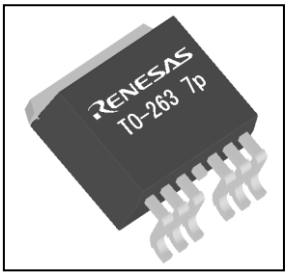
RAJ2800024H11HPF

Intelligent Power Device for automotive application

R07DS1394EJ0101
Rev. 1.01
Feb. 14. 2022

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
- 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
- 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}	4.5V to 28V
Under voltage shutdown	$V_{CC(Uv)}$	Max. 4.5V
On-state resistance at 25 degreeC	Ron	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.

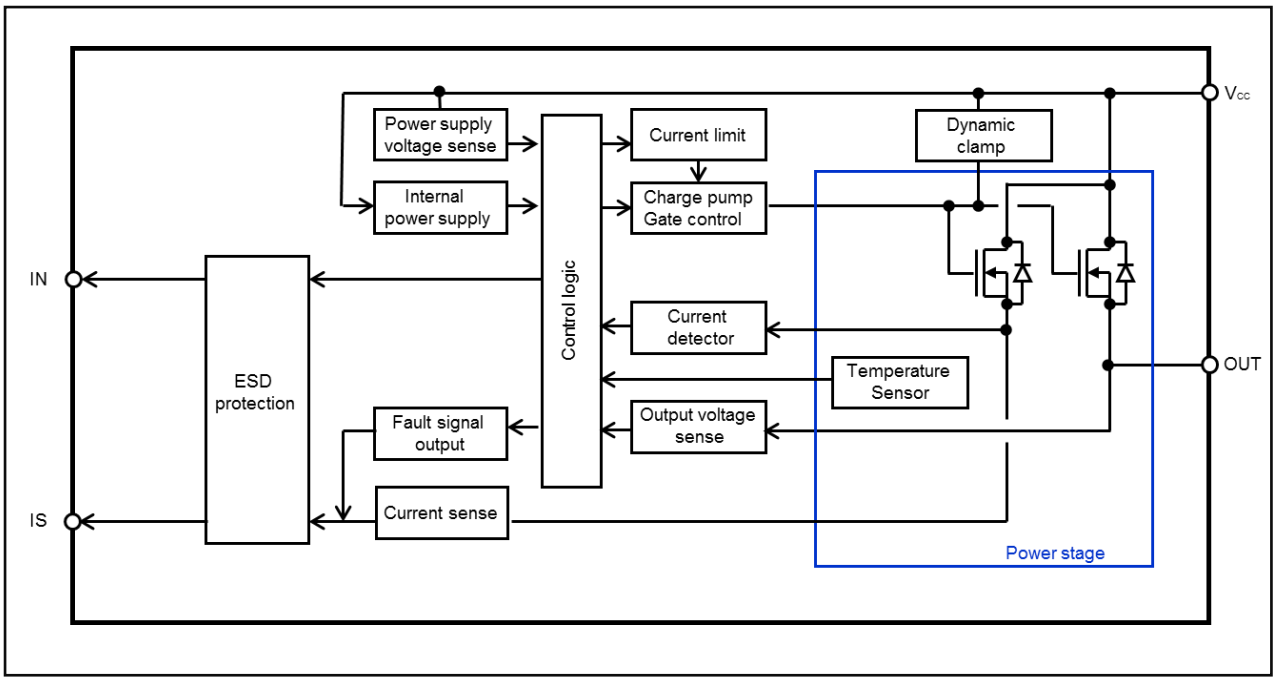
2. Ordering Information

Part No.	Lead plating	Packing	Package
RAJ2800024H11HPF	Pure Matte Sn	Tape 800pcs/reel	TO263-7

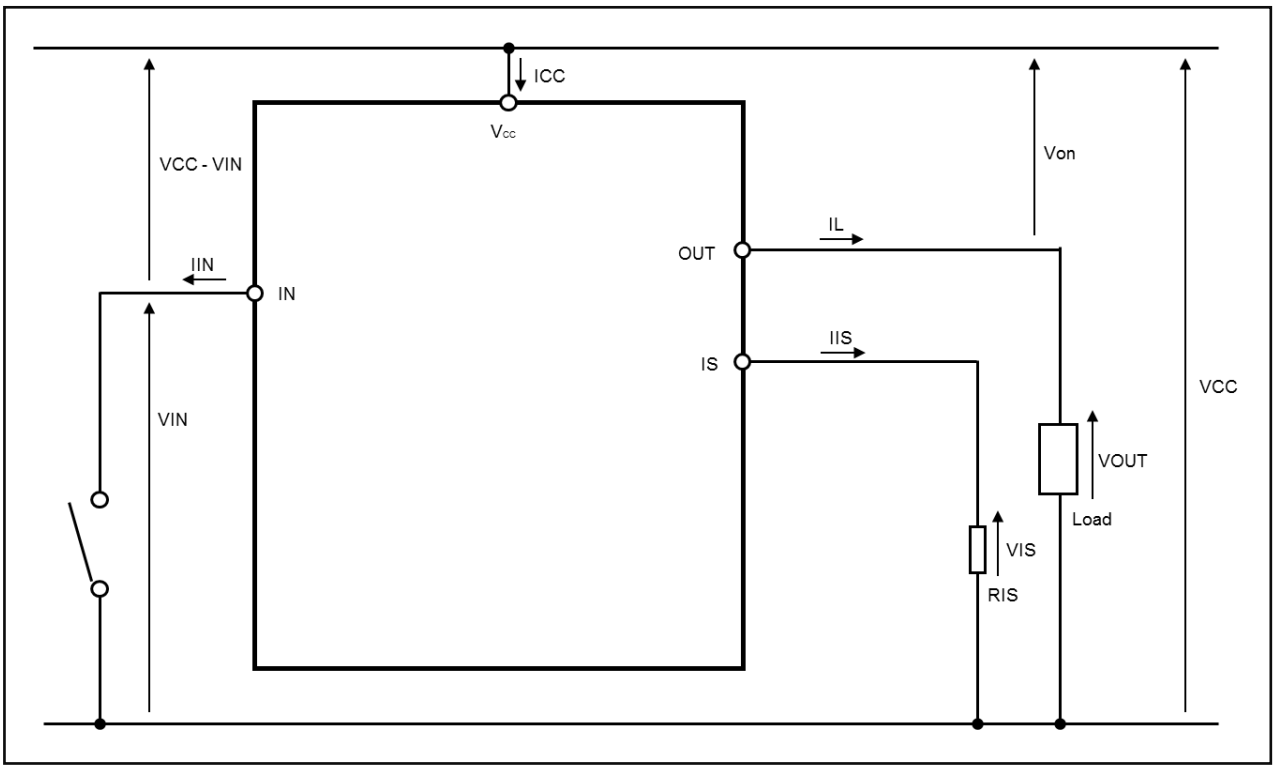
3. Specification

3.1 Block Diagram

3.1.1 Nch High-side Single Channel Device Block Diagram



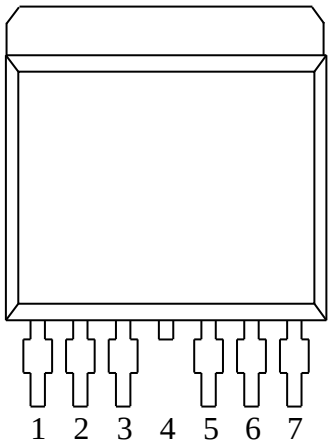
Voltage and Current Definition



3.2 Pin Configuration

3.2.1 TO263-7 Pin Configuration

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



Pin function

Terminal Name	Pin function	Recommended connection
IN	Activates the output, if it shorted to ground	Connected to GND through a 100 ohm resistor and switch
IS	Current sense and Diagnosis output signal	Connected to GND through a 1k-6k ohm resistor 1)
OUT	Protected high-side power output	Connected to load with 50-100nF capacitor in parallel
VCC	Positive power supply for output power supply	Connected to battery voltage with 100nF capacitor in parallel

1) A resistor is necessary to satisfy Von,clamp 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=100ohm, RIS=1kohm		
Vcc voltage under Load Dump condition	$V_{load\ dump}$	42	V	RI=1ohm, RL=Nominal load, RIS=1kohm, RIN=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}	Vcc-28	V	DC		
		Vcc+16		At reverse battery condition, t<2min, RIN=100ohm		
Voltage at IS pin	VIS	-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	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			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, Tch,start<150 degreeC, RL=Nominal load, Refer to 3.6.6		
Inductive load switch-off energy dissipation repetitive pulse	EAR	840	mJ	VCC=13.5V, Tch,start=85 degreeC, RL=Nominal load, Refer to 3.6.6		

Remark) All voltages refer to IN 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 otherwise specified

Parameter	Symbol	Min	Typ	Max	Unit	Test Condition	
Operating Voltage	V_{CC}	4.5		28	V	V_{IN}=0V, RL=Nominal load, Refer to 3.6.6	
Output Leakage current	$I_{L(off)}$			0.5	µA	Tch=25 degreeC	VCC=13.5V, IIN=0A, VIS=0V, VOUT=0V
				13		Tch=-40 to 125 degreeC	
Standby current	$I_{CC(off)}$			0.5	µA	Tch=25 degreeC	VCC=13.5V, IIN=0A, VIS=0V, VOUT=0V
				1.5		Tch=-40 to 85 degreeC	
On-state resistance	Ron		1.6	2.0	mohm	Tch=25 degreeC	IL= Nominal current, Refer to 3.6.6
				3.7		Tch=150 degreeC	
Input current in on state	IIH		2.5	5	mA		
Input current for turn-off	IIL			30	µA		
Cranking mode voltage	$V_{CC(cr)}$			4.5	V		
On-state resistance at cranking	Ron(cr)			8	mohm	VCC=3.2V, RIN=100ohm, Tch=25 degreeC, Pulse duration=24ms, IL=Nominal current Refer to 3.6.6	
Operating Voltage range for cranking	$V_{CC(Uv, cr)}$	3.2				RIN=100ohm, Tch=25 degreeC, Pulse duration=24ms, IL=Nominal current Refer to 3.6.6	
Under voltage shutdown	$V_{CC(Uv)}$			4.5	V		
Under voltage restart	$V_{CC(Cpr)}$			4.5	V		
Turn on time	ton		500	1000	µs	VCC=13.5V, RL=Nominal load, Refer to 3.6.6	
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 [1)]	Eon		30		mJ	VCC=13.5V, Tch=25 degreeC, RL=Nominal load, Refer to 3.6.6	
Turn off energy loss [1)]	Eoff		11		mJ		
Driving capability [1)]	Dr(capa)	75			mohm	Tch=25 degreeC, VCC=8 to 16V	
		100				Tch=105 degreeC, VCC=8 to16V	

Remark) All voltages refer to IN 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	
On-state resistance at reverse battery condition	Ron(rev)			2.5	mohm	Tch=25 degreeC	VCC=-13.5V, IL=Nominal current, Refer to 3.6.6
				4.6		Tch=150 degreeC	
IN current at reverse battery condition	IIN(rev)		-2		mA	VCC=-16V, Tch=25 degreeC	

Remark) All voltages refer to IN pin of the device

Diagnosis function

Tch=-40 to 150degreeC, Vcc=7 to 18V, unless other wise 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 depends on temperature	dKILIS	-20		20	%	VCC=13.5V, Tch,start=25 degreeC, IL =33A, Refer to 3.6.6
Sense current offset current	Iis,offset			50	µA	IL=0A, Tch =25 degreeC
Sense current under fault condition	Iis,fault	5.0			mA	VCC=13.5V, RIS=1kohm
		4.3				VCC=13.5V, RIS=2kohm
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, IIN=IIL to IIH, IL/IIS=KILIS, RL=Nominal load, Refer to 3.6.6
Sense current settling time after input signal negative slope [1)]	tsis(off)			10	µs	IIN=IIH to IIL
Sense current settling time during on-state [1)]	tsis(LC)			50	µs	RL= 2 * Nominal load to Nominal load,Refer to 3.6.6
Fault signal delay after over current detection [1)]	tdsc(fault)			10	µs	IIN=IIL to IIH, IL=IL(SC)
Fault signal delay after power limitation valid [1)]	tdpl(fault)			10	µs	Von>Von(CL1)
Fault signal delay after power limitation invalid [1)]	tdpl(off)			30	µs	Von<Von(CL1)
Fault signal delay after absolute thermal shutdown [1)]	tdot(fault)			10	µs	IIS→IIS,fault
Fault signal delay after input negative slope [1)]	tdoff(fault)			10	µs	IIN=IIH to IIL

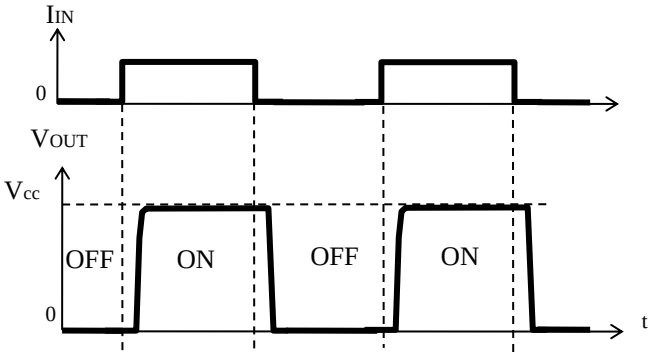
Remark) All voltages refer to IN pin of the device

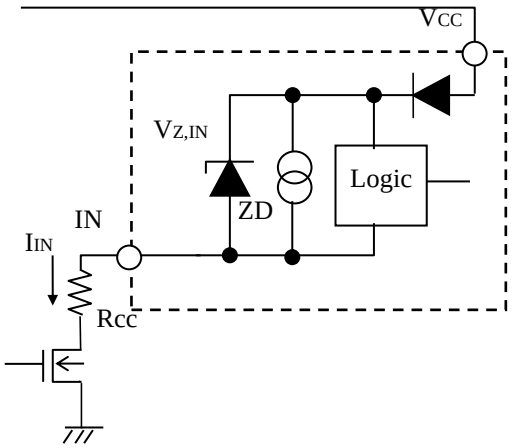
1) not subjected production test, guaranteed by design

3.6 Feature Description

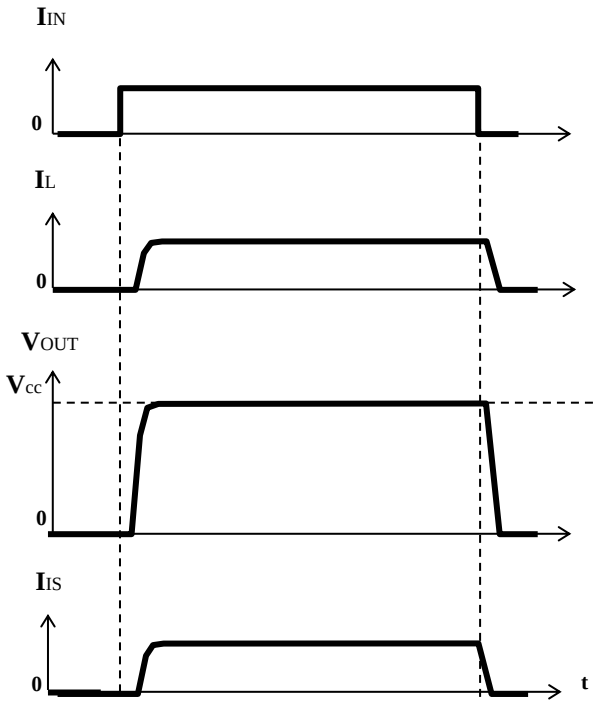
3.6.1 Driving Circuit

The high-side output is turned on, if the input pin is connected to ground through a low impedance path allowing a current of IIH. The high-side output is turned off, if the input current gets below IIL

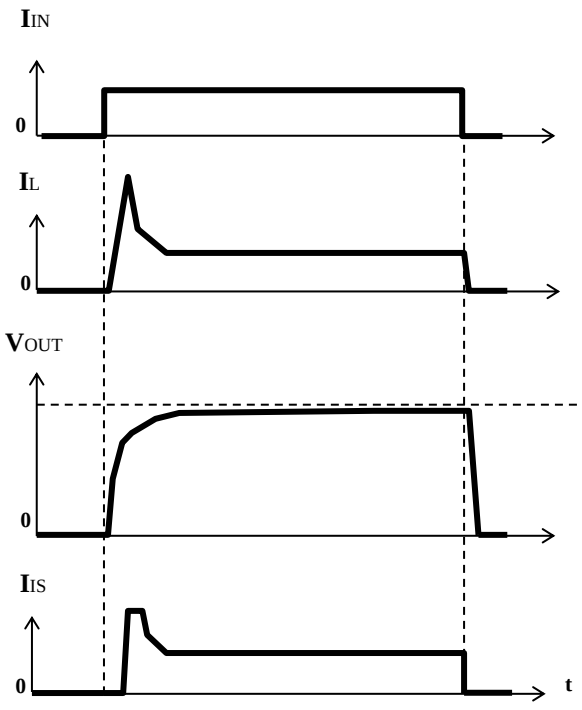




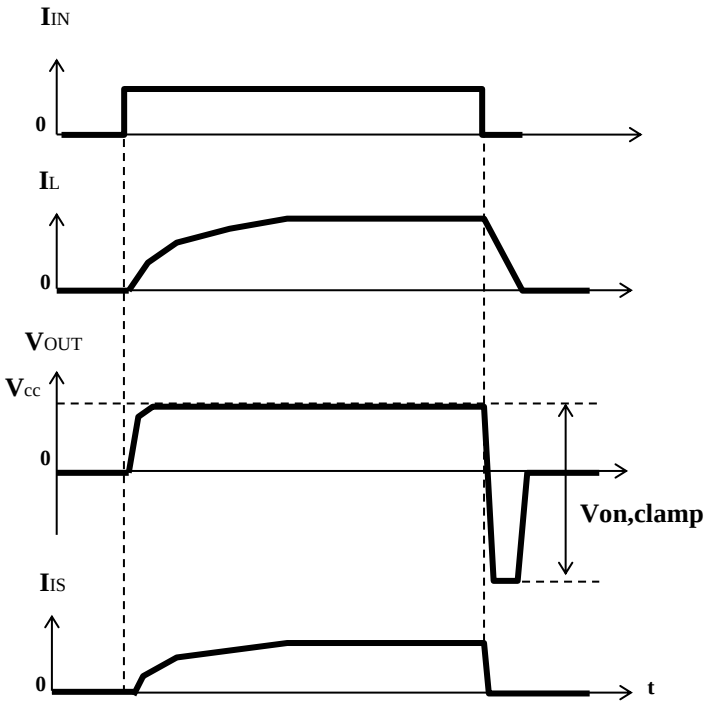
Switching a resistive load



Switching lamps



Switching an inductive load

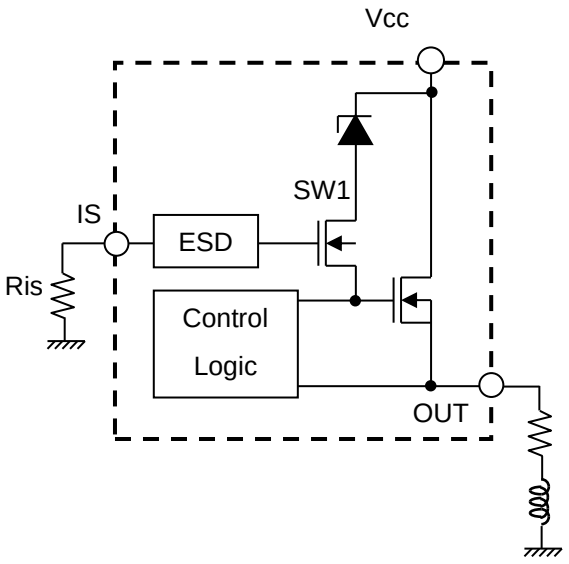


The dynamic clamp circuit works only when the inductive load is switched off. When the inductive load is switched off, the voltage of OUT falls below 0V. The gate voltage of SW1 is then nearly equal to GND. Next, the voltage at the source of SW1 (= gate of output MOS) falls below the GND voltage.

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

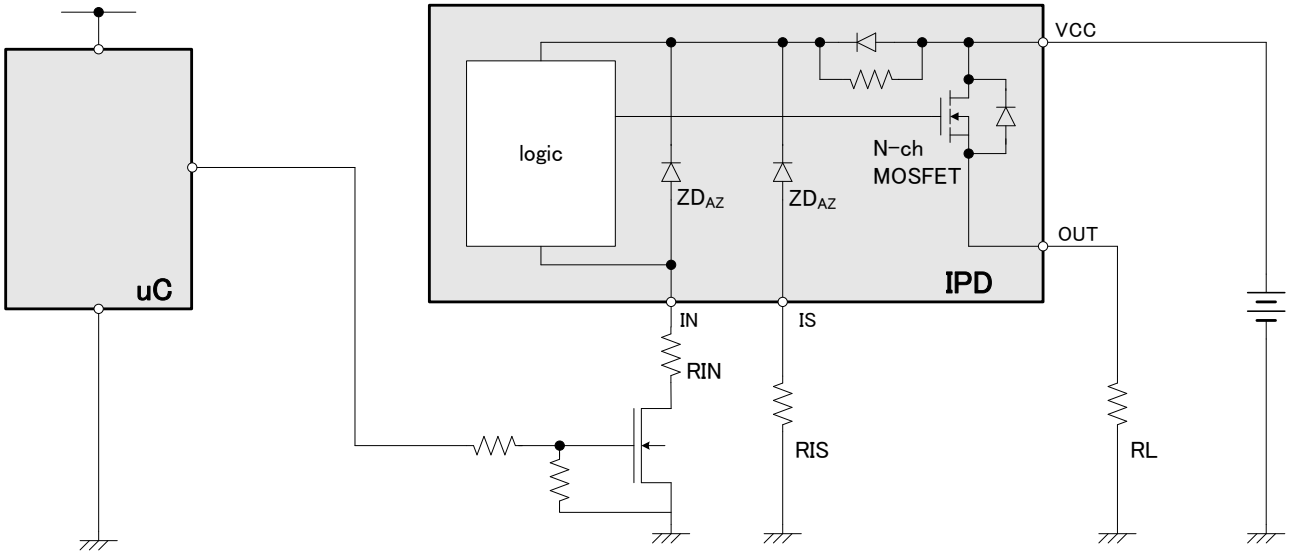
When the over-voltage is applied to VCC, the gate voltage and source voltage of SW1 are both nearly equal to GND. SW1 is not turned on, the clamp diode is not connected to the gate of the output MOS, and the dynamic clamp circuit is not activated.

The dynamic clamp works only if IS pin is connected to GND through a resistor.



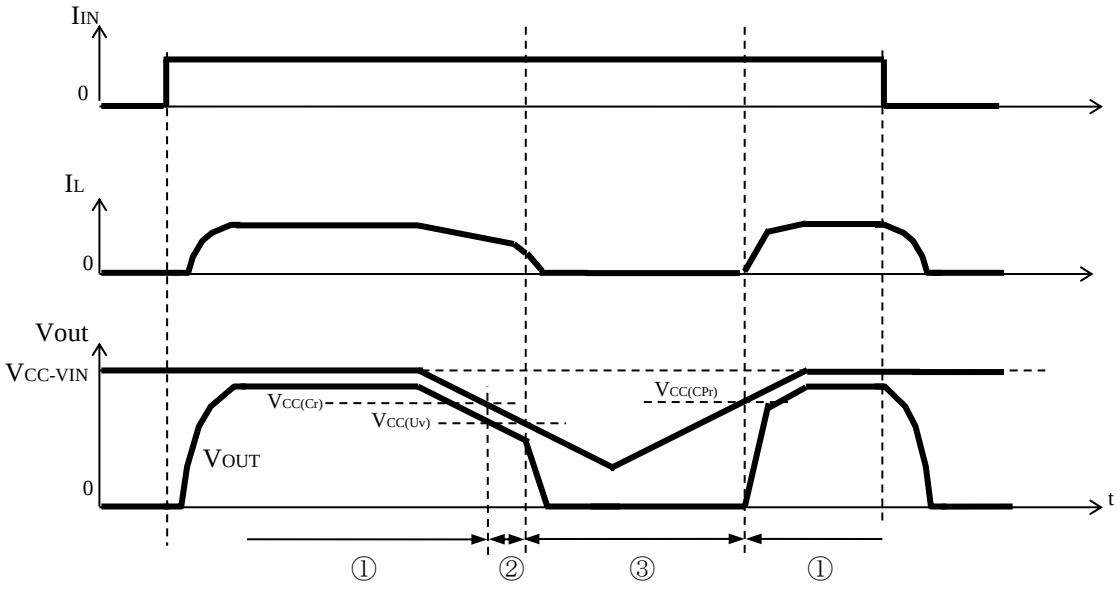
3.6.2 Device behavior at over voltage condition

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 the voltage supply (V_{CC} -V_{IN}) goes down under V_{CC}(Uv), the device outputs shuts down. If voltage supply (V_{CC} -V_{IN}) increase over V_{CC}(Cpr), the device outputs 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

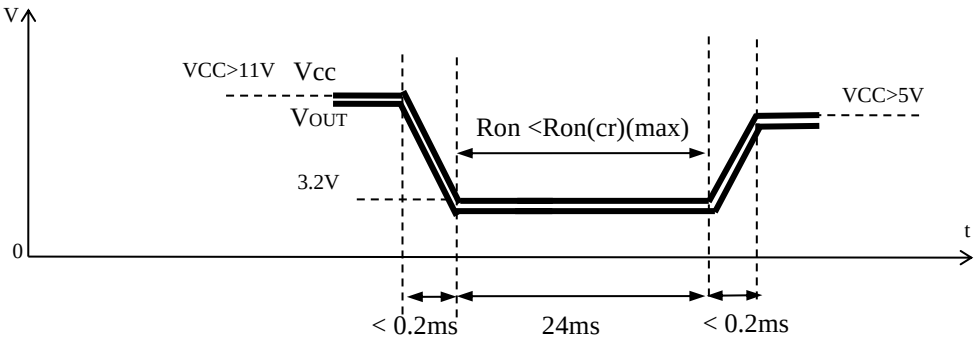
③ : Under voltage mode

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	○	○(*1)	×	(*1)Ron is defined as Ron(Cr).
Normal operation	KILIS function	○	×	×	In case of Von < Von(CL1)
Diagnosis	Von(CL1), td(CL)	○	×	×	Refer to 3.6.4
Protection	IL(SC)	○	×	×	Refer to 3.6.4
Protection	Von(CL2)	○	×	×	Refer to 3.6.4
Protection	aTch	○	○		Refer to 3.6.4
Protection	dTch	○	×	×	Refer to 3.6.4
Protection	Von(CL1)	×	○	○	Refer to 3.6.4

Definition of on-state resistance at cranking



3.6.4 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 Iis,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 output Iis,fault when (d) is detected.

(a) IL > IL(SC)

(b) deltaTch > dTth

(c) Tch > aTth

(d) Von > Von(CL1) after td(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 Von < Von(CL2). The device shuts down automatically when condition (f) is detected. The device restarts automatically in power limitation mode. The sense pin output Iis,fault during power limitation mode. The device shuts down automatically when condition (g) or (h) is detected. The sense pin output Iis,fault Shutdown is latched until the next reset via input pin.

(e) Von > Von(CL2)

(f) deltaTch > dTth

(g) Tch > aTth

(h) IL > IL(SC)

Power limitation control

Current limitation control with IL(CL) when auto restart from deltaTch protection.

During toggling mode due to Delta Tch protection, if Von>Von(CL1) or if the current is limited to IL(CL), the sense pin output Iis, fault. If Von<Von(CL2) and if the short current is not high enough to reach IL(CL) during toggling mode with delta Tch protection, then the sense pin outputs sense current at on-state and Iis,fault at off state.

delta Tch

Junction temperature differences between thermal sensors of power area.

3.6.5 Diagnostic signal

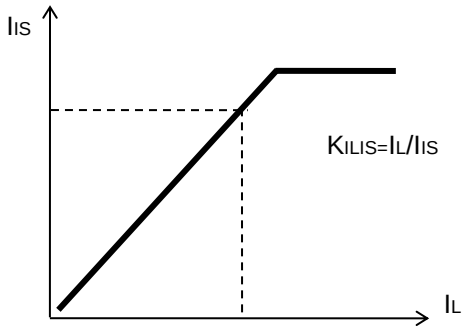
Truth table

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

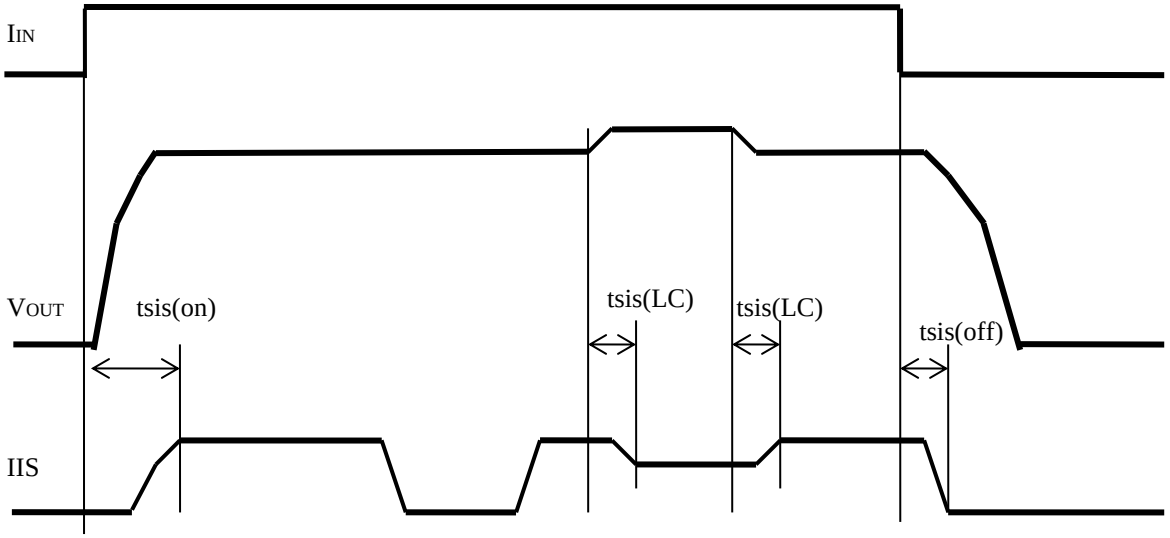
1) In case of OUT terminal is connected to GND via load.
2) In case of IS terminal is connected to GND via resister.
3) IS terminal keeps Iis,fault as long as input signal activate after the over current detection.
4) IS terminal keeps Iis,fault during power limitation if Von>Von(CL1).
5) IS terminal keeps Iis,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

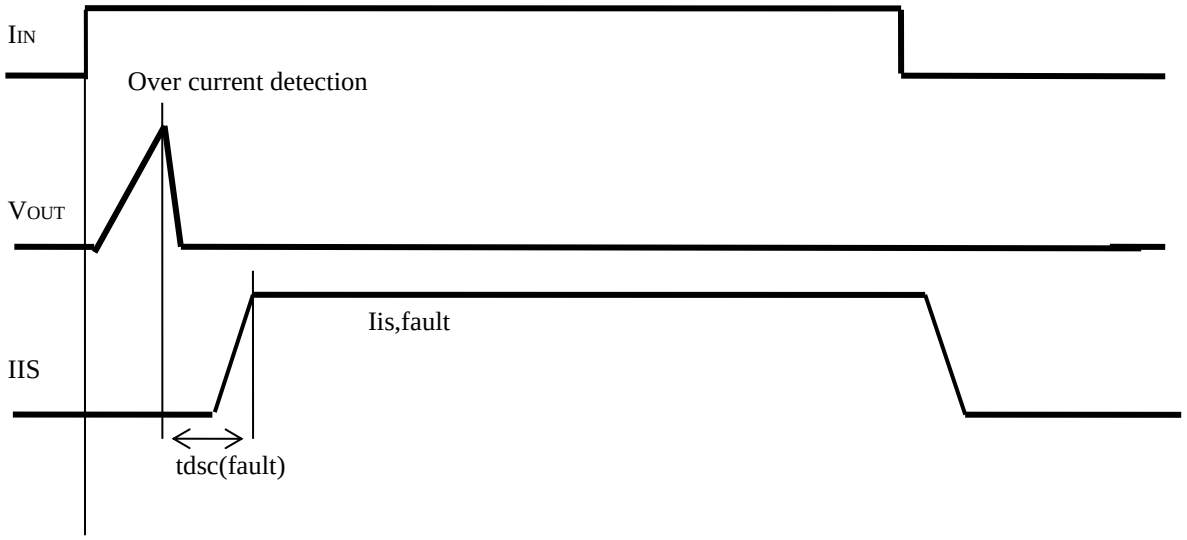
The device output analog feedback current proportional to output current from IS pin. In the case of much higher current than nominal load current, current sense output is saturated.



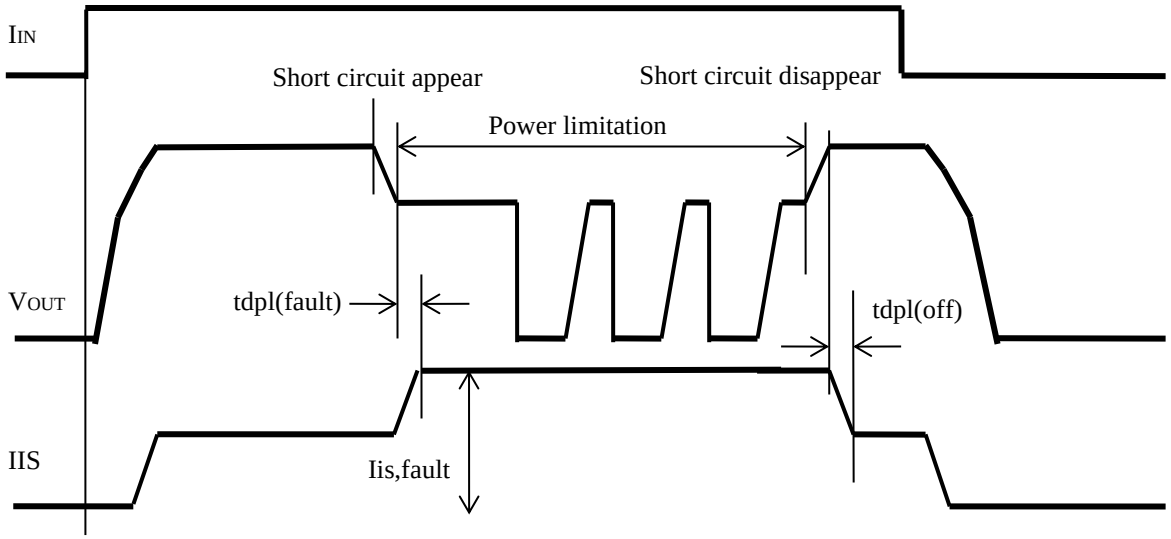
Sense voltage setting time



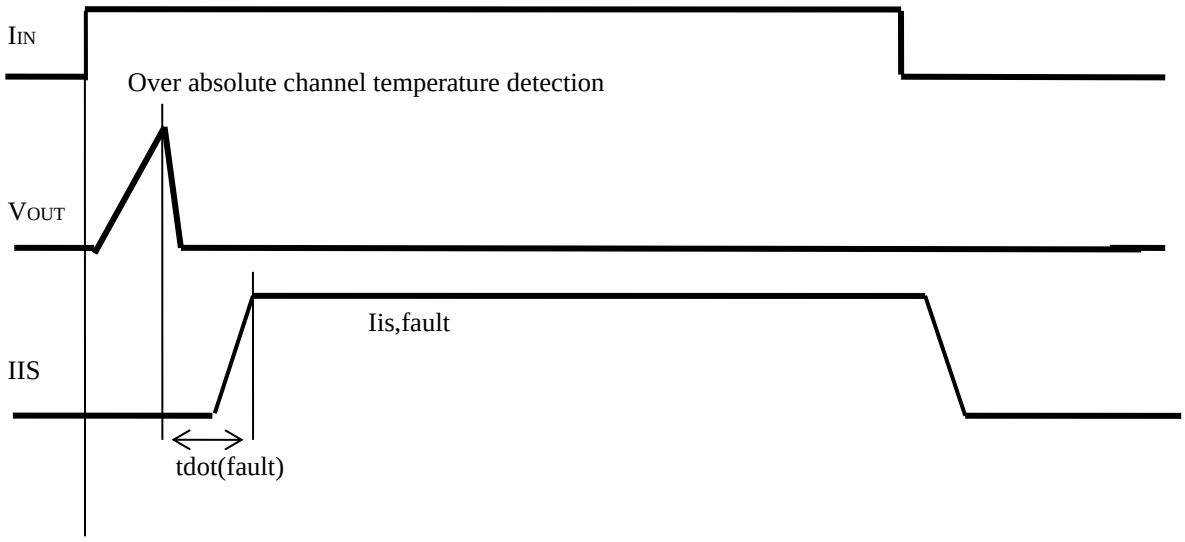
Fault signal delay time at over current detection



Fault signal delay time at power limitation



Fault signal delay time at over absolute channel temperature detection

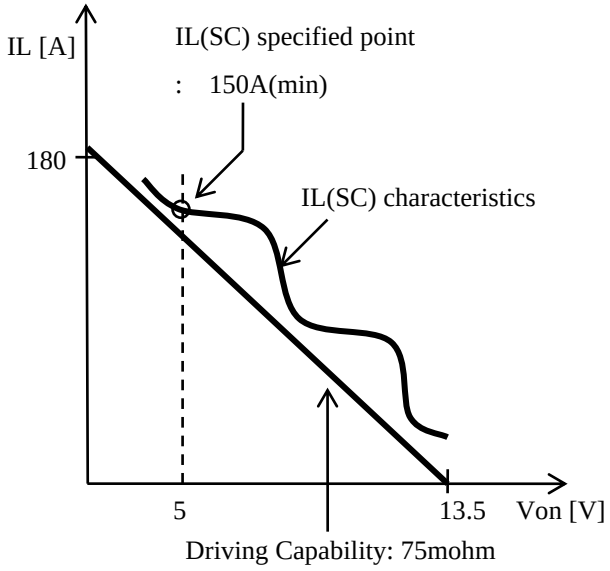


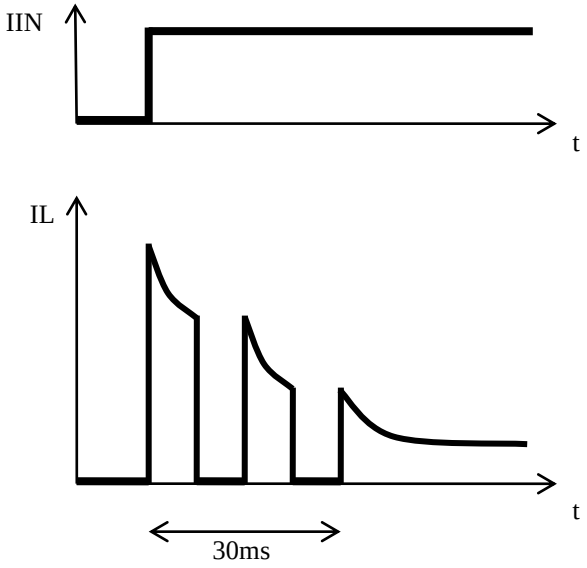
3.6.6 Nominal load and nominal current

Parameter	Values	Condition
Nominal load	0.5ohm	Tj ≦150 degreeC
Nominal current	33A	Tj ≦150 degreeC

3.6.7 Driving Capability

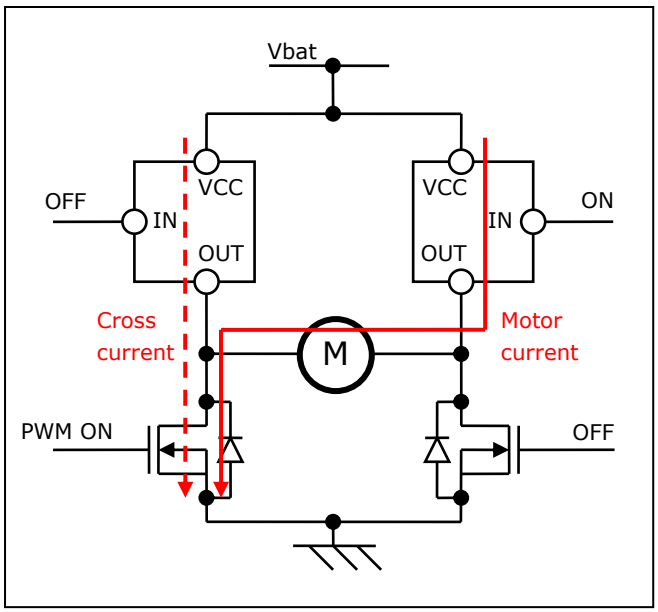
Driving Capability is specified as load impedance. Over current detection characteristics is designed above Driving Capability characteristics. If estimated load impedance which comes from peak inrush current is lower than Driving Capability characteristics, this means, the device does not detect inrush 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.





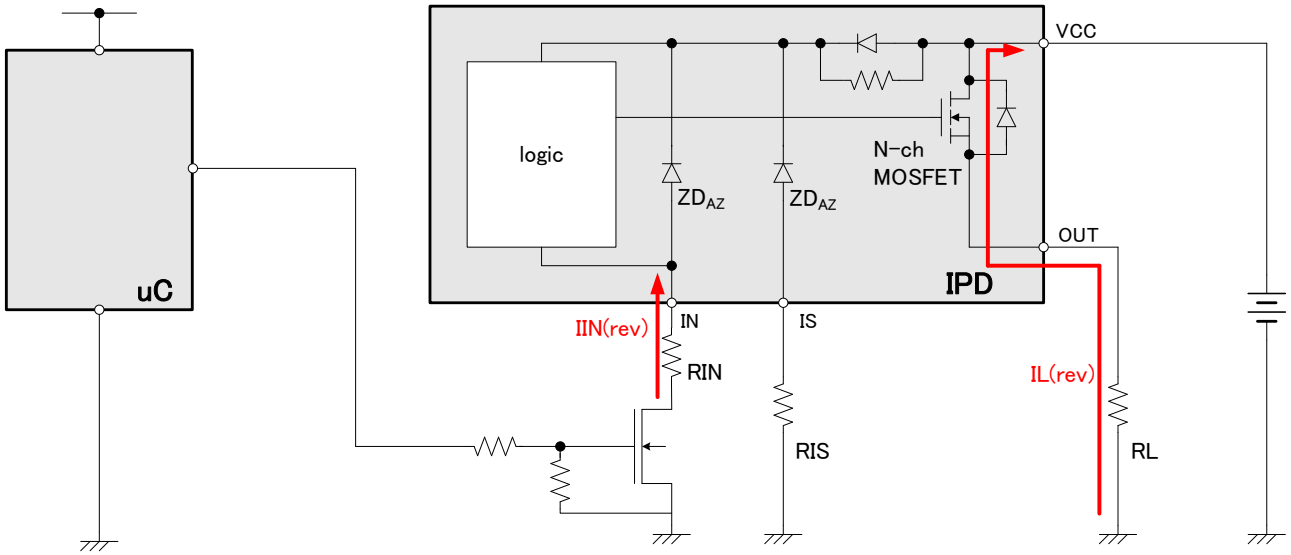
3.6.8 Cross current protection in case of H-bridge high side usage

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.



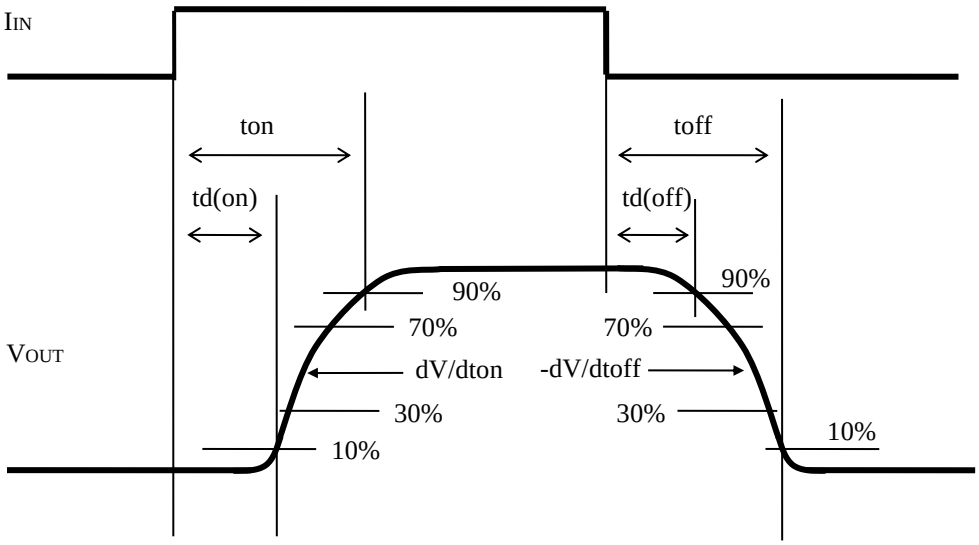
3.6.9 Reverse Battery Protection by turn on the output

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



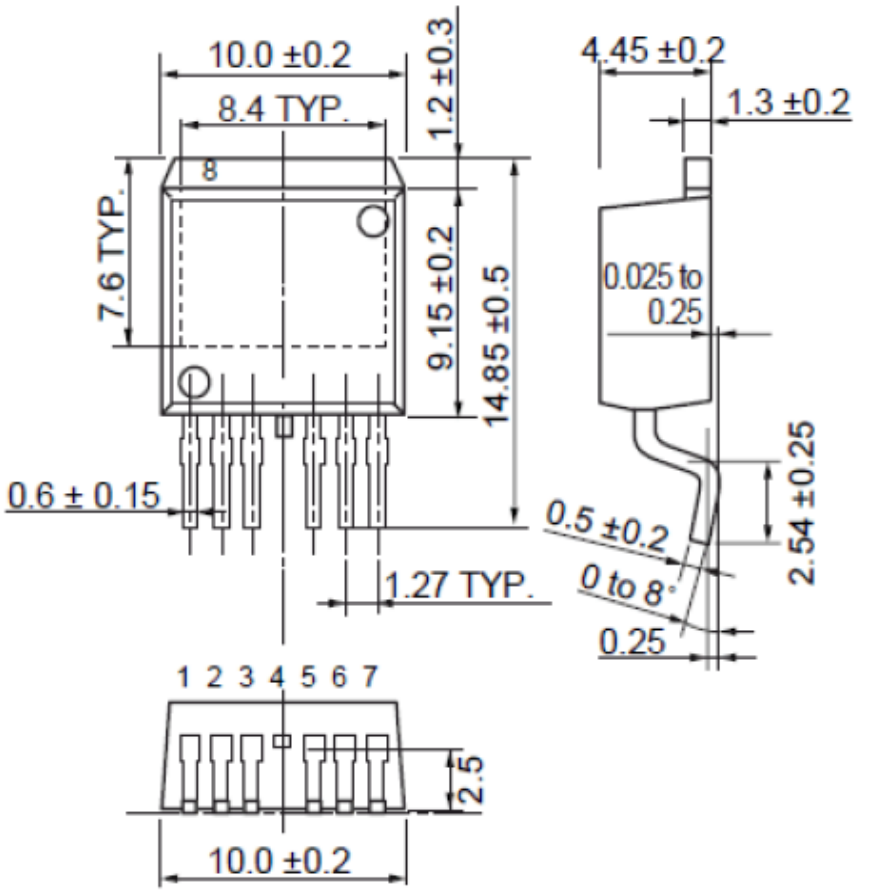
3.6.10 Measurement condition

Switching waveform of OUT terminal

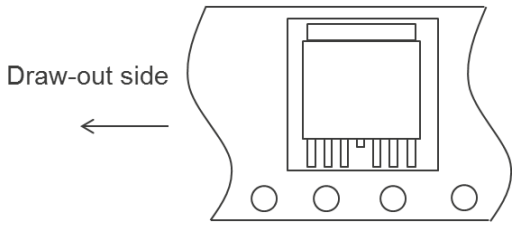


3.7 Package drawing

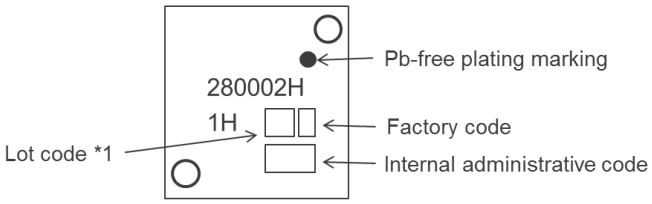
UNIT:mm



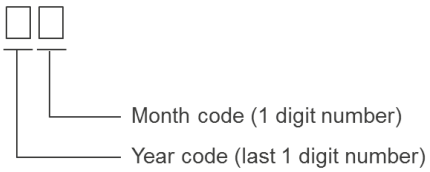
3.8 Taping information



3.9 Marking information

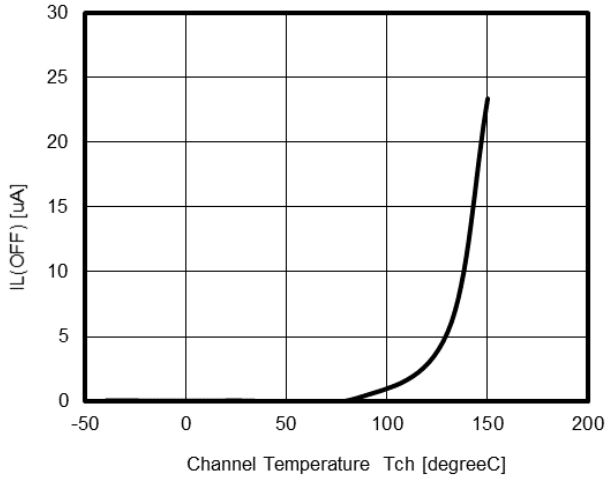


Note: *1. Composition of the lot code

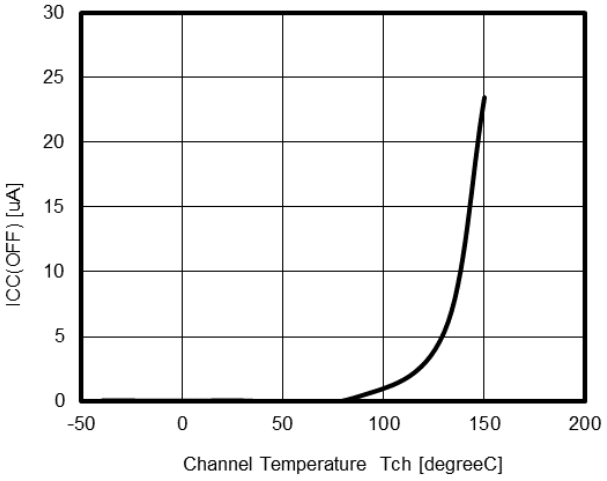


4 Typical characteristics

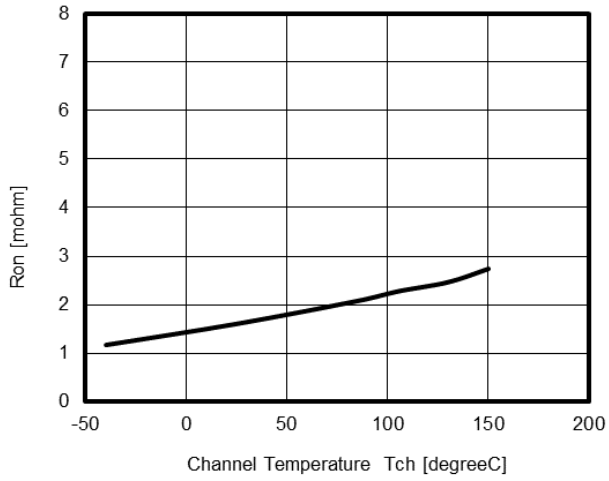
Output Leakage current per channel
VS. Channel TEMPERATURE



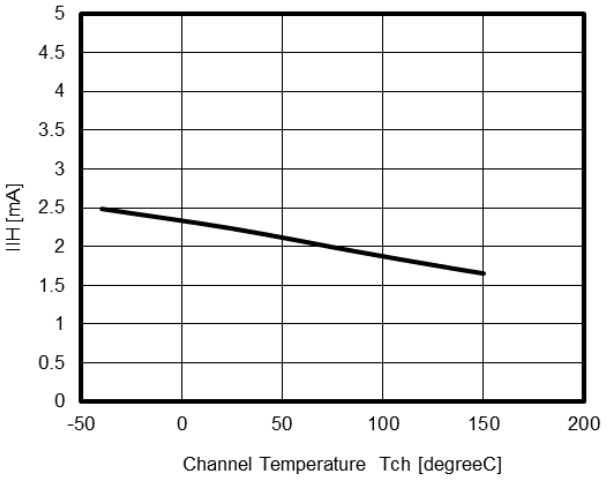
Standby current
VS. Channel TEMPERATURE



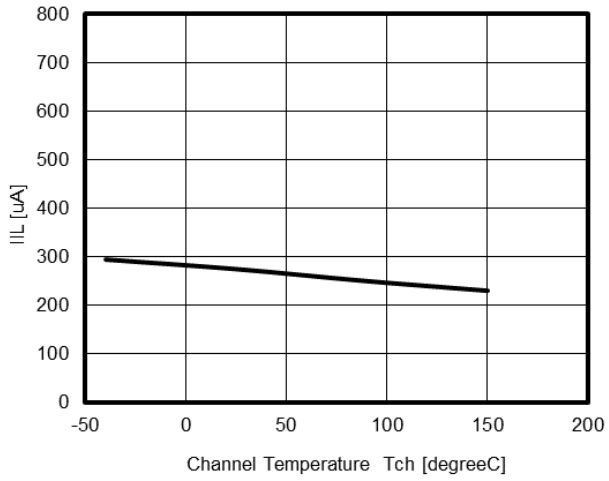
On-state resistance per channel
VS. Channel TEMPERATURE



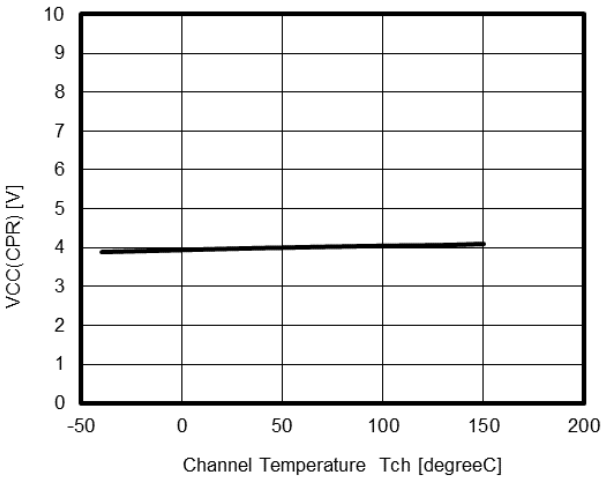
Input current in on state
VS. Channel TEMPERATURE



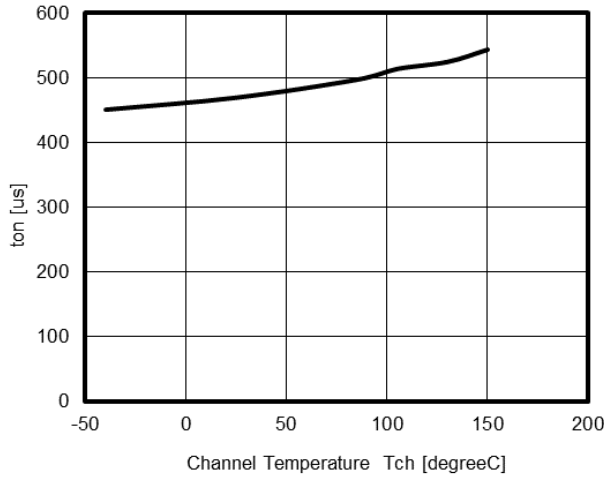
Input current for turn-off
VS. Channel TEMPERATURE



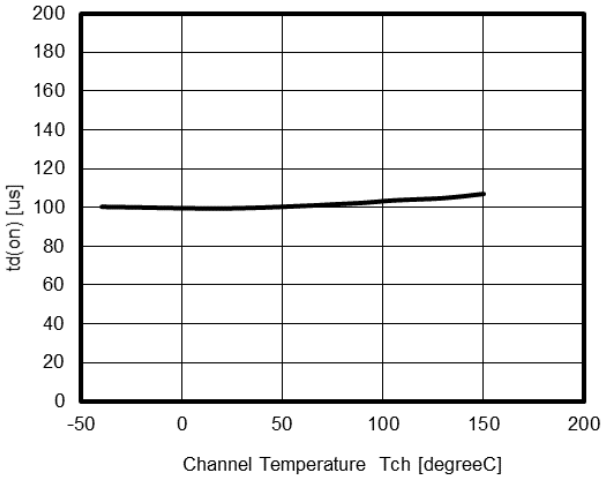
Under voltage restart
VS. Channel TEMPERATURE



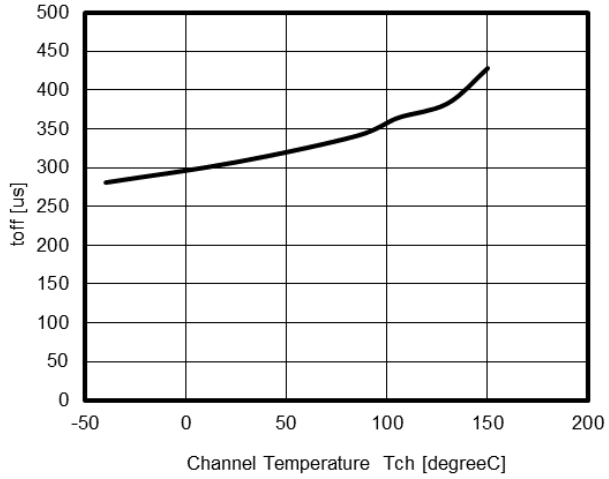
Turn on time
VS. Channel TEMPERATURE



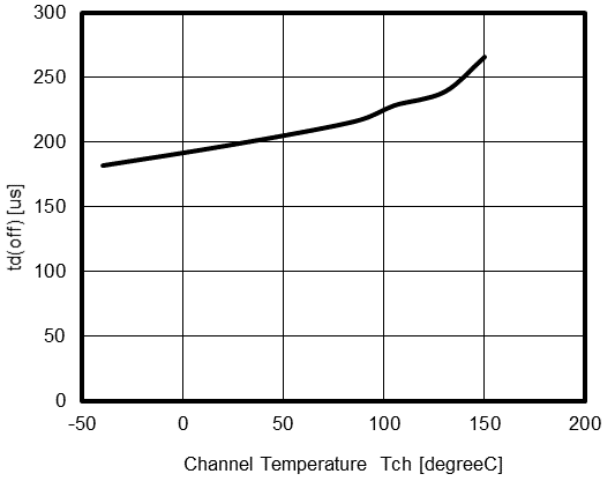
Turn on delay time
VS. Channel TEMPERATURE



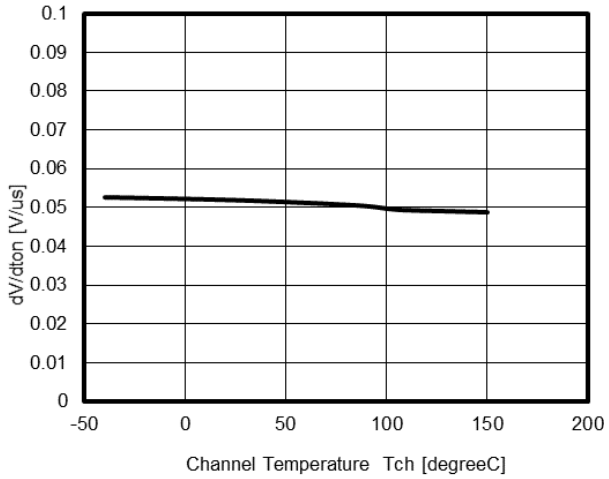
Turn off time
VS. Channel TEMPERATURE



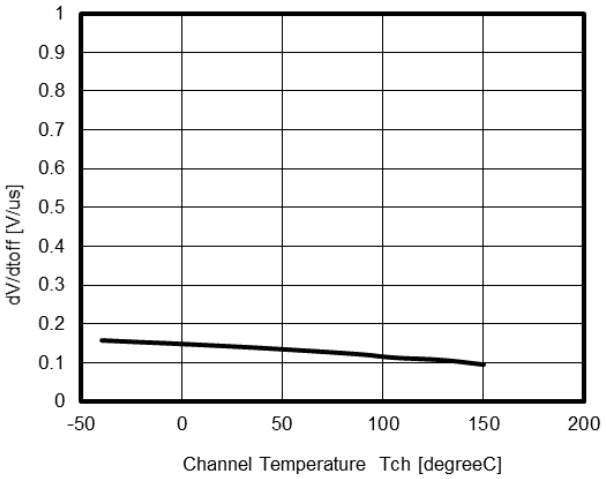
Turn off delay time
VS. Channel TEMPERATURE



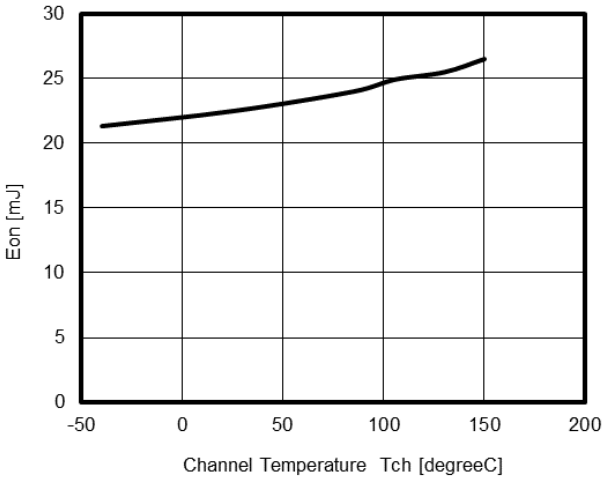
Slew rate on
VS. Channel TEMPERATURE



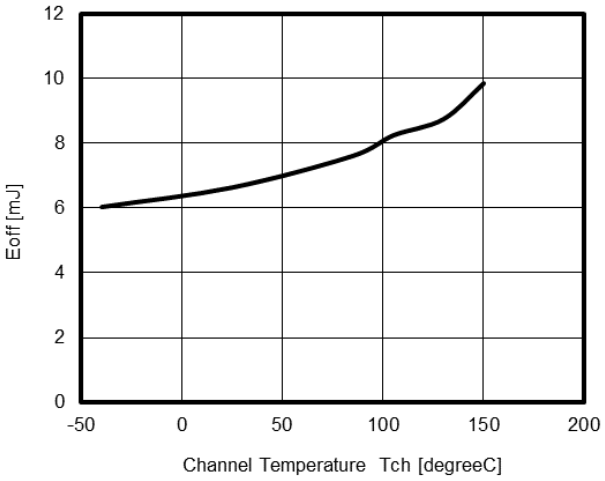
Slew rate off
VS. Channel TEMPERATURE



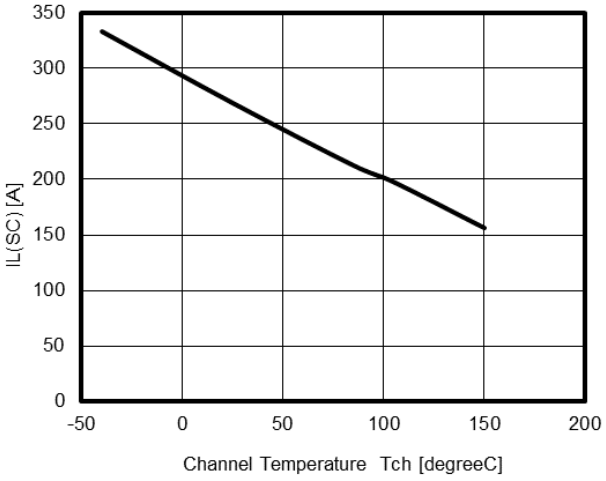
Turn on energy loss
VS. Channel TEMPERATURE



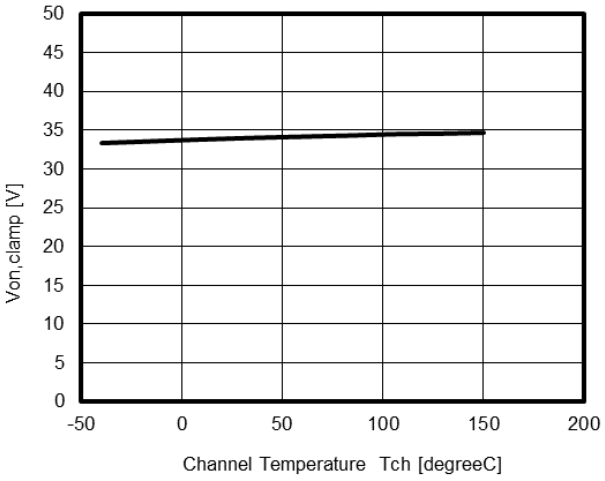
Turn off energy loss
VS. Channel TEMPERATURE



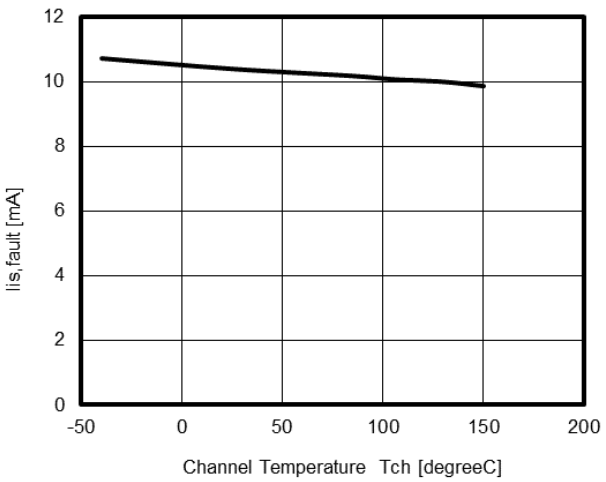
Over current detection current
VS. Channel TEMPERATURE



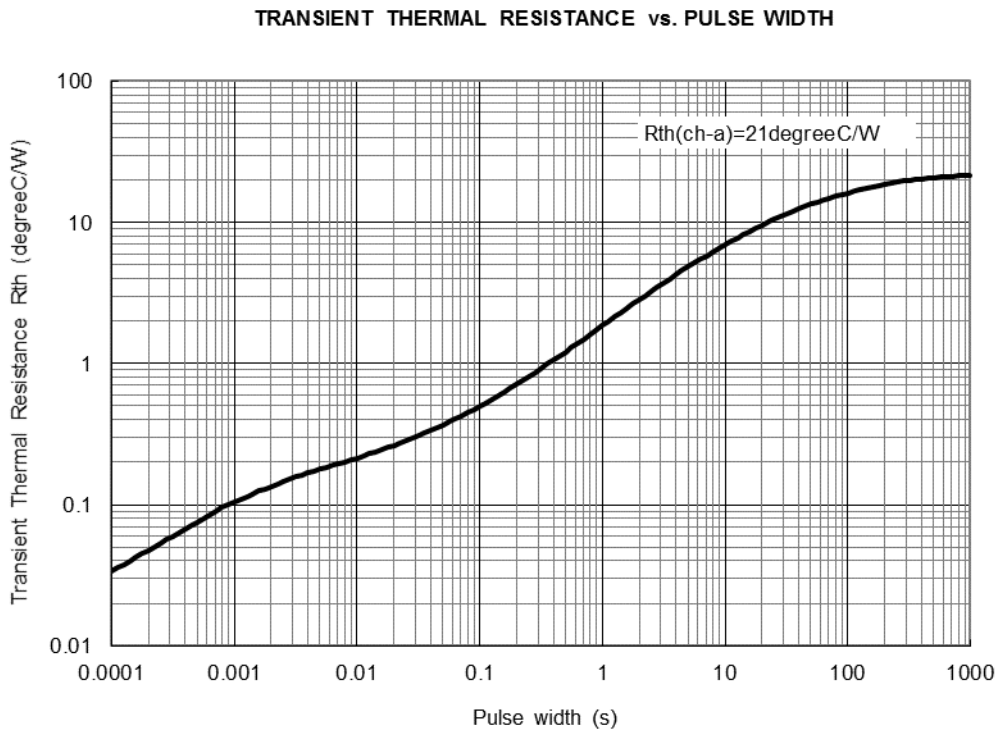
Output clamp at inductive load switch off
VS. Channel TEMPERATURE



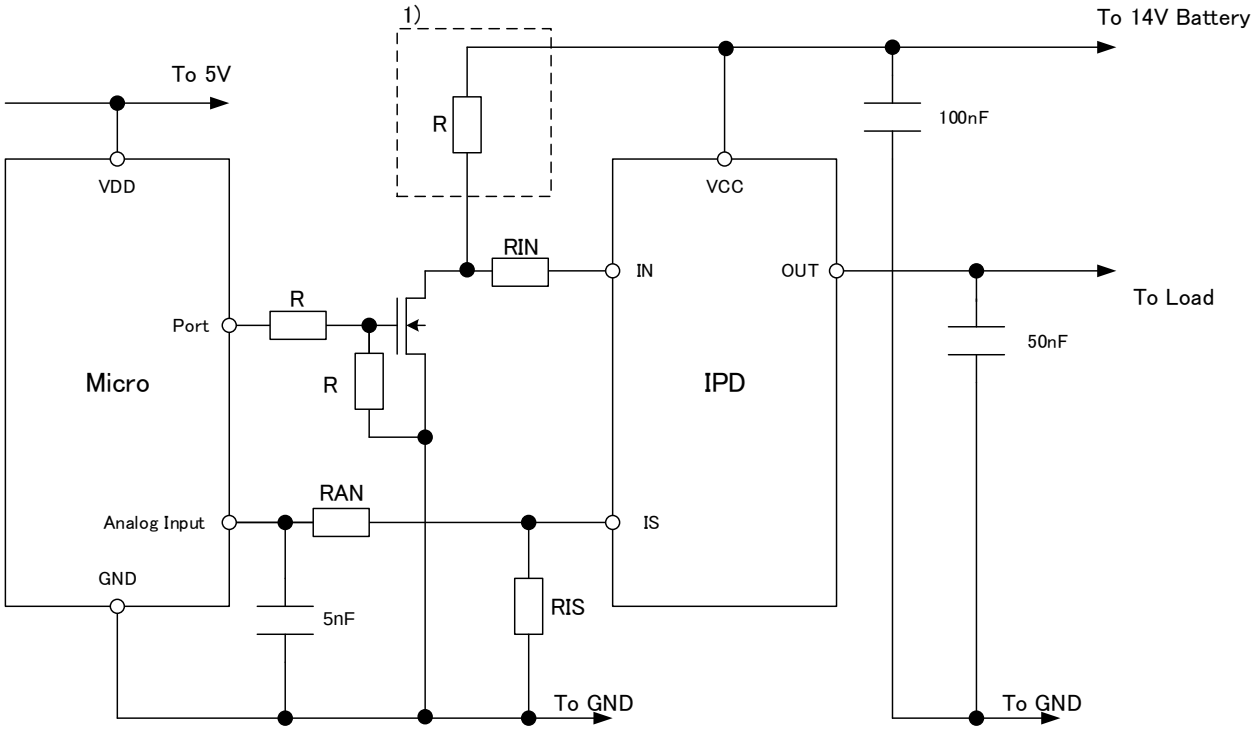
Sense current under fault condition
VS. Channel TEMPERATURE



5 Thermal characteristics



6 Application example in principle



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

1) In order to prevent leakage current through at IN terminal via PCB, it is recommended to pull up the IN terminal to VCC using around 1 to10 kohm (approx.) resistor.

Revision History	RAJ2800024H11HPF Datasheet

Rev.	Date	Description	
		Page	Summary
1.00	Aug. 1, 2017	1-26	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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