Standalone 1.2A Linear Lithium Battery Charger With Thermal Regulation

■ INTRODUCTION

The SMC4012H 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 SMC4012H is specifically designed to work with in USB power specifications. Its low external component count makes the SMC4012H ideally suited for portable applications. Thermal feedback regulates the charge current to limit their temperature during high power operation or high ambient temperature. The charge current can be programmed externally with a single resistor. The SMC4012H automatically terminates the charge cycle when the charge current drops to 1/10ththe programmed value after the final float voltage is reached. When the input supply (wall adapter or USB supply) is removed, the SMC4012H automatically enters a low power sleep mode, dropping the battery drain current to less than 2µA.The SMC4012H can be put into shutdown mode, reducing the supply current to 50µA.Other features include battery pack temperature monitor, under voltage lockout, automatic recharge and two status pins to indicate charging and charge termination.

■ 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 4.15V / 4.20V / 4.35V / 4.40V Charge Voltage
- Continuous Programmable Charge Current Up to 1.2A
- Recharge 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
- Battery Temperature Sensing
- 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
- Chip Enable Input

■ APPLICATIONS

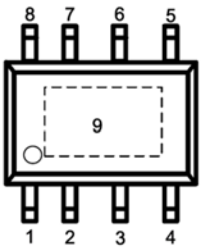
- Cellular phones, PDAs
- Portable Media Players
- Digital Still Cameras
- Bluetooth & GPS Applications
- Mobile Internet Device
- Charging Docks and Cradles

■ ORDER INFORMATION

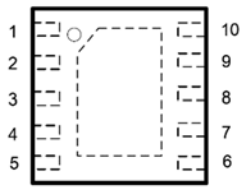
SMC4012H①②③④⑤⑥

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	ES	Package: ESOP8
	FB10	Package: DFN2X3-10
	FC10	Package: DFN3X3-10

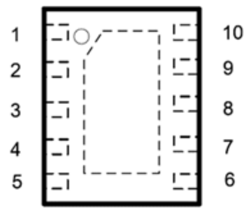
■ PIN CONFIGURATION (Top View)



ESOP8



DFN3X3-10



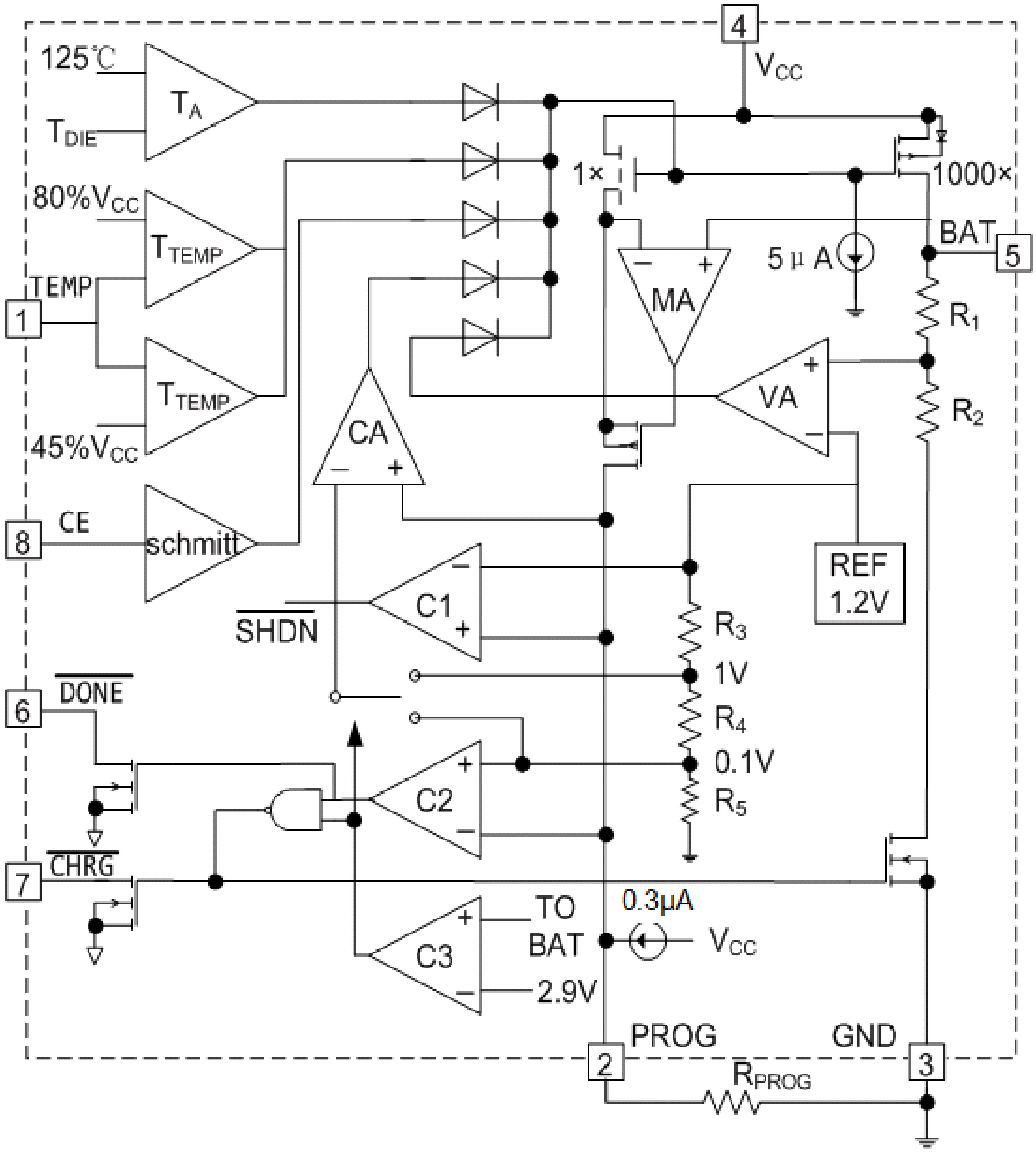
DFN2X3-10

Table 1. Pin Description

PIN NO.		PIN NAME	FUNCTION
ESOP8	DFN		
1	1	TEMP	**Battery temperature detection input**. Connecting TEMP pin to NTC thermistor's sensor output in Lithiumion battery pack. If the TEMP pin's voltage is less than45% or greater than 80% of the input voltage V_{CC}. This means the battery temperature is too high or too low, charging is suspended. If the TEMP pin's voltage level is between 45% and 80%of the input voltage V_{CC}, battery fault state is released, and charging will resume. If the TEMP pin direct access GND, battery temperature detection canceled, the other charged functioning properly.
2	2	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 0.1V. 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: $_{BAT}=(V_{PROG}/R_{PROG})$ X 1000.
3	3	GND	**Ground Terminal**.
4	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 20V and should be bypassed with at least a 4.7μF capacitor. When V_{CC} drops to within 80mv of the BAT pin voltage or $V_{CC} > V_{OVP}$, SMC4012H enters low

			power sleep mode, dropping BAT pin's current to less than 2μA.
5	7	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 shut down 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.
6	8	$\overline{\text{DONE}}$	**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.
7	9	$\overline{\text{CHRG}}$	**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.
8	10	CE	**Chip Enable Input**. A high input will put the device in the normal operating mode. Pulling the CE pin to low level will put the SMC4012H into disable mode. The CE pin can be driven by TTL or CMOS logic level. The CE pin is high impedance with internal 1.1MPull-up Resistor in the suspended state.
9	11	Thermal PAD	**Exposed Paddle (bottom)**. This pin should be soldered to the PCB ground as close as to the device for electrical contact and rated thermal performance.
	5、6	NC	**No Connection**

■ 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	
BAT Pin Voltage(2)		-5 ~ 12	
CE, $\overline{CHRG}$, $\overline{DONE}$ TEMP Pins Voltage(2)		-0.3 ~ 28	
BAT Short-Circuit Duration	-	Continuous	-
BAT Pin Output Current (Continuous)	I_{BAT}	1500	mA
Output sink current	$I_{\overline{CHRG}}$, $I_{\overline{DONE}}$	10	mA
Power dissipation	P_D	1500	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) 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 200pFcapacitor 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}		1200(6)	mA
Fast-charge current programming resistor(7)	R_{PROG}	0.82	10	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 bounder charged (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	
CE "High" Level Voltage	V_{CEH}			1.5		V_{CC}	V
CE "Low" Level Voltage	V_{CEL}					0.4	V
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} = 1K		90	100	110	mA
BAT Pin Current	I_{BAT}	R_{PROG} = 1K, Current Mode	V_{BAT} = 3.8V@420	900	1000	1100	mA
		R_{PROG} = 2K, Current Mode	V_{BAT} = 3.8V@420	450	500	550	

■ ELECTRICAL CHARACTERISTICS(continued)

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

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
BAT Pin Current	I_{BAT}	Standby Mode, V_{BAT} = V_{FLOAT}	0	-2	-6	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}			3		μA
Regulated Output (Float) Voltage	V_{FLOAT}	I_{BAT} = 20mA, R_{PROG} = 10K	4.100	4.150	4.200	V
			4.158	4.200	4.250	V
			4.300	4.350	4.400	V
			4.350	4.400	4.450	V
C/10 Termination Current Threshold	I_{TERM}	R_{PROG} = 1K		0.1		mA/mA
Recharge Battery Threshold	$\triangle V_{RECHG}$	V_{FLOAT} — V_{RECHG}		150		mV
Recharge Comparator Filter Time	$t_{RECHARGE}$	V_{BAT} High to Low	0.3	0.8	2.0	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
TEMP High Shift Voltage Level			76	80	82	%V_{CC}
TEMP Low Shift Voltage Level			43	45	49	
Power FET “ON” Resistance (Between V_{CC} and BAT)	R_{ON}	I_{BAT} = 1000mA		500		mΩ
Junction Temperature in Constant Temperature Mode	$T_{J(REG)}$			140		°C

■ TYPICAL APPLICATION CIRCUIT

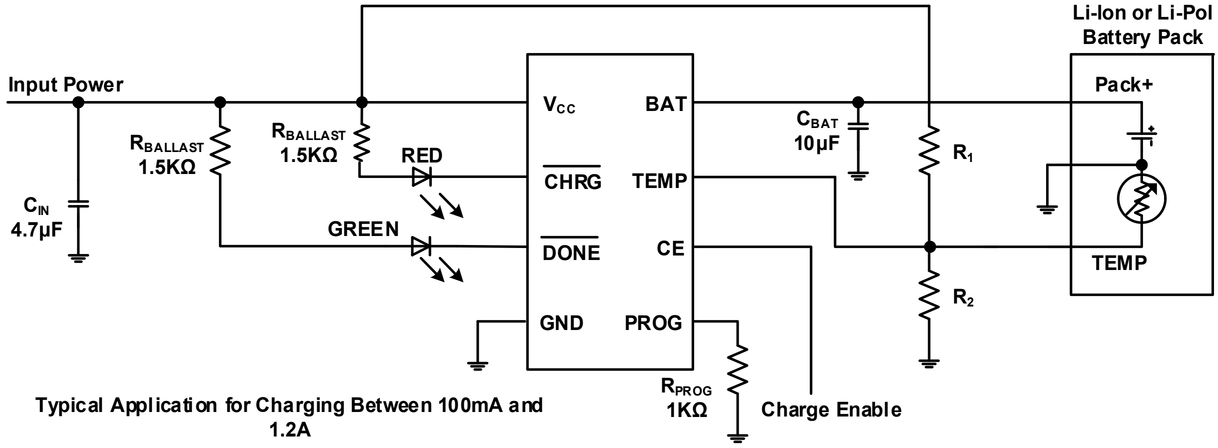


Figure2 Standard Application Circuit

■ FUNCTIONAL DESCRIPTION

The SMC4012H 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 to1200mA 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, $V_{CC} > V_{UVL}$, VCC > 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 1/10th of the programmed fast-charge current value in current regulation mode.

The SMC4012H series provide battery charge status via $\overline{\text{CHRG}}$&$\overline{\text{DONE}}$ status pins. $\overline{\text{CHRG}}$&$\overline{\text{DONE}}$ 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 Termination ($I_{BAT} < I_{TERM}$, Charge Done)	HI-Z	ON
Power Down (Under voltage 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
Fault TEMP(5% $V_{CC} < V_{TEMP} <$ 45%VCC||$V_{TEMP} >$ 80%VCC)	HI-Z	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

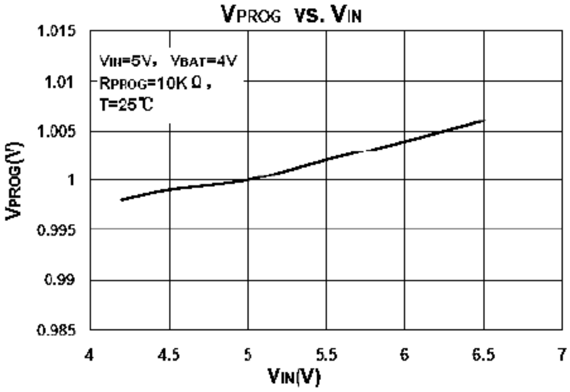


Figure 3

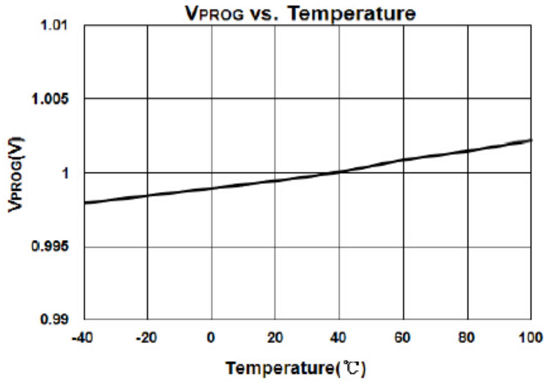


Figure 4

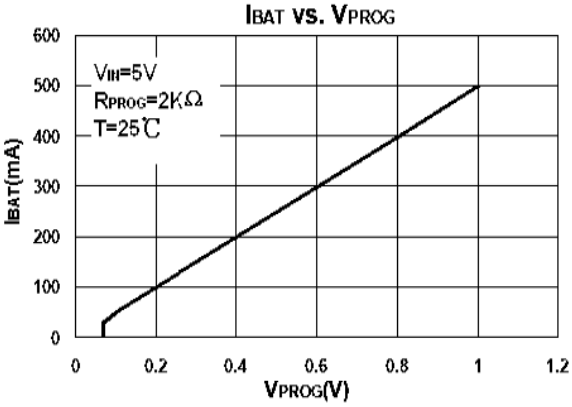


Figure5

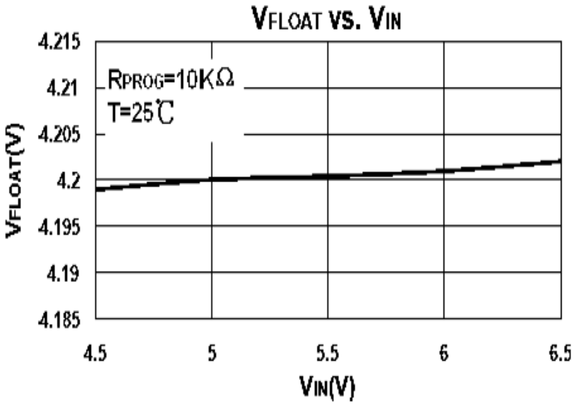


Figure6

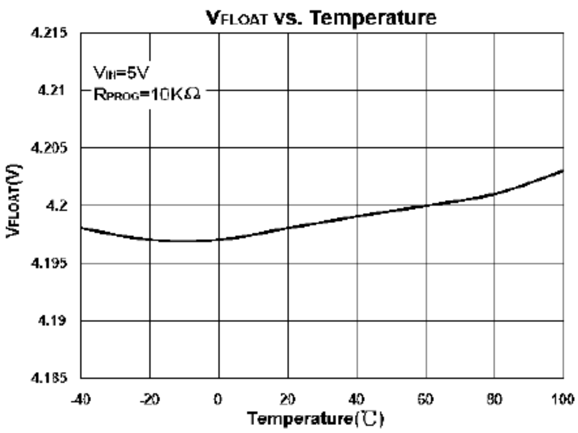


Figure7

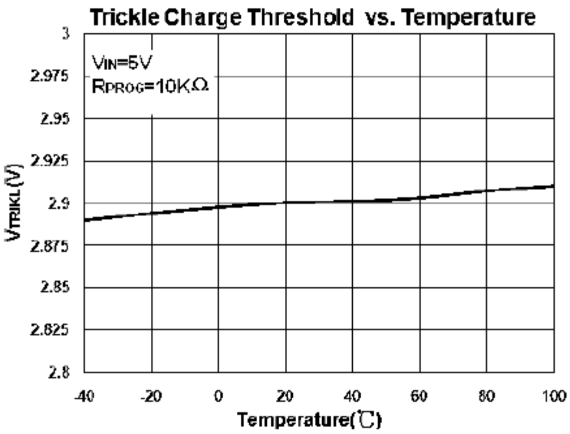


Figure8

■ TYPICAL PERFORMANCE CHARACTERISTICS(continued)

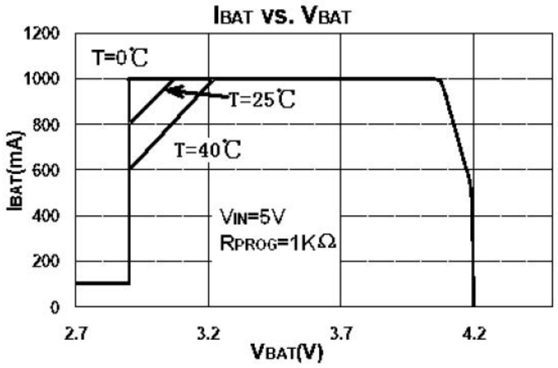


Figure9

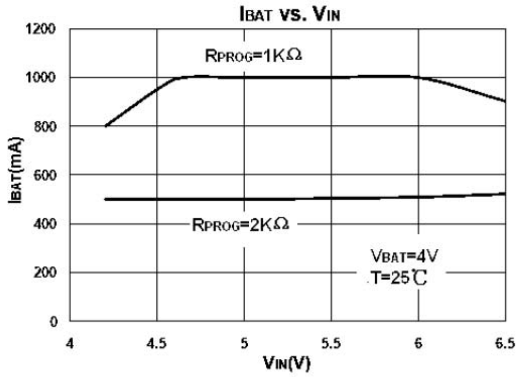


Figure10

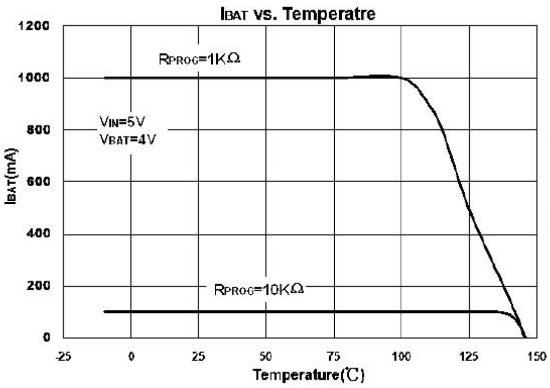


Figure11

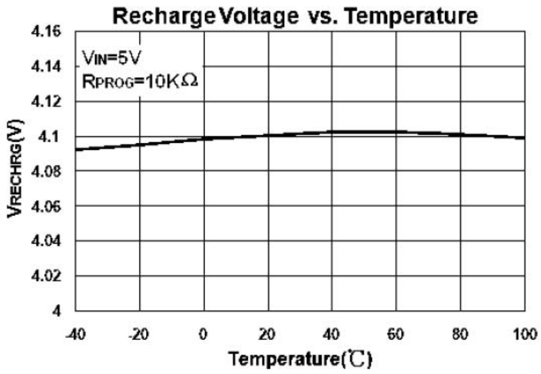
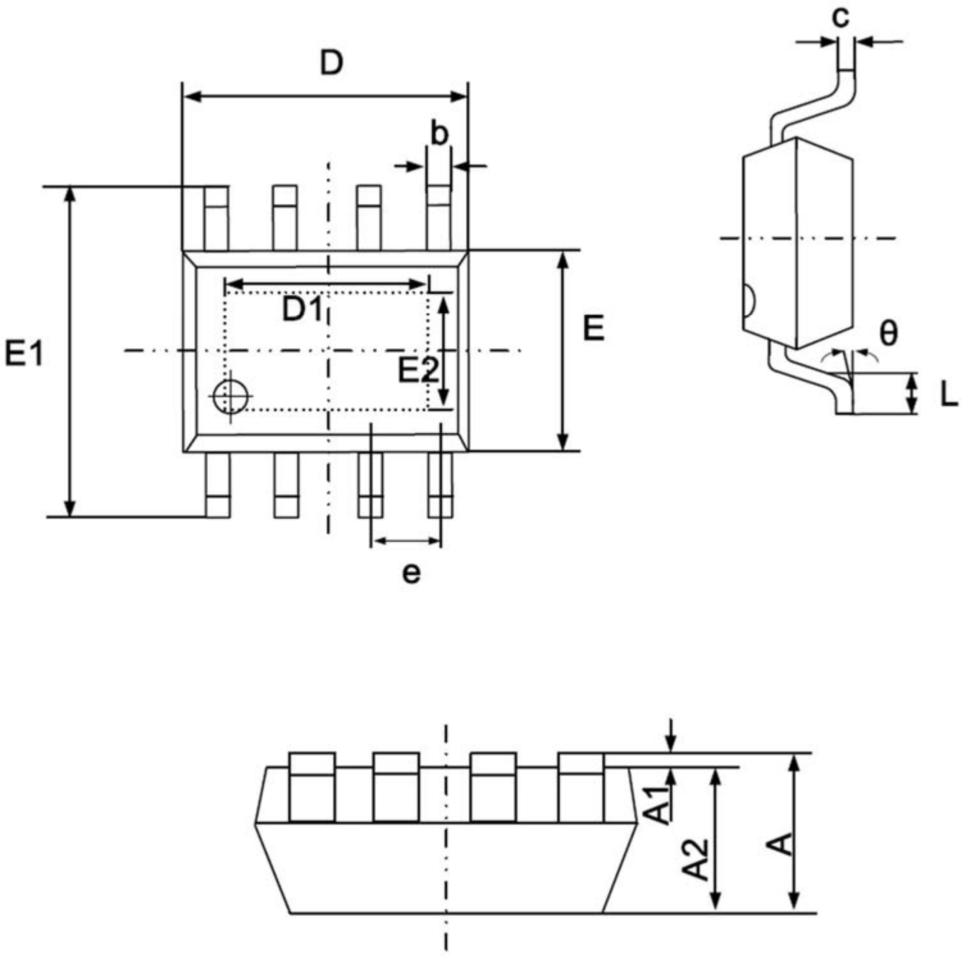


Figure12

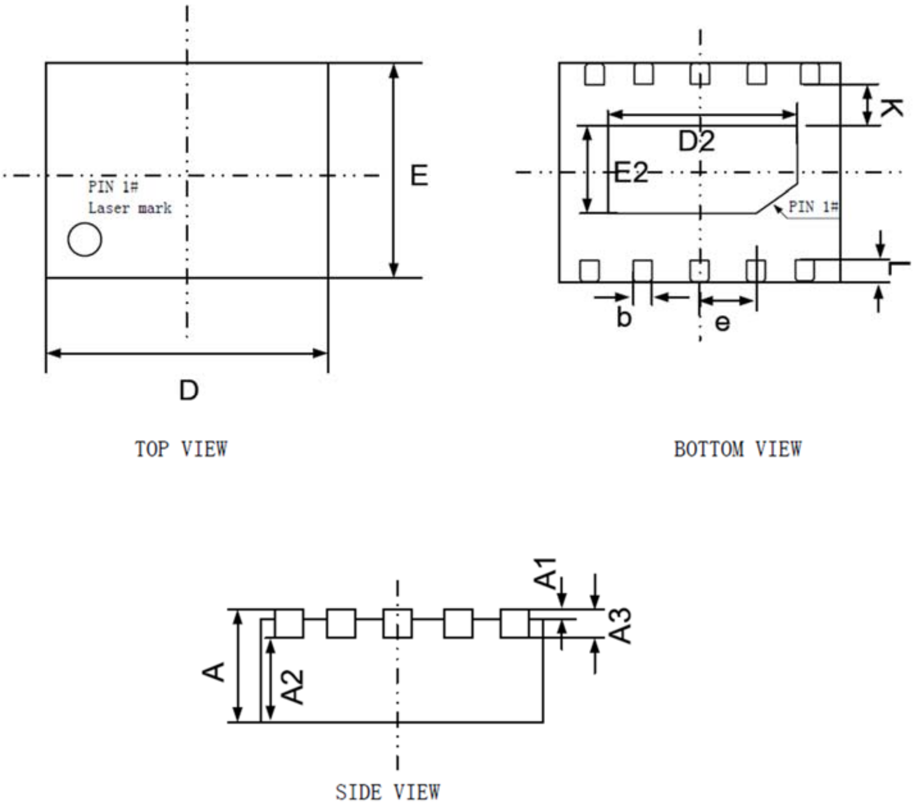
■ PACKAGING INFORMATION

● **ESOP8 Package Outline Dimensions**



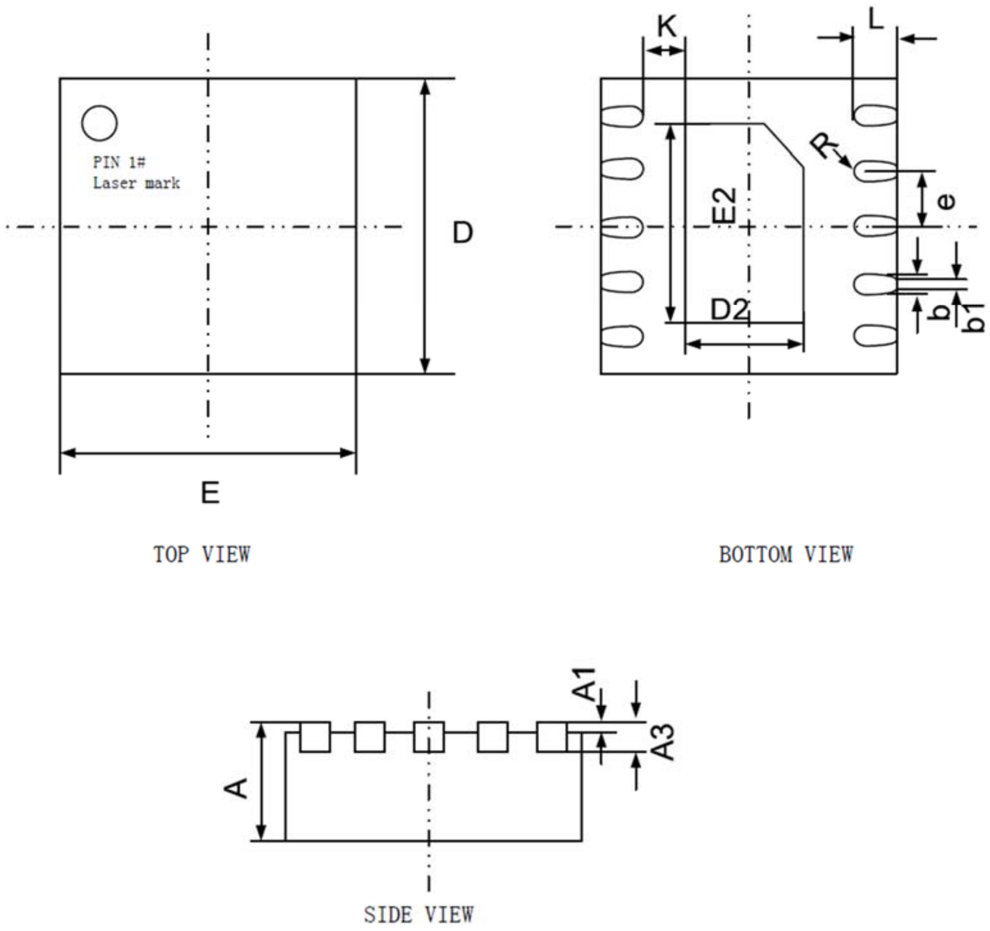
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0. 250	0.006	0.010
D	4.700	5.100	0.185	0.200
D1	3.100	3.500	0.122	0.137
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
E2	2.200	2.600	0.086	0.102
e	1.270(BSC)		0.050(BSC)	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°

- **DFN2X3-10 Package Outline Dimensions**



Symbol	Dimensions In Millimeters		
	Min.	Nom.	Max.
A	0.70	0.75	0.80
A1	0	0.02	0.05
A2	0.50	0.55	0.60
A3	0.20REF		
b	0.20	0.25	0.30
D	2.90	3.00	3.10
E	1.90	2.00	2.10
D2	2.30	2.40	2.50
E2	0.80	0.90	1.00
e	0.45	0.50	0.55
K	0.15	-	-
L	0.22	0.27	0.32

- **DFN3X3-10 Package Outline Dimensions**



Symbol	Dimensions In Millimeters		
	Min.	Nom.	Max.
A	0.70	0.75	0.80
A1	0	0.02	0.05
A3	0.20 REF		
b	0.20	0.25	0.30
b1	0.20 REF		
D	2.90	3.00	3.10
E	2.90	3.00	3.10
D2	1.50	1.60	1.70
E2	2.40	2.50	2.60
e	0.40	0.50	0.60
K	0.20	-	-
L	0.30	0.40	0.50
R	0.13	-	-