

**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
  - ♦ Overcharge detection voltage 4.00 V  $\pm$  25 mV to 4.60 V  $\pm$  25 mV  
5 mV- step
  - ♦ Overcharge release voltage 3.70 V  $\pm$  50 mV to 4.60 V  $\pm$  50m V  
5 mV- step

(The Overcharge release voltage can be selected within the range where the difference from Overcharge detection voltage is 0 to 0.3 V)
  - ♦ Overdischarge detection voltage 1.70 V  $\pm$  80 mV to 2.50 V  $\pm$  80 mV  
50 mV- step
  - ♦ Overdischarge release voltage 1.70 V  $\pm$  100 mV to 3.50 V  $\pm$  100 mV  
50 mV - step

(The overdischarge release voltage can be selected within the range where a difference from overdischarge detection voltage is 0 to 1.0V)
  - ♦ Overcurrent detection voltage 1 0.06 V  $\pm$  20 mV to 0.30 V  $\pm$  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) Wide operating range: -40 to +85 °C
- (5) The delay time for every detection can be set via an external capacitor.  
Each delay time for Overcharge detection, Overdischarge detection, Overcurrent detection are "Proportion of hundred to ten to One." or "Proportion of fifty to ten to One."
- (6) Two overcurrent detection levels (protection for short-circuiting)
- (7) Internal auxiliary over voltage detection circuit (Fail safe for over voltage)
- (8) Internal charge circuit for 0V battery (Unavailable is option)
- (9) Low current consumption
  - ♦ Operation 7.5  $\mu$ A typ. 13.7  $\mu$ A max. (-40 to +85 °C)
  - ♦ Power-down mode 0.2 nA typ. 0.14  $\mu$ A max. (-40 to +85 °C)
- (10) MSOP package (8-pin) 4.0 mm $\times$ 2.95 mm

**■ Applications**

Lithium-ion rechargeable battery packs

## ■ Selection Guide(6, Aug, 1999)

A / N series

Table1

Model/Item	Overcharge detection voltage	Overcharge release voltage	Overdischarge detection voltage	Overdischarge release voltage	Overcurrent detection voltage1	Overcharge detection delay (C2=0.047 $\mu$ F)	0V battery charging function	Auxiliary overcharge detection vol. Magnification *3
S-8231AAFN-CAA-T2	4.25V $\pm$ 25mV	4.05 $\pm$ 50mV	2.30V $\pm$ 80mV	2.70V $\pm$ 100mV	0.100V $\pm$ 20mV	1.0 sec	Available	1.24
S-8231ABFN-CAB-T2	4.35V $\pm$ 25mV	4.10 $\pm$ 50mV	2.30V $\pm$ 80mV	3.00V $\pm$ 100mV	0.100V $\pm$ 20mV	1.0 sec	Available	1.24
S-8231ACFN-CAC-T2	4.25V $\pm$ 25mV	4.05 $\pm$ 50mV	2.30V $\pm$ 80mV	2.50V $\pm$ 100mV	0.120V $\pm$ 20mV	0.5 sec	Unavailable	1.24
S-8231ADFN-CAD-T2	4.25V $\pm$ 25mV	4.05 $\pm$ 50mV	2.30V $\pm$ 80mV	2.50V $\pm$ 100mV	0.240V $\pm$ 20mV	0.5 sec	Unavailable	1.24
S-8231AEFN-CAE-T2	4.25V $\pm$ 25mV	3.95 $\pm$ 50mV	2.30V $\pm$ 80mV	3.00V $\pm$ 100mV	0.100V $\pm$ 20mV	1.0 sec	Available	1.24
S-8231AGFN-CAG-T2	4.25V $\pm$ 25mV	4.05 $\pm$ 50mV	2.30V $\pm$ 80mV	2.70V $\pm$ 100mV	0.150V $\pm$ 20mV	1.0 sec	Available	1.24
S-8231AHFN-CAH-T2	4.35V $\pm$ 25mV	4.28 $\pm$ 50mV	2.30V $\pm$ 80mV	2.80V $\pm$ 100mV	0.100V $\pm$ 20mV	1.0 sec	Available	1.24
S-8231AIFN-CAI-T2	4.25V $\pm$ 25mV	4.05V *2	2.30V $\pm$ 80mV	2.70V $\pm$ 100mV	0.150V $\pm$ 20mV	1.0 sec	Available	1.24
S-8231AJFN-CAJ-T2	4.25V $\pm$ 25mV	4.05 $\pm$ 50mV	2.30V $\pm$ 80mV	2.50V $\pm$ 100mV	0.120V $\pm$ 20mV	0.5 sec	Available	1.24
S-8231AKFN-CAK-T2	4.25V $\pm$ 25mV	4.05 $\pm$ 50mV	2.30V $\pm$ 80mV	2.50V $\pm$ 100mV	0.240V $\pm$ 20mV	0.5 sec	Available	1.24
S-8231ALFN-CAL-T2	4.295V $\pm$ 25mV	4.20 $\pm$ 50mV	2.50V $\pm$ 80mV	3.00V $\pm$ 100mV	0.150V $\pm$ 20mV	1.0 sec	Unavailable	1.10
S-8231AMFN-CAM-T2	4.25V $\pm$ 25mV	4.05 $\pm$ 50mV	2.30V $\pm$ 80mV	2.70V $\pm$ 100mV	0.130V $\pm$ 20mV	1.0 sec	Unavailable	1.24
S-8231ANFN-CAN-T2	4.35V $\pm$ 25mV	4.10 $\pm$ 50mV	2.30V $\pm$ 80mV	3.00V $\pm$ 100mV	0.100V $\pm$ 20mV	0.5 sec	Unavailable	1.24
S-8231AOFN-CAO-T2	4.295V $\pm$ 25mV	4.295V *1	2.30V $\pm$ 80mV	3.00V $\pm$ 100mV	0.300V $\pm$ 20mV	1.0 sec	Unavailable	1.10
S-8231AQFN-CAQ-T2	4.20V $\pm$ 25mV	4.10 $\pm$ 50mV	2.30V $\pm$ 80mV	2.50V $\pm$ 100mV	0.200V $\pm$ 20mV	1.0 sec	Unavailable	1.24
S-8231ARFN-CAR-T2	4.20V $\pm$ 25mV	4.10 $\pm$ 50mV	2.30V $\pm$ 80mV	2.50V $\pm$ 100mV	0.100V $\pm$ 20mV	1.0 sec	Unavailable	1.24
S-8231ASFN-CAS-T2	4.12V $\pm$ 25mV	4.12V *1	2.30V $\pm$ 80mV	2.50V $\pm$ 100mV	0.200V $\pm$ 20mV	1.0 sec	Unavailable	1.10
S-8231ATFN-CAT-T2	4.35V $\pm$ 25mV	4.10 $\pm$ 50mV	2.30V $\pm$ 80mV	3.00V $\pm$ 100mV	0.250V $\pm$ 20mV	1.0 sec	Available	1.24
S-8231AUFN-CAU-T2	4.28V $\pm$ 25mV	4.05 $\pm$ 50mV	2.30V $\pm$ 80mV	2.70V $\pm$ 100mV	0.130V $\pm$ 20mV	1.0 sec	Available	1.24
S-8231AVFN-CAV-T2	4.28V $\pm$ 25mV	4.05 $\pm$ 50mV	2.30V $\pm$ 80mV	2.70V $\pm$ 100mV	0.130V $\pm$ 20mV	1.0 sec	Unavailable	1.24
S-8231AWFN-CAW-T2	4.28V $\pm$ 25mV	4.18 $\pm$ 50mV	2.30V $\pm$ 80mV	2.90V $\pm$ 100mV	0.080V $\pm$ 20mV	1.0 sec	Unavailable	1.24
S-8231AXFN-CAX-T2	4.295V $\pm$ 25mV	4.295V *1	2.30V $\pm$ 80mV	3.00V $\pm$ 100mV	0.300V $\pm$ 20mV	1.0 sec	Unavailable	Unavailable
S-8231NAFN-CDA-T2	4.33V $\pm$ 25mV	4.28 $\pm$ 50mV	2.30V $\pm$ 80mV	2.80V $\pm$ 100mV	0.100V $\pm$ 20mV	1.0 sec	Available	1.24
S-8231NBFN-CDB-T2	4.28V $\pm$ 25mV	3.98 $\pm$ 50mV	2.30V $\pm$ 80mV	2.35V $\pm$ 100mV	0.125V $\pm$ 20mV	1.0 sec	Unavailable	1.24
S-8231NCFN-CDC-T2	4.28V $\pm$ 25mV	4.18 $\pm$ 50mV	2.30V $\pm$ 80mV	2.90V $\pm$ 100mV	0.060V $\pm$ 20mV	1.0 sec	Unavailable	1.24
S-8231NDFN-CDD-T2	4.25V $\pm$ 25mV	4.05 $\pm$ 50mV	2.30V $\pm$ 80mV	2.70V $\pm$ 100mV	0.130V $\pm$ 20mV	1.0 sec	Available	Unavailable
S-8231NEFN-CDE-T2	4.20V $\pm$ 25mV	4.07 $\pm$ 50mV	2.50V $\pm$ 80mV	2.75V $\pm$ 100mV	0.200V $\pm$ 20mV	1.0 sec	Unavailable	1.24

B series

Model/Item	Overcharge detection voltage (0 to 50°C)	Overcharge release voltage	Overdischarge detection voltage	Overdischarge release voltage	Overcurrent detection voltage1	Overcharge detection delay (C2=0.047 μF)	OV battery charging function	Auxiliary overcharge detection vol. Magnification *3
S-8231BAFN-CCA-T2	4.18V±30mV	3.98V±50mV	2.60V±80mV	2.90V±100mV	0.110V±20mV	1.0 sec	Available	1.24
S-8231BBFN-CCB-T2	4.18V±30mV	4.08V±50mV	2.30V±80mV	2.90V±100mV	0.110V±20mV	1.0 sec	Available	1.24
S-8231BGFN-CCG-T2	4.28V±30mV	4.08V±50mV	2.60V±80mV	2.90V±100mV	0.080V±20mV	1.0 sec	Unavailabl	1.24
S-8231BIFN-CCI-T2	4.28V±30mV	4.08V±50mV	2.60V±80mV	2.90V±100mV	0.080V±20mV	1.0 sec	Available	1.24
S-8231BKFN-CCK-T2	4.22V±30mV	4.22V *1	2.3 0V±80mV	2.30V *4	0.200V±20mV	0.5 sec	Available	Unavailable

\*1) Without overcharge detection / release hysteresis.

\*2) Discharging will be unable when overcharge detected. (Overcharge lock type)

\*3) Auxiliary overcharge detection voltage comes in three types, i.e., overcharge detection voltage (VCU) x 1.24 times, overcharge detection voltage (VCU) x 1.10 times, and no final overcharge detection function.

\*4) No hysteresis is set between overdischarge detection and release.

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

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

Table 2

Overdischarge detection voltage (VDD)	Overcharge detection voltage (VCU)	Voltage difference between Overcharge detection voltage and Overcharge 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

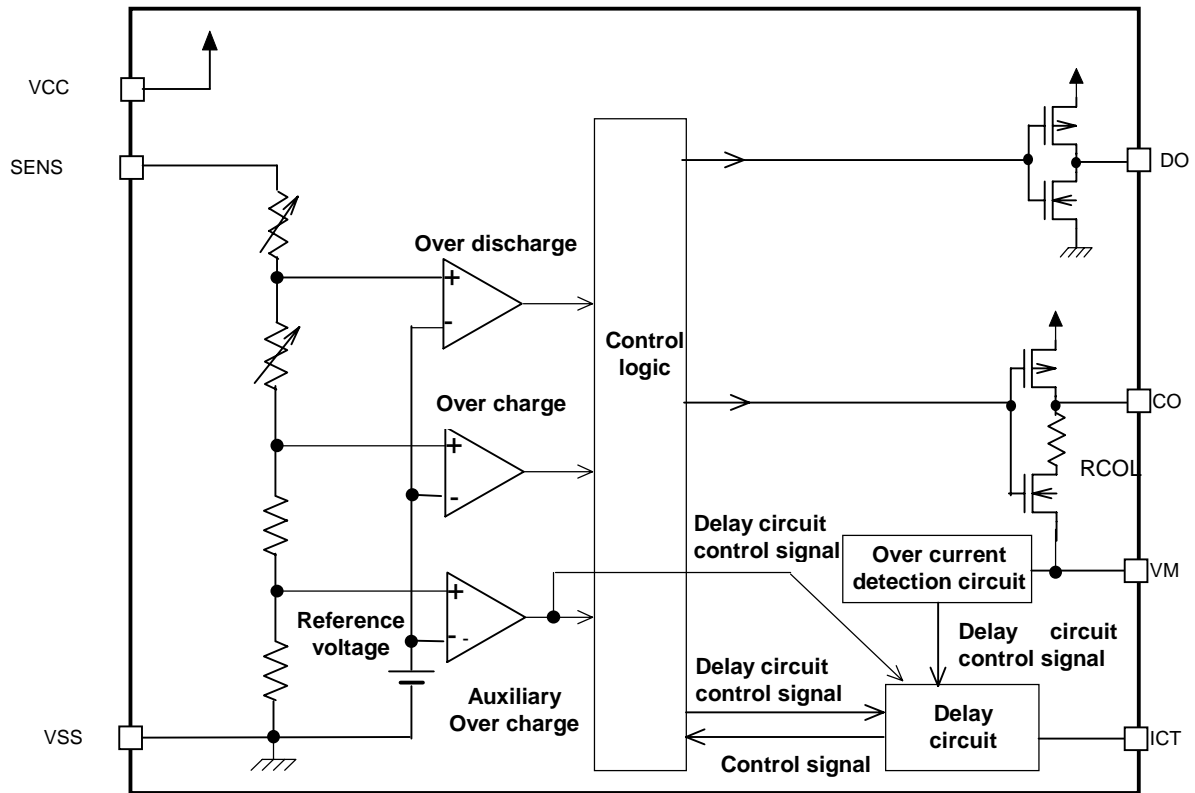


Figure 1

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

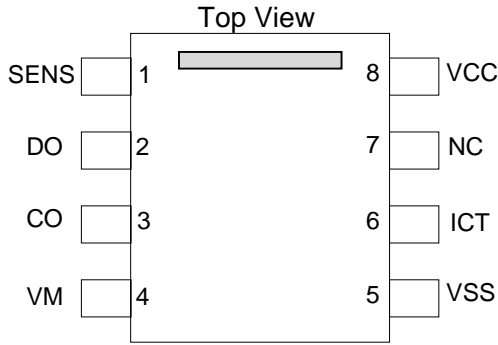


Figure 2  
MSOP - 8

■ Pin Description

Table.3

No.	Name	Description
1	SENS	Detects voltage between Vss to SENS(Overcharge/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(Overcurrent 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
<b>Detection voltage</b>								
Overcharge detection voltage (S-8231A /N series)	VCU	1	1	4.00 to 4.60 Adjustment	VCU -0.025	VCU	VCU +0.025	V
Auxiliary overcharge 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
Overcharge release voltage	VCD	1	1	3.70 to 4.60 Adjustment	VCD-0.05	VCD	VCD+0.05	V
Overdischarge detection voltage	VDD	1	1	1.70 to 2.50 Adjustment	VDD-0.08	VDD	VDD+0.08	V
Overdischarge release voltage	VDU	1	1	1.70 to 3.50 Adjustment	VDU-0.10	VDU	VDU+0.10	V
Overcurrent detection voltage1	VIOV1	2	1	0.06 to 0.30V Adjustment	VIOV1 -0.020	VIOV1	VIOV1 +0.020	V
Overcurrent 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
<b>Delay time(C2=0.047μF)</b>								
Overcharge detection delay time 1.0 sec / 0.5 sec (*4)	tCU	7	5	1.0 S Type	0.72	1.0	1.32	S
	tCU	7	5	0.5 S Type	0.36	0.5	0.66	S
Overdischarge detection delay time	tDD	7	5	0.1 S	71	100	139	mS
Overcurrent detection delay time 1	tIOV1	8	5	0.01 S	6.8	10	13.8	mS
<b>Input voltage</b>								
Input voltage between VCC and VSS	VDS	—	—	absolute maximum rating	-0.3	—	18	V
<b>Operating voltage</b>								
Operating voltage between VCC and VSS (*5)	VDSOP	—	—		1.5	—	16	V
<b>Current consumption</b>								
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
<b>Output voltage</b>								
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
<b>CO pin internal resistance</b>								
Resistance between Vss and CO	RCOL	6	4	VSS-CO=4.7V	0.29	0.60	1.43	MΩ
<b>VM Internal resistance</b>								
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
<b>0V battery charging function</b>								
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 overcharge detection voltage, overcharge release voltage, overdischarge detection voltage, and overdischarge release voltage.

(\*2) Voltage temperature factor 2 indicates overcurrent detection voltage.

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

(\*4) The overcharge 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
<b>Detection voltage</b>								
Overcharge detection voltage	VCU	1	1	4.00 to 4.60 Adjustment	VCU -0.045	VCU	VCU +0.035	V
Auxiliary overcharge 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
Overcharge release voltage	VCD	1	1	3.70 to 4.60 Adjustment	VCD-0.070	VCD	VCD+0.060	V
Overdischarge detection voltage	VDD	1	1	1.70 to 2.50 Adjustment	VDD-0.100	VDD	VDD+0.090	V
Overdischarge release voltage	VDU	1	1	1.70 to 3.50 Adjustment	VDU-0.120	VDU	VDU+0.110	V
Overcurrent detection voltage1	VIOV1	2	1	0.06 to 0.30V Adjustment	VIOV1 -0.027	VIOV1	VIOV1 +0.027	V
Overcurrent 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
<b>Delay time(C2=0.047μF)</b>								
Overcharge 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
Overdischarge detection delay time	tDD	7	5	0.1 S	58	100	190	mS
Overcurrent detection delay time 1	tIOV1	8	5	0.01 S	6.7	10	14.0	mS
<b>Input voltage</b>								
Input voltage between VCC and VSS	VDS	—	—	absolute maximum rating	-0.3	—	18	V
<b>Operating voltage</b>								
Operating voltage between VCC and VSS (*5)	VDSOP	—	—		1.5	—	16	V
<b>Current consumption</b>								
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
<b>Output voltage</b>								
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
<b>CO pin internal resistance</b>								
Resistance between Vss and CO	RCOL	6	4	VSS-CO=4.7V	0.24	0.60	1.95	MΩ
<b>VM Internal resistance</b>								
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
<b>0V battery charging function</b>								
0V charge starting voltage	VOCHA	9	6	0V batt. cha. Available	0.43	0.73	1.41	V
0V charge inhibiting voltage	VOINH	10	6	0V batt. cha. Unavailable	0.31	0.61	1.20	V

(\*1) Voltage temperature factor 1 indicates overcharge detection voltage, overcharge release voltage, overdischarge detection voltage, and overdischarge release voltage.

(\*2) Voltage temperature factor 2 indicates overcurrent detection voltage.

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

(\*4) The overcharge 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
<b>Detection voltage</b>								
Overcharge detection voltage	VCU	1	1	4.00 to 4.60 Adjustment	VCU1 -0.060	VCU	VCU1 +0.035	V
Auxiliary overcharge 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
Overcharge release voltage	VCD	1	1	3.70 to 4.60 Adjustment	VCD-0.085	VCD	VCD+0.060	V
Overdischarge detection voltage	VDD	1	1	1.70 to 2.50 Adjustment	VDD-0.115	VDD	VDD+0.090	V
Overdischarge release voltage	VDU	1	1	1.70 to 3.50 Adjustment	VDU-0.135	VDU	VDU+0.110	V
Overcurrent detection voltage1	VIOV1	2	1	0.06 to 0.30V Adjustment	VIOV1 -0.030	VIOV1	VIOV1 +0.030	V
Overcurrent 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
<b>Delay time(C2=0.047μF)</b>								
Overcharge 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
Overdischarge detection delay time	tDD	7	5	0.1 S	54	100	212	mS
Overcurrent detection delay time 1	tIOV1	8	5	0.01 S	6.7	10	14.1	mS
<b>Input voltage</b>								
Input voltage between VCC and VSS	VDS	—	—	absolute maximum rating	-0.3	—	18	V
<b>Operating voltage</b>								
Operating voltage between VCC and VSS (*5)	VDSOP	—	—		1.5	—	16	V
<b>Current consumption</b>								
Current consumption (during normal operation)	IOPE	3	2	VCC=3.6V	2.0	7.5	13.7	μA
Current consumption at power down	IPDN	3	2	VCC=1.5V	0	0.0002	0.14	μA
<b>Output voltage</b>								
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
<b>CO pin internal resistance</b>								
Resistance between Vss and CO	RCOL	6	4	VSS-CO=4.7V	0.22	0.60	2.18	MΩ
<b>VM Internal resistance</b>								
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
<b>0V battery charging function</b>								
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 overcharge detection voltage, overcharge release voltage, overdischarge detection voltage, and overdischarge release voltage.

(\*2) Voltage temperature factor 2 indicates overcurrent detection voltage.

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

(\*4) The overcharge 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 overcharge detection voltage 1 (VCU). Decrease V1 gradually.  
The V1 voltage when CO = 'H' is overcharge release voltage 1 (VCD). Further decrease V1.  
The V1 voltage when DO = 'L' is overdischarge voltage 1 (VDD). Increase V1 gradually.  
The V1 voltage when DO = 'H' is overdischarge 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 overcharge 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 overcurrent 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 overcurrent 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 overdischarge 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 overdischarge 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 overcurrent 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  $\mu$ A is DO 'H' voltage (VDO (H)).  
Set S1=OFF, S2=ON, V1=3.6V, and V2=0.5 V under overcurrent condition. Increase V4 from 0 V gradually. The V4 voltage when I2 = 10  $\mu$ A 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  $\mu$ A 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  $V1=3.6V$  ,  $V2=0V$  and  $V1 = (VCU - 0.2V)$  under normal condition. Increase  $V1$  from  $(VCU - 0.2V)$  to  $(VCU + 0.2V)$  immediately (within  $10\ \mu s$ ). The time after  $V1$  becomes  $(VCU + 0.2V)$  until  $CO$  goes 'L' is the overcharge detection delay time ( $t_{CU}$ ).

Set  $V1=3.6V$  ,  $V2=0V$  and  $V1 = (VDD + 0.2V)$  under normal condition. Decrease  $V1$  from  $(VDD + 0.2V)$  to  $(VDD - 0.2V)$  immediately (within  $10\ \mu s$ ). The time after  $V1$  becomes  $(VDD - 0.2V)$  until  $DO$  goes 'L' is the overdischarge detection delay time 1 ( $t_{DD}$ ).

**(8) Measurement 8 Measurement circuit 5**

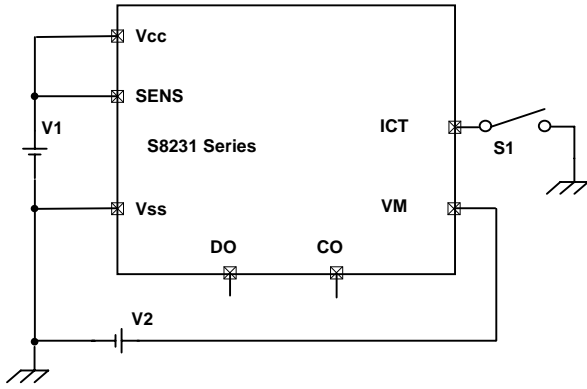
Set  $V1=3.6V$  under normal condition. Increase  $V2$  from  $0V$  to  $0.5V$  immediately (within  $10\ \mu s$ ). The time after  $V2$  becomes  $0.5V$  until  $DO$  goes 'L' is the overcurrent detection delay time 1 ( $t_{IOV1}$ ).

**(9) Measurement 9 Measurement circuit 6**

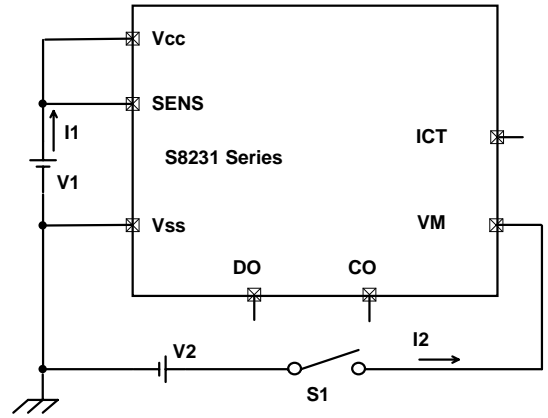
Set  $V1=0V$  , and  $V2=2V$  , and decrease  $V2$  gradually. The  $V2$  voltage when  $CO = 'L'$  ( $VCC - 0.3V$  or lower) is the 0V charge starting voltage ( $V_{OCHA}$ ).

**(10) Measurement 10 Measurement circuit 6**

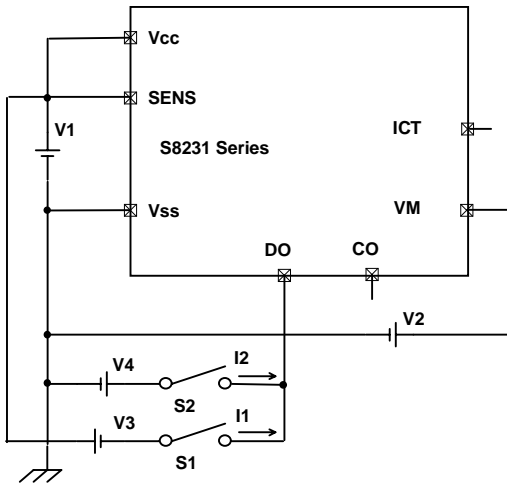
Set  $V1=0V$  , and  $V2=16V$  , and increase  $V1$  gradually. The  $V1$  voltage when  $CO = 'H'$  ( $V_M + 0.3V$  or higher) is the 0V charge inhibiting voltage ( $V_{OINH}$ ).



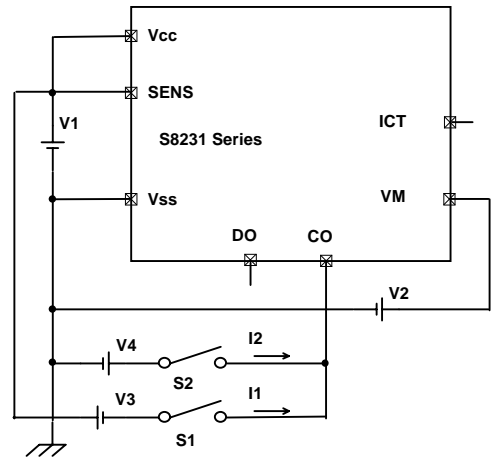
Measurement circuit 1



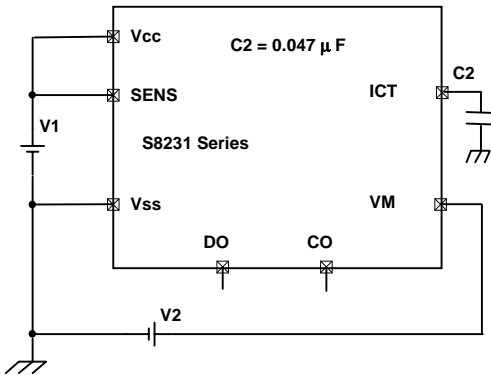
Measurement circuit 2



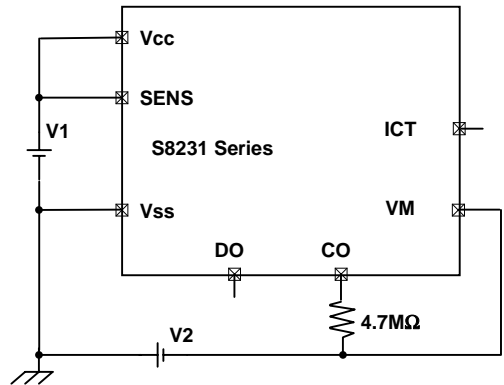
Measurement circuit 3



Measurement circuit 4



Measurement circuit 5



Measurement circuit 6

## ■ Description of Operation

### 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 overdischarge detection voltage (VDD) to the overcharge 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 overcurrent 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.

### Overcurrent 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 overcurrent detection voltage) during discharging under normal condition and it continues for the overcurrent detection delay time (tIOV1) or longer, the discharging FET turns off to stop discharging. This condition is called an overcurrent 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 overcurrent 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 overcurrent detection voltage 1 (VIOV1) and returns to the normal condition.

### Overcharge condition

The overcharge condition is **detected in two cases:**

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

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

$$VCUaux [V] = 1.24 \times VCU [V]$$

[ For without Overcharge detection / release hysteresis ]

$$VCUaux [V] = 1.10 \times VCU [V]$$

The overcharge condition is **released in two cases:**

- ① The battery voltage which exceeded the overcharge detection voltage (VCU) falls below the overcharge release voltage (VCD), the charging FET turns on and the normal condition returns.
- ② If the battery voltage which exceeded the overcharge detection voltage (VCU) is equal or higher than the overcharge 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 (overcurrent detection voltage 1 or higher), releases the overcharge condition and returns to the normal condition.

Note: Function of [ Overcharge lock type (S-8231AIFN) ]

If the battery voltages becomes higher than the overcharge 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 overcharge detected. This mechanism can realize more safety Li-ion battery pack.

### Overdischarge condition

If the battery voltages falls below the overdischarge detection voltage (VDD) during discharging under normal condition and it continues for the overdischarge detection delay time (tDD) or longer, the discharging FET turns off and discharging stops. This condition is called the overdischarge 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 overdischarge 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 (overcurrent detection voltage 2). When the battery voltages becomes equal to or higher than the overdischarge release voltage (VDU) in this condition, the overdischarge condition changes to the normal condition.

### Delay circuits

The overcharge detection delay time (tCU), overdischarge detection delay time (tDD), and overcurrent detection delay time 1 (tIOV1) are changed with external capacitors (C2). The delay time for overcharge and overdischarge and overcurrent 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]

**Overcharge delay time : Overdischarge delay time: Overcurrent delay time = 100 : 10 : 1**

[For tCU=0.5 S type]

**Overcharge delay time : Overdischarge delay time: Overcurrent delay time = 50 : 10 : 1**

The delay times are calculated by the following equations: ( $T_a = -40 \sim +85^\circ\text{C}$ )

<u>Overcharge detection delay time</u>	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]
<u>Overdischarge detection delay time</u>	tDD[S] = Delay factor ( 1.149,	2.128,	4.511 ) X C2 [uF]
<u>Overcurrent detection delay time</u>	tIOV1[S] = Delay factor ( 0.143,	0.213,	0.300 ) X C2 [uF]

! Note: The delay time for overcurrent 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 (VOCHA) 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 overdischarge 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 overdischarge 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. Overcharge and overdischarge detection

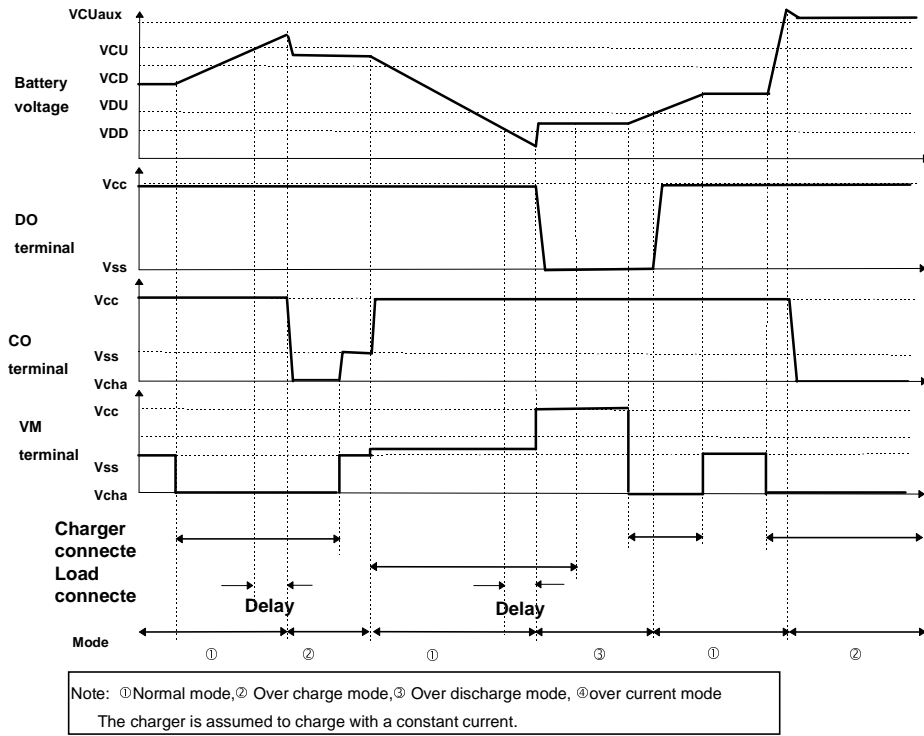


Figure 3

2. Overcurrent detection

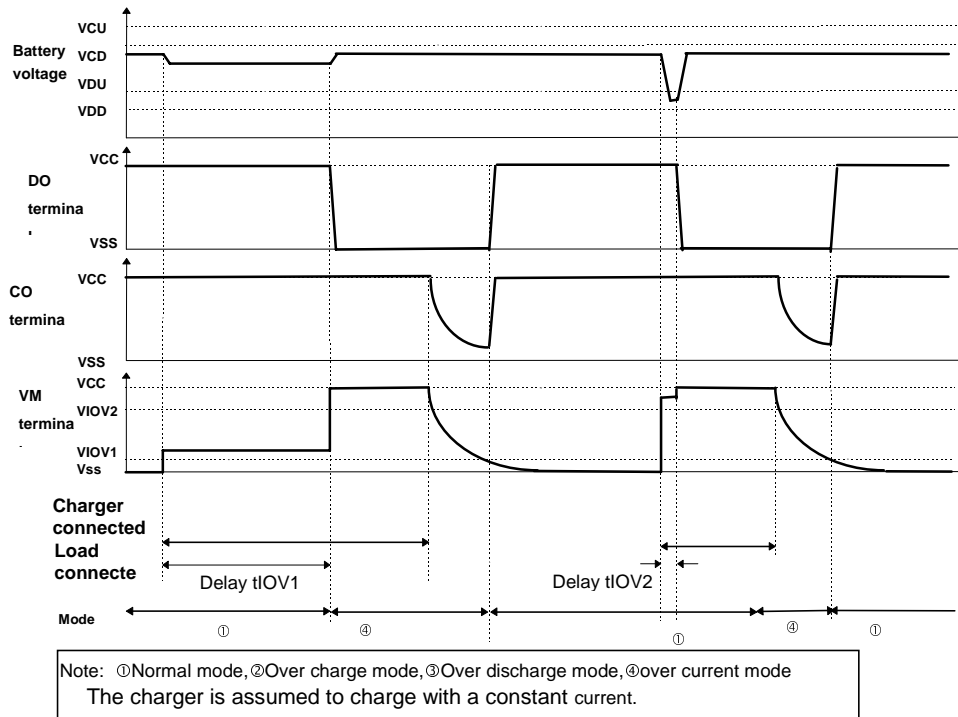


Figure 4

■ Battery Protection IC Connection Example

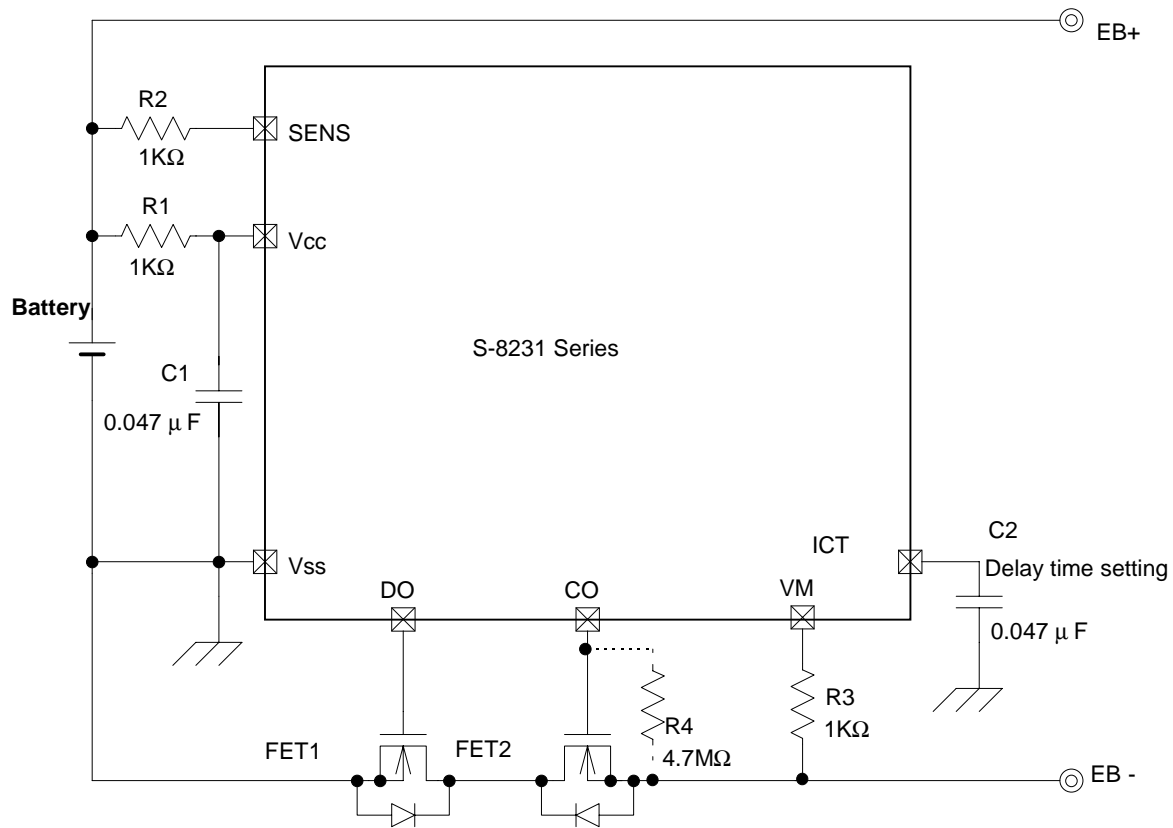


Figure 5 Circuit

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) $C1 \times R1 > 2.2 \times 10^{-5}$ is recommended
C1	Chip capacitor	Filter	0.047μ-F	0.022μ-F	1μ-F	*1) $C1 \times R1 > 2.2 \times 10^{-5}$ 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 overcurrent condition.  $C1 \times R1 > 2.2 \times 1E-5$  is required.  
If  $C1 \times R1$  is lower than  $2.2 \times 1E-5$ , condition moved to power down mode when load is shorted.
- \*2)  $R2 = R1$  is required. Overcharge detection voltage is increased by R2. For example  $10k\Omega(R2)$  increase Overcharge detection voltage by 6.3mV.
- \*3) The overcharge detection delay time( $t_{CU}$ ), the overdischarge detection delay time( $t_{CD}$ ), and the Over current detection delay time( $t_{IOV}$ ) 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  $300\Omega$  or more.  
But excessive R3 causes increasing of Overcurrent detection voltage 1 (VIOV1).  
Please refer the following formulation.  
$$\Delta V_{IOV1} = (R3 + R_{vsm}) / R_{vsm} \times V_{IOV1} - V_{IOV1}$$
  
For example  $50k\Omega(R3)$  increase Overcurrent detection voltage 1 (VIOV1= $0.100V$ ) by 19mV.
- \*5)  $4.7M\Omega$  (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 overcurrent detection delay, if the battery voltage is equal to the overdischarge detection voltage(VDD) or lower, the overdischarge 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 overcurrent 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 overdischarge voltage(VDD) after overcurrent detected. It means that the battery capacity is small and must be charged in the near future. Even if the state changes to overdischarge condition, the battery package capacity is same as typical. (Refer fig.6)

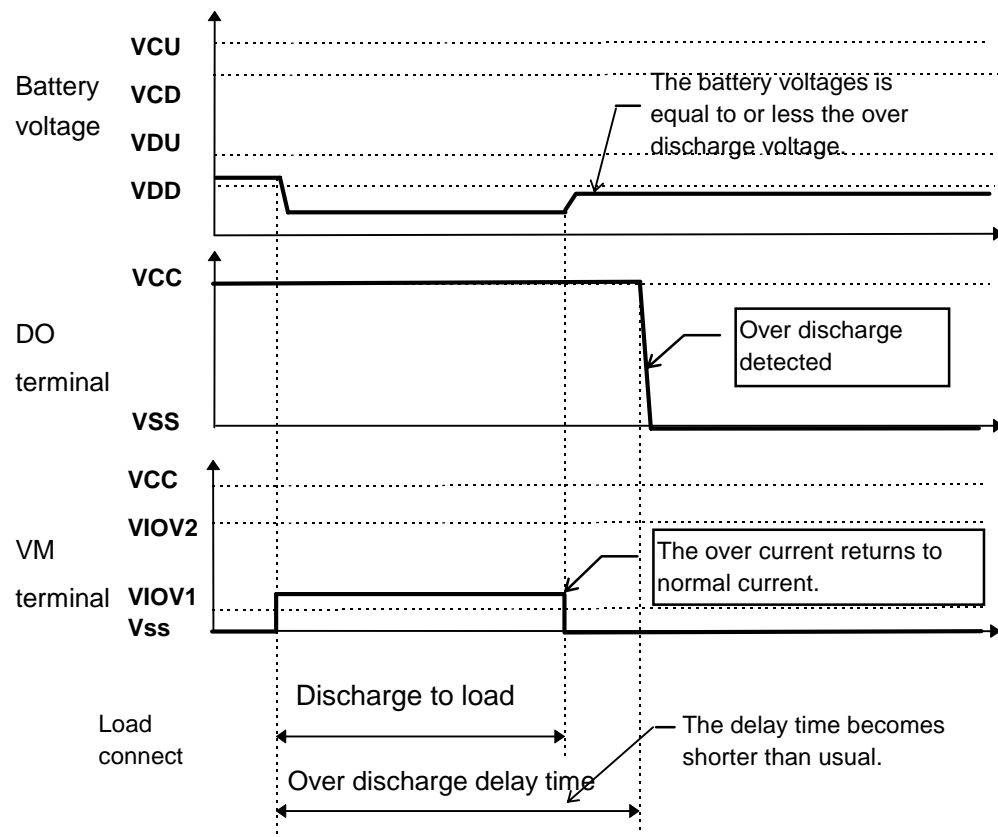
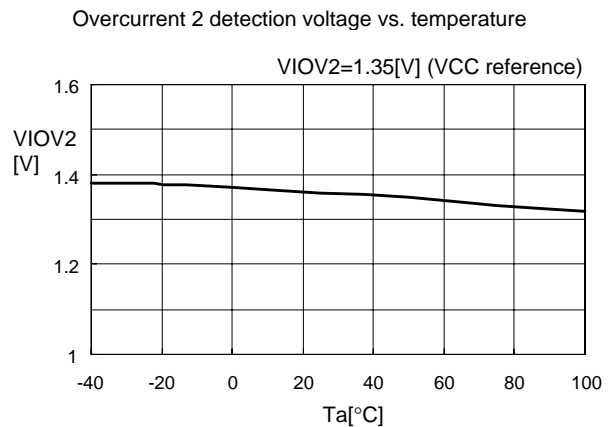
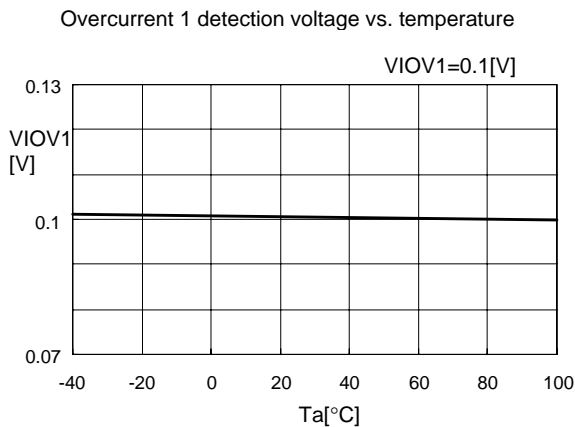
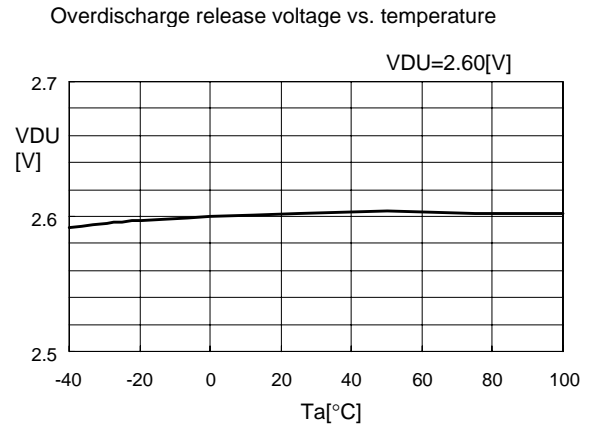
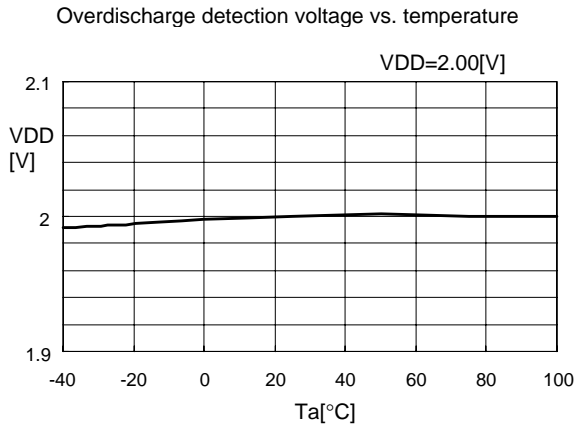
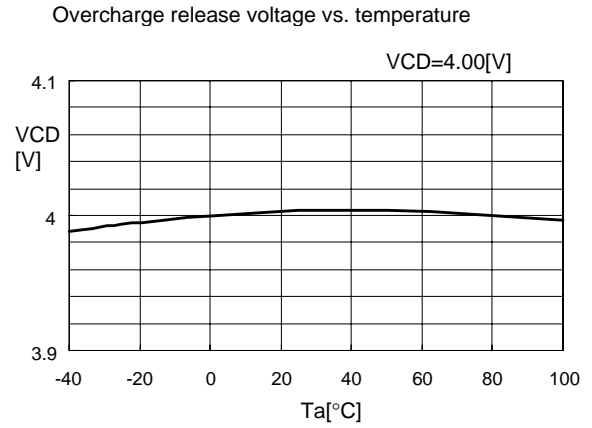
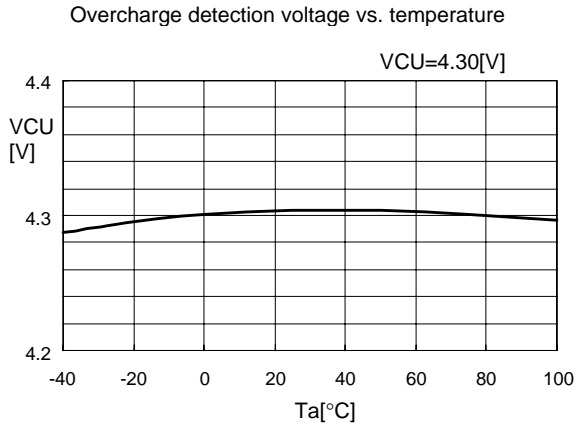


Figure 6

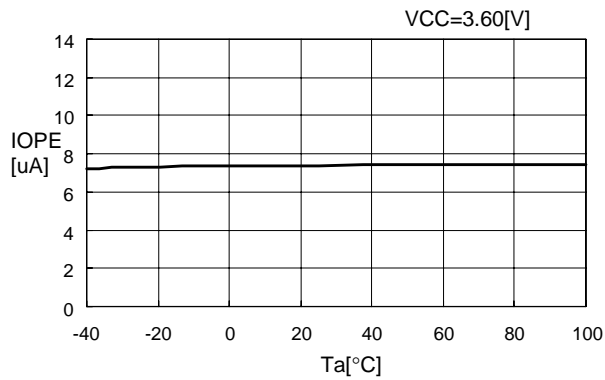
■ Characteristics (typical characteristics)

Detection voltage temperature characteristics

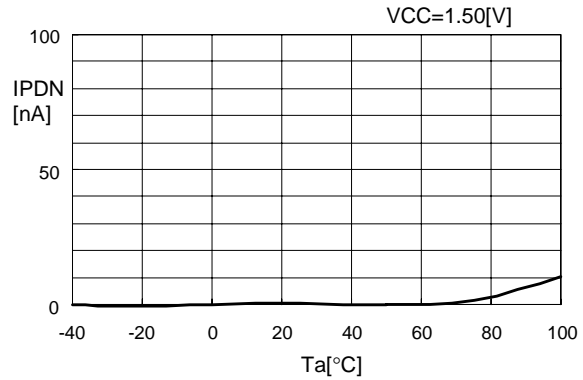


2. Current consumption temperature characteristics

Current consumption vs. temperature in normal mode

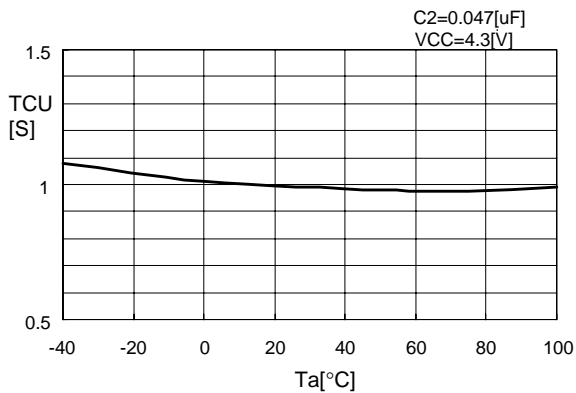


Current consumption vs. temperature in power-down mode

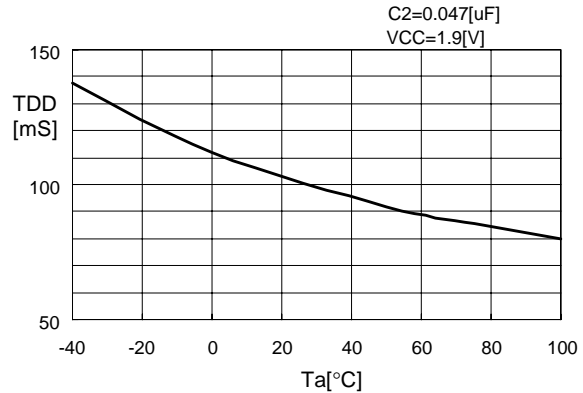


3. Delay time temperature characteristics

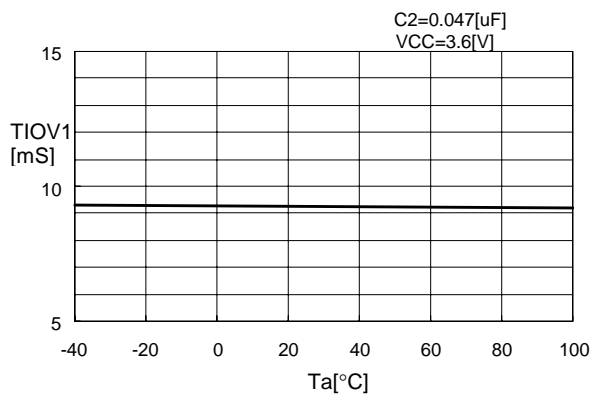
Overcharge detection time vs. temperature



Overdischarge detection time vs. temperature



Overcurrent 1 detection time vs. temperature



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

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