



## VN5E010AH

### 10 mΩ high-side driver with analog current sense for automotive applications

#### Features

|                          |            |                     |
|--------------------------|------------|---------------------|
| Max supply voltage       | $V_{CC}$   | 41 V                |
| Operating voltage range  | $V_{CC}$   | 4.5 V to 28 V       |
| Typ. ON-state resistance | $R_{ON}$   | 10 mΩ               |
| Current limitation (typ) | $I_{LIMH}$ | 85 A                |
| OFF-state supply current | $I_S$      | 2 μA <sup>(1)</sup> |

1. Typical value with all loads connected

- General
  - Inrush current active management by power limitation
  - Very low standby current
  - 3 V CMOS compatible inputs
  - Optimized electromagnetic emissions
  - Very low electromagnetic susceptibility
  - In compliance with the 2002/95/EC european directive
  - Very low current sense leakage
- Diagnostic functions
  - Proportional load current sense
  - High current sense precision for wide current range
  - Current sense disable
  - OFF-state open-load detection
  - Output short to  $V_{CC}$  detection
  - Overload and short to ground (power limitation) indication
  - Thermal shutdown indication
- Protection
  - Undervoltage shutdown
  - Overvoltage clamp
  - Load current limitation
  - Self limiting of fast thermal transients
  - Protection against loss of ground and loss of  $V_{CC}$
  - Overtemperature shut down with autorestart (thermal shutdown)



- Reverse battery protection with self switch on of the Power MOSFET (see [Figure 32](#))
- Electrostatic discharge protection

#### Applications

- All types of resistive, inductive and capacitive loads
- Suitable as LED driver

#### Description

The VN5E010AH is a single-channel high-side driver manufactured in the ST proprietary VIPower M0-5 technology and housed in the tiny HPak package. The VN5E010AH is designed to drive 12 V automotive grounded loads delivering protection, diagnostics and easy 3 V and 5 V CMOS compatible interface with any microcontroller.

The device integrates advanced protective functions such as load current limitation, inrush and overload active management by power limitation, overtemperature shut-off with auto-restart and overvoltage active clamp. A dedicated analog current sense pin is associated with every output channel in order to provide enhanced diagnostic functions including fast detection of overload and short-circuit to ground through power limitation indication, overtemperature indication, short-circuit to  $V_{CC}$  diagnosis and ON- and OFF-state open-load detection.

The current sensing and diagnostic feedback of the whole device can be disabled by pulling the CS\_DIS pin high to allow sharing of the external sense resistor with other similar devices.

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# 1 Block diagram and pin configuration

Figure 1. Block diagram

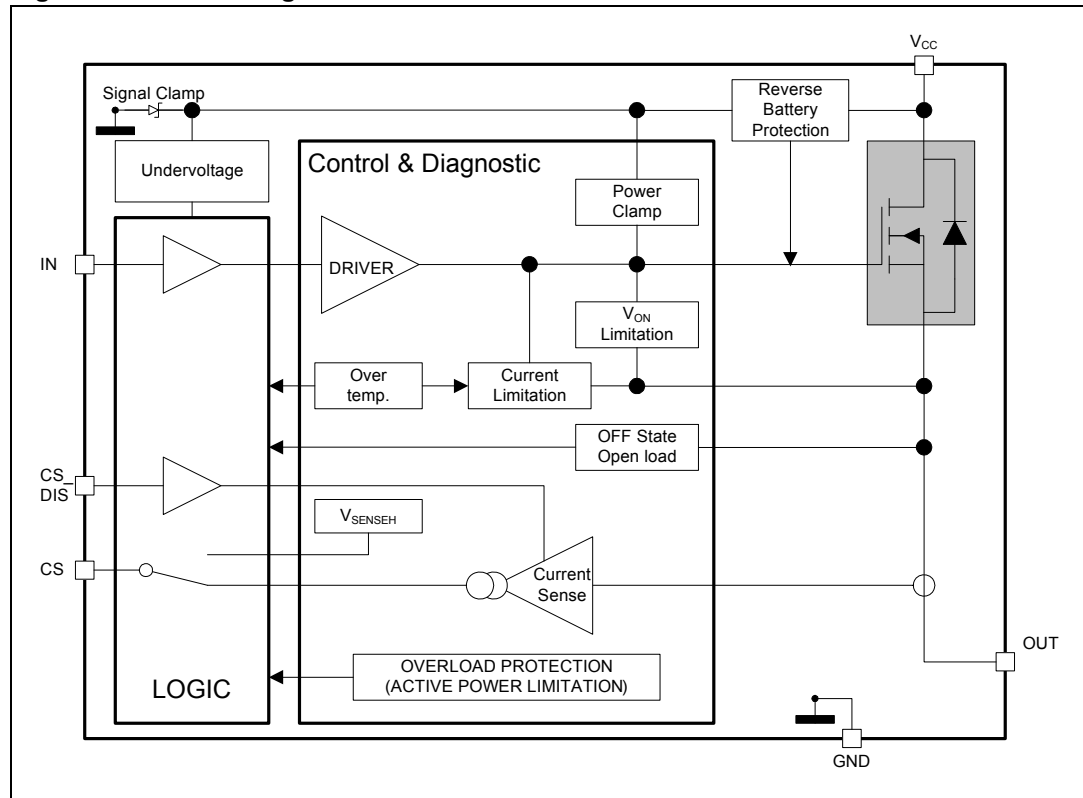


Table 1. Pin functions

| Name            | Function                                                                                    |
|-----------------|---------------------------------------------------------------------------------------------|
| V <sub>CC</sub> | Battery connection                                                                          |
| OUT             | Power output <sup>(1)</sup>                                                                 |
| GND             | Ground connection                                                                           |
| IN              | Voltage controlled input pin with hysteresis, CMOS compatible. Controls output switch state |
| CS              | Analog CS pin, delivers a current proportional to the load current                          |
| CS_DIS          | Active high CMOS compatible pin, to disable the CS pin                                      |

1. Pins 1 and 7 must be externally tied together.

Figure 2. Configuration diagram (top view) not in scale

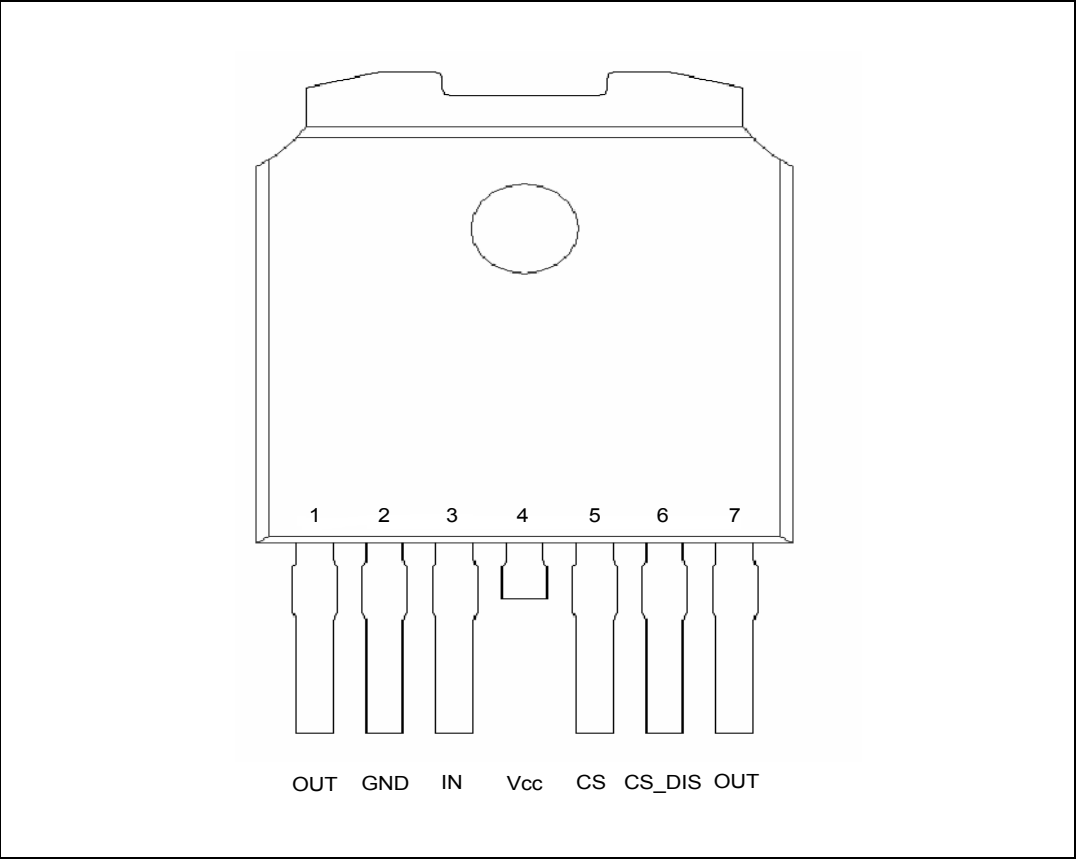
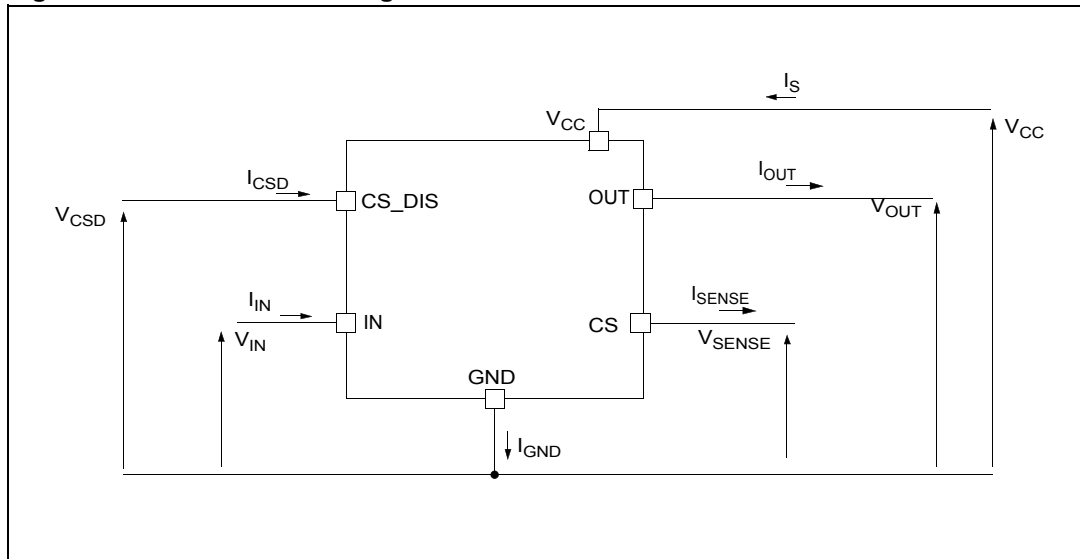


Table 2. Suggested connections for unused and not connected pins

| Connection / pin | CS                    | OUT                    | IN                     | CS_DIS                 |
|------------------|-----------------------|------------------------|------------------------|------------------------|
| Floating         | Not allowed           | X                      | X                      | X                      |
| To ground        | Through 1 kΩ resistor | Through 22 kΩ resistor | Through 10 kΩ resistor | Through 10 kΩ resistor |

## 2 Electrical specifications

Figure 3. Current and voltage conventions



### 2.1 Absolute maximum ratings

Stressing the device above the rating listed in the [Table 3: Absolute maximum ratings](#) may cause permanent damage to the device. These are stress ratings only and operation of the device at these or any other conditions above those indicated in the operating sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. Refer also to the STMicroelectronics SURE program and other relevant quality document.

Table 3. Absolute maximum ratings

| Symbol       | Parameter                                                                                                                                                                                                 | Value                      | Unit   |
|--------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|--------|
| $V_{CC}$     | DC supply voltage                                                                                                                                                                                         | 41                         | V      |
| $-V_{CC}$    | Reverse DC supply voltage                                                                                                                                                                                 | 16                         | V      |
| $I_{OUT}$    | DC output current                                                                                                                                                                                         | Internally limited         | A      |
| $-I_{OUT}$   | Reverse DC output current                                                                                                                                                                                 | 20                         | A      |
| $I_{IN}$     | DC input current                                                                                                                                                                                          | -1 to 10                   | mA     |
| $I_{CSD}$    | DC current sense disable input current                                                                                                                                                                    | -1 to 10                   | mA     |
| $V_{CSENSE}$ | Current sense maximum voltage ( $V_{CC} > 0$ )                                                                                                                                                            | $V_{CC} - 41$<br>$+V_{CC}$ | V<br>V |
| $E_{MAX}$    | Maximum switching energy (single pulse)<br>( $L = 2.2 \text{ mH}$ ; $R_L = 0 \text{ } \Omega$ ; $V_{BAT} = 13.5 \text{ V}$ ; $T_{jstart} = 150 \text{ } ^\circ\text{C}$ ;<br>$I_{OUT} = I_{limL}(Typ.)$ ) | 645                        | mJ     |

**Table 3. Absolute maximum ratings (continued)**

| Symbol    | Parameter                                                                                      | Value      | Unit |
|-----------|------------------------------------------------------------------------------------------------|------------|------|
| $V_{ESD}$ | Electrostatic discharge<br>(human body model: $R = 1.5\text{ k}\Omega$ ; $C = 100\text{ pF}$ ) |            |      |
|           | – IN                                                                                           | 4000       | V    |
|           | – CS                                                                                           | 2000       | V    |
|           | – CS_DIS                                                                                       | 4000       | V    |
|           | – OUT                                                                                          | 5000       | V    |
|           | – $V_{CC}$                                                                                     | 5000       | V    |
| $V_{ESD}$ | Charge device model (CDM-AEC-Q100-011)                                                         | 750        | V    |
| $T_j$     | Junction operating temperature                                                                 | -40 to 150 | °C   |
| $T_{stg}$ | Storage temperature                                                                            | -55 to 150 | °C   |

## 2.2 Thermal data

**Table 4. Thermal data**

| Symbol         | Parameter                           | Max. value | Unit |
|----------------|-------------------------------------|------------|------|
| $R_{thj-case}$ | Thermal resistance junction-case    | 0.55       | °C/W |
| $R_{thj-amb}$  | Thermal resistance junction-ambient | 67.7       | °C/W |



## 2.3 Electrical characteristics

Values specified in this section are for  $8\text{ V} < V_{CC} < 28\text{ V}$ ,  $-40\text{ °C} < T_j < 150\text{ °C}$ , unless otherwise specified.

**Table 5. Power section**

| Symbol        | Parameter                                 | Test conditions                                                                                        | Min. | Typ. | Max. | Unit |
|---------------|-------------------------------------------|--------------------------------------------------------------------------------------------------------|------|------|------|------|
| $V_{CC}$      | Operating supply voltage                  |                                                                                                        | 4.5  | 13   | 28   | V    |
| $V_{USD}$     | Undervoltage shutdown                     |                                                                                                        |      | 3.5  | 4.5  | V    |
| $V_{USDhyst}$ | Undervoltage shutdown hysteresis          |                                                                                                        |      | 0.5  |      | V    |
| $R_{ON}$      | ON-state resistance                       | $I_{OUT} = 6\text{ A}$ ; $T_j = 25\text{ °C}$                                                          |      | 10   |      | mΩ   |
|               |                                           | $I_{OUT} = 6\text{ A}$ ; $T_j = 150\text{ °C}$                                                         |      |      | 20   |      |
|               |                                           | $I_{OUT} = 6\text{ A}$ ; $V_{CC} = 5\text{ V}$ ; $T_j = 25\text{ °C}$                                  |      |      | 13   |      |
| $R_{ON-Rev}$  | $R_{DS(on)}$ in reverse battery condition | $V_{CC} = -13\text{ V}$ ; $I_{OUT} = -6\text{ A}$ ; $T_j = 25\text{ °C}$                               |      | 10   |      | mΩ   |
| $V_{clamp}$   | Clamp voltage                             | $I_{CC} = 20\text{ mA}$ ; $I_{OUT} = 0\text{ A}$                                                       | 41   | 46   | 52   | V    |
| $I_S$         | Supply current                            | OFF-state: $V_{CC} = 13\text{ V}$ ; $T_j = 25\text{ °C}$ ; $V_{IN} = V_{OUT} = V_{SENSE} = 0\text{ V}$ |      | 2    | 5    | μA   |
|               |                                           | ON-state: $V_{CC} = 13\text{ V}$ ; $V_{IN} = 5\text{ V}$ ; $I_{OUT} = 0\text{ A}$                      |      | 1.5  | 3    | mA   |
| $I_{L(off)}$  | OFF-state output current                  | $V_{IN} = V_{OUT} = 0\text{ V}$ ; $V_{CC} = 13\text{ V}$ ; $T_j = 25\text{ °C}$                        | 0    | 0.01 | 3    | μA   |
|               |                                           | $V_{IN} = V_{OUT} = 0\text{ V}$ ; $V_{CC} = 13\text{ V}$ ; $T_j = 125\text{ °C}$                       | 0    |      | 5    |      |

**Table 6. Switching ( $V_{CC} = 13\text{ V}$ ,  $T_j = 25\text{ °C}$ )**

| Symbol                | Parameter                                          | Test conditions                                         | Min. | Typ.                             | Max. | Unit |
|-----------------------|----------------------------------------------------|---------------------------------------------------------|------|----------------------------------|------|------|
| $t_{d(on)}$           | Turn-on delay time                                 | $R_L = 2.2\text{ Ω}$<br>(see <a href="#">Figure 6</a> ) | -    | 40                               | -    | μs   |
| $t_{d(off)}$          | Turn-off delay time                                | $R_L = 2.2\text{ Ω}$<br>(see <a href="#">Figure 6</a> ) | -    | 28                               | -    | μs   |
| $(dV_{OUT}/dt)_{on}$  | Turn-on voltage slope                              | $R_L = 2.2\text{ Ω}$                                    | -    | (see <a href="#">Figure 26</a> ) | -    | V/μs |
| $(dV_{OUT}/dt)_{off}$ | Turn-off voltage slope                             | $R_L = 2.2\text{ Ω}$                                    | -    | (see <a href="#">Figure 28</a> ) | -    | V/μs |
| $W_{ON}$              | Switching energy losses at turn-on ( $t_{won}$ )   | $R_L = 2.2\text{ Ω}$<br>(see <a href="#">Figure 6</a> ) | -    | 2                                | -    | mJ   |
| $W_{OFF}$             | Switching energy losses at turn-off ( $t_{woff}$ ) | $R_L = 2.2\text{ Ω}$<br>(see <a href="#">Figure 6</a> ) | -    | 0.6                              | -    | mJ   |

**Table 7. Logic inputs**

| Symbol          | Parameter                 | Test conditions          | Min. | Typ. | Max. | Unit          |
|-----------------|---------------------------|--------------------------|------|------|------|---------------|
| $V_{IL}$        | Low-level input voltage   |                          |      |      | 0.9  | V             |
| $I_{IL}$        | Low-level input current   | $V_{IN} = 0.9\text{ V}$  | 1    |      |      | $\mu\text{A}$ |
| $V_{IH}$        | High-level input voltage  |                          | 2.1  |      |      | V             |
| $I_{IH}$        | High-level input current  | $V_{IN} = 2.1\text{ V}$  |      |      | 10   | $\mu\text{A}$ |
| $V_{I(hyst)}$   | Input hysteresis voltage  |                          | 0.25 |      |      | V             |
| $V_{ICL}$       | Input clamp voltage       | $I_{IN} = 1\text{ mA}$   | 5.5  |      | 7    | V             |
|                 |                           | $I_{IN} = -1\text{ mA}$  |      | -0.7 |      |               |
| $V_{CSDL}$      | Low-level CS_DIS voltage  |                          |      |      | 0.9  | V             |
| $I_{CSDL}$      | Low-level CS_DIS current  | $V_{CSD} = 0.9\text{ V}$ | 1    |      |      | $\mu\text{A}$ |
| $V_{CSDH}$      | High-level CS_DIS voltage |                          | 2.1  |      |      | V             |
| $I_{CSDH}$      | High-level CS_DIS current | $V_{CSD} = 2.1\text{ V}$ |      |      | 10   | $\mu\text{A}$ |
| $V_{CSD(hyst)}$ | CS_DIS hysteresis voltage |                          | 0.25 |      |      | V             |
| $V_{CSCL}$      | CS_DIS clamp voltage      | $I_{CSD} = 1\text{ mA}$  | 5.5  |      | 7    | V             |
|                 |                           | $I_{CSD} = -1\text{ mA}$ |      | -0.7 |      |               |

**Table 8. Protection and diagnostics<sup>(1)</sup>**

| Symbol      | Parameter                                    | Test conditions                                                                                   | Min.          | Typ.          | Max.          | Unit               |
|-------------|----------------------------------------------|---------------------------------------------------------------------------------------------------|---------------|---------------|---------------|--------------------|
| $I_{limH}$  | Short-circuit current                        | $V_{CC} = 13\text{ V}$                                                                            | 60            | 85            | 120           | A                  |
|             |                                              | $5\text{ V} < V_{CC} < 28\text{ V}$                                                               |               |               | 120           |                    |
| $I_{limL}$  | Short-circuit current during thermal cycling | $V_{CC} = 13\text{ V};$<br>$T_R < T_J < T_{TSD}$                                                  |               | 21            |               | A                  |
| $T_{TSD}$   | Shutdown temperature                         |                                                                                                   | 150           | 175           | 200           | $^{\circ}\text{C}$ |
| $T_R$       | Reset temperature                            |                                                                                                   | $T_{RS} + 1$  | $T_{RS} + 5$  |               | $^{\circ}\text{C}$ |
| $T_{RS}$    | Thermal reset of status                      |                                                                                                   | 135           |               |               | $^{\circ}\text{C}$ |
| $T_{HYST}$  | Thermal hysteresis ( $T_{TSD} - T_R$ )       |                                                                                                   |               | 7             |               | $^{\circ}\text{C}$ |
| $V_{DEMAG}$ | Turn-off output voltage clamp                | $I_{OUT} = 2\text{ A}; V_{IN} = 0;$<br>$L = 6\text{ mH}$                                          | $V_{CC} - 41$ | $V_{CC} - 46$ | $V_{CC} - 52$ | V                  |
| $V_{ON}$    | Output voltage drop limitation               | $I_{OUT} = 0.5\text{ A};$<br>$T_J = -40\text{ }^{\circ}\text{C}$ to $150\text{ }^{\circ}\text{C}$ |               | 25            |               | mV                 |

1. To ensure long term reliability under heavy overload or short-circuit conditions, protection and related diagnostic signals must be used together with a proper software strategy. If the device is subjected to abnormal conditions, this software must limit the duration and number of activation cycles

Table 9. Current sense (8 V < V<sub>CC</sub> < 18 V)

| Symbol                                         | Parameter                                      | Test conditions                                                                                                                          | Min.         | Typ.         | Max.           | Unit |
|------------------------------------------------|------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|--------------|--------------|----------------|------|
| K <sub>0</sub>                                 | I <sub>OUT</sub> /I <sub>SENSE</sub>           | I <sub>OUT</sub> = 0.25 A; V <sub>SENSE</sub> = 0.5 V<br>T <sub>j</sub> = -40 °C to 150 °C<br>T <sub>j</sub> = 25 °C to 150 °C           | 3000<br>3000 | 7410<br>7410 | 12000<br>11600 |      |
| K <sub>1</sub>                                 | I <sub>OUT</sub> /I <sub>SENSE</sub>           | I <sub>OUT</sub> = 6 A; V <sub>SENSE</sub> = 0.5 V<br>T <sub>j</sub> = -40 °C to 150 °C<br>T <sub>j</sub> = 25 °C to 150 °C              | 5350<br>5510 | 6740<br>6740 | 8500<br>7745   |      |
| dK <sub>1</sub> /K <sub>1</sub> <sup>(1)</sup> | Current sense ratio drift                      | I <sub>OUT</sub> = 6 A; V <sub>SENSE</sub> = 0.5 V;<br>V <sub>CSD</sub> = 0 V;<br>T <sub>j</sub> = -40 °C to 150 °C                      | -15          |              | 15             | %    |
| K <sub>2</sub>                                 | I <sub>OUT</sub> /I <sub>SENSE</sub>           | I <sub>OUT</sub> = 10 A; V <sub>SENSE</sub> = 4 V<br>T <sub>j</sub> = -40 °C to 150 °C<br>T <sub>j</sub> = 25 °C to 150 °C               | 5850<br>5800 | 6570<br>6570 | 7690<br>7195   |      |
| dK <sub>2</sub> /K <sub>2</sub> <sup>(1)</sup> | Current sense ratio drift                      | I <sub>OUT</sub> = 10 A; V <sub>SENSE</sub> = 4 V;<br>V <sub>CSD</sub> = 0 V;<br>T <sub>j</sub> = -40 °C to 150 °C                       | -11          |              | 11             | %    |
| K <sub>3</sub>                                 | I <sub>OUT</sub> /I <sub>SENSE</sub>           | I <sub>OUT</sub> = 25 A; V <sub>SENSE</sub> = 4 V<br>T <sub>j</sub> = -40 °C to 150 °C<br>T <sub>j</sub> = 25 °C to 150 °C               | 5915<br>5850 | 6420<br>6420 | 7000<br>6755   |      |
| dK <sub>3</sub> /K <sub>3</sub> <sup>(1)</sup> | Current sense ratio drift                      | I <sub>OUT</sub> = 25 A; V <sub>SENSE</sub> = 4 V;<br>V <sub>CSD</sub> = 0 V;<br>T <sub>j</sub> = -40 °C to 150 °C                       | -8           |              | 8              | %    |
| I <sub>SENSE0</sub>                            | Analog sense leakage current                   | I <sub>OUT</sub> = 0 A; V <sub>SENSE</sub> = 0 V;<br>V <sub>CSD</sub> = 5 V; V <sub>IN</sub> = 0 V;<br>T <sub>j</sub> = -40 °C to 150 °C | 0            |              | 1              | μA   |
|                                                |                                                | I <sub>OUT</sub> = 0 A; V <sub>SENSE</sub> = 0 V;<br>V <sub>CSD</sub> = 0 V; V <sub>IN</sub> = 5 V;<br>T <sub>j</sub> = -40 °C to 150 °C | 0            |              | 2              |      |
|                                                |                                                | I <sub>OUT</sub> = 2 A; V <sub>SENSE</sub> = 0 V;<br>V <sub>CSD</sub> = 5 V; V <sub>IN</sub> = 5 V;<br>T <sub>j</sub> = -40 °C to 150 °C |              |              | 1              |      |
| I <sub>OL</sub>                                | Open load ON-state current detection threshold | V <sub>IN</sub> = 5 V, 8 V < V <sub>CC</sub> < 18 V<br>I <sub>SENSE</sub> = 5 μA                                                         | 5            |              | 80             | mA   |
| V <sub>SENSE</sub>                             | Max analog sense output voltage                | I <sub>OUT</sub> = 18 A; R <sub>SENSE</sub> = 3.9 kΩ                                                                                     | 5            |              |                | V    |
| V <sub>SENSEH</sub> <sup>(2)</sup>             | Analog sense output voltage in fault condition | V <sub>CC</sub> = 13 V; R <sub>SENSE</sub> = 3.9 kΩ                                                                                      |              | 8            |                | V    |
| I <sub>SENSEH</sub> <sup>(2)</sup>             | Analog sense output current in fault condition | V <sub>CC</sub> = 13 V; V <sub>SENSE</sub> = 5 V                                                                                         |              | 9            |                | mA   |

**Table 9. Current sense (8 V < V<sub>CC</sub> < 18 V) (continued)**

| Symbol                 | Parameter                                                                                  | Test conditions                                                                                                                                                                                | Min. | Typ. | Max. | Unit |
|------------------------|--------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------|------|------|
| t <sub>DSENSE1H</sub>  | Delay response time from falling edge of CS_DIS pin                                        | V <sub>SENSE</sub> < 4 V,<br>1.5 A < I <sub>OUT</sub> < 25 A<br>I <sub>SENSE</sub> = 90% of I <sub>SENSE max</sub><br>(see <a href="#">Figure 4</a> )                                          |      | 50   | 100  | μs   |
| t <sub>DSENSE1L</sub>  | Delay response time from rising edge of CS_DIS pin                                         | V <sub>SENSE</sub> < 4 V,<br>1.5 A < I <sub>OUT</sub> < 25 A<br>I <sub>SENSE</sub> = 10% of I <sub>SENSE max</sub><br>(see <a href="#">Figure 4</a> )                                          |      | 5    | 20   | μs   |
| t <sub>DSENSE2H</sub>  | Delay response time from rising edge of IN pin                                             | V <sub>SENSE</sub> < 4 V,<br>1.5 A < I <sub>OUT</sub> < 25 A<br>I <sub>SENSE</sub> = 90% of I <sub>SENSE max</sub><br>(see <a href="#">Figure 4</a> )                                          |      | 270  | 600  | μs   |
| Δt <sub>DSENSE2H</sub> | Delay response time between rising edge of output current and rising edge of current sense | V <sub>SENSE</sub> < 4 V,<br>I <sub>SENSE</sub> = 90% of I <sub>SENSEMAX</sub> ,<br>I <sub>OUT</sub> = 90% of I <sub>OUTMAX</sub><br>I <sub>OUTMAX</sub> = 3 A (see <a href="#">Figure 7</a> ) |      |      | 310  | μs   |
| t <sub>DSENSE2L</sub>  | Delay response time from falling edge of IN pin                                            | V <sub>SENSE</sub> < 4 V,<br>1.5 A < I <sub>OUT</sub> < 25 A<br>I <sub>SENSE</sub> = 10% of I <sub>SENSE max</sub><br>(see <a href="#">Figure 4</a> )                                          |      | 100  | 250  | μs   |

1. Parameter guaranteed by design, it is not tested.
2. Fault condition includes: power limitation, over-temperature and open load OFF-state detection.

**Table 10. Open load detection (8 V < V<sub>CC</sub> < 18 V)**

| Symbol                | Parameter                                                                             | Test conditions                                                                                                           | Min. | Typ.                         | Max. | Unit |
|-----------------------|---------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|------|------------------------------|------|------|
| V <sub>OL</sub>       | Open-load OFF-state voltage detection threshold                                       | V <sub>IN</sub> = 0 V                                                                                                     | 2    | See <a href="#">Figure 5</a> | 4    | V    |
| t <sub>DSTKON</sub>   | Output short-circuit to V <sub>CC</sub> detection delay at turn-off                   | See <a href="#">Figure 5</a>                                                                                              | 180  |                              | 1200 | μs   |
| I <sub>L(off2)r</sub> | OFF-state output current at V <sub>OUT</sub> = 4 V                                    | V <sub>IN</sub> = 0 V; V <sub>SENSE</sub> = 0 V<br>V <sub>OUT</sub> rising from 0 V to 4 V                                | -120 |                              | 90   | μA   |
| I <sub>L(off2)f</sub> | OFF-state output current at V <sub>OUT</sub> = 2 V                                    | V <sub>IN</sub> = 0 V; V <sub>SENSE</sub> = V <sub>SENSEH</sub> ;<br>V <sub>OUT</sub> falling from V <sub>CC</sub> to 2 V | -50  |                              | 90   | μA   |
| t <sub>d_vol</sub>    | Delay response from output rising edge to V <sub>SENSE</sub> rising edge in open-load | V <sub>OUT</sub> = 4 V; V <sub>IN</sub> = 0 V<br>V <sub>SENSE</sub> = 90% of V <sub>SENSEH</sub>                          |      |                              | 20   | μs   |

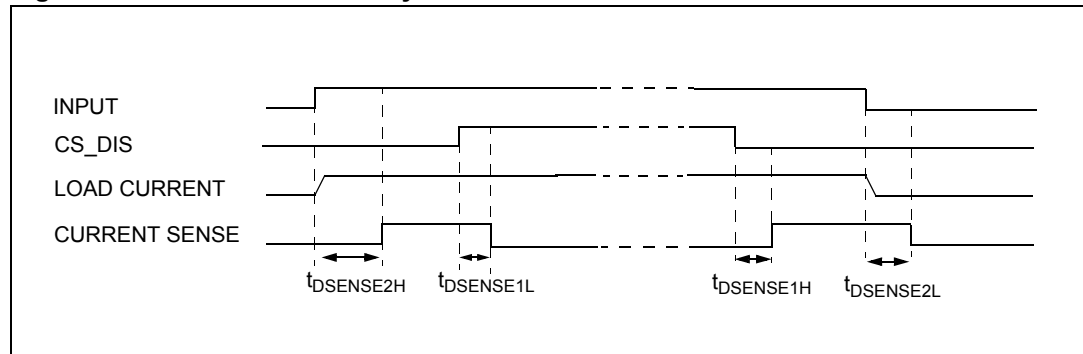
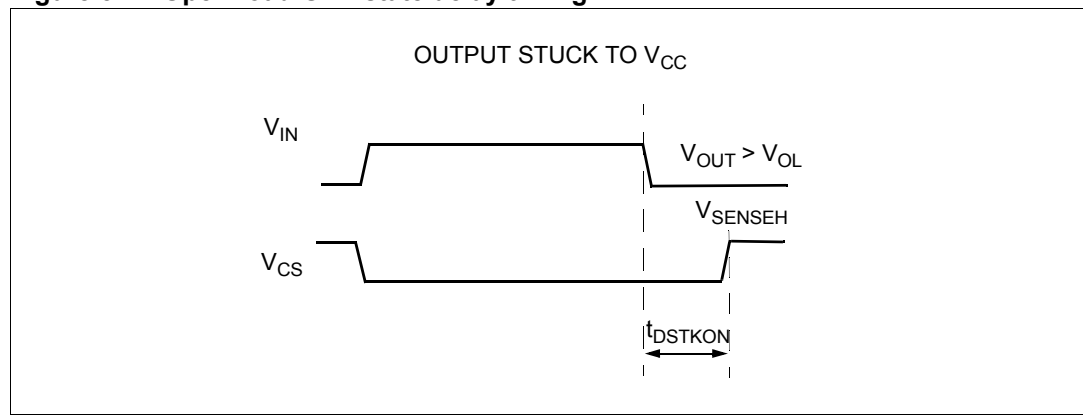
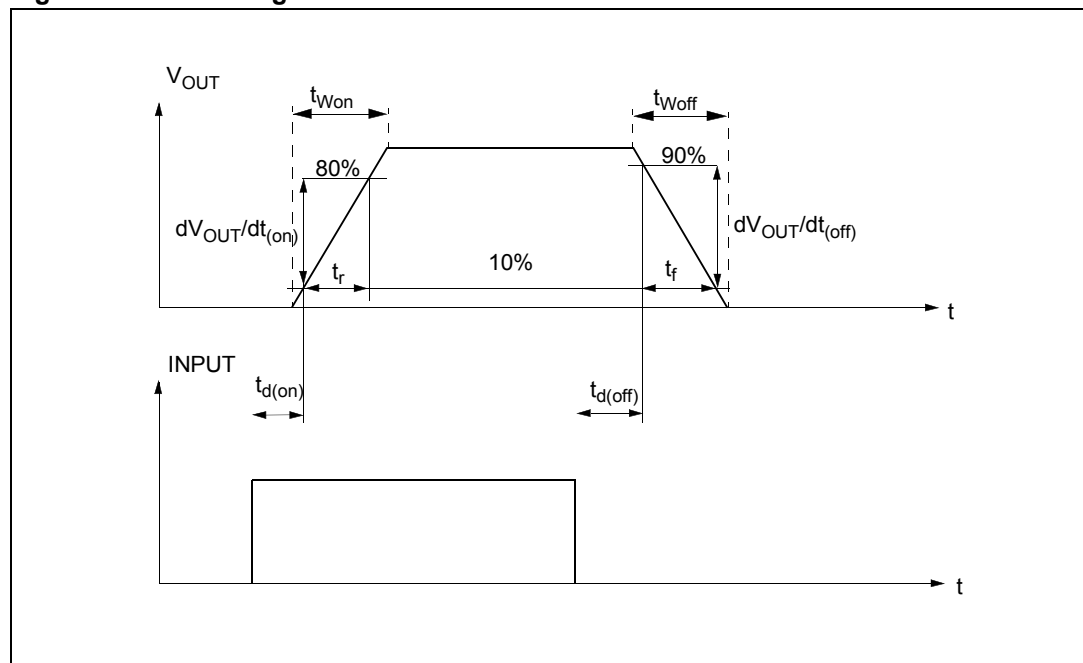
**Figure 4. Current sense delay characteristics****Figure 5. Open-load OFF-state delay timing****Figure 6. Switching characteristics**

Figure 7. Delay response time between rising edge of output current and rising edge of current sense (CS enabled)

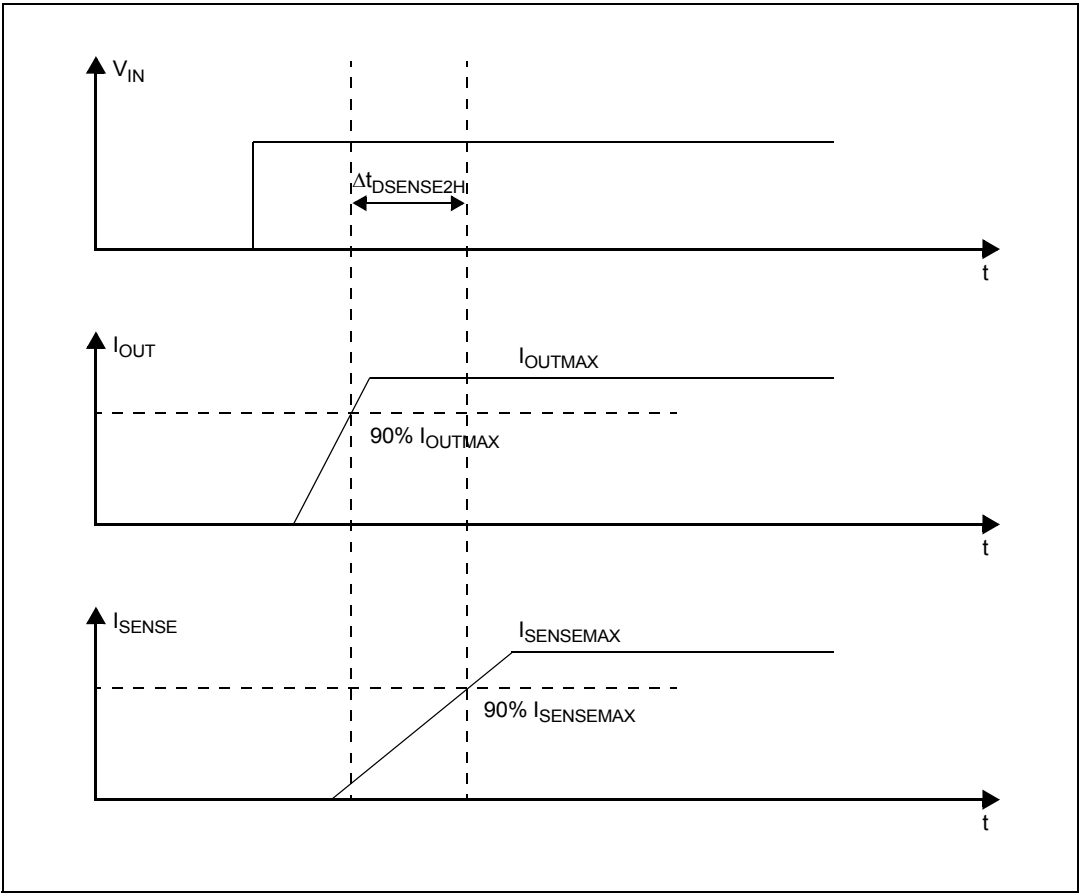


Figure 8. Output voltage drop limitation

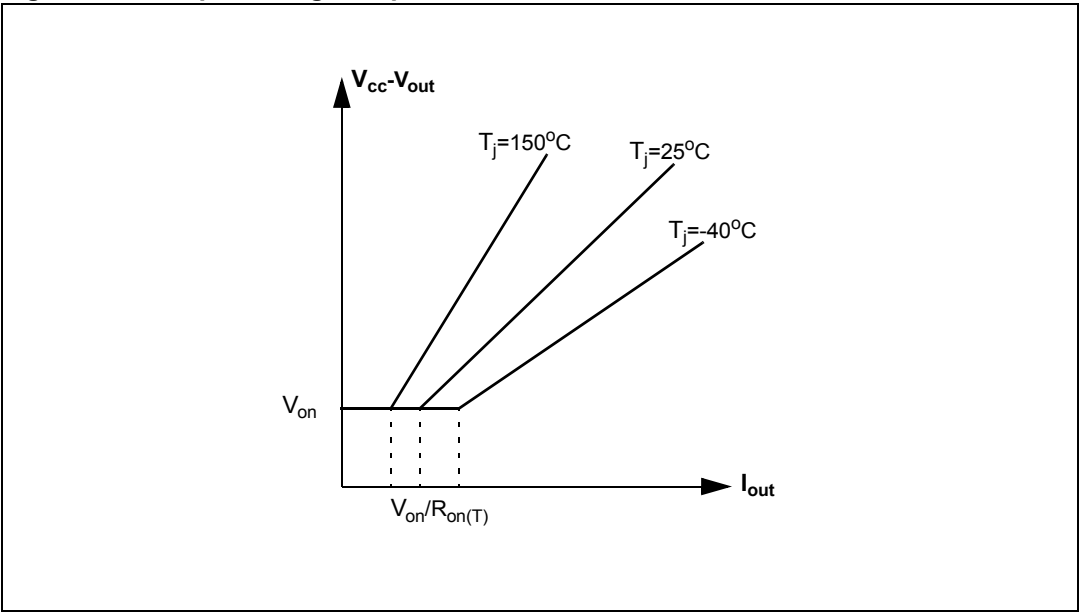
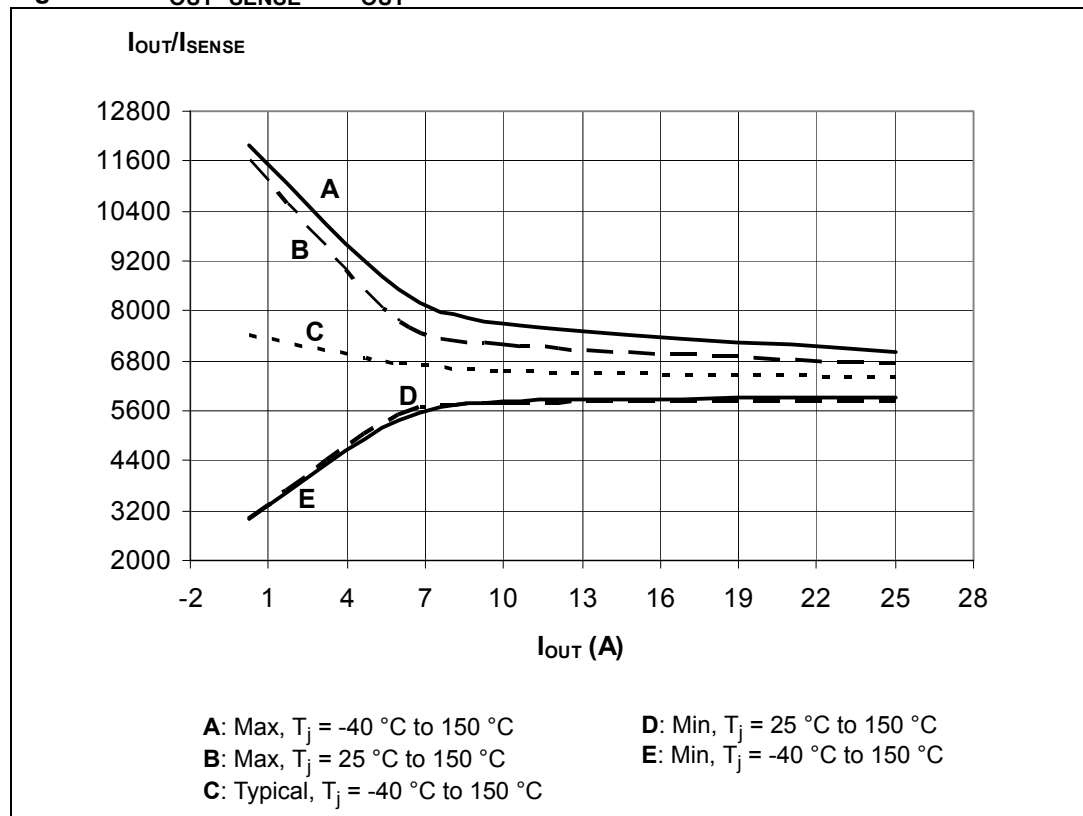
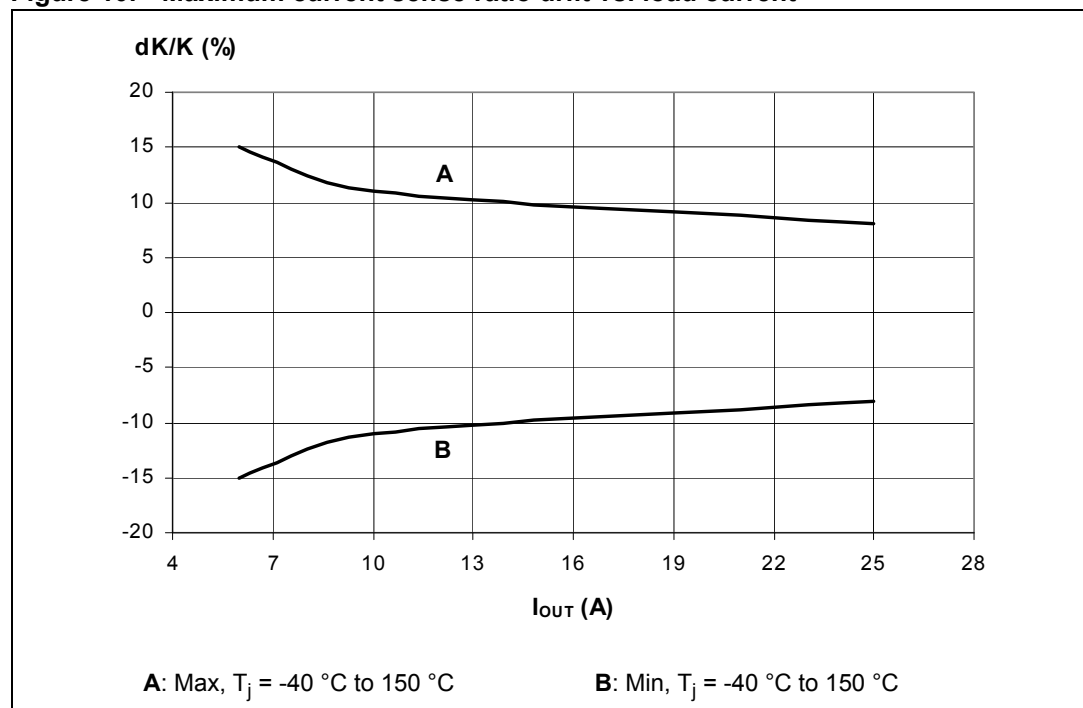


Figure 9.  $I_{OUT}/I_{SENSE}$  vs.  $I_{OUT}$ Figure 10. Maximum current sense ratio drift vs. load current<sup>(1)</sup>

1. Parameter guaranteed by design; it is not tested.

Table 11. Truth table

| Conditions                                                      | Input | Output                        | SENSE ( $V_{CSD} = 0\text{ V}$ ) <sup>(1)</sup> |
|-----------------------------------------------------------------|-------|-------------------------------|-------------------------------------------------|
| Normal operation                                                | L     | L                             | 0                                               |
|                                                                 | H     | H                             | Nominal                                         |
| Overtemperature                                                 | L     | L                             | 0                                               |
|                                                                 | H     | L                             | $V_{SENSEH}$                                    |
| Undervoltage                                                    | L     | L                             | 0                                               |
|                                                                 | H     | L                             | 0                                               |
| Overload                                                        | H     | X<br>(no power limitation)    | Nominal                                         |
|                                                                 | H     | Cycling<br>(power limitation) | $V_{SENSEH}$                                    |
| Short-circuit to GND<br>(power limitation)                      | L     | L                             | 0                                               |
|                                                                 | H     | L                             | $V_{SENSEH}$                                    |
| Open load OFF-state<br>(with external pull-up)                  | L     | H                             | $V_{SENSEH}$                                    |
| Short-circuit to $V_{CC}$<br>(external pull-up<br>disconnected) | L     | H                             | $V_{SENSEH}$                                    |
|                                                                 | H     | H                             | $V_{SENSEH}$<br>< Nominal                       |
| Negative output voltage<br>clamp                                | L     | L                             | 0                                               |

1. If the  $V_{CSD}$  is high, the SENSE output is at a high-impedance, its potential depends on leakage currents and external circuit.



**Table 12. Electrical transient requirements (part 1)**

| ISO 7637-2:<br>2004(E)<br>Test pulse | Test levels <sup>(1)</sup> |        | Number of<br>pulses or<br>test times | Burst cycle/pulse<br>repetition time |        | Delays and<br>Impedance  |
|--------------------------------------|----------------------------|--------|--------------------------------------|--------------------------------------|--------|--------------------------|
|                                      | III                        | IV     |                                      | Min.                                 | Max.   |                          |
| 1                                    | -75 V                      | -100 V | 5000 pulses                          | 0.5 s                                | 5 s    | 2 ms, 10 $\Omega$        |
| 2a                                   | +37 V                      | +50 V  | 5000 pulses                          | 0.2 s                                | 5 s    | 50 $\mu$ s, 2 $\Omega$   |
| 3a                                   | -100 V                     | -150 V | 1h                                   | 90 ms                                | 100 ms | 0.1 $\mu$ s, 50 $\Omega$ |
| 3b                                   | +75 V                      | +100 V | 1h                                   | 90 ms                                | 100 ms | 0.1 $\mu$ s, 50 $\Omega$ |
| 4                                    | -6 V                       | -7 V   | 1 pulse                              |                                      |        | 100 ms, 0.01 $\Omega$    |
| 5b <sup>(2)</sup>                    | +65 V                      | +87 V  | 1 pulse                              |                                      |        | 400 ms, 2 $\Omega$       |

1. The above test levels must be considered referred to  $V_{CC} = 13.5$  V except for pulse 5b.

2. Valid in case of external load dump clamp: 40 V maximum referred to ground.

**Table 13. Electrical transient requirements (part 2)**

| ISO 7637-2:<br>2004(E)<br>Test pulse | Test level results |    |
|--------------------------------------|--------------------|----|
|                                      | III                | IV |
| 1                                    | C                  | C  |
| 2a                                   | C                  | C  |
| 3a                                   | C                  | C  |
| 3b                                   | C                  | C  |
| 4                                    | C                  | C  |
| 5b <sup>(1)</sup>                    | C                  | C  |

1. Valid in case of external load dump clamp: 40V maximum referred to ground.

**Table 14. Electrical transient requirements (part 3)**

| Class | Contents                                                                                                                                                                 |
|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| C     | All functions of the device are performed as designed after exposure to disturbance.                                                                                     |
| E     | One or more functions of the device are not performed as designed after exposure to disturbance and cannot be returned to proper operation without replacing the device. |

2.4 Waveforms

Figure 11. Normal operation

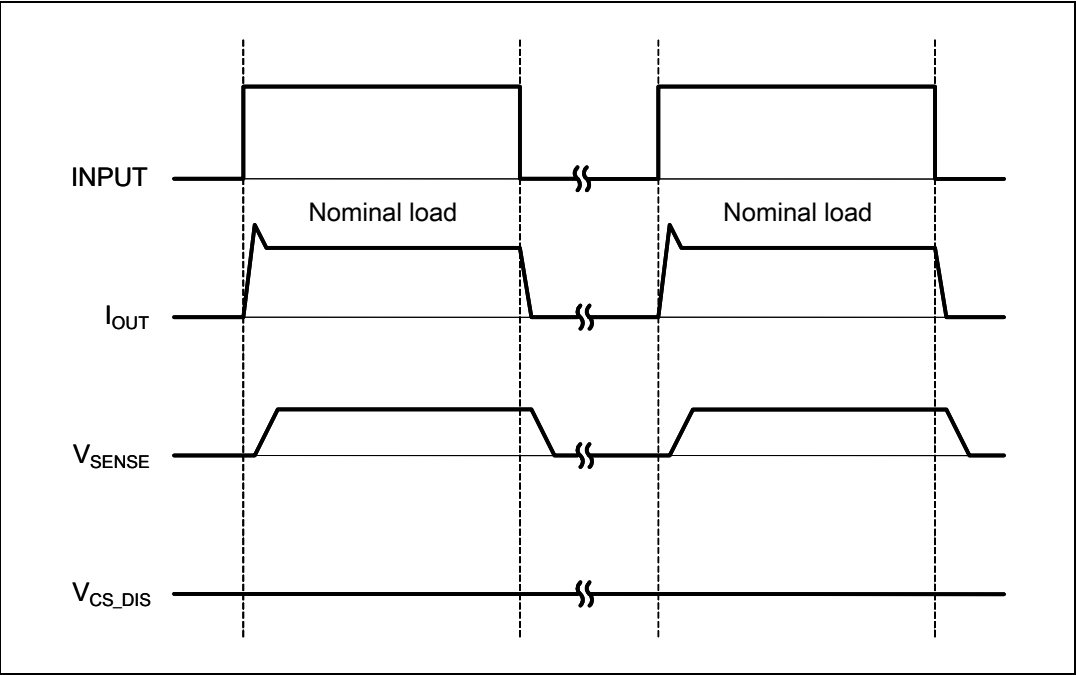


Figure 12. Overload or short to GND

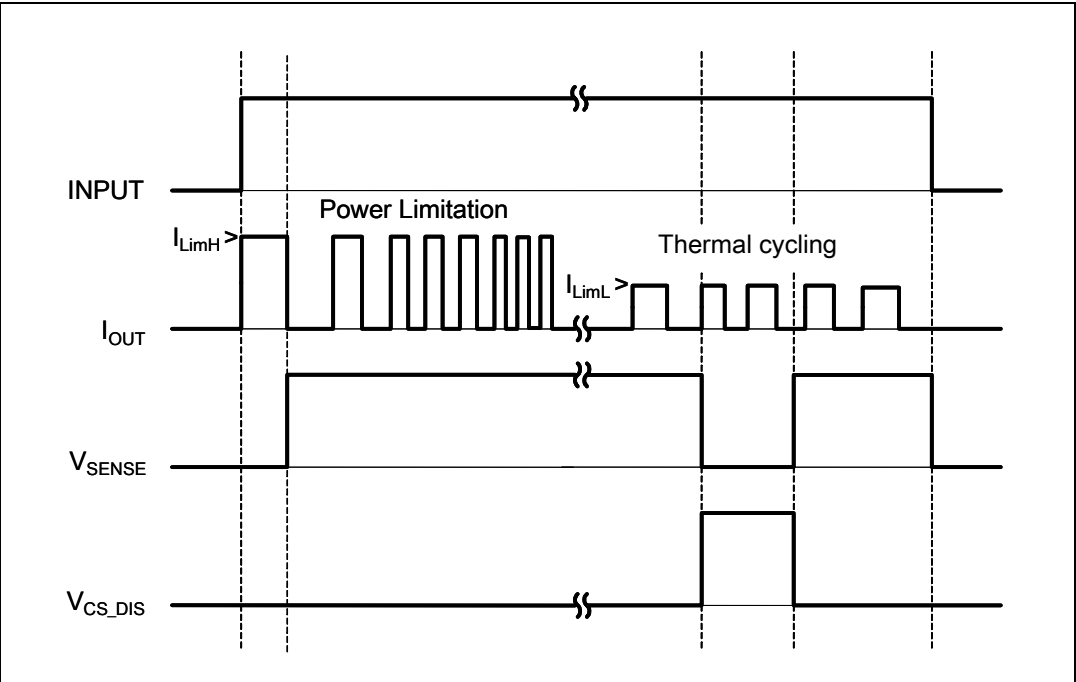


Figure 13. Intermittent overload

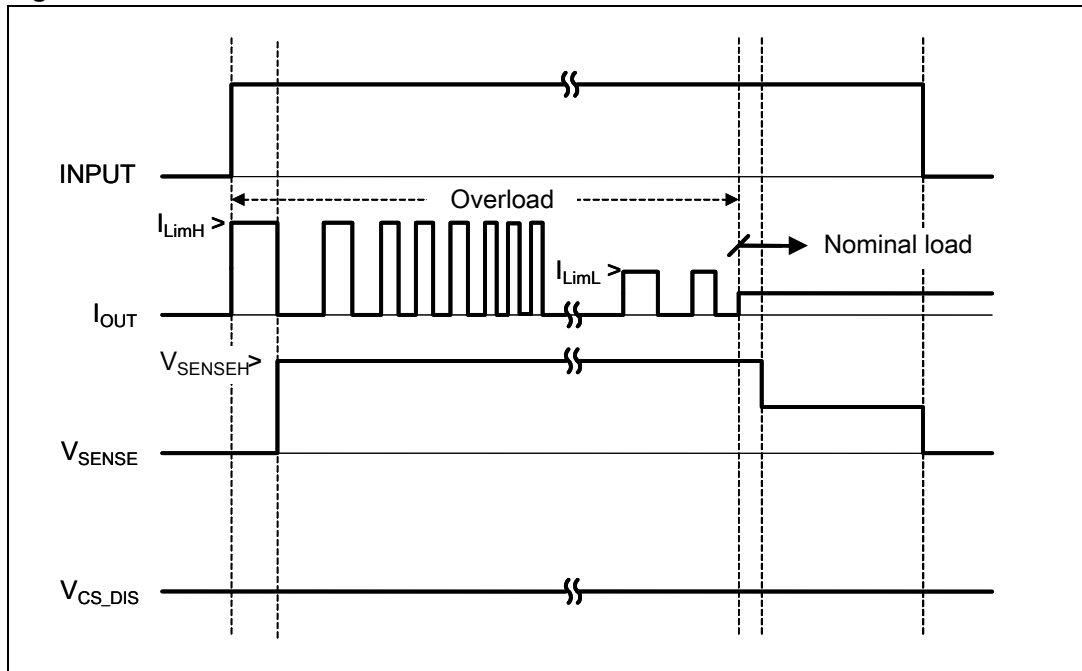


Figure 14. OFF-state open-load with external circuitry

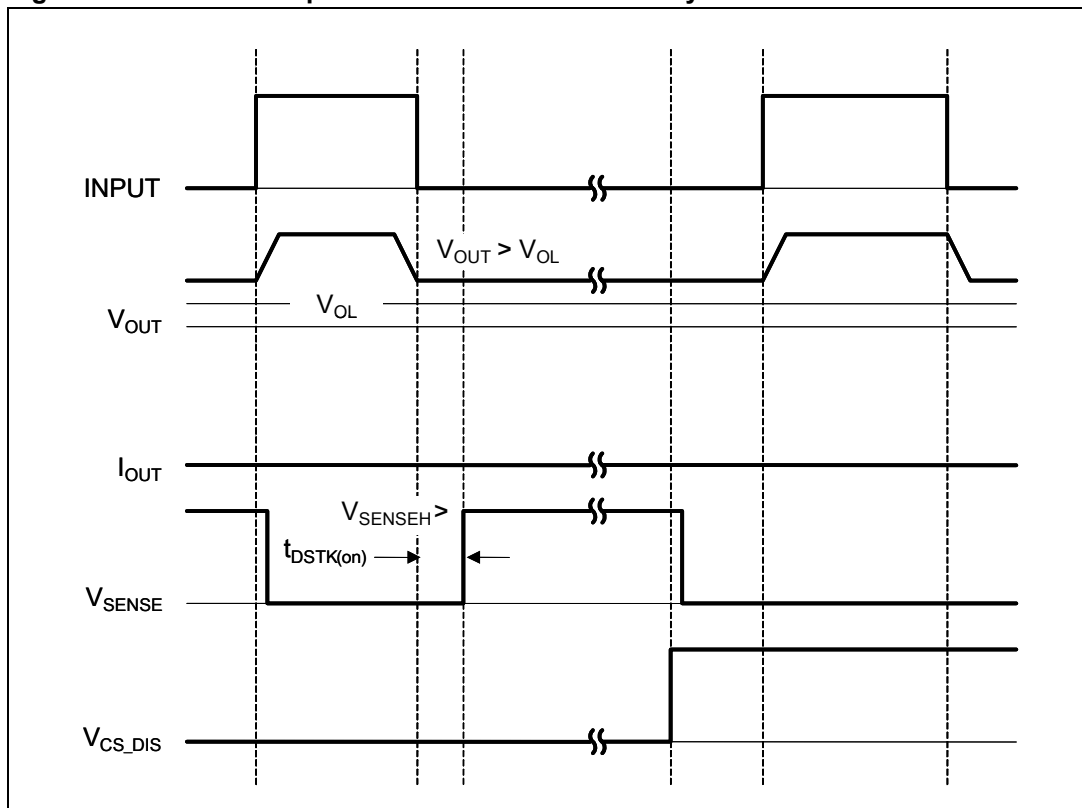


Figure 15. Short to  $V_{CC}$

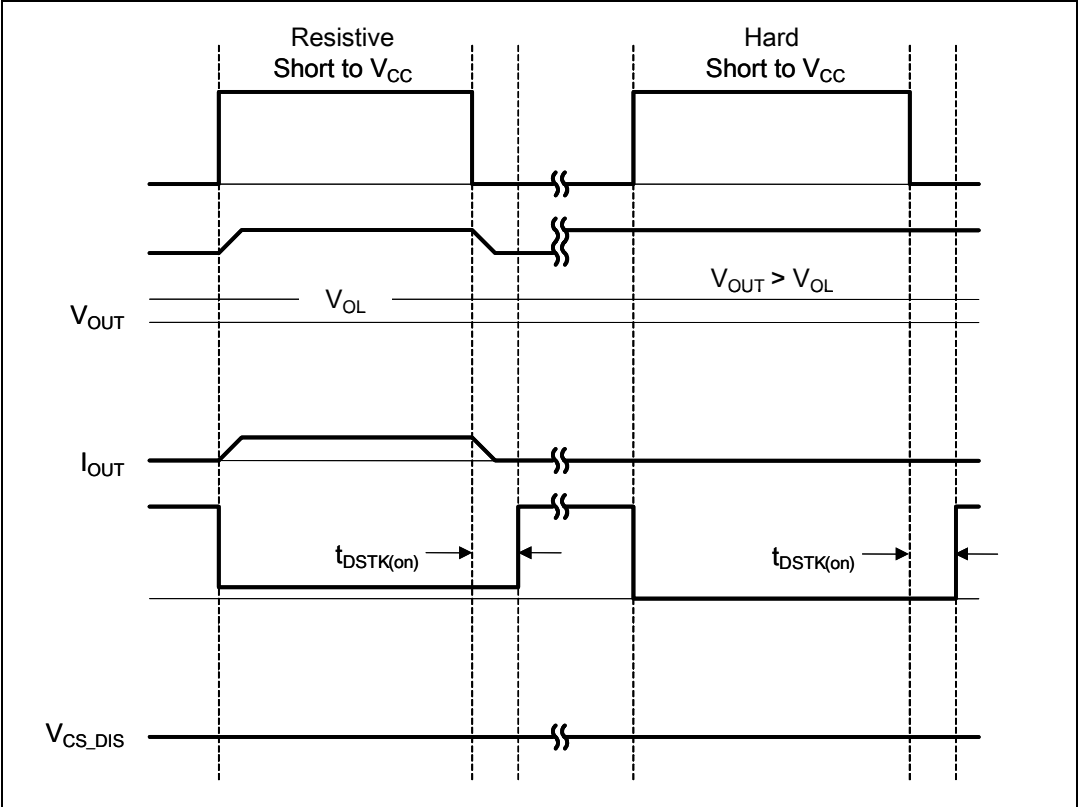
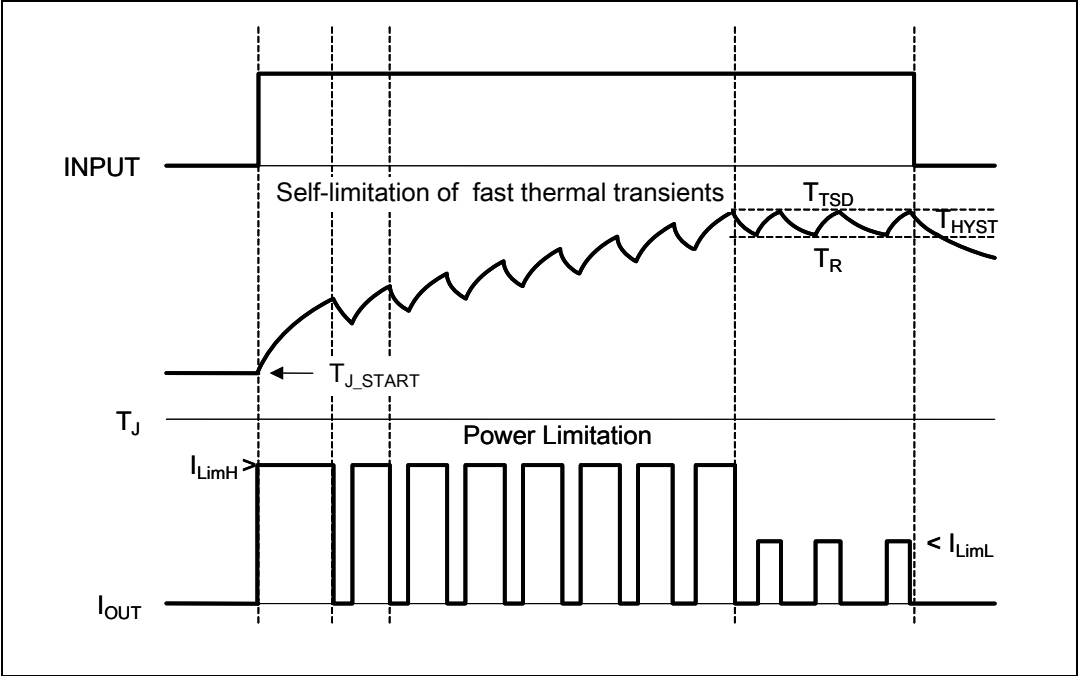


Figure 16.  $T_J$  evolution in overload or short to GND



## 2.5 Electrical characteristics curves

Figure 17. OFF-state output current

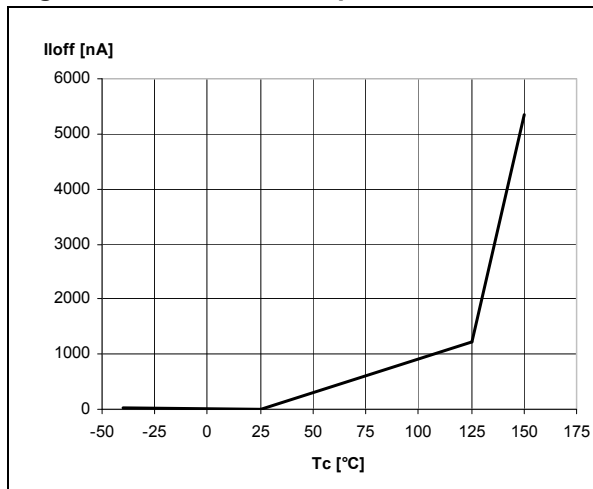


Figure 18. High-level input current

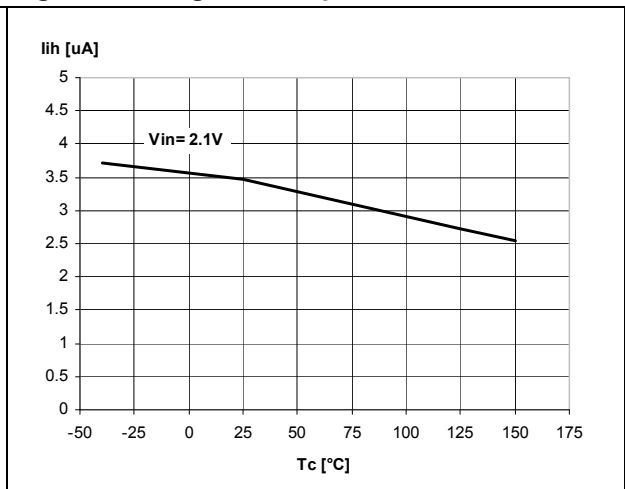


Figure 19. Input clamp voltage

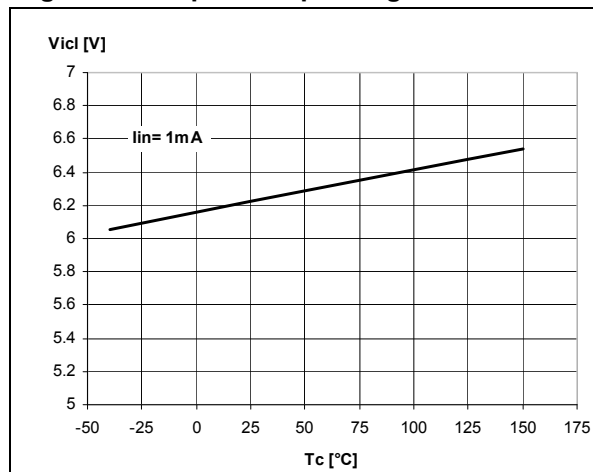


Figure 20. Low-level input voltage

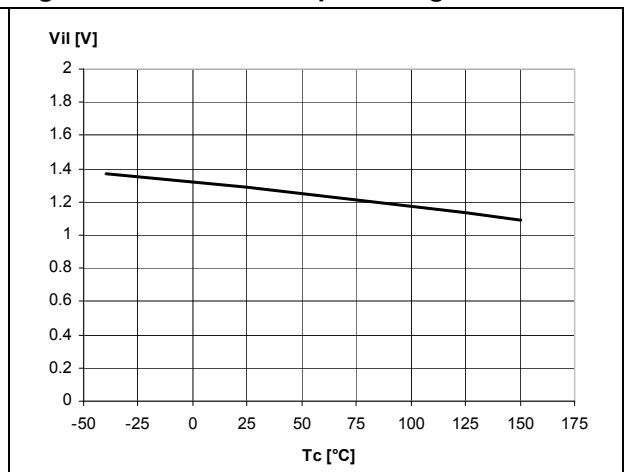


Figure 21. High-level input voltage

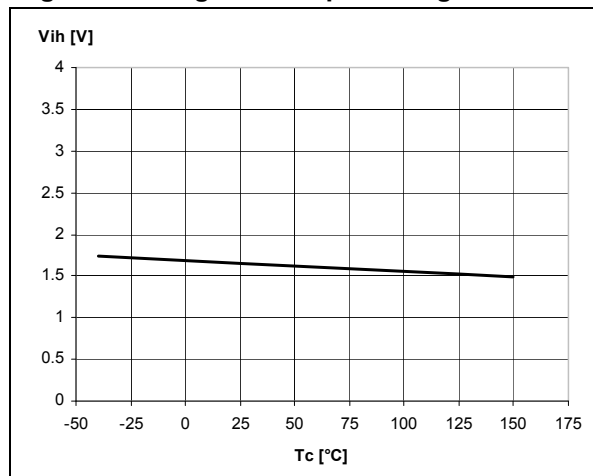


Figure 22. Input hysteresis voltage

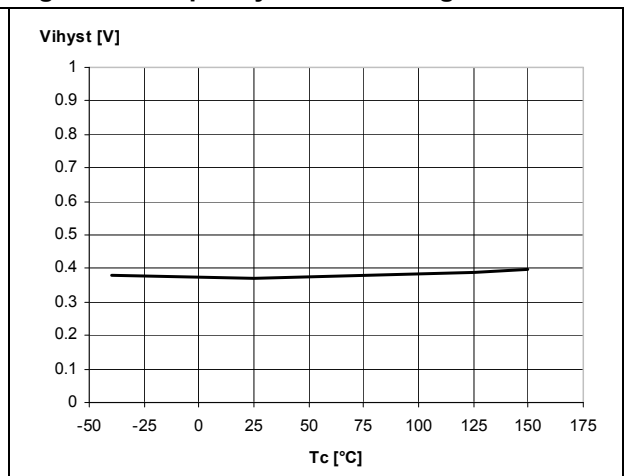


Figure 23. ON-state resistance vs.  $T_{case}$

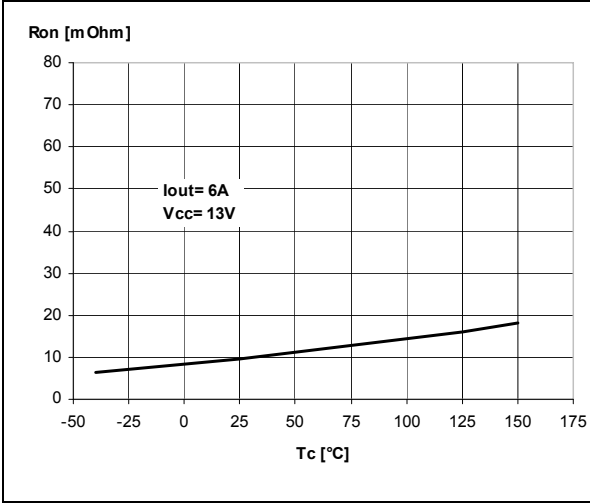


Figure 24. ON-state resistance vs.  $V_{CC}$

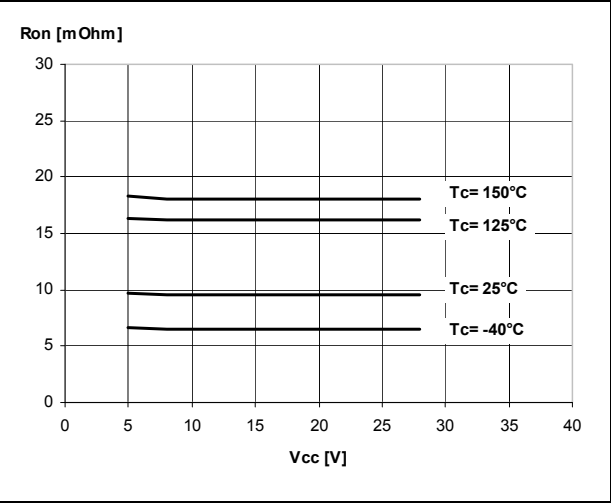


Figure 25. Undervoltage shutdown

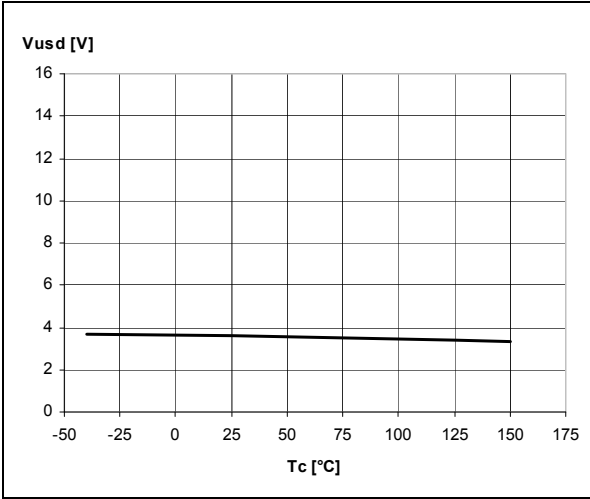


Figure 26. Turn-on voltage slope

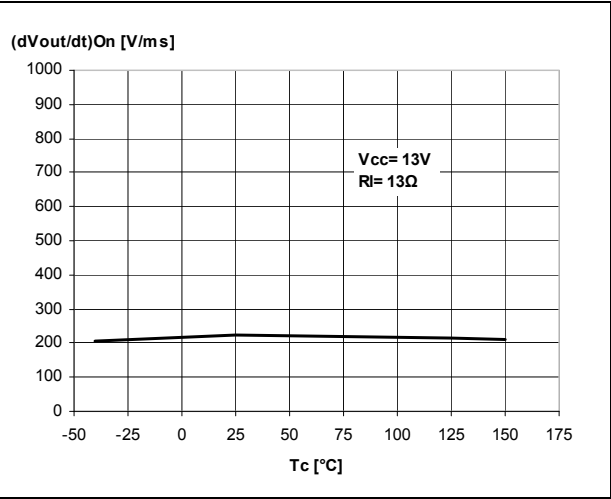


Figure 27.  $I_{LIMH}$  Vs.  $T_{case}$

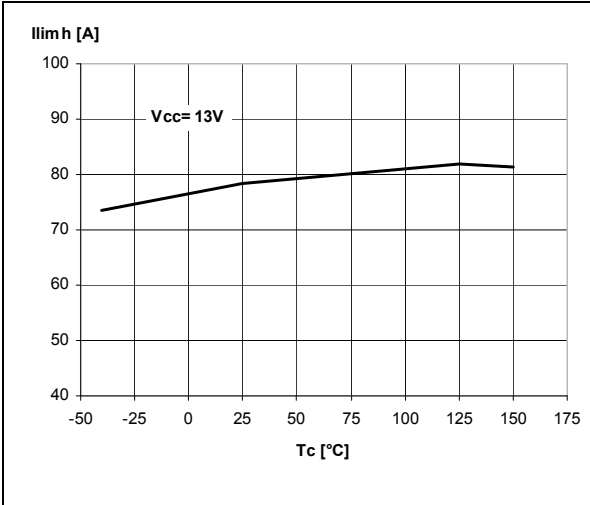


Figure 28. Turn-off voltage slope

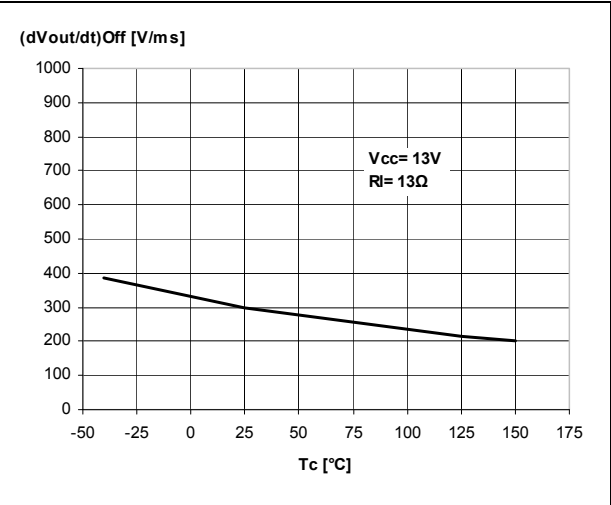


Figure 29. High-level CS\_DIS voltage

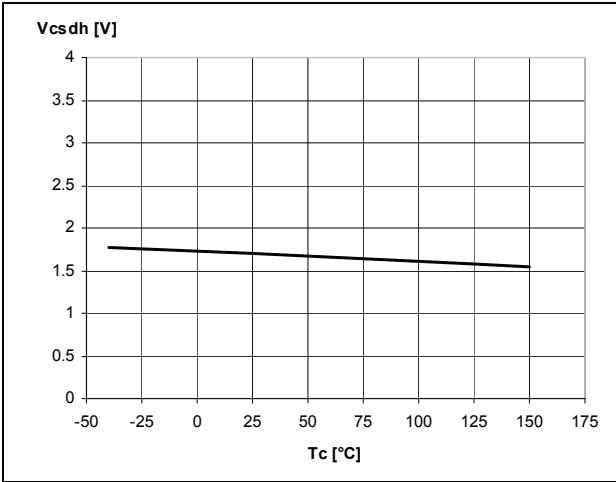


Figure 30. CS\_DIS clamp voltage

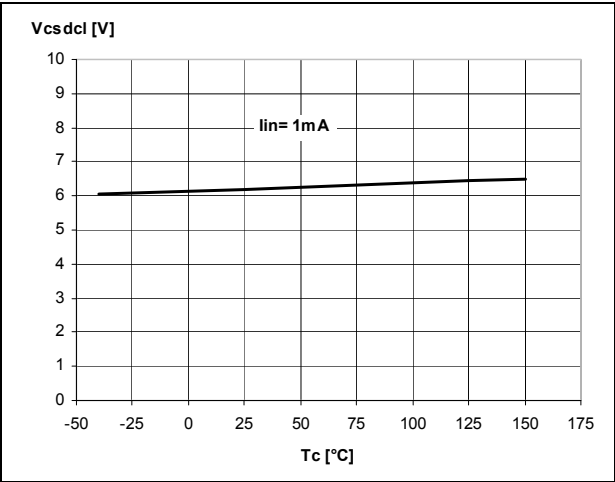
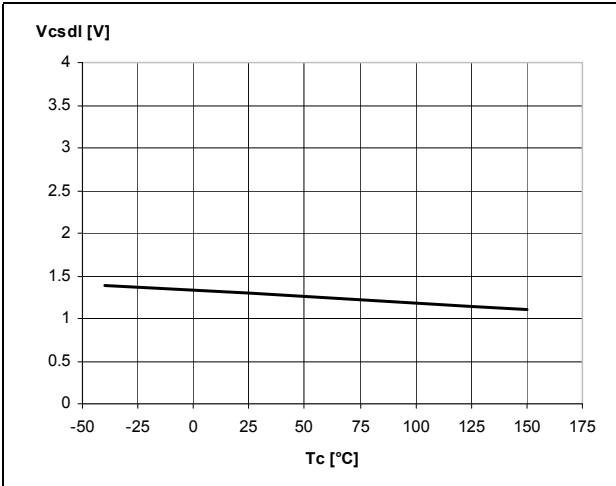
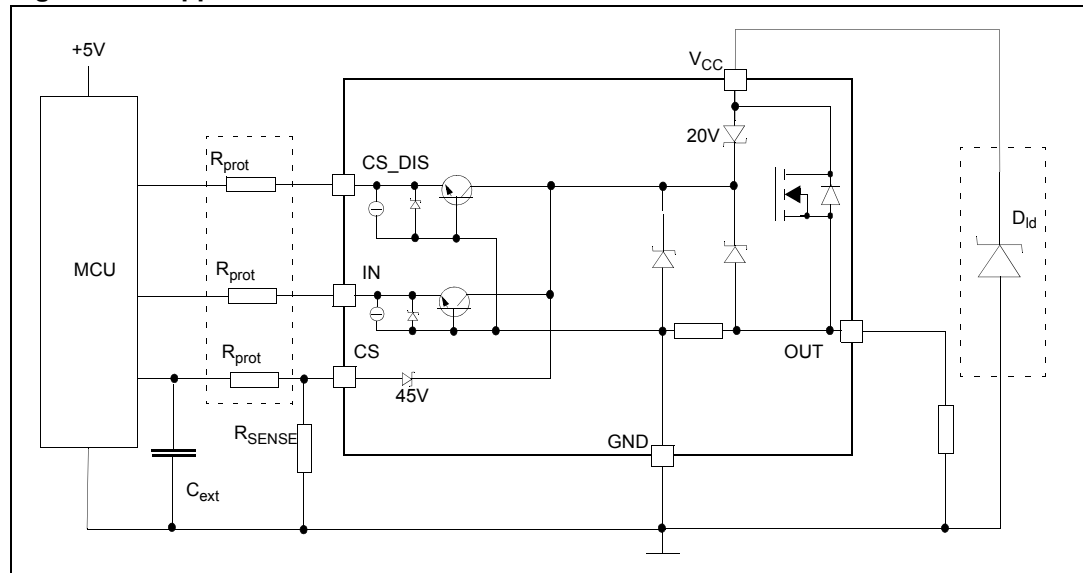


Figure 31. Low-level CS\_DIS voltage



### 3 Application information

Figure 32. Application schematic



#### 3.1 Load dump protection

$D_{ld}$  is necessary (voltage transient suppressor) if the load dump peak voltage exceeds the  $V_{CC}$  max DC rating. The same applies if the device is subject to transients on the  $V_{CC}$  line that are greater than the ones shown in the ISO 7637-2 2004 (E) table.

#### 3.2 MCU I/Os protection

When negative transients are present on the  $V_{CC}$  line, the control pins is pulled negative to approximately -1.5 V. ST suggests to insert a resistor ( $R_{prot}$ ) in line to prevent the microcontroller I/Os pins to latch-up.

The value of these resistors is a compromise between the leakage current of microcontroller and the current required by the HSD I/Os (input levels compatibility) with the latch-up limit of microcontroller I/Os.

##### Equation 1

$$-V_{CCpeak} / I_{latchup} \leq R_{prot} \leq (V_{OH\mu C} - V_{IH}) / I_{IHmax}$$

Calculation example:

For  $V_{CCpeak} = -1.5$  V;  $I_{latchup} \geq 20$  mA;  $V_{OH\mu C} \geq 4.5$  V

$$75 \Omega \leq R_{prot} \leq 240 \text{ k}\Omega.$$

Recommended values:  $R_{prot} = 10 \text{ k}\Omega$ ,  $C_{EXT} = 10 \text{ nF}$ .



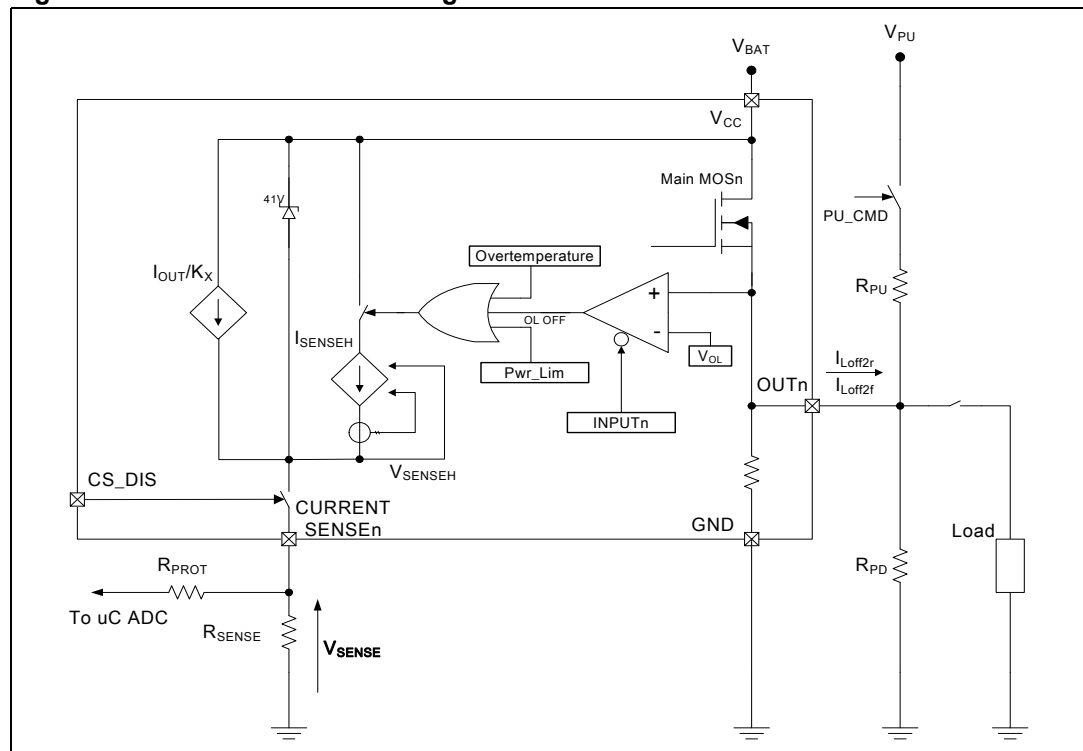
### 3.3 Current sense and diagnostic

The current sense pin performs a double function (see [Figure 33: Current sense and diagnostic](#)):

- ? **Current mirror of the load current in normal operation**, delivering a current proportional to the load one according to a know ratio  $K_X$ .  
The current  $I_{SENSE}$  can be easily converted to a voltage  $V_{SENSE}$  by means of an external resistor  $R_{SENSE}$ . Linearity between  $I_{OUT}$  and  $V_{SENSE}$  is ensured up to 5 V minimum (see parameter  $V_{SENSE}$  in [Table 9: Current sense \(8 V <  \$V\_{CC}\$  < 18 V\)](#)). The current sense accuracy depends on the output current (refer to current sense electrical characteristics [Table 9: Current sense \(8 V <  \$V\_{CC}\$  < 18 V\)](#)).
- ? **Diagnostic flag in fault conditions**, delivering a fixed voltage  $V_{SENSEH}$  up to a maximum current  $I_{SENSEH}$  in case of the following fault conditions (refer to [Table 11: Truth table](#)):
  - Power limitation activation
  - Overtemperature
  - Short to  $V_{CC}$  in OFF-state
  - Open load in OFF-state with additional external components.

A logic level high on CS\_DIS pin sets at the same time all the current sense pins of the device in a high-impedance state, thus disabling the current monitoring and diagnostic detection. This feature allows multiplexing of the microcontroller analog inputs by sharing of sense resistance and ADC line among different devices.

**Figure 33. Current sense and diagnostic**



### 3.3.1 Short to $V_{CC}$ and OFF-state open-load detection

#### Short to $V_{CC}$

A short-circuit between  $V_{CC}$  and output is indicated by the relevant current sense pin set to  $V_{SENSEH}$  during the device OFF-state. Small or no current is delivered by the current sense during the ON-state depending on the nature of the short-circuit.

#### OFF-state open-load with external circuitry

Detection of an open load in off mode requires an external pull-up resistor  $R_{PU}$  connecting the output to a positive supply voltage  $V_{PU}$ .

It is preferable  $V_{PU}$  to be switched off during the module standby mode in order to avoid the overall standby current consumption to increase in normal conditions, i.e. when load is connected.

An external pull-down resistor  $R_{PD}$  connected between output and GND is mandatory to avoid misdetection in case of floating outputs in OFF-state (see [Figure 33: Current sense and diagnostic](#)).

$R_{PD}$  must be selected in order to ensure  $V_{OUT} < V_{OLmin}$  unless pulled-up by the external circuitry:

#### Equation 2

$$V_{OUT}|_{Pull-up\_OFF} = R_{PD} \cdot I_{L(off2)f} < V_{OLmin} = 2\text{ V}$$

$R_{PD} \leq 22\text{ k}\Omega$  is recommended.

For proper open load detection in OFF-state, the external pull-up resistor must be selected according to the following formula:

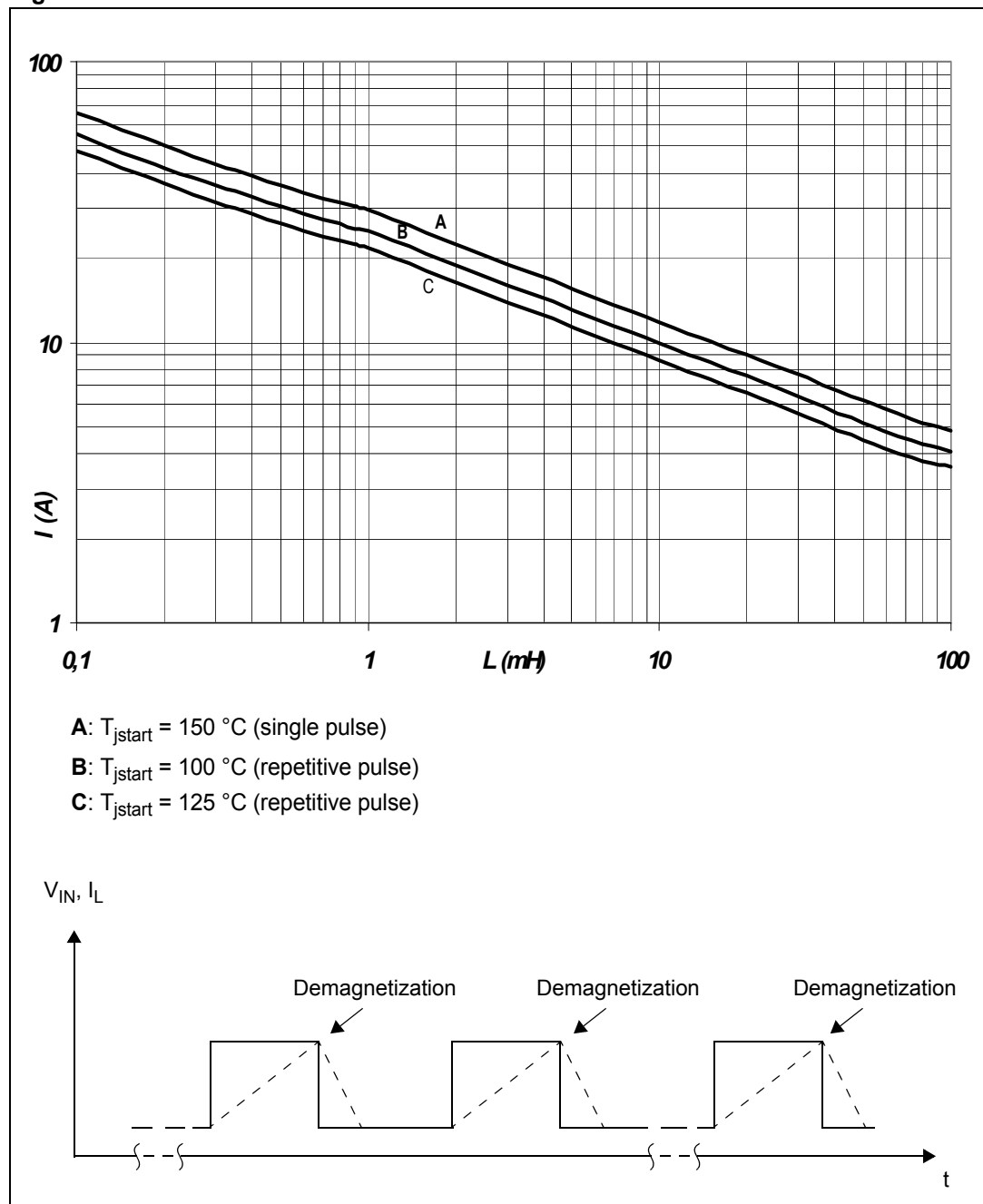
#### Equation 3

$$V_{OUT}|_{Pull-up\_ON} = \frac{(R_{PD} \cdot V_{PU}) - (R_{PU} \cdot R_{PD} \cdot I_{L(off2)r})}{(R_{PU} + R_{PD})} > V_{OLmax} = 4\text{ V}$$

For the values of  $V_{OLmin}$ ,  $V_{OLmax}$ ,  $I_{L(off2)r}$  and  $I_{L(off2)f}$  (see [Table 10: Open load detection \(8 V <  \$V\_{CC}\$  < 18 V\)](#)).

### 3.4 Maximum demagnetization energy ( $V_{CC} = 13.5\text{ V}$ )

Figure 34. Maximum turn-off current versus inductance<sup>(1)</sup>



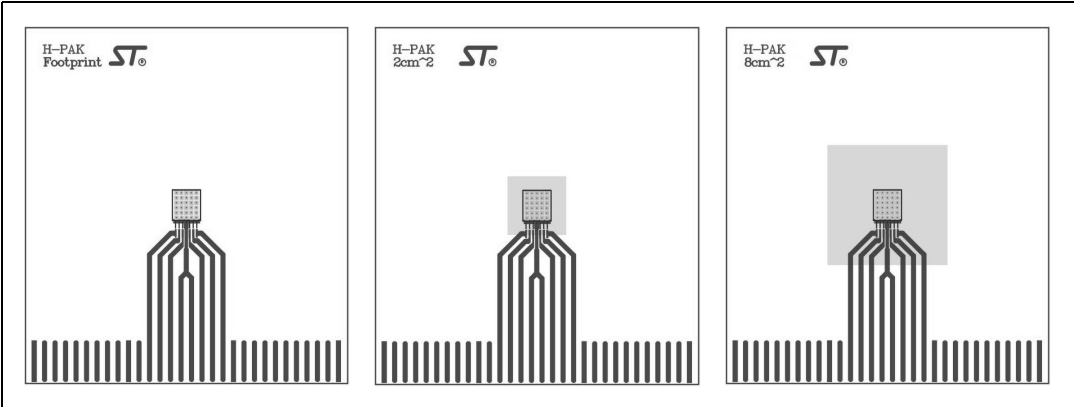
1. Values are generated with  $R_L = 0\ \Omega$ .

In case of repetitive pulses,  $T_{jstart}$  (at beginning of each demagnetization) of every pulse must not exceed the temperature specified above for curves A and B.

## 4 Package and PC board thermal data

### 4.1 HPAK thermal data

Figure 35. PC board<sup>(1)</sup>



1. Layout condition of R<sub>th</sub> and Z<sub>th</sub> measurements (PCB FR4 area = 58 mm x 58 mm, PCB thickness = 1.8 mm, Cu thickness = 70 μm, Copper areas: from minimum pad lay-out to 8 cm<sup>2</sup>).

Figure 36. R<sub>thj-amb</sub> vs. PCB copper area in open box free air condition

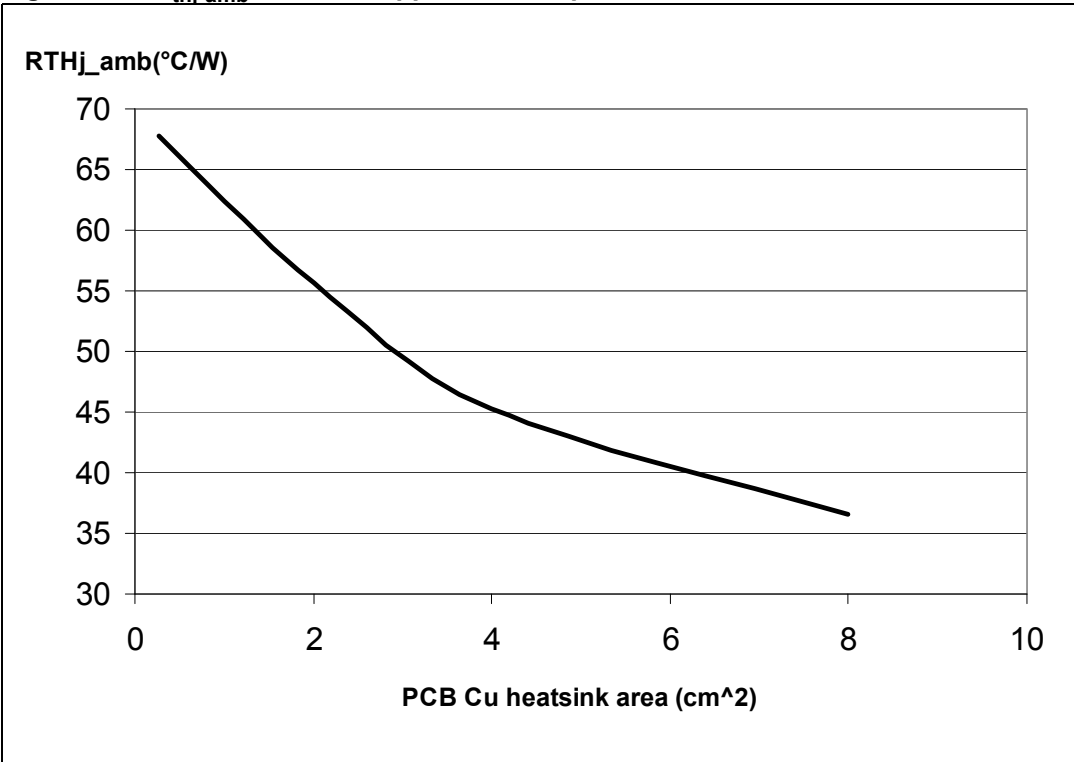
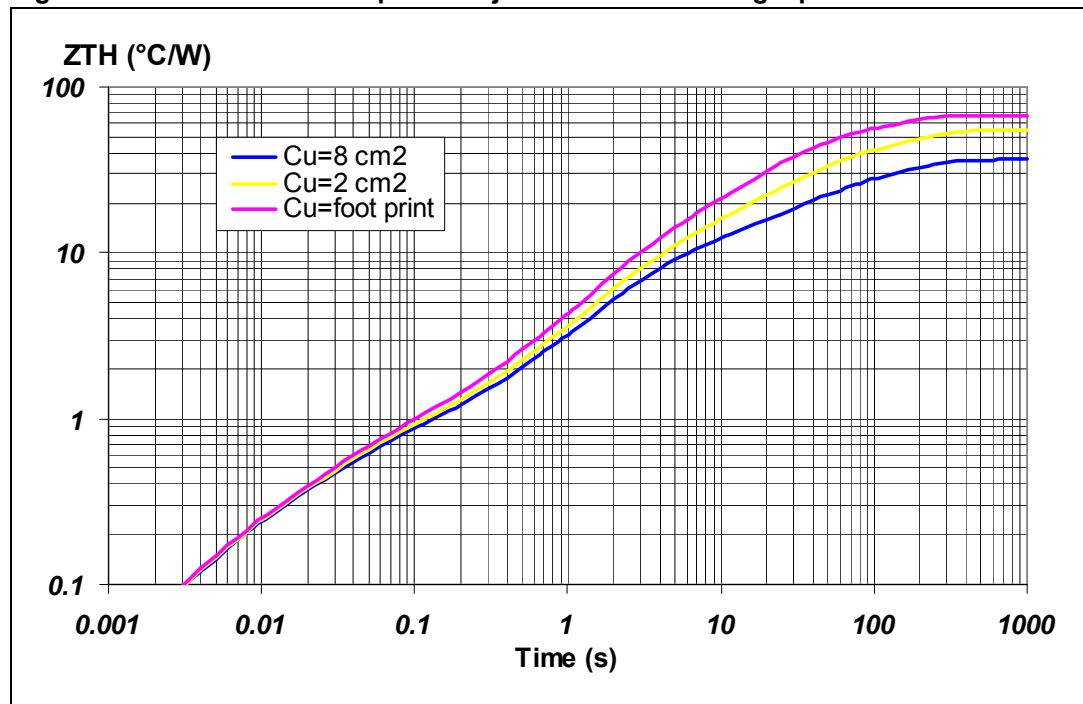
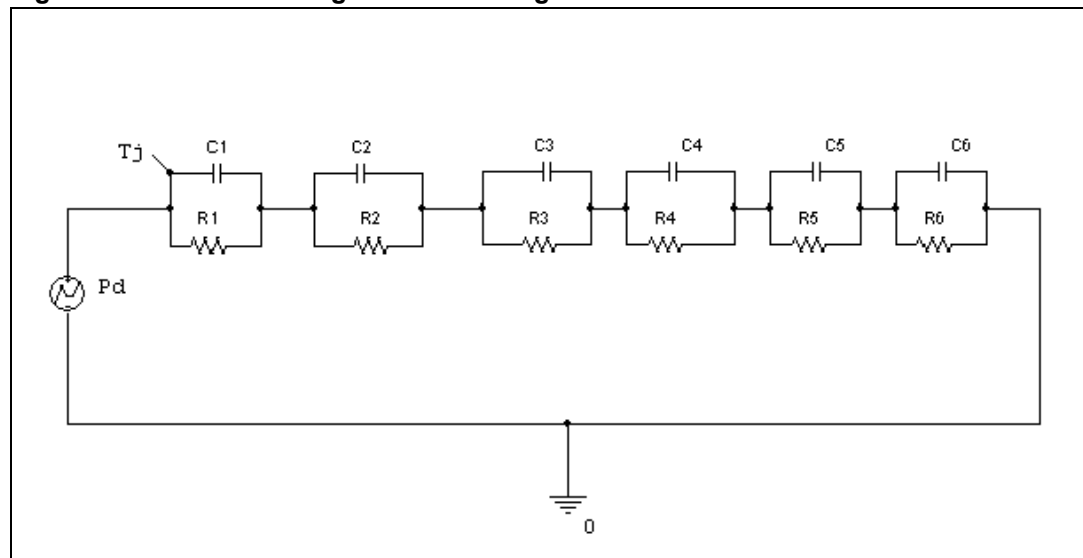


Figure 37. HPAK thermal impedance junction ambient single pulse

Figure 38. Thermal fitting model of a single-channel HSD in HPAK<sup>(1)</sup>

1. The fitting model is a simplified thermal tool and is valid for transient evolutions where the embedded protections (power limitation or thermal cycling during thermal shutdown) are not triggered.

**Equation 4: pulse calculation formula**

$$Z_{TH\delta} = R_{TH} \cdot \delta + Z_{THtp}(1 - \delta)$$

where  $\delta = t_p/T$

**Table 15. Thermal parameter**

| Area/island (cm <sup>2</sup> ) | Footprint | 4   | 8  |
|--------------------------------|-----------|-----|----|
| R1 (°C/W)                      | 0.01      |     |    |
| R2 (°C/W)                      | 0.15      |     |    |
| R3 (°C/W)                      | 0.5       |     |    |
| R4 (°C/W)                      | 8         |     |    |
| R5 (°C/W)                      | 28        | 22  | 12 |
| R6 (°C/W)                      | 31        | 25  | 16 |
| C1 (W.s/°C)                    | 0.005     |     |    |
| C2 (W.s/°C)                    | 0.05      |     |    |
| C3 (W.s/°C)                    | 0.1       |     |    |
| C4 (W.s/°C)                    | 0.4       |     |    |
| C5 (W.s/°C)                    | 0.8       | 1.4 | 3  |
| C6 (W.s/°C)                    | 3         | 6   | 9  |

## 5 Package and packing information

### 5.1 ECOPACK®

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK® packages, depending on their level of environmental compliance. ECOPACK® specifications, grade definitions and product status are available at: [www.st.com](http://www.st.com). ECOPACK® is an ST trademark.

### 5.2 HPAK mechanical data

Figure 39. HPAK package dimension

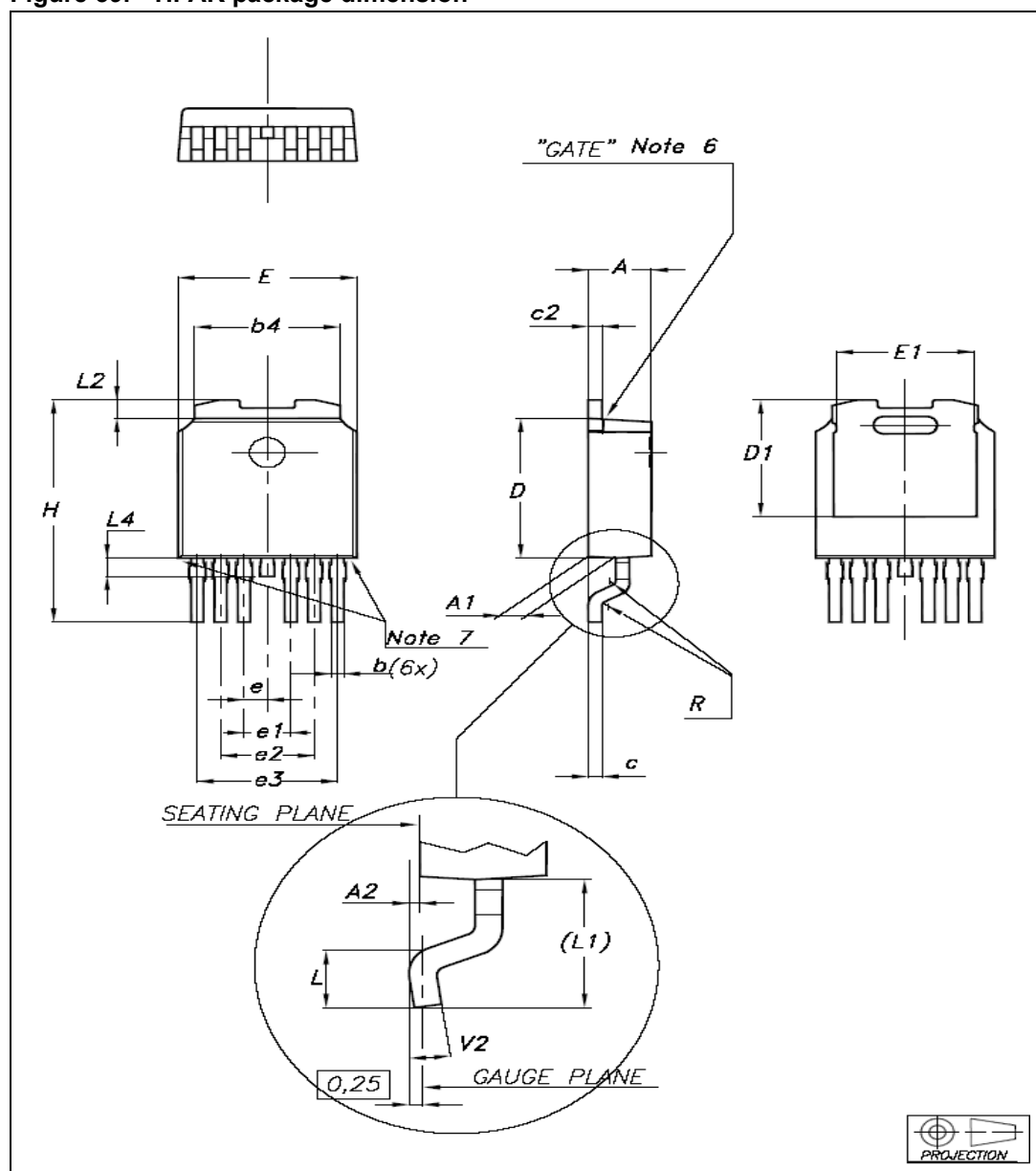


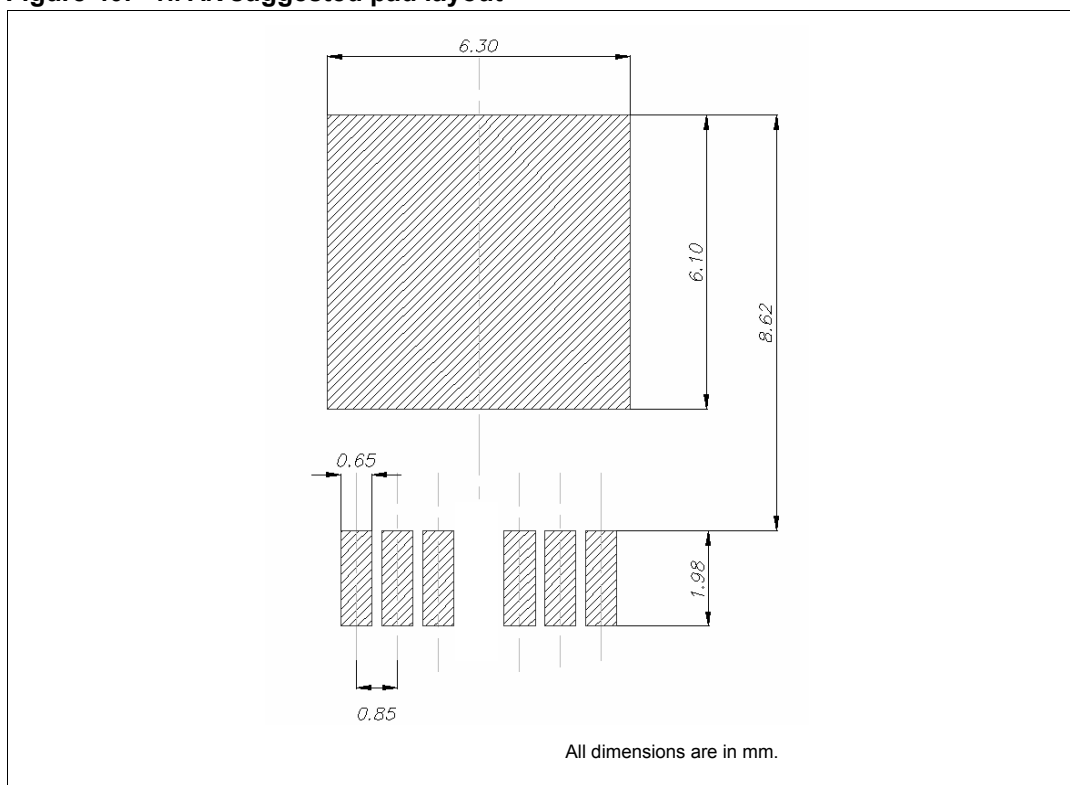
Table 16. HPAK mechanical data

| Ref. dim | Data book mm |      |       |
|----------|--------------|------|-------|
|          | Nom.         | Min. | Max.  |
| A        |              | 2.20 | 2.40  |
| A1       |              | 0.90 | 1.10  |
| A2       |              | 0.03 | 0.23  |
| b        |              | 0.40 | 0.55  |
| b4       |              | 5.20 | 5.40  |
| c        |              | 0.45 | 0.60  |
| c2       |              | 0.48 | 0.60  |
| D        |              | 6.00 | 6.20  |
| D1       | 5.10         |      |       |
| E        |              | 6.40 | 6.60  |
| E1       | 5.20         |      |       |
| e        | 0.85         |      |       |
| e1       |              | 1.60 | 1.80  |
| e2       |              | 3.30 | 3.50  |
| e3       |              | 5.00 | 5.20  |
| H        |              | 9.35 | 10.10 |
| L        |              | 1    |       |
| (L1)     | 2.80         |      |       |
| L2       | 0.80         |      |       |
| L4       |              | 0.60 | 1.00  |
| R        | 0.20         |      |       |
| V2       |              | 0°   | 8°    |



### 5.3 HPAK suggested land pattern

Figure 40. HPAK suggested pad layout<sup>(1)</sup>

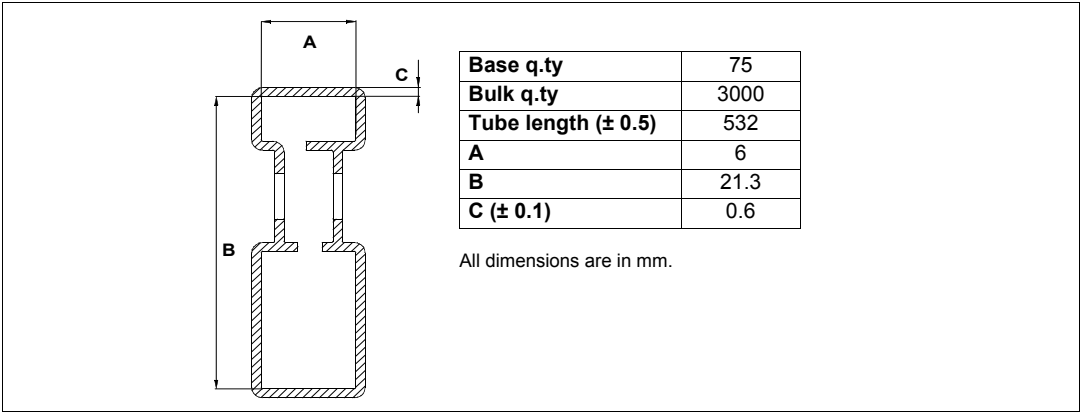


1. The land pattern proposed is not intended to overrule User's PCB design, manufacturing and soldering process rules

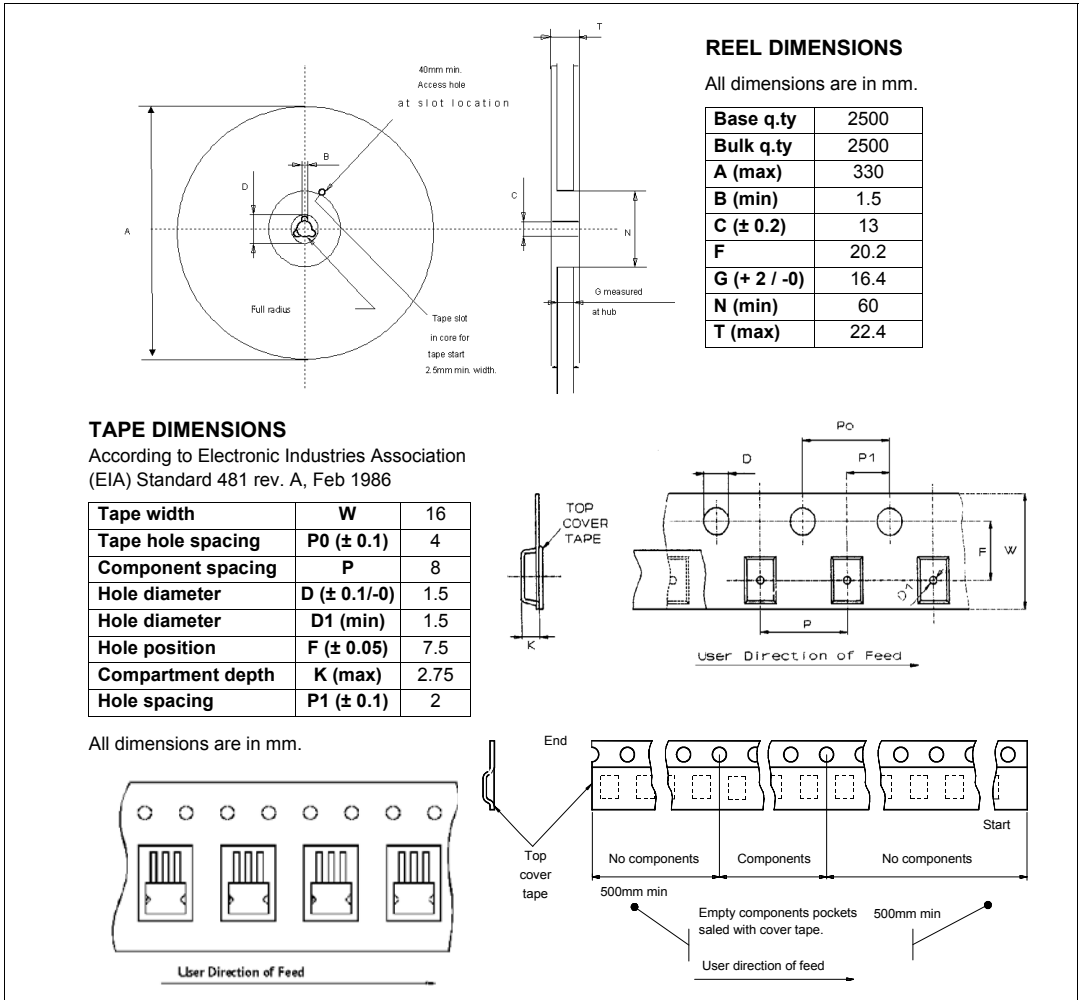
# 5.4 Packing information

The devices can be packed in tube or tape and reel shipments (see [Table 17: Device summary](#)).

**Figure 41. HPAK tube shipment (no suffix)**



**Figure 42. HPAK tape and reel (suffix “TR”)**



## 6 Order codes

Table 17. Device summary

| Package     | Order codes |               |
|-------------|-------------|---------------|
|             | Tube        | Tape and reel |
| 6 pins HPAK | VN5E010AH-E | VN5E010AHTR-E |

## 7 Revision history

**Table 18. Document revision history**

| Date        | Revision | Changes                                                                          |
|-------------|----------|----------------------------------------------------------------------------------|
| 2-Jul-2009  | 1        | Initial release.                                                                 |
| 02-Oct-2009 | 2        | Updated <a href="#">Table 10: Open load detection (8 V &lt; VCC &lt; 18 V)</a> . |
| 19-Sep-2013 | 3        | Updated Disclaimer.                                                              |

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