LP28009A

Standalone Dual-Cell Linear Charger

Features

- Easy-to-use standalone dual-cell charger
- High input voltage linear charger
  - Support up to 14V input voltage with 30V absolute maximum input rating
  - Maximum BAT withstand voltage up to 24V
  - Support up to 1A fast charge current
  - Trickle charge 15% of fast charge current
- High integration
  - Integrated reverse blocking MOSFET
  - Internal loop compensation
  - Built-in charge status indication driver
- Support full charge cycle-- trickle charge, constant current charge and constant voltage charge
- Battery leakage current 2μA(typical)
- Protections
  - Input under-voltage lockout (UVLO)
  - Input over-voltage protection (OVP)
  - Thermal regulation foldback
  - Battery temperature protection
- RoHS Compliant and 100% Lead (Pb)-Free
- Package: ESOP-8

Applications

- Wireless Speaker
- Cordless Power Tools
- Gaming Devices
- Portable Media Players
- Handheld Battery-Powered Devices
- Charging Docks and Cradles
- Toys

General Description

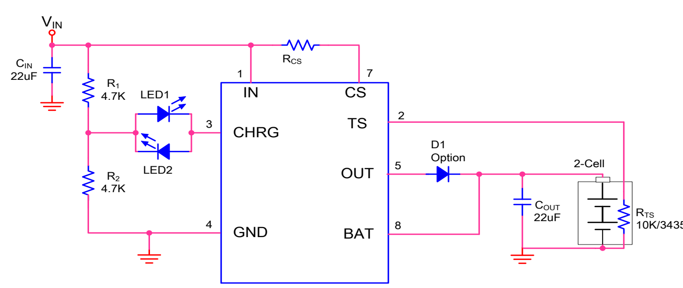
The LP28009A device is a highly advanced linear charger for dual-cell Li-Ion and Li-Polymer battery. The device is ideally suited for portable applications since the small ESOP-8 package and low number of external components required.

The device employs a full charge algorithm with trickle current/constant current/constant voltage mode. The device supports charge current up to 1A programmed by a current sense resistor. The device can withstand an input voltage up to 30V which can protect from the accidental insertion of high voltage. The device can withstand a BAT voltage up to 24V which is suited for power battery application. Without input supply, the battery leakage current is about 2μA (typical) with 8.4V battery voltage.

The device provides various safety features for battery charging, including input under voltage lockout, input over-voltage protection, battery temperature protection which is implemented by an internal constant current source and an external NTC thermistor, thermal regulation foldback protection which is implemented by reducing the charge current while the junction temperature attempts to rise up to 160℃.

The LP28009A is available in an ESOP-8 package.

Typical Application Circuit



Preliminary Datasheet

Order Information

LP28009A □□ □

- F: Pb-Free
- Package Type
  SP: ESOP-8

Device Information

Part Number	Top Marking	Battery Voltage	Moisture Sensitivity Level	Package	Shipping
LP28009ASPF	LPS LP28009A 84YWX	2 cells 8.40V	MSL3	ESOP-8	4K/REEL
Marking indication: Y: Production year. W: Production week. X: Series number.					

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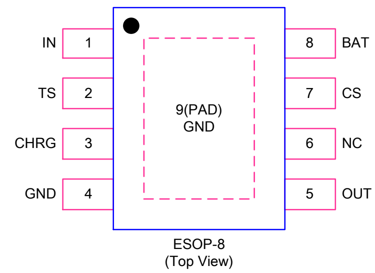
Pin Diagram



ESOP-8 (Top View)

Pin Description

Pin	Name	Description
1	IN	Positive Supply Voltage Input. This Pin is used as internal circuit power supply and input voltage sense and charge current sense positive input. Place a 22μF ceramic capacitor from IN to GND and place the capacitor as close as possible to chip.
2	TS	Battery Temperature Sense Thermistor Input. This pin senses the temperature of the battery pack and charge is suspended if the battery temperature is out of range.
3	CHRG	Push-pull Charge Status Output. When the device is in charging state, the CHRG pin pull-down to GND by an internal NMOS. When the device is not charging but VIN is higher than UVLO and lower than OVP, the CHRG pin pull-up to VIN.
4	GND	GND. Connect to the system ground.
5	OUT	OUT. Connect to the battery directly to flow the charge current to the battery, a 22μF capacitor is needed typically.
6	NC	No connect.
7	CS	Charge Current Sense Negative Input. Connect this pin to external current sense resistor Rcs to IN pin.
8	BAT	Battery Voltage Sense Pin. Connect to the battery, and short to OUT pin.
9	PAD	Ground reference for the device that is also the thermal pad used to conduct heat from the device.

Preliminary Datasheet

Absolute Maximum Ratings [1]

- IN, CS, CHRG to GND -- -0.3V to 30V
- BAT, OUT to GND --0.3V to 24V
- TS to GND -- -0.3V to 6V
- Output Current --- 1200mA
- Maximum Junction Temperature (T_J) --- 150℃
- Storage Temperature -- -55℃ to 150℃
- Maximum Soldering Temperature (at leads, 10 sec) -- 260℃

Note: **(1)** Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ESD Susceptibility

- HBM(Human Body Model) -- 2KV
- MM(Machine Model) -- 200V

Recommended Operating Conditions

- Input Voltage --- 9V to 13.5V
- Maximum Charge Current -- 1000mA
- Operating Junction Temperature Range (T_J) --- -40℃ to 150℃
- Operating Ambient Temperature Range (T_A) --- -40℃ to 85℃

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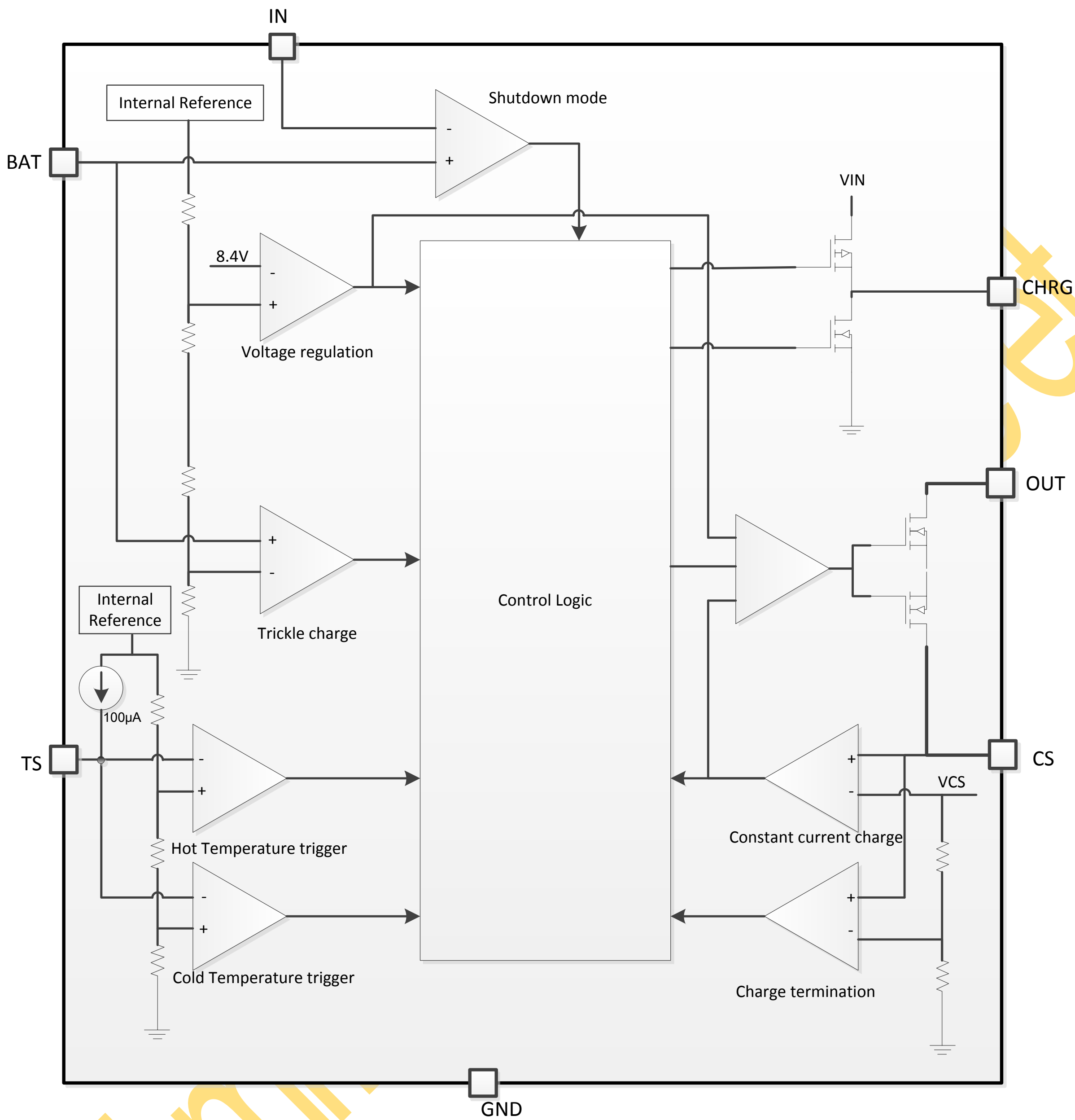
Functional Block Diagram



Preliminary Datasheet

Electrical Characteristics

(The specifications are at T_A=25℃, V_{IN} = 10V, unless otherwise noted.)

Symbol	Parameter	Condition	Min	Typ	Max	Units
INPUT VOLTAGE AND CURRENT						
V_{IN}	Input Voltage Range		9		13.5	V
I_{CC}	Input Supply Current	Charge terminated, V_{IN}=10V, V_{BAT}=8.4V		0.4	1	mA
V_{UVLO}	Under Voltage Lockout of V_{IN}	V_{IN} Rising		5.25		V
V_{UVLO_HYS}	V_{UVLO} Hysteresis	V_{IN} Falling		150		mV
V_{OVP}	Over-Voltage Protection Threshold Voltage	V_{IN} Rising		14.0		V
V_{OVP_HYS}	OVP Hysteresis	V_{IN} Falling		200		mV
QUIESCENT CURRENT						
$I_{BAT\_Leakage}$	Battery Leakage Current	V_{IN} floating, V_{BAT}=8.4V		-2		μA
$I_{BAT\_Standby}$	Battery Standby Current	Charge TS protected V_{IN}=10V, V_{BAT}=8.5V		-12		μA
BATTTERY CHARGER						
V_{FLOAT}	Regulated Output Voltage		8.316	8.4	8.484	V
V_{CS}	Current Regulation Threshold	R_{CS}=2Ω Constant Current Mode	180	200	220	mV
I_{BAT}	Constant Charge Current	R_{CS}=2Ω Constant Current Mode		100		mA
		R_{CS}=0.5Ω Constant Current Mode		380		mA
I_{TRIKL}	Trickle Charge Current			15%		I_{BAT}
V_{TRIKL}	Trickle Charge Threshold Voltage	V_{BAT} Rising		6		V
V_{TRHYS}	Trickle Charge Hysteresis Voltage	V_{BAT} Falling		100		mV
I_{BAT_Term}	Charge Termination Indication Threshold	I_{BAT} Falling		10%		I_{BAT}
I_{BAT_Resume}	Charge Termination Resume Indication Threshold	I_{BAT} Rising		30%		I_{BAT}
$\Delta V_{Headroom}$	IN-BAT Voltage Difference Threshold, (V_{IN} -V_{BAT})			280		mV
T_{J_LIMIT}	Junction Temperature Limit	Thermal protection state		160		℃
R_{DS}	CS to OUT MOSFET Minimum on-resistance			600		mΩ

Preliminary Datasheet

CHARGE STATUS						
V_{STAT_LOW}	STAT Pin Output Low Voltage	I_{STAT}=-5mA			0.5	V
V_{STAT_HIGH}	STAT Pin Output High Voltage	I_{STAT}=5mA	V_{IN}-0.5		V_{IN}	V
I_{STAT_LOW}	CHRG Pin Sink Current				5	mA
I_{STAT_HIGH}	CHRG Pin Source Current				5	mA
BATTERY TEMPERATURE MONITORING						
V_{NTC_H}	NTC threshold (Hot)	V_{NTC_H} falling		0.49		V
$V_{NTC\_H\_Hys}$	NTC threshold (Hot) Hysteresis	V_{NTC_H} rising		30		mV
V_{NTC_C}	NTC threshold (Cold)	V_{NTC_C} rising		2.75		V
$V_{NTC\_C\_Hys}$	NTC threshold (Cold) Hysteresis	V_{NTC_H} falling		30		mV
I_{TS}	TS Source Current		97	100	103	μA

Preliminary Datasheet

Typical Characteristics

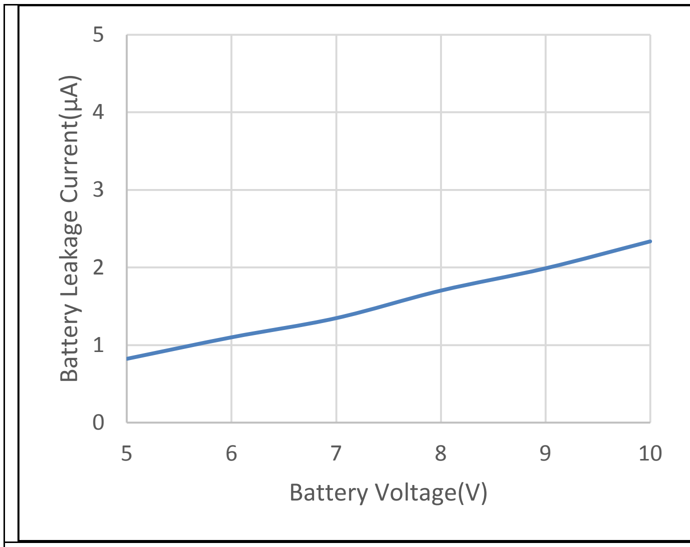


Figure 1. Battery leakage current vs Battery voltage
V_{IN}=Floating, 25C°

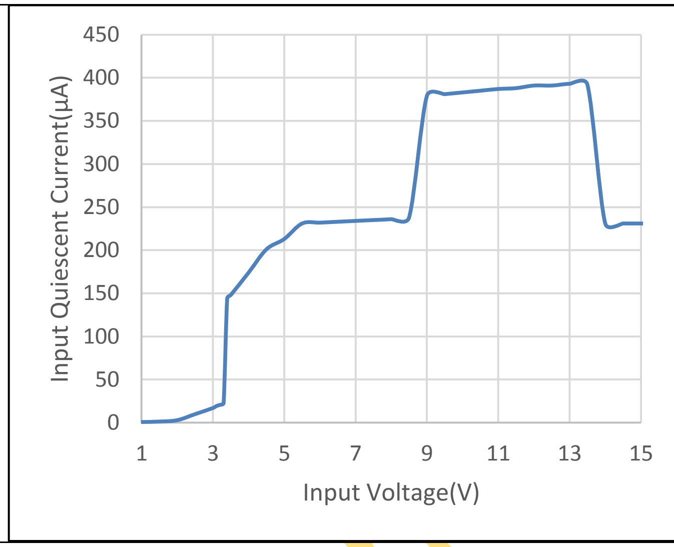


Figure 2. Input quiescent current vs input voltage
V_{OUT}=V_{BAT}=Floating, 25C°

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Detailed Description

Overview

The LP28009A device is a highly advanced linear charger with up to 1A maximum charge current for dual-cell Li-Ion and Li-Polymer battery. The device charges the battery with full cycle: trickle current mode, constant current mode and constant voltage mode.

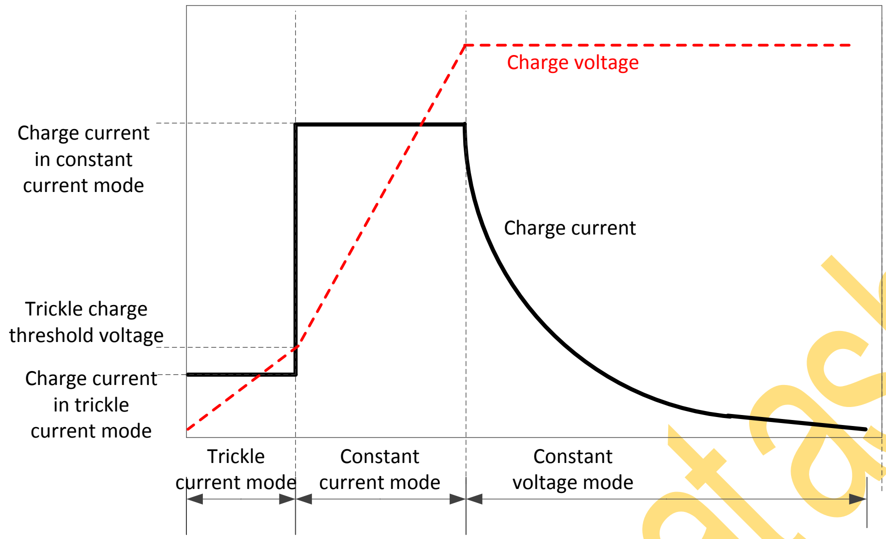


Figure 3. Typical Charge Profile

When the battery voltage is lower than trickle charge threshold voltage 6V (typical), the device charges in trickle current mode, the charge current will be set as approximately 15% of the sense resistor programmed constant current to bring the battery voltage up to a safe level for full current charging. When the battery voltage rises to be higher than trickle charge threshold voltage, the device enters the constant current mode, where the charge current is 100% of the programmed current. When the battery voltage approaches the float voltage, the device goes to constant voltage mode, the charge current starts to decrease.

When the charge current decrease to lower than 10% of the sense resistor programmed current, the indicator driver of CHRG will be pul-up to VIN by internal high-side MosFET to indicate the battery is full, but the charging is not terminated.

R_{CS} Programming Constant Current

The constant charge current (I_{BAT}) is set by a current sense resistor (R_{CS}) connecting from the IN pin to CS pin. The relationship of the constant current and the programming resistance is established by the following formula:

$$I_{BAT} = \frac{V_{CS}}{R_{CS}}$$

Where V_{CS} =200mV (typical), which is current regulation threshold.

Undervoltage Lockout (UVLO)

An internal UVLO circuit monitors the input voltage and keeps the device in shutdown mode until the input supply rises above the UVLO threshold. The UVLO circuitry has a built-in hysteresis of 150 mV. The UVLO circuit is always active. During any UVLO condition, the battery reverse discharge current is about 2μA.

Preliminary Datasheet

Minimum Headroom

The input supply must be higher a level 280mV ($V_{Headroom}$, typical) than the battery voltage before the LP28009A become operational. Whenever the input supply is within +280 mV of the voltage above the VBAT pin, the LP28009A are placed in shutdown mode.

Charge Status Indicator (CHAG)

While VIN is higher than UVLO and lower than OVP, CHRG pull-down state indicates that the LP28009A is in a charge cycle, at this time LED1 lights on in the typical application circuit. When the charger is not in charging status, the CHRG pin will become high voltage level to pull-up to VIN by an internal MosFET, and then LED2 lights on in the typical application circuit.

It should pay more attention to the constant voltage charge mode, when the charge current is lower than 10%(I_{BAT_Term}) of programmed constant current, the CHRG will pull-up to VIN by an internal high-side MosFET, but the charging is not terminated. If there is a large discharging current discharges the battery and leads the charge current be higher and above 30%(I_{BAT_Resume}) of programmed current, the CHRG will pull-down to GND by an internal MosFET.

VIN	Charge status	CHRG	LED
UVLO<VIN <OVP	1.Trickle charging 2.CC charging 3.CV charging (IBAT≥10%)	Pull-down to GND	LED1 ON
	1.CV Charging (IBAT <10%) 2. No Charging	Pull-up to VIN	LED2 ON
VIN<UVLO or VIN>OVP	Protected	High-Z	Both OFF

Junction Temperature-Limit Protection

An internal thermal regulation foldback loop reduces charge current if the junction temperature attempts to rise above a preset value of approximately 160℃. This function protects the device from excessive temperature and allows the user to get the limits of the power handling capability of a given circuit board without risk of damaging the device. The charge current can be set according to typical ambient temperature with the assurance that the charger will automatically reduce the current in worst-case conditions.

Battery Temperature Protection

The LP28009A device continuously monitor the battery temperature by measuring the voltage between the TS pin and GND pin. The devices compare V_{TS} to its internal thresholds V_{NTC_H} and V_{NTC_C}, and then determine whether charging is allowed, if VTS is out of V_{NTC_H} to V_{NTC_C} voltage range, the device terminates battery charging. There is a current source inside the device and outputs constant 100μA(typical) current to TS pin, and V_{TS} voltage can be derived from the below formula:

$$V_{TS} = I_{TS} * R_{TS}$$

If the allowed charge temperature is 0 to 45 ℃, it is recommended to use a typical 10kΩ-3435K NTC thermistor.

Preliminary Datasheet

Application Information

Thermal Consideration

Due to the low efficiency of linear charging, the most important factors are thermal design and cost, which are a direct function of the input voltage, output charge current and thermal impedance between the battery charger and the ambient cooling air.

Nearly all of the power dissipation is generated by the internal MOSFETs, the power dissipation can be calculated approximately:

$$P_D = (V_{IN} - V_{BAT}) \times I_{BAT}$$

Where P_D is the power dissipation, V_{IN} is the input supply voltage, V_{BAT} is the battery voltage and I_{BAT} is the charge current.

The worst-case situation is when the device has transitioned from the trickle current mode to the constant current mode. In this situation, the battery charger has to dissipate the maximum power.

In this case, with a 10V input voltage source, 1A constant current, the max power dissipation could be:

$$P_{Dmax} = (10V - 6V) \times 1A = 4W$$

This power dissipation with the battery charger in the ESOP-8 package may cause thermal regulation to decrease the charge current. Then a trade-off must be made between the charge current, cost and thermal requirements of the charger.

External Capacitors

In order to maintain good stability in the whole charge cycle, a minimum capacitance of 22μF is recommended to bypass the VBAT pin to GND. In addition, the battery and interconnections appear inductive at high frequencies. These elements are in the control feedback loop during constant voltage mode. Therefore, the bypass capacitance may be necessary to compensate for the inductive nature of the battery pack.

Again, a minimum capacitance of 22μF is recommended to bypass the VIN pin to GND.

Current Sense Resistor

In order to acquire the constant and termination current accuracy, better than 1% precision resistance is recommended.

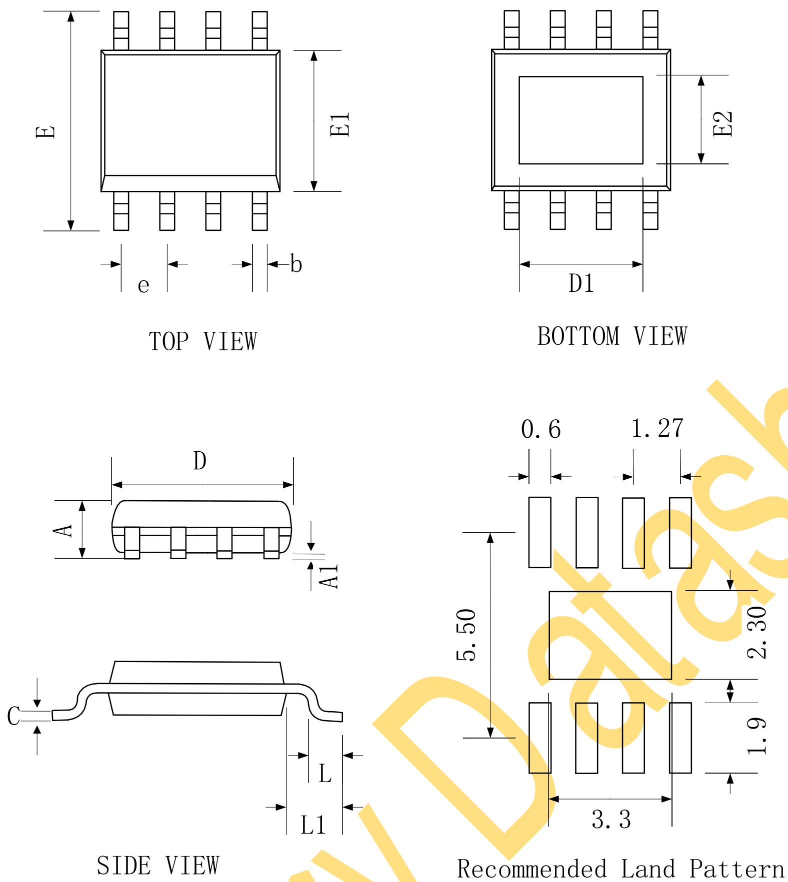
Layout Consideration

For optimum voltage regulation, place the battery pack as close as possible to the device's BAT and GND pins. This is recommended to minimize voltage drops along the high current-carrying PCB traces. If the PCB layout is used as a heat sink, adding many vias in the heat sink pad can help conduct more heat to the PCB backplane, thus reducing the maximum junction temperature. It is also recommended to place the capacitor C_{IN} and C_{OUT} as close as possible to the corresponding pins and GND pin.

Preliminary Datasheet

Packaging Information

ESOP-8



SYMBOL	Dimensions In Millimeters		
	MIN	NOM	MAX
A	1.35	-	1.75
A1	0.00	-	0.15
b	0.30	0.40	0.50
c	0.20 REF		
D	4.70	4.90	5.10
D1	3.2 REF		
E	5.70	6.00	6.30
E1	3.70	3.90	4.10
E2	2.30 REF		
e	1.27 BSC		
L	0.40	0.60	0.80
L1	1.05 REF		

Preliminary Datasheet