# 南京拓品微电子有限公司

**Nan Jing Top Power ASIC Corp.**



# TP4060 Standalone Linear Li-Lon Battery Charger with Thermal Regulation in ESOP8

# （ Reverse battery protection)

## DESCRIPTION

The TP4060 is a complete constant-current/constant-voltage linear charger for single cell lithium-ion batteries, Reverse battery protection. Its ESOP8 package and low external component count make the TP4060 ideally suited for portable applications. Furthermore, the TP4060 can work within USB and wall adapter.

No external sense resistor is needed, and no blocking diode is required due to the internal PMOSFET architecture and have prevent to negative Charge Current Circuit. Thermal feedback regulates the charge current to limit the die temperature during high power operation or high ambient temperature. The charge voltage is fixed at 4.2V, and the charge current can be programmed externally with a single resistor. The TP4060 automatically terminates the charge cycle when the charge current drops to 1/10th the programmed value after the final float voltage is reached.

When the input supply (wall adapter or USB supply) is removed, the TP4060 automatically enters a low current state, dropping the battery drain current to less than 2uA. The TP4060 can be put into shut down mode, reducing the supply current to 120uA. Other features include current monitor, under voltage lockout, automatic recharge and two status pin to indicate charge termination and the presence of an input voltage.

## FEATURES

·lithium-ion batteries Reverse battery protection

·Programmable Charge Current Up to 800mA

·No MOSFET, Sense Resistor or Blocking Diode Required

·Complete Linear Charger in ESOP8 Package for Single Cell Lithium-Ion Batteries

·Constant-Current/Constant-Voltage Operation with Thermal Regulation to Maximize Charge Rate Without Risk of Overheating

·Charges Single Cell Li-Ion Batteries Directly from USB Port

·Preset 4.2V Charge Voltage with 1% Accuracy

·Charge Current Monitor Output for Gas Gauging

·Automatic Recharge

·Charge Status Output Pin

·C/10 Charge Termination

·120uA Supply Current in Shutdown

·2.9V Trickle Charge Threshold (TP4060)

·Soft-Start Limits Inrush Current

·Available in ESOP8 Package

## ABSOLUTE MAXIMUM RATINGS

·Input Supply Voltage($V_{CC}$)：-0.3V～9V

·PROG：-0.3V～$V_{CC}$+0.3V

·BAT：-4.2V～7V

·$\overline{CHRG}$：-0.3V～9V

·BAT Short-Circuit Duration：Continuous

·BAT Pin Current：500mA

·PROG Pin Current：800uA

·Maximum Junction Temperature：145℃

·Operating Ambient Temperature Range：-40℃～85℃

·Storage Temperature Range：-65℃～125℃

·Lead Temperature(Soldering, 10sec)：260℃

## APPLICATIONS

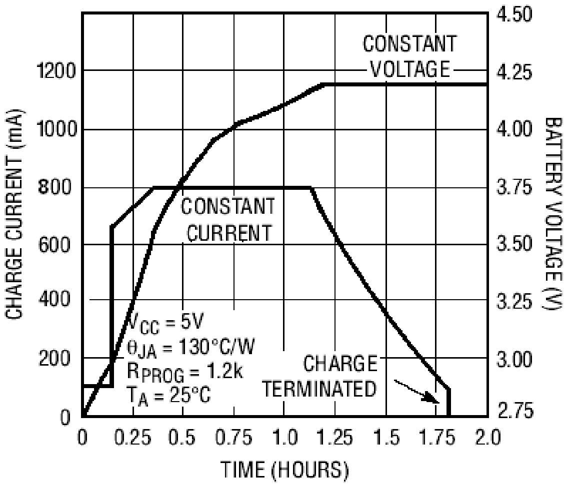
·Cellular Telephones, PDAs,

.MP3 Players

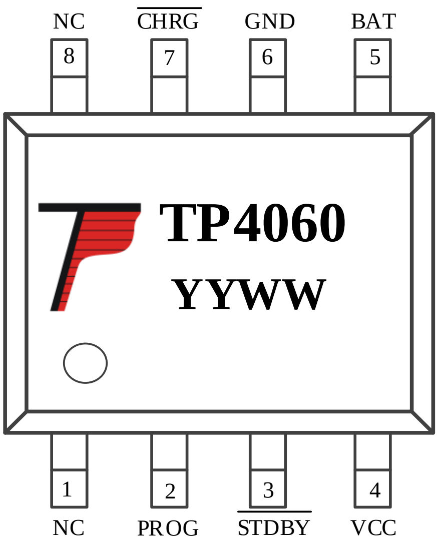
·Charging Docks and Cradles

·Blue tooth Applications

## 800mA Complete Charge Cycle (800mAh Battery)



## PACKAGE DESCRIPTION

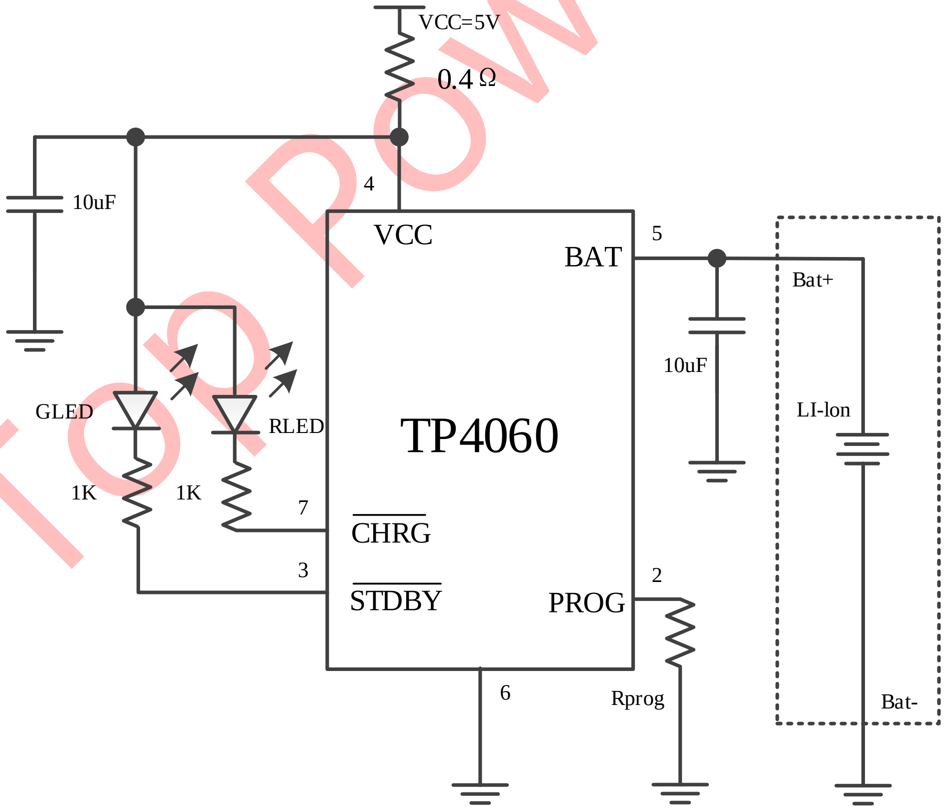



PACKAGE 8-LEAD PLASTIC
(ESOP8)

| ORDER PART NUMBER |
| --- |
| TP4060-42-ESOP8 |
| PART MARKING |
| TP4060 |

(NC pin, there is no internal connection, it is recommended to ground it)

## TYPICAL APPLICATIONG



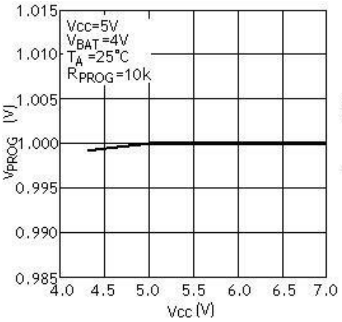
# ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are at $T_A$=25℃，$V_{CC}$=5V，unless otherwise noted.

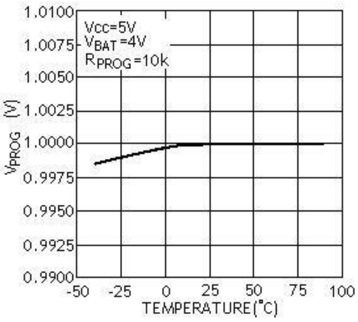
| SYMBOL | PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| $V_{CC}$ | Input Supply Voltage | | ● | 4.0 | 5 | 9.0 | V |
| $I_{CC}$ | Input Supply Current | Charge Mode, $R_{PROG}$ = 10k | ● | | 150 | 500 | µA |
| | | Standby Mode (Charge Terminated) | ● | | 140 | 190 | µA |
| | | Shutdown Mode ($R_{PROG}$ Not Connected, VCC < $V_{BAT}$, or $V_{CC}$ < $V_{UV}$) | ● | | 120 | 140 | µA |
| $V_{FLOAL}$ | Regulated Output (Float) Voltage | 0℃≤$T_A$≤85℃，$I_{BAT}$=40mA | | 4.158 | 4.2 | 4.242 | V |
| $I_{BAT}$ | BAT Pin Current | $R_{PROG}$ = 10k, Current Mode | ● | 90 | 100 | 110 | mA |
| | | $R_{PROG}$ = 1.2k, Current Mode | ● | 780 | 800 | 820 | mA |
| | | Standby Mode, $V_{BAT}$ = 4.2V | ● | 0 | -2.5 | -6 | µA |
| | | Shutdown Mode ($R_{PROG}$ Not Connected) | ● | | ±1 | ±2 | µA |
| | | Sleep Mode, $V_{CC}$ = 0V | ● | | -1 | -2 | µA |
| $I_{TRIKL}$ | Trickle Charge Current | $V_{BAT}$<$V_{TRIKL}$, $R_{PROG}$=10K | ● | 8 | 10 | 15 | mA |
| $V_{UV}$ | $V_{CC}$ Under voltage Lockout Threshold | From $V_{CC}$ Low to High | ● | 3.4 | 3.6 | 3.8 | V |
| $I_{TERM}$ | C/10 Termination Current Threshold | $R_{PROG}$=10K | ● | 8 | 10 | 12 | mA |
| | | $R_{PROG}$=1.66K | ● | 30 | 40 | 50 | mA |
| $V_{PROG}$ | PROG Pin Voltage | $R_{PROG}$=10K，Current Mode | ● | 0.9 | 1.0 | 1.1 | V |
| $I_{\overline{CHRG}}$ | $\overline{CHRG}$ Pin Leakage Current | $V_{\overline{CHRG}}$ =5V(Standby Mode) | | | 0 | 1 | µA |
| $V_{\overline{CHRG}}$ | $\overline{CHRG}$ Pin Low Level | $I_{\overline{CHRG}}$ =5mA | | | 0.3 | 0.6 | V |
| $I_{PROG}$ | PROG Pin Pull-up Current | | | | 2.5 | | µA |
| $T_{LIM}$ | Junction temperature in limited temperature mode | | | | 120 | | ℃ |
| $R_{ON}$ | Power FET "conduction" Resistance | | | | 800 | | mΩ |
| $I_{\overline{STDBY}}$ | $\overline{STDBY}$ Pin Leakage Current | $V_{\overline{STDBY}}$ =5V(Standby Mode) | | | 0 | 1 | µA |
| $V_{\overline{STDBY}}$ | $\overline{STDBY}$ Pin Low Level | $I_{\overline{STDBY}}$ =5mA | | | 0.3 | 0.6 | V |
| $\Delta V_{RECHRG}$ | Recharge battery threshold voltage | $V_{FLOAT}$ - $V_{RECHRG}$ | | 100 | 150 | 200 | mV |
| $I_{PROG}$ | PROG Pin pull-up current | | | | 2.5 | | µA |

# TYPICAL PERFORMANCE CHARACTERISTICS

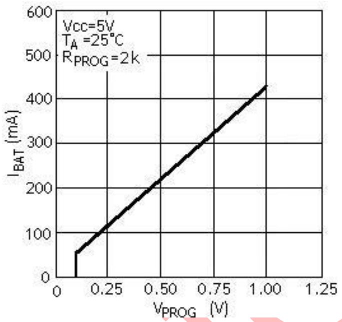
**PROG Pin Voltage vs Supply Voltage (in constant current mode)**



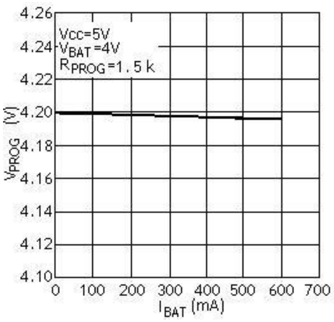

**PROG Pin Voltage vs Temperature**



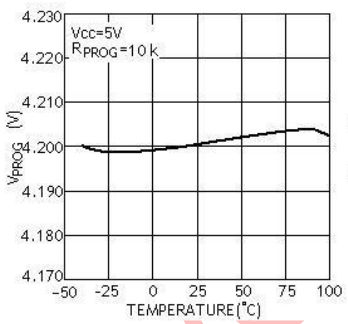

**Recharging Current vs PROG Pin Voltage**



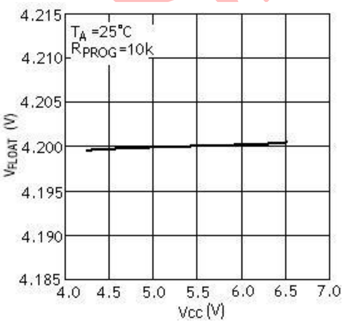

**Regulated Output (Float) Voltage vs Charge Current**



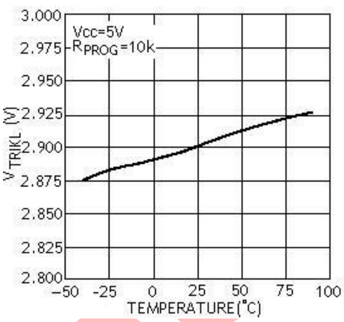

**Regulated Output (Float) Voltage vs Temperature**



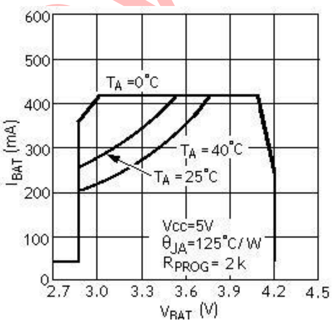

**Regulated Output (Float) Voltage vs Supply Voltage**



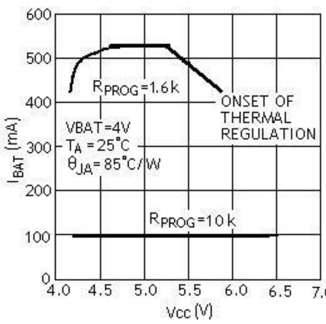

**Trickle Charge Threshold Voltage vs Temperature**



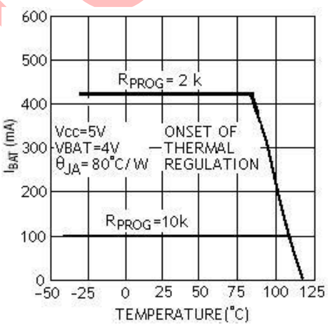

**Recharging Current vs Battery Voltage**



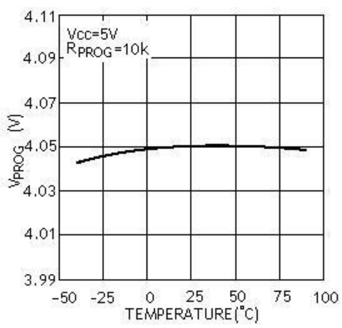

**Recharging Current vs Supply Voltage**



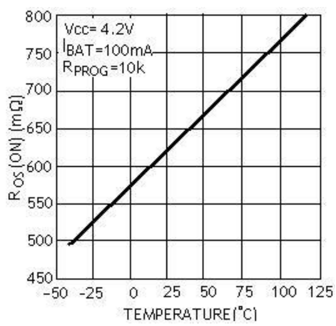

**Recharging Current vs Temperature**




**Recharge Threshold Voltage vs Temperature**




**Power FET “ON” Resistance vs Temperature**



# PIN FUNCTION

**NC (PIN 1):** There is no internal connection, grounding is recommended.

**PROG (PIN 2):** This is the pin for charging current setting, charging current monitoring and shutdown. Connect a resistor RPROG with an accuracy of 1% between the pin and the ground to set the charging current. When charging in constant current mode, the voltage of the pin is maintained at 1V.

The PROG pin can also be used to turn off the charger. Disconnect the setting resistor from the ground, with an internal 2.5μA current pulls PROG pin to high level. When the voltage of this pin reaches the shutdown threshold voltage of 2.7V, the charger enters the shutdown mode, the charging stops and the input power current drops to 145μA。Reconnecting the RPROG to the ground will restore the charger to normal operation.

$\overline{\text{STDBY}}$ **(PIN 3):** Battery charging completion indicator. When the battery charging is completed, STDBY is pulled to the low level by the internal switch, indicating that the charging is completed. In addition, the STDBY pin will be in the high resistance state.

**VCC (PIN 4):** This pin supplies power to the charger. The VCC varies from 4V to 9V and should pass at least one 1μF Capacitor is bypassed. When VCC drops to within 30mV of BAT pin voltage, TP4060 enters the shutdown mode, thus reducing IBAT to 2μA below.

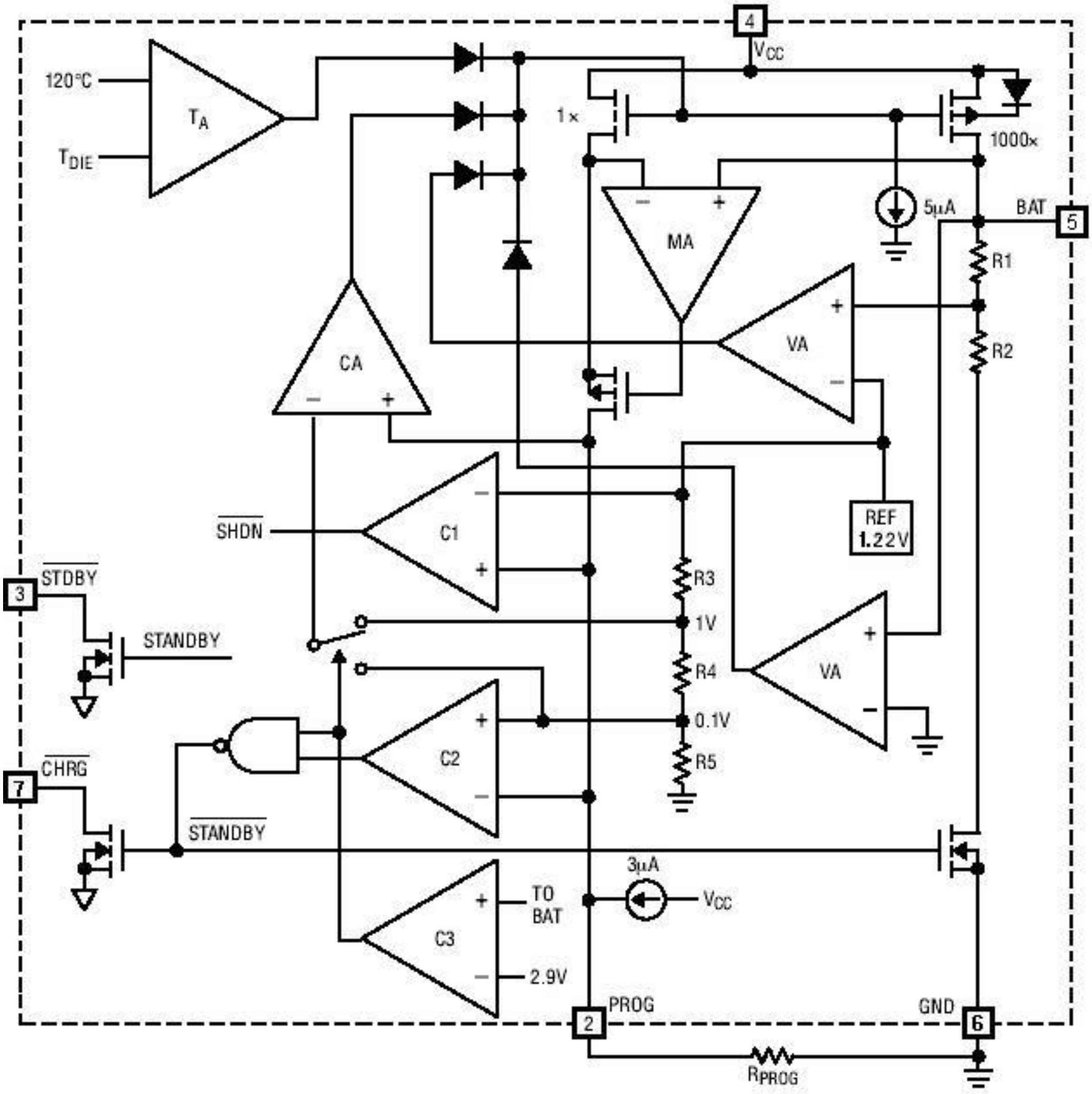
**BAT (PIN 5):** This pin provides charging current to the battery and adjusts the final floating charge voltage to 4.2V. An accurate internal resistance voltage divider of this pin sets the floating charge voltage. In the shutdown mode, the internal resistance voltage divider is disconnected.

**GND (PIN 6):** GND.

$\overline{\text{CHRG}}$ **(PIN 7):** The charging state indicator terminal of open drain output. When the charger charges the battery, the $\overline{\text{CHRG}}$ pin is pulled to the low level by the internal switch, indicating that the charging is in progress; Otherwise, $\overline{\text{CHRG}}$ pin is in high resistance state.

**NC (PIN 8):** There is no internal connection, grounding is recommended.

# BLOCK DIAGRAM



# OPERATION

TP4060 is a single cell lithium-ion battery charger that uses a constant current/constant voltage algorithm. It can provide a charging current of 800mA (with the help of a well-designed PCB layout) and an internal P-channel power MOSFET and thermal regulation circuit. No need to isolate diodes or external current detection resistors; Therefore, the basic charger circuit only requires two external components. Not only that, TP4060 can also obtain working power from a USB power supply.

When the voltage of the Vcc pin rises above the UVLO threshold level and a set resistor with an accuracy of 1% is connected between the PROG pin and ground, or when a battery is connected to the output of the charger, a charging cycle begins. If the BAT pin level is below 2.9V, the charger enters trickle charging mode. In this mode, TP4060 provides approximately 1/10 of the set charging current to raise the current and voltage to a safe level, thereby achieving full current charging.

When the voltage of the BAT pin rises above 2.9V, the charger enters constant current mode, providing a constant charging current to the battery. When the voltage of the BAT pin reaches the final float voltage (4.2V), TP4060 enters a constant voltage mode and the charging current begins to decrease. When the charging current drops to 1/10 of the set value, the charging cycle ends.

## Programming Charge Current

The charging current is set using a resistor connected between the PROG pin and ground. The resistor and charging current are calculated using the following formula: Determine the resistance value of the resistor based on the required charging current,

Formula One: $R_{PROG} = \frac{1000}{I_{BAT}}$ ($I_{BAT} \leq 0.3A$)

Example 1: When setting the charging current to IBAT=0.2A, formula 1 is used to calculate:

$R_{PROG} = \frac{1000}{0.2} = 5000$（Ω），即 $R_{PROG}$＝5kΩ

Formula Two: $R_{PROG} = \frac{1000}{I_{BAT}} \times (1.3 - I_{BAT})$

($I_{BAT} > 0.3A$)

In applications above 0.3A, the chip heat is relatively high, and temperature protection will reduce the charging current. The testing current in different environments and the theoretical value calculated by the formula also become inconsistent. In customer applications, RPROGs of appropriate size can be selected according to needs.

The relationship between RPROG and charging current can be determined by referring to the following table:

| RPROG (kΩ) | $I_{BAT}$ (mA) |
|---|---|
| 20 | 50 |
| 10 | 100 |
| 5 | 180 |
| 4 | 220 |
| 3 | 290 |
| 2 | 430 |
| 1.5 | 560 |
| 1.2 | 800 |

## Charge Termination

When the charging current drops to 1/10 of the set value after reaching the final float charging voltage, the charging cycle is terminated. This article

The device is detected by monitoring the PROG pins using an internal filtering comparator. When the voltage of the PROG pin drops below 100mV for more than (usually 1.8ms), charging is terminated. The charging current is locked off, and TP4060 enters standby mode. At this time, the input power current drops to 40 μ A. (Note: C/10 termination fails in trickle charging and thermal limit mode).

During charging, the transient load on the BAT pin will cause the voltage of the PROG pin to briefly drop below 100mV when the DC charging current drops to 1/10 of the set value. The 1.8ms filtering time on the termination comparator ensures that transient loads of this nature do not cause premature termination of the charging cycle. Once the average charging current drops below 1/10 of the set value, TP4060 terminates the charging cycle and stops providing any current through the BAT pin. In this state, all loads on the BAT pin must be powered by the battery.

In standby mode, TP4060 continuously monitors the voltage of the BAT pin. If the voltage of the pin drops below the recharge threshold of 4.1V, another charging cycle begins and current is supplied to the battery again. When manually restarting the charging cycle in standby mode, it is necessary to cancel and then apply input voltage, or the charger must be turned off and restarted using the PROG pin. Figure 2 shows a state diagram of a typical charging cycle.

## Battery Reverse Connection Protection Function

TP4060 has a lithium battery reverse connection protection function. The positive and negative poles of the lithium battery are reverse connected to the TP4060 current output pin, and the TP4060 will stop and display a fault status without charging current. Both charging indicator pins are in high resistance state, and both LED lights are off. At this time, the reverse connected lithium battery leakage current is less than 5mA. Connect the reversed battery correctly, and TP4060 will automatically start the charging cycle.

After the reverse connection of TP4060, when the battery is removed, the TP4060 indicator light will not immediately light up normally because the output terminal BAT pin capacitance potential of TP4060 is still negative. Only by correctly connecting the battery can charging be automatically activated. Alternatively, if the negative potential of the BAT terminal capacitor is discharged for a long time, and the BAT terminal potential is greater than zero volts, TP4060 will display a normal no battery indicator light status.

In reverse connection, the power supply voltage should be around 5V of the standard voltage and should not exceed 8V. When the battery voltage is reversed, the chip voltage difference will exceed 10V, so the power voltage should not be too high in reverse connection.

## Charge Status Indicator ( CHRG and STDBY )

TP4060 has two open drain status indicator outputs, and. When the charger is in the charging state, it is pulled to a low level, and in other states, it is in a high resistance state. When the battery is not connected to the charger, an output pulse signal indicates that the battery is not installed. When the external capacitance of the BAT pin at the battery connection end is 10uF, the flashing cycle is about 0.5-2 seconds.

When the status indicator function is not used, connect the unused status indicator output terminal to ground.

| Charger's Status | Red LED CHRG | Green LED STDBY |
|---|---|---|
| Charging | ON | OFF |
| Charging Completes | OFF | ON |
| Battery reverse connection and power supply undervoltage | OFF | OFF |

There are three options for the status of the battery free connection indicator light:

| Battery free standby mode | Red LED | Green LED |
|---|---|---|
| BAT connected to a 10uf electrolytic capacitor | TWINKLE | ON |
| BAT terminal 100k resistor to power supply | OFF | ON |
| Add a 5k resistor to the BAT terminal and connect it to the power supply (i.e. replace the above 100k resistor with a 5k resistor. See Figure P12) | OFF | |

Note: When connecting a 5k resistor to the power supply at the BAT end, the power supply will charge the battery through the resistor, with a size of approximately 0.2mA. This small current, even if not removed in a timely manner after the battery is fully charged, will not cause harm to the battery such as overcharging.

## Thermal Limiting

If the chip temperature attempts to rise above the preset value of about 120 ℃, an internal thermal feedback loop will reduce the set charging current. This function can prevent TP4060 from overheating and allow users to increase the upper limit of the given circuit board's power processing capacity without the risk of damaging TP4060. On the premise of ensuring that the charger will automatically reduce the current under worst-case conditions, the charging current can be set based on typical (rather than worst-case) ambient temperature. The considerations regarding ESOP power will be further discussed in the "Thermal Considerations" section.

## Under Voltage Lockout (UVLO)

An internal undervoltage blocking circuit monitors the input voltage and keeps the charger in shutdown mode before Vcc rises above the undervoltage blocking threshold. The UVLO circuit will keep the charger in shutdown mode. If the UVLO comparator jumps, the charger will not exit shutdown mode until Vcc rises to 50mV higher than the battery voltage

## Manual Shutdown

At any time during the charging cycle, TP4060 can be placed in shutdown mode by removing the RPROG (thereby floating the PROG pin). This reduces the battery leakage current to 2 µ Below A, and the power supply current drops to 120 µ Below A. Reconnecting the setting resistor can initiate a new charging cycle.

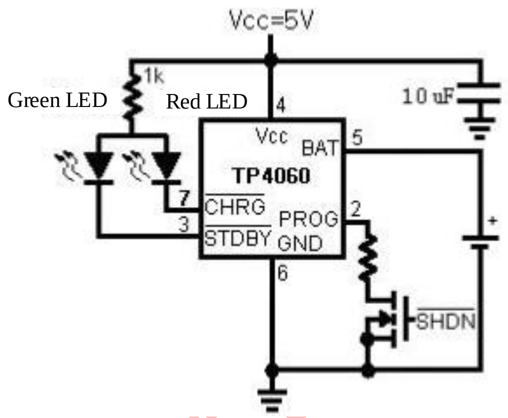



Fig.1 Signal controlled charging circuit

## Automatic Recharge

Once the charging cycle is terminated, TP4060 immediately uses a comparator with a filtering time of 1.8ms to continuously monitor the voltage on the BAT pin. When the battery voltage drops below 4.1V (roughly corresponding to 80% to 90% of the battery capacity), the charging cycle resumes. This ensures that the battery is maintained at (or close to) a fully charged state and eliminates the need for periodic charging cycles to start. During the recharge cycle, the output of pin $\overline{CHRG}$ enters a strong pull-down state again, and the output of pin $\overline{STDBY}$ enters a high resistance state again.

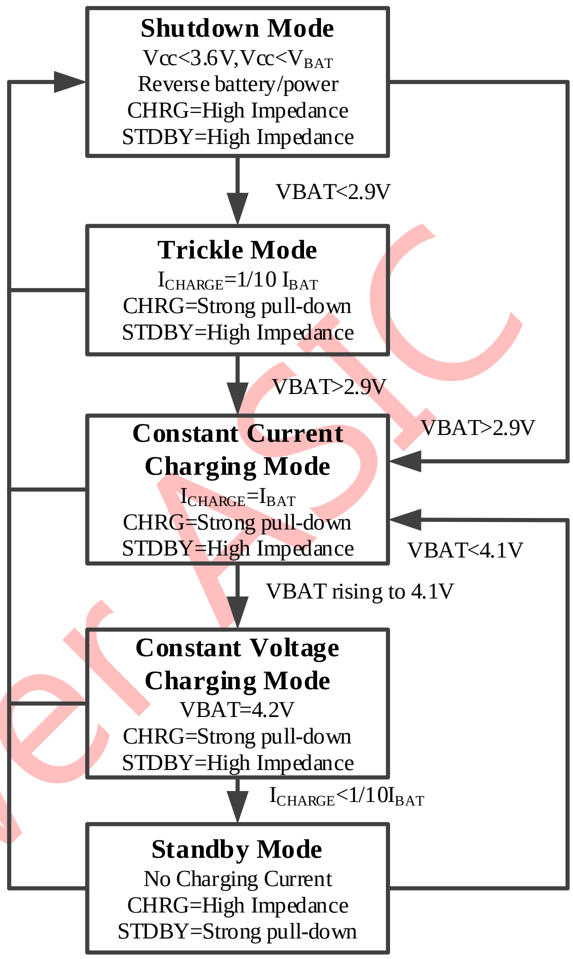



Fig.2 State diagram of a typical charge cycle

## Stability Considerations

As long as the battery is connected to the output of the charger, the constant voltage mode feedback loop can remain stable without using an external capacitor. When not connected to the battery, it is recommended to use an output capacitor to reduce the ripple voltage. When using high value low ESR ceramic capacitors, it is recommended to add a 1Ω resistor in series with the capacitor. If tantalum capacitors are used, there is no need to connect resistors in series.

In constant current mode, the PROG pin is located in the feedback loop, not the battery. The stability of constant current mode is affected by the impedance of PROG pins. When there is no additional capacitor on the PROG pin, the maximum allowable resistance of the set resistor will be reduced. The pole frequency on the PROG pin should be maintained at $C_{PROG}$, and the maximum resistance value of RPROG can be calculated using the following formula:

$$R_{PROG} \le \frac{1}{2\pi \bullet 10^5 \bullet C_{PROG}}$$

For users, they may be more interested in charging current rather than transient current. For example, if a switching power supply running in low current mode is connected in parallel with a battery, the average current flowing out of the BAT pin is usually more important than transient current pulses. In this scenario, a simple RC filter can be used on the PROG pin to measure the average battery current (as shown in Figure 3). A 10k resistor has been added between the PROG pin and the filtering capacitor to ensure stability.

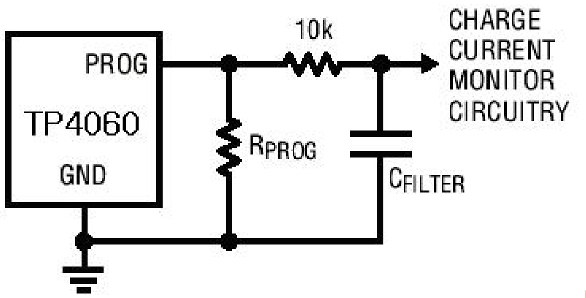



Fig.3 Isolating Capacitive Load on PROG Pin and Filtering

## Thermal Considerations

Poor heat dissipation in high current applications (above 600mA) may cause a decrease in charging current due to temperature protection. Please design a thermal dissipation resistor based on the actual power supply voltage. The optimal input voltage at the Vcc end of the chip is 4.6V, which can obtain a larger charging current. Generally, the thermal dissipation resistor is 0.5 to 0.8 ohms. It is equally important to adopt a well-designed PC board layout to maximize the usable charging current. The heat dissipation path used to dissipate the heat generated by the IC is from the chip to the lead frame, and reaches the copper surface of the PC board through the post peak lead (especially the grounding lead). The copper surface of the PC board is a heat sink. The copper foil area connected to the pins should be as wide as possible and extend outward to a larger copper area to dissipate heat into the surrounding environment. The through holes to the internal or back copper circuit layer are also quite useful in improving the overall thermal performance of the charger. When designing a PC board layout, other heat sources on the circuit board that are not related to the charger must also be considered, as they will have an impact on the overall temperature rise and maximum charging current.

## VCC Bypass Capacitor

Multiple types of capacitors can be used for input bypass. However, caution must be exercised when using multi-layer ceramic capacitors. Due to the characteristics of self-resonance and high Q value of some types of ceramic capacitors, high voltage transient signals may be generated under certain startup conditions (such as connecting the charger input to a working power supply). It is recommended to use electrolytic capacitors or tantalum capacitors.

## Soft Start Of Charging Current

TP4060 includes a soft start circuit for minimizing inrush current at the beginning of the charging cycle. When a charging cycle is initiated, the charging current will rise from 0 to the full-scale value in about 50us. During the startup process, this can minimize the transient current load on the power supply.

## Input Voltage Reverse Polarity Protection

In some applications, reverse polarity voltage protection is required on VCC. If the power supply voltage is high enough, a series isolation diode can be used. In other situations where low voltage reduction is necessary, a P-channel MOSFET can be used (as shown in Figure 4).

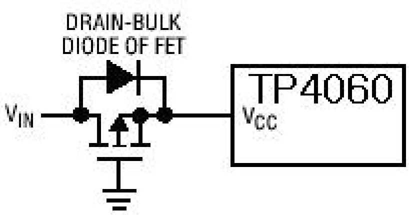
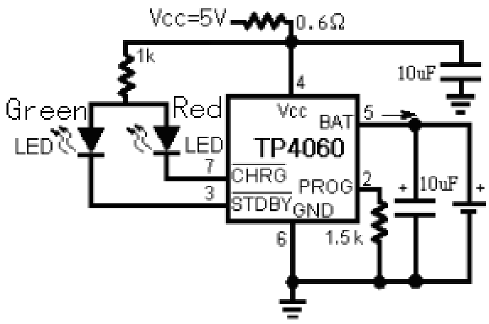
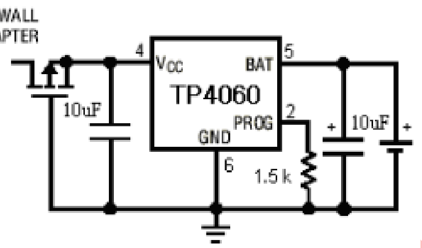



Fig.4 Low loss input reverse polarity protection

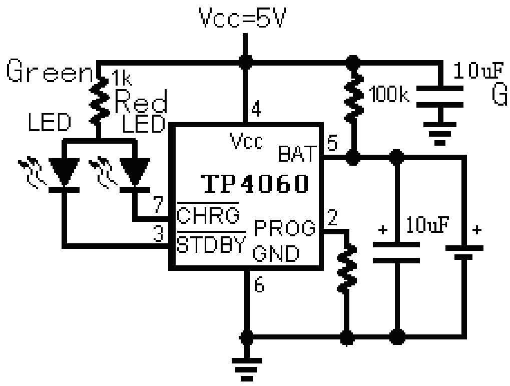
# TYPICAL APPLICATIONS



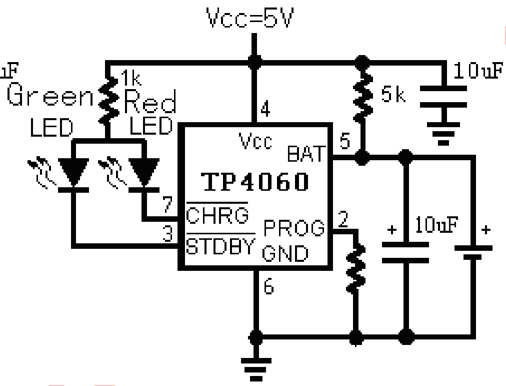

500mA Single Cell Li-lon Charger




Low Loss Input Reverse Polarity Protection




No battery RED LED not flashing




Light body without battery

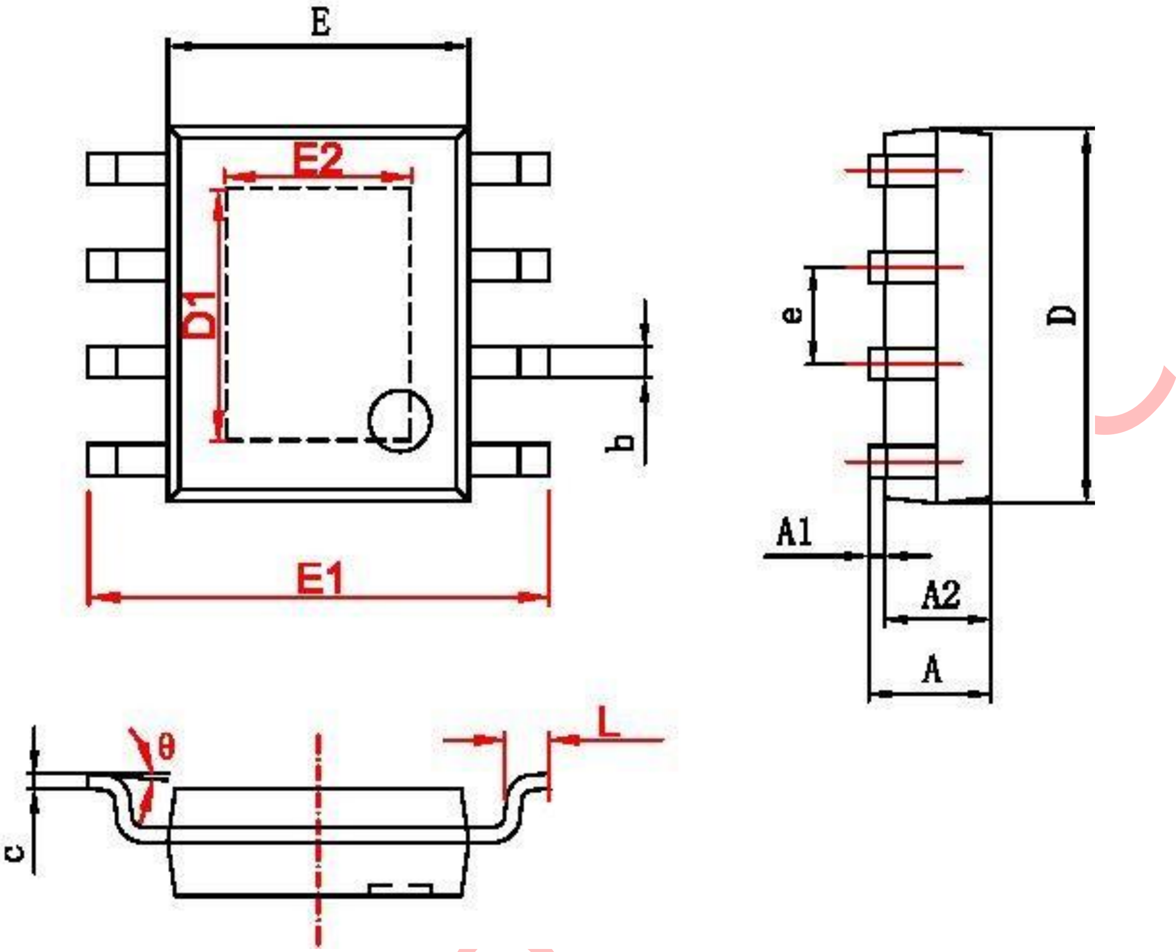
# PRECAUTIONS FOR USE

1.In the TP4060 charging current test, the BAT end (Pin 5) of the chip should be directly connected to the battery positive pole, and the ammeter can't be connected in series. The ammeter can be connected to the Vcc end of the chip.

2.In order to ensure reliable use under various conditions and prevent chip damage caused by spike and burr voltage, it is recommended that the Vcc end and BAT end of TP4060 application be connected with 10uF capacitor, and if possible, another 0.1u ceramic capacitor can be connected. All capacitor positions should be close to the chip pin, not too far.

3.With ESOP8 packaging, poor cooling effect in high current applications (above 600mA) may cause the charging current to be reduced due to temperature protection. The customer is advised to connect the dissipation resistor. The best input voltage at the Vcc end of the chip is 4.6V, which can obtain a large charging current. Generally, the thermal dissipation resistance is 0.4 to 0.8 ohms. The same good PCB layout can effectively reduce the impact of temperature on the current of customers in high-current charging applications.

# PACKAGE DESCRIPTION




| 字符 | Dimensions In Millimeters | | Dimensions In Inches | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| A | 1.350 | 1.750 | 0.053 | 0.069 |
| A1 | 0.050 | 0.150 | 0.004 | 0.010 |
| A2 | 1.350 | 1.550 | 0.053 | 0.061 |
| b | 0.330 | 0.510 | 0.013 | 0.020 |
| c | 0.170 | 0.250 | 0.006 | 0.010 |
| D | 4.700 | 5.100 | 0.185 | 0.200 |
| D1 | 3.202 | 3.402 | 0.126 | 0.134 |
| E | 3.800 | 4.000 | 0.150 | 0.157 |
| E1 | 5.800 | 6.200 | 0.228 | 0.244 |
| E2 | 2.313 | 2.513 | 0.091 | 0.099 |
| e | 1.270(BSC) | | 0.050(BSC) | |
| L | 0.400 | 1.270 | 0.016 | 0.050 |
| θ | 0° | 8° | 0° | 8° |