

# μPD166024T1K

## INTELLIGENT POWER DEVICE

R07DS1111EJ0200

Rev.2.00

May 22, 2015

### 1. Overview

#### 1.1 Description

##### Family:

μPD166024T1K is part of 2nd Generation Intelligent Power Devices (IPD). This is N-channel high-side switch with charge pump, voltage controlled input, diagnostic feedback with proportional load current sense and embedded protection function. Family includes up to 14 devices depending on on-state resistance, package and channel number combination.

##### 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, 2nd Generation Intelligent Power Devices achieve 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)
  - Absolute Tch over temperature protection
- Built-in diagnostic function
  - Proportional load current sensing
  - Defined fault signal in case of abnormal load condition
- Loss of ground protection
- Under voltage lock out
- Active clamp operation at inductive load switch off
- Cross current protection in case of H-bridge high side usage
- AEC Qualified
- RoHS compliant

#### 1.3 Application

- Light bulb switching from 55W to 65W
- Switching of all types of 14V DC grounded loads, such as LED, inductor, resistor and capacitor
- Power supply switch, fail-safe switch of 14V DC grounded system

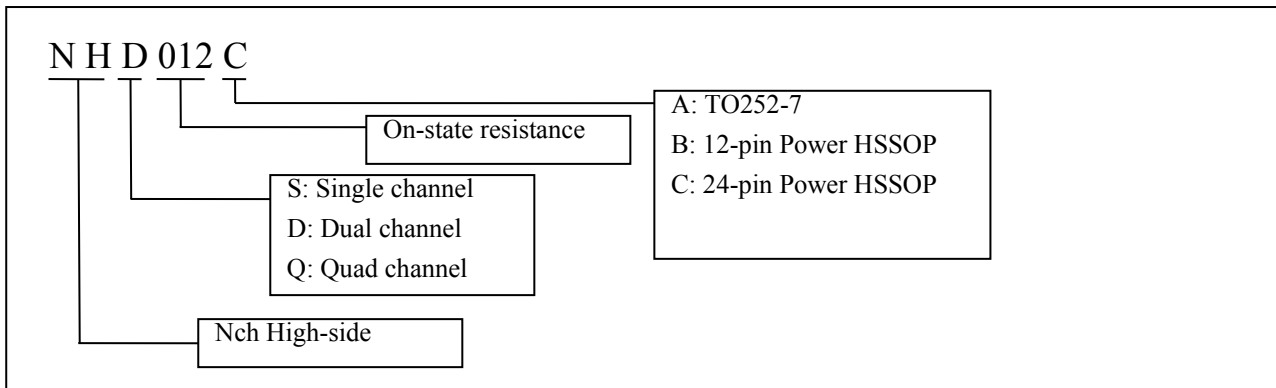
**Note: The information contained in this document is the one that was obtained when the document was issued, and may be subject to change.**

2. Ordering Information

Part No.	Nick name	Lead plating	Packing	Package
UPD166024T1K-E1-AY	NHD012C	Pure Matte Sn	Tape 1500 p/reel	24-pin Power HSSOP
UPD166024T1K-E2-AY	NHD012C	Pure Matte Sn	Tape 1500 p/reel	24-pin Power HSSOP

Note: MSL: 1, profile acc. J-STD-20C

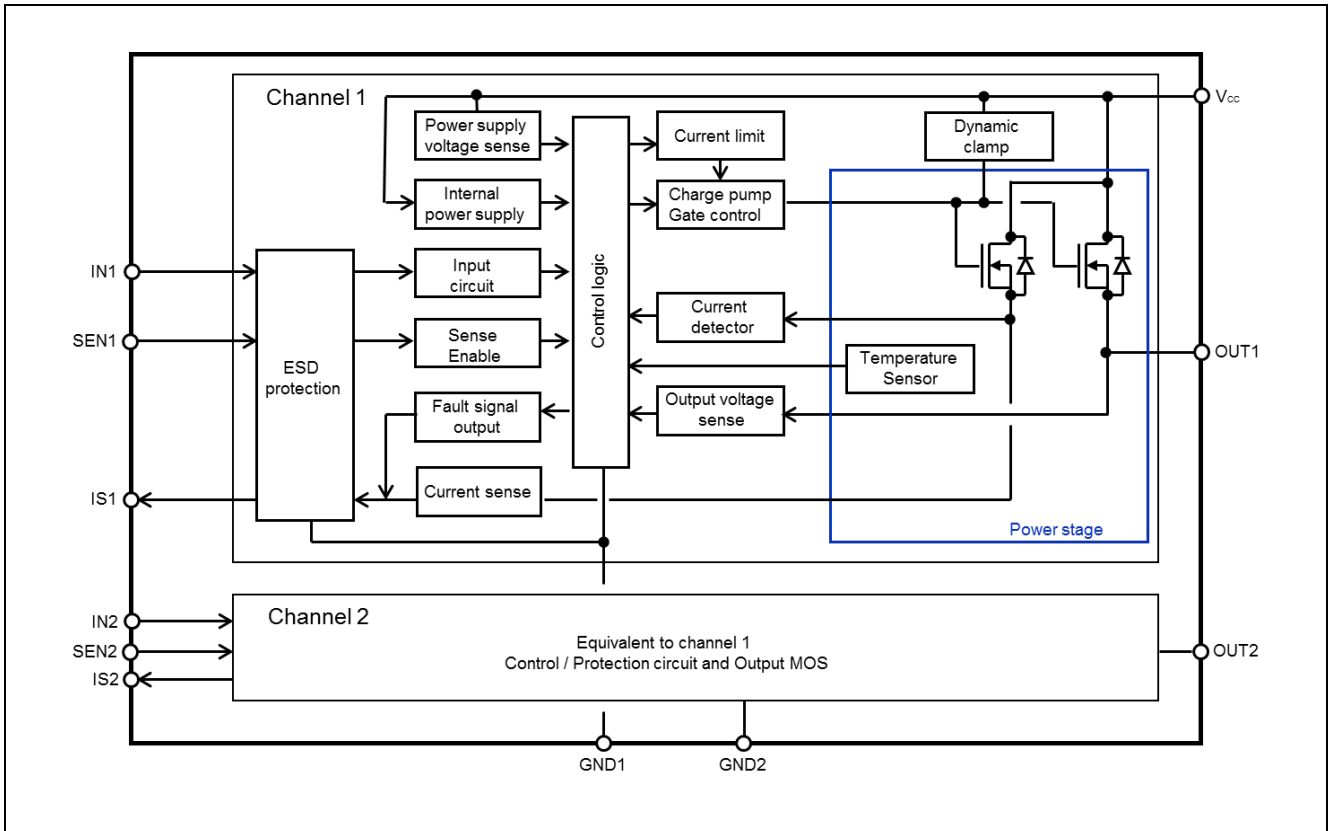
2.1 Nick name



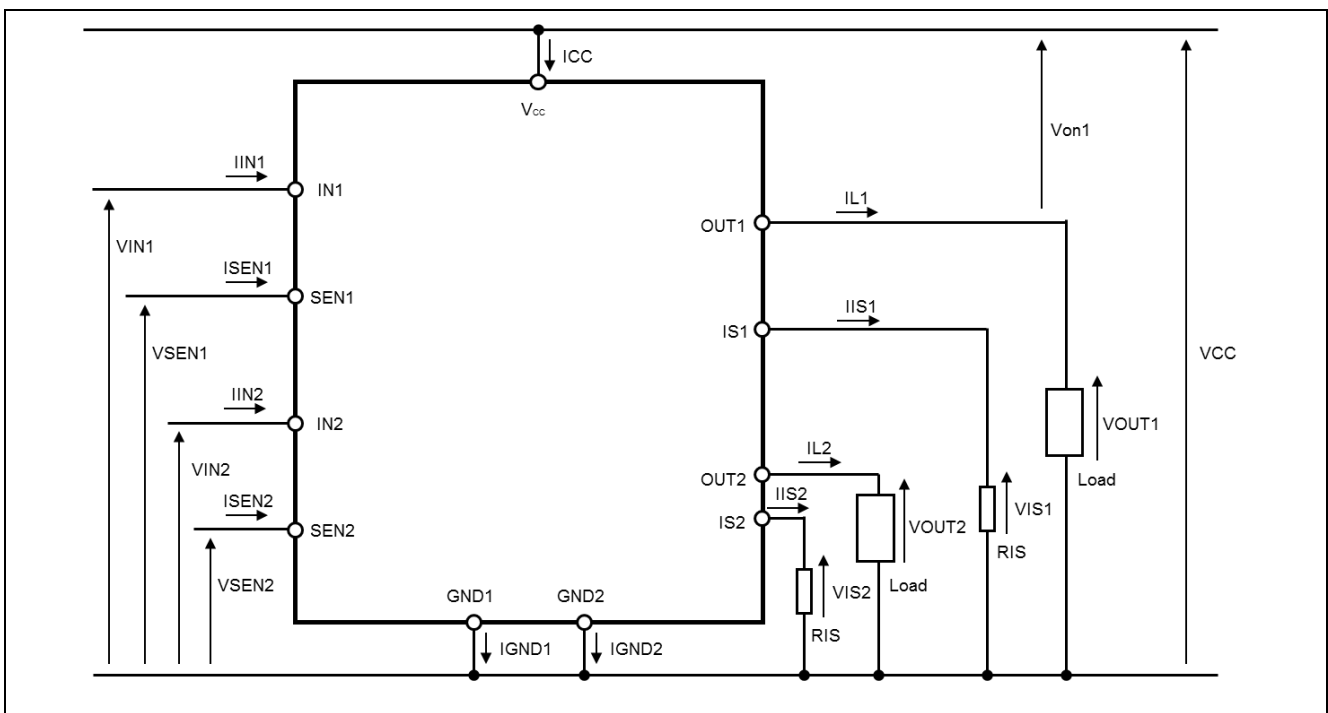
### 3. Specification

#### 3.1 Block Diagram

##### 3.1.1 Nch High-side Dual Device



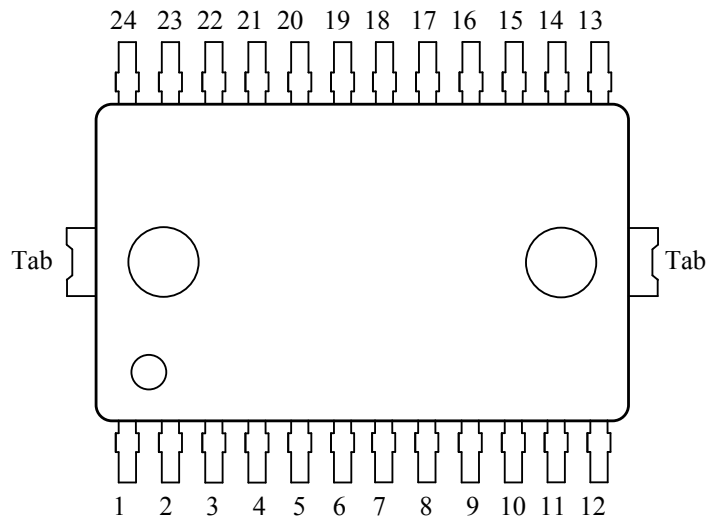
#### Voltage and Current Definition



### 3.2 Pin Configuration

#### 3.2.1 24-pin Power HSSOP Pin Configuration

Pin No.	Terminal Name
1	GND1
2	N.C.
3	IS1
4	N.C.
5	IN1
6	N.C.
7	GND2
8	N.C.
9	IS2
10	N.C.
11	IN2
12	VCC
13	SEN2
14	OUT2
15	OUT2
16	OUT2
17	OUT2
18	N.C.
19	SEN1
20	OUT1
21	OUT1
22	OUT1
23	OUT1
24	VCC
Tab	VCC



#### Pin function for dual channel

Terminal Name	Pin function	Recommended connection
GNDn	Ground connection channel n (n=1 to 2)	Connected to GND through a 100 Ohm resistor or a diode for reverse current protection Refer chapter 6.
INn	Input signal for channel n (n=1 to 2)	Connected to MCU port through 2k-50K serial resistor
ISn	Current sense and Diagnosis output signal channel n (n=1 to 2)	Connected to GND through a 0.67K-5K resistor
SENn	Sense enable input for channel n (n=1 to 2)	Connected to MCU port through 2k-50K serial resistor
OUTn	Protected high-side power output channel n (n=1 to 2)	Connected to load with small 50-100nf capacitor in parallel
VCC	Positive power supply for logic supply as well as output power supply	Connected to battery voltage with small 100nf capacitor in parallel
N.C.	Non connection	Left open

3.3 Absolute Maximum Ratings

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	RL=2ohm, t<2min, RIN=2kohm, RSEN=2kohm, RIS=1kohm, RGND=100ohm		
GND Reverse current at reverse battery condition	I <sub>GND(Rev)</sub>	200	mA	RL=2ohm, t<2min		
Vcc voltage under Load Dump condition	V <sub>load dump</sub>	42	V	RI=1ohm, RL=2ohm, RIS=1kohm, RIN=2kohm, RSEN=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>	2.16	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 ~ 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>	VCC	V	DC RIS=1kohm		
		-16	V	At reverse battery condition, t<2min, RL=2ohm, RIS=1kohm		
IS Reverse current at reverse battery condition	I <sub>IS(Rev)</sub>	-30	mA	At reverse battery condition, t<2min, RL=2ohm		
Voltage at SEN pin	V <sub>SEN</sub>	-2 ~ 16	V	DC RSEN=2kohm		
		-16		At reverse battery condition, t<2min RSEN=2kohm		
SEN pin current	I <sub>SEN</sub>	10	mA	DC		
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	130	mJ	VCC=13.5V, T <sub>ch,start</sub> <150degreeC, RL=2ohm		
Inductive load switch-off energy dissipation repetitive pulse	EAR	89	mJ	VCC=13.5V, T <sub>ch,start</sub> =85degreeC, RL=2ohm		

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)		30		degree C/W	According to JEDEC JESD51-2, -5, -7 on FR4 2s2p board
	Rth(ch-c)		1.0		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 <sub>CC</sub>	4.5		28	V	V <sub>IN</sub> =4.5V RL=2ohm	
Operating current per channel	I <sub>GND</sub>		2.2	4	mA	V <sub>IN</sub> =4.5V	
Output Leakage current per channel	I <sub>L(off)</sub>			0.5	μA	Tch=25°C	VCC=13.5V, VIN=0V, VSEN=0V, VIS=0V, VOUT=0V, VGND=0V
				3		Tch=-40~125°C	
Standby current	I <sub>CC(off)</sub>			0.7	μA	Tch=25°C	VCC=13.5V, VIN=0V, VSEN=0V, VIS=0V, VOUT=0V, VGND=0V
				2		Tch=-40~85°C	
On-state resistance per channel	Ron		12		mohm	Tch=25°C, IL=6.8A	
				24		Tch=150°C, IL=6.8A	
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		25	μA	V <sub>IN</sub> =0.8V	
High level IN pin current	I <sub>IH</sub>	2		25	μA	V <sub>IN</sub> =2.5V	
Clamping IN pin voltage <sup>1)</sup>	V <sub>ZIN</sub>	5	6		V		
Low level SEN pin voltage	V <sub>SENL</sub>			0.8	V		
High level SEN pin voltage	V <sub>SENH</sub>	2.5			V		
Low level SEN pin current	I <sub>SENL</sub>	2		25	μA	V <sub>SEN</sub> =0.8V	
High level SEN pin current	I <sub>SENH</sub>	2		25	μA	V <sub>SEN</sub> =2.5V	
Clamping SEN pin voltage <sup>1)</sup>	V <sub>ZSEN</sub>	5	6		V		
Under voltage shutdown	V <sub>CC(Uv)</sub>			4.5	V		
Under voltage restart	V <sub>CC(Cpr)</sub>			5.0	V		
Turn on time	ton			200	μs	VCC=13.5V, RL=2ohm	
Turn on delay time	td(on)			100	μs		
Turn off time	toff			200	μs		
Turn off delay time	td(off)			150	μs		
Slew rate on	dV/dton			1.0	V/μs		
Slew rate off	-dV/dtoff			1.0	V/μs		
Switching drift <sup>1)</sup>	ton-toff	-50		+50	μs	Vcc = 9 to 18V drift from Vcc=13.5V, Tch=-40 to 150degreeC drift from Tch=25degreeC ton; Vout=Vcc-1.5V after input signal active	
Turn on energy loss <sup>1)</sup>	Eon		1.2	2.4	mJ	VCC=13.5V, Tch=25°C, RL=2ohm	
Turn off energy loss <sup>1)</sup>	Eoff		1.2	2.4	mJ		
Driving capability <sup>1)</sup>	Dr(capa)	118			mohm	Tch=25°C, VCC=8~16V	
		150				Tch=105°C, 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 otherwise specified

Parameter	Symbol	Min	Typ	Max	Unit	Test Condition	
Over current detection current	IL(SC)	72	121		A	VCC=13.5V, Von=5V, Tch=25°C	
Current limitation under power limitation toggling	IL(CL)		53		A	VCC=13.5V	
Current limitation under absolute thermal toggling	IL(TT)		21		A	VCC=13.5V	
Current limitation trigger threshold during turn-on	Von(CL1)		2.0		V	VCC=13.5V	
Current limitation trigger threshold during on-state	Von(CL2)		0.3		V	VCC=13.5V	
Current limitation trigger time after input signal positive slope	td(CL)		500		μs	VCC=13.5V	
Absolute thermal shutdown temperature	aTth	150			°C		
Thermal hysteresis for absolute thermal toggling	aTth,hys		20		°C		
Power limitation thermal shutdown temperature	dTth		50		°C		
Power limitation restart temperature	dTth,rest art		25		°C		
Output clamp at inductive load switch off	Von,clamp	30		40	V	VCC=13.5V, IL=40mA, Tch=25°C	
Output current while GND disconnection	IL(GND)			1	mA	IIN=0A, ISEN=0A, IGND=0A, IIS=0A	
Output voltage drop at reverse battery condition	Vds(rev)			0.9	V	Tch=25°C	VCC=-13.5V, RL=2ohm
				0.7		Tch=150°C	

Remark) All voltages refer to ground pin of the device



**Diagnosis function**

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

Parameter	Symbol	Min	Typ	Max	Unit	Test Condition
Current sense ratio	KILIS	5000	6250	7500		IL=4.6A
		4375	6250	8125		IL=0.9A
Current sense drift depend on temperature	dKILIS	-15		15	%	VCC=13.5V, Tch,start=25°C, RL=2ohm
Sense current offset current	lis,offset			2	μA	IL<10mA
Sense current leakage current	lis,dis			1	μA	VIN=0V, VSEN=0V
Sense current under fault condition	lis,fault	3		9.5	mA	VCC=13.5V, RIS=0.67kohm
		3.5		9		VCC=13.5V, RIS=1kohm
		3.5		5.5		VCC=13.5V, RIS=2kohm
Minimum output current for current sense output	IL(CSE)	10		100	mA	IIS>5μA
Open load detection threshold at off-state	VOUT(OL)	2.0		5.0	V	VIN=0V, Tch=-40~105°C
OUT terminal current at Open load condition	IOUT(OL)	-1.0			μA	VIN =0V
Open load detection delay after input negative slope	tdop		300		μs	VIN=4.5V to 0V, VOUT>VOUT(OL)

Remark) All voltages refer to ground pin of the device

**Diagnosis function**

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

Parameter	Symbol	Min	Typ	Max	Unit	Test Condition
Sense current settling time after input signal positive slope	tsis(on)			250	μs	VCC=13.5V, VIN=0V to 4.5V, IL/IIS=KILIS, RL=2ohm
Sense current settling time after input signal negative slope	tsis(off)			10	μs	VIN=4.5V to 0V
Sense current settling time after sense enable during on-state <sup>1)</sup>	tssen(on)			20	μs	VSEN=0V to 4.5V, RL=2ohm
Sense current settling time after sense disable during on-state <sup>1)</sup>	tssen(off)			20	μs	VSEN=4.5V to 0V, RL=2ohm
Sense current settling time during on-state <sup>1)</sup>	tsis(LC)			20	μs	RL=2ohm to 1ohm
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	IIS→IIS,fault
Fault signal delay after open load detection at off-state <sup>1)</sup>	tdop(fault)			10	μs	VIN=0V, VOUT>VOUT(OL)
Fault signal delay after input negative slope <sup>1)</sup>	tdoff(fault)			10	μs	VIN=4.5V to 0V

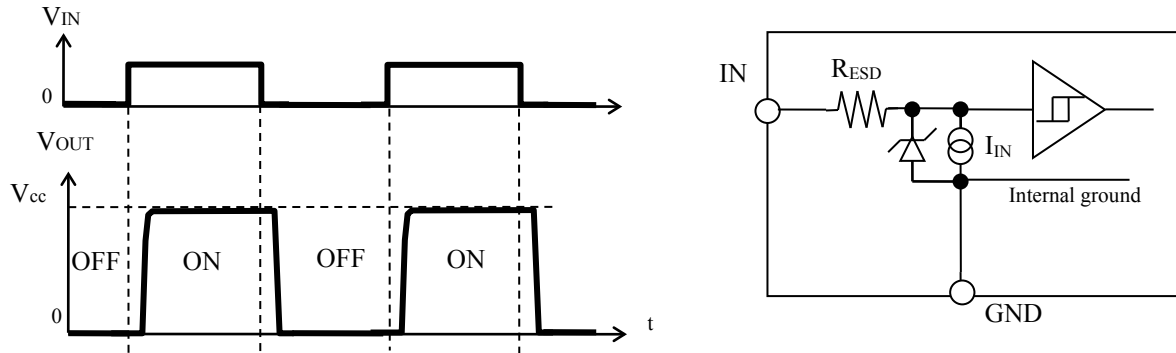
Remark) All voltages refer to ground pin of the device

1) not subjected production test, guaranteed by design

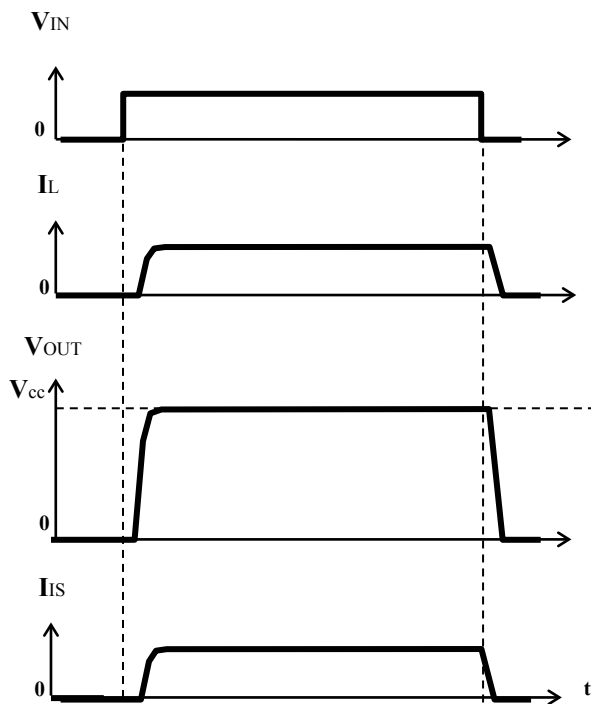
### 3.6 Feature Description

#### 3.6.1 Driving Circuit

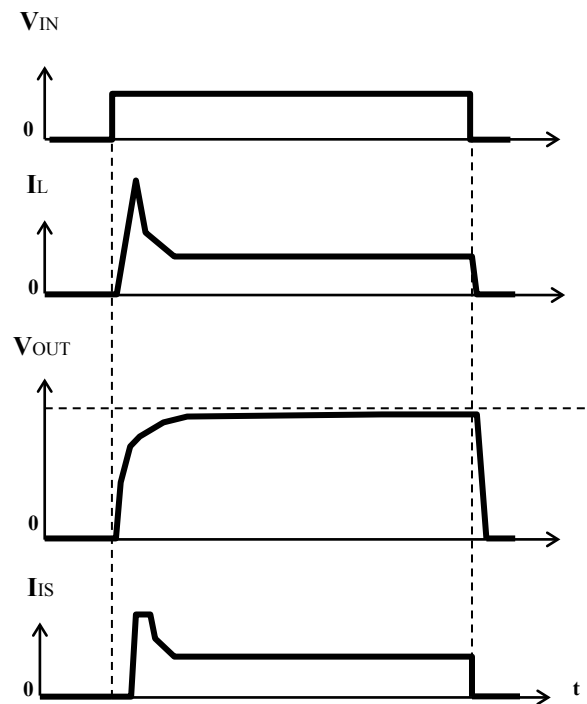
The high-side output is turned on, if the input pin is over  $V_{IH}$ . The high-side output is turned off, if the input pin is open or the input pin is below  $V_{IL}$ . Threshold is designed between  $V_{IH}$  min and  $V_{IL}$  max with hysteresis. IN terminal is pulled down with constant current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



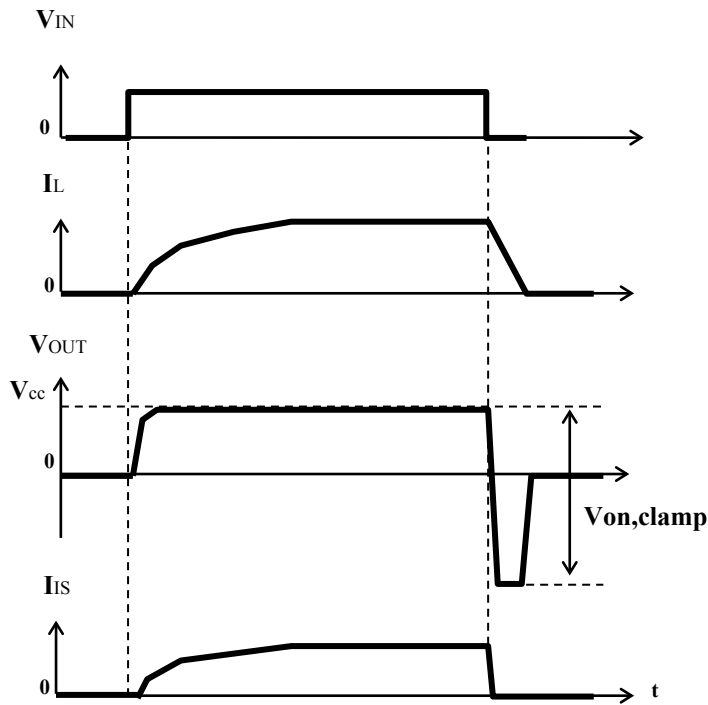
Switching a resistive load



Switching lamps



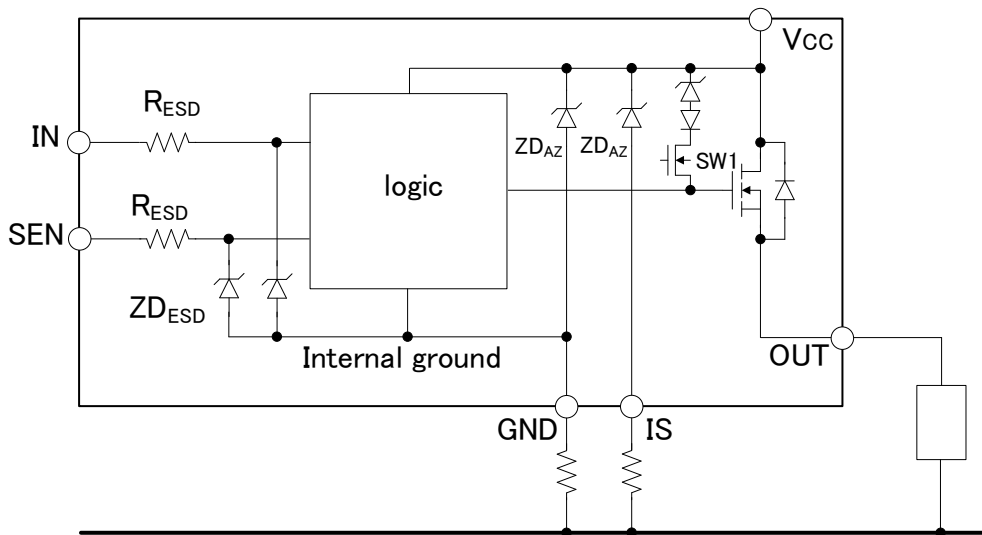
Switching an inductive load



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.

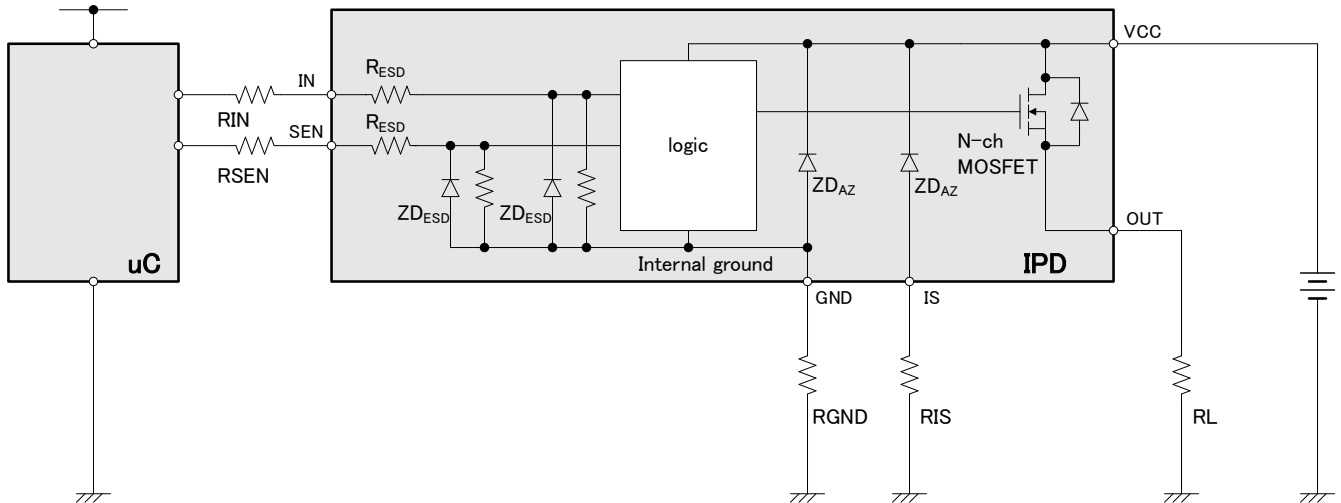
SW1 is turned on, and the clamp diode is connected to the gate of the output MOS, activating the dynamic clamp circuit.

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.



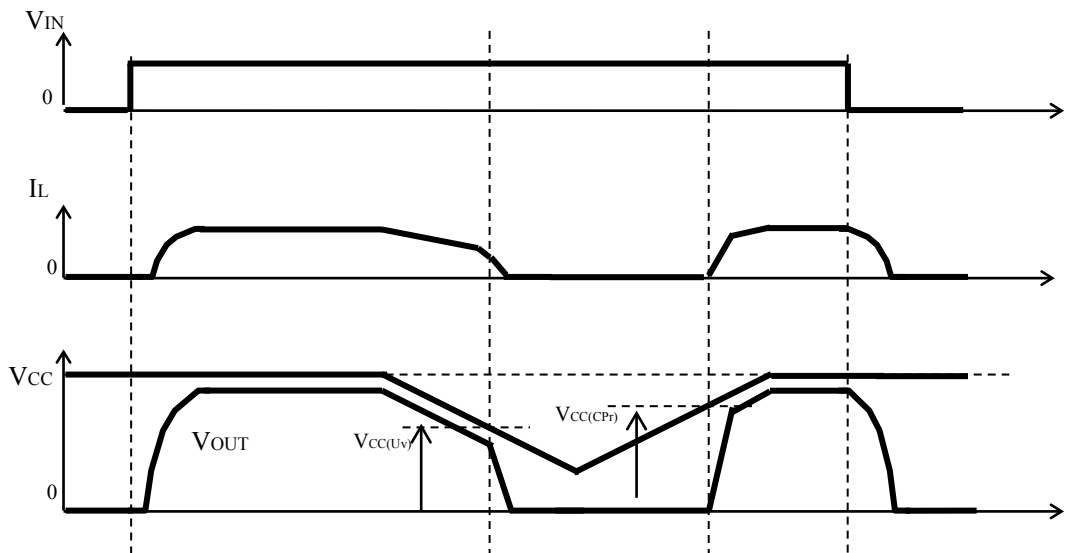
### 3.6.2 Device behavior at over voltage condition

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  $V_{CC}$ .



### 3.6.3 Device behavior at low voltage condition

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



### 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  $V_{IN}$  was initially greater than  $V_{IH}$  state or keeps off state if  $V_{IN}$  was initially lower than  $V_{IL}$  state.

In case of device loss of ground, IN and SEN terminal will/ could/ might be at  $V_{CC}$  voltage.

### 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) 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 device shuts down automatically when condition (c) is detected and restarts automatically in absolute thermal toggling mode. The device starts current limitation when (d) is detected. The sense pin output Iis,fault during power limitation mode or thermal toggling mode.

- (a)  $IL > IL(SC)$
- (b)  $\Delta T_{ch} > \Delta T_{th}$
- (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 (a) is detected once after  $V_{on} < V_{on}(CL2)$ . The device shuts down automatically when condition (b) is detected. The device restarts automatically in power limitation mode. The device shuts down automatically when condition (c) is detected and restarts automatically in absolute thermal toggling mode. The sense pin output Iis,fault during power limitation mode or thermal toggling mode.

- (a)  $V_{on} > V_{on}(CL2)$
- (b)  $\Delta T_{ch} > \Delta T_{th}$
- (c)  $T_{ch} > aT_{th}$

#### Power limitation control

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

During the current limitation operation and  $V_{on} > V_{on}(CL1)$ , the sense pin outputs Iis,fault. Even auto restart from  $\Delta T_{ch}$  protection, if  $V_{on} < V_{on}(CL1)$  depends on short circuit impedance condition, the device does not operate as current limitation with  $IL(CL)$ . In this case, the sense pin output sense current at on-state, Iis,fault at off-state during toggling operation with power limitation mode.

#### Absolute thermal toggling

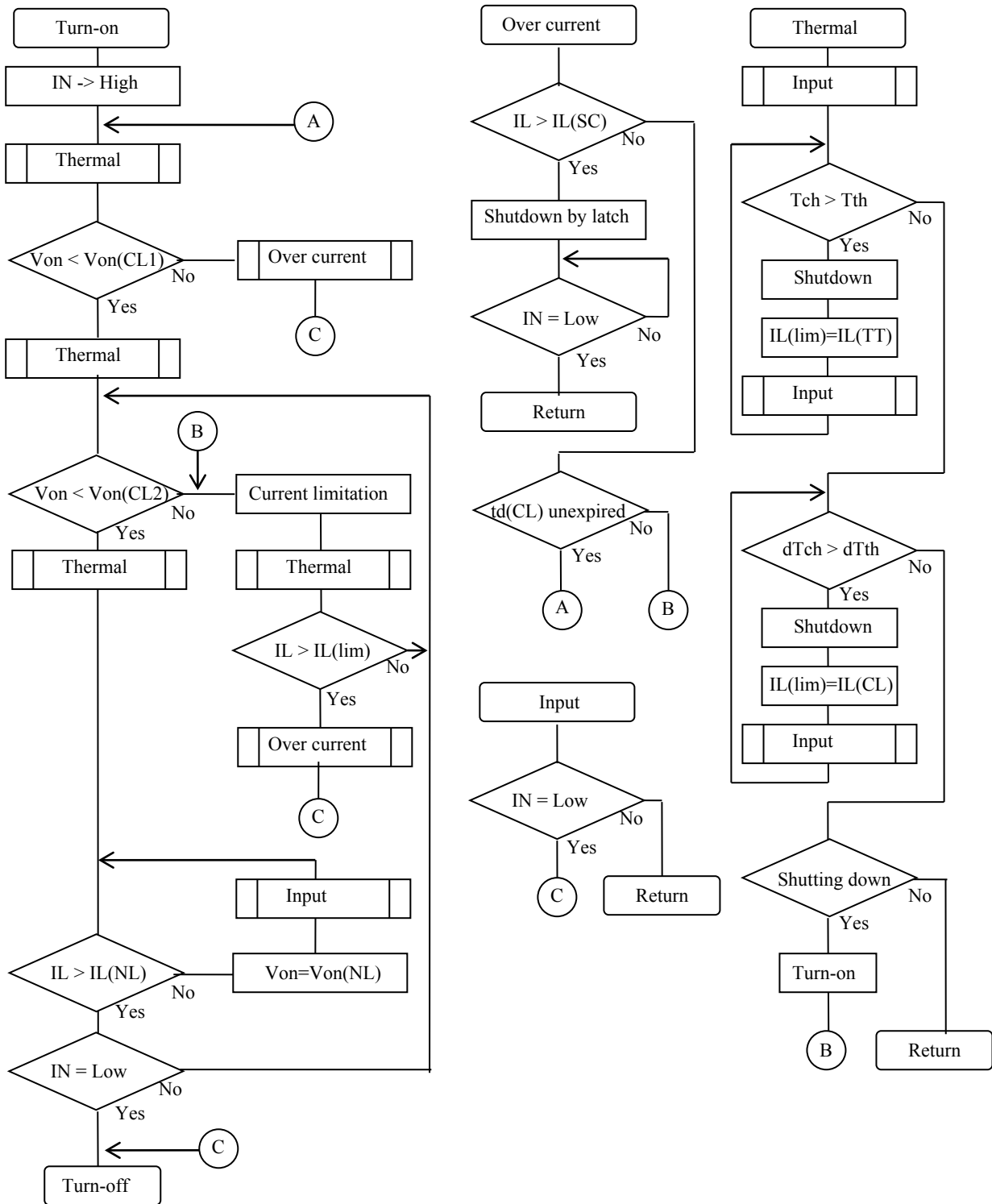
Current limitation control with  $IL(TT)$  when auto restart from absolute  $T_{ch}$  protection.

During the current limitation operation and  $V_{on} > V_{on}(CL1)$ , the sense pin outputs Iis,fault. Even auto restart from absolute  $T_{ch}$  protection, if  $V_{on} < V_{on}(CL1)$  depends on short circuit impedance condition, the device does not operate as current limitation with  $IL(TT)$ . In this case, the sense pin output sense current at on-state, Iis,fault at off-state during toggling operation with thermal toggling mode.

#### delta T<sub>ch</sub>

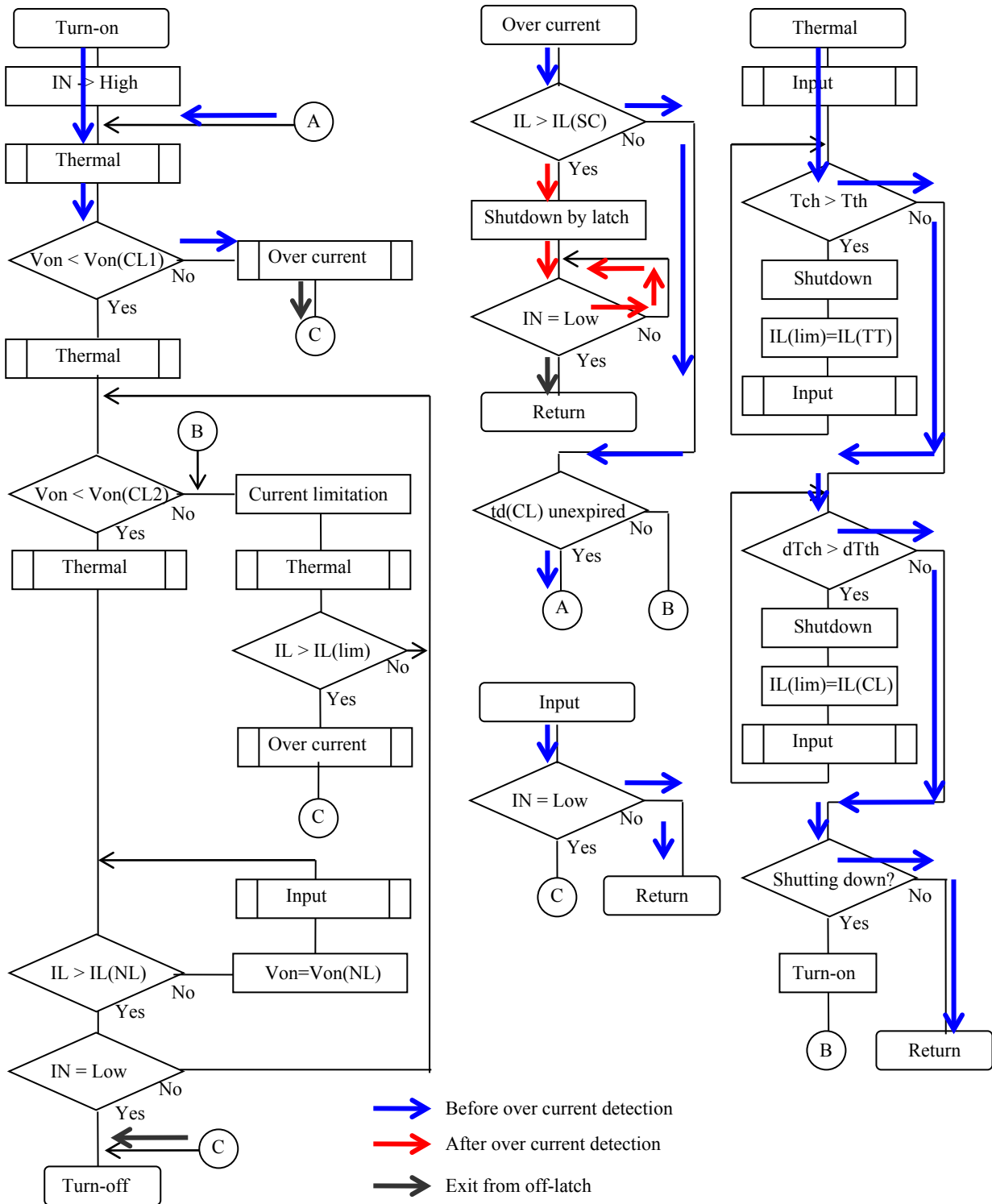
Junction temperature differences between thermal sensor of power area and thermal sensor of control area.

State transition diagram



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

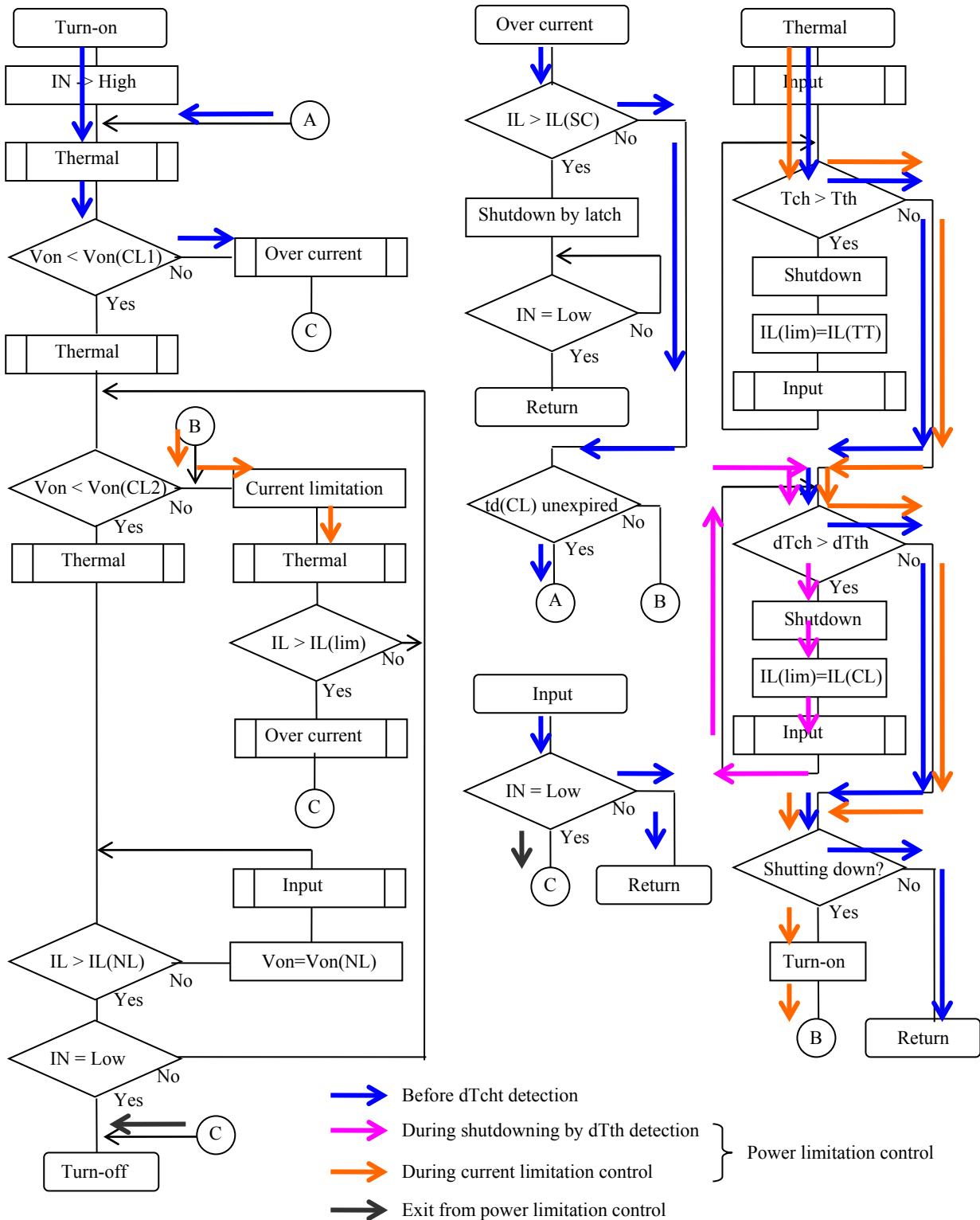
(a)  $IL > IL(SC)$





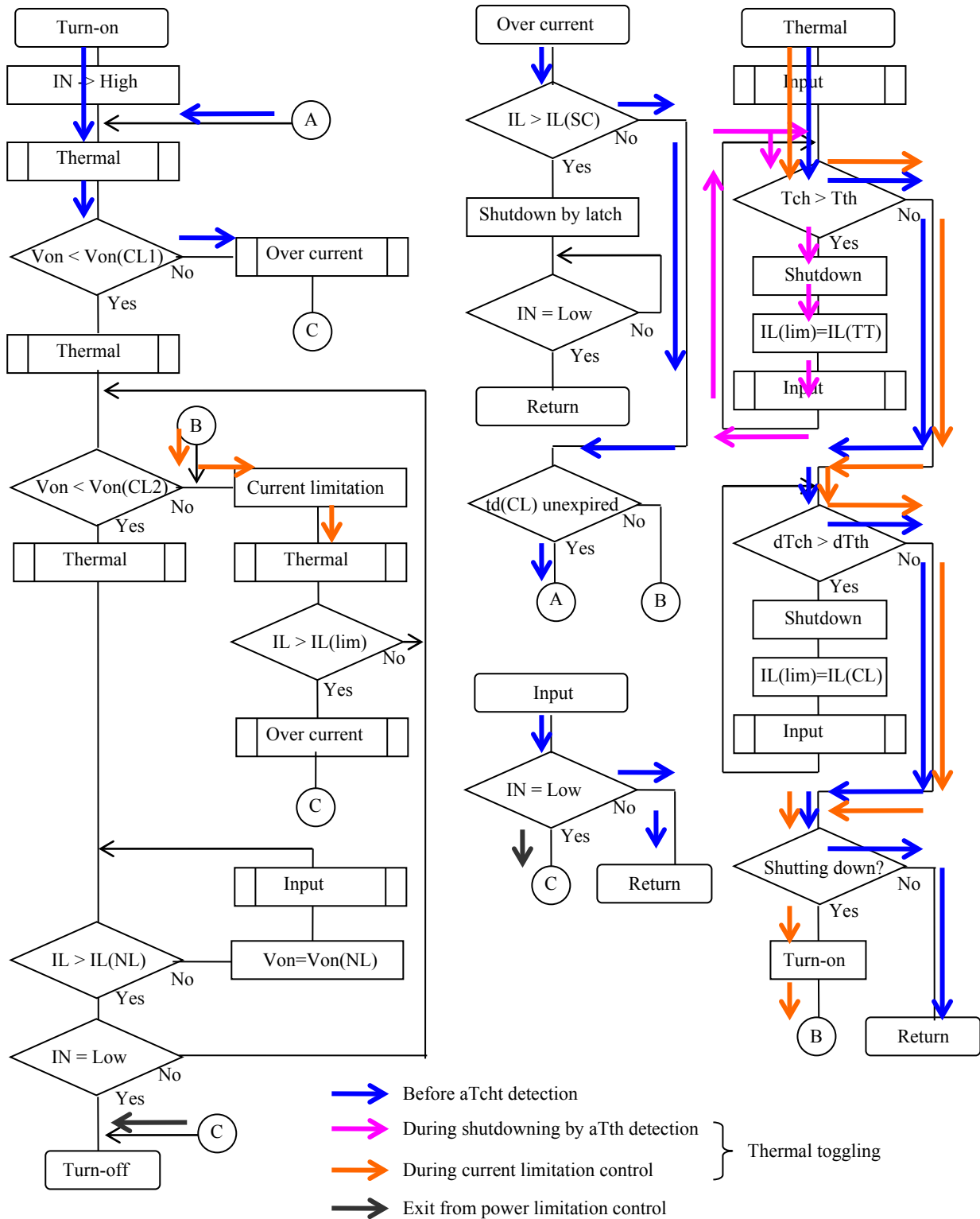
Turn-on in an over load condition including short circuit condition

(b)  $\Delta T_{ch} > \Delta T_{th}$



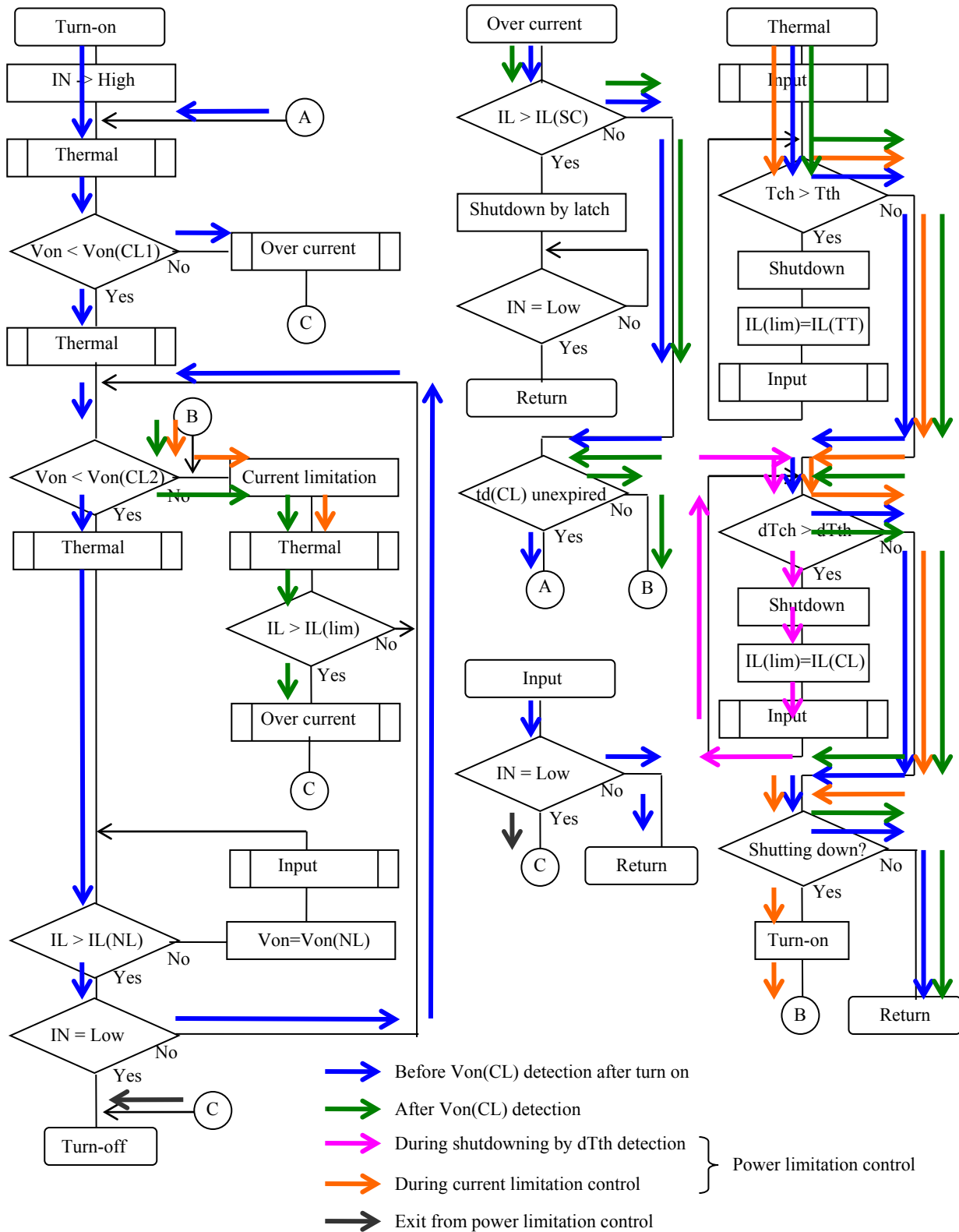
Turn-on in an over load condition including short circuit condition

(c)  $T_{ch} > aT_{th}$



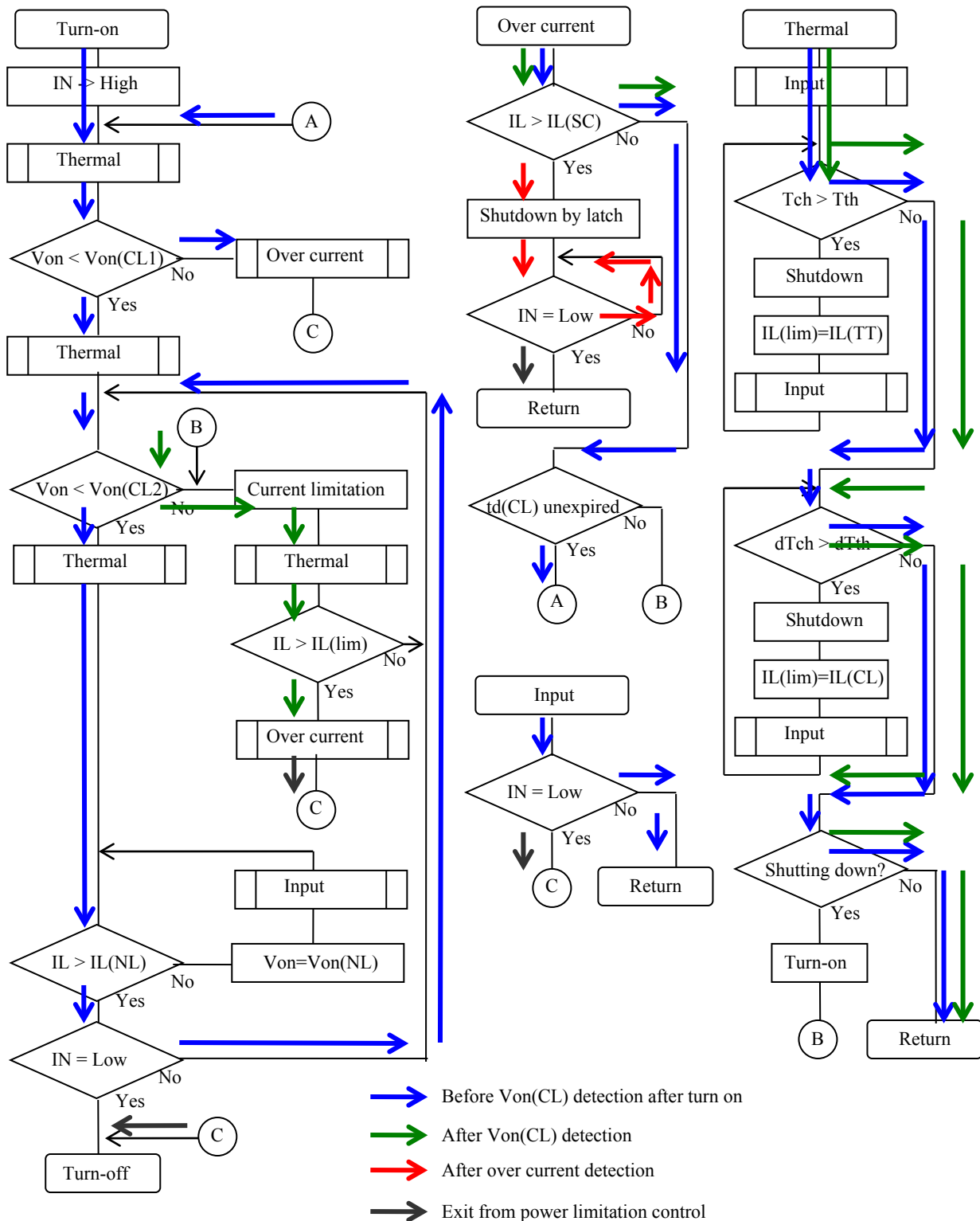
An over load condition which is include a short circuit condition during on-state

(a)  $V_{on} > V_{on}(CL)$  with weak short condition



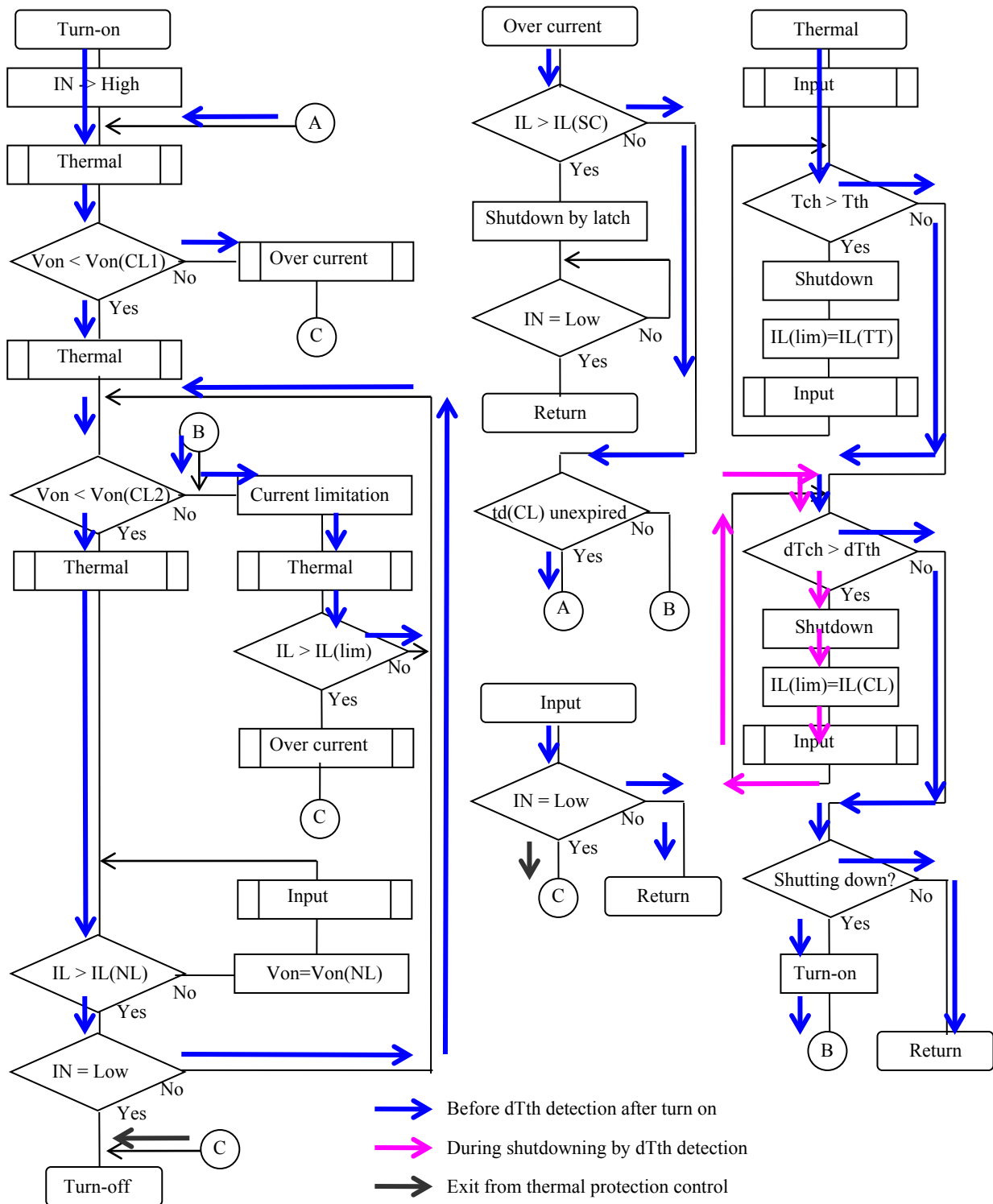
An over load condition including short circuit condition during on-state

(a)  $V_{on} > V_{on(CL)}$  with dead condition



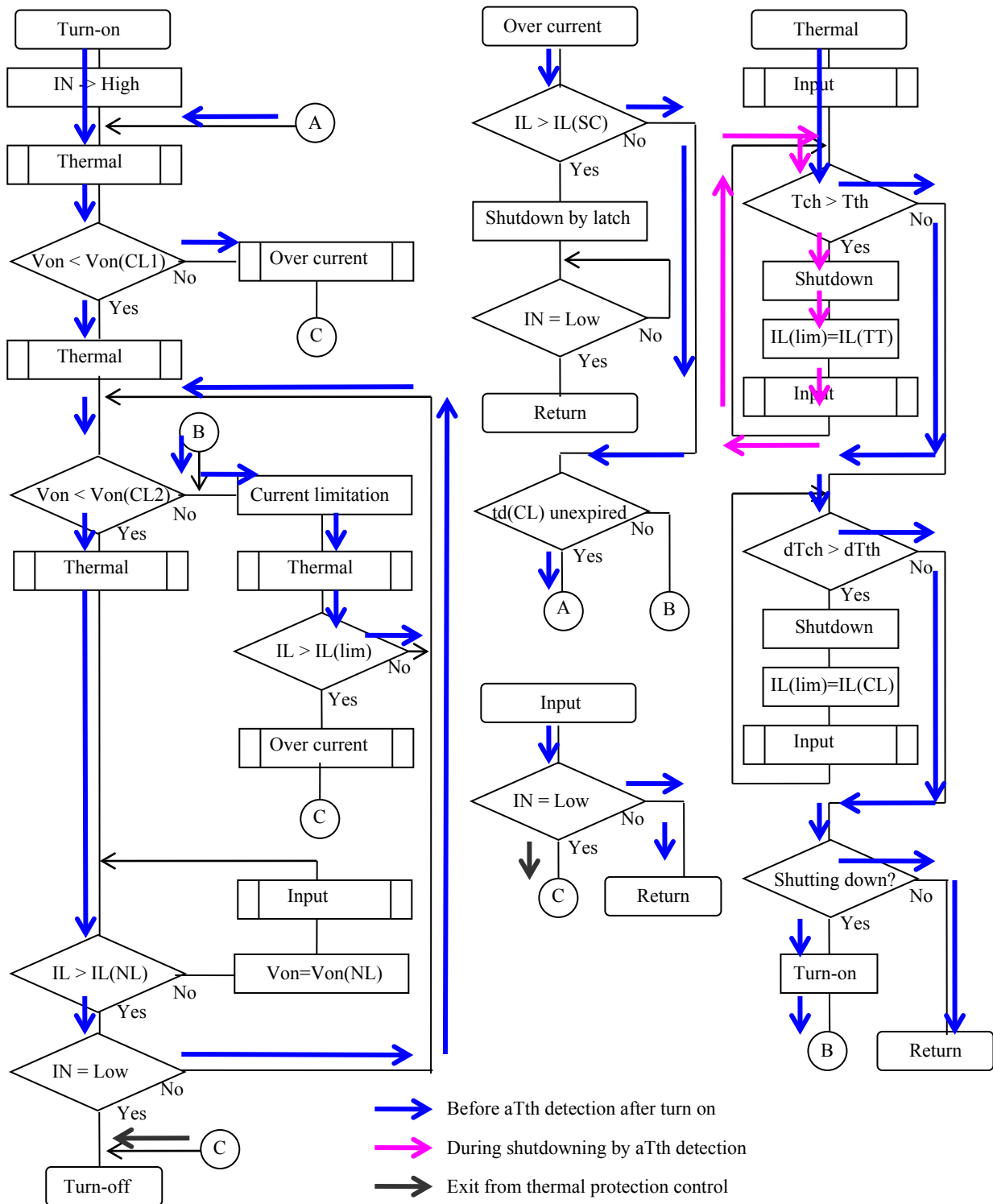
An over load condition including short circuit condition during on-state

(b)  $\Delta T_{ch} > \Delta T_{th}$



An over load condition including short circuit condition during on-state

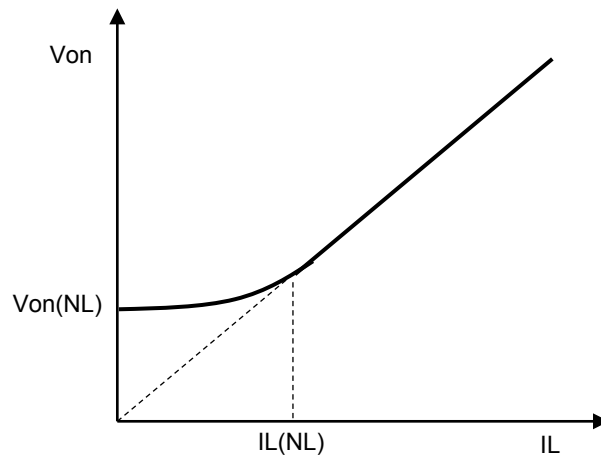
(c)  $T_{ch} > aT_{th}$



### 3.6.6 Device behavior at small load current conduction

The device has a function which controls Ron in order to improve KILIS accuracy at small load current conduction.

Von (VCC-OUT) is proportionate to IL under normal conditions. Under  $IL < IL(NL)$  condition, Ron is controlled to increase to be  $Von = Von(NL) = 30mV$ (typ).



### 3.6.7 Diagnostic signal

Truth table

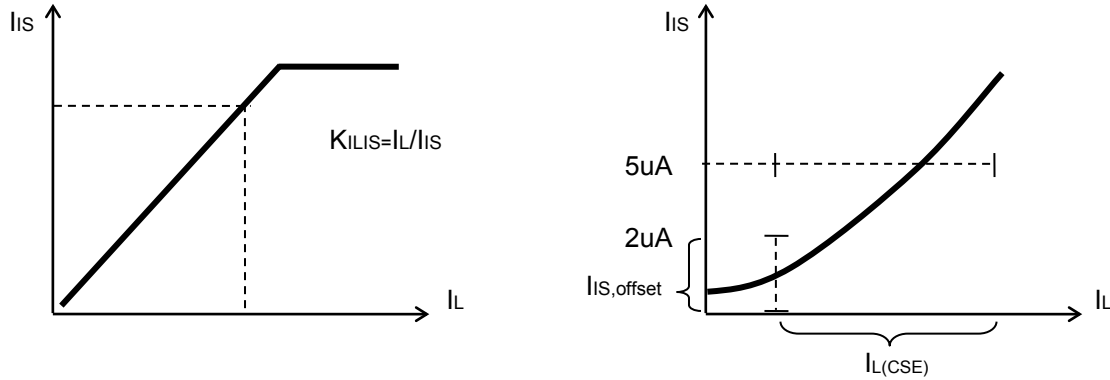
	SEN	Input	Output	Diagnostic output <sup>2)</sup>
Normal Operation	H	H	VCC	IIS = IL/KILIS
		L	L <sup>1)</sup>	< 1uA (Iis,dis)
Shutdown by over current detection		H	L <sup>1)</sup>	Iis,fault <sup>3)</sup>
		L	L <sup>1)</sup>	< 1uA (Iis,dis)
Power limitation		H	VOUT <sup>6)</sup>	IIS = IL/KILIS in case of Von<Von(CL1)
				Iis,fault <sup>4)</sup> in case of Von>Von(CL1)
		L <sup>1)</sup>	Iis,fault <sup>4)</sup>	
Thermal toggling		H	VOUT <sup>6)</sup>	IIS = IL/KILIS in case of Von<Von(CL1)
				Iis,fault <sup>5)</sup> in case of Von>Von(CL1)
		L <sup>1)</sup>	Iis, fault <sup>5)</sup>	
Short circuit to VCC		H	VCC	< 2uA (Iis,offset)
		L	VOUT <sup>7)</sup>	Iis,fault in case of VOUT>VOUT(OL)
Open Load		H	VCC	< 2uA (Iis,offset)
		L	VOUT <sup>7)</sup>	Iis,fault in case of VOUT>VOUT(OL)
X <sup>8)</sup>	L	X <sup>8)</sup>	X <sup>8)</sup>	< 1uA (Iis,dis)

- 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 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 during thermal toggling if Von>Von(CL1)..
- 6) VOUT depends on the short circuit condition
- 7) VOUT depends on the ratio of VCC-OUT-GND resistive component.
- 8) Don't care



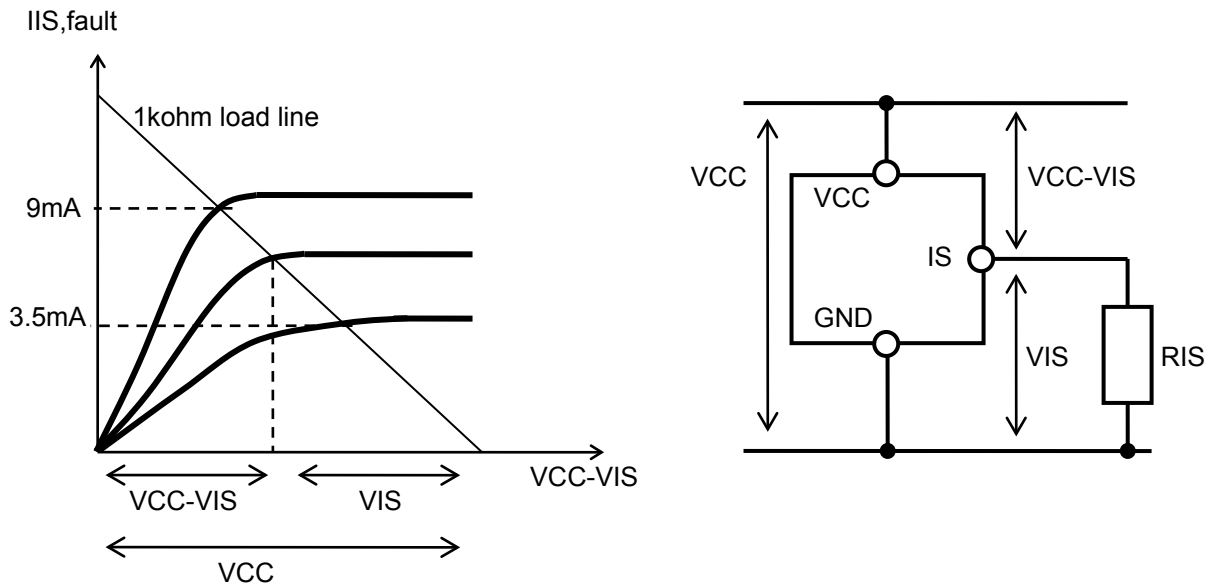
**Current sense output**

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. In the case of much lower current than nominal load current, current sense output is above 5uA if output current is above  $I_{L(CSE) \text{ max}}$ , current sense output is below 2uA,  $I_{IS,offset \text{ max}}$ , if output current is below  $I_{L(CSE) \text{ min}}$ .

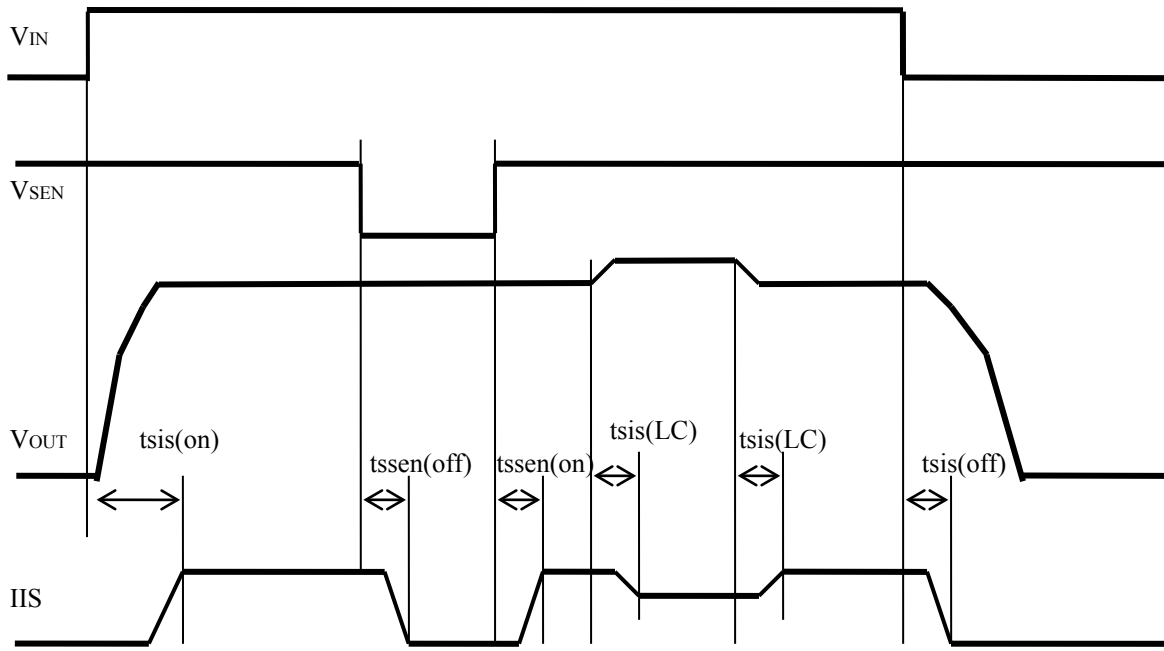


**Sense current under fault condition**

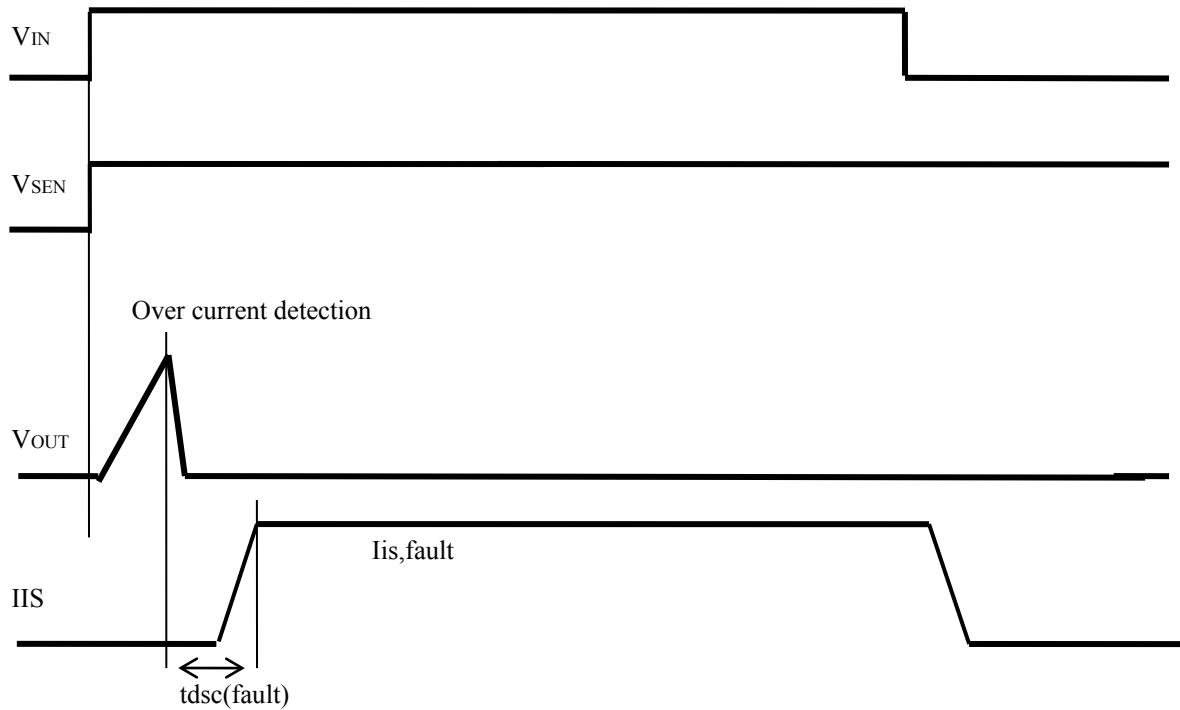
The device output  $I_{IS,fault}$ , constant current, from IS pin under fault condition such as after over current detection, during power limitation and during thermal toggling.  $I_{IS,fault}$  is specified with  $R_{IS}=1\text{kohm}$  condition.  $I_{IS,fault}$  is attenuated depends on  $V_{CC-VIS}$  voltage. Operation point as  $I_{IS,fault}$  output is also depends on  $R_{IS}$  condition. For example, In the case of  $R_{IS}=1\text{kohm}$ ,  $I_{IS,fault}$  could be 3.5mA to 9mA,  $V_{CC-VIS}$  could be 4.5V to 10V,  $V_{IS}$  could be 9V to 3.5V if  $V_{CC}=13.5\text{V}$ . In the case of  $R_{IS}$  is higher than 1kohm, Operation point as  $I_{IS,fault}$  is lower than specified value but  $V_{IS}$  should be higher than  $R_{IS}=1\text{kohm}$  condition.



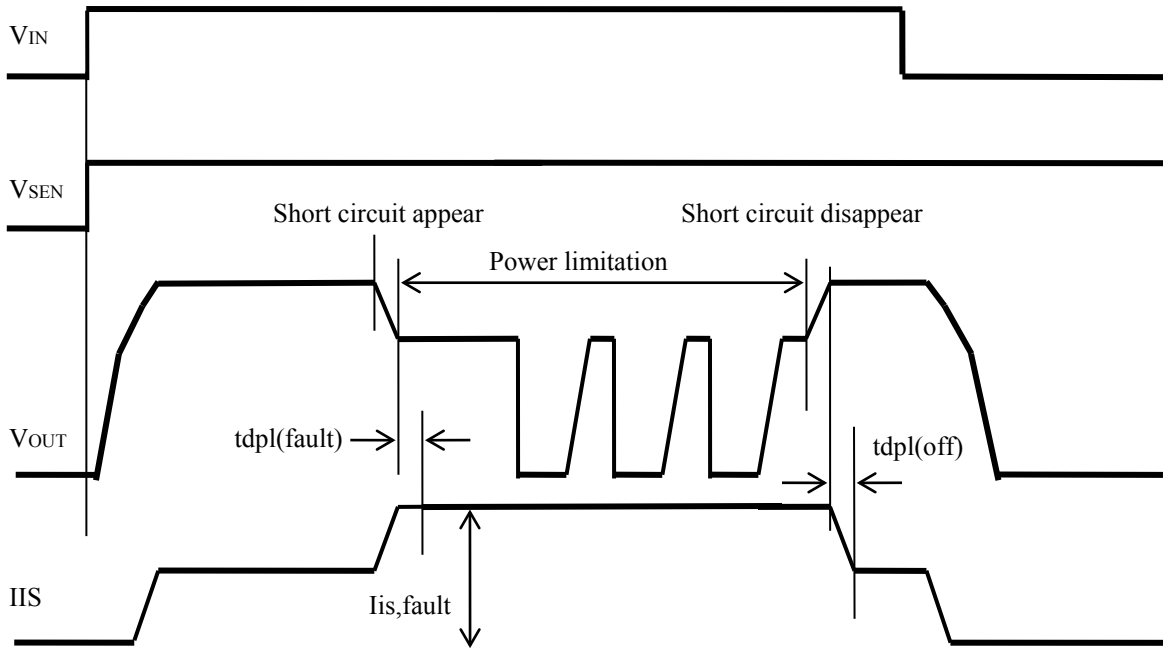
Sense current settling time



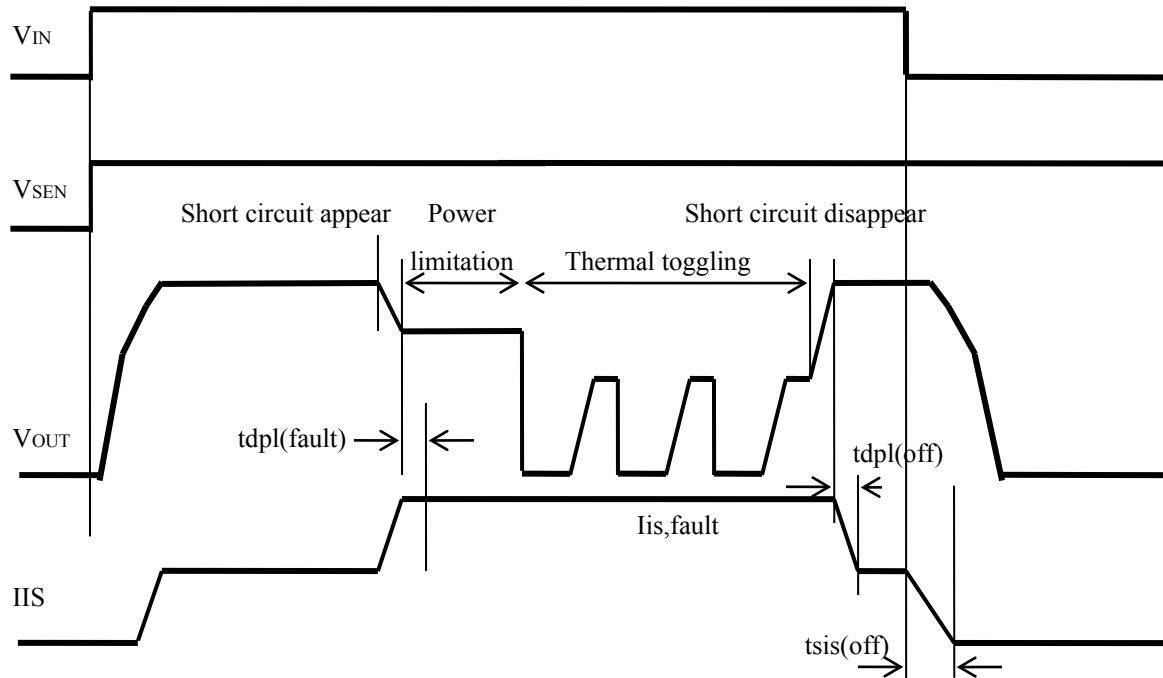
Fault signal delay time at over current detection



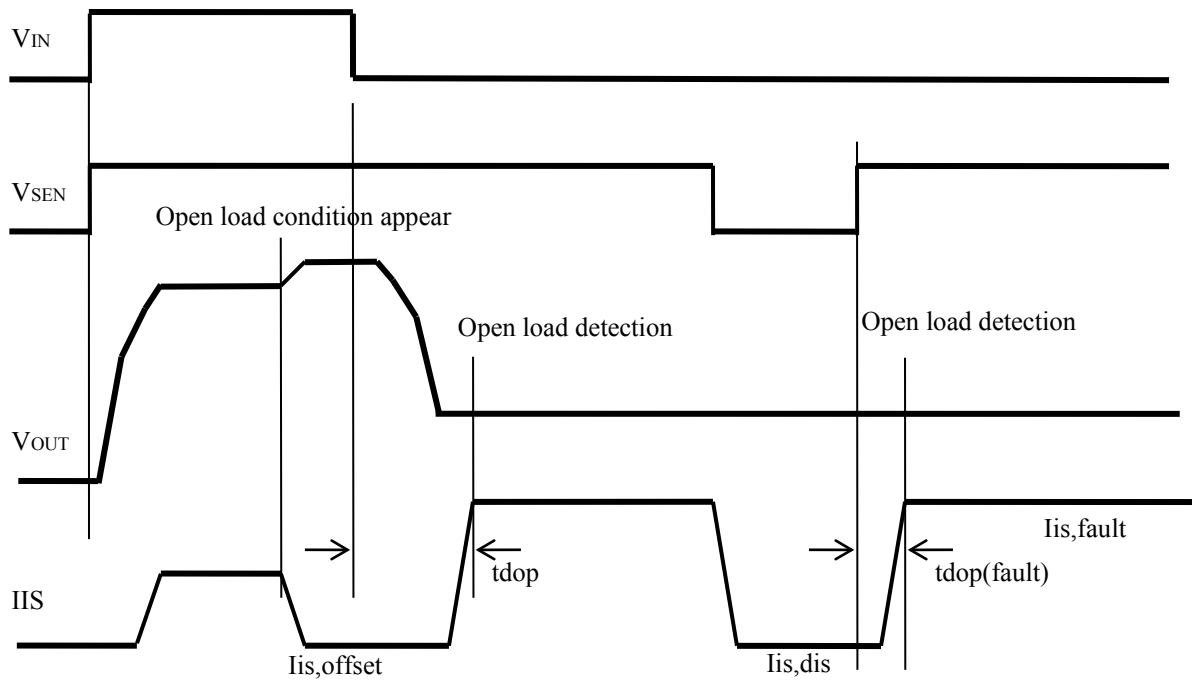
Fault signal delay time at power limitation



Fault signal delay time at Thermal toggling



Fault signal delay time at open load detection

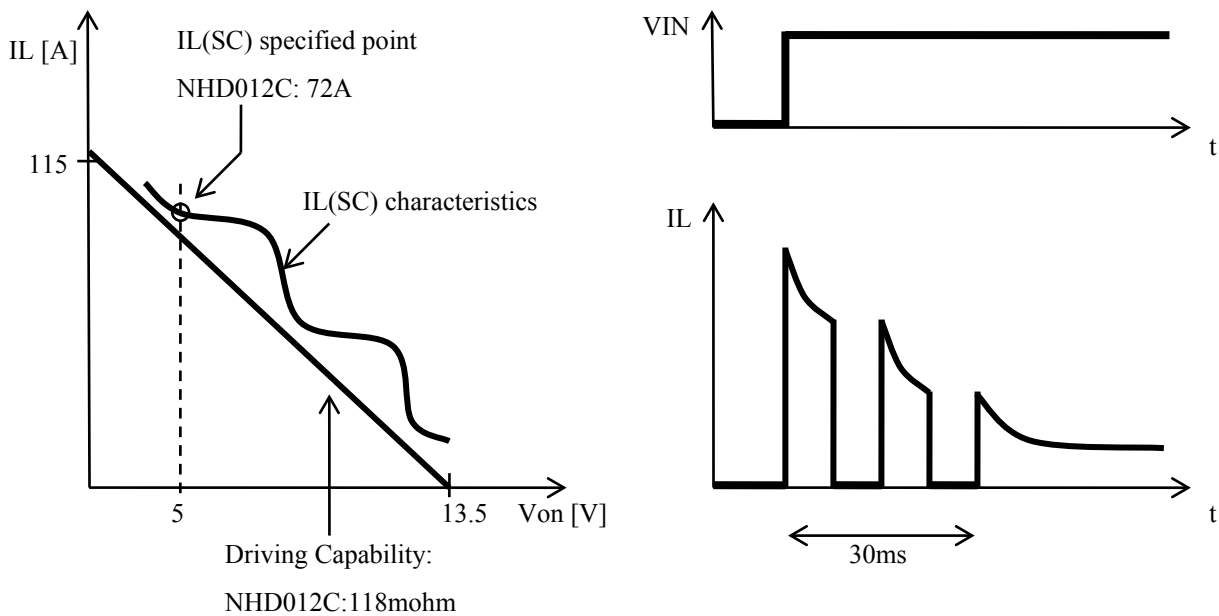


### 3.6.8 Nominal load

Product	Nominal load
NHD012C	2.0ohm

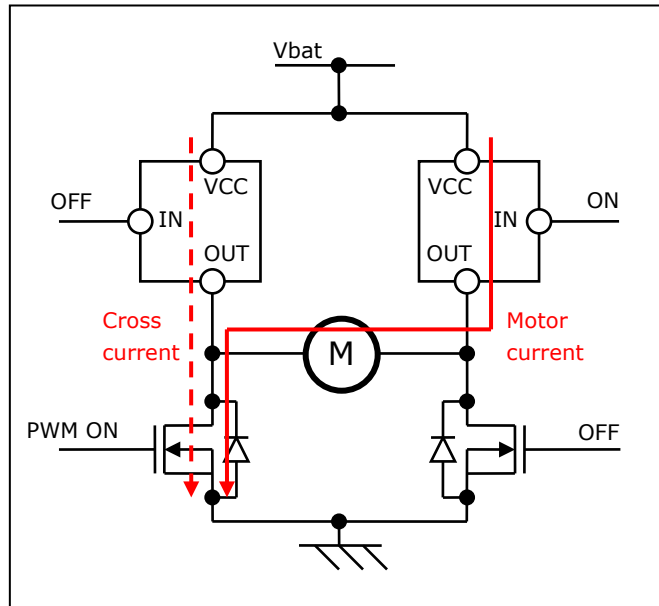
### 3.6.9 Driving Capability

Driving Capability is specified as load impedance. Over current detection characteristics is designed below Driving Capability characteristics. If estimated load impedance which comes from peak inrush current is higher 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 higher 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.



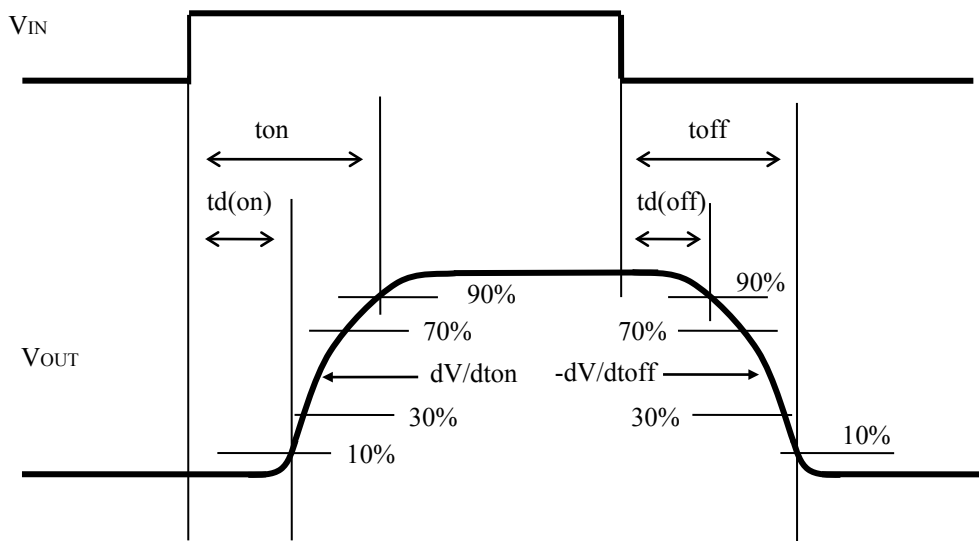
### 3.6.10 Cross current protection in case of H-bridge high side usage

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.



### 3.6.11 Measurement condition

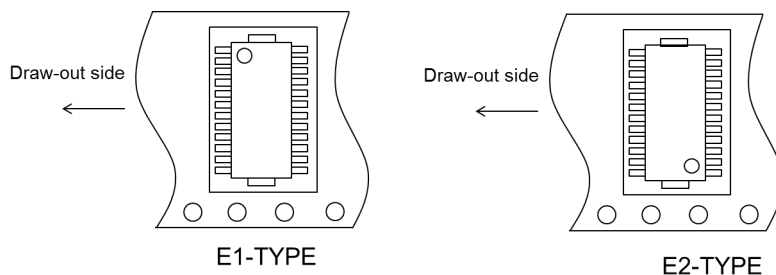
Switching waveform of OUT terminal





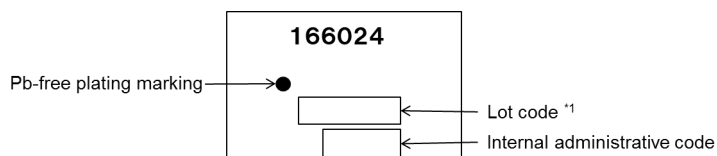
### 3.8 Taping information

uPD166024T1K

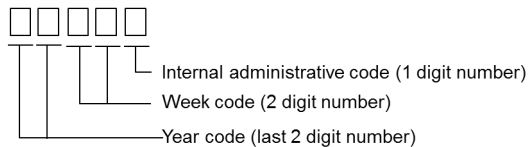


### 3.9 Marking information

uPD166024T1K



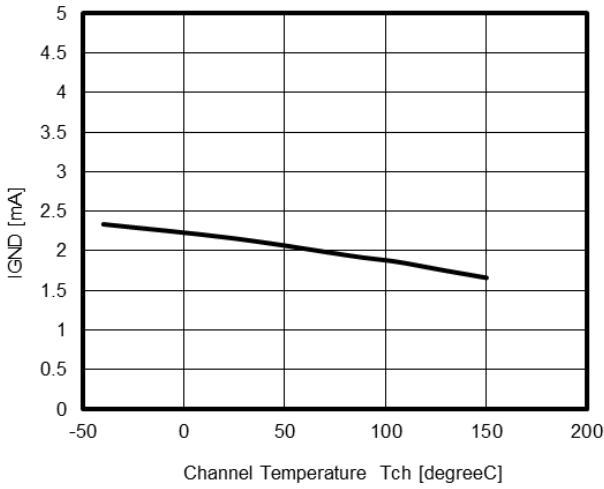
Note: \*1. Composition of the lot code



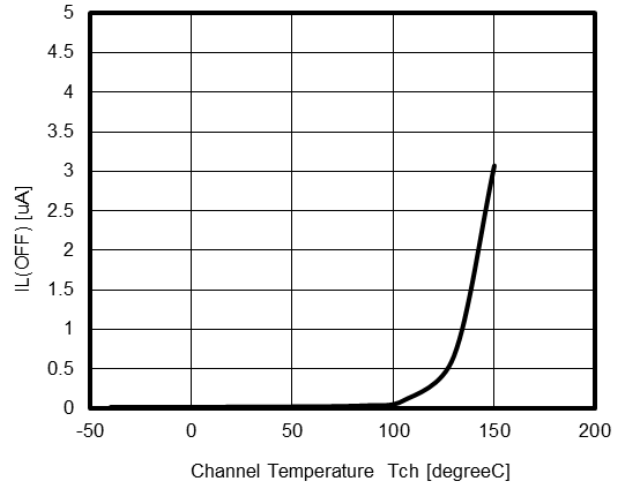


4. Typical characteristics

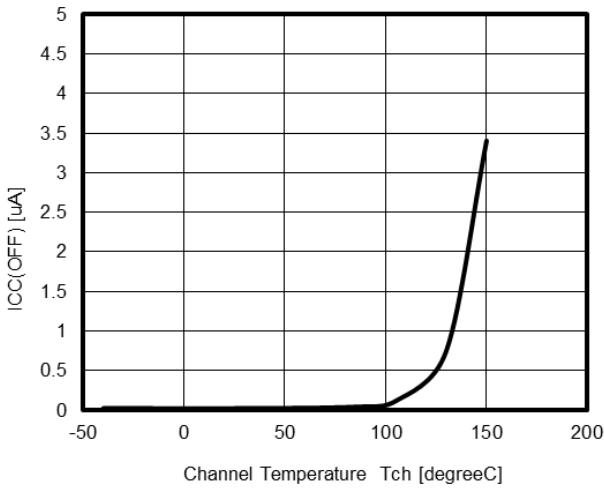
Operating current per channel  
VS. Channel TEMPERATURE



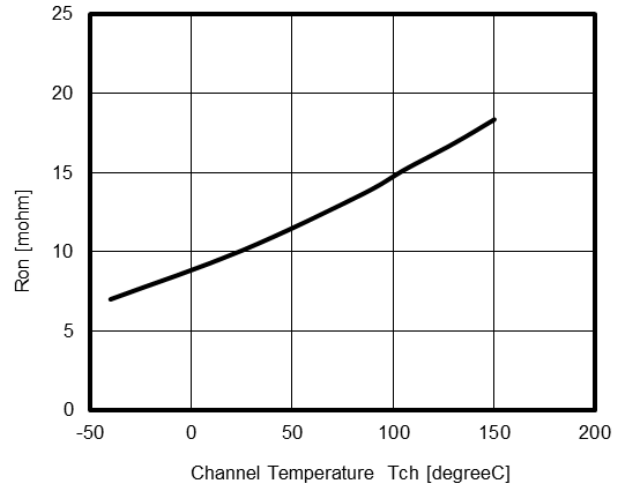
Output Leakage current per channel  
VS. Channel TEMPERATURE



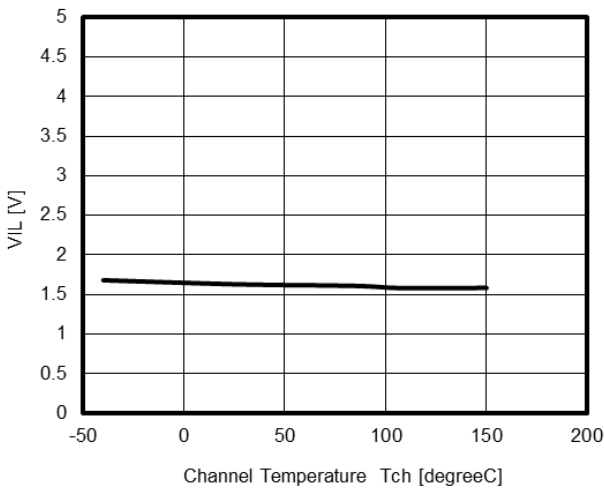
Standby current  
VS. Channel TEMPERATURE



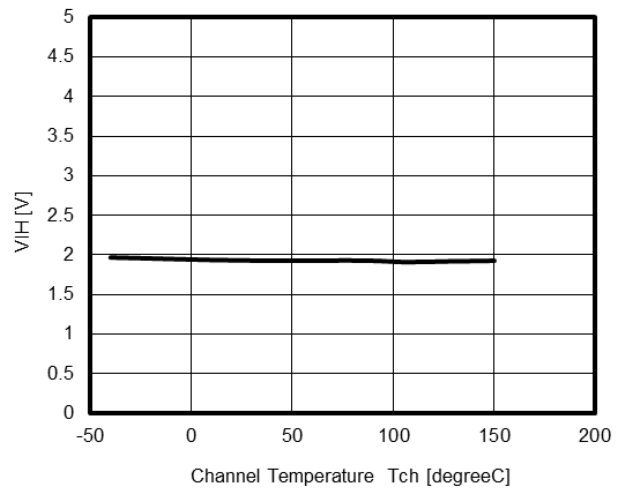
On-state resistance per channel  
VS. Channel TEMPERATURE



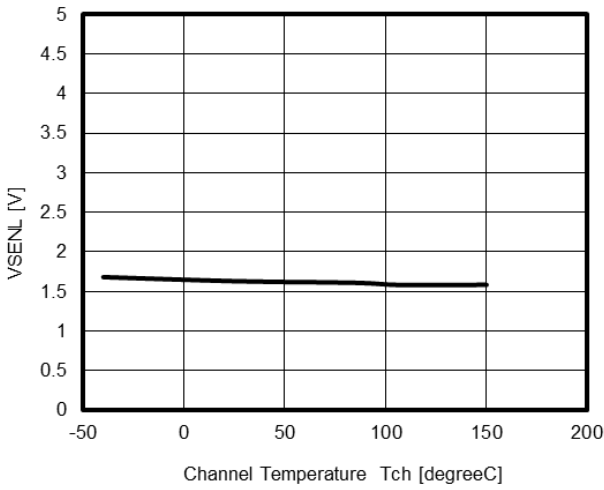
Low level IN pin voltage  
VS. Channel TEMPERATURE



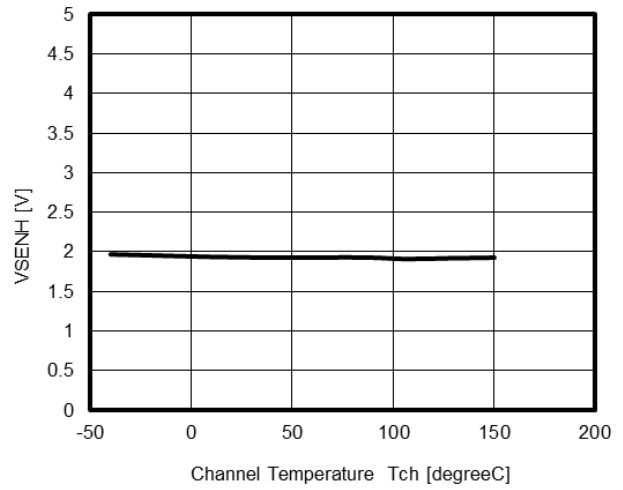
High level IN pin voltage  
VS. Channel TEMPERATURE



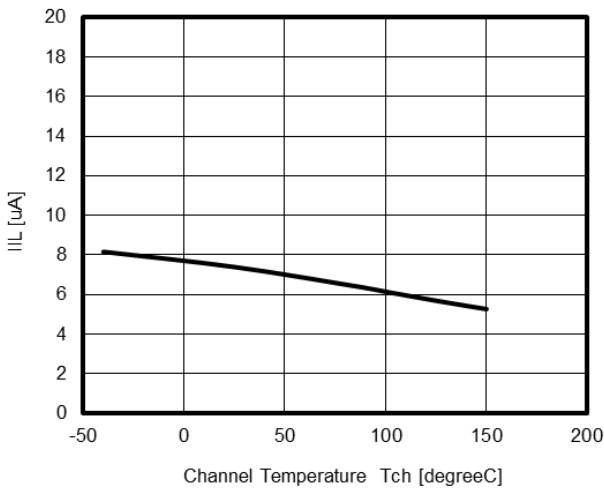
Low level SEN pin voltage  
VS. Channel TEMPERATURE



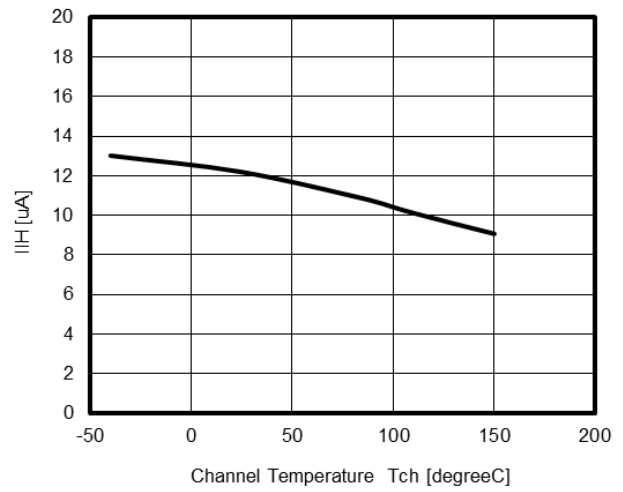
High level SEN pin voltage  
VS. Channel TEMPERATURE



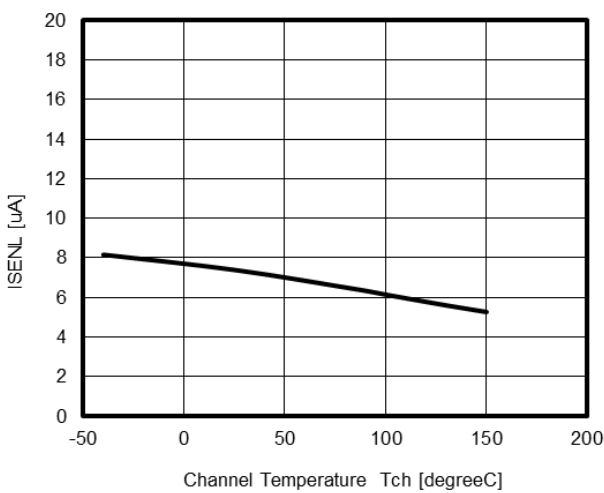
Low level IN pin current  
VS. Channel TEMPERATURE



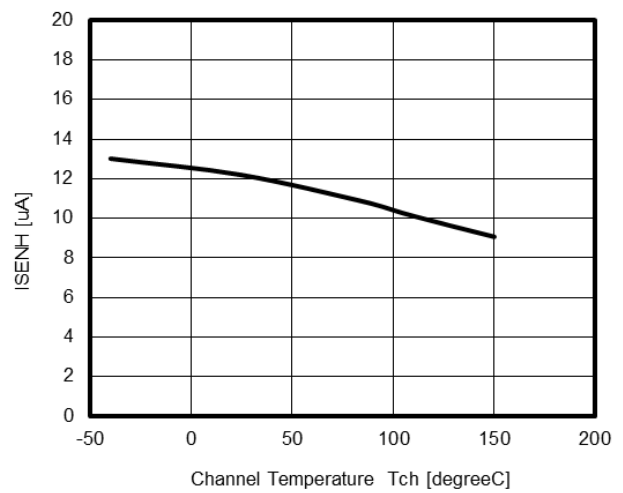
High level IN pin current  
VS. Channel TEMPERATURE

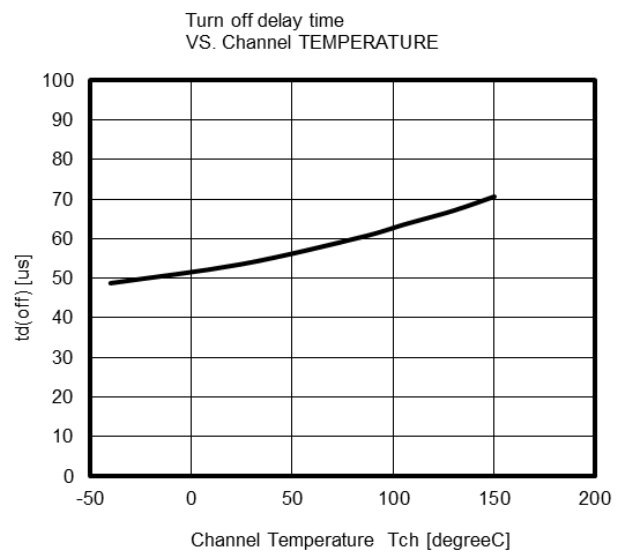
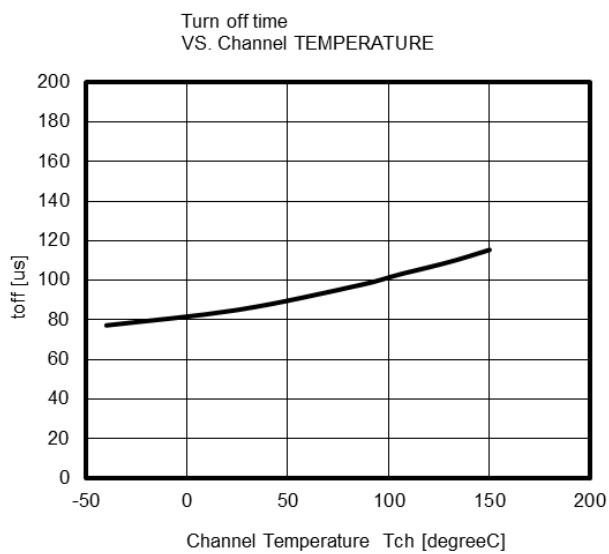
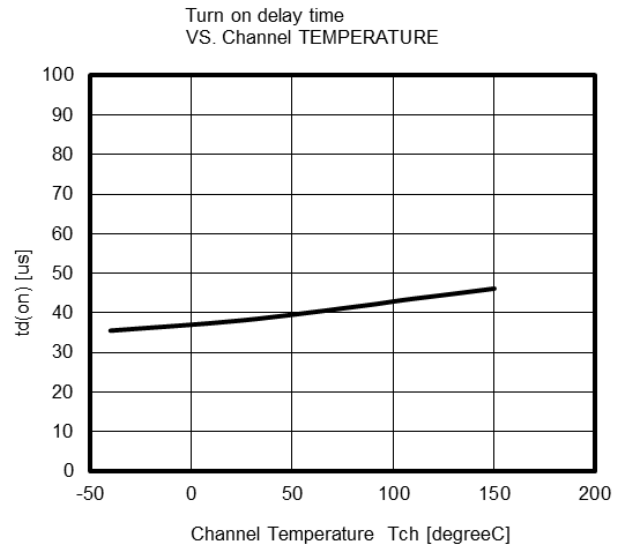
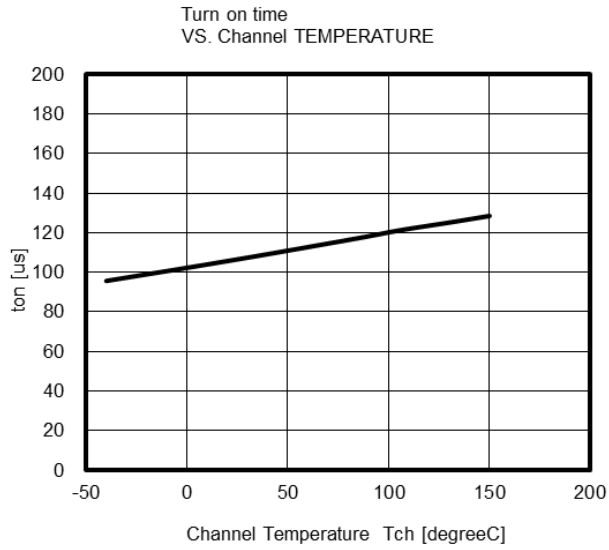
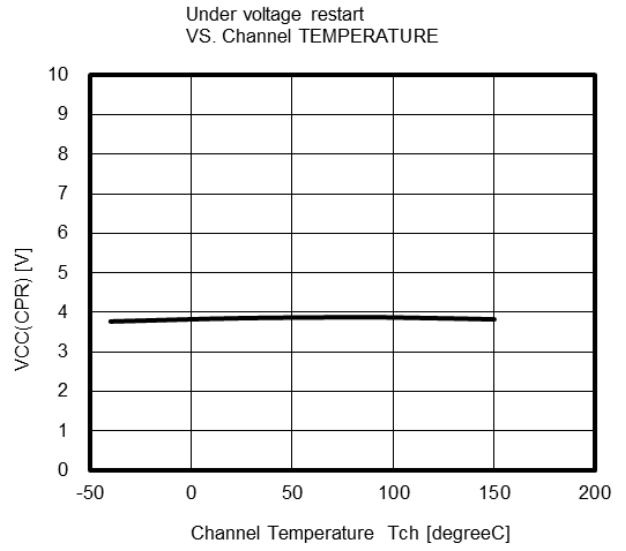
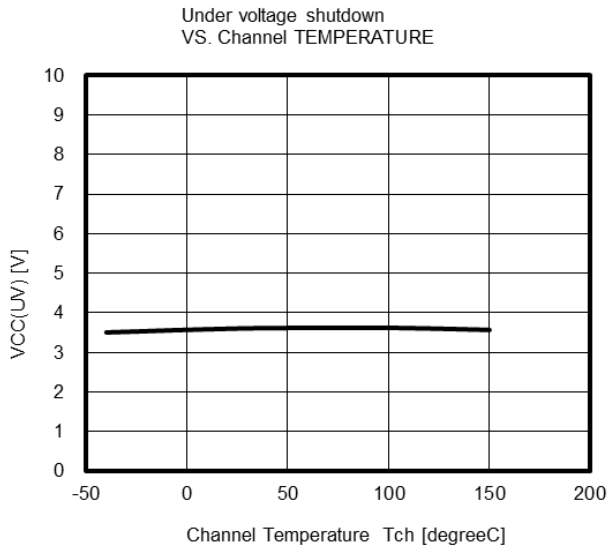


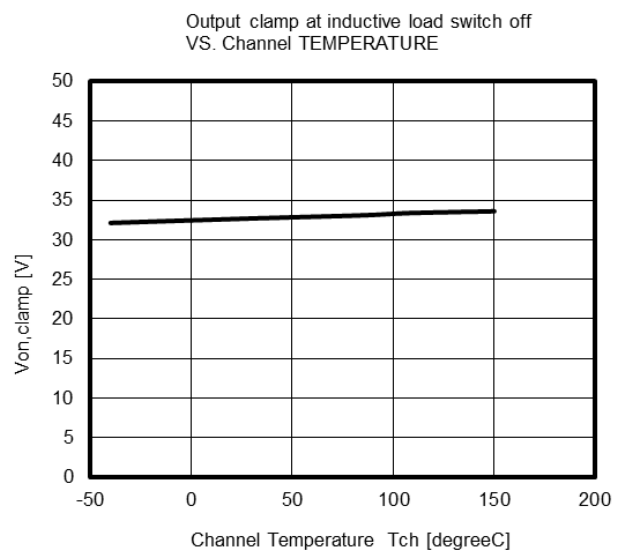
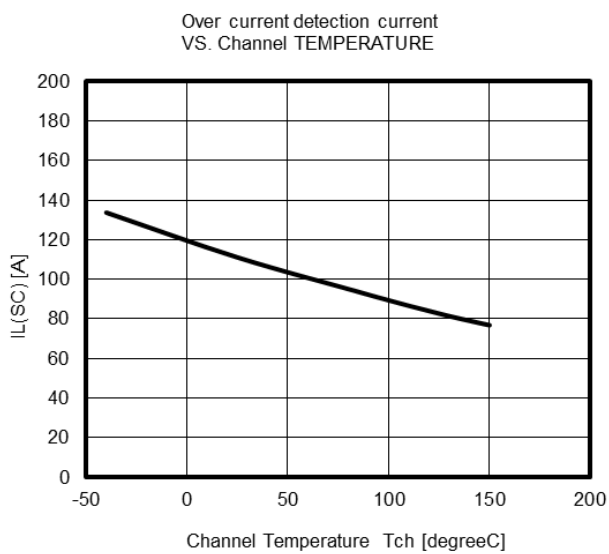
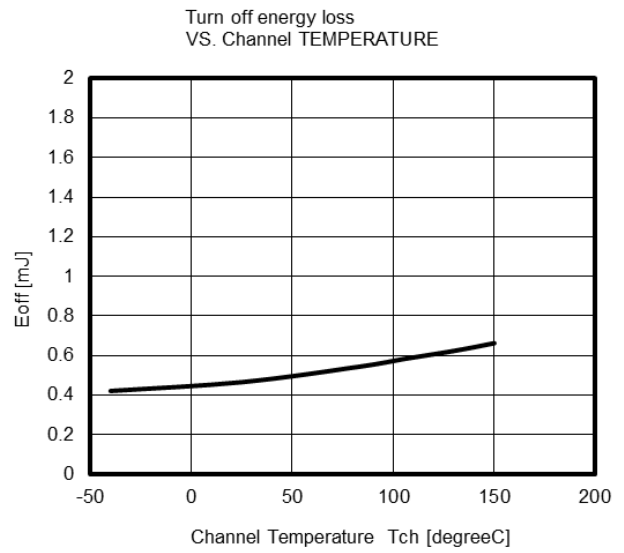
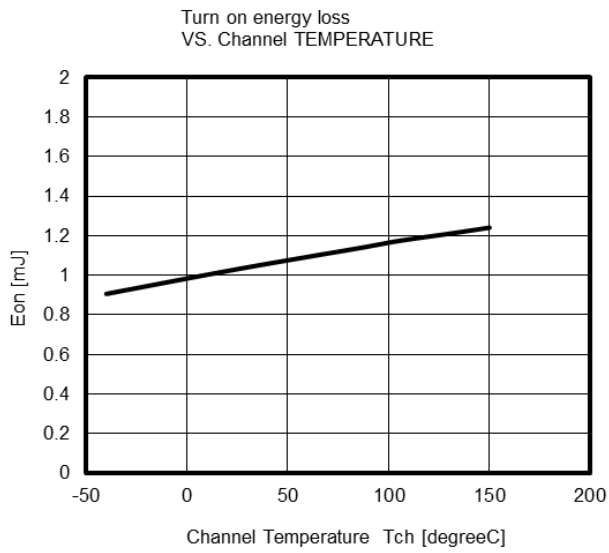
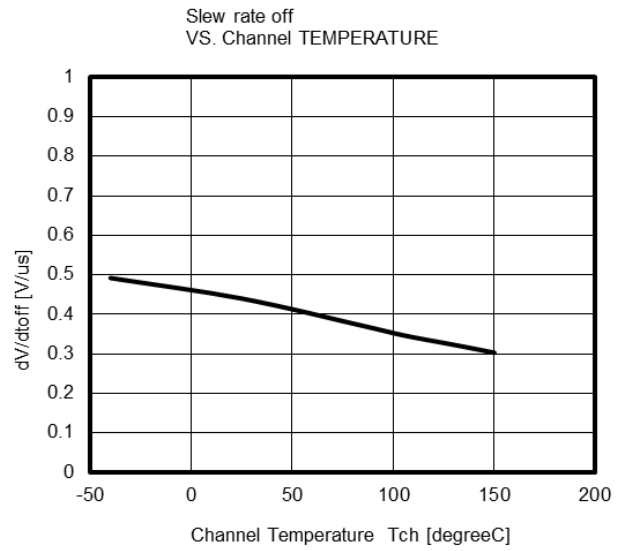
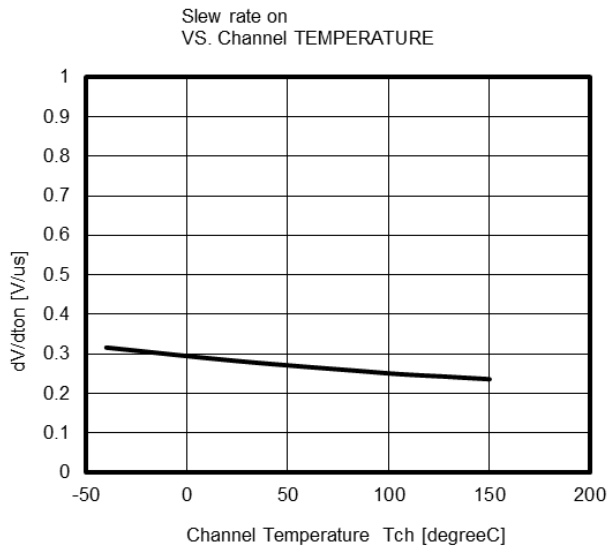
Low level SEN pin current  
VS. Channel TEMPERATURE



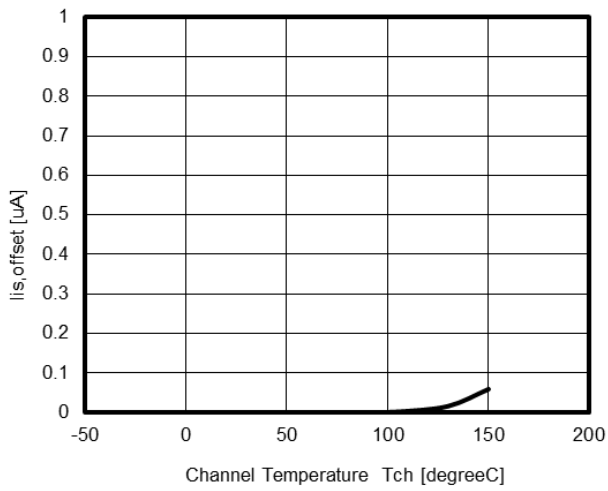
High level SEN pin current  
VS. Channel TEMPERATURE



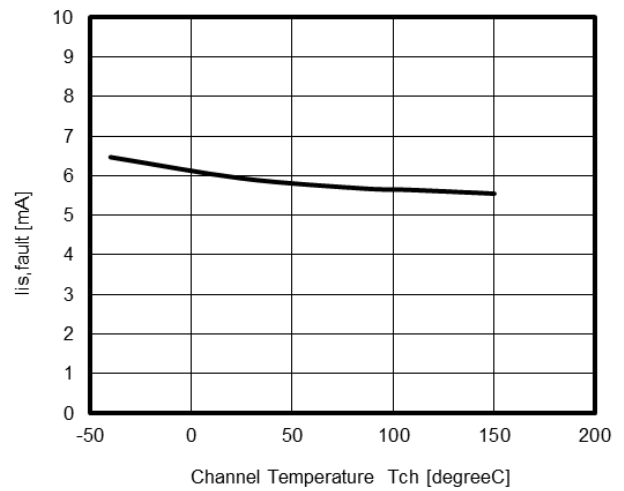




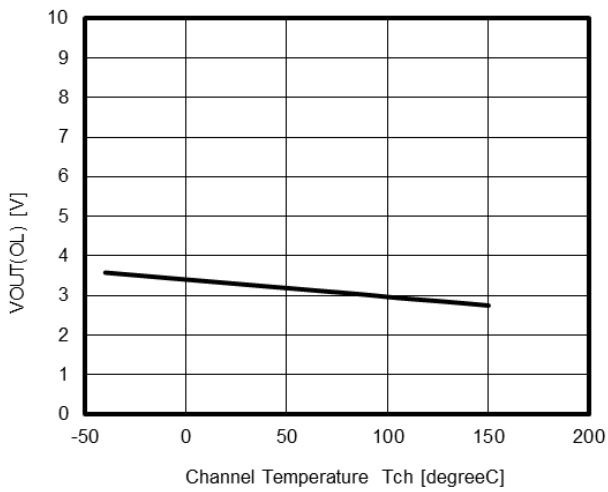
Sense current offset current  
VS. Channel TEMPERATURE



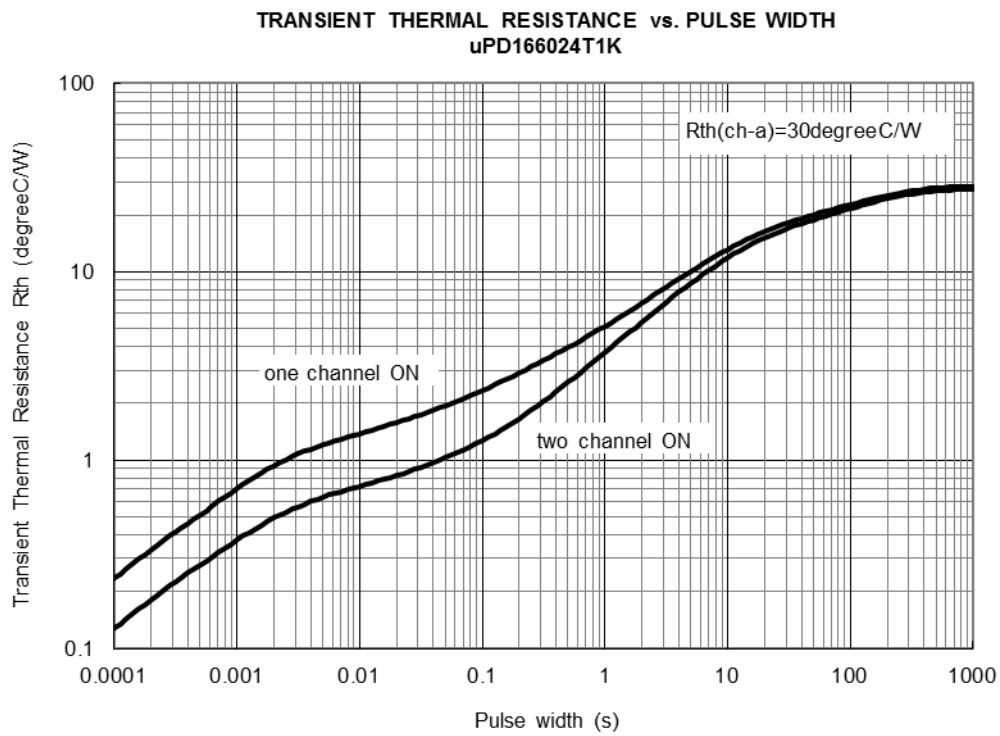
Sense current under fault condition  
VS. Channel TEMPERATURE



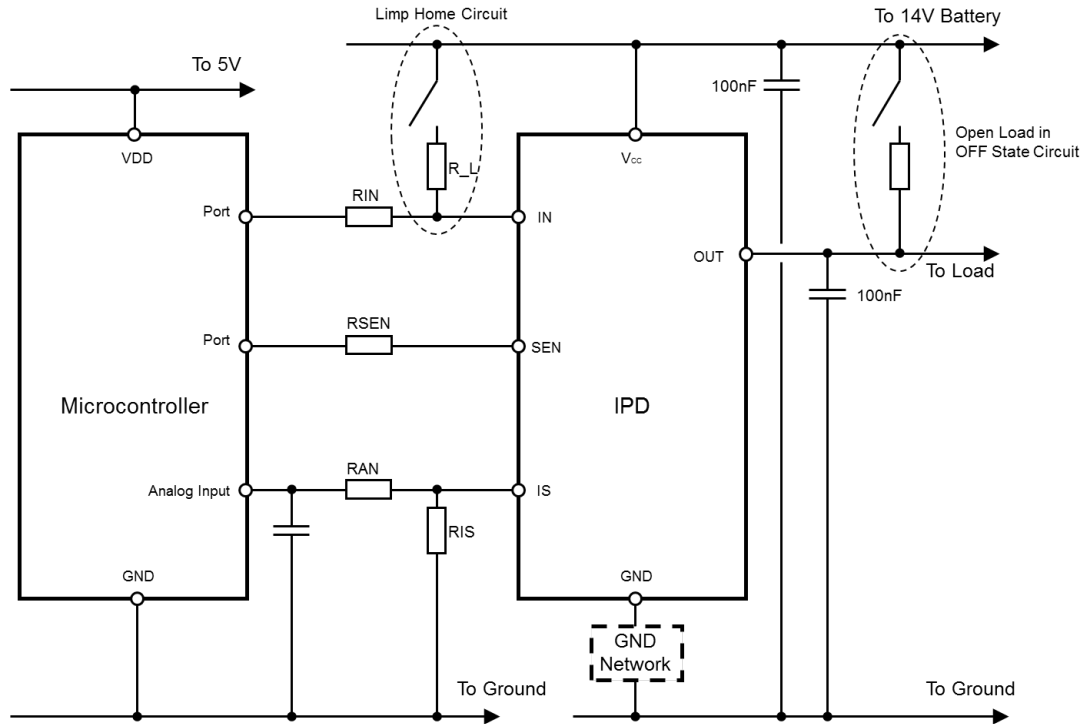
Open load detection threshold at off-state  
VS. Channel TEMPERATURE



5. Thermal characteristics



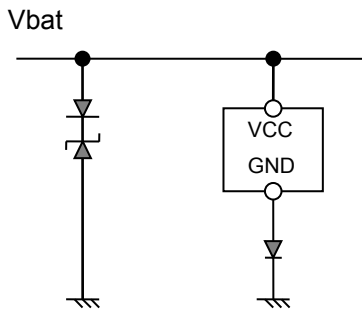
6. Application example in principle



RIN, RSEN, 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

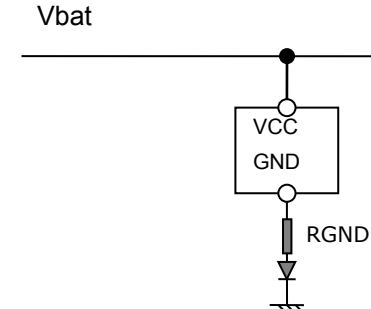
GND Network recommendation

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



External diode is recommended in order to prevent reverse current toward control logic part at reverse battery condition.

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



External diode and resistor are recommended in order to prevent reverse current toward control logic part at reverse battery condition and limit the current through ZD<sub>AZ</sub> at load dump condition. 100ohm is recommended as RGND.

Note: If other component is installed to prevent reverse current at reverse battery condition, diode is not required in GND Network.

Note: Approx. 10kohm additional resistor in parallel with diode is recommended depends on V<sub>f</sub>- I<sub>f</sub> performance of the diode.

<b>Revision History</b>	<b>μPD166024T1K Datasheet</b>
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Rev.	Date	Description	
		Page	Summary
1.00	Sep. 17, 2013	1-38	1st issue
2.00	May 22, 2015	23	"Device behavior at small load current conduction" is added.

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