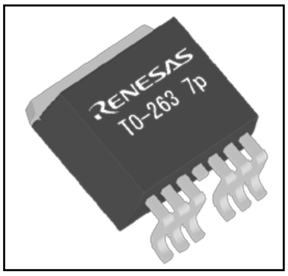
RAJ2800044H12HPF

Intelligent Power Device for automotive application

R07DS1397EJ0100
Rev.1.00
Aug 1, 2017

1. Overview

1.1 Description



Family:

RAJ280004 is 3.8mohm single channel Intelligent Power Devices (IPD) embedded in TO263-7 package. It is N-channel high-side switches with charge pump, diagnostic feedback with proportional load current sense and embedded protection function. Family includes up to 4 devices depending on on-state resistance, input interface combination between current driven and voltage driven.

Scalability:

Variety of on-state resistance combined with standardized package on pin-out give user high flexibility for unit design depending on target load.

Robustness:

Because of advanced protection method, RAJ280004 achieves high robustness against long term and repetitive short circuit condition.

1.2 Features

- Built-in charge pump
- 3.3V compatible logic interface
- Low standby current
- Short circuit protection
  - Shutdown by over current detection
  - Shutdown by over load detection
  - Shutdown by delta Tch detection
  - Shutdown by absolute channel over temperature detection
- Built-in diagnostic function
  - Proportional load current sensing
  - Defined fault signal in case of abnormal load condition
- Reverse battery protection by self-turn ON
- Loss of ground protection
- Under voltage lock out
- Active clamp operation at inductive load switch off
- AEC Qualified
- RoHS compliant

1.3 Product summary

Parameter	Symbol	Values
Operating Voltage	V_{CC}	5.3V ~ 28V
Under voltage shutdown	$V_{CC(Uv)}$	Max. 5.3V
On-state resistance at 25℃	Ron	Max. 4.6mohm, Typ. 3.8mohm
Inductive load switch-off energy dissipation single pulse	EAS	500mJ
Inductive load switch-off energy dissipation repetitive pulse	EAR	320mJ
Minimum Over current detection current	IL(SC)	100A

1.4 Application

- All types of resistive, inductive and capacitive loads, especially for high current loads.
- Power management application such as Power distribution switches, Heaters, glow plugs, etc

NOTE: The information contained in this document is the one that was obtained when the document was issued, and may be subject to change.

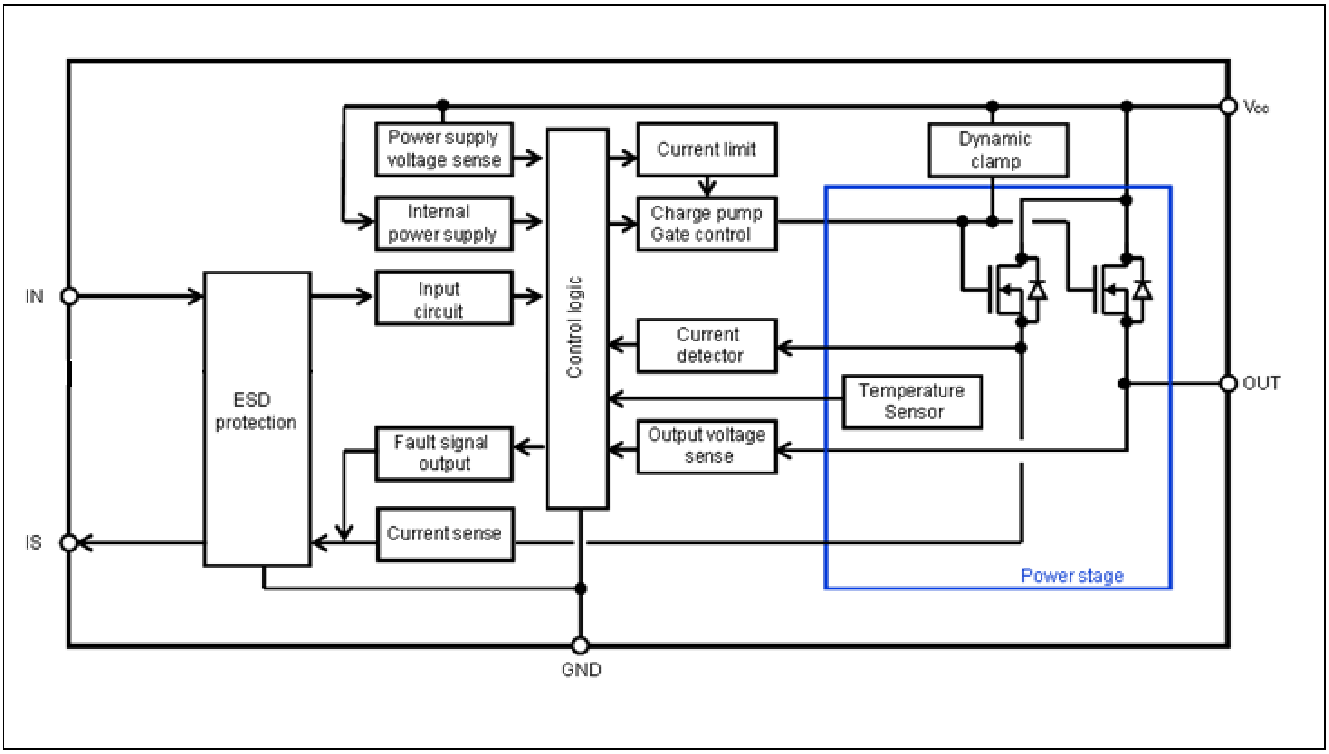
2. Ordering Information

Part No.	Lead plating	Packing	Package
RAJ2800044H12HPF	Pure Matte Sn	Tape 800 pcs/reel	TO263-7

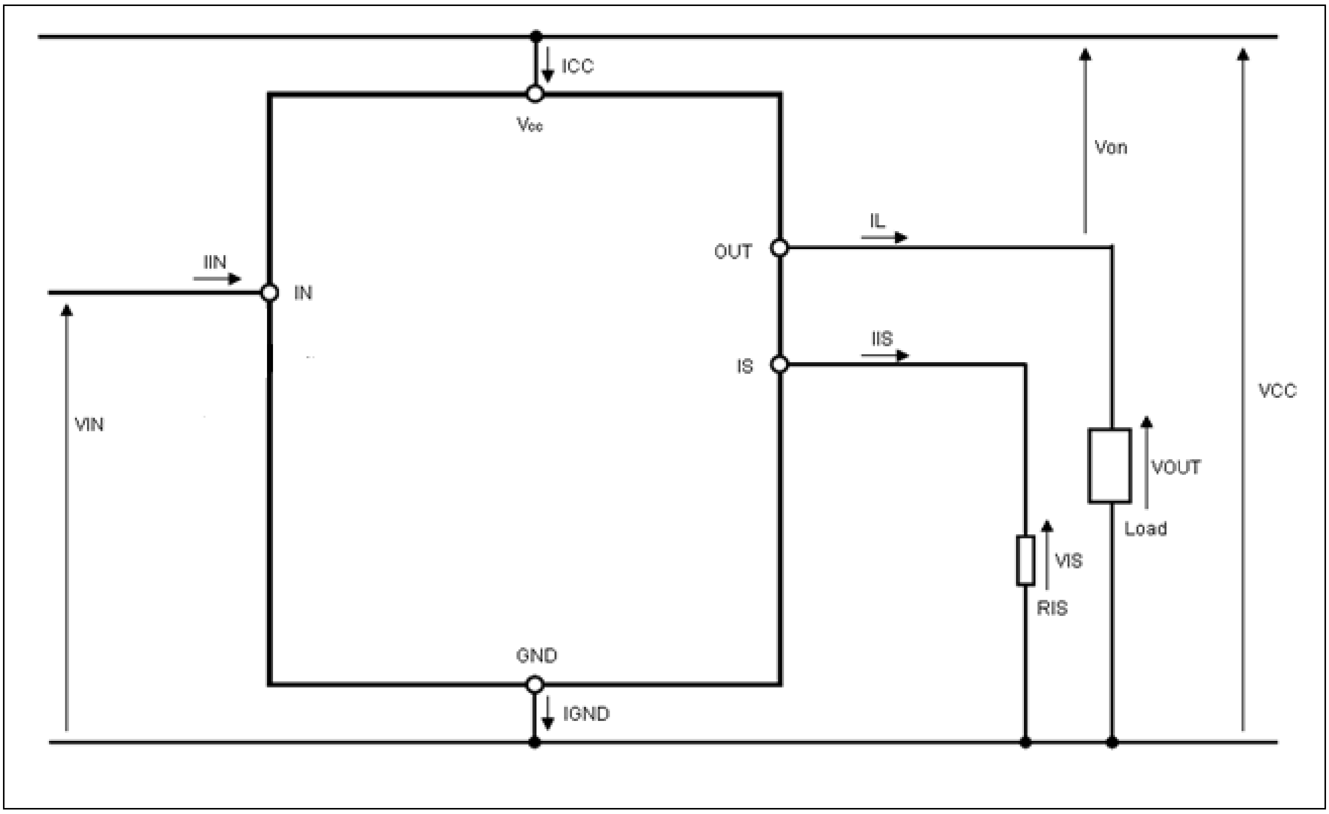
3. Specification

3.1 Block Diagram

3.1.1 Nch High-side Single Channel Device Block Diagram



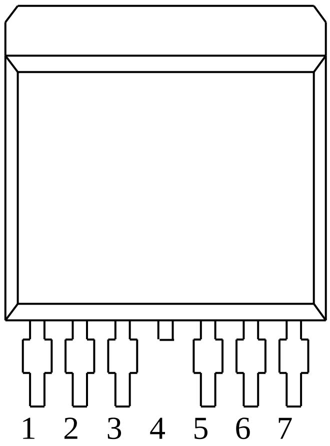
Voltage and Current Definition



3.2 Pin Configuration

3.2.1 TO263-7 Pin Configuration

Pin No.	Terminal Name
1	GND
2	IN
3	IS
4, Tab	VCC
5	OUT
6	OUT
7	OUT



Pin function

Terminal Name	Pin function	Recommended connection
GND	Ground connection	Connected to GND through a 100 Ohm resistor
IN	Input signal for channel activation Active high	Connected to MCU port through a 2k-50K serial resistor
IS	Current sense and Diagnosis output signal	Connected to GND through a 1K-6K resistor [1)]
OUT	Protected high-side power output	Connected to load with 50-100nf capacitor in parallel
VCC	Positive power supply for logic supply as well as output power supply	Connected to battery voltage with 100nf capacitor in parallel

1) A resistor is necessary to satisfy standby current characteristics

3.3 Absolute Maximum Ratings

Stress values that exceed those listed here may cause permanent damage to the device. Exposure to absolute maximum rating condition for extended periods may affect device reliability.

Integrated protection functions are designed to prevent IC destruction under fault condition described in the data sheet. Fault conditions are considered as out of normal operation. Protection function shall not be intended to be used for continuous repetitive operation.

Ta=25degreeC, unless other specified

Parameter	Symbol	Rating	Unit	Test Condition
Vcc Voltage	V_{CC}	28	V	
Vcc Voltage at reverse battery condition	$-V_{CC}$	-16	V	At nominal load current, t<2min, RIN=2kohm, RIS=1kohm, RGND=100ohm
Vcc voltage under Load Dump condition	$V_{load\ dump}$	42	V	Rl=1ohm, RL=Nominal load, RIS=1kohm, RIN=2kohm, RGND=100ohm, td=400ms,
Load Current	I_L	Self limited	A	
Total power dissipation for whole device (DC)	P_D	3.10	W	Ta=85degreeC, Device on 50mmx50mmx1.5mm epoxy PCB FR4 with 6 cm2 of 70 um copper area
Voltage at IN pin	V_{IN}	-2 ~ 16	V	DC RIN=2kohm
		-16		At reverse battery condition, t<2min, RIN=2kohm
IN pin current	I_{IN}	10	mA	DC
Voltage at IS pin	VIS	-2 ~ VCC	V	DC RIS=1kohm
		-16	V	At reverse battery condition, t<2min, RL= Nominal load, RIS=1kohm
IS Reverse current at reverse battery condition	IIS(Rev)	-30	mA	At reverse battery condition, t<2min, RL= Nominal load
Channel Temperature	Tch	-40 to +150	degreeC	
Storage Temperature	Tstg	-55 to +150	degreeC	
ESD susceptibility	V_{ESD}	2000	V	HBM: AEC-Q100-002 std. R=1.5kohm, C=100pF; All pin
		4000		HBM: IEC61000-4-2 std. R=330ohm, C=150pF, 100nF at VCC and OUT; VCC, OUT
		200	V	MM: AEC-Q100-003 std. R=0ohm, C=200pF
Inductive load switch-off energy dissipation single pulse	EAS	500	mJ	VCC=13.5V, Tch,start<150degreeC, RL=Nominal load, Refer to 3.6.7
Inductive load switch-off energy dissipation repetitive pulse	EAR	320	mJ	VCC=13.5V, Tch,start=85degreeC, RL=Nominal load, Refer to 3.6.7

Remark) All voltages refer to ground pin of the device

3.4 Thermal Characteristics

Parameter	Symbol	Min	Typ	Max	Unit	Test Condition
Thermal characteristics	Rth(ch-a)		21		degree C/W	According to JEDEC JESD51-2, -5, -7 on FR4 2s2p board
	Rth(ch-c)		0.39		degree C/W	

3.5 Electrical Characteristics

Operation function

Tch=-40 to 150degreeC, Vcc=7 to 18V, unless other wise specified

Parameter	Symbol	Min	Typ	Max	Unit	Test Condition
Operating Voltage	V_{CC}	5.3		28	V	V_{IN}=4.5V, RL=Nominal load, Refer to 3.6.7
Operating current	I_{GND}		2.5	5	mA	VIN=4.5V
Output Leakage current	$I_{L(off)}$			0.5	µA	Tch=25℃; VCC=13.5V, VIN=0V, VIS=0V, VOUT=0V, VGND=0V
				13		Tch=-40~125℃; VCC=13.5V, VIN=0V, VIS=0V, VOUT=0V, VGND=0V
Standby current	$I_{CC(off)}$			0.5	µA	Tch=25℃; VCC=13.5V, VIN=0V, VIS=0V, VOUT=0V, VGND=0V
				1.5		Tch=-40~85℃; VCC=13.5V, VIN=0V, VIS=0V, VOUT=0V, VGND=0V
On-state resistance	Ron		3.8	4.6	mohm	Tch=25℃; IL= Nominal current, Refer to 3.6.7, VIN>2.5V
				8.5		Tch=150℃; IL= Nominal current, Refer to 3.6.7, VIN>2.5V
Low level IN pin voltage	V_{IL}			0.8	V	
High level IN pin voltage	V_{IH}	2.5			V	
Low level IN pin current	I_{IL}	2		30	µA	VIN=0.8V
High level IN pin current	I_{IH}	2		30	µA	VIN=2.5V
Clamping IN pin voltage [1]	V_{ZIN}	5	6		V	
Operating current at cranking	IGND(cr)		0.4		mA	VCC=3.2V, RGND=100ohm, Pulse duration=24ms, IL= Nominal current, Refer to 3.6.7
Cranking mode voltage	$V_{CC(cr)}$			5.3	V	
On-state resistance at cranking	Ron(cr)			20	mohm	VCC=3.2V, RGND=100ohm, Tch=25℃, Pulse duration=24ms, IL= Nominal current, Refer to 3.6.7
Operating Voltage range for cranking	$V_{CC(Uv,cr)}$	3.2				RGND=100ohm, Tch=25℃, Pulse duration=24ms, IL=Nominal current Refer to 3.6.7
Under voltage shutdown	$V_{CC(Uv)}$			5.3	V	
Under voltage restart	$V_{CC(Cpr)}$			5.3	V	
Turn on time	ton		500	1000	µs	VCC=13.5V, RL=Nominal load, Refer to 3.6.7
Turn on delay time	td(on)		160	300	µs	
Turn off time	toff		350	1000	µs	
Turn off delay time	td(off)		200	700	µs	
Slew rate on	dV/dton		0.05	0.1	V/µs	
Slew rate off	-dV/dtoff		0.1	0.2	V/µs	
Turn on energy loss [1]	Eon		13		mJ	VCC=13.5V,Tch=25℃, RL=Nominal load, Refer to 3.6.7
Turn off energy loss [1]	Eoff		8		mJ	
Driving capability [1]	Dr(capa)	105			mohm	Tch=25℃, VCC=8~16V
		145				Tch=105℃, VCC=8~16V

Remark) All voltages refer to ground pin of the device

1) not subjected production test, guaranteed by design

Protection function

Tch=-40 to 150degreeC, Vcc=7 to 18V, unless other wise specified

Parameter	Symbol	Min	Typ	Max	Unit	Test Condition
Over current detection current	IL(SC)	100	160		A	VCC=13.5V, Von=5V, Tch=25℃
Over load detection current 1[1)]	IL(OL1)		56		A	VCC=13.5V, Tch=25 ℃, IL>IL(OL1) after td(OL), Refer to 3.6.5
Over load detection current 2[1)]	IL(OL2)		100		A	VCC=13.5V, Tch=25℃, td(OL) after IL>IL(OL2), Refer to 3.6.5
Sense current output trigger threshold	Von(CL1)		1.0		V	VCC=13.5V
Over load detection timer	td(OL)		1.6		ms	VCC=13.5V
Absolute thermal shutdown temperature	aTth	150			℃	
delta Tch thermal shutdown temperature	dTth		40		℃	
Output clamp at inductive load switch off	Von,clamp	30		40	V	VCC=13.5V, IL=40mA, Tch=25℃
Output current while GND disconnection	IL(GND)			1	mA	IIN=0A, IGND=0A, IIS=0A
On-state resistance at reverse battery condition	Ron(rev)			6	mohm	Tch=25℃; VCC=-13.5V, IL=Nominal current, Refer to 3.6.7
				11		Tch=150℃; VCC=-13.5V, IL=Nominal current, Refer to 3.6.7
Gnd current at reverse battery condition	IGND(rev)		-2		mA	VCC=-16V, Tch=25 ℃

Remark) All voltages refer to ground pin of the device

1) not subjected production test, guaranteed by design

Diagnosis function

Tch=-40 to 150degreeC, Vcc=7 to 18V, VIN=4.5V, unless other wise specified

Parameter	Symbol	Min	Typ	Max	Unit	Test Condition
Current sense ratio	KILIS	18000	34000	50000		IL= 11 A
		21000	34000	47000		IL= 22 A
Current sense drift depend on temperature	dKILIS	-20		20	%	VCC=13.5V, Tch,start=25℃, IL =22A, Refer to 3.6.7
Sense current offset current	Iis,offset			50	µA	IL=0A, Tch =25deg
Sense voltage under fault condition	Vis,fault	4.5	5.6	7.0	V	RIS=1kohm
Load current to output sense current	IL,min	2.0			A	VCC=13.5V, Tch=25degreeC, IIS>1uA
Sense current settling time after input signal positive slope	tsis(on)		500	1100	µs	VCC=13.5V, VIN=0V to 4.5V, IL/IIS=KILIS, RL=Nominal load, Refer to 3.6.7
Sense current settling time after input signal negative slope [1)]	tsis(off)			10	µs	VIN=4.5V to 0V
Sense current settling time during on-state [1)]	tsis(LC)			50	µs	RL= 2 * Nominal load to Nominal load, Refer to 3.6.7
Fault signal delay after over current detection [1)]	tdsc(fault)			10	µs	VIN=0V to 4.5V, IL=IL(SC)
Fault signal delay after power limitation valid [1)]	tdpl(fault)			10	µs	Von>Von(CL1)
Fault signal delay after absolute thermal shutdown [1)]	tdot(fault)			10	µs	VIS→VIS,fault
Fault signal delay after input negative slope [1)]	tdoff(fault)			10	µs	VIN=4.5V to 0V

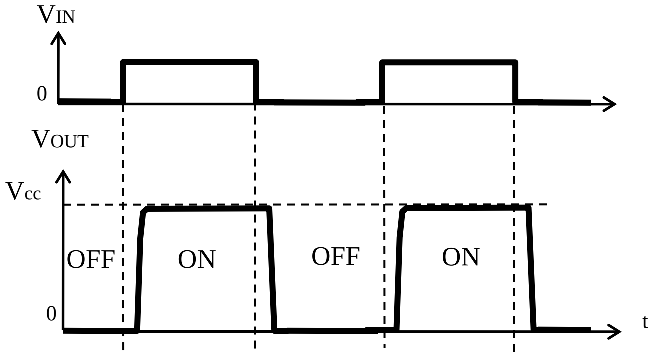
Remark) All voltages refer to ground pin of the device

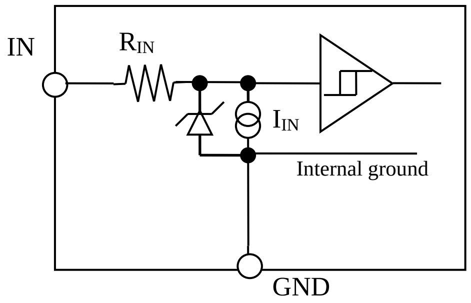
1) not subjected production test, guaranteed by design

3.6 Feature Description

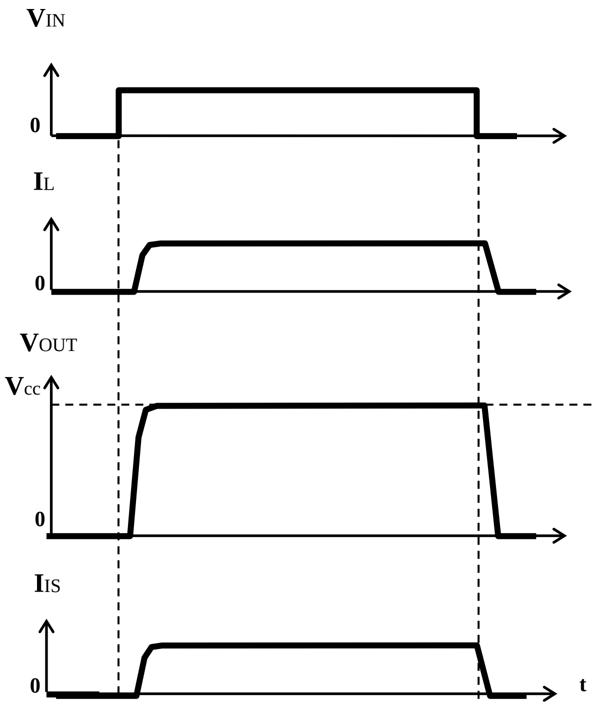
3.6.1 Driving Circuit

The high-side output is turned on, if the input pin is over VIH. The high-side output is turned off, if the input pin is open or the input pin is below VIL. Threshold is designed between VIH min and VIL max with hysteresis. IN terminal is pulled down with constant current source.

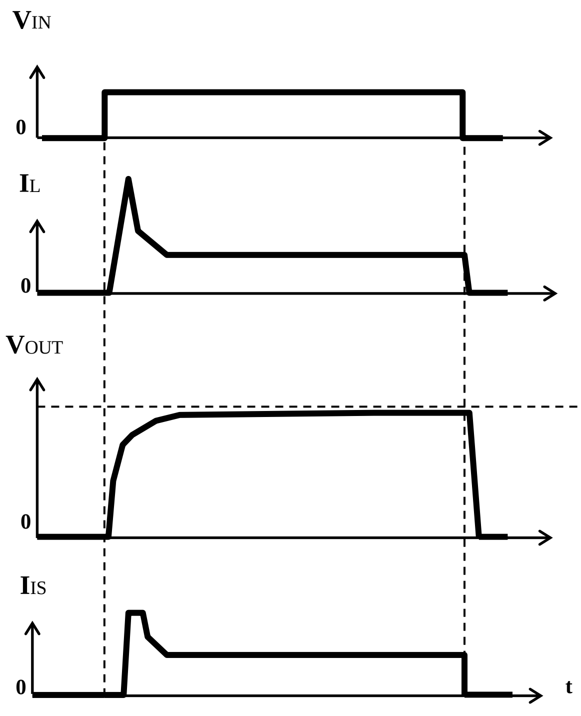




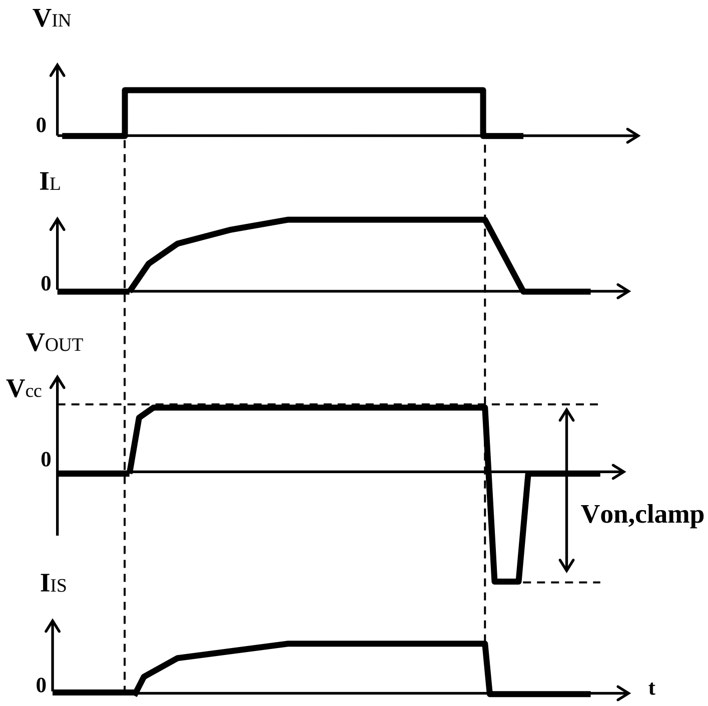
Switching a resistive load



switching lamps



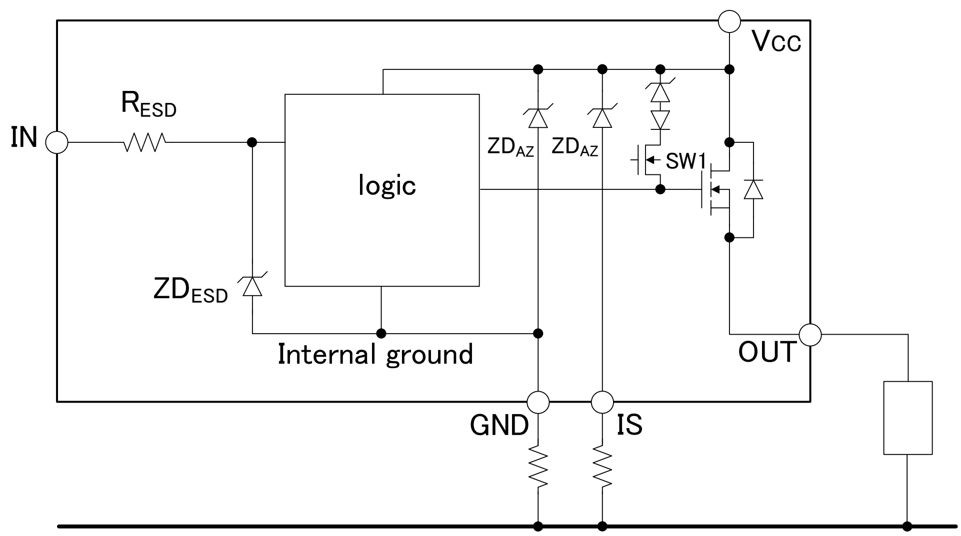
Switching an inductive load



The dynamic clamp circuit works only when the inductive load is switched off. When the inductive load is switched off, the voltage of OUT falls below 0V. The gate voltage of SW1 is then nearly equal to GND. Next, the voltage at the source of SW1 (= gate of output MOS) falls below the GND voltage.

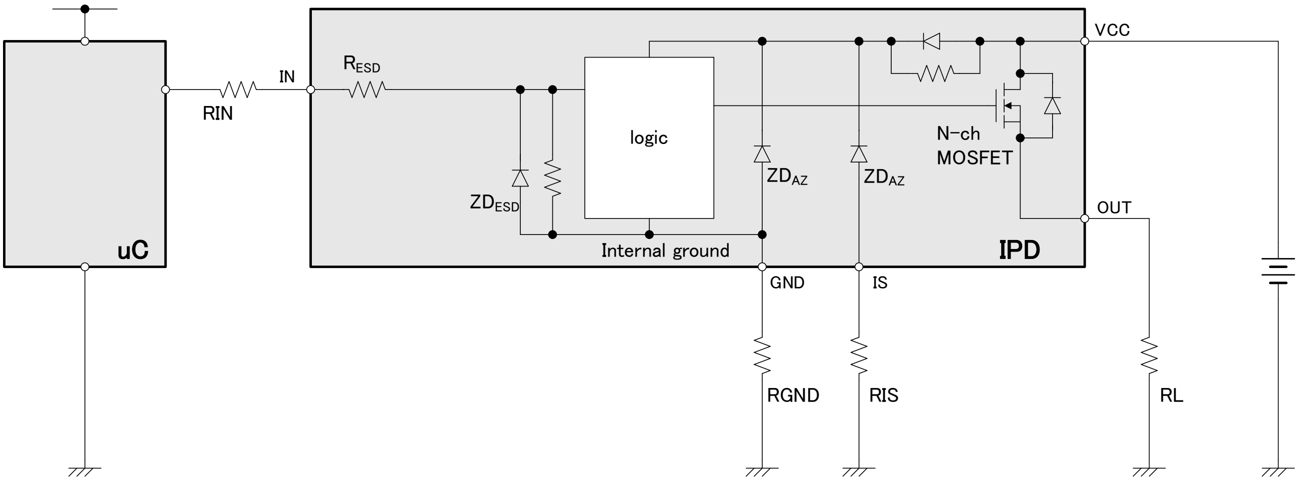
SW1 is turned on, and the clamp diode is connected to the gate of the output MOS, activating the dynamic clamp circuit.

When the over-voltage is applied to VCC, the gate voltage and source voltage of SW1 are both nearly equal to GND. SW1 is not turned on, the clamp diode is not connected to the gate of the output MOS, and the dynamic clamp circuit is not activated.



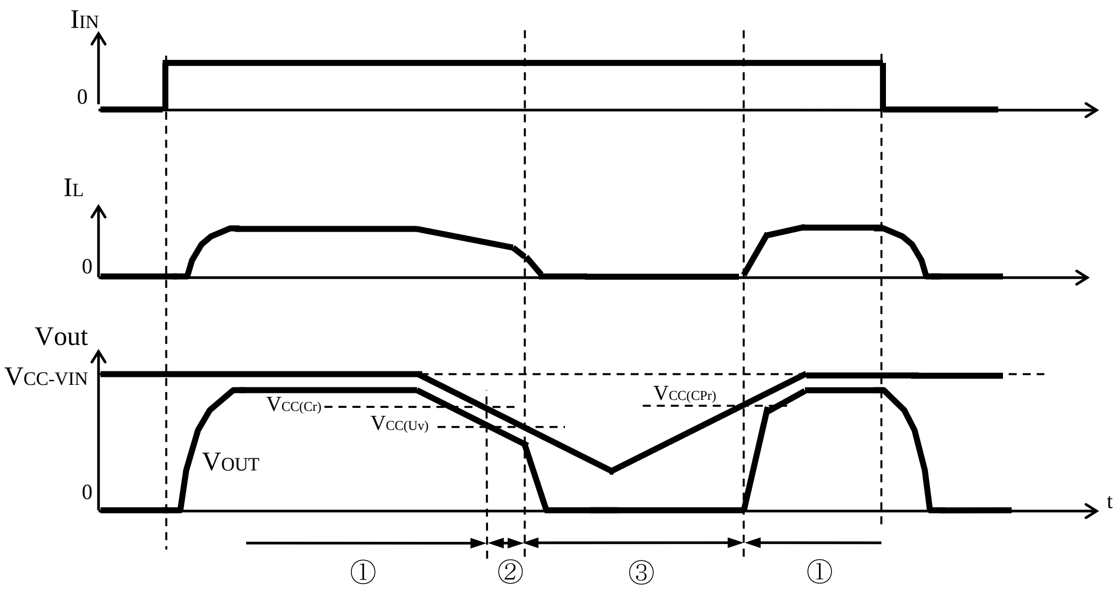
3.6.2 Device behavior at over voltage condition

In case of supply voltage greater than Vload dump, logic part is clamped by ZD_{AZ} (35V min). And current through of logic part is limited by external ground resistor. In addition, the power transistor switches off in order to protect the load from over voltage. Permanent supply voltage than V_{load} dump must not be applied to VCC.



3.6.3 Device behavior at low voltage condition

If V_{CC} goes down under V_{CC}(Uv), the device outputs shuts down. If voltage supply (V_{CC}) increase over V_{CC}(Cpr), the device output turns back on automatically. The device keeps off state after under voltage shutdown. The IS output is cleared during off-state.



① : Normal operating mode

② : Cranking mode

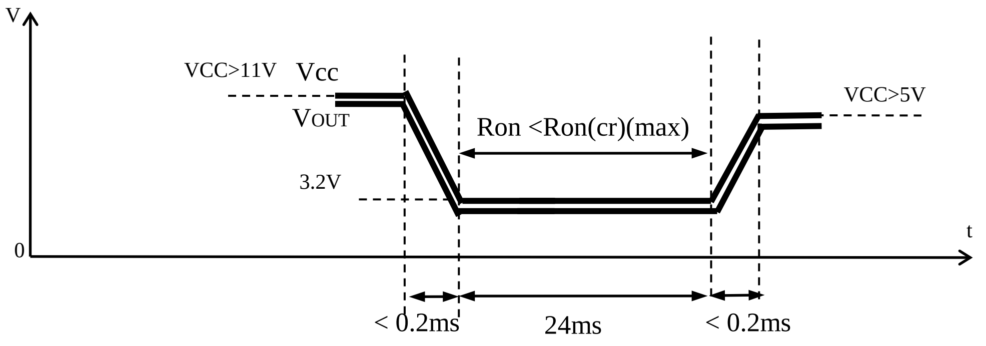
③ : Under voltage mode

Availability of each function in each mode

○: Enable, ×: Disable

	Function	①	②	③	
Normal operation	Turn on	○	×	×	
Normal operation	Turn off	○	○		
Normal operation	Keep on-state	○	○(*1)	×	(*1)Ron is defined as Ron(Cr).
Normal operation	KILIS function	○	×	×	In case of Von < Von(CL1)
Protection	IL(OL), td(OL)	○	×	×	Refer to 3.6.5
Protection	IL(SC)	○	×	×	Refer to 3.6.5
Protection	aTch	○	○		Refer to 3.6.5
Protection	dTch	○	×	×	Refer to 3.6.5
Protection	Von(CL1)	×	○	○	Refer to 3.6.5

Definition of on-state resistance at cranking



3.6.4 Loss of Ground protection

In case of complete loss of the device ground connection, but connected load ground, the device securely changes to off if VIN was initially greater than VIH state or keeps off state if VIN was initially lower than VIL state.

In case of device loss of ground, IN terminal will/ could/ might be at VCC voltage.

3.6.5 Short circuit protection

Turn-on in an over load condition including short circuit condition

The device shuts down automatically when one of the following condition (a), (b), (c) and (d) is detected. The sense pin output Iis,fault. Shutdown is latched until the next reset via input pin.

(a) IL > IL(SC)

(b) deltaTch > dTth

(c) Tch > aTth

(d) IL > IL(OL1) after td(OL)

Over load condition including short circuit condition during on-state

The device shuts down automatically when one of the following condition (e), (f), (g) and (h) is detected. The sense pin output Iis,fault Shutdown is latched until the next reset via input pin.

(e) deltaTch > dTth

(f) Tch > aTth

(g) IL > IL(SC)

(h) td(OL) after IL > IL(OL2)

delta Tch

Junction temperature differences between thermal sensors of power area.

3.6.6 Diagnostic signal

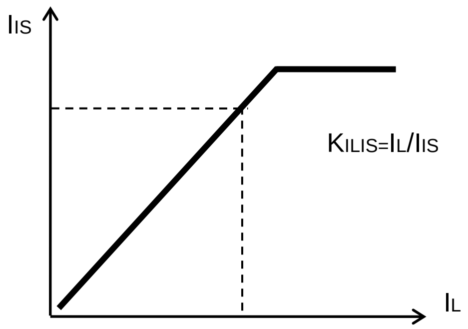
Truth table

	Input	Output	Diagnostic output
Normal Operation	H	VCC	IIS = IL/KILIS
	L	L [1]	L [2]
Shutdown by over current detection	H	L [1]	Vis,fault [3]
	L	L [1]	L [2]
Shutdown by delta Tch detection	H	L [1]	Vis,fault [4]
	L	L [1]	L [2]
Shutdown by over absolute channel temperature detection	H	L [1]	Vis,fault [5]
	L	L [1]	L [2]
Shutdown by over load detection	H	L [1]	Vis,fault [6]
	L	L [1]	L [2]
Short circuit to VCC	H	VCC	<IIS
	L	VOUT [7]	L [2]

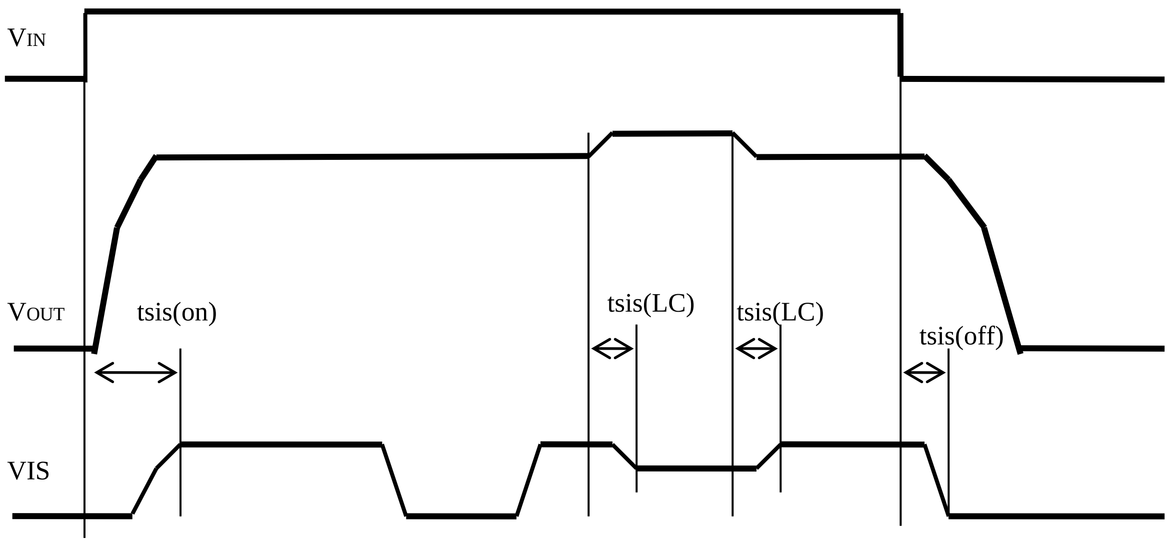
1) In case of OUT terminal is connected to GND via load.
2) In case of IS terminal is connected to GND via resister.
3) IS terminal keeps Vis,fault as long as input signal activate after the over current detection.
4) IS terminal keeps Vis,fault as long as input signal activate after the delta Tch detection
5) IS terminal keeps Vis,fault as long as input signal activate after over absolute channel temperature detection.
6) IS terminal keeps Vis,fault as long as input signal activate after over load detection.
7) VOUT depends on the ratio of VCC-OUT-GND resistive component.

Current sense output

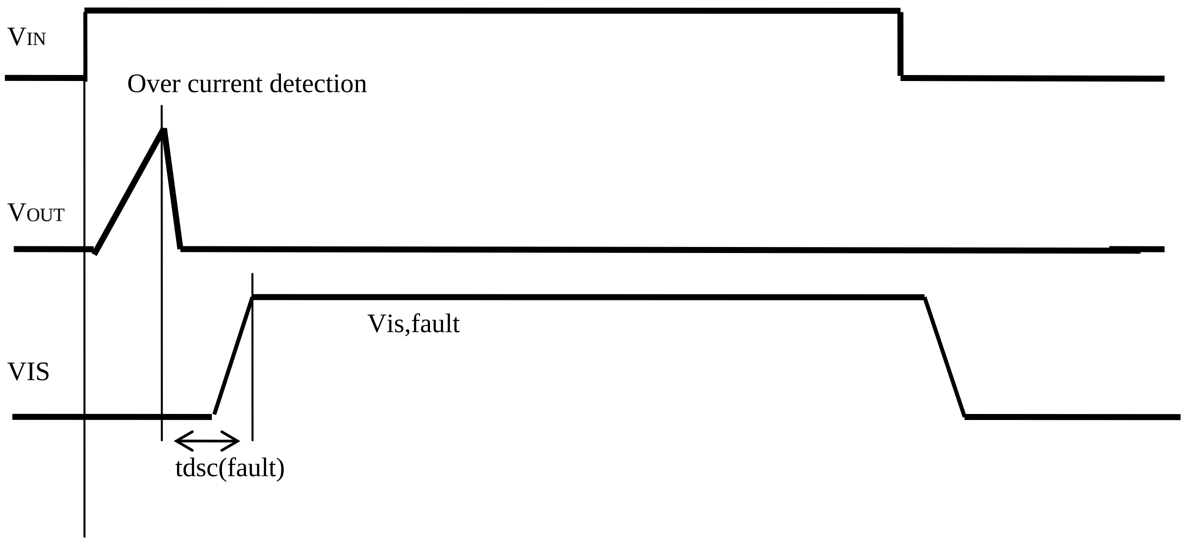
The device output analog feedback current proportional to output current from IS pin. In the case of much higher current than nominal load current, current sense output is saturated.



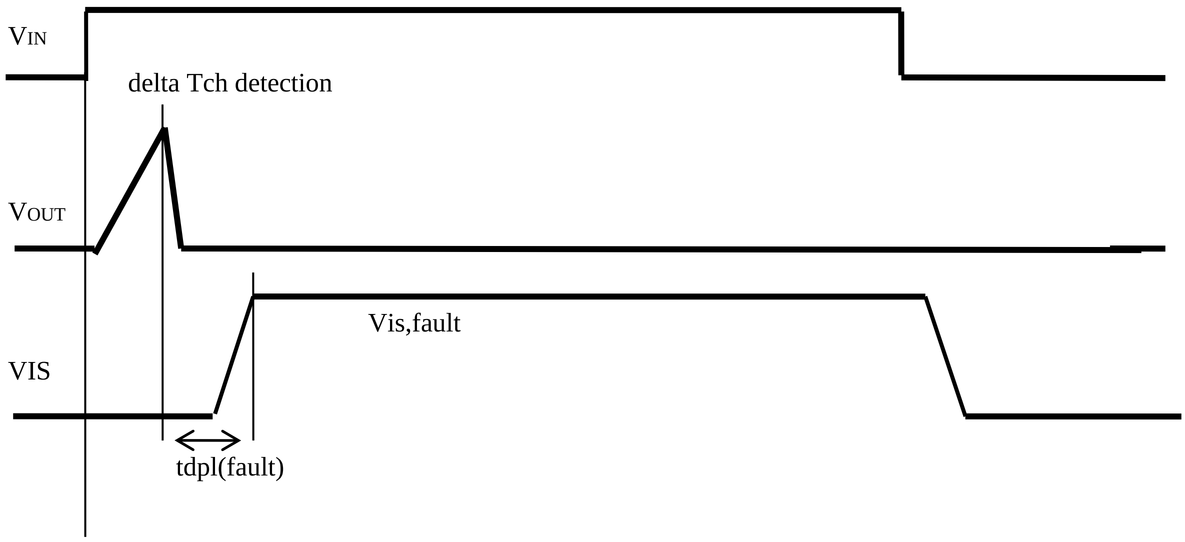
Sense voltage setting time



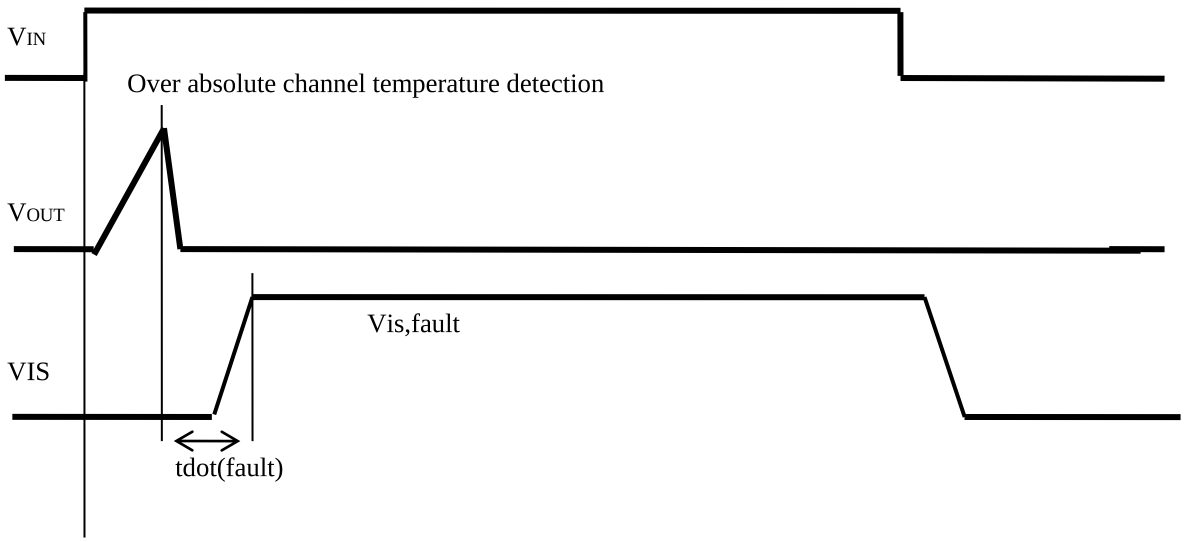
Fault signal delay time at over current detection



Fault signal delay time at delta Tch detection



Fault signal delay time at over absolute channel temperature detection

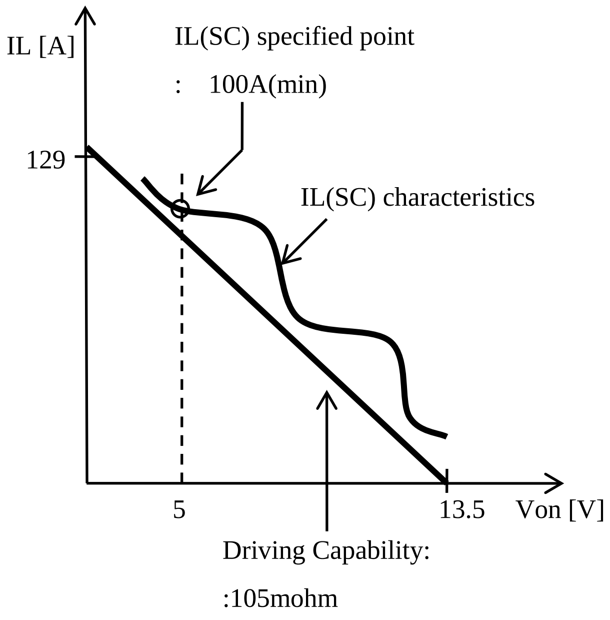


3.6.7 Nominal load and nominal current

Parameter	Values	Condition
Nominal load	0.8ohm	Tj ≦150℃
Nominal current	22A	Tj ≦150℃

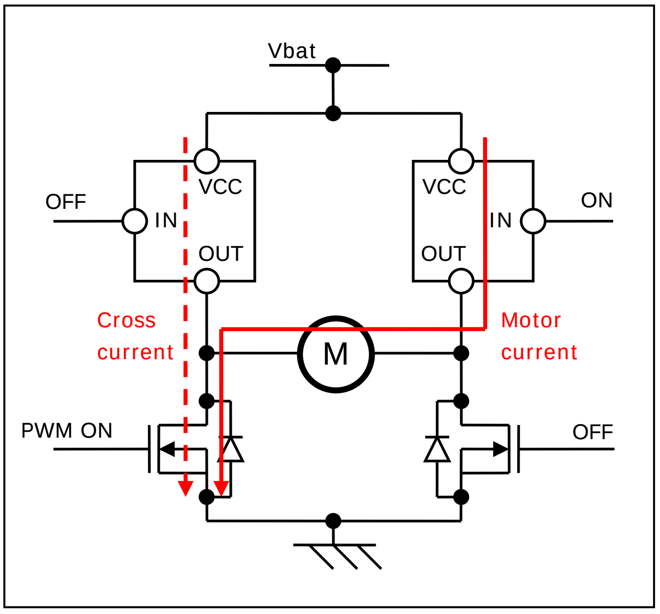
3.6.8 Driving Capability

Driving Capability is specified as load impedance. Over current detection characteristics is designed above Driving Capability characteristics. If estimated load impedance which comes from peak inrush current is lower than Driving Capability characteristics, this means, the device does not detect inrush current as over current and does not shutdown the output. However depend on the conditions, the device may shutdown during inrush current by delta Tch detection or Over Load detection. This parameter does not mean that the device can drive the resistive load up to Driving Capability characteristics.



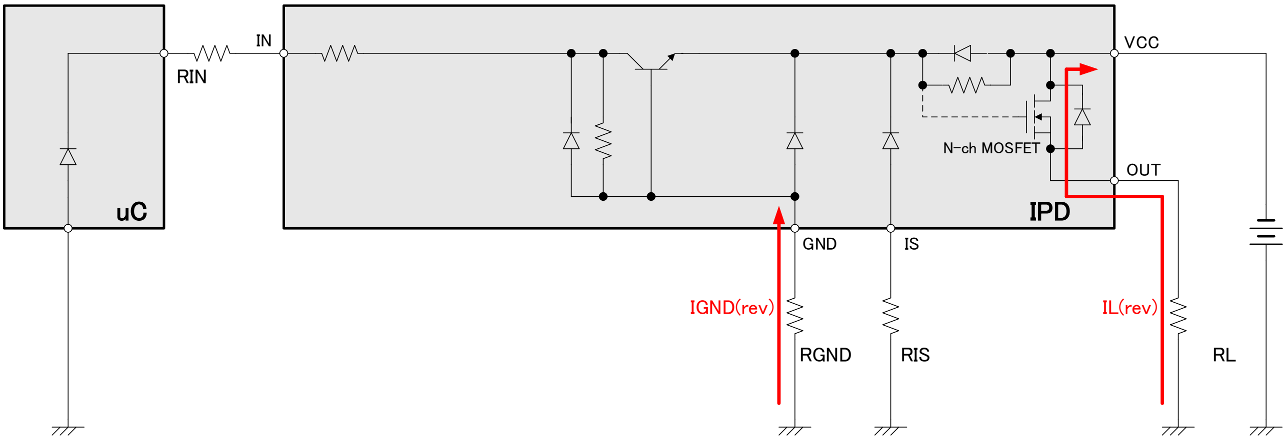
3.6.9 Cross current protection in case of H-bridge high side usage

In case of using High side driver in H-bridge circuit, High side driver protects High side driver itself and also low side driver from high power dissipation by cross current when low side driver switching on.



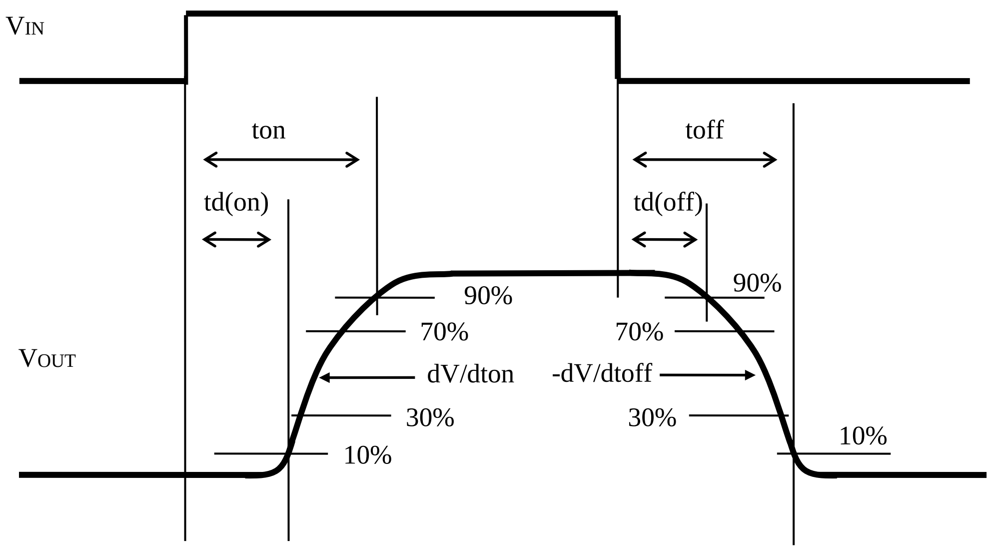
3.6.10 Reverse Battery Protection by turn on the output

In case of a reverse battery is applied to the device, the N-ch MOSFET will turn on only if reverse current flow from GND pin. The reverse current through the N-ch MOSFET has to be limited by the connected load. IGND(rev) is limited internally approx. 2mA even without external RGND. Reverse current flow from IN, IS should be limited by external component such as recommendation value in Pin function, refer 3.2 Pin configuration.

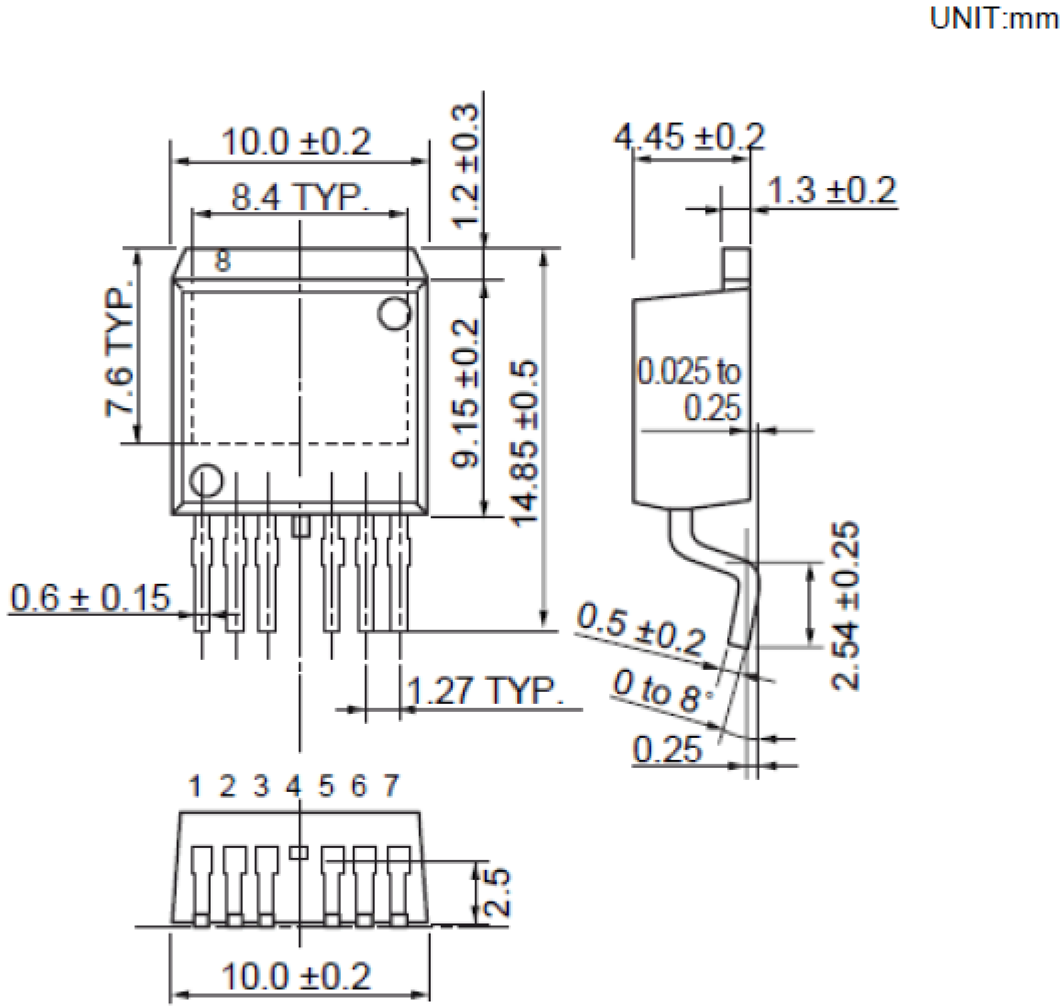


3.6.11 Measurement condition

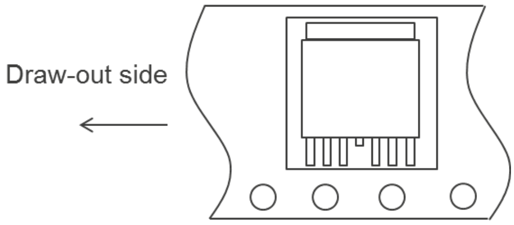
Switching waveform of OUT terminal



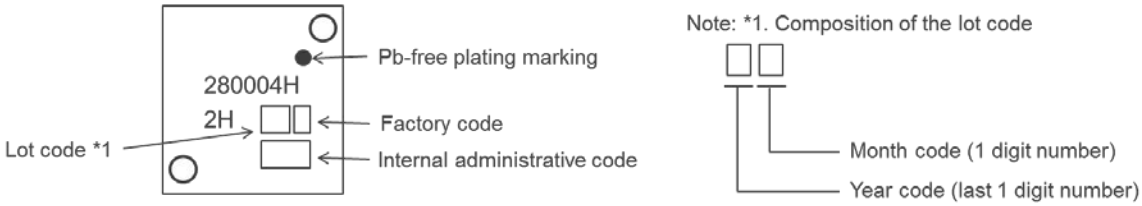
3.7 Package drawing



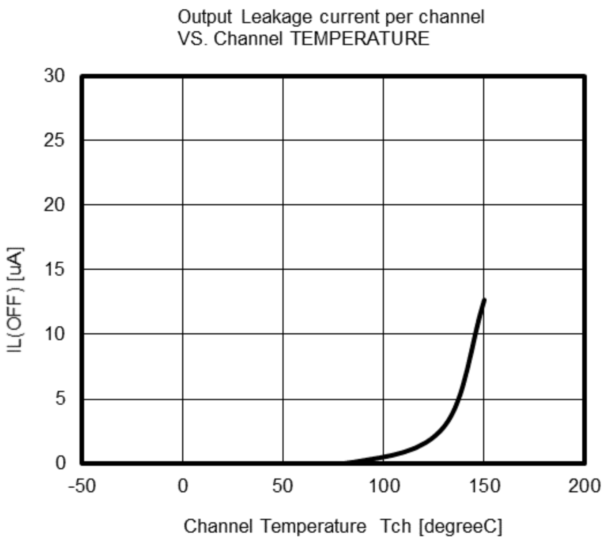
3.8 Taping information

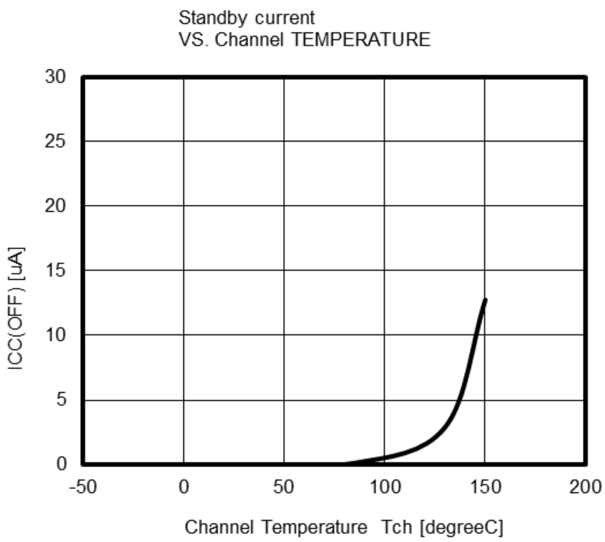


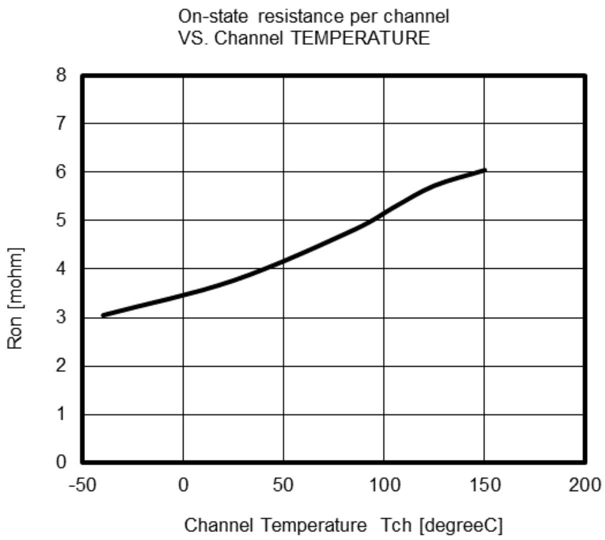
3.9 Marking information

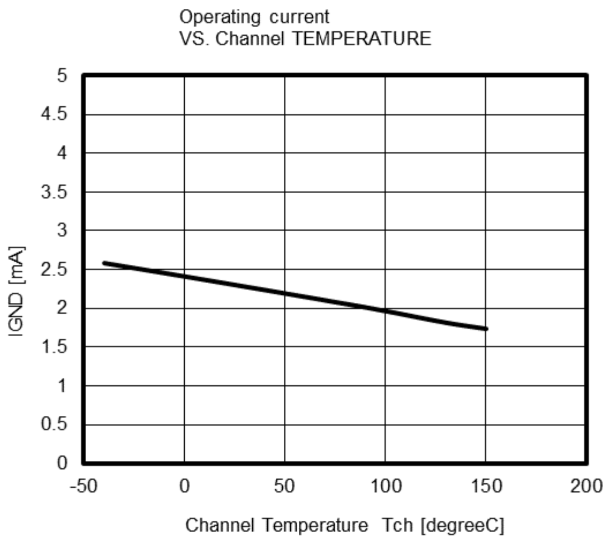


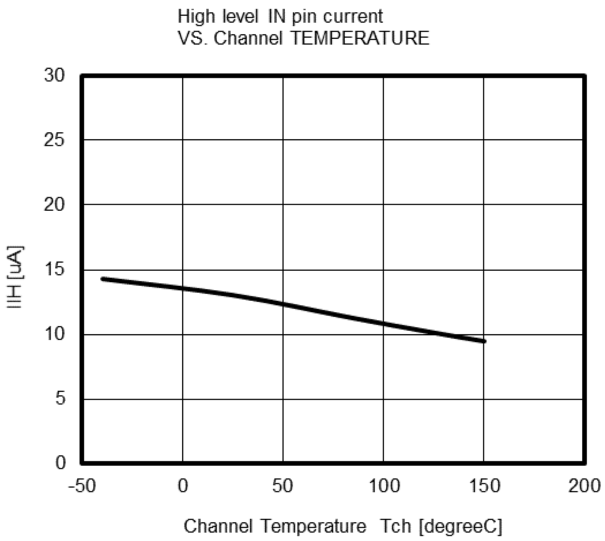
4 Typical characteristics

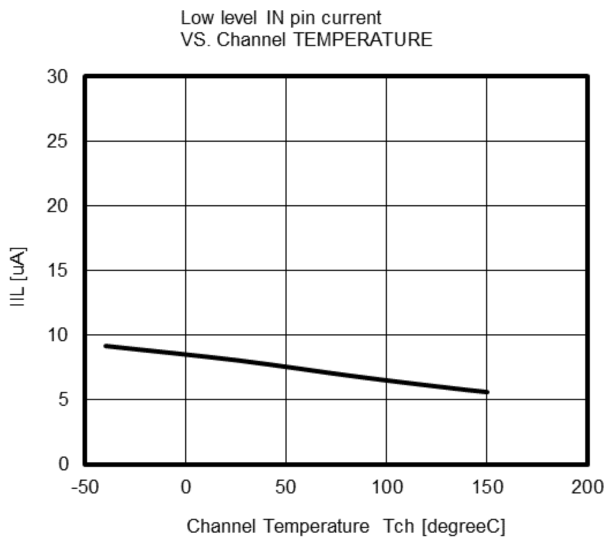


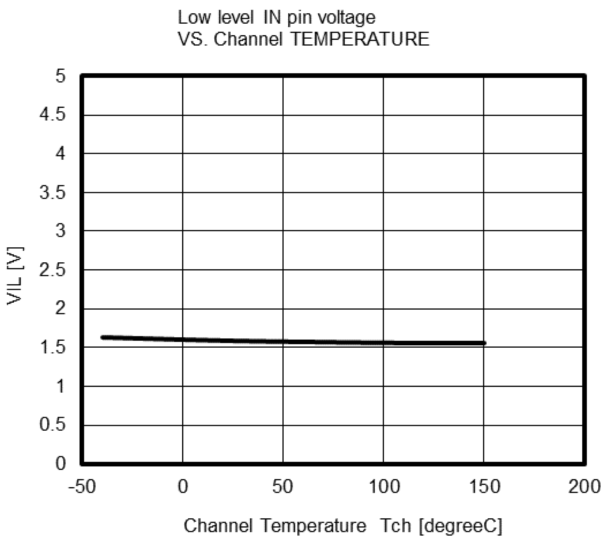


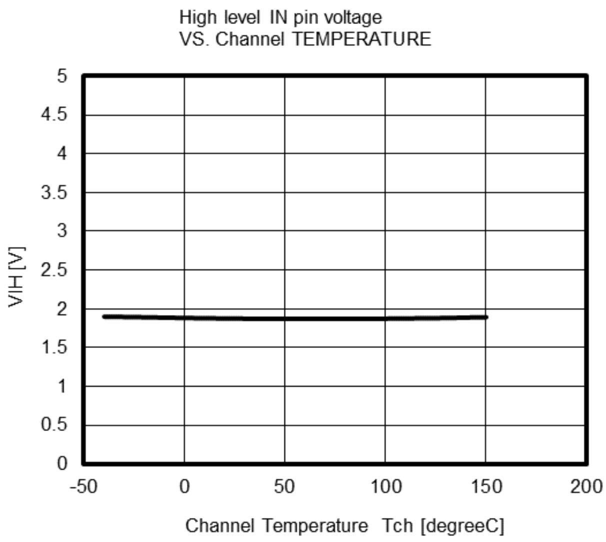


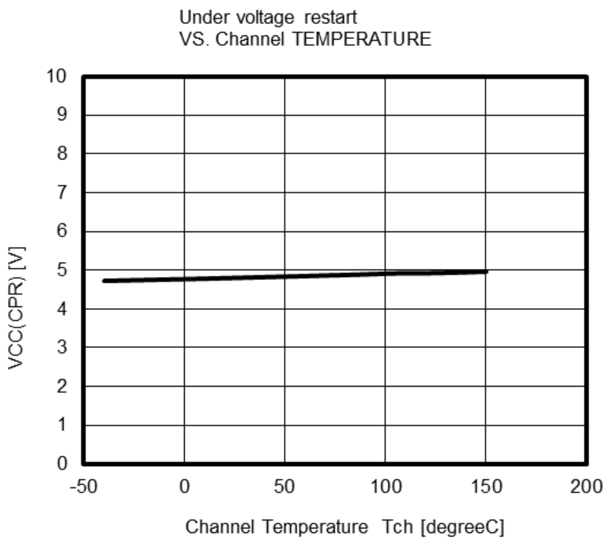


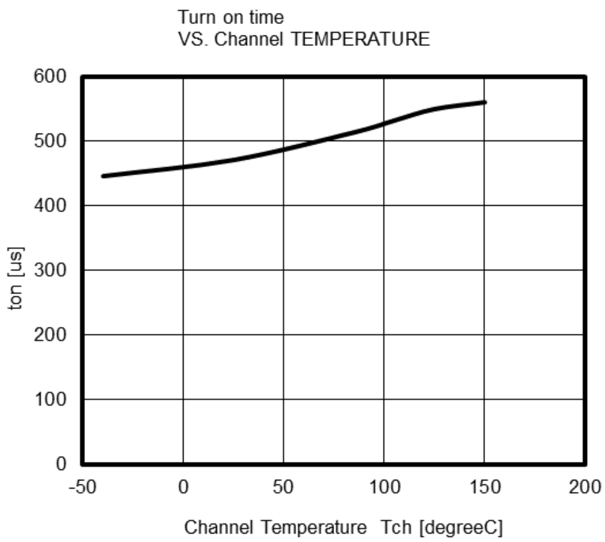


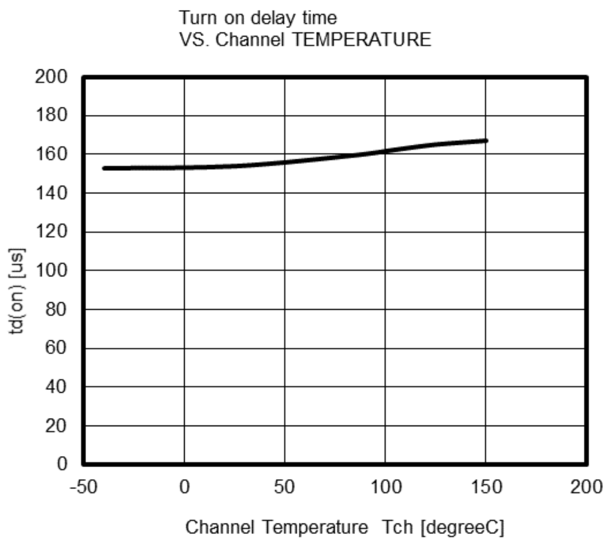


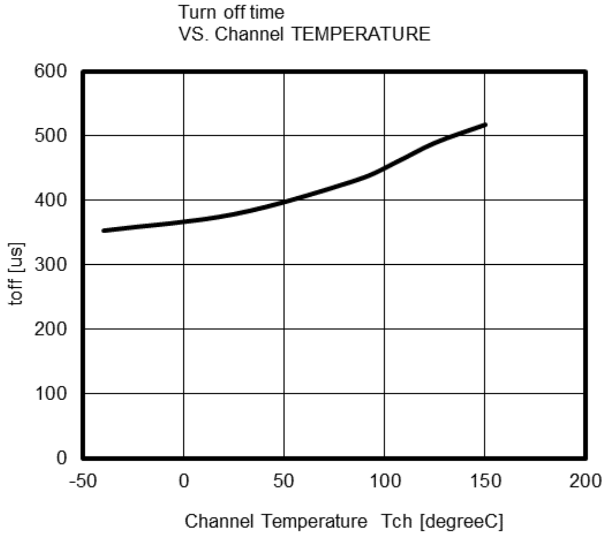

Low level IN pin voltage
VS. Channel TEMPERATURE
VIL [V]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-50
0
50
100
150
200
Channel Temperature Tch [degreeC]

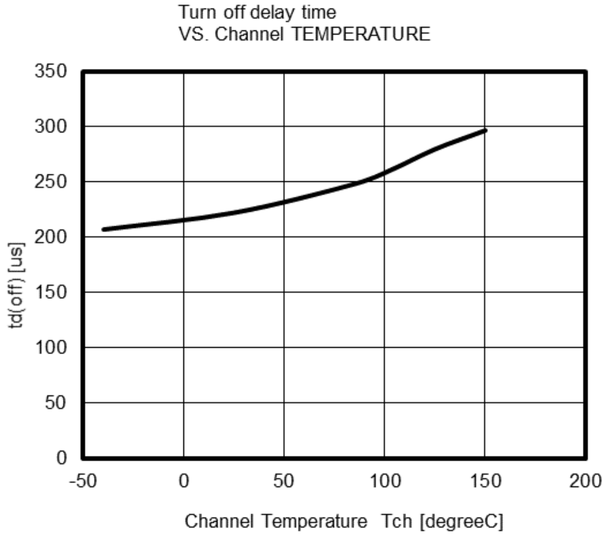

High level IN pin voltage
VS. Channel TEMPERATURE
VIH [V]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-50
0
50
100
150
200
Channel Temperature Tch [degreeC]

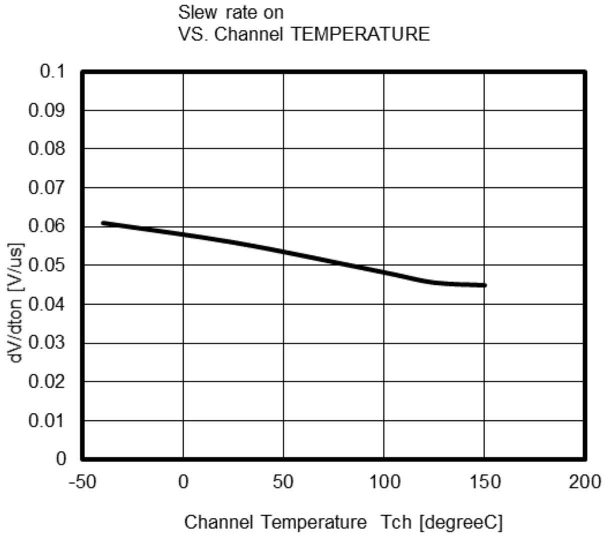

Under voltage restart
VS. Channel TEMPERATURE
VCC(CPR) [V]
10
9
8
7
6
5
4
3
2
1
0
-50
0
50
100
150
200
Channel Temperature Tch [degreeC]

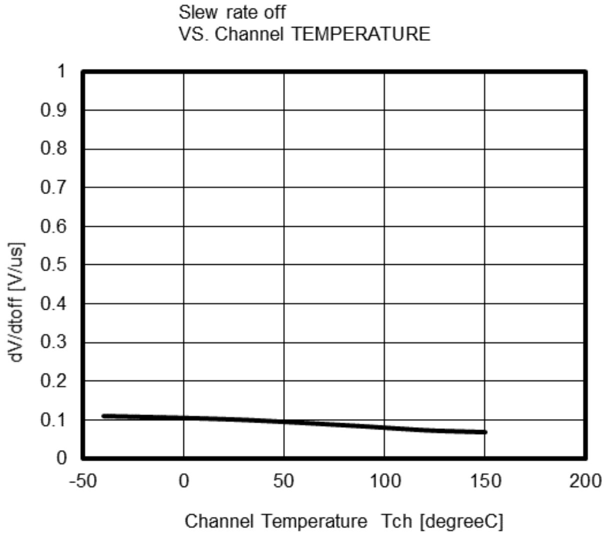

Turn on time
VS. Channel TEMPERATURE
ton [us]
600
500
400
300
200
100
0
-50
0
50
100
150
200
Channel Temperature Tch [degreeC]

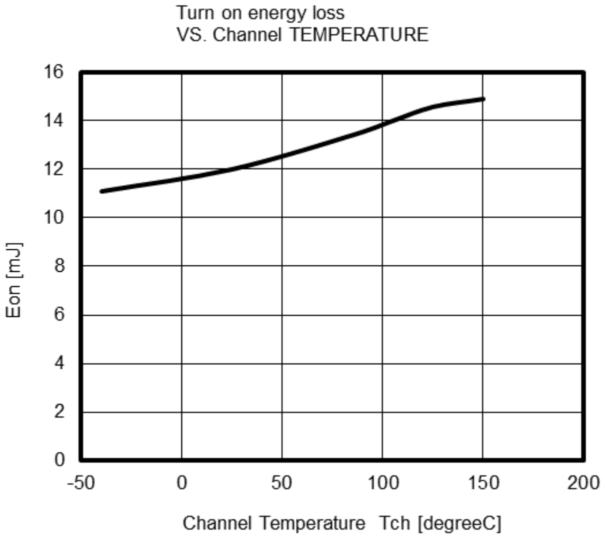

Turn on delay time
VS. Channel TEMPERATURE
td(on) [us]
200
180
160
140
120
100
80
60
40
20
0
-50
0
50
100
150
200
Channel Temperature Tch [degreeC]

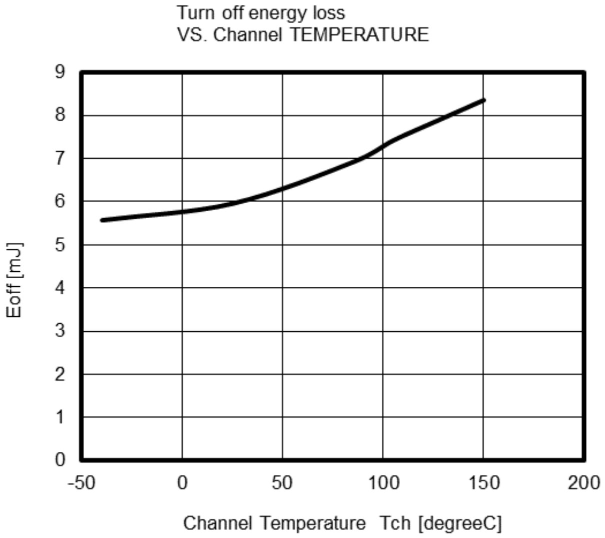

Turn off time
VS. Channel TEMPERATURE
toff [us]
Channel Temperature Tch [degreeC]

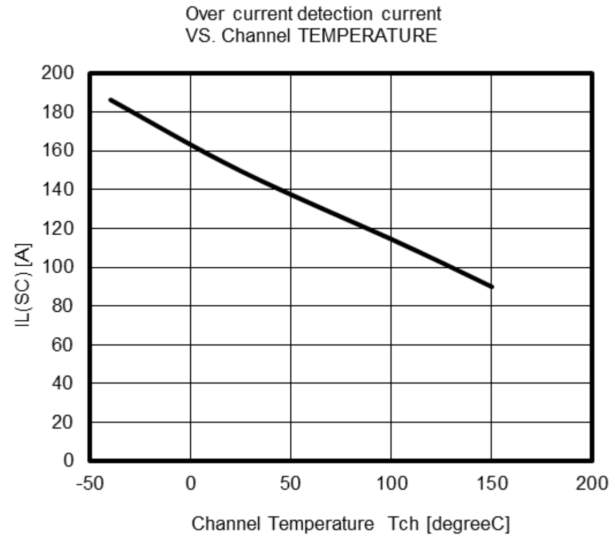

Turn off delay time
VS. Channel TEMPERATURE
td(off) [us]
Channel Temperature Tch [degreeC]


Slew rate on
VS. Channel TEMPERATURE
dV/dton [V/us]
Channel Temperature Tch [degreeC]

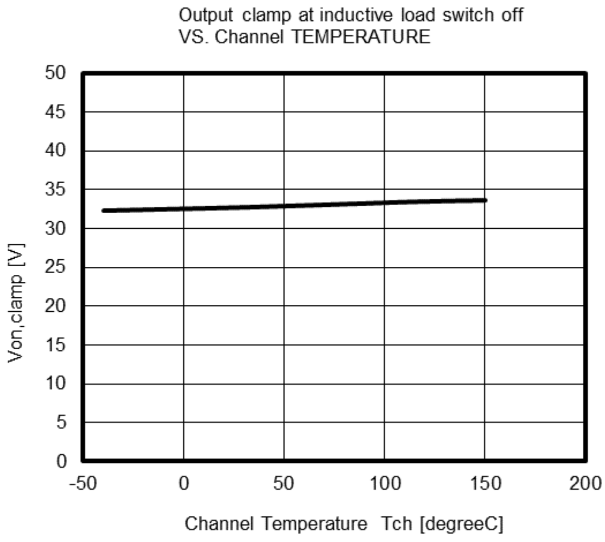

Slew rate off
VS. Channel TEMPERATURE
dV/dtoff [V/us]
Channel Temperature Tch [degreeC]


Turn on energy loss
VS. Channel TEMPERATURE
Eon [mJ]
Channel Temperature Tch [degreeC]

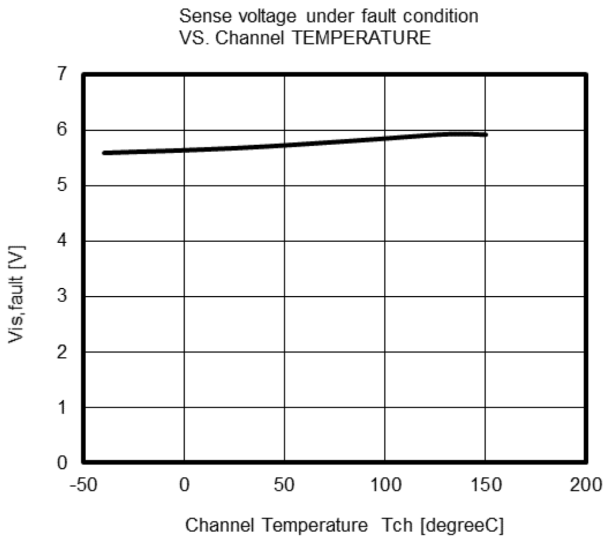

Turn off energy loss
VS. Channel TEMPERATURE
Eoff [mJ]
Channel Temperature Tch [degreeC]



Over current detection current
VS. Channel TEMPERATURE
IL(SC) [A]
200
180
160
140
120
100
80
60
40
20
0
-50
0
50
100
150
200
Channel Temperature Tch [degreeC]

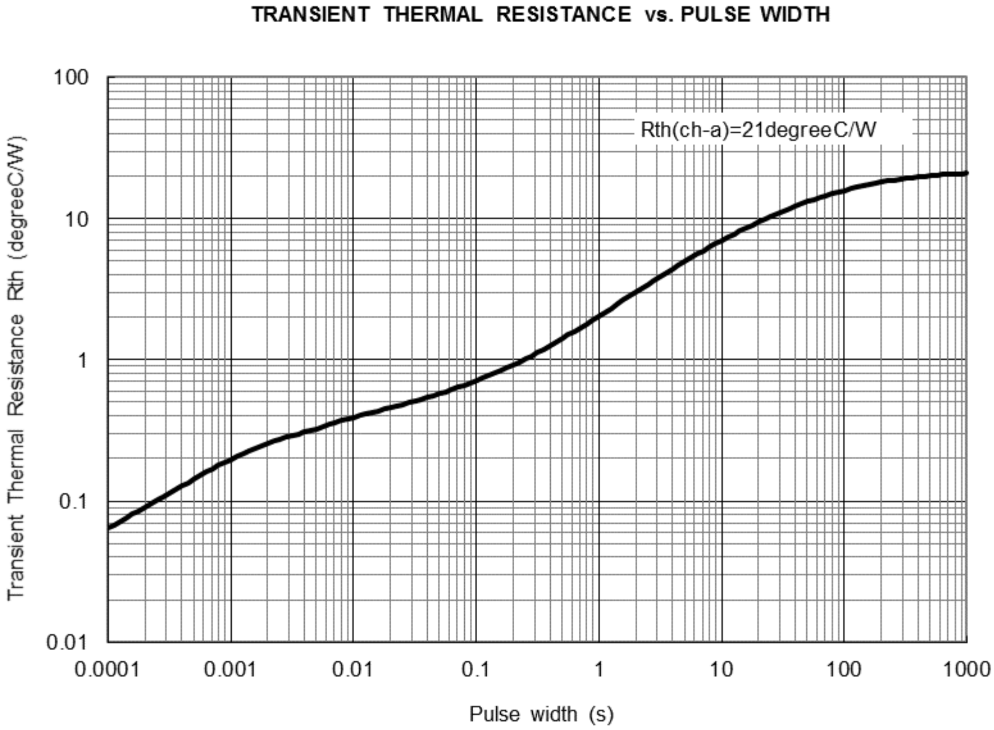


Output clamp at inductive load switch off
VS. Channel TEMPERATURE
Von,clamp [V]
50
45
40
35
30
25
20
15
10
5
0
-50
0
50
100
150
200
Channel Temperature Tch [degreeC]

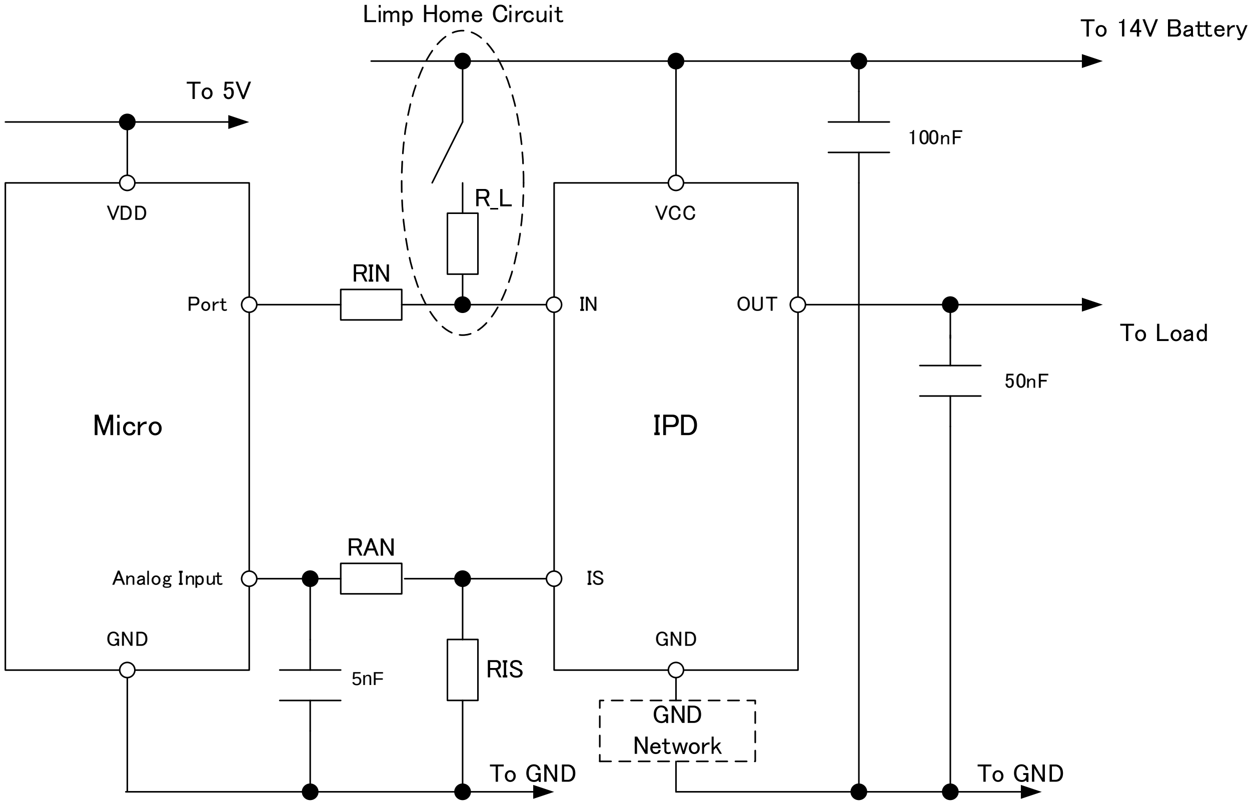


Sense voltage under fault condition
VS. Channel TEMPERATURE
Vis,fault [V]
7
6
5
4
3
2
1
0
-50
0
50
100
150
200
Channel Temperature Tch [degreeC]

5 Thermal characteristics



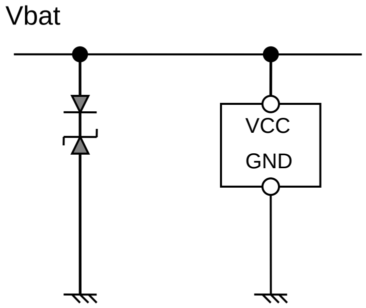
6 Application example in principle



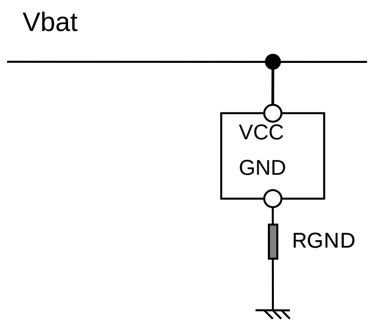
RIN, RAN values are in range of 2k to 50kohm depending microcontroller while R_L value is typically 4kohm.
If necessary to raise HBM tolerated dose, adding resister between OUT terminal and Ground is effective. Resister's value is typically 100kohm

GND Network recommendation

In case of V_loaddump < 35V



In case of 35V < V_loaddump < 42V



No external component is required.

External resistor is recommended in order to limit the current through ZD_{AZ} at load dump condition. 100ohm is recommended as RGND.

Revision History	RAJ2800044H12HPF Datasheet

Rev.	Date	Description	
		Page	Summary
1.00	Aug. 1, 2017	1-27	1st issue

All documents should contain the following section break and paragraph as the last item. The footers of this document refer to the paragraph in order to reference the last page of the document.

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