

N-channel 600 V, 0.13  $\Omega$  typ., 23 A FDmesh™ II Power MOSFETs  
in D<sup>2</sup>PAK, TO-220FP, TO-220 and TO-247 packages

Datasheet - production data

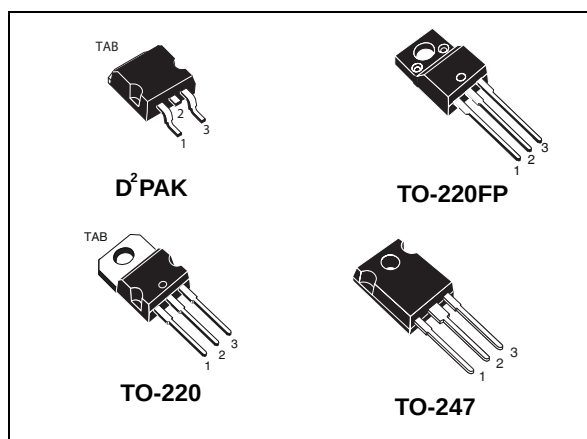
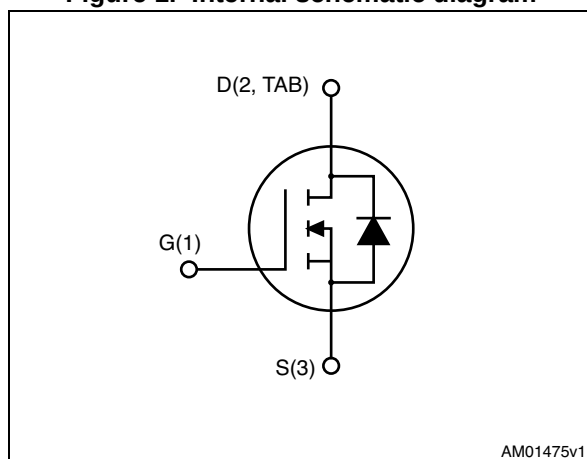


Figure 1. Internal schematic diagram



## Features

| Order codes | $V_{DS} @ T_J \text{ max.}$ | $R_{DS(on) \text{ max}}$ | $I_D$ |
|-------------|-----------------------------|--------------------------|-------|
| STB28NM60ND | 650 V                       | 0.150 $\Omega$           | 23 A  |
| STF28NM60ND |                             |                          |       |
| STP28NM60ND |                             |                          |       |
| STW28NM60ND |                             |                          |       |

- Intrinsic fast-recovery body diode
- 100% avalanche tested
- Low input capacitance and gate charge
- Low gate input resistance
- Extremely high dv/dt and avalanche capabilities

## Applications

- Switching applications

## Description

These FDmesh™ II Power MOSFETs with intrinsic fast-recovery body diode are produced using the second generation of MDmesh™ technology. Utilizing a new strip-layout vertical structure, these revolutionary devices feature extremely low on-resistance and superior switching performance. They are ideal for bridge topologies and ZVS phase-shift converters.

Table 1. Device summary

| Order codes | Marking  | Packages           | Packaging     |
|-------------|----------|--------------------|---------------|
| STB28NM60ND | 28NM60ND | D <sup>2</sup> PAK | Tape and reel |
| STF28NM60ND |          | TO-220FP           | Tube          |
| STP28NM60ND |          | TO-220             |               |
| STW28NM60ND |          | TO-247             |               |

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# 1 Electrical ratings

Table 2. Absolute maximum ratings

| Symbol                         | Parameter                                                                                                    | Value                                 |                     | Unit |
|--------------------------------|--------------------------------------------------------------------------------------------------------------|---------------------------------------|---------------------|------|
|                                |                                                                                                              | D <sup>2</sup> PAK, TO-220,<br>TO-247 | TO-220FP            |      |
| 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                                                         | 23                                    | 23 <sup>(1)</sup>   | A    |
| I <sub>D</sub>                 | Drain current (continuous) at T <sub>C</sub> = 100 °C                                                        | 14.5                                  | 14.5 <sup>(1)</sup> | A    |
| I <sub>DM</sub> <sup>(2)</sup> | Drain current (pulsed)                                                                                       | 92                                    | 92(1)               | A    |
| P <sub>TOT</sub>               | Total dissipation at T <sub>C</sub> = 25 °C                                                                  | 190                                   | 35                  | W    |
| dv/dt <sup>(3)</sup>           | Peak diode recovery voltage slope                                                                            | 40                                    |                     | 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   |

1. Limited by maximum junction temperature
2. Pulse width limited by safe operating area
3. I<sub>SD</sub> ≤ 23 A, di/dt ≤ 600 A/μs, V<sub>DD</sub> = 80% V<sub>(BR)DSS</sub>

Table 3. Thermal data

| Symbol                              | Parameter                               | D <sup>2</sup> PAK | TO-220FP | TO-220 | TO-247 | Unit |
|-------------------------------------|-----------------------------------------|--------------------|----------|--------|--------|------|
| R <sub>thj-case</sub>               | Thermal resistance junction-case max    | 0.66               | 3.6      | 0.66   |        | °C/W |
| R <sub>thj-amb</sub>                | Thermal resistance junction-ambient max |                    | 62.5     |        | 50     | °C/W |
| R <sub>thj-pcb</sub> <sup>(1)</sup> | Thermal resistance junction-pcb max     | 30                 |          |        |        | °C/W |

1. When mounted on 1inch<sup>2</sup> FR-4 board, 2 oz Cu

Table 4. Avalanche characteristics

| Symbol          | Parameter                                                                                                                  | Max value | Unit |
|-----------------|----------------------------------------------------------------------------------------------------------------------------|-----------|------|
| I <sub>AR</sub> | Avalanche current, repetitive or not-repetitive (pulse width limited by T <sub>J</sub> max)                                | 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) | 450       | mJ   |

## 2 Electrical characteristics

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

**Table 5. On/off states**

| Symbol        | Parameter                                        | Test conditions                                                           | Value |      |           | Unit          |
|---------------|--------------------------------------------------|---------------------------------------------------------------------------|-------|------|-----------|---------------|
|               |                                                  |                                                                           | Min.  | Typ. | Max.      |               |
| $V_{(BR)DSS}$ | Drain-source breakdown voltage                   | $I_D = 1\text{ mA}$ , $V_{GS} = 0$                                        | 600   |      |           | V             |
| $dv/dt^{(1)}$ | Drain source voltage slope                       | $V_{DD} = 480\text{ V}$ , $I_D = 23\text{ A}$ ,<br>$V_{GS} = 10\text{ V}$ | 45    |      |           | V/ns          |
| $I_{DSS}$     | Zero gate voltage drain current ( $V_{GS} = 0$ ) | $V_{DS} = 600\text{ V}$                                                   |       |      | 1         | $\mu\text{A}$ |
|               |                                                  | $V_{DS} = 600\text{ V}$ , $T_C = 125\text{ }^{\circ}\text{C}$             |       |      | 100       | $\mu\text{A}$ |
| $I_{GSS}$     | Gate-body leakage current ( $V_{DS} = 0$ )       | $V_{GS} = \pm 20\text{ V}$                                                |       |      | $\pm 100$ | nA            |
| $V_{GS(th)}$  | Gate threshold voltage                           | $V_{DS} = V_{GS}$ , $I_D = 250\text{ }\mu\text{A}$                        | 3     | 4    | 5         | V             |
| $R_{DS(on)}$  | Static drain-source on resistance                | $V_{GS} = 10\text{ V}$ , $I_D = 11.5\text{ A}$                            |       | 0.13 | 0.15      | $\Omega$      |

1. Characteristic value at turn off on inductive load.

**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>$V_{GS} = 0$                                                                               | -    | 2090 | -    | pF       |
| $C_{oss}$                  | Output capacitance            |                                                                                                                                              | -    | 90   | -    | pF       |
| $C_{rss}$                  | Reverse transfer capacitance  |                                                                                                                                              | -    | 5.5  | -    | pF       |
| $C_{oss\text{ eq.}}^{(1)}$ | Equivalent output capacitance | $V_{GS} = 0$ , $V_{DS} = 0\text{ to }480\text{ V}$                                                                                           | -    | 312  | -    | pF       |
| $t_{d(on)}$                | Turn-on delay time            | $V_{DD} = 300\text{ V}$ , $I_D = 11.5\text{ A}$<br>$R_G = 4.7\text{ }\Omega$ , $V_{GS} = 10\text{ V}$<br>(see Figure 18),<br>(see Figure 20) | -    | 23.5 | -    | ns       |
| $t_r$                      | Rise time                     |                                                                                                                                              | -    | 21.5 | -    | ns       |
| $t_{d(off)}$               | Turn-off delay time           |                                                                                                                                              | -    | 92   | -    | ns       |
| $t_f$                      | Fall time                     |                                                                                                                                              | -    | 27   | -    | ns       |
| $Q_g$                      | Total gate charge             | $V_{DD} = 480\text{ V}$ , $I_D = 23\text{ A}$ ,<br>$V_{GS} = 10\text{ V}$ ,<br>(see Figure 10)                                               | -    | 62.5 | -    | nC       |
| $Q_{gs}$                   | Gate-source charge            |                                                                                                                                              | -    | 11   | -    | nC       |
| $Q_{gd}$                   | Gate-drain charge             |                                                                                                                                              | -    | 38   | -    | nC       |
| $R_g$                      | Gate input resistance         | $f = 1\text{ MHz}$ ,<br>test signal level = 20 mV,<br>$I_D = 0$                                                                              | -    | 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%  $V_{DSS}$

Table 7. Source drain diode

| Symbol          | Parameter                     | Test conditions                                                                                                                                 | Min. | Typ. | Max. | Unit |
|-----------------|-------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|------|------|------|------|
| $I_{SD}$        | Source-drain current          |                                                                                                                                                 | -    |      | 23   | A    |
| $I_{SDM}^{(1)}$ | Source-drain current (pulsed) |                                                                                                                                                 | -    |      | 92   | A    |
| $V_{SD}^{(2)}$  | Forward on voltage            | $I_{SD} = 23\text{ A}$ , $V_{GS} = 0$                                                                                                           | -    |      | 1.6  | V    |
| $t_{rr}$        | Reverse recovery time         | $I_{SD} = 23\text{ A}$ , $V_{DD} = 60\text{ V}$<br>$di/dt = 100\text{ A}/\mu\text{s}$<br>(see Figure 17)                                        | -    | 170  |      | ns   |
| $Q_{rr}$        | Reverse recovery charge       |                                                                                                                                                 | -    | 1160 |      | nC   |
| $I_{RRM}$       | Reverse recovery current      |                                                                                                                                                 | -    | 14   |      | A    |
| $t_{rr}$        | Reverse recovery time         | $I_{SD} = 23\text{ A}$ , $V_{DD} = 60\text{ V}$<br>$di/dt = 100\text{ A}/\mu\text{s}$ ,<br>$T_J = 150\text{ }^\circ\text{C}$<br>(see Figure 17) | -    | 237  |      | ns   |
| $Q_{rr}$        | Reverse recovery charge       |                                                                                                                                                 | -    | 2090 |      | nC   |
| $I_{RRM}$       | Reverse recovery current      |                                                                                                                                                 | -    | 18   |      | 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 D<sup>2</sup>PAK and TO-220

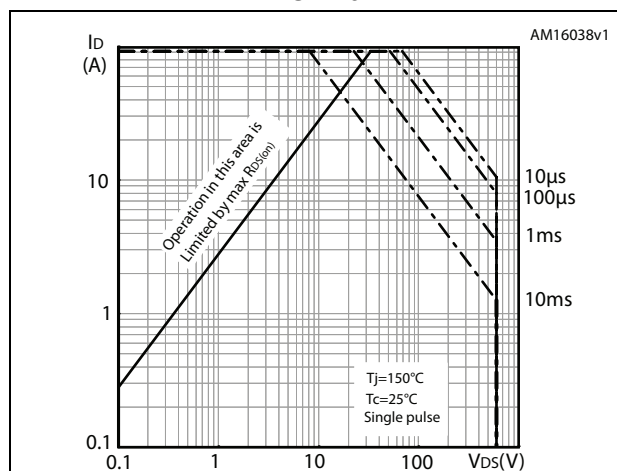


Figure 3. Thermal impedance for D<sup>2</sup>PAK and TO-220

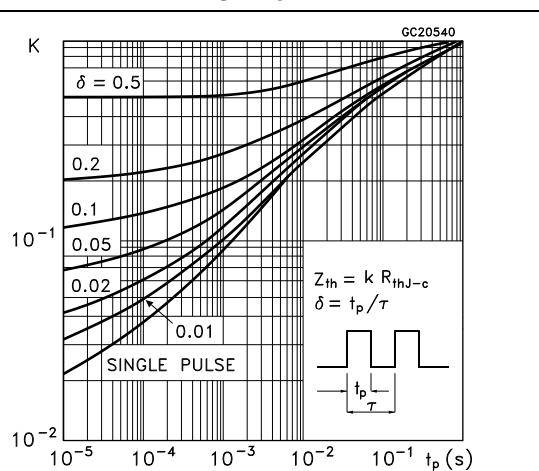


Figure 4. Safe operating area for TO-220FP

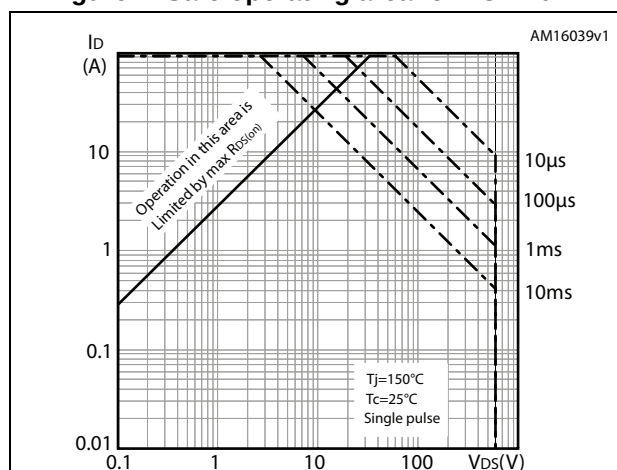


Figure 5. Thermal impedance for TO-220FP

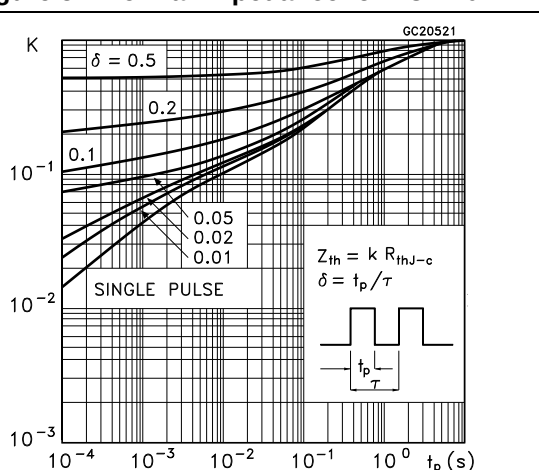


Figure 6. Safe operating area for TO-247

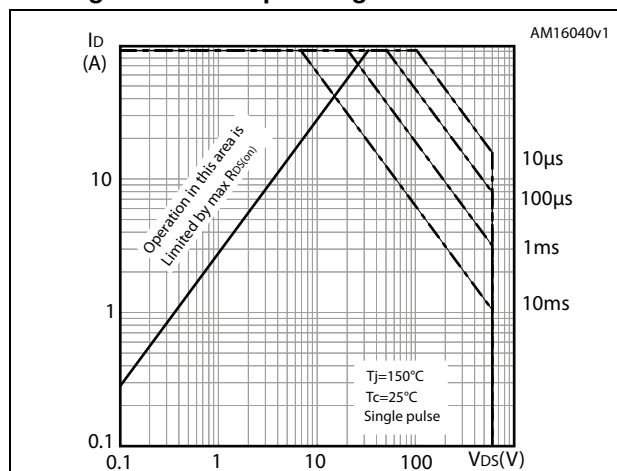


Figure 7. Thermal impedance for TO-247

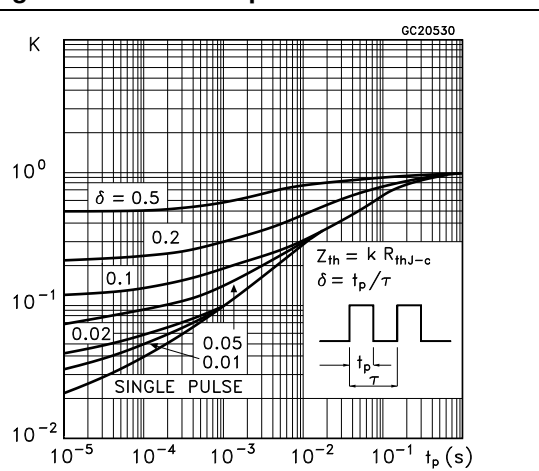


Figure 8. Output characteristics

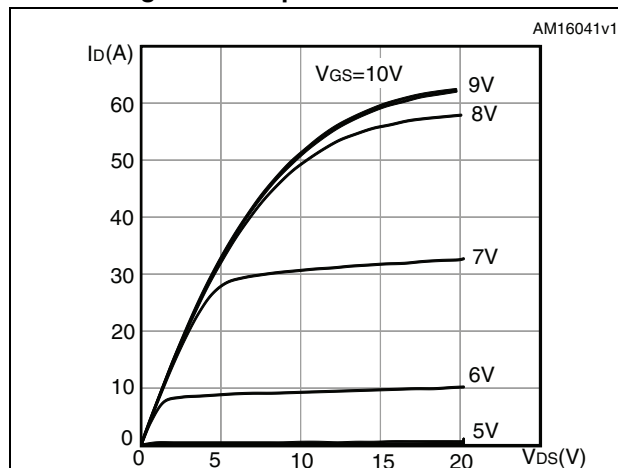


Figure 9. Transfer characteristics

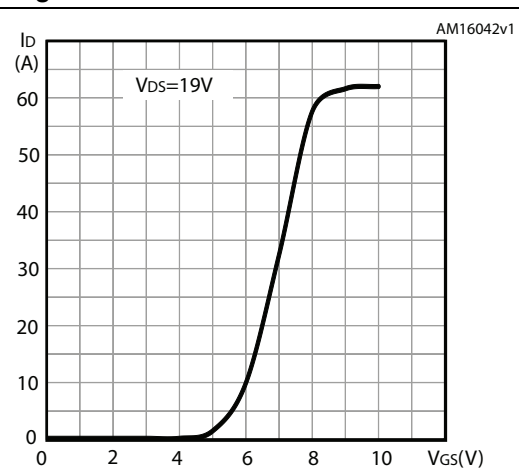


Figure 10. Gate charge vs gate-source voltage

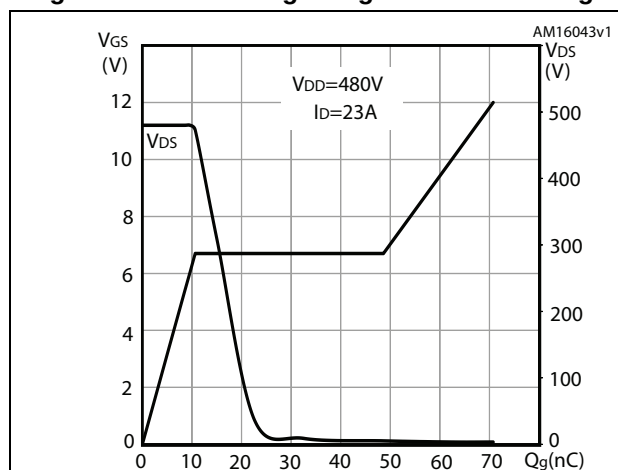


Figure 11. Static drain-source on-resistance

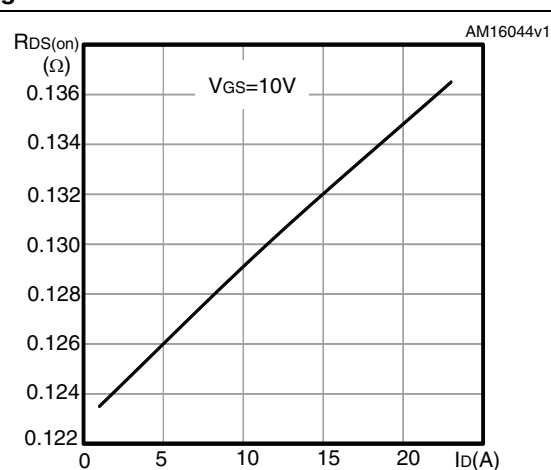


Figure 12. Capacitance variations

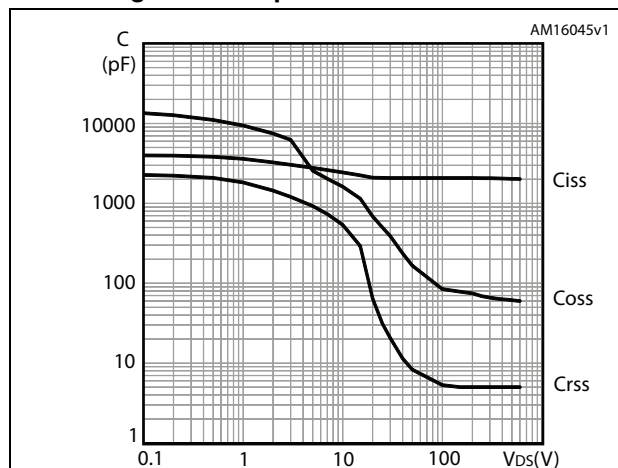


Figure 13. Output capacitance stored energy

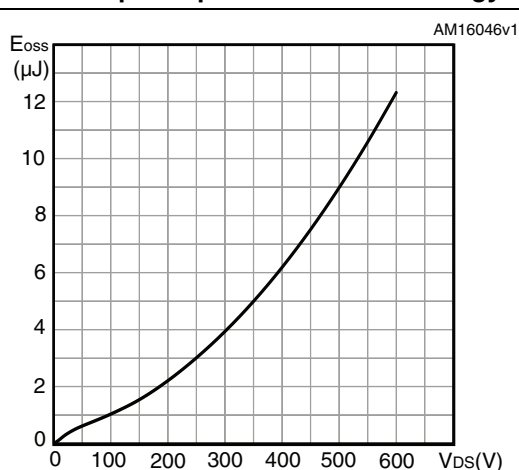


Figure 14. Normalized gate threshold voltage vs temperature

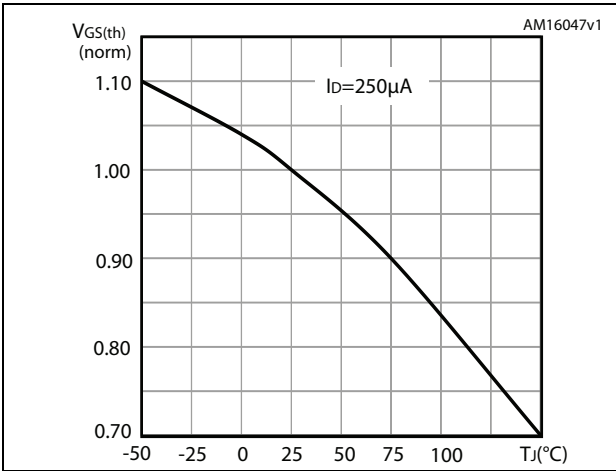


Figure 15. Normalized on-resistance vs temperature

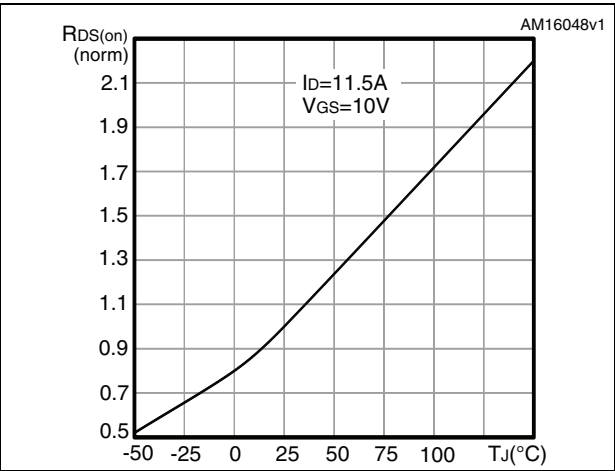


Figure 16. Source-drain diode forward characteristics

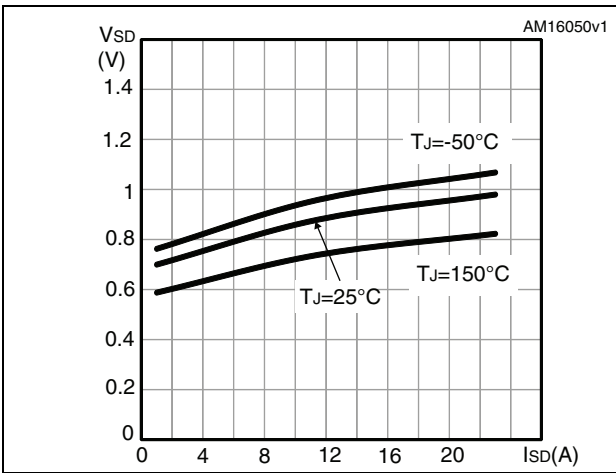
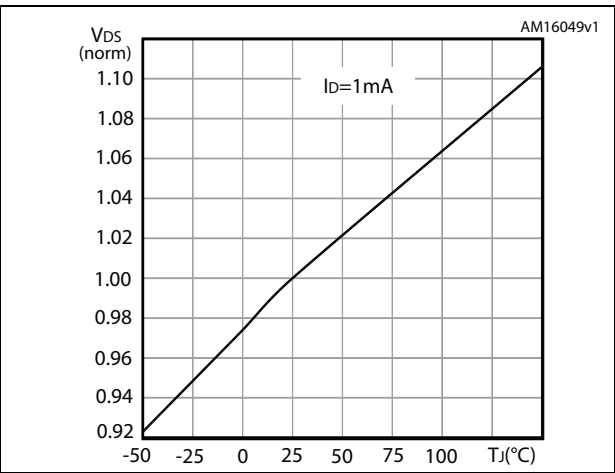


Figure 17. Normalized  $V_{DS}$  vs temperature



### 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.

## 4.1 D<sup>2</sup>PAK, STB28NM60ND

Figure 24. D<sup>2</sup>PAK (TO-263) drawing

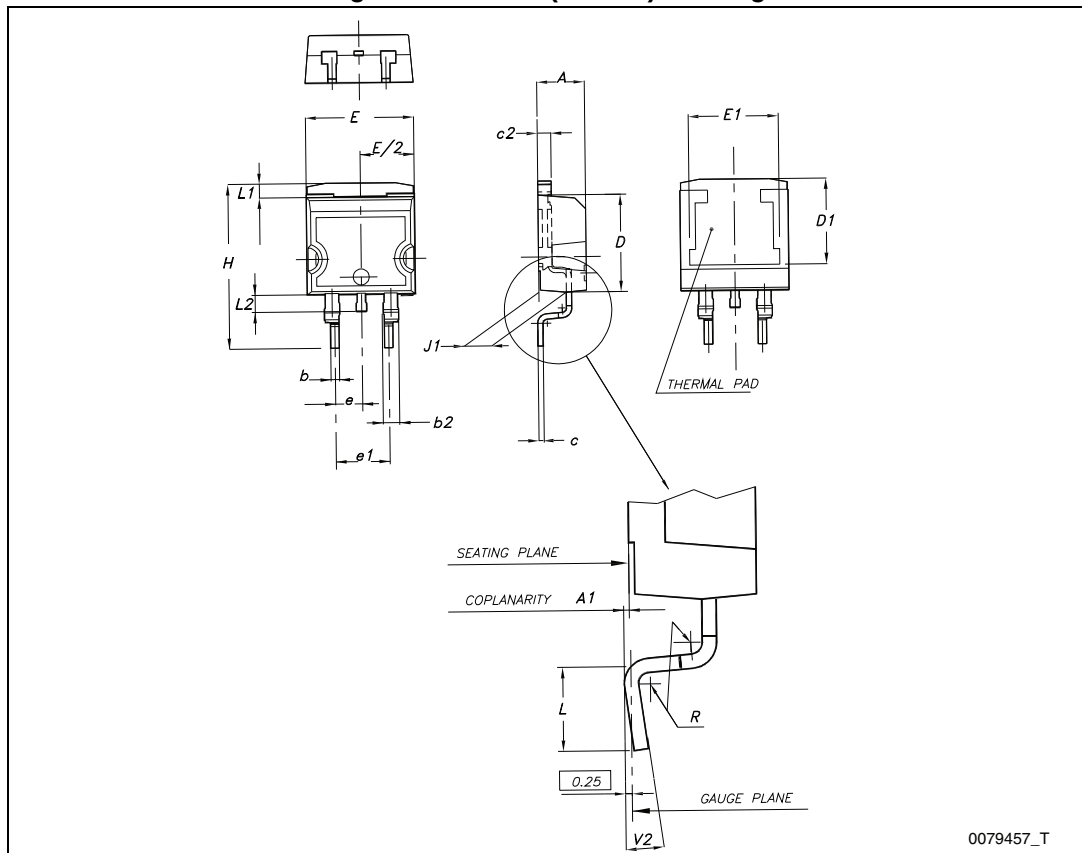
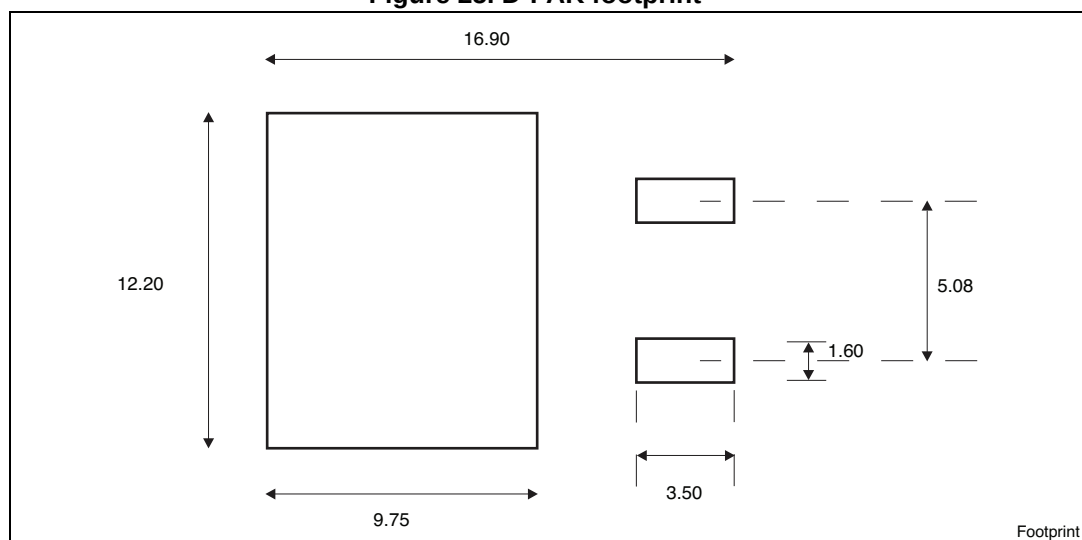


Table 8. D<sup>2</sup>PAK (TO-263) mechanical data

| Dim. | mm   |      |       |
|------|------|------|-------|
|      | Min. | Typ. | Max.  |
| A    | 4.40 |      | 4.60  |
| A1   | 0.03 |      | 0.23  |
| b    | 0.70 |      | 0.93  |
| b2   | 1.14 |      | 1.70  |
| c    | 0.45 |      | 0.60  |
| c2   | 1.23 |      | 1.36  |
| D    | 8.95 |      | 9.35  |
| D1   | 7.50 |      |       |
| E    | 10   |      | 10.40 |
| E1   | 8.50 |      |       |
| e    |      | 2.54 |       |
| e1   | 4.88 |      | 5.28  |
| H    | 15   |      | 15.85 |
| J1   | 2.49 |      | 2.69  |
| L    | 2.29 |      | 2.79  |
| L1   | 1.27 |      | 1.40  |
| L2   | 1.30 |      | 1.75  |
| R    |      | 0.4  |       |
| V2   | 0°   |      | 8°    |

Figure 25. D<sup>2</sup>PAK footprint<sup>(a)</sup>

a. All dimension are in millimeters



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  |

## 4.3 TO-220, STP28NM60ND

Figure 27. TO-220 type A drawing

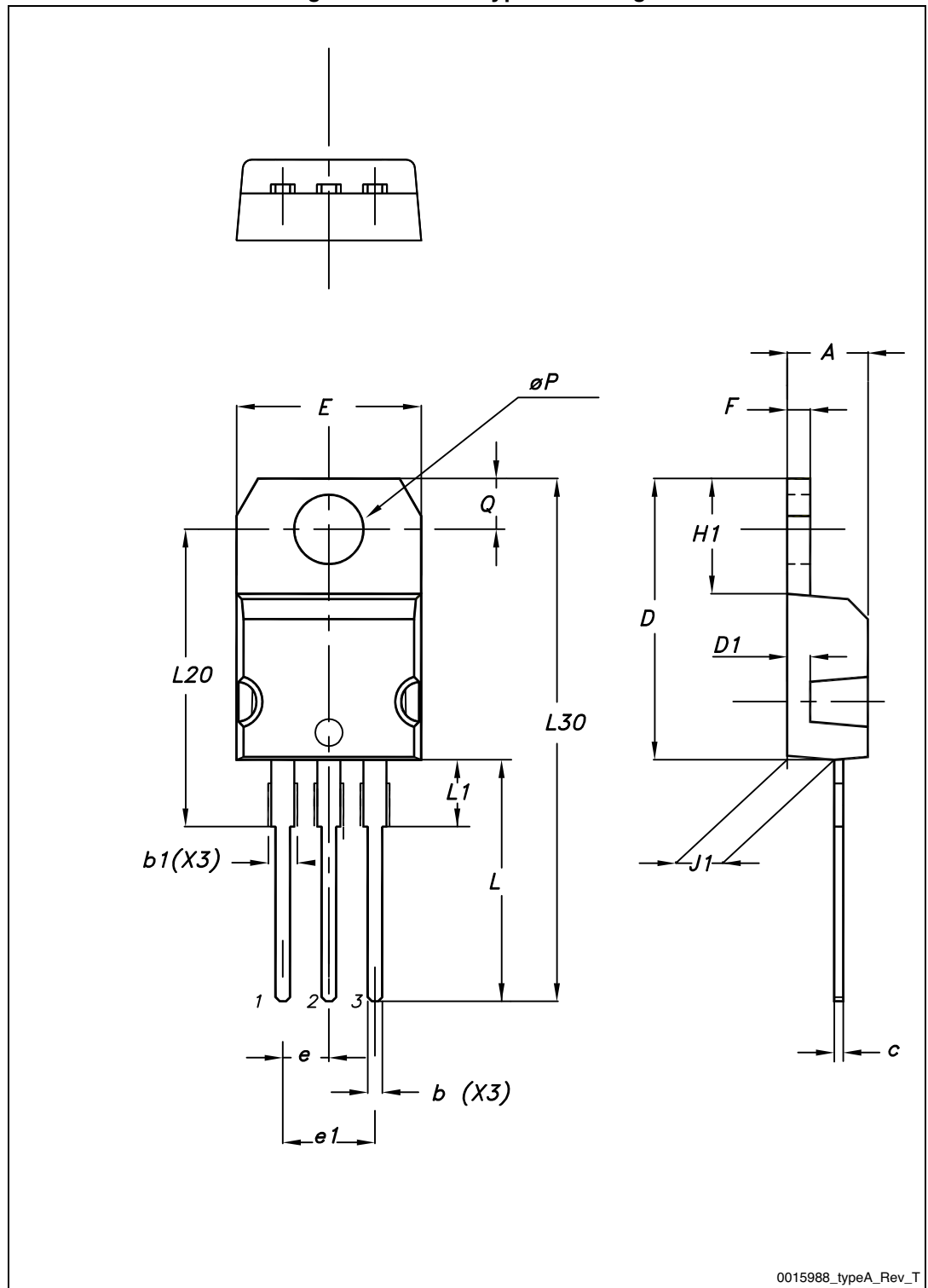


Table 10. TO-220 type A mechanical data

| 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  |

## 4.4 TO-247, STW28NM60ND

Figure 28. TO-247 drawing

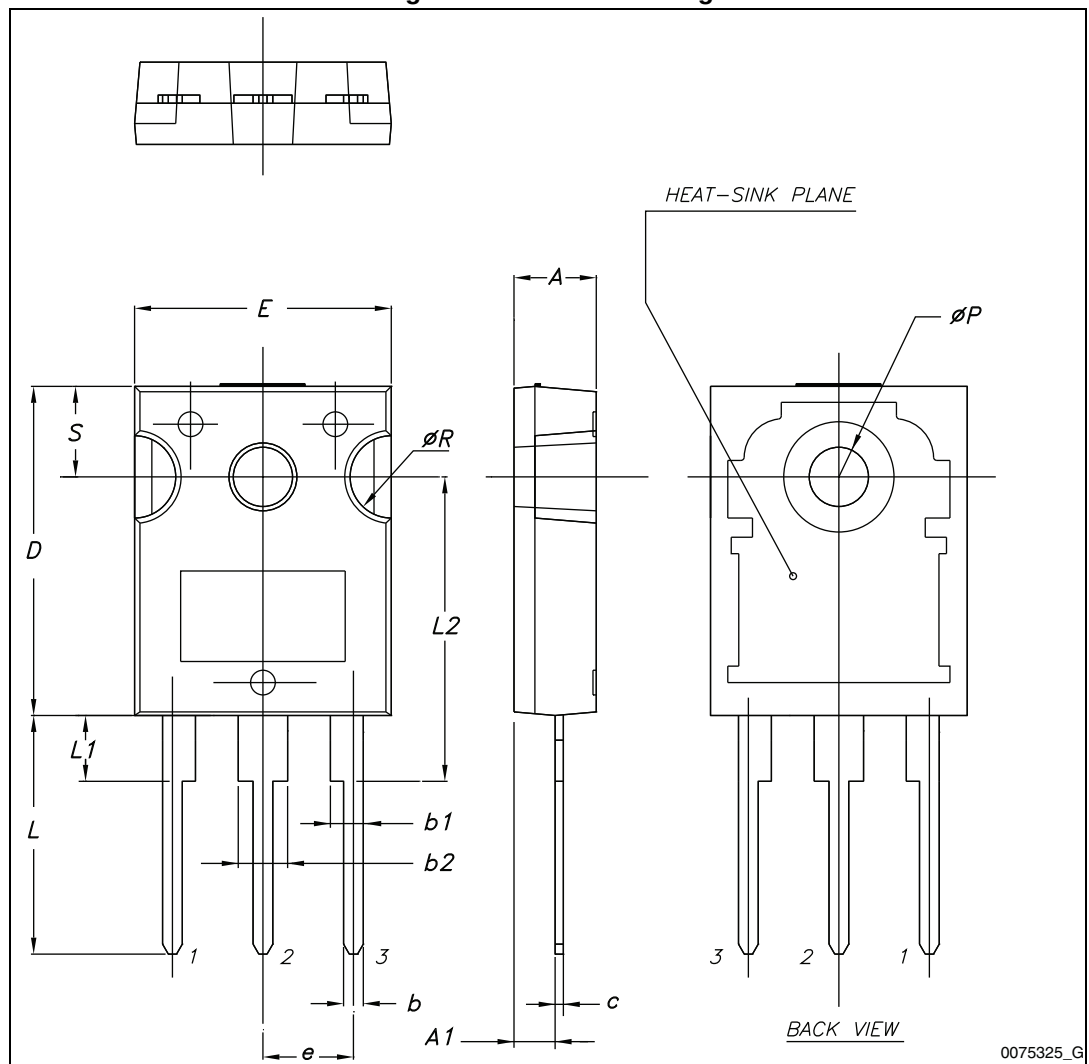


Table 11. TO-247 mechanical data

| 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  |

## 5 Packing mechanical data

Figure 29. Tape

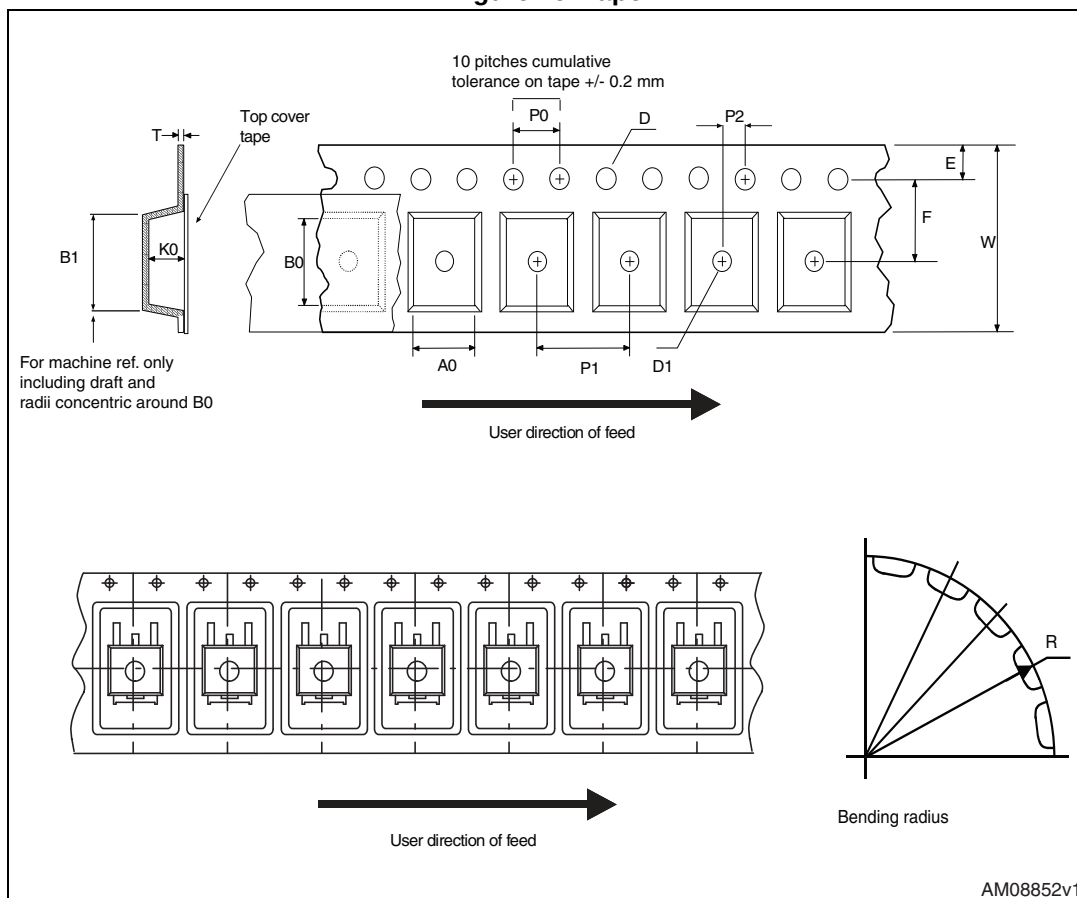
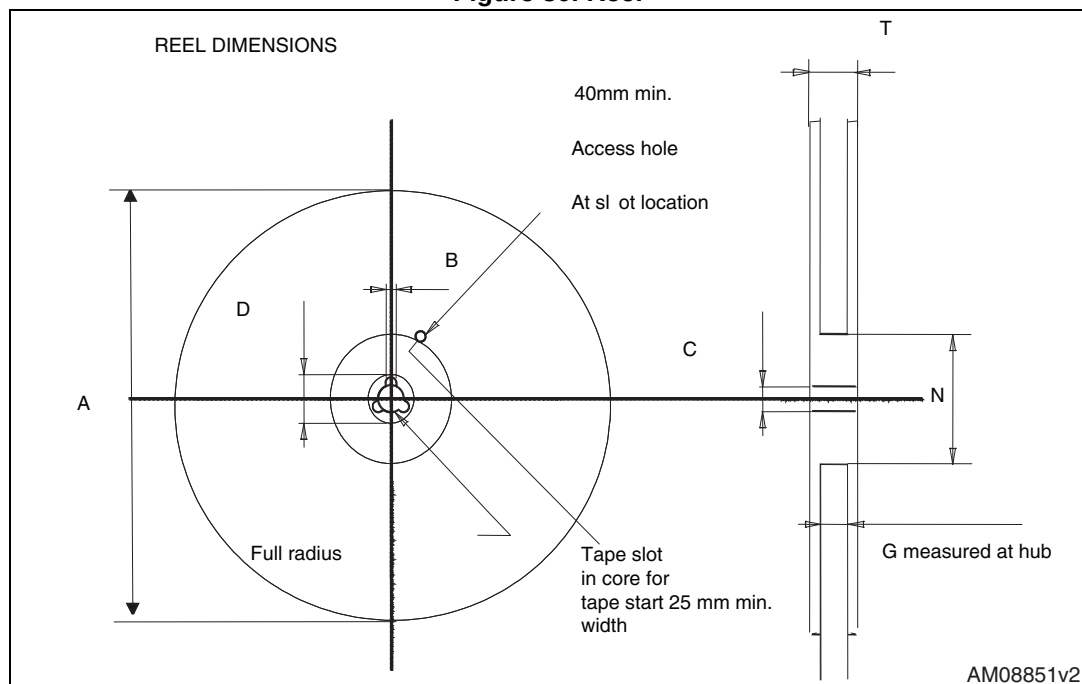


Table 12. D<sup>2</sup>PAK (TO-263) tape and reel mechanical data

| Tape |      |      | Reel     |      |      |
|------|------|------|----------|------|------|
| Dim. | mm   |      | Dim.     | mm   |      |
|      | Min. | Max. |          | Min. | Max. |
| A0   | 10.5 | 10.7 | A        |      | 330  |
| B0   | 15.7 | 15.9 | B        | 1.5  |      |
| D    | 1.5  | 1.6  | C        | 12.8 | 13.2 |
| D1   | 1.59 | 1.61 | D        | 20.2 |      |
| E    | 1.65 | 1.85 | G        | 24.4 | 26.4 |
| F    | 11.4 | 11.6 | N        | 100  |      |
| K0   | 4.8  | 5.0  | T        |      | 30.4 |
| P0   | 3.9  | 4.1  |          |      |      |
| P1   | 11.9 | 12.1 | Base qty |      | 1000 |
| P2   | 1.9  | 2.1  | Bulk qty |      | 1000 |
| R    | 50   |      |          |      |      |
| T    | 0.25 | 0.35 |          |      |      |
| W    | 23.7 | 24.3 |          |      |      |

Figure 30. Reel



## 6 Revision history

**Table 13. Document revision history**

| Date        | Revision | Changes                                                                                                                                                                                                                                                                                                                                                                                    |
|-------------|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 15-Apr-2013 | 1        | First release.                                                                                                                                                                                                                                                                                                                                                                             |
| 25-Nov-2013 | 2        | <ul style="list-style-type: none"><li>– Document status changed from preliminary to production data</li><li>– Modified: typical values in <a href="#">Table 6</a> and <a href="#">7</a></li><li>– Added: <a href="#">Section 2.1: Electrical characteristics (curves)</a></li><li>– Updated: <a href="#">Table 10</a> and <a href="#">Figure 27</a></li><li>– Minor text changes</li></ul> |
| 05-May-2014 | 3        | <ul style="list-style-type: none"><li>– Modified: <math>E_{AS}</math> value in <a href="#">Table 4</a></li><li>– Minor text changes</li></ul>                                                                                                                                                                                                                                              |

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