



The Future of Analog IC Technology®

# MP2681B

CC/CV Controller

with Full Protection and Indication

One Chip Solution for Power Tools Applications

## DESCRIPTION

The MP2681B is a highly integrated Li-ion or Li-polymer switch-mode battery-charge controller with full protection and status indication. This part integrates a precision voltage reference and charge status indications suitable for AC adapter input and cradle charger applications.

The MP2681B detects automatically the battery cell through a battery ID resistor and regulates the battery voltage according to the corresponding cell configurations: 3S, 4S, and 5S. Then, the AC adapter output is regulated automatically according to the chosen battery configuration. Additionally, if the battery pack does not have an ID resistor, the charge termination voltage can be configured by setting a dedicated voltage to the ID pin, according to the pre-set VID values representing the battery configuration. The MP2681B charges the battery in three phases: pre-charge, constant current and constant voltage. Charge is terminated when the current reaches a minimum set level. An internal charge timer provides safety back-up. The MP2681B provides a fixed pre-charge mode for deeply-discharged batteries and safety features that include battery temperature monitoring, NTC control, charge time-out, and fault control.

MP2681B is available in a 16-pin SOIC package.

## FEATURES

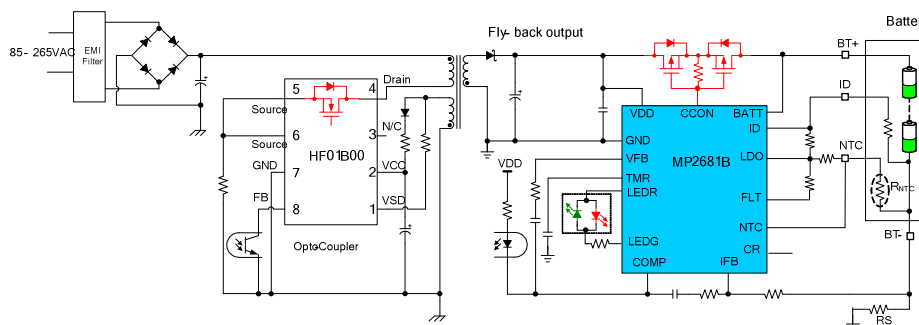
- Constant Voltage and Constant-Current Control
- Pre-Charge Mode for Deeply-Discharged Batteries
- Automatic Battery-Cell Detection
- Two 1MHz Bandwidth Operational Amplifiers Output Connected with OR Logic
- Wide Input-Voltage Range: 5.0V to 30V
- Auto-Recharge
- Charge On/Off Control
- Programmable Internal Timer
- Battery Temperature Monitoring
- Charge-Status Indication
- Power-Line Fault Detection
- Over-Temperature Protection
- 16-pin SOIC Package

## APPLICATIONS

- Battery Charger for Portable Tools
- Stand-Alone Fast Charger

All MPS parts are lead-free and adhere to the RoHS directive. For MPS green status, please visit MPS website under Quality Assurance. "MPS" and "The Future of Analog IC Technology" are Registered Trademarks of Monolithic Power Systems, Inc.

## TYPICAL APPLICATION



## ORDERING INFORMATION

| Part Number* | Package | Top Marking |
|--------------|---------|-------------|
| MP2681BGS    | SOIC-16 | See Below   |

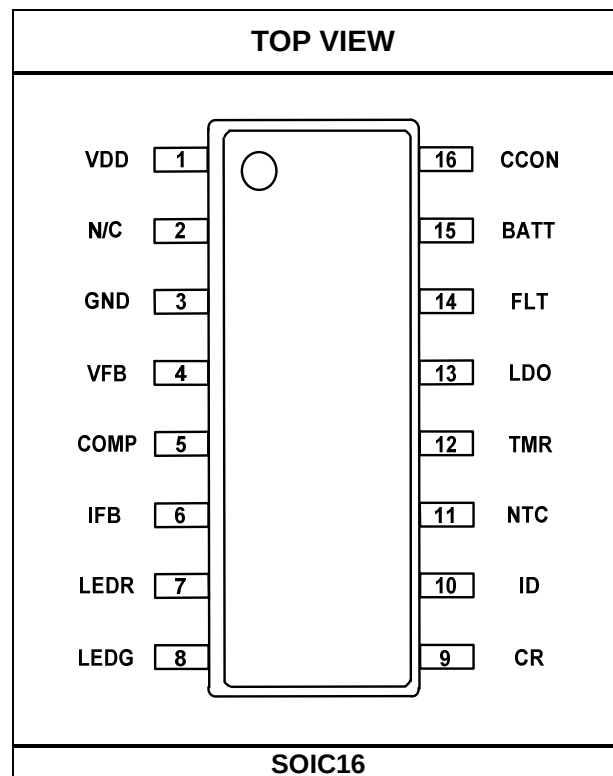
\* For Tape & Reel, add suffix –Z (e.g. MP2681BGS–Z).

## TOP MARKING

**MPSYYWW**  
**MP2681B**  
**LLLLLLLL**

MP2681B: product code of MP2681BGS;  
MPS: MPS prefix;  
YY: year code;  
WW: week code;  
LLL: lot number;

## PACKAGE REFERENCE



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

|                                                                     |                 |
|---------------------------------------------------------------------|-----------------|
| VDD, COMP, BATT to GND .....                                        | -0.3V to +36V   |
| CCON to GND.....                                                    | -0.3V to +36V   |
| All Other Pins.....                                                 | -0.3V to +6.5V  |
| Continuous Power Dissipation (T <sub>A</sub> =+25°C) <sup>(2)</sup> | 1.6W            |
| Junction Temperature.....                                           | 150°C           |
| Lead Temperature (Solder).....                                      | 260°C           |
| Storage Temperature....                                             | -65°C to +150°C |

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

|                                               |                 |
|-----------------------------------------------|-----------------|
| VDD to GND.....                               | 5.0V to 30V     |
| Operating Junct. Temp. (T <sub>J</sub> )..... | -40°C to +125°C |

| Thermal Resistance <sup>(4)</sup> | $\theta_{JA}$ | $\theta_{JC}$ |      |
|-----------------------------------|---------------|---------------|------|
| SOIC-16.....                      | 80.....       | 35            | °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<sub>J</sub> (MAX), the junction-to-ambient thermal resistance  $\theta_{JA}$ , and the ambient temperature T<sub>A</sub>. The maximum allowable continuous power dissipation at any ambient temperature is calculated by P<sub>D</sub> (MAX) = (T<sub>J</sub> (MAX)-T<sub>A</sub>)/ $\theta_{JA}$ . Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the regulator will 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

VDD= 18V, T<sub>A</sub> = 25°C, unless otherwise noted.

| Parameter                   | Symbol                    | Condition                                      | Min   | Typ                     | Max   | Units             |
|-----------------------------|---------------------------|------------------------------------------------|-------|-------------------------|-------|-------------------|
| Input UVLO                  | V <sub>IN</sub>           |                                                | 4.1   | 4.5                     | 4.9   | V                 |
| Total Supply Current        | I <sub>DD</sub>           | VDD = 18V, No Load                             | 0.4   | 0.49                    | 0.6   | mA                |
| <b>OPERATIONAL MPLIFIER</b> |                           |                                                |       |                         |       |                   |
| Output Sink Current         | I <sub>comp_sink</sub>    | T <sub>A</sub> = 25°C, V <sub>comp</sub> =0.5V |       | 15                      |       | mA                |
| Output Leakage Current      | I <sub>COMP leakage</sub> | T <sub>A</sub> = 25°C                          |       |                         | 0.5   | μA                |
| <b>VOLTAGE REFERENCE</b>    |                           |                                                |       |                         |       |                   |
| LDO Output Voltage          | V <sub>LDO</sub>          | I <sub>LDO</sub> =0mA to 20mA                  | 4.8   | 5.0                     | 5.2   | V                 |
| <b>CHARGE CONTORL</b>       |                           |                                                |       |                         |       |                   |
| Pre-Charge Threshold        | V <sub>Pre charge</sub>   |                                                | 2.9   | 3.0                     | 3.1   | V/cell            |
| No-Charge Threshold         | V <sub>No charge</sub>    |                                                | 1.0   | 1.2                     | 1.4   | V/cell            |
| Battery-Regulation Voltage  | V <sub>BATT</sub>         | T <sub>A</sub> = 25°C                          | 4.125 | 4.158                   | 4.175 | V/cell            |
| Re-Charge Voltage           |                           |                                                | 3.8   | 3.95                    | 4.0   | V/cell            |
| Pre-Charge Current          | I <sub>TC</sub>           | V <sub>BATT</sub> <3.0V/cell                   |       | 200                     |       | mA                |
| Termination Charge Current  | I <sub>BF</sub>           | Fast Charging                                  | 5     | 10                      | 15    | %I <sub>CC</sub>  |
|                             |                           | Slow Charging                                  |       | 30                      |       | %I <sub>CC</sub>  |
| FLT Sink Current            |                           | PIN Voltage=0.4V                               |       | 17                      |       | mA                |
| LEDR/LEDG Sink Current      |                           | PIN Voltage=0.4V                               | 8     |                         |       | mA                |
| LEDR/LEDG Source Current    |                           | PIN Voltage=V <sub>LDO</sub> -0.3V             |       |                         | 20    | mA                |
| <b>PROTECTION</b>           |                           |                                                |       |                         |       |                   |
| NTC Control Window          | V <sub>NTC</sub>          | R <sub>NTC</sub> =3.603k, 50°C                 | 23    | 25                      | 27    | %V <sub>LDO</sub> |
|                             |                           | R <sub>NTC</sub> =4.365k, 45°C                 | 30    | 32                      | 34    | %V <sub>LDO</sub> |
|                             |                           | R <sub>NTC</sub> =33.105k, 0°C                 | 73    | 77                      | 82    | %V <sub>LDO</sub> |
|                             |                           | R <sub>NTC</sub> =101.143k, -20°C              | 85    | 90                      | 94    | %V <sub>LDO</sub> |
|                             |                           | NTC Float (No Battery Detection)               | 94.5  | 96                      | 98    | %V <sub>LDO</sub> |
| Pre-Charge Timer            |                           | C <sub>TMR</sub> =0.1μF                        |       | 60                      |       | min               |
| Total Charge Time           | Fast Charge               | C <sub>TMR</sub> =0.1μF                        |       | 2                       |       | hr                |
|                             | Slow Charge               | C <sub>TMR</sub> =0.1μF                        |       | 8                       |       | hr                |
| Timer Frequency             |                           | C <sub>TMR</sub> =0.1μF                        |       | 15                      |       | Hz                |
| CCON High Threshold         | V <sub>CCON_H</sub>       | VDD>V <sub>BATT</sub>                          |       | VDD-0.6V                |       | V                 |
|                             |                           | V <sub>BATT</sub> >VDD                         |       | V <sub>BATT</sub> -0.6V |       | V                 |
| CCON Low Threshold          | V <sub>CCON_L</sub>       |                                                |       | 0.3                     |       | V                 |

# ELECTRICAL CHARACTERISTICS *(continued)*

VDD= 18V, T<sub>A</sub> = 25°C, unless otherwise noted.

| Parameter                       | Symbol              | Condition                                              | Min | Typ | Max | Units |
|---------------------------------|---------------------|--------------------------------------------------------|-----|-----|-----|-------|
| CCON Rise Time                  | t <sub>r_CCON</sub> | V <sub>CCON</sub> : 10% to 90% C <sub>CCON</sub> =10nF |     | 400 | 500 | μs    |
| CCON Fall Time                  | t <sub>f_CCON</sub> | V <sub>CCON</sub> : 90% to 10% C <sub>CCON</sub> =10nF |     | 22  | 100 | μs    |
| CR High Logic                   | V <sub>CRH</sub>    | Fast Charge                                            | 2.5 |     |     | V     |
| CR Low Logic                    | V <sub>CRL</sub>    | Slow Charge                                            |     |     | 0.4 | V     |
| Thermal Shutdown <sup>(5)</sup> | T <sub>SHTDWN</sub> |                                                        |     | 150 |     | °C    |

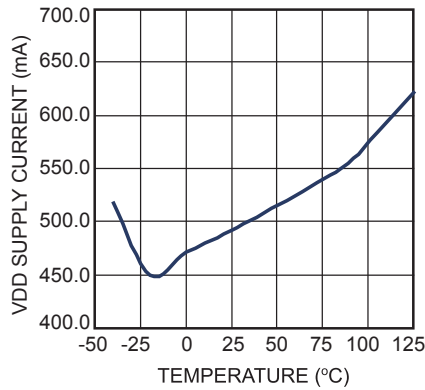
## Notes:

(5). Guaranteed by design

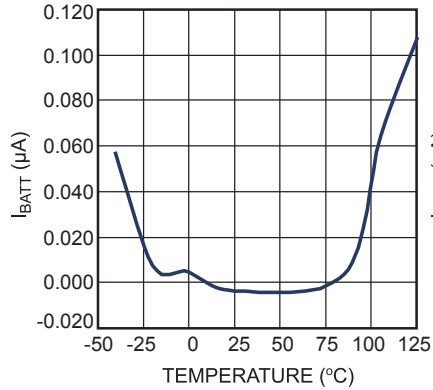
## TYPICAL CHARACTERISTICS

V<sub>DD</sub>= 18V, unless otherwise noted.

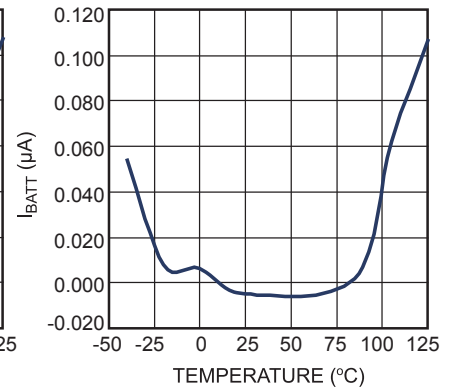
**V<sub>DD</sub> Supply Current vs. Temperature**



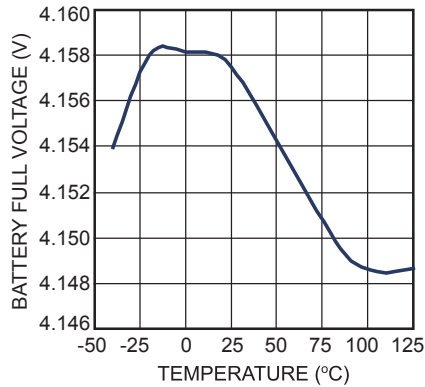
**I<sub>BATT</sub> @ V<sub>DD</sub> Float vs. Temperature**



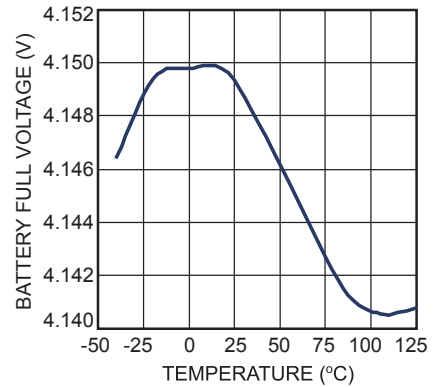
**I<sub>BATT</sub> @ V<sub>DD</sub>=36V, V<sub>BATT</sub>=0V vs. Temperature**



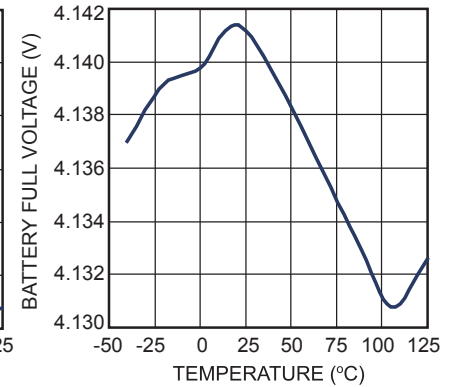
**Battery Regulation @ 3 Cell vs. Temperature**



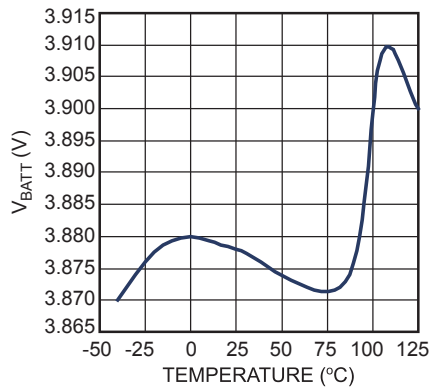
**Battery Regulation @ 4 Cell vs. Temperature**



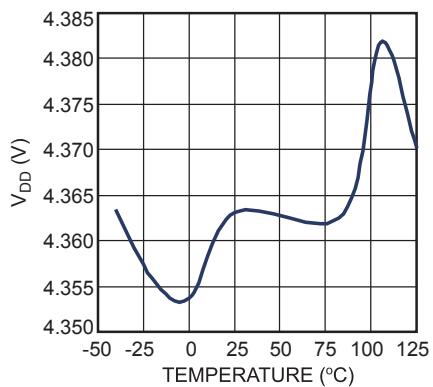
**Battery Regulation @ 5 Cell vs. Temperature**



**Battery Auto-Recharge Threshold vs. Temperature**

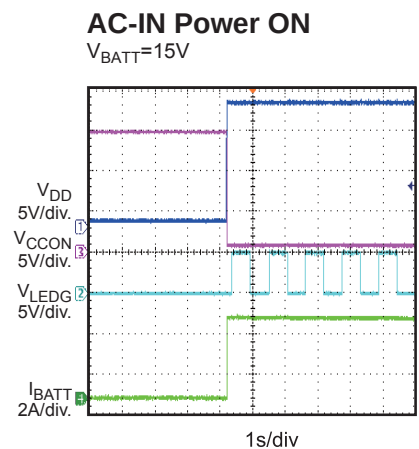
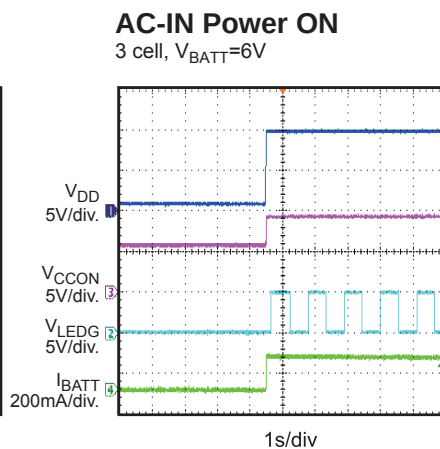
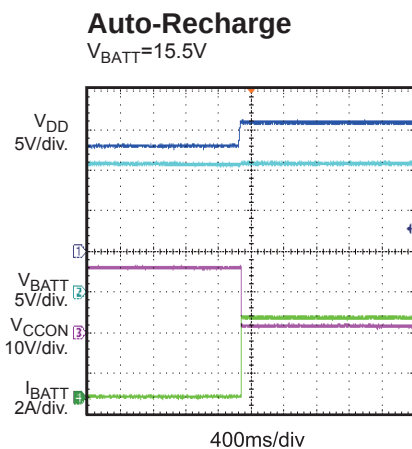
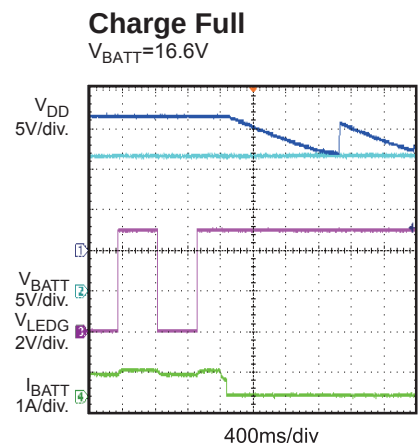
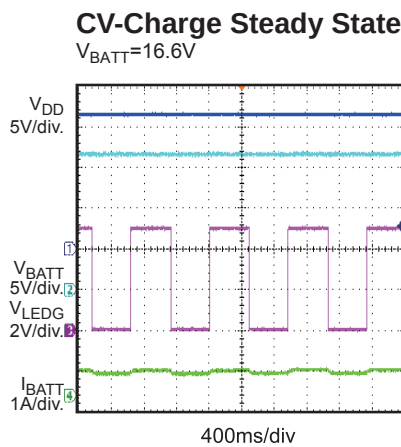
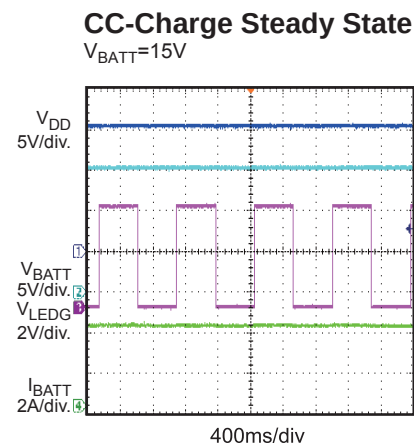
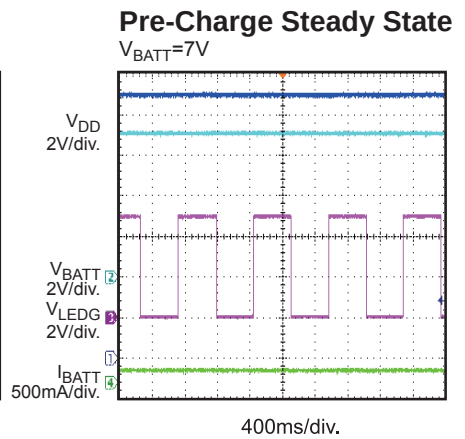
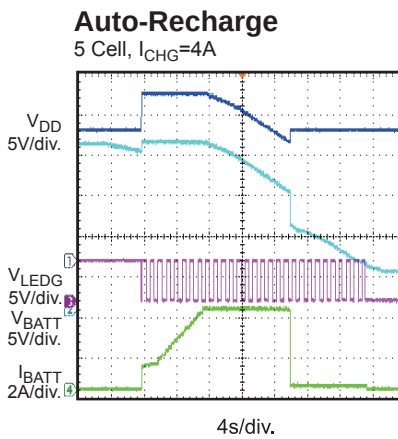
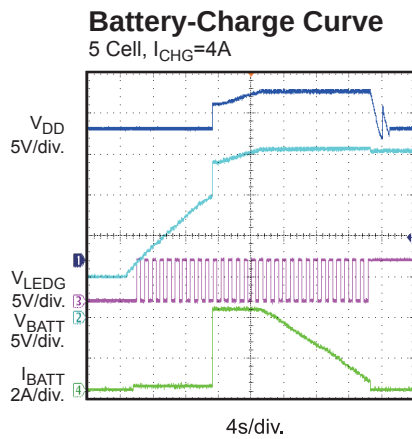


**V<sub>DD</sub> OVP vs. Temperature**



## TYPICAL PERFORMANCE CHARACTERISTICS

VDD = 18V, T<sub>A</sub> = 25°C, unless otherwise noted.

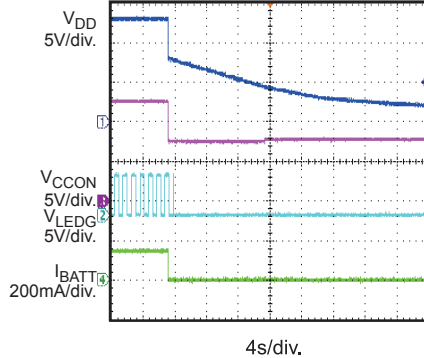


# TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

VDD = 18V, T<sub>A</sub> = 25°C, unless otherwise noted.

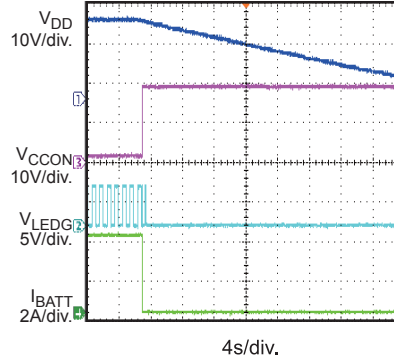
**AC-IN Power OFF**

V<sub>BATT</sub>=8V



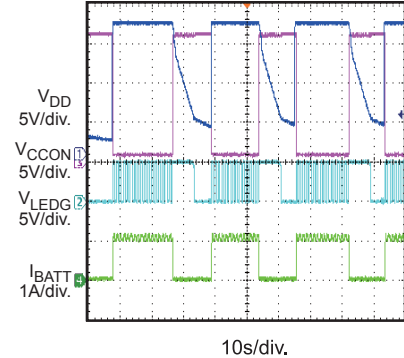
**AC-IN Power OFF**

5cell, V<sub>BATT</sub>=19V, I<sub>CHG</sub>=4A



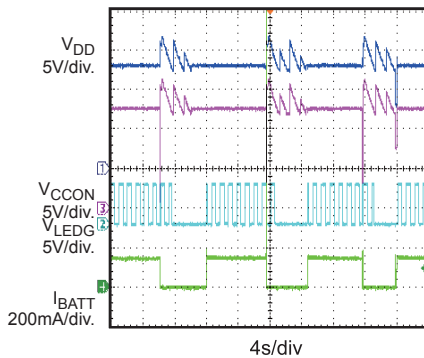
**AC-IN Power ON/ OFF**

V<sub>BATT</sub>=16.6V



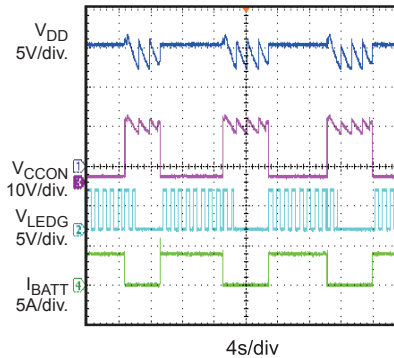
**Battery Insertion/ Removal**

V<sub>BATT</sub>=8V



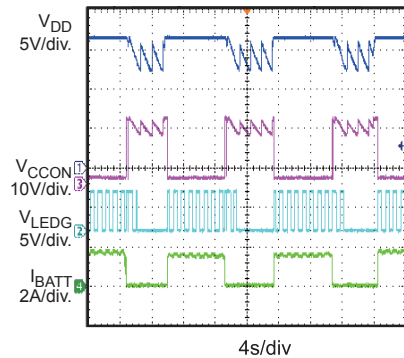
**Battery Insertion/ Removal**

V<sub>BATT</sub>=15V



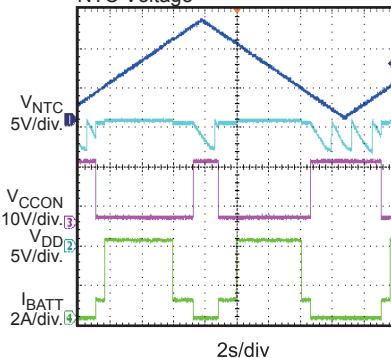
**Battery Insertion/ Removal**

V<sub>BATT</sub>=16.6V



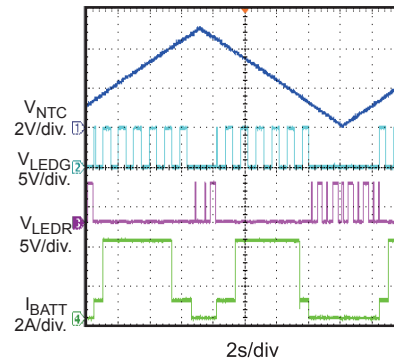
**NTC Fault Control**

V<sub>BATT</sub>=15.5V, Ramp Up and Down  
NTC Voltage



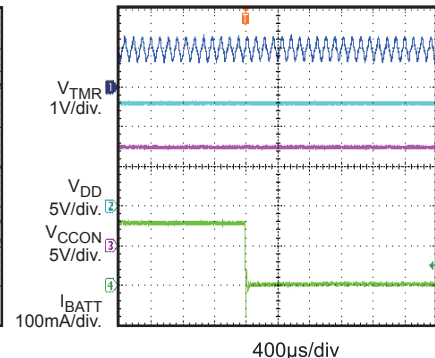
**NTC Fault Indication**

V<sub>BATT</sub>=15.5V



**Timer-Out Protection**

CTMR=150pF, V<sub>BATT</sub>=10V

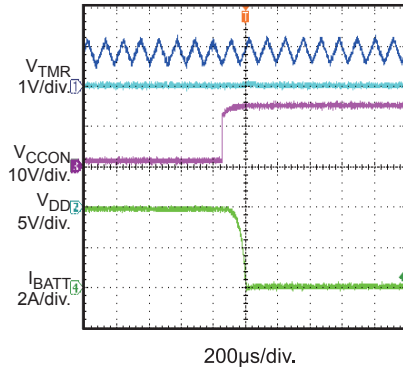


## TYPICAL PERFORMANCE CHARACTERISTICS (continued)

VDD = 18V, TA = 25°C, unless otherwise noted.

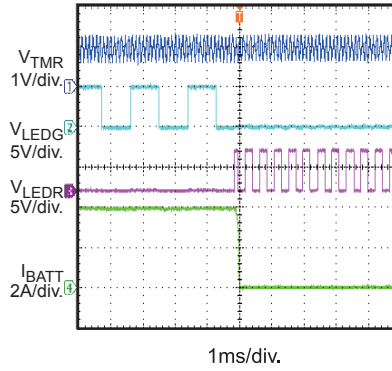
### Timer-Out Protection

CTMR=150pF, VBATT=15V



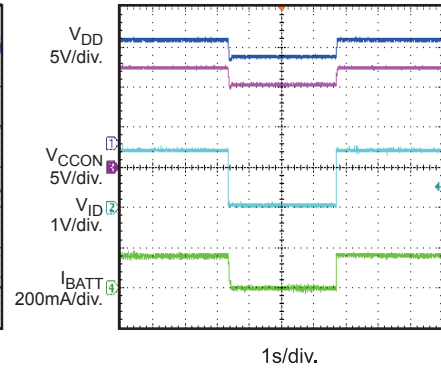
### Timer-Out Indication

CTMR=150pF, VBATT=15.5V



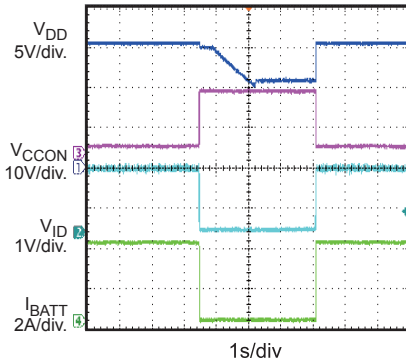
### ID Short Protection

VBATT=10V



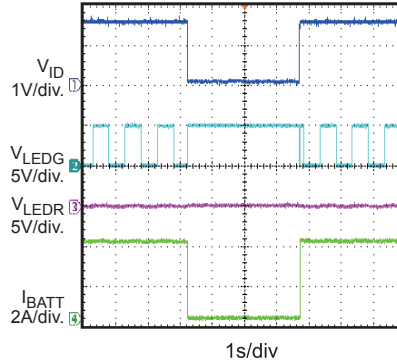
### ID Short Protection

VBATT=15V



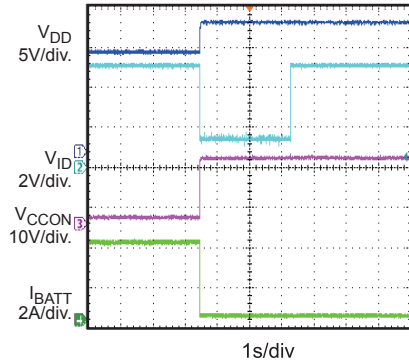
### ID Short Indication

VBATT=15V



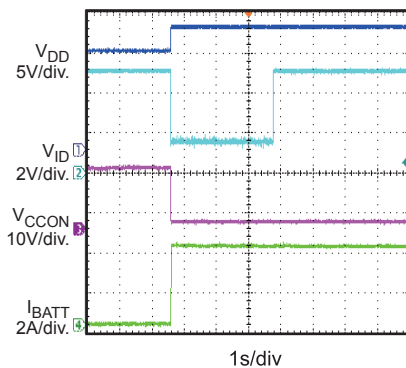
### ID Open Protection

VBATT=12V



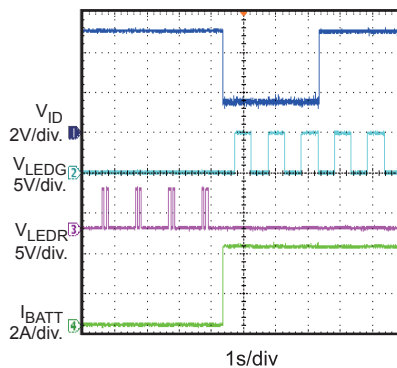
### ID Open Protection

VBATT=15V



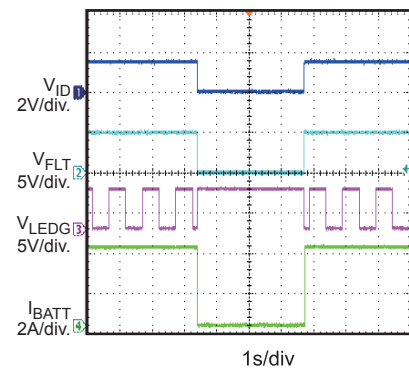
### ID Open Indication

VBATT=15V



### Fault Signal under ID Short

VBATT=15V



## PIN FUNCTIONS

| Package Pin # | Name | Description                                                                                                                                                                                                  |
|---------------|------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1             | VDD  | Power Supply Input. Bypass VDD to GND with a capacitor (at least 4.7μF).                                                                                                                                     |
| 2             | NC   | No Connected.                                                                                                                                                                                                |
| 3             | GND  | Ground.                                                                                                                                                                                                      |
| 4             | VFB  | Voltage Feedback. Connect VFB to the compensation of the voltage-regulation loop externally.                                                                                                                 |
| 5             | COMP | Output Common to Voltage Regulation and Current-Limitation Loops. Connect COMP to the cathode of the opto-coupler.                                                                                           |
| 6             | IFB  | Current Feedback. Connect IFB to the current-sense resistor.                                                                                                                                                 |
| 7             | LEDR | Charging Status Indicator (see Table 3 for indication).                                                                                                                                                      |
| 8             | LEDG | Charging Status Indicator (see Table 3 for indication).                                                                                                                                                      |
| 9             | CR   | Charge-Rate Setting. Pull CR to logic high to set the charger in fast-charge or pull CR to logic low to set the charger in slow-charge. Floating CR sets the charger in fast-charge as the default setting.  |
| 10            | ID   | Battery Type Detection. Connect to the ID resistor output of the battery pack. ID is used to detect the battery type.                                                                                        |
| 11            | NTC  | Battery Temperature Monitoring (see Figure 2 for proper connection).                                                                                                                                         |
| 12            | TMR  | Timer Setting. Connect TMR to a capacitor from TMR to GND to set the oscillator cycle. The timer-setting period changes according to the oscillation cycle. <b>Short TMR to ground to disable the timer.</b> |
| 13            | LDO  | LDO Output for Pulling High Voltage of NTC, FLT, and ID.                                                                                                                                                     |
| 14            | FLT  | Drain Output to Detect a Charge-Fault Condition. FLT is pulled low when a fault occurs. Connect FLT to the battery-pack pin (if available). Pull FLT high to LDO through a resistor.                         |
| 15            | BATT | Battery Sense Voltage Input.                                                                                                                                                                                 |
| 16            | CCON | External Charge On/Off Control MOSFET Gate Control. CCON cuts off the charge path when a fault occurs or protection is triggered.                                                                            |



Table 1 summarizes all the charge-voltage settings for the MP2681B. The real ID voltage threshold for every battery pack is about  $\pm 65\text{mV}$

wider than the ones listed in the table, taking into consideration reference variations, comparator offsets, and hysteresis.

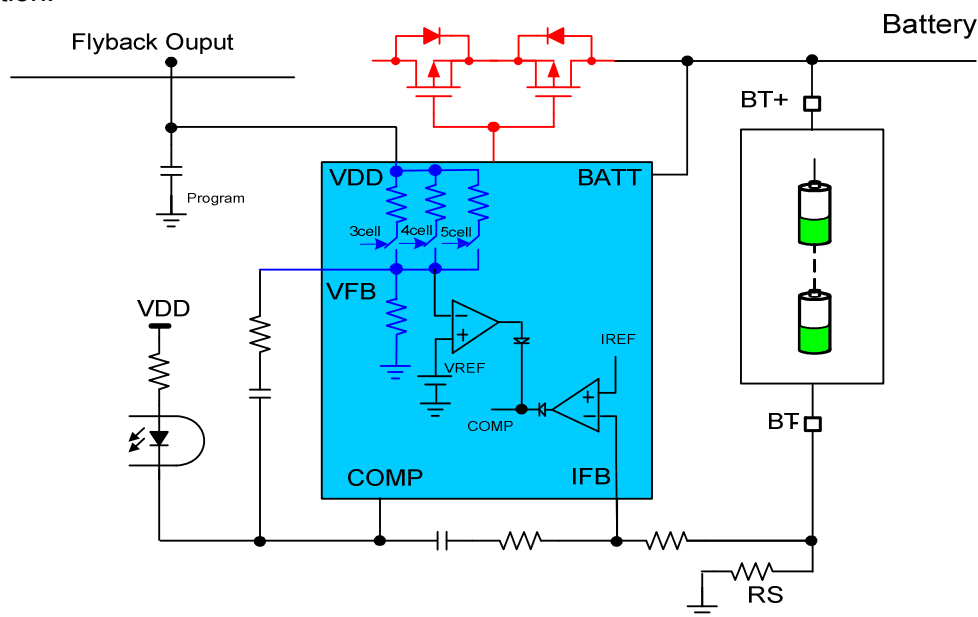
**Table1. Charge-Voltage Setting Summary**

| ID Resistor |           | Detect Voltage                         | Operation Mode | Battery Spec | VDD    | VBATT  |
|-------------|-----------|----------------------------------------|----------------|--------------|--------|--------|
| Float       | NTC Float | $V_{ID} > 2.65\text{V}$                | Sleep Mode     | No Battery   | 10.8V  | 0      |
|             | NTC OK    |                                        | Default Mode   | 3S           | 12.44V | 12.44V |
| 1.8k        |           | $0.3\text{V} < V_{ID} < 0.7\text{V}$   | Automatic Mode | 3S           | 12.44V | 12.44V |
| 6.8k        |           | $0.95\text{V} < V_{ID} < 1.6\text{V}$  |                | 4S           | 16.59V | 16.59V |
| 15k         |           | $1.75\text{V} < V_{ID} < 2.65\text{V}$ |                | 5S           | 20.74V | 20.74V |
| Short       |           | $V_{ID} < 0.3\text{V}$                 | Sleep Mode     | Unknown      | 10.8V  | 0      |

ID voltage is detected out of range based on the values specified in Table 1 (possibly caused by the insertion of a wrong battery-pack configuration). The MP2681B detects this fault condition and cuts off the external MOSFET to stop charging and protect the battery. Under this condition, the output voltage is set to a default value of 10.8V, causing the MP2681B to enter sleep mode. Also, the MP2681B provides a fault indication. No battery condition is detected when both NTC and ID are floating; when there is no battery, the indication is off. If the NTC is ok (while ID is floating), it means the battery has no ID resistor, and the MP2681B will default set it as a 3 cell condition.

The MP2681B compares the VFB voltage to its internal voltage reference in order to maintain voltage regulation. If this voltage is higher than 2.075V, the output of the voltage-loop operational amplifier decreases; the opto-coupler current will increase, reducing the output voltage of the PWM controller.

Figure 3 shows the CC and CV control circuit.



**Figure 3. CC/CV Control Circuit of MP2681B**

### Charge-Current Setting

The current limitation ( $I_{CHG}$ ) is performed by sensing the voltage across the sense resistor (RS) and comparing it to the charge-current reference ( $V_{IREF}$ ). When the sense voltage on RS is higher than  $V_{IREF}$ , the output of the current-limitation loop operational amplifier decreases. The opto-coupler current increases and tends to reduce the output voltage by the way of the PWM controller (see Figure 3).

Choose the sense resistor RS according to the charge current and the following formula:

$$RS = \frac{V_{IREF}}{I_{CHG}}$$

The charge-current reference is controlled by CR to set the charge rate. If CR is logic high,  $V_{IREF}$  is fixed at 0.16V internally; the charge current can be programmed only by changing the sense resistor. Pull CR low to set the IC in slow-charge.  $V_{IREF}$  is set to 0.016V to decrease the charge current without changing the external resistor. With CR, the MP2681B can set the charger in fast or slow charge automatically. Floating CR sets the charger in fast-charge as per the default setting.

To avoid large currents flowing into the battery, the MP2681B implements an over-current protection scheme. When voltage over 500mV is detected on IFB, the MP2681B cuts off the charge-current path to the battery.

### Pre-Charge Mode

Before the charging cycle starts, the MP2681B senses the battery voltage.

If the battery voltage is lower than 1.0V/cell, the MP2681B acts as if there is a dead battery, and it never starts charging. If the battery voltage is lower than 3.0V/cell, the MP2681B goes into pre-charge mode. The external MOSFET is off in this mode, and the output-voltage control of the flyback is set at a default value of 3.2V/cell. The MP2681B acts as a constant current source, supplying a constant 150mA current to charge the battery pack through BATT.

This period lasts until the battery voltage increases over the 3.0V/cell threshold or during time-out. A fixed timer starts when pre-charge mode starts. The MP2681B sets the time period for pre-charge at 60min with a 0.1uF timer capacitor ( $C_{TMR}$ ). Changing the capacitor value will change the time period only during charge mode but not during pre-charge mode.

The pre-charge mode ensures that any deeply discharged battery will be charged safely.

### Charge Cycle (Mode Change: CC→ CV)

At the end of the pre-charge cycle (and when the battery voltage is at least equal to 3.0V/cell), the external MOSFET is turned on, and the MP2681B enters constant-current charge mode. This mode of operation will stay as long as the battery voltage does not cross the full, pre-set charge threshold.

After the battery voltage is over 3.0V/cell, the IC begins to charge at the programmed constant current rate ( $I_{CHG}$ ). This is referred to the constant current in CC mode. Once the output voltage reaches the battery-regulation voltage, the charger operates in constant-voltage (CV) mode until the battery is fully charged. During this time, the charge current starts to decrease down to the  $I_{BF}$  threshold (usually 10% of the programmed constant-current value).

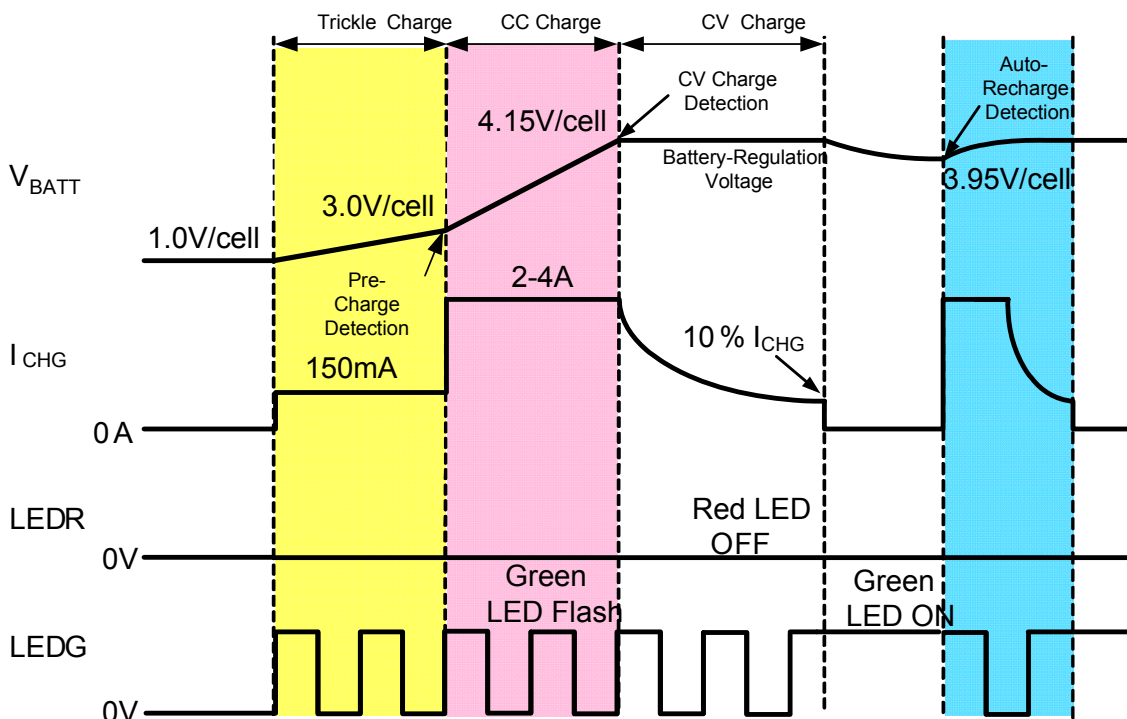


Figure 4. Typical Charge Profile

### Charge Termination

The charge cycle is considered complete when the charge current reaches the programmed termination-current threshold ( $I_{BF}$ ). Please refer to Figure 4 for a complete view of the charging cycle and LED operation.

### Automatic Re-Charge

The MP2681B allows the battery to be re-charged automatically when the battery voltage drops below the auto-recharge threshold (3.95V/cell). The MP2681B re-sets the reference voltage to the normal charging value and turns on the CCON driver to re-start the charge cycle until the  $I_{BF}$  condition is met again.

### LDO Output

The MP2681B implements a 5V LDO which provides a pull-up voltage for the NTC, ID resistor, and FLT detection. It supplies up to 20mA current. When VDD is higher than 5V, the LDO output is regulated at 5V. If the VDD input voltage is lower than 5V, the FET is fully on and the LDO output is nearly equal to the input voltage VDD.

### Timer Operation

The MP2681B provides a safety timer in case of a defective battery pack.

During pre-charge mode the charge timer is fixed with a set capacity. During CC and CV charge mode, the timer duration is proportional to the charge rate. The timer will start counting every time the charger process starts up (as in initial power-up or automatic re-charge). The timer will limit pre-charge time to T1 oscillating cycles on TMR. If the charger stays in pre-charge mode for longer than T1 cycles, the MP2681B terminates the charging operation by disconnecting the battery from the charger. The output voltage is regulated to the default value. The timer-fault indication is set by flashing LEDR and keeping LEDG low. After a fault-reporting condition, the charger can be re-initiated only by recycling the power supply. The timer limit in the pre-charge mode is fixed, and it will not change when the IC is set to slow-charge or fast-charge mode via CR.

If the charger goes through pre-charge successfully within the allowed time limit, it will start CC charge and then CV charge. If the total charge time exceeds T2 cycles (and the battery full has not been reached), the MP2681B terminates the charger; then the CCON output is pulled high to turn off the switch and stop charge. Also, the timer-out fault indication will be set (by flashing LEDR and LEDG low). This function prevents charging a dead battery for a prolonged duration of time. Table 2 shows the timer for the pre-charge and total-charge duration limit.

**Table 2. Timer Cycles**

| T1    | T2                         |
|-------|----------------------------|
| 57600 | Fast:115200<br>Slow:460800 |

TMR is used to set the internal oscillator frequency. The timer function can be disabled by shorting TMR to ground, although this is not recommended.

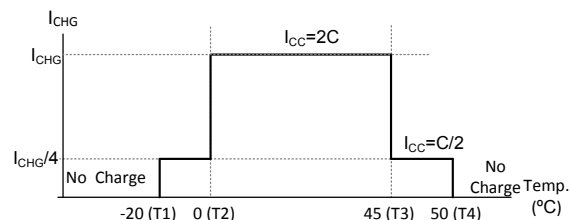
The timer frequency according to the TMR capacitor is as follows:

$$T(s) = 0.6 \times C(\mu F)$$

### Smart Negative-Temperature Coefficient (NTC) Protection

The MP2681B monitors continuously the battery temperature by measuring the voltage on the NT, which is generated by a negative temperature coefficient (NTC) thermistor and an external voltage divider. The controller compares this voltage against its internal thresholds to determine if charging is allowed. To initiate a charge cycle, the voltage on NTC must be within the  $V_{T1}$  to  $V_{T4}$  thresholds (see Figure 5). If the  $V_{NTC}$  is outside of this range, the controller suspends charge and waits until the battery temperature is back within the  $V_{T1}$  to  $V_{T4}$  range. During the  $V_{T2}$  and  $V_{T3}$  range, the charge current is usually set at a 2C rating corresponding to  $I_{CHG}$  set by the user. If the NTC voltage is between  $V_{T1}$  and  $V_{T2}$  the MP2681B decreases the charge current to  $I_{CHG}/4$ . When the IC is in pre-charge or slow-charge mode, the charge current is set to low and NTC will not have any effect on the

charge current. Figure 5 shows the charge-current setting by the NTC window control.



**Figure 5. NTC control window**

### CCON

The CCON is a driver output pin used to turn on/off the external MOSFET to connect or cut off the charge path according to the charge condition. If the MP2681B is under normal charge operation, the CCON is pulled low. If a fault occurs, CCON is pulled high to cut off the charge path.

### Status Indication

The MP2681B integrates two driver outputs (LEDG and LEDR). Connecting a bi-color back-to-back LED between these two pins can output a variety of indication states to help distinguish each operation, including: charging, charge termination, NTC fault, timer out, ID open, ID out of range, ID short, and power-line fault.

Table 3 summarizes the status of the two indication LEDs under the different charge states based on the LEDR and LEDG outputs (see Figure 6).

**Table 3. LED Indicator Table**

| Condition                      | Red LED | Green LED | CCON |
|--------------------------------|---------|-----------|------|
| Charging                       | OFF     | Flash     | Low  |
| Charging Finish/ID Short       | OFF     | ON        | High |
| NTC Fault                      | Flash   | OFF       | High |
| Timer Fault<br>ID Out of Range | Flash   | OFF       | High |
| Power-Line Fault               | Flash   | OFF       | High |
| NTC Float (No Battery)         | OFF     | OFF       | High |

## Power Supply

The MP2681B does not operate when VDD voltage is under the UVLO threshold. The charge starts to work when the output voltage is 200mV higher than the battery voltage. Also, the MP2681B integrates over-voltage protection on VDD to protect the battery. When the power supply is under the UVLO threshold (or VBATT+200mV), and when the VDD voltage is 100mV/cell over the battery-limit value (4.15V/cell), the power supply is detected as invalid and the MP2681B turns off the external power switch to stop charging.

## Battery-Voltage Sense

BATT is used to sense the battery voltage. It is connected to the positive output of the battery pack. The MP2681B detects the battery voltage through BATT to enable the correct charge setting. During start-up (after the supply voltage is above the UVLO threshold), the MP2681B detects the battery voltage. If  $V_{BATT}$  is lower than 1.0V/cell (dead or no battery) the MP2681B will not start charging. This condition stays as long as  $V_{BATT}$  exceeds 1.0V/cell. If the battery voltage

detected is lower than 3.0V/cell, the MP2681B goes into pre-charge mode and a fixed constant current of 150mA will flow from BATT to the battery pack to charge the battery. In pre-charge mode, the external MOSFET stays off to cut off the charge path; the output voltage is set at the default 3.2V/cell. During normal charge operation (if the battery is removed), the MP2681B detects this condition through  $V_{BATT} < 1.0V/cell$ . The MP2681B regulates the reference voltage to set the flyback output to the default value of 10.8V. It will never start charging unless  $V_{BATT}$  is higher than 1.0V/cell.

## Fault Protection

FLT is an open-drain output, and it is pulled low when a fault condition is assessed. Connect FLT to the LDO output through a resistor. Under any fault condition including NTC fault, timer out, and ID fault, FLT is pulled low. Meanwhile, the MP2681B pulls CCON high to cut off immediately the flyback output from the battery and regulates the reference voltage to set the flyback output to the default 3.2V/cell.

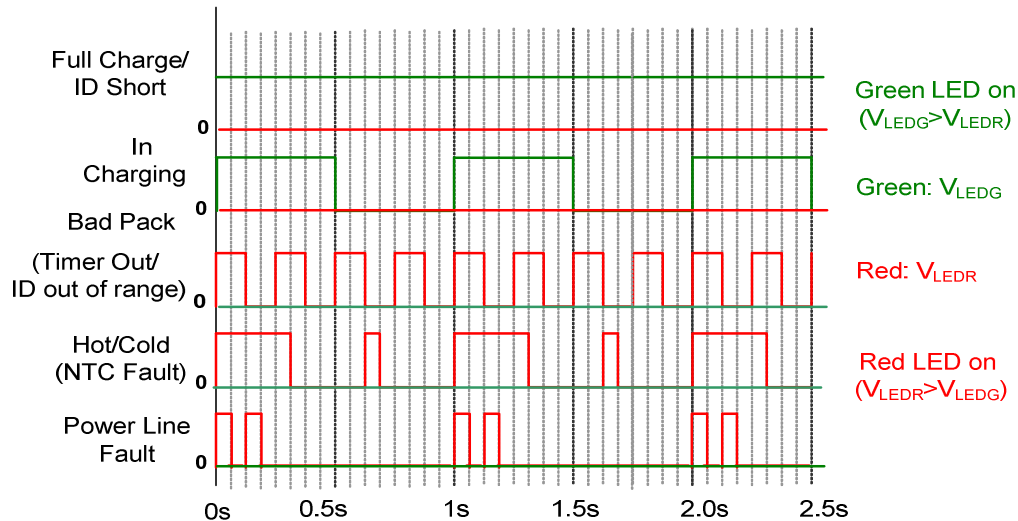
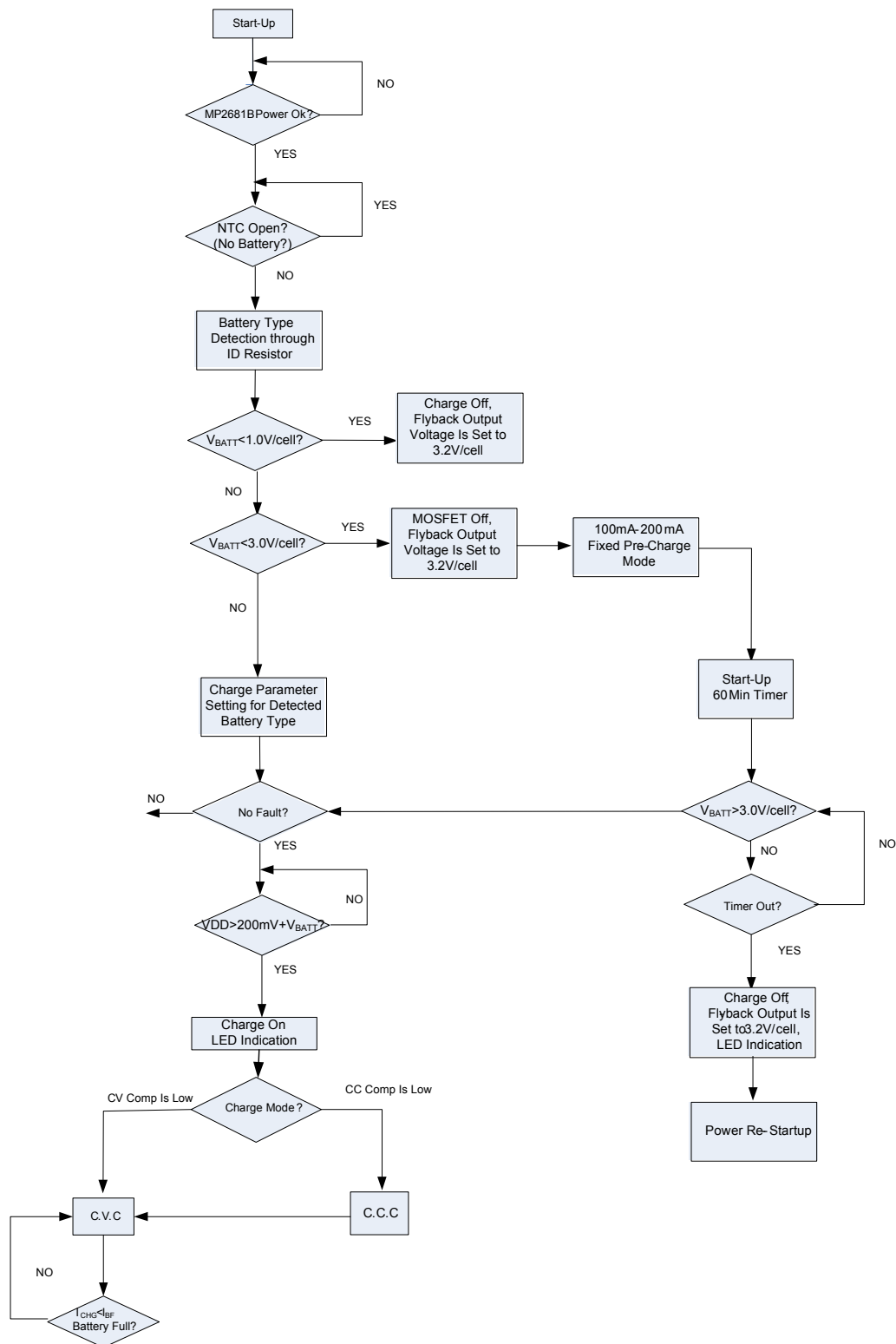


Figure 6. Schematic plot of the output voltage at LEDG/LEDR

# CONTROL FLOWCHART



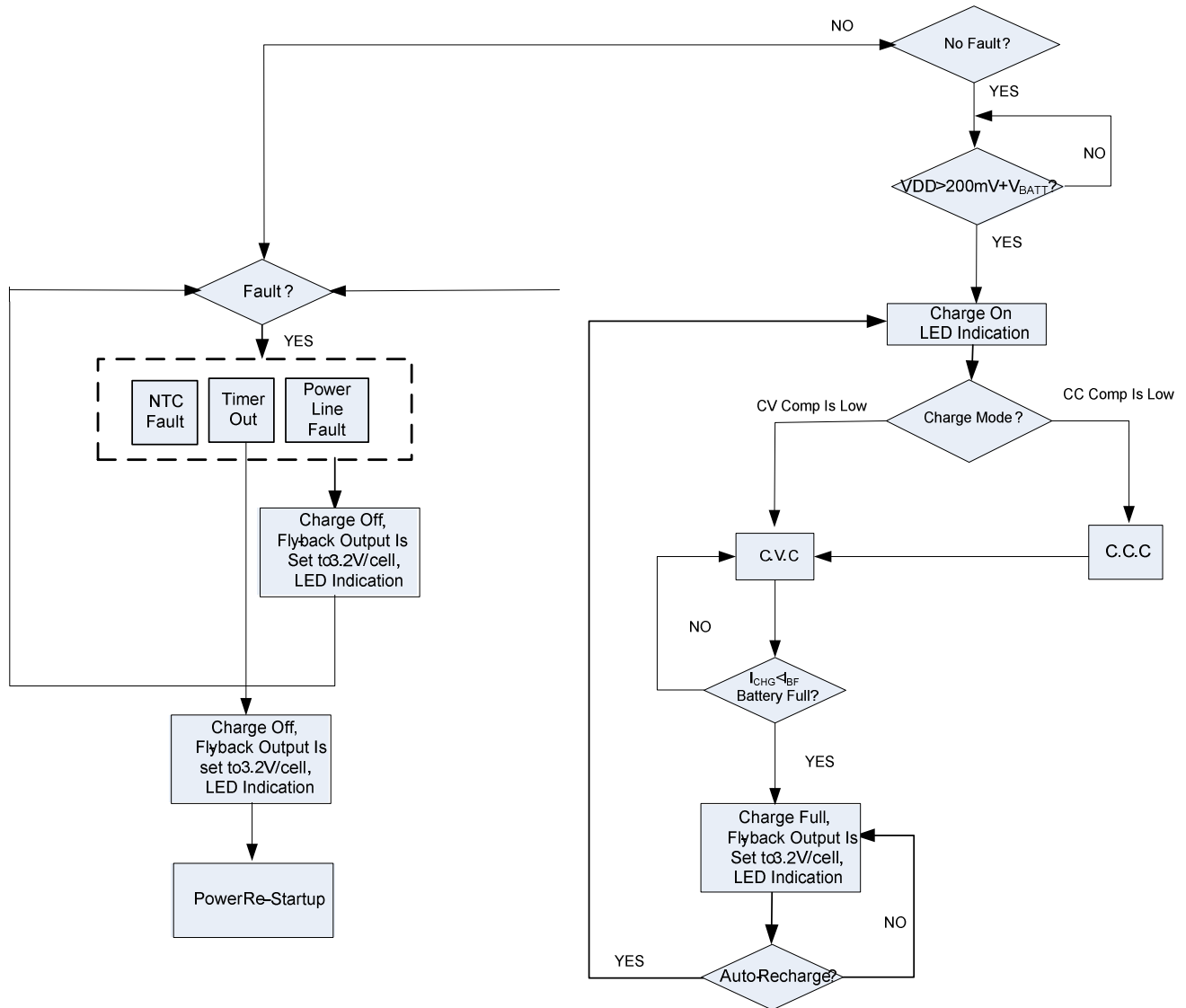
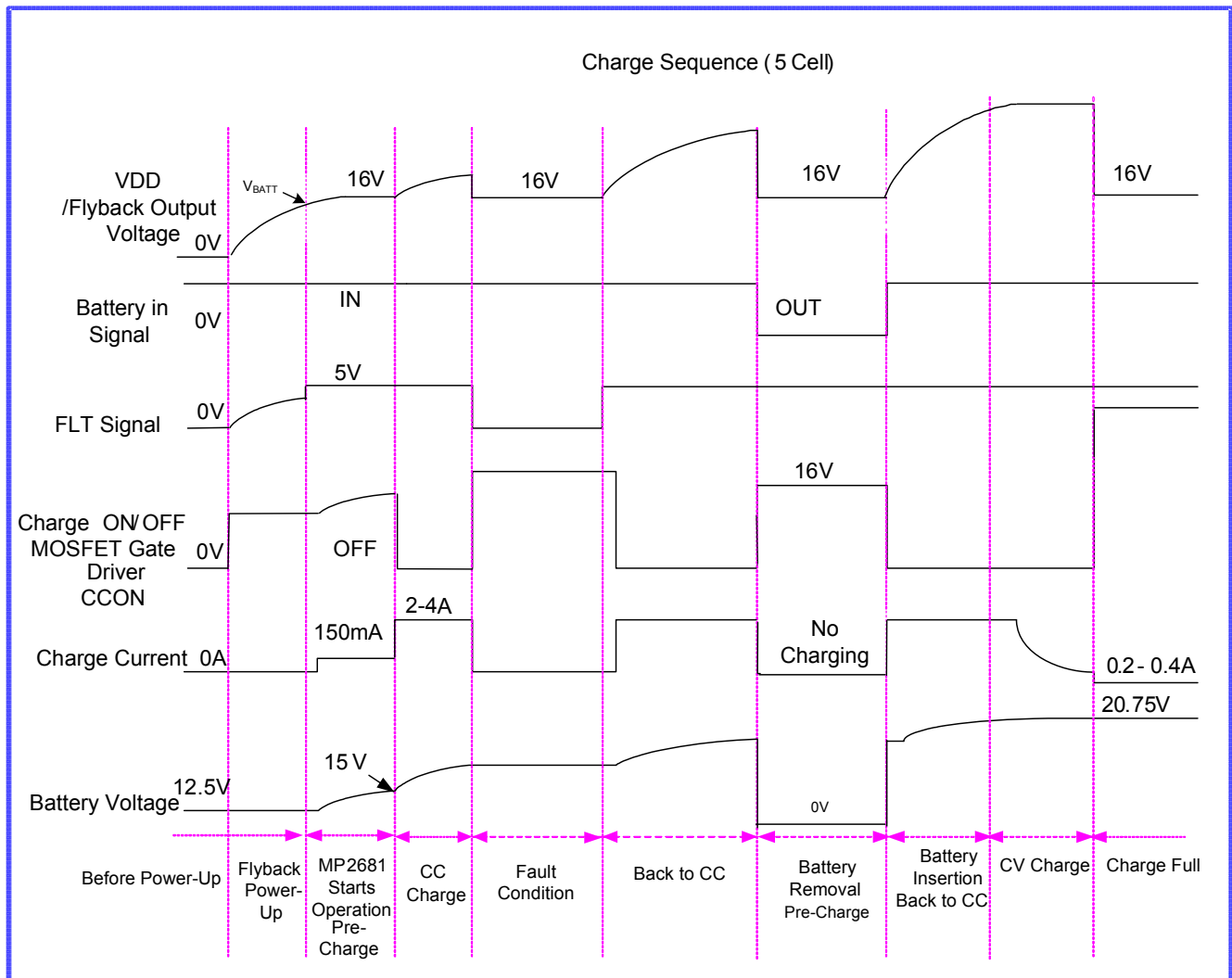


Figure 7. MP2681B Control Flow Chart

## OPERATION WAVEFORM



**Figure 8. MP2681B Charge Sequence (5 Cell)**

## APPLICATION INFORMATION

### COMPONENT SELECTION

#### Setting the VDD Voltage

VDD voltage is regulated based on the battery specifications, according to the ID resistor.

Refer to Table 1 for the relationship between the ID voltage and the VDD voltage.

#### Setting the Charge Current

The current limitation ( $I_{CHG}$ ) is performed by sensing the voltage across the sense resistor  $R_S$  and comparing it to the charge-current reference ( $V_{IREF}$ ), refer to formula (1):

$$R_S = \frac{V_{IREF}}{I_{CHG}} \quad (1)$$

The charge-current reference is controlled by CR to set the charge rate. If CR is logic high,  $V_{IREF}$  is fixed at 0.16V internally. Pull CR low to set the charger in slow-charge ( $V_{IREF}$  is set to 0.016V).

#### Timer Setting

TMR is used to set the internal oscillator frequency. Refer to timer-setting formulas below:

Pre-charge timer

$$T_{Pre-1P}(s) = 34560 \times C(uF) \quad (2)$$

Total-charge timer:

Fast charge:

$$T_{Total-1P-fast}(s) = 69120 \times C(uF) \quad (3)$$

Slow charge:

$$T_{Total-1P-slow}(s) = 276480 \times C(uF) \quad (4)$$

#### Choosing the Resistor for NTC Sensor

Figure 9 shows an internal resistor-divider reference circuit to limit the four temperature thresholds at 90%·LDO, 77%·LDO, 32%·LDO, and 25%·LDO, respectively (to specify operation under cold, cool, warm, and hot conditions). For a given NTC thermistor, select appropriate  $R_{T1}$  and  $R_{T2}$  to set the NTC window:

$$\frac{R_{T2} // R_{NTC\_Cold}}{R_{T1} + R_{T2} // R_{NTC\_Cold}} = \frac{V_{T1}}{LDO} = 90\% \quad (5)$$

$$\frac{R_{T2} // R_{NTC\_Cool}}{R_{T1} + R_{T2} // R_{NTC\_Cool}} = \frac{V_{T2}}{LDO} = 77\% \quad (6)$$

$$\frac{R_{T2} // R_{NTC\_Warm}}{R_{T1} + R_{T2} // R_{NTC\_Warm}} = \frac{V_{T3}}{LDO} = 32\% \quad (7)$$

$$\frac{R_{T2} // R_{NTC\_Hot}}{R_{T1} + R_{T2} // R_{NTC\_Hot}} = \frac{V_{T4}}{LDO} = 25\% \quad (8)$$

$R_{NTC\_Hot}$  is the value of the NTC resistor at the highest temperature of the required temperature-operation range.  $R_{NTC\_Cold}$  is the value of the NTC resistor at the lowest temperature.

The two resistors ( $R_{T1}$  and  $R_{T2}$ ), allow the high-temperature limit and low-temperature limit to be programmed independently.

It should satisfy the 4 equations above. Refer to Figure 9 for NTC function block.

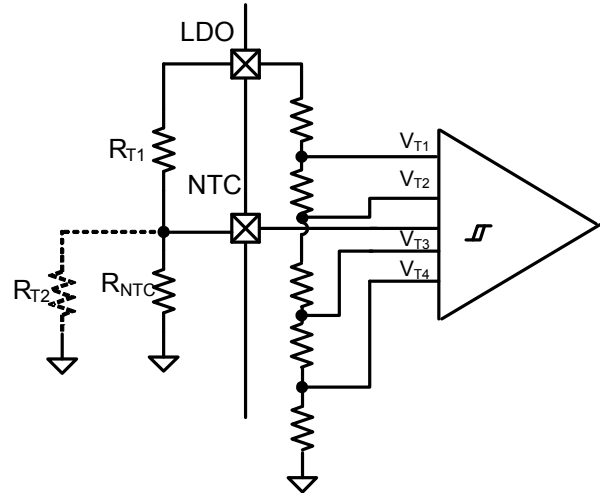


Figure 9. NTC Function Block

#### PCB Layout Guidelines

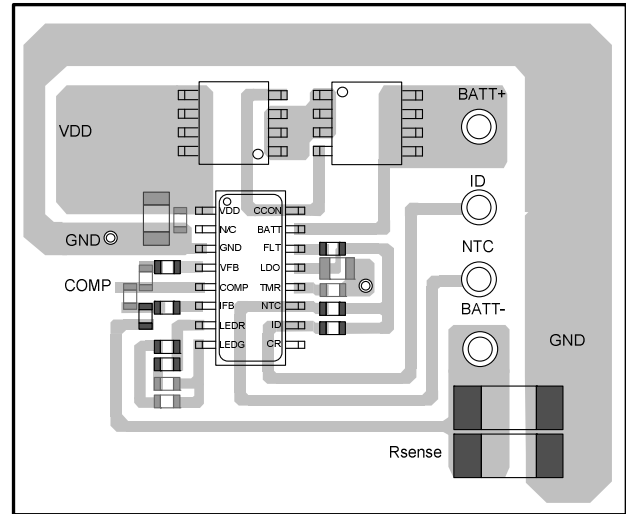
Efficient PCB layout is critical to meet specified noise, efficiency, and stability requirements. Refer to Figure 10 and the following design considerations to improve circuit performance:

- 1) Route the power stage adjacent to their grounds. Trace lengths in the high-current paths and the current-sense resistor trace.
- 2) Keep the power ground away from all small control signals, especially the feedback network.
- 3) Place the input capacitor as close as possible to VDD and PGND.

4) IFB and VFB are sensitive. Make the compensation components between FB and COMP close to the pins.

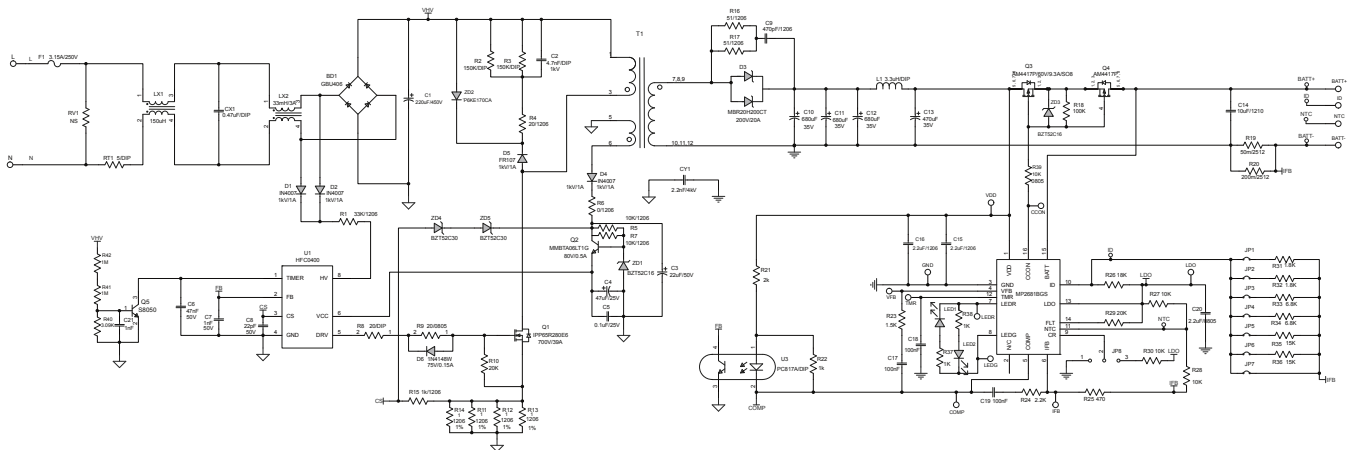
5) The PCB should have a ground plane connected directly to the return of all components through vias (two vias per capacitor for power-stage capacitors, one via per capacitor for small-signal components). If possible, it is recommended to place vias inside the PGND pads. Typically, a star-ground design approach is used to keep circuit-block currents isolated (high-power/low-power, small-signal), which reduces noise-coupling and ground-bounce issues.

6) A single ground plane for this design produces good results. With the small layout and single ground plane, ground-bounce is not an issue. The segregated components minimize coupling between signals.



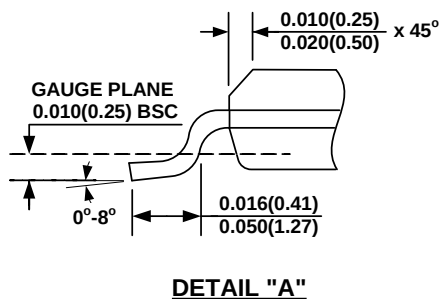
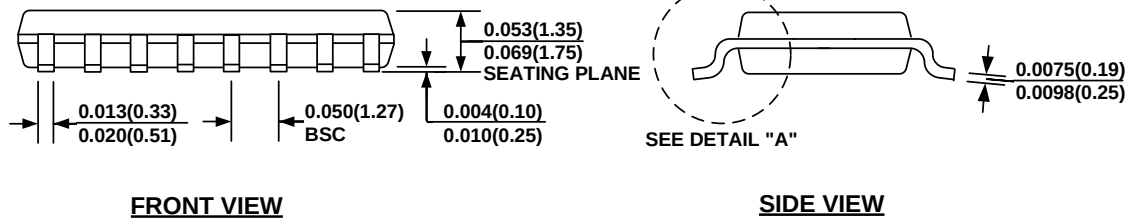
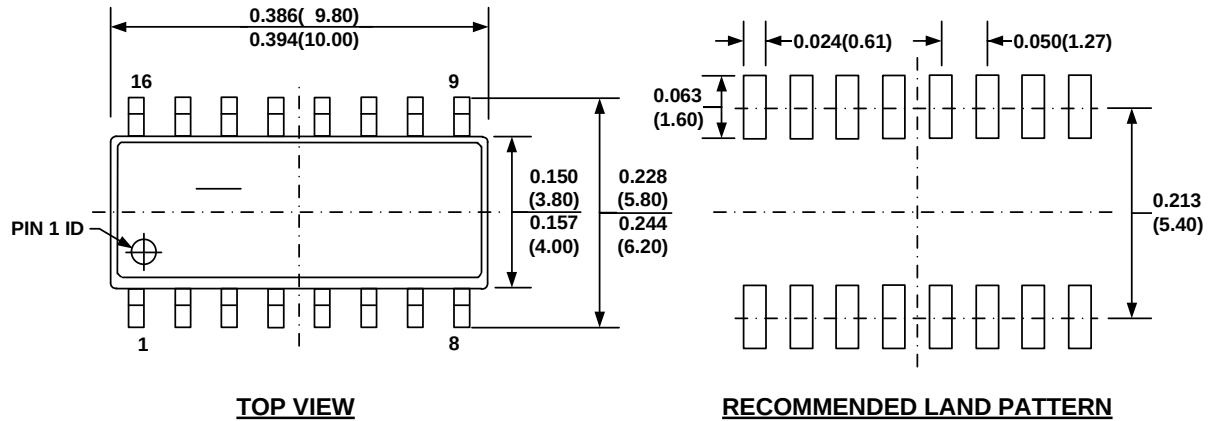
**Figure 10. Recommended PCB Layout**

## TYPICAL APPLICATION CIRCUITS



## PACKAGE INFORMATION

### SOIC-16



#### NOTE:

- 1) CONTROL DIMENSION IS IN INCHES. DIMENSION IN BRACKET IS IN MILLIMETERS.
- 2) PACKAGE LENGTH DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS.
- 3) PACKAGE WIDTH DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSIONS.
- 4) LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.004" INCHES MAX.
- 5) DRAWING CONFORMS TO JEDEC MS-012, VARIATION AC.
- 6) DRAWING IS NOT TO SCALE.

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