

## 1-Cell Li-ion Battery Protection IC with Built-in Driver for High-side Nch FETs and Temperature Protection

No.EA-533-210927

### OUTLINE

The R5445Z is one-cell Li-ion / polymer battery protection IC provides overcharge, overdischarge, discharge / charge overcurrent, and temperature detections. The IC can drive external high-side Nch MOSFETs and provides a high-accuracy detection at overcharge and overcurrent, and a high-accuracy charge inhibition for 0V battery.

Furthermore, the IC can reduce the supply current after overdischarge detection to a minimum by stopping the internal circuits. Using the CTL pin can forcefully enter the IC into standby mode.

### FEATURES

- Absolute Maximum Rating ..... 6.5 V
- Supply Current at Normal Mode ..... Typ.5.0  $\mu$ A
- Standby Current ..... Max.0.04  $\mu$ A

#### Detector Selectable Range and Accuracy (Unless otherwise provided, Ta=25°C)

- Overcharge Detection Voltage ..... 4.2 V to 4.6 V (in 0.005 V step,  $\pm 10$  mV <sup>(1)</sup>)
- Overdischarge Detection Voltage ( $V_{DET2}$ ) <sup>(2)</sup> ..... 2.0 V to 3.4 V (in 0.005 V step,  $\pm 2.0\%$ )
- Discharge Overcurrent Detection Voltage ( $V_{DET3}$ ) ..... 0.015 V to 0.150 V (in 0.001 V step,  
0.015 V to 0.030 V:  $\pm 3$ mV /  
0.031 V to 0.050 V:  $\pm 10\%$  /  
0.051 V to 0.150 V:  $\pm 5$ mV)
- Charge Overcurrent Detection Voltage ..... -0.150 V to -0.015V (in 0.001 V step,  
-0.150 V to -0.041 V:  $\pm 8$ mV /  
-0.040 V to -0.021 V:  $\pm 20\%$  /  
-0.020 V to -0.015 V:  $\pm 4$ mV)
- Short-circuit Detection Voltage ( $V_{SHORT}$ ) <sup>(3)</sup> ..... 0.040 V to 0.200 V (in 0.005V step,  $\pm 5$  mV)  
 $V_{SHORT}$  configurable range varies depending on a set value for  $V_{DET3}$ .

$V_{DET3}$ Set Value	$V_{SHORT}$ Configurable Range
0.015 V to 0.033 V	0.040 V to 0.200 V
0.034 V to 0.065 V	0.060 V to 0.200 V
0.066 V to 0.110 V	0.126 V to 0.200 V
0.111 V to 0.150 V	0.181 V to 0.200 V

- 0 V Battery Charge Inhibition Voltage ..... 1.25 V to 2.00 V (in 0.05V step,  $\pm 50$  mV)
- Thermal Detection Temperature <sup>(4)</sup> ..... 40°C to 85°C (in 5°C step,  $\pm 3^\circ$ C)

<sup>(1)</sup> When  $0^\circ\text{C} \leq T_a \leq 50^\circ\text{C}$

<sup>(2)</sup>  $V_{DET2}$  requires at least 0.1V higher than  $V_{NOCHG}$ .

<sup>(3)</sup>  $V_{SHORT}$  requires at least 15mV higher than  $V_{DET3}$ .

<sup>(4)</sup> Refer to "Selection Guide" and "Application Information" for details.

**Internal Fixed Output Delay Time**

- Overcharge Detection Delay Time ..... 1024 ms / 2048 ms / 3072 ms / 4096 ms
- Overdischarge Detection Delay Time ..... 16 ms / 32 ms / 128 ms
- Discharge Overcurrent Detection Delay Time ..... 32 ms / 128 ms / 256 ms / 512 ms / 1024 ms
- Short-circuit Detection Delay Time ..... 280  $\mu$ s
- Charge Overcurrent Detection Delay Time ..... 8 ms
- Thermal Detection Delay Time ..... 128 ms / 512 ms / 1024 ms / 4096 ms
- Thermal Release Delay Time ..... 128 ms

**Optional Functions**

- Charge Overcurrent Detection ..... Enabled / Disabled
- 0 V Battery Charging ..... Inhibition
- Overcurrent Detection ..... High-side (RSENS to V+)
- Thermal Protection ..... Charge and Discharge Current
- External NTC Thermistor <sup>(1)</sup> ..... 100 k $\Omega$  / 470 k $\Omega$
- Temperature Monitoring Cycle
  - Non-sense Time ( $T_{TNS}$ ) ..... 90 ms / 528 ms / 1040 ms
  - Sense Time ( $T_{TS}$ ) ..... 10 ms
- Current Sense ..... Resistor / FET

**APPLICATIONS**

- Li+ / Li- polymer protector of overcharge, overdischarge, and overcurrent for battery pack
- High precision protectors for smart-phones and any other electronic gadgets using on-board Li+ / Li-polymer battery

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<sup>(1)</sup> An NTC thermistor, having a reference resistance value of 100k $\Omega$  or 470k $\Omega$   $\pm$ 1% at 25°C and B-constant of 4250K $\pm$ 1%, is required. Refer to "Application Information" for details.

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## SELECTION GUIDE

### Selection Guide

Product Name	Package	Quantity per Reel	Pb Free	Halogen Free
R5445Zxxx\$*-E2-F	WLCSP-8-P4	5,000 pcs	Yes	Yes

xxx: Specify a code combining the following set voltages. Refer to "Product Code List" for details.

\$: Specify a code that combines delay times from the table below.

Code	tVDET1 [ms]	tVDET2 [ms]	tVDET3 [ms]	tVDET4 [ms]	tVREL1 [ms]	tVREL2/3 [ms]	tVREL4 [ms]	tSHORT [ms]	tDET [ms]	tREL [ms]	t <sub>s</sub> [ms]	t <sub>NS</sub> [ms]
H	4096	32	32	8	16	1.1	1.1	0.28	4096	128	10	90
L	1024	32	32	8	16	1.1	1.1	0.28	1024	128	10	90
M	1024	128	128	8	16	1.1	1.1	0.28	4096	128	10	90

\*: Specify a code that combines optional functions from the table below.

Code	Overcharge Release	Overdischarge Release	Discharge Overcurrent Release	Charge Overcurrent Detection	0V Battery Charging	Current Sense
A	Latch	Latch	Auto Release	Disable	Inhibition	Resistor
B	Latch	Latch	Auto Release	Disable	Inhibition	FET
C	Latch	Latch	Latch	Disable	Inhibition	Resistor
D	Latch	Latch	Latch	Disable	Inhibition	FET
E	Latch	Latch	Auto Release	Enable	Inhibition	Resistor
F	Latch	Latch	Auto Release	Enable	Inhibition	FET
G	Latch	Latch	Latch	Enable	Inhibition	Resistor
H	Latch	Latch	Latch	Enable	Inhibition	FET

**Product Code List**

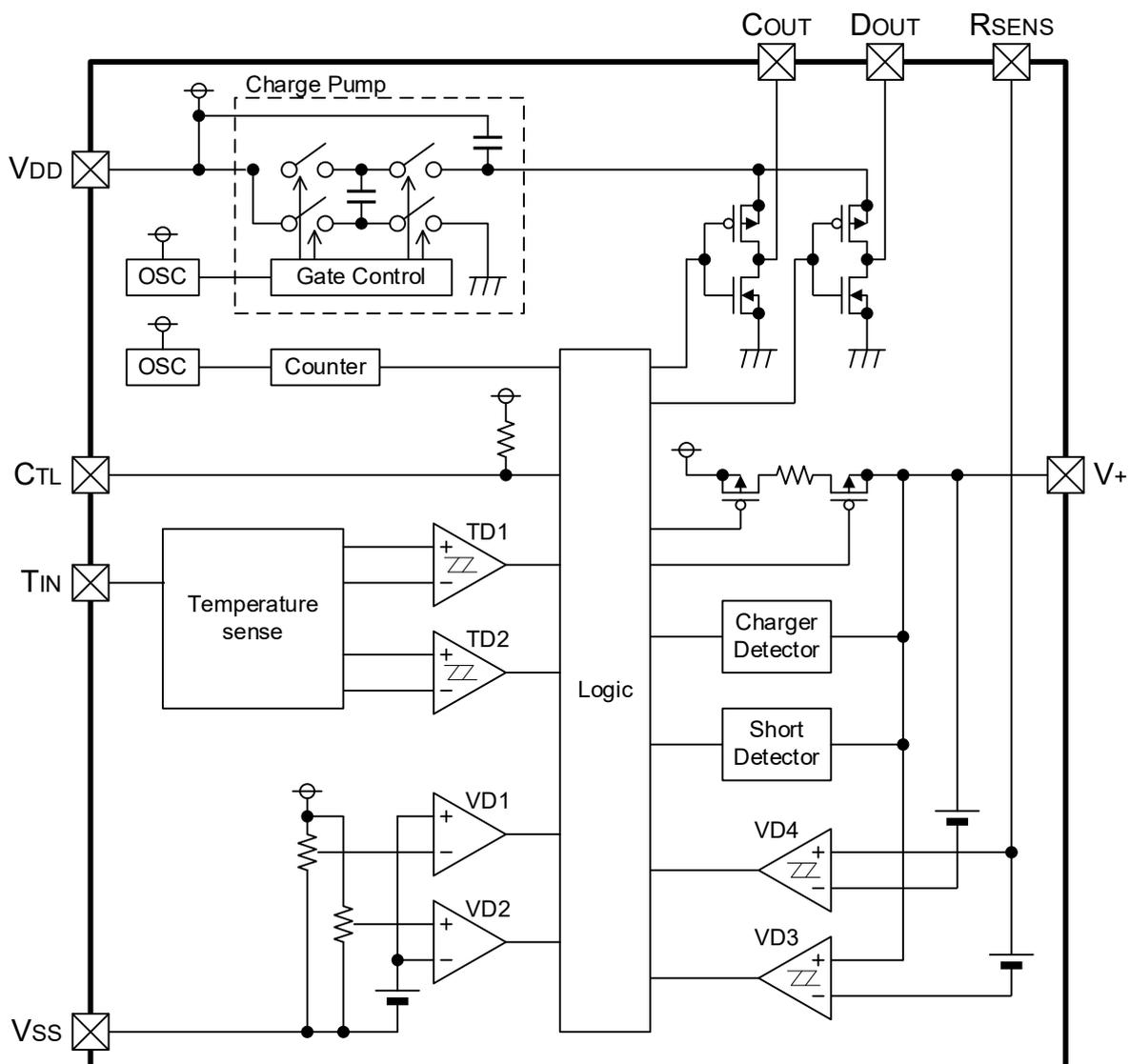
The product code is determined by the combination of the set voltage, the thermal detection temperature, and the optional function.

**Product Code Table**

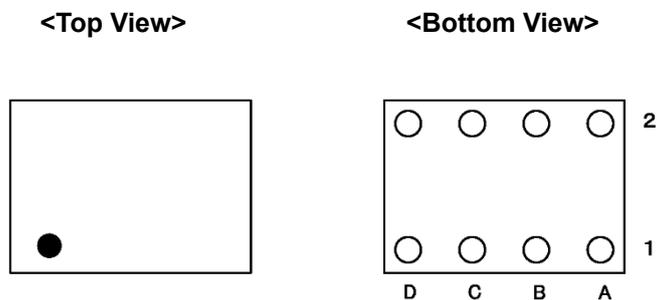
Product Code	Set Voltage [V]						Thermal Detection Temperature [°C]				NTC Thermistor [kΩ]
	V <sub>DET1</sub>	V <sub>DET2</sub>	V <sub>DET3</sub>	V <sub>DET4</sub>	V <sub>SHORT</sub>	V <sub>NOCHG</sub>	T <sub>DET1</sub>	T <sub>REL1</sub>	T <sub>DET2</sub>	T <sub>REL2</sub>	R <sub>TH</sub>
R5445Z <b>107</b> HE	4.425	2.395	0.015	-0.017	0.040	1.550	75	65	75	65	470
R5445Z <b>201</b> LE	4.500	2.900	0.021	-0.015	0.085	1.500	65	60	65	60	100
R5445Z <b>202</b> LE	4.500	2.900	0.026	-0.024	0.055	1.500	65	60	65	60	100
R5445Z <b>203</b> ME	4.510	2.900	0.028	-0.015	0.100	1.500	71	67	71	67	100
R5445Z <b>204</b> ME	4.510	2.900	0.033	-0.024	0.070	1.500	71	67	71	67	100

Note: The IC requires setting each of threshold temperatures of T<sub>DET1</sub> and T<sub>DET2</sub>, and T<sub>REL1</sub> and T<sub>REL2</sub> to the same temperature.

### BLOCK DIAGRAM



R5445Z Block Diagram

**PIN DESCRIPTION****R5445Z Pin Description**

Pin No.	Symbol	Pin Description
A1	VSS	Ground pin, the substrate level of the IC
B1	TIN	Thermistor input pin for temperature detection
C1	CTL	Control input pin for VDET2
D1	RSENS	Overcurrent detection input pin
A2	VDD	Power supply pin
B2	COUT	Overcharge detection pin, CMOS output
C2	DOUT	Overdischarge detection pin, CMOS output
D2	V+	Charger positive input pin

## ABSOLUTE MAXIMUM RATINGS

### Absolute Maximum Ratings

(Ta = 25°C, V<sub>SS</sub> = 0 V)

Symbol	Parameter	Rating	Unit
V <sub>DD</sub>	Supply Voltage	-0.3 to 6.5	V
V+	V+ Pin Voltage	-0.3 to 30	V
V <sub>RSENS</sub>	RSENS Pin Voltage	-0.3 to 30	V
V <sub>TIN</sub>	TIN Pin Voltage	-0.3 to 6.5	V
V <sub>CTL</sub>	CTL Pin Voltage	-0.3 to 6.5	V
V <sub>COUT</sub>	COUT Pin Voltage	-0.3 to VDD + 6.5	V
V <sub>DOUT</sub>	DOUT Pin Voltage	-0.3 to VDD + 6.5	V
P <sub>D</sub>	Power Dissipation	Refer to Appendix "Power Dissipation".	
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 permanent damage and may degrade the lifetime 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

### Recommended Operating Conditions

Symbol	Parameter	Rating	Unit
V <sub>DD1</sub>	Operating Input 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 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

## R5445Zxxxxx Electrical Characteristics

(Ta = 25°C)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit	Test Circuit (1)	
V <sub>DD1</sub>	Operating Input Voltage	V <sub>DD</sub> - V <sub>SS</sub>	1.5		5.0	V	–	
V <sub>NOCHG</sub>	Maximum Operating Voltage at Inhibition of Charging	Voltage defined as V <sub>DD</sub> - V <sub>SS</sub> , V <sub>+</sub> - V <sub>SS</sub> = 4 V	V <sub>NOCHG</sub> - 0.050	V <sub>NOCHG</sub>	V <sub>NOCHG</sub> + 0.050	V	A	
V <sub>DET1</sub>	Overcharge Detection Voltage	R1 = 330 Ω, 0 °C ≤ Ta ≤ 50 °C (2)	V <sub>DET1</sub> - 0.010	V <sub>DET1</sub>	V <sub>DET1</sub> + 0.010	V	A	
t <sub>VDET1</sub>	Overcharge Detection Delay Time	V <sub>DD</sub> = 3.9 V → 4.6 V	t <sub>VDET1</sub> × 0.80	t <sub>VDET1</sub>	t <sub>VDET1</sub> × 1.20	ms	B	
t <sub>VREL1</sub>	Overcharge Release Delay Time	V <sub>DD</sub> = 3.9 V, V <sub>+</sub> = 3.9 V → 2.9 V	12.0	16.0	20.0	ms	C	
V <sub>DET2</sub>	Overdischarge Detection Voltage	Detect falling edge of V <sub>DD</sub>	V <sub>DET2</sub> × 0.98	V <sub>DET2</sub>	V <sub>DET2</sub> × 1.02	V	D	
t <sub>VDET2</sub>	Overdischarge Detection Delay Time	V <sub>DD</sub> = 3.9 V → 2.0 V	t <sub>VDET2</sub> × 0.80	t <sub>VDET2</sub>	t <sub>VDET2</sub> × 1.20	ms	E	
t <sub>VREL2</sub>	Overdischarge Release Delay Time	V <sub>DD</sub> = 3.9 V, V <sub>+</sub> = 0 V → 3.9 V	0.85	1.10	1.35	ms	E	
V <sub>DET3</sub>	Discharge Overcurrent Detection Voltage	V <sub>RSENS</sub> - V <sub>+</sub> voltage, V <sub>DD</sub> = 3.9 V, Detect falling edge of V <sub>+</sub>	0.015 V to 0.030 V	V <sub>DET3</sub>	V <sub>DET3</sub> - 0.003	V	F	
			0.031 V to 0.050 V		V <sub>DET3</sub> × 0.900			V <sub>DET3</sub> + 0.003
			0.051 V to 0.150 V		V <sub>DET3</sub> - 0.005			V <sub>DET3</sub> × 1.100
V <sub>REL3</sub>	Discharge Overcurrent Released Voltage	Voltage defined as V <sub>+</sub> - V <sub>SS</sub> Detect rising edge of V <sub>+</sub>	V <sub>DD</sub> - 0.18	V <sub>DD</sub> - 0.12	V <sub>DD</sub> - 0.06	V	F	
t <sub>VDET3</sub>	Discharge Overcurrent Detection Delay Time	V <sub>DD</sub> = V <sub>RSENS</sub> = 3.9 V, V <sub>+</sub> = 3.9 V → 3.9 V - V <sub>DET3</sub> - 0.010 V	t <sub>VDET3</sub> × 0.80	t <sub>VDET3</sub>	t <sub>VDET3</sub> × 1.20	ms	G	
t <sub>VREL3</sub>	Discharge Overcurrent Release Delay Time	V <sub>DD</sub> = V <sub>RSENS</sub> = 3.9 V, V <sub>+</sub> = 0V → 3.9V	0.85	1.10	1.35	ms	G	
V <sub>DET4</sub>	Charge Overcurrent Detection Voltage	V <sub>RSENS</sub> - V <sub>+</sub> voltage, V <sub>DD</sub> = 3.9 V, Detect rising edge of V <sub>+</sub>	-0.020 V to -0.015 V	V <sub>DET4</sub>	V <sub>DET4</sub> - 0.004	V	W	
			-0.040 V to -0.021 V		V <sub>DET4</sub> × 0.800			V <sub>DET4</sub> + 0.004
			-0.150 V to -0.040 V		V <sub>DET4</sub> - 0.008			V <sub>DET4</sub> × 1.200
t <sub>VDET4</sub>	Charge Overcurrent Detection Delay Time	V <sub>DD</sub> = V <sub>RSENS</sub> = 3.9 V, V <sub>+</sub> = 3.9 V → 3.9 V - V <sub>DET4</sub> + 0.010 V	6.4	8.0	9.6	ms	X	
t <sub>VREL4</sub>	Charge Overcurrent Release Delay Time	V <sub>DD</sub> = V <sub>RSENS</sub> = 3.9 V, V <sub>+</sub> = 3.9 V - V <sub>DET4</sub> + 0.010 V → 3.7 V	0.85	1.10	1.35	ms	X	

(1) Refer to *Test Circuits*.

(2) This specification is guaranteed by design, not mass production tested.

## R5445Zxxxxx Electrical Characteristics (Continued)

(Ta = 25°C)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit	Test Circuit (1)
V <sub>SHORT</sub>	Short Protection Voltage	V <sub>RSNS</sub> - V <sub>+</sub> voltage, V <sub>DD</sub> = 3.9V, Detect falling edge of V <sub>+</sub>	V <sub>SHORT</sub> - 0.005	V <sub>SHORT</sub>	V <sub>SHORT</sub> + 0.005	V	F
t <sub>SHORT</sub>	Short Protection Delay Time	V <sub>DD</sub> = V <sub>RSNS</sub> = 3.9V, V <sub>+</sub> = 3.9 V → 3.9 V - V <sub>SHORT</sub> - 0.010 V	210	280	350	μs	G
R <sub>SHORT</sub>	Discharge overcurrent release resistance	V <sub>DD</sub> = 3.9 V, V <sub>+</sub> = 2.9 V	15	45	70	kΩ	H
V <sub>CHGDET</sub>	V <sub>+</sub> Voltage for Release from Standby	R2 = 1kΩ, V <sub>DD</sub> = 3.9 V, Voltage defined as V <sub>+</sub> - V <sub>SS</sub>	V <sub>DD</sub> × 0.4	V <sub>DD</sub> × 0.5	V <sub>DD</sub> × 0.7	V	I
V <sub>BST1</sub>	Charge Pump Output Voltage 1	V <sub>DD</sub> = 3.9 V, V <sub>COU</sub> / V <sub>DOU</sub> , I <sub>COU</sub> = I <sub>DOU</sub> = 0 μA	7.4	7.65		V	J
V <sub>BST2</sub>	Charge Pump Output Voltage 2	V <sub>DD</sub> = 3.9 V, V <sub>COU</sub> / V <sub>DOU</sub> , I <sub>COU</sub> = I <sub>DOU</sub> = -1 μA	6.5	6.95		V	J
V <sub>OL1</sub>	COU Nch ON-Voltage	I <sub>OL</sub> = 10 μA, V <sub>DD</sub> = 4.7 V		0.030	0.100	V	K
V <sub>OL21</sub>	DOU Nch ON-Voltage	I <sub>OL</sub> = 10 μA, V <sub>DD</sub> = 1.9 V, V <sub>+</sub> = V <sub>DD</sub>		0.065	0.150	V	L
V <sub>OL22</sub>	DOU Nch ON-Voltage (at Standby mode)	I <sub>OL</sub> = 1 μA, V <sub>DD</sub> = 1.9 V, V <sub>+</sub> = V <sub>SS</sub> after t <sub>VDET2</sub>		0.020	0.100	V	M
I <sub>DD1</sub>	Supply Current	V <sub>DD</sub> = V <sub>+</sub> = 3.9 V, I <sub>OUT</sub> = 0 μA		5.0	8.0	μA	N
I <sub>STANDBY</sub>	Standby Current	V <sub>DD</sub> = 1.9 V			0.04	μA	O
T <sub>DET1</sub>	Detection Temperature 1 for External NTC (2)	COU Control [NTC performance] Resistance: 470kΩ±1% / 100kΩ±1% (25°C) B-Constant: 4250K±1%	T <sub>DET1</sub> - 3.0	T <sub>DET1</sub>	T <sub>DET1</sub> + 3.0	°C	P
T <sub>REL1</sub>	Release Temperature 1 for External NTC (2)		T <sub>REL1</sub> - 3.0	T <sub>REL1</sub>	T <sub>REL1</sub> + 3.0	°C	P
T <sub>DET2</sub>	Detection Temperature 2 for External NTC (2)	DOU Control [NTC performance] Resistance: 470kΩ±1% / 100kΩ±1% (25°C) B-Constant: 4250K±1%	T <sub>DET2</sub> - 3.0	T <sub>DET2</sub>	T <sub>DET2</sub> + 3.0	°C	Q
T <sub>REL2</sub>	Release Temperature 2 for External NTC (2)		T <sub>DET2</sub> - 3.0	T <sub>DET2</sub>	T <sub>DET2</sub> + 3.0	°C	Q

(1) Refer to *Test Circuits*.

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## R5445Zxxxxx Electrical Characteristics (Continued)

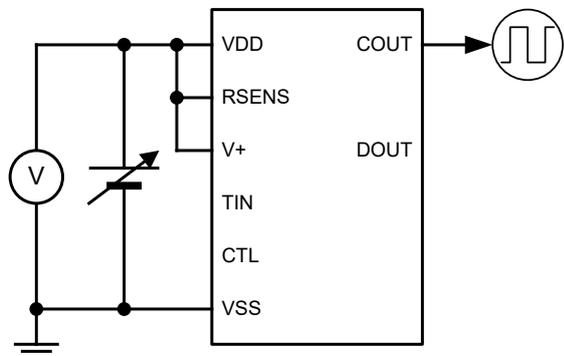
(Ta = 25°C)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit	Test Circuit (1)	
t <sub>TDET</sub>	Delay Time for T <sub>DET</sub> x	V <sub>DD</sub> = 3.9 V	t <sub>TDET</sub> × 0.80	t <sub>TDET</sub>	t <sub>TDET</sub> × 1.20	ms	R	
t <sub>TREL</sub>	Delay Time for T <sub>REL</sub> x	V <sub>DD</sub> = 3.9 V	102	128	154	ms	R	
t <sub>TS</sub>	Temperature Sense Time	V <sub>DD</sub> = 3.9 V	8	10	12	ms	S	
t <sub>TNS</sub>	Temperature Non-sense Time	V <sub>DD</sub> = 3.9 V	t <sub>TNS</sub> × 0.80	t <sub>TNS</sub>	t <sub>TNS</sub> × 1.20	ms	S	
R <sub>TIN</sub>	Internal Resistance for Temperature Sense	V <sub>DD</sub> = V <sub>TIN</sub> = 3.9 V, TIN Current R <sub>TIN</sub> = 3.9 / TIN Current	NTC Resistance: 470kΩ	65	150	270	kΩ	T
			NTC Resistance: 100kΩ	14	35	65		
V <sub>DS</sub>	Delay Time Shortening Mode Voltage	V <sub>DD</sub> = 3.9 V, Voltage defined as V+ - V <sub>SS</sub>	V <sub>DD</sub> + 1.4		V <sub>DD</sub> + 2.2	V	U	
V <sub>RCDET</sub>	V+ Voltage for Detecting Standby Voltage within V <sub>DD1</sub>	V <sub>DD</sub> = 3.9 V, Voltage defined as V+ - V <sub>SS</sub>	V <sub>DD</sub> × 0.35	V <sub>DD</sub> × 0.45	V <sub>DD</sub> × 0.65	V	U	
V <sub>BSTDET</sub>	Detection Voltage for COUT / DOUT Boost Voltage	V <sub>DD</sub> = 3.9 V, Voltage defined as V <sub>COUT</sub> - V <sub>SS</sub> or V <sub>DOUT</sub> - V <sub>SS</sub>	V <sub>DD</sub> + 0.8	V <sub>DD</sub> + 1.3	V <sub>DD</sub> + 1.6	V	V	
R <sub>CTL</sub>	Pull-up Resistance for CTL		1.2	3.0	4.7	MΩ	Y	
V <sub>CTLDET</sub>	CTL Detection Voltage	V <sub>DD</sub> = 3.9 V, Voltage defined as V <sub>CTL</sub> - V <sub>SS</sub>	V <sub>DD</sub> - 1.6		V <sub>DD</sub> - 0.5	V	Y	
t <sub>VCTL</sub>	CTL Detection Delay Time	t <sub>VCTL</sub> = t <sub>VDET2</sub> , V <sub>DD</sub> = 3.9 V, V <sub>CTL</sub> = 3.9 V → 0 V	t <sub>VDET2</sub> × 0.80	t <sub>VDET2</sub>	t <sub>VDET2</sub> × 1.20	ms	Y	

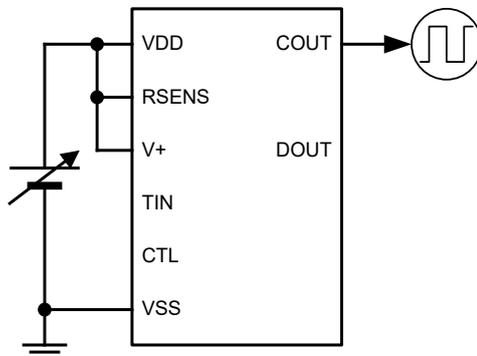
(1) Refer to Test Circuits.

Test Circuits

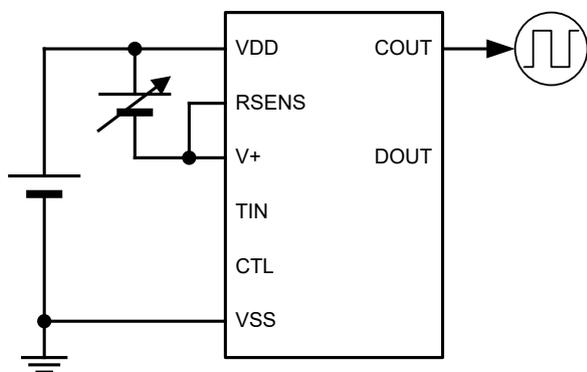
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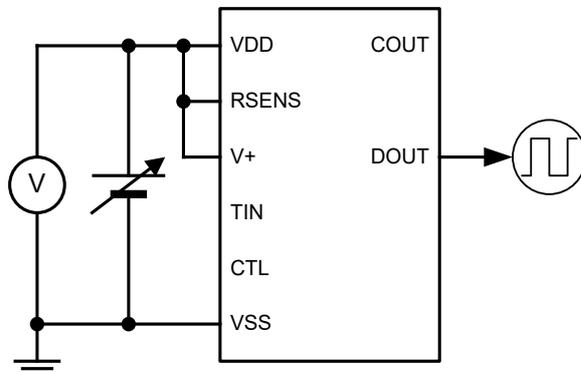
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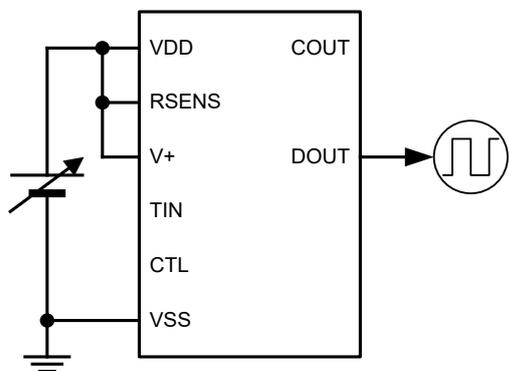
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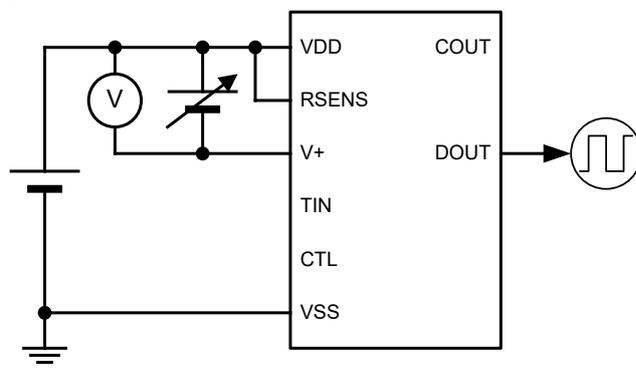
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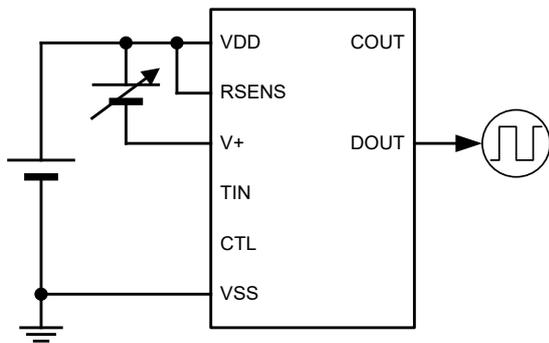
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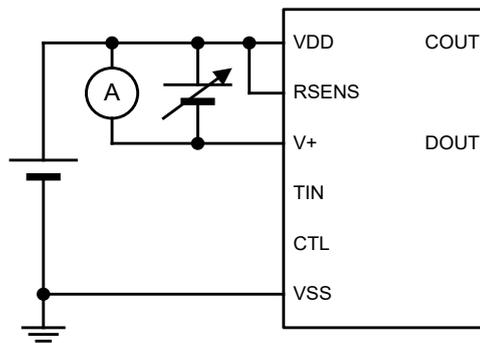
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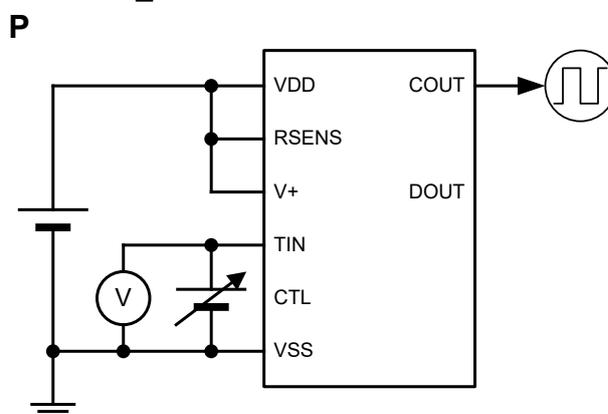
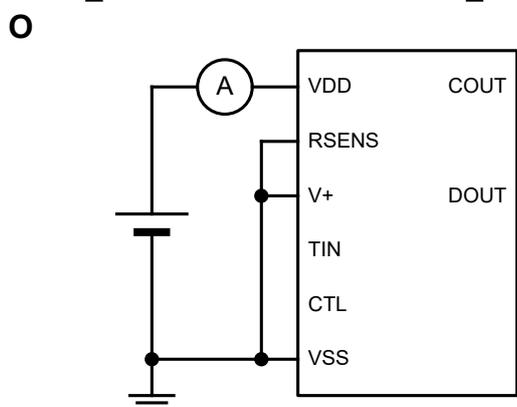
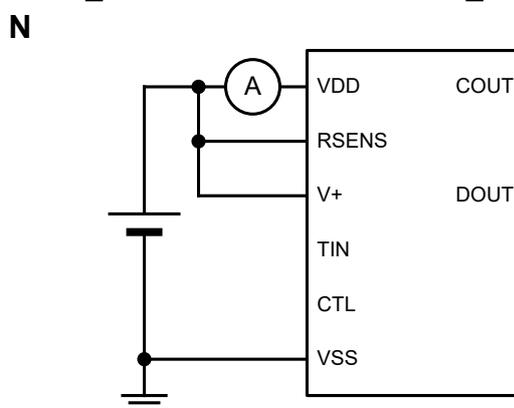
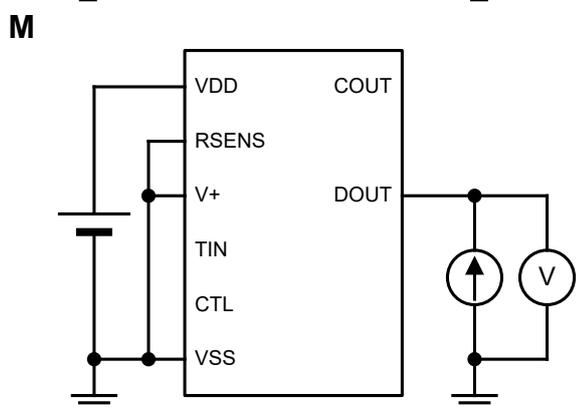
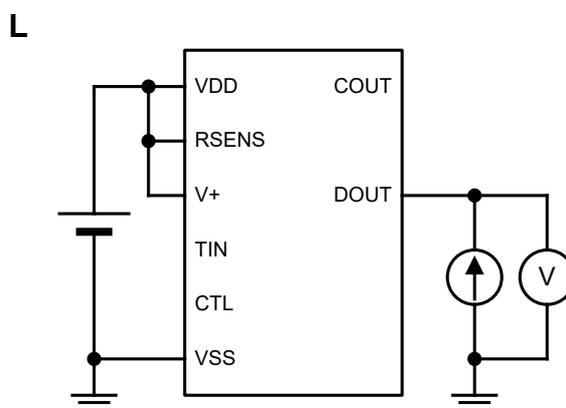
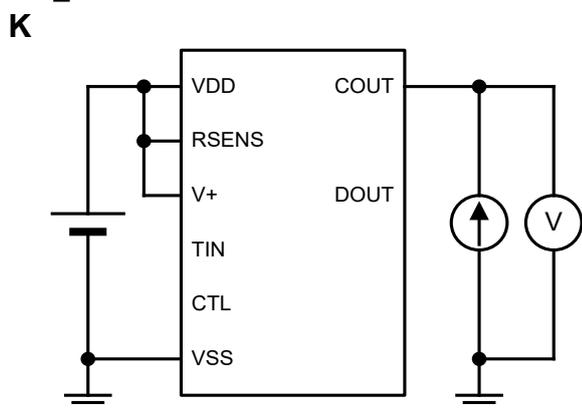
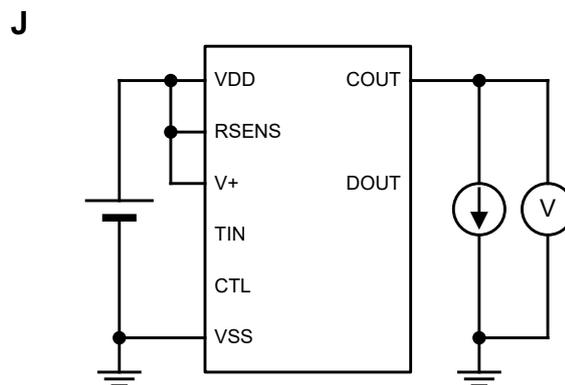
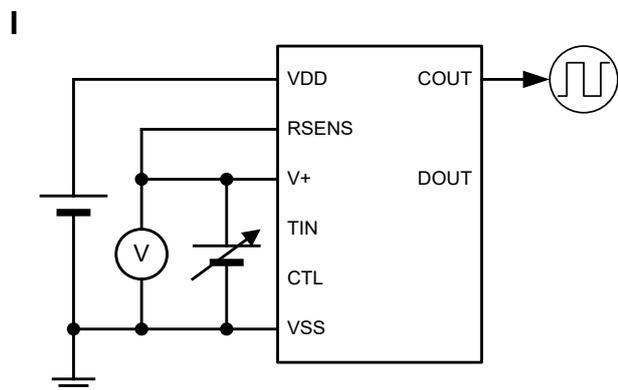


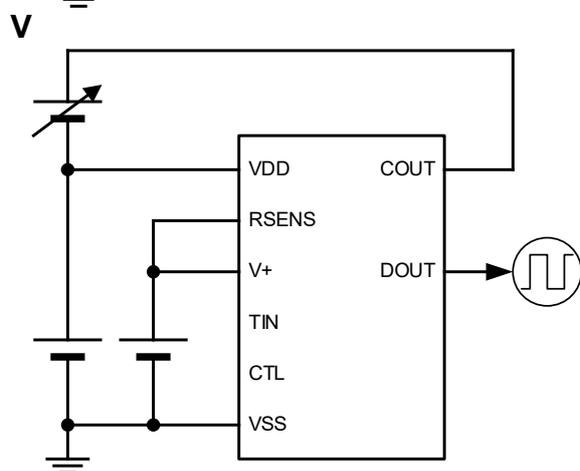
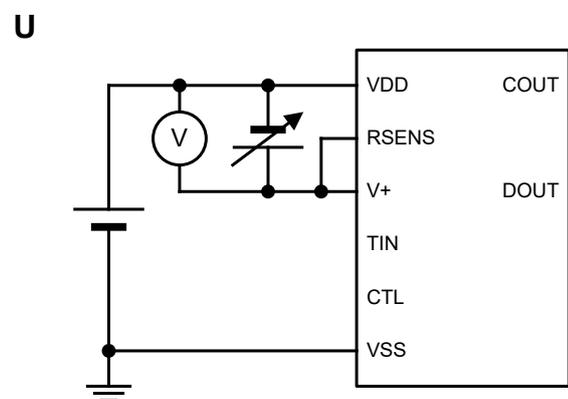
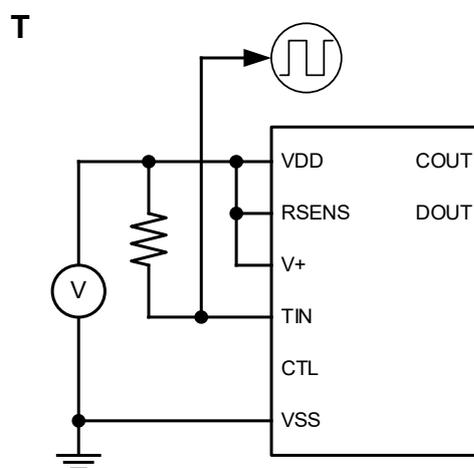
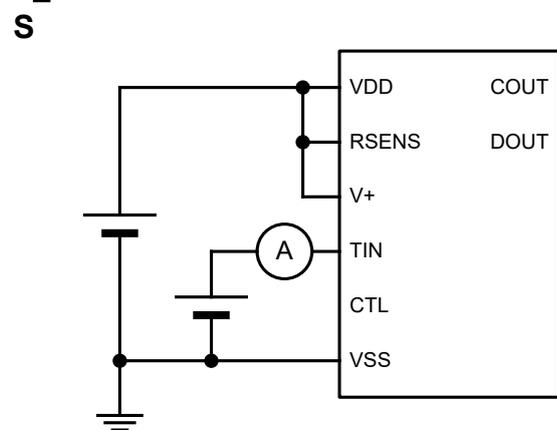
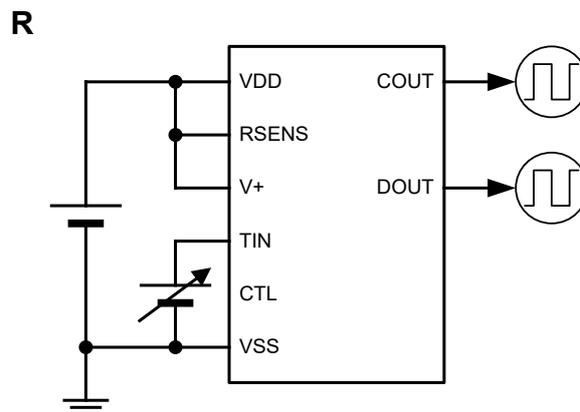
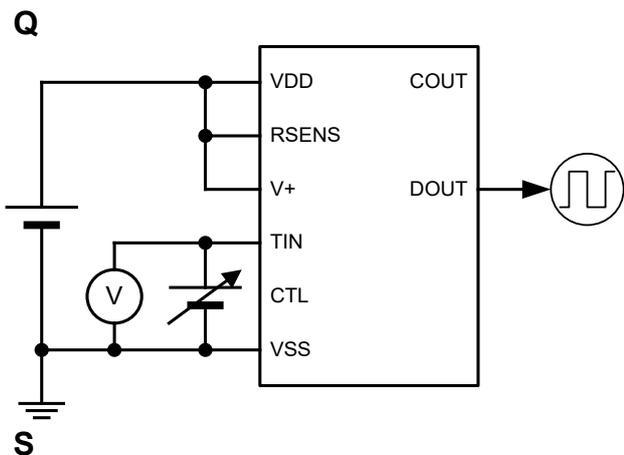
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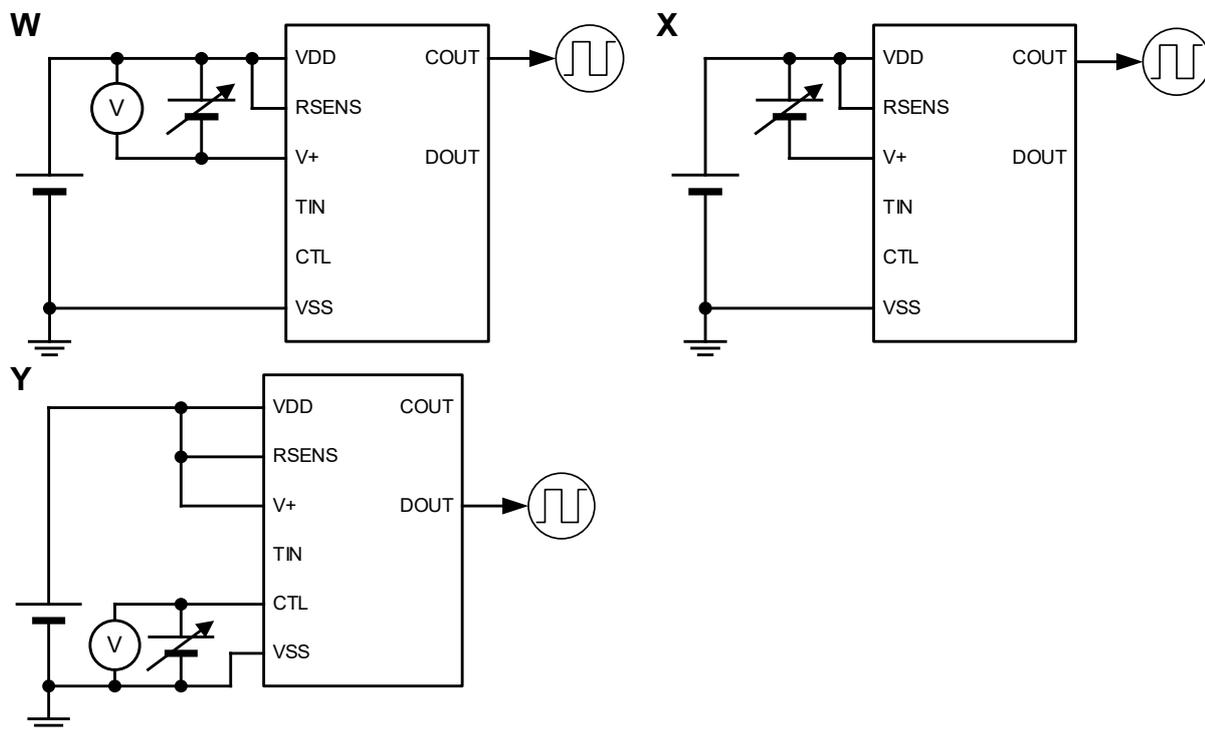


H









## THEORY OF OPERATION

### VD1: Overcharge Detector

The VD1 monitors the VDD pin voltage ( $V_{DD}$ ) during charge. When  $V_{DD}$  becomes more than or equal to the overcharge detection voltage ( $V_{DET1}$ ), the VD1 senses the overcharge condition, the COUT pin becomes Low and stops charging by turning off an external Nch MOSFET.

After detecting the overcharge,  $V_{DD}$  becomes less than  $V_{DET1}$ , and the VD1 is released after disconnecting a charger. The release condition may be not enough depending on the characteristics of external components such as MOSFETs, and some load must be set to release the overcharge. Then, the COUT pin becomes High, and the battery charger can recharge by turning on the Nch MOSFET. In other words, once detecting the overcharge even if the cell voltage becomes less than  $V_{DET1}$ , the battery is not recharged while a charger is connected to the battery pack. Therefore, there is no hysteresis for the VD1. The V+ pin voltage becomes less than the discharge overcurrent release voltage ( $V_{REL3}$ ) by connecting some load, and the overcharge condition is released.

When  $V_{DD}$  becomes higher than  $V_{DET1}$  and a load is connected to the battery pack without connecting the charger, the COUT pin becomes Low, and the load current might flow through a parasitic diode of the Nch MOSFET. When  $V_{DD}$  becomes lower than  $V_{DET1}$ , the COUT pin becomes High.

Output delay times for overcharge detection and release are internally fixed, respectively.

When  $V_{DD}$  becomes higher than  $V_{DET1}$  and then falls below  $V_{DET1}$  within the overcharge detection delay time ( $t_{V_{DET1}}$ ), VD1 does not enter the overcharged condition.

The high level of the COUT pin becomes the approximate value of  $V_{DD} \times 2$  ( $= V_{BST}$ ) because a level shifter is built in a buffer driver for the COUT pin. The output level of the COUT pin, a CMOS output type, is in between  $V_{BST}$  and  $V_{SS}$ .

### VD2: Overdischarge Detector

The VD2 monitors the VDD pin voltage ( $V_{DD}$ ) during discharge. When  $V_{DD}$  becomes less than or equal to the overdischarge detection voltage ( $V_{DET2}$ ), the VD2 senses the overdischarge condition and stops discharging by turning off an external Nch MOSFET.

After detecting the overdischarge,  $V_{DD}$  becomes higher than  $V_{DET2}$  and the V+ pin voltage ( $V_{+}$ ) is higher than the standby release voltage ( $V_{CHGDET}$ ), the VD2 is released. Then, the DOUT becomes High, and the battery charger can discharge by turning on the Nch MOSFET. When  $V_{DD}$  becomes higher than  $V_{DET2}$ , as defined as release voltage, under the connection between the charger and the battery pack, and the DOUT pin becomes High immediately.

The IC goes into Standby state when  $V_{DET2}$  is reached and V+ is below  $V_{RCDET}$ . When  $V_{DD}$  is below  $V_{NOCHG}$ , then IC continues to stay in the Standby state. When V+ exceeds  $V_{CHGDET}$ , the IC interprets this as a charger is connected. As the IC detects charger connect along with  $V_{DD}$  being less than  $V_{NOCHG}$ , it will transition to 0V charge inhibition state. When  $V_{DD}$  becomes less than the maximum voltage for charging inhibition ( $V_{NOCHG}$ ),

the COUT pin retains Low even if a charger is connected to the battery pack, and the system is not allowed to charge.

Output delay times for overdischarge detection and release are fixed internally. When  $V_{DD}$  becomes higher than  $V_{DET2}$  and then falls below  $V_{DET2}$  within the overdischarge detection delay time ( $t_{VDET2}$ ), VD2 does not enter the overdischarged condition.

When  $V+$  becomes more than or equal to  $V_{RCDET}$  after detecting the overdischarge, the supply current decreases ( $V_{DD} = 1.9V$ , Max.  $0.04\mu A$ ) because the IC halts all circuits and enters the standby mode. The COUT pin keeps High and the COUT pin becomes equal to  $V_{DD}$  because the charge pump stops, and the boost voltage goes down from the approximate value of  $V_{DD} \times 2$  ( $= V_{BST}$ ) to  $V_{DD}$ . The output level of the DOUT pin, a CMOS output type, is in between  $V_{BST}$  and  $V_{SS}$ .

### **VD3: Discharge Overcurrent Detector, Short Circuit Protector**

The VD3 monitors the voltage level between the  $V+$  pin and the RSENS pin when charge and discharge are available with connecting to the battery pack. The IC detects the voltage difference, which is generated by the current flows through an external sense resistance, as the RSENS pin voltage ( $V_{RSENS}$ ). The VD3 works when  $V_{RSENS}$  becomes more than or equal to the discharge overcurrent detection voltage ( $V_{DET3}$ ) and less than the short detection voltage ( $V_{SHORT}$ ) owing to an external short-circuit. The short-circuit protection works when  $V_{RSENS}$  becomes more than or equal to  $V_{SHORT}$  and then the DOUT pin becomes Low. The VD3 can prevent to flow extremely large current by turning off an external Nch MOSFET.

Output delay times for the discharge overcurrent detection and release and the short-circuit are internally fixed. The VD3 does not work when  $V_{RSENS}$  becomes less than  $V_{DET3}$  within the output delay time even if  $V_{RSENS}$  becomes more than or equal to  $V_{DET3}$ , and the short-circuit protection does not work when  $V_{RSENS}$  becomes less than  $V_{SHORT}$  within the short detection delay time ( $t_{SHORT}$ ) even if  $V_{RSENS}$  becomes more than or equal to  $V_{SHORT}$ .

The  $V+$  pin has a built-in pulled up resistor (Typ.  $45k\Omega$ ) connected to the  $V_{DD}$  pin.

After the discharge overcurrent or the short circuit protection is detected, by removing a cause of the overcurrent or the external short circuit, the  $V+$  pin is pulled up through the resistor to  $V_{DD}$  in order to release from the overcurrent condition. Then, the discharge overcurrent and the short-circuit protections are released when  $V+$  becomes more than or equal to the discharge overcurrent release voltage ( $V_{REL3}$ ). The resistor to release from the discharge overcurrent is active when the discharge overcurrent or the short circuit is detected, but it is inactive when charge and discharge are available with connecting to the battery pack or the normal mode.

**VD4: Charge Overcurrent Detector**

The VD4 monitors the voltage level between V+ pin and RSENS pin when charge and discharge are available with connecting to the battery pack. The VD4 works when the voltage between pins RSENS to V+ becomes less than or equal to the charge overcurrent detection voltage ( $V_{DET4}$ ) and the COUT pin becomes Low. The VD4 can prevent to flow extremely large current by turning off an external Nch MOSFET.

Output delay times for the charge overcurrent detection and release are internally fixed.

The VD4 does not work when the voltage between pins RSENS to V+ becomes more than  $V_{DET4}$  within the delay time even if the voltage becomes less than or equal to  $V_{DET4}$ . The VD4 can be released with disconnecting the charger.

**TD: Thermal Detector**

This IC converts the temperature, which is detected by a built-in resistor ( $R_{TIN}$ ) and a thermistor connected with the TIN pin, to the voltage and monitors it. The thermistor works only a period of 10ms every cycle of  $t_{TNS}$  to save the supply current.

The COUT pin becomes Low when the temperature higher than  $T_{DET1}$  is detected and sustained over  $t_{TDET}$ , and charging stops by turning off the external Nch MOSFET. Likewise, the DOUT pin becomes Low when the temperature higher than  $T_{DET2}$  is detected and sustained over  $t_{TDET}$  and discharging stops by turning off it.

The COUT or DOUT pin becomes High when the temperature decreases lower than  $T_{REL1}$  or  $T_{REL2}$  for a delay time of  $t_{TREL}$ .

**DS (Delay Shortening) Function**

This IC can enter the test mode by forcing the V+ pin to be more than or equal to the delay time shortening mode voltage ( $V_{DS}$ , Min. $V_{DD}+1.5V$ ). However, this mode cannot be set while either the COUT or the DOUT pin voltage is lower than the boost voltage detection voltage ( $V_{BSTDET}$ ) and then over a time period (typ.32 ms) after the COUT and the DOUT pin voltages become higher than  $V_{BSTDET}$ .

The following effects can be obtained in this mode.

- Each output delay time is shorten.
- Boost circuit is turned off.
- Temperature is always monitored (The sampling cycle is stopped).
- $V_{DET3}$ ,  $V_{SHORT}$ , and  $V_{DET4}$  are disabled.

### **Forced Overdischarge Detection by CTL Pin**

When the CTL pin is OPEN, the CTL pin voltage ( $V_{CTL}$ ) is VDD level because the CTL pin is pulled up to VDD by the built-in resistor ( $R_{CTL}$ ). When the CTL pin is driven to VSS, this IC detects an overdischarge after  $t_{VDET2}$ . As a result, the IC can enter the standby mode by detecting  $V_{DET2}$  forcefully with using the CTL pin, without lowering the battery voltage actually and minimize the consumption current.

It is required connecting the charger for the IC to release from the standby mode, but the DOUT pin retains Low while the CTL pin is driven to VSS even when connecting the charger.

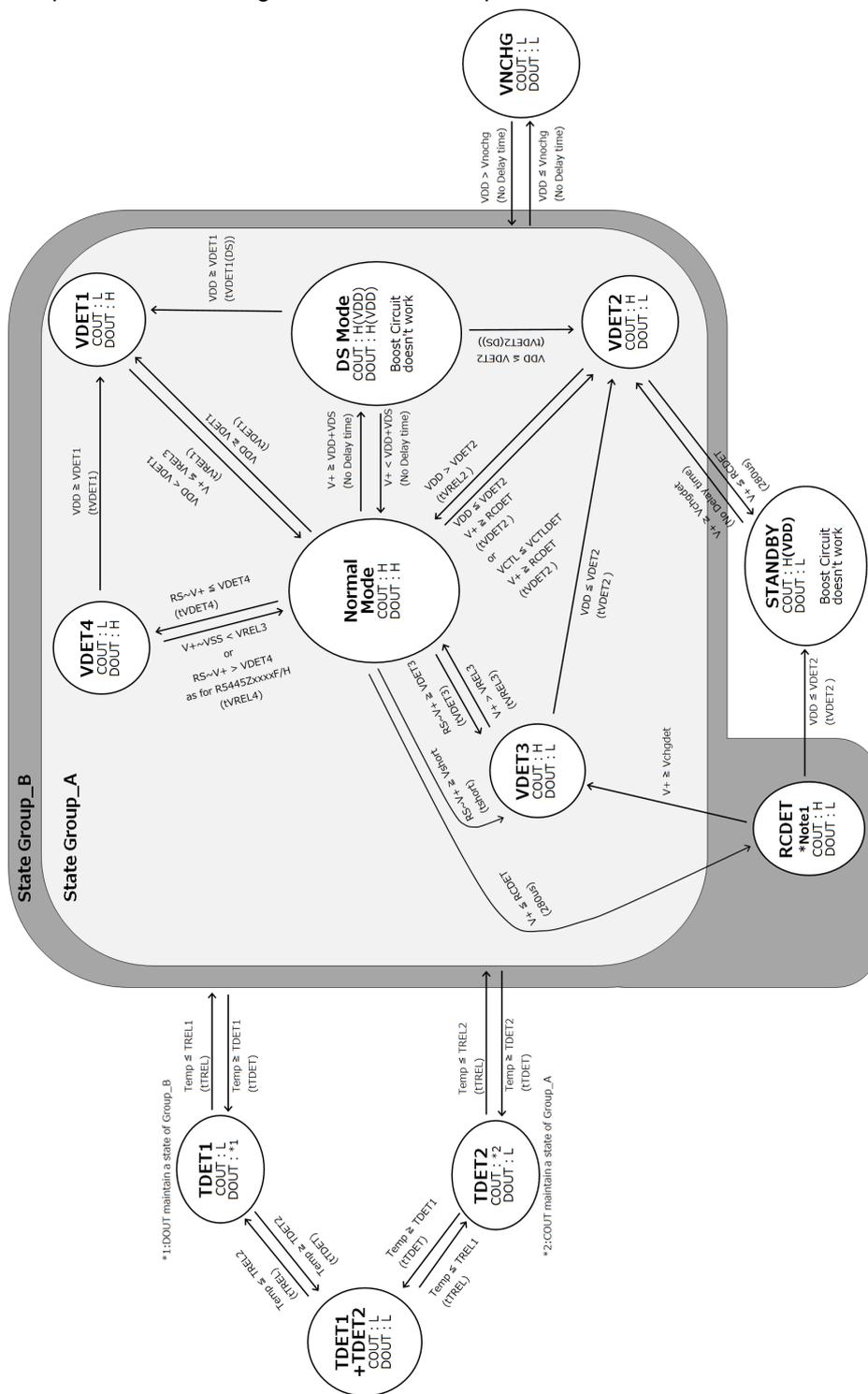
### **Voltage Boosting Circuit Function**

This IC has the built-in charge pump that boosts the high level of the COUT and the DOUT pins to about twice the VDD pin voltage. The charge pump stops when the IC enters the standby mode.

The boost voltage detection voltage ( $V_{BSTDET}$ ) can detect whether or not each voltage of the COUT and the DOUT pins is boosted.

State Diagram

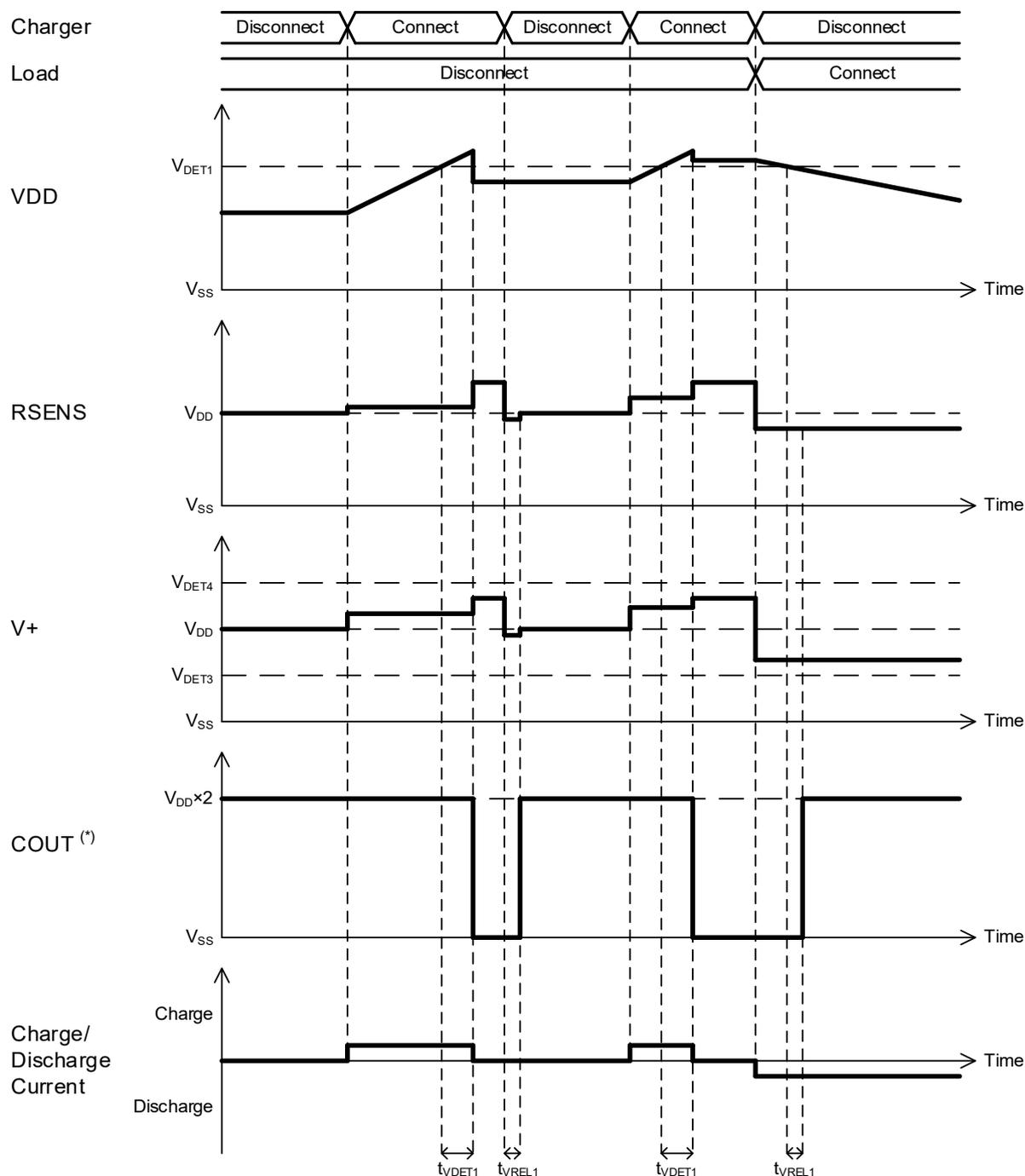
Unless otherwise provided, the voltage indicates with respect to VSS.



\*Note1:  
RcDET is the reverse connection detection of the charger.  
This function is not guaranteed because voltage above the absolute maximum rating may apply to IC.

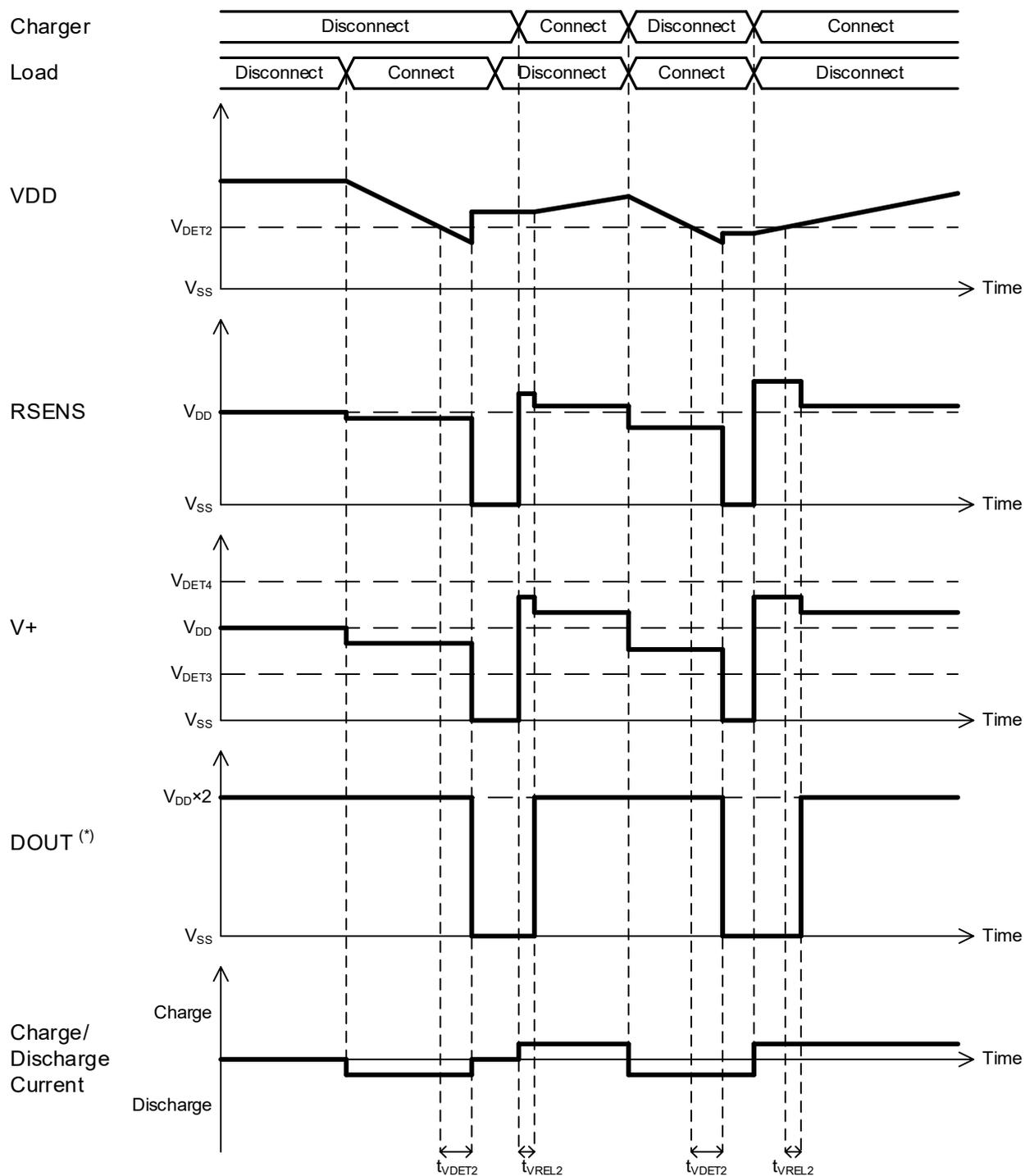
## Timing Diagrams

The following show timing charts when using the current sensing resistor. When using the current sensing FET, timing charts for RSENS and VDD pins become the same.



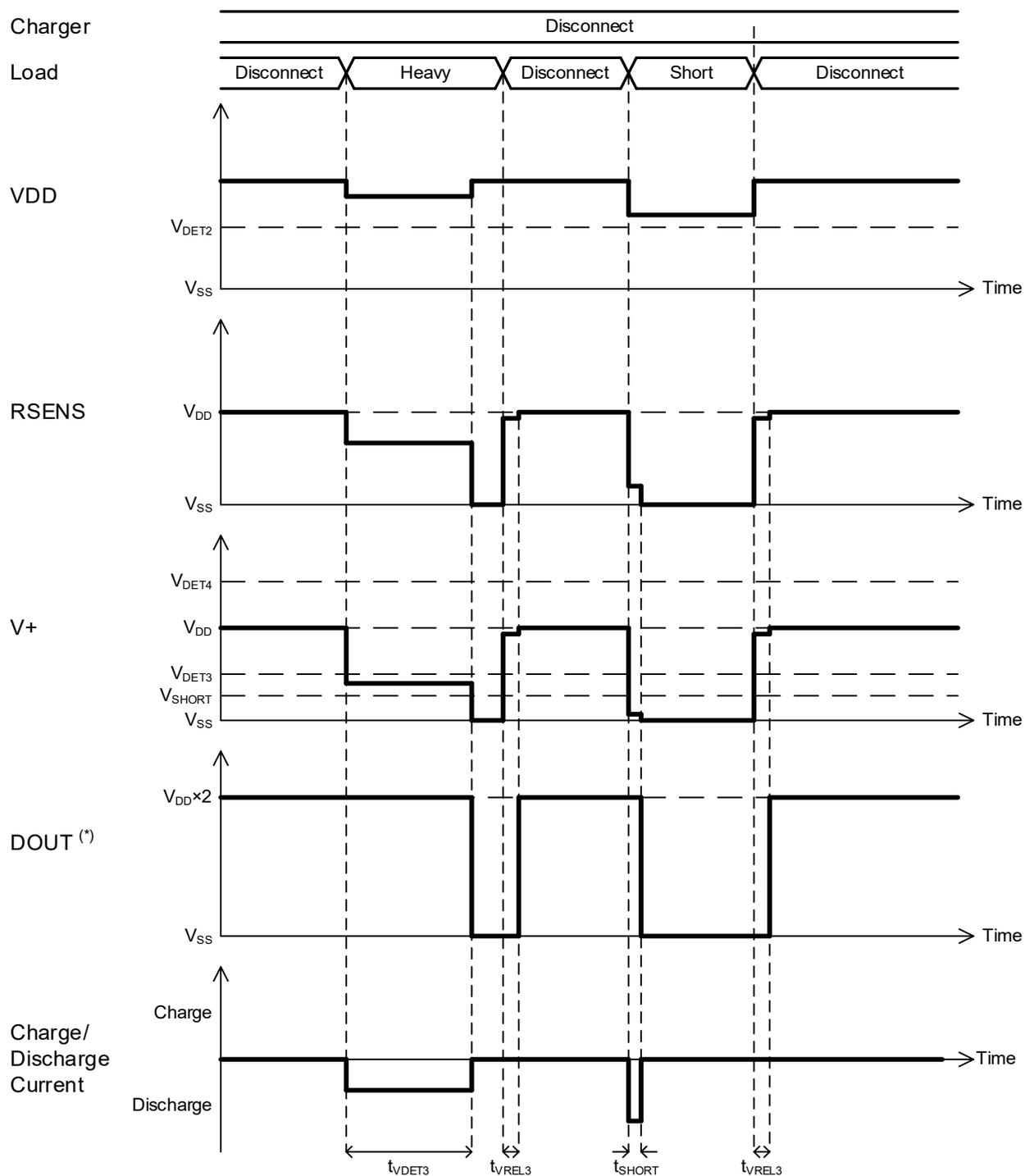
Overcharge Detector (VD1) Timing Diagram

(\*) The COUT pin output is an approximate value of  $V_{DD} \times 2$  but it is simplified to draw with a square wave in the diagram.



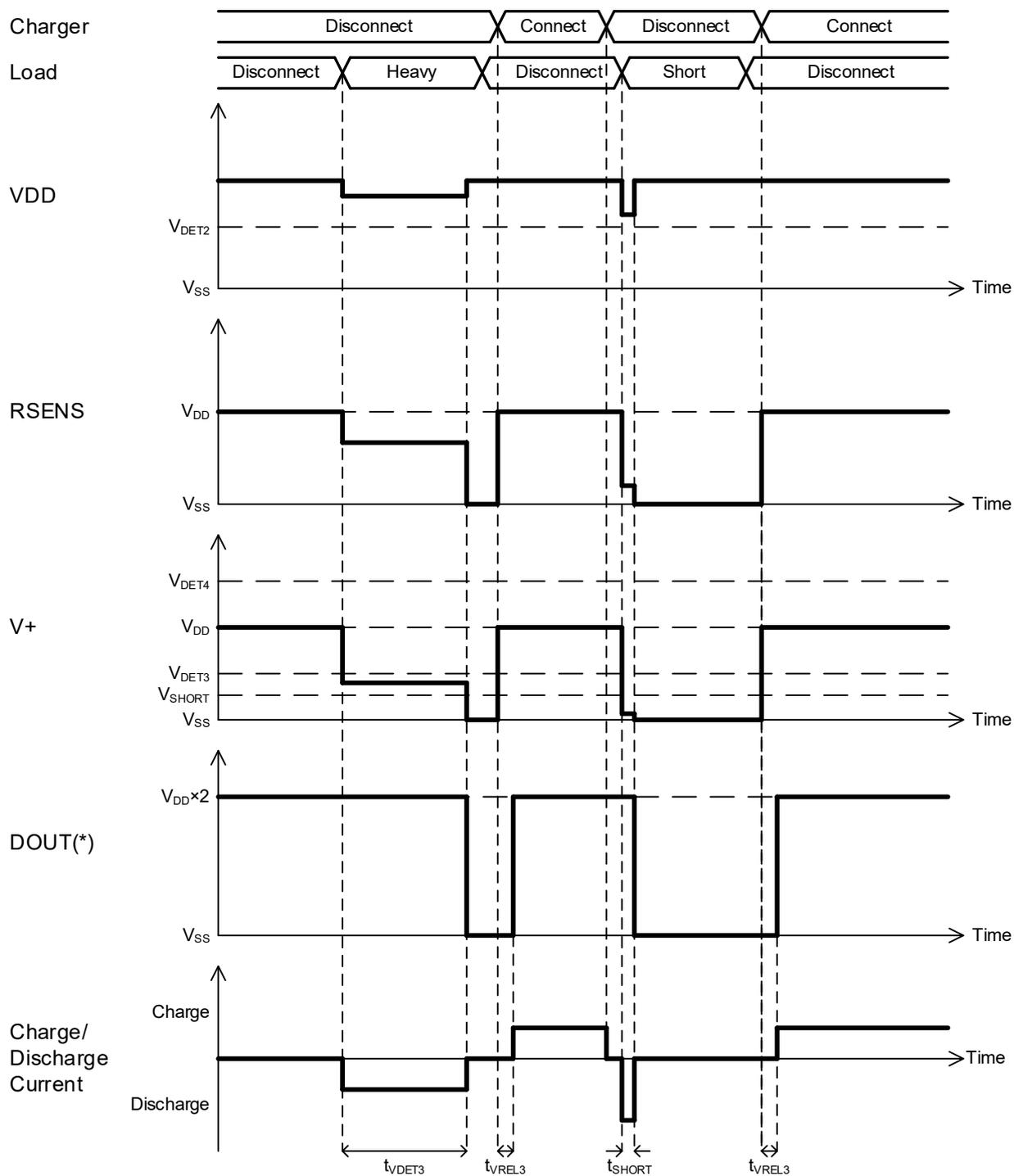
Overdischarge Detector (VD2) Timing Diagram

(\*) The DOUT pin output is an approximate value of  $V_{DD} \times 2$  but it is simplified to draw with a square wave in the diagram.



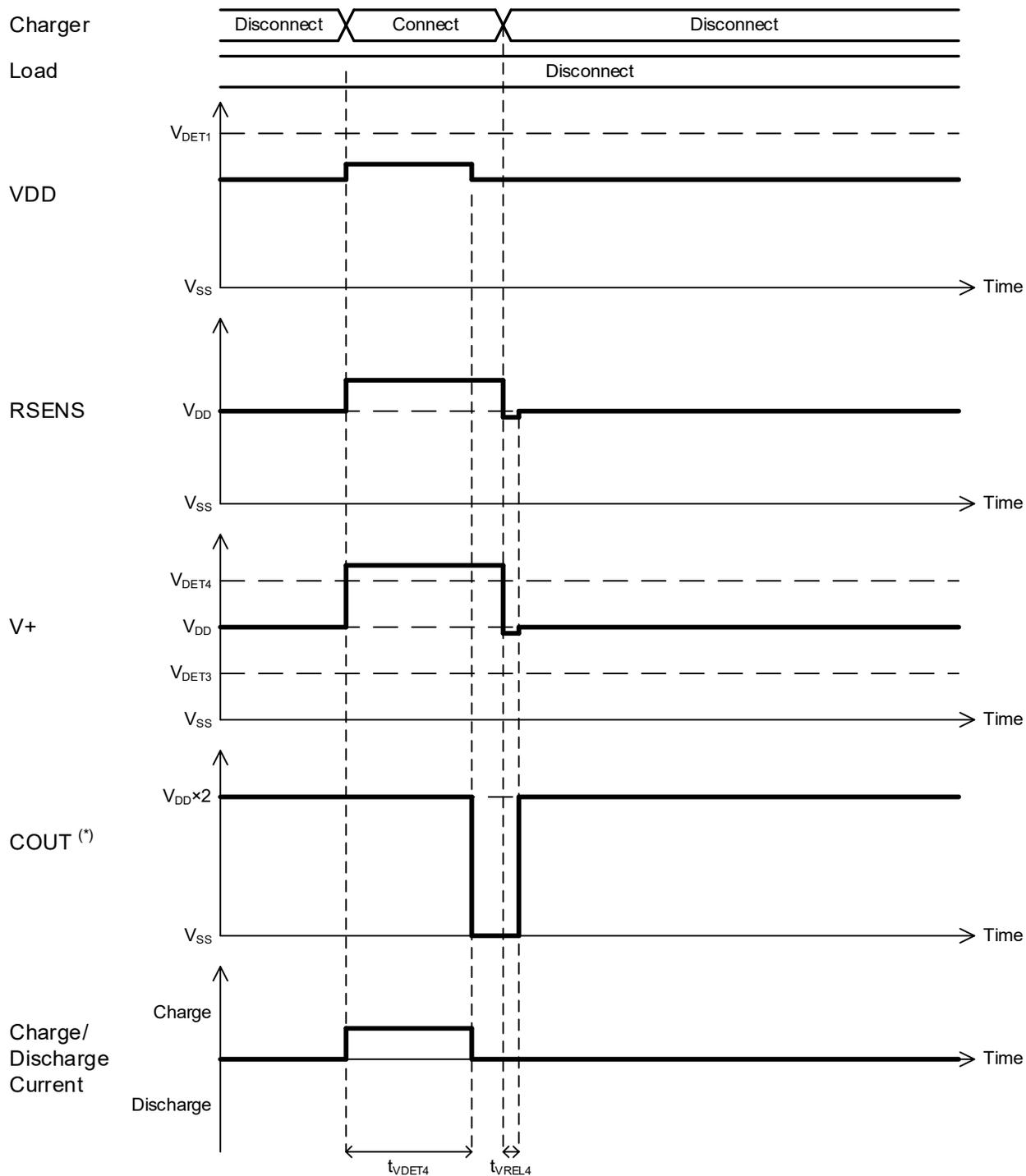
**Discharge Overcurrent Detector (VD3 Auto Release Type) and Short-circuit Timing Diagram**

(\*) The DOUT pin output is an approximate value of  $V_{DD} \times 2$  but it is simplified to draw with a square wave in the diagram.



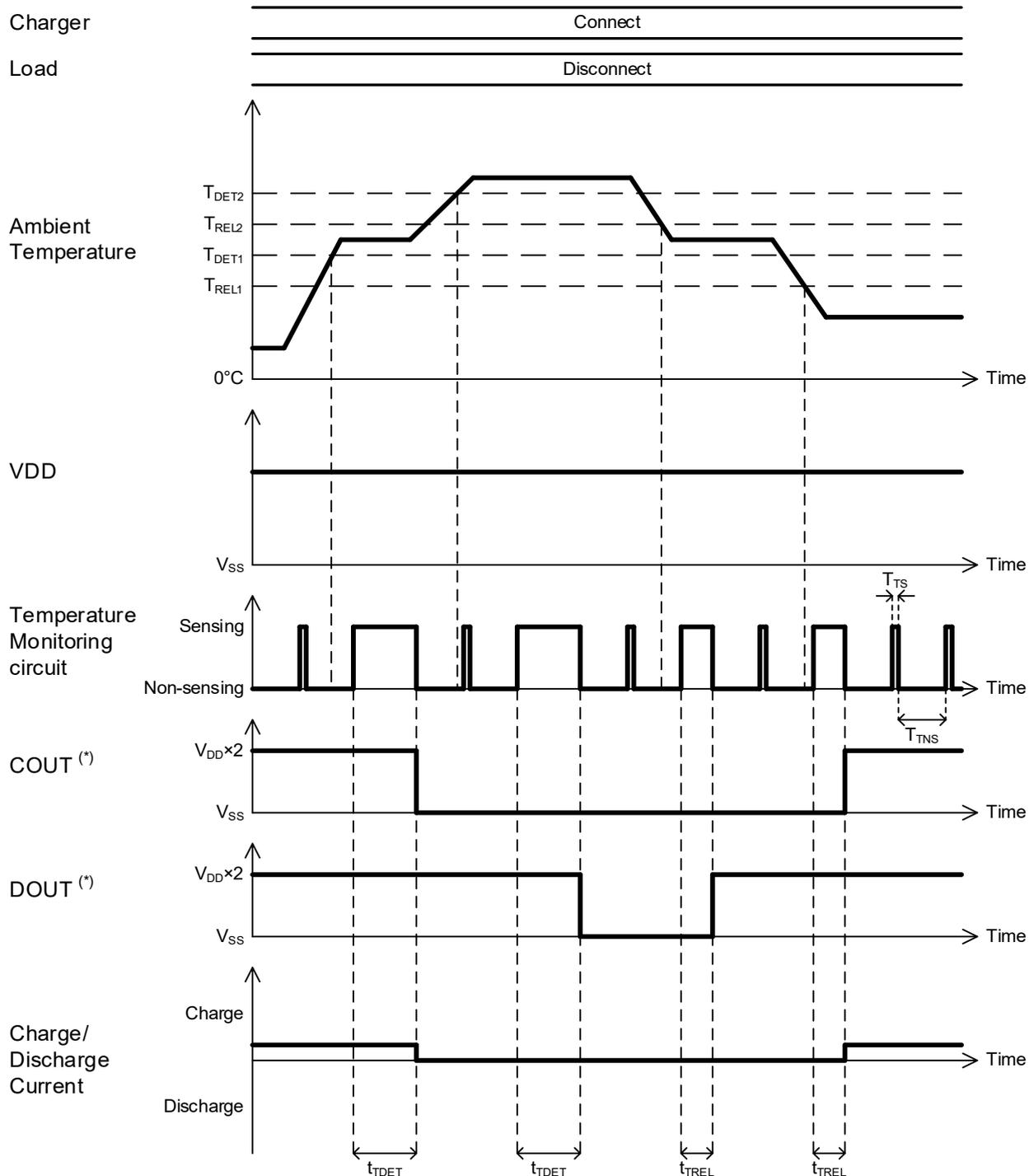
**Discharge Overcurrent Detector (VD3 Latch Type) and Short-circuit Timing Diagram**

(\*) The DOUT pin output is an approximate value of  $V_{DD} \times 2$  but it is simplified to draw with a square wave in the diagram.



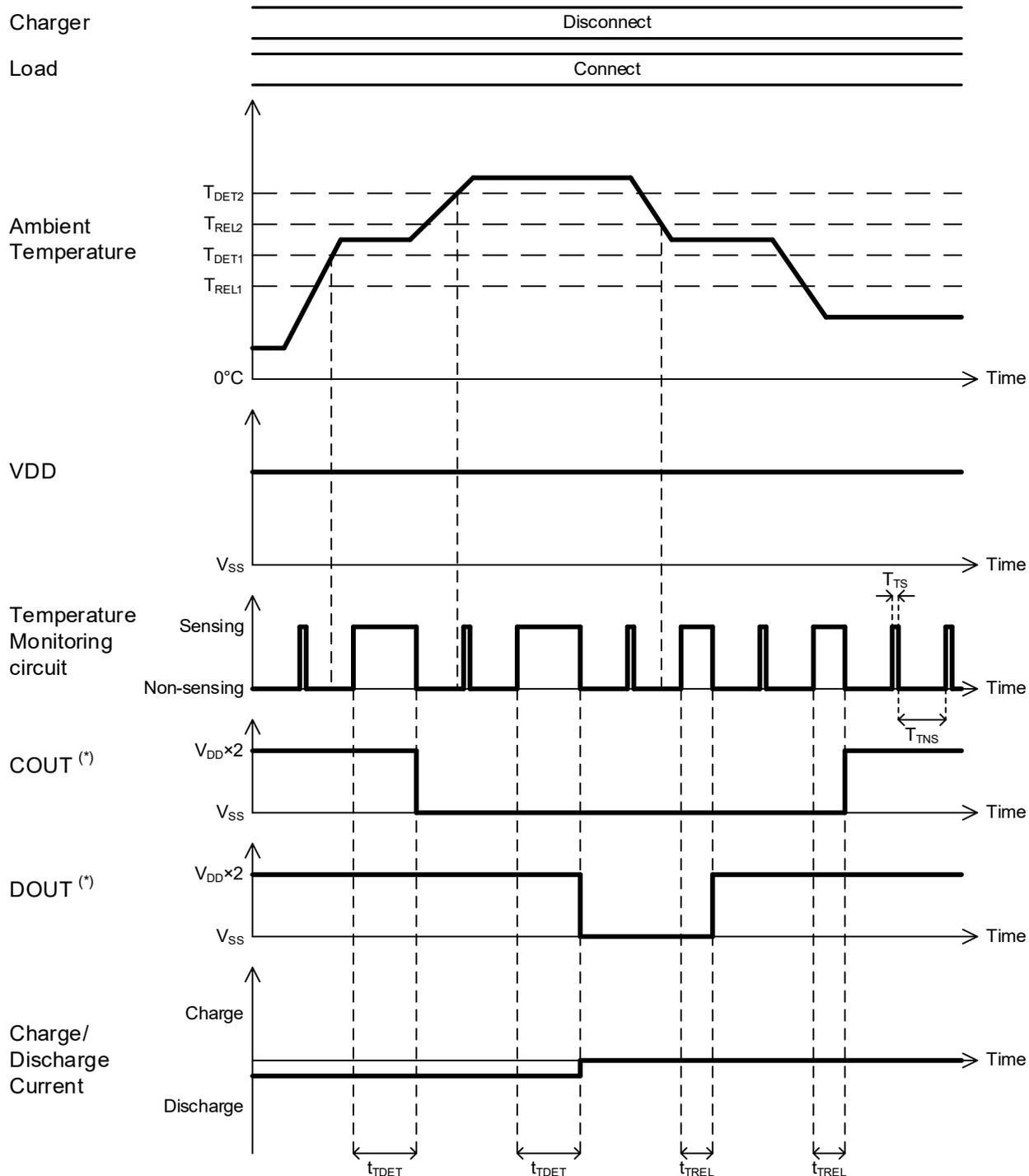
Charge Overcurrent Detector (VD4) Timing Diagram

(\*) The COUT pin output is an approximate value of  $V_{DD} \times 2$  but it is simplified to draw with a square wave in the diagram.



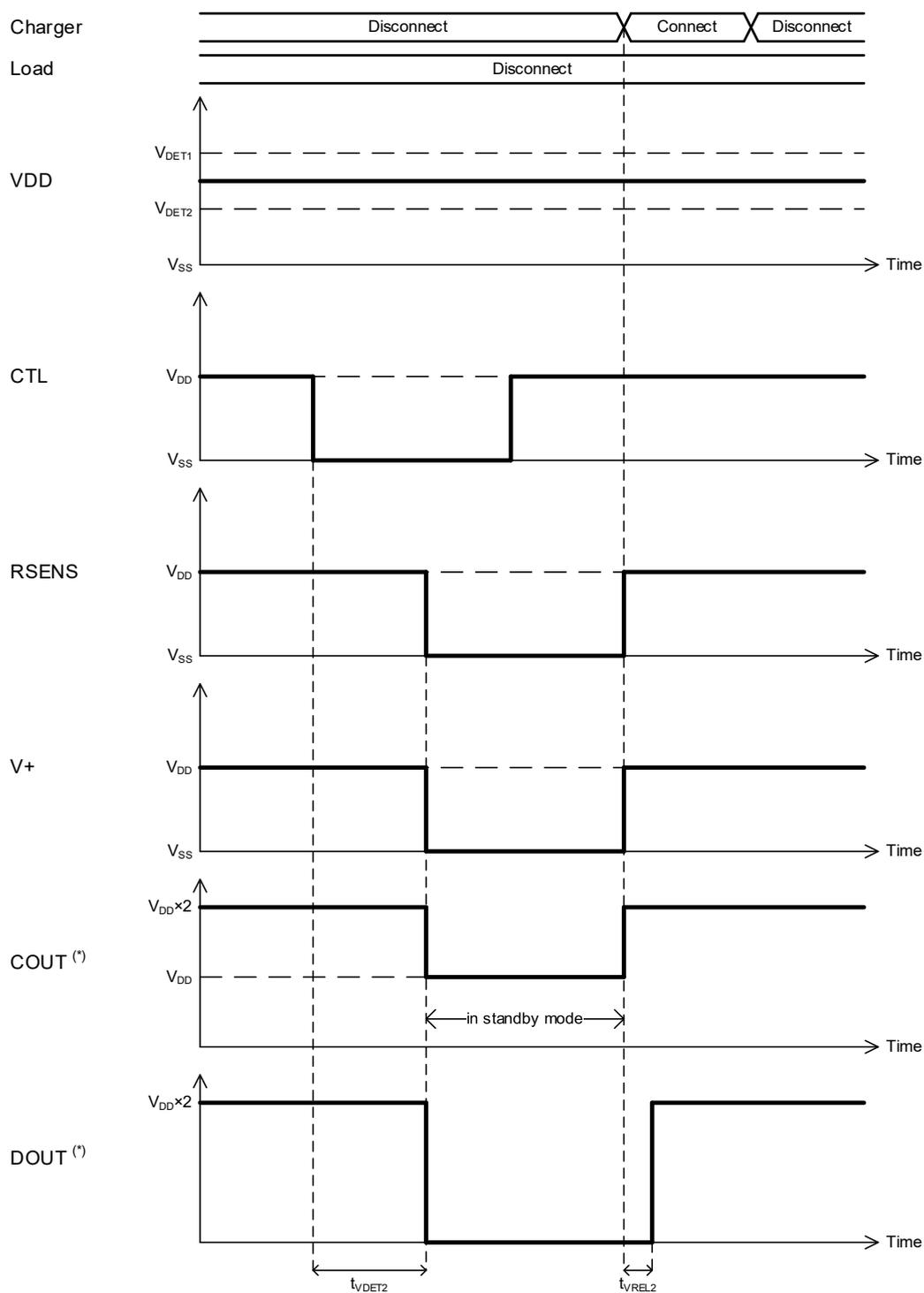
**Thermal Protection ( $T_{DET1}$ ,  $T_{DET2}$ ) with Charger Timing Diagram**

(\*) Each output of the COUT and the DOUT pins is an approximate value of  $V_{DD} \times 2$  but it is simplified to draw with a square wave in the diagram.



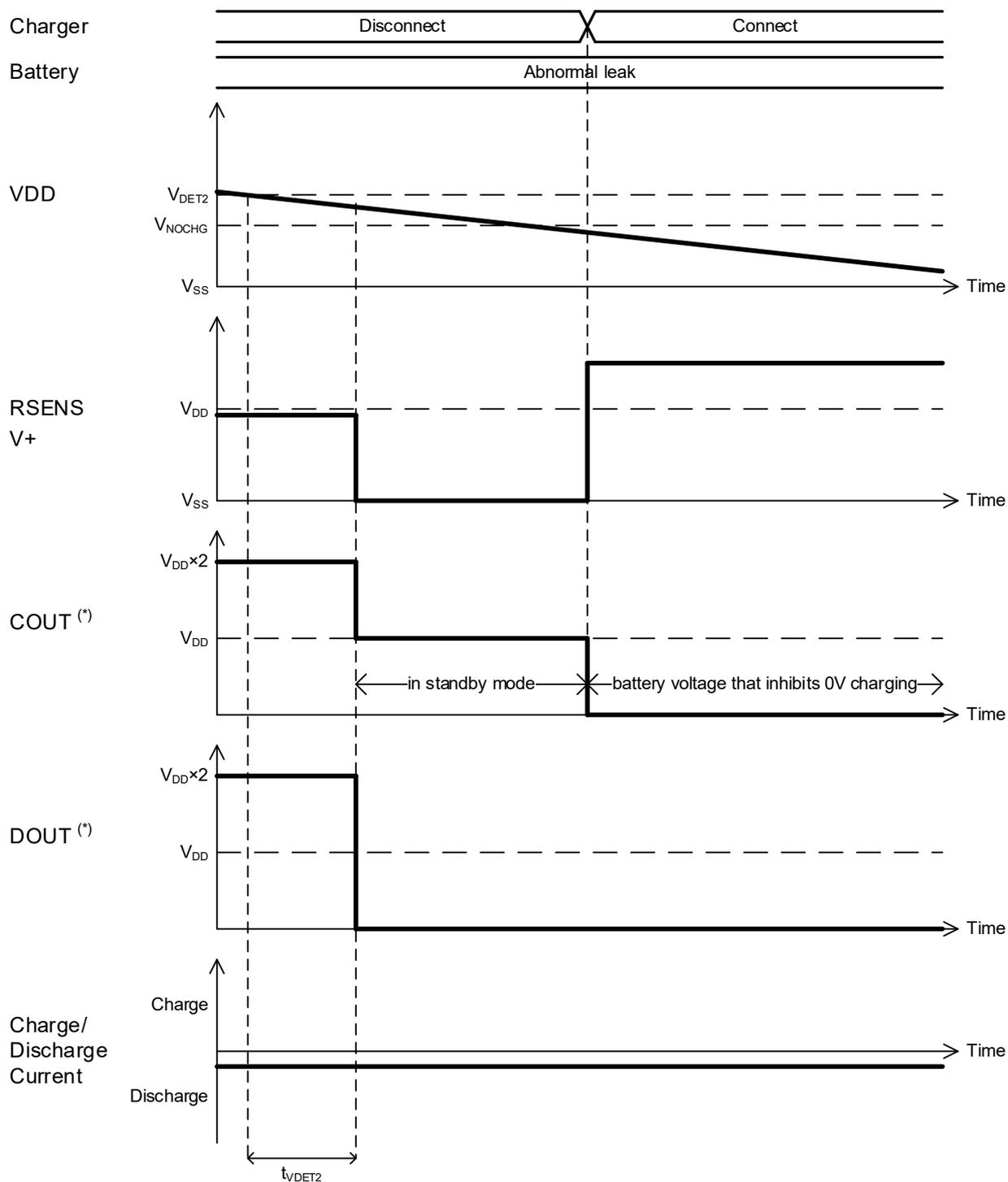
Thermal Protection ( $T_{DET1}$ ,  $T_{DET2}$ ) with Load Timing Diagram

(\*) Each output of the COUT and the DOUT pins is an approximate value of  $V_{DD} \times 2$  but it is simplified to draw with a square wave in the diagram.



**$V_{DET2}$  Forced Detection by CTL Pin Timing Diagram**

(\*) Each output of the COUT and the DOUT pins is an approximate value of  $V_{DD} \times 2$  but it is simplified to draw with a square wave in the diagram.

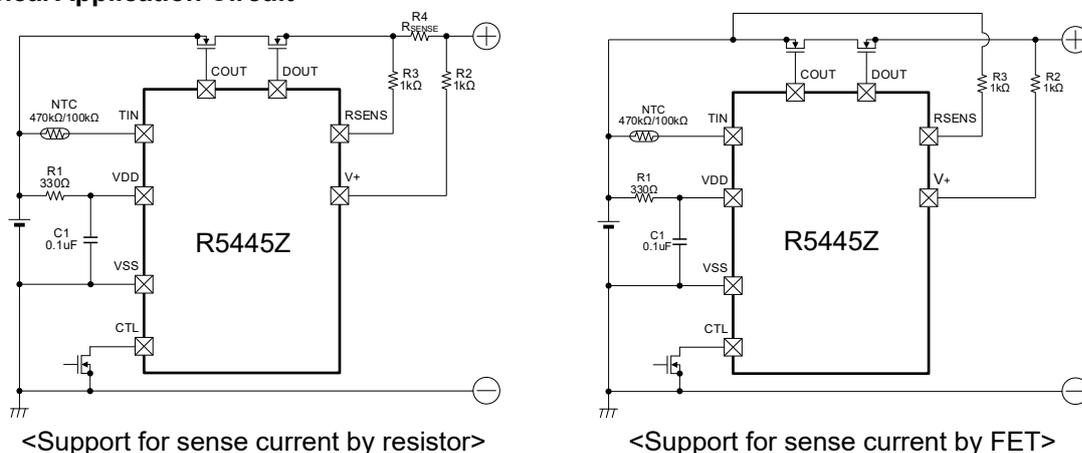


Maximum Operating Voltage at Charging Inhibition ( $V_{NOCHG}$ ) Timing Diagram

(\*) Each output of the COUT and the DOUT pins is an approximate value of  $V_{DD} \times 2$  but it is simplified to draw with a square wave in the diagram.

## APPLICATION INFORMATION

### Typical Application Circuit



<Support for sense current by resistor>

<Support for sense current by FET>

**R5445Z Typical Application Circuit Diagrams**

R1 and C1 stabilize a supply voltage to this IC. A recommended R1 value is less than 330Ω. A large value of R1 makes detection voltage shift higher because of conduction current flowed in the IC. Further, to stabilize the IC operation, use the C1 with the value of 0.01μF or more.

R2 also operate as parts that protect the IC by limiting the current that flows inside the IC when reverse charging occurs. While small value of R2 may cause over the power dissipation rating of the IC. Besides, if large value of R2 is set, release from overdischarge by connecting a charger might not be possible and overcurrent detection accuracy gets worse. Recommended R2 value is 1kΩ.

R3 is used for the same purpose as R2. R4 is a resistor for sensing an overcurrent. If the resistance value is too large, power loss becomes also large. By the overcurrent, if the R4 is not appropriate, the power loss may be beyond the power dissipation of R4. Choose an appropriate R4 according to the cell specification.

This IC requires an NTC thermistor having following characteristics.

#### NTC performance

Product Name	R5445Zxxxxx	
Vendor	muRata	
Part Number	NCP02WF474F05RH	NCP03WF104F05RL
Resistance	470kΩ±1% (25°C)	100kΩ±1% (25°C)
B-Constant	4250K±1%	

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.

Overvoltage and the overcurrent beyond the absolute maximum rating should not be forced to the protection IC and external components.

Although the short protection circuit is built in the IC, if the positive terminal and the negative terminal of the battery pack are short, during the delay time of short limit detector, large current flows through the FET. Select an appropriate FET with large enough current capacity to prevent the IC from burning damage.

The power dissipation of the package is dependent on PCB material, layout, and environmental conditions. The following measurement conditions are based on JEDEC STD. 51.

**Measurement Conditions**

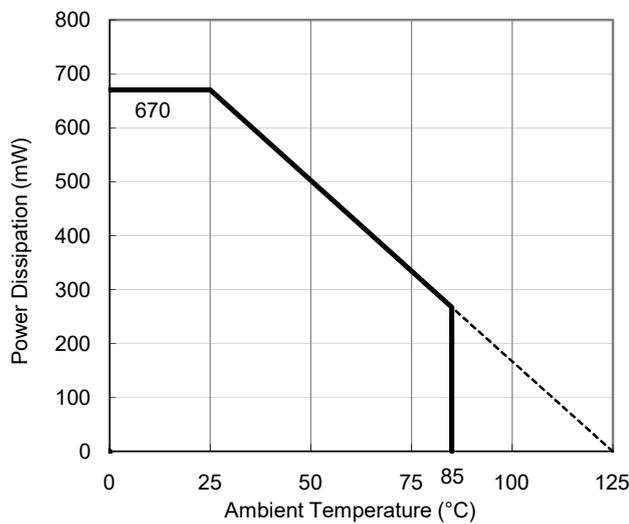
Item	Measurement Conditions
Environment	Mounting on Board (Wind Velocity = 0 m/s)
Board Material	Glass Cloth Epoxy Plastic (Four-Layer Board)
Board Dimensions	101.5 mm x 114.5 mm x 1.6 mm
Copper Ratio	Outer Layer (First Layer): 10% Inner Layers (Second and Third Layers): 99.5 x 99.5mm 100% Outer Layer (Fourth Layer): 10%

**Measurement Result**

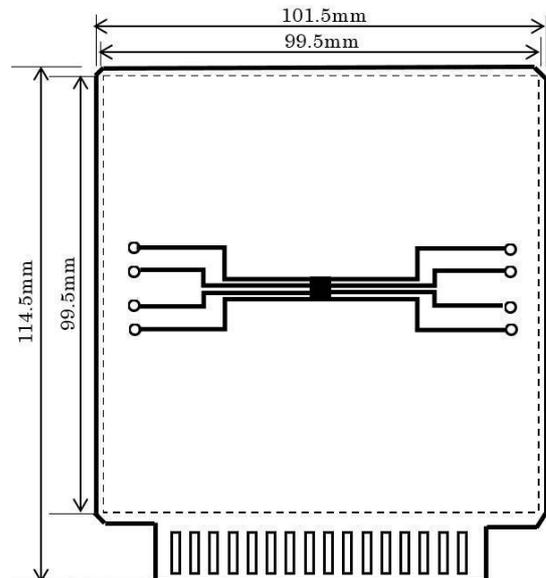
(Ta = 25°C, Tjmax = 125°C)

Item	Measurement Result
Power Dissipation	670 mW
Thermal Resistance ( $\theta_{ja}$ )	$\theta_{ja} = 149^{\circ}\text{C/W}$

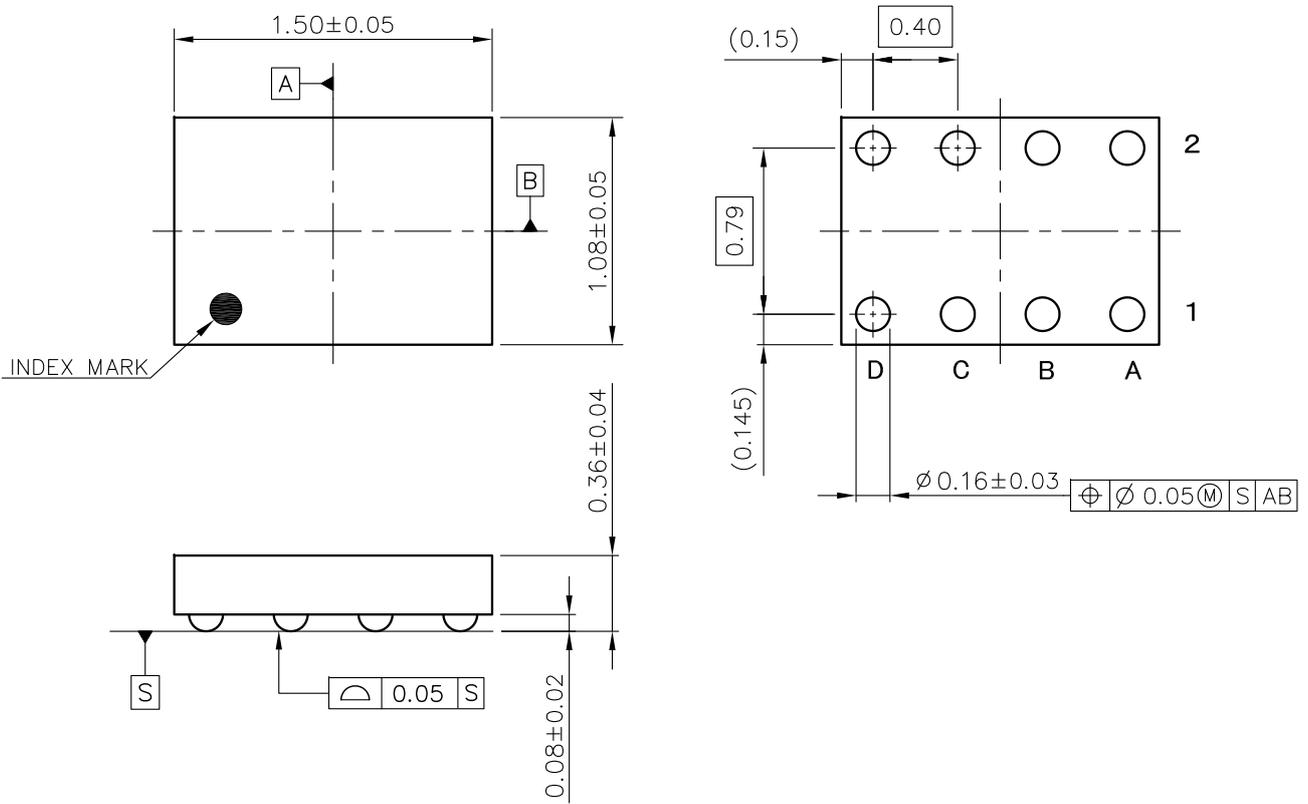
$\theta_{ja}$ : Junction-to-Ambient Thermal Resistance



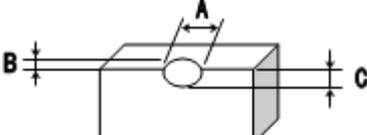
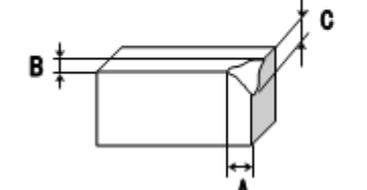
**Power Dissipation vs. Ambient Temperature**



**Measurement Board Pattern**



WLCSP-8-P4 Package Dimensions

No.	Inspection Items	Inspection Criteria	Figure
1	Package chipping	<p><math>A \geq 0.2\text{mm}</math> is rejected  <math>B \geq 0.2\text{mm}</math> is rejected  <math>C \geq 0.2\text{mm}</math> is rejected                      And, Package chipping to Si surface and to bump is rejected.</p>	
2	Si surface chipping	<p><math>A \geq 0.2\text{mm}</math> is rejected  <math>B \geq 0.2\text{mm}</math> is rejected  <math>C \geq 0.2\text{mm}</math> is rejected                      But, even if <math>A \geq 0.2\text{mm}</math>, <math>B \leq 0.1\text{mm}</math> is acceptable.</p>	
3	No bump	No bump is rejected.	
4	Marking miss	To reject incorrect marking, such as another product name marking or another lot No. marking.	
5	No marking	To reject no marking on the package.	
6	Reverse direction of marking	To reject reverse direction of marking character.	
7	Defective marking	To reject unreadable marking. (Microscope: X15/ White LED/ Viewed from vertical direction)	
8	Scratch	To reject unreadable marking character by scratch. (Microscope: X15/ White LED/ Viewed from vertical direction)	
9	Stain and Foreign material	To reject unreadable marking character by stain and foreign material. (Microscope: X15/ White LED/ Viewed from vertical direction)	



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