BATTERY PROTECTION IC (FOR A SINGLE-CELL PACK) S-8231 SERIES

The 8231 is a series of lithium-ion rechargeable battery protection ICs incorporating high-accuracy voltage detection circuits and delay circuits. It is suitable for a single-cell lithium-ion battery pack.

■ Features

(1) Internal high-accuracy voltage detection circuit

- Over charge detection voltage 4.00 V ± 25 mV to 4.60 V ± 25 mV
  5 mV- step
- Over charge release voltage 3.70 V ± 50 mV to 4.60 V ± 50m V
  5 mV- step

  (The Over charge release voltage can be selected within the range where the difference from Over charge detection voltage is 0 to 0.3 V)
- Over discharge detection voltage 1.70 V ± 80 mV to 2.50 V ± 80 mV
  50 mV- step
- Over discharge release voltage 1.70 V ± 100 mV to 3.50 V ± 100 mV
  50 mV - step

  (The over discharge release voltage can be selected within the range where a difference from over discharge detection voltage is 0 to 1.0V)
- Over current detection voltage 1 0.06 V ± 20 mV to 0.30 V ± 20 mV
  5 mV-step

(2) High input-voltage device (absolute maximum rating: 18 V)

(3) Wide operating voltage range: 1.5 V to 16 V

(4) The delay time for every detection can be set via an external capacitor.
Each delay time for Over charge detection, Over discharge detection, Over current detection are "Proportion of hundred to ten to One." or "Proportion of fifty to ten to One."

(5) Two over current detection levels (protection for short-circuiting)

(6) Internal auxiliary over voltage detection circuit (Fail safe for over voltage)

(7) Internal charge circuit for 0V battery (Unavailable is option)

(8) Low current consumption

- Operation 7.5 μA typ. 13.7 μA max. (-40 to +85 °C)
- Power-down mode 0.2 nA typ. 0.14 μA max. (-40 to +85 °C)

(9) MSOP package (8-pin) 4.0 mm×2.95 mm

■ Applications

Lithium-ion rechargeable battery packs

- The Information herein is subject to change without notice.

■ Selection Guide(12 Nov , 1997)

Table1

Model/ Item	Over charge detection voltage	Over charge release voltage	Over discharge detection voltage	Over discharge release voltage	Over current detection voltage1	Over charge detection delay (C2=0.047 μ·F)	0V battery charging function	Auxiliary over charge detection vol. Magnification *3
S-8231AAFN-CAA-T2	4.25V±25mV	4.05±50mV	2.30V±80mV	2.70V±100mV	0.100V±20mV	1.0 sec	Available	1.24
S-8231ABFN-CAB-T2	4.35V±25mV	4.10±50mV	2.30V±80mV	3.00V±100mV	0.100V±20mV	1.0 sec	Available	1.24
S-8231ACFN-CAC-T2	4.25V±25mV	4.05±50mV	2.30V±80mV	2.50V±100mV	0.120V±20mV	0.5 sec	Unavailable	1.24
S-8231ADFN-CAD-T2	4.25V±25mV	4.05±50mV	2.30V±80mV	2.50V±100mV	0.240V±20mV	0.5 sec	Unavailable	1.24
S-8231AEFN-CAE-T2	4.25V±25mV	3.95±50mV	2.30V±80mV	3.00V±100mV	0.100V±20mV	1.0 sec	Available	1.24
S-8231AGFN-CAG-T2	4.25V±25mV	4.05±50mV	2.30V±80mV	2.70V±100mV	0.150V±20mV	1.0 sec	Available	1.24
S-8231AHFN-CAH-T2	4.35V±25mV	4.28±50mV	2.30V±80mV	2.80V±100mV	0.100V±20mV	1.0 sec	Available	1.24
S-8231AIFN-CAI-T2	4.25V±25mV	4.05V *2	2.30V±80mV	2.70V±100mV	0.150V±20mV	1.0 sec	Available	1.24
S-8231AJFN-CAJ-T2	4.25V±25mV	4.05±50mV	2.30V±80mV	2.50V±100mV	0.120V±20mV	0.5 sec	Available	1.24
S-8231AKFN-CAK-T2	4.25V±25mV	4.05±50mV	2.30V±80mV	2.50V±100mV	0.240V±20mV	0.5 sec	Available	1.24
S-8231ALFN-CAL-T2	4.295V±25mV	4.20±50mV	2.50V±80mV	3.00V±100mV	0.150V±20mV	1.0 sec	Unavailable	1.10
S-8231AMFN-CAM-T2	4.25V±25mV	4.05±50mV	2.30V±80mV	2.70V±100mV	0.130V±20mV	1.0 sec	Unavailable	1.24
S-8231ANFN-CAN-T2	4.35V±25mV	4.10±50mV	2.30V±80mV	3.00V±100mV	0.100V±20mV	0.5 sec	Unavailable	1.24
S-8231AOFN-CAO-T2	4.295V±25mV	4.295V *1	2.30V±80mV	3.00V±100mV	0.300V±20mV	1.0 sec	Unavailable	1.10
S-8231AQFN-CAQ-T2	4.20V±25mV	4.10±50mV	2.30V±80mV	2.50V±100mV	0.200V±20mV	1.0 sec	Unavailable	1.24
S-8231ARFN-CAR-T2	4.20V±25mV	4.10±50mV	2.30V±80mV	2.50V±100mV	0.100V±20mV	1.0 sec	Unavailable	1.24
S-8231ASFN-CAS-T2	4.12V±25mV	4.12V *1	2.30V±80mV	2.50V±100mV	0.200V±20mV	1.0 sec	Unavailable	1.10
S-8231ATFN-CAT-T2	4.35V±25mV	4.10±50mV	2.30V±80mV	3.00V±100mV	0.250V±20mV	1.0 sec	Available	1.24
S-8231AVFN-CAV-T2	4.28V±25mV	4.05±50mV	2.30V±80mV	2.70V±100mV	0.130V±20mV	1.0 sec	Unavailable	1.24
S-8231AWFN-CAW-T2	4.28V±25mV	4.18±50mV	2.30V±80mV	2.90V±100mV	0.080V±20mV	1.0 sec	Unavailable	1.24
S-8231AXFN-CAX-T2	4.295V±25mV	4.295V *1	2.30V±80mV	3.00V±100mV	0.300V±20mV	1.0 sec	Unavailable	Unavailable
S-8231AYFN-CAY-T2	4.35V±25mV	4.28±50mV	2.30V±80mV	2.80V±100mV	0.100V±20mV	1.0 sec	Available	Unavailable
S-8231NAFN-CDA-T2	4.33V±25mV	4.28±50mV	2.30V±80mV	2.80V±100mV	0.100V±20mV	1.0 sec	Available	1.24
S-8231NBFN-CDB-T2	4.28V±25mV	3.98±50mV	2.30V±80mV	2.35V±100mV	0.125V±20mV	1.0 sec	Unavailable	1.24

*1) Without over charge detection / release hysteresis.
*2) Discharging will be unable when over charge detected. (Over charge lock type)
*3) Auxiliary over charge detection voltage comes in three types, i.e., over charge detection voltage (VCU) x 1. 24 times, over charge detection voltage (VCU) x 1.10 times, and no final over charge detection function.

Change in the detection voltage is available in products other than the above listed ones.
Please contact with our sales division.

The over discharge detection voltage can be selected within the range from 1.7 to 3.0V. When the Over discharge detection voltage is higher than 2.5V, the Over charge detection voltage and the Over charge release voltage are limited as follows table.

Table 2

Over discharge detection voltage (VDD)	Over charge detection voltage (VCU)	Voltage difference between Over charge detection voltage and Over charge release voltage
1.70 to 2.50 V	4.00 to 4.60 V	0 to 0.30 V
1.70 to 2.70 V	4.00 to 4.50 V	0 to 0.20 V
1.70 to 3.00 V	4.00 to 4.35 V	0 to 0.10 V

■ Block Diagram

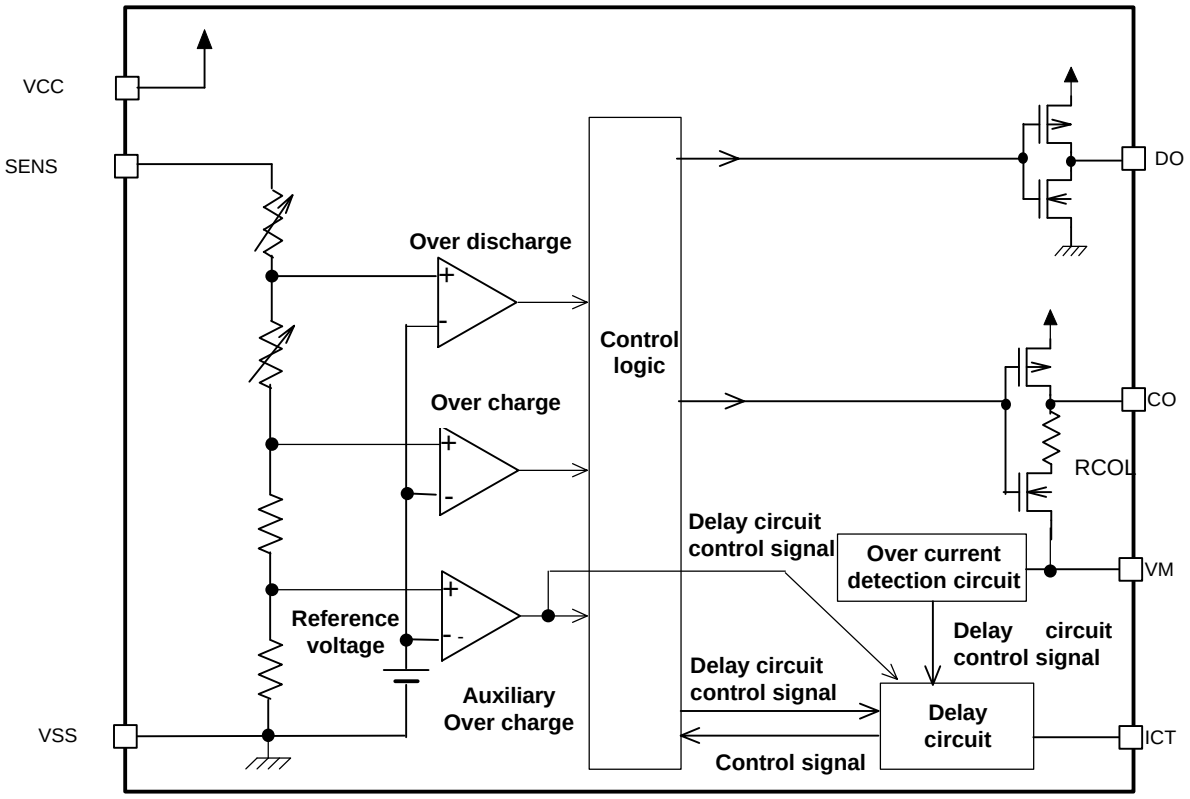


Figure 1

Output impedance when CO terminal output 'L' is higher than DO terminal. Resistor (RCOL) is connected with CO terminal. Please refer 'Electric Characteristics'.

■ Pin Assignment

Top View

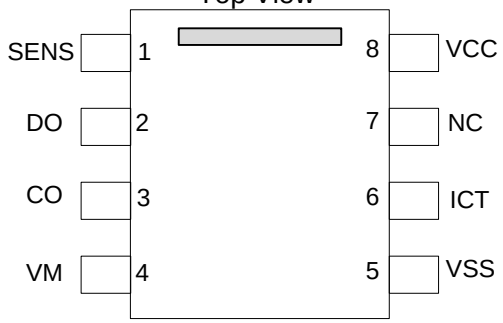


Figure 2
MSOP - 8

■ Pin Description

Table.3

No.	Name	Description
1	SENS	Detects voltage between Vss to SENS(Over charge/discharge detection pin)
2	DO	Connects FET gate for discharge control (CMOS output)
3	CO	Connects FET gate for charge control (CMOS output)
4	VM	Detects voltage between VSS to VM(Over current detection pin)
5	VSS	Negative power input
6	ICT	Connects capacitor for every detection delay circuit
7	NC	Non connect
8	VCC	Positive power input and connects battery positive voltage

■ Absolute Maximum Ratings

Table 4 Ta = 25°C

Item	Sym.	Applied Pins	Rating	Unit
Input voltage between VCC and VSS	VDS	VCC	VSS-0.3 to VSS+18	V
ICT input terminal voltage	VICT	ICT	VSS-0.3 to VCC+0.3	V
VM input terminal voltage	VVM	VM	VCC-18 to VCC+0.3	V
DO output terminal voltage	VDO	DO	VSS-0.3 to VCC+0.3	V
CO output terminal voltage	VCO	CO	VM-0.3 to VCC+0.3	V
Power dissipation	PD		150	mW
Operating temperature range	Topr		-40 to +85	°C
Storage temperature range	Tstg		-40 to +125	°C

■ Electrical Characteristics

Table 5 **Ta = 25°C**

Item	Symbol	Condition	Circuit	Notice	Min.	Typ.	Max.	Unit
Detection voltage								
Over charge detection voltage	VCU	1	1	4.00 to 4.60 Adjustment	VCU -0.025	VCU	VCU +0.025	V
Auxiliary over charge detection voltage VCU×1.24 /×1.10 (*3)	VCUaux	1	1	VCU×1.24 Fixed Type	VCU ×1.20	VCU ×1.24	VCU ×1.28	V
	VCUaux	1	1	VCU×1.10 Fixed Type	VCU ×1.06	VCU ×1.10	VCU ×1.14	V
Over charge release voltage	VCD	1	1	3.70 to 4.60 Adjustment	VCD-0.05	VCD	VCD+0.05	V
Over discharge detection voltage	VDD	1	1	1.70 to 2.50 Adjustment	VDD-0.08	VDD	VDD+0.08	V
Over discharge release voltage	VDU	1	1	1.70 to 3.50 Adjustment	VDU-0.10	VDU	VDU+0.10	V
Over current detection voltage1	VIOV1	2	1	0.06 to 0.30V Adjustment	VIOV1 -0.020	VIOV1	VIOV1 +0.020	V
Over current detection voltage 2	VIOV2	2	1	Vcc Reference	-1.72	-1.35	-0.98	V
Voltage temperature factor 1 (*1)	TCOE1	—	—	(*1)Ta=-40 to 85°C	-0.5	0	0.5	mV/°C
Voltage temperature factor 2 (*2)	TCOE2	—	—	(*2)Ta=-40 to 85°C	-0.15	0	0.15	mV/°C
Delay time(C2=0.047μF)								
Over charge detection delay time	tCU	7	5	1.0 S Type	0.72	1.0	1.32	S
1.0 sec / 0.5 sec (*4)	tCU	7	5	0.5 S Type	0.36	0.5	0.66	S
Over discharge detection delay time	tDD	7	5	0.1 S	71	100	139	mS
Over current detection delay time 1	tIOV1	8	5	0.01 S	6.8	10	13.8	mS
Input voltage								
Input voltage between VCC and VSS	VDS	—	—	absolute maximum rating	-0.3	—	18	V
Operating voltage								
Operating voltage between VCC and VSS (*5)	VDSOP	—	—		1.5	—	16	V
Current consumption								
Current consumption (during normal operation)	IOPE	3	2	VCC=3.6V	2.3	7.5	12.2	μA
Current consumption at power down	IPDN	3	2	VCC=1.5V	0	0.0002	0.06	μA
Output voltage								
DO"H"voltage	VDO(H)	5	3	Iout=10uA	VCC-0.07	VCC-0.006	VCC	V
DO"L"voltage	VDO(L)	5	3	Iout=10uA	VSS	VSS+0.006	VSS+0.07	V
CO"H"voltage	VCO(H)	6	4	Iout=10uA	VCC-0.25	VCC-0.032	VCC	V
CO pin internal resistance								
Resistance between Vss and CO	RCOL	6	4	VSS-CO=4.7V	0.29	0.60	1.43	MΩ
VM Internal resistance								
Resistance between VCC and VM	Rvcm	4	2	VCC-VM=0.5V	0.07	0.16	0.38	MΩ
Resistance between VSS and VM	Rvsm	4	2	VSS-VM=1.1V	0.73	1.05	1.73	MΩ
0V battery charging function								
0V charge starting voltage	V0CHA	9	6	0V batt. cha. Available	0.52	0.73	1.32	V
0V charge inhibiting voltage	V0INH	10	6	0V batt. cha. Unavailable	0.40	0.61	1.11	V

(*1) Voltage temperature factor 1 indicates over charge detection voltage, over charge release voltage, over discharge detection voltage, and over discharge release voltage.
(*2)Voltage temperature factor 2 indicates over current detection voltage.
(*3) The final over charge detection voltage of the products without over charge hysteresis is 1.10 times the over charge detection voltage.
(*4) The over charge detection delay time is either 1.0 s or 0.5 s depending upon the product type (C2 = 0.047μF).
(*5) The operation voltage indicates the voltage between VCC and VSS where the DO and CO logic are established.
(*6) The 0 V battery function is either "0 V battery charging function" or "0 V battery charge inhibiting function" depending upon the product type.

Table 6 **Ta = -20 ~ +70°C**

Item	Symbol	Condition	Circuit	Notice	Min.	Typ.	Max.	Unit
Detection voltage								
Over charge detection voltage	VCU	1	1	4.00 to 4.60 Adjustment	VCU -0.045	VCU	VCU +0.035	V
Auxiliary over charge detection voltage VCU×1.24 /×1.10 (*3)	VCUaux	1	1	VCU×1.24 Fixed Type	VCU ×1.18	VCU ×1.24	VCU ×1.30	V
	VCUaux	1	1	VCU×1.10 Fixed Type	VCU ×1.04	VCU ×1.10	VCU ×1.16	V
Over charge release voltage	VCD	1	1	3.70 to 4.60 Adjustment	VCD-0.070	VCD	VCD+0.060	V
Over discharge detection voltage	VDD	1	1	1.70 to 2.50 Adjustment	VDD-0.100	VDD	VDD+0.090	V
Over discharge release voltage	VDU	1	1	1.70 to 3.50 Adjustment	VDU-0.120	VDU	VDU+0.110	V
Over current detection voltage1	VIOV1	2	1	0.06 to 0.30V Adjustment	VIOV1 -0.027	VIOV1	VIOV1 +0.027	V
Over current detection voltage 2	VIOV2	2	1	Vcc Reference	-1.81	-1.35	-0.89	V
Voltage temperature factor 1 (*1)	TCOE1	—	—	(*1)Ta=-40 to 85°C	-0.5	0	0.5	mV/°C
Voltage temperature factor 2 (*2)	TCOE2			(*2)Ta=-40 to 85°C	-0.15	0	0.15	mV/°C
Delay time(C2=0.047μF)								
Over charge detection delay time 1.0 sec / 0.5 sec (*4)	tCU	7	5	1.0 S Type	0.67	1.0	1.42	S
	tCU	7	5	0.5 S Type	0.33	0.5	0.71	S
Over discharge detection delay time	tDD	7	5	0.1 S	58	100	190	mS
Over current detection delay time 1	tIOV1	8	5	0.01 S	6.7	10	14.0	mS
Input voltage								
Input voltage between VCC and VSS	VDS	—	—	absolute maximum rating	-0.3	—	18	V
Operating voltage								
Operating voltage between VCC and VSS (*5)	VDSOP	—	—		1.5	—	16	V
Current consumption								
Current consumption (during normal operation)	IOPE	3	2	VCC=3.6V	2.1	7.5	13.4	μA
Current consumption at power down	IPDN	3	2	VCC=1.5V	0	0.0002	0.08	μA
Output voltage								
DO"H"voltage	VDO(H)	5	3	Iout=10uA	VCC-0.16	VCC-0.006	VCC	V
DO"L"voltage	VDO(L)	5	3	Iout=10uA	VSS	VSS+0.006	VSS+0.16	V
CO"H"voltage	VCO(H)	6	4	Iout=10uA	VCC-0.34	VCC-0.032	VCC	V
CO pin internal resistance								
Resistance between Vss and CO	RCOL	6	4	VSS-CO=4.7V	0.24	0.60	1.95	MΩ
VM Internal resistance								
Resistance between VCC and VM	Rvcm	4	2	VCC-VM=0.5V	0.06	0.16	0.52	MΩ
Resistance between VSS and VM	Rvsm	4	2	VSS-VM=1.1V	0.60	1.05	2.35	MΩ
0V battery charging function								
0V charge starting voltage	V0CHA	9	6	0V batt. cha. Available	0.43	0.73	1.41	V
0V charge inhibiting voltage	V0INH	10	6	0V batt. cha. Unavailable	0.31	0.61	1.20	V

(*1) Voltage temperature factor 1 indicates over charge detection voltage, over charge release voltage, over discharge detection voltage, and over discharge release voltage.
(*2)Voltage temperature factor 2 indicates over current detection voltage.
(*3) The final over charge detection voltage of the products without over charge hysteresis is 1.10 times the over charge detection voltage.
(*4) The over charge detection delay time is either 1.0 s or 0.5 s depending upon the product type (C2 = 0.047μF).
(*5) The operation voltage indicates the voltage between VCC and VSS where the DO and CO logic are established.
(*6) The 0 V battery function is either "0 V battery charging function" or "0 V battery charge inhibiting function" depending upon the product type.

Table 7 **Ta = -40 ~ +85°C**

Item	Symbol	Condition	Circuit	Notice	Min.	Typ.	Max.	Unit
Detection voltage								
Over charge detection voltage	VCU	1	1	4.00 to 4.60 Adjustment	VCU1 -0.060	VCU	VCU1 +0.035	V
Auxiliary over charge detection voltage VCU×1.24 /×1.10 (*3)	VCUaux	1	1	VCU×1.24 Fixed Type	VCU ×1.18	VCU ×1.24	VCU ×1.30	V
	VCUaux	1	1	VCU×1.10 Fixed Type	VCU ×1.04	VCU ×1.10	VCU ×1.16	V
Over charge release voltage	VCD	1	1	3.70 to 4.60 Adjustment	VCD-0.085	VCD	VCD+0.060	V
Over discharge detection voltage	VDD	1	1	1.70 to 2.50 Adjustment	VDD-0.115	VDD	VDD+0.090	V
Over discharge release voltage	VDU	1	1	1.70 to 3.50 Adjustment	VDU-0.135	VDU	VDU+0.110	V
Over current detection voltage1	VIOV1	2	1	0.06 to 0.30V Adjustment	VIOV1 -0.030	VIOV1	VIOV1 +0.030	V
Over current detection voltage 2	VIOV2	2	1	Vcc Reference	-1.85	-1.35	-0.86	V
Voltage temperature factor 1 (*1)	TCOE1			(*1)Ta=-40 to 85°C	-0.5	0	0.5	mV/°C
Voltage temperature factor 2 (*2)	TCOE2			(*2)Ta=-40 to 85°C	-0.15	0	0.15	mV/°C
Delay time(C2=0.047μF)								
Over charge detection delay time 1.0 sec / 0.5 sec (*4)	tCU	7	5	1.0 S Type	0.64	1.00	1.46	S
	tCU	7	5	0.5 S Type	0.32	0.50	0.73	S
Over discharge detection delay time	tDD	7	5	0.1 S	54	100	212	mS
Over current detection delay time 1	tIOV1	8	5	0.01 S	6.7	10	14.1	mS
Input voltage								
Input voltage between VCC and VSS	VDS	—	—	absolute maximum rating	-0.3	—	18	V
Operating voltage								
Operating voltage between VCC and VSS (*5)	VDSOP	—	—		1.5	—	16	V
Current consumption								
Current consumption (during normal operation)	IOPE	3	2	VCC=3.6V	2.0	7.5	13.7	μ·A
Current consumption at power down	IPDN	3	2	VCC=1.5V	0	0.0002	0.14	μ·A
Output voltage								
DO"H"voltage	VDO(H)	5	3	Iout=10uA	VCC-0.19	VCC-0.006	VCC	V
DO"L"voltage	VDO(L)	5	3	Iout=10uA	VSS	VSS+0.006	VSS+0.19	V
CO"H"voltage	VCO(H)	6	4	Iout=10uA	VCC-0.37	VCC-0.032	VCC	V
CO pin internal resistance								
Resistance between Vss and CO	RCOL	6	4	VSS-CO=4.7V	0.22	0.60	2.18	MΩ
VM Internal resistance								
Resistance between VCC and VM	Rvcm	4	2	VCC-VM=0.5V	0.05	0.16	0.58	MΩ
Resistance between VSS and VM	Rvsm	4	2	VSS-VM=1.1V	0.56	1.05	2.63	MΩ
0V battery charging function								
0V charge starting voltage	V0CHA	9	6	0V batt. cha. Available	0.40	0.73	1.45	V
0V charge inhibiting voltage	V0INH	10	6	0V batt. cha. Unavailable	0.28	0.61	1.24	V

(*1) Voltage temperature factor 1 indicates over charge detection voltage, over charge release voltage, over discharge detection voltage, and over discharge release voltage.

(*2)Voltage temperature factor 2 indicates over current detection voltage.

(*3) The final over charge detection voltage of the products without over charge hysteresis is 1.10 times the over charge detection voltage.

(*4) The over charge detection delay time is either 1.0 s or 0.5 s depending upon the product type (C2 = 0.047μF).

(*5) The operation voltage indicates the voltage between VCC and VSS where the DO and CO logic are established.

(*6) The 0 V battery function is either "0 V battery charging function" or "0 V battery charge inhibiting function" depending upon the product type.

■ Measurement Circuits

(1) Measurement 1 Measurement circuit 1

Set S1=OFF, V1=3.6V, and V2=0V under normal condition. Increase V1 from 3.6V gradually.
The V1 voltage when CO = 'L' is over charge detection voltage 1 (VCU). Decrease V1 gradually.
The V1 voltage when CO = 'H' is over charge release voltage 1 (VCD). Further decrease V1.
The V1 voltage when DO = 'L' is over discharge voltage 1 (VDD). Increase V1 gradually.
The V1 voltage when DO = 'H' is over discharge release voltage 1 (VDU).
Set S1=ON,and V1=3.6V and V2=0V under normal condition. Increase V1 from 3.6V gradually.
The V1 voltage when CO = 'L' is auxiliary over charge detection voltage 1 (VCUaux).

(2) Measurement 2 Measurement circuit 1

Set S1=OFF,V1=3.6V, and V2=0V under normal condition. Increase V2 from 0V gradually.
The V2 voltage when DO = 'L' is over current detection voltage 1 (VIOV1).
Set S1=ON,V1=3.6V, and V2=0V under normal condition. Increase V2 gradually from 0V (The voltage change rate < 1.0V/msec). (V2-V1) voltage when DO = 'L' is over current detection voltage 2 (VIOV2).

(3) Measurement 3 Measurement circuit 2

Set S1=ON, V1=3.6V, and V2=0 V under normal condition and measure current consumption.
Current consumption I1 is the normal condition current consumption (IOPE).
Set S1=OFF, V1=V2=1.5 V under over discharge condition and measure current consumption.
Current consumption I1 is the power-down current consumption (IPDN).

(4) Measurement 4 Measurement circuit 2

Set S1=ON, V1=1.5V and V2=1.0V under over discharge condition. (V1-V2)/I2 is the internal resistance between Vcc and VM (Rvcm).
Set S1=ON, V1=3.6 V, and V2=1.1V under over current condition. V2/I2 is the internal resistance between Vss and VM (Rvsm).

(5) Measurement 5 Measurement circuit 3

Set S1=ON, S2=OFF, V1=3.6V, and V2=0V under normal condition. Increase V3 from 0 V gradually.
The V3 voltage when I1 = 10 μA is DO 'H' voltage (VDO (H)).
Set S1=OFF, S2=ON, V1=3.6V, and V2=0.5 V under over current condition. Increase V4 from 0 V gradually. The V4 voltage when I2 = 10 μA is the DO 'L' voltage (VDO (L)).

(6) Measurement 6 Measurement circuit 4

Set S1=ON, S2=OFF, V1=3.6V and V2=0 V under normal condition. Increase V3 from 0 V gradually.
The V3 voltage when I1 = 10 μA is the CO'H' voltage (VCO (H)).
Set S1=OFF S2=ON, V1=4.7 V2=0 V and V4=4.7V under over voltage condition. (V4)/I2 is the CO pin internal resistance (RCOL).

(7) Measurement 7 Measurement circuit 5

Set V1=3.6V , V2=0 V and V1 = (VCU - 0.2V) under normal condition. Increase V1 from (VCU - 0.2V) to (VCU + 0.2V) immediately (within 10 μs). The time after V1 becomes (VCU + 0.2V) until CO goes 'L' is the over charge detection delay time (tCU).

Set V1=3.6V , V2=0V and V1 = (VDD + 0.2V) under normal condition. Decrease V1 from (VDD + 0.2V) to (VDD - 0.2 V) immediately (within 10 μs). The time after V1 becomes (VDD - 0.2 V) until DO goes 'L' is the over discharge detection delay time 1 (tDD).

(8) Measurement 8 Measurement circuit 5

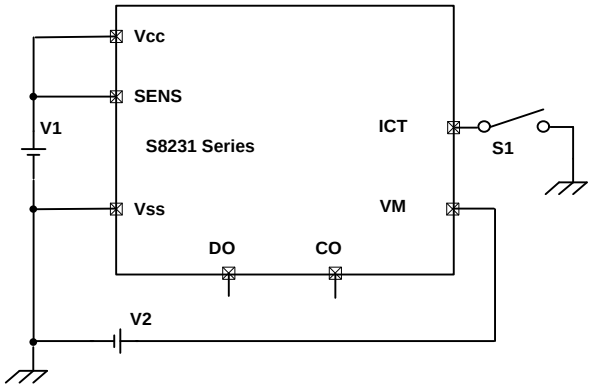
Set V1=3.6V under normal condition. Increase V2 from 0 V to 0.5 V immediately (within 10 μs). The time after V2 becomes 0.5V until DO goes 'L' is the over current detection delay time 1 (tIOV1).

(9) Measurement 9 Measurement circuit 6

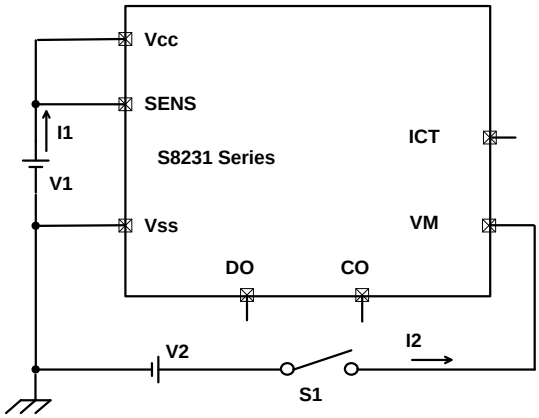
Set V1=0 V, and V2=2 V, and decrease V2 gradually. The V2 voltage when CO = 'L' (VCC- 0.3 V or lower) is the 0V charge starting voltage (V0CHA).

(10) Measurement 10 Measurement circuit 6

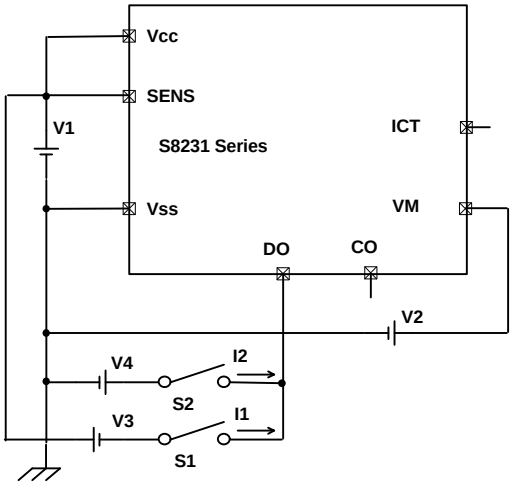
Set V1=0 V, and V2=16 V, and increase V1 gradually. The V1 voltage when CO = 'H' (VM+0.3 V or higher) is the 0V charge inhibiting voltage (V0INH).



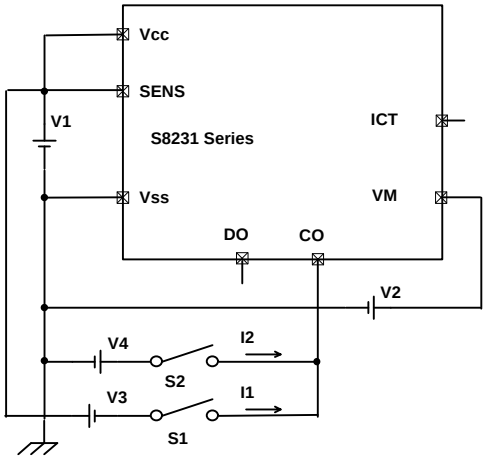
Measurement circuit 1



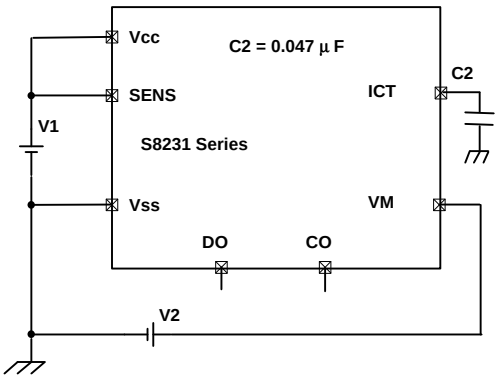
Measurement circuit 2



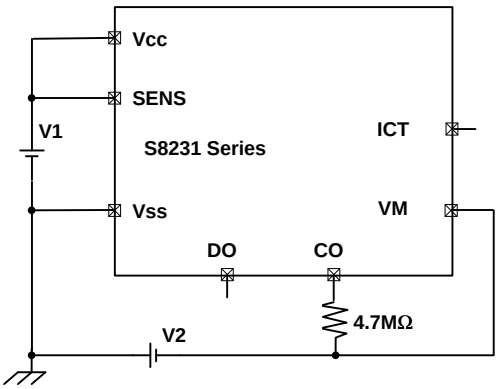
Measurement circuit 3



Measurement circuit 4



Measurement circuit 5



Measurement circuit 6

■ Description

Normal condition(*1)

This IC monitors the voltages of the battery and the discharge current to control charging and discharging. If the voltages of the battery is in the range from the over discharge detection voltage (VDD) to the over charge detection voltage (VCU), and the current flowing through the battery becomes equal or lower than a specified value (the VM terminal voltage is equal or lower than over current detection voltage 1), the charging and discharging FETs turn on. In this condition, charging and discharging can be carried out freely. This condition is called the normal condition. In this condition, the VM and Vss terminals are shorted by the Rvsm resistor.

Over current condition

If the discharging current becomes equal to or higher than a specified value (the VM terminal voltage is equal to or higher than the over current detection voltage) during discharging under normal condition and it continues for the over current detection delay time (tIOV1) or longer, the discharging FET turns off to stop discharging. This condition is called an over current condition. The VM and Vss terminals are shorted by the Rvsm resistor at this time. Also the charging FET turns off. When the discharging FET is off and a load is connected, the VM terminal voltage equals the Vcc potential.

The over current condition returns to the normal condition when the load is released and the impedance between the EB- and EB+ terminals (see Figure 7 for a connection example) is 200MΩ or higher. When the load is released, the VM terminal, which and the Vss terminal are shorted with the Rvsm resistor, goes back to the Vss potential. The IC detects that the VM terminal potential returns to over current detection voltage 1 (VIOV1) and returns to the normal condition.

Over charge condition

The over charge condition is **detected in two cases:**

(1) If the battery voltages becomes higher than the over charge detection voltage (VCU) during charging under normal condition and it continues for the over charge detection delay time (tCU) or longer, the charging FET turns off to stop charging.

(2) If the battery voltages becomes higher than the auxiliary over charge detection voltage (VCUaux) the charging FET turns off immediately to stop charging.

The VM and VSS terminals are shorted by the Rvsm resistor under the over charge condition.

The auxiliary over charge detection voltage (VCUaux) is fixed internally and calculated by the over charge detection voltage (VCU) as follows:

VCUaux [V] = 1.24 X VCU [V]

[For without Over charge detection / release hysteresis]
VCUaux [V] = 1.10 X VCU [V]

The over charge condition is **released in two cases:**

① The battery voltage which exceeded the over charge detection voltage (VCU) falls below the over charge release voltage (VCD), the charging FET turns on and the normal condition returns.

② If the battery voltage which exceeded the over charge detection voltage (VCU) is equal or higher than the over charge release voltage (VCD), but the charger is removed, a load is placed, and discharging

starts, the charging FET turns on and the normal condition returns.

The release mechanism is as follows: the discharge current flows through an internal parasitic diode of the charging FET immediately after a load is installed and discharging starts, and the VM terminal voltage increases by about 0.6 V from the Vss terminal voltage momentarily. The IC detects this voltage (over current detection voltage 1 or higher), releases the over charge condition and returns to the normal condition.

Note: Function of [Over charge lock type (S-8231AIFN)]
If the battery voltages becomes higher than the over charge detection voltage (VCU), the charging FET turns off to stop charging. When a load is placed, at that condition, the discharging FET turns off too. Both charging and discharging are unable once over charge detected. This mechanism can realize more safety Li-ion battery pack.

Over discharge condition

If the battery voltages falls below the over discharge detection voltage (VDD) during discharging under normal condition and it continues for the over discharge detection delay time (tDD) or longer, the discharging FET turns off and discharging stops. This condition is called the over discharge condition. When the discharging FET turns off, the VM terminal voltage becomes equal to the Vcc voltage and the IC's current consumption falls below the power-down current consumption (IPDN). This condition is called the power-down condition. The VM and Vcc terminals are shorted by the Rvcm resistor under the over discharge and power-down conditions.

The power-down condition is canceled when the charger is connected and the voltage between VM and Vcc is 1.35 V or higher (over current detection voltage 2). When the battery voltages becomes equal to or higher than the over discharge release voltage (VDU) in this condition, the over discharge condition changes to the normal condition.

Delay circuits

The over charge detection delay time (tCU), over discharge detection delay time (tDD), and over current detection delay time 1 (tIOV1) are changed with external capacitors (C2).The delay time for over charge and over discharge and over current detection is changed via an external capacitor. Those three detection delay times are consistent with each other, describe as below.

[For tCU=1.0 S type]

Over charge delay time : Over discharge delay time: Over current delay time = 100 : 10 : 1

[For tCU=0.5 S type]

Over charge delay time : Over discharge delay time: Over current delay time = 50 : 10 : 1

The delay times are calculated by the following equations: (Ta=-40 ~ +85°C)

Over charge detection delay time	Min	Typ.	Max.	
[tCU=1.0 S type]	tCU[S] = Delay factor (	13.62,	21.28,	31.06) X C2 [uF]
[tCU=0.5 S type]	tCU[S] = Delay factor (	6.809,	10.63,	15.53) X C2 [uF]

Over discharge detection delay time

tDD[S] = Delay factor (1.149, 2.128, 4.511) X C2 [uF]

Over current detection delay time

tIOV1[S] = Delay factor (0.143, 0.213, 0.300) X C2 [uF]

! Note:The delay time for over current detection 2 is fixed by an internal IC circuit. The delay time cannot be changed via an external capacitor.

0V battery charging function (*2)

This function is used to recharge the connected battery after it self-discharge to 0V. When the 0V charging start voltage (V0CHA) or higher is applied to between VM and Vcc by connecting the charger, the charging FET gate is fixed to Vcc potential.

When the voltage between the gate sources of the charging FET becomes equal to or higher than the turn-on voltage by the charger voltage, the charging FET turns on to start charging. At this time, the discharging FET turns off and the charging current flows through the internal parasitic diode in the discharging FET. If the battery voltages become equal to or higher than the over discharge release voltage (VDU), the normal condition returns.

0V battery charge inhibiting function (*2)

This function is used to inhibit recharge the connected battery after it self-discharge to 0V or shorted internally. If the battery voltages become 0.6V or lower, the charging FET gate is fixed to EB- potential.

If the battery voltages is 0.6V or higher, the charging FET gate turns on.

4.7MΩ resistor is required between CO terminal and EB- terminal. Please refer figure 5.

(*1)

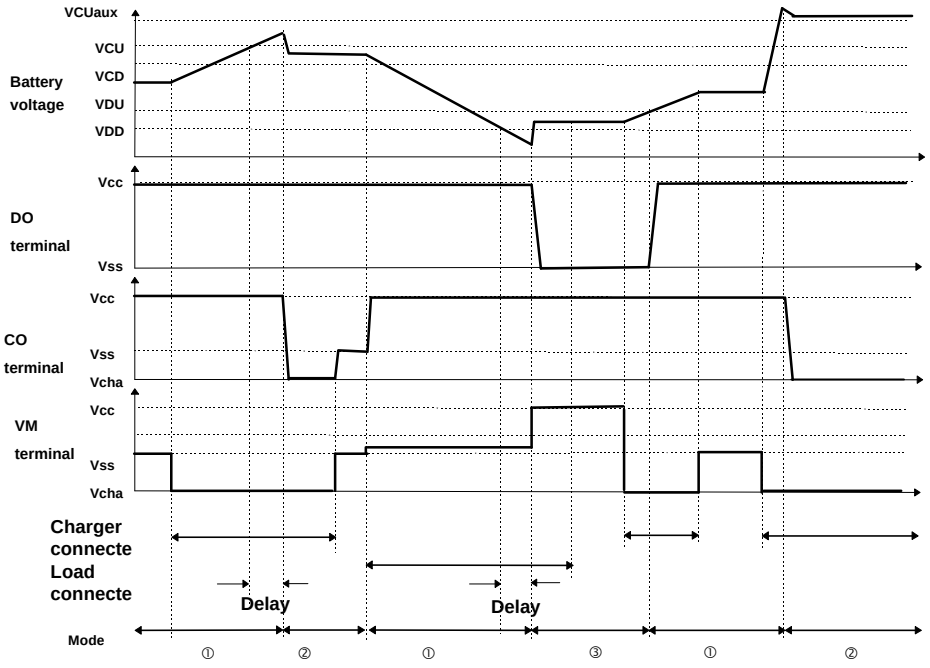
If the battery voltages is equal to or lower than the over discharge release voltage (VDU) when they are connected for the first time, the normal condition may not be entered. If the VM terminal voltage is made equal to or lower than the Vss voltage (if a charger is connected), the normal condition is entered.

(*2)

Some battery providers do not recommend charge for 0V batteries(complete self-discharged). Please refer to battery providers.

■ Operation Timing Charts

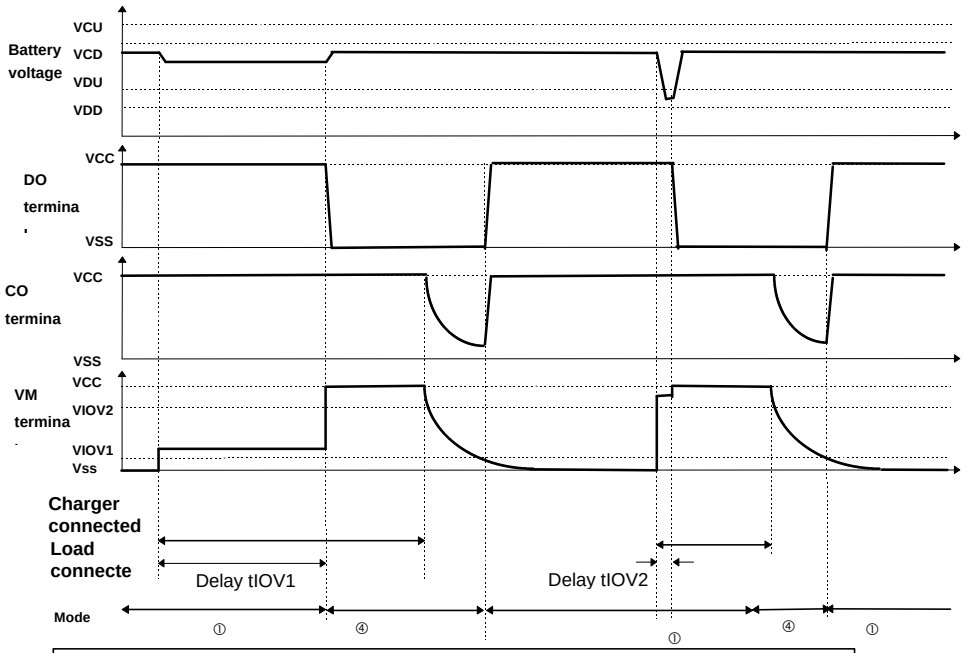
1. Over charge and over discharge detection



Note: ①Normal mode,② Over charge mode,③ Over discharge mode, ④over current mode
The charger is assumed to charge with a constant current.

Figure 3

2. Over current detection



Note: ①Normal mode,②Over charge mode,③Over discharge mode,④over current mode
The charger is assumed to charge with a constant current.

Figure 4

■ Battery Protection IC Connection Example

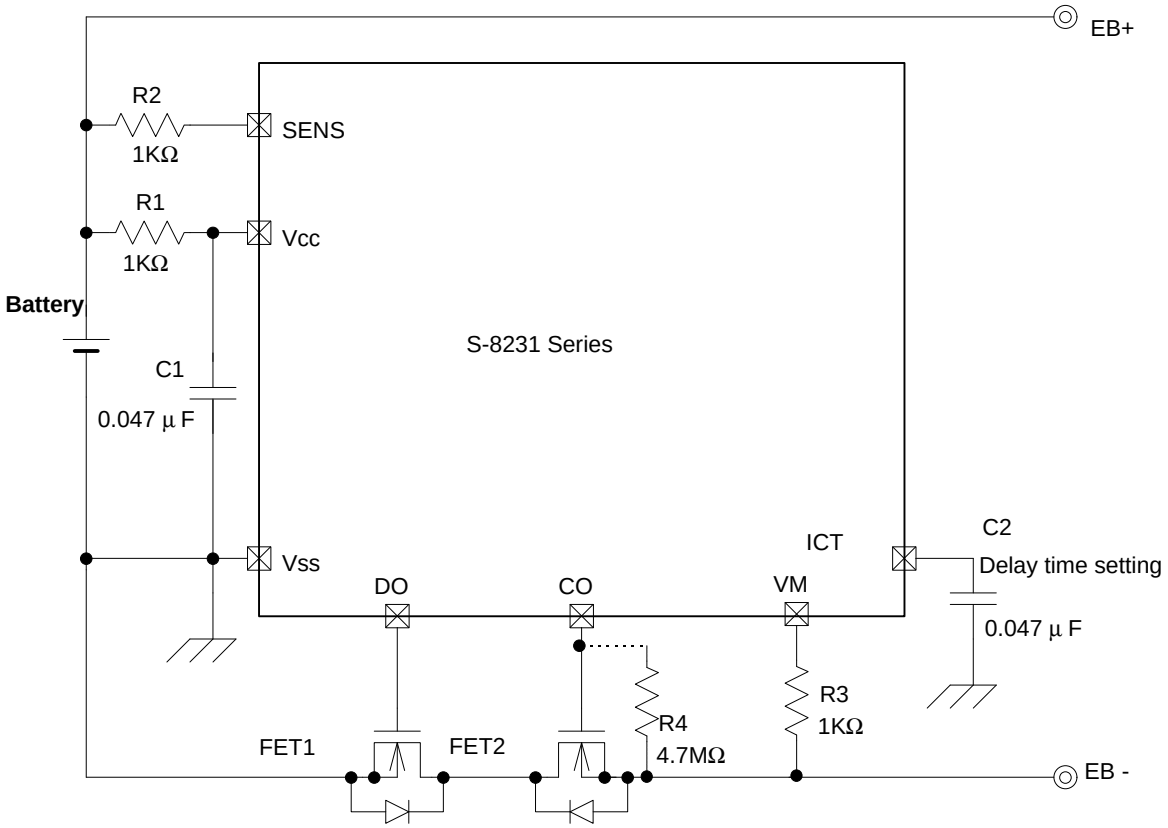


Figure 5 Circuit

Table 8 Constant

Symbol	Parts	Purpose	Recommend	min.	max.	Remarks
FET1	Nch MOSFET	Charge control	-----	-----	-----	-----
FET2	Nch MOSFET	Discharge control	-----	-----	-----	-----
R1	Chip resistor	For ESD	1kΩ	300Ω	1kΩ	***1)*** **C1×R1>2.2×1E-5** is recommended
C1	Chip capacitor	Filter	0.047μ·F	0.022μ·F	1μ·F	***1)*** **C1×R1>2.2×1E-5** is recommended
R2	Chip resistor	For ESD	1KΩ	=R1min	=R1max	***2)*** Put same value resistor as R1
C2	Chip capacitor	Setting delay time	0.047μ·F	0μF	1.0μ·F	***3)*** Note leak current of C2
R3	Chip resistor	Protection at reverse connecting of a charger	1kΩ	300Ω	5kΩ	***4)*** 300Ω or higher resistor is necessary.
R4	Chip resistor	0V battery charge prevent	(4.7MΩ)	(1.0MΩ)	(10MΩ)	***5)*** lower resistor increases current consumption.

*1) R1 and C1 prevent from oscillation under over current condition. **C1 X R1 > 2.2 X 1E-5** is required.
If C1 x R1 is lower than 2.2 X 1E-5, condition moved to power down mode when load is shorted.

*2) R2 =R1 is required. Over charge detection voltage is increased by R2. For example 10kΩ(R2) increase Over charge detection voltage by 6.3mV.

*3) The over charge detection delay time(tCU), the over discharge detection delay time(tCD), and the Over current detection delay time(tIOV) are changed with external capacitor C2. See the electrical characteristics.

*4) R3 is necessary to protect the IC when the charger is connected in reverse. Connect 300Ω or more.
But excessive R3 causes increasing of Over current detection voltage 1 (VIOV1).
Please refer the following formulation.
$\Delta VIOV1=(R3+Rvsm)/Rvsm \times VIOV1-VIOV1$
For example 50kΩ(R3) increase Over current detection voltage 1 (VIOV1=0.100V) by 19mV.

*5) 4.7MΩ (R4) prevents 0V battery from charging. Current consumption is increased by R4.
Don't connect R4 for 0v charging available type.

!Note:
The above connection diagram and constants do not guarantee proper operations. Evaluate your actual application and set constants properly.

■ Precautions

After the over current detection delay, if the battery voltage is equal to the over discharge detection voltage(VDD) or lower, the over discharge detection delay time becomes shorter than 10mS(min.). It occurs because capacitor C2 sets all delay times.

[Cause]

Capacitor C2 sets all delay times. When over current detection is released until tIOV1 , the capacitor C2 is being charged by S-8231. IF the battery voltage is lower than VDD at that time, charging to C2 goes on. So delay time is shorter than typical under the condition.

[Conclusion]

This phenomenon occurs when battery voltage is nearly equal to the over discharge voltage(VDD) after over current detected. It means that the battery capacity is small and must be charged in the near future. Even if the state changes to over discharge condition , the battery package capacity is same as typical. (Refer fig.6)

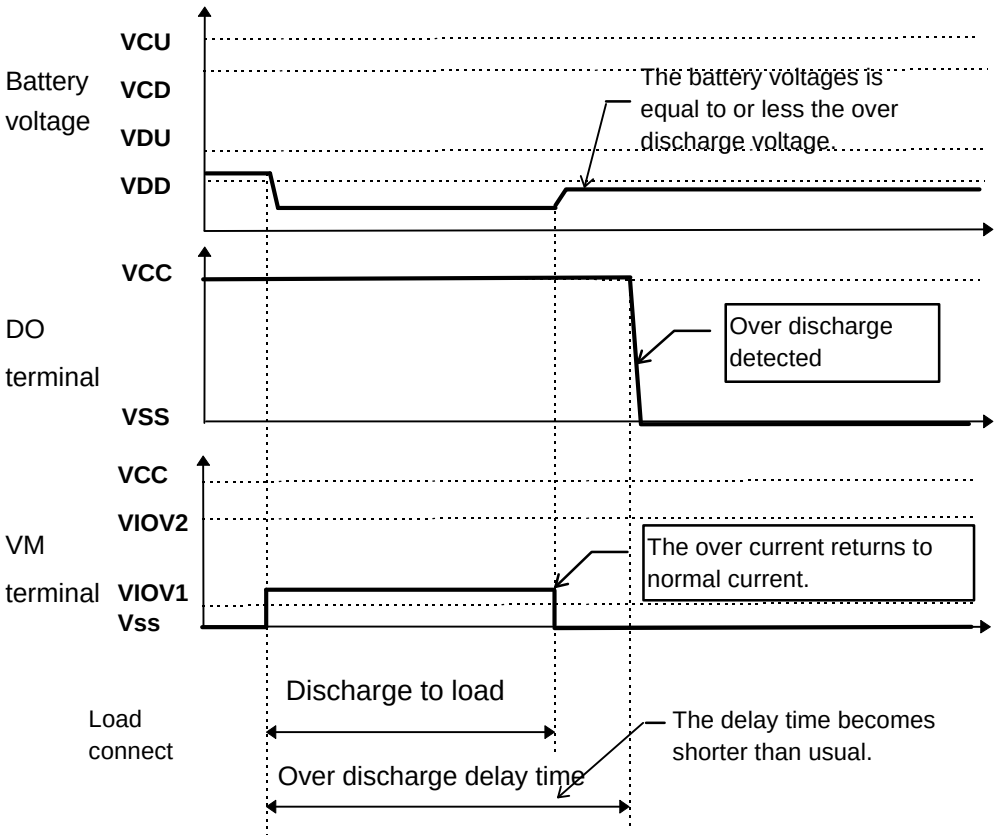
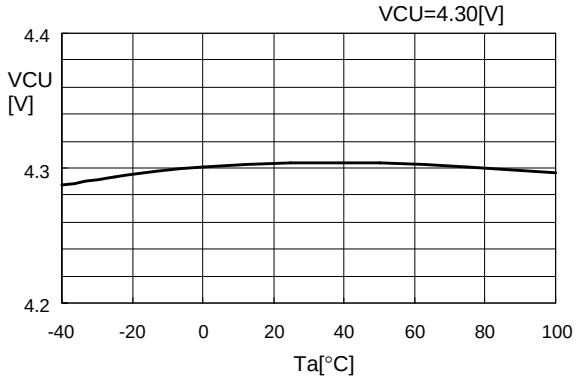


Figure 6

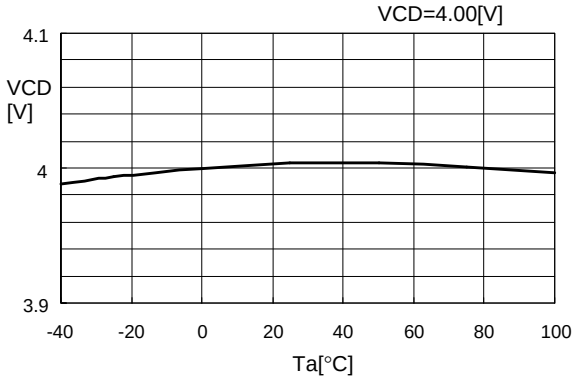
■ Characteristics (typical characteristics)

Detection voltage temperature characteristics

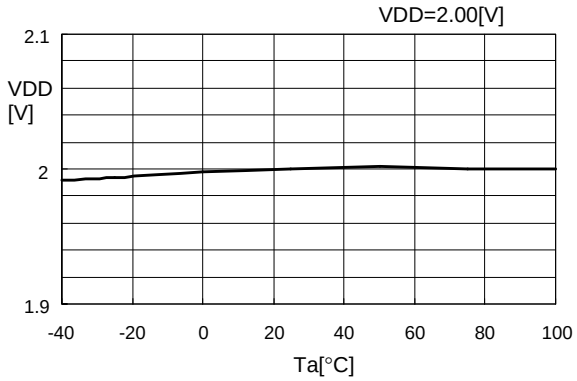
Over charge detection voltage vs. temperature



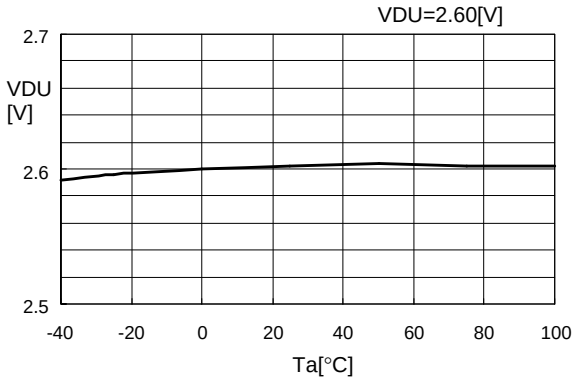
Over charge release voltage vs. temperature



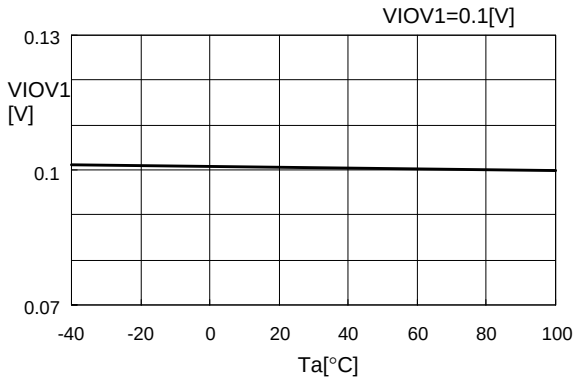
Over discharge detection voltage vs. temperature



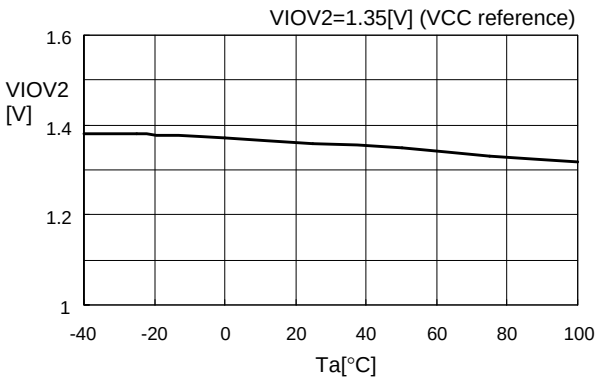
Over discharge release voltage vs. temperature



Over current 1 detection voltage vs. temperature

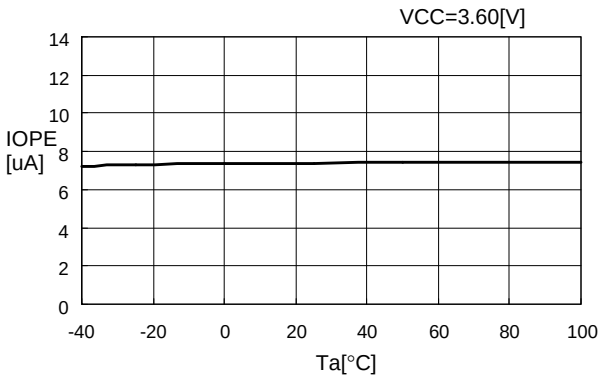


Over current 2 detection voltage vs. temperature

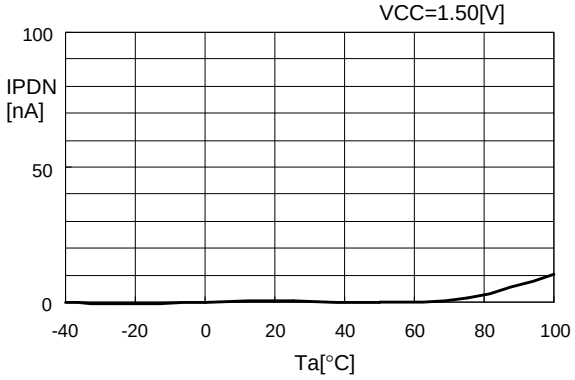


2. Current consumption temperature characteristics

Current consumption vs. temperature in normal mode

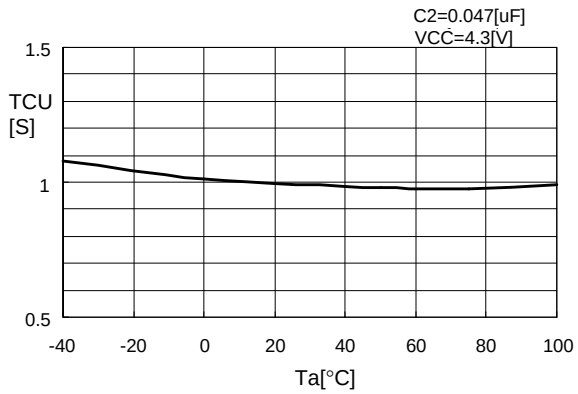


Current consumption vs. temperature in power-down mode

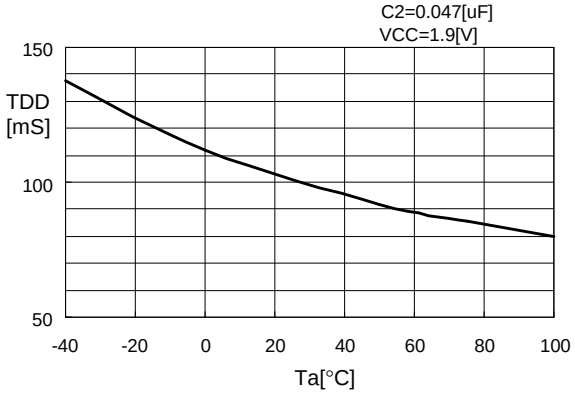


3. Delay time temperature characteristics

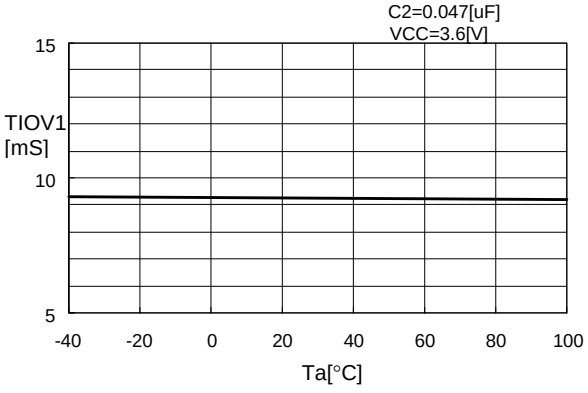
Over charge detection time vs. temperature



Over discharge detection time vs. temperature



Over current 1 detection time vs. temperature



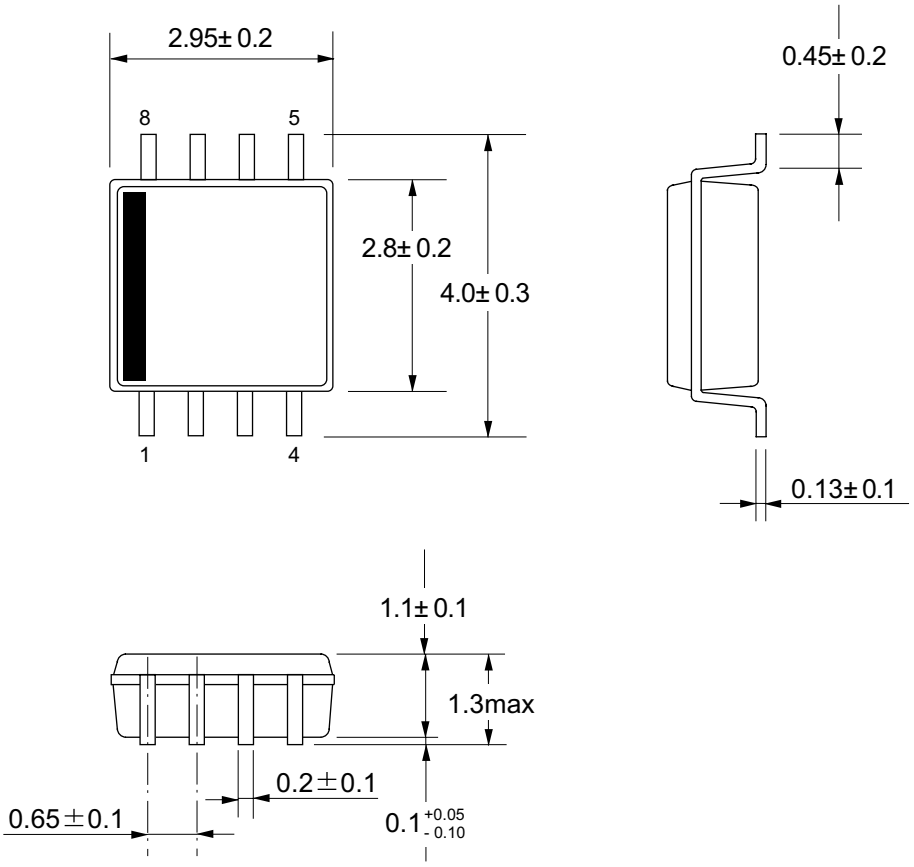
* Please design all applications of the S-8231 Series with safety in mind.

FN008-A 990531

■ 8-pin MSOP

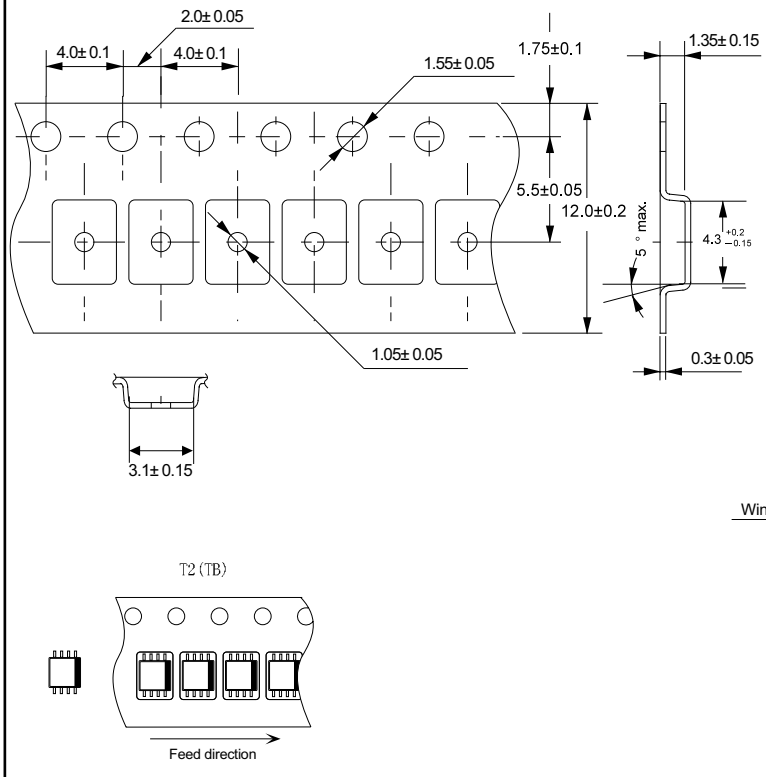
●Dimensions

Unit:mm



No.：FN008－A－P－SD－1．0

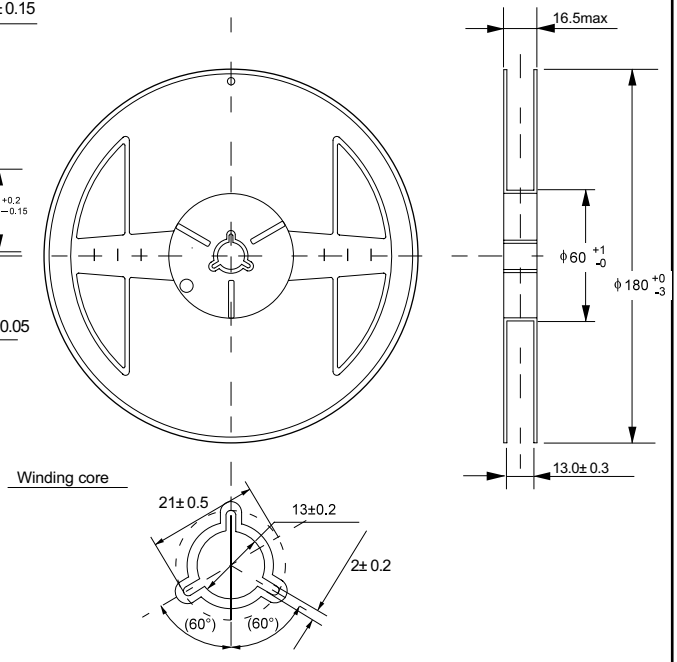
●Taping Specifications



No.：FN008－A－C－SD－1．0

●Reel Specifications

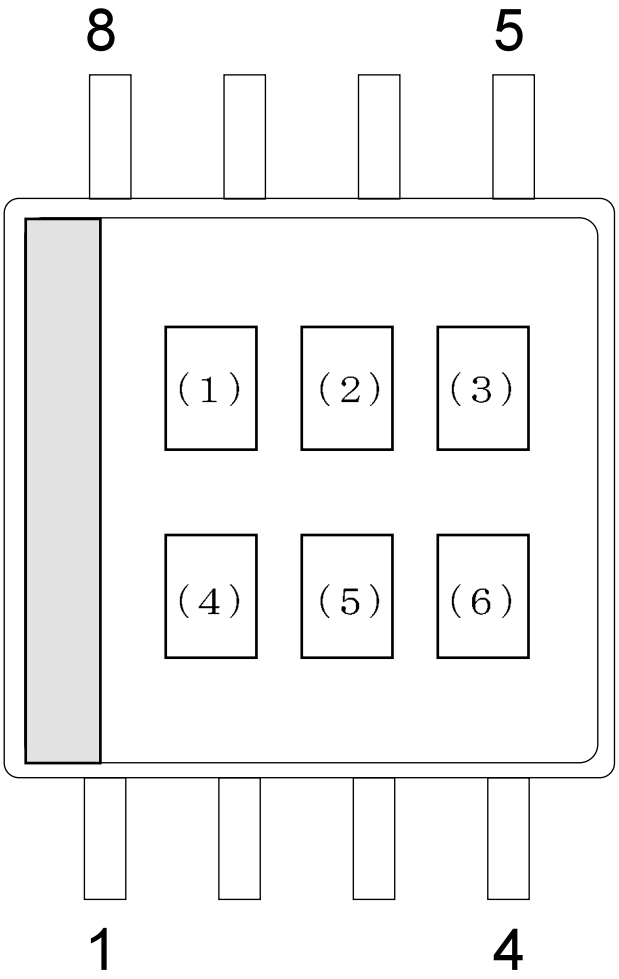
1 reel holds 3000 ICs.



No.：FN008－A－R－SD－1．0

■Markings

● 8-pin MSOP



(1) to (3) : Product name (abbreviation)

(4) : Year of assembly

(5) : Month of assembly

(6) : Week of assembly

No.：FN008－A－M－S1－1．0

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