



# THE DATASHEET OF GAN041-650WSBQ





# GAN041-650WSB

650 V, 35 mΩ Gallium Nitride (GaN) FET in a TO-247 package

4 June 2024

Product data sheet

## 1. General description

The GAN041-650WSB is a 650 V, 35 mΩ Gallium Nitride (GaN) FET in a TO-247 package. It is a normally-off device that combines Nexperia's latest high-voltage GaN HEMT H2 technology and low-voltage silicon MOSFET technologies — offering superior reliability and performance.

## 2. Features and benefits

- Ultra-low reverse recovery charge
- Simple gate drive (0 V to +10 V or 12 V)
- Robust gate oxide ( $\pm 20$  V capability)
- High gate threshold voltage (+4 V) for very good gate bounce immunity
- Very low source-drain voltage in reverse conduction mode
- Transient over-voltage capability

## 3. Applications

- Hard and soft switching converters for industrial and datacom power
- Bridgeless totempole PFC
- PV and UPS inverters
- Servo motor drives

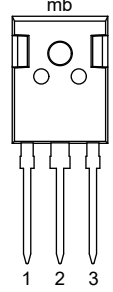
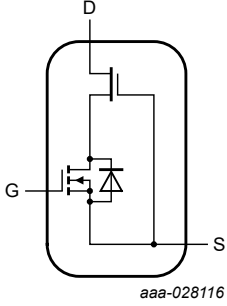
## 4. Quick reference data

Table 1. Quick reference data

| Symbol                         | Parameter                        | Conditions  | Min | Typ | Max  | Unit |
|--------------------------------|----------------------------------|---|-----|-----|------|------|
| $V_{DS}$                       | drain-source voltage             | $-55\text{ °C} \leq T_j \leq 175\text{ °C}$   | -   | -   | 650  | V    |
| $I_D$                          | drain current                    | $V_{GS} = 10\text{ V}; T_{mb} = 25\text{ °C}; \text{Fig. 2}$  | -   | -   | 47.2 | A    |
| $P_{tot}$                      | total power dissipation          | $T_{mb} = 25\text{ °C}; \text{Fig. 1}$  | -   | -   | 187  | W    |
| $T_j$                          | junction temperature             |   | -55 | -   | 175  | °C   |
| <b>Static characteristics</b>  |                                  |   |     |     |      |      |
| $R_{DSon}$                     | drain-source on-state resistance | $V_{GS} = 10\text{ V}; I_D = 32\text{ A}; T_j = 25\text{ °C}; \text{Fig. 11}$   | -   | 35  | 41   | mΩ   |
| <b>Dynamic characteristics</b> |                                  |   |     |     |      |      |
| $Q_{GD}$                       | gate-drain charge                | $I_D = 32\text{ A}; V_{DS} = 400\text{ V}; V_{GS} = 10\text{ V}; T_j = 25\text{ °C}; \text{Fig. 13}; \text{Fig. 14}$  | -   | 6.6 | -    | nC   |
| $Q_{G(tot)}$                   | total gate charge                |   | -   | 22  | -    | nC   |
| <b>Source-drain diode</b>      |                                  |   |     |     |      |      |
| $Q_r$                          | recovered charge                 | $I_S = 32\text{ A}; di_S/dt = -1000\text{ A}/\mu\text{s}; V_{GS} = 0\text{ V}; V_{DS} = 400\text{ V}; \text{Fig. 20}$ | -   | 150 | -    | nC   |

## 5. Pinning information

Table 2. Pinning information

| Pin | Symbol | Description                        | Simplified outline  | Graphic symbol  |
|-----|--------|------------------------------------|---|---|
| 1   | G      | gate                               |  <p>TO-247-3L (SOT429-3)</p> |  <p>aaa-028116</p> |
| 2   | S      | source                             |   |   |
| 3   | D      | drain                              |   |   |
| mb  | S      | mounting base; connected to source |   |   |

## 6. Ordering information

Table 3. Ordering information

| Type number   | Package   |  |          |
|---------------|-----------|--|----------|
|               | Name      | Description  | Version  |
| GAN041-650WSB | TO-247-3L | Plastic single-ended through-hole package; heatsink mounted; 1 mounting hole; 3-lead TO-247-3L | SOT429-3 |

## 7. Marking

Table 4. Marking codes

| Type number   | Marking code     |
|---------------|------------------|
| GAN041-650WSB | GAN041<br>650WSB |

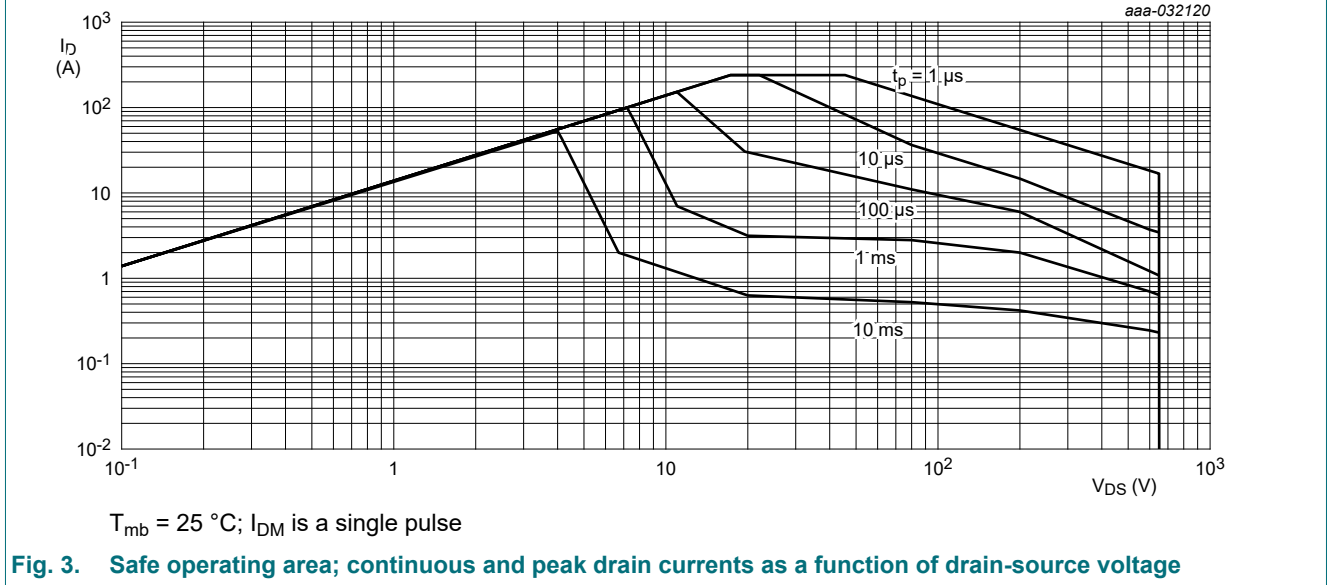
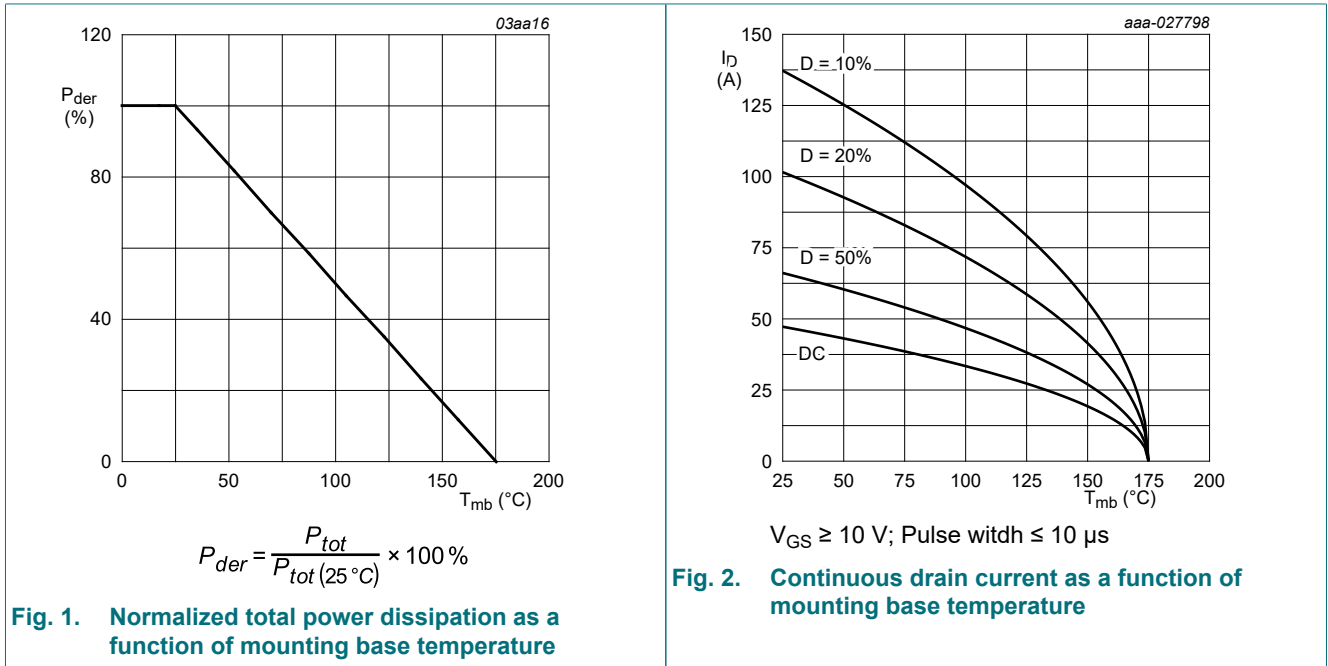
## 8. Limiting values

Table 5. Limiting values

In accordance with the Absolute Maximum Rating System (IEC 60134).

| Symbol       | Parameter                         | Conditions  | Min | Max  | Unit |
|--------------|-----------------------------------|---|-----|------|------|
| $V_{DS}$     | drain-source voltage              | $-55\text{ °C} \leq T_j \leq 175\text{ °C}$   | -   | 650  | V    |
| $V_{TDS}$    | transient drain to source voltage | pulsed; $t_p = 1\text{ }\mu\text{s}$ ; $\delta_{factor} = 0.01$                             | -   | 725  | V    |
| $V_{GS}$     | gate-source voltage               |   | -20 | 20   | V    |
| $P_{tot}$    | total power dissipation           | $T_{mb} = 25\text{ °C}$ ; <a href="#">Fig. 1</a>  | -   | 187  | W    |
| $I_D$        | drain current                     | $V_{GS} = 10\text{ V}$ ; $T_{mb} = 25\text{ °C}$ ; <a href="#">Fig. 2</a>                   | -   | 47.2 | A    |
|              |                                   | $V_{GS} = 10\text{ V}$ ; $T_{mb} = 100\text{ °C}$ ; <a href="#">Fig. 2</a>                  | -   | 33.4 | A    |
| $I_{DM}$     | peak drain current                | pulsed; $t_p \leq 10\text{ }\mu\text{s}$ ; $T_{mb} = 25\text{ °C}$ ; <a href="#">Fig. 3</a> | -   | 240  | A    |
| $T_{stg}$    | storage temperature               |   | -55 | 175  | °C   |
| $T_j$        | junction temperature              |   | -55 | 175  | °C   |
| $T_{sld(M)}$ | peak soldering temperature        |   | -   | 260  | °C   |

| Symbol                    | Parameter           | Conditions  | Min | Max  | Unit |
|---------------------------|---------------------|---|-----|------|------|
| <b>Source-drain diode</b> |                     |   |     |      |      |
| I <sub>S</sub>            | source current      | T <sub>mb</sub> = 25 °C; V <sub>GS</sub> = 0 V          | -   | 47.2 | A    |
| I <sub>SM</sub>           | peak source current | pulsed; t <sub>p</sub> ≤ 10 μs; T <sub>mb</sub> = 25 °C | -   | 240  | A    |



## 9. Thermal characteristics

Table 6. Thermal characteristics

| Symbol                | Parameter   | Conditions | Min | Typ | Max | Unit |
|-----------------------|---|------------|-----|-----|-----|------|
| R <sub>th(j-mb)</sub> | thermal resistance from junction to mounting base | Fig. 4     | -   | -   | 0.8 | K/W  |
| R <sub>th(j-sp)</sub> | thermal resistance from junction to solder point  |            | -   | -   | 40  | K/W  |

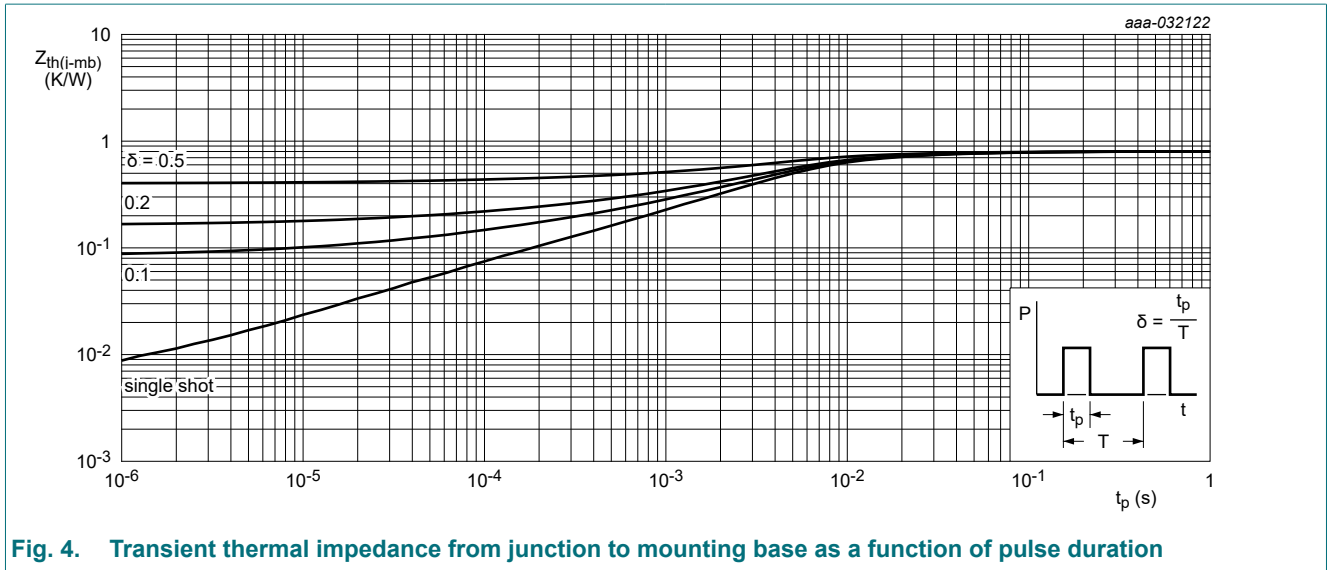


Fig. 4. Transient thermal impedance from junction to mounting base as a function of pulse duration

## 10. Characteristics

Table 7. Characteristics

| Symbol                         | Parameter                                    | Conditions   | Min | Typ  | Max | Unit          |
|--------------------------------|--|--|-----|------|-----|---------------|
| <b>Static characteristics</b>  |  |  |     |      |     |               |
| $V_{GS(th)}$                   | gate-source threshold voltage                | $I_D = 1 \text{ mA}; V_{DS}=V_{GS}; T_j = 25 \text{ }^\circ\text{C}$   | 3.4 | 3.9  | 4.5 | V             |
|                                |  | $I_D = 1 \text{ mA}; V_{DS}=V_{GS}; T_j = 175 \text{ }^\circ\text{C};$<br><a href="#">Fig. 10</a>  | 2.2 | -    | -   | V             |
|                                |  | $I_D = 1 \text{ mA}; V_{DS}=V_{GS}; T_j = -55 \text{ }^\circ\text{C};$<br><a href="#">Fig. 10</a>  | -   | -    | 5.2 | V             |
| $I_{DSS}$                      | drain leakage current                        | $V_{DS} = 650 \text{ V}; V_{GS} = 0 \text{ V}; T_j = 25 \text{ }^\circ\text{C}$  | -   | 2.5  | 25  | $\mu\text{A}$ |
|                                |  | $V_{DS} = 650 \text{ V}; V_{GS} = 0 \text{ V}; T_j = 175 \text{ }^\circ\text{C}$   | -   | 20   | -   | $\mu\text{A}$ |
| $I_{GSS}$                      | gate leakage current                         | $V_{GS} = -20 \text{ V}; V_{DS} = 0 \text{ V}; T_j = 25 \text{ }^\circ\text{C}$  | -   | 10   | 400 | nA            |
|                                |  | $V_{GS} = 20 \text{ V}; V_{DS} = 0 \text{ V}; T_j = 25 \text{ }^\circ\text{C}$   | -   | 10   | 400 | nA            |
| $R_{DSon}$                     | drain-source on-state resistance             | $V_{GS} = 10 \text{ V}; I_D = 32 \text{ A}; T_j = 25 \text{ }^\circ\text{C};$<br><a href="#">Fig. 11</a>   | -   | 35   | 41  | mΩ            |
|                                |  | $V_{GS} = 10 \text{ V}; I_D = 32 \text{ A}; T_j = 175 \text{ }^\circ\text{C};$<br><a href="#">Fig. 12</a>  | -   | 84   | 98  | mΩ            |
| $R_G$                          | gate resistance                              | $f = 1 \text{ MHz}$  | 0.8 | 1.9  | 4.8 | Ω             |
| <b>Dynamic characteristics</b> |  |  |     |      |     |               |
| $Q_{G(tot)}$                   | total gate charge                            | $I_D = 32 \text{ A}; V_{DS} = 400 \text{ V}; V_{GS} = 10 \text{ V};$<br>$T_j = 25 \text{ }^\circ\text{C};$ <a href="#">Fig. 13</a> ; <a href="#">Fig. 14</a> | -   | 22   | -   | nC            |
| $Q_{GS}$                       | gate-source charge                           |  | -   | 8.4  | -   | nC            |
| $Q_{GD}$                       | gate-drain charge                            |  | -   | 6.6  | -   | nC            |
| $C_{iss}$                      | input capacitance                            | $V_{DS} = 400 \text{ V}; V_{GS} = 0 \text{ V}; f = 1 \text{ MHz};$<br>$T_j = 25 \text{ }^\circ\text{C};$ <a href="#">Fig. 15</a>                             | -   | 1500 | -   | pF            |
| $C_{oss}$                      | output capacitance                           |  | -   | 147  | -   | pF            |
| $C_{rss}$                      | reverse transfer capacitance                 |  | -   | 5    | -   | pF            |
| $C_{o(er)}$                    | effective output capacitance, energy related | $0 \text{ V} \leq V_{DS} \leq 400 \text{ V}; V_{GS} = 0 \text{ V};$<br>$f = 1 \text{ MHz}; T_j = 25 \text{ }^\circ\text{C};$ <a href="#">Fig. 16</a>         | -   | 220  | -   | pF            |
| $C_{o(tr)}$                    | effective output capacitance, time related   | $0 \text{ V} \leq V_{DS} \leq 400 \text{ V}; V_{GS} = 0 \text{ V};$<br>$f = 1 \text{ MHz}; T_j = 25 \text{ }^\circ\text{C}$                                  | -   | 380  | -   | pF            |

| Symbol                    | Parameter             | Conditions   | Min | Typ | Max | Unit |
|---------------------------|-----------------------|--|-----|-----|-----|------|
| $t_{d(on)}$               | turn-on delay time    | $V_{DS} = 400\text{ V}; R_L = 12.5\ \Omega; V_{GS} = 12\text{ V}; R_{G(ext)} = 12\ \Omega; I_S = 32\text{ A};$ <a href="#">Fig. 17</a> ; <a href="#">Fig. 18</a> | -   | 14  | -   | ns   |
| $t_r$                     | rise time             |  | -   | 14  | -   | ns   |
| $t_{d(off)}$              | turn-off delay time   |  | -   | 36  | -   | ns   |
| $t_f$                     | fall time             |  | -   | 17  | -   | ns   |
| $Q_{oss}$                 | output charge         | $V_{GS} = 0\text{ V}; V_{DS} = 400\text{ V}$   | -   | 150 | -   | nC   |
| <b>Source-drain diode</b> |                       |  |     |     |     |      |
| $V_{SD}$                  | source-drain voltage  | $I_S = 32\text{ A}; V_{GS} = 0\text{ V}; T_j = 25\text{ }^\circ\text{C};$ <a href="#">Fig. 19</a>  | -   | 1.8 | -   | V    |
|                           |                       | $I_S = 16\text{ A}; V_{GS} = 0\text{ V}; T_j = 25\text{ }^\circ\text{C};$ <a href="#">Fig. 19</a>  | -   | 1.3 | -   | V    |
| $t_{rr}$                  | reverse recovery time | $I_S = 32\text{ A}; di_S/dt = -1000\text{ A}/\mu\text{s};$   | -   | 59  | -   | ns   |
| $Q_r$                     | recovered charge      | $V_{GS} = 0\text{ V}; V_{DS} = 400\text{ V};$ <a href="#">Fig. 20</a>  | -   | 150 | -   | nC   |

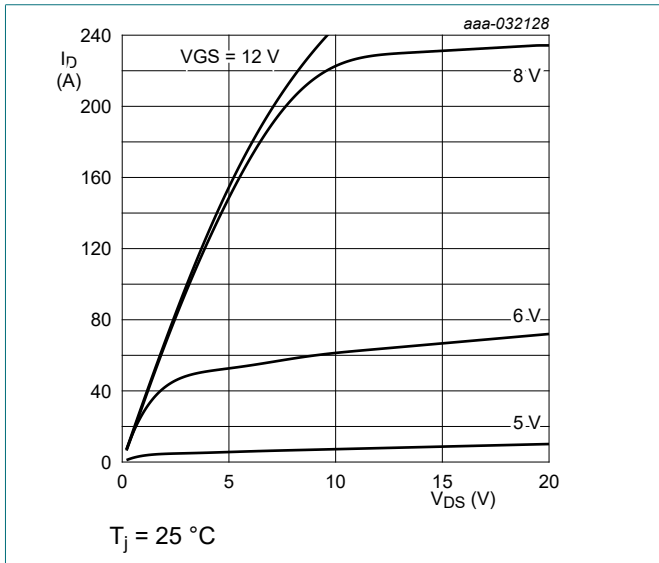


Fig. 5. Output characteristics; drain current as a function of drain-source voltage; typical values

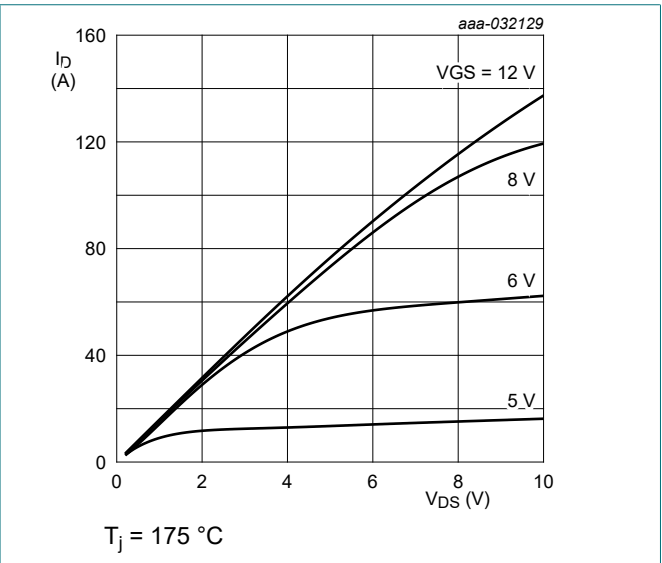


Fig. 6. Output characteristics; drain current as a function of drain-source voltage; typical values

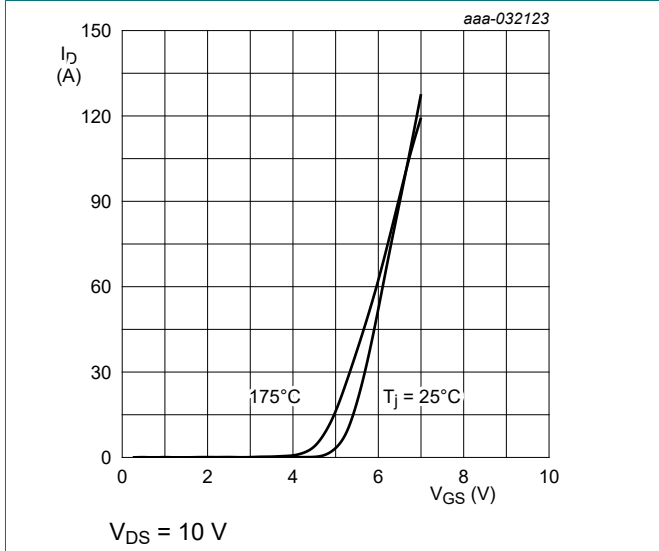


Fig. 7. Transfer characteristics; drain current as a function of gate-source voltage; typical values

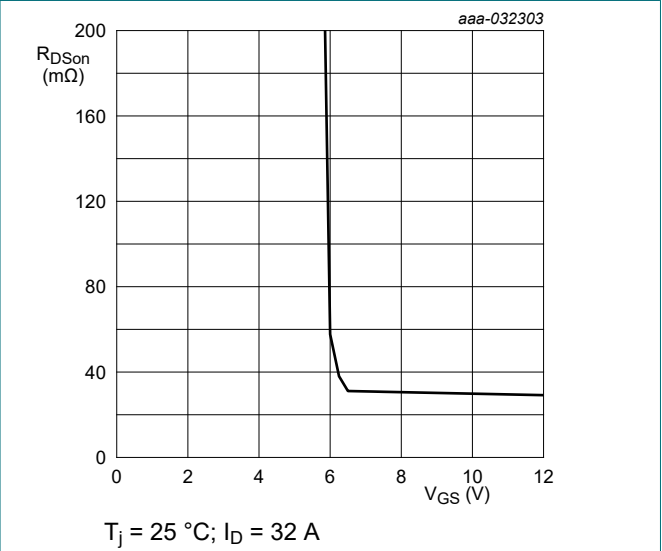


Fig. 8. Drain-source on-state resistance as a function of gate-source voltage; typical values

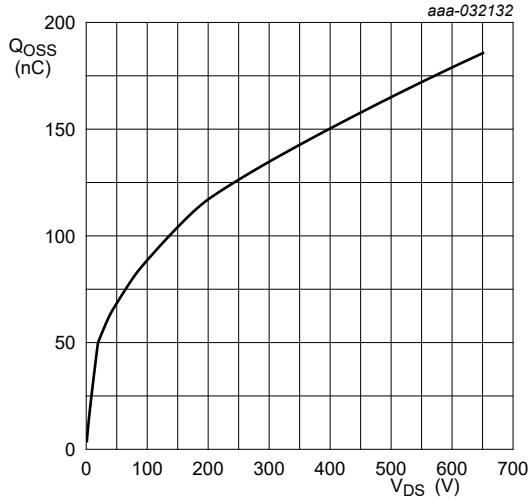
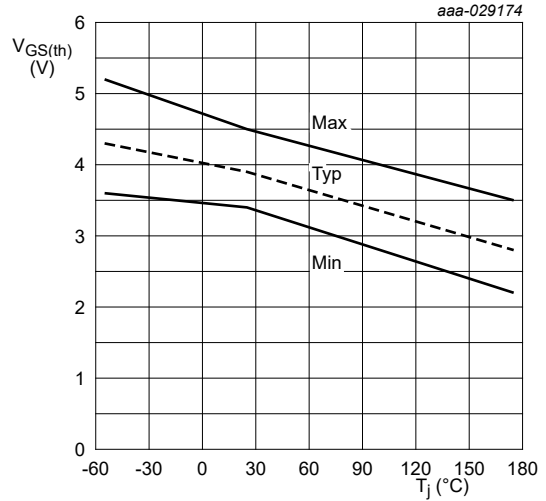
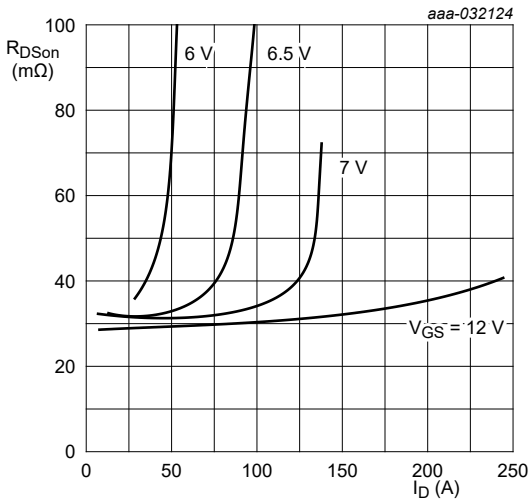


Fig. 9. Typical QOSS



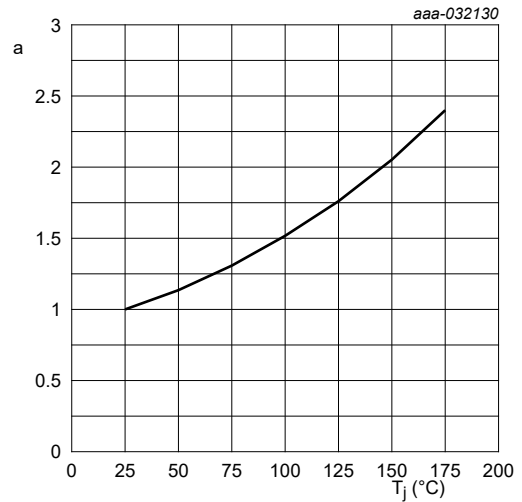
$I_D = 1 \text{ mA} ; V_{DS} = V_{GS}$

Fig. 10. Gate-source threshold voltage as a function of junction temperature



$T_j = 25 \text{ }^\circ\text{C}$

Fig. 11. Drain-source on-state resistance as a function of drain current; typical values



$$a = \frac{R_{DSon}}{R_{DSon}(25^\circ\text{C})}$$

Fig. 12. Normalized drain-source on-state resistance factor as a function of junction temperature

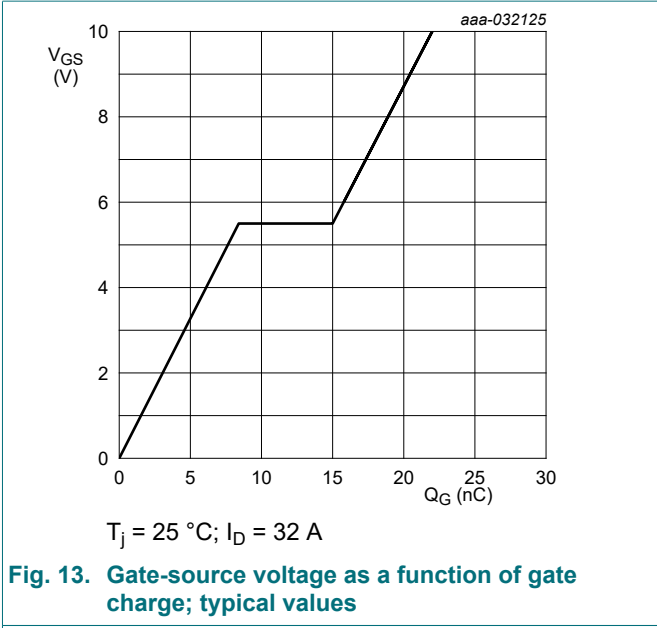


Fig. 13. Gate-source voltage as a function of gate charge; typical values

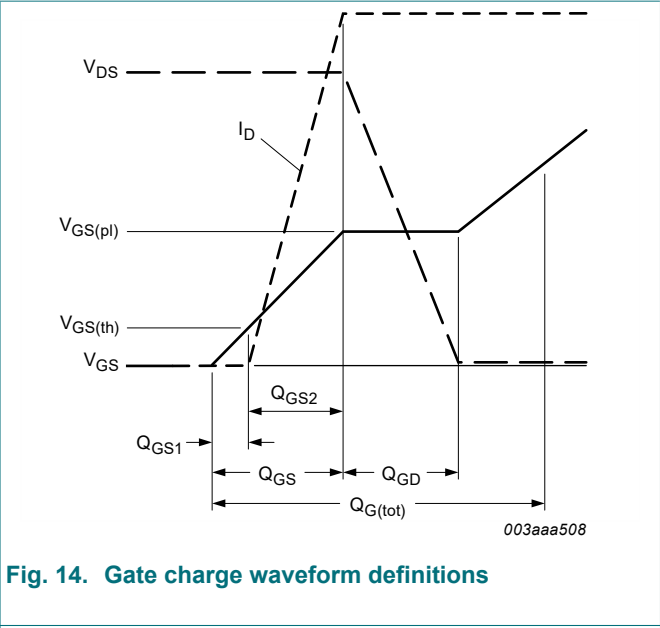


Fig. 14. Gate charge waveform definitions

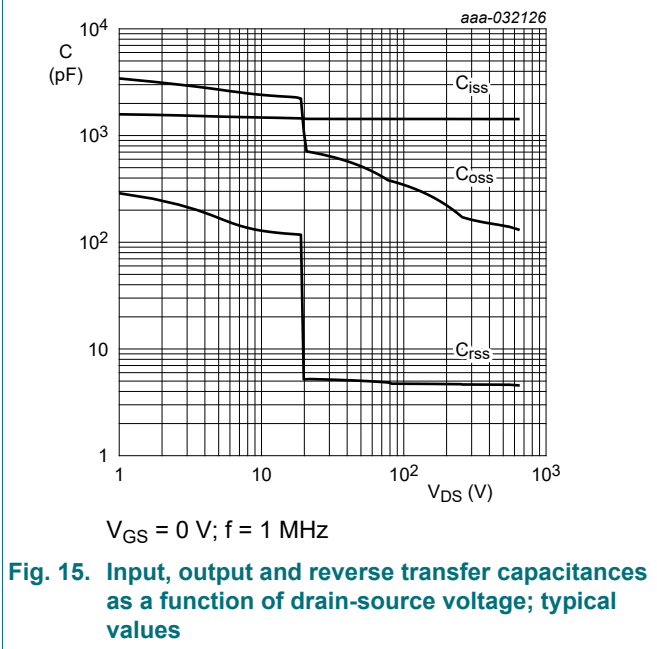


Fig. 15. Input, output and reverse transfer capacitances as a function of drain-source voltage; typical values

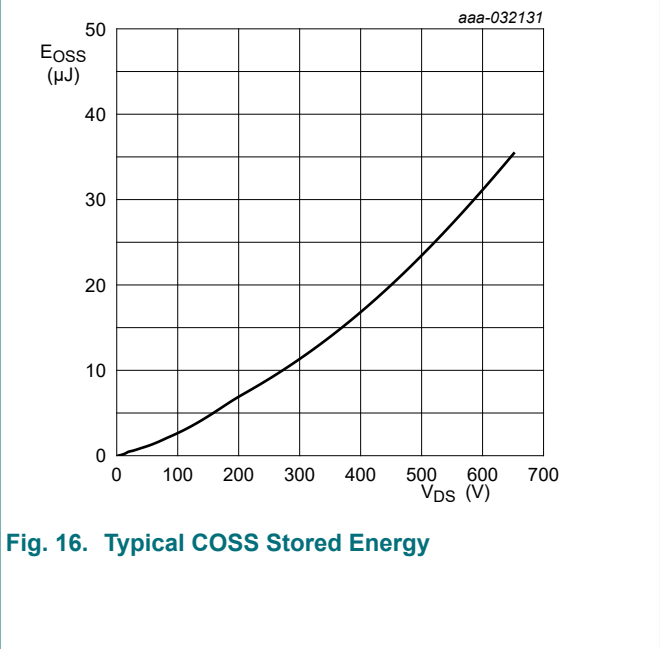


Fig. 16. Typical COSS Stored Energy

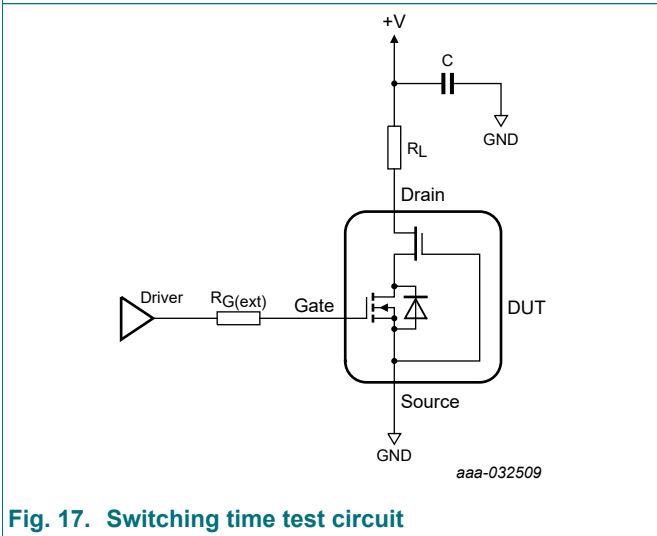


Fig. 17. Switching time test circuit

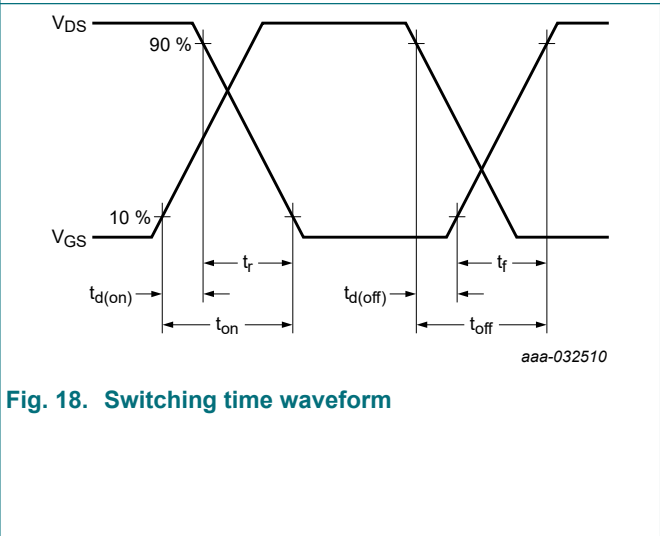
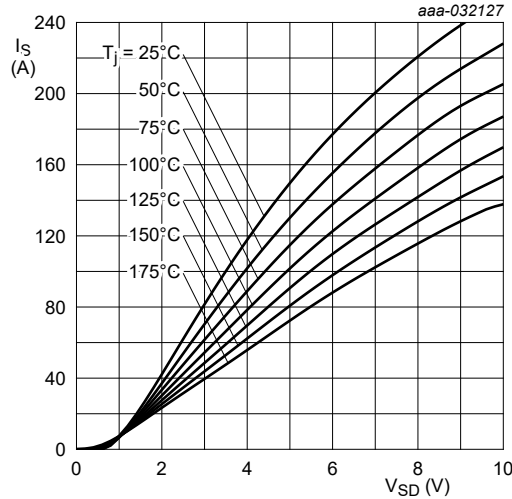


Fig. 18. Switching time waveform



VGS = 0 V

Fig. 19. Source-drain (diode forward) current as a function of source-drain (diode forward) voltage; typical values

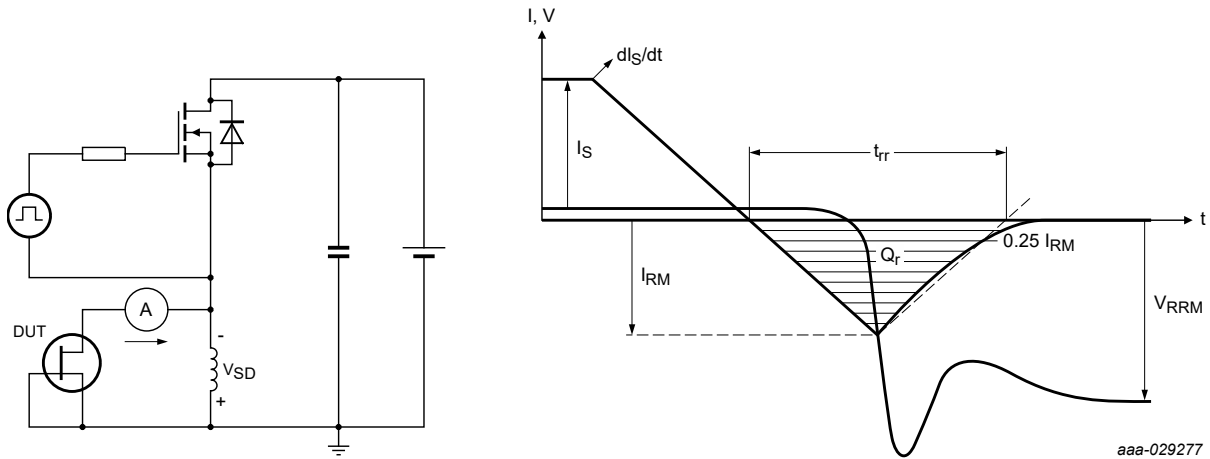


Fig. 20. Diode reverse recovery test circuit and waveform

## 11. Application information

A Ferrite bead must be fitted in series with the gate of the GaN FET and should be located as close as possible to the gate pin, (see figure below). Keeping the gate-source loop as compact as possible minimizes the gate loop inductance. The Ferrite bead damps the resonant circuit made up of the gate source loop inductance and the GaN FET input capacitance, thus providing fast switching stability. It is recommended that the impedance of the ferrite bead should be 200Ω—270Ω @ 100 MHz, (recommended p/n BLM18AG221SN1D).

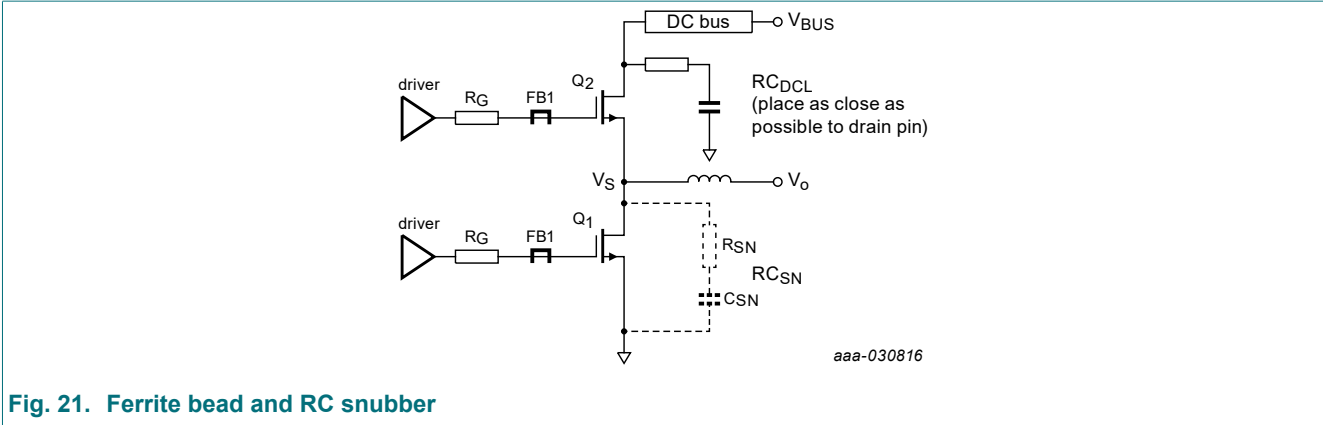


Fig. 21. Ferrite bead and RC snubber

A DC-link resonance damper is recommended in all cases. Optimal is 20 nF in series with 4 Ω, most easily achieved with parallel combination 10 nF and 8 Ω. This resonance damper lowers the Q factor of any resonance in the bus. That resonance will act as a load on the high gain amplifier that is the GaN FET and can lead to instability. For very high current, an RC snubber is recommended for the switching node. This will increase switching loss, so this is only recommended at high power levels where the losses are a very small percentage of the total power.

12. Package outline

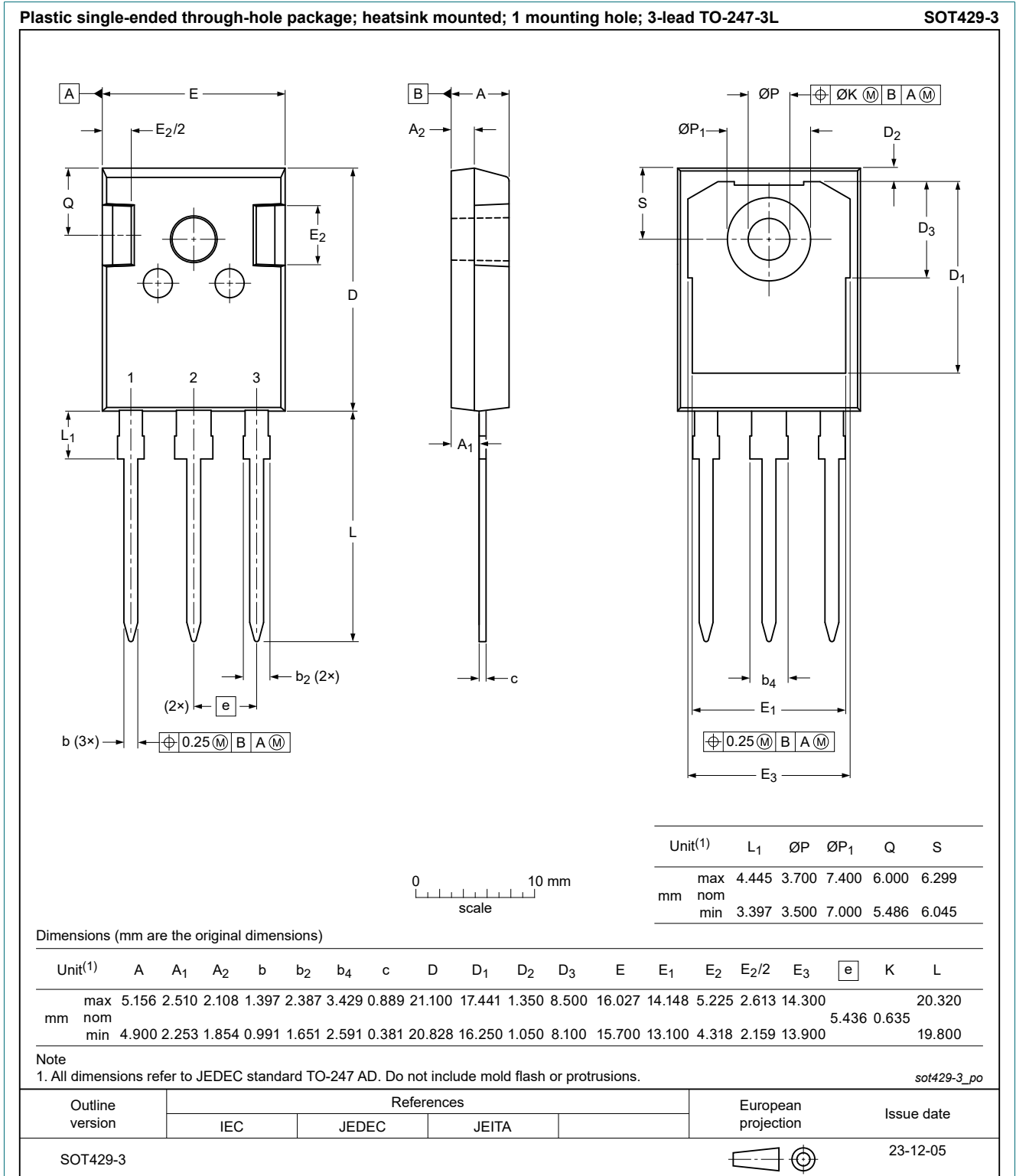


Fig. 22. Package outline TO-247-3L (SOT429-3)

## 13. Legal information

### Data sheet status

| Document status [1][2]         | Product status [3] | Definition  |
|--------------------------------|--------------------|---|
| Objective [short] data sheet   | Development        | This document contains data from the objective specification for product development. |
| Preliminary [short] data sheet | Qualification      | This document contains data from the preliminary specification.                       |
| Product [short] data sheet     | Production         | This document contains the product specification.                                     |

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- [2] The term 'short data sheet' is explained in section "Definitions".
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