# 1.0A Compatible With The USB Interface, Linear Battery Management Chip

## ■ General Description

The XT2051 is a constant- current / constant- voltage charger circuit for single cell lithium-ion batteries. The device includes an internal power transistor, does not need external current sense resistor and blocking diode in applications. XT2051 requires minimal external components, and meet the USB bus specification, is very suitable for portable applications in the field.

Thermal modulation circuit can control the internal chip temperature in a safe range when the device power dissipation be relatively large or the ambient temperature be higher. Within a fixed constant charge voltage 4.2V, can also be adjusted by an external resistor. Charge current set by an external resistor.

When the input voltage (AC adapter or USB power supply) power is lost, XT2051 automatically enters a low power sleep mode, then the battery current consumption is less than 0.1µA. Built-in protection circuits against irrigation, when the battery voltage is higher than the input voltage, automatically turn off built-in power MOSFET. Other features include low input voltage latch, automatic recharge, the battery temperature monitoring, Built - in OVP protection and charge status / charge status indication functions. XT2051 uses thermally enhanced 8-pin small outline package eSOP-8/PP or eMSOP-8/PP.

## ■ Features

- Programmable charge current up to 1A
- No MOSFET, sense resistor or blocking diode required
- Complete linear charger in small 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
- Monitor output charge current
- default charging voltage of 4.2V±1%, can be adjusted by the FB
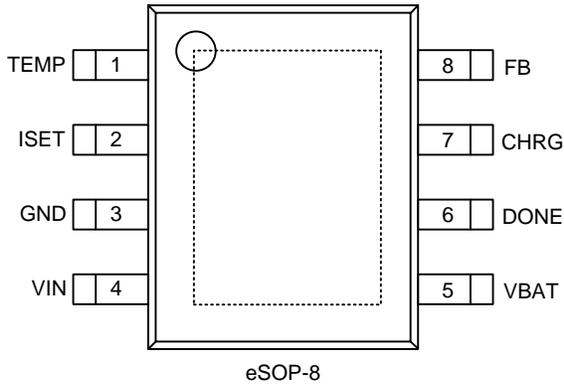
- Automatic recharge
- Charge status output pin
- 1/10 charge current termination
- 40µA supply current in shutdown
- 2.9V trickle charge threshold
- Soft-Start limits inrush current
- OVP protection function , the input is higher than 6.8V, stop charging
- Output with protection against anti-irrigation
- Available in eSOP-8/PP or eMSOP-8/PP Package
- When you unplug VIN , the IC does not consume battery power
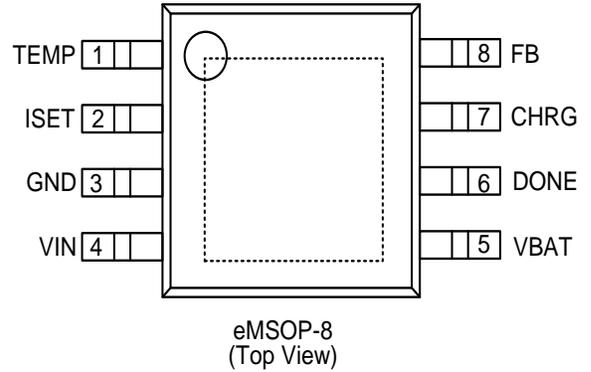
## ■ Applications

- Mobile phones
- Digital Cameras
- MP4 Player
- Bluetooth applications
- Electronic Dictionary
- portable devices
- all kinds of charger
- Mobile power

## ■ Package

- eSOP-8/PP

| TEMP | 1 | | 8 | FB |
| ISET | 2 | | 7 | CHRG |
| GND | 3 | | 6 | DONE |
| VIN | 4 | | 5 | VBAT |

eSOP-8

- eMSOP-8/PP

| TEMP | 1 | | 8 | FB |
| ISET | 2 | | 7 | CHRG |
| GND | 3 | | 6 | DONE |
| VIN | 4 | | 5 | VBAT |

eMSOP-8
(Top View)

## ■ Ordering Information

**XT2051①②③④⑤**

| Designator | Description | Symbol | Description |
|---|---|---|---|
| ① | Type | X | No trickle charge |
| | | Y | Have trickle charge |
| ② | The first part of regulator Output Voltage | 0 | 4.0 |
| | | 1 | 4.1 |
| | | 2 | 4.2 |
| ③ | The second part of regulator Output Voltage | A | ②00 |
| | | B | ②25 |
| | | C | ②50 |
| | | D | ②75 |
| ④ | Packaging Types | S | eSOP-8 |
| | | Q | eMSOP-8 |
| ⑤ | Device Orientation | R | positive |
| | | L | negative |

## ■ Pin Function

- **TEMP (Pin 1):** The TEMP pin to the battery of the NTC sensor output. If the TEMP pin voltage is less than the input voltage of 30% or greater than 60% of the input voltage means the battery temperature is too low or too high, then the charge will be suspended. If the TEMP input voltage between 30% and 60%, then the battery fault condition will be cleared, the charge will continue.

- **ISET (Pin 2):** Charge current programming, charge current monitoring and close pin. Charge current is controlled by a resistor of precision of 1%to the ground. In the constant charge current state, this port provides 1V voltage. In all conditions, this port charge current can be calculated using the following formula:

$$I_{BAT} = (V_{ISET}/R_{ISET}) \times 1000$$

ISET port can also be used to turn off the charger. Resistance to side with the separation of programming can pull the 3µA

current source to increase ISET port voltage. When the suspension reached the limit voltage 1.21V, the device enters stop state, after charging the input current drop to 25µA. This port pinch-off voltage is about 2.4V. If supply this port voltage more than pinch-off voltage, the current will be 1.5 mA. Through combinating ISET pin to the ground, the charger will back to normal.

- **GND (Pin 3):** Ground terminal .The EXPOSED pin is also connected with pin 3.

- **VIN (Pin 4):** Supply positive input voltage. Power supply for the charger. VCC can be 4.25V to 6.5V and must have at least 1F bypass capacitor. If the BAT pin voltage of VCC down to within 30 mV, LN2052 into the suspension state, and make BAT Current less than 2A.

- **BAT (Pin 5):** Make the battery's positive terminal connected to this pin. When the power supply voltage lower than the threshold latch voltage or sleep mode voltage, BAT pin current is less than 2µA. BAT pin provide the battery charge current and constant voltage charging voltage.

- **DONE (Pin 6):** When charging end, DONE pin is pulled low by internal switch represents that charge has ended; otherwise DONE pin is high impedance state.

- **CHRG (Pin 7):** When the charger to the battery charging, CHRG pin is pulled low by the internal switch,represents charging being; otherwise CHRG pin is in high impedance state.

- **FB ( Pin 8):** This pin can test Kelvin battery voltage, and thus precisely modulated constant voltage battery charging voltage, avoiding the positive from the battery to the BAT pin XT2051 or contact resistance between the resistance wire and other parasitic resistance of the charge. If the FB pin and the BAT pin is an indirect one resistor, users can adjust the constant charging voltage

## ■ Marking Rule

- **eSOP-8/eMSOP-8**

XT2051
①②③∗
∗∗∗∗∗∗∗∗

①②③Represents the version number

∗∗∗∗∗∗:Number of several, represents the quality tracking information!

## ■ Absolute Maximum Ratings

| Parameter | Symbol | Maximum Rating | Unit |
|---|---|---|---|
| Input Supply Voltage | $V_{cc}$ | $V_{SS}-0.3 \sim V_{SS}+7$ | V |
| ISET pin Voltage | Vprog | $V_{SS}-0.3 \sim V_{cc}+0.3$ | |
| BAT pin Voltage | Vbat | $V_{ss}-0.3 \sim 6$ | |
| DONE pin Voltage | Vdone | $V_{SS}-0.3 \sim V_{SS}+7$ | |

| CHAG pin Voltage | Vchrg | V$_{SS}$-0.3～V$_{SS}$+7 | |
|---|---|---|---|
| BAT pin Current | Ibat | 1500 | mA |
| ISET pin Current | Iprog | 1500 | µA |
| Operating Ambient Temperature | Topa | -40～+85 | °C |
| Storage Temperature | Tstr | -65～+125 | |

**Caution**: The absolute maximum ratings are rated values exceeding which the product could suffer physical damage. These values must therefore not be exceeded under any conditions.
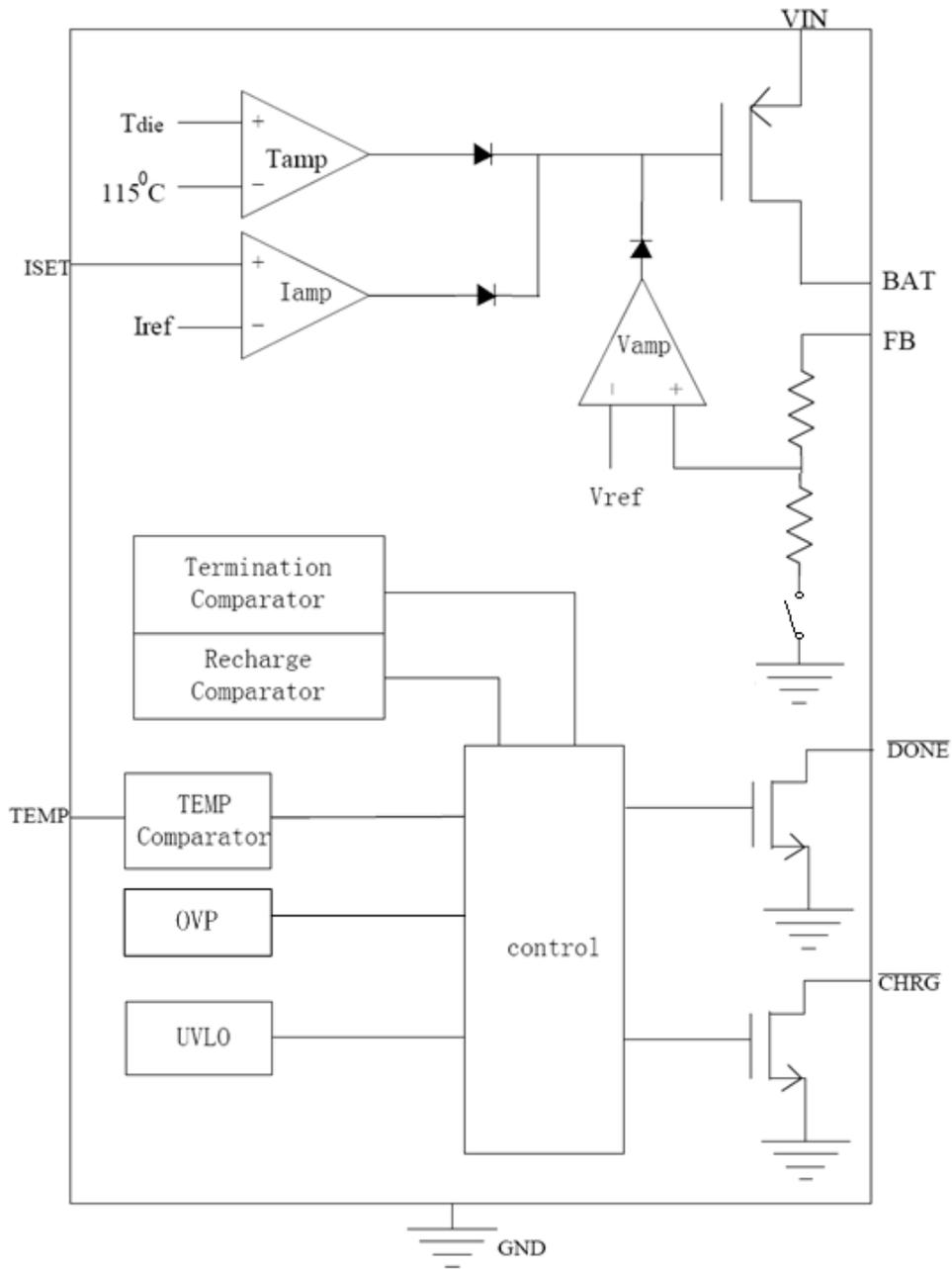
## ■ Block Diagram



**Figure 1.**

## ■ Typical Application Circuit

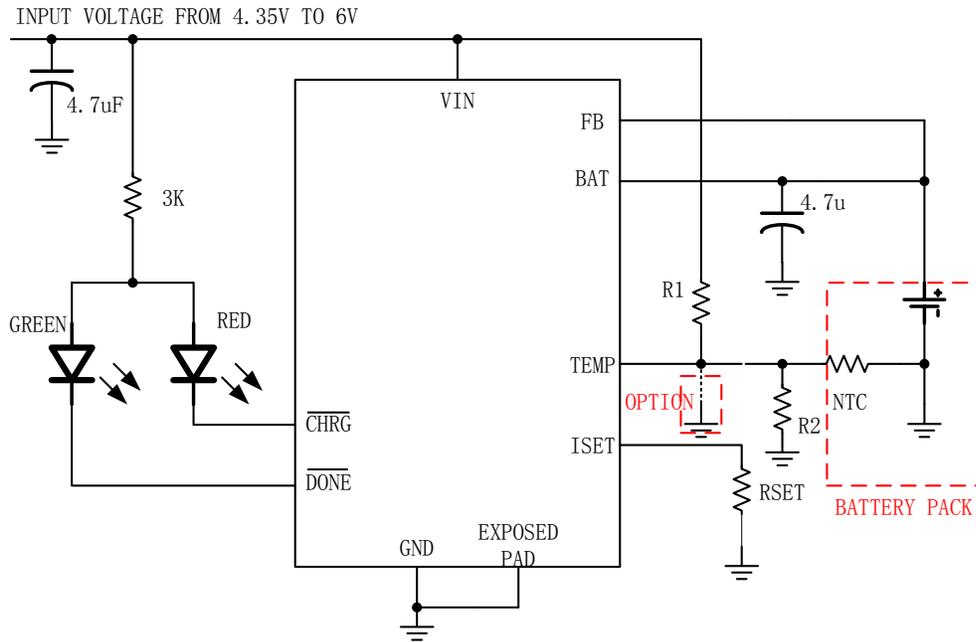- **Constant- Current / Constant- Voltage 4.2V Charging Application**



INPUT VOLTAGE FROM 4.35V TO 6V

**Figure 2.**

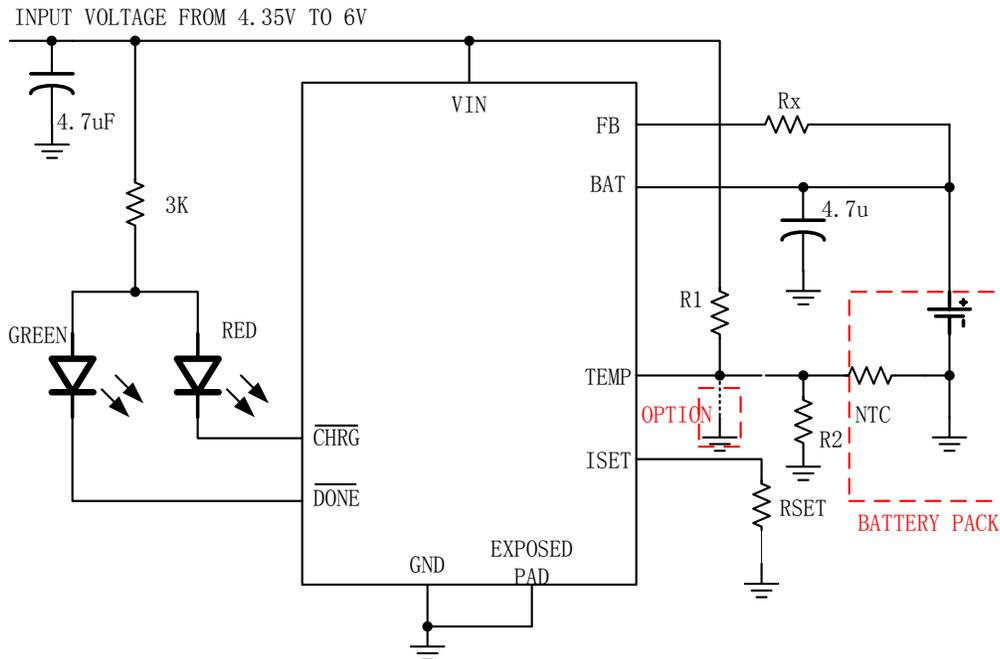- **The use of an external resistor adjustable constant current and constant voltage charging applications**



INPUT VOLTAGE FROM 4.35V TO 6V

**Figure 3.**

## ■ Electrical Characteristics

(Ta=25℃,Unless specifically designated)

| Parameter | Symbol | Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Input supply voltage | Vcc | | 4.25 | | 6.5 | V |
| Input supply current | Icc | Charge mode,Riset=10K | | 200 | 2000 | µA |
| | | Standby mode | | 200 | 500 | µA |
| | | Shutdown mode(Riset not connected,Vcc<Vbat or Vcc<Vuv) | | 25 | 70 | µA |
| Regulated Output Voltage | Vfloat | 0℃≤TA≤85℃,IBAT=40mA | 4.158 | 4.2 | 4.242 | V |
| BAT pin Current | Ibat | Riset=10k,Current mode | 90 | 100 | 110 | mA |
| | | Riset=1k,Current mode | 900 | 1000 | 1100 | mA |
| | | Standby mode,Vbat=4.2V | 0 | -2.5 | -6 | µA |
| | | Shutdown mode | | | ±0.1 | µA |
| | | Sleep mode,Vcc=0V | | | ±0.1 | µA |
| Trickle charge current | Itrikl | Vbat<Vtrikl,Rprog=2k | 90 | 100 | 110 | mA |
| Trickle charge Threshold Voltage | Vtrikl | Riset=10K，Vbat Rising | 2.8 | 2.9 | 3.0 | V |
| Trickle voltage hysteresis voltage | Vtrhys | Riset=10k | 60 | 80 | 110 | mV |
| Vcc Undervoltage lockout Threshold | Vuv | From Vcc low to high | 3.7 | 3.8 | 3.93 | V |
| Vcc undervoltage lockout hysteresis | Vuvhys | | 150 | 200 | 300 | mV |
| Manual shutdown threshold voltage | Vmsd | Iset pin rising | 1.15 | 1.21 | 1.30 | V |
| | | Iset pin falling | 0.9 | 1.0 | 1.1 | V |
| Vcc-Vbat Lockout Threshold voltage | Vasd | Vcc from low to high | 70 | 100 | 140 | mV |
| | | Vcc from high to low | 5 | 30 | 50 | mV |
| C/10 Termination Current Threshold | Iterm | Riset=10k | 8 | 10 | 12 | mA |
| | | Riset=2k | 40 | 50 | 65 | mA |
| PROG pin Voltage | Vprog | Riset=10k, Current mode | 0.93 | 1.0 | 1.07 | V |
| CHRG pin Output low voltage | Vdone | Idone=5mA | | 0.35 | 0.6 | V |
| CHRG pin Output low voltage | Vchrg | Ichrg=5mA | | 0.35 | 0.6 | V |
| Recharge Battery threshold Voltage | ΔVrecg | VFLOAT - VRECHRG | | 150 | 200 | mV |

# ■ Application Information

- **Kelvin battery voltage detection**

     XT2051 Kelvin detect a battery voltage input (FB), this pin through the chip internal precision resistor divider network connected to the constant voltage error amplifier. FB pin can be connected directly to the battery cathode, it can effectively prevent the parasitic resistance(including lead resistance, contact resistance, etc.) between the battery and the 5th pin of XT2051 . The parasitic resistance will make the charger early enters the constant state and extend the charging time, even charge the battery discontent, by using Kelvin battery voltage detection can solve these problems. If the Kelvin detect input pin (FB) not connect, then the XT2051 has been in a pre-charge state, charging current is 1 / 10 of the set constant charge current.

- **Adjust the constant charging voltage**

     If connect a resistor between the XT2051 battery voltage Kelvin test input pin (FB) and the positive battery , it can increase the battery charging voltage, as shown in Figure 3, then the positive battery voltage Vbat is:

$$Vbat(V) \ = \ 4.2 + 4.03 \times 10^{-6} \times Rx(\Omega)$$

     When using an external resistor to adjust the charging voltage constant, due to internal and external temperature of chip and chip production inconsistent with the process variation and other factors, may cause the accuracy of the output voltage variation and temperature coefficient.

- **Set the charge current**

   In constant-current mode, formula for calculating charge current: ICH = 1000V / RISET.

   H represents the charge current, units is ampere, RISET represents ISET pin to ground resistance in ohms.For example, if you need 500 mA charge current, according to the following formula: RISET = 1000V/0.5A = 2KΩ

   In order to ensure good stability and temperature characteristics, RISET recommend the use of 1% precision metal film resistors

- **Application of USB and AC adapter while charging at the same time**

     XT2051 can not only use USB interface to charge the battery, users can also use a wall adapter to charge the battery. Figure 3 shows   the same time using the USB interface and the AC adapter to charge the battery through the XT2051 .when the two co-exist, the AC adapter has priority. M1 is the P-channel MOSFET, M1 is used to prevent current from a wall adapter into the USB interface, USB interface, Schottky diode D1 prevents the consumption of energy through the 1K resistor.
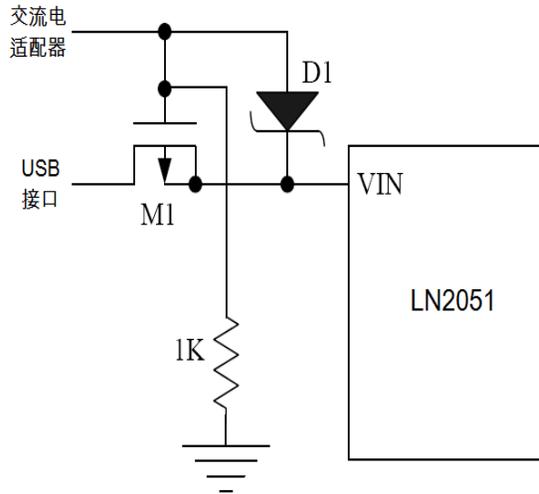
**Figure 4. While using the AC adapter and USB interfaces**

- **Battery temperature monitoring**

    In order to prevent the battery temperature is too high or too low on the battery damage, XT2051 internal battery temperature monitoring of integrated circuits. Battery temperature monitoring is by measuring the TEMP pin voltage to achieve, TEMP pin voltage is within the battery NTC thermistor and a resistor divider network, and illustrated in Figure 2.

    XT2051 the TEMP pin voltage with the chip and the two thresholds VLOW VHIGH compared to confirm whether the battery temperature exceeds the normal range. In the XT2051, VLOW were fixed in 30% × VIN, VHIGH were fixed in 60% × VIN. If the TEMP pin voltage VTEMP <VLOW or VTEMP> VHIGH, the battery temperature is too high or too low, charging will be suspended; If the TEMP pin voltage VTEMP VLOW and VHIGH in between, the charge cycle will continue.

- **Enable design**

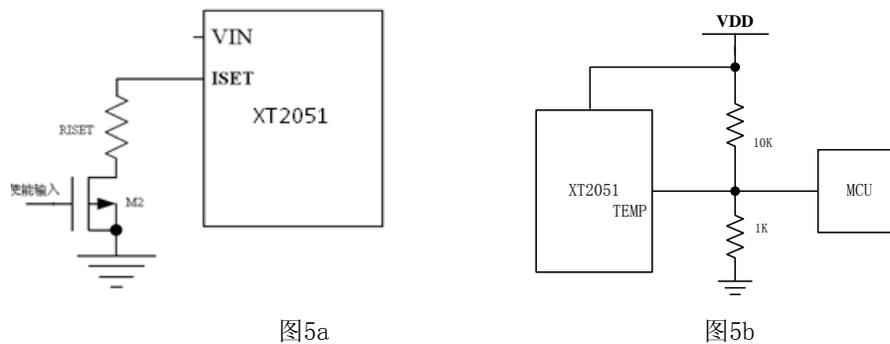  By controlling whether the ISET pin resistor connected, users can reach close XT2051 function. Figure 4:



图5a                           图5b

**Figure 5.   XT2051 Enable Design**

- **Determine the value of R1, R2**

    The value of R1 and R2 according to battery temperature monitoring range and the thermistor resistance values to determine, are described as follows: assume that the temperature range of the battery set TL ~ TH, (TL <TH); batteries used in negative temperature coefficient thermistor (NTC), RTL TL when its temperature resistance, RTH its resistance when the temperature TH, then the RTL> RTH, then the temperature TL, the first pin TEMP-side voltage is:

$$V_{TEMPL} = \frac{R_2 // R_{TL}}{R_1 + R_2 // R_{TL}} \times Vin$$

When temperature reach TH, the first side of the TEMP pin voltage is: $V_{TEMPH} = \frac{R_2 // R_{TH}}{R_1 + R_2 // R_{TH}} \times Vin$

then，according to: $V_{TEMPL} = V_{HIGH} = K2 \times V_{IN}(K2 = 0.6)$

$$V_{TEMPH} = V_{LOW} = K1 \times V_{IN}(K1 = 0.3)$$

Can solve for： $R1 = \frac{R_{TL}R_{TH}(K2-K1)}{(R_{TL}-R_{TH})K1K2}$

$$R2 = \frac{R_{TL}R_{TH}(K2-K1)}{R_{TL}(K1-K1K2) - R_{TH}(K2-K1K2)}$$

Similarly, if the battery is the positive temperature coefficient of internal (PTC) thermistor, the RTH> RTL, we can calculate:

$$R1 = \frac{R_{TL}R_{TH}(K2-K1)}{(R_{TH}-R_{TL})K1K2}$$

$$R2 = \frac{R_{TL}R_{TH}(K2-K1)}{R_{TH}(K1-K1K2) - R_{TL}(K2-K1K2)}$$

From the above derivation can be seen to be setting the temperature range and supply voltage VIN is irrelevant, only with R1, R2, RTH, RTL; one, RTH, RTL can access the relevant manuals or through experimental test battery be.

In practice, if only one side of the temperature characteristics of concern, such as over-temperature protection, then R2 can not, and can only R1. R1 derivation becomes very simple, not discussed here.

● **Open-drain output status indication**

XT2051 has two open-drain status indication sides, CHAG and DONE, the two status indicator LEDs client can drive or microcontroller port. CHAG used to indicate charging status, charging time, CHAG is low; DONE to indicate the charging end of the state, when the charging end, DONE is low. When the battery temperature is outside the normal temperature range more than 0.15 seconds, CHAG and the DONE pin is high impedance output state.

When the battery charger not received, the charger will quickly charge the output capacitor to the constant voltage value, as the battery voltage detection the BAT pin input leakage current, the BAT pin voltage will slowly down to recharge threshold, so the BAT pin voltage is 150mv to form a ripple waveform, while CHAG output pulse signal that there is no battery installed. When the battery BAT pin external connectors for the 4.7uF capacitor, the pulse period of about 2Hz.

The following table lists CHAG and DONE pin status in each case：

| State | Charge | Full | Without Battery | Error |
|---|---|---|---|---|
| CHAG | Always bright | Always off | Flashing | Always off |
| DONE | Always off | Always bright | Always bright | Always off |

**Note: 1.** CHAG flicker frequency with external capacitor when not connect battery, generally recommended 4.7uF.**The greater the capacitance ,the smaller frequency flicker.**

    **2.** The error situation: Beyond the operating temperature range (temperature too high or too low), Iset side vacant, Vin <Vbat, Vin <3.8V and so on.

● **The large current output design**

   Since the XT2051 using the internal constant power technology, therefore , when the input VIN and BAT pressure is too large , will lead to smaller the BAT voltage range of the maximum current , so that the charging time becomes longer , in order to make the maximum current charging interval larger by an external resistor or Schottky methods to achieve.

   The assumption the XT2051 of SOP8/PP inside the package the maximum allowable power 1.2W, maximum charge current is set to 1.0A. If uses a resistive, We assume that the use of the resistance of 0.5Ω (1W), High current charging, the voltage drop across the resistor is 0.5*1.0=0.6V. The XT2051 real operating voltage is 4.4V. Thus, in this state, (VIN-VBAT) *1.0<1.2W, therefore VBAT>3.4V，The batter5y voltage is above 3.4V 1.0A charging support. Below 3.4V, the XT2051 will automatically reduce the charge current to maintain the chip internal power balance.

   If Schottky similar calculation can be made , according to the Schottky voltage drop at different current .

   **In addition , in the high-current applications need to pay attention XT2051 PCB layout design must consider increasing EXPOSED PAD area , and will be connected to the EXPOSED PAD to GND in order to improve the thermal performance , and ensure the stable operation of the chip .**
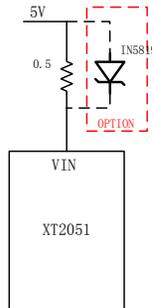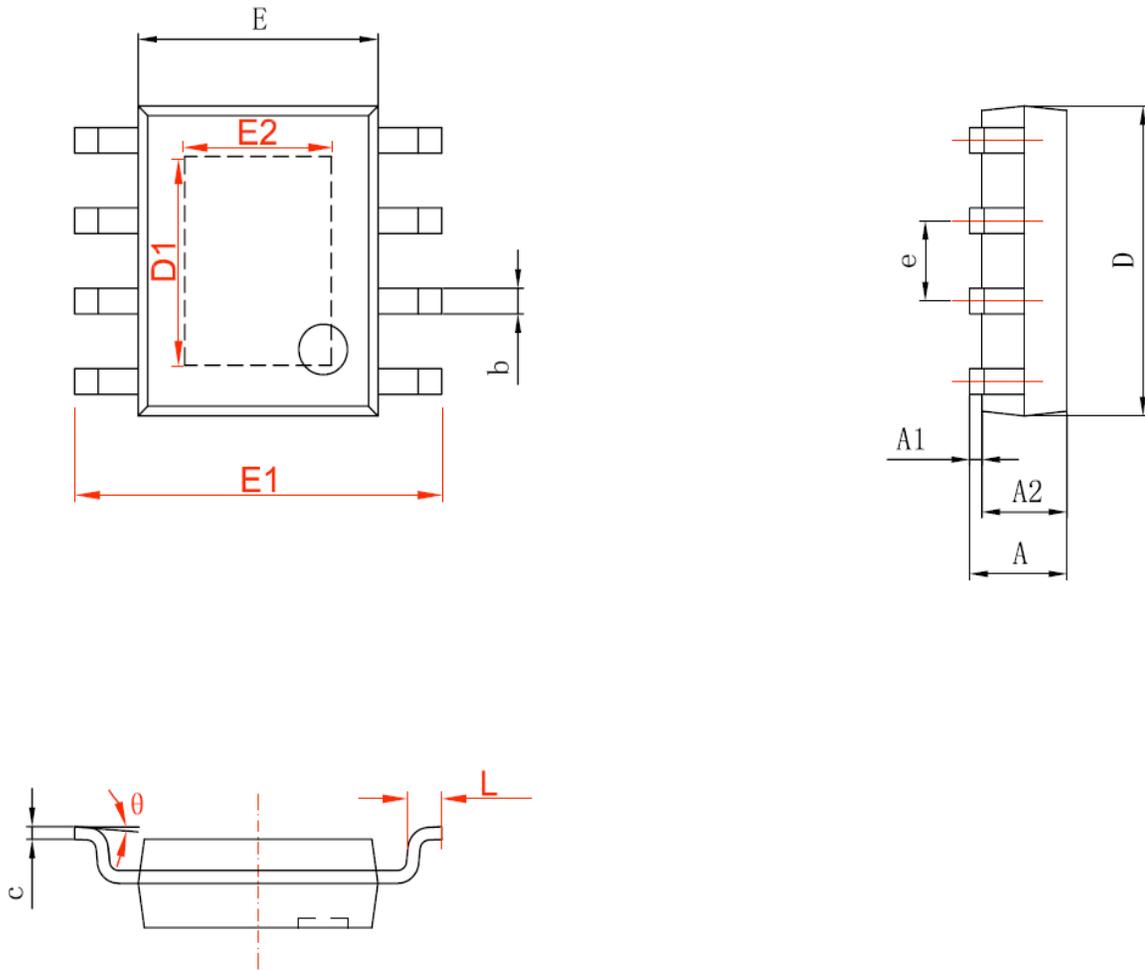
## ■ Package Information

● **eMSOP-8/PP**
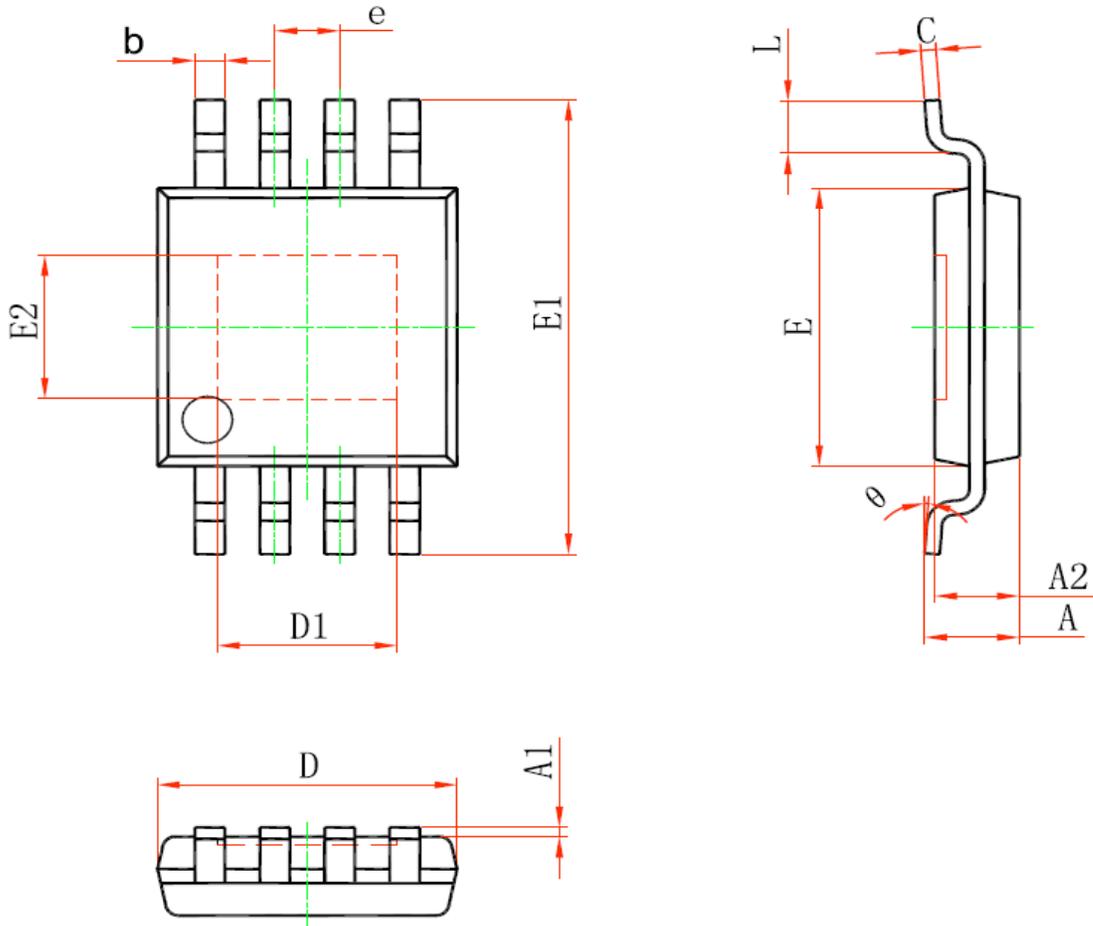


| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|--------|------|------|------|------|
| | Min | Max | Min | Max |
| A | 0.820 | 1.100 | 0.032 | 0.043 |
| A1 | 0.020 | 0.150 | 0.001 | 0.006 |
| A2 | 0.750 | 0.950 | 0.030 | 0.037 |
| b | 0.250 | 0.380 | 0.010 | 0.015 |
| c | 0.090 | 0.230 | 0.004 | 0.009 |
| D | 2.900 | 3.100 | 0.114 | 0.122 |
| D1 | 1.700 | 1.900 | 0.067 | 0.075 |
| e | 0.65（BSC） | | 0.026（BSC） | |
| E | 2.900 | 3.100 | 0.114 | 0.122 |
| E1 | 4.750 | 5.050 | 0.187 | 0.199 |
| E2 | 1.450 | 1.650 | 0.057 | 0.065 |
| L | 0.400 | 0.800 | 0.016 | 0.031 |
| θ | 0° | 6° | 0° | 6° |

● **eSOP-8/PP**



| 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 | 0.002 | 0.006 |
| A2 | 1.350 | 1.550 | 0.053 | 0.061 |
| b | 0.330 | 0.510 | 0.013 | 0.020 |
| c | 0.170 | 0.250 | 0.007 | 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° |

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