

Nanjing extension of Microelectronics Co., Ltd.

~~Nanjing Nanjing Top Power ASIC Corp.~~

Data Sheet

DATASHEET

**TP5100**

**2A-switch buck 8.4V / 4.2V rechargeable lithium battery**

**Chip**

**Outline**

TP5100 is a step-down switching double 8.4V / 4.2V single lithium battery charge management chip. QFN16 ultra small package with its simple external circuit, so that the large current charging management application TP5100 ideal for portable devices. Meanwhile, TP5100 built-in input overcurrent, undervoltage protection, over temperature protection, short circuit protection, battery temperature monitoring, reverse battery protection.

TP5100 having a wide input voltage 5V-18V, the battery trickle charging into pre-charge, constant current, constant-voltage three phase, pre-charge current trickle charge current is adjusted through an external resistor, the maximum charging current of 2A. TP5100 using frequency of 400kHz switching mode makes it possible to use a smaller peripheral devices, and still maintain a smaller amount of heat in the large current charging. TP5100 built-in power of the PMOSFET, anti-intrusion circuit, there is no need peripheral anti-intrusion protection Schottky diode.

**characteristic**

- Dual / single 8.4V / 4.2V rechargeable lithium battery
- Built-in power MOSFET, a switching mode of operation, less heating device, a simple peripheral
- Programmable charge current, 0.1A - 2A
- Programmable precharge current, 10% - 100%
- No external Schottky diode anti-intrusion
- Wide operating voltage, maximum reach 18V
- Red and green LED indicates the state of charge
- Chip temperature protection, overcurrent, undervoltage protection
- Battery temperature protection, reverse battery shutdown, short circuit protection
- Switching frequency of 400KHz, and more available inductance 20uH
- PWR\_ON- power, battery-powered switching control
- Charging voltage control accuracy of less than 1%
- Trickle, constant current, constant voltage charging three sections, a battery protected
- QFN16 4mm \* 4mm using ultra small package

**Absolute Maximum Ratings**

- Static input supply voltage (VIN): 20V
- **BAT : -8.4V ~ 20V**
- BAT Short circuit duration: Continuous
- Maximum junction temperature: 120 °C
- Working temperature range: -40 °C ~ 85 °C
- Storage Temperature Range: -65 °C ~ 125 °C
- Lead Temperature (welding time of 10 seconds): 260 °C

**application**

- Portable equipment, various chargers
- Smart phone, PDA, mobile cellular phone
- MP4, MP5 players, tablet computers
- HM
- electrical tools

**typical application**

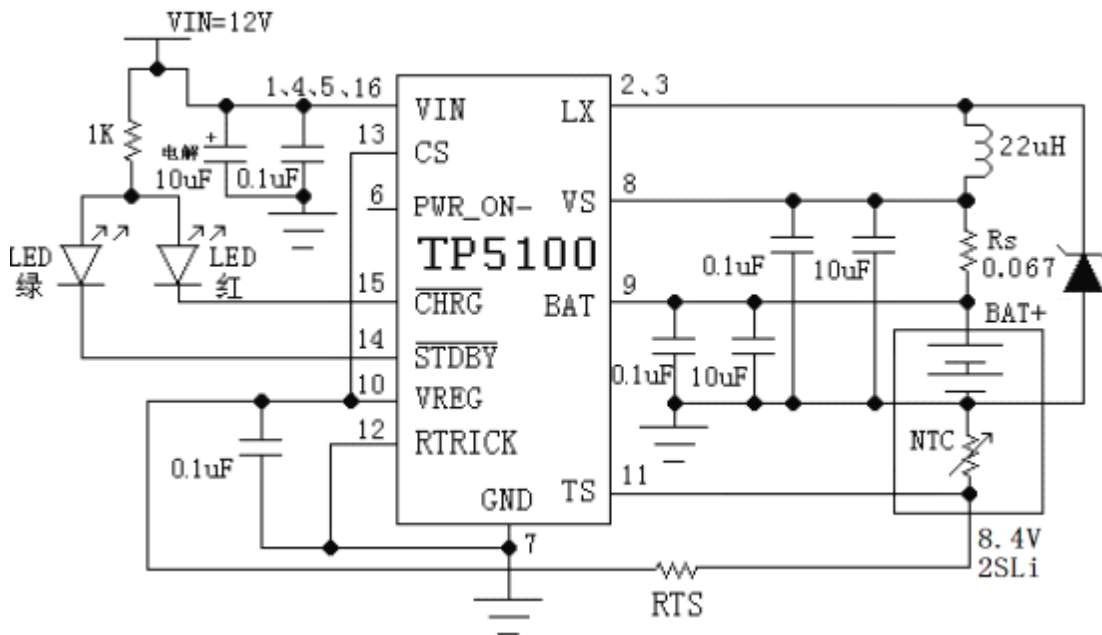


FIG 2 TP5100 lithium ion battery is 8.4V 1.5A double charge (precharge 150mA) Application schematic

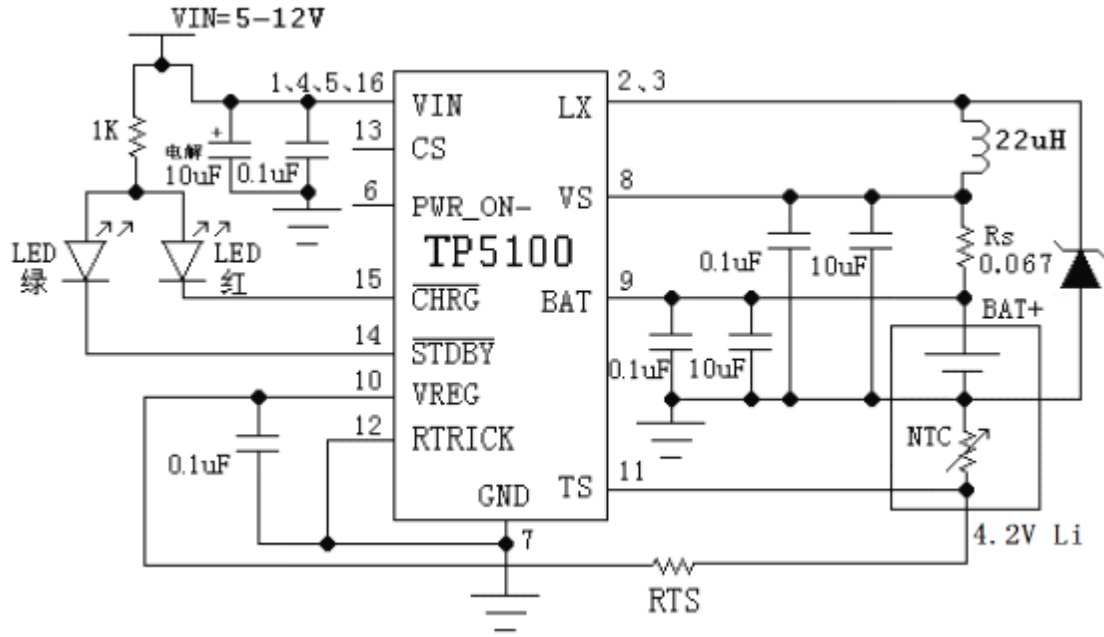
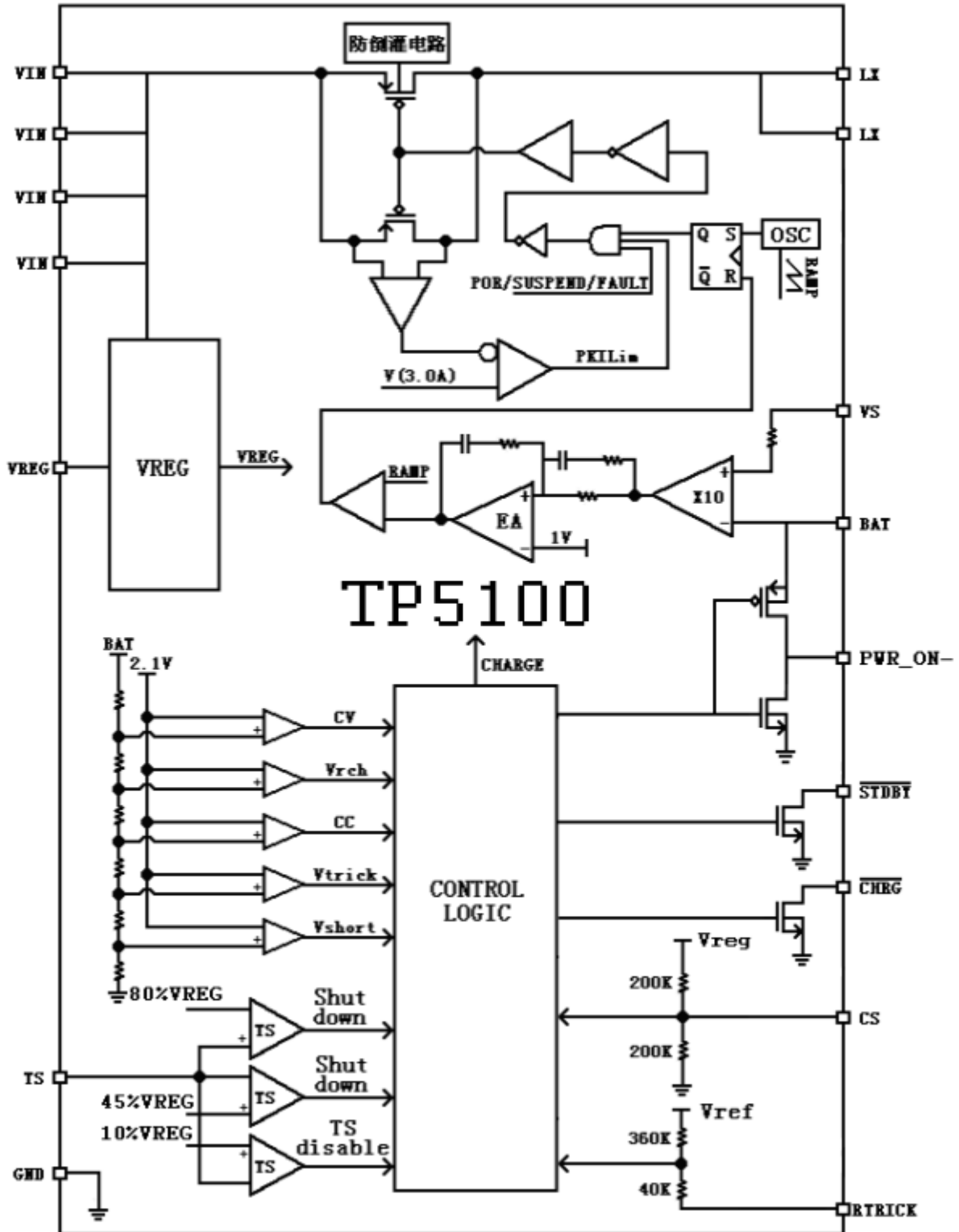


FIG 1 TP5100 is a single 4.2V rechargeable lithium ion battery 1.5A (prefilled 150MA) Application schematic

Ordering Information Package IIII

<p>16 Pin 4mm * 4mm QFN16 A top view of the package (Fin ground)</p>	<p><b>Orders models</b></p>
	<p>TP5100-QFN16</p>
	<p><b>Device Marking</b></p>
	<p>TP5100</p>
	<p><b>Physical picture</b></p>

TP5100 Functional





Map 3 TP5100 Functional Block Diagram

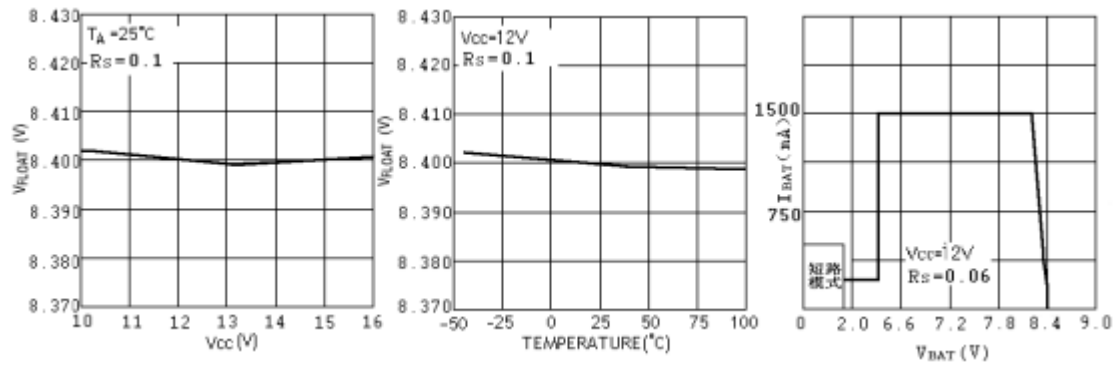
**Electrical characteristics**

Table 1 TP5100 electric characteristics can parameter

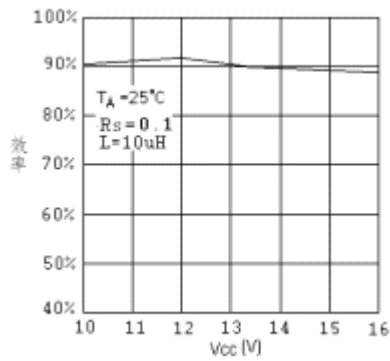
Where • denotes specifications which apply 8.4V, 4.2V mode, otherwise specifications 8.4V, T<sub>a</sub> 25 °C, VIN = 12V, except where indicated otherwise.

symbol	parameter	condition	Min Typ Max Units				
VIN	Input supply voltage		•	4.5	12	18	V
Icc	Input supply current	No battery mode, R <sub>s</sub> 0.1 Ω standby	•		150	180	μ A
		mode (charge termination) Stop	•		120	140	μ A
		mode ( CS = GND ,	•		120	140	μ A
		V <sub>in</sub> V <sub>BAT</sub> ,Or V <sub>in</sub> V <sub>UV</sub> )			120	140	
V <sub>FLOAT</sub>	Charge cutoff voltage	4.2V Lithium Ion Battery		4.158	4.2	4.242	V
		8.4V Lithium Ion Battery		8.316	8.4	8.484	V
I <sub>BAT</sub>	BAT Pin Current: ( Current mode test conditions CS = VREG Battery = 7.5V)	R <sub>s</sub> = 0.1 Ω, constant current mode	•	950	1000	1100	mA
		R <sub>s</sub> 0.067 [Omega], the constant current	•	1450	1500	1600	mA
		mode, a standby mode, V <sub>BAT</sub> 8.4V VIN	•	0	-1	-1	uA
		= 0V , V <sub>BAT</sub> 8.4V	•	0	-1	-1	uA
I <sub>TRIKL</sub>	Trickle pre-charge current RTRICK Pin to ground	1.2V <V <sub>BAT</sub> V <sub>TRIKL</sub> , R <sub>s</sub> 0.067	•	80	100	120	mA
F	The oscillation frequency		•	350	400	500	KHz
D <sub>MAX</sub>	The maximum duty cycle		•		100%		
D <sub>MIN</sub>	The minimum duty cycle		•	0%			
V <sub>TRIKL</sub>	Trickle charge threshold voltage ( 8.4V ) Trickle charge threshold voltage ( 4.2V ) R <sub>s</sub> = 0.067 Ω, V <sub>BAT</sub> rise			5.6	5.8	6.0	V
				2.8	2.9	3.0	
V <sub>TRHYS</sub>	Trickle charge voltage hysteresis	R <sub>s</sub> = 0.067 Ω		60	80	100	mV
V <sub>UV</sub>	V <sub>IN</sub> Undervoltage lockout threshold	From V <sub>IN</sub> Low to High	•	3.5	3.6	3.8	V
V <sub>UVHYS</sub>	V <sub>IN</sub> Undervoltage lockout hysteresis		•	150	200	300	mV
V <sub>ASD</sub>	V <sub>IN</sub> V <sub>BAT</sub> Lockout threshold voltage	V <sub>IN</sub> From low to high		60	100	140	mV
		V <sub>IN</sub> High to Low		5	30	50	mV
I <sub>TERM</sub>	C / 10 Termination current threshold	R <sub>s</sub> = 0.067 Ω	•	80	100	120	mA
V <sub>CHRG</sub>	 Low voltage output pin	I <sub>CHRG</sub> = 5mA	•		0.3	0.6	V
V <sub>STDBY</sub>	 Pin output low	I <sub>STDBY</sub> = 5mA	•		0.3	0.6	V
V <sub>TEMP-H</sub>	TEMP Pin high voltage shutdown		•		> 80	82	% * VREG
V <sub>TEMP-L</sub>	TEMP Pin low-end voltage shutdown		•	43	<45		% * VREG
Δ V <sub>RECHRG</sub>	Threshold voltage of the rechargeable battery	V <sub>FLOAT</sub> V <sub>RECHRG</sub>	•	80	150	200	mV
T <sub>LIM</sub>	Chip temperature protection				110		°C
R <sub>ON</sub>	power FET "On" resistance				170		m Ω
t <sub>ss</sub>	Soft start time	I <sub>BAT</sub> 0 to I <sub>BAT</sub> 0.1V / R <sub>s</sub>			20		u S
t <sub>RECHARGE</sub>	Filter Time recharge	V <sub>BAT</sub> High to Low		0.8	1.8	4	mS
t <sub>TERM</sub>	Termination Comparator Filter Time	I <sub>BAT</sub> Drops C 10 the following		0.8	1.8	4	mS

Typical performance indicators (CS Set 8.18V Lithium battery charging mode)



The relationship between cut off voltage and the supply voltage and the ambient temperature relation of the charging voltage and the battery current-voltage relationship



Efficiency versus supply voltage

**Pin Function**

**VIN VIN VIN (Pins 1111 , 1111, 1111):** Input voltage at the

end . This voltage is the power supply pin of the internal circuit,

**VIN Changes in scope 5V to 18V Between, and through a 10uF with 0.1uF**

Bypass capacitor. when VIN with

**V<sub>BAT</sub> Pressure lower than 30mv Time, TP5100 Enter shutdown mode,**

reducing the I<sub>BAT</sub> Drops 1 μ A .

**LX LX LX LX (Pins 2222 , 3333 ): Built-in power drain of PMOSFET connection point . LX is TP5100 current output terminal of the external inductor is connected to a battery charging current input terminal.**

**(PWR\_ON)- PWR\_ON-- (6):** Power switching control pin.

When the chip is connected to the power supply, PWR\_ON- Internal switch

is pulled low, the drive PMOS Conducting, when the chip is not connected

to the power supply, PWR\_ON- Internal switch is pulled to a high level

BAT End of the battery voltage, the driving PMOS Shutdown. This pin can

be used to switch the power supply, the power source can also be used to

establish the detection is normal.

**GND GND GND GND (Pins 7777 ): Power**

**VS VS VS VS (Pins 8888 ): Positive input of the output current detection .**

**BAT BAT BAT BAT (Pins 9999 ): Battery voltage detection terminal .**  
The positive terminal of the battery is connected to this pin.

**VREG (Pins 1010 ): Internal power supply . VREG is a**

An internal power supply, it is an external bypass capacitor 0.1uF to

ground, the maximum possible drive 5mA.

**TS TS TS TS (Pins 1111): Battery temperature detection input**

TS Pin to battery NTC (Negative temperature coefficient thermistor) sensor

output. in case TS Less than the voltage at pin VREG of 45% Or greater than

VREG Voltage 80% It means that the battery temperature is too low or too

high, the charging is suspended. in case TS Direct access GND Battery

temperature detection function is canceled, another charging function

properly.

**RTRICK RTRICK (Pins 1212):** Trickle precharge current set

will RTRICK Pin to ground to the pre-charge current 10%

Setting a constant current, the precharge current may be provided by an

external resistor. in case RTRICK Floating the precharge current equals the

constant current.

**CS CS CS CS (Pins 1313 ): State lithium ion chip select input . CS**

Input terminal of the high level ( VREG ) Will TP5100 In the

lithium-ion battery 8.4V Off-state voltage. CS The vacant end TP5100

In the lithium ion battery 4.2V Off-state voltage. Low input level so TP5100

It is shutdown. CS End can be TTL or CMOS Level of the drive

control.

**STDBY STDBY (Pins 1414):** Green battery charge means is

Shows an end . When the battery is fully charged STDBY Internal switch

is pulled low to indicate the completion of charging. In addition,

STDBY The pin is in high impedance state.

**CHRG CHRG (Pins 1515 ): Red charging status indicator**

end . When the battery is being charged, CHRG Internal switch pin is

pulled low, indicating the charging progress; otherwise CHRG Pin is

high impedance.

## working principle

TP5100 is designed for double 8.4V / 4.2V single lithium ion battery designed for switching high current charger IC, a power transistor chip inside the battery using the trickle, constant current and constant voltage charging. The charging current can be programmed with an external resistor, the charging current up to the maximum duration. 2A, does not require additional anti-intrusion diode. TP5100 comprising two open-drain output state indication output terminal, the charging indicator status **CHRG** And **FULL** status outputs **STDBY** . Chip internal power management circuitry automatically reduces the charging current of the chip junction temperature exceeds 145 deg.] C, this feature allows the user to use the maximum power handling capability of the chip, do not worry about damaging the chip or the chip overheating external components.

When the input voltage is greater than the threshold voltage and the chip enable the chip enable input terminal **HIGH** (the **VREG**) or **floating**, TP5100 start charging the battery, **CHRG** Output pin low to indicate that charging is in progress. If the lithium ion battery voltage is lower than double 5.8V (Single lithium cell voltage is lower than the electron 2.9V ), The battery trickle charger for pre-charging (pre-charge current through the external adjustable resistance) with a small current. The constant current VS Pin and **VBAT** Determining the resistance between the pin. When the lithium ion battery voltage is close to double 8.4V (Single lithium-ion batteries close 4.2V ), The charge cut-off voltage of about from 50mV (Connection resistance to the internal resistance of the battery voltage differs depending on the circuit), the charging current is gradually reduced, TP5100 constant voltage charging mode. When the charge current is reduced to the off current, the charging period ends, **CHRG** End a high impedance state, **STDBY** The low potential side.

When the battery voltage falls below the recharge threshold (lithium ion battery double 8.1V / A single lithium ion battery 4.05V ), The charge cycle starts automatically. Inside the chip precision voltage reference source, an error amplifier and the resistor divider network to ensure that the battery terminal voltage cutoff accuracy + - 1% Or less, to meet the requirements of a lithium ion rechargeable battery. When the input voltage or input voltage down below the battery voltage, the charger enters a low power shutdown mode, no external anti-intrusion diode chip drain from the battery approaches 1uA .

### Charge cutoff voltage selection

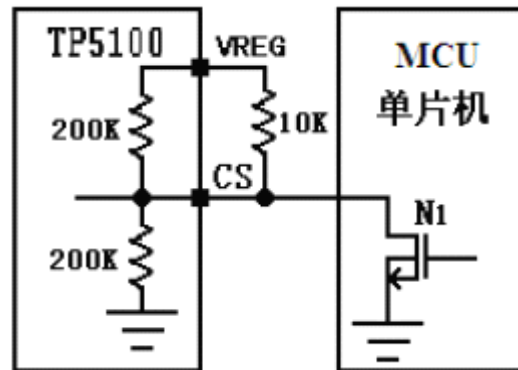
TP5100 with double / single lithium two charging

Select the cutoff voltage. when CS Connected to the high potential terminal **VREG** When, for the 8.4V double standard lithium-ion battery, 8.4V cut-off voltage. When the vacant terminal CS, the battery charging standard battery Li-Ion, cutoff voltage 4.2V. When CS Termination low GND , The charger stops charging.

TP5100 composite design of the CS terminal can be determined by an external control TP5100 is in charging mode is switched to the stop mode.

When the vacant terminal CS, expressed as TP5100 single lithium-ion batteries.

Double 8.4V lithium-ion battery shutdown state Switching mode. 4, the output port of the CS terminal via an open-drain, the gate of NMOS transistor if the input low, NI off, then terminating CS high, the charge-cutoff voltage of 8.4V, TP5100 double Li-ion batteries. When the NMOS transistor gate input high, NI turned on, when CS is pulled down to GND, TP5100 is a stop mode. 5mA VREG output pin drive current, pull-up resistor optional 1k-100k.



Map 4 By external control 8.4V Shaped lithium-ion battery

State and stopping state of the switch



### Charging current setting

Battery charging current  $I_{BAT}$  is determined by the external current sense resistor  $R_s$ .  $R_s$  ratio adjust the threshold voltage  $V_s$  and the constant charge current across the resistor is determined by the voltage across the constant current condition  $R_s$  is 100mV.

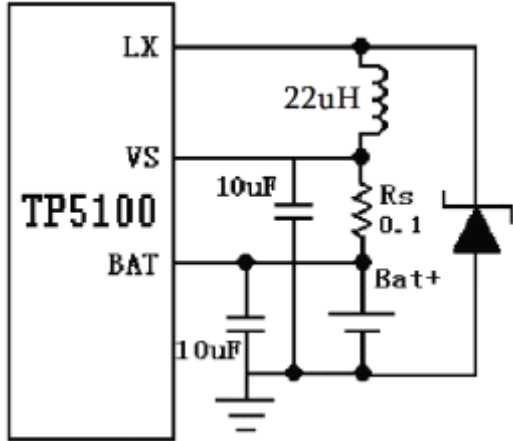


FIG 5 is provided a battery charging current and the

charging current setting resistor is calculated using the following equation:

$$I_{BAT} = \frac{0.1}{R_s} \quad (\text{Current units A Resistance per unit } \Omega)$$

For example:

To set the charging current 1A, Calculated into the formula

$$R_s = 0.1 \Omega$$

table 2 It gives some different settings corresponding to the current  $R_s$  Resistance,

to facilitate rapid design desired circuit. table 2:  $R_s$  The charge current and

the corresponding

$R_s (\Omega)$	$I_{BAT} \text{ (mA)}$
1	100
0.2	500
0.1	1000
0.067	1500
0.05	2000

### Trickle precharge current is provided

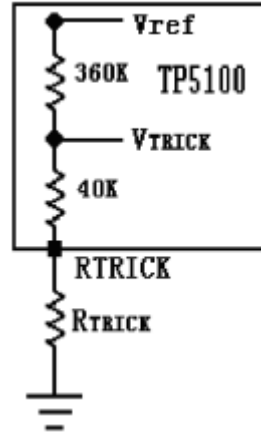
If the battery voltage is below the precharge threshold voltage,

TP5100 A pre-charging operation starts charging the battery, TP5100

The pre-charge current by TRICK

Port settings. A precharge current is employed in connection

TRICK Resistor connected between the pin and ground to set.



Map 6 TRICK From the end of the inner circuit diagram of FIG.

As can be seen, if  $R_{TRICK}$  Port directly to ground, the resistance ratio obtained by dividing the precharge voltage is the trickle charge current ratio of the constant current. Precharging current is constant charge current 1/10. This pin only changes trickle current, shutdown current is not affected by this, still 10% Constant current.

Setting resistor and a pre-charge current is calculated using the following equation:

$$R_{TRICK} = \frac{40400 \cdot I_{TRICK}}{I_{BAT}}$$

In order to facilitate customers to quickly design, table 3 Gives  $R_{TRICK}$

And the precharge current and constant trickle current setting of  $I_{BAT}$

Relationship. table 3:  $R_{TRICK}$  And setting the constant current trickle current  $I_{BAT}$  Relationship:

$R_{TRICK} \text{ (k)}$	$I_{TRICK} \text{ (mA)}$
0	10% $I_{BAT}$
50k	20% $I_{BAT}$
114k	30% $I_{BAT}$
320k	50% $I_{BAT}$
Pin floating	100% $I_{BAT}$

### Charge termination

CV phase, when the charging current drops below the maximum value constant 1/10 When the charge cycle is terminated. This condition is achieved by using an internal filtered comparator  $R_s$  The pressure drop is monitored to detect. when  $R_s$  To a voltage difference across the 10mV For longer than  $t_{TERM}$  (Typically 1.8ms), the Charging is terminated. Charging current is turned off, TP5100 enters standby mode, where the input supply current to 120 A, the battery drain current flowing about 1uA.

In standby mode, TP5100 of BAT Pin voltage is continuously monitored. If the lithium ion battery double this voltage drops 8.25V (single lithium battery voltage drops below 4.05V) recharging limit switches  $V_{RECHRG}$  Or less, the new The charge cycle begins again and supplying current to the battery.

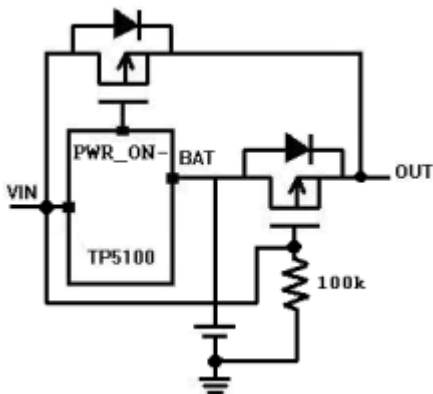
**Charging status indicator**

**TP5100 Two open-drain status output terminal, CHRG with STDBY**  
 . When the charger is in the charging state, CHRG It is pulled low, in other states, CHRG In a high impedance state. When the outside temperature of the battery is in a normal temperature range, CHRG with STDBY Pins are high impedance. When no indication state, the pin can not be connected to ground. Table 4: state of charge indicator

Green STDBY	red light CHRG	charging
Destroy	bright	Charging status
bright	Destroy	Battery is fully charged state
Destroy	Destroy	Voltage, battery temperature is too high, too low or non-fault state battery Access (TS end use)
Green light, red light flashes T = 0.5-1S		BAT termination 10u capacitor, no battery standby state (TS ground)

**Power, battery switching control**

TP5100 integrated power, battery power supply switch control pin PWR\_ON-. When the input VIN, PWR\_ON- output low, may be turned on PMOS. When VIN is removed, PWR\_ON- outputting the high potential (battery voltage) can be closed PMOS.



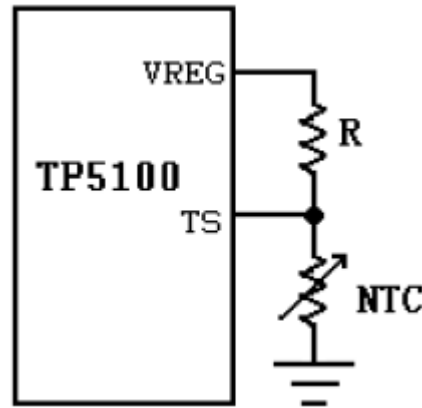
Map 7 A schematic view of the control power supply switch

**Battery over-temperature protection**

In order to prevent the temperature is too high or too low battery damage caused, TP5100 integrated internal battery temperature detecting circuit. Battery temperature is detected by measuring the voltage pin TS implemented, the voltage pin TS is an NTC thermistor in a battery and a resistor divider network, as shown in FIG. TP5100 inside the TS pin chip with two voltage thresholds  $V_{LOW}$

$V_{HIGH}$  Compared to Confirm that the battery temperature exceeds a normal range. Inside the TP5100,  $V_{IS}$  is fixed 45%  $V_{REG}$  ,  $V_{HIGH}$  Is fixed 80%  $V_{REG}$  . If the TS pin voltage  $V_{TS} < V_{LOW}$  or  $V_{TS} > V_{HIGH}$  , The battery The temperature is too high or too low, the charging process is suspended; if voltage pin TS  $V_{IN} < V_{LOW}$   $V_{HIGH}$   $V_{IT}$  Among the charge cycle continues. If the TS pin to ground, battery temperature detection function can be disabled.

Example: room temperature 25 °C  $R_{NTC} = 10k$ , set protection temperature 60 °C, at 60 °C  $R_{NTC} = 3k$ ,  $R = 3.6k$  the calculated time, the NTC resistor-divider ratio of 45%  $V_{REG}$  voltage, i.e., when the stop 60 °C TP5100 charge.



Map 8 NTC Connection diagram

**Chip internal thermal limit**

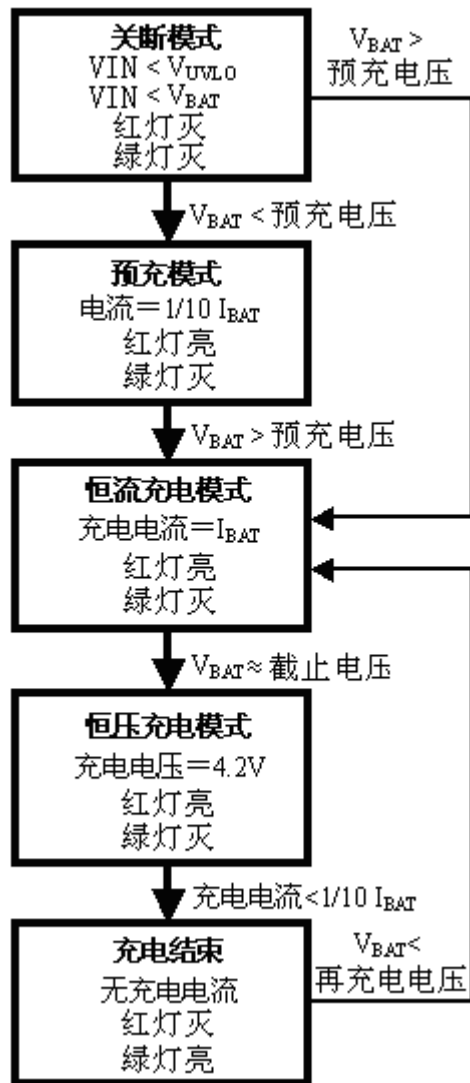
If the chip temperature attempts to rise to about 110 °C predetermined value or more, the heat inside a feedback loop to reduce the charge current is set. This feature prevents overheating TP5100, and allows the user increases the maximum for a given power handling capability of the circuit board without risk of damaging the TP5100. In ensuring the charger will automatically reduce the current in the worst case conditions of the premise, according to a typical (but not the worst case) the ambient temperature is set to the charging current.

### Limiting the short-circuit and an output

TP5100 integrates a variety of protection, the chip input limiting the maximum peak current. 3A, to prevent chip damage due to excessive current. When the output voltage below about 1.2V, the chip into short-circuit protection mode, the chip input current limit is 10% of the maximum peak current of about 450mA. Of different magnitude of the current with the input voltage difference.

### Automatic restart

Once the charge cycle is terminated, TP5100 immediately takes time having a 1.8ms filter (RECHARGE t) of Comparator continuously monitors the voltage on the BAT pin. When the battery voltage falls below 90% of the battery capacity, the charging cycle begins again. This ensures that the battery is maintained at (or near) a fully charged state. In the recharge cycle, CHRG Output pin to re-enter a strong pull-down state.



Map 9 A typical lithium-ion battery circulation state in FIG.

### Undervoltage lockout

An internal undervoltage lockout circuit monitors the input voltage, and Vin It rises above the undervoltage lockout threshold before the charger in shutdown mode. UVLO Charger circuitry will remain in shutdown mode, no discharge current of the battery. in case UVLO The comparator transition occurs at VIN Raised higher than the battery voltage 50mV Before charger will not exit the shutdown mode. So customers do not worry about the battery level is vented when the input power shortage situation.

### Input, output, terminal of the capacitor VS

You can use many types of capacitors, but requires high-quality power capacitors. When the multilayer ceramic capacitor with particular care must be taken, some types of ceramic capacitors having high EMI characteristic values, therefore, under certain conditions (such as the battery charger is connected to the power supply input and a work) may produce a high voltage transient damaging the chip signal form, and recommended 0.1uF capacitor 10uF X5R or X7R material or ceramic capacitor, and the capacitance connected to a position close to the chip pin sure.

### Thermal Considerations

although QFN16 The small form factor package, but its good heat dissipation properties, but need PCB With the preferred version of the design, it is preferably designed using a hot well PCB Plate layout to most significantly increase the charging current may be used. For dissipate IC Cooling path of the generated heat from the chip to the lead frame, by die and reaches the bottom of the fin PCB Board copper. The footprint copper pads should be as wide, and extends outwardly to a large copper area to spread the heat to the surroundings. It recommended to pay more through holes inside or backside copper layer, to improve the overall thermal performance of the charger. When performing PCB Board layout design, other heat sources related to the charger board also must be considered, because they will affect overall temperature rise and the maximum charge current has been affected.

### Inductor Selection

To ensure system stability, and constant current charging the pre-charge phase, the system needs to ensure that operate in continuous mode (CCM). The inductor current equation:

$$\Delta I_L = \frac{V_{IN} - V_{BAT}}{FS \cdot L} \cdot \frac{1}{FS}$$

among them the inductor ripple, FS is the switching frequency, in order

To ensure that the precharge and a constant current charging mode are in CCM,

**Δ Take pre-charge current value, that is 1/5 of the constant current**

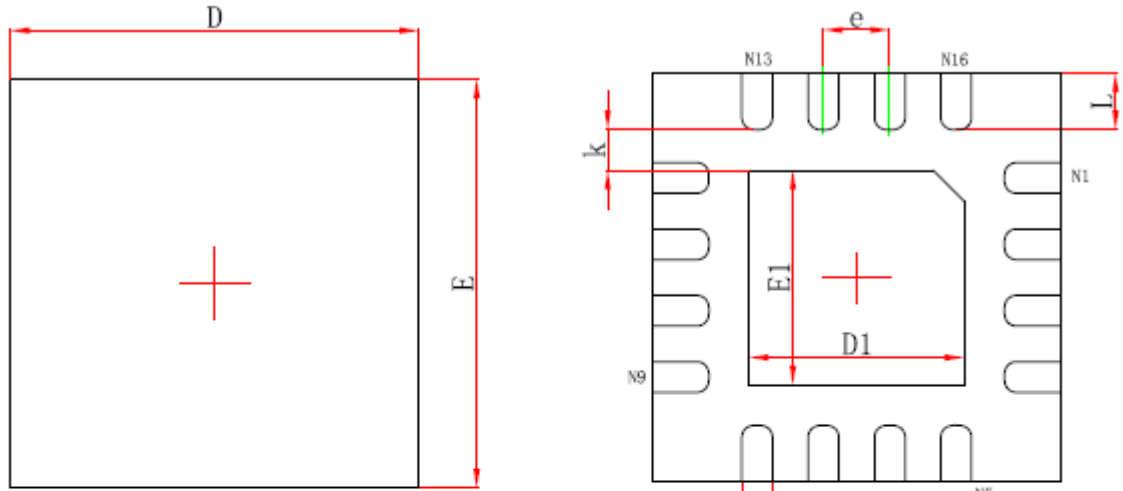
charging, the inductance value can be calculated according to the input voltage requirements.

22uH inductance values and above (inductance bigger and more stable), recommended 22uH. If the power source VIN set 5V, 4.2V using a single lithium-ion battery charging mode, and sets the charging current of 500mA or more, may be employed 10uH inductance.

Inductor rated current greater than a charge current is chosen, the smaller the internal resistance of power inductors.

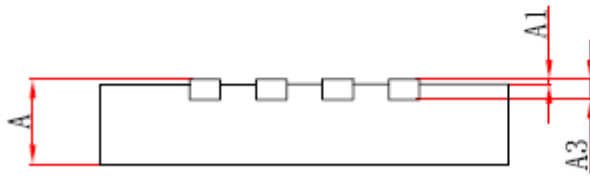
Package Description

4mm \* 4mm 16 Pin QFN Package



Top View

Bottom View

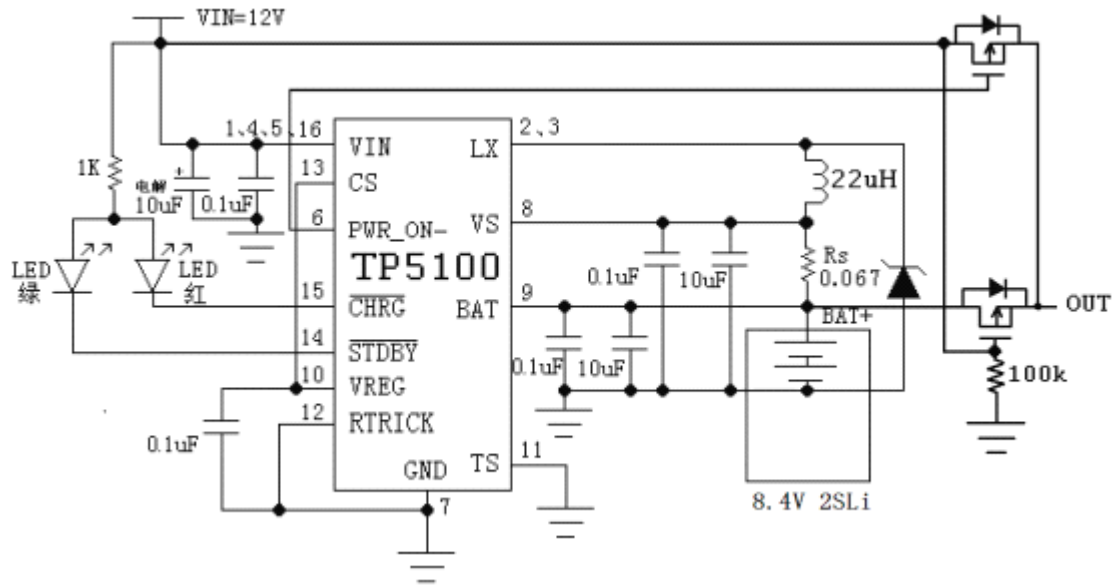


Side View

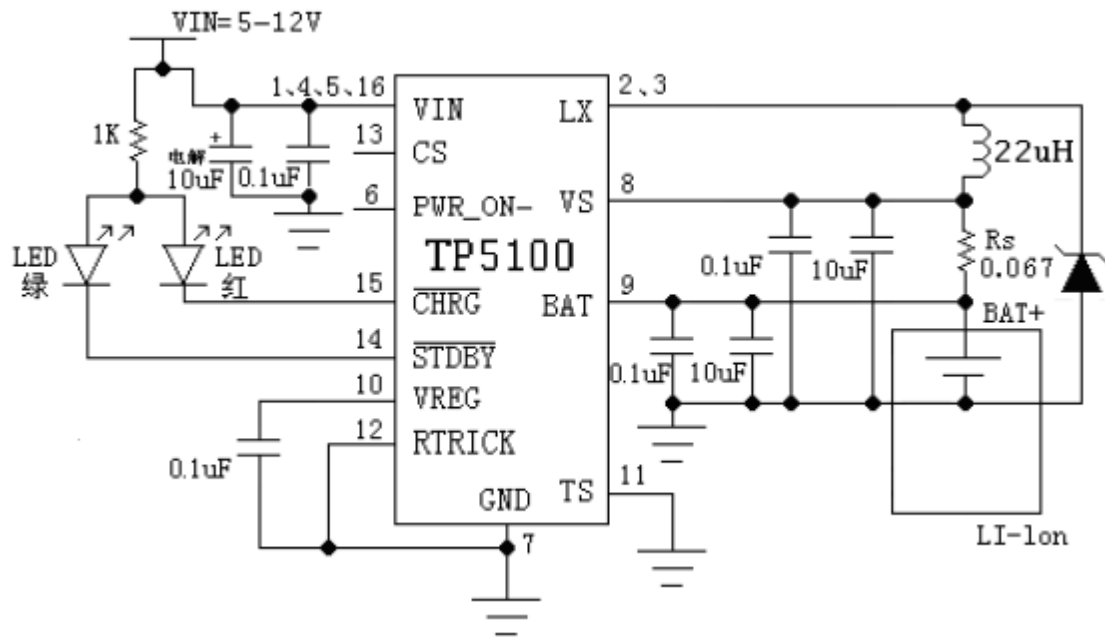
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	0.700/0.800	0.800/0.900	0.028/0.031	0.031/0.035
A1	0.000	0.050	0.000	0.002
A3	0.203REF.		0.008REF.	
D	3.900	4.100	0.154	0.161
E	3.900	4.100	0.154	0.161
D1	2.000	2.200	0.079	0.087
E1	2.000	2.200	0.079	0.087
k	0.200MIN.		0.008MIN.	
b	0.250	0.350	0.010	0.014
e	0.650TYP.		0.026TYP.	
L	0.450	0.650	0.018	0.026

Only package reel / disc / disc / cartridge box / boxes / box					
QFN4 * 4	13 Inch	5000	1	8	40,000

TP5100-1.5A



Map 10 TP5100 is 8.4V A lithium ion battery without the battery temperature protection 1.5A Application schematic charging



Map 11 TP5100 is 4.2V A lithium ion battery without the battery temperature constant-current protection 1.5A Application schematic charging  
( CS , PWR\_ON- Pin floating)

## TP5100 Precautions

1. The circuit chip capacitors should be as close as possible.
2. VS terminal VIN and the BAT terminal and the terminal using 10u electrolytic capacitor 0.1uF, X5R or X7R ceramic capacitor level.
3. Please choose the inductor current capability enough power inductors.
4. Selection Schottky diode voltage drop greater than or equal 2A small current capability of the Schottky diode.
5. For VIN and LX to be wider than the signal line common trace current loop.
6. Note that the capacitance of each node location of the grounding line, that the grounding point should be focused, well grounded.
7. chip large current should be considered a good heat sink and the bottom of the chip to the PCB, to ensure good heat dissipation.