SLM6400

28V, 1A Linear Li-Ion Battery Charger

Description

The SLM6400 is a complete single-cell Li-Ion battery with a constant current constant voltage linear charger. The DFN-8L package with heat sink on the bottom and fewer external components make the SLM6400 ideal for portable applications. The SLM6400 is suitable for USB power and adapter power supplies.

Due to the internal PMOSFET architecture and anti-reverse charging path, no external isolation diodes are required. Thermal feedback automatically adjusts the charge current to limit chip temperature during high power operation or high ambient temperature conditions. The charging voltage is fixed at 4.2V, and the charging current can be externally set by a resistor. When the charging current drops to the set value of 1/10 after reaching the final float voltage, the SLM6400 will automatically terminate the charge cycle.

When the input voltage is removed, the SLM6400 automatically enters a low current state, reducing the battery leakage current to less than 5uA. The SLM6400 can also be placed in shutdown mode when there is power to reduce the supply current to 60uA.

Absolute Maximum Ratings

- Input power supply voltage (Vcc): -0.3V~28V
- PROG, NTC: -0.3V~8.0V
- BAT: -0.3V~12.0V
- NCHRG, NSTDBY, NCE: -0.3V~Vcc+0.3V
- BAT Short Circuit Duration: Continuous
- BAT Pin Current: 1200mA
- Maximum Junction Temperature: 145°C
- Operation Temperature Range: -40°C~85°C
- Storage Temperature Range: -65°C~125°C
- Lead Temperature (Soldering, 10 sec): 260℃

Features

- Input withstand voltage up to 28V
- Up to 1000mA charging current
- No MOSFET, sense resistor or isolation diode required
- For single-cell lithium-ion batteries
- Constant current/constant voltage operation with thermal regulation for maximum charge rate without risk of overheating
- 4.2V preset charging voltage with ±1% accuracy
- Charge current monitor output for battery charge detection
- Automatic recharge
- Charge status dual output, no battery and fault status display
- C/10 charge termination
- 2.6V trickle charge threshold
- Soft start limits inrush current
- Battery temperature monitoring
- Available in a miniaturized DFN3*3-8L package

Application

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

Complete Charge Cycle

(1000mAh battery)

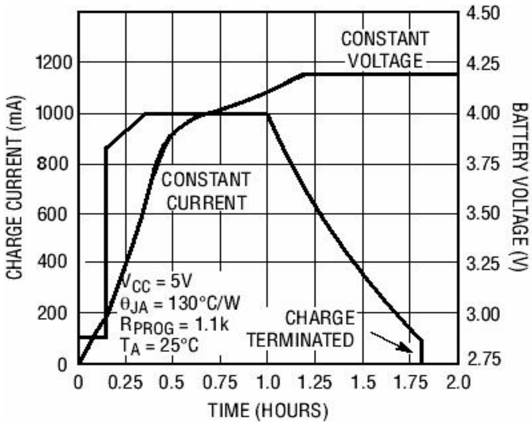


Figure 1

Typical Applications

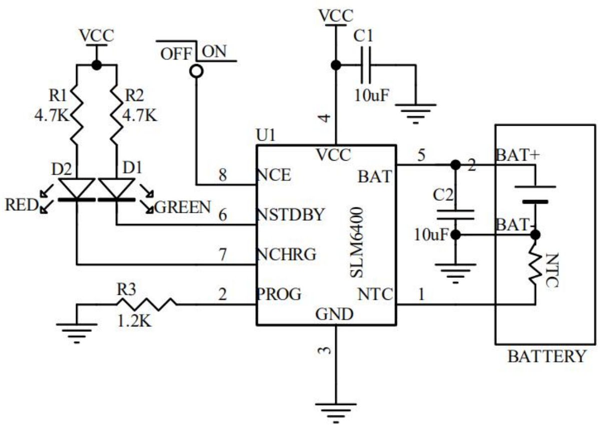


Figure 2

Application Tips

In order to maximize the charge current, PCB board layout design should be optimized to provide IC within DFN-8L package effective heat dissipation.

The thermal path for the heat generated by IC is from the die to lead frame, and finally to the PCB board copper through the bottom heat sink. As the heat sink of IC, the copper pads of PCB 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 PCB board, as figure 3 illustrates, place a 1.5*2.0mm pad as the heat sink of SLM6400, and then place 2 cooling holes with 0.8mm diameter and 1.2mm 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 SLM6400 is effectively connected to the cooling pad.

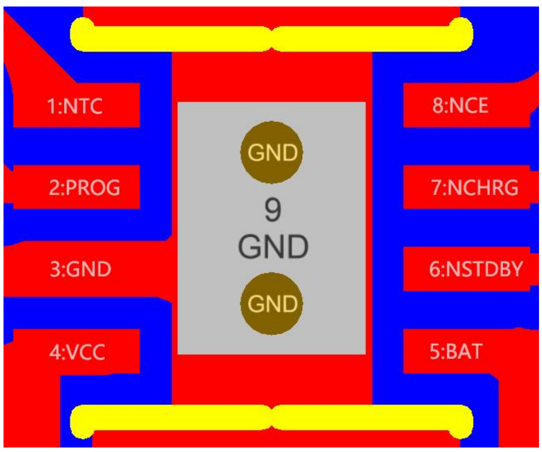


Figure 3

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

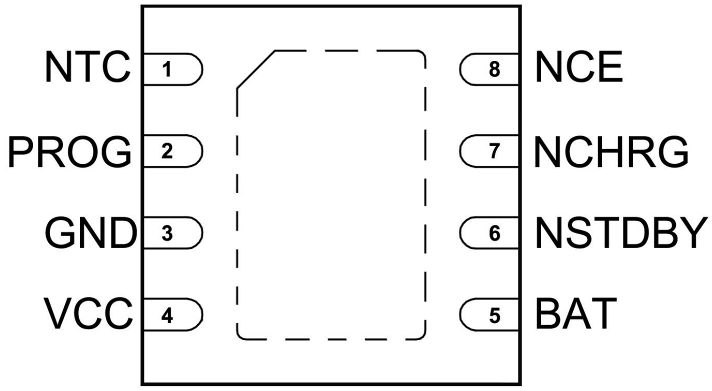


Figure 4

Pin	Symbol	Function
1	NTC	Battery temperature detection input.
2	PROG	Constant current charging current setting and charging current monitoring terminal.
3	GND	Power ground.
4	VCC	Input voltage positive input.
5	BAT	Battery connection Pin.
6	NSTDBY	Charge terminated status output.
7	NCHRG	Open-Drain charge status output.
8	NCE	Chip enable input.

Pin Description

NTC (Pin 1): Battery temperature detection input. Connect this pin to the output of the battery's NTC sensor. If the voltage of the NTC pin is less than 150mV or greater than 1.2V, it means that the battery temperature is too high or too low and charging is suspended. If the NTC is left floating or a resistor of 1 MΩ or more is connected to the ground, the battery temperature detection function is canceled, and other charging functions are normal.

PROG (Pin 2): 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:

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

GND (Pin 3): Power ground.

VCC (Pin 4): Input voltage positive input. This pin voltage is the operating power of the internal circuit. When the voltage difference between VCC and BAT pins is less than 30mV, the SLM6400 will enter a low-power shutdown mode where the current at the BAT pin will be less than 2uA.

BAT (Pin 5): Battery connection pin. Connect the positive end of the battery to this pin. When the chip is disabled or in sleep mode, the leakage current of the BAT pin is less than 2uA. The BAT pin provides a charging current and a 4.2V limiting voltage to the battery.

NSTDBY (Pin 6): 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.

NCHRG (Pin 7): 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.

NCE (Pin 8): Chip enable input. A low input will put the chip in normal operation, a high input will put the chip in a disabled state. The NCE pin can be driven by TTL level or CMOS level.

Electrical Characteristics

(If not specified, V_{CC} = 5V ±5% , T_A = 25°C)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
V_{CC}	Input supply voltage		4.0	5	6.0	V
I_{CC}	Input supply current	Shandby mode (charge ends)		102	200	uA
		Shutdown mode (R_{PROG} not connected ,V_{CC}<V_{BAT} or V_{CC}<V_{UV})		60	100	uA
V_{FLOAT}	Stable output (floating charge) voltage	0°C≤T_A≤85°C	4.158	4.2	4.242	V
I_{BAT}	BAT pin current: (current mode test condition is V_{BAT} = 4.0V)	R_{PROG}=2.4K, current mode	450	500	550	mA
		R_{PROG}=1.2K, current mode	900	1000	1100	mA
		Standby mode, V_{BAT} = 4.3V	0	2.5	5	uA
		Shutdown mode (NCE to V_{CC})		0	±2	uA
		Sleep mode, Vcc=0V			5	uA
I_{TRIKL}	Trickle charging current	V_{BAT}<V_{TRIKL},R_{PROG}=1.2K	150	200	250	mA
V_{TRIKL}	Trickle charge threshold voltage	R_{PROG}=1.2K, V_{BAT} rises	2.4	2.6	2.8	V
V_{TRHYS}	Trickle charge hysteresis voltage	R_{PROG}=1.2K		70		mV
V_{UV}	V_{CC} under-voltage lockout threshold	From $_{VCC}$ low to high	3.6	3.8	4.0	V
V_{UVHYS}	V_{CC} under-voltage 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
I_{NTC}	NTC pin current		36	40	44	uA
V_{NTC-H}	NTC high threshold voltage			1.2		V
V_{NTC-L}	NTC low threshold voltage			0.15		V
V_{NCE-H}	NCE pin active high		1.2			V
V_{NCE-L}	NCE pin active low				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 SLM6400 is a linear charger designed for single lithium-ion battery or lithium-polymer battery. It uses a power transistor inside the chip to charge the battery with constant current and constant voltage. The charging current can be programmed with an external resistor. The maximum continuous charging current can be up to 1A without the need for an external blocking diode and current sense resistor. The SLM6400 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 SLM6400 will automatically reduce the charging current.

When the input voltage is larger than the under-voltage detection threshold of the power supply and is less than the over-voltage protection threshold, the chip NCE is low voltage normal time, SLM6400 starts to output the low level NCHRG pin output high resistance state to the battery charging pin, indicating that the charge is in progress.

If the battery voltage is less than 2.5V, the charger uses trickle mode to charge the battery. When the battery voltage is higher than 2.5V, the battery is converted to fast charging mode, and the charging current is determined by R_{PROG}. When the battery voltage is close to 4.2V, the charging current will gradually decrease and SLM6400 will enter constant voltage mode.

When the charge current is reduced to the charge, At the end threshold, the NCHRG end of the charging cycle outputs a high resistance state and a low level output from the NSTDBY terminal.

The charge end threshold is 10% of the current of the constant current charge. The SLM6400 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. If the enable terminal NCE is connected high, the charger will stop charging.

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 SLM6400 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 SLM6400 terminates the charge cycle. In this state, all loads on the BAT pin must be powered by the battery.

In standby mode, the SLM6400 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 SLM6400 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 NTC terminal is used as a typical connection, the battery is not connected to the charger SLM6400 and is judged to be in a fault state. The red and green lights are not lit. When the NTC pin is connected to GND, the battery temperature detection does not work. 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 SLM6400 from overheating and allows users to increase the power handling capacity of a given circuit board within the allowable range of SLM6400.

Battery Temperature Monitoring

In order to prevent damage to the battery caused by excessive or too low temperature, the SLM6400 integrates a battery temperature monitoring circuit.

Battery temperature monitoring is achieved by monitoring the thermistor that is in close proximity to the negative temperature coefficient of the battery. The thermistor is connected between NTC and GND.

Inside the chip, the NTC pin is connected to the input of two voltage comparators with a low voltage threshold of 150mV, corresponding to the upper temperature point of the normal temperature range; the high voltage threshold is 1.2V, corresponding to the lower temperature point of the normal temperature range. If the voltage of the NTC pin is within this range, the chip is normally charged, otherwise the battery temperature is too high or too low, and the charging process will be suspended.

The pull-up current of the NTC pin is 40uA,so the thermal resistance value of negative temperature coefficient should be 10K_at 25°C, about 3.75K_at the upper limit temperature (about 52°C), and about 30K at the lower limit temperature (about -1°C). Users can choose the right type according to the specific needs.

If you need to adjust the upper or lower temperature protection point, you can do this by connecting a normal resistor in parallel with the thermistor or in series.

If you do not need the battery temperature monitoring function, just leave the NTC pin floating, or connect a resistor of 1MΩ or more to GND.

Under-voltage Lockout

An internal under-voltage blocking circuit monitors the input voltage and keeps the charger in shutdown mode before the Vcc rises above the under-voltage blocking threshold. The UVLO circuit will keep the charger in shutdown mode. If the UVLO comparator jumps, the charger will not exit the stop mode until the Vcc rises to 1000mV above the battery voltage.

Manual Shutdown

The SLM6400 can be set to stop mode at any time during the charging cycle by setting the NCE end to high level or by removing the R_{PROG}. This makes the battery drain current drop to 2uA and the power supply current drop to about 60uA. Reset the NCE end to low level or link R_{PROG} to restart the charging cycle.

Automatic Restart

After the completion of a single charging cycle, SLM6400 immediately adopted a comparator with a 1.8ms filter time ($t_{RECHARGE}$) to continuously monitor the voltage on the BAT pin. When the battery voltage drops to 4.05v (roughly equivalent to 80-90% of the battery capacity), the charging cycle begins again. This ensures that the battery is maintained at (or near) a full charge state and eliminates the need for periodic charging cycle initiation. During recharging, NCHRG pin output enters a strong pull-down state.

Thermal Considerations

In order to maximize the charge current, PCB board layout design should be optimized to provide IC within DFN-8L package effective heat dissipation.

The thermal path for the heat generated by IC is from the die to lead frame, and finally to the PCB board copper through the bottom heat sink. As the heat sink of IC, the copper pads of PCB 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 PCB board, as figure 3 illustrates, place a 1.5*2.0mm pad as the heat sink of SLM6400, and then place 2 cooling holes with 0.8mm diameter and 1.2mm 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 SLM6400 is effectively connected to the cooling pad.

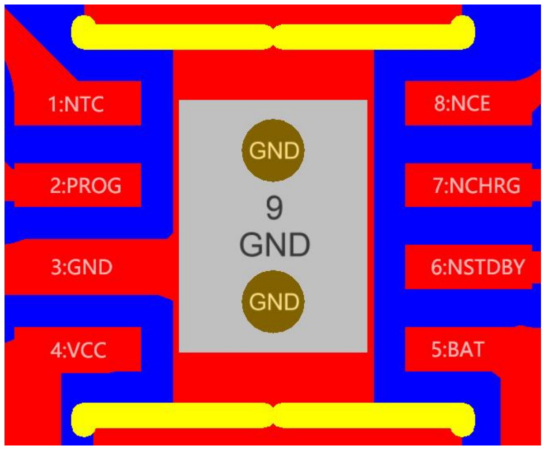


Figure 3

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.

Increase Thermal Regulation Current

Reducing the pressure drop at both ends of the internal MOSFET can significantly reduce the power consumption in IC. This has the effect of increasing the current transmitted to the battery during thermal regulation. One strategy is to dissipate some power through an external element, such as a resistor or diode.

Example: Programmatically set a SLM6400 that draws operating power from a 5V AC adapter to a fully charged current of 800mA to a discharged Li-ion battery with 3.75V. Assuming JA q is 125 ° C / W, ° C is at 25 ° C ambient temperature conditions, the charging current is approximately:

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

By reducing the voltage across a resistor in series with a 5V AC adapter, the on-chip power dissipation can be reduced, thereby increasing the thermally regulated charging current:

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

We can figure out:

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

Take R_{CC}=0.25Ω, V_S=5V, V_{BAT}=3.75V, TA=25°C. And at 125 °C / W, we can calculate the thermal adjustment Charging current: I_{BAT}=948mA, the result shows that the structure can be Output 800mA full-scale charge at higher ambient temperature.

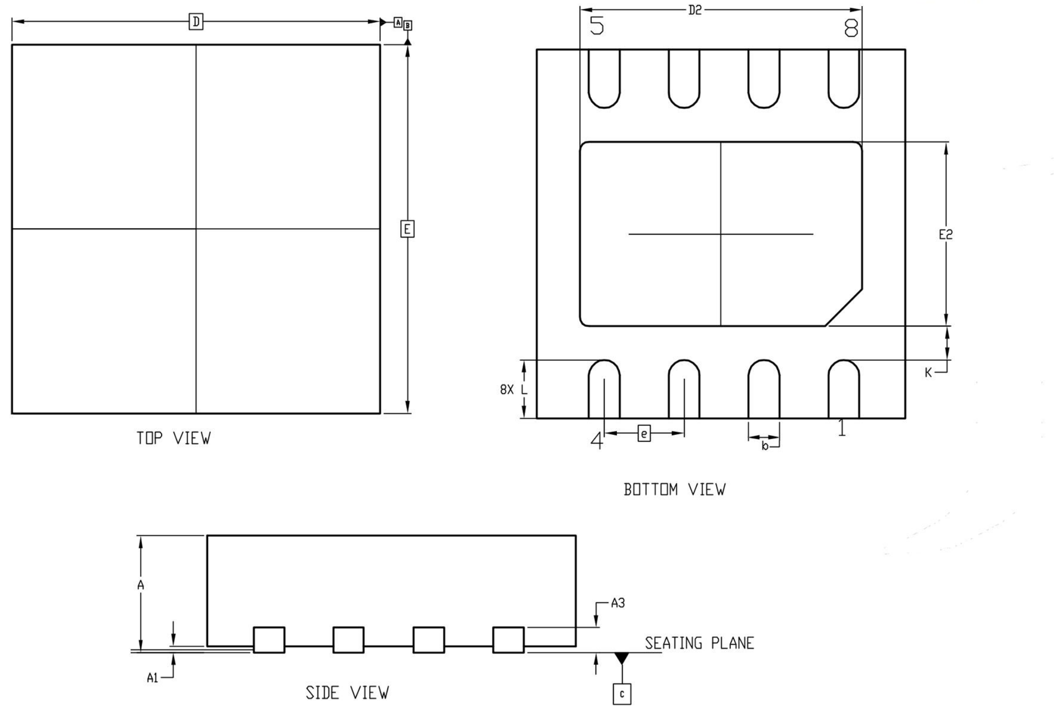
While this application can deliver more energy to the battery and shorten the charging time in the thermal mode, in voltage mode, if V_{CC} becomes low enough to put the SLM6400 in a low-dropout state, it may actually extend the charge. time. This technique works best when the R_{CC} value is minimized in order to keep the size of the components small and to avoid pressure drops. Remember to choose a resistor with sufficient power handling capability.

Package Description

DFN3X3 -8L

PACKAGE OUTLINE DIMENSIONS

Unit: mm



DIM / SYMBOL	MIN.	NOM.	MAX.
A	0.70	0.75	0.80
	0.80	0.85	0.90
A1	0	0.02	0.05
A3	–	0.20 REF	–
b	0.20	0.25	0.30
D	3.00BSC		
E	3.00BSC		
D2	2.25	2.30	2.35
E2	1.45	1.50	1.55
e	0.65BSC		
L	0.425	0.475	0.525
K	0.20		