1-cell Li-ion Battery Protection IC with High-accuracy Overcurrent Detection, Reset signal

NO.EA-393-190123

OUTLINE

The R5611L is a one-cell Li- ion / polymer battery protection IC provides an overcurrent detection with using an external resistor. An external FET can be switched ON / OFF by the reset signal of RST. The discharge overcurrent can be detected with high-accuracy of ±3.0mV (-20°C ≤ Ta ≤ 60°C).

FEATURES

- Absolute Maximum Rating ··········· 12 V
- Supply Current at Normal Mode ··········· Typ.3.0µA / Max.6µA (Ta=25°C)
- Standby Current ··········· Max.0.5µA (Ta=25°C)

Reset Function

- Reset detection / release voltage ··········· Typ.1.2V (±0.3V, Ta=25°C)
- Reset detection delay time ··········· 50ms
- Reset release delay time ··········· 32ms / 48ms

Detector Selectable Range and Accuracy (Unless otherwise provided, -20°C ≤ Ta ≤ 60°C[1])

- Overcharge detection voltage ··········· 4.430V to 4.495V (in 5mV step, ±20mV)
- Overcharge release voltage ··········· 4.03V to 4.495V
  (in 5mV step, ±55mV, Hysteresis ≤ 0.4V)
- Overdischarge detection voltage ··········· 2.1V to 3.0V (in 50mV step, ±55mV)
- Overdischarge release voltage ··········· 2.3V to 3.1V (in 50mV step, +105mV/-65mV)
- Discharge overcurrent detection voltage 1 ··········· 0.015V to 0.025V (in 1mV step, ±3mV)
- Discharge overcurrent detection voltage 2 ··········· 0.024V to 0.045V (in 1mV step, ±5mV)
- Charge overcurrent detection voltage ··········· -0.017V to -0.024V (in 1mV step, ±3mV)
- Short-circuit detection voltage ··········· 0.055V to 0.200V (in 10mV step, ±20mV)

Output delay time

- Overcharge detection delay time ··········· 1.0s
- Overcharge release delay time ··········· 1.2ms
- Overcdischarge detection delay time ··········· 64ms
- Overdischarge release delay time ··········· 1.2ms
- Selectable discharge overcurrent detection delay time 1 ··········· 4096ms
- Selectable discharge overcurrent detection delay time 2 ··········· 16ms
- Short-circuit detection delay time ··········· 280µs
- Discharge overcurrent release delay time ··········· 8.5ms
- Charge overcurrent detection delay time ··········· 17ms
- Charge overcurrent release delay time ··········· 4ms

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

Functions

- Selectable 0V-battery charge ·· Permission
- Selectable overcharge detection ····································· Auto-release
- Selectable overdischarge detection ································· Auto-release
- Discharge overcurrent ·· Auto-release

Package

- Small Package ··· DFN1616-8

APPLICATIONS

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

SELECTION GUIDE

Set voltages, Delay times are, and Optional functions are user-selectable.

Selection Guide

Product Name	Package	Quantity per Reel	Pb Free	Halogen Free
R5611Lxxx$∗-TR	DFN1616-8	5,000 pcs	Yes	Yes

xxx: Specify the combination of the following set output voltages. Refer to *Product Code List* for details.

Overcharge detection voltage (V_{DET1}): 4.430 V to 4.495 V in 5 mV step
Overcharge release voltage (V_{REL1}): 4.030 V to 4.495 V in 5 mV step
Overdischarge detection voltage (V_{DET2}): 2.1 V to 3.0 V in 50 mV step
Overdischarge release voltage (V_{REL2}): 2.3 V to 3.1 V in 50 mV step
Discharge overcurrent detection voltage 1 (V_{DET31}): 0.015 V to 0.025 V in 1 mV step
Discharge overcurrent detection voltage 2 (V_{DET32}): 0.024 V to 0.045 V in 1 mV step
Short-circuit detection voltage (V_{SHORT}): 0.055 V to 0.200 V in 10 mV step
Charge overcurrent detection voltage (V_{DET4}): -0.017 V to -0.024 V in 1mV step

$: Specify the combination of 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}). Refer to *Delay Time Code Table* for details.

∗: Specify the combination of functions. Refer to *Function Code Table* for details.

Delay Time Code Table / Function Code Table

Code	t_{RREL}	Unit	Reset Released
BC	48	ms	RST only
DE	32	ms	RST or V_{SHORT2}

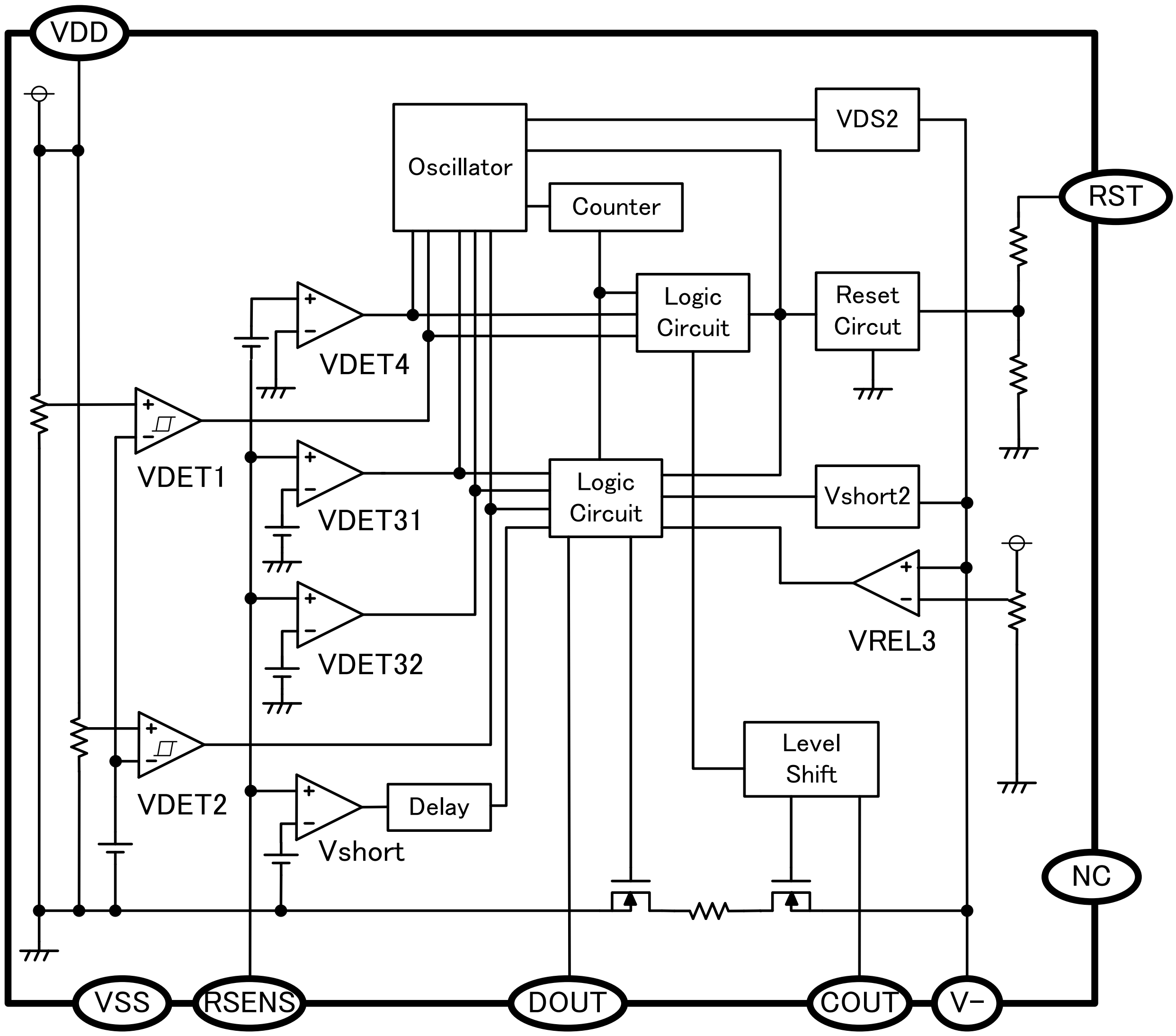
Product Code List

The product code is determined by a combination of the three digits set output voltage code, the delay time code, and the function code.

Product Code Table

Product Name	Set Output Voltage (V)								Delay Time
	V_{DET1}	V_{REL1}	V_{DET2}	V_{REL2}	V_{DET31}	V_{DET32}	V_{SHORT}	V_{DET4}	t_{RREL}
R5611L**201**BC	4.445	4.295	2.350	2.550	0.0210	0.030	0.080	-0.021	48
R5611L**201**DE	4.445	4.295	2.350	2.550	0.0210	0.030	0.080	-0.021	32
R5611L**205**DE	4.475	4.325	2.350	2.550	0.0210	0.030	0.080	-0.021	32
R5611L**205**BC	4.475	4.325	2.350	2.550	0.0210	0.030	0.080	-0.021	48

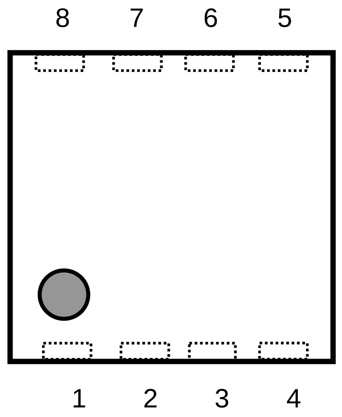
BLOCK DIAGRAMS



R5611L Block Diagram

PIN DESCRIPTIONS

DFN1616-8



Pin No	Symbol	Pin Description
1	RST	Forced OFF input pin for COUT and DOUT pins
2	V-	Charger negative input pin
3	COUT	Overcharge detection output pin, CMOS output
4	DOUT	Overdischarge 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

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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(1)	150	mW
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 operation at or over these absolute maximum ratings is 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.

(1) Refer to *POWER DISSIPATION* in *SUPPLEMENTSRY ITEMS* for detail information.

ELECTRICAL CHARACTERISTICS

R5611LxxxXX Electrical Characteristics **(Ta = 25°C)**

Symbol	Items	Conditions	Min.	Typ.	Max.	Unit	Circuit (1)
V_{DD1}	Operating input voltage	V_{DD}-V_{SS}	1.5		5.0	V	A
V_{ST}	Minimum operating voltage for 0V battery charge	V_{DD}-V-, V_{DD}-V_{SS} = 0V			1.8	V	A
V_{DET1}	Overcharge detection voltage	R1 = 330Ω	V_{DET1} -0.020	V_{DET1}	V_{DET1} +0.020	V	B
V_{REL1}	Overcharge release voltage	R1 = 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	0.7	1.0	1.3	s	C
t_{VREL1}	Overcharge release delay time	V_{DD} = 4.8V → V_{REL1}-0.1V	0.7	1.2	2.5	ms	C
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} -0.100	V_{REL2}	V_{REL2} +0.100	V	E
t_{VDET2}	Overdischarge detection delay time	V_{DD} = V_{DET2}+0.15V → V_{DET2}-0.1V	44	64	84	ms	D
t_{VREL2}	Overdischarge release delay time	V_{DD} = V_{DET2}-0.2V → V_{REL2}+0.25V	0.6	1.2	1.7	ms	E
V_{DET31}	Discharge overcurrent detection voltage 1	Detect rising edge of RSENS pin voltage V_{DD} = 3.6V, V- = V_{RSENS}	V_{DET31} -0.0025	V_{DET31}	V_{DET31} +0.0025	V	F
t_{VDET31}	Discharge overcurrent 1 detection delay time	V_{DD} = 3.6V, V_{RSENS}=0V → V_{DET31}+0.005V V- = V_{RSENS}	3072	4096	4916	ms	F
V_{DET32}	Discharge overcurrent detection voltage 2	Detect rising edge of RSENS pin voltage V_{DD} = 3.6V, V- = V_{RSENS}	V_{DET32} -0.0035	V_{DET32}	V_{DET32} +0.0035	V	F
t_{VDET32}	Discharge overcurrent 2 detection delay time	V_{DD} = 3.6V, V_{RSENS} = 0V → V_{DET32}+0.010V V- = V_{RSENS}	11	16	21	ms	F
V_{SHORT1}	Short detection voltage 1	Detect rising edge of RSENS pin voltage V_{DD} = 3.6V, V_{RSENS} = V-	V_{SHORT1} -0.015	V_{SHORT1}	V_{SHORT1} +0.015.	V	F

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

R5611LxxxXX Electrical Characteristics (Continued) **(Ta = 25°C)**

Symbol	Items	Conditions	Min.	Typ.	Max.	Unit	Circuit (1)
t_{SHORT}	Short detection delay time (2)	V_{DD} = 3.6V, V_{RSENS} = 0V → 1V V- = V_{RSENS}	170	280	400	µs	F
V_{SHORT2}	Short detection voltage 2	Detect rising edge of V- pin voltage V_{DD} = 3.6V, V_{RSENS} = 0V	V_{DD}-1.8	V_{DD}-1.45	V_{DD}-1.1	V	F
V_{REL3}	Discharge overcurrent release voltage	Detect falling edge of V- pin voltage V_{DD} = 3.6V, V_{RSENS} = 0V	0.706×V_{DD} -0.12	0.706 ×V_{DD}	0.706×V_{DD} +0.12	V	F
R_{SHORT}	Discharge overcurrent release resistance	V_{DD} = 3.6V, V- = 2.662V	5.5	9.5	14.5	kΩ	F
t_{VREL3}	Discharge overcurrent release delay time	V_{DD} = 3.6V, V- = 3.6V → 0V V_{RSENS} = 0V	5.9	8.5	11.1	ms	F
V_{DET4}	Charge overcurrent detection voltage	Detect falling edge of RSENS pin voltage V_{DD} = 3.6 V, V- = V_{RSENS}	V_{DET4} -0.0025	V_{DET4}	V_{DET4} +0.0025	V	G
t_{VDET4}	Charge overcurrent detection delay time	V_{DD} = 3.6 V, V_{RSENS} = 0V → -0.5V V- = V_{RSENS}	11	17	23	ms	G
t_{VREL4}	Charge overcurrent release delay time	V_{DD}=3.6V, V- = -0.5V → 0V V- = V_{RSENS}	2.8	4	5.2	ms	G
V_{DS}	Delay Time Shortening Mode Voltage	V_{DD} = 3.6 V	-2.6	-2.0	-1.4	V	-
V_{RDET}	Detection and Release voltage at Charge and discharge OFF mode	Detect rising edge of RST pin voltage V_{DD}=3.6V, V- = V_{RSENS} = 0V	0.9	1.2	1.5	V	M
I_{RST}	RST pin "High" input current	V_{DD} = 3.6V, RST=3.6V V- = RSENS = 0V			1.2	µA	M
R_{RST}	RST pin resistance	V_{DD} = 3.6V, RST=3.6V V- = RSENS = 0V	3.0			MΩ	M
t_{RST}	RST pin delay time	V_{DD}=3.6V, RST = 0V → 3.6V V- = V_{RSENS} = 0V	35	50	65	ms	M
t_{RREL}	RST pin release delay time	V_{DD}=3.6V, RST = 3.6V → 0V V- = V_{RSENS} = 0V	t_{RREL} x 0.7	t_{RREL}	t_{RREL} x 1.3	ms	M
V_{OL1}	COUT Nch. ON voltage	I_{OL} = 50µA, V_{DD} = 4.55 V		0.4	0.5	V	H
V_{OH1}	COUT Pch. ON voltage	I_{OH} = -50µA, V_{DD} = 3.9 V	3.4	3.7		V	I
V_{OL2}	DOUT Nch. ON voltage	I_{OL} = 50µA, V_{DD} = 1.9 V		0.2	0.5	V	J
V_{OH2}	DOUT Pch. ON voltage	I_{OH} = -50µA, V_{DD} = 3.9 V	3.4	3.7		V	K
I_{DD}	Supply current	V_{DD} = 3.9 V, V- = 0 V		3	6	µA	L
$I_{STANDBY}$	Standby current	V_{DD} = 1.9 V			0.5	µA	L

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

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

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

R5611LxxxXX 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_{ST}	Minimum operating voltage for 0V battery charge	V_{DD}-V-, V_{DD}-V_{SS} = 0V			1.8	V	A
V_{DET1}	Overcharge detection voltage	R1 = 330Ω	V_{DET1} -0.020	V_{DET1}	V_{DET1} +0.020	V	B
V_{REL1}	Overcharge release voltage	R1 = 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	0.5	1.0	2.0	s	C
t_{VREL1}	Overcharge release delay time	V_{DD} = 4.8V → V_{REL1}-0.1V	0.5	1.2	3.0	ms	C
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	32	64	128	ms	D
t_{VREL2}	Overdischarge release delay time	V_{DD} = V_{DET2}-0.2V → V_{REL2}+0.25V	0.5	1.2	3.0	ms	E
V_{DET31}	Discharge overcurrent detection voltage 1	Detect rising edge of RSENS pin voltage V_{DD} = 3.6V, V- = V_{RSENS}	V_{DET31} -0.003	V_{DET31}	V_{DET31} +0.003	V	F
t_{VDET31}	Discharge overcurrent 1 detection delay time	V_{DD} = 3.6V, V_{RSENS}=0V → V_{DET31}+0.005V V- = V_{RSENS}	2660	4096	5530	ms	F
V_{DET32}	Discharge overcurrent detection voltage 2	Detect rising edge of RSENS pin voltage V_{DD} = 3.6V, V- = V_{RSENS}	V_{DET32} -0.005	V_{DET32}	V_{DET32} +0.005	V	F
t_{VDET32}	Discharge overcurrent 2 detection delay time	V_{DD} = 3.6V, V_{RSENS} =0V → V_{DET32}+0.010V V- = V_{RSENS}	8	16	24	ms	F
V_{SHORT1}	Short detection voltage 1	Detect rising edge of RSENS pin voltage V_{DD} = 3.6V, V_{RSENS} = V-	V_{SHORT1} -0.020	V_{SHORT1}	V_{SHORT1} +0.020	V	F

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

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

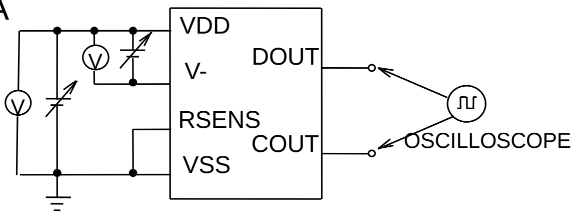
R5611LxxxXX Electrical Characteristics (Continued) **(-20°C ≤ Ta ≤ 60°C)**

Symbol	Items	Conditions	Min.	Typ.	Max.	Unit	Circuit [1]
t_{SHORT}	Short detection delay time [2]	V_{DD} = 3.6V, V_{RSENS} = 0V → 1V $V-$ = V_{RSENS}	140	280	560	µs	F
V_{SHORT2}	Short detection voltage 2	Detect rising edge of V- pin voltage V_{DD} = 3.6V, V_{RSENS} = 0V	V_{DD}-1.9	V_{DD}-1.45	V_{DD}-1.0	V	F
V_{REL3}	Discharge overcurrent release voltage	Detect falling edge of V- pin voltage V_{DD} = 3.6V, V_{RSENS} = 0V	0.706×V_{DD} -0.15	0.706 ×V_{DD}	0.706×V_{DD} +0.15	V	F
R_{SHORT}	Discharge overcurrent release resistance	V_{DD} = 3.6V, V- = 2.662V	5.0	9.5	15	kΩ	F
t_{VREL3}	Discharge overcurrent release delay time	V_{DD} = 3.6V, V- = 3.6V → 0V V_{RSENS} = 0V	4.25	8.5	17	ms	F
V_{DET4}	Charge overcurrent detection voltage	Detect falling edge of RSENS pin voltage V_{DD} = 3.6 V, V- = V_{RSENS}	V_{DET4} -0.003	V_{DET4}	V_{DET4} +0.003	V	G
t_{VDET4}	Charge overcurrent detection delay time	V_{DD} = 3.6 V, V_{RSENS} = 0V → -0.5V V- = V_{RSENS}	10	17	25	ms	G
t_{VREL4}	Charge overcurrent release delay time	V_{DD}=3.6V, V- = -0.5V → 0V V- = V_{RSENS}	2	4	8	ms	G
V_{DS}	Delay Time Shortening Mode Voltage	V_{DD} = 3.6 V	-2.7	-2.0	-1.2	V	-
V_{RDET}	Detection and Release voltage at Charge and discharge OFF mode	Detect rising edge of RST pin voltage V_{DD}=3.6V, V- = V_{RSENS} = 0V	0.3	1.2	1.8	V	M
I_{RST}	RST pin "High" input current	V_{DD} = 3.6V, RST=3.6V V- = RSENS = 0V			3.6	µA	M
R_{RST}	RST pin resistance	V_{DD} = 3.6V, RST=3.6V V- = RSENS = 0V	1			MΩ	M
t_{RST}	RST pin delay time	V_{DD}=3.6V, RST = 0V → 3.6V V- = V_{RSENS} = 0V	25	50	75	ms	M
t_{RREL}	RST pin release delay time	V_{DD}=3.6V, RST = 3.6V → 0V V- = V_{RSENS} = 0V	t_{RREL} x 0.5	t_{RREL}	t_{RREL} x 1.5	ms	M
V_{OL1}	COUT Nch. ON voltage	I_{OL} = 50µA, V_{DD} = 4.55 V		0.4	0.5	V	H
V_{OH1}	COUT Pch. ON voltage	I_{OH} = -50µA, V_{DD} = 3.9 V	3.4	3.7		V	I
V_{OL2}	DOUT Nch. ON voltage	I_{OL} = 50µA, V_{DD} = 1.9 V		0.2	0.5	V	J
V_{OH2}	DOUT Pch. ON voltage	I_{OH} = -50µA, V_{DD} = 3.9 V	3.4	3.7		V	K
I_{DD}	Supply current	V_{DD} = 3.9 V, V- = 0 V		3	8	µA	L
$I_{STANDBY}$	Standby current	V_{DD} = 1.9 V			0.6	µA	L

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

Test Circuits

A



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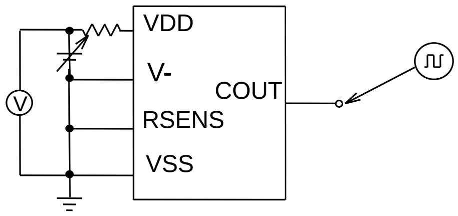

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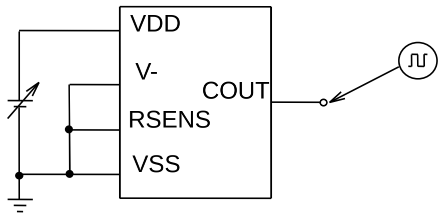

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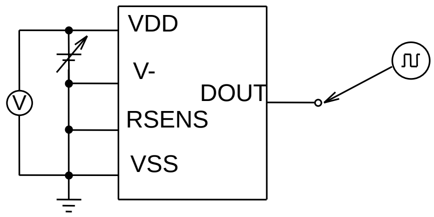

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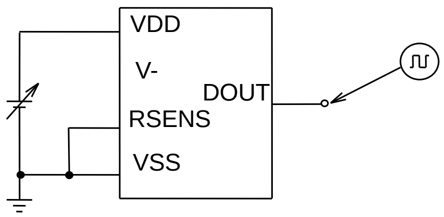

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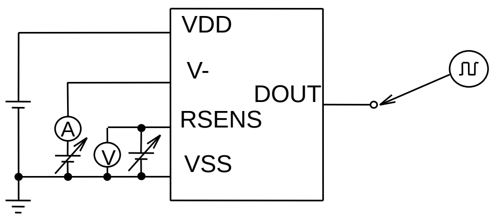

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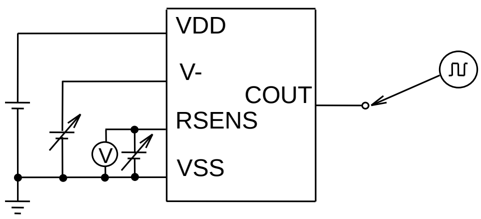

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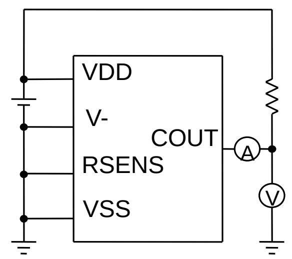

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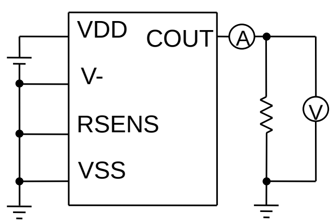

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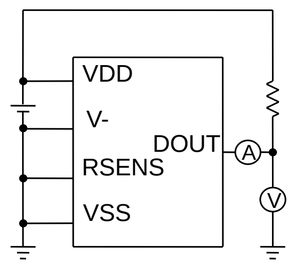

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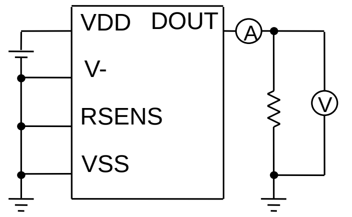
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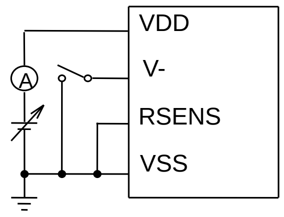
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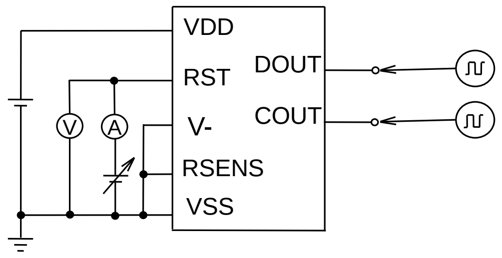

VDD
RST
DOUT
COUT
V-
RSENS
VSS
V
A

OPERATION

Overcharge Detection, VD1

The VD1 monitors a VDD pin voltage during charge. When the VDD voltage crosses overcharge detection voltage (V_{DET1}) [1], the VD1 can sense overcharge and the output of COUT pin becomes "L" and stop charging by turning off the external Nch. MOSFET. After detecting overcharge, when the VDD pin voltage is equal or less than the released voltage from overcharge (V_{REL1}) [1], or when the VDD pin voltage is less than the overcharge detection voltage (V_{DET1}) [1], if the charger is removed, VD1 is released, then the output level of COUT becomes "H" and by turning on the external Nch. MOSFET, the battery charger is ready to work again. However, depending on the characteristics of external components such as MOSFETs, release conditions may be not enough and a kind of load must be set to release the overcharge. When the Input level of VDD pin is equal or more than overcharge detector threshold, and while a charger is disconnected from the battery pack, if a load system is connected to the battery pack, the output level of COUT pin is "L". However, load current can be drawn through a parasitic diode of an external Nch. MOSFET. Then, when the voltage level of VDD pin becomes lower than overcharge detector threshold, the output level of COUT pin becomes "H".

Output delay time for overcharge detect and released overcharge is internally fixed respectively. Although the VDD pin voltage goes up to a higher level than overcharge detector threshold within the output delay time (t_{VDET1})[1], VD1 would not work for detecting overcharge. If the action for VD1 to release is done and the condition returns to the initial one within the output delay time (t_{VREL1}) [1], VD1 cannot be released.

A level shifter is built in a buffer driver for the COUT pin, therefore, the "L" level is equal to the voltage level of V- pin. The output type of COUT pin is CMOS type and its output level is in between VDD and V-.

Overdischarge Detection, VD2 or VDET2

The VD2 monitors a VDD pin voltage during discharge. When the VDD pin voltage crosses the overdischarge detector threshold (V_{DET2}) [1] from a high level to a lower level than V_{DET2}, the VD2 senses overdischarge and stop discharge by turning off an external Nch. MOSFET.

To reset the VD2 with the DOUT pin level being "H" again after detecting overdischarge, if VDD pin voltage is equal or less than overcharge detector threshold, a charge current flows through a parasitic diode of the external Nch. MOSFET. After that, when V_{DD} voltage is more than overdischarge threshold, D_{OUT} pin becomes "H", and by tuning on the external Nch. MOSFET, discharge is possible. In the case that a charger is connected to the battery pack, and V_{DD} level is more than overdischarge detection voltage, the output level of DOUT pin becomes "H" immediately. Without connecting a charger, if VDD pin voltage is equal or more than the released voltage from overdischarge (V_{REL2}) [1], the output level of DOUT becomes "H".

When a cell voltage is equal to 0V, connecting a charger to the battery pack makes COUT pin become "H" and the system is allowable for charge while the voltage of the charger is more than the maximum limit of the minimum operating voltage (V_{ST}) [1] for 0V charge.

An output delay for overdischarge detection (t_{VDET2}) [1] is fixed internally. Although the voltage of VDD pin becomes equal or less than overdischarge detector threshold and if it becomes higher than overdischarge detector threshold within output delay time, overdischarge detector does not work. Output delay time for release from overdischarge (t_{VREL2}) [1] is also set internally. After detecting overdischarge by VD2, supply current would decrease, (V_{DD}=2.0V, Max. 0.5µA.) because unnecessary circuits are halted and being standby.

The output type of DOUT pin is CMOS type and its output level is in between V_{DD} and V_{SS}.

[1] Indicates the value shown in the table of "[5] Electrical Characteristics".

Discharge overcurrent detection / Short-circuit protection, VD31 and VD32

While charge and discharge are acceptable with the battery pack, current flows through an external sense resistance and the generated drop voltage by the current is detected as RSENS pin voltage, VD3 monitors the voltage level of RSENS pin. In the cause of such as the external short circuit, if the voltage level of RSENS pin may become equal or more than the discharge overcurrent detection voltage (V_{DET3}) [1] and less than the short detector threshold (V_{SHORT}) [1], the discharge overcurrent detection works. When the voltage level of RSENS pin becomes equal or more than the short detector threshold voltage, the short circuit protector works and the output level of DOUT becomes “L”, and by turning off an external Nch. MOSFET, VD3 protects against flowing extremely large current into the circuit.

An output delay time for the discharge overcurrent detection is internally fixed. Even if the voltage of RSENS pin becomes equal or more than the discharge overcurrent detection voltage and less than the short detection voltage (V_{SHORT}) [1], if the RSENS pin voltage becomes less than the overcurrent detection voltage within the output delay time (t_{VDET3}) [1], the overcurrent detection does not work. Even if RSENS pin becomes equal or more than the short circuit detection voltage, if RSENS pin becomes lower than the short detection voltage within the short detection delay time (t_{SHORT}) [1], the short detection does not work. Output delay time for release from discharge overcurrent, short circuit is also set internally (t_{VREL3}) [1].

The V- pin has a built-in pull down resistor connected to the V_{SS} pin.

After a discharge overcurrent or short circuit protection is detected, by removing a cause of overcurrent or external short circuit, the voltage level of V- is pulled down through the resistor for release from overcurrent to the V_{SS} level. While charge and discharge are acceptable for the battery pack, or normal mode, the resistor is inactive.

Then, when the voltage level of V- pin becomes equal or less than the released voltage from discharge overcurrent (V_{REL3}) [1], both protection circuits are released automatically. Resistor for release from discharge overcurrent is active when discharge overcurrent or short circuit is detected.

V- pin voltage is represented by the equation below when V- pin is pulled down by discharge overcurrent or short detecting.

$$V_{-} = \frac{R_{short}}{R_L + R_2 + R_{short}} V_{DD}$$

V_{DD} : Input Voltage (Cell Voltage) [2]

R_{SHORT} : Internal resistance of V- pin when it is pulled down[1]

R_2 : External resistor between Pack minus and V- pin [2]

R_L : Resistance of load between Pack plus and Pack minus [2]

Output delay time for discharge overcurrent is necessarily set shorter than output delay time for overdischarge. Therefore, if discharge overcurrent is detected, and at the same time, V_{DD} pin voltage becomes lower than overdischarge detection voltage, discharge overcurrent detection is predominant. By disconnecting load from the battery pack, the battery pack is automatically released from overcurrent state.

(1) Indicates the value shown in the table of “[5] Electrical Characteristics”.
(2) Indicates the value shown in the table of “[8] Technical Notes”.

Charge overcurrent detection, VD4

While charge and discharge are acceptable with the battery pack, VD4 senses RSENS pin voltage. For example, if the battery pack is charged by an inappropriate charger, overcurrent flows through an external resistance and the generated voltage drop is monitored as RSENS pin voltage, and the RSENS pin voltage becomes equal or less than the charge overcurrent detection voltage (V_{DET4}) [1], then, the output of C_{OUT} becomes “L”, and VD4 protects against flowing excess current in the circuit by turning off the external Nch MOSFET. Output delay of the excess charge current is internally fixed. (t_{VDET4}) [1] Even the voltage level of RSENS pin becomes equal or lower than the charge overcurrent detection voltage, if the voltage is higher than the VD4 threshold within the delay time, the charge overcurrent state is not detected. Output delay time for release from charge overcurrent is also set internally (t_{VREL4}) [1].
VD4 can be released by disconnecting the abnormal charger.

Delay time in short-circuit mode

When the COUT pin is "H", the output delay time of overcharge, and overdischarge can be shorter than those setting values by forcing equal or lower than the delay shortening mode detection voltage (V_{DS2} Typ. -2.0V) and more than -3.0V to V- pin.

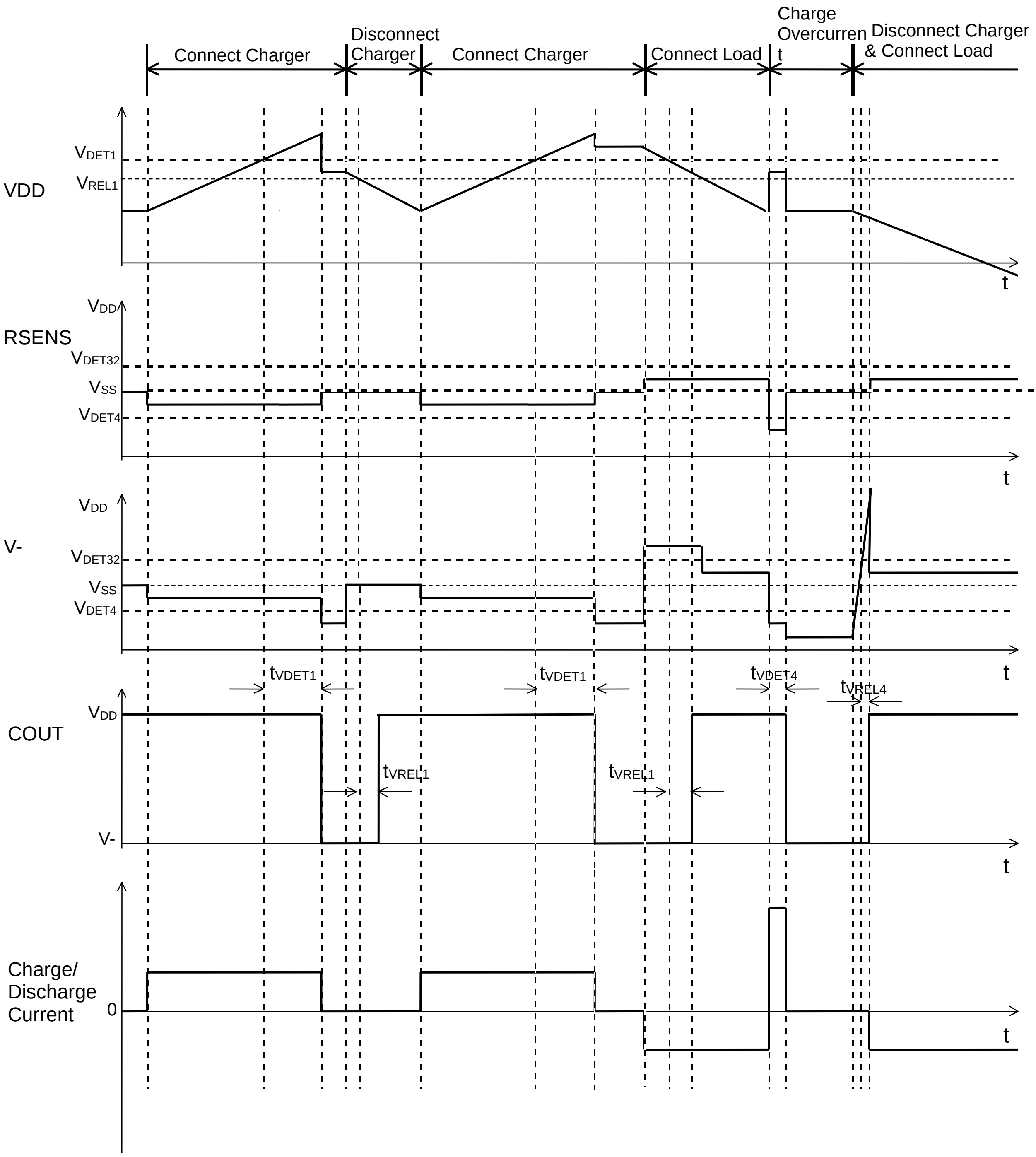
RESET function

When the R5611 receives a reset signal as RST to input “H”, not only the output of DOUT pin but the output of COUT switches to “L” level after the internal fixed delay time. After detecting reset signal, the R5611 can be reset and the output of DOUT and COUT becomes “H” after RST is made open or V- voltage. RST terminal is connected to V- internal resistance. After detecting reset signal, V_{DETx} (x=1,2,31,32,4) and V_{SHORT} can’t work. On the other hands, after detecting V_{DETX} or V_{SHORT}, Reset can’t work.

[1] Indicates the value shown in the table of “[5] Electrical Characteristics”.

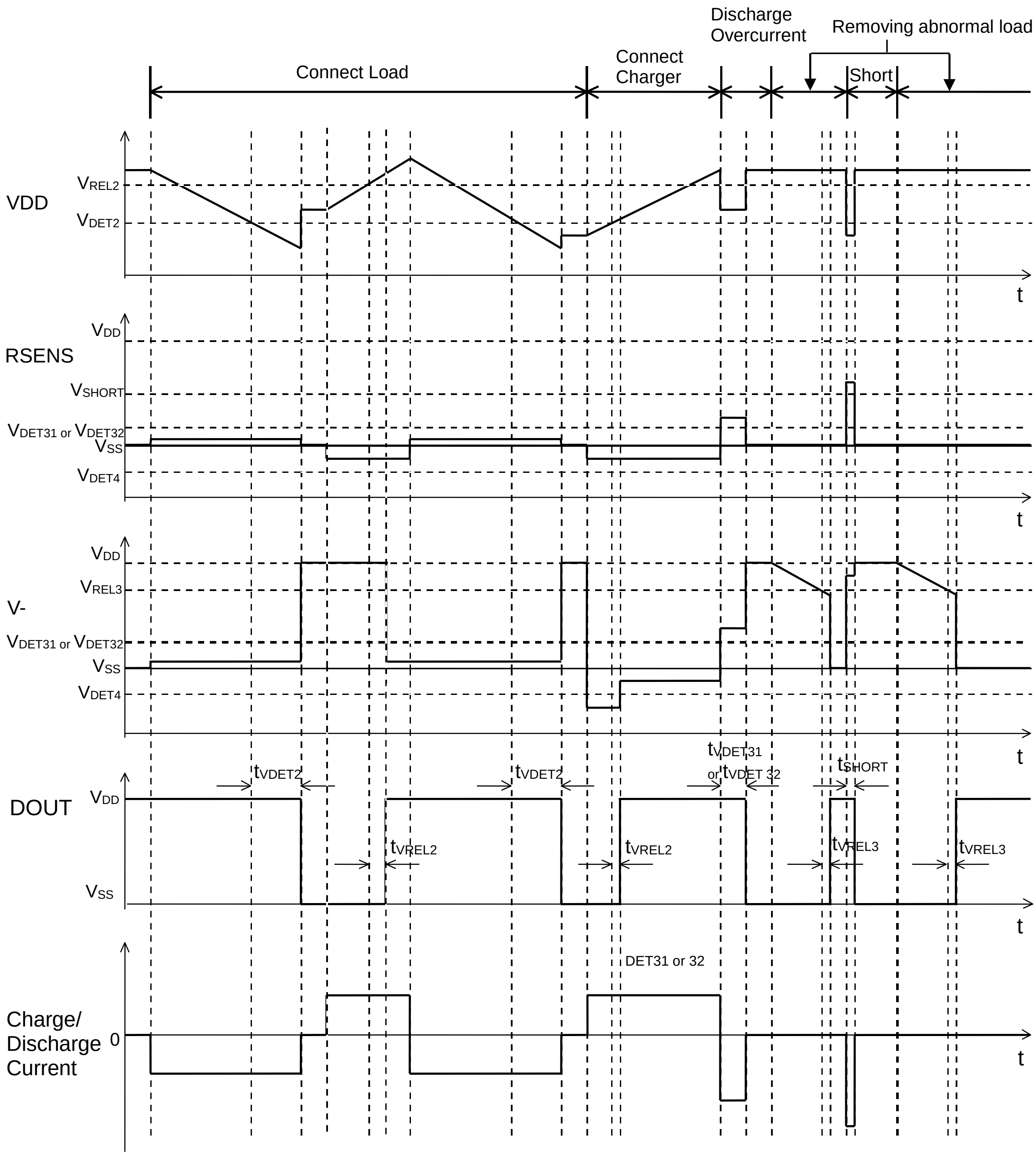
Timing Charts

Overcharge voltage and Overcharge current



Overcharge Timing Diagram

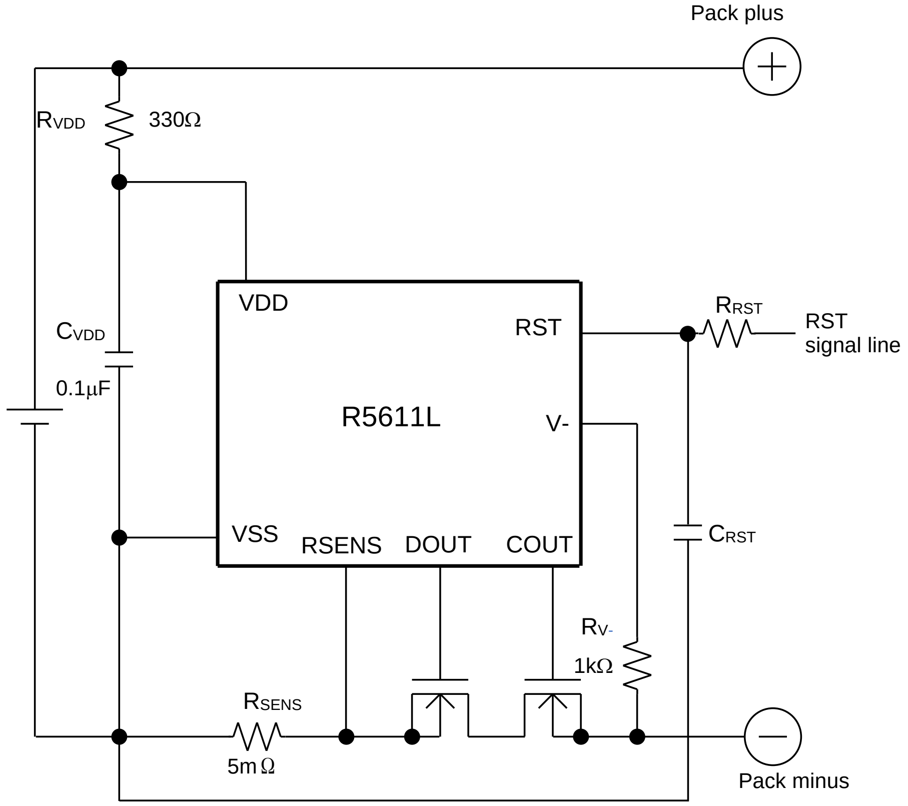
Overdischarge, Discharge overcurrent, and Short-circuit



Overdischarge, Discharge Overcurrent, and Short-circuit Timing Diagram

APPLICATION INFORMATION

Typical Application Circuit



R5611LxxxXX Typical Application Circuit

External Components

Symbol	Min.	Typ.	Max.
Resistor			
R_{VDD} (1)		330Ω	1kΩ
R_{V-} (1)	-	1kΩ	1.3kΩ
R_{SENS}	-	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 the Selection Components

- The voltage fluctuation is stabilized with R_{VDD} and C_{VDD}. If a R_{VDD} is too large, by the conduction current at detection, the detection voltage rises. Therefore, 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} in order to stabilize the operation.

- 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 excess current. If the resistance value is too large, power loss becomes also large. By the excess current, 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. R_{RST} and C_{RST} are used to control noise. R_{RST} must be less than 10kΩ.

- 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 delay time until detecting the short circuit. Therefore, select an appropriate FET with large enough current capacitance in order to endure the large current during the delay time.

Selection of External FET

Short mode is detected by the current base or the relation between V_{DD} at short and total on resistance of external MOSFETs for COUT and DOUT.

If short must be detected by the current base determined by V_{SHORT1}, V_{SHORT2}, and R3, the next formula must be true, otherwise, the short current limit becomes (V_{SHORT2}) / (R3 + R_{SS} (on))

$$\frac{\mathrm{Vshort2}}{\mathrm{R3}+\mathrm{Rss(on)}} \geq \frac{\mathrm{Vshort1}}{\mathrm{R3}}$$

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)

R3 = External current sense Resistance (Ω)

R_{SS} (on) = external MOSFETs' total ON Resistance (Ω)

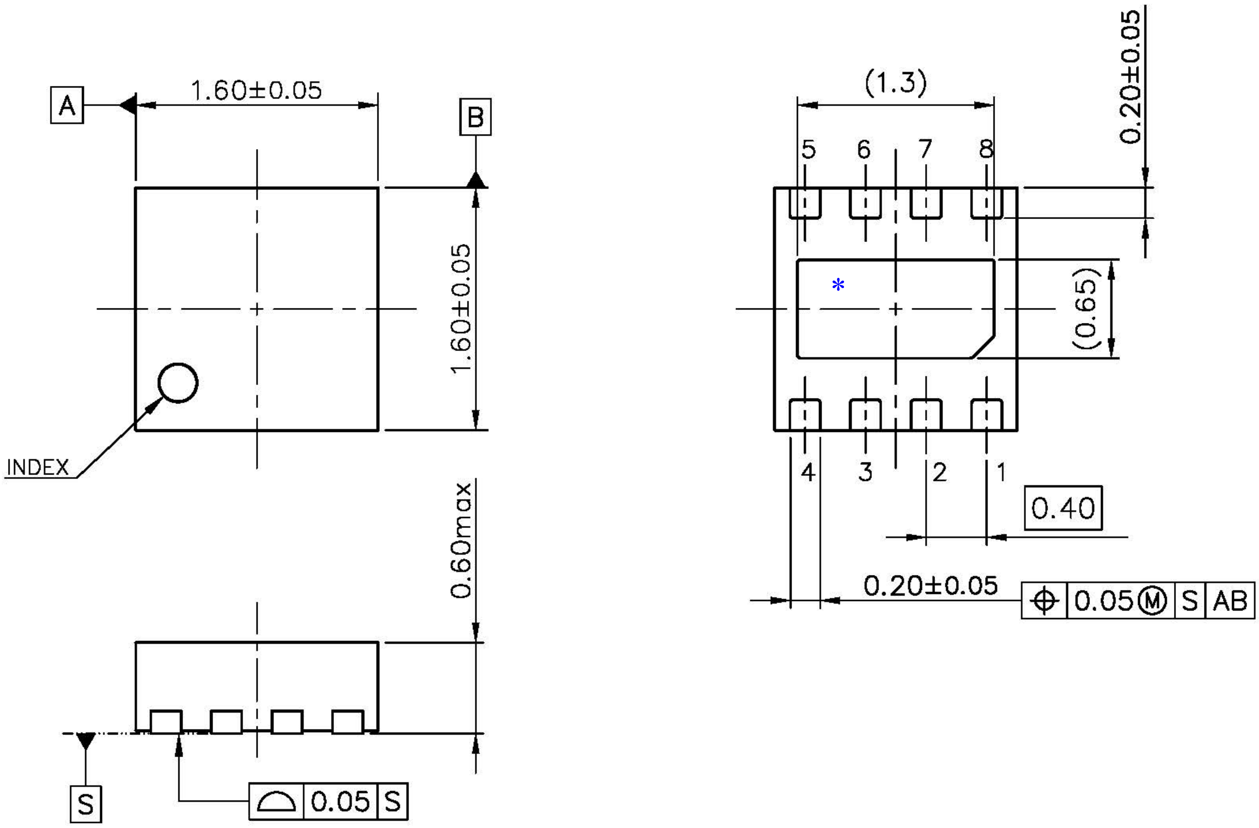
Notes: in case of the short mode is specified at short current determined by the relation between R3 and V_{SHORT} value,

Ex.

As the R_{SENS}, in case that the 3mΩ is selected as R3 and if the V_{DD}* becomes 3.3V, to detect short at 26.7A with V_{SHORT1} = 0.080V and V_{SHORT2}=VDD-1.45, the R_{SS} (on) must be 66mΩ or lower.

Otherwise, according to the R_{SS} (on), short current limit is lower than expected.

Ver. A



DFN-1616-8 Package Dimensions (Unit: mm)

* The tab on the bottom of the package shown by blue circle is a substrate potential (GND). It is recommended that this tab be connected to the ground plane on the board but it is possible to leave the tab floating.

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