

Two-Cell Lithium-Ion Battery Protection IC

FEATURES

- Ultra-low quiescent current at 10 μ A ($V_{CC}=7V$, $V_C=3.5V$).
- Ultra-low power-down current at 0.2 μ A ($V_{CC}=3.8V$, $V_C=1.9V$).
- Wide supply range: 2V to 18V.
- Precision over-charge protection voltage
 - 4.35V \pm 30mV for the SS6802A
 - 4.30V \pm 30mV for the SS6802B
 - 4.25V \pm 30mV for the SS6802C
- Built-in delay circuits for over-charge, over-discharge and over-current protection.
- Over-charge and over-discharge delay time can be extended by external capacitors.
- Built-in cell-balancing bleeding network under over-charge condition.

DESCRIPTION

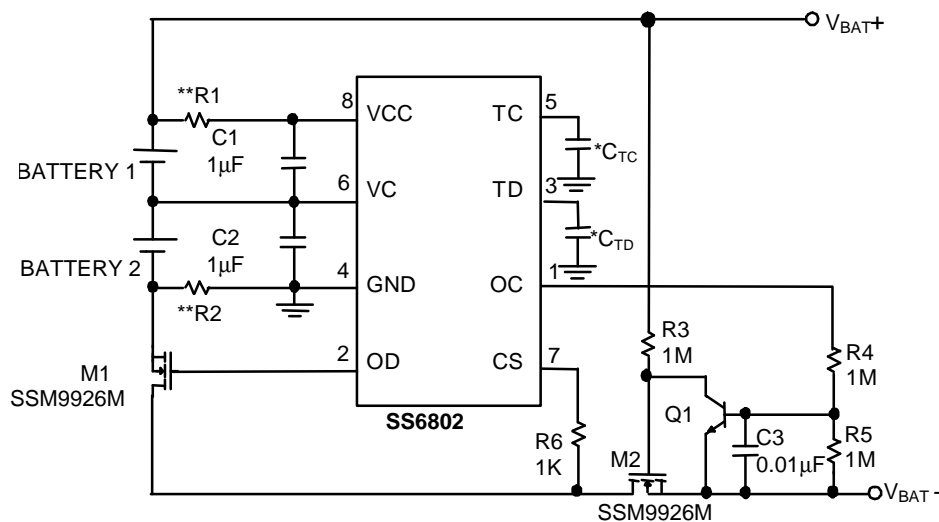
The SS6802 battery protection IC is designed to protect lithium-ion batteries from damage due to over-charging, over-discharging, and over-current for two-series cells in portable phones and laptop computers. It can be a part of a low-cost charge control system within a two-cell lithium-ion battery pack.

Safe charging with full utilization is ensured by the accurate $\pm 30mV$ overcharge detection. Three different specification values for overcharge protection voltage are provided for various protection requirements. The very low standby current drains little current from the cells while in storage.

APPLICATIONS

Protection IC for Two-Cell Lithium-Ion Battery Pack.

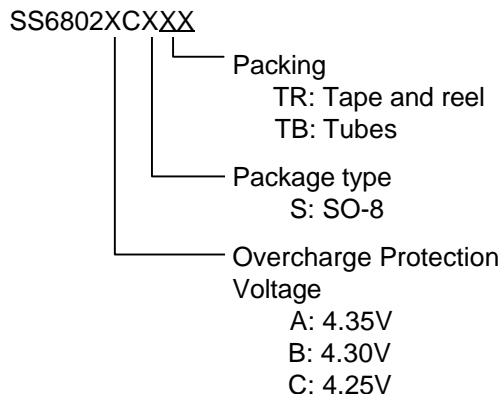
TYPICAL APPLICATION CIRCUIT



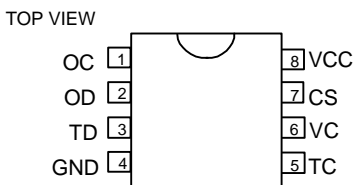
* C_{TC} & C_{TD} are optional for delay time adjustment.
 **R1 & R2: Refer to "Application information".

Protection Circuit for Two-Cell Lithium-Ion Battery Pack

ORDERING INFORMATION



PIN CONFIGURATION



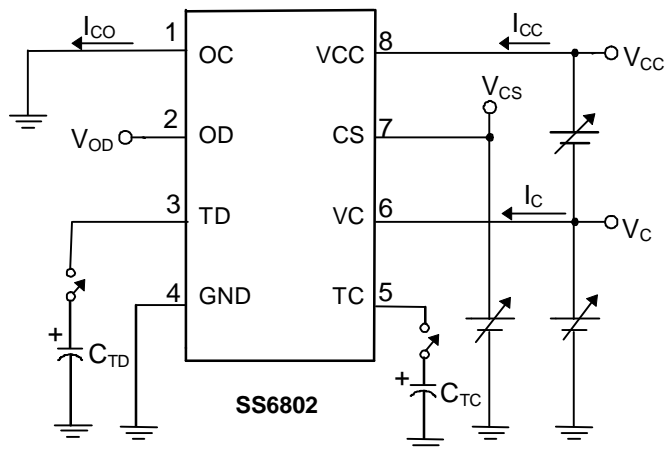
Example: SS6802ACSTR

→ 4.35V version, in SO-8 package, shipped on tape and reel

ABSOLUTE MAXIMUM RATINGS

Supply Voltage	18V
DC Voltage Applied on VC, CS, OC, OD Pins	18V
DC Voltage Applied on TC, TD Pins	5V
Operating Temperature Range	-40°C~85°C
Storage Temperature Range	-65°C~150°C

TEST CIRCUIT



ELECTRICAL CHARACTERISTICS (T_A=25°C, unless otherwise specified.)

PARAMETER	TEST CONDITIONS	SYMBOL	MIN.	TYP.	MAX.	UNIT
Supply Current in Normal Mode	V _{CC} =7V, V _C =3.5V	I _{CC}		10	15	μA
Supply Current in Power-Down Mode	V _{CC} =4.8V, V _C =2.4V	I _{PD}		0.8	1.2	μA
VC Pin Input Current	V _{CC} =7V, V _C =3.5V	I _C		400	600	nA
Over-charge Protection Voltage	SS6802A	V _{OCP}	4.32	4.35	4.38	V
	SS6802B		4.27	4.30	4.33	
	SS6802C		4.22	4.25	4.28	
Over-charge Release Voltage		V _{OCR}	3.85	4.0	4.15	V
Over-discharge Protection Voltage		V _{ODP}	2.25	2.4	2.55	V
Over-discharge Release Voltage		V _{ODR}	2.85	3.0	3.15	V
Over-current Protection Voltage	V _{CC} =7V	V _{OIP}	135	150	165	mV
Over-charge Delay Time (1)	V _{CC} =8.6V, V _C =4.3V, C _{TC} =0μF	T _{OC1}	12	25	38	ms
Over-charge Delay Time (2)	V _{CC} =8.6V, V _C =4.3V, C _{TC} =0.47μF	T _{OC2}	0.7	1.1	1.5	s
Over-discharge Delay Time (1)	V _{CC} =4.8V, V _C =2.4V, C _{TD} =0μF	T _{OD1}	12	25	38	ms
Over-discharge Delay Time (2)	V _{CC} =4.8V, V _C =2.4V, C _{TD} =0.47μF	T _{OD2}	0.7	1.1	1.5	s
Over-current Delay Time (1)	V _{CC} =7V, V _C =3.5V, V _{CS} =0.15V	T _{OI1}	4	9	14	ms
Over-current Delay Time (2)	V _{CC} =7V, V _C =3.5V, V _{CS} =0.36V	T _{OI2}	1.0	2.0	3.0	ms
OC Pin Source Current	V _{CC} =8.6V, V _C =4.3V, OC Pin Short to GND	I _{CO}	270	400	530	μA
OD Pin Output "H" Voltage		V _{DL}	V _{CC} -0.1 V _{CC} -0.02			V

ELECTRICAL CHARACTERISTICS (Continued)

PARAMETER	TEST CONDITIONS	SYMBOL	MIN.	TYP.	MAX.	UNIT
OD Pin Output "L" Voltage		V_{DH}		0.01	0.1	V
Charge Detection Threshold Voltage	$V_{CC}=4.8V$	V_{CH}	-0.55	-0.4		V
Unbalance Discharge Current	$V_{CC}=8.3V, V_C=4V$	I_{UD}	5.4	7.7	10	mA

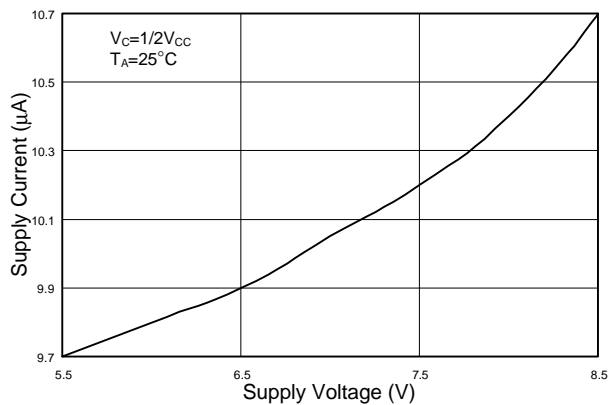
TYPICAL PERFORMANCE CHARACTERISTICS


Fig. 1 Supply Current vs. Supply Voltage

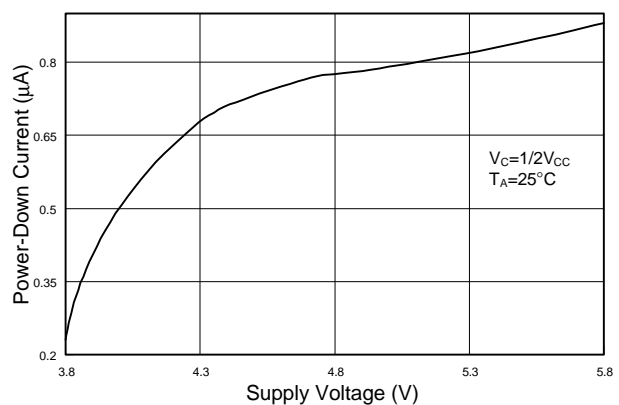


Fig. 2 Power-down Current vs. Supply Voltage

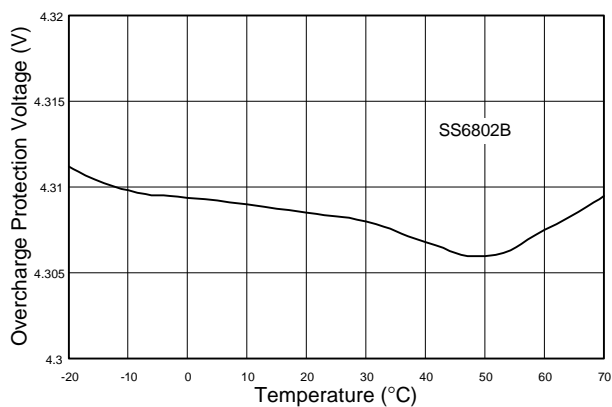


Fig. 3 Overcharge Protection Voltage vs. Temperature

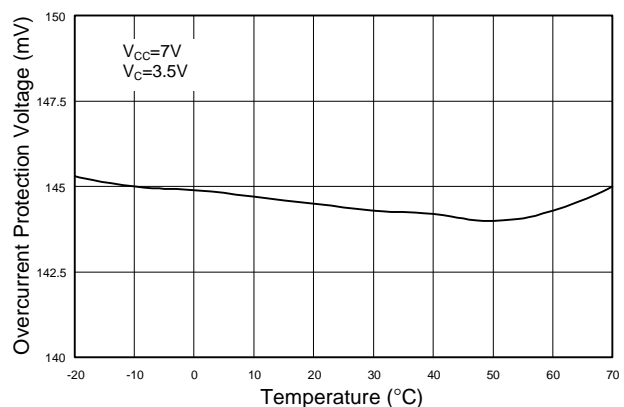


Fig. 4 Overcurrent Protection Voltage vs. Temperature

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

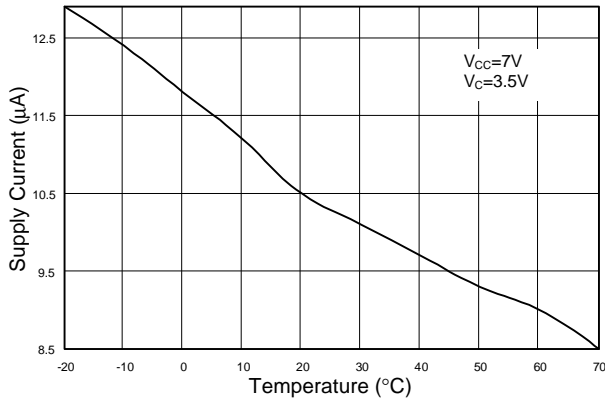


Fig. 5 Supply Current vs. Temperature

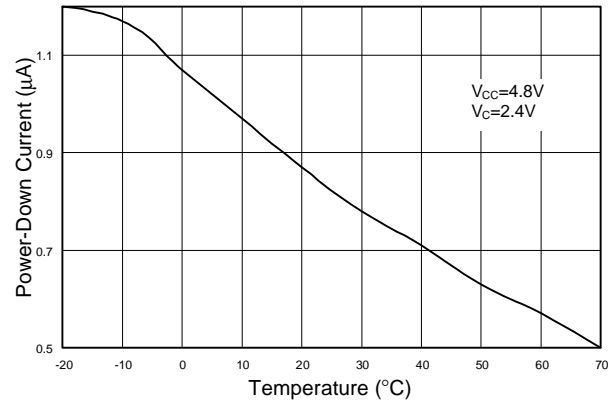


Fig. 6 Power-Down Current vs. Temperature

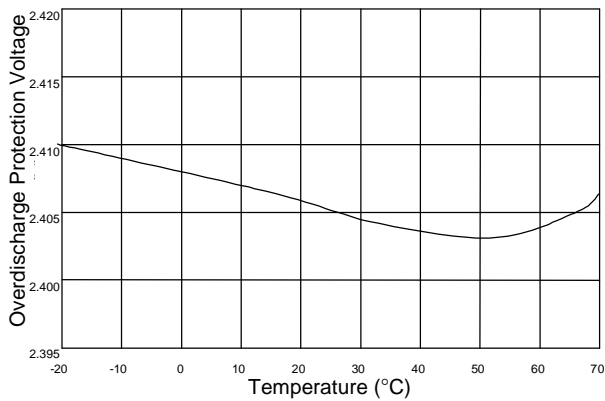


Fig. 7 Overdischarge Protection Voltage vs. Temperature

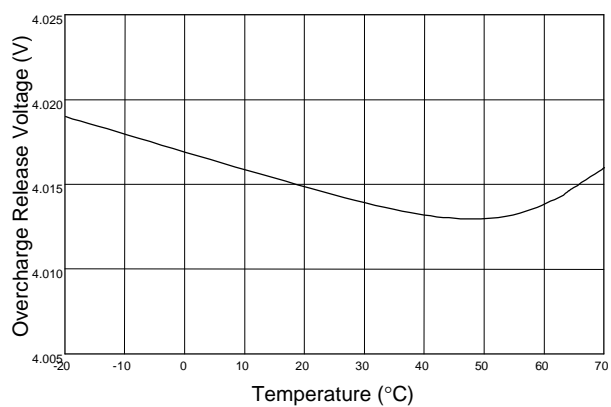


Fig. 8 Overcharge Release Voltage vs. Temperature

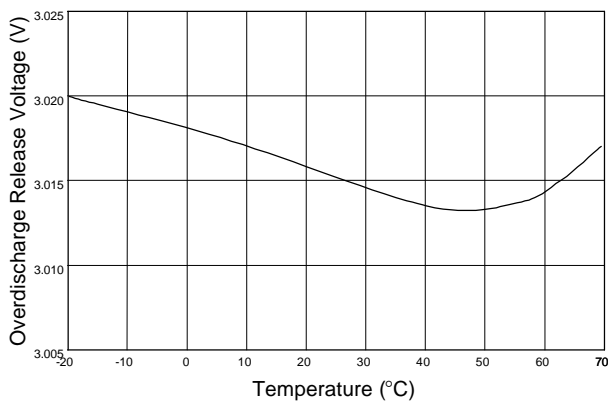
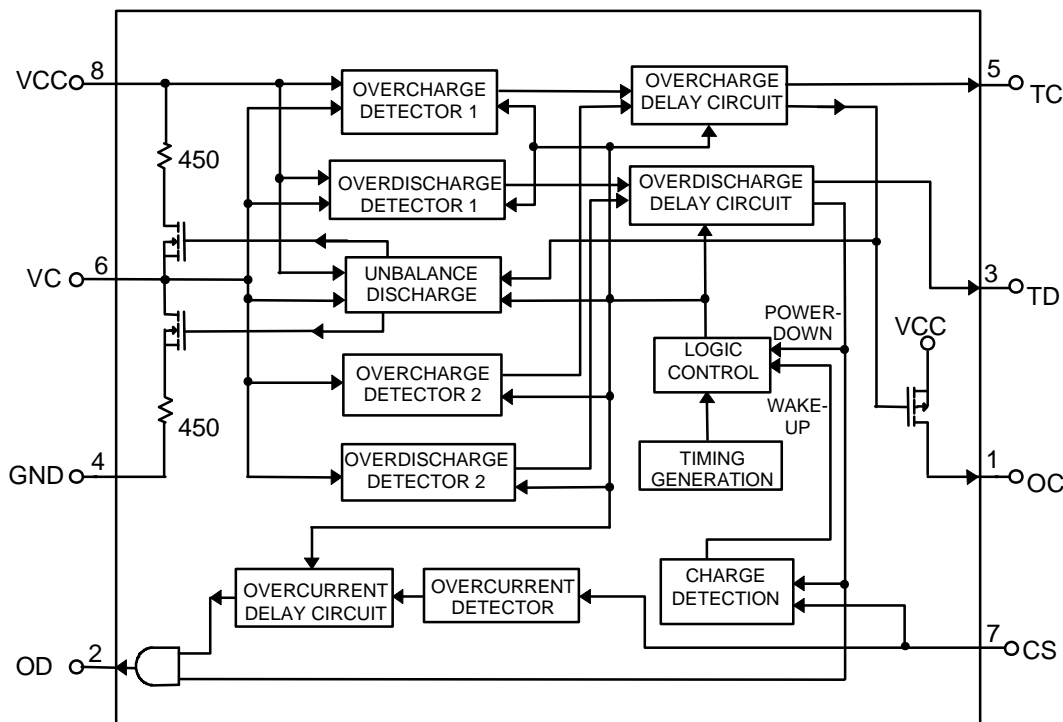


Fig. 9 Overdischarge Release Voltage vs. Temperature

BLOCK DIAGRAM



PIN DESCRIPTIONS

- | | |
|---|---|
| <p>PIN 1: OC - PMOS open drain output for control of the charge control MOSFET M2. When over-charge occurs, this pin sources current to switch the external NPN Q1 on, and charging is halted by turning off the charge control MOSFET M2.</p> | <p>PIN 5: TC - Over-charge delay time setting pin.</p> |
| <p>PIN 2: OD - Output pin for control of the discharge control MOSFET M1. When over-discharge occurs, this pin goes low to turn off the discharge control MOSFET M1 and discharging is halted.</p> | <p>PIN 6: VC - To be connected to the positive terminal of the lower cell and the negative terminal of the upper cell.</p> |
| <p>PIN 3: TD - Over-discharge delay time setting pin.</p> | <p>PIN 7: CS - Input pin for current sensing. Using the drain-source voltage of the discharge control MOSFET M1 (voltage between CS and GND), it senses discharge current during normal mode and detects whether charging current is present during power down mode.</p> |
| <p>PIN 4: GND - Ground pin. This pin is to be connected to the negative terminal of the lower battery cell.</p> | <p>PIN 8: VCC - Power supply pin. It is to be connected to the positive terminal of the upper cell.</p> |

APPLICATION INFORMATION

OPERATION

Over-charge protection

When the voltage of either of the battery cells exceeds V_{OCP} (over-charge protection voltage) for longer than the over-charge delay time period, charging is halted by turning off the charge control MOSFET M2. The over-charge delay time (T_{OC}) defaults to 25ms and can be extended by adding a capacitor C_{TC} . Charging is immediately resumed when the voltage of the over-charged cell becomes lower than V_{OCR} (over-charge release voltage) through discharge.

Over-discharge protection

When the voltage of either of the battery cells goes below V_{ODP} (over-discharge protection voltage) for longer than the over-discharge delay time period, discharging is halted by turning off the discharge control MOSFET M1. The over-discharge delay time (T_{OD}) defaults to 25ms and can be extended by adding a capacitor C_{TD} . Discharging is immediately resumed when the voltage of the over-discharged cell becomes higher than V_{ODR} (over-discharge release voltage) through charging.

Power-down after over-discharge

When over-discharge occurs, the SS6802 will go into power-down mode, turning off all the timing generation and detection circuitry to reduce the quiescent current to $0.8\mu A$ ($V_{CC}=4.8V$). In the unusual case where one battery cell is over-discharged while the other is in an over-charge condition, the SS6802 will turn off all the detection circuits except the over-charge detection circuit for the cell under over-charge condition.

Charge detection after over-discharge

When over-charge occurs, the discharge control MOSFET M1 turns off and discharging is halted. However, charging is still permitted through the parasitic diode of M1. Once the charger is connected to the battery pack, the SS6802 immediately turns on all the timing generation and detection circuitry and goes into normal mode. Charging is determined to be in progress if the voltage between CS and GND is below $-0.4V$ (charge detection threshold voltage V_{CH})

Over-current protection

In normal mode, the SS6802 continuously monitors the discharge current by sensing the voltage of the CS pin. If the voltage of the CS pin exceeds V_{OIP} (over-current protection voltage) for longer than the over-current delay time (T_{OI}), the over-current protection circuit operates and discharging is halted by turning off the discharge control MOSFET M1. Discharging must be halted for at least 256ms after over-current takes place to avoid damage to external control MOSFETs due to the rapidly switching transient between V_{BAT+} and V_{BAT-} terminals. The over-current condition returns to the normal mode when the load is released and the impedance between the V_{BAT+} and V_{BAT-} terminals is $10M\Omega$ or higher. For the sake of protection of the external MOSFETs, the larger the CS pin voltage (which means the larger the discharge current) the shorter the over-current delay time. The relationship between the voltage of the CS pin and the over-current delay time T_{OI} is tabulated below.

V _{CS} (V)	T _{OI} (sec)
150mV	9.0ms
200mV	5.6ms
300mV	2.8ms
360mV	2.0ms
1V	540μs
3V	290μs
5V	270μs

C _{TC} (F)	T _{OC} (sec)
0μF	25ms
0.1μF	320ms
0.3μF	890ms
0.47μF	1.12s
0.57μF	1.43s

C _{TD} (F)	T _{OD} (sec)
0μF	25ms
0.1μF	320ms
0.3μF	820ms
0.47μF	1.08s
0.57μF	1.39s

Unbalanced discharge after overcharge

When either of the battery cells is over-charged, the SS6802 will automatically discharge the over-charged cell at about 7.7mA until the voltage of the over-charged cell is equal to the voltage of the other cell. If the voltage of the other cell is below V_{OCR}, the internal cell-balance “bleeding” will proceed until the voltage of the over-charged cell decreases to V_{OCR}.

DESIGN GUIDE

Adjustment of overcharge and over-discharge delay time

Both the over-charge and over-discharge delay times default to 25ms and can be extended by adding the external capacitors C_{TC} and C_{TD}, respectively. Increasing the capacitance value will increase the delay time. The relationship between capacitance of the external capacitors and delay time is tabulated below:

Selection of external control MOSFETs

Because the over-current protection voltage is preset, the threshold current for over-current detection is determined by the on-resistance of the discharge control MOSFET M1. The on-resistance of the external control MOSFETs can be determined by the equation: $R_{ON} = V_{OIP} / I_T$ (I_T is the over-current threshold current). For example, if the over-current threshold current I_T is designed to be 5A, the on-resistance of the external control MOSFETs must be 30mΩ. Users should be aware that on-resistance of MOSFETs changes with temperature variation due to heat dissipation. It changes with the voltage between gate and source as well. (On-resistance of a MOSFET increases as the voltage between gate and source decreases). Once the on-resistance of the external MOSFET changes, the over-current threshold current will change accordingly.

Suppressing the ripple and disturbance from the charger

To suppress the ripple and disturbance from charger, connecting C1 to cell 1 and C2 to cell 2 is recommended.

Controlling the charge control MOSFET

R3, R4, R5 and NPN transistor Q1 are used to switch the charge control MOSFET M2. If over-charge does not occur, no current flows out from the OC pin, Q1 is turned off, and M2 is turned on. When over-charge occurs, current flows out from the OC pin, Q1 is turned on, which turns off M2 in turn. High resistance for R3, R4, and R5 is recommended for reducing loading of the batteries.

Latch-up protection at CS pin

R6 is used for latch-up protection when the charger is connected under over-discharge conditions, and also for over-stress protection when the charger is connected in reverse. The charge detection function after over-discharge can be disabled by a large value of R6. Resistance of 1K Ω is recommended.

Selection of R1 and R2

R1 and R2 are used to avoid large current flows through the battery pack caused by a damaged IC or a shorted pin. However, the resistance of R1 and R2 will affect the over-charge release voltage and bleeding function. The relationship between Vrelease1, Vrelease2, R1, and R2 is shown in the

following equations:

$$V_{\text{release1}} = V_{\text{OCR}} + I_{\text{UD}} \cdot R1$$

$$V_{\text{release2}} = V_{\text{OCR}} + I_{\text{UD}} \cdot R2$$

where

Vrelease1 is Battery 1, real over-charge release voltage

Vrelease2 is Battery 2, real over-charge release voltage

Therefore, the resistance of R1 and R2 should not be higher than 30 Ω , otherwise the over-charge release voltage would be higher than the over-charge protection voltage and the charging current may oscillate. In addition, if over-charge protection occurs, the SS6802 will discharge the over-charged cell and will stop the bleeding function even if the voltage is not equal to the other.

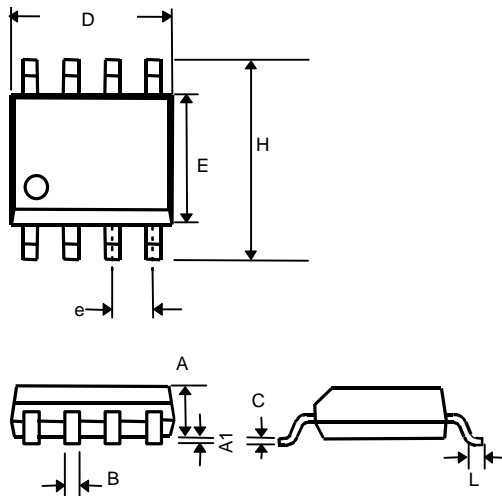
The recommended resistance of R1 and R2 is from 20 to 30 Ω .

Effect of C3

C3 must be attached to the circuit, to keep the SS6802 charging after an over-discharge has occurred. In addition, when the differential voltage between the charger and battery pack is higher than 2.1V and the over-charge protection function works, C3 will stop the battery pack from being charged even if the battery voltage is lower than 4V (to avoid the battery pack from being charged under a charger malfunction situation). The battery pack cannot be charged again until it is removed from the charger.

PHYSICAL DIMENSIONS

8 LEAD PLASTIC SO (unit: mm)



SYMBOL	MIN	MAX
A	1.35	1.75
A1	0.10	0.25
B	0.33	0.51
C	0.19	0.25
D	4.80	5.00
E	3.80	4.00
e	1.27(TYP)	
H	5.80	6.20
L	0.40	1.27

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