



# STF13N95K3, STFI13N95K3, STP13N95K3, STW13N95K3

N-channel 950 V, 0.68  $\Omega$  typ., 10 A Zener-protected SuperMESH3™  
Power MOSFET in TO-220FP, I<sup>2</sup>PAKFP, TO-220 and TO-247

Datasheet — production data

## Features

| Order codes | V <sub>DSS</sub> | R <sub>DS(on)</sub> max | I <sub>D</sub> | P <sub>TOT</sub> |
|-------------|------------------|-------------------------|----------------|------------------|
| STF13N95K3  | 950 V            | < 0.85 $\Omega$         | 10 A           | 40 W             |
| STFI13N95K3 |                  |                         |                |                  |
| STP13N95K3  |                  |                         |                |                  |
| STW13N95K3  |                  |                         |                | 190 W            |

- Gate charge minimized
- Extremely large avalanche performance
- 100% avalanche tested
- Very low intrinsic capacitance
- Zener-protected

## Applications

- Switching applications

## Description

These SuperMESH3™ Power MOSFETs are the result of improvements applied to STMicroelectronics' SuperMESH™ technology, combined with a new optimized vertical structure. These devices boast an extremely low on-resistance, superior dynamic performance and high avalanche capability, rendering them suitable for the most demanding applications.

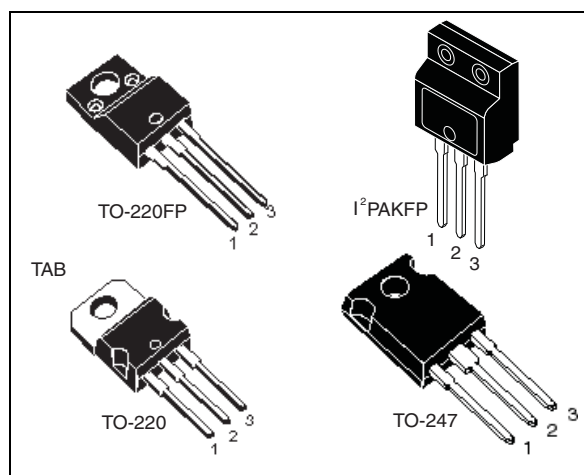
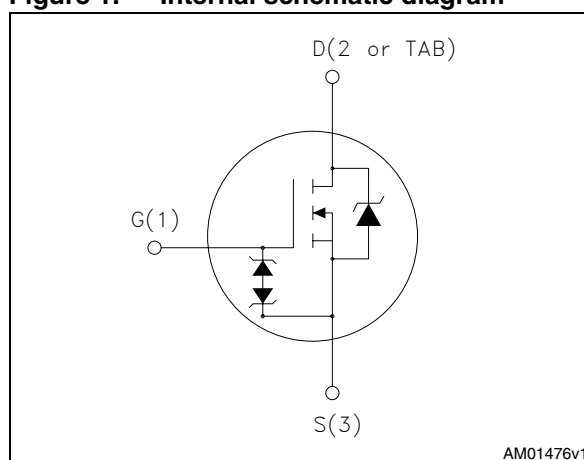


Figure 1. Internal schematic diagram



AM01476v1

Table 1. Device summary

| Order codes | Marking | Package              | Packaging |
|-------------|---------|----------------------|-----------|
| STF13N95K3  | 13N95K3 | TO-220FP             | Tube      |
| STFI13N95K3 |         | I <sup>2</sup> PAKFP |           |
| STP13N95K3  |         | TO-220               |           |
| STW13N95K3  |         | TO-247               |           |

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# 1 Electrical ratings

**Table 2. Absolute maximum ratings**

| Symbol                             | Parameter                                                                                                                 | Value            |                                  | Unit |
|------------------------------------|---------------------------------------------------------------------------------------------------------------------------|------------------|----------------------------------|------|
|                                    |                                                                                                                           | TO-220<br>TO-247 | TO-220FP<br>I <sup>2</sup> PAKFP |      |
| V <sub>DS</sub>                    | Drain source voltage                                                                                                      | 950              |                                  | V    |
| V <sub>GS</sub>                    | Gate- source voltage                                                                                                      | ± 30             |                                  | V    |
| I <sub>D</sub>                     | Drain current (continuous) at T <sub>C</sub> = 25 °C                                                                      | 10               | 10 <sup>(1)</sup>                | A    |
| I <sub>D</sub>                     | Drain current (continuous) at T <sub>C</sub> = 100 °C                                                                     | 6                | 6 <sup>(1)</sup>                 | A    |
| I <sub>DM</sub> <sup>(2)</sup>     | Drain current (pulsed)                                                                                                    | 40               | 40 <sup>(1)</sup>                | A    |
| P <sub>TOT</sub>                   | Total dissipation at T <sub>C</sub> = 25 °C                                                                               | 190              | 40                               | W    |
| I <sub>AR</sub>                    | Max current during repetitive or single pulse avalanche (pulse width limited by T <sub>jmax</sub> )                       | 13               |                                  | A    |
| E <sub>AS</sub>                    | Single pulse avalanche energy (starting T <sub>J</sub> = 25 °C, I <sub>D</sub> =I <sub>AS</sub> , V <sub>DD</sub> = 50 V) | 400              |                                  | mJ   |
| V <sub>ISO</sub>                   | Insulation withstand voltage (RMS) from all three leads to external heat sink (t = 1 s; T <sub>C</sub> = 25 °C)           |                  | 2500                             | V    |
| dv/dt <sup>(3)</sup>               | Peak diode recovery voltage slope                                                                                         | 9                |                                  | V/ns |
| T <sub>j</sub><br>T <sub>stg</sub> | 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<sub>SD</sub> ≤ 10 A, di/dt ≤ 400 A/μs, V<sub>Peak</sub> ≤ V<sub>(BR)DSS</sub>.

**Table 3. Thermal data**

| Symbol                | Parameter                            | Value  |        |                                  | Unit |
|-----------------------|--------------------------------------|--------|--------|----------------------------------|------|
|                       |                                      | TO-220 | TO-247 | TO-220FP<br>I <sup>2</sup> PAKFP |      |
| R <sub>thj-case</sub> | Thermal resistance junction-case max | 0.66   |        | 3.13                             | °C/W |
| R <sub>thj-amb</sub>  | Thermal resistance junction-amb max  | 62.5   | 50     | 62.5                             | °C/W |

## 2 Electrical characteristics

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

**Table 4. On/off states**

| Symbol        | Parameter                                        | Test conditions                                                              | Min. | Typ. | Max.     | Unit                           |
|---------------|--------------------------------------------------|------------------------------------------------------------------------------|------|------|----------|--------------------------------|
| $V_{(BR)DSS}$ | Drain-source breakdown voltage                   | $I_D = 1\text{ mA}$ , $V_{GS} = 0$                                           | 950  |      |          | V                              |
| $I_{DSS}$     | Zero gate voltage drain current ( $V_{GS} = 0$ ) | $V_{DS} = 950\text{ V}$ ,<br>$V_{DS} = 950\text{ V}$ , $T_C = 125\text{ °C}$ |      |      | 1<br>50  | $\mu\text{A}$<br>$\mu\text{A}$ |
| $I_{GSS}$     | Gate body leakage current ( $V_{DS} = 0$ )       | $V_{GS} = \pm 20\text{ V}$                                                   |      |      | $\pm 10$ | $\mu\text{A}$                  |
| $V_{GS(th)}$  | Gate threshold voltage                           | $V_{DS} = V_{GS}$ , $I_D = 100\text{ }\mu\text{A}$                           | 3    | 4    | 5        | V                              |
| $R_{DS(on)}$  | Static drain-source on-resistance                | $V_{GS} = 10\text{ V}$ , $I_D = 5\text{ A}$                                  |      | 0.68 | 0.85     | $\Omega$                       |

**Table 5. Dynamic**

| Symbol            | Parameter                             | Test conditions                                             | Min. | Typ. | Max. | Unit     |
|-------------------|---------------------------------------|-------------------------------------------------------------|------|------|------|----------|
| $C_{iss}$         | Input capacitance                     | $V_{DS} = 100\text{ V}$ , $f = 1\text{ MHz}$ , $V_{GS} = 0$ | -    | 1620 | -    | pF       |
| $C_{oss}$         | Output capacitance                    |                                                             |      | 117  |      | pF       |
| $C_{rss}$         | Reverse transfer capacitance          |                                                             |      | 1.2  |      | pF       |
| $C_{o(tr)}^{(1)}$ | Equivalent capacitance time related   | $V_{GS} = 0$ , $V_{DS} = 0\text{ to }760\text{ V}$          | -    | 115  | -    | pF       |
| $C_{o(er)}^{(2)}$ | Equivalent capacitance energy related |                                                             |      | 131  |      | pF       |
| $R_G$             | Intrinsic gate resistance             | $f = 1\text{ MHz}$ open drain                               | -    | 2.3  | -    | $\Omega$ |
| $Q_g$             | Total gate charge                     | $V_{DD} = 760\text{ V}$ , $I_D = 10\text{ A}$               | -    | 51   | -    | nC       |
| $Q_{gs}$          | Gate-source charge                    | $V_{GS} = 10\text{ V}$                                      |      | 10   |      | nC       |
| $Q_{gd}$          | Gate-drain charge                     | (see <a href="#">Figure 20</a> )                            |      | 30   |      | nC       |

1. Time related is defined as a constant equivalent capacitance giving the same charging time as  $C_{oss}$  when  $V_{DS}$  increases from 0 to 80%  $V_{DSS}$
2. Energy related is defined as a constant equivalent capacitance giving the same stored energy as  $C_{oss}$  when  $V_{DS}$  increases from 0 to 80%  $V_{DSS}$

**Table 6. Switching times**

| Symbol       | Parameter           | Test conditions                                                                                                                    | Min. | Typ. | Max. | Unit |
|--------------|---------------------|------------------------------------------------------------------------------------------------------------------------------------|------|------|------|------|
| $t_{d(on)}$  | Turn-on delay time  | $V_{DD} = 475\text{ V}$ , $I_D = 5\text{ A}$ ,<br>$R_G = 4.7\ \Omega$ , $V_{GS} = 10\text{ V}$<br>(see <a href="#">Figure 22</a> ) | -    | 18   | -    | ns   |
| $t_r$        | Rise time           |                                                                                                                                    |      | 16   |      | ns   |
| $t_{d(off)}$ | Turn-off delay time |                                                                                                                                    |      | 50   |      | ns   |
| $t_f$        | Fall time           |                                                                                                                                    |      | 21   |      | ns   |

**Table 7. Source drain diode**

| Symbol         | Parameter                     | Test conditions                                                                                                                                                  | Min. | Typ. | Max. | Unit          |
|----------------|-------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------|------|---------------|
| $I_{SD}$       | Source-drain current          |                                                                                                                                                                  | -    |      | 10   | mA            |
| $I_{SDM}$      | Source-drain current (pulsed) |                                                                                                                                                                  |      |      | 40   | A             |
| $V_{SD}^{(1)}$ | Forward on voltage            | $I_{SD} = 10\text{ A}$ , $V_{GS} = 0$                                                                                                                            | -    |      | 1.6  | V             |
| $t_{rr}$       | Reverse recovery time         | $I_{SD} = 10\text{ A}$ , $V_{DD} = 60\text{ V}$<br>$di/dt = 100\text{ A}/\mu\text{s}$ ,<br>(see <a href="#">Figure 21</a> )                                      | -    | 500  |      | ns            |
| $Q_{rr}$       | Reverse recovery charge       |                                                                                                                                                                  |      | 9    |      | $\mu\text{C}$ |
| $I_{RRM}$      | Reverse recovery current      |                                                                                                                                                                  |      | 36   |      | A             |
| $t_{rr}$       | Reverse recovery time         | $I_{SD} = 10\text{ A}$ , $V_{DD} = 60\text{ V}$<br>$di/dt = 100\text{ A}/\mu\text{s}$ ,<br>$T_j = 150\text{ }^\circ\text{C}$ (see<br><a href="#">Figure 21</a> ) | -    | 624  |      | ns            |
| $Q_{rr}$       | Reverse recovery charge       |                                                                                                                                                                  |      | 11   |      | $\mu\text{C}$ |
| $I_{RRM}$      | Reverse recovery current      |                                                                                                                                                                  |      | 37   |      | A             |

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

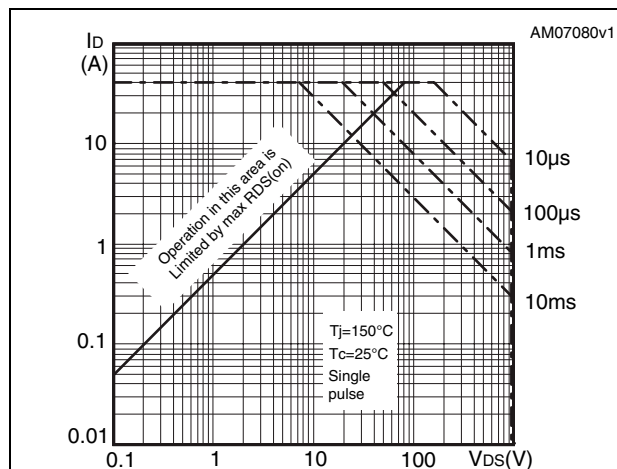
**Table 8. Gate-source Zener diode**

| Symbol     | Parameter                     | Test conditions                         | Min. | Typ. | Max. | Unit |
|------------|-------------------------------|-----------------------------------------|------|------|------|------|
| $BV_{GSO}$ | Gate-source breakdown voltage | $I_{gs} \pm 1\text{ mA}$ , (open drain) | 30   | -    |      | V    |

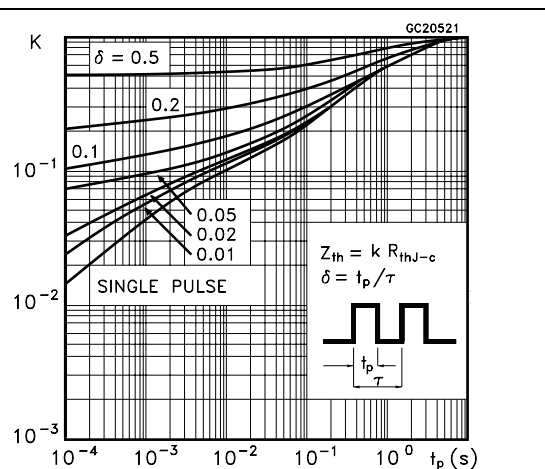
The built-in-back Zener diodes have specifically been designed to enhance not only the device's ESD capability, but also to make them safely absorb possible voltage transients that may occasionally be applied from gate to source. In this respect the Zener voltage is appropriate to achieve an efficient 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)

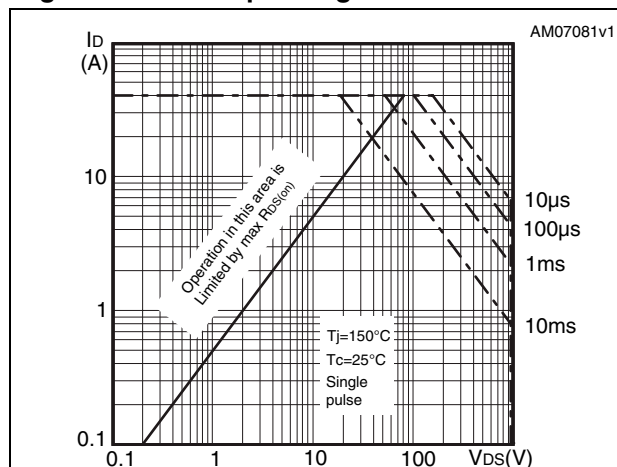
**Figure 2. Safe operating area for TO-220FP and I<sup>2</sup>PAKFP**



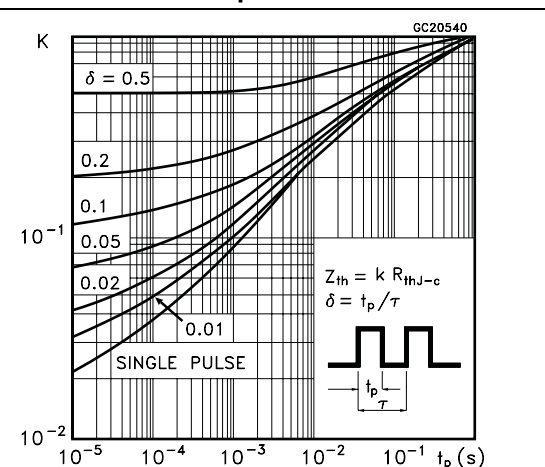
**Figure 3. Thermal impedance for TO-220FP and I<sup>2</sup>PAKFP**



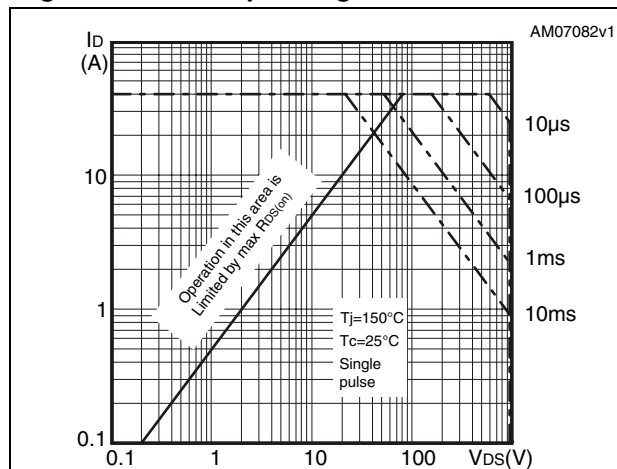
**Figure 4. Safe operating area for TO-220**



**Figure 5. Thermal impedance for TO-220**



**Figure 6. Safe operating area for TO-247**



**Figure 7. Thermal impedance for TO-247**

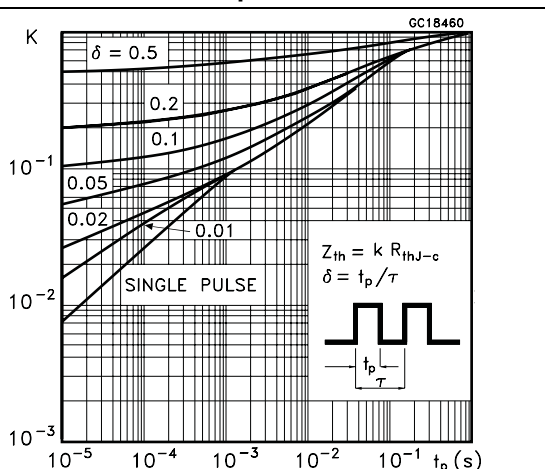


Figure 8. Output characteristics

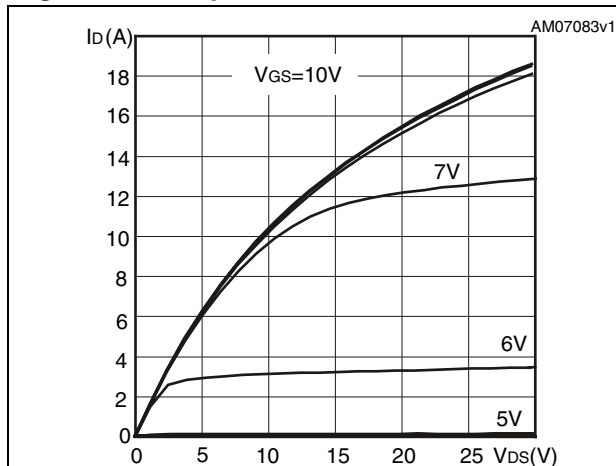


Figure 9. Transfer characteristics

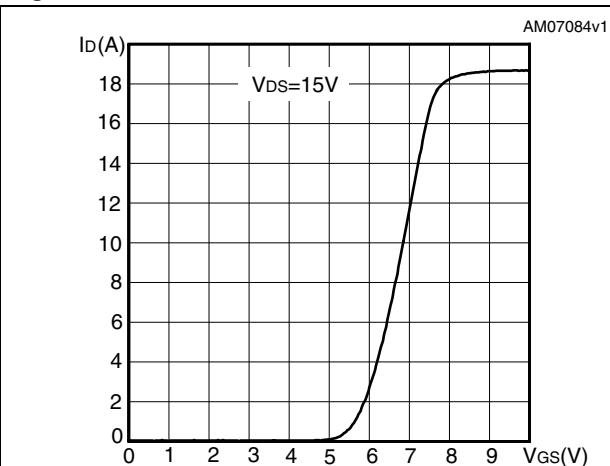


Figure 10. Gate charge vs gate-source voltage

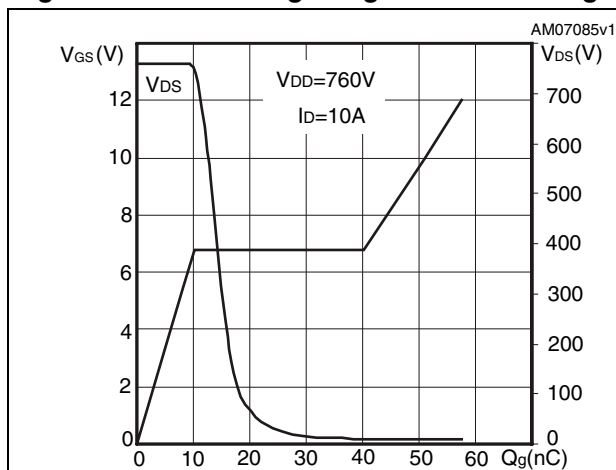


Figure 11. Static drain-source on-resistance

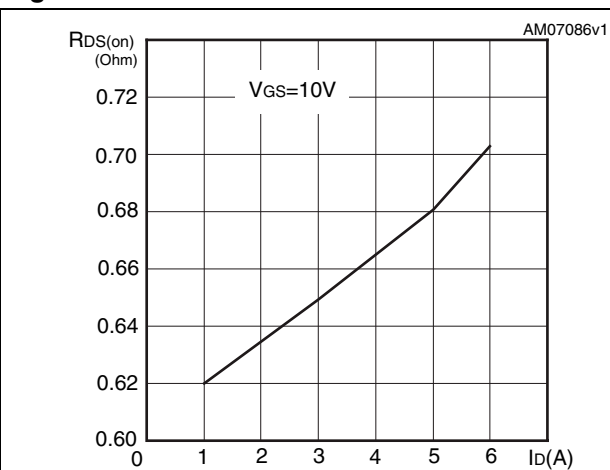


Figure 12. Capacitance variations

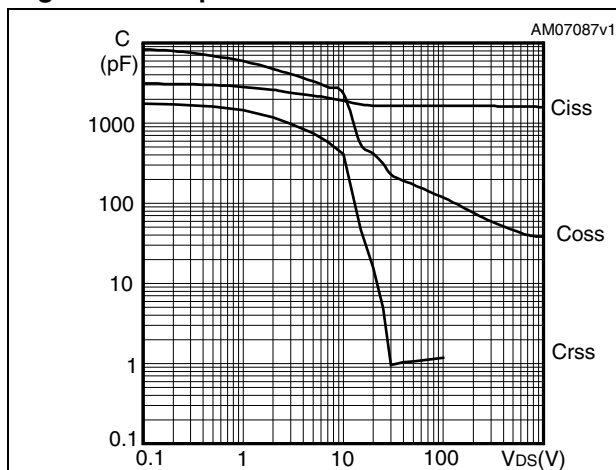


Figure 13. Output capacitance stored energy

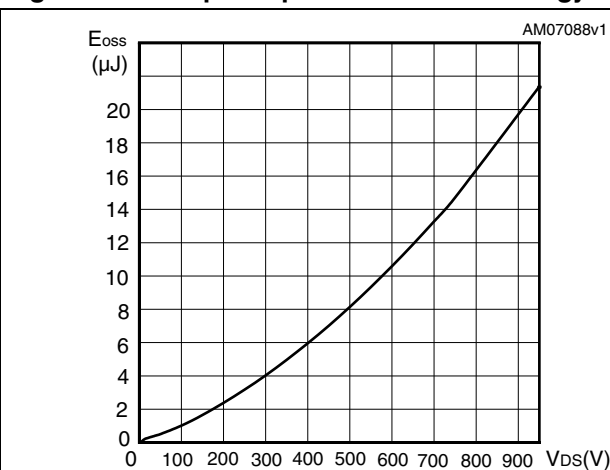


Figure 14. Normalized gate threshold voltage vs temperature

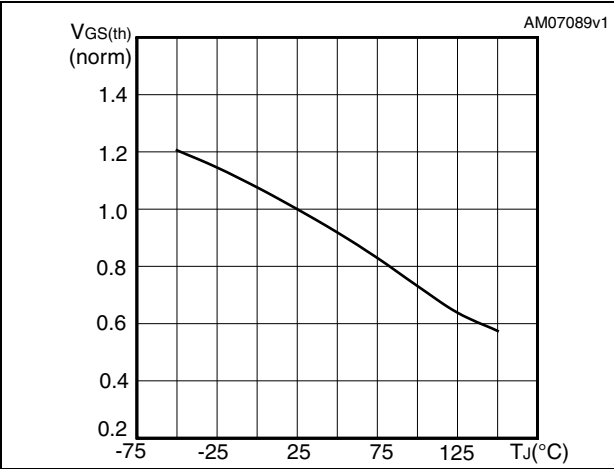


Figure 15. Normalized on-resistance vs temperature

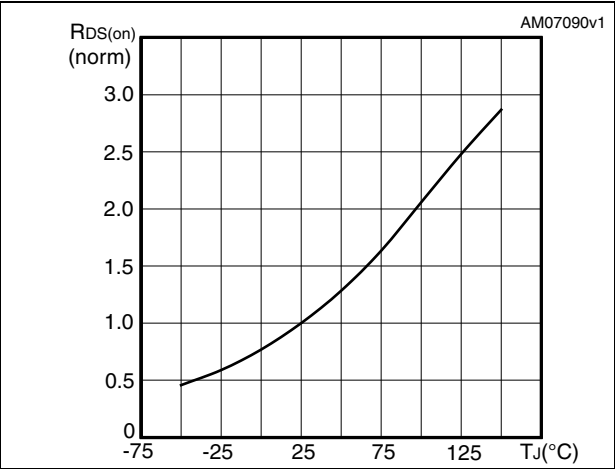


Figure 16. Source-drain diode forward characteristics

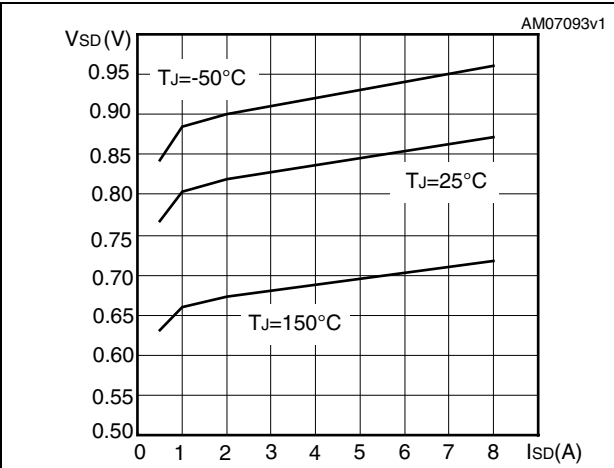


Figure 17. Normalized  $B_{VDSS}$  vs temperature

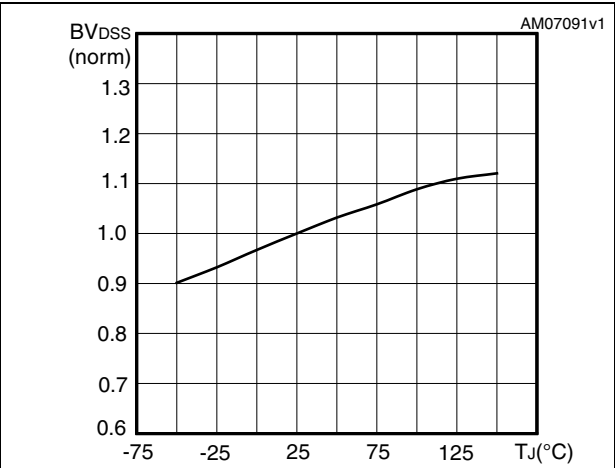
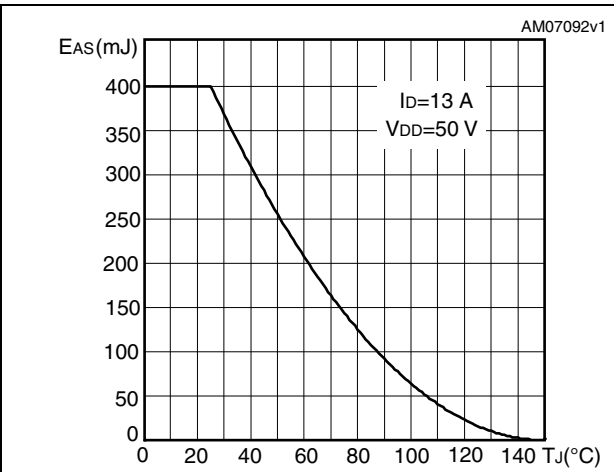


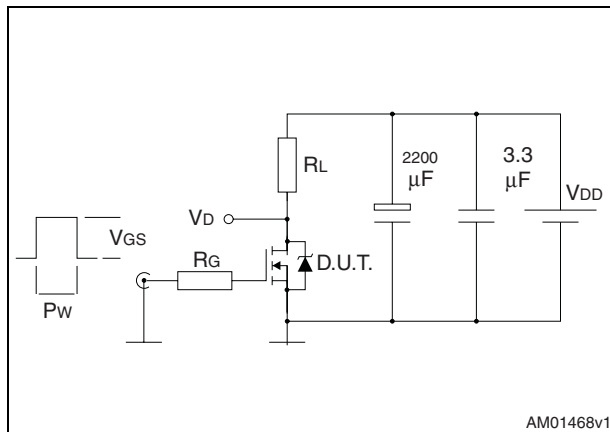
Figure 18. Maximum avalanche energy vs starting  $T_J$



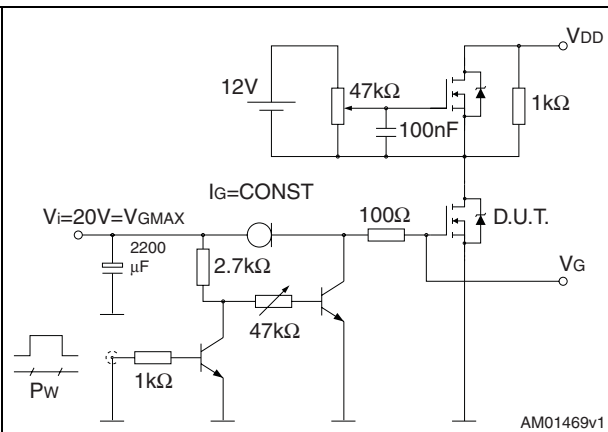


### 3 Test circuits

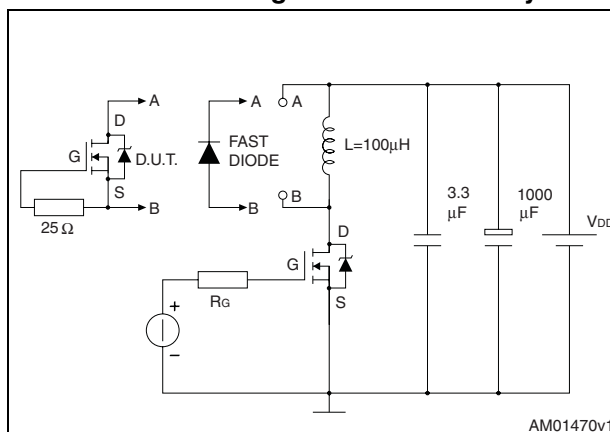
**Figure 19. Switching times test circuit for resistive load**



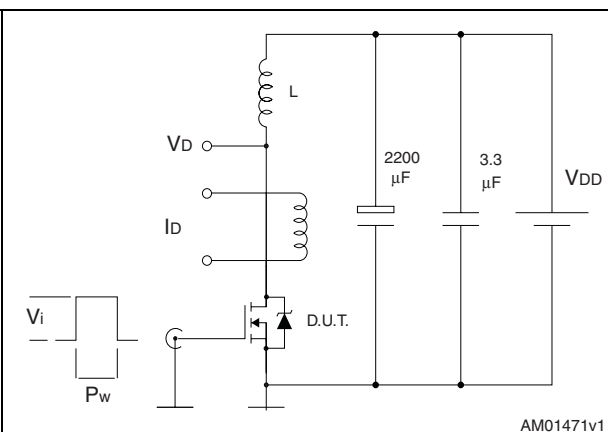
**Figure 20. Gate charge test circuit**



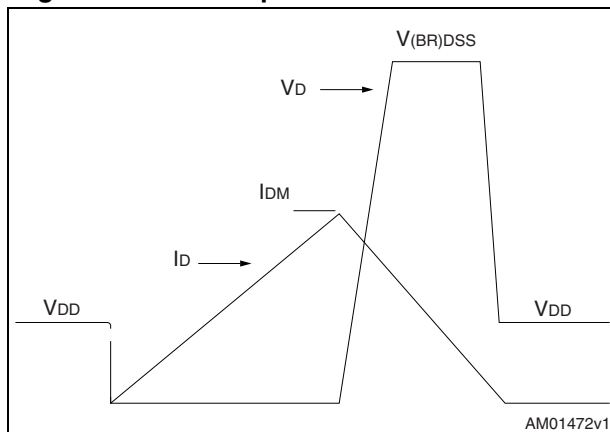
**Figure 21. Test circuit for inductive load switching and diode recovery times**



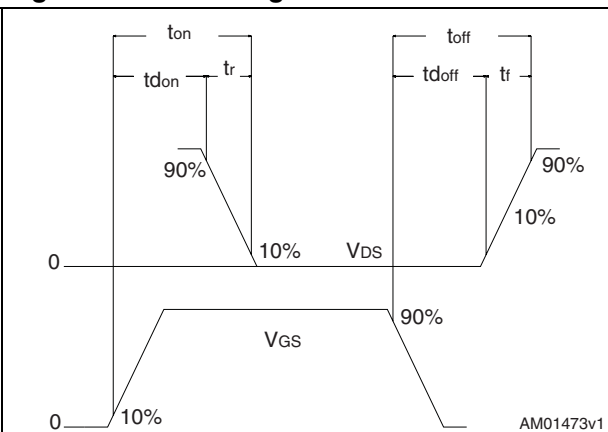
**Figure 22. Unclamped inductive load test circuit**



**Figure 23. Unclamped inductive waveform**



**Figure 24. 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. 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 25. TO-220FP drawing

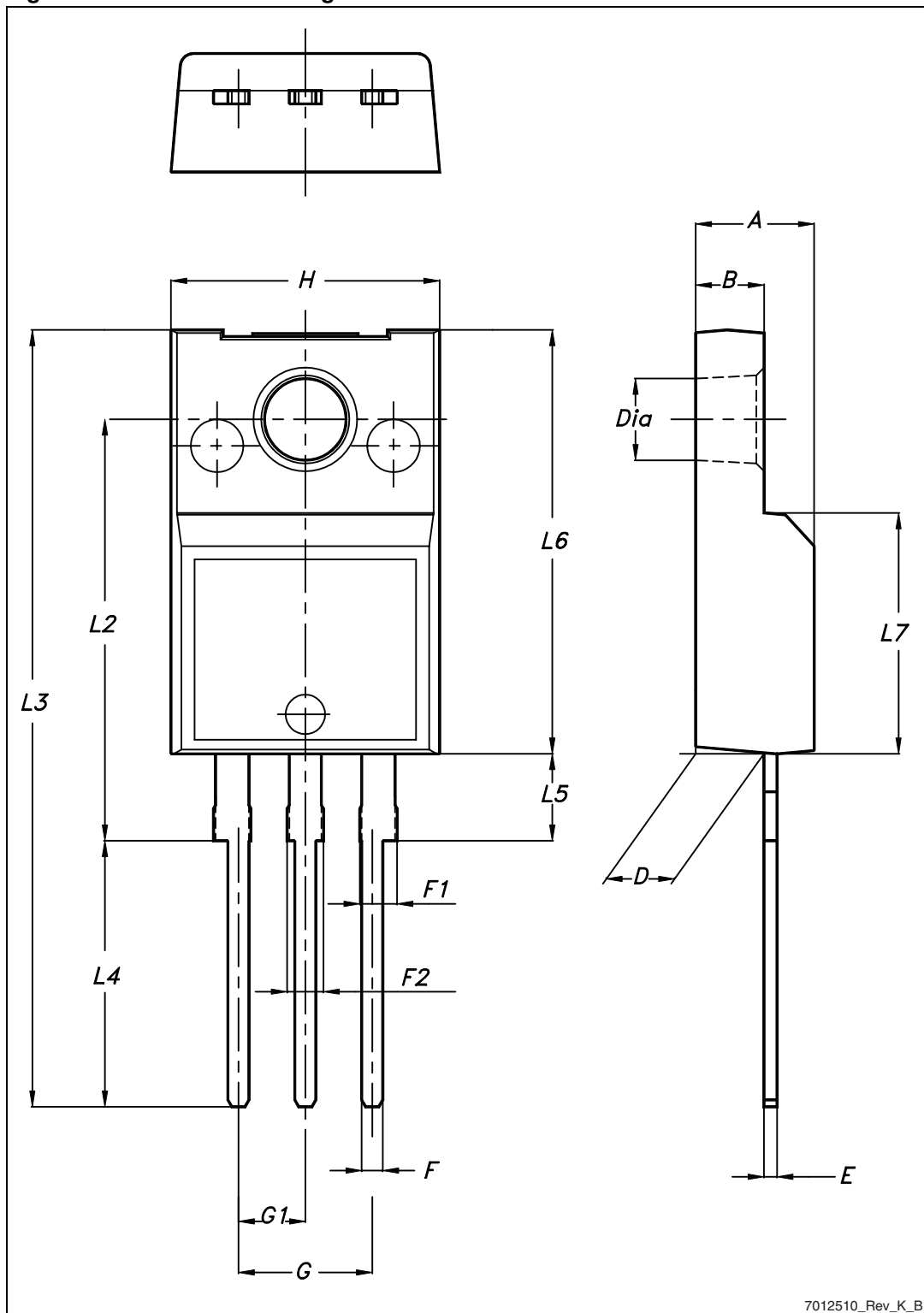


Table 10. I<sup>2</sup>PAKFP mechanical data

| Dim. | mm    |      |       |
|------|-------|------|-------|
|      | Min.  | Typ. | Max.  |
| A    | 4.40  | -    | 4.60  |
| B    | 2.50  |      | 2.70  |
| D    | 2.50  |      | 2.75  |
| D1   | 0.65  |      | 0.85  |
| E    | 0.45  |      | 0.70  |
| F    | 0.75  |      | 1.00  |
| F1   |       |      | 1.20  |
| G    | 4.95  |      | 5.20  |
| H    | 10.00 |      | 10.40 |
| L1   | 21.00 |      | 23.00 |
| L2   | 13.20 |      | 14.10 |
| L3   | 10.55 |      | 10.85 |
| L4   | 2.70  |      | 3.20  |
| L5   | 0.85  |      | 1.25  |
| L6   | 7.30  |      | 7.50  |

Figure 26. I<sup>2</sup>PAKFP drawing

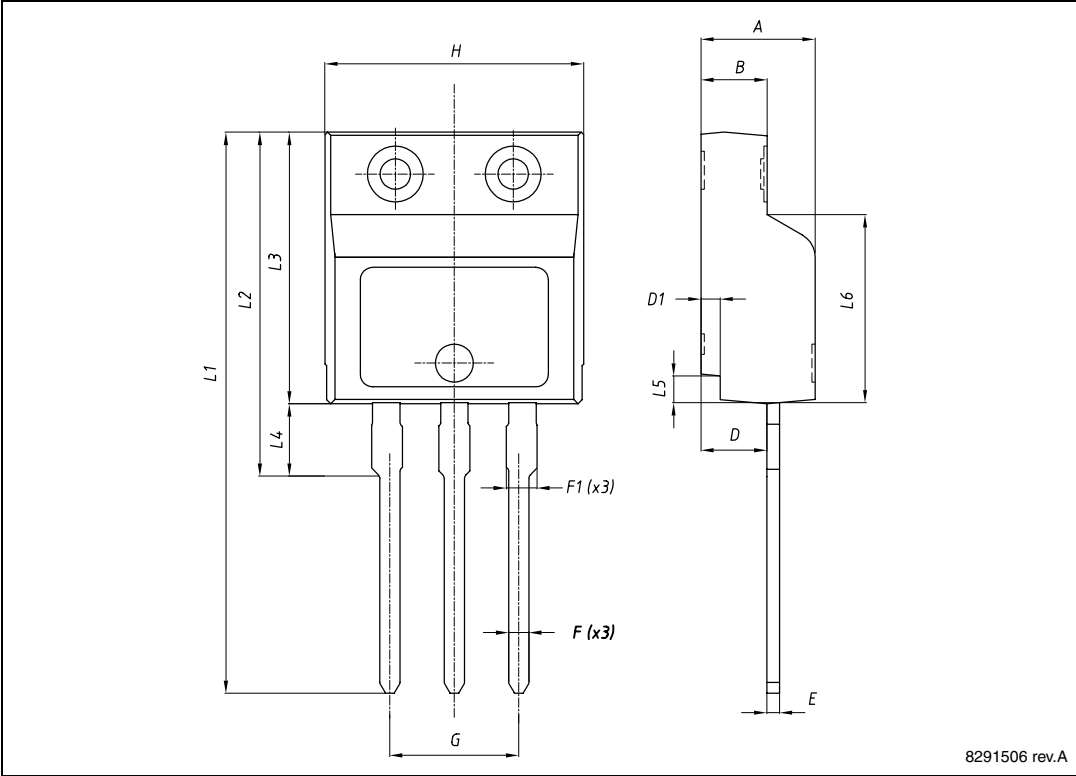


Table 11. TO-220 type A mechanical data

| 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

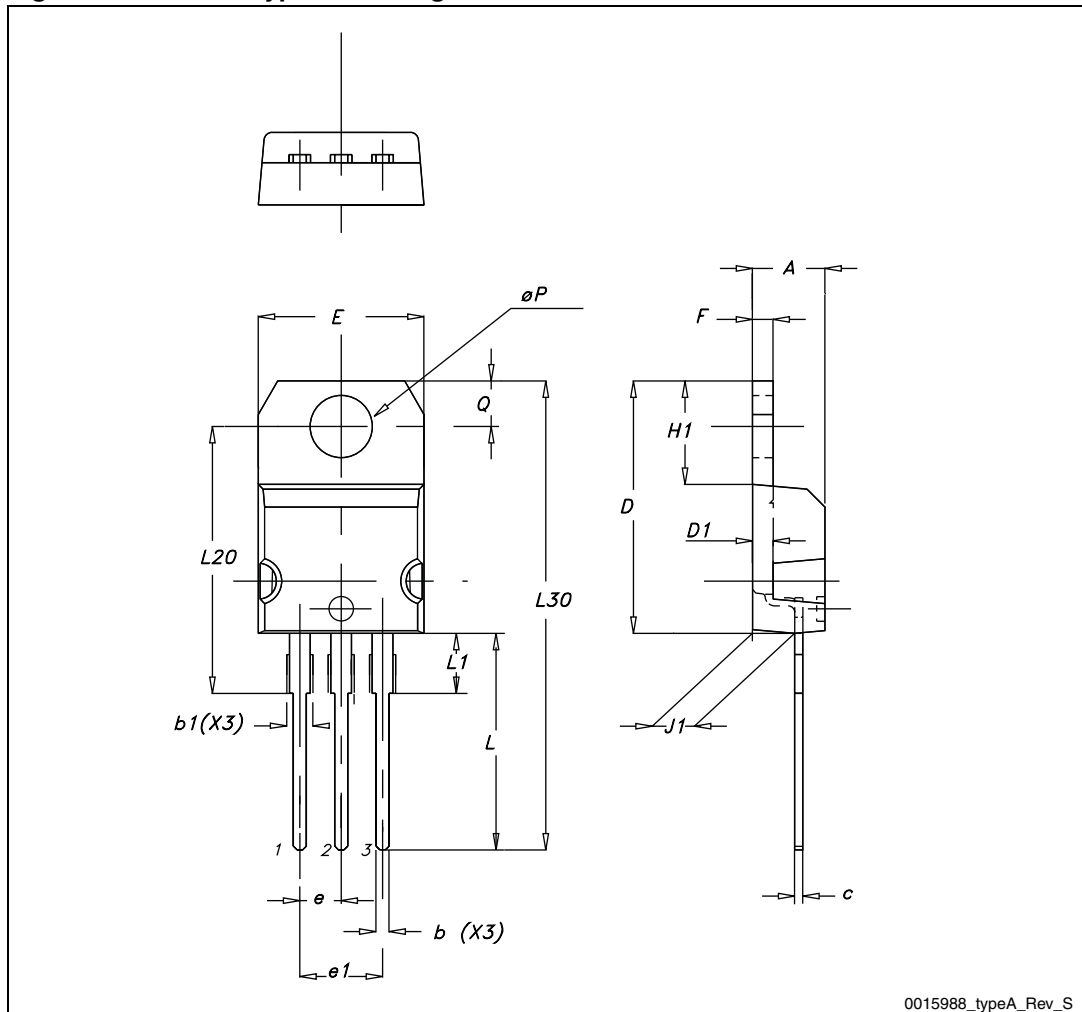
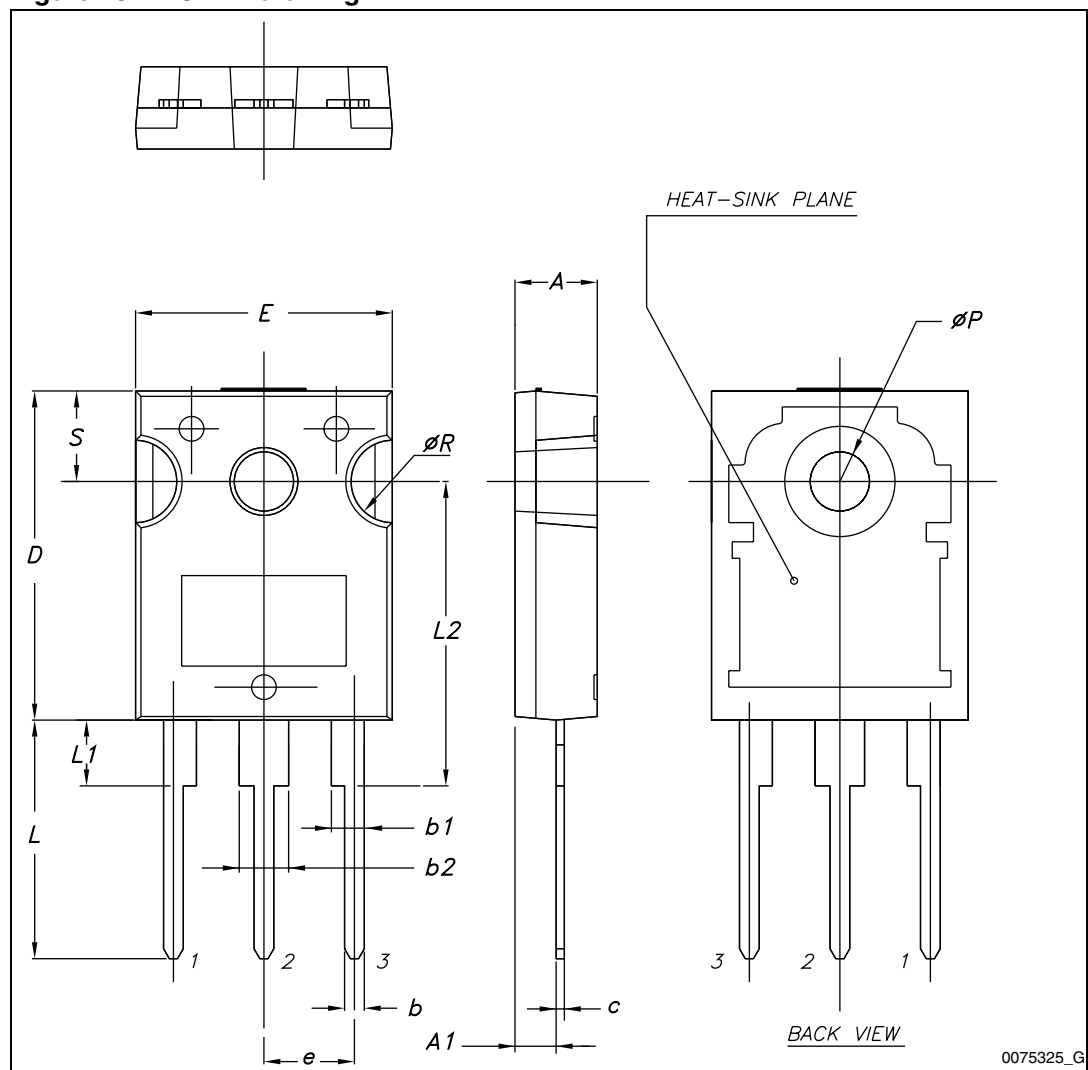


Table 12. TO-247 mechanical data

| Dim. | mm.   |       |       |
|------|-------|-------|-------|
|      | Min.  | Typ.  | Max.  |
| A    | 4.85  |       | 5.15  |
| A1   | 2.20  |       | 2.60  |
| b    | 1.0   |       | 1.40  |
| b1   | 2.0   |       | 2.40  |
| b2   | 3.0   |       | 3.40  |
| c    | 0.40  |       | 0.80  |
| D    | 19.85 |       | 20.15 |
| E    | 15.45 |       | 15.75 |
| e    | 5.30  | 5.45  | 5.60  |
| L    | 14.20 |       | 14.80 |
| L1   | 3.70  |       | 4.30  |
| L2   |       | 18.50 |       |
| ØP   | 3.55  |       | 3.65  |
| ØR   | 4.50  |       | 5.50  |
| S    | 5.30  | 5.50  | 5.70  |



Figure 28. TO-247 drawing



## 5 Revision history

**Table 13. Document revision history**

| Date        | Revision | Changes                                                                                                                                                                                                                                                                                                                                                                                                                     |
|-------------|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 15-May-2009 | 1        | First release.                                                                                                                                                                                                                                                                                                                                                                                                              |
| 02-Sep-2010 | 2        | Document status promoted from preliminary data to datasheet.                                                                                                                                                                                                                                                                                                                                                                |
| 21-Jun-2012 | 3        | Added new device in I <sup>2</sup> PAKFP.<br><i>Table 1: Device summary, Table 2: Absolute maximum ratings, Table 3: Thermal data, Figure 2: Safe operating area for TO-220FP and I<sup>2</sup>PAKFP, Figure 3: Thermal impedance for TO-220FP and I<sup>2</sup>PAKFP</i> have been modified accordingly.<br><i>Table 10: I<sup>2</sup>PAKFP mechanical data and Figure 26: I<sup>2</sup>PAKFP drawing</i> have been added. |

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