RICOH

R5460x SERIES

Li-ION/POLYMER 2-CELL PROTECTOR

NO.EA-165-091221

OUTLINE

The R5460xxxxxx Series are high voltage CMOS-based protection ICs for over-charge/discharge of rechargeable two-cell Lithium-ion (Li+) / Lithium polymer, further include a short circuit protection circuit for preventing large external short circuit current and the protection circuits against the excess discharge-current and excess charge current.

Each of these ICs is composed of six voltage detectors, a reference unit, a delay circuit, a short circuit protector, an oscillator, a counter, and a logic circuit. When the over-charge voltage threshold or excess-charge current threshold crosses the each detector threshold from a low value to a high value, the output of C_{OUT} pin switches to “L” level after internal fixed delay time. To release over-charge detector 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. In case that a charger is continuously connected to the battery pack, if the cell voltage becomes lower than the over-charge detector threshold, over-charge state is also released.

The output of D_{OUT} pin, the output of the over-discharge detector and the 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}.

The conditions to release over-discharge voltage detector after detecting over-discharge voltage are as follows:

A/D versions: after connecting a charger, when the cell voltage becomes higher than over-discharge detector threshold or, without connecting charger, when the cell voltage becomes equal or higher than over-discharge released voltage.

C version: after connecting a charger, when the cell voltage becomes higher than over-discharge detector threshold voltage.

E version: whether connecting a charger, or not, when the cell voltage becomes higher than released voltage from over-discharge.

F version: after connecting a charger, when the cell voltage becomes higher than released voltage from over-discharge.

In case that connecting a charger, for A/C/D versions, there is no hysteresis for over-discharge detector. For E/F versions, even if a charger is connected to the battery pack, the hysteresis of over-discharge detector exists.

To satisfy the release conditions for over-discharge voltage protector, the output voltage of DOUT becomes "H".

Even if a battery is discharged to 0V, charge current is acceptable.

After detecting excess-discharge current or short current, when the load is disconnected, the excess discharged or short condition is released and DOUT becomes “H”.

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

When the output of COUT is “H”, if V- pin level is set at -1.6V, the delay time of detector can be shortened. Especially, the delay time of the over-charge detector can be reduced into approximately 1/60 and test time for protection circuit PCB can be reduced. The output type of COUT and DOUT is CMOS.

FEATURES

Manufactured with High Voltage Tolerant Process .... Absolute Maximum Rating 30V

Low supply current ....Supply current (At normal mode) Typ. 4.0μA
Standby current Typ. 1.2μA(A/ D/ E version)
Max. 0.1μA(C/ F version)

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
Excess charge-current detector ±40mV

Variety of detector threshold
Over-charge detector threshold(A/ C/ E/ F version) 4.1V-4.5V step of 0.005V(VD1U / VD1L)
Over-discharge detector threshold(D version) 3.5V-4.0V step of 0.005V(VD1U / VD1L)
Over-discharge detector threshold 2.0V-3.0V step of 0.005V(VD2U / VD2L)
Excess charge-current threshold 0.05V-0.20V step of 0.005V
3 options of Excess charge-current threshold (1) -0.4V±40mV
....(2) -0.2V±30mV
....(3) -0.1V±30mV
Over-charge released voltage 0.1V-0.4V step of 0.05V(VH1U / VH1L)
Over-discharge released voltage 0.2V-0.7V step of 0.1V(VH2U / VH2L)
Short Detector Threshold Fixed at 0.8V

Internal fixed Output delay time ....Over-charge detector Output Delay 1.0s
Over-discharge detector Output Delay 128ms
Excess charge-current detector Output Delay 8ms
Short Circuit detector Output Delay 300μs

Output Delay Time Shortening Function ....At COUT is “H”, if V- level is set at –1.6V, the Output Delay time of detect and release the over-charge and over-discharge can be reduced.
(Delay Time for over-charge becomes about 1/60 of normal state.)

0V-battery charge .... acceptable

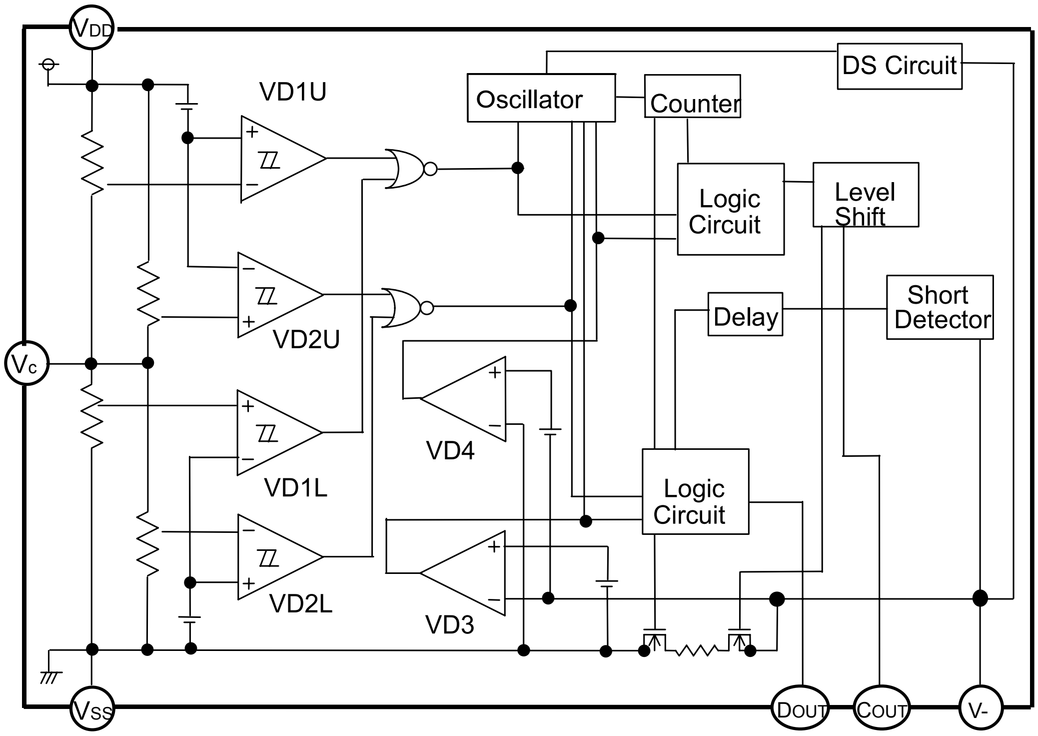
Ultra Small package .... SOT-23-6,DFN(PLP)1820-6

APPLICATIONS

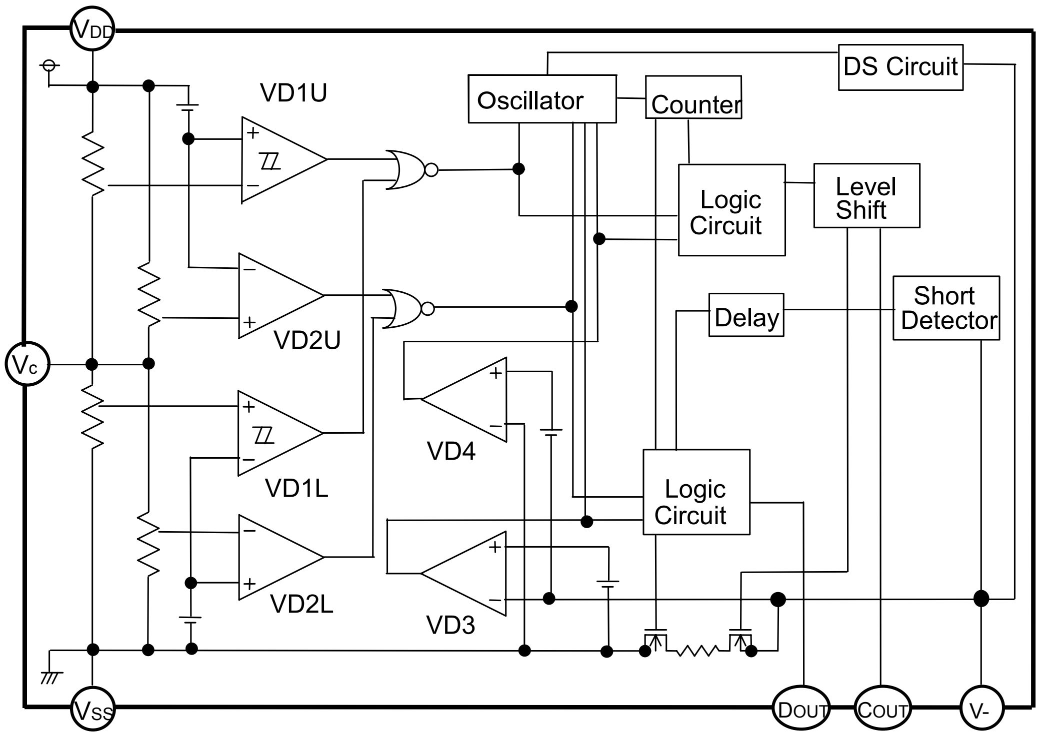
Li+ / Li Polymer protector of over-charge, over-discharge, excess-current for battery pack
High precision protectors for cell-phones and any other gadgets using on board Li+ / Li Polymer battery

BLOCK DIAGRAMS

A/ D/ E/ F version



C version



SELECTION GUIDE

In the R5460xxxxxx Series, input threshold of over-charge, over-discharge, excess discharge current, and the package and taping can be designated.

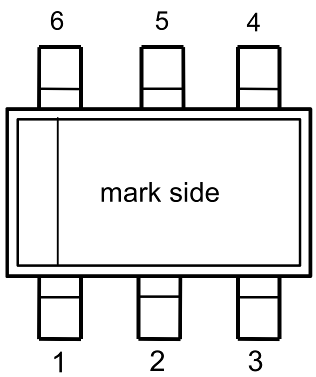
Part Number is designated as follows:

R5460x xxxxx-xx← Part Number
↑ ↑ ↑↑ ↑
a b c d e

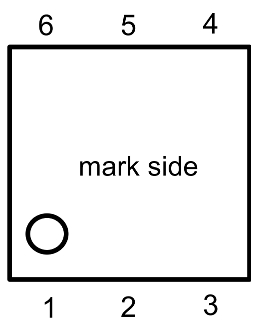
Code	Contents
a	Package Type N: SOT-23-6 K:DFN(PLP)1820-6
b	Serial Number for the R5402 Series designating input threshold for over-charge, over-discharge, excess discharge-current detectors.
c	Designation of Output delay option of over-charge and excess discharge-current.
d	Designation of version symbols
e	Taping Type: TR (refer to Taping Specification)

PIN CONFIGURATIONS

SOT-23-6



DFN(PLP)1820-6



PIN DESCRIPTIONS

Pin No.		Symbol	Description
SOT23-6	PLP1820-6		
1	3	D_{OUT}	Output pin of over-discharge detection, CMOS output
2	1	C_{OUT}	Output pin of over-charge detection, CMOS output
3	2	V-	Pin for charger negative input
4	6	VC	Input Pin of the center voltage between two-cell
5	5	V_{DD}	Power supply pin, the substrate voltage level of the IC.
6	4	V_{SS}	Vss pin. Ground pin for the IC

The backside tab of DFN(PLP)1820-6 package is connected to the substrate level. (V_{DD}) Note that avoiding short with other level.

ABSOLUTE MAXIMUM RATINGS

Symbol	Item	Ratings	Unit
V_{DD}	Supply voltage	-0.3 to 12	V
 Vc V-	Input voltage Center pin voltage between two-cell Charger negative input V- pin	 V_{SS} -0.3 to V_{DD}+0.3 V_{DD} -30 to V_{DD}+0.3	V
 VC_{OUT} VD_{OUT}	Output voltage C_{OUT} pin D_{OUT} pin	 V_{DD} -30 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

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

ELECTRICAL CHARACTERISTICS

R5460x2xxAA/AD/AE version Unless otherwise specified, Topt=25°C

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit	Note1
V_{DD1}	Operating input voltage	Voltage defined as V_{DD}-Vss	1.5		10.0	V	A
Vst	Minimum operating Voltage for 0V charging *Note 1	Voltage defined as V_{DD}-V- V_{DD}-Vss=0V			1.8	V	A
V_{DET1U}	CELL1 Over-charge threshold	Detect rising edge of supply Voltage R1=330Ω R1=330Ω (Topt=-5 to 55°C)*Note3	V_{DET1U}-0.025 V_{DET1U}-0.030	V_{DET1U} V_{DET1U}	V_{DET1U}+0.025 V_{DET1U}+0.030	V V	B B
V_{REL1U}	CELL1 Over-charge released voltage	R1=330Ω	V_{REL1U}-0.050	V_{REL1U}	V_{REL1U}+0.050	V	B
tV_{DET1}	Output delay of over-charge	V_{DD}=3.2V to 4.5V, Vc-Vss=3.2V	0.7	1.0	1.3	s	B
tV_{REL1}	Output delay of release from over-charge	V_{DD}=4.5V to 3.2V, Vc-Vss=3.2V	11	16	21	ms	B
V_{DET1L}	CELL2 Over-charge detector threshold	Detect rising edge of supply voltage R2=330Ω R2=330Ω (Topt=-5 to 55°C)*Note3	V_{DET1L}-0.025 V_{DET1L}-0.030	V_{DET1L} V_{DET1L}	V_{DET1L}+0.025 V_{DET1L}+0.030	V V	C C
V_{REL1L}	CELL2 Over-charge released voltage	R2=330Ω	V_{REL1L}-0.05	V_{REL1L}	V_{REL1L}+0.05	V	C
V_{DET2U}	CELL1 Over-discharge threshold	Detect falling edge of supply voltage	V_{DET2U}×0.975	V_{DET2U}	V_{DET2U}×1.025	V	D
V_{REL2U}	CELL1 Released Voltage from Over-discharge	Detect rising edge of supply voltage	V_{REL2U}×0.975	V_{REL2U}	V_{REL2U}×1.025	V	D
tV_{DET2}	Output delay of over-discharge	V_{DD}=3.2V to 1.9V, Vc-Vss=3.2V	89	128	167	ms	D
tV_{REL2}	Output delay of release from over-discharge	V_{DD}=1.9V to 3.2V, Vc-Vss=3.2V	0.7	1.2	1.7	ms	D
V_{DET2L}	CELL2 Over-discharge threshold	Detect falling edge of supply voltage	V_{DET2L}×0.975	V_{DET2L}	V_{DET2L}×1.025	V	E
V_{REL2L}	CELL2 Released Voltage from Over-discharge	Detect rising edge of supply voltage	V_{REL2L}×0.975	V_{REL2L}	V_{REL2L}×1.025	V	E
V_{DET3}	Excess discharge-current Threshold	Detect rising edge of 'V-' pin voltage	V_{DET3}-0.015	V_{DET3}	V_{DET3}+0.015	V	F
tV_{DET3}	Output delay of excess discharge current	V_{DD}-Vc=Vc-Vss=3.2V, V-=0V to 0.5V	8	12	16	ms	F
tV_{REL3}	Output delay of release from excess discharge-current	V_{DD}-Vc=Vc-Vss=3.2V, V-=3V to 0V	0.7	1.2	1.7	ms	F
V_{DET4}	Excess charge-current threshold	Detect falling edge of 'V-' pin voltage	-0.44 -0.23 -0.13	-0.40 -0.20 -0.10	-0.36 -0.17 -0.07	V	G
tV_{DET4}	Output delay of excess charge-current	V_{DD}-Vc=Vc-Vss=3.2V, V-=0V to -1V	5	8	11	ms	G
tV_{REL4}	Output delay of release from excess charge-current	V_{DD}-Vc=Vc-Vss=3.2V, V-=-1V to 0V	0.7	1.2	1.7	ms	G
Vshort	Short protection voltage	V_{DD}-Vc=Vc-Vss=3.2V	0.7	1.1	1.5	V	F
tshort	Output Delay of Short protection	V_{DD}-Vc=Vc-Vss=3.2V, V-=0V to 6.4V	150	300	500	μs	F
Rshort	Reset resistance for Excess discharge-current protection	V_{DD}-Vc=Vc-Vss=3.2V, V-=1V	25	40	75	kΩ	F
V_{DS}	Delay Shortening Mode input voltage	V_{DD}-Vc=Vc-Vss=4.0V	-2.2	-1.6	-1.0	V	G
V_{OL1}	Nch ON voltage of C_{OUT}	Iol=50μA V_{DD}-Vc=Vc-Vss=4.5V		0.4	0.5	V	H
V_{OH1}	Pch ON voltage of C_{OUT}	Ioh=-50μA V_{DD}-Vc=Vc-Vss=3.2V	6.8	7.4		V	I
V_{OL2}	Nch ON voltage of D_{OUT}	Iol=50μA V_{DD}-Vc=Vc-Vss=1.9V		0.2	0.5	V	J
V_{OH2}	Pch ON voltage of D_{OUT}	Ioh=-50μA, V_{DD}-Vc=Vc-Vss=3.2V	6.8	7.4		V	K
I_{DD}	Supply current	V_{DD}-Vc=Vc-Vss=3.2V, V-=0V		4.0	8.0	μA	L
I_S	Standby current	V_{DD}-Vc=Vc-Vss=1.9V		1.2	2.0	μA	L

*Note: We compensate for this characteristic related to temperature by laser-trim, however, this specification is guaranteed by design, not production tested.
*Note2: Indicates test circuits shown in 19-20 page.

RICOH

R5460x2xxAC version Unless otherwise specified, Topt=25°C

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit	Note1
V_{DD1}	Operating input voltage	Voltage defined as V_{DD}-Vss	1.5		10.0	V	A
Vst	Minimum operating Voltage for 0V charging *Note 1	Voltage defined as V_{DD}-V- V_{DD}-Vss=0V			1.8	V	A
V_{DET1U}	CELL1 Over-charge threshold	Detect rising edge of supply Voltage R1=330Ω R1=330Ω (Topt=-5 to 55°C)*Note3	V_{DET1U}-0.025 V_{DET1U}-0.030	V_{DET1U} V_{DET1U}	V_{DET1U}+0.025 V_{DET1U}+0.030	V V	B B
V_{REL1U}	CELL1 Over-charge released voltage	R1=330Ω	V_{REL1U}-0.050	V_{REL1U}	V_{REL1U}+0.050	V	B
tV_{DET1}	Output delay of over-charge	V_{DD}=3.2V to 4.5V, Vc-Vss=3.2V	0.7	1.0	1.3	s	B
tV_{REL1}	Output delay of release from over-charge	V_{DD}=4.5V to 3.2V, Vc-Vss=3.2V	11	16	21	ms	B
V_{DET1L}	CELL2 Over-charge detector threshold	Detect rising edge of supply voltage R2=330Ω R2=330Ω (Topt=-5 to 55°C)*Note3	V_{DET1L}-0.025 V_{DET1L}-0.030	V_{DET1L} V_{DET1L}	V_{DET1L}+0.025 V_{DET1L}+0.030	V V	C C
V_{REL1L}	CELL2 Over-charge released voltage	R2=330Ω	V_{REL1L}-0.05	V_{REL1L}	V_{REL1L}+0.05	V	C
V_{DET2U}	CELL1 Over-discharge threshold	Detect falling edge of supply voltage	V_{DET2U}×0.975	V_{DET2U}	V_{DET2U}×1.025	V	D
tV_{DET2}	Output delay of over-discharge	V_{DD}=3.2V to 1.9V, Vc-Vss=3.2V	89	128	167	ms	D
tV_{REL2}	Output delay of release from over-discharge	V_{DD}=1.9V to 3.2V, Vc-Vss=3.2V	0.7	1.2	1.7	ms	D
V_{DET2L}	CELL2 Over-discharge threshold	Detect falling edge of supply voltage	V_{DET2L}×0.975	V_{DET2L}	V_{DET2L}×1.025	V	E
V_{DET3}	Excess discharge-current Threshold	Detect rising edge of 'V-' pin voltage	V_{DET3}-0.015	V_{DET3}	V_{DET3}+0.015	V	F
tV_{DET3}	Output delay of excess discharge current	V_{DD}-Vc=Vc-Vss=3.2V, V-=0V to 0.5V	8	12	16	ms	F
tV_{REL3}	Output delay of release from excess discharge-current	V_{DD}-Vc=Vc-Vss=3.2V, V-=3V to 0V	0.7	1.2	1.7	ms	F
V_{DET4}	Excess charge-current threshold	Detect falling edge of 'V-' pin voltage	-0.44 -0.23 -0.13	-0.40 -0.20 -0.10	-0.36 -0.17 -0.07	V	G
tV_{DET4}	Output delay of excess charge-current	V_{DD}-Vc=Vc-Vss=3.2V, V-=0V to -1V	5	8	11	ms	G
tV_{REL4}	Output delay of release from excess charge-current	V_{DD}-Vc=Vc-Vss=3.2V, V-=-1V to 0V	0.7	1.2	1.7	ms	G
Vshort	Short protection voltage	V_{DD}-Vc=Vc-Vss=3.2V	0.7	1.1	1.5	V	F
tshort	Output Delay of Short protection	V_{DD}-Vc=Vc-Vss=3.2V, V-=0V to 6.4V	150	300	500	μs	F
Rshort	Reset resistance for Excess discharge-current protection	V_{DD}-Vc=Vc-Vss=3.2V, V-=1V	25	40	75	kΩ	F
V_{DS}	Delay Shortening Mode input voltage	V_{DD}-Vc=Vc-Vss=4.0V	-2.2	-1.6	-1.0	V	G
V_{OL1}	Nch ON voltage of COUT	Iol=50μA V_{DD}-Vc=Vc-Vss=4.5V		0.4	0.5	V	H
V_{OH1}	Pch ON voltage of COUT	Ioh=-50μA V_{DD}-Vc=Vc-Vss=3.2V	6.8	7.4		V	I
V_{OL2}	Nch ON voltage of DOUT	Iol=50μA V_{DD}-Vc=Vc-Vss=1.9V		0.2	0.5	V	J
V_{OH2}	Pch ON voltage of DOUT	Ioh=-50μA, V_{DD}-Vc=Vc-Vss=3.2V	6.8	7.4		V	K
I_{DD}	Supply current	V_{DD}-Vc=Vc-Vss=3.2V, V-=0V		4.0	8.0	μA	L
I_S	Standby current	V_{DD}-Vc=Vc-Vss=1.9V			0.1	μA	L

*Note: We compensate for this characteristic related to temperature by laser-trim, however, this specification is guaranteed by design, not production tested.
*Note2: Indicates test circuits shown in 19-20 page.

R5460x2xxAF version

Unless otherwise specified, Topt=25°C

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit	Note1
V_{DD1}	Operating input voltage	Voltage defined as V_{DD}-Vss	1.5		10.0	V	A
Vst	Minimum operating Voltage for 0V charging *Note 1	Voltage defined as V_{DD}-V- V_{DD}-Vss=0V			1.8	V	A
V_{DET1U}	CELL1 Over-charge threshold	Detect rising edge of supply Voltage R1=330Ω R1=330Ω (Topt=-5 to 55°C)*Note3	V_{DET1U}-0.025 V_{DET1U}-0.030	V_{DET1U} V_{DET1U}	V_{DET1U}+0.025 V_{DET1U}+0.030	V V	B B
V_{REL1U}	CELL1 Over-charge released voltage	R1=330Ω	V_{REL1U}-0.050	V_{REL1U}	V_{REL1U}+0.050	V	B
tV_{DET1}	Output delay of over-charge	V_{DD}=3.2V to 4.5V, Vc-Vss=3.2V	0.7	1.0	1.3	s	B
tV_{REL1}	Output delay of release from over-charge	V_{DD}=4.5V to 3.2V, Vc-Vss=3.2V	11	16	21	ms	B
V_{DET1L}	CELL2 Over-charge detector threshold	Detect rising edge of supply voltage R2=330Ω R2=330Ω (Topt=-5 to 55°C)*Note3	V_{DET1L}-0.025 V_{DET1L}-0.030	V_{DET1L} V_{DET1L}	V_{DET1L}+0.025 V_{DET1L}+0.030	V V	C C
V_{REL1L}	CELL2 Over-charge released voltage	R2=330Ω	V_{REL1L}-0.05	V_{REL1L}	V_{REL1L}+0.05	V	C
V_{DET2U}	CELL1 Over-discharge threshold	Detect falling edge of supply voltage	V_{DET2U}×0.975	V_{DET2U}	V_{DET2U}×1.025	V	D
V_{REL2U}	CELL1 Released Voltage from Over-discharge	Detect rising edge of supply voltage	V_{REL2U}×0.975	V_{REL2U}	V_{REL2U}×1.025	V	D
tV_{DET2}	Output delay of over-discharge	V_{DD}=3.2V to 1.9V, Vc-Vss=3.2V	89	128	167	ms	D
tV_{REL2}	Output delay of release from over-discharge	V_{DD}=1.9V to 3.2V, Vc-Vss=3.2V	0.7	1.2	1.7	ms	D
V_{DET2L}	CELL2 Over-discharge threshold	Detect falling edge of supply voltage	V_{DET2L}×0.975	V_{DET2L}	V_{DET2L}×1.025	V	E
V_{REL2L}	CELL2 Released Voltage from Over-discharge	Detect rising edge of supply voltage	V_{REL2L}×0.975	V_{REL2L}	V_{REL2L}×1.025	V	E
V_{DET3}	Excess discharge-current Threshold	Detect rising edge of 'V-' pin voltage	V_{DET3}-0.015	V_{DET3}	V_{DET3}+0.015	V	F
tV_{DET3}	Output delay of excess discharge current	V_{DD}-Vc=Vc-Vss=3.2V, V-=0V to 0.5V	8	12	16	ms	F
tV_{REL3}	Output delay of release from excess discharge-current	V_{DD}-Vc=Vc-Vss=3.2V, V-=3V to 0V	0.7	1.2	1.7	ms	F
V_{DET4}	Excess charge-current threshold	Detect falling edge of 'V-' pin voltage	-0.44 -0.23 -0.13	-0.40 -0.20 -0.10	-0.36 -0.17 -0.07	V	G
tV_{DET4}	Output delay of excess charge-current	V_{DD}-Vc=Vc-Vss=3.2V, V-=0V to -1V	5	8	11	ms	G
tV_{REL4}	Output delay of release from excess charge-current	V_{DD}-Vc=Vc-Vss=3.2V, V-=-1V to 0V	0.7	1.2	1.7	ms	G
Vshort	Short protection voltage	V_{DD}-Vc=Vc-Vss=3.2V	0.7	1.1	1.5	V	F
tshort	Output Delay of Short protection	V_{DD}-Vc=Vc-Vss=3.2V, V-=0V to 6.4V	150	300	500	μs	F
Rshort	Reset resistance for Excess discharge-current protection	V_{DD}-Vc=Vc-Vss=3.2V, V-=1V	25	40	75	kΩ	F
V_{DS}	Delay Shortening Mode input voltage	V_{DD}-Vc=Vc-Vss=4.0V	-2.2	-1.6	-1.0	V	G
V_{OL1}	Nch ON voltage of COUT	Iol=50μA V_{DD}-Vc=Vc-Vss=4.5V		0.4	0.5	V	H
V_{OH1}	Pch ON voltage of COUT	Ioh=-50μA V_{DD}-Vc=Vc-Vss=3.2V	6.8	7.4		V	I
V_{OL2}	Nch ON voltage of DOUT	Iol=50μA V_{DD}-Vc=Vc-Vss=1.9V		0.2	0.5	V	J
V_{OH2}	Pch ON voltage of DOUT	Ioh=-50μA, V_{DD}-Vc=Vc-Vss=3.2V	6.8	7.4		V	K
I_{DD}	Supply current	V_{DD}-Vc=Vc-Vss=3.2V, V-=0V		4.0	8.0	μA	L
I_S	Standby current	V_{DD}-Vc=Vc-Vss=1.9V			0.1	μA	L

*Note: We compensate for this characteristic related to temperature by laser-trim, however, this specification is guaranteed by design, not production tested.
*Note2: Indicates test circuits shown in 19-20 page.

OPERATION

VDET1U,VDET1L / Over-Charge Detectors

The VDET1U and VDET1L monitor the voltage between V_{DD} pin and V_c pin (the voltage of Cell1) and the voltage between V_C pin and V_{SS} pin (the voltage of Cell2), if either voltage becomes equal or more than the over-charge detector threshold, the over-charge is detected, and an external charge control Nch MOSFET turns off with C_{OUT} pin being at "L" level.
VDET1U is the detector of Cell1, and the VDET1L is the detector of Cell2.

To reset the over-charge and make the C_{OUT} pin level to "H" again after detecting over-charge, in such conditions that a time when the both Cell1 and Cell2 are down to a level lower than over-charge voltage, by connecting a kind of load to V_{DD} after disconnecting a charger from the battery pack. Then, the 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 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. By connecting some load, V- pin voltage becomes equal or more than excess-discharge current detector threshold, and reset the over-charge detecting state.

Further, either or both voltage of Cell1 and Cell2 is higher than the over-charge detector threshold, if a charger is removed and some load is connected, COUT outputs “L”, however, load current can flow through the parasitic diode of the external charge control Nch MOSFET. After that, when the VDD pin voltage becomes lower than the over-charge detector threshold, COUT becomes “H”.

Internal fixed output delay times for over-charge detection and release from over-charge exist. If either or both of the voltage of Cell1 or Cell2 keeps its level more than the over-charge detector threshold, and output delay time passes, over-charge voltage is detected. Even when the voltage of Cell1 or Cell2 pin level becomes equal or higher level than V_{DET1} if these voltages would be back to a level lower than the over-charge detector threshold within a time period of the output delay time, the over-charge is not detected. Besides, after detecting over-charge, while the both of Cell1 and Cell2 voltages are lower than the over-charge detector threshold, 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.

VDET2U,VDET2L / Over-Discharge Detectors

The VDET2U and VDET2L monitor the voltage between V_{DD} pin and VC pin (Cell1 voltage) and the voltage between VC pin and VSS pin (Cell2 Voltage). When either of the cell1 or cell2 voltage becomes equal or less than the over-discharge detector threshold, the over-discharge is detected and discharge stops by the external discharge control Nch MOSFET turning off with the D_{OUT} pin being at "L" level.

The conditions to release over-discharge voltage detector after detecting over-discharge voltage are as follows:

A/D versions: after connecting a charger, when the cell voltage becomes higher than over-discharge detector threshold or, without connecting charger, when the cell voltage becomes equal or higher than over-discharge released voltage.

C version: after connecting a charger, when the cell voltage becomes higher than over-discharge detector threshold voltage.

E version: whether connecting a charger, or not, when the cell voltage becomes higher than released voltage from over-discharge.

F version: after connecting a charger, when the cell voltage becomes higher than released voltage from over-discharge.

In case that connecting a charger, for A/C/D versions, there is no hysteresis for over-discharge detector.

For E/F versions, even if a charger is connected to the battery pack, the hysteresis of over-discharge

detector exists.
When a cell voltage equals to zero, if the voltage of a charger is equal or more than 0V-charge minimum voltage (Vst), C_{OUT} pin becomes "H" and a system is allowable to charge.

The output delay time for over-discharge detect is fixed internally. Even if the voltage of Cell1 or Cell2 is down to equal or lower than the over-discharge detector threshold, if the voltage of Cell1 or Cell2 would be back to a level higher than the over-discharge detector threshold within a time period of the output delay time, the over-discharge is not detected. Output delay time for release from over-discharge is also set.

After detecting over-discharge, supply current would be reduced and be into standby by halting unnecessary circuits and consumption current of the IC itself is made as small as possible.
C version: after detecting over-discharge, all the circuits are halted and the R5460 will be into standby mode.

Others: after detecting over-discharge, whole circuits except over-discharge released detector function are halted, and the R5460 will be into standby mode.

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

VDET3 /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 /V_{DD} and excess discharge-current threshold V_{DET3}, VDET3 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.

An output delay time for the excess discharge-current detector is internally fixed.
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.

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

The V - pin has a built-in pull-down resistor to the Vss 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 the 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 R5460xxxxxx is at excess discharge-current detection mode. By disconnecting a load, VDET3 is automatically released from excess discharge-current.

VDET4/ Excess charge-current detector

When the battery pack is chargeable and discharge is also possible, VDET4 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 VDET4 threshold within the delay time, the excess charge current is not detected. Output delay for the release from excess charge current is also set.

VDET4 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 to V- pin when the COUT is “H”.

Operation against 2-Cell Unbalance

A/D/E version: If one of the cells detects over-charge and the output of COUT becomes "L" and keeps the status, even if the other cell detects over-charge or over-discharge or short, the over-charge status is maintained and the output of COUT keeps "L". If one of the cell detects over-charge and the output of COUT becomes "L", the other cell detects over-discharge and the former cell is released from over-charge, after the delay time of the released from over-charge, the output of COUT becomes "H", and after the delay time of detecting over-discharge, the output of DOUT becomes "L". After detecting over-discharge, A version halts internal unnecessary circuits and be into the standby mode. (Supply current Max. 2.0μA)

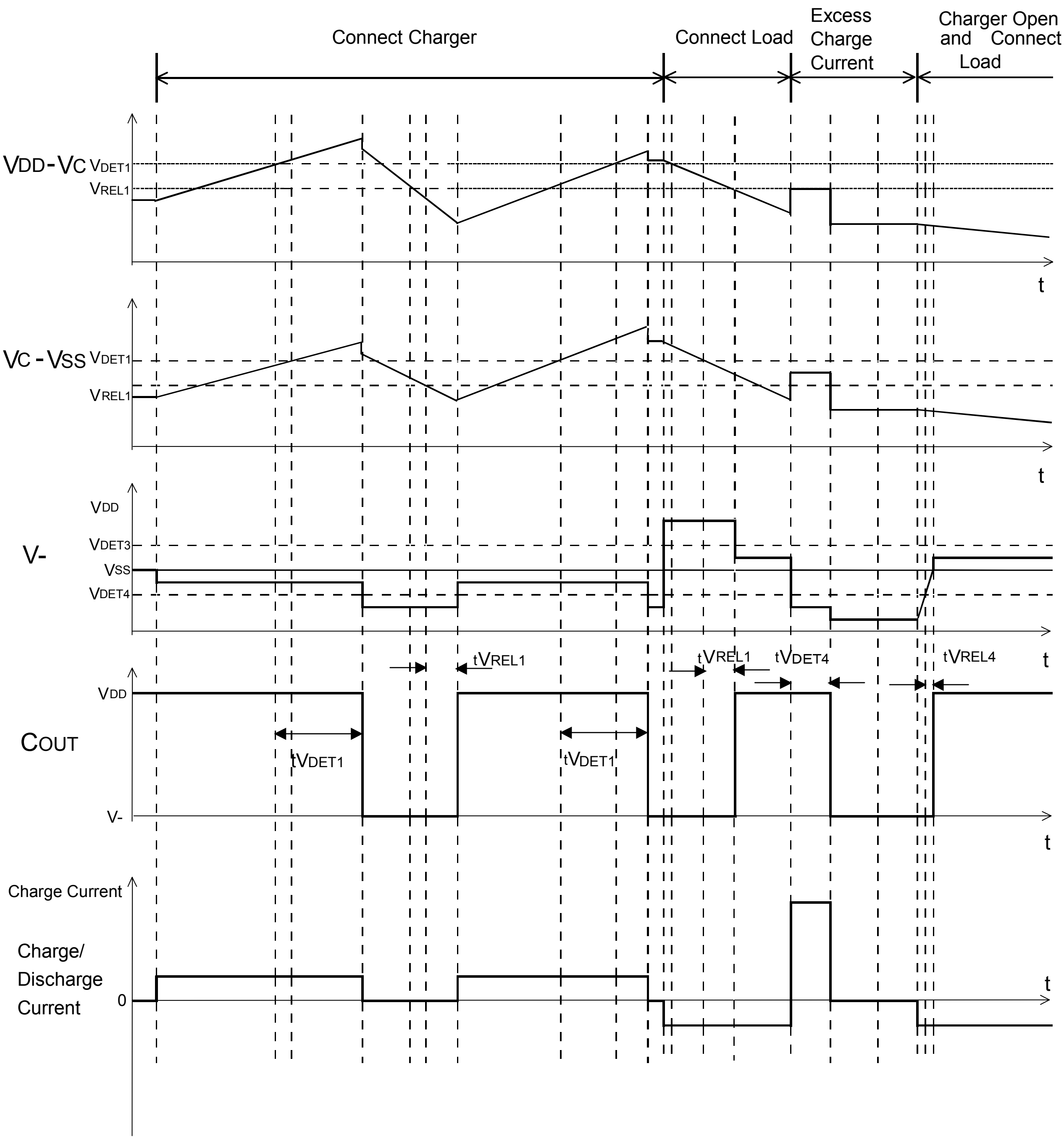
C/F version: If one of the cells detect over-charge, and when the COUT becomes "L", even if the other cell would detect over-discharge or short, the over-charge detector will be dominant and COUT keeps the "L" level. If one of the cell detects the over-discharge, and when the DOUT becomes "L", in case that a charger is connected to the battery pack and the other cell detects over-charge, the internal counter will start and after the delay time of over-discharge detector, DOUT will become "H". After the delay time of over-charge release from when the internal counter starts, COUT will be "L". If the over-discharge is detected, internal unnecessary circuits will be cut off and the standby mode will be realized. (Standby current Max. 0.1μA)

In any versions, the external FETs do not turn off at the same time.

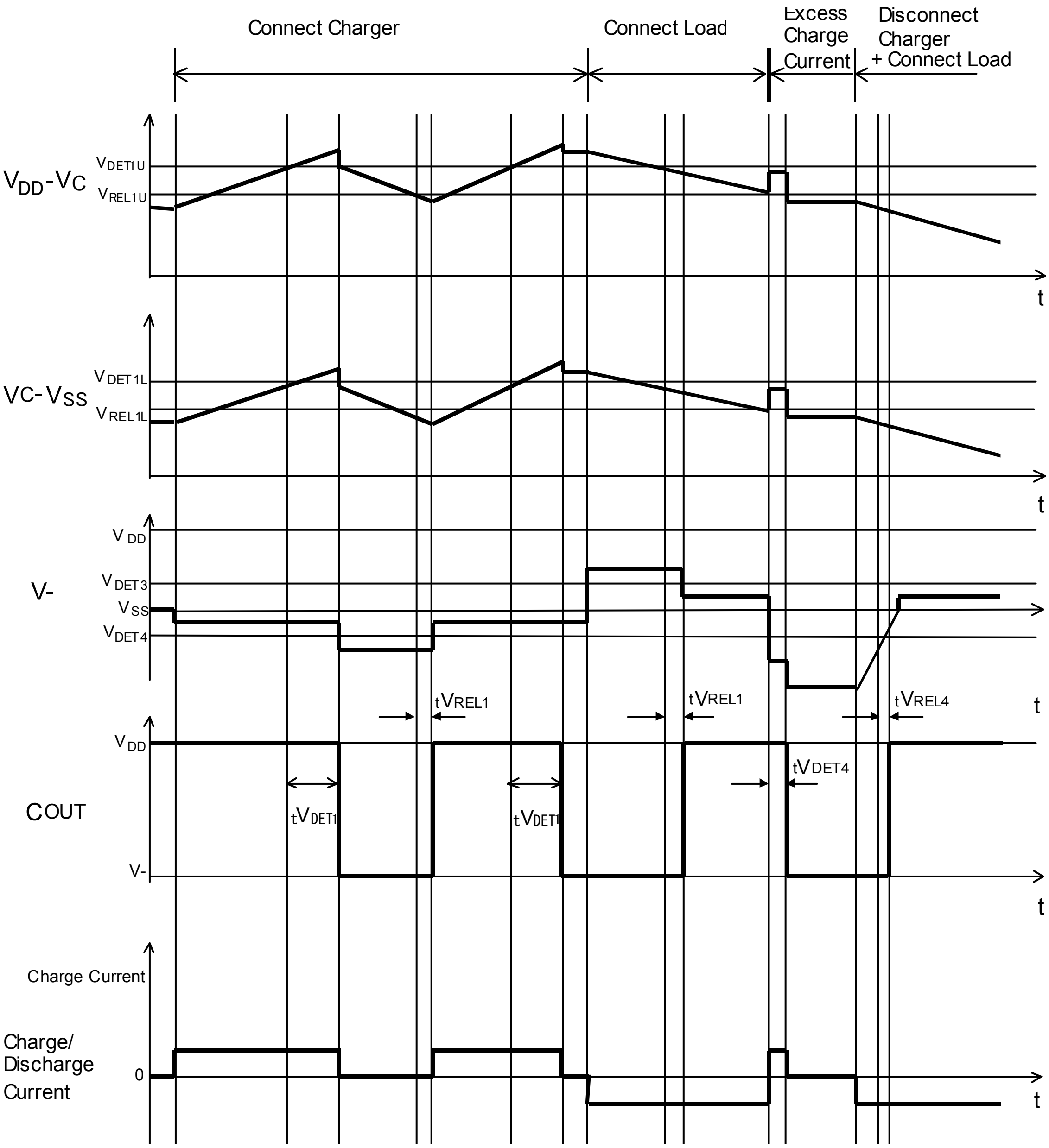
TIMING CHART

1) Timing diagram of Over-charge,Excess charge current

AA/AC/AD version

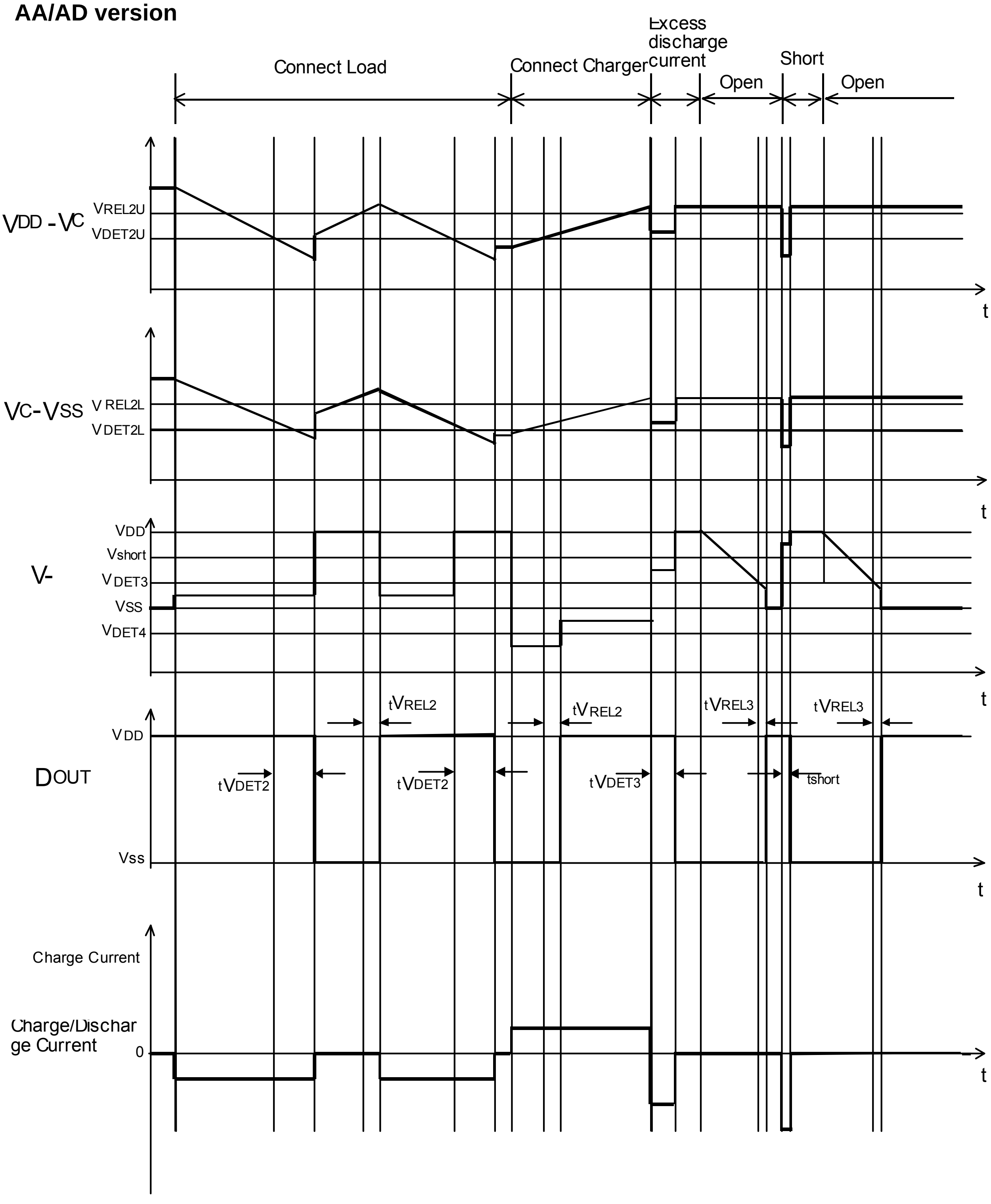


AE/AF version

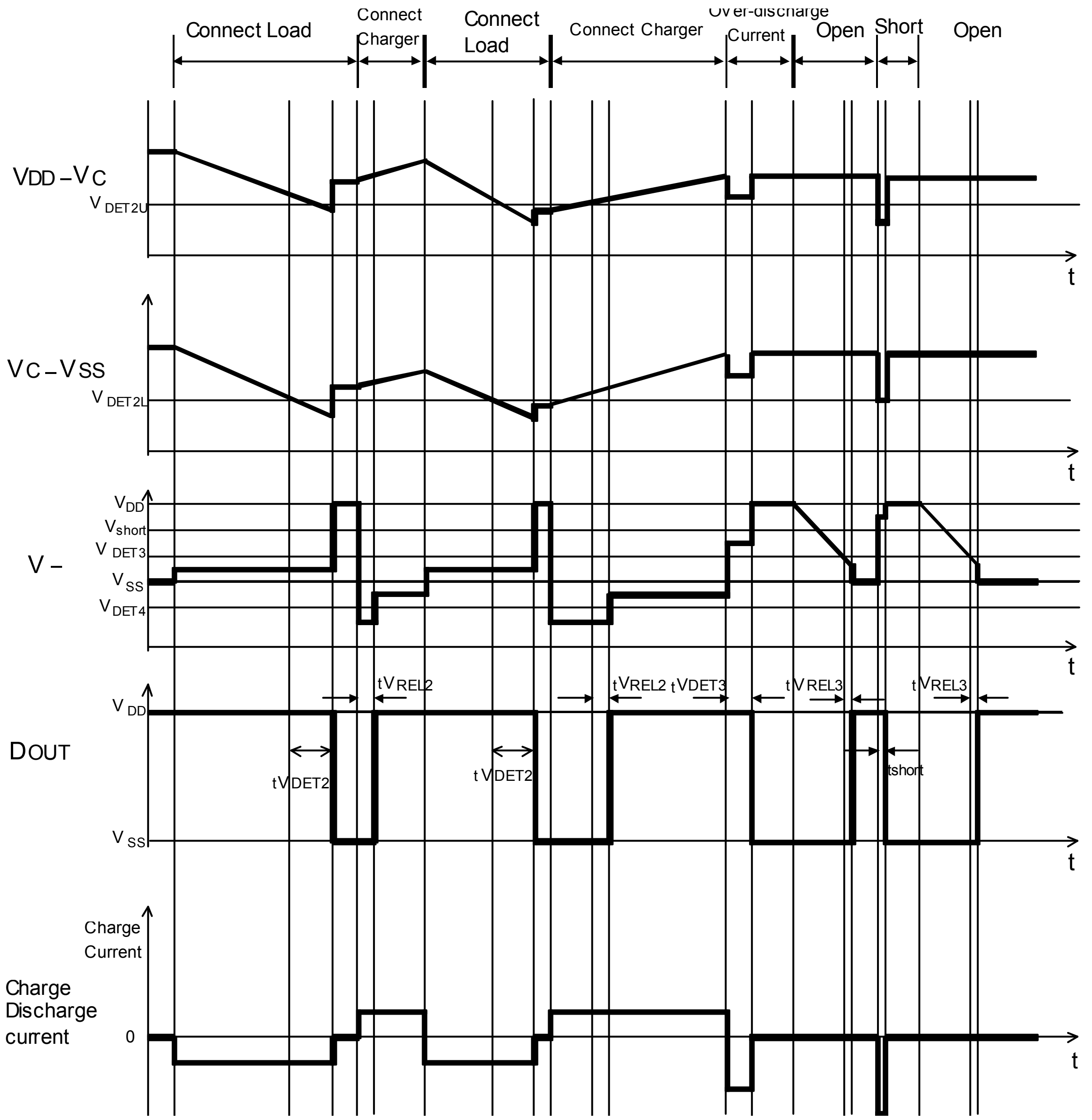


2) Over-discharge, Excess discharge current, Short circuit

AA/AD version

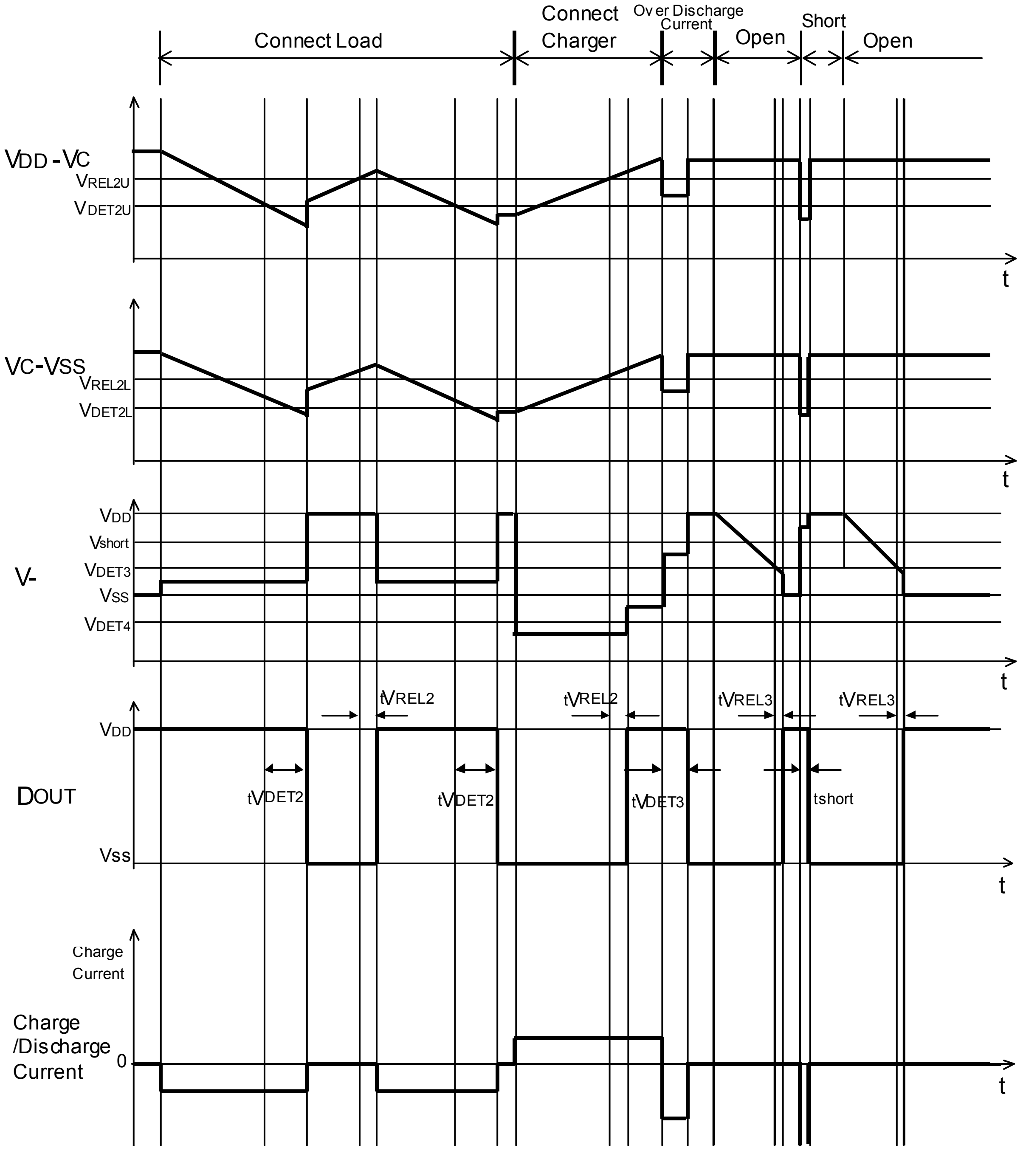


AC version



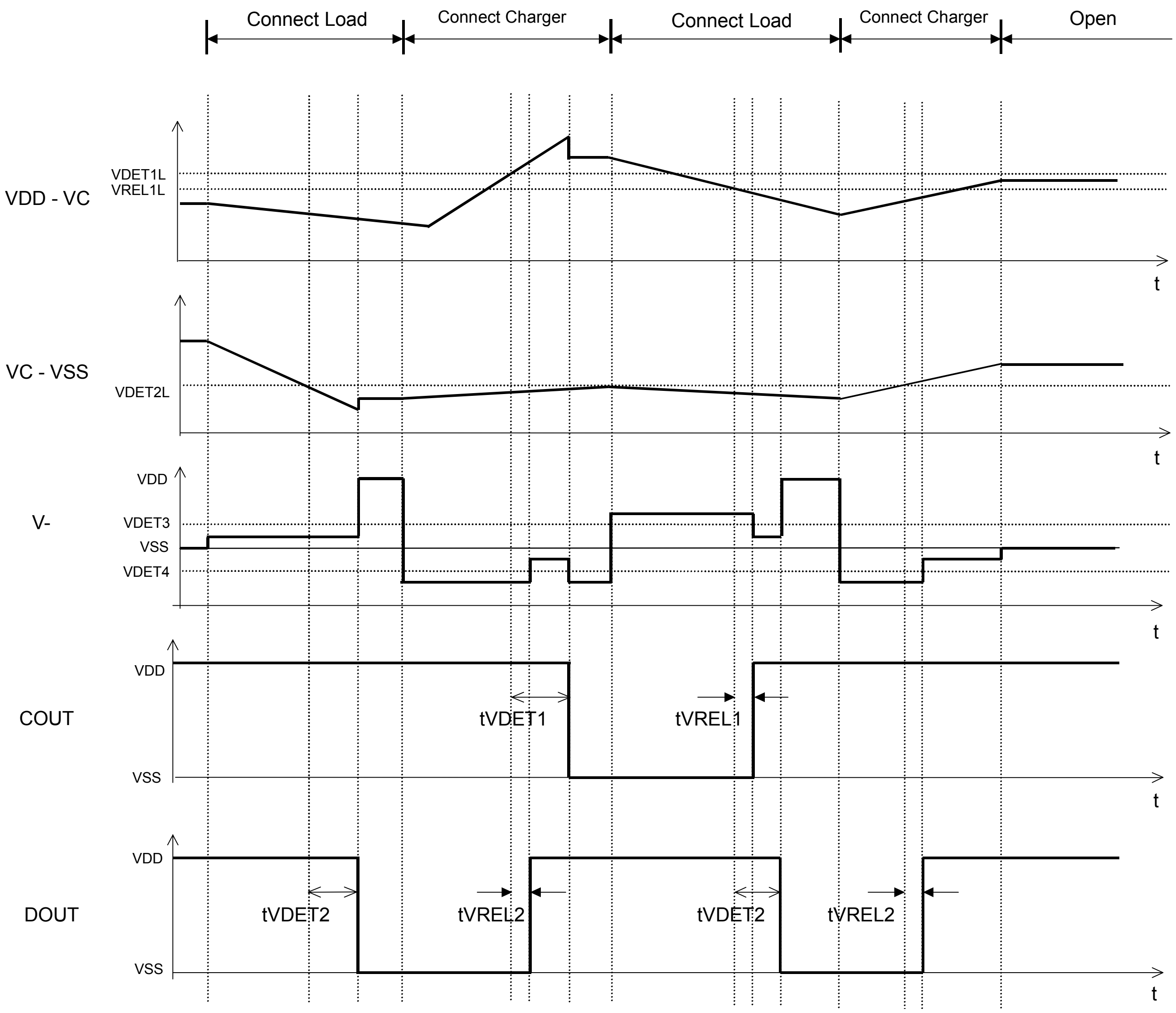
Connect Load
Connect Charger
Connect Load
Connect Charger
Over-discharge Current
Open
Short
Open
VDD – VC
V DET2U
t
VC – VSS
V DET2L
t
V –
VDD
Vshort
V DET3
V SS
V DET4
t
DOUT
V DD
V SS
tVREL2
tVREL2
tVDET3
tVREL3
tVREL3
tVDET2
tVDET2
tshort
t
Charge Current
Charge Discharge current
0
t

AE version

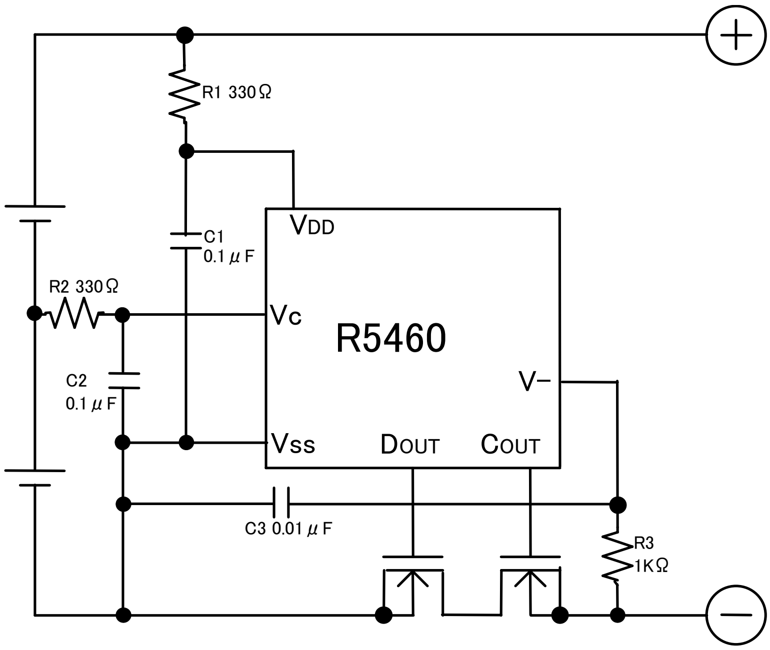

Connect Load
Connect Charger
Over Discharge Current
Open
Short
Open
VDD-VC
VREL2U
VDET2U
t
VC-VSS
VREL2L
VDET2L
t
VDD
Vshort
VDET3
V-
VSS
VDET4
t
tVREL2
tVREL2
tVREL3
tVREL3
VDD
DOUT
tVDET2
tVDET2
tVDET3
tshort
Vss
t
Charge Current
Charge /Discharge Current
0
t

3) Operation with unbalanced cells

AC version



TYPICAL APPLICATION AND TECHNICAL NOTES



TECHNICAL NOTES

R1, R2, C1 and C2 stabilize a supply voltage to the R5460xxxxxx. A recommended R1, R2 value is less than 1kΩ.

A larger value of R1 and R2 makes the detection voltage shift higher because of some conduction current in the R5460xxxxxx.

To stabilize the operation, the value of C1 and C2 should be equal or more than 0.01μF.

R1 and R3 can operate also as parts for current limit circuit against reverse charge or applying a charger with excess charging voltage beyond the absolute maximum rating of the R5460xxxxxx, the battery pack. Small value of R1 and R3 may cause over-power consumption rating of power dissipation of the R5460xxxxx. Thus, the total value of 'R1+R3' should be equal or more than 1kΩ.

If R3 value is set too large, after detecting over-discharge, release operation by connecting a charger may be impossible, our recommendation value as R3 is 3kΩ or less.

To stabilize the operation of the IC, use 0.01μF or more capacitor as C3.

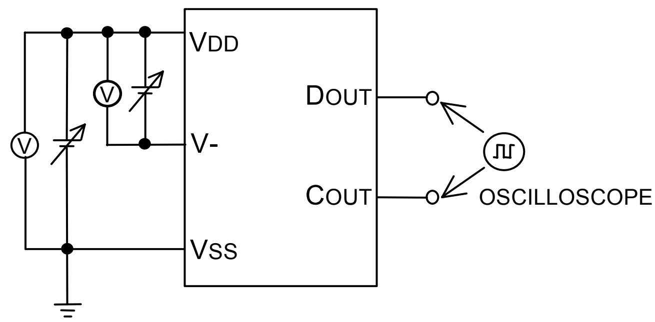
The typical application circuit diagram is just an example. This circuit performance largely depends on the PCB layout and external components. In the actual application, fully evaluation is necessary.

Over-voltage and the over current beyond the absolute maximum rating should not be forced to the protection IC and external components.

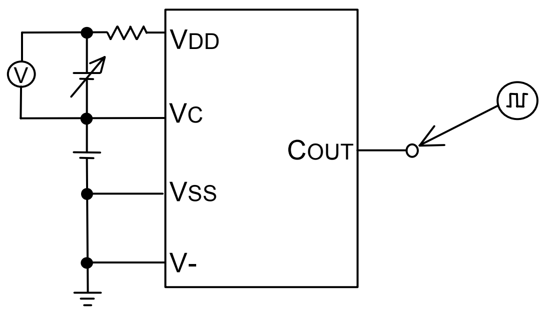
Ricoh cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Ricoh product. If technical notes are not complied with the circuit which is used Ricoh product, Ricoh is not responsible for any damages and any accidents.

TEST CIRCUITS

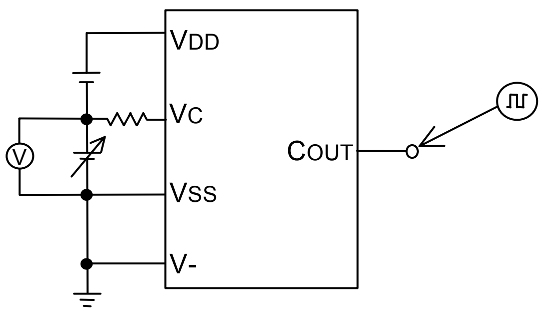
A



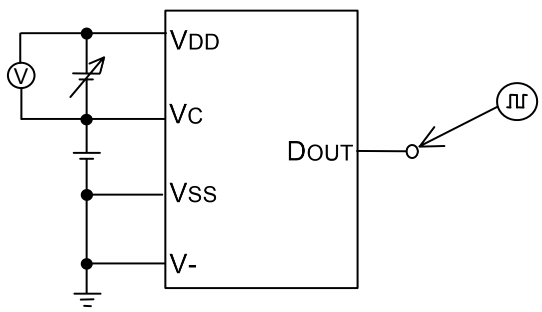
B



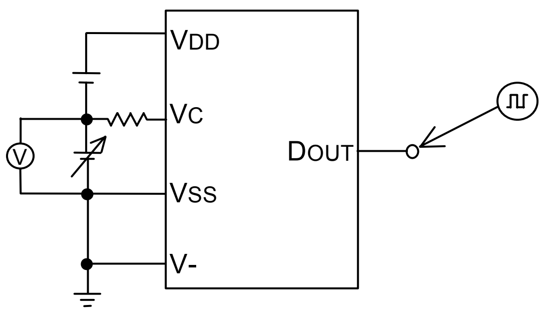
C



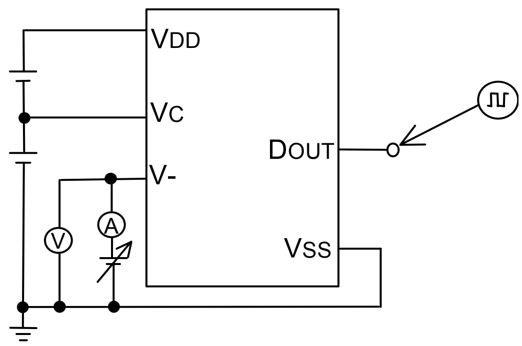
D



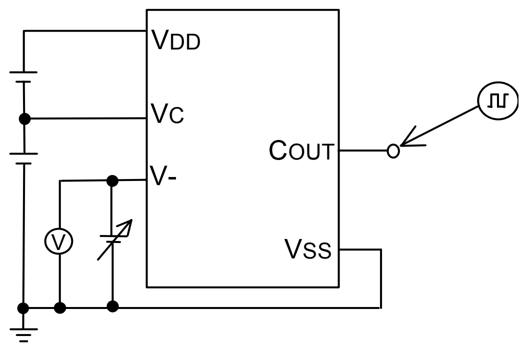
E



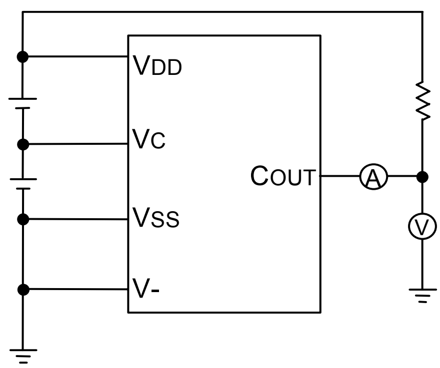
F



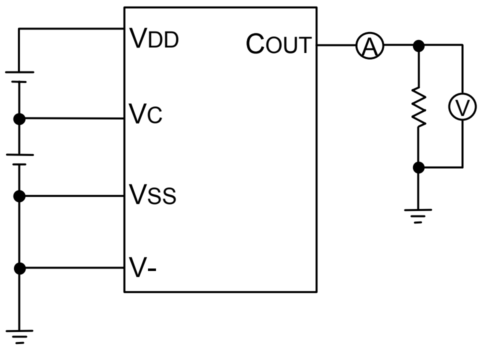
G



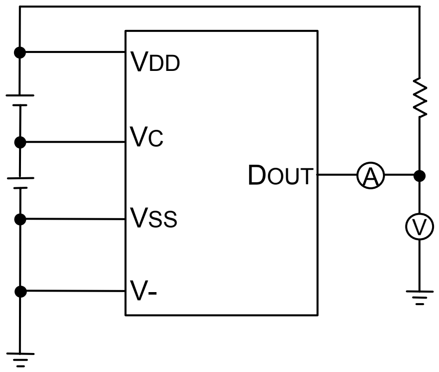
H



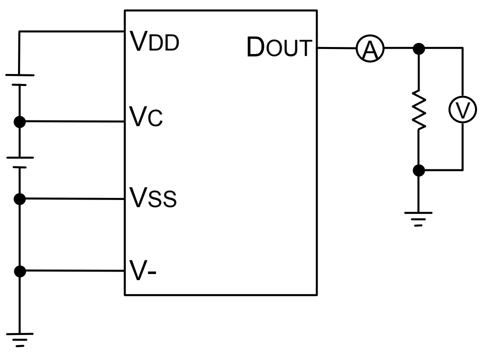
I


VDD
COUT
A
V
VC
VSS
V-

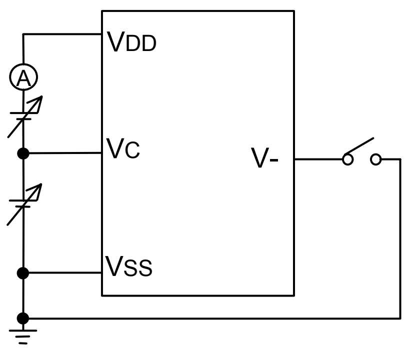
J


VDD
VC
DOUT
A
V
VSS
V-

K


VDD
DOUT
A
V
VC
VSS
V-

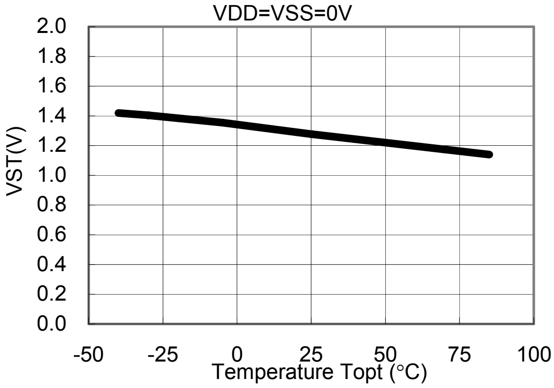
L


VDD
A
VC
V-
VSS

TYPICAL CHARACTERISTICS (Part 1)

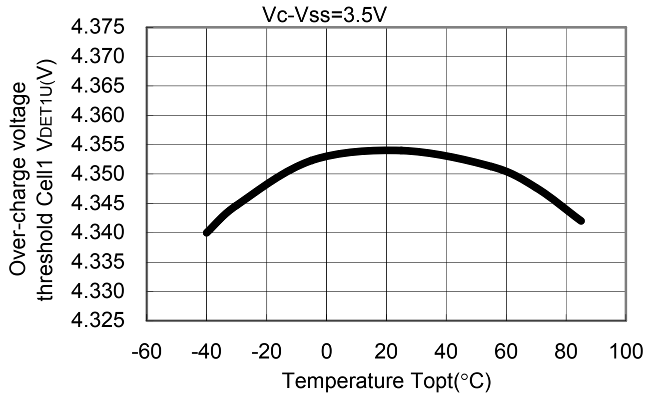
1) Minimum Operating Voltage for 0V Cell Charging

R5460x201AC



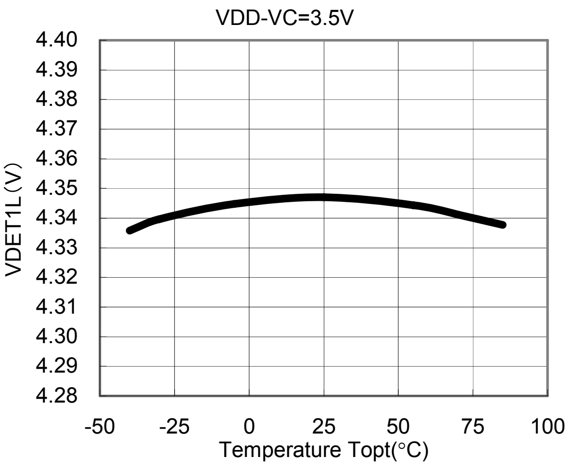
2) Over-charge voltage threshold (Cell1) vs. Temperature

R5460x201AC



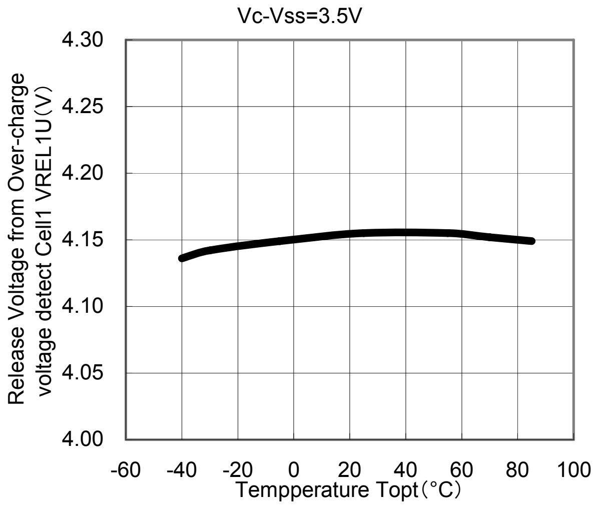
3) Over-Charge Voltage Threshold (Cell2) vs. Temperature
Temperature

R5460x201AC



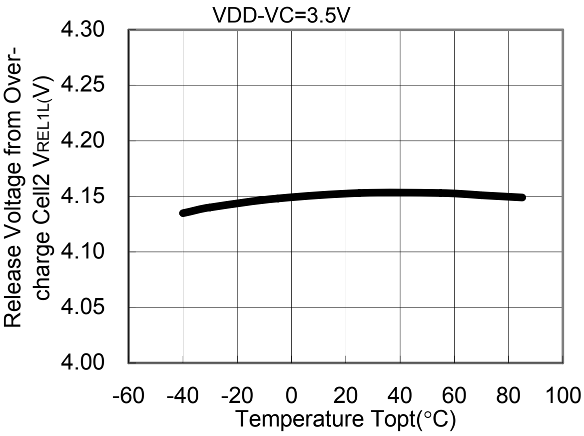
4)Release Voltage from Over-charge (Cell1) vs.

R5460x201AC



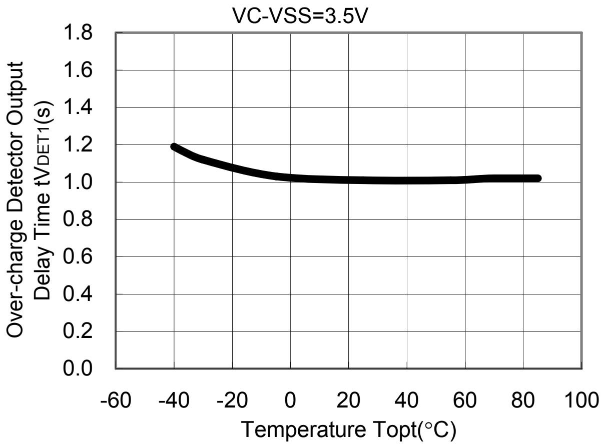
5) Release Voltage from Over-charge (Cell2) vs. Temperature

R5460x201AC



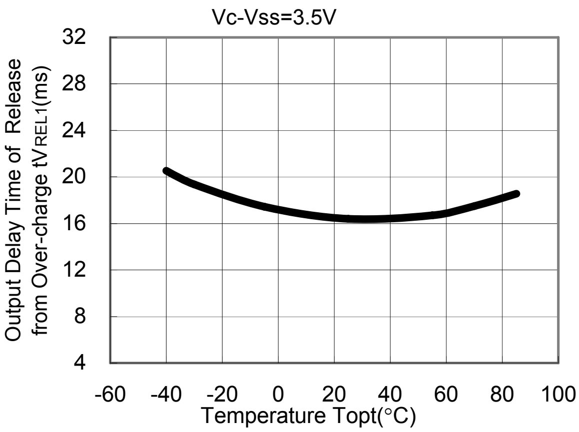
6) Output Delay of Over-charge Detector vs. Temperature

R5460x201AC



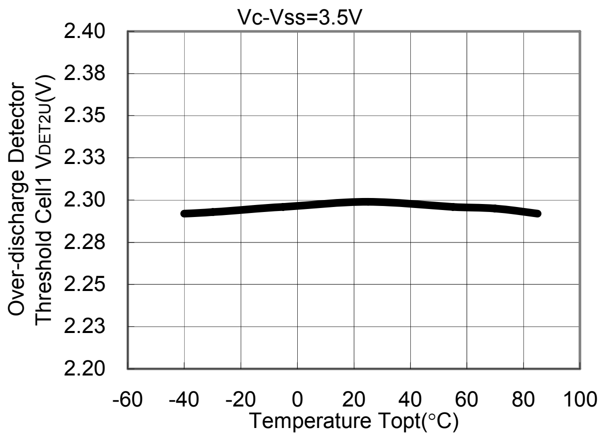
7) Output Delay of Release from Over-charge vs. Temperature

R5460x201AC



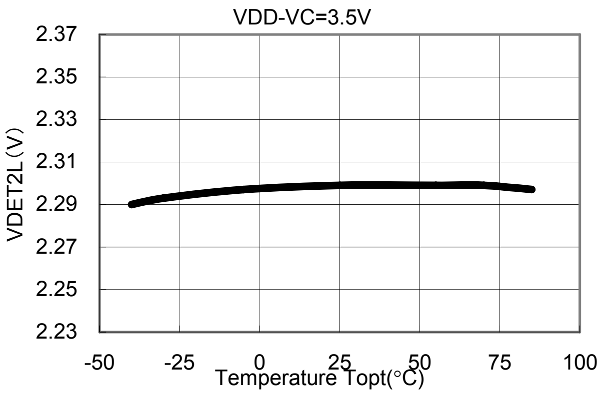
8) Over-discharge Detector Threshold (Cell1) vs. Temperature

R5460x201AC



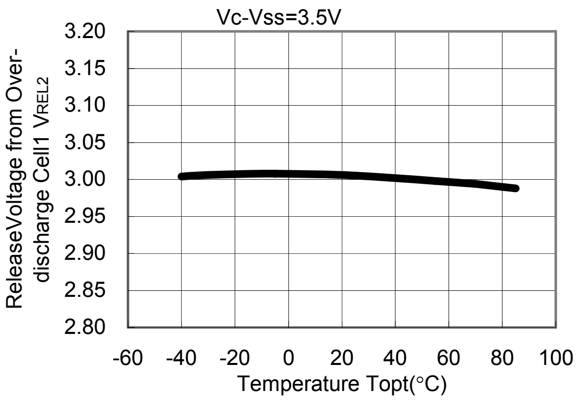
9) Over-discharge Detector Threshold (Cell2) vs. Temperature

R5460x201AC



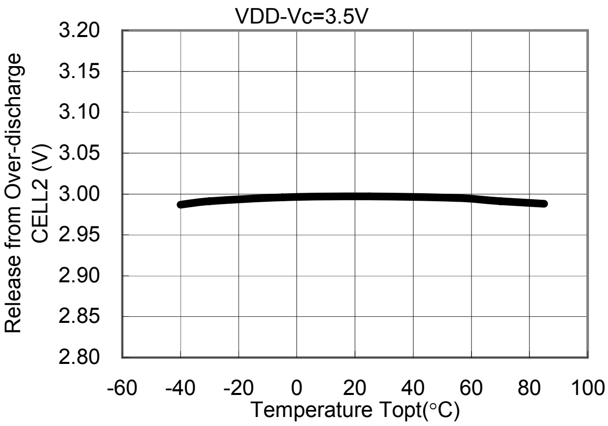
10) Release Voltage from Over-discharge (Cell1) vs. Temperature

R5460x202AA



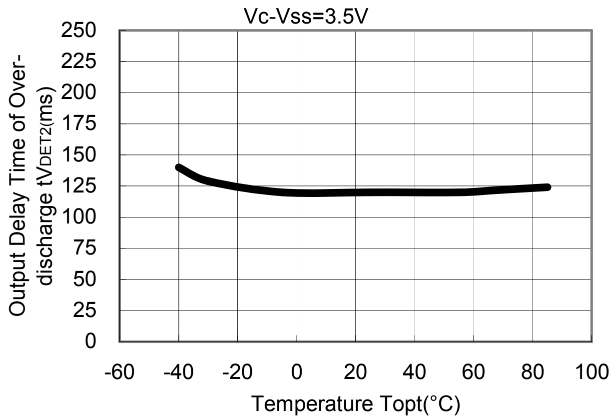
11) Release Voltage from Over-discharge (Cell2) vs. Temperature
Temperature

R5460x202AA



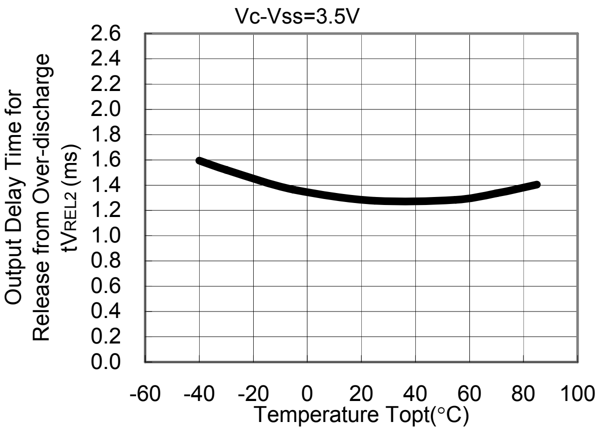
12) Output Delay Time for Over-discharge vs.

R5460x201AC



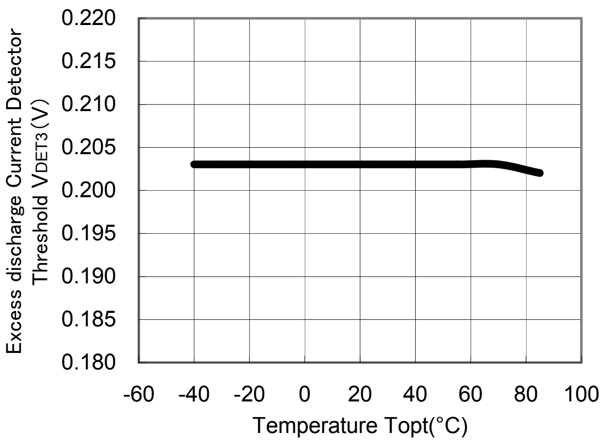
13) Output Delay of Release from Over-discharge vs. Temperature

R5460x201AC



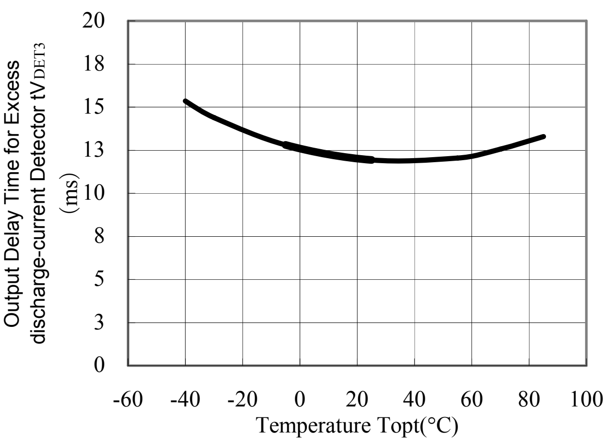
14) Excess discharge Current Detector Threshold vs. Temperature

R5460x201AC



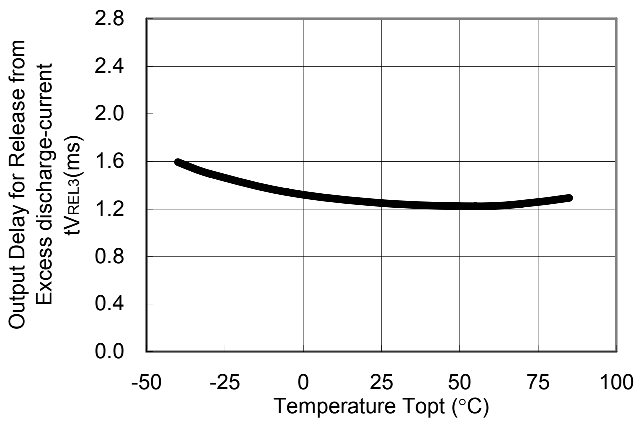
15) Output Delay Time for Excess discharge-current Detector vs. Temperature

R5460x201AC



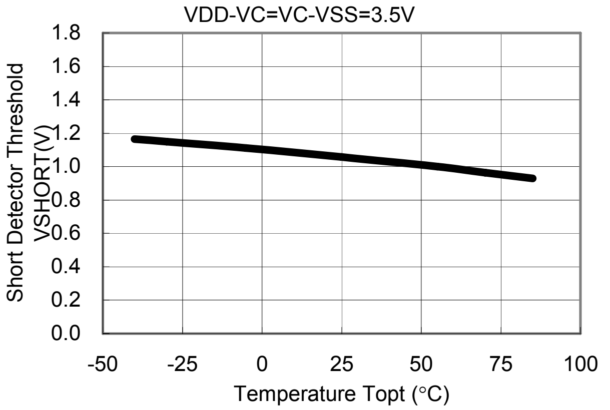
16) Output Delay for Release from Excess discharge-current vs. Temperature

R5460x201AC



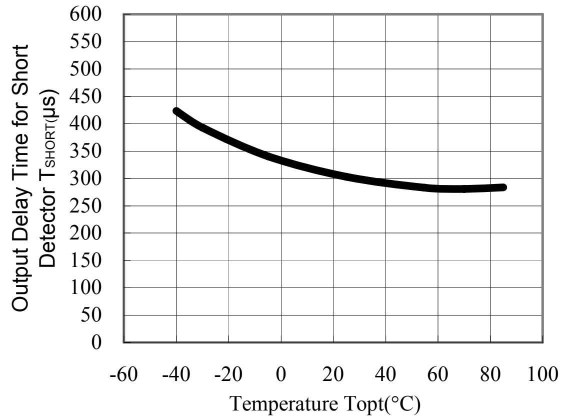
17) Short Detector Voltage Threshold vs. Temperature

R5460x201AC



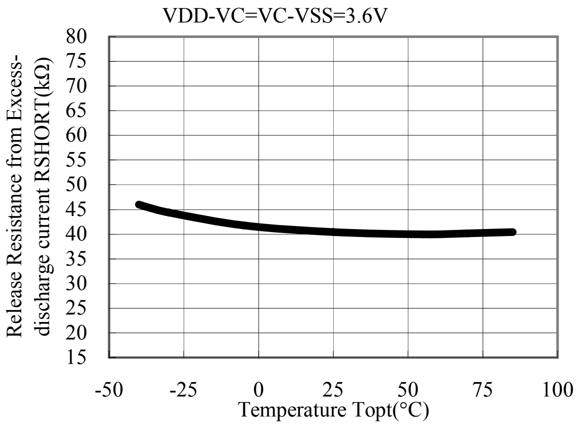
18) Output Delay for Short Detector vs. Temperature

R5460x201AC



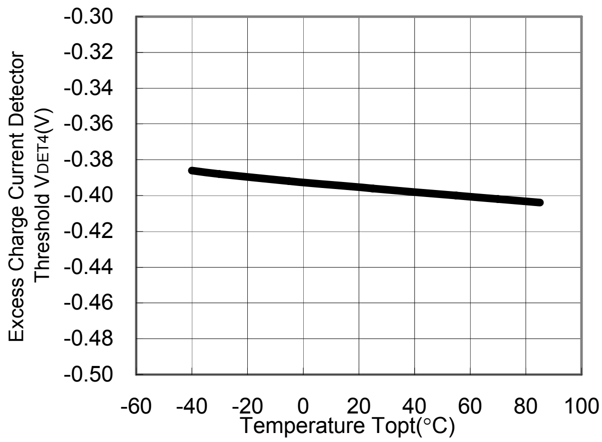
19) Release resistance from Excess-discharge current vs. Temperature

R5460x201AC



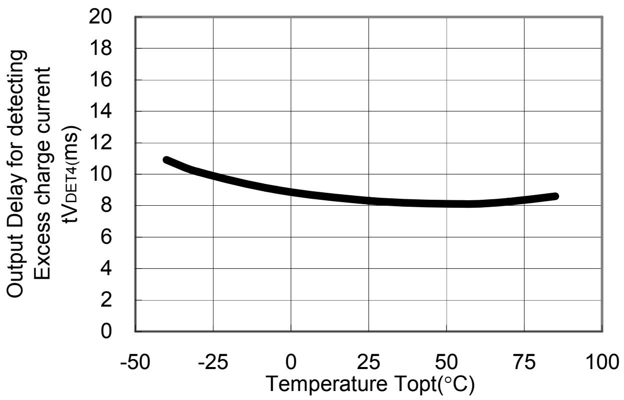
20) Excess-charge current Detector Threshold vs. Temperature

R5460x201AC



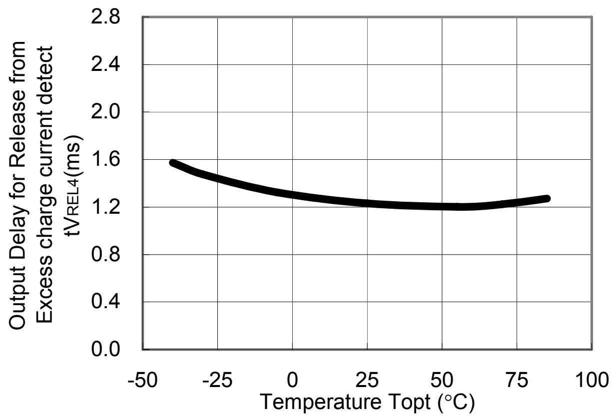
21) Output Delay Time of Excess-charge current Detector Threshold vs. Temperature

R5460x201AC



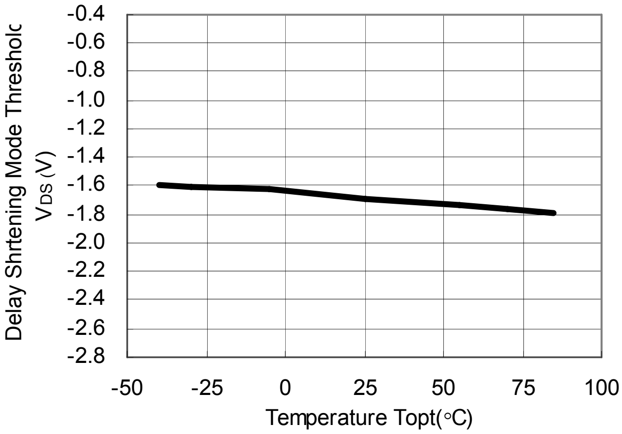
22) Output Delay Time for Release from Excess-charge current vs. Temperature

R5460x201AC

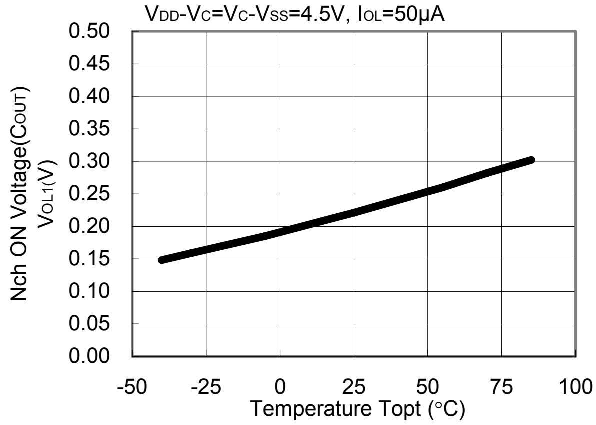


RICOH

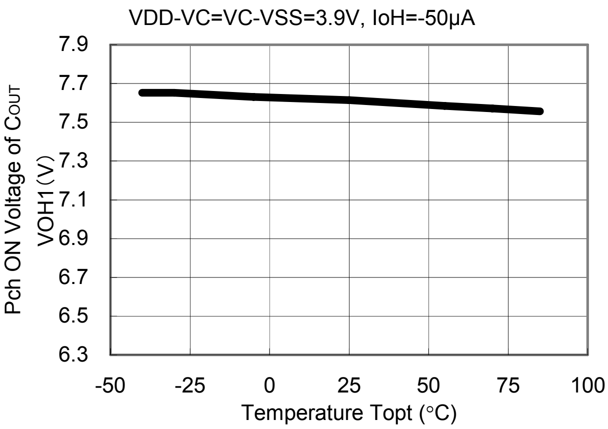
23) Delay Shortening Mode Voltage vs. Temperature
R5460x201AC



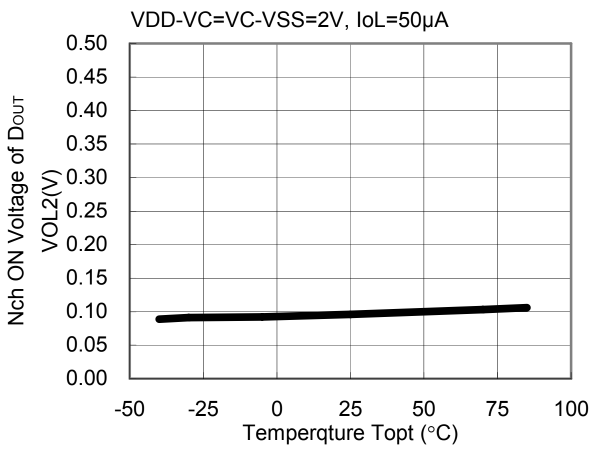
24) Nch ON Voltage of COUT vs. Temperature
R5460x201AC



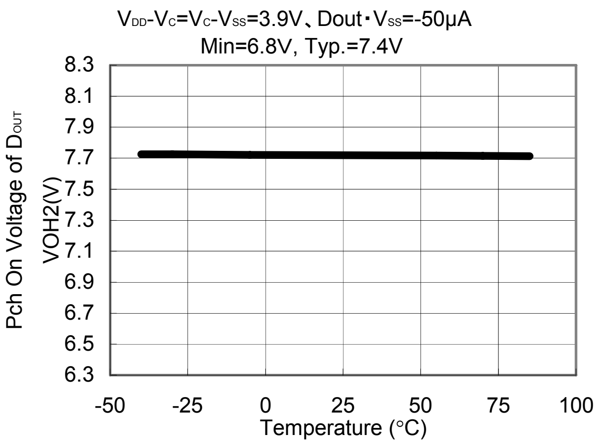
25) Pch ON Voltage of COUT vs. Temperature
R5460x201AC



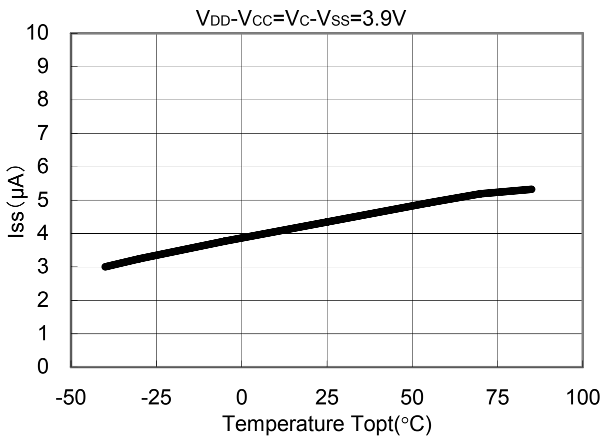
26) Nch ON Voltage of DOUT vs. Temperature
R5460x201AC



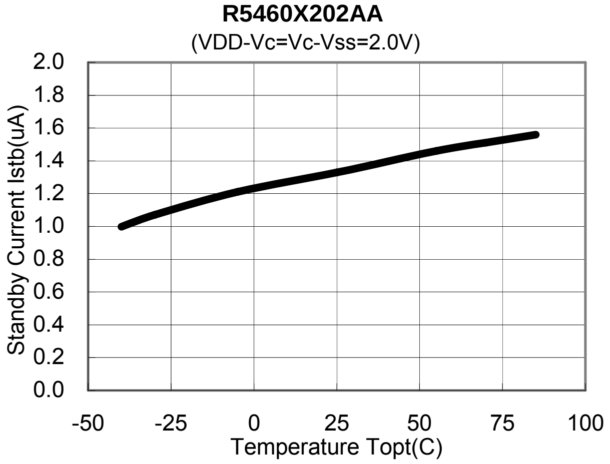
27) Pch ON Voltage of DOUT vs. Temperature
R5460x201AC



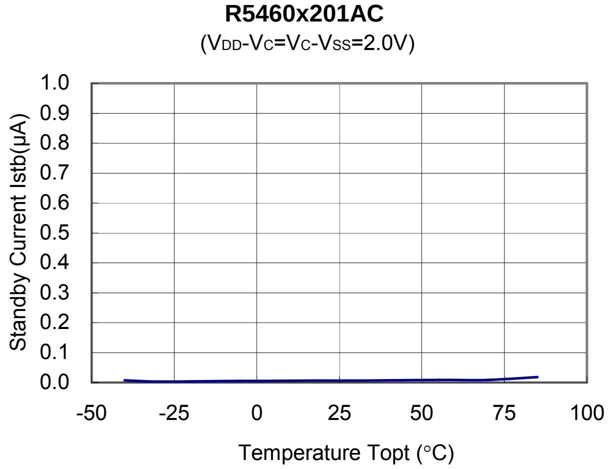
28) Supply Current vs. Temperature
R5460x201AC



29) Standby Current vs. Temperature (Ver. A.)

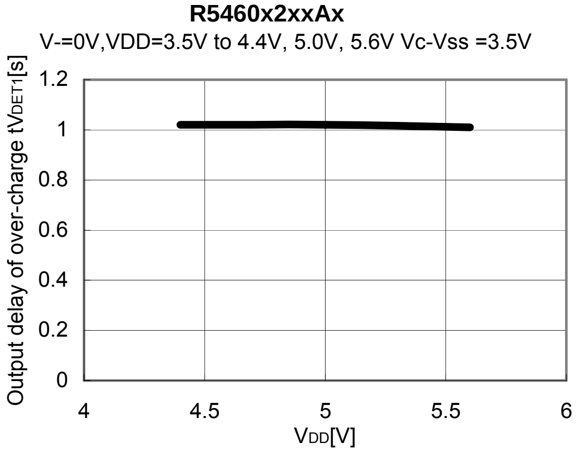


30) Standby Current vs. Temperature (Ver. C.)

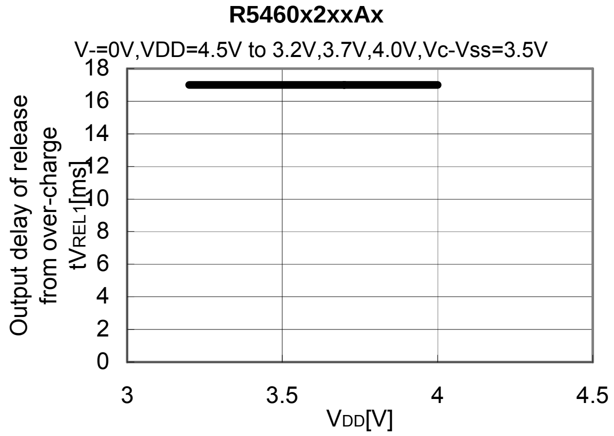


Part 2 Delay Time dependence on V_{DD}

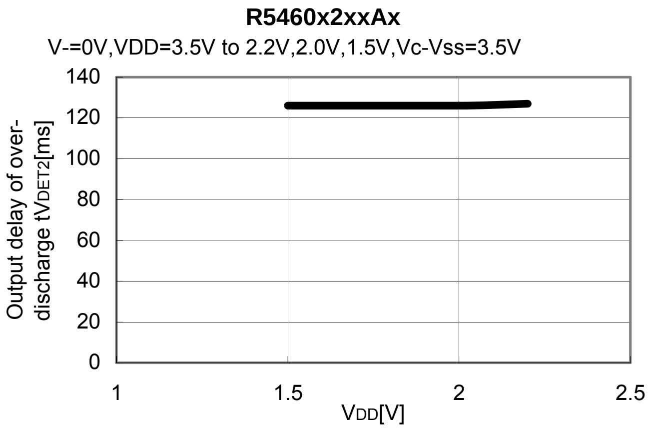
1) Delay Time for Over-charge detector vs. V_{DD}



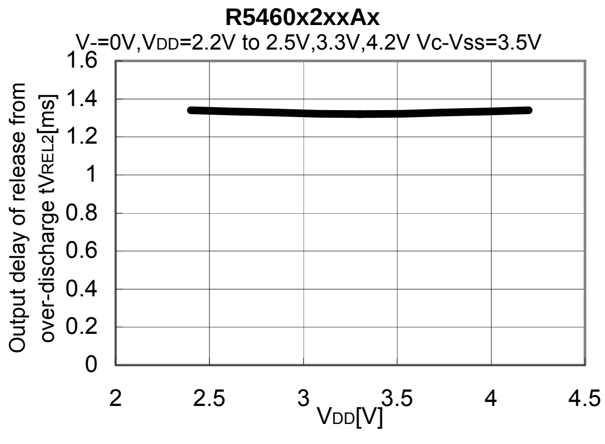
2) Delay Time for Release from Over-charge vs. V_{DD}



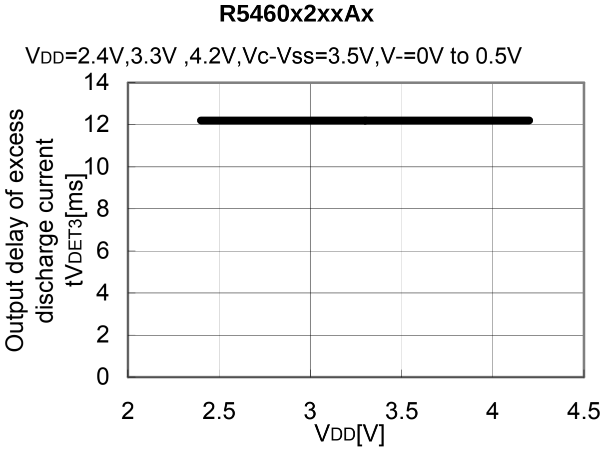
3) Output Delay of Over-discharge detector vs. V_{DD}



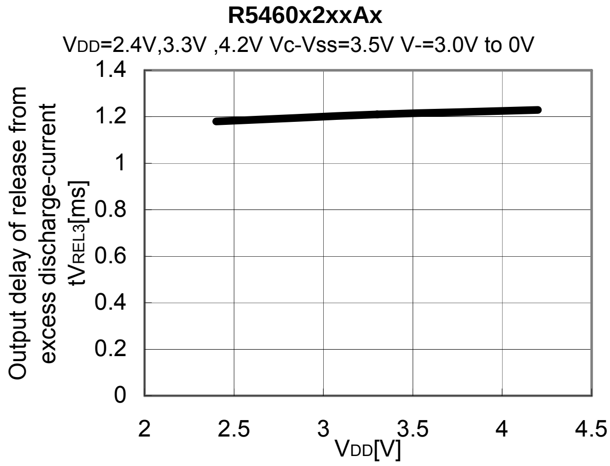
4) Output Delay for Release from Over-discharge vs. V_{DD}



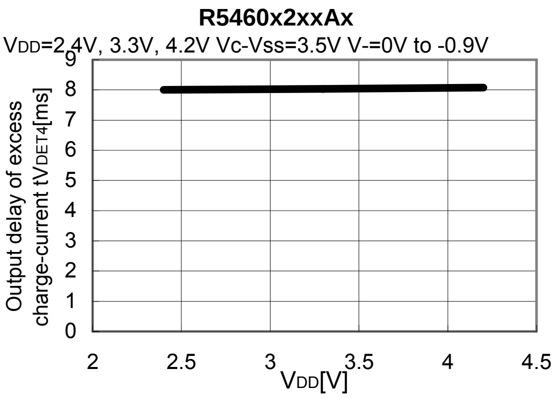
5) Output Delay for Excess Discharge Current Discharge vs. V_{DD}



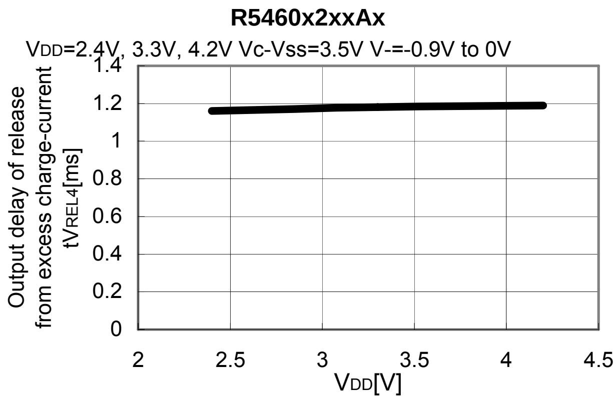
6) Output Delay for Release from Excess Current Detect vs. V_{DD}



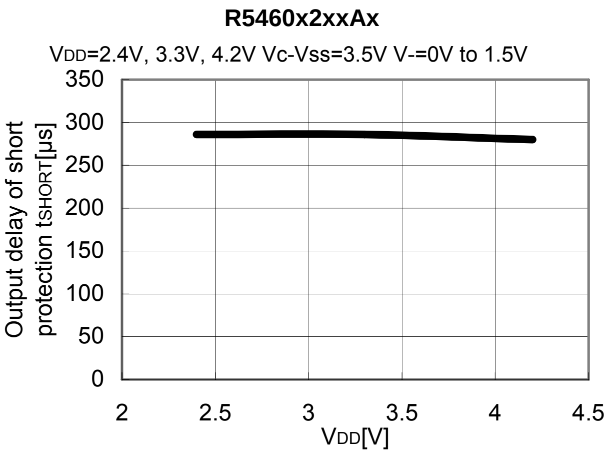
7) Delay Time for Excess Charge Current Detector vs. V_{DD}



8) Delay Time for release from Excess charge current detect vs. V_{DD}

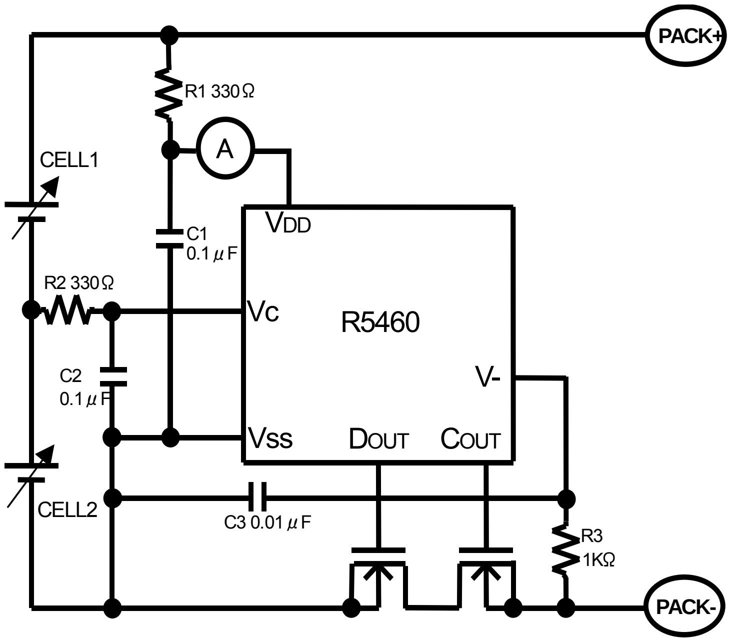


9) Output Delay for Short vs. V_{DD}

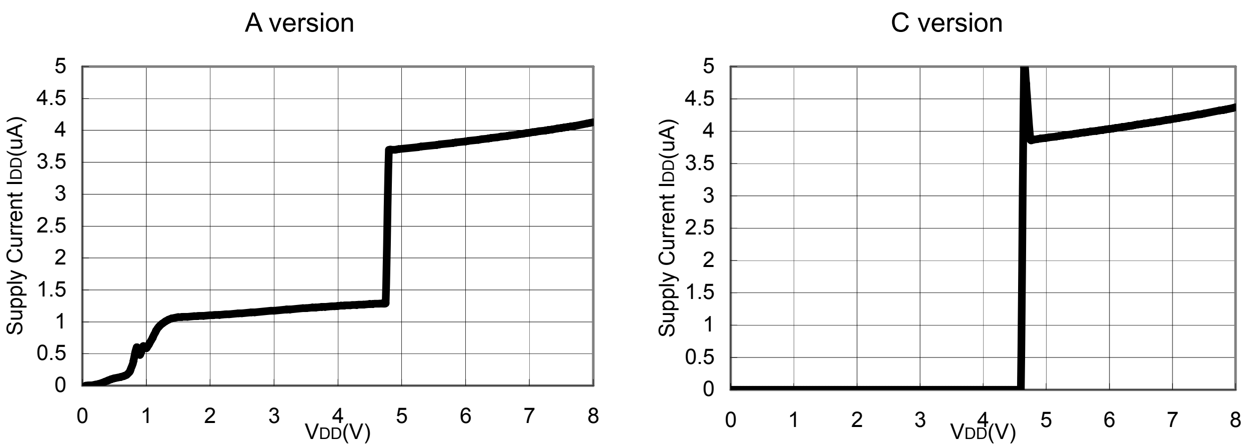


Part 3 Supply Current dependence on V_{DD}

Test Circuit

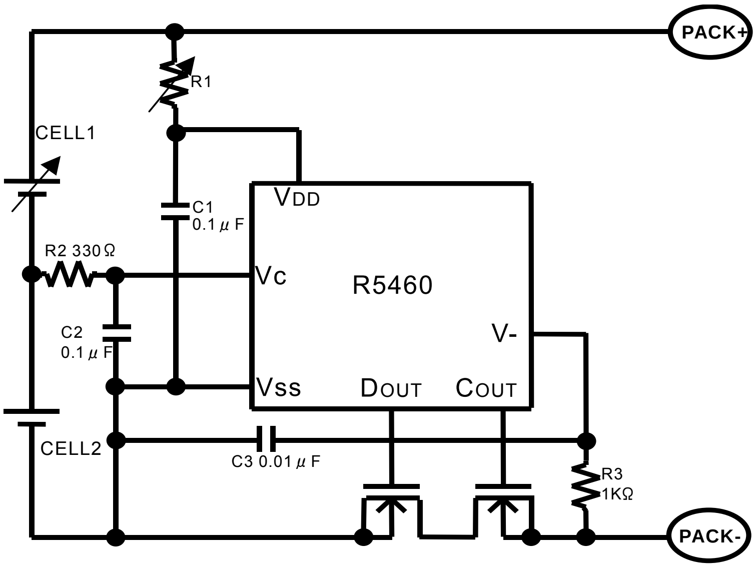


Supply Current vs. V_{DD}

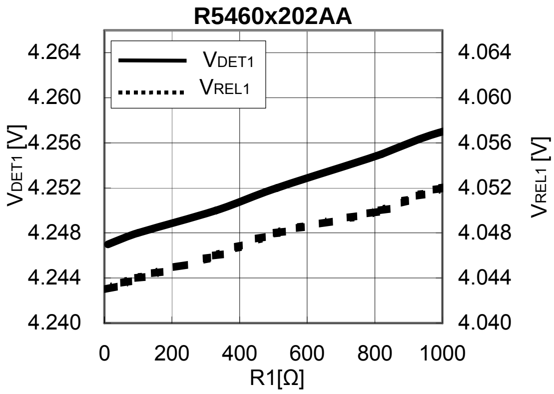


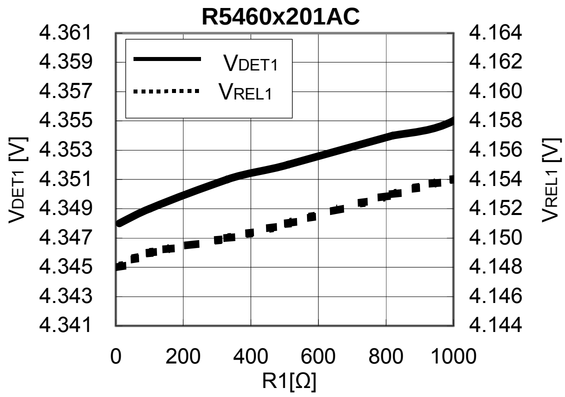
Part 4 Over-charge detector, Release voltage from Over-charge, Over-discharge detector, Release voltage from Over-discharge dependence on External Resistance value

Test Circuit

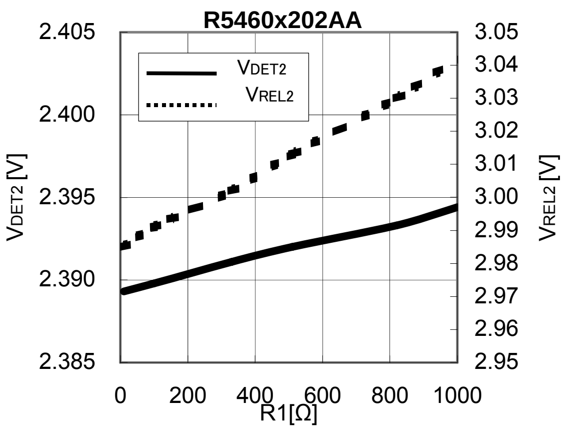


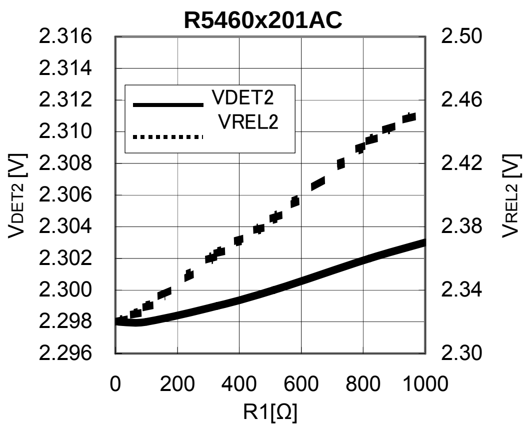
Over-charge Detector Threshold(VDET1) / Released Voltage from Over-discharge(VREL1) vs. R1





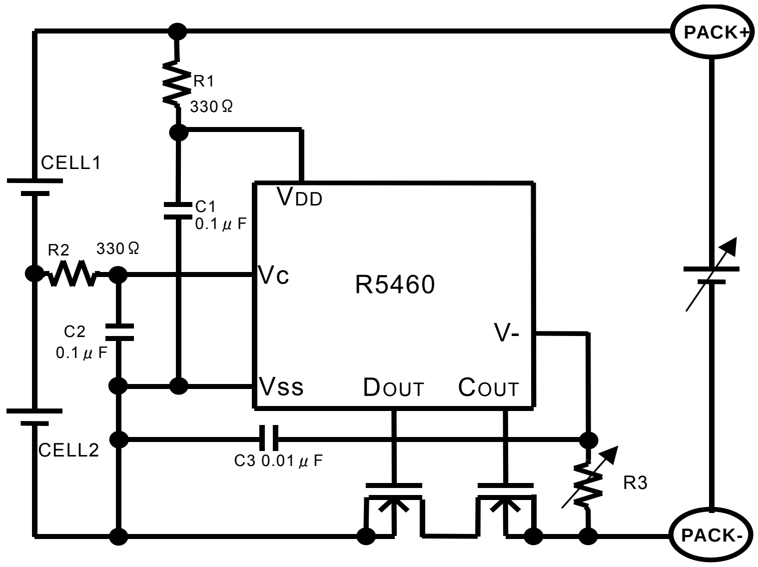
Over-discharge(VDET2) / Released from Over-charge Threshold(VREL2) vs. R1





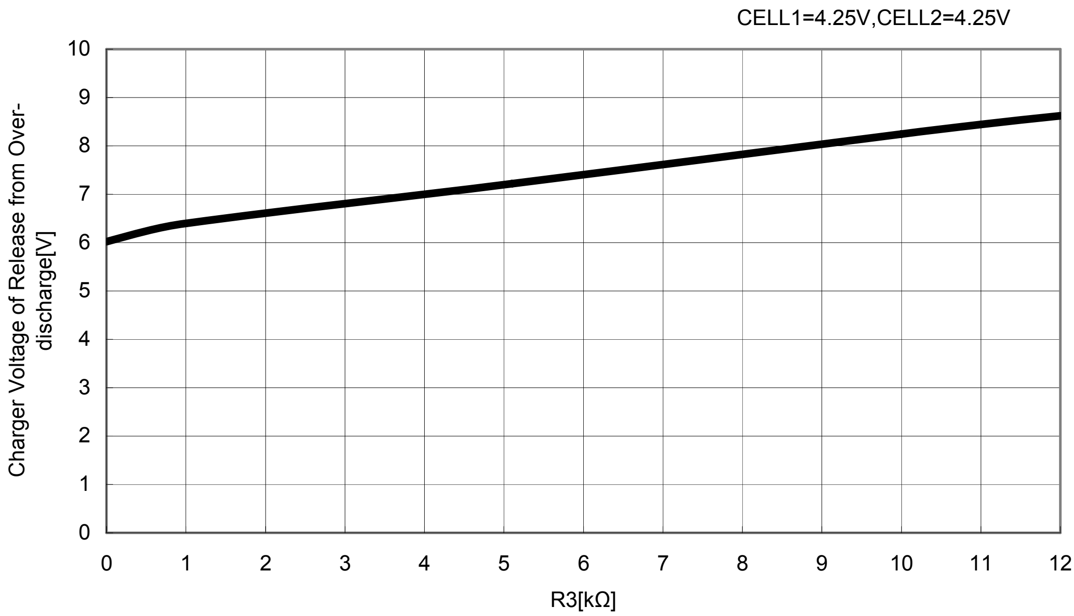
Part 5 Charger Voltage at Released from Over-discharge with a Charger dependence on R2

Test Circuit



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

R5460x201AC



R5460x CODE LIST

Part No.	VDET1(V)	VREL1(V)	VDET2(V)	VREL2(V)	VDET3(V)	VDET4(V)	tVDET1(s)	tVDET2(ms)	tVDET3(ms)	tVDET4(ms)	tSHORT(us)	0V Charge
R5460N201AC	4.350	4.150	2.300	-	0.200	-0.400	1	128	12	8	300	OK
R5460N202AA	4.250	4.050	2.400	3.000	0.150	-0.400	1	128	12	8	300	OK
R5460N203AA	4.350	4.150	2.300	3.000	0.200	-0.400	1	128	12	8	300	OK
R5460N204AA	4.350	4.150	2.300	3.000	0.150	-0.200	1	128	12	8	300	OK
R5460N205AA	4.250	4.050	2.400	3.000	0.100	-0.200	1	128	12	8	300	OK
R5460N206AA	4.290	4.050	2.900	3.100	0.150	-0.200	1	128	12	8	300	OK
R5460N207AA	4.350	4.150	2.300	3.000	0.200	-0.200	1	128	12	8	300	OK
R5460N207AE	4.350	4.150	2.300	3.000	0.200	-0.200	1	128	12	8	300	OK
R5460N207AF	4.350	4.150	2.300	3.000	0.200	-0.200	1	128	12	8	300	OK
R5460N208AA	4.250	4.050	2.400	3.000	0.200	-0.200	1	128	12	8	300	OK
R5460N208AE	4.250	4.050	2.400	3.000	0.200	-0.200	1	128	12	8	300	OK
R5460N208AF	4.250	4.050	2.400	3.000	0.200	-0.200	1	128	12	8	300	OK
R5460N209AD	3.650	3.450	2.500	3.000	0.200	-0.200	1	128	12	8	300	OK
R5460N210AD	3.650	3.450	2.000	2.500	0.200	-0.200	1	128	12	8	300	OK
R5460N211AA	4.250	4.050	3.000	3.200	0.150	-0.200	1	128	12	8	300	OK
R5460N212AA	4.290	4.050	3.000	3.200	0.200	-0.200	1	128	12	8	300	OK
R5460N212AE	4.290	4.050	3.000	3.200	0.200	-0.200	1	128	12	8	300	OK
R5460N212AF	4.290	4.050	3.000	3.200	0.200	-0.200	1	128	12	8	300	OK
R5460N213AD	3.900	3.450	2.000	2.500	0.200	-0.200	1	128	12	8	300	OK
R5460N214AC	4.250	4.050	2.800	3.000	0.200	-0.200	1	128	12	8	300	OK
R5460N214AE	4.250	4.050	2.800	3.000	0.200	-0.200	1	128	12	8	300	OK
R5460N214AF	4.250	4.050	2.800	3.000	0.200	-0.200	1	128	12	8	300	OK
R5460N215AF	4.300	4.100	3.200	3.400	0.150	-0.200	1	128	12	8	300	OK
R5460N218AF	4.250	4.050	2.800	3.000	0.200	-0.100	1	128	12	8	300	OK
R5460K201AC	4.350	4.150	2.300	-	0.200	-0.400	1	128	12	8	300	OK
R5460K202AA	4.250	4.050	2.400	3.000	0.150	-0.400	1	128	12	8	300	OK
R5460K203AA	4.350	4.150	2.300	3.000	0.200	-0.400	1	128	12	8	300	OK
R5460K204AA	4.350	4.150	2.300	3.000	0.150	-0.200	1	128	12	8	300	OK
R5460K205AA	4.250	4.050	2.400	3.000	0.100	-0.200	1	128	12	8	300	OK
R5460K206AA	4.290	4.050	2.900	3.100	0.150	-0.200	1	128	12	8	300	OK
R5460K207AA	4.350	4.150	2.300	3.000	0.200	-0.200	1	128	12	8	300	OK
R5460K208AA	4.250	4.050	2.400	3.000	0.200	-0.200	1	128	12	8	300	OK
R5460K209AD	3.650	3.450	2.500	3.000	0.200	-0.200	1	128	12	8	300	OK
R5460K210AD	3.650	3.450	2.000	2.500	0.200	-0.200	1	128	12	8	300	OK
R5460K211AA	4.250	4.050	3.000	3.200	0.150	-0.200	1	128	12	8	300	OK
R5460K213AD	3.900	3.450	2.000	2.500	0.200	-0.200	1	128	12	8	300	OK
R5460K214AC	4.250	4.050	2.800	3.000	0.200	-0.200	1	128	12	8	300	OK

(as of 2009/12/21)

R5460 x 2xx A x

Package Type
N : SOT23-6
K : PLP1820-6

Function Version
- A : Over-Charge = Auto-Release Over-Discharge = Auto Release
- C : Over-Charge = Auto-Release Over-Discharge = Latch
- D : Over-Charge = Auto-Release Over-Discharge = Auto Release VDET1U/L < 4.0V
- E : Over-Charge = Auto-Release Over-Discharge = Auto Release (No Hysteresis Cancellation)
- F : Over-Charge = Auto-Release Over-Discharge = Latch (Hysteresis)

Delay Time Version

Ver.	tVdet1(s)	tVdet2(ms)	tVdet3(ms)	tVdet4(ms)	tSHORT(us)
A	1	128	12	8	300

Voltage Version