RICOH

R5403x/R5405x SERIES

Li-ION/POLYMER 1CELL PROTECTOR

NO. EA-215-120911

OUTLINE

The R5403x Series and the R5405x Series are high voltage CMOS-based protection ICs for over-charge/discharge of rechargeable one-cell Lithium-ion/Lithium polymer excess load current, further include a short circuit protector for preventing large external short circuit current and excess charge/discharge-current.

Each of these ICs is composed of four voltage detectors, reference units, a delay circuit, a short circuit protector, an oscillator, a counter, and logic circuits.

The output of Over-charge detector or Excess charge-current detector switches to "L" level after internally fixed delay time, when discharged voltage crosses the detector threshold from a low value to a high value.

They have two types to release Over-charge detector. The one is called "Latch type". The output of C_{OUT} switches to "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.

The other is called "Auto Release type". The output of C_{OUT} switches to "H", when the cell voltage is lower than over-charge detector threshold, or by disconnecting a charger.

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

They have two types to release Over-discharge detector.

The one is called "Latch type". The output of D_{OUT} switches to "H" by connecting a charger to the battery pack when the battery supply voltage becomes higher than the over-discharge detector threshold.

The other is called "Auto Release type", in case that the charger is not connected, when the cell voltage becomes equal released voltage from over-discharge detector is released. In case that a charger is connected, and when the cell voltage becomes higher than the over-discharge detector threshold, or becomes released voltage from over-discharge without connecting a charger, the over-discharge detector is released.

Even if the battery is discharged to 0V, charge current is normally acceptable. However, KF version and KG version are 0V batteries unacceptable types.

An excess discharge-current and short circuit state can be sensed and cut off through the built in excess current detector with D_{OUT} being enabled to low level. Once after detecting excess discharge-current or short circuit 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 output of C_{OUT} is "H", if V- pin level is set at V_{SS}–2V or lower, the delay time of detector 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} are CMOS.

The R5403x Series have SOT-23-5 and DFN(PLP)1820-6.

The R5405x Series have SOT-23-6 and DFN(PLP)1616-6 and DFN1814-6.

FEATURES

Manufactured with High Voltage Tolerant Process

- Absolute Maximum Rating 30V

Low supply current

- Supply current (At normal mode) .....Typ. 4.0μA
- At detecting over-discharge.....Max. 0.1μA (Over-discharge Latch type)
  Max. 2.0μA (Over-discharge Auto-release type)

High accuracy detector threshold

- Over-charge detector .....±25mV (T_{opt}=25°C)
  .....±30mV (T_{opt}=−5°C to 55°C)
- Over-discharge detector.....±2.5%
- Excess discharge-current detector.....±15mV

Variety of detector threshold

- Over-charge detector threshold.....4.0V to 4.5V step of 0.005V
- Over-discharge detector threshold.....2.0V to 3.0V step of 0.100V
- Excess discharge-current threshold.....0.05V to 0.20V step of 0.005V
- Excess charge-current threshold .....−0.05V to −0.20V step of 0.005V

Internal fixed Output delay time

- Over-charge detector Output Delay 1.0s
- Over-discharge detector Output Delay.....20ms
- Excess discharge-current detector Output Delay ...6ms/12ms
- Excess charge-current detector Output Delay 8ms/16ms
- Short Circuit detector Output Delay 200μs/300μs/400μs

Output Delay Time Shortening Function

At C_{OUT} is "H", if V- level is set at typically –2V, the Output Delay time of all items except short-circuit can be reduced. (Delay Time for over-charge becomes about 1/60 of normal state.)

- 0V-battery charge option .....Acceptable/Unacceptable
- Conditions for release over-charge detector.....Latch type/Auto Release type
- Conditions for release over-discharge detector .....Latch type /Auto Release type

Ultra Small package

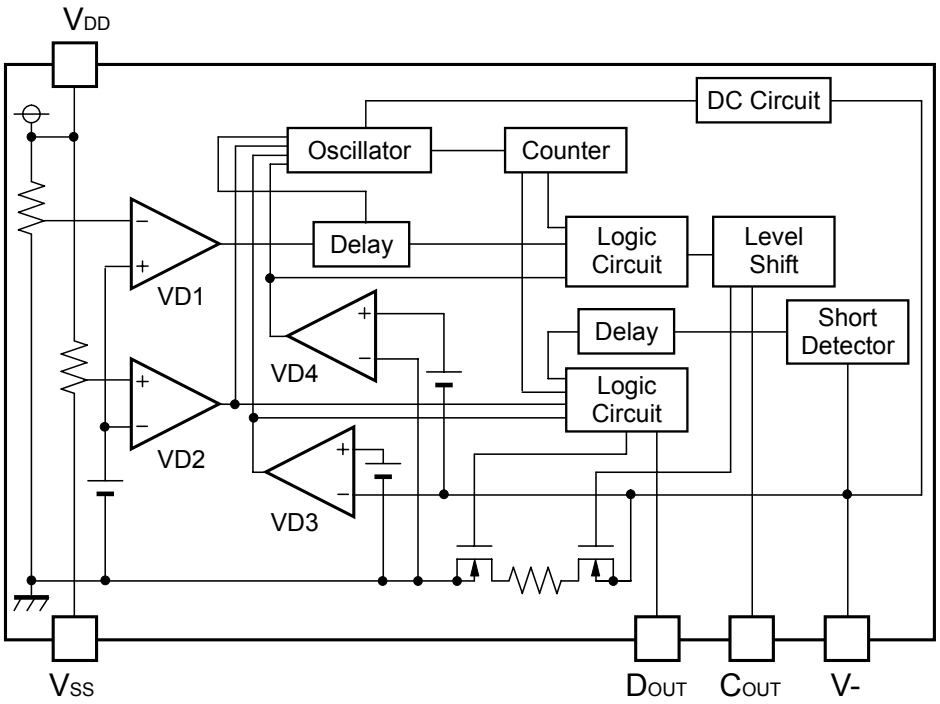
- The R5403x Series have SOT-23-5 and DFN(PLP)1820-6.
- The R5405x Series have SOT-23-6 and DFN(PLP)1616-6 and DFN1814-6.

APPLICATIONS

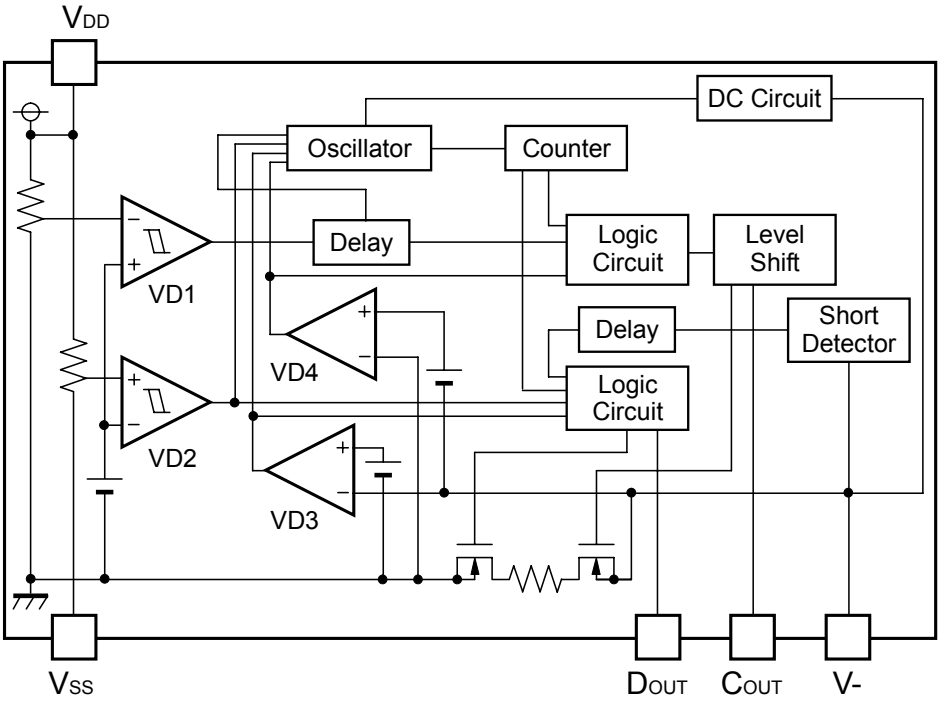
- Power source for portable communication equipment.
- Power source for electrical appliances such as cameras, VCRs and camcorders
- Power source for battery-powered equipment.

BLOCK DIAGRAMS

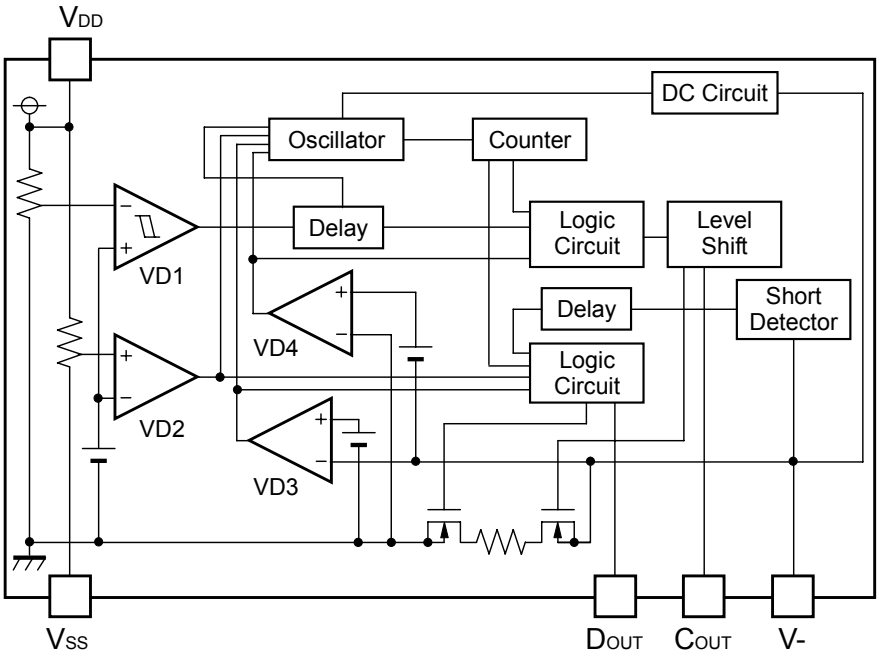
- **R5403/05xxxxCC, R5405xxxxEC, R5403/05xxxxKG, R5403/05xxxPG**



- **R5403/05xxxxKD, R5403/05xxxxKF**



- **R5403/05xxxxKE**



SELECTION GUIDE

The voltage version, on, and package. for the ICs can be selected at the user's request.

Product Name	Package	Quantity per Reel	Pb Free	Halogen Free
R5403Kxxx $*-TR	DFN(PLP)1820-6	5,000pcs	Yes	Yes
R5403Nxxx $*-TR-FE	SOT-23-5	3,000pcs	Yes	Yes
R5405Kxxx $*-TR	DFN(PLP)1616-6	5,000pcs	Yes	Yes
R5405Nxxx $*-TR-FE	SOT-23-6	3,000pcs	Yes	Yes
R5405Lxxx $*-TR	DFN1814-6	5,000pcs	Yes	Yes

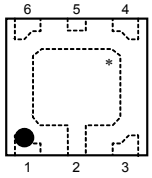
xxx : Setting voltage version
$: Designation of delay time version
* : Designation of Function version

Version	Over-Charge	Over-Discharge	0V Charge
C	Latch	Latch	OK
D	Auto-Release	Auto-Release	OK
E	Auto-Release	Latch	OK
F	Auto-Release	Auto-Release	NG
G	Latch	Latch	NG

PIN CONFIGURATIONS

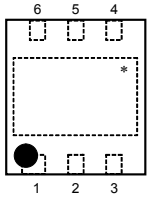
● **DFN(PLP)1616-6**

R5405K



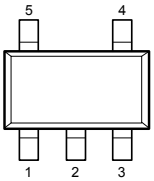
● **DFN(PLP)1820-6**

R5403K



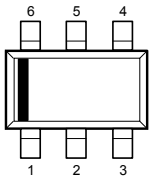
● **SOT-23-5**

R5403N

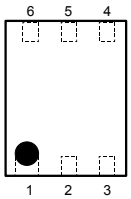


● **SOT-23-6**

R5405N



● **DFN1814-6**



PIN DESCRIPTIONS

Pin No.					Symbol	Description
R5405K	R5403K	R5403N	R5405N	R5405L		
DFN(PLP)1616-6	DFN(PLP)1820-6	SOT-23-5	SOT-23-6	DFN1814-6		
3	1	1	2	6	V-	Pin for charger negative input
2	5	2	5	5	V_{DD}	Power supply pin, the substrate voltage level of the IC
4	2	5	3	2	C_{OUT}	Output of over-charge detection, CMOS output
6	3	4	1	3	D_{OUT}	Output of over-discharge detection, CMOS output
5	6	–	4	1	NC	No Connection
1	4	3	6	4	V_{SS}	V_{SS} pin. Ground pin for the IC

∗) Tab is V_{DD} level. (They are connected to the reverse side of this IC.)
The tab is better to be connected to theV_{DD}, but leaving it open is also acceptable.

ABSOLUTE MAXIMUM RATINGS

Symbol	Item	Rating	Unit
V_{DD}	Input Voltage	−0.3 to 12.0	V
V-	Input Voltage V- pin	V_{DD}−30 to V_{DD}+0.3	V
V_{COUT}	Output Voltage (C_{OUT} pin)	V_{DD}−30 to V_{DD}+0.3	V
V_{DOUT}	Output Voltage (D_{OUT} pin)	V_{DD}−30 to V_{DD}+0.3	V
P_D	Power Dissipation (DFN(PLP)1616-6)*	640	mW
	Power Dissipation (DFN(PLP)1820-6)*	880	
	Power Dissipation (SOT-23-5)	420	
	Power Dissipation (SOT-23-6)	420	
Topt	Operating Temperature Range	−40 to 85	°C
Tstg	Storage Temperature Range	−55 to 125	°C

∗) For Power Dissipation, please refer to PACKAGE INFORMATION.

ABSOLUTE MAXIMUM RATINGS

Electronic and mechanical stress momentarily exceeded absolute maximum ratings may cause the permanent damages and may degrade the life time and safety for both device and system using the device in the field. The functional operation at or over these absolute maximum ratings is not assured.

ELECTRICAL CHARACTERISTICS

- **Topt=25°C**

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*1	Voltage defined as V_{DD}-V-, V_{DD}-V_{SS}=0V			1.8	V
Vnochg	Maximum voltage for inhibit charger*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)*3	 V_{DET1}−0.025 V_{DET1}−0.030	 V_{DET1} V_{DET1}	 V_{DET1}+0.025 V_{DET1}+0.030	 V V
V_{REL1}	Over-charge detector released voltage	R1=330Ω	V_{REL1}−0.05	V_{REL1}	V_{REL}+0.05	V
tV_{DET1}	Output delay of over-charge	V_{DD}=3.6V to 4.4V V_{DD}=3.6V to 4.6V*12	0.7	1.0	1.3	s
tV_{REL1}	Output delay of release from over-charge	V_{DD}=4.0V, V−=0V to 1V V_{DD}=4.5V to 3.6V*4 V_{DD}=4.6V to 3.6V*12	11	16	21	ms
V_{DET2}	Over-discharge threshold	Detect falling edge of supply voltage	V_{DET2}×0.975	V_{DET2}	V_{DET2}×1.025	V
V_{REL2}	Released Voltage from Over-discharge	Detect rising edge of supply voltage	V_{REL2}×0.975	V_{REL2}	V_{REL2}×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}=3.0V, V-=3V to 0V V_{DD}=3.1V, V-=3.1V to 0V*11 V_{DD}=2.2V to 3.1V*5 V_{DD}=2.2V to 3.5V*13 V_{DD}=3.3V, V-=3.3V to 0V*14	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 0.5V V_{DD}=3.1V, V-=0V to 0.5V*11, 13 V_{DD}=3.3V, V-=0V to 0.5V*14	4 8 12	6*7 12*8 18*15	8 16 24	ms
tV_{REL3}	Output delay of release from excess discharge-current	V_{DD}=3.0V, V-=3.0V to 0V V_{DD}=3.1V, V-=3.1V to 0V*11 V_{DD}=3.1V, V-=3.0V to 0V*13 V_{DD}=3.3V, V-=3.3V to 0V*14	0.7	1.2	1.7	ms
V_{DET4}	Excess charge-current threshold	Detect falling edge of V- pin voltage	V_{DET4}−0.03	V_{DET4}	V_{DET4}+0.03	V
tV_{DET4}	Output delay of excess charge-current	V_{DD}=3.0V, V-=0V to −1V V_{DD}=3.1V, V-=0V to −1V*11, 13 V_{DD}=3.3V, V-=0V to 3.3V*14	5 11	8*9 16*10	11 21	ms
Vshort	Short protection voltage	V_{DD}=3.0V V_{DD}=3.1V*11, 13 V_{DD}=3.3V*14	0.55	0.80	1.00	V

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
tV_{REL4}	Output delay of release from excess charge-current	V_{DD}=3.0V, V-=−1V to 0V V_{DD}=3.1V, V-=−1V to 0V*11, 13 V_{DD}=3.3V, V-=−1V to 0V*14	0.7	1.2	1.7	ms
t_{short}	Output Delay of Short protection	V_{DD}=3.0V, V-=0V to 3.0V V_{DD}=3.1V, V-=0V to 3.1V*11 V_{DD}=3.1V, V-=0V to 3.0V*13 V_{DD}=3.3V, V-=0V to 3.3V*14	150 230 300	200*7 300*8 400*15	300 500 600	μs
R_{short}	Reset resistance for Excess discharge-current protection	V_{DD}=3.6V, V-=1V	25	50	75	kΩ
V_{DS}	Delay Shortening Mode input voltage	V_{DD}=4.4V V_{DD}=4.6V*12	−2.6	−2.0	−1.4	V
V_{OL1}	Nch ON voltage of C_{OUT}	I_{OL}=50μA, V_{DD}=4.5V I_{OL}=50μA, V_{DD}=4.6V*12		0.4	0.5	V
V_{OH1}	Pch ON voltage of C_{OUT}	I_{OH}=−50μA, V_{DD}=3.9V	3.4	3.7		V
V_{OL2}	Nch ON voltage of D_{OUT}	I_{OL}=50μA, V_{DD}=2.0V		0.2	0.5	V
V_{OH2}	Pch ON voltage of D_{OUT}	I_{OH}=−50μA, V_{DD}=3.9V	3.4	3.7		V
I_{DD}	Supply current	V_{DD}=3.9V, V- =0V		4.0*1 4.0*2	6.5*1 8.0*2	μA
I_S	Standby current	V_{DD}=2.0V		1.2*5	0.1*6 2.0*5	μA

∗1 : Applied to the version by function: C, D, E
∗2 : Applied to the version by function: F, G
∗3 : We compensate for this characteristic related to temperature by laser-trim, however, this specification is guaranteed by design, not production tested.
∗4 : Applied to the version by function: D, E, F
∗5 : Applied to the version by function: D, F
∗6 : Applied to the version by function: C, G
∗7 : Applied to the version by function: E
∗8 : Applied to the version by function: C, K
∗9 : Applied to the version by function: E, K
∗10 : Applied to the version by function: C, P
∗11 : Applied to the code 163EC
∗12 : Applied to the code 169KD
∗13 : Applied to the code 138KF
∗14 : Applied to the code 157KG
∗15 : Applied to the version by function: P

RECOMMENDED OPERATING CONDITIONS (ELECTRICAL CHARACTERISTICS)

All of electronic equipment should be designed that the mounted semiconductor devices operate within the recommended operating conditions. The semiconductor devices cannot operate normally over the recommended operating conditions, even if when they are used over such conditions by momentary electronic noise or surge. And the semiconductor devices may receive serious damage when they continue to operate over the recommended operating conditions.

- **Topt=−40°C to 85°C**

Topt=−40°C to 85°C[*16]

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[*1]	Voltage defined as V_{DD}-V-, V_{DD}-V_{SS}=0V			1.98	V
Vnochg	Maximum voltage for inhibit charger[*2]	Voltage defined as V_{DD}-V_{SS}, V_{DD}-V-=4V	0.52	1.10	1.53	V
V_{DET1}	Over-charge threshold	Detect rising edge of supply voltage R1=330Ω	V_{DET1}−0.057	V_{DET1}	V_{DET1}+0.037	V
V_{REL1}	Over-charge detector released voltage	R1=330Ω	V_{REL1}−0.05	V_{REL1}	V_{REL}+0.05	V
tV_{DET1}	Output delay of over-charge	V_{DD}=3.6V to 4.4V V_{DD}=3.6V to 4.6V[*12]	0.63	1.00	1.70	s
tV_{REL1}	Output delay of release from over-charge	V_{DD}=4V, V-=0V to 1V V_{DD}=4.5V to 3.6V[*4] V_{DD}=4.6V to 3.6V[*12]	10.0	16.0	27.2	ms
V_{DET2}	Over-discharge threshold	Detect falling edge of supply voltage	V_{DET2}×0.975 −0.022	V_{DET2}	V_{DET2}×1.025+ 0.003	V
V_{REL2}	Released Voltage from Over-discharge	Detect rising edge of supply voltage	V_{REL2}×0.975 −0.022	V_{REL2}	V_{REL2}×1.025+ 0.003	V
tV_{DET2}	Output delay of over-discharge	V_{DD}=3.6V to 2.2V	13.2	20.0	33.1	ms
tV_{REL2}	Output delay of release from over-discharge	V_{DD}=3.0V, V-=3V to 0V V_{DD}=3.1V, V-=3.1V to 0V[*11] V_{DD}=2.2V, to 3.1V[*5] V_{DD}=2.2V to 3.5V[*13] V_{DD}=3.3V, V-=3.3V to 0V[*14]	0.62	1.20	2.11	ms
V_{DET3}	Excess discharge-current threshold	Detect rising edge of 'V-' pin voltage	V_{DET3}−0.018	V_{DET3}	V_{DET3}+0.016	V
tV_{DET3}	Output delay of excess discharge-current	V_{DD}=3.0V, V-=0V to 0.5V V_{DD}=3.1V, V-=0V to 0.5V[*11, 13] V_{DD}=3.3V, V-=0V to 0.5V[*14]	3.4 7.4 11.4	6.0[*7] 12.0[*8] 18.0[*16]	12.4 20.4 28.4	ms
tV_{REL3}	Output delay of release from excess discharge-current	V_{DD}=3.0V, V-=3V to 0V V_{DD}=3.1V, V-=3.1V to 0V[*11] V_{DD}=3.1V, V-=3V to 0V[*13] V_{DD}=3.3V, V-=3.3V to 0V[*14]	0.62	1.20	2.11	ms
V_{DET4}	Excess charge-current threshold	Detect falling edge of 'V-' pin voltage	V_{DET4}−0.032	V_{DET4}	V_{DET4}+0.033	V
tV_{DET4}	Output delay of excess charge-current	V_{DD}=3.0V, V-=0V to −1V V_{DD}=3.1V, V-=0V to −1V[*11, 13] V_{DD}=3.3V, V-=0V to −1V[*14]	4.6 10.2	8.0[*9] 16.0[*10]	14.0 27.0	ms
tV_{REL4}	Output delay of release from excess charge-current	V_{DD}=3.0V, V-=−1V to 0V V_{DD}=3.1V, V-=−1V to 0V[*11, 13] V_{DD}=3.3V, V-=−1V to 0V[*14]	0.61	1.20	2.13	ms

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
Vshort	Short protection voltage	V_{DD}=3.0V V_{DD}=3.1V*11, 13 V_{DD}=3.3V*14	0.48	0.80	1.08	V
tshort	Output Delay of Short protection	V_{DD}=3.0V, V-=0V to 3V	136 216 286	200*7 300*8 400*8	435 635 735	µs
Rshort	Reset resistance for Excess discharge-current protection	V_{DD}=3.6V, V-=1V	24.2	50	87.2	kΩ
V_{DS}	Delay Shortening Mode input voltage	V_{DD}=4.4V V_{DD}=4.6V*12	−2.63	−2.00	−1.37	V
V_{OL1}	Nch ON voltage of C_{OUT}	I_{OL}=50µA, V_{DD}=4.5V I_{OL}=50µA, V_{DD}=4.6V*12		0.4	0.5	V
V_{OH1}	Pch ON voltage of C_{OUT}	I_{OH}=−50µA, V_{DD}=3.9V	3.4	3.7		V
V_{OL2}	Nch ON voltage of D_{OUT}	I_{OL}=50µA, V_{DD}=2.0V		0.2	0.5	V
V_{OH2}	Pch ON voltage of D_{OUT}	I_{OH}=−50µA, V_{DD}=3.9V	3.4	3.7		V
I_{DD}	Supply current	V_{DD}=3.9V, V-=0V		4.0*1 4.0*2	7.52*1 9.02*2	µA
I_S	Standby current	V_{DD}=2.0V		1.2*5	0.12*6 2.3*5	µA

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∗2 : Applied to the version by function: F, G
∗3 : We compensate for this characteristic related to temperature by laser-trim, however, this specification is guaranteed by design, not production tested.
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∗9 : Applied to the version by function: E, K
∗10 : Applied to the version by function: C, P
∗11 : Applied to the code 163EC
∗12 : Applied to the code 169KD
∗13 : Applied to the code 138KF
∗14 : Applied to the code 157KG
∗16 : Guaranteed by design, not mass production tested at both high temperature and low temperature.

RECOMMENDED OPERATING CONDITIONS (ELECTRICAL CHARACTERISTICS)

All of electronic equipment should be designed that the mounted semiconductor devices operate within the recommended operating conditions. The semiconductor devices cannot operate normally over the recommended operating conditions, even if when they are used over such conditions by momentary electronic noise or surge. And the semiconductor devices may receive serious damage when they continue to operate over the recommended operating conditions.

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 detect over-charge and an external charge control Nch MOSFET turn off with C_{OUT} pin being at "L" level.

In terms of C, G version (Latch type), 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, by disconnecting a charger from the battery pack. Output voltage of C_{OUT} pin becomes "H", and it makes an external Nch MOSFET turn on, and charge cycle is available.

Depending on the external characteristics of external components such as FETs, just by disconnecting a charger, over-charge state may not be released. In such a case, by connecting some load, the over-charge state is released.) In other words, once over-charge is detected, even if the supply voltage becomes low enough, if a charger is continuously 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, the built-in 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 the over-charge detecting state.

In terms of D, E, F version (Auto Release type), after detecting over-charge, if V_{DD} pin voltage is equal or lower than the released voltage from over-charge, even if a charger is connected, over-charge detector is released. Further, in case that V_{DD} pin level is lower than the over-charge detector threshold, if a charger is removed, over-charge detector is also released. Depending on the characteristics of external components such as FETs, just by disconnecting a charger, over-charge detector may not be released, and in this case, by connecting some load, the over-charge state is released.

After detecting over-charge with the V_{DD} voltage of higher than V_{DET1}, 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} pin level becomes equal or 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 a load is connected, if 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 detect an over-discharge and the external discharge control Nch MOSFET turns off with the D_{OUT} pin being at "L" level.

In terms of C, E, G version(Latch type), 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}, then, D_{OUT} becomes "H" and discharging process would be able to advance through ON state 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}.

In terms of D, F version (Auto Release type), released operation by connecting a charger is same as the other latch type. However, without a charger, if V_{DD} pin voltage is equal or more than the released voltage from over-discharge, D_{OUT} pin becomes "H" immediately.

When a cell voltage equals to zero, C, D, E version (acceptable type): if the voltage of a charger is equal or more than 0V-charge minimum voltage limit (V_{st}), C_{OUT} pin becomes "H" and a system is allowable to charge.

F, G version (unacceptable type): if V_{DD} voltage is less than charger inhibit maximum voltage (V_{nochg}), even if a charger is connected, C_{OUT} level will be fixed at "L", and charge current will be cut off.

An output delay time for over-discharge detection is fixed internally. When the V_{DD} level is down to a equal or 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.

After detecting over-discharge by VD2, C, E, G version (Latch type): supply current would be reduced and be into standby by halting unnecessary circuits and consumption current of IC itself is made as small as possible. (Max. 0.1μA at V_{DD}=2.0V)

D, F version (Auto Release type): supply current would be reduced and be into standby by halting circuits except the over-discharge released by voltage function. (Max. 2.0μA at V_{DD}=2.0V)

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 (V_{short}) /V_{DD} and excess discharge-current threshold V_{DET3}, VD3 operates and further soaring of V- pin voltage higher than V_{short} (Typ. 0.8V) 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. An output delay time for the excess discharge-current detector is internally fixed. A quick recovery of V- pin level from a value between V_{short} 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.

When the short circuit protector is enabled, the D_{OUT} would be "L" and the delay time (Typ. 1.2ms) is also set.

The V- pin has a built-in pull-down resistor (Typ. 50kΩ) to the V_{SS} pin, that is, the resistance to release from excess-discharge current.

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. 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 R5403x /R5405x are at excess discharge-current detection mode. By disconnecting a load, VD3 is automatically released from excess discharge-current.

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

When the battery pack is chargeable and discharge is also possible, VD4 senses V- pin voltage. For example, in case that a battery pack is charged by an inappropriate charger, an excess current flows, then the voltage of V- pin becomes equal or less than excess charge-current detector threshold. Then, the output of C_{OUT} becomes

"L", and prevents from flowing excess current in the circuit by turning off the external Nch MOSFET.

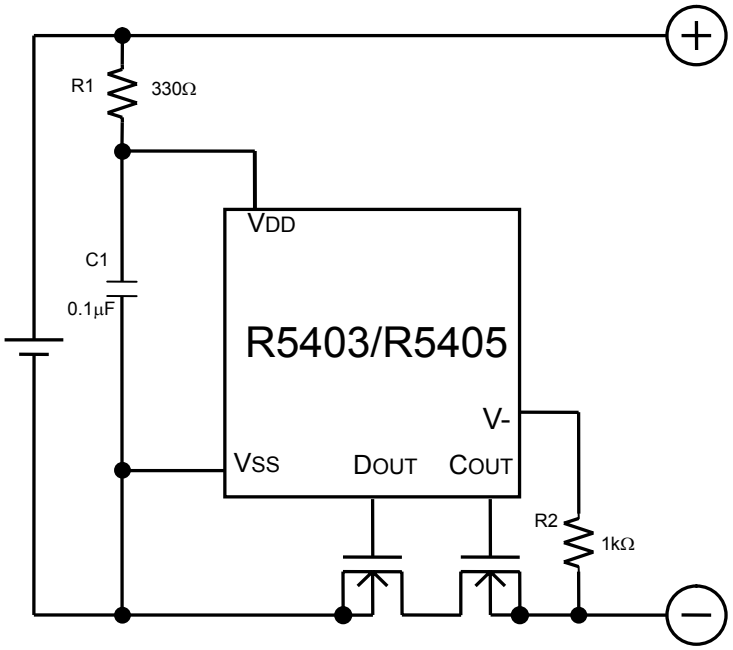
Output delay of excess charge current is internally fixed. Even the voltage level of V- pin becomes equal or lower than the excess charge-current detector threshold, the voltage is higher than the VD4 threshold within the delay time, the excess charge current is not detected. Output delay for the release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

VD4 can be released with disconnecting a charger and connecting a load.

- **DS (Delay Shorten) function**

Output delay time of over-charge, over-discharge, and release from those detecting modes can be shorter than those setting value by forcing equal or less than the delay shortening mode voltage (Typ. −2.0V) to V- pin.

TYPICAL APPLICATION



APPLICATION HINTS

R1 and C1 will stabilize a supply voltage to the R5403x /R5405x. A recommended R1 value is less than 1kΩ.

A larger value of R1 leads higher detection voltage, makes some errors because of some conduction current may flow in the R5403x /R5405x. To stabilize the operation, the value of C1 should be equal or more than 0.01μF.

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 R5403x /R5405x, battery pack. Small value of R1 and R2 may cause over-power consumption rating of power dissipation of the R5403x /R5405x. Thus, the 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.

The application circuit's performance is largely dependable on the actual PCB layout, therefore, fully evaluation and selection of the appropriate external components are necessary.

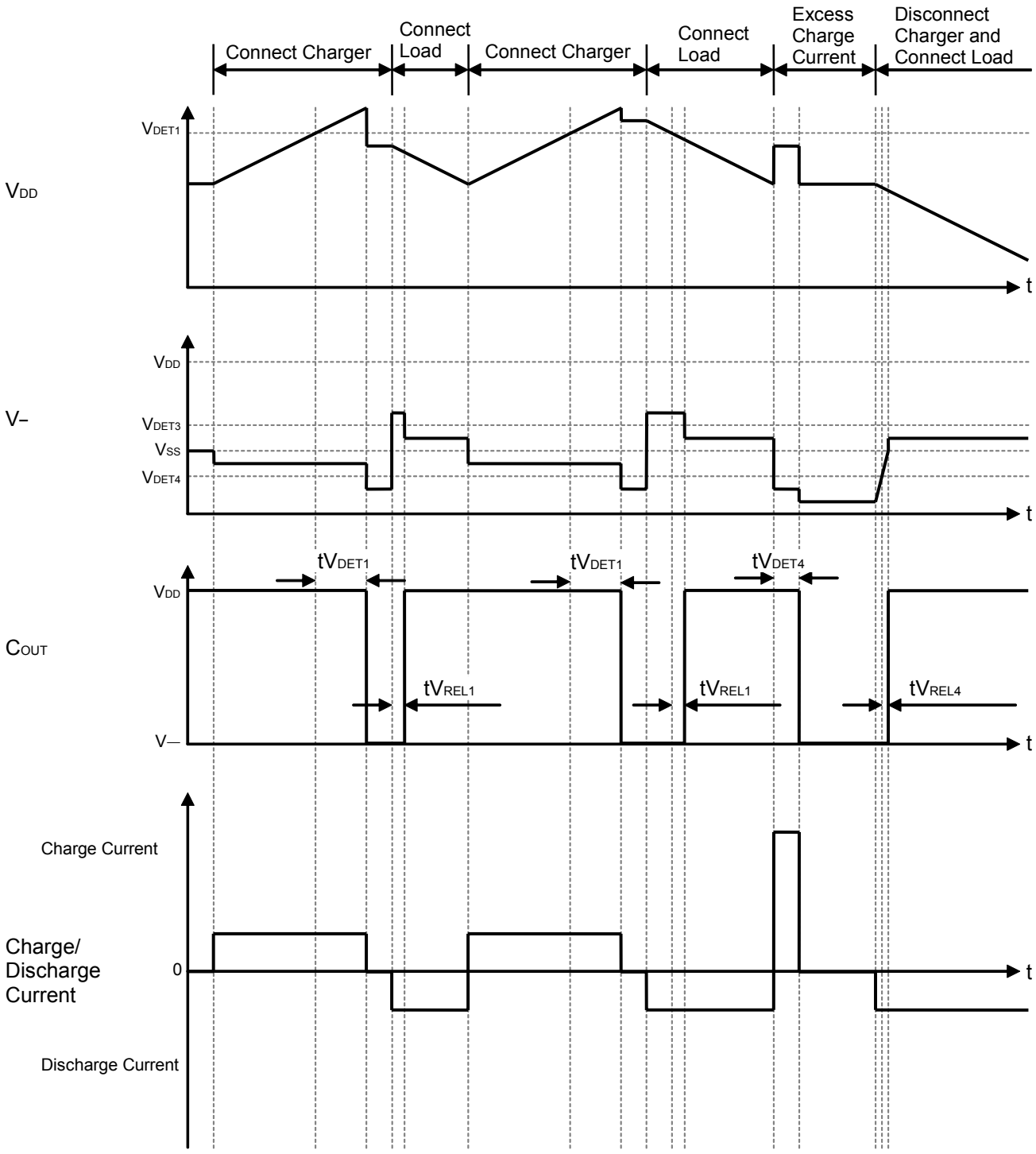
Large voltage or large current, which may exceed the absolute maximum ratings of the protection IC or the external components should not be forced on them.

We make an effort to keep our quality and reliability, however, there is the AQL for any semiconductors. As a result, be sure to the safe design against the any damage or misoperation. Ricoh cannot assume any responsibility for use of any circuitry other than circuitry entirely embodied in a Ricoh product.

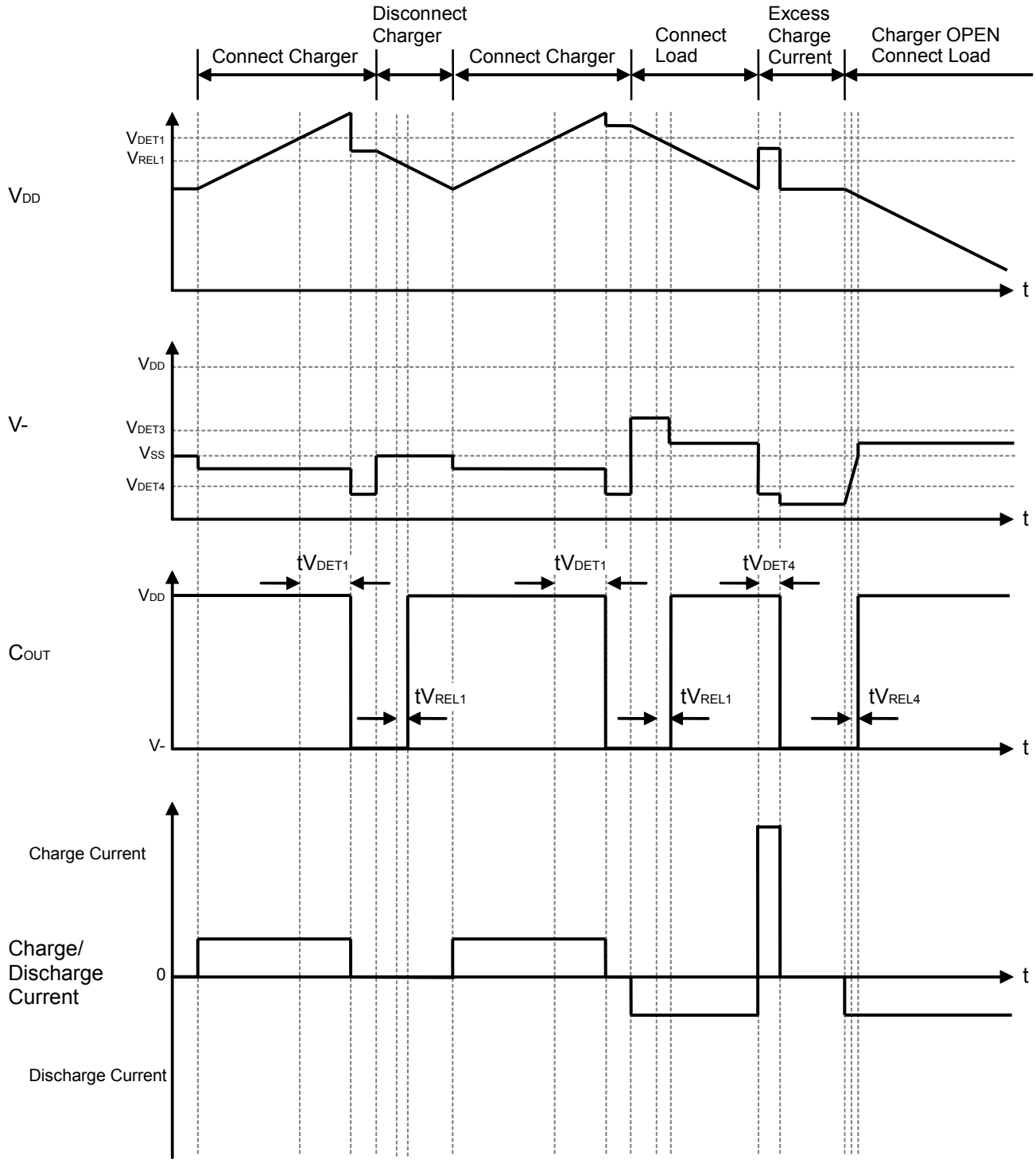
Ricoh reserves the right to change the circuitry and specifications without notice any time.

TIMING CHART

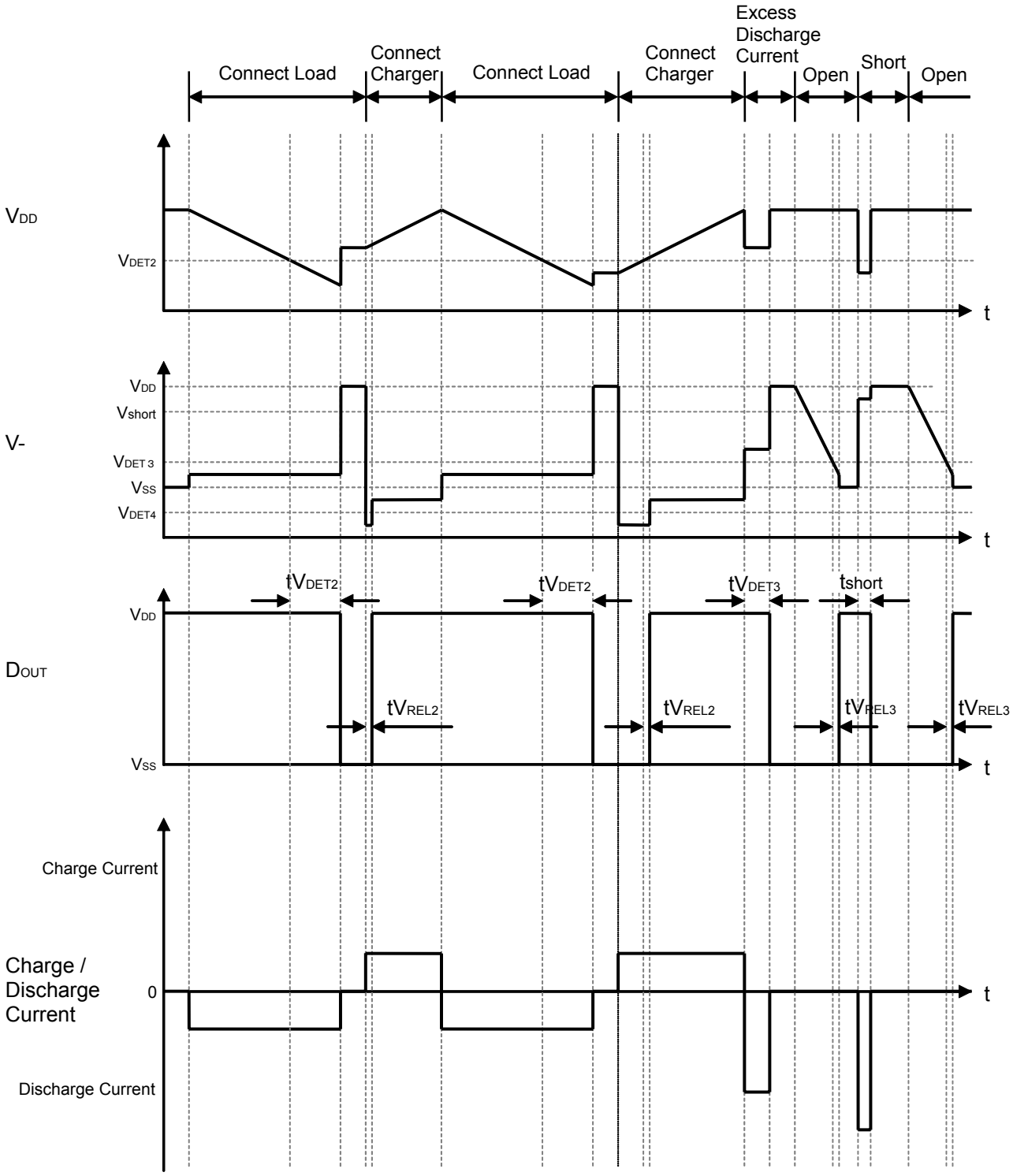
1) Timing diagram of over-charge (Latch type) voltage and over-charge current



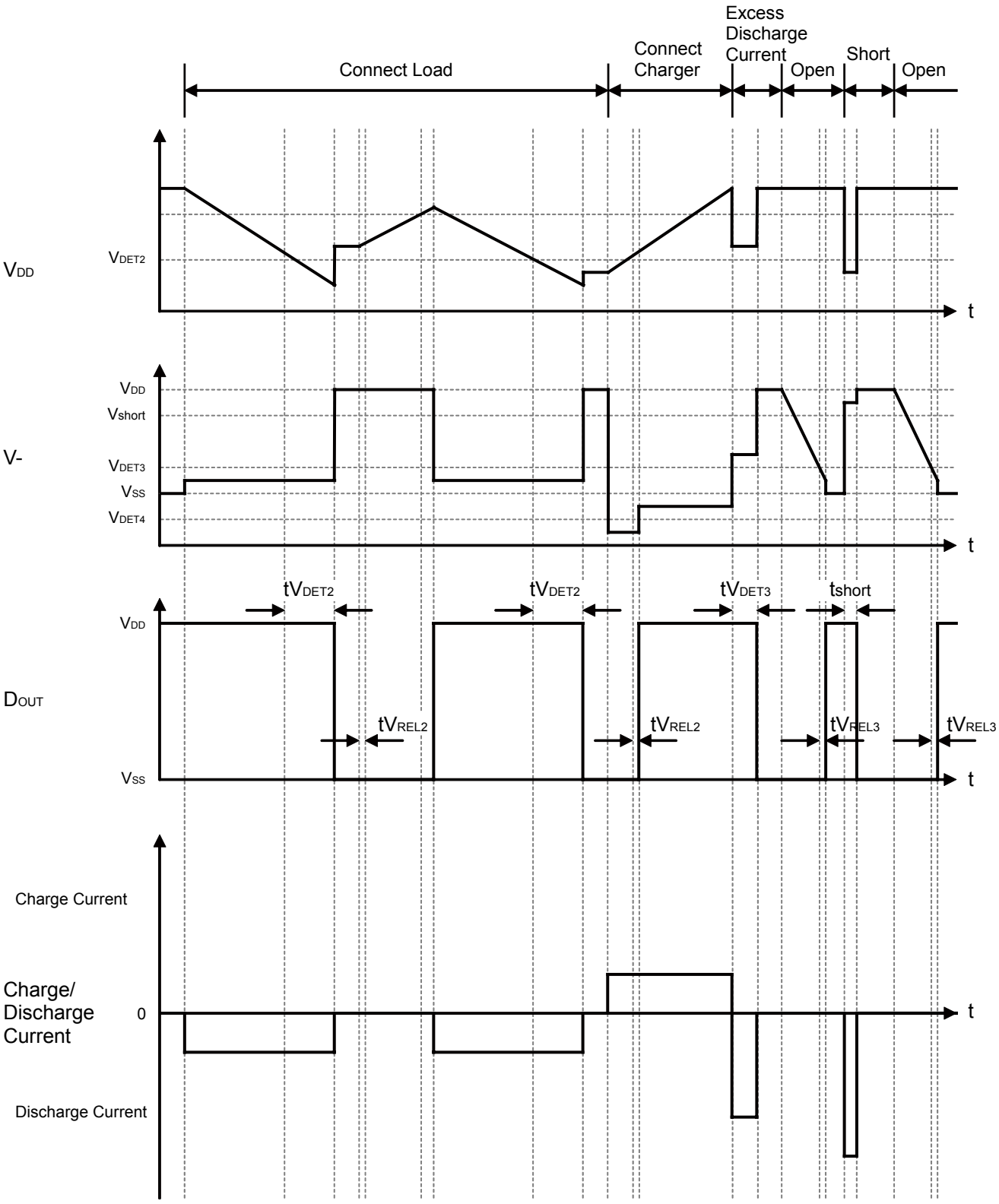
2) Over-charge (Released by voltage Type) voltage, Excess charge current Operation



3) Over-discharge (Latch Type), Excess discharge current, Short circuit

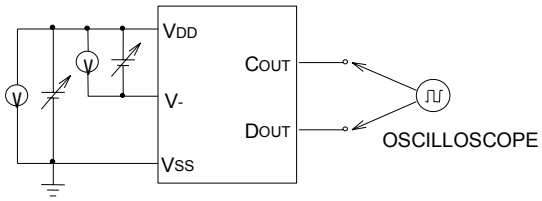


4) Over-discharge (Released by Voltage Type), Excess discharge current, Short circuit

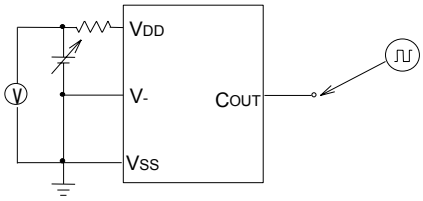


TEST CIRCUITS

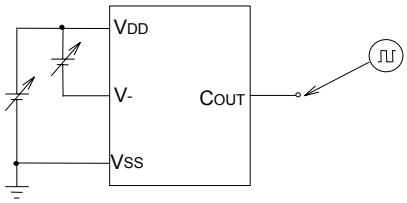
A



B



C



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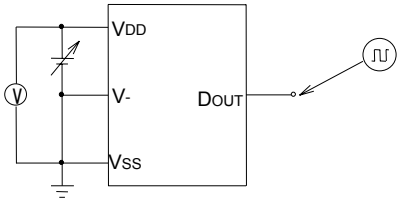
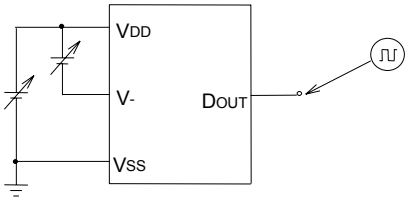


E



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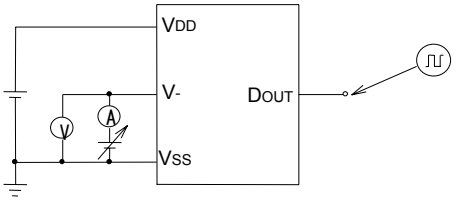
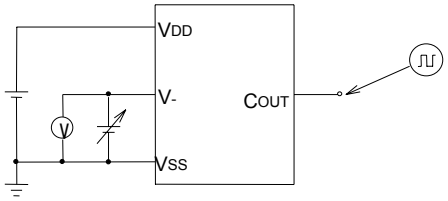
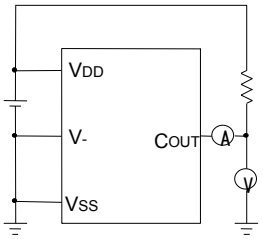


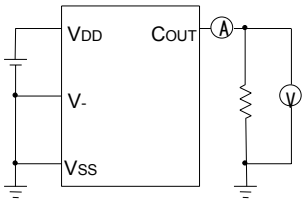
G



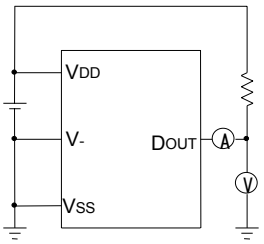
H



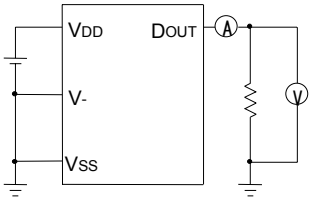
I



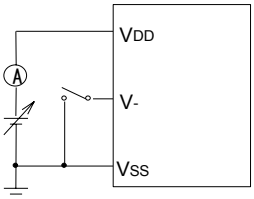
J



K

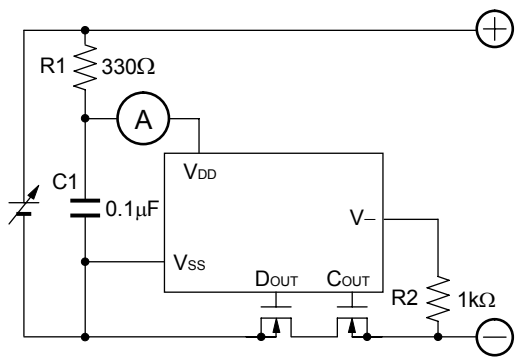


L

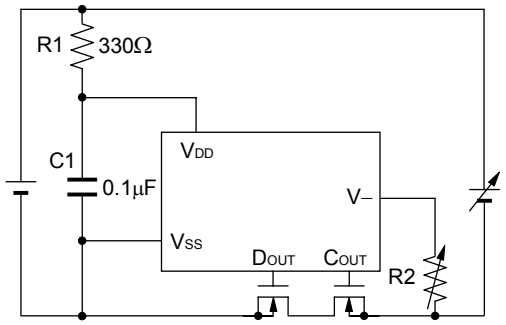


R5403x / R5405x

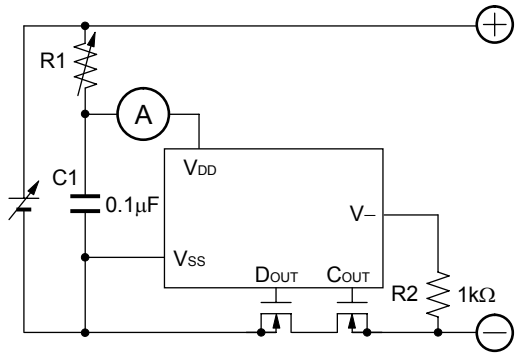
M



O



N



- **Part 1 Temperature Characteristics**

  Typical Characteristics were obtained with using those above circuits:
  Test Circuit A: Typical characteristics 1) 2)
  Test Circuit B: Typical characteristics 3) 4) 5)
  Test Circuit C: Typical characteristics 6)
  Test Circuit D: Typical characteristics 7) 8) 9)
  Test Circuit E: Typical characteristics 10)
  Test Circuit F: Typical characteristics 11) 12) 13) 14) 15) 16) 17)
  Test Circuit G: Typical characteristics 18) 19) 20) 21) 22)
  Test Circuit H: Typical characteristics 23)
  Test Circuit I: Typical characteristics 24)
  Test Circuit J: Typical characteristics 25)
  Test Circuit K: Typical characteristics 26)
  Test Circuit L: Typical characteristics 27) 28) 29)

- **Part 2 Delay Time dependence on V_{DD}**

- **Part 3 Supply Current dependence on V_{DD}**

  Test Circuit M: Typical characteristics 27) 28) 29)

- **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 N:

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

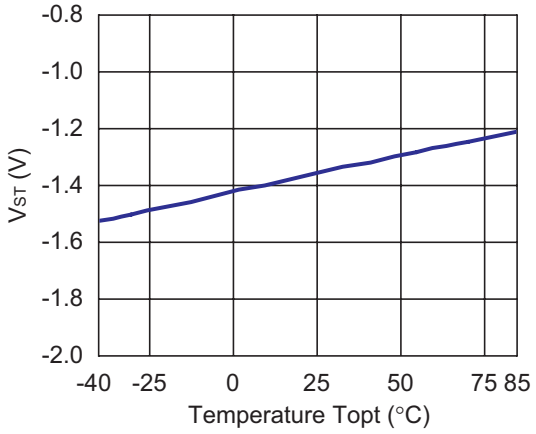
  Test Circuit O:

TYPICAL CHARACTERISTICS

Part 1: Temperature Characteristics

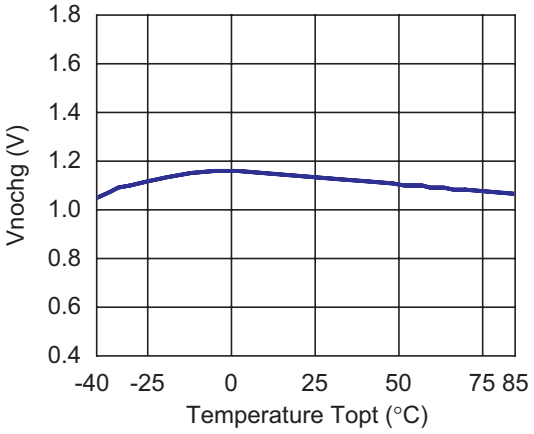
1) Minimum Operating Voltage for 0V Cell Charging vs. Temperature

R5403x156KE



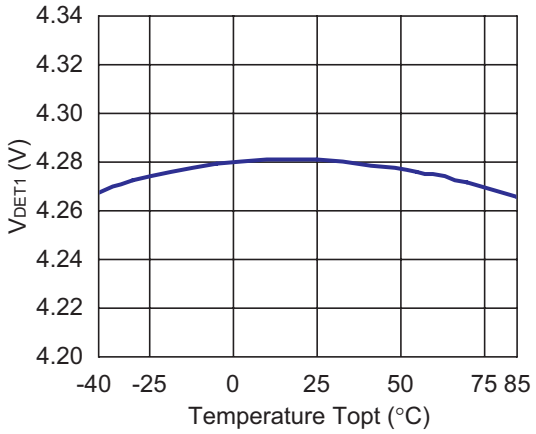
2) Maximum Battery Voltage Level for Low Voltage Battery Charge Inhibitory Circuit vs. Temperature

R5403x158KF



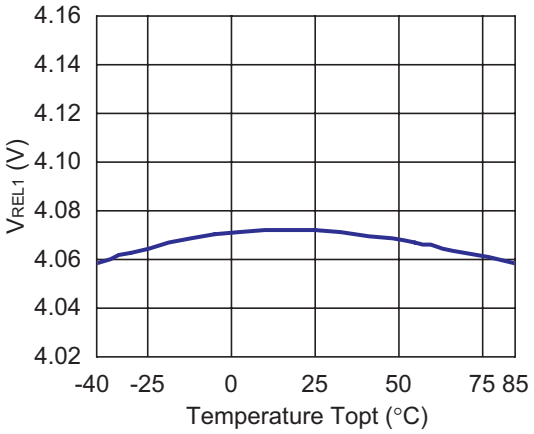
3) Over-Charge Threshold vs. Temperature

R5403x156KE



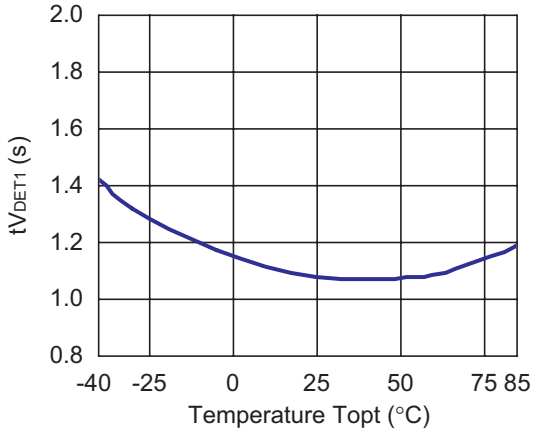
4) Released voltage from Over-charge vs. Temperature

R5403x156KE



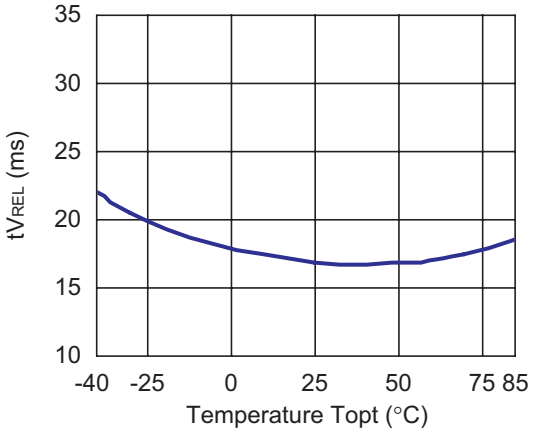
5) Output Delay of Over-charge vs. Temperature

R5403x156KE



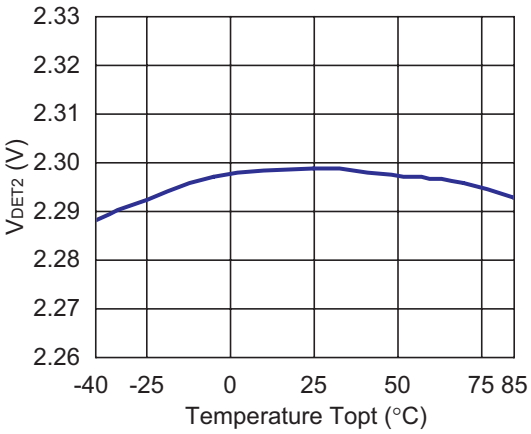
6) Output Delay of Release from Over-charge vs. Temperature

R5403x156KE



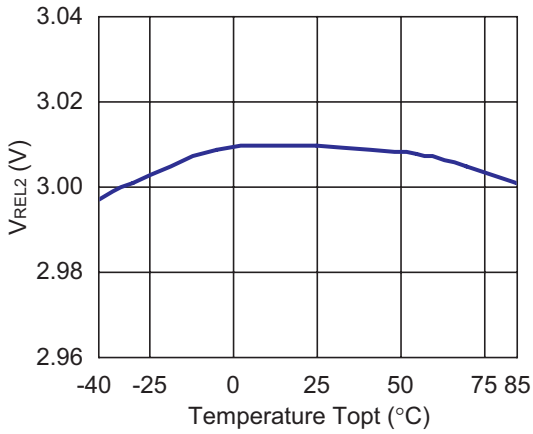
7) Over discharge Threshold vs. Temperature

R5403x156KE



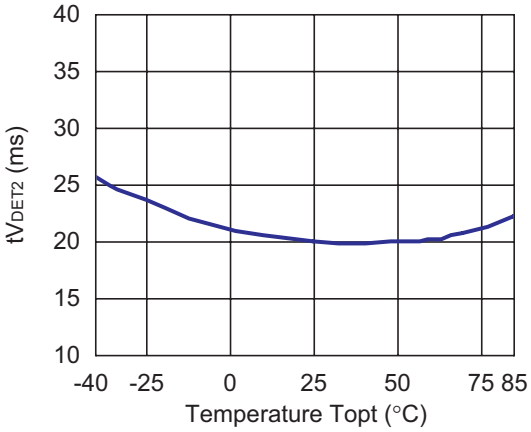
8) Released voltage from Over-discharge vs. Temperature

R5403x158KD



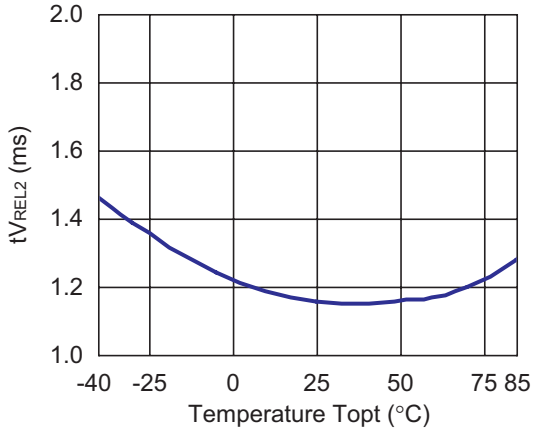
9) Output Delay of Over-discharge vs. Temperature

R5403x156KE



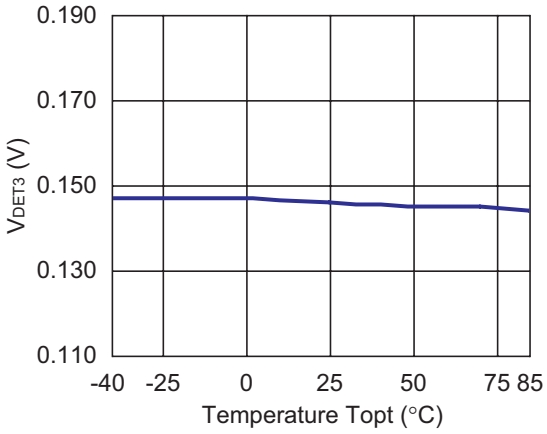
10) Output Delay of Release from Over-discharge vs. Temperature

R5403x156KE



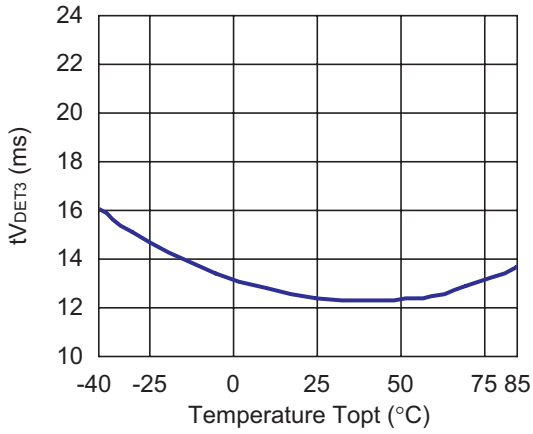
11) Excess Discharge-current Threshold vs. Temperature

R5403x156KE



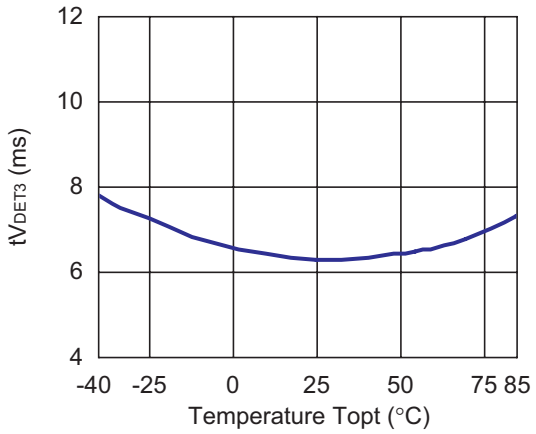
12) Output Delay of Excess Discharge-current vs. Temperature

R5403x156KE



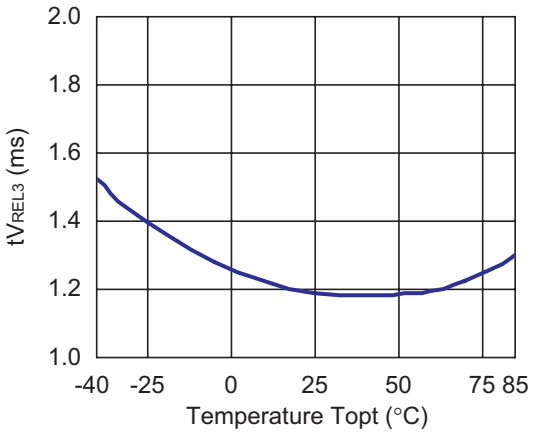
13) Output Delay of Excess Discharge-current vs. Temperature

R5403x106EC



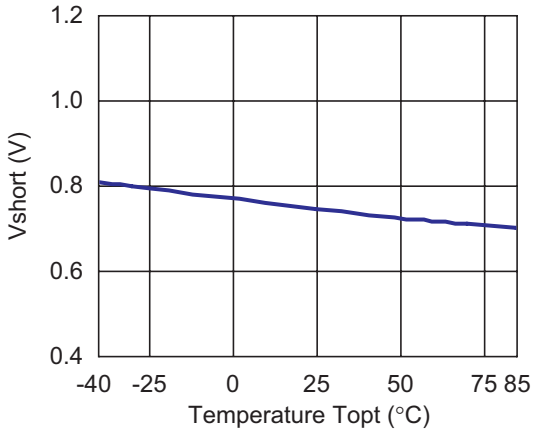
14) Output Delay of Release from Excess Discharge-current vs. Temperature

R5403x156KE



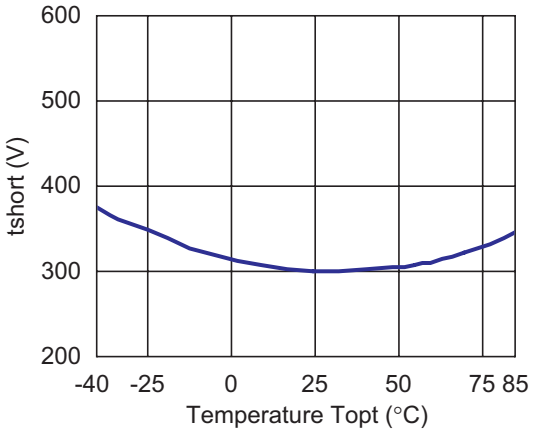
15) Short Detector Voltage vs. Temperature

R5403x156KE



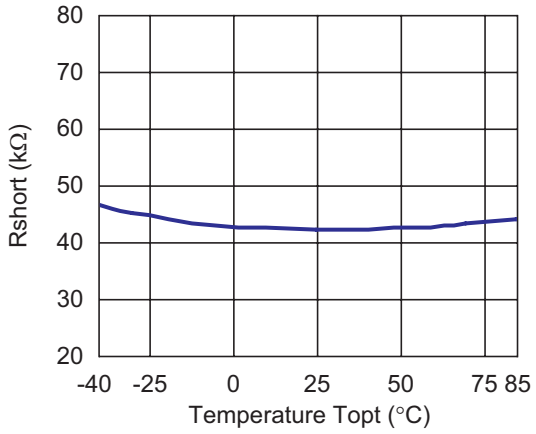
16) Output Delay of Short Protection vs. Temperature

R5403x156KE



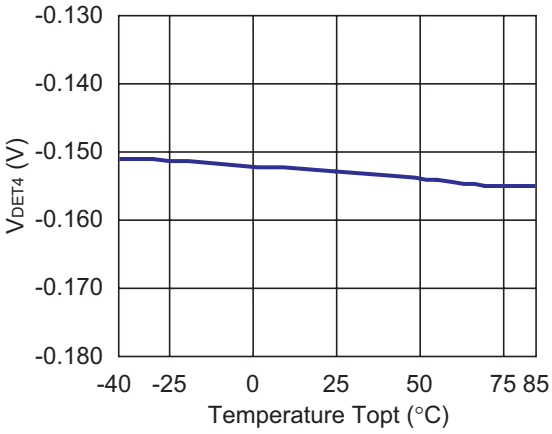
17) Reset Resistance for Excess Discharge Current Protection vs. Temperature

R5403x156KE



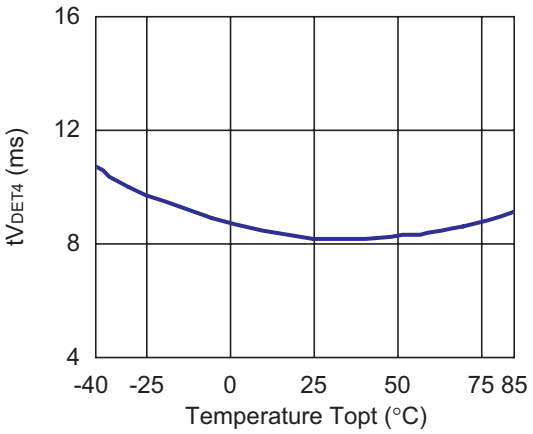
18) Excess charge-current Threshold vs. Temperature

R5403x156KE



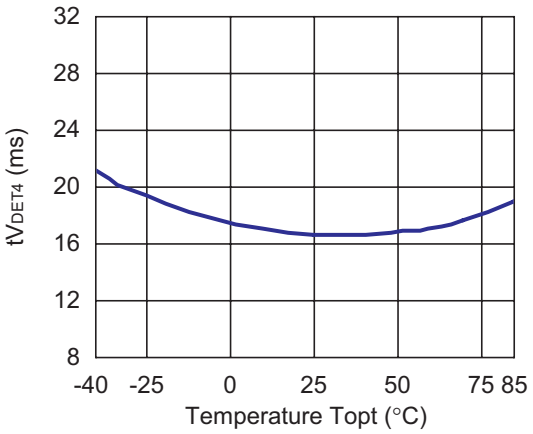
19) Output Delay of Excess charge-current vs. Temperature

R5403x156KE



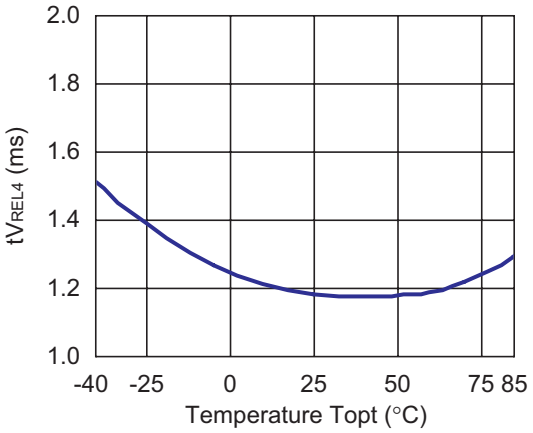
20) Output Delay of Excess charge-current vs. Temperature

R5403x106CC



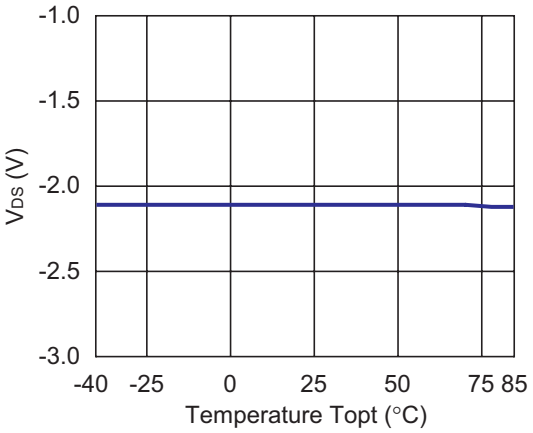
21) Output Delay of Release from Excess charge-current vs. Temperature

R5403x156KE



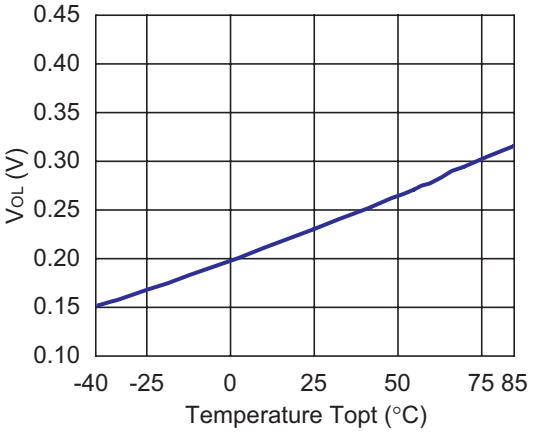
22) V- pin Test time shortening input Voltage vs. Temperature

R5403x156KE



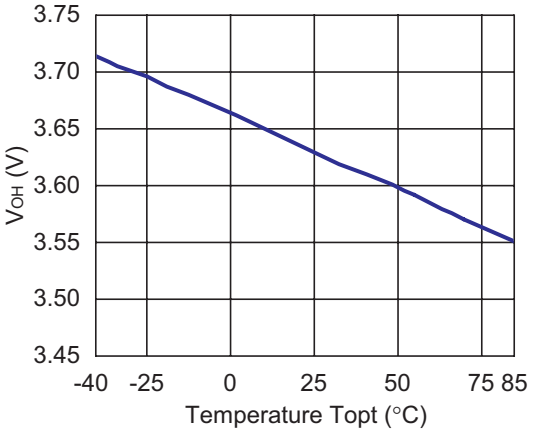
23) Nch on Voltage (C_{OUT} pin) vs. Temperature

R5403x156KE



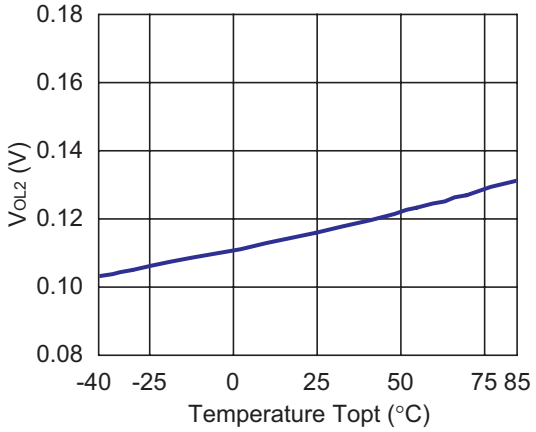
24) Pch on Voltage (C_{OUT} pin) vs. Temperature

R5403x156KE



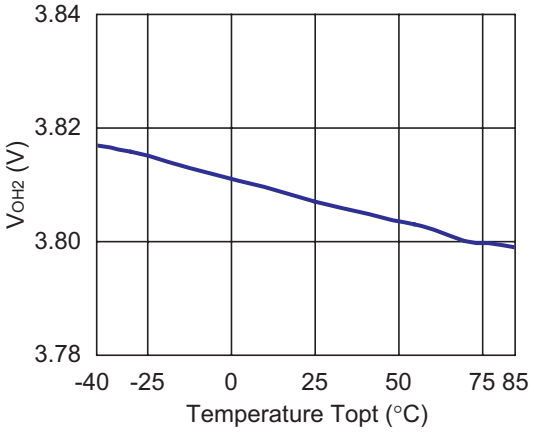
25) Nch on Voltage (D_{OUT} pin) vs. Temperature

R5403x156KE



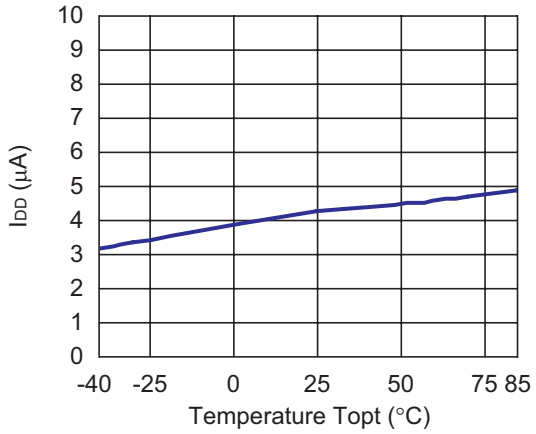
26) Pch on Voltage of D_{OUT} vs. Temperature

R5403x156KE



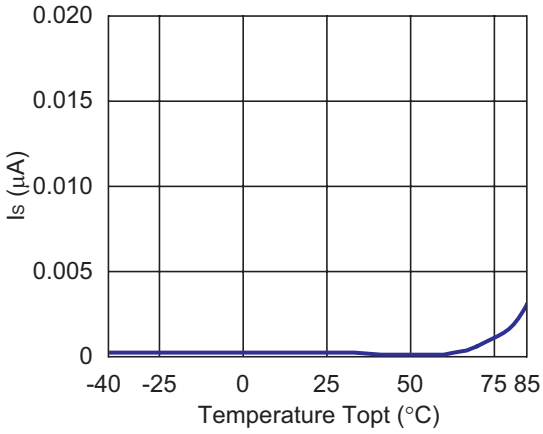
27) Supply Current vs. Temperature

R5403x156KE



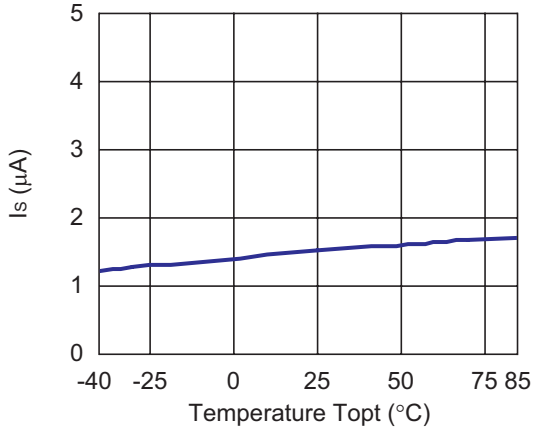
28) Standby Current vs. Temperature

R5403x156KE



29) Standby Current vs. Temperature

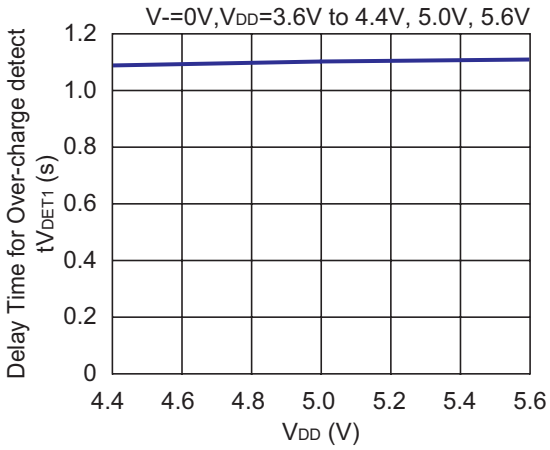
R5403x158KD



Part 2: Delay Time dependence on V_{DD}

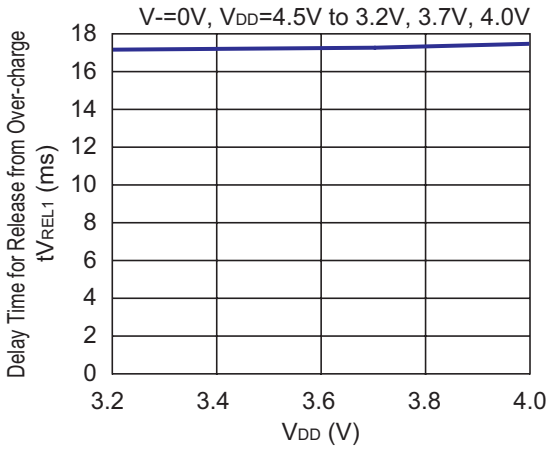
30) Delay Time for Over-charge detect vs. V_{DD}

R5403x156KE



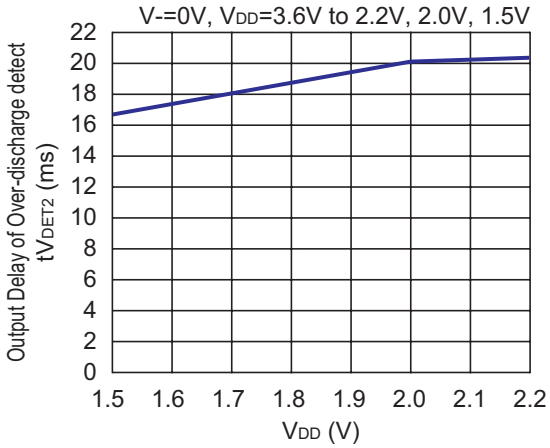
31) Delay Time for Release from Over-charge vs. V_{DD}

R5403x156KE



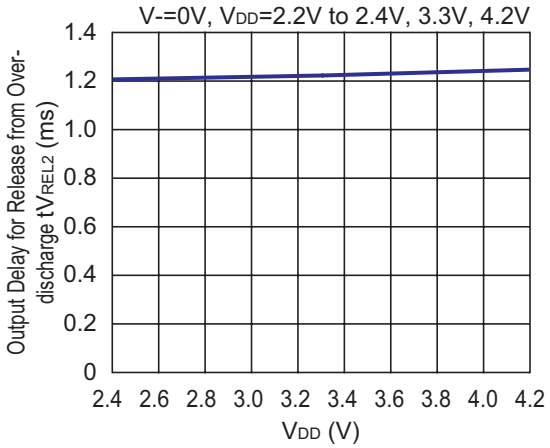
32) Output Delay of Over-discharge detect vs. V_{DD}

R5403x156KE



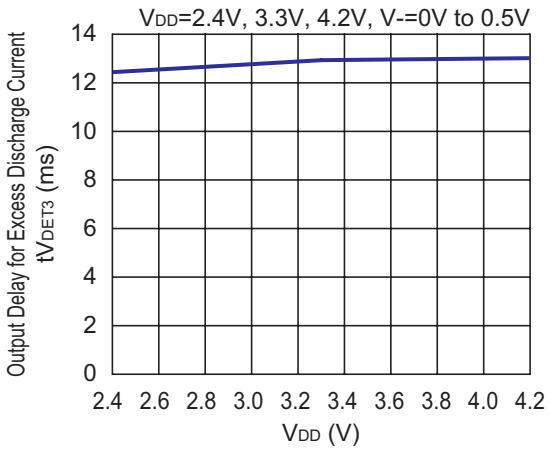
33) Output Delay for Release from Over-discharge vs. V_{DD}

R5403x156KE



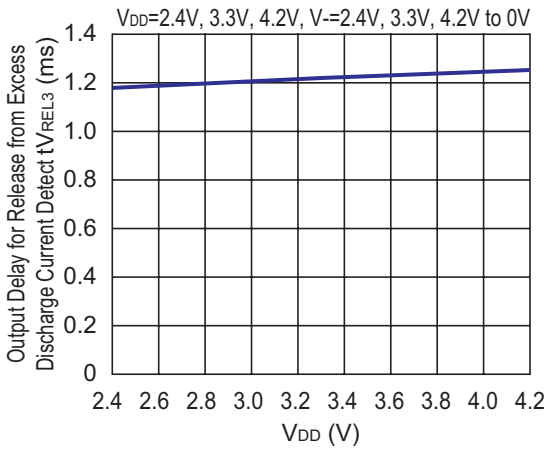
34) Output Delay for Excess Discharge Current vs. V_{DD}

R5403x156KE



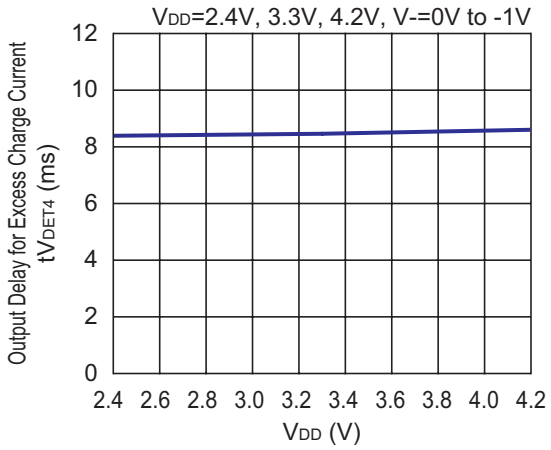
35) Output Delay for Release from Excess Discharge Current Detect vs. V_{DD}

R5403x156KE



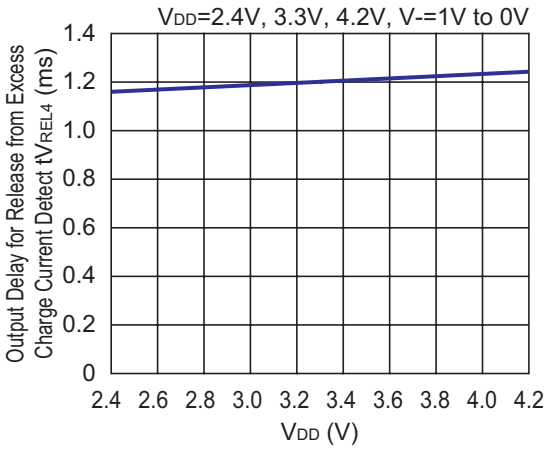
36) Output Delay for Excess Charge Current vs. V_{DD}

R5403x156KE



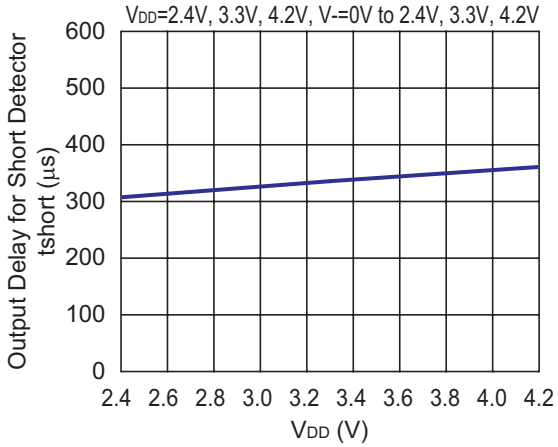
37) Output Delay for Release from Excess Charge Current Detect vs. V_{DD}

R5403x156KE



38) Output Delay for Short Detector vs. V_{DD}

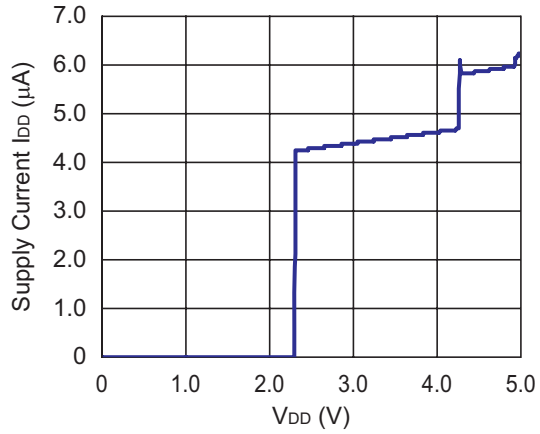
R5403x156KE



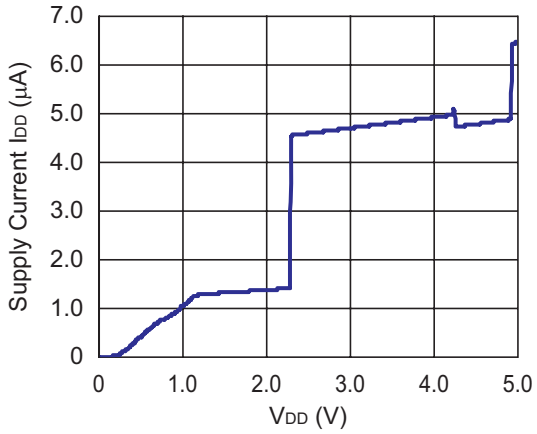
Part 3: Supply Current dependence on V_{DD}

39) Supply Current vs. V_{DD}

R5403x156KE



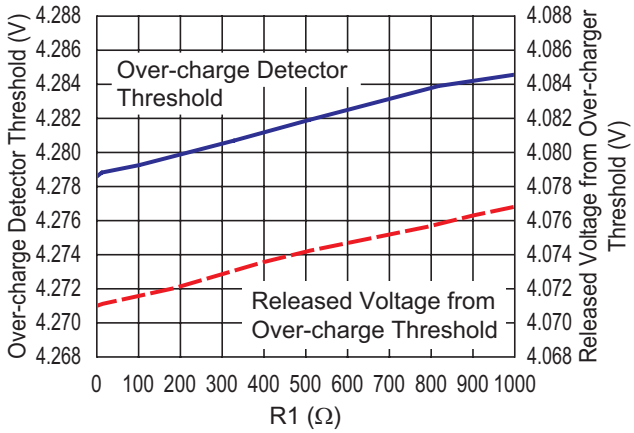
R5403x158KF



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

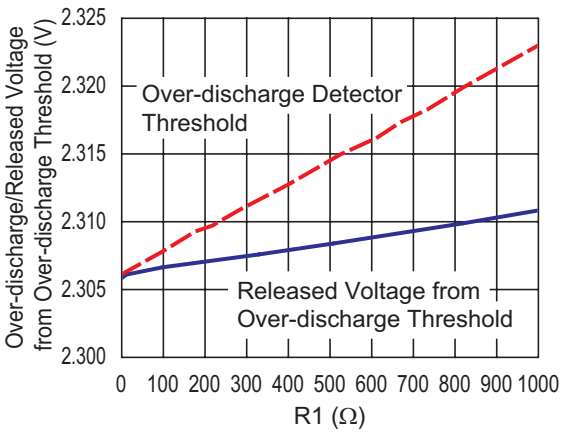
40) Over-charge Detector Threshold / Released Voltage Released from Over-charge Threshold vs. R1

R5403x156KE



41) Over-discharge Detector Threshold / from Over-discharge Threshold vs. R1

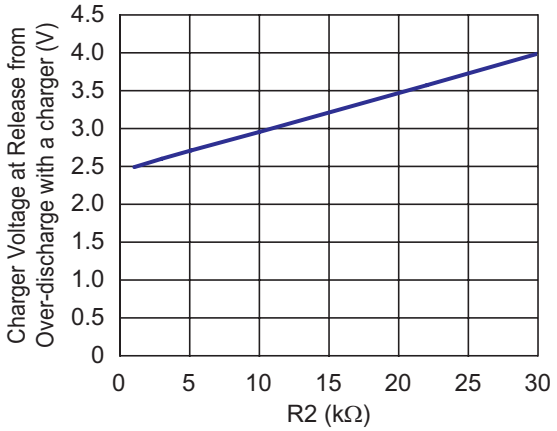
R5403x156KE



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

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

R5403x156KE



R5403 Series

Code	VDET1 (V)	VREL1 (V)	VDET2 (V)	VREL2 (V)	VDET3 (V)	VDET4 (V)	tVdet1 (s)	tVdet2 (ms)	tVdet3 (ms)	tVdet4 (ms)	tShort (μs)	0V Charge
R5403x106CC	4.275	-	2.300	-	0.100	-0.100	1	20	12	16	300	OK
R5403x111CC	4.280	-	2.300	-	0.150	-0.100	1	20	12	16	300	OK
R5403x143CC	4.280	-	2.300	-	0.150	-0.150	1	20	12	16	300	OK
R5403x102KD	4.350	4.150	2.500	3.000	0.200	-0.100	1	20	12	8	300	OK
R5403x106KD	4.275	4.075	2.300	3.000	0.100	-0.100	1	20	12	8	300	OK
R5403x110KD	4.280	4.080	2.300	3.000	0.125	-0.100	1	20	12	8	300	OK
R5403x117KD	4.280	4.080	2.300	3.000	0.200	-0.200	1	20	12	8	300	OK
R5403x120KD	4.325	4.125	2.300	3.000	0.150	-0.100	1	20	12	8	300	OK
R5403x149KD	4.280	4.080	2.900	3.100	0.125	-0.100	1	20	12	8	300	OK
R5403x155KD	4.250	4.050	2.400	2.900	0.100	-0.100	1	20	12	8	300	OK
R5403x158KD	4.250	4.050	2.300	3.000	0.150	-0.100	1	20	12	8	300	OK
R5403x156KE	4.275	4.075	2.300	-	0.150	-0.150	1	20	12	8	300	OK
R5403x155KF	4.250	4.050	2.400	2.900	0.100	-0.100	1	20	12	8	300	No
R5403x158KF	4.250	4.050	2.300	3.000	0.150	-0.100	1	20	12	8	300	No
R5403N157KG	4.300	-	3.200	-	0.150	-0.200	1	20	12	8	300	No

R5405 Series

Code	VDET1 (V)	VREL1 (V)	VDET2 (V)	VREL2 (V)	VDET3 (V)	VDET4 (V)	tVdet1 (s)	tVdet2 (ms)	tVdet3 (ms)	tVdet4 (ms)	tShort (µs)	0V Charge
R5405x106CC	4.275	-	2.300	-	0.100	-0.100	1	20	12	16	300	OK
R5405x110CC	4.280	-	2.300	-	0.125	-0.100	1	20	12	16	300	OK
R5405K111CC	4.280	-	2.300	-	0.150	-0.100	1	20	12	16	300	OK
R5405x120CC	4.325	-	2.300	-	0.150	-0.100	1	20	12	16	300	OK
R5405x124CC	4.275	-	2.300	-	0.050	-0.100	1	20	12	16	300	OK
R5403x143CC	4.280	-	2.300	-	0.150	-0.150	1	20	12	16	300	OK
R5405x106EC	4.275	-	2.300	-	0.100	-0.100	1	20	6	8	200	OK
R5405x127EC	4.280	-	2.900	-	0.050	-0.100	1	20	6	8	200	OK
R5405x128EC	4.280	-	2.800	-	0.050	-0.100	1	20	6	8	200	OK
R5405x139EC	4.425	-	2.300	-	0.100	-0.100	1	20	6	8	200	OK
R5405x163EC	4.280	-	3.000	-	0.100	-0.100	1	20	6	8	200	OK
R5405N176EC	4.280	-	2.300	-	0.130	-0.100	1	20	6	8	200	OK
R5405K102KD	4.250	4.050	2.500	3.000	0.200	-0.100	1	20	12	8	300	OK
R5405x106KD	4.275	4.075	2.300	3.000	0.100	-0.100	1	20	12	8	300	OK
R5405x110KD	4.280	4.080	2.300	3.000	0.125	-0.100	1	20	12	8	300	OK
R5405x120KD	4.325	4.125	2.300	3.000	0.150	-0.100	1	20	12	8	300	OK
R5405K149KD	4.280	4.080	2.900	3.100	0.125	-0.100	1	20	12	8	300	OK
R5405x155KD	4.250	4.050	2.400	2.900	0.100	-0.100	1	20	12	8	300	OK
R5405x169KD	4.475	4.275	2.300	2.800	0.100	-0.100	1	20	12	8	300	OK
R5405K178KD	4.250	4.050	2.300	3.000	0.125	-0.100	1	20	12	8	300	OK
R5405x180KD	4.325	4.075	2.800	3.000	0.100	-0.100	1	20	12	8	300	OK
R5405x186KD	4.275	4.175	2.300	2.500	0.150	-0.100	1	20	12	8	300	OK
R5405x195KD	4.270	4.070	2.300	2.500	0.100	-0.100	1	20	12	8	300	OK
R5405K134KE	4.300	4.100	2.300	-	0.130	-0.100	1	20	12	8	300	OK
R5405K148KE	4.300	4.100	2.100	-	0.170	-0.220	1	20	12	8	300	OK
R5405K156KE	4.275	4.075	2.300	-	0.150	-0.150	1	20	12	8	300	OK
R5405K172KE	4.300	4.100	2.300	-	0.150	-0.100	1	20	12	8	300	OK
R5405K174KE	4.300	4.100	2.300	-	0.090	-0.100	1	20	12	8	300	OK
R5405x138KF	4.325	4.125	3.000	3.400	0.050	-0.100	1	20	12	8	300	No
R5405x155KF	4.250	4.050	2.400	2.900	0.100	-0.100	1	20	12	8	300	No
R5405x158KF	4.250	4.050	2.300	3.000	0.150	-0.100	1	20	12	8	300	No
R5405x183KF	4.280	4.080	2.600	3.000	0.050	-0.050	1	20	12	8	300	No
R5405K183KG	4.280	-	2.600	-	0.050	-0.050	1	20	12	8	300	No
R5405K152PG	4.350	-	2.500	-	0.100	-0.120	1	20	18	16	400	No
R5405x193KD	4.280	4.180	2.800	2.900	0.150	-0.100	1	20	12	8	300	OK
R5405L208KE	4.280	4.100	2.300	-	0.150	-0.100	1	20	12	8	300	OK

R5405 Series

Code	VDET1 (V)	VREL1 (V)	VDET2 (V)	VREL2 (V)	VDET3 (V)	VDET4 (V)	tVdet1 (s)	tVdet2 (ms)	tVdet3 (ms)	tVdet4 (ms)	tShort (µs)	0V Charge
R5405x226KF	4.425	4.225	2.400	2.900	0.130	-0.130	1	20	12	8	300	No
R5405L249KG	4.280	-	2.300	-	0.130	-0.130	1	20	12	8	300	No

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