

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

Datasheet - production data



### Features

|                                   |            |                          |
|-----------------------------------|------------|--------------------------|
| Max transient supply voltage      | $V_{CC}$   | 41V                      |
| Operating voltage range           | $V_{CC}$   | 4.5 to 28V               |
| Max on-state resistance (per ch.) | $R_{ON}$   | 12 m $\Omega$            |
| Current limitation (typ)          | $I_{LIMH}$ | 74 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 standby current
  - 3.0 V CMOS compatible input
  - Optimized electromagnetic emission
  - Very low electromagnetic susceptibility
  - In compliance with the 2002/95/EC european directive
  - Proportional load current sense
  - High current sense precision for wide range current
  - Very low current sense leakage
- Diagnostic functions:
  - Off-state open-load detection
  - Current sense disable
  - Thermal shutdown indication
  - Output short to  $V_{CC}$  detection
  - Overload and short to ground (power limitation) indication
- Protection:

- Undervoltage shutdown
- Overvoltage clamp
- Load current limitation
- Self limiting of fast thermal transients
- Protection against loss of ground and loss of  $V_{CC}$
- Thermal shutdown
- Reverse battery protection with self switch of the Power MOS
- Electrostatic discharge protection

### Applications

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

### Description

The VND5E012AY-E is a device made using STMicroelectronics® VIPower® M0-5 technology. It is intended for driving resistive or inductive loads with one side connected to ground. Active  $V_{CC}$  pin voltage clamp protects the device against low energy spikes.

This device integrates an analog current sense which delivers a current proportional to the load current when CS\_DIS high leads the current sense pin in high impedance.

Fault conditions such as overload, overtemperature or openload are reported via the current sense pin.

Output current limitation protects the device in overload condition. In case of long overload duration, the device limits the dissipated power to safe level up to thermal shutdown intervention. Thermal shutdown with automatic restart allows the device to recover normal operation as soon as fault condition disappears.

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Figure 2. Configuration diagram (top view)

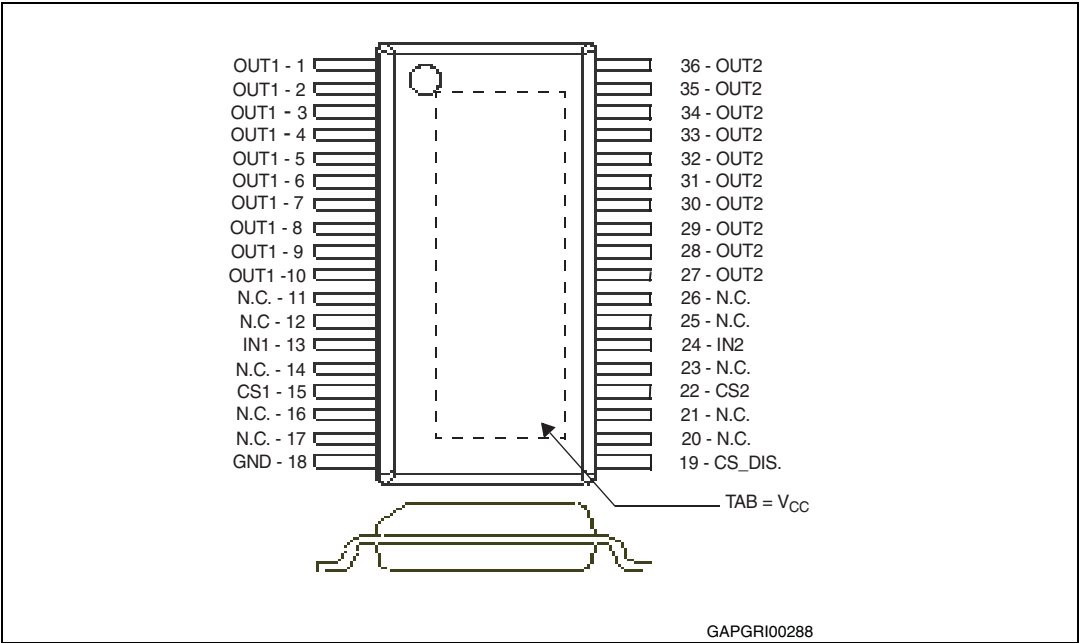
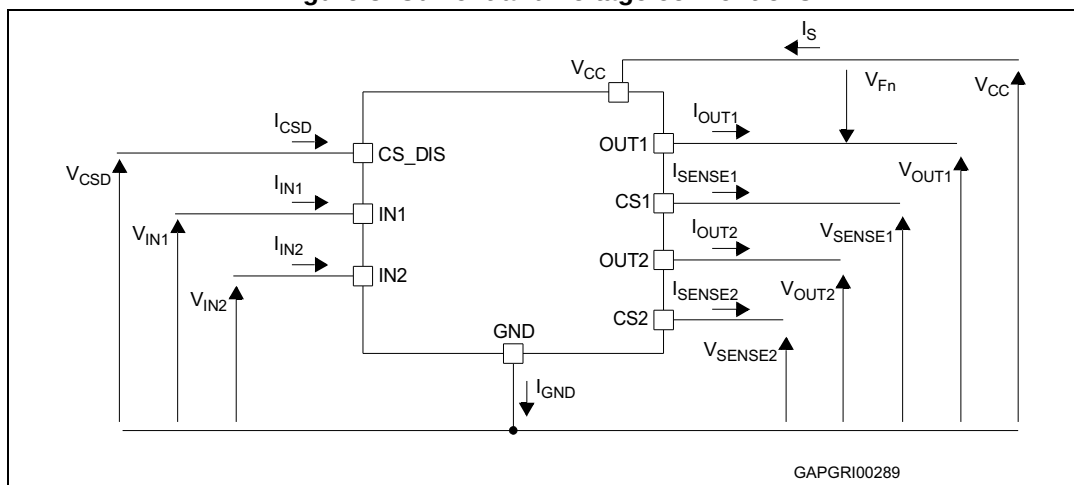


Table 2. Suggested connections for unused and not connected pins

| Connection / pin | Current sense                 | Not connected | Output      | Input                          | CS_DIS                         |
|------------------|-------------------------------|---------------|-------------|--------------------------------|--------------------------------|
| Floating         | Not allowed                   | X             | X           | X                              | X                              |
| To ground        | Through 1 K $\Omega$ resistor | X             | Not allowed | Through 10 K $\Omega$ resistor | Through 10 K $\Omega$ resistor |

## 2 Electrical specifications

Figure 3. Current and voltage conventions



### 2.1 Absolute maximum ratings

Applying stress which exceeds the ratings listed in the [Table 3](#) 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 this section for extended periods may affect device reliability.

Table 3. Absolute maximum ratings

| Symbol        | Parameter                                                                       | Value                    | Unit   |
|---------------|---------------------------------------------------------------------------------|--------------------------|--------|
| $V_{CC}$      | DC supply voltage                                                               | 28                       | V      |
| $V_{CCPK}$    | Transient supply voltage ( $T < 400$ ms, $R_{LOAD} > 0.5 \Omega$ )              | 41                       | V      |
| $-V_{CC}$     | Reverse DC supply voltage                                                       | 16                       | V      |
| $V_{CC\_LSC}$ | Maximum supply voltage for full protection to short-circuit (acc. AEC-Q100-012) | 18                       | V      |
| $-I_{GND}$    | DC reverse ground pin current                                                   | 200                      | mA     |
| $I_{OUT}$     | DC output current                                                               | Internally limited       | A      |
| $-I_{OUT}$    | Reverse DC output current                                                       | 50                       | A      |
| $I_{IN}$      | DC input current                                                                | -1 to 10                 | mA     |
| $I_{CSD}$     | DC current sense disable input current                                          | -1 to 10                 | mA     |
| $-I_{CSENSE}$ | DC Reverse CS pin current                                                       | 200                      | mA     |
| $V_{CSENSE}$  | Current sense maximum voltage                                                   | $V_{CC}-41$<br>$+V_{CC}$ | V<br>V |

Table 3. Absolute maximum ratings (continued)

| Symbol    | Parameter                                                                                                                                                                                        | Value                | Unit               |
|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|--------------------|
| $E_{MAX}$ | Maximum switching energy (single pulse)<br>( $L = 0.47\text{ mH}$ ; $R_L = 0\ \Omega$ ; $V_{bat} = 13.5\text{ V}$ ; $T_{jstart} = 150\text{ }^{\circ}\text{C}$ ;<br>$I_{OUT} = I_{limL}(Typ.)$ ) | 110                  | mJ                 |
| $V_{ESD}$ | Electrostatic Discharge (Human Body Model: $R=1.5\text{K}\Omega$ ;<br>$C=100\text{pF}$ )<br>– $V_{CC}$ , OUTPUT<br>– INPUT, CS_DIS<br>– CURRENT SENSE                                            | 5000<br>4000<br>2000 | V                  |
| $V_{ESD}$ | Charge device model (CDM-AEC-Q100-011)                                                                                                                                                           | 750                  | V                  |
| $T_j$     | Junction operating temperature                                                                                                                                                                   | -40 to 150           | $^{\circ}\text{C}$ |
| $T_{stg}$ | Storage temperature                                                                                                                                                                              | -55 to 150           | $^{\circ}\text{C}$ |

## 2.2 Thermal data

Table 4. Thermal data

| Symbol         | Parameter                                                 | Maximum value                                        | Unit                 |
|----------------|-----------------------------------------------------------|------------------------------------------------------|----------------------|
| $R_{thj-case}$ | Thermal resistance junction-case<br>(With one channel ON) | 2                                                    | $^{\circ}\text{C/W}$ |
| $R_{thj-amb}$  | Thermal resistance junction-ambient                       | See <a href="#">Figure 36</a> in the thermal section | $^{\circ}\text{C/W}$ |

## 2.3 Electrical characteristics

$8V < V_{CC} < 28V$ ;  $-40^{\circ}C < T_j < 150^{\circ}C$ , 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                 | $I_{OUT}=5A$ ; $T_j=25^{\circ}C$                        |      | 11    | 16    |            |
|               |                                     | $I_{OUT}=5A$ ; $T_j=150^{\circ}C$                       |      |       | 24    | m $\Omega$ |
|               |                                     | $I_{OUT}=5A$ ; $V_{CC}=5V$ ; $T_j=25^{\circ}C$          |      |       | 16    | m $\Omega$ |
| $R_{ON REV}$  | Reverse battery on-state resistance | $V_{CC}=-13V$ ; $I_{OUT}=-5A$ ; $T_j=25^{\circ}C$       |      |       | 12    | m $\Omega$ |
| $V_{clamp}$   | Clamp voltage                       | $I_S=20$ mA                                             | 41   | 46    | 52    | V          |
| $I_S$         | Supply current                      | Off-state; $V_{CC}=13V$ ; $T_j=25^{\circ}C$ ;           |      |       |       |            |
|               |                                     | $V_{IN}=V_{OUT}=V_{SENSE}=V_{CSD}=0$ V                  |      | 2 (1) | 5 (1) | $\mu A$    |
|               |                                     | On-state; $V_{CC}=13V$ ; $V_{IN}=5V$ ; $I_{OUT}=0A$     |      | 3.5   | 6.5   | mA         |
| $I_{L(off)}$  | Off-state output current (2)        | $V_{IN}=V_{OUT}=0V$ ; $V_{CC}=13V$ ; $T_j=25^{\circ}C$  | 0    | 0.01  | 3     |            |
|               |                                     | $V_{IN}=V_{OUT}=0V$ ; $V_{CC}=13V$ ; $T_j=125^{\circ}C$ | 0    |       | 5     | $\mu A$    |

1. PowerMOS leakage included

2. For each channel

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

| Symbol                | Parameter                                 | Test conditions                                 | Min. | Typ.                          | Max. | Unit       |
|-----------------------|-------------------------------------------|-------------------------------------------------|------|-------------------------------|------|------------|
| $t_{d(on)}$           | Turn-on delay time                        | $R_L=2.6\Omega$ (see <a href="#">Figure 8</a> ) | -    | 30                            | -    | $\mu s$    |
| $t_{d(off)}$          | Turn-off delay time                       | $R_L=2.6\Omega$ (see <a href="#">Figure 8</a> ) | -    | 20                            | -    | $\mu s$    |
| $(dV_{OUT}/dt)_{on}$  | Turn-on voltage slope                     | $R_L=2.6\Omega$                                 | -    | See <a href="#">Figure 28</a> | -    | V/ $\mu s$ |
| $(dV_{OUT}/dt)_{off}$ | Turn-off voltage slope                    | $R_L=2.6\Omega$                                 | -    | See <a href="#">Figure 29</a> | -    | V/ $\mu s$ |
| $W_{ON}$              | Switching energy losses during $t_{WON}$  | $R_L=2.6\Omega$ (see <a href="#">Figure 8</a> ) | -    | 1                             | -    | mJ         |
| $W_{OFF}$             | Switching energy losses during $t_{WOFF}$ | $R_L=2.6\Omega$ (see <a href="#">Figure 8</a> ) | -    | 0.5                           | -    | mJ         |

Table 7. 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> =0.25A; V <sub>SENSE</sub> =0.5V<br>T <sub>J</sub> = -40°C...150°C                                                                                                                                                                                                                        | 2615         | 5130         | 7770         |                |
| K <sub>1</sub>                                 | I <sub>OUT</sub> /I <sub>SENSE</sub>                     | I <sub>OUT</sub> =5A; V <sub>SENSE</sub> =0.5V<br>T <sub>J</sub> =-40°C...150°C<br>T <sub>J</sub> =25°C...150°C                                                                                                                                                                                            | 4155<br>4530 | 5330<br>5330 | 6650<br>6130 |                |
| dK <sub>1</sub> /K <sub>1</sub> <sup>(1)</sup> | Current sense ratio drift                                | I <sub>OUT</sub> =5A; V <sub>SENSE</sub> = 0.5V;<br>V <sub>CSD</sub> =0V;<br>T <sub>J</sub> = -40 °C to 150 °C                                                                                                                                                                                             | -8           |              | 8            | %              |
| K <sub>2</sub>                                 | I <sub>OUT</sub> /I <sub>SENSE</sub>                     | I <sub>OUT</sub> =10A; V <sub>SENSE</sub> =4V<br>T <sub>J</sub> =-40°C...150°C<br>T <sub>J</sub> =25°C...150°C                                                                                                                                                                                             | 4705<br>4865 | 5290<br>5290 | 5950<br>5715 |                |
| 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> =0V;<br>T <sub>J</sub> = -40 °C to 150 °C                                                                                                                                                                                           | -5           |              | 5            | %              |
| K <sub>3</sub>                                 | I <sub>OUT</sub> /I <sub>SENSE</sub>                     | I <sub>OUT</sub> =25A; V <sub>SENSE</sub> =4V<br>T <sub>J</sub> =-40°C...150°C<br>T <sub>J</sub> =25°C...150°C                                                                                                                                                                                             | 4935<br>4985 | 5250<br>5250 | 5565<br>5515 |                |
| 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> = 0V;<br>T <sub>J</sub> = -40 °C to 150 °C                                                                                                                                                                                          | -4           |              | 4            | %              |
| I <sub>SENSE0</sub>                            | Analog sense leakage current                             | I <sub>OUT</sub> =0A; V <sub>SENSE</sub> =0V;<br>V <sub>CSD</sub> =5V; V <sub>IN</sub> =0V;<br>T <sub>J</sub> =-40°C...150°C<br>V <sub>CSD</sub> =0V; V <sub>IN</sub> =5V;<br>T <sub>J</sub> =-40°C...150°C<br><br>I <sub>OUT</sub> =5A; V <sub>SENSE</sub> =0V;<br>V <sub>CSD</sub> =V <sub>IN</sub> =5V; | 0<br>0<br>0  |              | 1<br>2<br>1  | μA<br>μA<br>μA |
| V <sub>SENSE</sub>                             | Max analog sense output voltage                          | I <sub>OUT</sub> =15A; V <sub>CSD</sub> =0V                                                                                                                                                                                                                                                                | 5            |              |              | V              |
| V <sub>SENSEH</sub>                            | Analog sense output voltage in overtemperature condition | V <sub>CC</sub> =13V; R <sub>SENSE</sub> =10KΩ                                                                                                                                                                                                                                                             |              | 8            |              | V              |
| I <sub>SENSEH</sub>                            | Analog sense output current in overtemperature condition | V <sub>CC</sub> =13V; V <sub>SENSE</sub> =5V                                                                                                                                                                                                                                                               |              | 9            |              | mA             |
| t <sub>DSSENSE1H</sub>                         | Delay response time from falling edge of CS_DIS pin      | V <sub>SENSE</sub> <4V, 1.5A<I <sub>OUT</sub> <25A<br>I <sub>SENSE</sub> =90% of I <sub>SENSE</sub> max<br>(see fig <a href="#">Figure 4</a> )                                                                                                                                                             |              | 50           | 100          | μs             |

Table 7. Current sense (8V<V<sub>CC</sub><18V) (continued)

| Symbol                 | Parameter                                                                                  | Test conditions                                                                                                                                                                              | Min. | Typ. | Max. | Unit |
|------------------------|--------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------|------|------|
| t <sub>DSENSE1L</sub>  | Delay Response time from rising edge of CS_DIS pin                                         | V <sub>SENSE</sub> <4V, 1.5A<I <sub>out</sub> <25A<br>I <sub>SENSE</sub> =10% of I <sub>SENSE max</sub><br>(see fig <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, 1.5A<I <sub>out</sub> <25A<br>I <sub>SENSE</sub> =90% of I <sub>SENSE max</sub><br>(see fig <a href="#">Figure 4</a> )                                               |      | 70   | 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> = 5A (see <a href="#">Figure 9</a> ) |      |      | 300  | μs   |
| t <sub>DSENSE2L</sub>  | Delay Response time from falling edge of INPUT pin                                         | V <sub>SENSE</sub> <4V, 1.5A<I <sub>out</sub> <25A<br>I <sub>SENSE</sub> =10% of I <sub>SENSE max</sub><br>(see fig <a href="#">Figure 4</a> )                                               |      | 100  | 250  | μs   |

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

Table 8. Open-load 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                      | V <sub>IN</sub> = 0V                                                                                                  | 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> = 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> = 2V                   | V <sub>IN</sub> = 0 V; V <sub>SENSE</sub> = V <sub>SENSEH</sub><br>V <sub>OUT</sub> falling to V <sub>CC</sub> to 2 V | -50  | -   | 90   | μA   |

Table 9. Protections <sup>(1)</sup>

| Symbol            | Parameter                                    | Test conditions                                                        | Min.                | Typ.                | Max.       | Unit   |
|-------------------|----------------------------------------------|------------------------------------------------------------------------|---------------------|---------------------|------------|--------|
| I <sub>limH</sub> | DC Short circuit current                     | V <sub>CC</sub> =13V<br>5V<V <sub>CC</sub> <18V                        | 52                  | 74                  | 104<br>104 | A<br>A |
| I <sub>limL</sub> | Short circuit current during thermal cycling | V <sub>CC</sub> =13V; T <sub>R</sub> <T <sub>J</sub> <T <sub>TSD</sub> |                     | 18.5                |            | A      |
| T <sub>TSD</sub>  | Shutdown temperature                         |                                                                        | 150                 | 175                 | 200        | °C     |
| T <sub>R</sub>    | Reset temperature                            |                                                                        | T <sub>RS</sub> + 1 | T <sub>RS</sub> + 5 |            | °C     |
| T <sub>RS</sub>   | Thermal reset of STATUS                      |                                                                        | 135                 |                     |            | °C     |

Table 9. Protections <sup>(1)</sup> (continued)

| Symbol             | Parameter                                              | Test conditions                                                                             | Min.                | Typ.                | Max.                | Unit |
|--------------------|--------------------------------------------------------|---------------------------------------------------------------------------------------------|---------------------|---------------------|---------------------|------|
| T <sub>HYST</sub>  | Thermal hysteresis (T <sub>TSD</sub> -T <sub>R</sub> ) |                                                                                             |                     | 7                   |                     | °C   |
| V <sub>DEMAG</sub> | Turn-off output voltage clamp                          | I <sub>OUT</sub> =2A; V <sub>IN</sub> =0; L=6mH                                             | V <sub>CC</sub> -28 | V <sub>CC</sub> -31 | V <sub>CC</sub> -35 | V    |
| V <sub>ON</sub>    | Output voltage drop limitation                         | I <sub>OUT</sub> =0.4A; T <sub>j</sub> =-40°C...150°C (see fig. <a href="#">Figure 10</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 10. Logic input

| Symbol                 | Parameter                 | Test conditions                                 | Min. | Typ. | Max. | Unit   |
|------------------------|---------------------------|-------------------------------------------------|------|------|------|--------|
| V <sub>IL</sub>        | Input low level voltage   |                                                 |      |      | 0.9  | V      |
| I <sub>IL</sub>        | Low level input current   | V <sub>IN</sub> =0.9V                           | 1    |      |      | μA     |
| V <sub>IH</sub>        | Input high level voltage  |                                                 | 2.1  |      |      | V      |
| I <sub>IH</sub>        | High level input current  | V <sub>IN</sub> =2.1V                           |      |      | 10   | μA     |
| V <sub>I(hyst)</sub>   | Input hysteresis voltage  |                                                 | 0.25 |      |      | V      |
| V <sub>ICL</sub>       | Input clamp voltage       | I <sub>IN</sub> =1mA<br>I <sub>IN</sub> =-1mA   | 5.5  | -0.7 | 7    | V<br>V |
| V <sub>CSDL</sub>      | CS_DIS low level voltage  |                                                 |      |      | 0.9  | V      |
| I <sub>CSDL</sub>      | Low level CS_DIS current  | V <sub>CSD</sub> =0.9V                          | 1    |      |      | μA     |
| V <sub>CSDH</sub>      | CS_DIS high level voltage |                                                 | 2.1  |      |      | V      |
| I <sub>CSDH</sub>      | High level CS_DIS current | V <sub>CSD</sub> =2.1V                          |      |      | 10   | μA     |
| V <sub>CSD(hyst)</sub> | CS_DIS hysteresis voltage |                                                 | 0.25 |      |      | V      |
| V <sub>CSCL</sub>      | CS_DIS clamp voltage      | I <sub>CSD</sub> =1mA<br>I <sub>CSD</sub> =-1mA | 5.5  | -0.7 | 7    | V<br>V |

Figure 4. Current sense delay characteristics

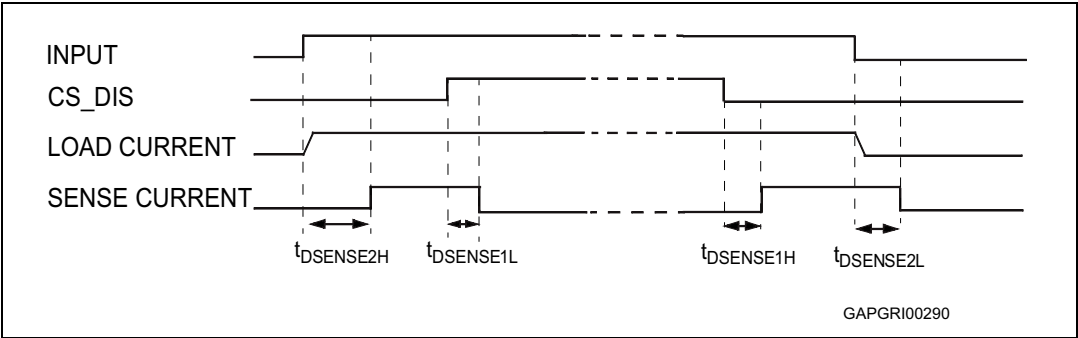


Figure 5. Open-load off-state delay timing

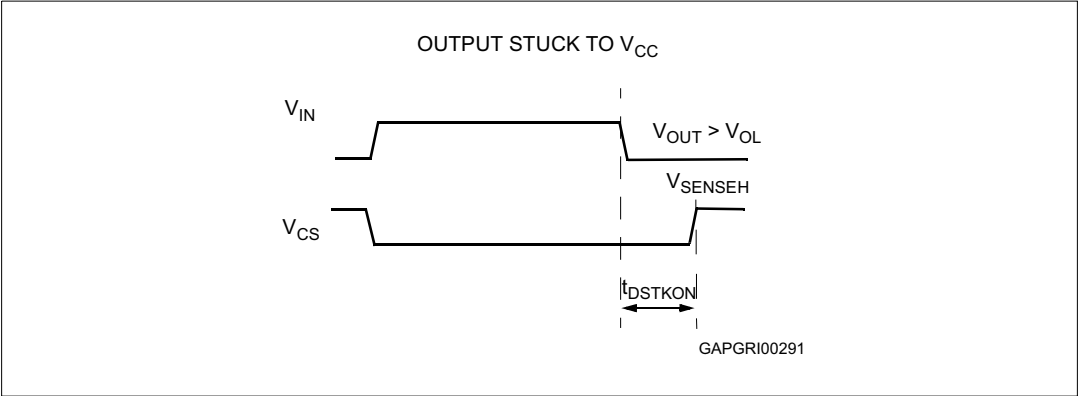


Figure 6.  $I_{OUT}/I_{SENSE}$  vs  $I_{OUT}$

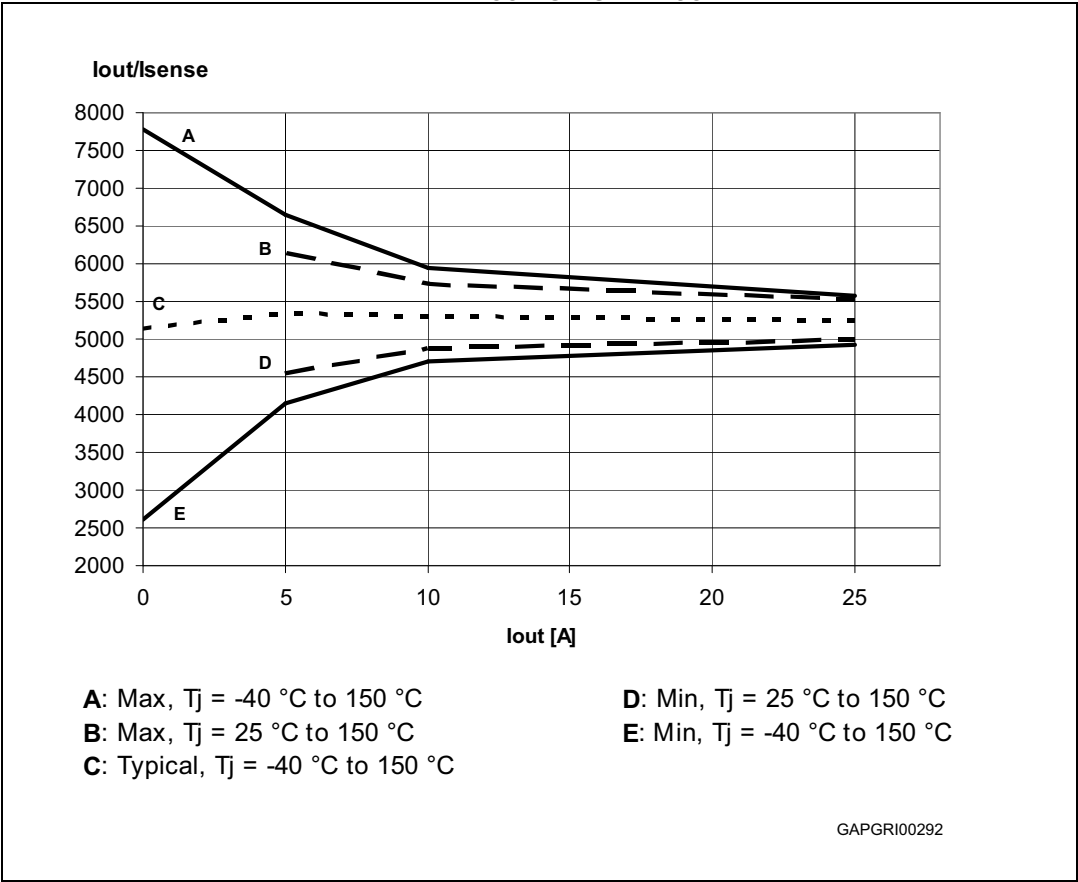


Figure 7. Maximum current sense ratio drift vs load current

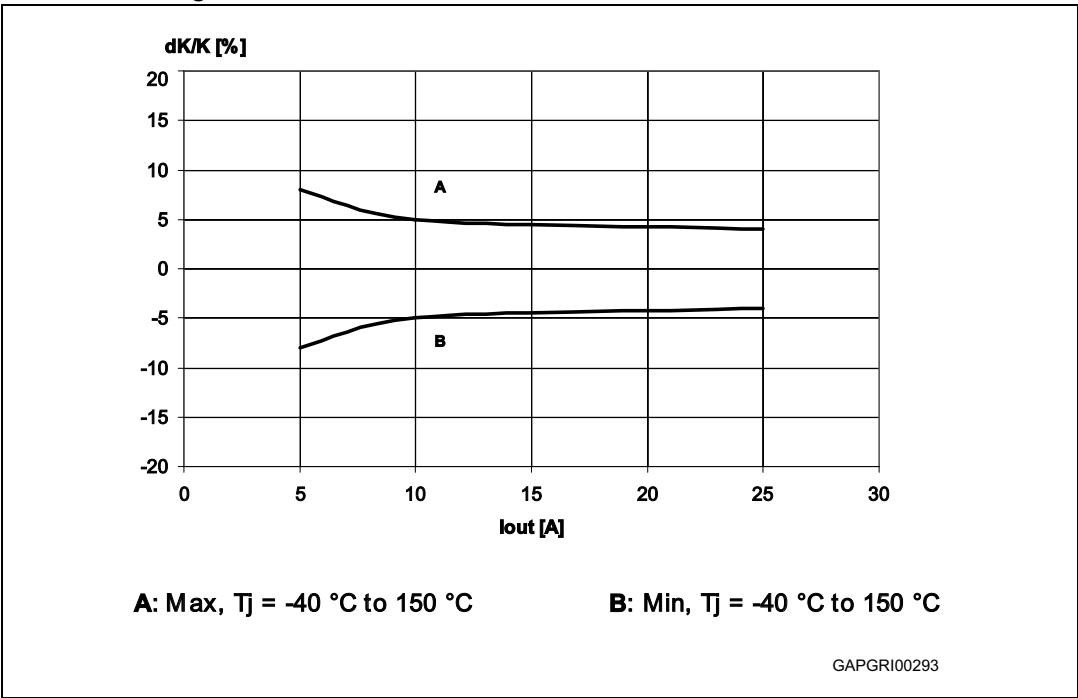


Table 11. Truth table

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

Figure 8. Switching characteristics

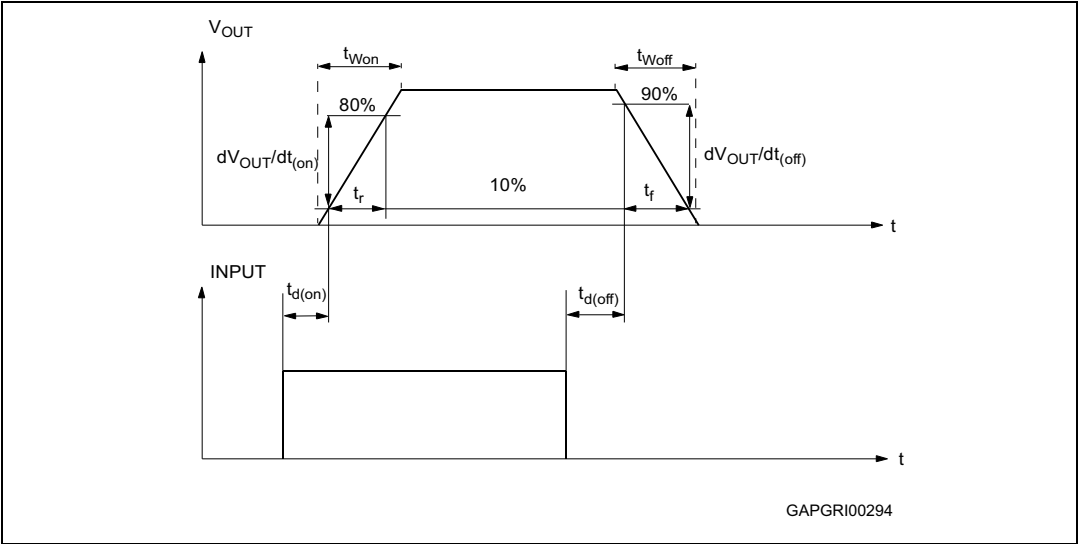


Figure 9. Delay response time between rising edge of ouput current and rising edge of current sense (CS enabled)

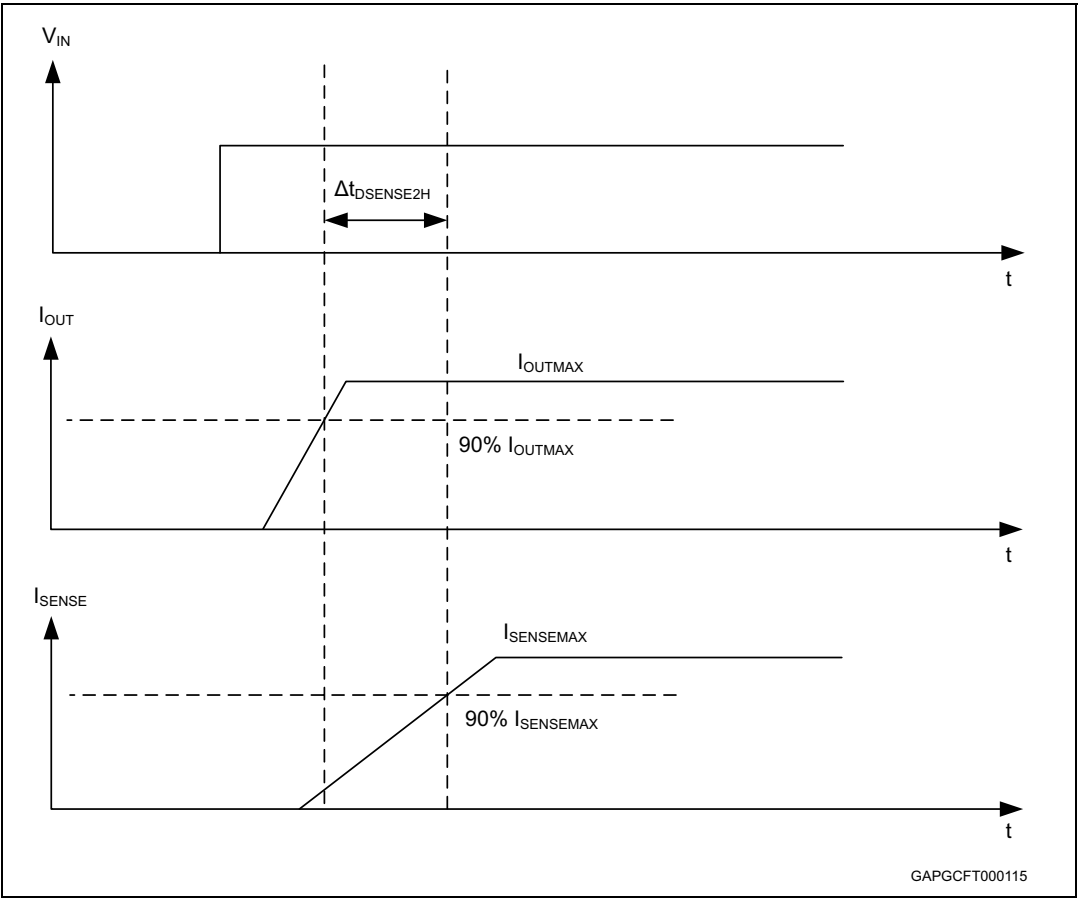


Figure 10. Output voltage drop limitation

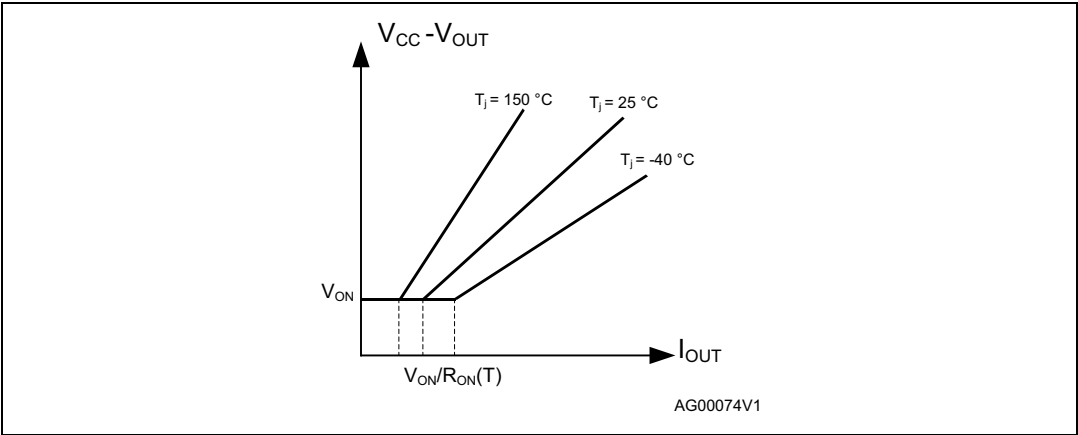


Table 12. Electrical transient requirements (part 1)

| 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     |                                      |                                      |        |                          |
| 1                                    | -75 V                      | -100 V | 5000<br>pulses                       | 0.5 s                                | 5 s    | 2 ms, 10 $\Omega$        |
| 2a                                   | +37 V                      | +50 V  | 5000<br>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: 40V maximum referred to ground. The protection strategy allows PowerMOS to be cyclically switched on during load dump, so distributing the load dump energy along the time and to transfer a part of it to the load.

Table 13. Electrical transient requirements (part 2)

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

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: 40V maximum referred to ground. The protection strategy allows PowerMOS to be cyclically switched on during load dump, so distributing the load dump energy along the time and to transfer a part of it to the load.
3. Suppressed load dump (pulse 5b) is withstood with a minimum load connected as specified in [Table 3: Absolute maximum ratings](#)

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

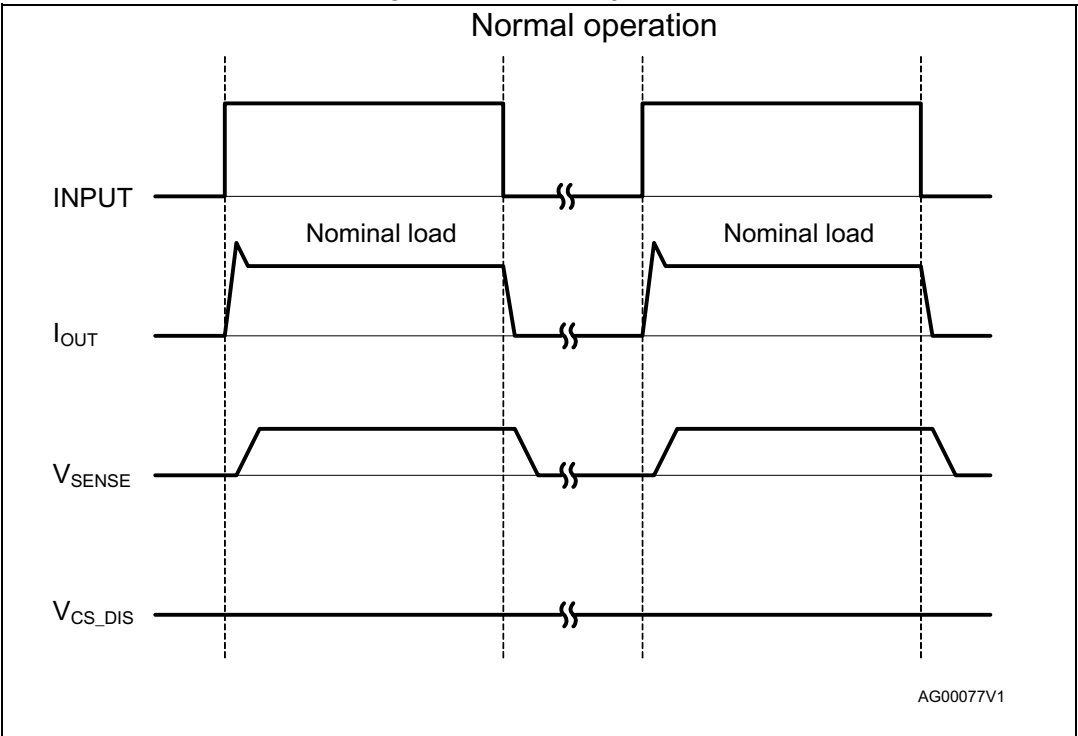


Figure 12. Overload or short to GND

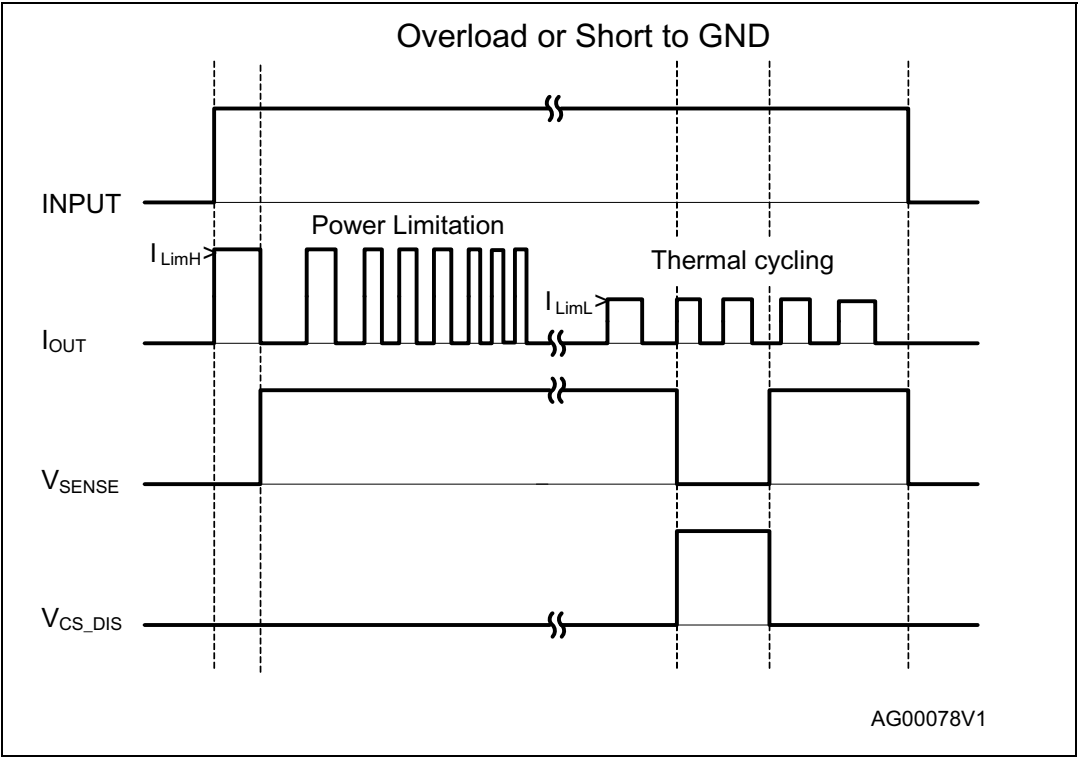


Figure 13. Intermittent overload

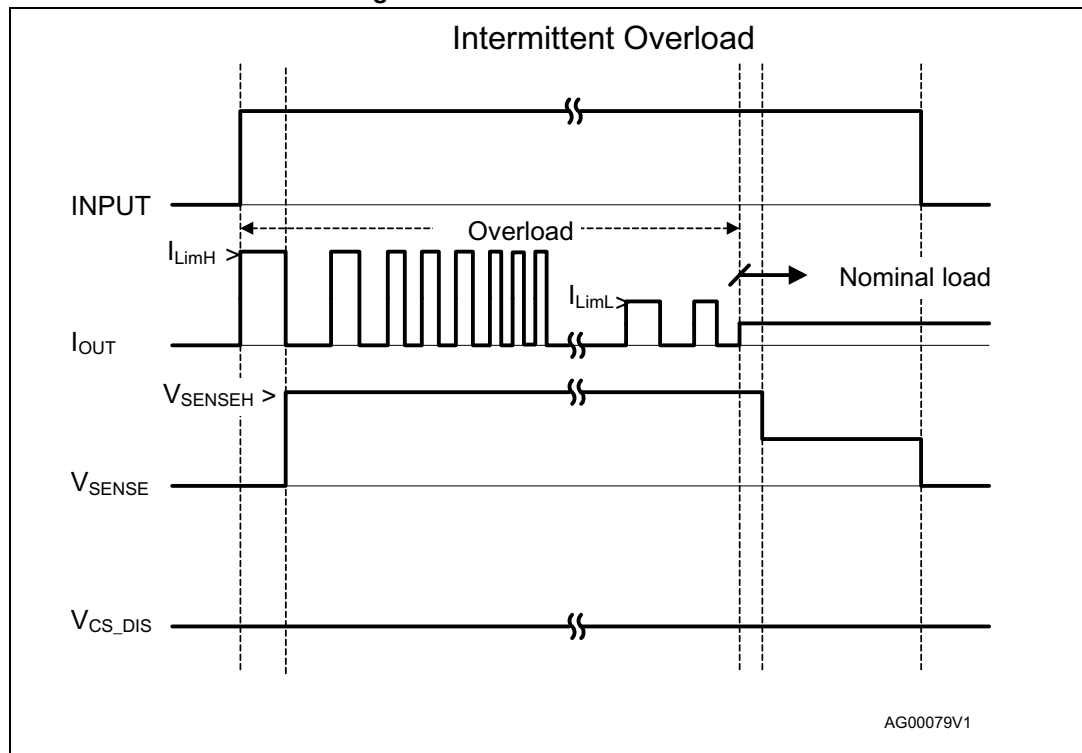


Figure 14. Off-state open-load with external circuitry

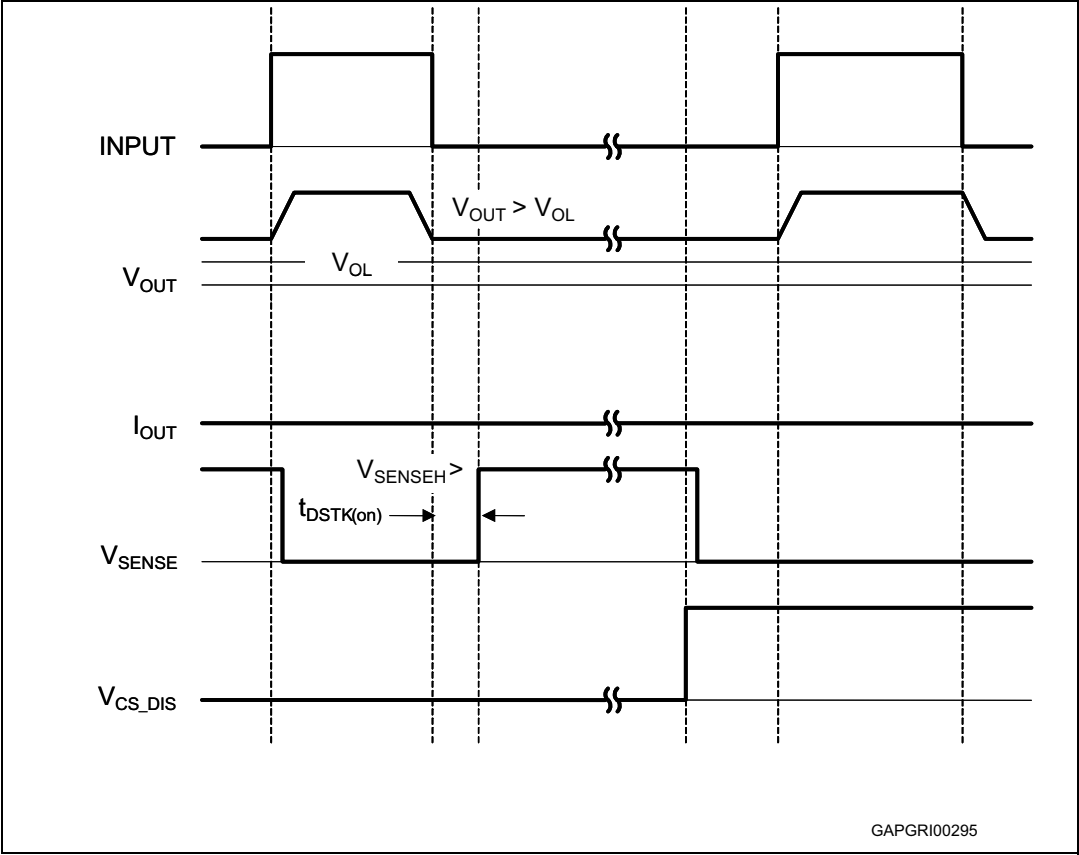


Figure 15. Short to  $V_{CC}$

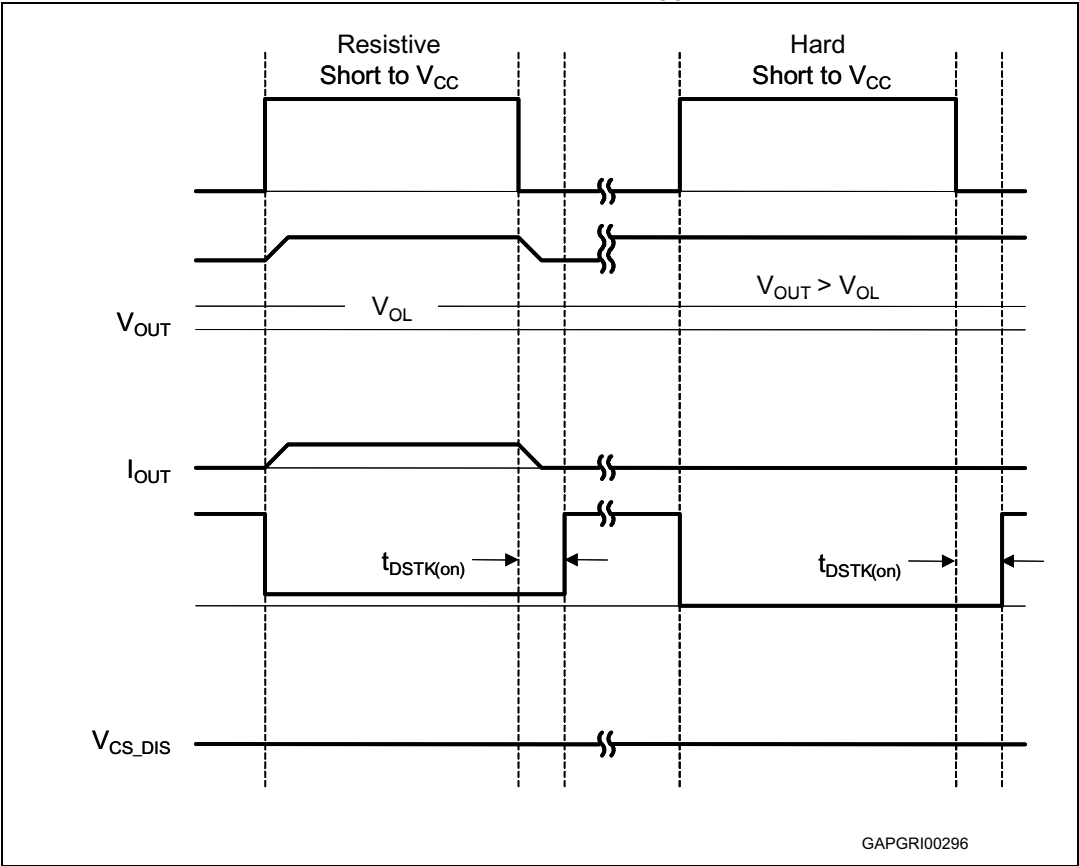
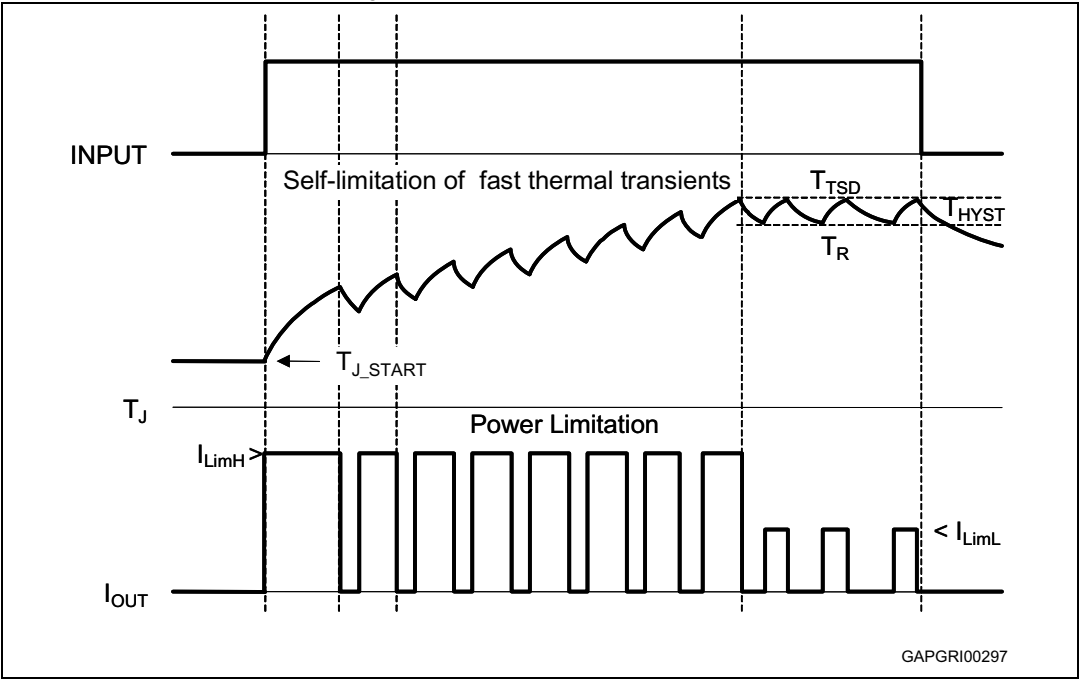


Figure 16.  $T_J$  evolution in overload or short to GND



2.5 Electrical characteristics curves

Figure 17. Off-state output current

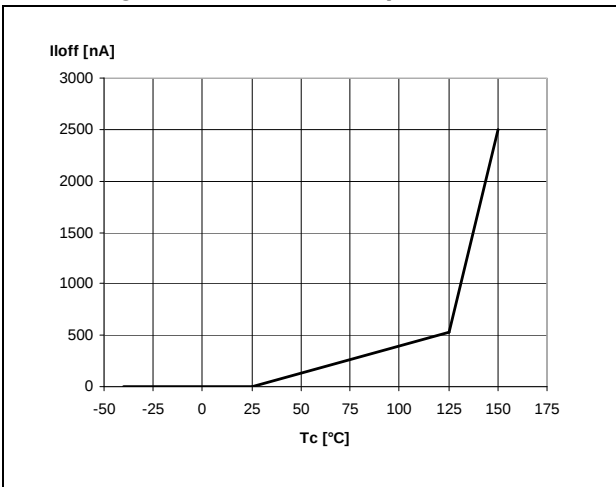


Figure 18. High level input current

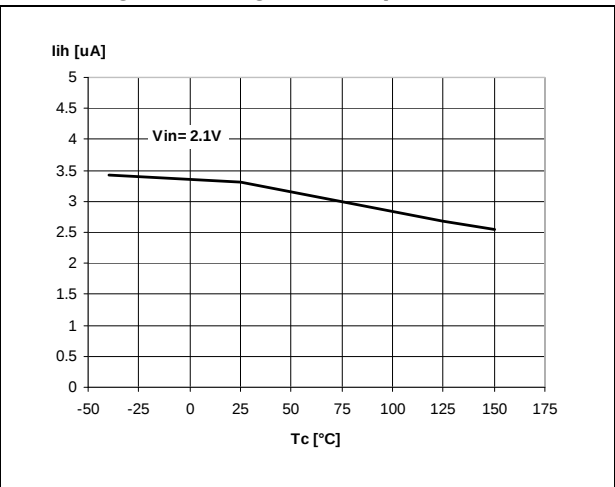


Figure 19. Input clamp voltage

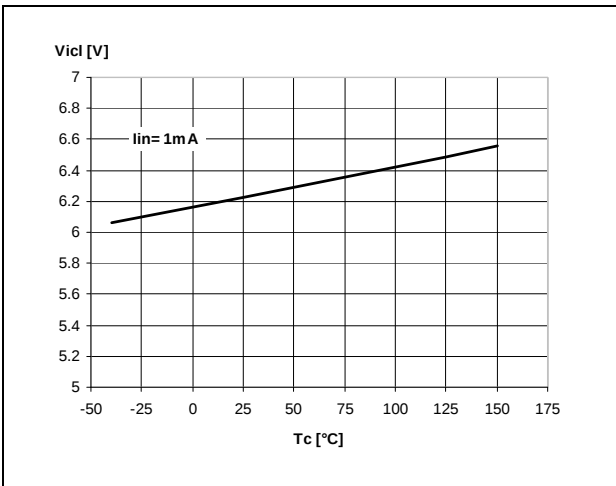


Figure 20. Input high level voltage

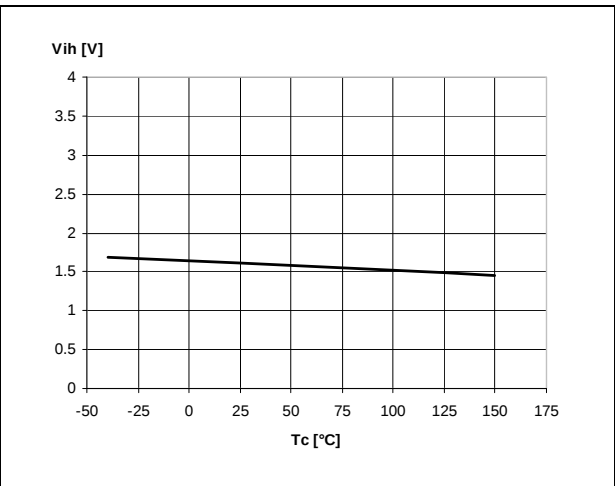


Figure 21. Input low level voltage

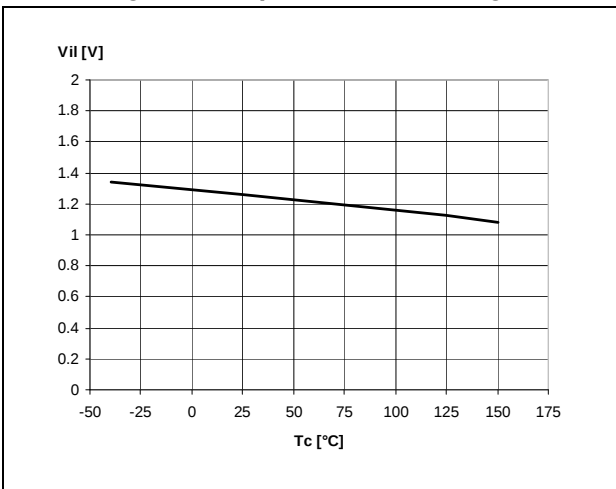


Figure 22. Input hysteresis voltage

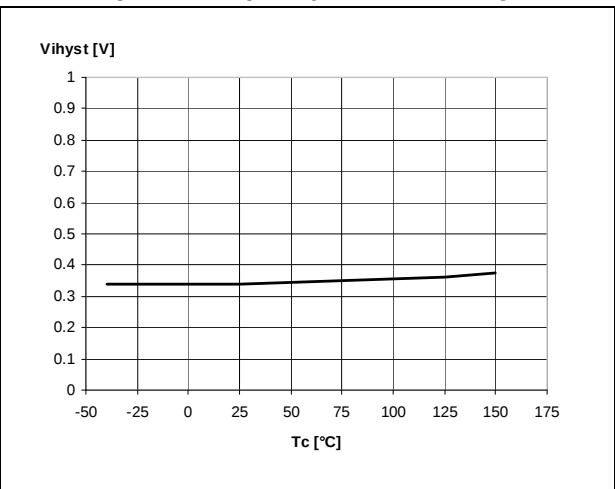


Figure 23. On-state resistance vs  $T_{case}$

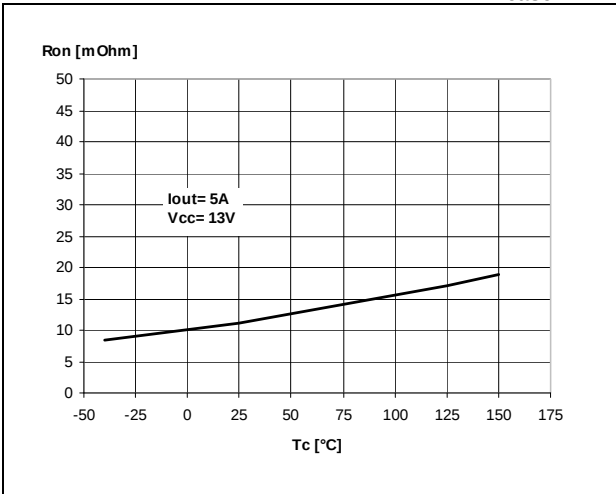


Figure 24. On-state resistance vs  $V_{CC}$

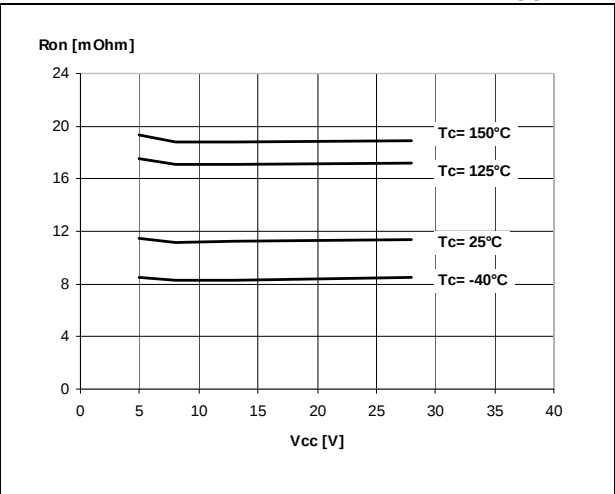


Figure 25. Undervoltage shutdown

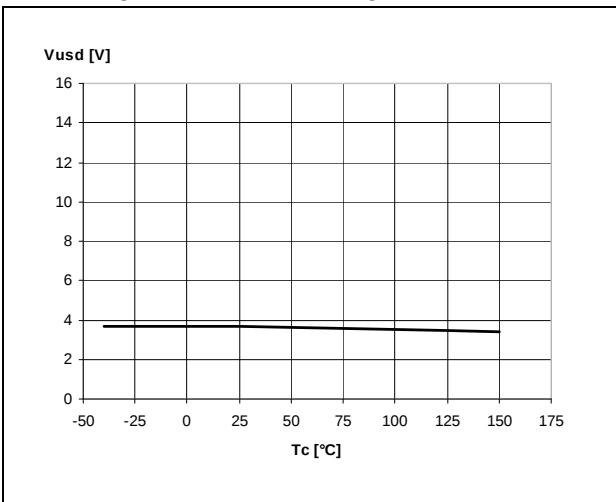


Figure 26.  $I_{LIMH}$  vs  $T_{case}$

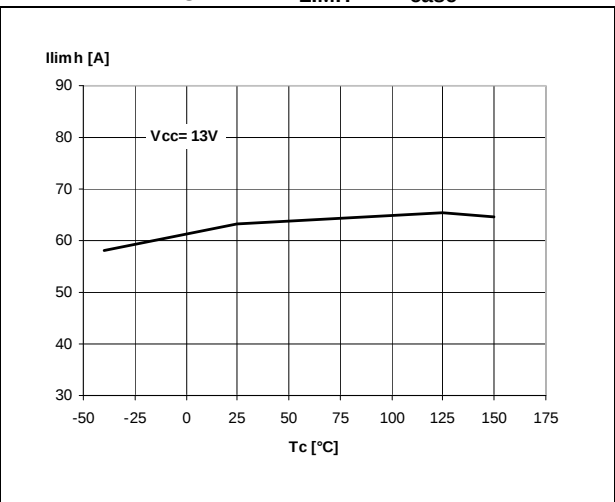


Figure 27. Turn-on voltage slope

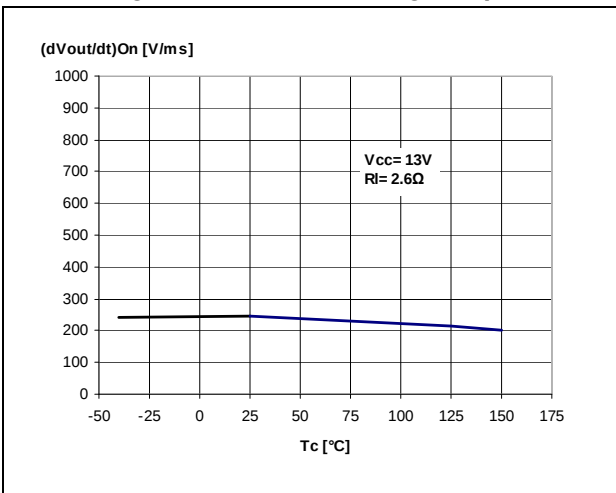


Figure 28. Turn-off voltage slope

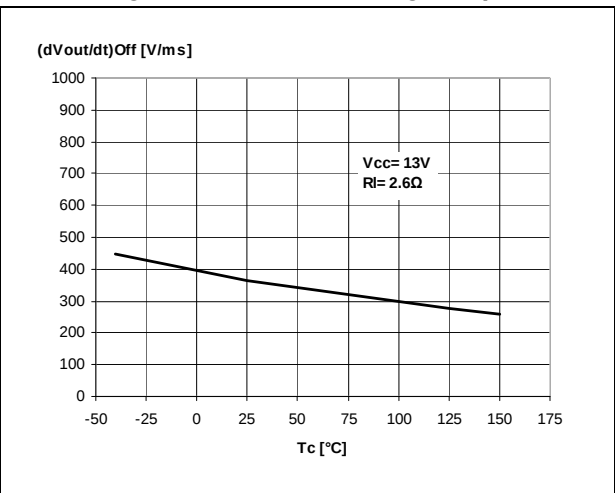


Figure 29. CS\_DIS clamp voltage

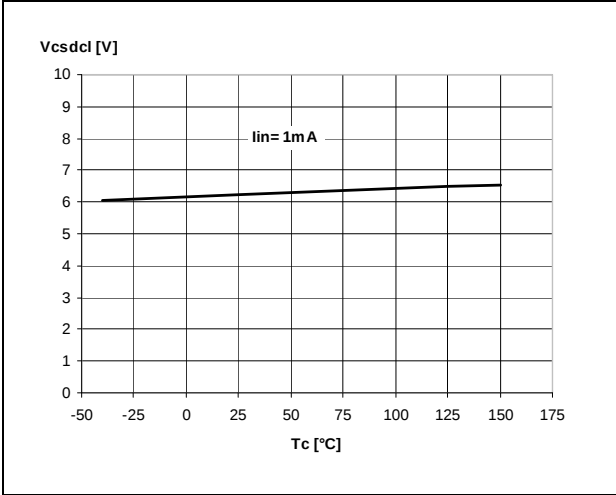


Figure 30. Low level CS\_DIS voltage

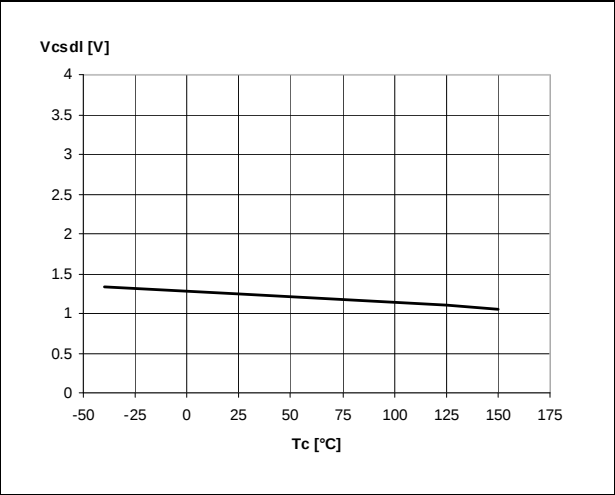
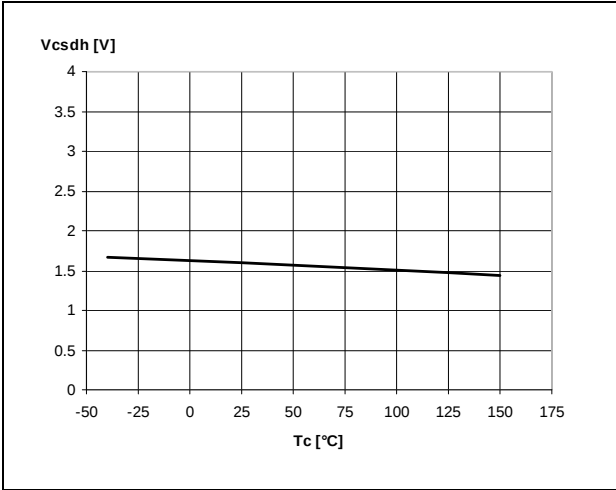
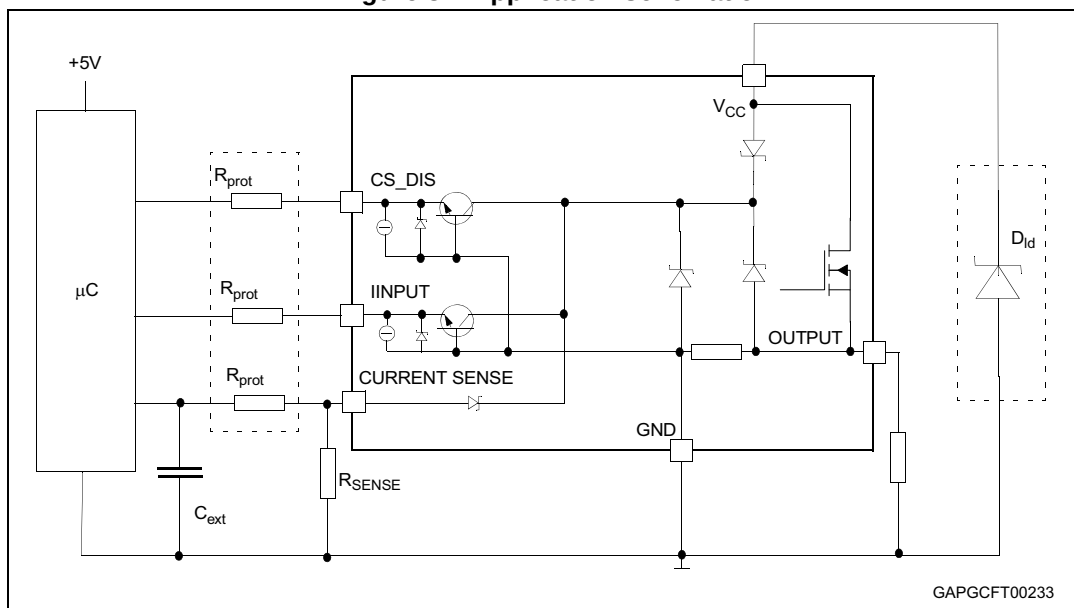


Figure 31. High level CS\_DIS voltage



### 3 Application information

Figure 32. Application schematic



Note: Channel 2 has the same internal circuit as channel 1.

#### 3.1 Load dump protection

$D_{ld}$  is necessary (Voltage Transient Suppressor) if the load dump peak voltage exceeds the  $V_{CCPK}$  max 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 T/R 7637/1 table.

#### 3.2 MCU I/Os protection

When negative transients are present on the  $V_{CC}$  line, the control pin 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 from latching-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:  $R_{\text{prot}} = 10 \text{ k}\Omega$ ,  $C_{\text{EXT}} = 10 \text{ nF}$ .

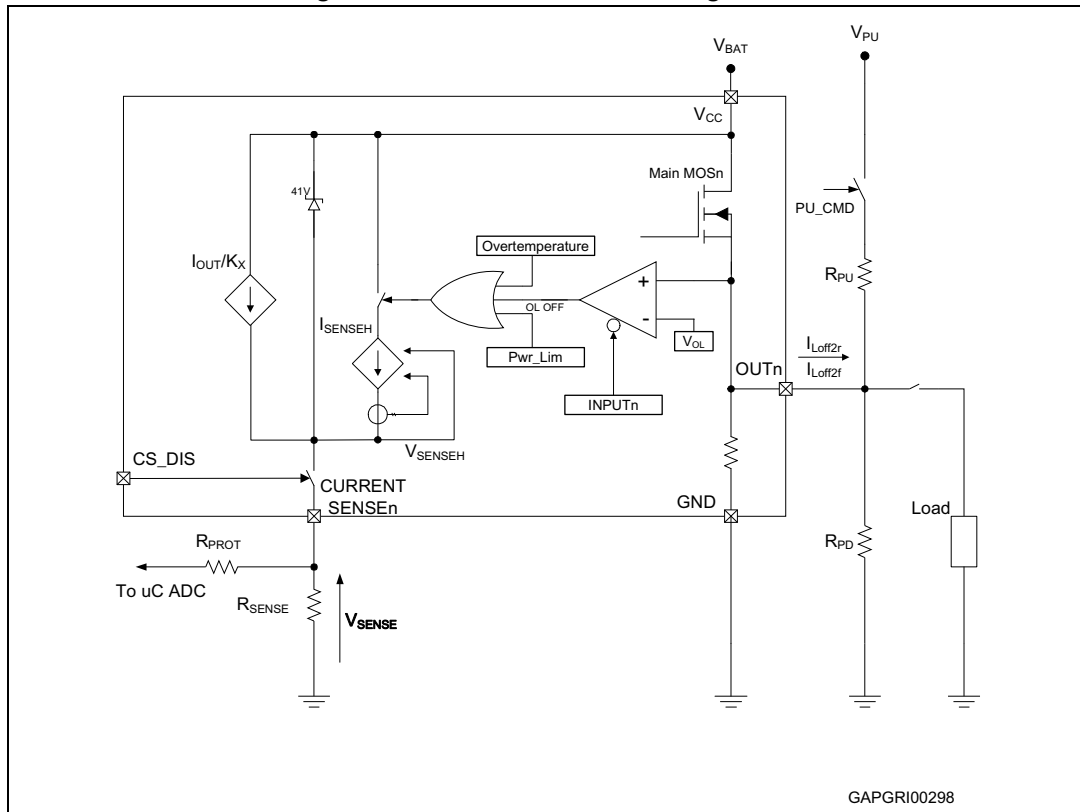
### 3.3 Current sense and diagnostic

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 known ratio  $K_X$ .  
The current  $I_{\text{SENSE}}$  can be easily converted to a voltage  $V_{\text{SENSE}}$  by means of an external resistor  $R_{\text{SENSE}}$ . Linearity between  $I_{\text{OUT}}$  and  $V_{\text{SENSE}}$  is ensured up to 5 V minimum (see parameter  $V_{\text{SENSE}}$  in [Table 7: Current sense \( \$8V < V\_{\text{CC}} < 18V\$ \)](#)). The current sense accuracy depends on the output current (refer to current sense electrical characteristics [Table 7: Current sense \( \$8V < V\_{\text{CC}} < 18V\$ \)](#)).
- **Diagnostic flag in fault conditions**, delivering a fixed voltage  $V_{\text{SENSEH}}$  up to a maximum current  $I_{\text{SENSEH}}$  in case of the following fault conditions (refer to [Table 11: Truth table](#)):
  - Power limitation activation
  - Overtemperature
  - Short to  $V_{\text{CC}}$  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**

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

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

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

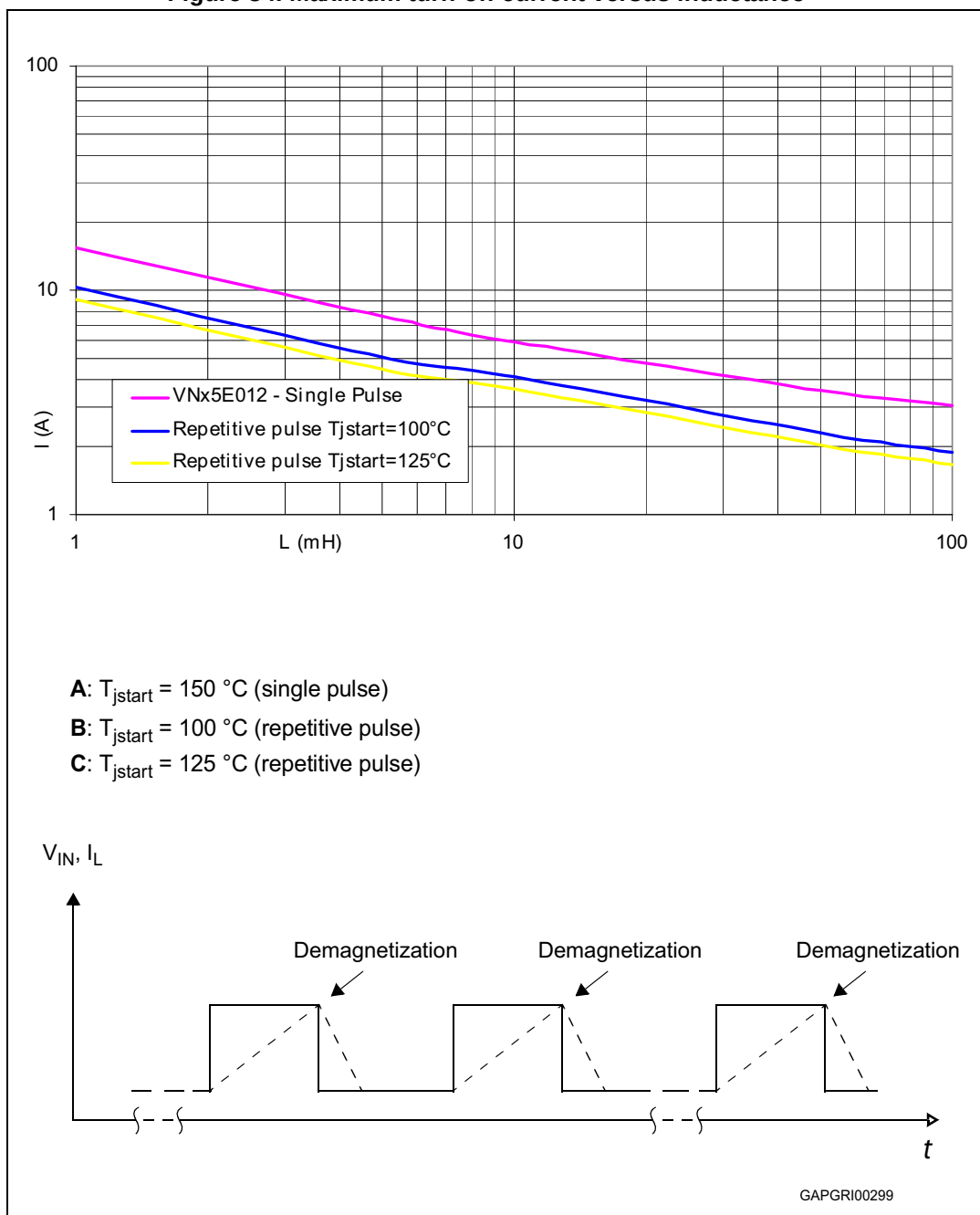
**Equation 3**

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

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

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

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



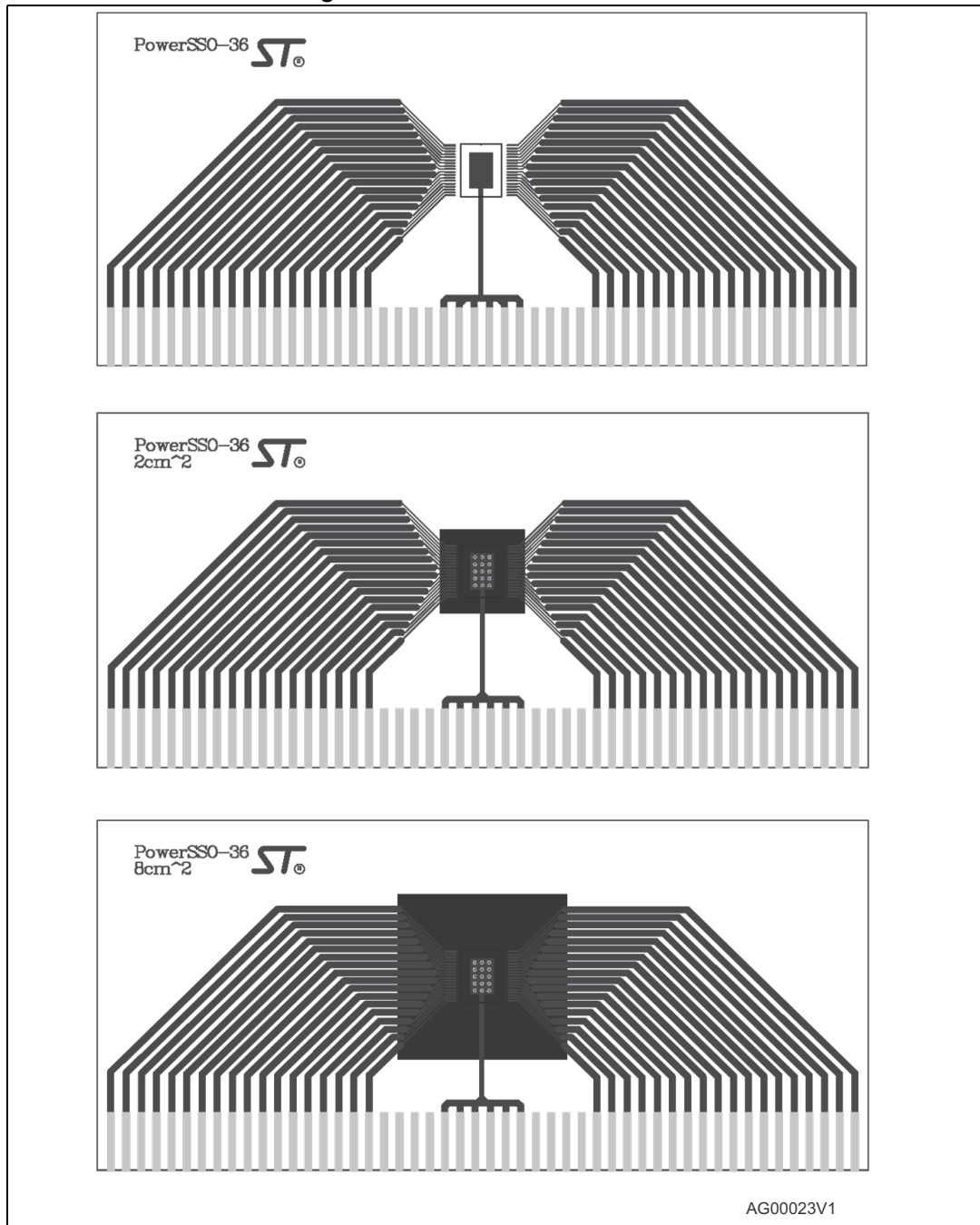
1. Values are generated with  $R_L = 0\ \Omega$ .

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 PCB thermal data

### 4.1 PowerSSO-36 thermal data

Figure 35. PowerSSO-36 PC board



**Note:** Layout condition of  $R_{th}$  and  $Z_{th}$  measurements (PCB: Double layer, Thermal Vias, FR4 area= 129mm x 60mm, PCB thickness=1.6mm, Cu thickness=70µm (front and back side), Copper areas: from minimum pad lay-out to 8cm<sup>2</sup>).

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

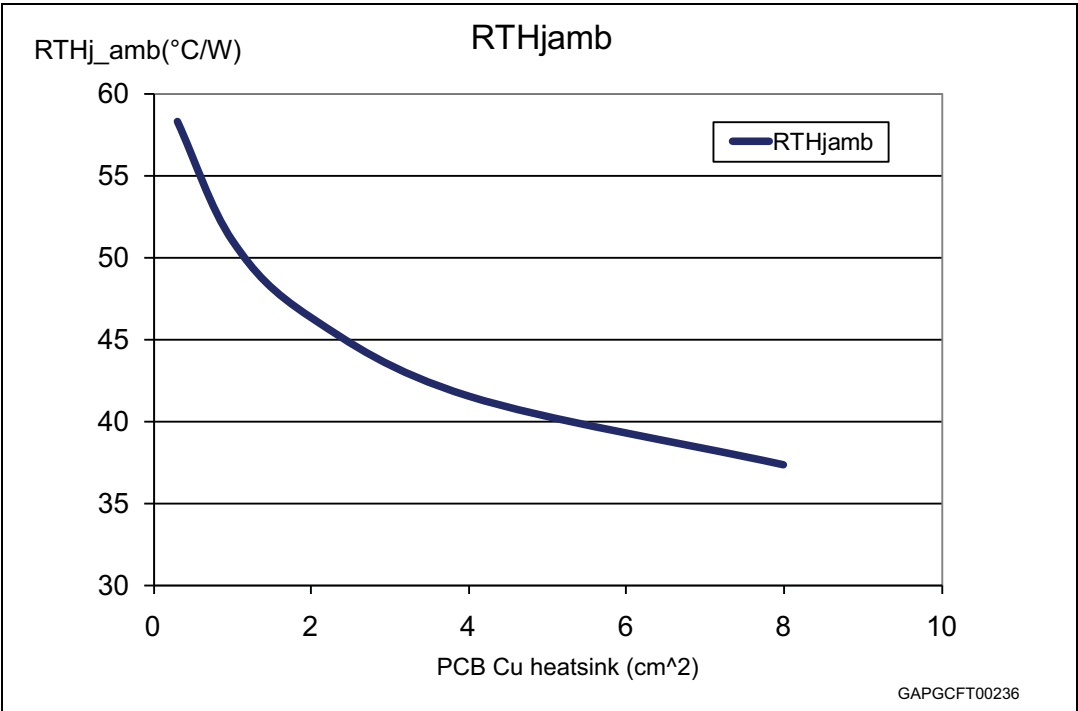
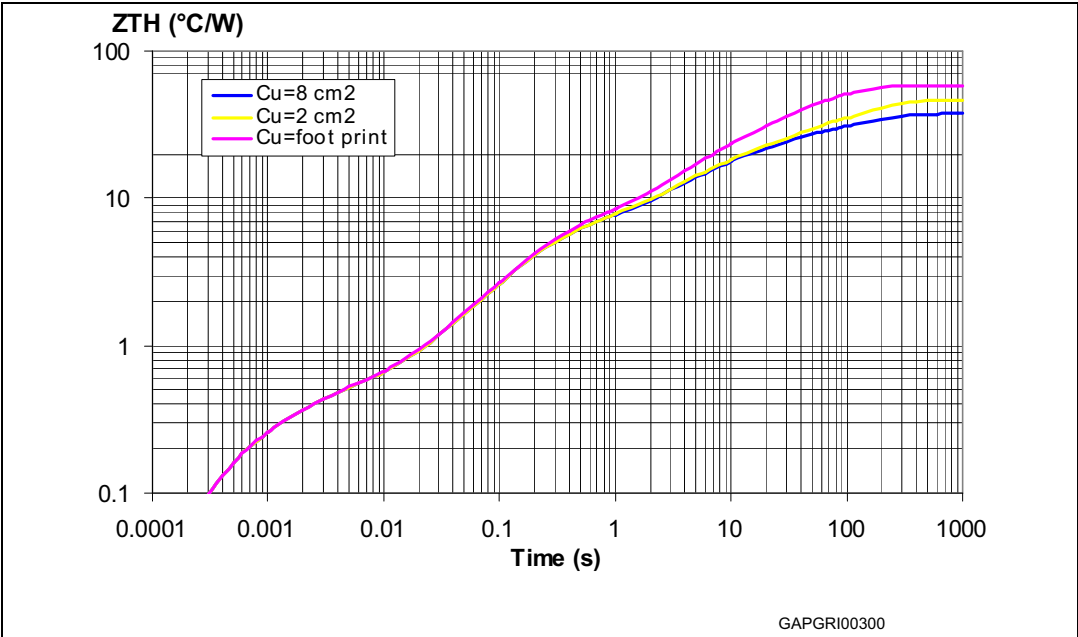
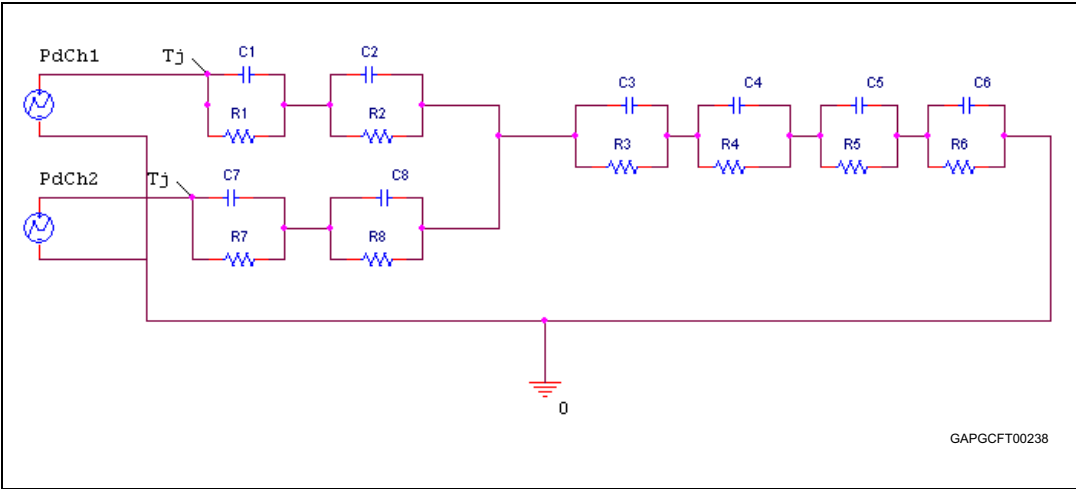


Figure 37. PowerSSO-36 Thermal impedance junction ambient single pulse (one channel ON)



**Figure 38. Thermal fitting model of a double channel HSD in PowerSSO-36<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:

**Equation 5**

$$\delta = t_p / T$$

**Table 15. Thermal parameter**

| Area/island (cm <sup>2</sup> ) | Footprint | 2  | 8  |
|--------------------------------|-----------|----|----|
| R1 (°C/W)                      | 0.1       |    |    |
| R2 (°C/W)                      | 0.3       |    |    |
| R3 (°C/W)                      | 5         |    |    |
| R4 (°C/W)                      | 8         |    |    |
| R5 (°C/W)                      | 18        | 10 | 10 |
| R6 (°C/W)                      | 27        | 23 | 14 |
| R7 (°C/W)                      | 0.1       |    |    |
| R8 (°C/W)                      | 0.3       |    |    |
| C1 (W.s/°C)                    | 0.0025    |    |    |
| C2 (W.s/°C)                    | 0.005     |    |    |
| C3 (W.s/°C)                    | 0.04      |    |    |
| C4 (W.s/°C)                    | 0.5       |    |    |
| C5 (W.s/°C)                    | 1         | 2  | 2  |
| C6 (W.s/°C)                    | 3         | 6  | 9  |

Table 15. Thermal parameter (continued)

| Area/island (cm <sup>2</sup> ) | Footprint | 2 | 8 |
|--------------------------------|-----------|---|---|
| C7 (W.s/°C)                    | 0.0025    |   |   |
| C8 (W.s/°C)                    | 0.005     |   |   |

## 5 Package information

### 5.1 ECOPACK<sup>®</sup> package

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

## 5.2 PowerSSO-36 mechanical data

Figure 39. PowerSSO-36 package dimensions

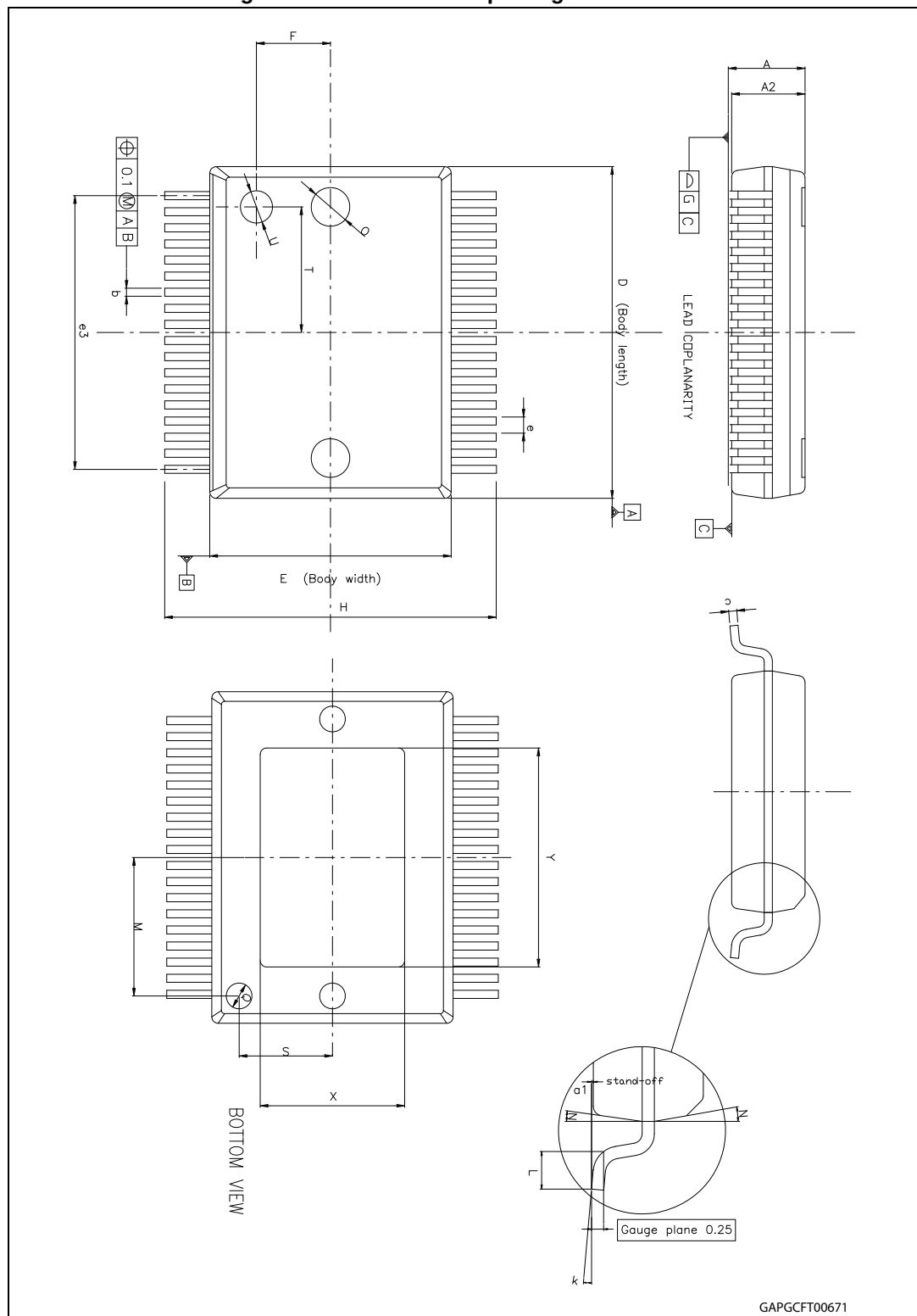
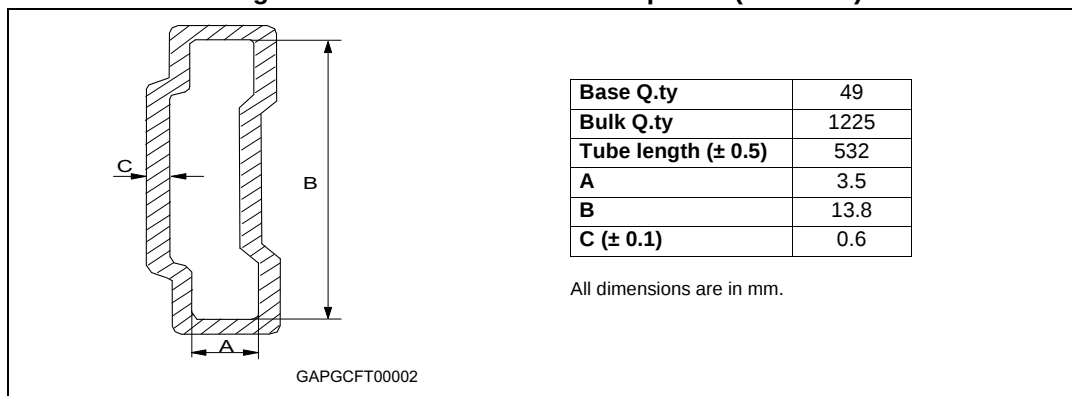


Table 16. PowerSSO-36 mechanical data

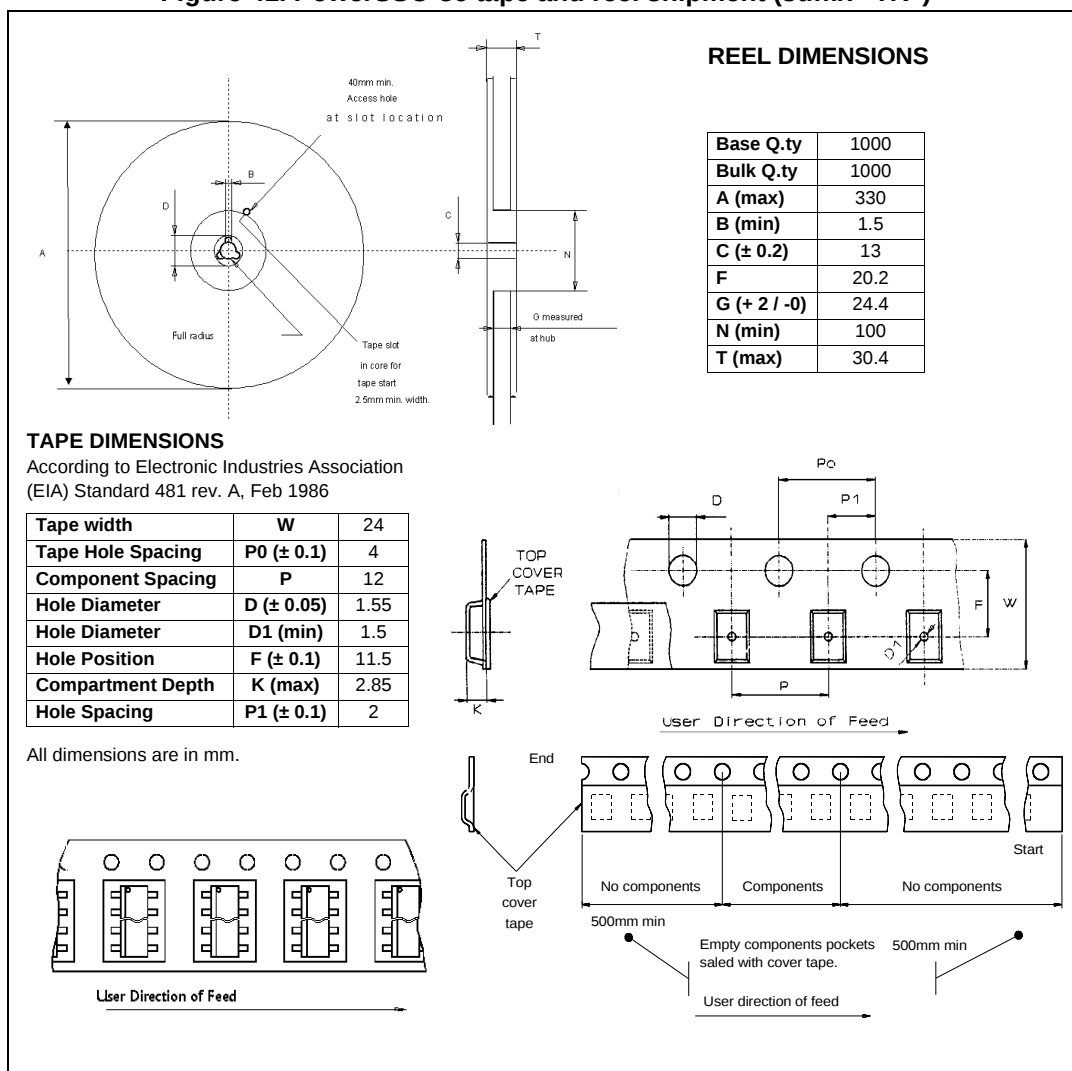
| Symbol | millimeters |     |        |
|--------|-------------|-----|--------|
|        | Min         | Typ | Max    |
| A      | 2.15        | -   | 2.47   |
| A2     | 2.15        | -   | 2.40   |
| a1     | 0           | -   | 0.075  |
| b      | 0.18        | -   | 0.36   |
| c      | 0.23        | -   | 0.32   |
| D      | 10.10       | -   | 10.50  |
| E      | 7.4         | -   | 7.6    |
| e      | -           | 0.5 | -      |
| e3     | -           | 8.5 | -      |
| G      | -           | -   | 0.1    |
| G1     | -           | -   | 0.06   |
| H      | 10.1        | -   | 10.5   |
| h      | -           | -   | 0.4    |
| L      | 0.55        | -   | 0.85   |
| N      | -           | -   | 10 deg |
| X      | 4.1         | -   | 4.7    |
| Y      | 6.5         | -   | 7.1    |

### 5.3 Packing information

**Figure 40. PowerSSO-36 tube shipment (no suffix)**



**Figure 41. PowerSSO-36 tape and reel shipment (suffix “TR”)**



## 6 Order codes

**Table 17. Device summary**

| package     | Order codes  |                |
|-------------|--------------|----------------|
|             | Tube         | Tape and reel  |
| PowerSSO-36 | VND5E012AY-E | VND5E012AYTR-E |

## 7 Revision history

**Table 18. Document revision history**

| Date         | Revision | Changes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|--------------|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 05-Jun-2007  | 1        | Initial release.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 21-Oct-2009  | 2        | <p>Updated <a href="#">Figure 3: Current and voltage conventions</a>.<br/> Updated following tables:</p> <ul style="list-style-type: none"> <li>– <a href="#">Table 3: Absolute maximum ratings</a></li> <li>– <a href="#">Table 4: Thermal data</a></li> <li>– <a href="#">Table 5: Power section</a></li> <li>– <a href="#">Table 6: Switching (<math>V_{CC} = 13V</math>; <math>T_j = 25^{\circ}C</math>)</a></li> <li>– <a href="#">Table 7: Current sense (<math>8V &lt; V_{CC} &lt; 18V</math>)</a></li> <li>– <a href="#">Table 8: Open-load detection (<math>8V &lt; V_{CC} &lt; 18V</math>)</a></li> </ul> <p>Added following figures:</p> <ul style="list-style-type: none"> <li>– <a href="#">Figure 7: Maximum current sense ratio drift vs load current</a></li> <li>– <a href="#">Figure 8: Switching characteristics</a></li> <li>– <a href="#">Figure 9: Delay response time between rising edge of output current and rising edge of current sense (CS enabled)</a></li> </ul> <p>Added <a href="#">Section 2.4: Waveforms</a> and <a href="#">Section 2.5: Electrical characteristics curves</a>.<br/> Updated <a href="#">Chapter 3: Application information</a>.<br/> Updated <a href="#">Section 4.1: PowerSSO-36 thermal data</a>:</p> <ul style="list-style-type: none"> <li>– Added <a href="#">Figure 35: PowerSSO-36 PC board</a>, <a href="#">Figure 36: <math>R_{thj-amb}</math> vs PCB copper area in open box free air condition (one channel ON)</a> and <a href="#">Figure 37: PowerSSO-36 Thermal impedance junction ambient single pulse (one channel ON)</a></li> <li>– Updated <a href="#">Figure 38: Thermal fitting model of a double channel HSD in PowerSSO-36<sup>(1)</sup></a></li> <li>– Added <a href="#">Table 15: Thermal parameter</a>.</li> </ul> <p>Updated <a href="#">Section 5.1: ECOPACK® package</a>.</p> |
| 03-Dec-2009  | 3        | Updated <a href="#">Section 4.1: PowerSSO-36 thermal data</a>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| 09-July-2012 | 4        | Updated <a href="#">Figure 39: PowerSSO-36 package dimensions</a>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 20-Sep-2013  | 5        | Updated Disclaimer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 28-Oct-2013  | 6        | Updated footnote 2 into the <a href="#">Table 12: Electrical transient requirements (part 1)</a> and <a href="#">Table 13: Electrical transient requirements (part 2)</a> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

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