Standalone Linear Lithium Battery Charger With Thermal Regulation

■ INTRODUCTION

The SMC4008H is a complete constant-current/ constant-voltage linear charger for single cell lithium rechargeable battery. No external sense resistor is needed, and no blocking diode is required due to the internal P-MOSFET architecture. Furthermore, the SMC4008H is specifically designed to work within USB power specifications. Its low external component count makes the SMC4008H ideally suited for portable applications. Thermal feedback regulates the charge current to limit the die temperature during high power operation or high ambient temperature. The charge current can be programmed externally with a single resistor. The SMC4008H automatically terminates the charge cycle when the charge current drops to 1/10th the programmed value after the final float voltage is reached. When the input supply (wall adapter or USB supply) is removed, the SMC4008H automatically enters a low power sleep mode, dropping the battery drain current to less than 2μA. The SMC4008H can be put into shutdown mode, reducing the supply current to 50μA. Other features include battery pack temperature monitor, undervoltage lockout, automatic recharge and two status pins to indicate charging and charge termination. The SMC4008H is available in thermally enhanced SOT package.

■ FEATURES

- Charges Single Cell Lithium Battery Directly from USB Port or AC Adapter
- Input Voltage Range From 4.5V to 24V
- Input OVP: 6.5V
- No External MOSFET, Sense Resistor or Blocking Diode Required
- Preset 4.20V / 4.35V / 4.40V Charge Voltage
- Continuous Programmable Charge Current Up to 600mA
- Precharge Conditioning for Reviving Deeply Discharged Cells and Minimizing Heat Dissipation during Initial Stage of Charge
- Constant-Current/Constant-Voltage/Constant-Temp Operation with Thermal Regulation to Maximize Charge Rate Without Risk of Overheating
- Battery Reverse Protection
- Automatic Recharge
- Charge state pairs of output, no battery and fault status display
- Charge Current Monitor Output for Gas Gauging
- Automatic Low Power Sleep Mode When Input Supply Voltage is Removed
- Soft-Start Limits Inrush Current

■ APPLICATIONS

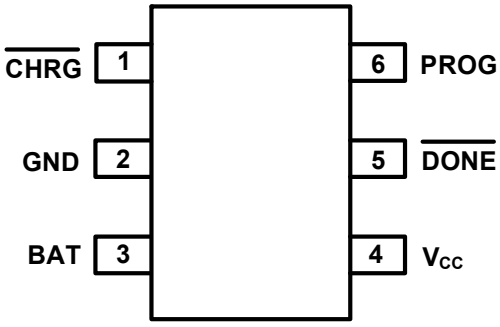
- Cellular phones, PDAs
- Portable Media Players
- Digital Still Cameras
- Bluetooth & GPS Applications
- Mobile Internet Device
- Charging Docks and Cradles

■ ORDER INFORMATION

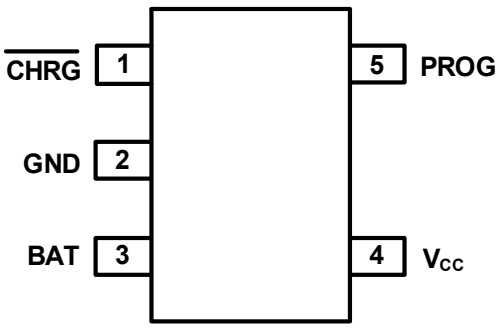
SMC4008H①②③④⑤⑥

DESIGNATOR	SYMBOL	DESCRIPTION
①	-	A Version Number
②	A	Standard
③④⑤	Integer	Output Voltage e.g.4.20V=③: 4, ④: 2, ⑤: 0
⑥	M	Package: SOT-23-5
	E	Package: SOT-23-6

■ PIN CONFIGURATION



SOT-23-6(Top View)

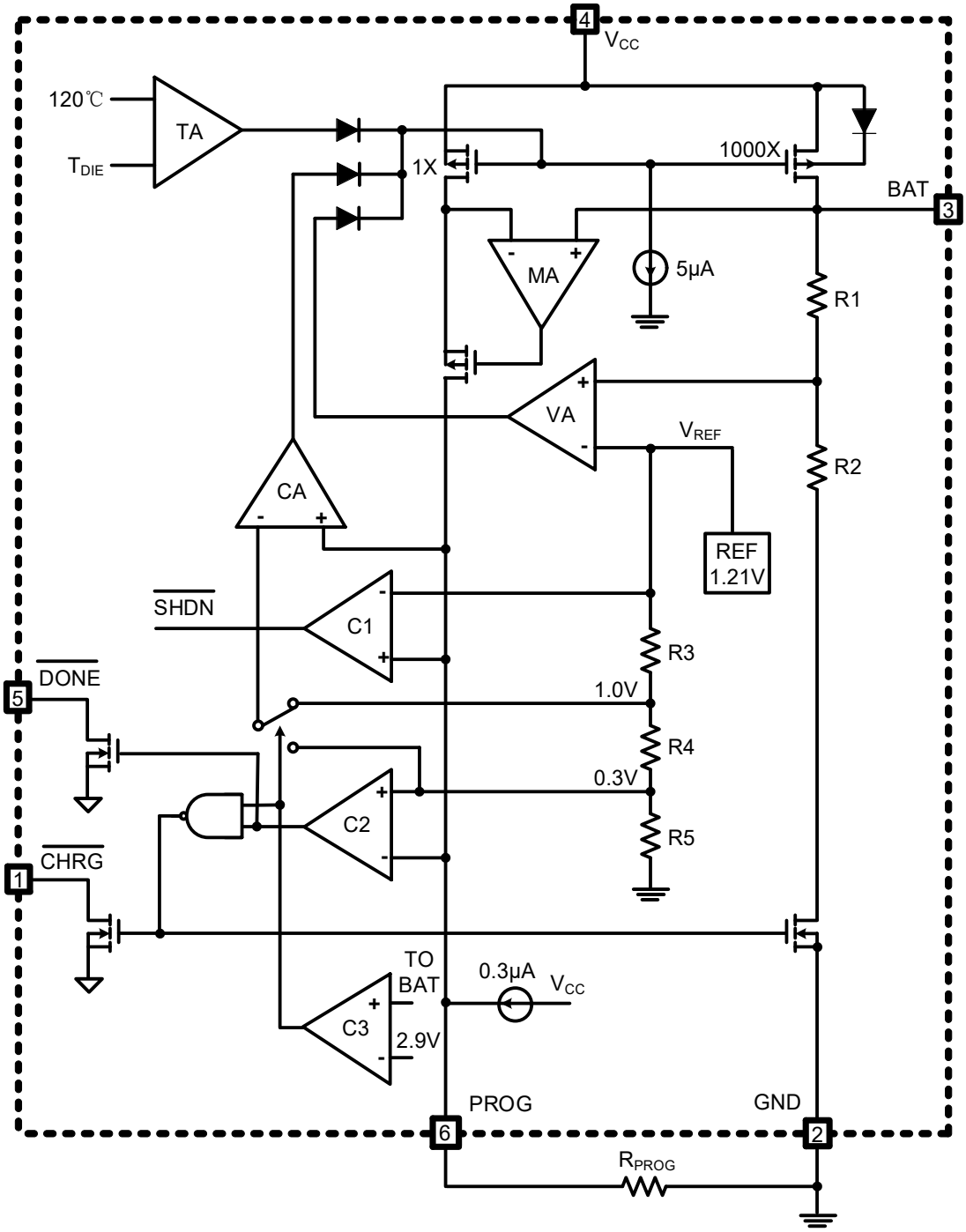


SOT-23-5(Top View)

Table 1. Pin Description（SOT-23-6）

PIN NO.	PIN NAME	FUNCTION
1	$\overline{\text{CHRG}}$	**Open Drain Charge Status Output**. When the battery is being charged, the $\overline{\text{CHRG}}$ pin is pulled low by an internal switch, otherwise $\overline{\text{CHRG}}$ pin is in high impedance state.
2	GND	**Ground Terminal**.
3	BAT	**Charger Power Stage Current Output and Battery Voltage Sense Input.** BAT pin provides charge current to the battery and regulates the final float voltage. An internal precision resistor divider from this pin sets the float voltage which is disconnected in shutdown mode. Connect the positive terminal of the battery to BAT pin. Bypass BAT to GND with 10μF to 47μF capacitor. BAT pin draws less than 2μA current in chip disable mode or in sleep mode.
4	V_{CC}	**Positive Input Supply Voltage**. V_{CC} is the power supply to the internal circuit. V_{CC} can range from 4.5V to 24V and should be bypassed with at least a 4.7μF capacitor. When V_{CC} drops to within 80mv of the BAT pin voltage or V_{CC}>V_{OVP}, SMC4008H enters low power sleep mode, dropping BAT pin's current to less than 2μA.
5	$\overline{\text{DONE}}$	**Open-Drain Charge termination Status Output**. In charge termination status, $\overline{\text{DONE}}$ is pulled low by an internal switch; Otherwise $\overline{\text{DONE}}$ pin is in high impedance state.
6	PROG	**Constant Charge Current Setting and Charge Current Monitor Pin**. The charge current is set by connecting a 1% accuracy metal film resistor R_{PROG} from this pin to GND. When charging in precharge mode, the PROG pin voltage is regulated to 0.3V. When charging in constant-current mode, the PROG pin voltage is regulated to 1V. In all modes during charging, the voltage on PROG pin can be used to measure the charge current as the following formula: $I_{BAT}=(V_{PROG}/R_{PROG})$ X 1000

■ BLOCK DIAGRAM



Future 1 Functional Block Diagram

■ ABSOLUTE MAXIMUM RATINGS(1)

(Unless otherwise specified, T_A = 25°C)

PARAMETER	SYMBOL	RATINGS	UNITS
Input Supply Voltage(2)	V_{CC}	-0.3 ~ 28	V
PROG Pins Voltage(2)		-0.3 ~ 7.0	
BAT Pin Voltage(2)		-5 ~ 12	
$\overline{CHRG}$ $\overline{DONE}$ Pins Voltage(2)		-0.3 ~ 28	
BAT Short-Circuit Duration	-	Continuous	-
BAT Pin Output Current (Continuous)	I_{BAT}	800	mA
Output sink current	$I_{\overline{CHRG}}$, $I_{\overline{DONE}}$	10	mA
Power dissipation	P_D	400	mW
Operating Ambient Temperature Range(3)	T_A	-40 ~ +85	°C
Junction Temperature	T_J	-40 ~ +150	°C
Storage Temperature	T_{stg}	-55 ~ +150	°C
Lead Temperature (Soldering, 10s)	T_{solder}	260	°C
ESD rating(4)	HBM	≥ 2000	V
	MM	≥ 200	V

(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 under recommended operating conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods my affect device reliability.

(2) All voltages are with respect to network ground terminal.

(3) The SMC4008H are 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.

(4) The human body model is a 100pF capacitor discharged through a 1.5kΩ resistor into each pin. The machine model is a 200pF capacitor discharged directly into each pin.

■ RECOMMENDED OPERATING CONDITIONS

PARAMETER	SYMBOL	MIN	MAX	UNITS
Input voltage range(5)	V_{CC}	4.5	24	V
BAT Pin Output Current (Continuous)	I_{BAT}		600(6)	mA
Fast-charge current programming resistor(7)	R_{PROG}	1.66	50	kΩ

(5) If V_{CC} is between UVLO and 4.5V, and above the battery voltage, then the IC is active (can deliver some charge to the battery), but the IC will have limited or degraded performance (some functions may not meet data sheet specifications). The battery may be undercharged (V_{FLOAT} less than in the specification), but will not be overcharged (V_{FLOAT} will not exceed specification).

(6) The thermal regulation feature reduces charge current if the IC's junction temperature reaches 125°C; Thus without a good thermal design the maximum programmed charge current may not be reached.

(7) Use a 1% tolerance metal film resistor for R_{PROG} to avoid issues with the R_{PROG} short test when using the maximum charge current setting.

■ ELECTRICAL CHARACTERISTICS

(V_{CC} = 5V, T_A = 25℃, Test Circuit Figure2, unless otherwise specified)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Input Supply Voltage			4.5		24	V
Input Over-Voltage Protection Voltage	V_{ovp}	V_{CC} Rising, Hys = 0.27V	6.1	6.5	6.9	V
Input Voltage Range for Charging			4.5		6.0	V
V_{CC} Under voltage Lockout Threshold	V_{UVL}	V_{CC} from Low to High		3.9		V
V_{CC} Under voltage Lockout Hysteresis	ΔV_{UVL}			150		mV
Input Supply Current	I_{CC}	Charge Mode, R_{PROG} = 10K		150	500	μA
		Standby Mode (Charge Terminated)		75	150	
		Shutdown Mode: R_{PROG} Not Connected, V_{CC} < V_{BAT}, or V_{CC} < V_{UVL}		50	100	
Trickle Charge Threshold	V_{TRIKL}	R_{PROG} = 10K, V_{BAT} Rising		2.9		V
Trickle Charge Hysteresis	ΔV_{TRIKL}	R_{PROG} = 10K		100		mV
Trickle Charge Current	I_{TRIKL}	R_{PROG} = 2K	45	50	55	mA
BAT Pin Current	I_{BAT}	R_{PROG} = 2K, Current Mode (V_{BAT}= 3.8V)	450	500	550	mA
		Standby Mode, V_{BAT} = V_{FLOAT}	0	-2.0	-6.0	μA
		Shutdown Mode (R_{PROG} Not Connected)		±1	±2	
		Sleep Mode, V_{CC} = 0V			-1	
PROG Pin Voltage	V_{PROG}	R_{PROG} = 1K, Current Mode	0.9	1.0	1.1	V
PROG Pin Pull-Up Current	I_{PROG}			0.3		μA
Regulated Output (Float) Voltage	V_{FLOAT}	0°C ≤ T_A ≤ 85°C, I_{BAT} = 45mA, R_{PROG} = 10K	4.158	4.200	4.250	V
			4.300	4.350	4.400	V
			4.350	4.400	4.450	V
1C/10 Termination Current Threshold	I_{TERM}	R_{PROG} = 2K		0.1		mA/mA

■ ELECTRICAL CHARACTERISTICS(continued)

(V_{CC} = 5V, T_A= 25℃, Test Circuit Figure2, unless otherwise specified)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Recharge Battery Threshold	$\triangle V_{RECHG}$	$V_{FLOAT}-V_{RECHG}$		150		mV
Recharge Comparator Filter Time	$t_{RECHARGE}$	V_{BAT} High to Low		0.8		mS
V_{CC}-V_{BAT} Lockout Threshold	A_{MSD}	V_{CC} from Low to High		100		mV
		V_{CC} from High to Low		80		mV
$\overline{CHRG}$ Pin Voltage	$V_{\overline{CHRG}}$	$I_{\overline{CHRG}}$ = 5mA		0.3		V
$\overline{DONE}$ Pin Voltage	$V_{\overline{DONE}}$	$I_{\overline{DONE}}$ = 5mA		0.3		V
Power FET "ON" Resistance (Between V_{CC} and BAT)	R_{ON}	I_{BAT} = 600mA		1000		mΩ
Junction Temperature in Constant Temperature Mode	$T_{J(REG)}$			140		°C

■ TYPICAL APPLICATION CIRCUIT

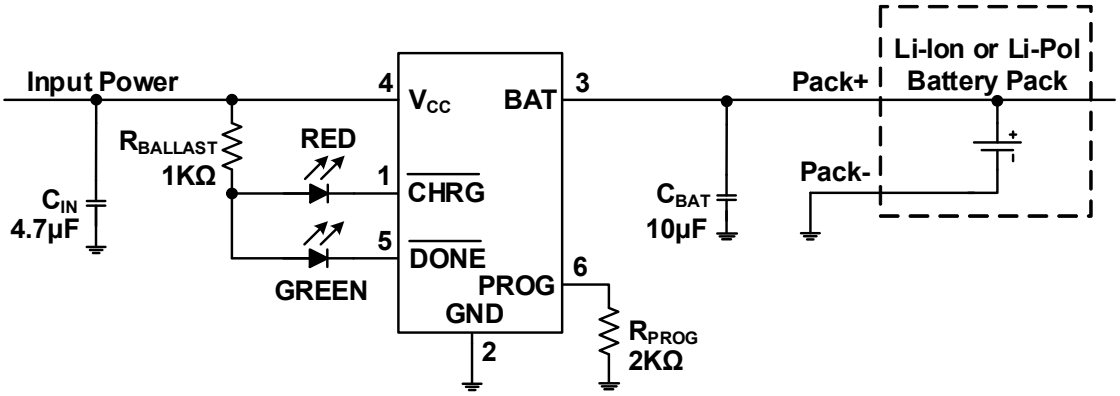


Figure 2 Standard Application Circuit

■ FUNCTIONAL DESCRIPTION

The SMC4008H series are highly integrated Li-Ion or Li-Pol linear battery chargers, targeted at space-limited portable applications. It operates from either a USB port or Wall Adapter and charges a single-cell Li-Ion or Li-Pol battery with up to 1000mA of charge current.

The charge current is programmable using external components (R_{PROG} resistor). The charge process starts when an external input power is connected to the system, $V_{CC} > V_{UVL}$, $V_{CC} > V_{BAT} + V_{(SLP\_EXIT)}$, the charger is enabled by the RPROG resistor connected and the battery voltage is below the recharge threshold, $V_{BAT} < V_{RECHG}$.

When the charger is enabled two control loops modulate the battery switch drain to source impedance to limit the BAT pin current to the programmed charge current value (charge current loop) or to regulate the BAT pin voltage to the programmed charge voltage value (charge voltage loop). If $V_{BAT} < V_{TRIKL}$ (2.9V typical), the BAT pin current is internally set to 3/10th of the programmed fast-charge current value in current regulation mode.

The SMC4008H series provide battery charge status via $\overline{CHRG}$ & $\overline{DONE}$ status pins. $\overline{CHRG}$ & $\overline{DONE}$ pins are internally connected to an N-channel open drain MOSFET.

The open drain status output that is not used should be tied to ground.

The following table lists the indicator status and its corresponding charging state.

Table 1. Charge Status Indicator (1)

Charge State Description	$\overline{CHRG}$	$\overline{DONE}$
Preconditioning-Current Mode (Trickle) Charge	ON	HI-Z
Constant-Current Mode (Fast) Charge	ON	HI-Z
Constant-Voltage Mode (Taper) Charge, $I_{BAT} > I_{TERM}$	ON	HI-Z
Charge Temination ($I_{BAT} < I_{TERM}$, Charge Done)	HI-Z	ON
Power Down (Undervoltage Lockout) Mode	HI-Z	HI-Z
Sleep Mode ($V_{UVL} < V_{CC} < V_{BAT} + V_{(SLP\_EXIT)}$, or the V_{CC} is removed)	HI-Z	HI-Z
Shutdown Mode (PROG pin floating)	HI-Z	HI-Z
OVP Mode（$V_{CC} > V_{OVP}$）	HI-Z	HI-Z
No battery with Charge Enabled	FLASH Rate depends on C_{BAT}	FLASH
Fault Condition (Battery Short Circuit)	ON	HI-Z

(1) Pulse loading on the BAT pin may cause the IC to cycle between Done and charging states (LEDs Flashing)

■ TYPICAL PERFORMANCE CHARACTERISTICS

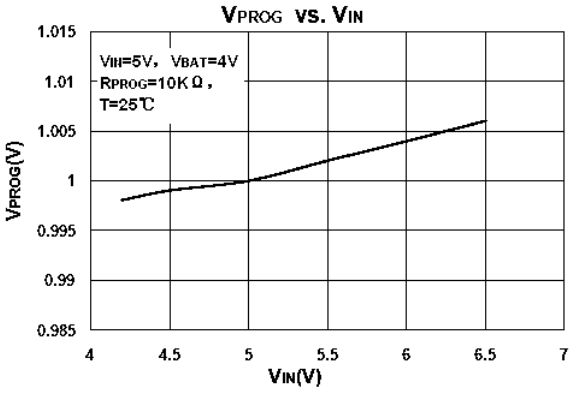


Figure 3

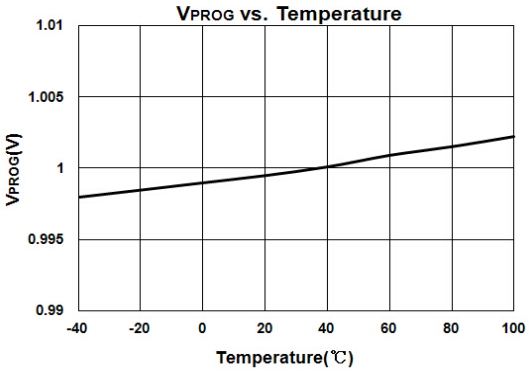


Figure 4

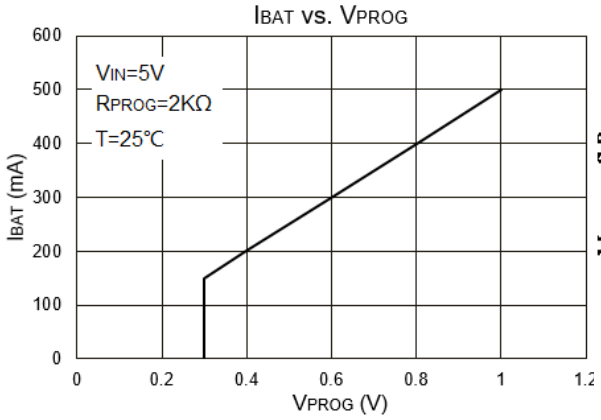


Figure 5

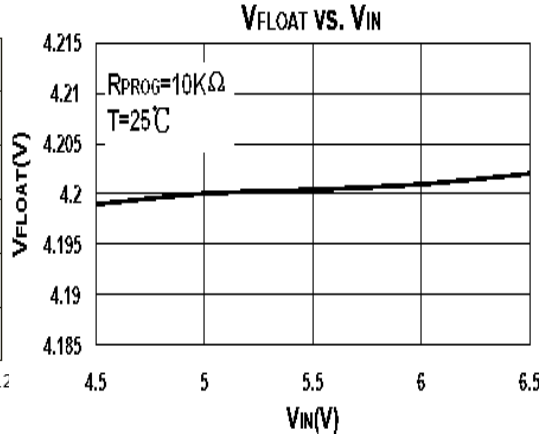


Figure 6

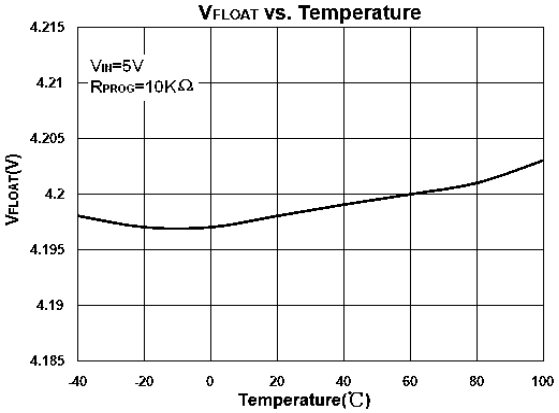


Figure 7

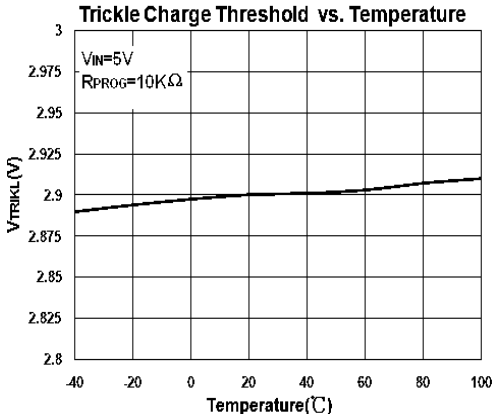
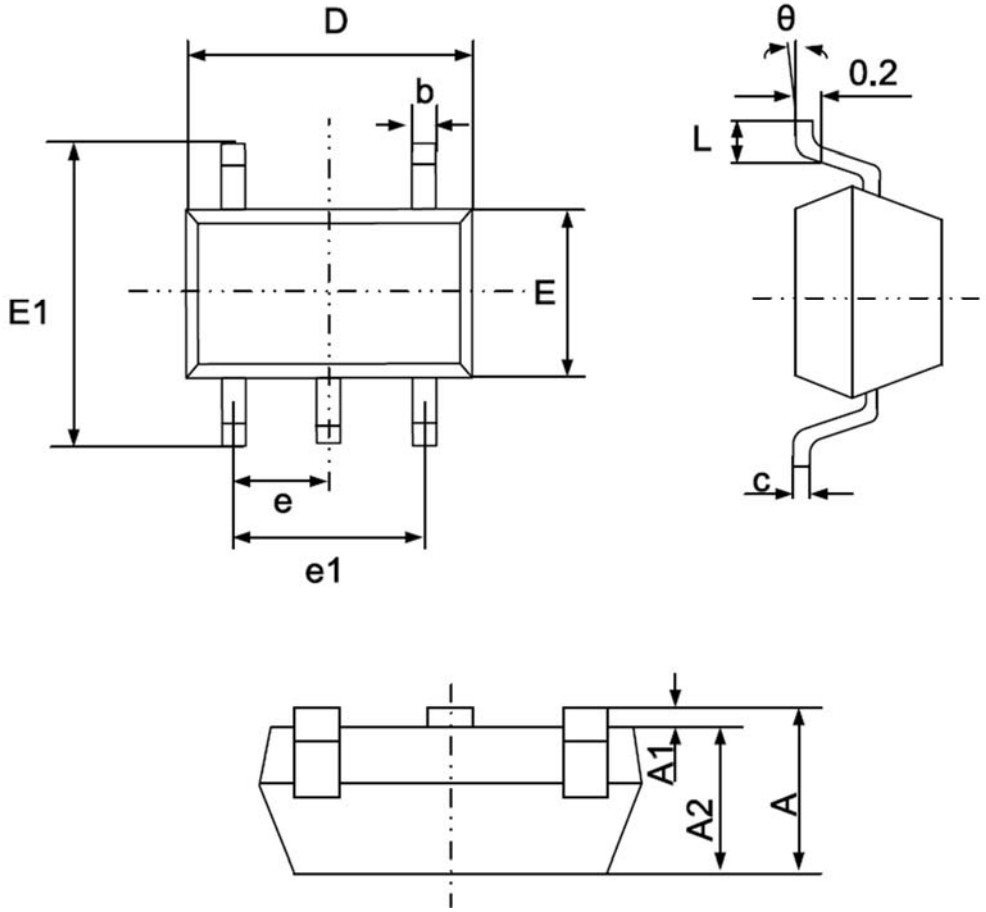


Figure 8

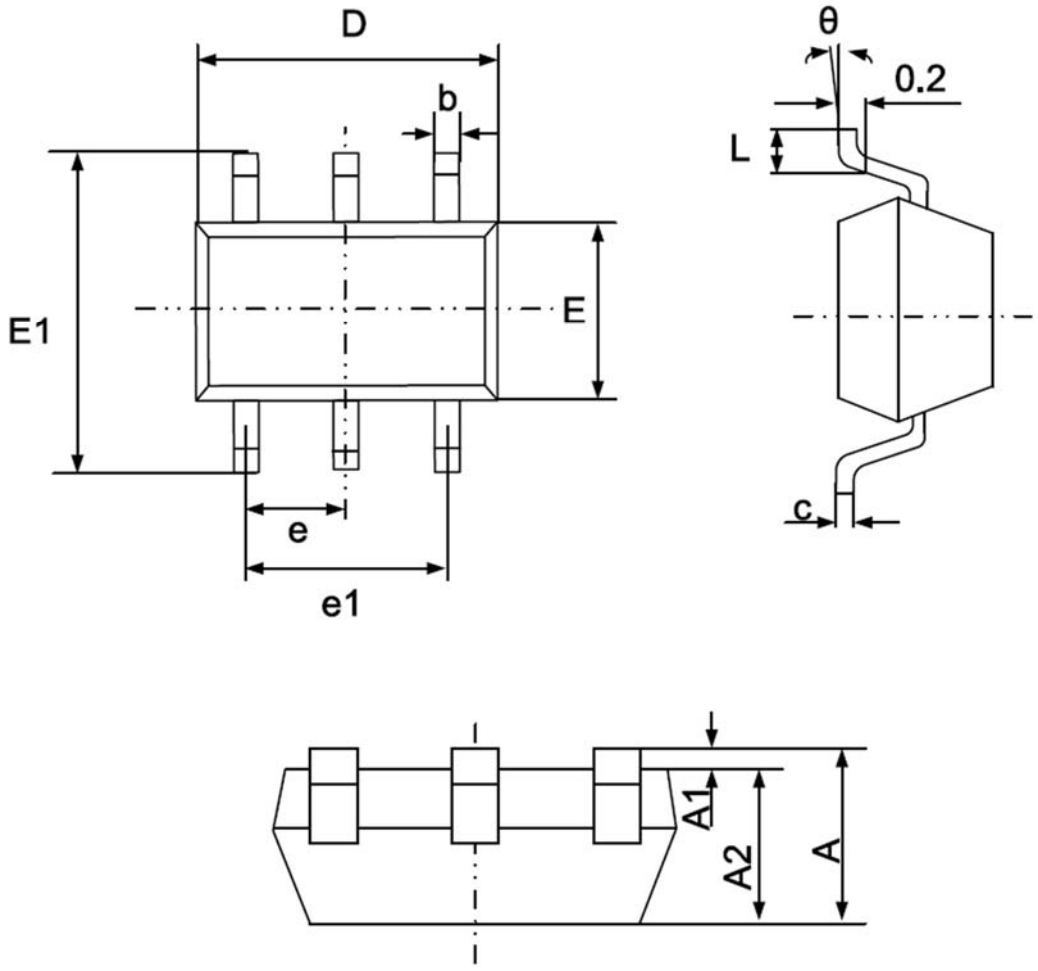
■ PACKAGING INFORMATION

● SOT-23-5 Package Outline Dimensions



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
θ	0°	8°	0°	8°

- **SOT-23-6 Package Outline Dimensions**



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
θ	0°	8°	0°	8°