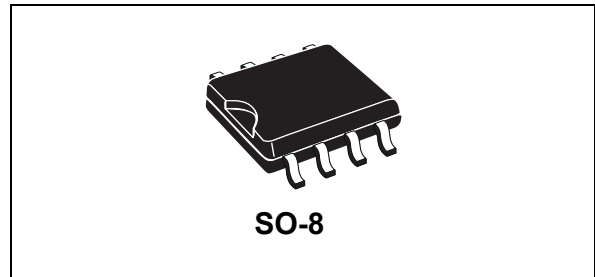


Features

Type	$R_{DS(on)}$	I_{OUT}	V_{CC}
VN750SMP-E	55 m Ω	6 A	36 V

- ECOPACK[®] : lead free and RoHS compliant
- Automotive Grade: compliance with AEC guidelines
- CMOS compatible input
- On-state open-load detection
- Off-state open-load detection
- Shorted load protection
- Undervoltage and overvoltage shutdown
- Protection against loss of ground
- Very low standby current
- Reverse battery protection (see [Application schematic on page 16](#))
- In compliance with the 2002/95/EC european directive



Description

The VN750SMP-E is a monolithic device designed in STMicroelectronics VIPower™ M0-3 Technology, intended for driving any kind of load with one side connected to ground.

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 help protect the device against overload.

The device detects open-load condition in on and off-state. The open-load threshold is aimed at detecting the 5W/12V standard bulb as an open-load fault in the on-state. Output shorted to V_{CC} is detected in the off-state. Device automatically turns off in case of ground pin disconnection.

Table 1. Device summary

Package	Order codes	
	Tube	Tape and reel
SO-8	VN750SMP-E	VN750SMPTR-E

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1 Block diagram and pin description

Figure 1. Block diagram

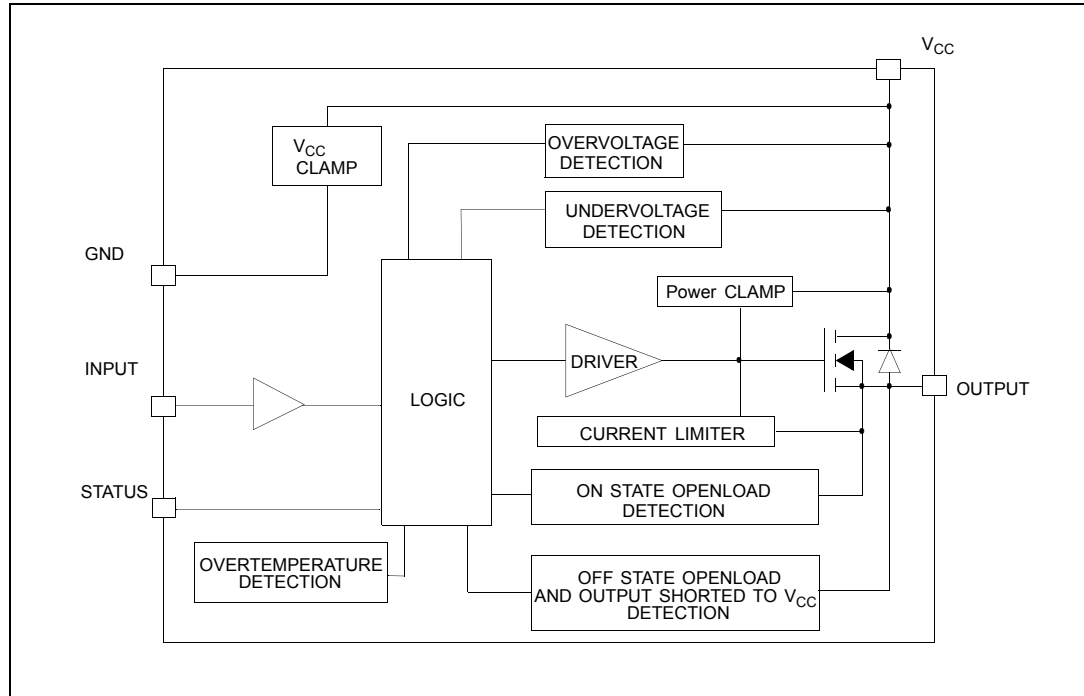


Figure 2. Configuration diagram (top view)

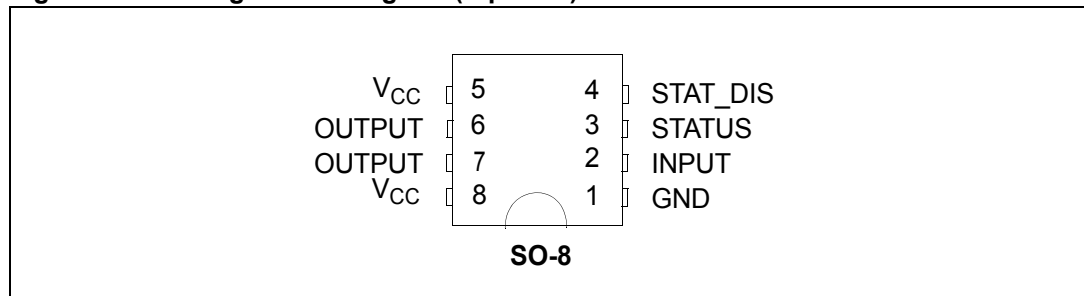
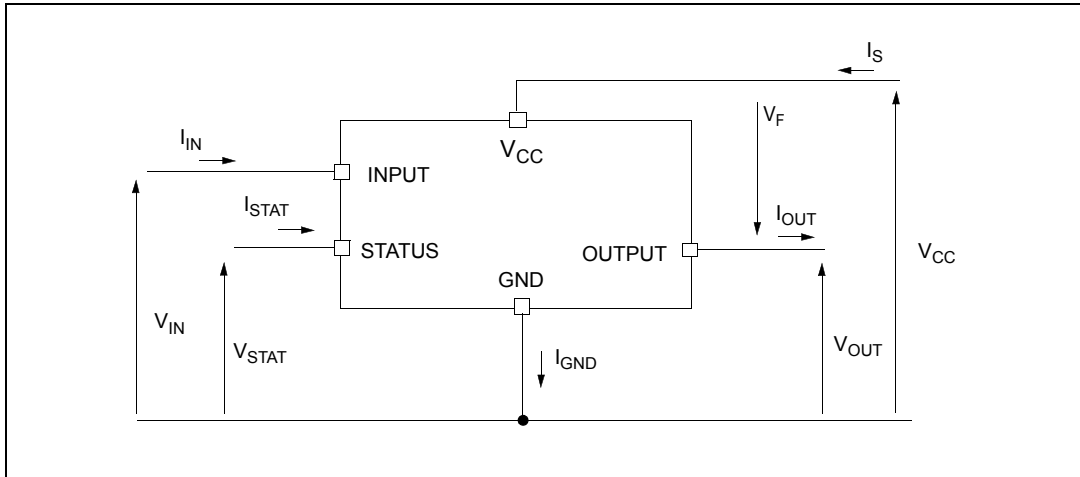


Table 2. Suggested connections for unused and not connected pins

Connection/pin	Status	N.C.	Output	Input
Floating	X	X	X	X
To ground		X		Through 10 KΩ resistor

2 Electrical specifications

Figure 3. Current and voltage conventions



2.1 Absolute maximum ratings

Stress values that exceed those listed in the “Absolute maximum ratings” table can cause permanent damage to the device. These are stress ratings only, and operation of the device at these, or any other conditions greater than 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 documents.

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=1.5 K Ω ; C=100pF)		
	- Input	4000	V
	- Status	4000	V
	- Output	5000	V
	- V_{CC}	5000	V

Table 3. Absolute maximum ratings (continued)

Symbol	Parameter	Value	Unit
E_{MAX}	Maximum switching energy ($L=1.3\text{mH}$; $R_L=0\Omega$; $V_{bat}=13.5\text{V}$; $T_{jstart}=150^\circ\text{C}$; $I_L=10\text{A}$)	90	mJ
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
$R_{thj-case}$	Thermal resistance junction-case	1.7		$^\circ\text{C/W}$
$R_{thj-amb}$	Thermal resistance junction-ambient	93 ⁽¹⁾	82 ⁽²⁾	$^\circ\text{C/W}$

- When mounted on a standard single-sided FR-4 board with 0.5cm^2 of Cu (at least $35\mu\text{m}$ thick) connected to all V_{CC} pins. Horizontal mounting and no artificial air flow.
- When mounted on a standard single-sided FR-4 board with 2cm^2 of Cu (at least $35\mu\text{m}$ thick) connected to all V_{CC} pins. Horizontal mounting and no artificial air flow.

2.3 Electrical characteristics

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

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
$V_{USDhyst}$	Undervoltage shutdown hysteresis			0.5		V
V_{OV}	Overvoltage shutdown		36			V
R_{ON}	On-state resistance	$I_{OUT}=2\text{ A}$; $T_j=25\text{ }^\circ\text{C}$; $V_{CC}>8\text{ V}$ $I_{OUT}=2\text{ A}$; $V_{CC}>8\text{ V}$			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; $V_{CC}=13\text{ V}$; $V_{IN}=V_{OUT}=0\text{ V}$; $T_j=25\text{ }^\circ\text{C}$ On-state; $V_{CC}=13\text{ V}$; $V_{IN}=5\text{ V}$; $I_{OUT}=0\text{ A}$		10 10 2	25 20 3.5	μA μA mA
$I_{L(off1)}$	Off-state output current	$V_{IN}=V_{OUT}=0\text{ V}$	0		50	μA
$I_{L(off2)}$	Off-state output current	$V_{IN}=0\text{V}$; $V_{OUT}=3.5\text{ V}$	-75		0	μA

Table 5. Power (continued)

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

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

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 $V_{OUT}=1.3\text{ V}$	-	40	-	μs
$t_{d(off)}$	Turn-off delay time	$R_L=6.5\ \Omega$ from V_{IN} falling edge to $V_{OUT}=11.7\text{ V}$	-	30	-	μs
$dV_{OUT}/dt_{(on)}$	Turn-on voltage slope	$R_L=6.5\ \Omega$ from $V_{OUT}=1.3\text{ V}$ to $V_{OUT}=10.4\text{ V}$	-	See relative diagram	-	$\text{V}/\mu\text{s}$
$dV_{OUT}/dt_{(off)}$	Turn-off voltage slope	$R_L=6.5\ \Omega$ from $V_{OUT}=11.7\text{ V}$ to $V_{OUT}=1.3\text{ V}$	-	See relative diagram	-	$\text{V}/\mu\text{s}$

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	$V_{IN}=1.25\text{ V}$	1			μA
V_{IH}	Input high level		3.25			V
I_{IH}	High level input current	$V_{IN}=3.25\text{ V}$			10	μA
V_{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

Table 8. V_{CC} output diode

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

Table 9. Status pin

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{STAT}	Status low output voltage	$I_{STAT}=1.6\text{ mA}$			0.5	V
I_{LSTAT}	Status leakage current	Normal operation; $V_{STAT}=5\text{ V}$			10	μA

Table 9. Status pin (continued)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
C_{STAT}	Status pin input capacitance	Normal operation; $V_{STAT}=5\text{ V}$			100	pF
V_{SCL}	Status clamp voltage	$I_{STAT}=1\text{ mA}$ $I_{STAT}=-1\text{ mA}$	6	6.8 -0.7	8	V V

Table 10. Protections⁽¹⁾

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 overload condition	$T_j > T_{jsh}$			20	ms
I_{lim}	Current limitation	$5.5\text{ V} < V_{CC} < 36\text{ V}$	6	10	12 12	A A
V_{demag}	Turn-off output clamp voltage	$I_{OUT}=2\text{ A}$; $V_{IN}=0\text{ V}$; $L=6\text{ mH}$	$V_{CC}-41$	$V_{CC}-48$	$V_{CC}-55$	V

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 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	$V_{IN}=5\text{ V}$	0.6	0.9	1.2	A
$t_{DOL(on)}$	Open-load on-state detection delay	$I_{OUT}=0\text{ A}$			200	μs
V_{OL}	Open-load off-state voltage detection threshold	$V_{IN}=0\text{ V}$	1.5	2.5	3.5	V
$t_{DOL(off)}$	Open-load detection delay at turn-off				1000	μs

Figure 4. Status timings

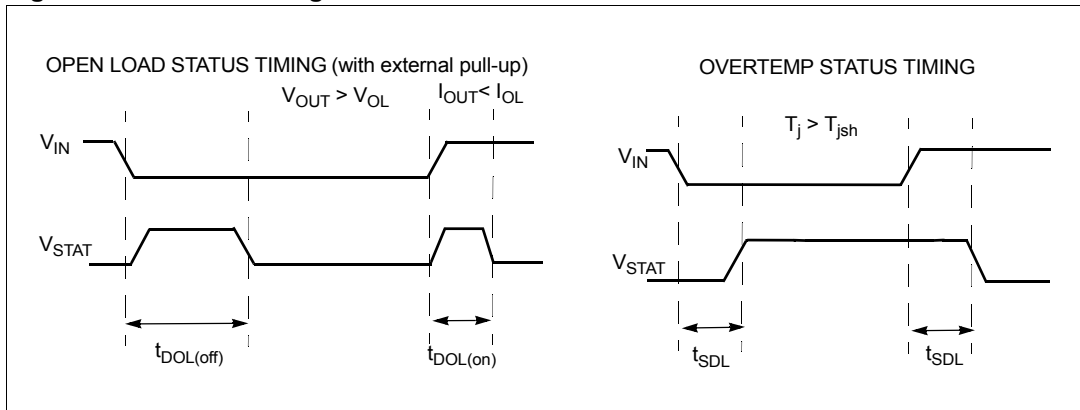


Figure 5. Switching time waveforms

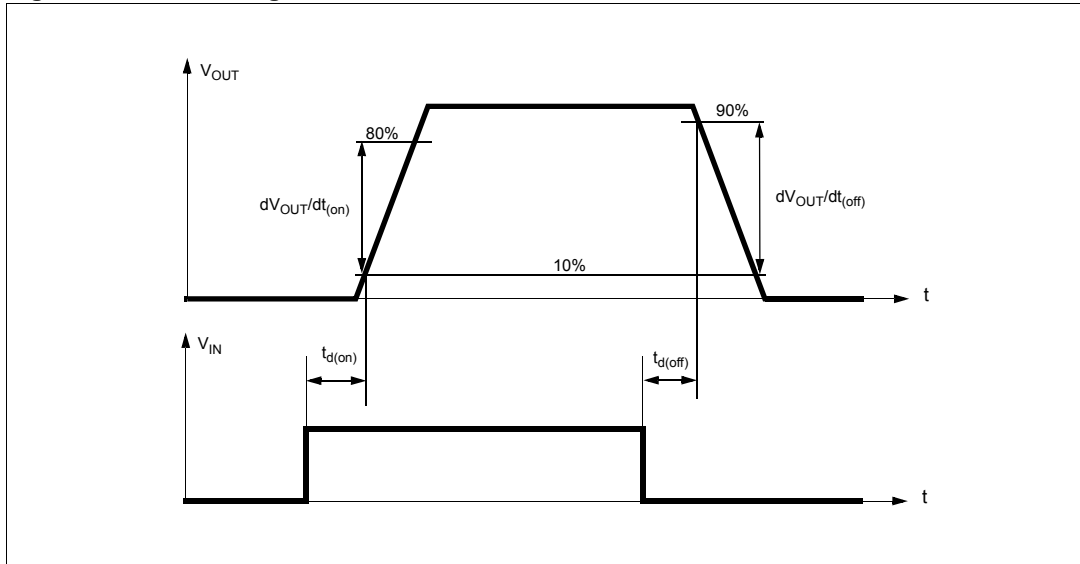


Table 12. Truth table

Conditions	Input	Output	Status
Normal operation	L	L	H
	H	H	H
Current limitation	L	L	H
	H	X	$(T_j < T_{TSD})$ H
	H	X	$(T_j > T_{TSD})$ L
Overtemperature	L	L	H
	H	L	L
Undervoltage	L	L	X
	H	L	X
Overvoltage	L	L	H
	H	L	H

Table 12. Truth table

Conditions	Input	Output	Status
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 on V_{CC} 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 μ s 50 Ω
3b	+25 V	+50 V	+75 V	+100 V	0.1 μ s 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

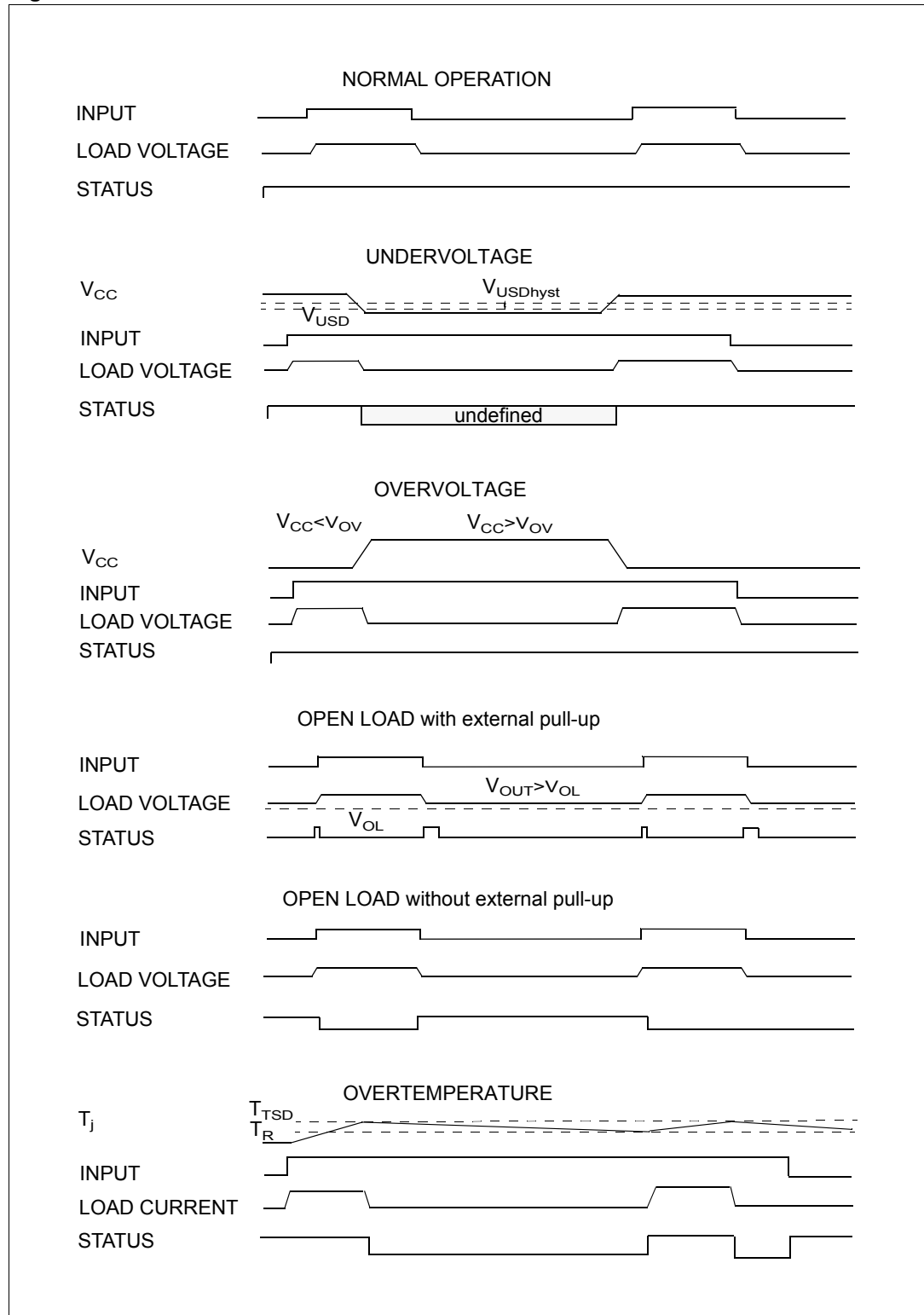
Table 14. Electrical transient requirements on V_{CC} pin (part 2/3)

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 15. Electrical transient requirements on V_{CC} 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

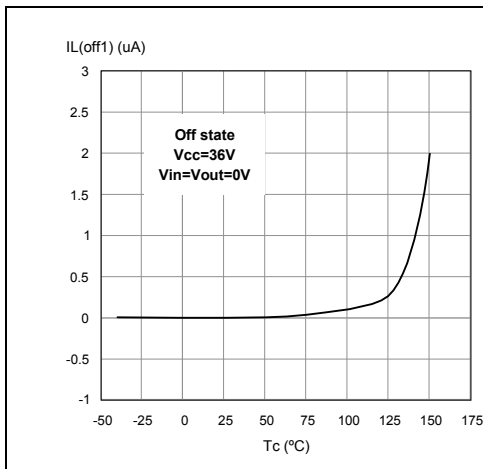


Figure 8. High level input current

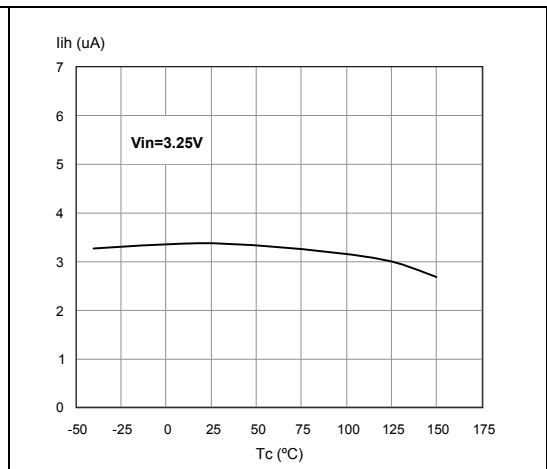


Figure 9. Input clamp voltage

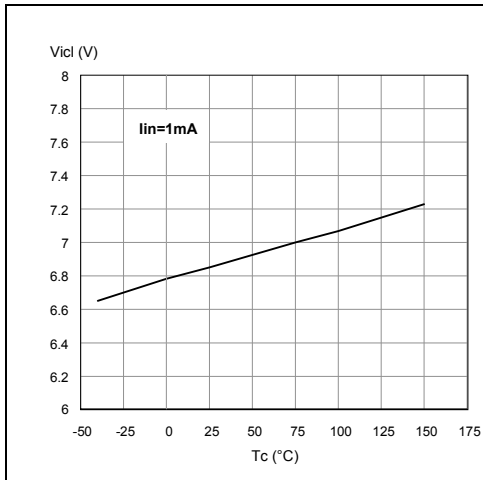


Figure 10. Status leakage current

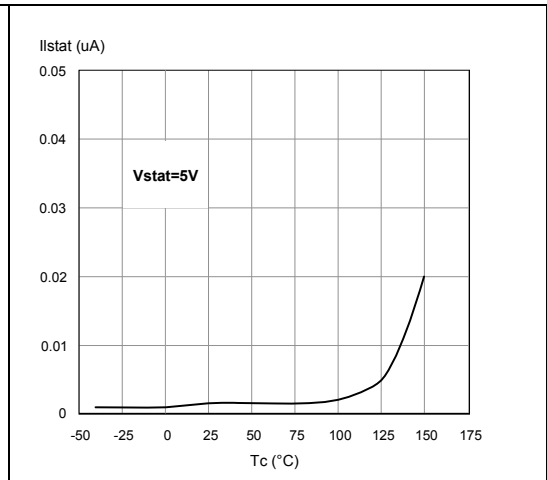


Figure 11. Status low output voltage

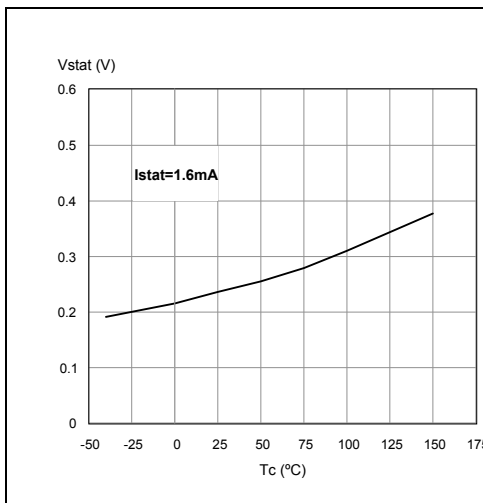


Figure 12. Status clamp voltage

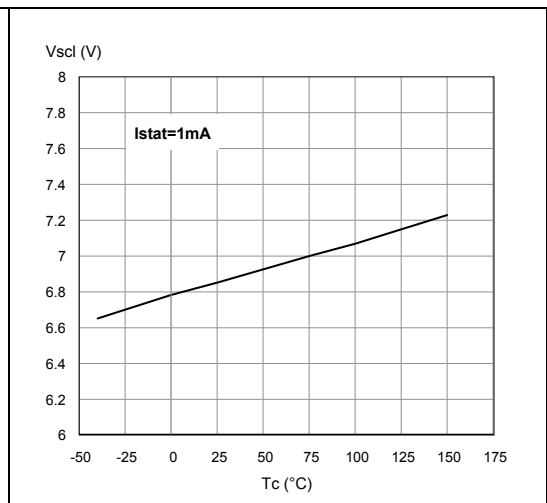


Figure 13. On-state resistance vs T_{case}

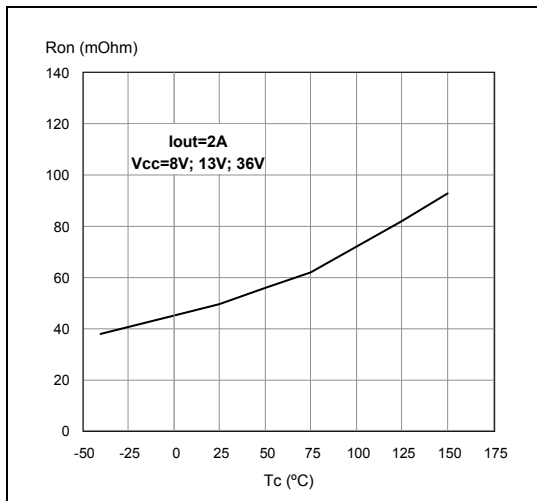


Figure 14. On-state resistance vs V_{CC}

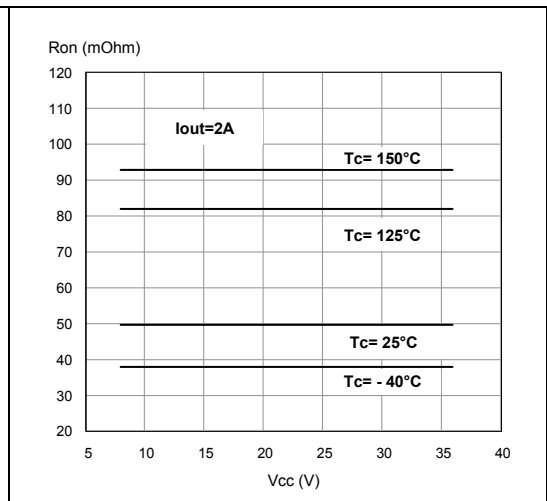


Figure 15. Open-load on-state detection threshold

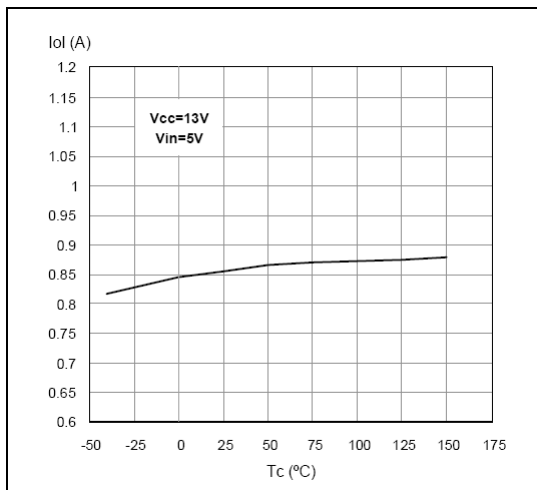


Figure 16. Open-load off-state voltage detection threshold

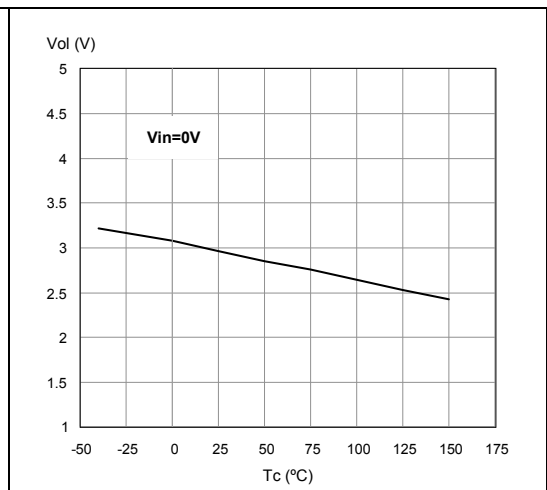


Figure 17. Input high level

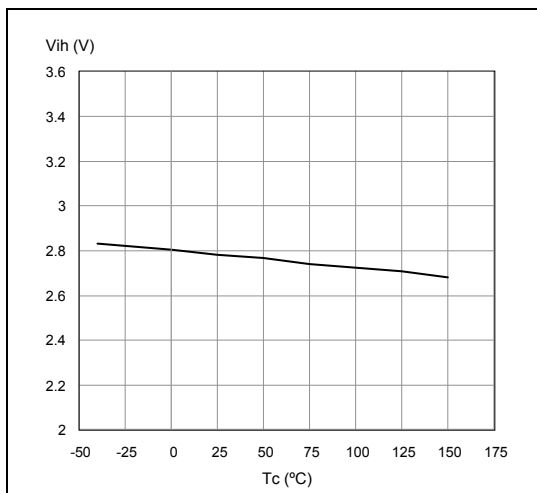


Figure 18. Input low level

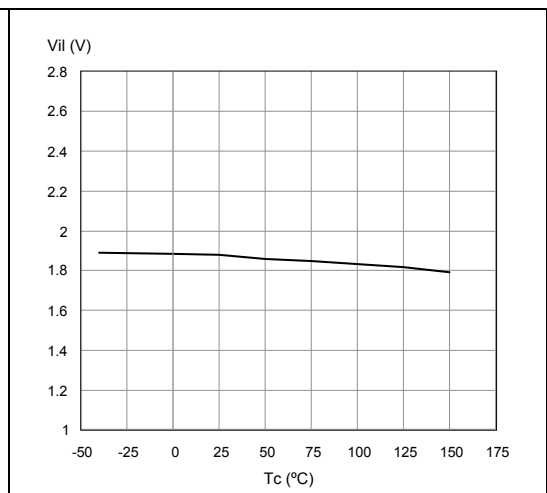


Figure 19. Turn-on voltage slope

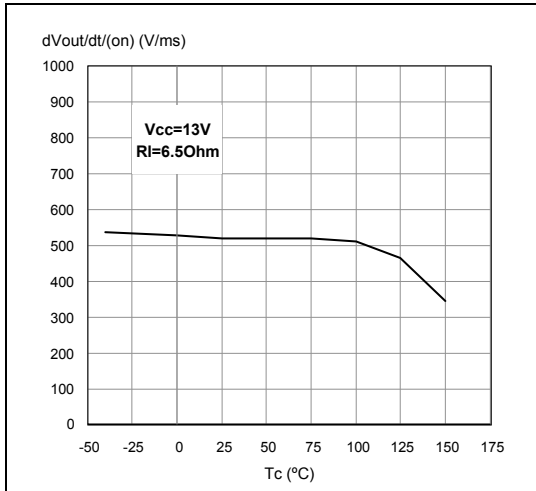


Figure 20. Turn-off voltage slope

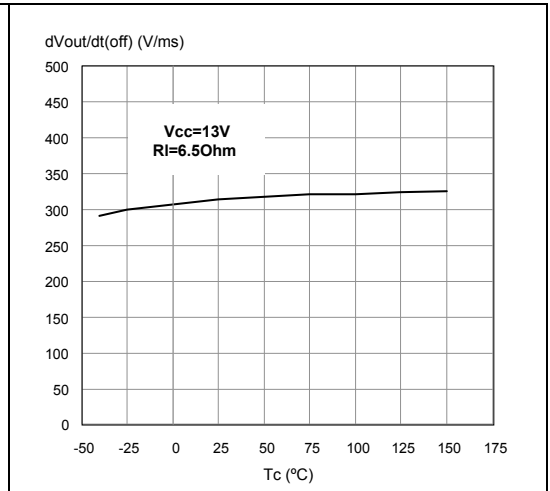


Figure 21. Overvoltage shutdown

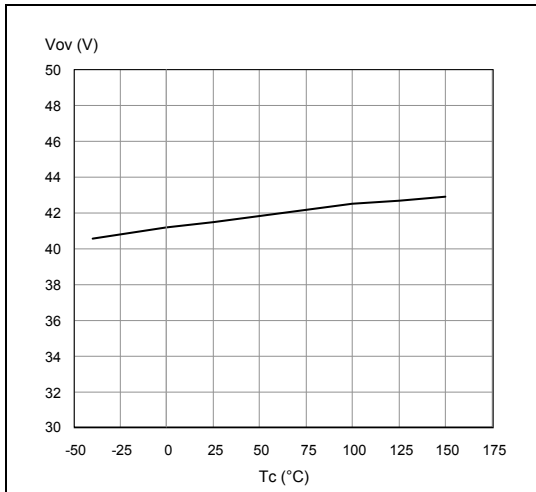


Figure 22. I_{lim} vs T_{case}

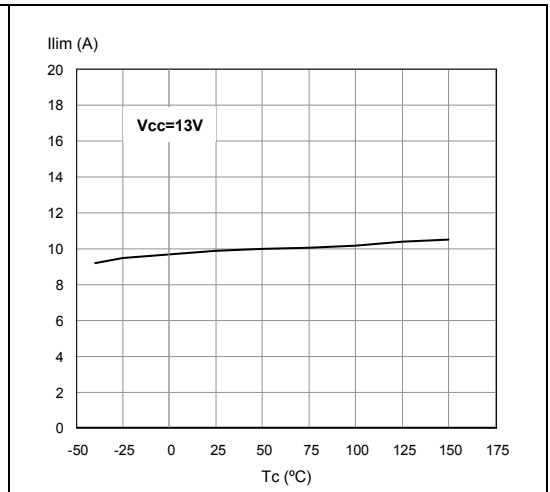


Figure 23. Input hysteresis voltage

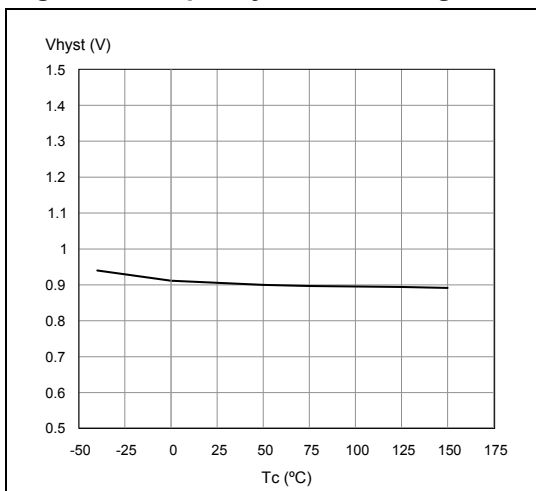
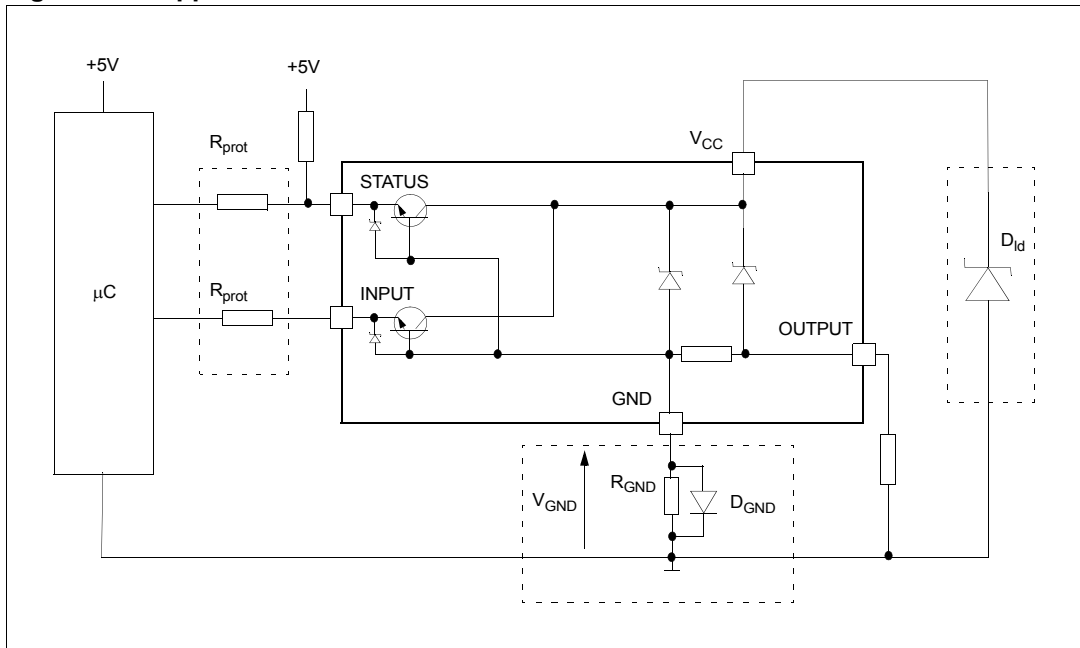


Figure 24. Application schematic



2.5 GND protection network against reverse battery

2.5.1 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} 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_{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).

2.5.2 Solution 2: diode (D_{GND}) in the ground line

A resistor ($R_{GND}=1\text{ k}\Omega$) 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 produces a shift ($\approx 600\text{mV}$) in the input threshold and in the status output values if the microprocessor ground is not common to 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 and status pin is to leave them unconnected.

2.6 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 T/R 7637/1 table.

2.7 Microcontroller I/Os protection

If a ground protection network is used and negative transient 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 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 $V_{CCpeak} = -100\text{ V}$ and $I_{latchup} \geq 20\text{ mA}$; $V_{OH\mu C} \geq 4.5\text{ V}$

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

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

2.8 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 +5 V line used to supply the microprocessor.

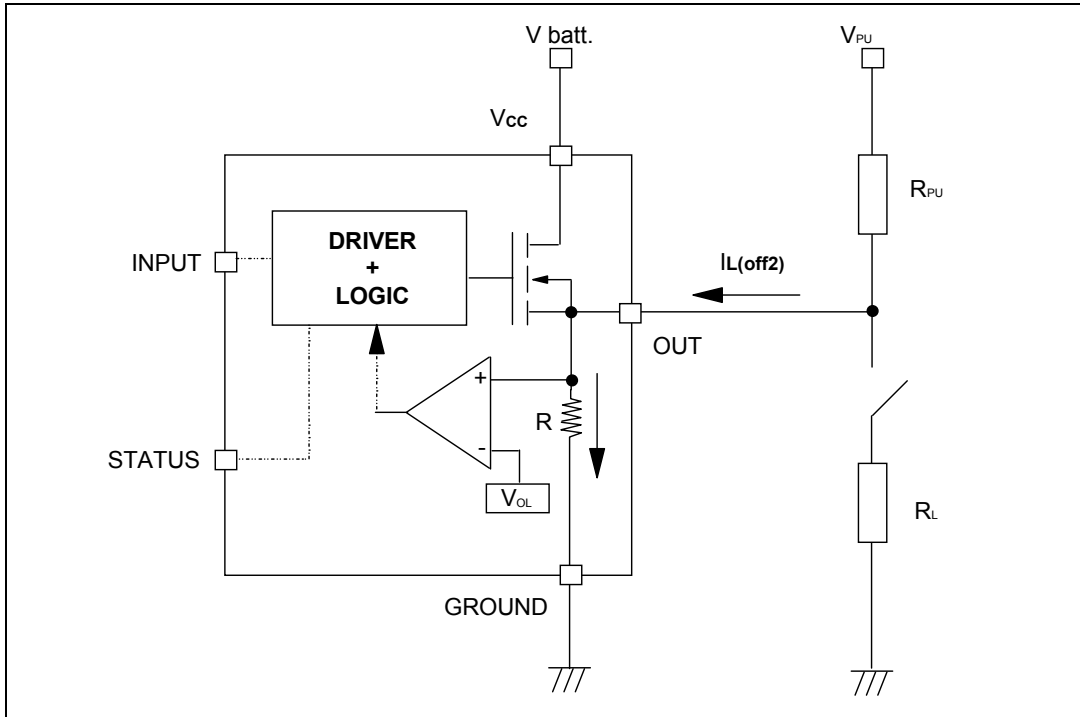
The external resistor has to be selected according to the following requirements:

- 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.

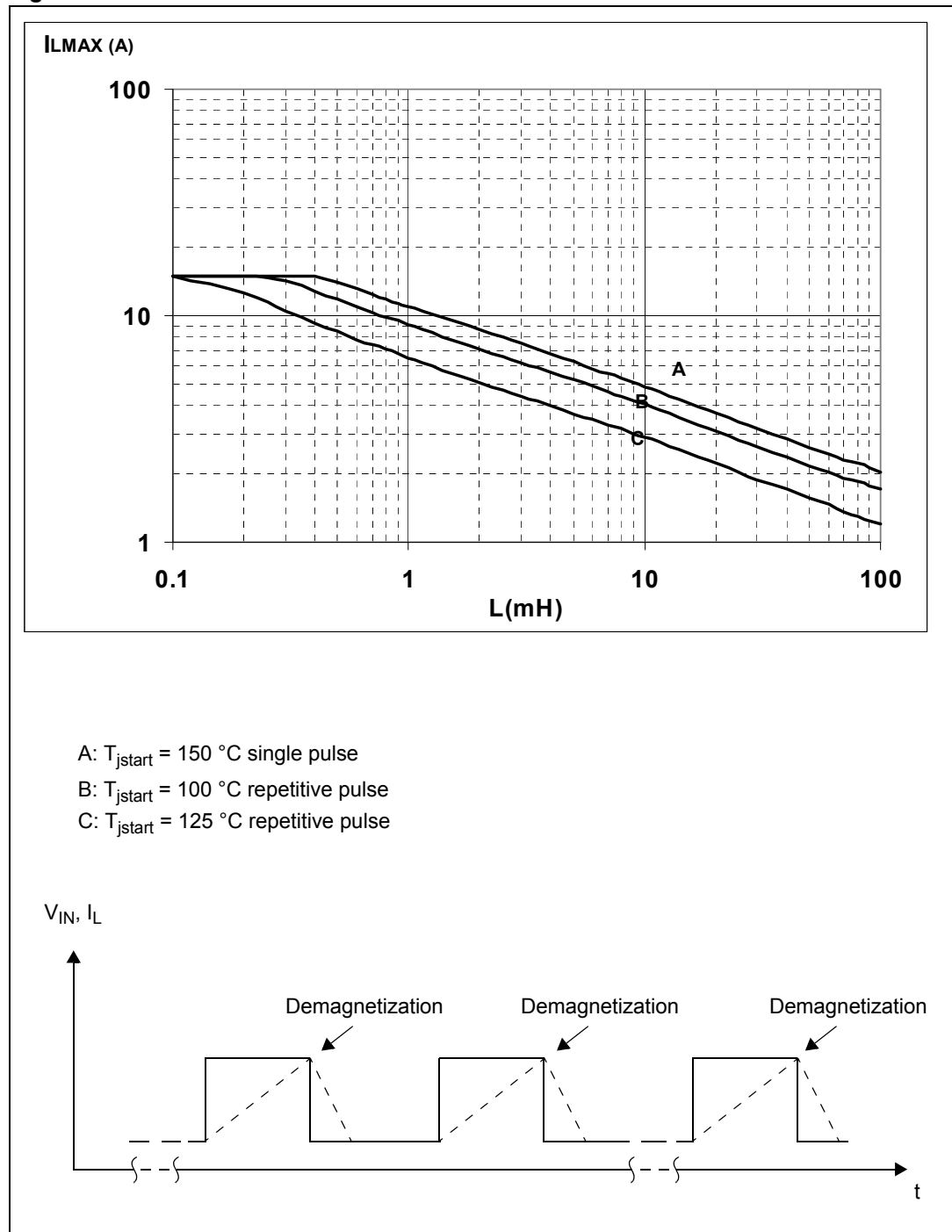
The values of V_{OLmin} , V_{OLmax} and $I_{L(off2)}$ are available in the electrical characteristics section.

Figure 25. Open-load detection in off-state



2.9 SO-8 maximum demagnetization energy ($V_{CC} = 13.5\text{ V}$)

Figure 26. SO-8 maximum turn-off current versus inductance

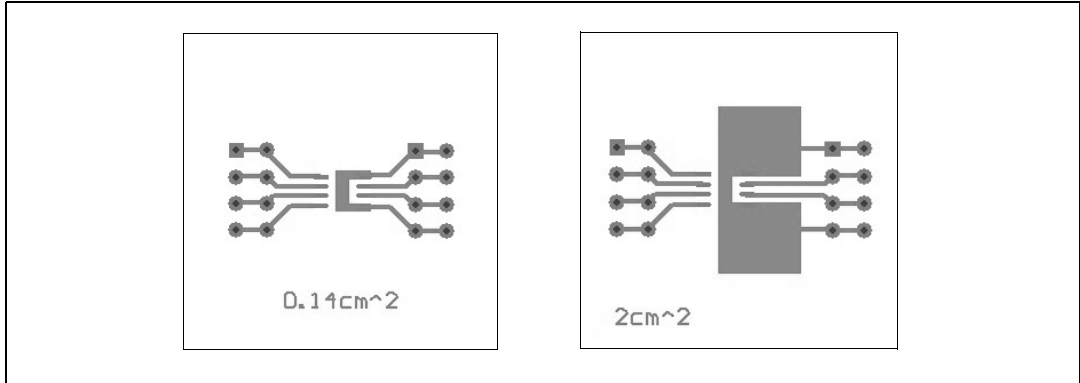


Note: Values are generated with $R_L = 0\ \Omega$. In case of repetitive pulses, T_{jstart} (at beginning of each demagnetization) of every pulse must not exceed the temperature specified above for curves B and C.

3 Package and PCB thermal data

3.1 SO-8 thermal data

Figure 27. SO-8 PC board



Note: Layout condition of R_{th} and Z_{th} measurements (PCB FR4 area = 58 mm x 58 mm, PCB thickness = 2 mm, Cu thickness=35 μ m, Copper areas: 0.14 cm², 2 cm²).

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

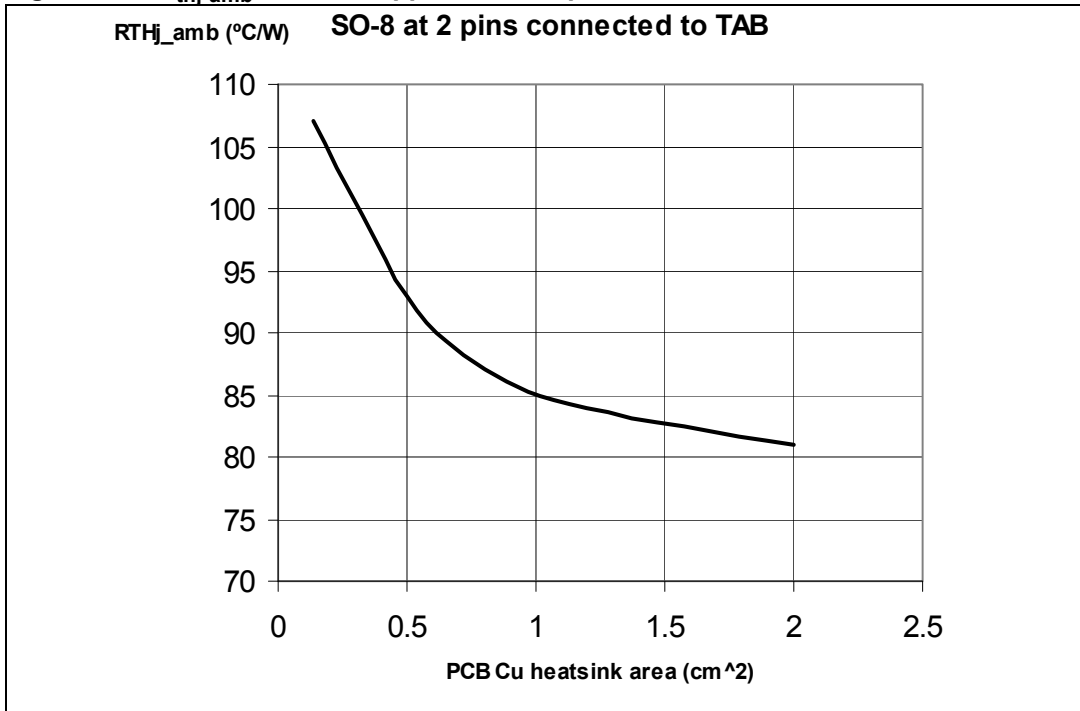
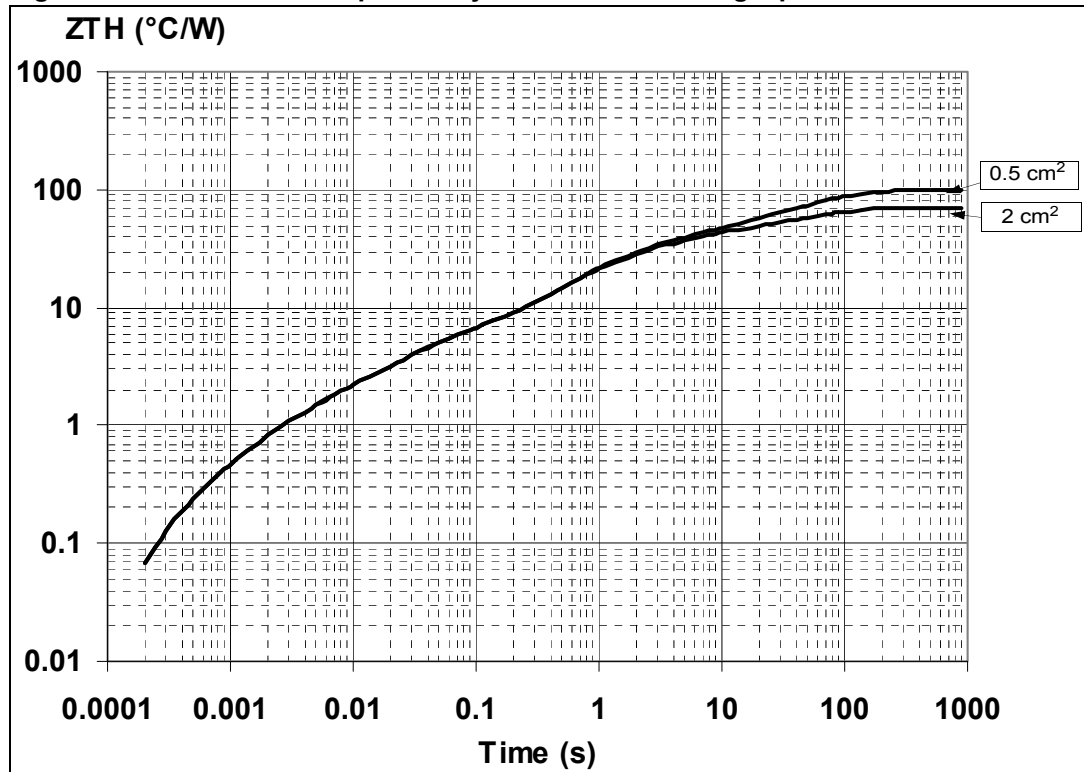


Figure 29. SO-8 thermal impedance junction ambient single pulse



Equation 1: pulse calculation formula

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

where $\delta = t_p/T$

Figure 30. SO-8 thermal fitting model of a single channel

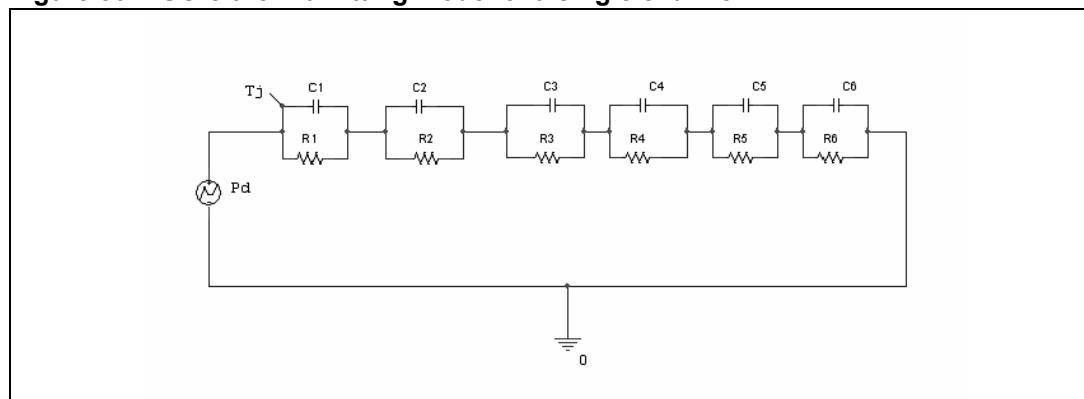


Table 16. SO-8 thermal parameter

Area/island (cm ²)	0.5	2
R1 (°C/W)	0.05	
R2 (°C/W)	0.8	
R3 (°C/W)	3.5	

Table 16. SO-8 thermal parameter (continued)

Area/island (cm ²)	0.5	2
R4 (°C/W)	21	
R5 (°C/W)	16	
R6 (°C/W)	58	28
C1 (W·s/°C)	0.006	
C2 (W·s/°C)	2.60E-03	
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

4 Package and packing information

4.1 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.

4.2 SO-8 mechanical data

Figure 31. SO-8 package dimensions

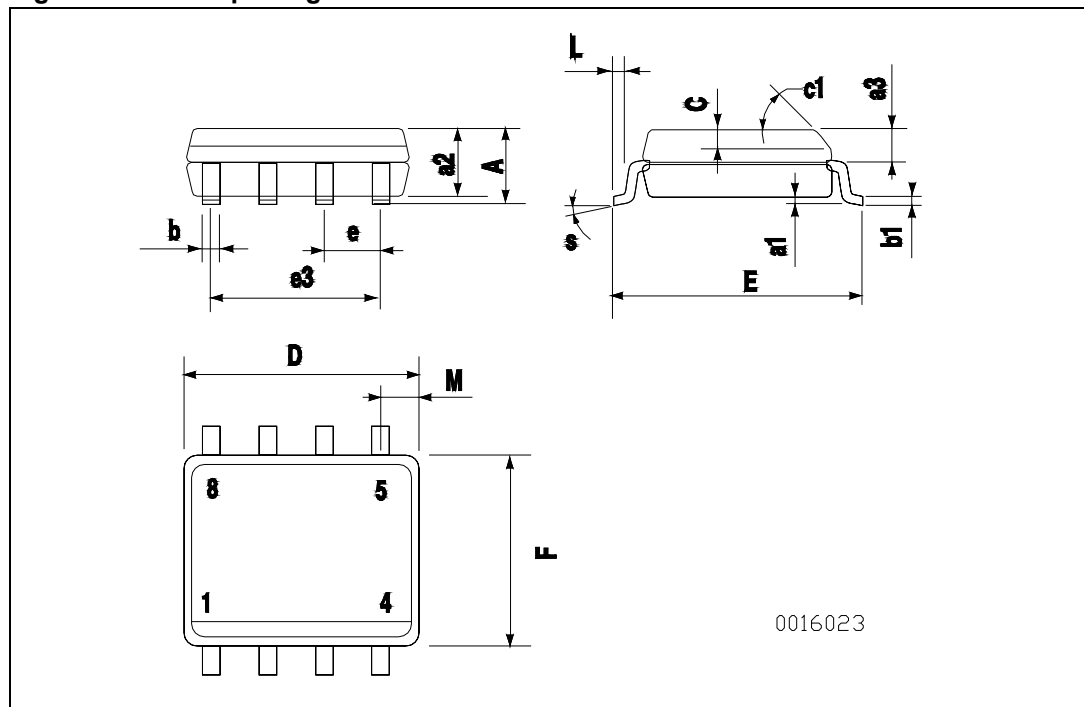


Table 17. SO-8 mechanical data

Dim.	Millimeter		
	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

Table 17. SO-8 mechanical data (continued)

Dim.	Millimeter		
	Min.	Typ.	Max.
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

4.3 Packing information

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

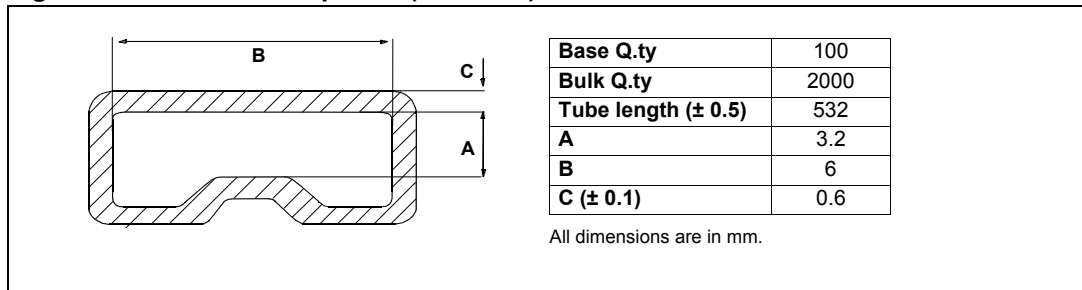
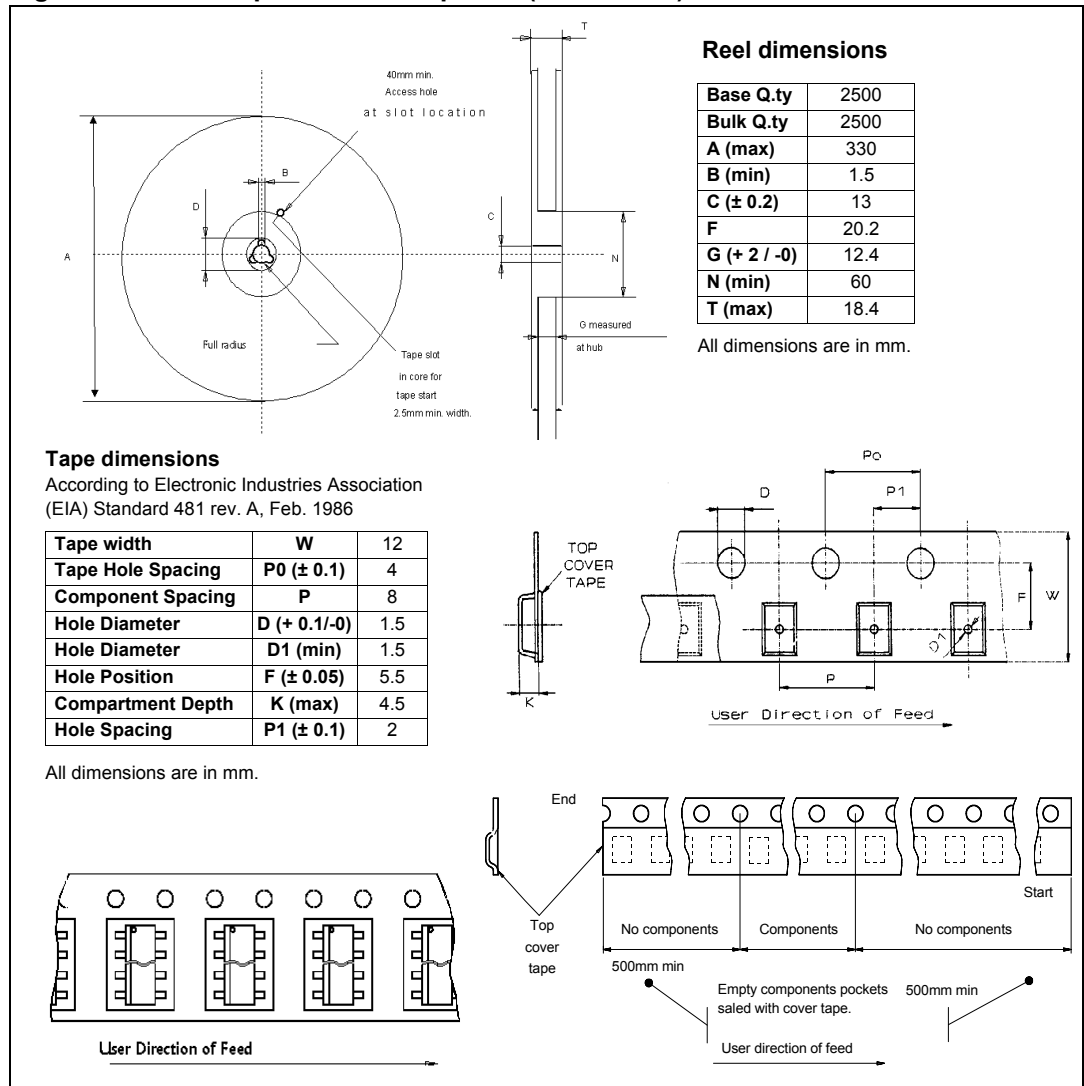


Figure 33. SO-8 tape and reel shipment (suffix “TR”)



5 Revision history

Table 18. Document revision history

Date	Revision	Changes
18-Nov-2009	1	Initial release.
20-Sep-2013	2	Updated Disclaimer.