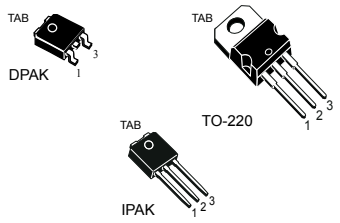
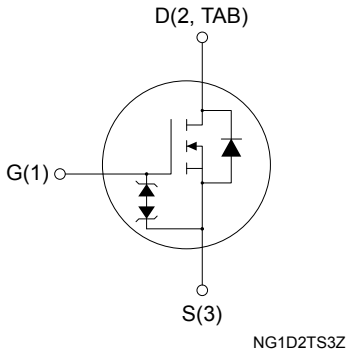
# STD5N60M2, STP5N60M2, STU5N60M2

Datasheet

## N-channel 600 V, 1.3 Ω typ., 3.5 A, MDmesh™ M2 Power MOSFETs in DPAK, TO-220 and IPAK packages




## Features

| Order code | $V_{DS}$@ $T_{Jmax}$ | $R_{DS(on)}$ max. | $I_D$ |
|---|---|---|---|
| STD5N60M2 | 650 V | 1.4 Ω | 3.5 A |
| STP5N60M2 | | | |
| STU5N60M2 | | | |

- 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 links |
|---|
| STD5N60M2 |
| STP5N60M2 |
| STU5N60M2 |

# 1 Electrical ratings

**Table 1. Absolute maximum ratings**

| Symbol | Parameter | Value | Unit |
|---|---|---|---|
| $V_{GS}$ | Gate-source voltage | ±25 | V |
| $I_D$ | Drain current (continuous) at $T_C$ = 25 °C | 3.5 | A |
| | Drain current (continuous) at $T_C$ = 100 °C | 2.2 | |
| $I_{DM}$ (1) | Drain current (pulsed) | 14 | A |
| $P_{TOT}$ | Total dissipation at $T_C$ = 25 °C | 45 | W |
| dv/dt (2) | Peak diode recovery voltage slope | 15 | V/ns |
| dv/dt (3) | MOSFET dv/dt ruggedness | 50 | |
| $T_{stg}$ | Storage temperature range | -55 to 150 | °C |
| $T_j$ | Operating junction temperature range | | |

1. *Pulse width limited by safe operating area.*
2. *$I_{SD}$ ≤ 3.5 A, di/dt ≤ 400 A/µs; $V_{DS}$ peak < $V_{(BR)DSS}$, $V_{DD}$ = 400 V.*
3. *$V_{DS}$ ≤ 480 V.*

**Table 2. Thermal data**

| Symbol | Parameter | Value | | | Unit |
|---|---|---|---|---|---|
| | | DPAK | TO-220 | IPAK | |
| $R_{thj\text{-}case}$ | Thermal resistance junction-case | 2.8 | | | °C/W |
| $R_{thj\text{-}pcb}$ (1) | Thermal resistance junction-pcb | 50 | | | |
| $R_{thj\text{-}amb}$ | Thermal resistance junction-ambient | | 62.5 | 100 | |

1. *When mounted on 1 inch² FR-4, 2 Oz copper board.*

**Table 3. Avalanche characteristics**

| Symbol | Parameter | Value | Unit |
|---|---|---|---|
| $I_{AR}$ | Avalanche current, repetitive or not repetitive (1) | 0.5 | A |
| $E_{AS}$ | Single pulse avalanche energy (2) | 80 | mJ |

1. *Pulse width limited by $T_{jmax}$*
2. *Starting $T_j$ = 25 °C, $I_D$ = $I_{AR}$, $V_{DD}$ = 50 V*

# 2 Electrical characteristics

($T_{case}$ = 25 °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 V, $I_D$ = 1 mA | 600 | | | V |
| $I_{DSS}$ | Zero gate voltage drain current | $V_{GS}$ = 0 V, $V_{DS}$ = 600 V | | | 1 | µA |
| | | $V_{GS}$ = 0 V, $V_{DS}$ = 600 V, $T_C$ = 125 °C (1) | | | 100 | |
| $I_{GSS}$ | Gate-body leakage current | $V_{DS}$ = 0 V, $V_{GS}$ = ±25 V | | | ±10 | µA |
| $V_{GS(th)}$ | Gate threshold voltage | $V_{DS}$ = $V_{GS}$, $I_D$ = 250 µA | 2 | 3 | 4 | V |
| $R_{DS(on)}$ | Static drain-source on-resistance | $V_{GS}$ = 10 V, $I_D$ = 1.7 A | | 1.3 | 1.4 | Ω |

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 V, f = 1 MHz, $V_{GS}$ = 0 V | - | 211 | - | pF |
| $C_{oss}$ | Output capacitance | | - | 13 | - | |
| $C_{rss}$ | Reverse transfer capacitance | | - | 0.75 | - | |
| $C_{oss\ eq.}$ (1) | Equivalent output capacitance | $V_{DS}$ = 0 to 480 V, $V_{GS}$ = 0 V | - | 19.5 | - | pF |
| $R_G$ | Intrinsic gate resistance | f = 1 MHz open drain | - | 6.2 | - | Ω |
| $Q_g$ | Total gate charge | $V_{DD}$ = 480 V, $I_D$ = 3.5 A, $V_{GS}$ = 0 to 10 V (see Figure 16. Test circuit for gate charge behavior) | - | 8 | - | nC |
| $Q_{gs}$ | Gate-source charge | | - | 1.6 | - | |
| $Q_{gd}$ | Gate-drain charge | | - | 4.4 | - | |

1. *$C_{oss\ eq.}$ 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 | $V_{DD}$ = 300 V, $I_D$ = 1.7 A, $R_G$ = 4.7 Ω, $V_{GS}$ = 10 V (see Figure 15. Test circuit for resistive load switching times and Figure 20. Switching time waveform) | - | 12 | - | ns |
| $t_r$ | Rise time | | - | 3 | - | |
| $t_{d(off)}$ | Turn-off delay time | | - | 70 | - | |
| $t_f$ | Fall time | | - | 15 | - | |

**Table 7. Source-drain diode**

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $I_{SD}$ | Source-drain current | | - | | 3.5 | A |
| $I_{SDM}$(1) | Source-drain current (pulsed) | | - | | 14 | A |
| $V_{SD}$(2) | Forward on voltage | $V_{GS}$ = 0 V, $I_{SD}$ = 3.5 A | - | | 1.6 | V |
| $t_{rr}$ | Reverse recovery time | $I_{SD}$ = 3.5 A, di/dt = 100 A/µs, $V_{DD}$ = 60 V (see Figure 17. Test circuit for inductive load switching and diode recovery times) | - | 220 | | ns |
| $Q_{rr}$ | Reverse recovery charge | | - | 1.05 | | µC |
| $I_{RRM}$ | Reverse recovery current | | - | 9.5 | | A |
| $t_{rr}$ | Reverse recovery time | $I_{SD}$ = 3.5 A, di/dt = 100 A/µs, $V_{DD}$ = 60 V, $T_j$ = 150 °C (see Figure 17. Test circuit for inductive load switching and diode recovery times) | - | 314 | | ns |
| $Q_{rr}$ | Reverse recovery charge | | - | 1.5 | | µC |
| $I_{RRM}$ | Reverse recovery current | | - | 9.5 | | A |

1. *Pulse width is limited by safe operating area.*
2. *Pulse test: pulse duration = 300 µs, duty cycle 1.5 %.*

## 2.1 Electrical characteristics (curves)

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

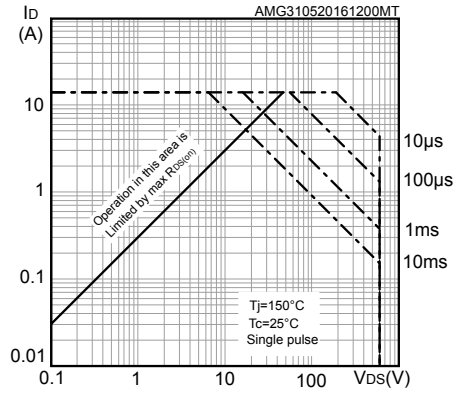



**Figure 2. Thermal impedance for DPAK and IPAK**

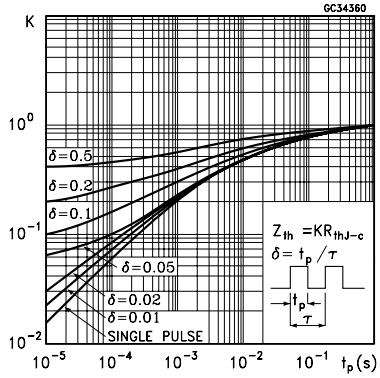



**Figure 3. Safe operating area for TO-220**

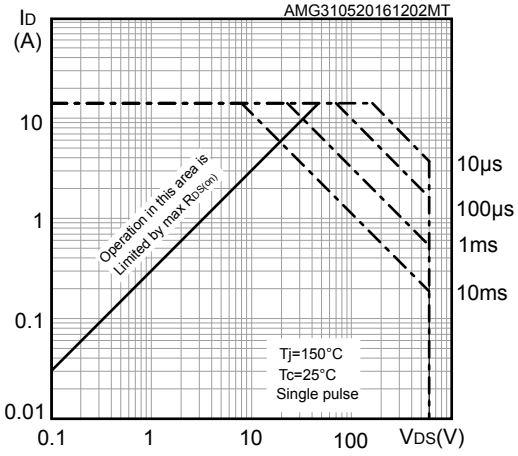



**Figure 4. Thermal impedance for TO-220**

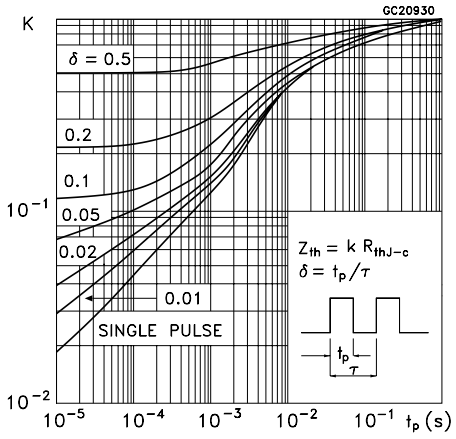



**Figure 5. Output characteristics**

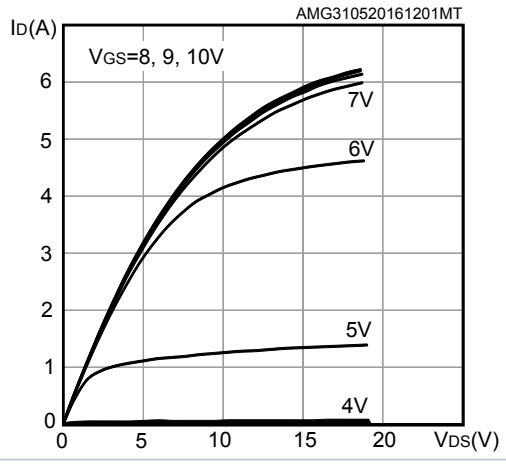



**Figure 6. Transfer characteristics**

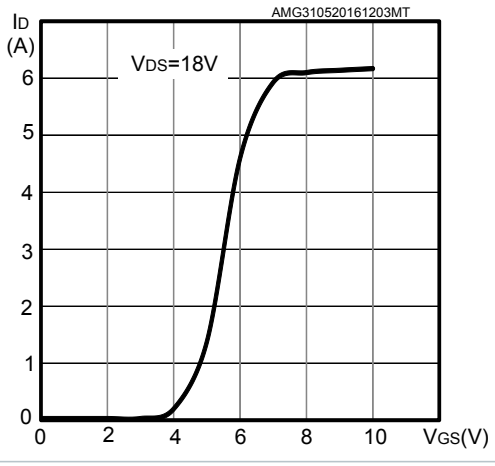


**Figure 7. Gate charge vs gate-source voltage**

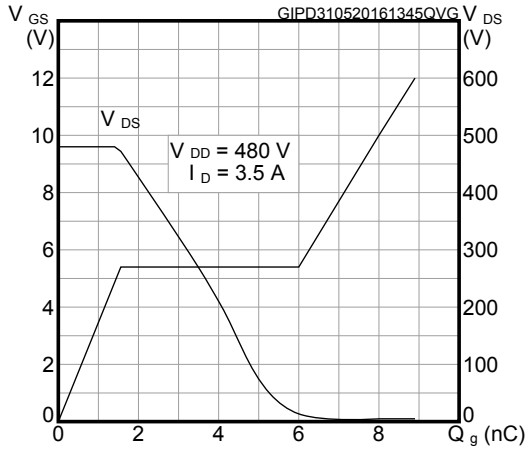



**Figure 8. Static drain-source on-resistance**

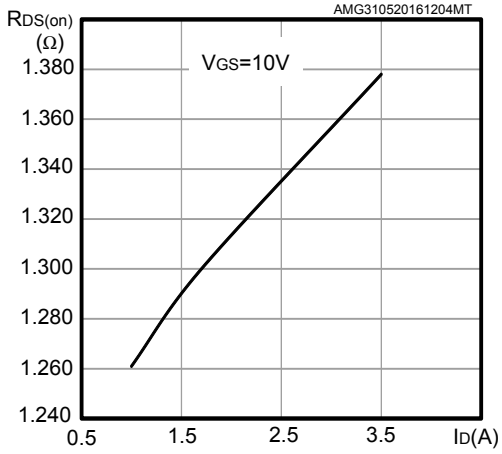



**Figure 9. Capacitance variations**

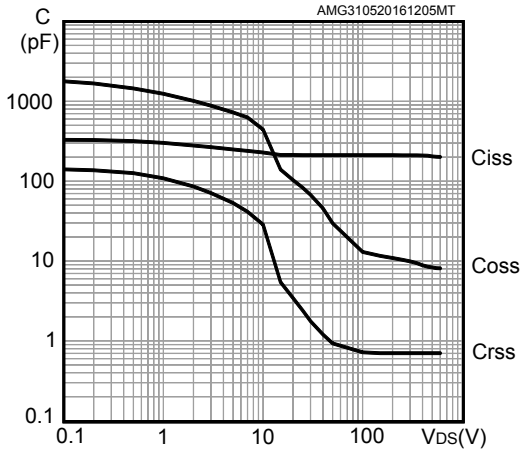



**Figure 10. Output capacitance stored energy**

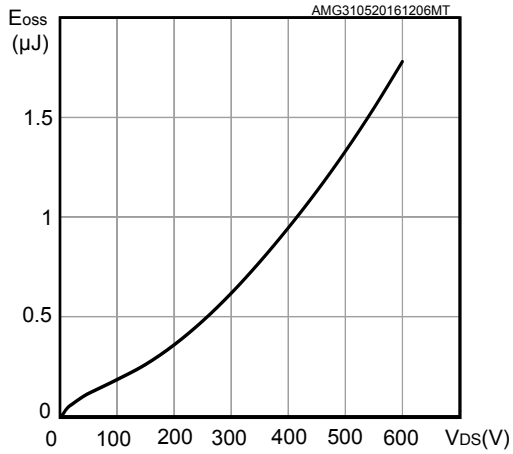



**Figure 11. Normalized gate threshold voltage vs temperature**

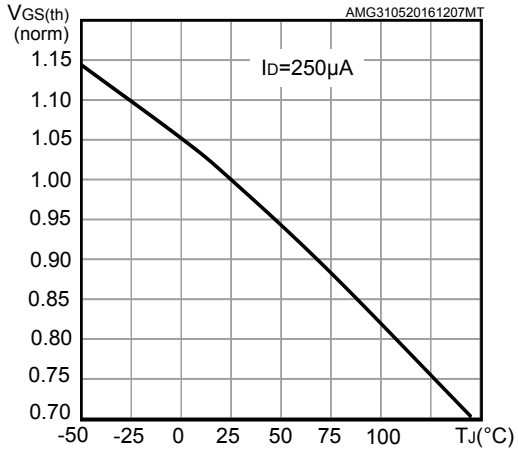



**Figure 12. Normalized on-resistance vs temperature**

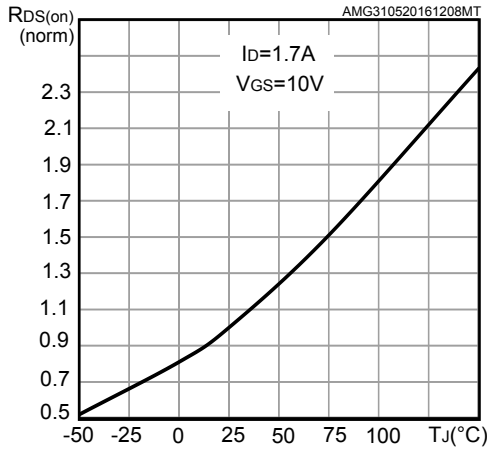


**Figure 13. Normalized $V_{(BR)DSS}$ vs temperature**

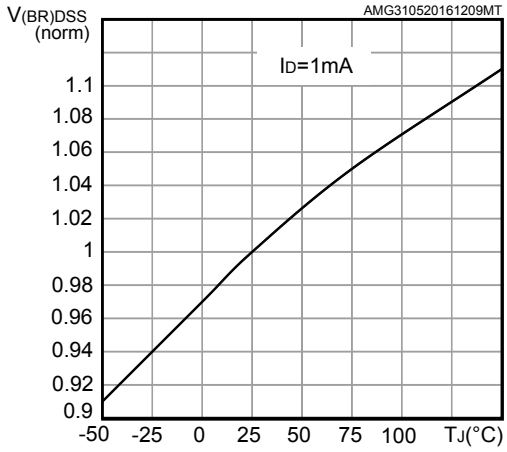
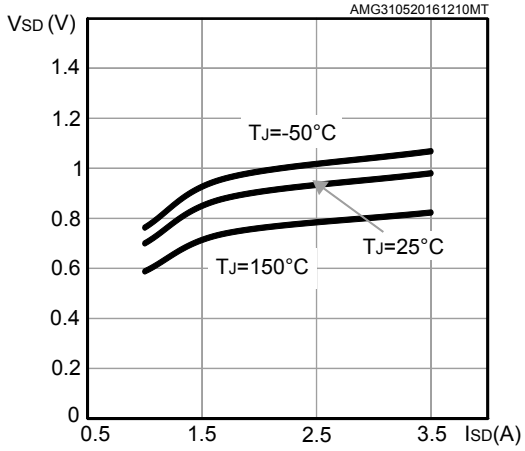



**Figure 14. Source- drain diode forward characteristics**



# 3 Test circuits

**Figure 15. Test circuit for resistive load switching times**

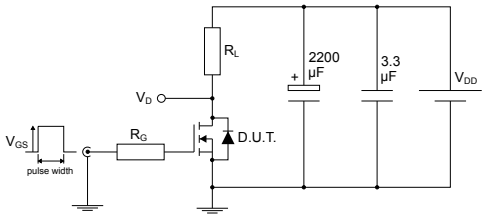



**Figure 16. Test circuit for gate charge behavior**

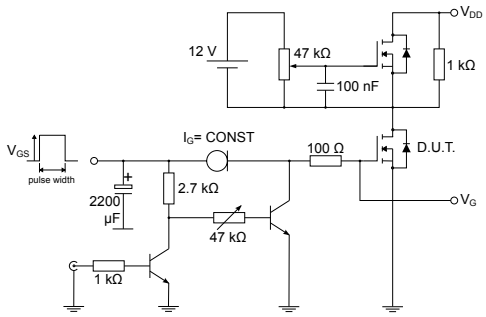



**Figure 17. Test circuit for inductive load switching and diode recovery times**

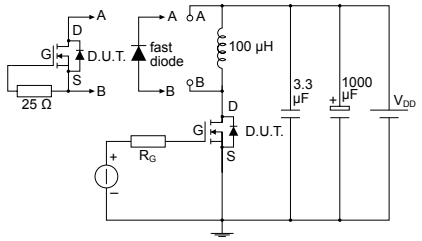



**Figure 18. Unclamped inductive load test circuit**

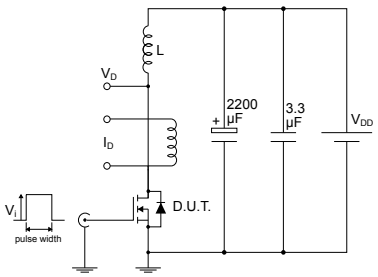



**Figure 19. Unclamped inductive waveform**

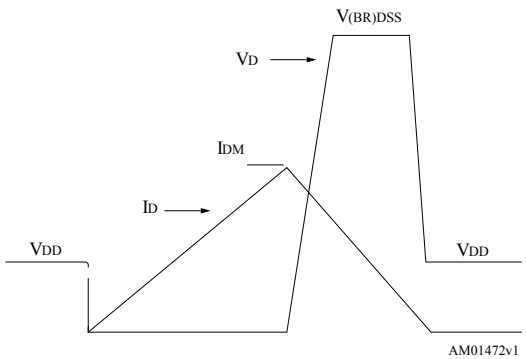
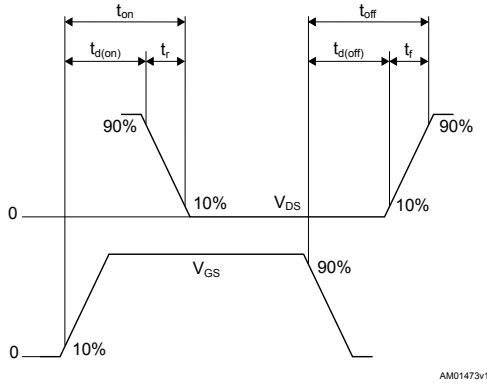



**Figure 20. Switching time waveform**



# 4 Package information

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. ECOPACK® is an ST trademark.

## 4.1 DPAK (TO-252) type A2 package information

Figure 21. **DPAK (TO-252) type A2 package outline**

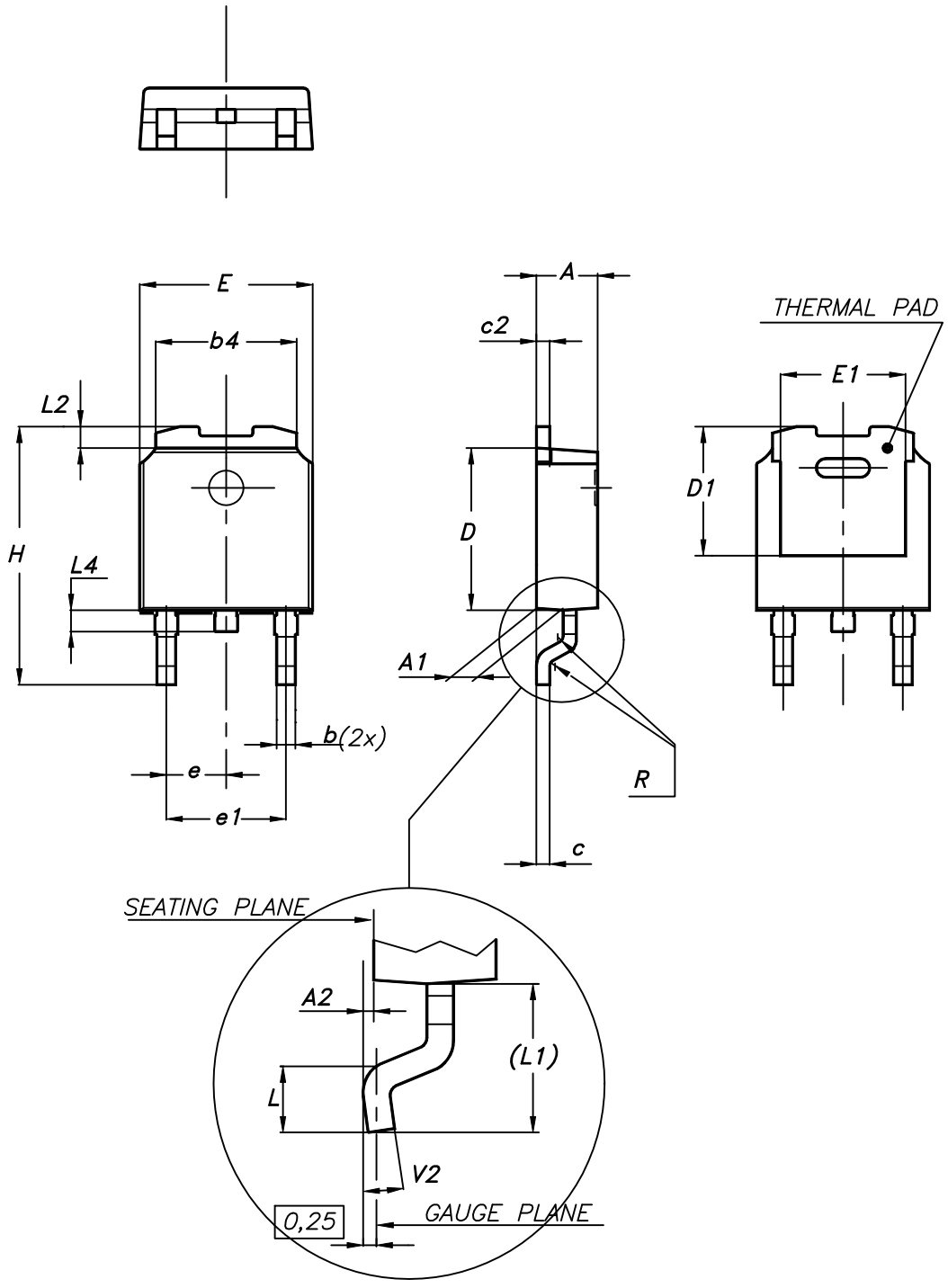
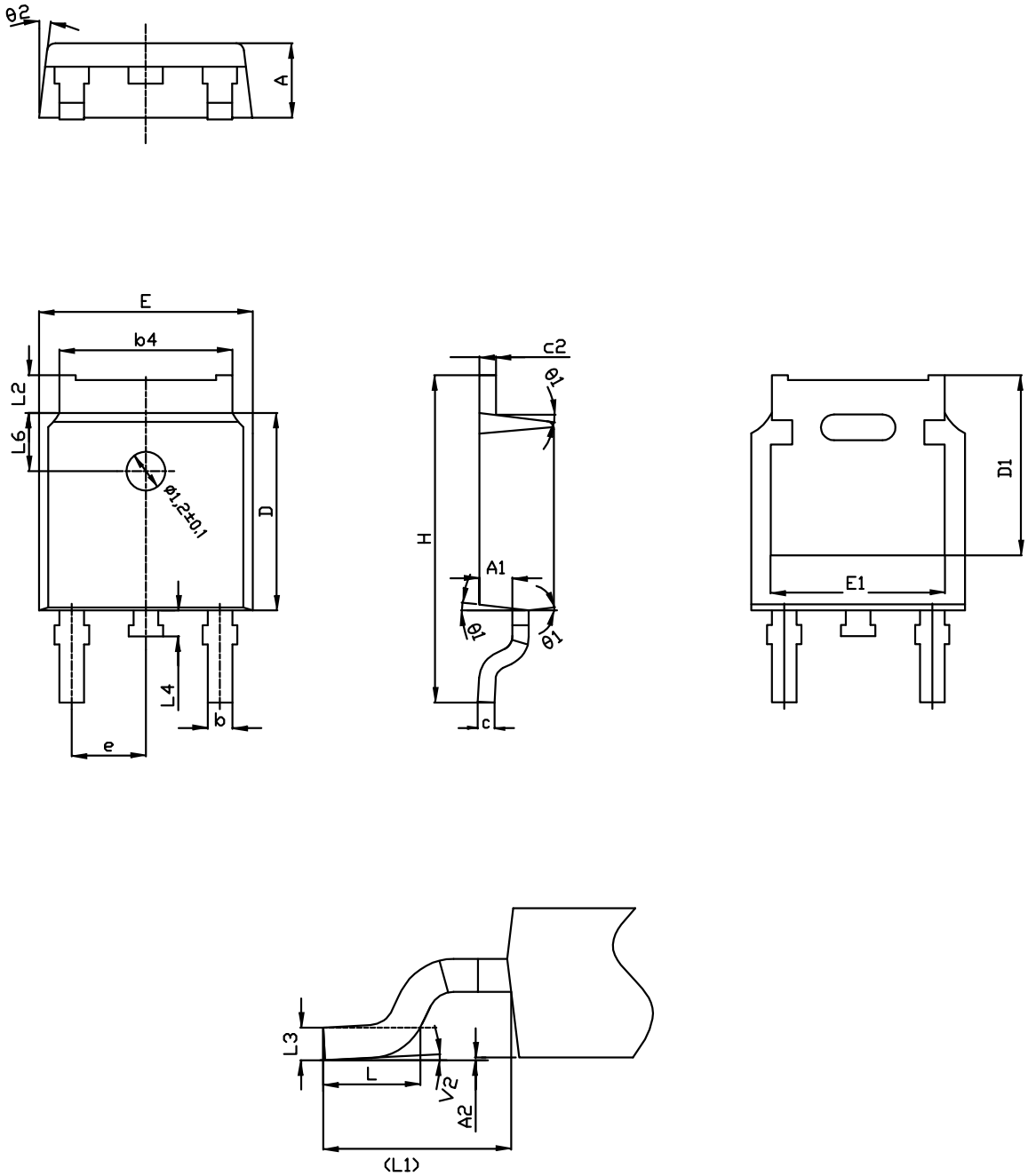


Table 8. **DPAK (TO-252) type A2 mechanical data**

| 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 | 5.10 | 5.20 | 5.30 |
| 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 22. **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° |

## 4.3 DPAK (TO-252) type E package information

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

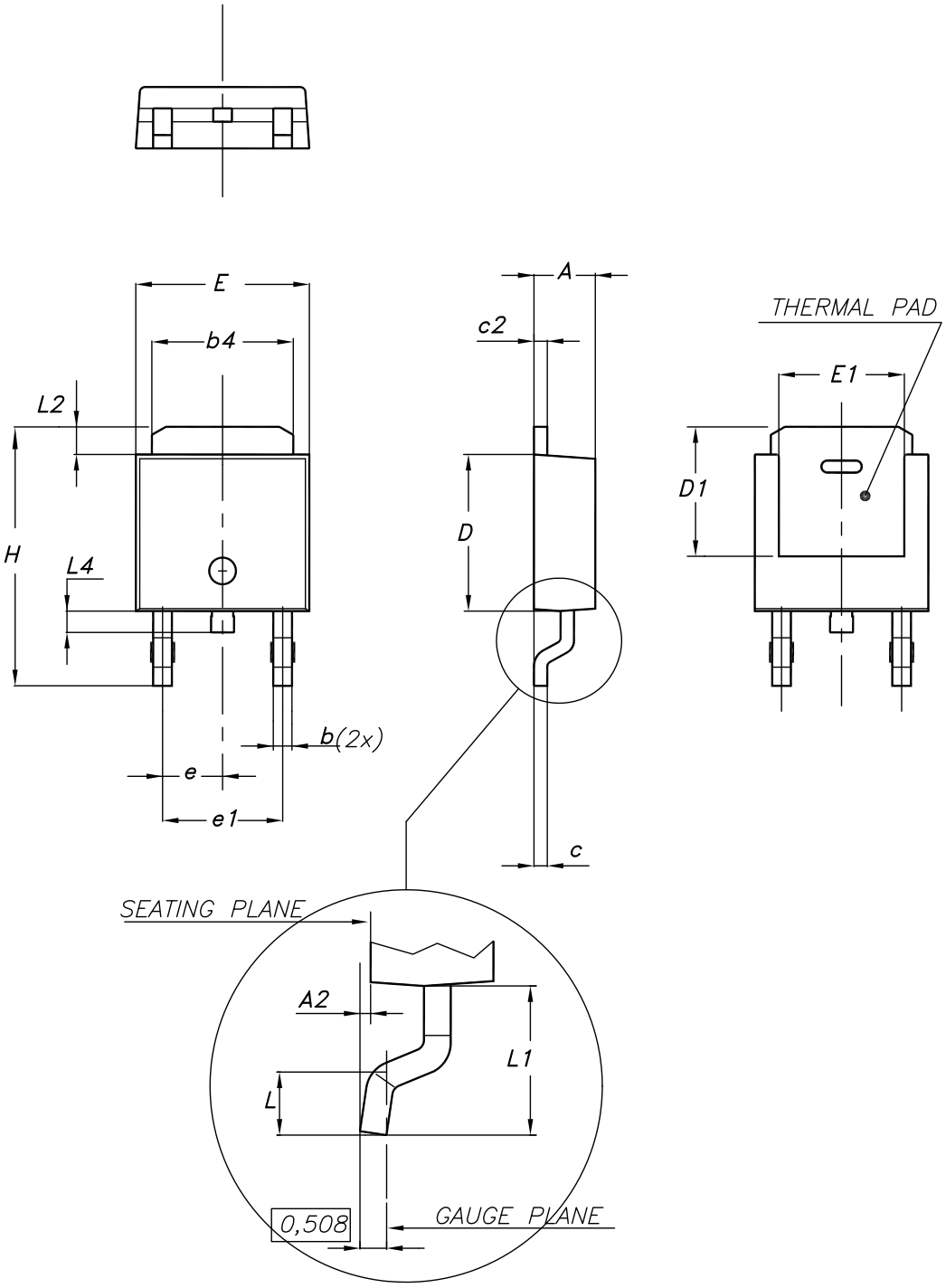
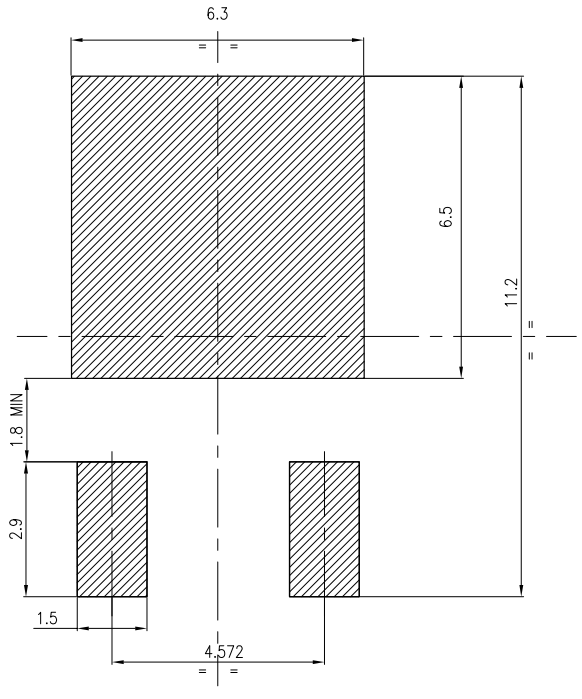


Table 10. **DPAK (TO-252) type E mechanical data**

| Dim. | mm | | |
|---|---|---|---|
| | Min. | Typ. | Max. |
| A | 2.18 | | 2.39 |
| A2 | | | 0.13 |
| b | 0.65 | | 0.884 |
| b4 | 4.95 | | 5.46 |
| c | 0.46 | | 0.61 |
| c2 | 0.46 | | 0.60 |
| D | 5.97 | | 6.22 |
| D1 | 5.21 | | |
| E | 6.35 | | 6.73 |
| E1 | 4.32 | | |
| e | | 2.286 | |
| e1 | | 4.572 | |
| H | 9.94 | | 10.34 |
| L | 1.50 | | 1.78 |
| L1 | | 2.74 | |
| L2 | 0.89 | | 1.27 |
| L4 | | | 1.02 |

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




FP_0068772_25

## 4.4 DPAK (TO-252) packing information

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

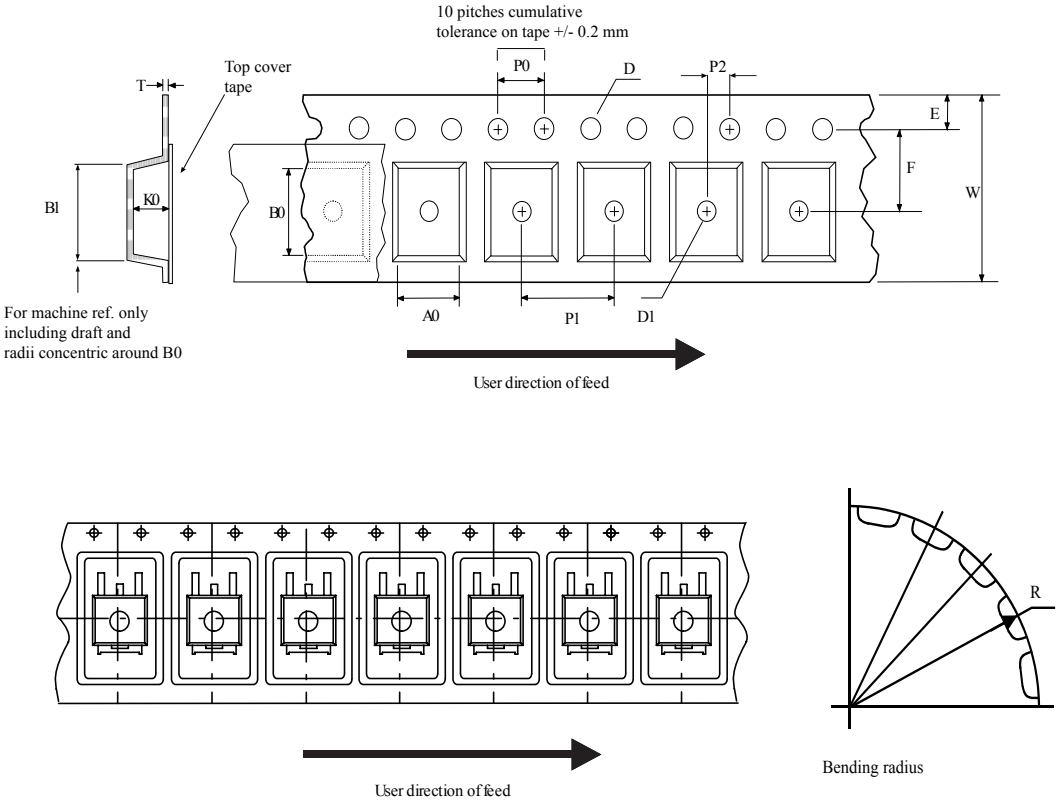
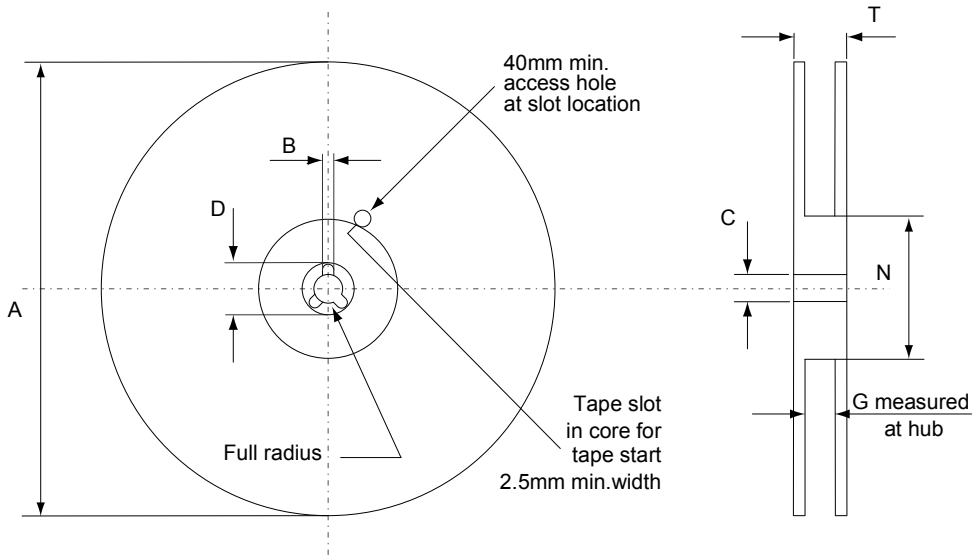


Figure 26. **DPAK (TO-252) reel outline**



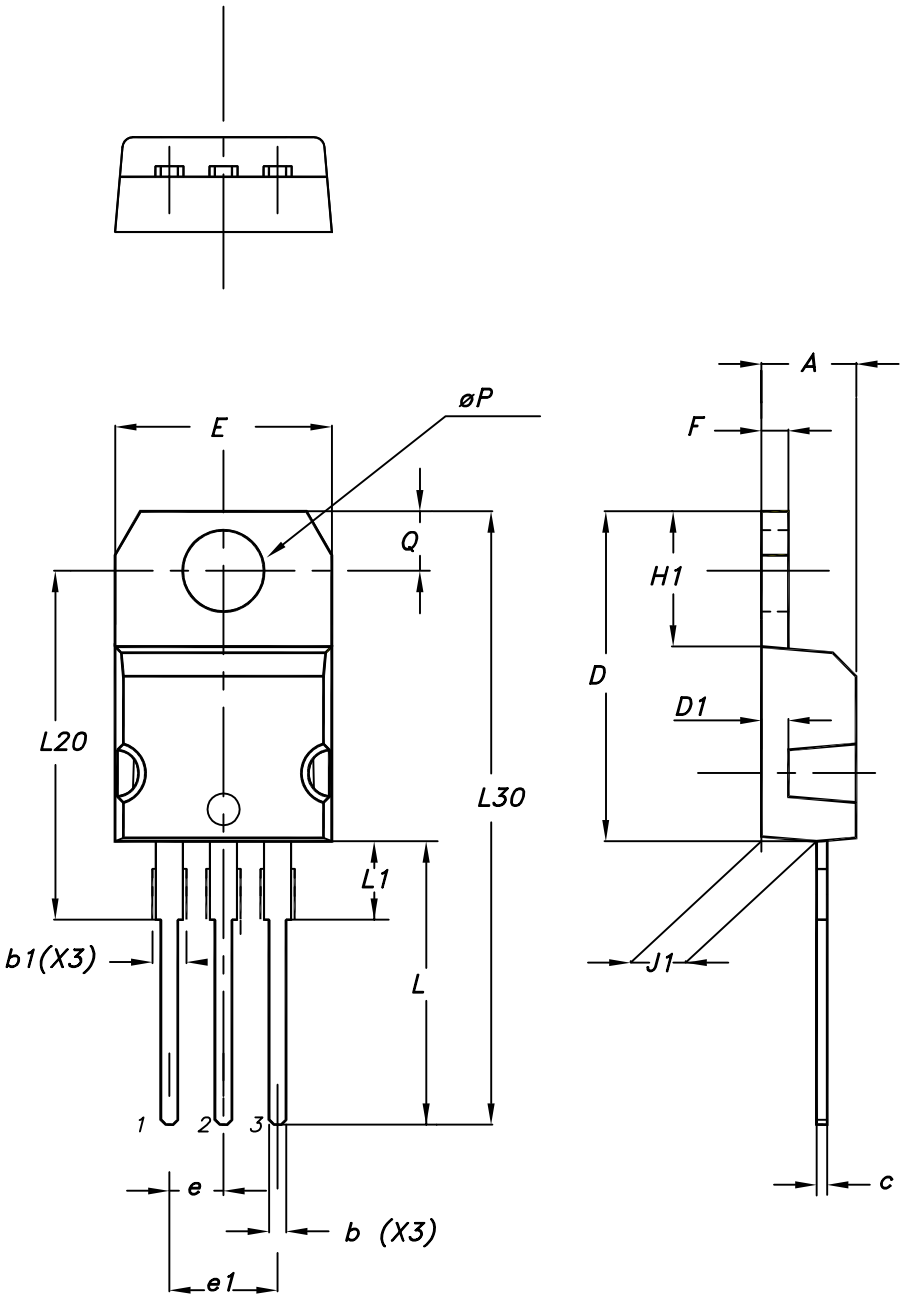

AM06038v1

Table 11. **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 | | | |

## 4.5 TO-220 type A package information

Figure 27. **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 |

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

Figure 28. **IPAK (TO-251) type A package outline**

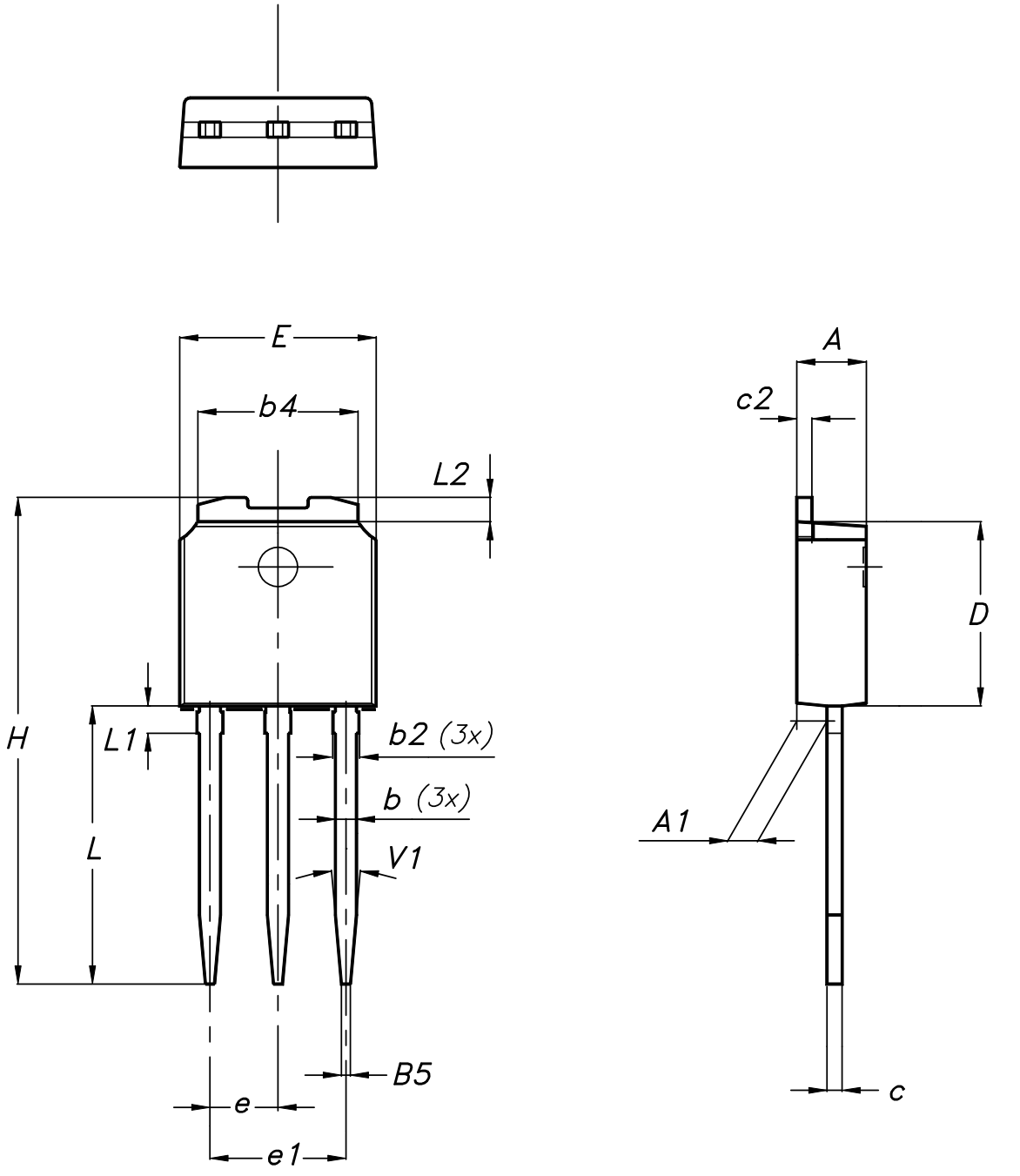
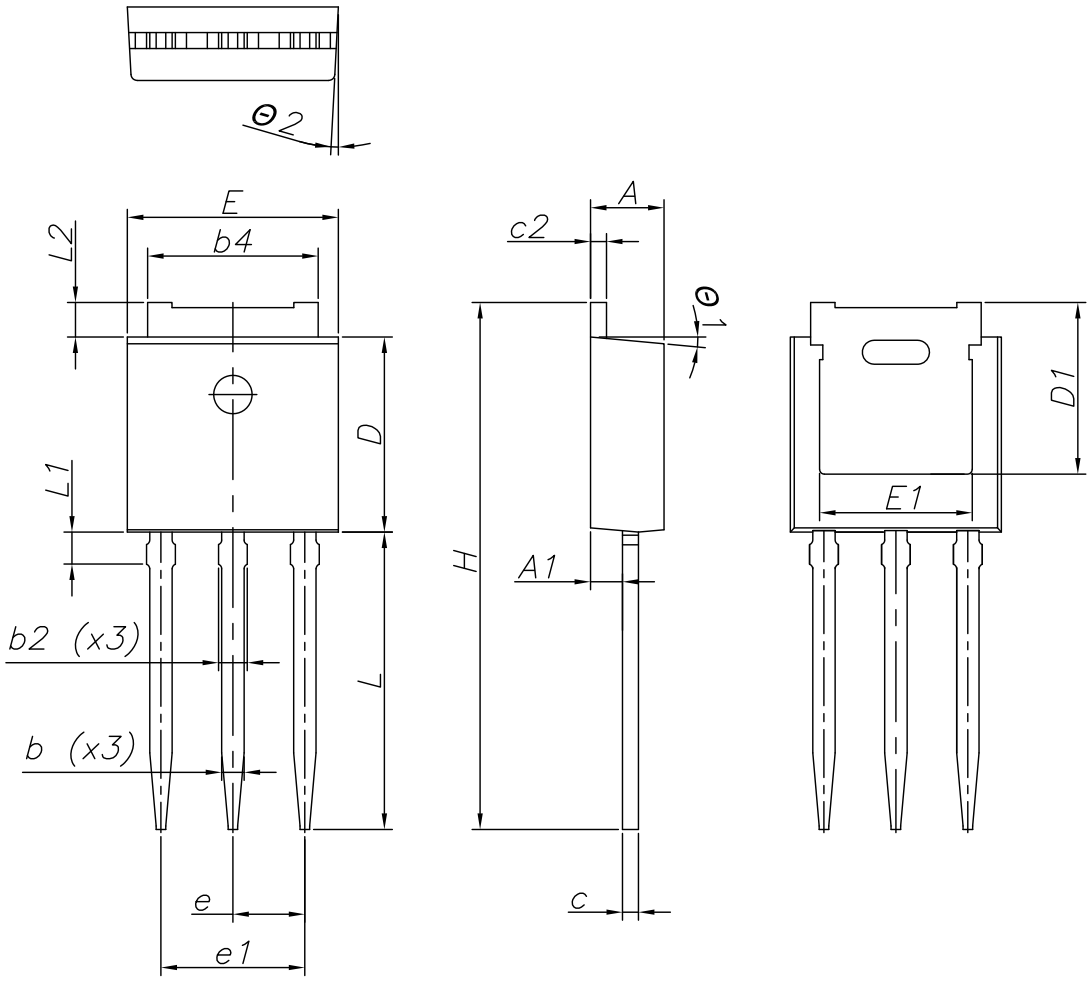


Table 13. **IPAK (TO-251) type A package mechanical data**

| 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 29. **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. **Ordering information**

| Order code | Marking | Package | Packing |
|---|---|---|---|
| STD5N60M2 | 5N60M2 | DPAK | Tape and reel |
| STP5N60M2 | | TO-220 | Tube |
| STU5N60M2 | | IPAK | |

## Revision history

Table 16. **Document revision history**

| Date | Revision | Changes |
|---|---|---|
| 30-Sep-2013 | 1 | First release. |
| 20-Mar-2014 | 2 | – Modified: ID, IDM and note 2 values in Table 2<br>– Modified: the entire values in Table 4<br>– Modified: RDS(on) typical and ID values in Table 5<br>– Modified: the entire typical values, ISD and ISDM in Table 6, 7 and 8<br>– Updated: Section 4.1: DPAK, STD5N60M2<br>– Minor text changes |
| 08-Jun-2016 | 3 | Updated title, features, applications and description in cover page. Updated *Section 1: "Electrical ratings"*, *Table 6: "Dynamic"* and *Section 2.1: "Electrical characteristics (curves)"*.<br>Updated IPAK C<br>Minor text changes |
| 16-Jun-2016 | 4 | Updated *Figure 1: "Internal schematic diagram"*.<br>Updated *Table 7: "Switching times"* and *Table 8: "Source-drain diode"*.<br>Minor text changes. |
| 01-Oct-2018 | 5 | Updated Section 4 Package information.<br>Minor text changes |

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