



## 1.2A Single-chip Li-ion and Li-POL Charge with Protection of Reverse Connection of Battery

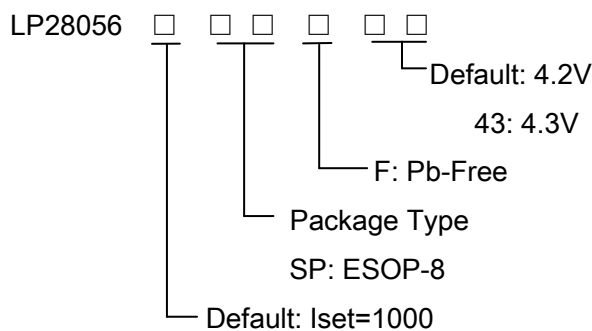
### General Description

The LP28056 is a complete constant-current/constant-voltage linear charger for single cell lithium-ion batteries. Its ESOP-8 package and low external component count make the LP28056 ideally suited for portable applications. 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/4.35V, and the charge current can be ISET rammed externally with a single resistor. The LP28056 automatically terminates the charge cycle when the charge current drops to 1/10th the ISET rammed value after the final float voltage is reached. When the input supply is removed, the LP28056 automatically enters a low current state, dropping the battery drain current to less than 1µA. The LP28056 can be put into shutdown mode, reducing the supply current to 1µA. Other features include charge current monitor, under voltage lockout, automatic recharge and a status pin to indicate charge termination and the presence of an input voltage.

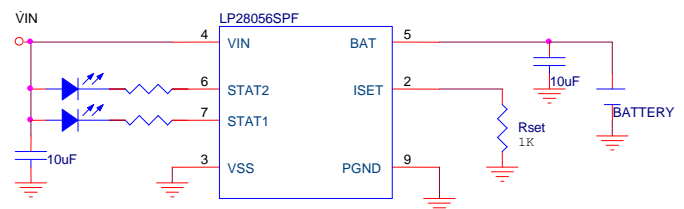
### Features

- ◆ Very Low Power Dissipation
- ◆ Short-circuit protection
- ◆ Protection of Reverse Connection of Battery
- ◆ Programmable Charge Current Up to 1200mA
- ◆ No MOSFET, Sense Resistor or Blocking Diode Required
- ◆ Constant-Current/Constant-Voltage Operation with Thermal Regulation to Maximize Charge Rate Without Risk of Overheating
- ◆ 1µA Supply Current in Shutdown
- ◆ Drainage Charge Current Thermal Regulation
- ◆ Status Outputs for LED or System Interface
- ◆ Indicates Charge and Full
- ◆ Optional Battery Temperature Monitoring Before and During Charge Automatic Sleep Mode for Low-Power
- ◆ Consumption Available in ESOP-8 Package
- ◆ RoHS Compliant and 100% Lead (Pb)-Free

### Order Information



### Typical Application Circuit



### Applications

- ✧ Portable Media Players/MP3 players
- ✧ Cellular and Smart mobile phone
- ✧ PDA/DSC
- ✧ Bluetooth Applications



## Functional Pin Description

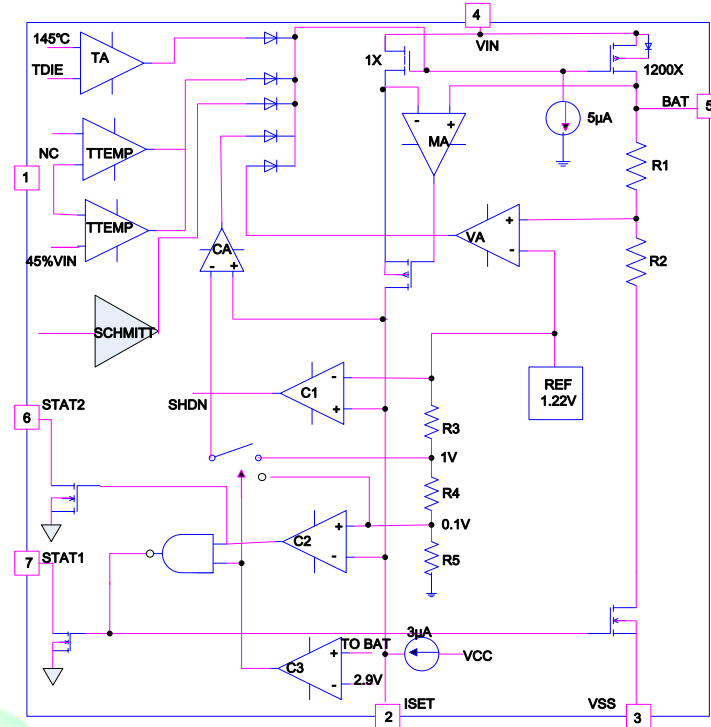
Package Type	Pin Configurations
ESOP-8	

## Pin Description

PIN	PIN Number	DESCRIPTION
1	NC	No Connector.
2	ISET	Charge Current Program, Charge Current Monitor and Shutdown Pin. The charge current is programmed by connecting a 1% resistor( $R_{PROG}$ )to ground. When charging in constant-current mode, this pin serves to 1V. In all modes, the voltage on this pin can be used to measure the charge current using the following formula: $I_{SET} = 1000/R_{PROG}$
3	VSS	VSS is the connection to system ground.
4	VIN	VIN is the input power source. Connect to a wall adapter.
5	BAT	BAT is the connection to the battery. Typically a 10 $\mu$ F Tantalum capacitor is needed for stability when there is no battery attached. When a battery is attached, only a 0.1 $\mu$ F ceramic capacitor is required.
6	STAT2	Open-Drain Charge Status Output. When the battery is charging, the STAT pin could be pulled High by an external pull high resistor. When the charge cycle is completed, the pin is pulled Low by an internal N-channel MOSFET.
7	STAT1	Open-Drain Charge Status Output. When the battery is charging, the STAT pin is pulled low by an internal N-channel MOSFET. When the charge cycle is completed, the pin could be pulled High by an external pull high resistor.
8	NC	No Connector.
9	PGND	ground.



### Function Block Diagram



### Absolute Maximum Ratings <sup>Note 1</sup>

- ◇ Input to GND(VIN) ----- -0.3V to 8V
- ◇ BAT to GND ----- -5V to 6V
- ◇ VIN to BAT ----- 8V
- ◇ Other Pin to GND ----- -0.3V to 6V
- ◇ BAT Short-circuit Duration ----- Continuous
- ◇ Maximum Junction Temperature ----- 150°C
- ◇ Storage Temperature ----- -45°C to 165°C
- ◇ Operating Junction Temperature Range (TJ) ----- -40°C to 85°C
- ◇ Maximum Soldering Temperature (at leads, 10 sec) ----- 260°C

**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.

### Thermal Information <sup>Note 2</sup>

- ◇ Maximum Power Dissipation (PD,TA=25°C) ----- 2W
- ◇ Thermal Resistance (JA) ----- 50°C/W

**Note 2.** JA is measured in the natural convection at TA = 25°C on a high effective thermal conductivity four-layer test board of JEDEC 51-7 thermal measurement standard

### ESD Susceptibility <sup>Note 3</sup>

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

**Note 3.** Devices are ESD sensitive. Handling precaution is recommended



## Electrical Characteristics

(The specifications which apply over the full operating temperature range, otherwise specifications are at TA = 25°C. VIN = 5V, unless otherwise noted.)

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP.	MAX	UNITS
VIN	Adapter/USB Voltage Range		4.5	5	6.5	V
ICC	Input Supply Current	Charge Mode, R <sub>ISET</sub> = 10k		300	2000	uA
		Standby Mode (Charge Terminated)		300	500	
		Shutdown Mode (R <sub>ISET</sub> Not Connected )			50	
V <sub>FLOAT</sub>	Regulated Output (Float) Voltage	I <sub>BAT</sub> = 40mA , LP28056SPF	4.158	4.2	4.242	V
		I <sub>BAT</sub> = 40mA , LP28056SPF-43	4.25	4.3	4.35	
I <sub>BAT</sub>	BAT Pin Current	R <sub>ISET</sub> = 1k V <sub>TRIKL</sub> < V <sub>BAT</sub> < V <sub>float</sub>	850	1000	1150	mA
		R <sub>ISET</sub> = 2k V <sub>TRIKL</sub> < V <sub>BAT</sub> < V <sub>float</sub>	430	500	570	
		Reverse Current, V <sub>BAT</sub> = -4.2V		-1		uA
		Standby Mode, V <sub>BAT</sub> = 4.2V Shutdown Mode (R <sub>ISET</sub> NC)	0	-2.5 ±1	-6 ±2	
I <sub>TRIKL</sub>	Trickle Charge Current	V <sub>BAT</sub> < V <sub>TRIKL</sub> R <sub>ISET</sub> = 1k		100		mA
V <sub>TRIKL</sub>	Trickle Charge Threshold Voltage	R <sub>ISET</sub> = 10k, V <sub>BAT</sub> Rising	2.8	2.9	3.0	V
V <sub>TRHYS</sub>	Trickle Charge Hysteresis Voltage	R <sub>ISET</sub> = 10k	60	80	110	mV
V <sub>UV</sub>	VIN Under voltage Lockout Threshold	From VIN Low to High	3.7	3.8	3.95	V
V <sub>UVHYS</sub>	VIN Under voltage Lockout Hysteresis			500		mV
V <sub>ASD</sub>	VIN –V <sub>BAT</sub> Lockout Threshold Voltage	VIN from Low to High	70	100	140	mV
V <sub>ASDHYS</sub>	V <sub>ASD</sub> Hysteresis Voltage			20		mV
I <sub>TERM</sub>	C/10 Termination Current Threshold	R <sub>ISET</sub> = 10k		10		%I <sub>BAT</sub>
		R <sub>ISET</sub> = 2k		10		%I <sub>BAT</sub>
V <sub>ISET</sub>	ISET Pin Voltage	R <sub>ISET</sub> = 10k, Current Mode		1.0		V
V <sub>STAT</sub>	STAT Pin Output Low Voltage	I <sub>STAT</sub> = 5mA		0.35	0.6	V
ΔV <sub>RESTAT</sub>	Recharge Battery Threshold Voltage	V <sub>FLOAT</sub> - V <sub>RESTAT</sub>	100	150	200	mV
T <sub>LIM</sub>	Junction Temperature in Constant Temperature Mode			150		°C
R <sub>ON</sub>	Power FET “ON” Resistance (Between VIN and BAT)			300		mΩ
t <sub>SS</sub>	Soft-Start Time	I <sub>BAT</sub> = 0 to I <sub>BAT</sub> = 850V/R <sub>ISET</sub>		200		uS
I <sub>ISET</sub>	ISET Pin Pull-Up Current			3		uA

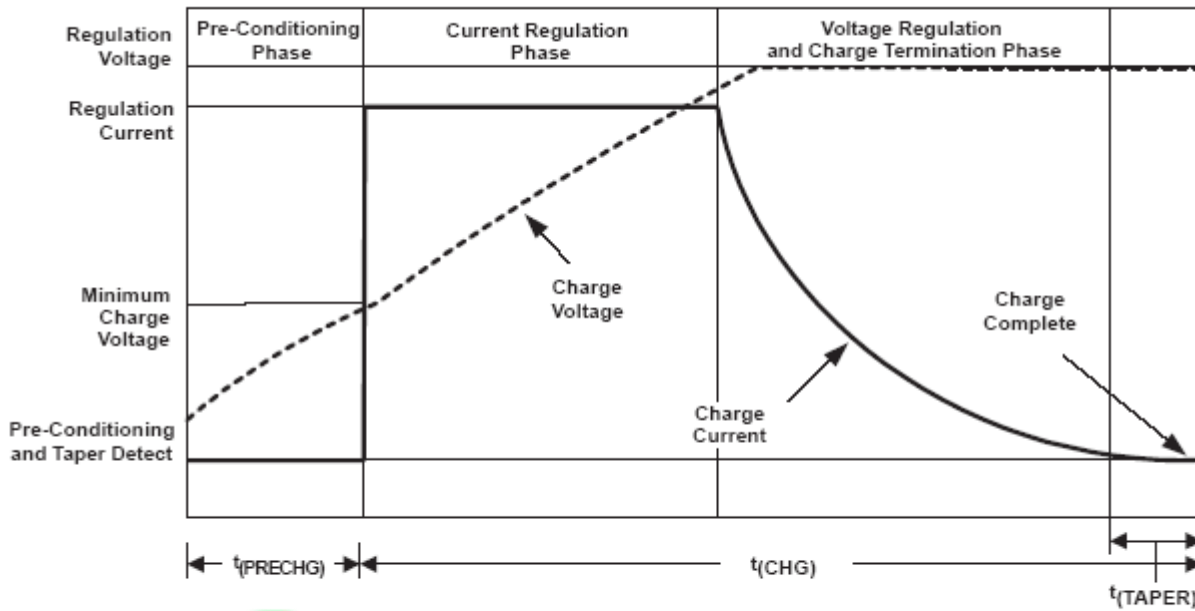


Figure 2. Typical Charging Profile





## Application Information

The LP28056 is a single cell lithium-ion battery charger using a constant-current/constant-voltage algorithm. It can deliver up to 1200mA of charge current (using a good thermal PCB layout) with a final float voltage accuracy of ±1%(4.2V/4.35V). The LP28056 includes an internal P-channel power MOSFET and thermal regulation circuitry. No blocking diode or external current sense resistor is required; thus, the basic charger circuit requires only two external components. Furthermore, the LP28056 is capable of operating from a USB power source.

### Normal Charge Cycle

A charge cycle begins when the voltage at the VIN pin rises above the UVLO threshold level and a 1% ISET ram resistor is connected from the ISET pin to ground or when a battery is connected to the charger output. If the BAT pin is less than 2.9V, the charger enters trickle charge mode. In this mode, the LP28056 supplies approximately 30mA current to bring the battery voltage up to a safe level for full current charging. When the BAT pin voltage rises above 2.9V, the charger enters constant-current mode, where the ISET rammed charge current is supplied to the battery. When the BAT pin approaches the final float voltage, the LP28056 enters constant-voltage mode and the charge current begins to decrease. When the charge current drops to 1/10 of the ISET rammed value, the charge cycle ends.

### ISET ramming Charge Current

The charge current is ISET rammed using a single resistor from the ISET pin to ground. The battery charge current is 1000 times the current out of the ISET pin. The ISET ram resistor and the charge current are calculated using the following equations:

$$R_{SET}=1000V/I_{CHG} , I_{CHG}= 1000V/R_{SET}$$

The charge current out of the BAT pin can be determined at any time by monitoring the ISET pin voltage using the following equation:

$$I_{BAT}= V_{SET} \times 1000/R_{SET}$$

Note: V<sub>SET</sub> is 1Volts.

### Charge Termination

A charge cycle is terminated when the charge current falls to 1/10th the ISET rammed value after the final float voltage is

reached. This condition is detected by using an internal, filtered comparator to monitor the ISET pin. When the ISET pin voltage falls below 100mV for longer than t<sub>TERM</sub> (typically 1ms), charging is terminated. The charge current is latched off and the LP28056 enters standby mode, where the input supply current drops to 300µA..

When charging, transient loads on the BAT pin can cause the ISET pin to fall below 200mV for short periods of time before the DC charge current has dropped to 1/10th the ISET rammed value. The 1ms filter time (t<sub>TERM</sub>) 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 ISET rammed value, the LP28056 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 LP28056 constantly monitors the BAT pin voltage in standby mode. If this voltage drops below the 4.05V recharge threshold (V<sub>RESTAT</sub>), another charge cycle begins and current is once again supplied to the battery. To manually restart a charge cycle when in standby mode, the input voltage must be removed and reapplied, or the charger must be shut down and restarted using the ISET pin.

### Charge Status Indicator (STAT)

The charge status output has two different states: strong pull-down (~5mA) and high impedance. The strong pull-down state indicates that the LP28056 is in a charge cycle. Once the charge cycle has terminated, the pin state is determined by under voltage lockout conditions. High impedance indicates that the LP28056 is in under voltage lockout mode: either VIN is less than 100mV above the BAT pin voltage or insufficient voltage is applied to the VIN pin.

A microprocessor can be used to distinguish between these two states—this method is discussed in the Applications Information section.

Function	STAT1(pin7)	STAT2(pin6)
Charging	Low	High
Charge END	High	Low



**Thermal Limiting**

An internal thermal feedback loop reduces the I<sub>SET</sub> rammged charge current if the die temperature attempts to rise above a preset value of approximately 120°C. This feature protects the LP28056 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 LP28056.

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. ESOP8 power considerations are discussed further in the Applications Information section.

**Under voltage Lockout (UVLO)**

An internal under voltage lockout circuit monitors the input voltage and keeps the charger in shutdown mode until VIN rises above the under voltage lockout threshold. The UVLO circuit has a built-in hysteresis of 200mV. Furthermore, to protect against reverse current in the power MOSFET, the UVLO circuit keeps the charger in shutdown mode if VIN falls to within 30mV of the battery voltage. If the UVLO comparator is tripped, the charger will not come out of shutdown mode until VIN rises 100mV above the battery voltage.

**Power Dissipation**

The conditions that cause the LP28056 to reduce charge current through thermal feedback can be approximated by considering the power dissipated in the IC. Nearly all of this power dissipation is generated by the internal MOSFET—this is calculated to be approximately:

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

where PD is the power dissipated, VIN is the input supply voltage, VBAT is the battery voltage and IBAT is the charge current. The approximate ambient temperature at which the thermal feedback begins to protect the IC is:

$$T_A = 125^\circ C - P_D \theta_{JA}$$

$$T_A = 125^\circ C - (V_{IN} - V_{BAT}) \cdot I_{BAT} \cdot \theta_{JA}$$

Example: An LP28056 operating from a 5V USB supply is programmed to supply 800mA full-scale current to a discharged Li-Ion battery with a voltage of 3.75V. Assuming  $\theta_{JA}$  is 50 °C /W (see Board Layout Considerations), the ambient temperature at which the LP28056 will begin to reduce the charge current is approximately:

$$\begin{aligned} T_A &= 125^\circ C - (5V - 3.75V) \cdot (800mA) \cdot 50^\circ C/W \\ &= 125^\circ C - 1W \cdot 50^\circ C/W = 125^\circ C - 50^\circ C \\ T_A &= 75^\circ C \end{aligned}$$

The LP28056 can be used above 75°C ambient, but the charge current will be reduced from 800mA. The approximate current at a given ambient temperature can be approximated by:

$$I_{BAT} = (125^\circ C - T_A) / \theta_{JA} / (V_{IN} - V_{BAT})$$

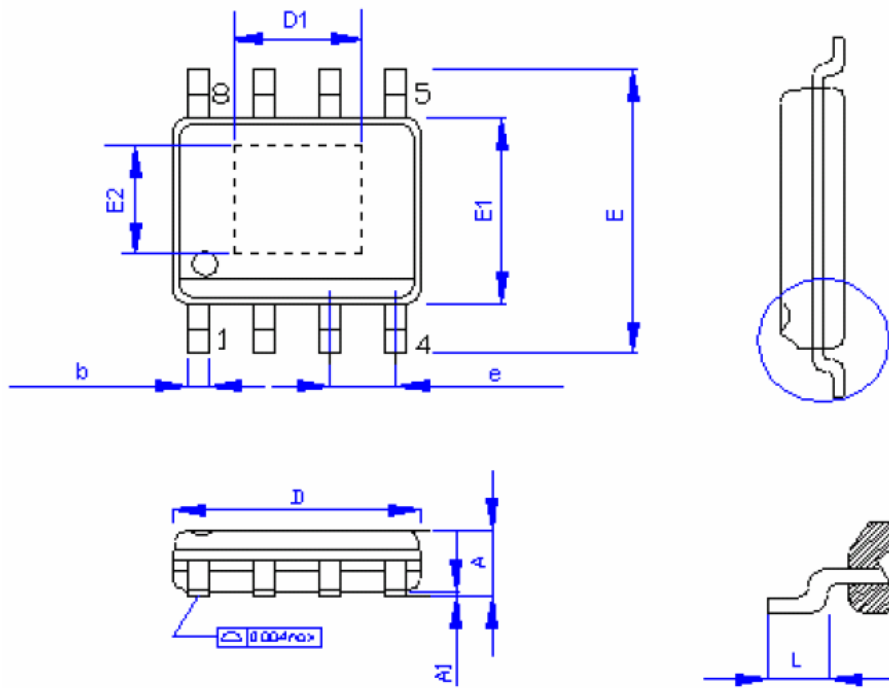
Using the previous example with an ambient temperature of 60°C, the charge current will be reduced to approximately:

$$I_{BAT} = 1.04A @ V_{BAT} = 3.75V$$

Moreover, when thermal feedback reduces the charge current, the voltage at the PROG pin is also reduced proportionally as discussed in the Operation section. It is important to remember that LP28056 applications do not need to be designed for worst-case thermal conditions since the IC will automatically reduce power dissipation when the junction temperature reaches approximately 125°C.



Packaging Information



SYMBOLS	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	1.35	1.75	0.053	0.069
A1	0.05	0.25	0.002	0.010
D	4.90		0.193	
E1	3.90		0.153	
E	5.80	6.20	0.228	0.244
L	0.40	1.27	0.016	0.050
b	0.33	0.51	0.013	0.020
e	1.27		0.500	
D1	2.06		0.081	
E2	2.06		0.081	