LI-ion/POLYMER 1CELL PROTECTOR

R5400xxxxx SERIES

OUTLINE

The R5400xxxxxx Series are high voltage CMOS-based protection ICs for over-charge/discharge of rechargeable one-cell Lithium-ion (Li+) / Lithium polymer excess load current, further include a short circuit protector for preventing large external short circuit current and excess discharge-current.

Each of these ICs is composed of three voltage detectors, a reference unit, a delay circuit, a short circuit detector, an oscillator, a counter, and a logic circuit. When an over-charge voltage crosses the detector threshold from a low value to a high value, the output of C_{OUT} pin switches to low level after internal fixed delay time. After detecting over-charge, the detector can be reset and the output of C_{OUT} becomes "H" when a kind of load is connected to V_{DD} after a charger is disconnected from the battery pack, and the cell voltage becomes lower than over-charge detector threshold. If a charger is continue to be connected to the battery pack, even the cell voltage becomes lower than over-charge detector threshold, over-charge state is not released.

The output of D_{OUT} pin, the output of Over-discharge detector and Excess discharge-current detector, switches to low level after internally fixed delay time, when discharged voltage crosses the detector threshold from a high value to a value lower than V_{DET2}.

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, VD2 is released and the voltage of D_{OUT} pin becomes "H" level.

An excess discharge-current and short circuit state can be sensed and cut off through the built in excess current detector, VD3, with D_{OUT} being enabled to low level. Once after detecting excess discharge-current or short circuit, the VD3 is released and D_{OUT} level switches to high by detaching a battery pack from a load system.

After detecting over-discharge, supply current will be kept extremely low by halting internal circuits' operation.

When the COUT is "H", if V- is set at the test shorten mode voltage (Typ. -2.0V) or lower than that, the delay time of the PCB can be shortened. Especially, the delay time of over-charge detector can be reduced into approximately 1/60, therefore, testing time of protector circuit board can be reduced. Output type of C_{OUT} and D_{OUT} is CMOS.

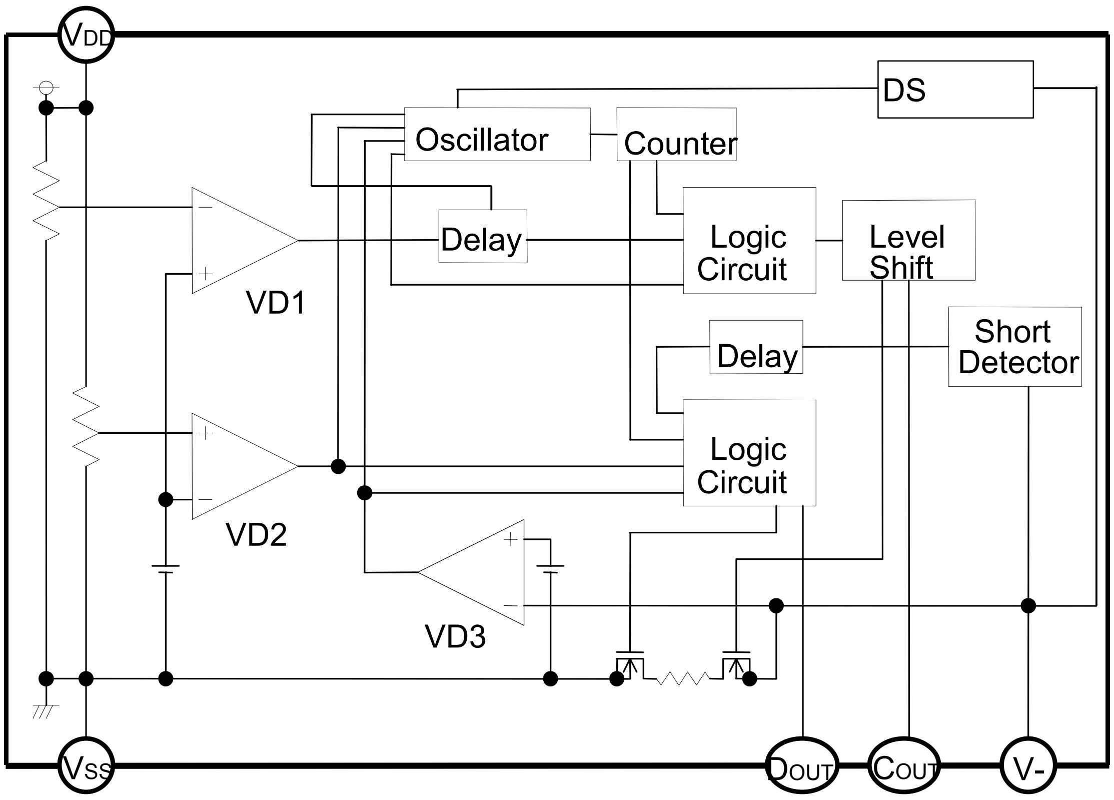
FEATURES

- Manufactured with High Voltage Tolerant Process… Absolute Maximum Rating 35V
- Low supply current .... Supply current(At normal mode)
  Typ. 3.5µA (0V charge acceptable type)
  Typ. 4.0µA (0V charge unacceptable type)
  Standby current (detecting over-discharge) Max. 0.1µA
- High accuracy detector threshold .... Over-charge detector (Topt=25°C) ±25mV
  (Topt=-5 to 55°C) ±30mV
  Over-discharge detector ±2.5%
  Excess discharge-current detector ±15mV
- Variety of detector threshold .... Over-charge detector threshold 4.0V-4.5V step of 0.005V
  Over-discharge detector threshold 2.0V-3.0V step of 0.005V
  Excess discharge-current threshold 0.05V-0.2V step of 0.005V
- Internal fixed Output delay time...................Over-charge detector Output Delay 1.1s
  (Select among the options) Over-discharge detector Output Delay 20ms
  Excess discharge-current detector Output Delay 12ms
  Short Circuit detector Output Delay 300µs
- Delay Time Reduction Function .... Set V-=-(Typ. -2.0V)(Test shorten Mode Voltage) or lower with COUT at "H" level, Output Delay time of all items except excess discharge current and short-circuit can be reduced. (Delay Time for over-charge becomes about 1/60 of normal state.)
- 0V-battery charge option......................... acceptable/unacceptable
- With Latch function after over-charge detect
- Ultra Small package................................ SOT-23-5 / SON1612-6pin

APPLICATIONS

- Li+ / Li Polymer protector of over-charge, over-discharge, excess-current for battery pack
- High precision protectors for cell-phones and any other gadgets using on board Li+ / Li Polymer battery

BLOCK DIAGRAM



SELECTION GUIDE

In the R5400xxxxx Series four of the input threshold for over-charge, over-discharge, and excess discharge current detectors, package type etc. can be designated.

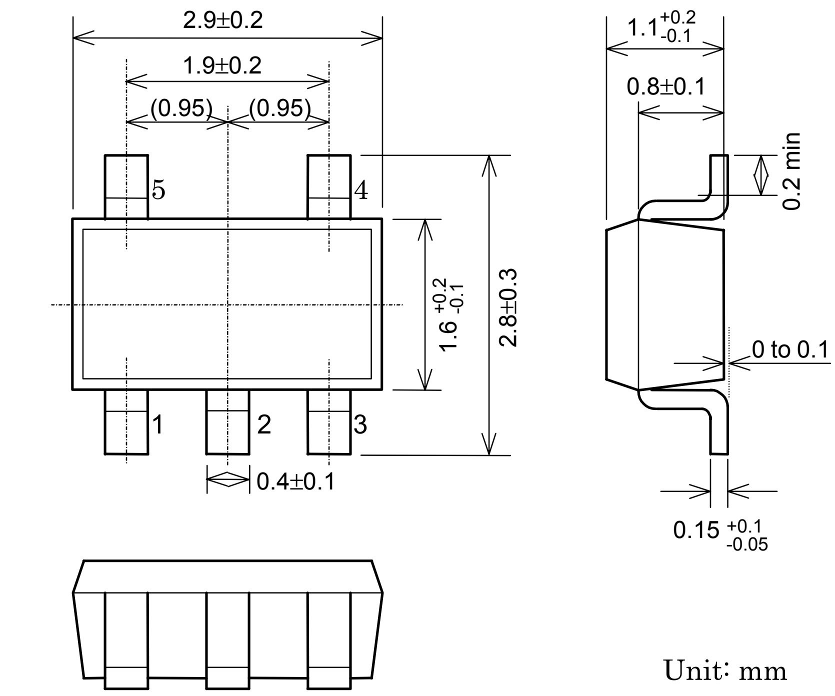
Part Number is designated as follows:

R5400x xxxxx-TR-Fx ←Part Number
↑ ↑ ↑↑ ↑ ↑
a b c de f

Code	Contents
a	Package Type N: SOT-23-5 D: SON1612-6
b	Serial Number for the R5400 Series designating input three threshold for over-charge, over-discharge, and excess discharge-current detectors.
c	Designation of Output delay time for over-charge and excess discharge-current. C: t_{VDET1}=1.1s, t_{VDET3}=12ms
d	Designation of version symbols A: 0V-charge acceptable B: 0V-charge unacceptable
e	Taping Type: TR (refer to Taping Specification)
f	Designation of Lead-Plating Material

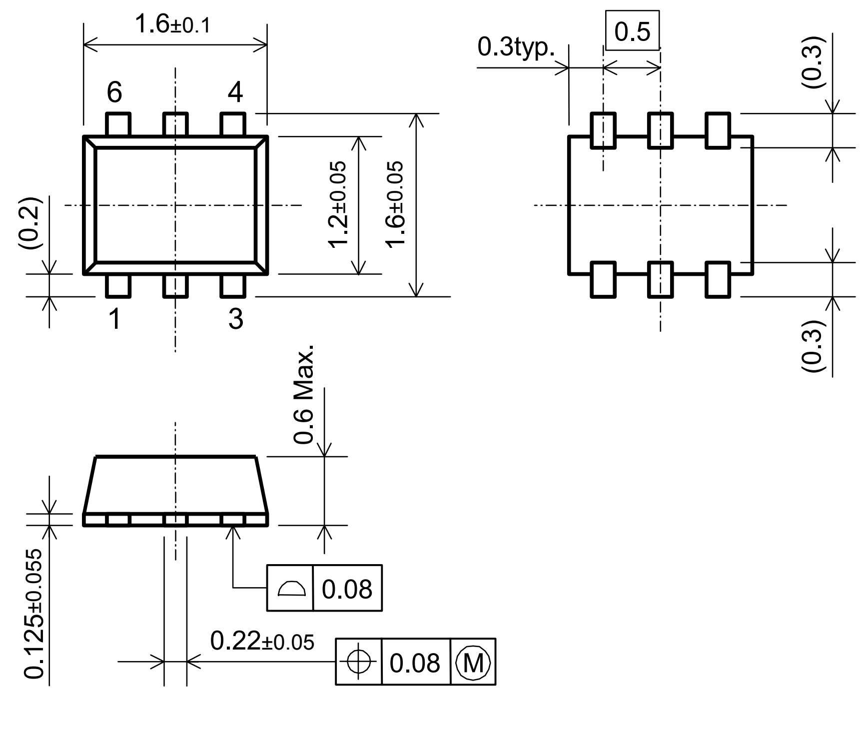
PIN CONFIGURATIONS

SOT-23-5



Unit: mm

SON1612-6



PIN DESCRIPTION

Pin No.		Symbol	Description
SOT-23-5	SON1612-6		
1	1	V-	Pin for charger negative input
2	2	V_{DD}	Power supply pin, the substrate voltage level of the IC.
5	3	C_{OUT}	Output of over-charge detection, CMOS output
4	4	D_{OUT}	Output of over-discharge detection, CMOS output
-	5	(V_{DD})	Common with pin#2 in regard to SON1612-6
3	6	V_{SS}	Vss pin. Ground pin for the IC

ABSOLUTE MAXIMUM RATINGS

V_{SS}=0V

Symbol	Item	Ratings	Unit
V_{DD}	Supply voltage	-0.3 to 12	V
V-	Input Voltage V- pin(Charger negative input pin)	V_{DD} -35 to V_{DD} +0.3	V
 VC_{OUT} VD_{OUT}	Output voltage C_{OUT} pin D_{OUT} pin	 V_{DD} -35 to V_{DD} +0.3 V_{SS} -0.3 to V_{DD} +0.3	 V V
P_D	Power dissipation	150	mW
Topt	Operating temperature range	-40 to 85	°C
Tstg	Storage temperature range	-55 to 125	°C

ELECTRICAL CHARACTERISTICS

Unless otherwise specified, Topt=25°C

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
V_{DD1}	Operating input voltage	Voltage defined as V_{DD}-V_{SS}	1.5		5.0	V
Vst	Minimum operating Voltage for 0V charging *Note 1	Voltage defined as V_{DD}-V-, V_{DD}-V_{SS}=0V			1.8	V
Vnochg	Maximum Battery Voltage level of low voltage battery charge inhibitory circuit *Note 2	Voltage defined as V_{DD}-V_{SS}, V_{DD}-V-=4V	0.7	1.1	1.5	V
V_{DET1}	Over-charge threshold	Detect rising edge of supply voltage R1=330Ω R1=330Ω (Topt=-5 to 55°C)*Note3	V_{DET1}-0.025 V_{DET1}-0.030	V_{DET1} V_{DET1}	V_{DET1}+0.025 V_{DET1}+0.030	V V
tV_{DET1}	Output delay of over-charge	V_{DD}=3.6V to 4.4V	tV_{DET1}×0.7	tV_{DET1}	tV_{DET1}×1.3	s
tV_{REL1}	Output delay of release from over-charge	V_{DD}=4V, V-=0V to 1V	12	17	22	ms
V_{DET2}	Over-discharge threshold	Detect falling edge of supply voltage	V_{DET2}×0.975	V_{DET2}	V_{DET2}×1.025	V
tV_{DET2}	Output delay of over-discharge	V_{DD}=3.6V to 2.2V	14	20	26	ms
tV_{REL2}	Output delay of release from over-discharge	V_{DD}=3V V-=3V to 0V	0.7	1.2	1.7	ms
V_{DET3}	Excess discharge-current threshold	Detect rising edge of 'V-' pin voltage	V_{DET3}-0.015	V_{DET3}	V_{DET3}+0.015	V
tV_{DET3}	Output delay of excess discharge-current	V_{DD}=3.0V, V-=0V to 1V	tV_{DET3}×2/3	tV_{DET3}	tV_{DET3}×4/3	ms
tV_{REL3}	Output delay of release from excess discharge-current	V_{DD}=3.0V, V-=3V to 0V	0.7	1.2	1.7	ms
Vshort	Short protection voltage	V_{DD}=3.0V	0.9	1.3	1.7	V
Tshort	Output Delay of Short protection	V_{DD}=3.0V, V-=0V to 3V	230	300	500	μs
Rshort	Reset resistance for Excess discharge-current protection	V_{DD}=3.6V, V-=1V	30	60	90	kΩ
V_{DS}	Output Delay Time Reduction Mode Voltage	V_{DD}=4.4V	-1.4	-2.0	-2.6	V
V_{OL1}	Nch ON voltage of COUT	Iol=50μA, V_{DD}=4.5V		0.2	0.5	V
V_{OH1}	Pch ON voltage of COUT	Ioh=-50μA, V_{DD}=3.9V	3.4	3.7		V
V_{OL2}	Nch ON voltage of DOUT	Iol=50μA, V_{DD}=2.0V		0.2	0.5	V
V_{OH2}	Pch ON voltage of DOUT	Ioh=-50μA, V_{DD}=3.9V	3.4	3.7		V
I_{DD}	Supply current	V_{DD}=3.9V, V- =0V		3.5*Note1 4.0*Note2	7.0*Note1 8.0*Note2	μA
I_S	Standby current	V_{DD}=2.0V			0.1	μA

*Note1: Specified for A version (0V Charge is acceptable.)

*Note2: Specified for B version (0V Charge is unacceptable.)

*Note3: We compensate for this characteristic related to temperature by laser-trim, however, this specification is guaranteed by design, not mass production tested.

OPERATION

- **VD1 / Over-Charge Detector**

The VD1 monitors V_{DD} pin voltage while charge the battery pack. When the V_{DD} voltage crosses over-charge detector threshold V_{DET1} from a low value to a value higher than the V_{DET1}, the VD1 can sense a over-charging and an external charge control Nch MOSFET turns off with C_{OUT} pin being at "L" level.

To reset the VD1 making the C_{OUT} pin level to "H" again after detecting over-charge, in such conditions that a time when the V_{DD} voltage is down to a level lower than over-charge voltage.
Connecting a kind of loading to V_{DD} after disconnecting a charger from the battery pack when the V_{DD} voltage is lower than Over-charge detector threshold, VD1 can be reset. Output voltage of C_{OUT} pin becomes "H", and it makes an external Nch MOSFET turn on, and charge cycle is available. In other words, once over-charge is detected, even the supply voltage becomes low enough, if a charger is continue to be connected to the battery pack, recharge is not possible. Therefore this over-charge detector has no hysteresis. 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.

After detecting over-charge with the V_{DD} voltage of higher than V_{DET1}, disconnecting a charger and connecting system load to the battery pack makes load current allowable through parasitic diode of external charge control FET.

The C_{OUT} level would be "H" when the V_{DD} level is down to a level below the V_{DET1} by continuous drawing of load current.

Internal fixed output delay times for over-charge detection and release from over-charge exist. Even when the V_{DD} level becomes a higher level than V_{DET1} if the V_{DD} voltage would be back to a level lower than the V_{DET1} within a time period of the output delay time, VD1 would not output a signal for turning off the charge control FET. Besides, after detecting over-charge, while the V_{DD} is lower than over-charge detector, even if a charger is removed and connect a load, when the voltage is recovered within output delay time of release from over-charge, over-charge state is not released.

A level shifter incorporated in a buffer driver for the C_{OUT} pin makes the "L" level of C_{OUT} pin to the V - pin voltage and the "H" level of C_{OUT} pin is set to V_{DD} voltage with CMOS buffer.

- **VD2 / Over-Discharge Detector**

The VD2 is monitoring a V_{DD} pin voltage. When the V_{DD} voltage crosses the over-discharge detector threshold V_{DET2} from a high value to a value lower than the V_{DET2}, the VD2 can sense an over-discharging and the external discharge control Nch MOSFET turns off with the D_{OUT} pin being at "L" level.

To reset the VD2 with the D_{OUT} pin level being "H" again after detecting over discharge, it is necessary to connect a charger to the battery pack. When the V_{DD} voltage stays under over-discharge detector threshold V_{DET2}, charge-current can flow through parasitic diode of an external discharge control MOSFET. Then after the V_{DD} voltage comes up to a value larger than V_{DET2}, D_{OUT} becomes "H" and discharging process would be able to advance through turning on MOSFET for discharge control.

Connecting a charger to the battery pack makes the D_{OUT} level being "H" instantaneously when the V_{DD} voltage is higher than V_{DET2}.

When a cell voltage equals to zero, operation varies and depends on the mask version.

A version (0V charge acceptable): the voltage of a charger is equal or more than 0V-charge minimum voltage (Vst), C_{OUT} pin becomes "H" and system allowable to charge

B Version (0V charge unacceptable): when the V_{DD} pin voltage is equal or lower than charge inhibitory maximum voltage (Vnochg), even a charger is connected to a battery pack, C_{OUT} pin is stacked at "L" and charge current cannot flow.

An output delay time for over-discharge detection is fixed internally. When the V_{DD} level is down to a lower level than V_{DET2} if the V_{DD} voltage would be back to a level higher than the V_{DET2} within a time period of the output delay time, VD2 would not output a signal for turning off the discharge control FET. Output delay time for release from over-discharge is also set typically at 1.2ms.

After detecting of over-discharge by VD2, supply current would be reduced to maximum 0.1μA at V_{DD}=2.0V and be into standby by halting all circuits and consumption current of IC itself is minimized.

The output type of D_{OUT} pin is CMOS having "H" level of V_{DD} and "L" level of V_{SS}.

- **VD3 /Excess discharge-current Detector, Short Circuit Protector**

Both of the excess current detector and short circuit protection can work when the both of control FETs are in "ON" state.

When the V- pin voltage is up to a value between the short protection voltage Vshort (Typ. 1.3V) and excess discharge-current threshold V_{DET3}, VD3 operates and further soaring of V- pin voltage higher than Vshort makes the short circuit protector enabled. This leads the external discharge control Nch MOSFET turns off with the D_{OUT} pin being at "L" level and prevents the circuit from a large current flowing. The output delay time for detecting excess discharge current is fixed at typically 1.2ms inside the IC.

A quick recovery of V- pin level from a value between Vshort and V_{DET3} within the delay time keeps the discharge control FET staying "H" state. Output delay time for Release from excess discharge-current detection is also set at typically 1.2ms.

When the short circuit protector is enabled, the D_{OUT} would be "L" and its delay time would be typically 300μs.

The V - pin has a built-in pulled down resistor, typically 60kΩ, with connecting to the V_{SS} pin.

After an excess discharge-current or short circuit protection is detected, removing a cause of excess discharge-current or external short circuit makes an external discharge control FET to an "ON" state automatically with the V- pin level being down to the V_{SS} level through built-in pulled down resistor.

When the V- pin voltage is equal or less than excess-discharge current detector threshold, the circuit is released from excess discharge or short circuit. The reset resistor of excess discharge-current is off at normal state. Only when detecting excess discharge-current or short circuit, the resistor is on.

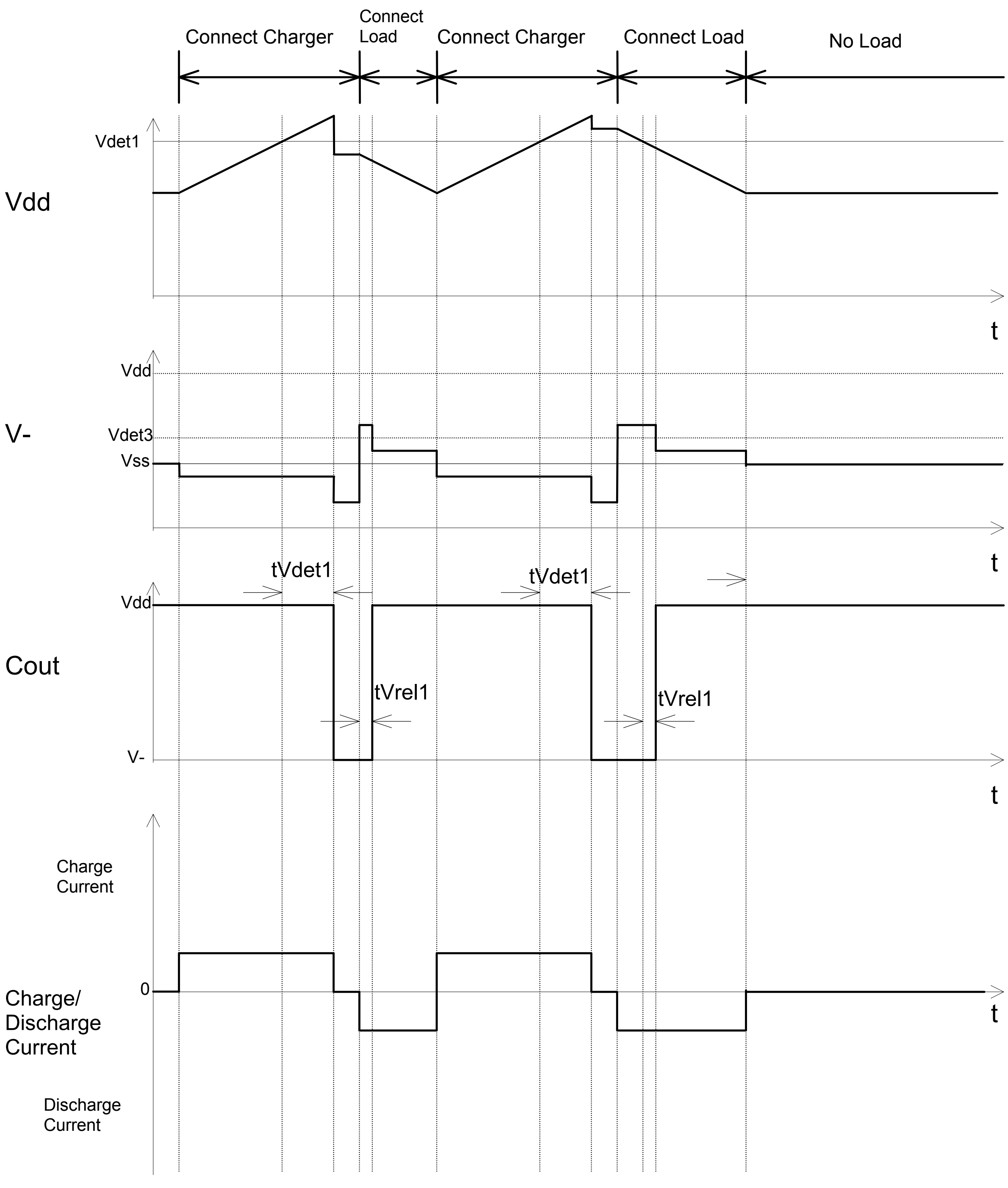
Output delay time of excess discharge-current is set shorter than the delay time for over-discharge detector. Therefore, if V_{DD} voltage would be lower than V_{DET2} at the same time as the excess discharge-current is detected, the R5400xxxxxx is at excess discharge-current detection mode. By disconnecting a load, VD3 is automatically released from excess discharge-current.

- **DS (Delay Shorten) function**

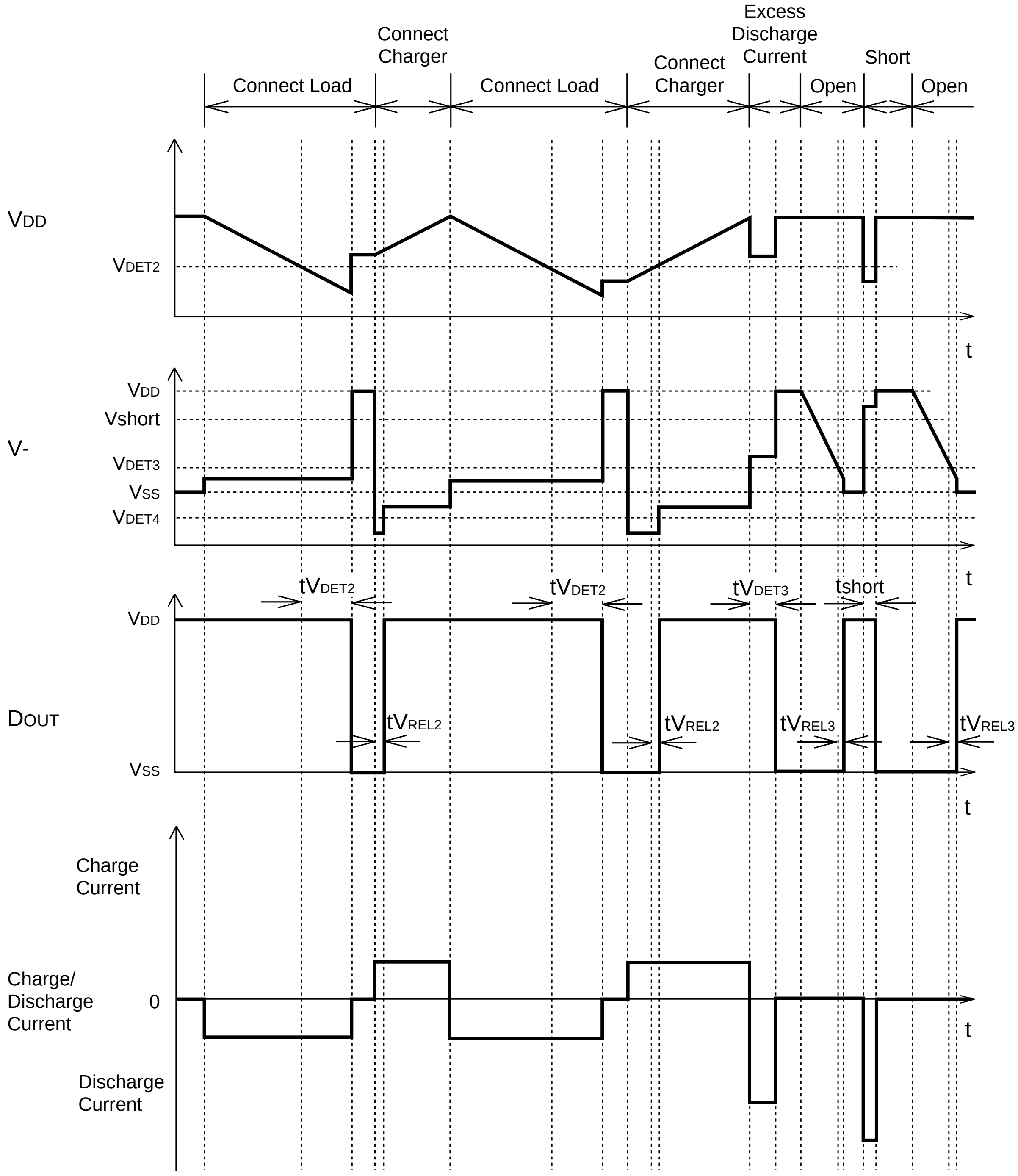
Output delay time of over-charge and over-discharge and release from those detecting modes can be shorter than those setting value by forcing the test shorten mode voltage, Typ. -2.0V or lower than that to V- pin.

TIMING CHART

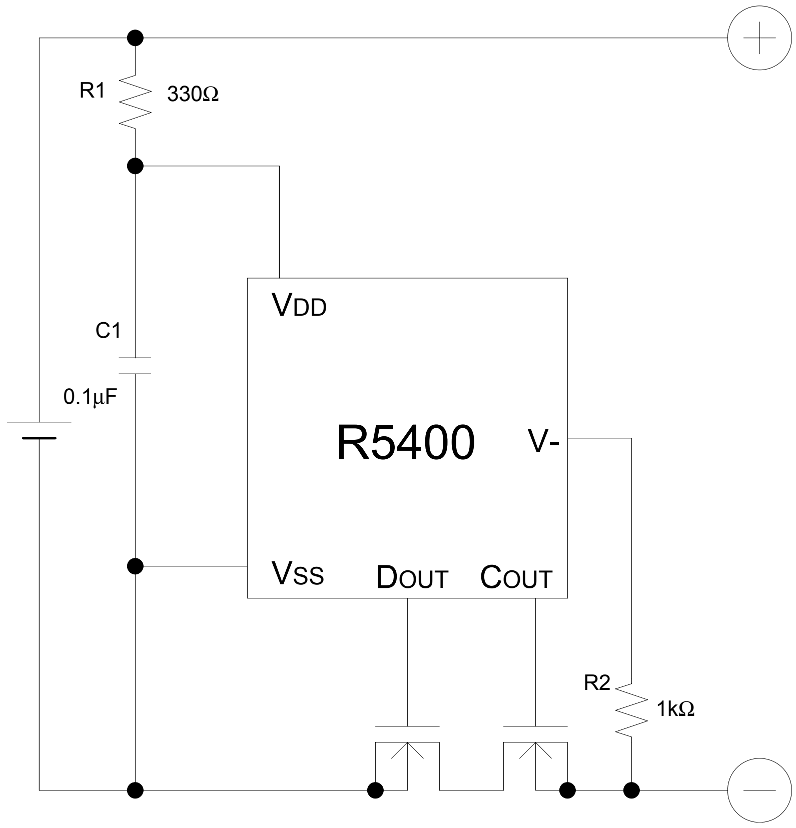
1. Detect and Release from Over-charge Operation



2. Over discharge, Excess-discharge current, Short-circuit operation



TYPICAL APPLICATION



APPLICATION HINTS

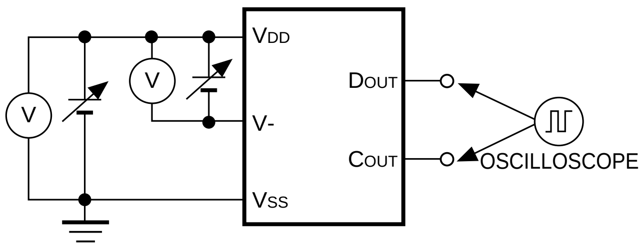
R1 and C1 will stabilize a supply voltage to the R5400xxxxxx. A recommended R1 value is less than 1kΩ.

A larger value of R1 leads higher detection voltage, makes some errors, because of conduction current flown at detecting operation of the R5400xxxxxx. For making stable operation, set C1 with a value of 0.01µF or more.

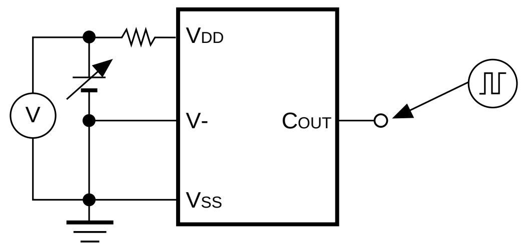
R1 and R2 can operate also as parts for current limit circuit against reverse charge or applying a charger with excess charging voltage to the battery pack. Small value of R1 and R2 may cause over-power consumption rating of power dissipation of the R5400xxxxx. Therefore, total value of 'R1+R2' should be equal or more than 1kΩ.

On the other hand, 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.

TEST CIRCUITS



A



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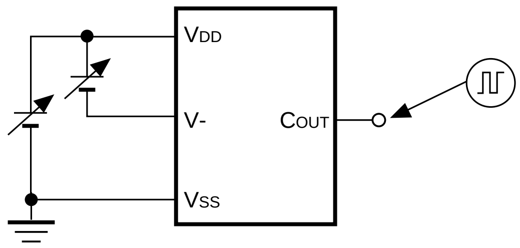
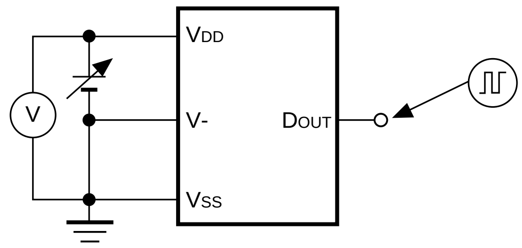


C



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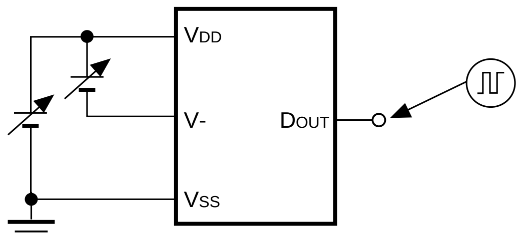

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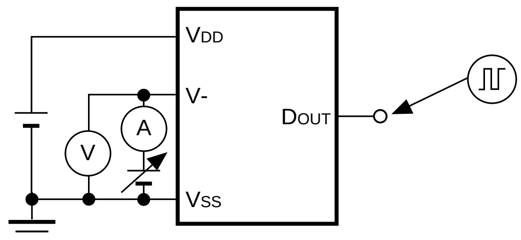

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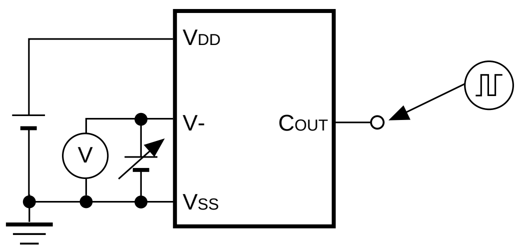

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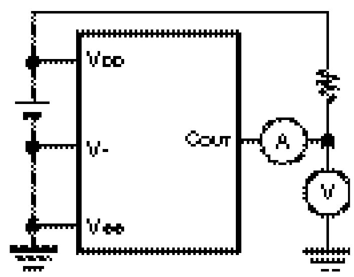
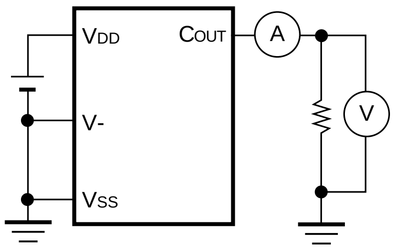


H



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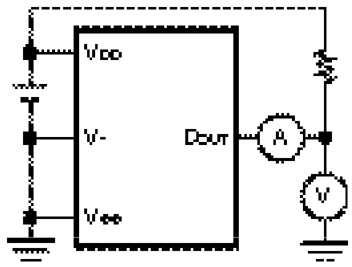

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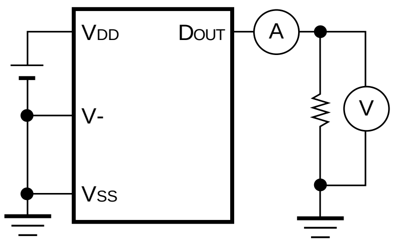

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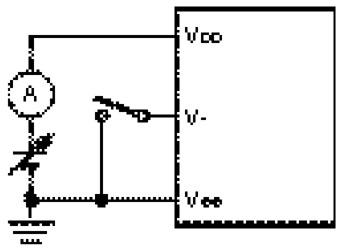


L

Typical Characteristics were obtained with using those above circuits:

Test Circuit A: Typical characteristics 1) 2)

Test Circuit B: Typical characteristics 3) 4)

Test Circuit C: Typical characteristics 5)

Test Circuit D: Typical characteristics 6) 7)

Test Circuit E: Typical characteristics 8)

Test Circuit F: Typical characteristics 9) 10) 11) 12) 13) 14)

Test Circuit G: Typical characteristics 15)

Test Circuit H: Typical characteristics 16)

Test Circuit I: Typical characteristics 17)

Test Circuit J: Typical characteristics 18)

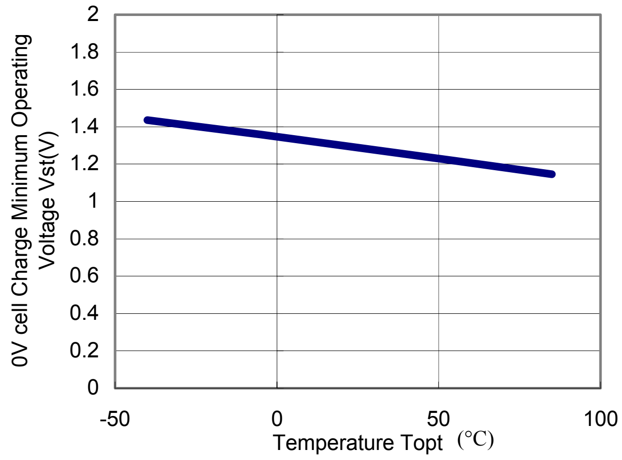
Test Circuit K: Typical characteristics 19)

Test Circuit L: Typical characteristics 20) 21) 22)

TYPICAL CHARACTERISTICS (Part 1: Temperature Characteristics)

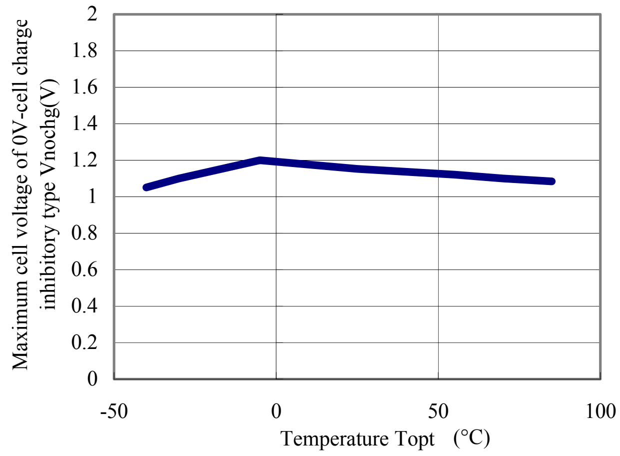
1) Minimum Operating Voltage for 0V Cell Charging vs. Temperature

R5400x105CA Vdd-Vss=0V



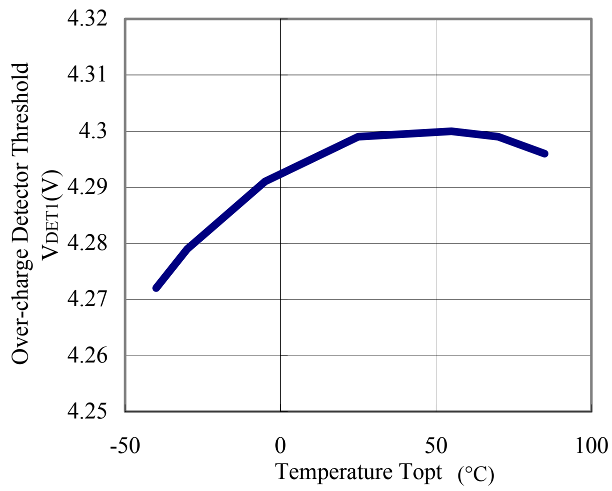
2) Maximum Battery Voltage Level for Low Voltage Battery Charge Inhibitory Circuit vs. Temperature

R5400x105CB Vdd-V-=4V



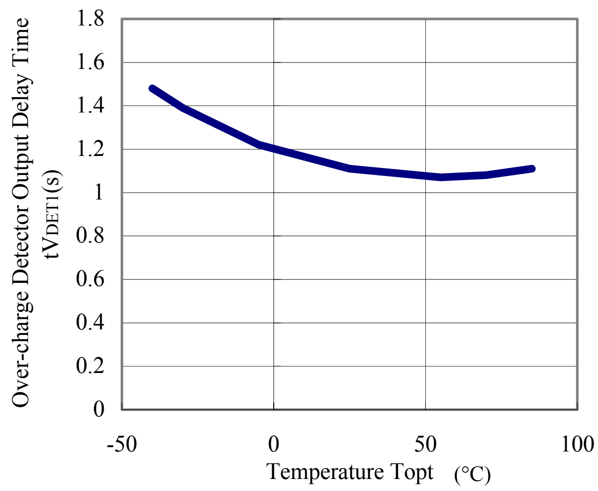
3) Over-Charge Threshold vs. Temperature

R5400x105CA



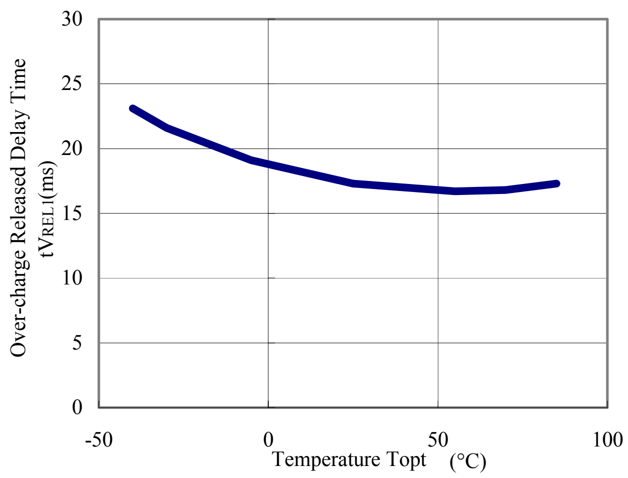
4) Output Delay of Over-charge vs. Temperature

R5400x105CA



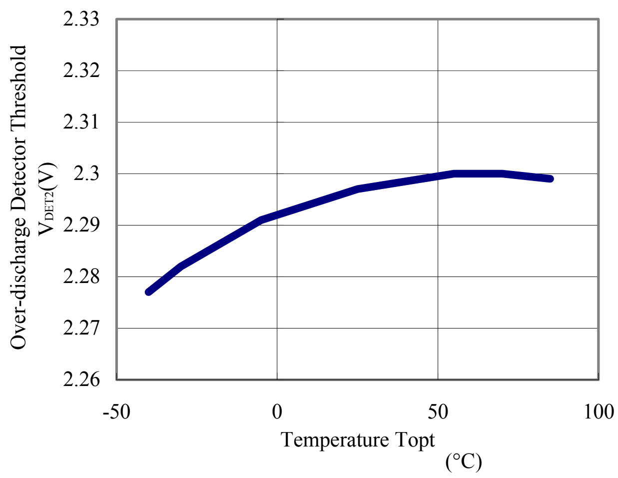
5) Output Delay of Release from Over-charge vs. Temperature

R5400x105CA



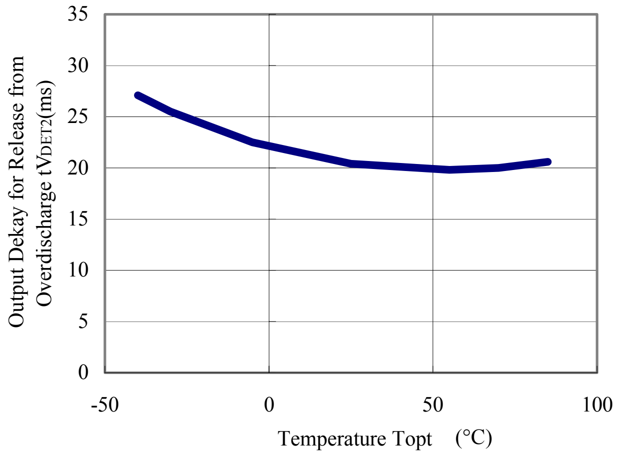
6) Over discharge Threshold vs. Temperature

R5400x105CA



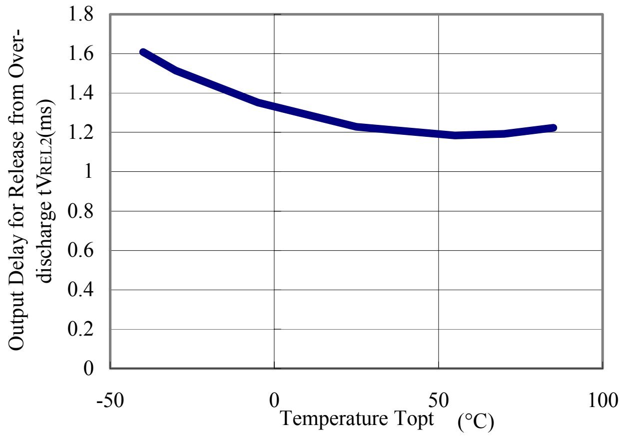
7) Output Delay of Over-discharge vs. Temperature

R5400x105CA



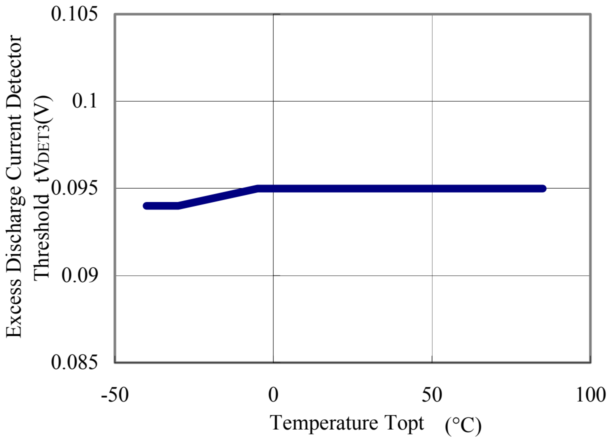
8) Output Delay of Release from Over-discharge vs. Temperature

R5400x105CA



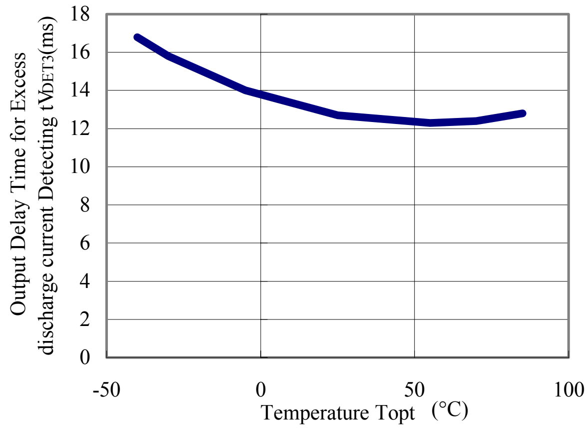
9) Excess Discharge-current Threshold vs. Temperature

R5400x105CA



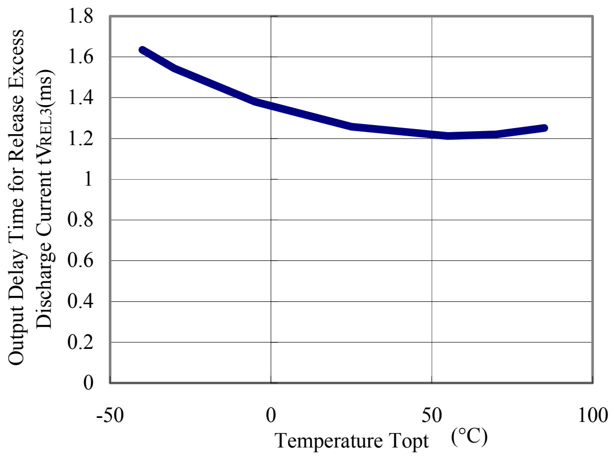
10) Output Delay of Excess Discharge-current vs. Temperature

R5400x105CA



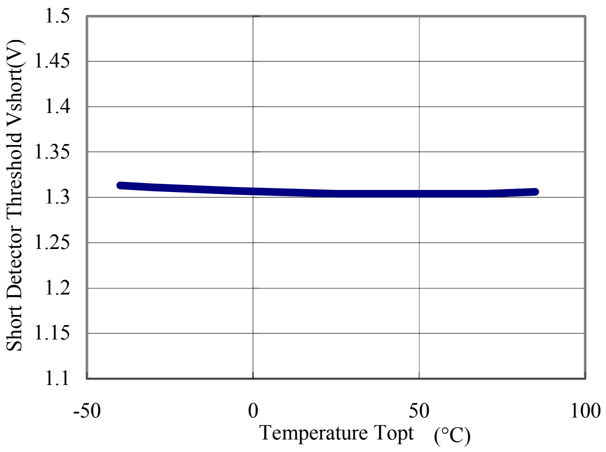
11) Output Delay of Release from Excess Dicharge-current vs. Temperature

R5400x105CA



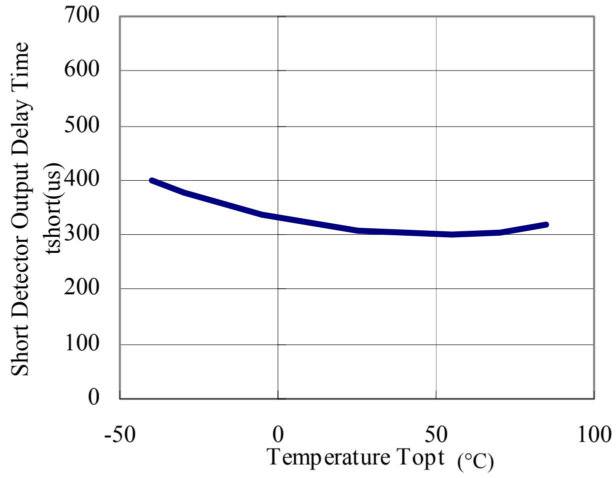
12) Short Detector Voltage vs. Temperature

R5400x105CA



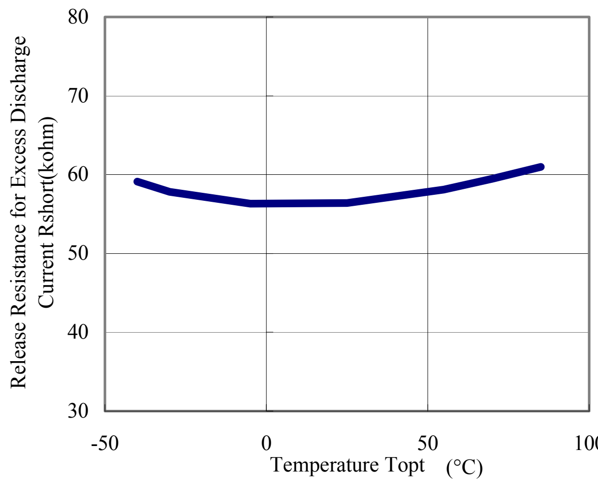
13) Output Delay of Short Protection vs. Temperature

R5400x105CA



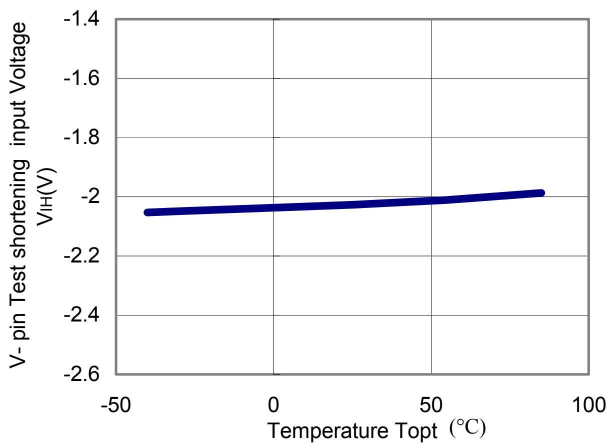
14) Reset Resistance for Excess Discharge current Protection vs. Temperature

R5400x105CA



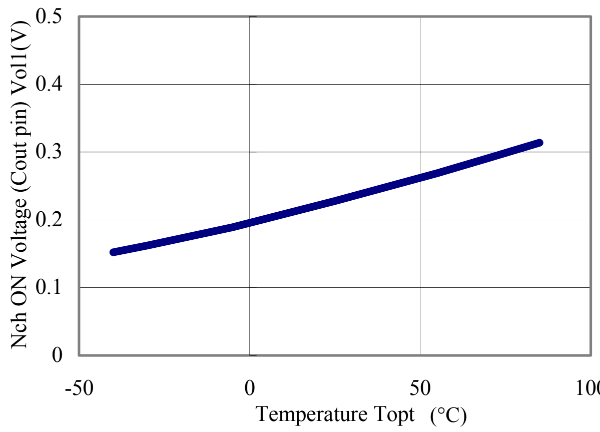
15) V- pin Test time shortening input Voltage vs. Temperature

R5400x105CA



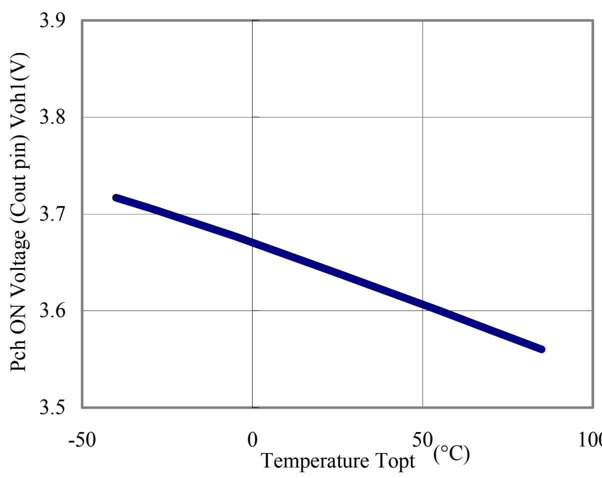
16) Nch On Voltage (COUT pin) vs. Temperature
IOL=50uA,Vdd=4.5V

R5400x105CA



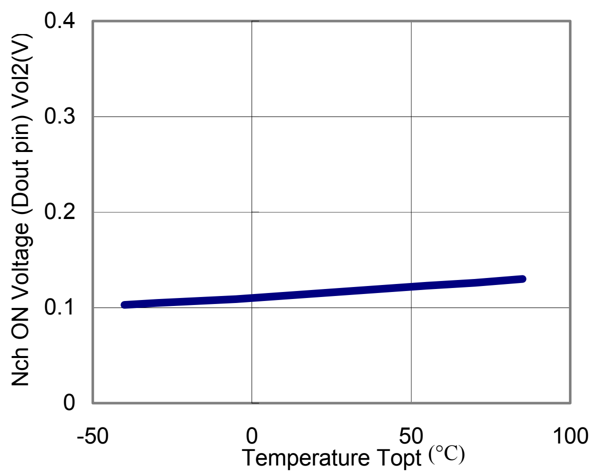
17) Pch On Voltage (COUT pin) vs. Temperature
Ioh=-50uA, Vdd=3.9V

R5400x105CA



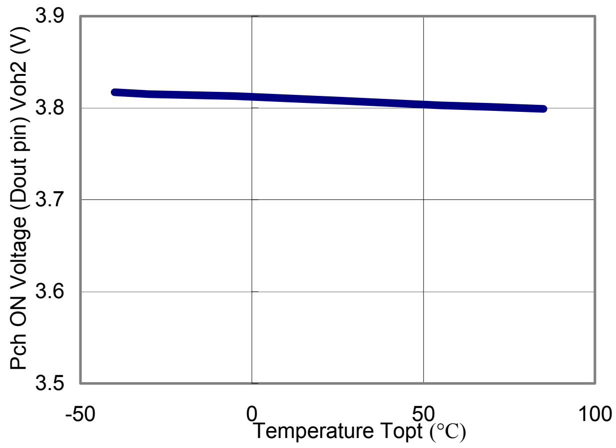
18) Nch On Voltage (DOUT pin) vs. Temperature
Iol=50uA, VDD=2V

R5400x105CA



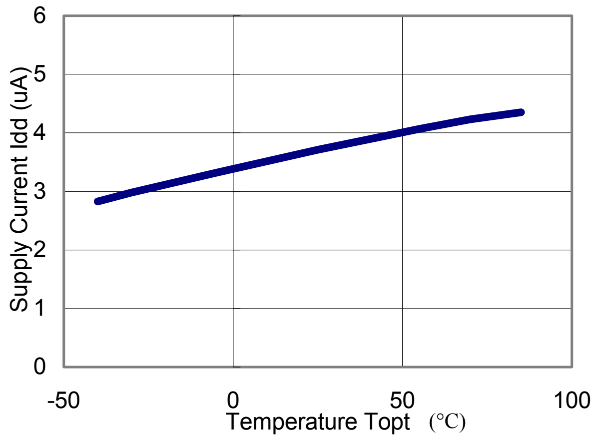
19) Pch ON Voltage of D_{OUT} vs. Temperature
Ioh=-50uA, Vdd=3.9V

R5400x105CA



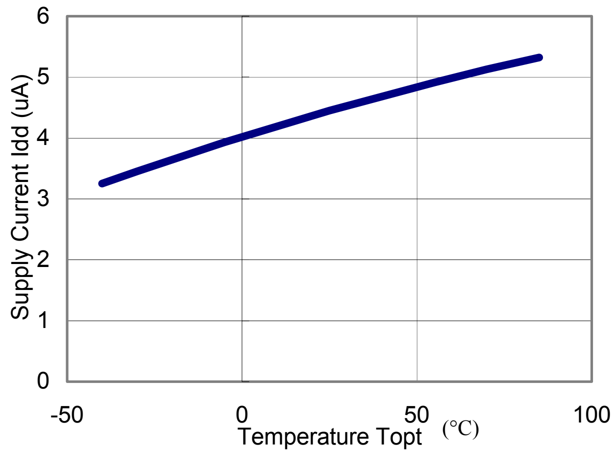
20) Supply Current vs. Temperature
Vdd=3.9V, V-=0V

R5400x105CA



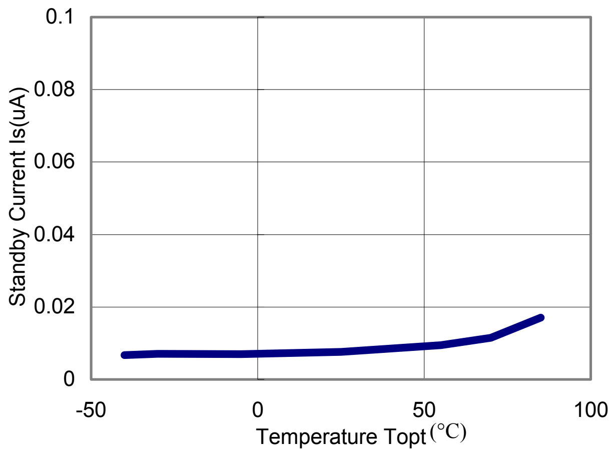
21) Supply Current vs. Temperature
Vdd=3.9V, V-=0V

R5400x105CB



22) Standby Current vs. Temperature
Vdd=2.0V

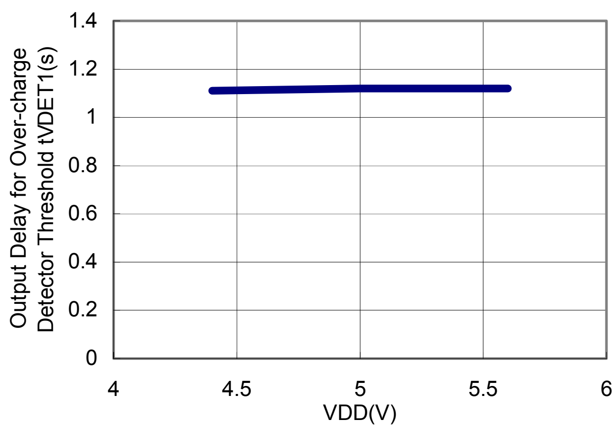
R5400x105CA



Part 2 Delay Time dependence on V_{DD}

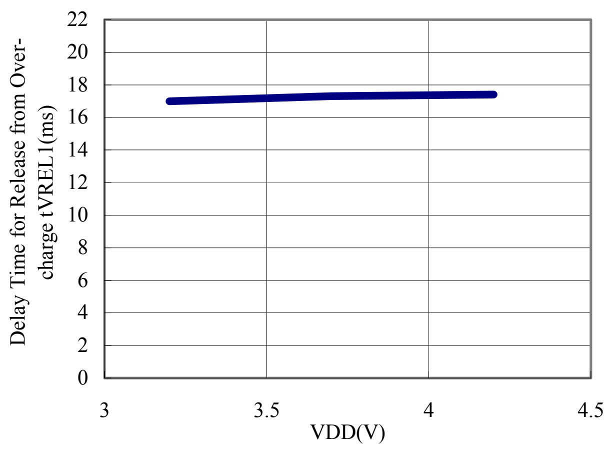
1) Delay Time for Over-charge detect vs. V_{DD}
V-=0V,Vdd=3.6V to 4.4V, 5.0V, 5.6V

R5400x105CA



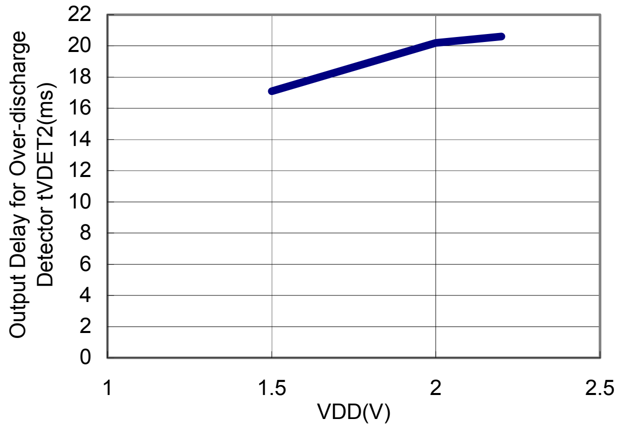
2) Delay Time for Release from Over-charge vs. V_{DD}
Vdd=3.2V, 3.7V, 4.2V, V-=0V to 1V

R5400x105CA



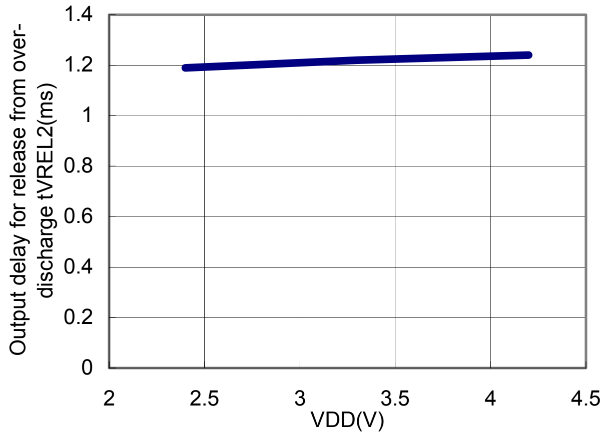
3) Output Delay of Over-discharge detect vs. V_{DD}
V-=0V, Vdd=3.6V to 2.2V, 2.0V, 1.5V

R5400x105CA



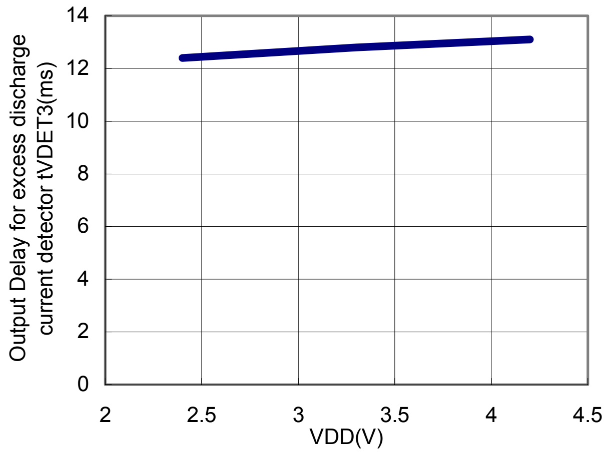
4) Output Delay for Release from Over-discharge vs. V_{DD}
V-=0V, Vdd=2.2V to 2.4V, 3.3V, 4.2V

R5400x105CA



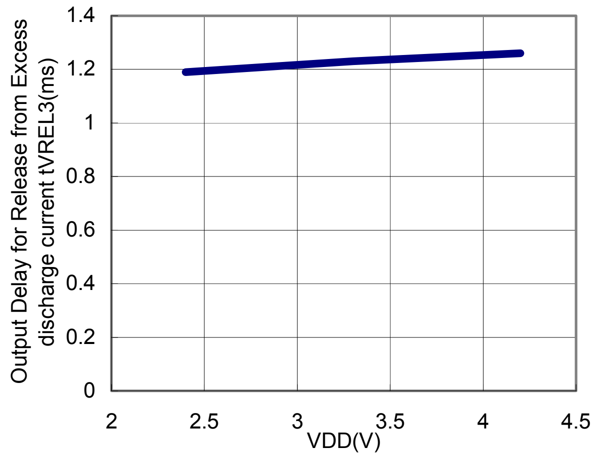
5) Output Delay for Excess Discharge Current vs. V_{DD}
V_{DD}=2.4V, 3.3V, 4,2V, V-=0V to 1V

R5400x105CA



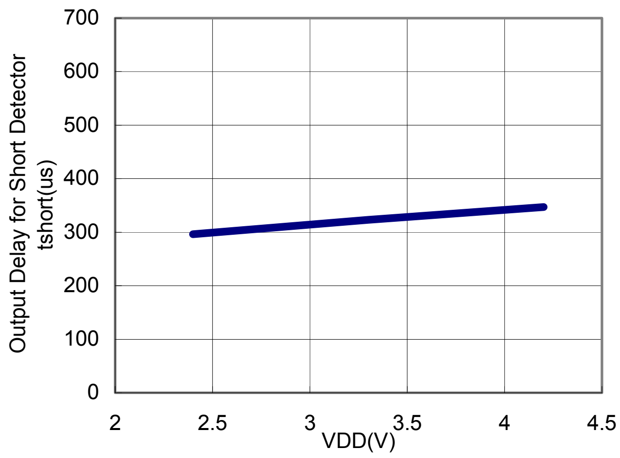
6) Output Delay for Release from Excess Discharge Current Detect vs. V_{DD}
VDD=2.4V, 3.3V, 4.2V, V-=2.4V, 3.3V, 4.2V to 0V

R5400x105CA



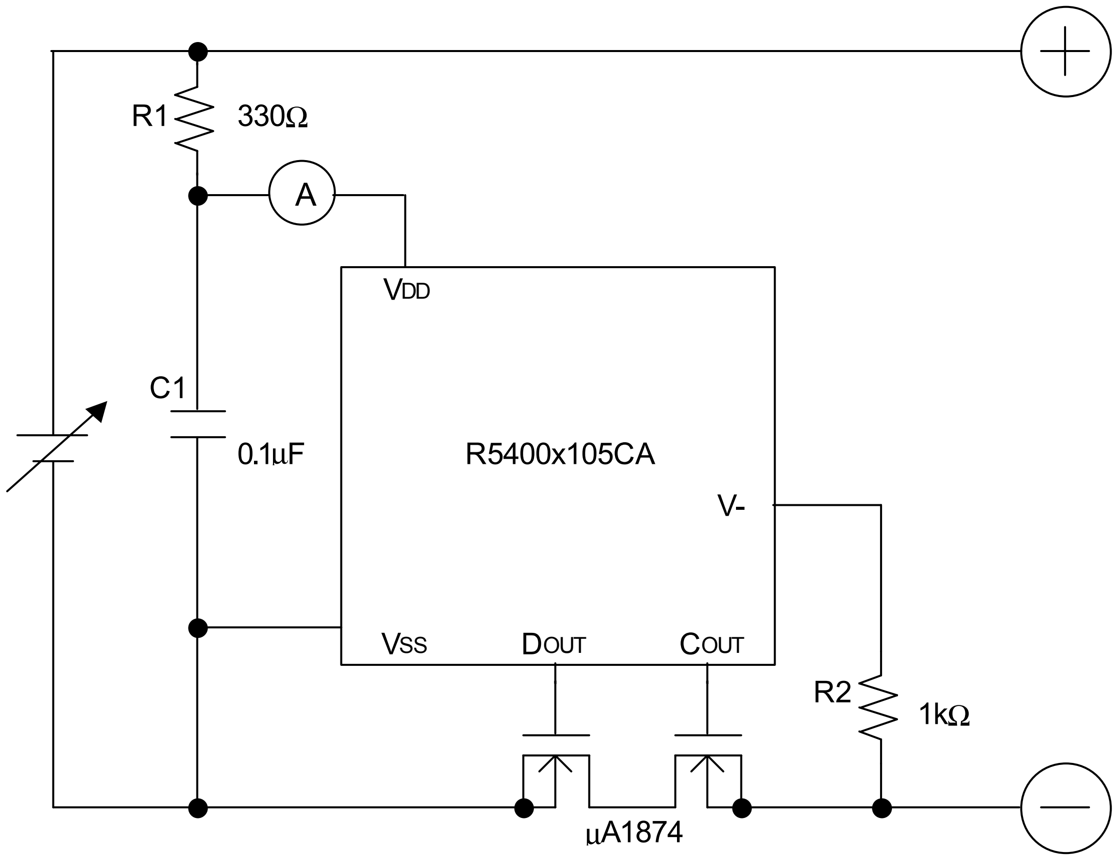
7) Output Delay for Short Detector vs. V_{DD}
V_{DD}=2.4V, 3.3V, 4.2V, V-=0V to 2.4V, 3.3V, 4.2V

R5400x105CA

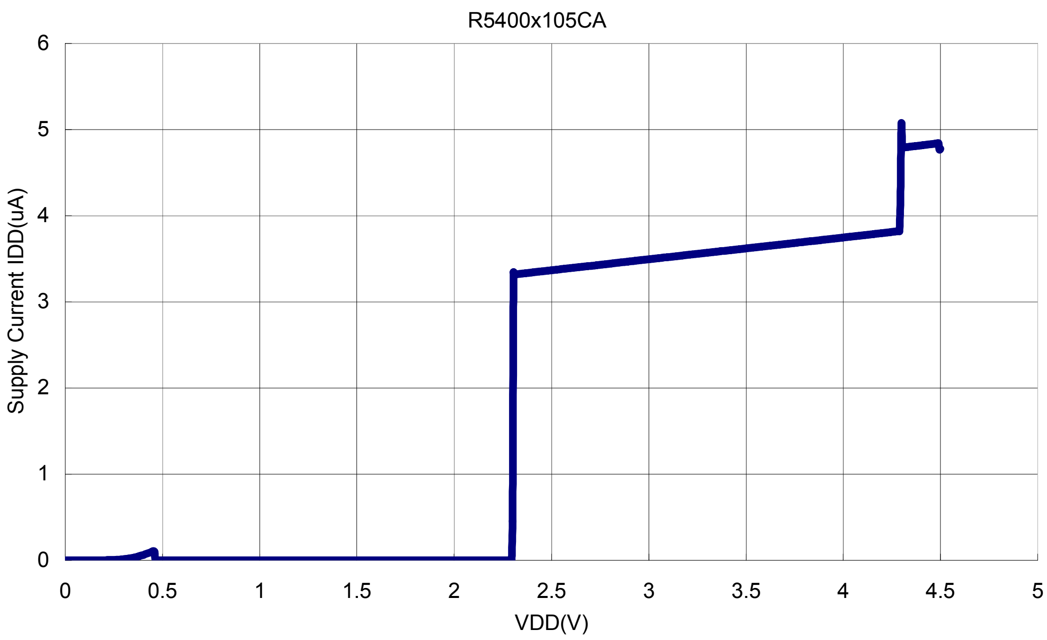


Part 3 Supply Current dependence on V_{DD}

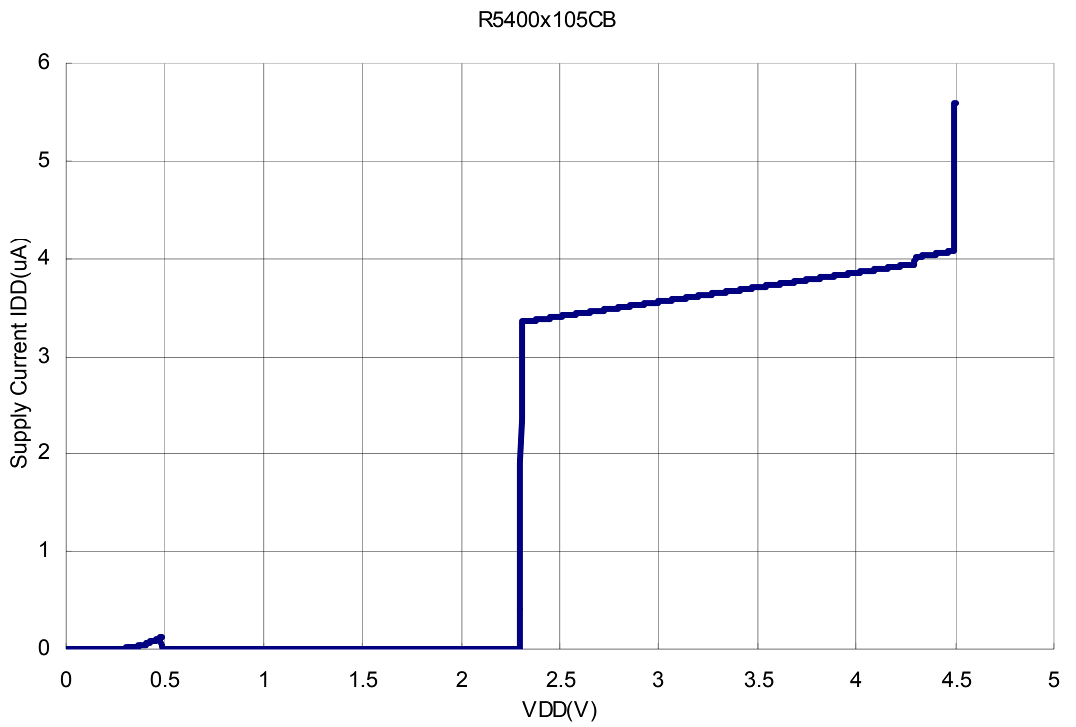
Test Circuit



Supply Current vs. V_{DD}

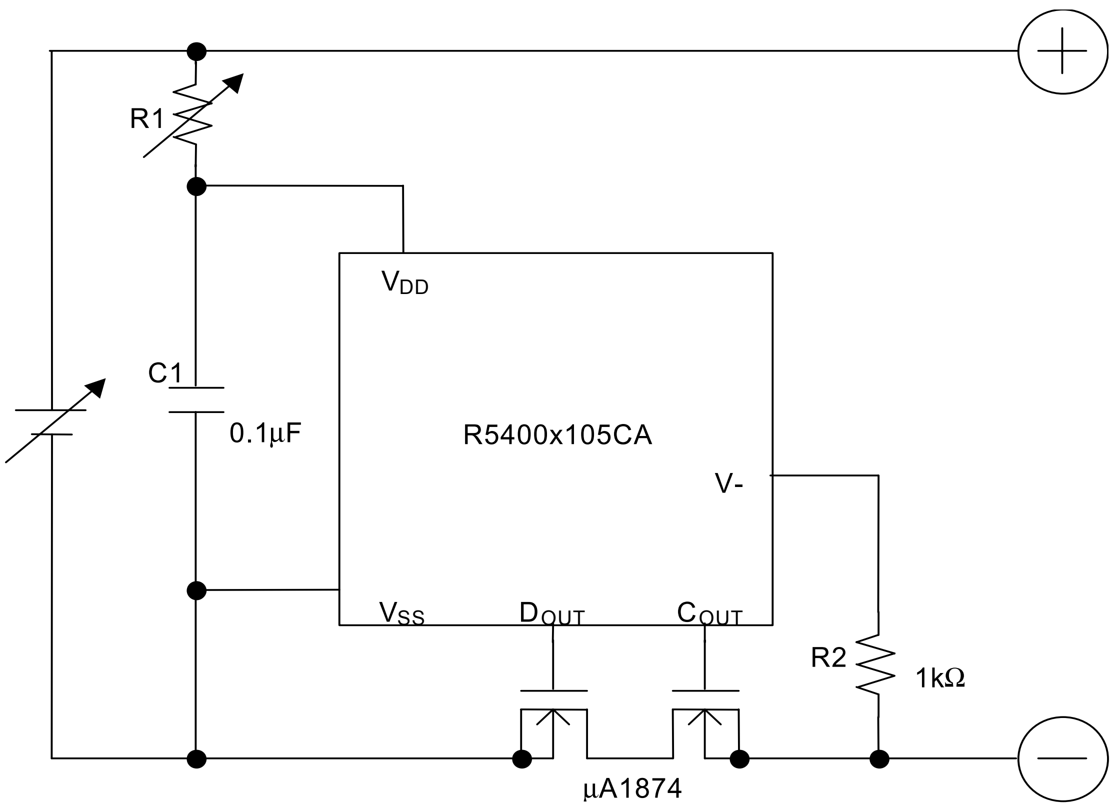


RICOH

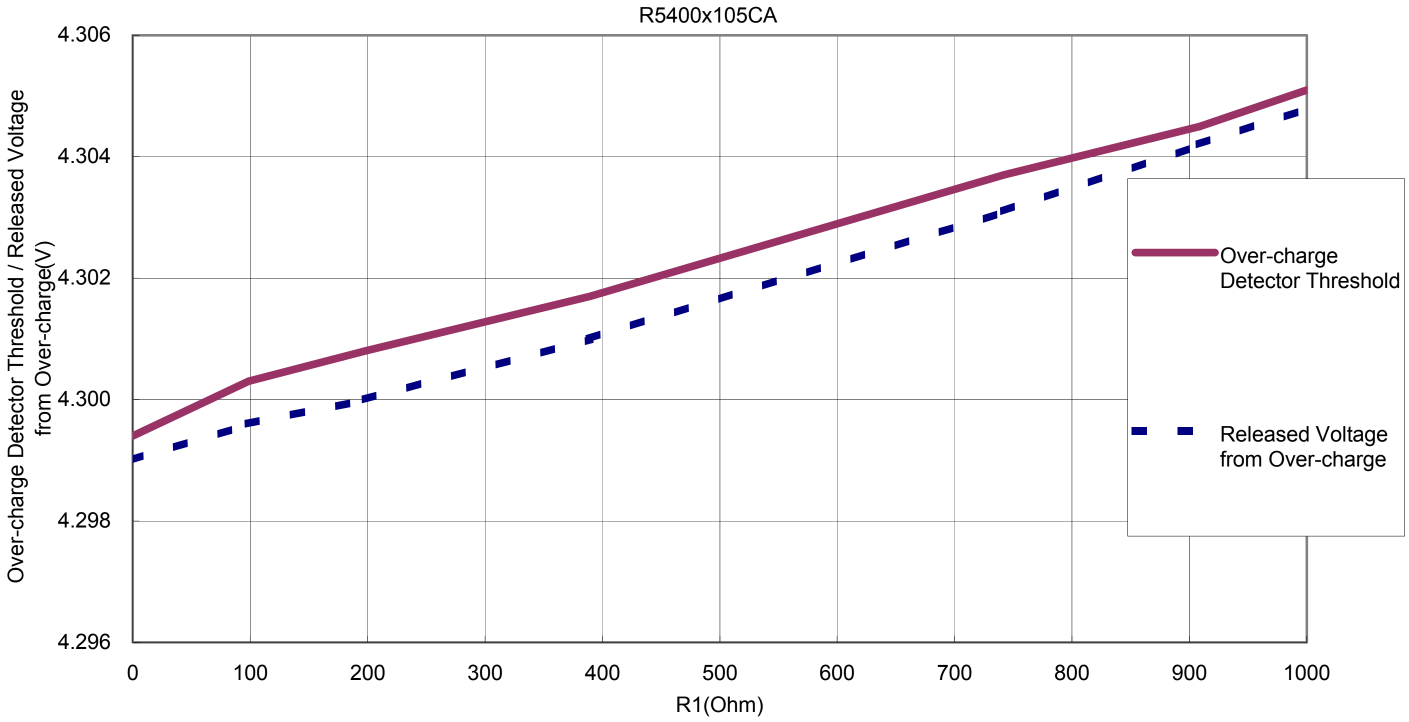


Part 4 Over-charge detector, Release voltage from Over-charge, Over-discharge detector, Release voltage from Over-discharge dependence on External Resistance value

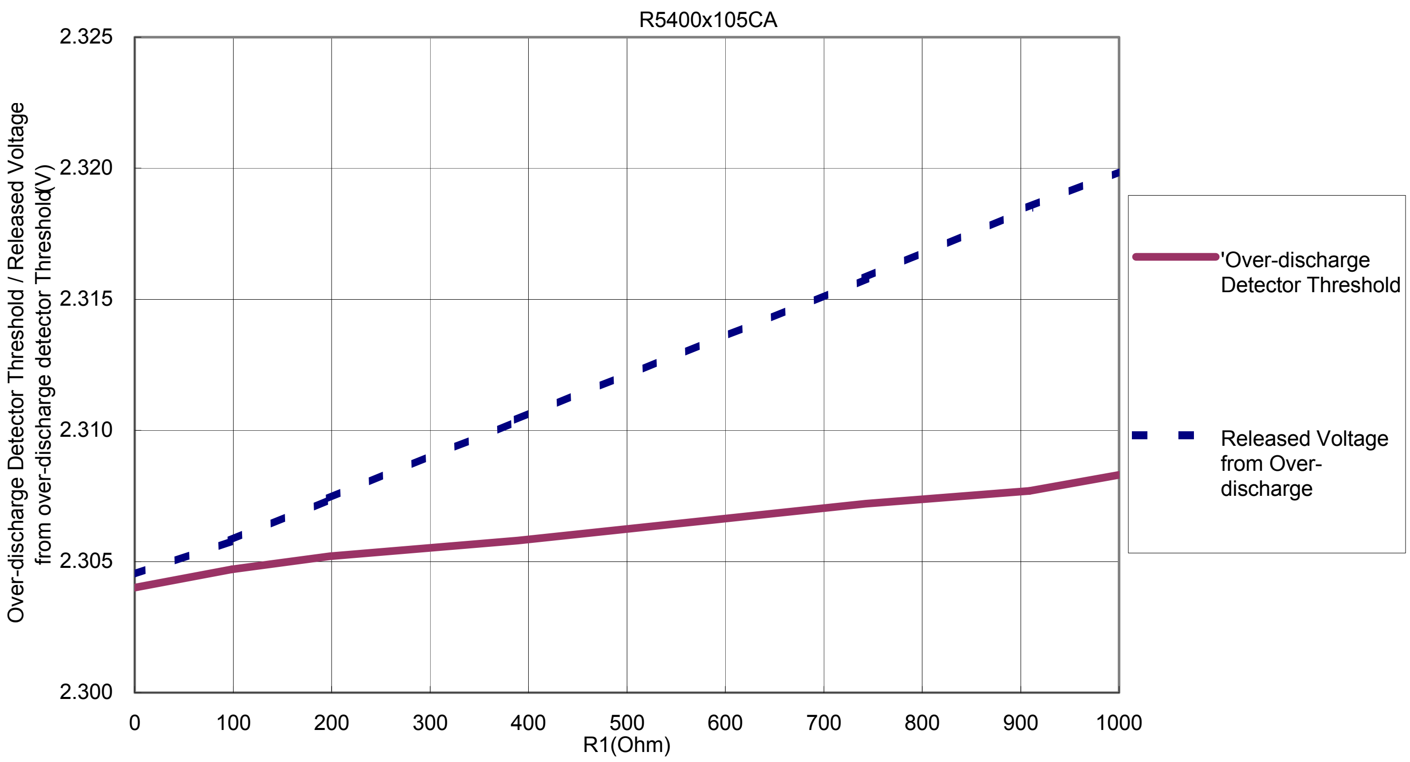
Test Circuit



Over-charge Detector Threshold / Released Voltage from Over-charge vs. R1

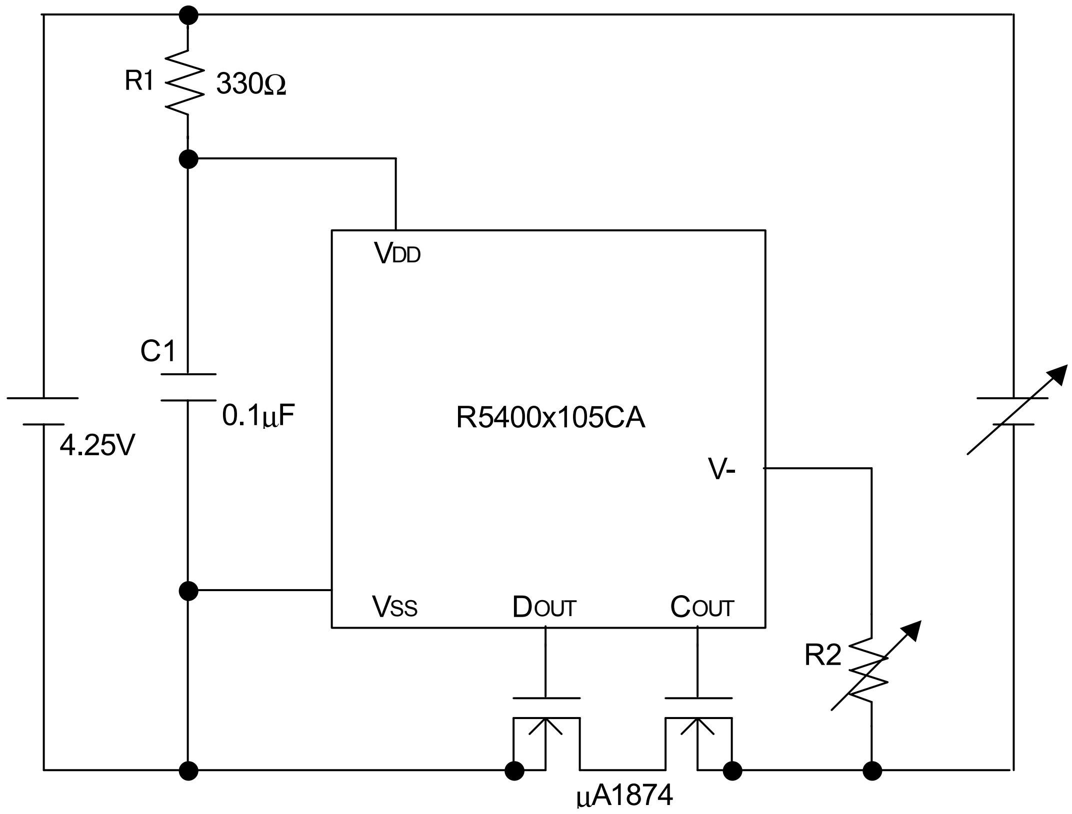


Over-discharge / Released from Over-discharge Threshold vs. R1



Part 5 Charger Voltage at Released from Over-discharge with a Charger dependence on R2

Test Circuit



Charger Voltage at Release from Over-discharge with a charger vs. R2