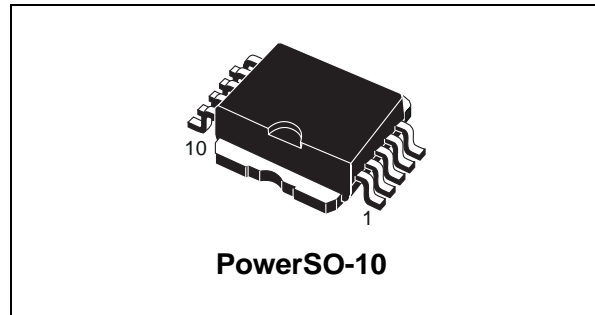


## Single channel high-side driver

### Features

Type	$R_{DS(on)}$	$I_{OUT}$	$V_{CC}$
VN610SP-E	10m $\Omega$	45 A	36V

- ECOPACK<sup>®</sup>: lead free and RoHS compliant
- Automotive Grade: compliance with AEC guidelines
- Output current: 45 A
- CMOS compatible inputs
- Proportional load current sense
- Undervoltage and overvoltage shutdown
- Overvoltage clamp
- Thermal shutdown
- Current limitation
- Very low standby power consumption
- Protection against loss of ground and loss of  $V_{CC}$
- Reverse battery protected
- In compliance with the 2002/95/EC european directive



### Description

The VN610SP-E 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 overload. Device automatically turns off in case of ground pin disconnection.

**Table 1. Device summary**

Package	Order codes	
	Tube	Tape and reel
PowerSO-10™	VN610SP-E	VN610SPTR-E

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# 1 Block diagram and pin description

Figure 1. Block diagram

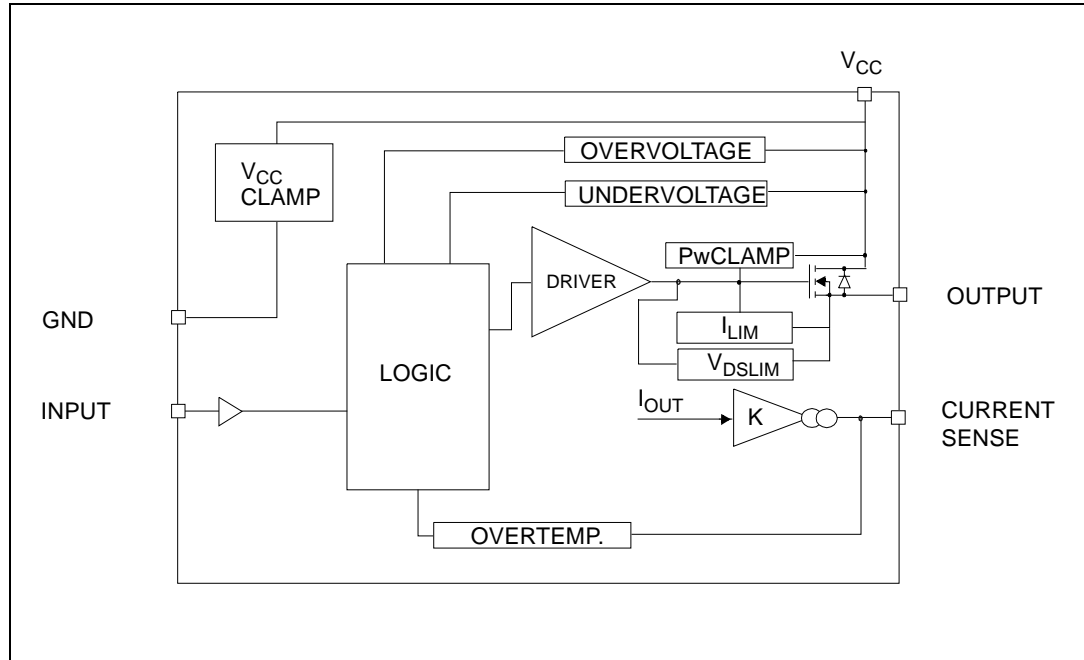


Figure 2. Configuration diagram (top view)

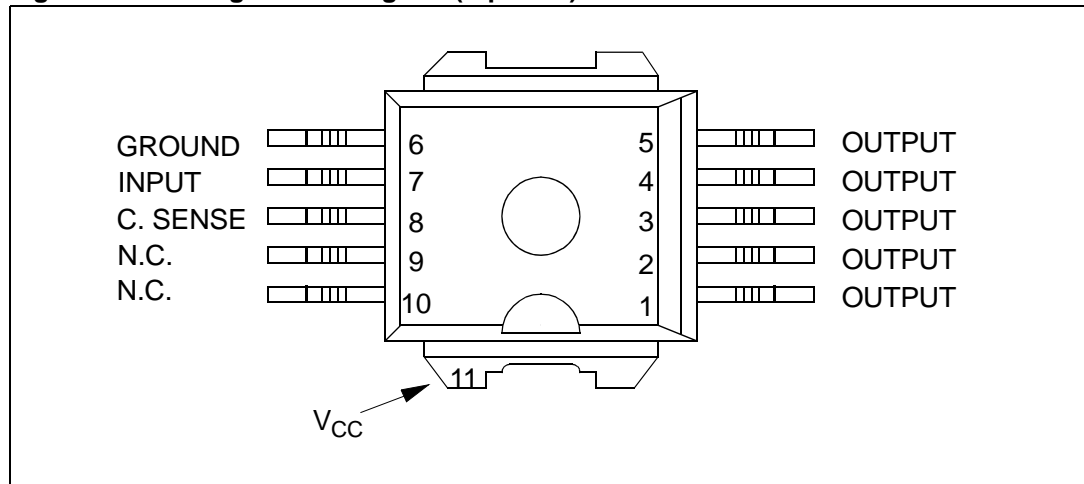
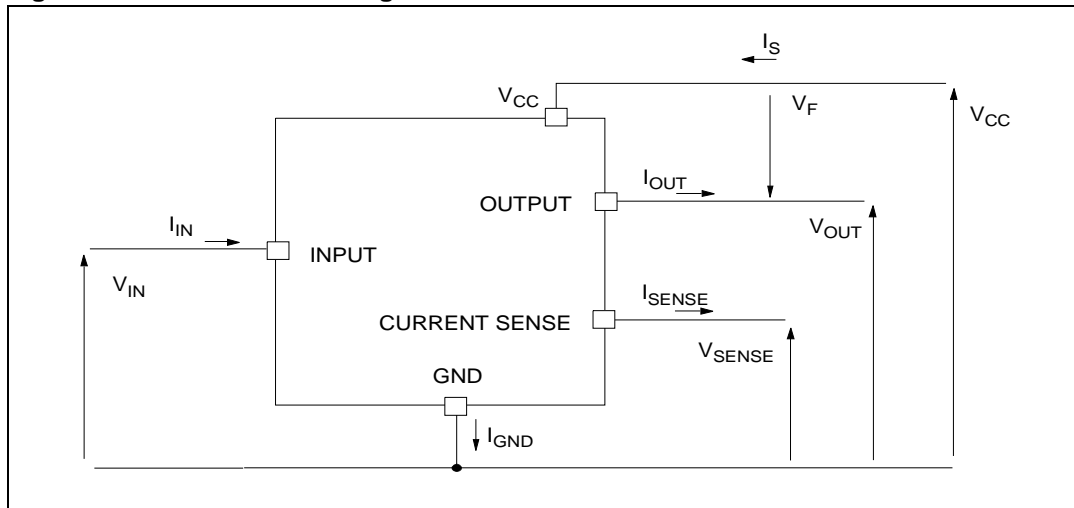


Table 2. Suggested connections for unused and not connected pins

Connection / pin	Current sense	N.C.	Output	Input
Floating		X	X	X
To ground	Through 1 K $\Omega$ resistor	X		Through 10 K $\Omega$ 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 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	- 50	A
$I_{IN}$	DC input current	+/- 10	mA
$V_{CSENSE}$	Current sense maximum voltage	- 3 + 15	V V
$V_{ESD}$	Electrostatic discharge (human body model: $R = 1.5K\Omega$ ; $C = 100pF$ )		
	- 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 (max)	0.9		$^\circ\text{C}/\text{W}$
$R_{thj-amb}$	Thermal resistance junction-ambient (max)	50.9 <sup>(1)</sup>	36 <sup>(2)</sup>	$^\circ\text{C}/\text{W}$

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

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

## 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. Per each channel.

**Table 5. Power**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{CC}$	Operating supply voltage		5.5	13	36	V
$V_{USD}$	Undervoltage shutdown		3	4	5.5	V
$V_{OV}$	Overvoltage shutdown	See <sup>(1)</sup>	36			V
$R_{ON}$	On-state resistance	$I_{OUT} = 15A$ ; $T_j = 25^{\circ}C$ $I_{OUT} = 15A$ ; $T_j = 150^{\circ}C$ $I_{OUT} = 9A$ ; $V_{CC} = 6V$			10 20 35	m $\Omega$ m $\Omega$ m $\Omega$
$V_{clamp}$	Clamp voltage	$I_{CC} = 20mA^{(1)}$	41	48	55	V
$I_S$	Supply current	Off-state; $V_{CC}=13V$ ; $V_{IN}=V_{OUT}=0V$  Off-state; $V_{CC}=13V$ ; $V_{IN}=V_{OUT}=0V$ ; $T_j=25^{\circ}C$  On-state; $V_{IN} = 5V$ ; $V_{CC} = 13V$ ; $I_{OUT} = 0A$ ; $R_{SENSE} = 3.9k\Omega$		10  10	25  20	$\mu A$  $\mu A$  5 mA
$I_{L(off1)}$	Off-state output current	$V_{IN} = V_{OUT} = 0V$	0		50	$\mu A$
$I_{L(off2)}$	Off-state output current	$V_{IN} = 0V$ ; $V_{OUT} = 3.5V$	-75		0	$\mu A$
$I_{L(off3)}$	Off-state output current	$V_{IN} = V_{OUT}=0V$ ; $V_{CC}=13V$ ; $T_j=125^{\circ}C$			5	$\mu A$
$I_{L(off4)}$	Off-state output current	$V_{IN}=V_{OUT} = 0V$ ; $V_{CC} = 13V$ ; $T_j = 25^{\circ}C$			3	$\mu A$

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

**Table 6. Protections<sup>(1)</sup>**

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		$^{\circ}C$



**Table 6. Protections<sup>(1)</sup> (continued)**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{\text{demag}}$	Turn-off output voltage clamp	$I_{\text{OUT}} = 2\text{A}; V_{\text{IN}} = 0\text{V}; L = 6\text{mH}$	$V_{\text{CC}}-41$	$V_{\text{CC}}-48$	$V_{\text{CC}}-55$	V
$V_{\text{ON}}$	Output voltage drop limitation	$I_{\text{OUT}} = 1.5\text{A}$ $T_{\text{J}} = -40^{\circ}\text{C}\dots+150^{\circ}\text{C}$		50		mV

1. 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.  $V_{\text{CC}}$  - output diode**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{\text{F}}$	Forward on voltage	$-I_{\text{OUT}} = 8\text{A}; T_{\text{J}} = 150^{\circ}\text{C}$	-	-	0.6	V

**Table 8. Current sense ( $9\text{V} \leq V_{\text{CC}} \leq 16\text{V}$ )<sup>(1)</sup>**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$K_1$	$I_{\text{OUT}}/I_{\text{SENSE}}$	$I_{\text{OUT}} = 1.5\text{A}; V_{\text{SENSE}} = 0.5\text{V};$ $T_{\text{J}} = -40^{\circ}\text{C}\dots150^{\circ}\text{C}$	3300	4400	6000	
$dK_1/K_1$	Current sense ratio drift	$I_{\text{OUT}} = 1.5\text{A}; V_{\text{SENSE}} = 0.5\text{V};$ $T_{\text{J}} = -40^{\circ}\text{C}\dots150^{\circ}\text{C}$	-10		+10	%
$K_2$	$I_{\text{OUT}}/I_{\text{SENSE}}$	$I_{\text{OUT}} = 15\text{A}; V_{\text{SENSE}} = 4\text{V};$ $T_{\text{J}} = -40^{\circ}\text{C}$ $T_{\text{J}} = 25^{\circ}\text{C}\dots150^{\circ}\text{C}$	4200 4400	4900 4900	6000 5750	
$dK_2/K_2$	Current sense ratio drift	$I_{\text{OUT}} = 15\text{A}; V_{\text{SENSE}} = 4\text{V};$ $T_{\text{J}} = 25^{\circ}\text{C}\dots150^{\circ}\text{C}$	-6		+6	%
$K_3$	$I_{\text{OUT}}/I_{\text{SENSE}}$	$I_{\text{OUT}} = 45\text{A}; V_{\text{SENSE}} = 4\text{V};$ $T_{\text{J}} = -40^{\circ}\text{C}$ $T_{\text{J}} = 25^{\circ}\text{C}\dots150^{\circ}\text{C}$	4200 4400	4900 4900	5500 5250	
$dK_3/K_3$	Current sense ratio drift	$I_{\text{OUT}} = 45\text{A}; V_{\text{SENSE}} = 4\text{V};$ $T_{\text{J}} = 25^{\circ}\text{C}\dots150^{\circ}\text{C}$	-6		+6	%
$I_{\text{SENSE0}}$	Analog sense current	$V_{\text{CC}} = 6\dots16\text{V}; I_{\text{OUT}} = 0\text{A};$ $V_{\text{SENSE}} = 0\text{V};$ $T_{\text{J}} = -40^{\circ}\text{C}\dots150^{\circ}\text{C}$ Off-state; $V_{\text{IN}} = 0\text{V}$ On-state; $V_{\text{IN}} = 5\text{V}$	0 0		5 10	$\mu\text{A}$ $\mu\text{A}$
$V_{\text{SENSE}}$	Max analog sense output voltage	$V_{\text{CC}} = 5.5\text{V}; I_{\text{OUT}} = 7.5\text{A};$ $R_{\text{SENSE}} = 10\text{k}\Omega$ $V_{\text{CC}} > 8\text{V}, I_{\text{OUT}} = 15\text{A};$ $R_{\text{SENSE}} = 10\text{k}\Omega$	3.5 5			V V
$V_{\text{SENSEH}}$	Analog sense output voltage in overtemperature condition	$V_{\text{CC}} = 13\text{V}; R_{\text{SENSE}} = 3.9\text{k}\Omega$		5.5		V

**Table 8. Current sense ( $9\text{ V} \leq V_{CC} \leq 16\text{ V}$ )<sup>(1)</sup> (continued)**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$R_{VSENSEH}$	Analog sense output impedance in overtemperature condition	$V_{CC} = 13\text{V}$ ; $T_j > T_{TSD}$ ; Output open		400		$\Omega$
$t_{DSENSE}$	Current sense delay response	To 90% $I_{SENSE}$ <sup>(2)</sup>			500	$\mu\text{s}$

1. See [Figure 4](#).

2. Current sense signal delay after positive input slope.

**Table 9. Switching ( $V_{CC} = 13\text{ V}$ )**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$t_{d(on)}$	Turn-on delay time	$R_L = 0.87\Omega$	-	50	-	$\mu\text{s}$
$t_{d(off)}$	Turn-on delay time	$R_L = 0.87\Omega$	-	50	-	$\mu\text{s}$
$(dV_{OUT}/dt)_{on}$	Turn-on voltage slope	$R_L = 0.87\Omega$	-	See <a href="#">Figure 15</a>	-	$\text{V}/\mu\text{s}$
$(dV_{OUT}/dt)_{off}$	Turn-off voltage slope	$R_L = 0.87\Omega$	-	See <a href="#">Figure 16</a>	-	$\text{V}/\mu\text{s}$

**Table 10. 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	$V_{IN} = 1.25\text{V}$	1			$\mu\text{A}$
$V_{IH}$	Input high level voltage		3.25			V
$I_{IH}$	High level input current	$V_{IN} = 3.25\text{V}$			10	$\mu\text{A}$
$V_{I(hyst)}$	Input hysteresis voltage		0.5			V
$V_{ICL}$	Input clamp voltage	$I_{IN} = 1\text{mA}$ $I_{IN} = -1\text{mA}$	6	6.8 -0.7	8	V V

Figure 4.  $I_{OUT}/I_{SENSE}$  versus  $I_{OUT}$

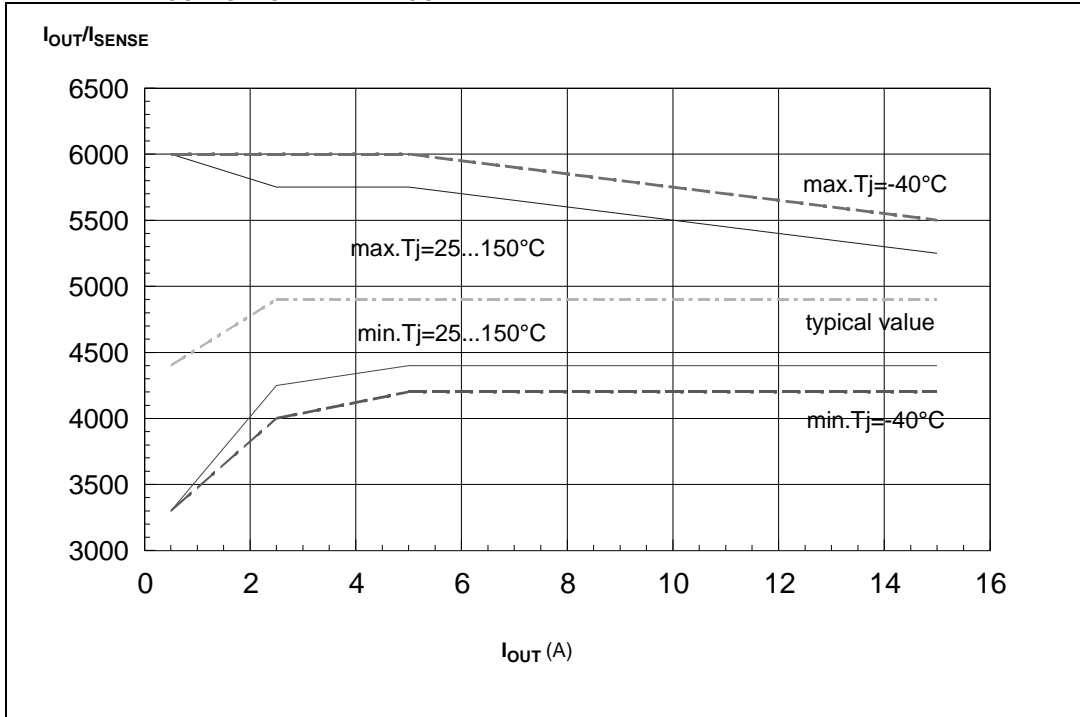


Table 11. Truth table

Conditions	Input	Output	Sense
Normal operation	L	L	0
	H	H	Nominal
Overtemperature	L	L	0
	H	L	$V_{SENSEH}$
Under-voltage	L	L	0
	H	L	0
Overvoltage	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

Figure 5. Switching characteristics

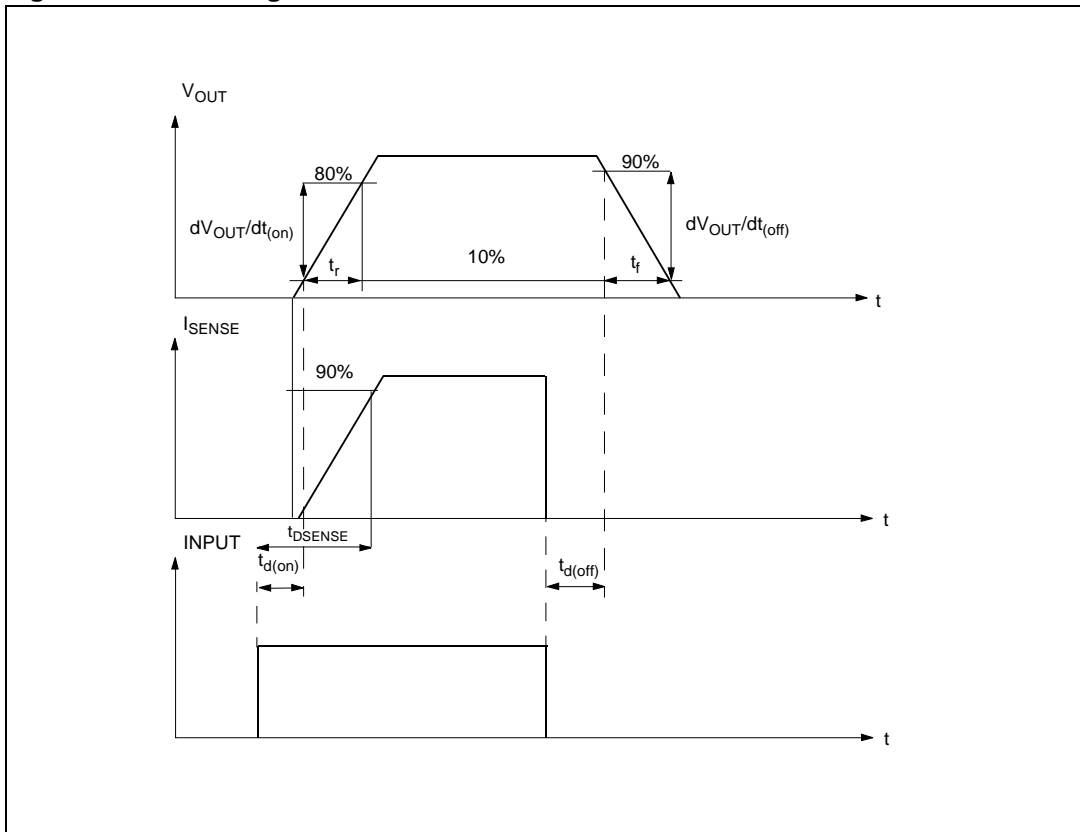


Table 12. Electrical transient requirements on V<sub>CC</sub> pin (part 1/3)

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

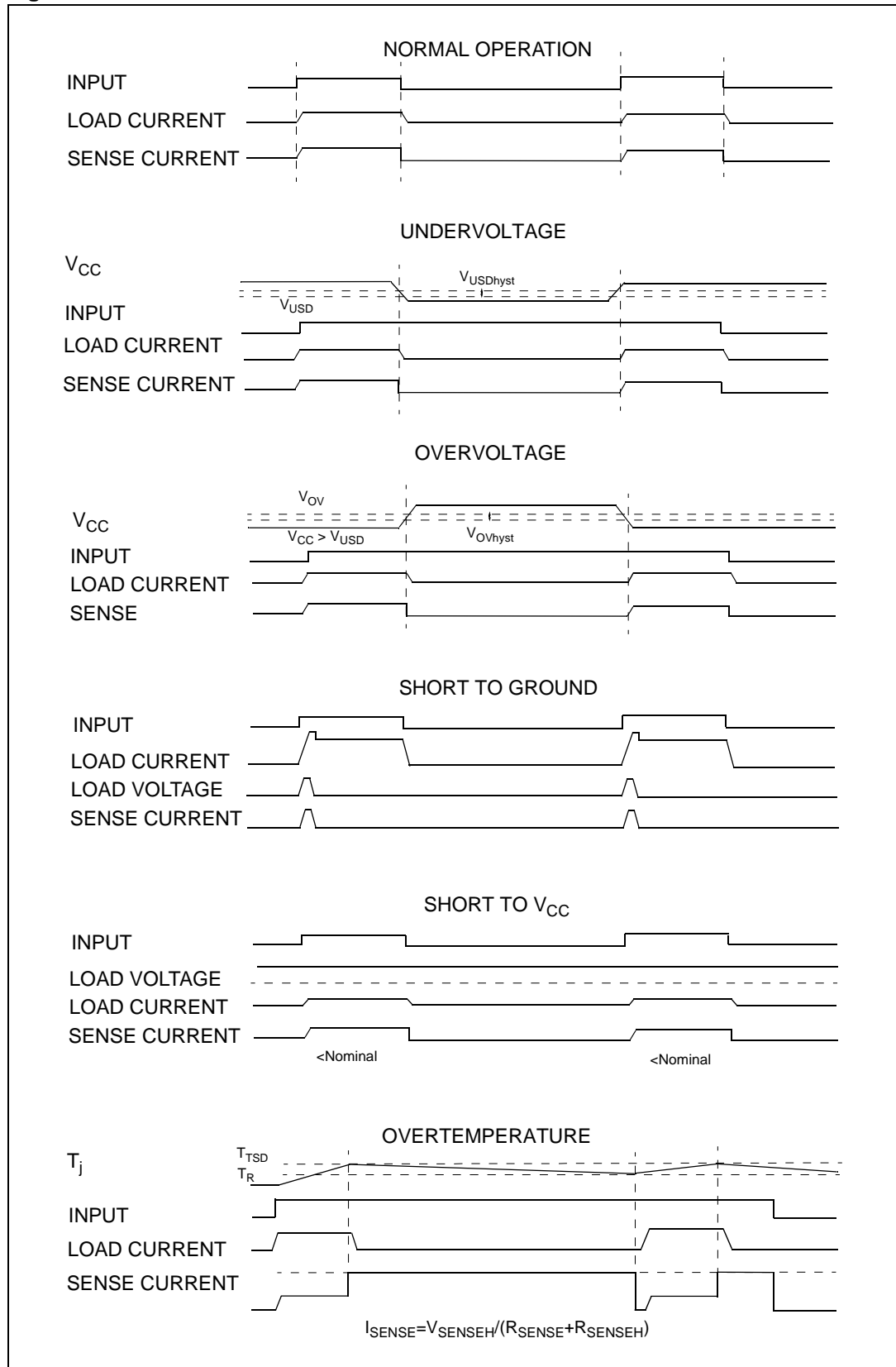
Table 13. Electrical transient requirements on V<sub>CC</sub> pin (part 2/3)

ISO T/R 7637/1 test pulse	Test levels results			
	I	II	III	IV
1	C	C	C	C
2	C	C	C	C
3a	C	C	C	C
3b	C	C	C	C
4	C	C	C	C
5	C	E	E	E

Table 14. Electrical transient requirements on V<sub>CC</sub> pin (part 3/3)

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

Figure 6. Waveforms



## 2.4 Electrical characteristics curves

Figure 7. Off-state output current

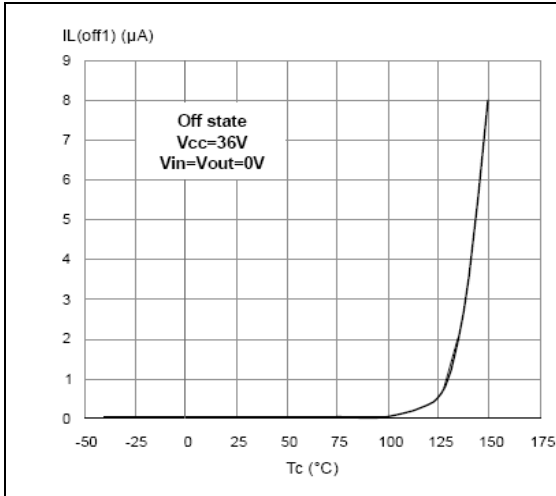


Figure 8. High level input current

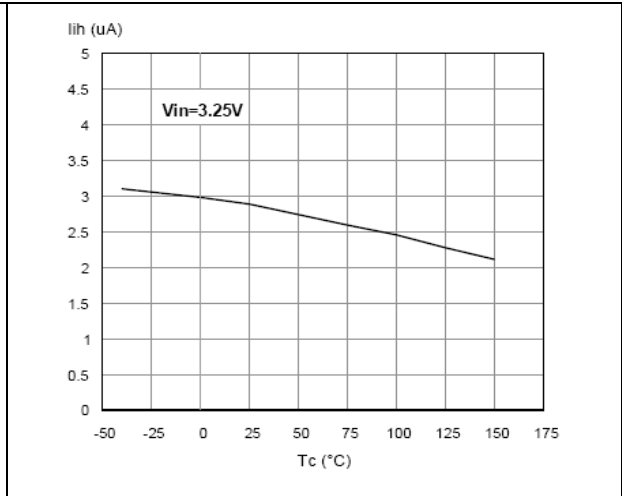


Figure 9. Input low level

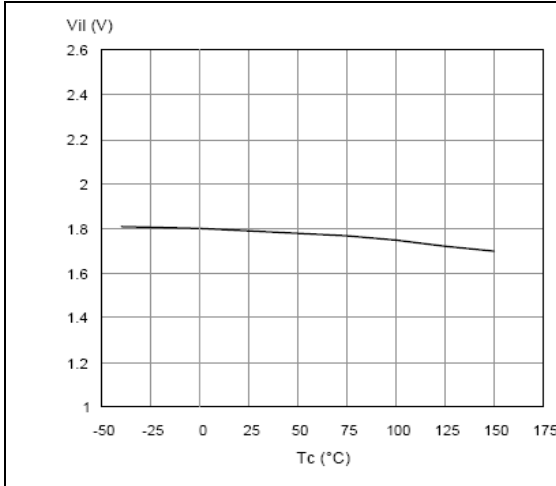


Figure 10. Input high level

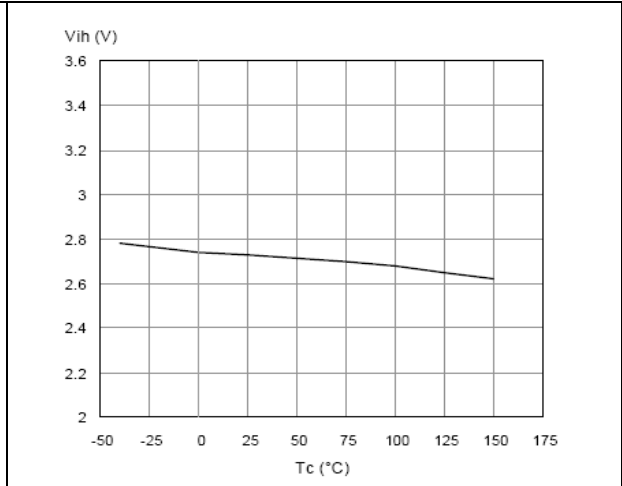


Figure 11. Input clamp voltage

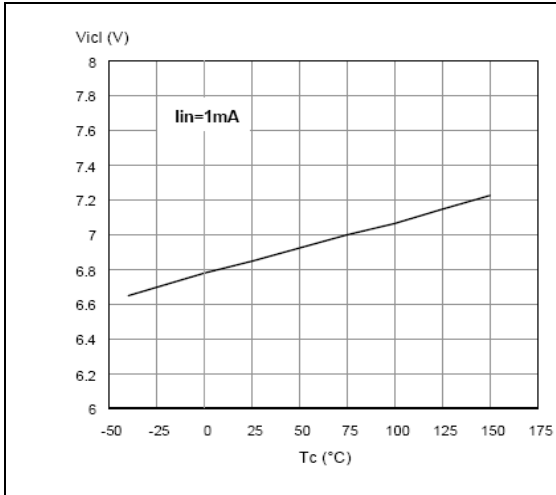


Figure 12. Input hysteresis voltage

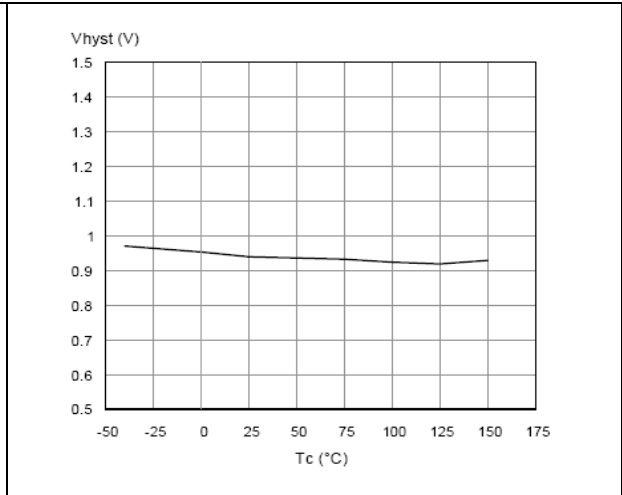


Figure 13. Overvoltage shutdown

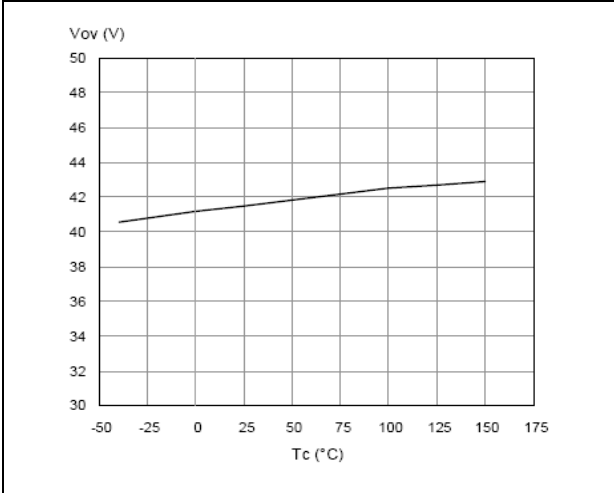


Figure 14. I<sub>LIM</sub> vs T<sub>case</sub>

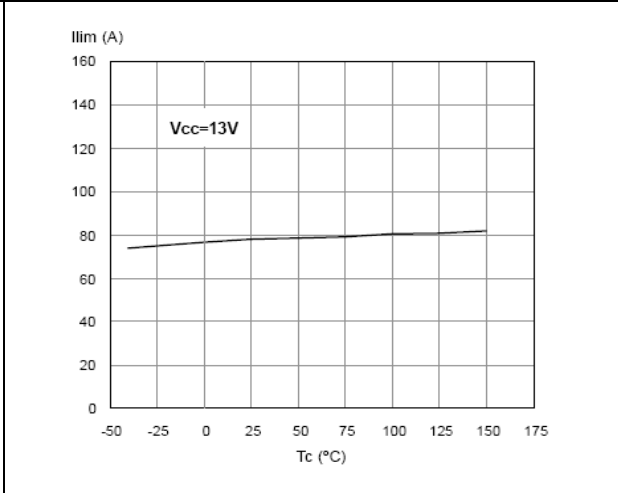


Figure 15. Turn-on voltage slope

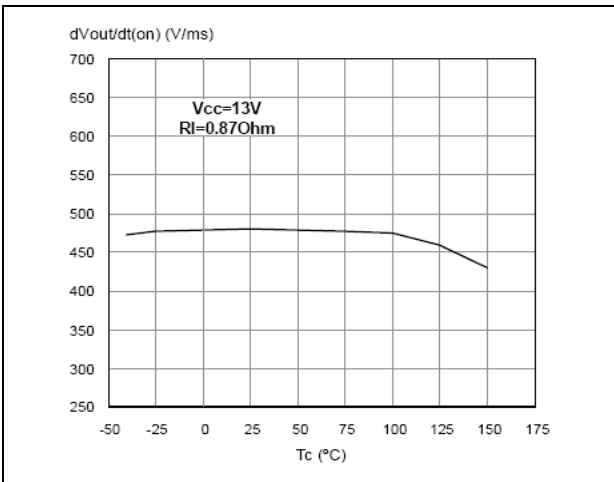


Figure 16. Turn-off voltage slope

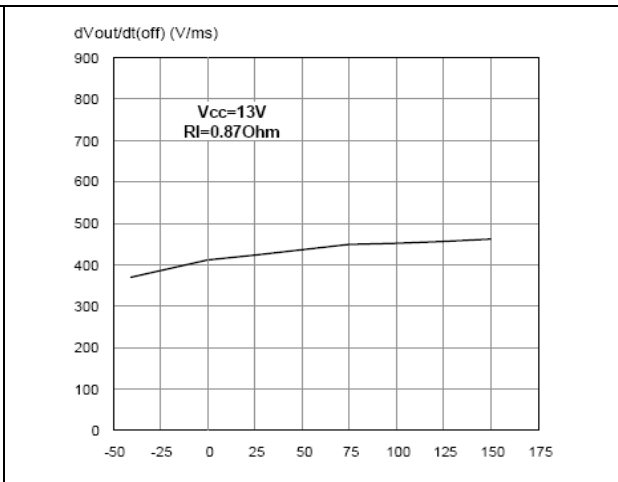


Figure 17. On-state resistance vs T<sub>case</sub>

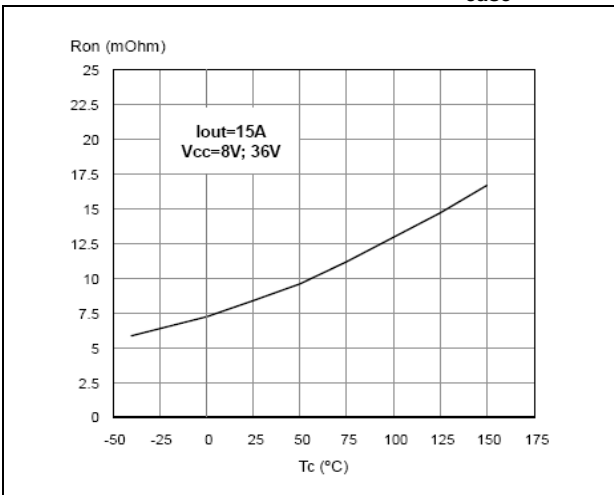
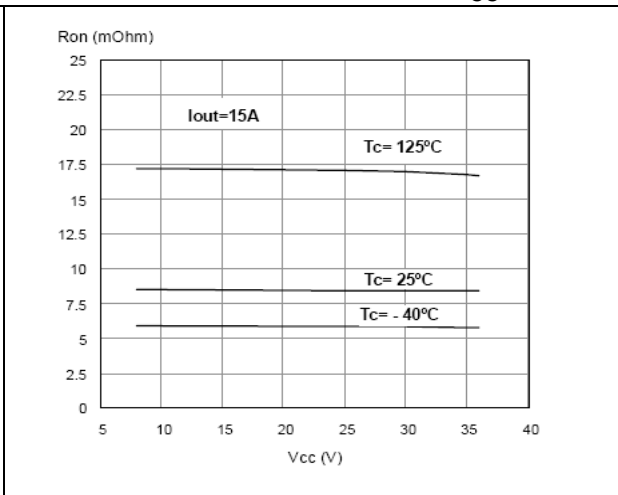


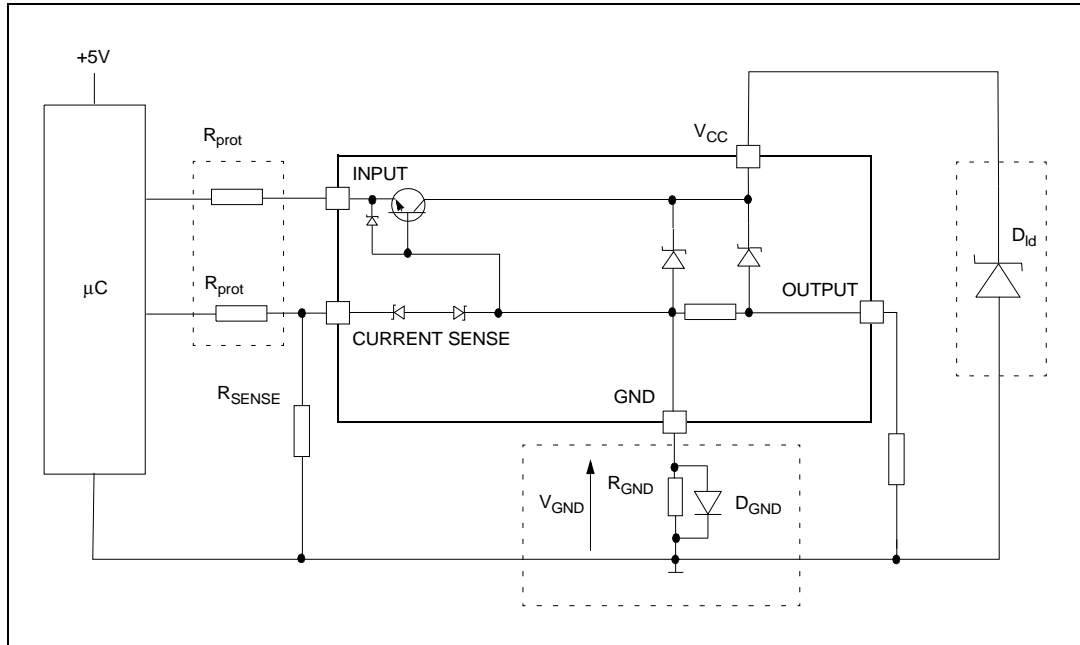
Figure 18. On-state resistance vs V<sub>CC</sub>





### 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<sub>GND</sub> only)

This can be used with any type of load.

The following show how to dimension the R<sub>GND</sub> resistor:

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

where  $-I_{GND}$  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<sub>GND</sub> (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<sub>GND</sub> produces a shift ( $I_{S(on)max} * R_{GND}$ ) in the input thresholds and the status output values. This shift varies depending on how many devices are ON in the case of several high-side drivers sharing the same R<sub>GND</sub>.

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 is 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 produces a shift ( $\approx 600mV$ ) in the input threshold and the status output values if the microprocessor ground is not common with the device ground. This shift not varies 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 pin is to leave them unconnected, while unused SENSE pin has to be connected to ground pin.

## 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 is pulled negative. ST suggests to insert a resistor ( $R_{prot}$ ) in line to prevent the  $\mu C$  I/O pins from latching up.

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

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

### Example

For the following conditions:

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

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

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

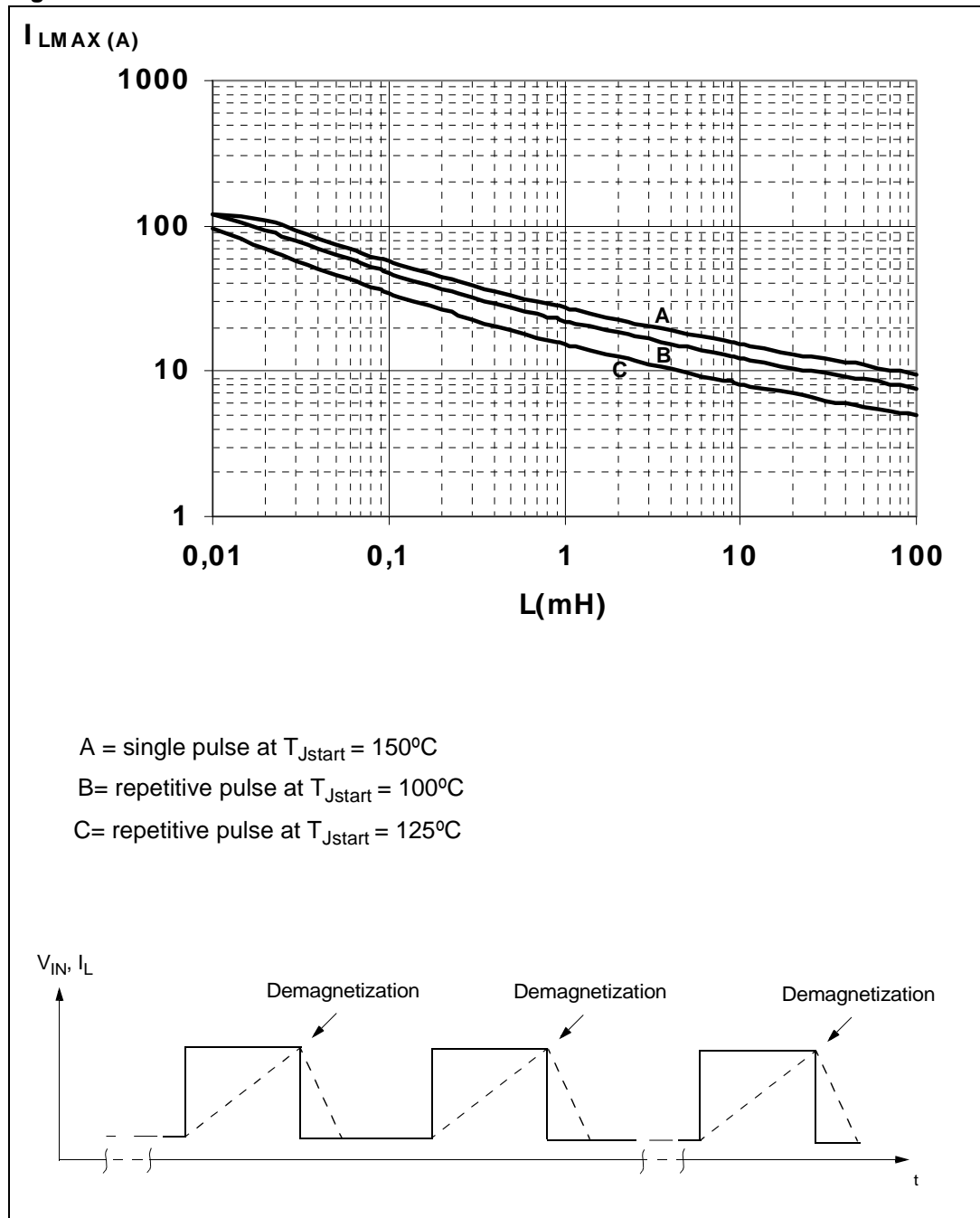
$$5k\Omega \leq R_{prot} \leq 65k\Omega.$$

Recommended values are:

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

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

Figure 20. Maximum turn-off current versus load inductance<sup>(1)</sup>

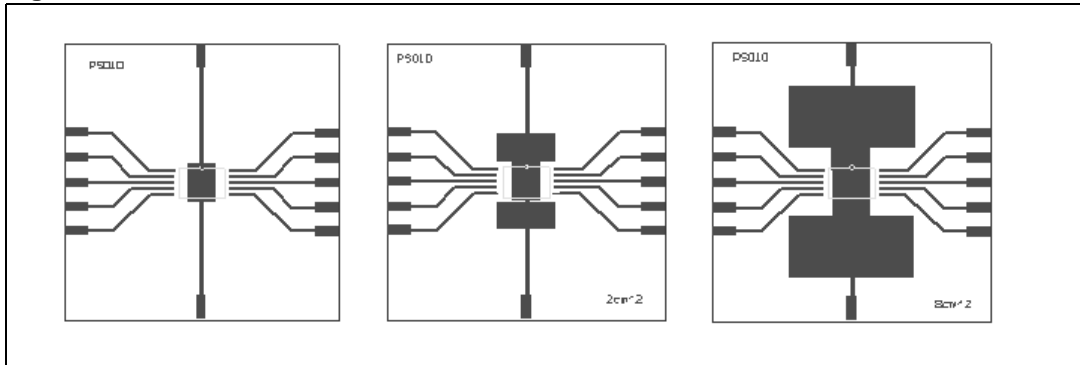


1. Values are generated with  $R_L = 0\Omega$ .  
 In case of repetitive pulses,  $T_{Jstart}$  (at beginning of each demagnetization) of every pulse must not exceed the temperature specified above for curves B and C.

## 4 Package and PCB thermal data

### 4.1 PowerSO-10 thermal data

Figure 21. PowerSO-10 PC board<sup>(1)</sup>



1. Layout condition of  $R_{th}$  and  $Z_{th}$  measurements (PCB FR4 area = 58mm x 58mm, PCB thickness = 2mm, Cu thickness = 35 $\mu$ m, Copper areas: from minimum pad-lay-out to 8cm<sup>2</sup>).

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

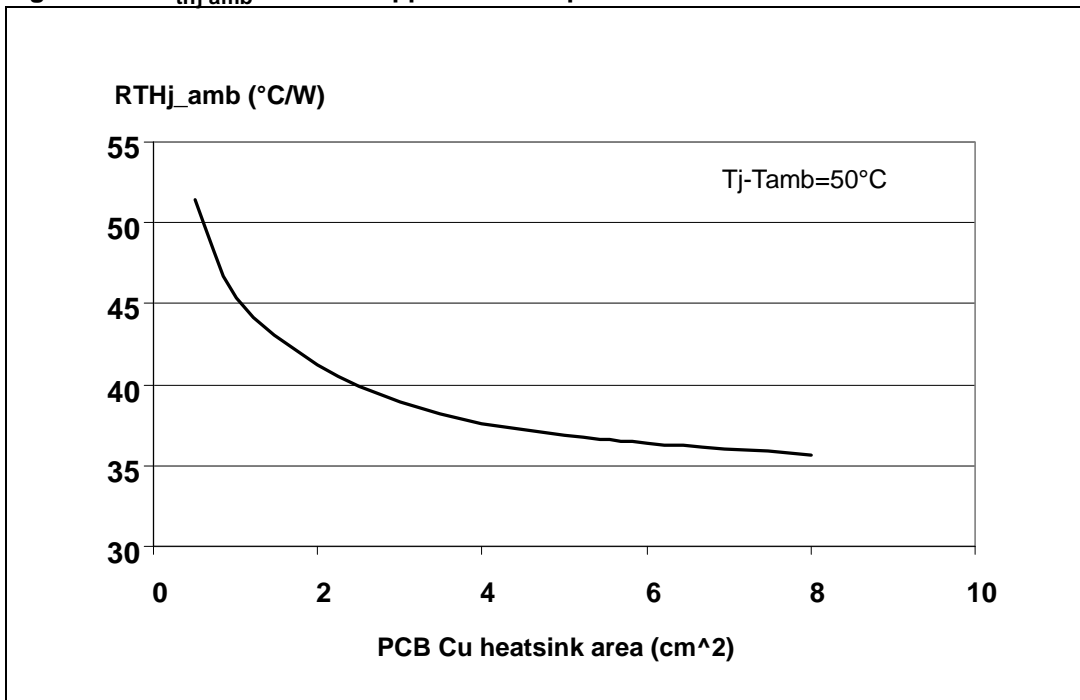
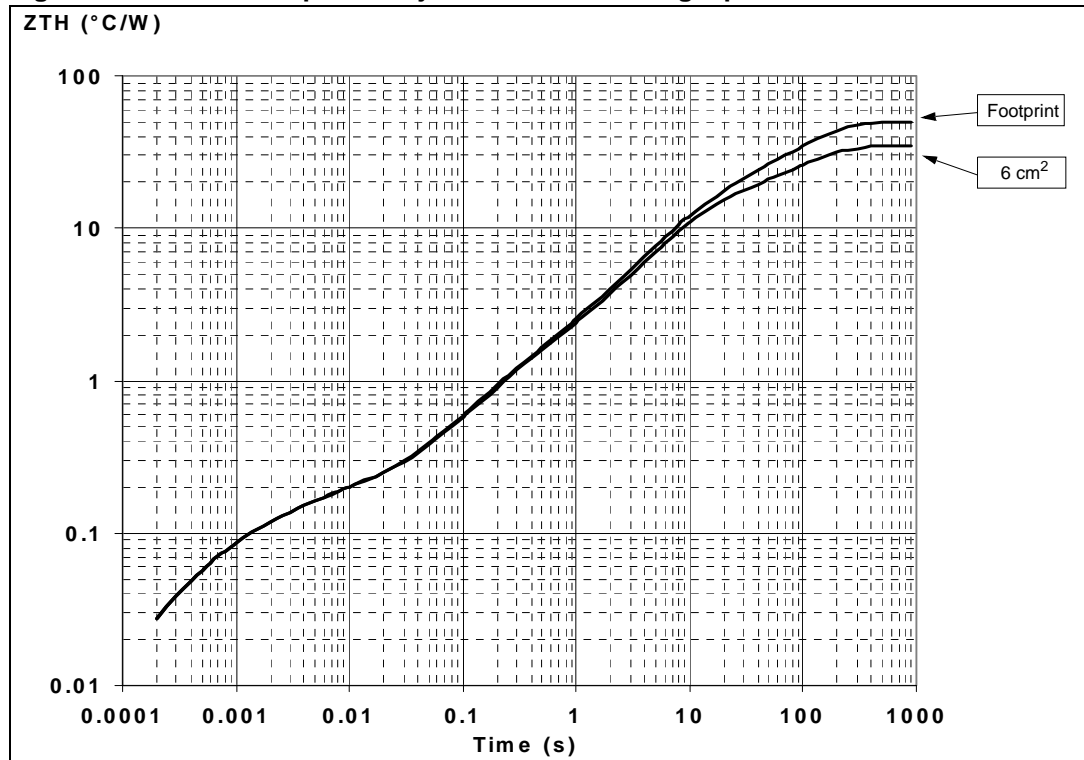


Figure 23. Thermal impedance junction ambient single pulse



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

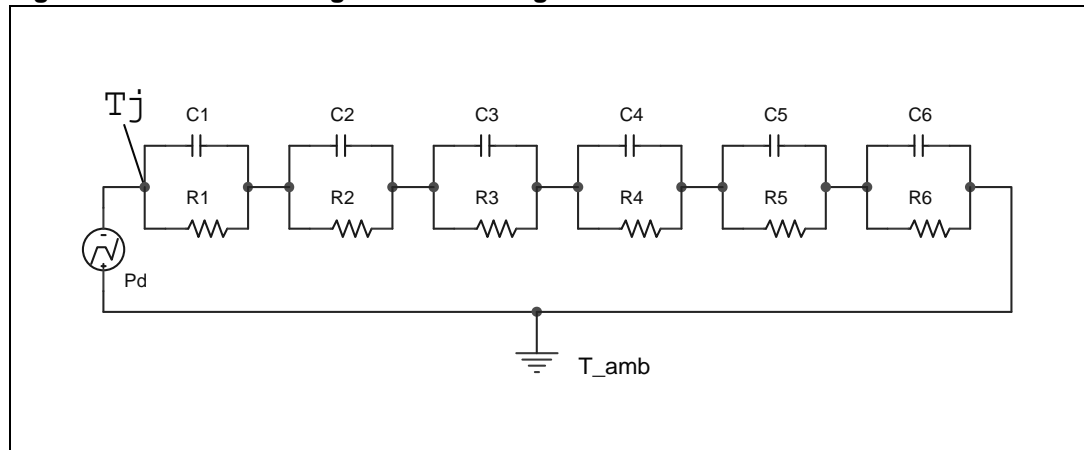


Table 15. Thermal parameters

Area / island (cm <sup>2</sup> )	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<sup>®</sup> packages

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 PowerSO-10 mechanical data

Figure 25. PowerSO-10 package dimensions

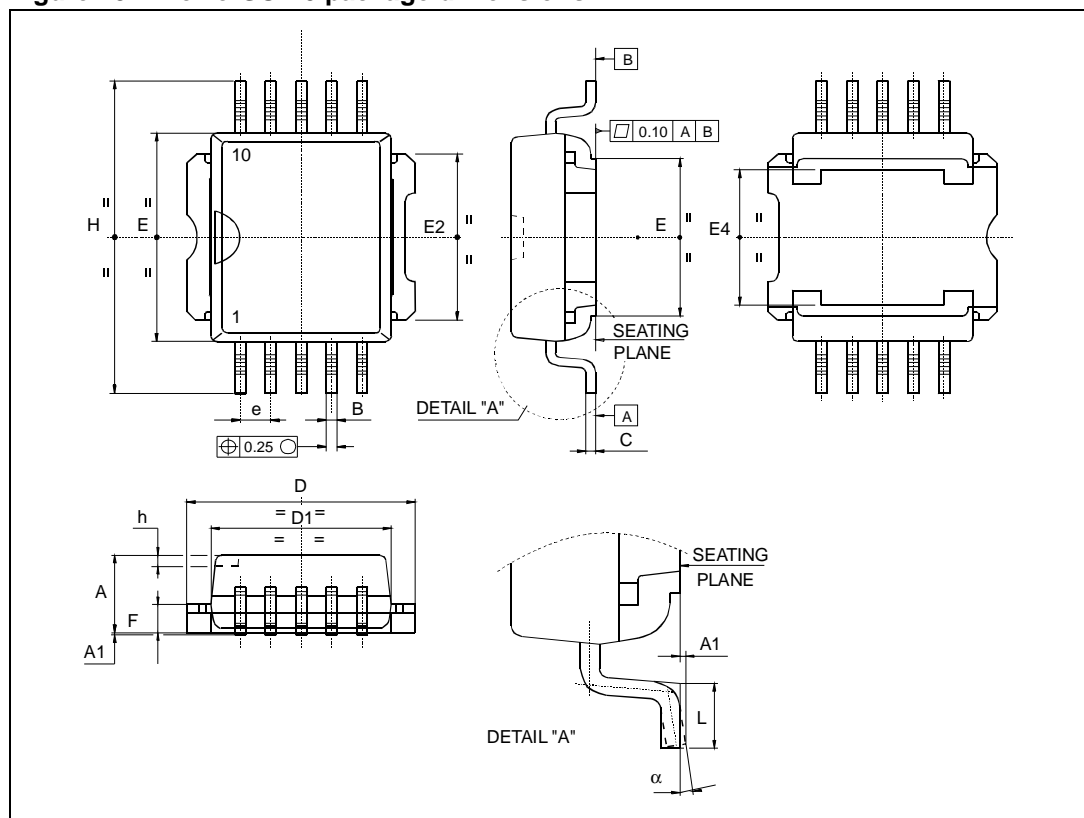


Table 16. PowerSO-10 mechanical data

Symbol	millimeters		
	Min	Typ	Max
A	3.35		3.65
A <sup>(1)</sup>	3.4		3.6
A1	0.00		0.10
B	0.40		0.60
B <sup>(1)</sup>	0.37		0.53
C	0.35		0.55
C <sup>(1)</sup>	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 <sup>(1)</sup>	7.30		7.50
E4	5.90		6.10
E4 <sup>(1)</sup>	5.90		6.30
e		1.27	
F	1.25		1.35
F <sup>(1)</sup>	1.20		1.40
H	13.80		14.40
H <sup>(1)</sup>	13.85		14.35
h		0.50	
L	1.20		1.80
L <sup>(1)</sup>	0.80		1.10
a	0°		8°
α <sup>(1)</sup>	2°		8°

1. Muar only POA P013P.



### 5.3 PowerSO-10 packing information

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

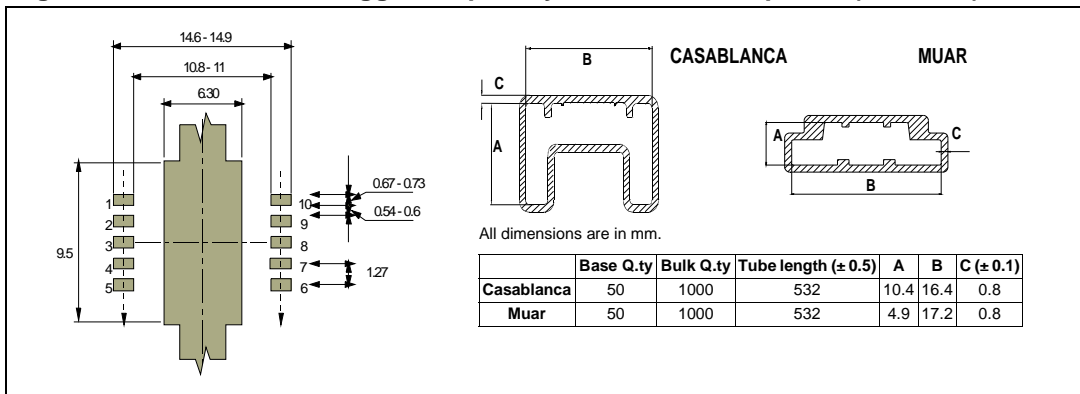
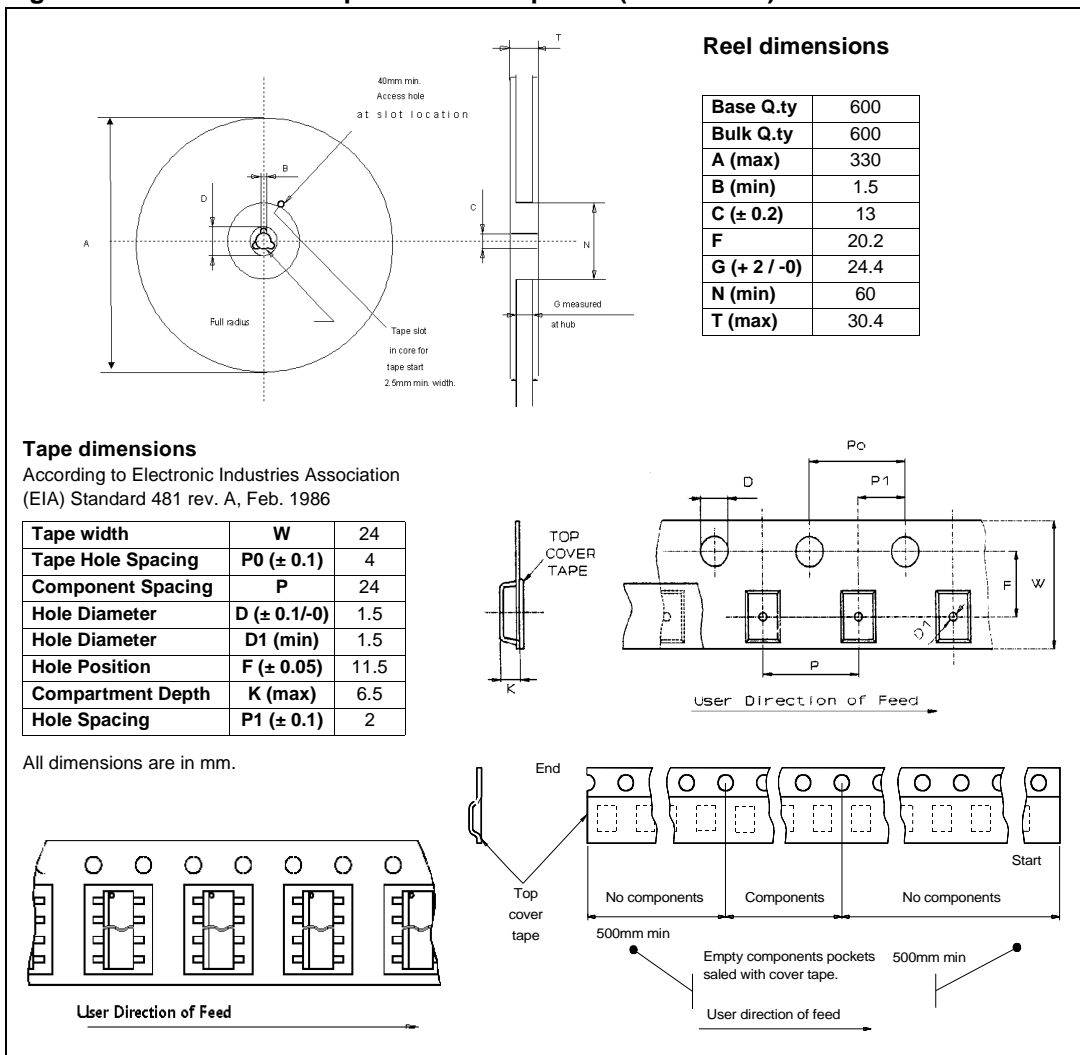


Figure 27. PowerSO-10 tape and reel shipment (suffix "TR")



## 6 Revision history

Table 17. Document revision history

Date	Revision	Changes
01-Oct-2004	1	Initial release.
23-Jun-2008	2	Changed template. Not changed document content.
11-Dec-2009	3	Formatted entire document. Updated features list.
29-Jun-2010	4	Updated following tables: – <i>Table 9: Switching (<math>V_{CC} = 13 V</math>)</i> – <i>Table 15: Thermal parameters</i> – Updated <i>Figure 24: Thermal fitting model of a single channel in PowerSO-10</i>
19-Sep-2013	5	Updated Disclaimer.

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