

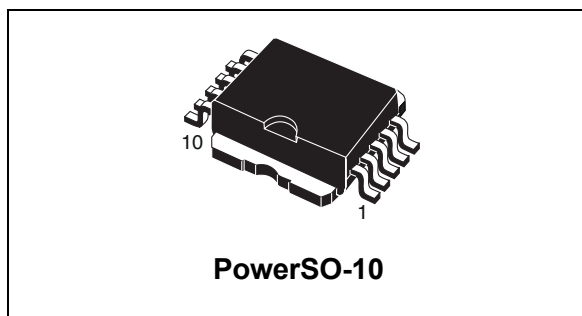
Single channel high-side solid state relay

Features

| Type | $R_{DS(on)}$ | I_{OUT} | V_{CC} |
|---------|-----------------------------|--------------------|----------|
| VN610SP | 10m Ω ⁽¹⁾ | 45A ⁽¹⁾ | 36V |

1. Per each channel.

- Output current: 45A
- CMOS compatible inputs
- Proportional load current sense
- Under-voltage and over-voltage shutdown
- Over-voltage clamp
- Thermal shutdown
- Current limitation
- Very low standby power consumption
- Protection against loss of ground and loss of V_{CC}
- Reverse battery protected



Description

The VN610SP is a monolithic device made using STMicroelectronics VIPower M0-3 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). This device integrates an analog current sense which delivers a current proportional to the load current (according to a known ratio).

Active current limitation combined with thermal shutdown and automatic restart protect the device against over-load. Device automatically turns off in case of ground pin disconnection.

Table 1. Device summary

| Package | Order codes | |
|------------|-------------|---------------|
| | Tube | Tape and reel |
| PowerSO-10 | VN610SP | VN610SP13TR |

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1 Block diagram and pin description

Figure 1. Block diagram

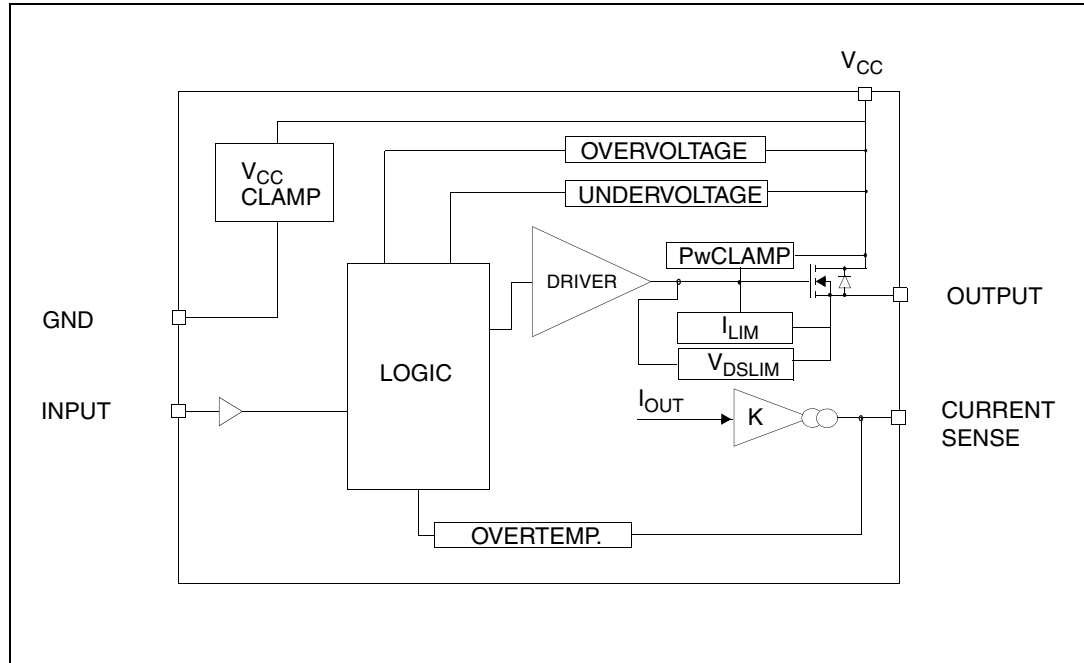


Figure 2. Configuration diagram (top view)

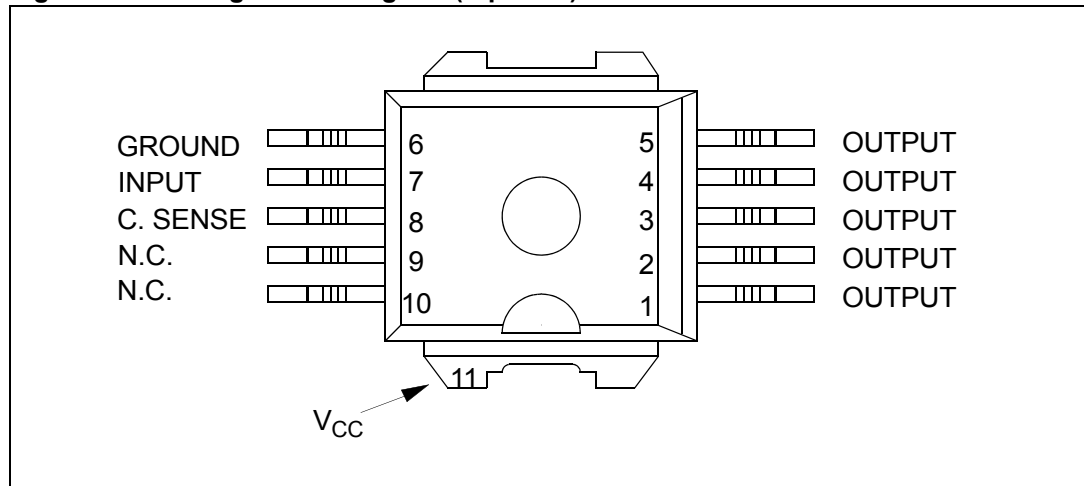
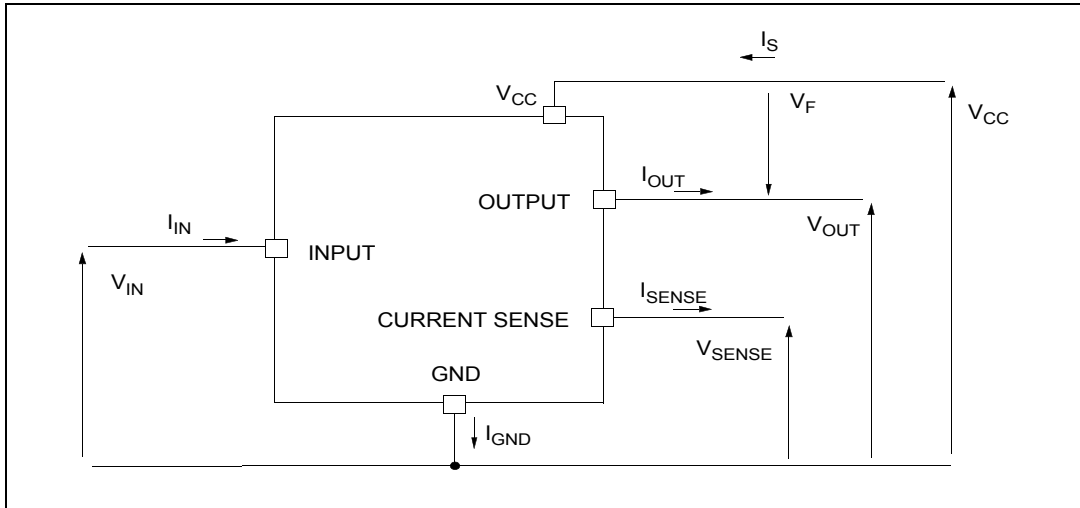


Table 2. Suggested connections for unused and not connected pins

| Connection / pin | Current sense | N.C. | Output | Input |
|------------------|----------------------|------|--------|-----------------------|
| Floating | | X | X | X |
| To ground | Through 1KΩ resistor | X | | Through 10KΩ resistor |

2 Electrical specifications

Figure 3. Current and voltage conventions



2.1 Absolute maximum ratings

Stressing the device above the rating listed in the “Absolute maximum ratings” table may cause permanent damage to the device. These are stress ratings only and operation of the device at these or any other conditions above those indicated in the Operating sections of this specification is not implied. Exposure to Absolute Maximum Rating conditions for extended periods may affect device reliability. Refer also to the STMicroelectronics SURE Program and other relevant quality document.

Table 3. Absolute maximum ratings

| Symbol | Parameter | Value | Unit |
|--------------|--|--------------------|--------|
| V_{CC} | DC supply voltage | 41 | V |
| $-V_{CC}$ | Reverse supply voltage | - 0.3 | V |
| $- I_{GND}$ | DC reverse ground pin current | - 200 | mA |
| I_{OUT} | Output current | Internally limited | A |
| I_R | Reverse output current | - 50 | A |
| I_{IN} | Input current | +/- 10 | mA |
| V_{CSENSE} | Current sense maximum voltage | - 3 + 15 | V V |
| V_{ESD} | Electrostatic discharge (human body model: R = 1.5KΩ; C = 100pF) | | |
| | - INPUT | 4000 | V |
| | - CURRENT SENSE | 2000 | V |
| | - OUTPUT | 5000 | V |
| | - V_{CC} | 5000 | V |

Table 3. Absolute maximum ratings (continued)

| Symbol | Parameter | Value | Unit |
|-----------|--|--------------------|------------------|
| E_{MAX} | Maximum switching energy ($L = 0.05\text{mH}$; $R_L = 0\Omega$; $V_{bat} = 13.5\text{V}$; $T_{jstart} = 150^\circ\text{C}$; $I_L = 75\text{A}$) | 193 | mJ |
| P_{tot} | Power dissipation at $T_c \leq 25^\circ\text{C}$ | 139 | W |
| T_j | Junction operating temperature | Internally limited | $^\circ\text{C}$ |
| T_c | Case 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 | Max. value | | Unit |
|----------------|-------------------------------------|---------------------|-------------------|---------------------------|
| $R_{thj-case}$ | Thermal resistance junction-case | 0.9 | | $^\circ\text{C}/\text{W}$ |
| $R_{thj-amb}$ | Thermal resistance junction-ambient | 50.9 ⁽¹⁾ | 36 ⁽²⁾ | $^\circ\text{C}/\text{W}$ |

1. When mounted on a standard single-sided FR-4 board with 0.5cm^2 of Cu (at least $35\ \mu\text{m}$ thick).

2. When mounted on a standard single-sided FR-4 board with $6\ \text{cm}^2$ of Cu (at least $35\ \mu\text{m}$ thick).

2.3 Electrical characteristics

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

Table 5. Power

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|----------------------|--------------------------|---|------|----------|----------------|--|
| V_{CC} | Operating supply voltage | | 5.5 | 13 | 36 | V |
| V_{USD} | Under-voltage shutdown | | 3 | 4 | 5.5 | V |
| V_{OV} | Over-voltage shutdown | | 36 | | | V |
| R_{ON} | On-state resistance | $I_{OUT} = 1.5\text{A}$; $T_j = 25^\circ\text{C}$ $I_{OUT} = 1.5\text{A}$; $T_j = 150^\circ\text{C}$ $I_{OUT} = 9\text{A}$; $V_{CC} = 6\text{V}$ | | | 10 20 35 | $\text{m}\Omega$ $\text{m}\Omega$ $\text{m}\Omega$ |
| V_{clamp} | Clamp voltage | $I_{CC} = 20\text{mA}$ ⁽¹⁾ | 41 | 48 | 55 | V |
| I_S ⁽¹⁾ | Supply current | Off-state; $V_{CC} = 13\text{V}$; $V_{IN} = V_{OUT} = 0\text{V}$ Off-state; $V_{CC} = 13\text{V}$; $V_{IN} = V_{OUT} = 0\text{V}$; $T_j = 25^\circ\text{C}$ On-state; $V_{IN} = 5\text{V}$; $V_{CC} = 13\text{V}$; $I_{OUT} = 0\text{A}$; $R_{SENSE} = 3.9\text{k}\Omega$ | | 10 10 | 25 20 5 | μA mA mA |
| $I_{L(off1)}$ | Off-state output current | $V_{IN} = V_{OUT} = 0\text{V}$ | 0 | | 50 | μA |

Table 5. Power (continued)

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|---------------|--------------------------|---|------|------|------|---------|
| $I_{L(off2)}$ | Off-state output current | $V_{IN} = 0V; V_{OUT} = 3.5V$ | -75 | | 0 | μA |
| $I_{L(off3)}$ | Off-state output current | $V_{IN} = V_{OUT} = 0V; V_{CC} = 13V;$ $T_j = 125^\circ C$ | | | 5 | μA |
| $I_{L(off4)}$ | Off-state output current | $V_{IN} = V_{OUT} = 0V; V_{CC} = 13V;$ $T_j = 25^\circ C$ | | | 3 | μA |

1. V_{clamp} and V_{OV} are correlated. Typical difference is 5V.

Table 6. Protections

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|-------------|--------------------------------|--|---------------|---------------|---------------|------------|
| I_{lim} | DC short circuit current | $V_{CC} = 13V$ $5.5V < V_{CC} < 36V$ | 45 | 75 | 120 120 | A A |
| T_{TSD} | Thermal shutdown temperature | | 150 | 175 | 200 | $^\circ C$ |
| T_R | Thermal reset temperature | | 135 | | | $^\circ C$ |
| T_{HYST} | Thermal hysteresis | | 7 | 15 | | $^\circ C$ |
| V_{demag} | Turn-off output voltage clamp | $I_{OUT} = 2A; V_{IN} = 0V; L = 6mH$ | $V_{CC} - 41$ | $V_{CC} - 48$ | $V_{CC} - 55$ | V |
| V_{ON} | Output voltage drop limitation | $I_{OUT} = 1.5A$ $T_j = -40^\circ C \dots +150^\circ C$ | | 50 | | mV |

Note: To ensure long term reliability under heavy over-load 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 7. V_{CC} - output diode

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|--------|--------------------|-----------------------------------|------|------|------|------|
| V_F | Forward on voltage | $I_{OUT} = 8A; T_j = 150^\circ C$ | | | 0.6 | V |

Table 8. Current sense ($9V \leq V_{CC} \leq 16V$)

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|---------------|---|---|--------------|--------------|--------------|--------------------|
| K_1 | I_{OUT}/I_{SENSE} | $I_{OUT} = 1.5A$; $V_{SENSE} = 0.5V$; $T_J = -40^\circ C \dots 150^\circ C$ | 3300 | 4400 | 6000 | |
| dK_1/K_1 | Current sense ratio drift | $I_{OUT} = 1.5A$; $V_{SENSE} = 0.5V$; $T_J = -40^\circ C \dots 150^\circ C$ | -10 | | +10 | % |
| K_2 | I_{OUT}/I_{SENSE} | $I_{OUT} = 15A$; $V_{SENSE} = 4V$; $T_J = -40^\circ C$ $T_J = 25^\circ C \dots 150^\circ C$ | 4200 4400 | 4900 4900 | 6000 5750 | |
| dK_2/K_2 | Current sense ratio drift | $I_{OUT} = 15A$; $V_{SENSE} = 4V$; $T_J = -40^\circ C \dots 150^\circ C$ | -6 | | +6 | % |
| K_3 | I_{OUT}/I_{SENSE} | $I_{OUT} = 45A$; $V_{SENSE} = 4V$; $T_J = -40^\circ C$ $T_J = 25^\circ C \dots 150^\circ C$ | 4200 4400 | 4900 4900 | 5500 5250 | |
| dK_3/K_3 | Current sense ratio drift | $I_{OUT} = 45A$; $V_{SENSE} = 4V$; $T_J = -40^\circ C \dots 150^\circ C$ | -6 | | +6 | % |
| I_{SENSE0} | Analog sense current | $V_{CC} = 6 \dots 16V$; $I_{OUT} = 0A$; $V_{SENSE} = 0V$; $T_J = -40^\circ C \dots 150^\circ C$ Off-state; $V_{IN} = 0V$ On-state; $V_{IN} = 5V$ | 0 0 | | 5 10 | μA μA |
| V_{SENSE} | Max analog sense output voltage | $V_{CC} = 5.5V$; $I_{OUT} = 7.5A$; $R_{SENSE} = 10k\Omega$ $V_{CC} > 8V$; $I_{OUT} = 15A$; $R_{SENSE} = 10k\Omega$ | 3.5 5 | | | V V |
| V_{SENSEH} | Analog sense output voltage in over-temperature condition | $V_{CC} = 13V$; $R_{SENSE} = 3.9k\Omega$ | | 5.5 | | V |
| $R_{VSENSEH}$ | Analog sense output impedance in over-temperature condition | $V_{CC} = 13V$; $T_J > T_{TSD}$; all channels open | | 400 | | Ω |
| t_{DSENSE} | Current sense delay response | To 90% $I_{SENSE}^{(1)}$ | | | 500 | μs |

1. Current sense signal delay after positive input slope.

Table 9. Logic inputs

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|---------------|--------------------------|-----------------------------------|------|-------------|------|---------|
| V_{IL} | Input low level voltage | | | | 1.25 | V |
| I_{IL} | Low level input current | $V_{IN} = 1.25V$ | 1 | | | μA |
| V_{IH} | Input high level voltage | | 3.25 | | | V |
| I_{IH} | High level input current | $V_{IN} = 3.25V$ | | | 10 | μA |
| $V_{I(hyst)}$ | Input hysteresis voltage | | 0.5 | | | V |
| V_{ICL} | Input clamp voltage | $I_{IN} = 1mA$ $I_{IN} = -1mA$ | 6 | 6.8 -0.7 | 8 | V V |

Table 10. Switching ($V_{CC} = 13V$)

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|-----------------------|------------------------|---|------|--------------------------------|------|-----------|
| $t_{d(on)}$ | Turn-on delay time | $R_L = 0.87\Omega$ (see Figure 4.) | | 30 | | μs |
| $t_{d(off)}$ | Turn-on delay time | $R_L = 0.87\Omega$ (see Figure 4.) | | 30 | | μs |
| $(dV_{OUT}/dt)_{on}$ | Turn-on voltage slope | $R_L = 0.87\Omega$ (see Figure 4.) | | See Figure 10. | | $V/\mu s$ |
| $(dV_{OUT}/dt)_{off}$ | Turn-off voltage slope | $R_L = 0.87\Omega$ (see Figure 4.) | | See Figure 12. | | $V/\mu s$ |

Table 11. Truth table

| Conditions | Input | Output | Sense |
|-------------------------------|-------|--------|------------------------------|
| Normal operation | L | L | 0 |
| | H | H | Nominal |
| Over-temperature | L | L | 0 |
| | H | L | V_{SENSEH} |
| Under-voltage | L | L | 0 |
| | H | L | 0 |
| Over-voltage | L | L | 0 |
| | H | L | 0 |
| Short circuit to GND | L | L | 0 |
| | H | L | $(T_j < T_{TSD}) 0$ |
| | H | L | $(T_j > T_{TSD}) V_{SENSEH}$ |
| Short circuit to V_{CC} | L | H | 0 |
| | H | H | < Nominal |
| Negative output voltage clamp | L | L | 0 |

Table 12. Electrical transient requirements

| ISO T/R 7637/1 Test pulse | Test level | | | | Delays and impedance |
|---------------------------------|------------------------|------------------------|------------------------|------------------------|----------------------|
| | I | II | III | IV | |
| 1 | - 25V ⁽¹⁾ | - 50V ⁽¹⁾ | - 75V ⁽¹⁾ | - 100V ⁽¹⁾ | 2ms, 10Ω |
| 2 | + 25V ⁽¹⁾ | + 50V ⁽¹⁾ | + 75V ⁽¹⁾ | + 100V ⁽¹⁾ | 0.2ms, 10Ω |
| 3a | - 25V ⁽¹⁾ | - 50V ⁽¹⁾ | - 100V ⁽¹⁾ | - 150V ⁽¹⁾ | 0.1μs, 50Ω |
| 3b | + 25V ⁽¹⁾ | + 50V ⁽¹⁾ | + 75V ⁽¹⁾ | + 100V ⁽¹⁾ | 0.1μs, 50Ω |
| 4 | - 4V ⁽¹⁾ | - 5V ⁽¹⁾ | - 6V ⁽¹⁾ | - 7V ⁽¹⁾ | 100ms, 0.01Ω |
| 5 | + 26.5V ⁽¹⁾ | + 46.5V ⁽²⁾ | + 66.5V ⁽²⁾ | + 86.5V ⁽²⁾ | 400ms, 2Ω |

1. All functions of the device are performed as designed after exposure to disturbance.
2. One or more functions of the device is not performed as designed after exposure and cannot be returned to proper operation without replacing the device.

Figure 4. Switching characteristics

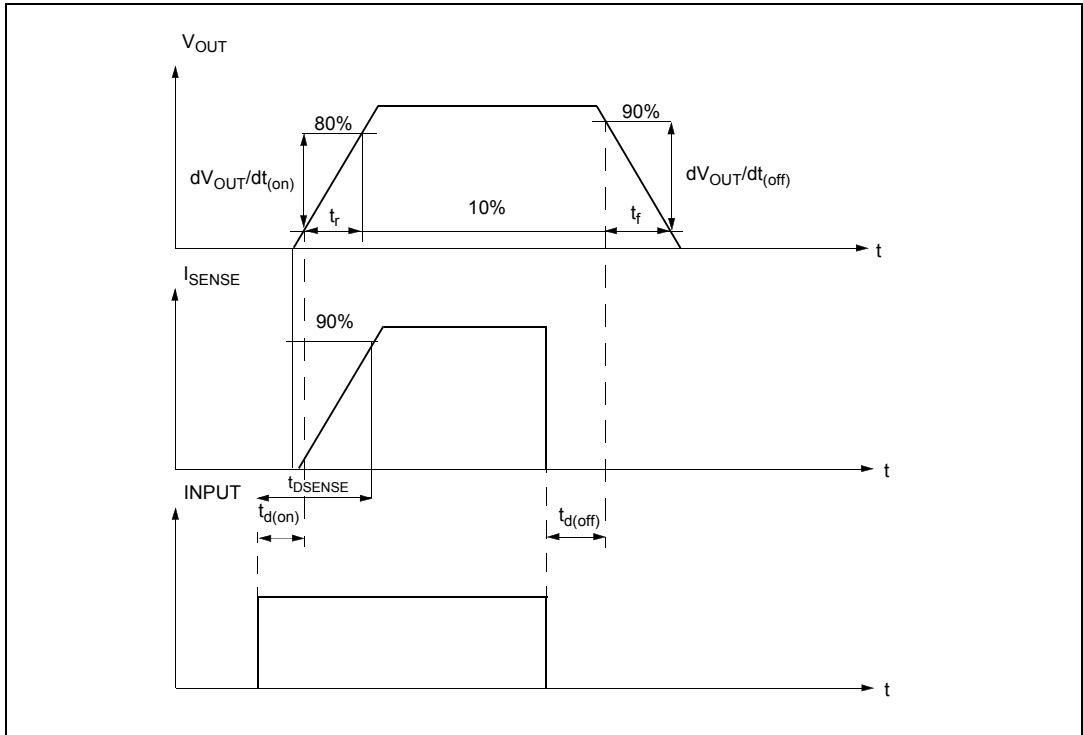


Figure 5. I_{OUT}/I_{SENSE} versus I_{OUT}

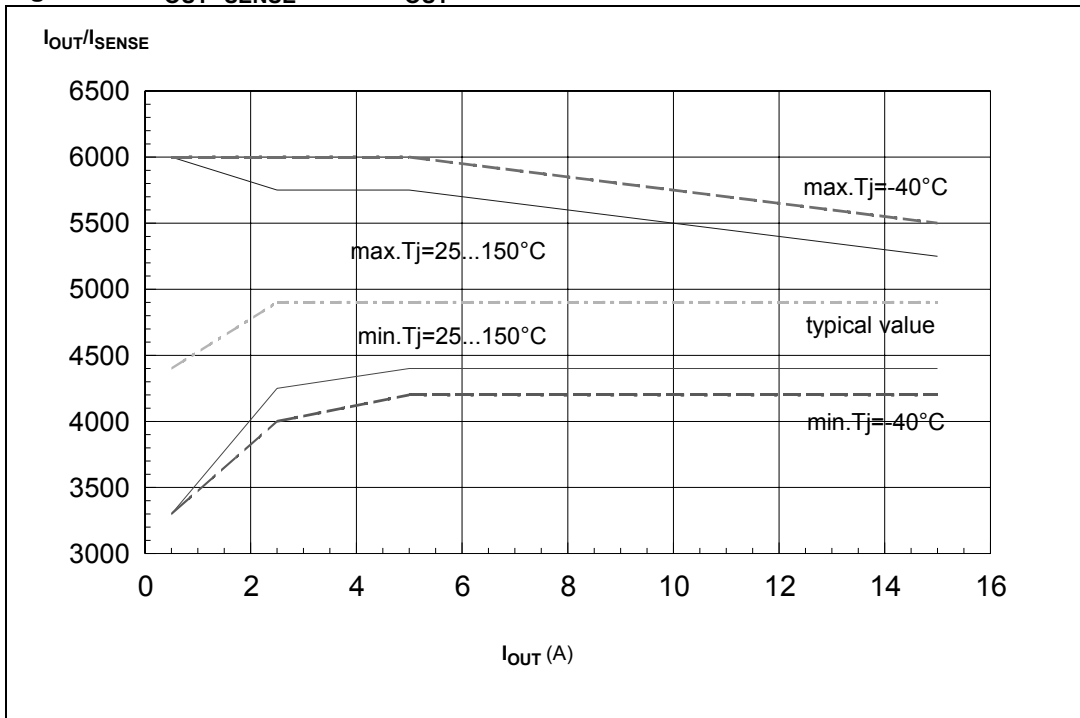
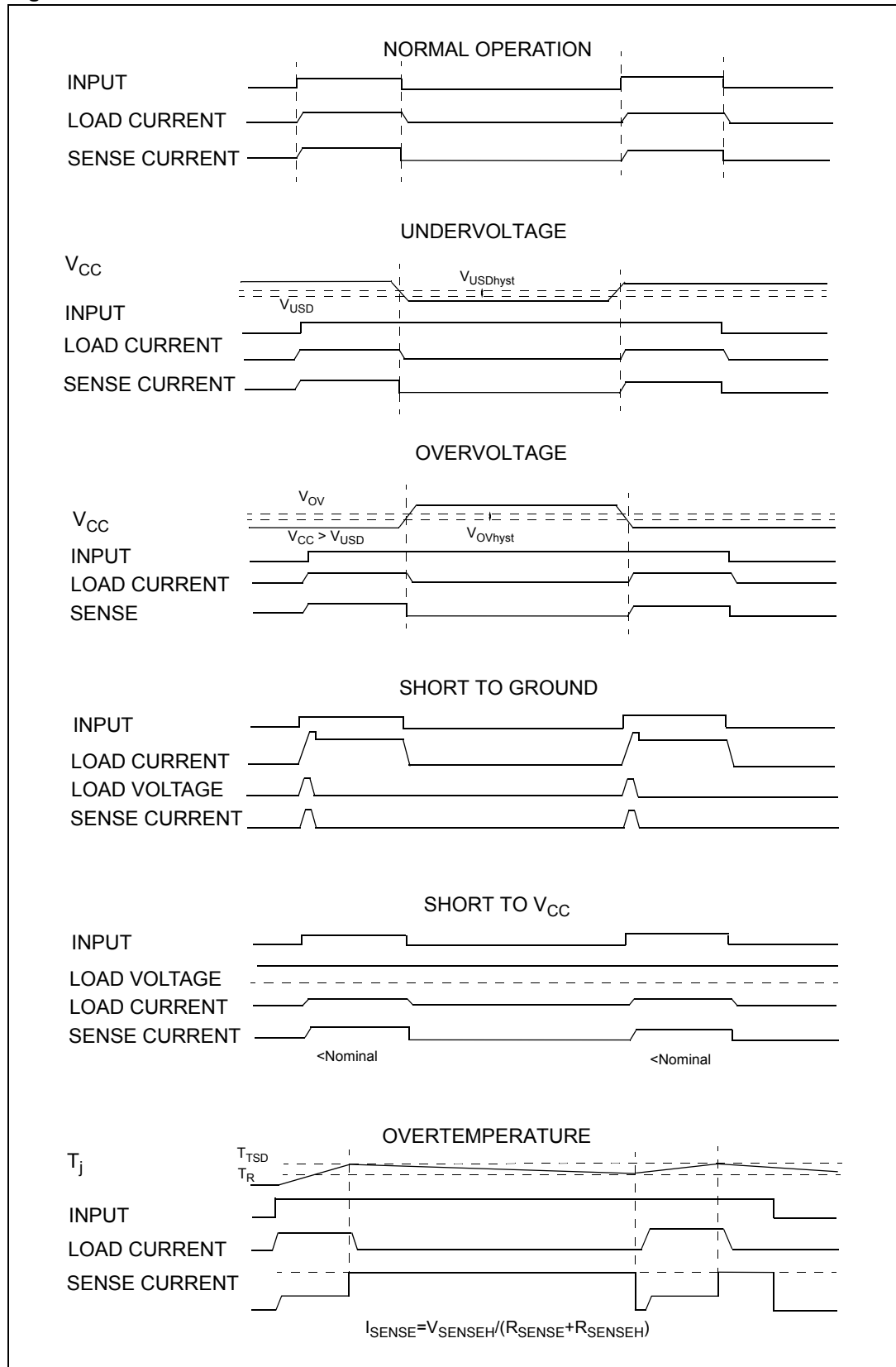


Figure 6. Waveforms



2.4 Electrical characteristics curves

Figure 7. Off-state output current

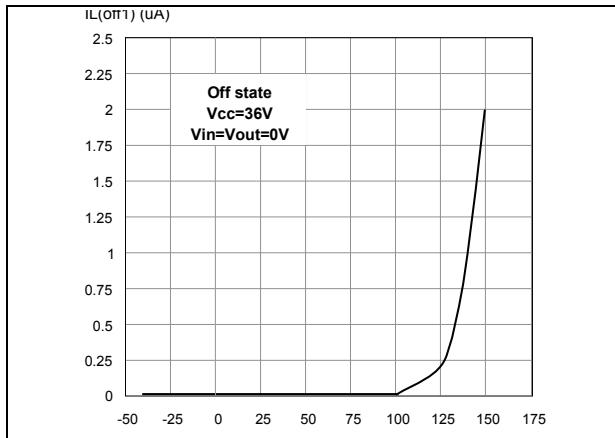


Figure 8. High level input current

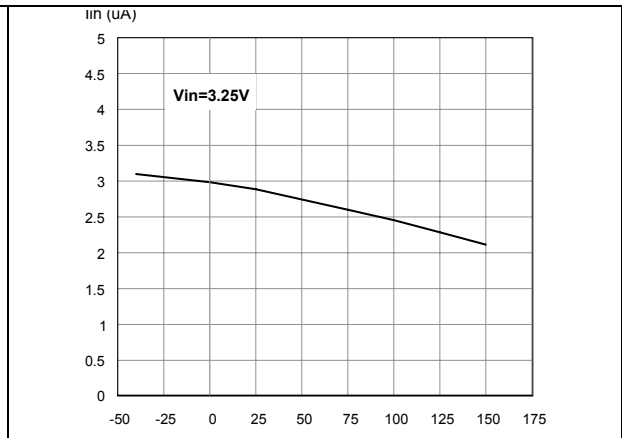


Figure 9. Input clamp voltage

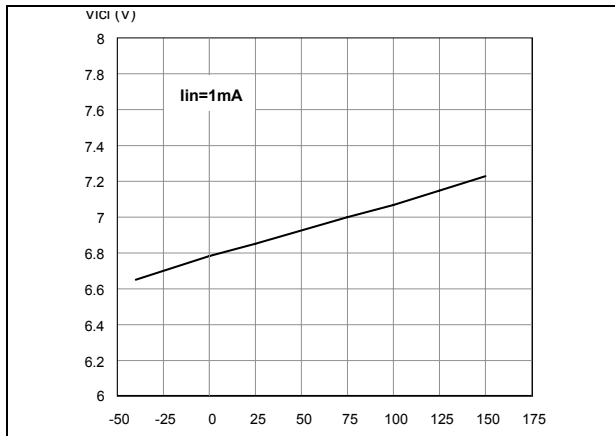


Figure 10. Turn-on voltage slope

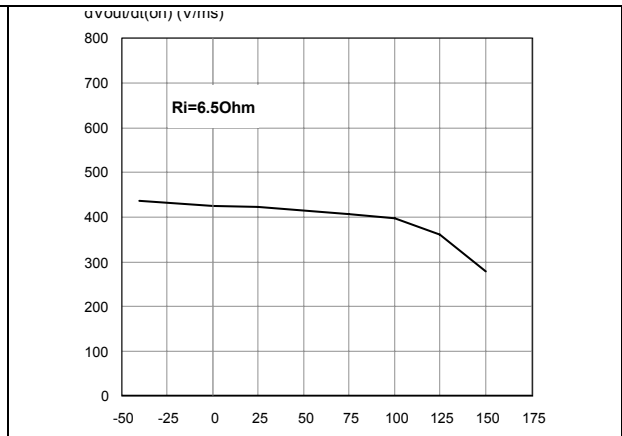


Figure 11. Over-voltage shutdown

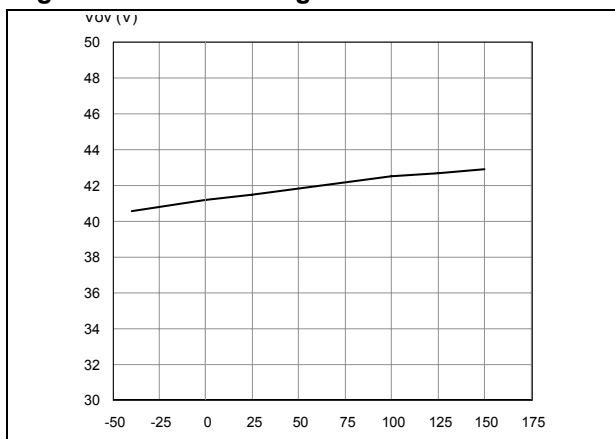


Figure 12. Turn-off voltage slope

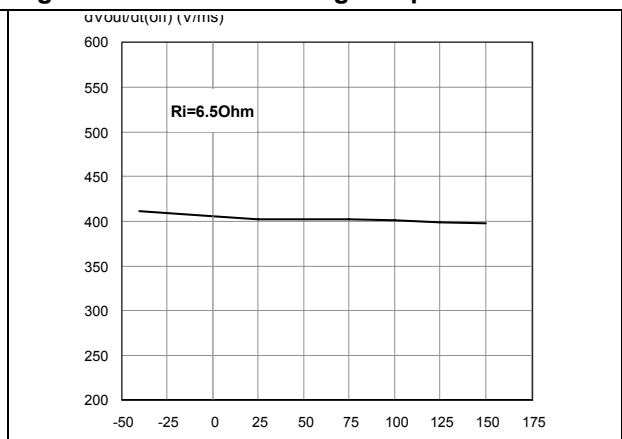


Figure 13. I_{LIM} vs T_{case}

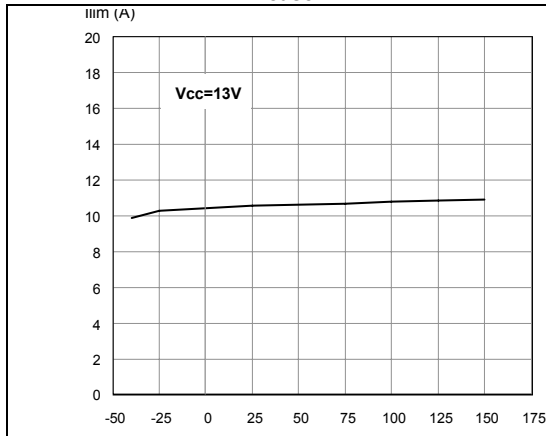


Figure 14. On-state resistance vs V_{CC}

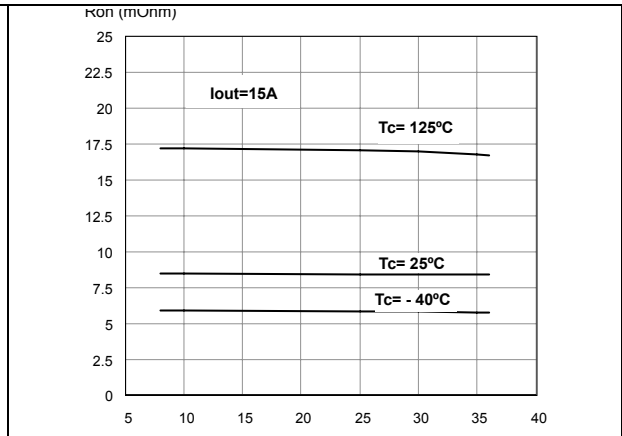


Figure 15. Input high level

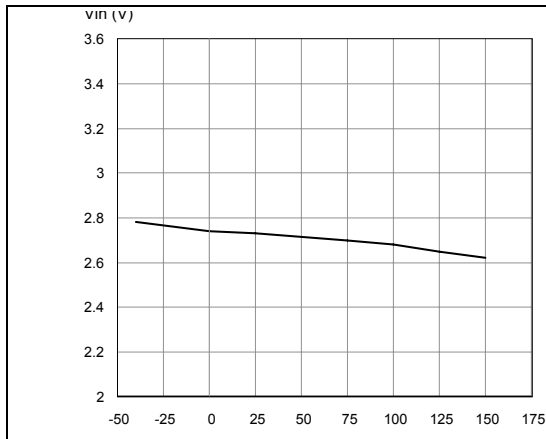


Figure 16. Input hysteresis voltage

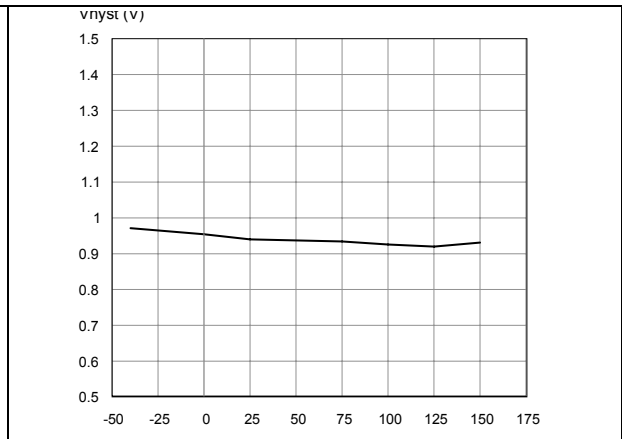


Figure 17. On-state resistance vs T_{case}

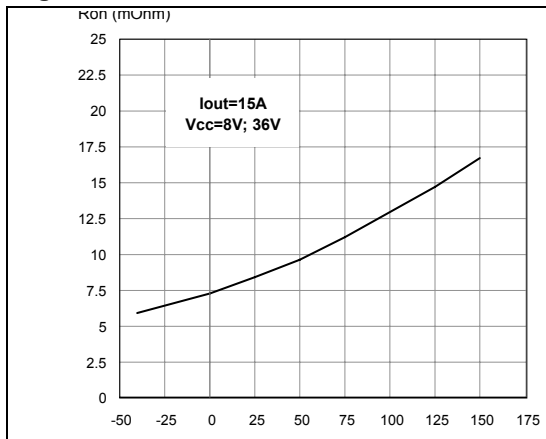
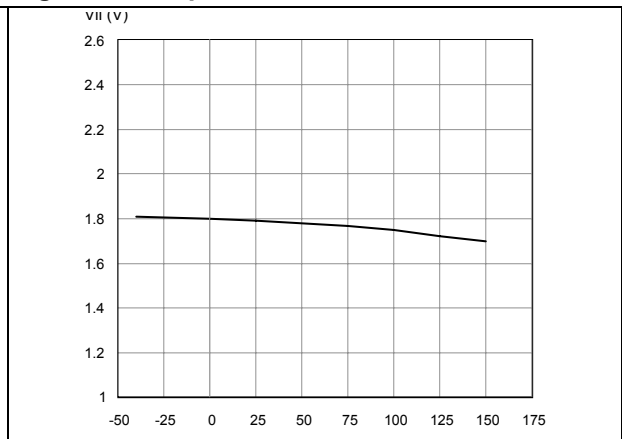
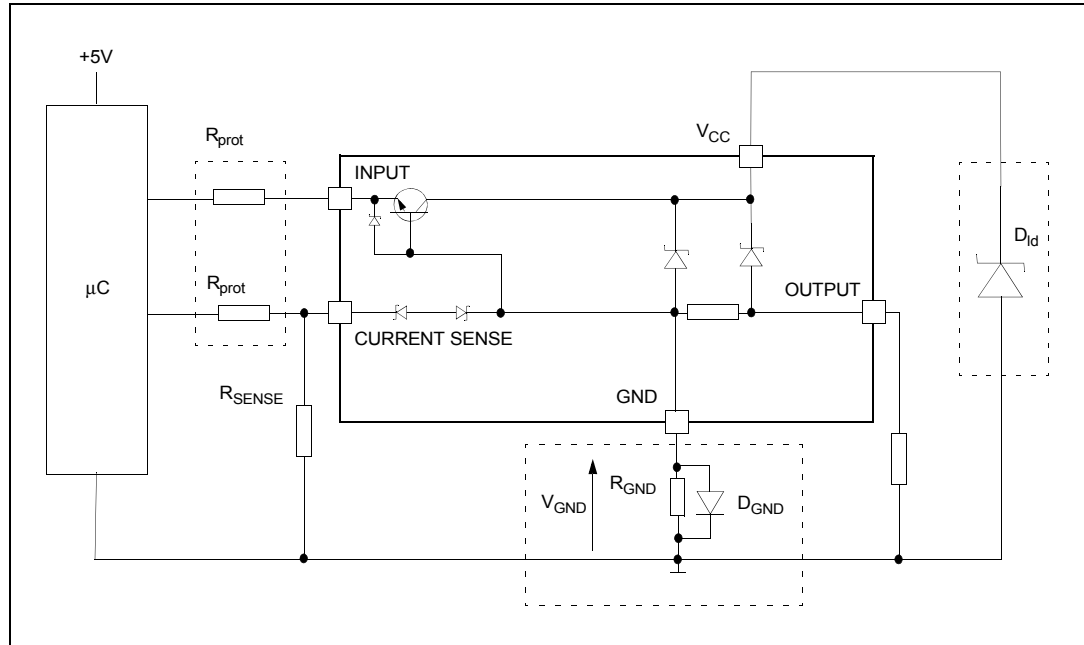


Figure 18. Input low level



3 Application information

Figure 19. Application schematic



3.1 GND protection network against reverse battery

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

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

This can be used with any type of load.

The following show how to dimension the R_{GND} resistor:

1. $R_{GND} \leq 600\text{mV} / 2 (I_{S(on)max})$
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 requires the use of a large resistor, or several devices have to share the same resistor, then ST suggests using solution 2 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 will be driving an inductive load. This small signal diode can be safely shared amongst several different HSD. Also in this case, the presence of the ground network will produce a shift ($\pm 600mV$) in the input threshold and the status output values if the microprocessor ground is not common with the device ground. This shift will not vary if more than one HSD shares the same diode/resistor network. Series resistor in INPUT and STATUS lines are also required to prevent that, during battery voltage transient, the current exceeds the Absolute Maximum Rating. Safest configuration for unused INPUT and STATUS pin is to leave them unconnected.

3.2 Load dump protection

D_{ld} is necessary (voltage transient suppressor) if the load dump peak voltage exceeds the V_{CC} maximum DC rating. The same applies if the device is subject to transients on the V_{CC} line that are greater than those shown in the ISO T/R 7637/1 table.

3.3 MCU I/O protection

If a ground protection network is used and negative transients 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/O pins from latching 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:

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

Example

For the following conditions:

$$V_{CCpeak} = -100V$$

$$I_{latchup} \geq 20mA$$

$$V_{OH\mu C} \geq 4.5V$$

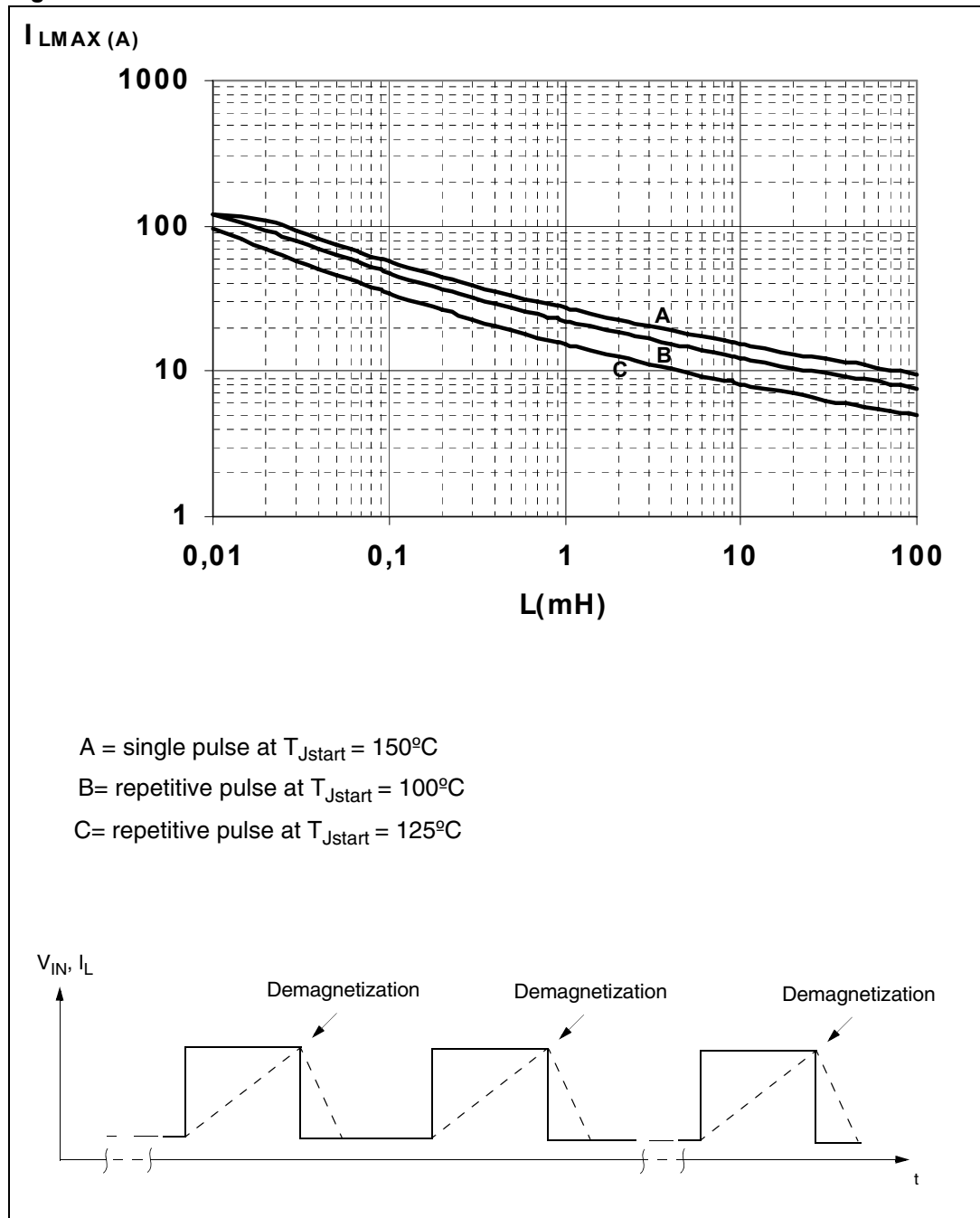
$$5k\Omega \leq R_{prot} \leq 65k\Omega$$

Recommended values are:

$$R_{prot} = 10k\Omega$$

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

Figure 20. Maximum turn-off current versus load inductance

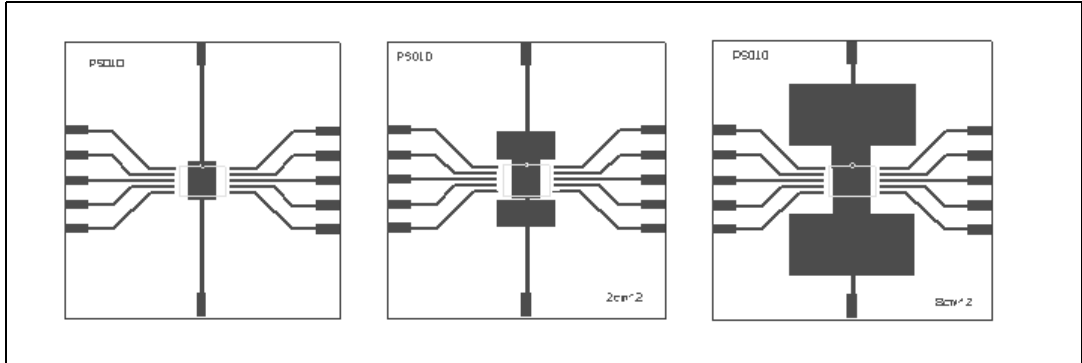


Note: Values are generated with $R_L = 0\Omega$.
 In case of repetitive pulses, T_{Jstart} (at beginning of each demagnetization) of every pulse must not exceed the temperature specified above for curves B and C.

4 Package and PCB thermal data

4.1 PowerSO-10 thermal data

Figure 21. PowerSO-10 PC board



Note: Layout condition of R_{th} and Z_{th} measurements (PCB FR4 area = 58mm x 58mm, PCB thickness = 2mm, Cu thickness = 35 μ m, Copper areas: from minimum pad-lay-out to 8cm²).

Figure 22. $R_{thj-amb}$ Vs PCB copper area in open box free air condition

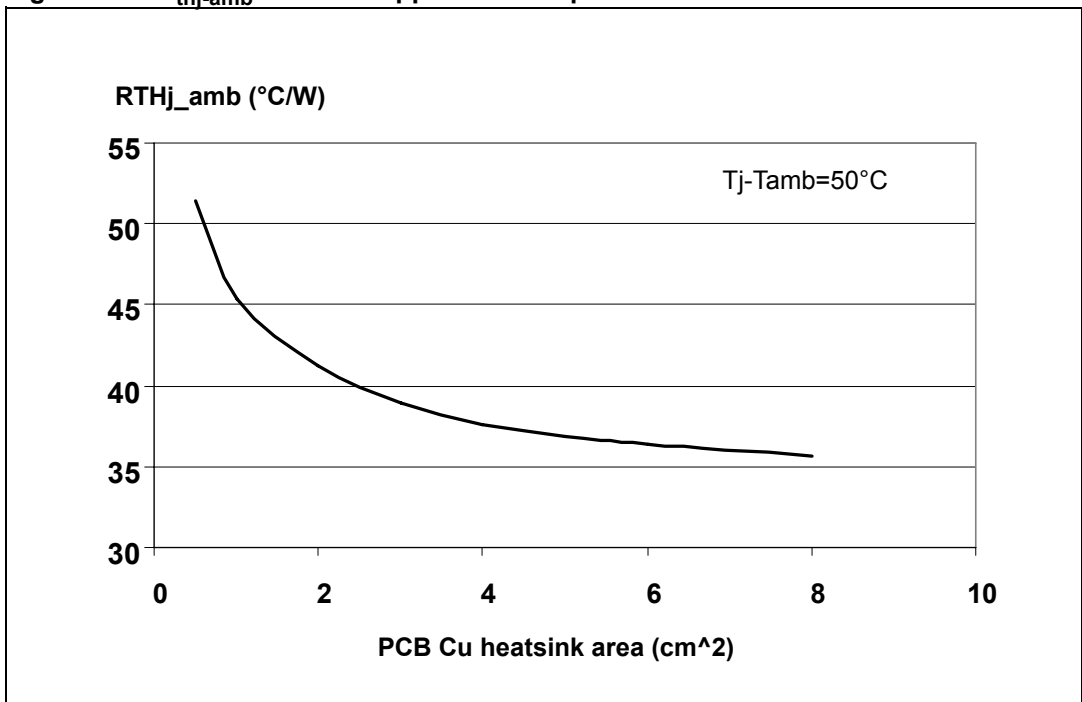
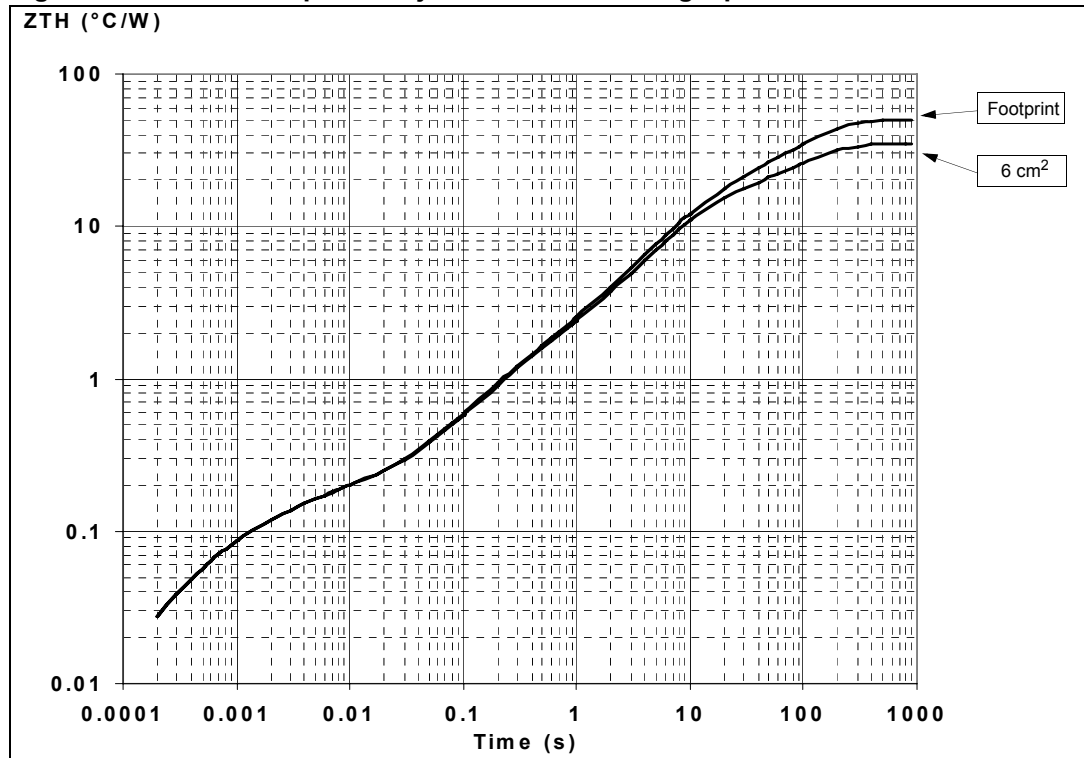


Figure 23. Thermal impedance junction ambient single pulse



Equation 1: pulse calculation formula

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

where $\delta = t_p/T$

Figure 24. Thermal fitting model of a single channel in PowerSO-10

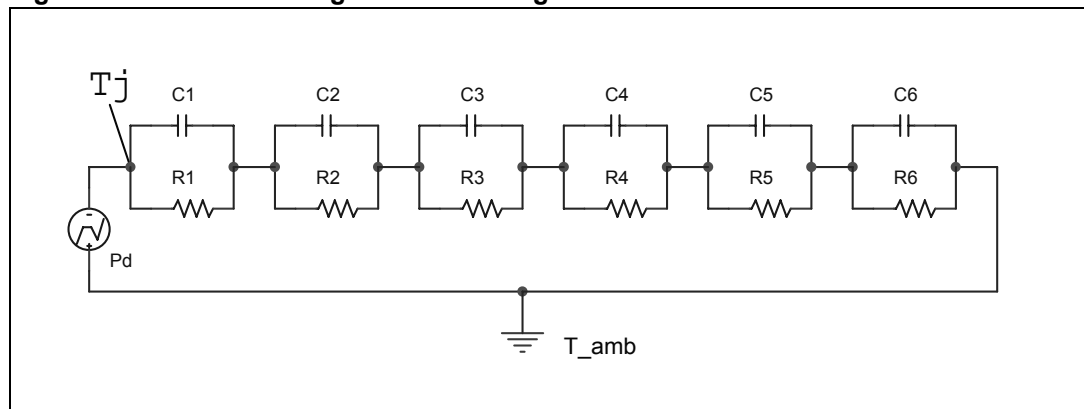


Table 13. Thermal parameters

| Area / island (cm ²) | Footprint | 6 |
|----------------------------------|-----------|----|
| R1 (°C/W) | 0.016 | |
| R2 (°C/W) | 0.06 | |
| R3 (°C/W) | 0.08 | |
| R4 (°C/W) | 0.8 | |
| R5 (°C/W) | 12 | |
| R6 (°C/W) | 37 | 22 |
| C1 (W.s/°C) | 0.002 | |
| C2 (W.s/°C) | 1E-02 | |
| C3 (W.s/°C) | 0.04 | |
| C4 (W.s/°C) | 0.3 | |
| C5 (W.s/°C) | 0.75 | |
| C6 (W.s/°C) | 3 | 5 |

5 Package and packing information

5.1 ECOPACK® packages

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

5.2 PowerSO-10 mechanical data

Figure 25. PowerSO-10 package dimensions

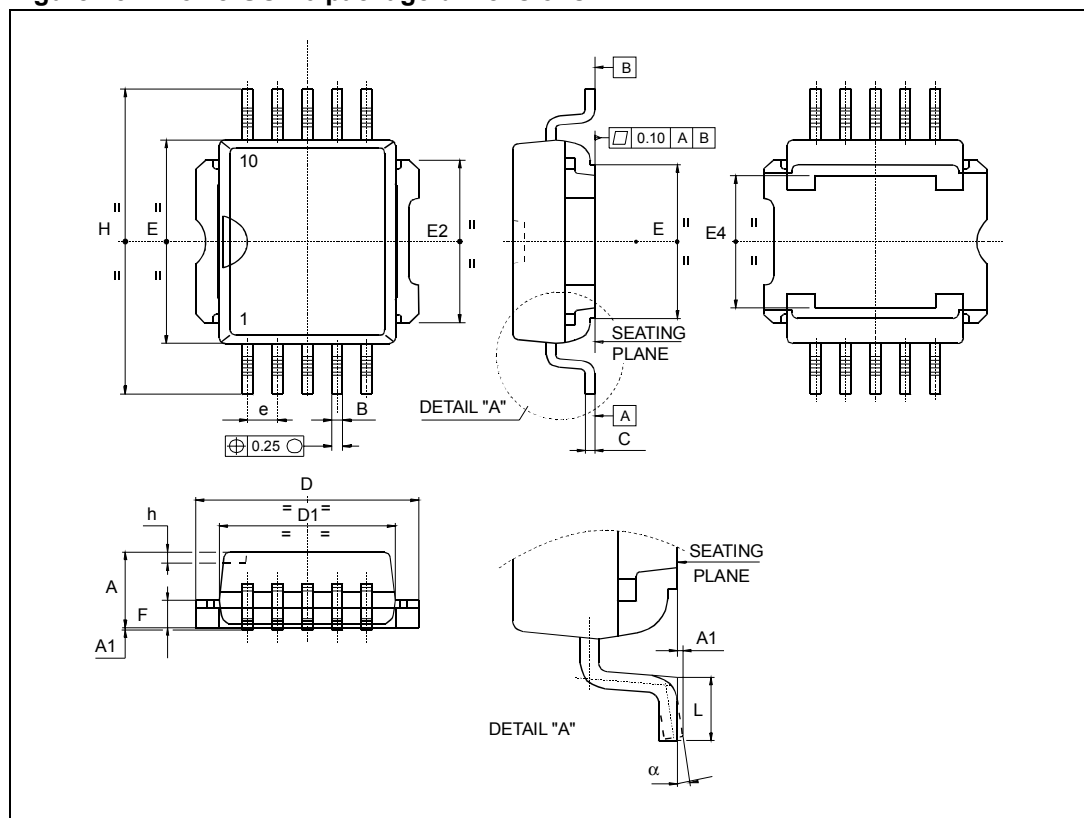


Table 14. PowerSO-10 mechanical data

| Dim. | mm | | |
|-------------------------|-------|------|-------|
| | Min. | Typ. | Max. |
| A | 3.35 | | 3.65 |
| A ⁽¹⁾ | 3.4 | | 3.6 |
| A1 | 0 | | 0.10 |
| B | 0.40 | | 0.60 |
| B ⁽¹⁾ | 0.37 | | 0.53 |
| C | 0.35 | | 0.55 |
| C ⁽¹⁾ | 0.23 | | 0.32 |
| D | 9.40 | | 9.60 |
| D1 | 7.40 | | 7.60 |
| E | 9.30 | | 9.50 |
| E2 | 7.20 | | 7.60 |
| E2 ⁽¹⁾ | 7.30 | | 7.50 |
| E4 | 5.90 | | 6.10 |
| E4 ⁽¹⁾ | 5.90 | | 6.30 |
| e | | 1.27 | |
| F | 1.25 | | 1.35 |
| F ⁽¹⁾ | 1.20 | | 1.40 |
| H | 13.80 | | 14.40 |
| H ⁽¹⁾ | 13.85 | | 14.35 |
| h | | 0.50 | |
| L | 1.20 | | 1.80 |
| L ⁽¹⁾ | 0.80 | | 1.10 |
| α | 0° | | 8° |
| α ⁽¹⁾ | 2° | | 8° |

1. Muar only POA P013P.

5.3 PowerSO-10 packing information

Figure 26. PowerSO-10 suggested pad layout Figure 27. PowerSO-10 tube shipment (no suffix)

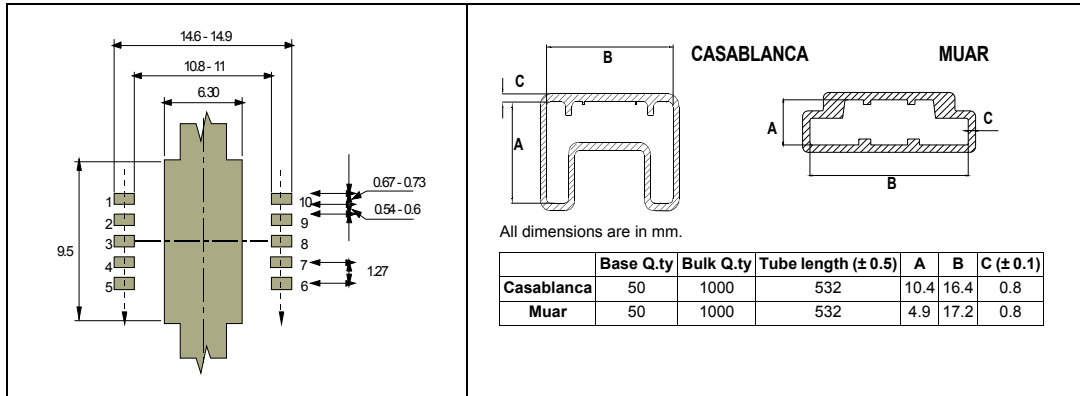
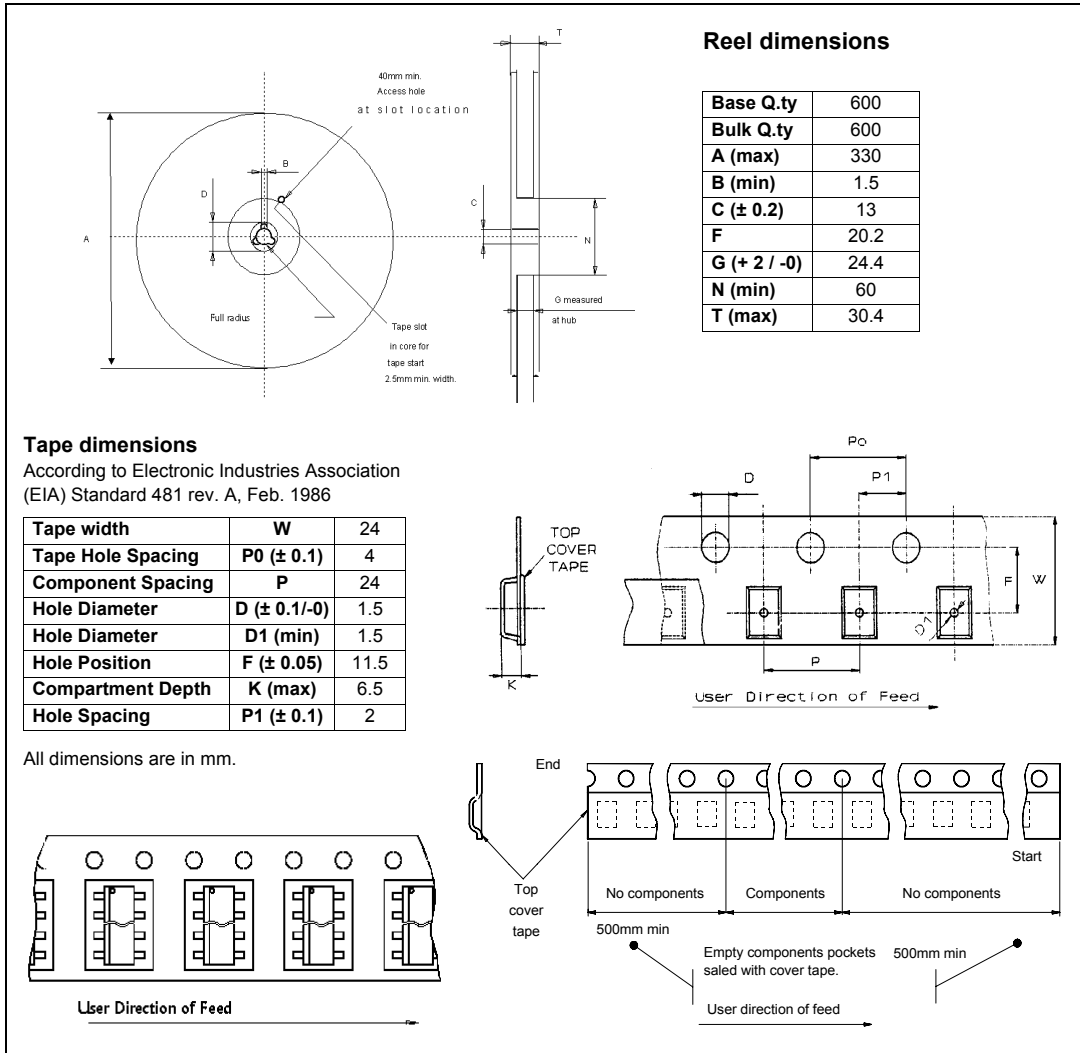


Figure 28. PowerSO-10 tape and reel shipment (suffix “TR”)



6 Revision history

Table 15. Document revision history

| Date | Revision | Changes |
|-------------|----------|---|
| 09-Sep-2004 | 1 | Initial release. |
| 29-Jan-2008 | 2 | Current and voltage convention update (page 2). Configuration diagram (top view) and suggested connections for unused and n.c. pins insertion (page 2). 6 cm ² Cu condition insertion in thermal data table (page 3). Protections note insertion (page 4). V _{CC} - output diode section update (page 5). Revision history table insertion (page 17). Disclaimers update (page 18). |
| 15-Dec-2008 | 3 | Document reformatted and restructured. Added contents, list of tables and figures. Added <i>ECOPACK[®] packages</i> information. |
| 29-Jul-2010 | 4 | Updated <i>Figure 24: Thermal fitting model of a single channel in PowerSO-10</i> |

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