



Standalone Linear Li-Ion Battery Charger with Thermal Regulation

Features

- Programmable Charge Current up to 700mA
- No MOSFET, Sense Resistor or Blocking Diode Required
- Constant-Current/Constant-Voltage Operation with Thermal Regulation to Maximize Charge Rate
- Charges Single Cell Li-Ion Batteries Directly from USB Port
- Preset 4.2V Charge Voltage with 1% Accuracy
- Automatic Recharge
- 2.9V Trickle Charge Threshold
- Available in 5-Lead SOT-23 Package

Applications

- Charger for Li-Ion Coin Cell Batteries
- Portable MP3 Players, Wireless Headsets
- Bluetooth Applications
- Multifunction Wristwatches

Description

The HX6001 is a complete constant-current/constant-voltage linear charger for single cell lithium-ion batteries. Its package and low external component count make the HX6001 ideally suited for portable applications. Furthermore, the HX6001 is specifically designed to work within USB power specifications.

No external sense resistor is needed, and no blocking diode is required due to the internal MOSFET architecture. The charge voltage is fixed at 4.2V, and the charge current can be programmed externally with a single resistor. The HX6001 automatically terminates the charge cycle when the charge current drops to 1/10th the programmed value after the final float voltage is reached.

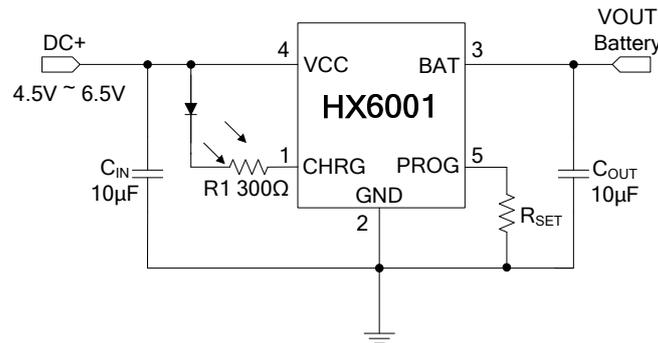
The HX6001 converters are available in the industry standard SOT-23-5L power packages (or upon request).

Order Information

HX6001- ① ②:

SYMBOL	DESCRIPTION
①	Denotes Output Voltage: N: 4.2V
②	Denotes Package Type: E: SOT-23-5L

Typical Application Circuit



* $I_{BAT} = (V_{PROG}/R_{SET}) \cdot 900$.

* When charging in constant-current mode, the V_{PROG} is usually 1V.

Pin Assignment and Description

TOP VIEW		PIN	NAME	DESCRIPTION
<p>SOT-23-5L</p>		1	CHRG	Open-Drain Charge Status Output
		2	GND	Ground
		3	BAT	Charge Current Output
		4	VCC	Positive Input Supply Voltage
		5	PROG	Charge Current Program

Absolute Maximum Ratings (Note 1)

- Input Supply Voltage (VCC) -0.3V ~ 7V
- PROG..... -0.3V ~ VCC + 0.3V
- BAT, CHRG..... -0.3V ~ 7V
- BAT Pin Current 800mA
- Maximum Junction Temperature..... +150°C
- Operating Ambient Temperature Range (Note 2).....-40°C ~ +85°C
- Storage Temperature Range -65°C ~ +125°C
- Lead Temperature (Soldering, 10 sec)..... +265°C

Note 1: Stresses listed as the above “Absolute Maximum Ratings” may cause permanent damage to the device.

Exposure to absolute maximum rating conditions for extended periods may remain possibility to affect device reliability.

Note 2: The HX6001 is guaranteed to meet performance specifications from 0°C to 70°C. Specifications over the -40°C to 85°C operating temperature range are assured by design, characterization and correlation with statistical process controls.

Electrical Characteristics

Operating Conditions: $T_A=25^{\circ}\text{C}$, $V_{CC}=5\text{V}$, unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{CC}	Input Supply Voltage		4.5	5.0	6.5	V
V_{OVLO}	OVLO Threshold	V_{IN} Rising		6.8		V
I_Q	Input Supply Current	Standby Mode (Charge Terminated)		48		μA
		Shutdown Mode (R_{PROG} Not Connected, $V_{CC} < V_{BAT}$)		80		μA
Battery Voltage Regulation Constant-Current Charge						
V_{FLOAT}	Regulated Output (Float) Voltage	$0^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$	4.16	4.2	4.24	V
I_{BAT}	BAT Pin Current	$R_{PROG} = 10\text{k}$, Current Mode		90		mA
		$R_{PROG} = 2\text{k}$, Current Mode		450		mA
		Standby Mode, $V_{BAT} = 4.2\text{V}$		-7		μA
		Shutdown Mode (R_{PROG} Not Connected)		± 13		μA
		Sleep Mode, $V_{CC} = 0\text{V}$		± 0.2	± 2	μA
V_{PROG}	PROG Pin Voltage	$R_{PROG} = 2\text{k}$, Current Mode	0.95	1	1.05	V
Trickle Charge						
I_{TRIKL}	Trickle Charge Current	$R_{PROG} = 2\text{k}$		45		mA
V_{TRIKL}	Trickle Charge Threshold Voltage	$R_{PROG} = 10\text{k}$, V_{BAT} Rising		2.9		V
I_{TERM}	C/10 Termination Current Threshold	$R_{PROG} = 2\text{k}$		45		mA
V_{RECHRG} Comparator (Battery Recharge Threshold)						
ΔV_{RECHRG}	Recharge Battery Threshold Voltage	$V_{FLOAT} - V_{RECHRG}$		250		mV

Pin Functions

CHRG (Pin 1): Open-Drain Charge Status Output. When the battery is being charged, the CHRG pin is pulled low by an internal N-channel MOSFET. When the charge cycle is completed or reverse battery lockout / No AC is detected, CHRG is forced high impedance.

GND (Pin 2): Ground.

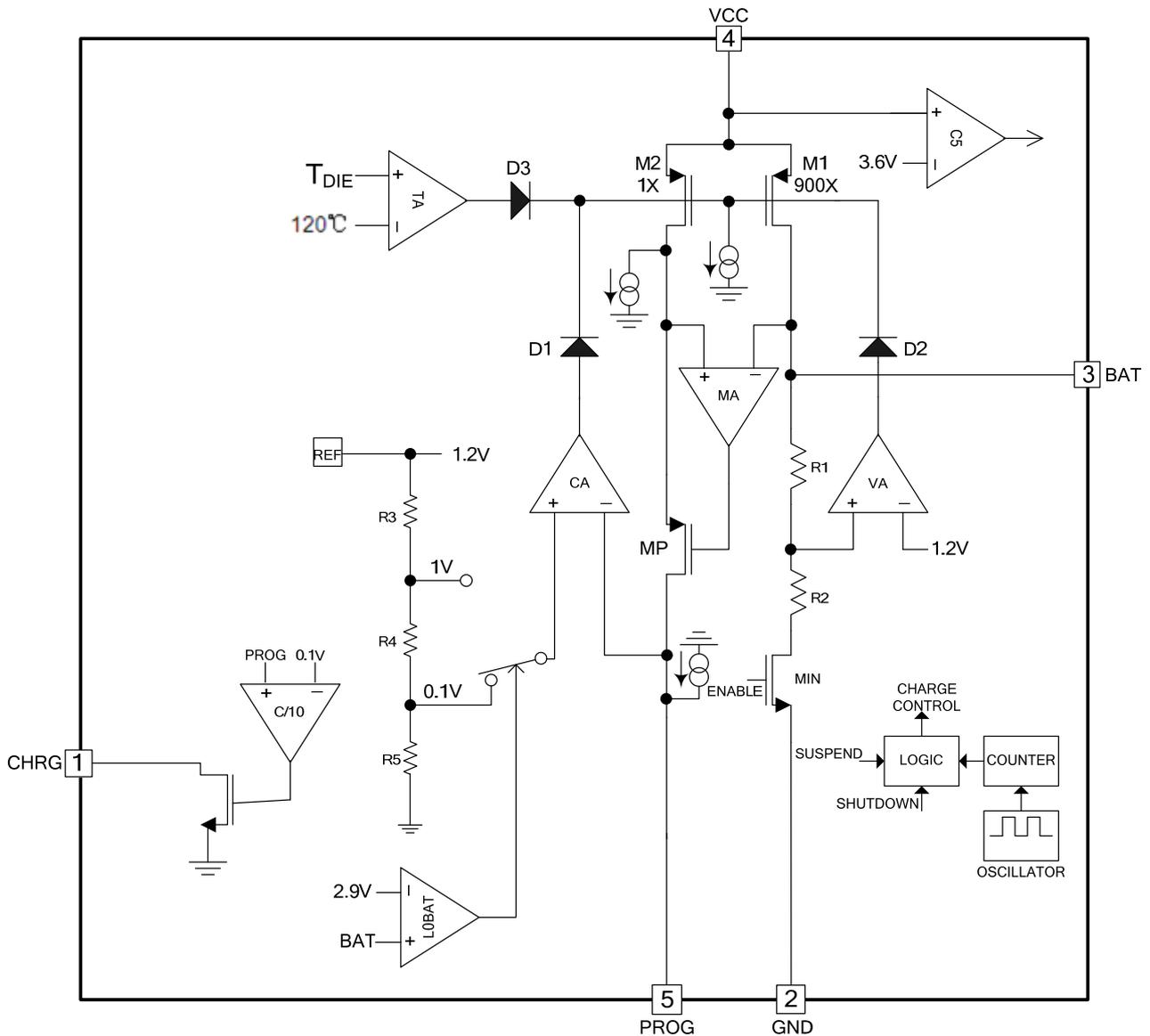
BAT (Pin 3): Charge Current Output. It should be bypassed with at least a 1 μ F capacitor. It Provides charge current to the battery and regulates the final float voltage to 4.2V. An internal precision resistor divider from this pin sets the float voltage which is disconnected in shutdown mode.

VCC (Pin 4): Positive Input Supply Voltage. It provides power to the charger. VCC can range from 4.5V to 6.5V and should be bypassed with at least a 1 μ F capacitor.

PROG (Pin 5): 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: $I_{BAT} = (V_{PROG}/R_{SET}) \cdot 900$.

The PROG pin can also be used to shut down the charger. Disconnecting the program resistor from ground, the charger enters shutdown mode. Reconnecting R_{PROG} to ground will return the charger to normal operation.

Block Diagram



Application Information

The HX6001 is a single cell lithium-ion battery charger using a constant-current/constant-voltage algorithm with programmable current. Charge current can be programmed to 700mA (using a good thermal PCB layout) with a final float voltage accuracy of $\pm 1\%$. The HX6001 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 less external components. Furthermore, the HX6001 is capable of operating from a USB power source.

Normal Charge Cycle

A charge cycle begins when the voltage at the VCC pin rises above 4.5V and a 1% program resistor is connected from the PROG 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 HX6001 supplies approximately 1/10 the programmed charge 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 goes into the fast charge constant-current mode, where the programmed charge current is supplied to the battery. When the BAT pin approaches the final float voltage (4.2V), the HX6001 enters constant-voltage mode and the charge current begins to decrease. The charge cycle ends when the charge current drops to 1/10 of the programmed value.

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 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. Once the average charge current drops below 1/10th the programmed value, the HX6001 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 HX6001 constantly monitors the BAT pin voltage in standby mode. If this voltage drops below the recharge threshold (V_{RECHRG}), another charge cycle begins and current is once again supplied to the battery. To manually restart a charge cycle in standby mode, the input voltage must be removed and reapplied, or the charger must be shut down and restarted using the PROG pin.

Shutdown Mode

The HX6001 can be shut down by floating PROG pin. In shutdown mode, the battery drain current is reduced to 13 μ A and the supply current to about 80 μ A. A new charge cycle can be initiated by reconnecting the program resistor. Removing the input power supply will put the charger into sleep mode.

Automatic Recharge

Once the charge cycle terminates, the HX6001 continuously monitors the BAT pin voltage using a comparator. When the battery voltage falls 250mV below 4.2V(which corresponds to approximately 80% to 90% battery capacity), a charge cycle will restart. This ensures that the battery is kept at or near a fully charged condition and eliminates the need for periodic charge cycle initiations. The CHRG output enters a strong pull down state during recharge cycles.

Programming Charge Current

The charge current is programmed using a single resistor R_{PROG} from PROG pin to ground. The battery charge current is 900 times the current out of the PROG pin. The R_{PROG} and the charge current can be calculated as following equation:

$$R_{PROG}=1V/I_{BAT} \cdot 900, I_{BAT}=1V/ R_{PROG} \cdot 900.$$

The charge current out of the BAT pin can be determined at any time by monitoring the PROG pin

voltage and using the following equation:

$$I_{BAT} = R_{PROG} / R_{PROG} \cdot 900.$$

Thermal Limiting

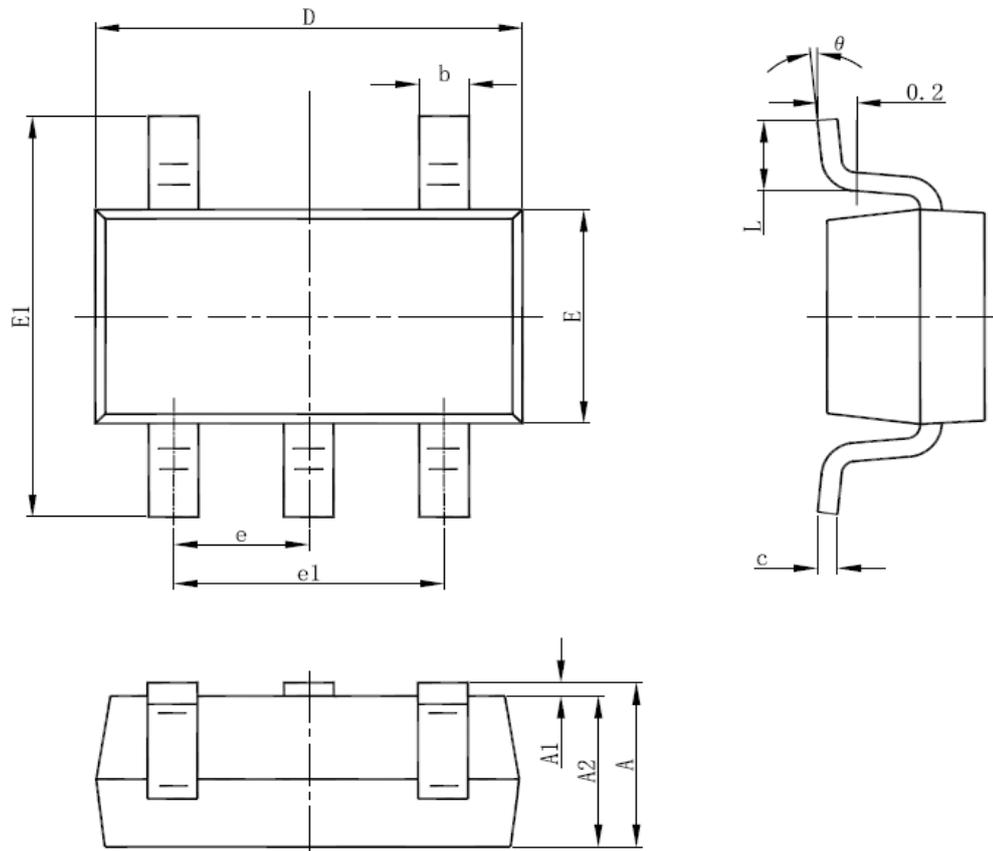
An internal thermal feedback loop reduces the programmed charge current if the die temperature attempts to rise above a preset value of approximately 120°C. This feature protects the HX6001 from excessive temperature and allows the user to push the limits of the power handling capability of a given circuit board without risk of damaging the HX6001. 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. Thin SOT power considerations are discussed further in the Applications Information section.

V_{CC} Bypass Capacitor

Many types of capacitors can be used for input bypassing, however, caution must be exercised when using multilayer ceramic capacitors. Because of the self-resonant and high Q characteristics of some types of ceramic capacitors, high voltage transients can be generated under some start-up conditions, such as connecting the charger input to a live power source. Adding a 1.5W resistor in series with an X5R ceramic capacitor will minimize start-up voltage transients.

Packaging Information

SOT-23-5L Package Outline Dimension



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950(BSC)		0.037(BSC)	
e1	1.800	2.000	0.071	0.079
L	0.300	0.600	0.012	0.024

Subject changes without notice.