271).
# Packaging Information

<table>
<thead>
<tr>
<th>Orderable Device</th>
<th>Status (1)</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>Package Qty</th>
<th>Eco Plan (2)</th>
<th>Lead/Ball Finish (6)</th>
<th>MSL Peak Temp (3)</th>
<th>Op Temp (°C)</th>
<th>Device Marking (4/5)</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>BQ25050DQCR</td>
<td>ACTIVE</td>
<td>WSON</td>
<td>DQC</td>
<td>10</td>
<td>3000</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>NIPDAU</td>
<td>Level-2-260C-1 YEAR</td>
<td>-40 to 85</td>
<td>DAM</td>
<td></td>
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<tr>
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<td>WSON</td>
<td>DQC</td>
<td>10</td>
<td>250</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>NIPDAU</td>
<td>Level-2-260C-1 YEAR</td>
<td>-40 to 85</td>
<td>DAM</td>
<td></td>
</tr>
</tbody>
</table>

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

(2) RoHS: TI defines “RoHS” to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, “RoHS” products are suitable for use in specified lead-free processes. TI may reference these types of products as “Pb-Free”.

**RoHS Exempt:** TI defines “RoHS Exempt” to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines “Green” to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

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

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

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

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**TAPE AND REEL INFORMATION**

<table>
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<tr>
<th>Device</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>SPQ</th>
<th>Reel Diameter (mm)</th>
<th>Reel Width W1 (mm)</th>
<th>A0  (mm)</th>
<th>B0  (mm)</th>
<th>K0  (mm)</th>
<th>P1  (mm)</th>
<th>W  (mm)</th>
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<td>Q1</td>
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<td>DQC</td>
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<td>1.05</td>
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<td>8.0</td>
<td>Q1</td>
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*All dimensions are nominal.*
### TAPE AND REEL BOX DIMENSIONS

*All dimensions are nominal

<table>
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<tr>
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<th>Width (mm)</th>
<th>Height (mm)</th>
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<td>DQC</td>
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<td>BQ25050DQCT</td>
<td>WSON</td>
<td>DQC</td>
<td>10</td>
<td>250</td>
<td>210.0</td>
<td>185.0</td>
<td>35.0</td>
</tr>
</tbody>
</table>
Images above are just a representation of the package family, actual package may vary. Refer to the product data sheet for package details.
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.
NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).

5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.
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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