



# VNQ5E160AK-E

## Quad channel high side driver with analog current sense for automotive applications

### Features

|                                   |            |                          |
|-----------------------------------|------------|--------------------------|
| Max supply voltage                | $V_{CC}$   | 41V                      |
| Operating voltage range           | $V_{CC}$   | 4.5 to 28 V              |
| Max on-state resistance (per ch.) | $R_{ON}$   | 160 m $\Omega$           |
| Current limitation (typ)          | $I_{LIMH}$ | 10 A                     |
| Off state supply current          | $I_S$      | 2 $\mu$ A <sup>(1)</sup> |

1. Typical value with all loads connected.

- General
  - Inrush current active management by power limitation
  - Very low stand-by current
  - 3.0 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 currents range
  - Current sense disable
  - Off state openload detection
  - Output short to Vcc detection
  - Thermal shutdown indication
  - Overload and short to ground (power limitation) indication
- Protections
  - Undervoltage shutdown
  - Overvoltage clamp
  - Load current limitation
  - Self limiting of fast thermal transients
  - Protection against loss of ground and loss of  $V_{CC}$
  - Over-temperature shutdown with autorestart (thermal shutdown)
  - Reverse battery protected (see [Figure 32](#))



- Electrostatic discharge protection

### Application

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

### Description

The VNQ5E160AK-E is a double channel high-side driver manufactured in the ST proprietary VIPower M0-5 technology and housed in the tiny PowerSSO-24 package. The VNQ5E160AK-E is designed to drive 12V automotive grounded loads delivering protection, diagnostics and easy 3V and 5V 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, over-temperature shut-off with auto-restart and over-voltage 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, over-temperature indication, short-circuit to Vcc diagnosis and on & 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

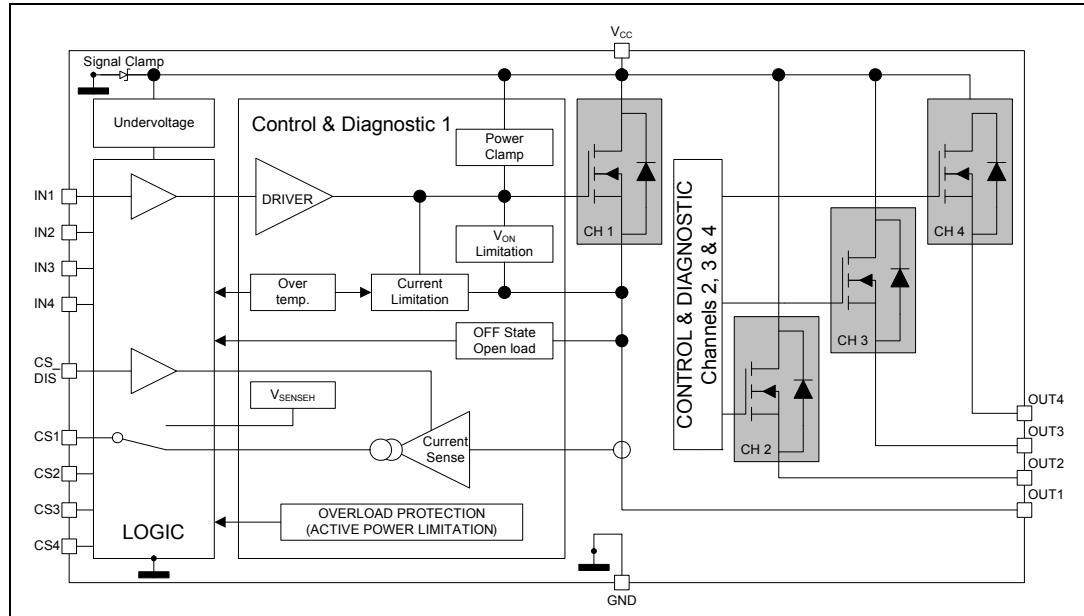


Table 1. Pin functions

| Name                       | Function  |
|----------------------------|---|
| V <sub>CC</sub>            | Battery connection  |
| OUTPUT <sub>n</sub>        | Power output  |
| GND                        | Ground connection. Must be reverse battery protected by an external diode/resistor network  |
| INPUT <sub>n</sub>         | Voltage controlled input pin with hysteresis, CMOS compatible. Controls output switch state |
| CURRENT SENSE <sub>n</sub> | Analog current sense pin, delivers a current proportional to the load current               |
| CS_DIS                     | Active high CMOS compatible pin, to disable the current sense pin                           |

Figure 2. Configuration diagram (top view)

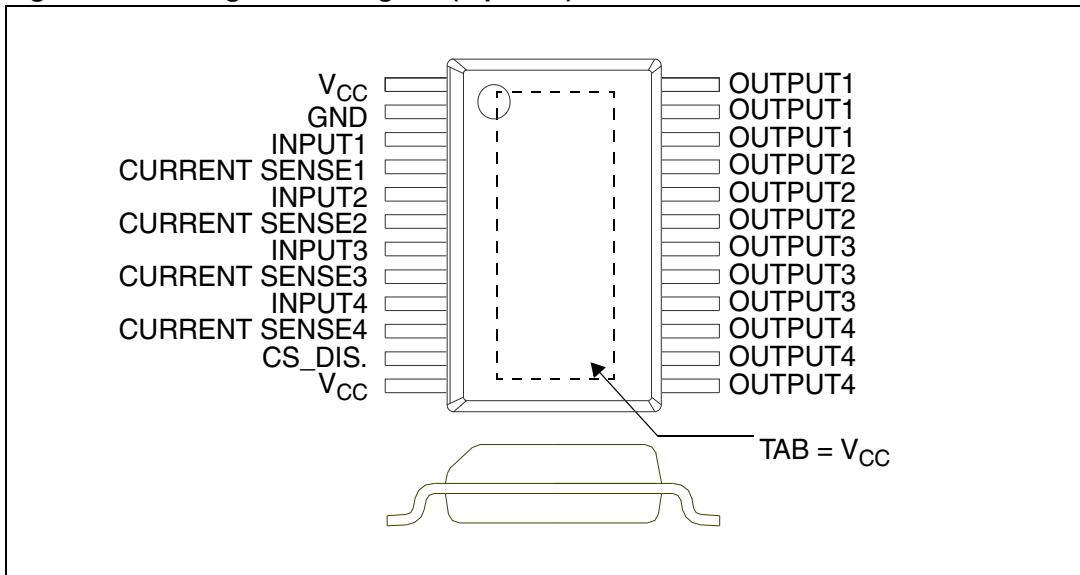
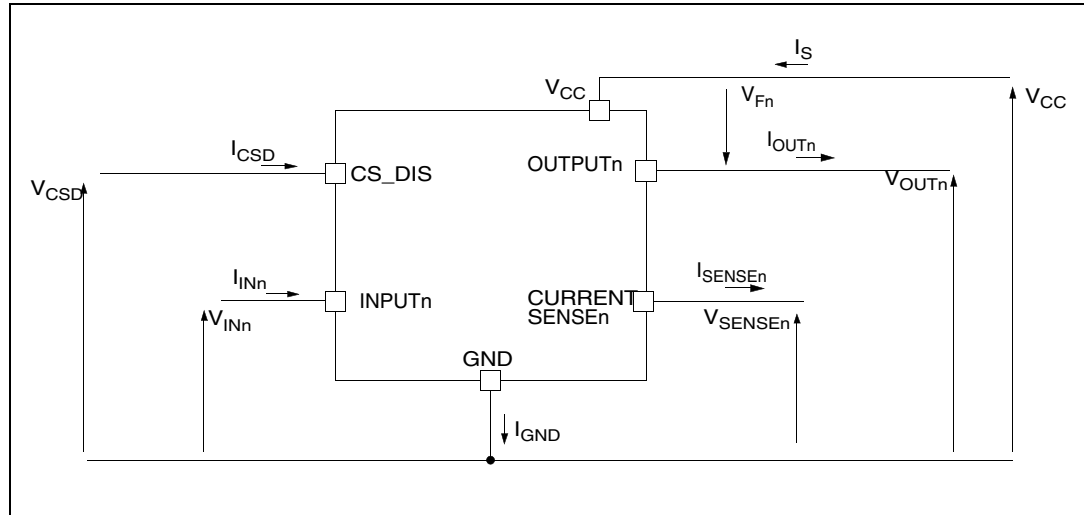


Table 2. Suggested connections for unused and not connected pins

| Connection / pin | Current Sense         | N.C. | Output      | Input                  | CS_DIS                 |
|------------------|-----------------------|------|-------------|------------------------|------------------------|
| Floating         | Not allowed           | X    | X           | X                      | X                      |
| To ground        | Through 1 kΩ resistor | X    | Not allowed | Through 10 kΩ resistor | Through 10 kΩ resistor |

## 2 Electrical specifications

Figure 3. Current and voltage conventions



Note:  $V_{Fn} = V_{OUTn} - V_{CC}$  during reverse battery condition.

### 2.1 Absolute maximum ratings

Stressing the device above the rating listed in the “Absolute maximum ratings” table 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 the conditions in table below 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 <sub>CC</sub>      | DC supply voltage   | 41                                      | V      |
| -V <sub>CC</sub>     | Reverse DC supply voltage   | 0.3                                     | V      |
| -I <sub>GND</sub>    | DC reverse ground pin current   | 200                                     | mA     |
| I <sub>OUT</sub>     | DC output current   | Internally limited                      | A      |
| -I <sub>OUT</sub>    | Reverse DC output current   | 6                                       | A      |
| I <sub>IN</sub>      | DC input current  | -1 to 10                                | mA     |
| I <sub>CSD</sub>     | DC current sense disable input current  | -1 to 10                                | mA     |
| -I <sub>CSENSE</sub> | DC reverse CS pin current   | 200                                     | mA     |
| V <sub>CSENSE</sub>  | Current sense maximum voltage   | V <sub>CC</sub> -41<br>+V <sub>CC</sub> | V<br>V |
| E <sub>MAX</sub>     | Maximum switching energy (single pulse)<br>(L= 12 mH; R <sub>L</sub> =0Ω; V <sub>bat</sub> =13.5V; T <sub>jstart</sub> =150°C; I <sub>OUT</sub> = I <sub>limL</sub> (Typ.)) | 34                                      | mJ     |

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

| Symbol           | Parameter   | Value      | Unit |
|------------------|---|------------|------|
| V <sub>ESD</sub> | Electrostatic discharge<br>(human body model: R= 1.5 KΩ; C= 100 pF) |            |      |
|                  | - Input   | 4000       | V    |
|                  | - Current sense   | 2000       | V    |
|                  | - CS_DIS  | 4000       | V    |
|                  | - Output  | 5000       | V    |
|                  | - V <sub>CC</sub>   | 5000       | V    |
| V <sub>ESD</sub> | Charge device model (CDM-AEC-Q100-011)                              | 750        | V    |
| T <sub>j</sub>   | Junction operating temperature                                      | -40 to 150 | °C   |
| T <sub>stg</sub> | Storage temperature   | -55 to 150 | °C   |

## 2.2 Thermal data

**Table 4. Thermal data**

| Symbol                | Parameter   | Max. value   | Unit |
|-----------------------|---|--|------|
| R <sub>thj-case</sub> | Thermal resistance junction-case (max)<br>(with one channel ON) | 8  | °C/W |
| R <sub>thj-amb</sub>  | Thermal resistance junction-ambient (max)                       | See <a href="#">Figure 36</a> in the thermal section | °C/W |



## 2.3 Electrical characteristics

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

**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 <sup>(2)</sup>             | $I_{OUT} = 1A; T_j = 25^{\circ}C$   |      |                  | 160              | m $\Omega$    |
|               |  | $I_{OUT} = 1A; T_j = 150^{\circ}C$  |      |                  | 320              |               |
|               |  | $I_{OUT} = 1A; V_{CC} = 5V; T_j = 25^{\circ}C$  |      |                  | 210              |               |
| $V_{clamp}$   | Clamp voltage                                  | $I_S = 20\text{ mA}$  | 41   | 46               | 52               | V             |
| $I_S$         | Supply current                                 | Off State; $V_{CC} = 13\text{ V}; T_j = 25^{\circ}C$ ;<br>$V_{IN} = V_{OUT} = V_{SENSE} = V_{CSD} = 0\text{ V}$ |      | 2 <sup>(1)</sup> | 5 <sup>(1)</sup> | $\mu\text{A}$ |
|               |  | On State; $V_{CC} = 13\text{ V}; V_{IN} = 5\text{ V};$<br>$I_{OUT} = 0\text{ A}$                                |      | 8                | 14               | mA            |
| $I_{L(off1)}$ | Off state output current <sup>(2)</sup>        | $V_{IN} = V_{OUT} = 0\text{ V}; V_{CC} = 13\text{ V};$<br>$T_j = 25^{\circ}C$                                   | 0    | 0.01             | 3                | $\mu\text{A}$ |
|               |  | $V_{IN} = V_{OUT} = 0\text{ V}; V_{CC} = 13\text{ V};$<br>$T_j = 125^{\circ}C$                                  | 0    |                  | 5                |               |
| $V_F$         | Output - $V_{CC}$ diode voltage <sup>(2)</sup> | $-I_{OUT} = 1\text{ A}; T_j = 150^{\circ}C$   |      |                  | 0.7              | V             |

1. PowerMOS leakage included.

2. For each channel.

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

| Symbol                | Parameter                                 | Test conditions                                     | Min. | Typ.                              | Max. | Unit             |
|-----------------------|---|---|------|-----------------------------------|------|------------------|
| $t_{d(on)}$           | Turn-on delay time                        | $R_L = 13\ \Omega$ (see <a href="#">Figure 6.</a> ) |      | 20                                |      | $\mu\text{s}$    |
| $t_{d(off)}$          | Turn-off delay time                       | $R_L = 13\ \Omega$ (see <a href="#">Figure 6.</a> ) |      | 10                                |      | $\mu\text{s}$    |
| $(dV_{OUT}/dt)_{on}$  | Turn-on voltage slope                     | $R_L = 13\ \Omega$                                  |      | See<br><a href="#">Figure 26.</a> |      | V/ $\mu\text{s}$ |
| $(dV_{OUT}/dt)_{off}$ | Turn-off voltage slope                    | $R_L = 13\ \Omega$                                  |      | See<br><a href="#">Figure 28.</a> |      | V/ $\mu\text{s}$ |
| $W_{ON}$              | Switching energy losses during $t_{won}$  | $R_L = 13\ \Omega$ (see <a href="#">Figure 6.</a> ) |      | 0.05                              |      | mJ               |
| $W_{OFF}$             | Switching energy losses during $t_{woff}$ | $R_L = 13\ \Omega$ (see <a href="#">Figure 6.</a> ) |      | 0.03                              |      | mJ               |

**Table 7. Logic Inputs**

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

**Table 8. Protections and diagnostics (1)**

| Symbol      | Parameter                                    | Test conditions   | Min.          | Typ.          | Max.          | Unit        |
|-------------|--|---|---------------|---------------|---------------|-------------|
| $I_{limH}$  | DC short circuit current                     | $V_{CC} = 13V$<br>$5V < V_{CC} < 28V$   | 7             | 10            | 14            | A           |
|             |  |   |               |               | 14            | A           |
| $I_{limL}$  | Short circuit current during thermal cycling | $V_{CC} = 13V; T_R < T_j < T_{TSD}$   |               | 2.5           |               | A           |
| $T_{TSD}$   | Shutdown temperature                         |   | 150           | 175           | 200           | $^{\circ}C$ |
| $T_R$       | Reset temperature                            |   | $T_{RS} + 1$  | $T_{RS} + 5$  |               | $^{\circ}C$ |
| $T_{RS}$    | Thermal reset of STATUS                      |   | 135           |               |               | $^{\circ}C$ |
| $T_{HYST}$  | Thermal hysteresis ( $T_{TSD} - T_R$ )       |   |               | 7             |               | $^{\circ}C$ |
| $V_{DEMAG}$ | Turn-off output voltage clamp                | $I_{OUT} = 1A; V_{IN} = 0; L = 20mH$  | $V_{CC} - 41$ | $V_{CC} - 46$ | $V_{CC} - 52$ | V           |
| $V_{ON}$    | Output voltage drop limitation               | $I_{OUT} = 0.03A;$<br>$T_j = -40^{\circ}C \dots 150^{\circ}C$<br>(see <a href="#">Figure 8.</a> ) |               | 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 (8V<V<sub>CC</sub><18V)

| Symbol   | Parameter   | Test conditions   | Min.       | Typ.       | Max.       | Unit |
|--|---|---|------------|------------|------------|------|
| K <sub>0</sub>                                 | I <sub>OUT</sub> /I <sub>SENSE</sub>                          | I <sub>OUT</sub> = 0.025 A;<br>V <sub>SENSE</sub> = 0.5 V; V <sub>CSD</sub> = 0 V;<br>T <sub>j</sub> = -40°C...150°C                                | 330        | 600        | 870        |      |
| K <sub>1</sub>                                 | I <sub>OUT</sub> /I <sub>SENSE</sub>                          | I <sub>OUT</sub> = 0.35A;<br>V <sub>SENSE</sub> = 0.5 V; V <sub>CSD</sub> = 0 V;<br>T <sub>j</sub> = -40°C...150°C<br>T <sub>j</sub> = 25°C...150°C | 345<br>395 | 475<br>475 | 600<br>555 |      |
| dK <sub>1</sub> /K <sub>1</sub> <sup>(1)</sup> | Current sense ratio drift                                     | I <sub>OUT</sub> = 0.35 A;<br>V <sub>SENSE</sub> = 0.5 V; V <sub>CSD</sub> = 0 V;<br>T <sub>j</sub> = -40°C...150°C                                 | - 12       |            | 12         | %    |
| K <sub>2</sub>                                 | I <sub>OUT</sub> /I <sub>SENSE</sub>                          | I <sub>OUT</sub> = 0.5A;<br>V <sub>SENSE</sub> =4V; V <sub>CSD</sub> = 0 V;<br>T <sub>j</sub> =-40°C...150°C<br>T <sub>j</sub> = 25°C...150°C       | 375<br>415 | 470<br>470 | 565<br>525 |      |
| dK <sub>2</sub> /K <sub>2</sub> <sup>(1)</sup> | Current sense ratio drift                                     | I <sub>OUT</sub> = 0.5 A;<br>V <sub>SENSE</sub> = 4 V; V <sub>CSD</sub> = 0 V;<br>T <sub>j</sub> = -40°C...150°C                                    | - 8        |            | 8          | %    |
| K <sub>3</sub>                                 | I <sub>OUT</sub> /I <sub>SENSE</sub>                          | I <sub>OUT</sub> = 1.5 A;<br>V <sub>SENSE</sub> = 4 V; V <sub>CSD</sub> = 0 V;<br>T <sub>j</sub> = -40°C...150°C<br>T <sub>j</sub> = 25°C...150°C   | 425<br>435 | 465<br>465 | 505<br>495 |      |
| dK <sub>3</sub> /K <sub>3</sub> <sup>(1)</sup> | Current sense ratio drift                                     | I <sub>OUT</sub> = 1.5 A;<br>V <sub>SENSE</sub> = 4 V; V <sub>CSD</sub> = 0 V;<br>T <sub>j</sub> = -40°C...150°C                                    | - 6        |            | 6          | %    |
| 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...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...150°C               | 0          |            | 2          |      |
|  |   | I <sub>OUT</sub> = 1A; V <sub>SENSE</sub> = 0V;<br>V <sub>CSD</sub> = 5V; V <sub>IN</sub> = 5V;<br>T <sub>j</sub> = -40°C...150°C                   | 0          |            | 1          |      |
| I <sub>OL</sub>                                | Openload on state current detection threshold                 | V <sub>IN</sub> = 5V,<br>I <sub>SENSE</sub> = 5 μA  | 1          |            | 5          | mA   |
| V <sub>SENSE</sub>                             | Max analog sense output voltage                               | I <sub>OUT</sub> = 1.5 A; V <sub>CSD</sub> = 0 V  | 5          |            |            | V    |
| V <sub>SENSEH</sub>                            | Analog sense output voltage in fault condition <sup>(2)</sup> | V <sub>CC</sub> = 13 V; R <sub>SENSE</sub> = 3.9 KΩ;  |            | 8          |            | V    |

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

| Symbol                             | Parameter  | Test conditions   | Min. | Typ. | Max. | Unit |
|------------------------------------|--|---|------|------|------|------|
| I <sub>SENSEH</sub> <sup>(2)</sup> | Analog sense output current in fault condition <sup>(2)</sup>                              | V <sub>CC</sub> = 13V; V <sub>SENSE</sub> = 5 V;  |      | 9    |      | mA   |
| t <sub>DSENSE1H</sub>              | Delay response time from falling edge of CS_DIS pin  | V <sub>SENSE</sub> <4V, 0.025A<I <sub>out</sub> <1.5A<br>I <sub>SENSE</sub> =90% of I <sub>SENSEMAX</sub><br>(see <a href="#">Figure 4</a> )  |      | 40   | 100  | μs   |
| t <sub>DSENSE1L</sub>              | Delay response time from rising edge of CS_DIS pin   | V <sub>SENSE</sub> <4V, 0.025A<I <sub>out</sub> <1.5A<br>I <sub>SENSE</sub> =10% of I <sub>SENSEMAX</sub><br>(see <a href="#">Figure 4</a> )  |      | 5    | 20   | μs   |
| t <sub>DSENSE2H</sub>              | Delay response time from rising edge of INPUT pin  | V <sub>SENSE</sub> <4V, 0.025A<I <sub>out</sub> <1.5A<br>I <sub>SENSE</sub> =90% of I <sub>SENSEMAX</sub><br>(see <a href="#">Figure 4</a> .)   |      | 120  | 300  | μs   |
| Δt <sub>DSENSE2H</sub>             | Delay response time between rising edge of output current and rising edge of current sense | V <sub>SENSE</sub> < 4V,<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> =1.5A (see <a href="#">Figure 7</a> ) |      |      | 110  | μs   |
| t <sub>DSENSE2L</sub>              | Delay response time from falling edge of INPUT pin   | V <sub>SENSE</sub> <4V, 0.025A<I <sub>out</sub> <1.5A<br>I <sub>SENSE</sub> =10% of I <sub>SENSEMAX</sub><br>(see <a href="#">Figure 4</a> .)   |      | 80   | 250  | μs   |

1. Parameter guaranteed by design; it is not tested

2. Fault condition includes: power limitation, overtemperature and open load off state detection.

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

| Symbol                | Parameter  | Test conditions  | Min. | Typ. | Max. | Unit |
|-----------------------|--|--|------|------|------|------|
| V <sub>OL</sub>       | Openload off state voltage detection threshold                                       |  | 2    |      | 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> = 4V                                    | 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 |      | 0    | μA   |
| I <sub>L(off2)f</sub> | Off state output current at V <sub>OUT</sub> = 2V                                    | 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 2V | -50  |      | 90   | μA   |
| td_vol                | Delay response from output rising edge to V <sub>SENSE</sub> rising edge in openload | 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

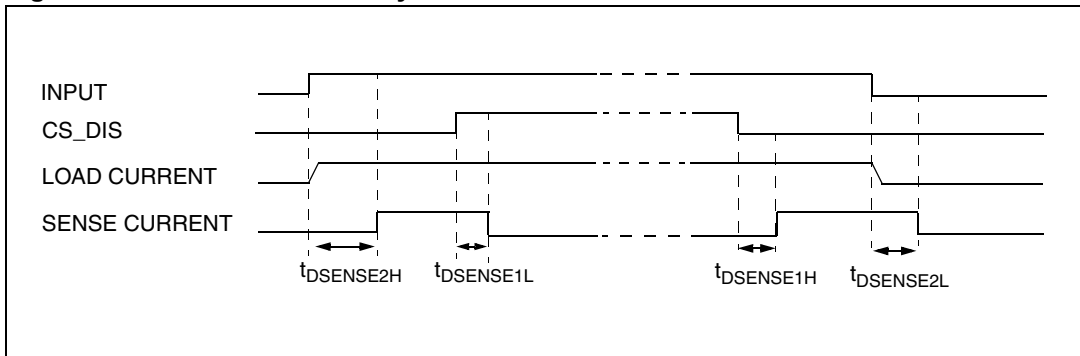


Figure 5. Openload off-state delay timing

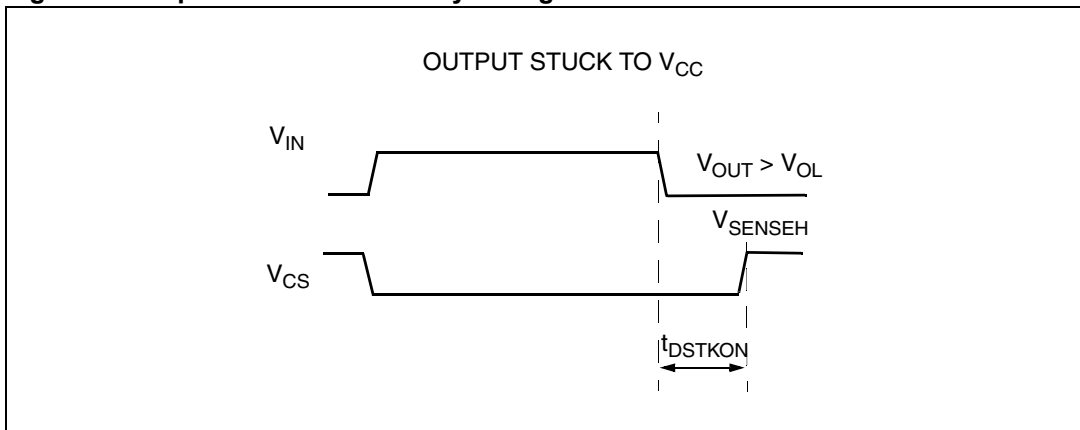
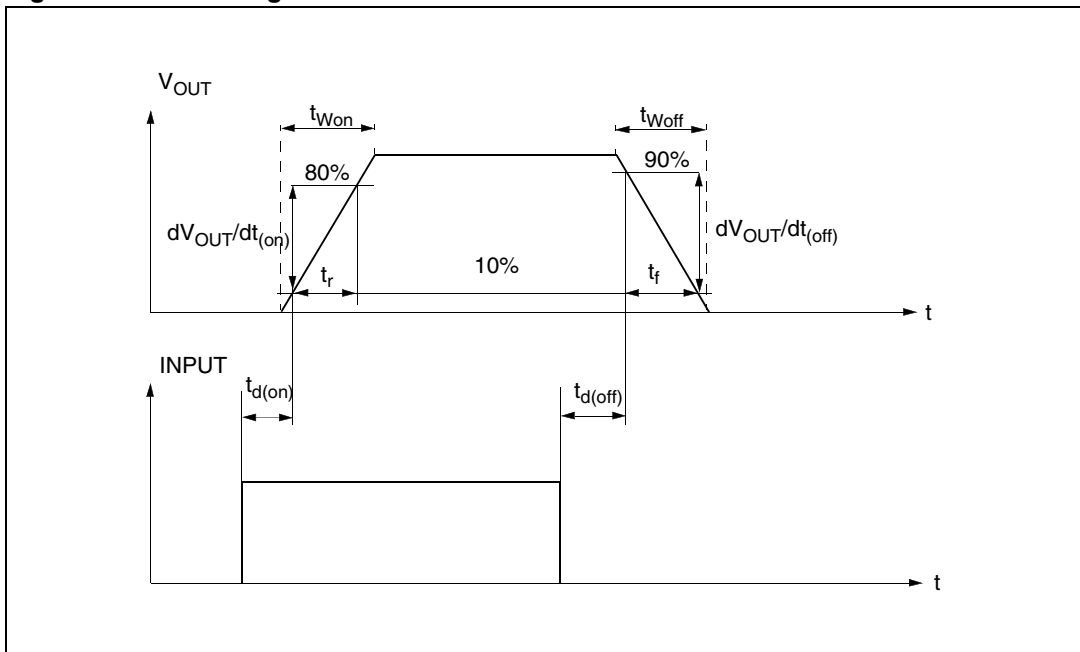
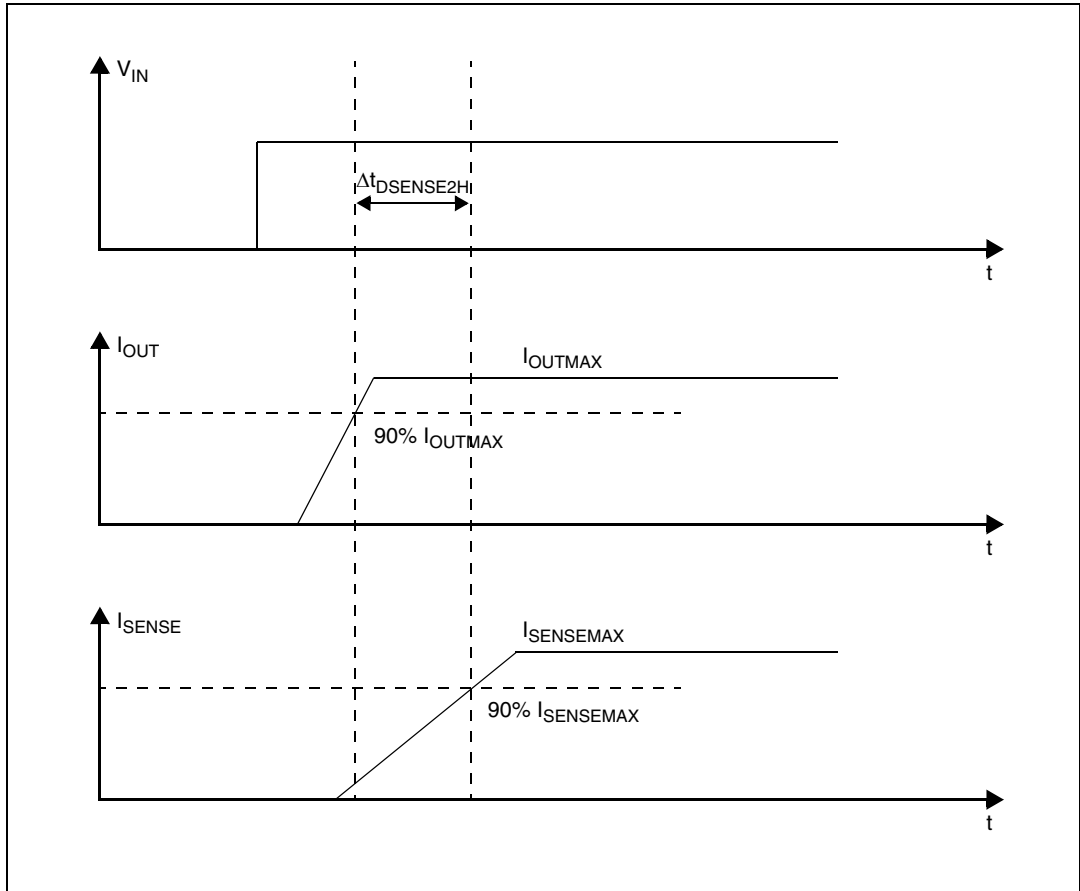


Figure 6. Switching characteristics



**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**

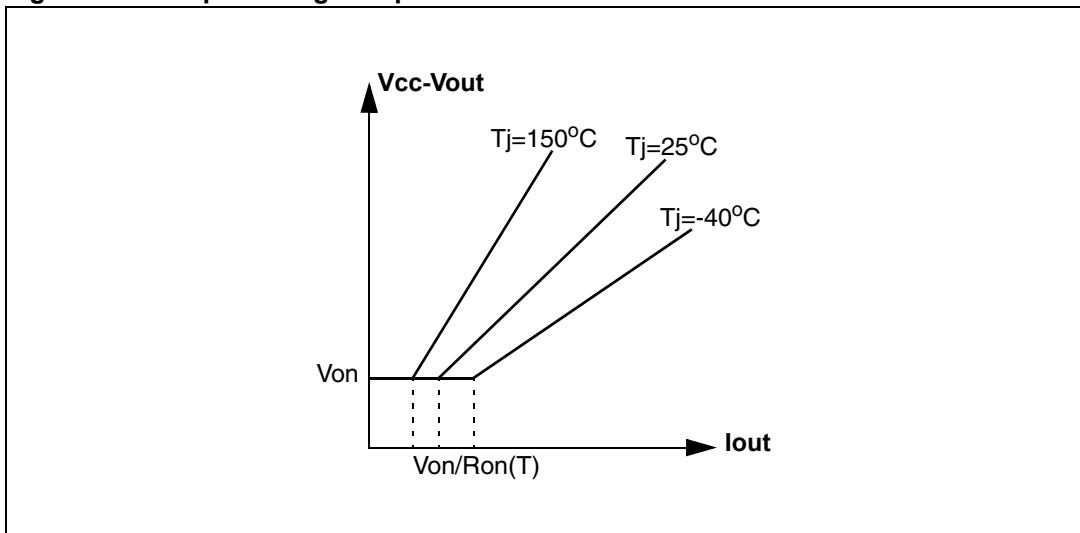


Figure 9.  $I_{out} / I_{sense}$  vs.  $I_{out}$

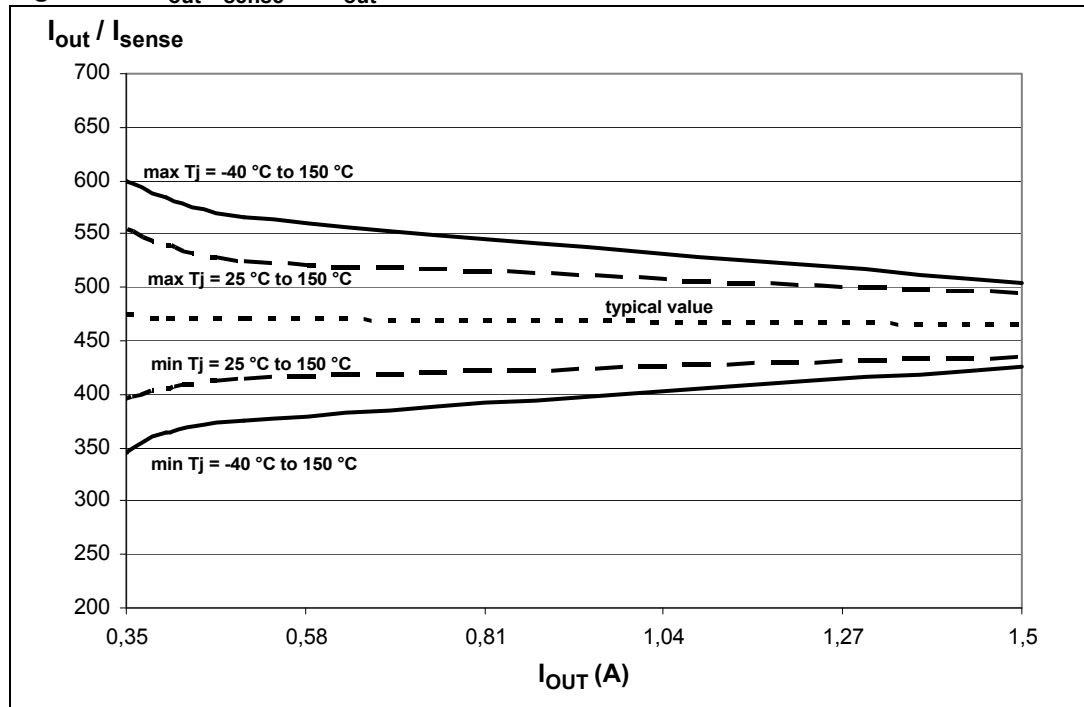
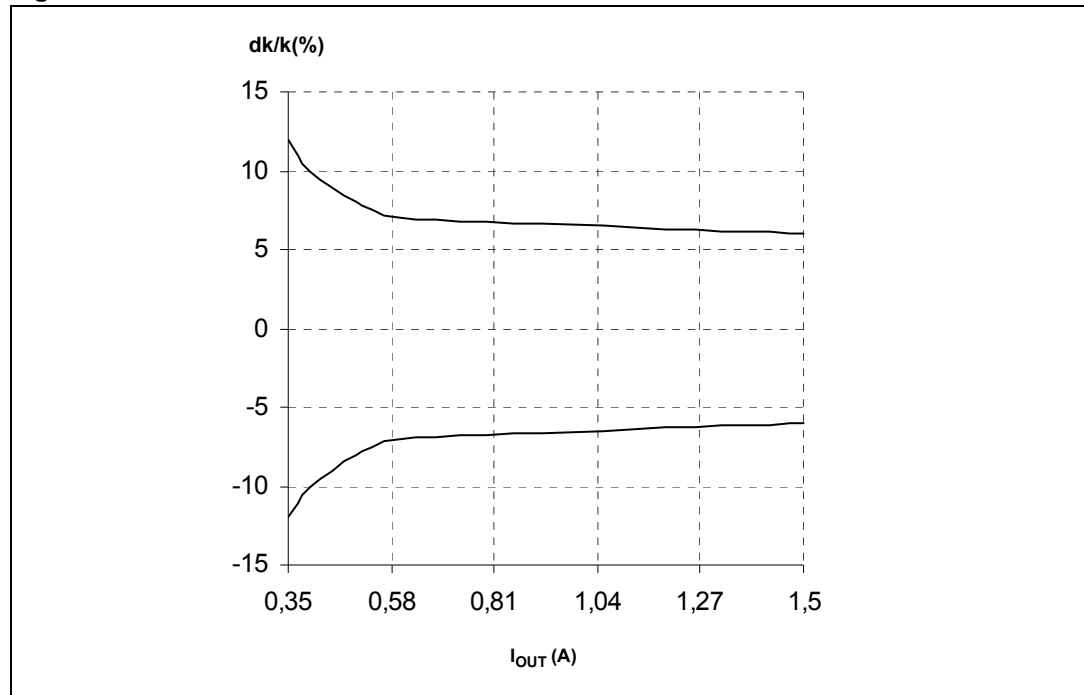


Figure 10. Maximum current sense ratio drift vs load current



Note: Parameter guaranteed by design; it is not tested.

Table 11. Truth table

| Conditions  | Input | Output                        | Sense ( $V_{CSD}=0V$ ) <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                             | < 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                                    | -75V                       | -100V | 5000 pulses                          | 0.5s                                 | 5s    | 2 ms, 10Ω               |
| 2a                                   | +37V                       | +50V  | 5000 pulses                          | 0.2s                                 | 5s    | 50μs, 2Ω                |
| 3a                                   | -100V                      | -150V | 1h                                   | 90ms                                 | 100ms | 0.1μs, 50Ω              |
| 3b                                   | +75V                       | +100V | 1h                                   | 90ms                                 | 100ms | 0.1μs, 50Ω              |
| 4                                    | -6V                        | -7V   | 1 pulse                              |                                      |       | 100ms, 0.01Ω            |
| 5b <sup>(2)</sup>                    | +65V                       | +87V  | 1 pulse                              |                                      |       | 400ms, 2Ω               |

1. The above test levels must be considered referred to  $V_{CC} = 13.5V$  except for pulse 5b.
2. Valid in case of external load dump clamp: 40V maximum referred to ground.

Table 13. Electrical transient requirements (part 2)

| ISO 7637-2:<br>2004E<br>Test pulse | Test level results |    |
|------------------------------------|--------------------|----|
|                                    | III                | VI |
| 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 performed as designed after exposure to disturbance.   |
| E     | One or more functions of the device did not perform as designed after exposure to disturbance and cannot be returned to proper operation without replacing the device. |

## 2.4 Waveforms

Figure 11. Normal operation

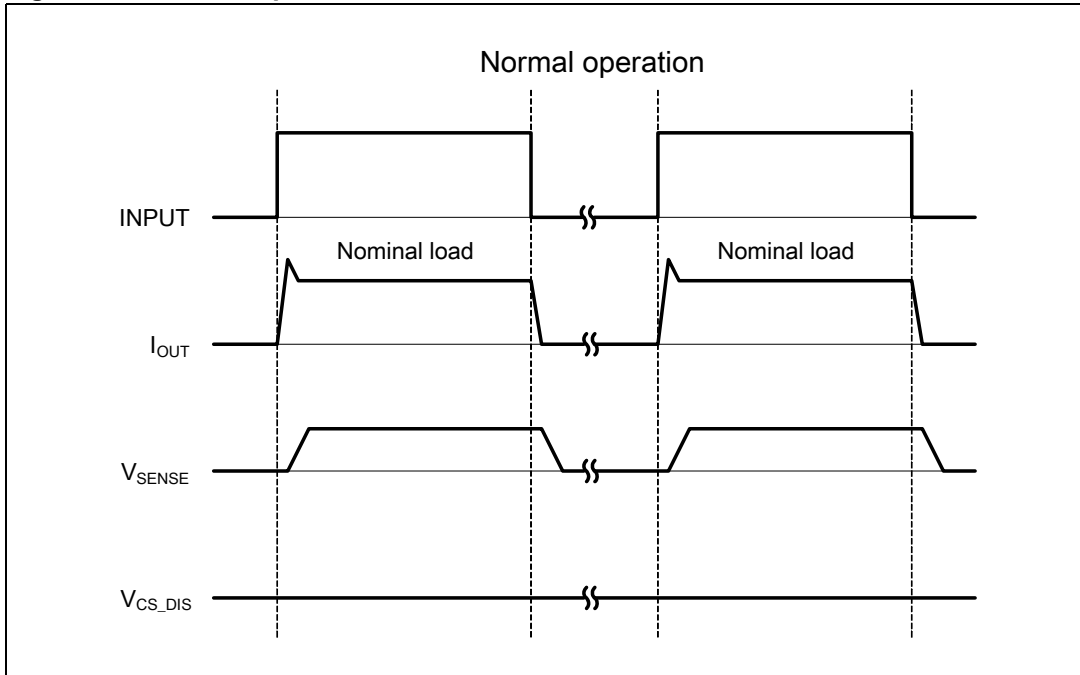


Figure 12. Overload or short to GND

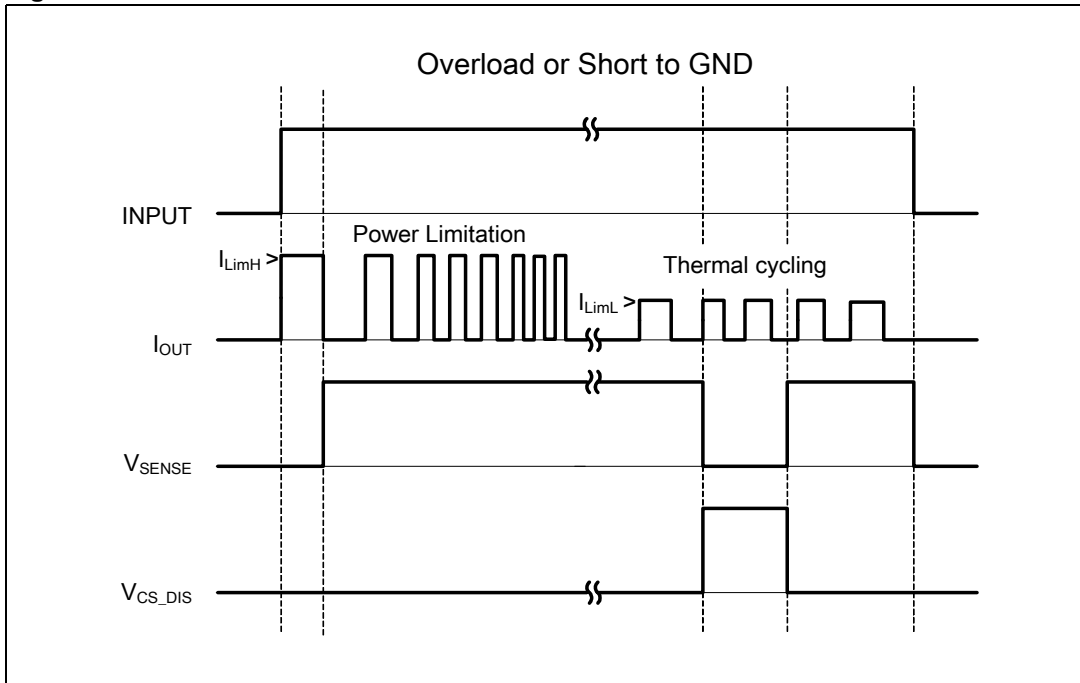


Figure 13. Intermittent overload

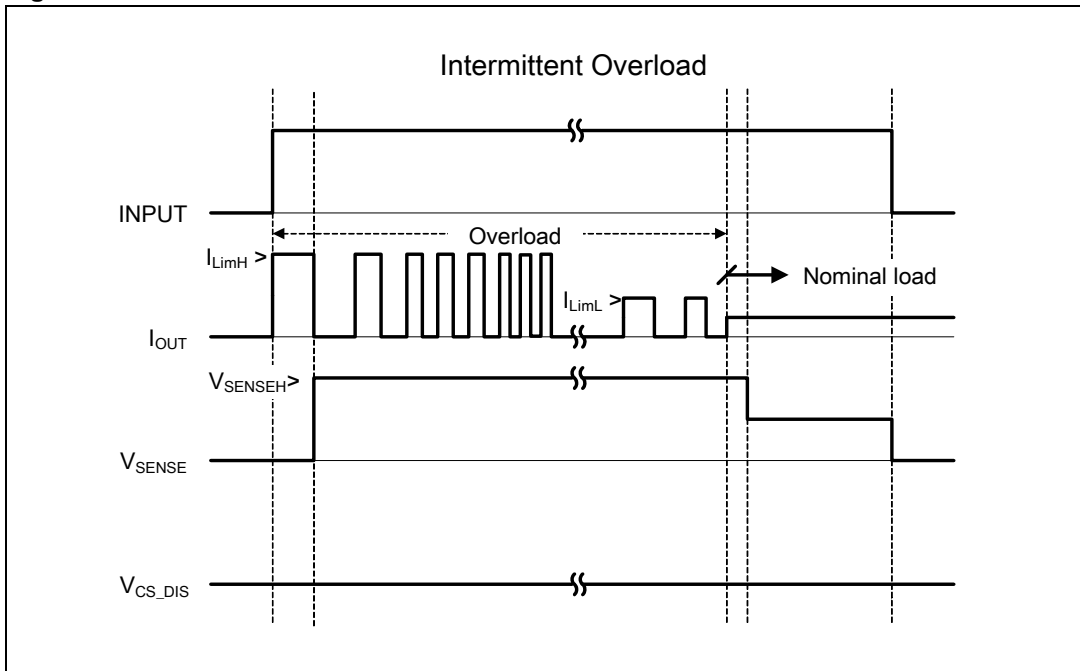


Figure 14. Off-state open load with external circuitry

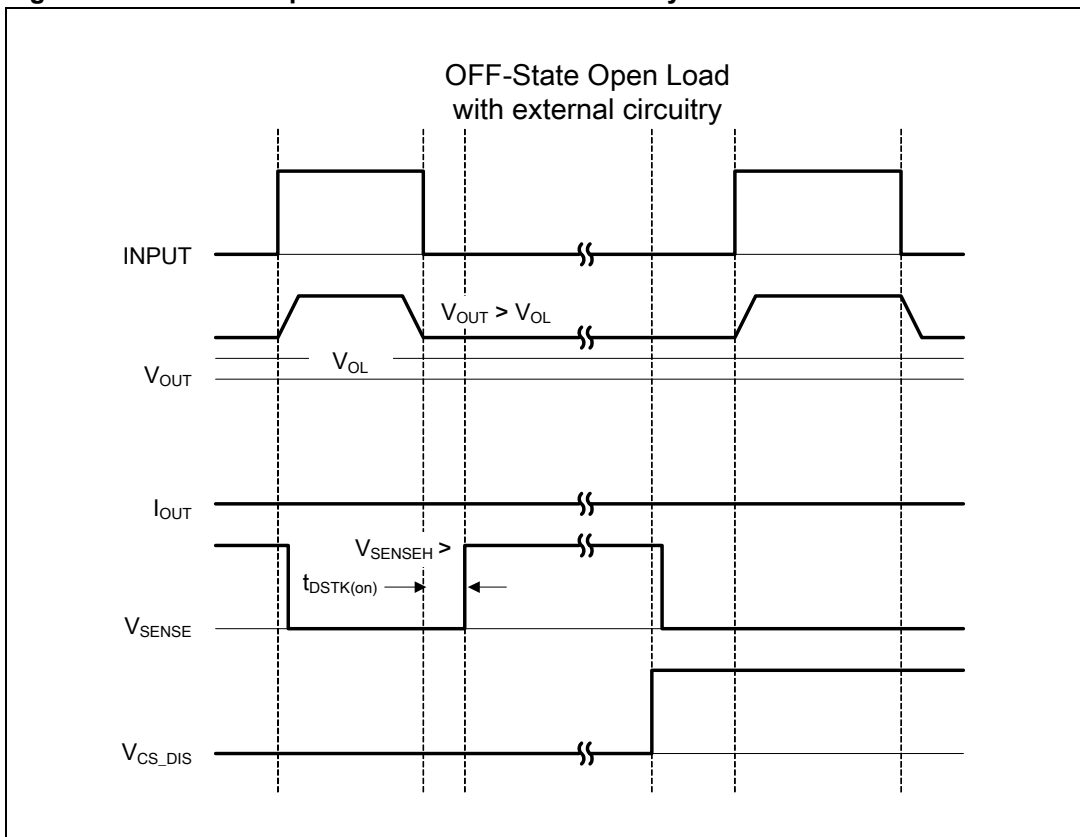


Figure 15. Short to  $V_{CC}$

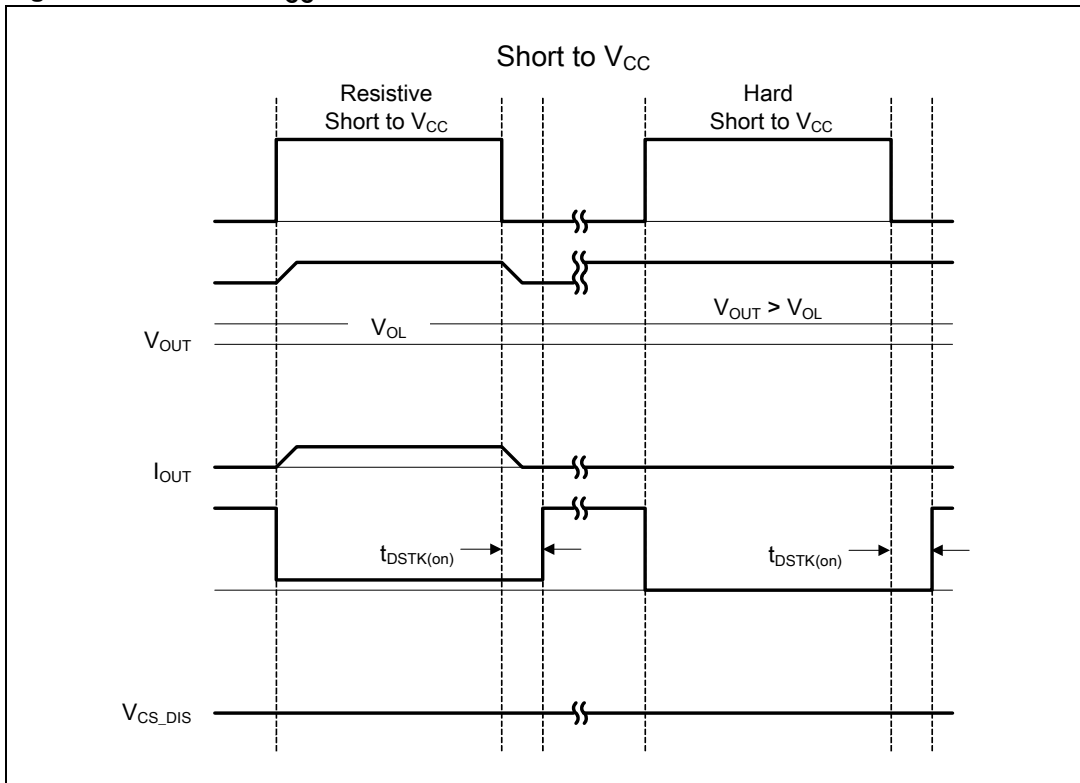
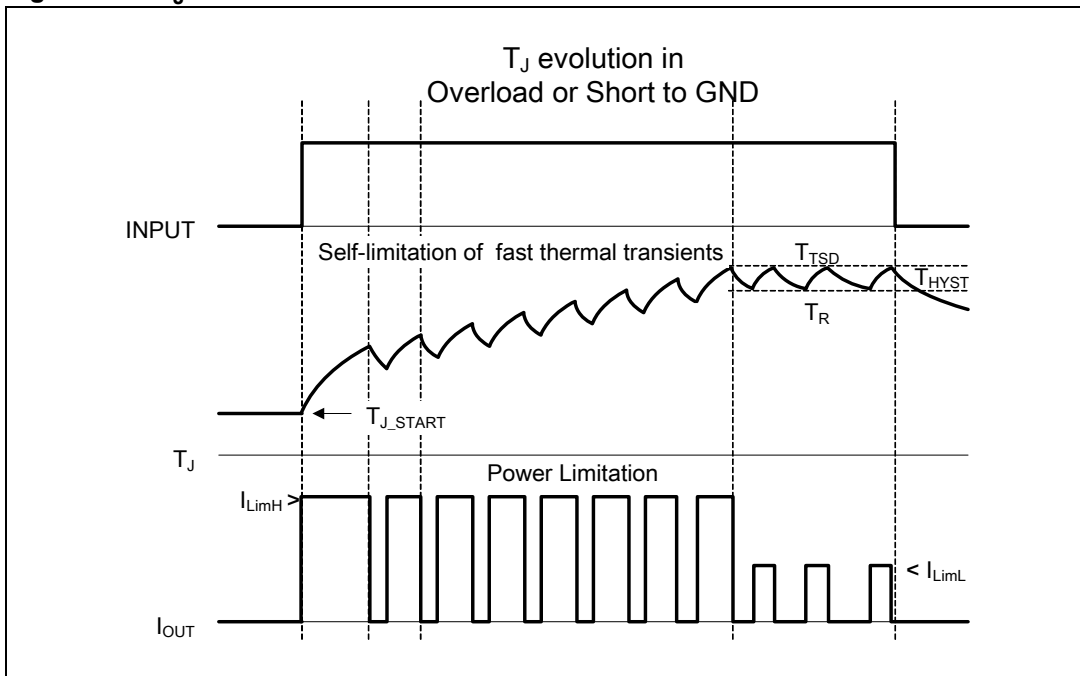


Figure 16.  $T_J$  evolution in overload or short to GND



## 2.5 Electrical characteristics curves

Figure 17. Off state output current

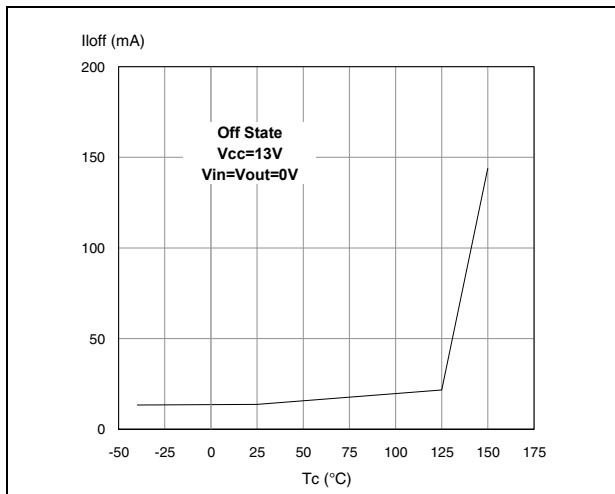


Figure 18. High level input current

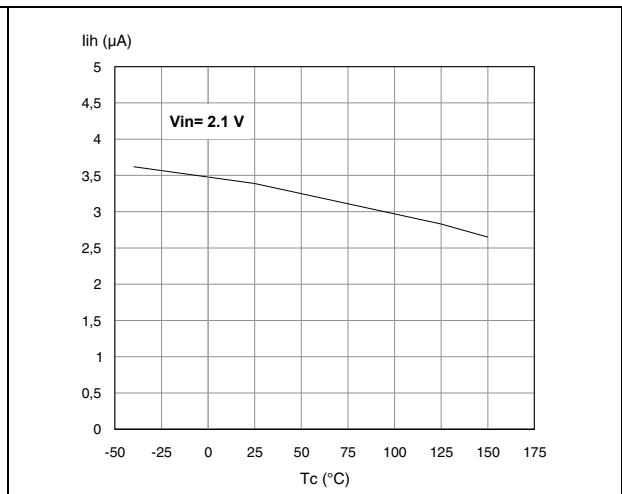


Figure 19. Input clamp voltage

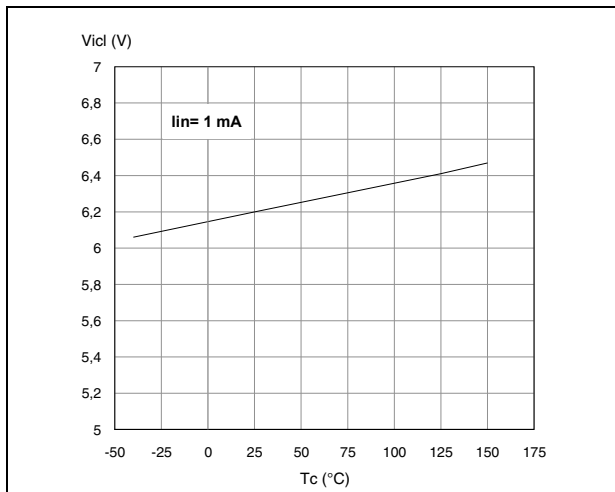


Figure 20. Input low level voltage

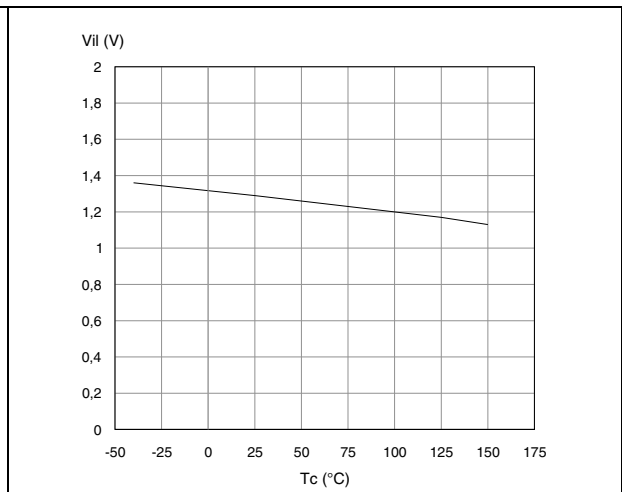


Figure 21. Input high level voltage

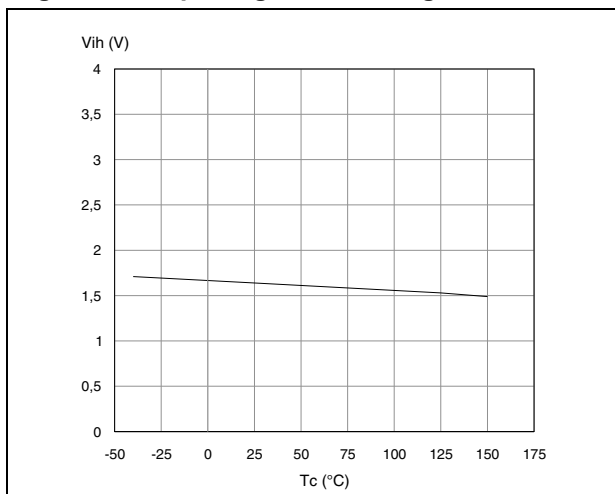


Figure 22. Input hysteresis voltage

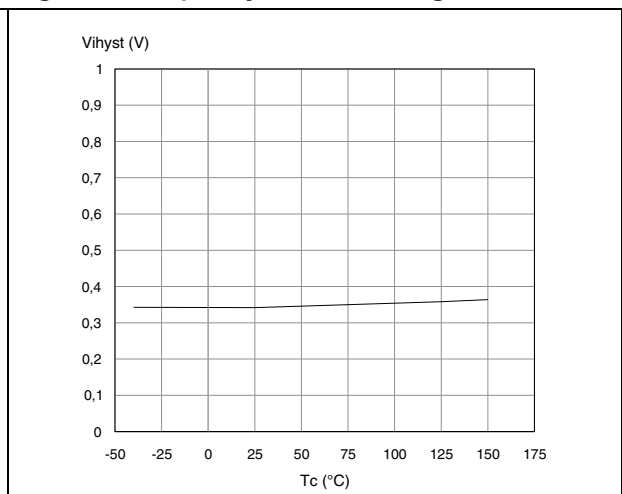


Figure 23. On state resistance vs.  $T_{case}$

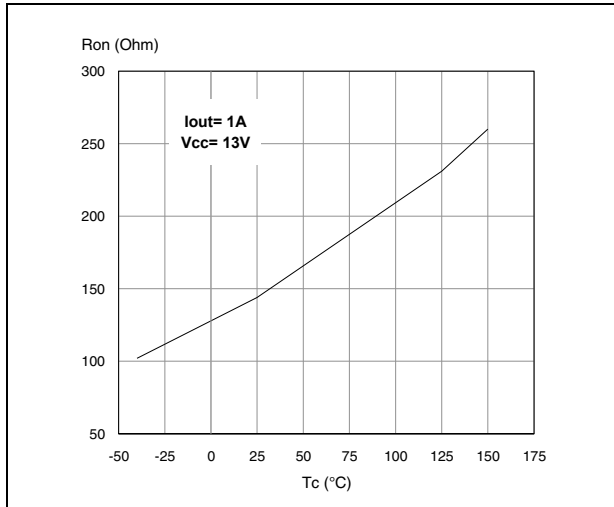


Figure 24. On state resistance vs.  $V_{CC}$

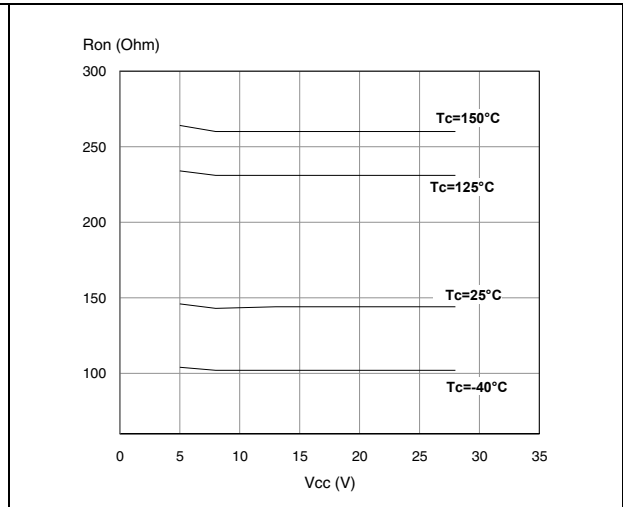


Figure 25. Undervoltage shutdown

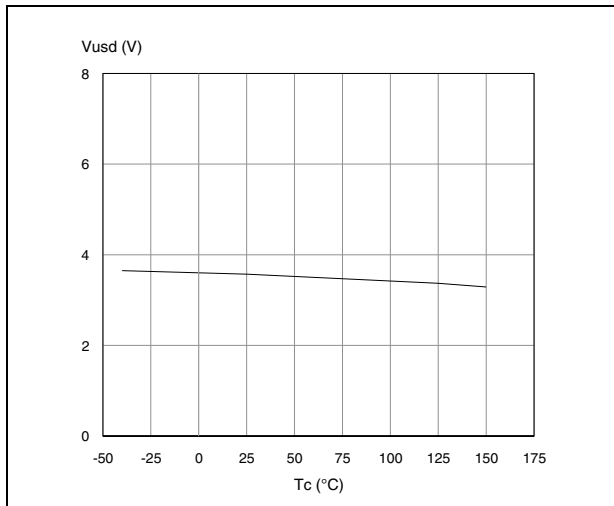


Figure 26. Turn-on voltage slope

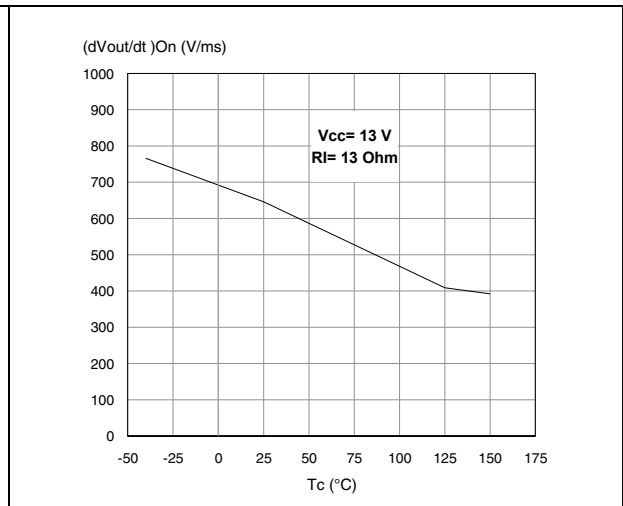


Figure 27.  $I_{LIMH}$  vs.  $T_{case}$

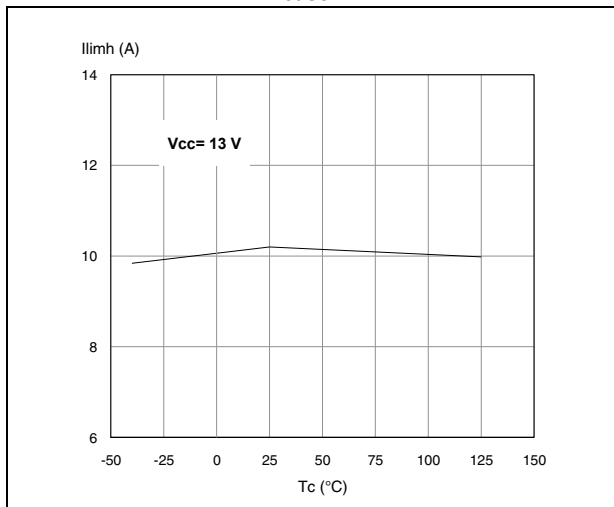


Figure 28. Turn-off voltage slope

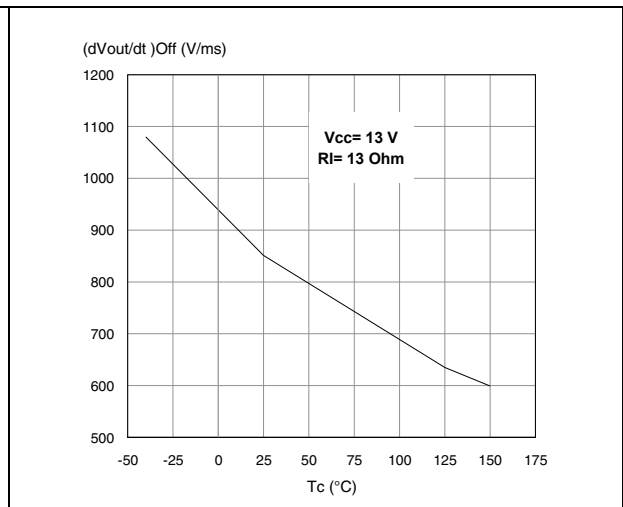


Figure 29. CS\_DIS high level voltage

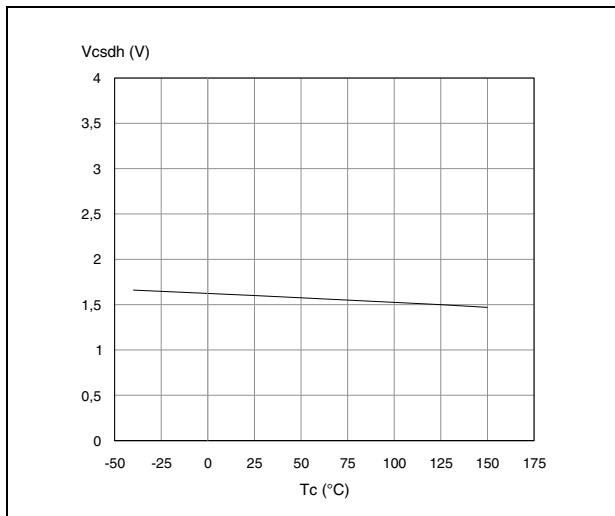


Figure 30. CS\_DIS clamp voltage

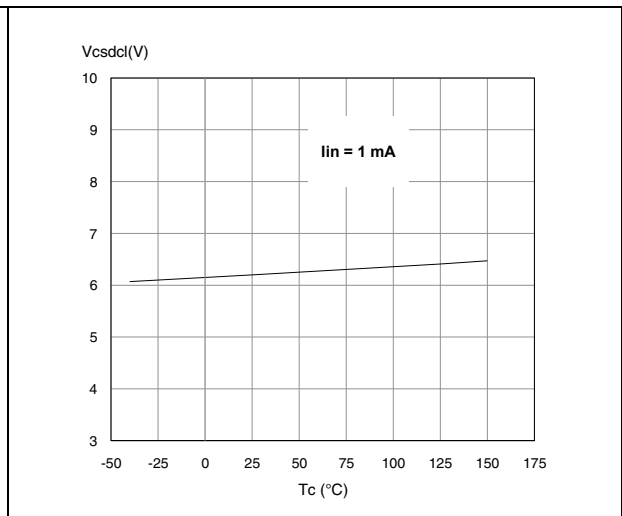
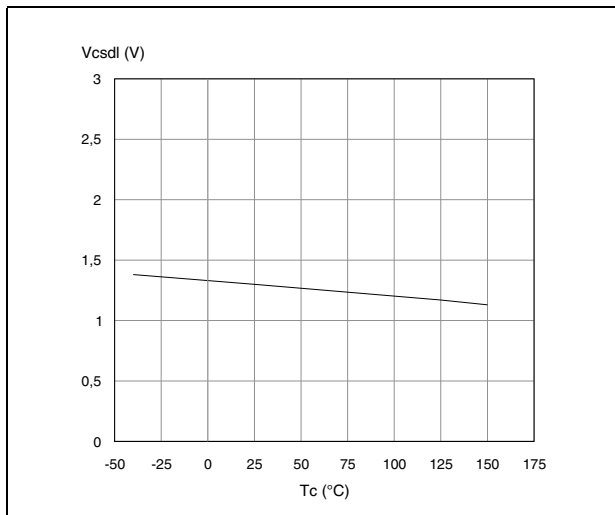
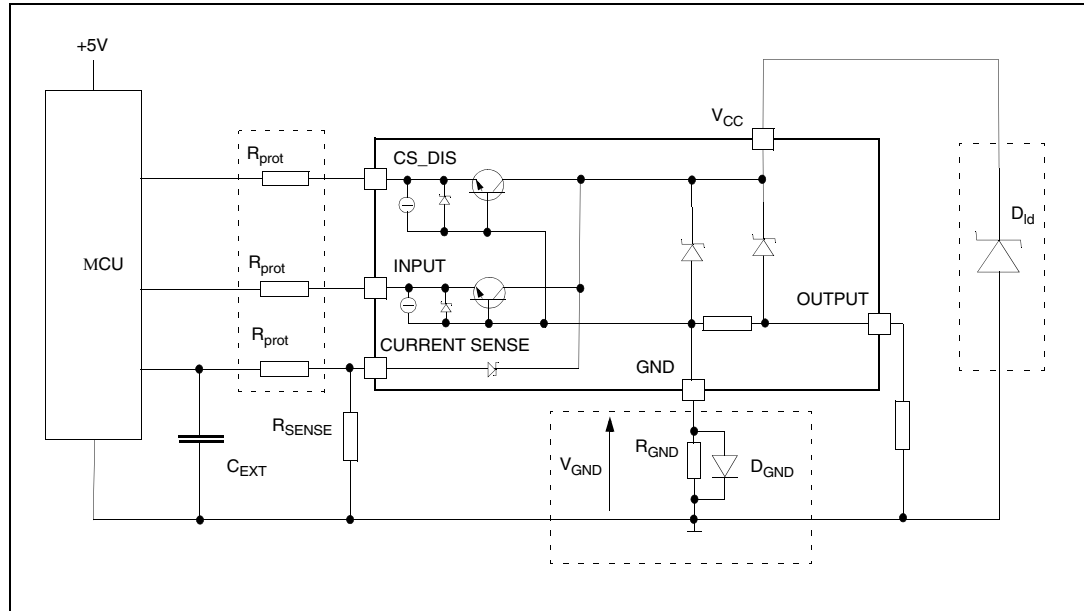


Figure 31. CS\_DIS low level voltage



### 3 Application information

Figure 32. Application schematic



Note: Channel 2, 3, 4 have the same internal circuit as channel 1.

### 3.1 GND protection network against reverse battery

This section provides two solutions for implementing a ground protection network against reverse battery.

#### 3.1.1 Solution 1 : resistor in the ground line (R<sub>GND</sub> only)

This can be used with any type of load.

The following is an indication on how to dimension the R<sub>GND</sub> resistor.

1.  $R_{GND} \leq 600\text{mV} / (I_{S(on)max})$
2.  $R_{GND} \geq (-V_{CC}) / (-I_{GND})$

where -I<sub>GND</sub> is the DC reverse ground pin current and can be found in the absolute maximum rating section of the device datasheet.

Power dissipation in R<sub>GND</sub> (when V<sub>CC</sub><0: during reverse battery situations) is:

#### Equation 1

$$P_D = (-V_{CC})^2 / R_{GND}$$



This resistor can be shared amongst several different HSDs. Please note that the value of this resistor should be calculated with formula (1) where  $I_{S(ON)max}$  becomes the sum of the maximum on-state currents of the different devices.

Please note that if the microprocessor ground is not shared by the device ground then the  $R_{GND}$  will produce a shift ( $I_{S(ON)max} * R_{GND}$ ) in the input thresholds and the status output values. This shift will vary depending on how many devices are on in the case of several high side drivers sharing the same  $R_{GND}$ .

If the calculated power dissipation leads to a large resistor or several devices have to share the same resistor then ST suggests to utilize [Section 3.1.2: Solution 2 : diode \(DGND\) in the ground line](#).

### 3.1.2 Solution 2 : diode ( $D_{GND}$ ) in the ground line

A resistor ( $R_{GND}=1k\Omega$ ) should be inserted in parallel to  $D_{GND}$  if the device drives an inductive load.

This small signal diode can be safely shared amongst several different HSDs. Also in this case, the presence of the ground network will produce a shift ( $\approx 600mV$ ) in the input threshold and in the status output values if the microprocessor ground is not common to the device ground. This shift will not vary if more than one HSD shares the same diode/resistor network.

## 3.2 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.

## 3.3 MCU I/Os protection

If a ground protection network is used and negative transient are present on the  $V_{CC}$  line, the control pins will be pulled negative. ST suggests to insert a resistor ( $R_{prot}$ ) in line to prevent the  $\mu C$  I/Os pins to latch-up.

The value of these resistors is a compromise between the leakage current of  $\mu C$  and the current required by the HSD I/Os (Input levels compatibility) with the latch-up limit of  $\mu C$  I/Os:

### Equation 2

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

Calculation example:

For  $V_{CCpeak} = -100V$  and  $I_{latchup} \geq 20mA$ ;  $V_{OH\mu C} \geq 4.5V$

$$5k\Omega \leq R_{prot} \leq 180k\Omega$$

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

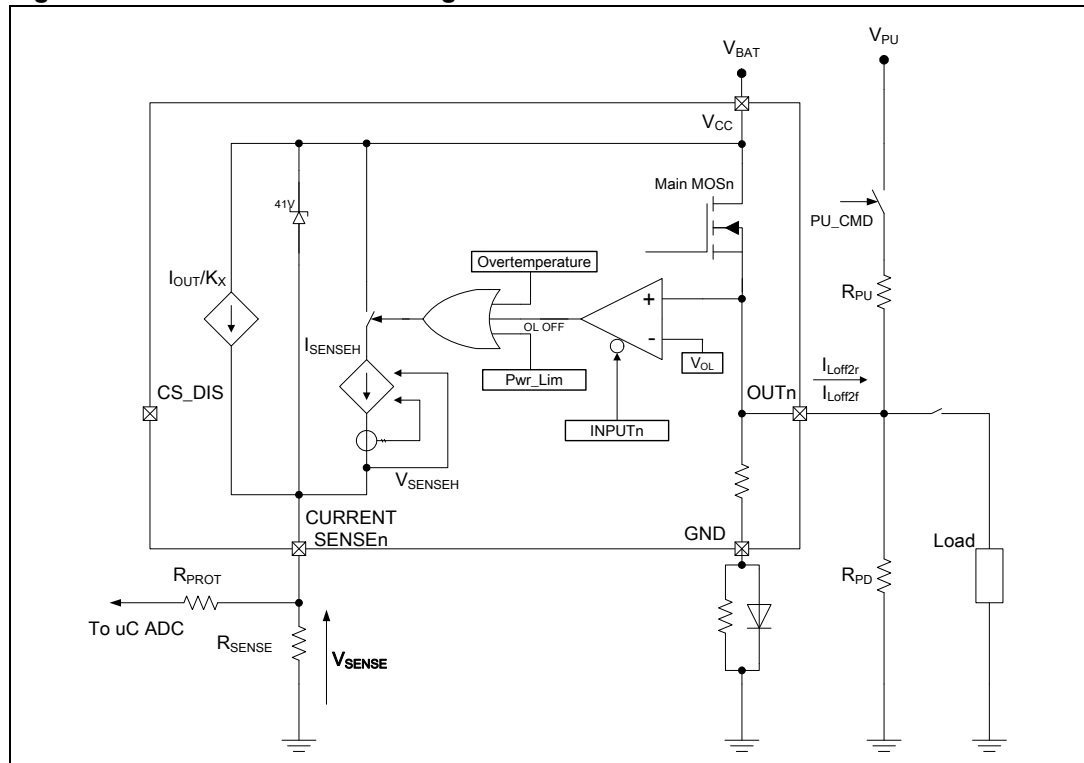
### 3.4 Current sense and diagnostic

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 5V minimum (see parameter  $V_{SENSE}$  in [Table 9: Current sense \(8V <  \$V\_{CC}\$  < 18V\)](#)). The current sense accuracy depends on the output current (refer to current sense electrical characteristics [Table 9: Current sense \(8V <  \$V\_{CC}\$  < 18V\)](#)).
- **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 [Truth table](#)):
  - Power limitation activation
  - Over-temperature
  - 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**



### 3.4.1 Short to V<sub>CC</sub> and off state open load detection

#### Short to V<sub>CC</sub>

A short circuit between V<sub>CC</sub> and output is indicated by the relevant current sense pin set to V<sub>SENSEH</sub> 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<sub>PU</sub> connecting the output to a positive supply voltage V<sub>PU</sub>.

It is preferable V<sub>PU</sub> to be switched off during the module stand-by mode in order to avoid the overall stand-by current consumption to increase in normal conditions, i.e. when load is connected.

An external pull down resistor R<sub>PD</sub> 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<sub>PD</sub> must be selected in order to ensure V<sub>OUT</sub> < V<sub>OLmin</sub> unless pulled up by the external circuitry:

#### Equation 3

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

R<sub>PD</sub> ≤ 22 KΩ is recommended.

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

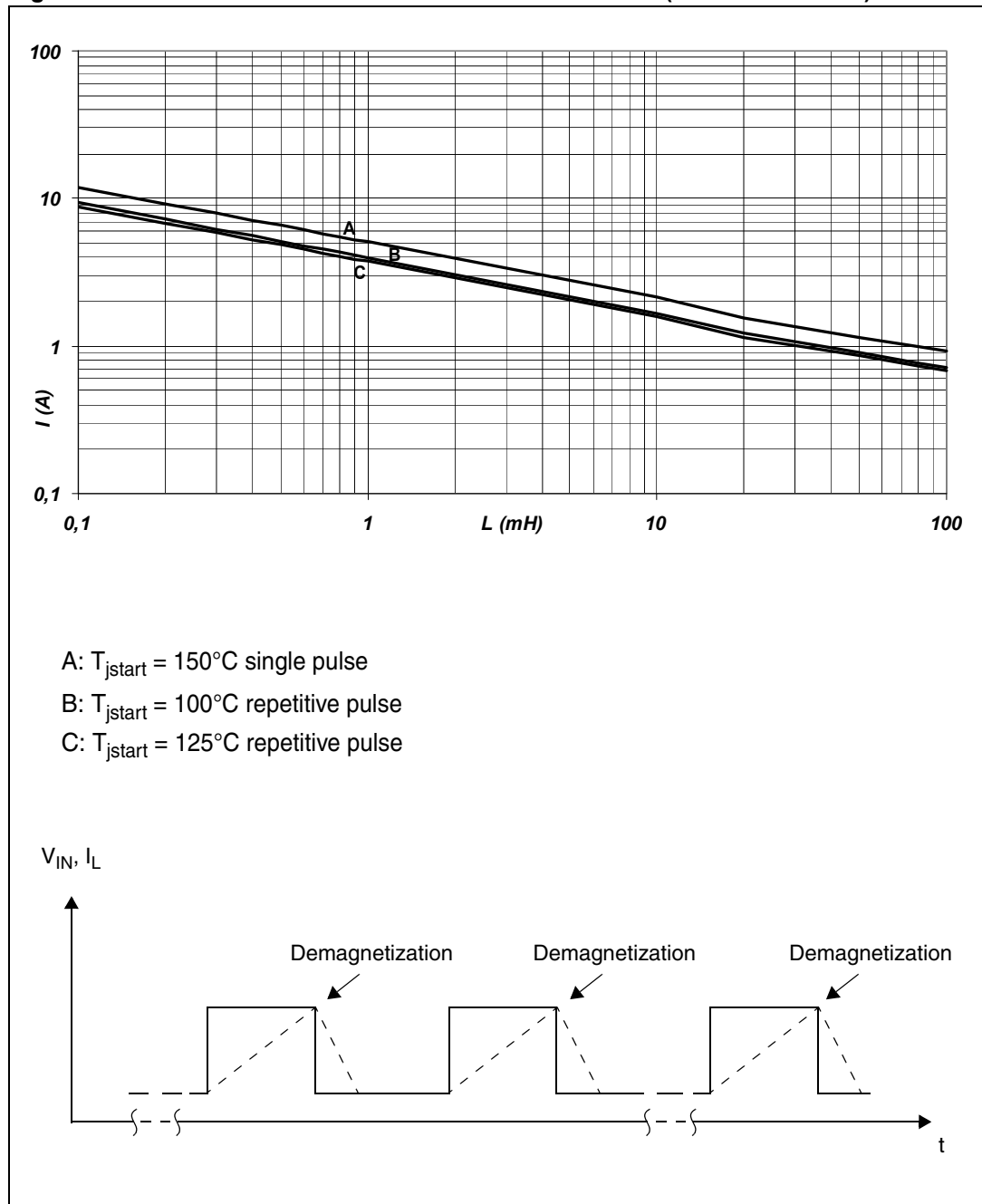
#### Equation 4

$$V_{OUT}|_{Pull-up\_ON} = \frac{R_{PD} \cdot V_{PU} - R_{PU} \cdot R_{PD} \cdot I_{L(off)2r}}{R_{PU} + R_{PD}} > V_{OLmax} = 4V$$

For the values of V<sub>OLmin</sub>, V<sub>OLmax</sub>, I<sub>L(off)2r</sub> and I<sub>L(off)2f</sub> see [Table 10: Openload detection \(8V < V<sub>CC</sub> < 18V\)](#).

### 3.5 Maximum demagnetization energy ( $V_{CC} = 13.5V$ )

Figure 34. Maximum turn-off current versus inductance (for each channel)

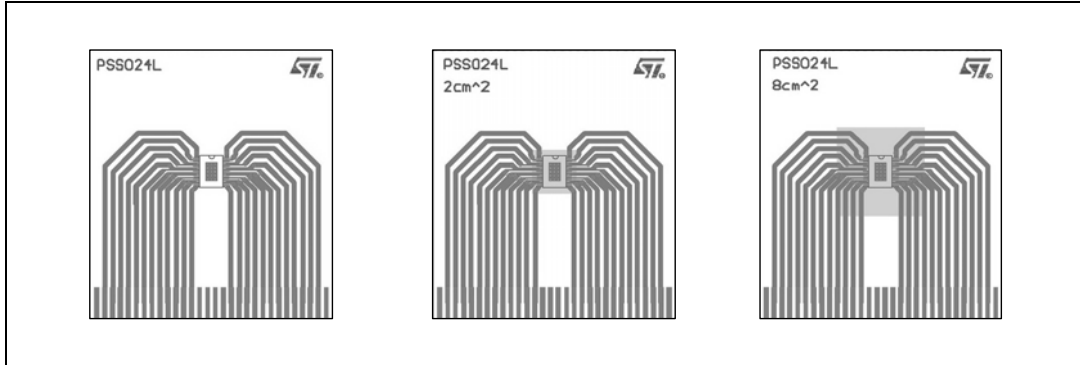


Note: Values are generated with  $R_L = 0 \Omega$ .  
 In case of repetitive pulses,  $T_{jstart}$  (at beginning of each demagnetization) of every pulse must not exceed the temperature specified above for curves A and B.

## 4 Package and PC board thermal data

### 4.1 PowerSSO-24 thermal data

Figure 35. PowerSSO-24 PC board



Note: Layout condition of  $R_{th}$  and  $Z_{th}$  measurements (PCB: Double layer, Thermal Vias, FR4 area= 77 mm x 86 mm, PCB thickness=1.6 mm, Cu thickness=70 mm (front and back side), Copper areas: from minimum pad lay-out to 8 cm<sup>2</sup>).

Figure 36.  $R_{thj-amb}$  vs. PCB copper area in open box free air condition (one channel ON)

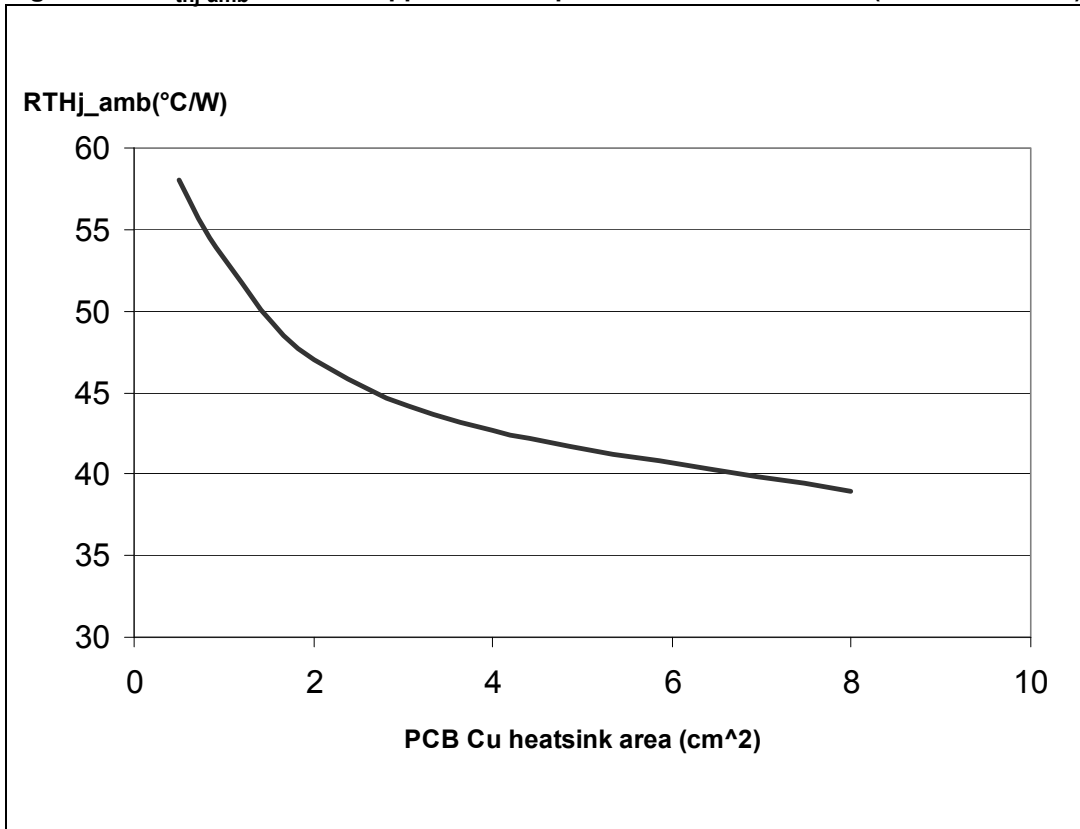


Figure 37. PowerSSO-24 thermal impedance junction ambient single pulse (one channel ON)

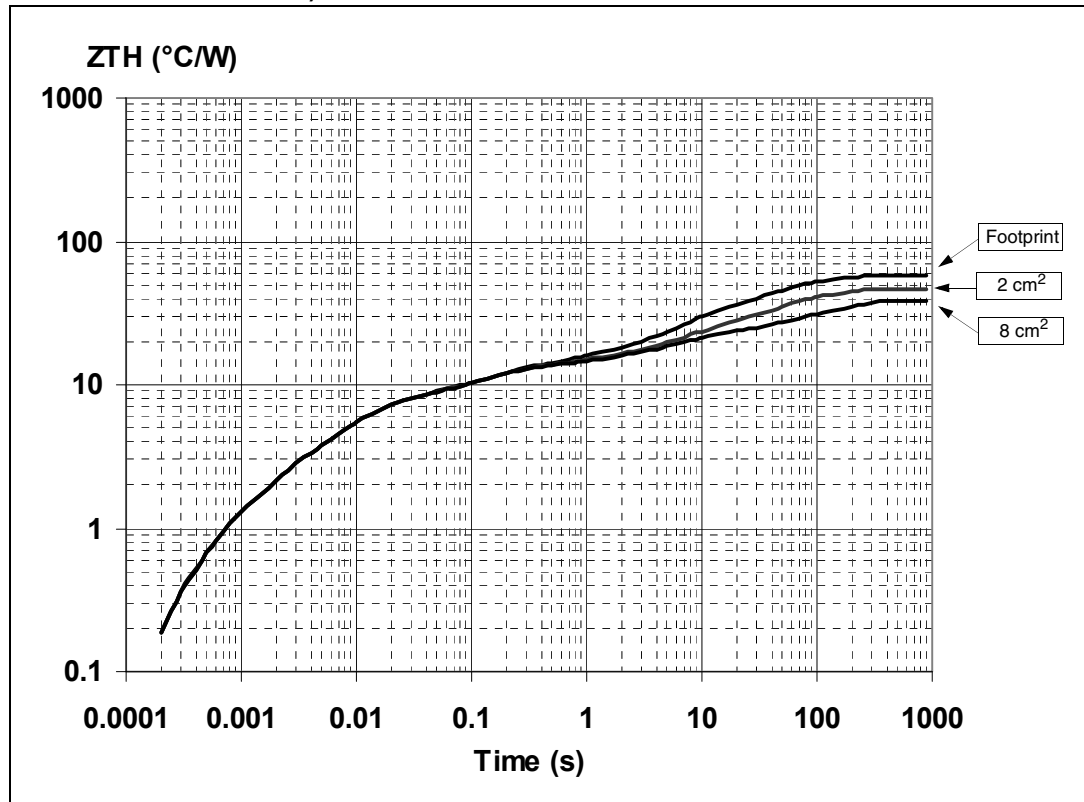
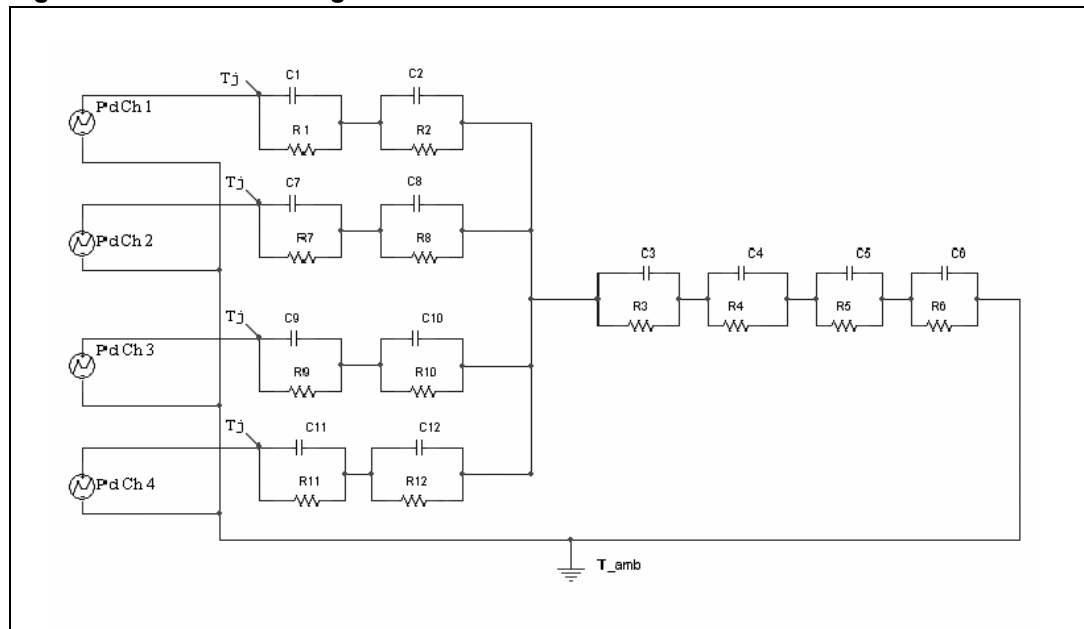


Figure 38. Thermal fitting model of a double channel hsd in PowerSSO-24 (a)



**Equation 5: pulse calculation formula:**

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

where  $\delta = t_p/T$

**Table 15. Thermal parameters**

| Area/island (cm <sup>2</sup> ) | Footprint | 2  | 8  |
|--------------------------------|-----------|----|----|
| R1 = R7 = R9 = R11 (°C/W)      | 1.2       |    |    |
| R2 = R8 = R10 = R12 (°C/W)     | 6         |    |    |
| R3 (°C/W)                      | 6         |    |    |
| R4 (°C/W)                      | 7.7       |    |    |
| R5 (°C/W)                      | 9         | 9  | 8  |
| R6 (°C/W)                      | 28        | 17 | 10 |
| C1 = C7 = C9 = C11 (W.s/°C)    | 0.0008    |    |    |
| C2 = C8 = C10 = C12 (W.s/°C)   | 0.0016    |    |    |
| C3 (W.s/°C)                    | 0.025     |    |    |
| C4 (W.s/°C)                    | 0.75      |    |    |
| C5 (W.s/°C)                    | 1         | 4  | 9  |
| C6 (W.s/°C)                    | 2.2       | 5  | 17 |

- a. 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.

## 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 PowerSSO-24 mechanical data

Figure 39. PowerSSO-24 package dimensions

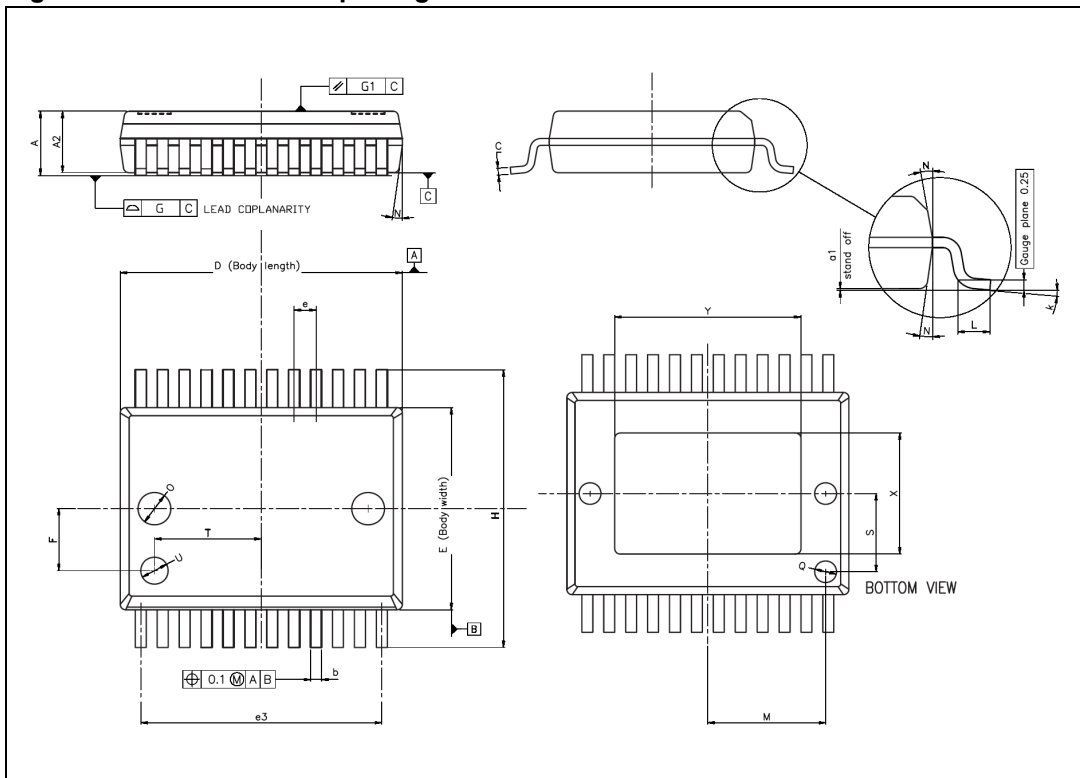




Table 16. PowerSSO-24 mechanical data<sup>(1) (2)</sup>

| Symbol           | Millimeters |      |       |
|------------------|-------------|------|-------|
|                  | Min.        | Typ. | Max.  |
| A                |             |      | 2.45  |
| A2               | 2.15        |      | 2.35  |
| a1               | 0           |      | 0.1   |
| b                | 0.33        |      | 0.51  |
| c                | 0.23        |      | 0.32  |
| D <sup>(3)</sup> | 10.10       |      | 10.50 |
| E <sup>(3)</sup> | 7.40        |      | 7.60  |
| e                |             | 0.8  |       |
| e3               |             | 8.8  |       |
| F                |             | 2.3  |       |
| G                |             |      | 0.1   |
| H                | 10.1        |      | 10.5  |
| h                |             |      | 0.4   |
| k                | 0°          |      | 8°    |
| L                | 0.6         |      | 1     |
| O                |             | 1.2  |       |
| Q                |             | 0.8  |       |
| S                |             | 2.9  |       |
| T                |             | 3.65 |       |
| U                |             | 1.0  |       |
| N                |             |      | 10°   |
| X                | 4.1         |      | 4.7   |
| Y                | 6.5         |      | 7.1   |

1. No intrusion allowed inwards the leads.
2. Flash or bleeds on exposed die pad shall not exceed 0.5 mm per side
3. "D and E" do not include mold flash or protusions.  
Mold flash or protusions shall not exceed 0.15 mm per side

### 5.3 Packing information

Figure 40. PowerSSO-24 tube shipment (no suffix)

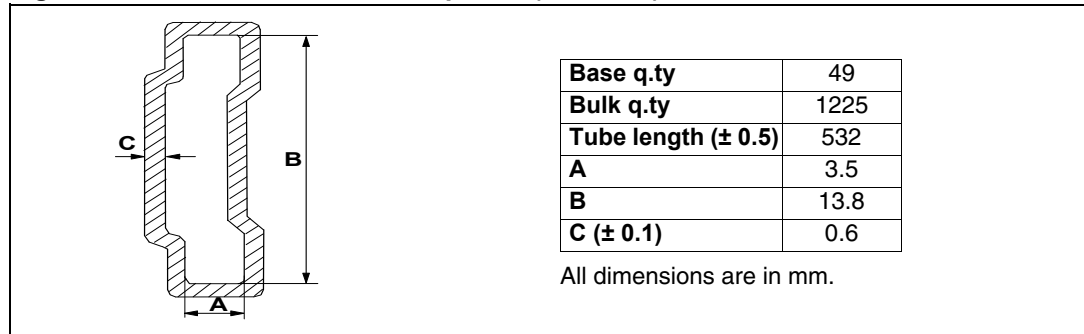
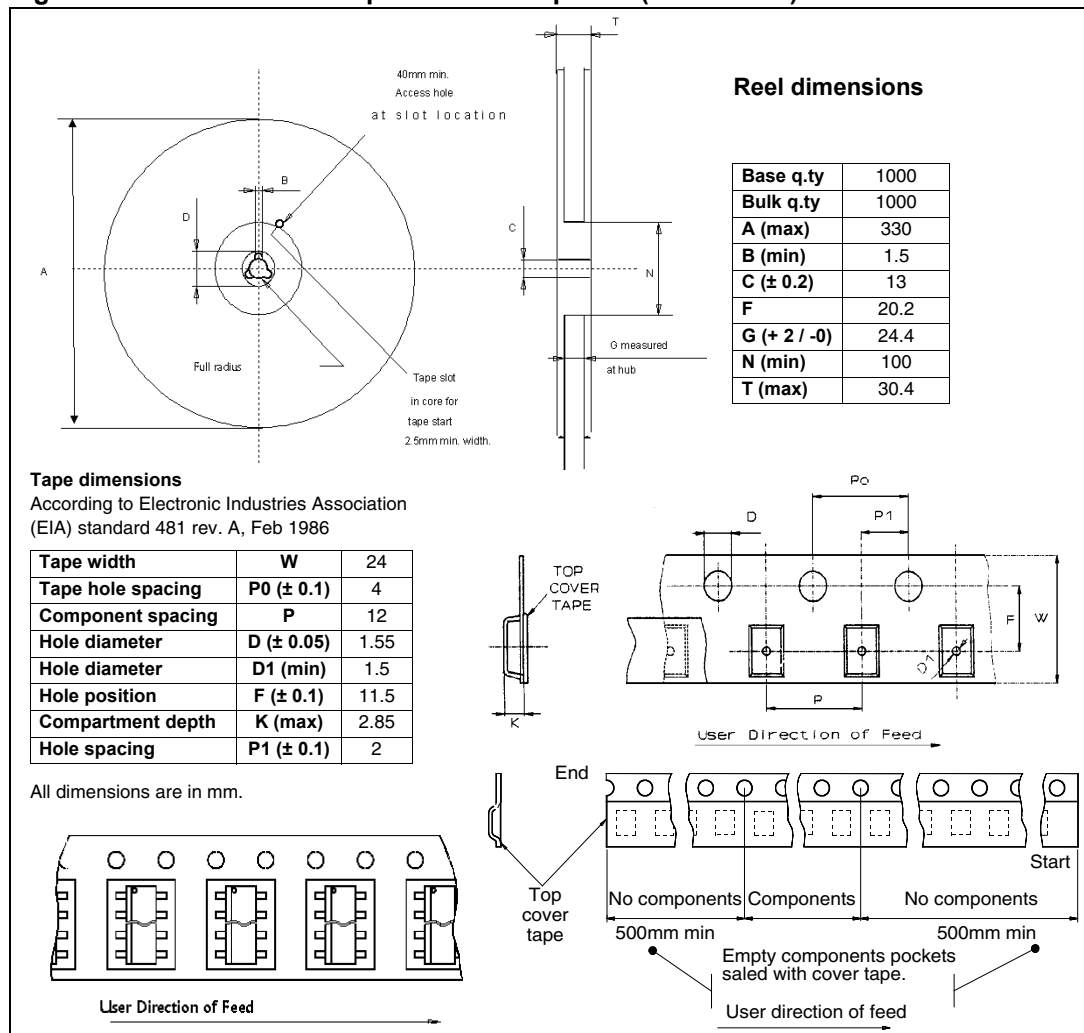


Figure 41. PowerSSO-24 tape and reel shipment (suffix "TR")



## 6 Order codes

Table 17. Device summary

| Package     | Order codes  |                |
|-------------|--------------|----------------|
|             | Tube         | Tape and reel  |
| PowerSSO-24 | VNQ5E160AK-E | VNQ5E160AKTR-E |

## 7 Revision history

**Table 18. Document revision history**

| Date        | Revision | Changes   |
|-------------|----------|---|
| 05-Jun-2007 | 1        | Initial release.  |
| 17-Mar-2009 | 2        | Document restructured.<br>Updated <a href="#">Table 9: Current sense (8V&lt;V<sub>CC</sub>&lt;18V)</a> :<br>– added k0, k1, k2, k3, dk1/k1, dk2/k2, dk3/k3, Δt <sub>DSENSE2H</sub> parameters values<br>Updated <a href="#">Table 10: Openload detection (8V&lt;V<sub>CC</sub>&lt;18V)</a> :<br>– added I <sub>L(off2)r</sub> , I <sub>L(off2)f</sub> and td_vol parameters<br>Added <a href="#">Figure 9.: I<sub>out</sub>/ I<sub>sense</sub> vs. I<sub>out</sub></a> .<br>Added <a href="#">Figure 10.: Maximum current sense ratio drift vs load current</a><br>Added <a href="#">Section 2.4: Waveforms</a> .<br>Added <a href="#">Section 2.5: Electrical characteristics curves</a> .<br>Updated <a href="#">Chapter 3: Application information</a> :<br>– added <a href="#">Section 3.4: Current sense and diagnostic</a><br>Added <a href="#">Chapter 4: Package and PC board thermal data</a> :<br>Updated <a href="#">Table 16: PowerSSO-24 mechanical data</a> |
| 19-Sep-2013 | 3        | Updated Disclaimer  |

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