Description

The SLM6401 is a complete single-cell lithium battery constant current and constant voltage linear charging IC with an operating voltage of 4.0 to 6.0V, a maximum withstand voltage of 28V, and a maximum charging current of 600mA. It is available in a tiny SOT-23-6L package and requires only a few external components to make it fully suitable for portable applications. The SLM6401 is designed for USB power features, while the SLM6401 can also be used as a stand-alone linear lithium battery charger.

Typical Applications

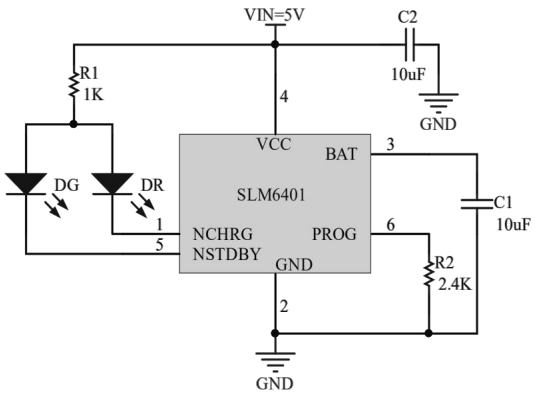


Figure 1

Features

- Input withstand voltage up to 28V
- Up to 600mA charging current
- No external MOSFET, diode and sense resistor required
- With battery anti-reverse function
- Over temperature protection
- Constant current/constant voltage charging
- Preset 4.2V charging voltage with an accuracy of ±1%
- 2.6V trickle charge threshold
- Automatic recharge
- C/10 charging termination
- Charging status dual output, no battery and fault status display
- Soft start limits inrush current
- RoHS SOT-23-6L package

Application

- Mobile charging power supply
- MP3, MP4 player
- Digital camera
- E-dictionary
- Electronic cigarette
- Portable devices, various chargers

Pin Configuration

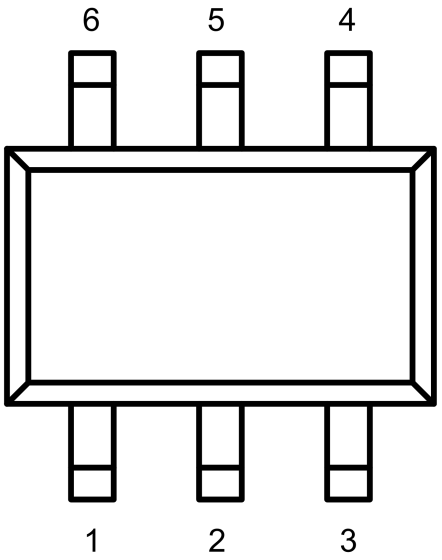


Figure 2

Pin number	Pin name	Features
1	NCHRG	Charging status indication
2	GND	Ground terminal
3	BAT	Battery
4	VCC	power input
5	NSTDBY	Charging status indication
6	PROG	Charge current programming pin

Pin Description

NCHRG (Pin 1): The charge status indicator of the open-drain output. When the charger charges the battery, the pin is pulled low by the internal switch, indicating that charging is in progress; otherwise the pin is in a high impedance state.

GND (Pin 2): Power ground.

BAT (Pin 3): Battery connection. Connect the positive end of the battery to this pin. The leakage current of the BAT pin is less than 2uA when the chip is disabled or in sleep mode. The BAT pin provides a charge current and a 4.2V limit voltage to the battery.

VCC (Pin 4): Input voltage positive input. This pin voltage is the operating power of the internal circuit. When the voltage difference between the VCC and BAT pins is less than 30mV, the SLM6401 will enter a low-power shutdown mode where the current at the BAT pin will be less than 2uA.

NSTDBY (Pin 5): The battery fill indicator of the open-drain output. When the battery is fully charged, the pin is pulled low by the internal switch, otherwise the pin is in a high impedance state.

PROG (Pin 6): Constant current charge current setting and charge current monitoring terminal. The charging current can be programmed by connecting an external resistor from the PROG pin to ground. During the precharge phase, the voltage at this pin is limited to 0.2V, during the constant current charging phase, the voltage at this pin is fixed at 1V. In all modes of charge state, the voltage of this pin can be measured according to the following formula:

$$I_{BAT} = V_{PROG} / R_{PROG} * 1200$$

Electrical Characteristics

(V_{CC} = 5V±5% , T_A = 25°C, unless otherwise specified)

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
V_{CC}	Input supply voltage		4.0	5	6.0	V
I_{CC}	Input supply current	Standby mode (charge termination)		102	200	uA
		Shutdown (R_{PROG} not connected, V_{CC}<V_{BAT} or V_{CC}<V_{UV})		60	100	uA
V_{FLOAT}	Stable output (floating charge) voltage		4.158	4.2	4.242	V
I_{BAT}	BAT pin current (The current mode test condition is V_{BAT}=4.0V)	R_{PROG}=2.4K,Current mode	450	500	550	mA
		R_{PROG}=12K,Current mode	90	100	110	mA
		Standby mode，V_{BAT}=4.3V	0	2.5	5	uA
		Sleep mode，Vcc=0V			5	uA
I_{TRIKL}	Trickle charging current	V_{BAT}<V_{TRIKL}，R_{PROG}=2.4K	75	100	125	mA
V_{TRIKL}	Trickle charge threshold voltage	R_{PROG}=2.4K，V_{BAT} rise	2.4	2.6	2.8	V
V_{TRHYS}	Trickle charging hysteresis voltage	R_{PROG}=2.4K		70		mV
V_{UV}	V_{CC} undervoltage lockout threshold	From V_{CC} low to high	3.6	3.8	4.0	V
V_{UVHYS}	V_{CC} undervoltage lockout hysteresis		150	250	350	mV
V_{OV}	V_{CC} over-voltage protection threshold	From V_{CC} low to high	6.1	6.3	6.5	V
V_{OVHYS}	V_{CC} over-voltage protection hysteresis		80	130	180	mV
I_{PROG}	Pull current on the PROG pin			1.0		uA
V_{PROG}	PROG pin voltage	R_{PROG}=1.2K, current mode	0.9	1.0	1.1	V
V_{ASD}	V_{CC}-V_{BAT} blocking threshold voltage	V_{CC} from low to high	60	150	240	mV
		V_{CC} from high to low	10	60	100	mV
I_{TERM}	C/10 termination current threshold	R_{PROG}=2.4K	40	50	60	mA
		R_{PROG}=1.2K	90	100	110	mA

V_{NCHRG}	NCHRG pin output low level	I_{NCHRG}=5mA		0.3	0.6	V
V_{NSTDBY}	NSTDBY pin output low level	I_{NPG}=5mA		0.3	0.6	V
ΔV_{RECHRG}	Recharge battery threshold voltage		100	170	220	mV
T_{LIM}	Junction temperature in limited temperature mode			145		°C
R_{ON}	Power FET ON resistor (between V_{CC} and BAT)			350		mΩ
t_{SS}	Soft start time	I_{BAT}=0 to I_{BAT}=1200/R_{PROG}		20		us
t_{RECHRG}	Recharge comparator filter time	V_{BAT} high to low	0.8	1.8	4	ms
t_{TERM}	Terminate comparator filter time	I_{BAT} falls below I_{CHRG}/10	0.8	1.8	4	ms

Principle

The SLM6401 is a linear charger circuit designed for single-cell Li-Ion or Li-Polymer batteries. It uses a power transistor inside the chip to charge the battery at constant current and constant voltage. The charging current can be programmed with an external resistor. The maximum continuous charging current can reach 600mA without the need for an external blocking diode and current sense resistor. The SLM6401 includes two open-drain status indicators, a charge status indicator NCHRG and a full status indicator NSTDBY. The internal power management circuit automatically reduces the charging current when the junction temperature exceeds 145 °C. This function allows the user to maximize the chip processing capability without worrying about chip overheating and damage the chip or damage external components. In this way, the user can design the charging current without considering the worst case, but only according to the typical situation, because in the limit case, the SLM6401 will automatically reduce the charging current.

When the input voltage is greater than the power supply undervoltage detection threshold and less than the overvoltage protection threshold, the SLM6401 begins to charge the battery, the NCHRG pin outputs a low level, and the NSTDBY terminal outputs a high impedance state, indicating that charging is in progress.

If the battery voltage is lower than 2.6V, the charger uses the trickle mode to charge the battery. When the battery voltage is higher than 2.6V, it is converted to fast charging mode. The charging current is determined by RPROG. When the battery voltage approaches 4.2V, the charging current will gradually decrease and the SLM6401 enters the constant voltage mode. When the charging current decreases to the charging end threshold, the charging cycle ends, the NCHRG terminal outputs a high-impedance state, and the NSTDBY terminal outputs a low level.

The charge end threshold is 10% of the current of the constant current charge. The SLM6401 automatically begins a new charge cycle when the battery voltage drops below the recharge threshold. The high-precision voltage reference source inside the chip, the error amplifier and the resistor divider network ensure that the battery-side modulation voltage progresses within 1%, meeting the requirements for accurate charging of lithium-ion batteries and lithium polymer batteries. When the input voltage is powered down or the input voltage is lower than the battery voltage, the charger enters a low-power sleep mode, and the battery terminal consumes less than 3uA, which increases standby time.

Charging Current Setting

The charge current is set using a resistor connected between the PROG pin and GND. Set the resistor and charge current using the following formula:

$R_{PROG}=1200 / I_{BAT}$ (error ±10%)

Users can choose the right size R_{PROG} according to their needs in the application.

Charge Termination

When the charging current drops to 1/10 of the set value after reaching the final floating voltage, the charging cycle is terminated. This condition is detected by monitoring the PROG pin with an internal filter comparator. When the PROG pin drops to 100mV for more than t_{TERM} (usually 1.8ms), the charging is stopped, the charging current is blocked, the NCHRG output is high impedance, and the NSTDBY output is low, and the battery is fully charged. The SLM6401 enters standby mode, where the input supply current drops to 100uA. (Note: C/10 termination fails in trickle charge mode and thermal limit charge mode).

When charging, the transient load on the BAT pin causes the PROG pin voltage to briefly drop to 100mV between 1/10 of the set DC charge current. Terminating the 1.8ms filter time (t_{TERM}) on the comparator ensures that transient loads of this nature do not cause the charge cycle to terminate prematurely. Once the average current drops to 1/10 of the set value, the SLM6401 terminates the charge cycle. In this state, all loads on the BAT pin must be powered by the battery.

In standby mode, the SLM6401 continuously monitors the BAT pin voltage. If the pin voltage drops below the recharge threshold of 4.05V (V_{RECHRG}), another charge cycle begins and current is supplied to the battery.

Charging Status Indication

The SLM6401 has two open-drain status indicator outputs.NCHRG and NSTDBY.

When the input voltage is between V_{UV} and V_{OV}, it indicates that the input voltage is in a chargeable state.

When the charger is in the charging state, NCHRG is pulled low. When it is in the fully charged state, NSTDBY is at a low level, and in other cases, it is in a high impedance state.

When the battery is not connected to the charger, the NCHRG pin output pulse signal indicates that the battery is not installed. When the external capacitor of the BAT pin is 10uF, the NCHRG blinking frequency is about 1-4 seconds, and NSTDBY is always on.

Chip Over Temperature Protection

If the chip temperature rises above the preset 140°C, an internal thermal feedback loop will reduce the charging current until the current above 150°C is reduced to 0. This feature prevents SLM6401 from overheating and allows users to increase the power handling capacity of a given circuit board within the allowable range of SLM6401.

Undervoltage, Overvoltage Lockout

An internal undervoltage and overvoltage lockout circuit monitors the input voltage and keeps the charger in shutdown mode when the Vcc voltage is below the undervoltage lockout threshold or above the overvoltage protection threshold. In a high resistance state. When the Vcc voltage is higher than the undervoltage lockout threshold and below the overvoltage protection threshold, the charger works normally.

Automatic restart

After a charge cycle is completed, the SLM6401 immediately uses a comparator with a 1.8ms filter time (tRECHARGE) to continuously monitor the voltage on the BAT pin. When the battery voltage drops below 4.10V (approximately approximately 90% of the battery capacity), the charge cycle begins again. This ensures that the battery is maintained at (or near) a fully charged state and eliminates the need to initiate a periodic charge cycle. During recharging, the NCHRG pin output enters a strong pull-down state.

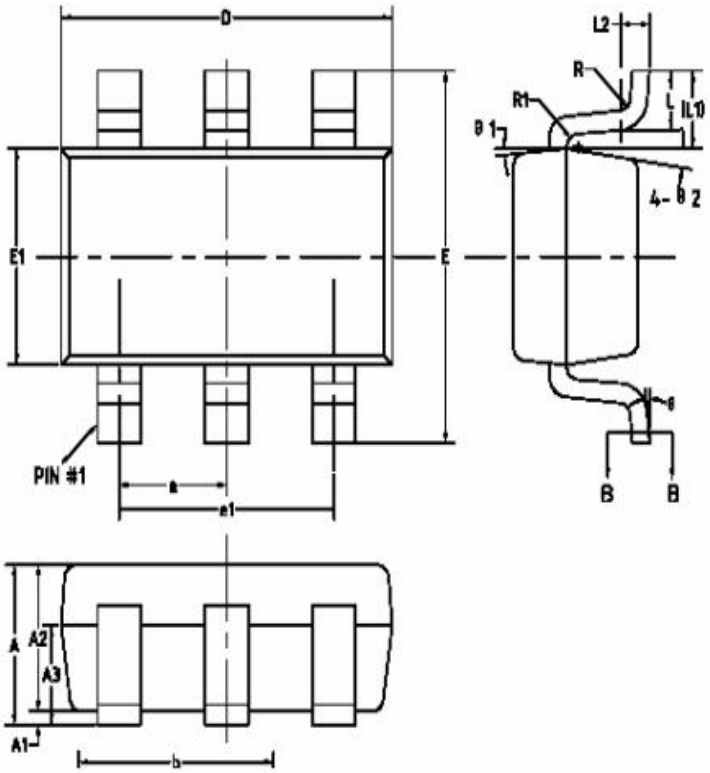
VCC Bypass Capacitor

Although various types of capacitors can be used as bypass capacitors, multilayer ceramic capacitors are preferred. Because the capacitor is subjected to high voltage transients under certain starting conditions, some ceramic capacitors will generate self-vibration. It is recommended to use a multilayer ceramic capacitor with a capacitance of 0.1uF ~ 1uF in parallel with GND at the Vcc input.

Heat Dissipation Considerations

Because this chip is a small-sized SOT-23-6L package, it is very important to maximize the charging current by dissipating heat through the PCB layout. The heat dissipation path is from the chip to the pin, then to the pad, and then to the copper of the PCB. As a heat sink, the PCB should be as wide as possible and the copper should be enlarged to spread the heat to the air. When designing the PCB layout, other heating components on the PCB must also be considered, and try to avoid being close to the charger, otherwise the overall temperature rise will also affect the charging current of the charger.

Package Description



COMMON DIMENSIONS
(UNITS OF MEASURE=MILLIMETER)

SYMBOL	MIN	NOM	MAX
A	–	–	1.25
A1	0	–	0.15
A2	1.00	1.10	1.20
A3	0.60	0.65	0.70
b	0.36	–	0.50
b1	0.36	0.38	0.45
c	0.14	–	0.20
c1	0.14	0.15	0.16
D	2.826	2.926	3.026
E	2.80	2.80	3.00
E1	1.526	1.626	1.726
e	0.95BSC		
e1	1.90BSC		
L	0.35	0.45	0.60
L1	0.59REF		
L2	0.25BSC		
R	0.10	–	–
R1	0.10	–	0.20
θ	0°	–	8°
θ1	3°	5°	7°
θ2	6°	8°	10°