

### Description

The VNL5160N3-E and VNL5160S5-E are monolithic devices, made using STMicroelectronics® VIPower® Technology, intended for driving resistive or inductive loads with one side connected to the battery. Built-in thermal shutdown protects the chip from overtemperature and short circuit. Output current limitation protects the devices in an overload condition. In the case of a long duration overload, the device limits the dissipated power to a safe level up to thermal shutdown intervention. Thermal shutdown, with automatic restart, allows the device to recover normal operation as soon as a fault condition disappears. Fast demagnetization of inductive loads is achieved at turn-off.

### Features

| Type        | V <sub>clamp</sub> | R <sub>DS(on)</sub> | I <sub>D</sub> |
|-------------|--------------------|---------------------|----------------|
| VNL5160N3-E | 41 V               | 160 mΩ              | 3.5 A          |
| VNL5160S5-E |                    |                     |                |

- Automotive qualified
- Drain current: 3.5A
- ESD protection
- Overvoltage clamp
- Thermal shutdown
- Current and power limitation
- Very low standby current
- Very low electromagnetic susceptibility
- In compliance with the 2002/95/EC European directive
- Open drain status output (VNL5160S5-E only)
- Specially intended for R10W or 2x R5W automotive signal lamps

Table 1. Device summary

| Package | Order codes |               |
|---------|-------------|---------------|
|         | Tube        | Tape and reel |
| SOT-223 | VNL5160N3-E | VNL5160N3TR-E |
| SO-8    | VNL5160S5-E | VNL5160S5TR-E |

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# 1 Block diagrams and pins configurations

Figure 1. VNL5160N3-E block diagram

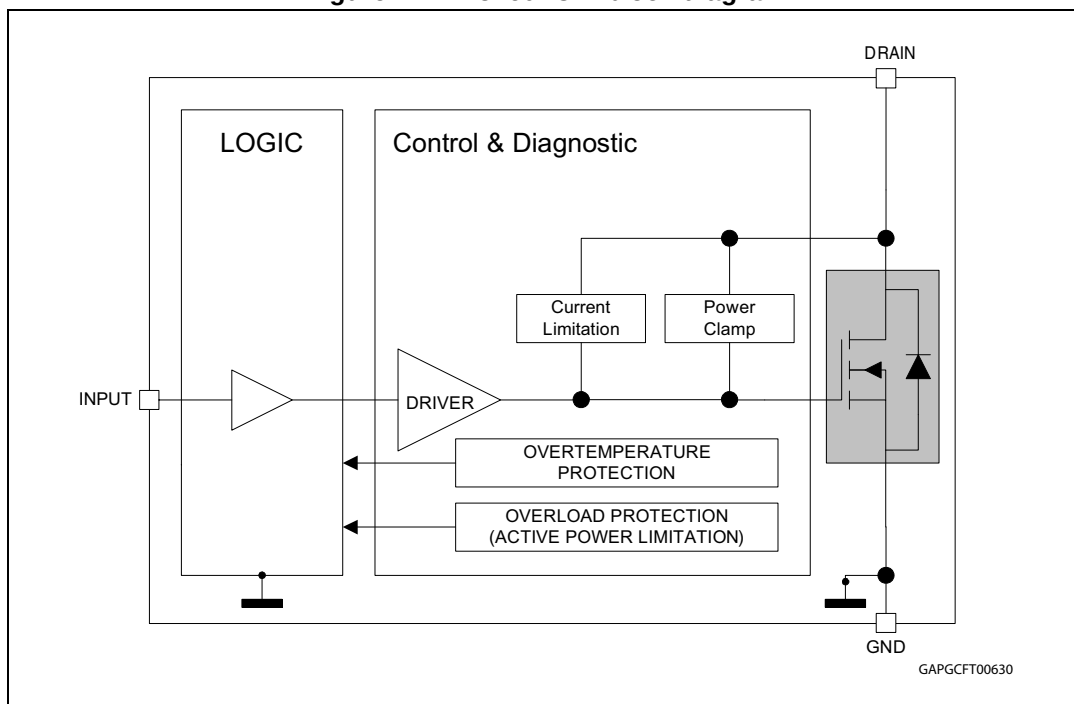


Figure 2. VNL5160S5-E block diagram

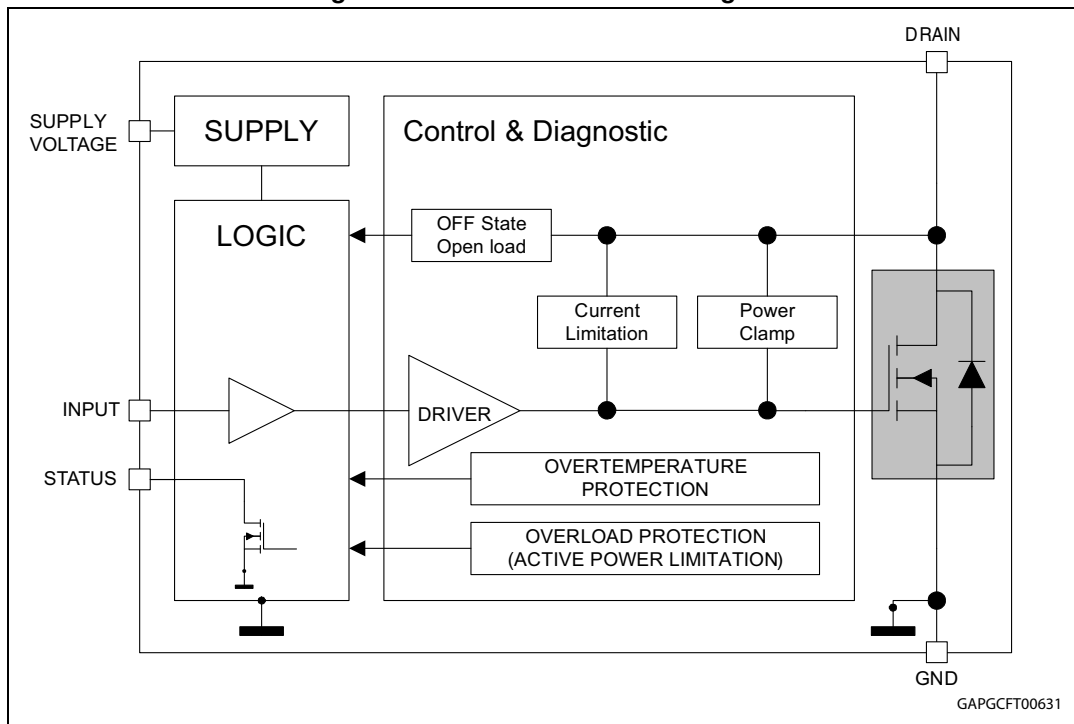


Table 2. Pin function

| Name           | Function                                                                                                   |
|----------------|------------------------------------------------------------------------------------------------------------|
| INPUT          | Voltage controlled input pin with hysteresis, CMOS compatible. Controls output switch state <sup>(1)</sup> |
| DRAIN          | PowerMOS drain                                                                                             |
| SOURCE         | PowerMOS source and ground reference for the control section                                               |
| SUPPLY VOLTAGE | Supply voltage connected to the signal part (5V)                                                           |
| STATUS         | Open drain digital diagnostic pin <sup>(2)</sup>                                                           |

1. Internally connected to  $V_{\text{supply}}$  in the VNL5160N3-E.

2. Valid for VNL5160S5-E only.

Figure 3. VNL5160N3-E current and voltage conventions

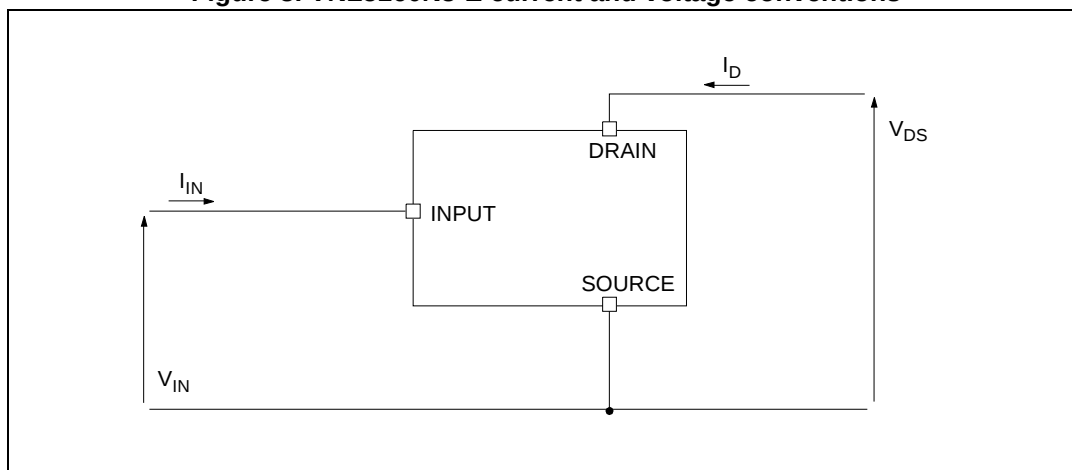


Figure 4. VNL5160S5-E current and voltage conventions

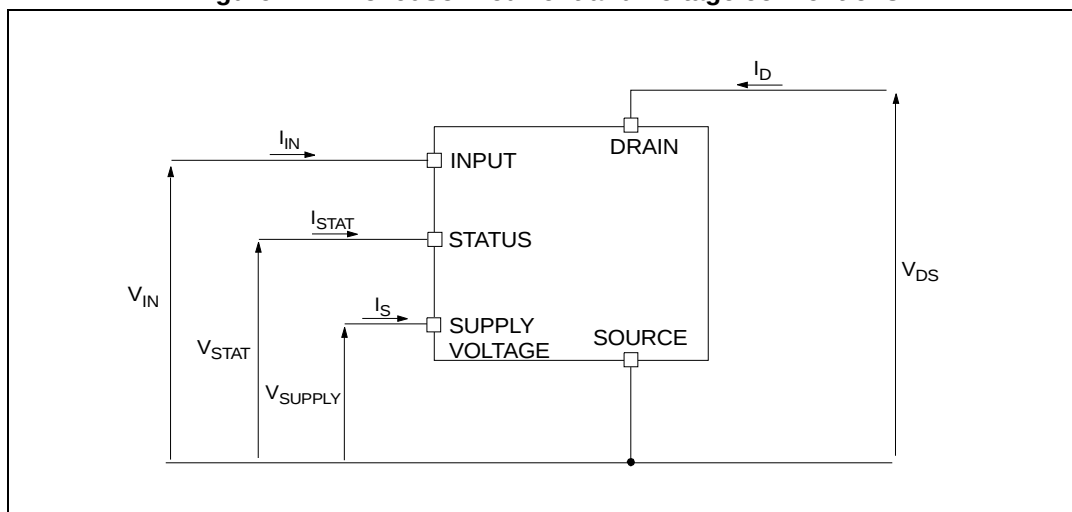


Figure 5. Configuration diagrams (top view)

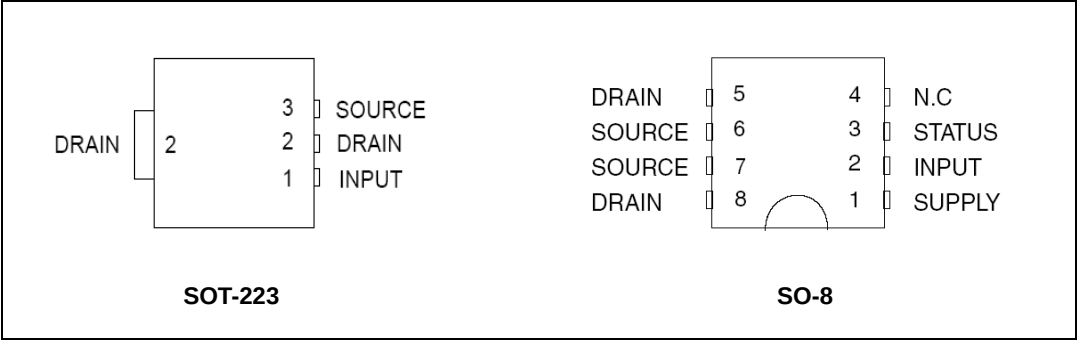


Table 3. Suggested connections for unused and not connected pins

| Connection/pin | Status      | N.C. | Input                 |
|----------------|-------------|------|-----------------------|
| Floating       | X           | X    | X                     |
| To ground      | Not allowed | X    | Through 10kΩ resistor |

## 2 Absolute maximum rating

Stressing the device above the rating listed in [Table 4](#) 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.

### 2.1 Absolute maximum ratings

Table 4. Absolute maximum ratings

| Symbol            | Parameter                                                                                                                                                       | Value              |          | Unit |
|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|----------|------|
|                   |                                                                                                                                                                 | SOT-223            | SO-8     |      |
| V <sub>DS</sub>   | Drain-source voltage (V <sub>IN</sub> =0V)                                                                                                                      | Internally clamped |          | V    |
| I <sub>D</sub>    | DC drain current                                                                                                                                                | Internally limited |          | A    |
| -I <sub>D</sub>   | Reverse DC drain current                                                                                                                                        | 4                  |          | A    |
| I <sub>S</sub>    | DC supply current                                                                                                                                               | -                  | -1 to 10 | mA   |
| I <sub>IN</sub>   | DC input current                                                                                                                                                | -1 to 10           |          | mA   |
| I <sub>STAT</sub> | DC status current                                                                                                                                               | -                  | -1 to 10 | mA   |
| V <sub>ESD1</sub> | Electrostatic discharge (R=1.5kΩ; C=100pF)                                                                                                                      |                    |          | V    |
|                   | – INPUT                                                                                                                                                         | 4000               |          |      |
|                   | – STATUS                                                                                                                                                        | 4000               |          |      |
|                   | – SUPPLY                                                                                                                                                        | 4000               |          |      |
|                   | – DRAIN                                                                                                                                                         | 5000               |          |      |
| V <sub>ESD2</sub> | Electrostatic discharge on output pin only (R=330Ω, C=150pF)                                                                                                    | 2000               |          | V    |
| T <sub>j</sub>    | Junction operating temperature                                                                                                                                  | -40 to 150         |          | °C   |
| T <sub>stg</sub>  | Storage temperature                                                                                                                                             | -55 to 150         |          | °C   |
| E <sub>as</sub>   | Single pulse avalanche energy<br>L = 8.5 mH, T <sub>j</sub> = 150 °C, R <sub>L</sub> = 0 Ω,<br>V <sub>batt</sub> = 13.5 V, I <sub>out</sub> = I <sub>limL</sub> | 37                 |          | mJ   |

## 2.2 Thermal data

Table 5. Thermal data

| Symbol        | Parameter                           | Maximum value        |       | Unit |
|---------------|-------------------------------------|----------------------|-------|------|
|               |                                     | SOT-223              | SO-8  |      |
| $R_{thj-amb}$ | Thermal resistance junction-ambient | 146.8 <sup>(1)</sup> | 103.1 | °C/W |

1. When mounted on a standard single-sided FR4 board with 0.5cm<sup>2</sup> of Cu (at least 35 µm thick) connected to all DRAIN pins

### 3 Electrical characteristics

Values specified in this section are for  $V_{IN} = V_{supply} = 4.5\text{ V to }5.5\text{ V}$ ,  $-40\text{ °C} < T_j < 150\text{ °C}$ , unless otherwise stated.

**Table 6. PowerMOS section**

| Symbol       | Parameter                            | Test conditions                                                           | Min. | Typ. | Max. | Unit |
|--------------|--------------------------------------|---------------------------------------------------------------------------|------|------|------|------|
| $V_{supply}$ | Operating supply voltage             |                                                                           | 3.5  | 5    | 5.5  | V    |
| $R_{ON}$     | On-state resistance                  | $V_{IN} = V_{supply} = 5\text{ V}; I_D = 1\text{ A}; T_j = 25\text{ °C}$  |      | 160  | 170  | mΩ   |
|              |                                      | $V_{IN} = V_{supply} = 5\text{ V}; I_D = 1\text{ A}; T_j = 150\text{ °C}$ |      |      | 320  | mΩ   |
| $V_{CLAMP}$  | Drain-source clamp voltage           | $V_{IN} = 0\text{ V}; I_D = 1\text{ A}$                                   | 41   | 46   | 52   | V    |
| $V_{CLTH}$   | Drain-source clamp threshold voltage | $V_{IN} = 0\text{ V}; I_D = 2\text{ mA}$                                  | 36   |      |      | V    |
| $I_{DSS}$    | Off-state output current             | $V_{IN} = 0\text{ V}; V_{DS} = 13\text{ V}; T_j = 25\text{ °C}$           | 0    |      | 3    | μA   |
|              |                                      | $V_{IN} = 0\text{ V}; V_{DS} = 13\text{ V}; T_j = 125\text{ °C}$          | 0    |      | 5    | μA   |

**Table 7. Source drain diode**

| Symbol   | Parameter          | Test conditions                         | Min. | Typ. | Max. | Unit |
|----------|--------------------|-----------------------------------------|------|------|------|------|
| $V_{SD}$ | Forward on voltage | $I_D = 1\text{ A}; V_{IN} = 0\text{ V}$ | —    | 0.8  | —    | V    |

**Table 8. Input section<sup>(1)</sup>**

| Symbol     | Parameter                     | Test conditions                                                  | Min. | Typ. | Max. | Unit |
|------------|-------------------------------|------------------------------------------------------------------|------|------|------|------|
| $I_{ISS}$  | Supply current from input pin | On-state $V_{IN} = V_{supply} = 5\text{ V}; V_{DS} = 0\text{ V}$ |      | 30   | 65   | μA   |
| $V_{ICL}$  | Input clamp voltage           | $I_S = 1\text{ mA}$                                              | 5.5  |      | 7    | V    |
|            |                               | $I_S = -1\text{ mA}$                                             |      | -0.7 |      | V    |
| $V_{INTH}$ | Input threshold voltage       | $V_{DS} = V_{IN}; I_D = 1\text{ mA}$                             | 1    |      | 3.5  | V    |

1. Valid for VNL5160N3-E option (input & supply pins connected together).

**Table 9. Status pin<sup>(1)</sup>**

| Symbol      | Parameter                 | Test conditions                           | Min. | Typ. | Max. | Unit |
|-------------|---------------------------|-------------------------------------------|------|------|------|------|
| $V_{STAT}$  | Status low output voltage | $I_{STAT} = 1\text{ mA}$                  |      |      | 0.5  | V    |
| $I_{LSTAT}$ | Status leakage current    | Normal operation, $V_{STAT} = 5\text{ V}$ |      |      | 10   | μA   |

Table 9. Status pin<sup>(1)</sup> (continued)

| Symbol     | Parameter                    | Test conditions                              | Min. | Typ. | Max. | Unit |
|------------|------------------------------|----------------------------------------------|------|------|------|------|
| $C_{STAT}$ | Status pin input capacitance | Normal operation;<br>$V_{STAT} = 5\text{ V}$ |      |      | 100  | pF   |
| $V_{STCL}$ | Status clamp voltage         | $I_{STAT} = 1\text{ mA}$                     | 5.5  |      | 7    | V    |
|            |                              | $I_{STAT} = -1\text{ mA}$                    |      | -0.7 |      | V    |

1. Valid for VNL5160S5-E option.

Table 10. Logic input<sup>(1)</sup>

| Symbol        | Parameter                | Test conditions         | Min. | Typ. | Max. | Unit          |
|---------------|--------------------------|-------------------------|------|------|------|---------------|
| $V_{IL}$      | Input low level voltage  |                         |      |      | 0.9  | V             |
| $I_{IL}$      | Low level input current  | $V_{IN} = 0.9\text{ V}$ | 1    |      |      | $\mu\text{A}$ |
| $V_{IH}$      | Input high level voltage |                         | 2.1  |      |      | V             |
| $I_{IH}$      | High level input current | $V_{IN} = 2.1\text{ V}$ |      |      | 10   | $\mu\text{A}$ |
| $V_{I(hyst)}$ | Input hysteresis voltage |                         | 0.13 |      |      | V             |
| $V_{ICL}$     | Input clamp voltage      | $I_{IN} = 1\text{ mA}$  | 5.5  |      | 7    | V             |
|               |                          | $I_{IN} = -1\text{ mA}$ |      | -0.7 |      | V             |

1. Valid for VNL5160S5-E option.

Table 11. Open-load detection<sup>(1)</sup>

| Symbol         | Parameter                                                                       | Test conditions        | Min. | Typ. | Max. | Unit          |
|----------------|---------------------------------------------------------------------------------|------------------------|------|------|------|---------------|
| $V_{OI}$       | Open-load off-state voltage detection threshold                                 | $V_{IN} = 0\text{ V}$  | 0.6  | 1.2  | 1.7  | V             |
| $t_{d(oloff)}$ | Delay between INPUT falling edge and STATUS falling edge in open-load condition | $I_{OUT} = 0\text{ A}$ | 45   | 425  | 1100 | $\mu\text{s}$ |

1. Valid for VNL5160S5-E option.

Table 12. Supply section<sup>(1)</sup>

| Symbol    | Parameter            | Test conditions                                                                           | Min. | Typ. | Max. | Unit          |
|-----------|----------------------|-------------------------------------------------------------------------------------------|------|------|------|---------------|
| $I_S$     | Supply current       | Off-state $T_j = 25\text{ }^\circ\text{C}$ ; $V_{IN} = V_{DRAIN} = 0\text{ V}$            |      | 10   | 25   | $\mu\text{A}$ |
|           |                      | On-state $T_j = 25\text{ }^\circ\text{C}$ ; $V_{IN} = 5\text{ V}$ ; $V_{DS} = 0\text{ V}$ |      | 25   | 65   | $\mu\text{A}$ |
| $V_{SCL}$ | Supply clamp voltage | $I_{SCL} = 1\text{ mA}$                                                                   | 5.5  |      | 7    | V             |
|           |                      | $I_{SCL} = -1\text{ mA}$                                                                  |      | -0.7 |      | V             |

1. Valid for VNL5160S5-E option.

Table 13. Switching characteristics ( $V_{CC} = 13\text{ V}^{(1)}$ )

| Symbol       | Parameter                           | Test conditions                                | SOT-223 <sup>(2)</sup> |      |     | SO-8 |      |      | Unit          |
|--------------|-------------------------------------|------------------------------------------------|------------------------|------|-----|------|------|------|---------------|
|              |                                     |                                                | Min.                   | Typ. | Max | Min. | Typ. | Max. |               |
| $t_{d(ON)}$  | Turn-on delay time                  | $R_L = 13\Omega$ , $V_{CC} = 13\text{V}^{(3)}$ |                        | 8.9  |     |      | 8.9  |      | $\mu\text{s}$ |
| $t_{d(OFF)}$ | Turn-off delay time                 | $R_L = 13\Omega$ , $V_{CC} = 13\text{V}$       |                        | 13.2 |     |      | 13.2 |      | $\mu\text{s}$ |
| $t_r$        | Rise time                           | $R_L = 13\Omega$ , $V_{CC} = 13\text{V}$       |                        | 14.1 |     |      | 14.1 |      | $\mu\text{s}$ |
| $t_f$        | Fall time                           | $R_L = 13\Omega$ , $V_{CC} = 13\text{V}$       |                        | 11.5 |     |      | 11.5 |      | $\mu\text{s}$ |
| $W_{ON}$     | Switching energy losses at turn-on  | $R_L = 13\Omega$ , $V_{CC} = 13\text{V}$       |                        | 34.3 |     |      | 34.3 |      | $\mu\text{J}$ |
| $W_{OFF}$    | Switching energy losses at turn-off | $R_L = 13\Omega$ , $V_{CC} = 13\text{V}$       |                        | 34.3 |     |      | 34.3 |      | $\mu\text{J}$ |

1. See [Figure 7: VNL5160N3-E application schematic](#) and [Figure 8: VNL5160S5-E application schematic](#).

2.  $3.5\text{ V} < V_{S_{supply}} = V_{in} < 5.5\text{ V}$ .

3. See [Figure 6: Switching characteristics](#).

Table 14. Protection and diagnostics

| Symbol         | Parameter                                    | Test conditions <sup>(1)</sup>                                                       | Min.       | Typ.       | Max. | Unit               |
|----------------|----------------------------------------------|--------------------------------------------------------------------------------------|------------|------------|------|--------------------|
| $I_{limH}$     | DC short circuit current                     | $V_{DS} = 13\text{V}$ ; $V_{IN} = V_{supply} = 5\text{V}$                            | 3.5        | 5          | 7.5  | A                  |
| $I_{limL}$     | Short circuit current during thermal cycling | $V_{DS} = 13\text{V}$ ; $T_R < T_J < T_{TSD}$ ;<br>$V_{IN} = V_{supply} = 5\text{V}$ |            | 2.5        |      | A                  |
| $t_{dlim}$     | Step response current limit                  | $V_{DS} = 13\text{V}$ ; $V_{input} = 5\text{V}$                                      |            | 20         |      | $\mu\text{s}$      |
| $T_{TSD}$      | Shutdown temperature                         |                                                                                      | 150        | 175        | 200  | $^{\circ}\text{C}$ |
| $T_R$          | Reset temperature                            |                                                                                      | $T_{RS}+1$ | $T_{RS}+5$ |      | $^{\circ}\text{C}$ |
| $T_{RS}^{(2)}$ | Thermal reset of STATUS                      |                                                                                      | 135        |            |      | $^{\circ}\text{C}$ |
| $T_{HYST}$     | Thermal hysteresis ( $T_{TSD} - T_R$ )       |                                                                                      |            | 7          |      | $^{\circ}\text{C}$ |

1.  $V_{supply}=V_{input}$  in VNL5160N3-E version.

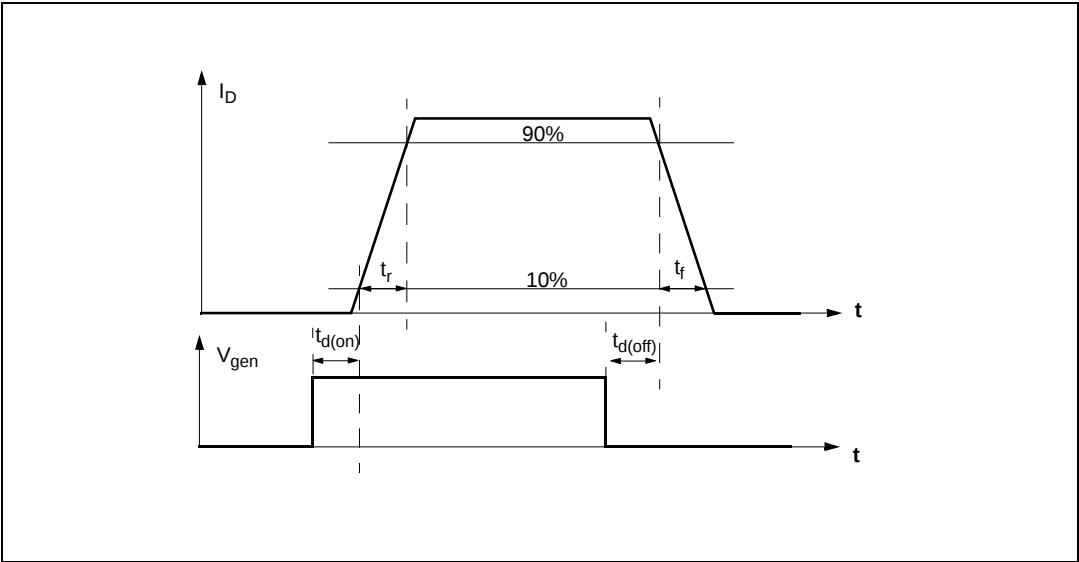
2. Valid for VNL5160S5-E option.

Table 15. Truth table (1)

| Conditions                       | INPUT | DRAIN | STATUS |
|----------------------------------|-------|-------|--------|
| Normal operation                 | L     | H     | H      |
|                                  | H     | L     | H      |
| Current limitation               | L     | H     | H      |
|                                  | H     | X     | H      |
| Overtemperature                  | L     | H     | H      |
|                                  | H     | H     | L      |
| Undervoltage                     | L     | H     | X      |
|                                  | H     | H     | X      |
| Output voltage < V <sub>OL</sub> | L     | L     | L      |
|                                  | H     | L     | H      |

1. Valid for VNL5160S5-E option

Figure 6. Switching characteristics



4 Application information

Figure 7. VNL5160N3-E application schematic

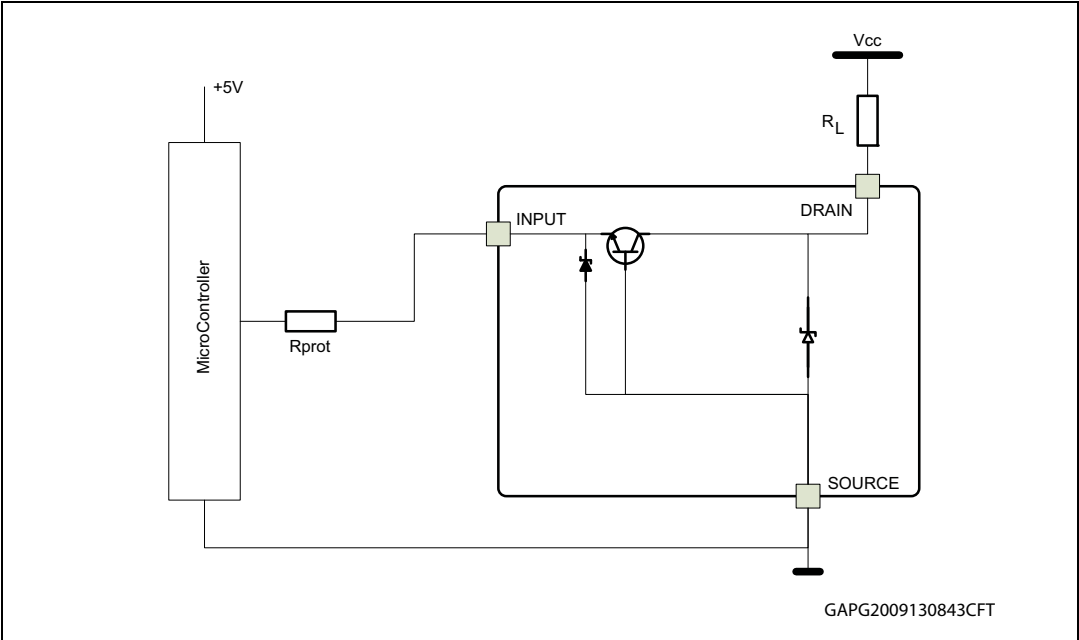
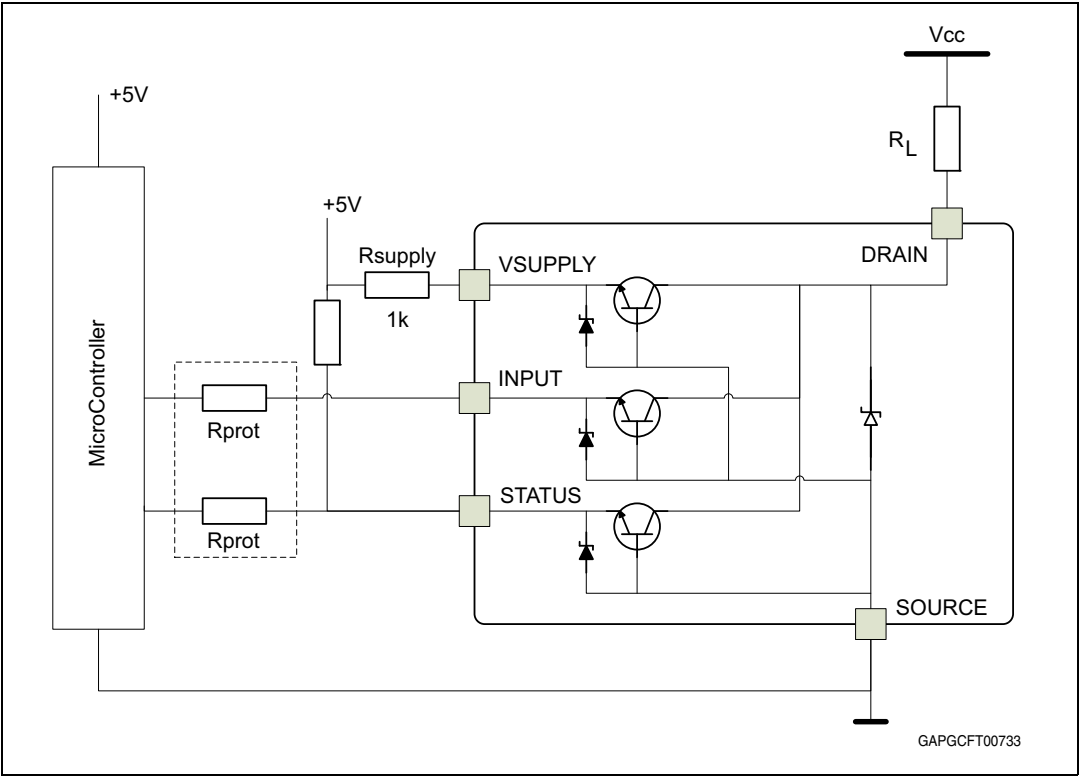


Figure 8. VNL5160S5-E application schematic



## 4.1 MCU I/O protection

ST suggests to insert a resistor ( $R_{prot}$ ) in line to prevent the  $\mu C$  I/O pins from latching up<sup>(a)</sup>. The value of these resistors is a compromise between the leakage current of  $\mu C$  and the current required by the LSD I/Os (Input levels compatibility) with the latch-up limit of  $\mu C$  I/Os:

$$0.7/I_{latchup} \leq R_{prot} \leq (V_{OH\mu C} - V_{IH}) / I_{IHmax}$$

Calculation example:

For the following conditions:

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

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

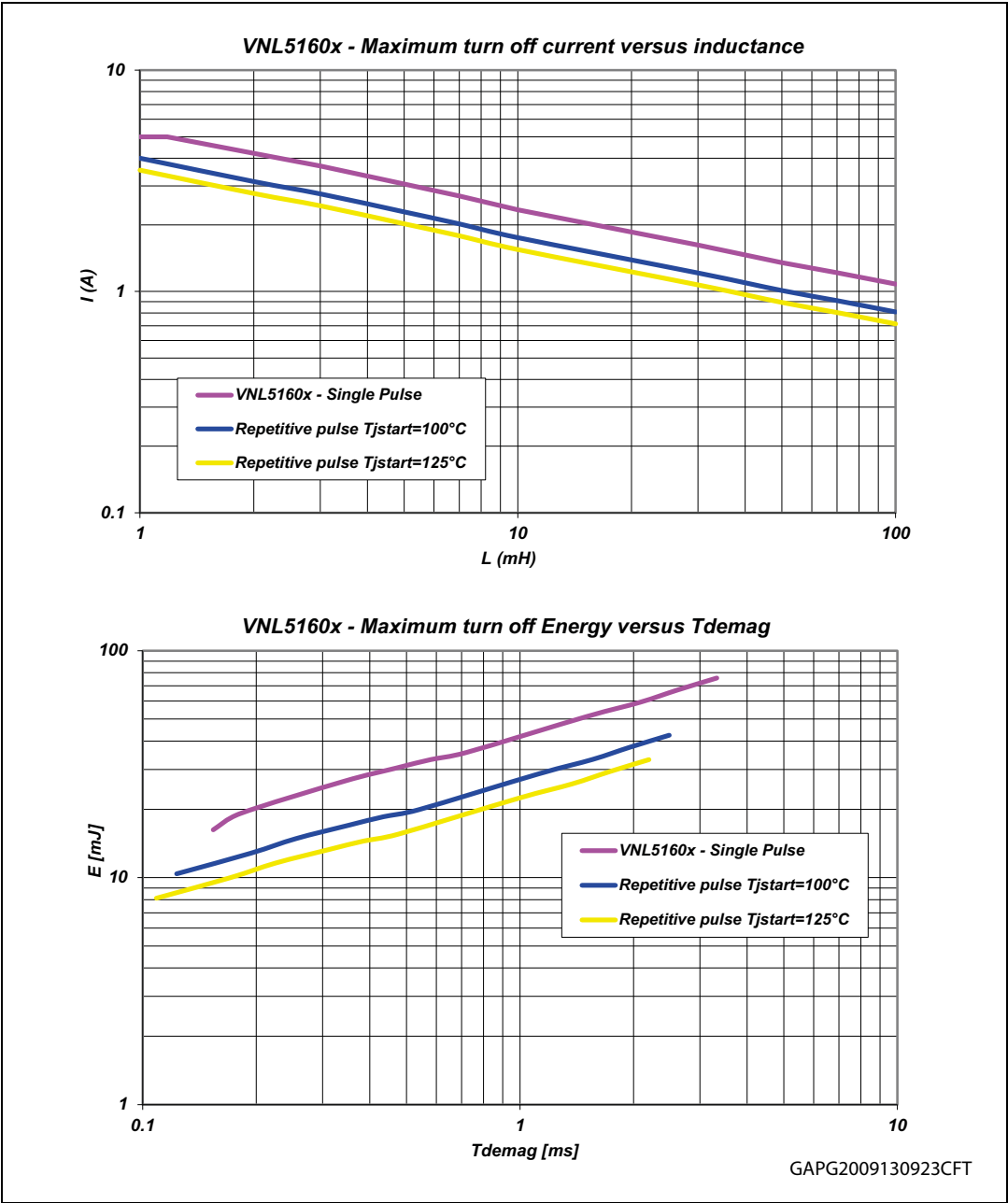
$$35\Omega \leq R_{prot} \leq 100k\Omega.$$

Recommended value is  $R_{prot} = 1 k\Omega$

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a. In case of negative transient on the drain pin.

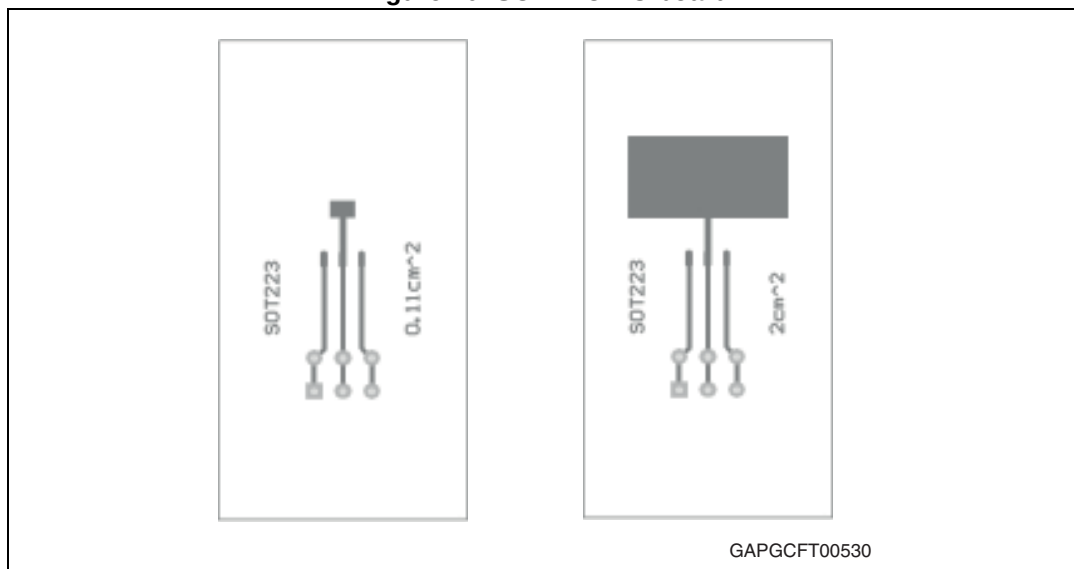
Figure 9. Maximum demagnetization energy



## 5 Package and PC board thermal data

### 5.1 SOT-223 thermal data

Figure 10. SOT-223 PC board



Note: Layout condition of  $R_{th}$  and  $Z_{th}$  measurements (PCB FR4 area = 30 mm x 30 mm, PCB thickness = 2 mm, Cu thickness = 35  $\mu$ m, Copper areas: from minimum pad layout to 0.8 cm<sup>2</sup>).

Figure 11. SOT-223  $R_{thj-amb}$  vs PCB copper area in open box free air condition

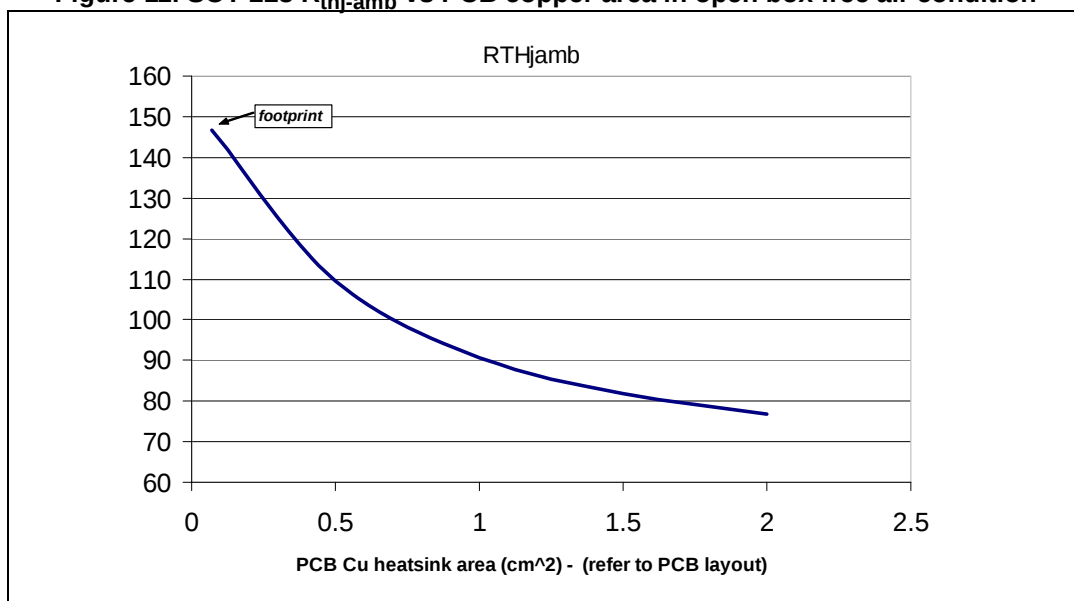
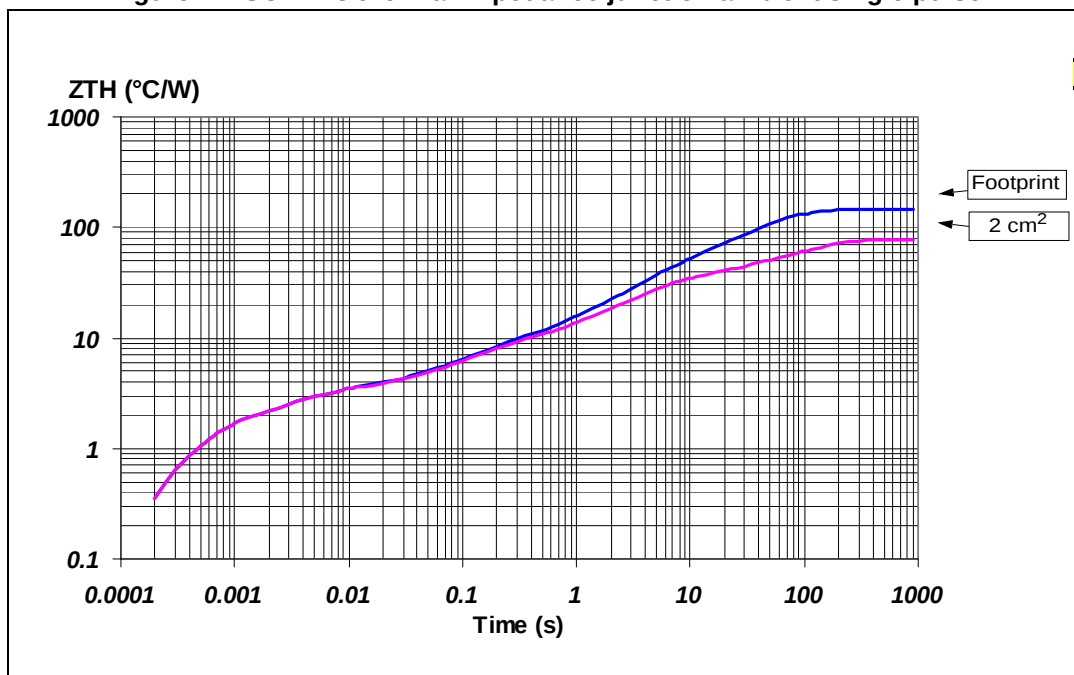


Figure 12. SOT-223 thermal impedance junction ambient single pulse

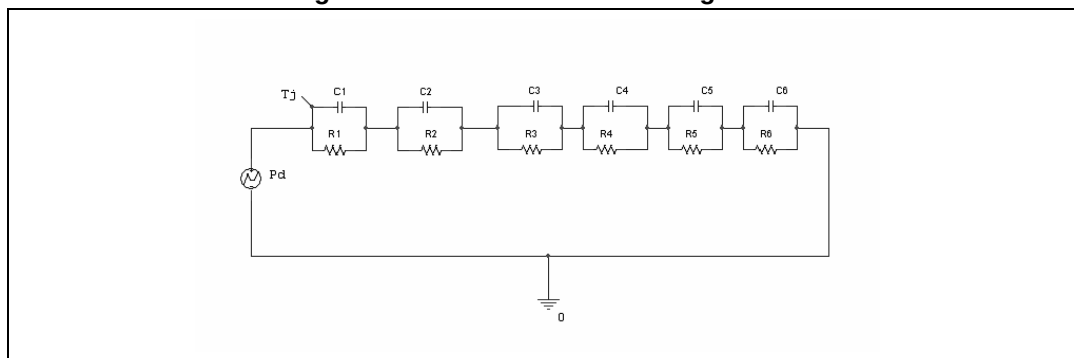


## Equation 1: pulse calculation formula

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

where  $\delta = t_p/T$

Figure 13. SOT-223 thermal fitting model



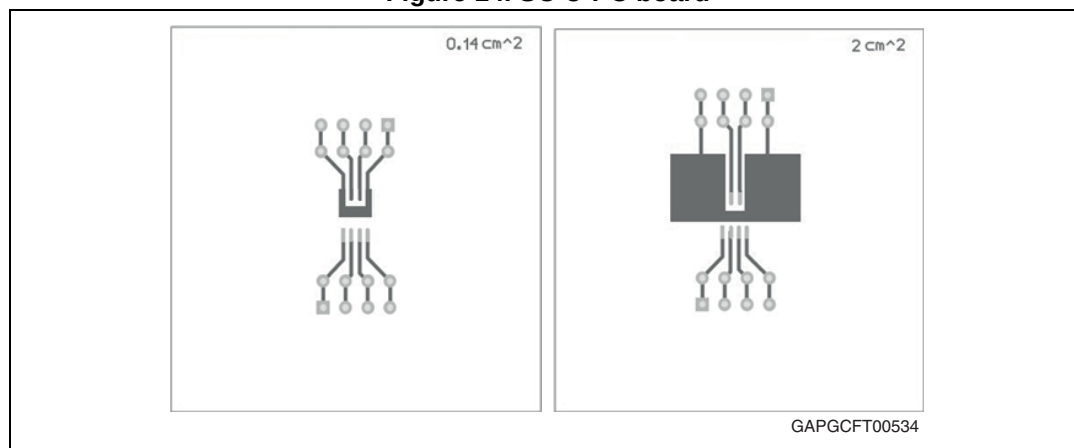
1. The fitting model is a simplified thermal tool and is valid for transient evolutions where the embedded protections (power limitation or thermal cycling during thermal shutdown) are not triggered.

Table 16. SOT-223 thermal parameter

| Area/island (cm <sup>2</sup> ) | FP     | 2  |
|--------------------------------|--------|----|
| R1 (°C/W)                      | 1.4    |    |
| R2 (°C/W)                      | 1.8    |    |
| R3 (°C/W)                      | 4.5    |    |
| R4 (°C/W)                      | 24     |    |
| R5 (°C/W)                      | 0.1    |    |
| R6 (°C/W)                      | 115    | 45 |
| C1 (W·s/°C)                    | 0.0003 |    |
| C2 (W·s/°C)                    | 0.002  |    |
| C3 (W·s/°C)                    | 0.03   |    |
| C4 (W·s/°C)                    | 0.16   |    |
| C5 (W·s/°C)                    | 1000   |    |
| C6 (W·s/°C)                    | 0.4    | 2  |

## 5.2 SO-8 thermal data

Figure 14. 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  $\mu$ m, Copper areas: from minimum pad layout to 2 cm<sup>2</sup>).

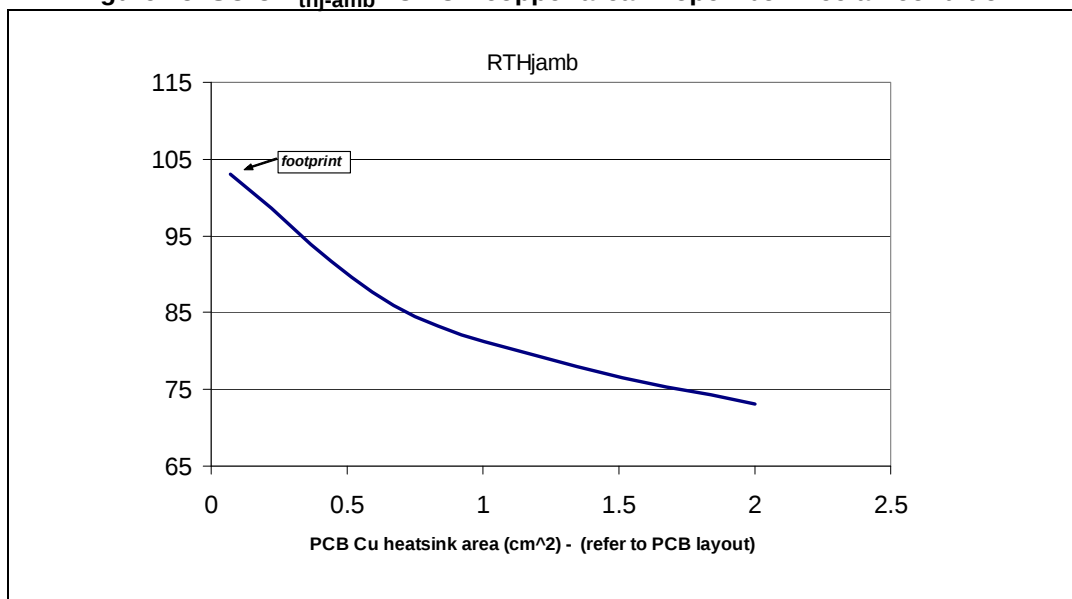
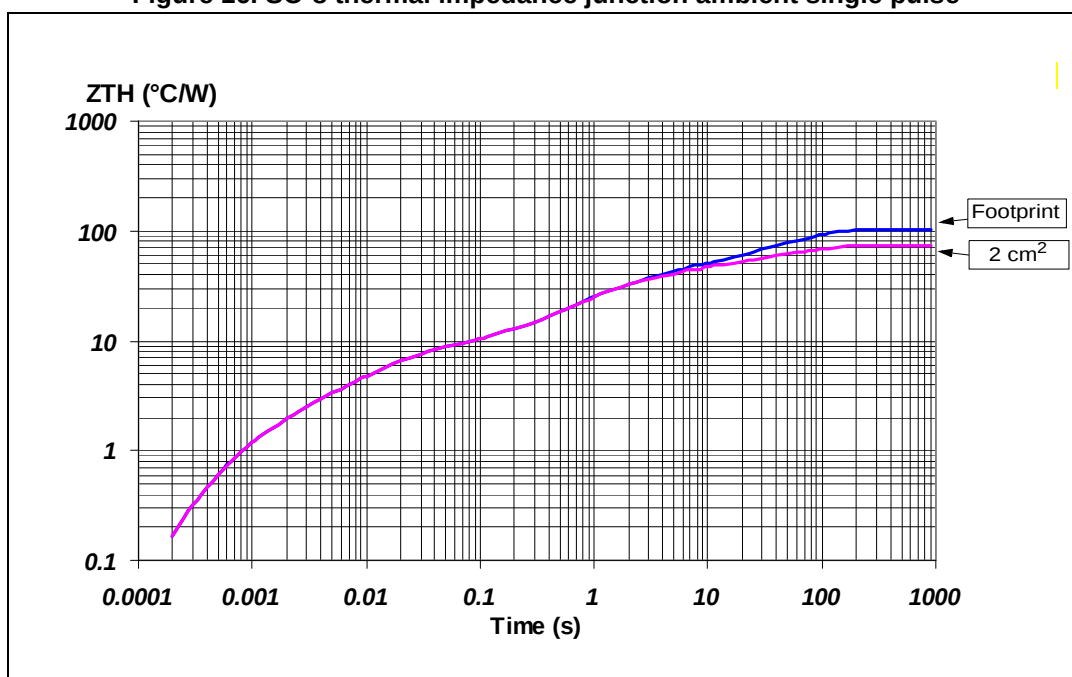
Figure 15. SO-8  $R_{thj-amb}$  vs PCB copper area in open box free air condition

Figure 16. SO-8 thermal impedance junction ambient single pulse

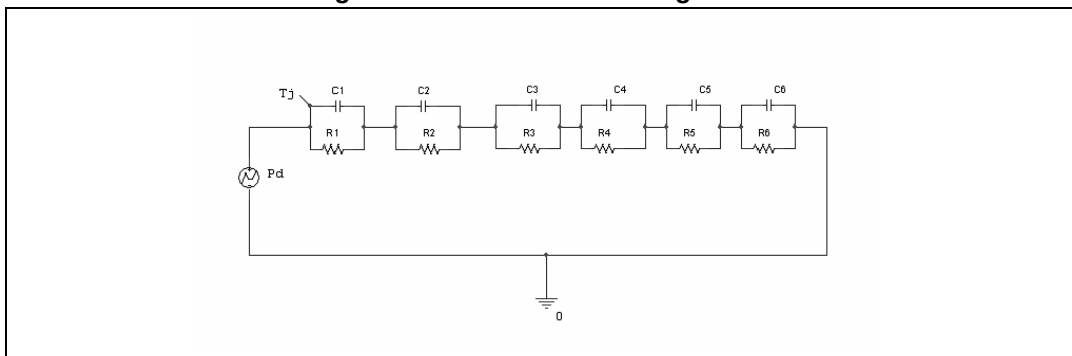


Equation 2: pulse calculation formula

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

where  $\delta = t_p/T$

Figure 17. SO-8 thermal fitting model



1. The fitting model is a simplified thermal tool and is valid for transient evolutions where the embedded protections (power limitation or thermal cycling during thermal shutdown) are not triggered.

Table 17. SO-8 thermal parameter

| Arealisland (cm <sup>2</sup> ) | 0.07   | 2  |
|--------------------------------|--------|----|
| R1 (°C/W)                      | 1.4    |    |
| R2 (°C/W)                      | 3.2    |    |
| R3 (°C/W)                      | 3.5    |    |
| R4 (°C/W)                      | 21     |    |
| R5 (°C/W)                      | 16     |    |
| R6 (°C/W)                      | 58     | 28 |
| C1 (W·s/°C)                    | 0.0008 |    |
| C2 (W·s/°C)                    | 0.0032 |    |
| 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  |

## 6 Package and packing information

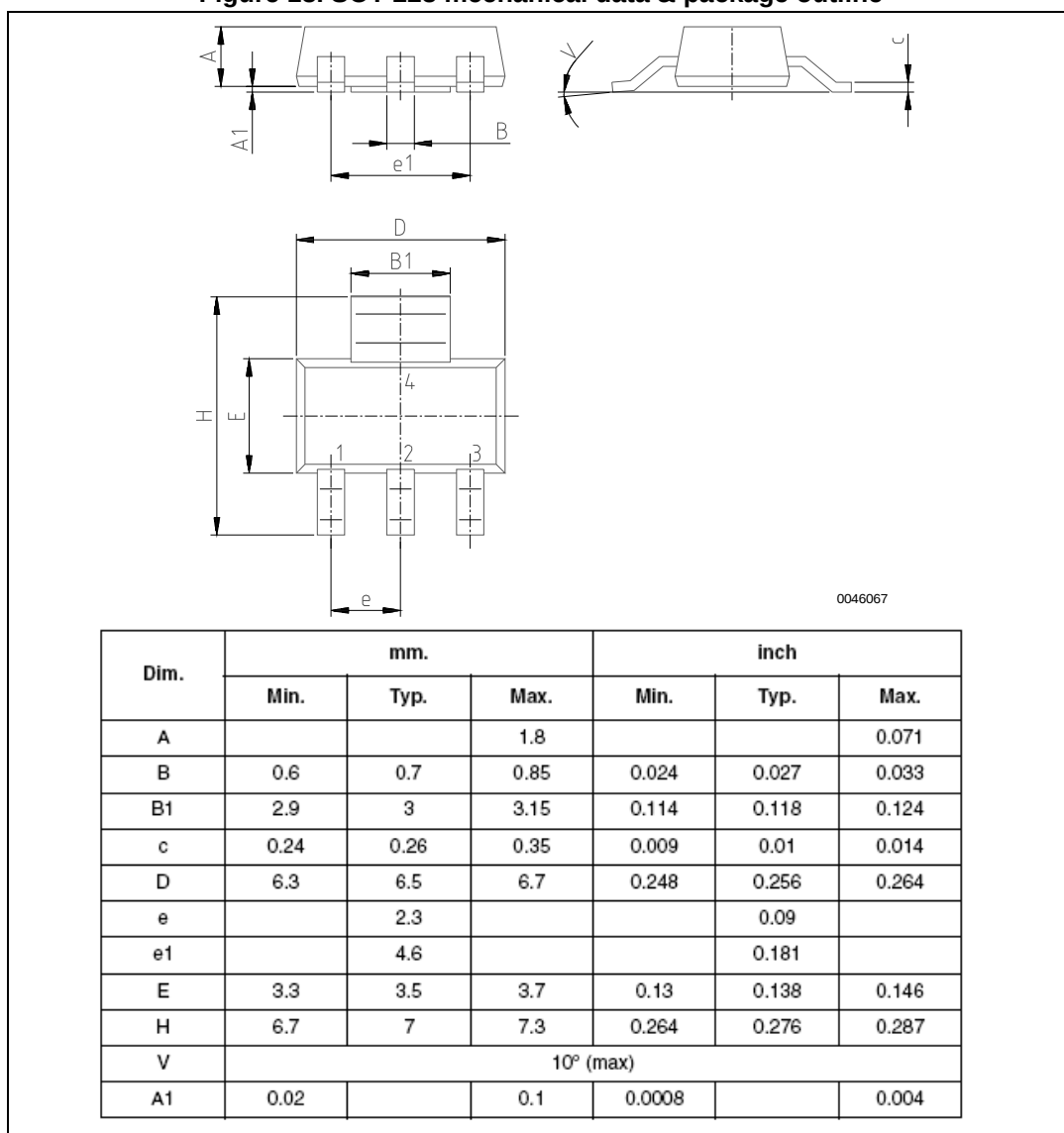
### 6.1 ECOPACK® packages

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

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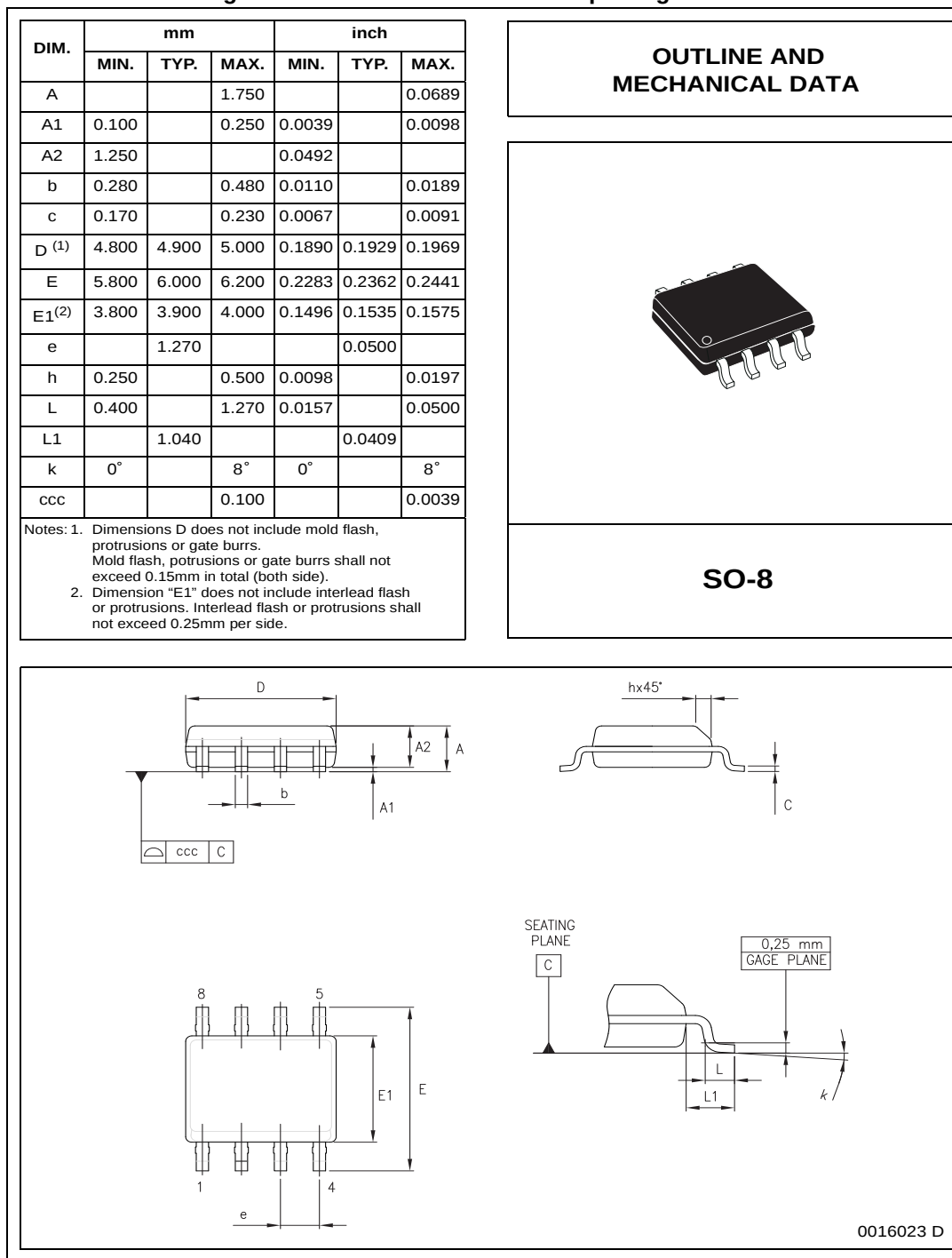
### 6.2 SOT-223 mechanical data

Figure 18. SOT-223 mechanical data & package outline



## 6.3 SO8 mechanical data

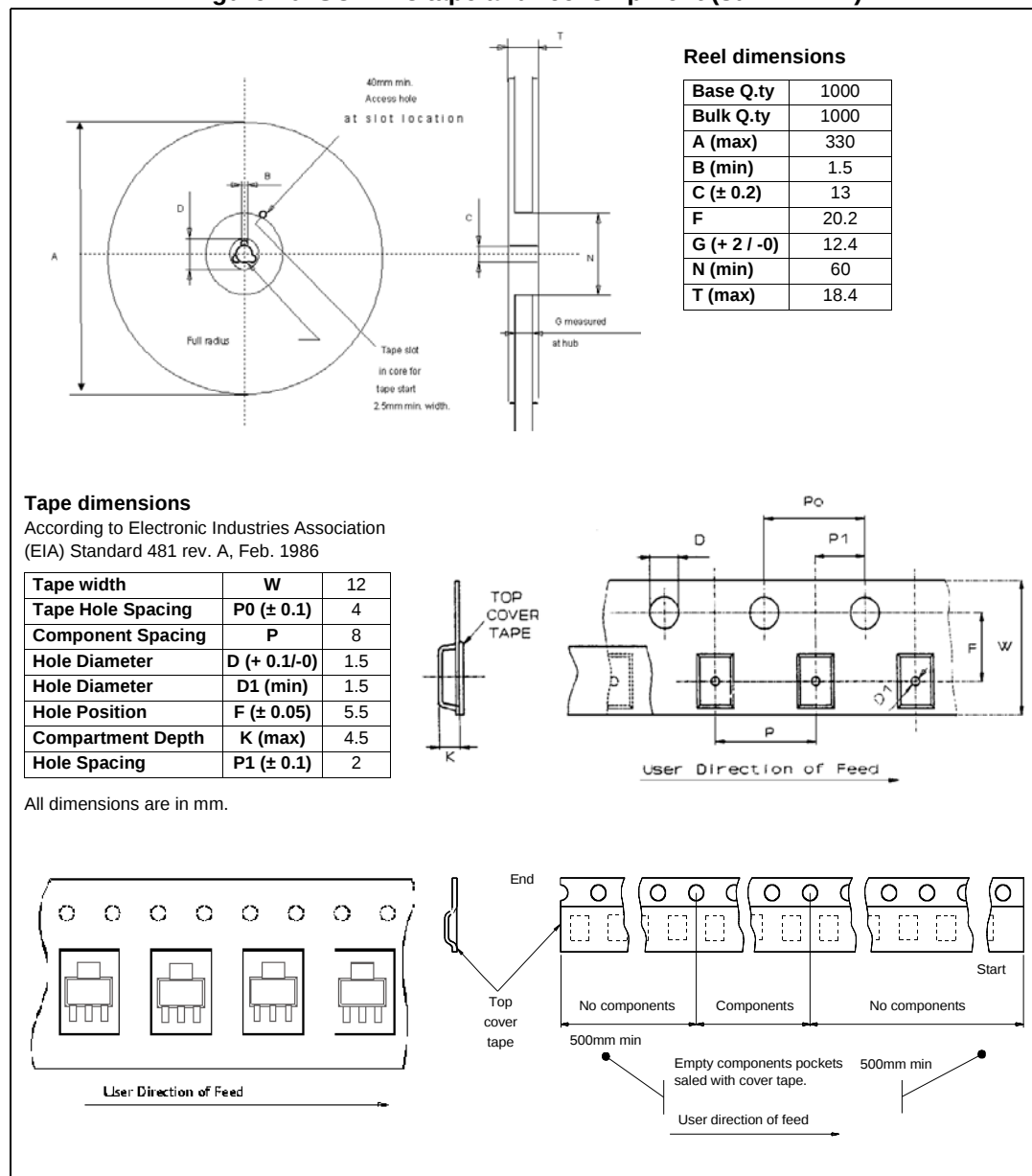
Figure 19. SO8 mechanical data &amp; package outline



## 6.4 SOT-223 packing information

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

Figure 20. SOT-223 tape and reel shipment (suffix "TR")



## 6.5 SO8 packing information

Figure 21. SO-8 tube shipment (no suffix)

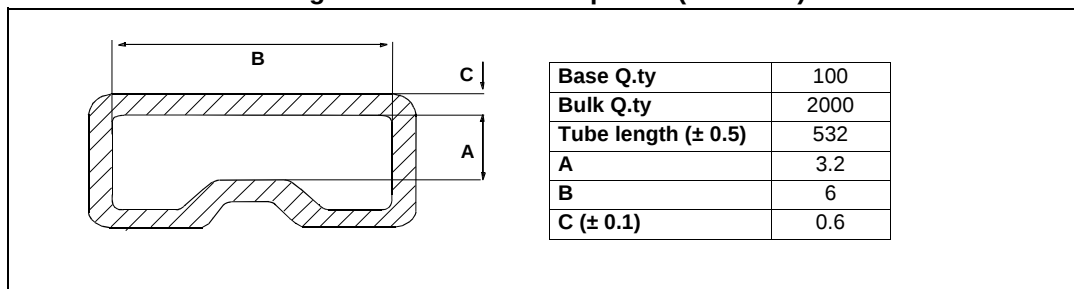
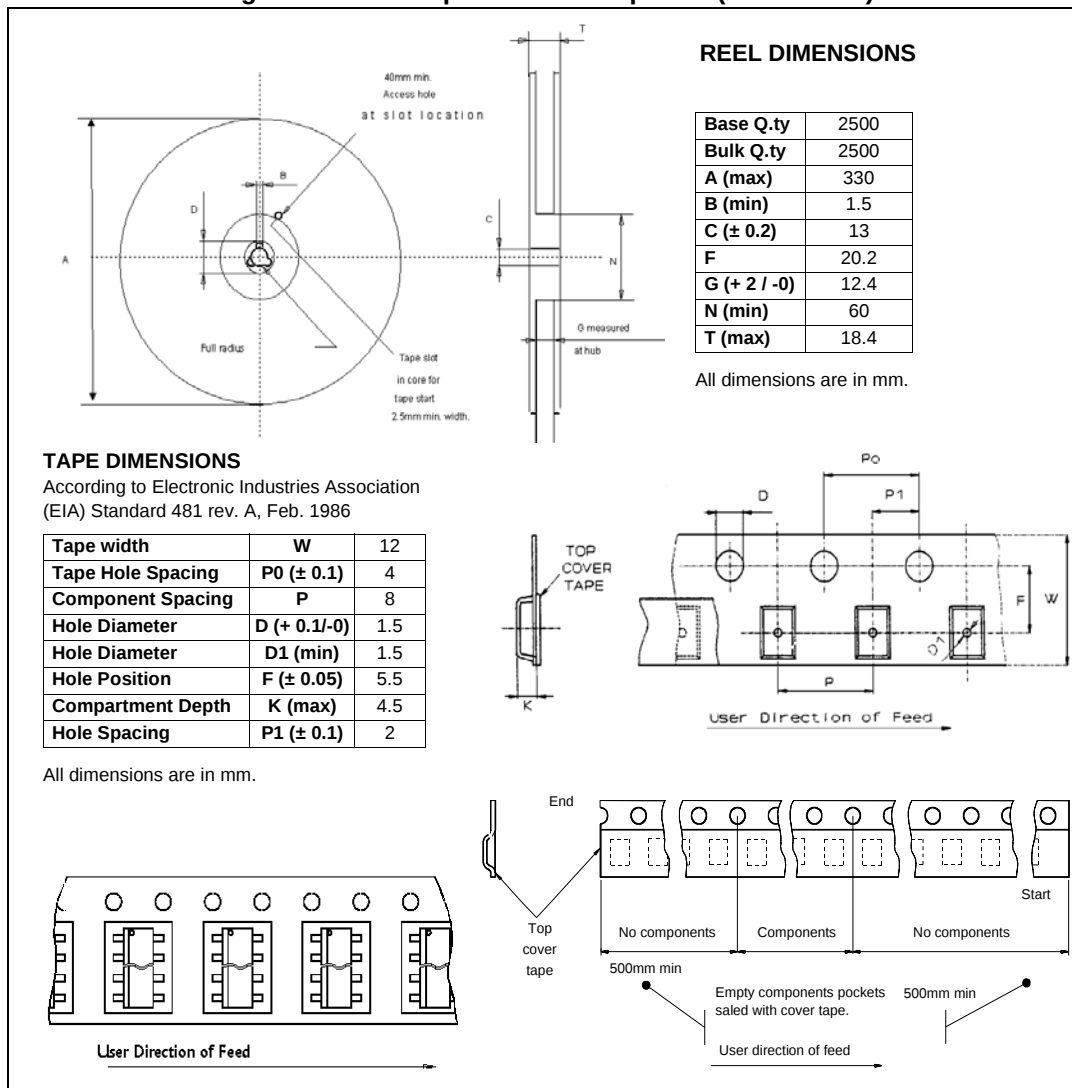


Figure 22. SO-8 tape and reel shipment (suffix "TR")



## 7 Revision history

Table 18. Document revision history

| Date        | Revision | Changes                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-------------|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 17-Nov-2009 | 1        | Initial release.                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 20-Feb-2012 | 2        | Update the entire document in ST template.<br>Update <a href="#">Section : Features</a> in cover page.                                                                                                                                                                                                                                                                                                                                                                 |
| 20-Sep-2013 | 3        | <a href="#">Table 9: Status pin</a> :<br>– $I_D$ : updated value<br><a href="#">Table 9: Status pin</a> :<br>– $I_{SS}$ : updated max value<br><a href="#">Table 13: Switching characteristics (<math>V_{CC} = 13 V</math>)</a> :<br>– $I_S$ : updated max value<br>Updated <a href="#">Figure 8: VNL5160S5-E application schematic</a><br>Updated <a href="#">Section 4.1: MCU I/O protection</a><br>Updated <a href="#">Figure 9: Maximum demagnetization energy</a> |

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