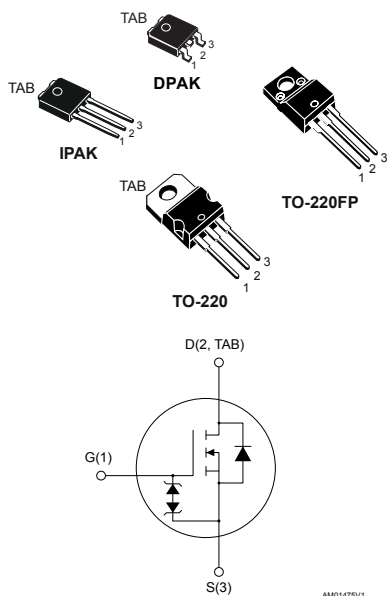


## N-channel 650 V, 0.79 $\Omega$ typ., 5 A MDmesh M2 Power MOSFETs in DPAK, TO-220FP, TO-220 and IPAK packages



### Features

| Order codes | $V_{DS}$ | $R_{DS(on)}$ max. | $I_D$ | Package  |
|-------------|----------|-------------------|-------|----------|
| STD9N65M2   | 650 V    | 0.90 $\Omega$     | 5 A   | DPAK     |
| STF9N65M2   |          |                   |       | TO-220FP |
| STP9N65M2   |          |                   |       | TO-220   |
| STU9N65M2   |          |                   |       | IPAK     |

- Extremely low gate charge
- Excellent output capacitance ( $C_{OSS}$ ) profile
- 100% avalanche tested
- Zener-protected

### Applications

- Switching applications

### Description

These devices are N-channel Power MOSFETs developed using the MDmesh M2 technology. Thanks to their strip layout and improved vertical structure, these devices exhibit low on-resistance and optimized switching characteristics, rendering them suitable for the most demanding high-efficiency converters.



#### Product status link

[STD9N65M2](#)

[STF9N65M2](#)

[STP9N65M2](#)

[STU9N65M2](#)

# 1 Electrical ratings

**Table 1. Absolute maximum ratings**

| Symbol                         | Parameter                                                                                                       | Value              |                    | Unit |
|--------------------------------|-----------------------------------------------------------------------------------------------------------------|--------------------|--------------------|------|
|                                |                                                                                                                 | DPAK, TO-220, IPAK | TO-220FP           |      |
| V <sub>GS</sub>                | Gate-source voltage                                                                                             | ±25                |                    | V    |
| I <sub>D</sub>                 | Drain current (continuous) at T <sub>C</sub> = 25 °C                                                            | 5                  | 5 <sup>(1)</sup>   | A    |
| I <sub>D</sub>                 | Drain current (continuous) at T <sub>C</sub> = 100 °C                                                           | 3.2                | 3.2 <sup>(1)</sup> |      |
| I <sub>DM</sub> <sup>(2)</sup> | Drain current (pulsed)                                                                                          | 20                 |                    | A    |
| P <sub>TOT</sub>               | Total power dissipation at T <sub>C</sub> = 25 °C                                                               | 60                 | 20                 | W    |
| 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) |                    | 2.5                | kV   |
| dv/dt <sup>(3)</sup>           | Peak diode recovery voltage slope                                                                               | 15                 |                    | V/ns |
| dv/dt <sup>(4)</sup>           | MOSFET dv/dt ruggedness                                                                                         | 50                 |                    |      |
| T <sub>stg</sub>               | Storage temperature range                                                                                       | -55 to 150         |                    | °C   |
| T <sub>J</sub>                 | Operating junction temperature range                                                                            |                    |                    |      |

1. Current limited by package.
2. Pulse width is limited by safe operating area.
3.  $I_{SD} \leq 5\text{ A}$ ,  $di/dt = 400\text{ A}/\mu\text{s}$ ;  $V_{DS(peak)} < V_{(BR)DSS}$ ,  $V_{DD} = 400\text{ V}$ .
4.  $V_{DS} \leq 520\text{ V}$ .

**Table 2. Thermal data**

| Symbol                       | Parameter                           | Value |          |        |      | Unit                        |
|------------------------------|-------------------------------------|-------|----------|--------|------|-----------------------------|
|                              |                                     | DPAK  | TO-220FP | TO-220 | IPAK |                             |
| $R_{thj-case}$               | Thermal resistance junction-case    | 2.08  | 6.25     | 2.08   |      | $^{\circ}\text{C}/\text{W}$ |
| $R_{thj-pcb}$                | Thermal resistance junction-pcb     | 50    |          |        |      | $^{\circ}\text{C}/\text{W}$ |
| $R_{thj-amb}$ <sup>(1)</sup> | Thermal resistance junction-ambient |       | 62.5     |        | 100  | $^{\circ}\text{C}/\text{W}$ |

1. When mounted on 1 inch<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)                                     | 1     | A    |
| $E_{AS}$ | Single pulse avalanche energy (starting $T_J = 25\text{ }^{\circ}\text{C}$ , $I_D = I_{AR}$ ; $V_{DD} = 50\text{ V}$ ) | 105   | mJ   |

## 2 Electrical characteristics

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

**Table 4. On/off states**

| Symbol        | Parameter                         | Test conditions                                                                                      | Min. | Typ. | Max.     | Unit          |
|---------------|-----------------------------------|------------------------------------------------------------------------------------------------------|------|------|----------|---------------|
| $V_{(BR)DSS}$ | Drain-source breakdown voltage    | $V_{GS} = 0\text{ V}$ , $I_D = 1\text{ mA}$                                                          | 650  |      |          | V             |
| $I_{DSS}$     | Zero gate voltage drain current   | $V_{GS} = 0\text{ V}$ , $V_{DS} = 650\text{ V}$                                                      |      |      | 1        | $\mu\text{A}$ |
|               |                                   | $V_{GS} = 0\text{ V}$ , $V_{DS} = 650\text{ V}$ , $T_C = 125\text{ }^{\circ}\text{C}$ <sup>(1)</sup> |      |      | 100      | $\mu\text{A}$ |
| $I_{GSS}$     | Gate-body leakage current         | $V_{DS} = 0\text{ V}$ , $V_{GS} = \pm 25\text{ V}$                                                   |      |      | $\pm 10$ | $\mu\text{A}$ |
| $V_{GS(th)}$  | 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 | $V_{GS} = 10\text{ V}$ , $I_D = 2.5\text{ A}$                                                        |      | 0.79 | 0.90     | $\Omega$      |

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

**Table 5. Dynamic**

| Symbol                     | Parameter                             | Test conditions                                                      | Min. | Typ. | Max. | Unit     |
|----------------------------|---------------------------------------|----------------------------------------------------------------------|------|------|------|----------|
| $C_{iss}$                  | Input capacitance                     | $V_{DS} = 100\text{ V}$ , $f = 1\text{ MHz}$ , $V_{GS} = 0\text{ V}$ | -    | 310  | -    | pF       |
| $C_{oss}$                  | Output capacitance                    |                                                                      | -    | 18   | -    | pF       |
| $C_{rss}$                  | Reverse transfer capacitance          |                                                                      | -    | 0.9  | -    | pF       |
| $C_{oss\text{ eq.}}^{(1)}$ | Equivalent capacitance energy related | $V_{DS} = 0\text{ to }520\text{ V}$ , $V_{GS} = 0\text{ V}$          | -    | 109  | -    | pF       |
| $R_g$                      | Intrinsic gate resistance             | $f = 1\text{ MHz}$ open drain                                        | -    | 6.6  | -    | $\Omega$ |
| $Q_g$                      | Total gate charge                     | $V_{DD} = 520\text{ V}$ , $I_D = 5\text{ A}$                         | -    | 10.3 | -    | nC       |
| $Q_{gs}$                   | Gate-source charge                    | $V_{GS} = 0\text{ to }10\text{ V}$                                   | -    | 2.4  | -    | nC       |
| $Q_{gd}$                   | Gate-drain charge                     | (see Figure 18. Test circuit for gate charge behavior)               | -    | 4.8  | -    | 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 6. Switching times**

| Symbol       | Parameter           | Test conditions                                                                                            | Min. | Typ. | Max. | Unit |
|--------------|---------------------|------------------------------------------------------------------------------------------------------------|------|------|------|------|
| $t_{d(on)}$  | Turn-on delay time  | $V_{DD} = 325\text{ V}$ , $I_D = 2.5\text{ A}$ ,<br>$R_G = 4.7\text{ }\Omega$ , $V_{GS} = 10\text{ V}$     | -    | 7.5  | -    | ns   |
| $t_r$        | Rise time           |                                                                                                            | -    | 6.6  | -    | ns   |
| $t_{d(off)}$ | Turn-off delay time | (see Figure 17. Test circuit for resistive load switching times and<br>Figure 22. Switching time waveform) | -    | 22.5 | -    | ns   |
| $t_f$        | Fall time           |                                                                                                            | -    | 18   | -    | ns   |

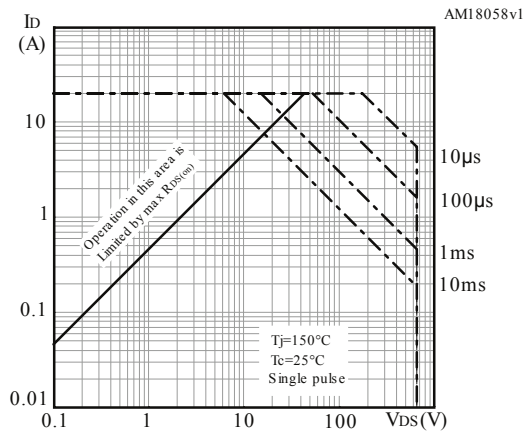
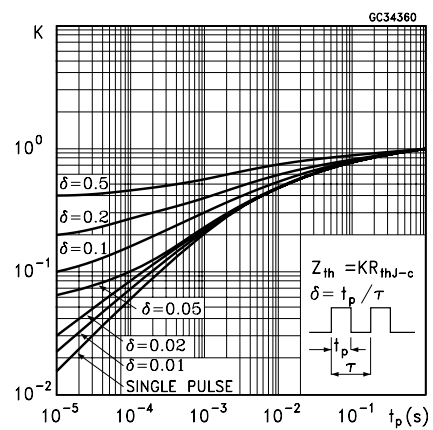
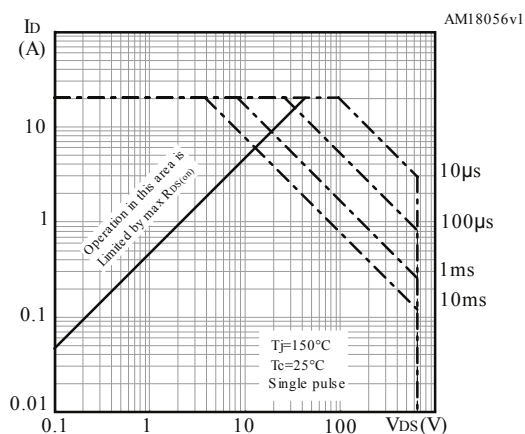
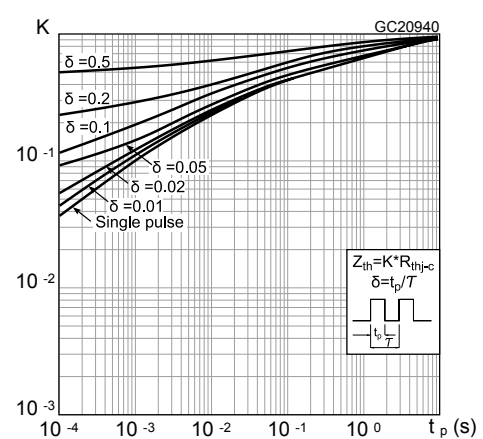
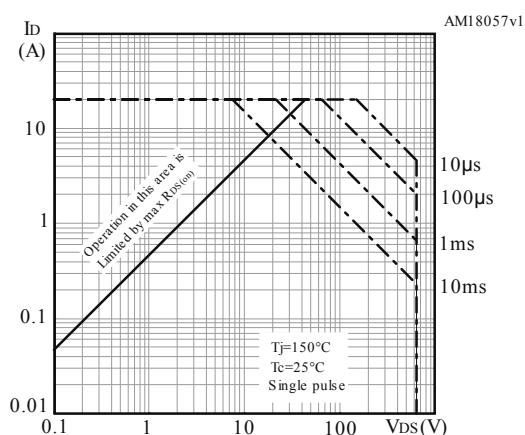
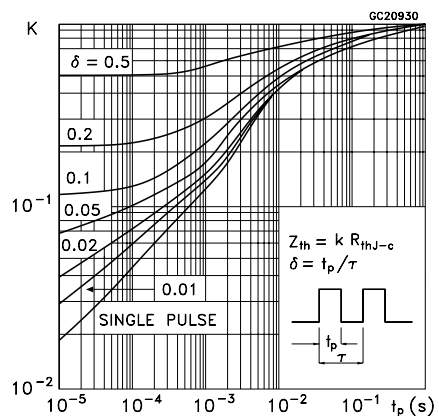
**Table 7. Source-drain diode**

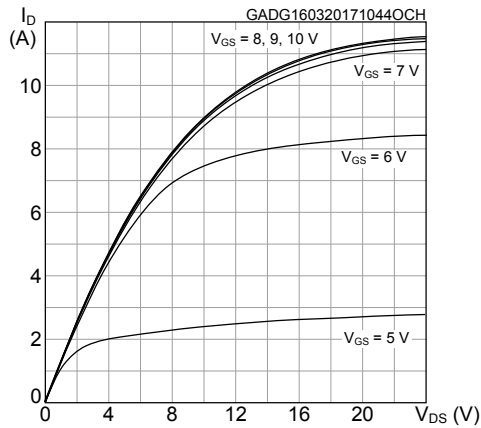
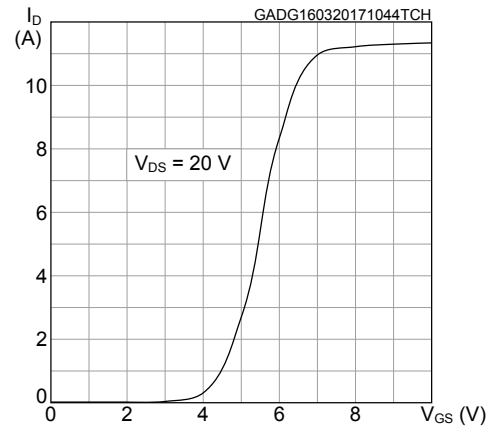
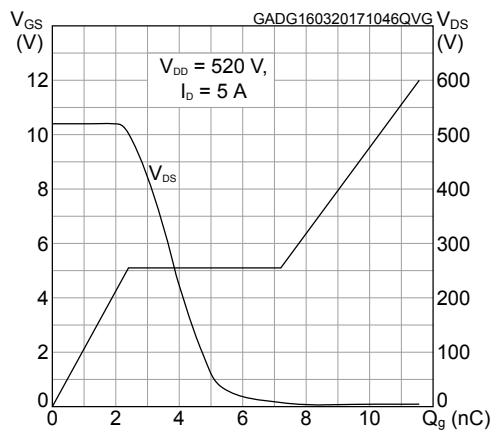
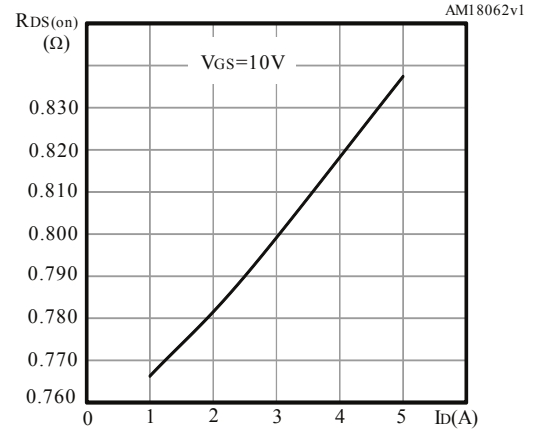
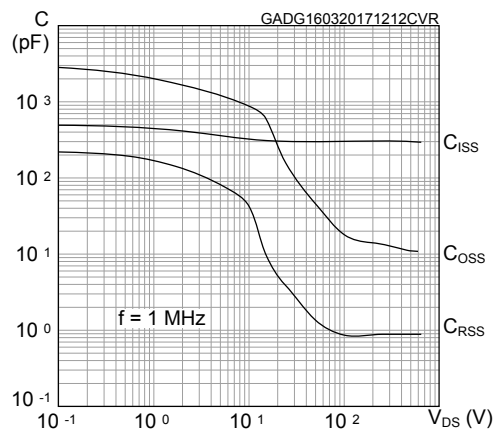
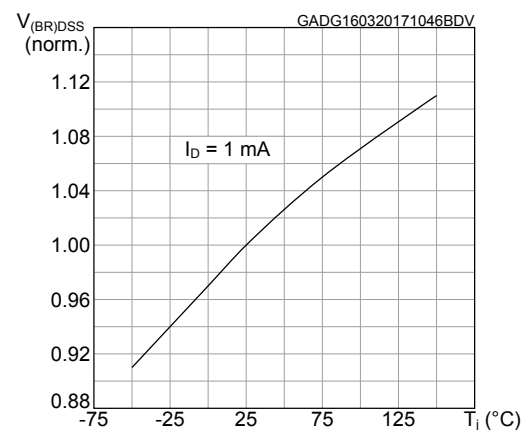
| Symbol          | Parameter                     | Test conditions                                                                                                                                                                                                     | Min. | Typ. | Max. | Unit          |
|-----------------|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------|------|---------------|
| $I_{SD}$        | Source-drain current          |                                                                                                                                                                                                                     | -    |      | 5    | A             |
| $I_{SDM}^{(1)}$ | Source-drain current (pulsed) |                                                                                                                                                                                                                     | -    |      | 20   | A             |
| $V_{SD}^{(2)}$  | Forward on voltage            | $I_{SD} = 5\text{ A}$ , $V_{GS} = 0\text{ V}$                                                                                                                                                                       | -    |      | 1.6  | V             |
| $t_{rr}$        | Reverse recovery time         | $I_{SD} = 5\text{ A}$ , $di/dt = 100\text{ A}/\mu\text{s}$ , $V_{DD} = 60\text{ V}$<br>(see Figure 19. Test circuit for inductive load switching and diode recovery times)                                          | -    | 276  |      | ns            |
| $Q_{rr}$        | Reverse recovery charge       |                                                                                                                                                                                                                     | -    | 1.7  |      | $\mu\text{C}$ |
| $I_{RRM}$       | Reverse recovery current      |                                                                                                                                                                                                                     | -    | 12.5 |      | A             |
| $t_{rr}$        | Reverse recovery time         | $I_{SD} = 5\text{ A}$ , $di/dt = 100\text{ A}/\mu\text{s}$ ,<br>$V_{DD} = 60\text{ V}$ , $T_J = 150\text{ }^{\circ}\text{C}$<br>(see Figure 19. Test circuit for inductive load switching and diode recovery times) | -    | 312  |      | ns            |
| $Q_{rr}$        | Reverse recovery charge       |                                                                                                                                                                                                                     | -    | 1.9  |      | $\mu\text{C}$ |
| $I_{RRM}$       | Reverse recovery current      |                                                                                                                                                                                                                     | -    | 12.4 |      | A             |

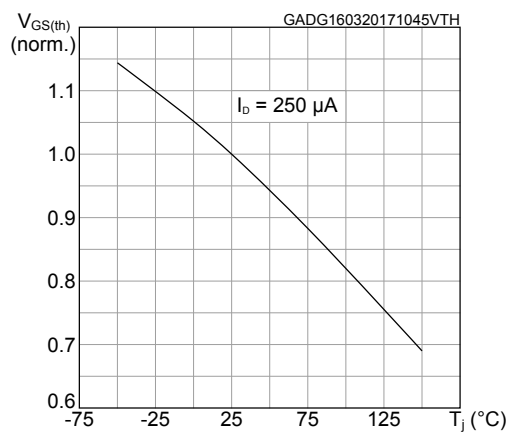
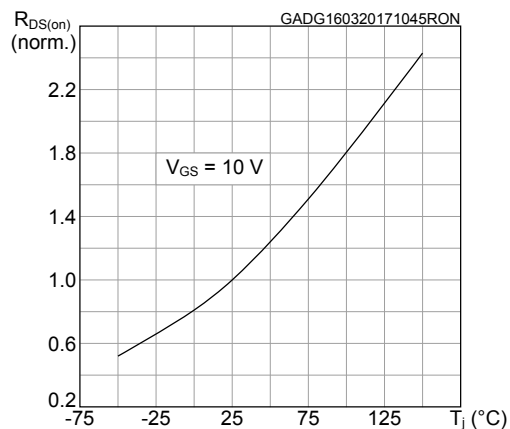
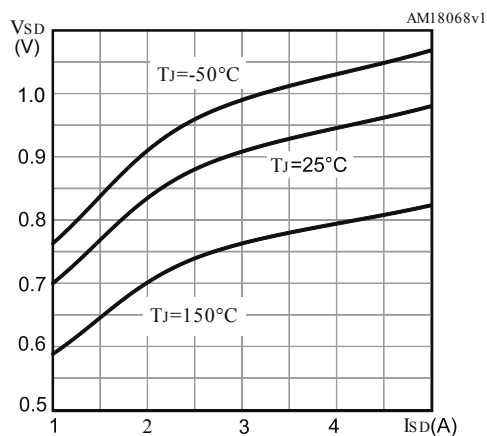
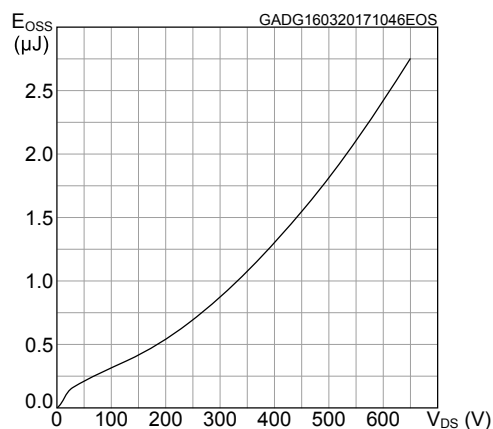
1. Pulse width is limited by safe operating area.

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

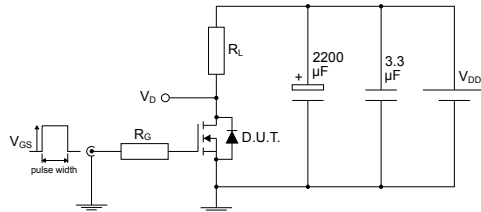
## 2.1 Electrical characteristics (curves)

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

**Figure 2. Thermal impedance for DPAK and IPAK**

**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**


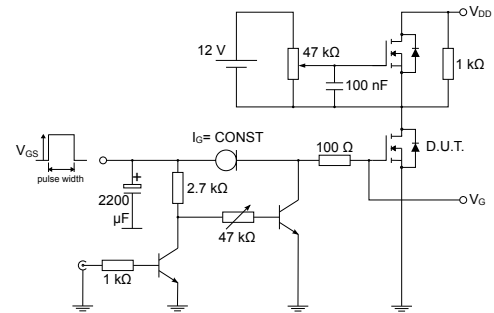
**Figure 7. Output characteristics**

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


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

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

**Figure 15. Source-drain diode forward characteristics**

**Figure 16. Output capacitance stored energy**


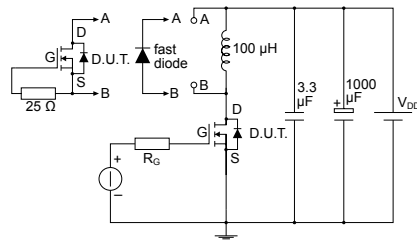
### 3 Test circuits

**Figure 17. Test circuit for resistive load switching times**


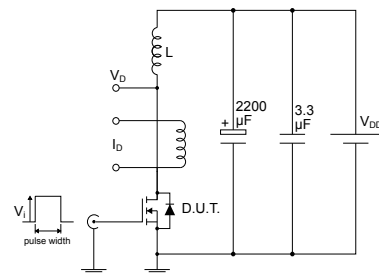
AM01468v1

**Figure 18. Test circuit for gate charge behavior**


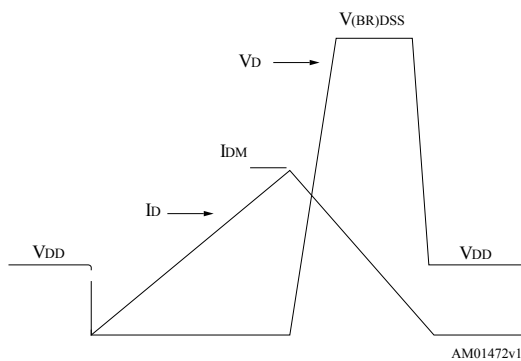
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**Figure 19. Test circuit for inductive load switching and diode recovery times**


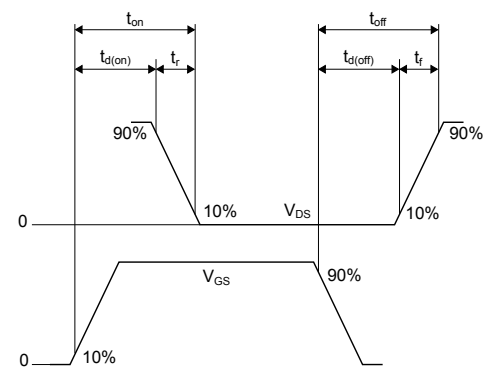
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**Figure 20. Unclamped inductive load test circuit**


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**Figure 21. Unclamped inductive waveform**


AM01472v1

**Figure 22. Switching time waveform**


AM01473v1



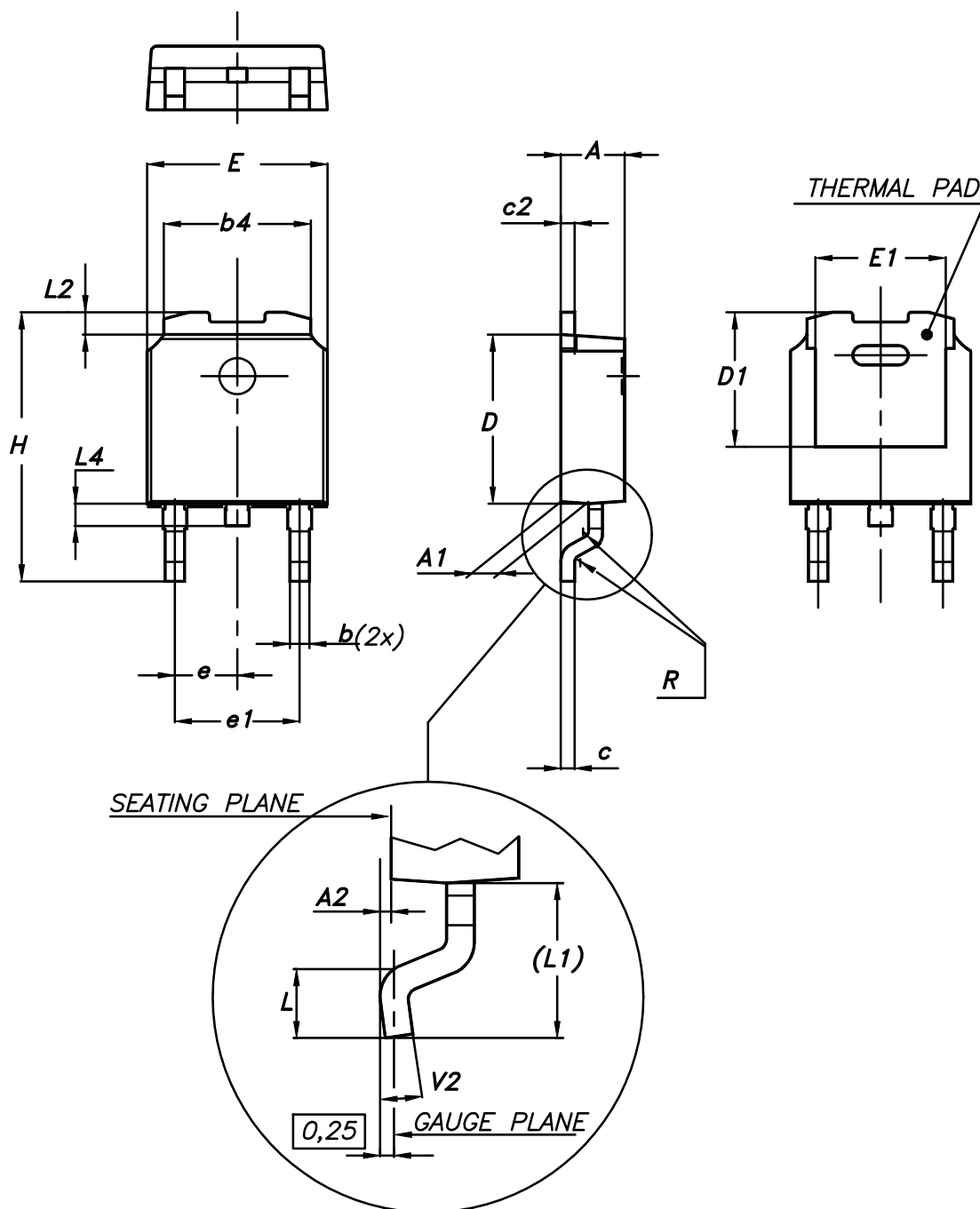
## 4 Package information

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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 23. DPAK (TO-252) type A package outline



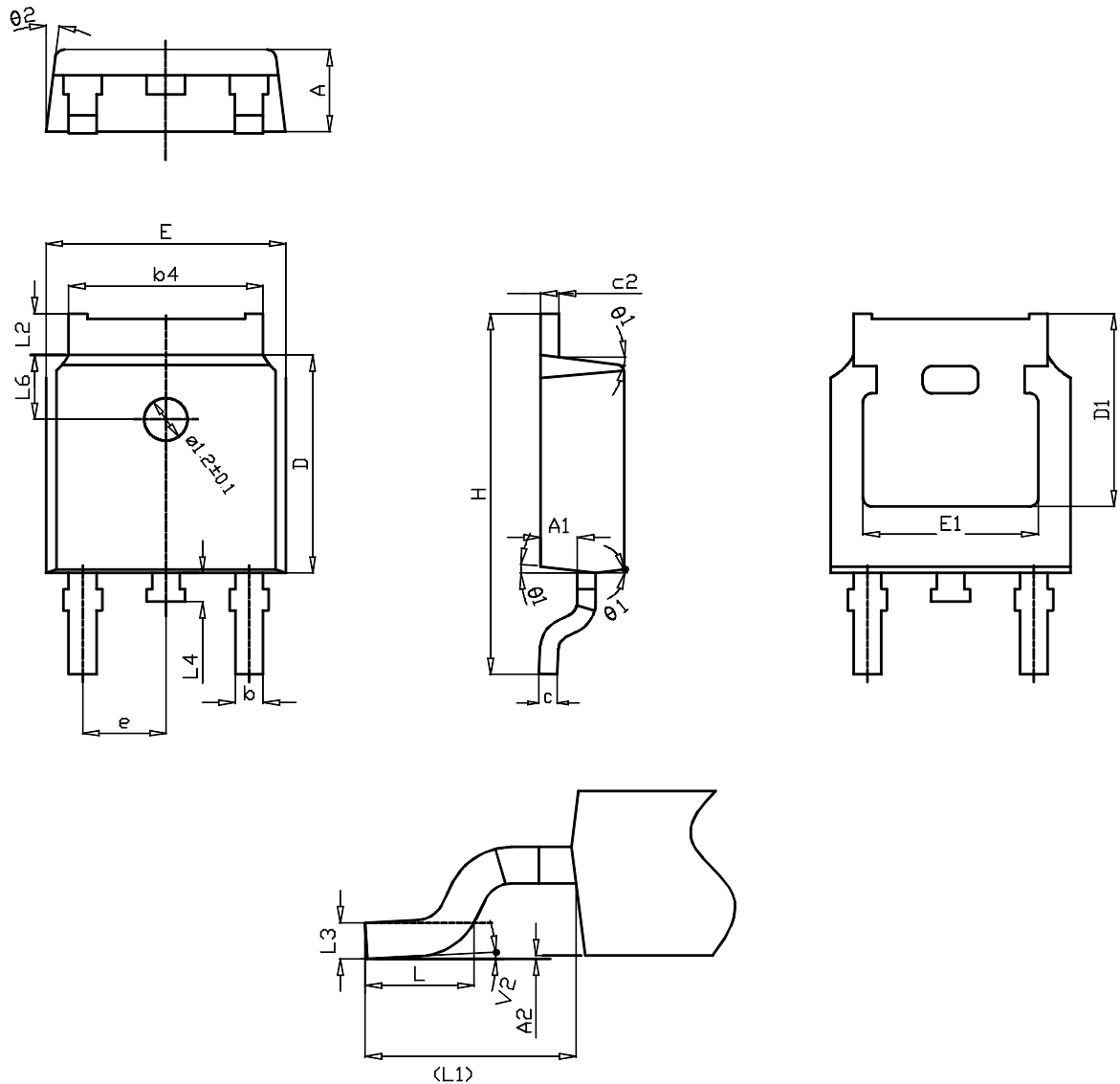
0068772\_A\_26

**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 C package information

Figure 24. DPAK (TO-252) type C package outline

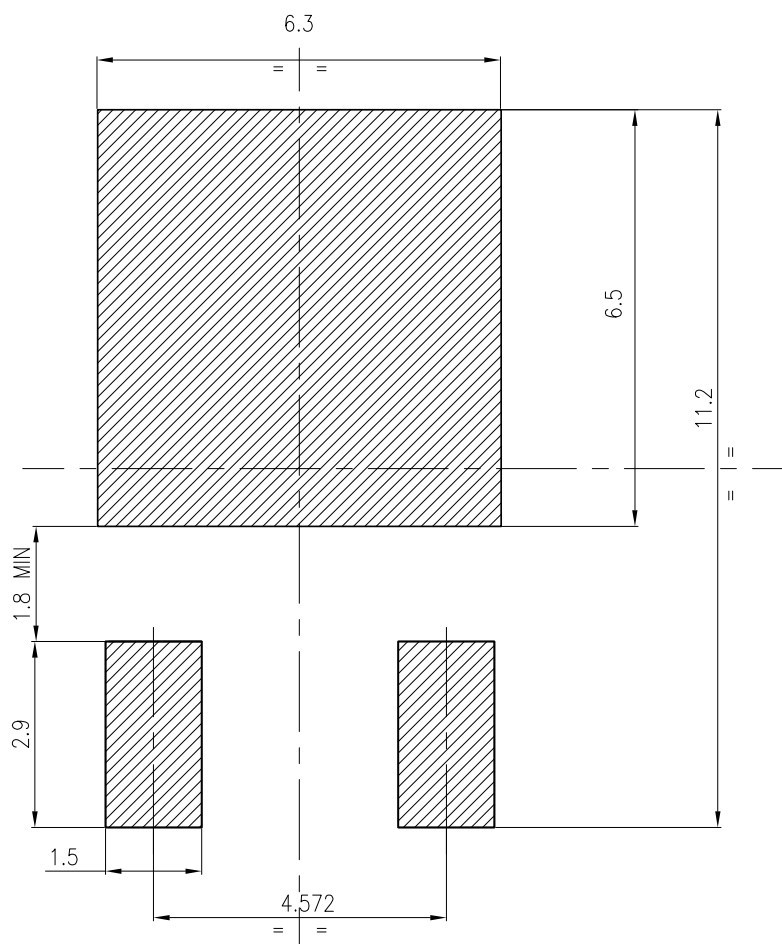


0068772\_C\_26

**Table 9. DPAK (TO-252) type C 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   | 5.25     |       |       |
| E    | 6.50     | 6.60  | 6.70  |
| E1   | 4.70     |       |       |
| 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°    |

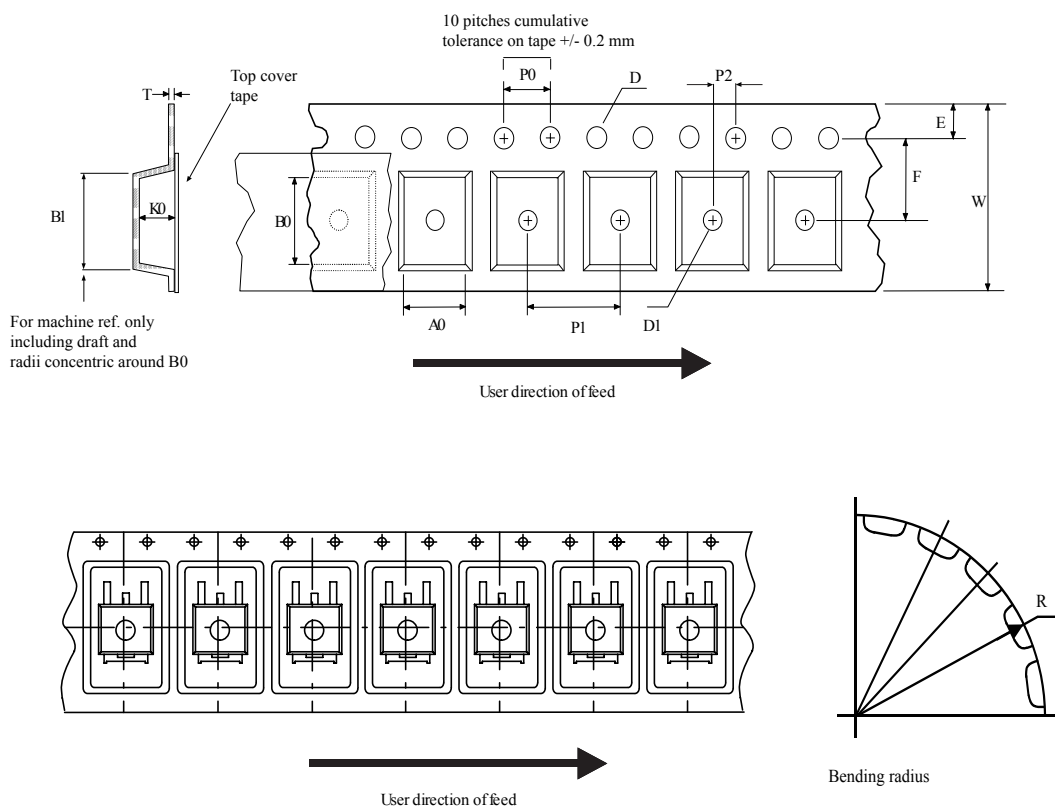
Figure 25. DPAK (TO-252) recommended footprint (dimensions are in mm)



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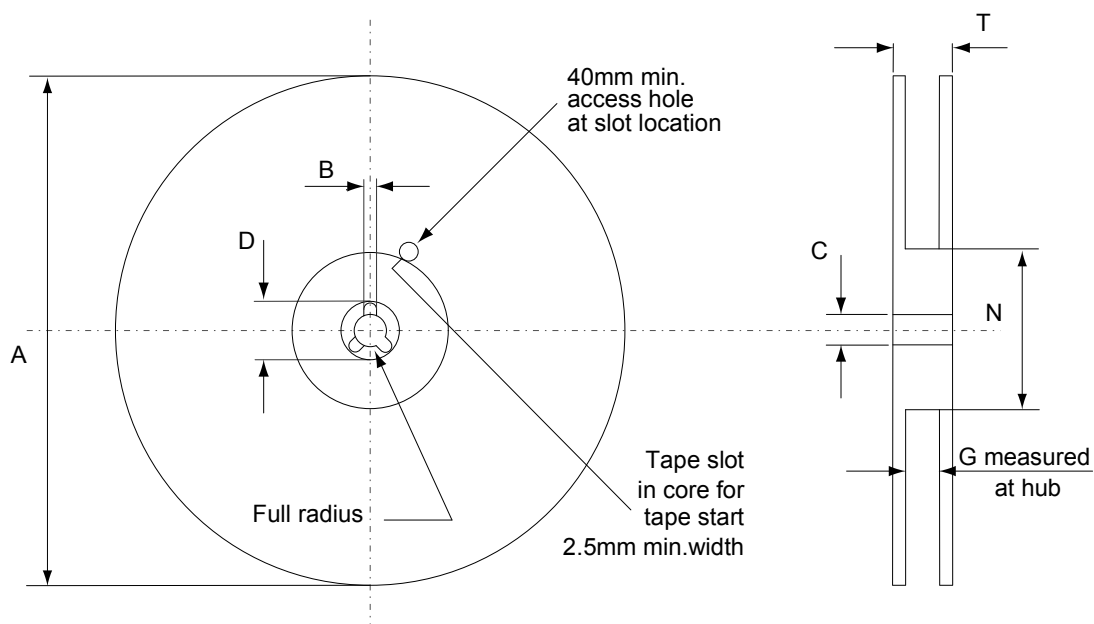
### 4.3 DPAK (TO-252) packing information

Figure 26. DPAK (TO-252) tape outline



AM08852v1

**Figure 27. DPAK (TO-252) reel outline**



AM06038v1

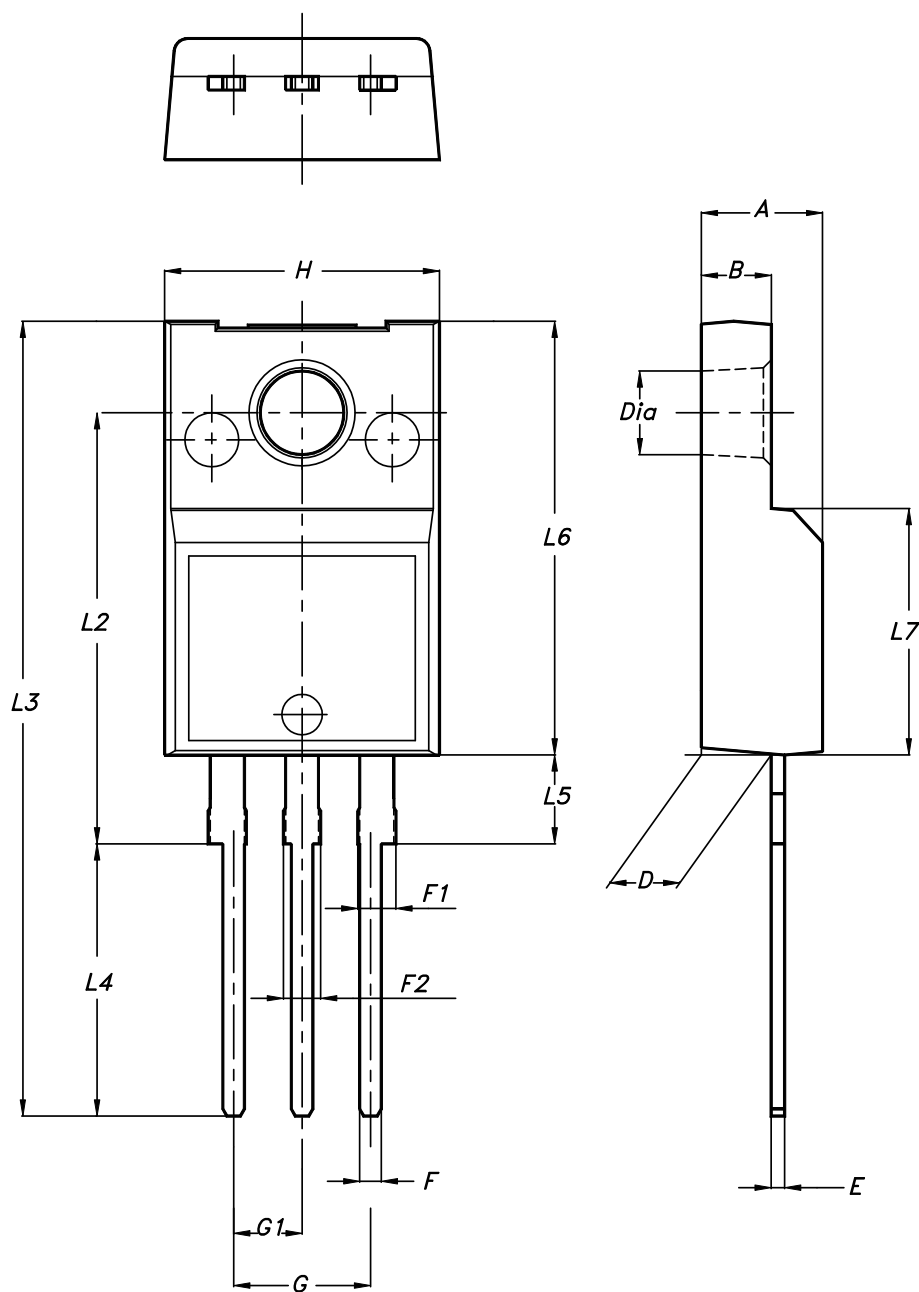
**Table 10. DPAK (TO-252) tape and reel mechanical data**

| 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 28. TO-220FP package outline**



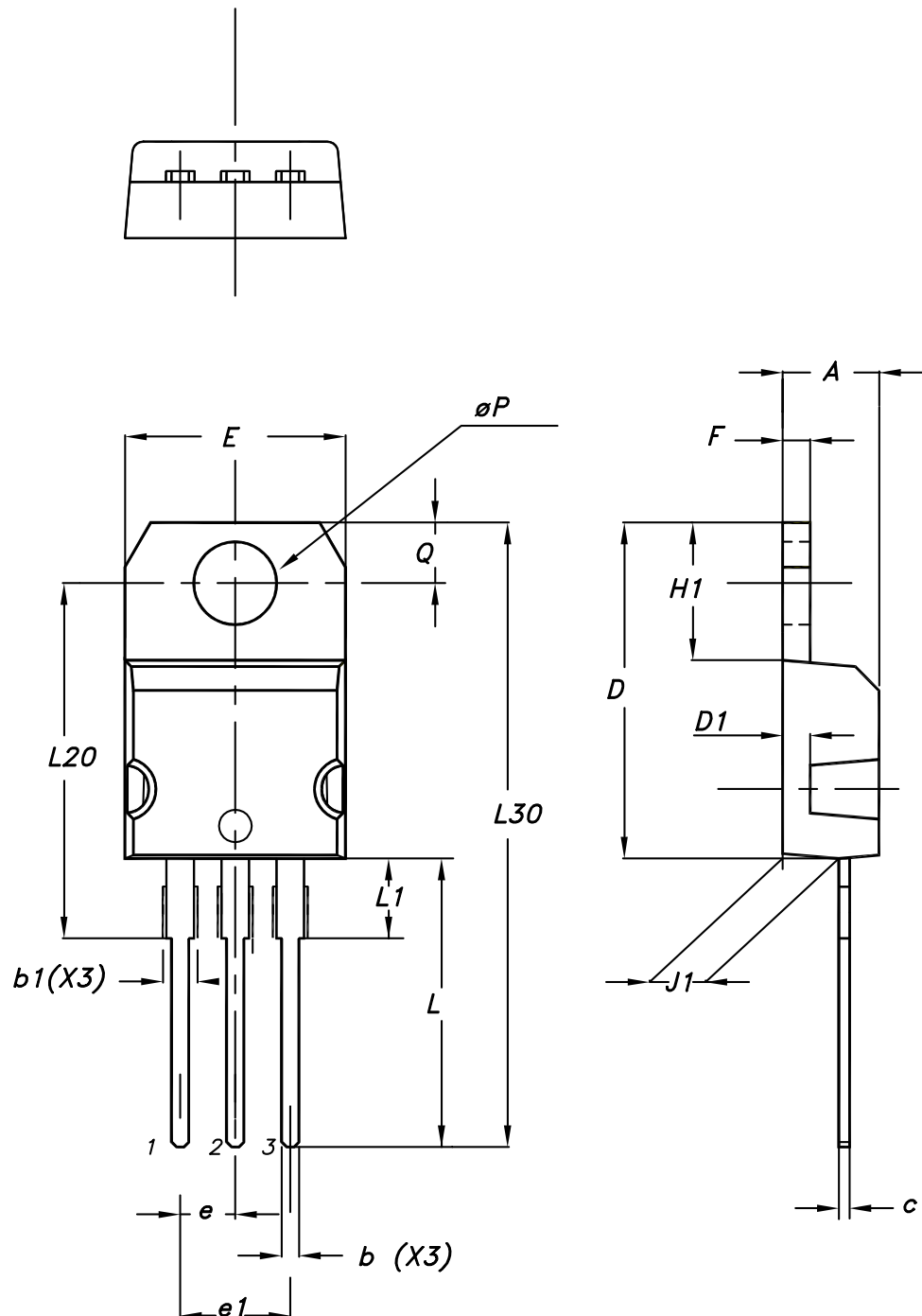
7012510\_Rev\_13\_B

**Table 11. TO-220FP package mechanical data**

| Dim. | mm    |       |       |
|------|-------|-------|-------|
|      | Min.  | Typ.  | Max.  |
| A    | 4.40  |       | 4.60  |
| B    | 2.50  |       | 2.70  |
| D    | 2.50  |       | 2.75  |
| E    | 0.45  |       | 0.70  |
| F    | 0.75  |       | 1.00  |
| F1   | 1.15  |       | 1.70  |
| F2   | 1.15  |       | 1.70  |
| G    | 4.95  |       | 5.20  |
| G1   | 2.40  |       | 2.70  |
| H    | 10.00 |       | 10.40 |
| L2   |       | 16.00 |       |
| L3   | 28.60 |       | 30.60 |
| L4   | 9.80  |       | 10.60 |
| L5   | 2.90  |       | 3.60  |
| L6   | 15.90 |       | 16.40 |
| L7   | 9.00  |       | 9.30  |
| Dia  | 3.00  |       | 3.20  |

## 4.5 TO-220 type A package information

Figure 29. TO-220 type A package outline



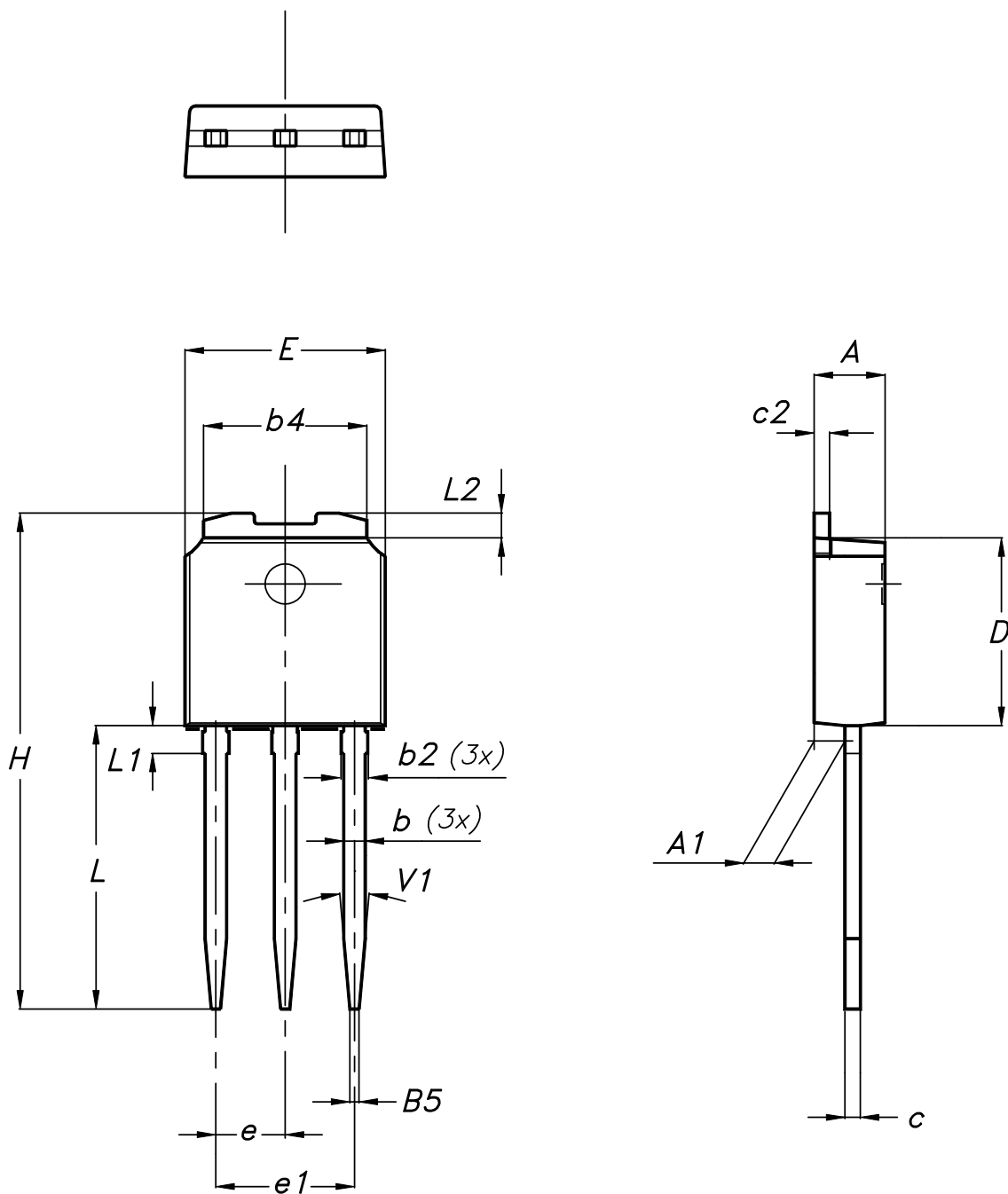
0015988\_typeA\_Rev\_22

**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  |

#### 4.6 IPAK (TO-251) type A package information

Figure 30. IPAK (TO-251) type A package outline



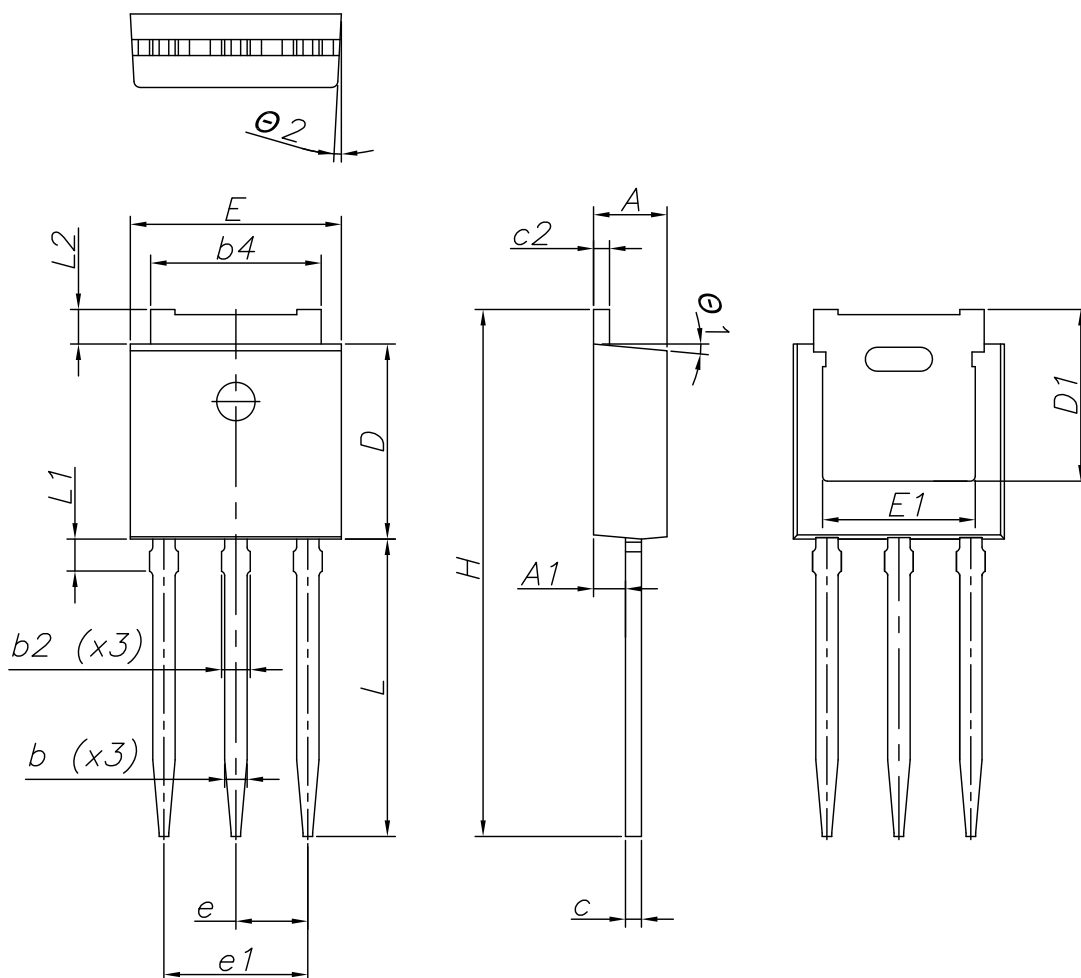
0068771\_IK\_typeA\_rev14

**Table 13.** IPAK (TO-251) type A package 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   |      | 0.30  |      |
| 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°   |      |

## 4.7 IPAK (TO-251) type C package information

Figure 31. IPAK (TO-251) type C package outline



0068771\_IK\_typeC\_rev14

**Table 14. IPAK (TO-251) type C package mechanical data**

| Dim. | mm    |       |       |
|------|-------|-------|-------|
|      | Min.  | Typ.  | Max.  |
| A    | 2.20  | 2.30  | 2.35  |
| A1   | 0.90  | 1.00  | 1.10  |
| b    | 0.66  |       | 0.79  |
| b2   |       |       | 0.90  |
| b4   | 5.23  | 5.33  | 5.43  |
| c    | 0.46  |       | 0.59  |
| c2   | 0.46  |       | 0.59  |
| D    | 6.00  | 6.10  | 6.20  |
| D1   | 5.20  | 5.37  | 5.55  |
| E    | 6.50  | 6.60  | 6.70  |
| E1   | 4.60  | 4.78  | 4.95  |
| e    | 2.20  | 2.25  | 2.30  |
| e1   | 4.40  | 4.50  | 4.60  |
| H    | 16.18 | 16.48 | 16.78 |
| L    | 9.00  | 9.30  | 9.60  |
| L1   | 0.80  | 1.00  | 1.20  |
| L2   | 0.90  | 1.08  | 1.25  |
| θ1   | 3°    | 5°    | 7°    |
| θ2   | 1°    | 3°    | 5°    |



## 5 Ordering information

**Table 15. Order codes**

| Order code | Marking | Package  | Packing       |
|------------|---------|----------|---------------|
| STD9N65M2  | 9N65M2  | DPAK     | Tape and reel |
| STF9N65M2  |         | TO-220FP | Tube          |
| STP9N65M2  |         | TO-220   |               |
| STU9N65M2  |         | IPAK     |               |

## Revision history

**Table 16. Document revision history**

| Date        | Version | Changes                                                                                                                                                                                                                                                                                                             |
|-------------|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 24-Feb-2014 | 1       | First release.                                                                                                                                                                                                                                                                                                      |
| 15-Jul-2014 | 2       | <ul style="list-style-type: none"> <li>– Modified: title, <i>Features</i> and <i>Description</i></li> <li>– Modified: <i>Figure 5</i> and <i>15</i></li> <li>– Updated: <i>Figure 28</i> and <i>Table 12</i></li> <li>– Minor text changes.</li> </ul>                                                              |
| 19-Jun-2019 | 3       | <p>Removed maturity status indication from cover page. The document status is production data.</p> <p>Updated <a href="#">Section 1 Electrical ratings</a>, <a href="#">Section 2 Electrical characteristics</a> and <a href="#">Section 2.1 Electrical characteristics (curves)</a></p> <p>Minor text changes.</p> |

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