

# RAJ2800024H12HPF

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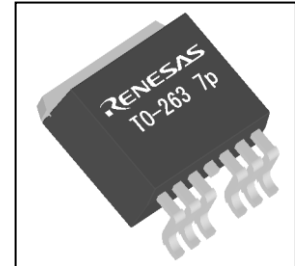
## Intelligent Power Device for automotive application

### 1. Overview

#### 1.1 Description

**Family:**

RAJ280002 is 1.6mohm 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, RAJ280002 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
  - Power limitation protection by over load detection (Power limitation: current limitation with delta Tch control)
  - 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 <sub>CC</sub>	4.5V to 28V
Under voltage shutdown	V <sub>CC(Uv)</sub>	Max. 4.5V
On-state resistance at 25 degreeC	R <sub>on</sub>	Max. 2.0mohm, Typ. 1.6mohm
Inductive load switch-off energy dissipation single pulse	EAS	1700mJ
Inductive load switch-off energy dissipation repetitive pulse	EAR	840mJ
Minimum Over current detection current	IL(SC)	150A

## 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.

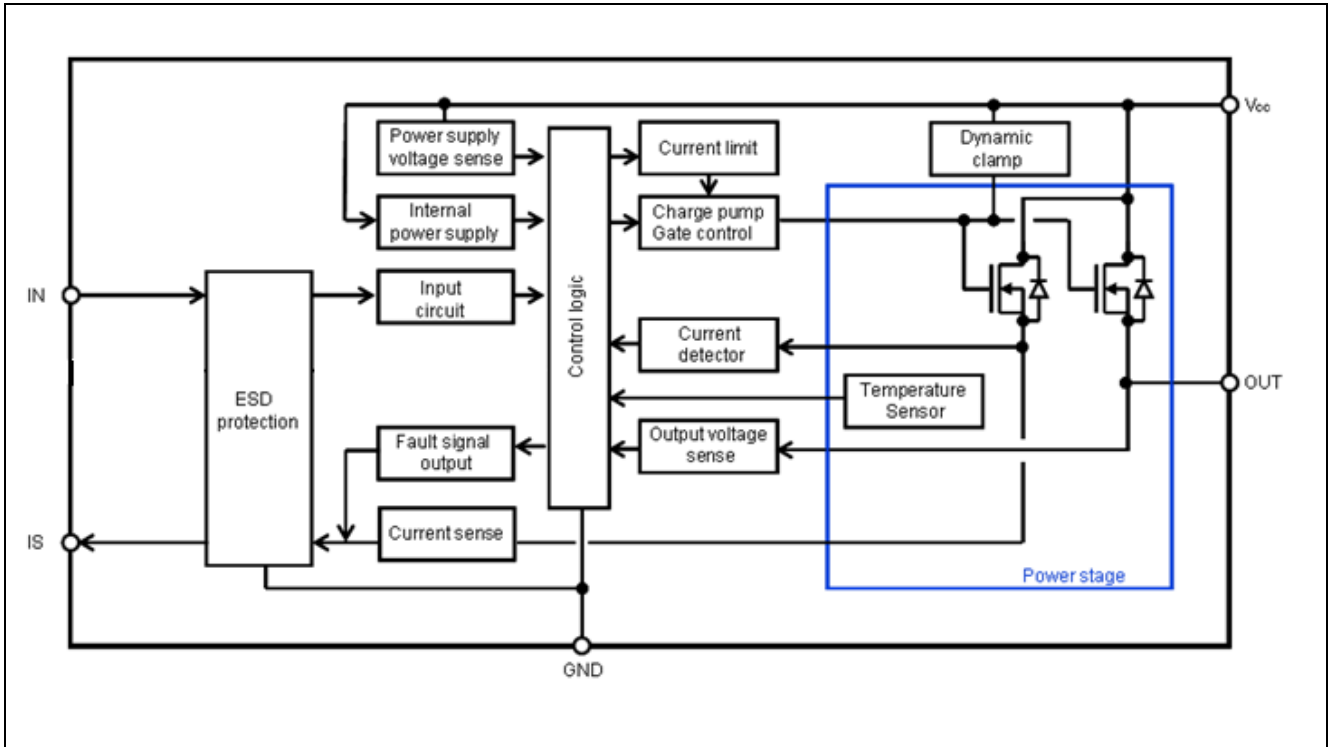
## 2. Ordering Information

Part No.	Lead plating	Packing	Package
RAJ2800024H12HPF	Pure Matte Sn	Tape 800pcs/reel	TO263-7

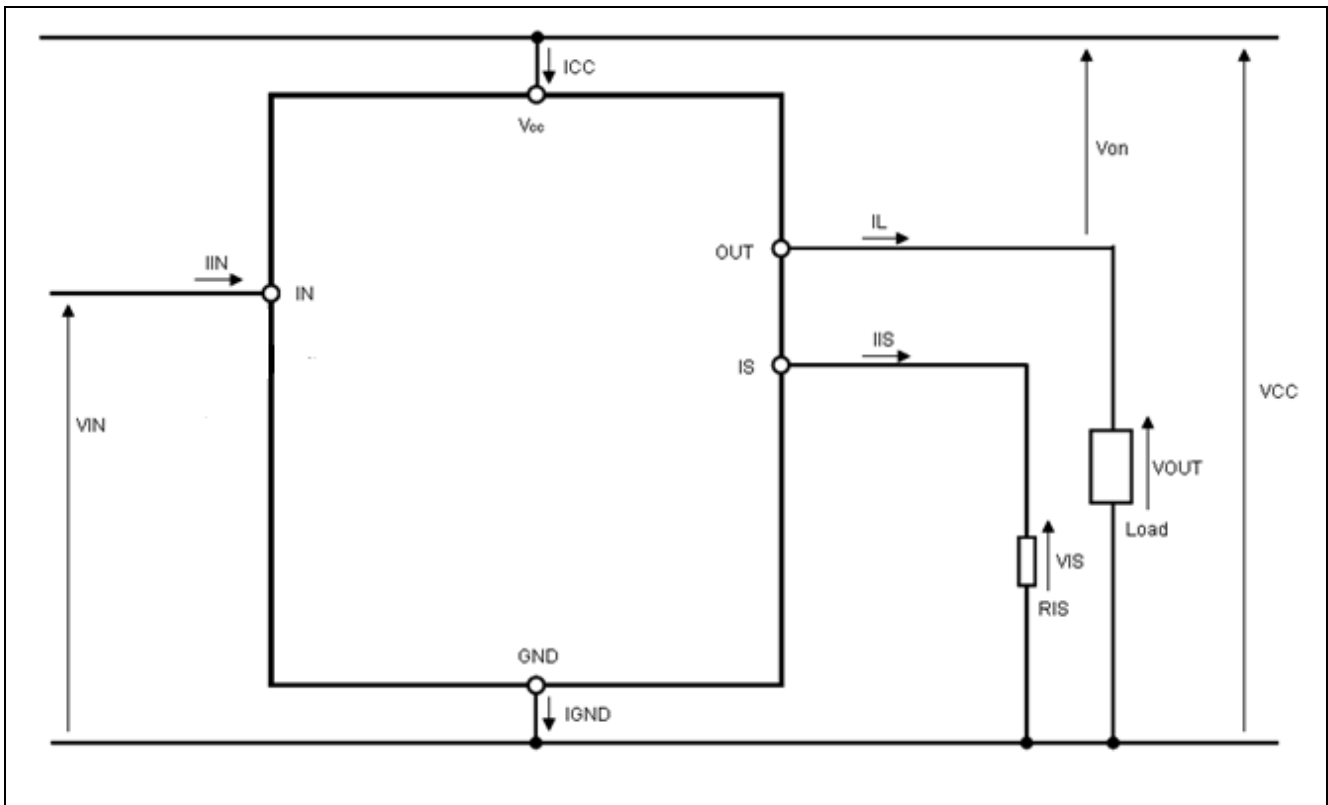
### 3. Specification

#### 3.1 Block Diagram

##### 3.1.1 Nch High-side Single Channel Device Block Diagram



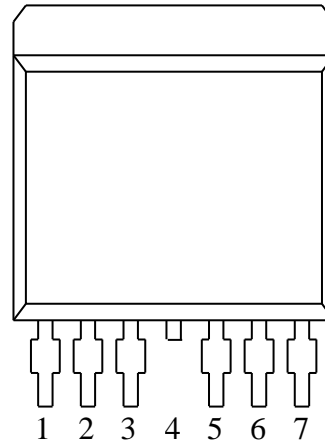
#### Voltage and Current Definition



## 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-50kohm serial resistor
IS	Current sense and Diagnosis output signal	Connected to GND through a 1k-6kohm 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 <sub>CC</sub>	28	V			
Vcc Voltage at reverse battery condition	-V <sub>CC</sub>	-16	V	At nominal load current, t<2min, RIN=2kohm, RIS=1kohm, RGND=100ohm		
Vcc voltage under Load Dump condition	V <sub>load dump</sub>	42	V	RI=1ohm, RL=Nominal load, RIS=1kohm, RIN=2kohm, RGND=100ohm, td=400ms,		
Load Current	I <sub>L</sub>	Self limited	A			
Total power dissipation for whole device (DC)	P <sub>D</sub>	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 <sub>IN</sub>	-2 to 16	V	DC RIN=2kohm		
		-16		At reverse battery condition, t<2min, RIN=2kohm		
IN pin current	I <sub>IN</sub>	10	mA	DC		
Voltage at IS pin	V <sub>IS</sub>	-2 to 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	T <sub>ch</sub>	-40 to +150	degreeC			
Storage Temperature	T <sub>stg</sub>	-55 to +150	degreeC			
ESD susceptibility	V <sub>ESD</sub>	2000	V	HBM	AEC-Q100-002 std. R=1.5kohm, C=100pF	All pin
		4000			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	1700	mJ	VCC=13.5V, T <sub>ch,start</sub> <150degreeC, RL=Nominal load, Refer to 3.6.7		
Inductive load switch-off energy dissipation repetitive pulse	EAR	840	mJ	VCC=13.5V, T <sub>ch,start</sub> =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)		0.21		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 <sub>CC</sub>	4.5		28	V	V <sub>IN</sub> =4.5V, R <sub>L</sub> =Nominal load, Refer to 3.6.7	
Operating current	I <sub>GND</sub>		2.5	5	mA	V <sub>IN</sub> =4.5V	
Output Leakage current	I <sub>L(off)</sub>			0.5	μA	Tch=25 degreeC	VCC=13.5V, VIN=0V, VIS=0V, VOUT=0V, VGND=0V
				13		Tch=-40 to 125 degreeC	
Standby current	I <sub>CC(off)</sub>			0.5	μA	Tch=25 degreeC	VCC=13.5V, VIN=0V, VIS=0V, VOUT=0V, VGND=0V
				1.5		Tch=-40 to 85 degreeC	
On-state resistance	R <sub>on</sub>		1.6	2.0	mohm	Tch=25 degreeC	IL= Nominal current, Refer to 3.6.7, VIN>2.5V
				3.7		Tch=150 degreeC	
Low level IN pin voltage	V <sub>IL</sub>			0.8	V		
High level IN pin voltage	V <sub>IH</sub>	2.5			V		
Low level IN pin current	I <sub>IL</sub>	2		30	μA	V <sub>IN</sub> =0.8V	
High level IN pin current	I <sub>IH</sub>	2		30	μA	V <sub>IN</sub> =2.5V	
Clamping IN pin voltage <sup>1)</sup>	V <sub>ZIN</sub>	5	6		V		
Operating current at cranking	I <sub>GND(cr)</sub>		0.4		mA	VCC=3.2V, RGND=100ohm, Pulse duration=24ms, IL= Nominal current, Refer to 3.6.7	
Cranking mode voltage	V <sub>CC(cr)</sub>			4.5	V		
On-state resistance at cranking	R <sub>on(cr)</sub>			8	mohm	VCC=3.2V, RGND=100ohm, Tch=25 degreeC, Pulse duration=24ms, IL= Nominal current, Refer to 3.6.7	
Operating Voltage range for cranking	V <sub>CC(Uv,cr)</sub>	3.2				RGND=100ohm, Tch=25 degreeC, Pulse duration=24ms, IL=Nominal current Refer to 3.6.7	
Under voltage shutdown	V <sub>CC(Uv)</sub>			4.5	V		
Under voltage restart	V <sub>CC(Cpr)</sub>			4.5	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)		100	200	μs		
Turn off time	toff		310	800	μs		
Turn off delay time	td(off)		200	500	μs		
Slew rate on	dV/dton		0.05	0.1	V/μs		
Slew rate off	-dV/dtoff		0.14	0.3	V/μs		
Turn on energy loss <sup>1)</sup>	E <sub>on</sub>		30		mJ	VCC=13.5V, Tch=25 degreeC, RL=Nominal load, Refer to 3.6.7	
Turn off energy loss <sup>1)</sup>	E <sub>off</sub>		11		mJ		
Driving capability <sup>1)</sup>	Dr(cap)	75			mohm	Tch=25 degreeC, VCC=8 to 16V	
		100				Tch=105 degreeC, VCC=8 to 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)	150	260		A	VCC=13.5V, Von=5V, Tch=25 degreeC	
Current limitation under power limitation toggling	IL(CL)		90		A	VCC=13.5V	
Sense current output trigger threshold	Von(CL1)		1.0		V	VCC=13.5V	
Current limitation trigger threshold during on-state	Von(CL2)		0.3		V	VCC=13.5V	
Turn-on check delay after input signal positive slope	td(CL)		1.6		ms	VCC=13.5V	
Absolute thermal shutdown temperature	aTth	150			degreeC		
Power limitation thermal shutdown temperature	dTth		40		degreeC		
Power limitation restart temperature	dTth, restart		19		degreeC		
Output clamp at inductive load switch off	Von,clamp	30		40	V	VCC=13.5V, IL=40mA, Tch=25 degreeC	
Output current while GND disconnection	IL(GND)			1	mA	IIN=0A, IGND=0A, IIS=0A	
On-state resistance at reverse battery condition	Ron(rev)			2.5	mohm	Tch=25 degreeC	VCC=-13.5V, IL=Nominal current, Refer to 3.6.7
				4.6		Tch=150 degreeC	
Gnd current at reverse battery condition	IGND(rev)		-2		mA	VCC=-16V, Tch=25 degreeC	

Remark) All voltages refer to ground pin of the device



## Diagnosis function

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

Parameter	Symbol	Min	Typ	Max	Unit	Test Condition
Current sense ratio	KILIS	35000	70000	110000		IL= 16.5 A
		40000	70000	105000		IL= 33 A
Current sense drift depend on temperature	dKILIS	-20		20	%	VCC=13.5V, Tch,start=25 degreeC, IL =33A, Refer to 3.6.7
Sense current offset current	lis,offset			50	μA	IL=0A, Tch =25 degreeC
Sense voltage under fault condition	Vis,fault	4.5	5.6	7.0	V	RIS=1kohm
Load current to output sense current	IL,min	3.5			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 <sup>1)</sup>	tsis(off)			10	μs	VIN=4.5V to 0V
Sense current settling time during on-state <sup>1)</sup>	tsis(LC)			50	μs	RL= 2 * Nominal load to Nominal load, Refer to 3.6.7
Fault signal delay after over current detection <sup>1)</sup>	tdsc(fault)			10	μs	VIN=0V to 4.5V, IL=IL(SC)
Fault signal delay after power limitation valid <sup>1)</sup>	tdpl(fault)			10	μs	Von>Von(CL1)
Fault signal delay after power limitation invalid <sup>1)</sup>	tdpl(off)			30	μs	Von<Von(CL1)
Fault signal delay after absolute thermal shutdown <sup>1)</sup>	tdot(fault)			10	μs	VIS→VIS,fault
Fault signal delay after input negative slope <sup>1)</sup>	tdoff(fault)			10	μs	VIN=4.5V to 0V

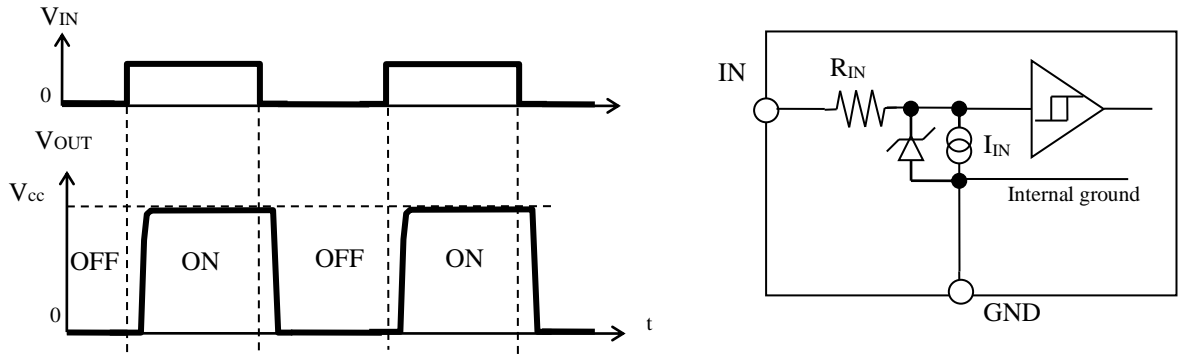
Remark) All voltages refer to ground pin of the device

1) not subjected production test, guaranteed by design

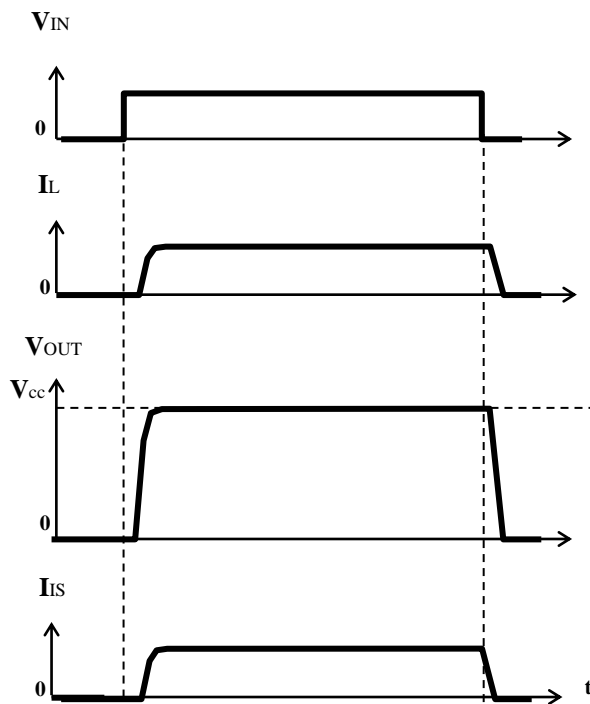
### 3.6 Feature Description

#### 3.6.1 Driving Circuit

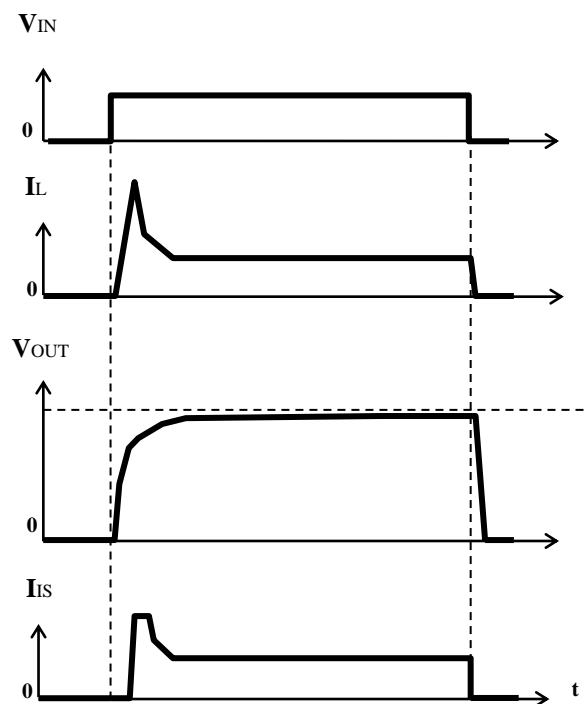
The high-side output is turned on, if the input pin is over  $V_{IH}$ . The high-side output is turned off, if the input pin is open or the input pin is below  $V_{IL}$ . Threshold is designed between  $V_{IH}$  min and  $V_{IL}$  max with hysteresis. IN terminal is pulled down with constant current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



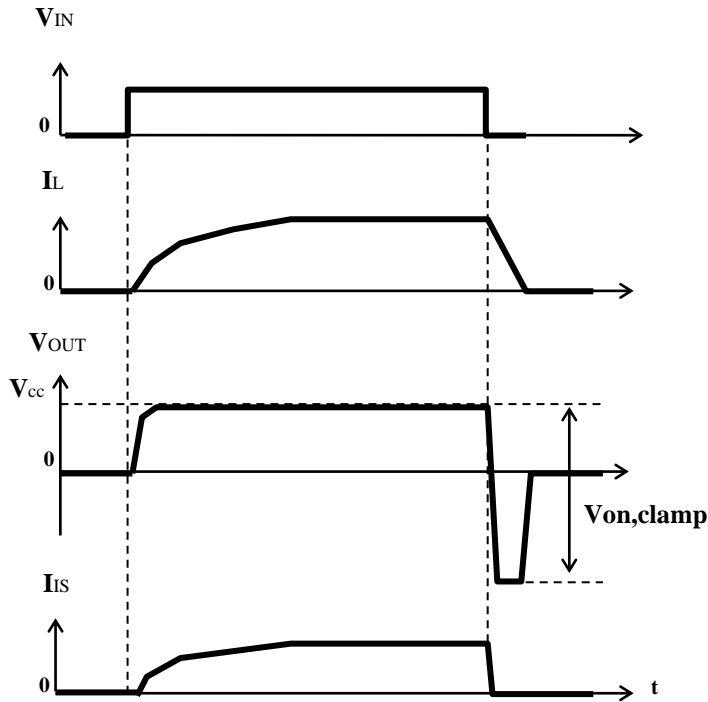
Switching a resistive load



Switching lamps



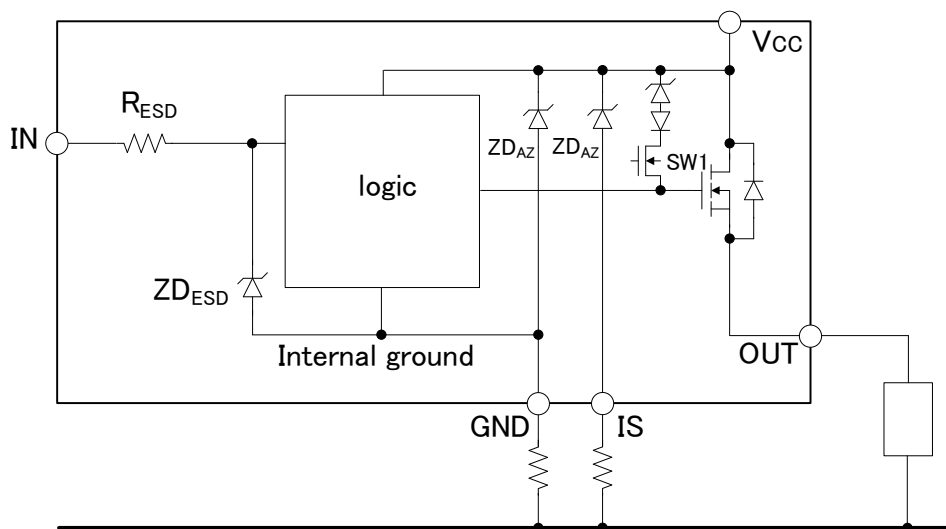
Switching an inductive load



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.

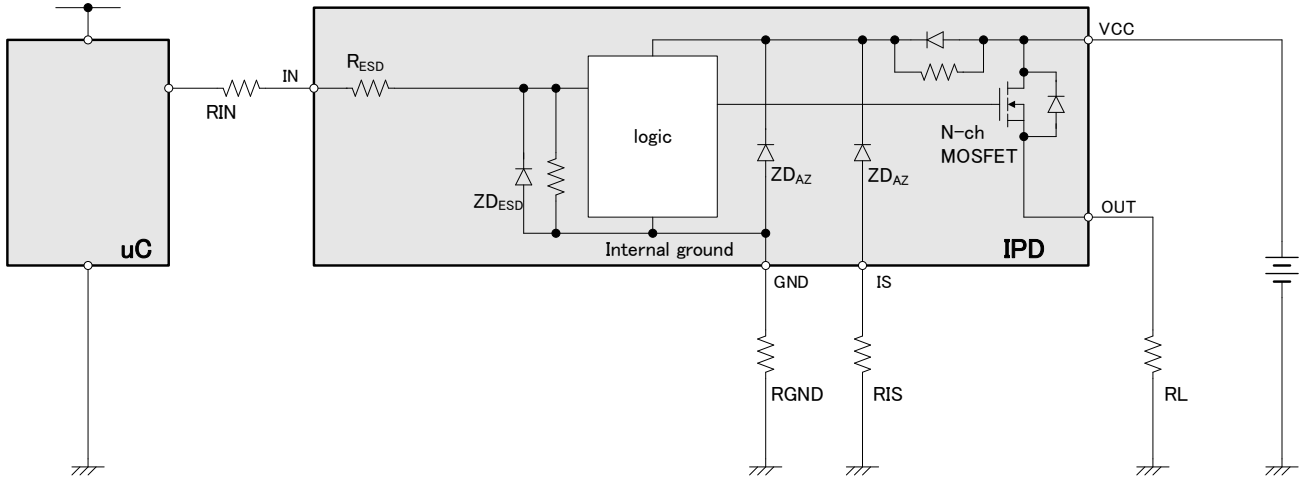
SW1 is turned on, and the clamp diode is connected to the gate of the output MOS, activating the dynamic clamp circuit.

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.



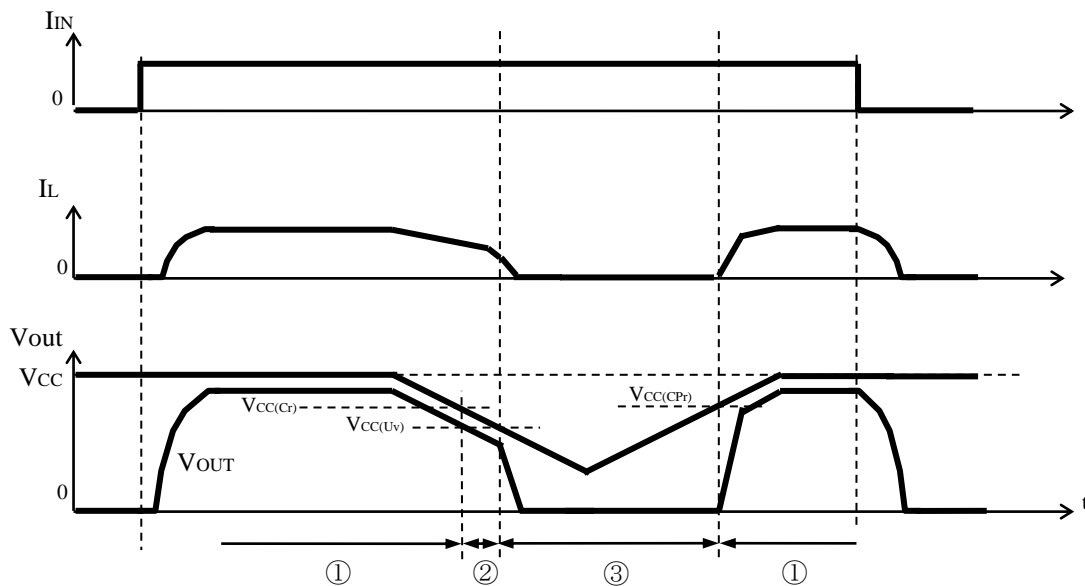
### 3.6.2 Device behavior at over voltage condition

In case of supply voltage greater than  $V_{load}$  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 VCC goes down under  $V_{CC}(Uv)$ , the device outputs shuts down. If voltage supply (VCC) 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.



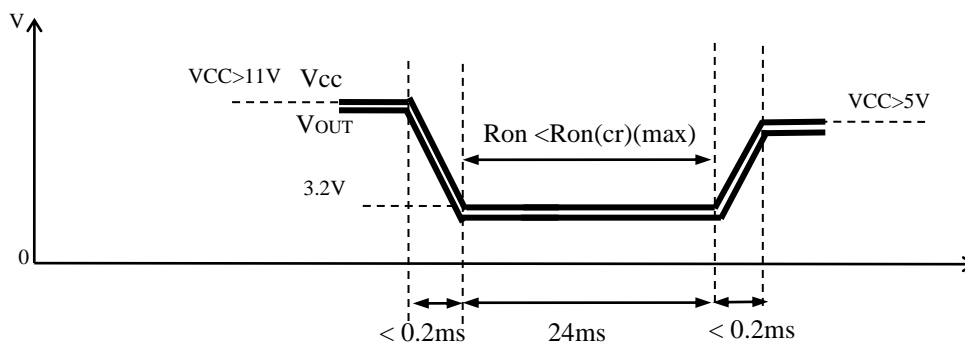
- ① : Normal operating mode
- ② : Cranking mode
- ③ : Under voltage mode

Availability of each function in each mode

○: Enable, ×: Disable

	Function	①	②	③	Note
Normal operation	Turn on	○	×	×	
Normal operation	Turn off	○	○		
Normal operation	Keep on-state	○	○ <sup>(*)</sup>	×	<sup>(*)</sup> Ron is defined as Ron(Cr).
Normal operation	KILIS function	○	×	×	In case of Von < Von(CL1)
Diagnosis	Von(CL1), td(CL)	○	×	×	Refer to 3.6.5
Protection	IL(SC)	○	×	×	Refer to 3.6.5
Protection	Von(CL2)	○	×	×	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 loss of ground, there is a potential that the current flow from IN terminal to MCU. Therefore, insert a protective resistor between MCU and IN terminal.

### 3.6.5 Short circuit protection

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

The device shuts down automatically when condition (a) or (c) is detected. The sense pin output Vis,fault. Shutdown is latched until the next reset via input pin. The device shuts down automatically when condition (b) is detected. The device restarts automatically in power limitation mode. The sense pin outputs Vis,fault when (d) is detected.

- (a)  $I_L > I_L(SC)$
- (b)  $\Delta T_{ch} > dT_{th}$
- (c)  $T_{ch} > aT_{th}$
- (d)  $V_{on} > V_{on}(CL1)$  after  $t_d(CL)$

#### Over load condition including short circuit condition during on-state

The device runs automatically into power limitation mode when condition (e) is detected once after  $V_{on} < V_{on}(CL2)$ . The device shuts down automatically when condition (f) is detected. The device restarts automatically in power limitation mode. The sense pin output Vis,fault during power limitation mode. The device shuts down automatically when condition (g) or (h) is detected. The sense pin output Vis,fault. Shutdown is latched until the next reset via input pin.

- (e)  $V_{on} > V_{on}(CL2)$
- (f)  $\Delta T_{ch} > dT_{th}$
- (g)  $T_{ch} > aT_{th}$
- (h)  $I_L > I_L(SC)$

#### Power limitation control

Current limitation control with  $I_L(CL)$  when auto restart from  $\Delta T_{ch}$  protection.

During toggling mode due to  $\Delta T_{ch}$  protection, if  $V_{on} > V_{on}(CL1)$  or if the current is limited to  $I_L(CL)$ , the sense pin output Vis, fault. If  $V_{on} < V_{on}(CL2)$  and if the short current is not high enough to reach  $I_L(CL)$  during toggling mode with  $\Delta T_{ch}$  protection, then the sense pin outputs sense current at on-state and Vis,fault at off state.

#### delta Tch

Junction temperature differences between thermal sensors of power area.

### 3.6.6 Diagnostic signal

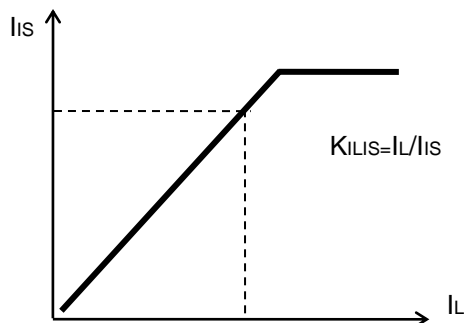
**Truth table**

	Input	Output	Diagnostic output
Normal Operation	H	VCC	IIS = IL/KILIS
	L	L <sup>1)</sup>	L <sup>2)</sup>
Shutdown by over current detection	H	L <sup>1)</sup>	Vis,fault <sup>3)</sup>
	L	L <sup>1)</sup>	L <sup>2)</sup>
Power limitation	H	VOUT <sup>6)</sup>	IIS = IL/KILIS in case of Von<Von(CL1) Vis,fault <sup>4)</sup> in case of Von>Von(CL1)
		L <sup>1)</sup>	Vis,fault <sup>4)</sup>
	L	L <sup>1)</sup>	L <sup>2)</sup>
Shutdown by over absolute channel temperature detection	H	L <sup>1)</sup>	Vis,fault <sup>5)</sup>
	L	L <sup>1)</sup>	L <sup>2)</sup>
Short circuit to VCC	H	VCC	<IIS
	L	VOUT <sup>7)</sup>	L <sup>2)</sup>

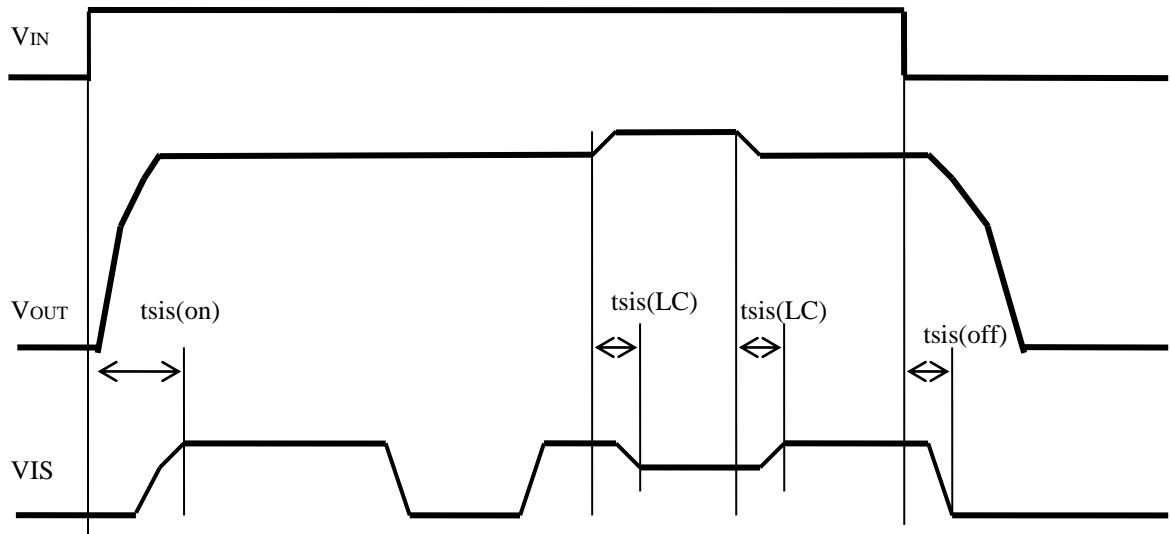
- 1) In case of OUT terminal is connected to GND via load.
- 2) In case of IS terminal is connected to GND via resistor.
- 3) IS terminal keeps Vis,fault as long as input signal activate after the over current detection.
- 4) IS terminal keeps Vis,fault during power limitation if Von>Von(CL1).
- 5) IS terminal keeps Vis,fault as long as input signal activate after over absolute channel temperature detection.
- 6) VOUT depends on the short circuit condition.
- 7) VOUT depends on the ratio of VCC-OUT-GND resistive component.

**Current sense output**

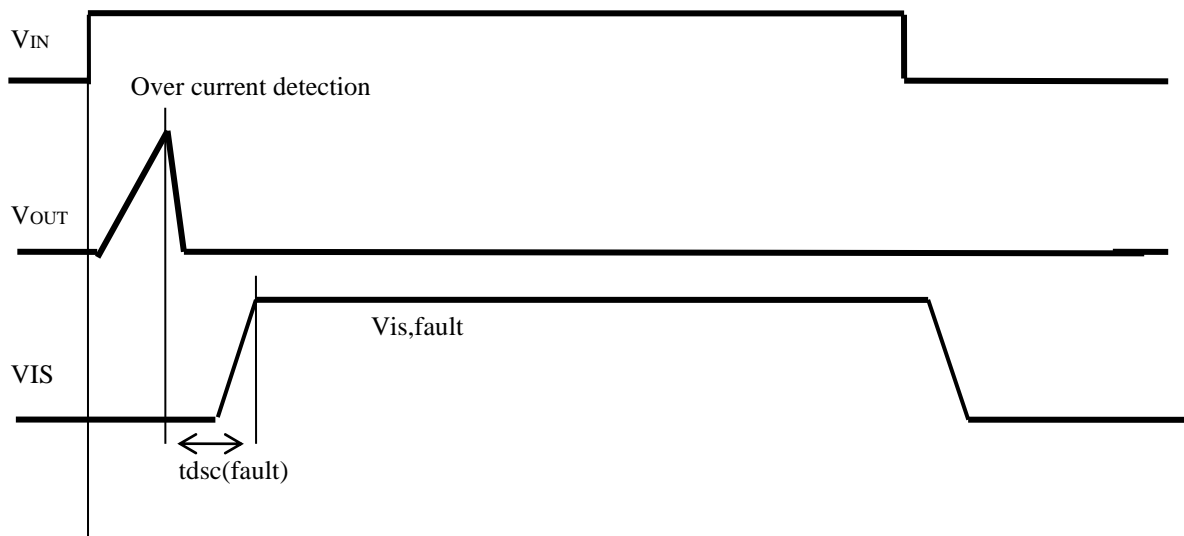
The device output analog feedback current proportional to output current from IS pin. In the case of much higher current than nominal load current, current sense output is saturated.



Sense voltage setting time

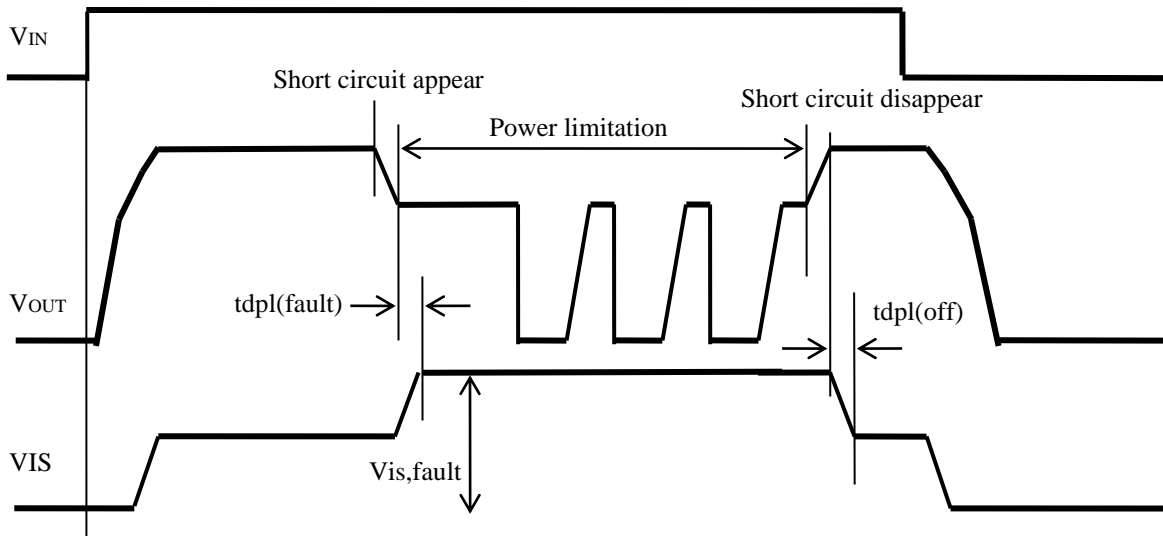


Fault signal delay time at over current detection

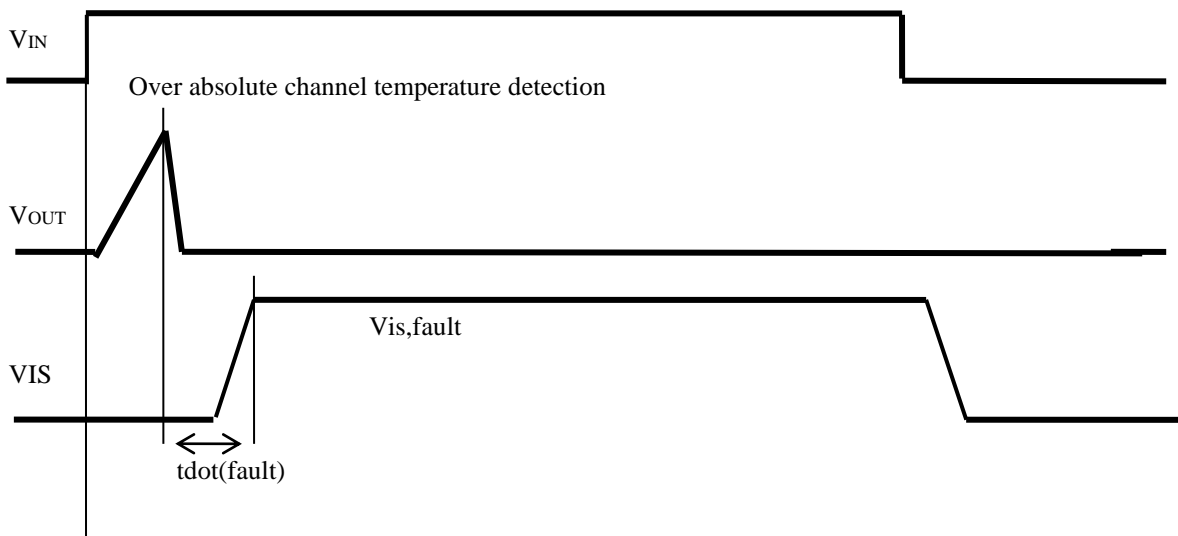




**Fault signal delay time at power limitation**



**Fault signal delay time at over absolute channel temperature detection**

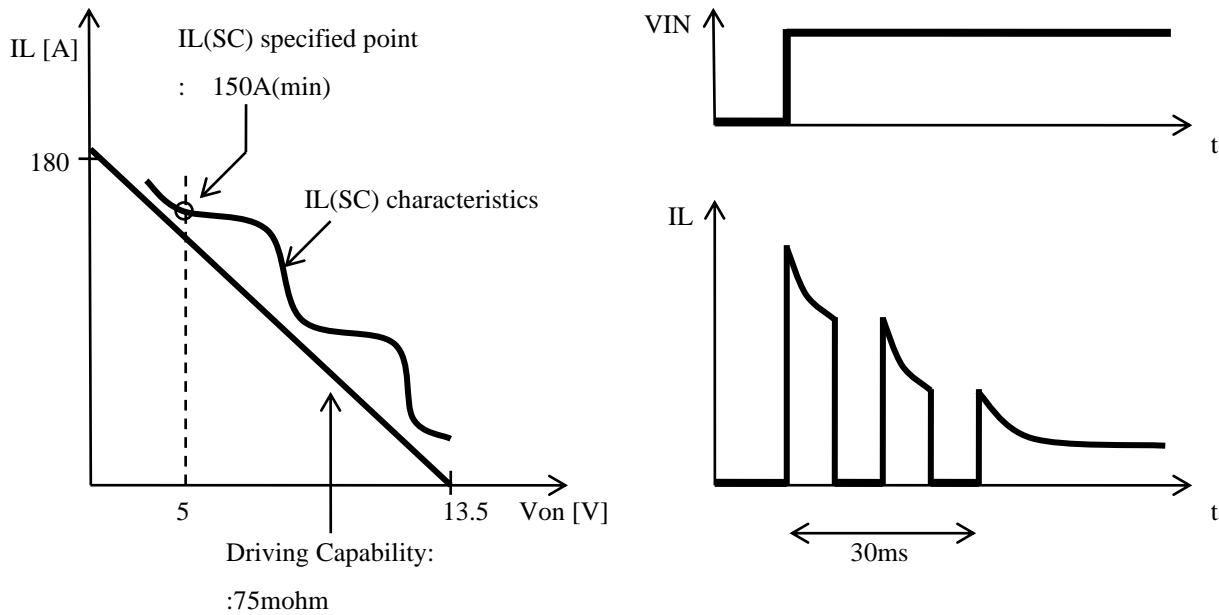


**3.6.7 Nominal load and nominal current**

Parameter	Values	Condition
Nominal load	0.5ohm	$T_j \leq 150$ degreeC
Nominal current	33A	$T_j \leq 150$ degreeC

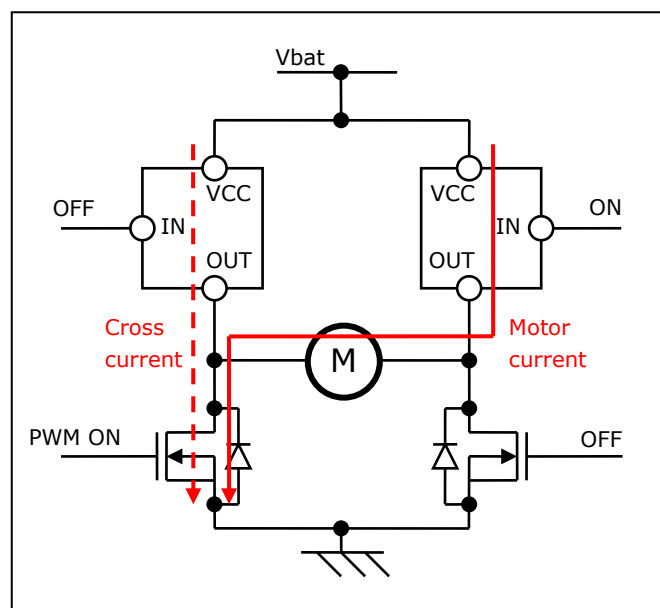
### 3.6.8 Driving Capability

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. Depend on the conditions, Power Limitation function may work during inrush current. If estimated load impedance which comes from peak inrush current is lower than Driving Capability characteristics, Power limitation disappear within 30ms. This parameter does not mean that the device can drive the resistive load up to Driving Capability characteristics.



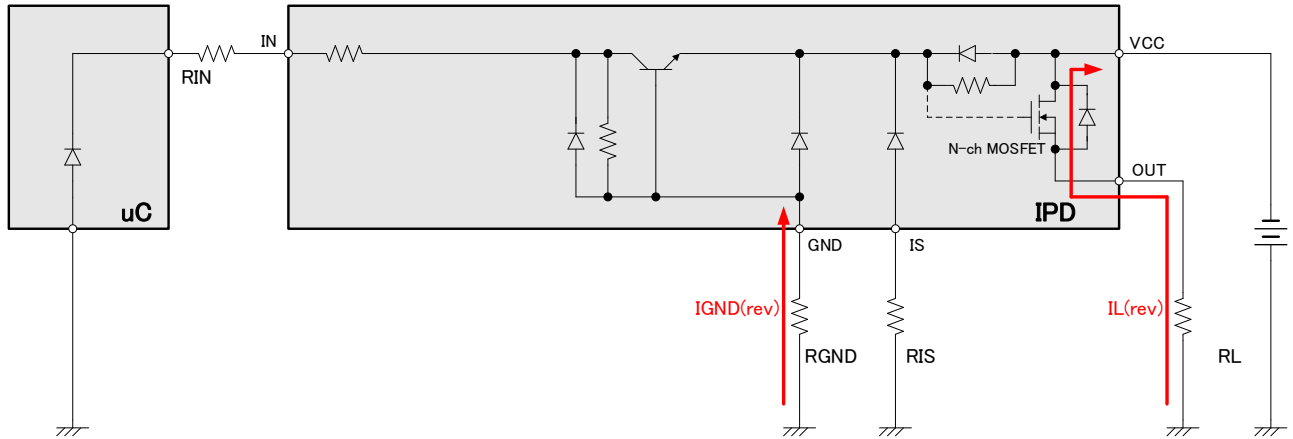
### 3.6.9 Cross current protection in case of H-bridge high side usage

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.



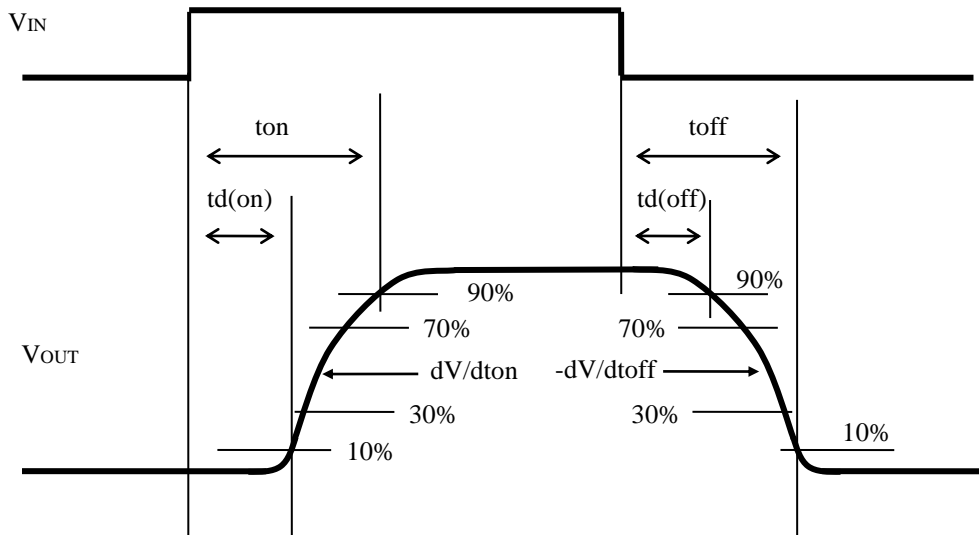
### 3.6.10 Reverse Battery Protection by turn on the output

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.  $I_{GND(rev)}$  is limited internally approx. 2mA even without external  $R_{GND}$ . Reverse current flow from IN, IS should be limited by external component such as recommendation value in Pin function, refer 3.2 Pin configuration.



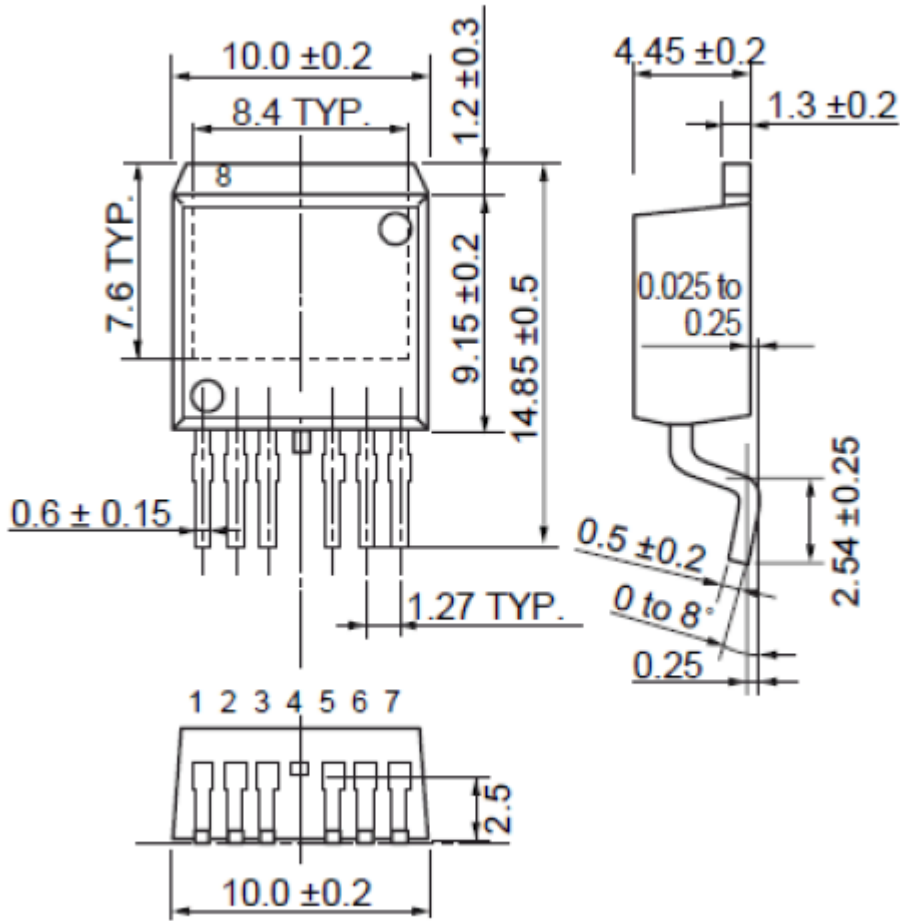
### 3.6.11 Measurement condition

#### Switching waveform of OUT terminal

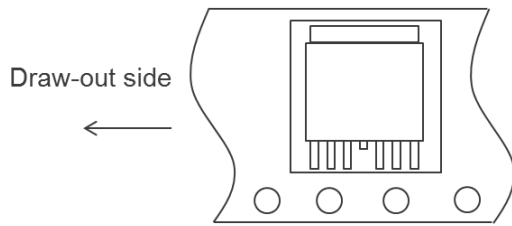


3.7 Package drawing

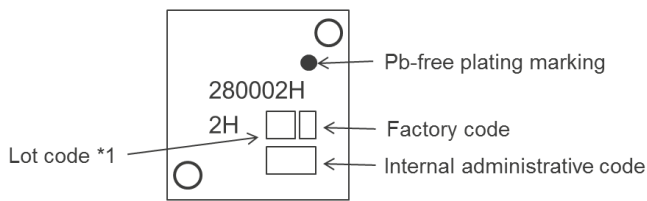
UNIT:mm



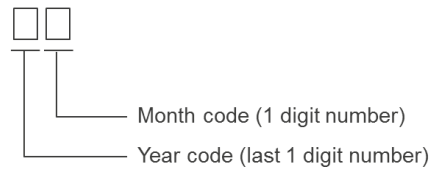
### 3.8 Taping information



### 3.9 Marking information

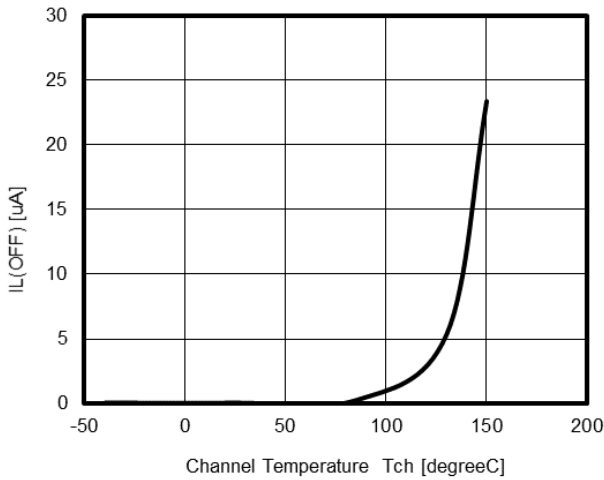


Note: \*1. Composition of the lot code

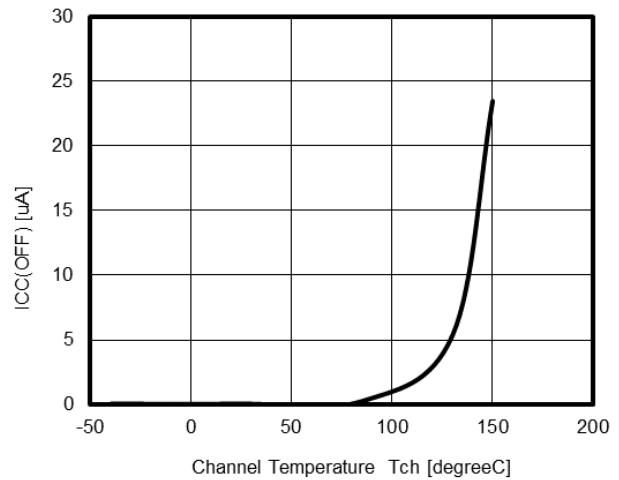


4 Typical characteristics

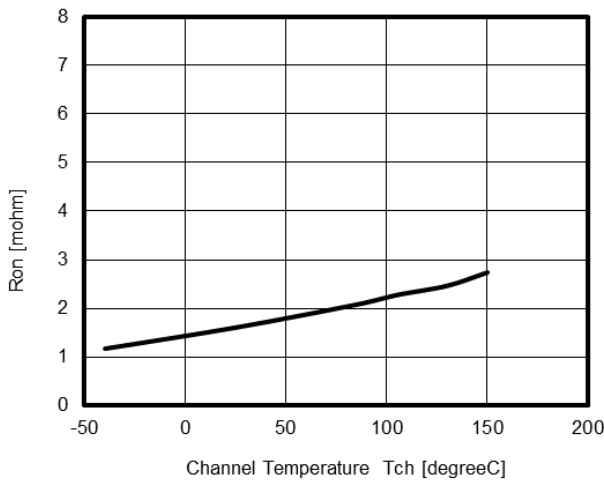
Output Leakage current per channel  
VS. Channel TEMPERATURE



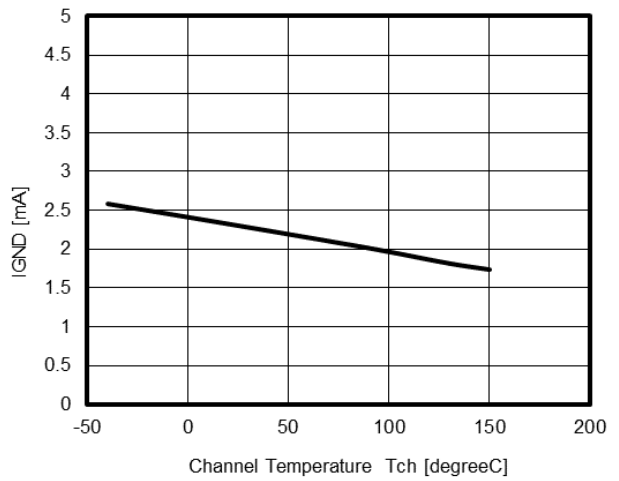
Standby current  
VS. Channel TEMPERATURE



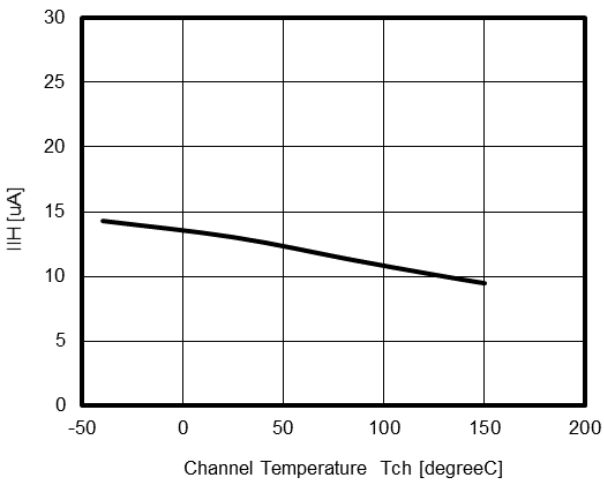
On-state resistance per channel  
VS. Channel TEMPERATURE



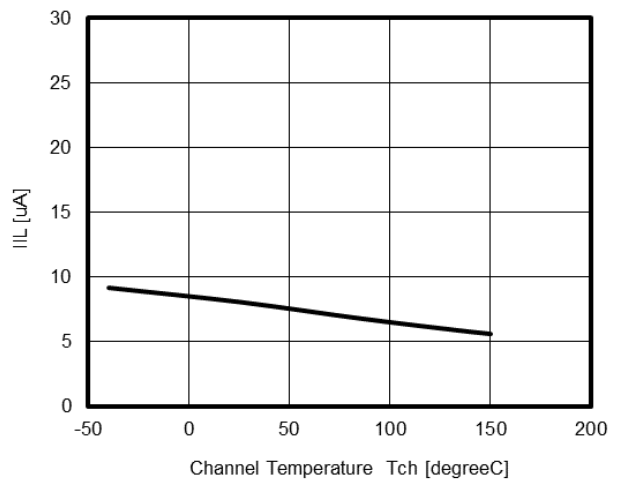
Operating current  
VS. Channel TEMPERATURE

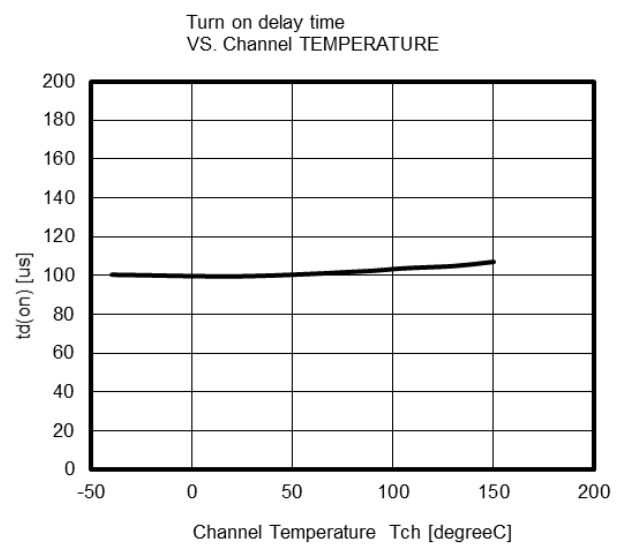
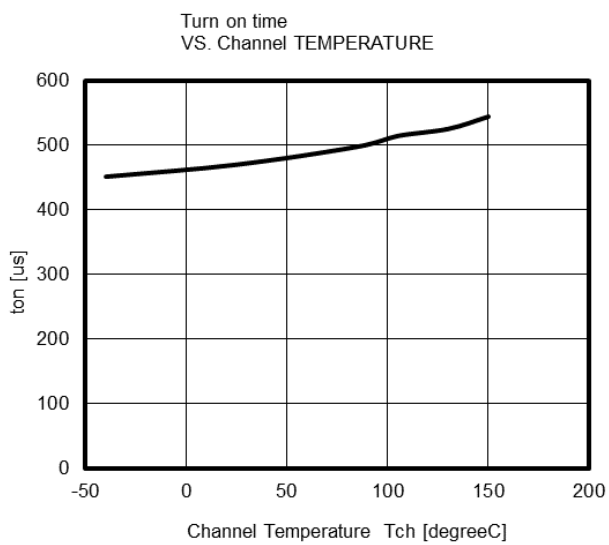
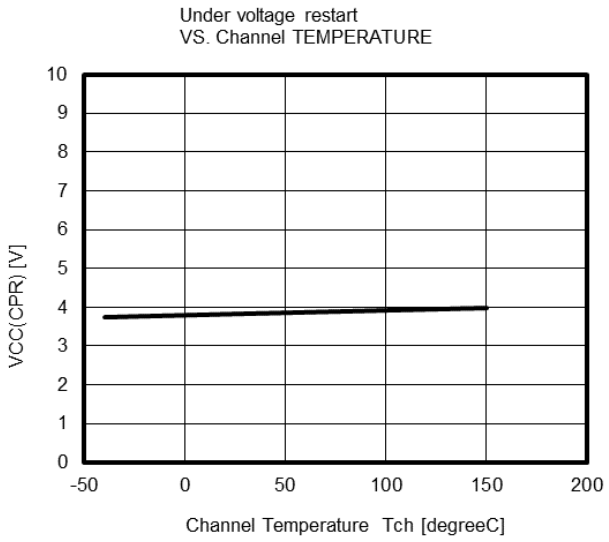
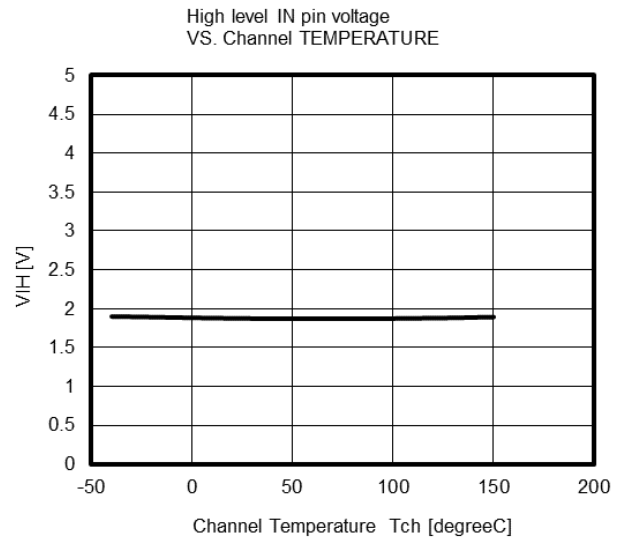
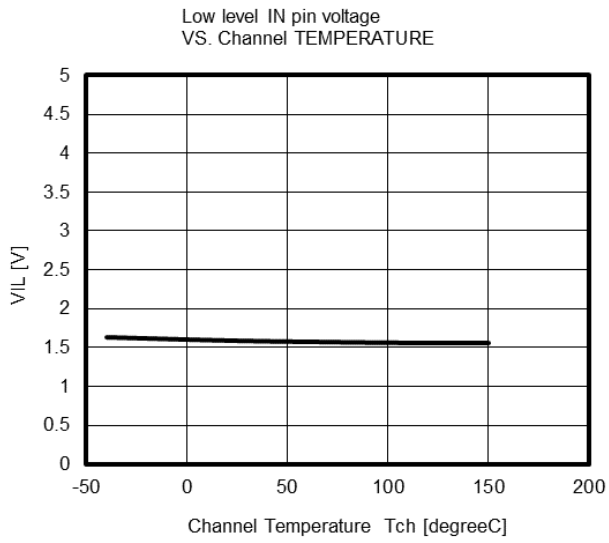


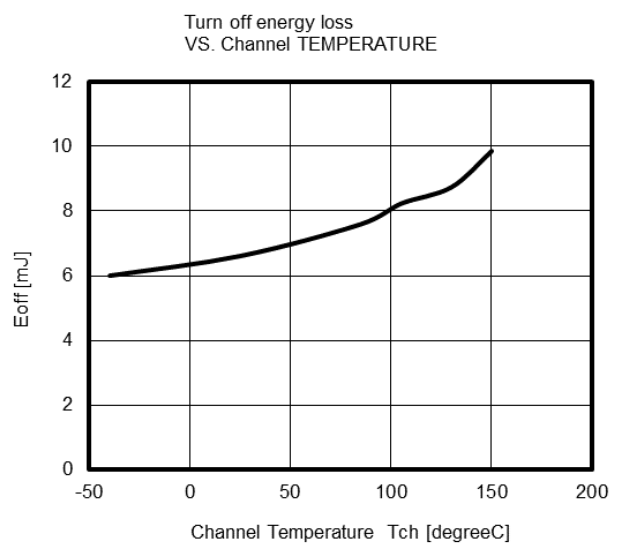
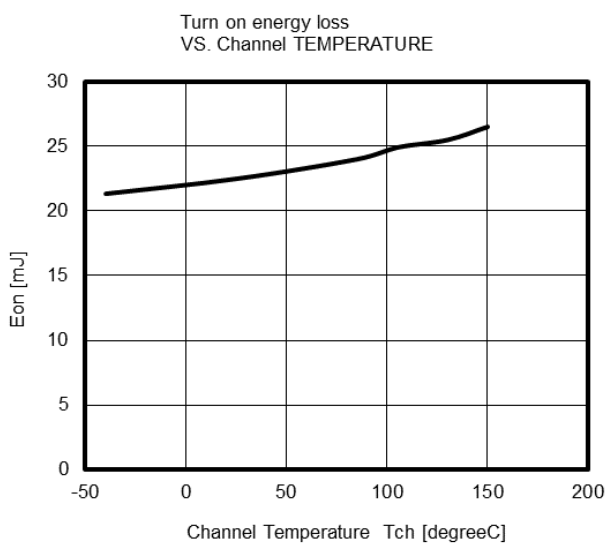
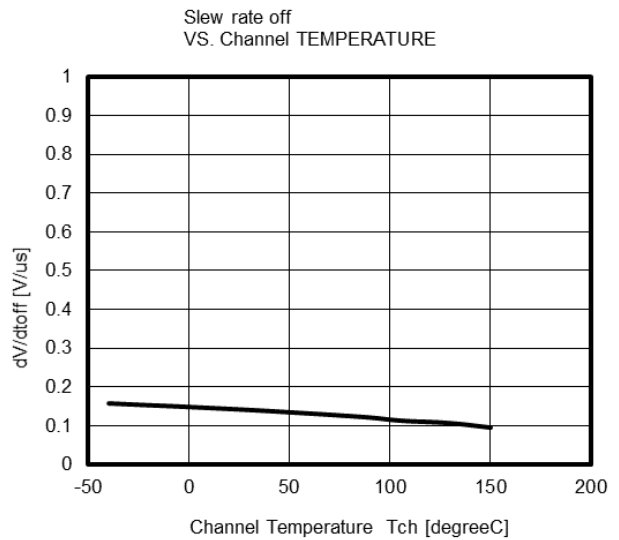
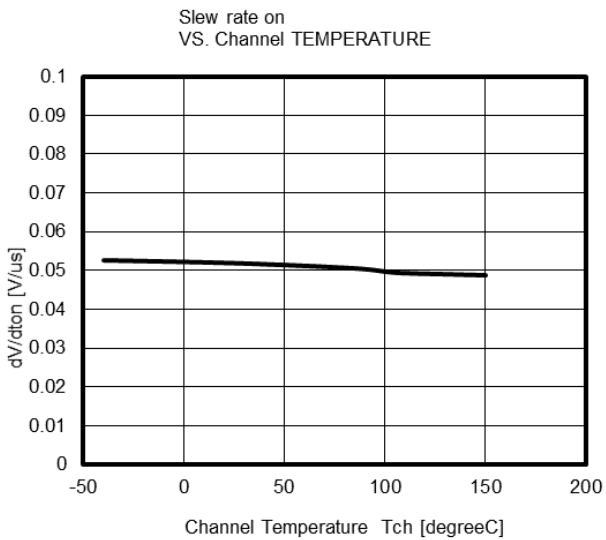
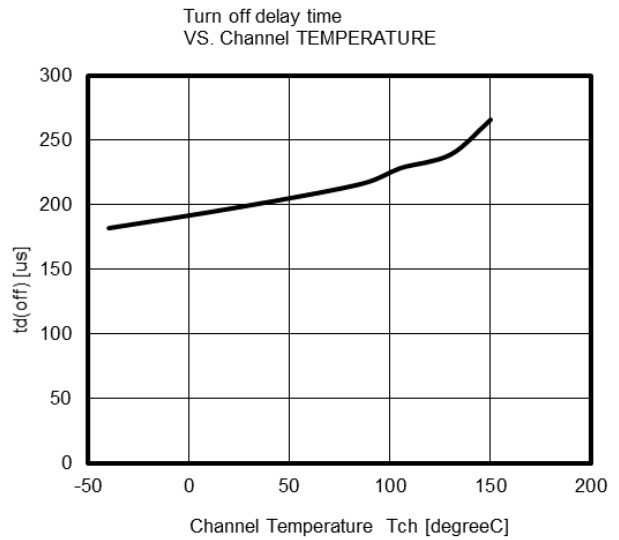
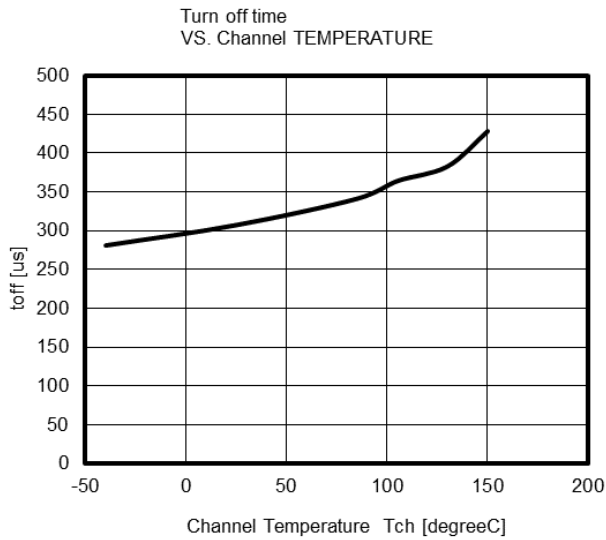
High level IN pin current  
VS. Channel TEMPERATURE



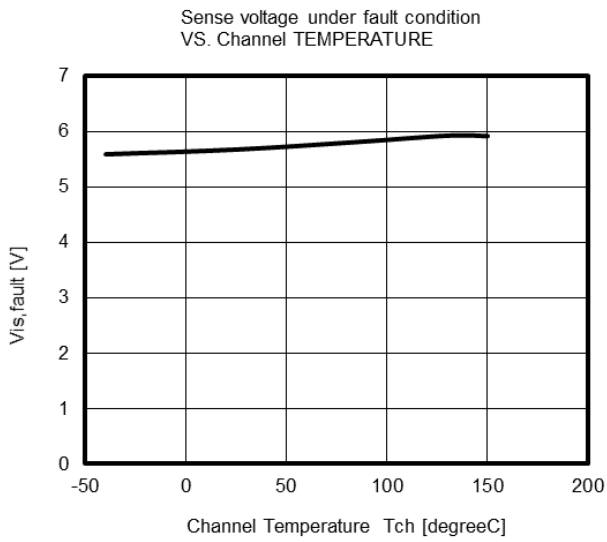
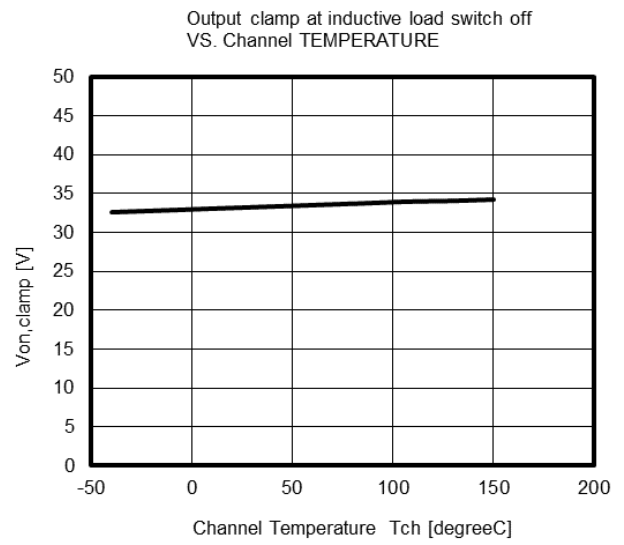
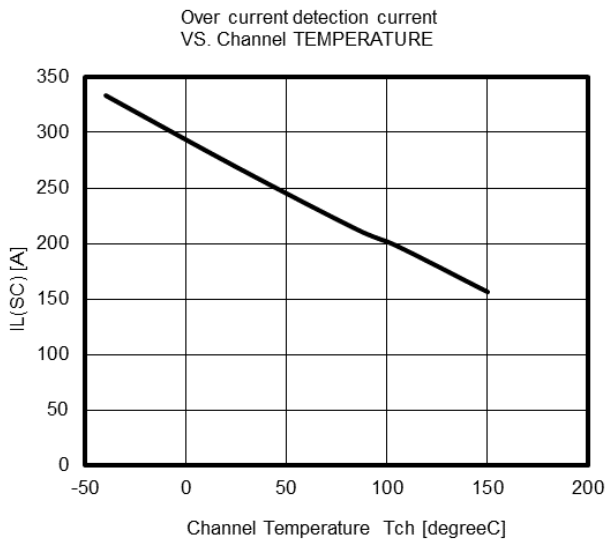
Low level IN pin current  
VS. Channel TEMPERATURE



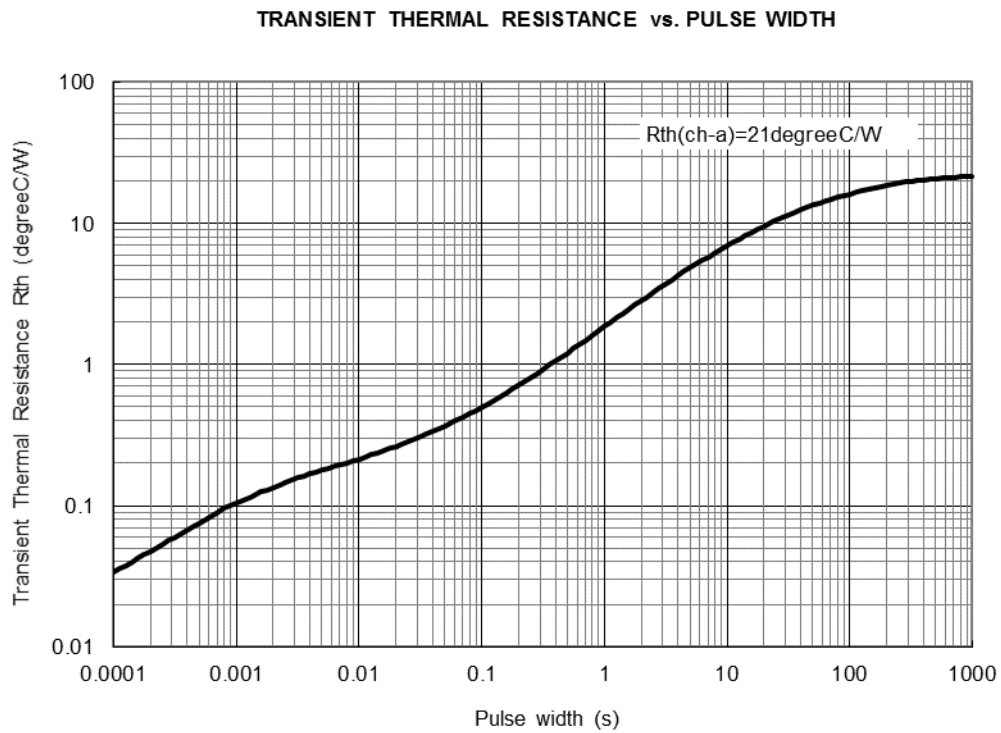




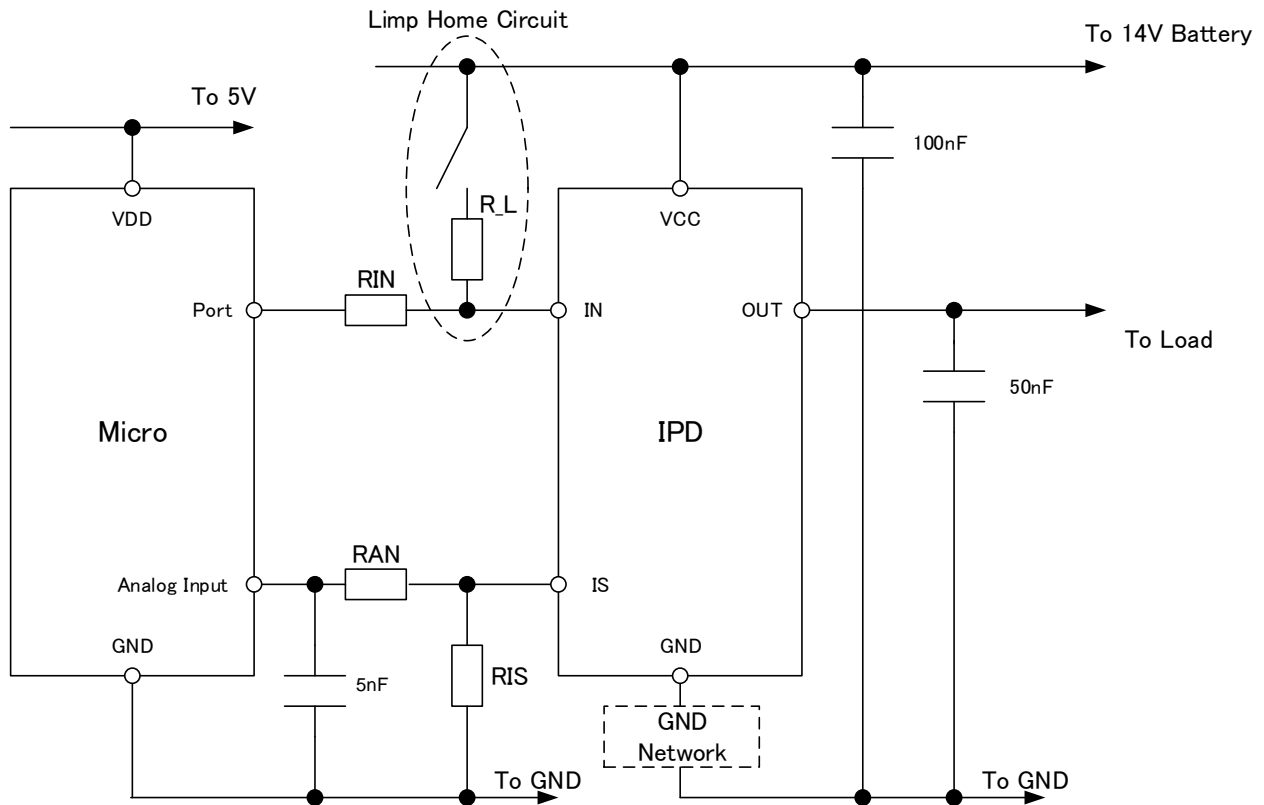




5 Thermal characteristics



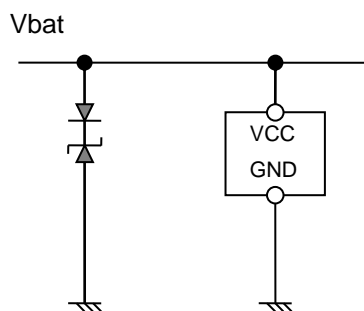
6 Application example in principle



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 resistor between OUT terminal and Ground is effective. Resistor's value is typically 100kohm

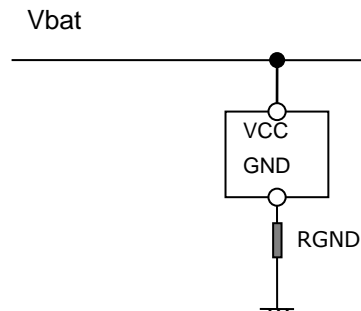
GND Network recommendation

In case of  $V_{loaddump} < 35V$



No external component is required.

In case of  $35V < V_{loaddump} < 42V$



External resistor is recommended in order to limit the current through ZD<sub>AZ</sub> at load dump condition. 100ohm is recommended as RGND.

<b>Revision History</b>	<b>RAJ2800024H12HPF Datasheet</b>
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Rev.	Date	Description	
		Page	Summary
1.00	Aug. 1, 2017	1-27	1st issue
1.01	Feb. 14, 2022	all	Typo corrected

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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