R5475N/R5478N SERIES

No. EA-291-121009

OUTLINE

The R5475N/R5478Nxxxxx Series are high voltage CMOS-based protection ICs for over-charge/discharge of rechargeable one-cell Lithium-ion (Li+) / Lithium polymer excess load current, further include a short circuit protector for preventing large external short circuit current and Excess discharge-current.

Each of these ICs is composed of three voltage detectors, a reference unit, a delay circuit, a short circuit protector, an oscillator, a counter, and a logic circuit. When the over-charge voltage crosses the detector threshold from a low value to a high value, the output of C_{OUT} pin switches to low level after internal fixed delay time. The conditions to release over-charge detector are different by mask options. In terms of so called “Latch function” version, after detecting over-charge, the detector can be reset and the output of C_{OUT} becomes "H" when a kind of load is connected to V_{DD} after a charger is disconnected from the battery pack, and the cell voltage becomes lower than over-charge detector threshold. If a charger is continue to be connected to the battery pack, even the cell voltage becomes lower than over-charge detector threshold, over-charge state is not released. On the other hand, in terms of so called, “ Released by voltage level” version, after detecting over-charge, when the cell voltage reaches the released voltage from over-charge, the output of COUT becomes “H”

The output of D_{OUT} pin, the output of Over-discharge detector and 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 detector are also different by mask options. In terms of so called “Latch function” version, after detecting over-discharge voltage, connect a charger to the battery pack, and when the battery supply voltage becomes higher than over-discharge detector threshold, VD2 is released and the voltage of D_{OUT} pin becomes "H" level. On the other hand, in terms of so called “Released by voltage level” version, in case that the charger is not connected, when the cell voltage becomes equal released voltage from over-discharge, over-discharge detector is released. In case that a charger is connected, and when the cell voltage becomes the released voltage from over-discharge, the over-discharge detector is released.

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

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

When the output of COUT is “H”, if V- pin level is set at Vss-2V, the delay time of detector can be shortened. Especially, the delay time of over-charge detector can be reduced into approximately 1/57. Therefore, testing time of protector circuit board can be reduced. Output type of C_{OUT} and D_{OUT} are CMOS. 6-pin, SOT-23-6 is available.

FEATURES

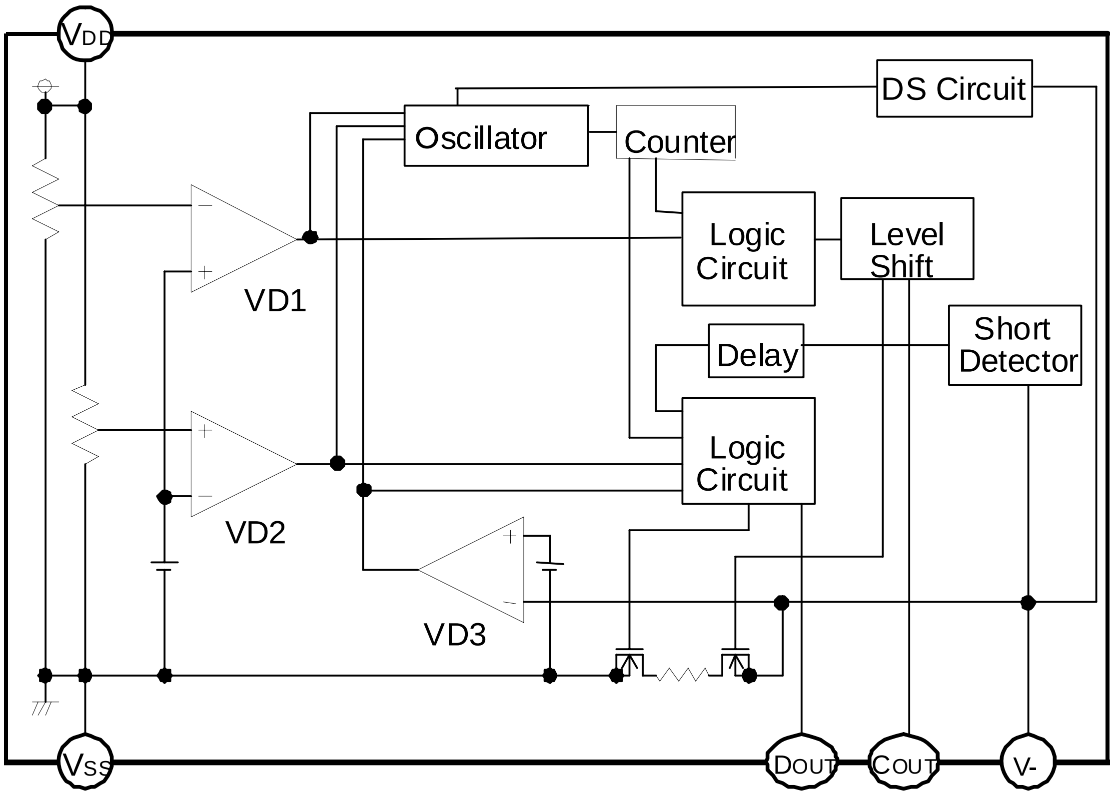
- Manufactured with High Voltage Tolerant Process ...Absolute Maximum Rating 30V
- Low supply current ....Supply current (At normal mode) Typ. 3.0μA
  C version: (detecting over-discharge) Max. 0.1μA
  D/J/K version: (detecting over-discharge) Typ. 1.2μA/Max. 2.0μA
- High accuracy detector threshold ....Over-charge detector (Topt=25°C) ±25mV
  (Topt=-5 to 55°C) ±30mV
  Over-discharge detector ±2.5%
  Excess discharge-current detector ±15mV
- Variety of detector threshold ....Over-charge detector threshold
  C/D version: 4.2V-4.5V step of 0.005V
  J version: 3.65V
  K version: 3.90V
  Over-discharge detector threshold
  C/D/J version: 2.1V-3.0V step of 0.100V
  K version: 1.9V-3.0V step of 0.100V
  Excess discharge-current threshold 0.05V-0.20V step of 0.005V
  Short Detector Threshold Fixed at 0.75V
- Internal fixed Output delay time...............Over-charge detector Output Delay 1s
  (Select among the options) Over-discharge detector Output Delay 20ms
  Excess discharge-current detector Output Delay 12ms(C Type) / 6ms(E Type)
  Short Circuit detector Output Delay 300μs(C Type) / 200μs(E Type)
- Output Delay Time Shortening Function..At COUT is "H", if V- level is set at –2V, the Output Delay time of all items except short-circuit can be reduced. (Delay Time for over-charge becomes about 1/57 of normal state.)
- Conditions for release over-charge detector With Latch function (C version)
  With Released voltage (D/J/K version)
- Conditions for Release over-discharge detector Latch Type: (C version)
  .... Released Voltage (D/J/K version)
- Ultra Small package ....SOT-23-5(R5475N) , SOT-23-6(R5478N)

APPLICATIONS

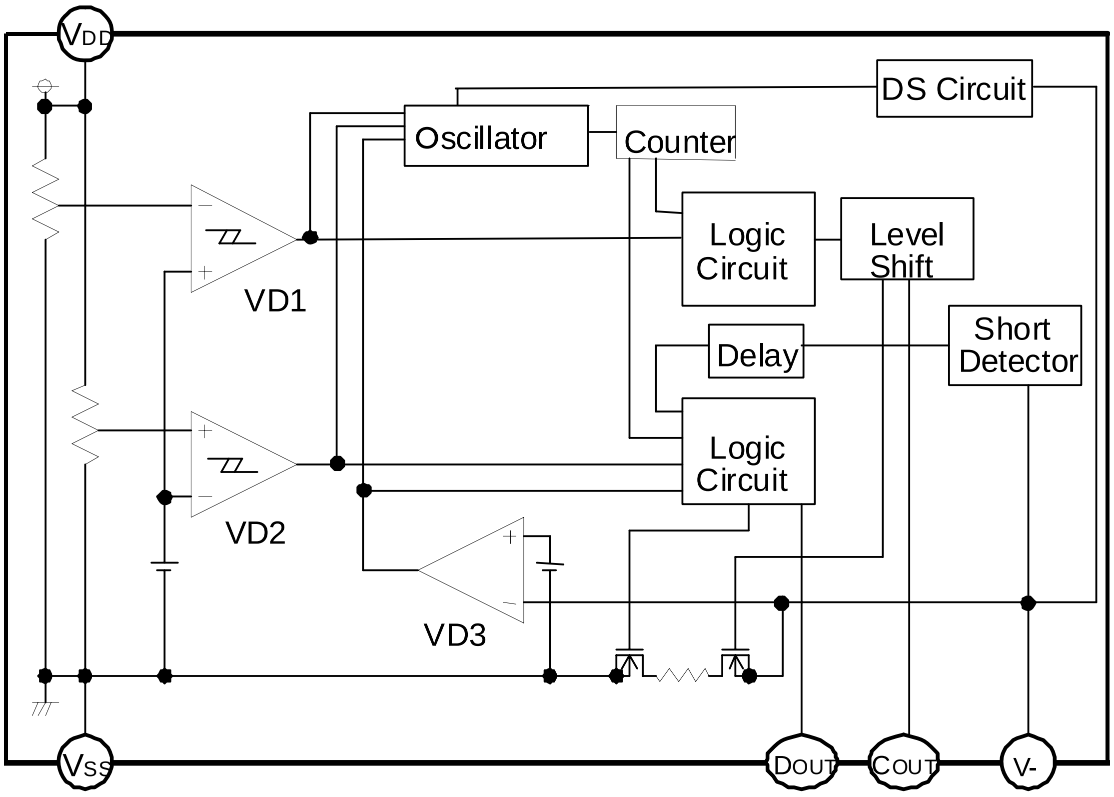
- Li+ / Li Polymer protector of over-charge, over-discharge, excess-current for battery pack
- High precision protectors for cell-phones and any other gadgets using on board Li+ / Li Polymer battery

BLOCK DIAGRAMS

C version



D/J/K version



SELECTION GUIDE

In the R5475/R5478xxxxx Series, three of the input threshold for over-charge, over-discharge, and excess discharge current detectors can be designated.

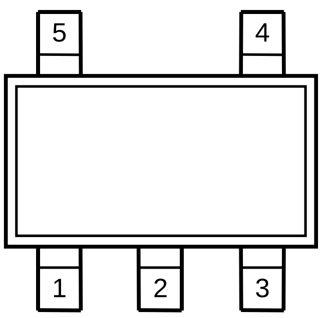
Part Number is designated as follows:

```
R547xN xxx x x-xx     ←Part Number
     ↑   ↑ ↑↑ ↑
     a   b c d e
```

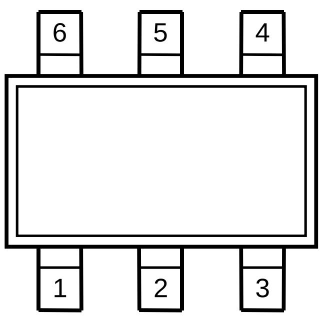
Code	Contents
a	Package Type R5475N: SOT-23-5 , R5478N: SOT-23-6
b	Serial Number for the R5475/R5478 Series designating input four threshold for over-charge, over-discharge, and excess discharge-current detectors.
c	Designation of Output delay option of over-charge, and excess discharge-current.
d	Designation of version symbols C version: With Latch function after Over-charge and Over-discharge D version: Released by voltage level from Over-charge and Over-discharge J version: Released by voltage level from Over-charge and Over-discharge Over-charge level = 3.65V Only K version: Released by voltage level from Over-charge and Over-discharge Over-charge level = 3.90V Only
e	Taping Type: TR (refer to Taping Specification)

PIN CONFIGURATIONS

SOT-23-5 (R5475N)



SOT-23-6 (R5478N)



PIN DESCRIPTION

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

ABSOLUTE MAXIMUM RATINGS

V_{SS}=0V

Symbol	Item	Ratings	Unit
V_{DD}	Supply voltage	-0.3 to 12	V
V-	Input Voltage V- pin	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.

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.

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.

ELECTRICAL CHARACTERISTICS

Unless otherwise specified, Topt=25°C

*R5478N1xxEC

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit	Note2
V_{DD1}	Operating input voltage	Voltage defined as V_{DD}-V_{SS}	1.5		5.0	V	F
Vst	Minimum operating Voltage for 0V charging	Voltage defined as V_{DD}-V-, V_{DD}-V_{SS}=0V			1.8	V	A
V_{DET1}	Over-charge threshold	Detect rising edge of supply voltage R1=330Ω R1=330Ω (Topt=-5 to 55°C)*Note1	V_{DET1}-0.025 V_{DET1}-0.030	V_{DET1} V_{DET1}	V_{DET1}+0.025 V_{DET1}+0.030	V V	B
tV_{DET1}	Output delay of over-charge	V_{DD}=3.6V to 4.4V	0.7	1.0	1.3	s	B
tV_{REL1}	Output delay of release from over-charge	V_{DD}=4.5V to 3.6V, V-=0V to 0.4V	11	16	21	ms	C
V_{DET2}	Over-discharge threshold	Detect falling edge of supply voltage	V_{DET2}×0.975	V_{DET2}	V_{DET2}×1.025	V	D
tV_{DET2}	Output delay of over-discharge	V_{DD}=3.6V to 2.2V	14	20	26	ms	D
tV_{REL2}	Output delay of release from over-discharge	V_{DD}=2.2V to 3.6V	0.7	1.2	1.7	ms	D
V_{DET3}	Excess discharge-current threshold	Detect rising edge of 'V-' pin voltage	V_{DET3}-0.015	V_{DET3}	V_{DET3}+0.015	V	E
tV_{DET3}	Output delay of excess discharge-current	V_{DD}=3.0V, V-=0V to 0.4V	4	6	8	ms	E
tV_{REL3}	Output delay of release from excess discharge-current	V_{DD}=3.0V, V-=3V to 0V	0.7	1.2	1.7	ms	E
Vshort	Short protection voltage	V_{DD}=3.0V	0.50	0.75	0.95	V	E
Tshort	Output Delay of Short protection	V_{DD}=3.0V, V-=0V to 3V	150	200	300	μs	E
Rshort	Reset resistance for Excess discharge-current protection	V_{DD}=3.6V, V-=1V	25	50	75	kΩ	F
V_{DS}	Delay Shortening Mode input voltage	V_{DD}=4.4V	-2.6	-2.0	-1.4	V	G
V_{OL1}	Nch ON voltage of COUT	Iol=50μA, V_{DD}=4.5V		0.4	0.5	V	H
V_{OH1}	Pch ON voltage of COUT	Ioh=-50μA, V_{DD}=3.9V	3.4	3.7		V	I
V_{OL2}	Nch ON voltage of DOUT	Iol=50μA, V_{DD}=2.0V		0.2	0.5	V	J
V_{OH2}	Pch ON voltage of DOUT	Ioh=-50μA, V_{DD}=3.9V	3.4	3.7		V	K
I_{DD}	Supply current	V_{DD}=3.9V, V- =0V		3.0	7.0	μA	L
I_S	Standby current	V_{DD}=2.0V			0.1	μA	L

*Note1: Considering of variation in process parameters, we compensate for this characteristic related to temperature by laser-trim, however, this specification is guaranteed by design, not mass production tested.

*Note2: indicates test circuits shown in page 17-20.

*R5475N/R5478N1xxCD **Unless otherwise specified, Topt=25°C**

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit	Note2
V_{DD1}	Operating input voltage	Voltage defined as V_{DD}-V_{SS}	1.5		5.0	V	F
Vst	Minimum operating Voltage for 0V charging	Voltage defined as V_{DD}-V-, V_{DD}-V_{SS}=0V			1.8	V	A
V_{DET1}	Over-charge threshold	Detect rising edge of supply voltage R1=330Ω R1=330Ω (Topt=-5 to 55°C)*Note	 V_{DET1}-0.025 V_{DET1}-0.030	 V_{DET1} V_{DET1}	 V_{DET1}+0.025 V_{DET1}+0.030	 V V	B
V_{REL1}	Released Voltage from Over-charge	Detect falling edge of supply voltage	V_{REL1}-0.05	V_{REL1}	V_{REL1}+0.05	V	B
tV_{DET1}	Output delay of over-charge	V_{DD}=3.6V to 4.4V	0.7	1.0	1.3	s	B
tV_{REL1}	Output delay of release from over-charge	V_{DD}=4.5V to 3.6V	11	16	21	ms	B
V_{DET2}	Over-discharge threshold	Detect falling edge of supply voltage	V_{DET2}×0.975	V_{DET2}	V_{DET2}×1.025	V	D
V_{REL2}	Released Voltage from Over-discharge	Detect rising edge of supply voltage	V_{REL2}×0.975	V_{REL2}	V_{REL2}×1.025	V	D
tV_{DET2}	Output delay of over-discharge	V_{DD}=3.6V to 2.2V	14	20	26	ms	D
tV_{REL2}	Output delay of release from over-discharge	V_{DD}=3V V-=3V to 0V	0.7	1.2	1.7	ms	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	E
tV_{DET3}	Output delay of excess dis-charge-current	V_{DD}=3.0V, V-=0V to 0.4V	8	12	16	ms	E
tV_{REL3}	Output delay of release from excess discharge-current	V_{DD}=3.0V, V-=3V to 0V	0.7	1.2	1.7	ms	E
Vshort	Short protection voltage	V_{DD}=3.0V	0.50	0.75	0.95	V	E
Tshort	Output Delay of Short protection	V_{DD}=3.0V, V-=0V to 3V	230	300	500	µs	E
Rshort	Reset resistance for Excess dis-charge-current protection	V_{DD}=3.6V, V-=1V	25	50	75	kΩ	F
V_{DS}	Delay Shortening Mode input voltage	V_{DD}=4.4V	-2.6	-2.0	-1.4	V	G
V_{OL1}	Nch ON voltage of C_{OUT}	Iol=50µA, V_{DD}=4.5V		0.4	0.5	V	H
V_{OH1}	Pch ON voltage of C_{OUT}	Ioh=-50µA, V_{DD}=3.9V	3.4	3.7		V	I
V_{OL2}	Nch ON voltage of D_{OUT}	Iol=50µA, V_{DD}=2.0V		0.2	0.5	V	J
V_{OH2}	Pch ON voltage of D_{OUT}	Ioh=-50µA, V_{DD}=3.9V	3.4	3.7		V	K
I_{DD}	Supply current	V_{DD}=3.9V, V- =0V		3.0	7.0	µA	L
I_S	Standby current	V_{DD}=2.0V		1.2	2.0	µA	L

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

*Note2: indicates test circuits shown in page 17-20.

*R5478N1xxCJ **Unless otherwise specified, Topt=25°C**

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit	Note2
V_{DD1}	Operating input voltage	Voltage defined as V_{DD}-V_{SS}	1.5		5.0	V	F
Vst	Minimum operating Voltage for 0V charging	Voltage defined as V_{DD}-V-, V_{DD}-V_{SS}=0V			1.8	V	A
V_{DET1}	Over-charge threshold	Detect rising edge of supply voltage R1=330Ω R1=330Ω (Topt=-5 to 55°C)*Note	 V_{DET1}-0.025 V_{DET1}-0.030	 V_{DET1} V_{DET1}	 V_{DET1}+0.025 V_{DET1}+0.030	 V V	B
V_{REL1}	Released Voltage from Over-charge	Detect falling edge of supply voltage	V_{REL1}-0.05	V_{REL1}	V_{REL1}+0.05	V	B
tV_{DET1}	Output delay of over-charge	V_{DD}=3.2V to 3.75V	0.7	1.0	1.3	s	B
tV_{REL1}	Output delay of release from over-charge	V_{DD}=3.9V to 3.2V	11	16	21	ms	B
V_{DET2}	Over-discharge threshold	Detect falling edge of supply voltage	V_{DET2}×0.975	V_{DET2}	V_{DET2}×1.025	V	D
V_{REL2}	Released Voltage from Over-discharge	Detect rising edge of supply voltage	V_{REL2}×0.975	V_{REL2}	V_{REL2}×1.025	V	D
tV_{DET2}	Output delay of over-discharge	V_{DD}=3.2V to 2.2V	14	20	26	ms	D
tV_{REL2}	Output delay of release from over-discharge	V_{DD}=2V to 3.1V	0.7	1.2	1.7	ms	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	E
tV_{DET3}	Output delay of excess discharge-current	V_{DD}=3.0V, V-=0V to 0.4V	8	12	16	ms	E
tV_{REL3}	Output delay of release from excess discharge-current	V_{DD}=3.0V, V-=3V to 0V	0.7	1.2	1.7	ms	E
Vshort	Short protection voltage	V_{DD}=3.0V	0.50	0.75	0.95	V	E
Tshort	Output Delay of Short protection	V_{DD}=3.0V, V-=0V to 3V	230	300	500	µs	E
Rshort	Reset resistance for Excess discharge-current protection	V_{DD}=3.2V, V-=1.0V	25	50	75	kΩ	F
V_{DS}	Delay Shortening Mode input voltage	V_{DD}=4.4V	-2.6	-2.0	-1.4	V	G
V_{OL1}	Nch ON voltage of C_{OUT}	Iol=50µA, V_{DD}=4.5V		0.4	0.5	V	H
V_{OH1}	Pch ON voltage of C_{OUT}	Ioh=-50µA, V_{DD}=3.2V	2.7	3.0		V	I
V_{OL2}	Nch ON voltage of D_{OUT}	Iol=50µA, V_{DD}=2.0V		0.2	0.5	V	J
V_{OH2}	Pch ON voltage of D_{OUT}	Ioh=-50µA, V_{DD}=3.2V	2.7	3.0		V	K
I_{DD}	Supply current	V_{DD}=3.2V, V- =0V		3.0	7.0	µA	L
I_S	Standby current	V_{DD}=2.0V		1.2	2.0	µA	L

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

*Note2: indicates test circuits shown in page 17-20.

*R5478N1xxCK **Unless otherwise specified, Topt=25°C**

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit	Note2
V_{DD1}	Operating input voltage	Voltage defined asV_{DD}-V_{SS}	1.5		5.0	V	F
Vst	Minimum operating Voltage for 0V charging	Voltage defined asV_{DD}-V-, V_{DD}-V_{SS}=0V			1.8	V	A
V_{DET1}	Over-charge threshold	Detect rising edge of supply voltage R1=330Ω R1=330Ω (Topt=-5 to 55°C)*Note	 V_{DET1}-0.025 V_{DET1}-0.030	 V_{DET1} V_{DET1}	 V_{DET1}+0.025 V_{DET1}+0.030	 V V	B
V_{REL1}	Released Voltage from Over-charge	Detect falling edge of supply voltage	V_{REL1}-0.05	V_{REL1}	V_{REL1}+0.05	V	B
tV_{DET1}	Output delay of over-charge	V_{DD}=3.2V to 3.75V	0.7	1.0	1.3	s	B
tV_{REL1}	Output delay of release from over-charge	V_{DD}=3.9V to 3.2V	11	16	21	ms	B
V_{DET2}	Over-discharge threshold	Detect falling edge of supply voltage	V_{DET2}×0.975	V_{DET2}	V_{DET2}×1.025	V	D
V_{REL2}	Released Voltage from Over-discharge	Detect rising edge of supply voltage	V_{REL2}×0.975	V_{REL2}	V_{REL2}×1.025	V	D
tV_{DET2}	Output delay of over-discharge	V_{DD}=3.2V to 1.9V	14	20	26	ms	D
tV_{REL2}	Output delay of release from over-discharge	V_{DD}=1.9V to 3.1V	0.7	1.2	1.7	ms	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	E
tV_{DET3}	Output delay of excess dis-charge-current	V_{DD}=3.0V, V-=0V to 0.4V	8	12	16	ms	E
tV_{REL3}	Output delay of release from excess discharge-current	V_{DD}=3.0V, V-=3V to 0V	0.7	1.2	1.7	ms	E
Vshort	Short protection voltage	V_{DD}=3.0V	0.50	0.75	0.95	V	E
Tshort	Output Delay of Short protection	V_{DD}=3.0V, V-=0V to 3V	230	300	500	μs	E
Rshort	Reset resistance for Excess dis-charge-current protection	V_{DD}=3.2V, V-=1.0V	25	50	75	kΩ	F
V_{DS}	Delay Shortening Mode input voltage	V_{DD}=4.4V	-2.6	-2.0	-1.4	V	G
V_{OL1}	Nch ON voltage of C_{OUT}	Iol=50μA, V_{DD}=4.5V		0.4	0.5	V	H
V_{OH1}	Pch ON voltage of C_{OUT}	Ioh=-50μA, V_{DD}=3.2V	2.7	3.0		V	I
V_{OL2}	Nch ON voltage of D_{OUT}	Iol=50μA, V_{DD}=1.9V		0.2	0.5	V	J
V_{OH2}	Pch ON voltage of D_{OUT}	Ioh=-50μA, V_{DD}=3.2V	2.7	3.0		V	K
I_{DD}	Supply current	V_{DD}=3.2V, V- =0V		3.0	7.0	μA	L
I_S	Standby current	V_{DD}=2.0V		1.2	2.0	μA	L

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

*Note2: indicates test circuits shown in page 17-20.

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 version, 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 connecting a kind of loading to V_{DD} after 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. 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/J/K version, after detecting over-charge, if VDD pin voltage is lower than released from over-charge, even if a charger is connected, over-charge detector is released. Further, in case that VDD pin level is lower than detector threshold and higher than released voltage from over-charge, if a charger is removed and some load is connected, over-charge detector is also 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 version, 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/J/K version, released operation by connecting a charger is same as C version. However, without a charger, if VDD pin voltage is equal or more than the released voltage from over-discharge, DOUT pin becomes “H” immediately.

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.

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, 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.

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

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

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

When the V- pin voltage is up to a value between the short protection voltage Vshort /V_{DD} and excess discharge-current threshold V_{DET3}, VD3 operates and further soaring of V- pin voltage higher than Vshort makes the short circuit protector enabled. This leads the external discharge control Nch MOSFET turns off with the D_{OUT} pin being at "L" level.

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 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.

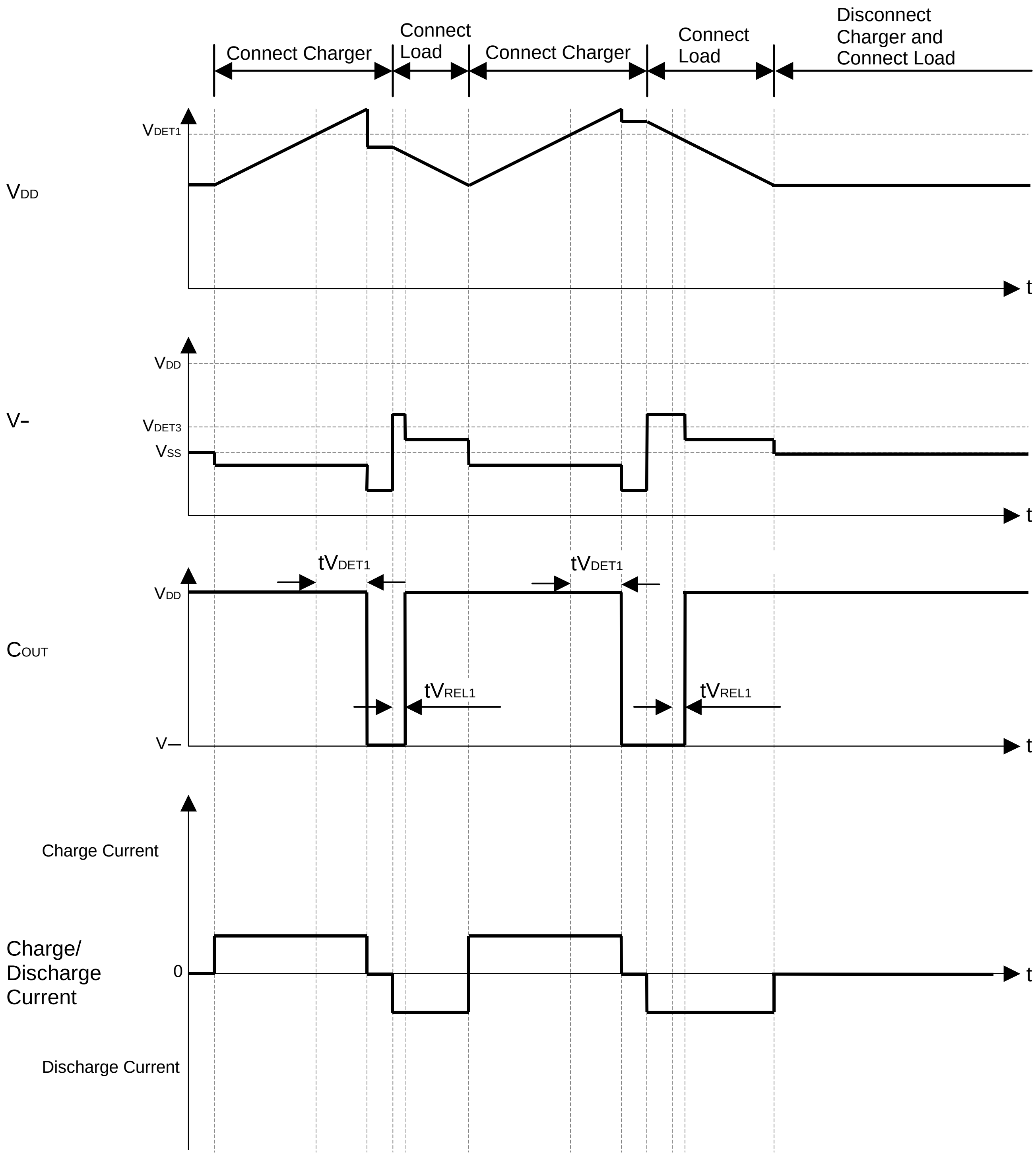
Output delay time of excess discharge-current is set shorter than the delay time for over-discharge detector. Therefore, if V_{DD} voltage would be lower than V_{DET2} at the same time as the excess discharge-current is detected, the R5478xxxxxx is at excess discharge-current detection mode. By disconnecting a load, VD3 is automatically released from excess discharge-current.

- **DS (Delay Shorten) function**

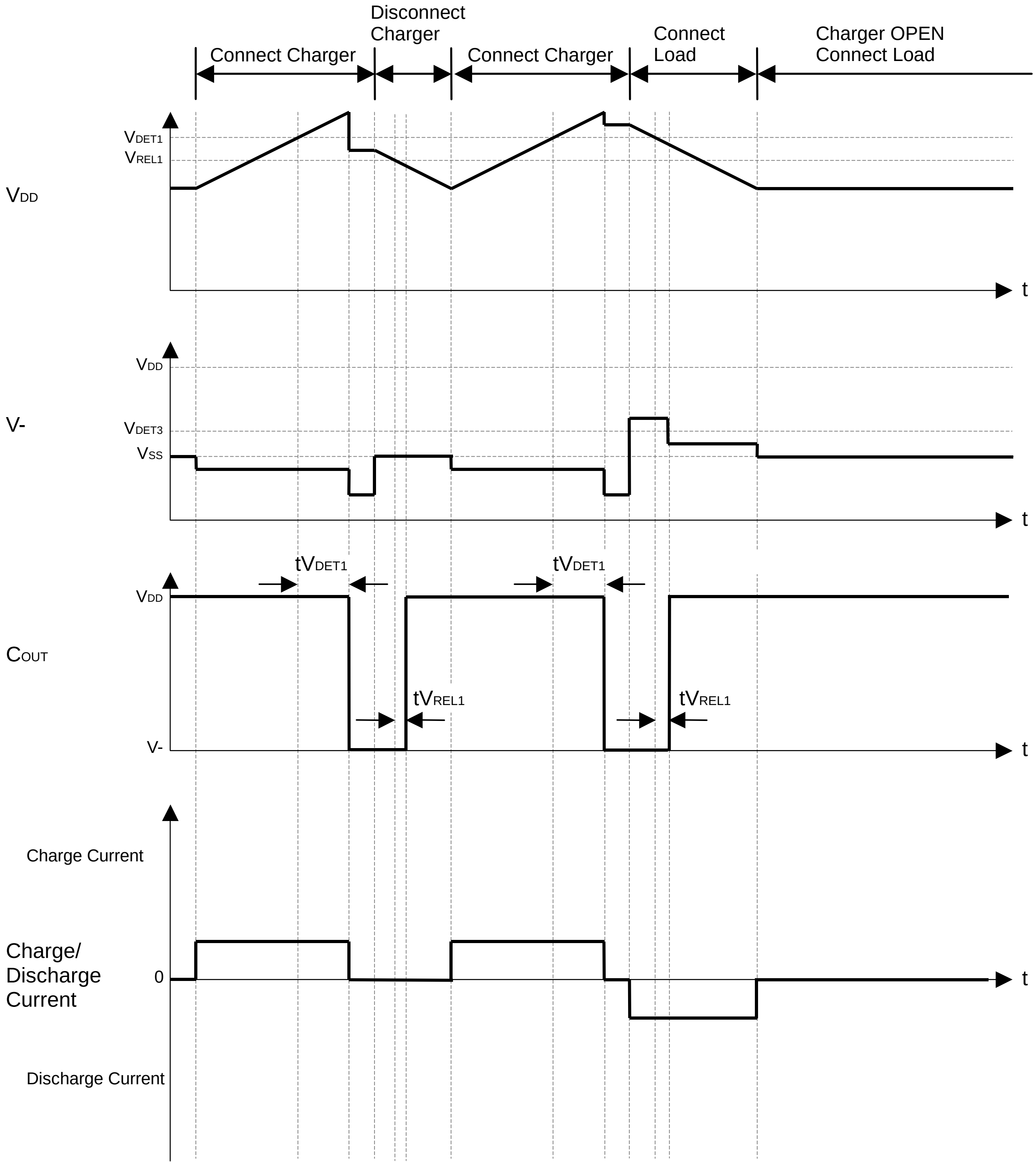
Output delay time of over-charge, over-discharge, and release from those detecting modes can be shorter than those setting value by forcing equal or less than the delay shortening mode voltage to V- pin.

TIMING CHART

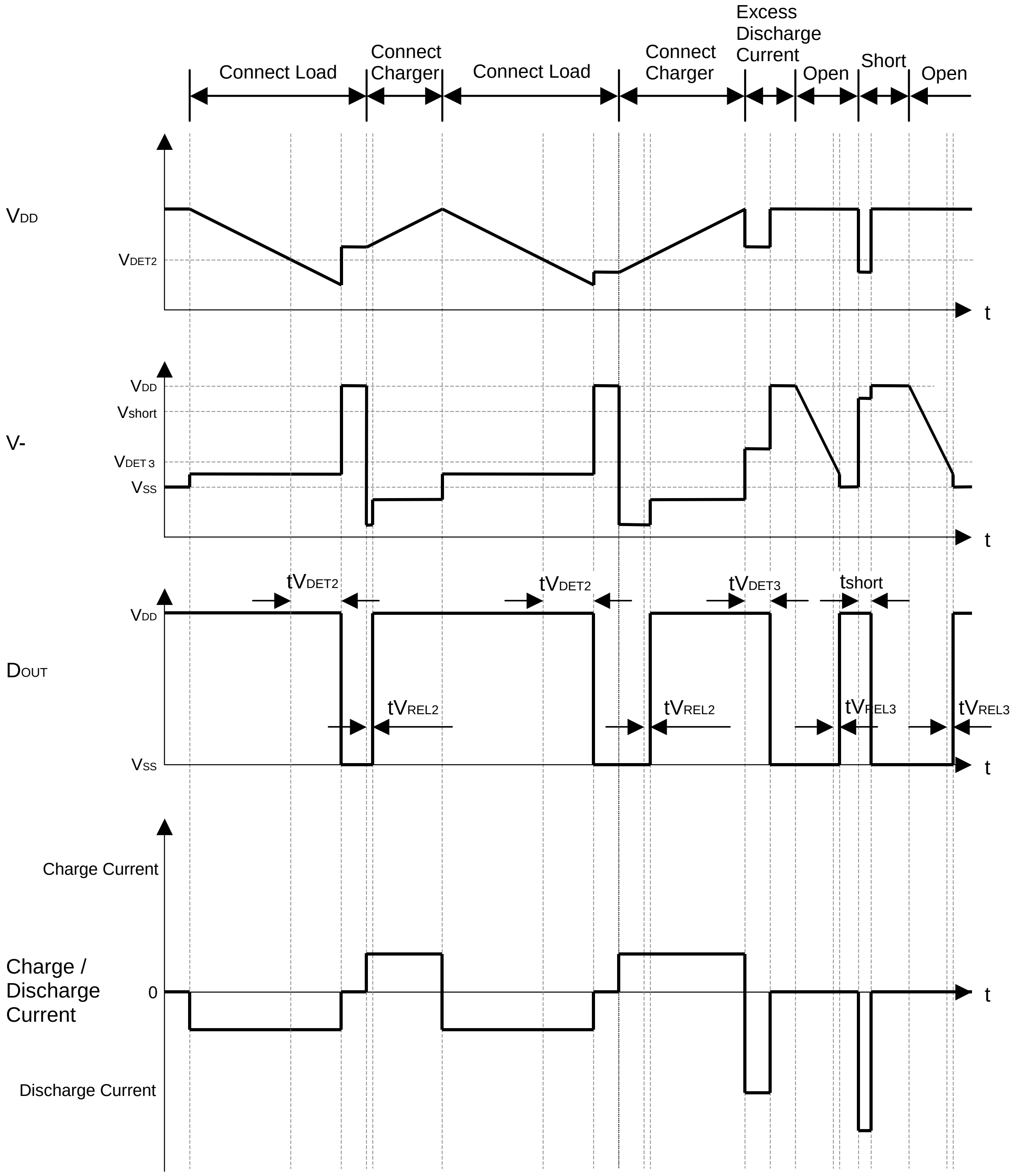
1. Over-charge (Latch Type) voltage, Excess charge current Operation



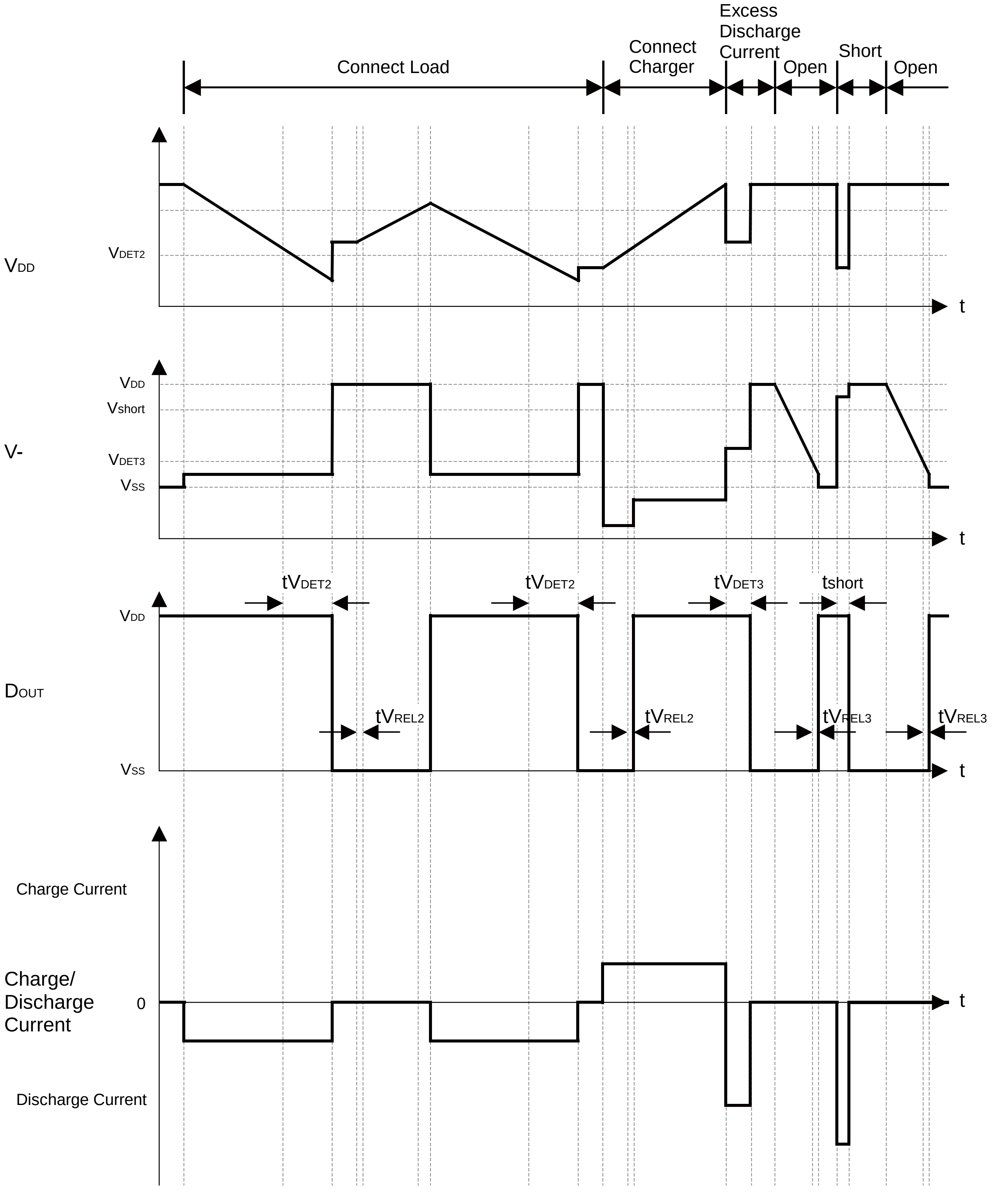
2. Over-charge (Released by voltage Type) voltage, Excess charge current Operation



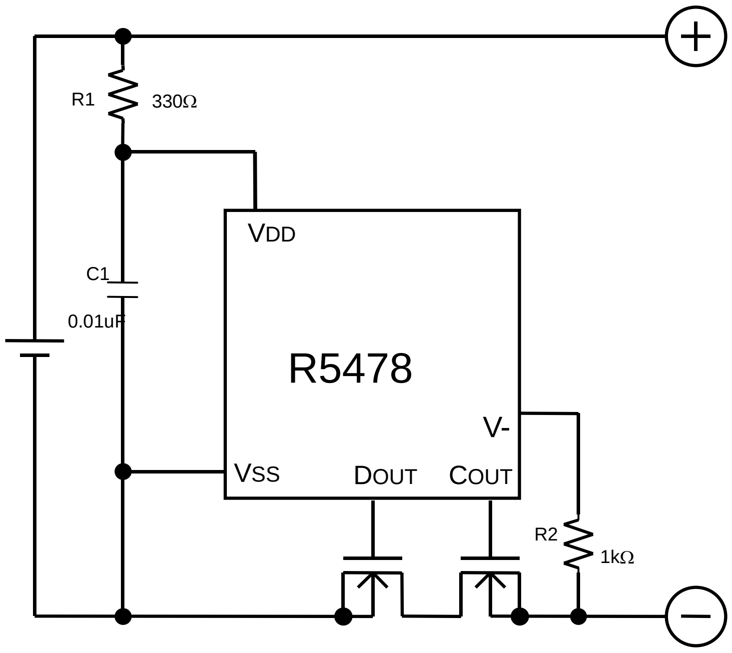
3. Over-discharge (Latch Type), Excess discharge current, Short circuit



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



TYPICAL APPLICATION



APPLICATION HINTS

R1 and C1 will stabilize a supply voltage to the R5478xxxxxx. 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 R5478xxxxxx.

Further, to stabilize the operation of the R5478, use the C1 with the value in the range from 0.001uF to 0.01uF. To choose the most suitable value of C1, fully evaluation is necessary.

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 R5478xxxxxx, battery pack. Small value of R1 and R2 may cause over-power consumption rating of power dissipation of the R5478xxxxx. 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 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.

TEST CIRCUITS

1, Minimum Operating Voltage for 0V Charging(0V battery charge function “available”)(Test circuit A)

The minimum operating voltage for 0V charging (Vst) is defined as the voltage between the VDD pin and the V- pin at which COUT goes to “H” (VDD - 0.1V or higher) when the voltage V2 is gradually decreased from the starting condition of V1 = 0V ,V2 = -0.3V.

2, Over-charge Threshold Voltage (Test circuit B)

The over-charge threshold voltage(VDET1) is defined as the voltage between the VDD pin and the VSS pin at which COUT goes from “H” to “L” when the voltage V1 is gradually increased from the starting condition of V1 = 3.5V with R1=330Ω between VDD and Pack+.

3, Release voltage from Over-charge (Test circuit B) *Except EC version

The release voltage from over-charge (VREL1) is defined as the voltage between the VDD pin and the VSS pin at which COUT goes from “L” to “H” when the voltage V1 is then gradually decreased with R1=330Ω between VDD and Pack+.

4, Output Delay of Over-charge (Test circuit B)

The output delay of over-charge (tVDET1) is the time needed for COUT to change from “H” to “L” just after the voltage V1 momentarily increases (within 10μs) from over-charge threshold voltage (VDET1) – 0.2V to over-charge threshold voltage (VDET1) + 0.2V under the set conditions of V2 = 0V.

5, Release Delay for VD1 (Test circuit B) *Except EC version

The release Delay for VD1 (tVREL1) is the time needed for COUT to change from “L” to “H” just after the voltage V1 momentarily decreases (within 10μs) from over-charge threshold voltage (VDET1) + 0.2V to overcharge release voltage (VREL1) - 0.2V under the set conditions of V2 = 0V.

6, Release Delay for VD1 (Test circuit C) *for EC version

The release Delay for VD1 (tVREL1) is the time needed for COUT to change from “L” to “H” just after the voltage V2 momentarily increases (within 10μs) from 0V to excess discharge-current threshold (VDET3) + 0.1V under the set conditions of V1 from over-charge threshold voltage (VDET1) + 0.2V to over-charge threshold voltage (VDET1) - 0.2V.

7, Overdischarge Threshold Voltage (Test circuit D)

The overdischarge threshold voltage(VDET2) is defined as the voltage between the VDD pin and the VSS pin at which DOUT goes from “H” to “L” when the voltage V1 is gradually decreased from the starting condition of V1 = 3.5V , V2 = 0V.

8, Released Voltage from Over-discharge (Test circuit E) *Except EC version

The released voltage from over-discharge (VREL2) is defined as the voltage between the VDD pin and the VSS pin at which DOUT goes from “L” to “H” when the voltage V1 is then gradually increased under the set conditions of V2 = V1.

9, Output Delay of Over-discharge (Test circuit D)

The output delay of over-discharge (tVDET2) is the time needed for DOUT to change from “H” to “L” just after the voltage V1 momentarily decreases (within 10μs) from over-discharge threshold voltage (VDET2) + 0.2V to over-discharge threshold voltage (VDET2) - 0.2V under the set conditions of V2 = 0V.

10, Release Delay for VD2 (Test circuit E) *Except EC version

The release delay for VD2 (tVREL2) is the time needed for DOUT to change from “L” to “H” just after the voltage V1 momentarily increases (within 10μs) from over-discharge threshold voltage (VDET2) - 0.2V to over-discharge release voltage (VREL2) + 0.2V under the set conditions of V2 = V1.

11, Release Delay for VD2 (Test circuit D) *For EC version

The release delay for VD2 (tVREL2) is the time needed for DOUT to change from “L” to “H” just after the voltage V1 momentarily increases (within 10μs) from over-discharge threshold voltage (VDET2) - 0.2V to over-discharge release voltage (VREL2) + 0.2V under the set conditions of V2 = 0V.

12, Excess discharge-current threshold (Test circuit E)

Excess discharge-current threshold (VDET3) is defined as the voltage between the V- pin and the VSS pin at which DOUT goes from “H” to “L” when the voltage V2 is then gradually increased from the starting condition of V1 = 3.0V , V2 = 0V.

13, Output delay of excess discharge-current, Release Delay for VD3 (Test circuit E)

The output delay of excess discharge-current (tVDET3) is the time needed for DOUT to go to “L” after the voltage V2 momentarily increases (within 10μs) from 0V to 0.40V under the set conditions of V1 =3.0V.
The Release Delay for VD3 (tVREL3) is the time needed for DOUT to go to “H” after the voltage V2 momentarily decreases (within 10μs) from 3.0V to 0V under the set conditions of V1 =3.0V.

14, Short Protection Voltage (Test circuit E)

The short protection voltage (Vshort) is defined as the voltage between the V- pin and the VSS pin whose delay time for changing DOUT from “H” to “L” lies between the minimum and the maximum value of load short-circuiting delay time when the voltage V2 is increased rapidly (within 10μs) from the starting condition of V1 = 3.0V , V2 = 0V.

15, Delay Time for Short Protection (Test circuit E)

The delay time for short protection (tshort) is the time needed for DOUT to go to “L” after the voltage V2 momentarily increases (within 10μs) from 0V to 3.0V under the set conditions of V1 =3.0V.

16, Reset Resistance for Excess Current Protection (Test circuit F)

The Reset Resistance for Excess Current Protection (Rshort) is the resistance between the V- pin and the VSS pin under the set conditions of V1 =3.6V, V2 = 1.0V.

17, Delay Time Shortening Mode Voltage (Test circuit G)

The Delay Time Shortening Mode Voltage (VDS) is the voltage is defined as the voltage between the V- pin and VSS pin at which tVDET1 becomes about 1/57 at V2 = 0V when the voltage V2 is then gradually decreased from the starting condition of V2 = 0V.

18, Nch ON-Voltage of C_{OUT} (Test circuit H)

The Nch ON-Voltage of C_{OUT} (VoL1) is the resistance at the COUT pin under the set conditions of V1 = 4.5V, V2 = 0V, I3 = 50uA.

19, Pch ON-Voltage of C_{OUT} (Test circuit I)

The Pch ON-Voltage of C_{OUT} (VoH1) is the Voltage at the COUT pin under the set conditions of V1 = 3.9V for EC,CD version / 3.8V for CK version / 3.5V for CJ version, V2 = 0V, I3 = -50uA.

20, Pch ON-Voltage of D_{OUT} (Test circuit J)

Pch ON-Voltage of D_{OUT} (VoH2) is the Voltage at the DOUT pin under the set conditions of V1 = 3.9V for EC,CD version / 3.8V for CK version / 3.5V for CJ version, V2 = 0V, I4 = -50uA.

21, Nch ON-Voltage of D_{OUT} (Test circuit K)

Nch ON-Voltage of D_{OUT} (VoL2) is the Voltage at the DOUT pin under the set conditions of V1 = 2.0V, V2 = 0V, I4 = 50uA.

22, Supply Current (Test circuit L)

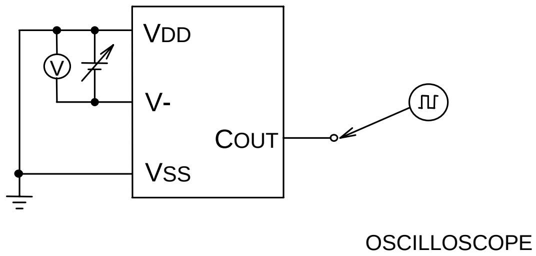
The supply current (IDD) is the current that flows through the VDD pin(IDD) under the set conditions of V1 = 3.9V for EC,CD version / 3.8V for CK version / 3.5V for CJ version and V2 = 0V (normal status).

23, Standby Current (Test circuit L)

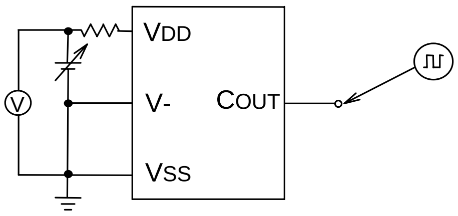
The standby current (Istandby) is the current that flows through the VDD pin(IDD) under the set conditions of V1 = V2 = 2.0V (overdischarge status).

V1 : The voltage between VDD pin and VSS pin.
V2 : The voltage between V- pin and VSS pin.
I3 : The current flow into COUT pin.
I4 : The current flow into DOUT pin.

A



B



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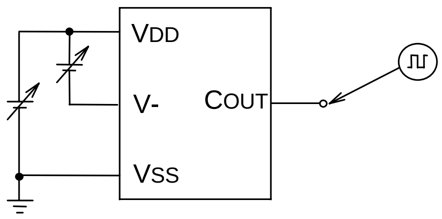
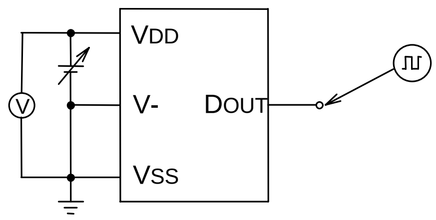
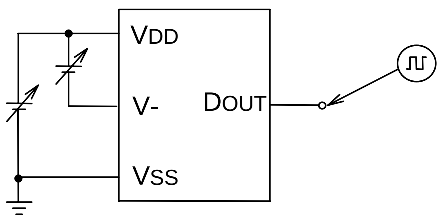


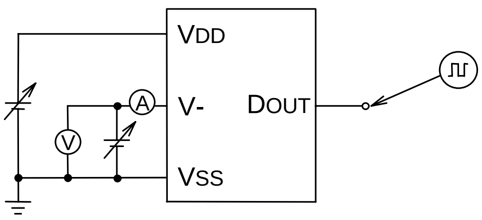
D



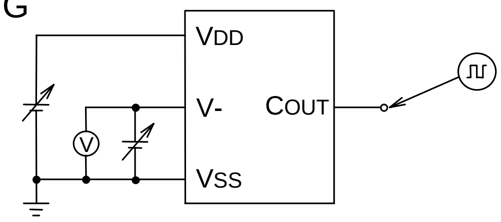
E



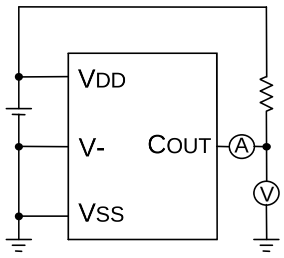
F



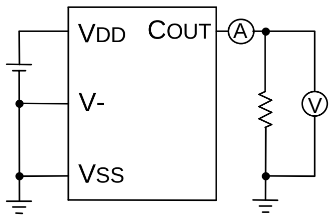
G



H



I



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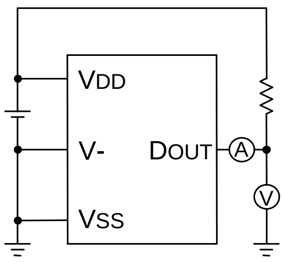

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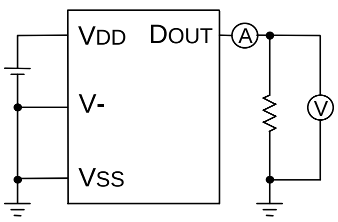
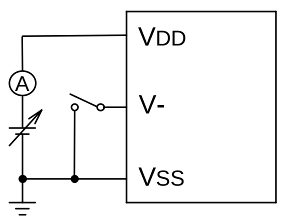


L



Typical Characteristics were obtained with using those above circuits:

Test Circuit A: Typical characteristics 1)

Test Circuit B: Typical characteristics 2)

Test Circuit C: Typical characteristics 3) 4)

Test Circuit D: Typical characteristics 5) 6) 7)

Test Circuit E: Typical characteristics 8) 9) 10) 11) 12)

Test Circuit F: Typical characteristics 13)

Test Circuit G: Typical characteristics 14)

Test Circuit H: Typical characteristics 15)

Test Circuit I: Typical characteristics 16)

Test Circuit J: Typical characteristics 17)

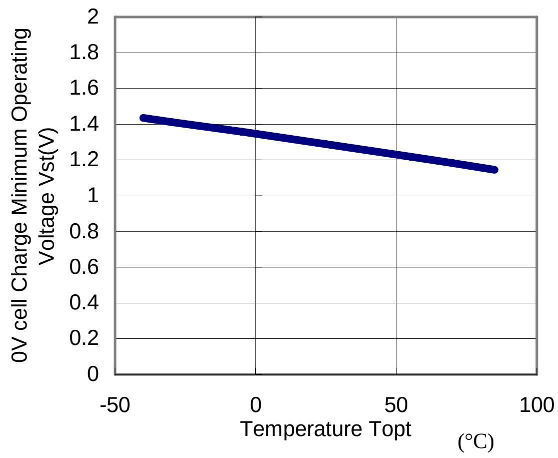
Test Circuit K: Typical characteristics 18)

Test Circuit L: Typical characteristics 19) 20)

TYPICAL CHARACTERISTICS

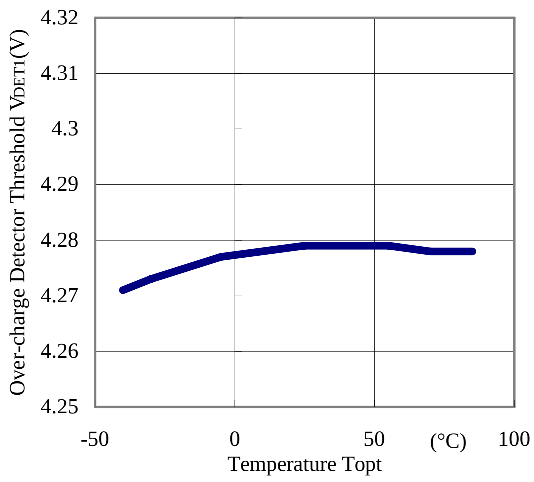
1) Minimum Operating Voltage for 0V Cell Charging vs. Temperature

R5478N128EC Vdd-Vss=0V



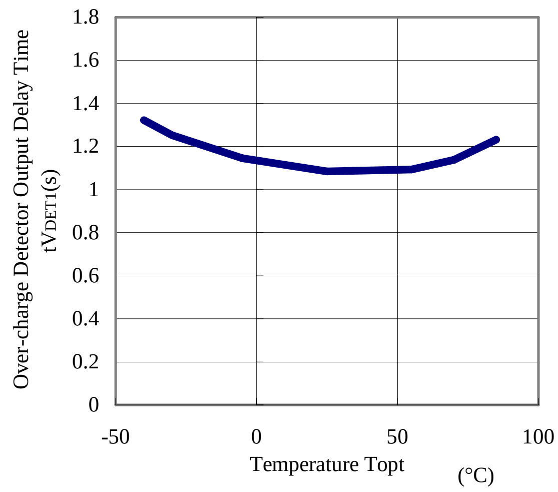
2) Over-Charge Threshold vs. Temperature

R5478N128EC



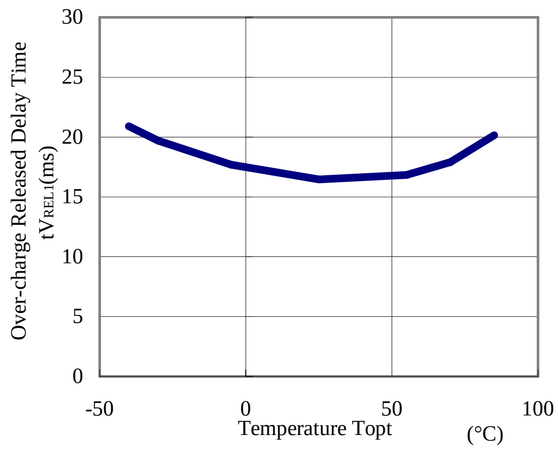
3) Output Delay of Over-charge vs. Temperature

R5478N128EC



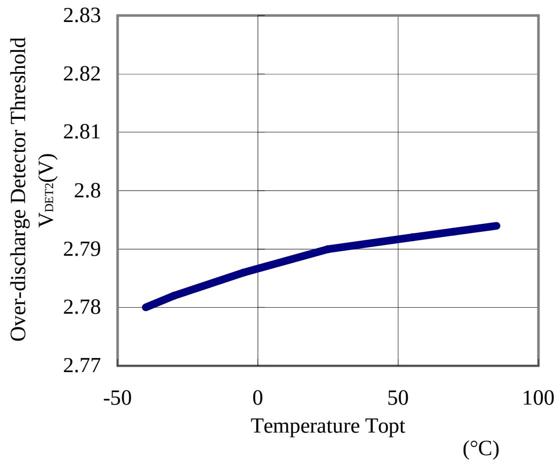
4) Output Delay of Release from Over-charge vs. Temperature

R5478N128EC



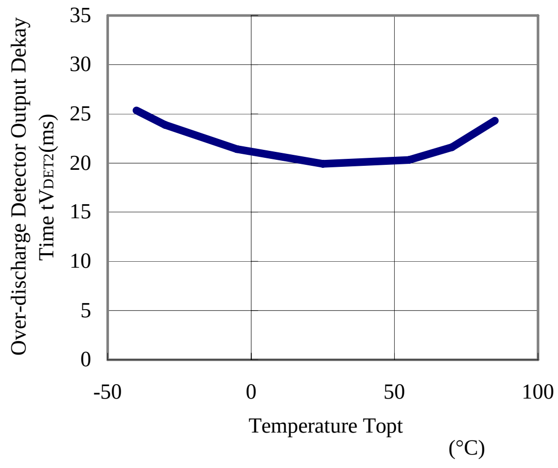
5) Over discharge Threshold vs. Temperature

R5478N128EC



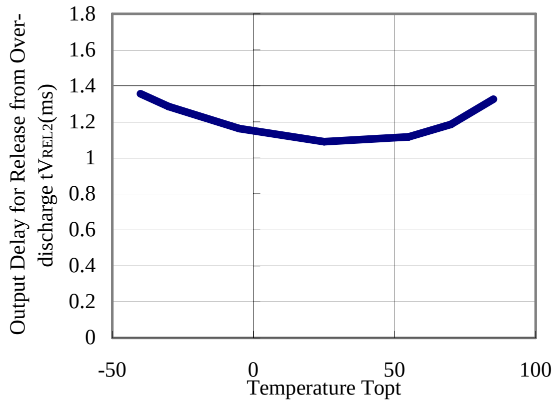
6) Output Delay of Over-discharge vs. Temperature

R5478N128EC



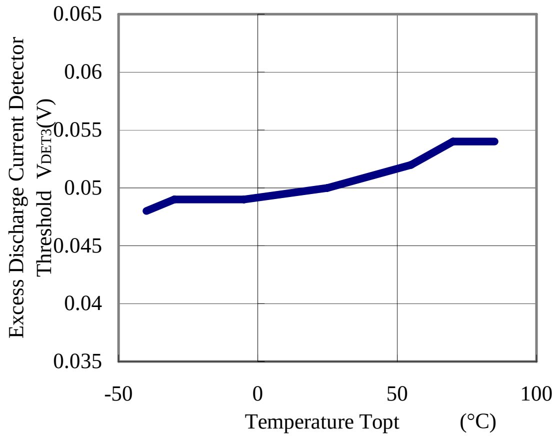
7) Output Delay of Release from Over-discharge vs. Temperature

R5478N128EC



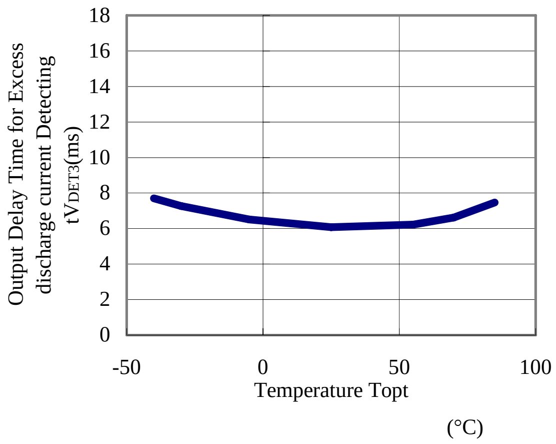
8) Excess Discharge-current Threshold vs. Temperature

R5478N128EC



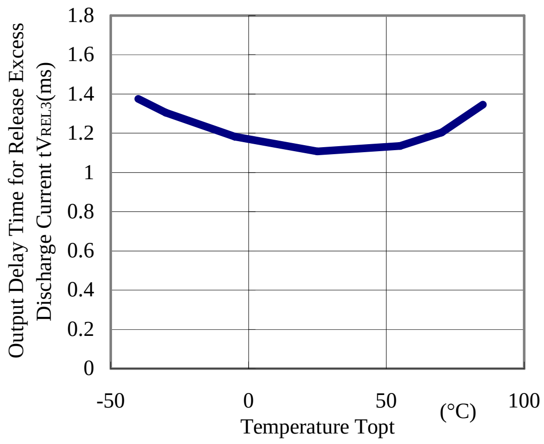
9) Output Delay of Excess Discharge-current vs. Temperature

R5478N128EC



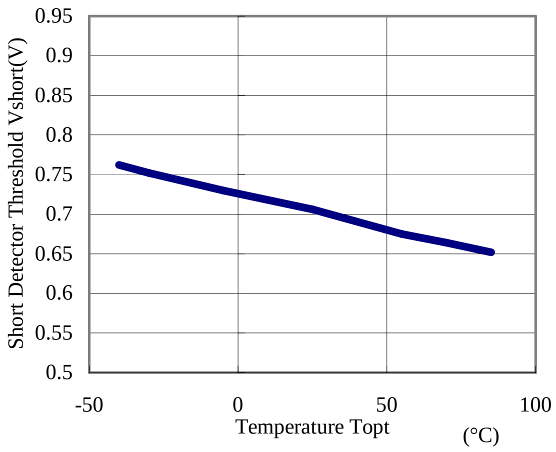
10) Output Delay of Release from Excess Dicharge-current vs. Temperature

R5478N128EC



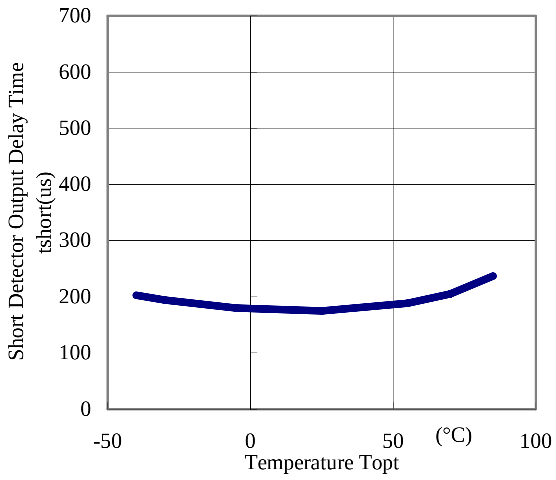
11) Short Detector Voltage vs. Temperature

R5478N128EC



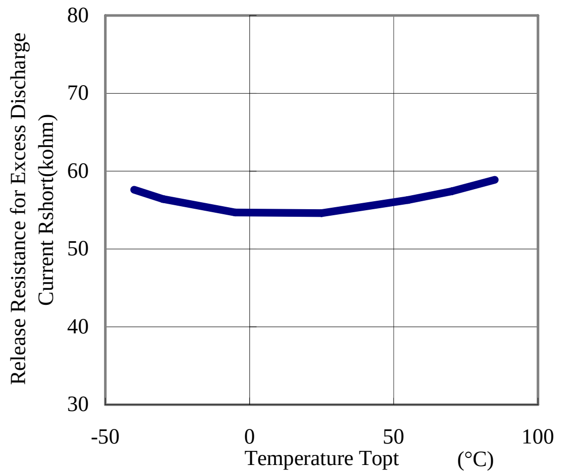
12) Output Delay of Short Protection vs. Temperature

R5478N128EC



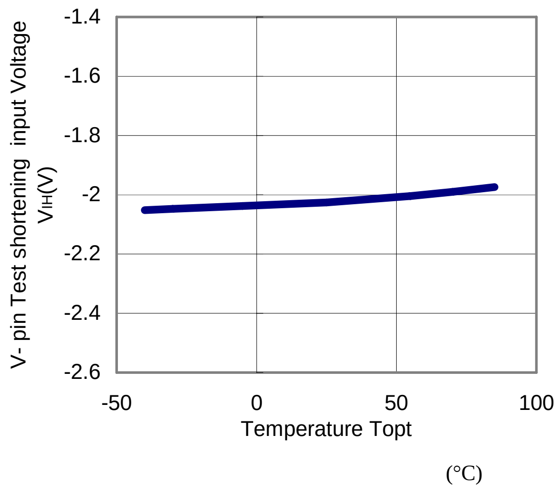
13) Reset Resistance for Excess Discharge current Protection vs. Temperature

R5478N128EC



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

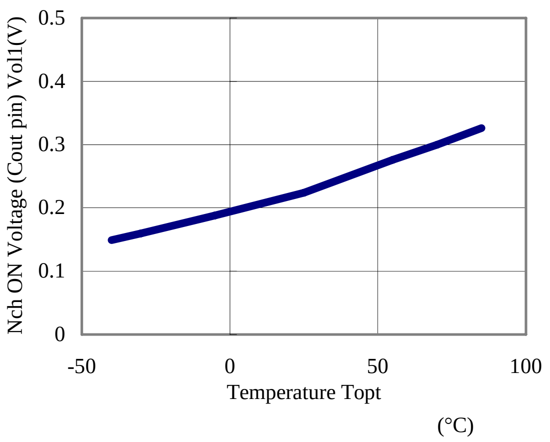
R5478N128EC



15) Nch On Voltage (COUT pin) vs. Temperature

IOL=50uA,Vdd=4.5V

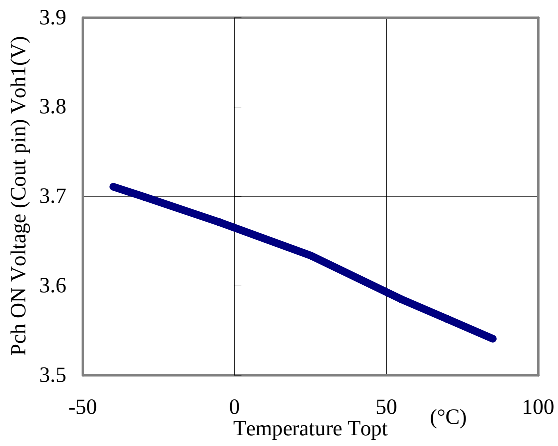
R5478N128EC



16) Pch On Voltage (COUT pin) vs. Temperature

Ioh=-50uA, Vdd=3.9V

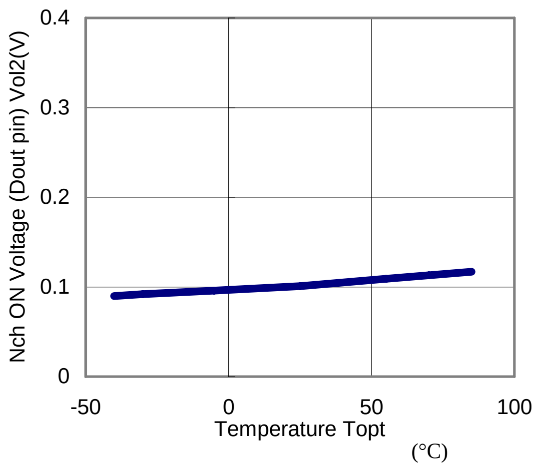
R5478N128EC



17) Nch On Voltage (DOUT pin) vs. Temperature

Iol=50uA, VDD=2V

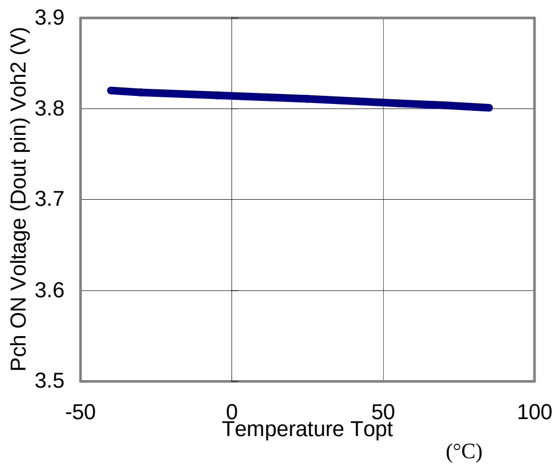
R5478N128EC



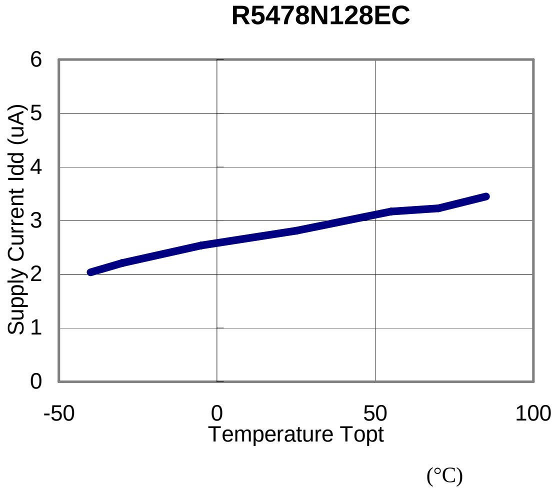
18) Pch ON Voltage of DOUT vs. Temperature

Ioh=-50uA, Vdd=3.9V

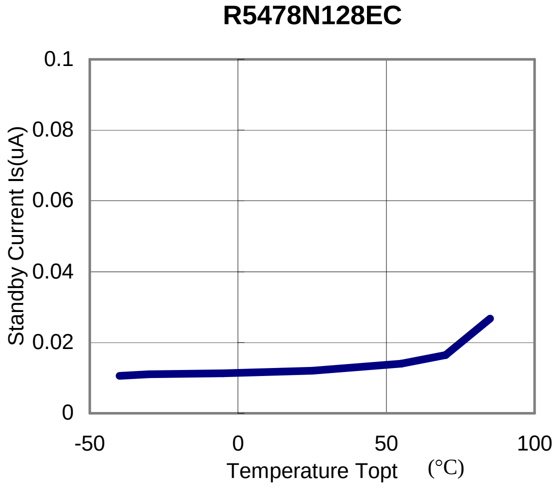
R5478N128EC



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



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



R5475N/R5478N Series

Code	Vdet1 (V)	Vrel1 (V)	Vdet2 (V)	Vrel2 (V)	Vdet3 (V)	tVdet1 (s)	tVdet2 (ms)	tVdet3 (ms)	tShort (μ s)	0V Charge	Package
R5478N128EC	4.280	-	2.800	-	0.050	1	20	6	200	OK	SOT-23-6
R5478N176EC	4.280	-	2.300	-	0.130	1	20	6	200	OK	SOT-23-6
R5478N101CD	4.250	4.050	2.500	3.000	0.200	1	20	12	300	OK	SOT-23-6
R5478N102CD	4.350	4.150	2.500	3.000	0.200	1	20	12	300	OK	SOT-23-6
R5478N106CD	4.275	4.075	2.300	3.000	0.100	1	20	12	300	OK	SOT-23-6
R5478N110CD	4.280	4.080	2.300	3.000	0.125	1	20	12	300	OK	SOT-23-6
R5478N120CD	4.325	4.125	2.300	3.000	0.150	1	20	12	300	OK	SOT-23-6
R5478N149CD	4.280	4.080	2.900	3.100	0.125	1	20	12	300	OK	SOT-23-6
R5478N163CD	4.280	4.100	3.000	3.200	0.100	1	20	12	300	OK	SOT-23-6
R5478N173CD	4.200	4.100	2.800	2.900	0.100	1	20	12	300	OK	SOT-23-6
R5478N187CD	4.250	4.050	3.000	3.200	0.100	1	20	12	300	OK	SOT-23-6
R5478N204CD	4.200	3.900	2.500	3.000	0.200	1	20	12	300	OK	SOT-23-6
R5478N205CD	4.200	3.900	3.000	3.200	0.200	1	20	12	300	OK	SOT-23-6
R5478N215CD	4.200	4.100	2.500	3.000	0.100	1	20	12	300	OK	SOT-23-6
R5478N216CD	4.170	4.170	2.500	3.000	0.100	1	20	12	300	OK	SOT-23-6
R5478N217CD	4.325	4.125	2.300	3.000	0.200	1	20	12	300	OK	SOT-23-6
R5478N218CD	4.250	4.050	2.800	3.000	0.150	1	20	12	300	OK	SOT-23-6
R5478N184CJ	3.650	3.650	2.500	3.000	0.200	1	20	12	300	OK	SOT-23-6
R5478N185CJ	3.650	3.450	2.500	3.000	0.200	1	20	12	300	OK	SOT-23-6
R5478N242CD	4.180	4.080	2.500	3.000	0.200	1	20	12	300	OK	SOT-23-6
R5478N248CD	4.280	4.080	2.300	2.800	0.150	1	20	12	300	OK	SOT-23-6
R5478N203CK	3.900	3.800	2.000	2.500	0.100	1	20	12	300	OK	SOT-23-6
R5475N110CD	4.280	4.080	2.300	3.000	0.125	1	20	12	300	OK	SOT-23-5

(as of 2012/07/04)

R5478 N 128 E C

Package Type
R5475N : SOT23-5
R5478N : SOT23-6

Function Version
C : Over-Charge = Latch Over-Discharge = Latch
D : Over-Charge = Auto-Release Over-Discharge = Auto Release
J : Over-Charge = Auto-Release Over-Discharge = Auto Release
Vdet1=3.65V only
K : Over-Charge = Auto-Release Over-Discharge = Auto Release
Vdet1=3.90V only Vdet2=1.9～3.0V

Delay Time Version

Voltage Version

Code	Return from Over-Charge	Return from Over-Discharge	tVdet1 (s)	tVdet2 (ms)	tVdet3 (ms)	tShort (μ s)
R5478N xxx EC	Latch	Latch	1	20	6	200
R5475N xxx CD	Auto-Release	Auto-Release	1	20	12	300
R5478N xxx CD	Auto-Release	Auto-Release	1	20	12	300
R5478N xxx CJ	Auto-Release	Auto-Release	1	20	12	300
R5478N xxx CK	Auto-Release	Auto-Release	1	20	12	300

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Halogen Free

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