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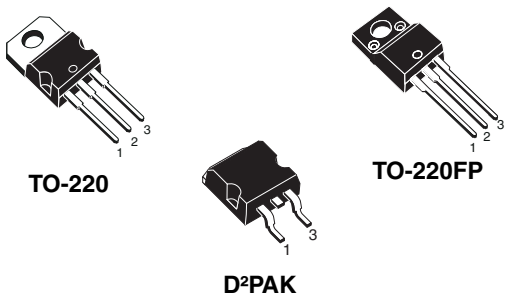
# STB9NK60ZD
# STF9NK60ZD - STP9NK60ZD

## N-channel 600 V - 0.85 Ω - 7 A - D²PAK, TO-220FP, TO-220 SuperFREDMesh™ Power MOSFET

## Features

| Type | $V_{DSS}$ | $R_{DS(on)}$ max | $I_D$ | Pw |
|---|---|---|---|---|
| STB9NK60ZD | 600 V | < 0.95 Ω | 7 A | 125 W |
| STF9NK60ZD | 600 V | < 0.95 Ω | 7 A | 30 W |
| STP9NK60ZD | 600 V | < 0.95 Ω | 7 A | 125 W |

- Very high dv/dt capability
- 100% avalanche tested
- Gate charge minimized
- Low intrinsic capacitances
- Fast internal recovery diode




## Application

- Switching applications

## Description

The SuperFREDMesh™ series associates all advantages of reduced on-resistance, zener gate protection and very high dv/dt capability with a Fast body-drain recovery diode. Such series complements the “FDmesh™” advanced technology.

**Figure 1. Internal schematic diagram**

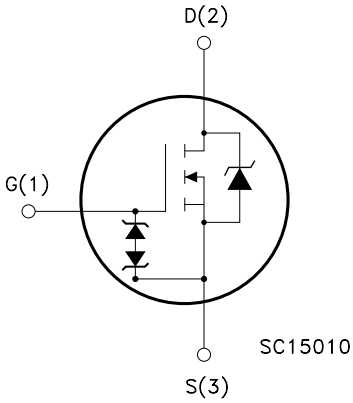



**Table 1. Device summary**

| Order codes | Marking | Package | Packaging |
|---|---|---|---|
| STB9NK60ZD | B9NK60ZD | D²PAK | Tape and reel |
| STF9NK60ZD | F9NK60ZD | TO-220FP | Tube |
| STP9NK60ZD | P9NK60ZD | TO-220 | Tube |

# Contents

# 1 Electrical ratings

**Table 2. Absolute maximum ratings**

| Symbol | Parameter | Value | | Unit |
|---|---|---|---|---|
| | | D²PAK/TO-220 | TO-220FP | |
| $V_{DS}$ | Drain-source voltage ($V_{GS}$ = 0) | 600 | | V |
| $V_{GS}$ | Gate- source voltage | ± 30 | | V |
| $I_D$ | Drain current (continuos) at $T_C$ = 25 °C | 7 | 7 (1) | A |
| $I_D$ | Drain current (continuos) at $T_C$ = 100 °C | 4.3 | 4.3 (1) | A |
| $I_{DM}$ (2) | Drain current (pulsed) | 28 | 28 (1) | A |
| $P_{TOT}$ | Total dissipation at $T_C$ = 25 °C | 125 | 30 | W |
| | Derating factor | 1 | 0.24 | W/°C |
| $V_{ESD(G-S)}$ | Gate source ESD (HBM-C=100 pF, R=1.5 kΩ) | 4000 | | V |
| dv/dt (3) | Peak diode recovery voltage slope | 15 | | V/ns |
| $V_{ISO}$ | Insulation withstand voltage (RMS) from all three leads to external heat sink (t=1 s;$T_C$=25 °C) | -- | 2500 | V |
| $T_j$<br>$T_{stg}$ | Operating junction temperature<br>Storage temperature | -55 to 150 | | °C |

1. Limited only by maximum temperature allowed
2. Pulse width limited by safe operating area
3. $I_{SD} \leq 7$ A, di/dt $\leq 500$ A/µs, $V_{DD} = 80\%V_{(BR)DSS}$

**Table 3. Thermal data**

| Symbol | Parameter | Value | | Unit |
|---|---|---|---|---|
| | | D²PAK/TO-220 | TO-220FP | |
| Rthj-pcb | Thermal resistance junction-pcb Max (when mounted on minimum footprint) | 30 | -- | °C/W |
| Rthj-case | Thermal resistance junction-case Max | 1 | 4.16 | °C/W |
| Rthj-amb | Thermal resistance junction-ambient Max | 62.5 | | °C/W |
| $T_l$ | Maximum lead temperature for soldering purpose | 300 | | °C |

**Table 4. Avalanche characteristics**

| Symbol | Parameter | Max value | Unit |
|---|---|---|---|
| $I_{AR}$ | Avalanche current, repetitive or not-repetitive (pulse width limited by $T_j$ max) | 7 | A |
| $E_{AS}$ | Single pulse avalanche energy (starting $T_j$ = 25 °C, $I_D = I_{AR}$, $V_{DD}$ = 50 V) | 235 | mJ |

# 2 Electrical characteristics

(Tcase = 25 °C unless otherwise specified)

**Table 5. On /off states**

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $V_{(BR)DSS}$ | Drain-source breakdown voltage | $I_D$ = 1 mA, $V_{GS}$ = 0 | 600 | | | V |
| $I_{DSS}$ | Zero gate voltage drain current ($V_{GS}$ = 0)<br>$V_{DS}$ = Max rating<br>$V_{DS}$ = Max rating, $T_C$ = 125 °C | | | | 1<br>50 | µA<br>µA |
| $I_{GSS}$ | Gate-body leakage current ($V_{DS}$ = 0) | $V_{GS}$ = ± 20 V | | | ±10 | µA |
| $V_{GS(th)}$ | Gate threshold voltage | $V_{DS}$ = $V_{GS}$, $I_D$ = 100 µA | 2.5 | 3.5 | 4.5 | V |
| $R_{DS(on)}$ | Static drain-source on resistance | $V_{GS}$ = 10 V, $I_D$ = 3.5 A | | 0.85 | 0.95 | Ω |

**Table 6. Dynamic**

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $g_{fs}$ (1) | Forward transconductance | $V_{DS}$ = 15 V, $I_D$ = 3.5 A | | 5.3 | | S |
| $C_{iss}$<br>$C_{oss}$<br>$C_{rss}$ | Input capacitance<br>Output capacitance<br>Reverse transfer capacitance | $V_{DS}$ = 25 V, f = 1 MHz, $V_{GS}$ = 0 | | 1110<br>135<br>30 | | pF<br>pF<br>pF |
| $C_{OSS\ eq}$ (2) | Equivalent output capacitance | $V_{GS}$ = 0, $V_{DS}$ = 0 to 480 V | | 72 | | pF |
| $Q_g$<br>$Q_{gs}$<br>$Q_{gd}$ | Total gate charge<br>Gate-source charge<br>Gate-drain charge | $V_{DD}$ = 480 V, $I_D$ = 7 A,<br>$V_{GS}$ = 10 V<br>*(see Figure 17)* | | 41<br>8.7<br>21 | 53 | nC<br>nC<br>nC |

1. Pulsed: Pulse duration = 300 µs, duty cycle 1.5%
2. $C_{oss\ eq}$. is defined as a constant equivalent capacitance giving the same charging time as $C_{oss}$ when $V_D$S increases from 0 to 80% $V_{DSS}$

**Table 7. Switching times**

| Symbol | Parameter | Test conditions | Min. | Typ. | Max | Unit |
|---|---|---|---|---|---|---|
| $t_{d(on)}$<br>$t_r$<br>$t_{d(off)}$<br>$t_f$ | Turn-on delay time<br>Rise time<br>Turn-off-delay time<br>Fall time | $V_{DD}$ = 300 V, $I_D$ = 3.5 A<br>$R_G$ = 4.7 Ω, $V_{GS}$ = 10 V<br>*(see Figure 16)* | | 11.4<br>13.6<br>23.1<br>15 | | ns<br>ns<br>ns<br>ns |
| $t_{r(Voff)}$<br>$t_f$<br>$t_c$ | Off-voltage rise time<br>Fall time<br>Cross-over time | $V_{DD}$ = 480 V, $I_D$ = 7 A,<br>$R_G$ = 4.7 Ω, $V_{GS}$ = 10 V<br>*(see Figure 16)* | | 11<br>8<br>20 | | ns<br>ns<br>ns |

**Table 8. Source drain diode**

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $I_{SD}$<br>$I_{SDM}$ (1) | Source-drain current<br>Source-drain current (pulsed) | | | | 7<br>28 | A<br>A |
| $V_{SD}$ (2) | Forward on voltage | $I_{SD}$ = 7 A, $V_{GS}$ = 0 | | | 1.6 | V |
| $t_{rr}$<br>$Q_{rr}$<br>$I_{RRM}$ | Reverse recovery time<br>Reverse recovery charge<br>Reverse recovery current | $I_{SD}$ = 7 A, di/dt = 100 A/µs<br>$V_{DD}$ = 30 V<br>*(see Figure 21)* | | 130<br>550<br>8.4 | | ns<br>nC<br>A |
| $t_{rr}$<br>$Q_{rr}$<br>$I_{RRM}$ | Reverse recovery time<br>Reverse recovery charge<br>Reverse recovery current | $I_{SD}$ = 7 A, di/dt = 100 A/µs<br>$V_{DD}$ = 30 V, $T_j$ = 150 °C<br>*(see Figure 21)* | | 176<br>880<br>10 | | ns<br>nC<br>A |

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

**Table 9. Gate-source Zener diode**

| Symbol | Parameter | Test conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $BV_{GSO}$ (1) | Gate-source breakdown voltage | Igs=± 1 mA (open drain) | 30 | | | V |

1. The built-in back-to-back Zener diodes have specifically been designed to enhance not only the device's ESD capability, but also to make them safely absorb possible voltage transients that may occasionally be applied from gate to source. In this respect the Zener voltage is appropriate to achieve an efficient and cost-effective intervention to protect the device's integrity. These integrated Zener diodes thus avoid the usage of external components

## 2.1 Electrical characteristics (curves)

**Figure 2. Safe operating area for TO-220 / D²PAK**

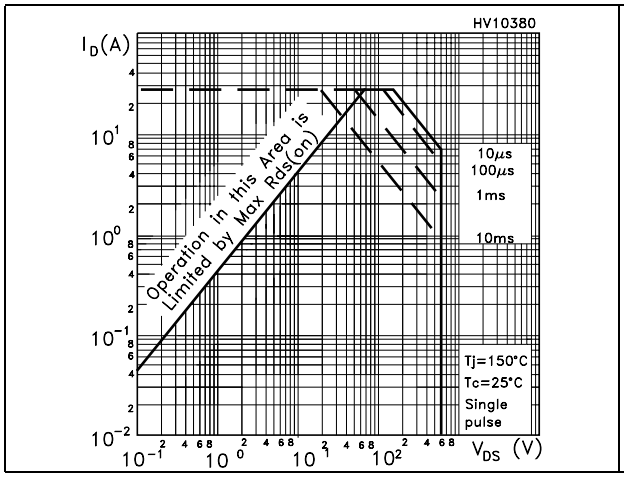



**Figure 3. Thermal impedance for TO-220 / D²PAK**

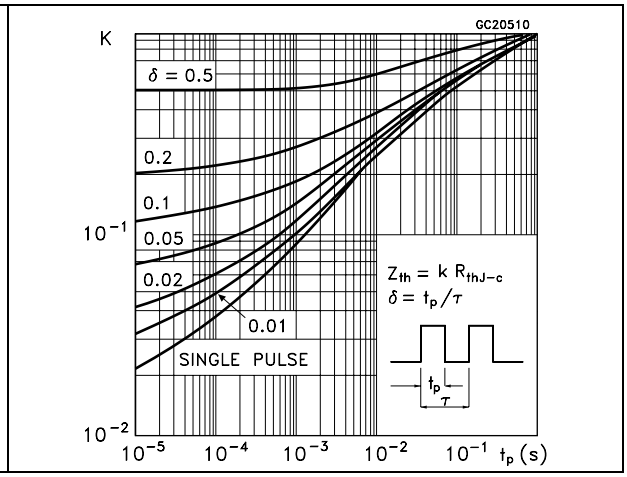



**Figure 4. Safe operating area for TO-220FP**

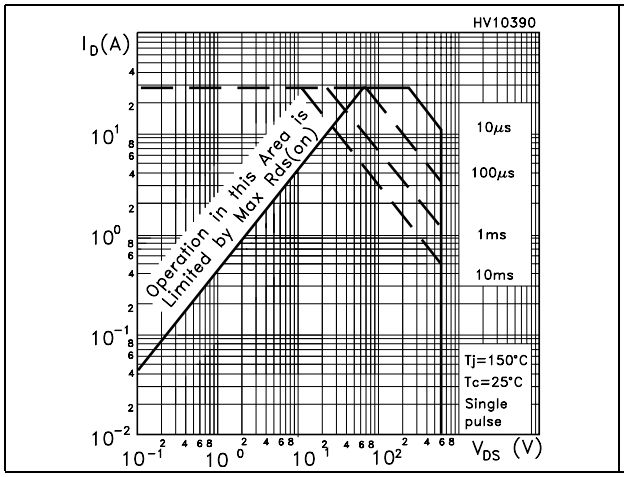



**Figure 5. Thermal impedance for TO-220FP**

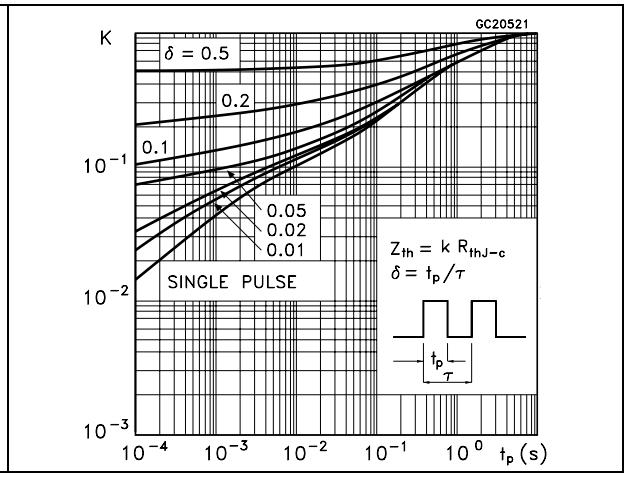



**Figure 6. Output characteristics**

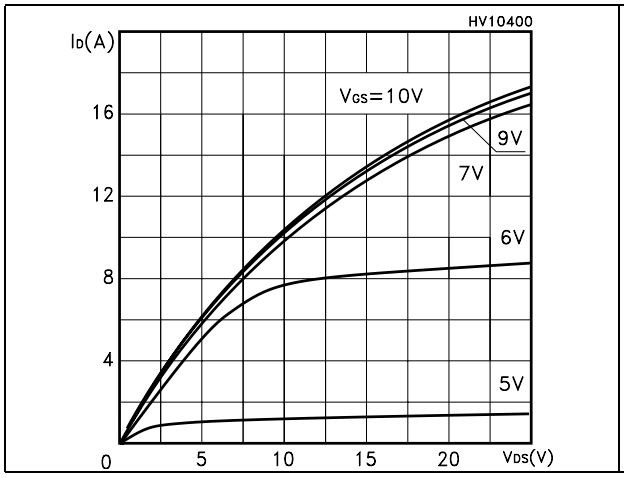



**Figure 7. Transfer characteristics**

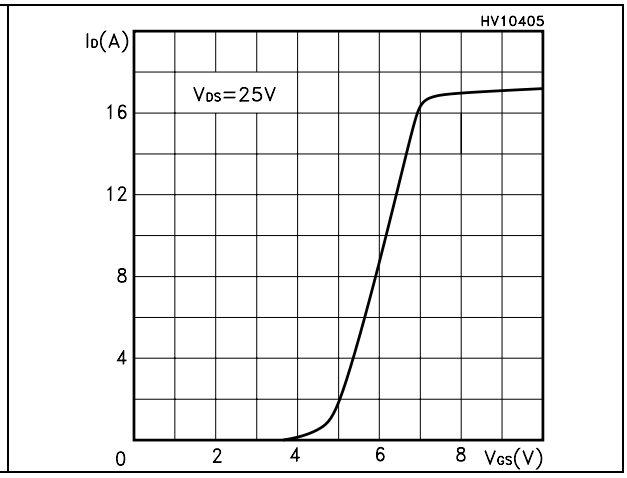


**Figure 8. Normalized $B_{VDSS}$ vs temperature**

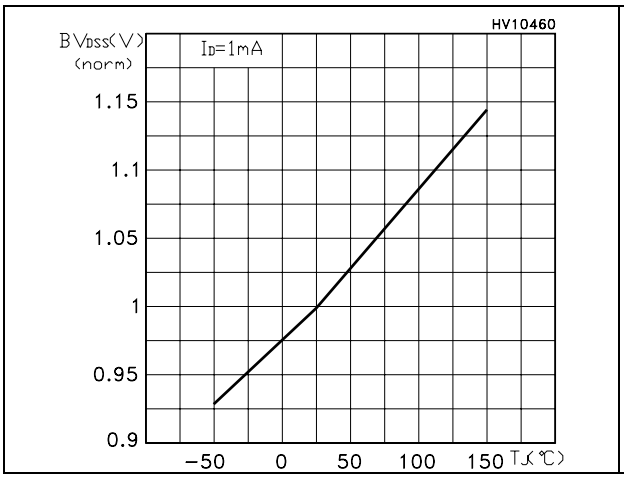



**Figure 9. Static drain-source on resistance**

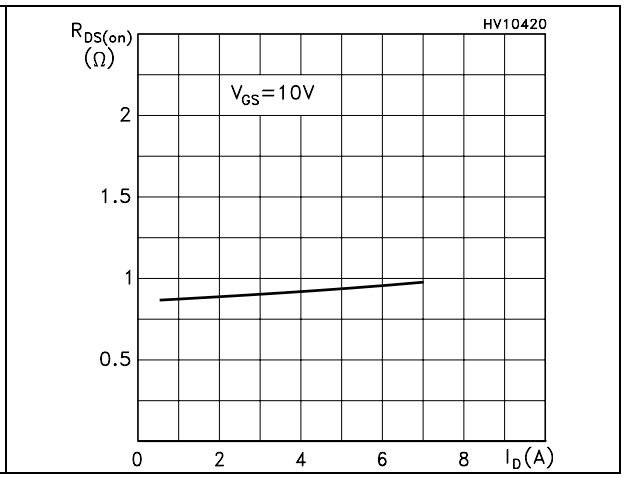



**Figure 10. Gate charge vs gate-source voltage**

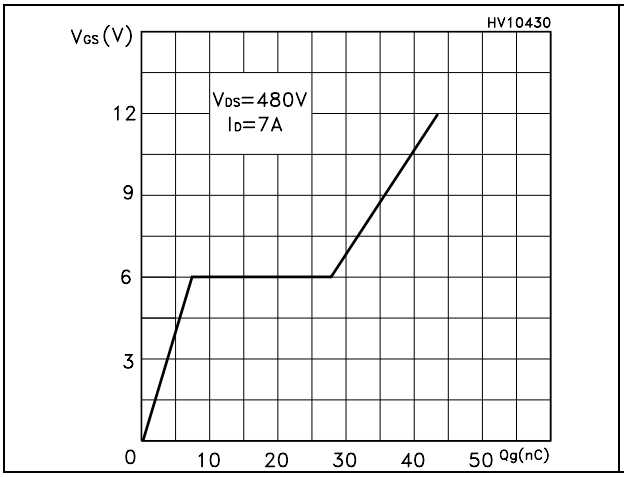



**Figure 11. Capacitance variations**

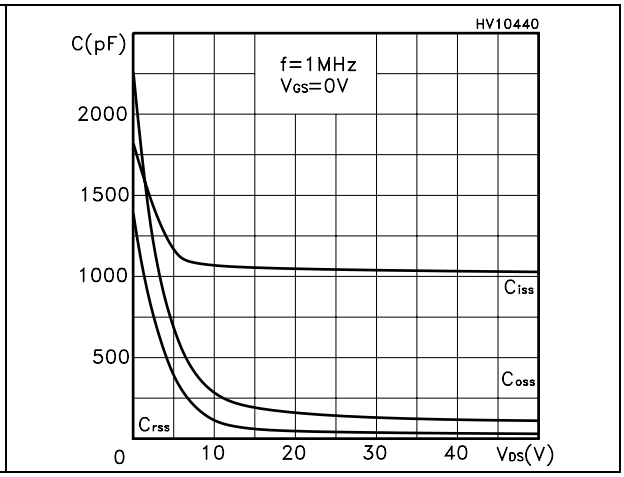



**Figure 12. Normalized gate threshold voltage vs temperature**

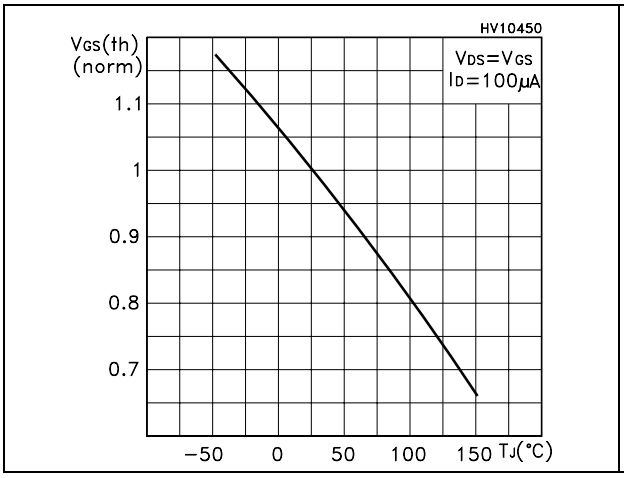



**Figure 13. Normalized on resistance vs temperature**

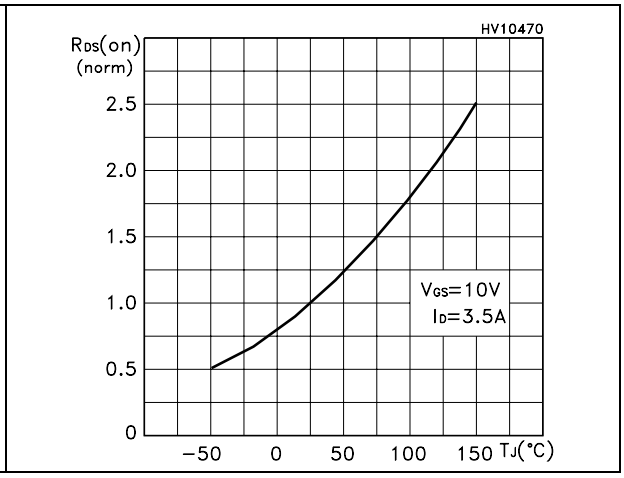


**Figure 14. Source-drain diode forward characteristics**

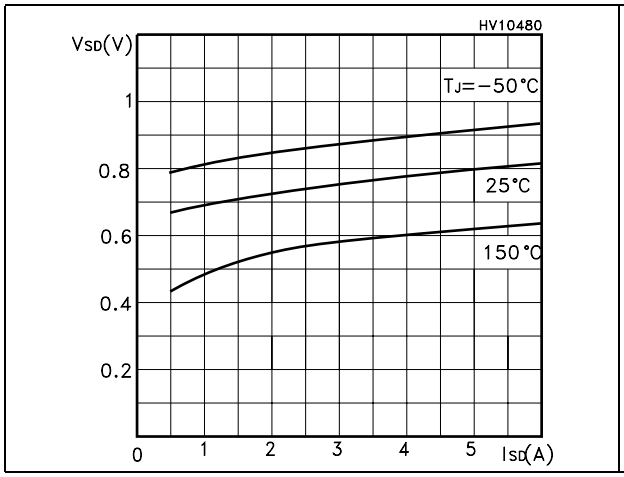
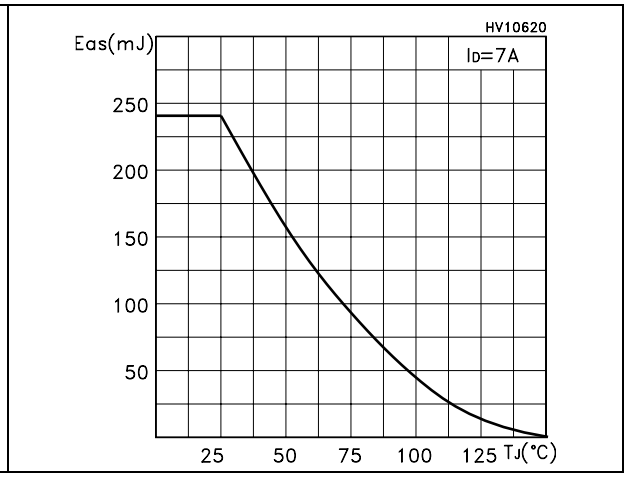



**Figure 15. Maximum avalanche energy vs temperature**



# 3 Test circuits

**Figure 16. Switching times test circuit for resistive load**

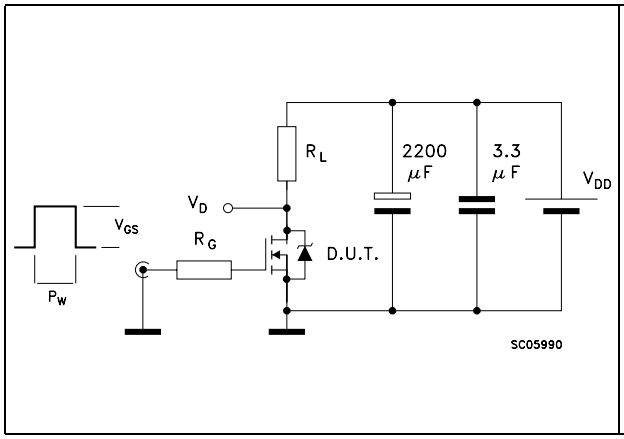



**Figure 17. Gate charge test circuit**

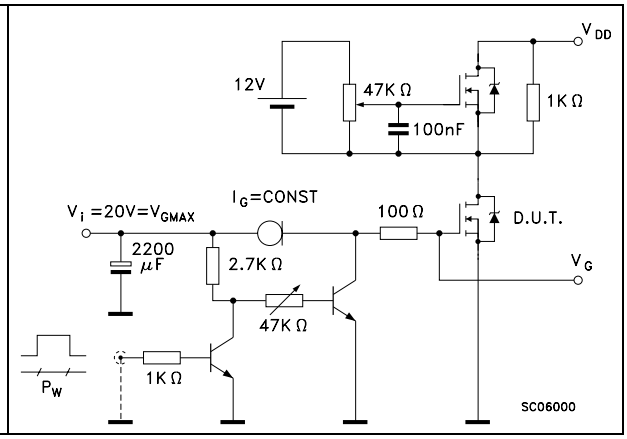



**Figure 18. Test circuit for inductive load switching and diode recovery times**

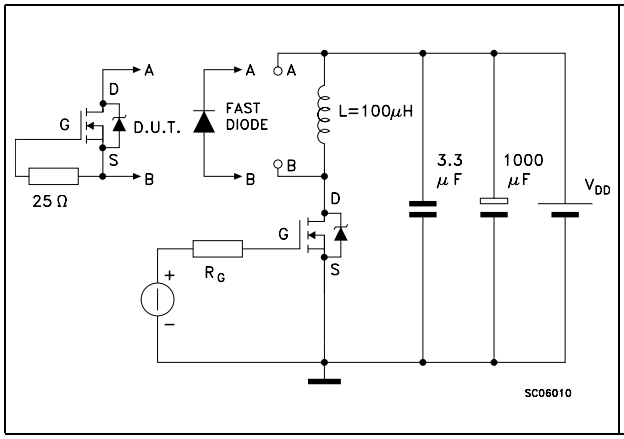



**Figure 19. Unclamped inductive load test circuit**

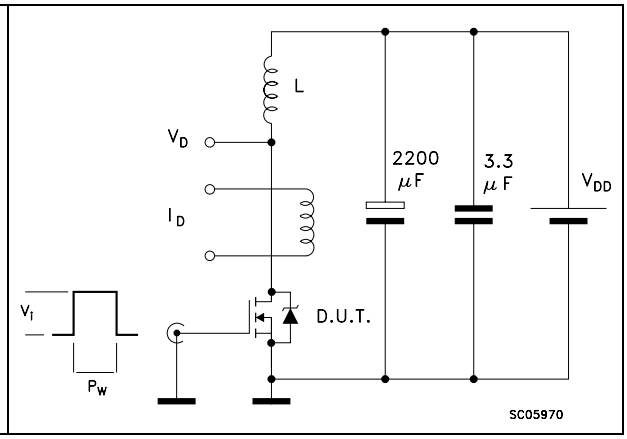



**Figure 20. Unclamped inductive waveform**

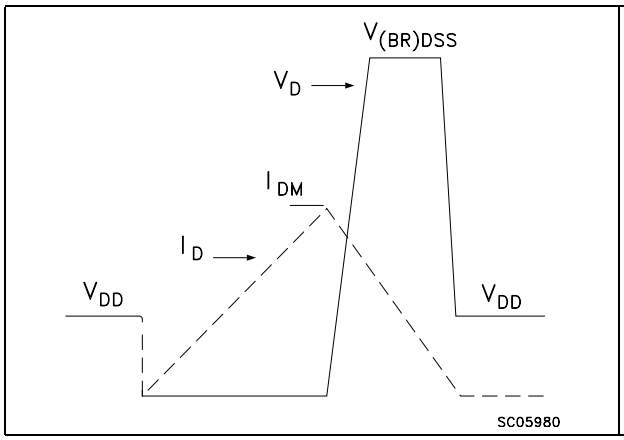
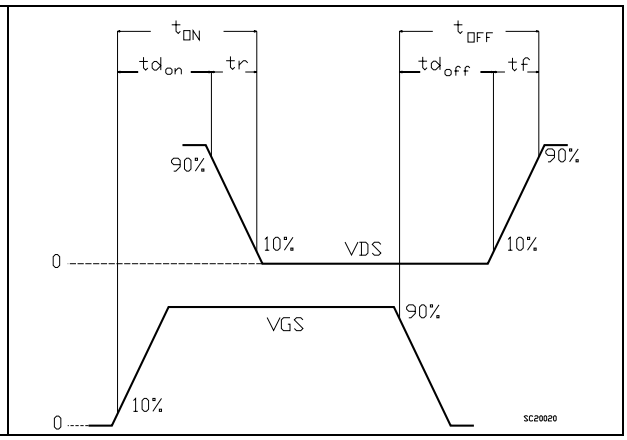



**Figure 21. Switching time waveform**

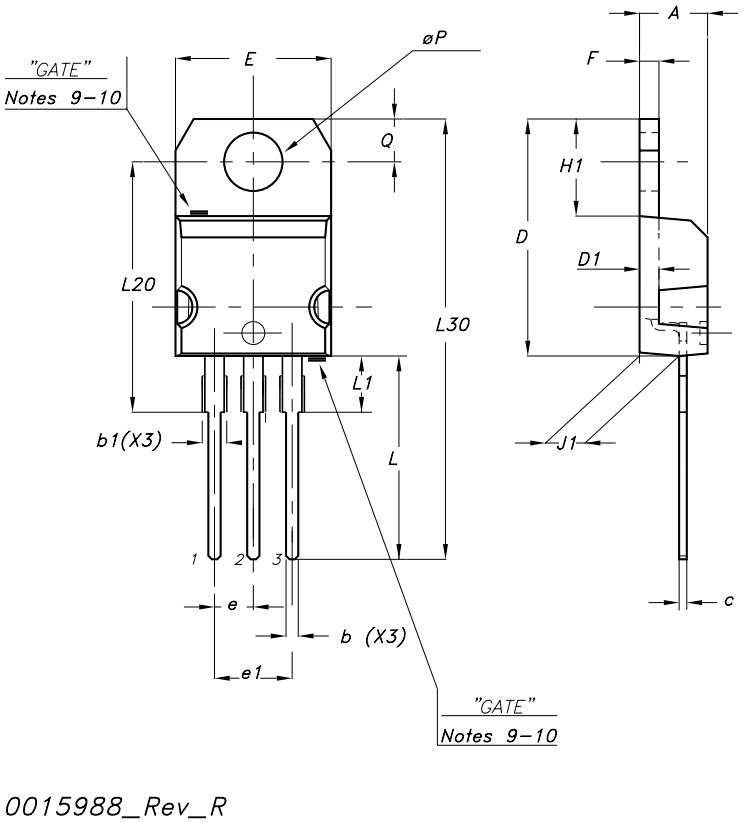


# 4 Package mechanical data

In order to meet environmental requirements, ST offers these devices in ECOPACK® packages. These packages have a Lead-free second level interconnect. The category of second level interconnect is marked on the package and on the inner box label, in compliance with JEDEC Standard JESD97. The maximum ratings related to soldering conditions are also marked on the inner box label. ECOPACK is an ST trademark. ECOPACK specifications are available at: *www.st.com*

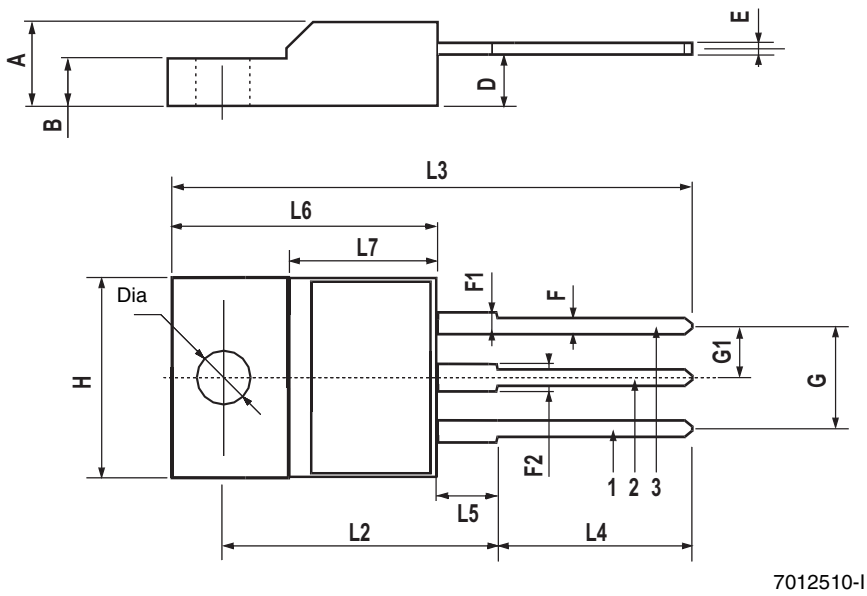
## TO-220 mechanical data

| Dim | mm | | | inch | | |
|---|---|---|---|---|---|---|
| | Min | Typ | Max | Min | Typ | Max |
| A | 4.40 | | 4.60 | 0.173 | | 0.181 |
| b | 0.61 | | 0.88 | 0.024 | | 0.034 |
| b1 | 1.14 | | 1.70 | 0.044 | | 0.066 |
| c | 0.48 | | 0.70 | 0.019 | | 0.027 |
| D | 15.25 | | 15.75 | 0.6 | | 0.62 |
| D1 | | 1.27 | | | 0.050 | |
| E | 10 | | 10.40 | 0.393 | | 0.409 |
| e | 2.40 | | 2.70 | 0.094 | | 0.106 |
| e1 | 4.95 | | 5.15 | 0.194 | | 0.202 |
| F | 1.23 | | 1.32 | 0.048 | | 0.051 |
| H1 | 6.20 | | 6.60 | 0.244 | | 0.256 |
| J1 | 2.40 | | 2.72 | 0.094 | | 0.107 |
| L | 13 | | 14 | 0.511 | | 0.551 |
| L1 | 3.50 | | 3.93 | 0.137 | | 0.154 |
| L20 | | 16.40 | | | 0.645 | |
| L30 | | 28.90 | | | 1.137 | |
| ∅P | 3.75 | | 3.85 | 0.147 | | 0.151 |
| Q | 2.65 | | 2.95 | 0.104 | | 0.116 |



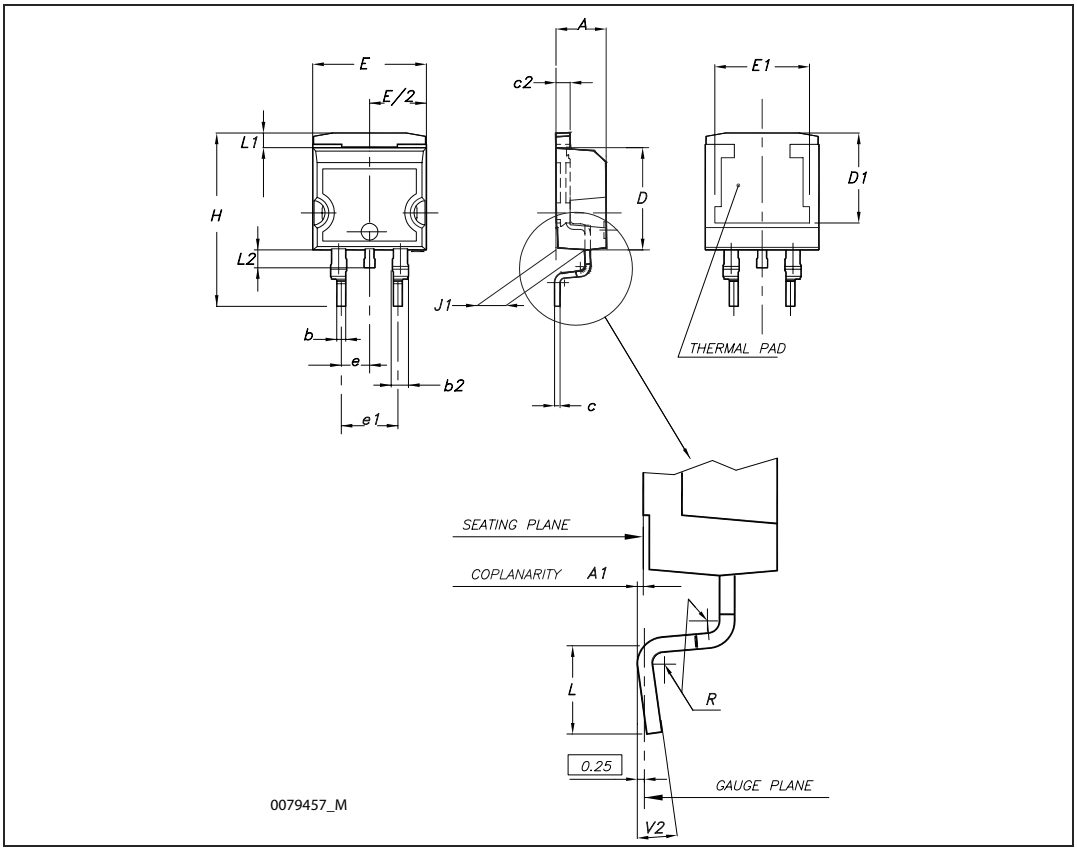
## TO-220FP mechanical data

| Dim. | mm. | | | inch | | |
|---|---|---|---|---|---|---|
| | Min. | Typ | Max. | Min. | Typ. | Max. |
| A | 4.40 | | 4.60 | 0.173 | | 0.181 |
| B | 2.5 | | 2.7 | 0.098 | | 0.106 |
| D | 2.5 | | 2.75 | 0.098 | | 0.108 |
| E | 0.45 | | 0.70 | 0.017 | | 0.027 |
| F | 0.75 | | 1.00 | 0.030 | | 0.039 |
| F1 | 1.15 | | 1.50 | 0.045 | | 0.067 |
| F2 | 1.15 | | 1.50 | 0.045 | | 0.067 |
| G | 4.95 | | 5.20 | 0.195 | | 0.204 |
| G1 | 2.40 | | 2.70 | 0.094 | | 0.106 |
| H | 10 | | 10.40 | 0.393 | | 0.409 |
| L2 | | 16 | | | 0.630 | |
| L3 | 28.6 | | 30.6 | 1.126 | | 1.204 |
| L4 | 9.80 | | 10.60 | 0.385 | | 0.417 |
| L5 | 2.9 | | 3.6 | 0.114 | | 0.141 |
| L6 | 15.90 | | 16.40 | 0.626 | | 0.645 |
| L7 | 9 | | 9.30 | 0.354 | | 0.366 |
| Dia | 3 | | 3.2 | 0.118 | | 0.126 |



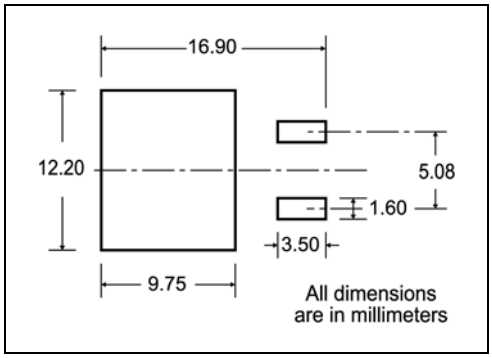
## D²PAK (TO-263) mechanical data

| Dim | mm | | | inch | | |
|---|---|---|---|---|---|---|
| | Min | Typ | Max | Min | Typ | Max |
| A | 4.40 | | 4.60 | 0.173 | | 0.181 |
| A1 | 0.03 | | 0.23 | 0.001 | | 0.009 |
| b | 0.70 | | 0.93 | 0.027 | | 0.037 |
| b2 | 1.14 | | 1.70 | 0.045 | | 0.067 |
| c | 0.45 | | 0.60 | 0.017 | | 0.024 |
| c2 | 1.23 | | 1.36 | 0.048 | | 0.053 |
| D | 8.95 | | 9.35 | 0.352 | | 0.368 |
| D1 | 7.50 | | | 0.295 | | |
| E | 10 | | 10.40 | 0.394 | | 0.409 |
| E1 | 8.50 | | | 0.334 | | |
| e | | 2.54 | | | 0.1 | |
| e1 | 4.88 | | 5.28 | 0.192 | | 0.208 |
| H | 15 | | 15.85 | 0.590 | | 0.624 |
| J1 | 2.49 | | 2.69 | 0.099 | | 0.106 |
| L | 2.29 | | 2.79 | 0.090 | | 0.110 |
| L1 | 1.27 | | 1.40 | 0.05 | | 0.055 |
| L2 | 1.30 | | 1.75 | 0.051 | | 0.069 |
| R | | 0.4 | | | 0.016 | |
| V2 | 0° | | 8° | 0° | | 8° |

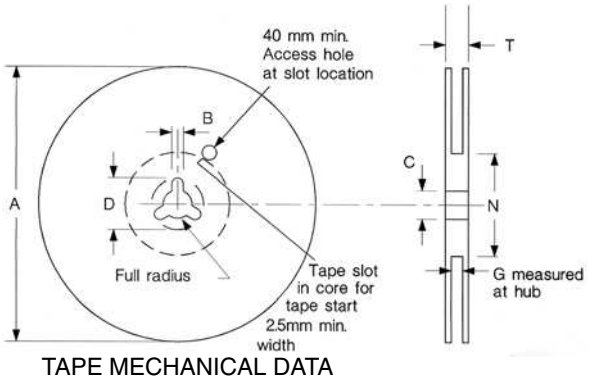


# 5 Packaging mechanical data

## D²PAK FOOTPRINT




## TAPE AND REEL SHIPMENT



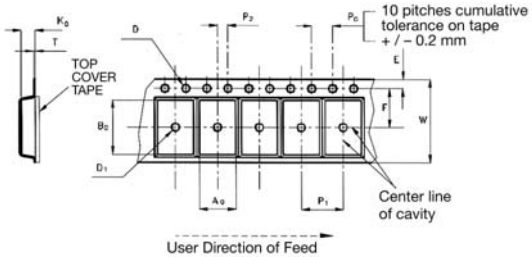

REEL MECHANICAL DATA

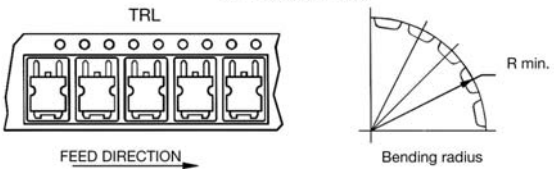
| DIM. | mm | | inch | |
|---|---|---|---|---|
| | MIN. | MAX. | MIN. | MAX. |
| A | | 330 | | 12.992 |
| B | 1.5 | | 0.059 | |
| C | 12.8 | 13.2 | 0.504 | 0.520 |
| D | 20.2 | | 0795 | |
| G | 24.4 | 26.4 | 0.960 | 1.039 |
| N | 100 | | 3.937 | |
| T | | 30.4 | | 1.197 |

| BASE QTY | BULK QTY |
|---|---|
| 1000 | 1000 |

TAPE MECHANICAL DATA

| DIM. | mm | | inch | |
|---|---|---|---|---|
| | MIN. | MAX. | MIN. | MAX. |
| A0 | 10.5 | 10.7 | 0.413 | 0.421 |
| B0 | 15.7 | 15.9 | 0.618 | 0.626 |
| D | 1.5 | 1.6 | 0.059 | 0.063 |
| D1 | 1.59 | 1.61 | 0.062 | 0.063 |
| E | 1.65 | 1.85 | 0.065 | 0.073 |
| F | 11.4 | 11.6 | 0.449 | 0.456 |
| K0 | 4.8 | 5.0 | 0.189 | 0.197 |
| P0 | 3.9 | 4.1 | 0.153 | 0.161 |
| P1 | 11.9 | 12.1 | 0.468 | 0.476 |
| P2 | 1.9 | 2.1 | 0.075 | 0.082 |
| R | 50 | | 1.574 | |
| T | 0.25 | 0.35 | 0.0098 | 0.0137 |
| W | 23.7 | 24.3 | 0.933 | 0.956 |




* on sales type

# 6 Revision history

**Table 10. Document revision history**

| Date | Revision | Changes |
|---|---|---|
| 29-Sep-2003 | 6 | Data updated |
| 13-Jun-2006 | 7 | The document has been reformatted |
| 14-Apr-2008 | 9 | – *Table 8* has been corrected<br>– *Package mechanical data* upadted. |

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