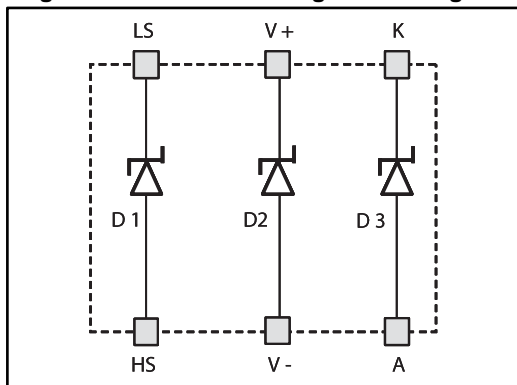
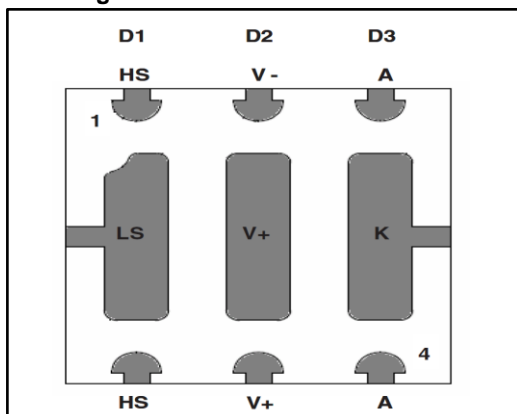


Automation sensor transient and overvoltage protection

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 μ s 2A maximum clamping voltage: 46 V
- Direct sensor switches 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 $RCC = 500 \Omega$: ± 1 kV
- Electrostatic discharge ESD, IEC 61000-4-2: ± 8 kV in contact, ± 15 kV in air
- Electrical transient immunity, IEC 61000-4-4: ± 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

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: "PNP high side sensor configuration"](#) 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.

1 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 maximum ratings (limiting values at $T_{amb} = 25\text{ °C}$ unless otherwise specified)

| Symbol | Diode | Parameter | Value | Unit |
|-----------|-------|--|------------|------|
| V_{pp} | All | ESD protection, IEC 61000-4-2, per diode, in air ⁽¹⁾ | 15 | kV |
| V_{pp} | All | ESD protection, IEC 61000-4-2, per diode, in contact ⁽¹⁾ | 8 | kV |
| V_{pp} | All | Peak Surge Voltage, IEC 61000-4-5, per diode, $R_{CC} = 500\ \Omega$ | 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 $L = 1\text{ H}$, $I_{RAS} = 0.3\text{ A}$, $R_S = 100\ \Omega$, $V_{CC} = 30\text{ V}$, $T_{amb} = 85\text{ °C}$ | 60 | mJ |
| T_j | All | Storage junction temperature range | -40 to 175 | °C |

Notes:

⁽¹⁾See system oriented test circuits in [Figure 11: "ESD test circuit according to IEC 61000-4-2"](#) (ESD) and [Figure 10: "Surge Voltage test circuit according to IEC 61000-4-5 with 500 \$\Omega\$ serial resistor"](#) (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 36 | 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 ⁽¹⁾ | -40 to 175 | °C |

Notes:

⁽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 °C unless otherwise specified)

| Symbol | Diode | Name | Test conditions | | Value | Unit |
|-----------------|-------|--|---|------|-------|----------------------|
| V _{RM} | All | Reverse stand off voltage ⁽¹⁾ | I _R = 0.2 μA | Min. | 33 | V |
| | | | I _R = 1 μA | Min. | 36 | V |
| I _{RM} | All | Leakage reverse current | V _{RM} = 33 V | Max. | 0.2 | μA |
| | | | V _{RM} = 33 V, T _J = 150 °C | Max. | 1 | μA |
| V _{BR} | All | Reverse breakdown voltage | I _R = 1 mA | Min. | 38 | V |
| | | | | Typ. | 41.4 | V |
| V _{CL} | All | Peak clamping voltage | I _{PP} = 2 A, t _P = 8 /20 μs | Max. | 46 | V |
| | | | | Typ. | 44 | V |
| R _D | All | | | Typ. | 0.5 | Ω |
| αT | All | | | Max. | 10 | 10 ⁻⁴ /°C |
| V _{CL} | D1 | | I _R = 0.3 A, L = 1 H, t _P = 8 /20 μs, V _{CC} = 30 V | Max. | 46 | V |
| V _F | D3 | | I _F = 300 mA | Max. | 1 | V |

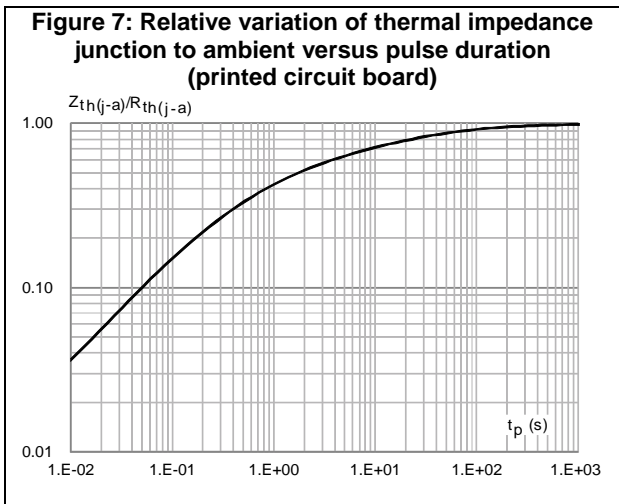
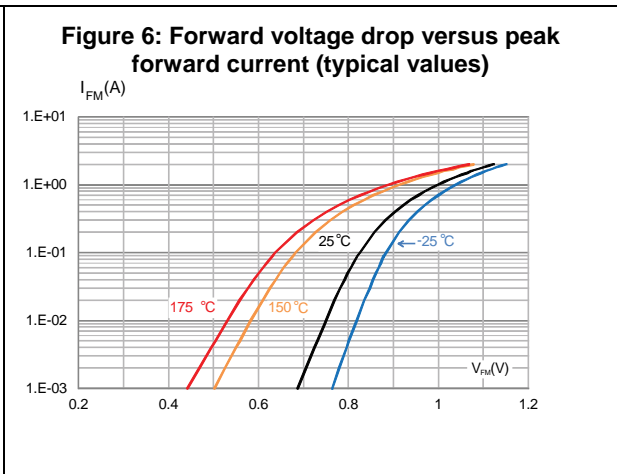
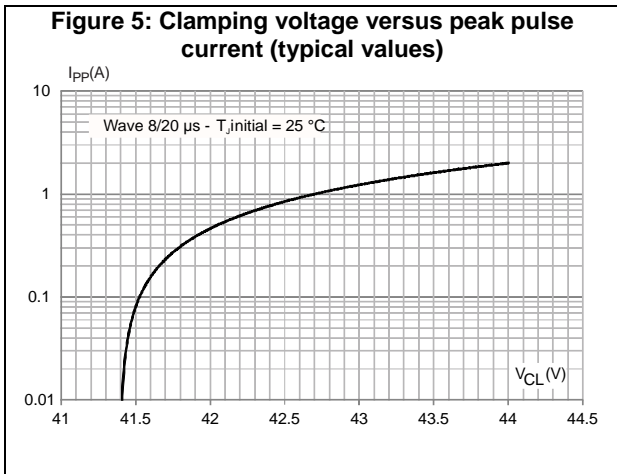
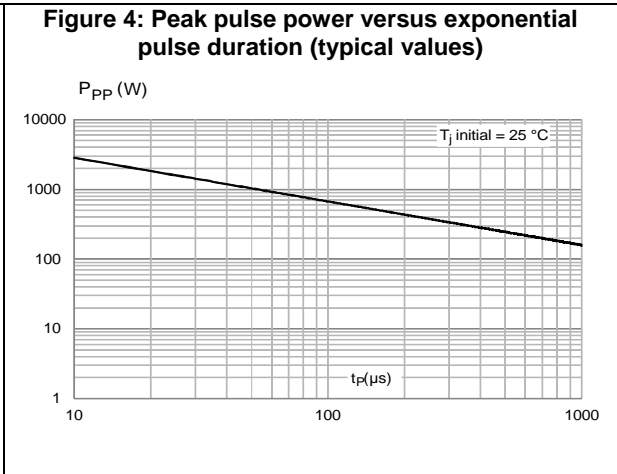
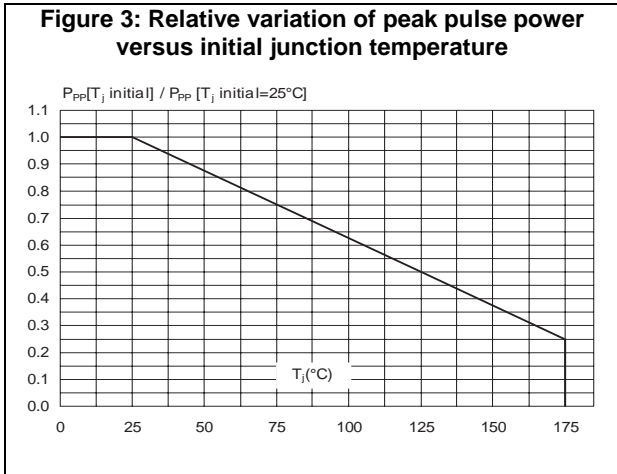
Notes:

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

Table 5: Thermal resistances

| Symbol | Parameter | Value | Unit |
|----------------------|---|-------|------|
| R _{th(j-a)} | SMD thermal resistance junction to ambient, per diode FR4 board, copper thickness = 35 μm, S _{Cu} = 0.85 mm ² | 330 | °C/W |
| Z _{th(j-a)} | SMD thermal transient impedance junction to ambient, per diode t _p = 15 ms, T _{amb} = 85 °C, S _{Cu} = 0.85 mm ² | 20 | °C/W |

1.1 Characteristics (curves)



2 SPT01-335DEE basic application

Figure 8: PNP high side sensor configuration

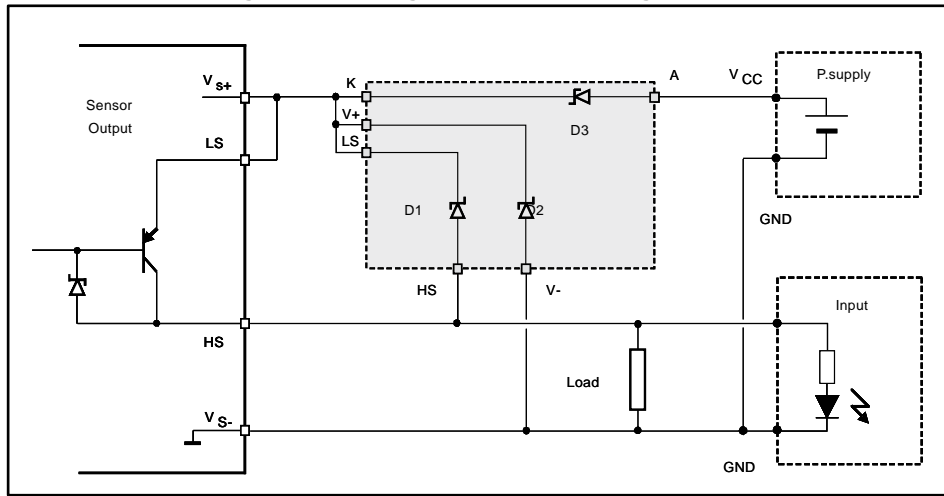


Figure 9: NPN low side sensor configuration

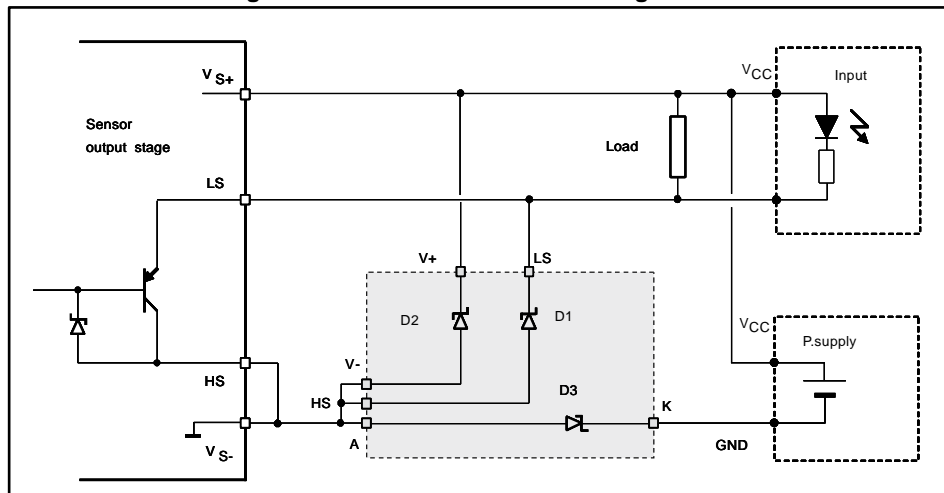


Table 6: SPT01-335 pin connection versus sensor output stage configuration as shown above

| Sensor type | SPT01-335 terminal connection | | | | | |
|-------------|-------------------------------|--------------------|--------------------|--------------------|-----------------------|-----------------------|
| | LS | HS | A | K | V+ | V- |
| PNP | To V _{S+} | Sensor HS | V _{CC} | To V _{S+} | Sensor s ₊ | Sensor s ₋ |
| NPN | Sensor LS | To V _{S-} | To V _{S-} | To GND | | |



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.

3 System related electromagnetic compatibility ratings

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

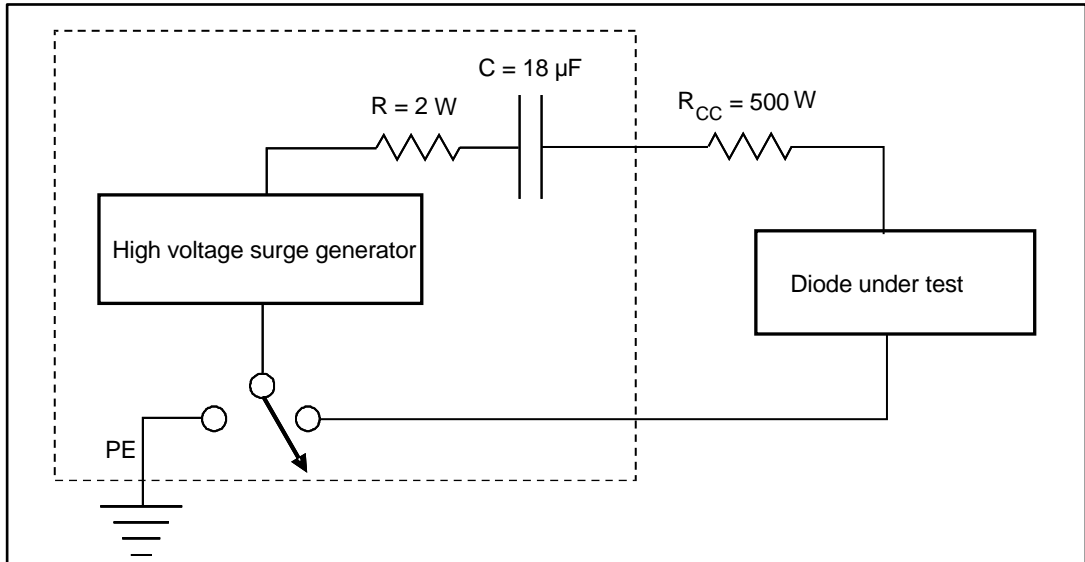
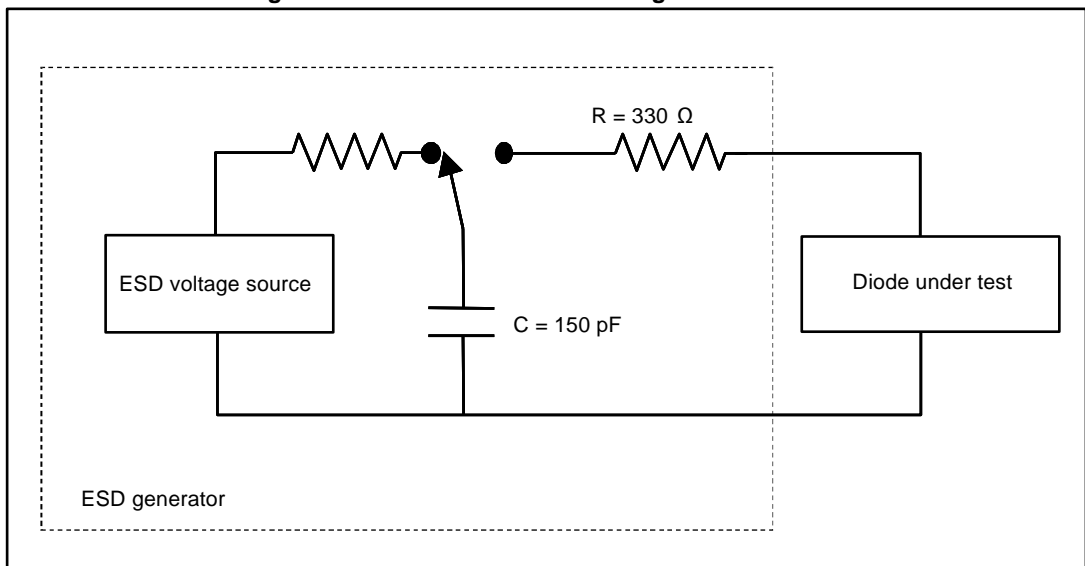


Figure 11: ESD test circuit according to IE 61000-4-2



4 Evaluation of the clamping voltage

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

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

4.1 Application considerations

4.1.1 Demagnetization of an inductive load driven by the switch protection diode

The turn off energy E_{OFF} that could be dissipated in the D1 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 D1 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:

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

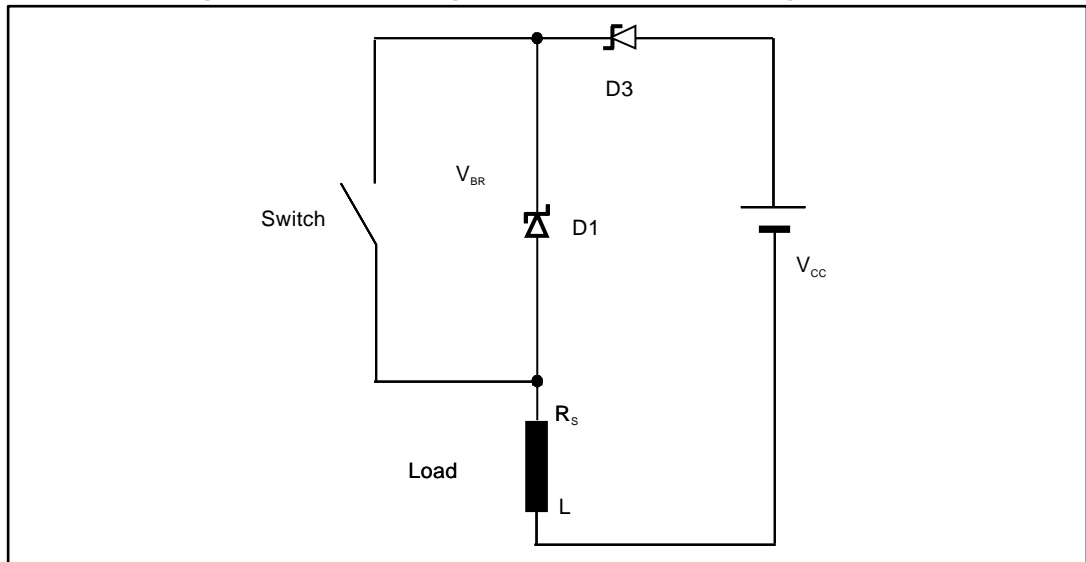
In a repetitive operation with an F repetitive rate:

- $P_{AV} = E_{OFF} \times F$
- $T_{(J_AV)} = T_{amb} + P_{AV} \times R_{th(j-a)}$

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



4.1.2 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, D1 normally. This can be done by increasing its PCB copper tab surface S_{Cu} .

5 Package information

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.

- Epoxy meets UL94,V0
- Lead-free package

5.1 QFN 3x3 package information

Figure 13: QFN 3x3 package outline

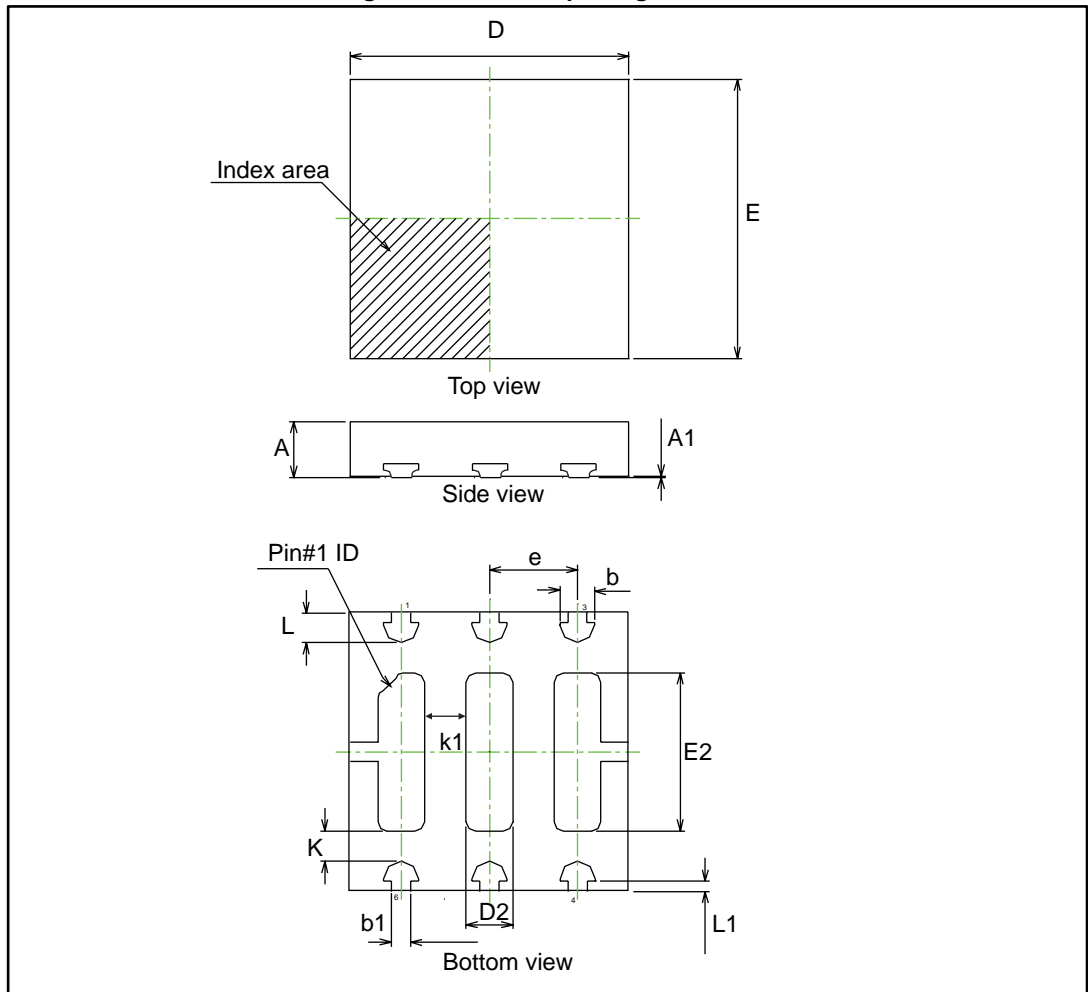


Table 7: QFN 3x3 package mechanical data

| 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 | 0.0000 | 0.0007 | 0.0019 |
| b | 0.35 | 0.40 | 0.45 | 0.013 | 0.015 | 0.017 |
| b1 | | 0.20 | | | 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 | | | 0.07 | | |
| 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: Footprint (dimensions in mm)

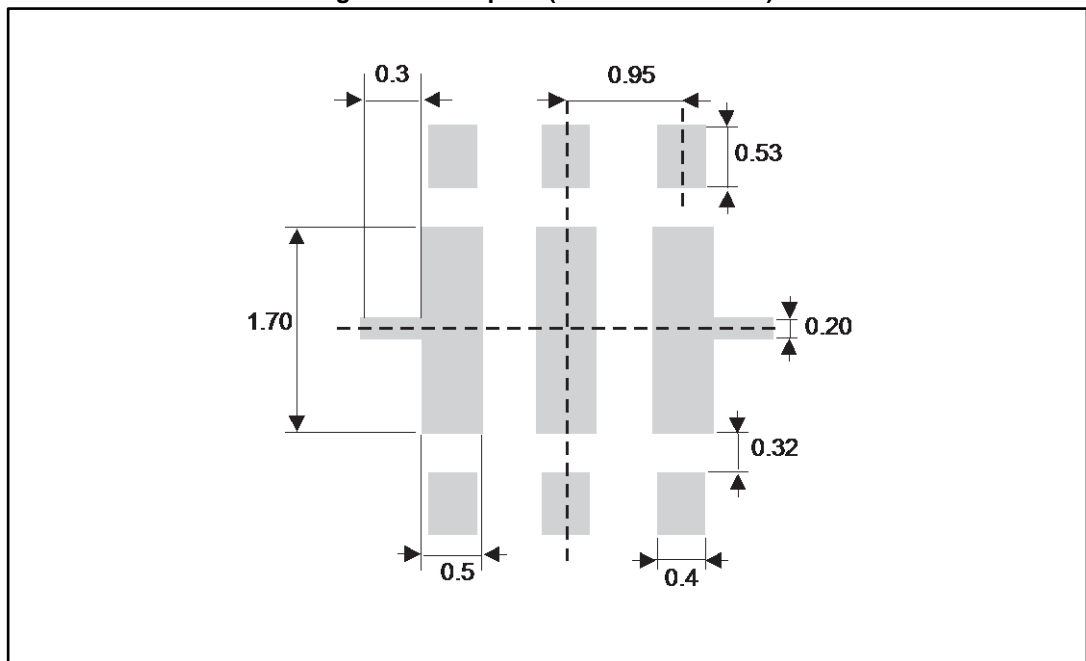


Figure 15: Tape and reel orientation

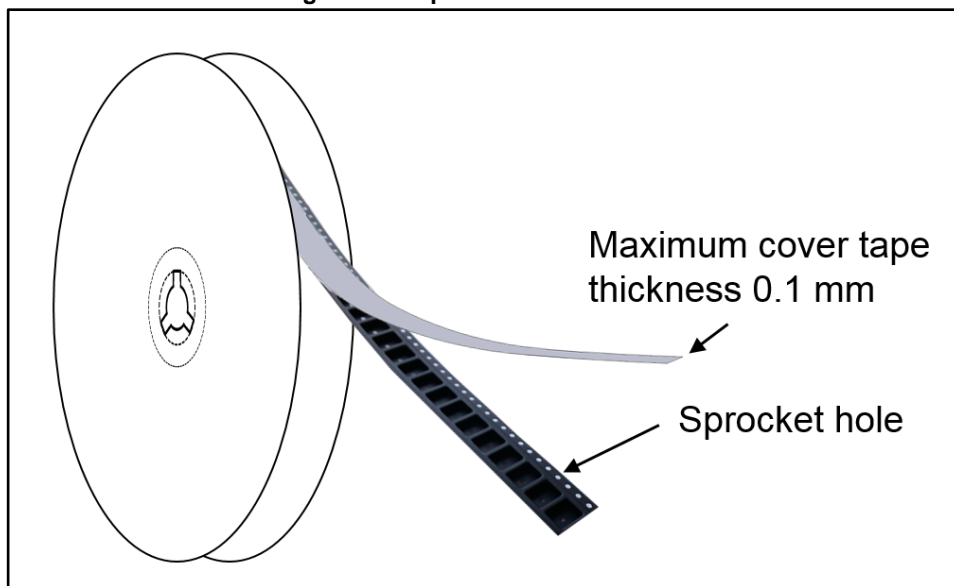


Figure 16: 13" Reel dimension definitions (mm)

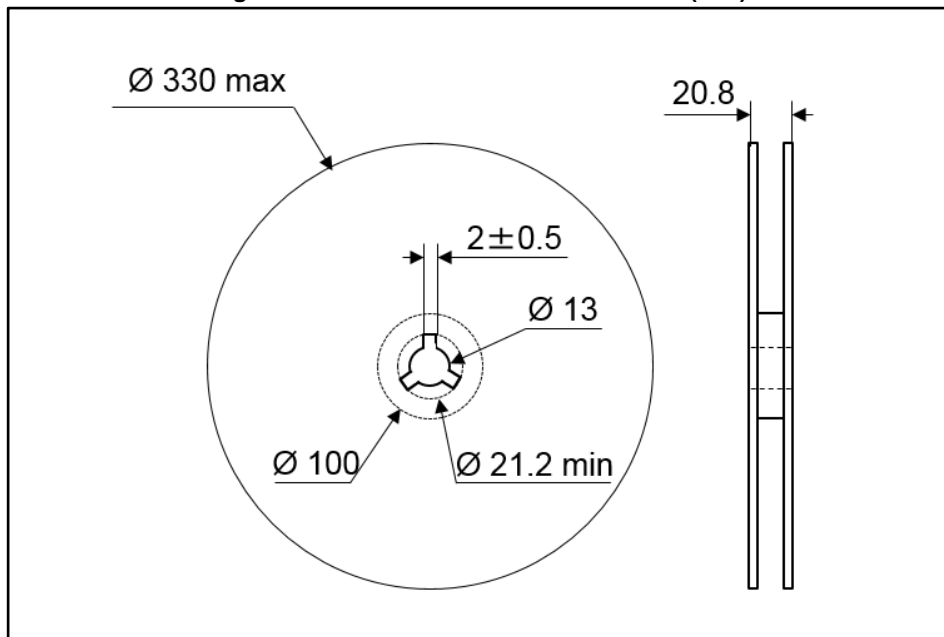


Figure 17: Tape and reel outline

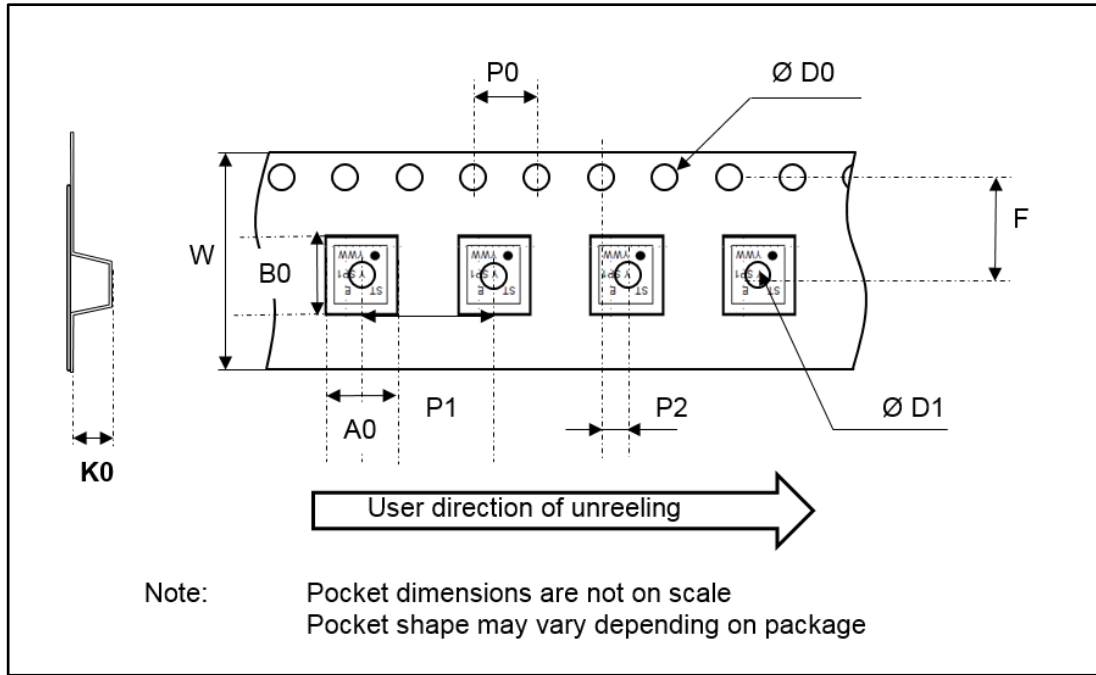


Table 8: Tape and reel mechanical data

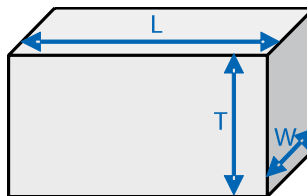
| Ref. | Dimensions | | |
|------|-------------|------|------|
| | Millimeters | | |
| | Min. | Typ. | Max. |
| P1 | 7.9 | 8.0 | 8.1 |
| P0 | 3.9 | 4.0 | 4.1 |
| ØD0 | 1.5 | 1.5 | 1.6 |
| ØD1 | 1.5 | | |
| F | 5.45 | 5.5 | 5.55 |
| K0 | | 1.1 | |
| P2 | 1.95 | 2.0 | 2.05 |
| W | 11.7 | 12 | 12.3 |
| A0 | | 3.3 | |
| B0 | | 3.3 | |

6 Recommendation on PCB assembly

6.1 Stencil opening design

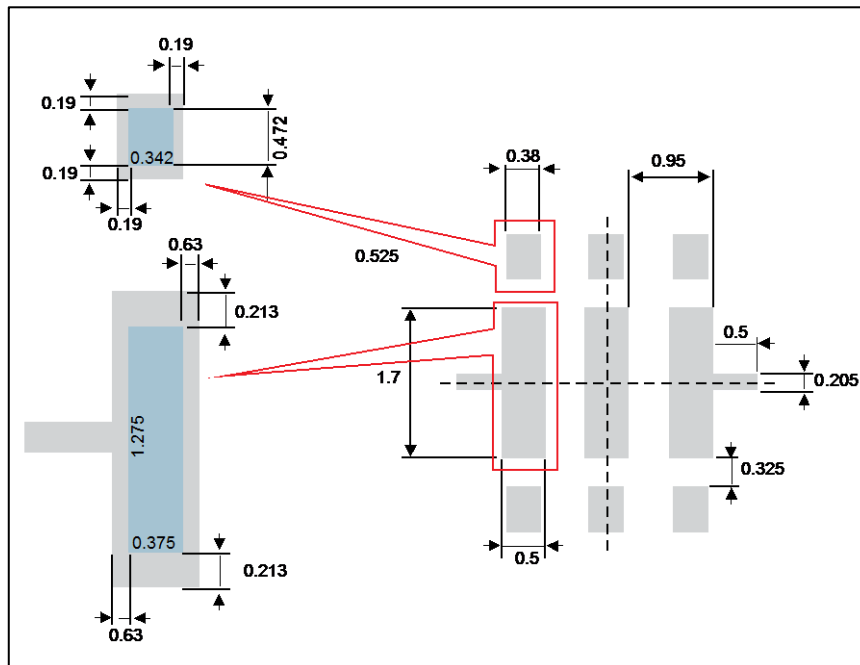
1. General recommendation on stencil opening design
 - a. Stencil opening dimensions: L (Length), W (Width), T (Thickness)

Figure 18: Stencil opening dimensions



- b. General design rule Stencil thickness (T) = 75 ~ 125 μm
 - Aspect Ratio = $W/T \geq 1,5$
 - Aspect Area = $(L \times W) / 2T (L + W) \geq 0,66$
 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 18: Recommended stencil window position in mm



6.2 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. Use solder paste with fine particles: powder particle size 20-45 μm .

6.3 Placement

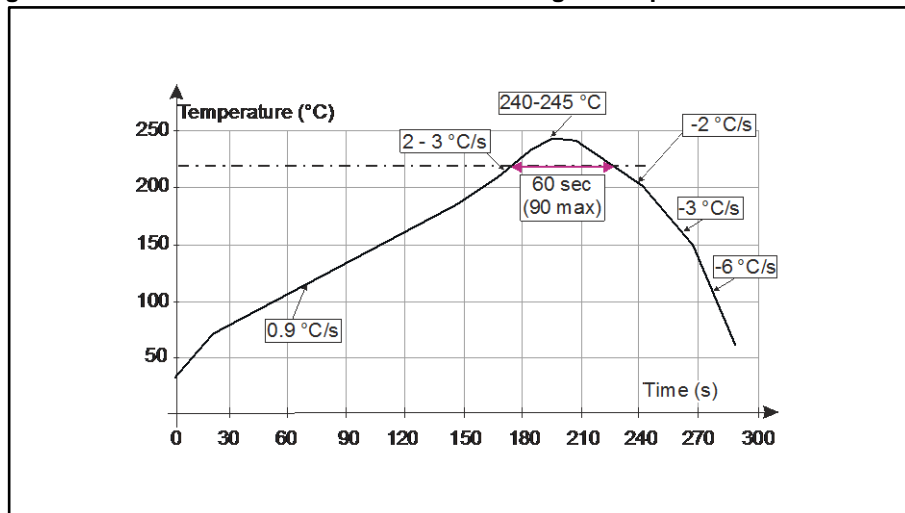
1. Manual positioning is not recommended.
2. It is recommended to use the lead recognition capabilities of the placement system, not the outline centering
3. Standard tolerance of ± 0.05 mm is recommended.
4. 3.5 N placement force is recommended. Too much placement force can lead to squeezed out solder 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.

6.4 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. A symmetrical layout is recommended, to avoid any tilt phenomena caused by asymmetrical solder paste due to solder flow away.

6.5 Reflow profile

Figure 19: ST ECOPACK® recommended soldering reflow profile for PCB mounting



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

7 Ordering information

Figure 20: Ordering information scheme

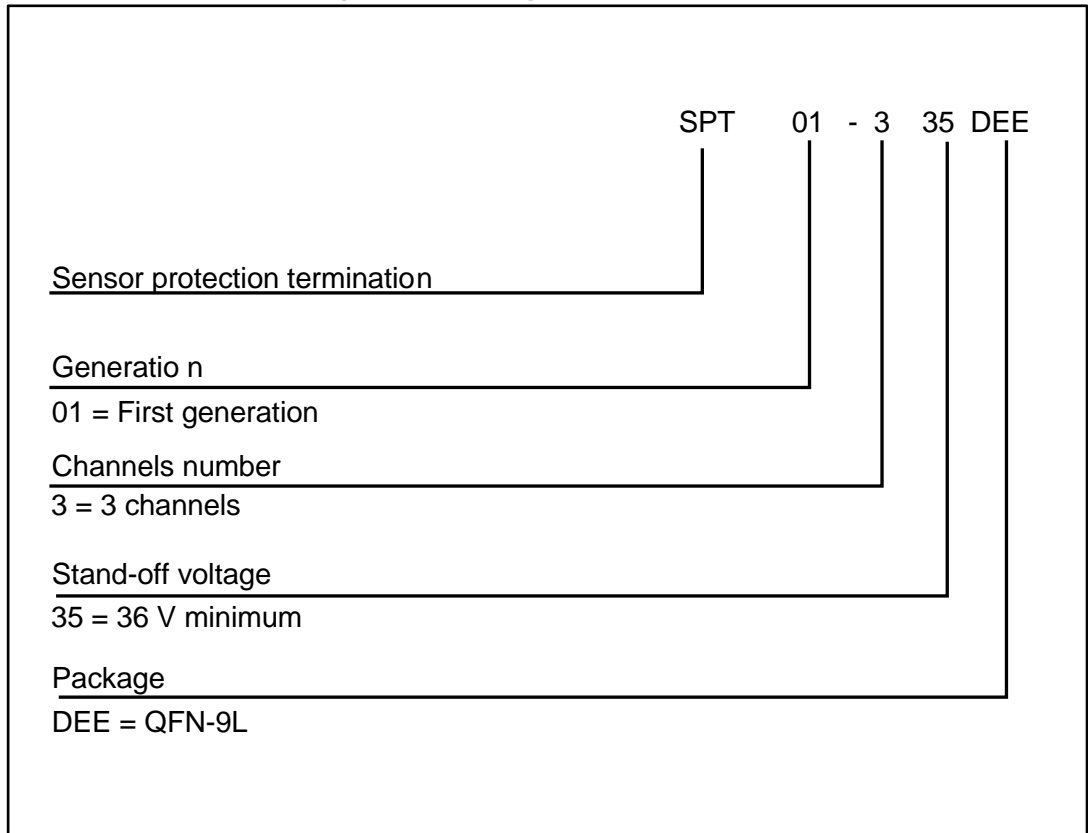


Table 9: Ordering information

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

8 Revision history

Table 10: Document revision history

| Date | Revision | Changes |
|-------------|----------|---|
| 21-Nov-2008 | 1 | First issue |
| 19-Mar-2012 | 2 | Added UL statement in Chapter 6 |
| 03-May-2013 | 3 | Updated features, Table 3, Table 4, Figure 17 and Figure 18. |
| 05-Feb-2018 | 4 | Added Figure 15: "Tape and reel orientation" , Figure 16: "13" Reel dimension definitions (mm) , Figure 17: "Tape and reel outline" and Table 8: "Tape and reel mechanical data " . |

9 Disclaimer

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