

N-channel 950 V, 4.2  $\Omega$  typ., 2 A Zener-protected SuperMESH™ 5 Power MOSFETs in DPAK, TO-220FP, TO-220 and IPAK packages

Datasheet - production data

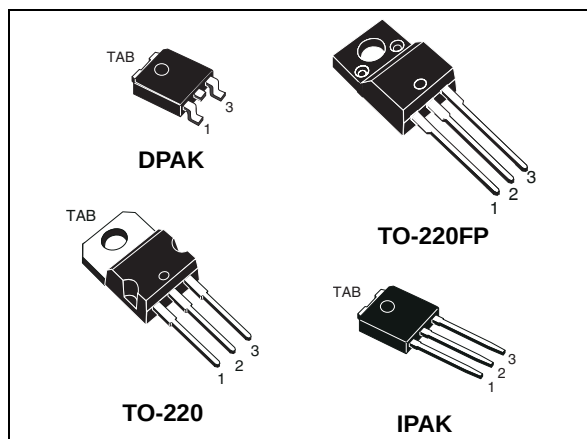
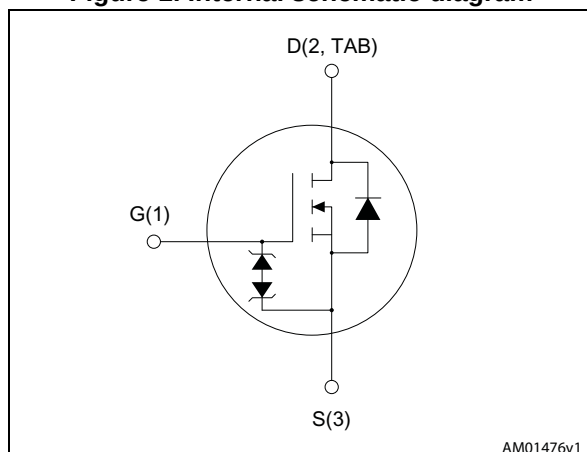


Figure 1. Internal schematic diagram



## Features

| Order codes | $V_{DS}$ | $R_{DS(on)}$ max | $I_D$ | $P_{TOT}$ |
|-------------|----------|------------------|-------|-----------|
| STD2N95K5   | 950 V    | 5 $\Omega$       | 2 A   | 45 W      |
| STF2N95K5   |          |                  |       | 20 W      |
| STP2N95K5   |          |                  |       | 45 W      |
| STU2N95K5   |          |                  |       |           |

- TO-220 worldwide best  $R_{DS(on)}$
- Worldwide best FOM (figure of merit)
- Ultra low gate charge
- 100% avalanche tested
- Zener-protected

## Applications

- Switching applications

## Description

These N-channel Zener-protected Power MOSFETs are designed using ST's revolutionary avalanche-rugged very high voltage SuperMESH™ 5 technology, based on an innovative proprietary vertical structure. The result is a dramatic reduction in on-resistance, and ultra-low gate charge for applications which require superior power density and high efficiency.

Table 1. Device summary

| Order codes | Marking | Package  | Packaging     |
|-------------|---------|----------|---------------|
| STD2N95K5   | 2N95K5  | DPAK     | Tape and reel |
| STF2N95K5   |         | TO-220FP | Tube          |
| STP2N95K5   |         | TO-220   |               |
| STU2N95K5   |         | IPAK     |               |

Contents

1      **Electrical ratings** ..... 3

2      **Electrical characteristics** ..... 4

      2.1    Electrical characteristics (curves) ..... 6

3      **Test circuits** ..... 9

4      **Package mechanical data** ..... 10

5      **Packaging mechanical data** ..... 20

6      **Revision history** ..... 22



# 1 Electrical ratings

Table 2. Absolute maximum ratings

| Symbol             | Parameter                                                                                                             | Value              |                    | Unit |
|--------------------|-----------------------------------------------------------------------------------------------------------------------|--------------------|--------------------|------|
|                    |                                                                                                                       | TO-220FP           | DPAK, TO-220, IPAK |      |
| $V_{GS}$           | Gate- source voltage                                                                                                  | 30                 |                    | V    |
| $I_D$              | Drain current (continuous) at $T_C = 25\text{ °C}$                                                                    | 2 <sup>(1)</sup>   | 2                  | A    |
| $I_D$              | Drain current (continuous) at $T_C = 100\text{ °C}$                                                                   | 1.3 <sup>(1)</sup> | 1.3                | A    |
| $I_{DM}^{(2)}$     | Drain current (pulsed)                                                                                                | 8                  |                    | A    |
| $P_{TOT}$          | Total dissipation at $T_C = 25\text{ °C}$                                                                             | 20                 | 45                 | W    |
| $I_{AR}$           | Max current during repetitive or single pulse avalanche                                                               | 1                  |                    | A    |
| $E_{AS}$           | Single pulse avalanche energy (starting $T_J = 25\text{ °C}$ , $I_D = I_{AS}$ , $V_{DD} = 50\text{ V}$ )              | 50                 |                    | mJ   |
| $dv/dt^{(3)}$      | Peak diode recovery voltage slope                                                                                     | 4.5                |                    | V/ns |
| $dv/dt^{(4)}$      | MOSFET $dv/dt$ ruggedness                                                                                             | 50                 |                    | V/ns |
| $V_{ISO}$          | Insulation withstand voltage (RMS) from all three leads to external heat sink ( $t=1\text{ s}$ ; $T_C=25\text{ °C}$ ) | 2500               |                    | V    |
| $T_J$<br>$T_{stg}$ | Operating junction temperature<br>Storage temperature                                                                 | - 55 to 150        |                    | °C   |

1. Limited by maximum junction temperature
2. Pulse width limited by safe operating area.
3.  $I_{SD} \leq 2\text{ A}$ ,  $di/dt \leq 100\text{ A}/\mu\text{s}$ ,  $V_{Peak} \leq V_{(BR)DSS}$ .
4.  $V_{SD} \leq 760\text{ V}$

Table 3. Thermal data

| Symbol         | Parameter                               | Value    |                    | Unit |
|----------------|-----------------------------------------|----------|--------------------|------|
|                |                                         | TO-220FP | DPAK, TO-220, IPAK |      |
| $R_{thj-case}$ | Thermal resistance junction-case max    | 6.25     | 2.78               | °C/W |
| $R_{thj-amb}$  | Thermal resistance junction-ambient max | 62.50    |                    | °C/W |

## 2 Electrical characteristics

(T<sub>case</sub> = 25 °C unless otherwise specified)

**Table 4. On /off states**

| Symbol               | Parameter                                               | Test conditions                                                             | Min. | Typ. | Max.    | Unit     |
|----------------------|---------------------------------------------------------|-----------------------------------------------------------------------------|------|------|---------|----------|
| V <sub>(BR)DSS</sub> | Drain-source breakdown voltage                          | I <sub>D</sub> = 1 mA, V <sub>GS</sub> = 0                                  | 950  |      |         | V        |
| I <sub>DSS</sub>     | Zero gate voltage, V <sub>GS</sub> = 0<br>drain current | V <sub>DS</sub> = 950 V<br>V <sub>DS</sub> = 950 V, T <sub>C</sub> = 125 °C |      |      | 1<br>50 | μA<br>μA |
| I <sub>GSS</sub>     | Gate-body leakage current                               | V <sub>GS</sub> = ± 20 V; V <sub>DS</sub> = 0                               |      |      | 10      | μA       |
| V <sub>GS(th)</sub>  | Gate threshold voltage                                  | V <sub>DS</sub> = V <sub>GS</sub> , I <sub>D</sub> = 100 μA                 | 3    | 4    | 5       | V        |
| R <sub>DS(on)</sub>  | Static drain-source on-resistance                       | V <sub>GS</sub> = 10 V, I <sub>D</sub> = 1 A                                |      | 4.2  | 5       | Ω        |

**Table 5. Dynamic**

| Symbol                            | Parameter                             | Test conditions                                                                                             | Min. | Typ. | Max. | Unit |
|-----------------------------------|---------------------------------------|-------------------------------------------------------------------------------------------------------------|------|------|------|------|
| C <sub>iss</sub>                  | Input capacitance                     | V <sub>DS</sub> = 100 V, f = 1 MHz, V <sub>GS</sub> = 0                                                     | -    | 105  | -    | pF   |
| C <sub>oss</sub>                  | Output capacitance                    |                                                                                                             | -    | 9    | -    | pF   |
| C <sub>rss</sub>                  | Reverse transfer capacitance          |                                                                                                             | -    | 0.5  | -    | pF   |
| C <sub>o(tr)</sub> <sup>(1)</sup> | Equivalent capacitance time related   | V <sub>GS</sub> = 0, V <sub>DS</sub> = 0 to 760 V                                                           | -    | 16   | -    | pF   |
| C <sub>o(er)</sub> <sup>(2)</sup> | Equivalent capacitance energy related |                                                                                                             | -    | 6    | -    | pF   |
| R <sub>G</sub>                    | Intrinsic gate resistance             | f = 1 MHz open drain                                                                                        | -    | 16   | -    | Ω    |
| Q <sub>g</sub>                    | Total gate charge                     | V <sub>DD</sub> = 760 V, I <sub>D</sub> = 2 A<br>V <sub>GS</sub> = 10 V<br>(see <a href="#">Figure 19</a> ) | -    | 10   | -    | nC   |
| Q <sub>gs</sub>                   | Gate-source charge                    |                                                                                                             | -    | 1.5  | -    | nC   |
| Q <sub>gd</sub>                   | Gate-drain charge                     |                                                                                                             | -    | 8    | -    | nC   |

1. Time related is defined as a constant equivalent capacitance giving the same charging time as C<sub>oss</sub> when V<sub>DS</sub> increases from 0 to 80% V<sub>DSS</sub>
2. energy related is defined as a constant equivalent capacitance giving the same stored energy as C<sub>oss</sub> when V<sub>DS</sub> increases from 0 to 80% V<sub>DSS</sub>

Table 6. Switching times

| Symbol       | Parameter           | Test conditions                                                                                                   | Min. | Typ. | Max | Unit |
|--------------|---------------------|-------------------------------------------------------------------------------------------------------------------|------|------|-----|------|
| $t_{d(on)}$  | Turn-on delay time  | $V_{DD} = 475\text{ V}$ , $I_D = 1\text{ A}$ ,<br>$R_G = 4.7\ \Omega$ , $V_{GS} = 10\text{ V}$<br>(see Figure 18) | -    | 8.5  | -   | ns   |
| $t_r$        | Rise time           |                                                                                                                   | -    | 13.5 | -   | ns   |
| $t_{d(off)}$ | Turn-off-delay time |                                                                                                                   | -    | 20.5 | -   | ns   |
| $t_f$        | Fall time           |                                                                                                                   | -    | 32.5 | -   | ns   |

Table 7. Source drain diode

| Symbol          | Parameter                     | Test conditions                                                                                                                             | Min. | Typ. | Max | Unit          |
|-----------------|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|------|------|-----|---------------|
| $I_{SD}$        | Source-drain current          |                                                                                                                                             | -    |      | 2   | A             |
| $I_{SDM}^{(1)}$ | Source-drain current (pulsed) |                                                                                                                                             | -    |      | 8   | A             |
| $V_{SD}^{(2)}$  | Forward on voltage            | $I_{SD} = 2\text{ A}$ , $V_{GS} = 0$                                                                                                        | -    |      | 1.5 | V             |
| $t_{rr}$        | Reverse recovery time         | $I_{SD} = 2\text{ A}$ , $di/dt = 100\text{ A}/\mu\text{s}$<br>$V_{DD} = 60\text{ V}$<br>(see Figure 20)                                     | -    | 300  |     | ns            |
| $Q_{rr}$        | Reverse recovery charge       |                                                                                                                                             | -    | 1.15 |     | $\mu\text{C}$ |
| $I_{RRM}$       | Reverse recovery current      |                                                                                                                                             | -    | 7.6  |     | A             |
| $t_{rr}$        | Reverse recovery time         | $I_{SD} = 2\text{ A}$ , $di/dt = 100\text{ A}/\mu\text{s}$<br>$V_{DD} = 60\text{ V}$ , $T_J = 150\text{ }^\circ\text{C}$<br>(see Figure 20) | -    | 525  |     | ns            |
| $Q_{rr}$        | Reverse recovery charge       |                                                                                                                                             | -    | 1.90 |     | $\mu\text{C}$ |
| $I_{RRM}$       | Reverse recovery current      |                                                                                                                                             | -    | 7.2  |     | A             |

1. Pulse width limited by safe operating area

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

Table 8. 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 been specifically designed to enhance not only the device's ESD capability, but also to make them capable of safely absorbing any voltage transients that may occasionally be applied from gate to source. In this respect, the Zener voltage is appropriate to achieve efficient and cost-effective protection of device integrity. The integrated Zener diodes thus eliminate the need for external components.

2.1 Electrical characteristics (curves)

Figure 2. Safe operating area for DPAK and IPAK

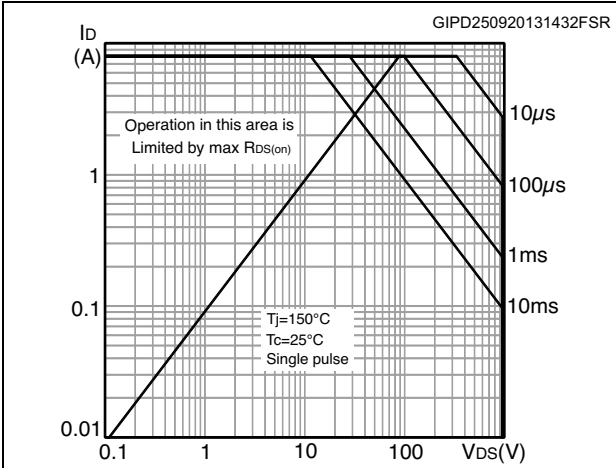


Figure 3. Thermal impedance for DPAK and IPAK

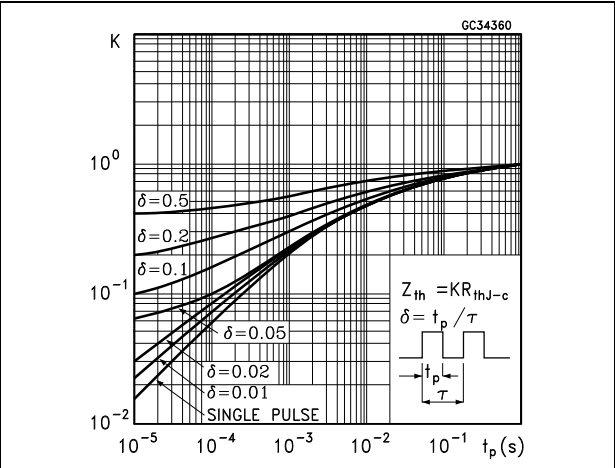


Figure 4. Safe operating area for TO-220FP

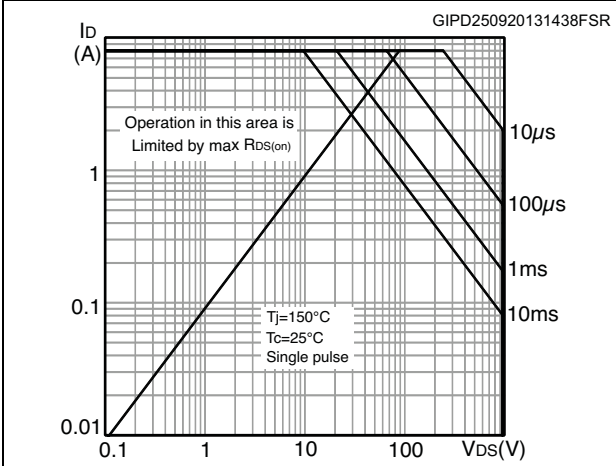


Figure 5. Thermal impedance for TO-220FP

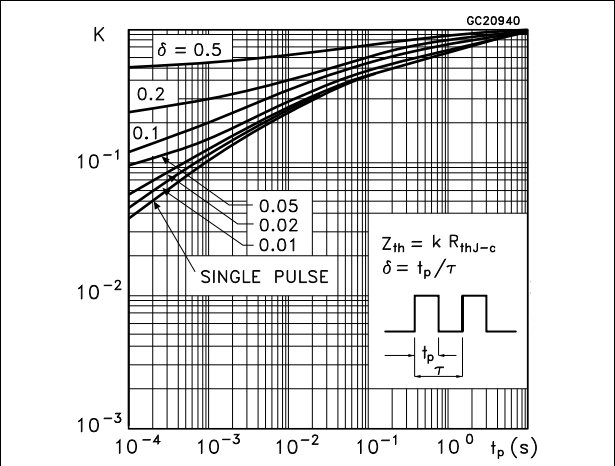


Figure 6. Safe operating area for TO-220

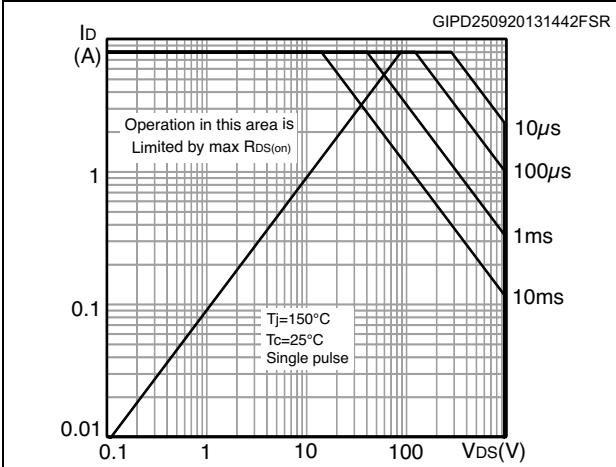


Figure 7. Thermal impedance for TO-220

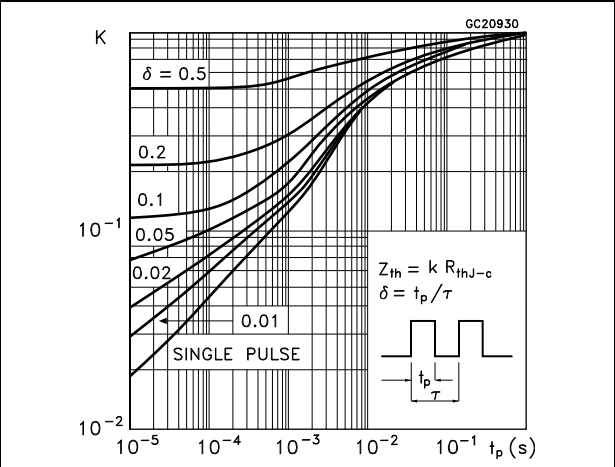


Figure 8. Output characteristics

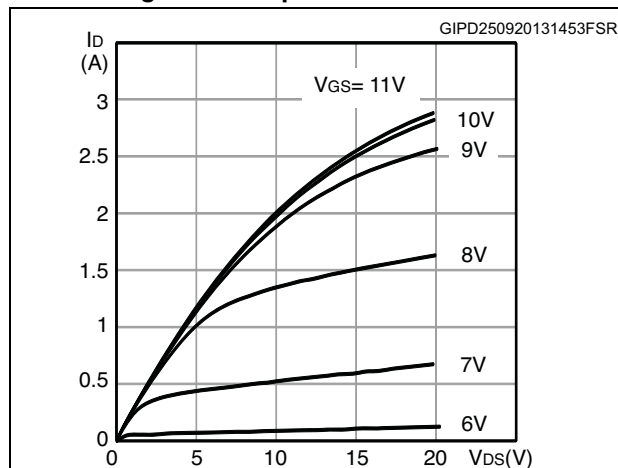


Figure 9. Transfer characteristics

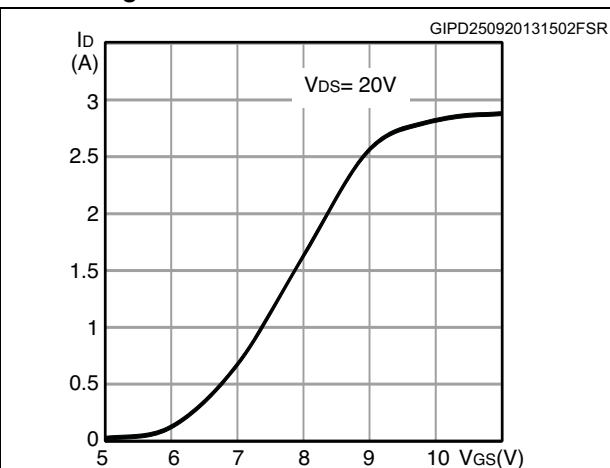


Figure 10. Gate charge vs gate-source voltage

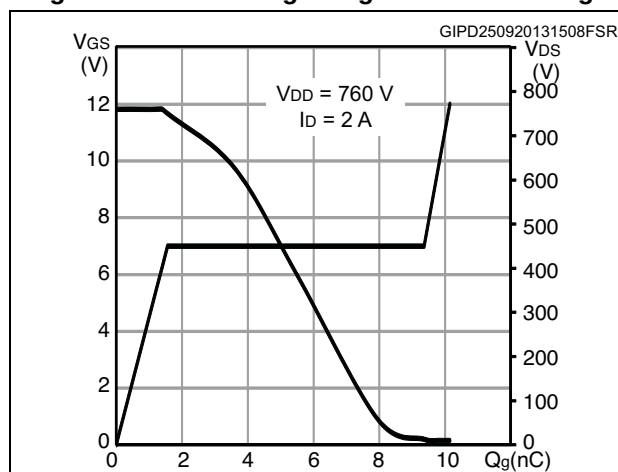


Figure 11. Static drain-source on-resistance

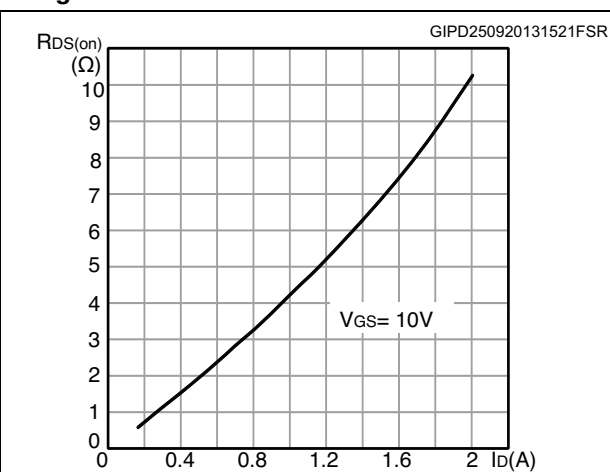


Figure 12. Capacitance variations

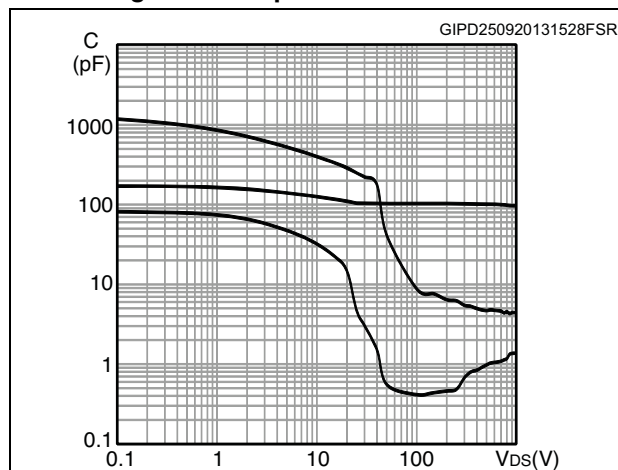


Figure 13. Output capacitance stored energy

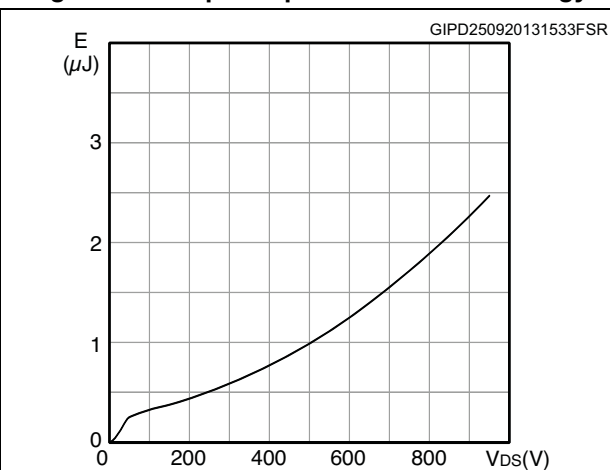


Figure 14. Normalized gate threshold voltage vs temperature

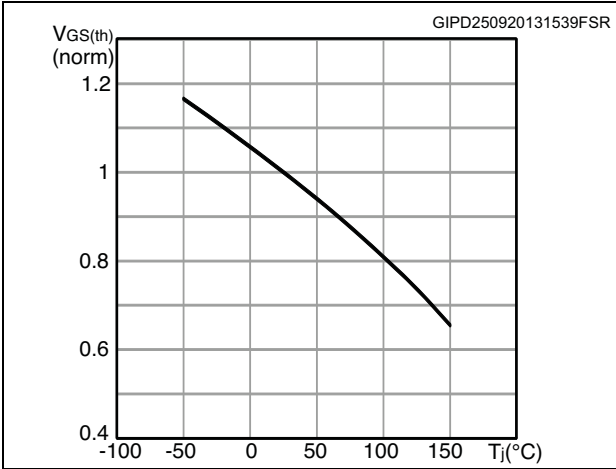


Figure 15. Normalized on-resistance vs temperature

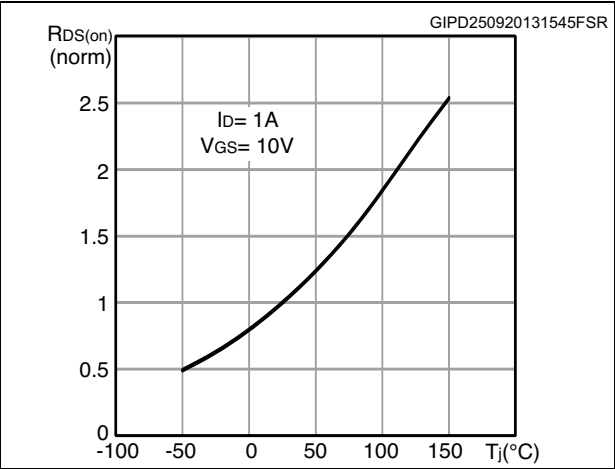


Figure 16. Source-drain diode forward characteristics

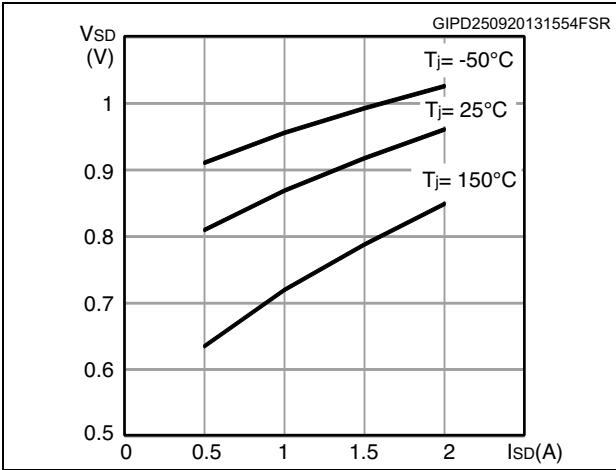
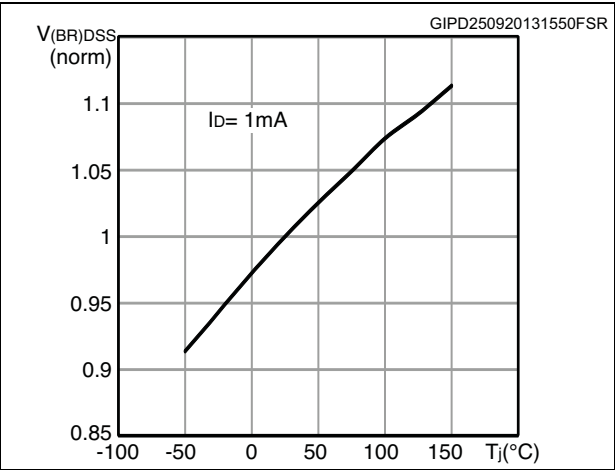


Figure 17. Normalized V<sub>(BR)DSS</sub> vs temperature



### 3 Test circuits

Figure 18. Switching times test circuit for resistive load

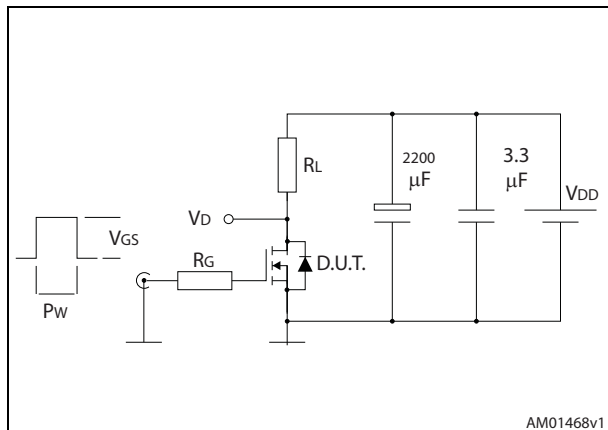


Figure 19. Gate charge test circuit



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



Figure 21. Unclamped inductive load test circuit



Figure 22. Unclamped inductive waveform

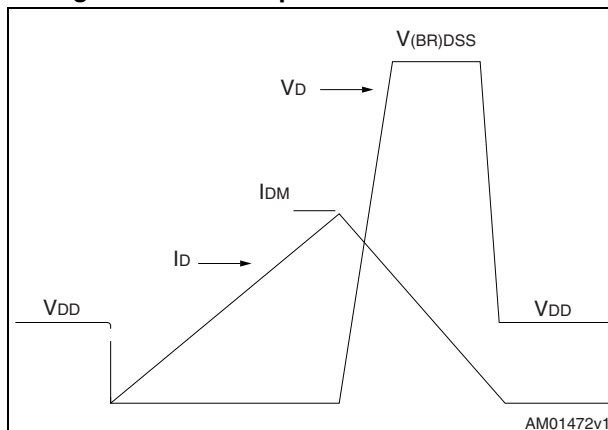
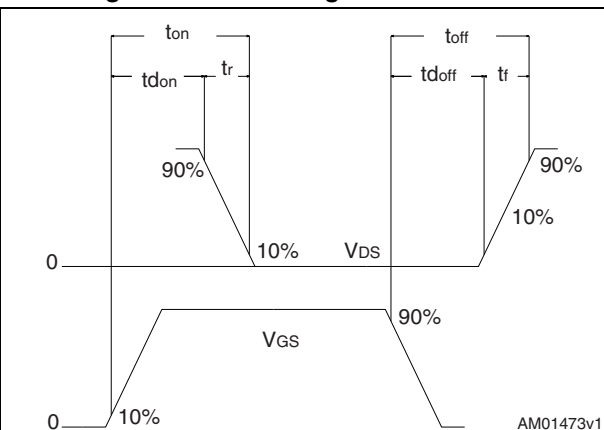


Figure 23. Switching time waveform



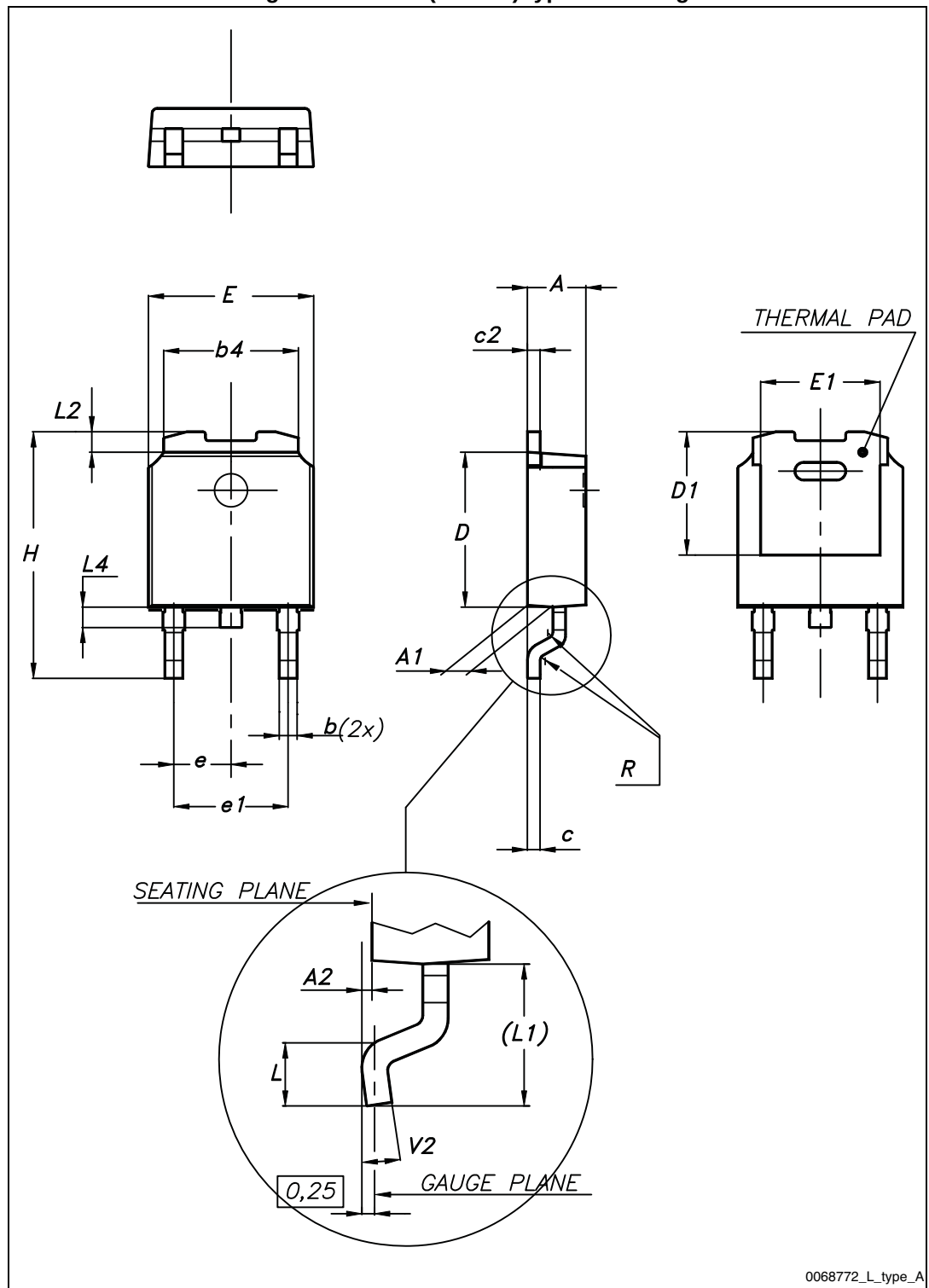
## 4 Package mechanical data

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.

Table 9. DPAK (TO-252) type A mechanical data

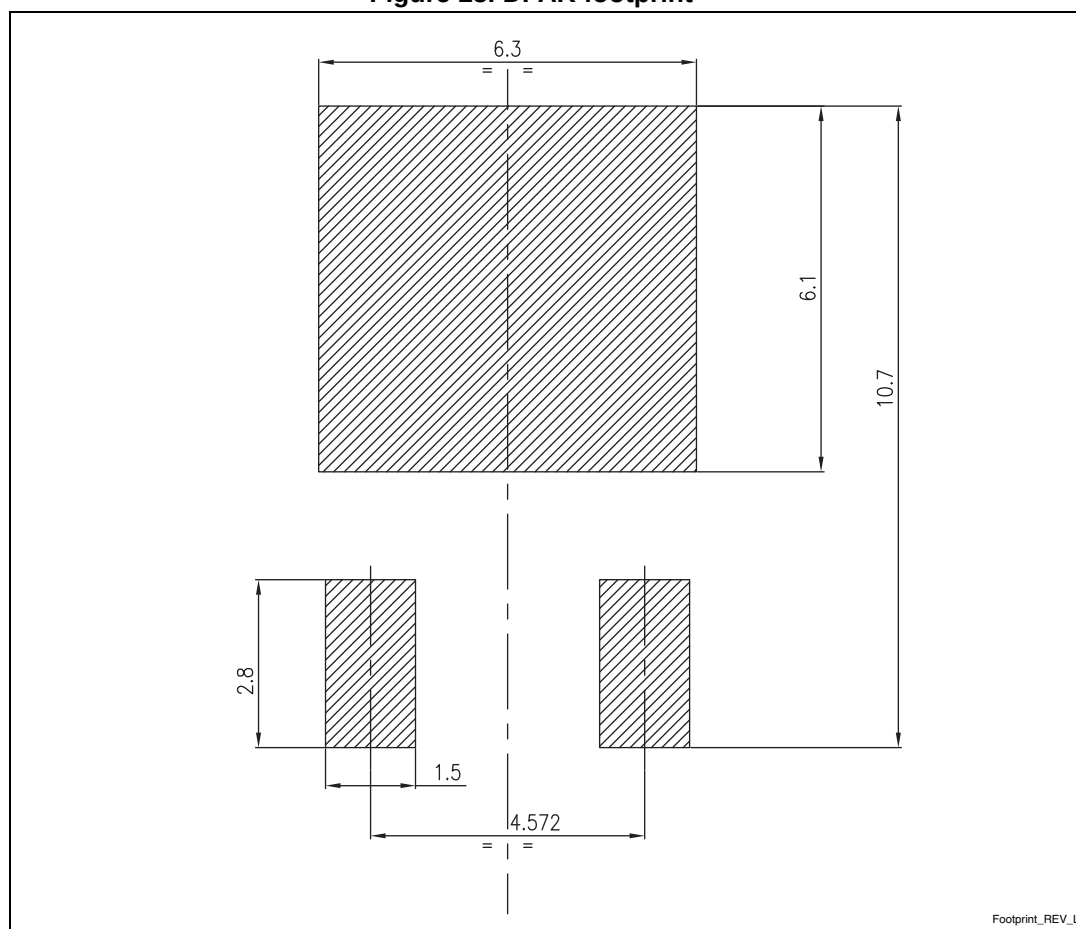
| Dim. | mm   |      |       |
|------|------|------|-------|
|      | Min. | Typ. | Max.  |
| A    | 2.20 |      | 2.40  |
| A1   | 0.90 |      | 1.10  |
| A2   | 0.03 |      | 0.23  |
| b    | 0.64 |      | 0.90  |
| b4   | 5.20 |      | 5.40  |
| c    | 0.45 |      | 0.60  |
| c2   | 0.48 |      | 0.60  |
| D    | 6.00 |      | 6.20  |
| D1   |      | 5.10 |       |
| E    | 6.40 |      | 6.60  |
| E1   |      | 4.70 |       |
| e    |      | 2.28 |       |
| e1   | 4.40 |      | 4.60  |
| H    | 9.35 |      | 10.10 |
| L    | 1.00 |      | 1.50  |
| (L1) |      | 2.80 |       |
| L2   |      | 0.80 |       |
| L4   | 0.60 |      | 1.00  |
| R    |      | 0.20 |       |
| V2   | 0°   |      | 8°    |

Figure 24. DPAK (TO-252) type A drawing



0068772\_L\_type\_A

Figure 25. DPAK footprint (a)



a. All dimensions are in millimeters

Table 10. TO-220FP mechanical data

| Dim. | mm   |      |      |
|------|------|------|------|
|      | Min. | Typ. | Max. |
| A    | 4.4  |      | 4.6  |
| B    | 2.5  |      | 2.7  |
| D    | 2.5  |      | 2.75 |
| E    | 0.45 |      | 0.7  |
| F    | 0.75 |      | 1    |
| F1   | 1.15 |      | 1.70 |
| F2   | 1.15 |      | 1.70 |
| G    | 4.95 |      | 5.2  |
| G1   | 2.4  |      | 2.7  |
| H    | 10   |      | 10.4 |
| L2   |      | 16   |      |
| L3   | 28.6 |      | 30.6 |
| L4   | 9.8  |      | 10.6 |
| L5   | 2.9  |      | 3.6  |
| L6   | 15.9 |      | 16.4 |
| L7   | 9    |      | 9.3  |
| Dia  | 3    |      | 3.2  |

Figure 26. TO-220FP drawing

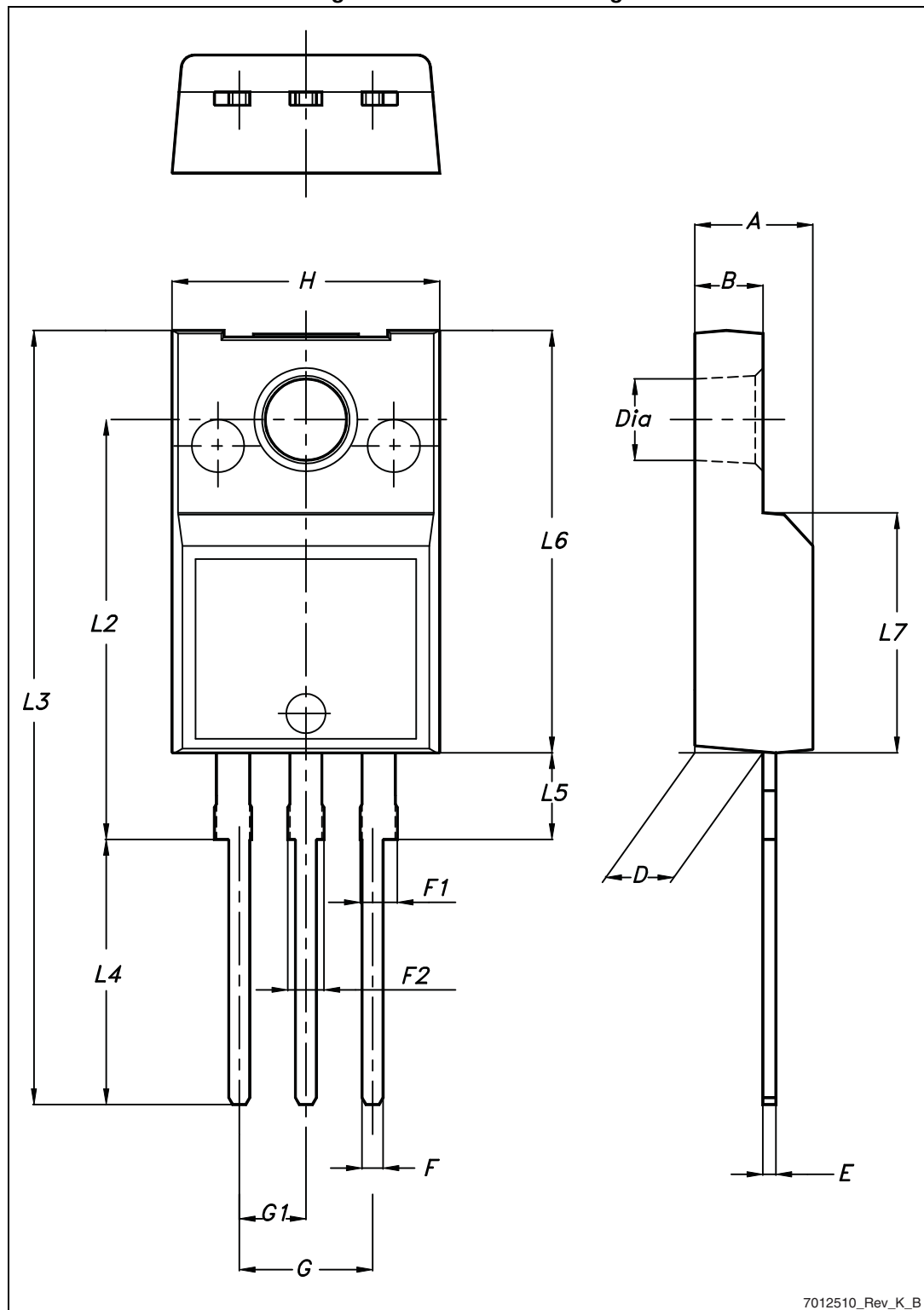


Table 11. TO-220 type A mechanical data

| Dim. | mm    |       |       |
|------|-------|-------|-------|
|      | Min.  | Typ.  | Max.  |
| A    | 4.40  |       | 4.60  |
| b    | 0.61  |       | 0.88  |
| b1   | 1.14  |       | 1.70  |
| c    | 0.48  |       | 0.70  |
| D    | 15.25 |       | 15.75 |
| D1   |       | 1.27  |       |
| E    | 10    |       | 10.40 |
| e    | 2.40  |       | 2.70  |
| e1   | 4.95  |       | 5.15  |
| F    | 1.23  |       | 1.32  |
| H1   | 6.20  |       | 6.60  |
| J1   | 2.40  |       | 2.72  |
| L    | 13    |       | 14    |
| L1   | 3.50  |       | 3.93  |
| L20  |       | 16.40 |       |
| L30  |       | 28.90 |       |
| ØP   | 3.75  |       | 3.85  |
| Q    | 2.65  |       | 2.95  |

Figure 27. TO-220 type A drawing

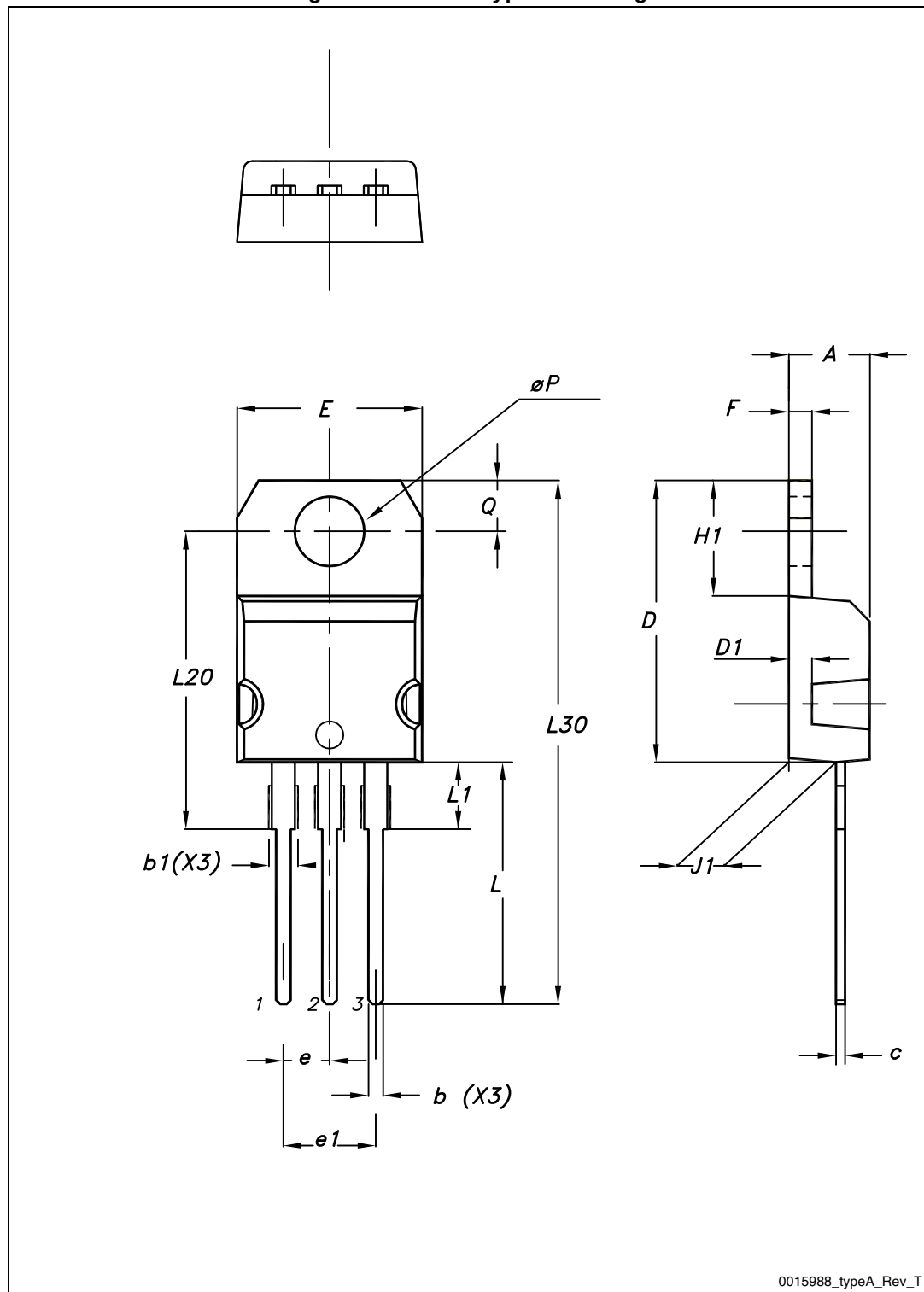
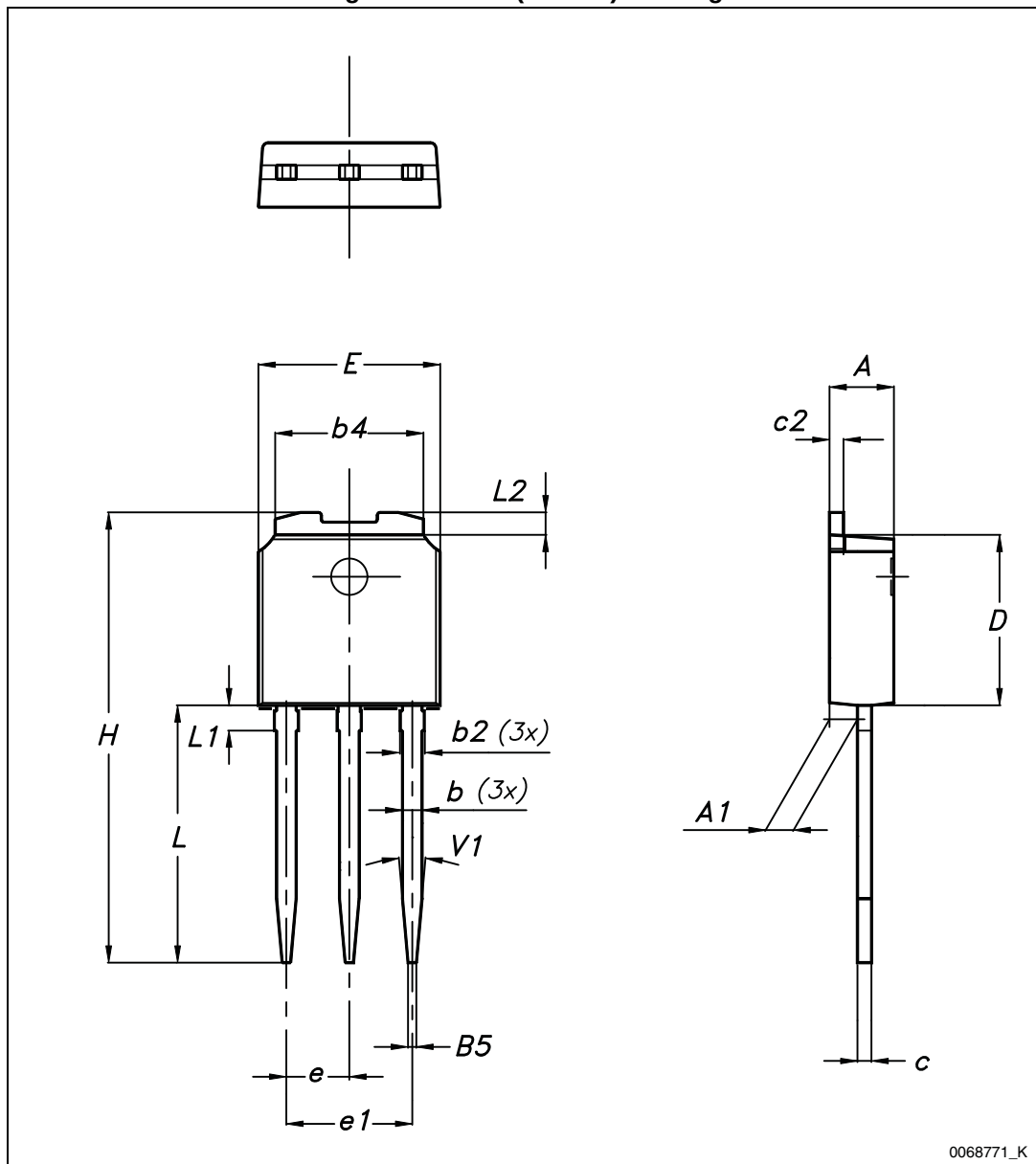


Table 12. IPAK (TO-251) mechanical data

| DIM | mm.  |       |      |
|-----|------|-------|------|
|     | min. | typ.  | max. |
| A   | 2.20 |       | 2.40 |
| A1  | 0.90 |       | 1.10 |
| b   | 0.64 |       | 0.90 |
| b2  |      |       | 0.95 |
| b4  | 5.20 |       | 5.40 |
| B5  |      | 0.30  |      |
| c   | 0.45 |       | 0.60 |
| c2  | 0.48 |       | 0.60 |
| D   | 6.00 |       | 6.20 |
| E   | 6.40 |       | 6.60 |
| e   |      | 2.28  |      |
| e1  | 4.40 |       | 4.60 |
| H   |      | 16.10 |      |
| L   | 9.00 |       | 9.40 |
| L1  | 0.80 |       | 1.20 |
| L2  |      | 0.80  | 1.00 |
| V1  |      | 10°   |      |

Figure 28. IPAK (TO-251) drawing



## 5 Packaging mechanical data

Table 13. DPAK (TO-252) tape and reel mechanical data

| Tape |      |      | Reel      |      |      |
|------|------|------|-----------|------|------|
| Dim. | mm   |      | Dim.      | mm   |      |
|      | Min. | Max. |           | Min. | Max. |
| A0   | 6.8  | 7    | A         |      | 330  |
| B0   | 10.4 | 10.6 | B         | 1.5  |      |
| B1   |      | 12.1 | C         | 12.8 | 13.2 |
| D    | 1.5  | 1.6  | D         | 20.2 |      |
| D1   | 1.5  |      | G         | 16.4 | 18.4 |
| E    | 1.65 | 1.85 | N         | 50   |      |
| F    | 7.4  | 7.6  | T         |      | 22.4 |
| K0   | 2.55 | 2.75 |           |      |      |
| P0   | 3.9  | 4.1  | Base qty. |      | 2500 |
| P1   | 7.9  | 8.1  | Bulk qty. |      | 2500 |
| P2   | 1.9  | 2.1  |           |      |      |
| R    | 40   |      |           |      |      |
| T    | 0.25 | 0.35 |           |      |      |
| W    | 15.7 | 16.3 |           |      |      |

Figure 29. Tape for DPAK (TO-252)

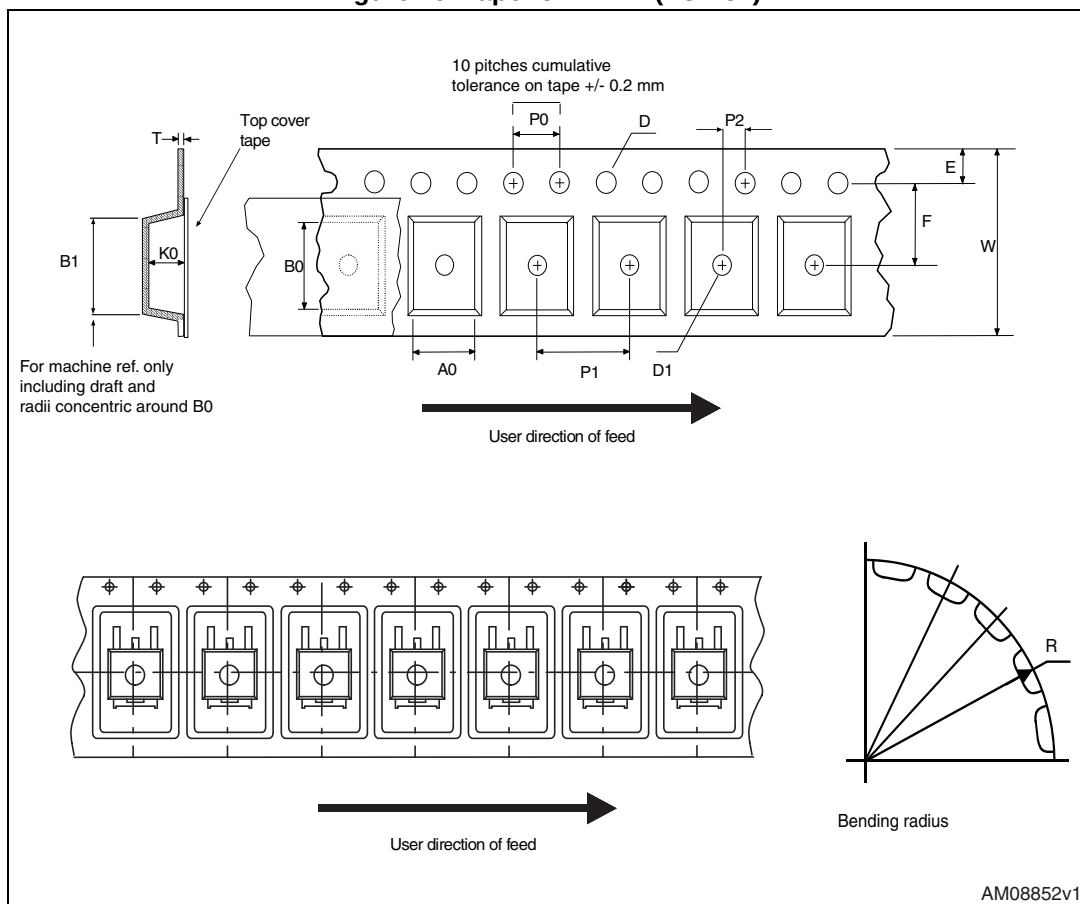
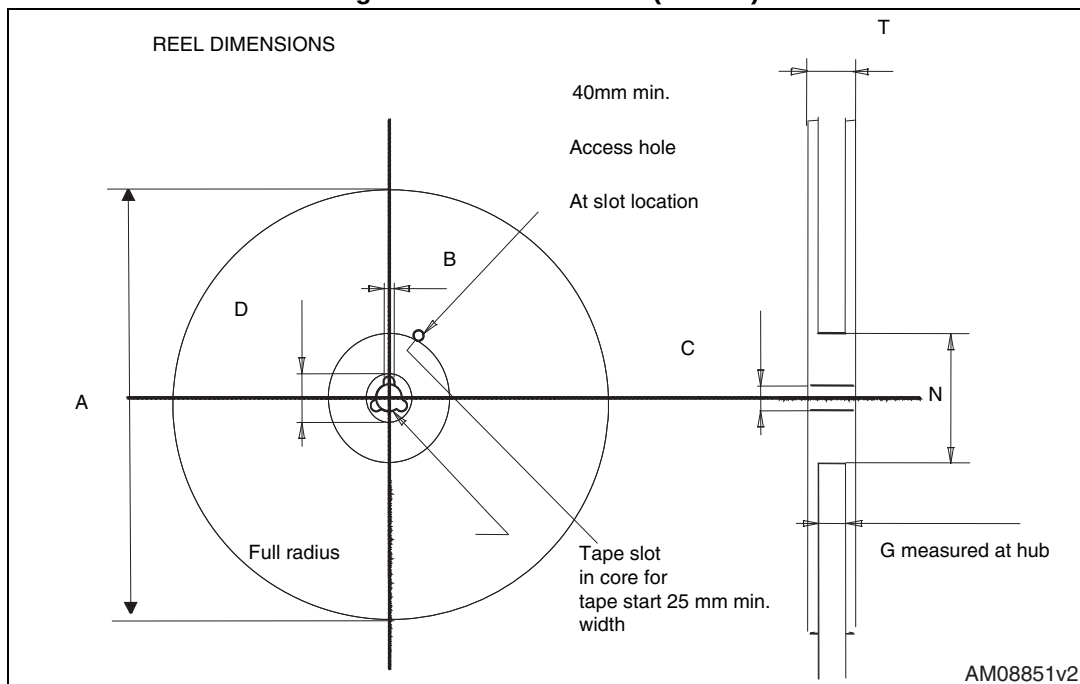


Figure 30. Reel for DPAK (TO-252)



## 6 Revision history

Table 14. Document revision history

| Date        | Revision | Changes        |
|-------------|----------|----------------|
| 25-Sep-2013 | 1        | First release. |

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