DESCRIPTION

The MP2660 is a highly integrated, single-cell, Li-ion/Li-polymer battery charger with system power path management for space-limited portable applications. This device takes input power from either an AC adapter or a USB port to supply the system load and charge the battery independently. The charger section features trickle charge, constant current (CC) and constant voltage (CV) regulation, charge termination, and auto-recharge.

The power path management function ensures continuous power to the system even with a dead battery by automatically selecting the input, the battery, or both to power the system. This power stage features a low dropout regulator from the input to the system and a 100mΩ switch from the battery to the system. Power path management separates the charging current from the system load, which allows for proper charge termination and keeps the battery in full-charge mode.

The MP2660 provides system short-circuit protection (SCP) by limiting the current from the input to the system and the battery to the system. This feature is especially critical for preventing the Li-ion battery from being damaged due to excessively high currents. An on-chip battery under-voltage lockout (UVLO) cuts off the path between the battery and the system if the battery voltage drops below the programmable battery UVLO threshold, which prevents the Li-ion battery from being over-discharged. An integrated I²C control interface allows the MP2660 to program the charging parameters including the input current limit, input voltage regulation limit, charging current, battery regulation voltage, safety timer, and battery UVLO.

The MP2660 is available in a 9-pin WLCSP (1.55mmx1.55mm) package.

FEATURES

- Compatible with 5V USB power sources
- Fully Autonomous Charger for Single-Cell Li-Ion/Li-Polymer Batteries
- Complete Power Path Management for Simultaneously Powering the System and Charging the Battery
- Programmable Input Current Limit and Minimum Input Voltage Regulation Thresholds
- ±0.5% Charging Voltage Accuracy
- 13V Maximum Voltage for the Input Source
- I²C Interface for Programming Charging Parameters and Status Reporting
- Fully Integrated Power Switches and No External Blocking Diode Required
- Built-In Robust Charging Protection Including Battery Temperature Monitoring and Programmable Timer
- Built-In Battery Disconnection Function for shipping mode
- Thermal Limiting Regulation on the Chip
- Available in an ultra-compact WLCSP-9 (1.55mmx1.55mm) Package

APPLICATIONS

- Wearable Devices
- Smart Handheld Devices
- Fitness Accessories
- Smart Watches
- Bluetooth Headphones

All MPS parts are lead-free, halogen-free, and adhere to the RoHS directive. For MPS green status, please visit the MPS website under Quality Assurance. “MPS” and “The Future of Analog IC Technology” are registered trademarks of Monolithic Power Systems, Inc.
Table 1: Operation Mode Table

<table>
<thead>
<tr>
<th>FET On/Off Change By Control</th>
<th>I²C Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HIZ = 1</td>
</tr>
<tr>
<td>LDO FET</td>
<td>OFF</td>
</tr>
<tr>
<td>Battery FET (charging)</td>
<td>x</td>
</tr>
<tr>
<td>Battery FET (discharging)</td>
<td>x</td>
</tr>
</tbody>
</table>

x = Don't Care

* FET_DIS goes back to 0 when the battery FET is off.
PART ORDERING INFORMATION

<table>
<thead>
<tr>
<th>Part Number*</th>
<th>Package</th>
<th>Top Marking</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP2660GC-xxxx**</td>
<td>WLCSP-9 (1.55mm x 1.55mm)</td>
<td>See Below</td>
</tr>
</tbody>
</table>

* For Tape & Reel, add suffix –Z (e.g. MP2660GC-xxxx–Z)

** “xxxx” is the configuration code identifier for the register settings. For the default case, the number is “0000.”
Each “x” can have a hexadecimal value between 0 and F. Please work with an MPS FAE to create this unique number, even if ordering the “0000” code.

TOP MARKING

DPY
LLL

DP: Product code of MP2660GC
Y: Year code
LLL: Lot number

EVALUATION KIT EVKT-MP2660

EVKT-MP2660 kit contents (items below can be ordered separately):

<table>
<thead>
<tr>
<th>#</th>
<th>Part Number</th>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>EV2660-C-01A</td>
<td>MP2660 evaluation board</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>EVKT-USBI2C-02-bag</td>
<td>Include one USB to I2C communication interface, one USB cable, and one ribbon cable</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Online resources</td>
<td>Include datasheet, user guide, product brief, and GUI</td>
<td>1</td>
</tr>
</tbody>
</table>

Order direct from MonolithicPower.com or our distributors.
### PACKAGE REFERENCE

**TOP VIEW**

<table>
<thead>
<tr>
<th>Pin</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>IN</td>
<td><strong>Input power.</strong> Place a ceramic capacitor (≥1μF) from IN to GND as close to the IC as possible.</td>
</tr>
<tr>
<td>A2</td>
<td>SYS</td>
<td><strong>System power supply.</strong> Place a ceramic capacitor (≥2.2μF) from SYS to GND as close to the IC as possible.</td>
</tr>
<tr>
<td>A3</td>
<td>BATT</td>
<td><strong>Battery.</strong> Place a ceramic capacitor (≥2.2μF) from BATT to GND as close to the IC as possible.</td>
</tr>
<tr>
<td>B1</td>
<td>NTC</td>
<td><strong>Temperature sense input.</strong> Connect a negative temperature coefficient thermistor to NTC. Program the hot and cold temperature window with a resistor divider from IN to NTC to GND. The charge is suspended when NTC is out of the range.</td>
</tr>
<tr>
<td>B2</td>
<td>INT</td>
<td><strong>Open-drain interrupt output.</strong> INT can send the charging status and fault interruption to the host. INT is used as the battery disconnection control as well. Pull INT low for &gt;8s to disconnect the battery from the system. The external pull-up resistor at INT should be no smaller than 100kΩ.</td>
</tr>
<tr>
<td>B3</td>
<td>VDD</td>
<td><strong>Internal control power supply.</strong> Connect a ceramic capacitor (0.1μF) from VDD to GND. No external load is allowed on VDD.</td>
</tr>
<tr>
<td>C1</td>
<td>SDA</td>
<td><strong>I²C Interface data.</strong> Connect SDA to the logic rail through a 10kΩ resistor.</td>
</tr>
<tr>
<td>C2</td>
<td>SCL</td>
<td><strong>I²C Interface clock.</strong> Connect SCL to the logic rail through a 10kΩ resistor.</td>
</tr>
<tr>
<td>C3</td>
<td>GND</td>
<td><strong>Ground.</strong></td>
</tr>
</tbody>
</table>
ABSOLUTE MAXIMUM RATINGS

- VIN: -0.3V to +13V
- All other pins to GND: -0.3V to +6.0V
- Continuous power dissipation (TA = +25°C): 0.88W
- Junction temperature: 150°C
- Lead temperature (solder): 260°C
- Storage temperature: -65°C to +150°C

RECOMMENDED OPERATING CONDITIONS

- Supply voltage (VIN): 4.35V to 5.5V (USB input)
- IIN: up to 455mA
- I_SYS: up to 1.6A
- I_CHG: up to 455mA
- VBATT: up to 4.545V
- Operating junction temp. (TJ): -40°C to +125°C

THERMAL RESISTANCE

- θJA: 114°C/W
- θJC: 12°C/W

NOTES:
1) Exceeding these ratings may damage the device.
2) The maximum allowable power dissipation is a function of the maximum junction temperature Tj(MAX), the junction-to-ambient thermal resistance θJA, and the ambient temperature TA. The maximum allowable continuous power dissipation at any ambient temperature is calculated by PD(MAX) = (Tj(MAX) - TA)/θJA. Exceeding the maximum allowable power dissipation produces an excessive die temperature, causing the regulator to go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
3) The device is not guaranteed to function outside of its operating conditions.
4) Measured on JESD51-7, 4-layer PCB.
### ELECTRICAL CHARACTERISTICS

$V_{IN} = 5.0V, V_{BATT} = 3.5V, T_A = +25^\circ C$, unless otherwise noted.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input Source and Battery Protection</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input voltage range</td>
<td>$V_{IN}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input operation voltage</td>
<td>$V_{IN}$</td>
<td></td>
<td>4.35</td>
<td>5.0</td>
<td>5.5</td>
<td>V</td>
</tr>
<tr>
<td>BATT input voltage</td>
<td>$V_{BATT}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input over-voltage protection threshold</td>
<td>$V_{IN_{OVP}}$</td>
<td>Input rising threshold</td>
<td>5.85</td>
<td>6.00</td>
<td>6.15</td>
<td>V</td>
</tr>
<tr>
<td>Input OVP hysteresis</td>
<td></td>
<td></td>
<td>335</td>
<td>mV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input under-voltage threshold</td>
<td>$V_{UV_{IN}}$</td>
<td>Input rising threshold</td>
<td>3.8</td>
<td>3.9</td>
<td>4.0</td>
<td>V</td>
</tr>
<tr>
<td>Input under-voltage threshold hysteresis</td>
<td></td>
<td></td>
<td>180</td>
<td>mV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input vs. battery threshold</td>
<td>$V_{IN_{BATT}}$</td>
<td>Input rising vs. battery</td>
<td>90</td>
<td>110</td>
<td>130</td>
<td>mV</td>
</tr>
<tr>
<td>Input vs. battery threshold hysteresis</td>
<td></td>
<td></td>
<td>66</td>
<td>mV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BATT under-voltage threshold</td>
<td>$V_{UV_{BATT}}$</td>
<td>BATT voltage falling, programmable, $V_{UV_{BATT}} = 2.8V$</td>
<td>2.6</td>
<td>2.8</td>
<td>3.0</td>
<td>V</td>
</tr>
<tr>
<td>Battery UVLO range</td>
<td></td>
<td>Programmable using I2C</td>
<td>2.4</td>
<td>3.1</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>BATT under-voltage threshold hysteresis</td>
<td></td>
<td>$V_{UV_{BATT}} = 2.8V$</td>
<td>235</td>
<td>mV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Battery over-voltage protection</td>
<td>$V_{BATT_{OVP}}$</td>
<td>Rising, higher than $V_{BATT_{REG}}$</td>
<td>120</td>
<td>mV</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Falling, higher than $V_{BATT_{REG}}$</td>
<td>65</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Power Path Management</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regulated system output voltage</td>
<td>$V_{SYS_{REG}}$</td>
<td>$V_{IN} = 5.5V, I_{SYS} = 10mA, I_{CHG} = 0A$</td>
<td>4.85</td>
<td>5.00</td>
<td>5.15</td>
<td>V</td>
</tr>
<tr>
<td>Input current limit range</td>
<td></td>
<td>I2C programmable</td>
<td>85</td>
<td>455</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>Input current limit</td>
<td>$I_{IN_{LIM}}$</td>
<td>Reg00[2:0] = 000 - 85mA</td>
<td>63</td>
<td>70</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reg00[2:0] = 001 - 130mA</td>
<td>102</td>
<td>116</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reg00[2:0] = 100 - 265mA</td>
<td>230</td>
<td>247</td>
<td>265</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reg00[2:0] = 111 - 455mA</td>
<td>400</td>
<td>428</td>
<td>455</td>
<td></td>
</tr>
<tr>
<td>Input voltage regulation threshold</td>
<td>$V_{IN_{REG}}$</td>
<td>I2C-programmable range</td>
<td>3.88</td>
<td>5.08</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I2C setting $V_{IN_{REG}} = 4.20V$</td>
<td>4.10</td>
<td>4.20</td>
<td>4.30</td>
<td></td>
</tr>
<tr>
<td>SYS output voltage</td>
<td>$V_{SYS}$</td>
<td>Charging mode, $V_{IN} = 5.5V$, $V_{BATT} = 3.7V$</td>
<td>4.85</td>
<td>5.00</td>
<td>5.15</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Supplement mode, $V_{BATT} = 3.7V$, $I_{BATT} = 100mA$</td>
<td>3.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{IN} &lt; V_{UV_{IN}}$ and $V_{BATT} &lt; V_{UV_{BATT}}$</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IN to SYS switch on resistance</td>
<td>$R_{ON_{SYS}}$</td>
<td>$V_{IN} = 5V, I_{SYS} = 100mA$</td>
<td>300</td>
<td>400</td>
<td>mΩ</td>
<td></td>
</tr>
<tr>
<td>Supply current at input</td>
<td>$I_{IN}$</td>
<td>$V_{IN} = 5.5V, CE = L$, enable, $I_{CHG} = 0A$, $I_{SYS} = 0A$</td>
<td>610</td>
<td></td>
<td>μA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{IN} = 5.5V, CE = H$, charge disabled</td>
<td>470</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ELECTRICAL CHARACTERISTICS (continued)

$V_{IN} = 5.0V, V_{BATT} = 3.5V, T_{A} = +25^\circ C$, unless otherwise noted.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply current at BATT input</td>
<td>$I_{BATT}$</td>
<td>$V_{IN} = 5V, CE = L, ISYS = 0A, V_{BATT} = 4.3V$</td>
<td></td>
<td></td>
<td>33</td>
<td>µA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{IN} = 0V, CE = H, ISYS = 0A, V_{BATT} = 4.35V$</td>
<td></td>
<td></td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{BATT} = 4.5V, V_{IN} = V_{SYS} = GND, FET_DIS = 1, disconnect mode$</td>
<td></td>
<td></td>
<td>4.512</td>
<td>5.017</td>
</tr>
<tr>
<td>BATT input to SYS switch on resistance</td>
<td>$R_{ON_BATT}$</td>
<td>$V_{IN} &lt; 2V, V_{BATT} = 3.5V, ISYS = 100mA$</td>
<td>100</td>
<td></td>
<td></td>
<td>mΩ</td>
</tr>
<tr>
<td>BATT to SYS current limit</td>
<td>$I_{BATT_MAX}$</td>
<td>Program range $V_{BATT} = 4.5V, V_{IN} = V_{SYS} = GND, disconnect mode$</td>
<td>200</td>
<td></td>
<td>1600</td>
<td>mA</td>
</tr>
<tr>
<td>BATT to SYS switch leakage</td>
<td></td>
<td>$V_{SYS} = 6V, V_{IN} = 4.5V, V_{BATT} = GND, CE = H$</td>
<td></td>
<td></td>
<td>1.2</td>
<td>µA</td>
</tr>
<tr>
<td>SYS reverse to BATT switch leakage</td>
<td></td>
<td>$V_{BATT} = 3.5V, ISYS = 100mA$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Battery discharge function controlled by INT (5)</td>
<td>$t_{INT}$</td>
<td>INT pull low lasting time to turn off the battery discharge function</td>
<td>8</td>
<td></td>
<td></td>
<td>s</td>
</tr>
<tr>
<td>Battery FET lasts for the off time before auto-on</td>
<td></td>
<td>Battery FET lasts for the off time before auto-on</td>
<td>500</td>
<td></td>
<td></td>
<td>ms</td>
</tr>
</tbody>
</table>

**Battery Charger**

Battery voltage regulation range

<table>
<thead>
<tr>
<th>$V_{BATT_REG}$</th>
<th>Programmable using I2C</th>
<th>3.600</th>
<th>4.545</th>
<th>V</th>
</tr>
</thead>
</table>

Battery voltage regulation ($V_{BATT\_REG} = 4.2V$)

<table>
<thead>
<tr>
<th>$V_{BATT}$</th>
<th>$T = +25^\circ C, I_{BATT} = 15mA$</th>
<th>4.179</th>
<th>4.200</th>
<th>4.221</th>
<th>V</th>
</tr>
</thead>
</table>

Battery charge full voltage [I2C]

<table>
<thead>
<tr>
<th>$V_{BATT_REG}$</th>
<th>$V_{BATT_REG} = 4.2V, reg04 bit[7:2] = 101000$</th>
<th>4.179</th>
<th>4.200</th>
<th>4.221</th>
<th>V</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>$V_{BATT_REG}$</th>
<th>$V_{BATT_REG} = 4.35V, reg04 bit[7:2] = 110010$</th>
<th>4.328</th>
<th>4.350</th>
<th>4.372</th>
<th>V</th>
</tr>
</thead>
</table>

Constant current regulation for charging

<table>
<thead>
<tr>
<th>$I_{CC}$</th>
<th>$V_{IN} = 5V, V_{BATT} = 3.8V, programmable range$</th>
<th>8</th>
<th>535</th>
<th>mA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$V_{IN} = 5V, V_{BATT} = 3.8V, I_{CC_SETTING} = 76mA$</td>
<td>65</td>
<td>76</td>
<td>87</td>
</tr>
<tr>
<td></td>
<td>$V_{IN} = 5V, V_{BATT} = 3.8V, I_{CC_SETTING} = 246mA$</td>
<td>220</td>
<td>245</td>
<td>270</td>
</tr>
</tbody>
</table>

Charging current thermal fold-back threshold (5)

<table>
<thead>
<tr>
<th>$I_{TC}$</th>
<th>Junction temperature regulation $reg06 bit[1:0] = 11 - Thermal_limit=120^\circ C$</th>
<th>120</th>
<th></th>
<th></th>
<th>°C</th>
</tr>
</thead>
</table>

Trickle current

| $I_{TC}$ | $I_{TC\_SETTING} = 20mA, reg03 bit[1:0] = 10$ | 13.0 | 16.5 | 20.0 | mA |
## ELECTRICAL CHARACTERISTICS (continued)

For $V_{IN} = 5.0V$, $V_{BATT} = 3.5V$, $T_A = +25^\circ C$, unless otherwise noted.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>End of charge (EOC) current threshold</td>
<td>$I_{BF}$</td>
<td>$I_{CC_SETTING} \leq 263mA$, $(\text{reg}02 \text{ bit}[4] = 0)$, $I_{TC_SETTING} = 6mA$</td>
<td>4.0</td>
<td>6.5</td>
<td>8.5</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$I_{CC_SETTING} \leq 263mA$, $(\text{reg}02 \text{ bit}[4] = 0)$, $I_{TC_SETTING} = 13mA$</td>
<td>10.0</td>
<td>13.0</td>
<td>16.5</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$I_{CC_SETTING} \leq 263mA$, $(\text{reg}02 \text{ bit}[4] = 0)$, $I_{TC_SETTING} = 20mA$</td>
<td>16</td>
<td>20</td>
<td>24</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$I_{CC_SETTING} \leq 263mA$, $(\text{reg}02 \text{ bit}[4] = 1)$, $I_{TC_SETTING} = 6mA$</td>
<td>22</td>
<td>27</td>
<td>31</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$I_{CC_SETTING} \leq 263mA$, $(\text{reg}02 \text{ bit}[4] = 1)$, $I_{TC_SETTING} = 13mA$</td>
<td>10.0</td>
<td>13.0</td>
<td>16.5</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$I_{CC_SETTING} \leq 263mA$, $(\text{reg}02 \text{ bit}[4] = 1)$, $I_{TC_SETTING} = 20mA$</td>
<td>22</td>
<td>27</td>
<td>32</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$I_{CC_SETTING} \geq 280mA$, $(\text{reg}02 \text{ bit}[4] = 0)$, $I_{TC_SETTING} = 6mA$</td>
<td>22</td>
<td>27</td>
<td>31</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$I_{CC_SETTING} \geq 280mA$, $(\text{reg}02 \text{ bit}[4] = 0)$, $I_{TC_SETTING} = 13mA$</td>
<td>34</td>
<td>41</td>
<td>48</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$I_{CC_SETTING} \geq 280mA$, $(\text{reg}02 \text{ bit}[4] = 0)$, $I_{TC_SETTING} = 20mA$</td>
<td>48.0</td>
<td>56.5</td>
<td>65.0</td>
<td>mA</td>
</tr>
<tr>
<td>Trickle charge threshold voltage $V_{BATT_LOW}$</td>
<td>$V_{BATT_LOW}$</td>
<td>$V_{BATT}$ rising, set $V_{BATT_LOW} = 3.0V$</td>
<td>2.8</td>
<td>3.0</td>
<td>3.1</td>
<td>V</td>
</tr>
<tr>
<td>Trickle voltage hysteresis</td>
<td></td>
<td></td>
<td>88</td>
<td></td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td>Recharge threshold below $V_{BATT_REG}$ $V_{RECHG}$</td>
<td>$V_{RECHG}$</td>
<td>reg04 bit[0] = 0</td>
<td>130</td>
<td>170</td>
<td>210</td>
<td>mV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reg04 bit[0] = 1</td>
<td>270</td>
<td>320</td>
<td>370</td>
<td>mV</td>
</tr>
</tbody>
</table>

### Thermal Protection

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Condition</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal shutdown rising threshold</td>
<td></td>
<td></td>
<td>150</td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>Thermal shutdown hysteresis</td>
<td></td>
<td></td>
<td>20</td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>NTC output current $I_{NTC}$</td>
<td>CE = L, $V_{NTC} = 3V$</td>
<td>-100</td>
<td>0</td>
<td>100</td>
<td>nA</td>
</tr>
<tr>
<td>NTC cold temp rising threshold $V_{COLD}$</td>
<td>As a percentage of $V_{IN}$</td>
<td>64</td>
<td>66</td>
<td>68</td>
<td>%</td>
</tr>
<tr>
<td>NTC cold temp rising threshold hysteresis</td>
<td></td>
<td></td>
<td>28</td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td>NTC hot temp falling threshold $V_{HOT}$</td>
<td>As a percentage of $V_{IN}$</td>
<td>33</td>
<td>35</td>
<td>37</td>
<td>%</td>
</tr>
<tr>
<td>NTC hot temp falling threshold hysteresis</td>
<td></td>
<td></td>
<td>65</td>
<td></td>
<td>mV</td>
</tr>
</tbody>
</table>

### Logic I/O Pin Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Condition</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low logic voltage threshold</td>
<td>$V_L$</td>
<td></td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>High logic voltage threshold</td>
<td>$V_H$</td>
<td></td>
<td></td>
<td></td>
<td>V</td>
</tr>
</tbody>
</table>

---

MP2660 Rev. 1.02

6/11/2019


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### ELECTRICAL CHARACTERISTICS (continued)

\( V_{IN} = 5V, \ T_A = 25°C\), unless otherwise noted.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I^2C Interface (SDA, SCL)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input high threshold level</td>
<td>(V_{\text{PULL_UP}} = 1.8V, \ \text{SDA and SCL})</td>
<td></td>
<td>1.3</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Input low threshold level</td>
<td>(V_{\text{PULL_UP}} = 1.8V, \ \text{SDA and SCL})</td>
<td></td>
<td>0.4</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Output low threshold level</td>
<td>(I_{\text{SINK}} = 5mA)</td>
<td></td>
<td>0.4</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>(I^2C) clock frequency</td>
<td>(F_{\text{SCL}})</td>
<td></td>
<td></td>
<td></td>
<td>400</td>
<td>kHz</td>
</tr>
</tbody>
</table>

| Digital Clock and Watchdog Timer | | | | | | |
| Digital clock 2 | \(F_{\text{DIG2}}\) | | | 32 | | kHz |
| Watchdog timer | \(t_{\text{WDT}}\) | Programmable (reg05 bit[5:4] = 11) | | 140 | 160 | 180 | s |
| Safety timer | \(t_{\text{TST}}\) | Programmable (reg05 bit[2:1] = 00), \(t_{\text{TST}} = 3hrs\) | | 2.7 | 3.0 | 3.3 | |
| | | Programmable (reg05 bit[2:1] = 01), \(t_{\text{TST}} = 5hrs\) | | 4.5 | 5.0 | 5.5 | |
| | | Programmable (reg05 bit[2:1] = 10), \(t_{\text{TST}} = 8hrs\) | | 7.2 | 8.0 | 8.8 | |
| | | Programmable (reg05 bit[2:1] = 11), \(t_{\text{TST}} = 12hrs\) | | 10.8 | 12.0 | 13.2 | |

**NOTE:**
5) Guaranteed by design.
**TYPICAL PERFORMANCE CHARACTERISTICS**

$V_{IN} = 5V$, $T_{A} = 25^\circ C$, $I_{IN\_LIM} = 455mA$, $I_{CC} = 246mA$, $V_{IN\_REG} = 4.76V$, unless otherwise noted.

- **Battery Full Voltage vs. Temperature**
  
  $V_{BATT\_REG}=4.2V$

- **System Regulation Voltage vs. Temperature**

- **Battery Current under Shipping Mode vs. Temperature**

- **Trickle Charge Current vs. Temperature**
  
  $I_{TC}=20mA$

- **CC Charge Current vs. Temperature**
  
  $I_{CC}=248mA$

- **Battery Full Termination Current vs. Temperature**
  
  $I_{FIM}=20mA$

- **Battery OVP Voltage vs. Temperature**
  
  Rising, higher than $V_{BATT\_REG}$

- **$I_{\_LIM\_455mA}$ vs. Temperature**
  
  $I_{N\_LIM}=455mA$

- **Input Regulation Voltage vs. Temperature**
  
  $V_{IN\_REG}=4.76V$
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

$V_{IN} = 5V$, $T_A = 25^\circ C$, $I_{IN\_LIM} = 455mA$, $I_{CC} = 246mA$, $V_{IN\_REG} = 4.76V$, unless otherwise noted.

**Battery Charge Curve**
$I_{SYS}=0A$

**Auto-Recharge**
$I_{SYS}=0A$

**Battery Charge Curve**
$I_{SYS}=200mA$

**CC Charge Steady State**
$V_{BATT}=3.7V$, $I_{SYS}=200mA$

**Supplement Mode Steady State**
$V_{BATT}=3.7V$, $I_{SYS}=600mA$

**Input Voltage Regulation based PPM**
$V_{IN}=5V/150mA$, $V_{BATT}=4.2V$, $V_{IN\_REG}=4.84V$

**Input Voltage Regulation based PPM**
$V_{IN}=5V/300mA$, $V_{BATT}=3.7V$

**Input Current Limit based PPM**
$V_{BATT}=3.7V$

**Input Current Limit based PPM**
$V_{BATT}=4.2V$, $I_{BATT}=100mA$. 
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Vin = 5V, TA = 25°C, IIN_LIM = 455mA, ICC = 246mA, VIN_REG = 4.76V, unless otherwise noted.

**Power On**
- V_BATT = 3.7V, I_SYS = 0A

**Power Off**
- V_BATT = 3.7V, I_SYS = 0A

**Power On @ Supplement Mode**
- V_BATT = 3.7V, I_SYS = 600mA

**Power Off @ Supplement Mode**
- V_BATT = 3.7V, I_SYS = 600mA

**EN On @ Input Current Limit Based PPM**
- V_BATT = 3.7V, I_SYS = 400mA

**EN Off @ Input Current Limit Based PPM**
- V_BATT = 3.7V, I_SYS = 400mA

**EN On @ Supplement Mode**
- V_BATT = 3.7V, I_SYS = 600mA

**EN Off @ Supplement Mode**
- V_BATT = 3.7V, I_SYS = 600mA

**Charge On**
- V_BATT = 3.7V, I_SYS = 0A
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

$V_{IN} = 5\,V$, $T_A = 25^\circ C$, $I_{IN\_LIM} = 455\,mA$, $I_{CC} = 246\,mA$, $V_{IN\_REG} = 4.76V$, unless otherwise noted.

Charge Off
$V_{BATT}=3.7V, I_{SYS}=0A$

Adding Load @ Discharge Mode
$V_{BATT}=3.7V$

Load Transient @ Discharge Mode
$V_{BATT}=3.7V, I_{SYS}=0-1A$

BATT Float Operation
$I_{SYS}=0A$

BATT Insertion
$V_{BATT}=3.7V, I_{SYS}=0A$

BATT Removal
$V_{BATT}=3.7V, I_{SYS}=0A$

NTC On/Off
$V_{BATT}=3.7V, I_{SYS}=0A$

VIN OVP Operation
$V_{BATT}=3.7V, I_{SYS}=0A$
Figure 1: Functional Block Diagram
OPERATION

The MP2660 is an I²C-controlled, single-cell, Li-ion or Li-polymer battery charger with complete power path management. The full charge function features trickle charge (TC), constant current (CC) and constant voltage (CV) regulation, charge termination, auto-recharge, and a built-in timer. The power path function allows the input source to power the system and charge the battery simultaneously. If the power source cannot supply enough current to the system load and to charge the battery, then the charge current will be reduced until it is necessary for the battery to supplement system power.

The IC integrates a 300mΩ LDO FET between IN and SYS and a 100mΩ battery FET between SYS and BATT.

During charging mode, the on-chip 100mΩ battery FET works as a full-featured linear charger with trickle charging, CC and CV charging, charge termination, auto-recharging, NTC monitoring, built-in timer control, and thermal protection. The charge current can be programmed via the I²C interface. The IC limits the charge current when the die temperature exceeds the programmable thermal regulation threshold (120°C default).

When the input power is not sufficient for powering the system load, the MP2660 enters supplement mode by fully turning on the 100mΩ battery FET. When the input is removed, the 100mΩ battery FET is also fully turned on, allowing the battery to power up the system.

When the system load is satisfied, the remaining current is used to charge the battery. The IC reduces the charging current or uses power from the battery to satisfy the system load when its demand is over the input power capacity or if either the input current or voltage loops are active.

Figure 2 shows the power path management structure for the MP2660.

Power Supply

The internal bias circuit of the IC is powered from the higher voltage of IN or BATT. When IN or BATT rises above the respective undervoltage lockout (UVLO) threshold, the sleep comparator, battery depletion comparator, and the battery FET driver are active. The I²C interface is ready for communication and all registers are reset to the default value. The host can access all registers.

Input OVP and UVLO

The MP2660 has an input over-voltage protection (OVP) threshold and an input UVLO threshold. Once the input voltage transitions out of the normal input voltage range, the Q1 FET is turned off immediately.

When the input voltage is identified as a good source, a 200μs immunity timer is active. If the input power is still sufficient when the 200μs timer expires, the system starts up. Otherwise, Q1 remains off (see Figure 3).
Power Path Management
The IC employs a direct power path structure with the battery FET decoupling the system from the battery, which allows for separate control between the system and the battery. The system is given the priority to start up even with a deeply discharged or missed battery. When the input power is available, even with a depleted battery, the system voltage is always regulated to $V_{SYS\_REG}$ by the integrated LDO FET.

As shown in Figure 2, the direct power structure is composed of a front-end LDO FET between IN and SYS pin and a battery FET between SYS and BATT pin.

The input LDO (using an LDO FET) provides power to the system, which drives the system load directly and charges the battery through the battery FET.

For the system voltage control, when the input voltage is higher than $V_{SYS\_REG}$, the system voltage is regulated to $V_{SYS\_REG}$. When the input voltage is lower than $V_{SYS\_REG}$, the LDO FET is fully on in drop-out with an input current limit.

Battery Charge Profile
The IC provides three main charging phases: trickle charge, constant-current charge, and constant-voltage charge (see Figure 4).

1. **Phase 1 (trickle-current charge):** The IC is able to safely trickle charge the deeply depleted battery until the battery voltage reaches the trickle charge to the fast charge threshold ($V_{BATT\_LOW}$). The trickle charge current is programmable via reg03 bit[1:0]. If $V_{BATT\_LOW}$ is not reached before the pre-charge timer (1hr) expires, the charge cycle is stopped, and a corresponding timeout fault signal is asserted.

2. **Phase 2 (constant-current charge):** When the battery voltage exceeds $V_{BATT\_LOW}$, the IC enters a constant-current charge (fast charge) phase. The fast charge current is programmable via reg02 bit[4:0].

3. **Phase 3 (constant-voltage charge):** When the battery voltage rises to the pre-programmable charge full voltage ($V_{BATT\_REG}$) set via reg04 bit[7:2], the charge mode changes from CC mode to CV mode, and the charge current begins to taper off.

The end of charge (EOC) current threshold ($I_{BF}$) value setting is shown in Table 2.

<table>
<thead>
<tr>
<th>Reg02 Bit[4]</th>
<th>$I_{BF}$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 ($I_{CC_SETTING}\leq263\text{mA}$)</td>
<td>$100% \times I_{TC}$</td>
</tr>
<tr>
<td>1 ($I_{CC_SETTING}\geq280\text{mA}$)</td>
<td>$200% \times I_{TC}$</td>
</tr>
</tbody>
</table>
Once the charge current reaches the EOC current threshold (I_{BF}) and the CV loop is still dominated, the IC has three possible actions after a 500µs delay depending on the settings of EN_{BF} (reg05 bit[6]) and TERM_TMR (reg05 bit[0]):

1. **EN_{BF} = 1, TERM_{TMR} = 0**, (default spec): The IC terminates the charge and changes the charge status to "charge done."
2. **EN_{BF} = 1, TERM_{TMR} = 1**: The IC changes the charge status to "charge done," but the charge current continues tapering off until it reaches 0.
3. **EN_{BF} = 0, TERM_{TMR} = x**: The charge status stays at "charge," but the charge current continues tapering off until it reaches 0.

During the charging process, the actual charge current may be less than the register setting due to other loop regulations, such as dynamic power management (DPM) regulation or thermal regulation. Refer to the Input Current- and Input Voltage-Based Power Management section for details.

If I_{BF} is not reached before the safety charge timer expires (see Safety Timer section), the charge cycle is ceased and corresponding timeout fault signal is asserted.

The following conditions can start a new charge cycle:
- The input power is recycled
- Battery charging is enabled by the I2C
- Auto-recharge kicks in

However, these conditions can stop a charge cycle:
- No thermistor fault at NTC
- No safety timer fault
- No battery over voltage
- Battery FET is not forced to turn off

**Automatic Recharge**

When the battery is fully charged and charging is terminated, the battery may be discharged due to the system consumption or a self-discharge. When the battery voltage is discharged below the recharge threshold, and \( V_{IN} \) is still in the operating range, the IC begins another new charging cycle automatically without the requirement of restarting a charging cycle manually. The auto-recharge function is valid only when \( EN_{BF} = 1 \) and \( TERM_{TMR} = 0 \).

**Battery Over-Voltage Protection (OVP)**

The IC is designed with a built-in battery over-voltage limit about 120mV higher than \( V_{BATT\_REG} \). When the battery over-voltage event occurs, the IC suspends the charging immediately and asserts a fault.

**Input Current- and Input Voltage-Based Power Management**

To meet the input source (usually USB) maximum current limit specification, the IC uses an input current-based power management by monitoring the input current continuously. The total input current limit can be programmable via the I2C to prevent the input source from overloading.

If the pre-set input current limit is higher than the rating of the input source, back-up input voltage-based power management also works to prevent the input source from being overloaded. If either the input current limit or the input voltage regulation is reached, the Q1 FET between IN and SYS is regulated so that the total input power is limited. As a result, the system voltage drops. Once the system declines to the minimum value of 4.8V or \( V_{IN} - 200mV \), the charge current is reduced to prevent the system voltage from dropping further.

The voltage-based dynamic power management (DPM) regulates the input voltage to \( V_{IN\_REG} \) when the load is over the input power capacity. \( V_{IN\_REG} \) set via the I2C should be at least 500mV higher than \( V_{BATT\_REG} \) to ensure the stable operation of the regulator.

**Battery Supplement Mode**

The charge current is reduced to keep the input current or input voltage in regulation when DPM occurs. If the charge current is at zero and the input source is still overloaded due to a heavy system load, the system voltage starts to fall off. Once the system voltage falls below the battery voltage, the IC enters battery supplement mode. When the system voltage is 30mV below the battery voltage, the ideal diode mode is enabled. The battery FET is regulated to maintain...
$V_{BATT} - V_{SYS}$ at 22.5mV. If the voltage drop of the battery FET ($I_{DSG} \cdot R_{ON_BATT}$) is higher than 22.5mV, the battery FET is fully turned on to keep the ideal forward voltage. When the system load decreases and $V_{SYS}$ is higher than $V_{BATT} + 20$mV, ideal diode mode is disabled.

Figure 5 shows the dynamic power management and battery supplement mode operation profile.

When $V_{IN}$ is not available, the IC operates in discharge mode, and the battery FET is always fully on to reduce loss.

![Figure 5: Dynamic Power Management and Battery Supplement Operation Profile](image)

**Battery Charge Full Voltage**

The battery voltage for the constant voltage regulation phase is $V_{BATT\_REG}$. When $V_{BATT\_REG}$ is 4.2V, it has a ±0.5% accuracy over the ambient temperature range of 0°C to +50°C. When the battery is removed, the $V_{BATT}$ voltage is between $V_{BATT\_REG} - V_{RECHG}$ and $V_{BATT\_REG}$.

**Thermal Regulation and Thermal Shutdown**

The IC monitors the internal junction temperature continuously to maximize power delivery and prevent the chip from overheating. When the internal junction temperature reaches the pre-set limit of $T_{REG}$ (default 120°C), the IC reduces the charge current to prevent higher power dissipation. The multiple thermal regulation thresholds from 60 - 120°C help the system design meet the thermal requirement in different applications. The junction temperature regulation threshold can be set via reg06 bit[1:0]. When the junction temperature reaches 150°C, both Q1 and Q2 are turned off.

**Negative Temperature Coefficient (NTC) Temperature Sensor**

NTC allows the IC to sense the battery temperature using the thermistor usually available in the battery pack to ensure a safe operating environment of the chip. A resistor with an appropriate value should be connected from IN to NTC, and the thermistor should be connected from NTC to ground. The voltage on NTC is determined by the resistor divider, whose divide ratio depends on the battery temperature. The IC sets a pre-determined upper and lower bound of the divide ratio internally for NTC cold and NTC hot.

The NTC function works in charge mode only. Once the NTC voltage falls out of the divide ratio (the temperature is outside the safe operating range), the IC stops the charging and reports it on the status bits. Charging resumes automatically after the temperature falls back into the safe range.

**Safety Timer**

The IC provides both a pre-charge and a fast-charge safety timer to prevent extended charging cycles due to abnormal battery conditions. The safety timer is one hour when the battery voltage is below $V_{BATT\_LOW}$. The fast-charge safety timer begins when the battery enters fast charging. Figure 4 shows the definition of the fast charge timer. The fast-charge safety timer can be programmed through the I2C. The safety timer feature can be disabled via the I2C.

The following actions can restart the safety timer:

- A new charge cycle is initiated.
- Reg01 bit[3] is written from 0 to 1 (charge enable).
- Reg05 bit[3] is written from 0 to 1 (safety timer enable).
- Reg01 bit[7] is written from 0 to 1 (software reset).
During PPM, the charge current is reduced because of insufficient input power (input current limit, input voltage limit), the timer period could be extended by 2 times with setting TMR2X_EN (Reg06 bit[6]) as 1.
1. TMR2X_EN = 1: enable 2X extended safety timer during PPM
2. TMR2X_EN = 0, (default spec): disable 2X extended safety timer during PPM

This feature avoids a false trigger indication for bad battery indication when there is little charge current delivered to the battery as a result of the insufficient input power.

**Host Mode and Default Mode**

The IC is a host-controlled device. After the power-on reset, the IC starts up in the watchdog timer expiration state or default mode. All registers are in the default settings.

Any write to the IC switches it into host mode. All charge parameters are programmable. If the watchdog timer (reg05 bit[5:4]) is not disabled, the host must reset the watchdog timer regularly by writing 1 to reg01 bit[6] before the watchdog timer expires to keep the device in host mode. Once the watchdog timer expires, the IC returns to default mode. The watchdog timer limit can also be programmed or disabled by the host control. When there is no VIN, the watchdog timer is suspended.

The operation can also be changed to default mode when one of the following conditions occur:

- Refresh input without battery
- Re-insert battery with no VIN
- Register reset reg01 bit[7] is reset

**Battery Discharge Function**

If the battery is connected and the input source is missing, the battery FET is fully on when VBATT is above the VUV_BATT threshold. The 100mΩ battery FET minimizes conduction loss during discharge. The quiescent current of the IC is as low as 11μA in this mode. The low on resistance and low quiescent current help extend the running time of the battery.

Once IBATT exceeds the programmable discharge current limit (default 1.0A), the battery FET is regulated to limit the discharge current.

Similarly, when the battery voltage falls below the programmable VUV_BATT threshold (default 2.8V), the battery MOSFET is turned off to prevent over-discharge.

**System Short-Circuit Protection (SCP)**

The MP2660 features SYS node short-circuit protection (SCP) for both the IN to SYS path and the BATT to SYS path.

The system voltage is monitored continuously. Once VSYS is lower than 1.5V, the over-current protection threshold for the BATT to SYS path is limited to 700mA (fast off). For details, please refer to the flow chart in Figure 11.

If the system short-circuit occurs when both the input and the battery are present, the protection mechanism of both paths work, with the faster one (the IN_to_SYS path protection mechanism) dominating the hiccup operation.

**Interrupt to Host (INT)**

The IC also has an alert mechanism, which can output an interrupt signal via INT pin to notifies the system ofn the operation by outputting a 256μs low- state INT pulse. Any of the below events can will trigger the INT output:

- Good input source detected
- UVLO or input OVP Charge completed
- Charging status change
- Any fault in reg08 (watchdog timer fault, input fault, thermal fault, safety timer fault, battery OVP fault)

When any fault occurs, the IC sends out an INT pulse and latches the fault state in reg08. After the IC exits the fault state, the fault bit can be released to 0 after the host reads reg08.

Note that the INT needs the external pull up resistor for its open-drain connection. Suggest the resistance not lower than 100kΩ.
Battery Disconnection Function

In applications where the battery is not removable, it is essential to disconnect the battery from the system to shipping mode, in stock mode, or to system reset mode for different applications (shown in Table 3).

1. Shipping Mode:

*Entering shipping mode*: The register bit FET_DIS (reg06 bit[5]), makes the IC enter shipping mode. During normal operation, the battery FET is turned on (the bit is 0). If this bit is set to 1 through the I2C, the battery FET is turned off, and the MP2660 enters shipping mode.

The FET_DIS bit is reset to 0 automatically after the battery FET is turned off.

*Exiting shipping mode*: The IC can exit shipping mode by pulling INT down for a very short time (>500ms).

2. Reset Mode:

The IC can use INT to cut off the path from the battery to the system under the condition needed to reset the system manually.

If the battery FET is on, once the logic at INT is set to low for more than 8s, the battery is disconnected from the system by turning off the battery FET. The battery can be connected in and out of the system by controlling INT (see Figure 6).

<table>
<thead>
<tr>
<th>FET On/Off Change By Control</th>
<th>INT Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H to L for 8s</td>
</tr>
<tr>
<td>Reset Mode</td>
<td></td>
</tr>
<tr>
<td>LDO FET</td>
<td>x</td>
</tr>
<tr>
<td>Battery FET</td>
<td>OFF</td>
</tr>
<tr>
<td>(charging)</td>
<td></td>
</tr>
<tr>
<td>Battery FET</td>
<td>OFF</td>
</tr>
<tr>
<td>(discharging)</td>
<td></td>
</tr>
</tbody>
</table>

![Figure 6: Disconnection Function Operation Profile](image-url)

Table 3: Battery Disconnection Control
### I2C REGISTER MAP

**IC Address:** 09h

#### Input Source Control Register/Address: 00h (Default: 0100 1111)

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>EN_HIZ</td>
<td>0: disable</td>
<td>read/write</td>
<td>Disable (0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: enable</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Input Voltage Regulation

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Value</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>V_IN_REG [3]</td>
<td>640mV</td>
<td>Offset: 3.88V</td>
<td>read/write</td>
<td>4.60V (1001)</td>
</tr>
<tr>
<td>5</td>
<td>V_IN_REG [2]</td>
<td>320mV</td>
<td>Range: 3.88V - 5.08V</td>
<td>read/write</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>V_IN_REG [1]</td>
<td>160mV</td>
<td>Default: 4.60V</td>
<td>read/write</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>V_IN_REG [0]</td>
<td>80mV</td>
<td>(1001)</td>
<td>read/write</td>
<td></td>
</tr>
</tbody>
</table>

#### Input Current Limit

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Value</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>I_IN_LIM [2]</td>
<td>000: 85mA</td>
<td>000: 85mA</td>
<td>read/write</td>
<td>455mA (111)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>001: 130mA</td>
<td>001: 130mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>010: 175mA</td>
<td>010: 175mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>011: 220mA</td>
<td>011: 220mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>100: 265mA</td>
<td>100: 265mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>101: 310mA</td>
<td>101: 310mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>110: 355mA</td>
<td>110: 355mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>111: 455mA</td>
<td>111: 455mA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Charge Configuration

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>CEB</td>
<td>0: charge enable</td>
<td>read/write</td>
<td>Charge enable(0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: charge disabled</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Battery UVLO Threshold

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Value</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>V_UV_BATT [2]</td>
<td>0.4V</td>
<td>Offset: 2.4V</td>
<td>read/write</td>
<td>2.8V (100)</td>
</tr>
<tr>
<td>1</td>
<td>V_UV_BATT [1]</td>
<td>0.2V</td>
<td>Range: 2.4V - 3.1V</td>
<td>read/write</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>V_UV_BATT [0]</td>
<td>0.1V</td>
<td>Default: 2.8V</td>
<td>read/write</td>
<td></td>
</tr>
</tbody>
</table>

### Power-On Configuration Register / Address: 01h (Default: 0000 0100)

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Register reset</td>
<td>0: keep current setting</td>
<td>read/write</td>
<td>Keep current register setting (0)</td>
</tr>
<tr>
<td>6</td>
<td>I2C watchdog timer reset</td>
<td>0: normal</td>
<td>read/write</td>
<td>Normal (0)</td>
</tr>
<tr>
<td>5</td>
<td>Reserved</td>
<td>Reserved</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Reserved</td>
<td>Reserved</td>
<td>NA</td>
<td></td>
</tr>
</tbody>
</table>

#### Battery UVLO Threshold

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Value</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>V_UV_BATT [2]</td>
<td>0.4V</td>
<td>Offset: 2.4V</td>
<td>read/write</td>
<td>2.8V (100)</td>
</tr>
<tr>
<td>1</td>
<td>V_UV_BATT [1]</td>
<td>0.2V</td>
<td>Range: 2.4V - 3.1V</td>
<td>read/write</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>V_UV_BATT [0]</td>
<td>0.1V</td>
<td>Default: 2.8V</td>
<td>read/write</td>
<td></td>
</tr>
</tbody>
</table>
## I2C REGISTER MAP (continued)

### Charge Current Control Register/ Address: 02h (Default: 0000 1110)

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Reserved</td>
<td>Reserved</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Reserved</td>
<td>Reserved</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Reserved</td>
<td>Reserved</td>
<td>NA</td>
<td></td>
</tr>
</tbody>
</table>

**Charge Current Setting**

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
</table>
| 4   | $I_{CC}[4]$ | 272mA      | read/write | Offset: 8mA  
     |        |             |            | Range: 8mA - 535mA  
     |        |             |            | Default: 246mA  
     |        |             |            | (01110)         |
| 3   | $I_{CC}[3]$ | 136mA      | read/write |         |
| 2   | $I_{CC}[2]$ | 68mA       | read/write |         |
| 1   | $I_{CC}[1]$ | 34mA       | read/write |         |
| 0   | $I_{CC}[0]$ | 17mA       | read/write |         |

### Pre-Charge/ Termination Current/ Address: 03h (Default: 0100 1010)

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Reserved</td>
<td>Reserved</td>
<td>NA</td>
<td></td>
</tr>
</tbody>
</table>

**BATT to SYS Discharge Current Limit**

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
</table>
| 6   | $I_{DCH}[3]$ | 800mA      | read/write | Offset: 200mA  
     |        |             |            | Range: 200mA - 1.6A  
     |        |             |            | Default: 1.0A  
     |        |             |            | (1001)           |
| 5   | $I_{DCH}[2]$ | 400mA      | read/write |         |
| 4   | $I_{DCH}[1]$ | 200mA      | read/write |         |
| 3   | $I_{DCH}[0]$ | 100mA      | read/write |         |
| 2   | Reserved | Reserved   | NA         |         |

**Pre-Charge / Terminal Current**

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
</table>
| 1   | $I_{TC}[1]$ | 14mA       | read/write | Offset: 6mA  
     |        |             |            | Range: 6mA - 27mA  
     |        |             |            | Default: 20mA (10) |
| 0   | $I_{TC}[0]$ | 7mA        | read/write |         |
### I²C REGISTER MAP (continued)

#### Charge Voltage Control Register / Address: 04h (Default: 1010 0011)

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>V_BATT_REG [5]</td>
<td>480mV</td>
<td>read/write</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>V_BATT_REG [4]</td>
<td>240mV</td>
<td></td>
<td>Offset: 3.60V</td>
</tr>
<tr>
<td>5</td>
<td>V_BATT_REG [3]</td>
<td>120mV</td>
<td></td>
<td>Range: 3.60V -</td>
</tr>
<tr>
<td>4</td>
<td>V_BATT_REG [2]</td>
<td>60mV</td>
<td></td>
<td>4.545V</td>
</tr>
<tr>
<td>3</td>
<td>V_BATT_REG [1]</td>
<td>30mV</td>
<td></td>
<td>Default: 4.2V</td>
</tr>
<tr>
<td>2</td>
<td>V_BATT_REG [0]</td>
<td>15mV</td>
<td></td>
<td>(101000)</td>
</tr>
</tbody>
</table>

#### Trickle Charge Threshold

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>V_BATT_LOW</td>
<td>0: 2.8V</td>
<td>read/write</td>
<td>3.0V (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: 3.0V</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Battery Recharge Threshold (below V_BATT_REG)

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>V_RECHG</td>
<td>0: 150mV</td>
<td>read/write</td>
<td>300mV (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: 300mV</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Charge Termination/Timer Control Register / Address: 05h (Default: 0100 1010)

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Reserved</td>
<td>Reserved</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>EN_BF</td>
<td>0: disable</td>
<td>read/write</td>
<td>Enable (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: enable</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### I²C Watchdog Timer Limit

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>WATCHDOG [1]</td>
<td>00: Disable timer</td>
<td>read/write</td>
<td>Disable timer (00)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>01: 40s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>WATCHDOG [0]</td>
<td>10: 80s</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>11: 160s</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Safety Timer Setting

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>EN_TIMER</td>
<td>0: disable</td>
<td>read/write</td>
<td>Enable timer (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: enable</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Safety Timer for Fast Charging Cycle

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>CHG_TMR [1]</td>
<td>00: 3hrs</td>
<td>read/write</td>
<td>5hrs (01)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>01: 5hrs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>CHG_TMR [0]</td>
<td>10: 8hrs</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>11: 12hrs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Termination Timer Control (when TERM_TMR is enabled, the IC will not suspend the charge current after charge termination)

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>TERM_TMR</td>
<td>0: disable</td>
<td>read/write</td>
<td>Disable (0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: enable</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### I²C REGISTER MAP (continued)

**Miscellaneous Operation Control Register**
- **Address:** 06h (Default: 0000 1011)

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Reserved</td>
<td>Reserved</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>TMR2X_EN</td>
<td>0: disable 2X extended safety timer during PPM</td>
<td>read/write</td>
<td>Disable (0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: enable 2X extended safety timer during PPM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>FET_DIS</td>
<td>0: enable 1: turn off</td>
<td>read/write</td>
<td>Enable (0)</td>
</tr>
<tr>
<td>4</td>
<td>Reserved</td>
<td>Reserved</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>EN_NTC</td>
<td>0: disable 1: enable</td>
<td>read/write</td>
<td>Enable (1)</td>
</tr>
<tr>
<td>2</td>
<td>Reserved</td>
<td>Reserved</td>
<td>NA</td>
<td></td>
</tr>
</tbody>
</table>

#### Thermal Regulation Threshold

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
</table>
| 1   | T_REG | 00: 60°C  
     |         | 01: 80°C  
     |         | 10: 100°C | 11: 120°C | read/write | 120°C (11) |
| 0   | T_REG | 00: 60°C  
     |         | 01: 80°C  
     |         | 10: 100°C | 11: 120°C |

**NOTE:**
7) This bit only controls the on and off of the battery FET, including charge and discharge.

### System Status Register
- **Address:** 07h (Default: 0000 0000)

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Reserved</td>
<td>Reserved</td>
<td>NA</td>
<td></td>
</tr>
</tbody>
</table>

#### Revision

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Rev [1]</td>
<td>Revision number</td>
<td>read only</td>
<td>(00)</td>
</tr>
<tr>
<td>5</td>
<td>Rev [0]</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 4   | CHG_STAT[1] | 00: not charging  
             |             | read only  | Not charging (00) |
| 3   | CHG_STAT[0] | 01: trickle charge  
             |             |           |           |
|     |          | 10: charge  
             |             |           |           |
|     |          | 11: charge done                                                            |            |           |
| 2   | PPM_STAT | 0: no PPM 1: in PPM                                                        | read only  | No PPM (0) |
|     |          | (no power-path management happens)                                         |            |           |
| 1   | PG_STAT  | 0: power fail 1: power good                                                | read only  | Power fail (0) |
| 0   | THERM_STAT | 0: no thermal regulation  
             |             | read only  | No thermal  |
|     |          | 1: in thermal regulation                                                   |            | regulation (0) |

---

### I2C REGISTER MAP (continued)

Fault Register/ Address: 08h (Default: 0000 0000)

<table>
<thead>
<tr>
<th>Bit</th>
<th>Symbol</th>
<th>Description</th>
<th>Read/Write</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Reserved</td>
<td>Reserved</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>WATCHDOG_FAULT</td>
<td>0: normal</td>
<td>Read only</td>
<td>Normal (0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: watchdog timer expiration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>VIN_FAULT</td>
<td>0: normal</td>
<td>Read only</td>
<td>Normal (0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: input fault (OVP or bad source)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>THEM_SD</td>
<td>0: normal</td>
<td>Read only</td>
<td>Normal (0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: thermal shutdown</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>BAT_FAULT</td>
<td>0: normal</td>
<td>Read only</td>
<td>Normal (0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: battery OVP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>STMR_FAULT</td>
<td>0: normal</td>
<td>Read only</td>
<td>Normal (0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: safety timer expiration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Reserved</td>
<td>Reserved</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>Reserved</td>
<td>Reserved</td>
<td>NA</td>
<td></td>
</tr>
</tbody>
</table>
### ONE-TIME PROGRAMMING MAP

<table>
<thead>
<tr>
<th>#</th>
<th>Bit7</th>
<th>Bit6</th>
<th>Bit5</th>
<th>Bit4</th>
<th>Bit3</th>
<th>Bit2</th>
<th>Bit1</th>
<th>Bit0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x02</td>
<td>N/A</td>
<td>N/A</td>
<td>I CC</td>
<td>8mA</td>
<td>535mA</td>
<td>17mA</td>
<td>step</td>
<td>I TC</td>
</tr>
<tr>
<td>0x03</td>
<td>N/A</td>
<td>N/A</td>
<td>I TC</td>
<td>6mA</td>
<td>27mA</td>
<td>7mA</td>
<td>step</td>
<td></td>
</tr>
<tr>
<td>0x04</td>
<td>N/A</td>
<td>N/A</td>
<td>V BATT REG</td>
<td>3.60V</td>
<td>4.545V</td>
<td>15mV</td>
<td>step</td>
<td></td>
</tr>
<tr>
<td>0x05</td>
<td>N/A</td>
<td>WATCHDOG</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### ONE-TIME PROGRAMMING DEFAULT

<table>
<thead>
<tr>
<th>One-Time Programmable Items</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>I CC</td>
<td>246mA</td>
</tr>
<tr>
<td>I TC</td>
<td>20mA</td>
</tr>
<tr>
<td>V BATT REG</td>
<td>4.2V</td>
</tr>
<tr>
<td>WATCHDOG</td>
<td>Disable Timer</td>
</tr>
</tbody>
</table>
STATE CONVERSION CHART

Figure 7: State Machine Conversion
CONTROL FLOW CHART

POR

V_{IN}>V_{GVDL0} or
V_{BAT}>V_{OTG_ULVD}?  
Yes

Sleep Comparator Active, Battery FET driver power up

No

I2C Write?

No

Default Mode
Registers set as default

Yes

Host Mode
Host Programs Registers

I2C Write?

No

I2C Watchdog Timer Reset (8)

Yes

I2C Watchdog Timer Disabled

No

I2C Watchdog Timer Reset

No

Watchdog Timer Expired?

Yes

Figure 8: Default Mode and Host Mode Selection (9)

NOTES:
8) Once the watchdog timer expires, the I2C watchdog timer reset is required, or the watchdog timer is not valid in the next cycle.
9) The watchdog timer is held when V_{IN} is not present.
CONTROL FLOW CHART (continued)

POR

VDD>2V?

Yes

VDD is powered by Max \( (V_{IN}, V_{BATT}) \)

No

I\(^2\)C is ready

HIZ Mode?

Yes

HIZ Mode, SYS is supplied by BATT

No

EN BG

NG VIN, Q1 is Off

All happen?

Yes

6.25V > \( V_{IN} > 3.9V \)
\( V_{IN} > V_{BATT} + 120mV \)
\( V_{IN} > V_{SYS} + 120mV \)
FETDIS = 0

No

Good VIN, Q1 is turned on and regulated

ENCHG is OK

VSYS > VBATT + 80mV
FETDIS = 0

All happen?

Yes

Any Fault?

Yes

ENCHG Regulate Q2

No

Figure 9: Input Power Start-Up Flow Chart
CONTROL FLOW CHART (continued)

Figure 10: Charging Process
CONTROL FLOW CHART (continued)

Figure 11: System Short-Circuit Protection
APPLICATION INFORMATION

Selecting a Resistor for the NTC Sensor

Figure 12 shows an internal resistor divider reference circuit to limit the low temperature threshold and high temperature threshold at \( V_{\text{HOT}} \) and \( V_{\text{COLD}} \), respectively.

![Figure 12: NTC Function Block](image)

For a given NTC thermistor, set the NTC window by selecting appropriate \( R_{T1} \) and \( R_{T2} \) values with Equation (1) and Equation (2):

\[
\frac{R_{T2}}{R_{T1} + R_{T2}} = V_{\text{COLD}} \quad (1) \\
\frac{R_{T2}}{R_{T1} + R_{T2}} = V_{\text{HOT}} \quad (2)
\]

Where \( R_{\text{NTC,Hot}} \) is the value of the NTC resistor at the high end of the required temperature operation range, and \( R_{\text{NTC,Cold}} \) is NTC resistor value at a low temperature. The two resistors (\( R_{T1} \) and \( R_{T2} \)) allow the high temperature limit and low temperature limit to be programmed independently. With this feature, the MP2660 can fit most NTC resistor types and different temperature operation range requirements.

The \( R_{T1} \) and \( R_{T2} \) values depend on the type of NTC resistor used. For example, for the thermistor NCP18XH103, \( R_{\text{NTC,Cold}} \) is 27.219k\( \Omega \) at 0°C, and \( R_{\text{NTC,Hot}} \) is 4.161k\( \Omega \) at 50°C.

Equation (1) and Equation (2) can be used to calculate \( R_{T1} = 6.59k\Omega \) and \( R_{T2} = 24.15k\Omega \), assuming that the NTC window is between 0°C and 50°C and using the \( V_{\text{COLD}} \) and \( V_{\text{HOT}} \) values from the EC table.

Selecting the External Capacitor

Like most low-dropout regulators, the MP2660 requires external capacitors for regulator stability and voltage spike immunity. The device is designed specifically for portable applications requiring minimum board space and small components. These capacitors must be selected correctly for optimal performance.

An input capacitor is required for stability. A capacitor of at least 1\( \mu \)F must be connected between IN to GND for stable operation over the entire load current range. There can be more output capacitance than input as long as the input is at least 1\( \mu \)F.

The IC is designed specifically to work with a very small ceramic output capacitor (typically 2.2\( \mu \)F). A ceramic capacitor with X5R or X7R type dielectrics at least 2.2\( \mu \)F is suitable in the MP2660 application circuit. For the MP2660, the output capacitor should be connected between SYS and GND with thick traces and small loop area.

A capacitor from BATT to GND is also necessary for the MP2660, and the typical capacitance value is 2.2\( \mu \)F. A ceramic capacitor with X5R or X7R type dielectrics at least 2.2\( \mu \)F is suitable for the application circuit.

A capacitor between VDD and GND is used to stabilize the VDD voltage to power the internal control and logic circuit. The typical value of this capacitor is 100nF.

PCB Layout Guidelines

Efficient PCB layout is critical for stable operation. For best results, follow the guidelines below.

1. Place the external capacitors as close to the IC as possible to ensure the smallest input inductance and the ground impedance.
2. Place the PCB trace connecting the capacitor between VDD and GND very close to the IC.
3. Keep the signal GND for the \( I^2C \) wire clean and away from power GND.
4. Route the \( I^2C \) wires (SDA, SCL) parallel with each other.
Figure 13: MP2660 Typical Application Circuit with 5V Input

Table 4: The Key BOM of Figure 13

<table>
<thead>
<tr>
<th>Qty</th>
<th>Ref</th>
<th>Value</th>
<th>Description</th>
<th>Package</th>
<th>Manufacture</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C1</td>
<td>4.7µF</td>
<td>Ceramic Capacitor; 16V; X5R or X7R</td>
<td>0603</td>
<td>Any</td>
</tr>
<tr>
<td>1</td>
<td>C2</td>
<td>2.2µF</td>
<td>Ceramic Capacitor; 16V; X5R or X7R</td>
<td>0603</td>
<td>Any</td>
</tr>
<tr>
<td>1</td>
<td>C3</td>
<td>2.2µF</td>
<td>Ceramic Capacitor; 16V; X5R or X7R</td>
<td>0603</td>
<td>Any</td>
</tr>
<tr>
<td>1</td>
<td>C4</td>
<td>100nF</td>
<td>Ceramic Capacitor; 16V; X5R or X7R</td>
<td>0603</td>
<td>Any</td>
</tr>
<tr>
<td>2</td>
<td>RT1, RT2</td>
<td>10kΩ</td>
<td>Film Resistor; 1%</td>
<td>0603</td>
<td>Any</td>
</tr>
</tbody>
</table>
PACKAGE INFORMATION

WLCSP-9 (1.55mm x 1.55mm)

NOTE:
1) ALL DIMENSIONS ARE IN MILLIMETERS.
2) BALL COPLANARITY SHALL BE 0.05 MILLIMETER MAX.
3) JEDEC REFERENCE IS MO-211, VARIATION BC.
4) DRAWING IS NOT TO SCALE.

RECOMMENDED LAND PATTERN