

N-channel 600 V, 13  $\Omega$  typ., 0.3 A Zener-protected SuperMESH™  
Power MOSFETs in SOT-223 and TO-92 packages

Datasheet - production data

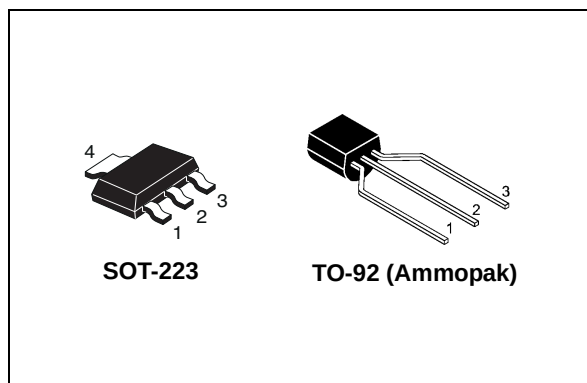
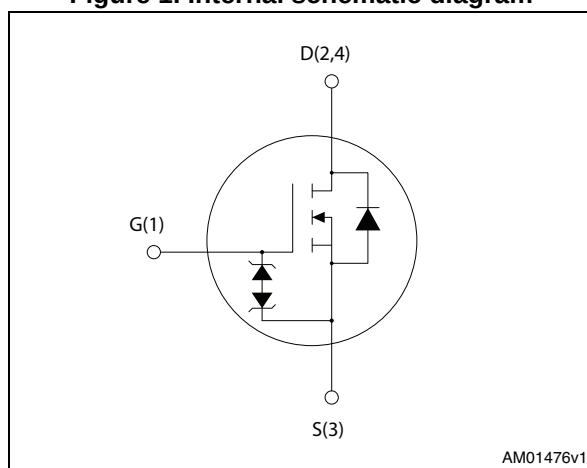


Figure 1. Internal schematic diagram



## Features

| Order codes   | $V_{DS}$ | $R_{DS(on)max}$ | $I_D$ | $P_{TOT}$ |
|---------------|----------|-----------------|-------|-----------|
| STN1NK60Z     | 600 V    | 15 $\Omega$     | 0.3 A | 3.3 W     |
| STQ1NK60ZR-AP |          |                 |       | 3 W       |

- 100% avalanche tested
- Extremely high dv/dt capability
- Gate charge minimized
- ESD improved capability
- Zener-protected

## Applications

- Switching applications

## Description

These devices are N-channel Zener-protected Power MOSFETs developed using STMicroelectronics' SuperMESH™ technology, achieved through optimization of ST's well established strip-based PowerMESH™ layout. In addition to a significant reduction in on-resistance, this device is designed to ensure a high level of dv/dt capability for the most demanding applications.

Table 1. Device summary

| Order codes   | Marking | Package | Packaging     |
|---------------|---------|---------|---------------|
| STN1NK60Z     | 1NK60Z  | SOT-223 | Tape and reel |
| STQ1NK60ZR-AP | 1NK60ZR | TO-92   | Ammopak       |

## Contents

|          |                                           |           |
|----------|-------------------------------------------|-----------|
| <b>1</b> | <b>Electrical ratings</b> .....           | <b>3</b>  |
| <b>2</b> | <b>Electrical characteristics</b> .....   | <b>4</b>  |
| 2.1      | Electrical characteristics (curves) ..... | 6         |
| <b>3</b> | <b>Test circuits</b> .....                | <b>9</b>  |
| <b>4</b> | <b>Package mechanical data</b> .....      | <b>10</b> |
| 4.1      | SOT-223, STN1NK60Z .....                  | 11        |
| 4.2      | TO-92 ammopack, STQ1NK60ZR-AP .....       | 13        |
| <b>5</b> | <b>Packaging mechanical data</b> .....    | <b>15</b> |
| <b>6</b> | <b>Revision history</b> .....             | <b>17</b> |

# 1 Electrical ratings

Table 2. Absolute maximum ratings

| Symbol         | Parameter                                                         | Value       |       | Unit                  |
|----------------|-------------------------------------------------------------------|-------------|-------|-----------------------|
|                |                                                                   | SOT-223     | TO-92 |                       |
| $V_{DS}$       | Drain-source voltage                                              | 600         |       | V                     |
| $V_{GS}$       | Gate-source voltage                                               | $\pm 30$    |       | V                     |
| $I_D$          | Drain current (continuous) at $T_C = 25\text{ }^{\circ}\text{C}$  | 0.3         |       | A                     |
| $I_D$          | Drain current (continuous) at $T_C = 100\text{ }^{\circ}\text{C}$ | 0.189       |       | A                     |
| $I_{DM}^{(1)}$ | Drain current (pulsed)                                            | 1.2         |       | A                     |
| $P_{TOT}$      | Total dissipation at $T_C = 25\text{ }^{\circ}\text{C}$           | 3.3         | 3     | W                     |
|                | Derating factor                                                   | 0.026       | 0.024 | W/ $^{\circ}\text{C}$ |
| ESD            | Human body model<br>C=100 pF, R=1.5 k $\Omega$                    | 800         |       | V                     |
| $dv/dt^{(2)}$  | Peak diode recovery voltage slope                                 | 4.5         |       | V/ns                  |
| $T_J$          | Operating junction temperature                                    | - 55 to 150 |       | $^{\circ}\text{C}$    |
| $T_{stg}$      | Storage temperature                                               |             |       | $^{\circ}\text{C}$    |

1. Pulse width limited by safe operating area
2.  $I_{SD} \leq 0.3\text{ A}$ ,  $di/dt \leq 200\text{ A}/\mu\text{s}$ ,  $V_{DD} = 80\%V_{(BR)DSS}$

Table 3. Thermal resistance

| Symbol         | Parameter                               | Value             |       | Unit                        |
|----------------|-----------------------------------------|-------------------|-------|-----------------------------|
|                |                                         | SOT-223           | TO-92 |                             |
| $R_{thj-amb}$  | Thermal resistance junction-ambient max | 38 <sup>(1)</sup> | 120   | $^{\circ}\text{C}/\text{W}$ |
| $R_{thj-lead}$ | Thermal resistance junction-lead max    |                   | 40    | $^{\circ}\text{C}/\text{W}$ |

1. When mounted on 1 inch<sup>2</sup> FR-4 board, 2 Oz Cu,  $t < 30\text{ s}$ .

Table 4. Avalanche data

| Symbol   | Parameter                                                                                                                 | Value | Unit |
|----------|---------------------------------------------------------------------------------------------------------------------------|-------|------|
| $I_{AR}$ | Avalanche current, repetitive or not repetitive<br>(pulse width limited by $T_{j\text{ max}}$ )                           | 0.3   | A    |
| $E_{AS}$ | Single pulse avalanche energy<br>(starting $T_J = 25\text{ }^{\circ}\text{C}$ , $I_D = I_{AR}$ , $V_{DD} = 50\text{ V}$ ) | 60    | mJ   |

## 2 Electrical characteristics

( $T_{CASE} = 25\text{ }^{\circ}\text{C}$  unless otherwise specified)

**Table 5. On/off states**

| Symbol        | Parameter                          | Test conditions                                                        | Min. | Typ. | Max.     | Unit          |
|---------------|------------------------------------|------------------------------------------------------------------------|------|------|----------|---------------|
| $V_{(BR)DSS}$ | Drain-source breakdown voltage     | $V_{GS} = 0, I_D = 1\text{ mA}$                                        | 600  |      |          | V             |
| $I_{DSS}$     | Zero gate voltage drain current    | $V_{GS} = 0, V_{DS} = 600\text{ V}$                                    |      |      | 1        | $\mu\text{A}$ |
|               |                                    | $V_{GS} = 0, V_{DS} = 600\text{ V}, T_C = 125\text{ }^{\circ}\text{C}$ |      |      | 50       | $\mu\text{A}$ |
| $I_{GSS}$     | Gate body leakage current          | $V_{DS} = 0, V_{GS} = \pm 20\text{ V}$                                 |      |      | $\pm 10$ | $\mu\text{A}$ |
| $V_{GS(th)}$  | Gate threshold voltage             | $V_{DS} = V_{GS}, I_D = 50\text{ }\mu\text{A}$                         | 3    | 3.75 | 4.5      | V             |
| $R_{DS(on)}$  | Static drain-source on- resistance | $V_{GS} = 10\text{ V}, I_D = 0.4\text{ A}$                             |      | 13   | 15       | $\Omega$      |

**Table 6. Dynamic**

| Symbol                    | Parameter                     | Test conditions                                      | Min. | Typ. | Max. | Unit |
|---------------------------|-------------------------------|------------------------------------------------------|------|------|------|------|
| $g_{fs}^{(1)}$            | Forward transconductance      | $V_{DS} = 15\text{ V}, I_D = 0.4\text{ A}$           | -    | 0.5  |      | S    |
| $C_{iss}$                 | Input capacitance             | $V_{GS} = 0, V_{DS} = 25\text{ V}, f = 1\text{ MHz}$ | -    | 94   |      | pF   |
| $C_{oss}$                 | Output capacitance            |                                                      | -    | 17.6 |      | pF   |
| $C_{rss}$                 | Reverse transfer capacitance  |                                                      | -    | 2.8  |      | pF   |
| $C_{oss\text{ eq}}^{(2)}$ | Equivalent output capacitance | $V_{GS} = 0, V_{DS} = 0\text{ to }480\text{ V}$      | -    | 11   |      | pF   |
| $Q_g$                     | Total gate charge             | $V_{DD} = 480\text{ V}, I_D = 0.8\text{ A}$          | -    | 4.9  | 6.9  | nC   |
| $Q_{gs}$                  | Gate-source charge            | $V_{GS} = 10\text{ V}$                               | -    | 1    |      | nC   |
| $Q_{gd}$                  | Gate-drain charge             | (see Figure 19)                                      | -    | 2.7  |      | nC   |

1. Pulsed: pulse duration=300 $\mu\text{s}$ , duty cycle 1.5%

2.  $C_{oss\text{ eq}}$  is defined as a constant equivalent capacitance giving the same charging time as  $C_{oss}$  when  $V_{DS}$  increases from 0 to 80%  $V_{DSS}$

Table 7. Switching times

| Symbol       | Parameter           | Test conditions                                                                                                     | Min. | Typ. | Max. | Unit |
|--------------|---------------------|---------------------------------------------------------------------------------------------------------------------|------|------|------|------|
| $t_{d(on)}$  | Turn-on delay time  | $V_{DD} = 300\text{ V}$ , $I_D = 0.4\text{ A}$ ,<br>$R_G = 4.7\ \Omega$ , $V_{GS} = 10\text{ V}$<br>(see Figure 18) | -    | 5.5  | -    | ns   |
| $t_r$        | Rise time           |                                                                                                                     | -    | 5    | -    | ns   |
| $t_{d(off)}$ | Turn-off delay time |                                                                                                                     | -    | 13   | -    | ns   |
| $t_f$        | Fall time           |                                                                                                                     | -    | 28   | -    | ns   |

Table 8. Source drain diode

| Symbol          | Parameter                     | Test conditions                                                                                                                 | Min. | Typ. | Max. | Unit |
|-----------------|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------|------|------|------|------|
| $I_{SD}$        | Source-drain current          |                                                                                                                                 | -    |      | 0.8  | A    |
| $I_{SDM}^{(1)}$ | Source-drain current (pulsed) |                                                                                                                                 | -    |      | 2.4  | A    |
| $V_{SD}^{(2)}$  | Forward on voltage            | $V_{GS}=0$ , $I_{SD} = 0.8\text{ A}$                                                                                            | -    |      | 1.6  | V    |
| $t_{rr}$        | Reverse recovery time         | $I_{SD} = 0.8\text{ A}$ ,<br>$di/dt = 100\text{ A}/\mu\text{s}$ ,<br>$V_{DD} = 20\text{ V}$                                     | -    | 135  |      | ns   |
| $Q_{rr}$        | Reverse recovery charge       |                                                                                                                                 | -    | 216  |      | nC   |
| $I_{RRM}$       | Reverse recovery current      |                                                                                                                                 | -    | 3.2  |      | A    |
| $t_{rr}$        | Reverse recovery time         | $I_{SD} = 0.8\text{ A}$ ,<br>$di/dt = 100\text{ A}/\mu\text{s}$ ,<br>$V_{DD} = 20\text{ V}$ , $T_j = 150\text{ }^\circ\text{C}$ | -    | 140  |      | ns   |
| $Q_{rr}$        | Reverse recovery charge       |                                                                                                                                 | -    | 224  |      | nC   |
| $I_{RRM}$       | Reverse recovery current      |                                                                                                                                 | -    | 3.2  |      | A    |

1. Pulse width limited by safe operating area.

2. Pulsed: pulse duration=300 $\mu\text{s}$ , duty cycle 1.5%

Table 9. Gate-source Zener diode

| Symbol        | Parameter                     | Test conditions                      | Min | Typ. | Max. | Unit |
|---------------|-------------------------------|--------------------------------------|-----|------|------|------|
| $V_{(BR)GSO}$ | Gate-source breakdown voltage | $I_{GS} = \pm 1\text{ mA}$ , $I_D=0$ | 30  | -    | -    | V    |

The built-in back-to-back Zener diodes have specifically been designed to enhance the device's ESD capability. In this respect the Zener voltage is appropriate to achieve an efficient and cost-effective intervention to protect the device's integrity. These integrated Zener diodes thus avoid the usage of external components.

## 2.1 Electrical characteristics (curves)

Figure 2. Safe operating area for SOT-223

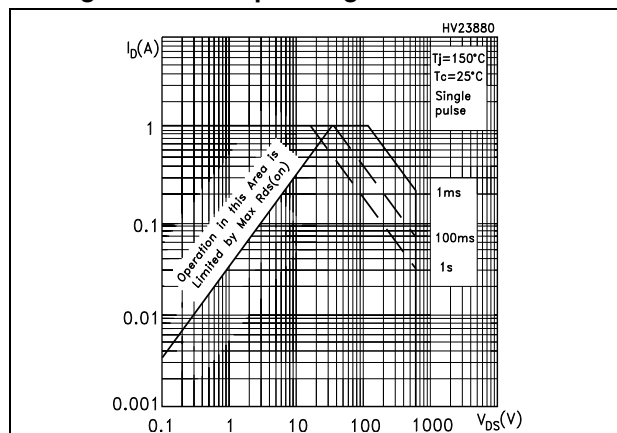


Figure 3. Thermal impedance for SOT-223

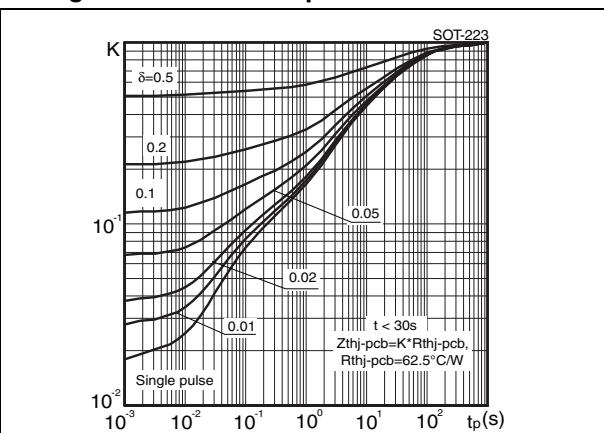


Figure 4. Safe operating area for TO-92

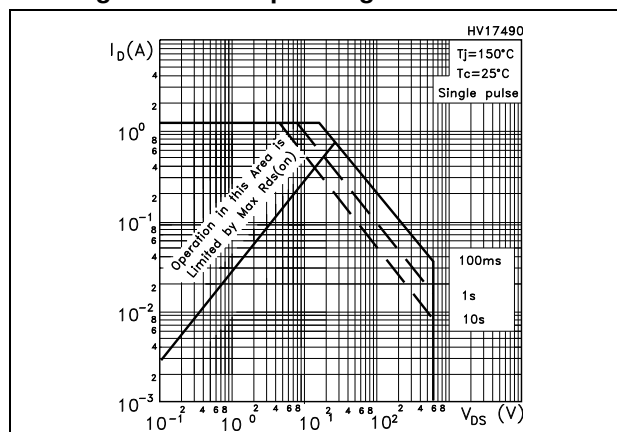


Figure 5. Thermal impedance for TO-92

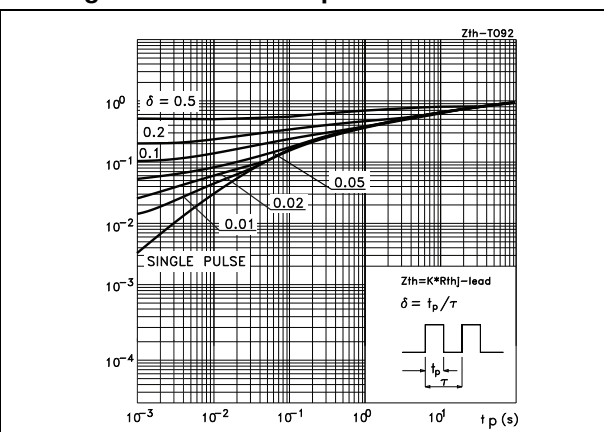


Figure 6. Output characteristics

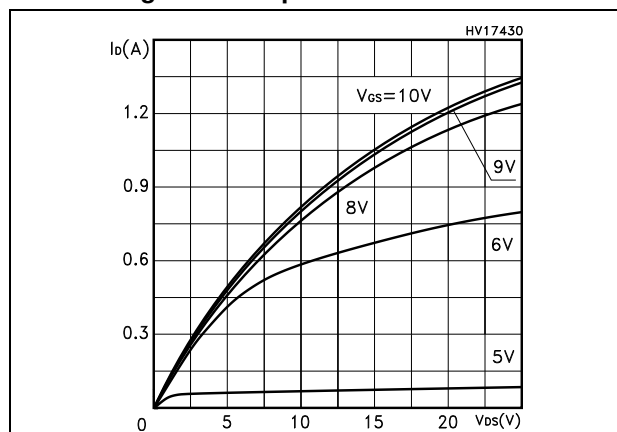


Figure 7. Transfer characteristics

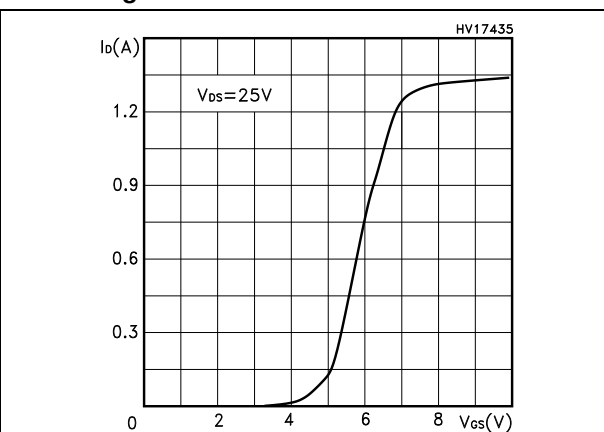


Figure 8. Transconductance

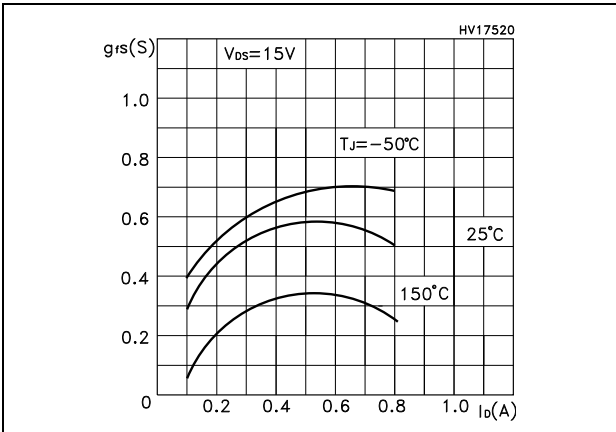


Figure 9. Static drain-source on-resistance

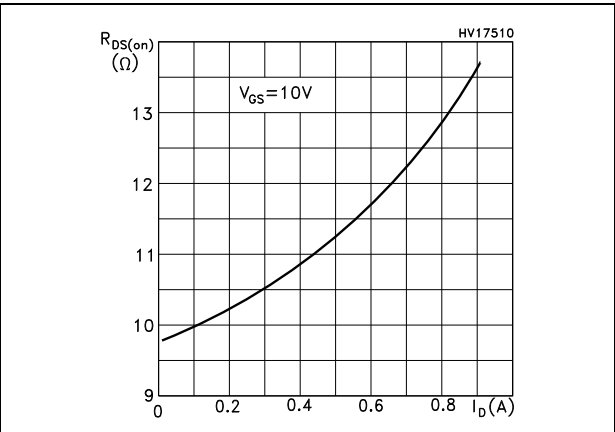


Figure 10. Gate charge vs gate-source voltage

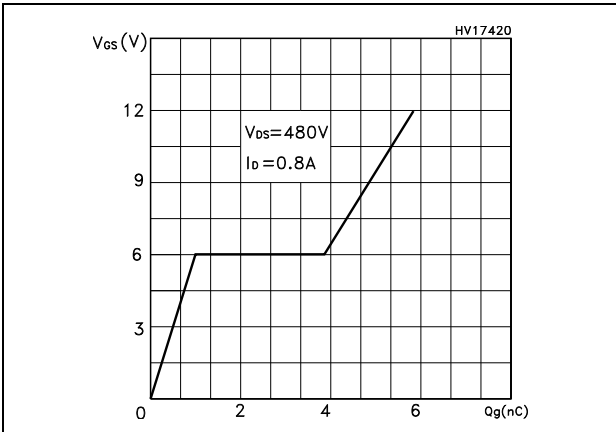


Figure 11. Capacitance variations

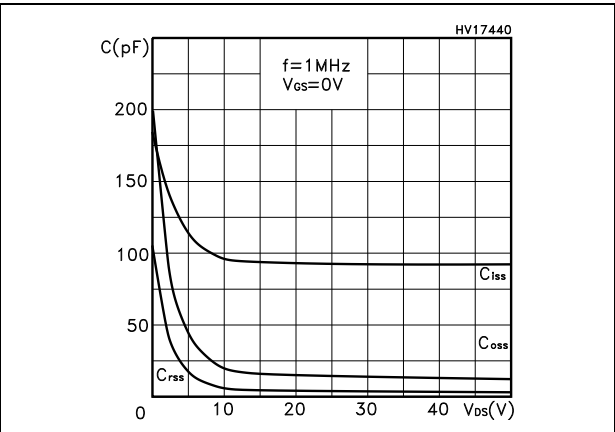


Figure 12. Normalized gate threshold voltage vs temperature

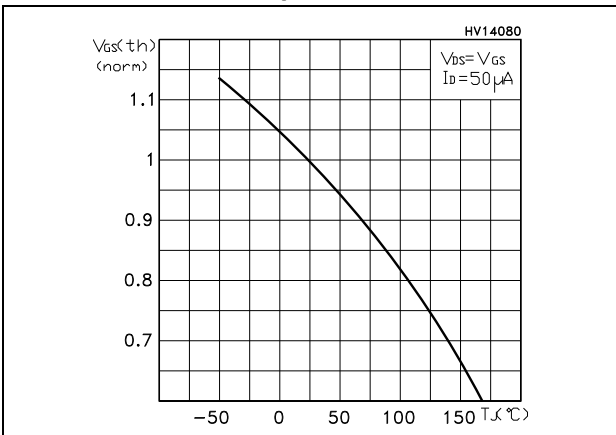


Figure 13. Normalized on-resistance vs temperature

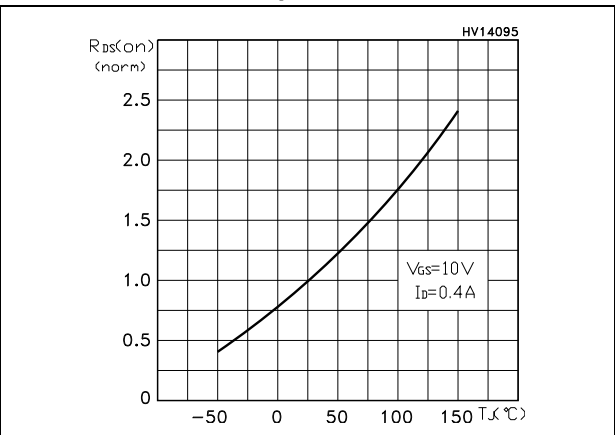


Figure 14. Source-drain diode forward characteristics

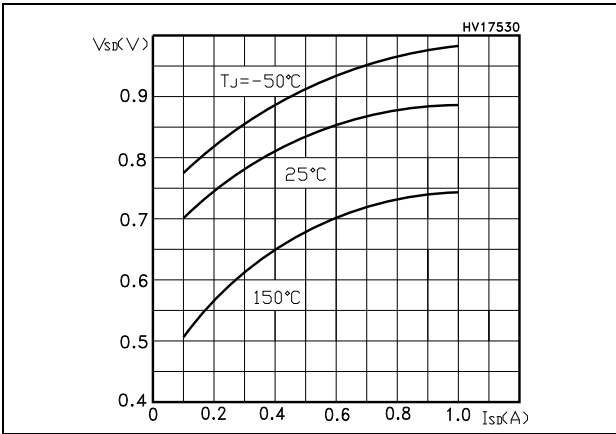


Figure 15. Normalized  $V_{BR(DSS)}$  vs temperature

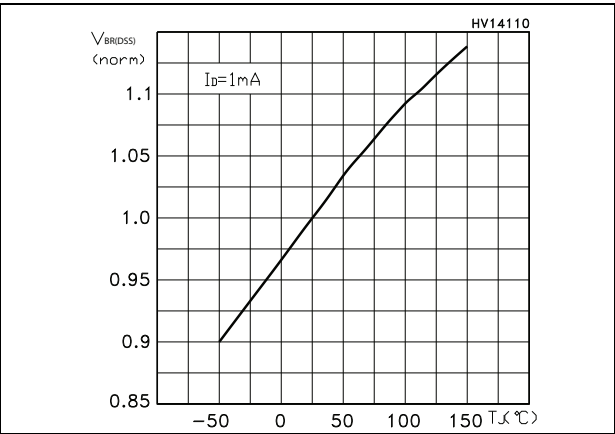


Figure 16. Maximum avalanche energy vs temperature

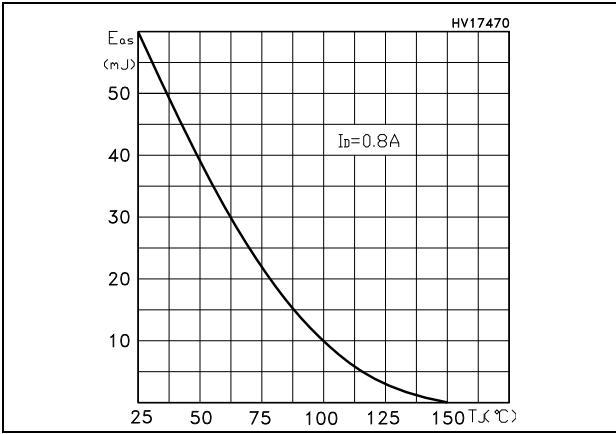
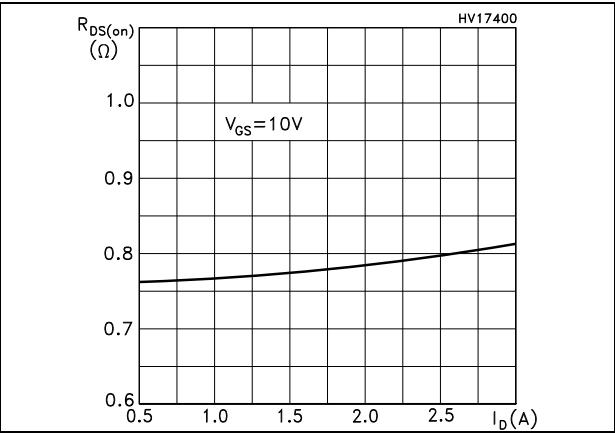


Figure 17. Max Id current vs Tc





### 3 Test circuits

Figure 18. Switching times test circuit for resistive load

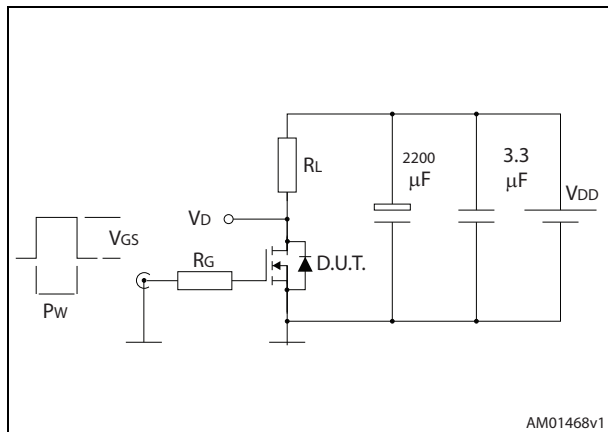


Figure 19. Gate charge test circuit

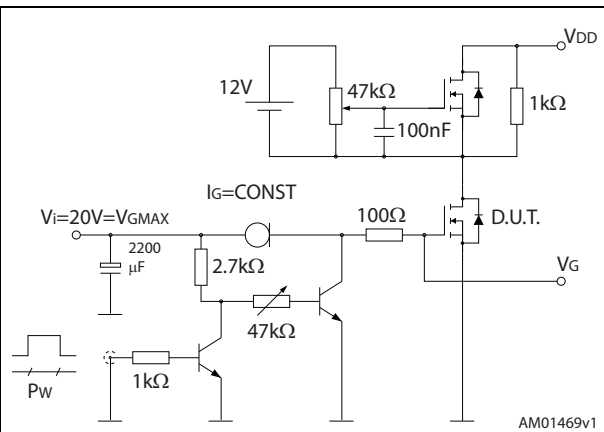


Figure 20. Test circuit for inductive load switching and diode recovery times

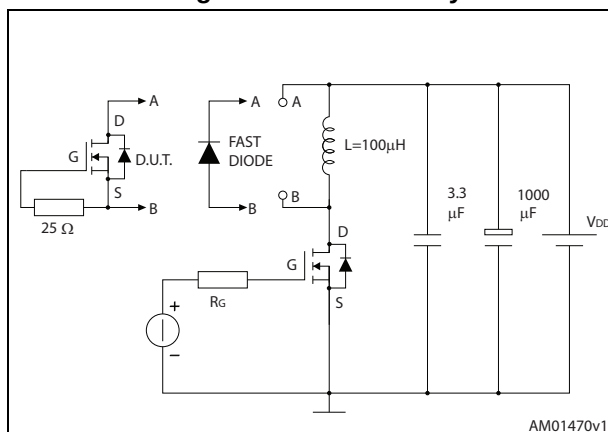


Figure 21. Unclamped inductive load test circuit

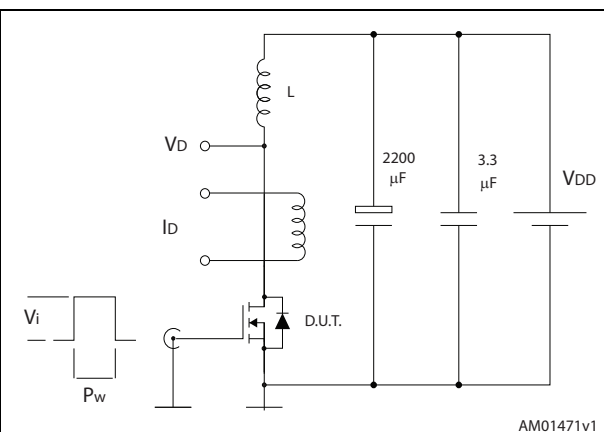


Figure 22. Unclamped inductive waveform

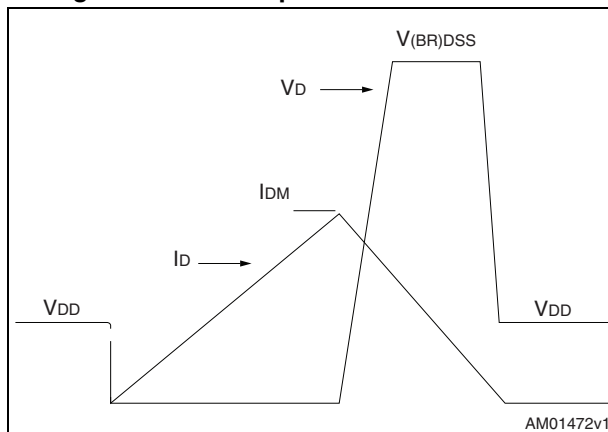
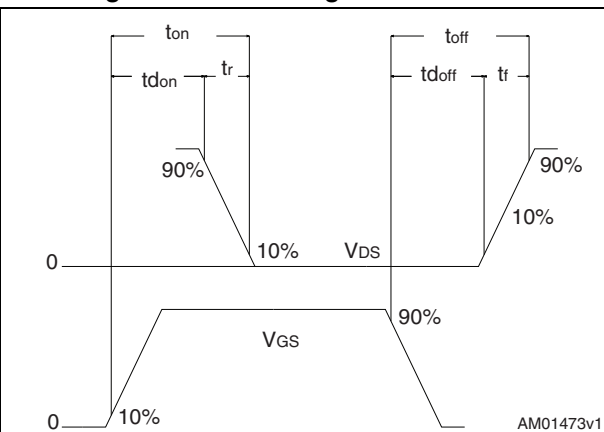


Figure 23. Switching time waveform



## 4 Package mechanical data

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK<sup>®</sup> packages, depending on their level of environmental compliance. ECOPACK<sup>®</sup> specifications, grade definitions and product status are available at: [www.st.com](http://www.st.com). ECOPACK<sup>®</sup> is an ST trademark.

Figure 24. SOT-223 mechanical data drawing

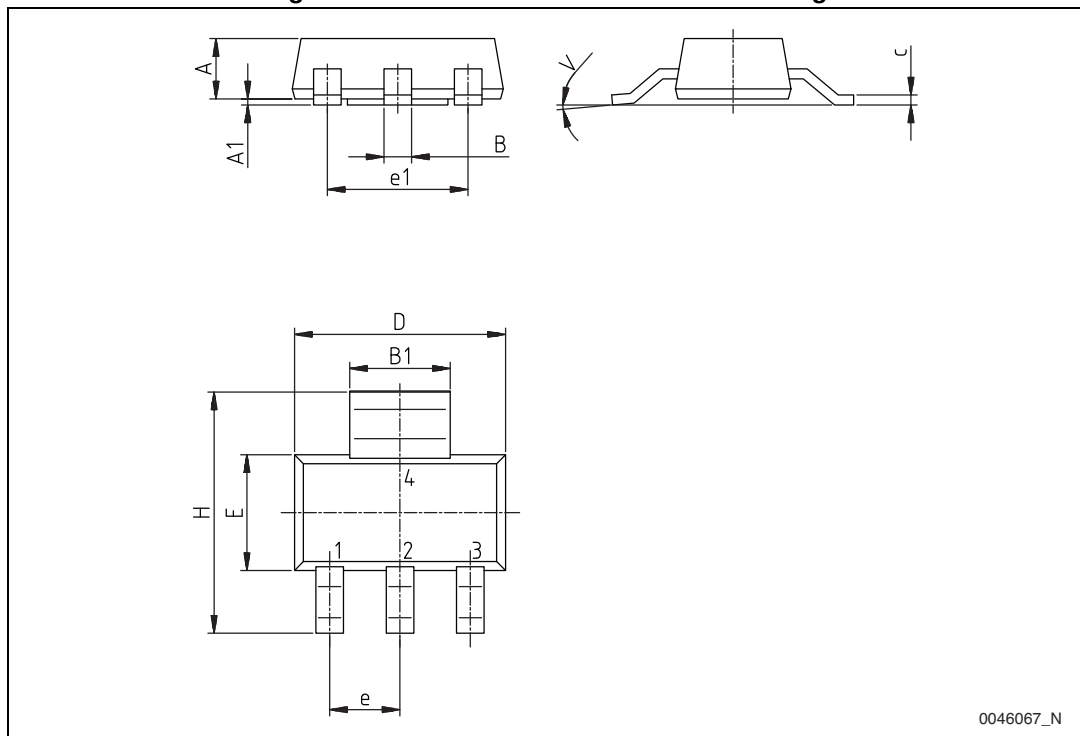
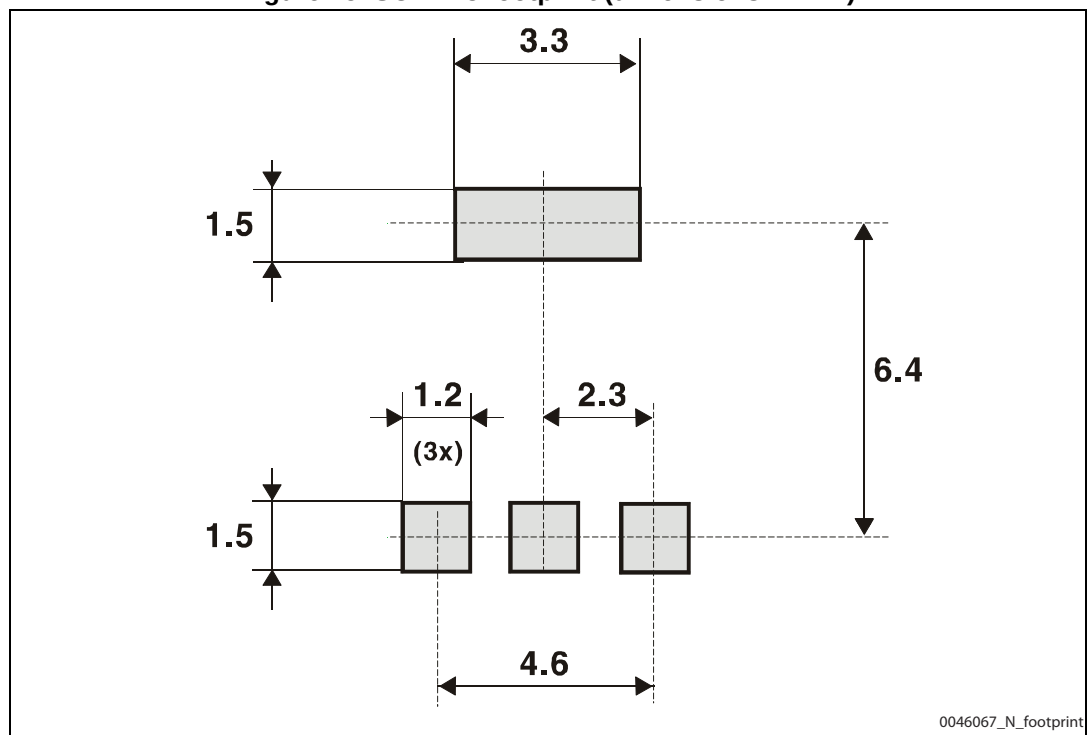


Table 10. SOT-223 mechanical data

| Dim. | mm   |      |      |
|------|------|------|------|
|      | Min. | Typ. | Max. |
| A    |      |      | 1.80 |
| A1   | 0.02 |      | 0.10 |
| B    | 0.60 | 0.70 | 0.85 |
| B1   | 2.9  | 3.0  | 3.15 |
| c    | 0.24 | 0.26 | 0.35 |
| D    | 6.30 | 6.50 | 6.70 |
| e    |      | 2.30 | 6.70 |
| e1   |      | 4.60 |      |
| E    | 3.30 | 3.50 | 3.70 |
| H    | 6.70 | 7.0  | 7.30 |
| V    |      |      | 10°  |

Figure 25. SOT-223 footprint (dimensions in mm)



#### 4.1 SOT-223, STN1NK60Z

#### 4.2 TO-92 ammopack, STQ1NK60ZR-AP

Figure 26. TO-92 ammopack mechanical data drawing

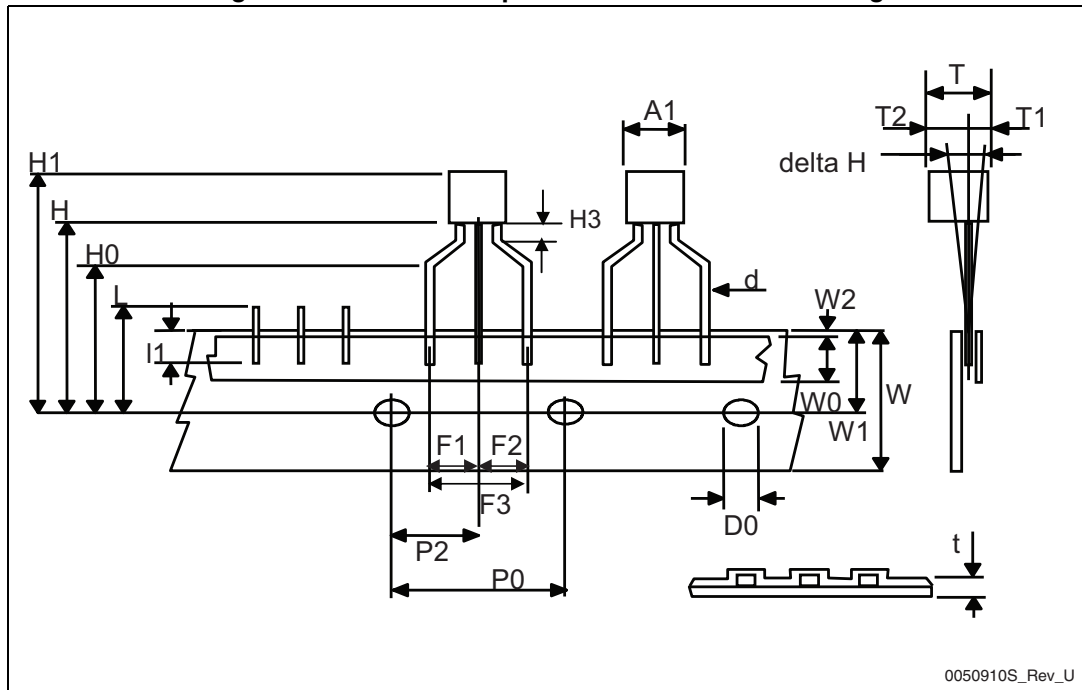


Table 11. TO-92 ammpack mechanical data

| Dim.    | mm    |       |       |
|---------|-------|-------|-------|
|         | Min.  | Typ.  | Max.  |
| A1      |       |       | 4.80  |
| T       |       |       | 3.80  |
| T1      |       |       | 1.60  |
| T2      |       |       | 2.30  |
| d       | 0.45  | 0.47  | 0.48  |
| P0      | 12.50 | 12.70 | 12.90 |
| P2      | 5.65  | 6.35  | 7.05  |
| F1, F2  | 2.40  | 2.50  | 2.94  |
| F3      | 4.98  | 5.08  | 5.48  |
| delta H | -2.00 |       | 2.00  |
| W       | 17.50 | 18.00 | 19.00 |
| W0      | 5.5   | 6.00  | 6.5   |
| W1      | 8.50  | 9.00  | 9.25  |
| W2      |       |       | 0.50  |
| H       |       | 18.50 | 21    |
| H3      | 0.5   | 1     | 2     |
| H0      | 15.50 | 16.00 | 18.8  |
| H1      |       | 25.0  | 27.0  |
| D0      | 3.80  | 4.00  | 4.20  |
| t       |       |       | 0.90  |
| L       |       |       | 11.00 |
| l1      | 3.00  |       |       |
| delta P | -1.00 |       | 1.00  |

## 5 Packaging mechanical data

Figure 27. Tape for SOT-223 (dimensions are in mm)

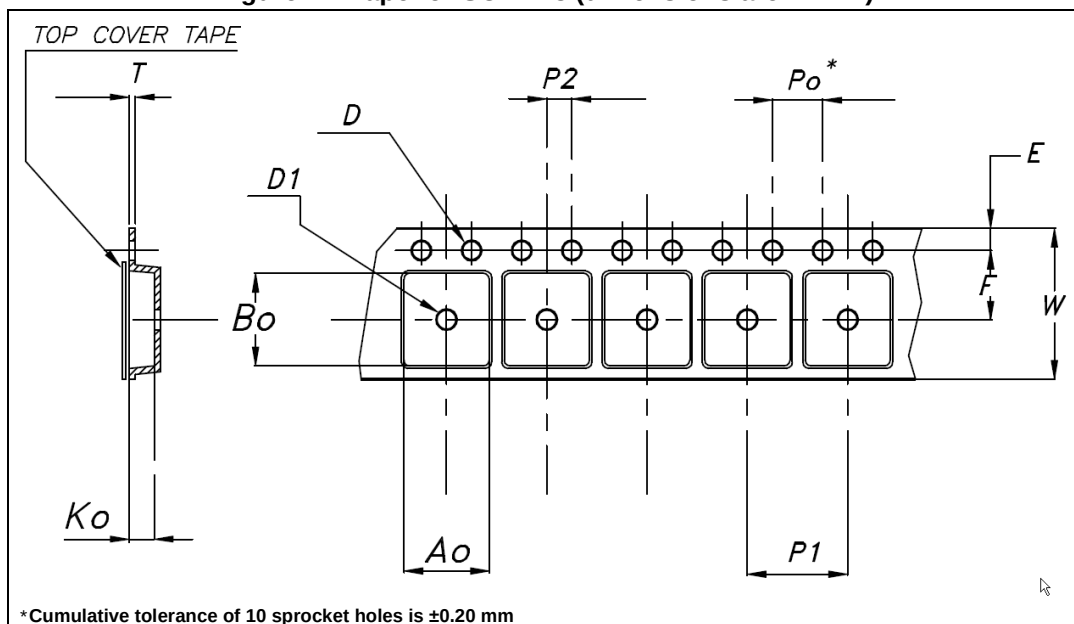


Figure 28. Reel for TO-223 (dimensions are in mm)

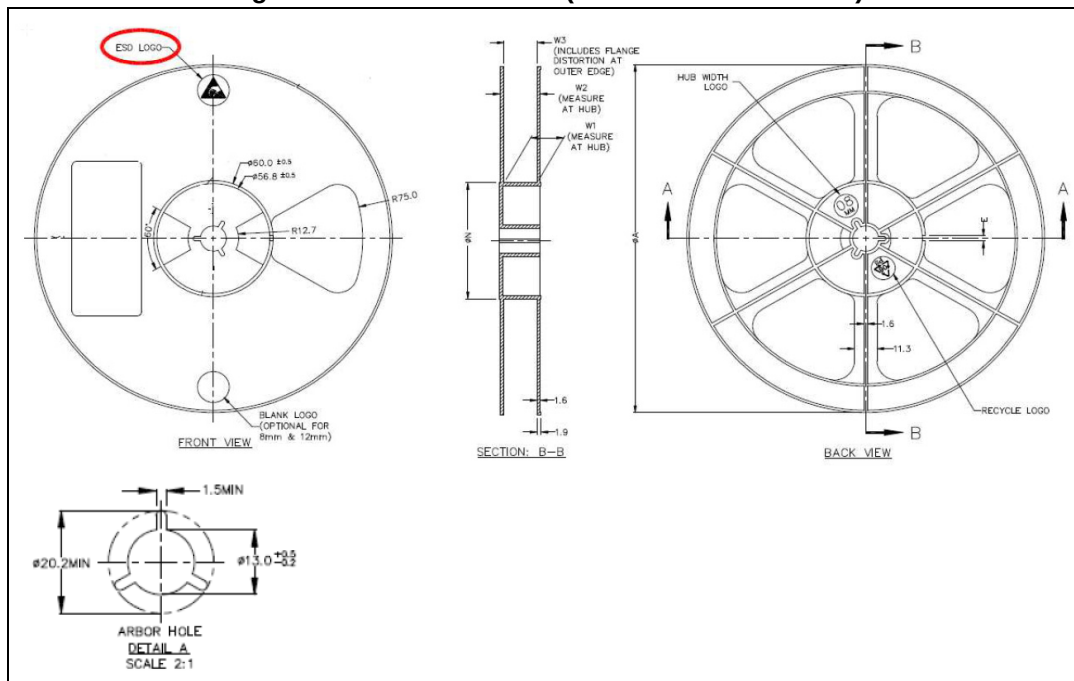


Table 12. SOT-223 tape and reel mechanical data

| Tape      |      |      |      | Reel              |      |      |
|-----------|------|------|------|-------------------|------|------|
| Dim.      | mm   |      |      | Dim.              | mm   |      |
|           | Min. | Typ. | Max. |                   | Min. | Max. |
| A0        | 6.75 | 6.85 | 6.95 | A                 |      | 180  |
| B0        | 7.30 | 7.40 | 7.50 | N                 | 60   |      |
| K0        | 1.80 | 1.90 | 2.00 | W1                |      | 12.4 |
| F         | 5.40 | 5.50 | 5.60 | W2                |      | 18.4 |
| E         | 1.65 | 1.75 | 1.85 | W3                | 11.9 | 15.4 |
| W         | 11.7 | 12   | 12.3 |                   |      |      |
| P2        | 1.90 | 2    | 2.10 | Base quantity pcs |      | 1000 |
| P0        | 3.90 | 4    | 4.10 | Bulk quantity pcs |      | 1000 |
| P1        | 7.90 | 8    | 8.10 |                   |      |      |
| T         | 0.25 | 0.30 | 0.35 |                   |      |      |
| D $\phi$  | 1.50 | 1.55 | 1.60 |                   |      |      |
| D1 $\phi$ | 1.50 | 1.60 | 1.70 |                   |      |      |



## 6 Revision history

Table 13. Revision history

| Date        | Revision | Changes                                                                                                                                                                                                                                                           |
|-------------|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 19-Mar-2003 | 3        | First electronic version                                                                                                                                                                                                                                          |
| 15-May-2003 | 4        | Removed DPAK                                                                                                                                                                                                                                                      |
| 09-Jun-2003 | 5        | Final datasheet                                                                                                                                                                                                                                                   |
| 17-Nov-2004 | 6        | Inserted SOT-223                                                                                                                                                                                                                                                  |
| 15-Feb-2005 | 7        | Modified <a href="#">Figure 4</a> .                                                                                                                                                                                                                               |
| 07-Sep-2005 | 8        | Inserted ecopack indication                                                                                                                                                                                                                                       |
| 22-Feb-2006 | 9        | The document has been reformatted                                                                                                                                                                                                                                 |
| 01-Jun-2007 | 10       | Order code table on first page has been updated                                                                                                                                                                                                                   |
| 19-Jul-2007 | 11       | <a href="#">Table 1: Device summary</a> has been updated                                                                                                                                                                                                          |
| 05-Jan-2011 | 12       | Corrected <a href="#">Figure 2: Safe operating area for SOT-223</a> and <a href="#">Figure 3: Thermal impedance for SOT-223</a>                                                                                                                                   |
| 05-Jun-2014 | 13       | <ul style="list-style-type: none"> <li>– Updated title.</li> <li>– Updated derating factor in <a href="#">Table 2: Absolute maximum ratings</a>.</li> <li>– Updated <a href="#">Section 4: Package mechanical data</a>.</li> <li>– Minor text changes.</li> </ul> |
| 04-Jul-2014 | 14       | – Updated <a href="#">Section 3: Test circuits</a> .                                                                                                                                                                                                              |

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