# MP2631

## 28V, 1A, Li-Ion, Linear Battery Charger with 10mA High Voltage LDO

The Future of Analog IC Technology

## DESCRIPTION

The MP2631 is a linear, high performance single cell Li-Ion or Li-Polymer battery charger with 10mA LDO. By integrating high voltage input protection into the charger IC, the MP2631 can tolerate an input surge up to 28V.

The internal 5V LDO can be used as a system watchdog supply to monitor charge status. The LDO is ON when the input voltage is greater than 3V and less than 7V, and remains ON when the MP2631 is in SHDN mode. When input is higher than 7.0V, the LDO output will be cut off from the input. When input is lower than 5V, the LDO will work in the dropout region.

The device features constant current (CC) and constant voltage (CV) charging modes with programmable charge current (200mA to 1A), auto-recharge and trickle charge. MP2631 provides ACOK and charge status indications to the system. The OVP circuitry will automatically disconnect both charger and LDO from input when $V_{IN}$ exceeds 7V.

For guaranteed safe operation, the MP2631 limits the die temperature to a preset value when the device is heated up due to limited PCB space. MP2631 is available in 10-pin 3mm x 3mm QFN package.

## FEATURES

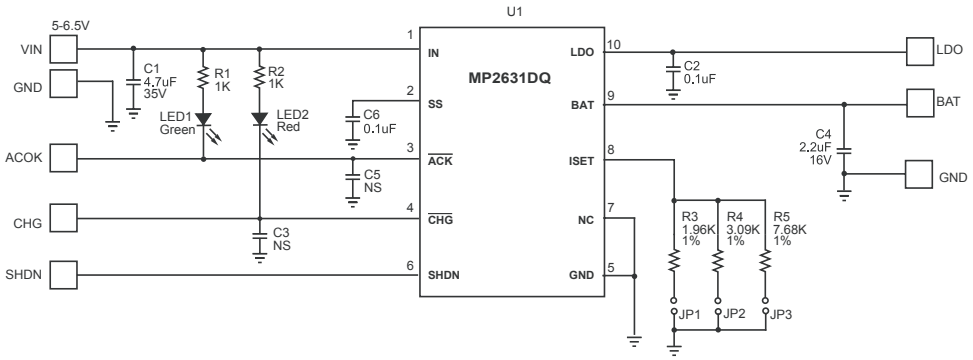
- Complete Solution for Charging Single-Cell Li-Ion Battery
- Input Surge Protection Up to 28V
- 5V LDO output
- 3V to 7V Input Operating Range
- Programmable Charge Current: 200mA to 1A
- Termination and auto-recharge
- 0.75% $V_{BATT}$ Accuracy over Temperature
- <1μA Battery Reverse Current
- Automatic die temperature limiting
- Fault and Charge Status Indicators
- External Soft-Start to Control Inrush Current
- 3mm x 3mm QFN Package

## APPLICATIONS

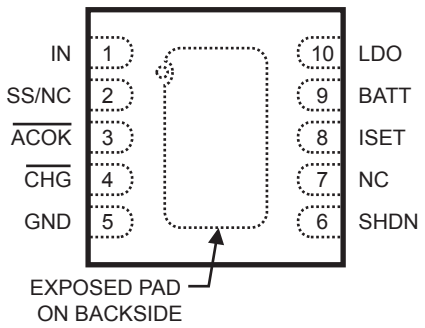
- Cell Phones
- Digital Cameras
- Smart Phones
- PDAs
- MP3 Players



## TYPICAL APPLICATION CIRCUIT



## PACKAGE REFERENCE




| Part Number* | Package | Temperature |
|---|---|---|
| MP2631DQ | QFN10 (3mm x 3mm) | –40°C to +85°C |

* For Tape & Reel, add suffix –Z (eg. MP2631DQ–Z)
For RoHS compliant packaging, add suffix –LF
(eg. MP2631DQ–LF–Z)

## ABSOLUTE MAXIMUM RATINGS (1)

IN to GND ..... –0.3V to 28V
All Other Pins to GND..... –0.3V to +6.5V
Junction Temperature..... 140°C
Lead Temperature ..... 260°C
Storage Temperature ..... –65°C to +150°C

### *Recommended Operating Conditions* (2)

Nominal Supply Voltage $V_{IN}$..... 3.5V to 5.5V
Operating Temperature ..... –40°C to +85°C

### *Thermal Resistance* (3)

| | $\theta_{JA}$ | $\theta_{JC}$ | |
|---|---|---|---|
| 3x3 QFN10 | 50 | 12 | °C/W |

**Notes:**
1) Exceeding these ratings may damage the device.
2) The device is not guaranteed to function outside of its operating conditions.
3) Measured on approximately 1" square of 1 oz copper.

## ELECTRICAL CHARACTERISTICS

**$V_{IN}$ = 5.2V, $V_{EN}$ = 0V, $T_A$ = +25°C, unless otherwise noted.**

| Parameter | Symbol | Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| Input Quiescent Current | $I_{SUPPLY}$ | SHDN= Low, $V_{BATT}$=4.25V, ILDO = 0A, $V_{IN} \geq$ 5.2V | | 950 | | µA |
| Battery Voltage Regulation | $V_{BATT}$ | T = –5°C to +75°C, $I_{BATT}$ = 0 | 4.16 | 4.20 | 4.24 | V |
| LDO OUT | $V_{OUT}$ | Iout = 0 - 10mA, Vin = 5.0 – 6.5 V | 4.85 | 5.0 | 5.15 | V |
| Min LDO Output Voltage | $V_{OUT\_MIN}$ | I=2mA, Vin=5.0V | 4.85 | | | V |
| LDO Load Regulation | | Load < 10mA | | 0.005 | | V/mA |
| LDO Short Current Limit | | | | 80 | | mA |
| OVP Threshold | | Input rising | 6.7 | 7.0 | 7.3 | V |
| Constant Current Regulation | $I_{CHG}$ | $V_{BATT}$ = 3.8V $R_{CHG}$ = 3.3k | 475 | 530 | 585 | mA |
| Constant Current Variation | | $V_{BATT}$ = 3.8V, $T_J$ = 0°C to +120°C, | 87 | 100 | 113 | $\%I_{CHG}$ (4) |
| Trickle Current | | $V_{BATT}$ = 2.3V | 5 | 10 | 15 | $\%I_{CHG}$ (4) |
| Trickle Threshold Voltage | | $V_{BATT}$ rising | 2.45 | 2.6 | 2.75 | V |
| Trickle Voltage Hysteresis | | | | 100 | | mV |
| IBF Threshold | $I_{BF}$ | In CV mode | 5 | 10 | 15 | $\%I_{CHG}$ |
| OVP Threshold | OVP | Vin rising | 6.7 | 7 | 7.3 | V |
| OVP Hysteresis | | | | 400 | | mV |
| UVLO | | Vin rising | 1.6 | 2.1 | 2.5 | V |

## ELECTRICAL CHARACTERISTICS *(continued)*

**$V_{IN}$ = 5.2V, $V_{EN}$ = 0V, $T_A$ = +25°C, unless otherwise noted.**

| Parameter | Symbol | Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| UVLO Hysteresis | | | | 150 | | mV |
| SHDN Trip Threshold High | | | 1.5 | | | V |
| SHDN Trip Threshold Low | | | | | 0.4 | V |
| $\overline{CHG}$ , $\overline{ACOK}$ Sink Current | | Pin Voltage = 0.2V | 4 | | | mA |
| Battery Reverse Current to BATT Pin | | SHDN = Low and Input = Floating or 0V | | | 1 | µA |
| Soft Thermal Shutdown Threshold | Tlim | | 105 | 120 | 135 | °C |
| Soft Thermal Shutdown Hysteresis | | | | 10 | | °C |
| Soft-Start Time | | From trickle to 90% of full current, (Css absent) | | 300 | | us |
| Recharge Voltage Threshold | $V_{RECHARGE}$ | $V_{BATT}$ falling from 4.2V | 3.9 | 4.0 | 4.1 | V |
| Recharge Voltage Hysteresis | | | | 100 | | mV |

**Notes:**

4) $I_{CHG}$ is the target preprogrammed charge current (Die temperature below 110°C).
5) $I_{BF}$ is the target preprogrammed battery full current threshold.

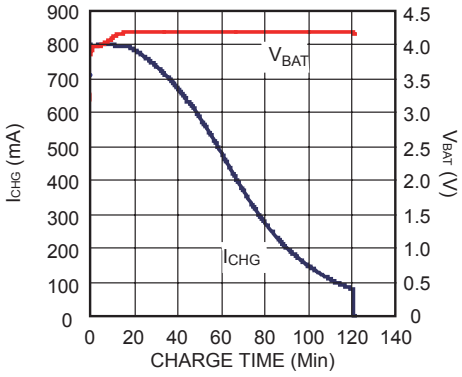
## PIN FUNCTIONS

| Pin # | Name | Description |
|---|---|---|
| 1 | IN | Input Supply Pin. IN receives the AC adapter or USB supply voltage. |
| 2 | SS/NC | Soft Start Pin. If it is left open, internal fixed SS is operated and the charger will not charge a battery when its initial voltage is higher than the recharge threshold (4.0V). |
| 3 | $\overline{ACOK}$ | Open-Drain Input Fault Indicator. This pin is low when 2.1V < Vin < 7.0V |
| 4 | $\overline{CHG}$ | Open-Drain Charge Indicator. This pin is low during charging, is High after battery full or termination. |
| 5 | GND Exposed Pad | Ground. Exposed pad and GND pin must be connected to same ground plane |
| 6 | SHDN | Used for Charger Termination. An input “Low” signal at this pin or if the pin floating will enable the charger. |
| 7 | NC | No Connection |
| 8 | ISET | Constant Charge Current Program pin. Connect this pin to an external resistor to program the charging current in CC Mode. |
| 9 | BATT | Charger Output |
| 10 | LDO | LDO output |

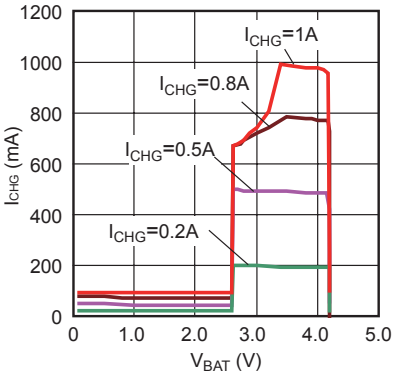
# TYPICAL PERFORMANCE CHARACTERISTICS

**C1=4.7uF, C2=0.1uF, C4=2.2uF, $V_{IN}$=5V, $T_A$=25ºC, unless otherwise noted.**

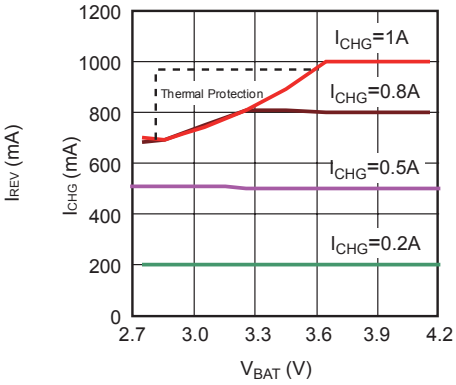
### Battery Charge Curve



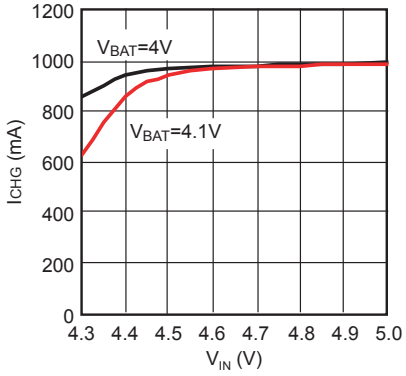

### Charge Current vs Battery Voltage



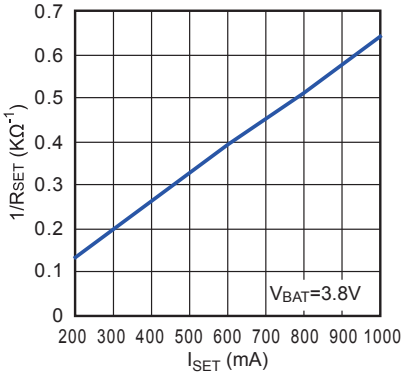

### Charge Current vs Battery Voltage



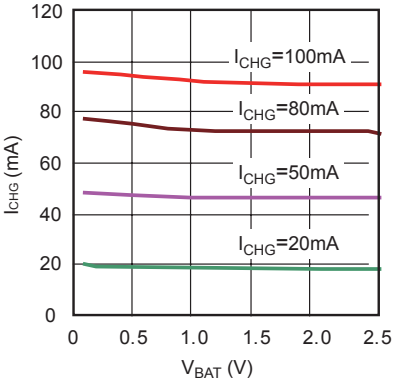

### Charge Current vs Input Voltage



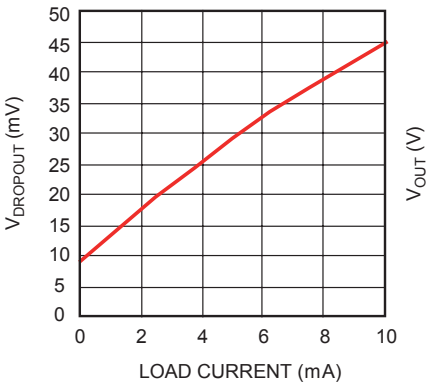

### 1/RSET vs. ISET



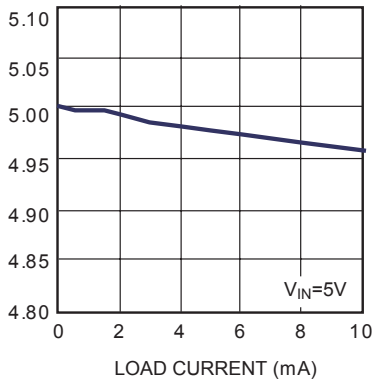

### Trickle Charge Curve




### LDO Voltage Dropout



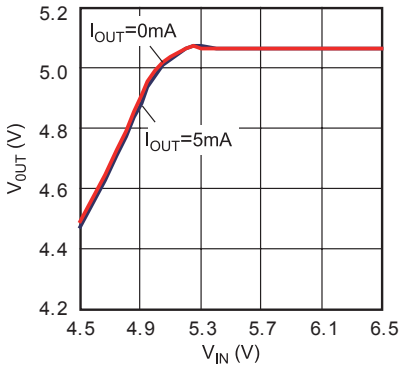

### LDO Load Regulation



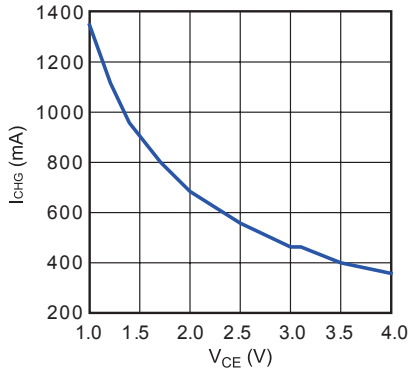
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**C1=4.7uF, C2=0.1uF, C4=2.2uF, $V_{IN}$=5V, $T_A$=25ºC, unless otherwise noted.**

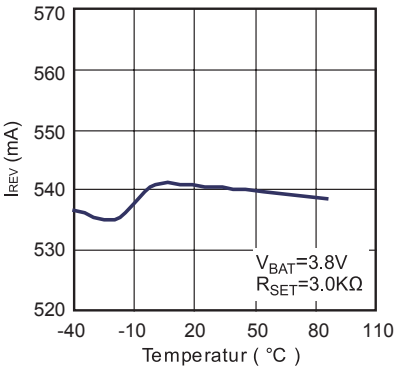
### LDO Line Regulation



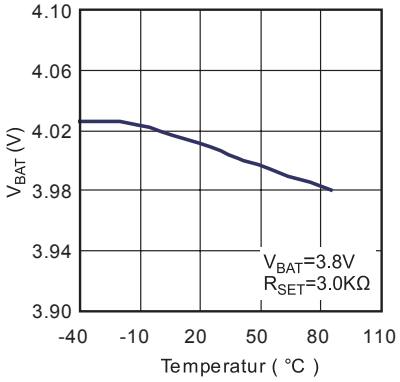

### Charger Thermal Protection




### Current Charge vs. Temperature

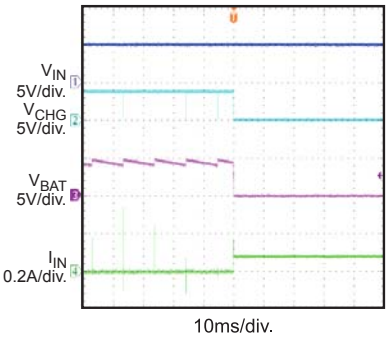



### $V_{BAT}$ vs. Temperature



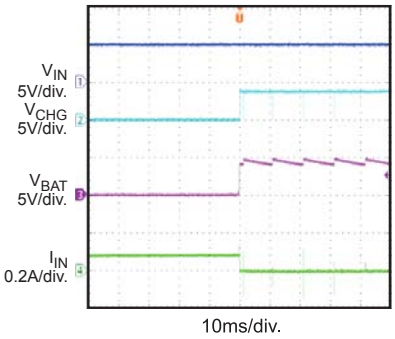

### Short Charger Circuit Protection

$V_{IN}$=5V, Battery doesn't Present



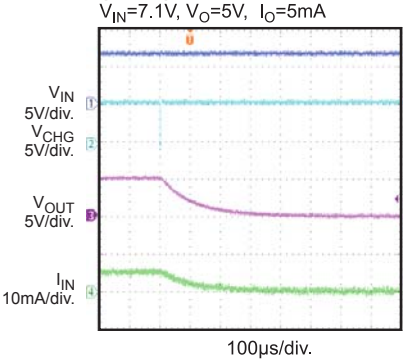

### Short Charger Circuit Recovery

$V_{IN}$=5V, Battery doesn't Present




### Over Input Voltage Protection (LDO)

$V_{IN}$=7.1V, $V_O$=5V, $I_O$=5mA

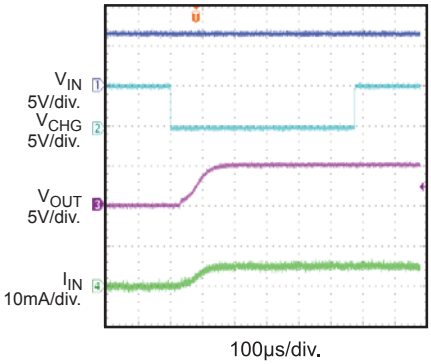


## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**C1=4.7uF, C2=0.1uF, C4=2.2uF, $V_{IN}$=5V, $T_A$=25ºC, unless otherwise noted.**

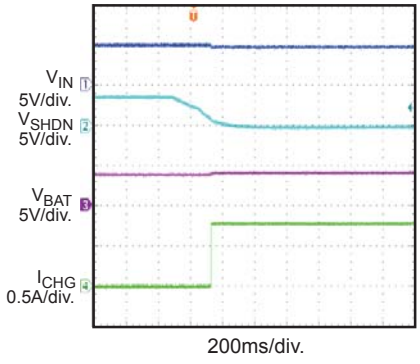
### Recovery Input Voltage (LDO)

$V_{IN}$=6.6V, $V_O$=5V, $I_O$=5mA



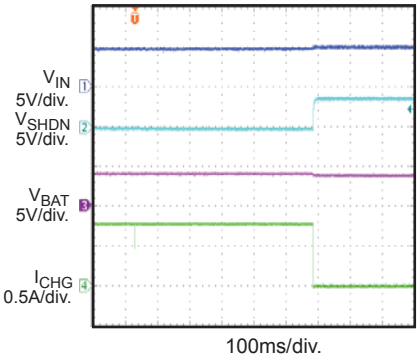

### Shut Down Low vs. Battery Charge

$I_{SET}$ Resistor=2.0KΩ



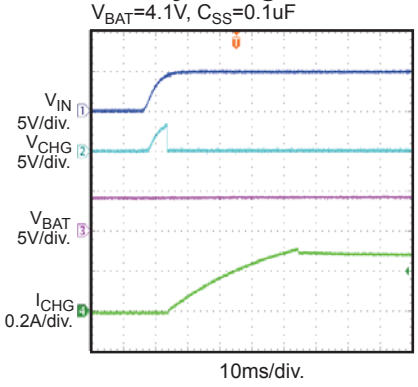

### Shut Down High vs. Battery Charge

$I_{SET}$ Resistor=2.0KΩ



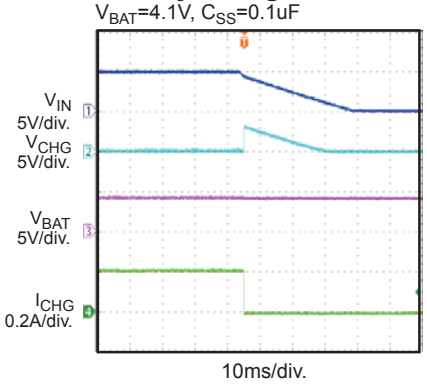

### Power Ramp Up vs. Battery Charge

$V_{BAT}$=4.1V, $C_{SS}$=0.1uF



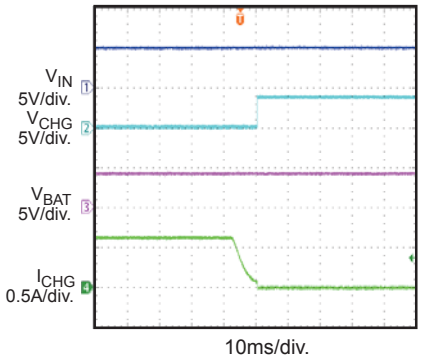

### Power Ramp Down vs. Battery Charge

$V_{BAT}$=4.1V, $C_{SS}$=0.1uF



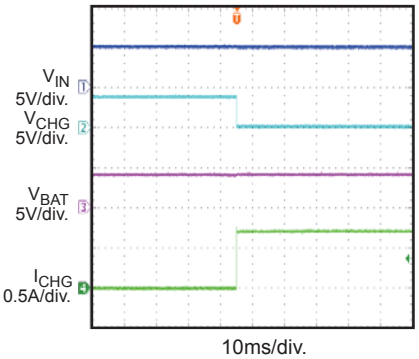

### Charge Full Terminated

$I_{SET}$ Resistor=3.0KΩ, $C_{SS}$=0.1uF
$V_{BAT}$=4.2V




### Terminated to Re-Charge

$I_{SET}$ Resistor=3.0KΩ, $C_{SS}$=0.1uF
$V_{BAT}$=4.1V



## BLOCK DIAGRAM

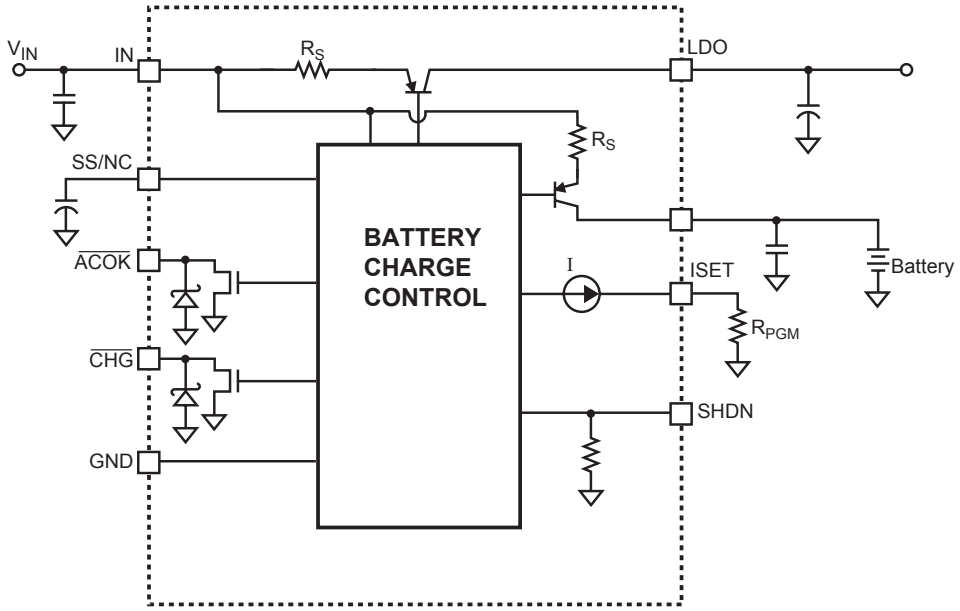



**Figure 1—Functional Block Diagram**

## OPERATION

### Input Voltage Range

The MP2631 has built-in input voltage surge protection as high as +28V. The charger IC will be automatically disabled when the input voltage is lower than 2.1V or higher than 7.0V. For MP2631, the open-drain pin $\overline{ACOK}$ is used to indicate an input power good condition (i.e. 3.5V<$V_{IN}$<6.5V). If the input voltage is lower than the battery voltage, the charge function is also disabled to prevent the battery from draining.

### Charge Cycle (Mode Change: Trickle->CC-> CV)

Figure 2 below shows the typical charging profile for the MP2631. It begins charging at the constant current of the programmed value ($I_{CHG}$). This is referred to as Constant Current (CC) mode. For a deeply discharged battery, it will start trickle at 10% of the programmed charge current until battery voltage reaches 2.6V. Once the battery voltage reaches 4.2V, the charger will operate in the constant voltage (CV) charge mode. The charge current drops during CV mode, and the battery full indication is set when the charge current reduces to the battery full value ($I_{BF}$) at 10% of the nominal charge current.

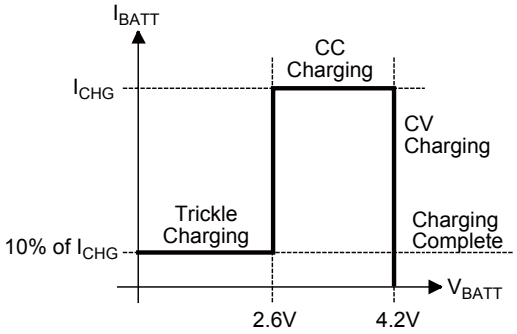



**Figure 2—MP2631 Typical Charging Profile**

### Programming of Charge Current and Battery Full Current

The charge current ($I_{CHG}$) is set by a resistor ($R_{PGM}$) connecting from the ISET pin to GND. The relationship of the charge current and the programming resistance is established by the following table and graph.

**Table 1—$R_{PGM}$ and $I_{CHG}$ Relationship**

| $R_{PGM}$ (kΩ) | $I_{CHG}$ (mA) |
|---|---|
| 1.55 | 1000 |
| 1.72 | 900 |
| 1.94 | 800 |
| 2.21 | 700 |
| 2.58 | 600 |
| 3.1 | 500 |
| 3.87 | 400 |
| 5.16 | 300 |
| 7.75 | 200 |
| 15.5 | 100 |

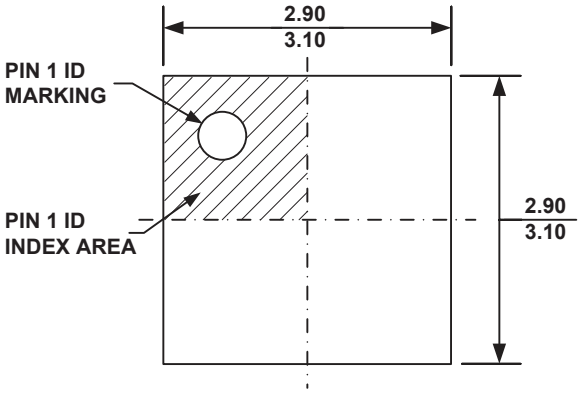
The open-drain pin $\overline{CHG}$ is used to indicate charging status. When the battery full condition is reached or any other condition prevents the charger from charging, $\overline{CHG}$ will become floating and the charge function is terminated. The charger will begin recharging when the battery voltage is reduced to 4.0V due to any kind of leakage.

### LDO Operation

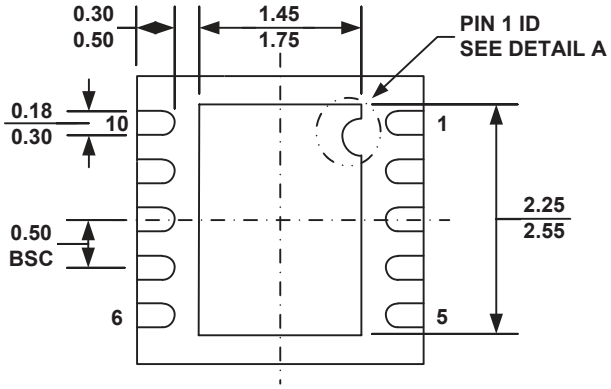
The on-chip current limited LDO will regulate its output at 5V for the input voltage from 5.1V to 6.5V. When $V_{IN}$ is below 5.1V, it will work in the dropout mode. LDO is always ON no matter what state of SHDN is, unless OVP is reached. It can handle a maximum load of 10mA. A 0.1uF -1uF cap at the output is recommended.

# PACKAGE INFORMATION

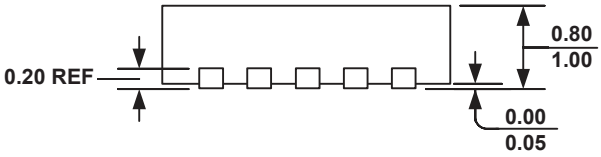
## QFN10 (3mm x 3mm)



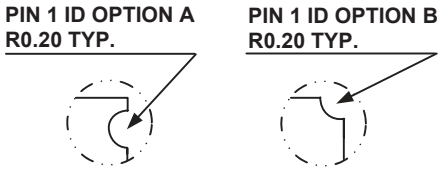

TOP VIEW



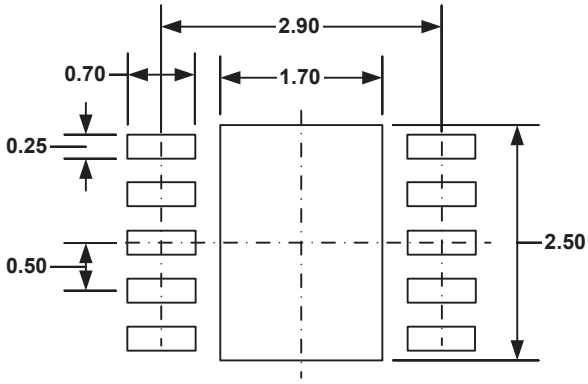

BOTTOM VIEW




SIDE VIEW




DETAIL A




RECOMMENDED LAND PATTERN

**NOTE:**

1) ALL DIMENSIONS ARE IN MILLIMETERS.
2) EXPOSED PADDLE SIZE DOES NOT INCLUDE MOLD FLASH.
3) LEAD COPLANARITY SHALL BE 0.10 MILLIMETER MAX.
4) DRAWING CONFORMS TO JEDEC MO-229, VARIATION VEED-5.
5) DRAWING IS NOT TO SCALE.