

南京拓品微电子有限公司

NanJing Top Power ASIC Corp.

TP5100

**2A Switching Buck Charger IC for
8.4V/4.2V Lithium-Ion Battery**

Description

TP5100 is a switching-buck type (double 8.4V / single 4.2V) lithium battery charging management chip. Its QFN16 ultra-compact packaging and simple peripheral circuit make TP5100 ideal for portable devices with large current charging management applications. Meanwhile, TP5100 has built-in input overcurrent protection, undervoltage protection, over temperature protection, short circuit protection, battery temperature monitoring, and reversing battery protection.

TP5100 has a wide range of input voltage, from 5V to 12V. The charging process includes three stages: trickle pre-charge, constant current, constant voltage. Trickle pre-charge current and constant current can be adjusted through an external resistor, with maximum charging current up to 2A. TP5100, with a switching operation mode of frequency of 400 kHz, uses smaller peripheral components, and produces less heat while in charging operation with large current. TP5100 has built-in power PMOSFET, anti-intrusion circuit, so there is no need to have external anti-intrusion protection with Schottky diode.

Characteristic

- Double / single 8.4V/4.2V rechargeable lithium battery
- Built-in power MOSFET, switching operation mode, less heat, simple peripheral
- Programmable charging current, 0.1A--2A
- Programmable pre-charge current, 20% - 100%
- No need of external Schottky diode for anti-intrusion
- Wide operating voltage up to 12V
- Red and green LED charging status indicator
- Chip temperature protection, overcurrent protection, undervoltage protection
- Battery temperature protection, reverse battery shutdown, short circuit protection
- Switching frequency: 400KHz, available inductance: 4.7uH-22uH
- PWR_ON-power, battery charging switching control
- Less than 1% of charging voltage control precision
- Trickle, constant current, constant voltage charging stages to protect battery
- using QFN16 4mm * 4mm ultra-small packaging

Absolute Maximum Ratings

- Static input voltage supply (VIN): 18V
- BAT: 10V
- BAT Short Duration: Continuous
- The maximum junction temperature: 120°C
- Operating ambient temperature range: -40°C ~ 85°C
- Storage temperature range: -65°C ~ 125°C
- Lead Temperature (Soldering, 10 sec): 260°C

Application

- portable devices, various chargers
- smart phones, PDAs, mobile cellular phone
- MP4, MP5 players, Tablet PC
- HM
- Power Tools
- PTT

Typical applications

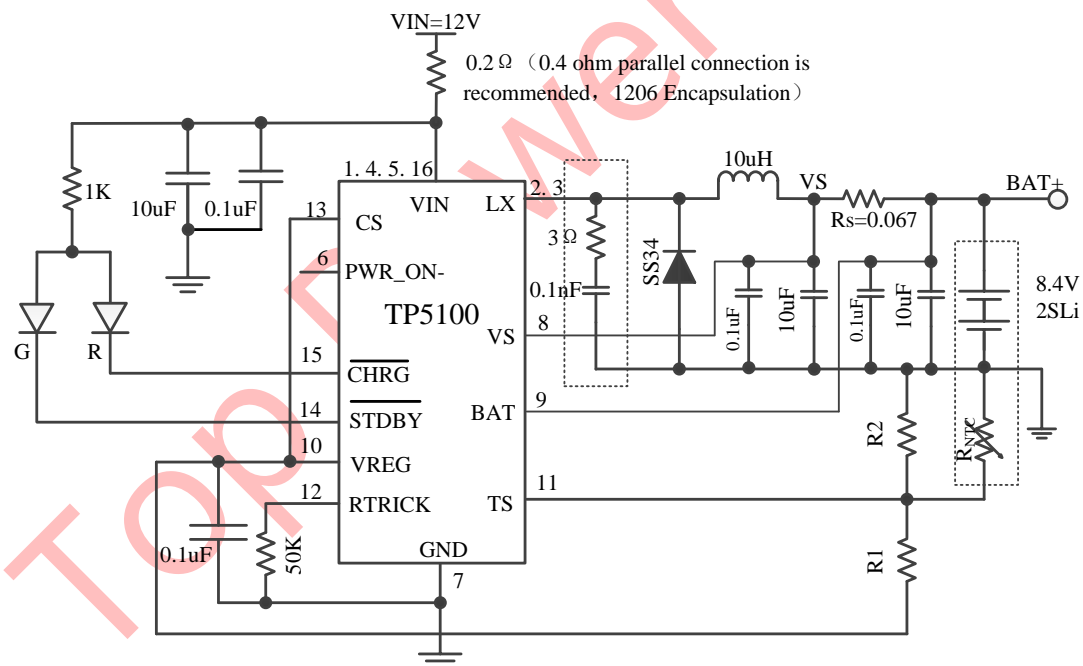


Figure 1 TP5100 double 8.4V-1.5A rechargeable lithium-ion battery (150mA pre-filled)
Application Diagram

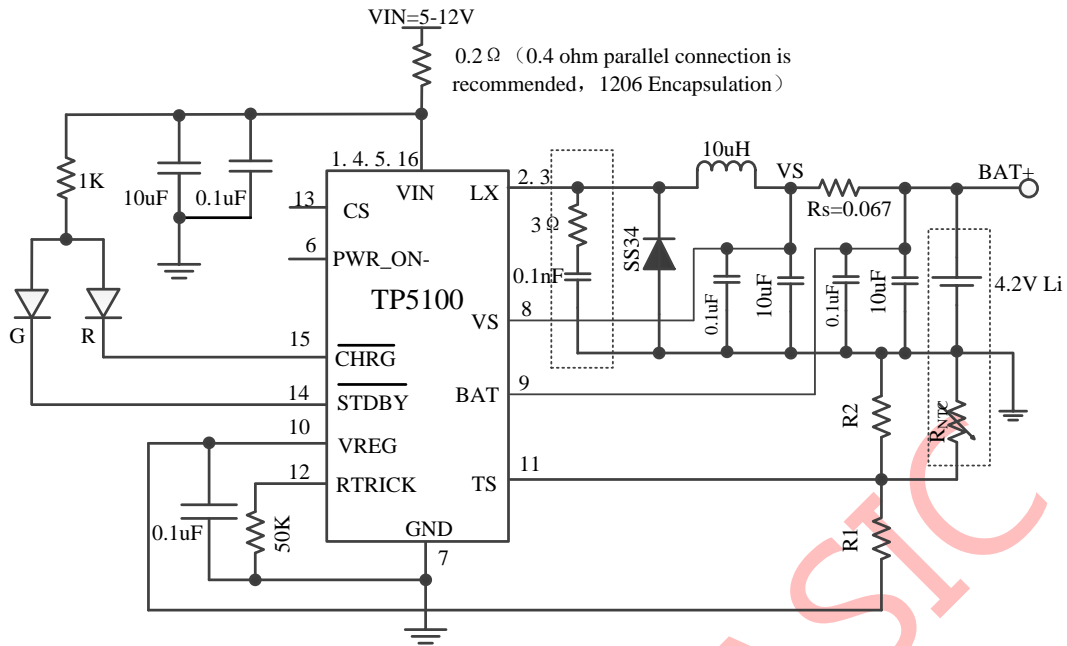


Figure 2 TP5100 single 4.2V-1.5A rechargeable lithium-ion battery (150MA preffilled) Application Diagram

Package / Ordering Information

<p>16-pin 4mm * 4mm QFN 16 package top view (Heat sink grounding can not be connected to other potential)</p>	<p>Orders Model</p> <p>TP5100-QFN16</p> <p>Device Marking</p> <p>TP5100</p> <p>Physical picture</p>
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TP5100 functional block diagram

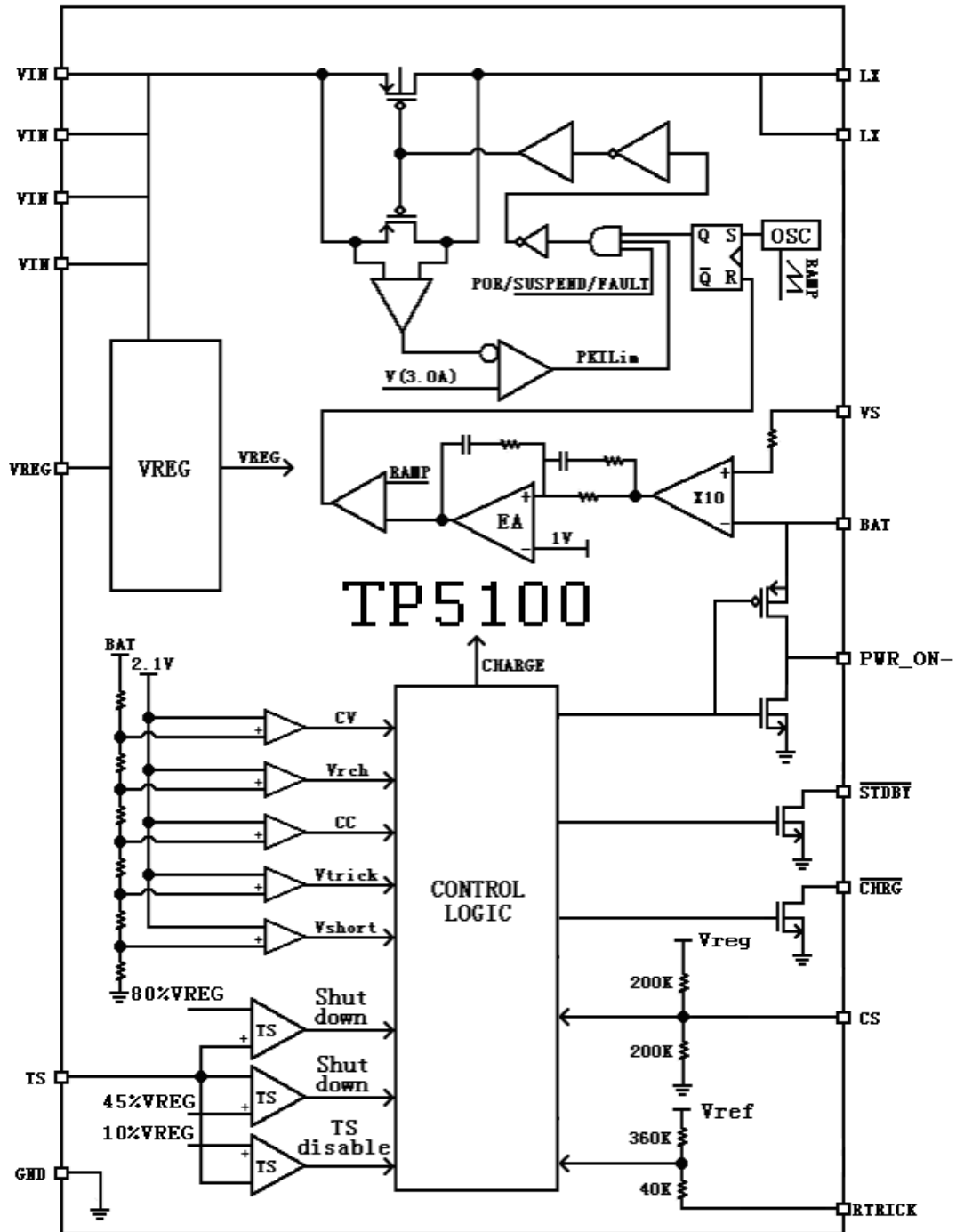


Figure 3 TP5100 Functional Block Diagram

Electrical characteristics

Table 1 TP5100 electrical characteristics of energy parameters

Where Note ● denotes the specifications 8.4V, 4.2V mode, otherwise refers only 8.4V, TRAR = 25 °C, VIN = 9V, unless otherwise stated.

Symbol	Parameter	Condition	Min	Typ	Max	Unit
VIN	Input supply voltage		4.5		12	V
ICC	Input supply current	No battery mode , RS=0.1Ω, Standby mode (Charge termination)		150	180	μA
		Shutdown mode (CS=GND, Vin<VBAT, or Vin<VUV)		120	140	μA
				120	140	μA
				120	140	μA
VFLOAL	Charge cut-off 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
IBAT	BAT Pin Current: (Current Mode test conditions are CS = VREG, battery = 7.5V)	RS=0.1Ω, Constant current mode, RS=67mΩ, Constant current mode, Standby Mode , VBAT=8.4V, VIN=0V , VBAT=8.4V	850	1000	1150	mA
			1300	1500	1700	mA
			0	-1	-1	uA
			0	-1	-1	uA
ITRIKL	Trickle pre-charge current RTRICK Pin to 50k Resistance	1.2V<VBAT<VTRIKL , RS=0.067	240	300	360	mA
F	Oscillation frequency		350	400	500	KHz
DMAX	Maximum Duty Cycle			100%		
DMIN	Minimum duty cycle		0%			
VTRIKL	Trickle Charge Threshold Voltage (8.4V)	RS=1Ω, VBAT Rise	5.6	5.8	6.0	V
	Trickle Charge Threshold Voltage (4.2V)		2.8	2.9	3.0	
VTRHYS	Hysteresis voltage trickle charging	RS=1Ω	60	80	100	mV
VUV	VIN Undervoltage lockout threshold	VIN From low to high	3.5	3.6	3.8	V
VUVHYS	VIN Undervoltage lockout threshold		150	200	300	mV
V _{ASD}	VIN-VBAT Lockout threshold voltage	VIN From low to high	60	100	140	mV
		VIN From high to low	5	30	50	mV
V _{CHRG}	CHRG Pin output low voltage	I _{CHRG} =5mA		0.3	0.6	V
V _{STDBY}	STDBY Pin output low voltage	I _{STDBY} =5mA		0.3	0.6	V

V_{TEMP-H}	TEMP Pin high-end shutdown voltage			>80	82	%* VR EG
V_{TEMP-L}	TEMP Pin low-end shutdown voltage		43	<45		%* VR EG
ΔV_{RECHRG}	Rechargeable battery threshold voltage	$V_{FLOAT}-V_{RECHRG}$	80	150	200	mV
T_{LIM}	Chip protection temperature			110		°C
R_{ON}	Power FET on-resistance			170		m Ω
t_{ss}	Soft-start time	$I_{RBATR}=0$ to $I_{BAT}=0.1V/R_s$		20		μ S
$t_{RECHARGE}$	Recharge Comparator Filter Time	V_{BAT} High to Low	0.8	1.8	4	mS
t_{TERM}	Termination Comparator Filter Time	IBAT Below C/10	0.8	1.8	4	mS

Typical performance indicators (CS set to 8.4V lithium battery charging mode)

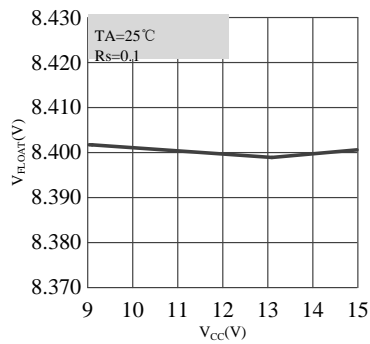


Figure 4

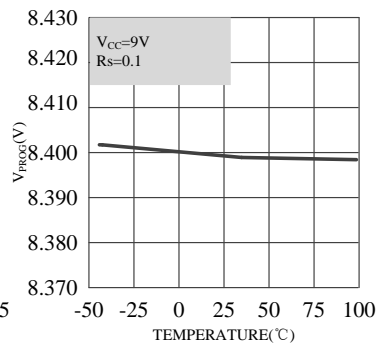


Figure 5

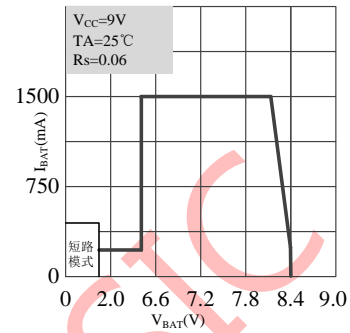


Figure 6

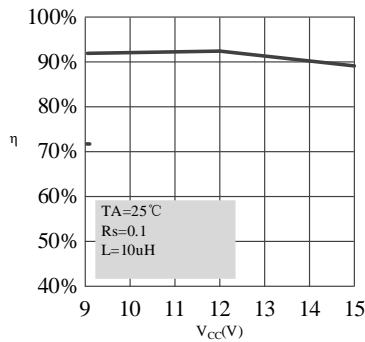


Figure 7

Figure 4 : Relationship between battery cut-off voltage and supply voltage

Figure 5 : Relationship between cut-off voltage and ambient temperature

Figure 6 : Relationship between charging current and battery voltage

Figure 7 : Relationship between efficiency and supply voltage

Pin Function

VIN (PIN 1、4、5、16): the positive input voltage terminal. Voltage across this pin is the power supply of the internal circuit, VIN varies between 5V to 12V with 10uF and 0.1uF bypass capacitors, Dissipative resistance connected in series with 0.2 ohm. When voltage

difference between VIN and VRBATR is less than 30mv, TP5100 enters shutdown mode, allowing IRBATR drops to 1μA.

LX (PIN 2、3): Built-PMOSFET power pipe drain connection. LX is TP5100's current output terminal, and it is connected to the external inductor as the input for battery's charging current.

PWR_ON-(PIN6):Power switching control pin. When the chip is connected to the power supply, PWR_ON-internal switch is pulled low, and PMOS is on; when the chip is not connected to the power supply, PWR_ON-switch is pulled high to BAT voltage, and PMOS is off. This pin can be used for power supply switching, and monitoring power supply functioning.

GND (Pin 7): Power Ground.

VS (Pin8): Positive input terminal for output current detection.

BAT(Pin9):Battery voltage detection terminal. The positive terminal of the battery is connected to this pin.

VREG(pin10): internal power supply. VREG is an internal power supply, with an external 0.1uF bypass capacitor to ground. Maximum current is up to 5mA.

TS(Pin11):The battery temperature detection input terminal. TS pin is connected to NTC (negative coefficient temperature thermistor) sensor's output terminal of the battery. If TS pin voltage is less than 45% or greater than 80% of VREG voltage, it means the battery temperature is too low or too high, charging is suspended. If TS is directly connected to GND, battery temperature detection function is canceled, the other charging function remain.

RTRICK(Pin12):Trickle pre-charge current setting terminal. If connecting RTRICK pin to 50K resistance, then pre-charging current is set to 20%

of pre-set constant current, through an external resistor. If RTRICK is floating then pre-charge current is set to the constant current.

CS (Pin13): Lithium ion status selection input terminal. CS pin high input voltage level (VREG) will make TP5100 the lithium-ion battery charging state until 8.4V and enters shutdown state. If CS pin is floating, TP5100 becomes 4.2V lithium-ion battery charging status until 4.2V, and enters shutdown state. Low input voltage level shutdown TP5100. CS pin can be driven by TTL or CMOS voltage level.

$\overline{\text{STDBY}}$ (Pin 14): Battery charging completion, green LED indicator. When the battery is fully charged, internal switch pulls $\overline{\text{STDBY}}$ to low, indicating the completion of charging. Otherwise, the pin will be in a high impedance state.

$\overline{\text{CHRG}}$ (Pin 15): Charging Status, Red LED indicator. When charging the battery, the internal switch pin is pulled low, which means that charging is in progress; otherwise the pin is in high impedance state.

operational principle

TP5100 is designed for 8.4V / 4.2V double/single-cell lithium-ion battery switching current charger chip, using a internal power transistor for battery's trickle, constant current and constant voltage charging. Charge current can be programmed by an external resistor, with maximum continuous charge current up to 2A, and it does not require additional anti-intrusion diodes. TP5100 consists of two open-drain status output indicating terminals, charging status $\overline{\text{CHRG}}$ terminal and battery fully charged status $\overline{\text{STDBY}}$ terminal. The internal chip power management circuitry automatically reduces the charging current when the chip junction temperature exceeds 145 °C; this feature allows users to maximize the use of the chip's power handling capability, and do not worry about overheating and damages to the chip or chip external components.

When the input voltage is greater than the chip start-up threshold voltage, the chip is connected to a high voltage level (VREG) or floating, TP5100 begins to charge the battery. $\overline{\text{CHRG}}$ pin outputs at low voltage, means that charging is in progress. If double lithium-ion battery voltage is lower than 5.8V (single-cell lithium ion battery voltage is lower than 2.9V), battery is pre-charged with trickle charger at a small current level (pre-charge current is adjustable through an external resistor). Constant

charging current is determined by the resistance between VS pin and VBAT pin. When the double lithium-ion battery voltage approaches 8.4V (single-cell lithium-ion battery close to 4.2V), about 50mV to cut-off voltage (depending on the resistance of the circuit connection and internal resistance of battery voltage), the charging current gradually decreases, TP5100 enters constant voltage charging mode. When the charge current is reduced to cut-off current, charging cycle is complete, the terminal $\overline{\text{CHRG}}$ outputs high-impedance state, while $\overline{\text{STDBY}}$ outputs lows voltage level.

When the battery voltage falls below the recharge threshold (double lithium-ion battery 8.1V / single-cell lithium-ion battery 4.05V), it automatically starts a new charging cycle. Chip precision internal voltage reference, error amplifier and the resistor divider network ensure the accuracy of the battery terminal cutoff voltage within $\pm 1\%$, which meets the lithium-ion battery charging requirements. Power failure or the battery voltage is lower than the input battery voltage, the charger enters a low-power shutdown mode, no external anti-intrusion diode is needed, chip leakage from the battery is closed to 1uA.

Charging cut-off voltage selector

selector

TP5100 has double / single lithium two battery charging cut-off voltage choices. When connecting CS terminal to the high potential (VREG), it is the 8.4V double lithium-ion battery charging standard with cut-off voltage 8.4V. When the CS terminal is vacant, it is single-cell lithium-ion battery charging standard, with cut-off voltage 4.2V. When CS is connected to GND, the charger stops charging.

TP5100 has CS composite design, which in under external control for switching between charging mode and shutdown mode.

When the CS side vacant, it means that TP5100 is a single-cell lithium-ion charging battery.

8.4V double lithium-ion battery's switching of charging and shutdown modes. As shown in Figure8, an open-drain output port is connected to the CS terminal. If the NMOS transistor gate inputs low, N1 off, then CS is high with cut-off charging voltage of 8.4V; TP5100 charges double lithium-ion batteries. When the NMOS transistor gate inputs high, N1 turns on, then CS terminal is pulled down to GND, TP5100 is in shutdown mode. VREG pin can output 5mA driving current, selectable pull-up resistance is within 1k-100k.

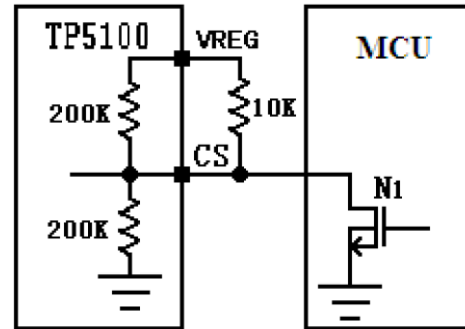


Figure 8 external controlled 8.4V lithium-ion battery's state of charging and shutdown mode switching

Charging current setting

Battery charging current I_{BAT} , is determined by the external current sensor resistor R_s , which can be determined by the ratio of the threshold voltage V_s across R_s and the constant charging current. The voltage across R_s under the constant current is 100mV.

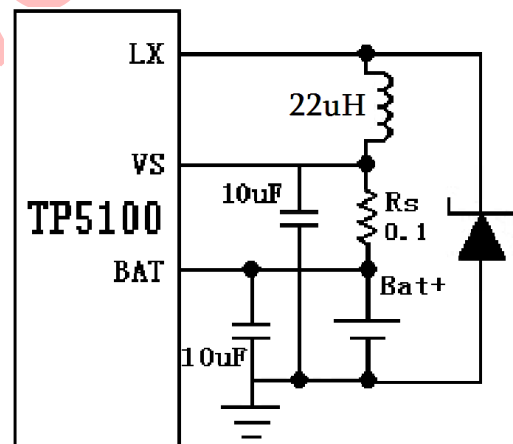


Figure 9 battery charging current setting
Setting resistor and the charge current are calculated using the following formula :

$$R_s = \frac{0.1V}{I_{BAT}} \quad (\text{Current units A,}$$

resistance units Ω).

Examples: To set the charging current to 1A, plugging into the formula, we get $R_s=0.1\Omega$

Table 2 shows different values of R_s , corresponding to different current setting, which is convenient for circuit design.

Table 2: R_s and its corresponding constant charging current

R_s (Ω)	I_{BAT} (mA)
1	100
0.2	500
0.1	1000
0.067	1500
0.05	2000

Trickle pre-charging current setting

If the battery voltage is lower than the pre-charge threshold voltage, TP5100 will start a pre-charging process to charge the battery; TP5100 pre-charging current can be set by TRICK port. The pre-charging current is set by a resistor connected in between TRICK pin and ground.

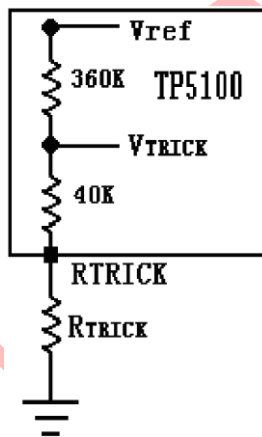


Figure 10 The TRICK end internal circuit diagram

As can be seen from figure 10, If R_{TRICK} port is connected to 50kohm resistance, the ratio of the voltage share across resistor is the ratio of the pre-charging trickle flow to the constant pre-charging current flow.

Then pre-charging current is 1/5 of the constant charging current. This pin only changes trickle current flow, it has no effects on shutdown current, which is still remained at 10% of constant current.

Setting resistor and pre-charging current is calculated using the following formula:

$$R_{TRICK} = \frac{400kI_{TRICK} - 40kI_{BAT}}{I_{BAT} - I_{TRICK}}$$

In order to facilitate the customers' design, table 3 shows the relationship between R_{TRICK} and setting its pre-charging trickle current based on constant current I_{BAT} .

Table 3: R_{TRICK} their settings trickle current and constant current I_{BAT} relationship:

R_{TRICK} (k)	I_{TRICK} (mA)
50k	20% I_{BAT}
114k	30% I_{BAT}
320k	50% I_{BAT}
NC	100% I_{BAT}

Charging termination

In constant voltage status, when the charging current drops to 1/10 of the maximum constant current value, the charging cycle is terminated. This condition is detected by using an internal comparator filter to monitor the voltage drop across R_s . When the time for voltage drop across R_s to reach 10mV is longer than t_{TERM} (typically 1.8ms), charging is terminated. When charging current is switched off, TP5100 enters standby mode, the input current supply drops to 120 μ A, and battery drain current outflow is around 1 μ A.

In standby mode, TP5100 continues to monitor the BAT pin voltage. If the double lithium-ion battery voltage across the pin falls below 8.25V (single lithium battery voltage drops to 4.05V), which is below the rechargeable threshold voltage V_{RECHRG} , the new charging cycle begins and recharges the battery.

Charging status indicator

TP5100 has two open-drain status output terminals, \overline{CHRG} and \overline{STDBY} . When the charger is charging, \overline{CHRG} is pulled low, in other states, \overline{CHRG} is in high-impedance state. When the battery temperature is outside the normal temperature range, both \overline{CHRG} and \overline{STDBY} pins output high impedance. When the status indicator is not used, the unused pin is connected to the ground.

Table 4: charging indicator status

Green \overline{STDBY}	Red \overline{CHRG}	State of charge
off	on	charging state
on	off	Fully charged state
off	off	Under-voltage, battery temperature is too high, too low, under other fault condition or without battery access. (TS used)
Green light, red light flashes T=0.5-2S		

Power supply, battery power switching control

TP5100 integrates power supply, battery power supply switching control pin PWR_ON-. When connecting VIN to input, PWR_ON-outputs low can turn on PMOS. When VIN is removed, PWR_ON-outputs high potential (battery voltage) can turn off PMOS.

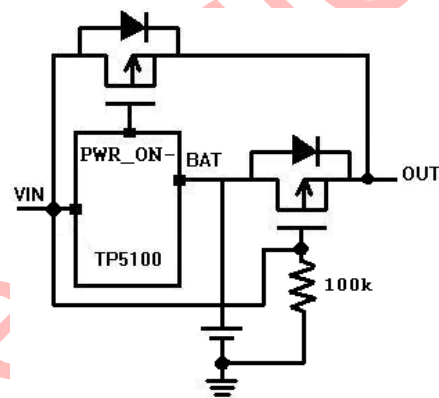


Figure 11 Schematic of power switching control

Battery over-temperature protection

To prevent damages caused by either high or low temperature to the battery, TP5100 integrated internal battery temperature detection circuit. Battery temperature is detected by measuring TS pin voltage; which is realized by the voltage division network of the internal NTC thermistor and a resistor, as shown in Figure 12. TP5100 compares its two internal threshold voltages V_{LOW} and V_{HIGH} to voltage across TS pin to determine whether the battery temperature is outside the

standard range. Inside TP5100, V_{LOW} is fixed at $45\% \times V_{REG}$ and V_{HIGH} is fixed at $80\% \times V_{REG}$. If the voltage across TS pin $V_{TS} < V_{LOW}$

or $V_{TS} > V_{HIGH}$, the battery

temperature is too high or too low, the charging process will be suspended; if the voltage across TS pin is in between V_{LOW} and V_{HIGH} , the charging cycle resumes. If the pin is connected to ground, battery temperature detection function will be disabled.

Example: under room temperature $25\text{ }^{\circ}\text{C}$, $R_{NTC} = 10\text{k}$; setting protection temperature to be $60\text{ }^{\circ}\text{C}$, then $R_{NTC} = 3\text{k}$, and the calculated $R_{NTC} = 3.6\text{k}$. The voltage across NTC resistor is 45% of V_{REG} , which would terminate charging at $60\text{ }^{\circ}\text{C}$.

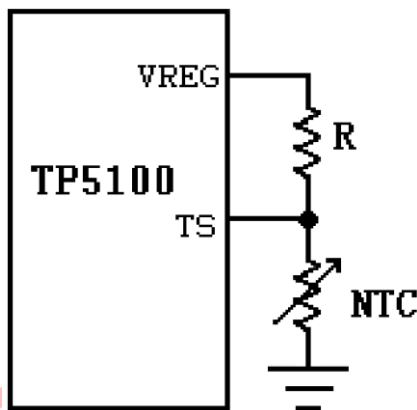


Figure 12 NTC connection diagram

Chip thermal limiting

If the chip temperature attempts to rise above $110\text{ }^{\circ}\text{C}$ default value, then an internal thermal feedback loop will reduce the charging current setting value. This feature prevents overheating of TP5100, and allows users to maximize the power managing capability for a

given circuit board without the risk of damaging TP5100. It ensures that the charger will automatically reduce the current under worst-case conditions, and users can set the charging current according to a typical (but not the worst case) ambient temperature.

Limiting and output short

circuit

TP5100 integrates a variety of protections; the chip has a limited input current which is 3A at maximum to prevent damages due to excessive current. When the output terminal voltage drops below approximately 1.2V , the chip enters short circuit protection mode, the chip input current is limited to 10% of the maximum current value, which is about 450mA . The current value varies regarding different input voltages.

Automatic restart

Once the charge cycle is terminated, TP5100 immediately adopts a comparator with 1.8ms filter time ($t_{RECHARGE}$) to monitor voltage across BAT pin continuously. When the battery voltage drops below 90% of the battery capacity, the charging cycle begins again. This ensures that the battery is maintained at (or near) a fully charged status. In the recharging cycle, $\overline{\text{CHRG}}$ pin output re-enters a strong pull-down state.

Undervoltage lockout

An internal undervoltage lockout

circuit monitors the input voltage, and keeps the charger in shutdown mode before V_{in} rises above the limited value of undervoltage lockout. UVLO circuit will keep the charger in shutdown mode and the battery has no discharging current. If the UVLO comparator jumps, then the charger will not exit shutdown mode until V_{IN} rises 50mV higher than the battery voltage. Thus, customers do not have to worry about the power leaking when input power supply is insufficient.

Thermal Considerations

Although QFN16 has small packaging dimensions, it has good thermal dissipation characteristics. The heat dissipation characteristics can be further improved with a proper PCB design. It is suggested to adopt a well-designed PCB board layout for thermal dissipation, in order to achieve increase in charging current. Thermal path for dissipating heat can be generated from the IC chip to the lead frame, and through heat sink to reach the bottom of the chip through the PCB copper surface. Copper area connected to the pin should be as wide as possible and extends out to larger copper areas to better dissipate heat to the surrounding environment. It is recommended to add more holes to internal and back copper circuit layer to improve the overall thermal performance of the charger. When making the PCB layout design, other heat sources on the board must also be

considered even are irrelevant to charger, because they will affect overall temperature increase and the maximum charging current.

Inductor Selection

To ensure system stability, in pre-charging and constant current charging phases, the system needs to ensure the operation is in continuous mode (CCM). According to the inductor current formula:

$$\Delta I = \frac{1}{L \times FS} \left(\frac{V_{IN} - V_{BAT}}{V_{IN}} \right) \times V_{BAT}$$

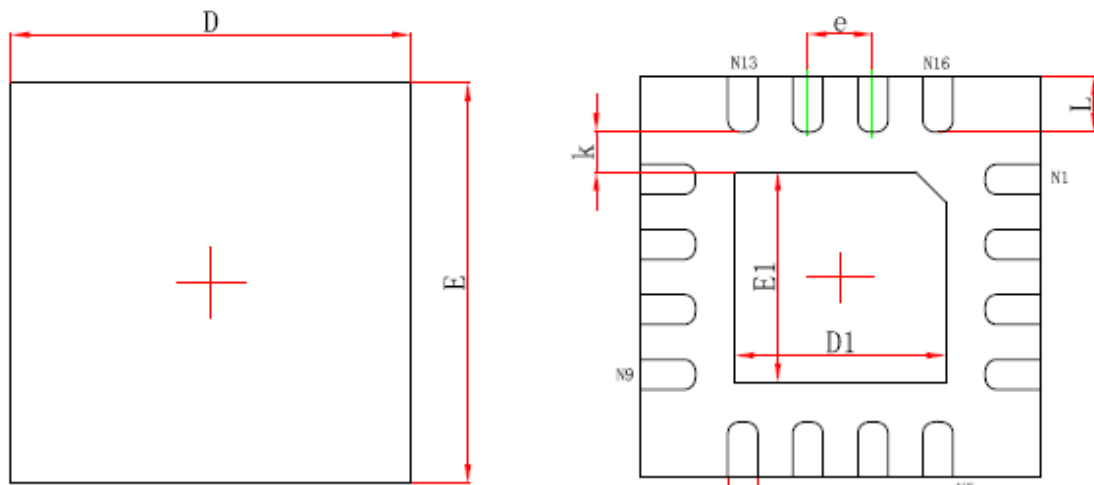
Where ΔI is the inductor ripple, FS is the switching frequency. In order to ensure both pre-charging and constant current charging mode are in CCM, ΔI is set to pre-charging current value, which is 1/5 of a constant charging current. The inductance can be calculated based on the input voltage requirements.

Inductance should be picked greater or equal to 22uH (more stable with larger inductance), it is recommended to use 22uH. If the power is set to have V_{IN} of 5V, single 4.2V lithium-ion battery charging mode is used, and when setting the charging current to be greater or equal to 500mA, 10uH inductance can be used.

Inductive charging current is set to be greater than the charging current and inductor with smaller internal resistance should be chosen.

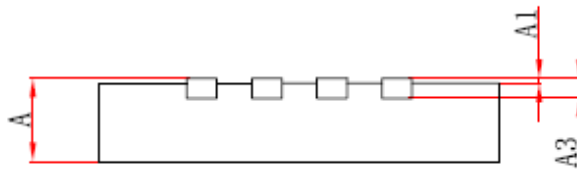
Packaging Description

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

Package	Reel	Pcs/ disc	Tray / box	Boxes / carton	Pcs / box
QFN4*4	13Inch	5000	1	8	40000

TP5100 Note

1. Capacitors should be as close as possible to the chip.
2. VS terminal, VIN terminal and BAT terminal should use parallel combination of ceramic capacitor of 0.1uF with 10uF electrolytic capacitor, X5R or X7R level ceramic capacitor.
3. Selecting inductors with sufficient power.
4. Choosing Schottky diode with better or equal capability of voltage conduction and decreasing current, compared with 2A Schottky diode.
5. For VIN and LX, the current loop should be wider than normal signal lines.
6. Pay attention to the nodal locations of each capacitance grounding wire, grounding point should be focused to have better grounding effects.
7. When using the chip in heavy-current work, users should pay attention to the connection of heat sink at the bottom of chip to PCB to ensure good heat dissipation.

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