

## Automation sensor transient and overvoltage protection

Datasheet – production data



Figure 1. SPT01-335 configuration diagram

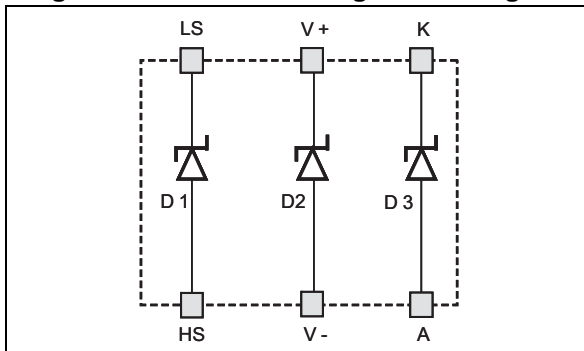
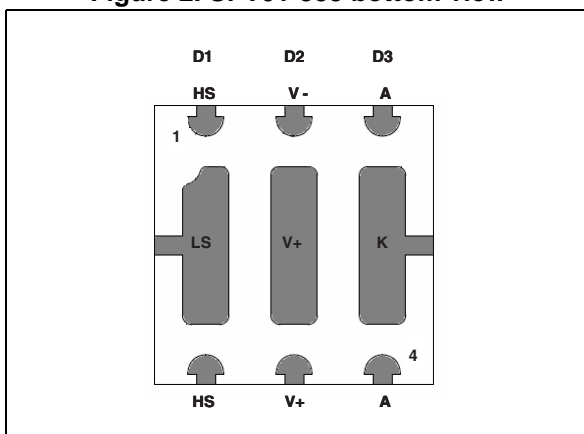


Figure 2. SPT01-335 bottom view



### Features

- Triple diode array for power bus protection, switch protection and reverse blocking protection

- Flexible connection for NPN low side or PNP high side sensor configuration
- 6 V to 36 V supply voltage range
- Stand-off voltage: 36 V
- Minimum breakdown voltage  $V_{BR}$ : 38 V
- 8/20  $\mu$ s 2A maximum clamping voltage: 46 V
- Direct sensor switch current: 300 mA
- Blocking diode drop forward voltage  $V_F$ : 1 V at 300 mA
- Blocking diode maximum 10 ms square pulse current  $I_{FSM}$ : 1 A
- Ambient temperature: -40 °C to +100 °C
- QFN3x3-6L 1 mm flat package: 3x3 mm
- Voltage surge: EN 60947-5-2 or IEC 61000-4-5 with  $R_{CC} = 500 \Omega$ :  $\pm 1$  kV
- Electrostatic discharge ESD, IEC 61000-4-2:  $\pm 8$  kV in contact,  $\pm 15$  kV in air
- Electrical transient immunity, IEC 61000-4-4:  $\pm 2$  kV

### Benefits

- Compliant for interface with logic input type 1, 2 and 3 IEC 61131-2 standard
- Recommended to protect any 3-wire sensor compliant with EN 60947-5-2 standard
- Highly compact with integrated power solution in SMD version

### Applications

- Factory automation sensor application
- Proximity sensor interface protection
- Transient and surge voltage protection
- Compliant with sensor standard, EN60947-5-2

# 1 Description

The SPT01-335 is specifically designed for the protection of 24 V proximity sensors. It implements the reverse polarity and the overvoltage protection of the sensor power supply and the power switch overvoltage protection.

It provides a very compact and flexible solution offering two connections for PNP or NPN sensors as shown in [Figure 8](#) and [Figure 9](#).

Thanks to high performance ST technology, the SPT01-335 protects the proximity sensor to the highest level compliant with IEC 61000-4-2, IEC 61000-4-4 and IEC 60947-5-2 / IEC 61000-4-5 standards.

## 2 Characteristics

**Table 1. Pinout connections (see [Figure 2](#))**

Pin #	Name	Description
Exposed pad aligned with pins 1 and 6	LS	D1 Power bus protection diode cathode
1, 6	HS	D1 Power bus protection diode anode
5, Exposed pad aligned with pins 2 and 5	V+	D2 sensor switch protection diode cathode; pin 5 internally connected to mid pad
2	V-	D2 sensor switch protection diode anode
Exposed pad aligned with pins 3 and 4	K	D3 reverse blocking protection diode cathode
3, 4	A	D3 reverse blocking protection diode anode

**Table 2. Absolute ratings ( $T_{amb} = 25\text{ °C}$ )**

Symbol	Diode	Parameter	Value	Unit
$V_{PP}$	All	ESD protection, IEC 61000-4-2, per diode, in air <sup>(1)</sup>	15	kV
		ESD protection, IEC 61000-4-2, per diode, in contact <sup>(1)</sup>	8	kV
$V_{PP}$	All	Peak Surge Voltage, IEC 61000-4-5, per diode, $R_{CC} = 500\ \Omega$ , <sup>(1)</sup>	1	kV
$I_{PP}$	All	Peak pulse forward and reverse current, $t_p = 8/20\ \mu\text{s}$	2	A
$P_{PP}$	All	Peak pulse power dissipation, $T_J = T_{amb} = 100\text{ °C}$ , $t_p = 8/20\ \mu\text{s}$	100	W
$I_{FSM}$	All	Maximum forward surge current, $t_p = 10\text{ ms square}$	1	A
$E_{AR}$	D1	Maximum repetitive avalanche energy $L = 1\text{ H}$ , $I_{RAS} = 0.3\text{ A}$ , $R_S = 100\ \Omega$ , $V_{CC} = 30\text{ V}$ , $T_{amb} = 85\text{ °C}$ <sup>(1)</sup>	60	mJ
$T_J$	All	Storage junction temperature range	- 40 to 175	°C

1. See system oriented test circuits in [Figure 11](#) (ESD) and [Figure 10](#) (Surge as also described in IEC 60947-5-2).

**Table 3. Recommended operating conditions**

Symbol	Parameter	Value	Unit
$V_{CC}$	Operating power bus supply voltage	-30 to 36	V
	Pulse repetitive voltage $t_p = 0.5\text{ s}$ , $R_{CC} = 500\ \Omega$	-30 to 35	V
$I_F$	D3 forward peak current $T_J = 150\text{ °C}$ duty cycle = 50%	300	mA
$T_{amb}$	Operating ambient temperature range	-40 to 100	°C
$T_J$	Operating junction temperature range <sup>(1)</sup>	-40 to 175	°C

1. Extended from DC operating at 150 °C up to peak repetitive value during the inductive load demagnetization

**Table 4. Electrical characteristics ( $T_J = 25\text{ }^\circ\text{C}$ , unless otherwise specified)**

Symbol	Diode	Name	Test conditions		Value	Unit
$V_{RM}$	All	Reverse stand off voltage <sup>(1)</sup>	$I_R = 0.2\ \mu\text{A}$	Min	33	V
			$I_R = 1\ \mu\text{A}$	Min	36	V
$I_{RM}$	All	Leakage reverse current	$V_{RM} = 33\ \text{V}$	Max	0.2	$\mu\text{A}$
			$V_{RM} = 33\ \text{V}$ , $T_J = 150\text{ }^\circ\text{C}$	Max	1	$\mu\text{A}$
$V_{BR}$	All	Reverse breakdown voltage	$I_R = 1\ \text{mA}$	Min	38	V
				Typ	41.4	V
$V_{CL}$	All	Peak clamping voltage	$I_{PP} = 2\ \text{A}$ , $t_P = 8/20\ \mu\text{s}$	Max	46	V
				Typ	44	V
$R_D$	All	8/20 $\mu\text{s}$ dynamic resistance		Typ	0.5	$\Omega$
$\alpha_T$	All	$V_{BR}$ Temperature sensitivity		Max	10	$10^{-4}/^\circ\text{C}$
$V_{CL}$	D1	Peak clamping voltage	$I_R = 0.3\ \text{A}$ , $L = 1\ \text{H}$ , $t_P = 8/20\ \mu\text{s}$ , $V_{CC} = 30\ \text{V}$	Max	46	V
$V_F$	D3	Forward drop voltage	$I_F = 300\ \text{mA}$	Max	1	V

1. Reverse stand-off voltage is valid for ambient temperature within the operating temperature range.

**Table 5. Thermal resistance**

Symbol	Parameter	Value	Unit
$R_{th(j-a)}$	SMD thermal resistance junction to ambient, per diode FR4 board, copper thickness = 35 $\mu\text{m}$ , $S_{Cu} = 0.85\ \text{mm}^2$	330	$^\circ\text{C}/\text{W}$
$Z_{th(j-a)}$	SMD thermal transient impedance junction to ambient, per diode $t_p = 15\ \text{ms}$ , $T_{amb} = 85\text{ }^\circ\text{C}$ , $S_{Cu} = 0.85\ \text{mm}^2$	20	$^\circ\text{C}/\text{W}$

Figure 3. Relative variation of peak pulse power versus initial junction temperature

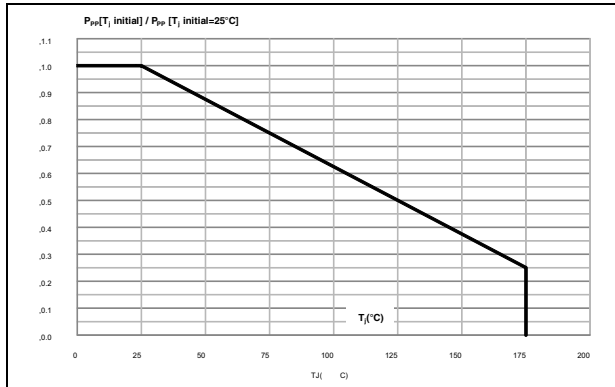


Figure 4. Peak pulse power versus exponential pulse duration (typical values)

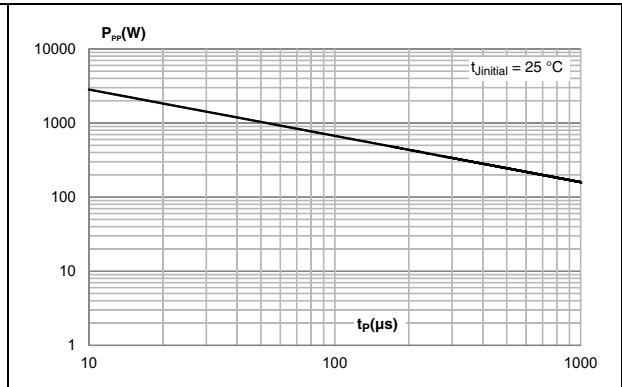


Figure 5. Clamping voltage versus peak pulse current (typical values)

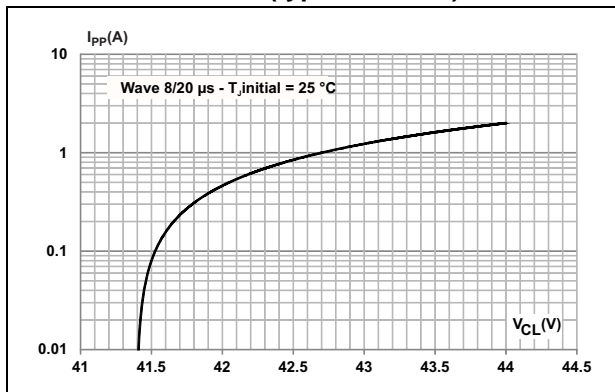


Figure 6. Forward voltage drop versus peak forward current (typical values)

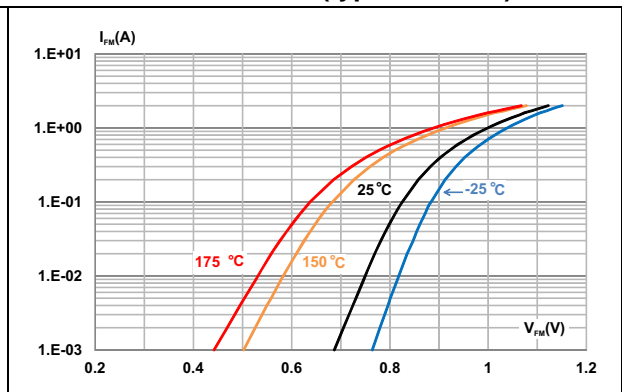
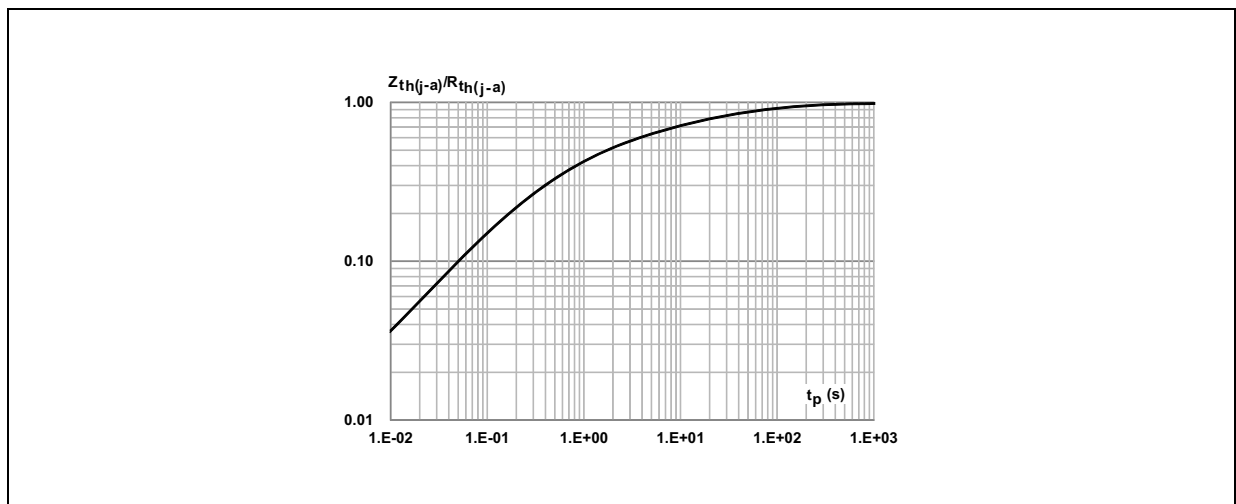


Figure 7. Relative variation of thermal impedance junction to ambient versus pulse duration (printed circuit board)



### 3 SPT01-335 basic application

Figure 8. PNP high side sensor configuration

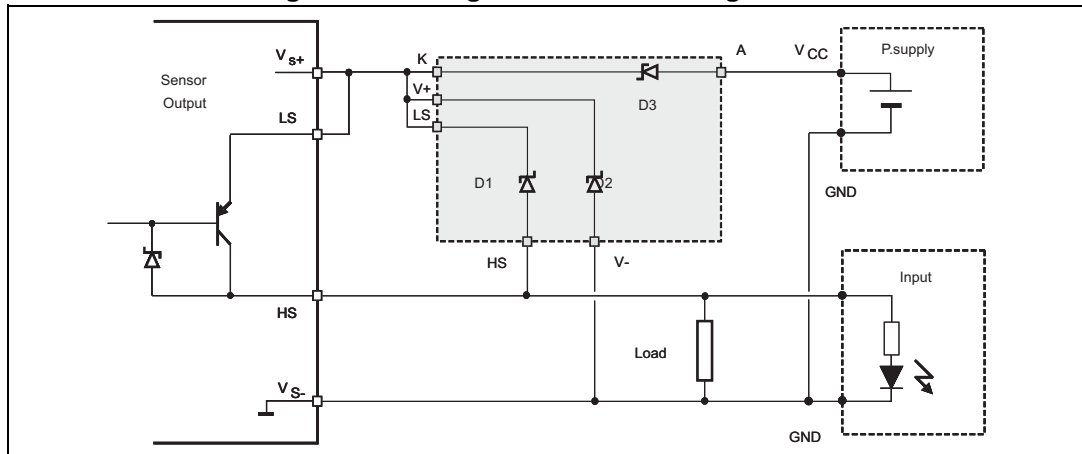


Figure 9. NPN low side sensor configuration

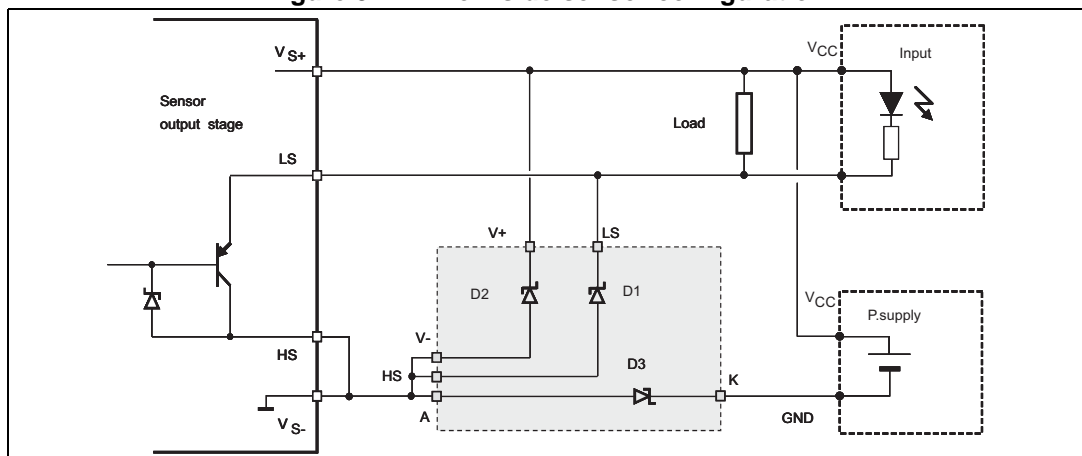


Table 6. SPT01-335 pin connection versus sensor output stage configuration as shown on [Figure 8](#). and [Figure 9](#)

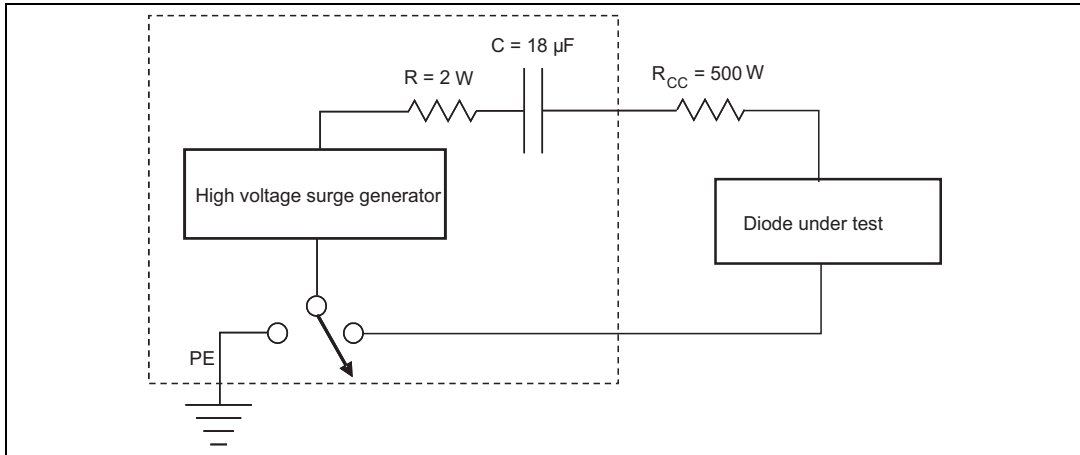
Sensor type	SPT01-335 terminal connection					
	LS	HS	A	K	V+	V-
PNP	To $V_{S+}$	Sensor HS	$V_{CC}$	To $V_{S+}$	Sensor $V_{S+}$	Sensor $V_{S-}$
NPN	Sensor LS	To $V_{S-}$	To $V_{S-}$	To GND		

*Note:* It is advised to use diodes D1 and D3, which are the external devices in the package, as switch overvoltage protection and power supply reverse polarity protection since they allow better cooling design with PCB pad implementation. D2, the middle diode, can be dedicated to the power supply overvoltage protection because it would run only in pulse mode with basic PCB pad footprint.

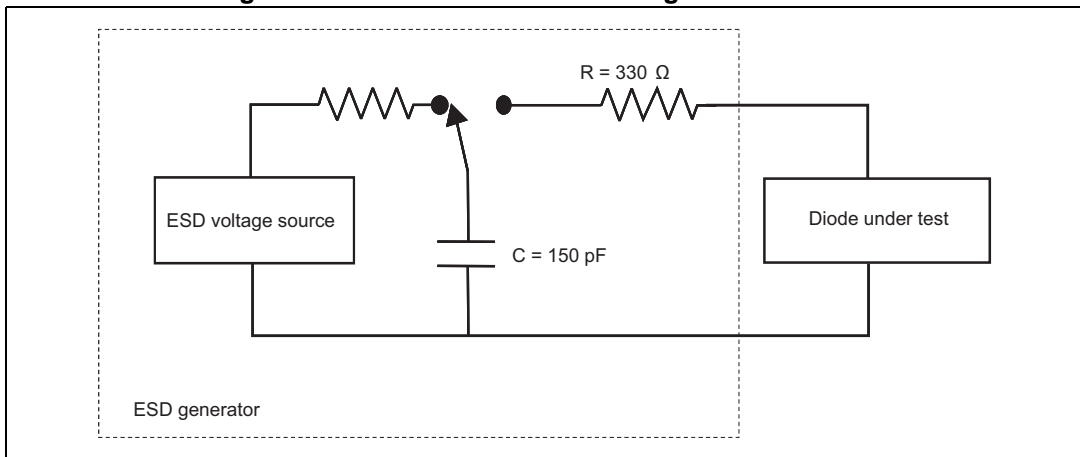
## 4 System related electromagnetic compatibility ratings

Refer to [Table 3](#) for test performance.

**Figure 10. Surge Voltage test circuit according to IEC 61000-4-5 with 500 Ω serial resistor**



**Figure 11. ESD test circuit according to IE 61000-4-2**



## 5 Evaluation of the clamping voltage

$$V_{BR}(T_J) = V_{BR}(25) \times (1 + \alpha T (T_J - 25))$$

$$V_{CL\ MAX}(8/20\ \mu s) = V_{BR\ MAX} + R_D \times I_{PP}$$

### 5.1 Application considerations

#### 5.1.1 Demagnetization of an inductive load driven by the switch protection diode

The turn off energy  $E_{OFF}$  that could be dissipated in the  $D_1$  diode is calculated as shown in AN587 and AN1351 application notes:

$$E_{OFF} = V_{BR} \times L \times [V_{CC} + (V_{CC} - V_{BR}) \times \ln(V_{BR} / (V_{BR} - V_{CC}))] / (R_S)^2$$

$$t_{OFF} = L \times \ln(V_{BR} / (V_{BR} - V_{CC})) / R_S$$

$$P_{OFF} = E_{OFF} / t_{OFF}$$

With  $L = 1\ H$ ;  $I = 0.3\ A$ ;  $V_{BR} = 39\ V$ ;  $V_{CC} = 30\ V$ ,  $R_S = 100\ \Omega$  the stress withstood by  $D_1$  becomes:

$$E_{OFF} = 65\ mJ; t_{OFF} = 15\ ms; P_{OFF} = 4.3\ W$$

In a single pulse mode operation, the junction temperature can be fairly estimated:

$$T_J = T_{amb} + [Z_{th}(t_{OFF}) \times P_{OFF}]$$

In a repetitive operation with an  $F$  repetitive rate,

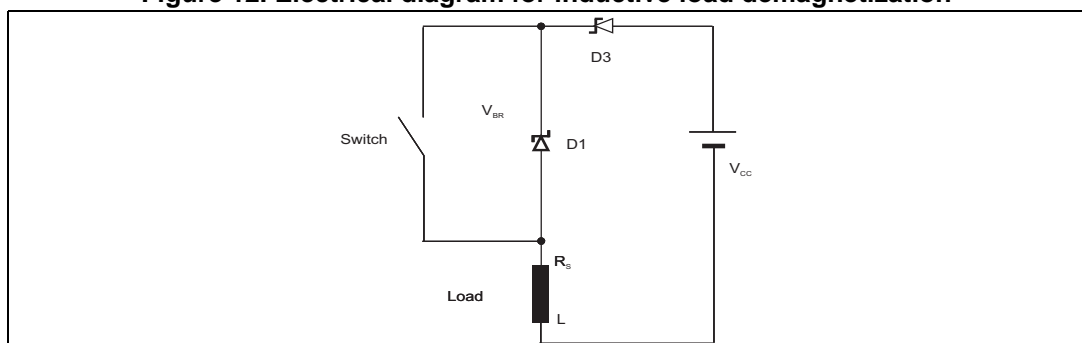
$$P_{AV} = E_{OFF} \times F$$

$$T_{(J\_AV)} = T_{amb} + P_{AV} \times R_{th(j-a)}$$

And during the demagnetization  $t_{OFF}$ ,  $T_{J\_PK} < T_{J\_AV} + P_{OFF} \times Z_{th}(t_{OFF})$

$Z_{TH}$  is the transient thermal impedance of each diode for a pulse having a duration  $t_{OFF}$ .

Figure 12. Electrical diagram for inductive load demagnetization





### 5.1.2 Life time considerations

Life time of the product is calculated to exceed 10 years. The key parameters to consider are the ambient temperature ( $T_{amb} < 100\text{ °C}$ ), the power supply voltage ( $V_{CC} < 30\text{ V}$ ), and the current in the reverse blocking diode ( $I_F = 0.1\text{ A}$  switching at 0.5 Hz with 50% duty cycle, the stand-by current being less than 1.5 mA).

For higher current or higher switching frequency operation, the life time should be calculated considering the peak and average junction temperature.

This junction temperature can be reduced by reducing the thermal resistance of the clamping diode,  $D_1$  normally. This can be done by increasing its PCB copper tab surface  $S_{Cu}$ .

## 6 Package information

- Epoxy meets UL94,V0
- Lead-free package

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](http://www.st.com). ECOPACK® is an ST trademark.

Figure 13. QFN 3x3 package dimension definitions

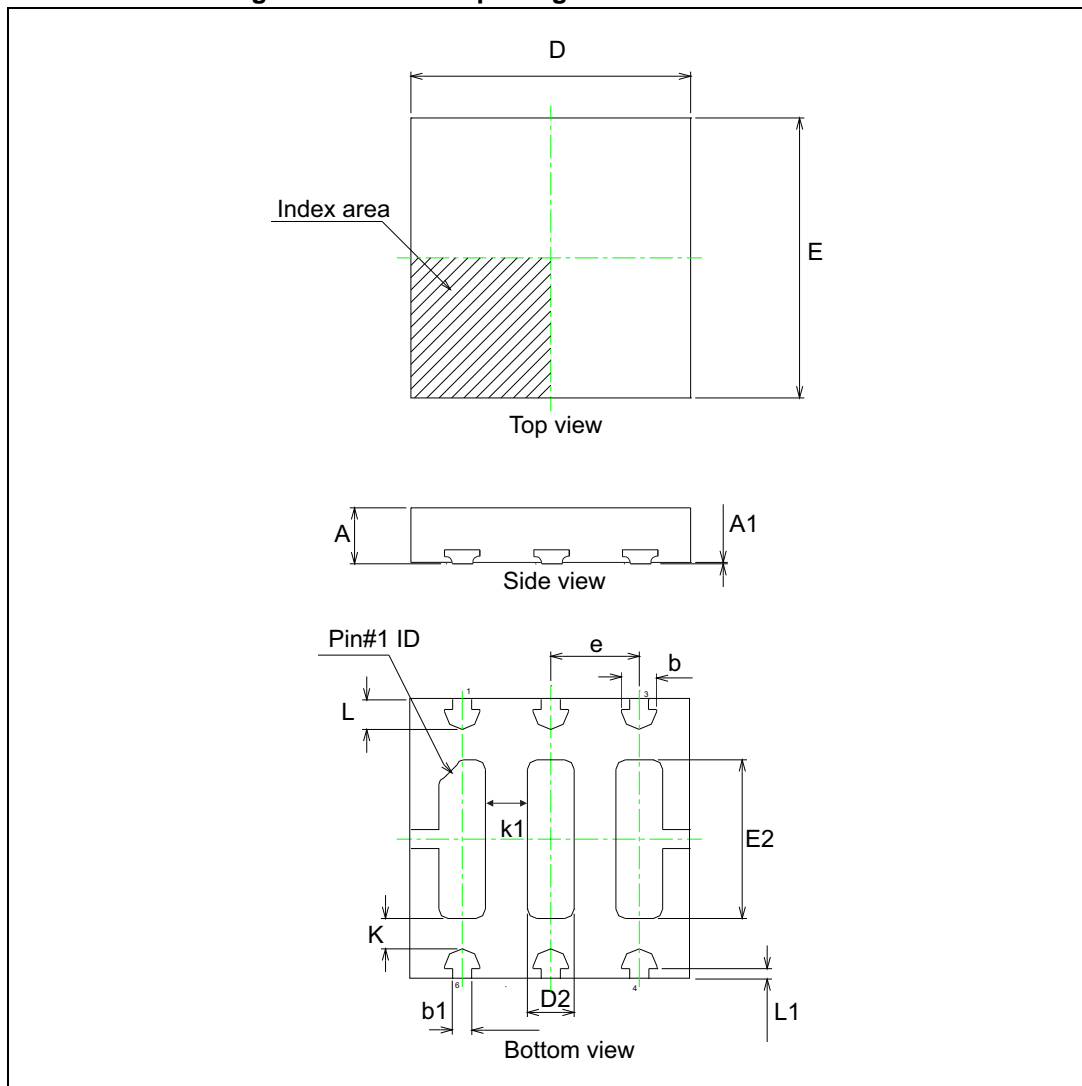
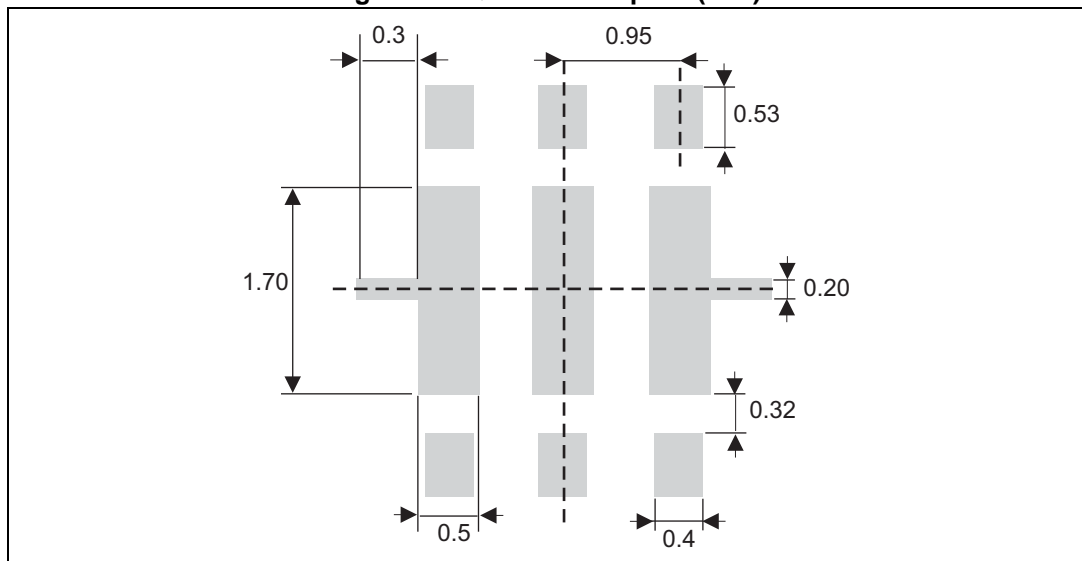


Table 7. QFN 3x3 package dimension values

Ref.	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	0.80	0.90	1.00	0.031	0.035	0.039
A1	0.00	0.02	0.05		0.0007	
b	0.35	0.40	0.45	0.013	0.015	0.017
b1		0.2			0.007	
D	2.95	3.00	3.05	0.116	0.118	0.12
D2	0.35	0.50	0.60	0.013	0.019	0.023
E	2.95	3.00	3.05	0.116	0.118	0.12
E2	1.55	1.70	1.80	0.06	0.066	0.07
e		0.95			0.037	
k	0.20			0.007		
k1		0.45			0.017	
L	0.22	0.33	0.43	0.008	0.012	0.016
L1		0.11			0.004	

Figure 14. QFN 3x3 footprint (mm)

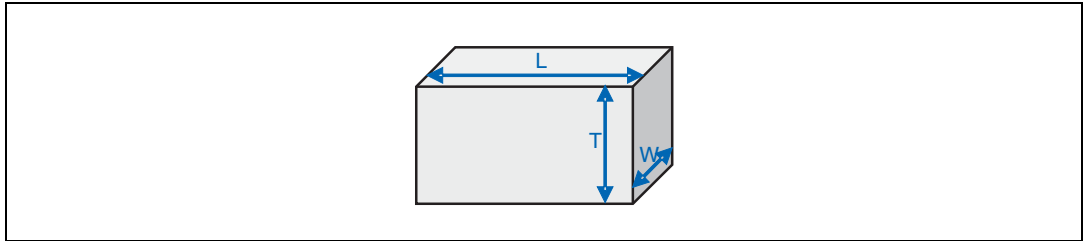


# 7 Recommendation on PCB assembly

## 7.1 Stencil opening design

1. General recommendation on stencil opening design
  - a) Stencil opening dimensions: L (Length), W (Width), T (Thickness).

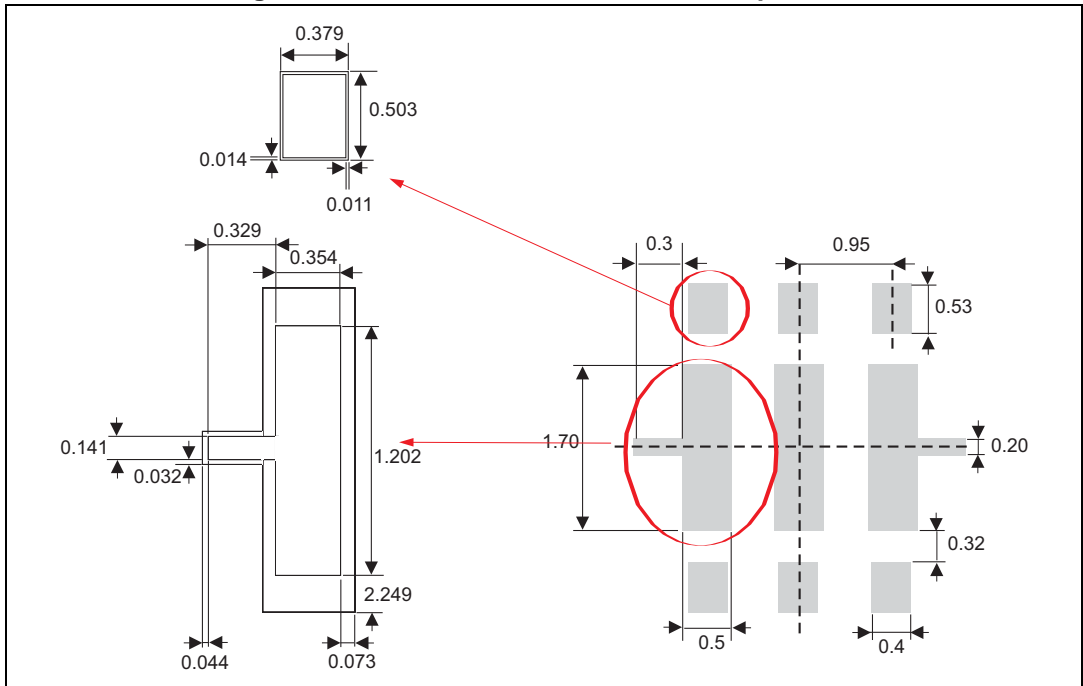
**Figure 15. Stencil opening dimensions**



- b) General design rule
  - Stencil thickness (T) = 75 ~ 125 μm
  - Aspect Ratio =  $\frac{W}{T} \geq 1,5$
  - Aspect Area =  $\frac{L \times W}{2T(L + W)} \geq 0,66$

2. Reference design
  - a) Stencil opening thickness: 100 μm
  - b) Stencil opening for central exposed pad: Opening to footprint ratio is 50%.
  - c) Stencil opening for leads: Opening to footprint ratio is 90%.

**Figure 16. Recommended stencil window position**



## 7.2 Solder paste

1. Halide-free flux qualification ROL0 according to ANSI/J-STD-004.
2. “No clean” solder paste is recommended.
3. Offers a high tack force to resist component movement during high speed.
4. Solder paste with fine particles: powder particle size is 20-45  $\mu\text{m}$ .

## 7.3 Placement

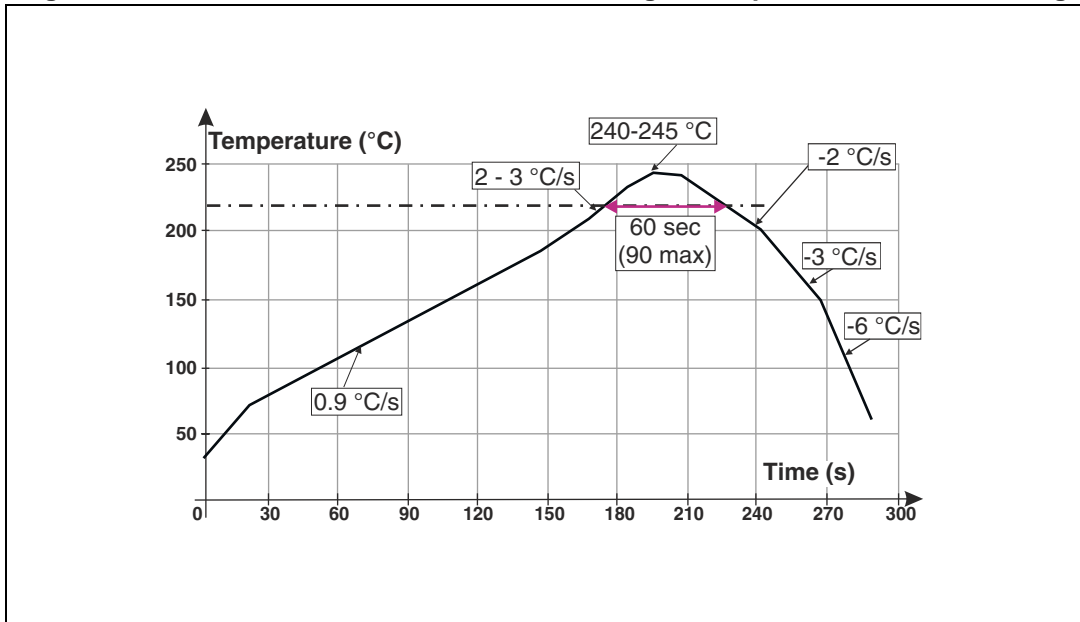
1. Manual positioning is not recommended.
2. It is recommended to use the lead recognition capabilities of the placement system, not the outline centering.
3. Standard tolerance of  $\pm 0.05$  mm is recommended.
4. 3.5 N placement force is recommended. Too much placement force can lead to squeezed out solder paste and cause solder joints to short. Too low placement force can lead to insufficient contact between package and solder paste that could cause open solder joints or badly centered packages.
5. To improve the package placement accuracy, a bottom side optical control should be performed with a high resolution tool.
6. For assembly, a perfect supporting of the PCB (all the more on flexible PCB) is recommended during solder paste printing, pick and place and reflow soldering by using optimized tools.

## 7.4 PCB design preference

1. To control the solder paste amount, the closed via is recommended instead of open vias.
2. The position of tracks and open vias in the solder area should be well balanced. The symmetrical layout is recommended, in case any tilt phenomena caused by asymmetrical solder paste amount due to the solder flow away.

### 7.5 Reflow profile

Figure 17. ST ECOPACK® recommended soldering reflow profile for PCB mounting



Note: Minimize air convection currents in the reflow oven to avoid component movement.

## 8 Ordering information

Figure 18. Ordering information scheme

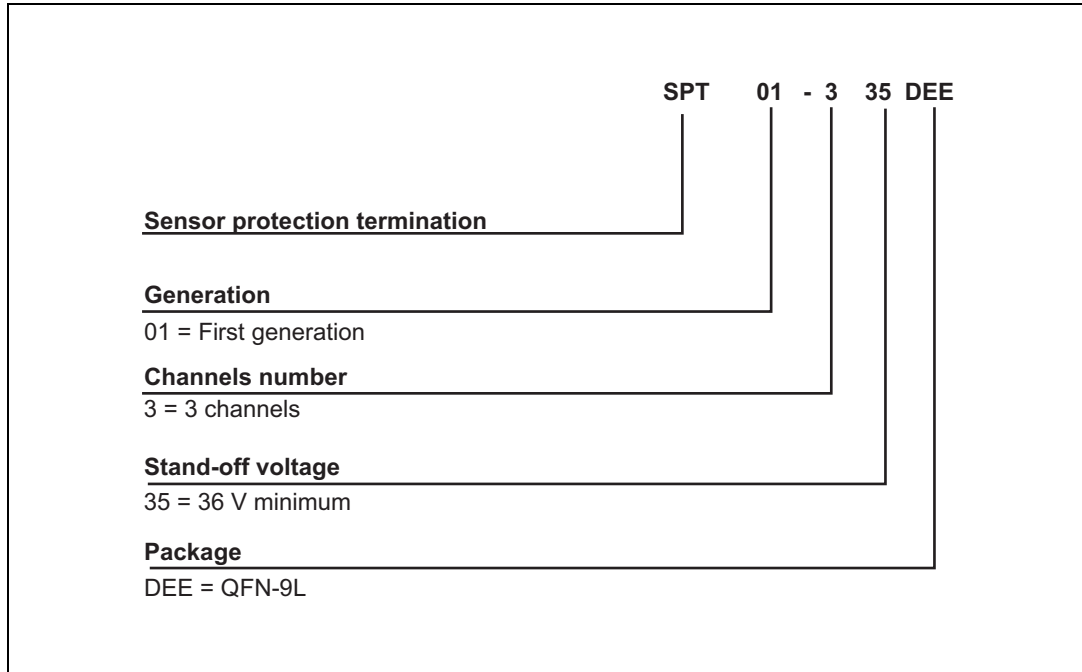


Table 8. Ordering information

Order code	Marking	Package	Weight	Packing
SPT01-335DEE	SP1	QFN 3x3	22.71 mg	Tape and reel

## 9 Revision history

Table 9. Document revision history

Date	Revision	Changes
21-Nov-2008	1	First issue
19-Mar-2012	2	Added UL statement in <a href="#">Chapter 6</a>
03-May-2013	3	Updated features, <a href="#">Table 3</a> , <a href="#">Table 4</a> , <a href="#">Figure 17</a> and <a href="#">Figure 18</a> .

**Please Read Carefully:**

Information in this document is provided solely in connection with ST products. STMicroelectronics NV and its subsidiaries ("ST") reserve the right to make changes, corrections, modifications or improvements, to this document, and the products and services described herein at any time, without notice.

All ST products are sold pursuant to ST's terms and conditions of sale.

Purchasers are solely responsible for the choice, selection and use of the ST products and services described herein, and ST assumes no liability whatsoever relating to the choice, selection or use of the ST products and services described herein.

No license, express or implied, by estoppel or otherwise, to any intellectual property rights is granted under this document. If any part of this document refers to any third party products or services it shall not be deemed a license grant by ST for the use of such third party products or services, or any intellectual property contained therein or considered as a warranty covering the use in any manner whatsoever of such third party products or services or any intellectual property contained therein.

**UNLESS OTHERWISE SET FORTH IN ST'S TERMS AND CONDITIONS OF SALE ST DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY WITH RESPECT TO THE USE AND/OR SALE OF ST PRODUCTS INCLUDING WITHOUT LIMITATION IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE (AND THEIR EQUIVALENTS UNDER THE LAWS OF ANY JURISDICTION), OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.**

**ST PRODUCTS ARE NOT AUTHORIZED FOR USE IN WEAPONS. NOR ARE ST PRODUCTS DESIGNED OR AUTHORIZED FOR USE IN: (A) SAFETY CRITICAL APPLICATIONS SUCH AS LIFE SUPPORTING, ACTIVE IMPLANTED DEVICES OR SYSTEMS WITH PRODUCT FUNCTIONAL SAFETY REQUIREMENTS; (B) AERONAUTIC APPLICATIONS; (C) AUTOMOTIVE APPLICATIONS OR ENVIRONMENTS, AND/OR (D) AEROSPACE APPLICATIONS OR ENVIRONMENTS. WHERE ST PRODUCTS ARE NOT DESIGNED FOR SUCH USE, THE PURCHASER SHALL USE PRODUCTS AT PURCHASER'S SOLE RISK, EVEN IF ST HAS BEEN INFORMED IN WRITING OF SUCH USAGE, UNLESS A PRODUCT IS EXPRESSLY DESIGNATED BY ST AS BEING INTENDED FOR "AUTOMOTIVE, AUTOMOTIVE SAFETY OR MEDICAL" INDUSTRY DOMAINS ACCORDING TO ST PRODUCT DESIGN SPECIFICATIONS. PRODUCTS FORMALLY ESCC, QML OR JAN QUALIFIED ARE DEEMED SUITABLE FOR USE IN AEROSPACE BY THE CORRESPONDING GOVERNMENTAL AGENCY.**

Resale of ST products with provisions different from the statements and/or technical features set forth in this document shall immediately void any warranty granted by ST for the ST product or service described herein and shall not create or extend in any manner whatsoever, any liability of ST.

ST and the ST logo are trademarks or registered trademarks of ST in various countries.

Information in this document supersedes and replaces all information previously supplied.

The ST logo is a registered trademark of STMicroelectronics. All other names are the property of their respective owners.

© 2013 STMicroelectronics - All rights reserved

STMicroelectronics group of companies

Australia - Belgium - Brazil - Canada - China - Czech Republic - Finland - France - Germany - Hong Kong - India - Israel - Italy - Japan - Malaysia - Malta - Morocco - Philippines - Singapore - Spain - Sweden - Switzerland - United Kingdom - United States of America

[www.st.com](http://www.st.com)