

## N-channel 600 V, 0.72 $\Omega$ typ., 5.5 A MDmesh II Plus™ low $Q_g$ Power MOSFETs in TO-220FP and I<sup>2</sup>PAKFP packages

Datasheet - production data

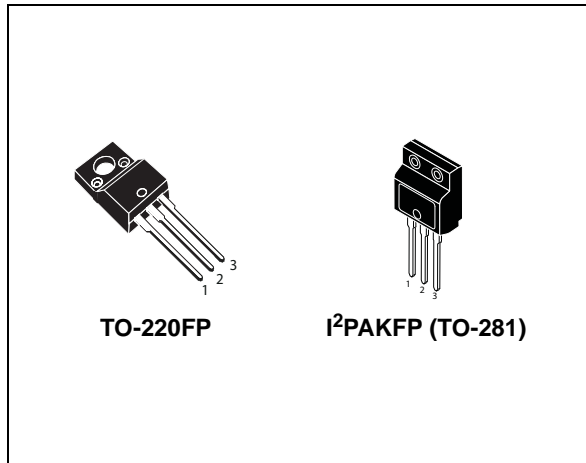
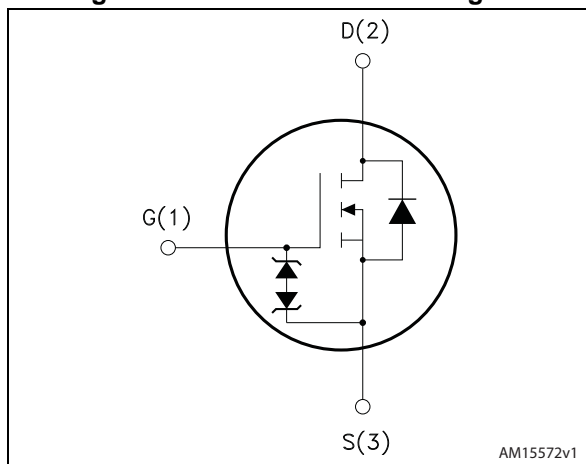


Figure 1. Internal schematic diagram



### Features

| Order codes | $V_{DS} @ T_{Jmax}$ | $R_{DS(on) max}$ | $I_D$ |
|-------------|---------------------|------------------|-------|
| STF9N60M2   | 650 V               | 0.78 $\Omega$    | 5.5 A |
| STFI9N60M2  |                     |                  |       |

- Extremely low gate charge
- Lower  $R_{DS(on)}$  x area vs previous generation
- Low gate input resistance
- 100% avalanche tested
- Zener-protected

### Applications

- Switching applications

### Description

These devices are N-channel Power MOSFETs developed using a new generation of MDmesh™ technology: MDmesh II Plus™ low  $Q_g$ . These revolutionary Power MOSFETs associate a vertical structure to the company's strip layout to yield one of the world's lowest on-resistance and gate charge. They are therefore suitable for the most demanding high efficiency converters.

Table 1. Device summary

| Order codes | Marking | Package              | Packaging |
|-------------|---------|----------------------|-----------|
| STF9N60M2   | 9N60M2  | TO-220FP             | Tube      |
| STFI9N60M2  |         | I <sup>2</sup> PAKFP |           |

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# Contents

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# 1 Electrical ratings

**Table 2. Absolute maximum ratings**

| Symbol         | Parameter   | Value              | Unit |
|----------------|---|--------------------|------|
| $V_{GS}$       | Gate-source voltage   | $\pm 25$           | V    |
| $I_D$          | Drain current (continuous) at $T_C = 25\text{ °C}$  | 5.5 <sup>(1)</sup> | A    |
| $I_D$          | Drain current (continuous) at $T_C = 100\text{ °C}$   | 3.6 <sup>(1)</sup> | A    |
| $I_{DM}^{(1)}$ | Drain current (pulsed)  | 22 <sup>(1)</sup>  | A    |
| $P_{TOT}$      | Total dissipation at $T_C = 25\text{ °C}$   | 20                 | W    |
| $V_{ISO}$      | Insulation withstand voltage (RMS) from all three leads to external heat sink ( $t=1\text{ s}$ ; $T_C=25\text{ °C}$ ) | 2500               | V    |
| $dv/dt^{(2)}$  | Peak diode recovery voltage slope   | 15                 | V/ns |
| $dv/dt^{(3)}$  | MOSFET $dv/dt$ ruggedness   | 50                 |      |
| $T_{stg}$      | Storage temperature   | - 55 to 150        | °C   |
| $T_j$          | Max. operating junction temperature   | 150                |      |

1. Pulse width limited by safe operating area.
2.  $I_{SD} \leq 5.5\text{ A}$ ,  $di/dt \leq 400\text{ A}/\mu\text{s}$ ;  $V_{DS\text{ peak}} < V_{(BR)DSS}$ ,  $V_{DD}=400\text{ V}$
3.  $V_{DS} \leq 480\text{ V}$

**Table 3. Thermal data**

| Symbol         | Parameter                               | Value | Unit |
|----------------|---|-------|------|
| $R_{thj-case}$ | Thermal resistance junction-case max    | 6.25  | °C/W |
| $R_{thj-amb}$  | Thermal resistance junction-ambient max | 62.5  | °C/W |

**Table 4. Avalanche characteristics**

| Symbol   | Parameter   | Value | Unit |
|----------|---|-------|------|
| $I_{AR}$ | Avalanche current, repetitive or not repetitive (pulse width limited by $T_{jmax}$ )      | 2     | A    |
| $E_{AS}$ | Single pulse avalanche energy (starting $T_j=25\text{ °C}$ , $I_D=I_{AR}$ ; $V_{DD}=50$ ) | 105   | mJ   |

## 2 Electrical characteristics

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

**Table 5. On /off states**

| Symbol        | Parameter  | Test conditions                                    | Min. | Typ. | Max.     | Unit          |
|---------------|--|--|------|------|----------|---------------|
| $V_{(BR)DSS}$ | Drain-source breakdown voltage                   | $I_D = 1\text{ mA}$ , $V_{GS} = 0$                 | 600  |      |          | V             |
| $I_{DSS}$     | Zero gate voltage drain current ( $V_{GS} = 0$ ) | $V_{DS} = 600\text{ V}$                            |      |      | 1        | $\mu\text{A}$ |
|               |  | $V_{DS} = 600\text{ V}$ , $T_C = 125\text{ °C}$    |      |      | 100      | $\mu\text{A}$ |
| $I_{GSS}$     | Gate-body leakage current ( $V_{DS} = 0$ )       | $V_{GS} = \pm 25\text{ V}$                         |      |      | $\pm 10$ | $\mu\text{A}$ |
| $V_{GS(th)}$  | Gate threshold voltage                           | $V_{DS} = V_{GS}$ , $I_D = 250\text{ }\mu\text{A}$ | 2    | 3    | 4        | V             |
| $R_{DS(on)}$  | Static drain-source on-resistance                | $V_{GS} = 10\text{ V}$ , $I_D = 3\text{ A}$        |      | 0.72 | 0.78     | $\Omega$      |

**Table 6. Dynamic**

| Symbol                     | Parameter                     | Test conditions  | Min. | Typ. | Max. | Unit     |
|----------------------------|-------------------------------|--|------|------|------|----------|
| $C_{iss}$                  | Input capacitance             | $V_{DS} = 100\text{ V}$ , $f = 1\text{ MHz}$ ,<br>$V_{GS} = 0$   | -    | 320  | -    | pF       |
| $C_{oss}$                  | Output capacitance            |  | -    | 18   | -    | pF       |
| $C_{rss}$                  | Reverse transfer capacitance  |  | -    | 0.68 | -    | pF       |
| $C_{oss\text{ eq.}}^{(1)}$ | Equivalent output capacitance | $V_{DS} = 0\text{ to }480\text{ V}$ , $V_{GS} = 0$   | -    | 88   | -    | pF       |
| $R_G$                      | Intrinsic gate resistance     | $f = 1\text{ MHz}$ open drain  | -    | 6.5  | -    | $\Omega$ |
| $Q_g$                      | Total gate charge             | $V_{DD} = 480\text{ V}$ , $I_D = 5.5\text{ A}$ ,<br>$V_{GS} = 10\text{ V}$<br>(see <a href="#">Figure 15</a> ) | -    | 10   | -    | nC       |
| $Q_{gs}$                   | Gate-source charge            |  | -    | 2    | -    | nC       |
| $Q_{gd}$                   | Gate-drain charge             |  | -    | 5.1  | -    | nC       |

1.  $C_{oss\text{ eq.}}$  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  | $V_{DD} = 300\text{ V}$ , $I_D = 3\text{ A}$ ,<br>$R_G = 4.7\text{ }\Omega$ , $V_{GS} = 10\text{ V}$<br>(see <a href="#">Figure 14</a> and <a href="#">Figure 19</a> ) | -    | 8.8  | -    | ns   |
| $t_r$        | Rise time           |  | -    | 7.5  | -    | ns   |
| $t_{d(off)}$ | Turn-off delay time |  | -    | 22   | -    | ns   |
| $t_f$        | Fall time           |  | -    | 13.5 | -    | ns   |

Table 8. Source drain diode

| Symbol          | Parameter                     | Test conditions  | Min. | Typ. | Max. | Unit          |
|-----------------|-------------------------------|--|------|------|------|---------------|
| $I_{SD}$        | Source-drain current          |  | -    |      | 5.5  | A             |
| $I_{SDM}^{(1)}$ | Source-drain current (pulsed) |  | -    |      | 22   | A             |
| $V_{SD}^{(2)}$  | Forward on voltage            | $I_{SD} = 5.5 \text{ A}$ , $V_{GS} = 0$  | -    |      | 1.6  | V             |
| $t_{rr}$        | Reverse recovery time         | $I_{SD} = 5.5 \text{ A}$ , $di/dt = 100 \text{ A}/\mu\text{s}$<br>$V_{DD} = 60 \text{ V}$ (see <a href="#">Figure 16</a> )   | -    | 265  |      | ns            |
| $Q_{rr}$        | Reverse recovery charge       |  | -    | 1.65 |      | $\mu\text{C}$ |
| $I_{RRM}$       | Reverse recovery current      |  | -    | 12.5 |      | A             |
| $t_{rr}$        | Reverse recovery time         | $I_{SD} = 5.5 \text{ A}$ , $di/dt = 100 \text{ A}/\mu\text{s}$<br>$V_{DD} = 60 \text{ V}$ , $T_j = 150 \text{ }^\circ\text{C}$<br>(see <a href="#">Figure 16</a> ) | -    | 377  |      | ns            |
| $Q_{rr}$        | Reverse recovery charge       |  | -    | 2.3  |      | $\mu\text{C}$ |
| $I_{RRM}$       | Reverse recovery current      |  | -    | 12.2 |      | A             |

1. Pulse width limited by safe operating area.
2. Pulsed: pulse duration = 300  $\mu\text{s}$ , duty cycle 1.5%

## 2.1 Electrical characteristics (curves)

Figure 2. Safe operating area

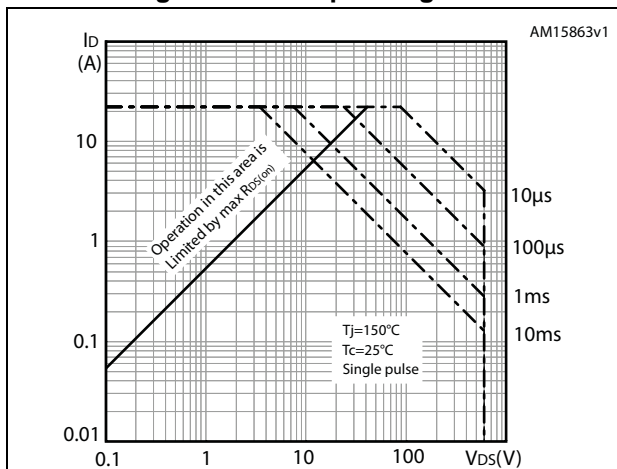


Figure 3. Thermal impedance

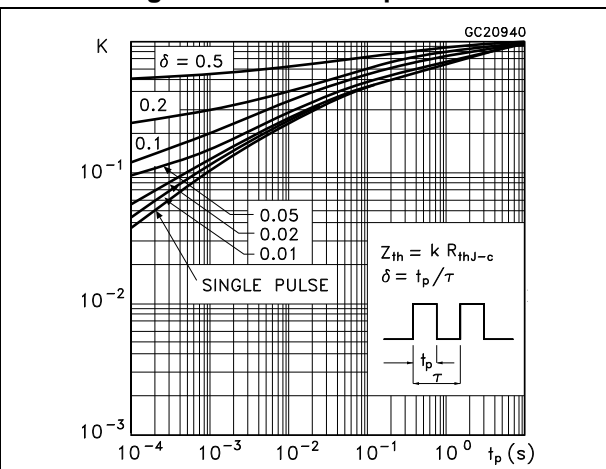


Figure 4. Output characteristics

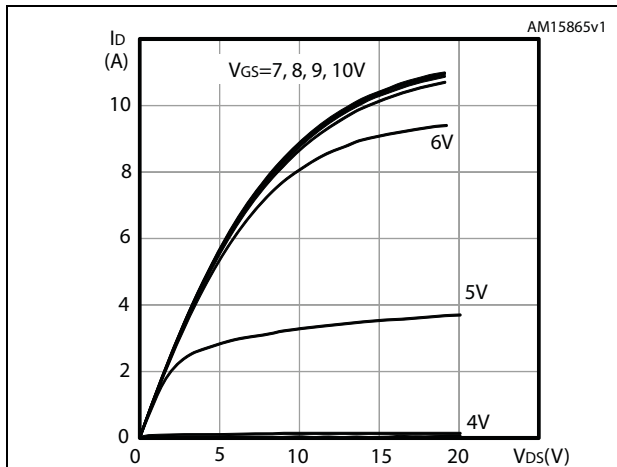


Figure 5. Transfer characteristics

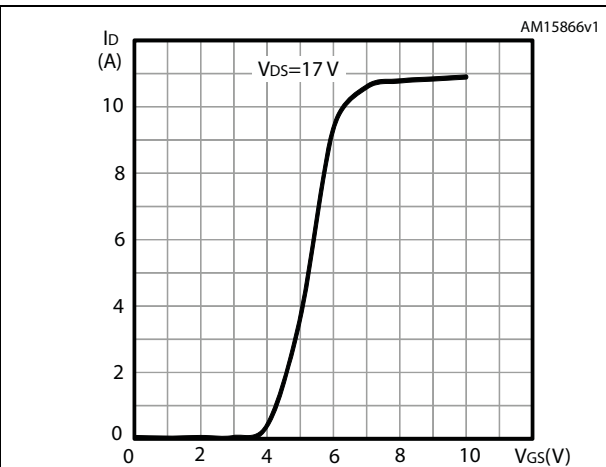


Figure 6. Gate charge vs gate-source voltage

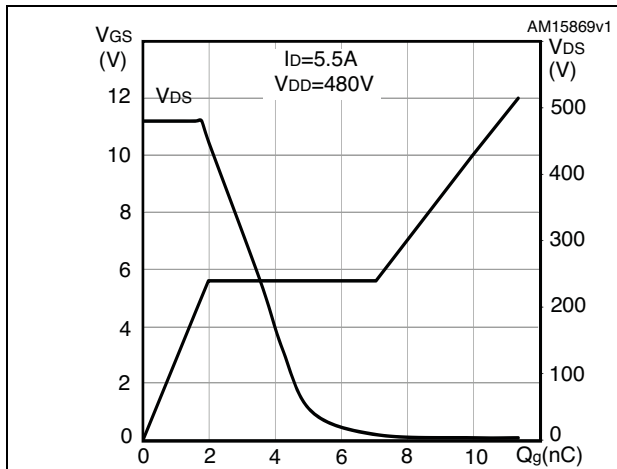


Figure 7. Static drain-source on-resistance

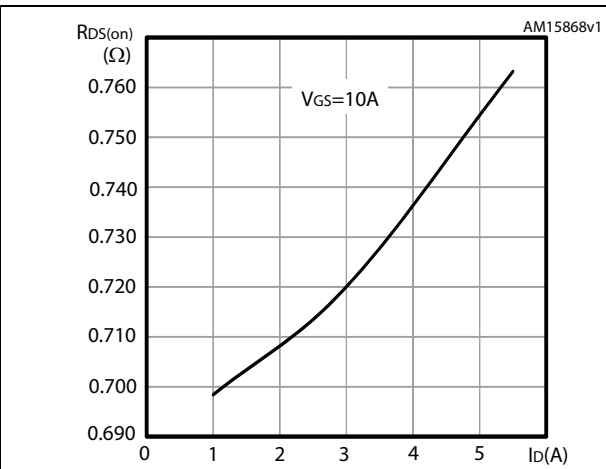


Figure 8. Capacitance variations

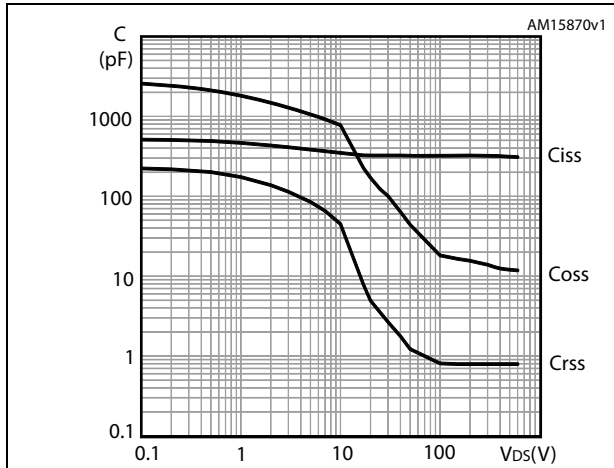


Figure 9. Output capacitance stored energy

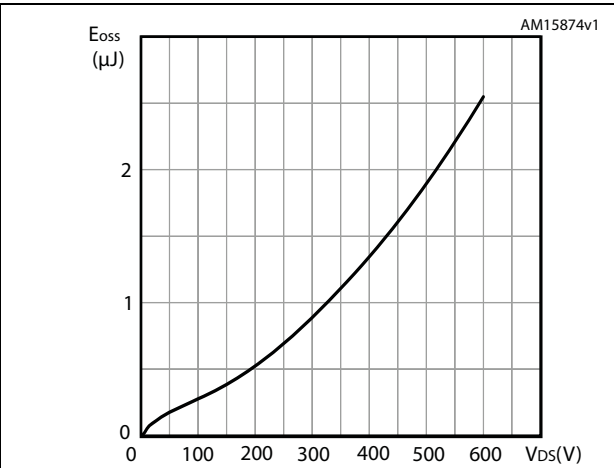


Figure 10. Normalized gate threshold voltage vs temperature

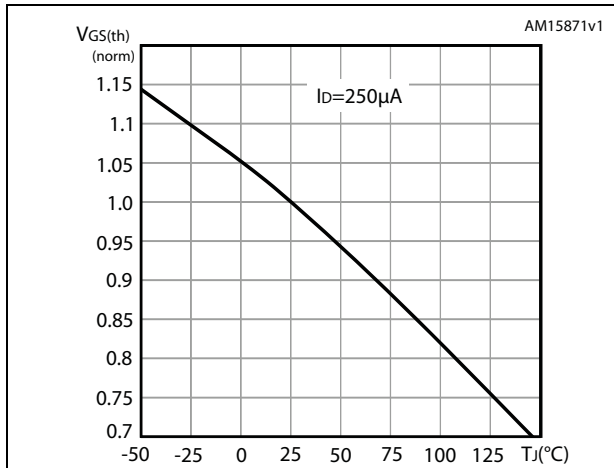


Figure 11. Normalized on-resistance vs temperature

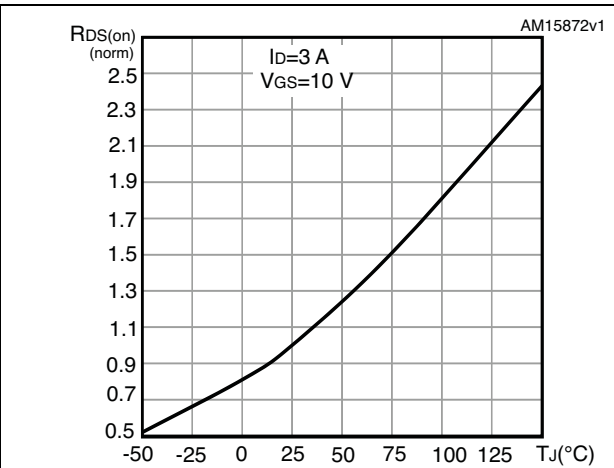


Figure 12. Source-drain diode forward characteristics

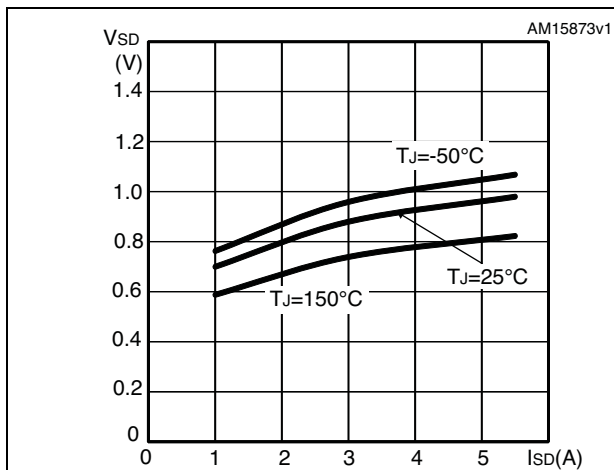
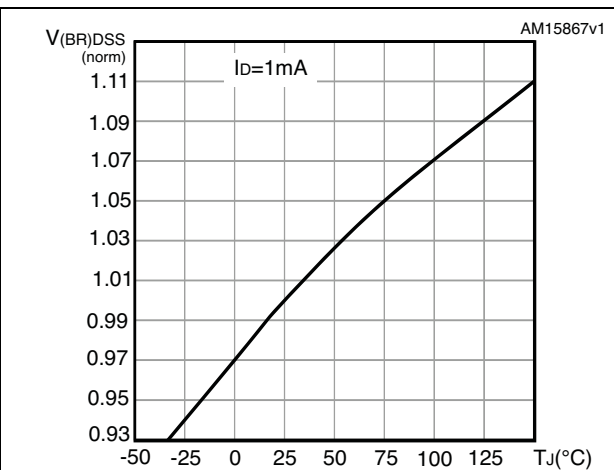


Figure 13. Normalized V(BR)DSS vs temperature



### 3 Test circuits

Figure 14. Switching times test circuit for resistive load



Figure 15. Gate charge test circuit



Figure 16. Test circuit for inductive load switching and diode recovery times



Figure 17. Unclamped inductive load test circuit



Figure 18. Unclamped inductive waveform

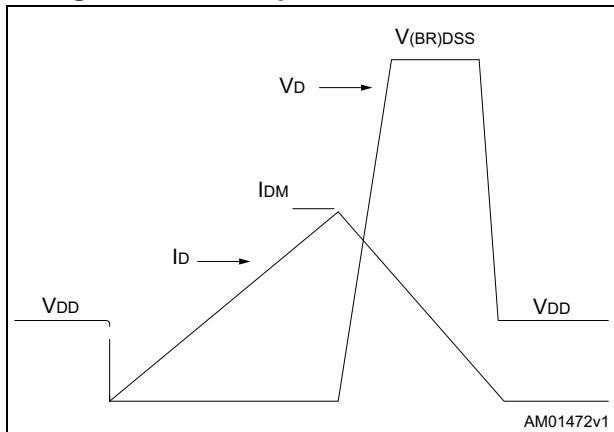


Figure 19. Switching time waveform



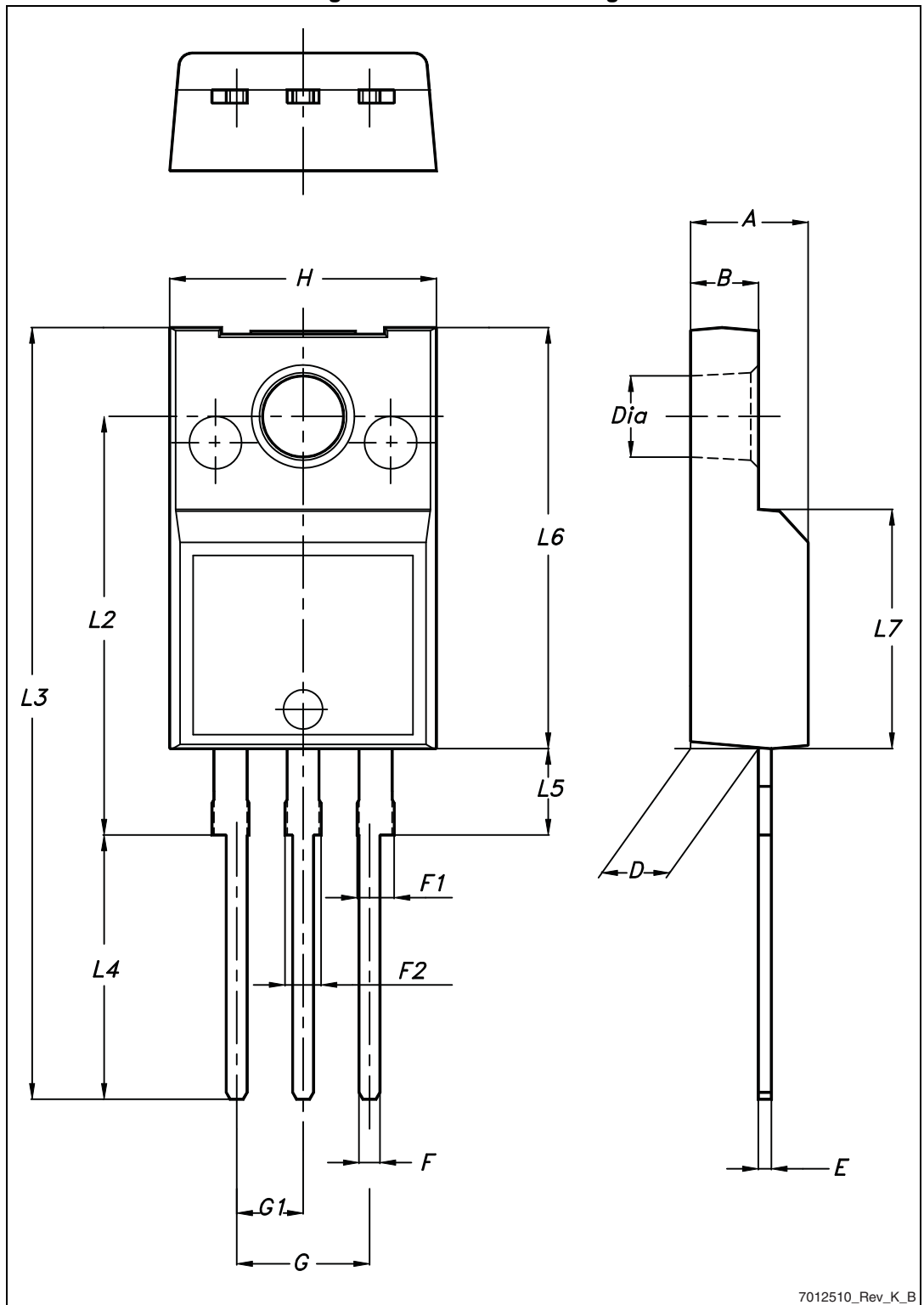


## 4 Package mechanical data

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.

### 4.1 TO-220FP, STF9N60M2

Figure 20. TO-220FP drawing



7012510\_Rev\_K\_B

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  |

### 4.2 I<sup>2</sup>PAKFP (TO-281), STF19N60M2

Figure 21. I<sup>2</sup>PAKFP (TO-281) drawing

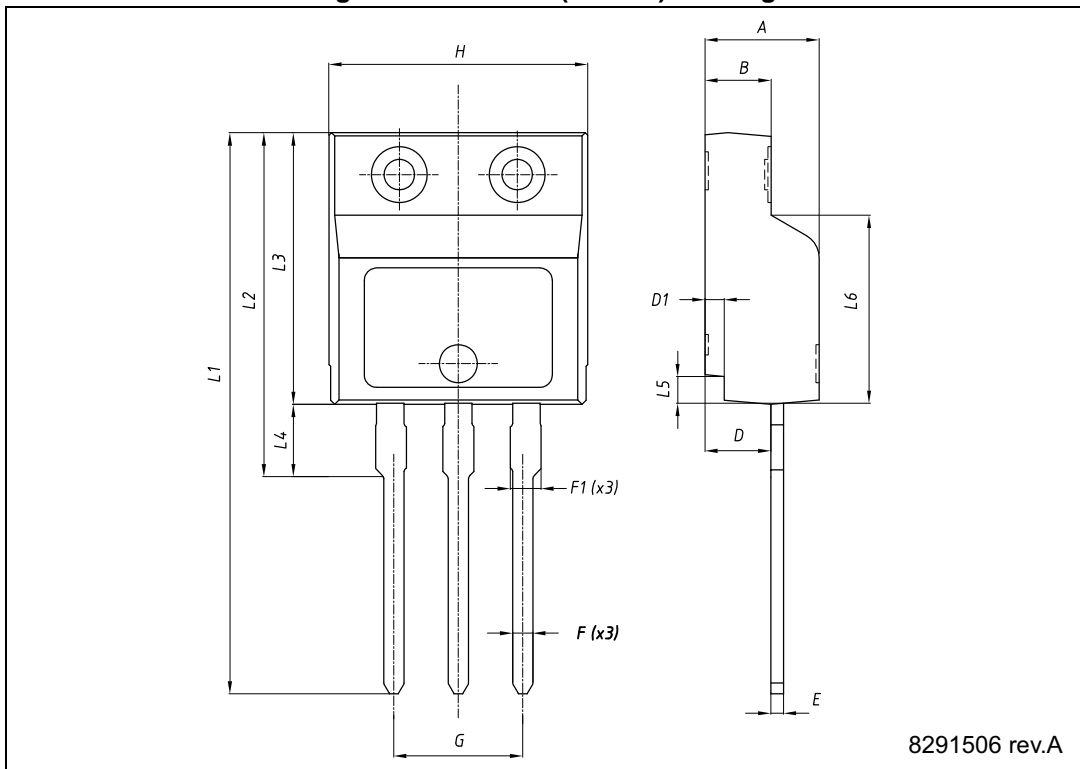


Table 10. I<sup>2</sup>PAKFP (TO-281) mechanical data

| 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  |

## 5 Revision history

**Table 11. Document revision history**

| Date        | Revision | Changes  |
|-------------|----------|--|
| 03-Jun-2013 | 1        | First release. The part number was previously included in datasheet DocID024399. |
| 10-Mar-2014 | 2        | Added: I <sup>2</sup> PAKFP package<br>Minor text changes                        |

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