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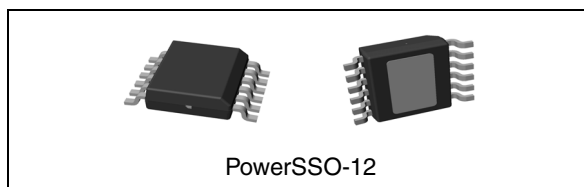
Double channel high side driver for automotive applications

Features

| | | |
|--------------------------------|------------|-----------------|
| Max supply voltage | V_{CC} | 41V |
| Operating voltage range | V_{CC} | 4.5 to 36V |
| Max on-state resistance | R_{ON} | 160 m Ω |
| Current limitation (typ) | I_{LIMH} | 5A |
| Off state supply current (typ) | I_S | 2 $\mu A^{(1)}$ |

1. Typical value with all loads connected.

- General
 - Inrush current active management by power limitation
 - Very low stand-by current
 - 3.0V CMOS compatible input
 - Optimized electromagnetic emission
 - Very low electromagnetic susceptibility
 - In compliance with the 2002/95/EC European directive
- Diagnostic functions
 - Open drain status output
 - On state open load detection
 - Off state open load detection
 - Thermal shutdown indication
- Protection
 - Undervoltage shut-down
 - Overvoltage clamp
 - Output stuck to Vcc detection
 - Load current limitation
 - Self limiting of fast thermal transients
 - Protection against loss of ground and loss of V_{CC}
 - Thermal shut down
 - Reverse battery protection (see [Figure 28](#))



PowerSSO-12

- Electrostatic discharge protection

Application

- All types of resistive, inductive and capacitive loads

Description

The VND5160J-E is a monolithic 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 (see ISO7637 transient compatibility table).

The device detects open load condition in both ON and OFF states, when STAT_DIS is left open or driven low. Output shorted to V_{CC} is detected in the OFF state.

When STAT_DIS is driven high, the STATUS pin is in a high impedance condition.

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

Table 1. Device summary

| Package | Order codes | |
|-------------|--------------------|---------------------------|
| | Part number (Tube) | Part number (Tape & Reel) |
| PowerSSO-12 | VND5160J-E | VND5160JTR-E |

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1 Block diagram and pin description

Figure 1. Block diagram

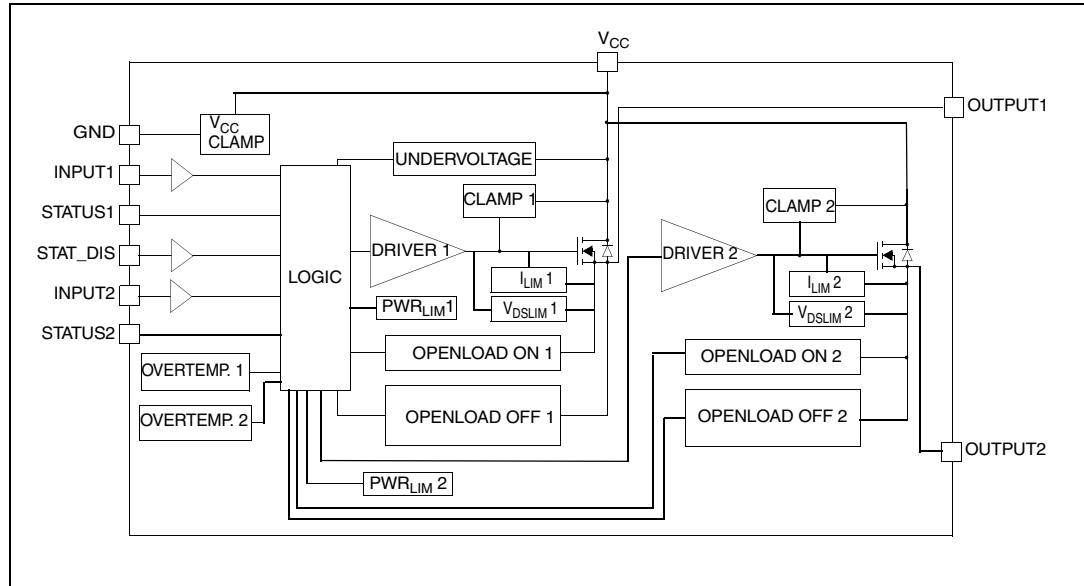


Table 2. Pin functions

| Name | Function |
|---------------------|--|
| V _{CC} | Battery connection. |
| OUTPUT _n | Power output. |
| GND | Ground connection. Must be reverse battery protected by an external diode/resistor network. |
| INPUT _n | Voltage controlled input pin with hysteresis, CMOS compatible. Controls output switch state. |
| STATUS _n | Open Drain digital diagnostic pin. |
| STAT_DIS | Active high CMOS compatible pin, to disable the STATUS pin. |

Figure 2. Configuration diagram (top view)

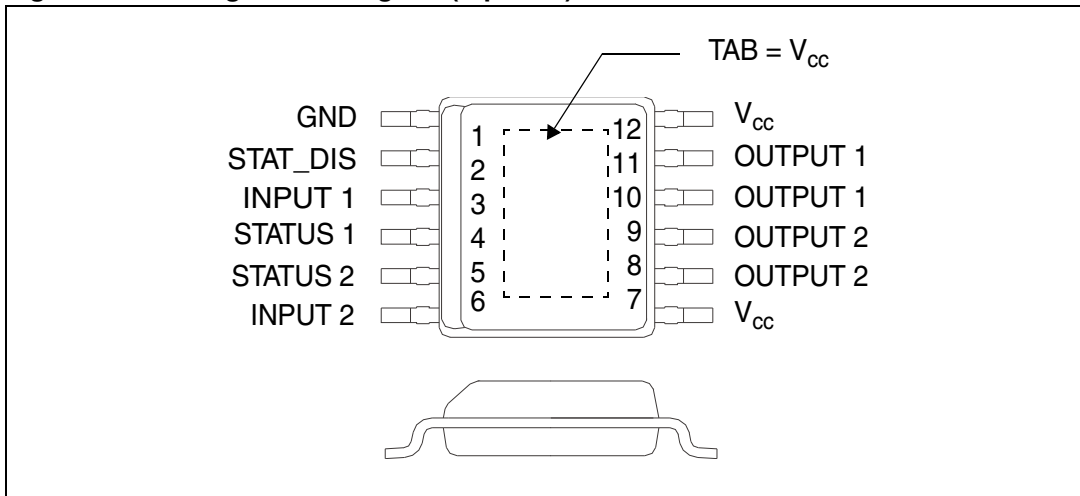


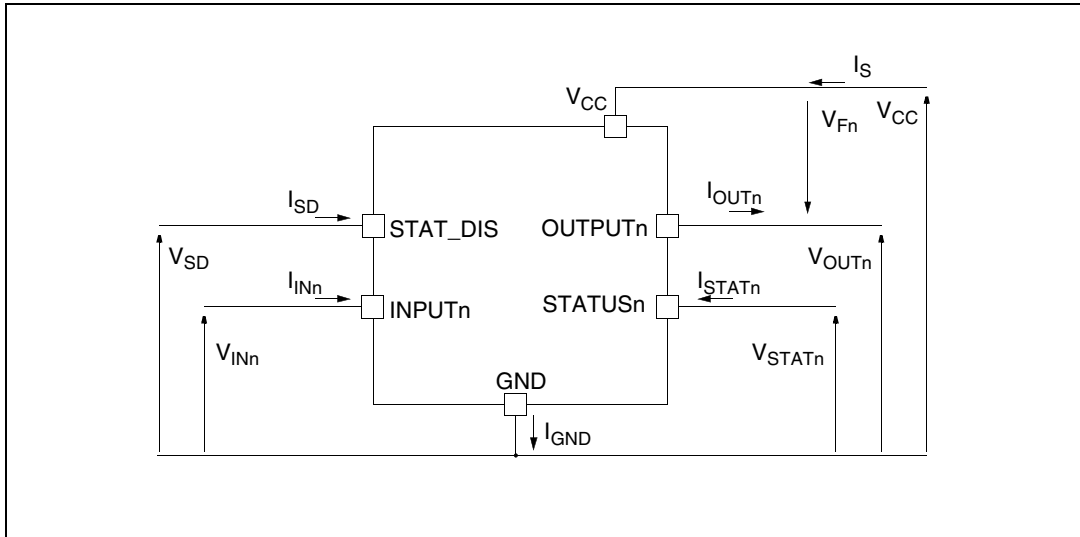
Table 3. Suggested connections for unused and N.C. pins

| Connection / Pin | STATUS | N.C. | OUTPUT | INPUT | STAT_DIS |
|------------------|---------------------|------|--------|-----------------------|-----------------------|
| Floating | X | X | X | X | X |
| To ground | N.R. ⁽¹⁾ | X | N.R. | Through 10kΩ resistor | Through 10kΩ resistor |

1. Not recommended.

2 Electrical specifications

Figure 3. Current and voltage conventions



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

2.1 Absolute maximum ratings

Stressing the device above the ratings listed in the “Absolute maximum ratings” tables 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. Refer also to the STMicroelectronics SURE Program and other relevant quality documents.

Table 4. Absolute maximum ratings

| Symbol | Parameter | Value | Unit |
|-----------------|---|--------------------|------|
| V_{CC} | DC supply voltage | 41 | V |
| $-V_{CC}$ | Reverse DC supply voltage | 0.3 | V |
| $-I_{GND}$ | DC reverse ground pin current | 200 | mA |
| I_{OUT} | DC output current | Internally limited | A |
| $-I_{OUT}$ | Reverse DC output current | 6 | A |
| I_{IN} | DC input current | +10 / -1 | mA |
| I_{STAT} | DC status current | +10 / -1 | mA |
| I_{STAT_DIS} | DC status disable current | +10 / -1 | mA |
| E_{MAX} | Maximum switching energy ($L=12\text{mH}$; $R_L=0\Omega$; $V_{bat}=13.5\text{V}$; $T_{jstart}=150^\circ\text{C}$; $I_{OUT} = I_{limL}(Typ.)$) | 33 | mJ |

Table 4. Absolute maximum ratings (continued)

| Symbol | Parameter | Value | Unit |
|------------------|--|------------|------|
| V _{ESD} | Electrostatic discharge (Human Body Model: R=1.5KΩ; C=100pF) | | |
| | – INPUT | 4000 | V |
| | – STATUS | 4000 | V |
| | – STAT_DIS | 4000 | V |
| | – OUTPUT | 5000 | V |
| | – V _{CC} | 5000 | V |
| V _{ESD} | Charge device model (CDM-AEC-Q100-011) | 750 | V |
| T _j | Junction operating temperature | -40 to 150 | °C |
| T _{stg} | Storage temperature | -55 to 150 | °C |

2.2 Thermal data

Table 5. Thermal data

| Symbol | Parameter | Max value | Unit |
|-----------------------|---|-------------------------------|------|
| R _{thj-case} | Thermal resistance junction-case (max.) (with one channel ON) | 8 | °C/W |
| R _{thj-amb} | Thermal resistance junction-ambient | See Figure 32 | °C/W |

2.3 Electrical characteristics

Values specified in this section are for $8V < V_{CC} < 36V$; $-40^{\circ}C < T_j < 150^{\circ}C$, unless otherwise stated.

Table 6. Power section

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|---------------|--|---|------|------------------|------------------|------------|
| V_{CC} | Operating supply voltage | | 4.5 | 13 | 36 | V |
| V_{USD} | Undervoltage shutdown | | | 3.5 | 4.5 | V |
| $V_{USDhyst}$ | Undervoltage Shut-down hysteresis | | | 0.5 | | V |
| R_{ON} | On state resistance ⁽²⁾ | $I_{OUT} = 1A$; $T_j = 25^{\circ}C$ | | | 160 | m Ω |
| | | $I_{OUT} = 1A$; $T_j = 150^{\circ}C$ | | | 320 | m Ω |
| | | $I_{OUT} = 1A$; $V_{CC} = 5V$; $T_j = 25^{\circ}C$ | | | 210 | m Ω |
| V_{clamp} | Clamp voltage | $I_S = 20mA$ | 41 | 46 | 52 | V |
| I_S | Supply current | Off State; $V_{CC} = 13V$; $V_{IN} = V_{OUT} = 0$ $T_j = 25^{\circ}C$; | | 2 ⁽¹⁾ | 5 ⁽¹⁾ | μA |
| | | On State; $V_{CC} = 13V$; $V_{IN} = 5V$; $I_{OUT} = 0A$ | | 3 | 6 | mA |
| $I_{L(off1)}$ | Off state output current ⁽²⁾ | $V_{IN} = V_{OUT} = 0V$; $V_{CC} = 13V$; $T_j = 25^{\circ}C$ | 0 | 0.01 | 3 | μA |
| | | $V_{IN} = V_{OUT} = 0V$; $V_{CC} = 13V$; $T_j = 125^{\circ}C$ | 0 | | 5 | |
| $I_{L(off2)}$ | | $V_{IN} = 0V$; $V_{OUT} = 4V$ | -75 | | 0 | |
| V_F | Output - V_{CC} diode voltage ⁽²⁾ | $-I_{OUT} = 0.6A$; $T_j = 150^{\circ}C$ | | | 0.7 | V |

1. PowerMOS leakage included.

2. For each channel.

Table 7. Switching ($V_{CC} = 13V$; $T_j = 25^{\circ}C$)

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|-----------------------|---|--|------|-------------------------------|------|------------|
| $t_{d(on)}$ | Turn-On delay time | $R_L = 13\Omega$ (see Figure 6) | | 10 | | μs |
| $t_{d(off)}$ | Turn-Off delay time | $R_L = 13\Omega$ (see Figure 6) | | 15 | | μs |
| $dV_{OUT}/dt_{(on)}$ | Turn-On voltage slope | $R_L = 13\Omega$ | | See Figure 21 | | V/ μs |
| $dV_{OUT}/dt_{(off)}$ | Turn-Off voltage slope | $R_L = 13\Omega$ | | See Figure 22 | | V/ μs |
| W_{ON} | Switching energy losses during t_{won} | $R_L = 13\Omega$ (see Figure 6) | | 0.07 | | mJ |
| W_{OFF} | Switching energy losses during t_{woff} | $R_L = 13\Omega$ (see Figure 6) | | 0.04 | | mJ |

Table 8. Status pin ($V_{SD}=0$)

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|-------------|------------------------------|---|------|------|------|---------------|
| V_{STAT} | Status low output voltage | $I_{STAT}= 1.6 \text{ mA}$, $V_{SD}=0\text{V}$ | | | 0.5 | V |
| I_{LSTAT} | Status leakage current | Normal operation or $V_{SD}=5\text{V}$, $V_{STAT}= 5\text{V}$ | | | 10 | μA |
| C_{STAT} | Status pin input capacitance | Normal operation or $V_{SD}=5\text{V}$, $V_{STAT}= 5\text{V}$ | | | 100 | pF |
| V_{SCL} | Status clamp voltage | $I_{STAT}= 1\text{mA}$ $I_{STAT}= -1\text{mA}$ | 5.5 | -0.7 | 7 | V V |

Table 9. Protection⁽¹⁾

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|-------------|--|---|--------------|--------------|-------------|--------------------|
| I_{limH} | DC short circuit current | $V_{CC}= 13\text{V}$ $5\text{V}<V_{CC}<36\text{V}$ | 3.5 | 5 | 7.5 7.5 | A A |
| I_{limL} | Short circuit current during thermal cycling | $V_{CC}= 13\text{V}$ $T_R<T_j<T_{TSD}$ | | 2 | | A |
| T_{TSD} | Shutdown temperature | | 150 | 175 | 200 | $^{\circ}\text{C}$ |
| T_R | Reset temperature | | $T_{RS} + 1$ | $T_{RS} + 5$ | | $^{\circ}\text{C}$ |
| T_{RS} | Thermal reset of STATUS | | 135 | | | $^{\circ}\text{C}$ |
| T_{HYST} | Thermal hysteresis ($T_{TSD}-T_R$) | | | 7 | | $^{\circ}\text{C}$ |
| t_{SDL} | Status delay in overload conditions | $T_j>T_{TSD}$ | | | 20 | μs |
| V_{DEMAG} | Turn-Off output voltage clamp | $I_{OUT}=1\text{A}$; $V_{IN}=0$; $L=20\text{mH}$ | $V_{CC}-41$ | $V_{CC}-46$ | $V_{CC}-52$ | V |
| V_{ON} | Output voltage drop limitation | $I_{OUT}= 0.03\text{A}$; $T_j= -40^{\circ}\text{C}\dots+150^{\circ}\text{C}$ (see Figure 5) | | 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. Openload detection

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|---------------|---|---|------|-------------------------------|-----------|---------|
| I_{OL} | Openload On state detection threshold | $V_{IN} = 5V, 8V < V_{CC} < 18V$ | 10 | See Figure 19 | 40 | mA |
| $t_{DOL(on)}$ | Openload On state detection delay | $I_{OUT} = 0A, V_{CC} = 13V$ (see Figure 4) | | | 200 | μs |
| t_{POL} | Delay between INPUT falling edge and STATUS rising edge in Openload condition | $I_{OUT} = 0A$ (see Figure 4) | 200 | 500 | 1000 | μs |
| V_{OL} | Openload Off state voltage detection threshold | $V_{IN} = 0V, 8V < V_{CC} < 16V$ | 2 | See Figure 20 | 4 | V |
| t_{DSTKON} | Output short circuit to V_{CC} detection delay at turn Off | See Figure 4 | 180 | | t_{POL} | μs |

Table 11. Logic input

| 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 | | | μA |
| V_{IH} | Input high level voltage | | 2.1 | | | V |
| I_{IH} | High level input current | $V_{IN} = 2.1V$ | | | 10 | μA |
| $V_{I(hyst)}$ | Input hysteresis voltage | | 0.25 | | | V |
| V_{ICL} | Input clamp voltage | $I_{IN} = 1mA$ $I_{IN} = -1mA$ | 5.5 | -0.7 | 7 | V V |
| V_{SDL} | STAT_DIS low level voltage | | | | 0.9 | V |
| I_{SDL} | Low level STAT_DIS current | $V_{CSD} = 0.9V$ | 1 | | | μA |
| V_{SDH} | STAT_DIS high level voltage | | 2.1 | | | V |
| I_{SDH} | High level STAT_DIS current | $V_{CSD} = 2.1V$ | | | 10 | μA |
| $V_{SD(hyst)}$ | STAT_DIS hysteresis voltage | | 0.25 | | | V |
| V_{SDCL} | STAT_DIS clamp voltage | $I_{SD} = 1mA$ $I_{SD} = -1mA$ | 5.5 | -0.7 | 7 | V V |

Figure 4. Status timings

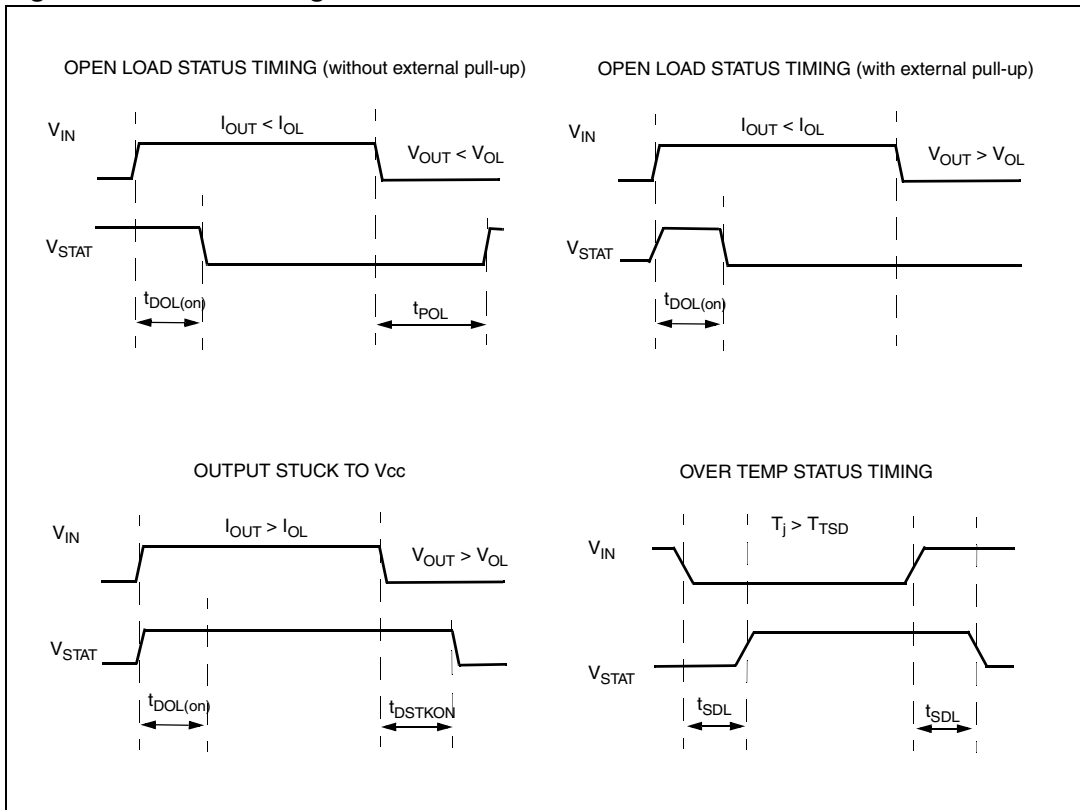


Figure 5. Output voltage drop limitation

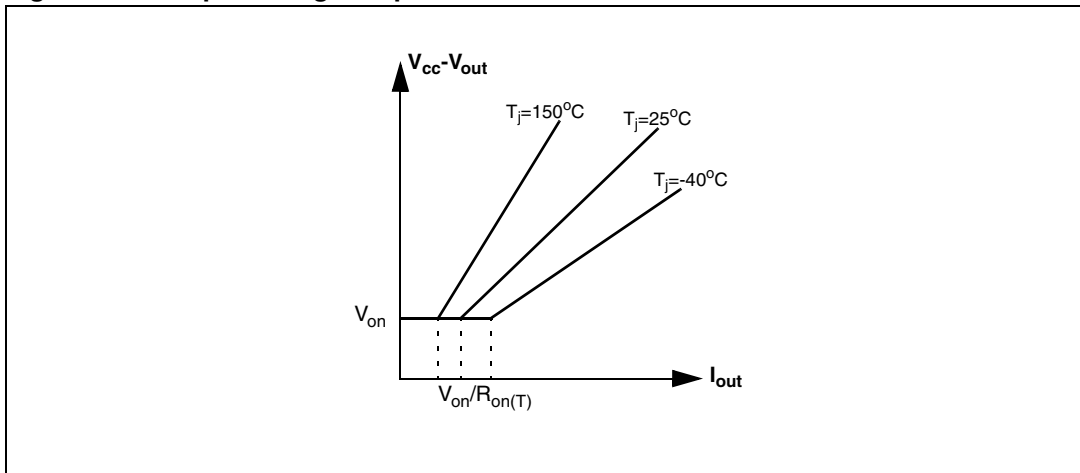


Table 12. Truth table

| Conditions | INPUT _n | OUTPUT _n | STATUS _n (V _{SD} =0V) ⁽¹⁾ |
|----------------------------------|--------------------|---------------------|--|
| Normal operation | L | L | H |
| | H | H | H |
| Current limitation | L | L | H |
| | H | X | H |
| Overtemperature | L | L | H |
| | H | L | L |
| Undervoltage | L | L | X |
| | H | L | X |
| Output Voltage > V _{OL} | L | H | L ⁽²⁾ |
| | H | H | H |
| Output Current < I _{OL} | L | L | H ⁽³⁾ |
| | H | H | L |

1. If the V_{SD} is high, the STATUS pin is in a high impedance.
2. The STATUS pin is low with a delay equal to t_{DSTKON} after INPUT falling edge.
3. The STATUS pin becomes high with a delay equal to t_{POL} after INPUT falling edge.

Figure 6. Switching characteristics

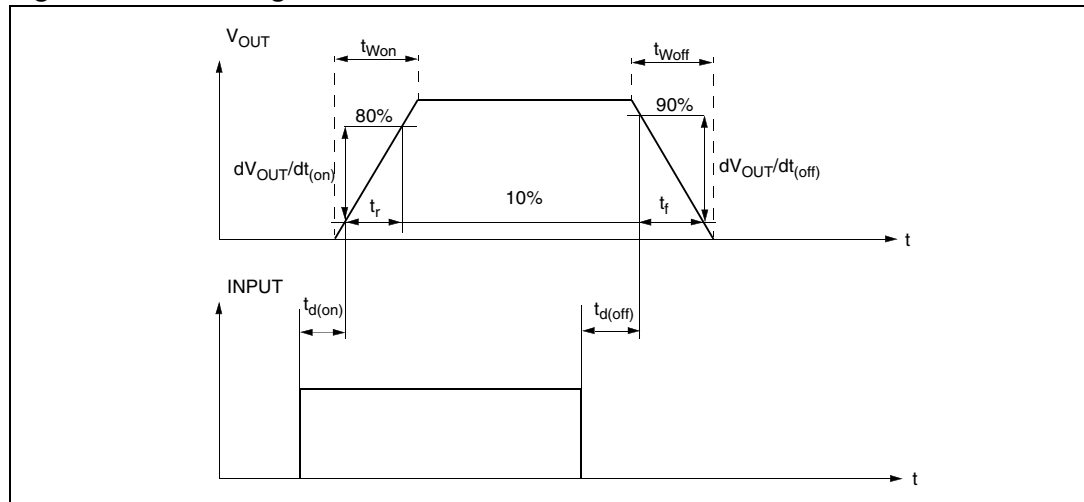


Table 13. Electrical transient requirements

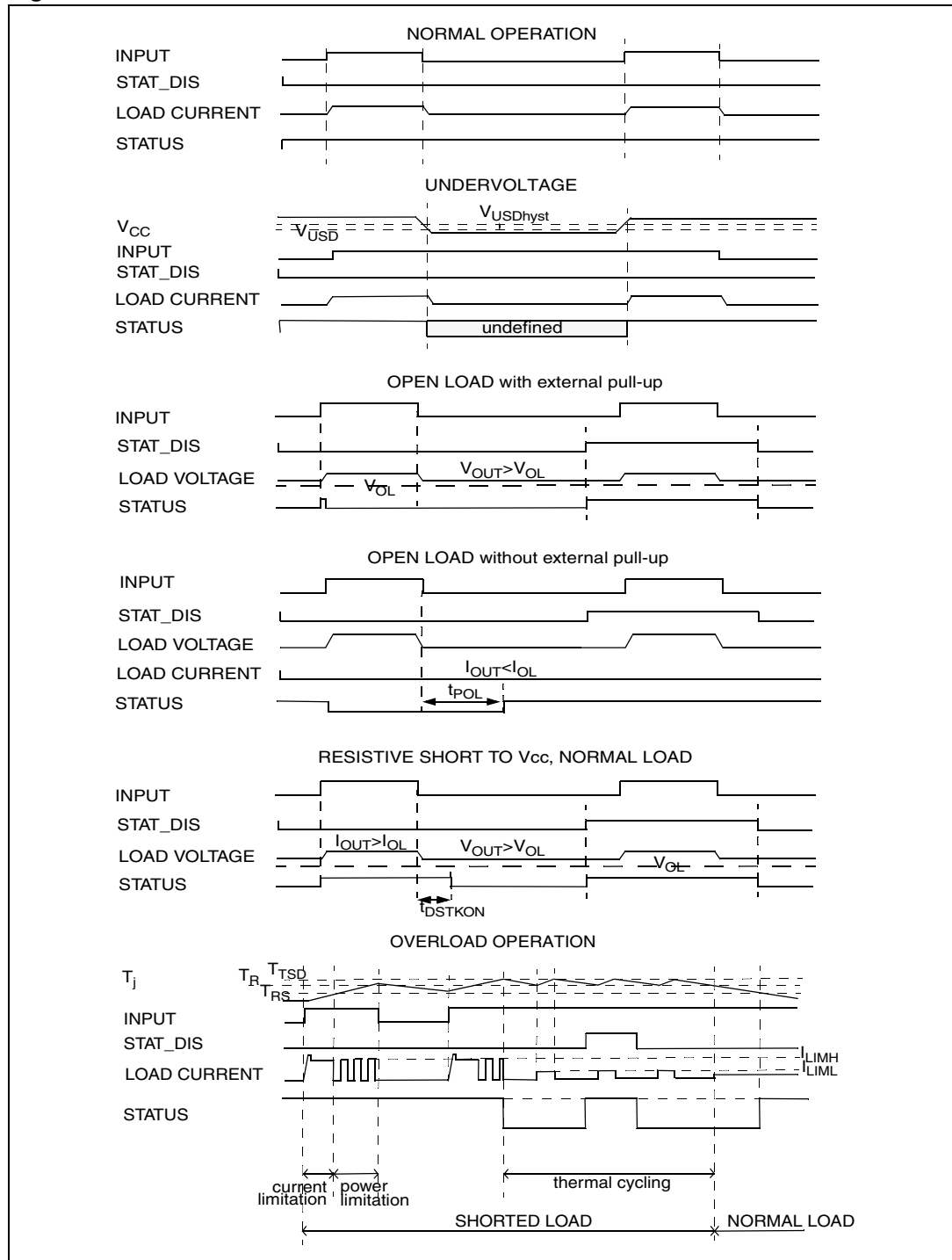
| ISO 7637-2: 2004(E) test pulse | Test levels ⁽¹⁾ | | Number of pulses or test times | Burst cycle/pulse repetition time | | Delays and impedance |
|--------------------------------------|----------------------------|-------|--------------------------------------|--------------------------------------|--------|-------------------------|
| | III | IV | | | | |
| 1 | -75V | -100V | 5000 pulses | 0.5 s | 5 s | 2 ms, 10 Ω |
| 2a | +37V | +50V | 5000 pulses | 0.2 s | 5 s | 50 μs, 2 Ω |
| 3a | -100V | -150V | 1h | 90 ms | 100 ms | 0.1 μs, 50 Ω |
| 3b | +75V | +100V | 1h | 90 ms | 100 ms | 0.1 μs, 50 Ω |
| 4 | -6V | -7V | 1 pulse | | | 100 ms, 0.01 Ω |
| 5b ⁽²⁾ | +65V | +87V | 1 pulse | | | 400 ms, 2 Ω |

| ISO 7637-2: 2004(E) test pulse | Test level results ⁽¹⁾ | |
|--------------------------------------|-----------------------------------|----|
| | III | IV |
| 1 | C | C |
| 2a | C | C |
| 3a | C | C |
| 3b | C | C |
| 4 | C | C |
| 5b ⁽²⁾ | C | C |

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

| 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. |

Figure 7. Waveforms



2.4 Electrical characteristics curves

Figure 8. Off state output current

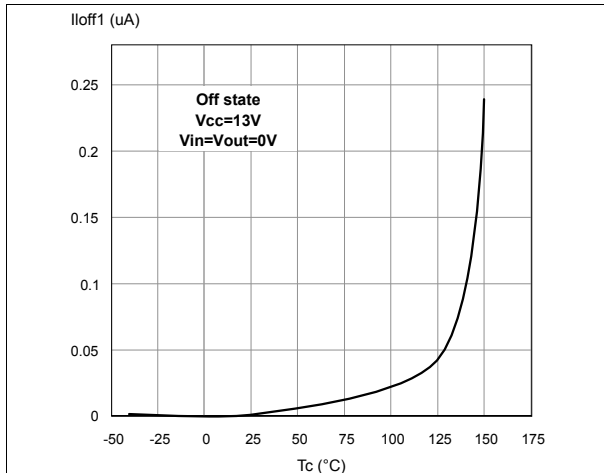


Figure 9. Input clamp voltage

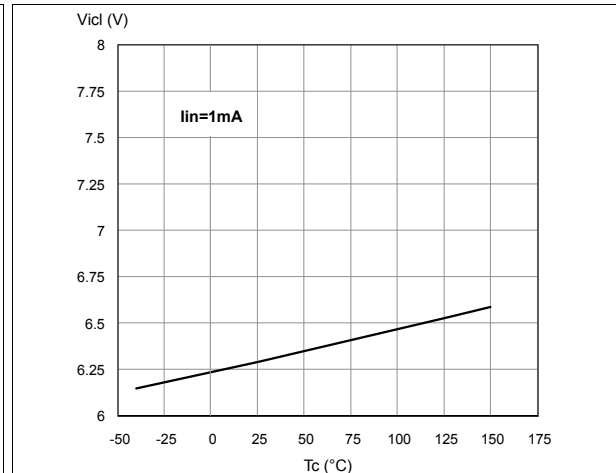


Figure 10. High level input current

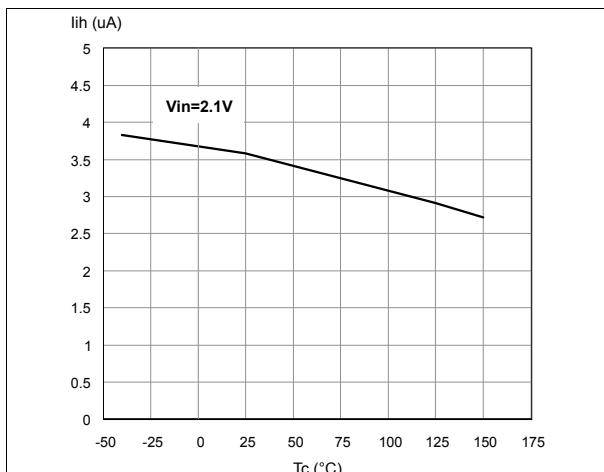


Figure 11. Input high level

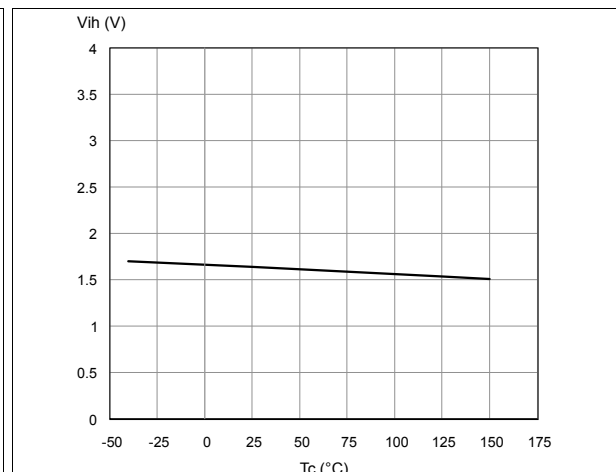


Figure 12. Input low level

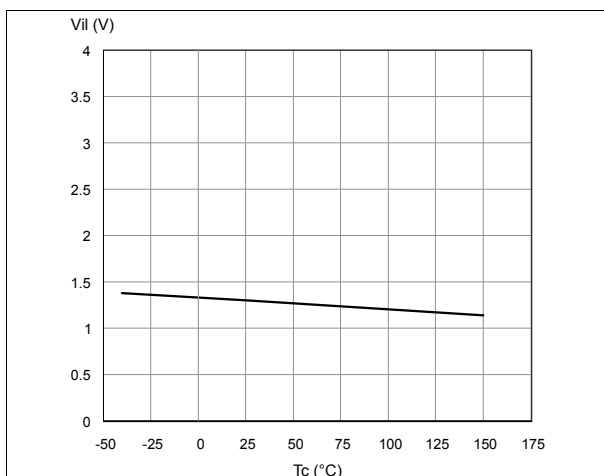


Figure 13. Input hysteresis voltage

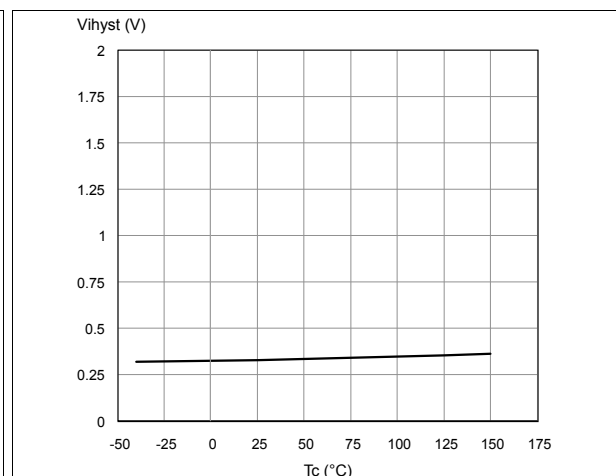


Figure 14. Status low output voltage

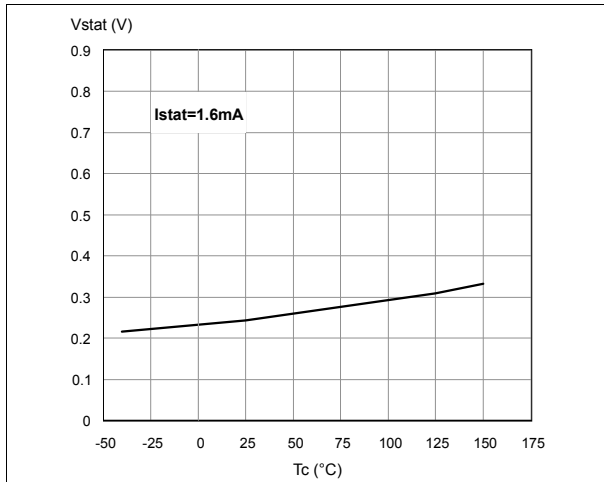


Figure 15. Status leakage current

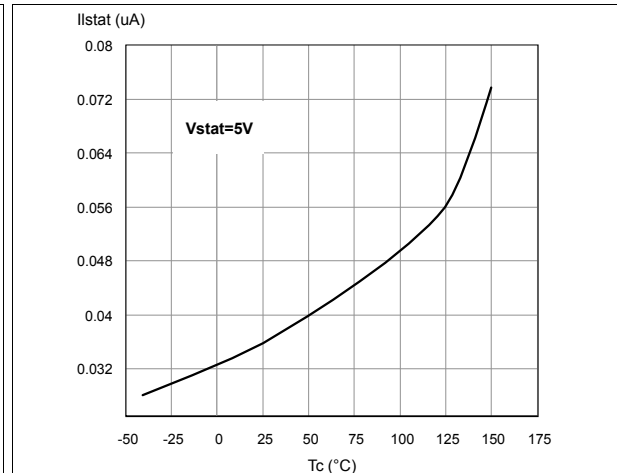


Figure 16. Status clamp voltage

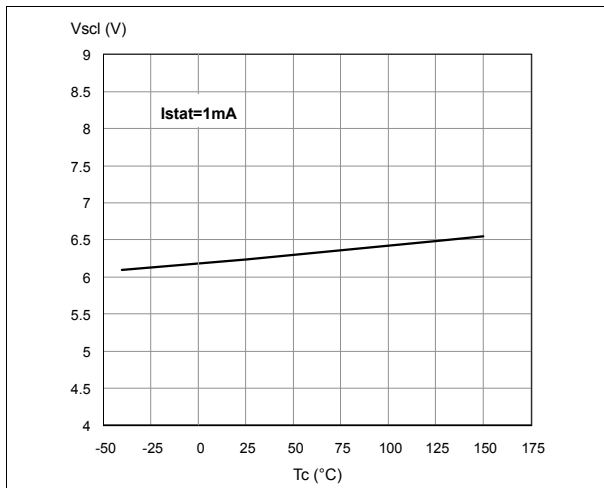


Figure 17. On state resistance vs T_{case}

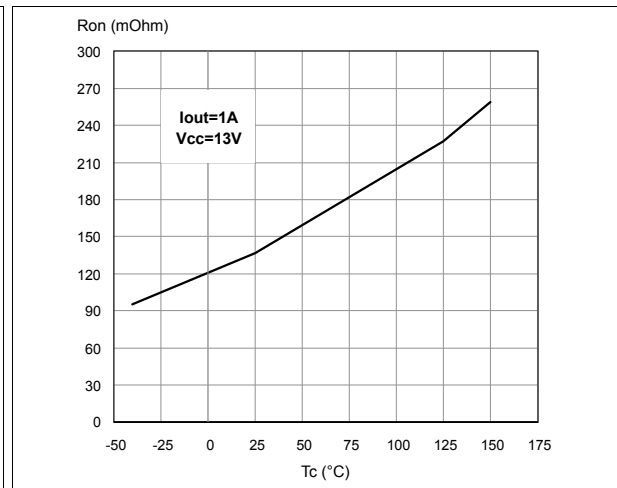


Figure 18. On state resistance vs V_{CC}

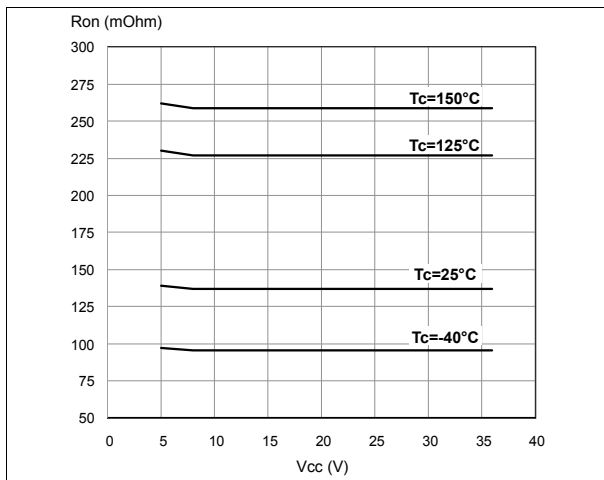


Figure 19. Openload On state detection threshold

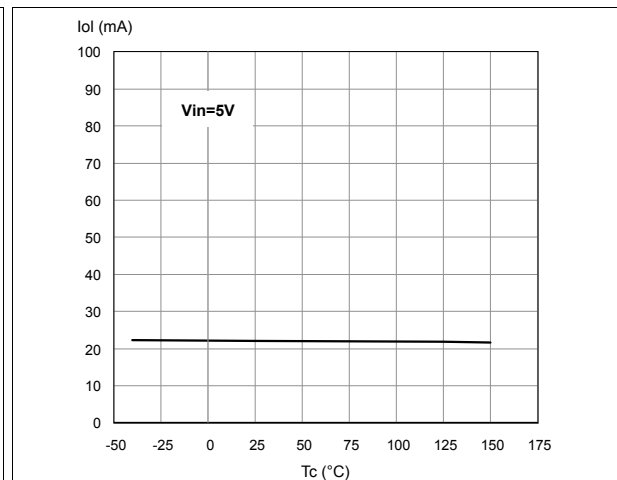


Figure 20. Openload Off state voltage detection threshold

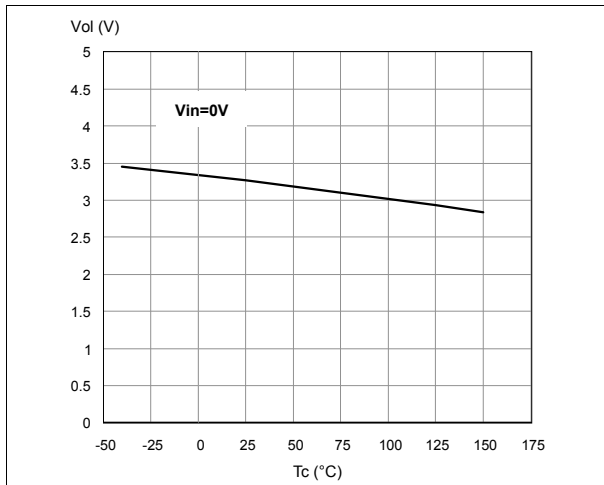


Figure 21. Turn - On voltage slope

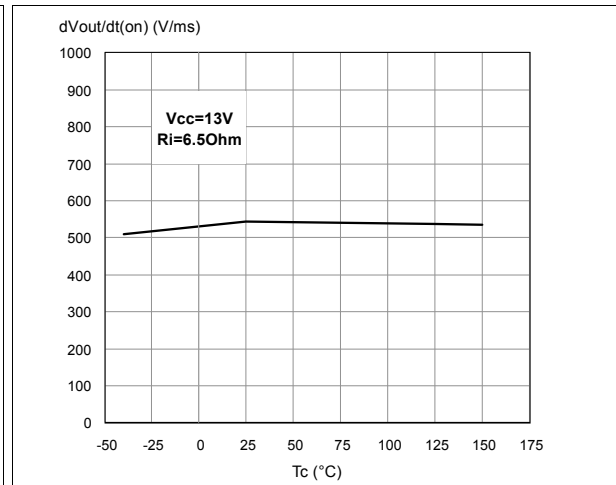


Figure 22. Turn - Off voltage slope

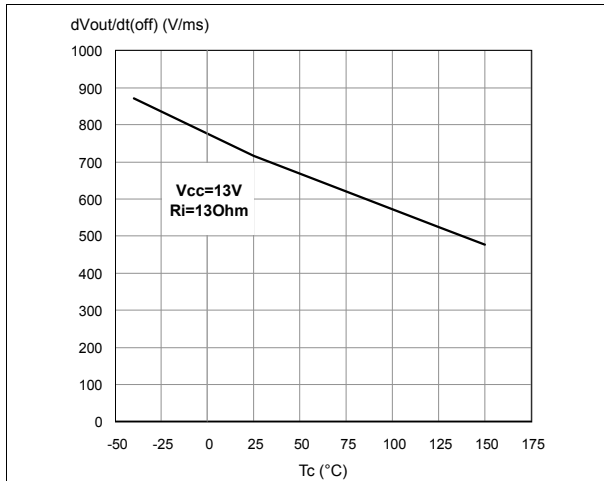


Figure 23. I_{LIM} vs T_{case}

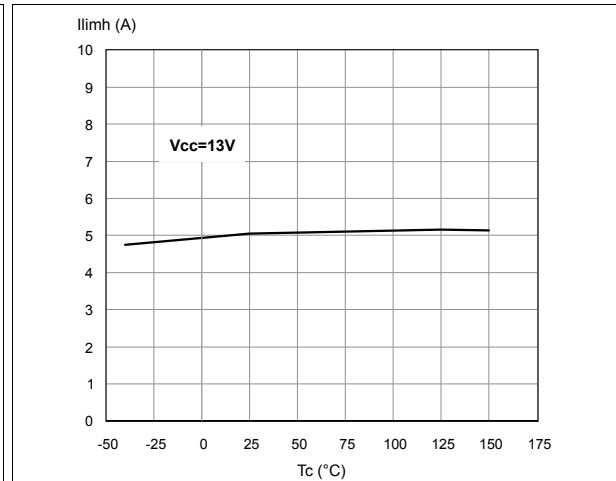


Figure 24. Undervoltage shutdown

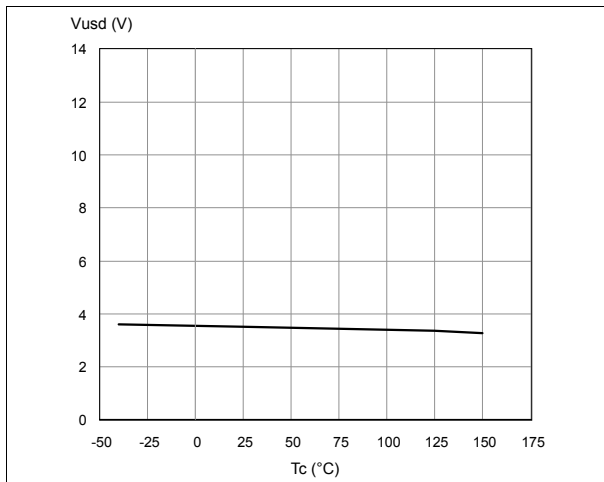


Figure 25. STAT_DIS clamp voltage

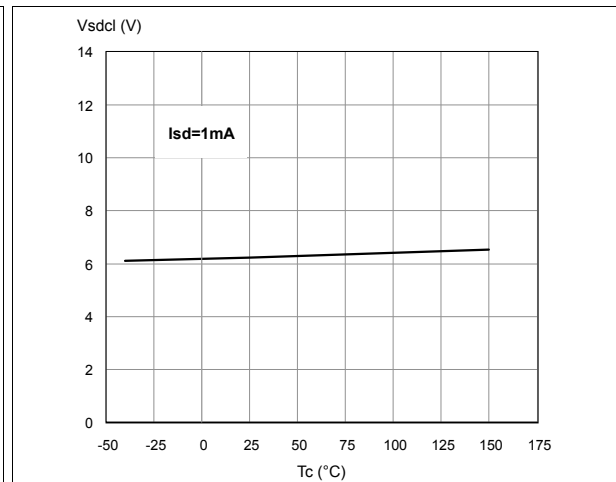


Figure 26. High level STAT_DIS voltage

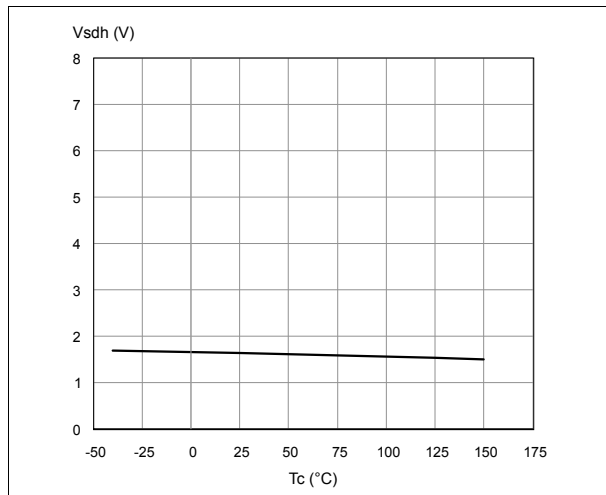
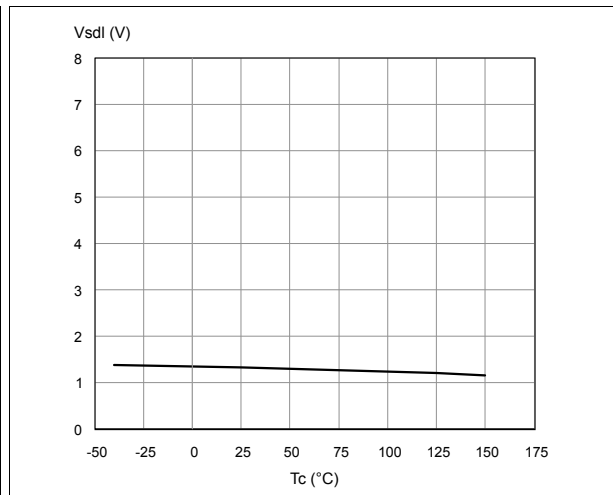
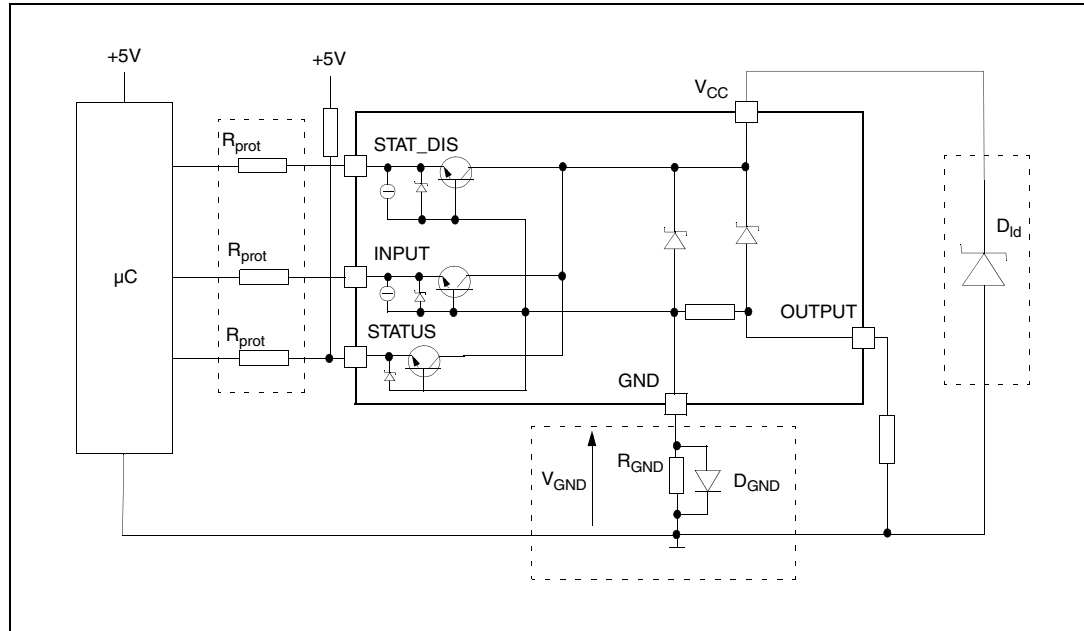


Figure 27. Low level STAT_DIS voltage



3 Application information

Figure 28. Application schematic



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

3.1 GND protection network against reverse battery

3.1.1 Solution 1 : resistor in the ground line (R_{GND} only)

This can be used with any type of load.

The following is an indication on how to dimension the R_{GND} resistor.

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

where -I_{GND} 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_{GND} (when V_{CC}<0: during reverse battery situations) is:

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

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 Solution 2 (see below).

3.1.2 Solution 2: a 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 μC I/Os pins to latch-up.

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

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

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 R_{prot} values is 10k Ω .

3.4 Open load detection in Off state

Off state open load detection requires an external pull-up resistor (R_{PU}) connected between OUTPUT pin and a positive supply voltage (V_{PU}) like the +5V line used to supply the microprocessor.

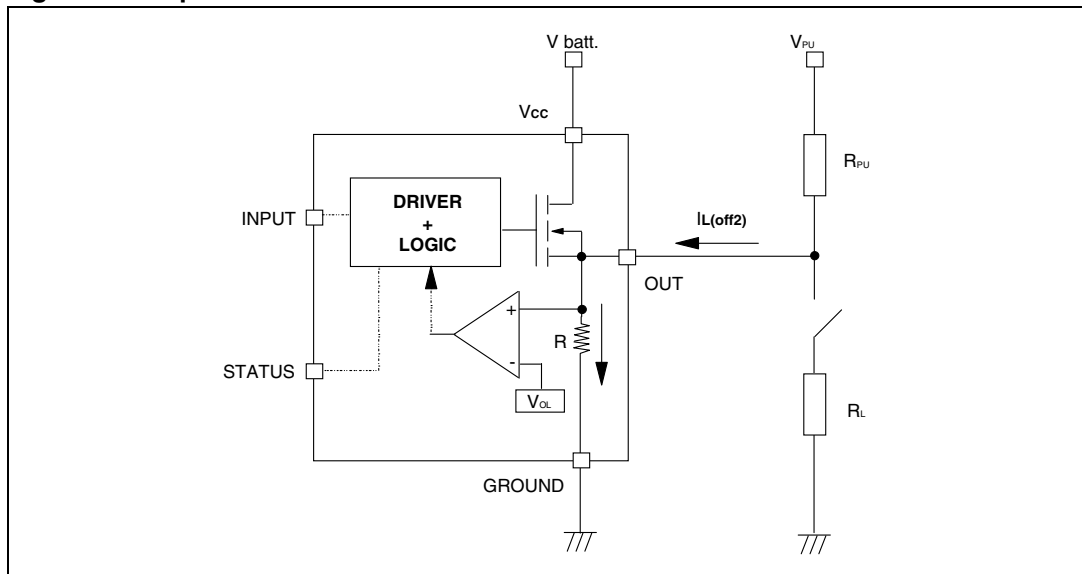
The external resistor has to be selected according to the following requirements:

- no false open load indication when load is connected: in this case we have to avoid V_{OUT} to be higher than V_{OLmin} ; this results in the following condition $V_{OUT} = (V_{PU} / (R_L + R_{PU})) R_L < V_{OLmin}$.
- no misdetection when load is disconnected: in this case the V_{out} has to be higher than V_{OLmax} ; this results in the following condition $R_{PU} < (V_{PU} - V_{OLmax}) / I_{L(off2)}$.

Because $I_{s(OFF)}$ may significantly increase if V_{out} is pulled high (up to several mA), the pull-up resistor R_{PU} should be connected to a supply that is switched OFF when the module is in standby.

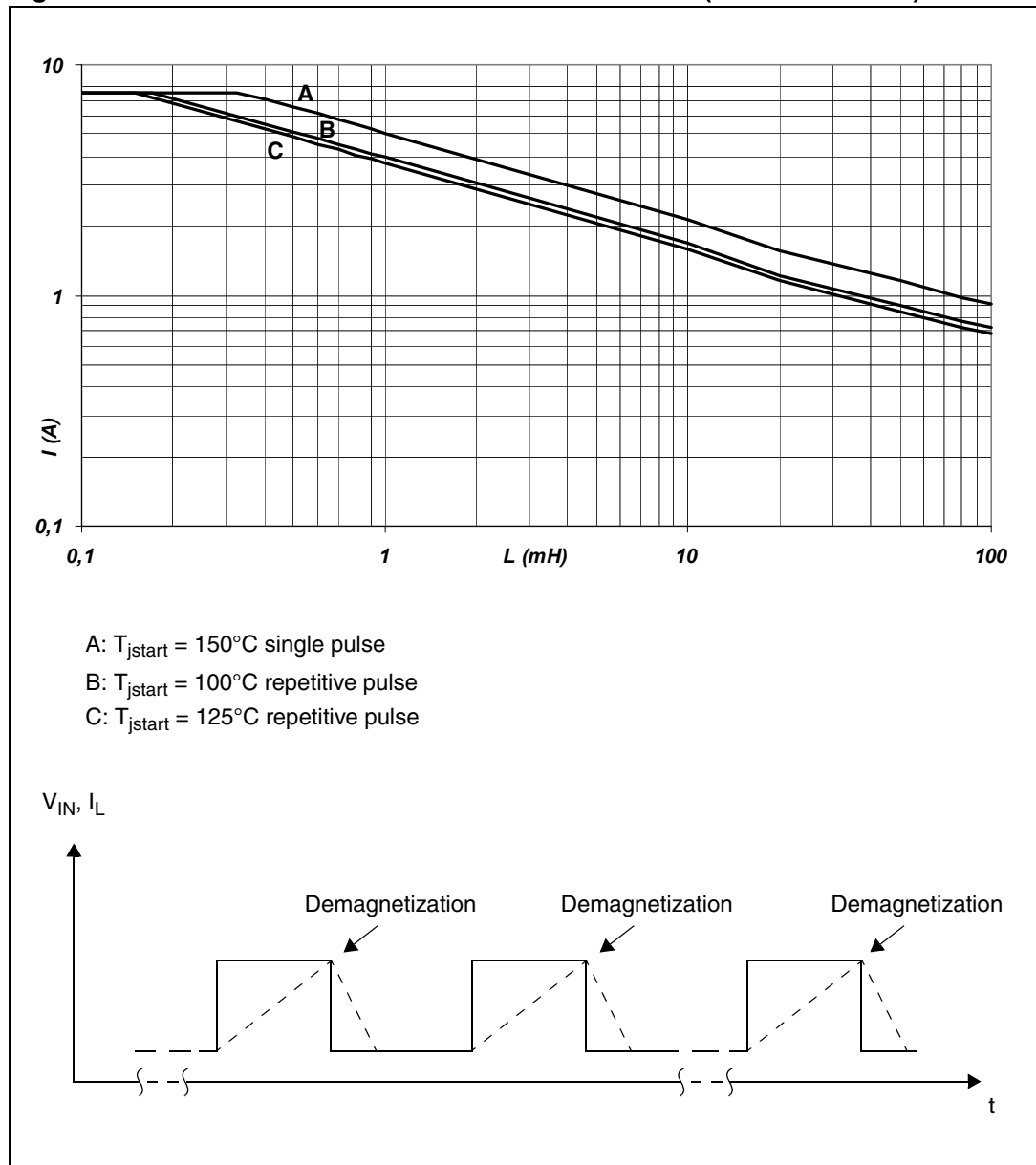
The values of V_{OLmin} , V_{OLmax} and $I_{L(off2)}$ are available in the Electrical characteristics section.

Figure 29. Open load detection in Off state



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

Figure 30. Maximum turn Off current versus inductance (for each channel)



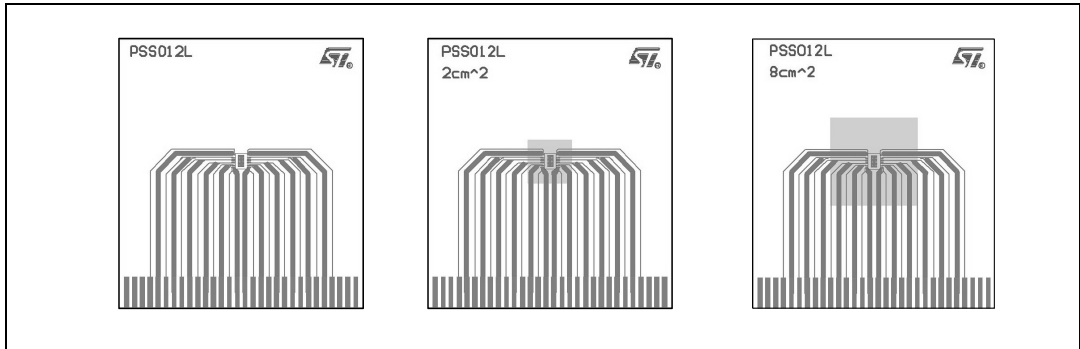
Note: Values are generated with $R_L = 0\Omega$.

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 PCB thermal data

4.1 PowerSSO-12™ thermal data

Figure 31. PowerSSO-12™ PC board



Note: Layout condition of R_{th} and Z_{th} measurements (PCB: Double layer, Thermal Vias, FR4 area= 77mm x 86mm, PCB thickness=1.6mm, Cu thickness=70µm (front and back side), Copper areas: from minimum pad lay-out to 8cm²).

Figure 32. $R_{thj-amb}$ vs. PCB copper area in open box free air condition (one channel ON)

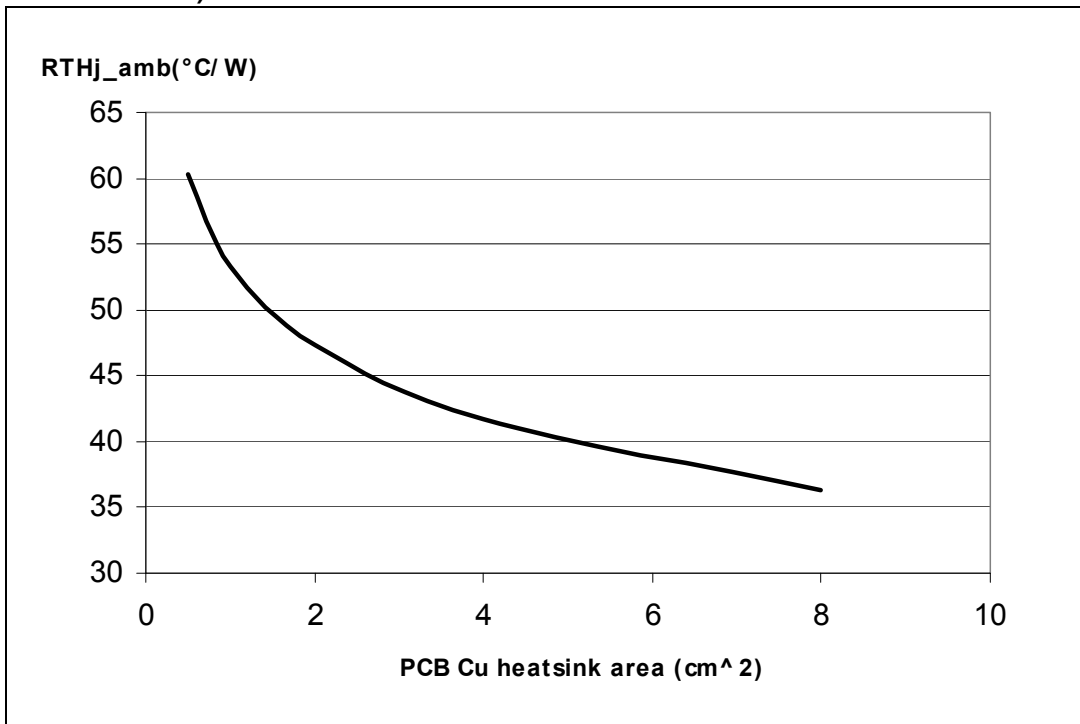
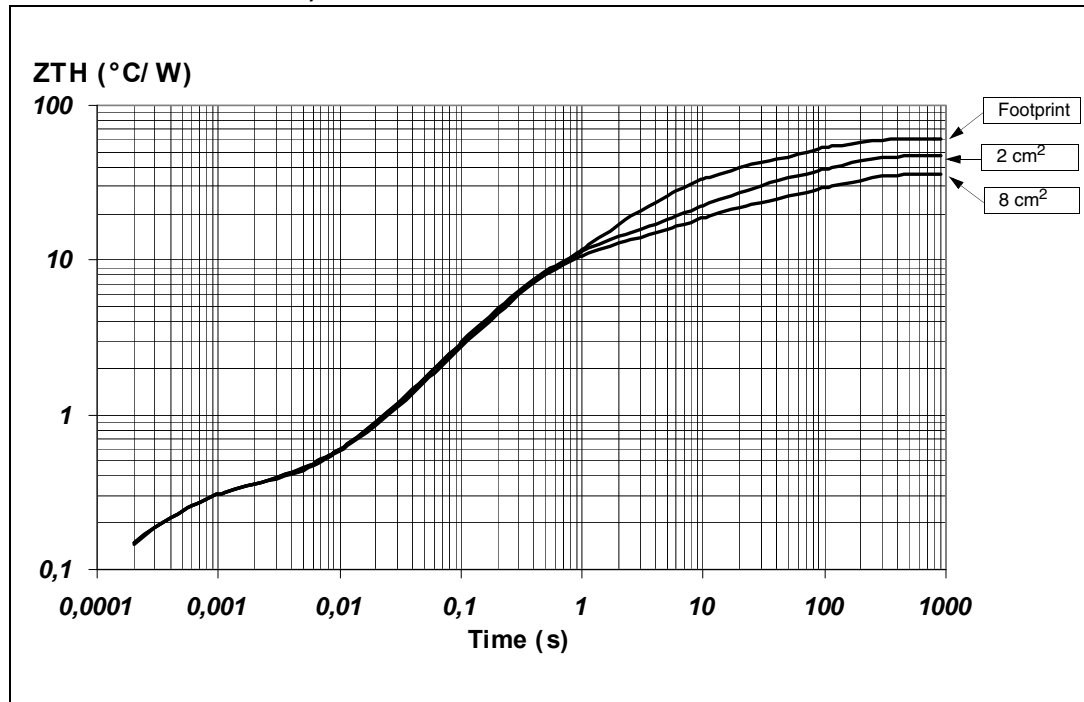


Figure 33. PowerSSO-12™ Thermal impedance junction ambient single pulse (one channel ON)

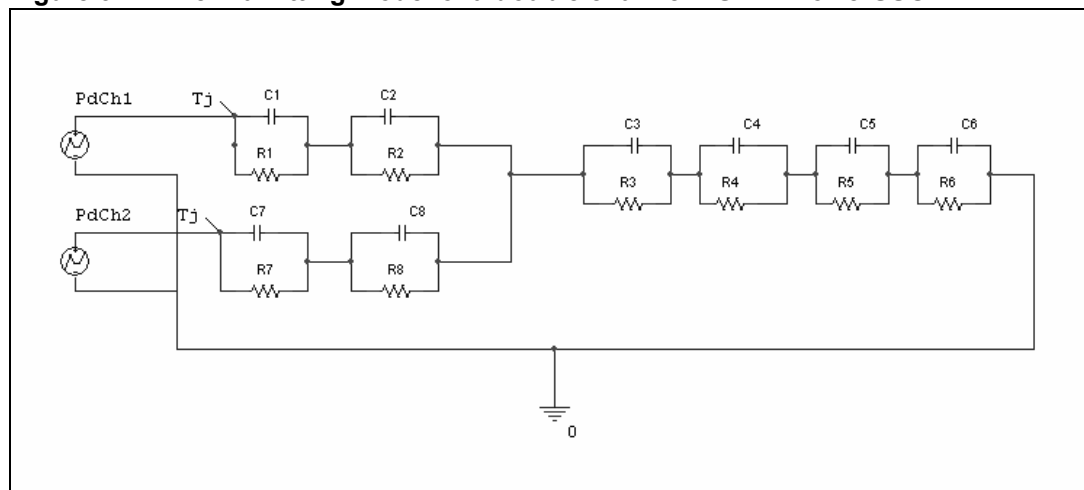


Pulse calculation formula

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

where $\delta = t_p/T$

Figure 34. Thermal fitting model of a double channel HSD in PowerSSO-12™(a)



- 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.