

- Diagnostic feedback through input pin
- ESD protection
- Direct access to the gate of the Power MOSFET (analog driving)
- Compatible with standard Power MOSFET

### Description

The VNB35NV04-E, VNP35NV04-E and VNV35NV04-E are monolithic devices designed in STMicroelectronics® VIPower® M0-3 Technology, intended for replacement of standard Power MOSFETs from DC up to 25 kHz applications.

Built-in thermal shutdown, linear current limitation and overvoltage clamp protect the chip in harsh environments. Fault feedback can be detected by monitoring the voltage at the input pin.

### Features

| Type                                      | $R_{DS(on)}$                 | $I_{lim}$ | $V_{clamp}$ |
|---|------------------------------|-----------|-------------|
| VNB35NV04-E<br>VNP35NV04-E<br>VNV35NV04-E | 10 m $\Omega$ <sup>(1)</sup> | 30 A      | 40 V        |

1. For PowerSO-10 only

- Linear current limitation
- Thermal shutdown
- Short circuit protection
- Integrated clamp
- Low current drawn from input pin

Table 1. Device summary

| Package            | Order codes |               |
|--------------------|-------------|---------------|
|                    | Tube        | Tape and reel |
| D <sup>2</sup> PAK | VNB35NV04-E | VNB35NV04TR-E |
| TO-220             | VNP35NV04-E | —             |
| PowerSO-10         | VNV35NV04-E | VNV35NV04TR-E |

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# 1 Block diagram and pin connection

Figure 1. Block diagram

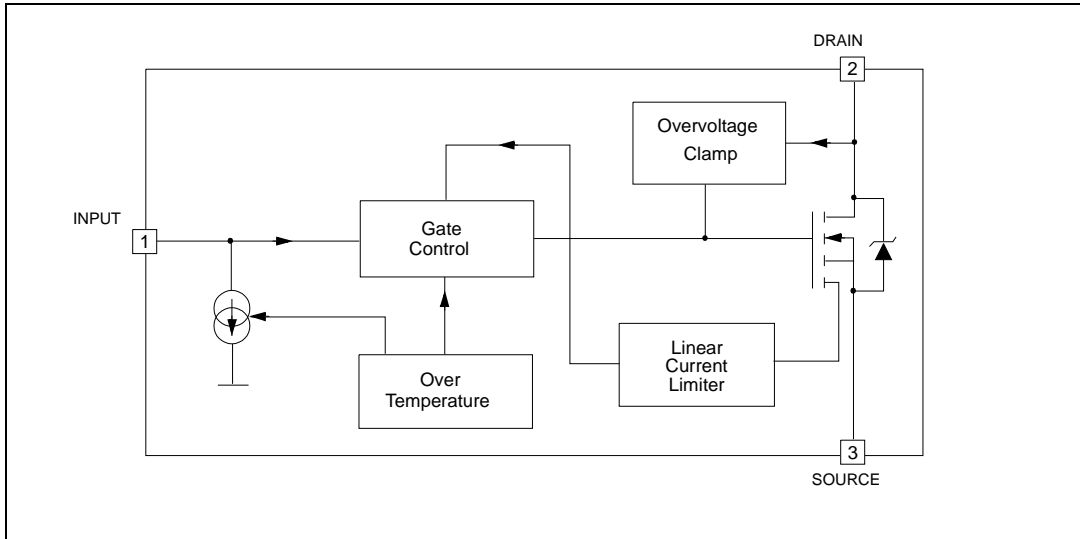
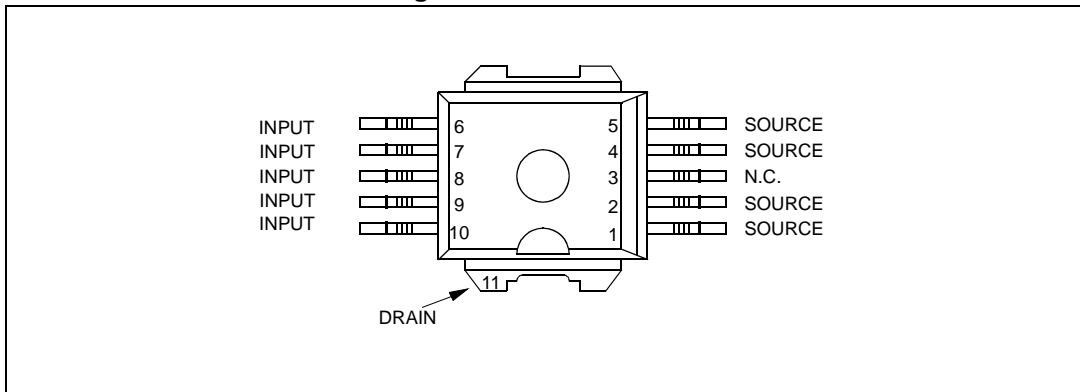


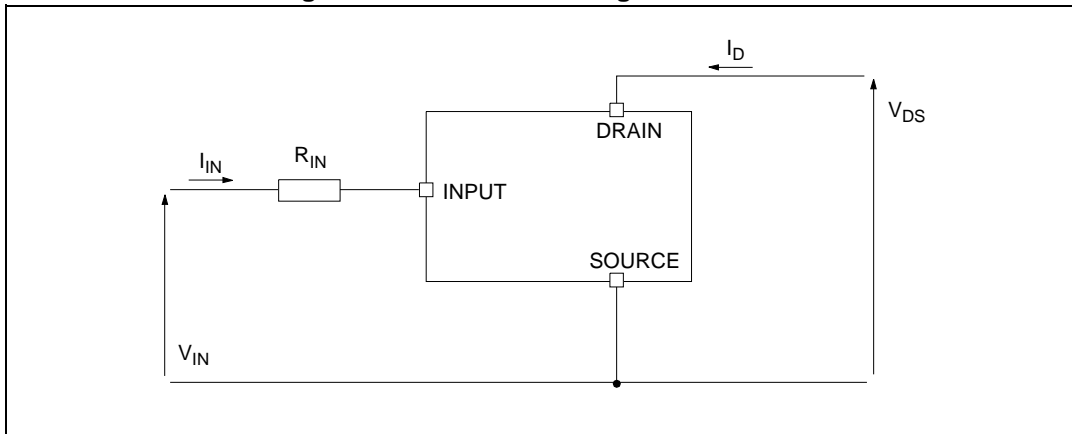
Figure 2. Pin connection



1. For the pins configuration related to TO-220, D<sup>2</sup>PAK, see [Figure 1](#).

## 2 Electrical specification

Figure 3. Current and voltage conventions



### 2.1 Absolute maximum ratings

Stressing the device above the rating listed in [Table 2](#) may cause permanent damage to the device. These are stress ratings only and operation of the device at these or any other conditions above those indicated in the operating sections of this specification is not implied. Exposure to the conditions in table below for extended periods may affect device reliability

Table 2. Absolute maximum ratings

| Symbol              | Parameter  | Value              |                    |        | Unit             |
|---------------------|--|--------------------|--------------------|--------|------------------|
|                     |  | PowerSO-10         | D <sup>2</sup> PAK | TO-220 |                  |
| $V_{DS}$            | Drain-source voltage ( $V_{IN} = 0\text{ V}$ )   | Internally clamped |                    |        | V                |
| $V_{IN}$            | Input voltage  | Internally clamped |                    |        | V                |
| $I_{IN}$            | Input current  | +/-20              |                    |        | mA               |
| $R_{IN\text{ MIN}}$ | Minimum input series impedance   | 4.7                |                    |        | $\Omega$         |
| $I_D$               | Drain current  | Internally limited |                    |        | A                |
| $I_R$               | Reverse DC output current  | -30                |                    |        | A                |
| $V_{ESD1}$          | Electrostatic discharge ( $R = 1.5\text{ K}\Omega$ , $C = 100\text{ pF}$ )             | 4000               |                    |        | V                |
| $V_{ESD2}$          | Electrostatic discharge on output pin only ( $R = 330\ \Omega$ , $C = 150\text{ pF}$ ) | 16500              |                    |        | V                |
| $P_{tot}$           | Total dissipation at $T_c = 25^\circ\text{C}$  | 125                | 125                | 125    | W                |
| $T_j$               | Operating junction temperature   | Internally limited |                    |        | $^\circ\text{C}$ |
| $T_c$               | Case operating temperature   | Internally limited |                    |        | $^\circ\text{C}$ |
| $T_{stg}$           | Storage temperature  | -55 to 150         |                    |        | $^\circ\text{C}$ |

## 2.2 Thermal data

Table 3. Thermal data

| Symbol                | Parameter                                 | Value             |                    |        | Unit |
|-----------------------|---|-------------------|--------------------|--------|------|
|                       |   | PowerSO-10        | D <sup>2</sup> PAK | TO-220 |      |
| R <sub>thj-case</sub> | Thermal resistance junction-case (max)    | 1                 | 1                  | 1      | °C/W |
| R <sub>thj-amb</sub>  | Thermal resistance junction-ambient (max) | 50 <sup>(1)</sup> | 50 <sup>(1)</sup>  | 50     | °C/W |

1. When mounted on a standard single-sided FR4 board with 50mm<sup>2</sup> of Cu (at least 35 mm thick) connected to all DRAIN pins.

## 2.3 Electrical characteristics

-40°C < T<sub>j</sub> < 150°C, unless otherwise specified.

Table 4. Off

| Symbol             | Parameter  | Test conditions   | Min  | Typ | Max  | Unit |
|--------------------|--|---|------|-----|------|------|
| V <sub>CLAMP</sub> | Drain-source clamp voltage                               | V <sub>IN</sub> = 0 V; I <sub>D</sub> = 15 A                          | 40   | 45  | 55   | V    |
| V <sub>CLTH</sub>  | Drain-source clamp threshold voltage                     | V <sub>IN</sub> = 0 V; I <sub>D</sub> = 2 mA                          | 36   |     |      | V    |
| V <sub>INTH</sub>  | Input threshold voltage                                  | V <sub>DS</sub> = V <sub>IN</sub> ; I <sub>D</sub> = 1 mA             | 0.5  |     | 2.5  | V    |
| I <sub>ISS</sub>   | Supply current from input pin                            | V <sub>DS</sub> = 0 V; V <sub>IN</sub> = 5 V                          |      | 100 | 150  | μA   |
| V <sub>INCL</sub>  | Input-source clamp voltage                               | I <sub>IN</sub> = 1 mA  | 6    | 6.8 | 8    | V    |
|                    |  | I <sub>IN</sub> = -1 mA   | -1.0 |     | -0.3 | V    |
| I <sub>DSS</sub>   | Zero input voltage drain current (V <sub>IN</sub> = 0 V) | V <sub>DS</sub> = 13 V; V <sub>IN</sub> = 0 V; T <sub>j</sub> = 25 °C |      |     | 30   | μA   |
|                    |  | V <sub>DS</sub> = 25 V; V <sub>IN</sub> = 0 V                         |      |     | 75   | μA   |

Table 5. On

| Symbol              | Parameter                         | Test conditions   | Max        |                           | Unit |
|---------------------|-----------------------------------|---|------------|---------------------------|------|
|                     |                                   |   | PowerSO-10 | D <sup>2</sup> PAK TO-220 |      |
| R <sub>DS(on)</sub> | Static drain-source on resistance | V <sub>IN</sub> = 5 V; I <sub>D</sub> = 15 A; T <sub>j</sub> = 25 °C  | 10         | 13                        | mΩ   |
|                     |                                   | V <sub>IN</sub> = 5 V; I <sub>D</sub> = 15 A; T <sub>j</sub> = 150 °C | 20         | 24                        | mΩ   |

$T_j = 25^\circ\text{C}$ , unless otherwise specified.

**Table 6. Dynamic**

| Symbol         | Parameter                | Test conditions   | Min | Typ  | Max | Unit |
|----------------|--------------------------|---|-----|------|-----|------|
| $g_{fs}^{(1)}$ | Forward transconductance | $V_{DD} = 13\text{ V}; I_D = 15\text{ A}$                     | —   | 35   | —   | S    |
| $C_{OSS}$      | Output capacitance       | $V_{DS} = 13\text{ V}; f = 1\text{ MHz}; V_{IN} = 0\text{ V}$ | —   | 1300 | —   | pF   |

1. Pulsed: Pulse duration = 300 ms, duty cycle 1.5%

**Table 7. Switching**

| Symbol         | Parameter             | Test conditions  | Min | Typ | Max  | Unit                   |
|----------------|-----------------------|--|-----|-----|------|------------------------|
| $t_{d(on)}$    | Turn-on delay time    | $V_{DD} = 15\text{ V}; I_D = 15\text{ A};$<br>$V_{gen} = 5\text{ V};$<br>$R_{gen} = R_{IN\text{ MIN}} = 4.7\ \Omega$ (see <a href="#">Figure 3</a> ) | —   | 150 | 500  | ns                     |
| $t_r$          | Rise time             |  | —   | 840 | 2500 | ns                     |
| $t_{d(off)}$   | Turn-off delay time   |  | —   | 980 | 3000 | ns                     |
| $t_f$          | Fall time             |  | —   | 600 | 1500 | ns                     |
| $t_{d(on)}$    | Turn-on delay time    | $V_{DD} = 15\text{ V}; I_D = 15\text{ A};$<br>$V_{gen} = 5\text{ V}; R_{gen} = 2.2\text{ K}\Omega$ (see <a href="#">Figure 3</a> )                   | —   | 4   | 12   | $\mu\text{s}$          |
| $t_r$          | Rise time             |  | —   | 27  | 100  | $\mu\text{s}$          |
| $t_{d(off)}$   | Turn-off delay time   |  | —   | 34  | 120  | $\mu\text{s}$          |
| $t_f$          | Fall time             |  | —   | 31  | 110  | $\mu\text{s}$          |
| $(di/dt)_{on}$ | Turn-on current slope | $V_{DD} = 15\text{ V}; I_D = 15\text{ A}; V_{gen} = 5\text{ V};$<br>$R_{gen} = R_{IN\text{ MIN}} = 4.7\ \Omega$                                      | —   | 18  |      | $\text{A}/\mu\text{s}$ |
| $Q_i$          | Total input charge    | $V_{DD} = 12\text{ V}; I_D = 15\text{ A}; V_{IN} = 5\text{ V};$<br>$I_{gen} = 2.13\text{ mA}$ (see <a href="#">Figure 8</a> )                        | —   | 118 |      | nC                     |

**Table 8. Source drain diode**

| Symbol         | Parameter                | Test Conditions   | Min | Typ | Max | Unit          |
|----------------|--------------------------|---|-----|-----|-----|---------------|
| $V_{SD}^{(1)}$ | Forward on voltage       | $I_{SD} = 15\text{ A}; V_{IN} = 0\text{ V}$   | —   | 0.8 | —   | V             |
| $t_{rr}$       | Reverse recovery time    | $I_{SD} = 15\text{ A}; di/dt = 100\text{ A}/\mu\text{s};$<br>$V_{DD} = 30\text{ V}; L = 200\ \mu\text{H}$ (see <a href="#">Figure 4</a> ) | —   | 400 | —   | ns            |
| $Q_{rr}$       | Reverse recovery charge  |   | —   | 1.4 | —   | $\mu\text{C}$ |
| $I_{RRM}$      | Reverse recovery current |   | —   | 7   | —   | A             |

1. Pulsed: Pulse duration = 300 ms, duty cycle 1.5%

**Table 9. Protections ( $-40^\circ\text{C} < T_j < 150^\circ\text{C}$ , unless otherwise specified)**

| Symbol     | Parameter                   | Test Conditions                             | Min | Typ | Max | Unit          |
|------------|-----------------------------|---|-----|-----|-----|---------------|
| $I_{lim}$  | Drain current limit         | $V_{IN} = 6\text{ V}; V_{DS} = 13\text{ V}$ | 30  | 45  | 60  | A             |
| $t_{dlim}$ | Step response current limit | $V_{IN} = 6\text{ V}; V_{DS} = 13\text{ V}$ |     | 50  |     | $\mu\text{s}$ |



Table 9. Protections ( $-40^{\circ}\text{C} < T_j < 150^{\circ}\text{C}$ , unless otherwise specified) (continued)

| Symbol    | Parameter                     | Test Conditions  | Min | Typ | Max | Unit               |
|-----------|-------------------------------|--|-----|-----|-----|--------------------|
| $T_{jsh}$ | Overtemperature shutdown      |  | 150 | 175 | 200 | $^{\circ}\text{C}$ |
| $T_{jrs}$ | Overtemperature reset         |  | 135 |     |     | $^{\circ}\text{C}$ |
| $I_{gf}$  | Fault Sink Current            | $V_{IN} = 5\text{ V}; V_{DS} = 13\text{ V}; T_j = T_{jsh}$   | 10  | 15  | 20  | mA                 |
| $E_{as}$  | Single pulse avalanche energy | Starting $T_j = 25^{\circ}\text{C}; V_{DD} = 24\text{ V}; V_{IN} = 5\text{ V}; R_{gen} = R_{IN\text{ MIN}} = 4.7\ \Omega; L = 24\text{ mH}$ (see <a href="#">Figure 6</a> and <a href="#">Figure 7</a> ) | 1.7 |     |     | J                  |

## 2.4 Protection features

During normal operation, the INPUT pin is electrically connected to the gate of the internal power MOSFET through a low impedance path.

The device then behaves like a standard power MOSFET and can be used as a switch from DC up to 25 KHz. The only difference from the user's standpoint is that a small DC current  $I_{ISS}$  (typ. 100  $\mu\text{A}$ ) flows into the INPUT pin in order to supply the internal circuitry.

The device integrates:

- **Overtoltage clamp protection:**  
internally set at 45 V, along with the rugged avalanche characteristics of the Power MOSFET stage give this device unrivalled ruggedness and energy handling capability. This feature is mainly important when driving inductive loads.
- **Linear current limiter circuit:**  
limits the drain current  $I_D$  to  $I_{lim}$  whatever the INPUT pin voltages is. When the current limiter is active, the device operates in the linear region, so power dissipation may exceed the capability of the heatsink. Both case and junction temperatures increase, and if this phase lasts long enough, junction temperature may reach the overtemperature threshold  $T_{jsh}$ .
- **Overtemperature and short circuit protection:**  
these are based on sensing the chip temperature and are not dependent on the input voltage. The location of the sensing element on the chip in the power stage area ensures fast, accurate detection of the junction temperature. Overtemperature cutout occurs in the range  $150^{\circ}\text{C}$  to  $190^{\circ}\text{C}$ , a typical value being  $170^{\circ}\text{C}$ . The device is automatically restarted when the chip temperature falls of about  $15^{\circ}\text{C}$  below shutdown temperature.
- **Status feedback:**  
in the case of an overtemperature fault condition ( $T_j > T_{jsh}$ ), the device tries to sink a diagnostic current  $I_{gf}$  through the INPUT pin in order to indicate fault condition. If driven from a low impedance source, this current may be used in order to warn the control circuit of a device shutdown. If the drive impedance is high enough so that the INPUT pin driver is not able to supply the current  $I_{gf}$ , the INPUT pin falls to 0 V. This does not however affect the device operation: no requirement is put on the current capability of the INPUT pin driver except to be able to supply the normal operation drive current  $I_{ISS}$ .

Additional features of this device are ESD protection according to the Human Body model and the ability to be driven from a TTL Logic circuit.

Figure 4. Switching time test circuit for resistive load

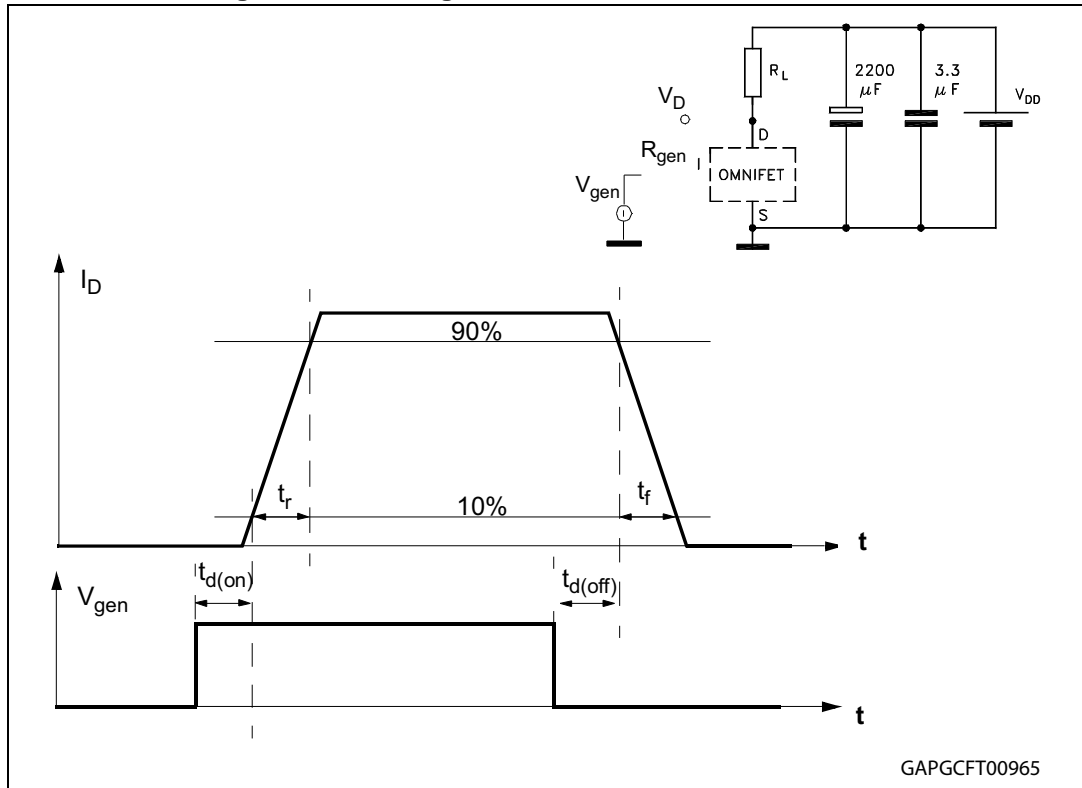


Figure 5. Test circuit for diode recovery times

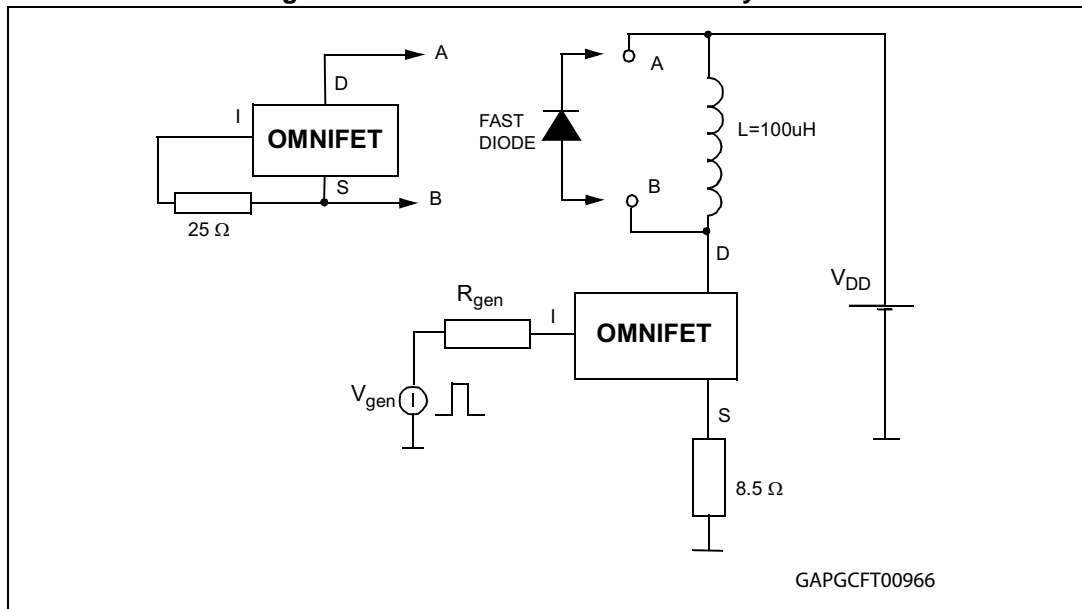


Figure 6. Unclamped inductive load test circuits

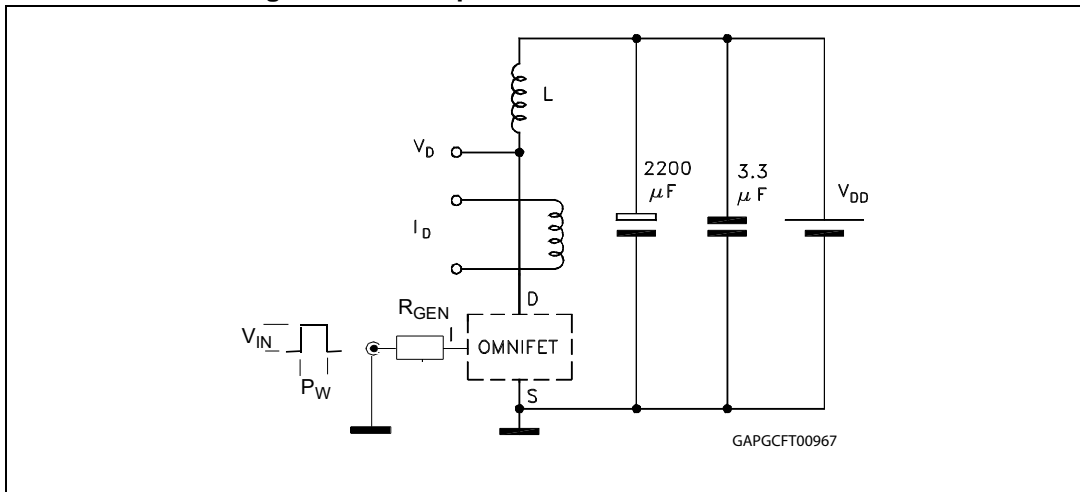


Figure 7. Unclamped inductive waveforms

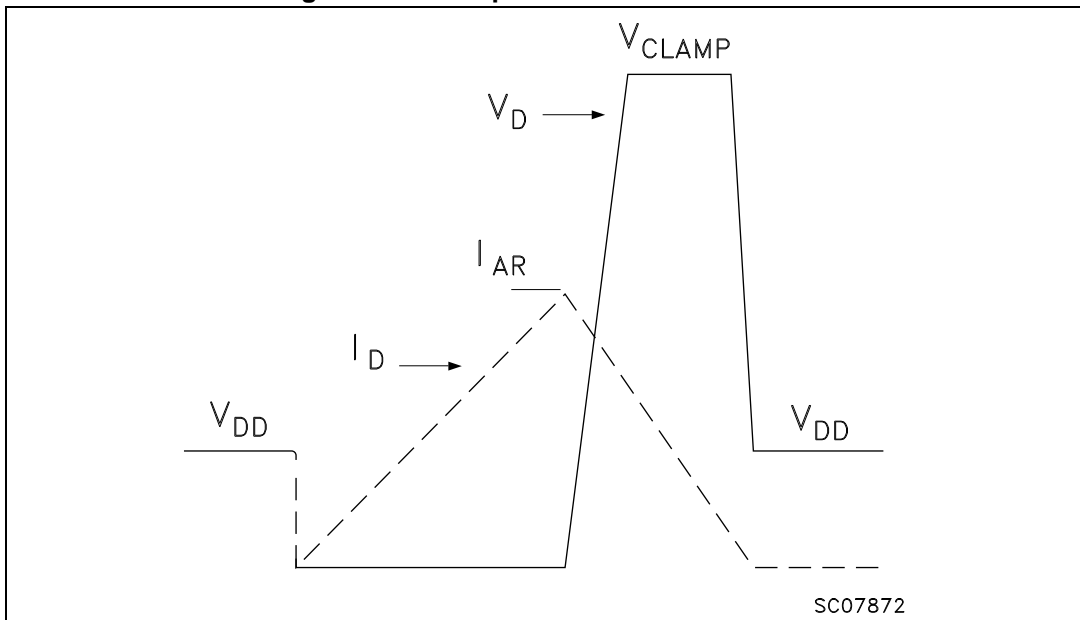


Figure 8. Input charge test circuit

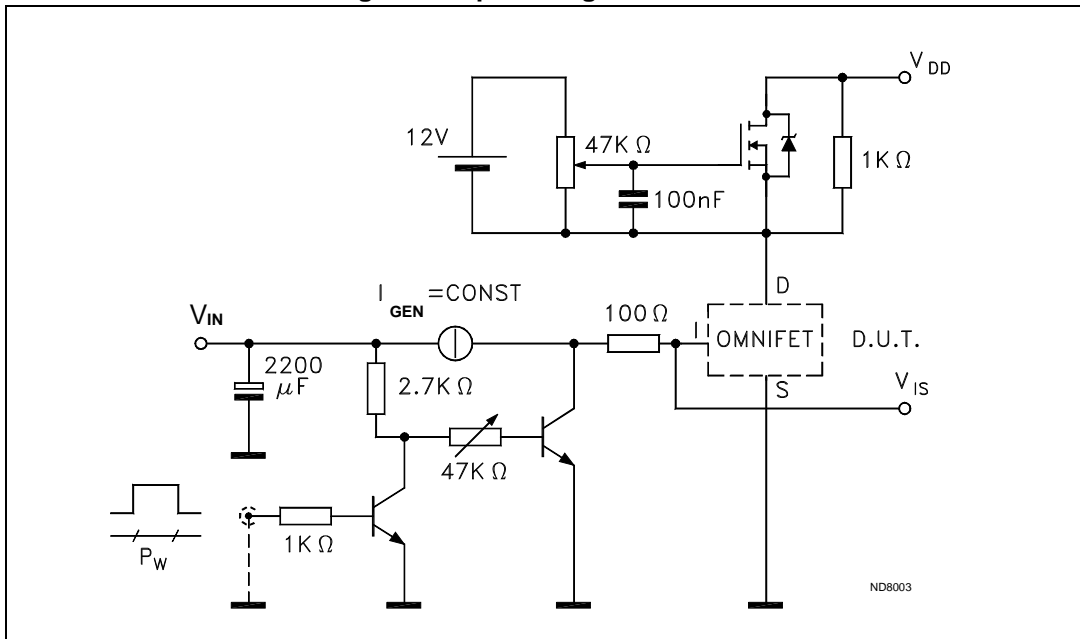
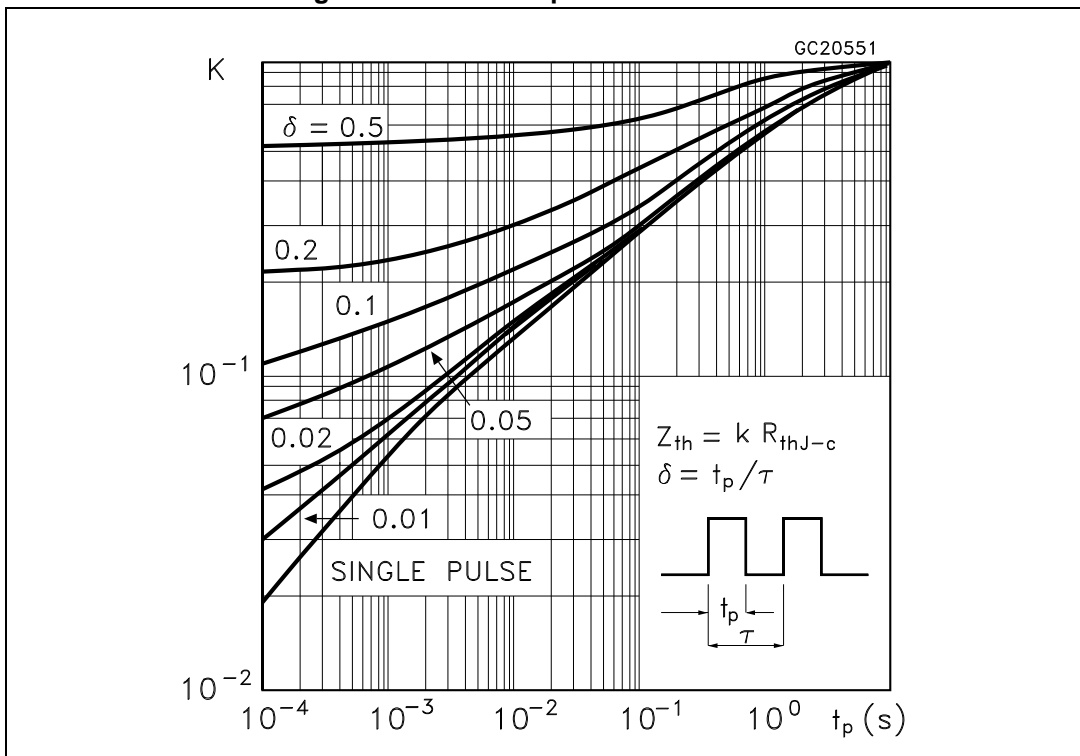
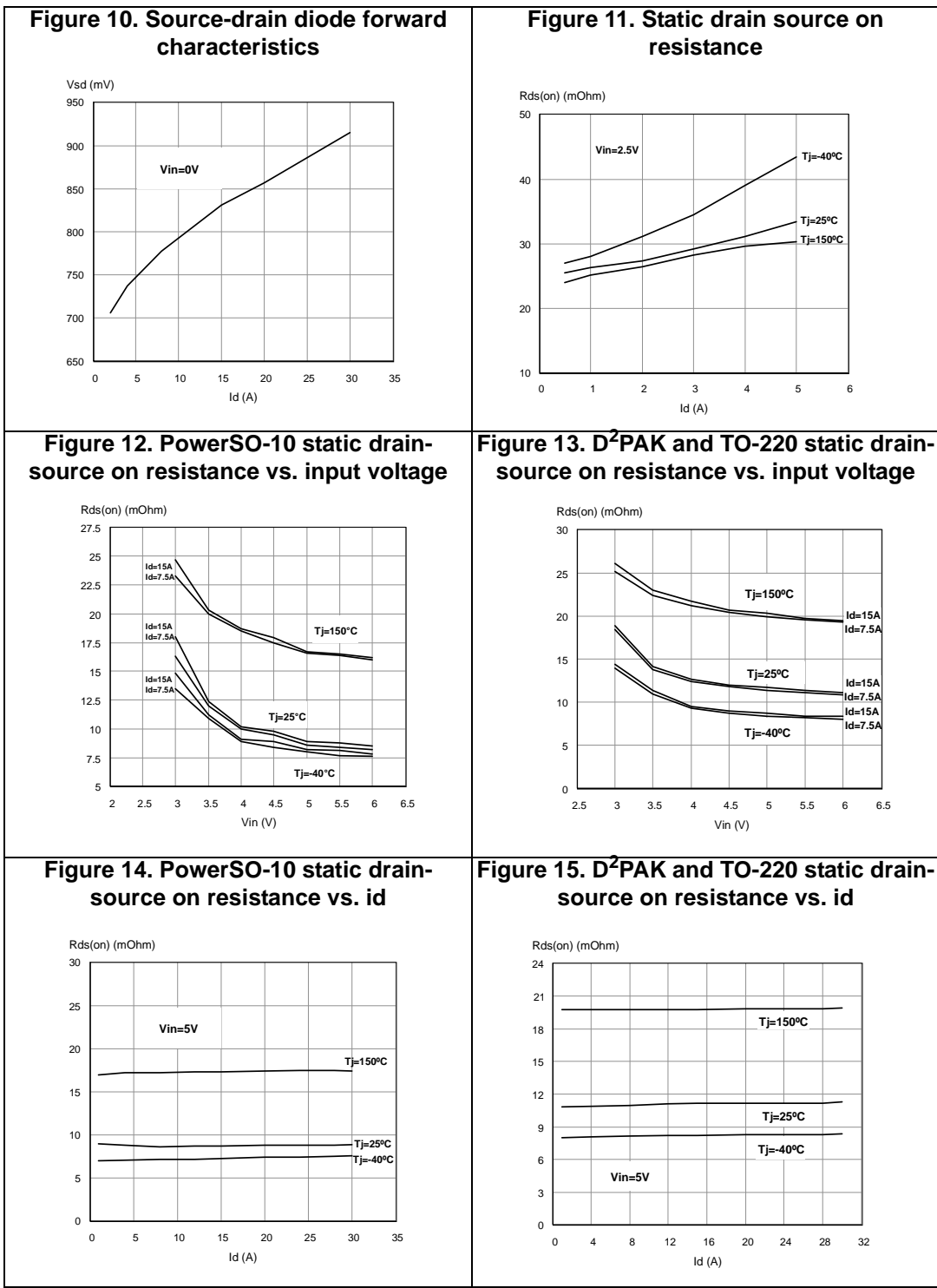


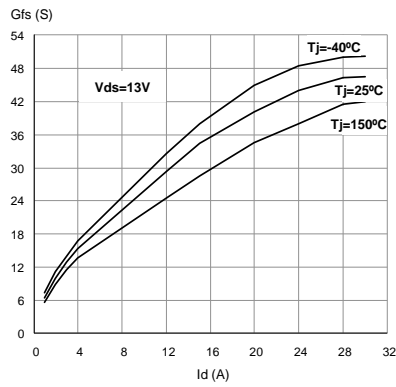
Figure 9. Thermal impedance for TO-220



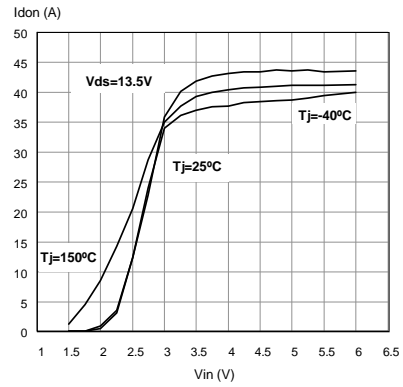
## 2.5 Electrical characteristics curves



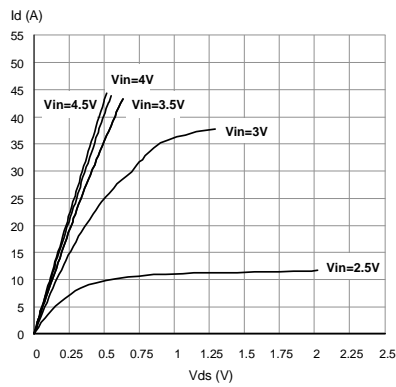
**Figure 16. Transconductance**



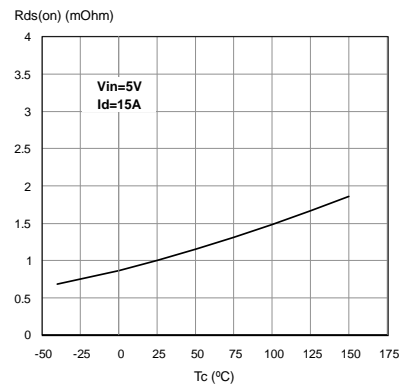
**Figure 17. Transfer characteristics**



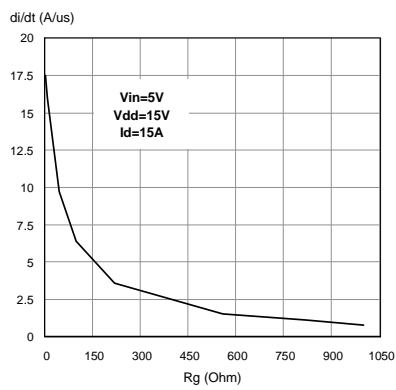
**Figure 18. Output characteristics**



**Figure 19. Normalized on resistance vs. temperature**



**Figure 20. Turn-on current slope,  $V_{IN} = 5V$**



**Figure 21. Turn-on current slope,  $V_{IN} = 3.5V$**

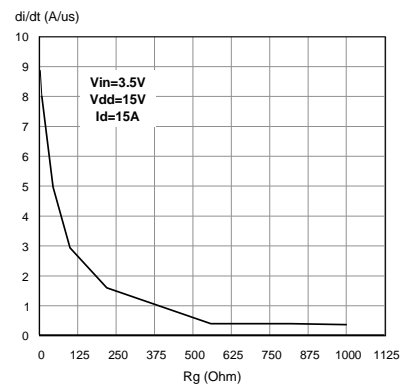


Figure 22. Input voltage vs. input charge

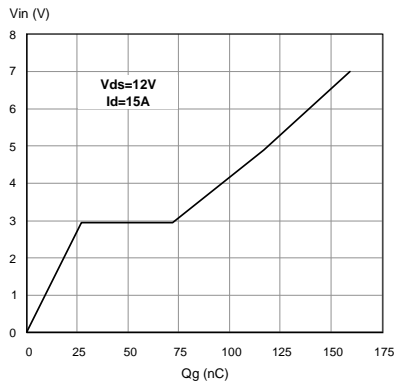


Figure 23. Turn off drain source voltage slope,  $V_{IN} = 5\text{ V}$

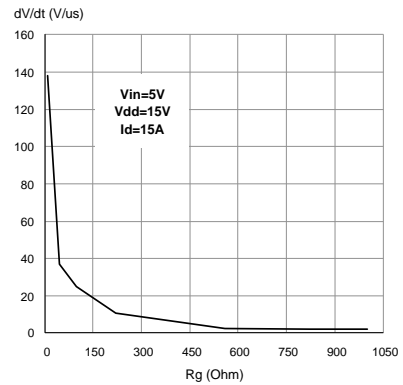


Figure 24. Turn off drain-source voltage slope,  $V_{IN} = 3.5\text{ V}$

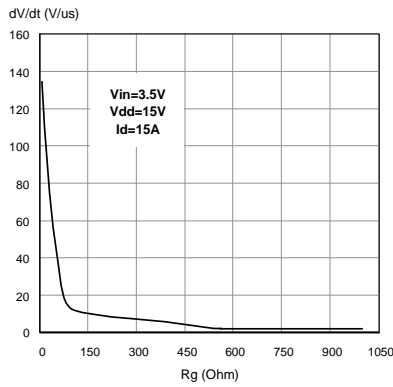


Figure 25. Switching time resistive load (part 1)

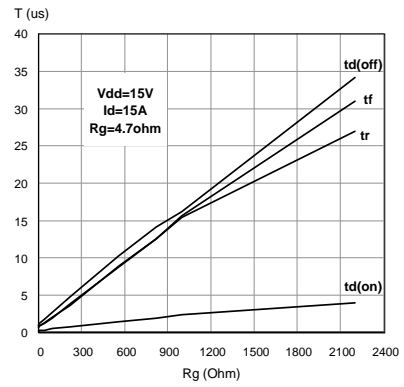


Figure 26. Switching time resistive load (part 2)

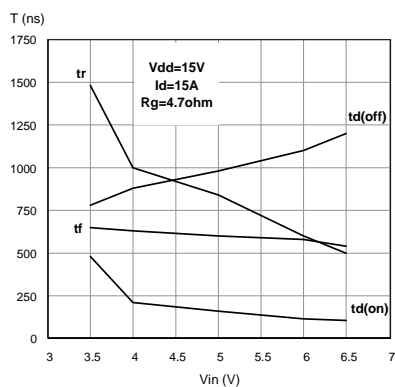
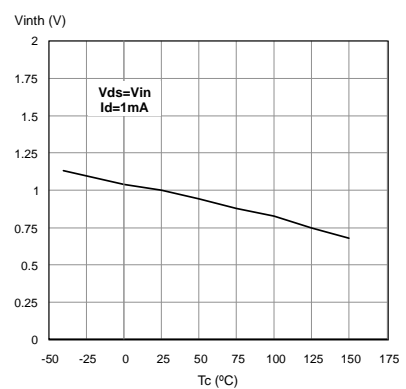
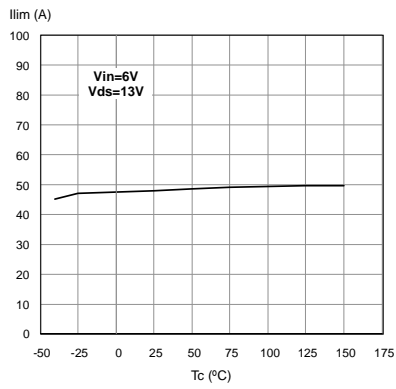


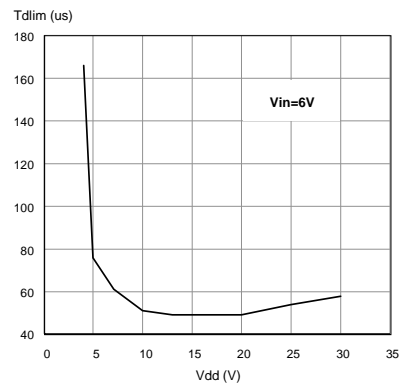
Figure 27. Normalized input threshold voltage vs. temperature



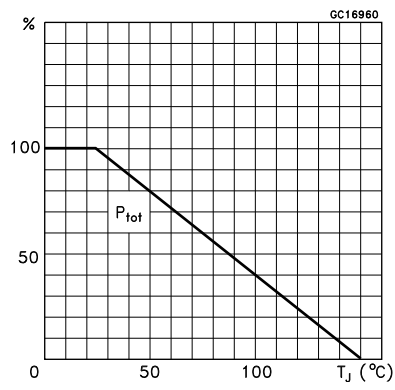
**Figure 28. Current limit vs. junction temperature**



**Figure 29. Step response current limit**



**Figure 30. Derating curve**





### 3 Package information

#### 3.1 ECOPACK®

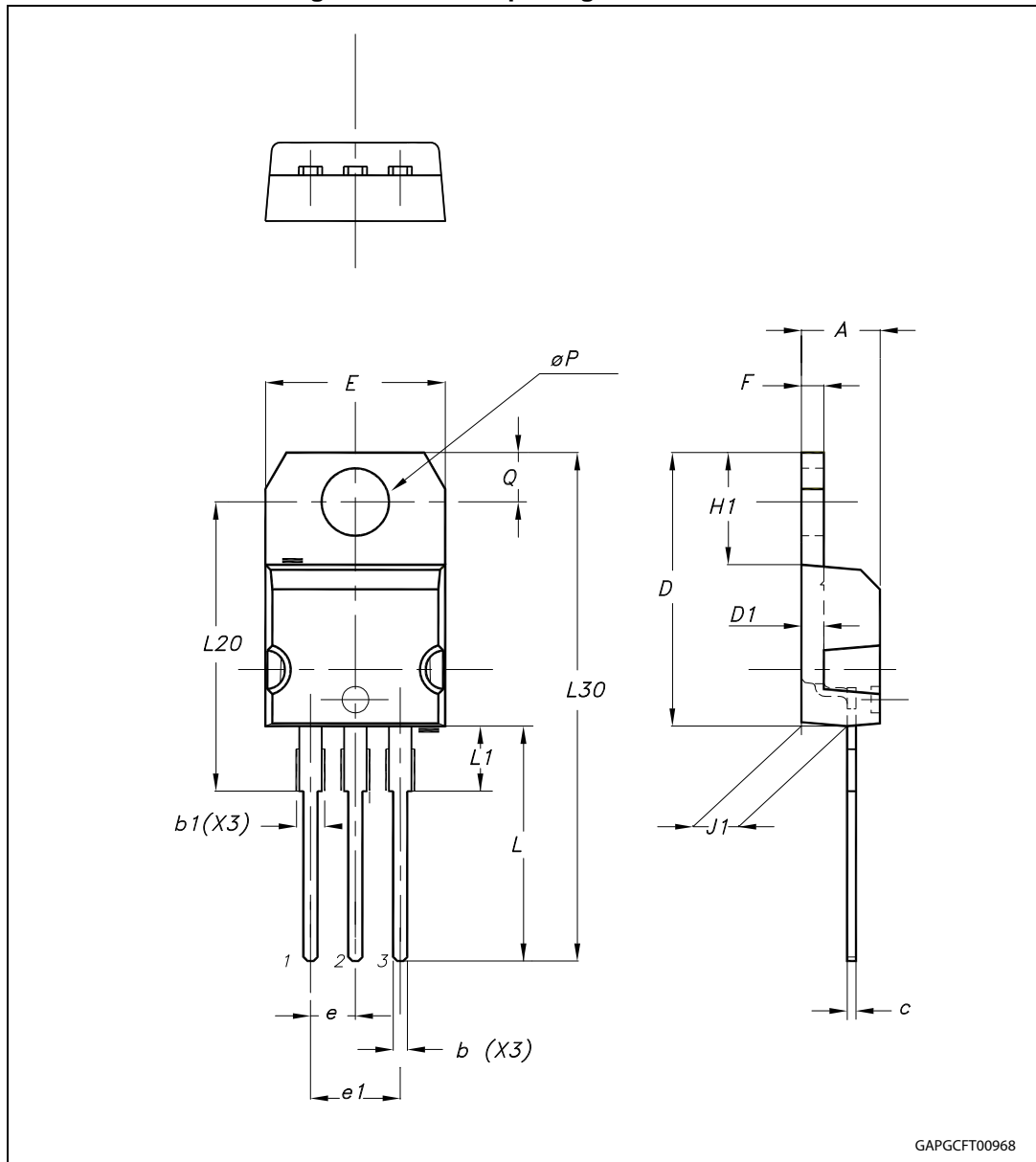
In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK® packages, depending on their level of environmental compliance. ECOPACK® specifications, grade definitions and product status are available at: [www.st.com](http://www.st.com). ECOPACK® is an ST trademark.

#### 3.2 TO-220 mechanical data

Table 10. TO-220 mechanical data

| Dim.           | mm.           |       |       |
|----------------|---------------|-------|-------|
|                | Min.          | Typ   | Max.  |
| A              | 4.40          |       | 4.60  |
| b              | 0.61          |       | 0.88  |
| b1             | 1.14          |       | 1.70  |
| c              | 0.48          |       | 0.70  |
| D              | 15.25         |       | 15.75 |
| D1             |               | 1.27  |       |
| E              | 10            |       | 10.40 |
| e              | 2.40          |       | 2.70  |
| e1             | 4.95          |       | 5.15  |
| F              | 1.23          |       | 1.32  |
| H1             | 6.20          |       | 6.60  |
| J1             | 2.40          |       | 2.72  |
| L              | 13            |       | 14    |
| L1             | 3.50          |       | 3.93  |
| L20            |               | 16.40 |       |
| L30            |               | 28.90 |       |
| ∅P             | 3.75          |       | 3.85  |
| Q              | 2.65          |       | 2.95  |
| Package weight | 1.9Gr. (Typ.) |       |       |

Figure 31. TO-220 package dimensions



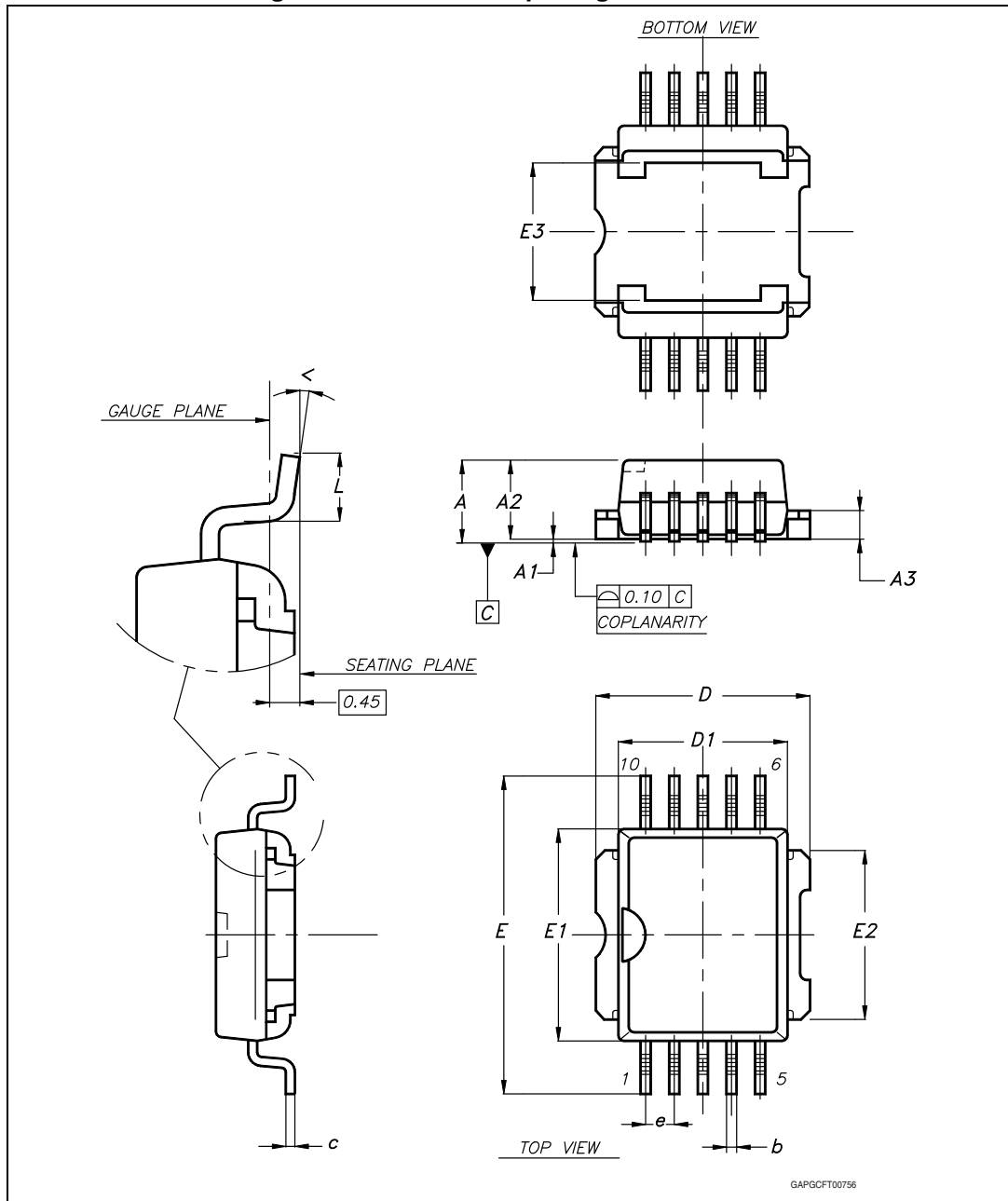
### 3.3 PowerSO-10 mechanical data

Table 11. PowerSO-10 mechanical data

| Dim.              | mm.   |      |       |
|-------------------|-------|------|-------|
|                   | Min.  | Typ. | Max.  |
| A                 |       |      | 3.70  |
| A1                | 0.00  |      | 0.10  |
| A2                | 3.40  |      | 3.60  |
| A3                | 1.25  |      | 1.35  |
| b                 | 0.40  |      | 0.53  |
| c                 | 0.35  |      | 0.55  |
| D                 | 9.40  |      | 9.60  |
| D1 <sup>(1)</sup> | 7.40  |      | 7.60  |
| E                 | 13.80 |      | 14.40 |
| E1 <sup>(1)</sup> | 9.30  |      | 9.50  |
| E2                | 7.20  |      | 7.60  |
| E3                | 5.90  |      | 6.10  |
| e                 |       | 1.27 |       |
| L                 | 0.95  |      | 1.65  |
| <                 | 0°    |      | 8°    |

1. Resin protrusion not included (max value: 0.20 mm per side)

Figure 32. PowerSO-10 package dimensions

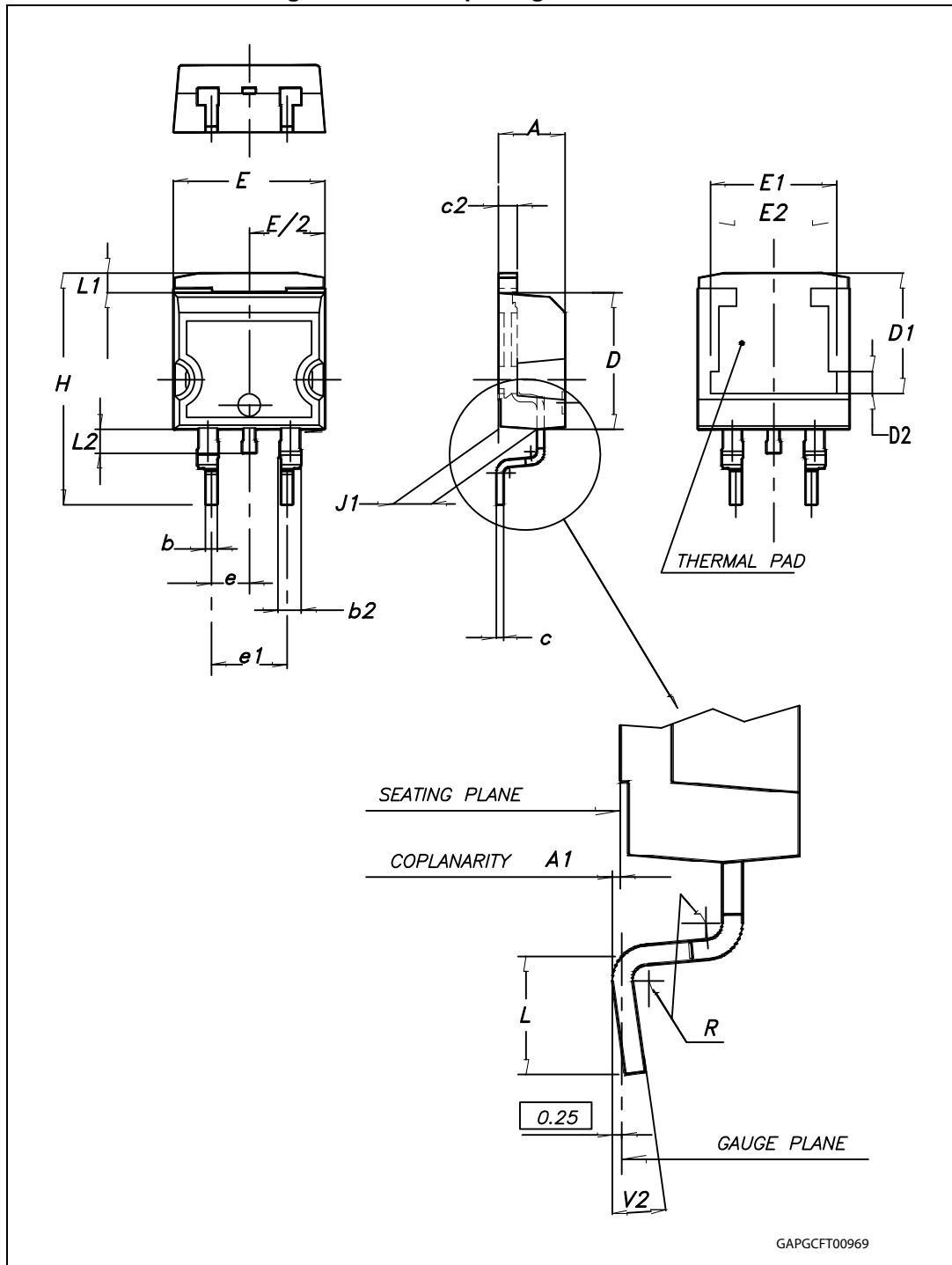


### 3.4 D<sup>2</sup>PAK mechanical data

Table 12. D<sup>2</sup>PAK mechanical data

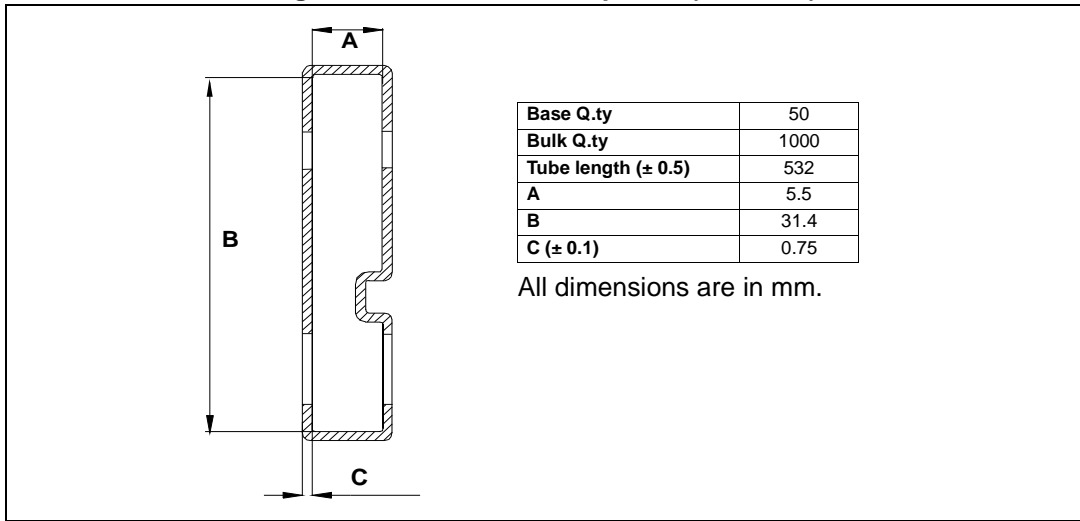
| Dim. | mm.  |      |       |
|------|------|------|-------|
|      | Min. | Typ  | Max.  |
| A    | 4.40 |      | 4.60  |
| A1   | 0.03 |      | 0.23  |
| b    | 0.70 |      | 0.93  |
| b2   | 1.14 |      | 1.70  |
| c    | 0.45 |      | 0.60  |
| c2   | 1.23 |      | 1.36  |
| D    | 8.95 |      | 9.35  |
| D1   | 7.50 | 7.75 | 8.00  |
| D2   | 1.10 | 1.30 | 1.50  |
| E    | 10   |      | 10.40 |
| E1   | 8.50 | 8.70 | 8.90  |
| E2   | 6.85 | 7.05 | 7.25  |
| e    |      | 2.54 |       |
| e1   | 4.88 |      | 5.28  |
| H    | 15   |      | 15.85 |
| J1   | 2.49 |      | 2.69  |
| L    | 2.29 |      | 2.79  |
| L1   | 1.27 |      | 1.40  |
| L2   | 1.30 |      | 1.75  |
| R    |      | 0.4  |       |
| V2   | 0°   |      | 8°    |

Figure 33. D<sup>2</sup>PAK package dimensions

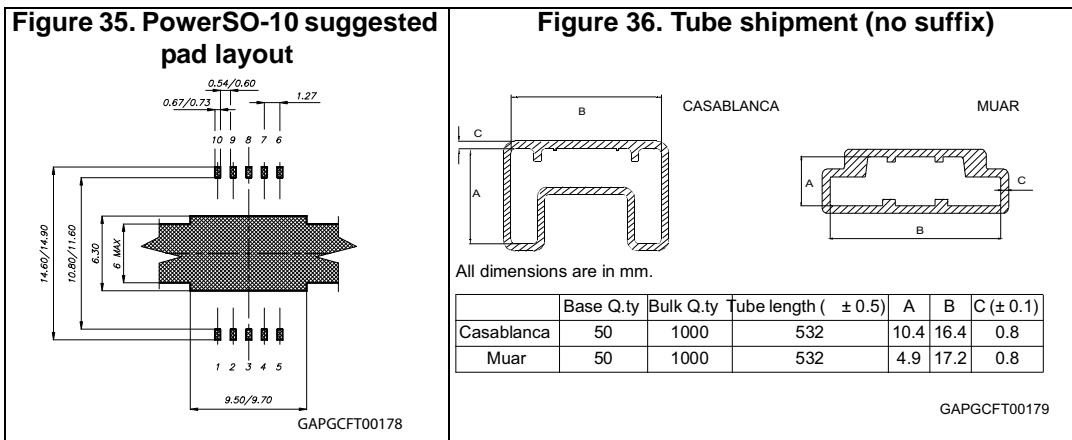


### 3.5 TO-220 packing information

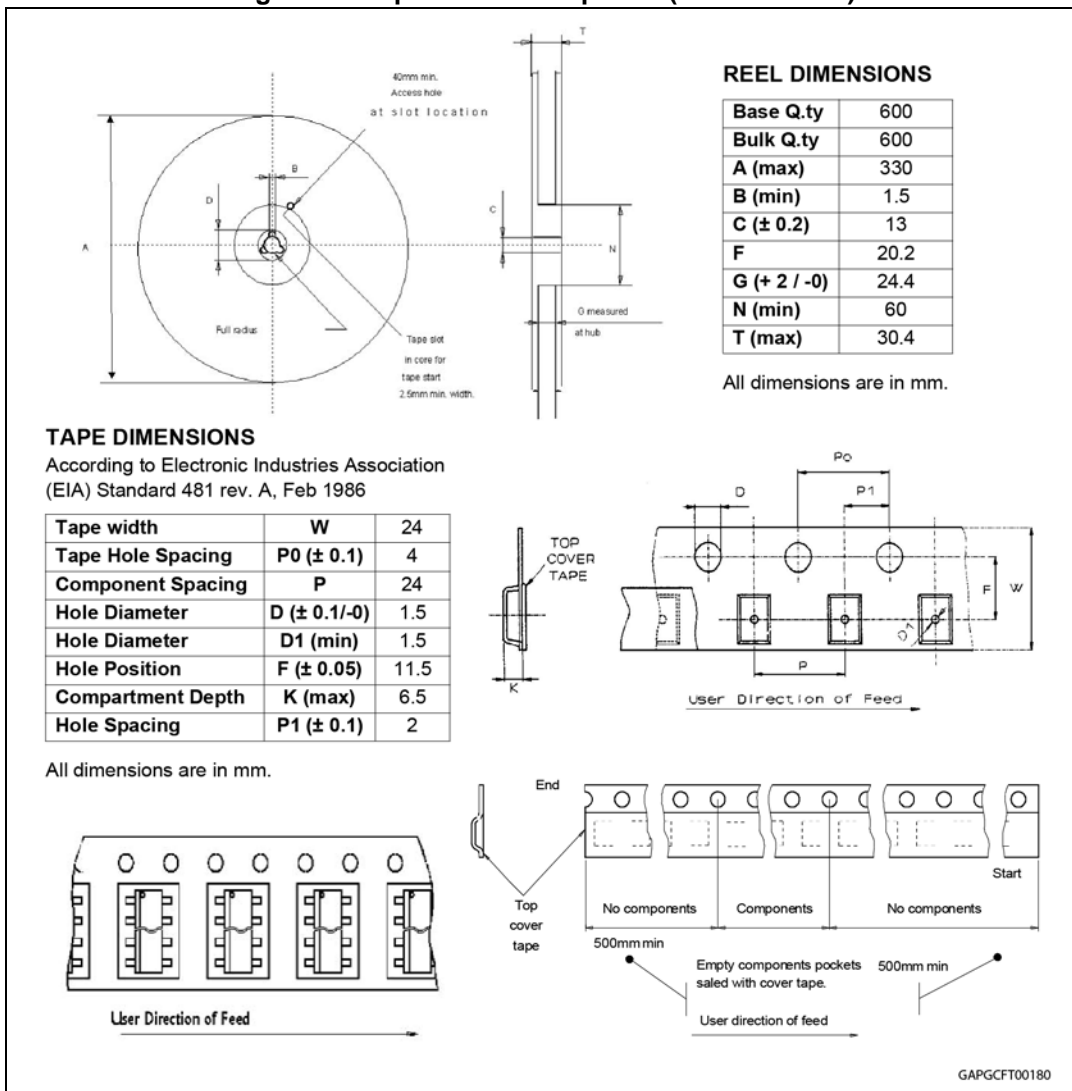
Figure 34. TO-220 tube shipment (no suffix)



### 3.6 PowerSO-10 packing information

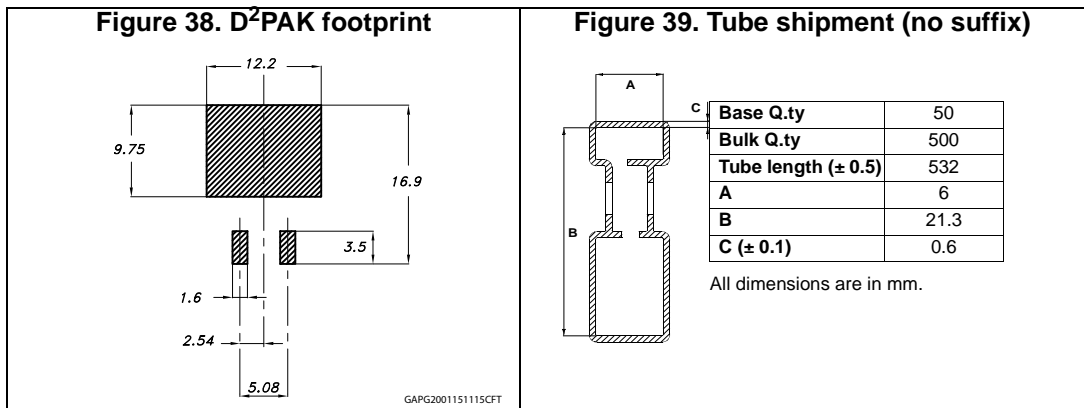


**Figure 37. Tape and reel shipment (suffix "13TR")**

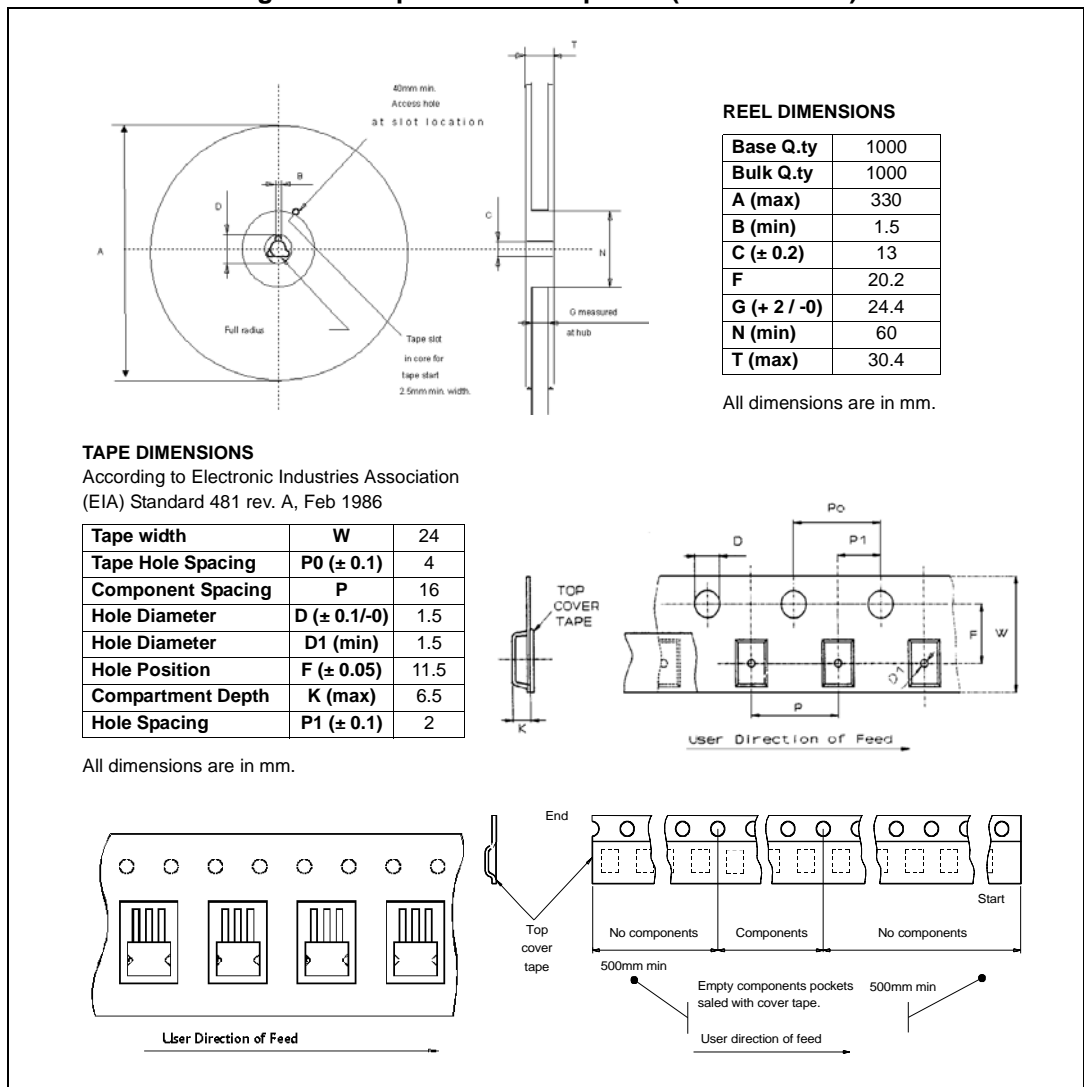




### 3.7 D<sup>2</sup>PAK packing information



**Figure 40. Tape and reel shipment (suffix "13TR")**



## 4 Revision history

Table 13. Document revision history

| Date        | Revision | Changes   |
|-------------|----------|---|
| 19-Sep-2012 | 1        | Initial release.  |
| 25-Sep-2013 | 2        | Updated disclaimer.   |
| 30-Sep-2013 | 3        | Added <a href="#">Table 5: On</a>   |
| 09-Oct-2013 | 4        | Corrections of typos  |
| 03-Feb-2015 | 5        | Updated <a href="#">Section 3.2: TO-220 mechanical data</a> and <a href="#">Section 3.4: D2PAK mechanical data</a><br>Updated <a href="#">Figure 38: D<sup>2</sup>PAK footprint</a> |

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