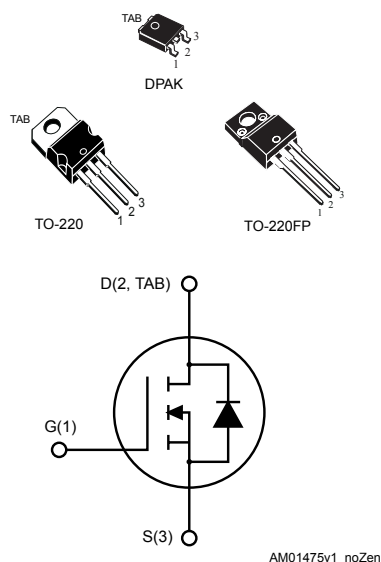


## N-channel 600 V, 0.63 $\Omega$ typ., 6.5 A MDmesh™ II Power MOSFETs in DPAK, TO-220FP and TO-220 packages



### Features

| Order code | V <sub>DS</sub> | R <sub>DS(on)</sub> max. | I <sub>D</sub> | Package  |
|------------|-----------------|--------------------------|----------------|----------|
| STD9NM60N  | 600 V           | 0.745 $\Omega$           | 6.5 A          | DPAK     |
| STF9NM60N  |                 |                          |                | TO-220FP |
| STP9NM60N  |                 |                          |                | TO-220   |

- 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. 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.

#### Product status link

[STD9NM60N](#)
[STF9NM60N](#)
[STP9NM60N](#)

# 1 Electrical ratings

**Table 1. Absolute maximum ratings**

| Symbol                  | Parameter                                                                                                                               | Value        |                    | Unit               |
|-------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|--------------|--------------------|--------------------|
|                         |                                                                                                                                         | DPAK, TO-220 | TO-220FP           |                    |
| $V_{DS}$                | Drain-source voltage                                                                                                                    | 600          |                    | V                  |
| $V_{GS}$                | Gate-source voltage                                                                                                                     | $\pm 25$     |                    | V                  |
| $I_D$                   | Drain current (continuous) at $T_C = 25\text{ }^{\circ}\text{C}$                                                                        | 6.5          | 6.5 <sup>(1)</sup> | A                  |
| $I_D$                   | Drain current (continuous) at $T_C = 100\text{ }^{\circ}\text{C}$                                                                       | 4            | 4 <sup>(1)</sup>   | A                  |
| $I_{DM}$ <sup>(2)</sup> | Drain current (pulsed)                                                                                                                  | 26           | 26 <sup>(1)</sup>  | A                  |
| $P_{TOT}$               | Total dissipation at $T_C = 25\text{ }^{\circ}\text{C}$                                                                                 | 70           | 25                 | W                  |
| $dv/dt$ <sup>(3)</sup>  | Peak diode recovery voltage slope                                                                                                       | 15           |                    | V/ns               |
| $V_{ISO}$               | Insulation withstand voltage (RMS) from all three leads to external heat sink ( $t = 1\text{ s}$ ; $T_C = 25\text{ }^{\circ}\text{C}$ ) |              | 2.5                | kV                 |
| $T_j$                   | Operating junction temperature range                                                                                                    | -55 to 150   |                    | $^{\circ}\text{C}$ |
| $T_{stg}$               | Storage temperature range                                                                                                               |              |                    |                    |

1. Limited by maximum junction temperature.
2. Pulse width limited by safe operating area.
3.  $I_{SD} \leq 6.5\text{ A}$ ,  $di/dt \leq 400\text{ A}/\mu\text{s}$ ,  $V_{DD} = 80\% V_{(BR)DSS}$ .

**Table 2. Thermal data**

| Symbol                              | Parameter                           | Value |        |          | Unit |
|-------------------------------------|-------------------------------------|-------|--------|----------|------|
|                                     |                                     | DPAK  | TO-220 | TO-220FP |      |
| R <sub>thj-case</sub>               | Thermal resistance junction-case    | 1.79  |        | 5        | °C/W |
| R <sub>thj-amb</sub>                | Thermal resistance junction-ambient |       | 62.5   |          |      |
| R <sub>thj-pcb</sub> <sup>(1)</sup> | Thermal resistance junction-pcb     | 50    |        |          |      |

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

**Table 3. Avalanche characteristics**

| Symbol   | Parameter                                                                                                              | Value | Unit |
|----------|------------------------------------------------------------------------------------------------------------------------|-------|------|
| $I_{AR}$ | Avalanche current, repetitive or not-repetitive (pulse width limited by $T_j$ Max)                                     | 2.5   | A    |
| $E_{AS}$ | Single pulse avalanche energy (starting $T_j = 25\text{ }^{\circ}\text{C}$ , $I_D = I_{AR}$ , $V_{DD} = 50\text{ V}$ ) | 115   | mJ   |

## 2 Electrical characteristics

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

**Table 4. On/off states**

| Symbol        | Parameter                         | Test conditions                                                                                      | Min. | Typ. | Max.  | Unit          |
|---------------|-----------------------------------|------------------------------------------------------------------------------------------------------|------|------|-------|---------------|
| $V_{(BR)DSS}$ | Drain-source breakdown voltage    | $I_D = 1\text{ mA}$ , $V_{GS} = 0\text{ V}$                                                          | 600  |      |       | V             |
| $I_{DSS}$     | Zero gate voltage drain current   | $V_{GS} = 0\text{ V}$ , $V_{DS} = 600\text{ V}$                                                      |      |      | 1     | $\mu\text{A}$ |
|               |                                   | $V_{GS} = 0\text{ V}$ , $V_{DS} = 600\text{ V}$ , $T_C = 125\text{ }^{\circ}\text{C}$ <sup>(1)</sup> |      |      | 100   | $\mu\text{A}$ |
| $I_{GSS}$     | Gate body leakage current         | $V_{DS} = 0\text{ V}$ , $V_{GS} = \pm 20\text{ V}$                                                   |      |      | 100   | nA            |
| $V_{GS(th)}$  | 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 | $V_{GS} = 10\text{ V}$ , $I_D = 3.25\text{ A}$                                                       |      | 0.63 | 0.745 | $\Omega$      |

1. Defined by design, not subject to production test.

**Table 5. Dynamic**

| Symbol                     | Parameter                     | Test conditions                                                                                                                               | Min. | Typ. | Max. | Unit          |
|----------------------------|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|------|------|------|---------------|
| $C_{iss}$                  | Input capacitance             | $V_{DS} = 50\text{ V}$ , $f = 1\text{ MHz}$ , $V_{GS} = 0\text{ V}$                                                                           | -    | 452  | -    | $\mu\text{F}$ |
| $C_{oss}$                  | Output capacitance            |                                                                                                                                               |      | 30   |      |               |
| $C_{rss}$                  | Reverse transfer capacitance  |                                                                                                                                               |      | 1.45 |      |               |
| $C_{oss\text{ eq.}}^{(1)}$ | Equivalent output capacitance | $V_{DS} = 0\text{ to }480\text{ V}$ , $V_{GS} = 0\text{ V}$                                                                                   | -    | 79   | -    | $\mu\text{F}$ |
| $R_g$                      | Gate input resistance         | $f = 1\text{ MHz}$ , $I_D = 0\text{ A}$                                                                                                       | -    | 4.8  | -    | $\Omega$      |
| $Q_g$                      | Total gate charge             | $V_{DD} = 480\text{ V}$ , $I_D = 6.5\text{ A}$ , $V_{GS} = 0\text{ to }10\text{ V}$<br>(see Figure 17. Test circuit for gate charge behavior) | -    | 17.4 | -    | nC            |
| $Q_{gs}$                   | Gate-source charge            |                                                                                                                                               |      | 3    |      |               |
| $Q_{gd}$                   | Gate-drain charge             |                                                                                                                                               |      | 9.7  |      |               |

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 6. Switching times**

| Symbol       | Parameter           | Test conditions                                                                                                                                                                                                   | Min. | Typ. | Max. | Unit |
|--------------|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------|------|------|
| $t_{d(on)}$  | Turn-on delay time  | $V_{DD} = 480\text{ V}$ , $I_D = 6.5\text{ A}$ ,<br>$R_G = 4.7\text{ }\Omega$ , $V_{GS} = 10\text{ V}$<br>(see Figure 16. Test circuit for resistive load switching times and Figure 21. Switching time waveform) | -    | 28   | -    | ns   |
| $t_r$        | Rise time           |                                                                                                                                                                                                                   |      | 23   |      |      |
| $t_{d(off)}$ | Turn-off delay time |                                                                                                                                                                                                                   |      | 52.5 |      |      |
| $t_f$        | Fall time           |                                                                                                                                                                                                                   |      | 26.7 |      |      |

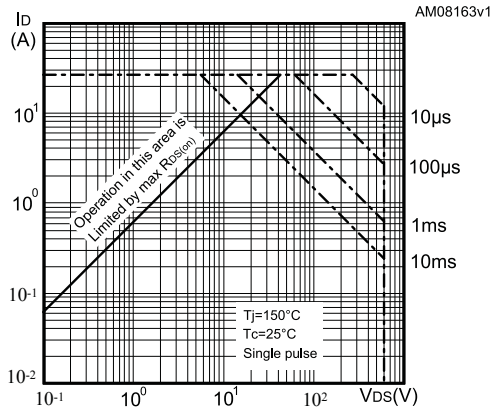
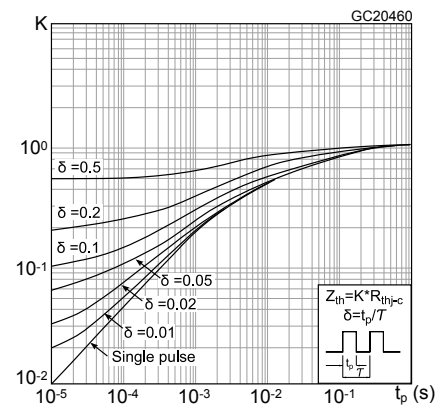
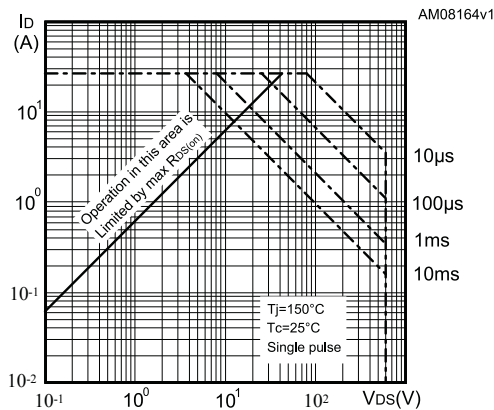
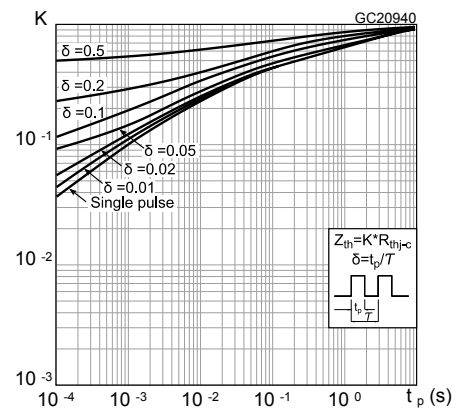
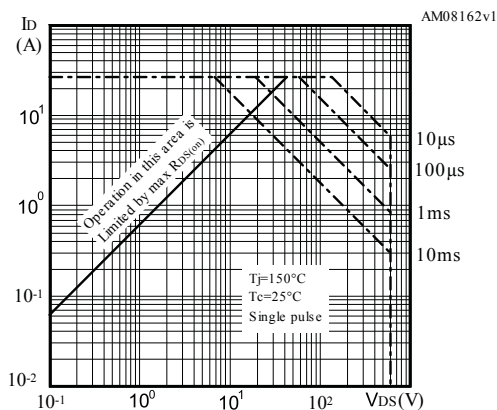
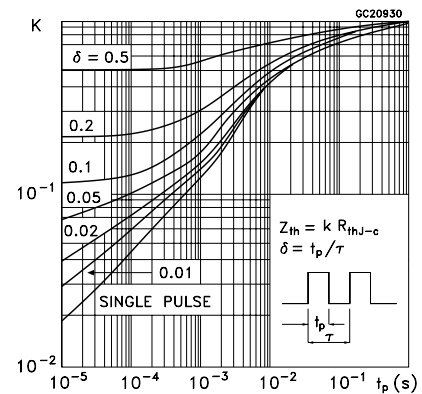
**Table 7. Source drain diode**

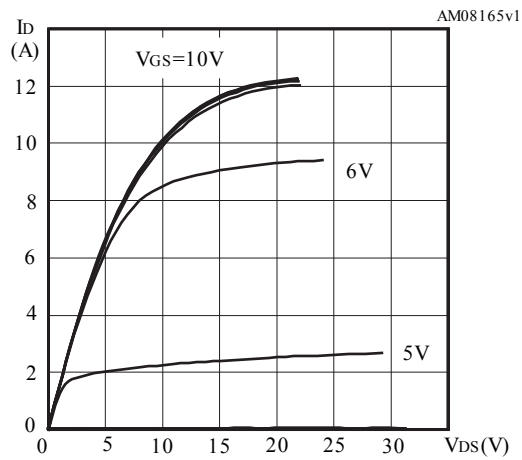
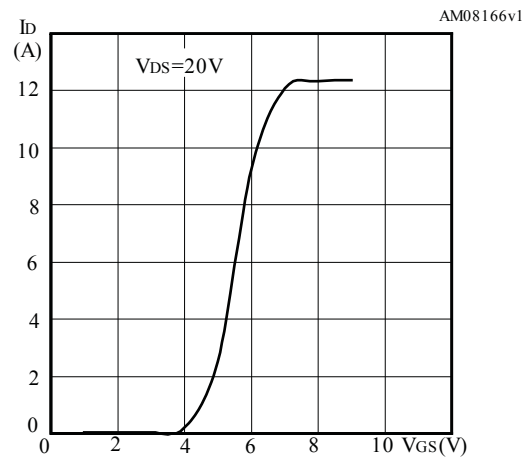
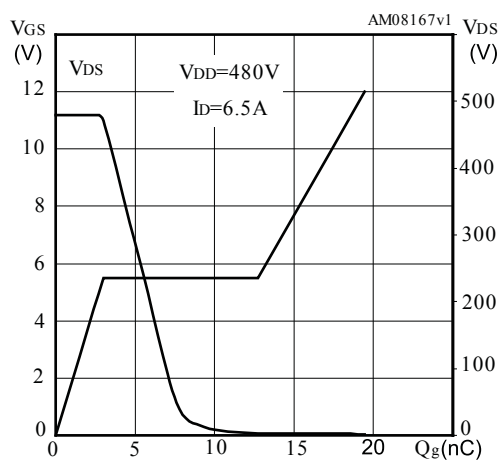
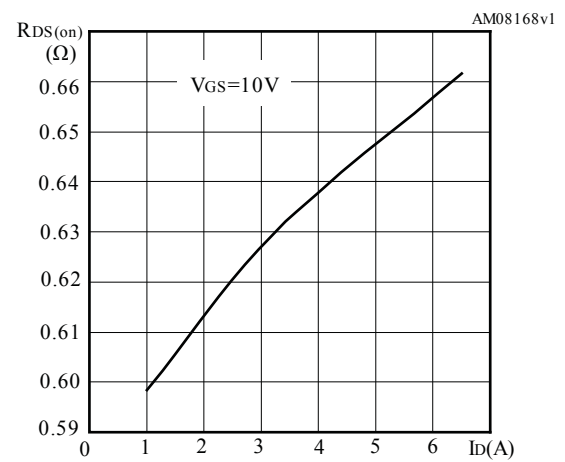
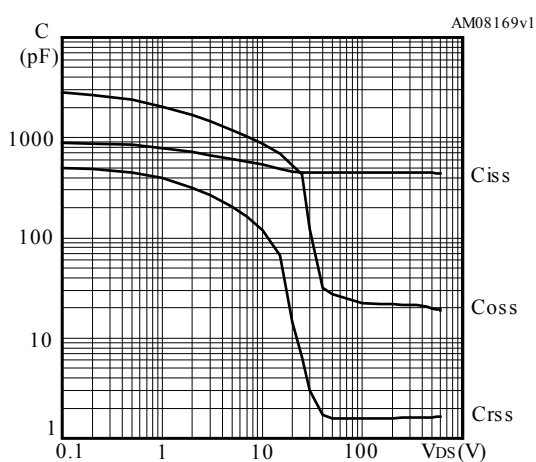
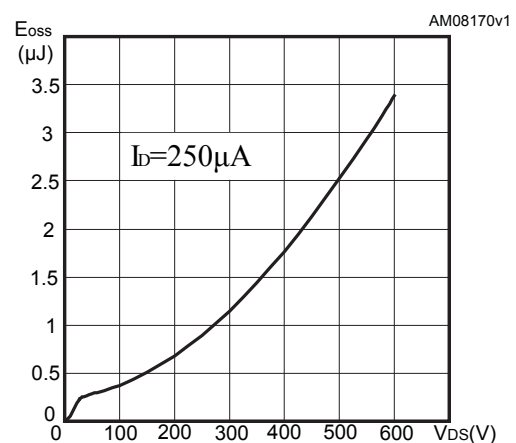
| Symbol          | Parameter                     | Test conditions                                                                                                                                                                                | Min. | Typ. | Max. | Unit          |
|-----------------|-------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------|------|---------------|
| $I_{SD}$        | Source-drain current          |                                                                                                                                                                                                | -    |      | 6.5  | A             |
| $I_{SDM}^{(1)}$ | Source-drain current (pulsed) |                                                                                                                                                                                                |      |      | 26   |               |
| $V_{SD}^{(2)}$  | Forward on voltage            | $I_{SD} = 6.5 \text{ A}$ , $V_{GS} = 0 \text{ V}$                                                                                                                                              | -    |      | 1.6  | V             |
| $t_{rr}$        | Reverse recovery time         | $I_{SD} = 6.5 \text{ A}$ , $di/dt = 100 \text{ A}/\mu\text{s}$<br>$V_{DD} = 60 \text{ V}$ (see <a href="#">Figure 18. Test circuit for inductive load switching and diode recovery times</a> ) | -    | 264  |      | ns            |
| $Q_{rr}$        | Reverse recovery charge       |                                                                                                                                                                                                |      | 1.9  |      | $\mu\text{C}$ |
| $I_{RRM}$       | Reverse recovery current      |                                                                                                                                                                                                |      | 14.6 |      | A             |
| $t_{rr}$        | Reverse recovery time         | $I_{SD} = 6.5 \text{ A}$ , $di/dt = 100 \text{ A}/\mu\text{s}$<br>$V_{DD} = 60 \text{ V}$ (see <a href="#">Figure 18. Test circuit for inductive load switching and diode recovery times</a> ) | -    | 324  |      | ns            |
| $Q_{rr}$        | Reverse recovery charge       |                                                                                                                                                                                                |      | 2.3  |      | $\mu\text{C}$ |
| $I_{RRM}$       | Reverse recovery current      |                                                                                                                                                                                                |      | 14.2 |      | A             |

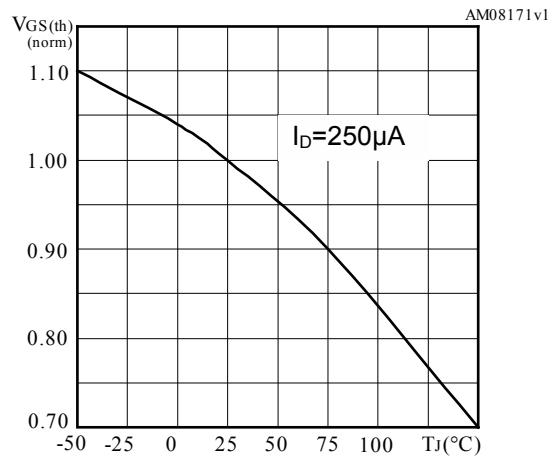
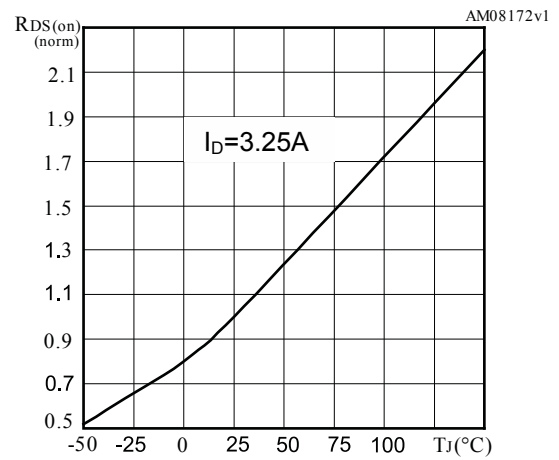
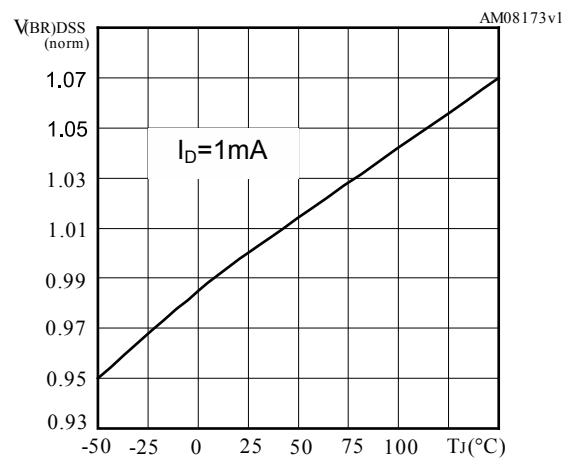
1. Pulse width limited by safe operating area.

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

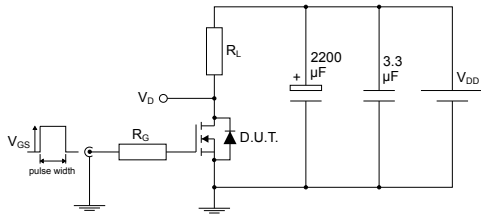
## 2.1 Electrical characteristics curves

**Figure 1. Safe operating area for DPAK**

**Figure 2. Thermal impedance for DPAK**

**Figure 3. Safe operating area for TO-220FP**

**Figure 4. Thermal impedance for TO-220FP**

**Figure 5. Safe operating area for TO-220**

**Figure 6. Thermal impedance for TO-220**


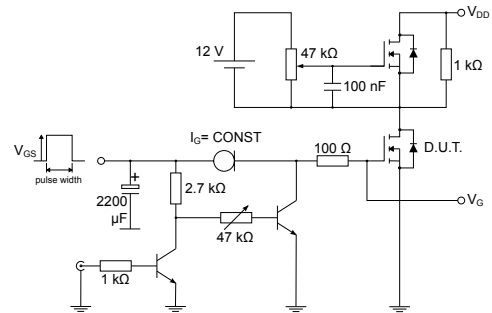
**Figure 7. Output characteristics**

**Figure 8. Transfer characteristics**

**Figure 9. Gate charge vs gate-source voltage**

**Figure 10. Static drain-source on resistance**

**Figure 11. Capacitance variations**

**Figure 12. Output capacitance stored energy**


**Figure 13. Normalized gate threshold voltage vs temperature**

**Figure 14. Normalized on resistance vs temperature**

**Figure 15. Normalized  $V_{(BR)DSS}$  vs temperature**


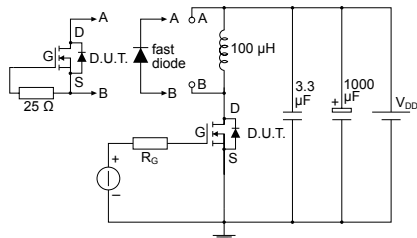
### 3 Test circuits

**Figure 16. Test circuit for resistive load switching times**


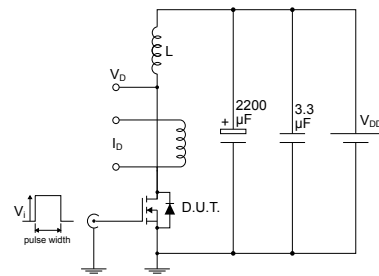
AM01468v1

**Figure 17. Test circuit for gate charge behavior**


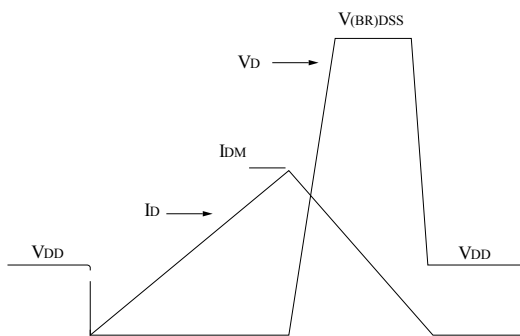
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**Figure 18. Test circuit for inductive load switching and diode recovery times**


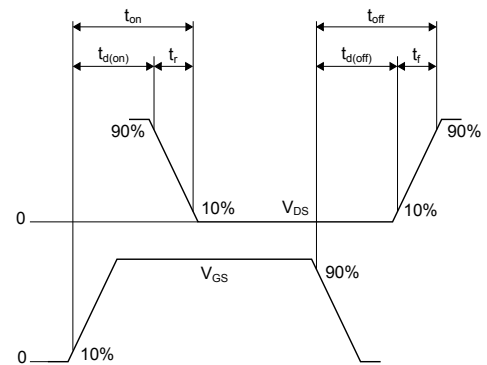
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**Figure 19. Unclamped inductive load test circuit**


AM01471v1

**Figure 20. Unclamped inductive waveform**


AM01472v1

**Figure 21. Switching time waveform**


AM01473v1

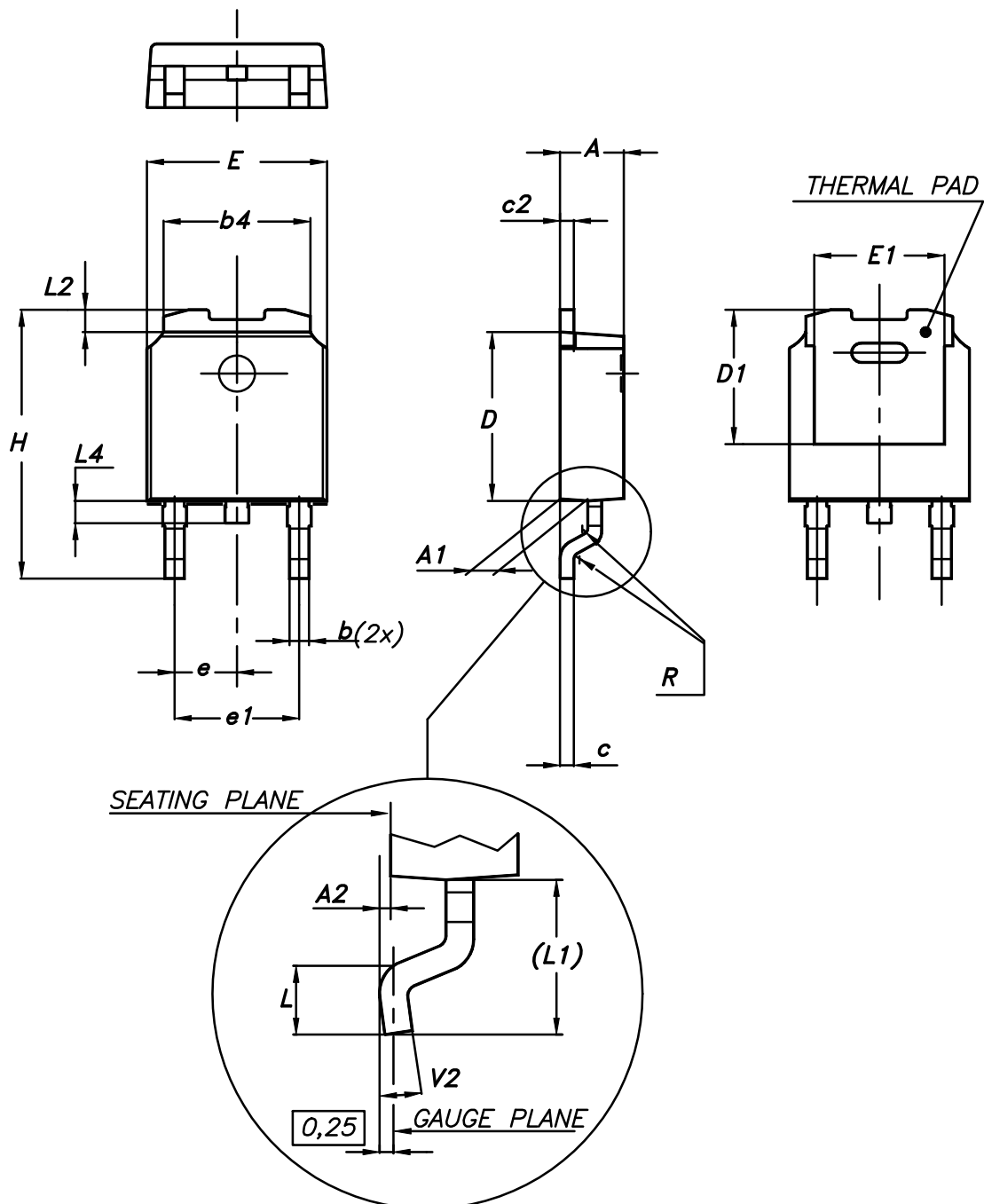
## **4 Package information**

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In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK® packages, depending on their level of environmental compliance. ECOPACK® specifications, grade definitions and product status are available at: [www.st.com](http://www.st.com). ECOPACK® is an ST trademark.

## 4.1 DPAK (TO-252) type A package information

Figure 22. DPAK (TO-252) type A package outline



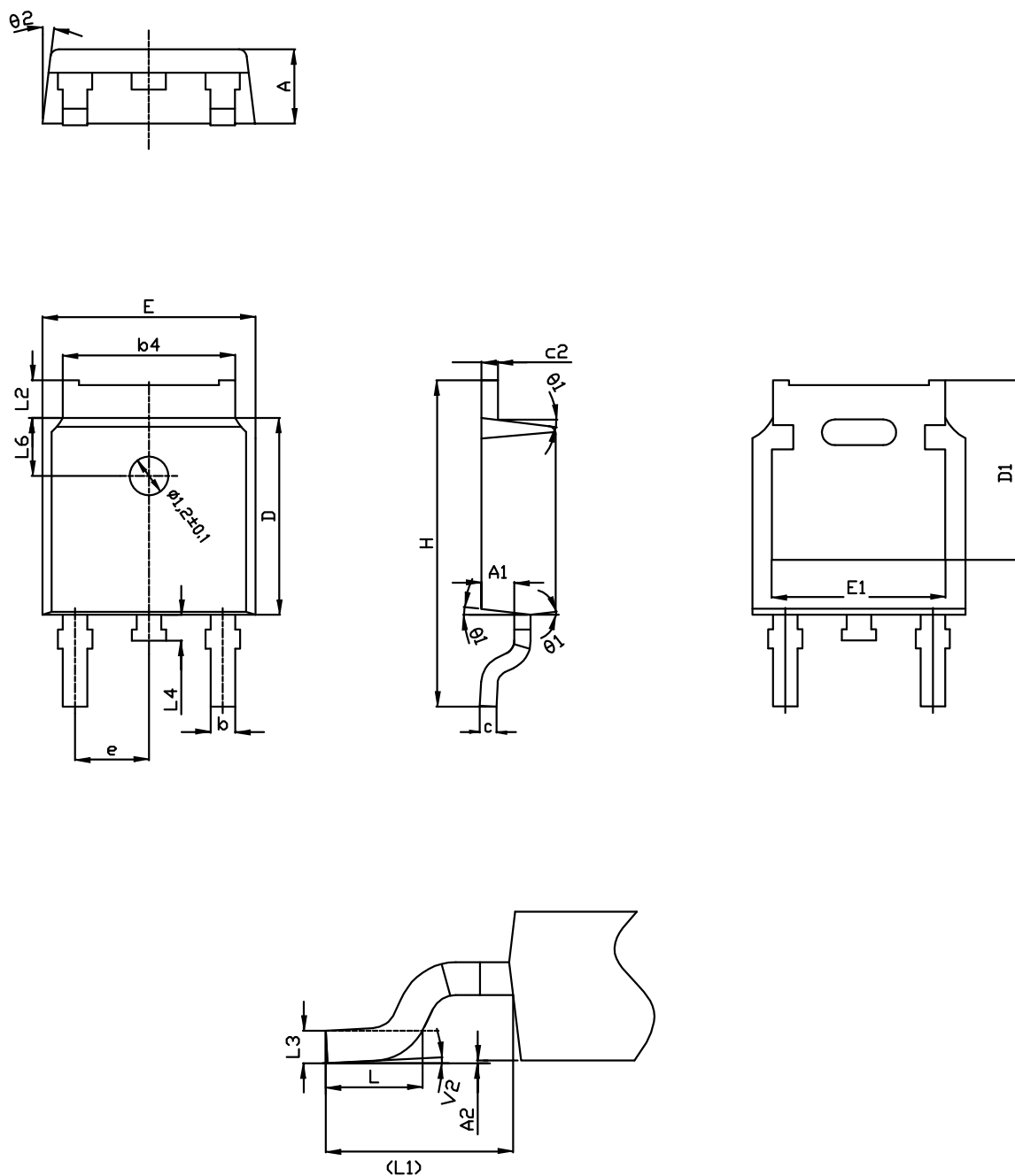
0068772\_A\_25

**Table 8. 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   | 4.95  | 5.10  | 5.25  |
| E    | 6.40  |       | 6.60  |
| E1   | 4.60  | 4.70  | 4.80  |
| e    | 2.159 | 2.286 | 2.413 |
| e1   | 4.445 | 4.572 | 4.699 |
| H    | 9.35  |       | 10.10 |
| L    | 1.00  |       | 1.50  |
| (L1) | 2.60  | 2.80  | 3.00  |
| L2   | 0.65  | 0.80  | 0.95  |
| L4   | 0.60  |       | 1.00  |
| R    |       | 0.20  |       |
| V2   | 0°    |       | 8°    |

## 4.2 DPAK (TO-252) type C2 package information

Figure 23. DPAK (TO-252) type C2 package outline

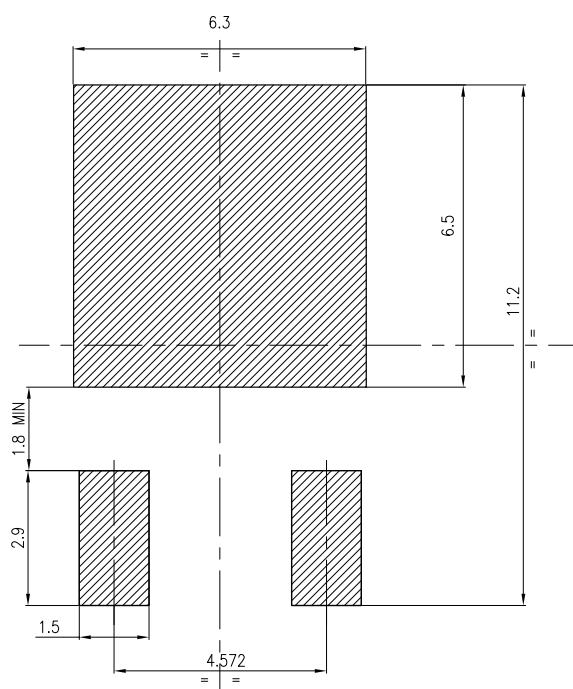


0068772\_C2\_25

**Table 9. DPAK (TO-252) type C2 mechanical data**

| Dim. | mm       |       |       |
|------|----------|-------|-------|
|      | Min.     | Typ.  | Max.  |
| A    | 2.20     | 2.30  | 2.38  |
| A1   | 0.90     | 1.01  | 1.10  |
| A2   | 0.00     |       | 0.10  |
| b    | 0.72     |       | 0.85  |
| b4   | 5.13     | 5.33  | 5.46  |
| c    | 0.47     |       | 0.60  |
| c2   | 0.47     |       | 0.60  |
| D    | 6.00     | 6.10  | 6.20  |
| D1   | 5.10     |       | 5.60  |
| E    | 6.50     | 6.60  | 6.70  |
| E1   | 5.20     |       | 5.50  |
| e    | 2.186    | 2.286 | 2.386 |
| H    | 9.80     | 10.10 | 10.40 |
| L    | 1.40     | 1.50  | 1.70  |
| L1   | 2.90 REF |       |       |
| L2   | 0.90     |       | 1.25  |
| L3   | 0.51 BSC |       |       |
| L4   | 0.60     | 0.80  | 1.00  |
| L6   | 1.80 BSC |       |       |
| θ1   | 5°       | 7°    | 9°    |
| θ2   | 5°       | 7°    | 9°    |
| V2   | 0°       |       | 8°    |

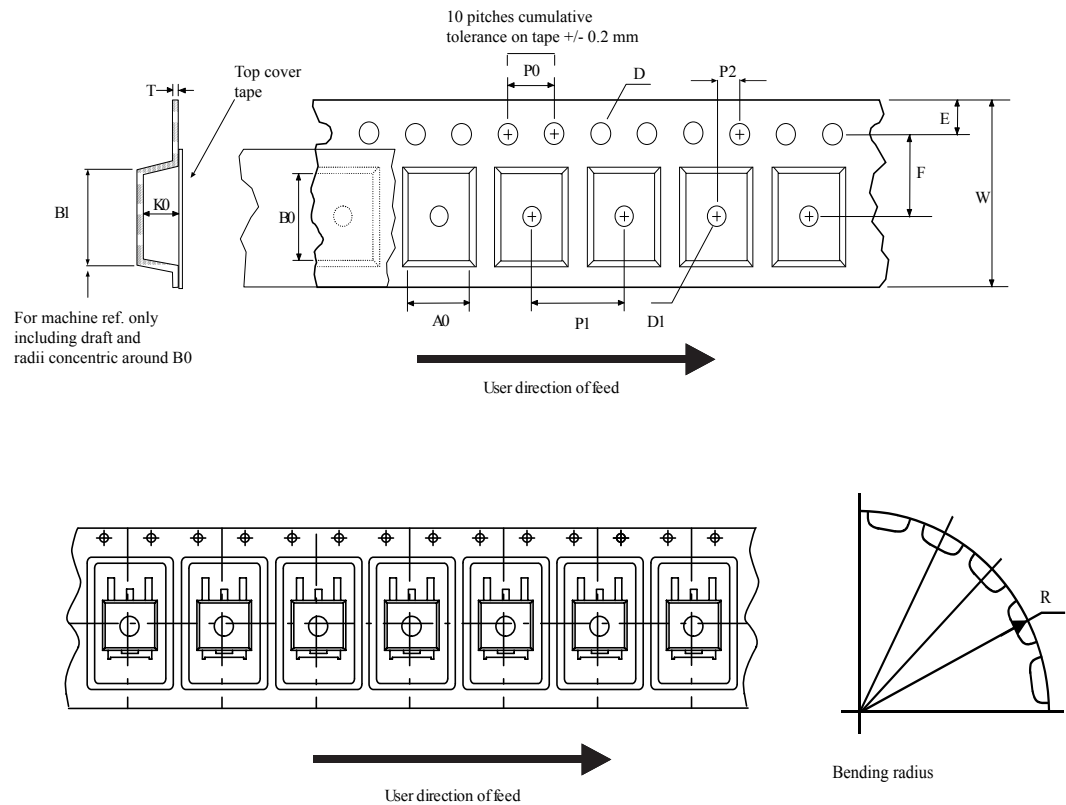
**Figure 24. DPAK (TO-252) recommended footprint (dimensions are in mm)**



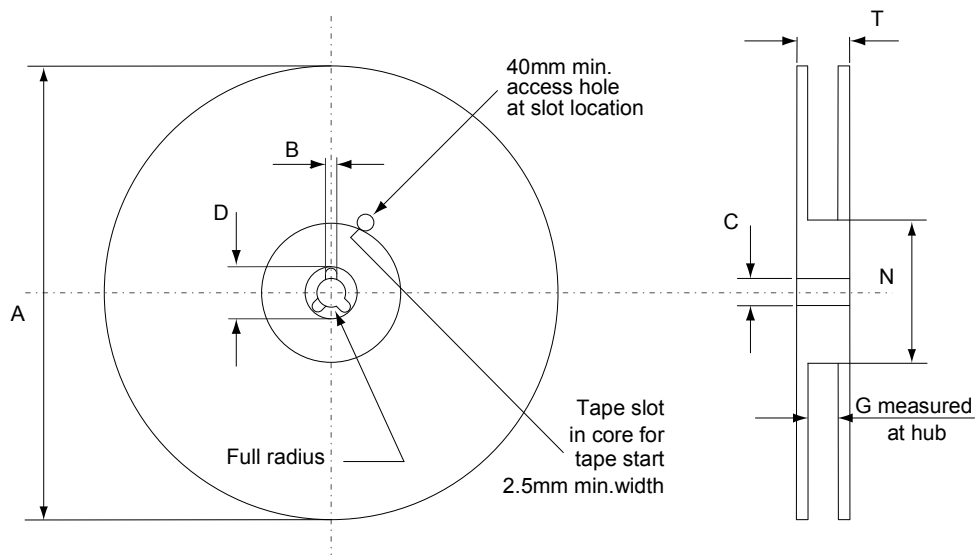
FP\_0068772\_25

### 4.3 DPAK (TO-252) packing information

**Figure 25. DPAK (TO-252) tape outline**



AM08852v1

**Figure 26. DPAK (TO-252) reel outline**


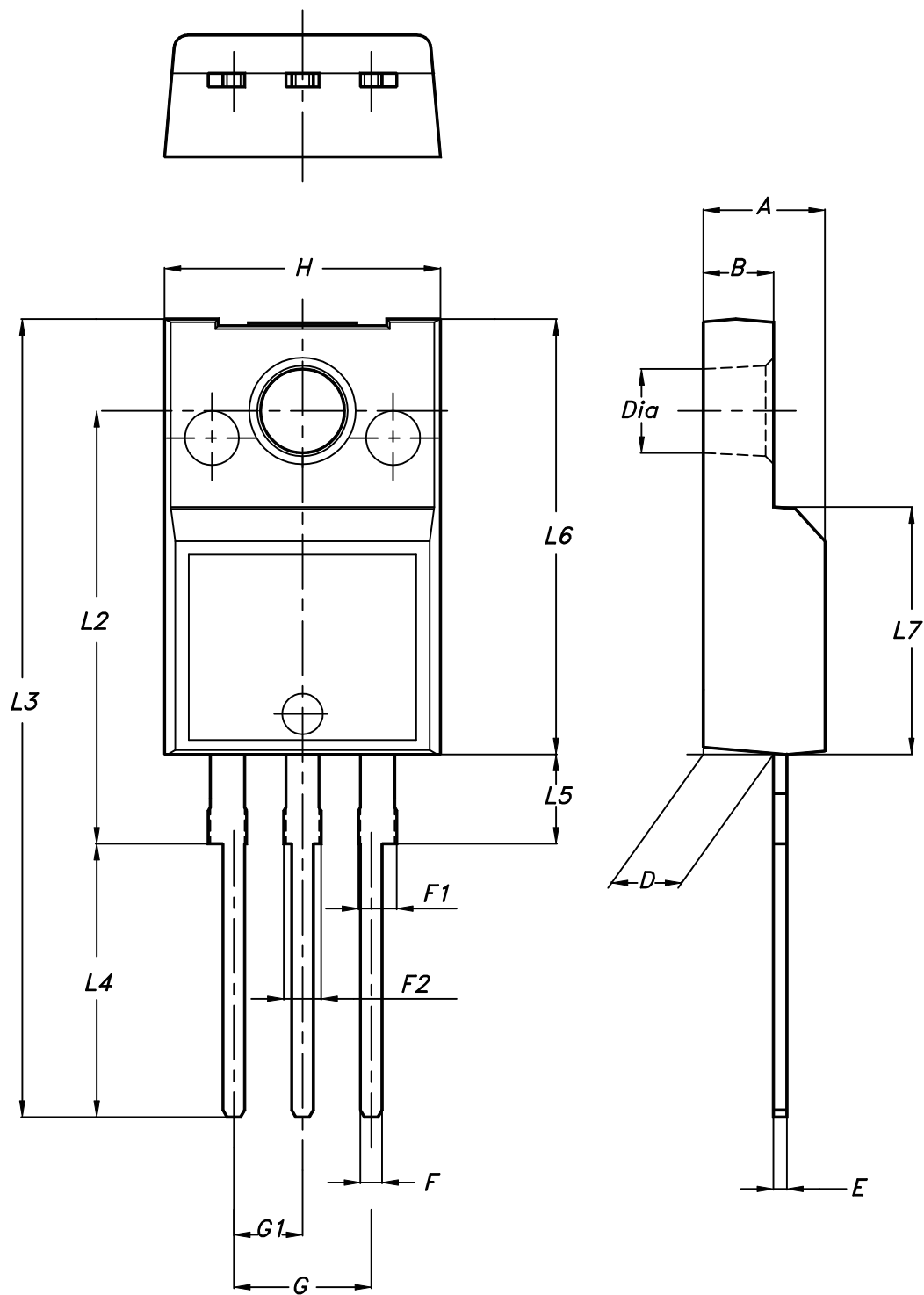
AM06038v1

**Table 10. 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 |           |      |      |

#### 4.4 TO-220FP package information

Figure 27. TO-220FP package outline



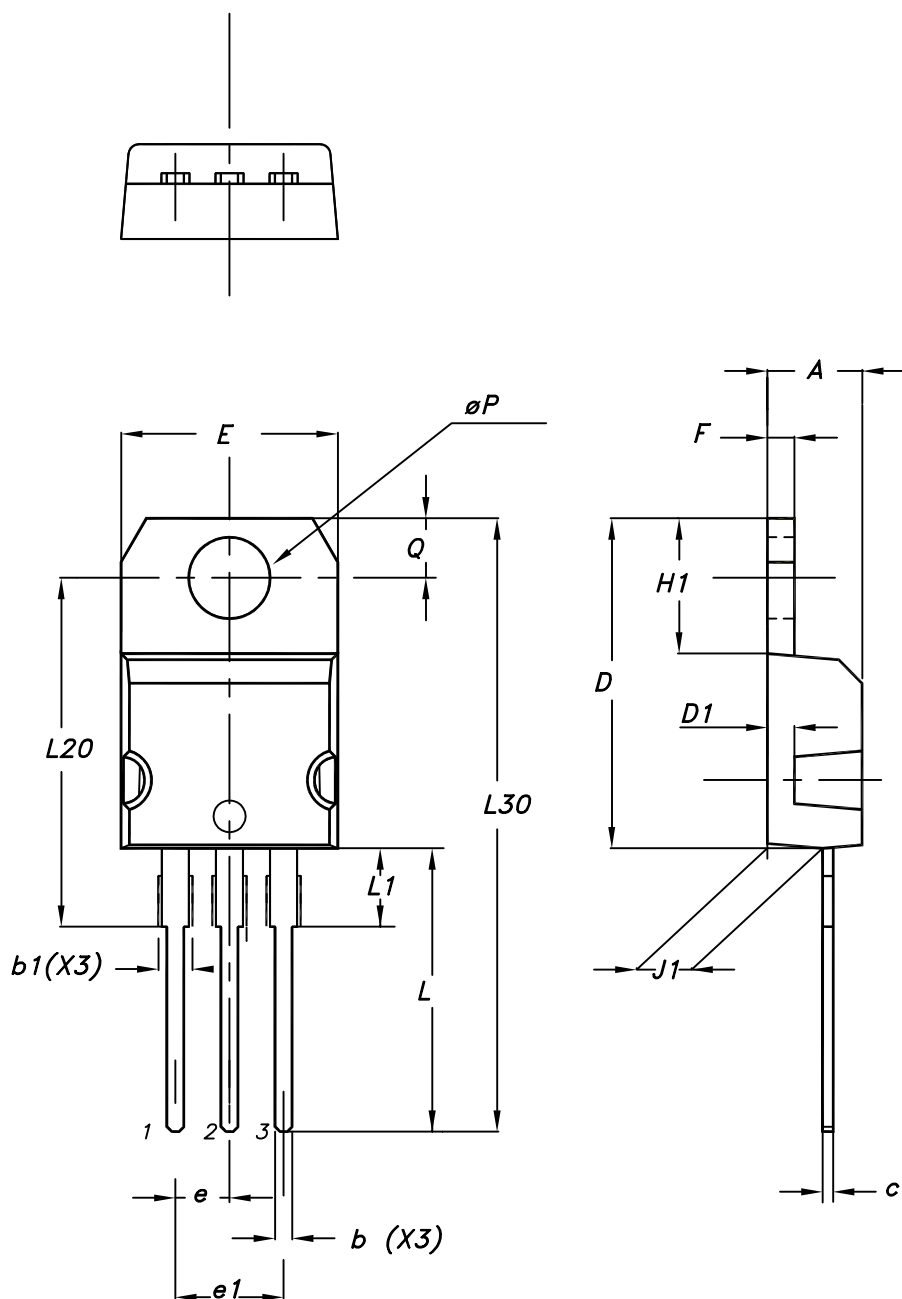
7012510\_Rev\_12\_B

**Table 11. TO-220FP package 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  |

## 4.5 TO-220 type A package information

Figure 28. TO-220 type A package outline



0015988\_typeA\_Rev\_21

**Table 12. TO-220 type A package mechanical data**

| Dim. | mm    |       |       |
|------|-------|-------|-------|
|      | Min.  | Typ.  | Max.  |
| A    | 4.40  |       | 4.60  |
| b    | 0.61  |       | 0.88  |
| b1   | 1.14  |       | 1.55  |
| c    | 0.48  |       | 0.70  |
| D    | 15.25 |       | 15.75 |
| D1   |       | 1.27  |       |
| E    | 10.00 |       | 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    | 13.00 |       | 14.00 |
| L1   | 3.50  |       | 3.93  |
| L20  |       | 16.40 |       |
| L30  |       | 28.90 |       |
| øP   | 3.75  |       | 3.85  |
| Q    | 2.65  |       | 2.95  |

## 5 Ordering information

**Table 13. Order codes**

| Order code | Marking | Package  | Packing       |
|------------|---------|----------|---------------|
| STD9NM60N  | 9NM60N  | DPAK     | Tape and reel |
| STF9NM60N  |         | TO-220FP | Tube          |
| STP9NM60N  |         | TO-220   |               |

## Revision history

**Table 14. Document revision history**

| Date        | Version | Changes                                                                                                                                                                       |
|-------------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 20-Oct-2010 | 1       | First release.                                                                                                                                                                |
| 25-Sep-2018 | 2       | Removed maturity status indication from cover page. The document status is production data.<br>Updated <a href="#">Section 4 Package information</a> .<br>Minor text changes. |

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