



# **MP2696B**

## **I<sup>2</sup>C-Controlled, Single-Cell Switching Charger with Power-Path Management, Boost Output, and 3.5A Input Current Limit**

### **DESCRIPTION**

The MP2696B is a highly integrated, flexible, switch-mode, battery-charging, power-path management device designed for a single-cell Li-ion and Li-polymer battery. This device can be used in a wide range of portable applications.

The MP2696B integrates three battery-charging phases: pre-charge, constant current charge, and constant voltage charge. This device also manages the input power source through input current limit regulation and minimum input voltage regulation.

The MP2696B can switch to boost mode to generate the system power output from the battery.

The MP2696B has an integrated IN to SYS pass-through path to pass the input voltage to the system.

Using an I<sup>2</sup>C interface, the host can flexibly configure the charge and boost parameters. The device operating status can also be read in the registers.

Safety features include SYS short-circuit protection (SCP), input over-voltage protection (OVP), battery under-voltage protection (UVP), thermal shutdown, and JEITA battery temperature monitoring.

The MP2696B is available in a QFN-21 (3mmx3mm) package.

### **FEATURES**

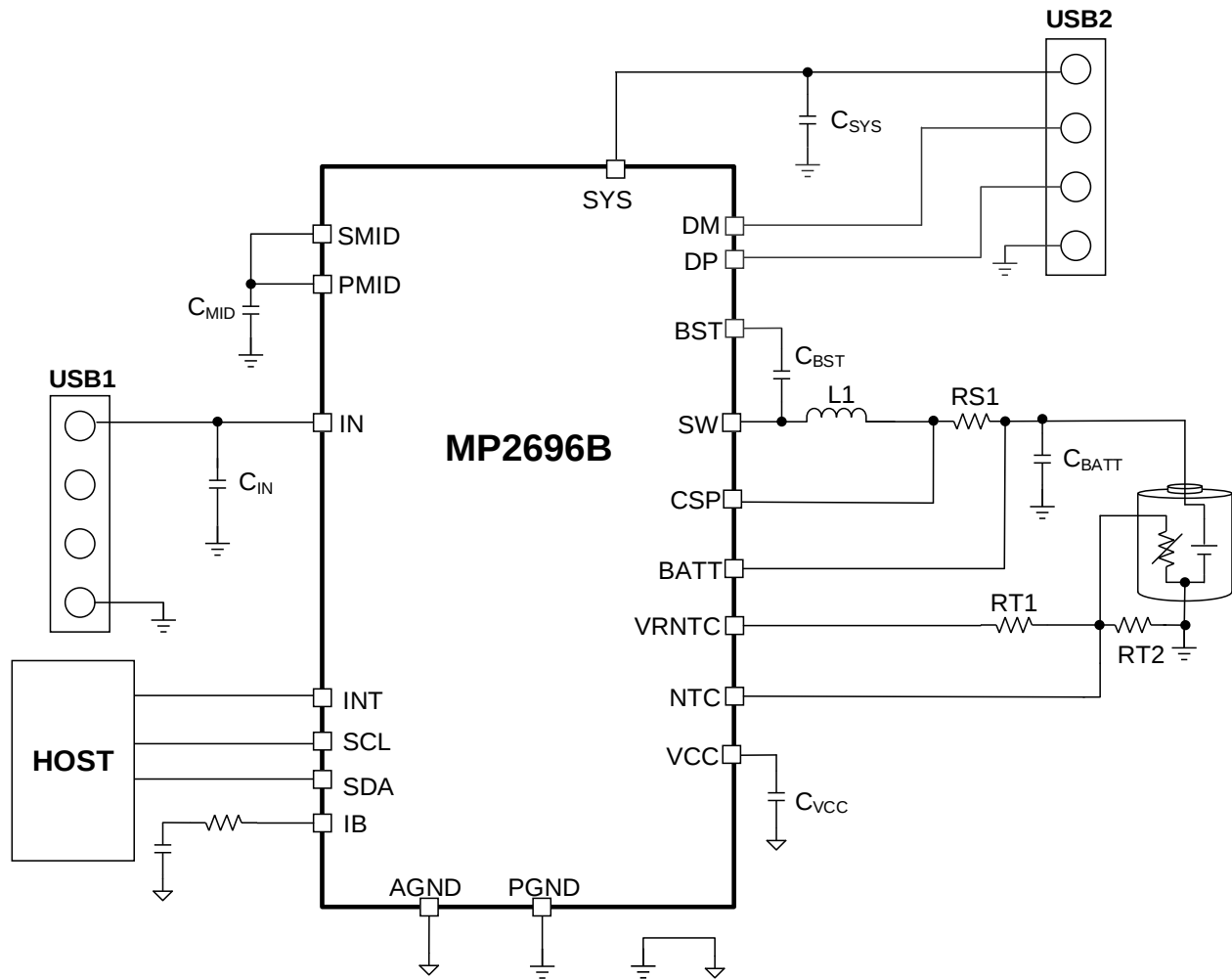
- 4.0V to 11V Operating Voltage Range
- Up to 16V Sustainable Input Voltage
- 500mA to 3.6A Configurable Charge Current
- 3.6V to 4.45V Configurable Charge Regulation Voltage with  $\pm 0.5\%$  Accuracy
- 500mA to 3.5A Configurable Input Current Limit with  $\pm 10\%$  Accuracy
- Minimum Input Voltage Loop for Maximum Adapter Power Tracking
- Ultra-Low 25 $\mu$ A Battery Discharge Current in Idle Mode
- Boost Converter with Up to 4.0A of Output Current:
  - Configurable Output Current Limit Loop
  - Configurable Boost Output Voltage
  - USB Output Cable Compensation
  - Configurable Inductor Peak Current Limiting
- Comprehensive Safety Features:
  - Fully Customizable JEITA Profile with Configurable Temperature Threshold
  - Charge Safety Timer
  - Input Over-Voltage Protection (OVP)
  - Thermal Shutdown
  - SYS Over-Current (OC) and Short-Circuit Protection (SCP)
- Analog Voltage Output IB Pin for Battery Current Monitoring
- SYS Plug-In Detection
- SYS No Load Detection
- SYS DP/DM Interface for BC1.2 and Non-Standard Adapters
- Status and Fault Monitoring
- Available in a QFN-21 (3mmx3mm) Package

### **APPLICATIONS**

- Sub-Battery Applications
- Power Bank Applications for Smartphones, Tablets, and Other Portable Devices

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", the MPS logo, and "Simple, Easy Solutions" are registered trademarks of Monolithic Power Systems, Inc. or its subsidiaries.

# TYPICAL APPLICATION



## ORDERING INFORMATION

| Part Number*     | Package          | Top Marking | MSL Rating |
|------------------|------------------|-------------|------------|
| MP2696BGQ-0000** | QFN-21 (3mmx3mm) | See Below   | 1          |
| EVKT-MP2696B     | Evaluation kit   | -           |            |

\* For Tape & Reel, add suffix -Z (e.g. MP2696BGQ-xxxx-Z).

\*\*“xxx” is the register setting option. The factory default is “0000.” This content can be viewed in the I<sup>2</sup>C register map. Contact an MPS FAE to obtain an “xxx” value.

## TOP MARKING

**BPFY**

**LLLL**

BPF: Product code of MP2696BGQ

Y: Year code

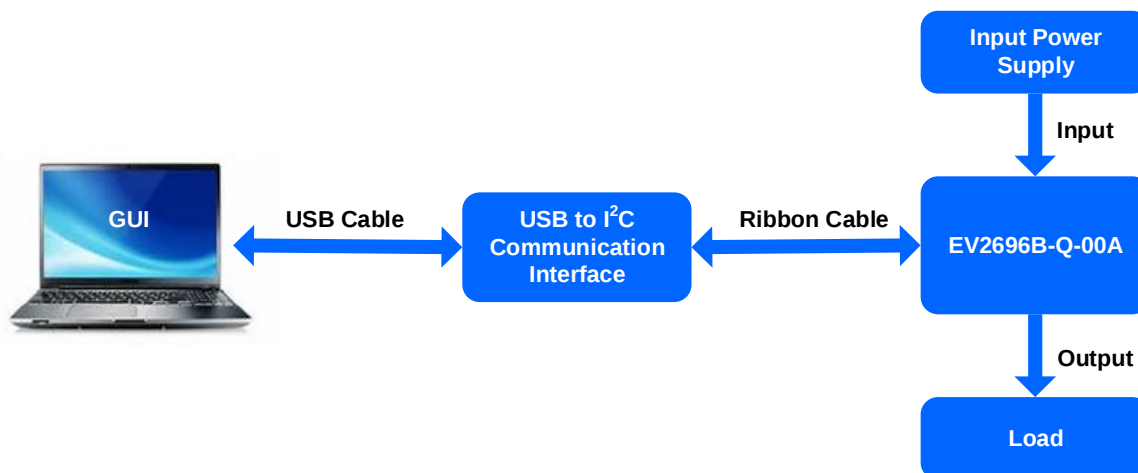
LLLL: Lot number

## EVALUATION KIT EVKT-MP2696B

EVKT-MP2696B kit contents (items below can be ordered separately):

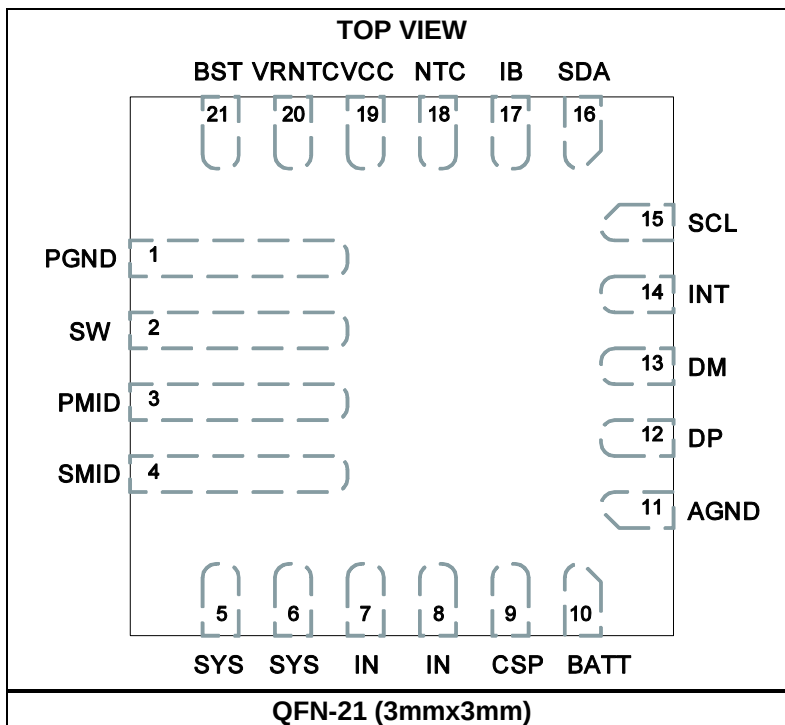
| # | Part Number       | Item                                                                                              | Quantity |
|---|-------------------|---------------------------------------------------------------------------------------------------|----------|
| 1 | EV2696B-Q-00A     | MP2696B evaluation board                                                                          | 1        |
| 2 | EVKT-USB2C-02-BAG | Includes one USB to I <sup>2</sup> C communication interface, one USB cable, and one ribbon cable | 1        |
| 3 | Online resources  | Include datasheet, user guide, product brief, and GUI                                             | 1        |

**Order directly from [MonolithicPower.com](http://MonolithicPower.com) or our distributors.**



**Figure 1: EVKT-MP2696B Evaluation Kit Set-Up**

## PACKAGE REFERENCE



## PIN FUNCTIONS

| Pin # | Name  | I/O   | Description                                                                                                                                                                                                                   |
|-------|-------|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1     | PGND  | Power | <b>Power ground.</b>                                                                                                                                                                                                          |
| 2     | SW    | Power | <b>Switching output node.</b> Connect SW to the inductor.                                                                                                                                                                     |
| 3     | PMID  | Power | <b>Drain of the high-side switching MOSFET.</b> Bypass PMID with ceramic capacitors from PMID to PGND, placed as close to the IC as possible.                                                                                 |
| 4     | SMID  | Power | <b>Connected to the drain of Q1 and Q2.</b> Short SMID to PMID on the PCB.                                                                                                                                                    |
| 5, 6  | SYS   | Power | <b>System power output.</b> Place ceramic capacitors from SYS to PGND.                                                                                                                                                        |
| 7, 8  | IN    | Power | <b>Power input of the IC.</b> Place ceramic capacitors from IN to PGND.                                                                                                                                                       |
| 9     | CSP   | I     | <b>Battery current-sense positive input.</b>                                                                                                                                                                                  |
| 10    | BATT  | I     | <b>Battery positive terminal.</b>                                                                                                                                                                                             |
| 11    | AGND  | Power | <b>Analog ground.</b> Short to PGND on the PCB.                                                                                                                                                                               |
| 12    | DP    | I/O   | <b>Positive port of the USB data for the output.</b> High ESD rating.                                                                                                                                                         |
| 13    | DM    | I/O   | <b>Negative port of the USB data for the output.</b> High ESD rating.                                                                                                                                                         |
| 14    | INT   | O     | <b>Open-drain interrupt output.</b> Connect INT to the logic rail through a 10kΩ resistor.                                                                                                                                    |
| 15    | SCL   | I     | <b>I<sup>2</sup>C interface clock.</b> Connect SCL to the logic rail through a 10kΩ resistor.                                                                                                                                 |
| 16    | SDA   | I/O   | <b>I<sup>2</sup>C interface data.</b> Connect SDA to the logic rail through a 10kΩ resistor.                                                                                                                                  |
| 17    | IB    | O     | <b>Battery current indicator.</b> The voltage at IB indicates the battery's charge current in charge mode, and the battery's discharge current in boost mode.                                                                 |
| 18    | NTC   | I     | <b>Temperature-sense input.</b> Connect NTC to a negative temperature coefficient thermistor. Configure the temperature window with a resistor divider from VRNTC to NTC to GND. Configurable JEITA thresholds are supported. |
| 19    | VCC   | Power | <b>Internal circuit and switch driver power supply.</b> Bypass VCC to AGND with a ceramic capacitor, placed as close to the IC as possible. For the external load capacity, see the VCC Power Supply section on page 15.      |
| 20    | VRNTC | Power | <b>Reference voltage output for powering up NTC.</b>                                                                                                                                                                          |
| 21    | BST   | Power | <b>Bootstrap.</b> Connect a 470nF bootstrap capacitor between BST and SW to form a floating supply across the high-side power switch driver.                                                                                  |

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

IN, PMID, SMID, SYS to PGND....-0.3V to +16V  
 SW to PGND.....-0.3V (-2V for 20ns) to  
 +14V (16V for 20ns)  
 BST to PGND.....SW to SW + 5V  
 All other pins to AGND.....-0.3V to +5.0V  
 Continuous power dissipation ( $T_A = 25^{\circ}\text{C}$ ) <sup>(2)</sup> .....  
 ..... 2.5W  
 Junction temperature .....150°C  
 Lead temperature (solder) .....260°C  
 Storage temperature.... -65°C to +150°C

## ESD Ratings

DP, DM pins:  
 Human body model (HBM) ..... 8000V  
 Charged device model (CDM) ..... 800V  
 All other pins:  
 Human body model (HBM) ..... 2000V  
 Charged device model (CDM) ..... 250V

## Recommended Operating Conditions <sup>(3)</sup>

Supply voltage ( $V_{IN}$ ) .....4V to 11V  
 Input current ( $I_{IN}$ ) .....Up to 3.5A  
 System current ( $I_{SYS}$ ).....Up to 4.0A  
 Charge current ( $I_{CC}$ ) .....Up to 3.6A  
 Battery voltage ( $V_{BATT}$ ) .....Up to 4.5V  
 Operating junction temp ( $T_J$ ).... -40°C to +125°C

**Thermal Resistance <sup>(4)</sup>**       $\theta_{JA}$        $\theta_{JC}$   
 QFN-21 (3mmx3mm)..... 50 ..... 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  $T_J$  (MAX), the junction-to-ambient thermal resistance  $\theta_{JA}$ , and the ambient temperature  $T_A$ . The maximum allowable continuous power dissipation at any ambient temperature is calculated by  $P_D$  (MAX) =  $(T_J$  (MAX) -  $T_A$ ) /  $\theta_{JA}$ . Exceeding the maximum allowable power dissipation can cause excessive die temperature, and the regulator may 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<sub>IN</sub> = 5.0V, V<sub>BATT</sub> = 3.5V, R<sub>S1</sub> = 10mΩ, T<sub>A</sub> = 25°C, unless otherwise noted.

| Parameters                                           | Symbol                 | Condition                                                                                                                             | Min  | Typ  | Max  | Units |
|------------------------------------------------------|------------------------|---------------------------------------------------------------------------------------------------------------------------------------|------|------|------|-------|
| <b>Quiescent Current</b>                             |                        |                                                                                                                                       |      |      |      |       |
| Battery discharge current in idle mode               | I <sub>BATT_IDLE</sub> | Idle mode                                                                                                                             |      | 25   | 36   | μA    |
| Input quiescent current without switching            | I <sub>IN_Q</sub>      | V <sub>IN</sub> > V <sub>IN_UVLO</sub> , V <sub>IN</sub> > V <sub>BATT</sub> + V <sub>HDRM</sub> , charge disabled, float SYS         |      | 0.6  | 1    | mA    |
| Input quiescent current when switching               | I <sub>IN_QSW</sub>    | V <sub>IN</sub> > V <sub>IN_UVLO</sub> , V <sub>IN</sub> > V <sub>BATT</sub> + V <sub>HDRM</sub> , charge enabled, float BATT and SYS |      | 1    |      | mA    |
| Battery discharge current in boost mode              | I <sub>BOOST_Q</sub>   | I <sub>SYS</sub> = 0, V <sub>BOOST</sub> , bits[2:0] = 5.15V, boost enabled, V <sub>BATT</sub> = 4.2V                                 |      | 2    |      | mA    |
| <b>Power On/Off</b>                                  |                        |                                                                                                                                       |      |      |      |       |
| IN operating range                                   | V <sub>IN_OP</sub>     | Converter switching                                                                                                                   | 4    |      | 11   | V     |
| Input under-voltage lockout                          | V <sub>IN_UV</sub>     | V <sub>IN</sub> falling                                                                                                               | 2.95 | 3.10 | 3.25 | V     |
| Input under-voltage lockout hysteresis               |                        | V <sub>IN</sub> rising                                                                                                                |      | 305  |      | mV    |
| Input vs. battery headroom                           | V <sub>HDRM</sub>      | V <sub>IN</sub> rising                                                                                                                |      | 200  | 310  | mV    |
|                                                      |                        | V <sub>IN</sub> falling                                                                                                               | 10   | 80   |      | mV    |
| Battery under-voltage lockout                        | V <sub>BATT_UV</sub>   | During boost                                                                                                                          | 2.4  | 2.5  | 2.6  | V     |
|                                                      |                        | Before boost starts                                                                                                                   | 2.8  | 2.9  | 3.0  | V     |
| VCC LDO output voltage                               | V <sub>VCC</sub>       | V <sub>IN</sub> = 5V, I <sub>VCC</sub> = 30mA                                                                                         | 3.3  | 3.55 | 3.8  | V     |
| VCC under-voltage lockout                            | V <sub>CC_UV</sub>     | VCC rising                                                                                                                            | 1.9  | 2.1  | 2.3  | V     |
| VCC under-voltage lockout hysteresis                 |                        |                                                                                                                                       |      | 80   |      | mV    |
| <b>Power Path</b>                                    |                        |                                                                                                                                       |      |      |      |       |
| IN to PMID MOSFET (Q1) on resistance                 | R <sub>ON_Q1</sub>     |                                                                                                                                       |      | 25   |      | mΩ    |
| PMID to SYS MOSFET (Q2) on resistance                | R <sub>ON_Q2</sub>     |                                                                                                                                       |      | 15   |      | mΩ    |
| High-side MOSFET (Q3) on resistance                  | R <sub>ON_HS</sub>     |                                                                                                                                       |      | 15   |      | mΩ    |
| Low-side MOSFET (Q4) on resistance                   | R <sub>ON_LS</sub>     |                                                                                                                                       |      | 14   |      | mΩ    |
| Peak current limit for high-side MOSFET in buck mode | I <sub>HS_PK</sub>     | Constant current charge mode                                                                                                          |      | 6.5  |      | A     |
|                                                      |                        | Pre-charge mode                                                                                                                       |      | 1.3  |      | A     |
| Peak current limit for low-side MOSFET in boost mode | I <sub>LS_PK</sub>     | BST_IPK, bits[1:0] = 6.5A                                                                                                             | 5.9  | 6.6  | 7.3  | A     |
|                                                      |                        | BST_IPK, bits[1:0] = 5A                                                                                                               | 4.2  | 4.9  | 5.6  | A     |
| Switching frequency                                  | f <sub>SW</sub>        | SW_FREQ = 700kHz                                                                                                                      |      | 720  |      | kHz   |
|                                                      |                        | SW_FREQ = 1200kHz                                                                                                                     |      | 1200 |      | kHz   |

## ELECTRICAL CHARACTERISTICS (continued)

V<sub>IN</sub> = 5.0V, V<sub>BATT</sub> = 3.5V, RS1 = 10mΩ, T<sub>A</sub> = 25°C, unless otherwise noted.

| Parameters                                     | Symbol                | Condition                                           | Min   | Typ  | Max   | Units |
|------------------------------------------------|-----------------------|-----------------------------------------------------|-------|------|-------|-------|
| Charge Mode                                    |                       |                                                     |       |      |       |       |
| Charge voltage regulation                      | V <sub>BATT_REG</sub> | BATT_REG range <sup>(5)</sup>                       | 3.6   |      | 4.45  | V     |
|                                                |                       | BATT_REG, bits[2:0] = 3.6V                          | 3.582 | 3.6  | 3.618 | V     |
|                                                |                       | BATT_REG, bits[2:0] = 4.1V                          | 4.080 | 4.1  | 4.120 | V     |
|                                                |                       | BATT_REG, bits[2:0] = 4.2V                          | 4.179 | 4.2  | 4.221 | V     |
|                                                |                       | BATT_REG, bits[2:0] = 4.3V                          | 4.279 | 4.3  | 4.321 | V     |
|                                                |                       | BATT_REG, bits[2:0] = 4.35V                         | 4.328 | 4.35 | 4.372 | V     |
|                                                |                       | BATT_REG, bits[2:0] = 4.4V                          | 4.378 | 4.40 | 4.422 | V     |
|                                                |                       | BATT_REG, bits[2:0] = 4.45V                         | 4.428 | 4.45 | 4.472 | V     |
| Fast charge current                            | I <sub>CC</sub>       | ICC, bits[4:0] = 3A                                 | 2.7   | 3    | 3.4   | A     |
|                                                |                       | ICC, bits[4:0] = 1.5A                               | 1.35  | 1.5  | 1.7   | A     |
|                                                |                       | ICC, bits[4:0] = 0.5A                               | 0.41  | 0.5  | 0.62  | A     |
| Charge termination current                     | I <sub>TERM</sub>     | ITERM, bits[1:0] = 100mA                            | 40    | 100  | 160   | mA    |
|                                                |                       | ITERM, bits[1:0] = 200mA                            | 100   | 200  | 300   | mA    |
| Recharge threshold below V <sub>BATT_REG</sub> | V <sub>RECH</sub>     | V <sub>BATT</sub> falling                           | 100   | 200  | 320   | mV    |
| Pre-charge to fast charge threshold            | V <sub>BATT_PRE</sub> | V <sub>BATT</sub> rising                            | 2.9   | 3.0  | 3.1   | V     |
| Pre-charge to fast charge hysteresis           |                       | V <sub>BATT</sub> falling                           |       | 290  |       | mV    |
| Pre-charge current                             | I <sub>PRE</sub>      | IPRE, bits[1:0] = 150mA, V <sub>BATT</sub> = 1.8V   |       | 150  |       | mA    |
|                                                |                       | IPRE, bits[1:0] = 350mA, V <sub>BATT</sub> = 1.8V   |       | 350  |       | mA    |
| Safety timer for charging cycle                |                       |                                                     |       | 20   |       | hours |
| Input Regulation                               |                       |                                                     |       |      |       |       |
| Input minimum voltage regulation               | V <sub>IN_MIN</sub>   | VINMIN, bits[2:0] = 4.5V                            | 4.41  | 4.51 | 4.61  | V     |
|                                                |                       | VINMIN, bits[2:0] = 4.65V                           | 4.56  | 4.66 | 4.76  | V     |
| Input current limit                            | I <sub>IN_LIM</sub>   | IINLIM, bits[2:0] = 3A                              | 2.62  | 2.75 | 2.9   | A     |
|                                                |                       | IINLIM, bits[2:0] = 1.5A                            | 1.3   | 1.38 | 1.5   | A     |
|                                                |                       | IINLIM, bits[2:0] = 0.5A                            | 0.4   | 0.45 | 0.5   | A     |
| Boost Mode                                     |                       |                                                     |       |      |       |       |
| Boost output voltage at PMID                   | V <sub>PMID_BST</sub> | VBOOST, bits[2:0] = 5.15V, I <sub>sys</sub> = 10mA  | 5.05  | 5.13 | 5.21  | V     |
|                                                |                       | VBOOST, bits[2:0] = 5.225V, I <sub>sys</sub> = 10mA | 5.13  | 5.21 | 5.29  | V     |
| Boost output current limit                     | I <sub>BST_LMT</sub>  | IOLIM, bits[3:0] = 3A                               | 3.0   | 3.16 | 3.37  | A     |
|                                                |                       | IOLIM, bits[3:0] = 2A                               | 2     | 2.25 | 2.5   | A     |
|                                                |                       | IOLIM, bits[3:0] = 1A                               | 1.05  | 1.25 | 1.45  | A     |

## ELECTRICAL CHARACTERISTICS *(continued)*

V<sub>IN</sub> = 5.0V, V<sub>BATT</sub> = 3.5V, R<sub>S1</sub> = 10mΩ, T<sub>A</sub> = 25°C, unless otherwise noted.

| Parameters                                       | Symbol                | Condition                                    | Min  | Typ | Max  | Units |
|--------------------------------------------------|-----------------------|----------------------------------------------|------|-----|------|-------|
| <b>Analog Control</b>                            |                       |                                              |      |     |      |       |
| SYS no load current threshold                    | I <sub>BST_OFF</sub>  | NOLOAD_THR, bits[1:0] = 30mA                 |      | 30  |      | mA    |
|                                                  |                       | NOLOAD_THR, bits[1:0] = 50mA                 |      | 50  |      | mA    |
|                                                  |                       | NOLOAD_THR, bits[1:0] = 75mA                 |      | 75  |      | mA    |
|                                                  |                       | NOLOAD_THR, bits[1:0] = 100mA                |      | 100 |      | mA    |
| SYS plug-in detection threshold                  | V <sub>PLUG_IN</sub>  | SYS falling, percentage of V <sub>BATT</sub> | 70   | 75  | 80   | %     |
| Discharge dummy load at IN                       | R <sub>IN_DUM</sub>   |                                              |      | 250 |      | Ω     |
| Discharge dummy load at SYS                      | R <sub>SYS_DUM</sub>  |                                              |      | 30  |      | Ω     |
| <b>Protection</b>                                |                       |                                              |      |     |      |       |
| Battery over-voltage threshold                   | V <sub>BATT_OVP</sub> |                                              | 102  | 104 | 106  | %     |
| BATT over-voltage hysteresis                     |                       |                                              |      | 1.5 |      | %     |
| IN over-voltage protection                       | V <sub>IN_OV</sub>    | V <sub>IN</sub> rising, VIN_OVP = 6V         | 5.8  | 6   | 6.2  | V     |
|                                                  |                       | V <sub>IN</sub> rising, VIN_OVP = 11V        | 10.6 | 11  | 11.4 | V     |
| IN over-voltage protection hysteresis            |                       | V <sub>IN</sub> falling                      |      | 300 |      | mV    |
| <b>Thermal Shutdown and Temperature Control</b>  |                       |                                              |      |     |      |       |
| Thermal shutdown rising threshold <sup>(5)</sup> | T <sub>J_SHDN</sub>   | T <sub>J</sub> rising                        |      | 150 |      | °C    |
| Thermal shutdown hysteresis <sup>(5)</sup>       |                       |                                              |      | 20  |      | °C    |

## ELECTRICAL CHARACTERISTICS (continued)

V<sub>IN</sub> = 5.0V, V<sub>BATT</sub> = 3.5V, R<sub>S1</sub> = 10mΩ, T<sub>A</sub> = 25°C, unless otherwise noted.

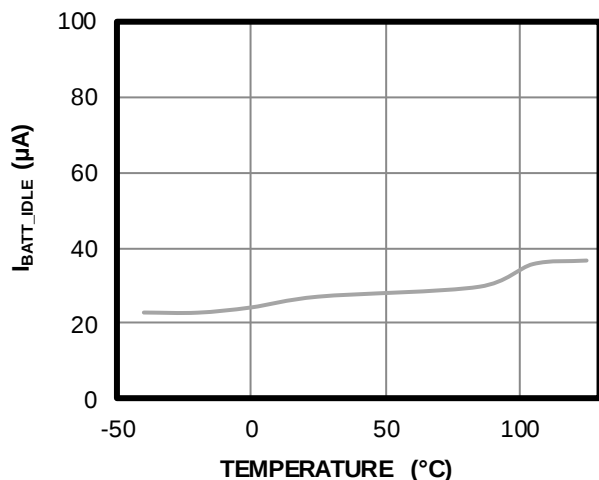
| Parameters                                      | Symbol                | Condition                                                                   | Min   | Typ   | Max   | Units |
|-------------------------------------------------|-----------------------|-----------------------------------------------------------------------------|-------|-------|-------|-------|
| VRNTC voltage                                   | V <sub>VRNTC</sub>    | V <sub>IN</sub> = 5V, I <sub>VRNTC</sub> = 100μA                            |       | 3.5   |       | V     |
| NTC low temp rising threshold                   | V <sub>COLD</sub>     | As a percentage of V <sub>VRNTC</sub> , V <sub>COLD</sub> , bits[1:0] = 72% | 72    | 73.1  | 74.3  | %     |
| NTC low temp rising threshold hysteresis        |                       | As a percentage of V <sub>VRNTC</sub>                                       |       | 1.6   |       | %     |
| NTC cool temp rising threshold                  | V <sub>COOL</sub>     | As a percentage of V <sub>VRNTC</sub> , V <sub>COOL</sub> , bits[1:0] = 60% | 59.7  | 61    | 62.2  | %     |
| NTC cool temp rising threshold hysteresis       |                       | As a percentage of V <sub>VRNTC</sub>                                       |       | 1.6   |       | %     |
| NTC warm temp falling threshold                 | V <sub>WARM</sub>     | As a percentage of V <sub>VRNTC</sub> , V <sub>WARM</sub> , bits[1:0] = 40% | 39.4  | 40.6  | 42    | %     |
| NTC warm temp falling threshold hysteresis      |                       | As a percentage of V <sub>VRNTC</sub>                                       |       | 1.6   |       | %     |
| NTC hot temp falling threshold                  | V <sub>HOT</sub>      | As a percentage of V <sub>VRNTC</sub> , V <sub>HOT</sub> , bits[1:0] = 36%  | 35.3  | 36.6  | 37.9  | %     |
| NTC hot temp falling threshold hysteresis       |                       | As percentage of V <sub>VRNTC</sub>                                         |       | 1.6   |       | %     |
| <b>SYS DP/DM Signaling</b>                      |                       |                                                                             |       |       |       |       |
| DP/DM source voltage 2V7                        | V <sub>SRC_2V7</sub>  |                                                                             | 2.6   | 2.7   | 2.8   | V     |
| DP/DM source resistance                         | R <sub>SRC</sub>      |                                                                             | 23    | 30    | 37    | kΩ    |
| DP/DM comparator threshold 2.9V                 | V <sub>TH_2V9</sub>   |                                                                             | 2.75  | 2.9   | 3.1   | V     |
| DP/DM comparator threshold 2.1V                 | V <sub>TH_2V1</sub>   |                                                                             | 1.95  | 2.1   | 2.25  | V     |
| Deglintch time for exiting non-standard adapter |                       |                                                                             | 8     | 10    | 12    | ms    |
| DP/DM short resistance                          | R <sub>SHORT</sub>    |                                                                             |       | 150   |       | Ω     |
| Pull-down resistor on DP pin                    | R <sub>PULL_DWN</sub> |                                                                             |       | 300   |       | kΩ    |
| Timer for DCP to enter non-standard adapter     |                       |                                                                             |       | 2     |       | s     |
| <b>I<sup>2</sup>C Interface</b>                 |                       |                                                                             |       |       |       |       |
| Input high threshold level                      |                       | SDA and SCL                                                                 | 1.3   |       |       | V     |
| Input low threshold level                       |                       | SDA and SCL                                                                 |       |       | 0.4   | V     |
| Output low threshold level                      |                       | I <sub>SINK</sub> = 5mA                                                     |       |       | 0.3   | V     |
| I <sup>2</sup> C clock frequency                | f <sub>SCL</sub>      |                                                                             |       |       | 400   | kHz   |
| <b>Battery Current Indicator</b>                |                       |                                                                             |       |       |       |       |
| IB voltage output                               |                       | I <sub>CC</sub> = 1A in charge mode                                         | 0.28  | 0.34  | 0.4   | V     |
|                                                 |                       | I <sub>DSCHG</sub> = 1A in boost mode                                       | 0.135 | 0.155 | 0.175 | V     |

### Note:

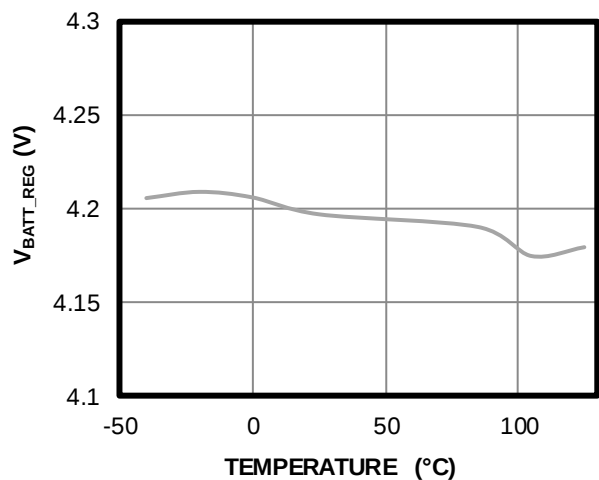
5) Guaranteed by design.

# TYPICAL CHARACTERISTICS

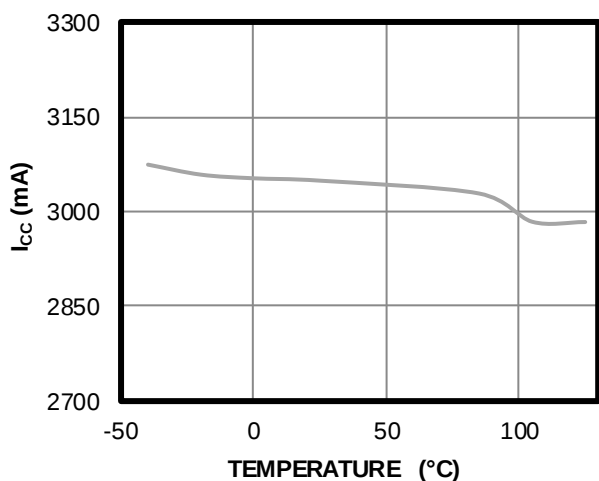
**I<sub>BATT\_IDLE</sub> vs. Temperature**  
V<sub>BATT</sub> = 5V



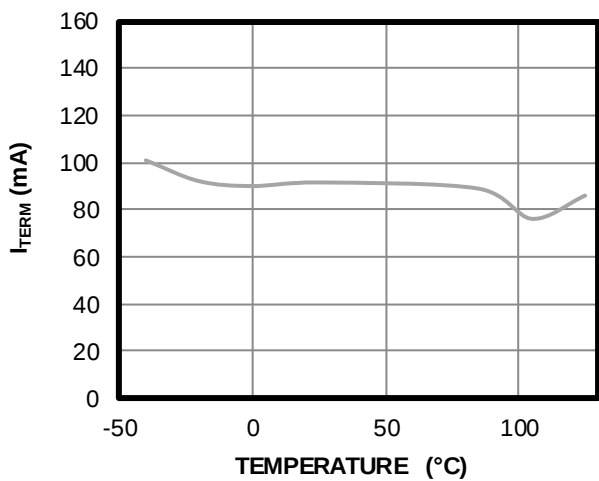
**V<sub>BATT\_REG</sub> vs. Temperature**  
V<sub>BATT\_REG</sub> = 4.2V



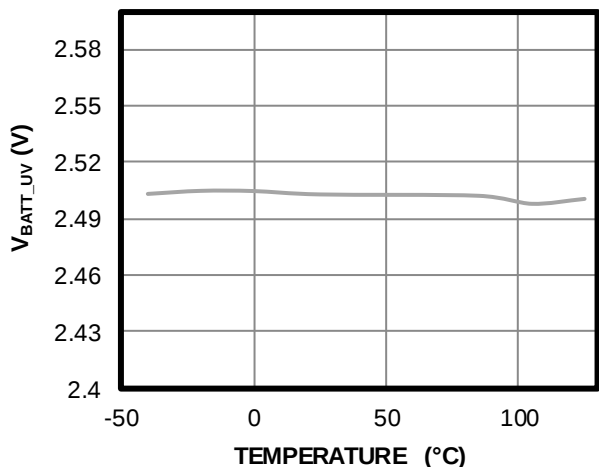
**I<sub>CC</sub> vs. Temperature**  
I<sub>CC</sub> = 3A



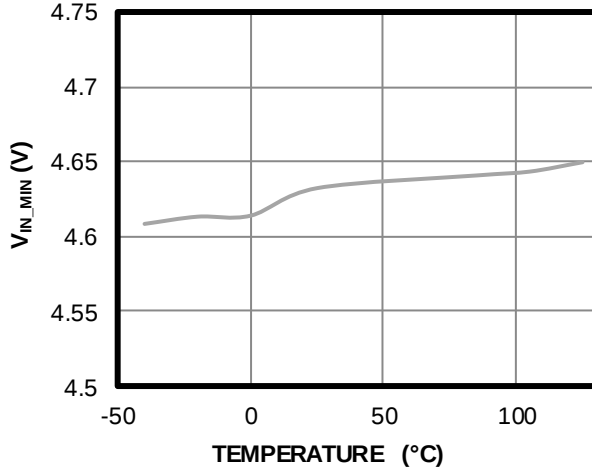
**I<sub>TERM</sub> vs. Temperature**  
I<sub>TERM</sub> = 100mA



**V<sub>BATT\_UV</sub> vs. Temperature**  
During boost



**V<sub>IN\_MIN</sub> vs. Temperature**  
V<sub>IN\_MIN</sub> = 4.65V

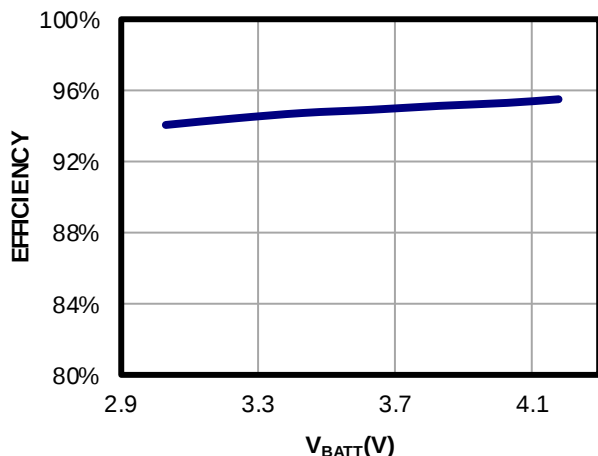


# TYPICAL PERFORMANCE CHARACTERISTICS

L1 = 1μH/10mΩ, C<sub>BATT</sub> = 22μF, RS1 = 10mΩ, T<sub>A</sub> = 25°C, battery simulator load, unless otherwise noted.

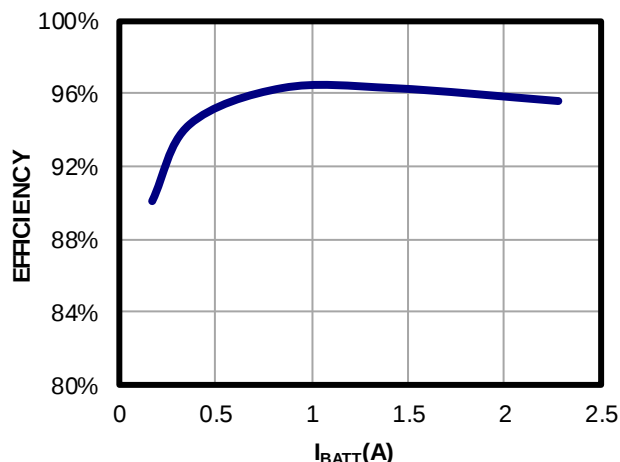
## Constant Current Charge Mode Efficiency

V<sub>IN</sub> = 5V, I<sub>CC</sub> = 2.5A



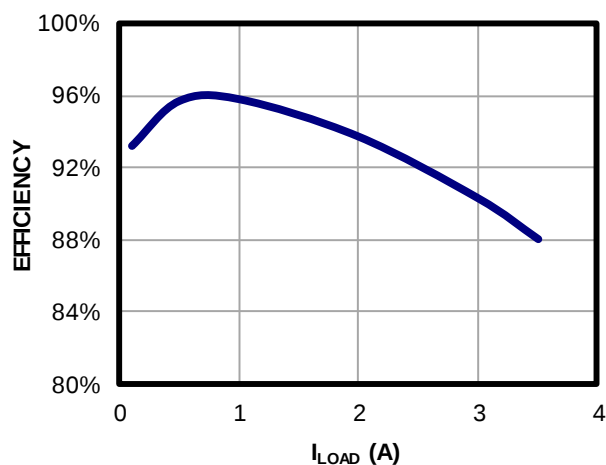
## Constant Voltage Charge Mode Efficiency

V<sub>IN</sub> = 5V, V<sub>BATT</sub> = 4.2V



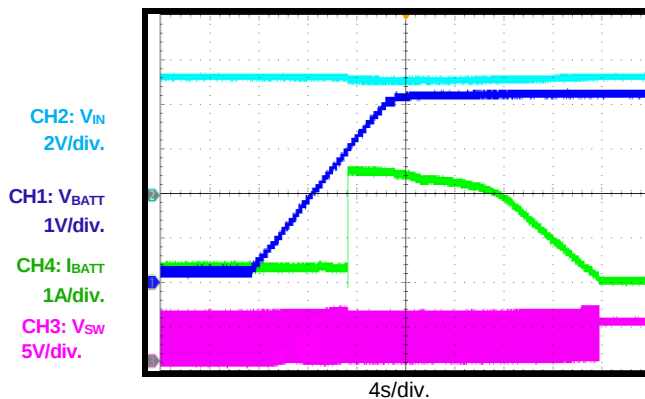
## Boost Mode Efficiency

V<sub>BATT</sub> = 3.5V, V<sub>SYS</sub> = 5.15V



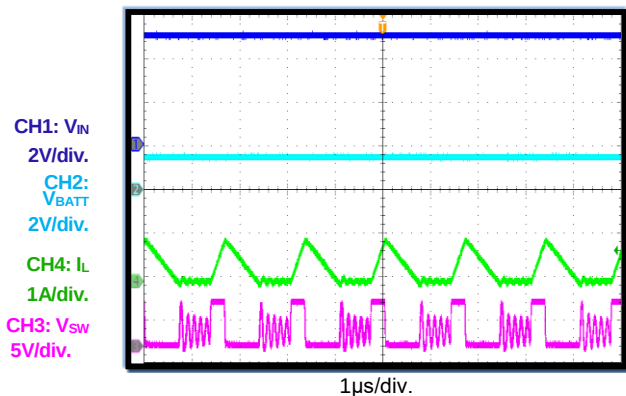
## Battery Charge Curve

V<sub>IN</sub> = 5V



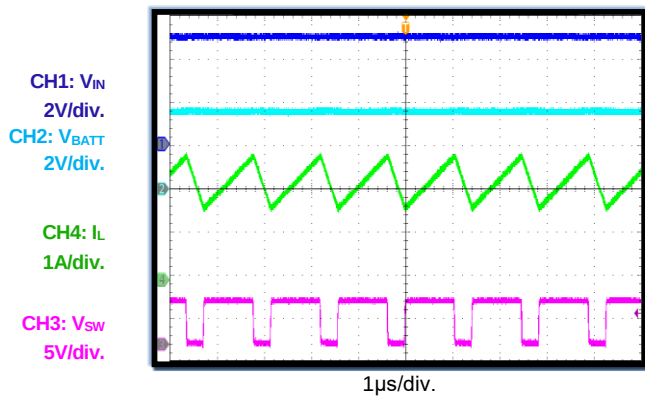
## Pre-Charge Steady State

V<sub>IN</sub> = 5V, V<sub>BATT</sub> = 1.5V, I<sub>PRE</sub> = 150mA



## Constant Current Charge Steady State

V<sub>IN</sub> = 5V, V<sub>BATT</sub> = 3.5V, I<sub>CC</sub> = 2A

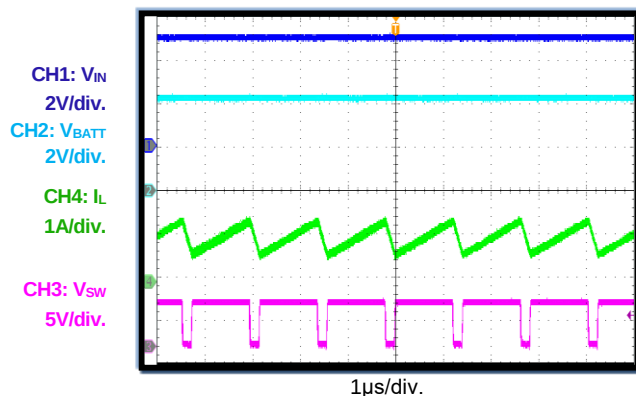


# TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

L1 = 1μH/10mΩ, C<sub>BATT</sub> = 22μF, RS1 = 10mΩ, T<sub>A</sub> = 25°C, battery simulator load, unless otherwise noted.

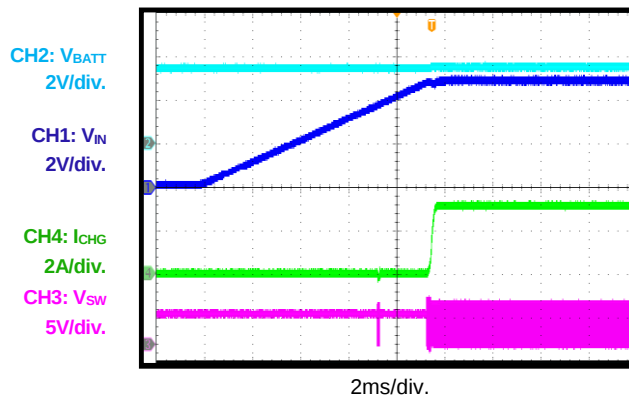
## Constant Voltage Charge Steady State

V<sub>IN</sub> = 5V, V<sub>BATT</sub> = 4.2V



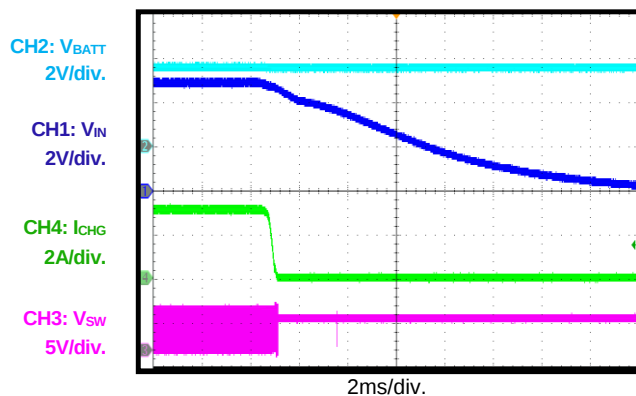
## Start-Up in Constant Current Charge Mode

V<sub>IN</sub> = 5V, V<sub>BATT</sub> = 3.5V, I<sub>CC</sub> = 3A



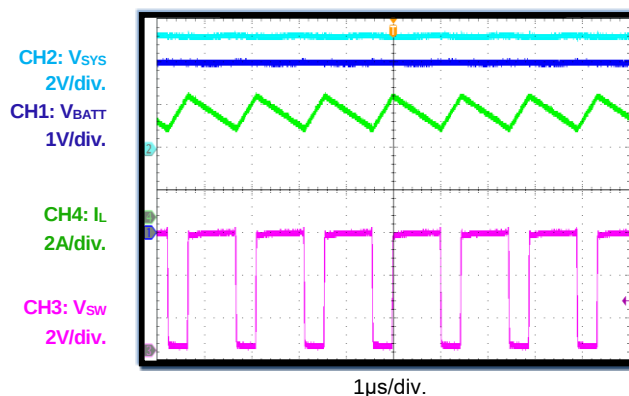
## Shutdown in Constant Current Charge Mode

V<sub>IN</sub> = 5V, V<sub>BATT</sub> = 3.5V, I<sub>CC</sub> = 3A

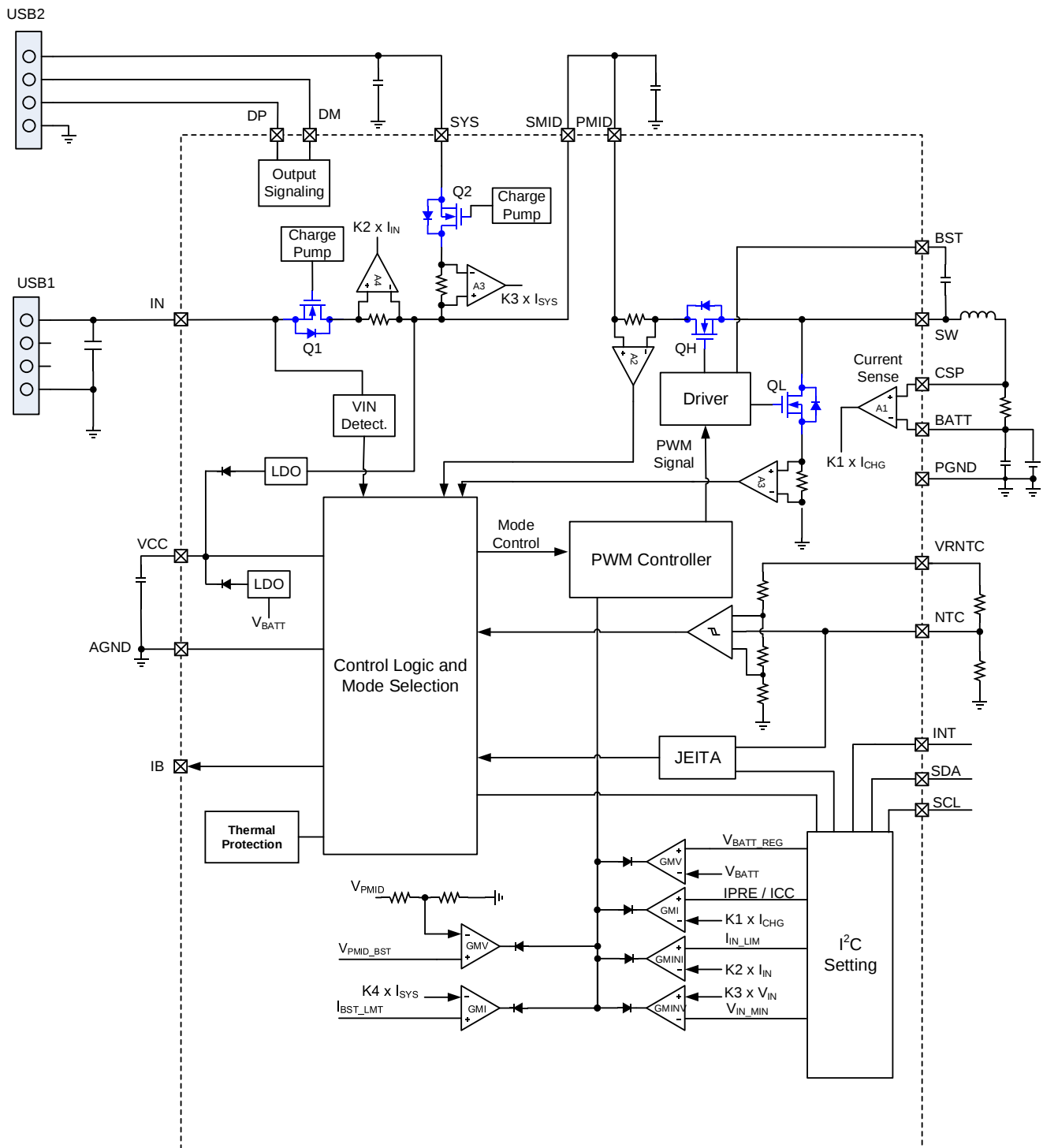


## Boost Steady State

V<sub>BATT</sub> = 4V, I<sub>SYS</sub> = 3.5A



## FUNCTIONAL BLOCK DIAGRAM



### Figure 2: Functional Block Diagram

## OPERATION

### Introduction

The MP2696B is an I<sup>2</sup>C-controlled switching charger with bidirectional operation that can step up the battery voltage to power the system. Depending on the input and output status, the device operates in one of three modes: charge mode, boost mode, or idle mode. In charge mode, the IC supports a precision Li-ion or Li-polymer charging system for single-cell applications. In boost mode, the IC boosts the battery voltage to a regulated voltage at SYS to power the load. In idle mode, the IC stops charging or boosting, and operates at a low current from the input or the battery. This reduces power consumption when the IC is not operating.

### VCC Power Supply

VCC provides power for the internal bias circuit, as well as the low-side switch driver. VCC is powered from the higher voltage between the PMID and BATT pins. When the VCC voltage rises above the under-voltage lockout threshold ( $V_{VCC\_UV}$ ), the I<sup>2</sup>C interface is ready for communication, and all the registers are reset to their default values. When the device is switching, VCC can provide up to 30mA for the external load.

## CHARGER MODE OPERATION

### Battery Charging Profile

The IC can run a charging cycle autonomously without host involvement. The host can also control the charge operations and parameters via the registers.

A new charge cycle can start when the following conditions are valid:

- $V_{IN}$  is above  $V_{IN\_UV}$
- $V_{IN}$  is below  $V_{IN\_OV}$
- $V_{IN}$  is above  $V_{BATT} + V_{HDM}$
- The NTC voltage is in the proper range (if the NTC\_STOP bit is set to 1)
- There is no charge timer fault
- Charging is enabled (CHG\_EN = 1)
- There is no battery over-voltage condition

After charging is done, unplug and re-insert VIN or toggle the CHG\_EN bit to start a new charge cycle.

### Charge Cycle

The IC checks the battery voltage to provide three main charging phases: pre-charge, constant current (CC) charge, and constant voltage (CV) charge.

The IC regulates the voltage drop on the current-sense resistor (RS1) for the battery pre-charge and constant current charge current. Table 1 shows the default value for a 10mΩ resistor.

**Table 1: Charge Current vs. Battery Voltage**  
(RS1 = 10mΩ)

| Battery Voltage | Charge Current  | Default Value | CHG_STAT |
|-----------------|-----------------|---------------|----------|
| BATT < 3V       | IPRE, bits[1:0] | 150mA         | 01       |
| BATT > 3V       | ICC, bits[4:0]  | 1A            | 10       |

The charge current can be scaled by implementing different current-sense resistor values. The charge current for constant current charge and pre-charge can be calculated with Equation (1) and Equation (2), respectively:

$$I_{CC} = \frac{ICC[4:0] \times 10m\Omega}{RS1} \quad (1)$$

$$I_{PRE} = \frac{IPRE[1:0] \times 10m\Omega}{RS1} \quad (2)$$

Note that the soldering tin for the current-sense resistor has resistance, which must be compensated.

During the entire charging process, the actual charge current may be less than the register setting due to other loop regulations, such as the input current limit or the input voltage limit.

### Charge Termination

Charging terminates if all of the following conditions are met:

- The charge current is below the termination threshold for 20ms.
- The IC works in a constant voltage charge loop.
- The IC is not in the input current loop or input voltage loop.

After termination, the status register CHG\_STAT is set to 11, and an INT pulse is generated (see Figure 3).

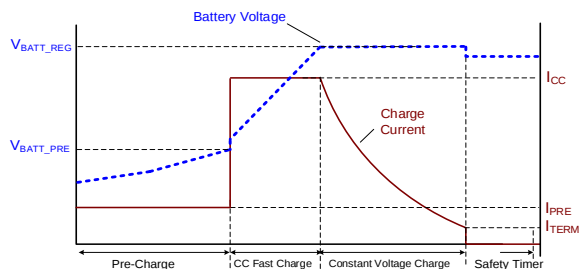


Figure 3: Battery Charge Profile

### Automatic Recharge

When the battery is fully charged and charging is terminated, the battery may be discharged because of the system consumption or self-discharge. When the battery voltage is discharged below the recharge threshold ( $V_{BATT\_REG} - 200\text{mV}$ ), the IC starts a new charging cycle automatically if the input power is valid. The timer restarts when the auto-recharge cycle begins.

### Safety Timer

The IC provides a safety timer to prevent extended charging cycles due to abnormal battery conditions. The safety timer feature can be disabled via the I<sup>2</sup>C. The safety timer does not operate in boost mode.

The safety timer restarts at the beginning of a new charging cycle. The following actions restart the safety timer:

- A new charge cycle starts
- The EN\_TIMER bit is toggled

An INT pulse is generated if the safety timer expires before charging is done. Then the charge cycle stops, and CHG\_FAULT is set to 11, which indicates that the safety timer has expired. Unplug and re-insert VIN can clear this fault after safety timer expires.

### Input Voltage Based and Input Current Based Power Management

The IC features both input current and input voltage based power management by monitoring the input current and input voltage continuously.

When the input current reaches the limit set by I<sub>INLIM</sub>, bits[2:0], the charge current tapers off to keep the input current from increasing further.

If the preset input current limit exceeds the adapter rating, the backup input voltage based power management also works to prevent the input source from being overloaded. When the input voltage falls below the input voltage regulation threshold set by VIN<sub>MIN</sub>, bits[2:0] due to the heavy load, the charge current is also reduced to keep the input voltage from dropping further.

An INT pulse is generated once the device enters a VINPPM or INPPM condition.

### Thermistor Qualification

VRNTC is driven to be equal to the VCC voltage when the IC is in charge/boost mode. The IC monitors the battery's temperature continuously by measuring the voltage at the NTC pin. The NTC function can be disabled by setting EN\_NTC = 0.

When NTC\_STOP is set to 1, the NTC voltage should be within the V<sub>HOT</sub> to V<sub>COLD</sub> range for both charge and boost operation. The IC resumes switching when the NTC voltage returns to the V<sub>HOT</sub> to V<sub>COLD</sub> range.

When NTC\_STOP is set to 0, the IC only generates an interrupt signal and reports the NTC pin status if the status changes on NTC\_FAULT, bits[2:0].

The JEITA profile is supported when the JEITA\_DIS bit is set to 0.

In the cool temperature range (V<sub>COLD</sub> to V<sub>COOL</sub>), the charge current is reduced according to the JEITA\_ISET setting (see Figure 4).

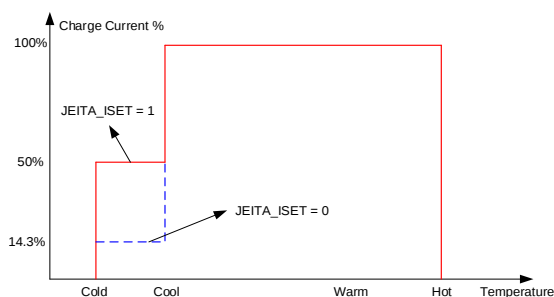
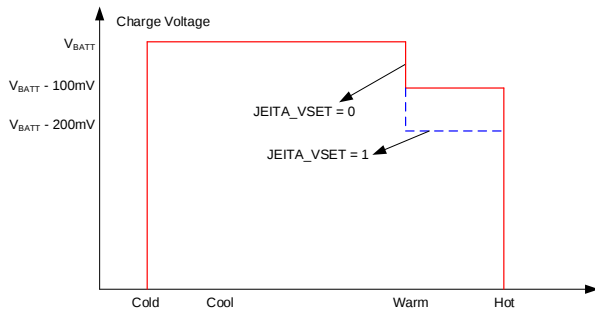


Figure 4: JEITA Profile (Charge Current)

In the warm temperature range (V<sub>WARM</sub> to V<sub>HOT</sub>), the charge voltage is reduced according to the JEITA\_VSET setting (see Figure 5).



**Figure 5: JEITA Profile (Charge Voltage)**

The hot and cold thresholds have two options in the register. The warm and cool thresholds have four options in the register, which offers accurate and flexible JEITA control.

### Interrupt to Host (INT)

A 50μs interrupt pulse is generated on the open-drain INT pin when any of the events below occur:

- A good input source is detected
- A USB2 plug-in is detected
- Status register 05h changes
- Fault register 06h changes

### Battery Over-Voltage Protection (OVP)

When the battery voltage exceeds 104% of  $V_{BATT\_REG}$ , the IC suspends charging immediately, and the BATT\_OVP bit is set to 1. An 800μA current source discharges the battery until the battery voltage returns to the normal range.

Battery over-voltage protection (OVP) can be disabled by setting the BATT\_OVP\_DIS bit to 1.

### Input Over-Voltage Protection (OVP)

Once IN senses a voltage greater than the  $V_{IN}$  over-voltage protection (OVP) threshold, the DC/DC converter stops immediately.

The input OVP threshold can be set to 6V or 11V by the VIN\_OVP bit.

## BOOST MODE OPERATION

The IC can supply a regulated 5V output at SYS to power the system. To ensure that the battery is not drained, boost mode does not start if BATT is below 2.9V. To enable boost mode, the IN voltage must be below 2.0V.

The boost output current limit can be configured to be between 1.0A and 4.0A. Boost mode has an output current limit loop when  $V_{SYS} > V_{BATT}$ .

Once boost mode is enabled, the IC boosts PMID to the preset voltage first, and then the block MOSFET (Q2) turns on linearly. When  $V_{SYS}$  is charged above 4.2V within 3ms, Q2 turns on fully. Otherwise, Q2 turns off and tries to turn on again after 300ms.

### Boost Power Limitation

During boost operation, the inductor peak current in each switching cycle is limited by the peak current limit of the low-side switch ( $Q_L$ ), set by BST\_IPK, bits[1:0]. This helps limit the maximum battery discharge current.

### Battery Under-Voltage Lockout (UVLO) Protection

If the battery voltage drops below 2.5V in boost mode, boost mode stops, and the BATT\_UVLO bit is set to 1. Boost mode recovers when the battery voltage rises above 2.9V, but the BATT\_UVLO bit is not reset until the input source plug-in and battery is charged again.

### SYS Over-Current (OC) and Short-Circuit Protection (SCP)

In boost mode, the MP2696B always monitors the current flowing through Q2. When the SYS output current exceeds the preset boost output current limit, the output current loop takes control, and both the PMID and SYS voltages decrease. When  $V_{SYS}$  drops to  $V_{BATT} + 200mV$ , Q2 turns off. After 300ms, Q2 tries to restart.

The IC also features fast SYS over-current protection (OCP) in both boost mode and pass-through mode. If the Q2 current exceeds 8A, Q2 turns off immediately. After 300ms, Q2 tries to restart.

### Impedance Compensation for Boost Output

The IC allows the user to compensate the intrinsic resistance of Q2 and the USB2 output wire voltage drop by adjusting the boost output voltage according to the system load current, calculated with Equation (3):

$$V_{PMID} = V_{BOOST} + (I_{SYS} \times R_{SYS\_CMP}) \quad (3)$$

Where  $V_{PMID}$  is the voltage at PMID, and  $V_{BOOST}$  is the boost regulation voltage set by VBOOST, bits[2:0].  $I_{SYS}$  is the real-time SYS load current during normal operation, and  $R_{SYS\_CMP}$  is the cable resistance compensation set by RSYS\_CMP, bits[2:0]

## USB2 Plug-In Detection

If the USB2\_EN\_PLUG bit is enabled in standby mode, the SYS voltage ( $V_{SYS}$ ) is pulled up to the BATT voltage ( $V_{BATT}$ ). After  $V_{SYS}$  reaches 90% of  $V_{BATT}$ , detection starts. Once  $V_{SYS}$  drops to 75% of  $V_{BATT}$ , the USB2 plug-in is detected, the USB2\_PLUG\_IN bit is set to 1, and an INT pulse is generated.

The host can respond to the interrupt signal and enable boost mode Q2.

The host must clear the USB2\_PLUG\_IN bit, and toggle the USB2\_EN\_PLUG bit for the next detection. Note that writing 1 to the USB2\_PLUG\_IN bit clears it to 0.

## No-Load Detection

During boost or pass-through operation, the Q2 current is monitored. If the Q2 current is below the value set by NOLOAD\_THR, bits[1:0], the NO\_LOAD bit is set to 1, and an INT pulse is generated. The host can monitor the NO\_LOAD bit to decide whether boost mode or Q2 must be turned off.

## Thermal Shutdown

The IC continuously monitors the internal junction temperature to maximize power delivery and avoid overheating the chip. If the junction temperature reaches 150°C, the converter shuts down. If the junction temperature drops to 120°C, normal operation resumes.

## Battery Current Analog Output

The device has an IB pin to obtain the real-time battery current value in both charge and boost mode. The voltage at IB is a fraction of the battery current. The IB pin indicates the current flowing in and out of the battery during charge and boost mode.

With a 10mΩ current-sense resistor, calculate the voltage at IB for charge mode and boost mode with Equation (4) and Equation (5), respectively:

$$V_{IB} = I_{CHG} \times 0.35(V) \quad (4)$$

$$V_{IB} = I_{DSCHG} \times 0.16(V) \quad (5)$$

Note that scaling the current-sense resistor also scales the gain of IB.

## Idle Mode

When the input power source is not present and boost mode is disabled, the IC goes into idle mode. In idle mode, all the MOSFETs and most of the internal circuits are turned off to minimize leakage and extend the battery run time.

## SYS DP/DM Signaling

Initially, the DP and DM pins are biased at 2.7V with an internal resistance of 30kΩ for non-standard adapter imitation.

If the DP or DM pin is out of the 2.1V to 2.9V range for 10ms in DCP mode, the 2.7V reference is disconnected, and DP and DM are tied together with a 100Ω resistor.

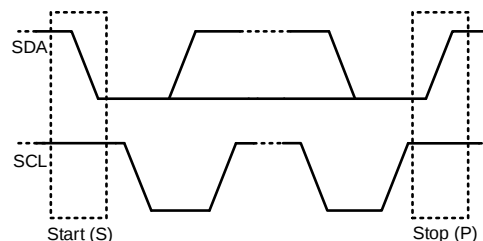
If DP stays below 0.35V for 2 seconds in DCP mode, the IC returns to non-standard adapter mode with DP/DM biased at 2.7V.

## Series Interface

The IC uses an I<sup>2</sup>C-compatible interface for flexible charging parameter setting and instantaneous device status reporting. I<sup>2</sup>C is a 2-wire serial interface with two bus lines required: a serial data line (SDA) and a serial clock line (SCL). Both SDA and SCL lines are open drain and must be connected to the positive supply voltage via a pull-up resistor.

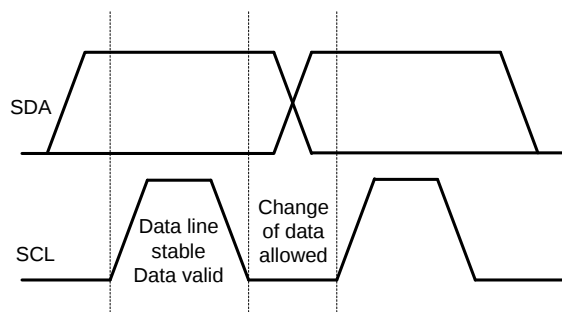
The IC operates as a slave device, receiving control inputs from the master device such as a microcontroller. The SCL line is always driven by the master device. The I<sup>2</sup>C interface supports both standard mode (up to 100kb/s), and fast mode (up to 400kb/s).

All transactions begin with a start (S) condition and are terminated by a stop (P) condition. The start and stop conditions are always generated by the master. A high to low transition on the SDA line while SCL is high defines a start condition. A low to high transition on the SDA line when the SCL is high defines a stop condition (see Figure 6).



**Figure 6: Start and Stop Conditions**

For data validity, the data on the SDA line must be stable during the high period of the clock. The high or low state of the SDA line can only change when the clock signal on the SCL line is low. Every byte on the SDA line must be 8 bits long. The number of bytes to be transmitted per transfer is unrestricted. Data is first transferred with the most significant bit (MSB) (see Figure 7).



**Figure 7: Bit Transfer on the I<sup>2</sup>C Bus**

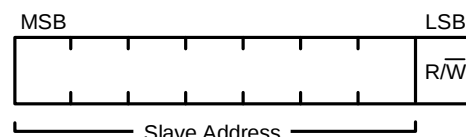
Each byte has to be followed by an acknowledge (ACK) bit, which is generated by the receiver, to signal to the transmitter that the byte was successfully received.

The ACK signal is defined as follows: the transmitter releases the SDA line during the

acknowledge clock pulse so the receiver can pull the SDA line low. The SDA line remains low during the high period of the ninth clock.

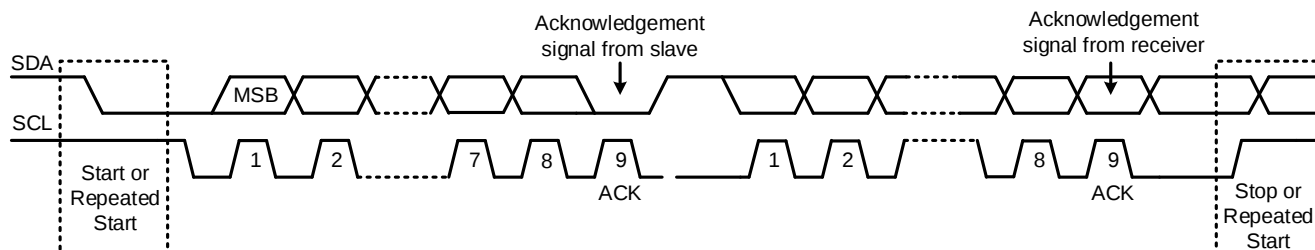
If SDA line is high during the ninth clock, this is defined as the not acknowledge (NACK) signal. The master can then generate either a stop condition to abort the transfer or a repeated start (Sr) condition to start a new transfer.

After the start signal is received, a slave address is sent. This address is 7 bits long, followed by the eighth bit as a data direction bit (bit R/W). A zero indicates a transmission (write), and a one indicates a request for data (read). Figure 8 shows the address bit arrangement.

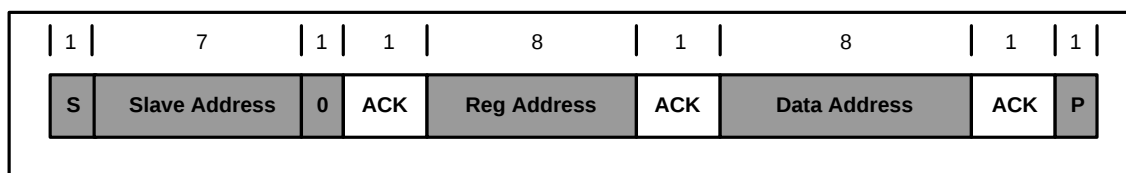


**Figure 8: 7-Bit Address**

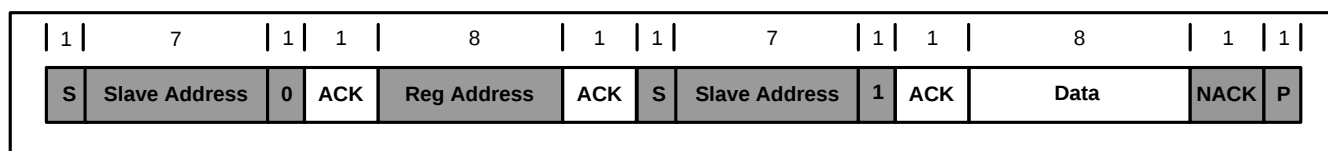
See Figure 9 through Figure 13 for detailed signal sequences.



**Figure 9: Data Transfer on the I<sup>2</sup>C Bus**



**Figure 10: Single Write**



**Figure 11: Single Read**

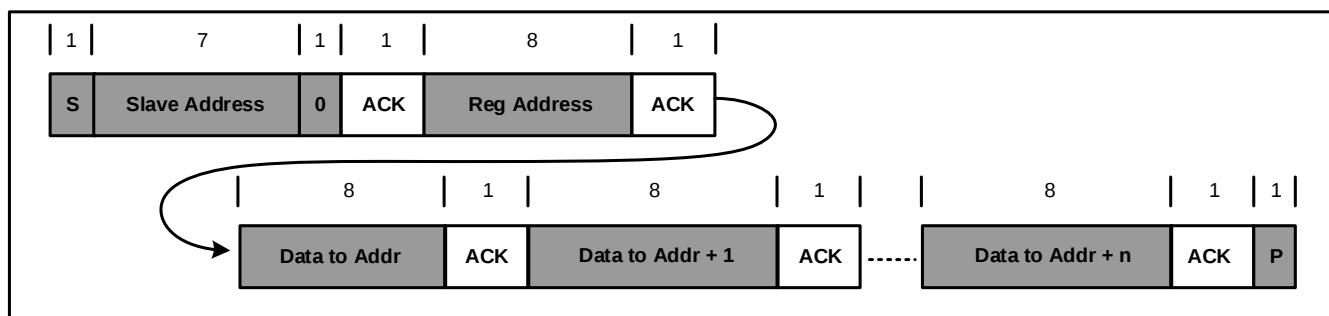


Figure 12: Multi-Write

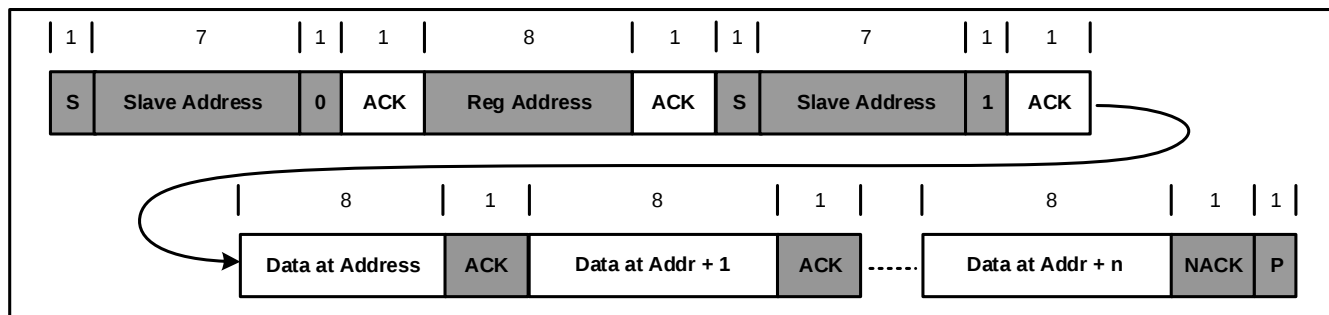


Figure 13: Multi-Read

## I<sup>2</sup>C REGISTER MAP

IC Address: 6Bh

| Register Name | Address | R/W | Description                                                          |
|---------------|---------|-----|----------------------------------------------------------------------|
| REG00h        | 0x00    | R/W | Input voltage regulation setting and input current limit setting.    |
| REG01h        | 0x01    | R/W | Charge current setting and pre-charge current setting.               |
| REG02h        | 0x02    | R/W | Battery regulation voltage and termination current setting.          |
| REG03h        | 0x03    | R/W | Boost output current limit setting and cable impedance compensation. |
| REG04h        | 0x04    | R/W | Boost output voltage setting and boost control.                      |
| REG05h        | 0x05    | R   | Status register.                                                     |
| REG06h        | 0x06    | R   | Fault register.                                                      |
| REG07h        | 0x07    | R/W | Boost no-load setting and miscellaneous control.                     |
| REG08h        | 0x08    | R/W | JEITA control.                                                       |

## REG00h

| Bit | Name      | POR | Reset by REG_RST | R/W | Description                                                                                                         | Comment                                                                                                                                         |
|-----|-----------|-----|------------------|-----|---------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| 7   | REG_RST   | 0   | Y                | R/W | 0: Keep current settings<br>1: Reset                                                                                | This bit resets all registers to their default values. After a reset, this bit returns to 0 automatically.                                      |
| 6   | EN_TIMER  | 1   | Y                | R/W | 0: Disabled<br>1: Enabled                                                                                           | This bit enables the charge safety timer control. This bit is set to 1 by default.                                                              |
| 5   | VINMIN[2] | 1   | Y                | R/W | 200mV                                                                                                               | These bits regulate the dynamic input voltage. They have a 4.45V offset, range between 4.45V and 4.8V, and are set to 200mV (4.65V) by default. |
| 4   | VINMIN[1] | 0   | Y                | R/W | 100mV                                                                                                               |                                                                                                                                                 |
| 3   | VINMIN[0] | 0   | Y                | R/W | 50mV                                                                                                                |                                                                                                                                                 |
| 2   | IINLIM[2] | 0   | Y                | R/W | 000: 500mA<br>001: 1000mA<br>010: 1500mA<br>011: 1800mA<br>100: 2100mA<br>101: 2400mA<br>110: 3000mA<br>111: 3500mA | These bits set the input current limit. They are set to 500mA by default.                                                                       |
| 1   | IINLIM[1] | 0   | Y                | R/W |                                                                                                                     |                                                                                                                                                 |
| 0   | IINLIM[0] | 0   | Y                | R/W |                                                                                                                     |                                                                                                                                                 |

## REG01h

| Bit | Name    | POR | Reset by REG_RST | R/W | Description                         | Comment                                                                                                                                                                                                                |
|-----|---------|-----|------------------|-----|-------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7   | ICC[4]  | 0   | Y                | R/W | 1600mA                              | These bits set the charge current for a 10mΩ sensing resistor. They have a 500mA offset, range between 500mA and 3.6A, and are set to 1A by default. A scaling sense resistor scales the sett value at the same ratio. |
| 6   | ICC[3]  | 0   | Y                | R/W | 800mA                               |                                                                                                                                                                                                                        |
| 5   | ICC[2]  | 1   | Y                | R/W | 400mA                               |                                                                                                                                                                                                                        |
| 4   | ICC[1]  | 0   | Y                | R/W | 200mA                               |                                                                                                                                                                                                                        |
| 3   | ICC[0]  | 1   | Y                | R/W | 100mA                               |                                                                                                                                                                                                                        |
| 2   | EN_NTC  | 1   | Y                | R/W | 0: Disabled<br>1: Enabled           | This bit is set to 1 by default.                                                                                                                                                                                       |
| 1   | IPRE[1] | 0   | Y                | R/W | 01: 150mA<br>10: 250mA<br>11: 350mA | These bits set the pre-charge current with a 10mΩ sensing resistor. These bits range between 150mA and 350mA, with a 150mA default.                                                                                    |
| 0   | IPRE[0] | 1   | Y                | R/W |                                     |                                                                                                                                                                                                                        |

**REG02h**

| Bit | Name         | POR | Reset by REG_RST | R/W | Description                                                                                                                                           | Comment                                                                                                                                                 |
|-----|--------------|-----|------------------|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7   | BATT_OVP_DIS | 0   | Y                | R/W | 0: Enable battery over-voltage protection (OVP)<br>1: Disable battery OVP                                                                             | This bit is set to 0 by default.                                                                                                                        |
| 6   | BATT_REG[2]  | 0   | Y                | R/W | 000: 3.6V<br>001: 4.1V<br>010: 4.2V<br>011: 4.3V<br>100: 4.35V<br>101: 4.4V<br>110: 4.45V                                                             | These bits set the regulated charge voltage. They are set to 010 by default.                                                                            |
| 5   | BATT_REG[1]  | 1   | Y                | R/W |                                                                                                                                                       |                                                                                                                                                         |
| 4   | BATT_REG[0]  | 0   | Y                | R/W |                                                                                                                                                       |                                                                                                                                                         |
| 3   | JEITA_DIS    | 1   | Y                | R/W | 0: JEITA enabled, NTC warm / cool decrease I <sub>CC</sub> or V <sub>BATT_REG</sub><br>1: JEITA disabled, NTC warm / cool only reports status and INT | This bit is set to 1 by default.                                                                                                                        |
| 2   | ITERM[1]     | 0   | Y                | R/W | 200mA                                                                                                                                                 | Charge termination current for a 10mΩ sensing resistor. These bits have a 100mA offset, range between 100mA and 400mA, and are set to 100mA by default. |
| 1   | ITERM[0]     | 0   | Y                | R/W | 100mA                                                                                                                                                 |                                                                                                                                                         |
| 0   | CHG_EN       | 1   | Y                | R/W | 0: Disable charge<br>1: Enable charge                                                                                                                 | This bit is set to 1 by default.                                                                                                                        |

**REG03h**

| Bit | Name        | POR | Reset by REG_RST | R/W | Description                        | Comment                                                                                                                    |
|-----|-------------|-----|------------------|-----|------------------------------------|----------------------------------------------------------------------------------------------------------------------------|
| 7   | IOLIM[3]    | 1   | Y                | R/W | 1600mA                             | These bits set the SYS output current limit. They have a 1A offset, range between 1A and 4A, and are set to 3A by default. |
| 6   | IOLIM[2]    | 0   | Y                | R/W | 800mA                              |                                                                                                                            |
| 5   | IOLIM[1]    | 1   | Y                | R/W | 400mA                              |                                                                                                                            |
| 4   | IOLIM[0]    | 0   | Y                | R/W | 200mA                              |                                                                                                                            |
| 3   | RSYS_CMP[2] | 0   | Y                | R/W | 80mΩ                               | These bits set the SYS cable voltage drop compensation threshold. They are set to 60mΩ by default.                         |
| 2   | RSYS_CMP[1] | 1   | Y                | R/W | 40mΩ                               |                                                                                                                            |
| 1   | RSYS_CMP[0] | 1   | Y                | R/W | 20mΩ                               |                                                                                                                            |
| 0   | NO_LOAD     | 0   | Y                | R   | 0: Q2 load normal<br>1: Q2 no load |                                                                                                                            |

## REG04h

| Bit | Name         | POR | Reset by REG_RST | R/W | Description                                                           | Comment                                                                                                                                                                                                                                                                  |
|-----|--------------|-----|------------------|-----|-----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7   | VBOOST[2]    | 0   | Y                | R/W | -100mV                                                                | These bits set the boost regulation voltage at the PMID pin. They have a 5.2V offset, range between 5.05V and 5.225V, and are set to 5.15V by default.                                                                                                                   |
| 6   | VBOOST[1]    | 1   | Y                | R/W | -50mV                                                                 |                                                                                                                                                                                                                                                                          |
| 5   | VBOOST[0]    | 0   | Y                | R/W | 25mV                                                                  |                                                                                                                                                                                                                                                                          |
| 4   | BST_EN       | 0   | Y                | R/W | 0: Disable boost mode<br>1: Enable boost mode                         | This bit is set to 0 by default. Boost mode can be enabled only when $V_{IN} < 2V$ .                                                                                                                                                                                     |
| 3   | Q2_EN        | 0   | Y                | R/W | 0: Q2 is off<br>1: Q2 is on                                           | This bit is set to 0 by default.                                                                                                                                                                                                                                         |
| 2   | SYS_DSC      | 0   | Y                | R/W | 0: Disable SYS discharge<br>1: Enable SYS discharge                   | This bit enables the SYS to GND discharge resistance (25Ω).                                                                                                                                                                                                              |
| 1   | USB2_EN_PLUG | 1   | Y                | R/W | 0: Disable USB2 plug-in detection<br>1: Enable USB2 plug-in detection | Enables the USB2 plug-in detection circuit. Toggle this bit for new detection.                                                                                                                                                                                           |
| 0   | USB2_PLUG_IN | 0   | Y                | R/W | 0: USB2 is not plugged in<br>1: USB2 plug-in has been detected        | After $V_{SYS}$ is pulled up to 90% of $V_{BATT}$ , detection starts. Once $V_{SYS}$ drops to 75% $V_{BATT}$ , the USB2 plug-in signal is asserted. Write 1 to this bit to reset it to 0. This bit should be cleared manually after a read to enable the next detection. |

## REG05h

An interrupt is asserted if any bit in REG 05h changes.

| Bit | Name         | POR | Reset by REG_RST | R/W | Description                                                                                              | Comment                                                                               |
|-----|--------------|-----|------------------|-----|----------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| 7   | CHIP_STAT[1] | 0   | Y                | R   | 00: Idle mode<br>01: Charge mode<br>10: Boost mode<br>11: Power path and charge                          |                                                                                       |
| 6   | CHIP_STAT[0] | 0   | Y                | R   |                                                                                                          |                                                                                       |
| 5   | CHG_STAT[1]  | 0   | Y                | R   | 00: Not charging<br>01: Pre-charge<br>10: Constant current or constant voltage charge<br>11: Charge done |                                                                                       |
| 4   | CHG_STAT[0]  | 0   | Y                | R   |                                                                                                          |                                                                                       |
| 3   | VPPM_STAT    | 0   | Y                | R   | 0: No VINPPM<br>1: VINPPM                                                                                |                                                                                       |
| 2   | IPPM_STAT    | 0   | Y                | R   | 0: No IINPPM<br>1: IINPPM                                                                                |                                                                                       |
| 1   | USB1_PLUG_IN | 0   | Y                | R   | 0: USB1 is not plugged in<br>1: USB1 is plugged in                                                       | This bit is set to 1 when $\max(V_{IN\_UV}, V_{BATT}+V_{HDMR}) < V_{IN} < V_{IN\_OV}$ |
| 0   | RESERVED     | 0   | Y                | R   |                                                                                                          |                                                                                       |

## REG06h

An interrupt is asserted if any bit in REG 06h changes.

| Bit | Name         | POR | Reset by<br>REG_RST | R/W | Description                                                                                                                                                                   | Comment                                                                                                                                                           |
|-----|--------------|-----|---------------------|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7   | BATT_UVLO    | 0   | Y                   | R   | 0: No battery under-voltage<br>lockout (UVLO) has occurred<br>1: Battery UVLO has occurred                                                                                    | If the battery reaches the<br>under-voltage lockout<br>(UVLO) threshold, this bit is<br>set to 1. This bit is reset to 0<br>once the battery is charged<br>again. |
| 6   | SYS_SHORT    | 0   | Y                   | R   | 0: Normal<br>1: A SYS short circuit has<br>occurred                                                                                                                           |                                                                                                                                                                   |
| 5   | BST_LMT      | 0   | Y                   | R   | 0: Normal<br>1: Boost mode works in the Q2<br>current limit                                                                                                                   |                                                                                                                                                                   |
| 4   | CHG_FAULT[1] | 0   | Y                   | R   | 00: Normal operation<br>01: A USB1 under-voltage (UV)<br>condition has occurred<br>10: A USB1 over-voltage (OV)<br>condition has occurred<br>11: The safety timer has expired |                                                                                                                                                                   |
| 3   | CHG_FAULT[0] | 0   | Y                   | R   |                                                                                                                                                                               |                                                                                                                                                                   |
| 2   | NTC_FAULT[2] | 0   | Y                   | R   | 000: Normal<br>001: Warm<br>010: Cool<br>011: Cold<br>100: Hot                                                                                                                |                                                                                                                                                                   |
| 1   | NTC_FAULT[1] | 0   | Y                   | R   |                                                                                                                                                                               |                                                                                                                                                                   |
| 0   | NTC_FAULT[0] | 0   | Y                   | R   |                                                                                                                                                                               |                                                                                                                                                                   |

**REG07h**

| Bit | Name          | POR | Reset by<br>REG_RST | R/W | Description                                                                                                                                 | Comment                                                                                                   |
|-----|---------------|-----|---------------------|-----|---------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------|
| 7   | NOLOAD_THR[1] | 0   | Y                   | R/W | 00: 30mA<br>01: 50mA<br>10: 75mA<br>11: 100mA                                                                                               | These bits set the SYS no load current threshold. This bit is set to 00 by default.                       |
| 6   | NOLOAD_THR[0] | 0   | Y                   | R/W |                                                                                                                                             |                                                                                                           |
| 5   | BATT_OVP      | 0   | Y                   | R   | 0: The battery is operating normally<br>1: Battery over-voltage protection (OVP) has occurred                                               |                                                                                                           |
| 4   | NTC_STOP      | 1   | Y                   | R/W | 0: Only report in the register if NTC is outside its threshold<br>1: Suspend the charge and boost operation if NTC is outside its threshold |                                                                                                           |
| 3   | VIN_OVP       | 0   | Y                   | R/W | 0: 6V<br>1: 11V                                                                                                                             | This bit sets the V <sub>IN</sub> over-voltage protection (OVP) threshold.                                |
| 2   | SW_FREQ       | 0   | Y                   | R/W | 0: 700kHz<br>1: 1200kHz                                                                                                                     | This bit is set to 0 by default.                                                                          |
| 1   | BST_IPK[1]    | 1   | Y                   | R/W | 00: 5A<br>01: 5.5A<br>10: 6A<br>11: 6.5A                                                                                                    | These bits set the low-side switch peak current limit in boost mode. These bits are set to 11 by default. |
| 0   | BST_IPK[0]    | 1   | Y                   | R/W |                                                                                                                                             |                                                                                                           |

**REG08h**

| Bit | Name       | POR | Reset by<br>REG_RST | R/W | Description                                                          | Comment                                                                  |
|-----|------------|-----|---------------------|-----|----------------------------------------------------------------------|--------------------------------------------------------------------------|
| 7   | JEITA_VSET | 1   | Y                   | R/W | 0: V <sub>BATT_REG</sub> - 100mV<br>1: V <sub>BATT_REG</sub> - 200mV | This bit is set to 1 by default.                                         |
| 6   | JEITA_ISET | 1   | Y                   | R/W | 0: 14.3% of I <sub>CC</sub><br>1: 50% of I <sub>CC</sub>             | This bit is set to 1 by default.                                         |
| 5   | VHOT       | 1   | Y                   | R/W | 0: 34%<br>1: 36%                                                     | This bit sets the hot threshold. This bit is set to 1 by default.        |
| 4   | VWARM[1]   | 0   | Y                   | R/W | 00: 44%<br>01: 40%<br>10: 38%<br>11: 36%                             | These bits sets the warm threshold. These bits are set to 01 by default. |
| 3   | VWARM[0]   | 1   | Y                   | R/W |                                                                      |                                                                          |
| 2   | VCOOL[1]   | 1   | Y                   | R/W | 00: 72%<br>01: 68%<br>10: 64%<br>11: 60%                             | These bit sets the cool threshold. These bit are set to 11 by default.   |
| 1   | VCOOL[0]   | 1   | Y                   | R/W |                                                                      |                                                                          |
| 0   | VCOLD      | 0   | Y                   | R/W | 0: 72%<br>1: 68%                                                     | This bit sets the cold threshold. This bit is set to 0 by default.       |

**REG0Ah <sup>(6)</sup>**

| Bit | Name     | POR | Reset by<br>REG_RST | R/W | Description                                                              | Comment                          |
|-----|----------|-----|---------------------|-----|--------------------------------------------------------------------------|----------------------------------|
| 7   | TMR      | 0   | N/A                 | N/A | 0: The charge timer is 20hrs<br>1: The charge timer is 10hrs             | This bit is set to 0 by default. |
| 6   | RESERVED | N/A | N/A                 | N/A | Reserved.                                                                |                                  |
| 5   | RESERVED | N/A | N/A                 | N/A | Reserved.                                                                |                                  |
| 4   | RESERVED | N/A | N/A                 | N/A | Reserved.                                                                |                                  |
| 3   | VPRE     | 0   | N/A                 | N/A | 0: The pre-charge threshold is 3V<br>1: The pre-charge threshold is 2.5V | This bit is set to 0 by default. |
| 2   | RESERVED | N/A | N/A                 | N/A | Reserved.                                                                |                                  |
| 1   | RESERVED | N/A | N/A                 | N/A | Reserved.                                                                |                                  |
| 0   | RESERVED | N/A | N/A                 | N/A | Reserved.                                                                |                                  |

**Note:**

6) Register 0Ah is for the one-time programmable (OTP) only. It is not accessible to users.

## OTP MAP

| #    | Bit[7]     | Bit[6]                  | Bit[5] | Bit[4]   | Bit[3]  | Bit[2] | Bit[1] | Bit[0] |
|------|------------|-------------------------|--------|----------|---------|--------|--------|--------|
| 0x02 | N/A        | BATT_REG: 3.6V to 4.45V |        |          | N/A     | N/A    | N/A    | N/A    |
| 0x07 | NOLOAD_THR |                         | N/A    | NTC_STOP | VIN_OVP | N/A    | N/A    | N/A    |
| 0x0A | TMR        | N/A                     | N/A    | N/A      | VPRE    | N/A    | N/A    | N/A    |

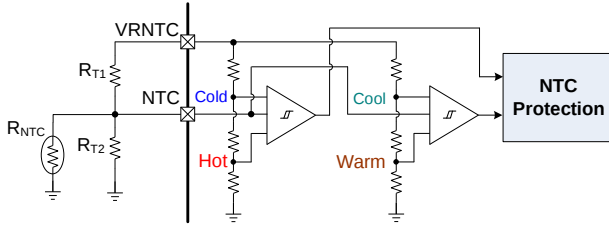
## OTP DEFAULT

| OTP Items             | Default                                                                   |
|-----------------------|---------------------------------------------------------------------------|
| BATT_REG, bits[2:0]   | 4.2V                                                                      |
| NOLOAD_THR, bits[1:0] | 30mA                                                                      |
| NTC_STOP              | 1: Suspend the charge and boost operation if NTC is outside its threshold |
| VIN_OVP               | 0: VIN_OVP = 6V                                                           |
| TMR                   | 0: The charge timer is 20hrs                                              |
| VPRE                  | 0: The pre-charge threshold is 3V                                         |

## APPLICATION INFORMATION

### Setting the NTC Resistor

Figure 14 shows the different temperature thresholds (cold, cool, warm, and hot) that are preset by the internal voltage divider reference circuit.



**Figure 14: JEITA-Controlled NTC Protection Circuit**

To set the NTC window for a given NTC thermistor, calculate  $R_{T1}$  and  $R_{T2}$  with Equation (6) and Equation (7), respectively:

$$R_{T1} = \frac{R_{NTC\_HOT} \times R_{NTC\_COLD} \times (V_{COLD} - V_{HOT})}{V_{COLD} \times V_{HOT} \times (R_{NTC\_COLD} - R_{NTC\_HOT})} \quad (6)$$

$$R_{T2} = \frac{R_{NTC\_HOT} \times R_{NTC\_COLD} \times (V_{COLD} - V_{HOT})}{V_{HOT} \times (1 - V_{COLD}) \times R_{NTC\_COLD} - V_{COLD} \times (1 - V_{HOT}) \times R_{NTC\_HOT}} \quad (7)$$

Where  $R_{NTC\_HOT}$  is the value of the NTC resistor at the upper bound of its operating temperature range, and  $R_{NTC\_COLD}$  is the value at the lower bound.  $V_{HOT}$  is the hot temperature threshold percentage, which can be set to 34% or 36% of  $V_{VRNTC}$ .  $V_{COLD}$  is the cold temperature threshold percentage, which can be set to 72% or 68% of  $V_{VRNTC}$ .

The warm and cool temperature thresholds can be calculated with Equation (8) and Equation (9), respectively:

$$V_{WARM} = \frac{R_{T2} // R_{NTC\_WARM}}{R_{T1} + R_{T2} // R_{NTC\_WARM}} \quad (8)$$

$$V_{COOL} = \frac{R_{T2} // R_{NTC\_COOL}}{R_{T1} + R_{T2} // R_{NTC\_COOL}} \quad (9)$$

Using the results from these calculations, choose the closest warm and cool thresholds in REG 08h.

If no external NTC is available, connect  $R_{T1}$  to  $R_{T2}$  to keep the voltage on NTC within the valid NTC window (e.g.  $R_{T1} = R_{T2} = 10k\Omega$ ).

### Selecting the Inductor

Inductor selection requires a tradeoff between cost, size, and efficiency. A smaller-value inductance results a physically smaller inductor, but also results in greater current ripple, magnetic hysteretic losses, and output capacitance. A higher-value inductor benefits from lower ripple current and smaller output filter capacitors, but results in a greater inductor DC resistance (DCR) loss.

Table 2 shows recommended values when selecting an inductor

**Table 2: Inductor Selection Guide**

| RS1 (mΩ) | Max I <sub>CC</sub> (A) | L (μH) |
|----------|-------------------------|--------|
| 10       | 3.6                     | 1      |
| 20       | 1.8                     | 2.2    |
| 30       | 1.2                     | 3.3    |
| 50       | 0.72                    | 4.7    |

Choose an inductor that does not saturate under the worst-case load condition.

### Selecting the PMID Capacitor (C<sub>PMID</sub>)

Select  $C_{PMID}$  based on the demand of the PMID current ripple for the mode being used.

In charge mode,  $C_{PMID}$  acts as the input capacitor of the buck converter in charge mode. The input current ripple can be calculated using Equation (10):

$$I_{RMS\_MAX} = I_{CC\_MAX} \times \frac{\sqrt{V_{BATT} \times (V_{IN} - V_{BATT})}}{V_{IN}} \quad (10)$$

In boost mode,  $C_{PMID}$  is the output capacitor of the boost converter.  $C_{PMID}$  keeps the system voltage ripple small and ensures feedback loop stability. The system current ripple can be estimated with Equation (11):

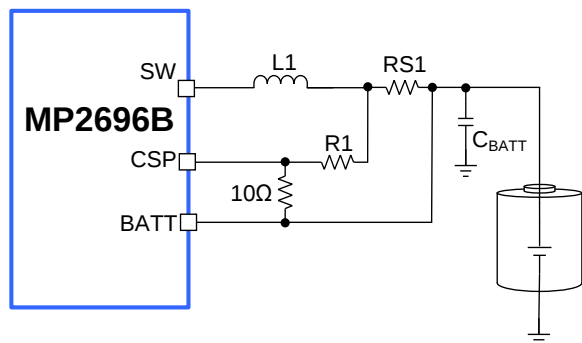
$$I_{RMS\_MAX} = I_{BATT} \times \frac{\sqrt{V_{BATT} \times (V_{SYS} - V_{BATT})}}{V_{SYS}} \quad (11)$$

Select the PMID capacitors based on the ripple current temperature rise, and ensure that the temperature rise does not exceed 10°C. For the best results, use ceramic capacitors with X5R dielectrics because of their low ESR and small temperature coefficients.

### Compensate the Current-Sense Resistor

The soldering tin has resistance. For a 10mΩ resistor soldered on the PCB, the total resistance between the resistor pads is between 11mΩ and 12mΩ.

One method to compensate for this resistance consists of applying a resistor divider to the CSP/BATT pins (see Figure 15).



**Figure 15: Current-Sense Compensation**

After the PCB is assembled, apply a 2A DC current source between SW and BATT. Measure the voltage drop across the current-sense resistor on its PCB pads ( $V_{CS}$ ). Calculate  $R1$  with Equation (12):

$$R1 = \frac{V_{CS} - 2 \times RS1}{2 \times RS1} \times 10\Omega \quad (12)$$

### PCB Layout Guidelines

Efficient PCB layout is critical to meet specified noise, efficiency, and stability requirements. For the best results, follow the guidelines below:

1. Place the PMID capacitor as close as possible to the PMID and PGND pins using a short copper plane connection. Place the PMID capacitor on the same layer as the IC.
2. Minimize the high-frequency current path loop between the PMID capacitor and the switching power MOSFETs (PMID pin to capacitor, capacitor to PGND pin).
3. Connect the IC's power pin to as many copper planes as possible to conduct heat away from the IC.
4. Place decoupling capacitors (e.g. the VCC pin capacitor) as close as possible to the IC pins, and make the connection as short as possible.
5. Ensure the number and physical size of the vias is sufficient for a current path.

# TYPICAL APPLICATION CIRCUIT

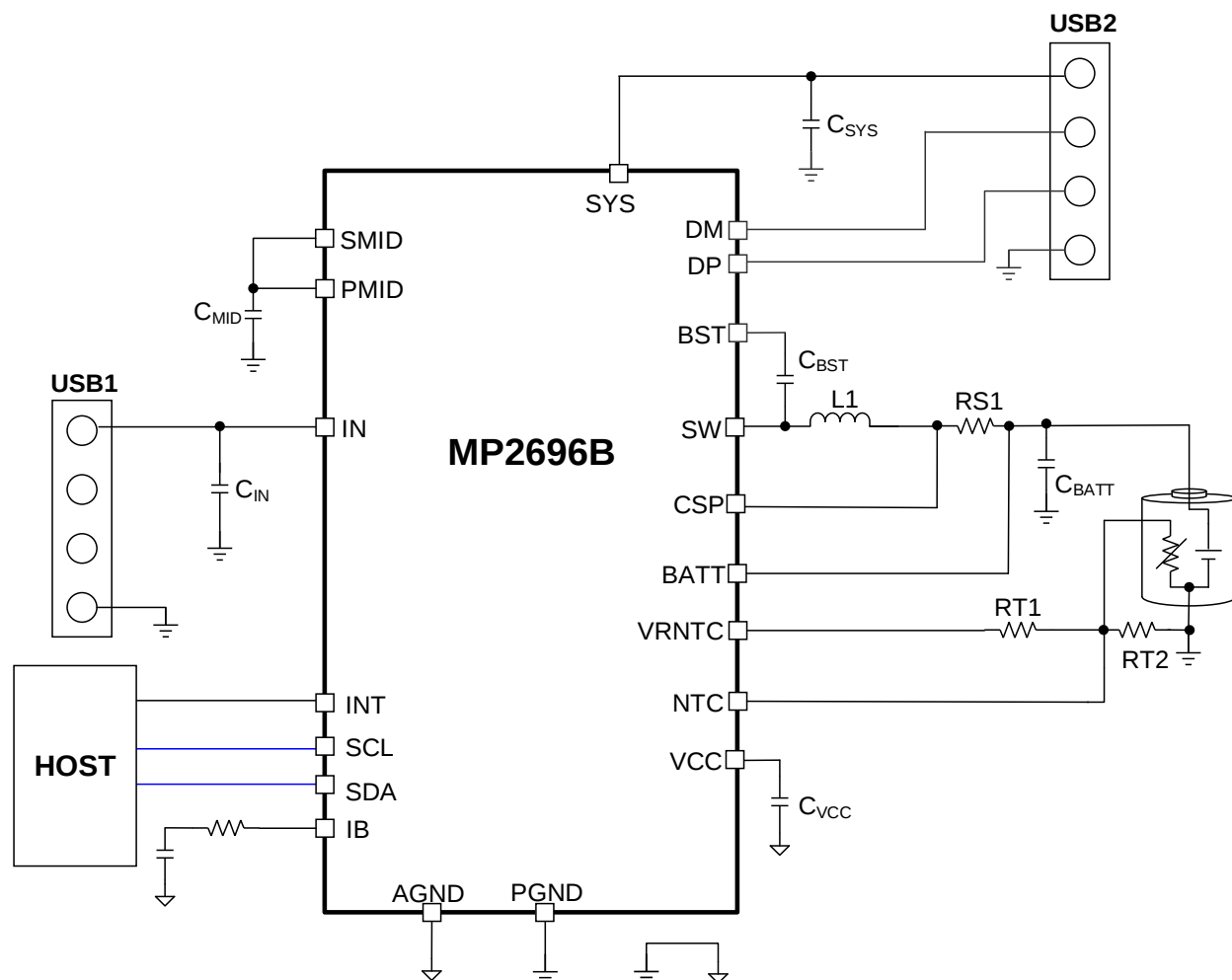


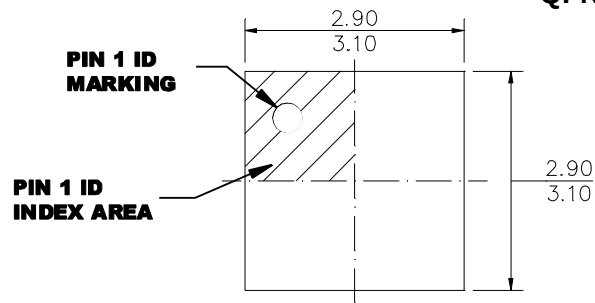
Figure 16: Typical Application Circuit for Power Bank

Table 3: Key BOM from Figure 16

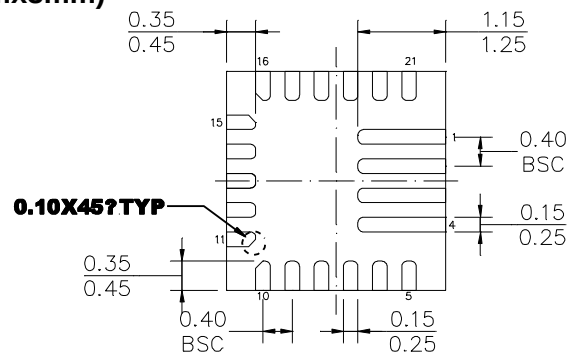
| Qty | Ref               | Value | Description                         | Package | Manufacturer |
|-----|-------------------|-------|-------------------------------------|---------|--------------|
| 1   | C <sub>IN</sub>   | 1µF   | Ceramic capacitor, 16V, X5R or X7R  | 0603    | Any          |
| 1   | C <sub>MID</sub>  | 10µF  | Ceramic capacitor, 16V, X5R or X7R  | 0805    | Any          |
| 2   | C <sub>SYS</sub>  | 10µF  | Ceramic capacitor, 16V, X5R or X7R  | 0805    | Any          |
| 1   | C <sub>BATT</sub> | 22µF  | Ceramic capacitor, 10V, X5R or X7R  | 0805    | Any          |
| 1   | C <sub>VCC</sub>  | 2.2µF | Ceramic capacitor, 6.3V, X5R or X7R | 0603    | Any          |
| 1   | C <sub>BST</sub>  | 470nF | Ceramic capacitor, 16V, X5R or X7R  | 0603    | Any          |
| 1   | L1                | 1µH   | Inductor, 1µH, low DCR              | SMD     | Any          |
| 1   | RS1               | 10mΩ  | Film resistor, 1%                   | 1206    | Any          |

# PACKAGE INFORMATION

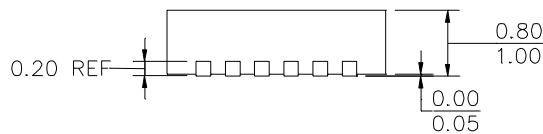
QFN-21 (3mmx3mm)



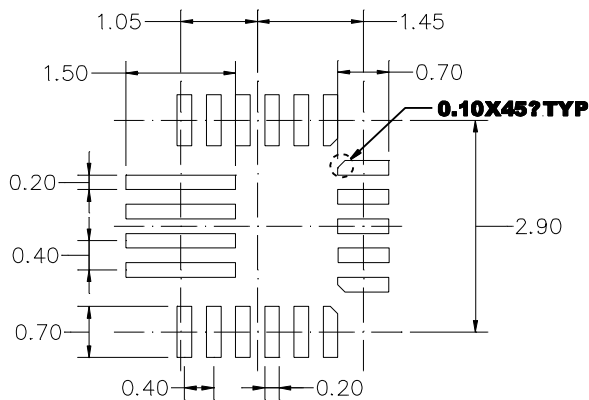
**TOP VIEW**



**BOTTOM VIEW**



**SIDE VIEW**

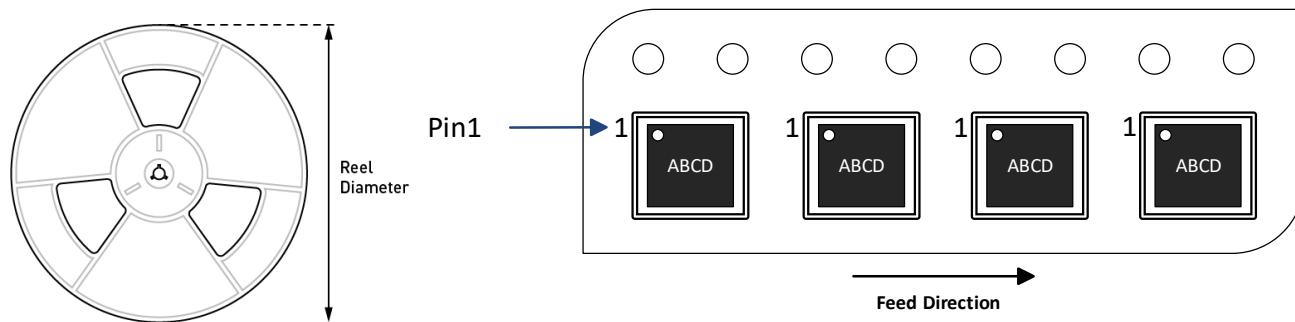


**RECOMMENDED LAND PATTERN**

## NOTE:

- 1) ALL DIMENSIONS ARE IN MILLIMETERS.
- 2) LEAD COPLANARITY SHALL BE 0.08 MILLIMETERS MAX.
- 3) JEDEC REFERENCE IS MO-220.
- 4) DRAWING IS NOT TO SCALE.

## CARRIER INFORMATION



| Part Number      | Package Description | Quantity/Reel | Quantity/ Tray | Quantity/ Tube | Reel Diameter | Carrier Tape Width | Carrier Tape Pitch |
|------------------|---------------------|---------------|----------------|----------------|---------------|--------------------|--------------------|
| MP2696BGQ-0000** | QFN-21 (3mmx3mm)    | 5000          | N/A            | N/A            | 13in          | 12mm               | 8mm                |

## REVISION HISTORY

| Revision # | Revision Date | Description     | Pages Updated |
|------------|---------------|-----------------|---------------|
| 1.0        | 4/16/2021     | Initial Release | -             |

**Notice:** The information in this document is subject to change without notice. Please contact MPS for current specifications. Users should warrant and guarantee that third-party Intellectual Property rights are not infringed upon when integrating MPS products into any application. MPS will not assume any legal responsibility for any said applications.