PRODUCT SPECIFICATIONS

R5408N185KH-TR-F

contents

[1] Outline

The R5408N185KH is high voltage tolerance CMOS-based protection IC for over-charge/discharge and over-current of rechargeable one-cell Lithium-ion (Li+)/Lithium polymer battery. The R5408N185KH can detect over-charge/discharge of Li+ one-cell and excess load current, further include a short circuit protector for preventing large external short circuit current and the excess charge-current. The R5408N185KH consists of four voltage detectors, a reference unit, a delay circuit, a short circuit detector, an oscillator, a counter, and a logic circuit.

When the R5408N185KH detects over-charge or over-charge current, the output of COUT pin switches to "L" level, that is, the charger's negative pin level after the internal fixed delay time. When the R5408N185KH detects over-discharge or excess discharge current, the output of DOUT pin switches to "L" level after the internal fixed delay time.

After detecting over-charge voltage or over-charge current, if the battery voltage is lower than over-charge detector threshold voltage, the R5408N185KH can be reset and the output of COUT becomes "H" when a charger is disconnected from the battery pack.

However, depending on the characteristics of external components such as MOSFETs, release conditions may be not enough just removing a charger from the battery pack. In that case, a kind of load must be set to release the over-charge detect.

If a charger is continuously connected to the battery pack, even if the cell voltage becomes lower than over-charge detector threshold, if the voltage difference between the charger and the battery is larger than the absolute value of over-charge current detector threshold, over-charge would not be released.

After detecting over-discharge voltage, connect a charger to the battery pack, and when the battery supply voltage becomes higher than over-discharge detector threshold, or the battery voltage becomes released voltage from over-discharge, the R5408N185KH is released and the voltage of DOUT pin becomes "H". If the battery discharges into 0V level, recharge current is accepted. Once after detecting excess discharge-current or short circuit, the R5408N185KH is released and DOUT level becomes "H" with detaching a battery pack from a load system. After detecting over-discharge, supply current is kept extremely low by halting internal circuits' operation.

When the output of COUT is "H", by setting the V- pin at equal or lower than the delay shortening mode voltage (Typ. -2.0V), the output delay can be shortened. Especially, the delay time of over charge detector can be reduced into approximately 1/60. Thus, testing time of protector circuit board can be reduced. Output type of COUT and DOUT is CMOS.

[2] Block Diagram
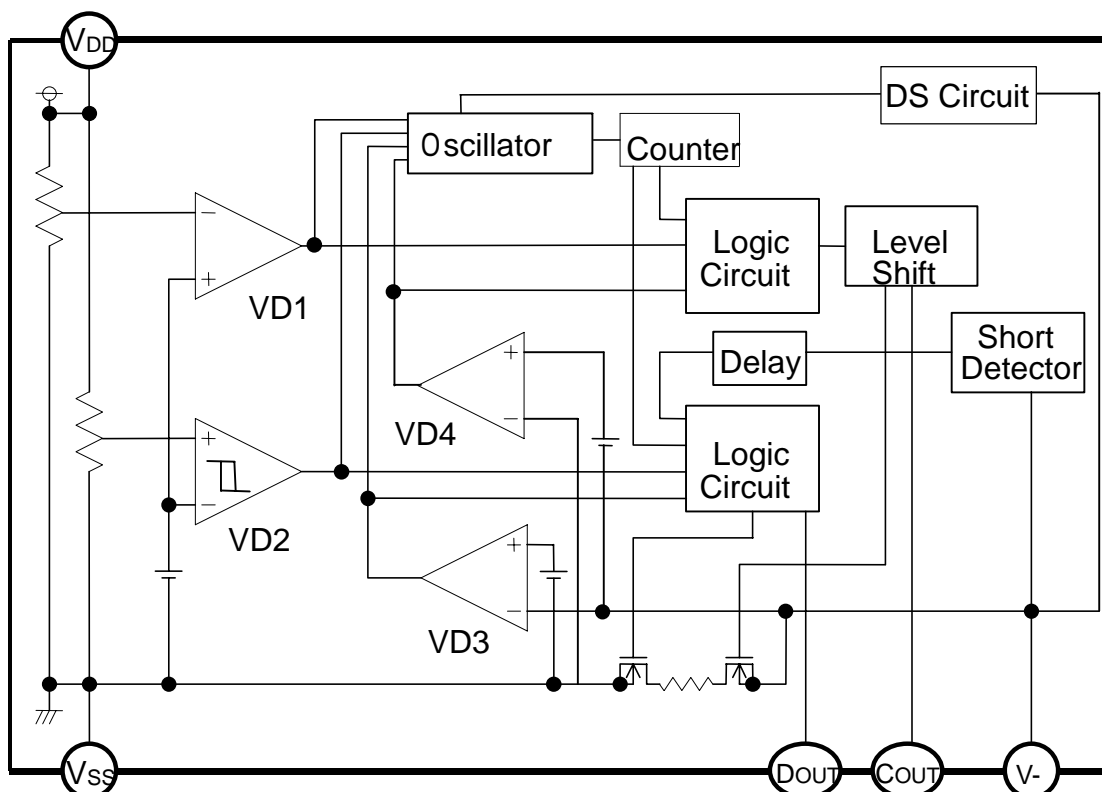
[3] Pin Description

Pin No.	Symbol	Pin description
1	DOUT	Output of Over-discharge detection, CMOS output
2	V-	Charger negative Input
3	COUT	Output of Over-charge detection, CMOS output
4	NC	No Connection
5	VDD	Power Supply Pin. Substrate level of the IC.
6	Vss	Ground Pin. (Ground level of the IC)

[4] Absolute Maximum Rating

Topt=25°C, Vss=0V

Item	Symbol	Ratings	Unit
Supply Voltage	VDD	-0.3 to 12	V
Input Voltage V- pin Voltage	V-	VDD-30 to VDD+0.3	V
Output Voltage COUT pin Voltage DOUT pin Voltage	VCOUT VDOUT	VDD-30 to VDD+0.3 Vss-0.3 to VDD+0.3	V V
Power Dissipation	PD	150	mW
Operating Temperature	Topr	-40 to 85	°C
Storage Temperature	Tstg	-55 to 125	°C

*Note: Exposure to the condition exceeded Absolute Maximum Ratings may cause the permanent damages and affects the reliability and safety of both device and systems using the device. The functional operations cannot be guaranteed beyond specified values in the Recommended   conditions.

## [5] Electrical Characteristics

•R5408N185KH

Topt=25°C

| Item	Symbol	Conditions	Min.	Typ.	Max.	Unit	Note1
Operating Input Voltage	$V_{DD}1$	V_{DD} - Vss	1.5		5.0	V	A
Minimum Operating Voltage for 0V Charging	Vst	Voltage Defined as V_{DD}-V-, VDD-Vss=0V			1.8	V	A
Over-charge Threshold Voltage	$V_{DET}1$	R1=330Ω	3.625	3.650	3.675	V	B
		R1=330Ω, Topt=-5°C to 55°C *Note2	3.620	3.650	3.680	V	B
Output Delay of Over-charge	$tV_{DET}1$	VDD=3.6V→4.4V	0.7	1.0	1.3	s	B
Release Delay for VD1	$tV_{REL}1$	VDD=4.0V,V-=0V→1V	11	16	21	ms	C
Over-discharge Threshold	$V_{DET}2$	Detect falling edge of supply voltage	2.438	2.500	2.562	V	D
Released Voltage from Over-discharge	$V_{REL}2$	Detect rising edge of supply voltage	2.925	3.000	3.075	V	D
Output Delay of Over-discharge	$tV_{DET}2$	VDD=3.6V→2.2V	14	20	26	ms	D
Release Delay for VD2	$tV_{REL}2$	VDD=2.2V→3.1V	0.7	1.2	1.7	ms	D
Excess discharge-current threshold	$V_{DET}3$	Detect rising edge of 'V-' pin voltage	0.185	0.200	0.215	V	E
Output delay of excess discharge-current	$tV_{DET}3$	VDD=3.0V, V-=0V to 0.5V	8	12	16	ms	F
Output delay of release from excess discharge-current	$tV_{REL}3$	VDD=3.0V, V-=3V to 0V	0.7	1.2	1.7	ms	F
Short Protection Voltage	Vshort	VDD=3.0V	0.55	0.80	1.00	V	F
Delay Time for Short Protection	tshort	VDD=3.0V, V-=0V to 3V	230	300	500	µs	F
Reset Resistance for Excess Current Protection	Rshort	VDD=3.6V,V- =1.0V	25	50	75	kΩ	F
Excess charge-current threshold	$V_{DET}4$	Detect falling edge of 'V-' pin voltage	-0.230	-0.200	-0.170	V	F
Output delay of excess charge-current	$tV_{DET}4$	VDD=3.0V, V-=0V to -1V	5	8	11	ms	G
Output delay of release from excess charge-current	$tV_{REL}4$	VDD=3.0V, V-=-1V to 0V	0.7	1.2	1.7	ms	G
Delay Time Shortening Mode Voltage	V_{DS}	VDD=4.4V	-2.6	-2.0	-1.4	V	G
Nch ON-Voltage of C_{OUT}	$V_{oL}1$	Iol=50µA, VDD=4.5V		0.4	0.5	V	G
Pch ON-Voltage of C_{OUT}	$V_{oH}1$	Ioh=-50µA, VDD=3.5V	3.0	3.3		V	H
Nch ON-Voltage of D_{OUT}	$V_{oL}2$	Iol=50µA, VDD=2.0V		0.2	0.5	V	I
Pch ON-Voltage of D_{OUT}	$V_{oH}2$	Ioh=-50µA, VDD=3.5V	3.0	3.3		V	J
Supply Current	I_{DD}	VDD=3.5V, V- =0V		4.0	6.5	µA	K
Standby Current	Istandby	VDD=2.0V			2.0	µA	L

•: 'Note1' indicates test circuits shown in next page.

Note2: Considering of variation in process parameters, we compensate for this characteristic related to temperature by laser-trim, however, this specification is guaranteed by design, not mass production tested.
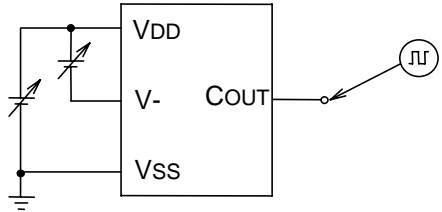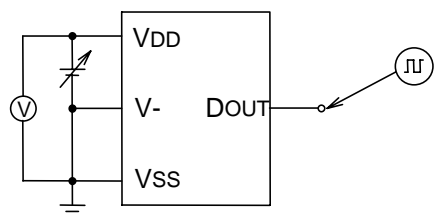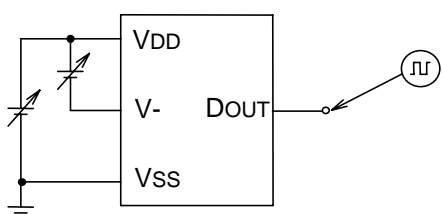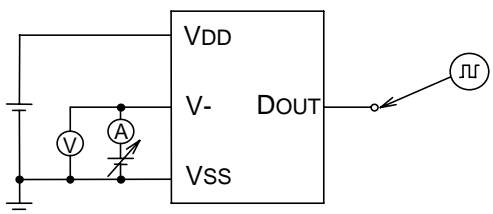
[6] Test Circuits

A
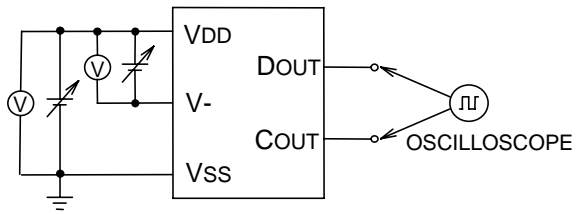
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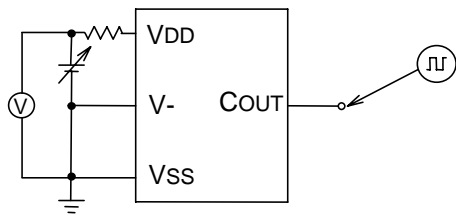
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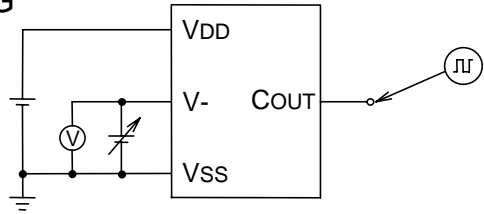
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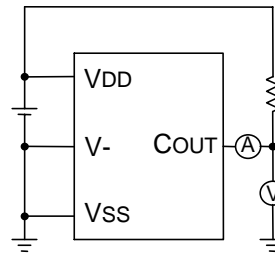
I

J

K

L

[7] Operation

- **VD1 / Over-charge Detector**

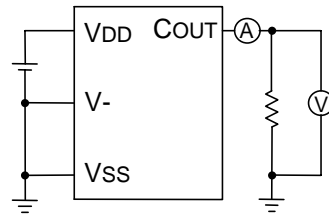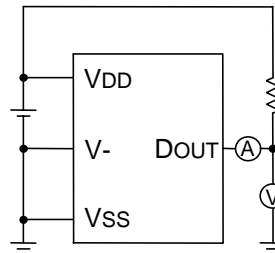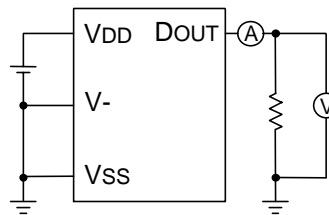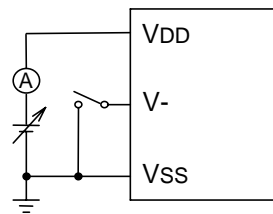The VD1 monitors V_{DD} pin voltage during charge. When the V_{DD} voltage crosses over-charge detector threshold V_{DET1} (Typ. 3.650V), the VD1 can sense over-charge and the output of C_{OUT} pin becomes "L" and stop charging by turning off the external Nch-MOSFET.

After detecting over-charge, when the voltage of VDD pin is less than over-charge detector threshold, and after disconnecting a charger, VD1 is released. However, depending on the characteristics of external components such as MOSFETs, release conditions may be not enough and a kind of load must be set to release the over-charge. And the output level of COUT becomes "H" and by turning on the external Nch-MOSFET, the battery charger is ready to work again. In other words, once detecting over-charge, even if the cell voltage would become lower than VDET1, if a charger is kept on set, recharge is impossible. Therefore, there is no hysteresis for VD1. To judge whether or not load is connected, Excess-discharge current detector is used. In other words, by connecting some load, V- pin voltage becomes equal or more than Excess-discharge current detector threshold, and reset Over-charge detecting state.

When the Input level of V_{DD} pin is equal or more than over-charge detector threshold, and while a charger is disconnected from the battery pack, if a load system is connected to the battery pack, the output level of C_{OUT} pin is "L". However, load current can be drawn through a parasitic diode of an external Nch-MOSFET. Then, when the voltage level of V_{DD} pin becomes lower than over-charge detector threshold, the output level of C_{OUT} pin becomes "H".

Output delay time for over-charge detect and released over-charge is internally fixed respectively. Although the V_{DD} voltage goes up to a higher level than over-charge detector threshold within the output delay time (Typ. 1s), VD1 would not work for detecting over-charge. If the action for VD1 to release is done and the condition returns to the initial one within the output delay time (Typ.16ms), VD1 cannot be released.

A level shifter is built in a buffer driver for the C_{OUT} pin, because of this, the "L" level is equal to the voltage level of V- pin.

The output type of C_{OUT} pin is CMOS type. (The Output level is between V_{DD} and V-.)

- **VD2/Over-discharge Detector**

The VD2 monitors a V_{DD} pin voltage during discharge. When the V_{DD} voltage crosses the over-discharge detector threshold V_{DET2} (Typ. 2.50V) from a high level to a lower level than V_{DET2}, the VD2 senses over-discharge and stop discharge by turning off an external Nch-MOSFET.

To reset the VD2 with the D_{OUT} pin level being "H" again after detecting over-discharge, if V_{DD} voltage is equal or less than over-charge detector threshold, a charge current flows through a parasitic diode of the external Nch MOSFET. After that, when V_{DD} voltage is more than over-discharge threshold, D_{OUT} pin becomes "H", and by tuning on the external Nch MOSFET, discharge is possible. In the case that a charger is connected to the battery pack, and V_{DD} level is more than over-discharge detector threshold, the output level of D_{OUT} becomes "H" immediately. Without connecting a charger, if V_{DD} pin voltage is equal or more than the released voltage from over-discharge (Typ.3.0V), the output level of D_{OUT} becomes "H".

When a cell voltage is equal to 0V, connecting a charger to the battery pack makes C_{OUT} pin become "H" and the system is allowable for charge while the voltage of the charger is more than the maximum limit of the minimum operating voltage (Vst) for 0V charge.

An output delay for over-discharge detection is fixed internally. (Typ. 20ms) Although the voltage of V_{DD} becomes equal or less than over-discharge detector threshold and if it becomes higher than over-discharge detector threshold within output delay time, over-discharge detector does not work. Output delay time for release from over-discharge is also set internally. (Typ. 1.2ms)

After detecting over-discharge by VD2, supply current would decrease, (V_{DD}=2.0V, Max. 2.0μA.) because unnecessary circuits are halted and being standby.

The output type of D_{OUT} pin is CMOS type and its output level is in between V_{DD} and V_{SS}.

- **VD3/ Excess Discharge Current Detector, Short Circuit Protector**

   While charge and discharge are acceptable with the battery pack, VD3 monitors the voltage level of V- pin. In the cause of such as the external short-circuit, if the voltage level of V- pin may become equal or more than the excess discharge current threshold (Typ. 0.20V) and less than the short detector threshold (Typ. 0.8V), the excess discharge current detector works. When the voltage level of V- pin becomes equal or more than short detector threshold voltage, the short circuit protector works and the output level of D_{OUT} becomes "L", and by turning off an external Nch MOSFET, VD3 protects against flowing extremely large current into the circuit.

   An output delay time for the excess discharge current detector is internally fixed at 12ms typical. Although the voltage of V- pin becomes equal or more than the excess discharge current threshold voltage and less than short detector threshold, if it becomes less than the excess current detector threshold voltage within the output delay time, the excess current detector does not work. Output delay time for release from excess discharge current is also set internally (Typ. 1.2ms).

   In terms of short circuit protector, output delay time is typically 300μs.

   The V- pin has a built-in pull down resistor, Typ. 50kΩ connected to the Vss pin.
   After an excess discharge current or short circuit protection is detected, by removing a cause of excess current or external short circuit, the voltage level of V- is pulled down through the resistor for release from excess current to the Vss level. Then, when the voltage level of V- pin becomes equal or less than the excess current threshold voltage, both protection circuits are released automatically. Resistor for release from excess discharge current is active when excess discharge current or short circuit is detected. While charge and discharge are acceptable for the battery pack, or normal mode, the resistor is inactive.

   Output delay time for excess discharge current is necessarily set shorter than output delay time for over-discharge. Therefore, if excess discharge current is detected, and at the same time, V_{DD} pin voltage becomes lower than over-discharge detector threshold level, excess discharge current detector is predominant. By disconnecting load from the battery pack, the battery pack is automatically released from excess current state.

- **VD4/ Excess charge-current detector**

   While charge and discharge are acceptable with the battery pack, VD4 senses V- pin voltage. For example, if the battery pack is charged by an inappropriate charger, excess current flows, then the voltage of V- pin becomes equal or less than excess charge-current detector threshold (Typ. –0.20V). Then, the output of C_{OUT} becomes "L", and protects against flowing excess current in the circuit by turning off the external Nch MOSFET.

   Output delay of excess charge current is internally fixed. (Typ. 16ms) Even the voltage level of V- pin becomes equal or lower than excess charge-current detector threshold, if the voltage is higher than the VD4 threshold within the delay time, excess charge-current state is not detected. Output delay time for release from excess charge current is also set internally. (Typ. 1.2ms)

   VD4 can be released by disconnecting a charger.

- **DS(Delay Shorter) function**

   When the C_{OUT} is "H", the output delay time of over-charge, over-discharge, and release from over-discharge can be shorter than those setting values by forcing equal or lower than the delay shortening mode voltage (Typ. -2.0V) to V- pin.

[8] Technical Notes
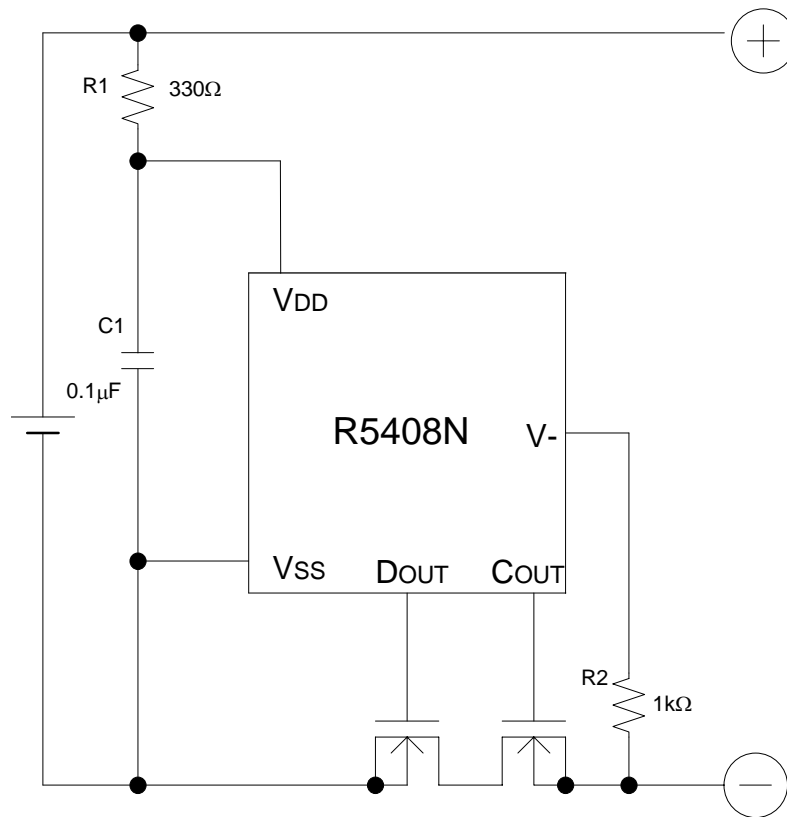
*R1 and C1 stabilize a supply voltage to the R5408. A recommended R1 value is less than 1kΩ. A large value of R1 makes detection voltage shift higher because of rush current flown in the R5408. Further, to stabilize the operation of R5408, use the C1 with the value of 0.01μF or more.

*R1 and R2 can operate as a current limit against setting cell reverse direction or applying excess charge voltage to the R5408. While small value of R1 and R2 may cause over power dissipation rating of the R5408, therefore a total of "R1+R2" should be 1kΩ or more. Besides, if large value of R2 is set, release from over-discharge by connecting a charger might not be possible. Recommended R2 value is equal or less than 10kΩ.

The typical application circuit diagram is just an example. This circuit performance largely depends on the PCB layout and external components. In the actual application, fully evaluation is necessary.

Over-voltage and the over current beyond the absolute maximum rating should not be forced to the protection IC and external components.
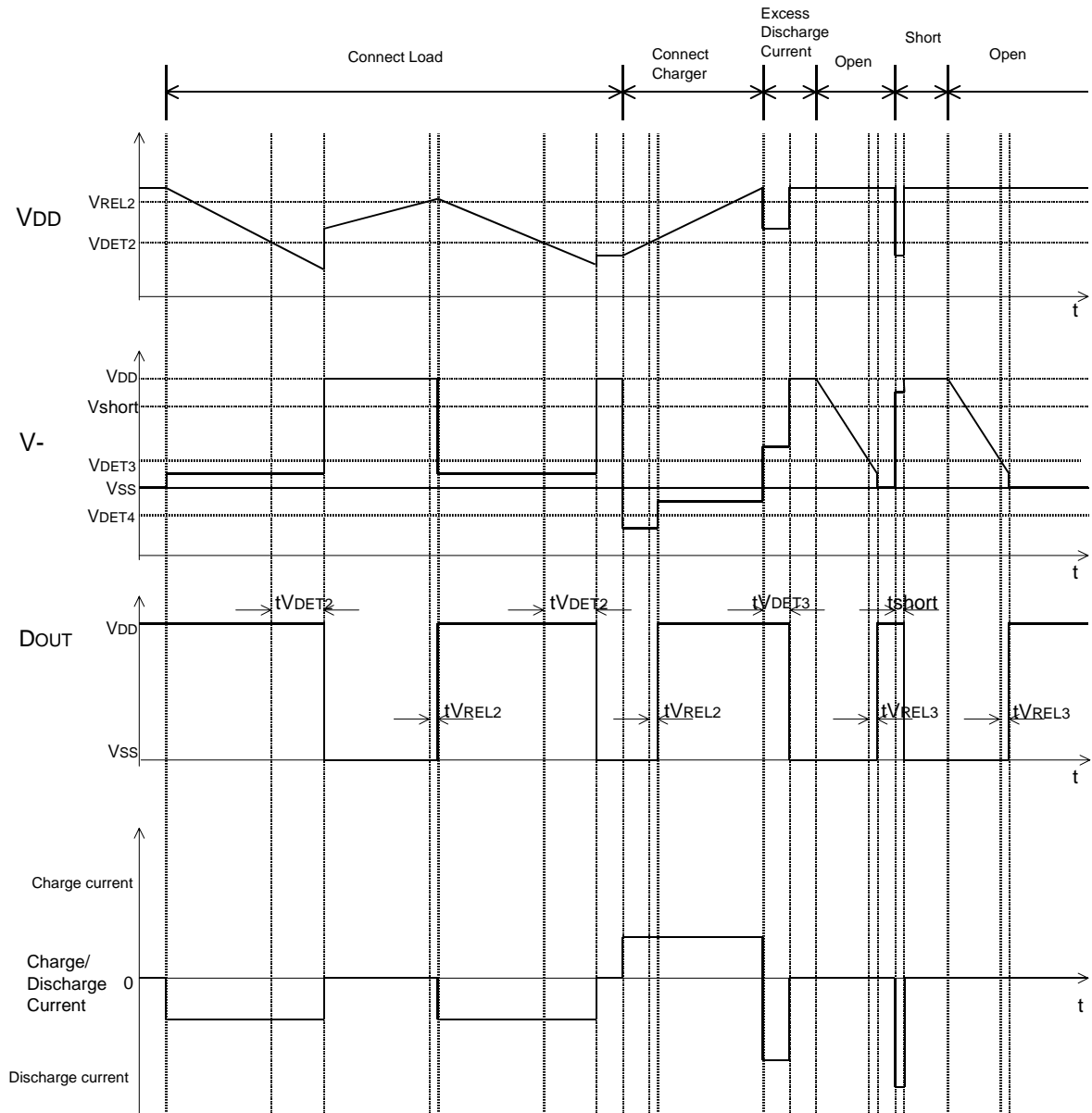
We are making our continuous effort to improve the quality and reliability of our products , but semiconductor products are likely to fail with certain probability. In order prevent any injury to persons or damages to property resulting from such failure, customers should be careful enough to incorporate safety measures in their design , such as redundancy feature , fire-containment feature and fail-safe feature. We do not assume any liability or responsibility for any loss or damage arising from misuse or inappropriate use of the products.
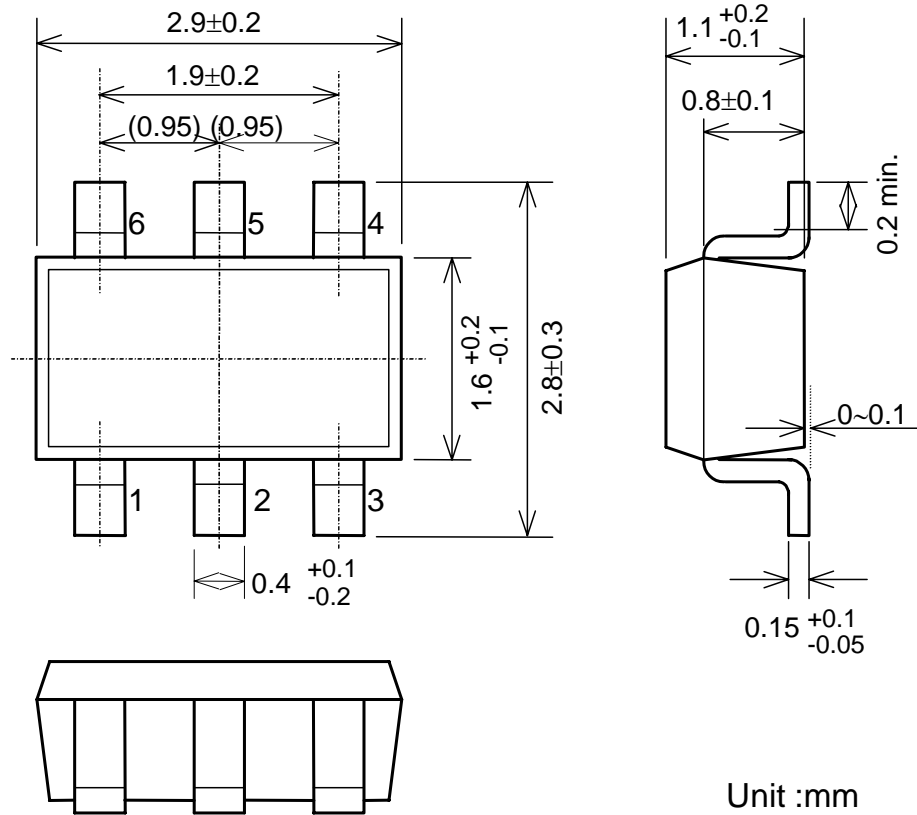
[9] Timing Diagram

(1) Timing diagram of over-charge voltage and over-charge current
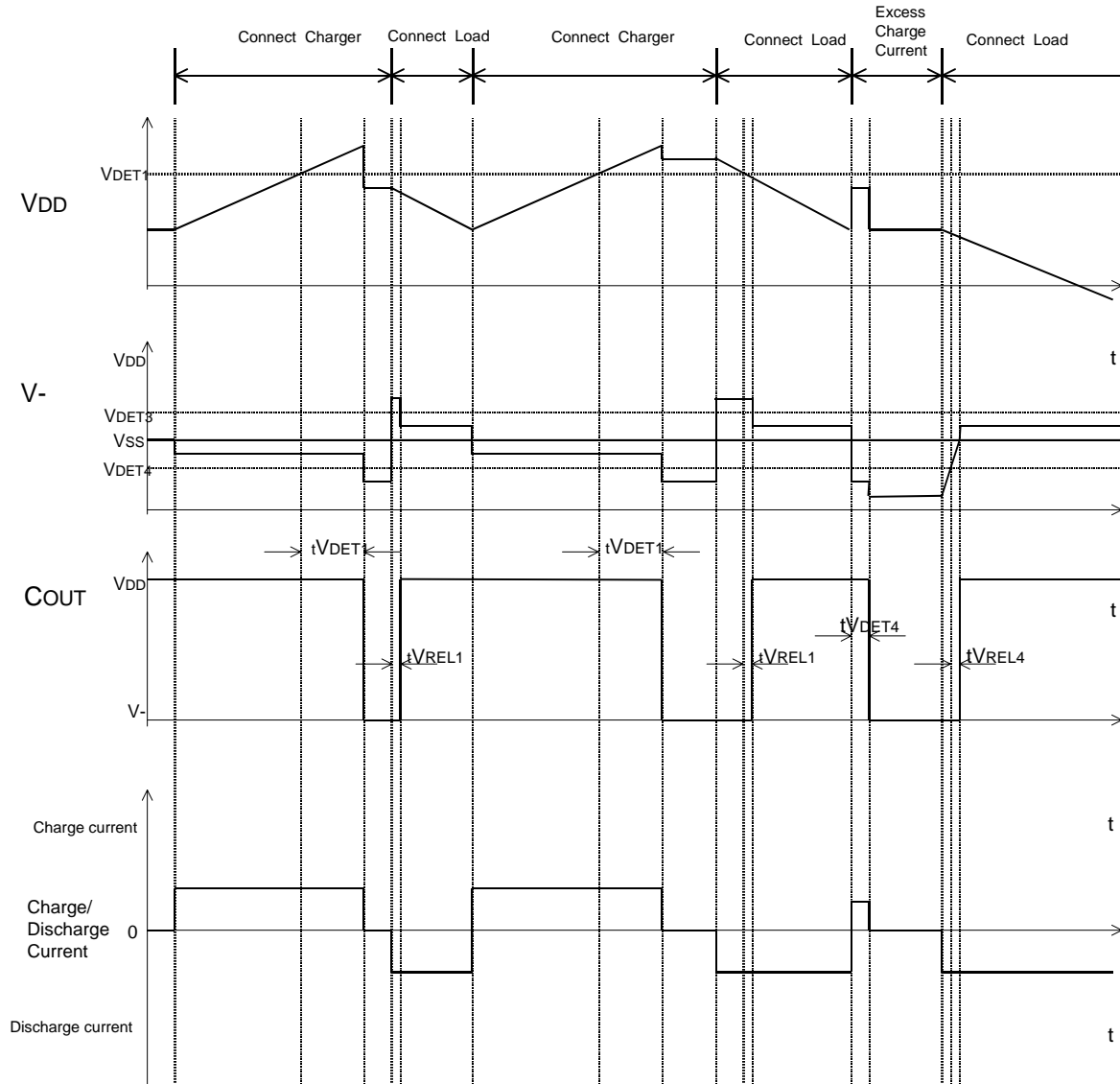
(2) Over-discharge, Excess discharge current, Short circuit

[10] Package Dimensions (SOT23-6)

2.9±0.2

1.9±0.2

(0.95) (0.95)

6 5 4

1 2 3

$1.6^{+0.2}_{-0.1}$

2.8±0.3

$0.4^{+0.1}_{-0.2}$

$1.1^{+0.2}_{-0.1}$

0.8±0.1

0.2 min.

0~0.1

$0.15^{+0.1}_{-0.05}$

Unit :mm

[11] Mark Specification

①② : Series Code Name … **XX**

③④ : Lot Number   (Alphanumeric serial number)

6 5 4

① ② ③ ④

1 2 3