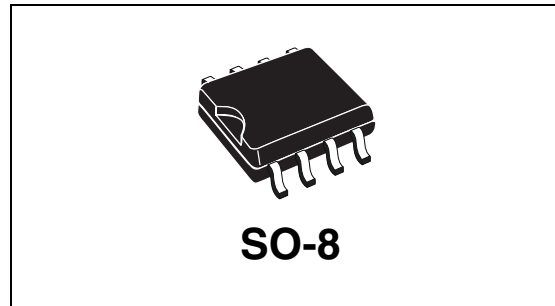


### Features

Type	$R_{DS(on)}$	$I_{OUT}$	$V_{CC}$
VN750SM	55 m $\Omega$	6 A	36 V

- CMOS compatible input
- On-state open load detection
- Off-state open load detection
- Shorted load protection
- Under-voltage and over-voltage shutdown
- Protection against loss of ground
- Very low stand-by current
- Reverse battery protected (see [Application schematic](#))



### Description

The VN750SM is a monolithic device designed in STMicroelectronics VIPower M0-3 technology. The VN750SM is intended for driving any type of load with one side connected to ground. The active  $V_{CC}$  pin voltage clamp protects the device against low energy spikes (see ISO7637 transient compatibility table).

Active current limitation combined with thermal shutdown and automatic restart protects the device against over-load. The device detects the open load condition in both the on and off-state.

The open load threshold is aimed at detecting the 5 W / 12 V standard bulb as an open load fault in the on-state.

In the off-state the device detects if the output is shorted to  $V_{CC}$ . The device automatically turns off in the case where the ground pin becomes disconnected.

**Table 1. Device summary**

Package	Order codes	
	Tube	Tape and reel
SO-8	VN750SM	VN750SM13TR

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# 1 Block diagram and pin description

Figure 1. Block diagram

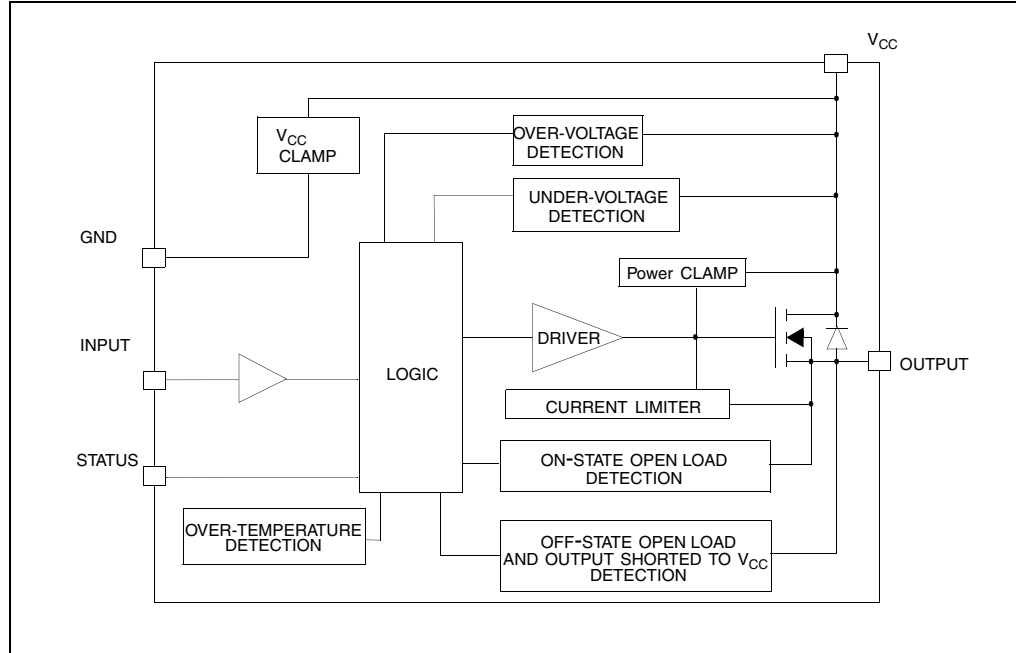


Figure 2. Configuration diagram (top view)

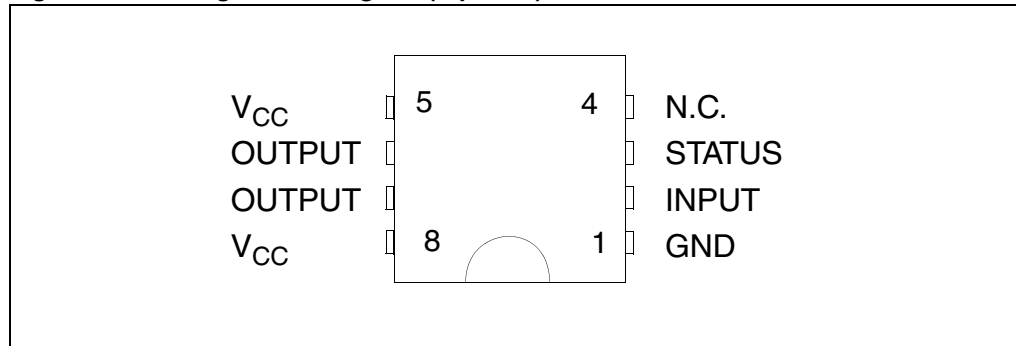
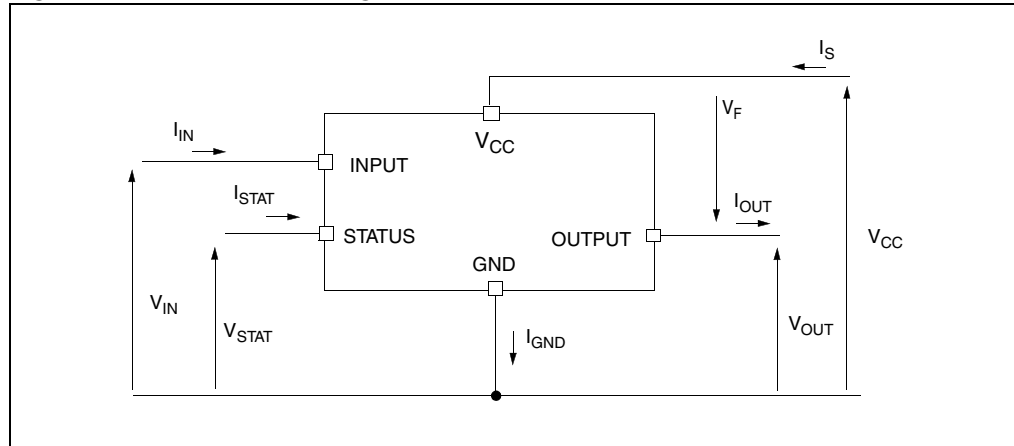


Table 2. Suggested connections for unused and not connected pins

Connection / pin	Status	N.C.	Output	Input
Floating	X	X	X	X
To ground		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 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	mA
$I_{STAT}$	DC status current	+/- 10	mA
$V_{ESD}$	Electrostatic discharge (human body model: $R = 1.5K\Omega$ ; $C = 100pF$ )		
	INPUT	4000	V
	STATUS	4000	V
	OUTPUT	5000	V
	$V_{CC}$	5000	V
$E_{MAX}$	Maximum switching energy ( $L = 1.3mH$ ; $R_L = 0\Omega$ ; $V_{bat} = 13.5V$ ; $T_{jstart} = 150^\circ C$ ; $I_L = 10A$ )	90	mJ

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

Symbol	Parameter	Value	Unit
$P_{tot}$	Power dissipation $T_C=25^\circ\text{C}$	4.2	W
$T_j$	Junction operating temperature	Internally limited	$^\circ\text{C}$
$T_{stg}$	Storage temperature	- 55 to 150	$^\circ\text{C}$

## 2.2 Thermal data

**Table 4. Thermal data**

Symbol	Parameter	Max. value		Unit
$R_{thj-lead}$	Thermal resistance junction-lead	30		$^\circ\text{C}/\text{W}$
$R_{thj-amb}$	Thermal resistance junction-ambient	93 <sup>(1)</sup>	82 <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 35µm thick) connected to all  $V_{CC}$  pins. Horizontal mounting and no artificial air flow.
2. When mounted on a standard single-sided FR-4 board with 2 cm<sup>2</sup> of Cu (at least 35µm thick). Horizontal mounting and no artificial air flow.

## 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
$V_{USDhyst}$	Under-voltage shutdown hysteresis			0.5		V
$V_{OV}$	Over-voltage shutdown		36			V
$R_{ON}$	On-state resistance	$I_{OUT} = 2\text{A}$ ; $T_j = 25^\circ\text{C}$ ; $V_{CC} > 8\text{V}$ $I_{OUT} = 2\text{A}$ ; $V_{CC} > 8\text{V}$			55 110	$\text{m}\Omega$ $\text{m}\Omega$
$I_S$	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; $V_{CC} = 13\text{V}$ ; $V_{IN} = 5\text{V}$ ; $I_{OUT} = 0\text{A}$		10  10  2	25  20  3.5	$\mu\text{A}$  $\mu\text{A}$  mA
$I_{L(off1)}$	Off-state output current	$V_{IN} = V_{OUT} = 0\text{V}$	0		50	$\mu\text{A}$
$I_{L(off2)}$	Off-state output current	$V_{IN} = 0\text{V}$ ; $V_{OUT} = 3.5\text{V}$	-75		0	$\mu\text{A}$

**Table 5. Power (continued)**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$I_{L(off3)}$	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	$\mu A$

**Table 6. Switching ( $V_{CC}=13V$ )**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$t_{d(on)}$	Turn-on delay time	$R_L = 6.5\Omega$ from $V_{IN}$ rising edge to $V_{OUT} = 1.3V$		40		$\mu s$
$t_{d(off)}$	Turn-off delay time	$R_L = 6.5\Omega$ from $V_{IN}$ falling edge to $V_{OUT} = 11.7V$		30		$\mu s$
$dV_{OUT}/dt_{(on)}$	Turn-on voltage slope	$R_L = 6.5\Omega$ from $V_{OUT} = 1.3V$ to $V_{OUT}=10.4V$	See <a href="#">Figure 21</a> .			$V/\mu s$
$dV_{OUT}/dt_{(off)}$	Turn-off voltage slope	$R_L = 6.5\Omega$ from $V_{OUT} = 11.7V$ to $V_{OUT}=1.3V$	See <a href="#">Figure 22</a> .			$V/\mu s$

**Table 7. Input pin**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{IL}$	Input low level				1.25	V
$I_{IL}$	Low level input current	$V_{IN} = 1.25V$	1			$\mu A$
$V_{IH}$	Input high level		3.25			V
$I_{IH}$	High level input current	$V_{IN} = 3.25V$			10	$\mu A$
$V_{hyst}$	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 8.  $V_{CC}$  output diode**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_F$	Forward on voltage	$-I_{OUT} = 1.4A$ ; $T_j = 150^\circ C$			0.6	V

**Table 9. Status pin**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{STAT}$	Status low output voltage	$I_{STAT} = 1.6mA$			0.5	V
$I_{LSTAT}$	Status leakage current	Normal operation; $V_{STAT} = 5V$			10	$\mu A$
$C_{STAT}$	Status pin input capacitance	Normal operation; $V_{STAT} = 5V$			100	pF
$V_{SCL}$	Status clamp voltage	$I_{STAT} = 1mA$ $I_{STAT} = -1mA$	6	6.8 - 0.7	8	V V



**Table 10. Protections<sup>(1)</sup>**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$T_{TSD}$	Shutdown temperature		150	175	200	°C
$T_R$	Reset temperature		135			°C
$T_{hyst}$	Thermal hysteresis		7	15		°C
$t_{SDL}$	Status delay in over-load condition	$T_j > T_{jsh}$			20	μs
$I_{lim}$	Current limitation	$9V < V_{CC} < 36V$ $5V < V_{CC} < 36V$	6	10	12 12	A A
$V_{demag}$	Turn-off output clamp voltage	$I_{OUT} = 2 A$ ; $V_{IN} = 0V$ ; $L = 6mH$	$V_{CC} - 41$	$V_{CC} - 48$	$V_{CC} - 55$	V

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 operates under abnormal conditions this software must limit the duration and number of activation cycles.

**Table 11. Open load detection**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$I_{OL}$	Open load on-state detection threshold	$V_{IN} = 5V$	0.6	0.9	1.2	A
$t_{DOL(on)}$	Open load on-state detection delay	$I_{OUT} = 0A$			200	μs
$V_{OL}$	Open load off-state voltage detection threshold	$V_{IN} = 0V$	1.5	2.5	3.5	V
$t_{DOL(off)}$	Open load detection delay at turn-off				1000	μs

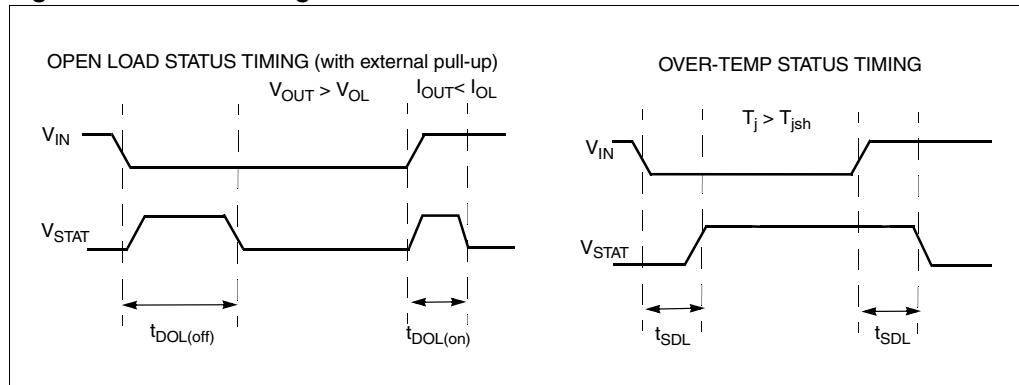
**Figure 4. Status timings**

Figure 5. Switching time waveforms

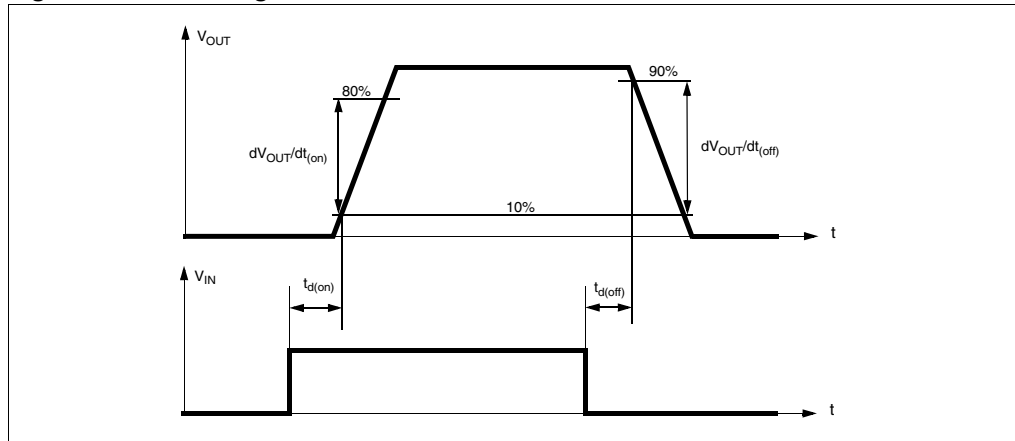


Table 12. Truth table

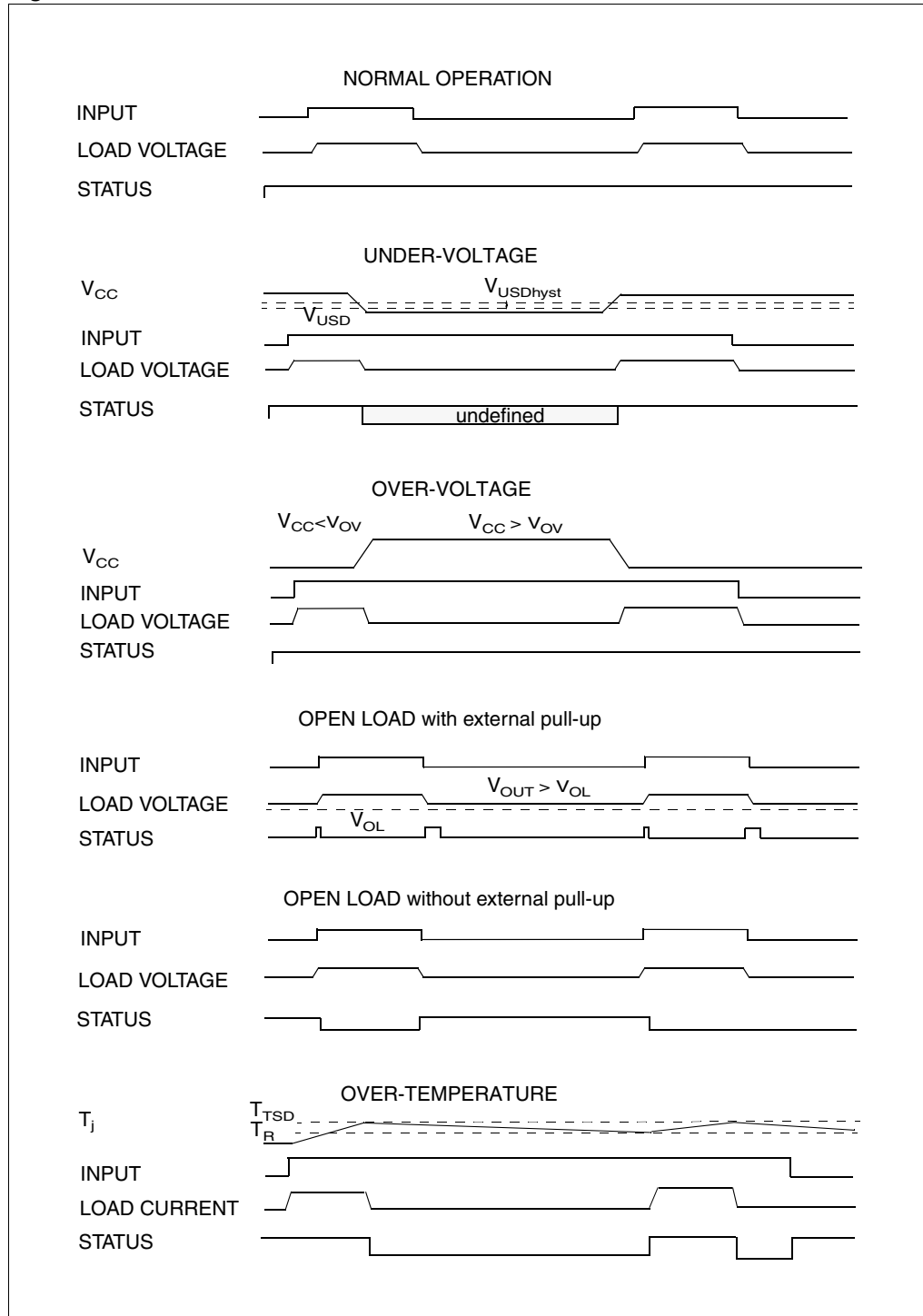
Conditions	Input	Output	Status
Normal operation	L	L	H
	H	H	H
Current limitation	L	L	H
	H	X	$(T_j < T_{TSD})$ H $(T_j > T_{TSD})$ L
Over-temperature	L	L	H
	H	L	L
Under-voltage	L	L	X
	H	L	X
Over-voltage	L	L	H
	H	L	H
Output voltage > $V_{OL}$	L	H	L
	H	H	H
Output current < $I_{OL}$	L	L	H
	H	H	L

Table 13. Electrical transient requirements

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



## 2.4 Electrical characteristics curves

Figure 7. Off-state output current

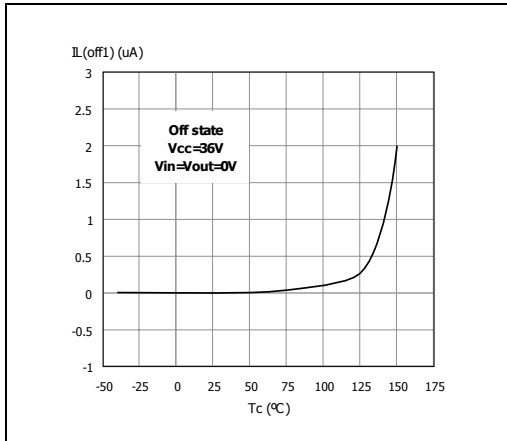


Figure 8. High level input current

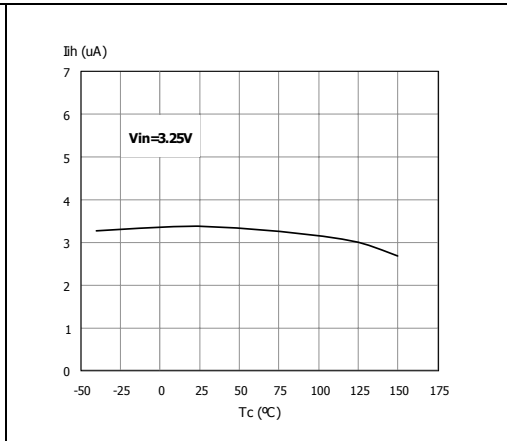


Figure 9. Input clamp voltage

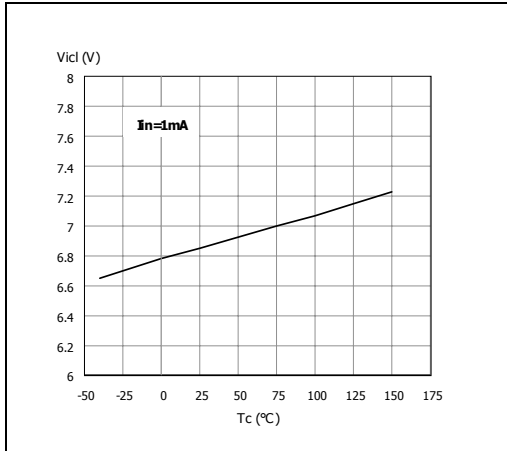


Figure 10. Status leakage current

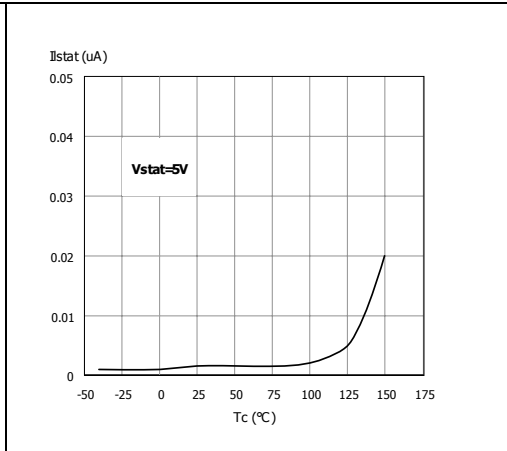


Figure 11. Status low output voltage

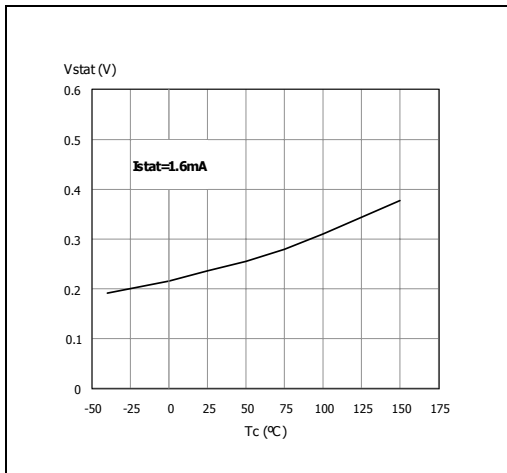


Figure 12. Status clamp voltage

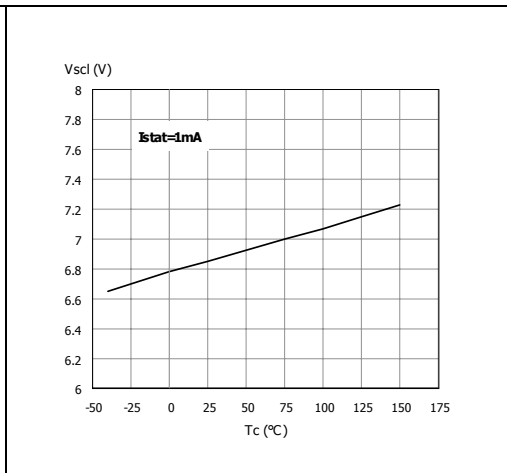


Figure 13. On-state resistance Vs  $T_{case}$

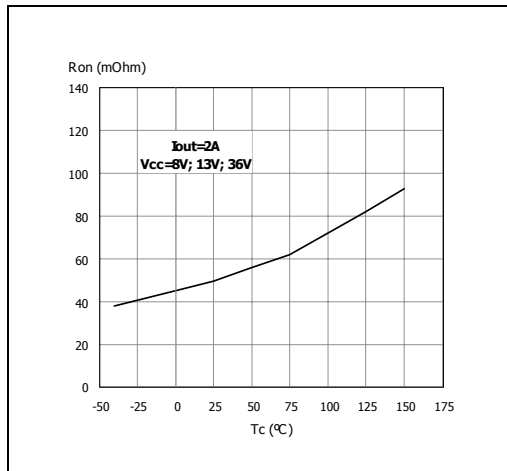


Figure 14. On-state resistance Vs  $V_{CC}$

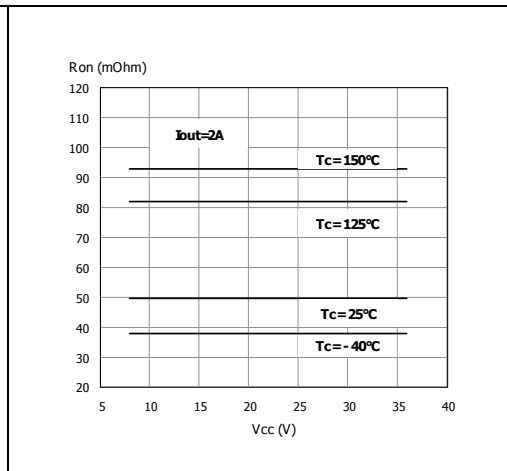


Figure 15. Open load on-state detection

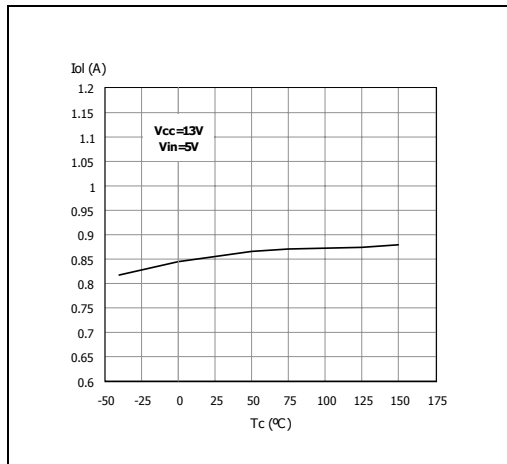


Figure 16. Input high level threshold

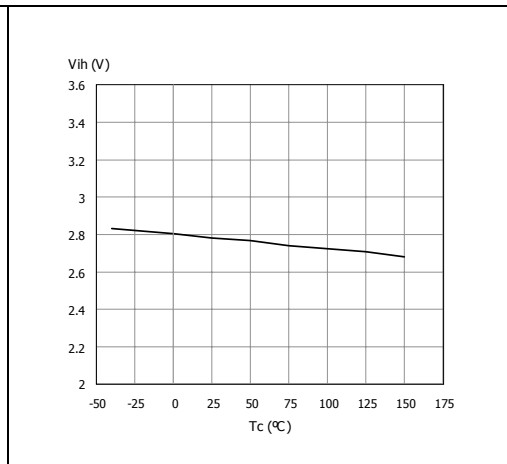


Figure 17. Input low level

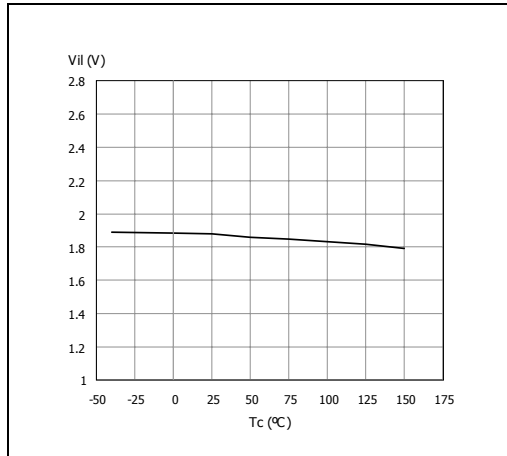


Figure 18. Input hysteresis voltage

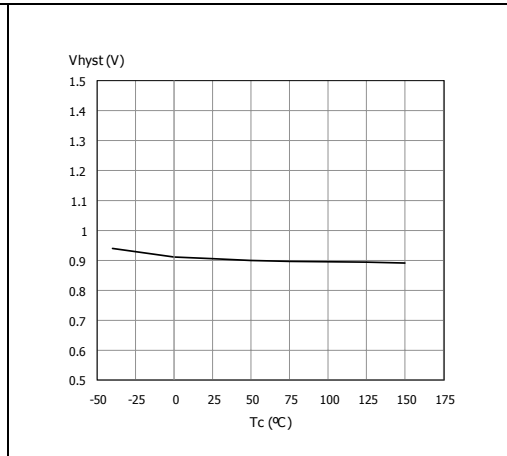


Figure 19. Over-voltage shutdown

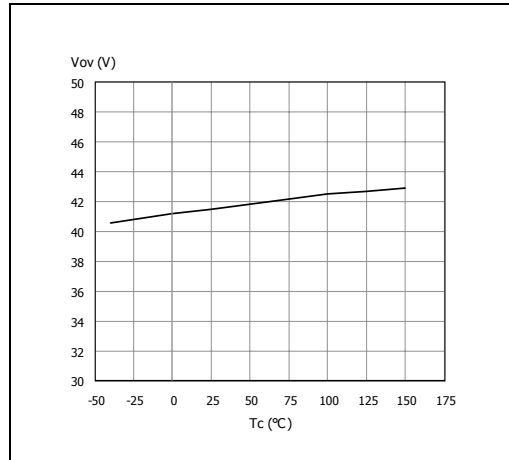


Figure 20. Open load off-state voltage detection threshold

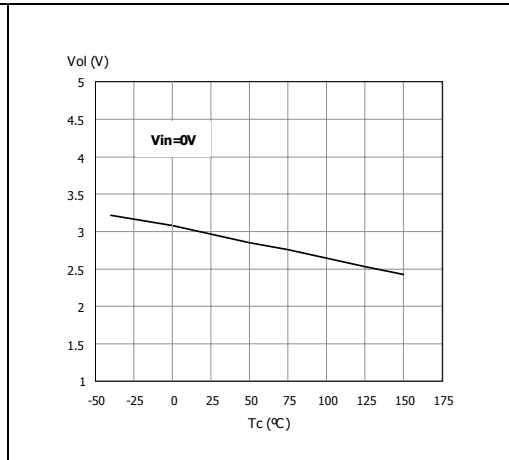


Figure 21. Turn-on voltage slope

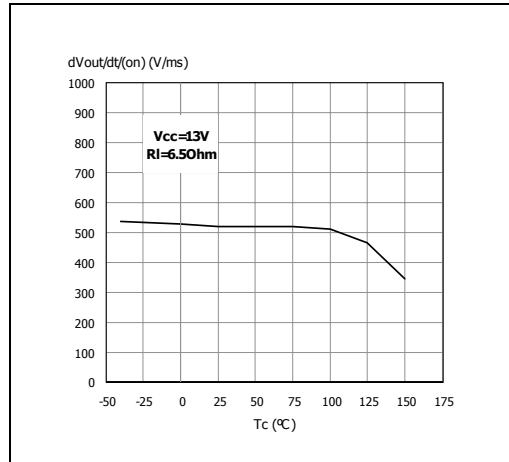


Figure 22. Turn-off voltage slope

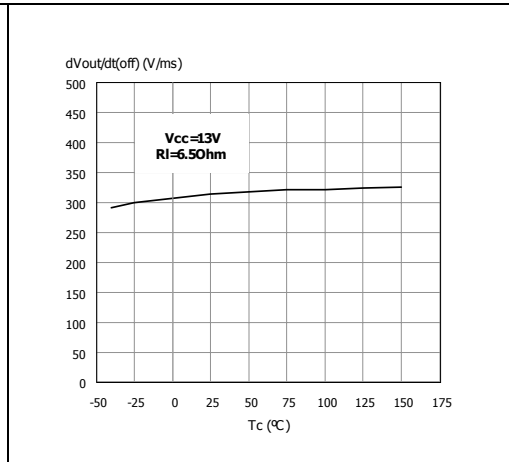
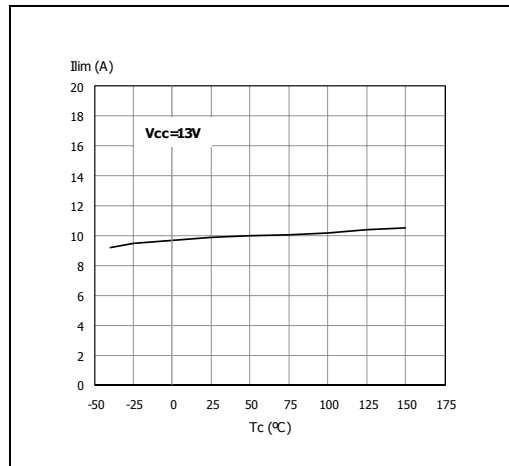
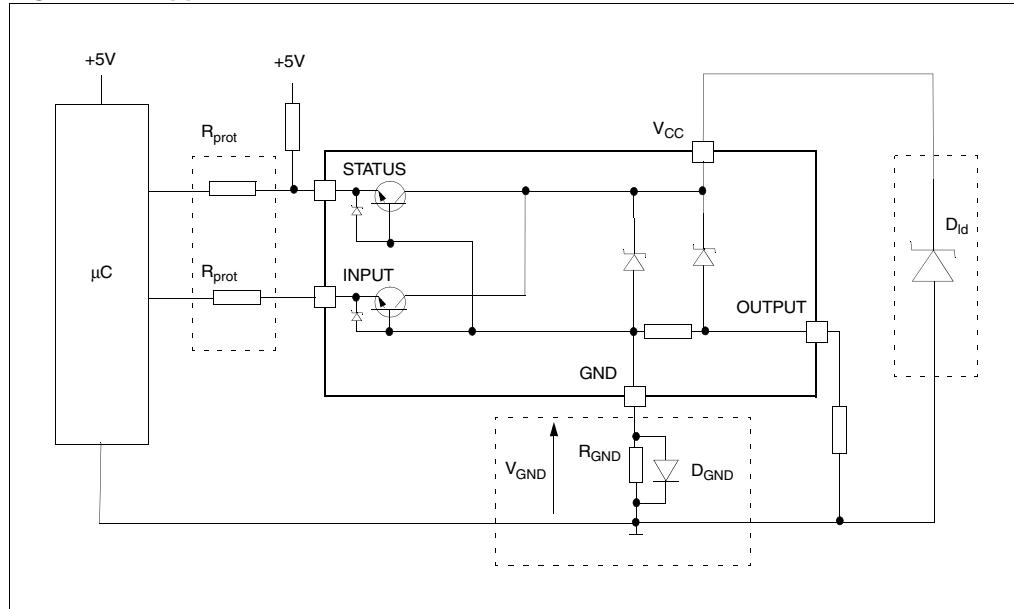


Figure 23. Ilim Vs Tcase



### 3 Application information

Figure 24. Application schematic



#### 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: 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.

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  $V_{CC}$  max DC rating. The same applies if the device is subject to transients on the  $V_{CC}$  line that are greater than the ones shown in the ISO 7637-2: 2004(E) table.

## 3.3 MCU I/Os protection

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

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

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

Calculation example:

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

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

Recommended values:  $R_{prot} = 10k\Omega$ .

### 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:

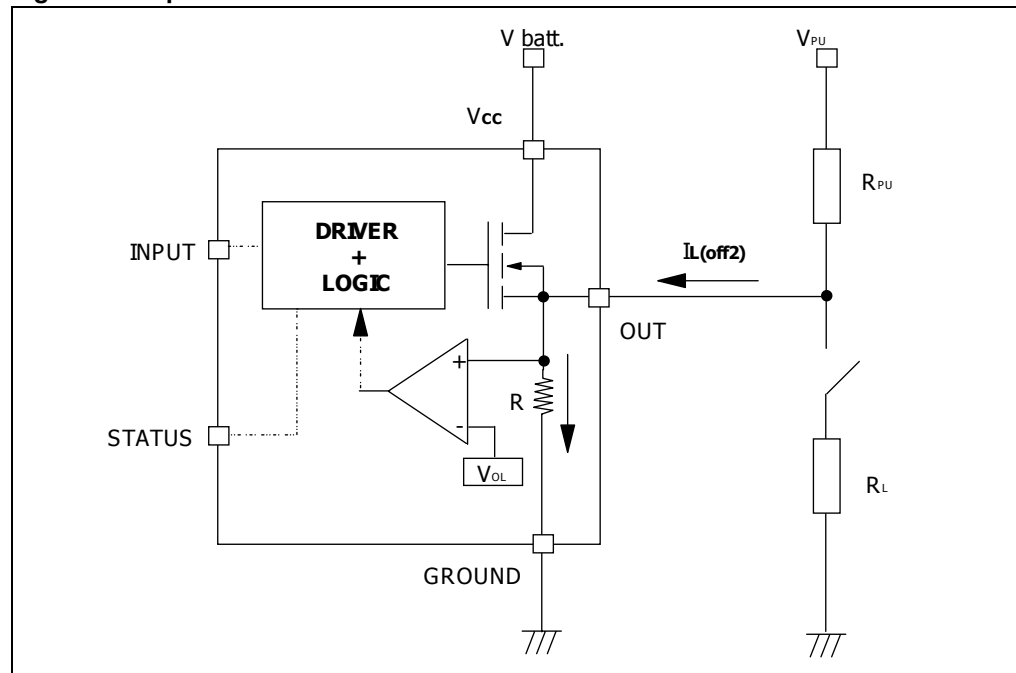
1. no false open load indication when load is connected: in this case we have to avoid  $V_{OUT}$  to be higher than  $V_{OLmin}$ ; this results in the following condition  

$$V_{OUT} = (V_{PU} / (R_L + R_{PU})) R_L < V_{OLmin}$$
2. 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.

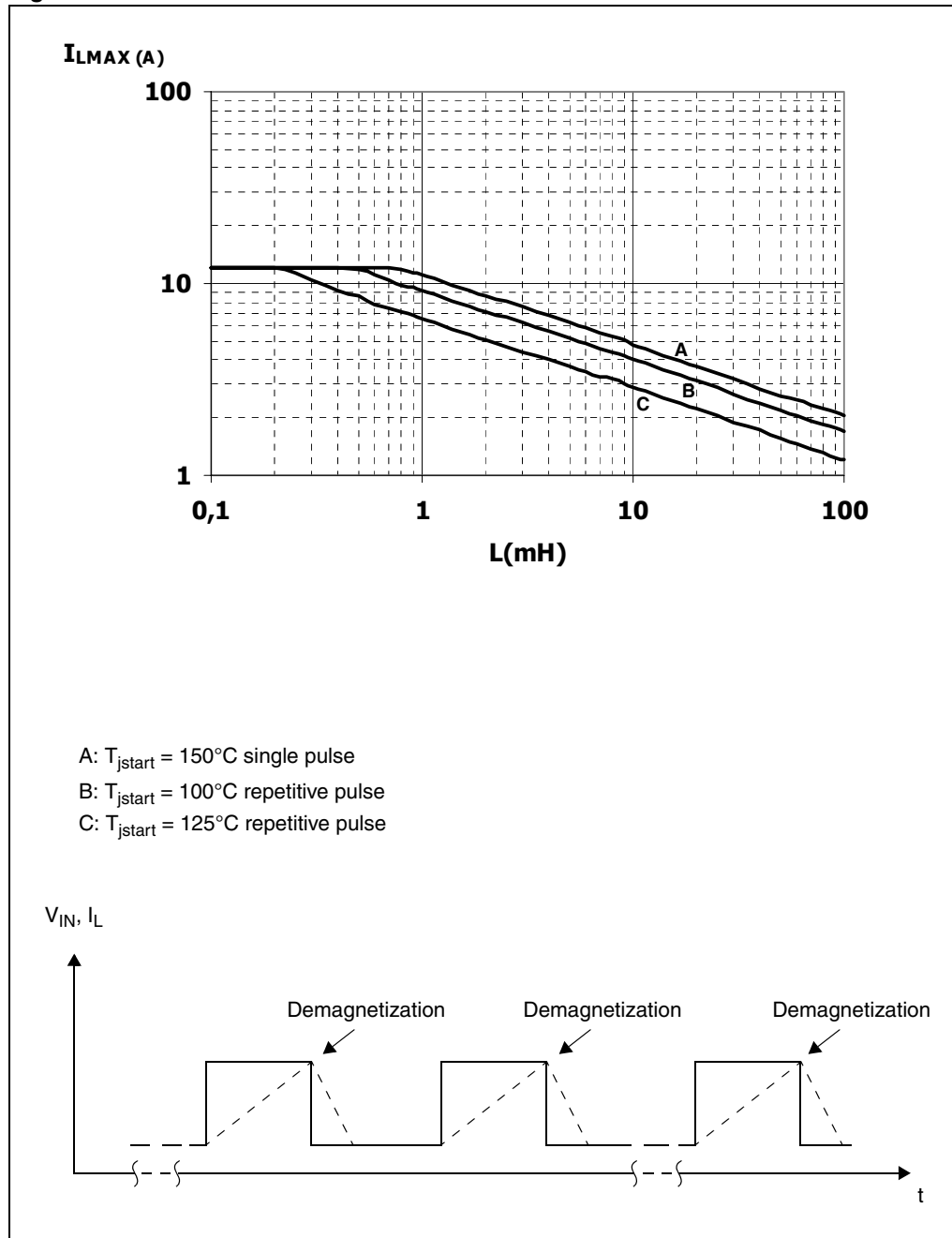
The values of  $V_{OLmin}$ ,  $V_{OLmax}$  and  $I_{L(off2)}$  are available in the electrical characteristics section.

**Figure 25. Open load detection in off-state**



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

Figure 26. Maximum turn-off current versus inductance

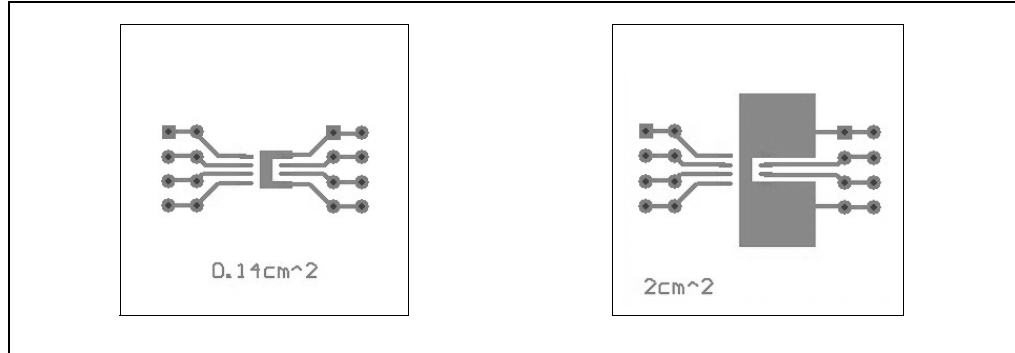


Note: Values are generated with  $R_L = 0 \Omega$ . In case of repetitive pulses,  $T_{jstart}$  (at beginning of each demagnetization) of every pulse must not exceed the temperature specified above for curves A and B.

## 4 Package and PCB thermal data

### 4.1 SO-8 thermal data

Figure 27. PC board



Note: *Layout condition of  $R_{th}$  and  $Z_{th}$  measurements (PCB FR4 area = 58mm x 58 mm, PCB thickness = 2 mm, Cu thickness = 35µm, Copper areas: 0.14 cm<sup>2</sup>, 2 cm<sup>2</sup>).*

Figure 28.  $R_{thj-amb}$  Vs. PCB copper area in open box free air condition

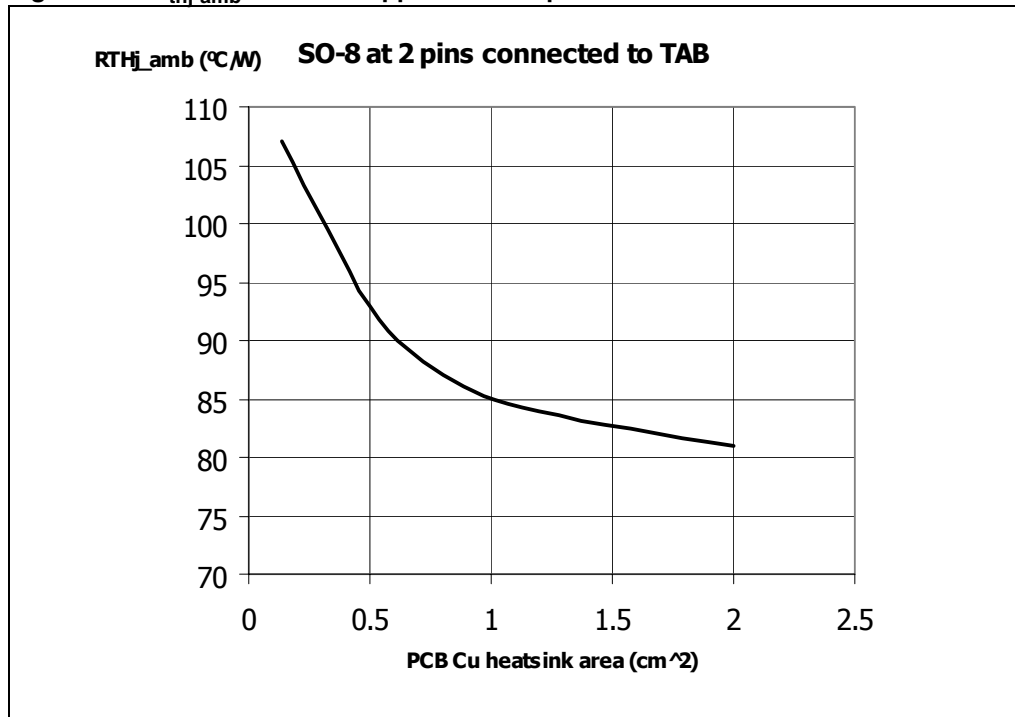
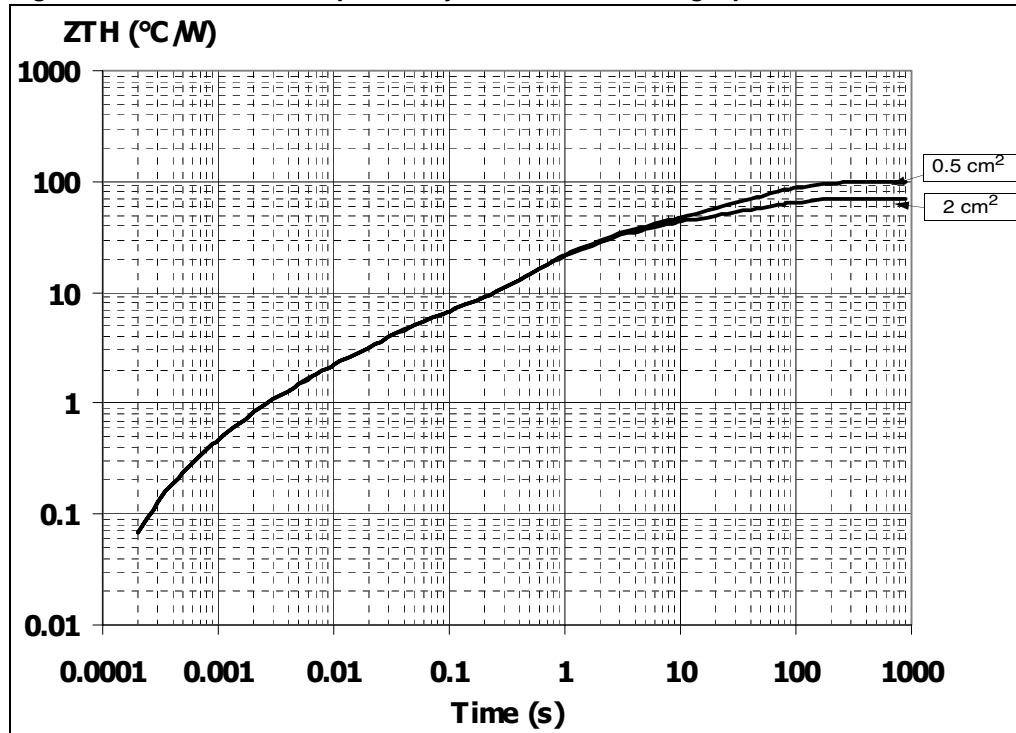


Figure 29. SO-8 thermal impedance junction ambient single pulse

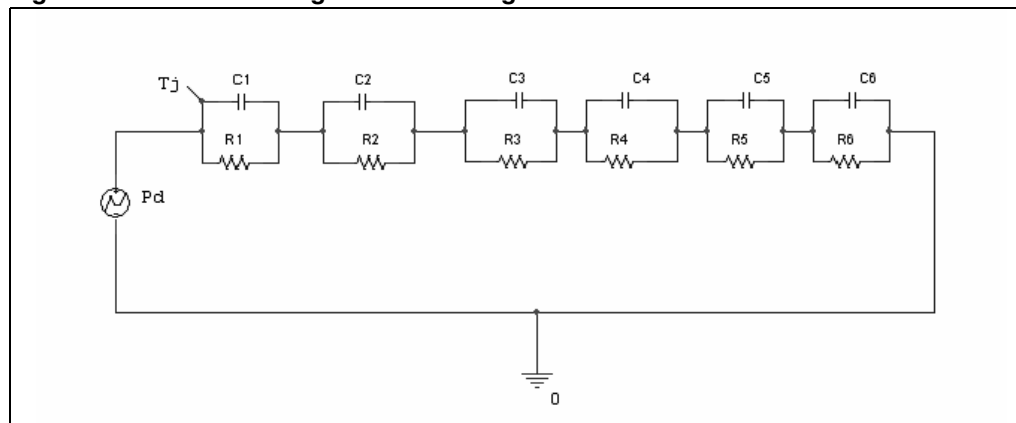


Equation 1: pulse calculation formula

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

where  $\delta = t_p/T$

Figure 30. Thermal fitting model of a single channel



**Table 14. Thermal parameter**

Area/island (cm <sup>2</sup> )	0.5	2
R1 (°C/W)	0.05	
R2 (°C/W)	0.8	
R3 (°C/W)	3.5	
R4 (°C/W)	21	
R5 (°C/W)	16	
R6 (°C/W)	58	28
C1 (W·s/°C)	0.006	
C2 (W·s/°C)	0.0026	
C3 (W·s/°C)	0.0075	
C4 (W·s/°C)	0.045	
C5 (W·s/°C)	0.35	
C6 (W·s/°C)	1.05	2

## 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 SO-8 package information

Figure 31. SO-8 package dimensions

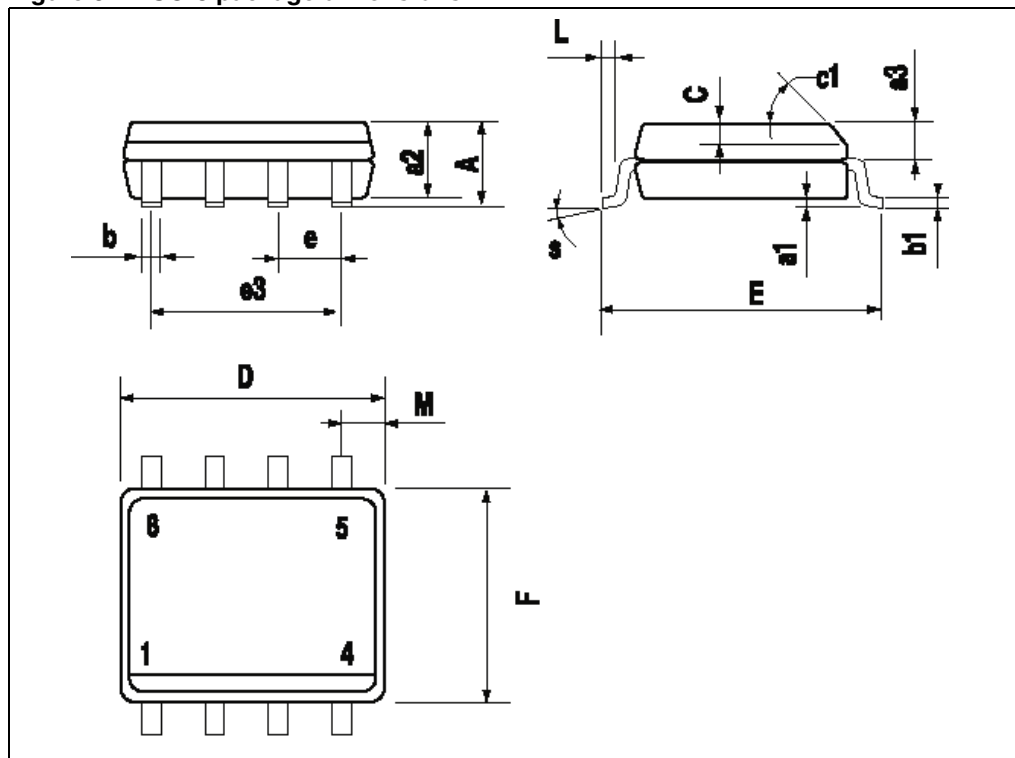


Table 15. SO-8 mechanical data

Dim.	mm		
	Min.	Typ.	Max.
A			1.75
a1	0.1		0.25
a2			1.65
a3	0.65		0.85
b	0.35		0.48
b1	0.19		0.25
C	0.25		0.5
c1	45 (typ.)		
D	4.8		5
E	5.8		6.2
e		1.27	
e3		3.81	
F	3.8		4
L	0.4		1.27
M			0.6
S	8 (max.)		
L1	0.8		1.2



### 5.3 SO-8 packing information

The devices can be packed in tube or tape and reel shipments (see the [Device summary on page 1](#)).

Figure 32. SO-8 tube shipment (no suffix)

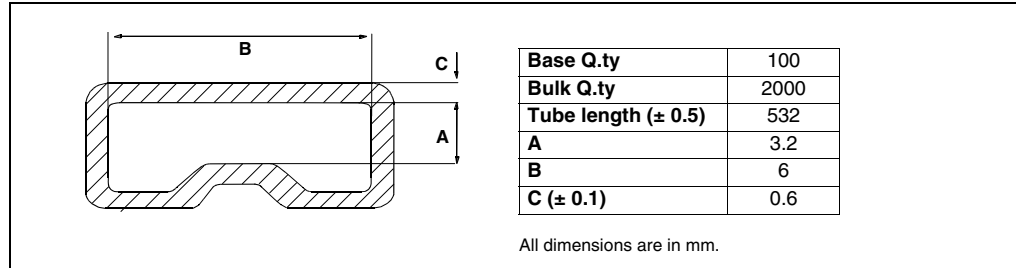
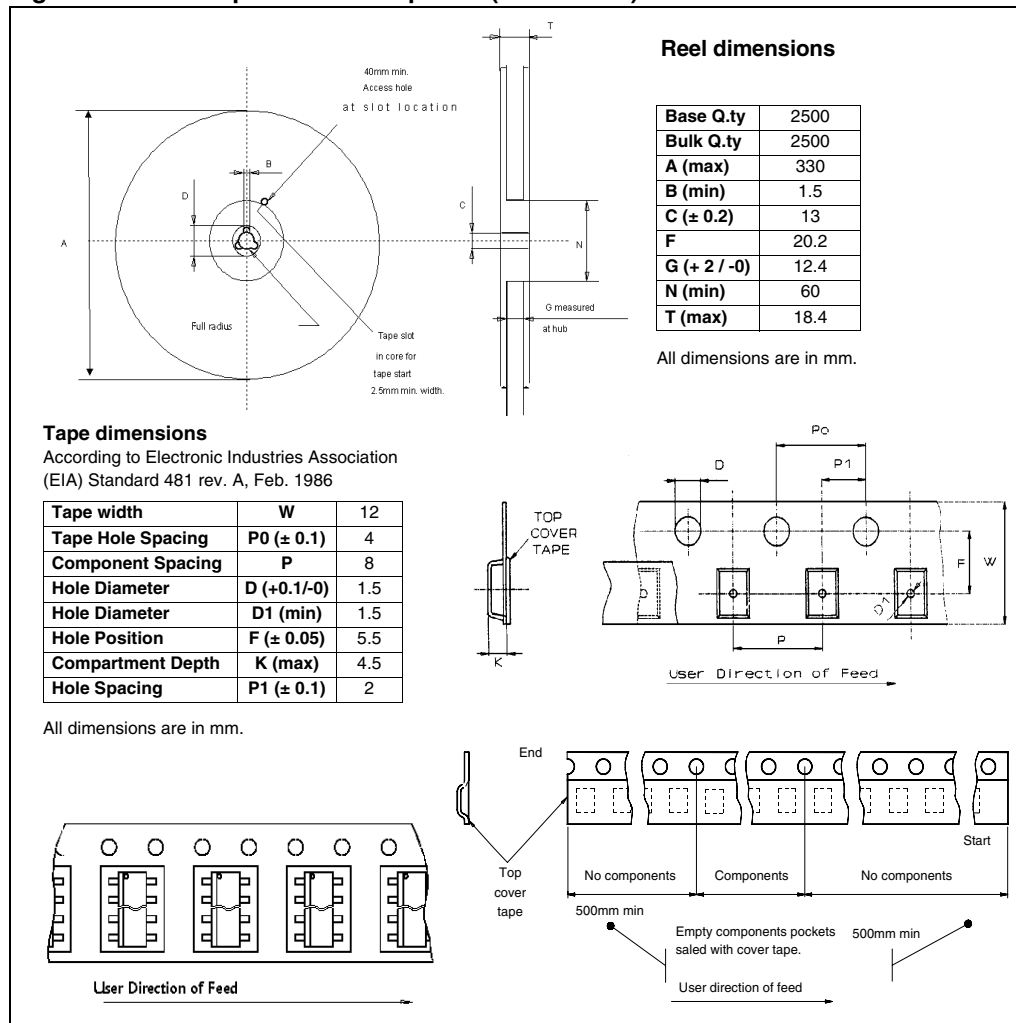


Figure 33. SO-8 tape and reel shipment (suffix "TR")



## 6 Revision history

Table 16. Document revision history

Date	Revision	Changes
09-Sep-2004	1	Initial release.
03-May-2006	2	Minor changes. Current and voltage convention update (page 2). Configuration diagram (top view) and suggested connections for unused and n.c. pins insertion (page 2). 2 cm <sup>2</sup> Cu condition insertion in thermal data table (page 3). V <sub>CC</sub> - output diode section update (page 4). Revision history table insertion (page 18). Disclaimers update (page 19).
16-Dec-2008	3	Document reformatted and restructured. Added content, list of figures and tables. Added <i>ECOPACK</i> <sup>®</sup> packages information.

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