

# TP4066L 1A Standalone Linear Li-Ion Battery Charger with Thermal Regulation in ESOP8 / DFN2\*2-8

## DESCRIPTION

The TP4066L is a complete constant-current/constant-voltage linear charger for single cell lithium-ion batteries. Its ESOP8/DFN2\*2-8 package and low external component count make the TP4066L ideally suited for portable applications. Furthermore, the TP4066L can work within USB and wall adapter.

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. Full voltage can be divided into three files: 4.35V, 4.2V, 3.6V. and the charge current can be programmed externally with a single resistor. The TP4066L automatically terminates the charge cycle when the charge current drops to 1/10th the programmed value after the final float voltage is reached.

TP4066L Other features include supply voltage self adaptive, current monitor, under voltage lockout, automatic recharge and two status pin to indicate charge termination and the presence of an input voltage.

## FEATURES

- Programmable Charge Current Up to 1000mA
- Complete Linear Charger in ESOP8 Package for Single Cell Lithium-Ion Batteries
- Constant-Current/Constant-Voltage
- Charges Single Cell Li-Ion Batteries Directly from USB Port
- Preset Charge Voltage with 1% Accuracy
- Lithium battery positive and negative polarity reverse connection protection (need to apply connection according to Figure 2)
- Automatic Recharge
- two Charge Status Output Pins
- C/10 Charge Termination
- 2.9V Trickle Charge Threshold
- Soft-Start Limits Inrush Current
- Available Radiator in 8-Lead ESOP/DFN2\*2 Package, the Radiator need connect GND or impending

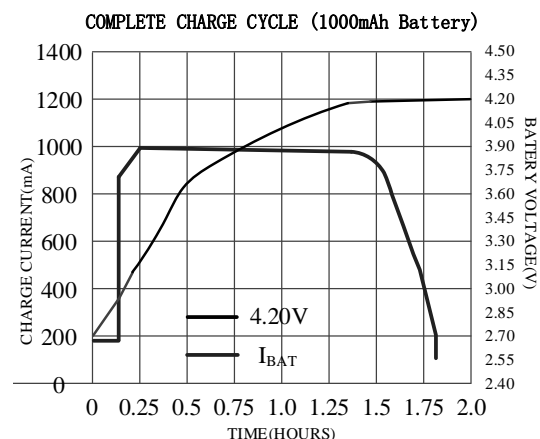
## APPLICATIONS

- Cellular Telephones, PDA, GPS
- Charging Docks and Cradles
- Digital Still Cameras, Portable Devices
- USB Bus-Powered Chargers, Chargers

## ABSOLUTE MAXIMUM RATINGS

- Input Supply Voltage(VCC): -0.3V~8V
- BAT: -4.35V~7V
- TEMP: -0.3V~8V
- CE: -0.3V~8V
- BAT Short-Circuit Duration: Continuous
- BAT Pin Current: 1000mA
- PROG Pin Current: 1000uA
- Maximum Junction Temperature: 145°C
- Operating Ambient Temperature Range: -40°C~85°C
- Lead Temp. (Soldering, 10sec) : 260°C

## COMPLETE CHARGE CYCLE (1000mAh Battery)



## TYPICAL APPLICATIONS

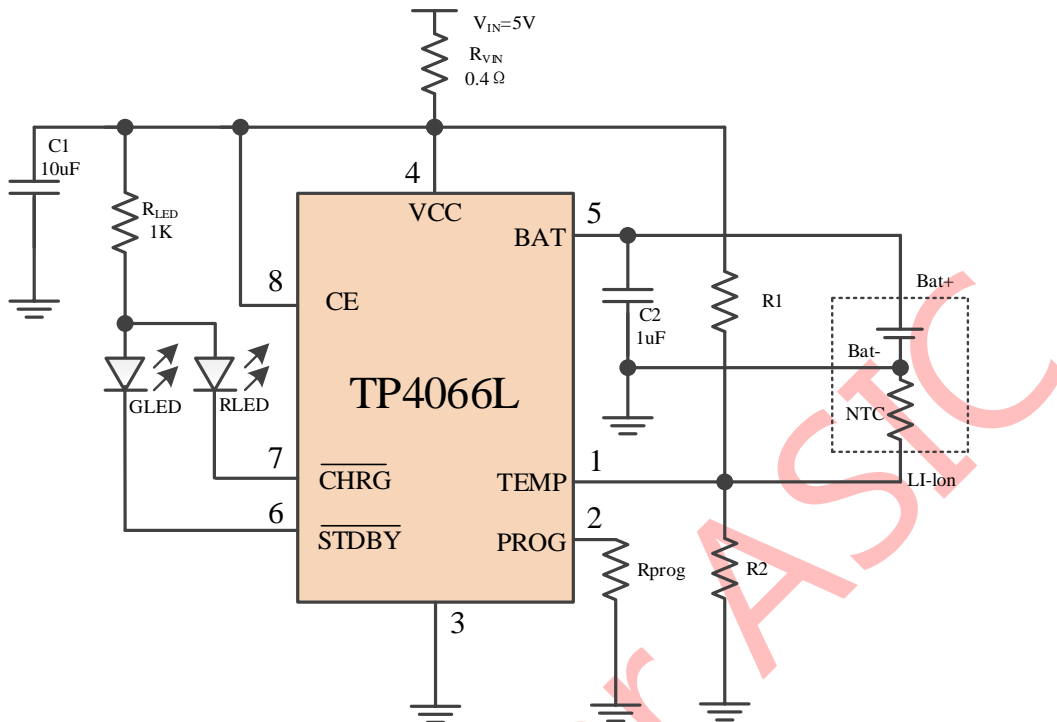


Figure 1 Typical application

## Applications with battery reverse connection protection

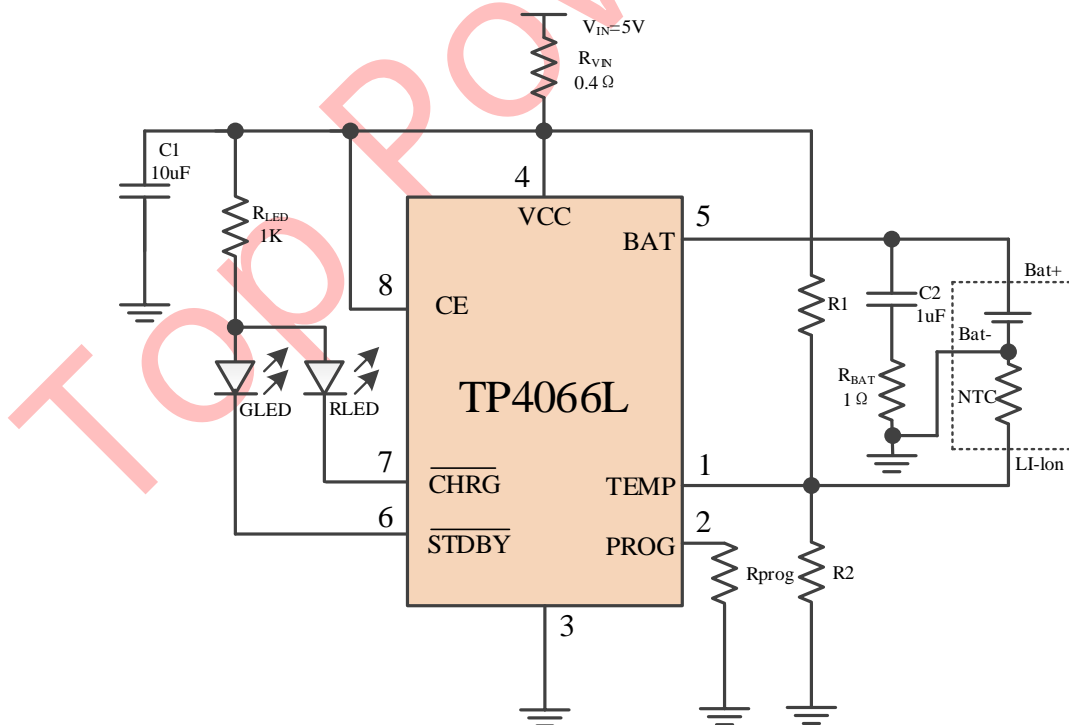
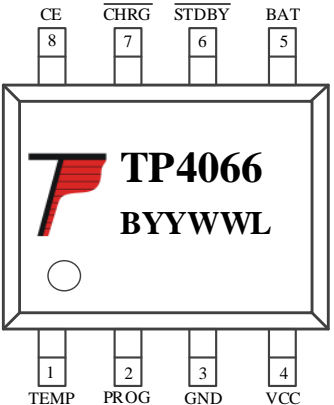
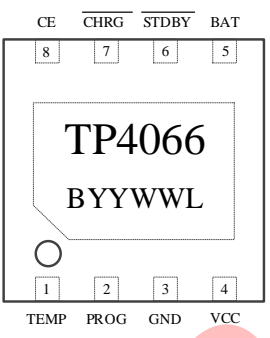


Figure 2 Applications with battery reverse connection protection

## PACKAGE/ORDER INFORMATION

 <p>ESOP8</p>	<b>ORDER PART NUMBER</b>
	TP4066L-4.35V-ESOP8 TP4066L-4.2V-ESOP8 TP4066L-3.6V-ESOP8
	<b>PART MARKING:</b> <b>AYYWWL</b> →4.35V <b>BYYWWL</b> →4.2V <b>CYYWWL</b> →3.6V
	BYYWWL (B is variable and represents different preset voltages. YYWW is the production lot number, variable. L fixed and unchanged)

 <p>DFN2*2-8</p>	<b>ORDER PART NUMBER</b>
	TP4066L-4.35V-DFN228 TP4066L-4.2V-DFN228 TP4066L-3.6V-DFN228
	<b>PART MARKING:</b> <b>AYYWWL</b> →4.35V <b>BYYWWL</b> →4.2V <b>CYYWWL</b> →3.6V
	BYYWW (B is variable and represents different preset voltages. YYWW is the production lot number, variable. L fixed and unchanged)

**ELECTRICAL CHARACTERISTICS**

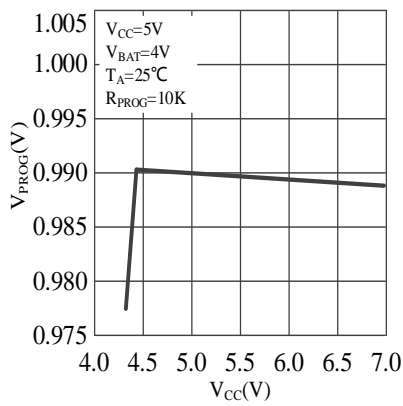
The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A=25^{\circ}\text{C}$ ,  $V_{CC}=5\text{V}$ , unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS	
$V_{CC}$	Input Supply Voltage		● 4.35	5	8.0	V	
$V_{OVP}$	Over Voltage Protection		● 6.5	7	7.5	V	
$I_{CC}$	Input Supply Current	Charge Mode, $R_{PROG} = 1.0\text{K}$	●	100	200	$\mu\text{A}$	
		Standby Mode (Charge Terminated),	●	70	200	$\mu\text{A}$	
		Shutdown Mode ( $R_{PROG}$ Not Connected, $V_{CC} < V_{BAT}$ , or $V_{CC} < V_{UV}$ )	●	70	200	$\mu\text{A}$	
$V_{FLOAT}$	Regulated Output (Float) Voltage	$0^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$		4.306	4.35	4.394	V
				4.158	4.2	4.242	V
				3.564	3.6	3.636	V
$I_{BAT}$	BAT Pin Current (Test condition: $V_{BAT}=4.0\text{V}$ )	$R_{PROG}=2.0\text{k}$ , Current Mode	●	450	500	550	mA
		$R_{PROG}=0.92\text{k}$ , Current Mode	●	900	1000	1100	mA
		Standby Mode, $V_{BAT} = 4.2\text{V}$	●	0	-2.5	-6	$\mu\text{A}$
		Shutdown Mode ( $R_{PROG}$ Not Connected)			$\pm 1$	$\pm 2$	$\mu\text{A}$
		Sleep Mode, $V_{CC} = 0\text{V}$			-1	-2	$\mu\text{A}$
$I_{TRIKL}$	Trickle Charge Current	$V_{BAT} < V_{TRIKL}$ , $R_{PROG}=1.0\text{K}$	● 150	200	250	mA	
$V_{TRIKL}$	Trickle Charge Threshold Voltage	$R_{PROG}=1.0\text{K}$ , $V_{BAT}$ Rising		2.8	2.9	3.0	V
$V_{TRHYS}$	Trickle Charge Hysteresis Voltage	$R_{PROG}=1.0\text{K}$		80	110	140	mV
$V_{UV}$	$V_{CC}$ UVLO Voltage	$V_{CC}$ from low to high	● 3.6	3.8	4.0	V	
$V_{UVHYS}$	$V_{CC}$ UVLO Hysteresis		● 150	200	300	mV	
$V_{ASD}$	$V_{CC}-V_{BAT}$ lockout threshold voltage	$V_{CC}$ from low to high		145	175	210	mV
		$V_{CC}$ from high to low		60	85	110	mV
$I_{TERM}$	C/10 termination current threshold	$R_{PROG}=2.0\text{K}$	●	30	45	60	mA
		$R_{PROG}=1.0\text{K}$	●	60	100	140	mA
$V_{PROG}$	PROG pin voltage	$R_{PROG}=1.0\text{K}$ , current mode	● 0.9	1.0	1.1	V	
$V_{\overline{\text{CHRG}}}$	$V_{\overline{\text{CHRG}}}$ Pin output low voltage	$I_{\overline{\text{CHRG}}} = 2.8\text{mA}$		0.3	0.6	V	
$V_{\overline{\text{STDBY}}}$	$V_{\overline{\text{STDBY}}}$ Pin output low voltage	$I_{\overline{\text{STDBY}}} = 2.8\text{mA}$		0.3	0.6	V	
$V_{TEMP-H}$	TEMP upper trip threshold			80	82	%Vcc	
$V_{TEMP-L}$	TEMP lower trip threshold		43	45		%Vcc	
$\Delta V_{RECHRG}$	Recharge battery threshold voltage	$V_{FLOAT} - V_{RECHRG}$		50	80	110	mV
$T_{LIM}$	Junction Temperature in Constant Temperature Mode			145		$^{\circ}\text{C}$	
$R_{ON}$	The resistance of power FET ON (between VCC and BAT)			800		m $\Omega$	

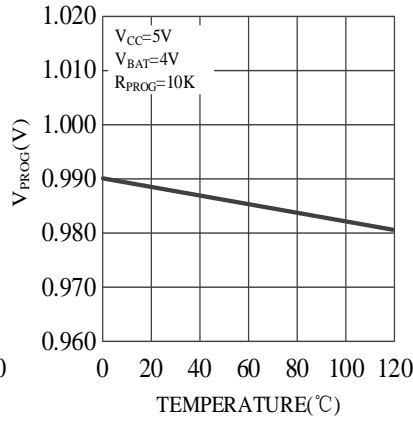
$t_{RECHARG}$ E	Recharge comparator filter time	$V_{BAT}$ from high to low	0.8	1.8	4	ms
$V_{ADPT}$	Vcc adaptive starting voltage	$R_{PROG}=1K$ , $V_{CC}$ from high to low	4.2	4.35	4.45	V

## TYPICAL PERFORMANCE CHARACTERISTICS

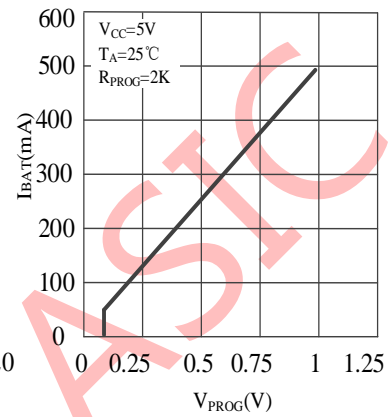
**PROG Pin Voltage vs Supply Voltage  
(Constant Current Mode)**



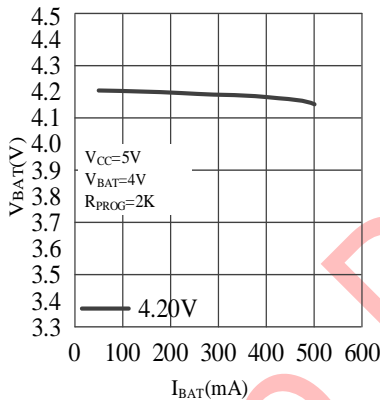
**PROG Pin Voltage vs Temperature**



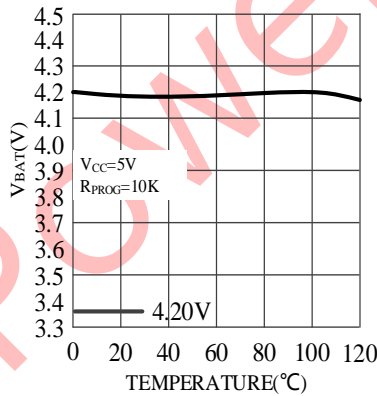
**Charge Current vs PROG Pin Voltage**



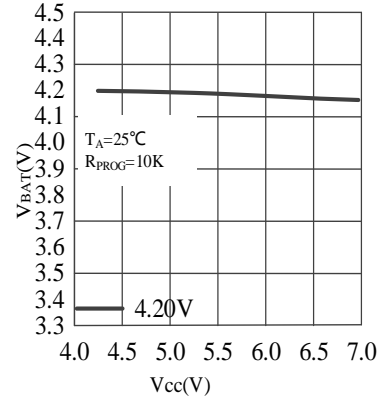
**Regulated Output (Float) Voltage vs Charge Current**



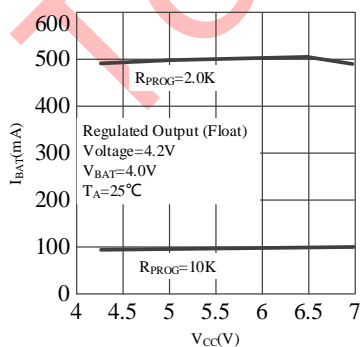
**Regulated Output (Float) Voltage vs Temperature**



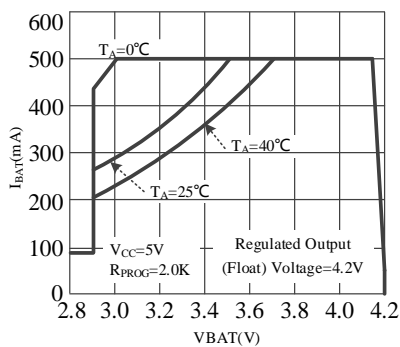
**Regulated Output (Float) Voltage vs Supply Voltage**



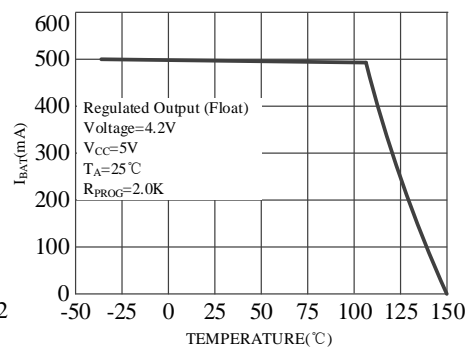
**4.2V Charge Current vs Supply Voltage**



**4.2V Charge Current vs Battery Voltage**



**4.2V Charge Current vs Temperature**



## Pin Description

### ▪TEMP(Pin 1) :Temperature Sense Input

Connecting TEMP pin to NTC thermistor's output in Lithium ion battery pack. If TEMP pin's voltage is below 45% or above 80% of supply voltage VIN for more than 0.15S, this means that battery's temperature is too high or too low, charging is suspended. The temperature sense function can be disabled by grounding the TEMP pin.

### ▪PROG(Pin 2): Constant Charge Current Setting and Charge Current Monitor Pin

charge current is set by connecting a resistor R<sub>ISET</sub> from this pin to GND. When in precharge mode, the ISET pin's voltage is regulated to 0.2V. When in constant charge current mode, the ISET pin's voltage is regulated to 1V. In all modes during charging, the voltage on ISET pin can be used to measure the charge current as follows:

$$I_{BAT} = \frac{930}{R_{PROG}} \pm 10\% \quad (I_{BAT} \leq 0.1A, I_{BAT} > 0.8A)$$

$$I_{BAT} = \frac{970}{R_{PROG}} \pm 10\% \quad (0.8A \geq I_{BAT} > 0.1A)$$

### ▪GND(Pin3): Ground Terminal

▪VCC(Pin 4): Positive Input Supply Voltage VIN is the power supply to the internal circuit. When VIN drops to within 60mV of the BAT pin voltage, TP4066L

enters low power sleep mode, dropping BAT pin's current to less than 1uA.

### ▪BAT(Pin5): Battery Connection Pin.

Connect the positive terminal of the battery to BAT pin. BAT pin draws less than 1uA current in chip disable mode or in sleep mode. BAT pin provides charge current to the battery and provides regulation voltage of 4.2V.

### ▪ $\overline{STDBY}$ (Pin6): Open Drain Charge

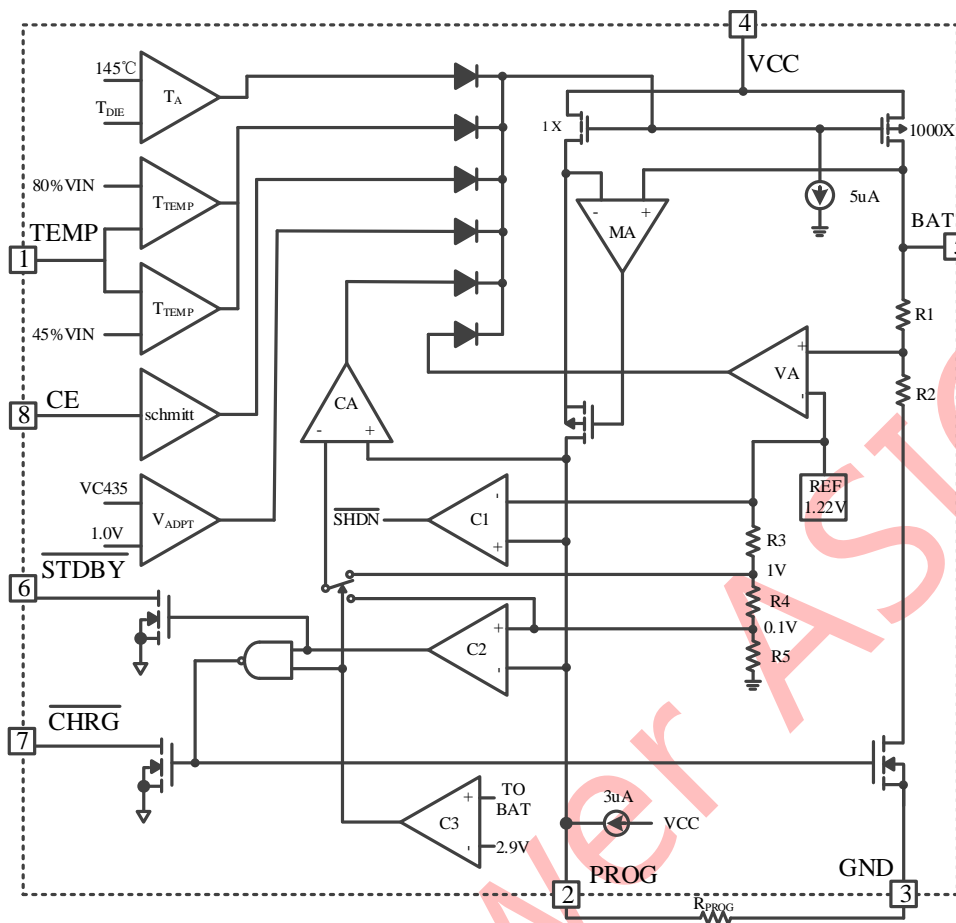
Status Output When the battery Charge Termination, the  $\overline{STDBY}$  pin is pulled low by an internal switch, otherwise  $\overline{STDBY}$  pin is in high impedance state.

### ▪ $\overline{CHRG}$ (Pin7): Open Drain Charge

Status Output When the battery is being charged, the  $\overline{CHRG}$  pin is pulled low by an internal switch, otherwise  $\overline{CHRG}$  pin is in high impedance state.

▪CE(Pin8): Chip Enable Input. A high input will put the device in the normal operating mode. Pulling the CE pin to low level will put the TP4066L into disable mode. The CE pin can be driven by TTL or CMOS logic level. The CE pin itself does not have an anti-reverse function. If you need this function, you need a series of resistors.

## BLOCK DIAGRAM



## OPERATION

The TP4066L is a complete CC/CV linear charger for single cell lithium-ion batteries. It can deliver up to 1A of charge current with a final float voltage accuracy of  $\pm 1\%$ . The TP4066L includes an internal PMOS architecture and thermal regulation circuitry. No blocking diode or external current sense resistor is required. TP4066L includes two charge status open-drain pins: charge status indicator  $\overline{CHRG}$  and

battery failure status output  $\overline{STDBY}$ . The internal thermal regulation circuit reduces the programmed charge current if the die temperature attempts to rise above a preset value of approximately  $145\text{ }^{\circ}\text{C}$ . This feature protects the TP4066L from excessive temperature, and allows the user to push the limits of the power handling

capability of a given circuit board without risk of damaging the TP4066L. Another benefit of adopting thermal regulation is that charge current can be set according to typical, not worst-case, ambient temperature for a given application with the assurance that the charger will automatically reduce the current in worst-case conditions.

### Normal Charge Cycle

The charge cycle begins when the voltage at the  $V_{CC}$  pin rises above the UVLO threshold level, a program resistor is connected from the PROG pin to ground, and the CE pin is pulled above the chip enable threshold. The  $\overline{CHRG}$  pin outputs a logic low to indicate that the charge cycle is on going. When the battery voltage is below 3V, the charger



enters trickle charge mode to bring the battery voltage up to a safe level for charging. When voltage on the BAT pin rises above 3V, the charger goes into the fast charge CC mode. In CC mode, the charge current is set by  $R_{PROG}$ . When the battery approaches the final float voltage of 4.2V, the charge current begins to decrease as the TP4066L enters the CV mode. When the charge current drops to 1/10th of the programmed value, the charge cycle terminates, and  $\overline{CHRG}$  pin becomes high

impedance while  $\overline{STDBY}$  pin is pulled low.

The charge cycle can also be automatically restarted if the BAT pin voltage falls below the recharge threshold. The on-chip reference voltage, error amplifier and the resistor divider network provide regulation voltage with 1% accuracy, which can meet the requirement of lithium-ion and lithium polymer batteries. When the input voltage is not present, or input voltage is below  $V_{BAT}$ , the charger enters a sleep mode, dropping battery drain current to less than 1  $\mu$  A. This greatly reduces the current drain on the battery and increases the standby time. The charger can be shut down by forcing the CE pin to GND.

### Programming Charge Current

The charge current is programmed using a single resistor from the PROG pin to ground. The program resistor and the charge current are calculated using the following equations.

$$R_{PROG} = \frac{970}{I_{BAT}} \quad (0.8A \geq I_{BAT} > 0.1A)$$

$$R_{PROG} = \frac{930}{I_{BAT}} \quad (I_{BAT} \leq 0.1A, I_{BAT} > 0.8A)$$

In applications, one can refer to the following chart showing the relation between  $R_{PROG}$  and charge current:

$R_{PROG}$ (K)	$I_{BAT}$ (mA)
30	27
20	44
10	93
5.1	190
3.9	250
3	325
2	495
1.5	650
1.2	800
1.0	945
0.92	1000

### Charge Termination

A charge cycle terminates when the charge current falls to 1/10th the programmed value after the final float voltage is reached. This condition is detected by using an internal filtered comparator to monitor the PROG pin. When the PROG pin voltage falls below 100mV for longer than  $t_{TEMP}$  (typically 1.8ms), charging is terminated. The charge current is latched off and the TP4066L enters standby mode, where the input supply current drops to 70  $\mu$ A.

**(Note: C/10 termination is disabled in trickle charging and thermal limiting modes).**

When charging, transient loads on the BAT pin can cause the PROG pin to fall below 100mV for short periods of time before the DC charge current has dropped to 1/10th the programmed value. The 1.8ms filter time ( $t_{TEMP}$ ) on the termination comparator ensures that transient loads of this nature do not result in premature charge cycle termination. Once the average charge current drops below 1/10th the programmed value, the TP4066L terminates the charge cycle and ceases to provide any current through the BAT pin. In this state all loads on the BAT pin must be supplied by the battery.

The TP4066L constantly monitors the BAT



pin voltage in standby mode. If this voltage drops below the 4.12V recharge threshold ( $V_{RECHRG}$ ), another charge cycle begins and charge current is once again supplied to the battery. Figure 1 shows the state diagram of a typical charge cycle.

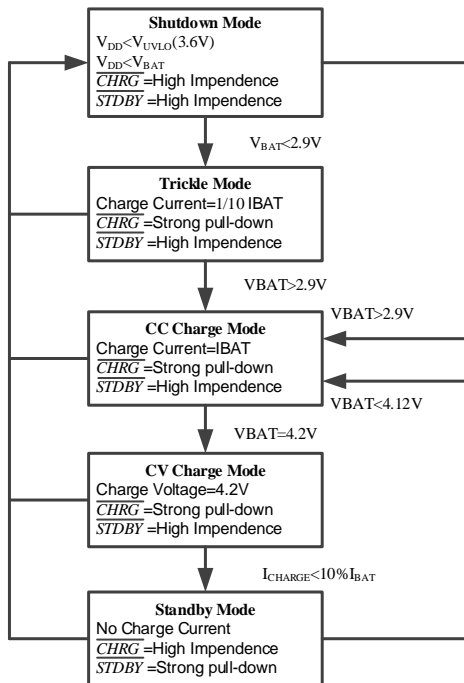


Fig.1 State diagram of a typical charge cycle

### Charge status indicator

TP4066L has two open-drain status indicator:  $\overline{CHRG}$  and  $\overline{STDBY}$ .  $\overline{CHRG}$  is pull-down when the TP4066L is in a charge cycle, and  $\overline{CHRG}$  becomes high impedance for other states. Both  $\overline{CHRG}$  and  $\overline{STDBY}$  will be high impedance when the battery is operating out of the normal temperature.

When TEMP pin is connected, and battery is not connected to charger: both red LED and green LED are OFF to indicate a failure mode. When TEMP is grounded, the battery temperature sense function is disabled. If battery is not connected to charger,  $\overline{CHRG}$  pin outputs a PWM level to indicate no

battery failure mode. If BAT pin connects to a 10 $\mu$ F capacitor, the frequency of  $\overline{CHRG}$  flicking will be with T=1-4s. If not using a status indicator, the pins should be connected to GND.

Charger's Status	Red LED $\overline{CHRG}$	Green LED $\overline{STDBY}$
Charging	ON	OFF
Charging Completes	OFF	ON
Under-voltage, battery's temperature is too high or too low, or not connect to battery (TEMP pin in use)	OFF	OFF
BAT pin is connected to 10uF capacitor, and not connect to battery (TEMP connects to GND)	Green LED ON, Red LED flicking with T=1-4s	

### Thermal limiting

An internal thermal feedback loop reduces the programmed charge current if the die temperature attempts to rise above a preset value of approximately 145 °C, and current will be reduced to zero if die temperature reaches beyond 150 °C. This feature protects the TP4066L from excessive temperature and allows the user to push the limits of the power handling capability of a given circuit board without risk of damaging the TP4066L. The charge current can be set according to typical (not worst-case) ambient temperature with the assurance that the charger will automatically reduce the current in worst-case conditions.

To prevent the damage caused by the very high or very low temperature done to the battery pack, the TP4066L continuously senses battery pack temperature by measuring the voltage at TEMP pin determined by the internal voltage divider circuit and the battery's internal NTC thermistor.

The TP4066L compares the voltage at TEMP pin ( $V_{TEMP}$ ) against its internal  $V_{TEMP\_L}$  and  $V_{TEMP\_H}$  thresholds to determine if charging is allowed.  $V_{TEMP\_L}$  is fixed at  $(45\% \times V_{CC})$ , while  $V_{TEMP\_H}$  is fixed at  $(80\% \times V_{CC})$ . If  $V_{TEMP} < V_{TEMP\_L}$  or  $V_{TEMP} > V_{TEMP\_H}$ , it indicates that the battery temperature is too high or too low and the charge cycle is suspended. When  $V_{TEMP}$  is in between  $V_{TEMP\_L}$  and  $V_{TEMP\_H}$ , charging cycle resumes. The battery temperature sense function can be disabled by connecting TEMP pin to GND.

### Selecting R1 and R2

The values of R1 and R2 in the application circuit can be determined according to the assumed temperature monitor range and thermistor's values. See following example as a reference:

Assume temperature monitor range is  $T_L \sim T_H$ , ( $T_L < T_H$ ); the thermistor in battery has negative temperature coefficient (NTC).  $R_{TL}$  is thermistor's resistance at  $T_L$ ,  $R_{TH}$  is the resistance at  $T_H$ , so  $R_{TL} > R_{TH}$ . Then at temperature  $T_L$ , the voltage at TEMP pin is:

$$V_{TEMP\_L} = \frac{R_2 \parallel R_{TL}}{R_1 + R_2 \parallel R_{TL}} \times V_{IN}$$

At temperature  $T_H$ , the voltage at TEMP pin is:

$$V_{TEMP\_H} = \frac{R_2 \parallel R_{TH}}{R_1 + R_2 \parallel R_{TH}} \times V_{IN}$$

We know

$$V_{TEMP\_L} = V_{HIGH} = K_2 \times V_{CC} \quad (K_2=0.8) ;$$

$$V_{TEMP\_H} = V_{LOW} = K_1 \times V_{CC} \quad (K_1=0.45)$$

Then we can have :

$$R_1 = \frac{R_{TL} R_{TH} (K_2 - K_1)}{(R_{TL} - R_{TH}) K_1 K_2}$$

$$R_2 = \frac{R_{TL} R_{TH} (K_2 - K_1)}{R_{TL} (K_1 - K_1 K_2) - R_{TH} (K_2 - K_1 K_2)}$$

Likewise, for positive temperature coefficient thermistor in battery, we have  $R_{TH} > R_{TL}$  and we can calculate:

$$R_1 = \frac{R_{TL} R_{TH} (K_2 - K_1)}{(R_{TH} - R_{TL}) K_1 K_2}$$

$$R_2 = \frac{R_{TL} R_{TH} (K_2 - K_1)}{R_{TH} (K_1 - K_1 K_2) - R_{TL} (K_2 - K_1 K_2)}$$

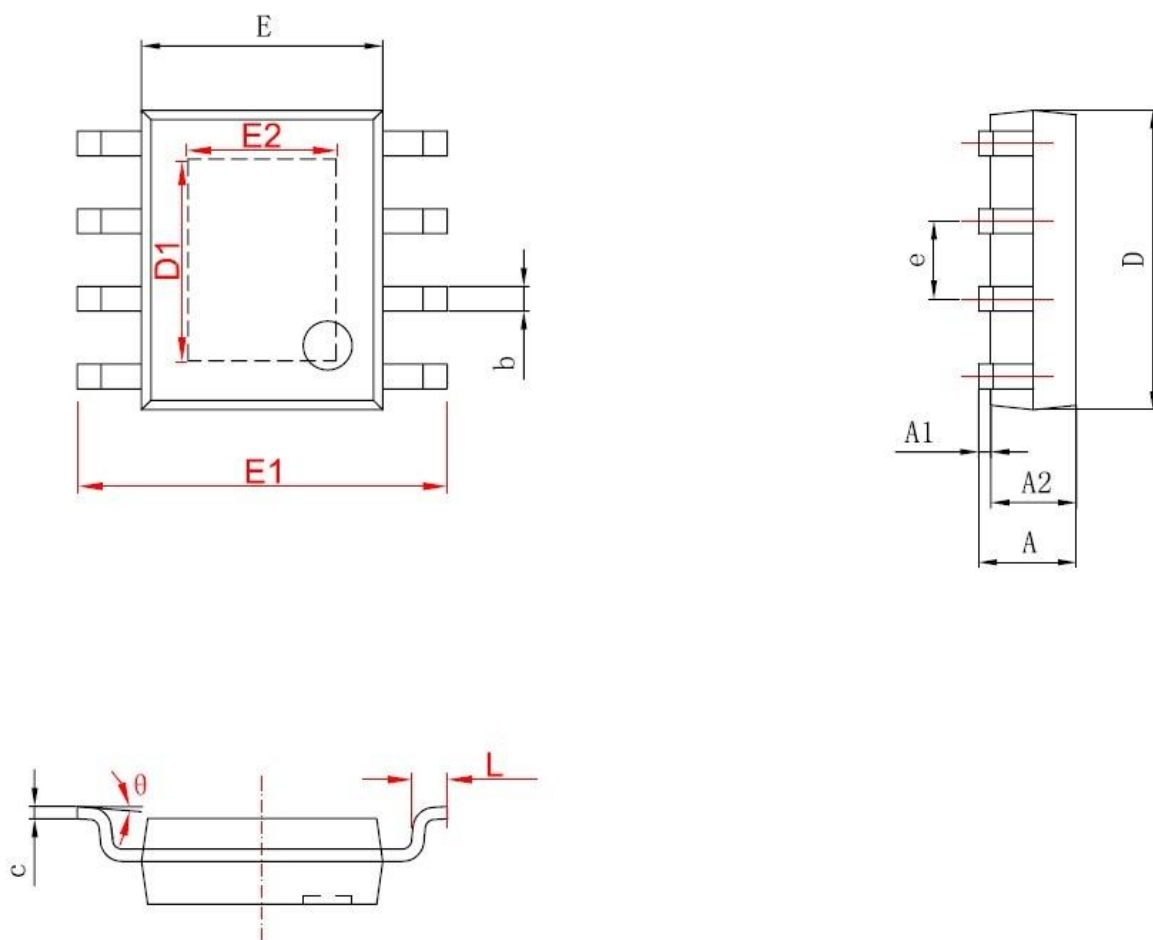
We can conclude that temperature monitor range is independent of power supply voltage  $V_{CC}$  and it only depends on R1, R2,  $R_{TL}$  and  $R_{TH}$ . The values of  $R_{TH}$  and  $R_{TL}$  can be found in the related battery handbook or deduced from testing data. In actual application, if considering only one terminal temperature (normally protecting from overheating), there is no need to use R2.

### Power adaptation

When the Supply Voltage drops to  $V_{ADPT}$ , the adaptive circuit starts; Automatically reduce the output current until the Supply Voltage no longer decreases. This function can use a USB or low-power power adapter or solar cell as the power source for the high current charging system, avoiding power reset or restart.

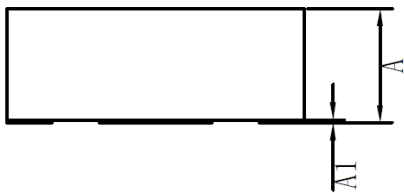
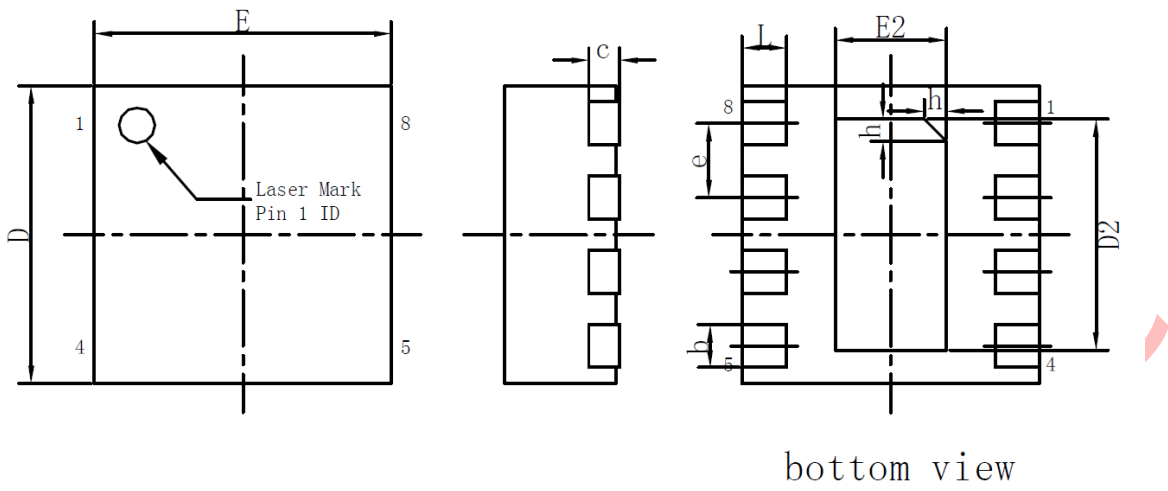
## Package Description

ESOP8 (Unit:mm)



	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
$\theta$	0°	8°	0°	8°

DFN2\*2 (Unit:mm)



	Min	Standard	Max		Min	Standard	Max
A	0.70	0.75	0.80	e	0.50BSC		
A1	0.00	0.02	0.05	E	1.95	2.00	2.05
b	0.18	0.29	0.30	E2	0.70	0.75	0.80
c	0.20REF			L	0.25	0.30	0.35
D	1.95	2.00	2.05	h	0.10	0.15	0.20
D2	1.50	1.55	1.60		L/F (mm) : 1.00*1.80		