SK895X Li-Ion Linear Battery Charger with LDOs

Description

The SK8953 is a highly integrated power management, embedding a linear battery charger, a low power LDO, 2 LDOs with configurable output voltage. Each LDO has an independent enable pin.

The SK8950/1/2 reduces the channel of LDO and en pins on the basis of the SK8953.

The SK895X uses a CC/CV algorithm to charge the battery. The constant charging current can be programmed using external resistor. The charger is automatically powered off when the VBUS pin is not connected to a valid power source.

The SK895X provides a minimum of 2.25 square millimeters of package, to achieve a multi-channel power control and charging.

Applications

- IOT
- Wearable devices
- Smart watches
- Fitness and medical accessories
- Wireless sensor networks
- Bluetooth beacon
- Ant+ device
- Embedded camera
- Remote control

Features

- Charges single-cell Li-Ion batteries with CC/CV algorithm and charge termination
- charge current from 10mA to 600 mA adjustable by external resistor
- Auto-recharge function
- Charging timeout
- Charge status output
- Linear charger with OVP,OCP and OTP
- 3.3V always-on 1.8uA I_Q LDO
- Enable pulse configuration LDO output voltage
- ESD HBM ±4kV   CDM ±2kV
- Package
  - SOT23-6L / MSOP-8L
  - DFN 1.5*1.5 8L
  - DFN 2*2 8L
  - QFN 2*2 12L

Typical Application

## Device Information

Part Number	Package	Size	Enable Signal	LDOs
SK8950ST	SOT23-6L	2.9mm∗1.6mm*1.2mm(H)	None	1
SK8950MS	MSOP-8L	5.0mm∗3.1mm *1.1mm(H)	ENLP	1
SK8951DN	DFN1.5*1.5 8L	1.5mm∗1.5mm*0.45mm(H)	EN1	2
SK8952DN	DFN 2*2 8L	2.0mm∗2.0mm*0.75mm(H)	ENLP,EN1	2
SK8953QN	QFN 2*2 12L	2.0mm∗2.0mm*0.55mm(H)	ENLP,EN1,EN2	3
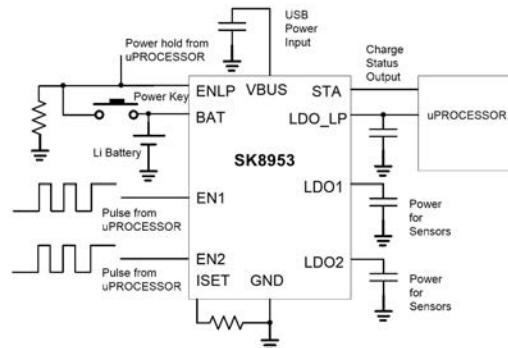
Pin Configuration
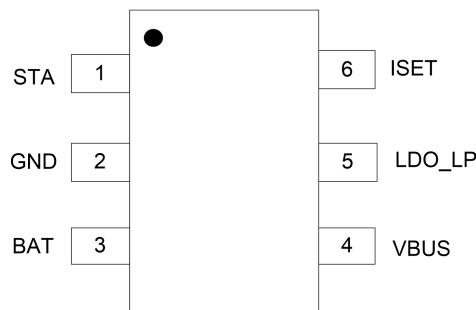
**Figure 1.1   SK8950 SOT23-6L Pin Assignment（Top View）**
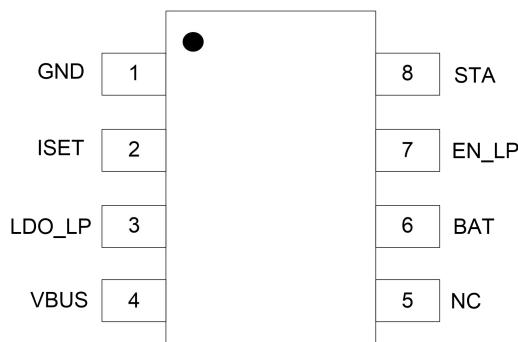
**Figure 1.2   SK8950 MSOP-8L Pin Assignment（Top View）**
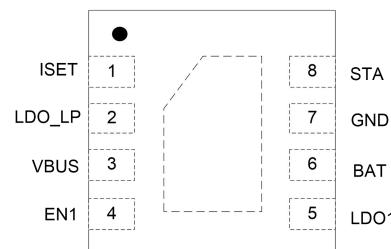

Figure 2   SK8951 DFN 1.5*1.5 8L Pin Assignment（Top View）
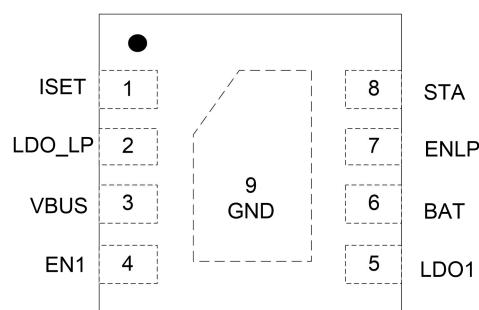
**Figure 3   SK8952 DFN 2*2 8L Pin Assignment（Top View）**
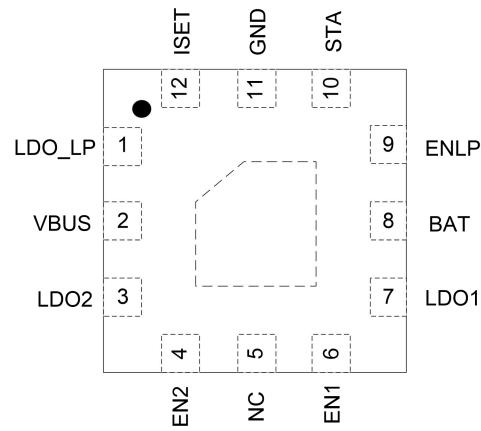
Figure 4   SK8953 QFN 2*2 12L Pin Assignment（Top View）

Pin Description

SK8950ST

Name	I/O	Description
ISET	I	Charge Current Program
GND	G	Ground
LDO_LP	O	3.3V output
BAT	P	Li-ion battery
VBUS	P	Power
STA	O	Open-Drain Charge Status Output, pull down when charging

SK8950MS

Name	I/O	Description
ISET	I	Charge Current Program
GND	G	Ground
LDO_LP	O	3.3V output
BAT	P	Li-ion battery
VBUS	P	Power
STA	O	Open-Drain Charge Status Output, pull down when charging
ENLP	I	Enable pin of LDO_LP, no pull down or pull up resistor, do not left floating

SK8951

Name	I/O	Description
ISET	I	Charge Current Program
EN1	I	Configuration pin of LDO1, 850k pull down resistor inside
GND	G	Ground
LDO_LP	O	3.3V output
LDO1	O	0.9~3.3V output
BAT	P	Li-ion battery
VBUS	P	Power
STA	O	Open-Drain Charge Status Output, pull down when charging

SK8952

Name	I/O	Description
ISET	I	Charge Current Program
ENLP	I	Enable pin of LDO_LP, no pull down or pull up resistor, do not left floating
EN1	I	Configuration pin of LDO1, 850k pull down resistor inside
GND	G	Ground
LDO_LP	O	3.3V output
LDO1	O	0.9~3.3V output
BAT	P	Li-ion battery
VBUS	P	Power
STA	O	Open-Drain Charge Status Output, pull down when charging

SK8953

| Name	I/O	Description
ISET	I	Charge Current Program
ENLP	I	Enable pin of LDO_LP, no pull down or pull up resistor, do not left floating
EN1	I	Configuration pin of LDO1, 850k pull down resistor inside
EN2	I	Configuration pin of LDO2, 850k pull down resistor inside
GND	G	Ground
LDO_LP	O	3.3V output
LDO1	O	0.9~3.3V output
LDO2	O	0.9~3.3V output
BAT	P	Li-ion battery
VBUS	P	Power
STA	O	Open-Drain Charge Status Output, pull down when charging
NC	/	None

Typical Applications
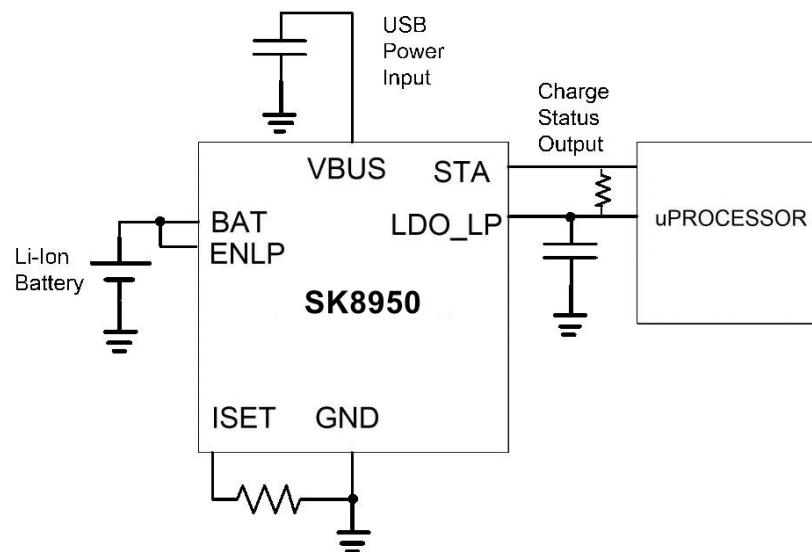
**Figure 5   SK8950 application**
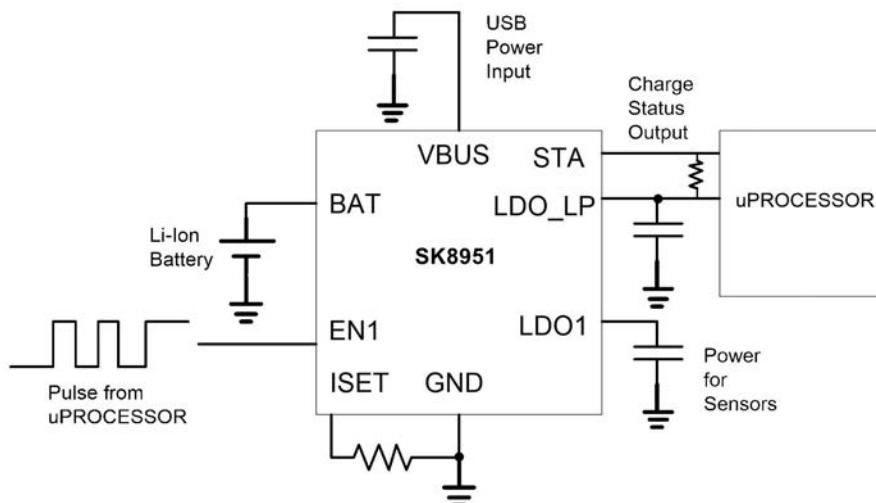
**Figure 6   SK8951 application**
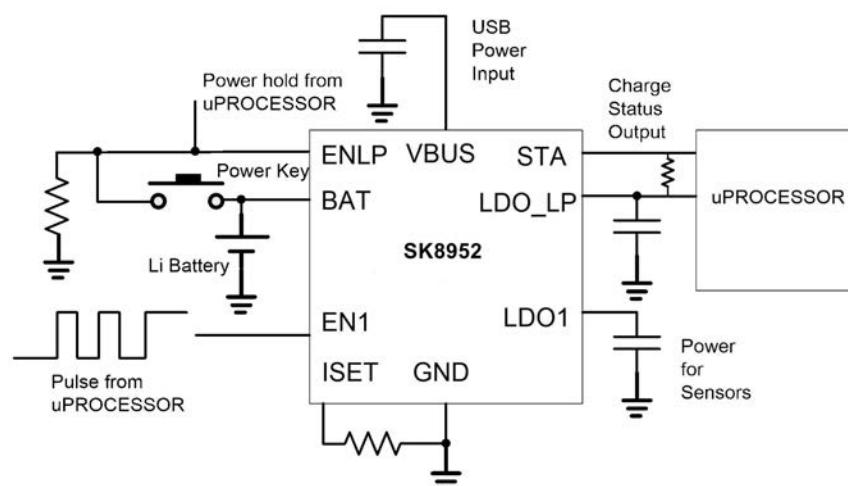

Figure 7   SK8952 application
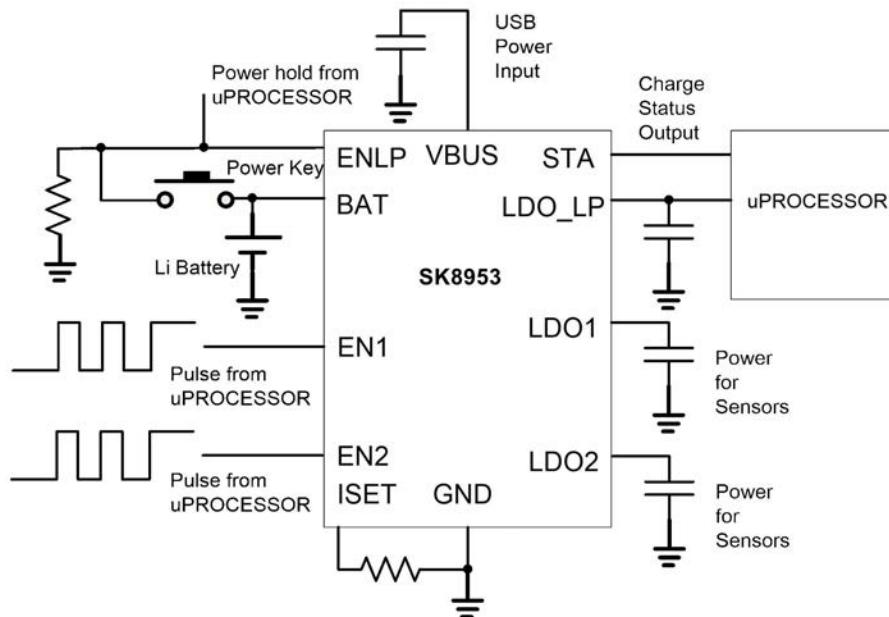
Figure 8 SK8953 application
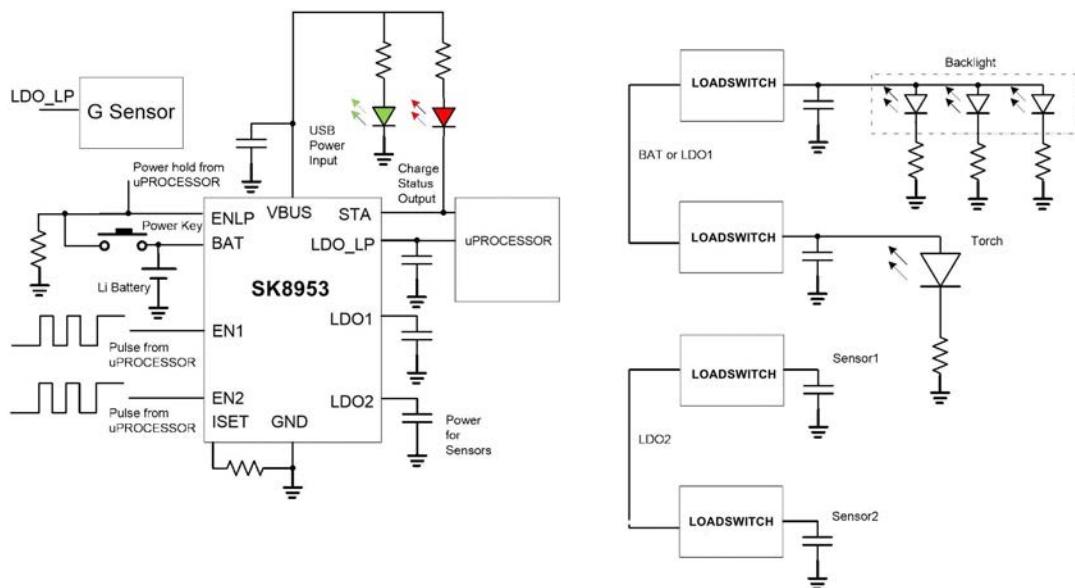
Figure 9 SK8953 application with loadswitches

Absolute Maximum Ratings*

Parameter	Range
VBUS voltage range	-0.3V～7V
Other than IN and OUT Pins	-0.3V～5.5V
Maximum junction temperature	150℃
Storage temperature range	-65℃~150℃
SOT23 Junction to ambient thermal resistance θJA	180℃/W
MSOP8 Junction to ambient thermal resistance θJA	180℃/W
DFN 1.5*1.5 Junction to ambient thermal resistance θJA	120℃/W
DFN 2*2 Junction to ambient thermal resistance θJA	80℃/W
QFN 2*2 Junction to ambient thermal resistance θJA	80℃/W

*note： 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 may affect device reliability.

Recommended Operating Conditions

Parameter	Min	Typ	Max	Unit
Input voltage range V_{BUS}	4.5	5.0	5.5	V
BAT voltage range	2.9		4.2	V
Operating Ambient Temperature T_A	-40		125	℃

ESD Ratings

V_{ESD} Electrostatic discharge	Human-body model (HBM), per MIL-STD-883J Method 3015.9	±4kV
	Charged-device model (CDM), per ANSI/ESDA/JEDEC JS-002-2014	±2kV

Electrical Characteristics

Parameter	Conditions	Min	Typ	Max	Unit
V_{VBUS}	Input Voltage Range of VBUS	4.5		6.5	V
I_{SHDN}	ENLP=0 (SK8952/3) No power on VBUS, T_A=25℃		0.1	0.3	uA
I_{Q_LP}	Quiescent Supply Current of LDO_LP No power on VBUS, T_A=25℃		1.8	2.2	uA
I_{Q_LDO}	Quiescent Supply Current of single channel LDO. No load, powered by battery.		40		uA
I_{CHA_FINISH}	Quiescent Supply Current of VBUS when battery charging finished		30		uA
I_{CHA}	Constant charging current ISET=100mA	90	100	110	mA
I_{CHA_range}	Charging current range Programmed by external resistor	10		600	mA
V_{LIM}	Max voltage of BAT (no-load battery voltage, When the charge is over) SK895X	4.16		4.20	V
V_{LIM_H}	Max voltage of BAT (no-load battery voltage, When the charge is over) SK895XB	4.32		4.36	V
V_{PRE_CHA}	Pre-charge to normal charge battery voltage threshold	2.8	2.9	3.0	V
$V_{PRE\_CHA\_HYS}$	Hysteresis of Pre-charge voltage		0.2		V
V_{ISET}	The voltage of ISET	0.97	1	1.03	V
V_{UVLO}	Threshold of VBUS UVLO	3.6	3.8	4.0	V
V_{UVLO_HYS}	Hysteresis of VBUS UVLO		0.2		V
V_{OVP}	Threshold of VBUS OVP	5.9	6.2	6.5	V
V_{OVP_HYS}	Hysteresis of VBUS OVP		0.3		V
T_{TO}	Charge timeout	6	7.5	9	hour
V_{LDO_LP}	Output of LDO_LP, only EN_LP=1	3.2	3.3	3.4	V
V_{LDO1}	Output of LDO1 (SK8951/2/3) Configured by EN1	0.9		3.3	V
V_{LDO2}	Output of LDO2 (SK8953) Configured by EN2	0.9		3.3	V
$V_{LDO\_accuracy}$	The accuracy of LDO1 & LDO2	-4		4	%
RO_{LDO_LP}	Output resistor of LDO_LP V_{LDO_LP}>2.3V, VBAT=3.4V		3		Ω

RO $_{LDO\_LP\_OL}$	Output resistor of LDO_LP when overload V_{LDO_LP}<1.5V, VBAT=3.4V		30		Ω
RO $_{LDO}$	Output resistor of LDO1 and LDO2,VBAT=3.4V		0.32		Ω
IO $_{LDO\_LP}$	Overload protection of LDO_LP, V_{LDO_LP}<1.5V, VBAT=3.8V	68	90		mA
IO $_{LDO1}$	Current limit of LDO1 (SK8951/2/3)	240	300	360	mA
IO $_{LDO2}$	Current limit of LDO2 (SK8953)	240	300	360	mA
V $_{EN\_H}$	ENLP,EN1,EN2 Rising Threshold,VBAT=4.2V	1.3			V
V $_{EN\_L}$	ENLP,EN1,EN2 Falling Threshold			0.4	V
R $_{PD}$	Pull down resistor on EN1 & EN2		850k		Ω
T $_{SHDN}$	EN1, EN2 Shutdown delay (none in SK8950)			2	ms
OTP	Over temperature of the switch		145		℃
OTP_HYS	Hysteresis of OTP		25		℃

Applications Information

Battery charger

The SK895X allows single-cell Li-Ion and Li-Poly battery chemistry to be charged up to a 4.2 V (4.35V on SK895XB) using a CC/CV charging algorithm. The charging cycle starts when a valid input voltage source (V_{UVLO} < VBUS < V_{OVP}) is detected and signaled by the STA pin toggling from a high impedance state to a low logic level.

If the battery is deeply discharged (the battery voltage is lower than V_{PRE_CHA}), the SK895X charger enters the pre-charge phase and starts charging in constant-current mode with the 20% of charge current set.
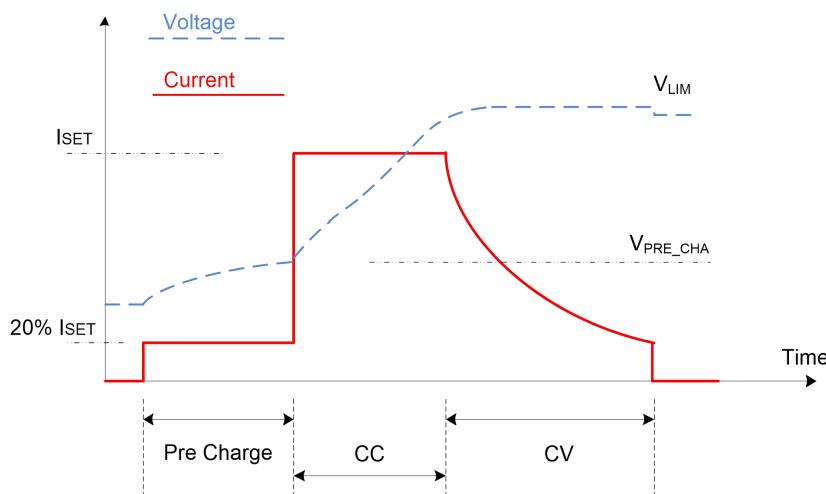

Figure 11 Charging Profile

Input OVP (over voltage protection), charge OCP (over current protection), charge timeout protection, recharge cycle, OTP (over temperature protection). Many of the above protection to protect the charge of the various abnormalities in the process will not damage the battery. Charging current should not exceed 1C, charging cut-off voltage should not exceed 4.2V.

LDOs

The low power LDO itself consumes only 1.8uA current, constant 3.3V output. It is not recommended to start the low power LDO with a load of more than 10mA because of an undesired overshoot.
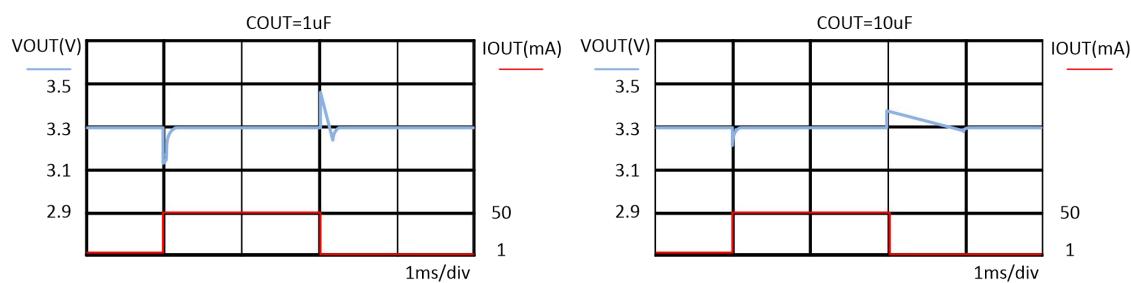
The output voltage of the other two LDOs is controlled by the respective enable pins.
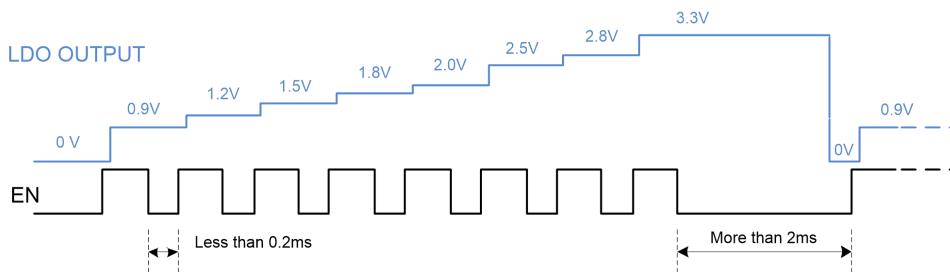

Figure 13 EN pulse vs. LDO Output

The number of pulses on the EN pin set the LDO output voltage. If the output needs 1.8V, then send 4 pulses is ok, if you need to change from 1.8V to 3.3V, then send four pulses. If you want to change from 1.8V to 1.2V, first pull down more than 2ms, and then send two pulses, rather than continue to send 6 pulses, although it can get 1.2V, but the output will experience a maximum of 3.3V.

Passive device selection

VBUS capacitors: 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 1.5 ohm resistor in series with an X5R ceramic capacitor will minimize start-up voltage transients. A 10uF 10V X5R ceramic capacitor is suitable.

LDO output capacitors: A 6V 1uF to 10uF X5R ceramic capacitor is suitable for each channel. When the load exceeds 100mA, it is recommended to use capacitors larger than 4.7uF. When the instantaneous load of 200mA or more, as long as the average load does not exceed 200mA, LDO can still work properly. To avoid excessive output ripple, it is recommended to use 10uF or more capacitors.

ISET resistor: The charge current is programmed using a single resistor from the ISET pin to ground. The charging current setting formula is as follow
ISET= 850V/R
It is recommended to use a 1% resistor.

VBAT capacitors: Usually do not need, but want to replace the battery when the system is still powered, it is recommended to connect a 1uF 6V capacitor.

Load switches for more power path

A system may require more than 3 different voltage power paths, but not at the same time, can be increased by the loadswitches to achieve multi-channel multiplexing power supply.

Capacity degradation of Li-ion battery at different charging conditions
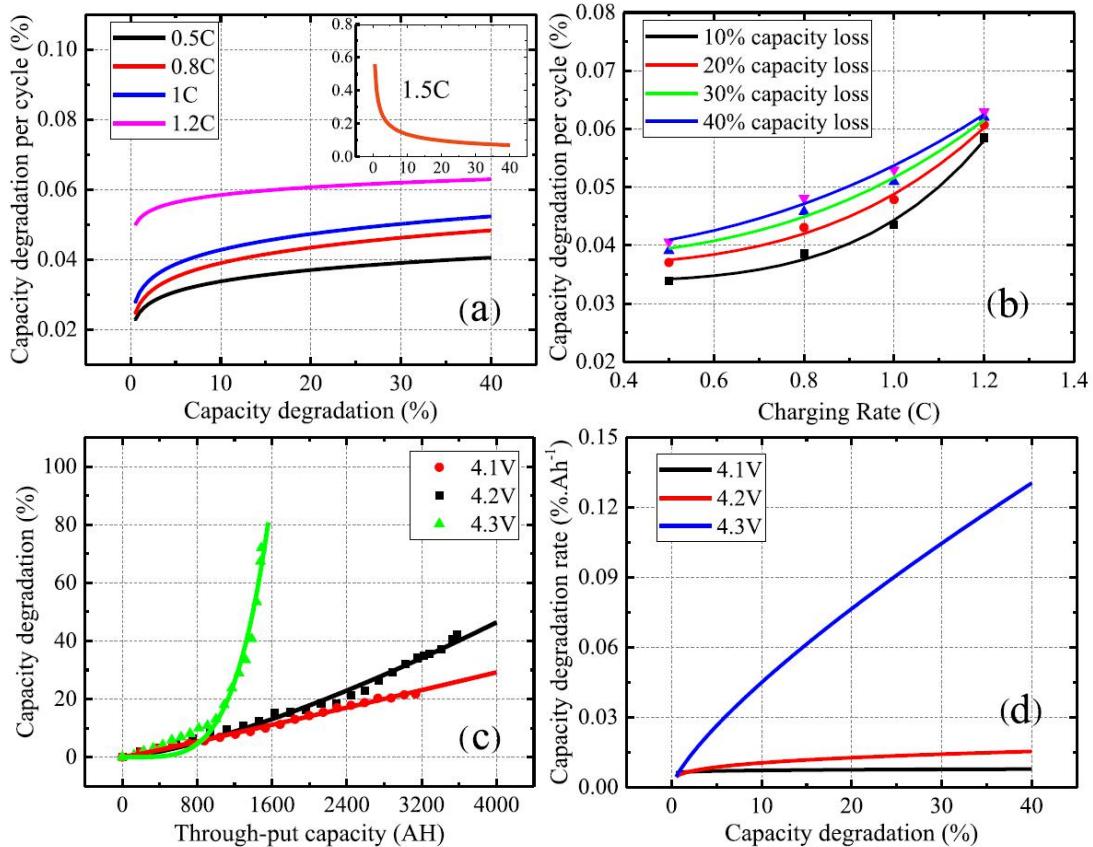

Figure 14 Capacity degradation

(a) Capacity degradation speed at different battery aging states.

(b) Capacity degradation speed at different charging current rates.

(c) The capacity degradation of the tested batteries upon continuous cycle aging at different cut-off voltages.

(d) Capacity degradation rate at different cut-off voltages.

References

[1] Lithium-ion battery aging mechanisms and life model under different charging stresses, Journal of Power Sources 336(2017)103~114.

Package Description

SOT23-6L
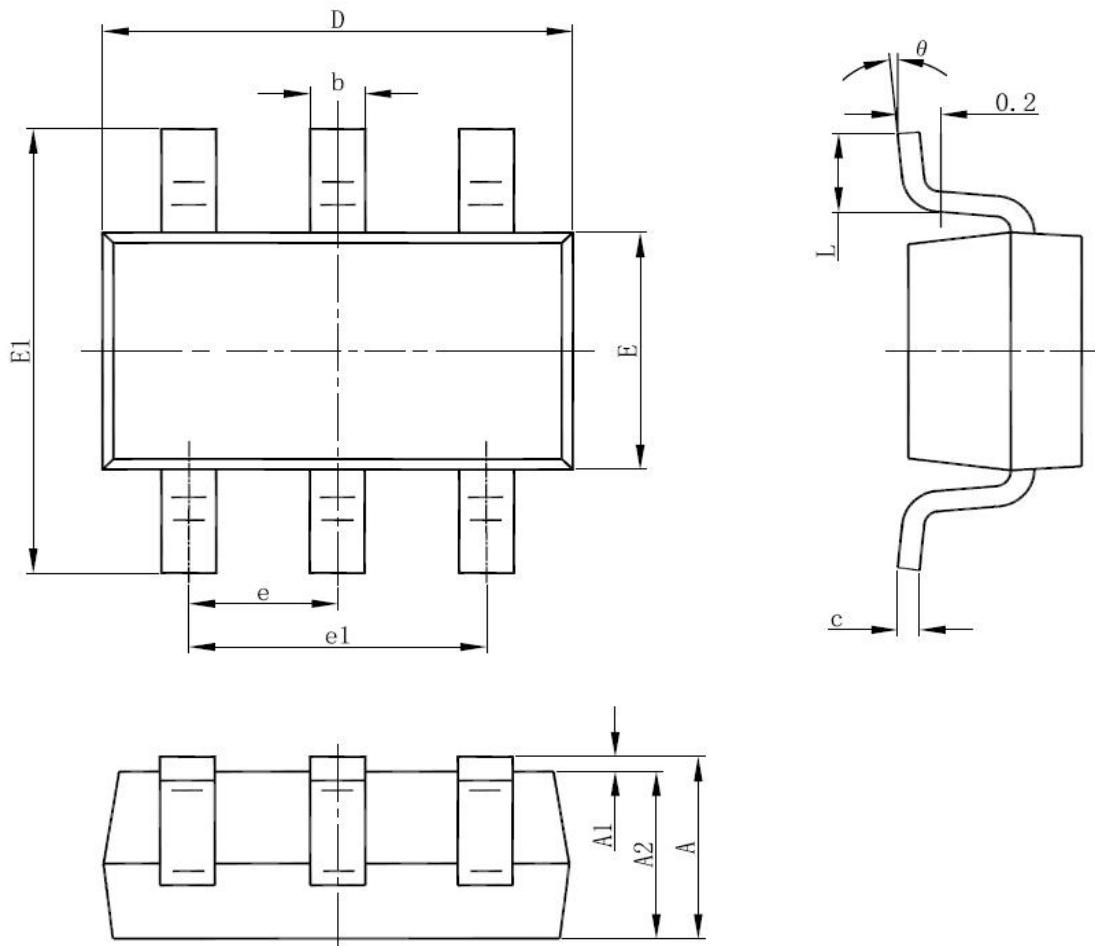
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E1	1.500	1.700	0.059	0.067
E	2.650	2.950	0.104	0.116
e	0.950(BSC)		0.037(BSC)	
e1	1.900(BSC)		0.075(BSC)	
L	0.300	0.600	0.012	0.024
θ	0º	8º	0º	8º

MSOP 8L
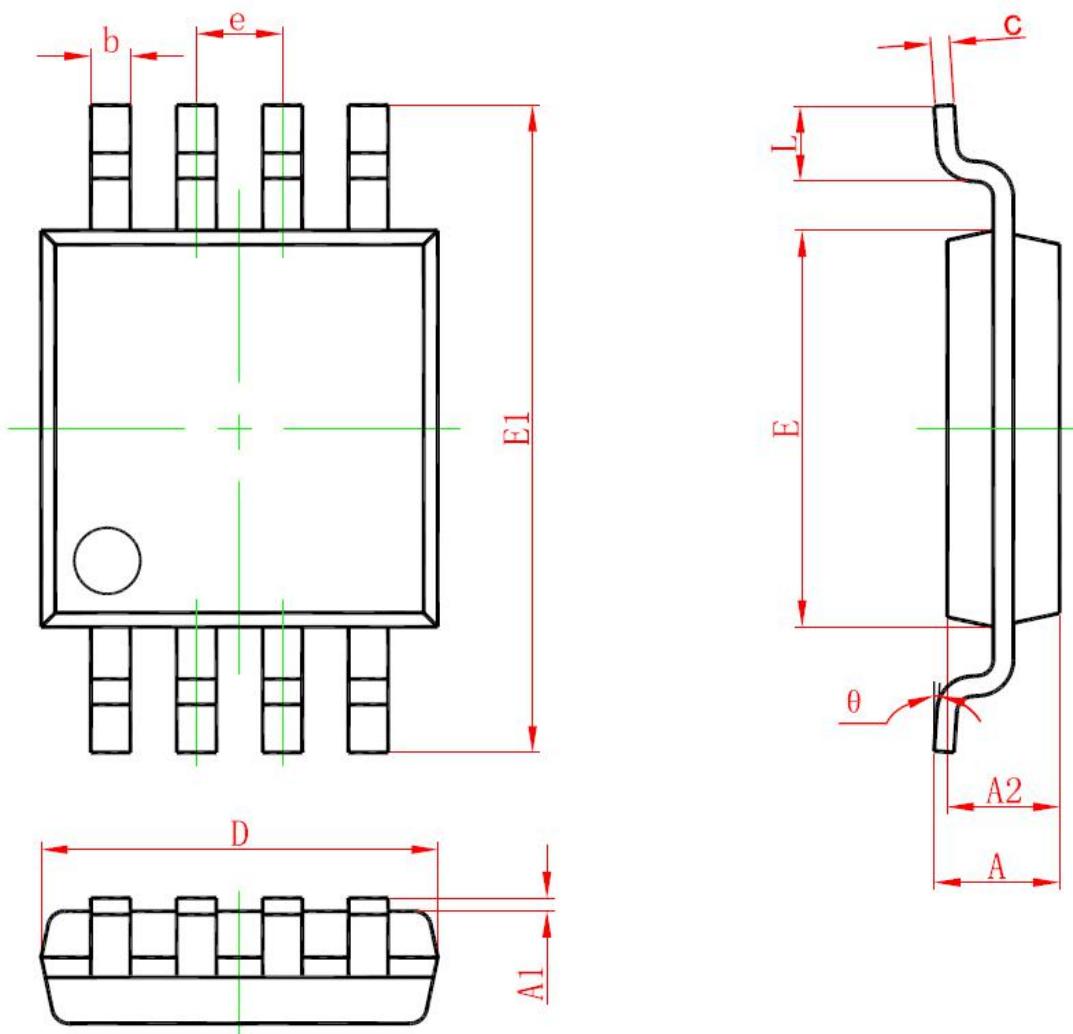
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.820	1.100	0.032	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
e	0.650(BSC)		0.026(BSC)	
E	2.900	3.100	0.114	0.122
E1	4.750	5.050	0.187	0.199
L	0.400	0.800	0.016	0.031
θ	0º	6º	0º	6º

DFN1.5*1.5 8L

TOP VIEW

SIDE VIEW

BOTTOM VIEW
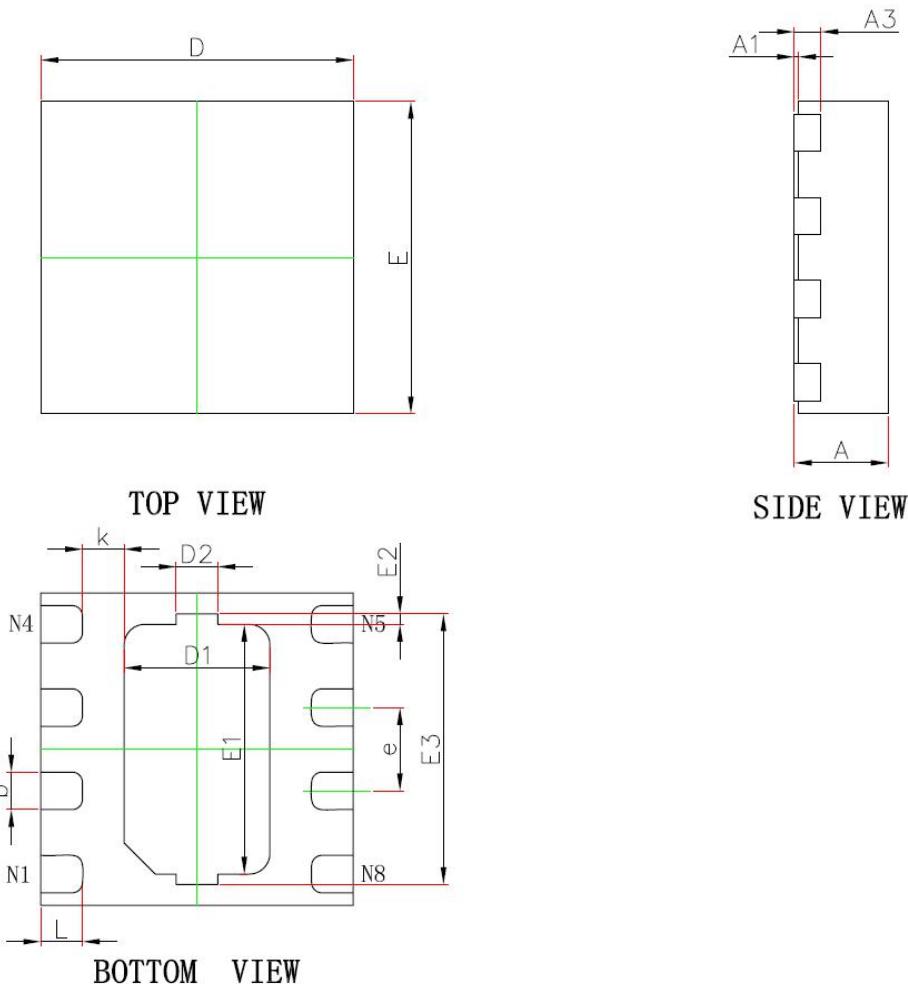
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.400	0.500	0.016	0.020
A1	0.000	0.050	0.000	0.002
A3	0.127REF		0.005REF	
D	1.450	1.550	0.057	0.061
E	1.450	1.550	0.057	0.061
D1	0.600	0.800	0.024	0.031
D2	0.200REF		0.008REF	
E1	1.100	1.300	0.043	0.051
E2	0.050REF		0.002REF	
E3	1.200	1.400	0.047	0.055
k	0.200REF		0.008REF	
b	0.150	0.250	0.006	0.010
e	0.400BSC		0.016BSC	
L	0.150	0.250	0.006	0.010

DFN2*2 8L
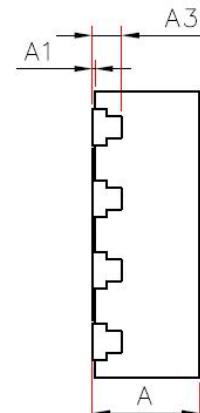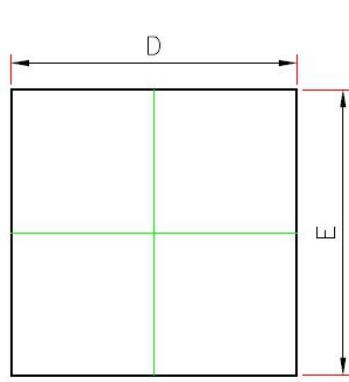
TOP VIEW

SIDE VIEW
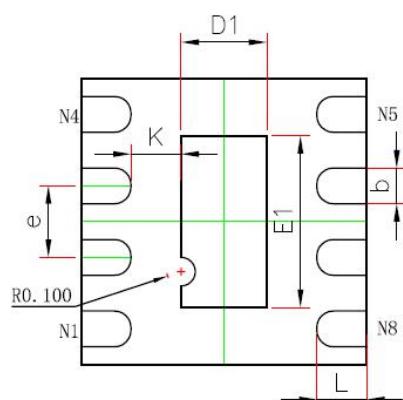
BOTTOM VIEW

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.700/0.800	0.800/0.900	0.028/0.031	0.031/0.035
A1	0.000	0.050	0.000	0.002
A3	0.203REF		0.008REF	
D	1.900	2.100	0.075	0.083
E	1.900	2.100	0.075	0.083
D1	0.500	0.700	0.020	0.028
E1	1.100	1.300	0.043	0.051
k	0.200MIN		0.008MIN	
b	0.200	0.300	0.008	0.012
e	0.500TYP		0.020TYP	
L	0.300	0.400	0.012	0.016

QFN2*2 12L
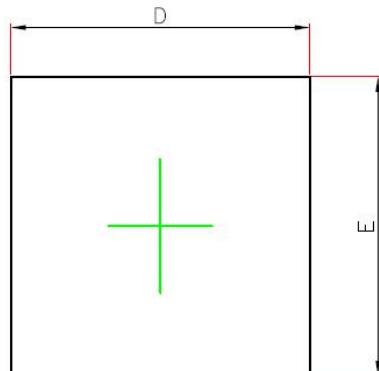
TOP VIEW
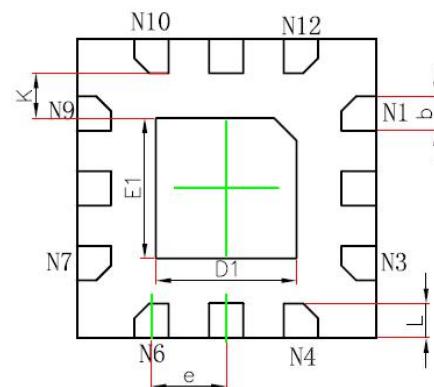
BOTTOM VIEW
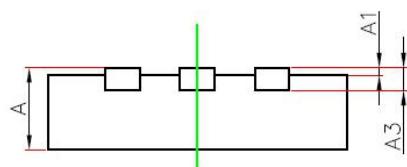
SIDE VIEW

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.500	0.600	0.020	0.024
A1	0.000	0.050	0.000	0.002
A3	0.152REF		0.006REF	
D	1.924	2.076	0.076	0.082
E	1.924	2.076	0.076	0.082
D1	0.840	1.040	0.033	0.041
E1	0.840	1.040	0.033	0.041
k	0.200REF		0.008REF	
b	0.180	0.280	0.007	0.011
e	0.500BSC		0.020BSC	
L	0.154	0.306	0.006	0.012

Ordering Information

Order Number	Temperature Range	Package	RoHS	Marking	Packing Type
SK8950ST6-A1	-40℃～85℃	SOT23-6L	YES	C4050/LLLL	3000 Pcs/reel
SK8950MS8-A1	-40℃～85℃	MSOP-8L	YES	4050/LLL	3000 Pcs/reel
SK8951DN8-A1	-40℃～85℃	DFN1.5*1.5-8L	YES	4051/LLL	3000 Pcs/reel
SK8952DN8-A1	-40℃～85℃	DFN2*2-8L	YES	4052/LLL	3000 Pcs/reel
SK8953QN12-A1	-40℃～85℃	QFN2*2-12L	YES	4053/LLL	3000 Pcs/reel
SK8950ST6-B1	-40℃～85℃	SOT23-6L	YES	C4B50/LLLL	3000 Pcs/reel
SK8951DN8-B1	-40℃～85℃	DFN1.5*1.5-8L	YES	4B51/LLL	3000 Pcs/reel
SK8952DN8-B1	-40℃～85℃	DFN2*2-8L	YES	4B52/LLL	3000 Pcs/reel
SK8953QN12-B1	-40℃～85℃	QFN2*2-12L	YES	4B53/LLL	3000 Pcs/reel

Note：

1. "LLL" represents Lot No
2. "*-A1" represents Voltage Version 4.2V, "*-B1" represents Voltage Version 4.35V