PRODUCT SPECIFICATIONS

R5460N212AF-TR-F

contents

[1] Outline

The R5460N212AF is 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 crosses the each detector threshold from a low value to a high value, the output of COUT pin switches to “L” level after internal fixed delay time. To release over-charge detector after detecting over-charge, or the detector will be released and the output of COUT becomes "H" when a kind of load is connected to VDD after a charger is disconnected from the battery pack and the cell voltage becomes lower than over-charge detector threshold. Even if a charger is continuously connected to the battery pack, when the cell voltage becomes lower than the over-charge detector released voltage, over-charge state is released.

The output of DOUT 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 the threshold.

To release over-discharge detector, after detecting over-discharge voltage, connect a charger to the battery pack, and when the battery supply voltage becomes higher than the released voltage from over-discharge, the over-discharge detector is released. In other words, the over-discharge voltage detector has hysteresis.

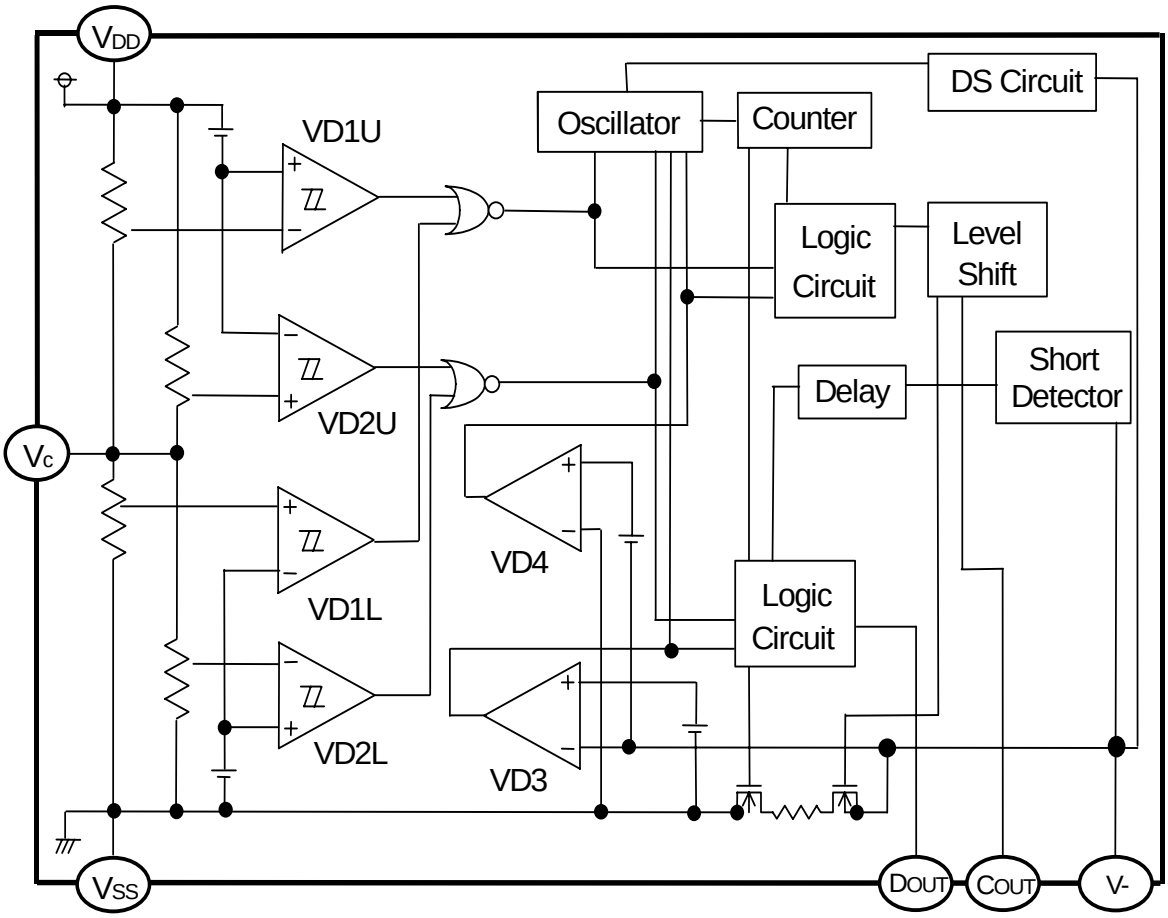
Even though a battery is discharged to 0V, charge current is acceptable.

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, the 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 typically equal or lower than -1.6V, the delay time of detectors can be shortened. Especially, the delay time of the over-charge detector can be reduced into approximately 1/60 and the test time for protection circuit of PCB can be reduced. The output type of COUT and DOUT is CMOS.

[2] Block Diagram



[3] Pin Description

Pin No.	Symbol	Pin description
1	DOUT	Output pin of Over-discharge detection, CMOS output
2	COUT	Output pin of Over-charge detection, CMOS output
3	V-	Charger negative Input Pin
4	Vc	Input Pin of the center voltage between two-cell
5	VDD	Power Supply pin. Substrate level of the IC.
6	Vss	Vss pin. (GND pin of the IC)

[4] Absolute Maximum Rating

Topt=25°C, Vss=0V

Item	Symbol	Ratings	Unit
Supply Voltage	V_{DD}	-0.3 to 12	V
Input Voltage			
Middle pin Voltage between 2-cell	Vc	Vss-0.3 to V_{DD}+0.3	V
V- pin Voltage (Charger negative input)	V-	V_{DD}-30 to V_{DD}+0.3	V
Output Voltage			
C_{OUT} pin Voltage	V_{COUT}	V_{DD}-30 to V_{DD}+0.3	V
D_{OUT} pin Voltage	V_{DOUT}	Vss-0.3 to V_{DD}+0.3	V
Power Dissipation	P_D	150	mW
Operating Temperature	Topr	-40 to 85	°C
Storage Temperature	Tstg	-55 to 125	°C

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

[5] Electrical Characteristics

●R5460N212AF

Unless otherwise specified Topt=25°C

Item	Symbol	Conditions	Min.	Typ.	Max.	Unit	Note1
Operating Input Voltage	V_{DD1}	V_{DD}-V_{SS}	1.5		10	V	A
Minimum Operating Voltage for 0V Charge	Vst	Voltage Defined as V_{DD}-V-, V_{DD}-V_{SS}=0V			1.8	V	A
Cell1 Over-charge Threshold Voltage	V_{DET1U}	R1=330Ω R1=330Ω, (Topt=-5°C to 55°C) *Note2	4.265 4.260	4.290 4.290	4.315 4.320	V V	B B
Cell1 Released Voltage	V_{REL1U}	R1=330Ω	4.000	4.050	4.100	V	B
Cell2 Over-charge Detector threshold	V_{DET1L}	R2=330Ω R2=330Ω, (Topt=-5°C to 55°C) *Note2	4.265 4.260	4.290 4.290	4.315 4.320	V V	C C
Cell2 Released Voltage	V_{REL1L}	R2=330Ω	4.000	4.050	4.100	V	C
Output Delay of Over-charge	tV_{DET1}	V_{DD}-V_C=3.2V to 4.5V V_C-V_{SS}=3.2V	0.7	1.0	1.3	s	B
Output Delay of Release from Over-charge	tV_{REL1}	V_{DD}-V_C=4.5V to 3.2V, V_C-V_{SS}=3.2V	11	16	21	ms	B
Cell1 Over-discharge Threshold	V_{DET2U}	Detect falling edge of the input voltage	2.925	3.000	3.075	V	D
Cell1 Release Voltage from Over-discharge Voltage	V_{REL2U}	Detect rising edge of the input voltage	3.120	3.200	3.280	V	D
Cell2 Over-discharge Threshold	V_{DET2L}	Detect falling edge of the input voltage	2.925	3.000	3.075	V	E
Cell2 Release Voltage from Over-discharge voltage	V_{REL2L}	Detect rising edge of the input voltage	3.120	3.200	3.280	V	E
Output Delay of Over-discharge	tV_{DET2}	V_{DD}-V_C=3.2V to 1.9V V_C-V_{SS} =3.2V	89	128	167	ms	D
Release Delay for VD2	tV_{REL2}	V_{DD}-V_C =1.9V to 3.2V V_C-V_{SS} =3.2V	0.7	1.2	1.7	ms	D
Excess Discharge-current Threshold	V_{DET3}	Detect rising edge of 'V-' pin voltage	0.185	0.200	0.215	V	F
Output Delay of Excess Discharge-current	tV_{DET3}	V_{DD}-V_C=3.2V,V_C-V_{SS}=3.2V V-=0V to 0.5V	8	12	16	ms	F
Output Delay of Release from Excess Discharge-current	tV_{REL3}	V_{DD}-V_C=3.2V,V_C-V_{SS}=3.2V V-=3V to 0V	0.7	1.2	1.7	ms	F
Short Protection Voltage	Vshort	V_{DD}-V_C=3.2V,V_C-V_{SS}=3.2V	0.7	1.1	1.5	V	F
Delay Time for Short Protection	tshort	V_{DD}-V_C=3.2V,V_C-V_{SS}=3.2V V-=0V to 6.4V	150	300	500	µs	F
Reset Resistance for Excess Current Protection	Rshort	V_{DD}-V_C=3.2V,V_C-V_{SS}=3.2V V-=1V	25	40	75	kΩ	F
Excess Charge-current Threshold	V_{DET4}	Detect falling edge of 'V-' pin voltage	-0.230	-0.200	-0.170	V	G
Output Delay of Excess Charge-current	tV_{DET4}	V_{DD}-V_C=3.2V, V_C-V_{SS}=3.2V V-=0V to -1V	5	8	11	ms	G
Output Delay of Release from Excess Charge-current	tV_{REL4}	V_{DD}-V_C=3.2V, V_C-V_{SS}=3.2V V-=-1V to 0V	0.7	1.2	1.7	ms	G
Delay Shortening Mode Voltage	V_{DS}	V_{DD}-V_C=4.0V, V_C-V_{SS}=4.0V	-2.2	-1.6	-1.0	V	G
Nch ON-Voltage of C_{OUT}	V_{OL1}	Iol=50µA, V_{DD}-V_C=4.5V V_C-V_{SS}=4.5V		0.4	0.5	V	H
Pch ON-Voltage of C_{OUT}	V_{OH1}	Ioh=-50µA, V_{DD}-V_C=3.2V V_C-V_{SS}=3.2V	6.8	7.4		V	I
Nch ON-Voltage of D_{OUT}	V_{OL2}	Iol=50µA, V_{DD}-V_C=1.9V V_C-V_{SS}=1.9V		0.2	0.5	V	J
Pch ON-Voltage of D_{OUT}	V_{OH2}	Ioh=-50µA, V_{DD}-V_C=3.2V V_C-V_{SS}=3.2V	6.8	7.4		V	K
Supply Current	I_{DD}	V_{DD}-V_C=3.2V, V_C-V_{SS}=3.2V V-=0V		4.0	8.0	µA	L
Standby Current	Istandby	V_{DD}-V_C=1.9V, V_C-V_{SS}=1.9V			0.1	µA	L

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

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

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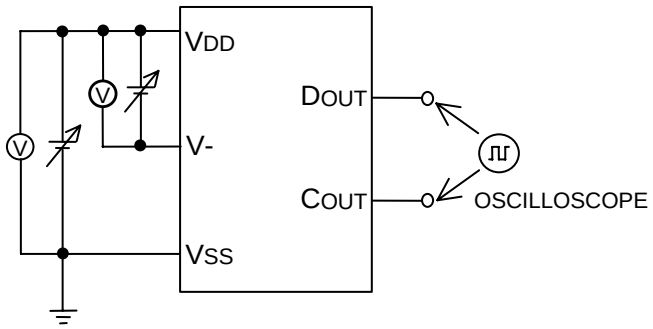
Topt=-40°C～+85℃

Item	Symbol	Conditions	Min.	Typ.	Max.	Unit	Note1
Operating Input Voltage	V_{DD1}	V_{DD}-V_{SS}	1.5		10	V	A
Minimum Operating Voltage for 0V Charge	Vst	Voltage Defined as V_{DD}-V-, V_{DD}-V_{SS}=0V			1.96	V	A
Cell1 Over-charge Threshold Voltage	V_{DET1U}	R1=330Ω	4.238	4.290	4.329	V	B
Cell1 Released Voltage	V_{REL1U}	R1=330Ω	3.967	4.050	4.104	V	B
Cell2 Over-charge Detector threshold	V_{DET1L}	R2=330Ω	4.240	4.290	4.327	V	C
Cell2 Released Voltage	V_{REL1L}	R2=330Ω	3.965	4.050	4.104	V	C
Output Delay of Over-charge	tV_{DET1}	V_{DD}-V_C=3.2V to 4.5V V_C-V_{SS}=3.2V	0.57	1.0	1.83	s	B
Output Delay of Release from Over-charge	tV_{REL1}	V_{DD}-V_C=4.5V to 3.2V, V_C-V_{SS}=3.2V	8.6	16	30	ms	B
Cell1 Over-discharge Threshold	V_{DET2U}	Detect falling edge of the input voltage	2.907	3.000	3.077	V	D
Cell1 Release Voltage from Over-discharge Voltage	V_{REL2U}	Detect rising edge of the input voltage	3.102	3.200	3.287	V	D
Cell2 Over-discharge Threshold	V_{DET2L}	Detect falling edge of the input voltage	2.906	3.000	3.078	V	E
Cell2 Release Voltage from Over-discharge voltage	V_{REL2L}	Detect rising edge of the input voltage	3.101	3.200	3.284	V	E
Output Delay of Over-discharge	tV_{DET2}	V_{DD}-V_C=3.2V to 1.9V V_C-V_{SS} =3.2V	73	128	233	ms	D
Release Delay for VD2	tV_{REL2}	V_{DD}-V_C =1.9V to 3.2V V_C-V_{SS} =3.2V	0.51	1.2	2.46	ms	D
Excess Discharge-current Threshold	V_{DET3}	Detect rising edge of 'V-' pin voltage	0.181	0.200	0.219	V	F
Output Delay of Excess Discharge-current	tV_{DET3}	V_{DD}-V_C=3.2V,V_C-V_{SS}=3.2V V-=0V to 0.5V	6.5	12	22.5	ms	F
Output Delay of Release from Excess Discharge-current	tV_{REL3}	V_{DD}-V_C=3.2V,V_C-V_{SS}=3.2V V-=3V to 0V	0.56	1.2	2.33	ms	F
Short Protection Voltage	Vshort	V_{DD}-V_C=3.2V,V_C-V_{SS}=3.2V	0.54	1.1	1.62	V	F
Delay Time for Short Protection	tshort	V_{DD}-V_C=3.2V,V_C-V_{SS}=3.2V V-=0V to 6.4V	115	300	664	μs	F
Reset Resistance for Excess Current Protection	Rshort	V_{DD}-V_C=3.2V,V_C-V_{SS}=3.2V V-=1V	21.3	40	90.4	kΩ	F
Excess Charge-current Threshold	V_{DET4}	Detect falling edge of 'V-' pin voltage	-0.242	-0.200	-0.156	V	G
Output Delay of Excess Charge-current	tV_{DET4}	V_{DD}-V_C=3.2V, V_C-V_{SS}=3.2V V-=0V to -1V	4	8	15.3	ms	G
Output Delay of Release from Excess Charge-current	tV_{REL4}	V_{DD}-V_C=3.2V, V_C-V_{SS}=3.2V V-=-1V to 0V	0.55	1.2	2.34	ms	G
Delay Shortening Mode Voltage	V_{DS}	V_{DD}-V_C=4.0V, V_C-V_{SS}=4.0V	-2.33	-1.6	-0.81	V	G
Nch ON-Voltage of C_{OUT}	V_{oL1}	Iol=50μA, V_{DD}-V_C=4.5V V_C-V_{SS}=4.5V		0.4	0.5	V	H
Pch ON-Voltage of C_{OUT}	V_{oH1}	Ioh=-50μA, V_{DD}-V_C=3.2V V_C-V_{SS}=3.2V	6.8	7.4		V	I
Nch ON-Voltage of D_{OUT}	V_{oL2}	Iol=50μA, V_{DD}-V_C=1.9V V_C-V_{SS}=1.9V		0.2	0.5	V	J
Pch ON-Voltage of D_{OUT}	V_{oH2}	Ioh=-50μA, V_{DD}-V_C=3.2V V_C-V_{SS}=3.2V	6.8	7.4		V	K
Supply Current	I_{DD}	V_{DD}-V_C=3.2V, V_C-V_{SS}=3.2V V-=0V		4.0	9.16	μA	L
Standby Current	Istandby	V_{DD}-V_C=1.9V, V_C-V_{SS}=1.9V			0.14	μA	L

●: The above-mentioned specification is guaranteed by design, not mass production tested.

[6] Test Circuits

A ← Refer to the note1 of Electrical Characteristics Table.



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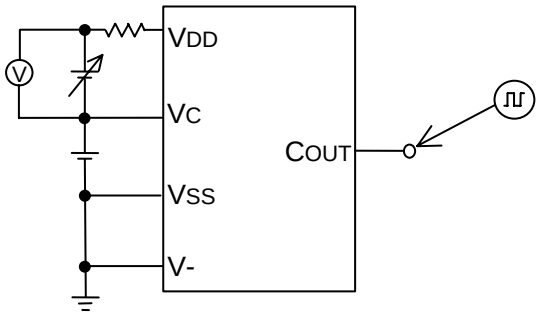

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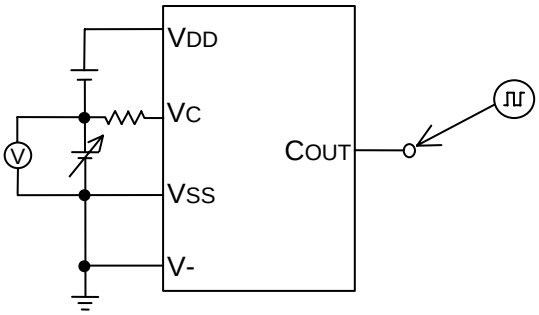

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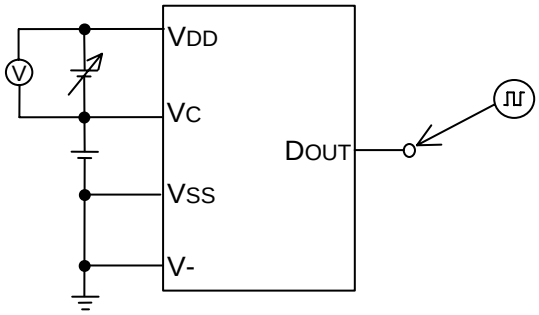

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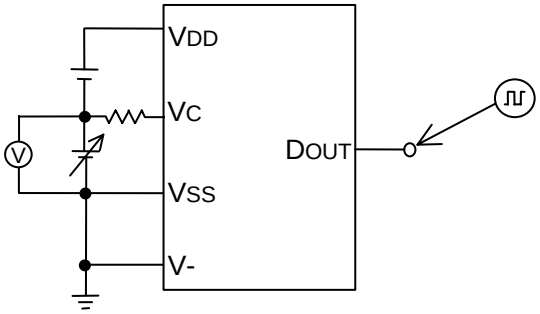

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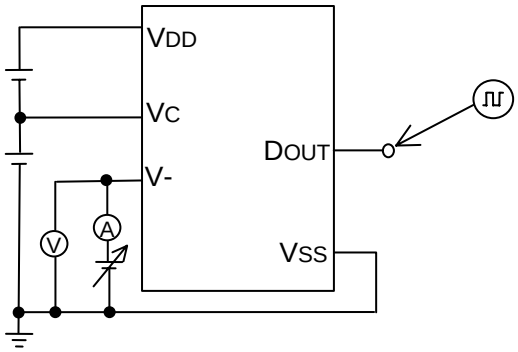

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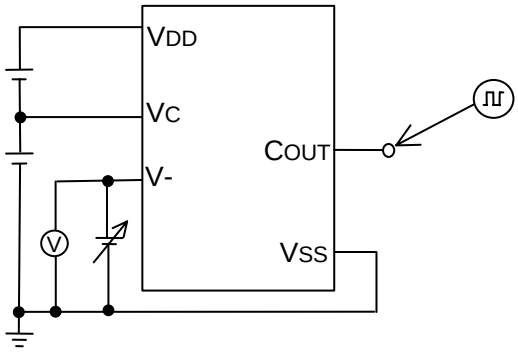

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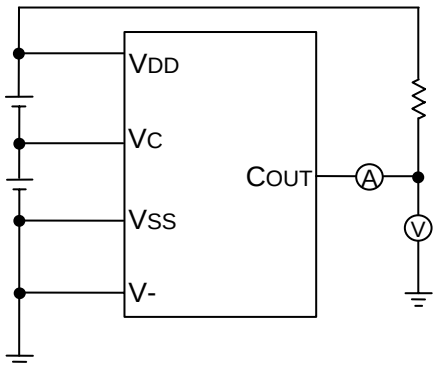

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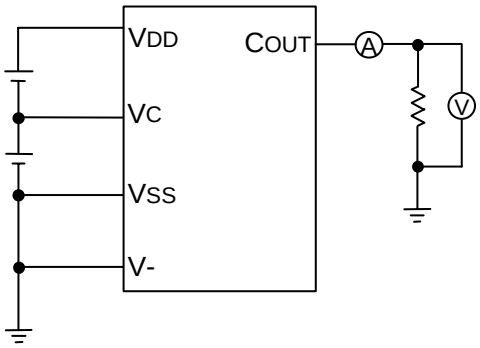
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COUT
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V
VC
VSS
V-

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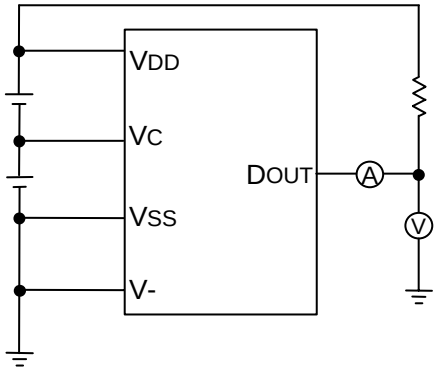
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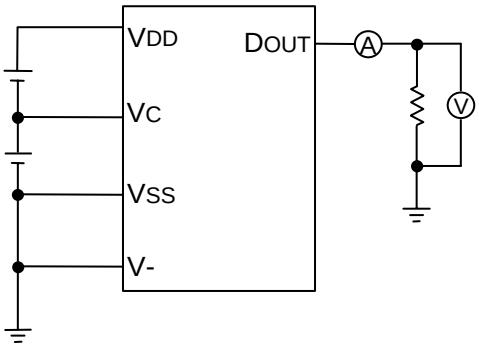
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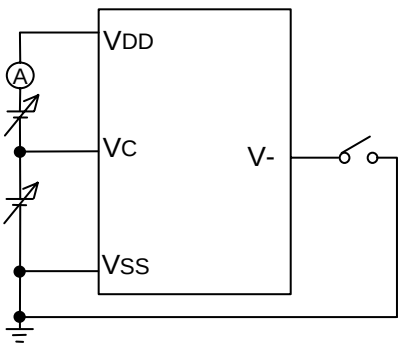

VDD
A
VC
V-
VSS

[7] Operation

• VD1 / Over-charge Detector

The V_{DET1x} monitors the voltage between V_{DD} pin and Vc 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 (Typ. 4.29V), the over-charge is detected, and an external charge control Nch MOSFET turns off with C_{OUT} pin being at "L" level.

To reset the over-charge and make the C_{OUT} pin level being "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 the over-charge released voltage (Typ. 4.05V), or when the both Cell1 and Cell2 are lower than the over-charge detector threshold, 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.

Further, in case that the voltage level of Cell1 and Cell2 is equal or higher than the over-charge detector threshold, when a charger is removed and some load is connected, C_{OUT} outputs “L”, however, load current can flow through the parasitic diode of the external charge control Nch MOSFET. After that, when the voltage level of Cell1 and Cell2 becomes lower than the over-charge detector threshold, C_{OUT} becomes “H”.

Internal fixed output delay time (Typ. 1.0s) for over-charge detection and released delay time (Typ. 16ms) exist. Even when the voltage of Cell1 or Cell2 pin level becomes equal or higher level than V_{DET} 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 voltage level of Cell1 and Cell2 is 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 (Typ. 16ms) 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 V_{DET2x} monitors the voltage between V_{DD} pin and V_C pin (Cell1 voltage) and the voltage between V_C pin and V_{SS} pin (Cell2 Voltage). When the either voltage becomes equal or less than the over-discharge detector threshold (Typ. 3.00V), 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.

To reset the over-discharge detector, connecting a charger is the only method. When the charger is connected, if Cell1 or Cell2 is less than the released voltage from over-discharge (Typ. 3.20V), a charge current flows through the parasitic diode of the external MOSFET. Then, the voltages of Cell1 and Cell2 become higher than the released voltage from over-discharge, D_{OUT} becomes “H” and the external MOSFET turns on and discharge will be possible. When a charger is connected, when the Cell1 and Cell2 voltages become equal or more than the released voltage from over-discharge, the over-discharge is released and the voltage of the D_{OUT} pin becomes “H” after the delay time. The over-discharge voltage detector has hysteresis.

When a cell voltage equals to zero, if the voltage of a charger is equal or more than 0V-charge maximum 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 (Typ. 128ms). 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 fixed internally (Typ. 1.2ms).

After detecting over-discharge, supply current would be reduced and be into standby by halting all the circuits and consumption current of the IC itself is made extremely low. (Max. 0.1μA at V_{DD}-V_C=V_C-V_{ss}=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

When the charge and discharge is acceptable, these detectors monitor the V- pin voltage.

If the V- pin voltage is up to a value equal or more than the excess discharge current detector threshold (Typ. 0.20V) and lower than the short protection voltage Vshort (Typ. 1.1V) the excess discharge current is detected. If the V- pin voltage becomes further higher than Vshort, the short circuit protector is enabled. This leads the external discharge control Nch MOSFET turning off with the D_{OUT} pin being at "L" level to prevent from flowing the large current into the circuit.

An output delay time for the excess discharge-current detector is internally fixed (Typ. 12ms).

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 the release from excess discharge-current detection is also fixed internally (Typ. 1.2ms).

When the short circuit protector is enabled, the D_{OUT} would be "L" and the delay time is also set (Typ. 300μs).

The V - pin has a built-in pull-down resistor to the Vss pin, that is, the resistance (Typ. 40kΩ) to release from excess-discharge current or short circuit.

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 an "ON" state automatically with the V- pin level being down to the V_{SS} level through the built-in pulled down resistor. (When the V- pin voltage becomes equal or less than excess discharge current threshold, the detector is released.) The reset resistor of excess discharge-current is off when the charge and discharge is acceptable, or 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, even if the voltage between V_{DD} and VC (Cell1) or the voltage between VC pin and Vss pin (Cell2) becomes 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, V_{DET3} is automatically released from excess discharge-current.

• VD4/ Excess charge-current detector

When the charge and discharge are acceptable, V_{DET4} 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 (Typ. -0.20V). 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. (Typ. 8ms) Even the voltage level of V- pin becomes equal or lower than the excess charge-current detector threshold, the voltage is higher than the V_{DET4} threshold within the delay time, the excess charge current is not detected. Output delay for the release from excess charge current is also set. (Typ. 1.2ms)

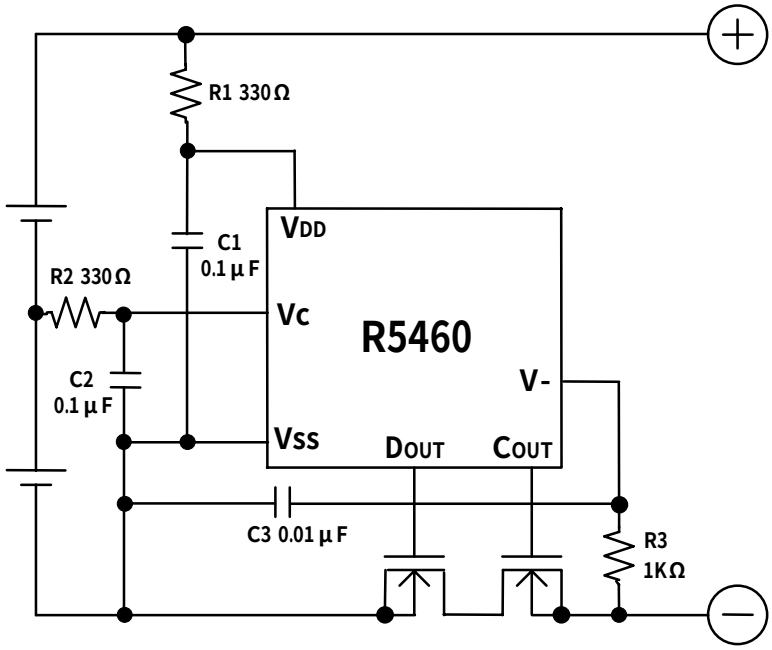
V_{DET4} can be released with disconnecting a charger and connecting a load.

• DS (Delay Shortening) function

Output delay time of over-charge and over-discharge can be made shorter than those setting values by forcing equal or lower than the test shortening mode voltage (Typ. -1.6V) to V- pin.

[8] Technical Notes (on external components)

*Typical Application



*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 a large value of R3 is set, after detecting over-discharge, the release by connecting a charger may not be possible. Therefore, recommendation value of R3 is equal or less than 3kΩ.

To stabilize the operation of the IC, make sure to mount 0.01μF or more capacitor as C3.

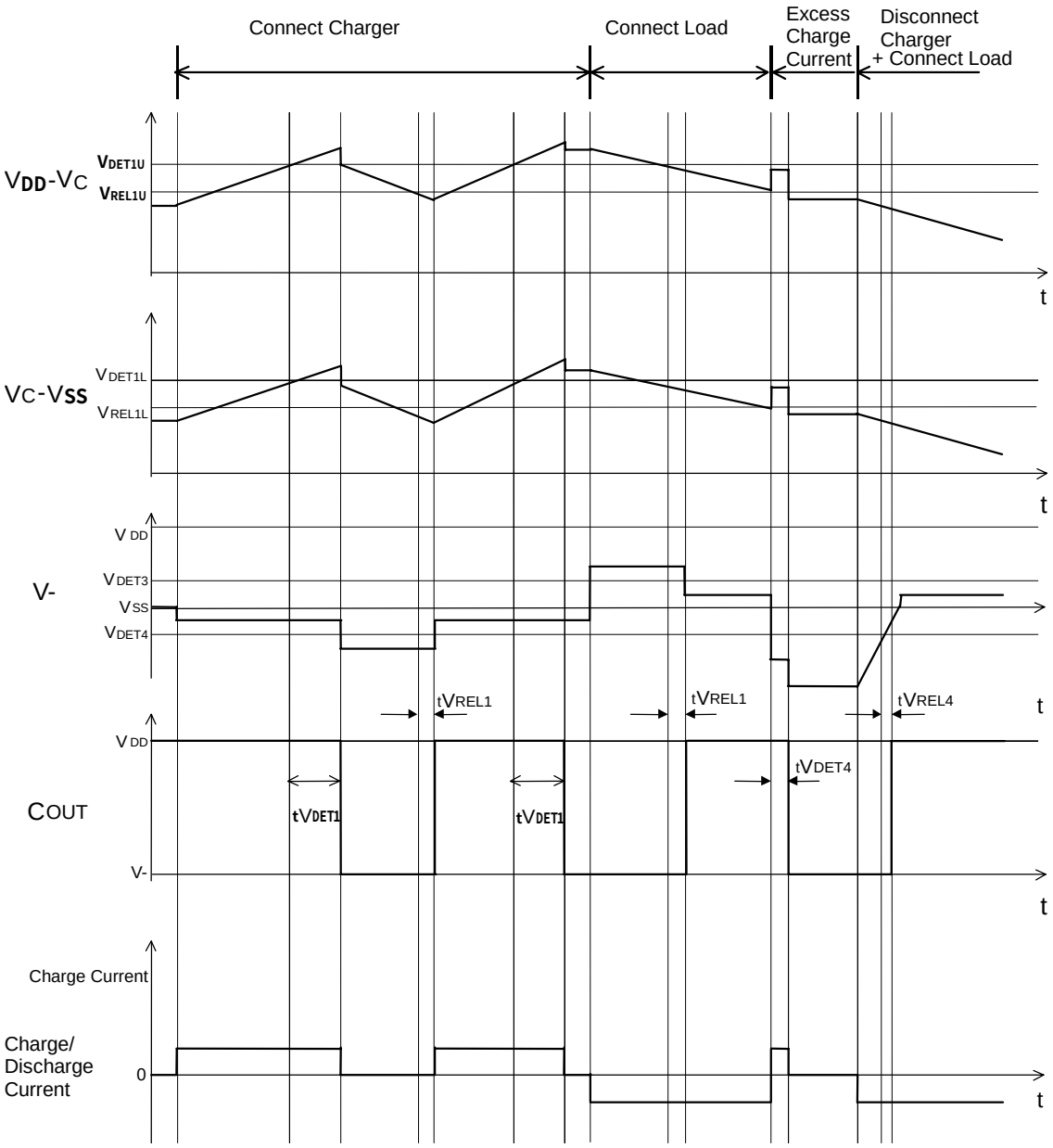
The typical application circuit diagram is just an example. This circuit performance largely depends on the PCB layout and external components. In the actual application, fully evaluation is necessary.

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

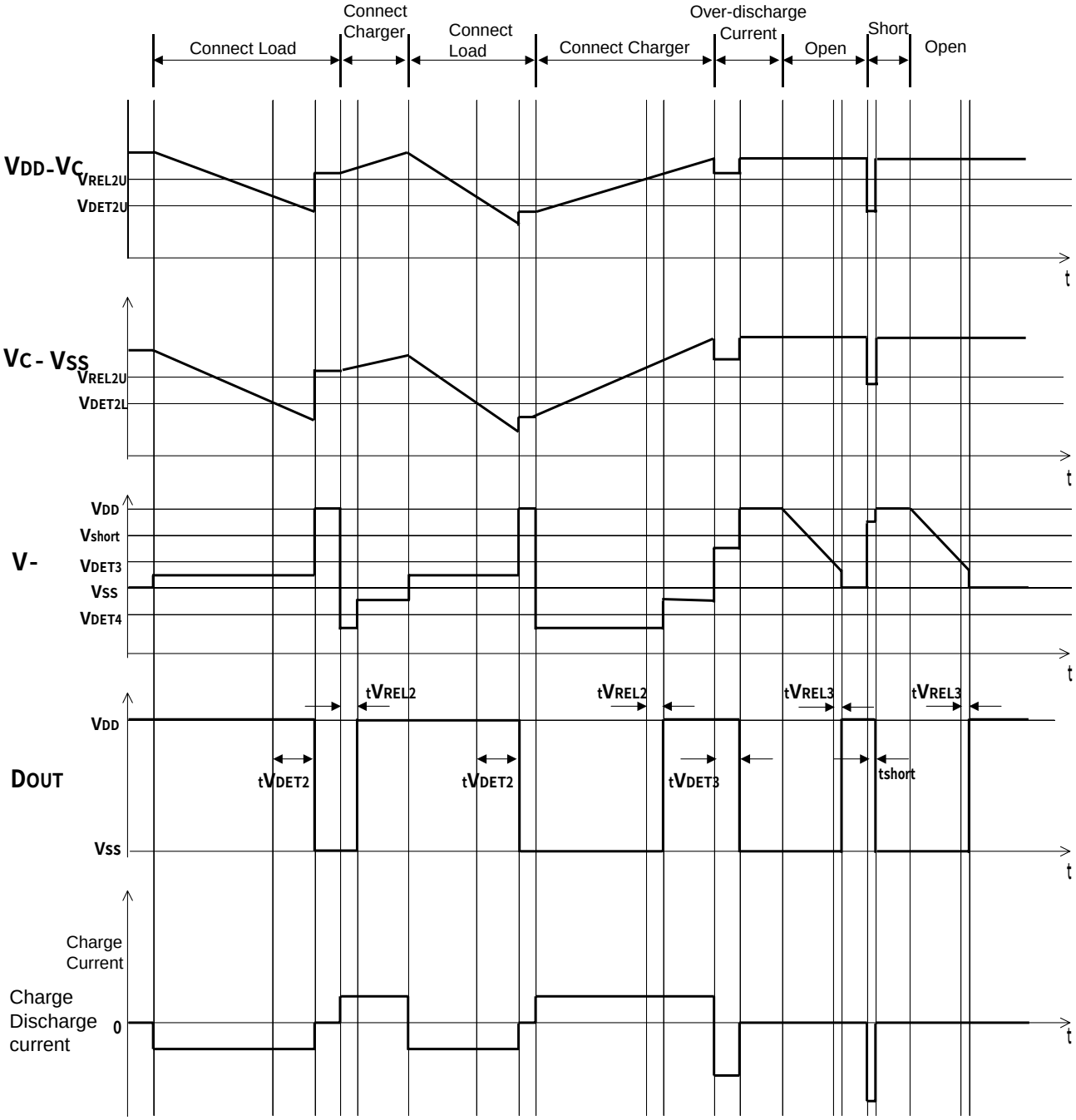
We are making our continuous effort to improve the quality and reliability of our products, but semiconductor products are likely to fail with certain probability. In order prevent any injury to persons or damages to property resulting from such failure, customers should be careful enough to incorporate safety measures in their design, such as redundancy feature, fire-containment feature and fail-safe feature. We do not assume any liability or responsibility for any loss or damage arising from misuse or inappropriate use of the products.

[9] Timing Diagram

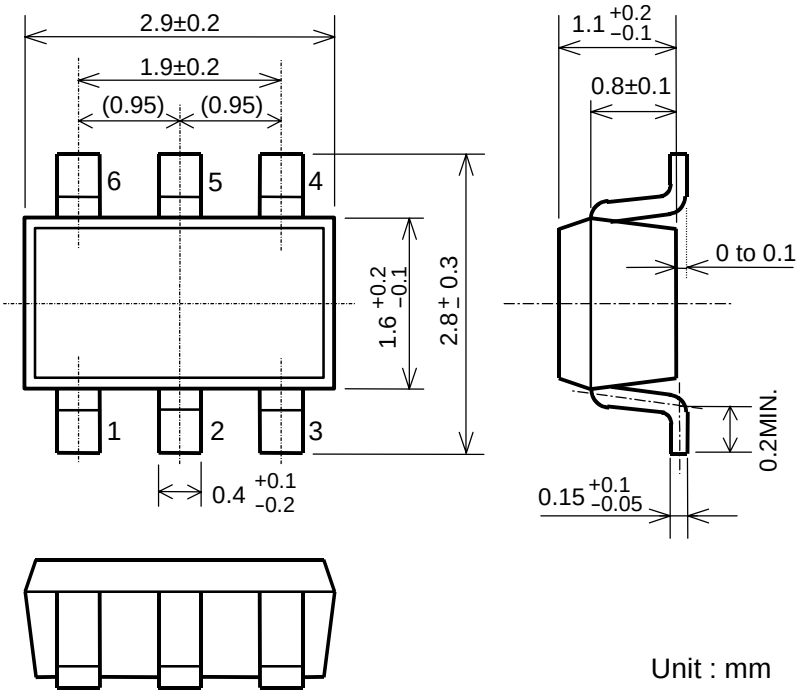
(1) Timing diagram of Over-charge, Excess charge current



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



[10] Package Dimensions (SOT23-6)



Unit : mm

[11] Mark Specification

①②: Product Code Name … 3Y
③④: Lot Number (Alphanumeric serial No.)