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### Li-ion/Li-polymer 1 Cell Protector

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NO. EA-357-160617

#### OUTLINE

The R5487L/R5497L Series is high voltage CMOS-based protection ICs for over-charge/discharge of rechargeable one-cell Lithium-ion/Lithium polymer excess load current, further include a short circuit protector for preventing large external short circuit current and excess charge/discharge-current.

The R5487L/R5497L Series is composed of four voltage detectors, reference units, a delay circuit, a short circuit protector, an oscillator, a counter, and logic circuits.

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

They have two types to release Over-charge detector. The one is called "Latch type". The output of  $C_{OUT}$  switches to "H" when a kind of load is connected to  $V_{DD}$  after a charger is disconnected from the battery pack, and the cell voltage becomes lower than over-charge detector threshold.

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

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

They have two types to release Over-discharge detector.

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

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

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

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

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

When the output of  $C_{OUT}$  is "H", if V- pin level is set at  $V_{SS}-2V$  or lower, the delay time of detector can be shortened. Especially, the delay time of over-charge detector can be reduced into approximately 1/60.

Therefore, testing time of protector circuit board can be reduced. Output type of  $C_{OUT}$  and  $D_{OUT}$  are CMOS.

The R5487L/R5497L Series have DFN1414-6B and DFN1814-6B.

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## R5487L/R5497L

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## FEATURES

### Manufactured with High Voltage Tolerant Process

- Absolute Maximum Rating ..... 30V

### Low Supply Current

- Supply current (At normal mode)..... Typ. 3.0 $\mu$ A
- At detecting over-discharge ..... Max. 0.1 $\mu$ A (Over-discharge Latch type)  
Max. 0.5 $\mu$ A (Over-discharge Auto-release type)

### High Accuracy Detector Threshold

- Over-charge detector .....  $\pm 20$ mV ( $T_a=25^\circ\text{C}$ )  
 $\pm 25$ mV ( $T_a = -20^\circ\text{C}$  to  $60^\circ\text{C}$ )
- Over-discharge detector .....  $\pm 35$ mV
- Excess discharge-current detector(VDET3) .....  $\pm 10$ mV ( $V_{DET3} \geq 0.100\text{V}$ )  
 $\pm 10\%$  ( $0.050\text{V} \leq V_{DET31} < 0.100\text{V}$ )  
 $\pm 5$ mV ( $V_{DET31} < 0.050\text{V}$ )
- Excess charge-current detector(VDET4).....  $\pm 10\%$  ( $V_{DET4} \leq -0.05\text{V}$ )  
 $\pm 5$ mV ( $V_{DET4} > -0.05\text{V}$ )

### Variety of Detector Threshold

- Over-charge detector threshold ..... 4.2V to 4.6V step of 0.005V
- Over-discharge detector threshold ..... 2.0V to 3.0V step of 0.100V
- Over-discharge release threshold ..... 2.4V to 3.2V step of 0.100V
- Excess discharge-current threshold ..... 0.025V to 0.15V step of 0.001V
- Vshort threshold ..... 0.15V to 0.40V step of 0.005V
- Excess charge-current threshold .....  $-0.15\text{V}$  to  $-0.02\text{V}$  step of 0.001V

### Internal Fixed Output Delay Time

- Over-charge detector Output Delay ..... 1.0s
- Over-discharge detector Output Delay ..... 20ms
- Excess discharge-current detector Output Delay .. 12ms
- Excess charge-current detector Output Delay ..... 8ms
- Short Circuit detector Output Delay ..... 250 $\mu$ s

### Output Delay Time Shortening Function

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

- 0V-battery charge option..... Acceptable/Unacceptable
- Conditions for release over-charge detector..... Latch type/Auto Release type
- Conditions for release over-discharge detector ..... Latch type /Auto Release type
- Conditions for release short-current detector ..... Normal type / Auto Release type \*Note1

\*Note1

Normal type: Return Load Resistance Threshold from Over-Discharge Current Status is less than about 300Kohm.

Auto Release type: Return Load Resistance Threshold from Over-Discharge Current Status is less than 25Kohm.

( $T_a = 25^\circ\text{C}$ )

### Ultra Small Package

- The R5487L/R5497L Series have DFN1414-6B and DFN1814-6B.

## APPLICATIONS

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

## SELECTION GUIDE

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

Product Name	Package	Quantity per Reel	Pb Free	Halogen Free
R5487L5xx \$*-TR-FE	DFN1414-6B ⇒wiring A	5,000 pcs	Yes	Yes
R5497L5xx \$*-TR-FE	DFN1414-6B ⇒wiring B	5,000 pcs	Yes	Yes
R5487L1xx \$*-TR-FE	DFN1814-6B	5,000 pcs	Yes	Yes

xxx : Setting voltage version

\$ : Designation of delay time version

\* : Designation of Function version

Version	Over-Charge	Over-Discharge	Excess-discharge-current *Note1	0V Charge
D	Auto-Release	Auto-Release	Normal	OK
F	Auto-Release	Auto-Release	Normal	NG
M	Auto-Release	Auto-Release	Auto-Release	OK
P	Auto-Release	Auto-Release	Auto-Release	NG
Q	Latch	Latch	Auto-Release	OK

Note1: Return Load Resistance Threshold from Over-Discharge Current Status

Normal : Less than about 300Kohm

Auto-Release: Less than 20Kohm

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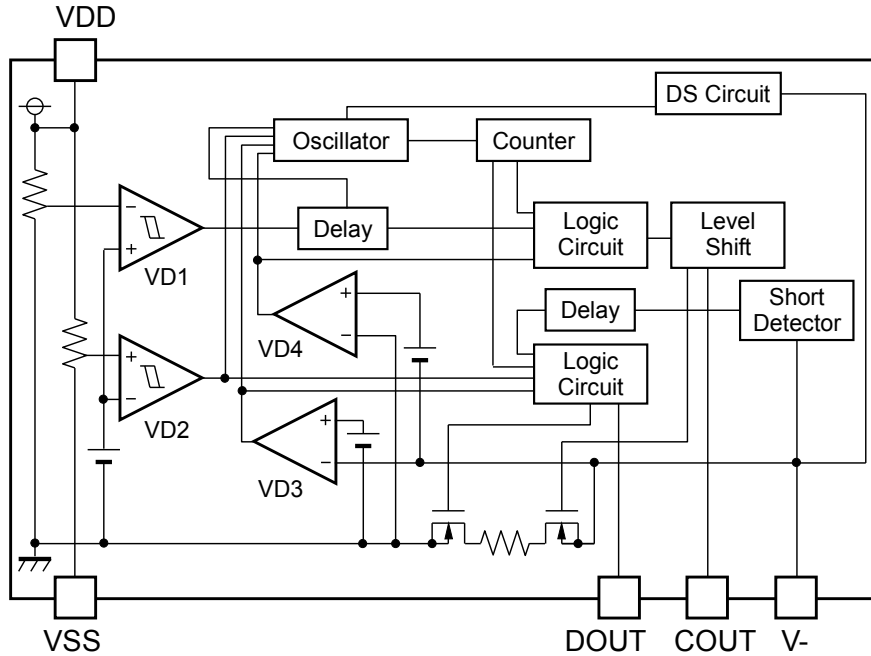
**R5487L/R5497L**

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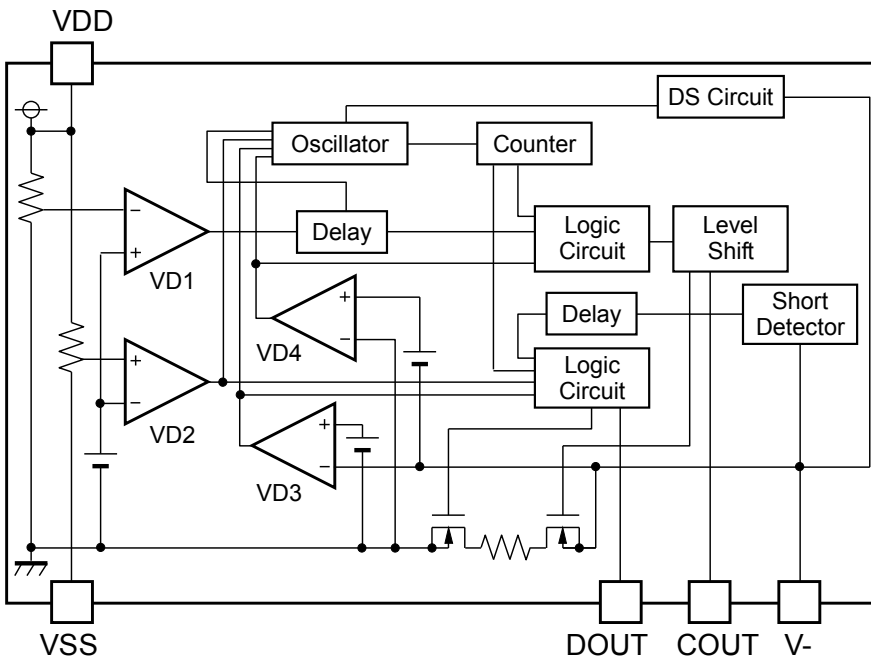
NO. EA-357-160617

**BLOCK DIAGRAMS**

- R5487L/R5497Lxxx\$D, R5487L/R5497Lxxx\$F, R5487L/R5497Lxxx\$P,  
R5487L/R5497Lxxx\$M



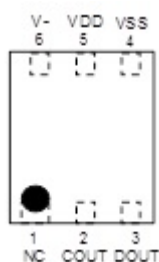
- R5487L/R5497Lxxx\$Q



## PIN DESCRIPTIONS

## • DFN1814-6B

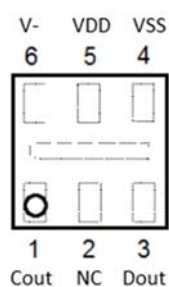
R5487Lyxxx (y:1~4)



## • DFN1414-6B

⇒wiring A

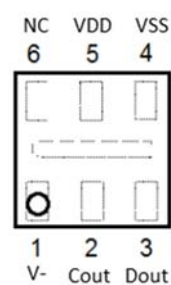
R5487Lyxxx (y:5~8)



## • DFN1414-6B

⇒wiring B

R5497Lyxxx (y:5~8)



Pin No.			Symbol	Description
R5487L1xxXX	R5487L5xxXX	R5497L5xxXX		
DFN1814-6B	DFN1414-6B ⇒wiring A	DFN1414-6B ⇒wiring B		
6	6	1	V-	Pin for charger negative input
5	5	5	VDD	Power supply pin, the substrate voltage level of the IC
2	1	2	COUT	Output of over-charge detection, CMOS output
3	3	3	DOUT	Output of over-discharge detection, CMOS output
1	2	6	NC	No Connection pin
4	4	4	VSS	VSS pin. Ground pin for the IC

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**R5487L/R5497L**

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NO. EA-357-160617

**ABSOLUTE MAXIMUM RATINGS**

Symbol	Item	Rating	Unit
V <sub>DD</sub>	Input Voltage	-0.3 to 12.0	V
V <sub>-</sub>	Input Voltage V- pin	V <sub>DD</sub> -30 to V <sub>DD</sub> +0.3	V
V <sub>COU</sub> T	Output Voltage (COU pin)	V <sub>DD</sub> -30 to V <sub>DD</sub> +0.3	V
V <sub>DOU</sub> T	Output Voltage (DOU pin)	V <sub>SS</sub> -0.3 to V <sub>DD</sub> +0.3	V
P <sub>D</sub>	Power Dissipation (DFN1414-6B)	150	mW
	Power Dissipation (DFN1814-6B)	150	
T <sub>J</sub>	Junction Temperature Range	-40 to 125	°C
T <sub>stg</sub>	Storage Temperature Range	-55 to 125	°C

**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**

Symbol	Item	Rating	Unit
V <sub>DD1</sub>	Operating Voltage	1.5 to 5.0	V
T <sub>a</sub>	Operating Temperature Range	-40 to 85	°C

**RECOMMENDED OPERATING CONDITIONS**

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 ratings 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

### R5487LxxxKD Electrical Characteristics

Unless otherwise provided, Ta=25°C

Item	Symbol	Conditions	Min.	Typ.	Max.	Unit
Minimum Operating Voltage for 0V Charging	Vst	Voltage Defined as $V_{DD}-V-$ , $V_{DD}-V_{SS}=0V$			1.8	V
Over-charge Threshold Voltage	VDET1	R1=330Ω R1=330Ω, Ta=-20°C to 60°C*Note2	VDET1-0.020	VDET1	VDET1+0.020	V
			VDET1-0.025	VDET1	VDET1+0.025	V
Released voltage from Over-charge	VREL1	R1=330Ω	VREL1-0.05	VREL1	VREL1+0.05	V
Output Delay of Over-charge	tVDET1	VDD=3.6V→4.65V	0.7	1.0	1.3	s
Release Delay for VD1	tVREL1	VDD=4.65V→3.6V	11	16	21	ms
Over-discharge Threshold	VDET2	Detect falling edge of supply voltage	VDET2-0.035	VDET2	VDET2+0.035	V
Released Voltage from Over-discharge	VREL2	Detect rising edge of supply voltage	VREL2 × 0.975	VREL2	VREL2 × 1.025	V
Output Delay of Over-discharge (VDET2 ≥ 2.1V)	tVDET2	VDD=3.6V→2.0V	14	20	26	ms
Output Delay of Over-discharge (VDET2 < 2.1V)	tVDET2	VDD=3.6V→1.9V	14	20	26	ms
Release Delay for VD2 (VDET2 ≥ 2.1V)	tVREL2	VDD=2.0V→3.6V	0.7	1.2	1.7	ms
Release Delay for VD2 (VDET2 < 2.1V)	tVREL2	VDD=1.9V→3.6V	0.7	1.2	1.7	ms
Excess discharge-current threshold (VDET3 ≤ 0.05V)	VDET3	Detect rising edge of 'V-' pin voltage. VDD =3.1V	VDET3-0.005	VDET3	VDET3+0.005	V
Excess discharge-current threshold (0.05V < VDET3 < 0.1V)	VDET3	Detect rising edge of 'V-' pin voltage. VDD =3.1V	VDET3 × 0.9	VDET3	VDET3 × 1.1	V
Excess discharge-current threshold (VDET3 ≥ 0.1V)	VDET3	Detect rising edge of 'V-' pin voltage. VDD =3.1V	VDET3-0.010	VDET3	VDET3+0.010	V
Output delay of excess discharge-current	tVDET3	VDD=3.1V, V-=0V to [ Vshort × 0.77-0.01V ]	8	12	16	ms
Output delay of release from excess discharge-current	tVREL3	VDD=3.1V, V-=3.1V to 0V	0.7	1.2	1.7	ms
Short Protection Voltage	Vshort	VDD=3.1V	Vshort × 0.75	Vshort	Vshort × 1.25	V

**R5487L/R5497L**

NO. EA-357-160617

**R5487LxxxKD Electrical Characteristics (Continued)** Unless otherwise provided, Ta=25°C

Item	Symbol	Conditions	Min.	Typ.	Max.	Unit
Delay Time for Short Protection	tshort	V <sub>DD</sub> =3.1V, V <sub>-</sub> =0V to 0.5V	180	250	425	μs
Reset Resistance for Excess Current Protection	Rshort	V <sub>DD</sub> =3.6V, V <sub>-</sub> =1.0V	14	20.5	27	kΩ
Excess charge-current Threshold (V <sub>DET4</sub> > -0.05V)	V <sub>DET4</sub>	Detect falling edge of 'V-' pin voltage. V <sub>DD</sub> =3.1V	V <sub>DET4</sub> -0.005	V <sub>DET4</sub>	V <sub>DET4</sub> +0.005	V
Excess charge-current Threshold (V <sub>DET4</sub> ≤ -0.05V)	V <sub>DET4</sub>	Detect falling edge of 'V-' pin voltage. V <sub>DD</sub> =3.1V	V <sub>DET4</sub> × 1.1	V <sub>DET4</sub>	V <sub>DET4</sub> × 0.9	V
Output delay of excess charge-current	tV <sub>DET4</sub>	V <sub>DD</sub> =3.1V, V <sub>-</sub> =0V to -1V	5	8	11	ms
Output delay of release from excess charge-current	tV <sub>REL4</sub>	V <sub>DD</sub> =3.1V, V <sub>-</sub> =-1V to 0V	0.7	1.2	1.7	ms
Delay Time Shortening Mode Voltage	V <sub>DS</sub>	V <sub>DD</sub> =3.6V	-2.6	-2.0	-1.4	V
Nch ON-Voltage of COUT	V <sub>oL1</sub>	I <sub>oL</sub> =50μA, V <sub>DD</sub> =4.8V		0.4	0.5	V
Pch ON-Voltage of COUT	V <sub>oH1</sub>	I <sub>oH</sub> =-50μA, V <sub>DD</sub> =3.9V	3.4	3.7		V
Nch ON-Voltage of DOUT (V <sub>DET2</sub> ≥ 2.1V)	V <sub>oL2</sub>	I <sub>oL</sub> =50μA, V <sub>DD</sub> =2.0V		0.2	0.5	V
Nch ON-Voltage of DOUT (V <sub>DET2</sub> < 2.1V)	V <sub>oL2</sub>	I <sub>oL</sub> =50μA, V <sub>DD</sub> =1.9V		0.2	0.5	V
Pch ON-Voltage of DOUT	V <sub>oH2</sub>	I <sub>oH</sub> =-50μA, V <sub>DD</sub> =3.9V	3.4	3.7		V
Supply Current	I <sub>DD</sub>	V <sub>DD</sub> =3.9V, V <sub>-</sub> =0V		3.0	6.0	μA
Standby Current (V <sub>DET2</sub> ≥ 2.1V)	I <sub>standby</sub>	V <sub>DD</sub> =2.0V			0.5	μA
Standby Current (V <sub>DET2</sub> < 2.1V)	I <sub>standby</sub>	V <sub>DD</sub> =1.9V			0.5	μA



## R5487LxxxKM Electrical Characteristics

Unless otherwise provided, Ta=25°C

Item	Symbol	Conditions	Min.	Typ.	Max.	Unit
Minimum Operating Voltage for 0V Charging	Vst	Voltage Defined as V <sub>DD</sub> -V <sub>-</sub> , V <sub>DD</sub> -V <sub>SS</sub> =0V			1.8	V
Over-charge Threshold Voltage	V <sub>DET1</sub>	R1=330Ω	V <sub>DET1</sub> -0.020	V <sub>DET1</sub>	V <sub>DET1</sub> +0.020	V
		R1=330Ω, Ta=-20°C to 60°C*Note2	V <sub>DET1</sub> -0.025	V <sub>DET1</sub>	V <sub>DET1</sub> +0.025	V
Released voltage from Over-charge	V <sub>REL1</sub>	R1=330Ω	V <sub>REL1</sub> -0.05	V <sub>REL1</sub>	V <sub>REL1</sub> +0.05	V
Output Delay of Over-charge	tV <sub>DET1</sub>	V <sub>DD</sub> =3.6V→4.65V	0.7	1.0	1.3	s
Release Delay for VD1	tV <sub>REL1</sub>	V <sub>DD</sub> =4.65V→3.6V	11	16	21	ms
Over-discharge Threshold	V <sub>DET2</sub>	Detect falling edge of supply voltage	V <sub>DET2</sub> -0.035	V <sub>DET2</sub>	V <sub>DET2</sub> +0.035	V
Released Voltage from Over-discharge	V <sub>REL2</sub>	Detect rising edge of supply voltage	V <sub>REL2</sub> × 0.975	V <sub>REL2</sub>	V <sub>REL2</sub> × 1.025	V
Output Delay of Over-discharge (V <sub>DET2</sub> ≥ 2.1V)	tV <sub>DET2</sub>	V <sub>DD</sub> =3.6V→2.0V	14	20	26	ms
Output Delay of Over-discharge (V <sub>DET2</sub> < 2.1V)	tV <sub>DET2</sub>	V <sub>DD</sub> =3.6V→1.9V	14	20	26	ms
Release Delay for VD2 (V <sub>DET2</sub> ≥ 2.1V)	tV <sub>REL2</sub>	V <sub>DD</sub> =2.0V→3.6V	0.7	1.2	1.7	ms
Release Delay for VD2 (V <sub>DET2</sub> < 2.1V)	tV <sub>REL2</sub>	V <sub>DD</sub> =1.9V→3.6V	0.7	1.2	1.7	ms
Excess discharge-current threshold (V <sub>DET3</sub> ≤ 0.05V)	V <sub>DET3</sub>	Detect rising edge of 'V-' pin voltage. V <sub>DD</sub> =3.1V	V <sub>DET3</sub> -0.005	V <sub>DET3</sub>	V <sub>DET3</sub> +0.005	V
Excess discharge-current threshold (0.05V < V <sub>DET3</sub> <0.1V)	V <sub>DET3</sub>	Detect rising edge of 'V-' pin voltage. V <sub>DD</sub> =3.1V	V <sub>DET3</sub> × 0.9	V <sub>DET3</sub>	V <sub>DET3</sub> × 1.1	V
Excess discharge-current threshold (V <sub>DET3</sub> ≥ 0.1V)	V <sub>DET3</sub>	Detect rising edge of 'V-' pin voltage. V <sub>DD</sub> =3.1V	V <sub>DET3</sub> -0.010	V <sub>DET3</sub>	V <sub>DET3</sub> +0.010	V
Released Voltage from Excess discharge-current	V <sub>REL3</sub>	Detect falling edge of 'V-' pin voltage. V <sub>DD</sub> =3.1V	1.82	1.935	2.05	V
Output delay of excess discharge-current	tV <sub>DET3</sub>	V <sub>DD</sub> =3.1V, V <sub>-</sub> =0V to [V <sub>short</sub> × 0.77-0.01V]	8	12	16	ms
Output delay of release from excess discharge-current	tV <sub>REL3</sub>	V <sub>DD</sub> =3.1V, V <sub>-</sub> =3.1V to 0V	0.7	1.2	1.7	ms
Short Protection Voltage	V <sub>short</sub>	V <sub>DD</sub> =3.1V	V <sub>short</sub> × 0.75	V <sub>short</sub>	V <sub>short</sub> × 1.25	V

**R5487L/R5497L**

NO. EA-357-160617

**R5487LxxxKM Electrical Characteristics (Continued)**

Unless otherwise provided, Ta=25°C

Item	Symbol	Conditions	Min.	Typ.	Max.	Unit
Delay Time for Short Protection	tshort	VDD=3.1V, V- =0V to 0.5V	180	250	425	μs
Reset Resistance for Excess Current Protection	Rshort	VDD=3.6V, V- =1.0V	18	22	26	kΩ
Excess charge-current Threshold (V <sub>DET4</sub> > -0.05V)	V <sub>DET4</sub>	Detect falling edge of 'V-' pin voltage. VDD =3.1V	V <sub>DET4</sub> -0.005	V <sub>DET4</sub>	V <sub>DET4</sub> +0.005	V
Excess charge-current Threshold (V <sub>DET4</sub> ≤ -0.05V)	V <sub>DET4</sub>	Detect falling edge of 'V-' pin voltage. VDD =3.1V	V <sub>DET4</sub> × 1.1	V <sub>DET4</sub>	V <sub>DET4</sub> × 0.9	V
Output delay of excess charge-current	tV <sub>DET4</sub>	VDD=3.1V, V- =0V to -1V	5	8	11	ms
Output delay of release from excess charge-current	tV <sub>REL4</sub>	VDD=3.1V, V- =-1V to 0V	0.7	1.2	1.7	ms
Delay Time Shortening Mode Voltage	V <sub>DS</sub>	VDD=3.6V	-2.6	-2.0	-1.4	V
Nch ON-Voltage of COUT	V <sub>oL1</sub>	I <sub>oL</sub> =50μA, VDD=4.8V		0.4	0.5	V
Pch ON-Voltage of COUT	V <sub>oH1</sub>	I <sub>oH</sub> =-50μA, VDD=3.9V	3.4	3.7		V
Nch ON-Voltage of DOUT (V <sub>DET2</sub> ≥ 2.1V)	V <sub>oL2</sub>	I <sub>oL</sub> =50μA, VDD=2.0V		0.2	0.5	V
Nch ON-Voltage of DOUT (V <sub>DET2</sub> < 2.1V)	V <sub>oL2</sub>	I <sub>oL</sub> =50μA, VDD=1.9V		0.2	0.5	V
Pch ON-Voltage of DOUT	V <sub>oH2</sub>	I <sub>oH</sub> =-50μA, VDD=3.9V	3.4	3.7		V
Supply Current	I <sub>DD</sub>	VDD=3.9V, V- =0V		3.0	6.0	μA
Standby Current (V <sub>DET2</sub> ≥ 2.1V)	I <sub>standby</sub>	VDD=2.0V			0.5	μA
Standby Current (V <sub>DET2</sub> < 2.1V)	I <sub>standby</sub>	VDD=1.9V			0.5	μA

**R5497LxxxKF Electrical Characteristics**

Unless otherwise provided, Ta=25°C

Item	Symbol	Conditions	Min.	Typ.	Max.	Unit
Maximum Operating Voltage for Inhibition of Charger	Vnochg	Voltage Defined as V <sub>DD</sub> -V <sub>SS</sub> , V <sub>DD</sub> -V <sub>-</sub> =4V	0.8	1.2	1.6	V
Over-charge Threshold Voltage	V <sub>DET1</sub>	R1=330Ω R1=330Ω, Ta=-20°C to 60°C*Note2	V <sub>DET1</sub> -0.020	V <sub>DET1</sub>	V <sub>DET1</sub> +0.020	V
			V <sub>DET1</sub> -0.025	V <sub>DET1</sub>	V <sub>DET1</sub> +0.025	V
Released voltage from Over-charge	V <sub>REL1</sub>	R1=330Ω	V <sub>REL1</sub> -0.05	V <sub>REL1</sub>	V <sub>REL</sub> +0.05	V
Output Delay of Over-charge	tV <sub>DET1</sub>	V <sub>DD</sub> =3.6V→4.65V	0.7	1.0	1.3	s
Release Delay for VD1	tV <sub>REL1</sub>	V <sub>DD</sub> =4.65V→3.6V	11	16	21	ms
Over-discharge Threshold	V <sub>DET2</sub>	Detect falling edge of supply voltage	V <sub>DET2</sub> -0.035	V <sub>DET2</sub>	V <sub>DET2</sub> +0.035	V
Released Voltage from Over-discharge	V <sub>REL2</sub>	Detect rising edge of supply voltage	V <sub>REL2</sub> × 0.975	V <sub>REL2</sub>	V <sub>REL2</sub> × 1.025	V
Output Delay of Over-discharge (V <sub>DET2</sub> ≥ 2.1V)	tV <sub>DET2</sub>	V <sub>DD</sub> =3.6V→2.0V	14	20	26	ms
Output Delay of Over-discharge (V <sub>DET2</sub> < 2.1V)	tV <sub>DET2</sub>	V <sub>DD</sub> =3.6V→1.9V	14	20	26	ms
Release Delay for VD2 (V <sub>DET2</sub> ≥ 2.1V)	tV <sub>REL2</sub>	V <sub>DD</sub> =2.0V→3.6V	0.7	1.2	1.7	ms
Release Delay for VD2 (V <sub>DET2</sub> < 2.1V)	tV <sub>REL2</sub>	V <sub>DD</sub> =1.9V→3.6V	0.7	1.2	1.7	ms
Excess discharge-current threshold (V <sub>DET3</sub> ≤ 0.05V)	V <sub>DET3</sub>	Detect rising edge of 'V-' pin voltage. V <sub>DD</sub> =3.1V	V <sub>DET3</sub> -0.005	V <sub>DET3</sub>	V <sub>DET3</sub> +0.005	V
Excess discharge-current threshold (0.05V < V <sub>DET3</sub> <0.1V)	V <sub>DET3</sub>	Detect rising edge of 'V-' pin voltage. V <sub>DD</sub> =3.1V	V <sub>DET3</sub> × 0.9	V <sub>DET3</sub>	V <sub>DET3</sub> × 1.1	V
Excess discharge-current threshold (V <sub>DET3</sub> ≥ 0.1V)	V <sub>DET3</sub>	Detect rising edge of 'V-' pin voltage. V <sub>DD</sub> =3.1V	V <sub>DET3</sub> -0.010	V <sub>DET3</sub>	V <sub>DET3</sub> +0.010	V
Output delay of excess discharge-current	tV <sub>DET3</sub>	V <sub>DD</sub> =3.1V, V <sub>-</sub> =0V to [ V <sub>short</sub> × 0.77-0.01V ]	8	12	16	ms
Output delay of release from excess discharge-current	tV <sub>REL3</sub>	V <sub>DD</sub> =3.1V, V <sub>-</sub> =3.1V to 0V	0.7	1.2	1.7	ms
Short Protection Voltage	V <sub>short</sub>	V <sub>DD</sub> =3.1V	V <sub>short</sub> × 0.75	V <sub>short</sub>	V <sub>short</sub> × 1.25	V
Delay Time for Short Protection	t <sub>short</sub>	V <sub>DD</sub> =3.1V, V <sub>-</sub> =0V to 0.5V	180	250	425	μs

**R5487L/R5497L**

NO. EA-357-160617

**R5497LxxxKF Electrical Characteristics (Continued)**

Unless otherwise provided, Ta=25°C

Item	Symbol	Conditions	Min.	Typ.	Max.	Unit
Reset Resistance for Excess Current Protection	Rshort	VDD=3.6V, V- =1.0V	14	20.5	27	kΩ
Excess charge-current Threshold (V <sub>DET4</sub> > -0.05V)	V <sub>DET4</sub>	Detect falling edge of 'V-' pin voltage. VDD =3.1V	V <sub>DET4</sub> -0.005	V <sub>DET4</sub>	V <sub>DET4</sub> +0.005	V
Excess charge-current Threshold (V <sub>DET4</sub> ≤ -0.05V)	V <sub>DET4</sub>	Detect falling edge of 'V-' pin voltage. VDD =3.1V	V <sub>DET4</sub> × 1.1	V <sub>DET4</sub>	V <sub>DET4</sub> × 0.9	V
Output delay of excess charge-current	tV <sub>DET4</sub>	VDD=3.1V, V- =0V to -1V	5	8	11	ms
Output delay of release from excess charge-current	tV <sub>REL4</sub>	VDD=3.1V, V- =-1V to 0V	0.7	1.2	1.7	ms
Delay Time Shortening Mode Voltage	V <sub>DS</sub>	VDD=3.6V	-2.6	-2.0	-1.4	V
Nch ON-Voltage of COUT	V <sub>oL1</sub>	I <sub>oL</sub> =50μA, VDD=4.8V		0.4	0.5	V
Pch ON-Voltage of COUT	V <sub>oH1</sub>	I <sub>oH</sub> =-50μA, VDD=3.9V	3.4	3.7		V
Nch ON-Voltage of DOUT (V <sub>DET2</sub> ≥ 2.1V)	V <sub>oL2</sub>	I <sub>oL</sub> =50μA, VDD=2.0V		0.2	0.5	V
Nch ON-Voltage of DOUT (V <sub>DET2</sub> < 2.1V)	V <sub>oL2</sub>	I <sub>oL</sub> =50μA, VDD=1.9V		0.2	0.5	V
Pch ON-Voltage of DOUT	V <sub>oH2</sub>	I <sub>oH</sub> =-50μA, VDD=3.9V	3.4	3.7		V
Supply Current	I <sub>DD</sub>	VDD=3.9V, V- =0V		3.0	6.0	μA
Standby Current (V <sub>DET2</sub> ≥ 2.1V)	I <sub>standby</sub>	VDD=2.0V			0.5	μA
Standby Current (V <sub>DET2</sub> < 2.1V)	I <sub>standby</sub>	VDD=1.9V			0.5	μA

## R5487LxxxKP Electrical Characteristics

Unless otherwise provided, Ta=25°C

Item	Symbol	Conditions	Min.	Typ.	Max.	Unit
Maximum Operating Voltage for Inhibition of Charger	Vnochg	Voltage Defined as VDD-Vss, VDD-V-=4V	0.8	1.2	1.6	V
Over-charge Threshold Voltage	VDET1	R1=330Ω	VDET1-0.020	VDET1	VDET1+0.020	V
		R1=330Ω, Ta=-20°C to 60°C*Note2	VDET1-0.025	VDET1	VDET1+0.025	V
Released voltage from Over-charge	VREL1	R1=330Ω	VREL1-0.05	VREL1	VREL+0.05	V
Output Delay of Over-charge	tVDET1	VDD=3.6V→4.65V	0.7	1.0	1.3	s
Release Delay for VD1	tVREL1	VDD=4.65V→3.6V	11	16	21	ms
Over-discharge Threshold	VDET2	Detect falling edge of supply voltage	VDET2-0.035	VDET2	VDET2+0.035	V
Released Voltage from Over-discharge	VREL2	Detect rising edge of supply voltage	VREL2 × 0.975	VREL2	VREL2 × 1.025	V
Output Delay of Over-discharge (VDET2 ≥ 2.1V)	tVDET2	VDD=3.6V→2.0V	14	20	26	ms
Output Delay of Over-discharge (VDET2 < 2.1V)	tVDET2	VDD=3.6V→1.9V	14	20	26	ms
Release Delay for VD2 (VDET2 ≥ 2.1V)	tVREL2	VDD=2.0V→3.6V	0.7	1.2	1.7	ms
Release Delay for VD2 (VDET2 < 2.1V)	tVREL2	VDD=1.9V→3.6V	0.7	1.2	1.7	ms
Excess discharge-current threshold (VDET3 ≤ 0.05V)	VDET3	Detect rising edge of 'V-' pin voltage. VDD =3.1V	VDET3-0.005	VDET3	VDET3+0.005	V
Excess discharge-current threshold (0.05V < VDET3 < 0.1V)	VDET3	Detect rising edge of 'V-' pin voltage. VDD =3.1V	VDET3 × 0.9	VDET3	VDET3 × 1.1	V
Excess discharge-current threshold (VDET3 ≥ 0.1V)	VDET3	Detect rising edge of 'V-' pin voltage. VDD =3.1V	VDET3-0.010	VDET3	VDET3+0.010	V
Released Voltage from Excess discharge-current	VREL3	Detect falling edge of 'V-' pin voltage. VDD =3.1V	1.82	1.935	2.05	V
Output delay of excess discharge-current	tVDET3	VDD=3.1V, V-=0V to [ Vshort × 0.77-0.01V ]	8	12	16	ms
Output delay of release from excess discharge-current	tVREL3	VDD=3.1V, V-=3.1V to 0V	0.7	1.2	1.7	ms
Short Protection Voltage	Vshort	VDD=3.1V	Vshort × 0.75	Vshort	Vshort × 1.25	V

**R5487L/R5497L**

NO. EA-357-160617

**R5487LxxxKP Electrical Characteristics (Continued)**

Unless otherwise provided, Ta=25°C

Item	Symbol	Conditions	Min.	Typ.	Max.	Unit
Delay Time for Short Protection	tshort	VDD=3.1V, V- =0V to 0.5V	180	250	425	μs
Reset Resistance for Excess Current Protection	Rshort	VDD=3.6V, V- =1.0V	18	22	26	kΩ
Excess charge-current Threshold (V <sub>DET4</sub> > -0.05V)	V <sub>DET4</sub>	Detect falling edge of 'V-' pin voltage. VDD =3.1V	V <sub>DET4</sub> -0.005	V <sub>DET4</sub>	V <sub>DET4</sub> +0.005	V
Excess charge-current Threshold (V <sub>DET4</sub> ≤ -0.05V)	V <sub>DET4</sub>	Detect falling edge of 'V-' pin voltage. VDD =3.1V	V <sub>DET4</sub> × 1.1	V <sub>DET4</sub>	V <sub>DET4</sub> × 0.9	V
Output delay of excess charge-current	tV <sub>DET4</sub>	VDD=3.1V, V- =0V to -1V	5	8	11	ms
Output delay of release from excess charge-current	tV <sub>REL4</sub>	VDD=3.1V, V- =-1V to 0V	0.7	1.2	1.7	ms
Delay Time Shortening Mode Voltage	V <sub>DS</sub>	VDD=3.6V	-2.6	-2.0	-1.4	V
Nch ON-Voltage of COUT	V <sub>oL1</sub>	I <sub>oL</sub> =50μA, VDD=4.8V		0.4	0.5	V
Pch ON-Voltage of COUT	V <sub>oH1</sub>	I <sub>oH</sub> =-50μA, VDD=3.9V	3.4	3.7		V
Nch ON-Voltage of DOUT (V <sub>DET2</sub> ≥ 2.1V)	V <sub>oL2</sub>	I <sub>oL</sub> =50μA, VDD=2.0V		0.2	0.5	V
Nch ON-Voltage of DOUT (V <sub>DET2</sub> < 2.1V)	V <sub>oL2</sub>	I <sub>oL</sub> =50μA, VDD=1.9V		0.2	0.5	V
Pch ON-Voltage of DOUT	V <sub>oH2</sub>	I <sub>oH</sub> =-50μA, VDD=3.9V	3.4	3.7		V
Supply Current	I <sub>DD</sub>	VDD=3.9V, V- =0V		3.0	6.0	μA
Standby Current (V <sub>DET2</sub> ≥ 2.1V)	I <sub>standby</sub>	VDD=2.0V			0.5	μA
Standby Current (V <sub>DET2</sub> < 2.1V)	I <sub>standby</sub>	VDD=1.9V			0.5	μA

## R5487LxxxKQ Electrical Characteristics

Unless otherwise provided, Ta=25°C

Item	Symbol	Conditions	Min.	Typ.	Max.	Unit
Minimum Operating Voltage for 0V Charging	Vst	Voltage Defined as VDD-V-, VDD-Vss=0V			1.8	V
Over-charge Threshold Voltage	VDET1	R1=330Ω R1=330Ω, Ta=-20°C to 60°C *Note2	VDET1-0.020 VDET1-0.025	VDET1 VDET1	VDET1+0.020 VDET1+0.025	V V
Output Delay of Over-charge	tVDET1	VDD=3.6V→4.65V	0.7	1.0	1.3	s
Release Delay for VD1	tVREL1	VDD=4.0V, V-=0V→0.2V	11	16	21	ms
Over-discharge Threshold	VDET2	Detect falling edge of supply voltage	VDET2-0.035	VDET2	VDET2+0.035	V
Output Delay of Over-discharge (VDET2 ≥ 2.1V)	tVDET2	VDD=3.6V→2.0V	14	20	26	ms
Output Delay of Over-discharge (VDET2 < 2.1V)	tVDET2	VDD=3.6V→1.9V	14	20	26	ms
Release Delay for VD2 (VDET2 ≥ 2.1V)	tVREL2	VDD=2.0V→3.6V	0.7	1.2	1.7	ms
Release Delay for VD2 (VDET2 < 2.1V)	tVREL2	VDD=1.9V→3.6V	0.7	1.2	1.7	ms
Excess discharge-current threshold (VDET3 ≤ 0.05V)	VDET3	Detect rising edge of 'V-' pin voltage. VDD =3.1V	VDET3-0.005	VDET3	VDET3+0.005	V
Excess discharge-current threshold (0.05V < VDET3 < 0.1V)	VDET3	Detect rising edge of 'V-' pin voltage. VDD =3.1V	VDET3 × 0.9	VDET3	VDET3 × 1.1	V
Excess discharge-current threshold (VDET3 ≥ 0.1V)	VDET3	Detect rising edge of 'V-' pin voltage. VDD =3.1V	VDET3-0.010	VDET3	VDET3+0.010	V
Released Voltage from Excess discharge-current	VREL3	Detect falling edge of 'V-' pin voltage. VDD =3.1V	1.82	1.935	2.05	V
Output delay of excess discharge-current	tVDET3	VDD=3.1V, V-=0V to [ Vshort × 0.77-0.01V ]	8	12	16	ms
Output delay of release from excess discharge-current	tVREL3	VDD=3.1V, V-=3.1V to 0V	0.7	1.2	1.7	ms
Short Protection Voltage	Vshort	VDD=3.1V	Vshort × 0.75	Vshort	Vshort × 1.25	V
Delay Time for Short Protection	tshort	VDD=3.1V, V-=0V to 0.5V	180	250	425	μs
Reset Resistance for Excess Current Protection	Rshort	VDD=3.6V, V-=1.0V	18	22	26	kΩ

**R5487L/R5497L**

NO. EA-357-160617

**R5487LxxxKQ Electrical Characteristics (Continued)** Unless otherwise provided, Ta=25°C

Item	Symbol	Conditions	Min.	Typ.	Max.	Unit
Excess charge-current Threshold ( $V_{DET4} > -0.05V$ )	$V_{DET4}$	Detect falling edge of 'V-' pin voltage. $V_{DD} = 3.1V$	$V_{DET4} - 0.005$	$V_{DET4}$	$V_{DET4} + 0.005$	V
Excess charge-current Threshold ( $V_{DET4} \leq -0.05V$ )	$V_{DET4}$	Detect falling edge of 'V-' pin voltage. $V_{DD} = 3.1V$	$V_{DET4} \times 1.1$	$V_{DET4}$	$V_{DET4} \times 0.9$	V
Output delay of excess charge-current	$t_{VDET4}$	$V_{DD} = 3.1V$ , $V_- = 0V$ to $-1V$	5	8	11	ms
Output delay of release from excess charge-current	$t_{VREL4}$	$V_{DD} = 3.1V$ , $V_- = -1V$ to $0V$	0.7	1.2	1.7	ms
Delay Time Shortening Mode Voltage	$V_{DS}$	$V_{DD} = 3.6V$	-2.6	-2.0	-1.4	V
Nch ON-Voltage of COUT	$V_{oL1}$	$I_{oL} = 50\mu A$ , $V_{DD} = 4.8V$		0.4	0.5	V
Pch ON-Voltage of COUT	$V_{oH1}$	$I_{oH} = -50\mu A$ , $V_{DD} = 3.9V$	3.4	3.7		V
Nch ON-Voltage of DOUT ( $V_{DET2} \geq 2.1V$ )	$V_{oL2}$	$I_{oL} = 50\mu A$ , $V_{DD} = 2.0V$		0.2	0.5	V
Nch ON-Voltage of DOUT ( $V_{DET2} < 2.1V$ )	$V_{oL2}$	$I_{oL} = 50\mu A$ , $V_{DD} = 1.9V$		0.2	0.5	V
Pch ON-Voltage of DOUT	$V_{oH2}$	$I_{oH} = -50\mu A$ , $V_{DD} = 3.9V$	3.4	3.7		V
Supply Current	$I_{DD}$	$V_{DD} = 3.9V$ , $V_- = 0V$		3.0	6.0	$\mu A$
Standby Current ( $V_{DET2} \geq 2.1V$ )	$I_{standby}$	$V_{DD} = 2.0V$			0.1	$\mu A$
Standby Current ( $V_{DET2} < 2.1V$ )	$I_{standby}$	$V_{DD} = 1.9V$			0.1	$\mu A$



**R5487LxxxSD Electrical Characteristics**

Unless otherwise provided, Ta=25°C

Item	Symbol	Conditions	Min.	Typ.	Max.	Unit
Minimum Operating Voltage for 0V Charging	Vst	Voltage Defined as V <sub>DD</sub> -V-, V <sub>DD</sub> -V <sub>SS</sub> =0V			1.8	V
Over-charge Threshold Voltage	VDET1	R1=330Ω R1=330Ω, Ta=-20°C to 60°C *Note2	V <sub>DET1</sub> -0.020 V <sub>DET1</sub> -0.025	V <sub>DET1</sub> V <sub>DET1</sub>	V <sub>DET1</sub> +0.020 V <sub>DET1</sub> +0.025	V V
Released voltage from Over-charge	VREL1	R1=330Ω	V <sub>REL1</sub> -0.05	V <sub>REL1</sub>	V <sub>REL1</sub> +0.05	V
Output Delay of Over-charge	tVDET1	V <sub>DD</sub> =3.6V→4.65V	0.7	1.0	1.3	s
Release Delay for VD1	tVREL1	V <sub>DD</sub> =4.65V→3.6V	11	16	21	ms
Over-discharge Threshold	VDET2	Detect falling edge of supply voltage	V <sub>DET2</sub> -0.035	V <sub>DET2</sub>	V <sub>DET2</sub> +0.035	V
Released Voltage from Over-discharge	VREL2	Detect rising edge of supply voltage	V <sub>REL2</sub> × 0.975	V <sub>REL2</sub>	V <sub>REL2</sub> × 1.025	V
Output Delay of Over-discharge (V <sub>DET2</sub> ≥ 2.1V)	tVDET2	V <sub>DD</sub> =3.6V→2.0V	14	20	26	ms
Output Delay of Over-discharge (V <sub>DET2</sub> < 2.1V)	tVDET2	V <sub>DD</sub> =3.6V→1.9V	14	20	26	ms
Release Delay for VD2 (V <sub>DET2</sub> ≥ 2.1V)	tVREL2	V <sub>DD</sub> =2.0V→3.6V	0.7	1.2	1.7	ms
Release Delay for VD2 (V <sub>DET2</sub> < 2.1V)	tVREL2	V <sub>DD</sub> =1.9V→3.6V	0.7	1.2	1.7	ms
Excess discharge-current threshold (V <sub>DET3</sub> ≤ 0.05V)	VDET3	Detect rising edge of 'V-' pin voltage. V <sub>DD</sub> = 3.1V	V <sub>DET3</sub> -0.005	V <sub>DET3</sub>	V <sub>DET3</sub> +0.005	V
Excess discharge-current threshold (0.05V < V <sub>DET3</sub> < 0.1V)	VDET3	Detect rising edge of 'V-' pin voltage. V <sub>DD</sub> = 3.1V	V <sub>DET3</sub> × 0.9	V <sub>DET3</sub>	V <sub>DET3</sub> × 1.1	V
Excess discharge-current threshold (V <sub>DET3</sub> ≥ 0.1V)	VDET3	Detect rising edge of 'V-' pin voltage. V <sub>DD</sub> = 3.1V	V <sub>DET3</sub> -0.010	V <sub>DET3</sub>	V <sub>DET3</sub> +0.010	V
Output delay of excess discharge-current	tVDET3	V <sub>DD</sub> =3.1V, V-=0V to [ Vshort × 0.77-0.01V ]	85	128	171	ms
Output delay of release from excess discharge-current	tVREL3	V <sub>DD</sub> =3.1V, V-=3.1V to 0V	0.7	1.2	1.7	ms
Short Protection Voltage	Vshort	V <sub>DD</sub> =3.1V	Vshort × 0.75	Vshort	Vshort × 1.25	V
Delay Time for Short Protection	tshort	V <sub>DD</sub> =3.1V, V-=0V to 0.5V	180	250	425	μs
Reset Resistance for Excess Current Protection	Rshort	V <sub>DD</sub> =3.6V, V- =1.0V	14	20.5	27	kΩ

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**R5487L/R5497L**

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NO. EA-357-160617

**R5487LxxxSD Electrical Characteristics (Continued)**

Unless otherwise provided, Ta=25°C

Item	Symbol	Conditions	Min.	Typ.	Max.	Unit
Excess charge-current Threshold (VDET4 > -0.05V)	VDET4	Detect falling edge of 'V-' pin voltage. VDD =3.1V	VDET4-0.005	VDET4	VDET4+0.005	V
Excess charge-current Threshold (VDET4 ≤ -0.05V)	VDET4	Detect falling edge of 'V-' pin voltage. VDD =3.1V	VDET4 × 1.1	VDET4	VDET4 × 0.9	V
Output delay of excess charge-current	tVDET4	VDD=3.1V, V- =0V to -1V	12	17	22	ms
Output delay of release from excess charge-current	tVREL4	VDD=3.1V, V- =-1V to 0V	0.7	1.2	1.7	ms
Delay Time Shortening Mode Voltage	VDS	VDD=3.6V	-2.6	-2.0	-1.4	V
Nch ON-Voltage of COUT	VoL1	Iol=50μA, VDD=4.8V		0.4	0.5	V
Pch ON-Voltage of COUT	VoH1	Ioh=-50μA, VDD=3.9V	3.4	3.7		V
Nch ON-Voltage of DOUT (VDET2 ≥ 2.1V)	VoL2	Iol=50μA, VDD=2.0V		0.2	0.5	V
Nch ON-Voltage of DOUT (VDET2 < 2.1V)	VoL2	Iol=50μA, VDD=1.9V		0.2	0.5	V
Pch ON-Voltage of DOUT	VoH2	Ioh=-50μA, VDD=3.9V	3.4	3.7		V
Supply Current	IDD	VDD=3.9V, V- =0V		3.0	6.0	μA
Standby Current (VDET2 ≥ 2.1V)	Istandby	VDD=2.0V			0.5	μA
Standby Current (VDET2 < 2.1V)	Istandby	VDD=1.9V			0.5	μA

## THEORY OF 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 "Latch type" 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 disconnecting a charger from the battery pack. Output voltage of  $C_{OUT}$  pin becomes "H", and it makes an external Nch MOSFET turn on, and charge cycle is available.

Depending on the external characteristics of external components such as FETs, just by disconnecting a charger, over-charge state may not be released. In such a case, by connecting some load, the over-charge state is released.) In other words, once over-charge is detected, even if the supply voltage becomes low enough, if a charger is continuously connected to the battery pack, recharge is not possible. Therefore this over-charge detector has no hysteresis. To judge whether or not load is connected, the built-in excess-discharge current detector is used. In other words, by connecting some load,  $V_{-}$  pin voltage becomes equal or more than excess-discharge current detector threshold, and reset the over-charge detecting state.

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

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

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

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

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

### VD2 / Over-Discharge Detector

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

In terms of "Latch type" 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.

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## R5487L/R5497L

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NO. EA-357-160617

Connecting a charger to the battery pack makes the D<sub>OUT</sub> level being "H" instantaneously when the V<sub>DD</sub> voltage is higher than V<sub>DET2</sub>.

In terms of "Auto Release type" version, released operation by connecting a charger is same as the other latch type. However, without a charger, if V<sub>DD</sub> pin voltage is equal or more than the released voltage from over-discharge, D<sub>OUT</sub> pin becomes "H" immediately.

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

"Unacceptable type" version: if V<sub>DD</sub> voltage is less than charger inhibit maximum voltage (V<sub>nochg</sub>), even if a charger is connected, C<sub>OUT</sub> level will be fixed at "L", and charge current will be cut off.

An output delay time for over-discharge detection is fixed internally. When the V<sub>DD</sub> level is down to equal or lower level than V<sub>DET2</sub> if the V<sub>DD</sub> voltage would be back to a level higher than the V<sub>DET2</sub> 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, "Latch type" version: supply current would be reduced and be into standby by halting unnecessary circuits and consumption current of IC itself is made as small as possible. (Max. 0.1μA at V<sub>DD</sub>=2.0V)

"Auto Release type" version: supply current would be reduced and be into standby by halting circuits except the over-discharge released by voltage function. (Max. 0.5μA at V<sub>DD</sub>=2.0V)

The output type of D<sub>OUT</sub> pin is CMOS having "H" level of V<sub>DD</sub> and "L" level of V<sub>SS</sub>.

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

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

When the V- pin voltage is up to a value between the short protection voltage (V<sub>short</sub>) /V<sub>DD</sub> and excess discharge-current threshold V<sub>DET3</sub>, VD3 operates and further soaring of V- pin voltage higher than V<sub>short</sub> makes the short circuit protector enabled. This leads the external discharge control Nch MOSFET turns off with the D<sub>OUT</sub> pin being at "L" level. An output delay time for the excess discharge-current detector is internally fixed. A quick recovery of V- pin level from a value between V<sub>short</sub> and V<sub>DET3</sub> 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<sub>OUT</sub> would be "L" and the delay time (Typ. 1.2ms) is also set. The V- pin has a built-in pull-down resistor (R<sub>short</sub>) to the V<sub>SS</sub> 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<sub>SS</sub> 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<sub>DD</sub> voltage would be lower than V<sub>DET2</sub> at the same time as the excess discharge-current is detected, the R5487 are at excess discharge-current detection mode. By disconnecting a load, VD3 is automatically released from excess discharge-current.

**VD4 /Excess charge-current detector**

When the battery pack is chargeable and discharge is also possible, VD4 senses V- pin voltage. For example, in case that a battery pack is charged by an inappropriate charger, an excess current flows, then the voltage of V- pin becomes equal or less than excess charge-current detector threshold. Then, the output of C<sub>OUT</sub> becomes "L", and prevents from flowing excess current in the circuit by turning off the external Nch MOSFET. Output delay of excess charge current is internally fixed. Even the voltage level of V- pin becomes equal or lower than the excess charge-current detector threshold, the voltage is higher than the VD4 threshold within the delay time, and the excess charge current is not detected. Output delay for the release from excess charge current (Typ. 1.2ms) is also set.

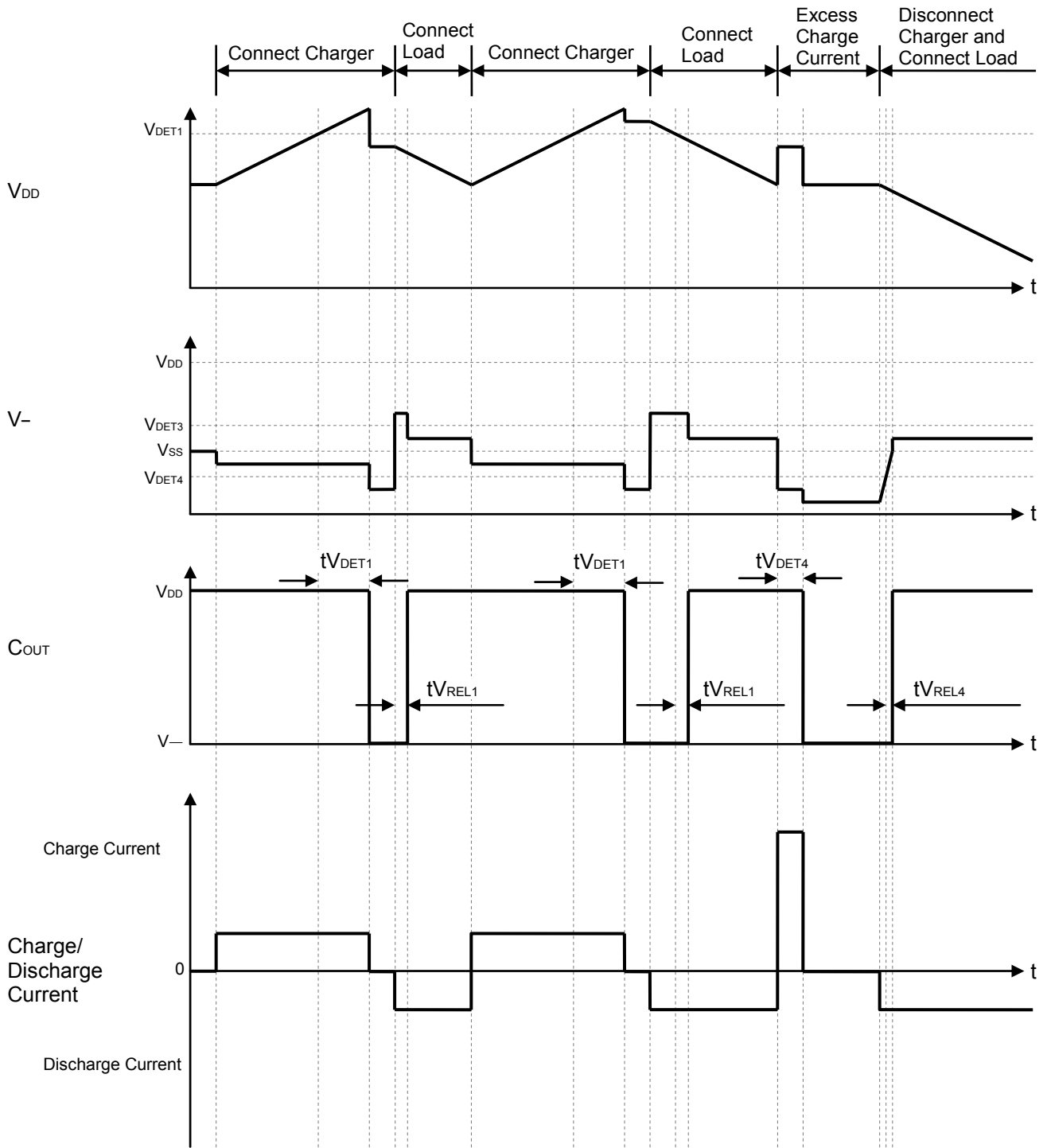
VD4 can be released with disconnecting a charger and connecting a load.

**DS (Delay Shorten) function**

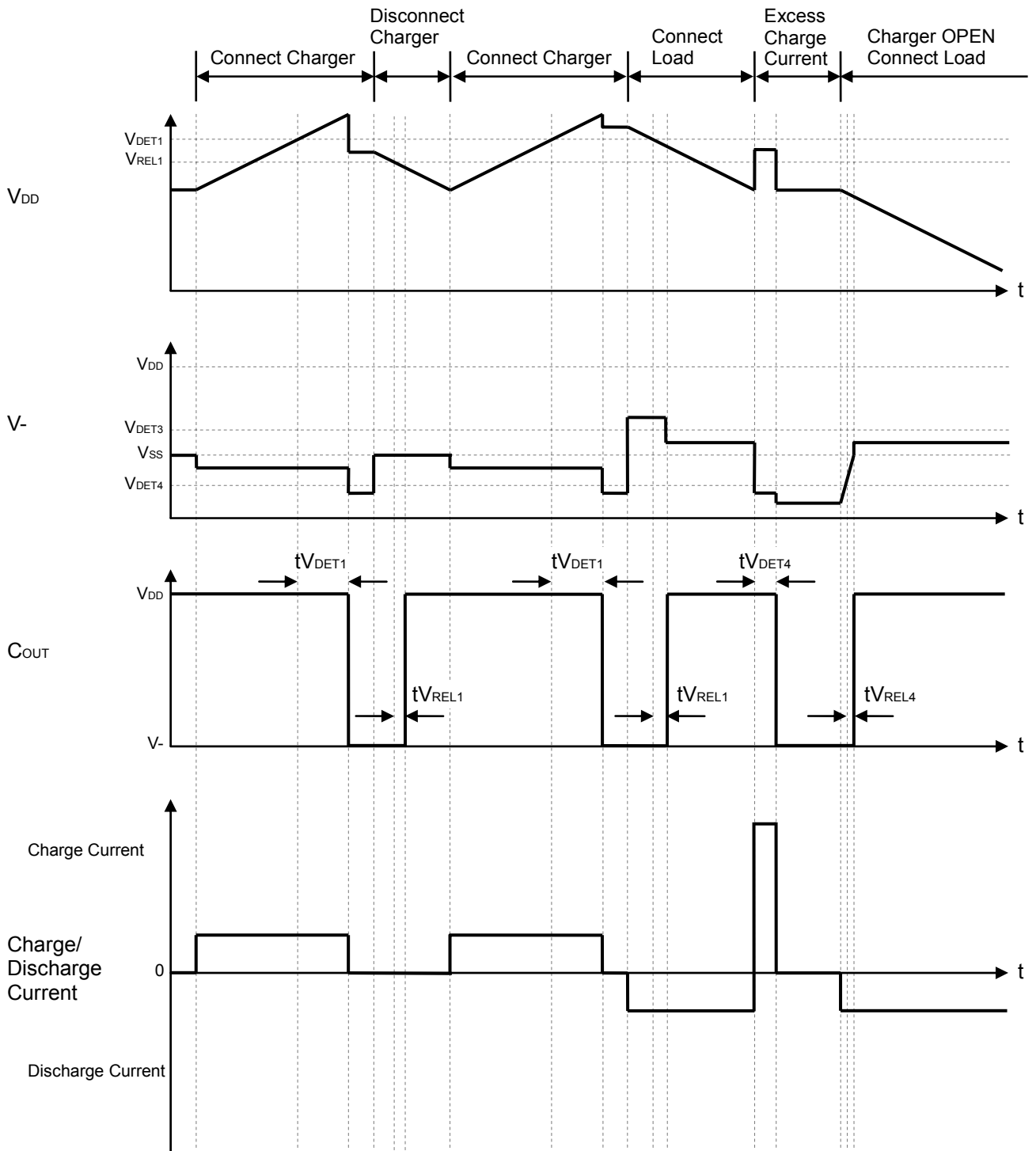
Output delay time of over-charge, over-discharge, and release from those detecting modes can be shorter than those setting value by forcing equal or less than the delay shortening mode voltage (Typ. -2.0V) to V- pin.

TIMING CHART

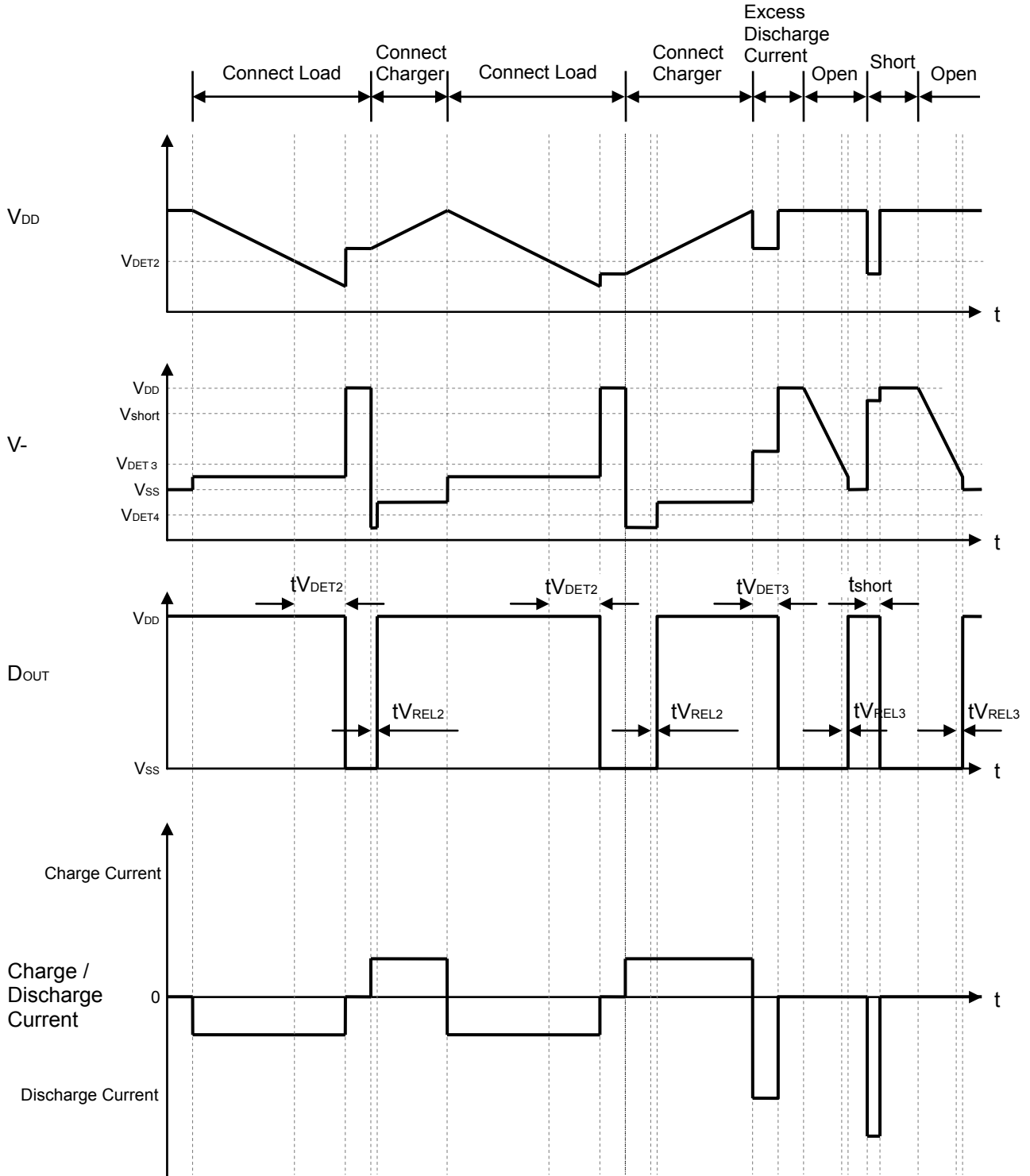
1) Timing diagram of over-charge (Latch type) voltage and over-charge current



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

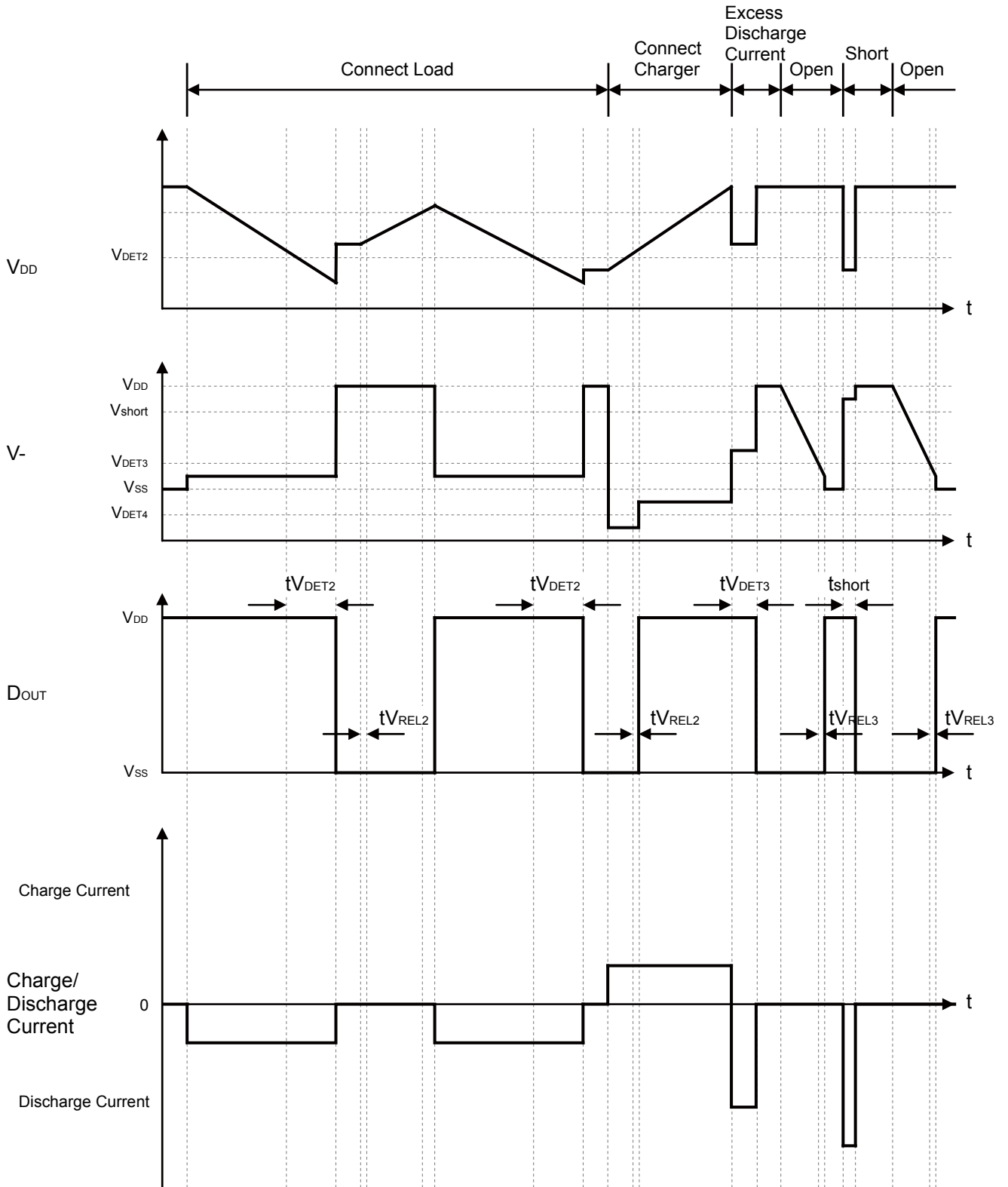


3) Over-discharge (Latch Type), Excess discharge current, Short circuit

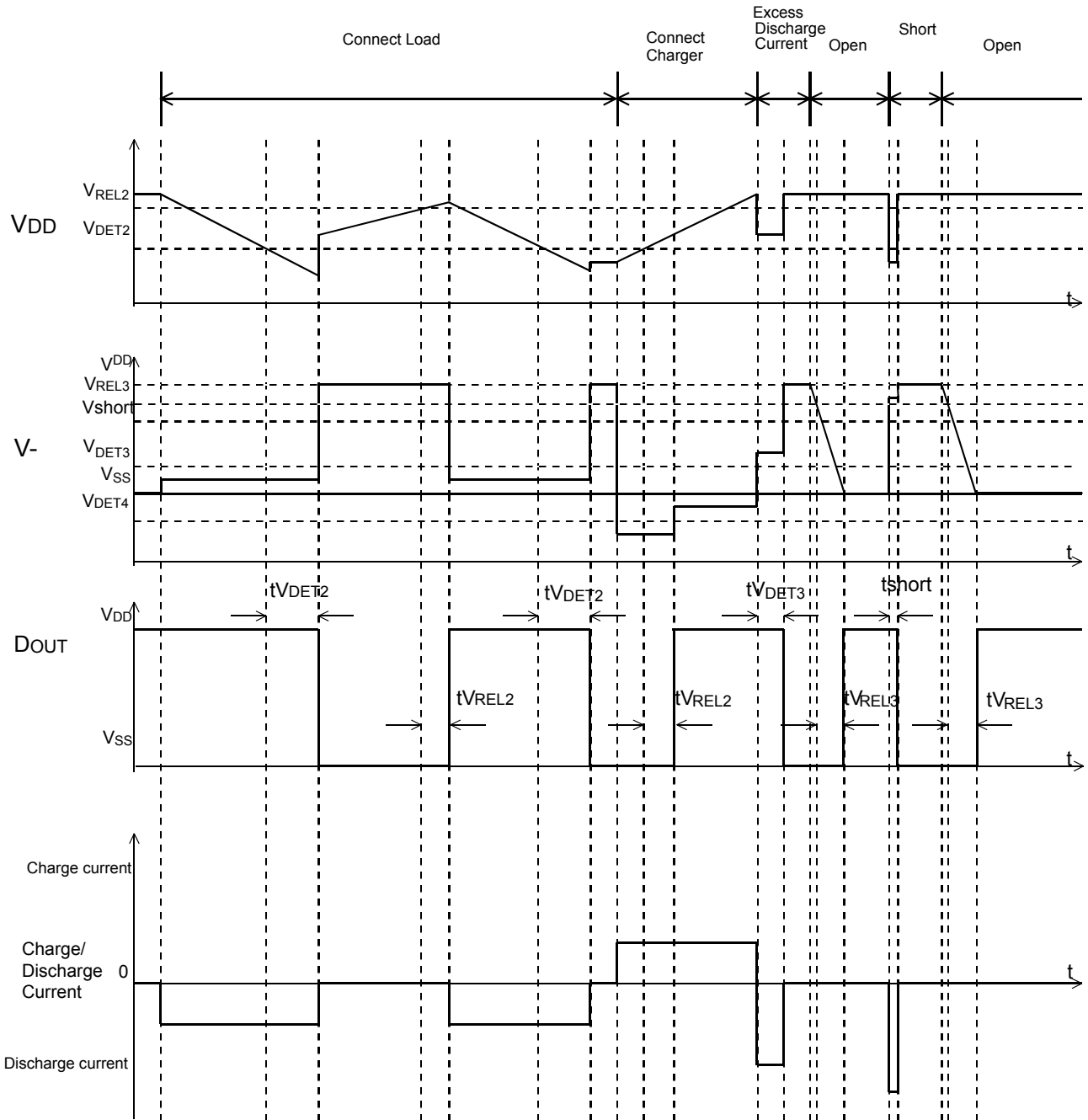




4) Over-discharge (Released by Voltage Type), Excess discharge current (Latch Type), Short circuit

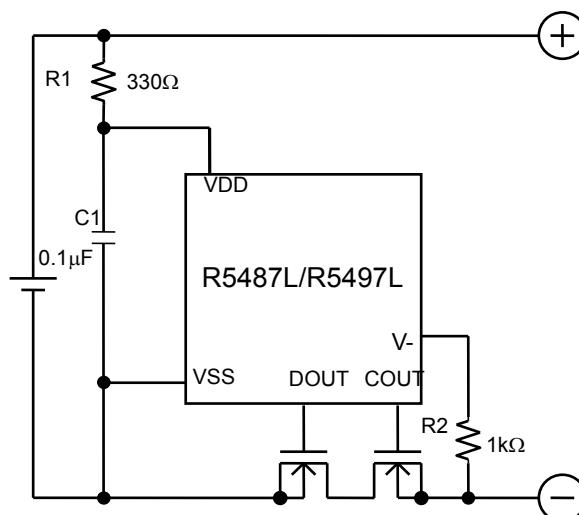


5) Over-discharge (Released by Voltage Type), Excess discharge current (Auto Release Type), Short circuit



## APPLICATION INFORMATION

### Typical Application Circuit



R1 and C1 stabilize a supply voltage to the R5487L/R5497L. A recommended R1 value is equal or less than 1kΩ. A large value of R1 makes detection voltage shift higher because of the conduction current flowed in the R5487L/R5497L. Further, to stabilize the operation of the R5487L/R5497L, use the C1 with the value in the range from 0.01μF to 0.1μF. To choose the most suitable value of C1, fully evaluation is necessary.

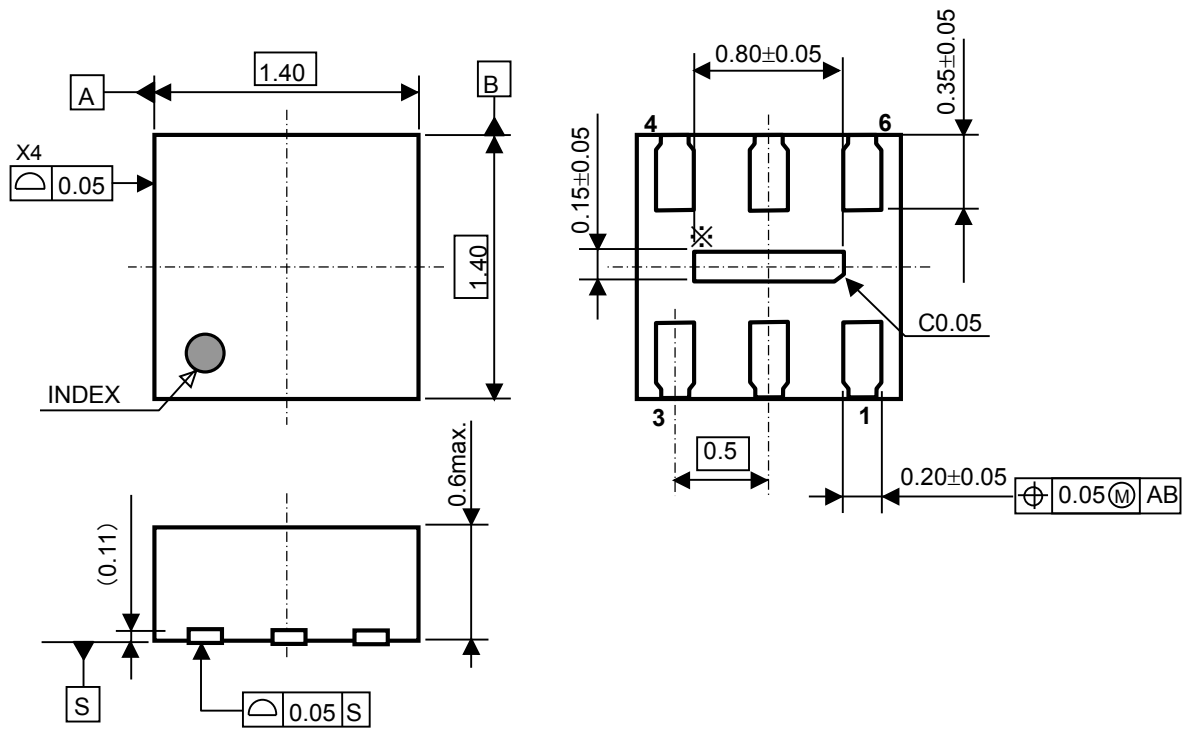
R1 and R2 can operate as a current limit against setting cell reverse direction or applying excess charge voltage to the R5487. While small value of R1 and R2 may cause over power dissipation rating of the R5487L/R5497L, therefore a total of “R1+R2” should be 1kΩ or more. Besides, if a large value of R2 is set, release from over-discharge by connecting a charger might not be possible.

In the case of “R5487L/R5497Lxxx\$M”, “R5487L/R5497Lxxx\$Q”, “R5487L/R5497Lxxx\$P”, k”, recommended R2 value is equal or less than 1kΩ. The recommended R2 value is 1kΩ. In the case of “R5487L/R5497Lxxx\$D” and “R5487L/R5497Lxxx\$F”, recommended R2 value is equal or less than 10kΩ. The recommended R2 value is 10kΩ.

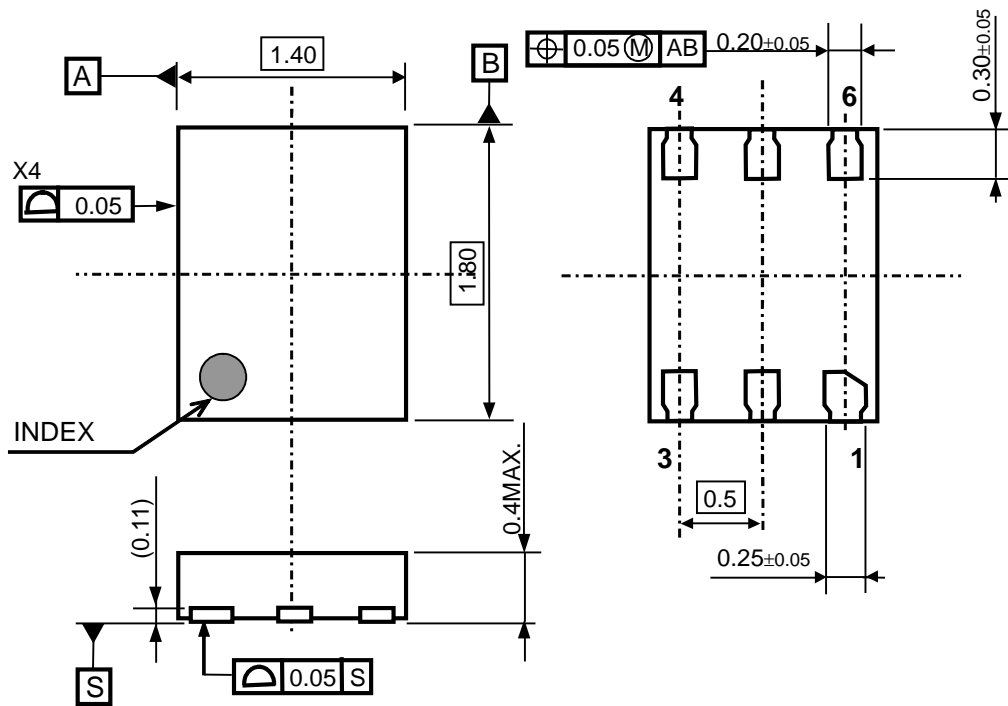
The typical application circuit diagram is just an example. This circuit performance largely depends on the PCB layout and external components. In the actual application, fully evaluation is necessary.

Over-voltage and the over current beyond the absolute maximum rating should not be forced to the protection IC and external components. If the positive terminal and the negative terminal of the battery pack are short, even though the short protection circuit is built in the IC, during the delay time until detecting the short circuit, a large current may flow through the FET. Select an FET with large enough current capacity in order to endure the large current during the delay time.

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DFN1414-6B Package Dimensions (Unit: mm)



DFN1814-6B Package Dimensions (Unit: mm)



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