

## PRODUCT SPECIFICATIONS

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### **R5402N101KD-TR-F**

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## [1] Outline

The R5402N101KD 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 R5402N101KD 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 R5402N101KD consists of four voltage detectors, a reference unit, a delay circuit, a short circuit detector, an oscillator, a counter, and a logic circuit.

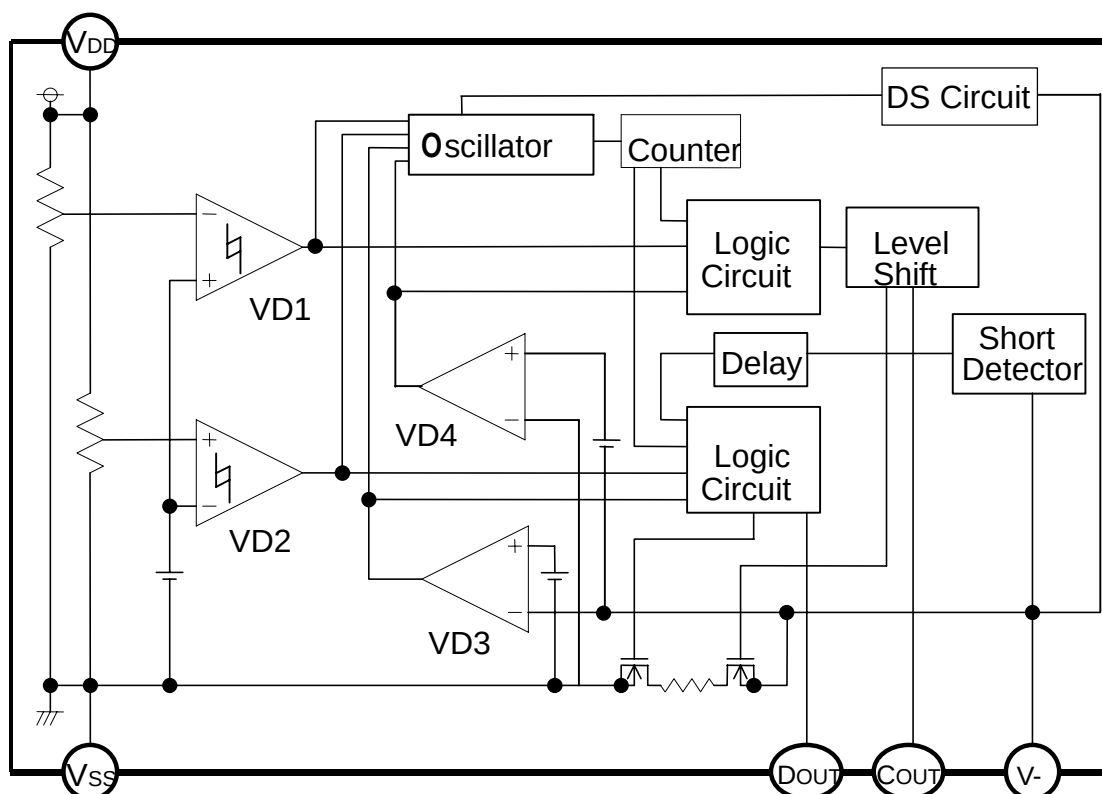
When the R5402N101KD detects over-charge or over-charge current, the output of COUT pin switches to "L" level, that is, the charger's negative pin level after the internal fixed delay time. When the R5402N101KD detects over-discharge or excess discharge current, the output of DOUT pin switches to "L" 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 R5402N101KD can be reset and the output of COUT becomes "H" when a kind of load is connected to VDD after a charger is disconnected from the battery pack. If a charger is continuously connected to the battery pack, when the cell voltage becomes equal or lower than the release voltage from over-charge, over-charge will be released and COUT becomes "H".

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 equal or more than the released voltage from over-discharge, the R5402N101KD 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 R5402N101KD 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 time shortening 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)            |

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## [4] Absolute Maximum Rating

T<sub>opt</sub>=25°C, V<sub>ss</sub>=0V

| Item                               | Symbol            | Ratings            | Unit |
|------------------------------------|-------------------|--------------------|------|
| Supply Voltage                     | VDD               | -0.3 to 12         | V    |
| Input Voltage<br>V- pin Voltage    | V-                | VDD-35 to VDD+0.3  | V    |
| Output Voltage<br>COUT pin Voltage | V <sub>COUT</sub> | VDD-35 to VDD+0.3  | V    |
| DOUT pin Voltage                   | V <sub>DOUT</sub> | VSS-0.3 to VDD+0.3 | V    |
| Power Dissipation                  | P <sub>D</sub>    | 150                | mW   |
| Operating Temperature              | T <sub>opr</sub>  | -40 to 85          | °C   |
| Storage Temperature                | T <sub>stg</sub>  | -55 to 125         | °C   |

## [5] Electrical Characteristics

## ●R5402N101KD

Unless otherwise provided, T<sub>opt</sub>=25°C

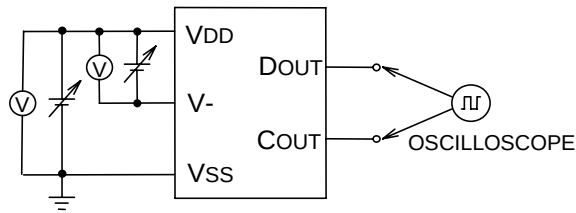
| Item                                                  | Symbol               | Conditions                                                                                | Min.           | Typ.           | Max.           | Unit   | Note1  |
|-------------------------------------------------------|----------------------|-------------------------------------------------------------------------------------------|----------------|----------------|----------------|--------|--------|
| Operating Input Voltage                               | V <sub>DD1</sub>     | V <sub>DD</sub> - V <sub>SS</sub>                                                         | 1.5            |                | 5.0            | V      | A      |
| Minimum Operating Voltage for 0V Charging             | V <sub>st</sub>      | Voltage Defined as V <sub>DD</sub> -V <sub>-</sub> , V <sub>DD</sub> -V <sub>SS</sub> =0V |                |                | 1.8            | V      | A      |
| Over-charge Threshold Voltage                         | V <sub>DET1</sub>    | R1=330Ω<br>R1=330Ω, T <sub>opt</sub> =-5°C to 55°C *Note2                                 | 4.225<br>4.220 | 4.250<br>4.250 | 4.275<br>4.280 | V<br>V | B<br>B |
| Released voltage from Over-charge                     | V <sub>REL1</sub>    | R1=330Ω                                                                                   | 4.000          | 4.050          | 4.100          | V      | B      |
| Output Delay of Over-charge                           | t <sub>VDET1</sub>   | V <sub>DD</sub> =3.6V→4.4V                                                                | 0.7            | 1.0            | 1.3            | s      | B      |
| Release Delay for VD1                                 | t <sub>VREL1</sub>   | V <sub>DD</sub> =4.5V→3.6V                                                                | 11             | 16             | 21             | ms     | B      |
| Over-discharge Threshold                              | V <sub>DET2</sub>    | Detect falling edge of supply voltage                                                     | 2.438          | 2.500          | 2.562          | V      | B      |
| Released Voltage from Over-discharge                  | V <sub>REL2</sub>    | Detect rising edge of supply voltage                                                      | 2.925          | 3.000          | 3.075          | V      | C      |
| Output Delay of Over-discharge                        | t <sub>VDET2</sub>   | V <sub>DD</sub> =3.6V→2.2V                                                                | 14             | 20             | 26             | ms     | D      |
| Release Delay for VD2                                 | t <sub>VREL2</sub>   | V <sub>DD</sub> =3V, V <sub>-</sub> =3V→0V                                                | 0.7            | 1.2            | 1.7            | ms     | D      |
| Excess discharge-current threshold                    | V <sub>DET3</sub>    | Detect rising edge of 'V-' pin voltage                                                    | 0.185          | 0.200          | 0.215          | V      | E      |
| Output delay of excess discharge-current              | t <sub>VDET3</sub>   | V <sub>DD</sub> =3.0V, V <sub>-</sub> =0V to 0.5V                                         | 8              | 12             | 16             | ms     | F      |
| Output delay of release from excess discharge-current | t <sub>VREL3</sub>   | V <sub>DD</sub> =3.0V, V <sub>-</sub> =3V to 0V                                           | 0.7            | 1.2            | 1.7            | ms     | F      |
| Short Protection Voltage                              | V <sub>short</sub>   | V <sub>DD</sub> =3.0V                                                                     | 0.55           | 0.80           | 1.00           | V      | F      |
| Delay Time for Short Protection                       | t <sub>short</sub>   | V <sub>DD</sub> =3.0V, V <sub>-</sub> =0V to 3V                                           | 230            | 300            | 500            | μs     | F      |
| Reset Resistance for Excess Current Protection        | R <sub>short</sub>   | V <sub>DD</sub> =3.6V, V <sub>-</sub> =1.0V                                               | 25             | 50             | 75             | kΩ     | F      |
| Excess charge-current threshold                       | V <sub>DET4</sub>    | Detect falling edge of 'V-' pin voltage                                                   | -0.130         | -0.100         | -0.070         | V      | F      |
| Output delay of excess charge-current                 | t <sub>VDET4</sub>   | V <sub>DD</sub> =3.0V, V <sub>-</sub> =0V to -1V                                          | 5              | 8              | 11             | ms     | G      |
| Output delay of release from excess charge-current    | t <sub>VREL4</sub>   | V <sub>DD</sub> =3.0V, V <sub>-</sub> =-1V to 0V                                          | 0.7            | 1.2            | 1.7            | ms     | G      |
| Delay Time Shortening Mode Voltage                    | V <sub>DS</sub>      | V <sub>DD</sub> =4.4V                                                                     | -1.4           | -2.0           | -2.6           | V      | G      |
| Nch ON-Voltage of COUT                                | V <sub>OL1</sub>     | I <sub>OL</sub> =50μA, V <sub>DD</sub> =4.5V                                              |                | 0.4            | 0.5            | V      | G      |
| Pch ON-Voltage of COUT                                | V <sub>OH1</sub>     | I <sub>OH</sub> =-50μA, V <sub>DD</sub> =3.9V                                             | 3.4            | 3.7            |                | V      | H      |
| Nch ON-Voltage of DOUT                                | V <sub>OL2</sub>     | I <sub>OL</sub> =50μA, V <sub>DD</sub> =2.0V                                              |                | 0.2            | 0.5            | V      | I      |
| Pch ON-Voltage of DOUT                                | V <sub>OH2</sub>     | I <sub>OH</sub> =-50μA, V <sub>DD</sub> =3.9V                                             | 3.4            | 3.7            |                | V      | J      |
| Supply Current                                        | I <sub>DD</sub>      | V <sub>DD</sub> =3.9V, V <sub>-</sub> =0V                                                 |                | 4.0            | 8.0            | μA     | K      |
| Standby Current                                       | I <sub>standby</sub> | V <sub>DD</sub> =2.0V                                                                     |                | 1.2            | 2.0            | μA     | L      |

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

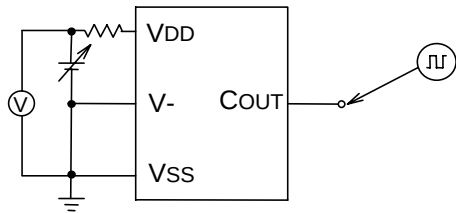
Note2: Considering of variation in process parameters, we compensate for this characteristic related to temperature by laser-trim, however, this specification is guaranteed by design, not mass production tested.

[6] Test Circuits

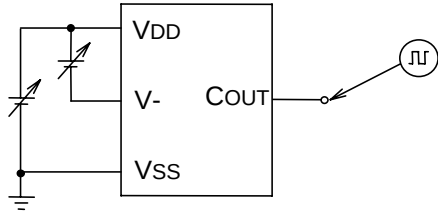
A



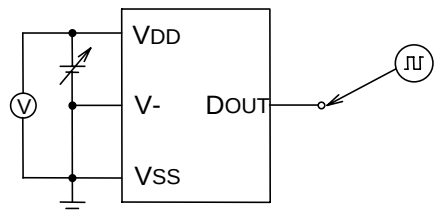
B



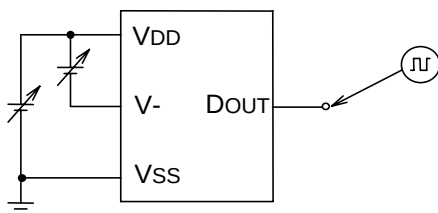
C



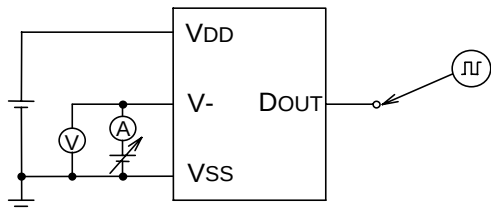
D



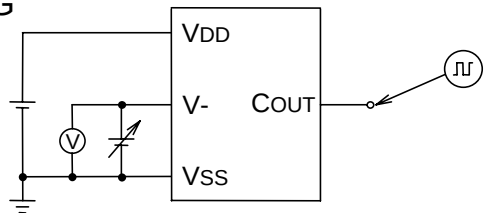
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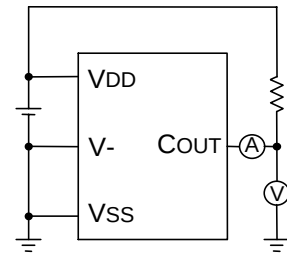
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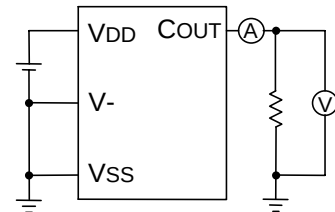
G



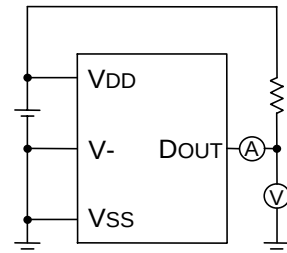
H



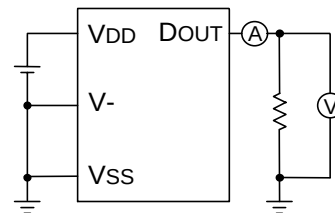
I



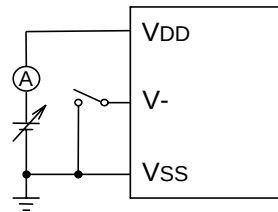
J



K



L



## [7] Operation

### • VD1 / Over-charge Detector

The VD1 monitors VDD pin voltage during charge. When the VDD voltage crosses over-charge detector threshold VDET1 (Typ. 4.250V), the VD1 can sense over-charge and the output of COUT pin becomes "L" and stop charging by turning off the external Nch-MOSFET.

After detecting over-charge, when the voltage of VDD pin is equal or less than the released voltage from over-charge (Typ. 4.050V), or when the VDD voltage is less than the over-charge detector threshold, if the charger is removed and connect a load, VD1 is released, then the output level of COUT becomes "H" and by turning on the external Nch-MOSFET, the battery charger is ready to work again.

When the Input level of VDD 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 COUT pin is "L". However, load current can be flown through a parasitic diode of an external Nch-MOSFET. Then, when the voltage level of VDD pin becomes lower than over-charge detector threshold, the output level of COUT pin becomes "H".

Output delay time for over-charge detect and released over-charge is internally fixed respectively. Although the VDD 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 COUT pin, because of this, the "L" level is equal to the voltage level of V- pin.

The output type of COUT pin is CMOS type. (The Output level is between VDD and V-.)

### • VD2/Over-discharge Detector

The VD2 monitors a VDD pin voltage during discharge. When the VDD voltage crosses the over-discharge detector threshold VDET2 (Typ. 2.50V) from a high level to a lower level than VDET2, the VD2 senses over-discharge and stop discharge by turning off an external Nch-MOSFET.

To reset the VD2 with the DOUT pin level being "H" again after detecting over-discharge, if VDD 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 VDD voltage is more than over-discharge threshold, DOUT 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 VDD level is more than over-discharge detector threshold, the output level of DOUT becomes "H" immediately. Without connecting a charger, if VDD pin voltage is equal or more than the released voltage from over-discharge (Typ.3.0V), the output level of DOUT becomes "H".

When a cell voltage is equal to 0V, connecting a charger to the battery pack makes COUT 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 VDD 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, (VDD=2.0V, Max. 2.0μA.) because unnecessary circuits are halted and being standby.

The output type of DOUT pin is CMOS type and its output level is in between VDD and Vss.

### • 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. 0.200V) 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 DOUT 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, VDD 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. -0.10V). Then, the output of COUT becomes "L", and protects against flowing excess current in the circuit by turning off the external Nch MOSFET.

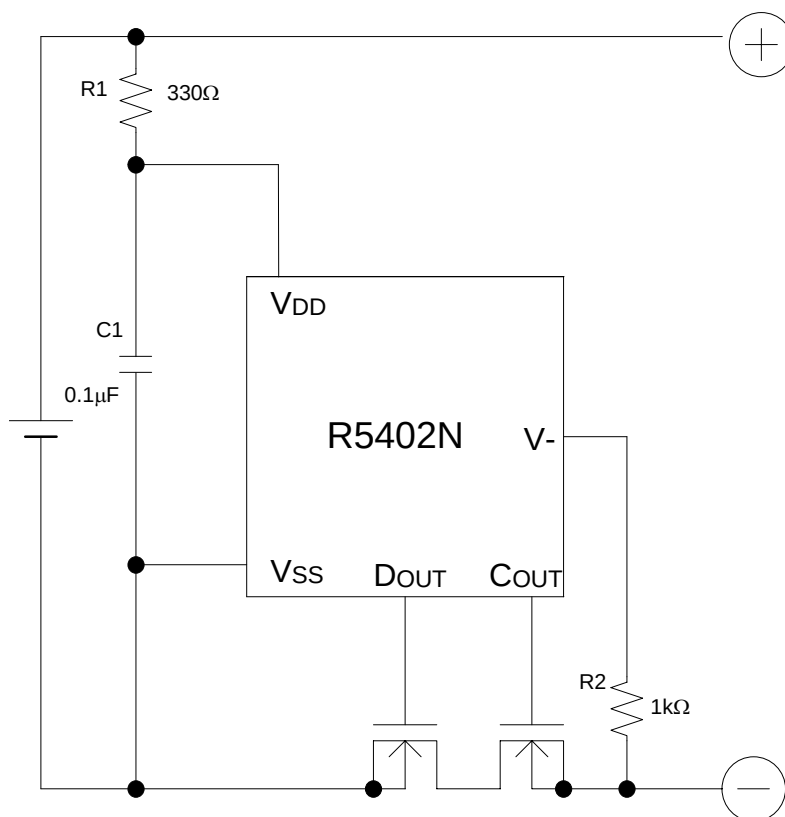
Output delay of excess charge current is internally fixed. (Typ. 8ms) Even the voltage level of V- pin becomes equal or lower than excess charge-current detector threshold, if the voltage is higher than the VD4 threshold within the delay time, excess charge-current state is not detected. Output delay time for release from excess charge current is also set internally.

VD4 can be released by disconnecting a charger and setting a load.

### • DS (Delay Shortening) function

When the COUT 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 R5402. A recommended R1 value is equal or less than 1kΩ. A large value of R1 makes detection voltage shift higher because of the conduction current flow in the R5402.

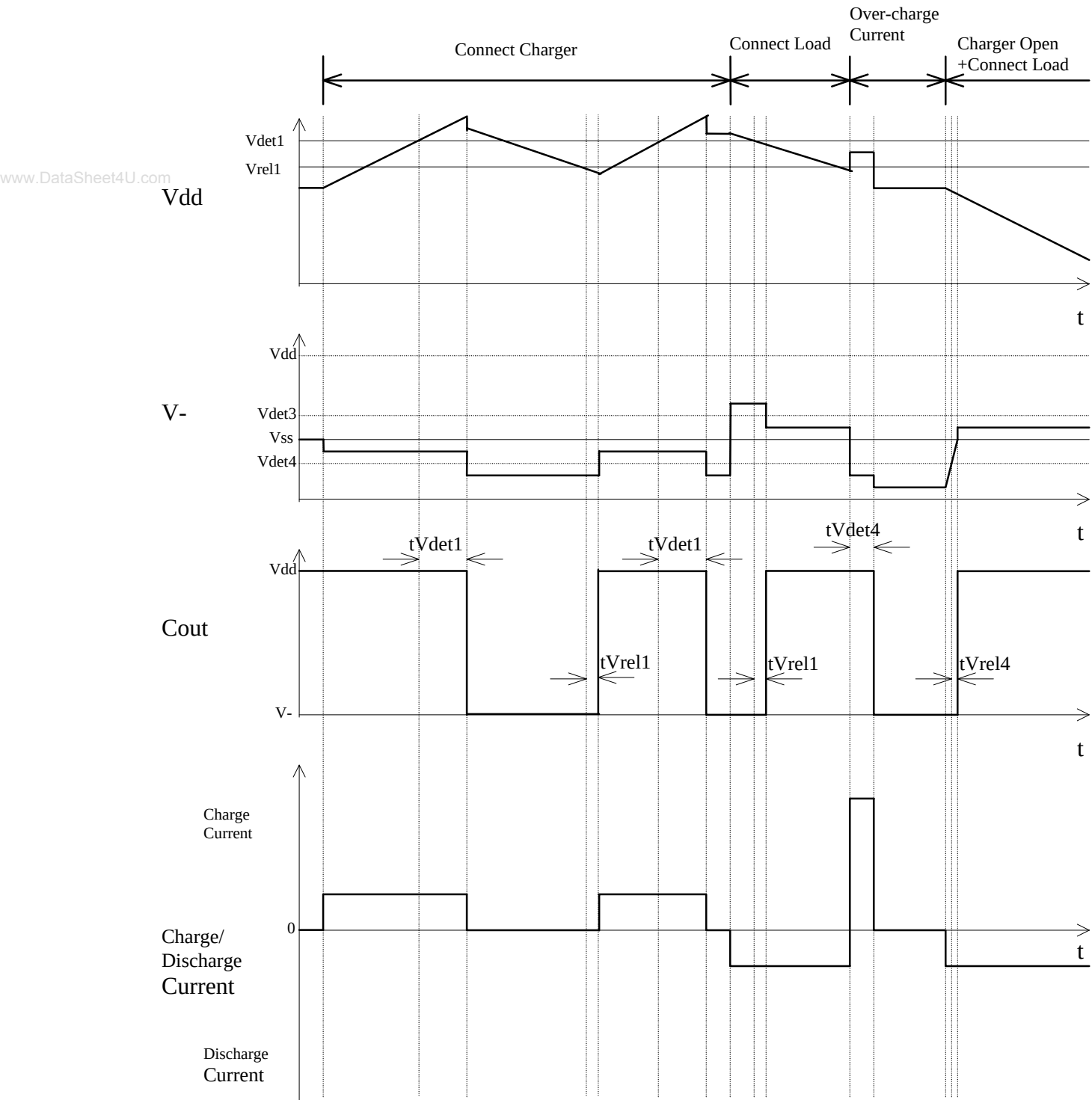
Further, to stabilize the operation of R5402, use the C1 with the value of 0.01μF or more.

\*R1 and R2 can operate as a current limit against setting cell reverse direction or applying excess charge voltage to the R5402. While small value of R1 and R2 may cause over power dissipation rating of the R5402, therefore a total of "R1+R2" should be 1kΩ or more. Besides, if a 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.

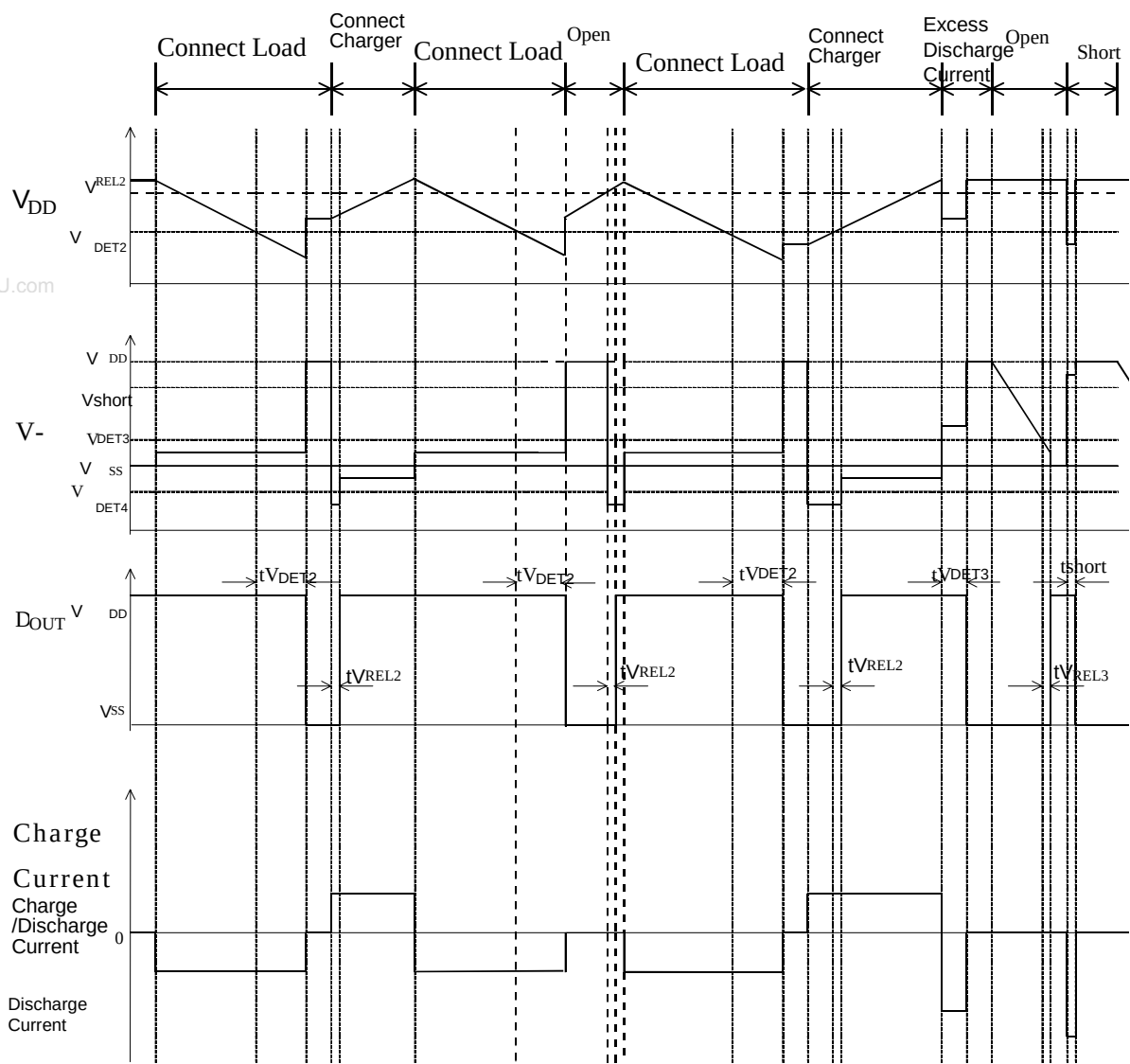


[9] Timing Diagrams

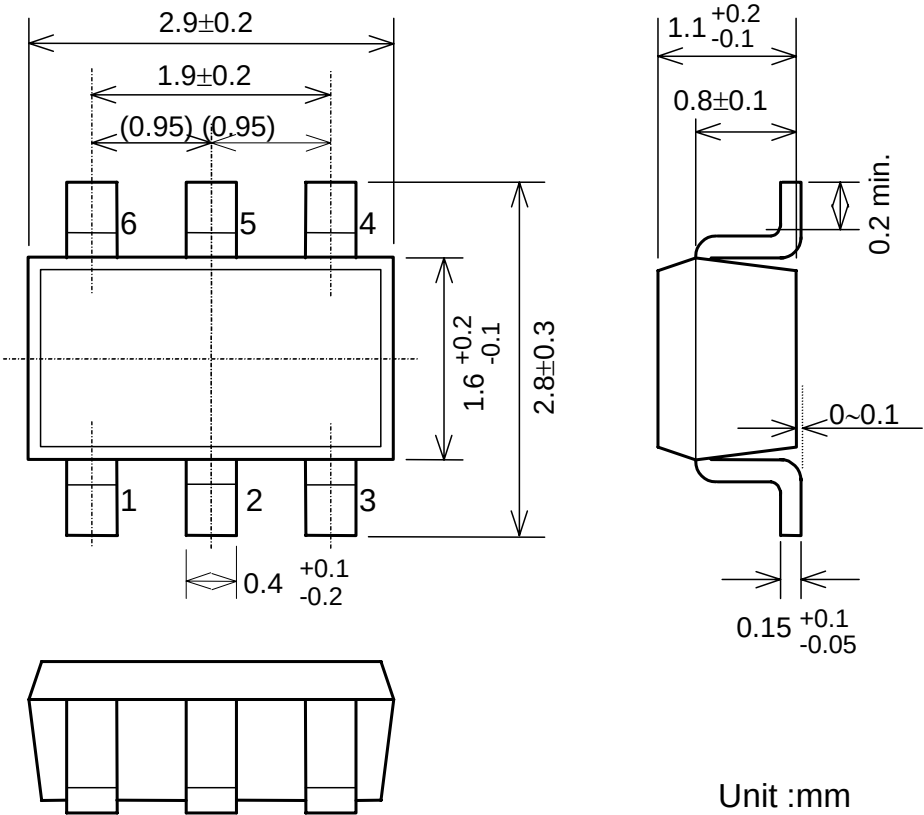
(1) Timing diagram of over-charge voltage and over-charge current



(2) Over-discharge, Excess discharge current, Short circuit



[10] Package Dimensions (SOT23-6)



[11] Mark Specification

- ①② : Series Code Name ... **VC**
- ③④ : Lot Number (Alphanumeric serial number)

