



# STF13NM60N, STI13NM60N, STP13NM60N, STU13NM60N, STW13NM60N

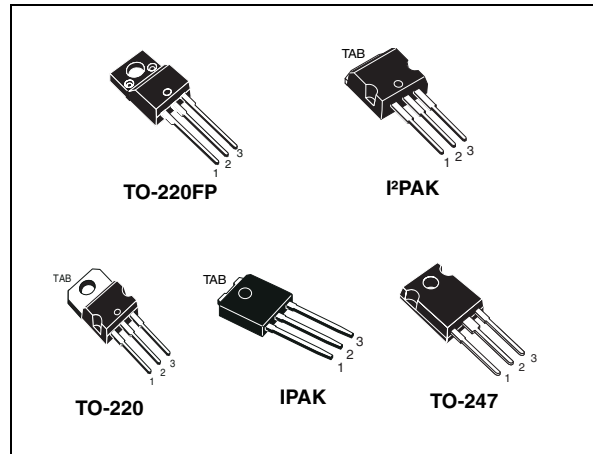
N-channel 600 V, 0.28  $\Omega$  typ., 11 A MDmesh™ II Power MOSFET  
in TO-220FP, I<sup>2</sup>PAK, TO-220, IPAK, TO-247 packages

Datasheet — production data

## Features

| Order codes  | V <sub>DSS</sub><br>(@T <sub>jmax</sub> ) | R <sub>DS(on)</sub><br>max | I <sub>D</sub> |
|--|---|----------------------------|----------------|
| STF13NM60N<br>STI13NM60N<br>STP13NM60N<br>STU13NM60N<br>STW13NM60N | 650 V                                     | < 0.36 $\Omega$            | 11 A           |

- 100% avalanche tested
- Low input capacitance and gate charge
- Low gate input resistance



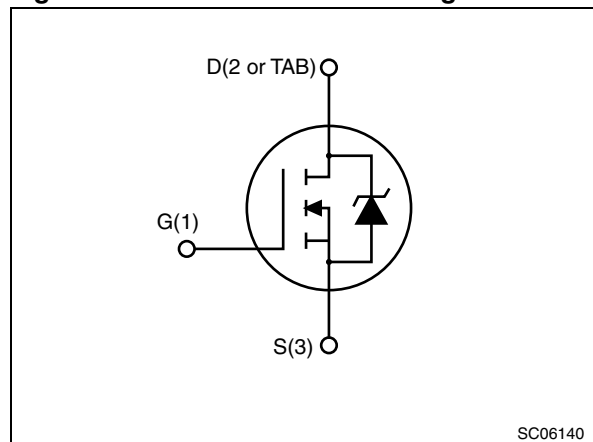
## Applications

- Switching applications

## Description

These devices are N-channel Power MOSFETs developed using the second generation of MDmesh™ technology. This revolutionary Power MOSFET associates a vertical structure to the company's strip layout to yield one of the world's lowest on-resistance and gate charge. It is therefore suitable for the most demanding high efficiency converters.

Figure 1. Internal schematic diagram



SC06140

Table 1. Device summary

| Order codes  | Marking | Packages   | Packaging                            |
|--|---------|--|--------------------------------------|
| STF13NM60N<br>STI13NM60N<br>STP13NM60N<br>STU13NM60N<br>STW13NM60N | 13NM60N | TO-220FP<br>I <sup>2</sup> PAK<br>TO-220<br>IPAK<br>TO-247 | Tube<br>Tube<br>Tube<br>Tube<br>Tube |

## Contents

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# 1 Electrical ratings

**Table 2. Absolute maximum ratings**

| Symbol                         | Parameter  | Value               |  | Unit |
|--------------------------------|--|---------------------|--|------|
|                                |  | TO-220FP            | I <sup>2</sup> PAK, TO-220, IPAK, TO-247 |      |
| V <sub>DS</sub>                | Drain-source voltage   | 600                 |  | V    |
| V <sub>GS</sub>                | Gate-source voltage  | ± 25                |  | V    |
| I <sub>D</sub>                 | Drain current (continuous) at T <sub>C</sub> = 25 °C   | 11 <sup>(1)</sup>   | 11                                       | A    |
| I <sub>D</sub>                 | Drain current (continuous) at T <sub>C</sub> = 100 °C  | 6.93 <sup>(1)</sup> | 6.93                                     | A    |
| I <sub>DM</sub> <sup>(2)</sup> | Drain current (pulsed)   | 44 <sup>(1)</sup>   | 44                                       | A    |
| P <sub>TOT</sub>               | Total dissipation at T <sub>C</sub> = 25 °C  | 25                  | 90                                       | W    |
| dv/dt <sup>(3)</sup>           | Peak diode recovery voltage slope  | 15                  |  | V/ns |
| 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    |
| T <sub>stg</sub>               | Storage temperature  | - 55 to 150         |  | °C   |
| T <sub>j</sub>                 | Max. operating junction temperature  | 150                 |  | °C   |

- Limited by maximum junction temperature
- Pulse width limited by safe operating area
- I<sub>SD</sub> ≤ 11 A, di/dt ≤ 400 A/μs, V<sub>DS peak</sub> ≤ V<sub>(BR)DSS</sub>, V<sub>DD</sub> = 80% V<sub>(BR)DSS</sub>.

**Table 3. Thermal data**

| Symbol                | Parameter                               | Value    |                           |      |        | Unit |
|-----------------------|---|----------|---------------------------|------|--------|------|
|                       |   | TO-220FP | I <sup>2</sup> PAK TO-220 | IPAK | TO-247 |      |
| R <sub>thj-case</sub> | Thermal resistance junction-case max    | 5        | 1.39                      |      |        | °C/W |
| R <sub>thj-amb</sub>  | Thermal resistance junction-ambient max | 62.5     | 62.5                      | 100  | 50     | °C/W |

**Table 4. Avalanche characteristics**

| Symbol          | Parameter   | Value | Unit |
|-----------------|---|-------|------|
| I <sub>AS</sub> | Avalanche current, repetitive or not-repetitive (pulse width limited by T <sub>j</sub> max)                             | 3.5   | 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) | 200   | mJ   |

## 2 Electrical characteristics

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

**Table 5. On/off states**

| Symbol        | Parameter  | Test conditions   | Min. | Typ. | Max.      | Unit                           |
|---------------|--|---|------|------|-----------|--------------------------------|
| $V_{(BR)DSS}$ | Drain-source breakdown voltage ( $V_{GS} = 0$ )  | $I_D = 1\text{ mA}$   | 600  |      |           | V                              |
| $I_{DSS}$     | Zero gate voltage drain current ( $V_{GS} = 0$ ) | $V_{DS} = 600\text{ V}$<br>$V_{DS} = 600\text{ V}, T_C = 125\text{ °C}$ |      |      | 1<br>100  | $\mu\text{A}$<br>$\mu\text{A}$ |
| $I_{GSS}$     | Gate-body leakage current ( $V_{DS} = 0$ )       | $V_{GS} = \pm 25\text{ V}$  |      |      | $\pm 0.1$ | $\mu\text{A}$                  |
| $V_{GS(th)}$  | 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                | $V_{GS} = 10\text{ V}, I_D = 5.5\text{ A}$                              |      | 0.28 | 0.36      | $\Omega$                       |

**Table 6. Dynamic**

| Symbol                     | Parameter                     | Test conditions  | Min. | Typ. | Max. | Unit     |
|----------------------------|-------------------------------|--|------|------|------|----------|
| $C_{iss}$                  | Input capacitance             | $V_{DS} = 50\text{ V}, f = 1\text{ MHz},$<br>$V_{GS} = 0$  | -    | 790  | -    | pF       |
| $C_{oss}$                  | Output capacitance            |  |      | 60   |      | pF       |
| $C_{rss}$                  | Reverse transfer capacitance  |  |      | 3.6  |      | pF       |
| $C_{oss\text{ eq.}}^{(1)}$ | Equivalent output capacitance | $V_{GS} = 0, V_{DS} = 0\text{ to }480\text{ V}$  | -    | 135  | -    | pF       |
| $Q_g$                      | Total gate charge             | $V_{DD} = 480\text{ V}, I_D = 11\text{ A},$<br>$V_{GS} = 10\text{ V},$<br><i>(see Figure 20)</i> | -    | 27   | -    | nC       |
| $Q_{gs}$                   | Gate-source charge            |  |      | 4    |      | nC       |
| $Q_{gd}$                   | Gate-drain charge             |  |      | 14   |      | nC       |
| $R_G$                      | Gate input resistance         | $f = 1\text{ MHz open drain}$  | -    | 4.7  | -    | $\Omega$ |

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%  $V_{DS}$

**Table 7. Switching times**

| Symbol       | Parameter           | Test conditions   | Min. | Typ. | Max. | Unit |    |
|--------------|---------------------|---|------|------|------|------|----|
| $t_{d(on)}$  | Turn-on delay time  | $V_{DD} = 300\text{ V}$ , $I_D = 5.5\text{ A}$<br>$R_G = 4.7\ \Omega$ , $V_{GS} = 10\text{ V}$<br>(see Figure 19) |      | 3    |      | ns   |    |
| $t_r$        | Rise time           |   |      | 8    |      | ns   |    |
| $t_{d(off)}$ | Turn-off delay time |   |      |      | 30   |      | ns |
| $t_f$        | Fall time           |   |      |      | 10   |      | ns |

**Table 8. Source drain diode**

| Symbol          | Parameter                     | Test conditions   | Min | Typ. | Max. | Unit          |
|-----------------|-------------------------------|---|-----|------|------|---------------|
| $I_{SD}$        | Source-drain current          |   |     |      | 11   | A             |
| $I_{SDM}^{(1)}$ | Source-drain current (pulsed) |   | -   |      | 44   | A             |
| $V_{SD}^{(2)}$  | Forward on voltage            | $I_{SD} = 11\text{ A}$ , $V_{GS} = 0$   | -   |      | 1.5  | V             |
| $t_{rr}$        | Reverse recovery time         | $I_{SD} = 11\text{ A}$ , $di/dt = 100\text{ A}/\mu\text{s}$<br>$V_{DD} = 100\text{ V}$<br>(see Figure 21)                                     |     | 230  |      | ns            |
| $Q_{rr}$        | Reverse recovery charge       |   |     | 2    |      | $\mu\text{C}$ |
| $I_{RRM}$       | Reverse recovery current      |   |     |      | 18   | A             |
| $t_{rr}$        | Reverse recovery time         | $I_{SD} = 11\text{ A}$ , $di/dt = 100\text{ A}/\mu\text{s}$<br>$V_{DD} = 100\text{ V}$ , $T_j = 150\text{ }^\circ\text{C}$<br>(see Figure 21) |     | 290  |      | ns            |
| $Q_{rr}$        | Reverse recovery charge       |   |     | 190  |      | $\mu\text{C}$ |
| $I_{RRM}$       | Reverse recovery current      |   |     |      | 17   | 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 for I<sup>2</sup>PAK and TO-220

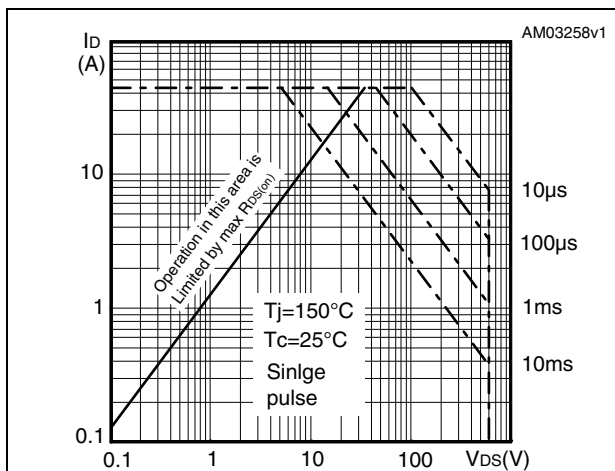


Figure 3. Thermal impedance for I<sup>2</sup>PAK and TO-220

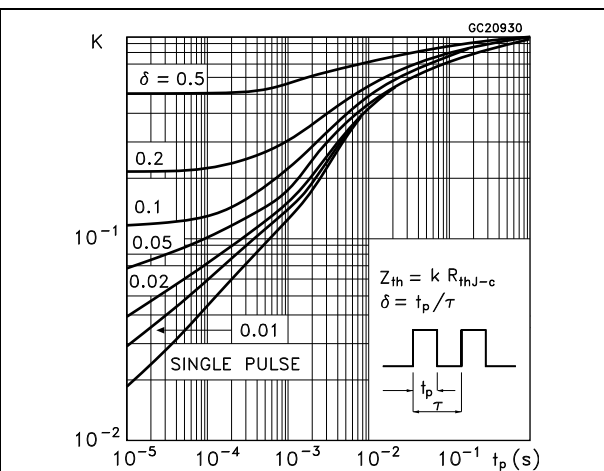


Figure 4. Safe operating area for TO-220FP

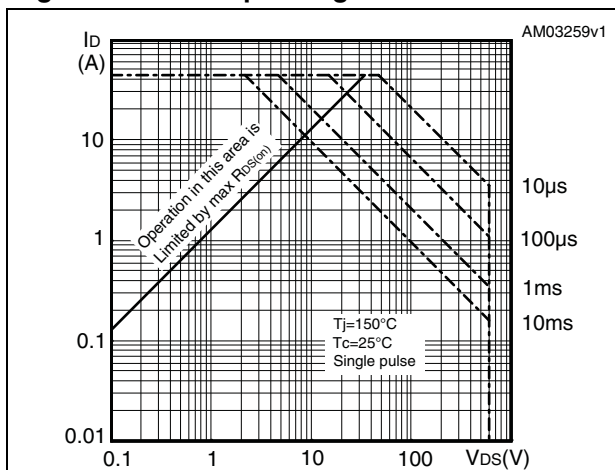


Figure 5. Thermal impedance for TO-220FP

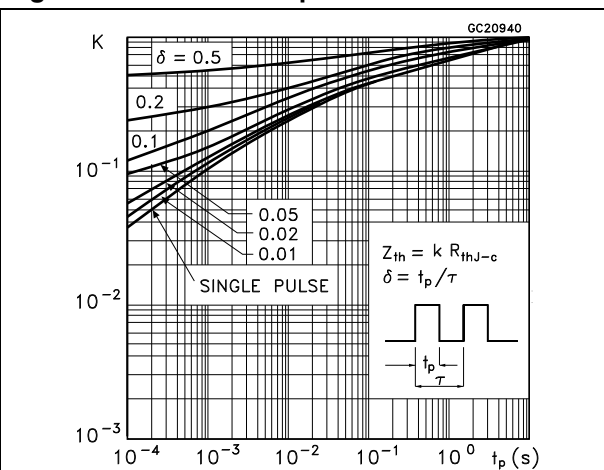


Figure 6. Safe operating area for TO-247

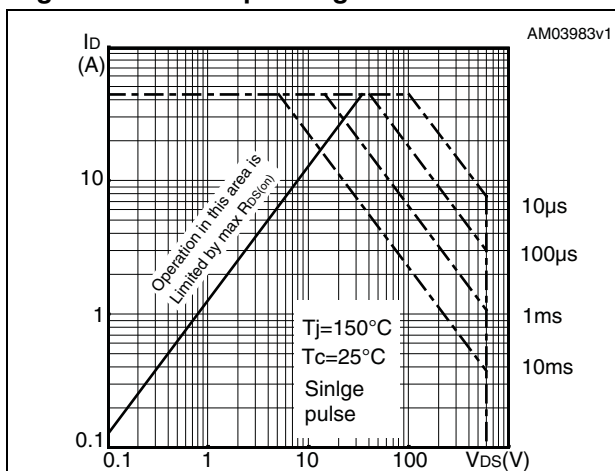


Figure 7. Thermal impedance for TO-247

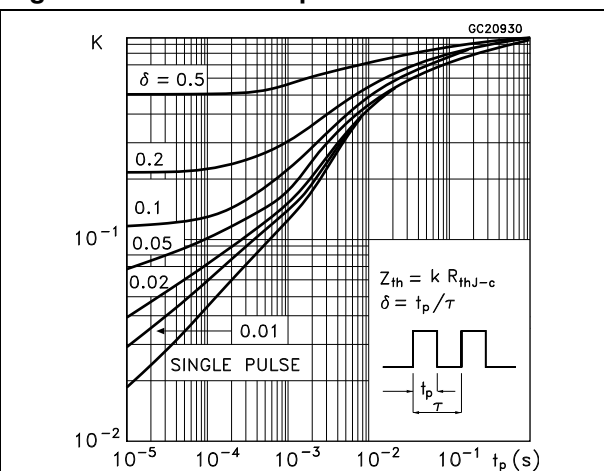


Figure 8. Safe operating area for IPAK

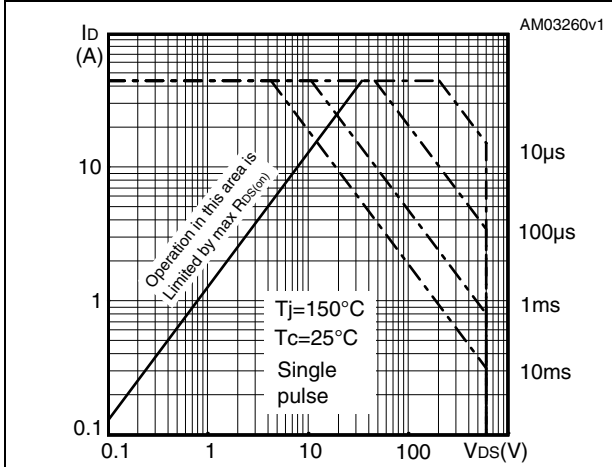


Figure 9. Thermal impedance for IPAK

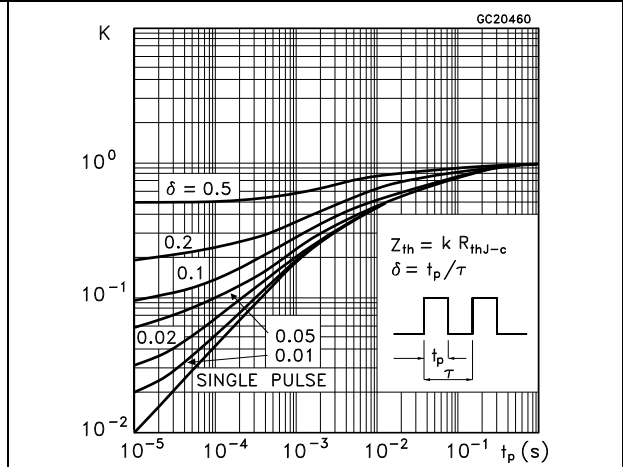


Figure 10. Output characteristics

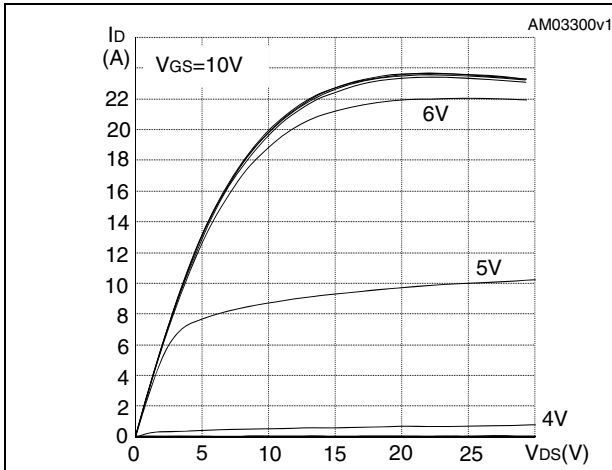


Figure 11. Transfer characteristics

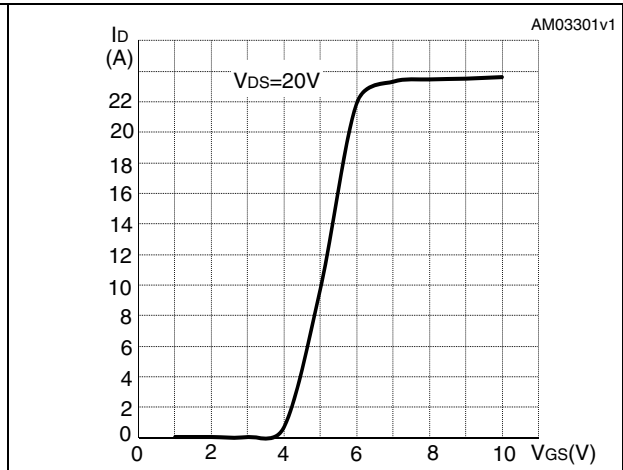


Figure 12. Normalized VDS vs temperature

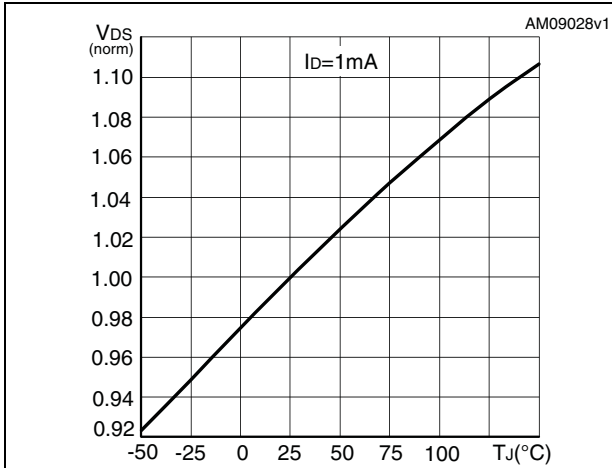


Figure 13. Static drain-source on-resistance

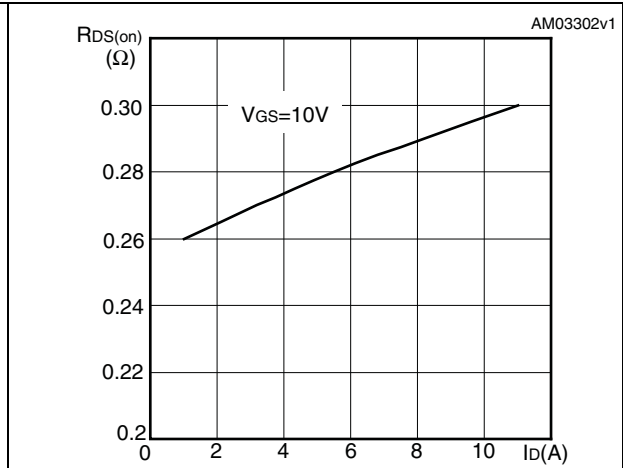


Figure 14. Gate charge vs gate-source voltage Figure 15. Capacitance variations

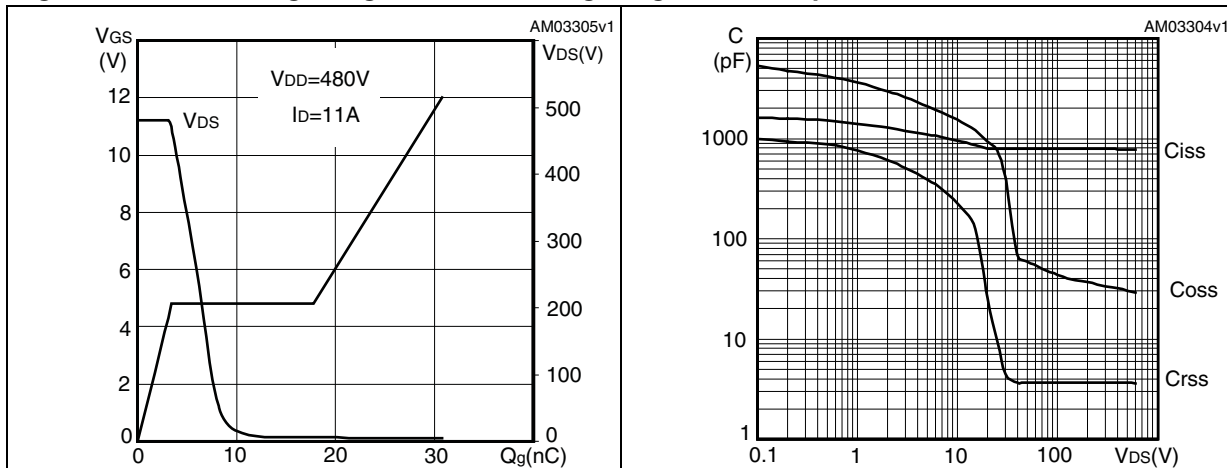


Figure 16. Normalized gate threshold voltage vs temperature Figure 17. Normalized on-resistance vs temperature

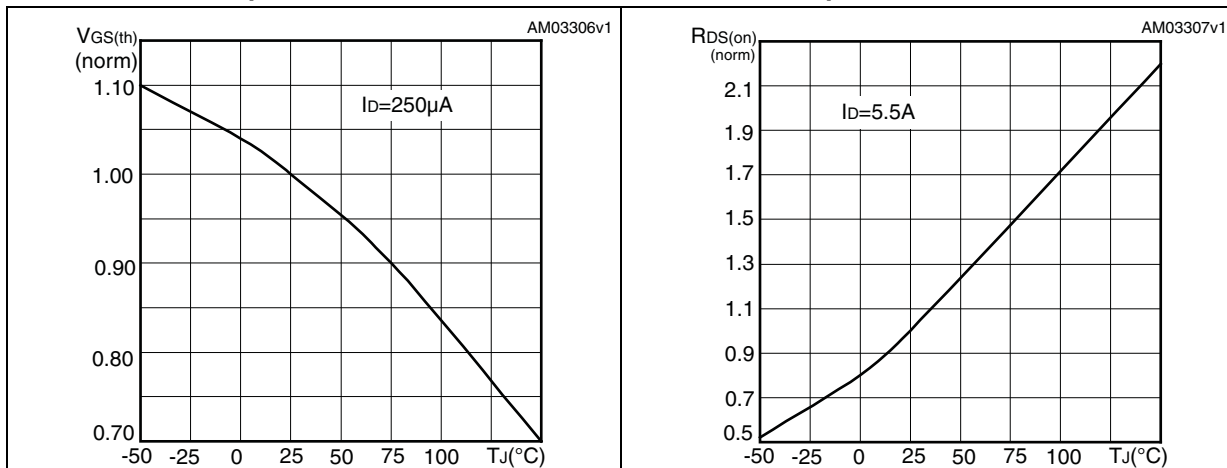
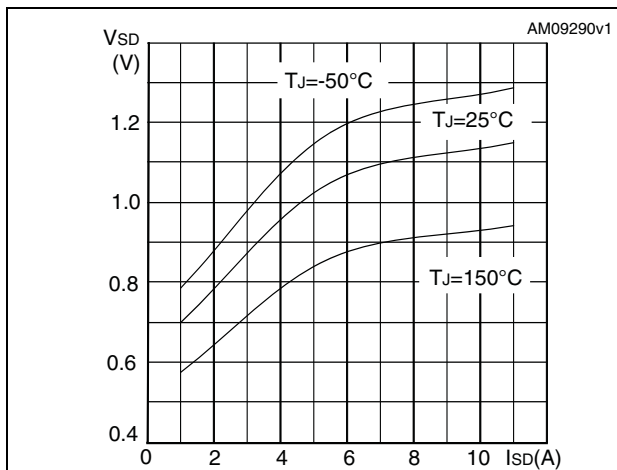


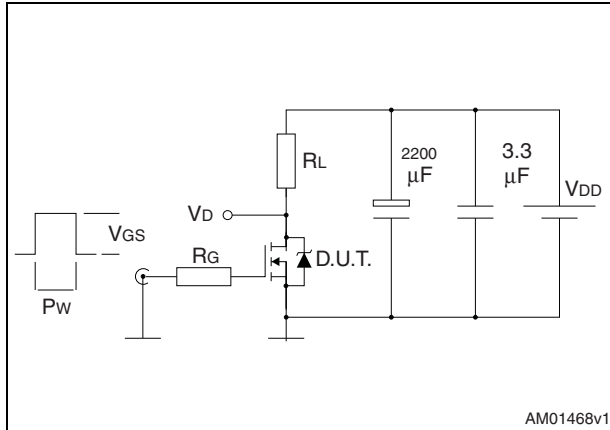
Figure 18. Source-drain diode forward characteristics



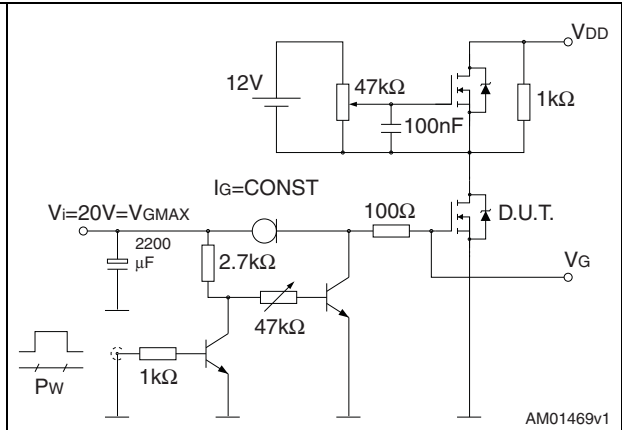


### 3 Test circuits

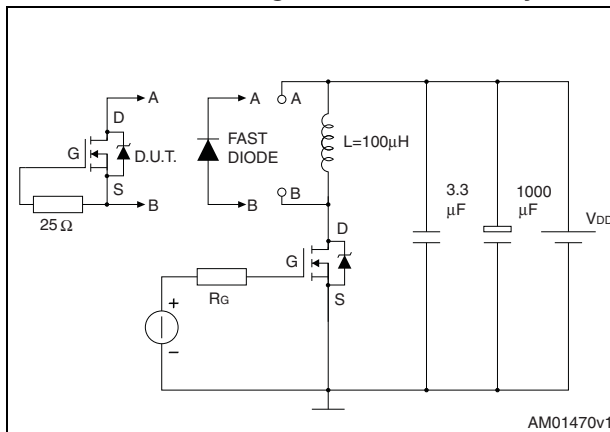
**Figure 19. Switching times test circuit for resistive load**



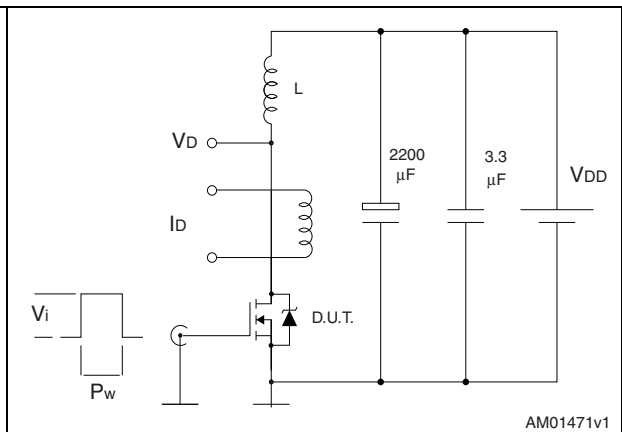
**Figure 20. Gate charge test circuit**



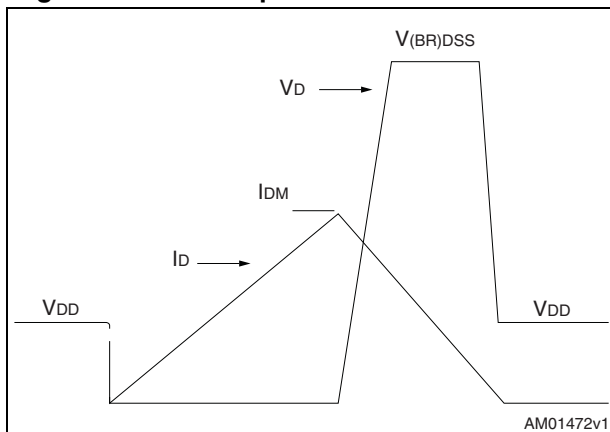
**Figure 21. Test circuit for inductive load switching and diode recovery times**



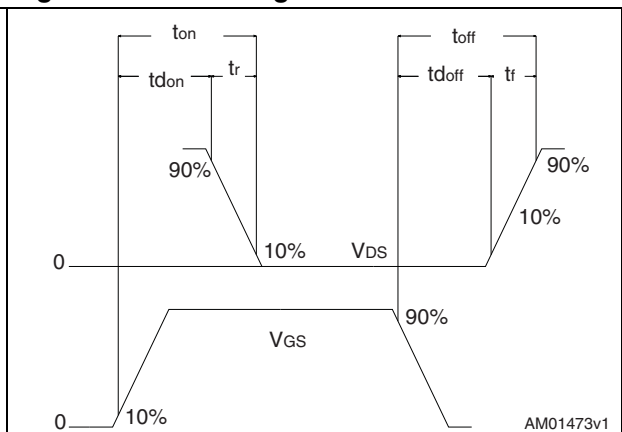
**Figure 22. Unclamped inductive load test circuit**



**Figure 23. Unclamped inductive waveform**



**Figure 24. Switching time waveform**



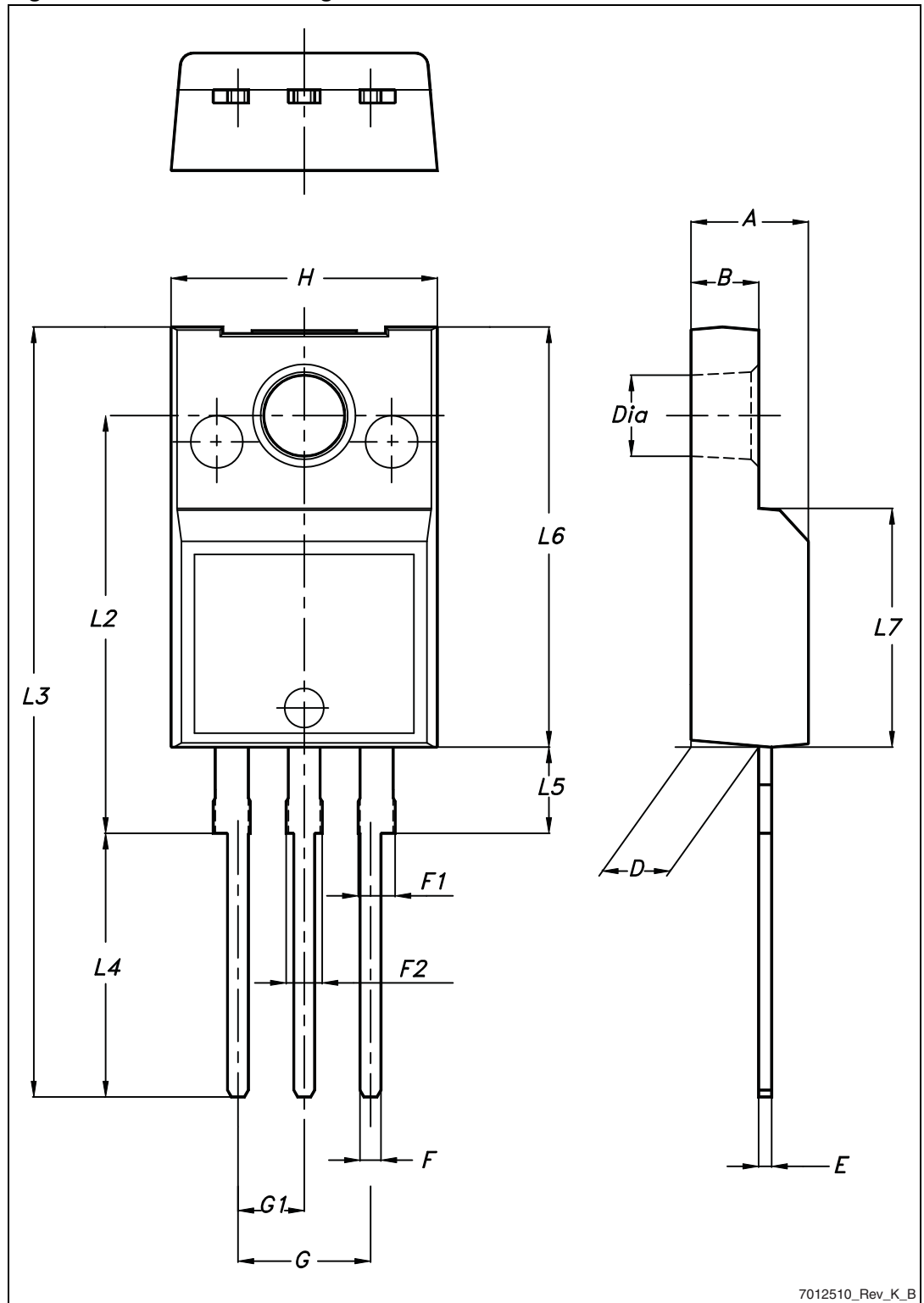
## 4 Package mechanical data

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 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

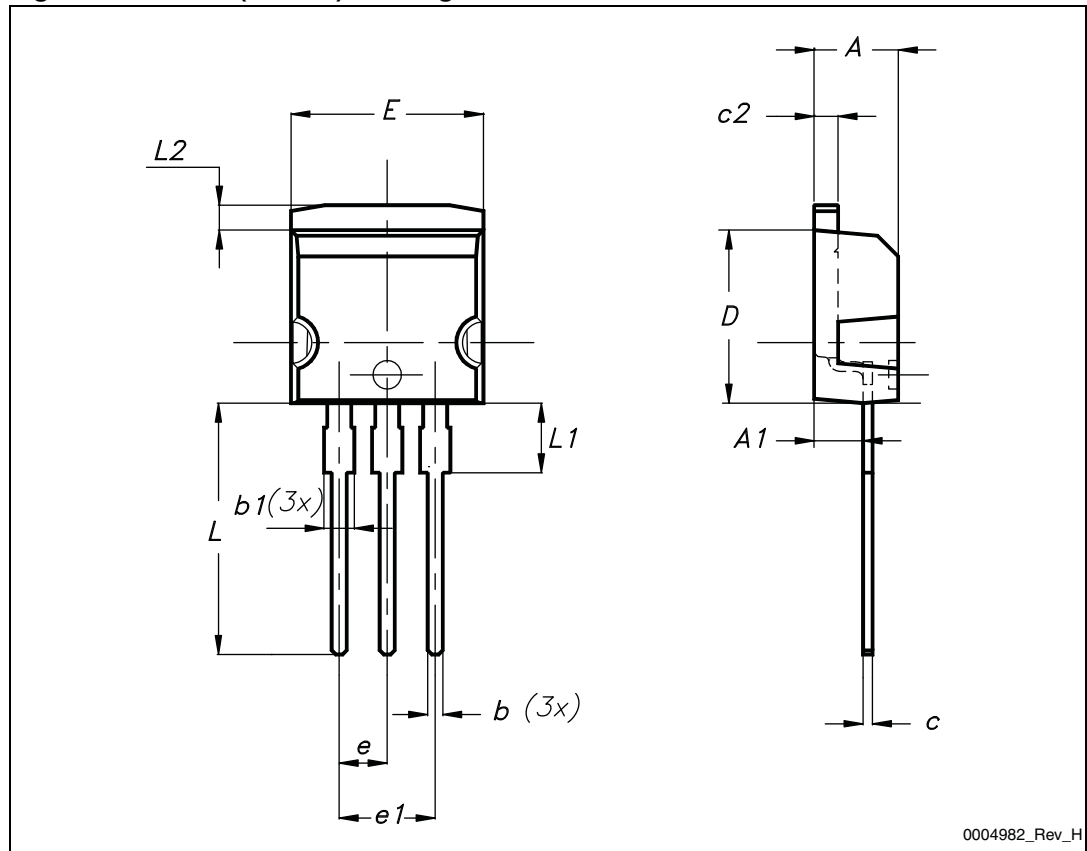


7012510\_Rev\_K\_B

Table 10. I<sup>2</sup>PAK (TO-262) mechanical data

| DIM. | mm.  |     |       |
|------|------|-----|-------|
|      | min. | typ | max.  |
| A    | 4.40 |     | 4.60  |
| A1   | 2.40 |     | 2.72  |
| b    | 0.61 |     | 0.88  |
| b1   | 1.14 |     | 1.70  |
| c    | 0.49 |     | 0.70  |
| c2   | 1.23 |     | 1.32  |
| D    | 8.95 |     | 9.35  |
| e    | 2.40 |     | 2.70  |
| e1   | 4.95 |     | 5.15  |
| E    | 10   |     | 10.40 |
| L    | 13   |     | 14    |
| L1   | 3.50 |     | 3.93  |
| L2   | 1.27 |     | 1.40  |

Figure 26. I<sup>2</sup>PAK (TO-262) drawing

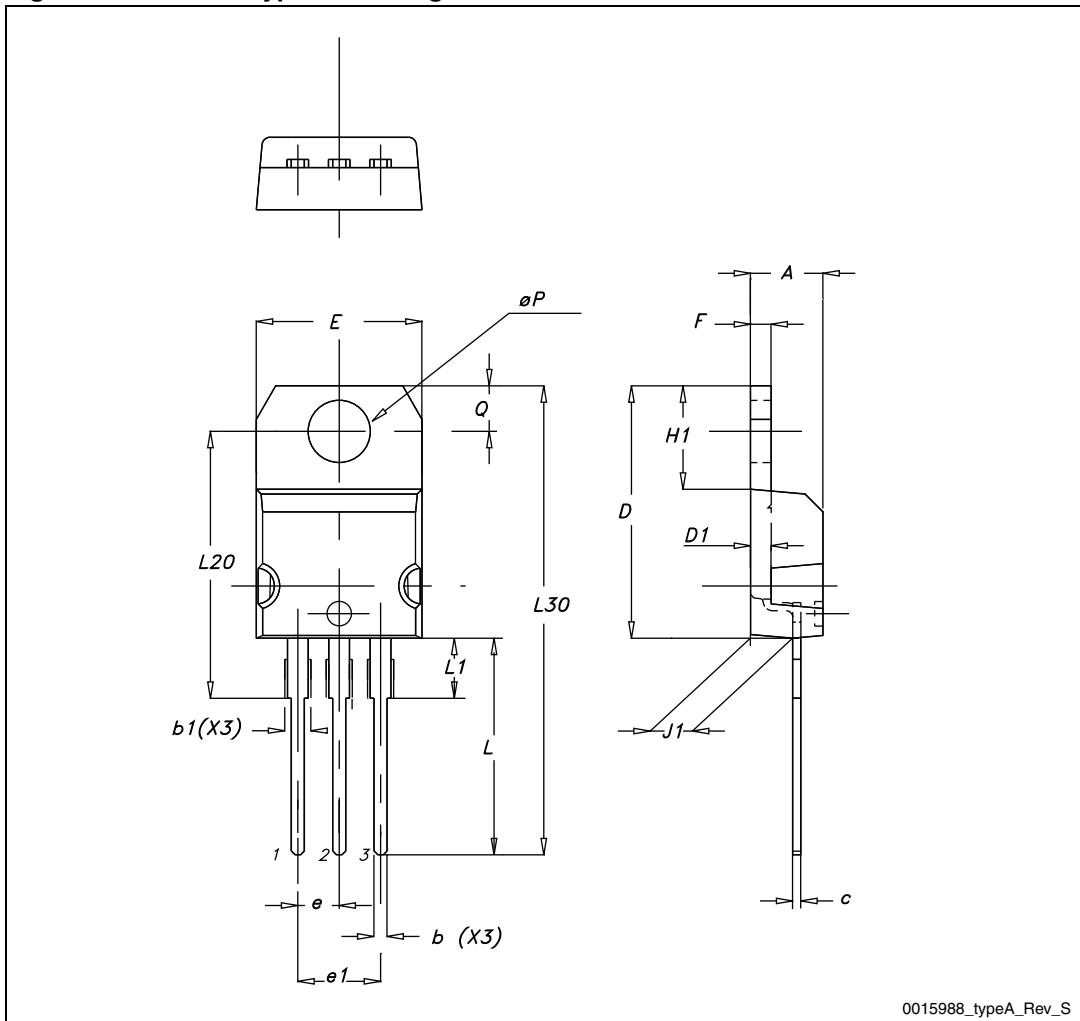


0004982\_Rev\_H

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



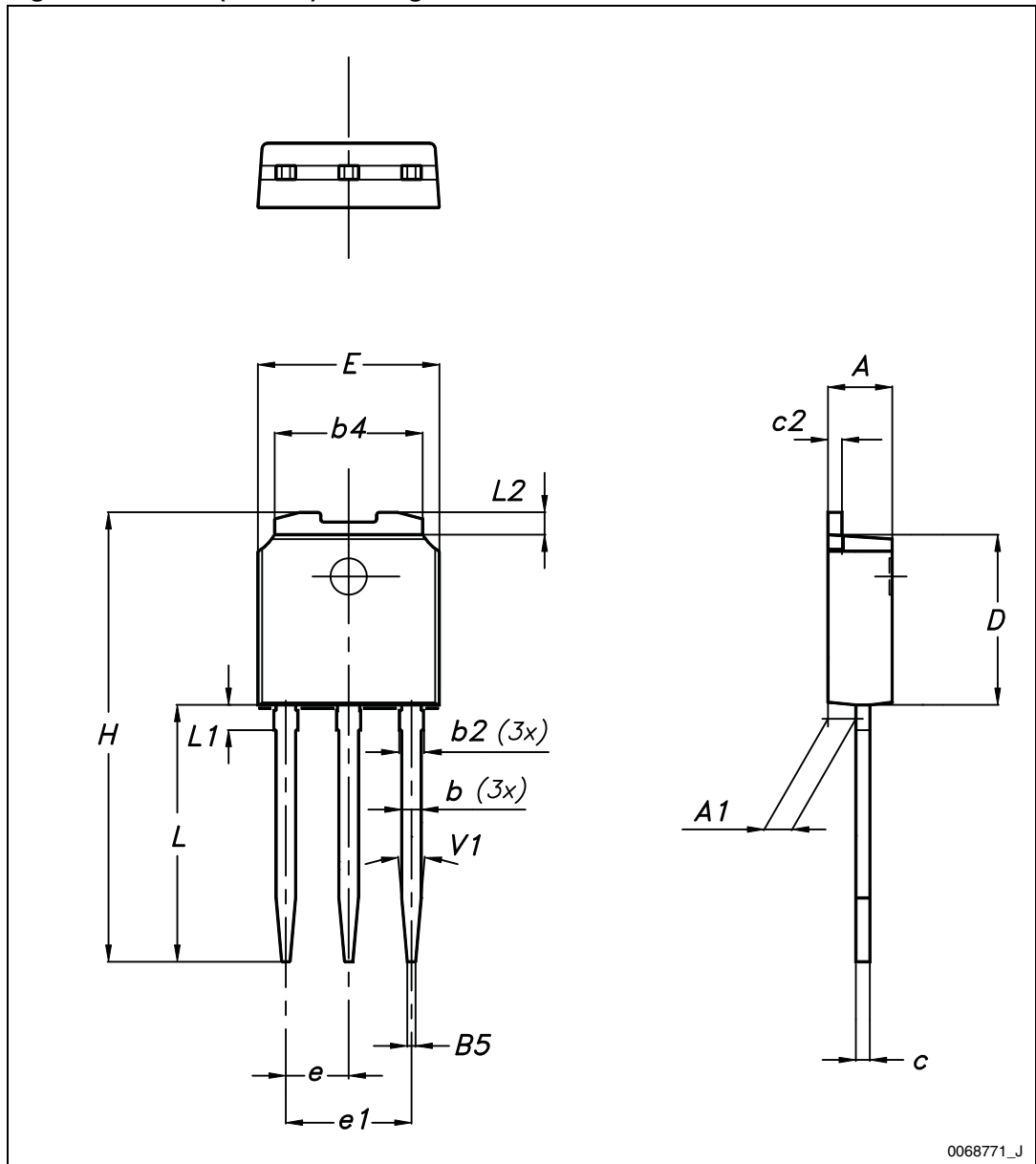
0015988\_typeA\_Rev\_S

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   |      | 0.3   |      |
| 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

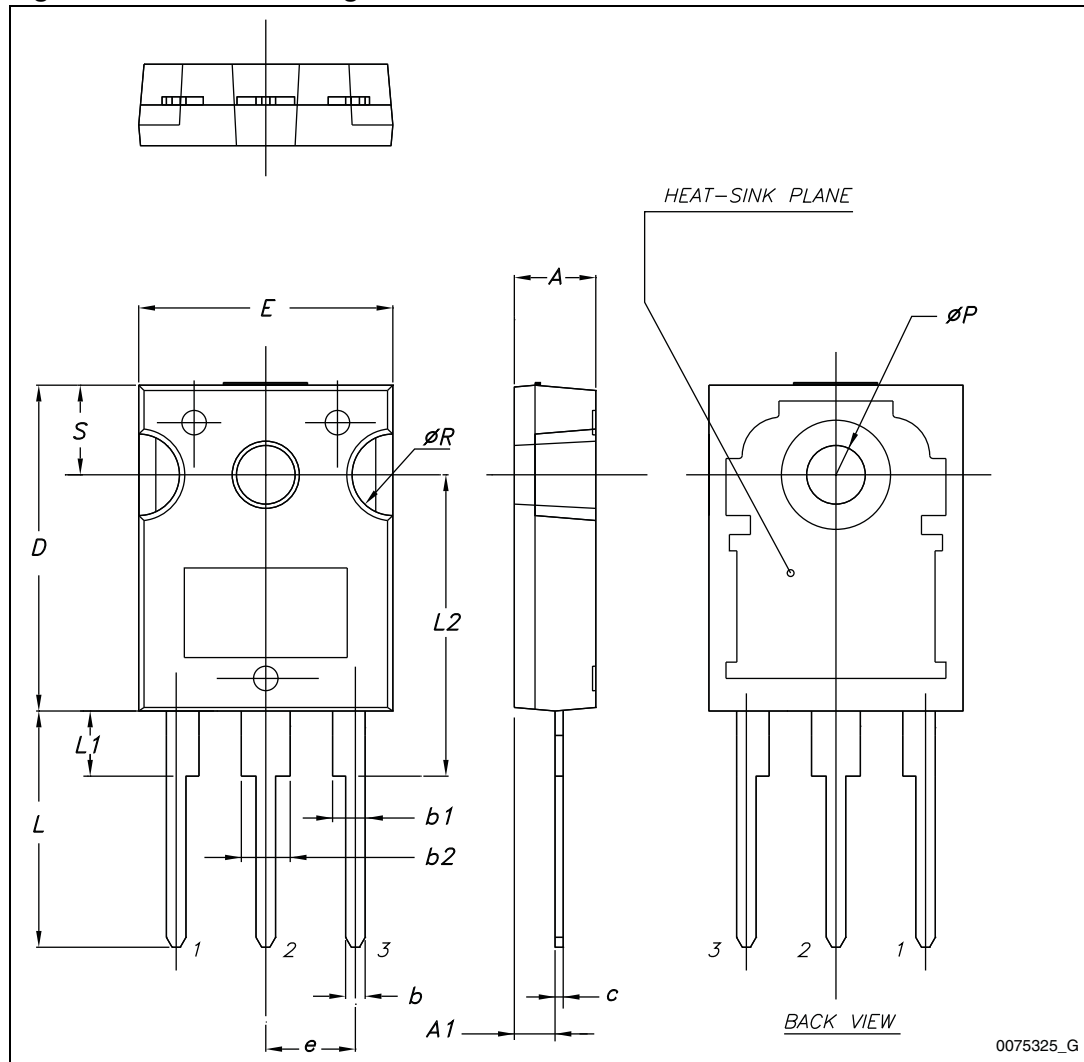


0068771\_J

Table 13. 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 29. TO-247 drawing



## 5 Revision history

**Table 14. Document revision history**

| Date        | Revision | Changes   |
|-------------|----------|---|
| 29-Feb-2009 | 1        | First release   |
| 13-Jan-2010 | 2        | – Added new package, mechanical data: TO-247<br>– Added new package, mechanical data: D <sup>2</sup> PAK  |
| 08-Nov-2010 | 3        | – Modified <a href="#">Figure 4</a><br>– Added new package, mechanical data: I <sup>2</sup> PAK   |
| 18-Jan-2012 | 4        | – Added new package, mechanical data: IPAK<br>– Minor text changes  |
| 14-Nov-2012 | 5        | The part numbers STB13NM60N and STD13NM60N have been moved to a separate datasheet.<br><a href="#">Section 4: Package mechanical data</a> has been updated. |

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