

# μPD166032T1U

## INTELLIGENT POWER DEVICE

R07DS1166EJ0200

Rev.2.00

May 22, 2015

## 1. Overview

### 1.1 Description

#### Family:

μPD166032T1U is part of 2nd Generation Intelligent Power Devices (IPD). They are N-channel high-side switches 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 according to on-state resistance
- 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

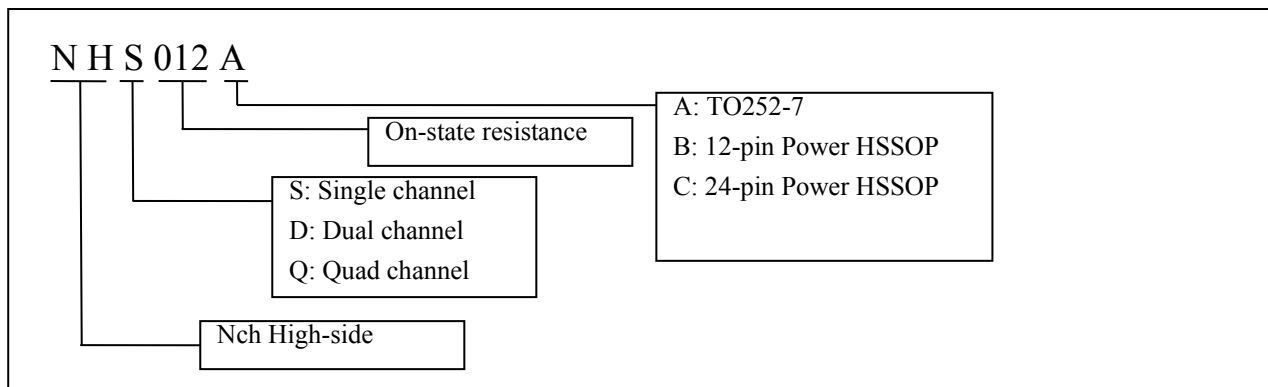
**Note:** The information contained in this document is the one that was obtained when the document was issued, and may be subject to change.

## 2. Ordering Information

| Part No.           | Nick name | Lead plating  | Packing          | Package |
|--------------------|-----------|---------------|------------------|---------|
| UPD166032T1U-E1-AY | NHS012A   | Pure Matte Sn | Tape 2500 p/reel | TO252-7 |

Note: Part No. and Nick name are tentative and might change at anytime without notice.

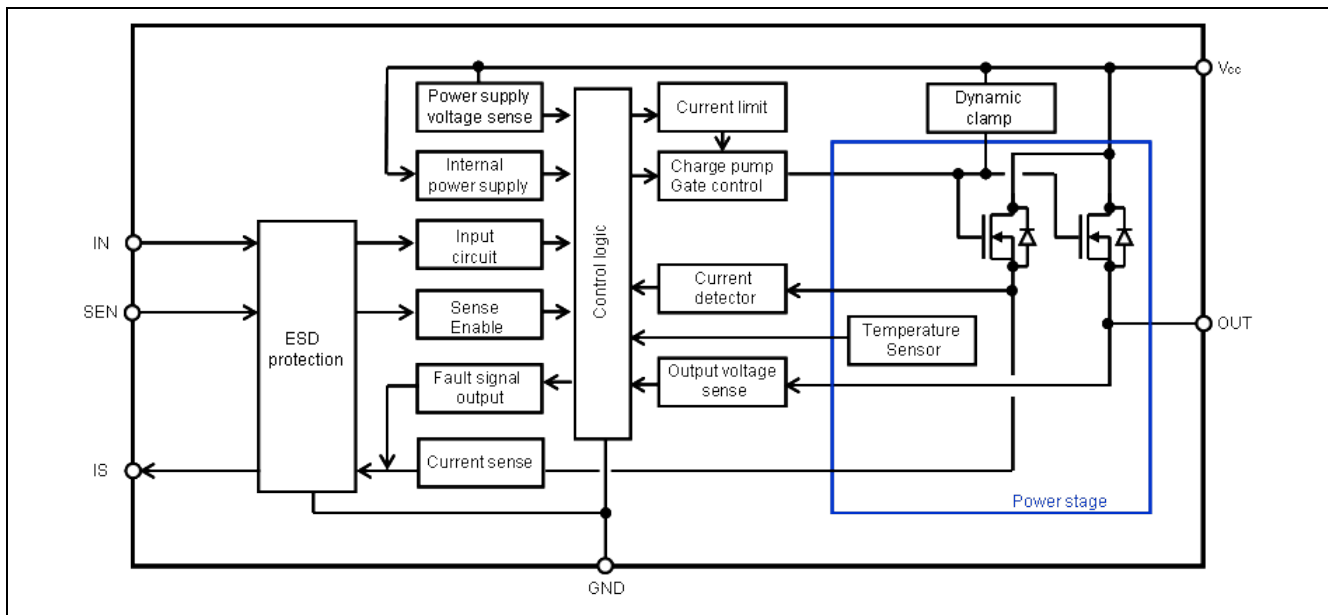
### 2.1 Nick name



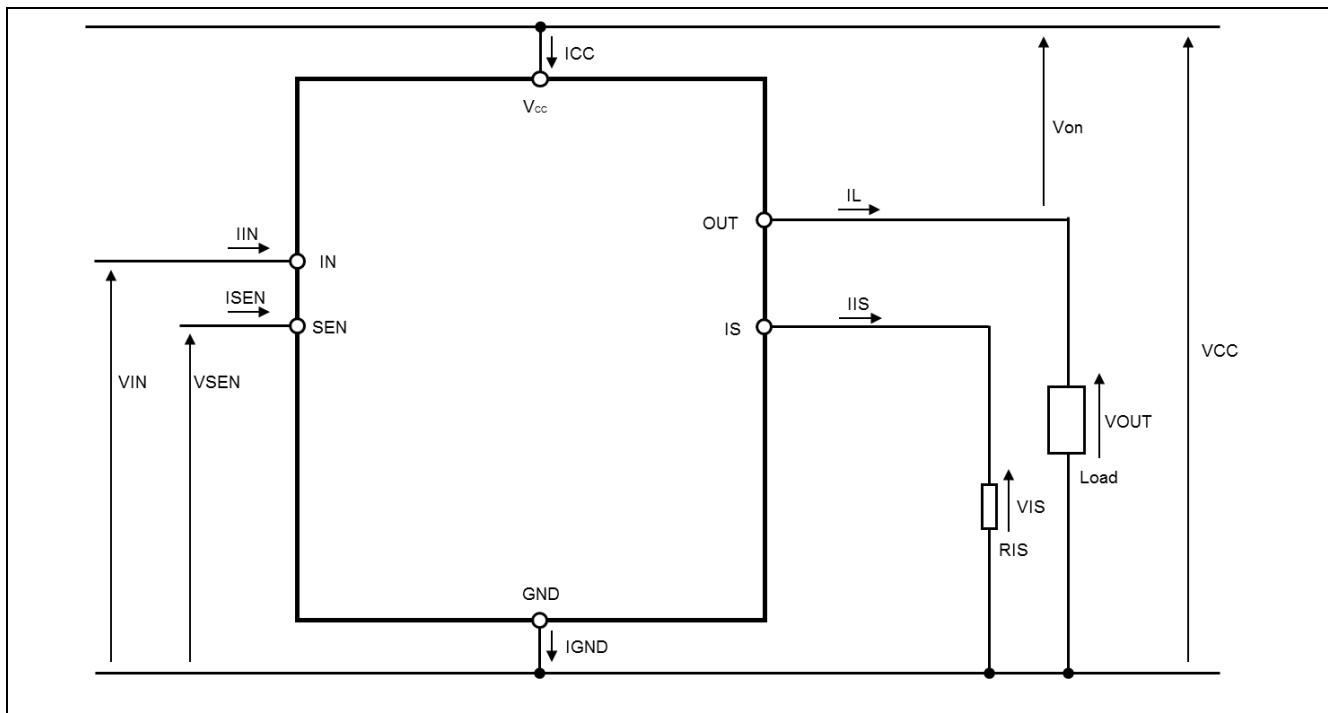
### 3. Specification

#### 3.1 Block Diagram

##### 3.1.1 Nch High-side Single Device



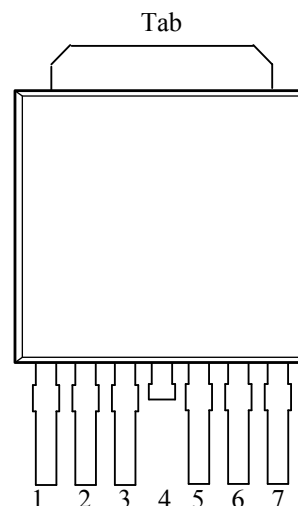
#### Voltage and Current Definition



## 3.2 Pin Configuration

### 3.2.1 TO252-7 Pin Configuration

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



#### Pin function

| Terminal Name | Pin function                                                          | Recommended connection                                                                                         |
|---------------|-----------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|
| GND           | Ground connection                                                     | Connected to GND through a 100 $\Omega$ resistor or a diode for reverse current protection<br>Refer chapter 6. |
| IN            | Input signal                                                          | Connected to MCU port through 2k-50K serial resistor.                                                          |
| IS            | Current sense and Diagnosis output signal                             | Connected to GND through a 0.67K-5K resistor.<br>Not connect if this pin is not used.                          |
| SEN           | Sense enable input                                                    | Connected to MCU port through 2k-50K serial resistor. Not connect if this pin is not used.                     |
| OUT           | Protected high-side power output                                      | 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.                                           |

### 3.3 Absolute Maximum Ratings

Ta=25°C, 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=2Ω, t<2min, RIN=2kΩ, RSEN=2kΩ, RIS=1kΩ, RGND=100Ω                                         |                                                            |          |
| GND Reverse current at reverse battery condition              | I <sub>GND(Rev)</sub>  | 200             | mA   | RL=2Ω, t<2min                                                                                |                                                            |          |
| Vcc voltage under Load Dump condition                         | V <sub>load dump</sub> | 42              | V    | RI=1Ω, RL=2Ω, RIS=1kΩ, RIN=2kΩ, RSEN=2kΩ, RGND=100Ω, td=400ms                                |                                                            |          |
| Load Current                                                  | I <sub>L</sub>         | Self limited    | A    |                                                                                              |                                                            |          |
| Total power dissipation for whole device (DC)                 | P <sub>D</sub>         | 1.85            | W    | Ta=85°C, Device on 50mm×50mm×1.5mm epoxy PCB FR4 with 6 cm <sup>2</sup> of 70 μm copper area |                                                            |          |
| Voltage at IN pin                                             | V <sub>IN</sub>        | -2 ~ 16         | V    | DC<br>RIN=2kΩ                                                                                |                                                            |          |
|                                                               |                        | -16             |      | At reverse battery condition, t<2min, RIN=2kΩ, RSEN=2kΩ                                      |                                                            |          |
| IN pin current                                                | I <sub>IN</sub>        | 10              | mA   | DC                                                                                           |                                                            |          |
| Voltage at IS pin                                             | V <sub>IS</sub>        | V <sub>CC</sub> | V    | DC<br>RIS=1kΩ                                                                                |                                                            |          |
|                                                               |                        | -16             | V    | At reverse battery condition, t<2min, RL=2Ω, RIS=1kΩ                                         |                                                            |          |
| IS Reverse current at reverse battery condition               | I <sub>IS(Rev)</sub>   | -30             | mA   | At reverse battery condition, t<2min, RL=2Ω                                                  |                                                            |          |
| Voltage at SEN pin                                            | V <sub>SEN</sub>       | -2 ~ 16         | V    | DC<br>RSEN=2kΩ                                                                               |                                                            |          |
|                                                               |                        | -16             |      | At reverse battery condition, t<2min<br>RIN=2kΩ, RSEN=2kΩ                                    |                                                            |          |
| SEN pin current                                               | I <sub>SEN</sub>       | 10              | mA   | DC                                                                                           |                                                            |          |
| Channel Temperature                                           | T <sub>ch</sub>        | -40 to +150     | °C   |                                                                                              |                                                            |          |
| Storage Temperature                                           | T <sub>stg</sub>       | -55 to +150     | °C   |                                                                                              |                                                            |          |
| ESD susceptibility                                            | V <sub>ESD</sub>       | 2000            | V    | HBM                                                                                          | AEC-Q100-002 std.<br>R=1.5kΩ, C=100pF                      | All pin  |
|                                                               |                        | 4000            |      |                                                                                              | IEC61000-4-2 std.<br>R=330Ω, C=150pF, 100nF at VCC and OUT | VCC, OUT |
|                                                               |                        | 200             | V    | MM                                                                                           | AEC-Q100-003 std.<br>R=0Ω, C=200pF                         |          |
| Inductive load switch-off energy dissipation single pulse     | EAS                    | 120             | mJ   | VCC=13.5V, T <sub>ch,start</sub> <150°C, RL=2Ω                                               |                                                            |          |
| Inductive load switch-off energy dissipation repetitive pulse | EAR                    | 70              | mJ   | VCC=13.5V, T <sub>ch,start</sub> =85°C, RL=2Ω                                                |                                                            |          |

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) |     | 35  |     | °C/W | According to JEDEC JESD51-2, -5, -7 on FR4 2s2p board |
|                         | Rth(ch-c) |     | 1.0 |     | °C/W |                                                       |

### 3.5 Electrical Characteristics

#### Operation function

Tch=-40 to 150°C, 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    | VIN=4.5V,<br>RL=2Ω                                                                                                           |                                                                     |
| Operating current                      | I <sub>GND</sub>     |     | 2.2 | 4   | mA   | VIN=4.5V                                                                                                                     |                                                                     |
| Output Leakage current                 | I <sub>L(off)</sub>  |     |     | 0.5 | μA   | Tch=25°C                                                                                                                     | VCC=13.5V,<br>VIN=0V,<br>VSEN=0V,<br>VIS=0V,<br>VOUT=0V,<br>VGND=0V |
|                                        |                      |     |     | 3   |      | Tch=-40~125°C                                                                                                                |                                                                     |
| Standby current                        | I <sub>CC(off)</sub> |     |     | 0.5 | μA   | Tch=25°C                                                                                                                     | VCC=13.5V,<br>VIN=0V,<br>VSEN=0V,<br>VIS=0V,<br>VOUT=0V,<br>VGND=0V |
|                                        |                      |     |     | 1.5 |      | Tch=-40~85°C                                                                                                                 |                                                                     |
| On-state resistance                    | Ron                  |     | 12  |     | mΩ   | Tch=25°C                                                                                                                     | IL=6.8A                                                             |
|                                        |                      |     |     | 24  |      | Tch=150°C                                                                                                                    |                                                                     |
| 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   | VIN=0.8V                                                                                                                     |                                                                     |
| High level IN pin current              | I <sub>IH</sub>      | 2   |     | 25  | μA   | VIN=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   | VSEN=0.8V                                                                                                                    |                                                                     |
| High level SEN pin current             | I <sub>SENH</sub>    | 2   |     | 25  | μA   | VSEN=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=2Ω                                                                                                             |                                                                     |
| 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              |     |     | 1.5 | V/μs |                                                                                                                              |                                                                     |
| Slew rate off                          | -dV/dtoff            |     |     | 1.5 | V/μs |                                                                                                                              |                                                                     |
| Switching drift <sup>1)</sup>          | ton-toff             | -50 |     | +50 | μs   | Vcc = 9 to 18V drift from Vcc=13.5V,<br>Tch=-40 to 150°C drift from Tch=25°C<br>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=2Ω                                                                                                    |                                                                     |
| Turn off energy loss <sup>1)</sup>     | Eoff                 |     | 1.2 | 2.4 | mJ   |                                                                                                                              |                                                                     |
| Driving capability <sup>1)</sup>       | Dr(capa)             | 118 |     |     | mΩ   | 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 150°C, 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=2Ω |
|                                                                   |               |     |     | 0.7 |      | Tch=150°C                        |                   |

Remark) All voltages refer to ground pin of the device

## Diagnosis function

Tch=-40 to 150°C, 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=2Ω |
| 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=0.67kΩ            |
|                                                      |            | 3.5  |      | 9    |      | VCC=13.5V, RIS=1kΩ               |
|                                                      |            | 3.5  |      | 5.5  |      | VCC=13.5V, RIS=2kΩ               |
| 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 150°C, 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=2Ω |
| 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 after sense enable during on-state <sup>1)</sup>  | tssen(on)    |     |     | 20  | μs   | VSEN=0V to 4.5V, RL=2Ω                         |
| Sense current settling time after sense disable during on-state <sup>1)</sup> | tssen(off)   |     |     | 20  | μs   | VSEN=4.5V to 0V, RL=2Ω                         |
| Sense current settling time during on-state <sup>1)</sup>                     | tsis(LC)     |     |     | 20  | μs   | RL=2Ω to 1Ω                                    |
| 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                                 |

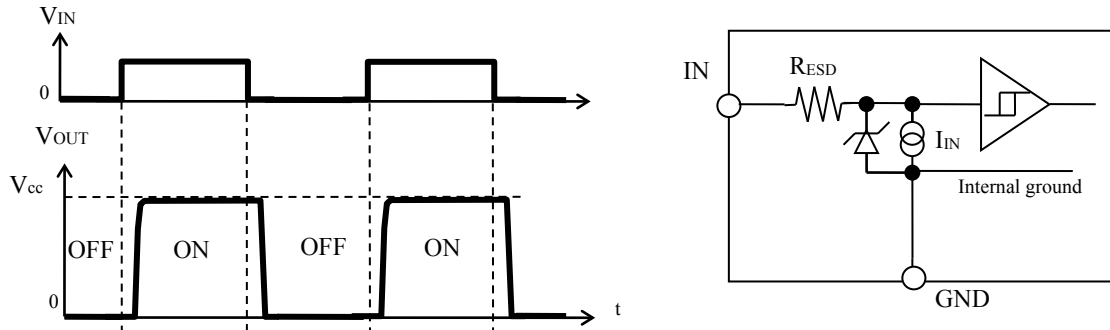
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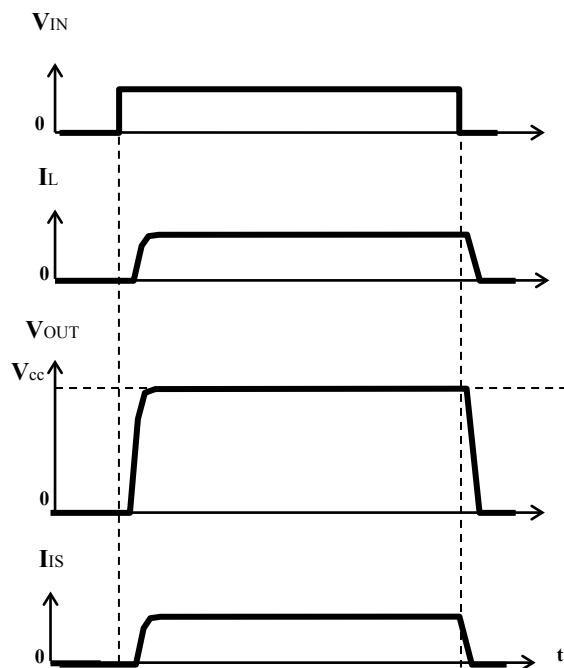
## 3.6 Feature Description

### 3.6.1 Driving Circuit

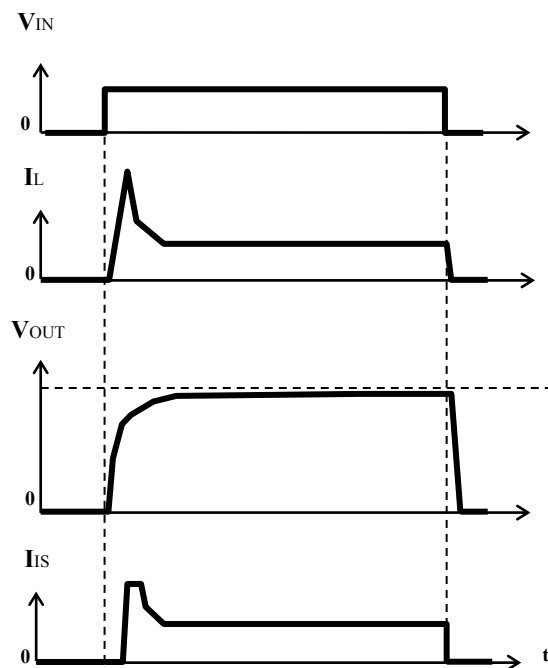
The high-side output is turned on, if the input pin is over  $V_{IH}$ . The high-side output is turned off, if the input pin is open or the input pin is below  $V_{IL}$ . Threshold is designed between  $V_{IH}$  min and  $V_{IL}$  max with hysteresis. IN terminal is pulled down with constant current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



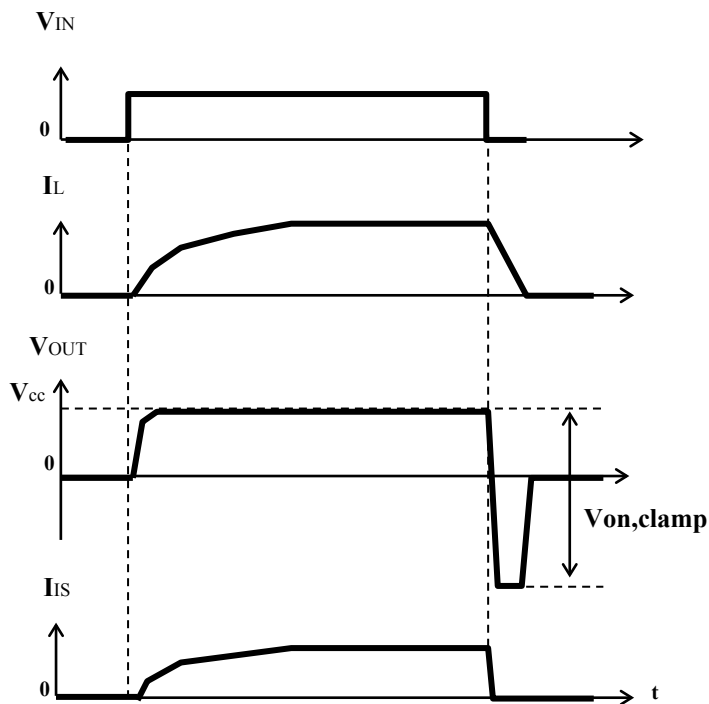
#### Switching a resistive load



#### Switching lamps



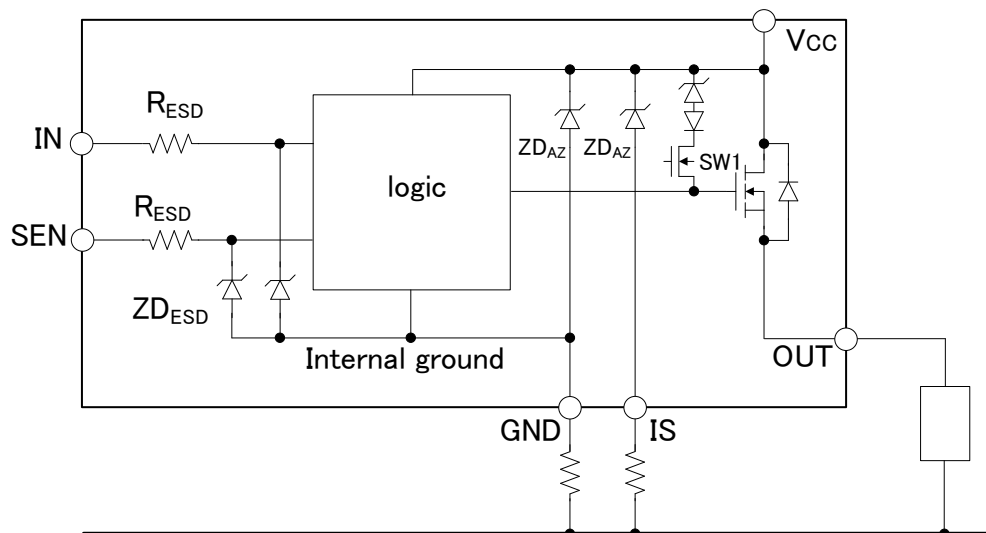
### Switching an inductive load



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.

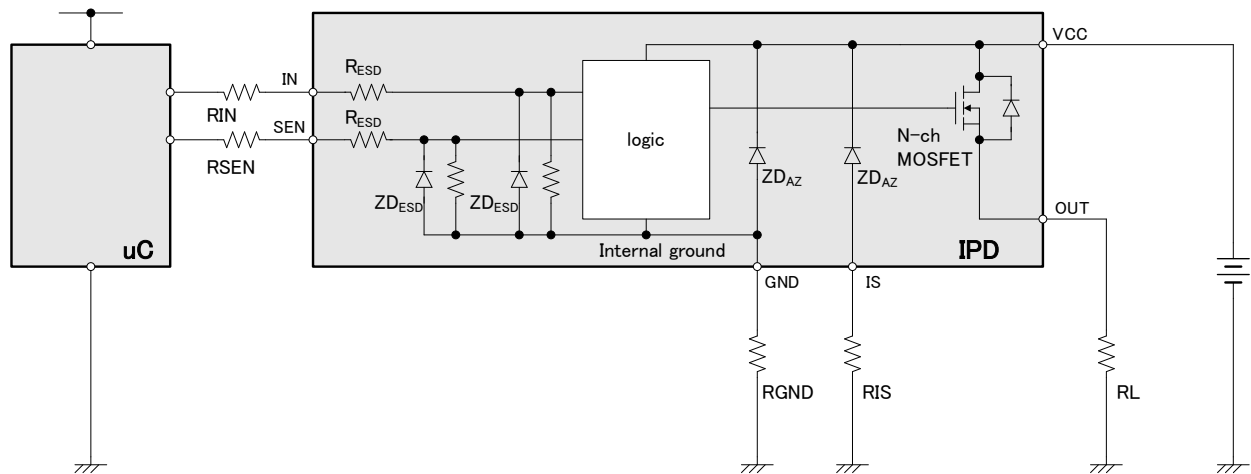
SW1 is turned on, and the clamp diode is connected to the gate of the output MOS, activating the dynamic clamp circuit.

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.



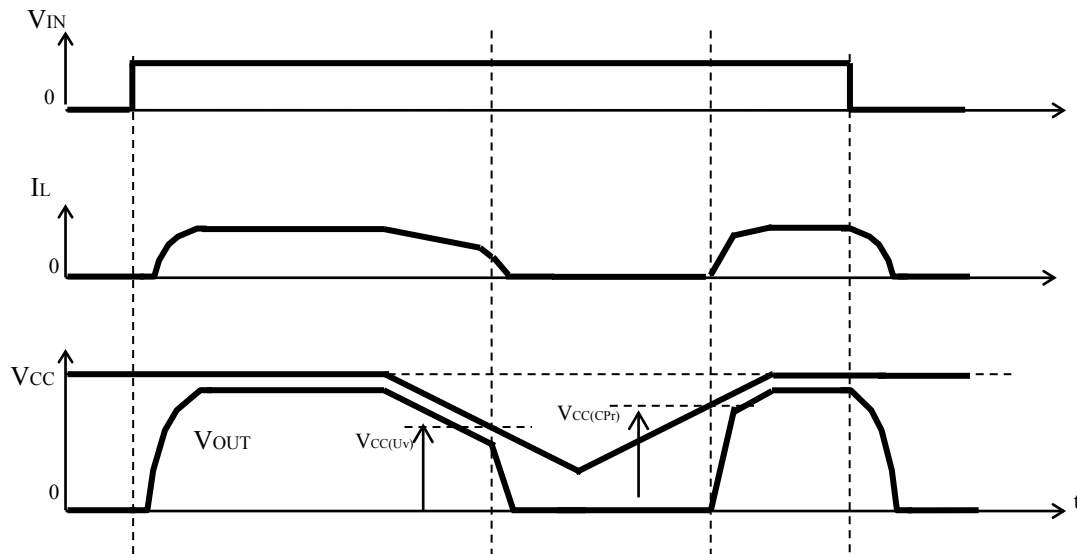
### 3.6.2 Device behavior at over voltage condition

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 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 VCC voltage.

### 3.6.5 Short circuit protection

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

The device shuts down automatically when 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)  $I_L > I_L(SC)$
- (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  $I_L(CL)$  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  $V_{on} < V_{on}(CL2)$  depends on short circuit impedance condition, the device does not operate as current limitation with  $I_L(CL)$ . 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

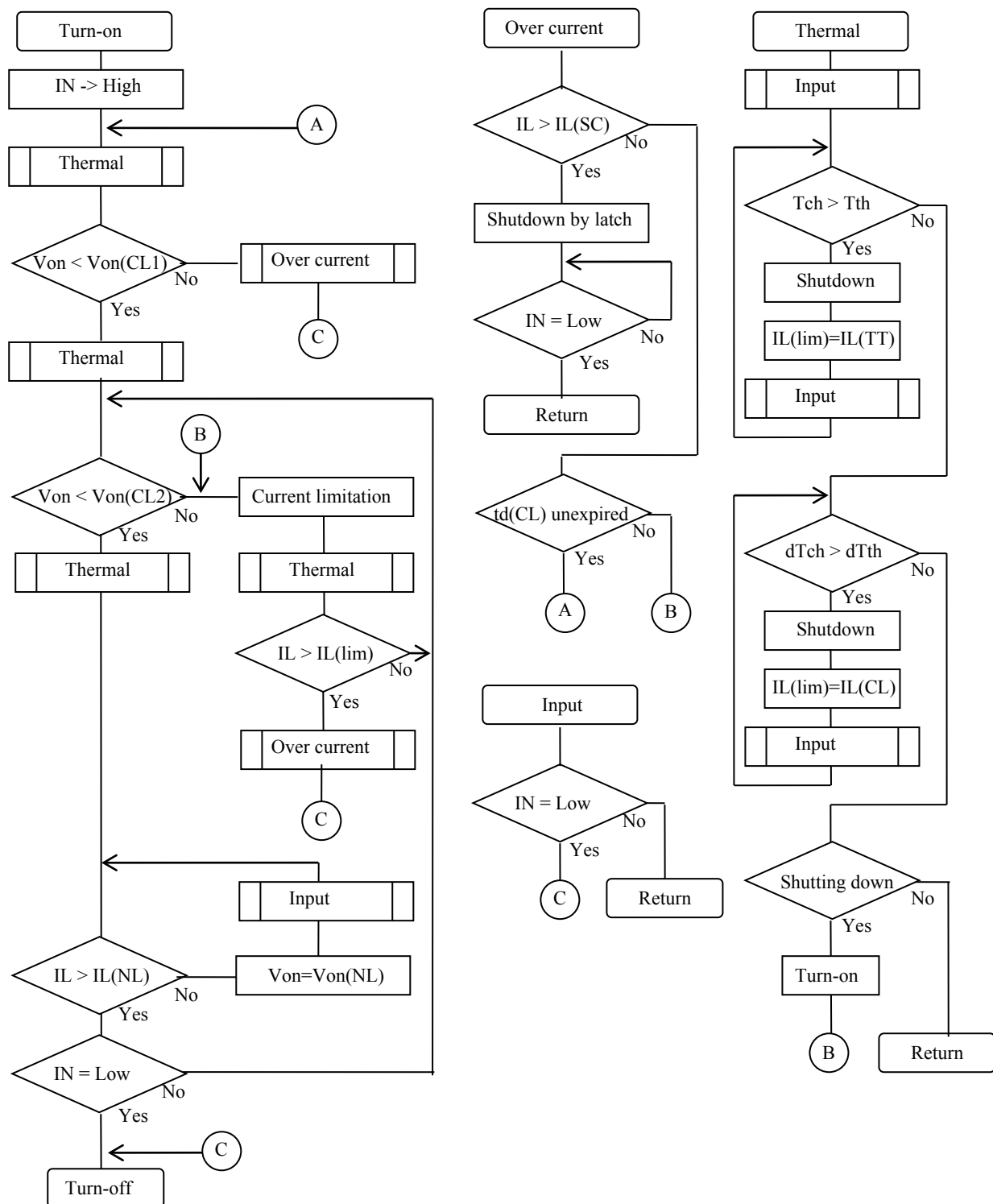
Current limitation control with  $I_L(TT)$  when auto restart from absolute  $T_{ch}$  protection.

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  $V_{on} < V_{on}(CL2)$  depends on short circuit impedance condition, the device does not operate as current limitation with  $I_L(TT)$ . In this case, the sense pin output sense current at on-state, Iis,fault at off-state during toggling operation with thermal toggling mode.

#### $\Delta T_{ch}$

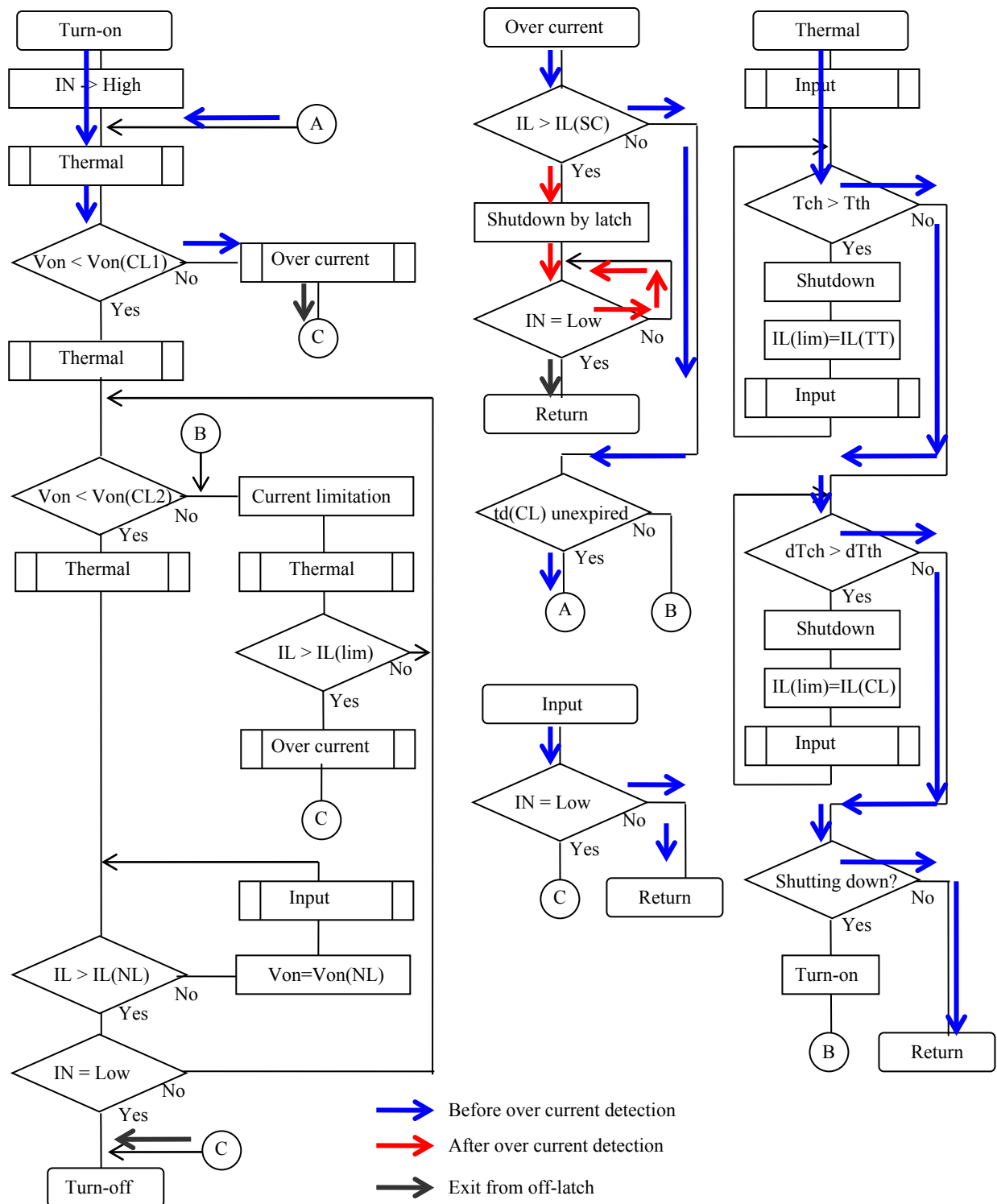
Junction temperature differences between thermal sensor of power area and thermal sensor of control area.

State transition diagram



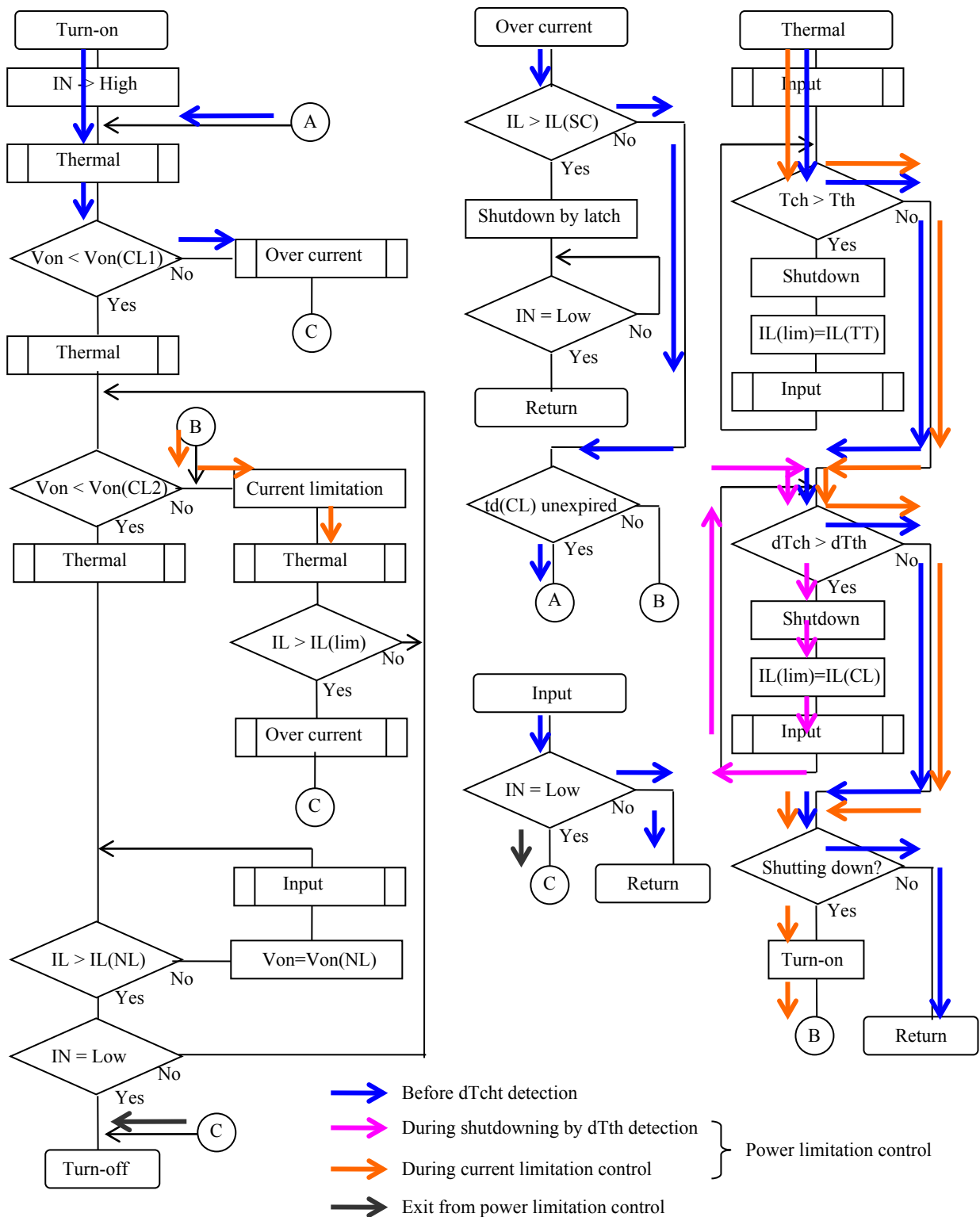
Turn-on in an over load condition including short circuit condition

(a)  $IL > IL(SC)$



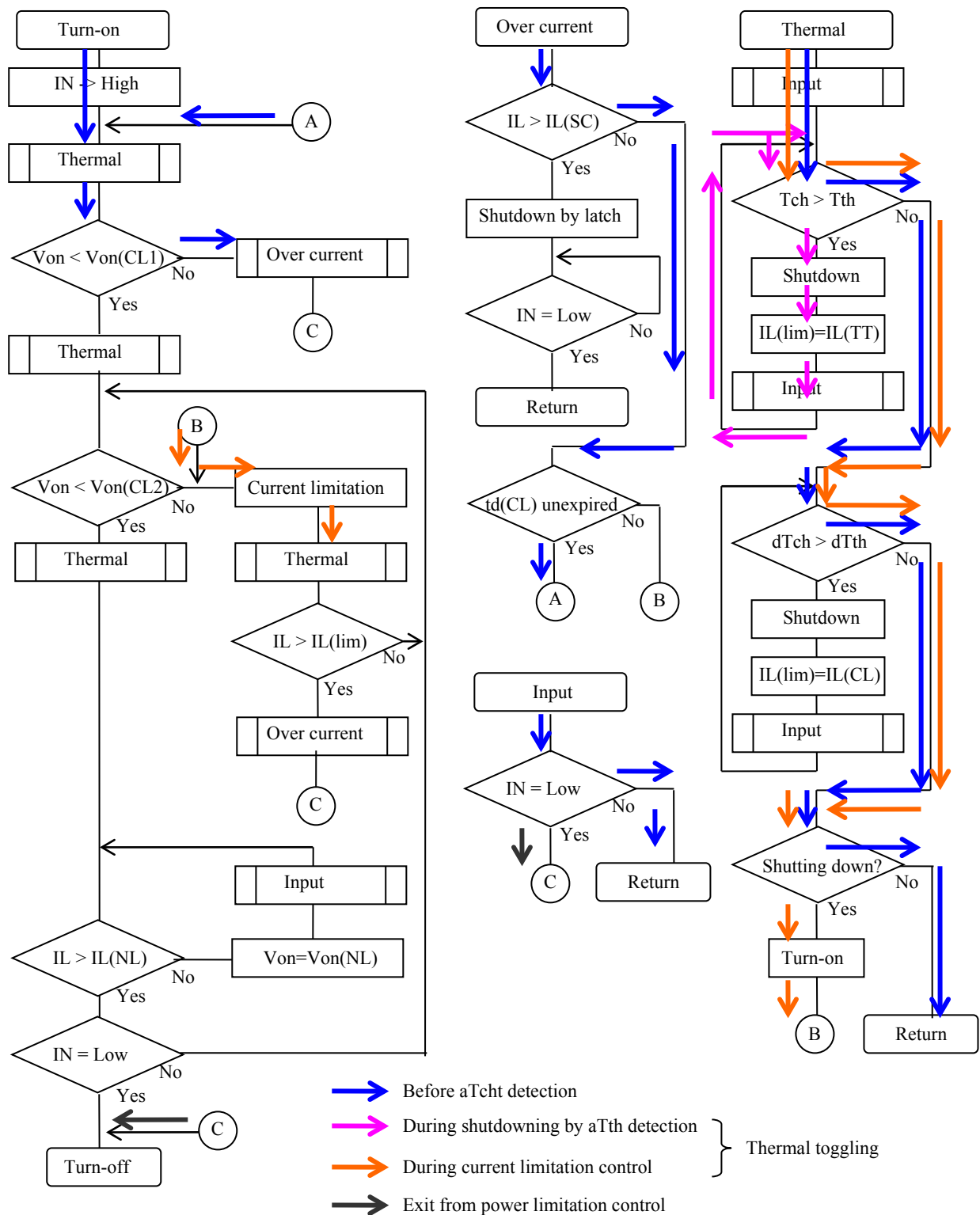
# Turn-on in an over load condition including short circuit condition

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



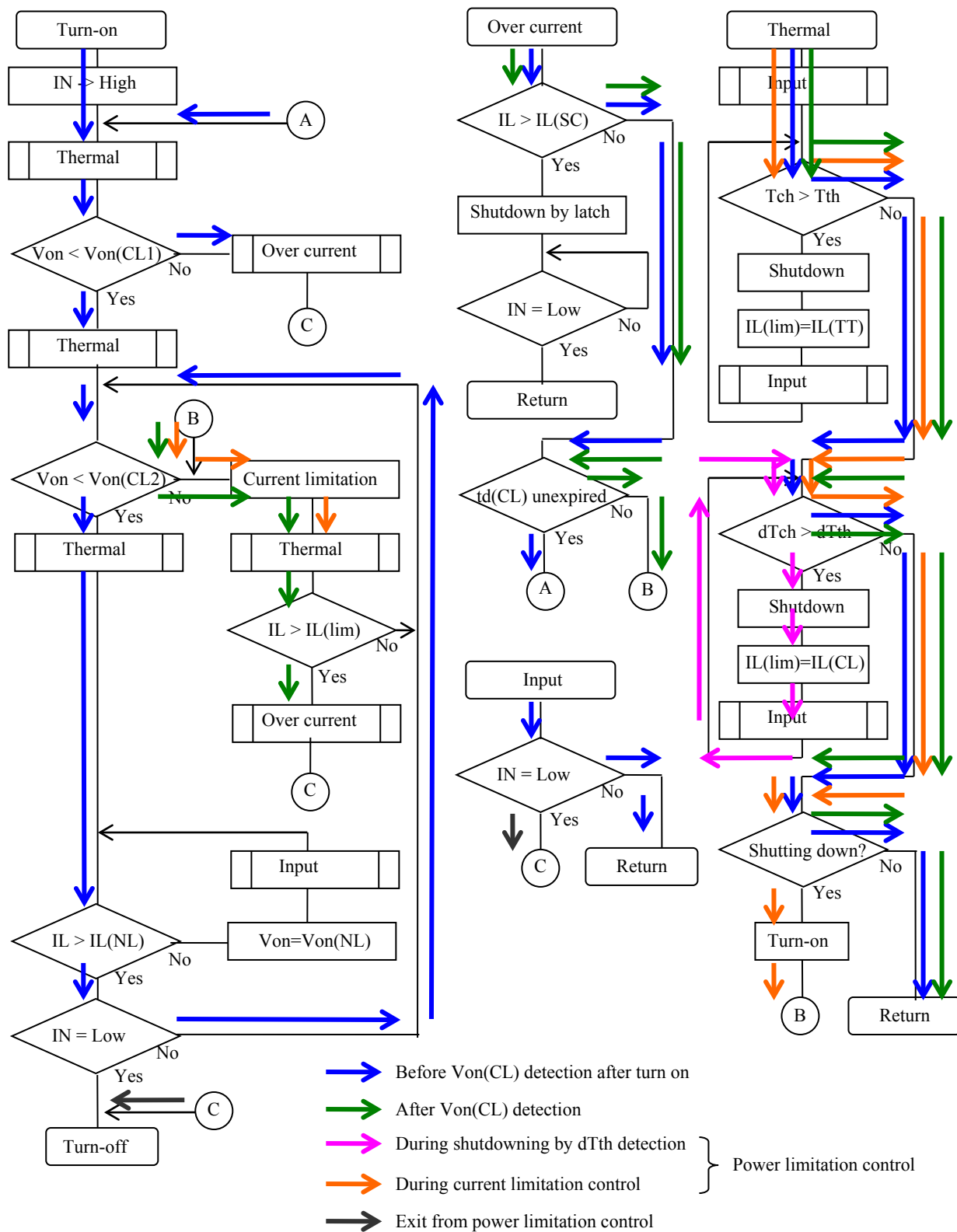
### Turn-on in an over load condition including short circuit condition

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



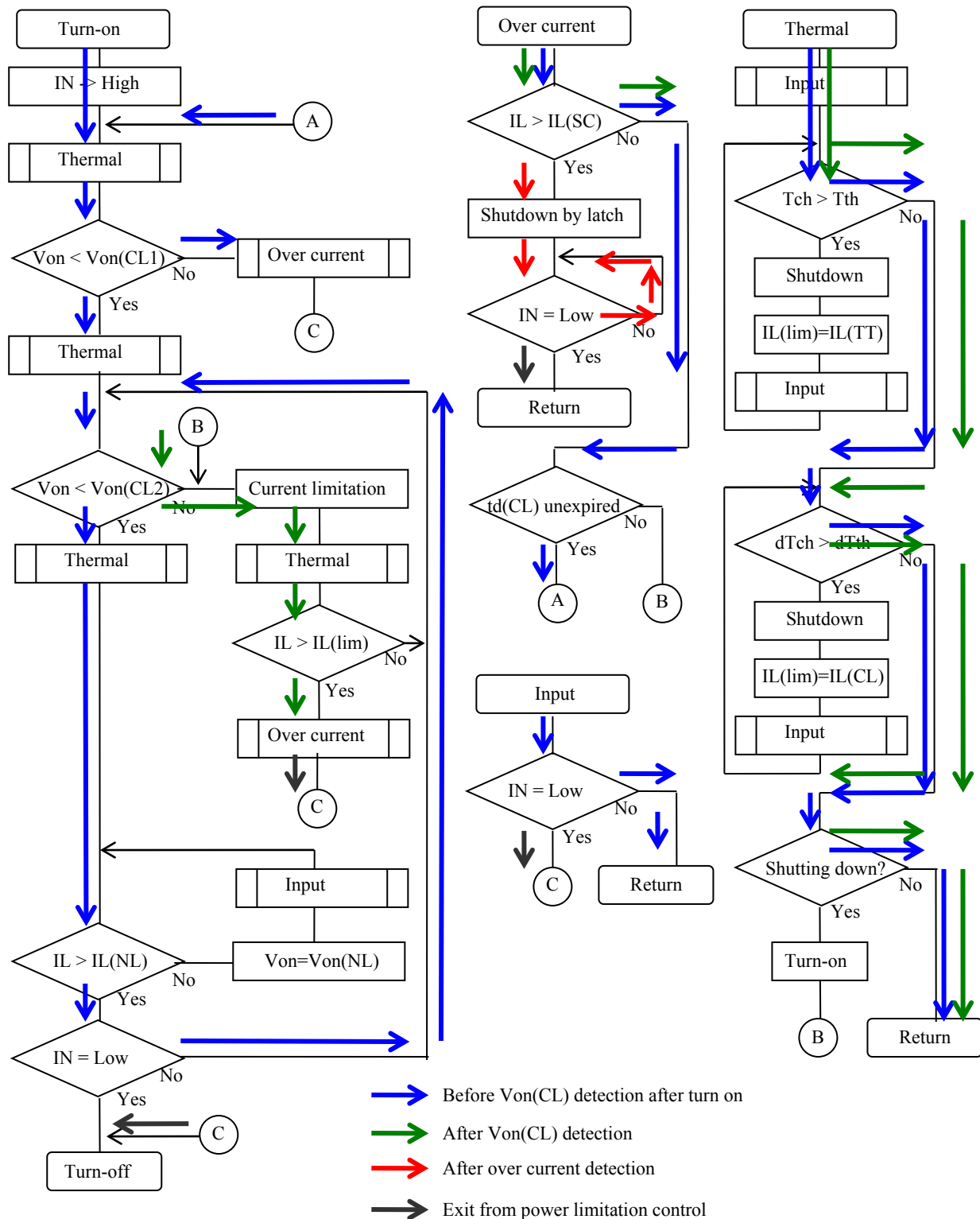
**An over load condition which is include a short circuit condition during on-state**

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



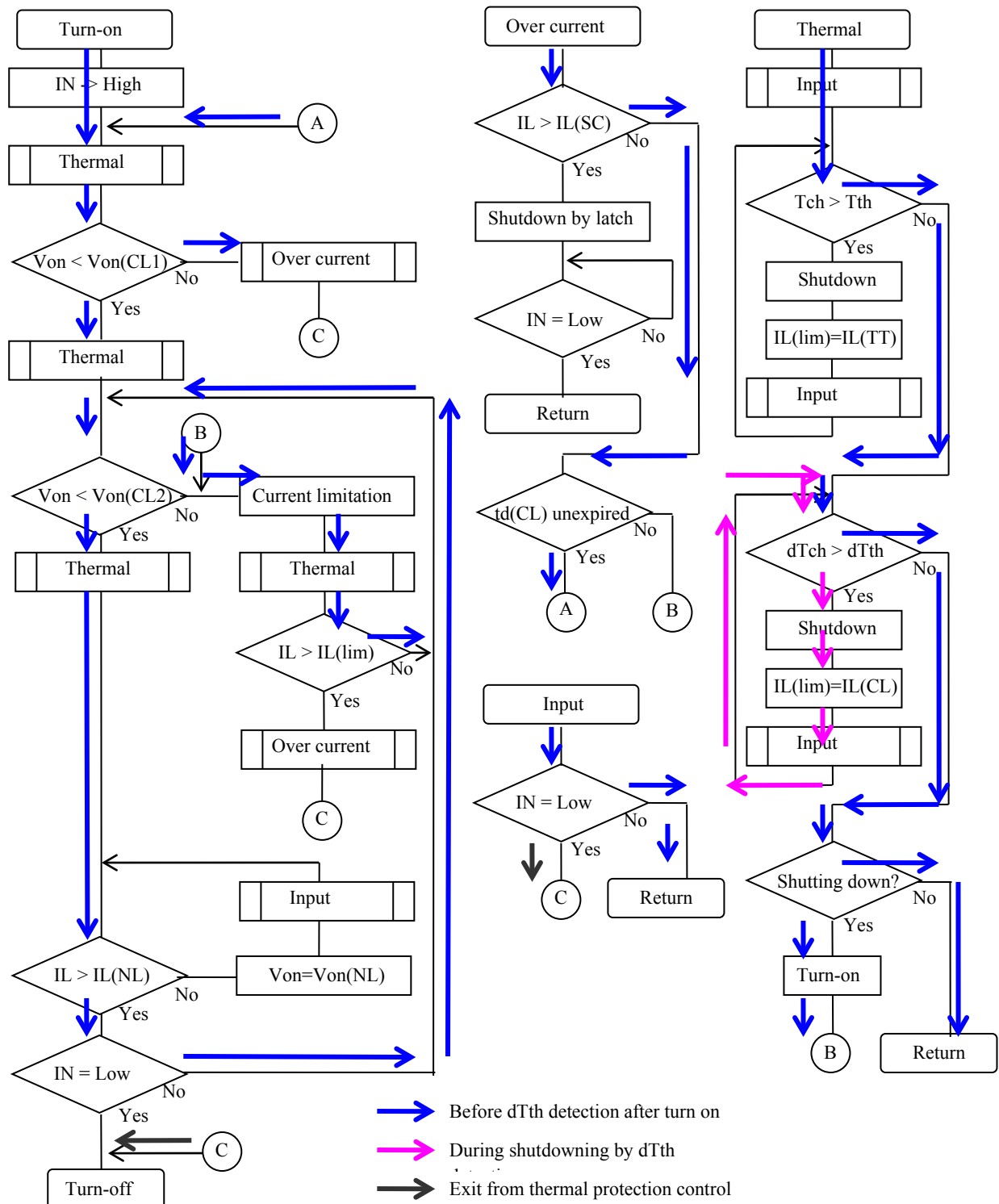
# An over load condition including short circuit condition during on-state

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

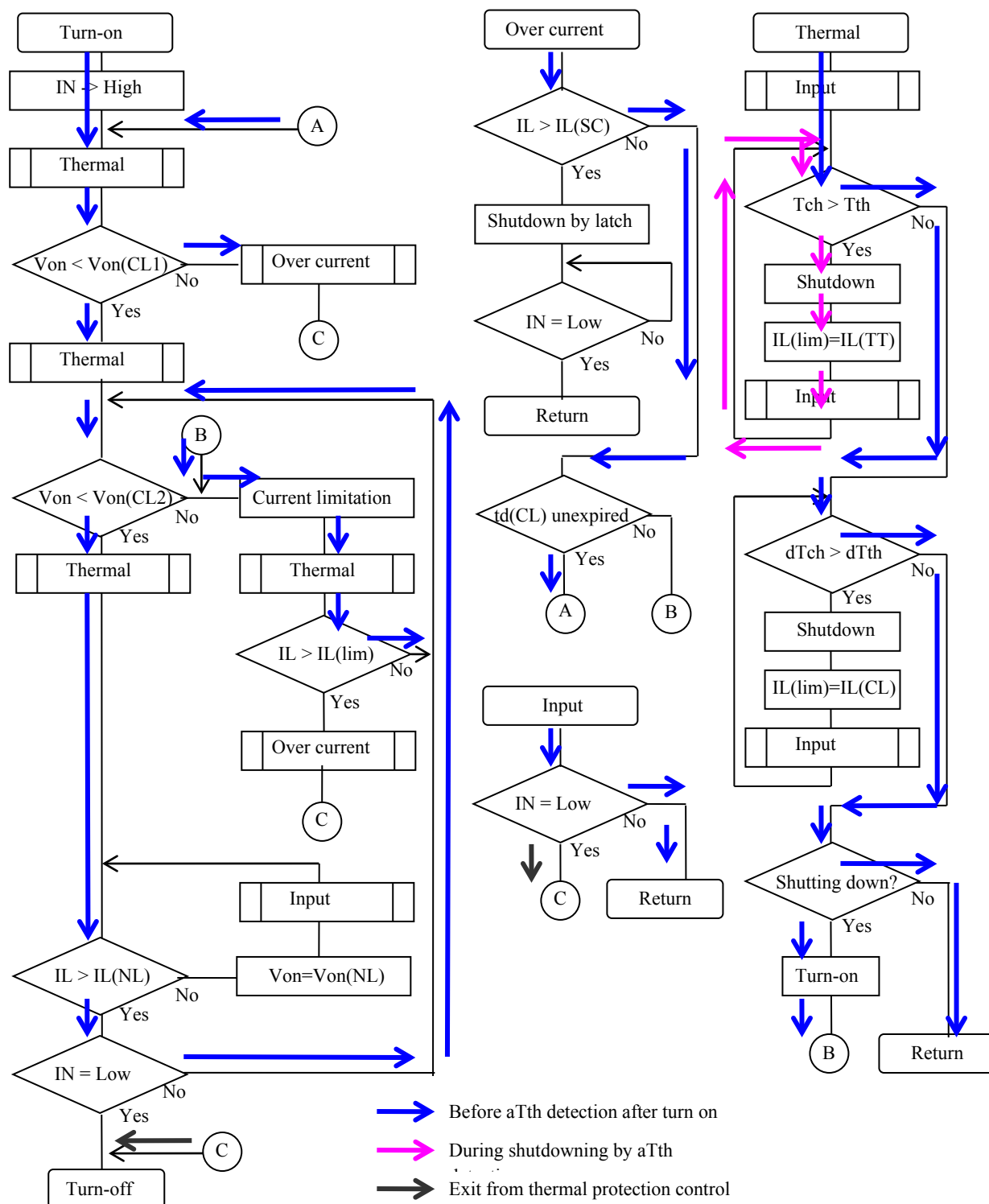


### An over load condition including short circuit condition during on-state

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



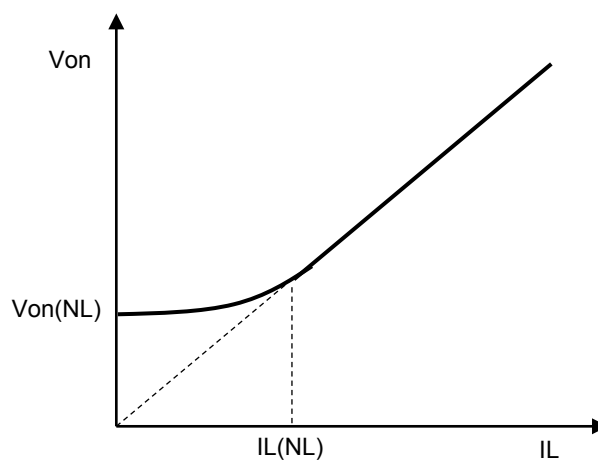
(c)  $T_{ch} > aT_{th}$



### 3.6.6 Device behavior at small load current conduction

The device has a function which controls  $R_{on}$  in order to improve KILIS accuracy at small load current conduction.

$V_{on}$  (VCC-OUT) is proportionate to  $I_L$  under normal conditions. Under  $I_L < I_L(NL)$  condition,  $R_{on}$  is controlled to increase to be  $V_{on} = V_{on}(NL) = 30\text{mV}(\text{typ})$ .



### 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>          | < 1μA (lis,dis)                                 |
| Shutdown by over current detection |     | H               | L <sup>1)</sup>          | lis,fault <sup>3)</sup>                         |
|                                    |     | L               | L <sup>1)</sup>          | < 1μA (lis,dis)                                 |
| Power limitation                   |     | H               | VOUT <sup>6)</sup>       | IIS = IL/KILIS in case of Von<Von(CL1)          |
|                                    |     |                 |                          | lis,fault <sup>4)</sup> in case of Von>Von(CL1) |
|                                    |     | L <sup>1)</sup> | lis,fault <sup>4)</sup>  |                                                 |
|                                    |     | L               | L <sup>1)</sup>          | < 1μA (lis,dis)                                 |
| Thermal toggling                   |     | H               | VOUT <sup>6)</sup>       | IIS = IL/KILIS in case of Von<Von(CL1)          |
|                                    |     |                 |                          | lis,fault <sup>5)</sup> in case of Von>Von(CL1) |
|                                    |     | L <sup>1)</sup> | lis, fault <sup>5)</sup> |                                                 |
|                                    |     | L               | L <sup>1)</sup>          | < 1μA (lis,dis)                                 |
| Short circuit to VCC               |     | H               | VCC                      | < 2μA (lis,offset)                              |
|                                    |     | L               | VOUT <sup>7)</sup>       | lis,fault in case of VOUT>VOUT(OL)              |
| Open Load                          |     | H               | VCC                      | < 2μA (lis,offset)                              |
|                                    |     | L               | VOUT <sup>7)</sup>       | lis,fault in case of VOUT>VOUT(OL)              |
| X <sup>8)</sup>                    | L   | X <sup>8)</sup> | X <sup>8)</sup>          | < 1μA (lis,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)..

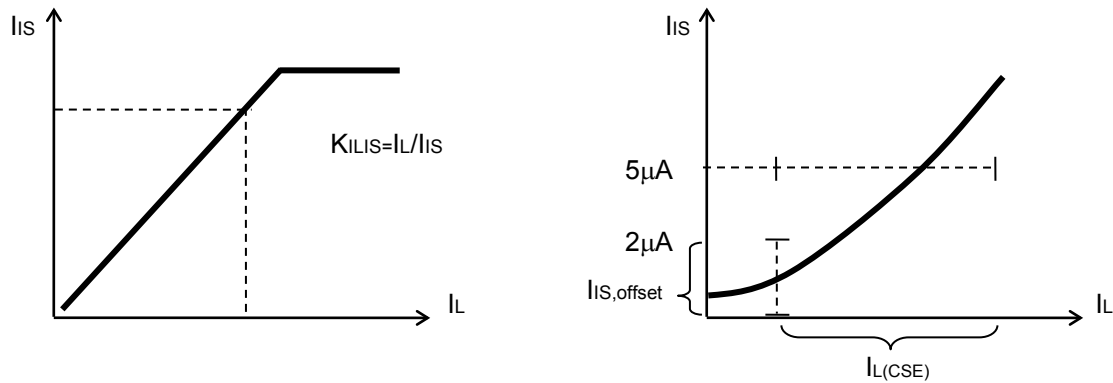
6) VOUT depends on the short circuit condition

7) VOUT depends on the ratio of VCC-OUT-GND resistive component.

8) Don't care

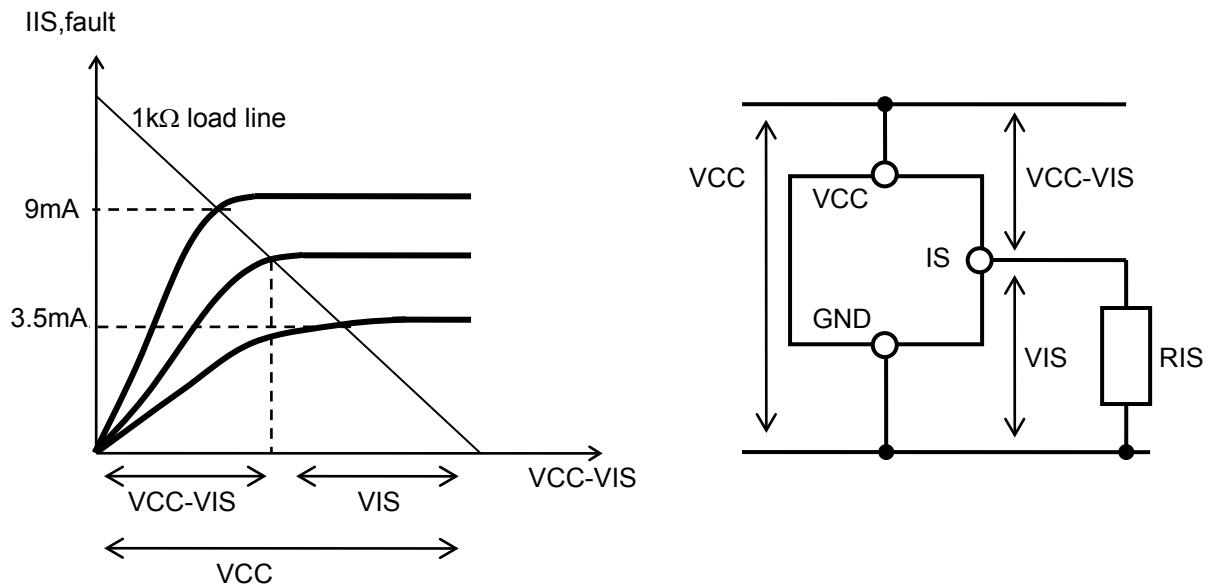
### Current sense output

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 5μA if output current is above  $I_{L(CSE) \text{ max}}$ , current sense output is below 2μA,  $I_{IS,offset \text{ max}}$ , if output current is below  $I_{L(CSE) \text{ min}}$ .

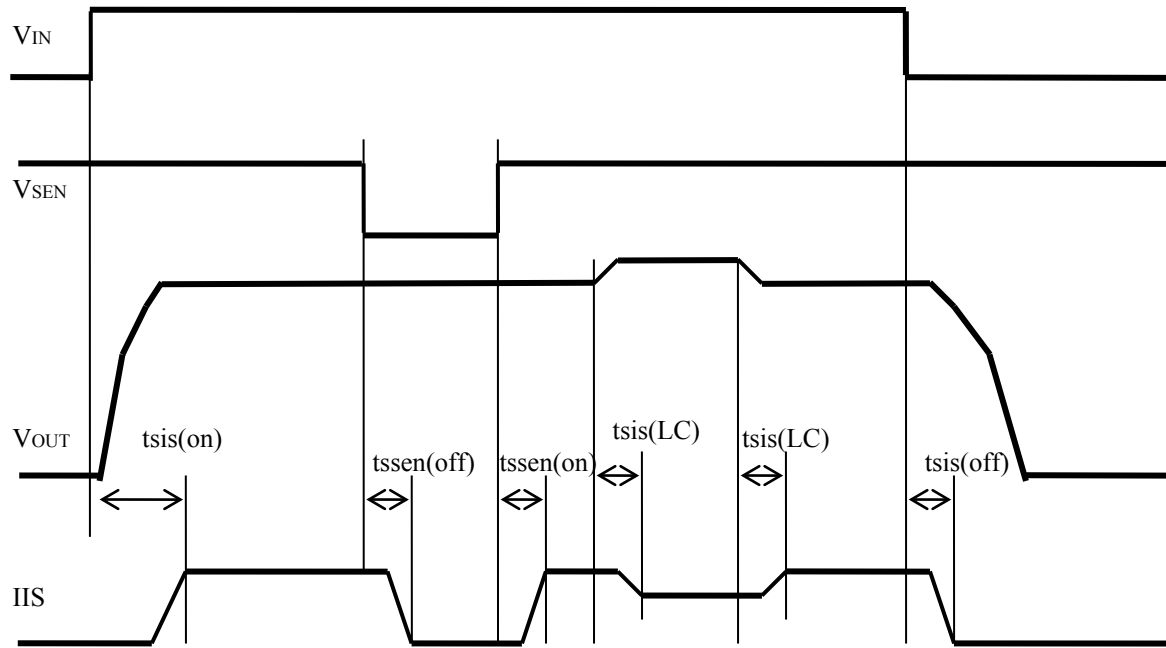


### Sense current under fault condition

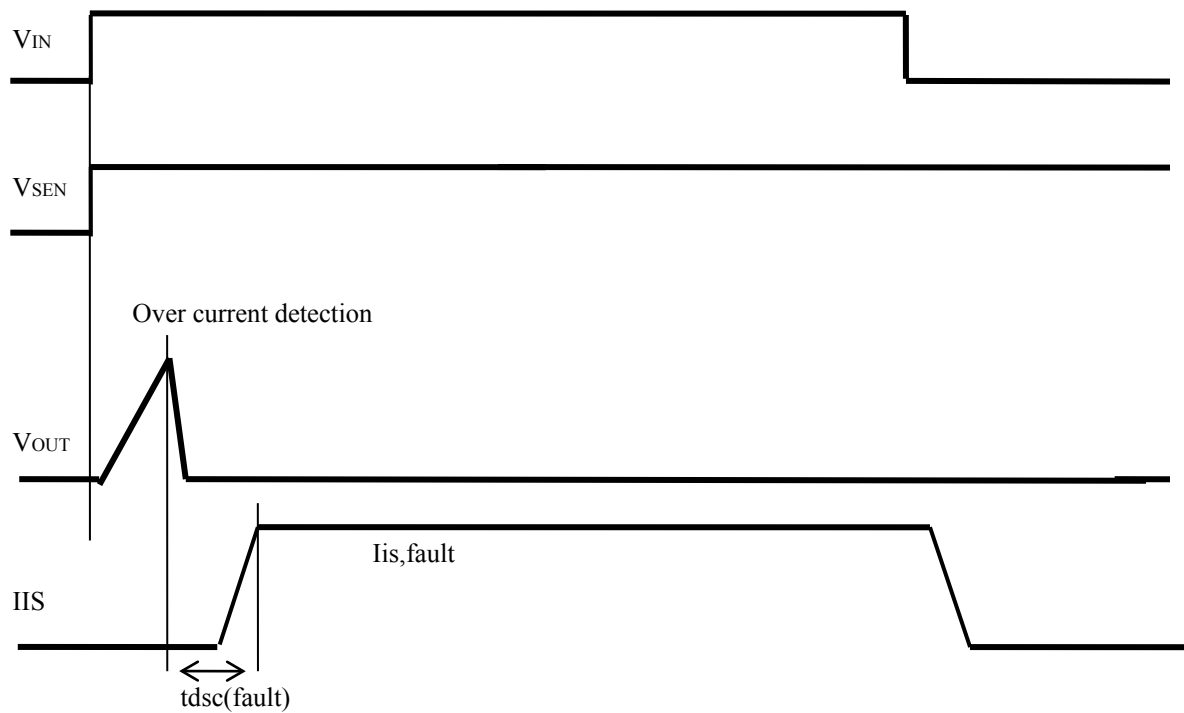
The device output  $I_{IS,fault}$ , constant current, from IS pin under fault condition such as after over current detection, during power limitation and during thermal toggling.  $I_{IS,fault}$  is specified with  $R_{IS}=1k\Omega$  condition.  $I_{IS,fault}$  is attenuated depends on  $V_{CC-VIS}$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



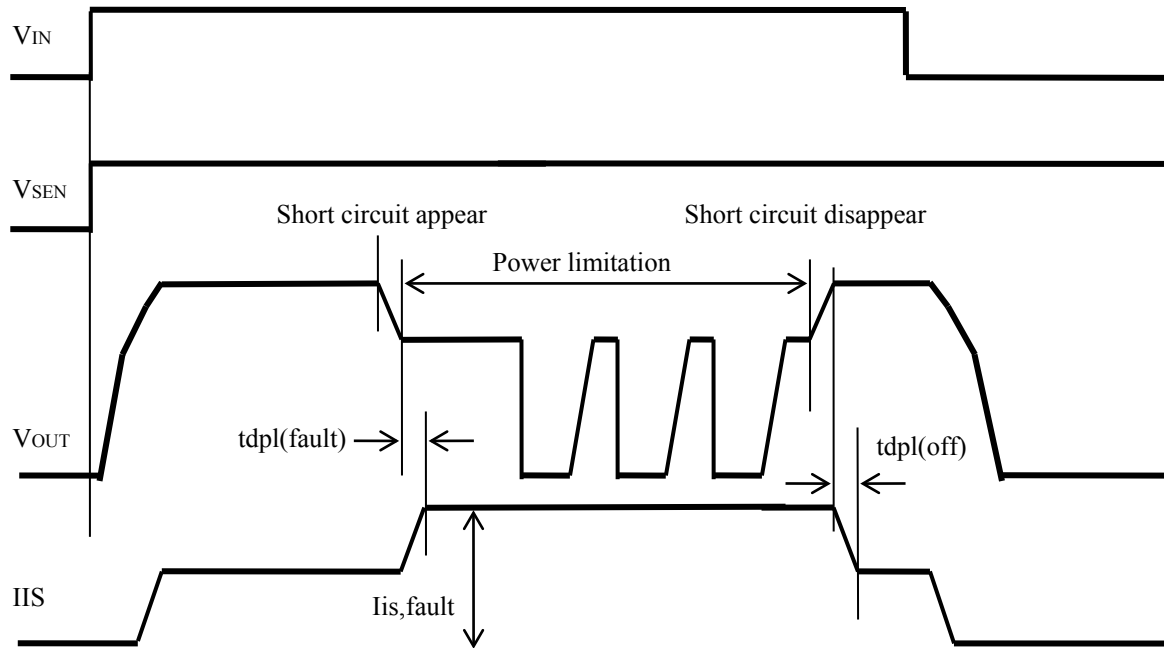
### Sense current settling time



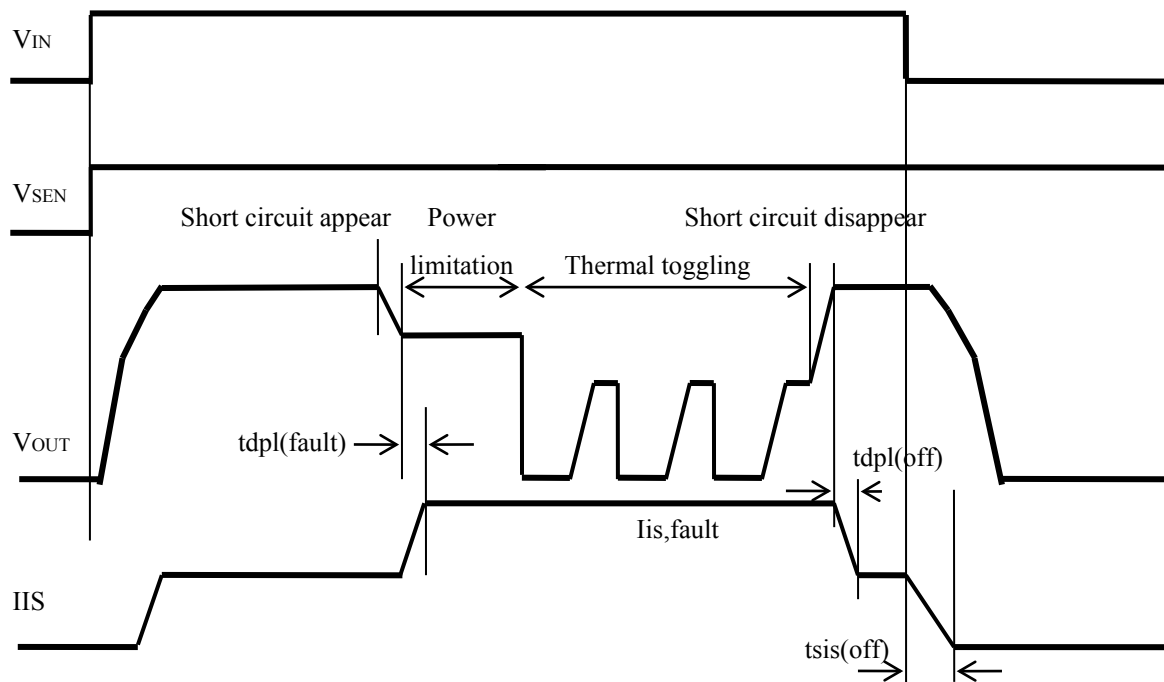
### Fault signal delay time at over current detection



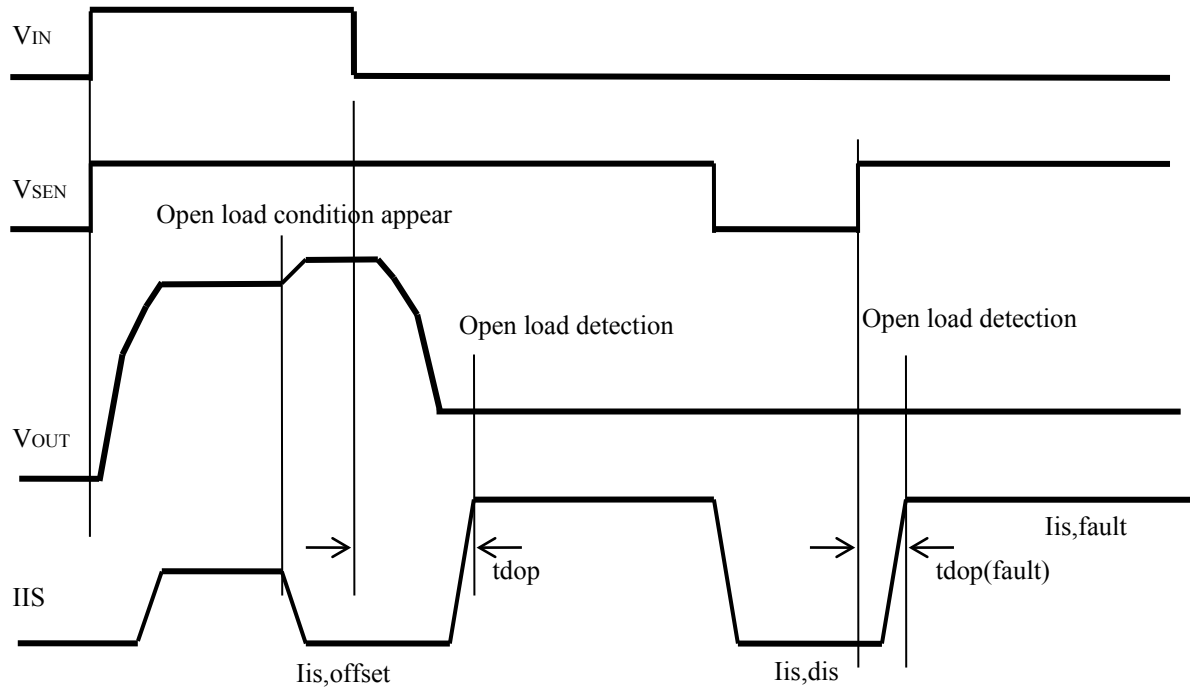
### Fault signal delay time at power limitation



### Fault signal delay time at Thermal toggling



Fault signal delay time at open load detection

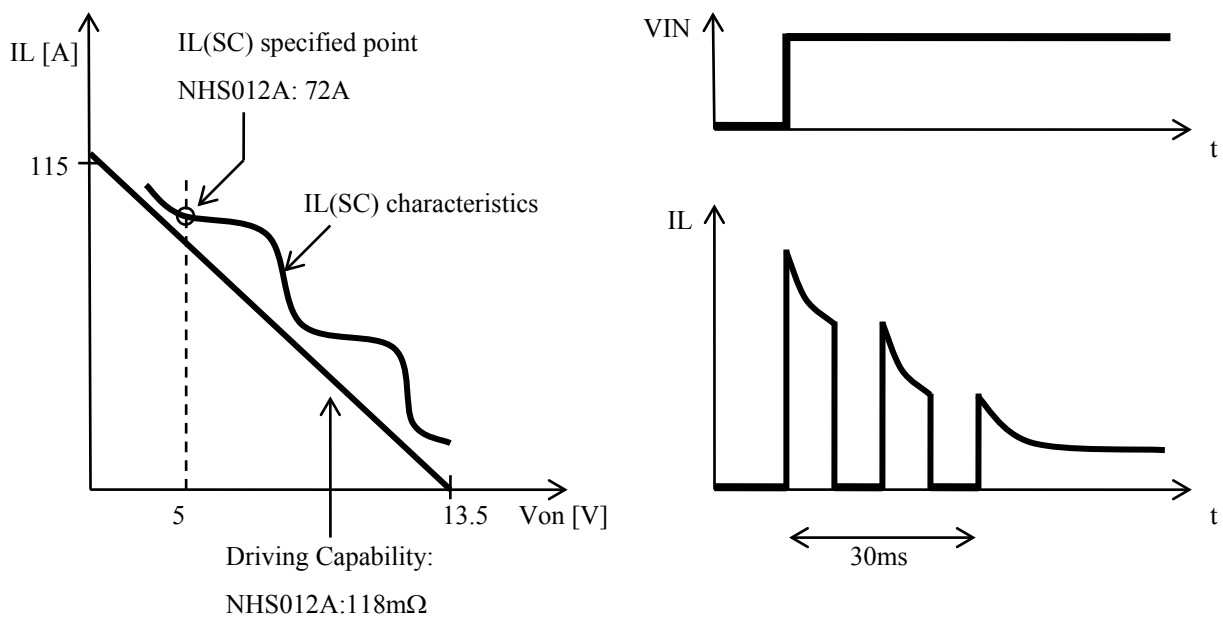


### 3.6.8 Nominal load

| Product | Nominal load |
|---------|--------------|
| NHS012A | 2.0Ω         |

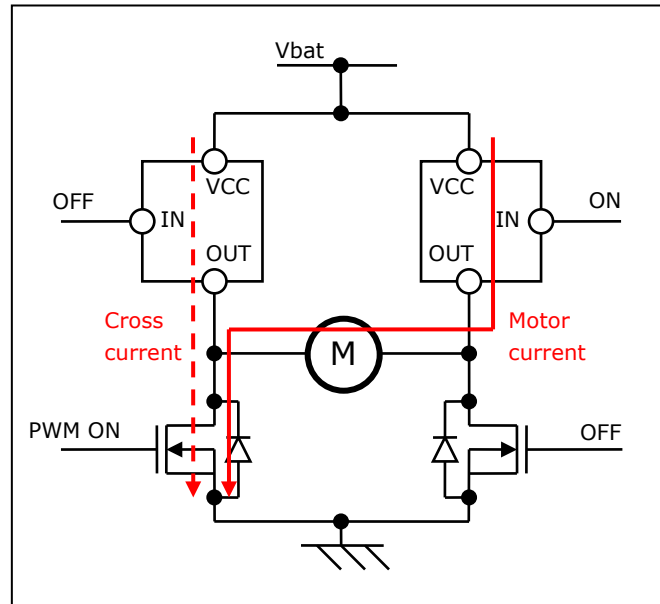
### 3.6.9 Driving Capability

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.



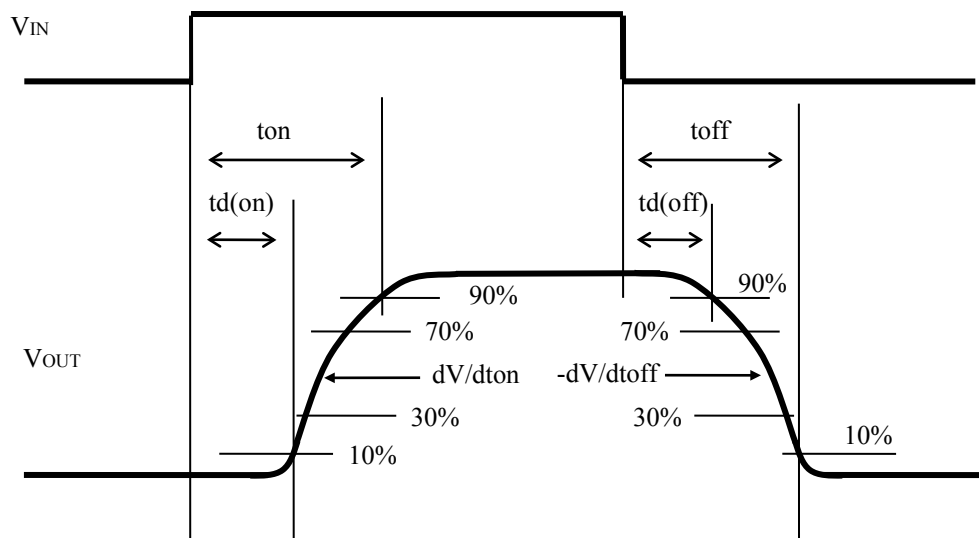
### 3.6.10 Cross current protection in case of H-bridge high side usage

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

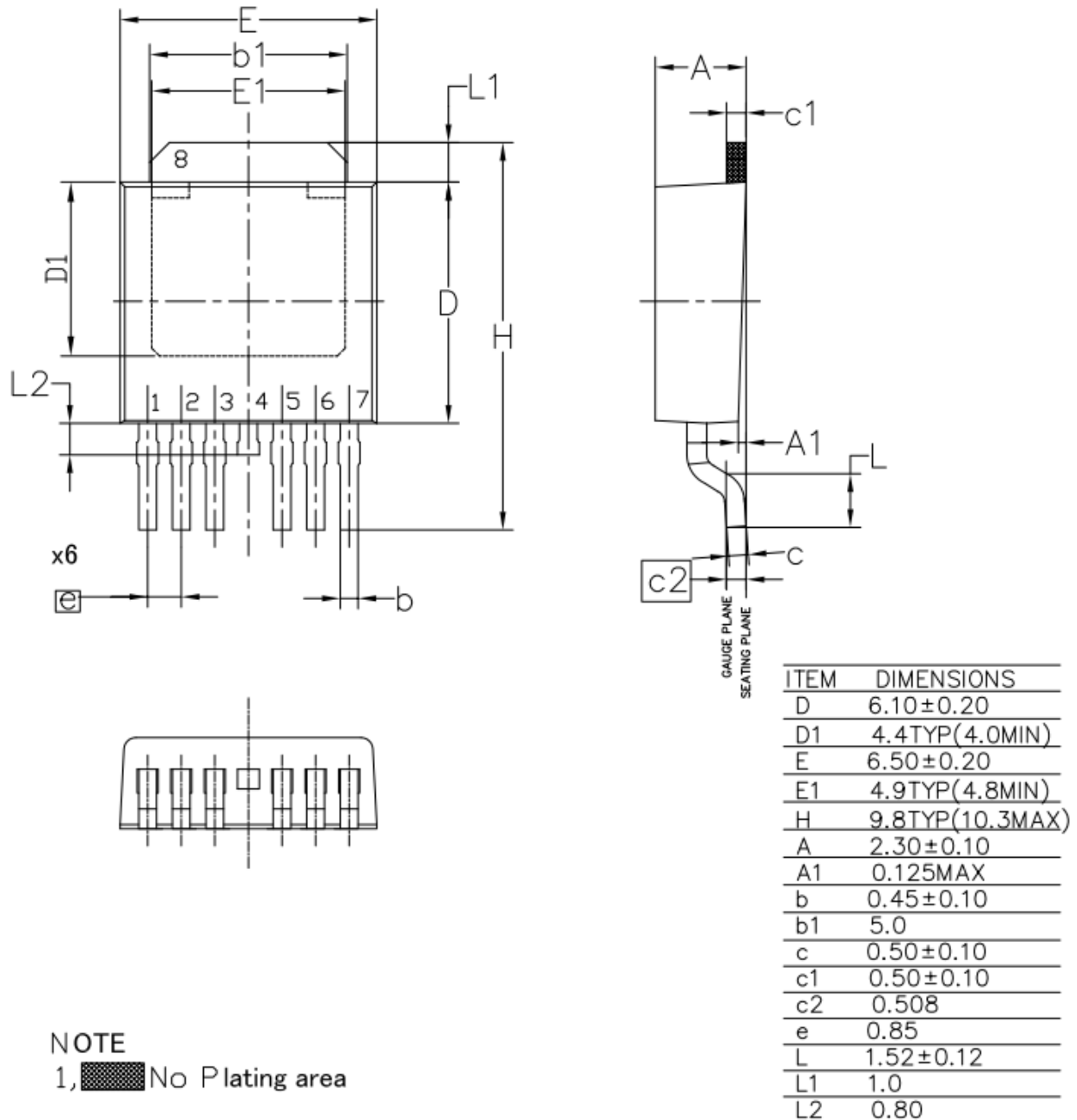
Switching waveform of OUT terminal



### 3.7 Package drawing

| JEITA Package Code | Renesas Code | Previous Code | Mass(TYP.)[g] |
|--------------------|--------------|---------------|---------------|
| -                  | PRSS0008ZA-A | P7J5-85-314   | 0.33          |

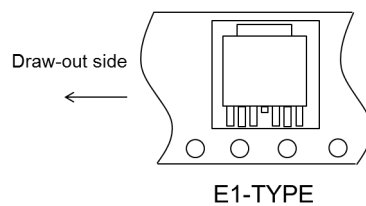
Unit : mm



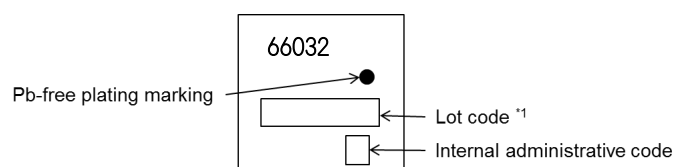
#### NOTE

1,  No Plating area

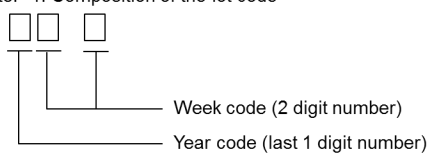
### 3.8 Taping information



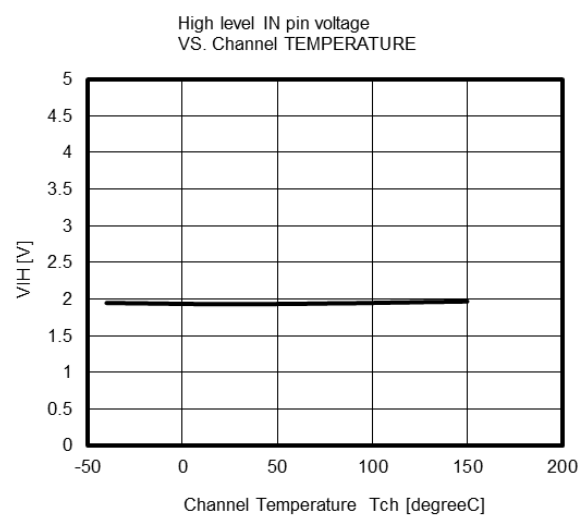
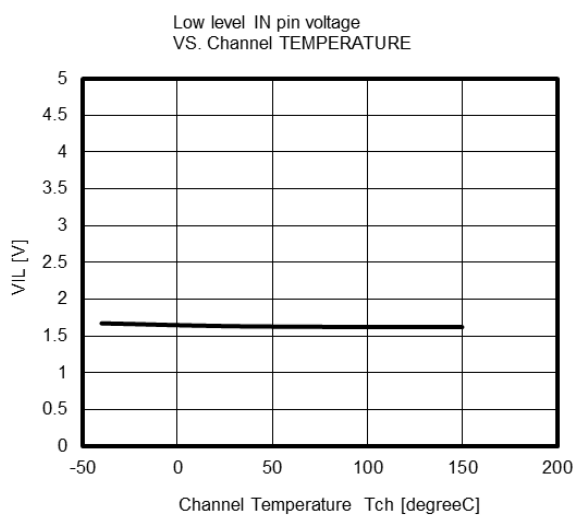
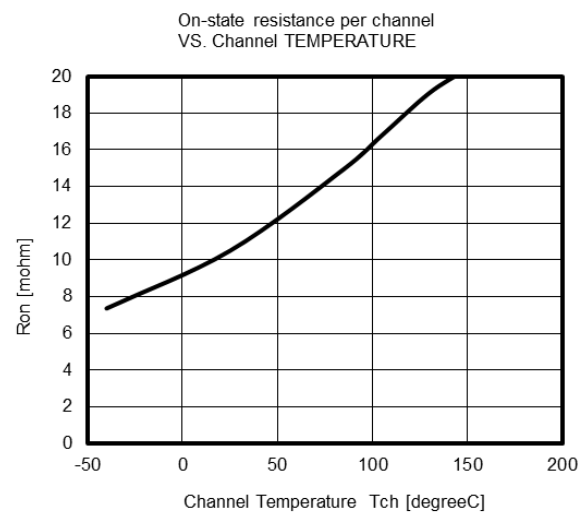
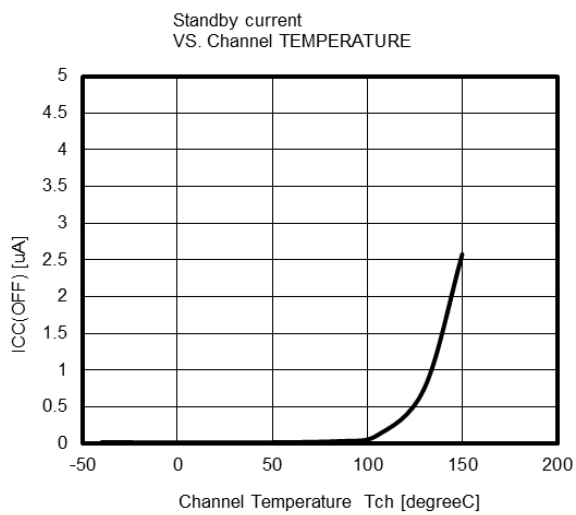
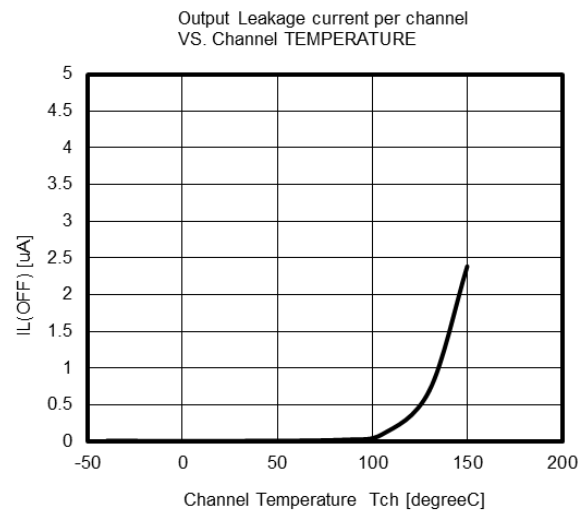
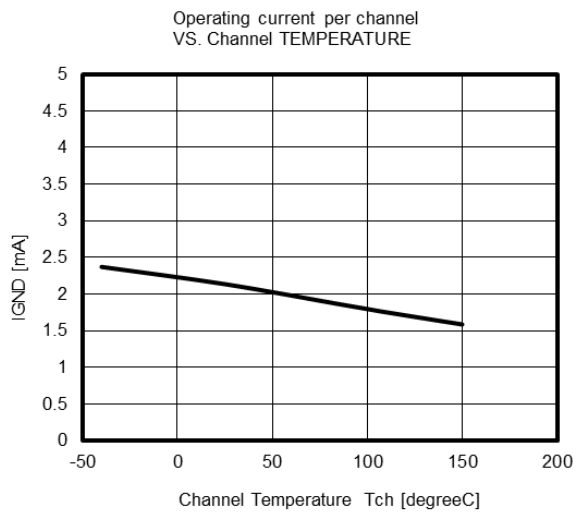
### 3.9 Marking information

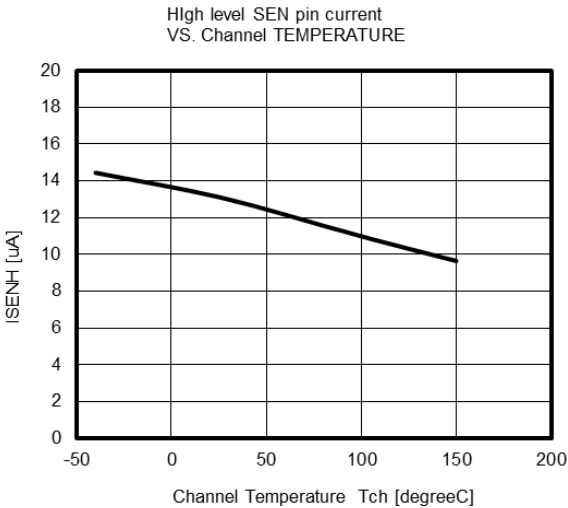
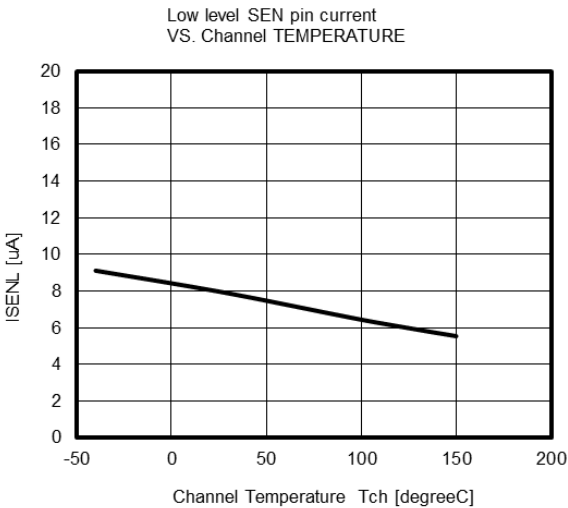
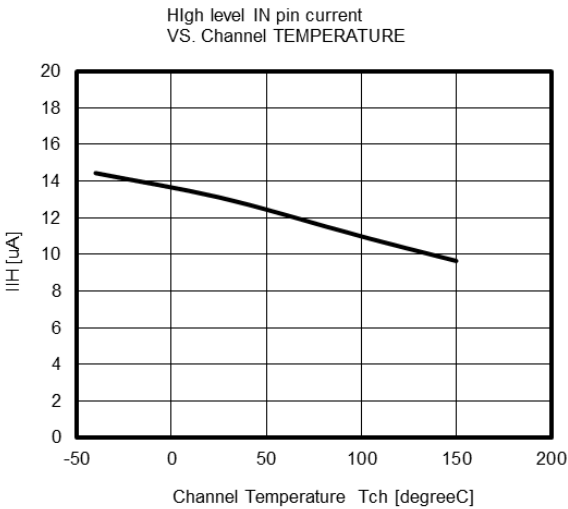
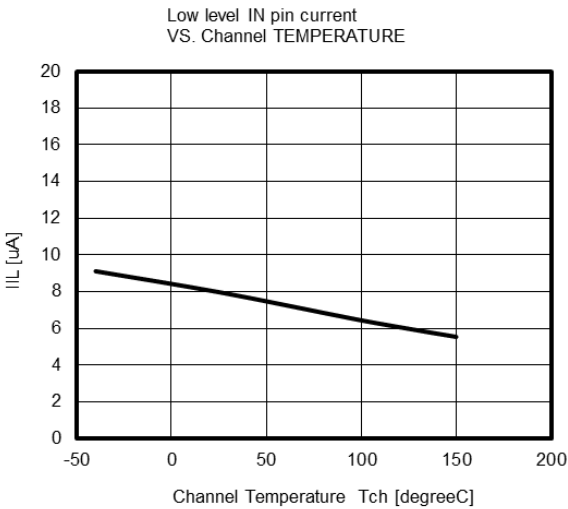
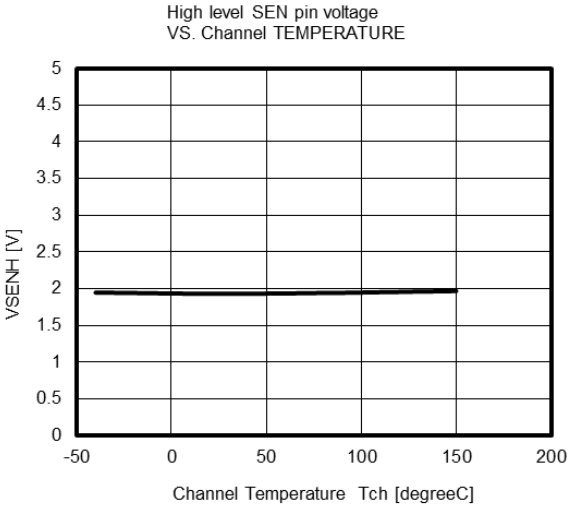
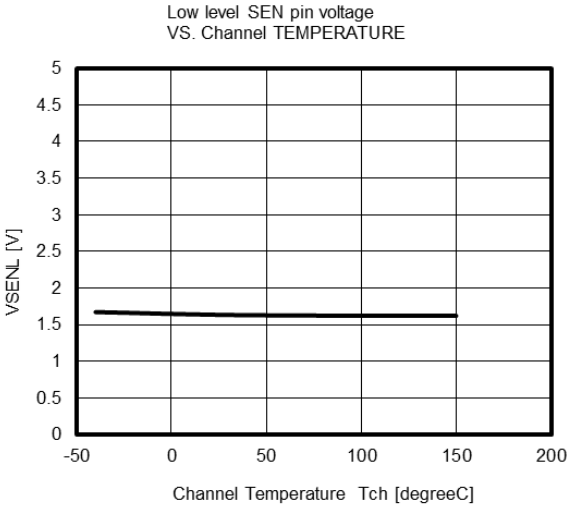


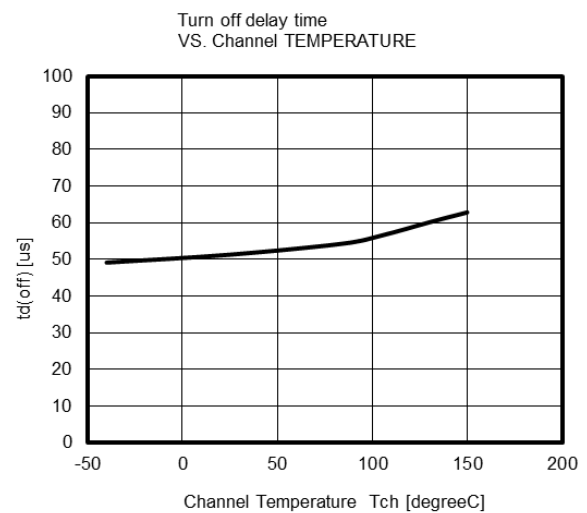
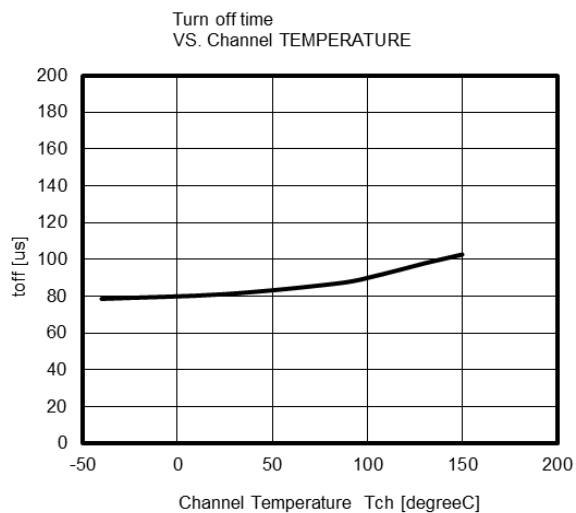
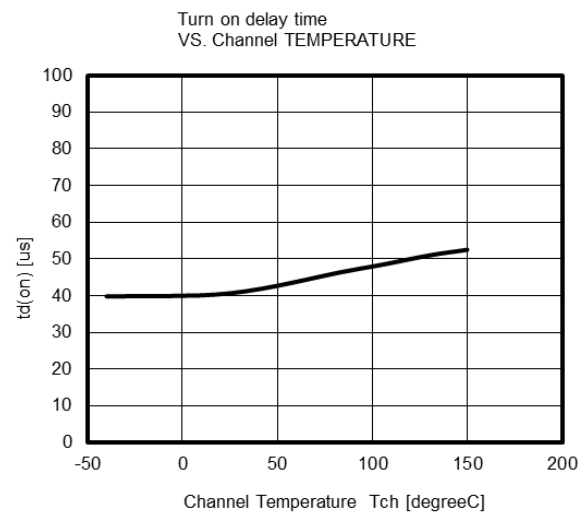
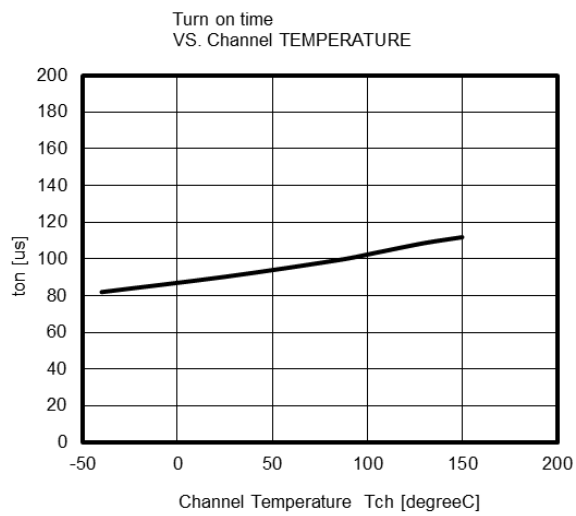
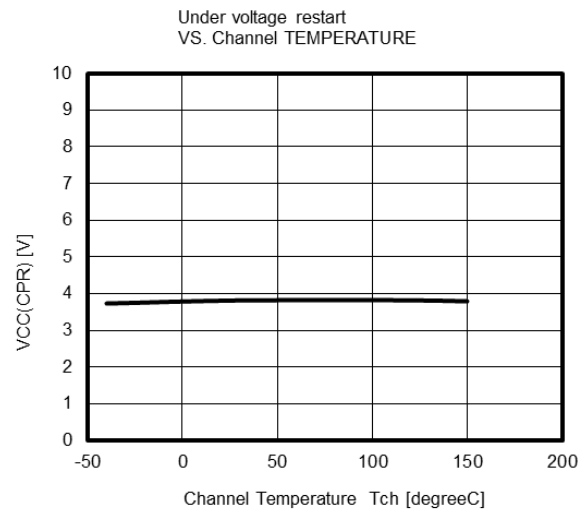
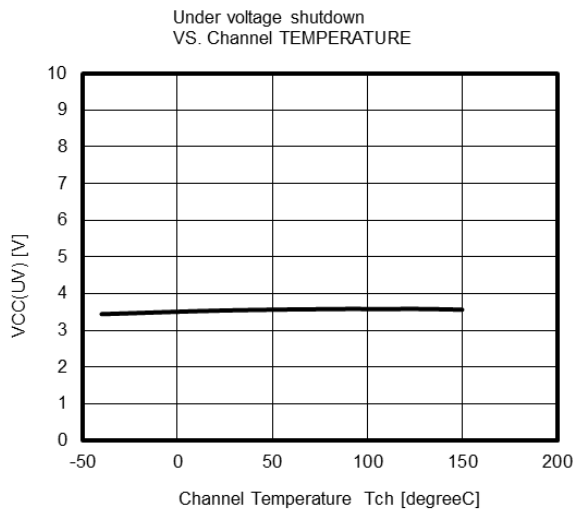
Note: \*1. Composition of the lot code

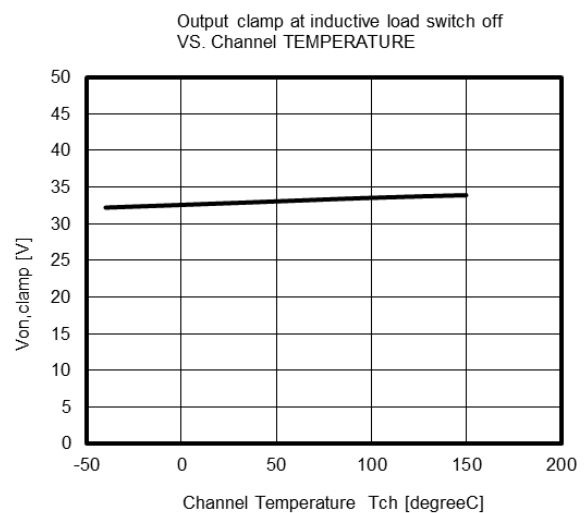
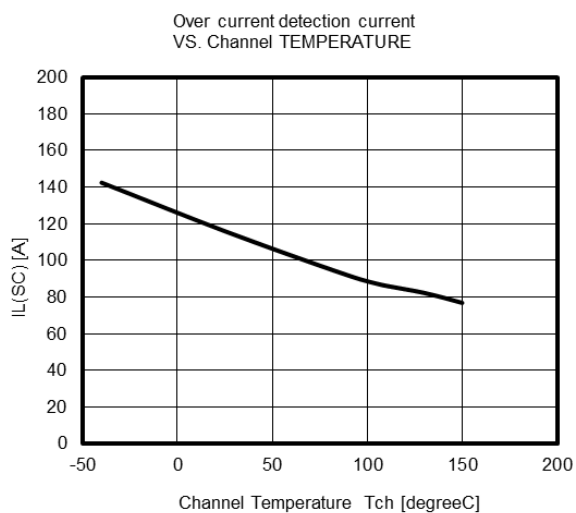
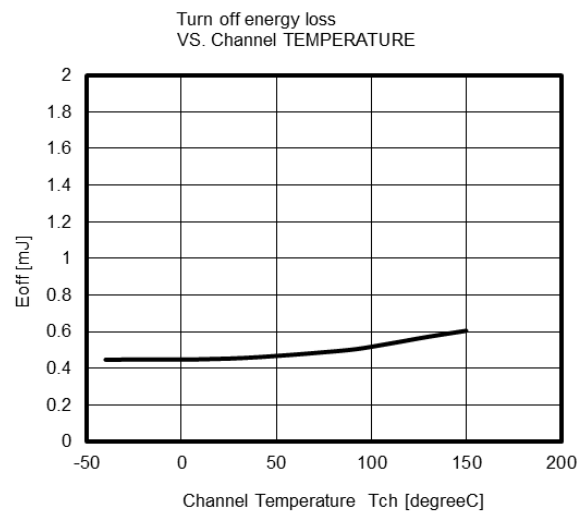
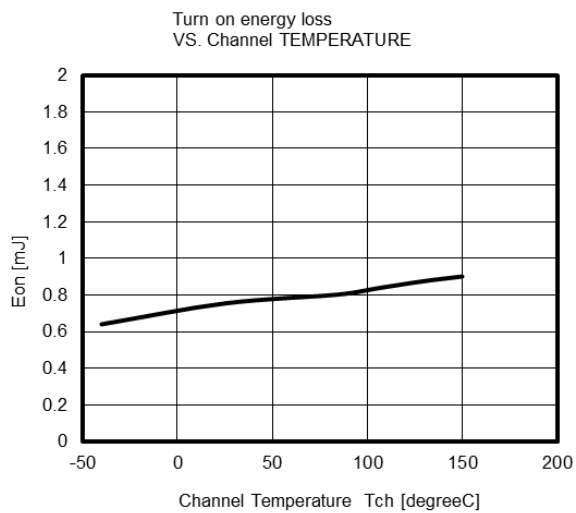
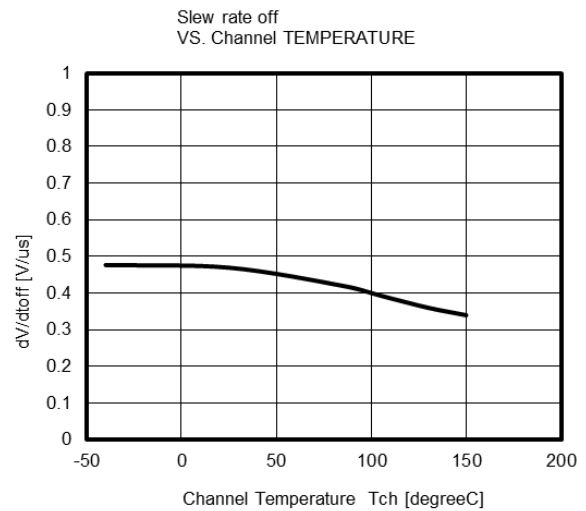
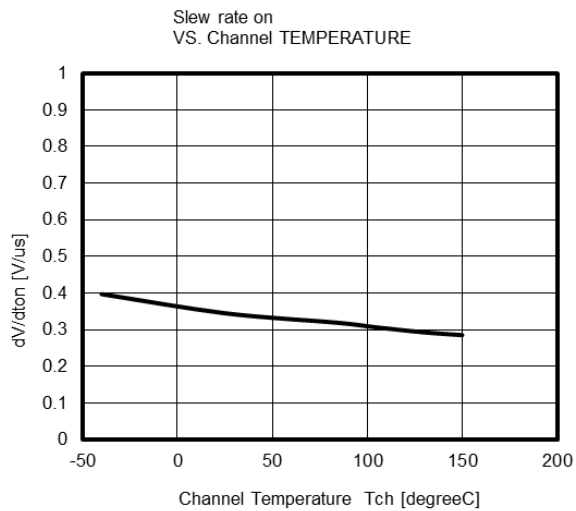


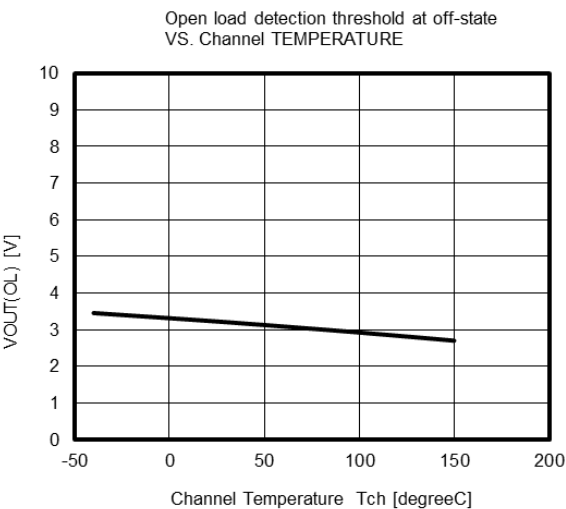
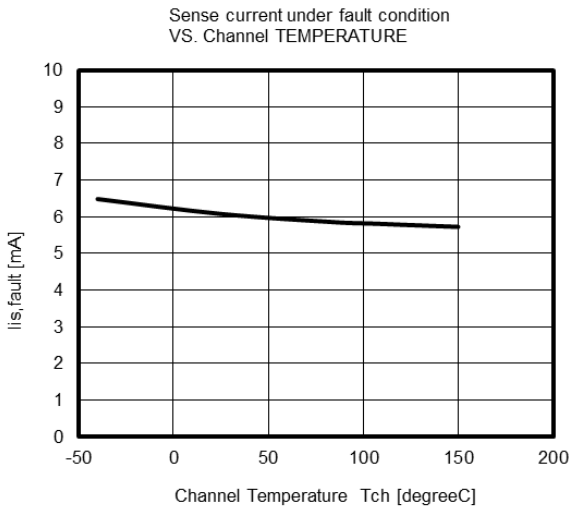
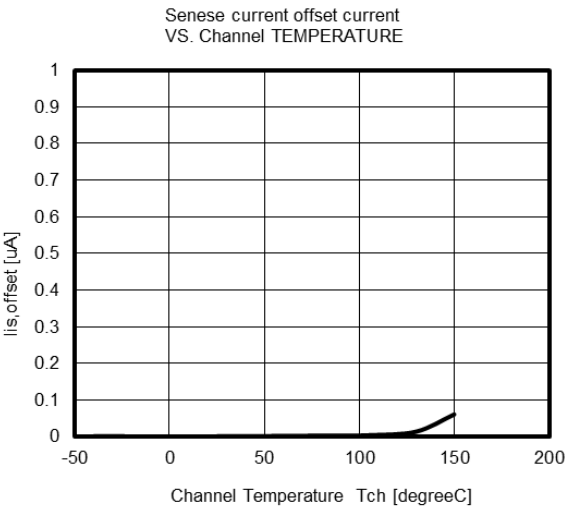
## 4. Typical characteristics



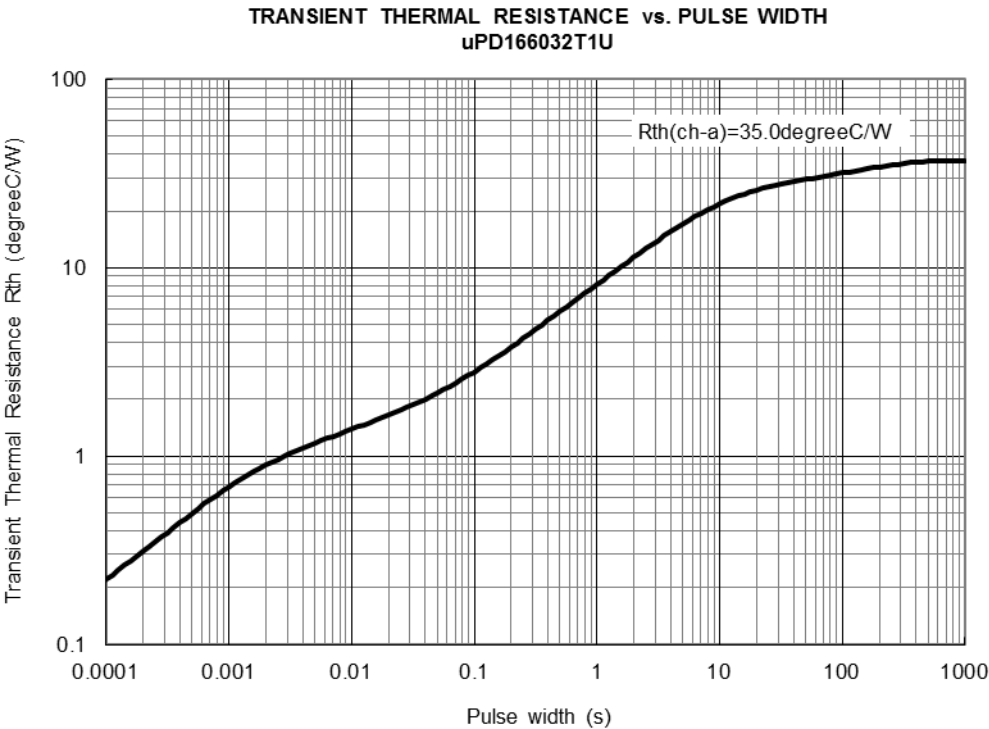




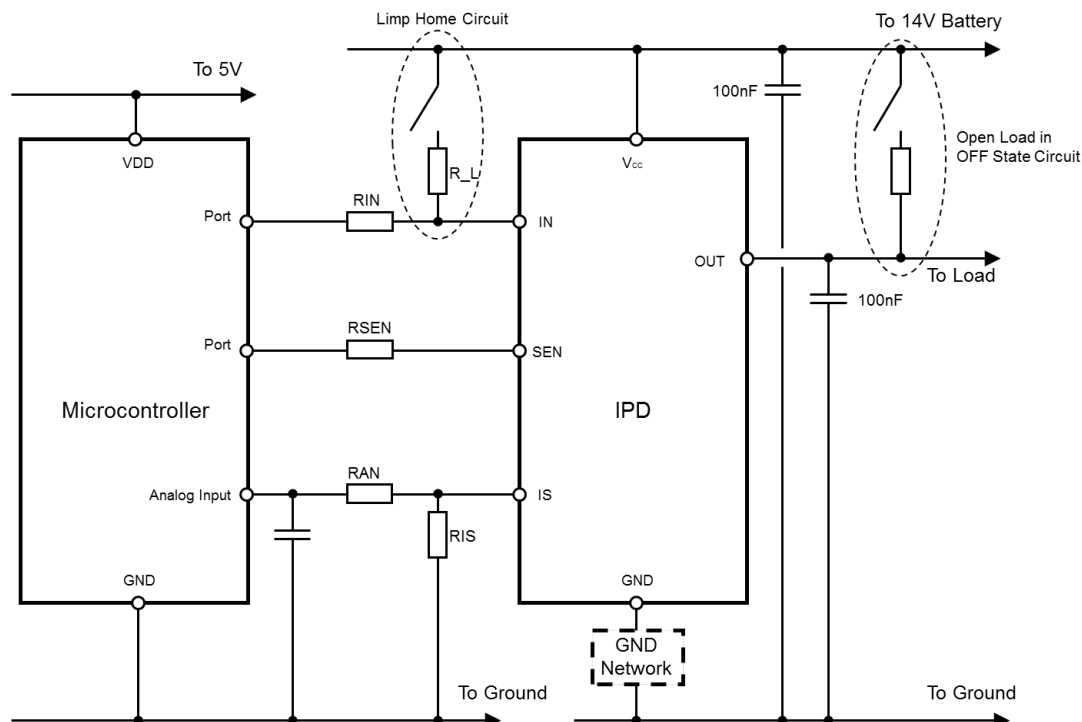




5. Thermal characteristics



## 6. Application example in principle

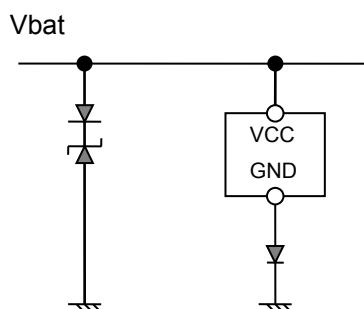


$R_{IN}$ ,  $R_{SEN}$ ,  $R_{AN}$  values are in range of 2k to 50k $\Omega$  depending microcontroller while  $R_L$  value is typically 4k $\Omega$ .

If necessary to raise HBM tolerated dose, adding resistor between OUT terminal and Ground is effective. Resistor's value is typically 100k $\Omega$

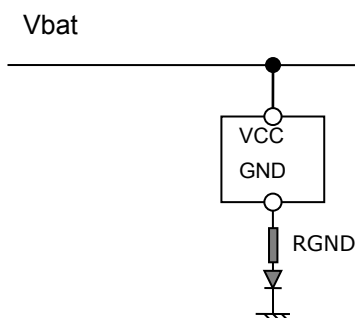
### GND Network recommendation

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



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

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



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  $ZD_{AZ}$  at load dump condition. 100 $\Omega$  is recommended as  $R_{GND}$ .

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

Note: Approx. 1k $\Omega$  additional resistor in parallel with the diode is recommended if  $V_f$  value of the diode is high.

|                         |                               |
|-------------------------|-------------------------------|
| <b>Revision History</b> | <b>μPD166032T1U Datasheet</b> |
|-------------------------|-------------------------------|

| Rev. | Date         | Description |                                                              |
|------|--------------|-------------|--------------------------------------------------------------|
|      |              | Page        | Summary                                                      |
| 1.00 | Mar 27, 2014 | 1-38        | 1st issue                                                    |
| 2.00 | May 22, 2015 | 23          | "Device behavior at small load current conduction" is added. |

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