SLM6150

1A Linear Li-Ion Battery Charger

Description

The SLM6150 is a complete constant current & constant voltage linear charger for single cell lithium-ion batteries.

Its SOP package low external component count make the SLM6150 ideally suited for portable applications. The SLM6150 is specifically designed to work within USB supply and adapter specifications.

No external sense resistor is needed, and no blocking diode is required due to the internal MOSFET architecture. Thermal feedback regulates the charge current to limit the die temperature during high power operation or high ambient temperature. The charge voltage is fixed at 4.2V, and the charge current can be programmed externally with a single resistor. The SLM6150 automatically terminates the charge cycle when the charge current drops to 1/10th of the programmed value after the final float voltage is reached.

When the input supply (Adapter or USB supply) is removed, the SLM6150 automatically enters a low current state, dropping the battery drain current to less than 2uA. The SLM6150 can be put into shutdown mode even if the power supply connected, and the supply current can be reduced to 55uA.

Other features of SLM6150 include Battery temperature monitor, under-voltage lockout, automatic recharge and two status pins to indicate charge and charge termination.

Absolute Maximum Ratings

- Vcc：-0.3V~8V
- PROG：-0.3V~Vcc+0.3V
- BAT：-0.3V~7V
- CHRG：-0.3V~10V
- STDBY：-0.3V~10V
- TEMP：-0.3V~10V
- CE：-0.3V~10V
- BAT Short-Circuit Duration：Continuous
- BAT Pin Current：1200mA
- PROG Pin Current：1200uA
- Maximum Junction Temperature：145℃
- Operating Temperature Range：-40℃~85℃
- Storage Temperature Range：-65℃~125℃
- Lead Temperature（Soldering, 10 sec）260℃

Features

- Programmable Charge Current Up to 1000mA
- No MOSFET, Sense Resistor or Blocking Diode Required
- Complete Linear Charge in SOP Package for Single Cell Lithium-Ion Batteries
- Constant-Current/Constant-Voltage Operation with Thermal Regulation to Maximize Charge Rate without Risk of Overheating
- Preset 4.2V Charge Voltage with ±1% Accuracy
- Charge Current Monitor Output
- Automatic Recharge
- Charge State Pairs of Output, No Battery and Fault Status Display
- C/10 Charge Termination
- 55uA Supply Current in Shutdown
- 2.9V Trickle Charge
- Soft-Start Limits Inrush Current
- Battery Temperature Monitoring
- Available in 8-Pin SOP/MSOP Package

Applications

- Cellular Telephones
- MP3, MP4 Players
- GPS, Digital Cameras
- Electronic Dictionaries
- Portable Devices, Chargers

Complete Charge Cycle（1000mAh Battery）

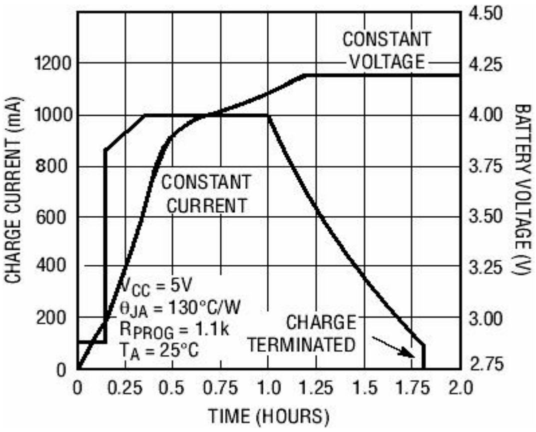


Figure 1

Typical Application

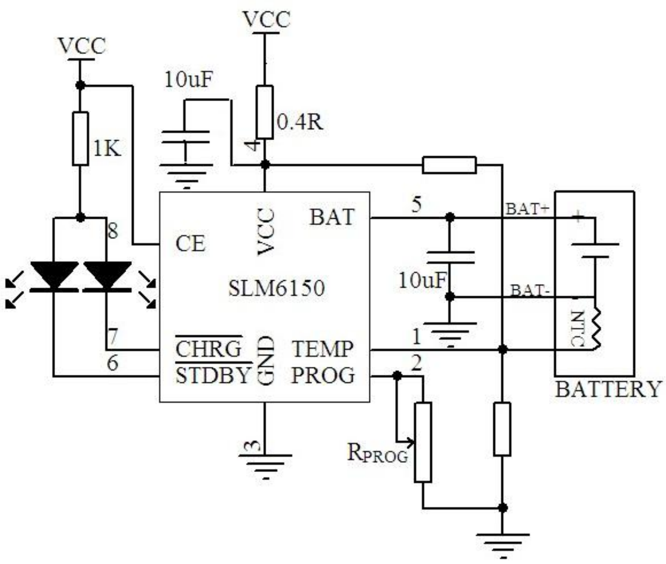


Figure 2

Application Tips

Effective heat dissipation is the key to ensure the chip to long-term maintain high charge current.

In order to maximize the charge current, PC board layout design should be optimized to provide IC within SOP8/MSOP package effective heat dissipation.

The thermal path for the heat generated by IC is from the die to lead frame, and finally to the PC board copper through the bottom heat sink. As the heat sink of IC, the copper pads of PC board should be as wide as possible, and extends out to other larger copper areas to dissipate heat into ambient environment

Another effective way to improve the heat dissipation ability of charger is to placing via to the internal or back layer of PC board, as figure 3 illustrates, place a 2.5*6.5mm pad as the heat sink of SLM6150, and then place 4 cooling holes with 1.2mm diameter and 1.6mm hole spacing on the pad. Solder should be injected into the cooling holes from the back layer of PC board to ensure that the bottom heat sink of SLM6150 is effectively connected to the cooling pad.

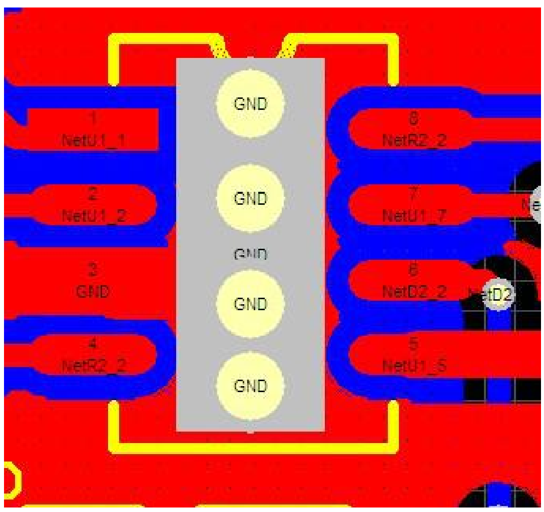


Figure 3

Other heat sources not related to the IC should also be considered when designing PC board layout, as they might influence the overall temperature rise and the maximum charge current.

Pin Configuration

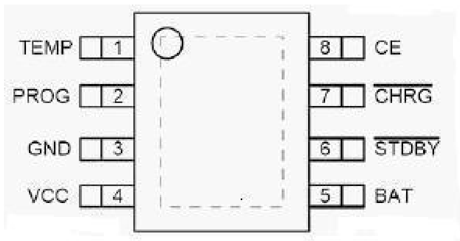


Figure 4. SLM6150 Package

Pin	Symbol	Function
1	TEMP	Battery temperature sense input
2	PROG	Constant Charge Current Setting and Charge Current Monitor Pin
3	GND	Ground
4	Vcc	Positive input supply voltage
5	BAT	Battery connection Pin
6	$\overline{\text{STDBY}}$	Charge terminated status output
7	$\overline{\text{CHRG}}$	Open-Drain charge status output
8	CE	Chip enable input

Pin Assignment

TEMP(Pin 1): Battery temperature sense input. Connecting TEMP pin to NTC sensor's output in Lithium ion battery pack. If TEMP pin's voltage is below 45% or above 80% of supply voltage V_{CC}, this means that battery's temperature is too low or too high, 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. The charge current is programmed by connecting a resistor R_{PROG} from this pin to GND. When in pre-charge mode, the PROG pin's voltage is regulated to 0.1V. When charging in constant-current mode this pin's voltage is regulated to 1V. In all modes during charging, the voltage on this pin can be used to measure the charge current based on the following formula:

$$I_{BAT} = V_{PROG}/R_{PROG}*1330$$

GND(Pin 3)： Ground.

Vcc(Pin 4)： Positive input supply voltage**.** It provides power to the internal circuit. When V_{CC} drops to within 30mV of the BAT pin voltage, the SLM6150 enters low power mode, dropping I_{BAT} to less than 2µA.

BAT(Pin 5): Battery connection Pin. Connect the positive terminal of the battery to this pin. Dropping BAT pin's current to less than 2µA when IC in disable mode or in sleep mode. BAT pin provides charge current to the battery and provides regulation voltage of 4.2V.

STDBY(Pin 6)： Charge terminated status output. STDBY is pulled low by an internal switch to indicate the termination of battery charge. Otherwise STDBY pin is in high impedance state.

CHRG（Pin 7）： Open-Drain charge status output**.** When the battery is being charged, the CHRG pin is pulled low by an internal switch to indicate the charge. Otherwise, CHRG pin is in high impedance state.

CE(Pin 8)： Chip enable input. A high level input will put the device in the normal operating mode. Pulling the CE pin to low level will put the SLM6150 into disable mode. The CE pin can be driven by TTL or CMOS logic level.

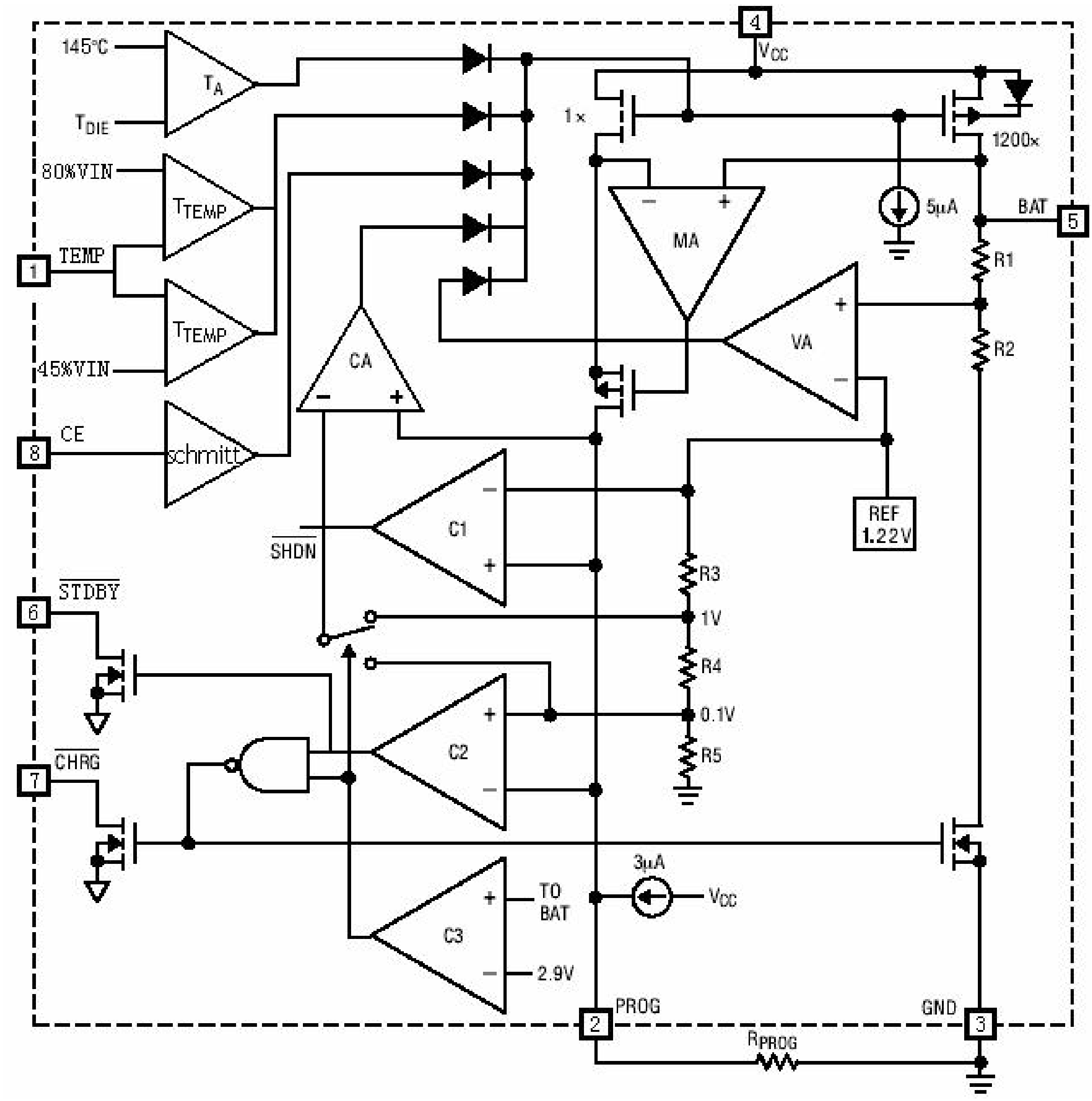
DC Characteristics

(Note: The ● denotes specifications which apply to the full operating temperature rang, otherwise specifications are at TA=25℃，VCC=5V，unless otherwise specified)

Symbol	Parameter	Condition		Min	Typ.	Max	Unit
Vcc	Input supply voltage		•	4.0	5	8.0	V
Icc	Input supply current	Charge mode	•		150	500	uA
		Standby mode (charge ends)	•		55	100	uA
		Shutdown mode (RPROG not connected, Vcc<VBAT or VCC<VUV)	•		55	100	uA
V_{FLOAL}	Regulated output voltage	0℃≤T_A≤85℃	•	4.158	4.2	4.242	V
I_{BAT}	BAT pin current (Test condition of current mode is V_{BAT}=3.9V)	R_{PROG}=2.4K,current mode	•	450	530	560	mA
		R_{PROG}=1.33k,current mode	•	900	950	1000	mA
		Standby mode，V_{BAT}=4.2V	•	0	-2.0	-5	uA
		Shutdown mode (RPROG not connected)			±1	±2	uA

		Sleep mode. Vcc=0V			-1	-2	uA
I_{TRIKL}	Trickle charge current	V_{BAT}<V_{TRIKL}，R_{PROG}=1.33k	•	80	100	110	mA
V_{TRIKL}	Trickle charge threshold voltage	R_{PROG}=1.33k，V_{BAT} rising		2.8	2.9	3.0	V
V_{TRHYS}	Trickle charge hysteresis voltage	R_{PROG}=1.33k		60	80	100	mV
V_{UV}	V_{CC} under voltage lockout threshold	Vcc from low to high	•	3.5	3.7	3.9	V
V_{UVHYS}	V_{CC} under voltage lockout hysteresis		•	150	200	300	mV
V_{PROG}	PROG pin voltage	R_{PROG}=1.33k，current mode	•	0.9	1.0	1.1	V
V_{ASD}	V_{CC}-V_{BAT} lockout threshold voltage	Vcc from low to high		60	100	140	mV
		Vcc from low to high		5	30	50	mV
I_{TERM}	C/10 termination current threshold	R_{PROG}=2.4K	•	40	50	60	mA
		R_{PROG}=1.33k	•	90	100	110	mA
$V_{\overline{CHRG}}$	$\overline{CHRG}$ Pin output low voltage	$I_{\overline{CHRG}}$=5mA			0.3	0.6	V
$V_{\overline{STDBY}}$	$\overline{STDBY}$ Pin output low voltage	$I_{\overline{STDBY}}$=5mA			0.3	0.6	V
V_{TEMP-H}	The voltage at TEMP increase				80	82	%Vcc
V_{TEMP-L}	The voltage at TEMP decrease			43	45		%Vcc
VCE-H	CE Pin high level			1.2			V
VCE-L	CE Pin low level					0.6	V
ΔV_{RECHRG}	Recharge battery threshold voltage	V_{FLOAT}-V_{RECHRG}		100	150	200	mV
T_{LIM}	Thermal protection temperature				145		℃
R_{ON}	The resistance of power FET "ON" （between V_{CC} and BAT）				650		mΩ
tss	Soft-start time	I_{BAT}=0 to I_{BAT}=1330V/R_{PROG}			20		us
t_{RECHRG}	Recharge comparator filter time	V_{BAT} from high to low		0.8	1.8	4	ms
t_{TERM}	Termination comparator filter time	I_{BAT} below I_{CHR}/10		0.8	1.8	4	ms
I_{PROG}	PROG pin pull-up current				2.0		uA

Function Block



Principle

The SLM6150 is a complete constant current & constant voltage linear charger for single cell lithium-ion batteries. Constant-current/constant-voltage to charger batter by internal MOSFET .Charge current can be programmed by external resistor. It can deliver up to 1A of charge current .No blocking diode or external current sense resistor is required. SLM6150 include two Open-Drain charge status Pins: Charge status indicator CHRG and battery failure status 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℃. This feature protects the SLM6150 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 SLM6150 or the external components. Thus, the charge current can be set according to typical, not worst-case, ambient temperatures for a given application with the assurance that the charger will automatically reduce the current in worst-case conditions.

The charge cycle begins when the voltage at the VCC pin rises above the threshold voltage, the CE pin is pulled above the chip enable threshold. The CHRG pin outputs a logic low to indicate that the charge cycle is on going. If the battery voltage is below 3V, the charger goes into the fast charge constant-current mode, and the charge current is set by RPROG. When the battery approaches the regulation voltage 4.2V, the charge current begins to decrease as the SLM6150 enters the constant-voltage mode. When the current drops to charge termination threshold, the charge cycle is terminated, and CHRG pin assumes a high impedance state and STDBY pin outputs a logic low level.

The charge termination threshold is 10% of the current in constant current mode. 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 provide regulation voltage with 1% accuracy which can meet the requirement of lithium-ion and lithium polymer batteries. When the input voltage is not connected, or below VBAT, the charger goes into a sleep mode, dropping battery drain current to less than 3μA. This greatly reduces the current drain on the battery and increases the standby time. The charger can be shutdown by forcing the CE pin to GND.

Programming Charging 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 formula:

$$R_{PROG}=1330/I_{BAT} \text{（error±10\%）}$$

R_{PROG} can be selected according to specific requirements.

Charge Termination

A charge cycle is terminated 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 SLM6150 enters standby mode, where the input supply current drops to 55μA (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 the transient loads do not result in premature charge cycle termination. Once the average charge current drops below 1/10th the programmed value, the SLM6150 terminated 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 SLM6150 constantly monitors the BAT pin voltage in standby mode. If this voltage drops below the 4.05V recharge threshold (V_{RECHRG}), another charge cycle begins and current is once again supplied to the battery.

Charge Status Indicator

SLM6150 has two open-drain status indicator output CHRG and STDBY. CHRG is pull-down when the SLM6150 in a charge cycle. In other status CHRG in high impedance, CHRG and STDBY are all in high impedance when the battery out of the normal temperature.

Represent in failure state, when TEMP pin in typical connecting, or the charger with no battery: red LED and green LED all don't light. The battery temperature sense function is disabled by connecting TEMP pin to GND. If the battery is not connected to charger, pin outputs a PWM level to indicate no battery. If BAT pin connects a 10μF capacitor, the frequency of flicker about 1-4S, if status indicator is not required, it should be connected to GND. (figure 5)

Charge Status	Red Led CHRG	Green Led STDBY
Charging	Light	Dark
Battery full state	Dark	Light
Under-voltage, battery's temperature is to high or too low, or not connect to battery(TEMP used)	Dark	Dark
BAT pin connects to 10uF capacitance, no battery mode (TEMP=GND)	Greed led lights, and Red led flickers, F=1-4S	

Figure 5

Thermal Limiting

An internal thermal feedback loop reduces the programmed charge current if the die temperature attempts to rise above a preset value of 140℃. The feature protects the SLM6150 from overheating and allows the user to push the limits of the power handling capability of a given circuit board without risk of damaging the SLM6150.

Battery Temperature Sense

To prevent the damage caused by the very high or very low temperature done to the battery, the SLM6150 continuously senses battery temperature by measuring the voltage at TEMP pin determined by the voltage divider circuit and the battery's internal NTC sensor as shown in Figure 2.

The SLM6150 compares the voltage at TEMP pin (V_{TEMP}) against its internal V_{LOW} and V_{HIGH} thresholds to determine if charging is allowed. In SLM6150, V_{LOW} is fixed at (45%×Vcc), while V_{HIGH} is fixed at (80%×Vcc). If $V_{TEMP}<V_{LOW}$ or $V_{TEMP}>V_{HIGH}$, it indicates that the battery temperature is too high or too low and the charge cycle is suspended. The battery temperature sense function can be disabled by connecting TEMP pin to GND.

The values of R1 and R2 in figure 2 can be determined according to the assumed temperature monitor range and thermal resistor's values. Following is an example: Assume temperature monitor range is TL～TH， the thermal resistor in battery has negative temperature coefficient （NTC），RTL is the resistance at TL， RTH is the resistance at TH， so RTL＞RTH， then at temperature TL, the voltage at TEMP pin is:

$$V_{TEMPL}=\frac{R_2\,||\,R_{TL}}{R_1+R_2\,||\,R_{TL}}\times V_{IN}$$

At temperature TH, the voltage at TEMP pin is:

$$V_{TEMPH}=\frac{R_2\,||\,R_{TH}}{R_1+R_2\,||\,R_{TH}}\times V_{IN}$$

from $V_{TEMPL}=V_{HIGH}=k2\times Vcc(k2=0.8)$

$V_{TEMPH}=V_{LOW}=k1\times Vcc(k1=0.45)$

derive：

$$R_1=\frac{R_{TL}R_{TH}(K_2-K_1)}{(R_{TL}-R_{TH})K_1K_2}$$

$$R_2=\frac{R_{TL}R_{TH}(K2-K1)}{R_{TL}(K_1-K_1K_2)-R_{TH}(K_2-K_1K_2)}$$

For positive temperature coefficient thermal resistor in battery, we have RTH＞RTL and we can calculate:

$$R1=\frac{R_{TL}R_{TH}(K_2-K_1)}{(R_{TH}-R_{TL})K_1K_2}$$

$$R_2=\frac{R_{TL}R_{TH}(K2-K1)}{R_{TH}(K_1-K_1K_2)-R_{TL}(K_2-K_1K_2)}$$

It is obvious that temperature monitor range is independent of power supply voltage VCC and it only depends on R1, R2, RTL and RTH: The values of RTH and RTL can be found in related battery handbook or deduced from testing data. In actual applications, if only one terminal temperature is concerned (protecting overheating), only R1 is needed.

Under Voltage Lockout

An internal under voltage lockout circuit monitors the input voltage and keeps the charger in shutdown mode until VCC rises above the under voltage lockout threshold . If the UVLO comparator is tripped, the charger will not come out of shutdown mode until VCC rises 1000mV above the battery voltage.

Manual Termination

At any time of the charging cycle will put the SLM6150 into disable mode through pulling CE pin to low level, or removing RPROG. This made the battery drain current to less than 2μA and reducing the supply current to 55μA. To restart the charge cycle, set CE pin in high level or connect a programming resistor.

Auto Restart

Once charge is terminated, SLM6150 immediately use a 1.8ms filter time （$t_{RECHARGE}$） comparator to monitor the voltage on BAT pin. If this voltage drops below the 4.05V recharge threshold (about between 80% and 90% of VCC), another charge cycle begins. This ensured the battery maintained (or approach) to a charge full status and avoid the requirement of restarting the periodic charging cycle. In the recharge cycle, CHRG pin enters a pulled down status.

Heat Dissipation

In order to maximize the charge current, PC board layout design should be optimized to provide IC within SOP8/MSOP package effective heat dissipation.

The thermal path for the heat generated by IC is from the die to lead frame, and finally to the PC board copper through the bottom heat sink. As the heat sink of IC, the copper pads of PC board should be as wide as possible, and extends out to other larger copper areas to dissipate heat into ambient environment

Another effective way to improve the heat dissipation ability of charger is to placing via to the internal or back layer of PC board, as figure 3 illustrates, place a 2.5*6.5mm pad as the heat sink of SLM6150, and then place 4 cooling holes with 1.2mm diameter and 1.6mm hole spacing on the pad. Solder should be injected into the cooling holes from the back layer of PC board to ensure that the bottom heat sink of SLM6150 is effectively connected to the cooling pad.

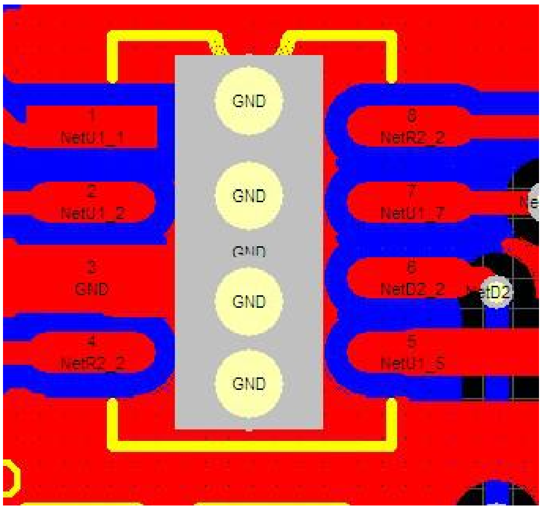


Figure 5

Other heat sources not related to the IC should also be considered when designing PC board layout, as they might influence the overall temperature rise and the maximum charge current.

Add Thermal Regulation Current

It will be effective to decrease the power dissipation through reduce the voltage of both ends of the inner MOSFET. In the thermal regulation, this action of transporting current to battery will raise. One of the measure is through an external component (as a resistor or diode) to consume some power dissipation.

For example: The SLM6150 with 5V supply voltage through programmable provides full limiting current 800mA to a charge lithium-ion battery with 3.75V voltage. If RthJ-A is 125℃/W, so that at 25℃ ambient temperature, the charge current is calculated to be approximately:

$$I_{BAT} = \frac{145℃ - 25℃}{(5V - 3.75V) \bullet 125℃/W} = 768mA$$

It is easy to decrease the power dissipation of the IC through reducing the voltage of both two ends of the resistor which connecting in series with a 5V AC adapter:

$$I_{BAT} = \frac{145℃ - 25℃}{(V_S - I_{BAT}R_{CC} - V_{BAT}) \bullet \theta_{JA}}$$

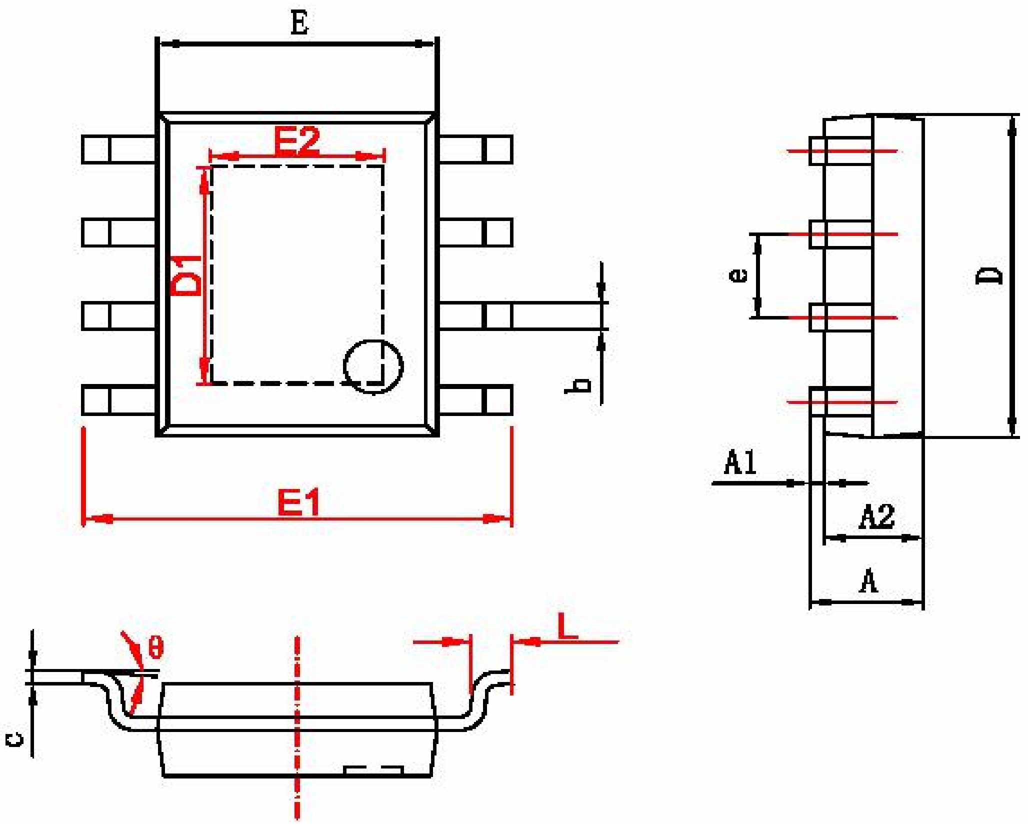
We can have：

$$I_{BAT} = \frac{(V_S - V_{BAT}) - \sqrt{(V_S - V_{BAT})^2 - \frac{4R_{CC}(145℃ - T_A)}{\theta_{JA}}}}{2R_{CC}}$$

If RCC=0.25Ω, VS=5V, VBAT=3.75V, TA=25℃ and Rthj-a =125℃/W, we can calculate the thermal regulation charge current: IBAT = 948mA. It means that in this structure it can output 800mA full limiting charge current at much higher ambient temperature environment. Although it can transport more energy and reduce the charge time in this application, it actually spreads charge time, if SLM6150 stays in under-voltage state, when VCC becomes too low in voltage mode. This technique will act the best function when in order to minimize the dimension of the components and avoid voltage decrease to minimize RCC.

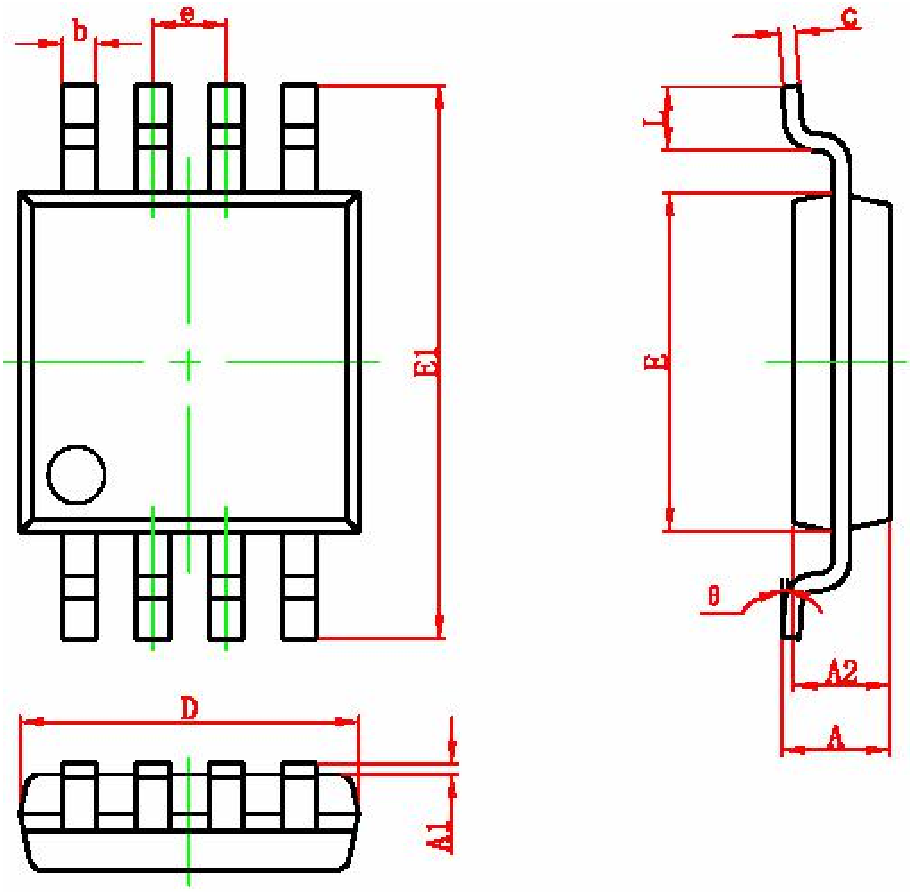
Packaging Information

8-Pin SOP Package（Unit mm）



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1. 350	1. 750	0. 053	0. 069
A1	0. 050	0. 150	0. 004	0. 010
A2	1. 350	1. 550	0. 053	0. 061
b	0. 330	0. 510	0. 013	0. 020
c	0. 170	0. 250	0. 006	0. 010
D	4. 700	5. 100	0. 185	0. 200
D1	3. 202	3. 402	0. 126	0. 134
E	3. 800	4. 000	0. 150	0. 157
E1	5. 800	6. 200	0. 228	0. 244
E2	2. 313	2. 513	0. 091	0. 099
e	1. 270 (BSC)		0. 050 (BSC)	
L	0. 400	1. 270	0. 016	0. 050
θ	0°	8°	0°	8°

8-Pin MSOP Package
（Unit mm）



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
e	0.650(BSC)		0.026(BSC)	
E	2.900	3.100	0.114	0.122
E1	4.750	5.050	0.187	0.199
L	0.400	0.800	0.016	0.031
θ	0°	6°	0°	6°