RICOH

R5613L Series

One-cell Li-ion Battery Protection IC with High-accuracy Overcurrent Detection and Selectable RESET Function

NO.EA-525-210831

OVERVIEW

The R5613L is a one-cell Li- ion / polymer battery protection IC providing overcharge, overdischarge and charge-/discharge-overcurrent detections. Major features of this device include charge-/discharge-overcurrent detectors with high-accuracy of ±1.0 mV and the RST pin function which can switch for an external MOSFET to either a RESET or a forced-standby state.

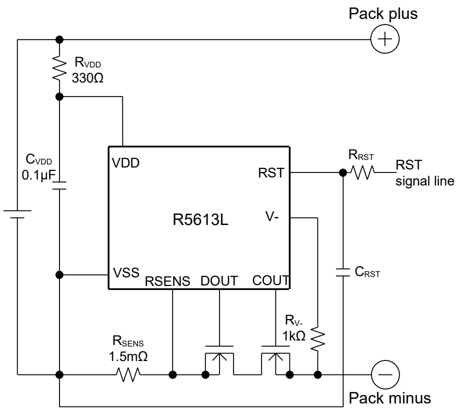
KEY BENEFITS

- Lower-resistance of Sense Resistor by Overcurrent Detector with Lower-voltage and High-accuracy: Achieving Heat Reduction on Board
- Low Consumption Current and Low Standby Current: Achieving Longer Driving Time with A Battery of Small Capacity
- Switching to RESET or Forced-standby State by RST Pin: Allowed External Control of Load

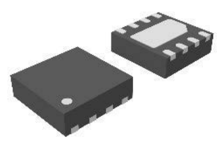
KEY SPECIFICATIONS

- Supply Current
  Normal Mode: Typ. 2.5 µA / Max. 4.8 µA
  (Only when selected 0 V Battery Charging “Inhibition” and Discharge Overcurrent Detection with Two-level),
  Typ. 2.0 µA / Max. 4.0 µA
  (Except for the above selection)
  Standby Mode: Max.0.2 µA (V_{DET2}: Auto Release type)
  Max.0.04 µA (V_{DET2}: Latch type)
- Detector Selectable Range and Accuracy
  Overcharge detection voltage (V_{DET1}): 4.2 V to 4.7 V, ±20 mV,
  Overdischarge detection voltage (V_{DET2}): 2.1 V to 3.2 V, ±35 mV
  Discharge overcurrent detection voltage1 (V_{DET31}):
  0.0070 V to 0.0300 V, ±1 mV
  Discharge overcurrent detection voltage2 (V_{DET32}):
  0.011 V to 0.060 V, ±2 mV
  Charge overcurrent detection voltage (V_{DET4}):
  -0.0070 V to -0.0300 V, ±1 mV
  Short-circuit detection voltage (V_{SHORT1}):
  $0.030\ V \le V_{SHORT1} \le 0.120\ V$, ±4 mV
  $0.120\ V < V_{SHORT1} \le 0.200\ V$, ±5 mV
- RST Pin Function type selectable: RESET / Forced-standby type
- 0 V Battery Charging: Permission / Inhibition
  0 V Charge Inhibition Voltage: 1.000 / 1.200 / 1.500 / 2.200 / 2.350 V
- Overcharge / Overdischarge Release Voltage Type selectable:
  Auto Release / Latch
- Discharge Overcurrent Release Voltage Type selectable:
  Auto Release1 (V- = V_{DD}×0.8 V) / Auto Release2 (V- = 0.1 V) / Latch
- Discharge Overcurrent Detection having two-level voltage detection (V_{DET31}/V_{DET32}) selectable: Enable / Disable

TYPICAL APPLICATION CIRCUIT



PACKAGE



DFN1616-8B
1.6 mm x 1.6 mm x 0.4 mm

APPLICATIONS

- Smart Phone, Tablet PC
- Game, Hearing Aid

SELECTION GUIDE

Set Output Voltages, Delay Times, and Optional Functions are user-selectable.

Selection Guide

Product Name	Package	Quantity per Reel	Pb Free	Halogen Free
R5613Lxxx$∗-TR	DFN1616-8B	5,000 pcs	Yes	Yes

xxx: Specify a code that combines the following set output voltages. Refer to *Product Code List* for details.

Overcharge Detection Voltage (V_{DET1}): 4.2 V to 4.7 V in 5 mV step
Overcharge Release Voltage (V_{REL1}): 4.0 V to 4.5 V in 5 mV step
Overdischarge Detection Voltage (V_{DET2}) (1): 2.1 V to 3.2 V in 50 mV step
Overdischarge Release Voltage (V_{REL2}): 2.3 V to 3.2 V in 50 mV step
Discharge Overcurrent Detection Voltage 1 (V_{DET31}) (2): 0.0070 V to 0.0300 V in 0.5 mV step
Discharge Overcurrent Detection Voltage 2 (V_{DET32}) (2): 0.011 V to 0.060 V in 0.5 mV step
Short-Circuit Detection Voltage (V_{SHORT1}) (2): 0.030 V to 0.200 V in 0.5 mV step
Charge Overcurrent Detection Voltage (V_{DET4}): -0.0070 V to -0.0300 V in 0.5mV step
0 V Charge Inhibition Voltage (V_{NOCHG}): 1.000 V / 1.200 V / 1.500 V / 2.200 V / 2.350 V
RST Pin Function Detection Voltage (V_{RDET}): 0.800 V / 1.200 V

$: Specify a code that combines the following delay times. Refer to *Delay Time Code Table* for details.

Overcharge Detection / Release Delay Time (t_{VDET1} / t_{VREL1})
Overdischarge Detection / Release Delay Time (t_{VDET2} / t_{VREL2})
Discharge Overcurrent Delay Time1/2 (t_{VDET31} / t_{VDET32})
Discharge Overcurrent Release Delay Time (t_{VREL3})
Charge Overcurrent Detection / Release Delay Time (t_{VDET4} / t_{VREL4})
Reset Detection / Release Delay Time (t_{RST}/ t_{RREL})

Delay Time Code Table

Code	t_{VDET1} [ms]	t_{VREL1} [ms]	t_{VDET2} [ms]	t_{VREL2} [ms]	t_{VDET31} [ms]	t_{VDET32} [ms]	t_{VREL3} [ms]	t_{VDET4} [ms]	t_{VREL4} [ms]	t_{SHORT} [ms]	t_{RST} [ms]	t_{RREL} [ms]
A	1024	1.2	64	1.2	3584	16	8.5	17	4	0.28	50	32
D	1024	16	32	1.2	4096	12	8.5	17	4	0.28	50	48
E	1024	16	20	1.2	12	-	8.5	17	4	0.28	50	32
F	1024	16	20	1.2	5120	12	8.5	17	4	0.28	50	48
G	1024	16	128	1.2	16	-	8.5	9	4	0.28	50	32

(1) In the case of 0 V Charging Prohibition (R5613LxxxxD/E/G), set the set output voltage of V_{DET2} to meet V_{DET2} > V_{NOCHG} in consideration of their output voltage accuracy.
(2) When selecting each set output voltage of V_{DET31}, V_{DET32} and V_{SHORT1}, keep from overlapping among them in consideration of their output voltage accuracy. Especially, V_{SHORT1} should be higher than 7.5 mV from V_{DET31} and V_{DET32}.

∗: Specify a code that combines the following functions. Refer to *Function Code Table* for details.

Function Code Table

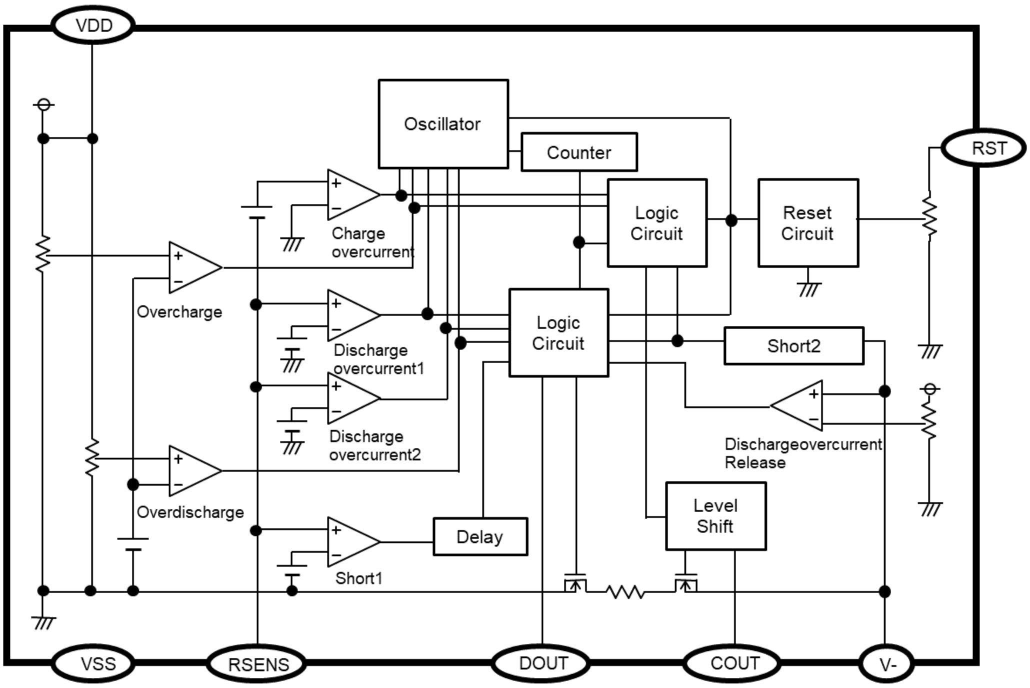
Code	RST Pin Function	RST Pin Function Detection Voltage (V_{RDET})	Overcharge Release	Overdischarge Release	Discharge Overcurrent		0 V Battery Charging	0 V Battery Charging Inhibition Voltage (V_{NOCHG})
					Release	Detection (V_{DET32})		
A	RESET	1.200 V	Auto Release	Auto Release	Auto Release1	Available	Permission	−
C	RESET	1.200 V	Auto Release	Auto Release	Auto Release1	Unavailable	Permission	−
D	RESET	1.200 V	Auto Release	Auto Release	Auto Release1	Unavailable	Inhibition	1.000 V to 2.200 V
E	Forced-standby	0.800 V	Latch	Latch	Auto Release2	Available	Inhibition	1.000 V to 2.200 V
G	Forced-standby	0.800 V	Latch	Latch	Latch	Unavailable	Inhibition	2.350 V

Product Code List

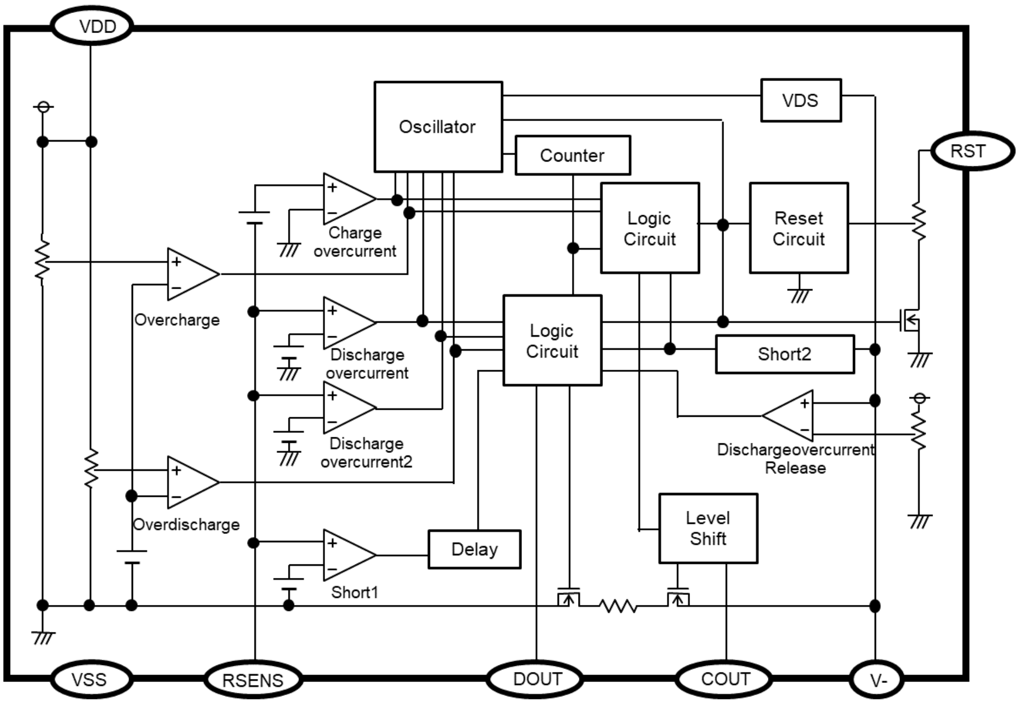
Product Code Table

Product Name	Set Output Voltage [V]								
	V_{DET1}	V_{REL1}	V_{DET2}	V_{REL2}	V_{DET31}	V_{DET32}	V_{SHORT1}	V_{DET4}	V_{NOCHG}
R5613L**101**AA	4.445	4.295	2.350	2.550	0.0105	0.0150	0.0400	-0.0150	−
R5613L**102**DE	4.280	−	2.900	−	0.0100	0.0150	0.0500	-0.0100	2.200
R5613L**102**FE	4.280	−	2.900	−	0.0100	0.0150	0.0500	-0.0100	2.200
R5613L**103**EC	4.445	4.295	2.350	2.550	0.0105	−	0.0400	-0.0150	−
R5613L**104**ED	4.445	4.295	2.350	2.550	0.0105	−	0.0400	-0.0150	1.200
R5613L**106**AA	4.475	4.325	2.350	2.550	0.0105	0.0150	0.0400	-0.0150	−
R5613L**107**GG	4.450	−	3.200	−	0.0150	−	0.0400	-0.0150	−
R5613L**108**AA	4.445	4.295	2.350	2.550	0.0150	0.0195	0.0420	-0.0150	−
R5613L**109**GG	4.285	−	2.750	−	0.0100	−	0.1000	-0.0100	−
R5613L**110**ED	4.280	4.240	2.300	2.500	0.0200	−	0.0600	-0.0200	1.200
R5613L**111**DE	4.275	−	2.900	−	0.0300	0.0180	0.1750	-0.0130	2.200
R5613L**112**AA	4.475	4.325	2.350	2.550	0.0150	0.0200	0.0560	-0.0190	−
R5613L**113**GG	4.240	−	3.100	−	0.0225	−	0.0300	-0.0160	−
R5613L**114**EC	4.275	4.075	2.300	2.500	0.0175	−	0.0840	-0.0150	−
R5613L**115**GG	4.375	−	2.750	−	0.0220	−	0.0500	-0.0160	2.350

BLOCK DIAGRAMS

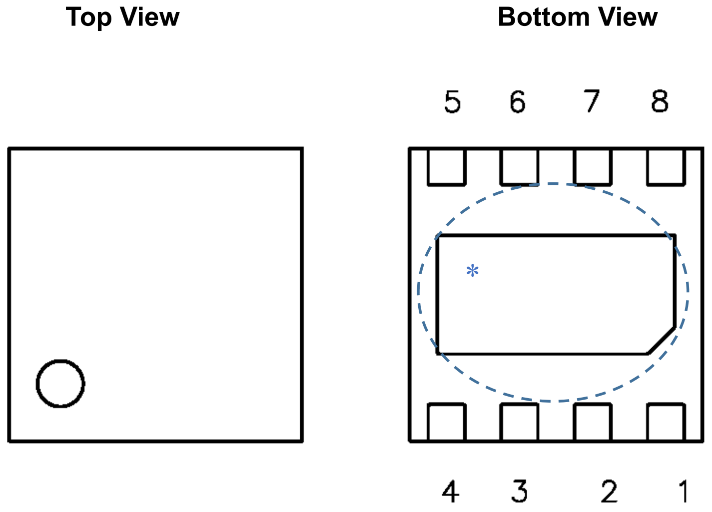


R5613L (RESET type) Block Diagram



R5613L (Forced-standby type) Block Diagram

PIN DESCRIPTION



R5613L (DFN1616-8B) Pin Configuration

R5613L Pin Description

Pin No	Symbol	Pin Description
1	RST	RESET / Forced-Standby state input pin
2	V-	Charge negative input pin
3	COUT	Charge detection output pin, CMOS output
4	DOUT	Discharge detection output pin, CMOS output
5	VSS	Ground pin for the IC
6	VDD	Power supply pin, the substrate level of the IC
7	RSENS	Overcurrent detection input pin
8	NC	No connection

* The tab on the bottom of the package is substrate level (V_{DD}). It is recommended that the tab be connected to the VDD pin on the board, or otherwise be left floating.

RICOH

ABSOLUTE MAXIMUM RATINGS

(Ta = 25°C, V_{SS} = 0V)

Symbol	Item	Rating	Unit
V_{DD}	Supply voltage	-0.3 to 12	V
V-	V- pin input voltage	V_{DD}-30 to V_{DD}+0.3	V
V_{RSENS}	RSENS pin input voltage	V_{SS}-0.3 to V_{DD}+0.3	V
V_{RST}	RST pin input voltage	V_{SS}-0.3 to V_{DD}+0.3	V
V_{COUT}	COUT pin output voltage	V_{DD}-30 to V_{DD}+0.3	V
V_{DOUT}	DOUT pin output voltage	V_{SS}-0.3 to V_{DD}+0.3	V
P_D	Power Dissipation	Refer to Appendix "Power Dissipation"	
Tj	Junction Temperature Range	-40 to 125	°C
Tstg	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 operations at or over these absolute maximum ratings are not assured.

RECOMMENDED OPERATING CONDITION

Symbol	Item	Rating	Unit
V_{DD}	Operating Input Voltage	1.5 to 5.0	V
Ta	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

R5613LxxxXX Electrical Characteristics **(Ta = 25°C)**

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit	Circuit [1]
V_{DD1}	Operating input voltage	V_{DD}-V_{SS}		1.5		5.0	V	A
V_{STCHG}	Minimum charging voltage for 0 V battery charger [2]	V_{DD}-V-, V_{DD}-V_{SS} = 0V				1.8	V	A
V_{NOCHG}	0 V battery charging inhibition voltage [3]	V_{DD}-V_{SS} V_{DD}-V- =4V	V_{NOCHG} ≤ 1.500V	V_{NOCHG} -0.25	V_{NOCHG}	V_{NOCHG} +0.25	V	A
			V_{NOCHG} = 2.200V	2.000	2.200	2.500		
			V_{NOCHG} = 2.350V	2.050	2.350	2.550		
V_{DET1}	Overcharge detection voltage	R_{VDD} = 330Ω		V_{DET1} -0.020	V_{DET1}	V_{DET1} +0.020	V	B
V_{REL1}	Overcharge release voltage	R_{VDD} = 330Ω		V_{REL1} -0.045	V_{REL1}	V_{REL1} +0.045	V	B
t_{VDET1}	Overcharge detection delay time	V_{DD} = 3.6V → V_{DET1}+0.1V		t_{VDET1} ×0.75	t_{VDET1}	t_{VDET1} ×1.30	s	C
t_{VREL1}	Overcharge release delay time	V_{DD} = 4.8V → V_{REL1}-0.1V	t_{VREL1} = 1.2ms	0.7	1.2	2.5	ms	C
			t_{VREL1} = 16ms	11.2	16	20.8		
V_{DET2}	Overdischarge detection voltage	Detect falling edge of supply voltage		V_{DET2} -0.035	V_{DET2}	V_{DET2} +0.035	V	D
V_{REL2}	Overdischarge release voltage	Detect rising edge of supply voltage		V_{REL2} -0.055	V_{REL2}	V_{REL2} +0.095	V	E
t_{VDET2}	Overdischarge detection delay time	V_{DD} = V_{DET2}+0.15V → V_{DET2}-0.1V		t_{VDET2} ×0.75	t_{VDET2}	t_{VDET2} ×1.30	ms	D
t_{VREL2}	Overdischarge release delay time	V_{DD} = V_{DET2}-0.2V → V_{REL2}+0.25 V		0.9	1.2	1.7	ms	E
V_{CHGDET}	Charger connection detection voltage	V_{DD} = V_{DET2}+0.020V, V_{RSENS} = 0V		0.500	0.800	1.100	V	A
V_{DET31}	Discharge overcurrent detection voltage 1	V_{DD} = 3.6V, V- = V_{RSENS}		V_{DET31} -0.0010	V_{DET31}	V_{DET31} +0.0010	V	F
t_{VDET31}	Discharge overcurrent 1 detection delay time	V_{DD} = 3.6V, V_{RSENS} = 0V → V_{DET31}+0.005V V- = V_{RSENS}		t_{VDET31} ×0.75	t_{VDET31}	t_{VDET31} ×1.30	ms	F
V_{DET32}	Discharge overcurrent detection voltage 2	V_{DD} = 3.6V, V- = V_{RSENS}		V_{DET32} -0.002	V_{DET32}	V_{DET32} +0.002	V	F
t_{VDET32}	Discharge overcurrent 2 detection delay time	V_{DD} = 3.6V, V_{RSENS} = 0V → V_{DET32}+0.005V V- = V_{RSENS}		t_{VDET32} ×0.75	t_{VDET32}	t_{VDET32} ×1.30	ms	F

(1) Refer to *TEST CIRCUITS* for detail information.
(2) 0 V battery charging permission supported product only
(3) 0 V battery charging inhibition supported product only

R5613LxxxXX Electrical Characteristics (Continued) **(Ta = 25°C)**

Symbol	Items	Conditions		Min.	Typ.	Max.	Unit	Circuit (1)
V_{SHORT1}	Short detection voltage 1	Detect rising edge of RSENS pin voltage, V_{DD} = 3.6V, V_{RSENS} = V-	0.030V ≤ V_{SHORT1} ≤ 0.120V	V_{SHORT1} -0.004	V_{SHORT1}	V_{SHORT1} +0.004	V	F
			0.120V < V_{SHORT1} ≤ 0.200V	V_{SHORT1} -0.005		V_{SHORT1} +0.005		
t_{SHORT}	Short detection delay time (2)	V_{DD} = 3.6V, V_{RSENS} = 0V → 1V, V- = V_{RSENS}		210	280	380	μs	F
V_{SHORT2}	Short detection voltage 2	Detect rising edge of V- pin voltage, V_{DD} = 3.6V, V_{RSENS} = 0V		V_{DD}×0.850 -0.050	V_{DD} ×0.850	V_{DD}×0.850 +0.050	V	F
V_{REL3}	Discharge overcurrent release voltage	V_{DD} = 3.6V, V_{RSENS} = 0V	Auto Release1	V_{DD}×0.800 -0.050	V_{DD} ×0.800	V_{DD}×0.800 +0.050	V	F
			Auto Release2	0.010	0.100	0.250		
			Latch	V_{DD}×0.780 -0.100	V_{DD} ×0.780	V_{DD}×0.780 +0.100		
R_{SHORT}	Discharge overcurrent release resistance	Auto Release1: 3.2 ≤ V_{DD} ≤ 4.4V, V- = 2.93V		6.5	10.0	13.5	kΩ	F
		Auto Release2: V_{DD} = 3.6V, V- = 0.2V		20	45	70		
t_{VREL3}	Discharge overcurrent release delay time	V_{DD} = 3.6V, V- = 3.6V → 0V, V_{RSENS} = 0V		6.3	8.5	11.1	ms	F
V_{DET4}	Charge overcurrent detection voltage	V_{DD} = 3.6V, V- = V_{RSENS}		V_{DET4} -0.0010	V_{DET4}	V_{DET4} +0.0010	V	G
t_{VDET4}	Charge overcurrent detection delay time	V_{DD} = 3.6V, V_{RSENS} = 0V → -0.5V, V- = V_{RSENS}		t_{VDET4} ×0.75	t_{VDET4}	t_{VDET4} ×1.30	ms	G
V_{REL4}	Charge overcurrent release voltage	V_{DD} = 3.6V, V_{RSENS} = 0V		0.010	0.100	0.250	V	G
t_{VREL4}	Charge overcurrent release delay time	V_{DD} = 3.6V, V- = -0.5V → 1V V- = V_{RSENS}		3.0	4	5.2	ms	G
V_{RDET}	RST pin function detection voltage	Detect rising edge of RST pin voltage, V_{DD} = 3.6V, V- = V_{RSENS} = 0V		V_{RDET}-0.3	V_{RDET}	V_{RDET}+0.3	V	M
V_{RREL}	RST pin function release voltage	V_{DD} = 3.6V, V_{RSENS} = 0V	RESET: Detect rising edge of V- pin voltage	0.500	0.800	1.100	V	N
			Forced Standby: Detect falling edge of V- pin voltage					

(1) Refer to *TEST CIRCUITS* for detail information.

(2) Short release delay time 1 is the same value as t_{VREL3}.

R5613LxxxXX Electrical Characteristics (Continued) **(Ta = 25°C)**

Symbol	Items	Conditions		Min.	Typ.	Max.	Unit	Circuit (1)
I_{RST}	RST pin input current, "High"	V_{DD} = 3.6V, R_{ST} = 3.6V, V- = V_{RSENS} = 0V				1.2	μA	M
R_{RST}	RST pin input resistance	V_{DD} = 3.6V, R_{ST} = 3.6V, V- = V_{RSENS} = 0V		3.0			MΩ	M
t_{RST}	RST pin function detection delay time	V_{DD} = 3.6V, R_{ST} = 0V → 3.6V, V- = V_{RSENS} = 0V		35	50	65	ms	M
t_{RREL}	RST pin function release delay time	V_{DD}=3.6V, V_{RSENS}=0V	RESET: R_{ST} = 3.6V→0V, V- = 0V	t_{RREL} ×0.70	t_{RREL}	t_{RREL} ×1.30	ms	N
			Forced Standby: V- = 3.6V→0V, R_{ST} = 0V					
V_{OL1}	COUT pin NMOS ON voltage	I_{OL} = 50μA, V_{DD} = 4.55V			0.4	0.5	V	H
V_{OH1}	COUT pin PMOS ON voltage	I_{OH} = -50μA, V_{DD} = 3.9V		3.4	3.7		V	I
V_{OL2}	DOUT pin NMOS ON voltage	I_{OL} = 50μA, V_{DD} = 1.9V			0.2	0.5	V	J
V_{OH2}	COUT pin PMOS ON voltage	I_{OH} = -50μA, V_{DD} = 3.9V		3.4	3.7		V	K
I_{DD}	Supply current	V_{DD}=3.9V, V- = 0V	Support for the 0 V battery charging "Inhibition" and the discharge overcurrent detection with two levels.		2.5	4.8	μA	L
			Except for the above support		2.0	4.0		
$I_{STANDBY}$	Standby current	V_{DD}=1.9V	V_{DET2}: Auto Release			0.2	μA	L
			V_{DET2}: Latch			0.04		

(1) Refer to *TEST CIRCUITS* for detail information.

The specifications are guaranteed by design engineering at -20°C ≤ Ta ≤ 60°C.

R5613LxxxXX Electrical Characteristics **(-20°C ≤ Ta ≤ 60°C)**

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit	Circuit (1)
V_{DD1}	Operating input voltage	V_{DD}-V_{SS}		1.5		5.0	V	A
V_{STCHG}	Minimum charging voltage for 0 V battery charger (2)	V_{DD}-V-, V_{DD}-V_{SS} = 0V				1.8	V	A
V_{NOCHG}	0 V battery charging inhibition voltage (3)	V_{DD}-V_{SS}, V_{DD}-V- = 4V	V_{NOCHG} ≤ 1.500V	V_{NOCHG} -0.30	V_{NOCHG}	V_{NOCHG} +0.30	V	A
			V_{NOCHG} = 2.200V	1.900	2.200	2.600		
			V_{NOCHG} = 2.350V	2.000	2.350	2.650		
V_{DET1}	Overcharge detection voltage	R_{VDD} = 330Ω		V_{DET1} -0.025	V_{DET1}	V_{DET1} +0.025	V	B
V_{REL1}	Overcharge release voltage	R_{VDD} = 330Ω		V_{REL1} -0.055	V_{REL1}	V_{REL1} +0.055	V	B
t_{VDET1}	Overcharge detection delay time	V_{DD} = 3.6V → V_{DET1}+0.1V		t_{VDET1} ×0.70	t_{VDET1}	t_{VDET1} ×1.40	s	C
t_{VREL1}	Overcharge release delay time	V_{DD} = 4.8V → V_{REL1}-0.1V	t_{VREL1} = 1.2ms	0.5	1.2	3.0	ms	C
			t_{VREL1} = 16ms	8	16	40		
V_{DET2}	Overdischarge detection voltage	Detect falling edge of supply voltage		V_{DET2} -0.055	V_{DET2}	V_{DET2} +0.055	V	D
V_{REL2}	Overdischarge release voltage	Detect rising edge of supply voltage		V_{REL2} -0.065	V_{REL2}	V_{REL2} +0.105	V	E
t_{VDET2}	Overdischarge detection delay time	V_{DD} = V_{DET2}+0.15V → V_{DET2}-0.1V		t_{VDET2} ×0.70	t_{VDET2}	t_{VDET2} ×1.40	ms	D
t_{VREL2}	Overdischarge release delay time	V_{DD} = V_{DET2}-0.2V → V_{REL2}+0.25V		0.84	1.20	2.00	ms	E
V_{CHGDET}	Charger Connection Detection Voltage	V_{DD} = V_{DET2}+0.020V, V_{RSENS}= 0V		0.400	0.800	1.200	V	A
V_{DET31}	Discharge overcurrent detection voltage 1	V_{DD} = 3.6V, V- = V_{RSENS}		V_{DET31} -0.0015	V_{DET31}	V_{DET31} +0.0015	V	F
t_{VDET31}	Discharge overcurrent 1 detection delay time	V_{DD} = 3.6V, V_{RSENS}=0V → V_{DET31}+0.005V V- = V_{RSENS}		t_{VDET31} ×0.75	t_{VDET31}	t_{VDET31} ×1.35	ms	F
V_{DET32}	Discharge overcurrent detection voltage 2	V_{DD} = 3.6V, V- = V_{RSENS}		V_{DET32} -0.0025	V_{DET32}	V_{DET32} +0.0025	V	F
t_{VDET32}	Discharge overcurrent 2 detection delay time	V_{DD} = 3.6V, V_{RSENS} = 0V → V_{DET32}+0.005V V- = V_{RSENS}		t_{VDET32} ×0.70	t_{VDET32}	t_{VDET32} ×1.40	ms	F

(1) Refer to *TEST CIRCUITS* for detail information.
(2) 0 V battery charging permission supported product only
(3) 0 V battery charging inhibition supported product only

R5613LxxxXX Electrical Characteristics (Continued) **($-20°C \leq Ta \leq 60°C$)**

Symbol	Items	Conditions		Min.	Typ.	Max.	Unit	Circuit [1]
V_{SHORT1}	Short detection voltage 1	Detect rising edge of RSENS pin voltage, V_{DD} = 3.6V, V_{RSENS} = V-	0.030V ≤ V_{SHORT1} ≤ 0.120V	V_{SHORT1} -0.005	V_{SHORT1}	V_{SHORT1} +0.005	V	F
			0.120V < V_{SHORT1} ≤ 0.200V	V_{SHORT1} -0.008		V_{SHORT1} +0.008		
t_{SHORT}	Short detection delay time [2]	V_{DD}=3.6V, V_{RSENS}= 0V → 1V V- = V_{RSENS}		175	280	420	µs	F
V_{SHORT2}	Short detection voltage 2	Detect rising edge of V- pin voltage, V_{DD} = 3.6V, V_{RSENS} = 0V		V_{DD}×0.850 -0.100	V_{DD} ×0.850	V_{DD}×0.850 +0.100	V	F
V_{REL3}	Discharge overcurrent release voltage	V_{DD} = 3.6V, V_{RSENS} = 0V	Auto Release1	V_{DD}×0.800 -0.100	V_{DD} ×0.800	V_{DD}×0.800 +0.100	V	F
			Auto Release2	0.000	0.100	0.300		
			Latch	V_{DD}×0.780 -0.200	V_{DD} ×0.780	V_{DD}×0.780 +0.200		
R_{SHORT}	Discharge overcurrent release resistance	Auto Release1: 3.2 ≤ V_{DD} ≤ 4.4V, V- = 2.93V		5.5	10.0	14.5	kΩ	F
		Auto Release2: V_{DD} = 3.6V, V- = 0.2V		17.1	45.0	71.0		
t_{VREL3}	Discharge overcurrent release delay time	V_{DD} = 3.6V, V- = 3.6V → 0V V_{RSENS} = 0 V		5.95	8.5	12.0	ms	F
V_{DET4}	Charge overcurrent detection voltage	V_{DD} = 3.6 V, V- = V_{RSENS}		V_{DET4} -0.0015	V_{DET4}	V_{DET4} +0.0015	V	G
t_{VDET4}	Charge overcurrent detection delay time	V_{DD} = 3.6 V, V_{RSENS} = 0V → -0.5V, V- = V_{RSENS}		t_{VDET4} ×0.70	t_{VDET4}	t_{VDET4} ×1.40	ms	G
V_{REL4}	Charge overcurrent release voltage	V_{DD} = 3.6V, V_{RSENS} = 0V		0.000	0.100	0.300	V	G
t_{VREL4}	Charge overcurrent release delay time	V_{DD} = 3.6V, V- = -0.5V → 1V, V- = V_{RSENS}		2.8	4	5.6	ms	G
V_{RDET}	RST pin function detection voltage	Detect rising edge of RST pin voltage, V_{DD} = 3.6V, V- = V_{RSENS} = 0V		V_{RDET}-0.5	V_{RDET}	V_{RDET}+0.5	V	M
V_{RREL}	RST pin function release voltage	V_{DD}=3.6V, V_{RSENS}=0V	RESET: Detect rising edge of V- pin voltage	0.400	0.800	1.200	V	N
			Forced Standby: Detect falling edge of V- pin voltage					

[1] Refer to *TEST CIRCUITS* for detail information.
[2] Short release delay time 1 is the same value as t_{VREL3}.

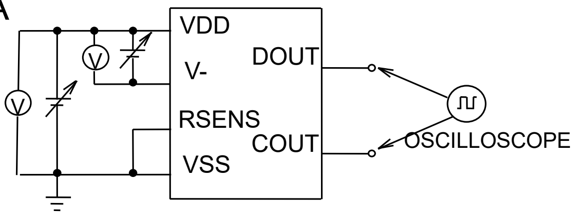
R5613LxxxXX Electrical Characteristics (Continued) **($-20°C \leq Ta \leq 60°C$)**

Symbol	Items	Conditions		Min.	Typ.	Max.	Unit	Circuit (1)
I_{RST}	RST pin input current, "High"	V_{DD} = 3.6V, R_{ST} = 3.6V, V- = V_{RSENS} = 0V				3.6	μA	M
R_{RST}	RST pin input resistance	V_{DD} = 3.6V, R_{ST} = 3.6V, V- = V_{RSENS} = 0V		1.0			MΩ	M
t_{RST}	RST pin function detection delay time	V_{DD} = 3.6V, R_{ST} = 0V → 3.6V, V- = V_{RSENS} = 0V		25	50	75	ms	M
t_{RREL}	RST pin function release delay time	V_{DD}=3.6V, V_{RSENS}=0V	RESET: R_{ST}= 3.6V→0V, V- = 0V	t_{RREL} ×0.50	t_{RREL}	t_{RREL} ×1.50	ms	N
			Forced Standby: V- = 3.6V→0V, R_{ST} = 0V					
V_{OL1}	COUT pin NMOS ON voltage	I_{OL} = 50μA, V_{DD} = 4.55 V			0.4	0.5	V	H
V_{OH1}	COUT pin PMOS ON voltage	I_{OH} = -50μA, V_{DD} = 3.9 V		3.4	3.7		V	I
V_{OL2}	DOUT pin NMOS ON voltage	I_{OL} = 50μA, V_{DD} = 1.9 V			0.2	0.5	V	J
V_{OH2}	COUT pin PMOS ON voltage	I_{OH} = -50μA, V_{DD} = 3.9 V		3.4	3.7		V	K
I_{DD}	Supply current	V_{DD}=3.9V, V- = 0V	Support for the 0 V battery charging "Inhibition" and the discharge overcurrent detection with two levels.		2.5	6.0	μA	L
			Except for the above support		2.0	5.0		
$I_{STANDBY}$	Standby current	V_{DET2}: Auto Release, V_{DD}=1.6V				0.3	μA	L
		V_{DET2}: Latch, V_{DD}=1.9V				0.1		

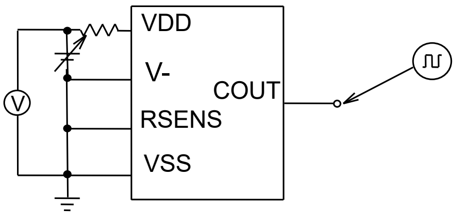
(1) Refer to *TEST CIRCUITS* for detail information.

Test Circuits

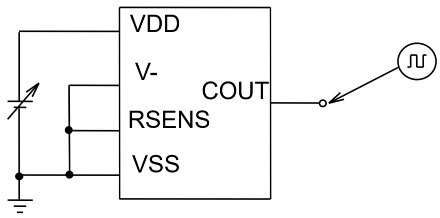
A



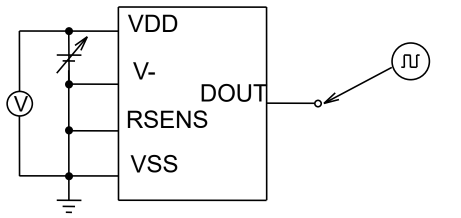
B



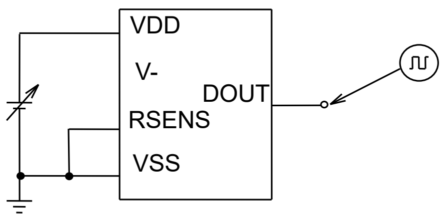
C



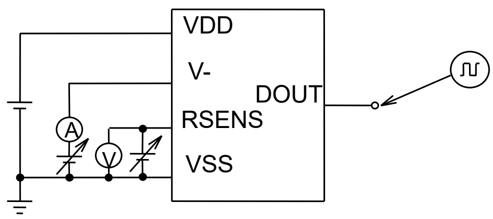
D



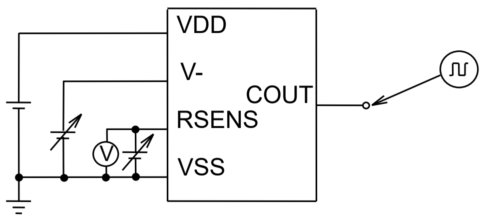
E



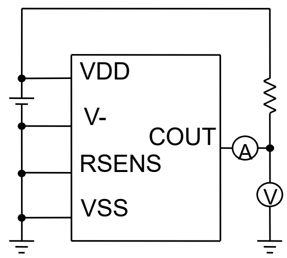
F



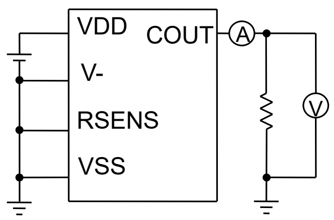
G



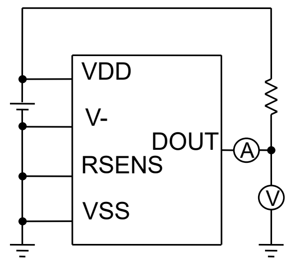
H



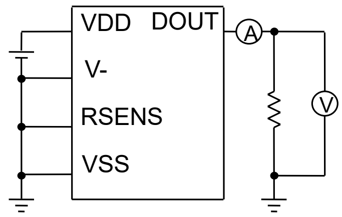
I



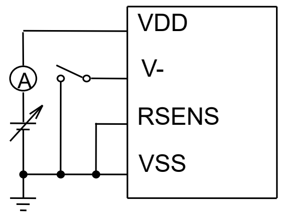
J



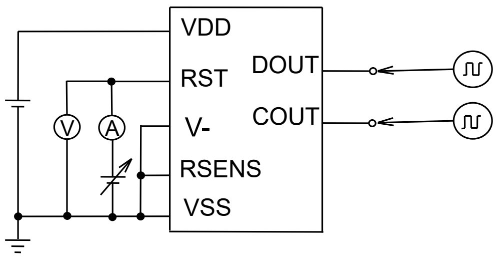
K


VDD
DOUT
A
V-
RSENS
VSS
V

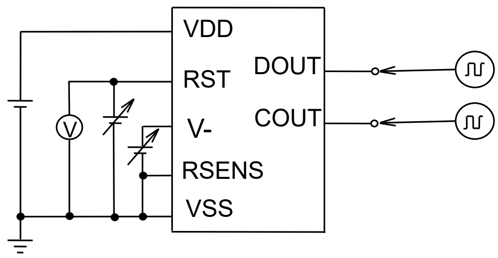
L


VDD
V-
A
RSENS
VSS

M


VDD
RST
DOUT
COUT
V
A
V-
RSENS
VSS

N


VDD
RST
DOUT
COUT
V
V-
RSENS
VSS

THEORY OF OPERATION

Overcharge Protection

When the overcharge detection delay time (t_{VDET1}) passes under the condition that the VDD pin voltage (V_{DD}) exceeds the overcharge detection voltage (V_{DET1}), this IC enters the overcharge state.
In this state, the COUT pin becomes Low and the charge control FET is turned off to stop charging. The V- pin voltage (V-) increases by the Vf voltage (Vf) of the internal parasitic diode than the VSS pin voltage (V_{SS}), because the discharge current flows via the parasitic diode even when the charge control FET is off.
A release from the overcharge state must meet the following pin conditions and delay time according to the selected release type.

Type	Pin Conditions	Delay Time
Auto Release	V- < V_{REL4} and V_{DD} < V_{REL1} or V- > V_{REL4} and V_{DD} < V_{DET1}	t_{VREL1}
Latch	V- > V_{REL4} and V_{DD} < V_{DET1}	t_{VREL1}

Overdischarge Protection

When the overdischarge detection delay time (t_{VDET2}) passes under the condition that the VDD pin voltage (V_{DD}) falls below the overdischarge detection voltage (V_{DET2}), this IC enters the overdischarge state.
In this state, the DOUT pin becomes Low and the discharge control FET is turned off to stop discharging. The V- pin voltage (V-) decreases by the Vf voltage (Vf) of the internal parasitic diode than the VSS pin voltage (V_{SS}), because the charge current flows via the parasitic diode even when the discharge control FET is off.
In addition, when V- is pulled up to V_{DD} level and exceeds the charger detection voltage (V_{CHGDET}), the IC enters the standby state. It results in reducing the consumption current to a minimum.
A release from the overdischarge state must meet the following pin conditions and delay time according to the selected release type.

Type	Pin Conditions	Delay Time
Auto Release	V- > V_{CHGDET} and V_{DD} > V_{REL2} or V- < V_{CHGDET} and V_{DD} > V_{DET2}	t_{VREL2}
Latch	V- < V_{CHGDET} and V_{DD} > V_{DET2}	t_{VREL2}

Discharge Overcurrent Protection

In order to monitor a discharge current, this IC measures a voltage difference of the sense resistor (R_{SENS}) connected between the RSENS and the VSS pins to detect the current value.
This IC has two levels of the discharge overcurrent detection voltage 1/2 (V_{DET31} / V_{DET32}). When the discharge overcurrent detection delay time (t_{VDET31}) passes under the condition that the discharge current, which is converted through R_{SENS} for current-to-voltage conversion, exceeds V_{DET31}, this IC enters the discharge overcurrent state. In a case where V_{DET32} is enabled, this IC enters the discharge overcurrent state when the discharge overcurrent detection delay time (t_{VDET32}) passes under the condition exceeding V_{DET32}.
In this state, the DOUT pin becomes Low and the discharge control FET is turned off to shut off the discharge current.
A release from the discharge overcurrent state must meet the following pin condition and delay time according to the selected release type.

Type	Pin Condition	Delay Time	Remarks
Auto Release	V- < V_{REL3}	t_{VREL3}	V- is pulled down to the VSS level inside the IC. Note1
Latch	V- < V_{REL3}	t_{VREL3}	V- is pulled up to the VDD level inside the IC. Note2

Note1: It is possible to release the abnormal condition of the load connected to the battery pack. When the discharge overcurrent release delay time (t_{VREL3}) passes under the condition V- falls below V_{REL3}, this IC releases from the discharge overcurrent state. V- can be expressed by the following equation.

$$V- = V_{CELL} \times R_{SHORT} / (R_{SHORT} + R_{V-} + R_{LOAD})$$

V_{CELL} : Battery voltage
R_{SHORT} : Discharge overcurrent release resistance
R_{V-} : External resistor for V- pin
R_{LOAD} : Load resistance to a battery pack

Note2: When connecting a charger to pull V- down, this IC releases from the discharge overcurrent state.

Short-circuit Current Protection

In order to monitor a short-circuit current, this IC measures a voltage difference of the sense resistor (R_{SENS}) connected between the RSENS and the VSS pins to detect the current value. When the short-circuit detection delay time (t_{SHORT}) passes under the condition that the short-circuit current, which is converted through RSENS for current-to-voltage conversion, exceeds the short-circuit detection voltage (V_{SHORT}), this IC enters the short-circuit state.
In this state, the DOUT pin becomes Low and the discharge control FET is turned off to shut off the short-circuit current.
A release from the short-circuit state must meet the same condition and delay time as the discharge overcurrent protection.

Charge Overcurrent Protection

In order to monitor a charge current, this IC measures a voltage difference of the sense resistor (R_{SENS}) connected between the RSENS and the VSS pins to detect the current value. When the charge overcurrent detection delay time (t_{VDET4}) passes under the condition that the charge current, which is converted through RSENS for current-to-voltage conversion, falls below the charge overcurrent detection voltage (V_{DET4}), this IC enters the charge overcurrent state.
In this state, the COUT pin becomes Low and the charge control FET is turned off to shut off the charge current.
A release from the charge overcurrent state must meet the following pin condition and delay time according to the selected release type.

Type	Pin Condition	Delay Time	Remarks
Auto Release	$V- > V_{REL4}$	t_{VREL4}	V- is pulled up to the VDD level inside the IC. Note

Note: By disconnecting the charger, this IC releases from the charge overcurrent state.

RST Pin Function

The RST pin function has two types: RESET type and Forced-standby type.

RESET Type

The RST input pin supports a Pch open-drain output type and has an internal resistor (R_{RST}) to pull down to VSS.
When the RST pin function detection delay time (t_{RST}) passes under the condition of $V_{RST} > V_{RDET}$ (V_{RST}: the RST pin input voltage, V_{RDET}: the RST pin function detection voltage), this IC enters the RESET state.
After entering the RESET state, the IC turns off the charge and the discharge control FETs to shut off between the battery and the charger. Then protections for overcharge, overdischarge, discharge overcurrent, and short-circuit are stopped.
When the RST pin function release delay time (t_{RREL}) passes under the condition of $V_{RST} < V_{RDET}$ or $V- > V_{RREL}$, this IC releases from the RESET state.

Forced-standby Type

On the Forced-standby type, a battery pack must not be connected with a charger when the RST pin function runs.
The RST input pin supports a CMOS output type and has an internal resistor (R_{RST}) to pull down to VSS.
When the RST pin function detection delay time (t_{RST}) passes under the condition of $V_{RST} > V_{RDET}$ (V_{RST}: the RST pin input voltage, V_{RDET}: the RST pin function detection voltage), the IC turns off the discharge control FET and pulls the V- pin up to VDD inside. Then protections for overcharge, overdischarge, discharge overcurrent, and short-circuit are stopped. After that, the IC enters the Forced-standby state when the V- pin voltage (V-) exceeds the RST pin function release voltage (V_{RREL}). It results in reducing the consumption current to a minimum. The RST pin becomes OPEN when an internal switch is turned off.
When the RST pin function release delay time (t_{RREL}) passes under the condition is transited from $V- > V_{RREL}$ to $V- < V_{RREL}$ by connecting the charger, this IC releases from the Forced-standby state. At the time of release, avoid meeting the detection condition ($V_{RST} > V_{RDET}$).

0 V Battery Charging

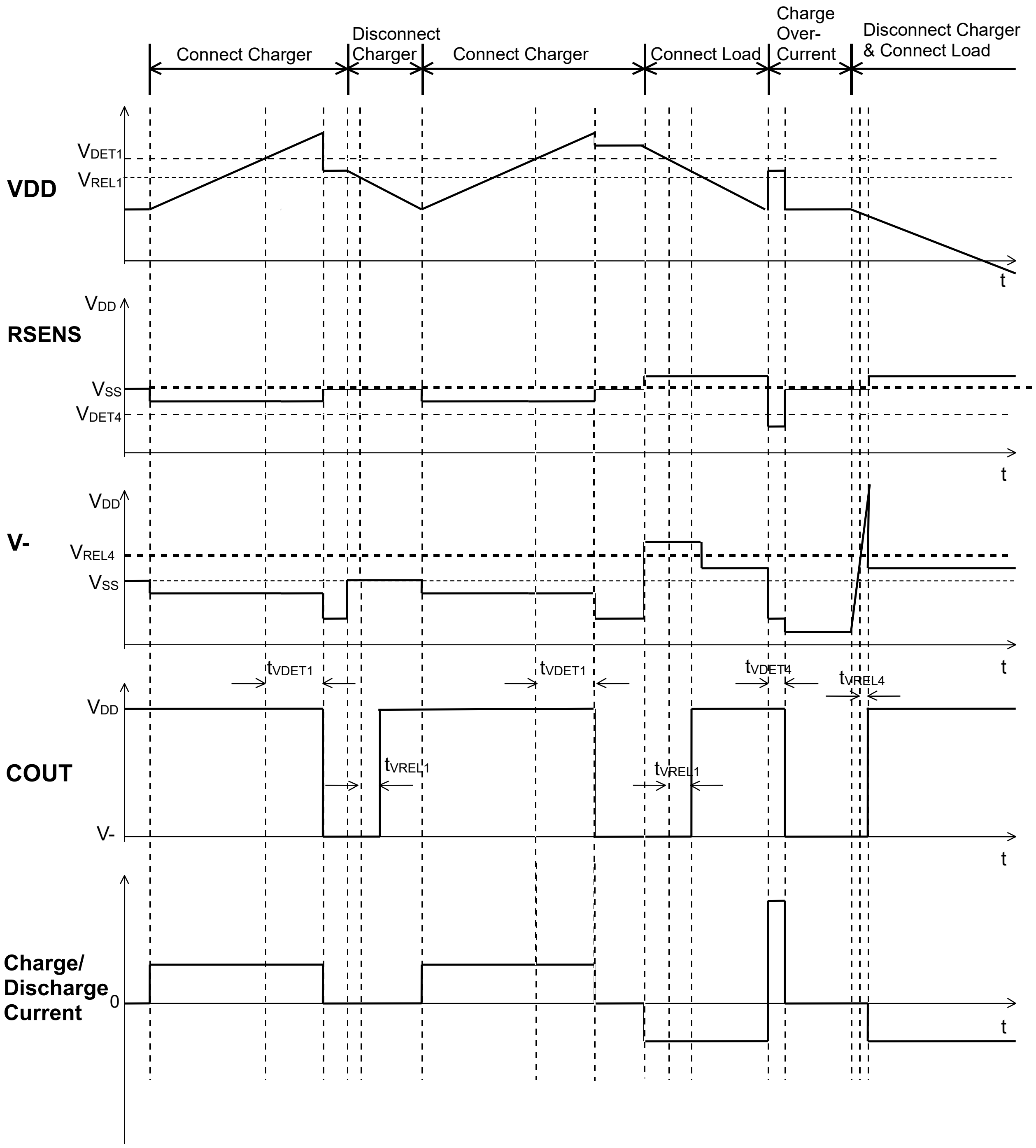
This IC has the selectable charging function for the battery discharged to 0 V.

0 V Battery Charge Function "Permission"
This function allows to charge to the 0 V battery by connecting the charger with the minimum charging voltage (V_{STCHG}) and more.

0 V Battery Charge Function "Inhibition"
This function inhibits to charge to the battery with the 0 V-battery charging inhibition voltage (V_{NOCHG}) or less even if connecting the charger.

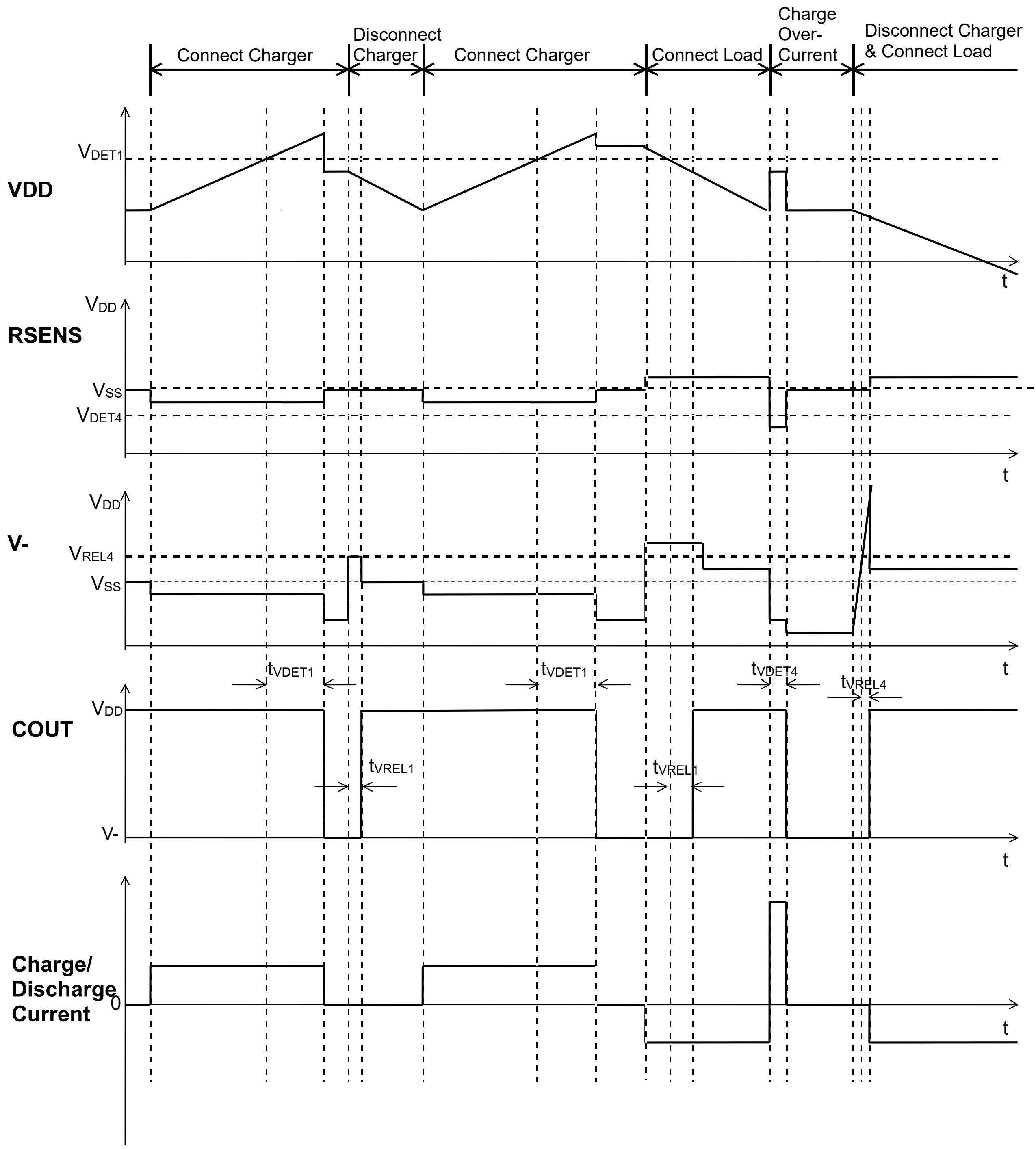
Timing Charts

Overcharge voltage and Overcharge current



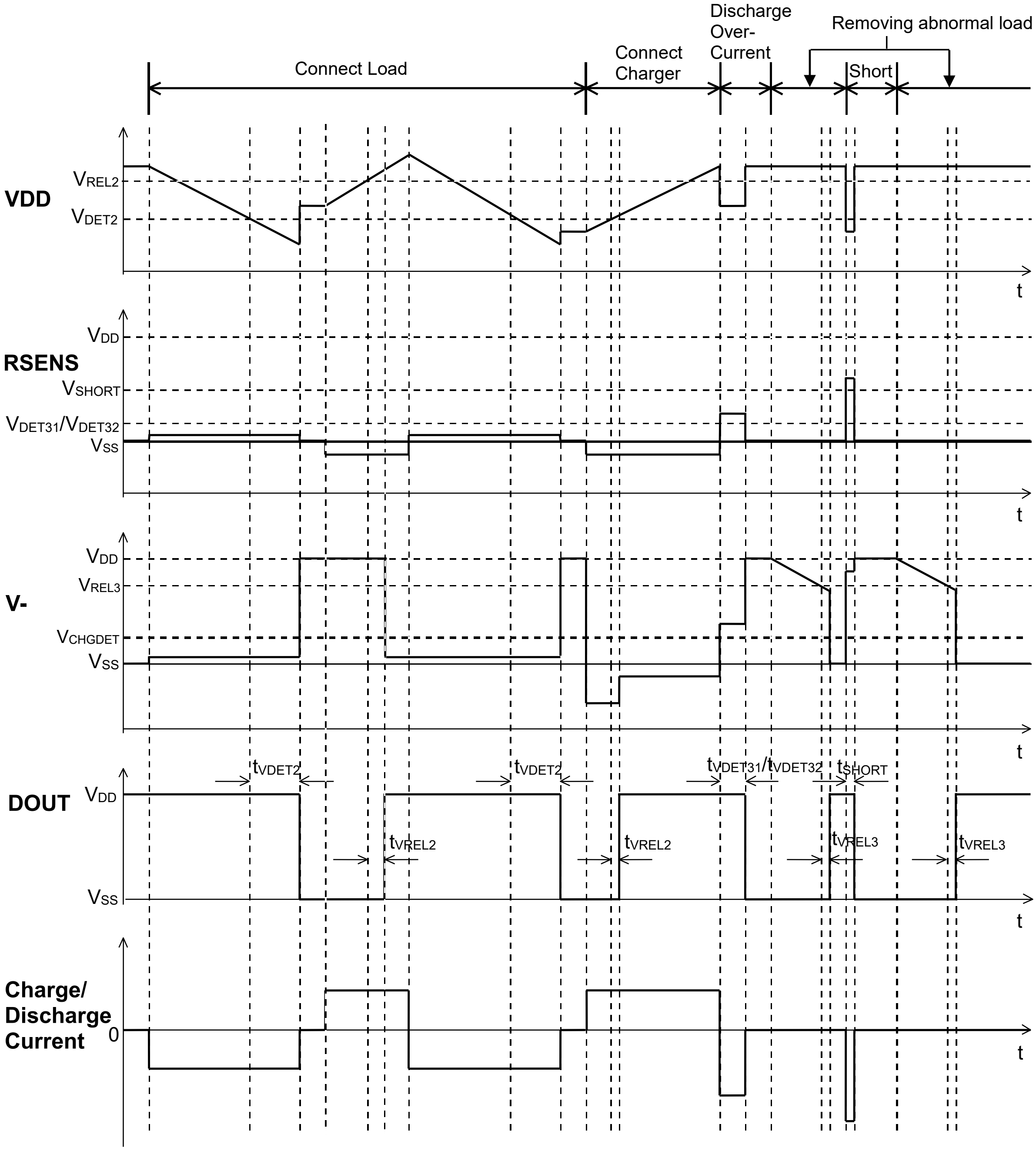
Overcharge (Auto Release type) Timing Diagram

RICOH

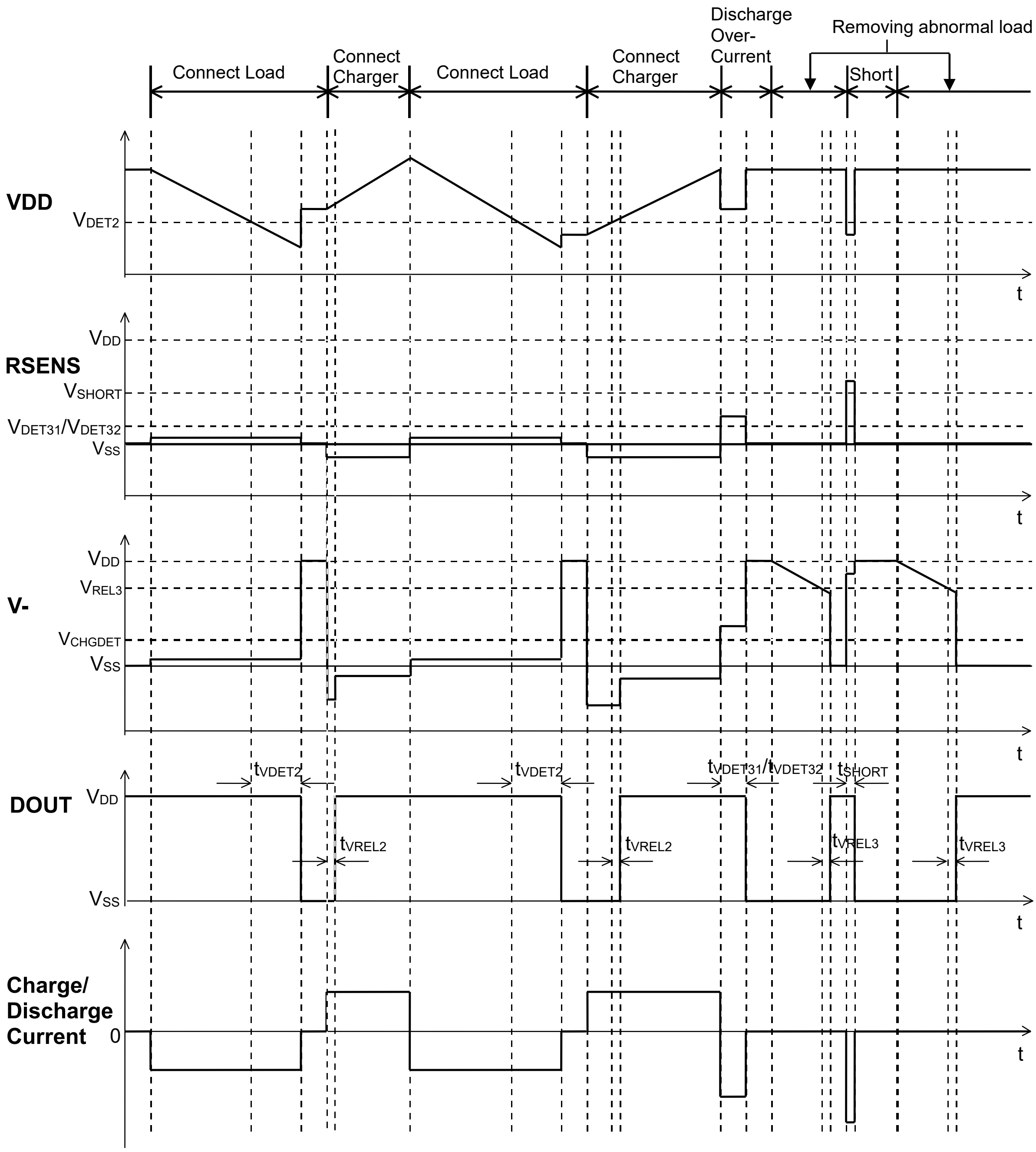


Overcharge (Latch type) Timing Diagram

Overdischarge, Discharge overcurrent, and Short-circuit

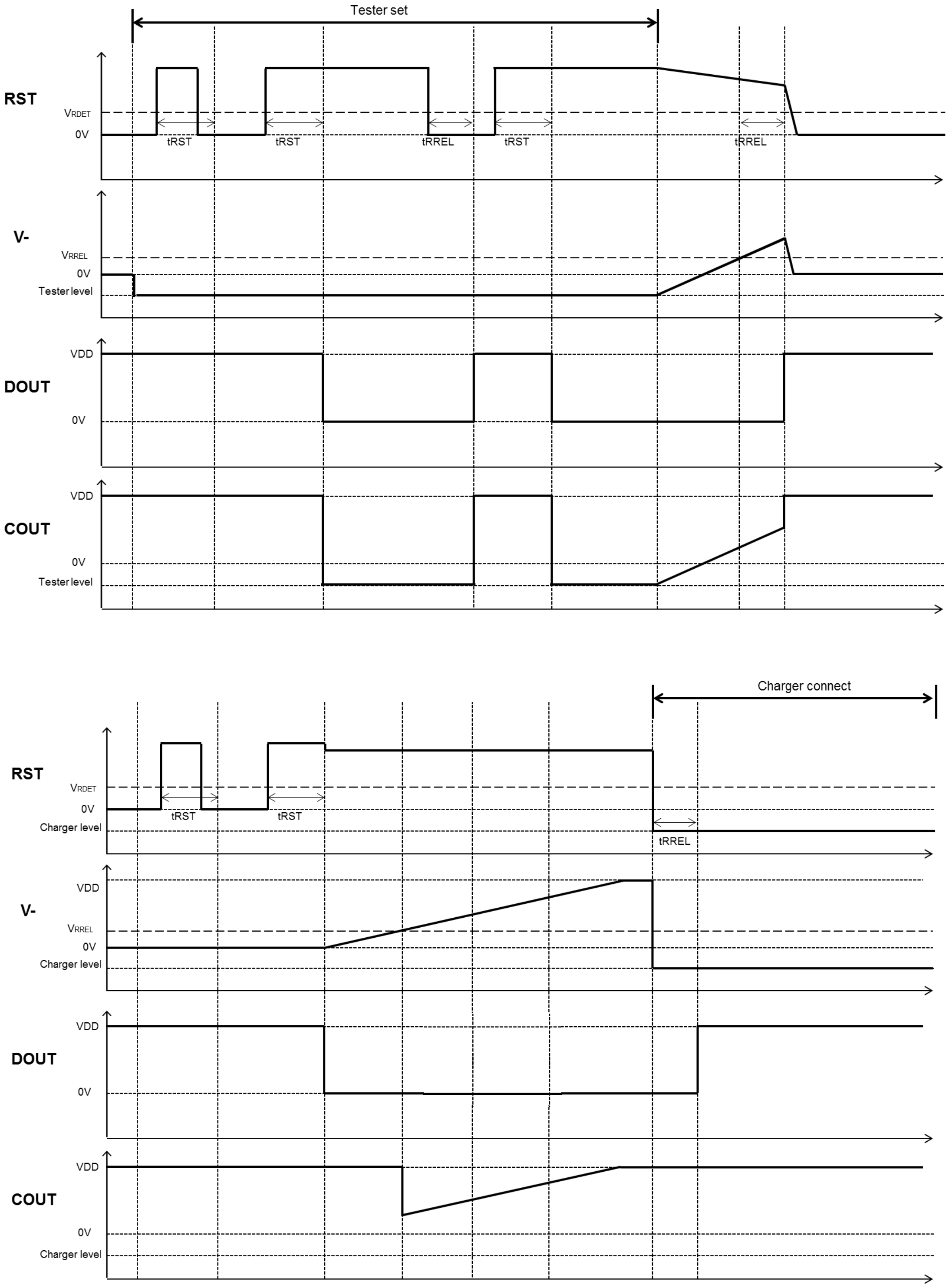


Overdischarge / Discharge Overcurrent (Auto Release type), Short-circuit Timing Diagram



Overdischarge / Discharge Overcurrent (Latch type), Short-circuit Timing Diagram

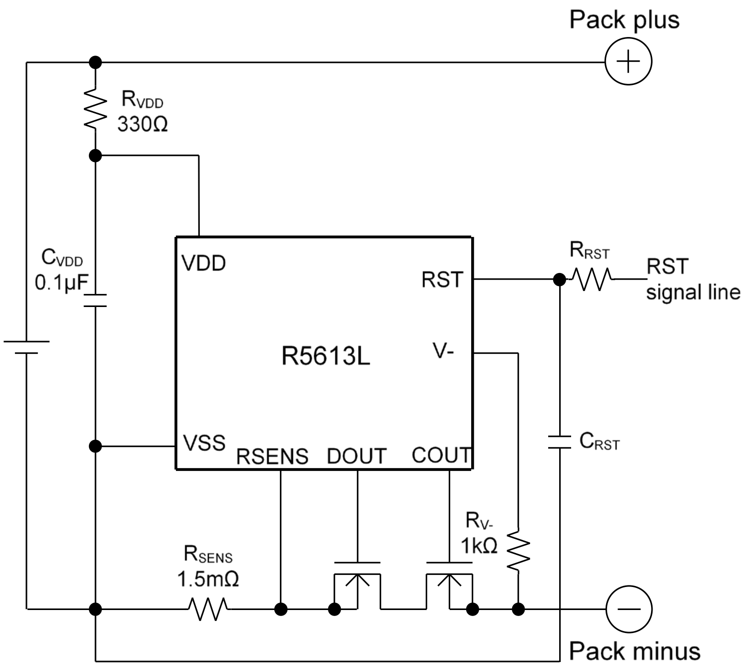
RESET signal



RST Pin Function (Forced-standby type) Timing Diagram

APPLICATION INFORMATION

Typical Application Circuit



R5613LxxxXX Typical Application Circuit

External Components

Symbol	Min.	Typ.	Max.
Resistor			
R_{VDD} [1]		330Ω	1kΩ
R_{V-} [1]	−	1kΩ	1.3kΩ
R_{SENS}	−	1.5mΩ	20mΩ
R_{RST}	−	1kΩ	10kΩ
Capacitor			
C_{VDD}	0.01µF	0.1µF	1µF
C_{RST}	−	0.1µF	−

(1) The total resistance of R_{VDD} and R_V must be 1kΩ or more.

Technical Notes on External Components

- The voltage fluctuation is stabilized with R_{VDD} and C_{VDD}. If a R_{VDD} is too large, the detection voltage rises by the conduction current at detection. To stabilize the operation, it is recommended to use a resistor of 1kΩ or less for R_{VDD} and a capacitor of 0.01 μF to 1.0 μF for C_{VDD}.

- R_{VDD} and R_{V-} serve as a current limit resistor when the battery pack is charged with reversed polarity or a voltage of the connected charger is more than the absolute maximum rating. When using a small resistor for R_{VDD} and R_{V-}, the device's power dissipation might be exceeded. Therefore, a total of R_{VDD} and R_{V-} must be 1kΩ or more. When using a large resistor for R_{V-}, the charger might not be released by re-connecting to the battery pack after the overdischarge detection. Therefore, R_{V-} must be 1.3 kΩ or less. Production variation and temperature properties are included in the value. R_{SENS} is a resistor for sensing an overcurrent. If the resistance value is too large, power loss becomes also large. By the overcurrent, if the R_{SENS} is not appropriate, the power loss may be beyond the power dissipation of R_{SENS}. Choose an appropriate R_{SENS} according to the cell specification.

- The typical application circuit diagrams are just examples. This circuit performance largely depends on the PCB layout and external components. In the actual application, fully evaluation is necessary.

- If the positive terminal and the negative terminal of the battery pack are short even though the device has the short protection circuit, a large current may flow through the FET during the short detection delay time. Therefore, select an appropriate FET with large enough current capacitance in order to endure the large current during the delay time.

Selection of External Sense Resistor and MOSFET

Short mode is detected by the current base or the relation between V_{DD} at short and total on resistance of external MOSFETs for C_{OUT} and D_{OUT}. If short must be detected by the current base determined by V_{SHORT1}, V_{SHORT2}, and R_{SENS}, the next formula must be true, otherwise, the short current limit becomes (V_{SHORT2}) / (R_{SENS} + R_{SS} (on)).

$$\frac{V_{SHORT2}}{R_{SENS} + Rss(on)} \geq \frac{V_{SHORT1}}{R_{SENS}}$$

V_{SHORT1} = Threshold value of detecting short circuit using R_{SENS} terminal [V]
V_{SHORT2} =Threshold value of detecting short circuit using V- terminal [V]
R_{SENS}: = External current sense resistance [Ω]
R_{SS} (on) = external MOSFETs' total ON resistance [Ω]

In the short mode, a short current is determined by the relation between R_{SENS} and V_{SHORT} value.

PD-DFN1616-8B-(85125)-JE-A

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

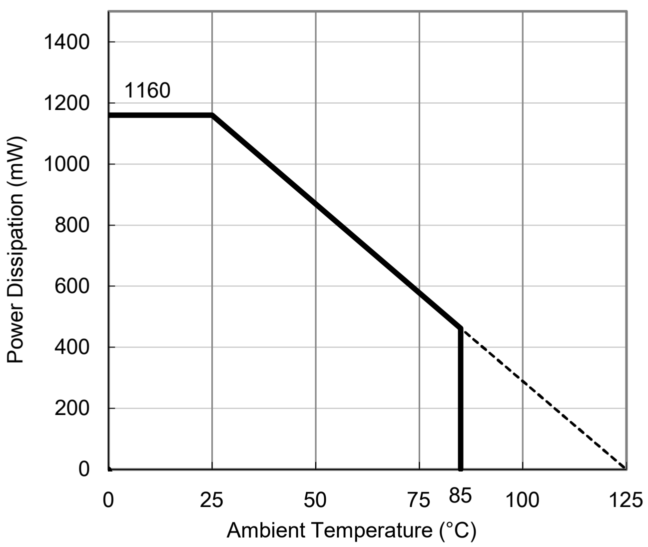
Item	Measurement Conditions
Environment	Mounting on Board (Wind Velocity = 0 m/s)
Board Material	Glass Cloth Epoxy Plastic (Four-Layer Board)
Board Dimensions	76.2 mm × 114.3 mm × 1.6 mm
Copper Ratio	Outer Layer (First Layer): Less than 95% of 50 mm Square Inner Layers (Second and Third Layers): Approx. 100% of 50 mm Square Outer Layer (Fourth Layer): Approx. 100% of 50 mm Square
Through-holes	ϕ 0.25 mm × 24 pcs

Measurement Result (Ta = 25°C, Tjmax = 125°C)

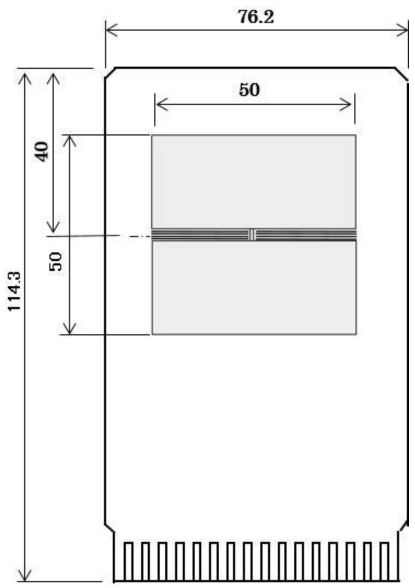
Item	Measurement Result
Power Dissipation	1160 mW
Thermal Resistance (θja)	θja = 86°C/W
Thermal Characterization Parameter (ψjt)	ψjt = 53°C/W

θja: Junction-to-Ambient Thermal Resistance

ψjt: Junction-to-Top Thermal Characterization Parameter

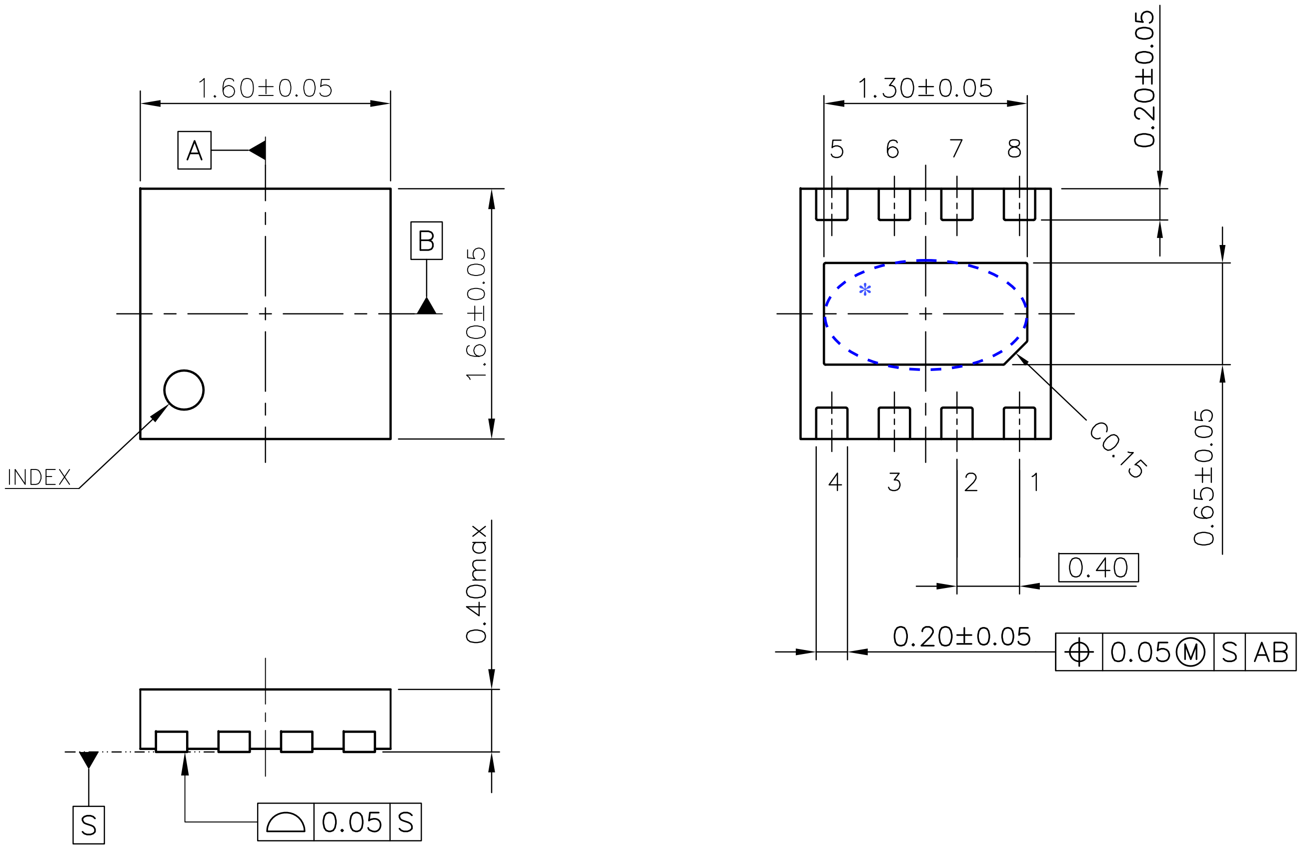


Power Dissipation vs. Ambient Temperature



Measurement Board Pattern

Ver. A



DFN1616-8B Package Dimensions (Unit:mm)

*The tab on the bottom of the package shown by blue circle is a substrate potential (V_{DD}). It is recommended that this tab be connected to the VDD pin on the board but it is possible to leave the tab floating.

1. The products and the product specifications described in this document are subject to change or discontinuation of production without notice for reasons such as improvement. Therefore, before deciding to use the products, please refer to Ricoh sales representatives for the latest information thereon.
2. The materials in this document may not be copied or otherwise reproduced in whole or in part without prior written consent of Ricoh.
3. Please be sure to take any necessary formalities under relevant laws or regulations before exporting or otherwise taking out of your country the products or the technical information described herein.
4. The technical information described in this document shows typical characteristics of and example application circuits for the products. The release of such information is not to be construed as a warranty of or a grant of license under Ricoh's or any third party's intellectual property rights or any other rights.
5. The products listed in this document are intended and designed for use as general electronic components in standard applications (office equipment, telecommunication equipment, measuring instruments, consumer electronic products, amusement equipment etc.). Those customers intending to use a product in an application requiring extreme quality and reliability, for example, in a highly specific application where the failure or misoperation of the product could result in human injury or death (aircraft, spacevehicle, nuclear reactor control system, traffic control system, automotive and transportation equipment, combustion equipment, safety devices, life support system etc.) should first contact us.
6. 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 to 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.
7. Anti-radiation design is not implemented in the products described in this document.
8. The X-ray exposure can influence functions and characteristics of the products. Confirm the product functions and characteristics in the evaluation stage.
9. WLCSP products should be used in light shielded environments. The light exposure can influence functions and characteristics of the products under operation or storage.
10. There can be variation in the marking when different AOI (Automated Optical Inspection) equipment is used. In the case of recognizing the marking characteristic with AOI, please contact Ricoh sales or our distributor before attempting to use AOI.
11. Please contact Ricoh sales representatives should you have any questions or comments concerning the products or the technical information.

RoHS Compliant
Halogen Free

Ricoh is committed to reducing the environmental loading materials in electrical devices with a view to contributing to the protection of human health and the environment.
Ricoh has been providing RoHS compliant products since April 1, 2006 and Halogen-free products since April 1, 2012.

RICOH RICOH ELECTRONIC DEVICES CO., LTD.

Official website
https://www.n-redc.co.jp/en/
Contact us
https://www.n-redc.co.jp/en/buy/