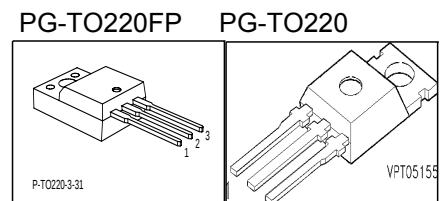


## Cool MOS™ Power Transistor

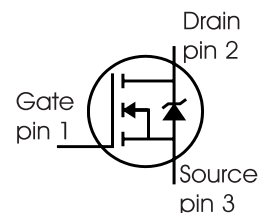
### Feature

- New revolutionary high voltage technology
- Ultra low gate charge
- Periodic avalanche rated
- Extreme  $dv/dt$  rated
- High peak current capability
- Improved transconductance
- PG-TO-220-3-31;-3-111: Fully isolated package (2500 VAC; 1 minute)
- Pb-free lead plating; RoHS compliant
- Qualified according to JEDEC<sup>0)</sup> for target applications

|                     |      |          |
|---------------------|------|----------|
| $V_{DS} @ T_{jmax}$ | 650  | V        |
| $R_{DS(on)}$        | 0.95 | $\Omega$ |
| $I_D$               | 4.5  | A        |



| Type       | Package    | Ordering Code | Marking |
|------------|------------|---------------|---------|
| SPP04N60C3 | PG-TO220   | Q67040-S4366  | 04N60C3 |
| SPA04N60C3 | PG-TO220FP | SP000216299   | 04N60C3 |



### Maximum Ratings

| Parameter                                                                                                         | Symbol               | Value      |                                        | Unit             |
|-------------------------------------------------------------------------------------------------------------------|----------------------|------------|----------------------------------------|------------------|
|                                                                                                                   |                      | SPP        | SPA                                    |                  |
| Continuous drain current<br>$T_C = 25^\circ\text{C}$<br>$T_C = 100^\circ\text{C}$                                 | $I_D$                | 4.5<br>2.8 | 4.5 <sup>1)</sup><br>2.8 <sup>1)</sup> | A                |
| Pulsed drain current, $t_p$ limited by $T_{jmax}$                                                                 | $I_{D \text{ puls}}$ | 13.5       | 13.5                                   | A                |
| Avalanche energy, single pulse<br>$I_D=3.4, V_{DD}=50\text{V}$                                                    | $E_{AS}$             | 130        | 130                                    | mJ               |
| Avalanche energy, repetitive $t_{AR}$ limited by $T_{jmax}$ <sup>2)</sup><br>$I_D=4.5\text{A}, V_{DD}=50\text{V}$ | $E_{AR}$             | 0.4        | 0.4                                    |                  |
| Avalanche current, repetitive $t_{AR}$ limited by $T_{jmax}$                                                      | $I_{AR}$             | 4.5        | 4.5                                    | A                |
| Gate source voltage static                                                                                        | $V_{GS}$             | $\pm 20$   | $\pm 20$                               | V                |
| Gate source voltage AC ( $f > 1\text{Hz}$ )                                                                       | $V_{GS}$             | $\pm 30$   | $\pm 30$                               |                  |
| Power dissipation, $T_C = 25^\circ\text{C}$                                                                       | $P_{tot}$            | 50         | 31                                     | W                |
| Operating and storage temperature                                                                                 | $T_j, T_{stg}$       | -55...+150 |                                        | $^\circ\text{C}$ |
| Reverse diode $dv/dt$ <sup>7)</sup>                                                                               | $dv/dt$              | 15         |                                        | V/ns             |

**Maximum Ratings**

| Parameter                                                                                                  | Symbol  | Value | Unit |
|------------------------------------------------------------------------------------------------------------|---------|-------|------|
| Drain Source voltage slope<br>$V_{DS} = 480 \text{ V}$ , $I_D = 4.5 \text{ A}$ , $T_j = 125^\circ\text{C}$ | $dv/dt$ | 50    | V/ns |

**Thermal Characteristics**

| Parameter                                                                                         | Symbol                | Values |      |      | Unit |
|---------------------------------------------------------------------------------------------------|-----------------------|--------|------|------|------|
|                                                                                                   |                       | min.   | typ. | max. |      |
| Thermal resistance, junction - case                                                               | $R_{thJC}$            | -      | -    | 2.5  | K/W  |
| Thermal resistance, junction - case, FullPAK                                                      | $R_{thJC \text{ FP}}$ | -      | -    | 4    |      |
| Thermal resistance, junction - ambient, leaded                                                    | $R_{thJA}$            | -      | -    | 62   |      |
| Thermal resistance, junction - ambient, FullPAK                                                   | $R_{thJA \text{ FP}}$ | -      | -    | 80   |      |
| SMD version, device on PCB:<br>@ min. footprint<br>@ 6 cm <sup>2</sup> cooling area <sup>3)</sup> | $R_{thJA}$            | -      | -    | 62   |      |
|                                                                                                   |                       | -      | 35   | -    |      |
| Soldering temperature, wavesoldering<br>1.6 mm (0.063 in.) from case for 10s <sup>4)</sup>        | $T_{sold}$            | -      | -    | 260  | °C   |

**Electrical Characteristics, at  $T_j=25^\circ\text{C}$  unless otherwise specified**

| Parameter                                | Symbol        | Conditions                                                            | Values |      |      | Unit          |
|------------------------------------------|---------------|-----------------------------------------------------------------------|--------|------|------|---------------|
|                                          |               |                                                                       | min.   | typ. | max. |               |
| Drain-source breakdown voltage           | $V_{(BR)DSS}$ | $V_{GS}=0\text{V}$ , $I_D=0.25\text{mA}$                              | 600    | -    | -    | V             |
| Drain-Source avalanche breakdown voltage | $V_{(BR)DS}$  | $V_{GS}=0\text{V}$ , $I_D=4.5\text{A}$                                | -      | 700  | -    |               |
| Gate threshold voltage                   | $V_{GS(th)}$  | $I_D=200\mu\text{A}$ , $V_{GS}=V_{DS}$                                | 2.1    | 3    | 3.9  |               |
| Zero gate voltage drain current          | $I_{DSS}$     | $V_{DS}=600\text{V}$ , $V_{GS}=0\text{V}$ ,<br>$T_j=25^\circ\text{C}$ | -      | 0.5  | 1    | $\mu\text{A}$ |
|                                          |               | $T_j=150^\circ\text{C}$                                               | -      | -    | 50   |               |
| Gate-source leakage current              | $I_{GSS}$     | $V_{GS}=30\text{V}$ , $V_{DS}=0\text{V}$                              | -      | -    | 100  | nA            |
| Drain-source on-state resistance         | $R_{DS(on)}$  | $V_{GS}=10\text{V}$ , $I_D=2.8\text{A}$ ,<br>$T_j=25^\circ\text{C}$   | -      | 0.85 | 0.95 | $\Omega$      |
|                                          |               | $T_j=150^\circ\text{C}$                                               | -      | 2.3  | -    |               |
|                                          |               |                                                                       | -      |      |      |               |
| Gate input resistance                    | $R_G$         | $f=1\text{MHz}$ , open drain                                          | -      | 0.95 | -    |               |

### Electrical Characteristics

| Parameter                                                     | Symbol       | Conditions                                                                 | Values |      |      | Unit |
|---------------------------------------------------------------|--------------|----------------------------------------------------------------------------|--------|------|------|------|
|                                                               |              |                                                                            | min.   | typ. | max. |      |
| Transconductance                                              | $g_{fs}$     | $V_{DS} \geq 2 \cdot I_D \cdot R_{DS(on)max}$ ,<br>$I_D = 2.8A$            | -      | 4.4  | -    | S    |
| Input capacitance                                             | $C_{iss}$    | $V_{GS} = 0V$ , $V_{DS} = 25V$ ,<br>$f = 1MHz$                             | -      | 490  | -    | pF   |
| Output capacitance                                            | $C_{oss}$    |                                                                            | -      | 160  | -    |      |
| Reverse transfer capacitance                                  | $C_{rss}$    |                                                                            | -      | 15   | -    |      |
| Effective output capacitance, <sup>5)</sup><br>energy related | $C_{o(er)}$  | $V_{GS} = 0V$ ,<br>$V_{DS} = 0V$ to $480V$                                 | -      | 20   | -    |      |
| Effective output capacitance, <sup>6)</sup><br>time related   | $C_{o(tr)}$  |                                                                            | -      | 35   | -    |      |
| Turn-on delay time                                            | $t_{d(on)}$  | $V_{DD} = 380V$ , $V_{GS} = 0/10V$ ,<br>$I_D = 4.5A$ ,<br>$R_G = 18\Omega$ | -      | 6    | -    | ns   |
| Rise time                                                     | $t_r$        |                                                                            | -      | 2.5  | -    |      |
| Turn-off delay time                                           | $t_{d(off)}$ |                                                                            | -      | 58.5 | 80   |      |
| Fall time                                                     | $t_f$        |                                                                            | -      | 9.5  | 14   |      |

### Gate Charge Characteristics

|                       |                 |                                                           |   |     |    |    |
|-----------------------|-----------------|-----------------------------------------------------------|---|-----|----|----|
| Gate to source charge | $Q_{gs}$        | $V_{DD} = 480V$ , $I_D = 4.5A$                            | - | 2.2 | -  | nC |
| Gate to drain charge  | $Q_{gd}$        |                                                           | - | 8.8 | -  |    |
| Gate charge total     | $Q_g$           | $V_{DD} = 480V$ , $I_D = 4.5A$ ,<br>$V_{GS} = 0$ to $10V$ | - | 19  | 25 |    |
| Gate plateau voltage  | $V_{(plateau)}$ | $V_{DD} = 480V$ , $I_D = 4.5A$                            | - | 5   | -  | V  |

<sup>0</sup>J-STD20 and JESD22

<sup>1</sup>Limited only by maximum temperature

<sup>2</sup>Repetitive avalanche causes additional power losses that can be calculated as  $P_{AV} = E_{AR} \cdot f$ .

<sup>3</sup>Device on 40mm\*40mm\*1.5mm epoxy PCB FR4 with 6cm<sup>2</sup> (one layer, 70 µm thick) copper area for drain connection. PCB is vertical without blown air.

<sup>4</sup>Soldering temperature for TO-263: 220°C, reflow

<sup>5</sup> $C_{o(er)}$  is a fixed capacitance that gives the same stored energy as  $C_{oss}$  while  $V_{DS}$  is rising from 0 to 80%  $V_{DSS}$ .

<sup>6</sup> $C_{o(tr)}$  is a fixed capacitance that gives the same charging time as  $C_{oss}$  while  $V_{DS}$  is rising from 0 to 80%  $V_{DSS}$ .

<sup>7</sup> $I_{SD} \leq I_D$ ,  $di/dt \leq 400A/\mu s$ ,  $V_{DClamp} = 400V$ ,  $V_{peak} < V_{BR, DSS}$ ,  $T_j < T_{j,max}$ .

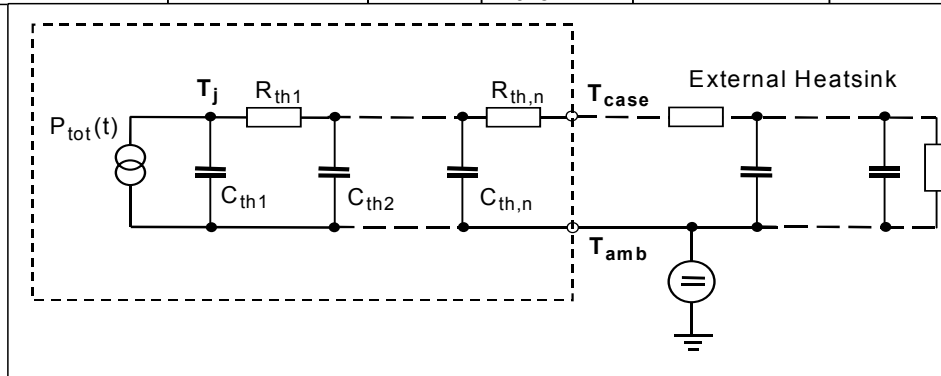
Identical low-side and high-side switch.

### Electrical Characteristics

| Parameter                                     | Symbol       | Conditions                                                  | Values |      |      | Unit                   |
|-----------------------------------------------|--------------|-------------------------------------------------------------|--------|------|------|------------------------|
|                                               |              |                                                             | min.   | typ. | max. |                        |
| Inverse diode continuous forward current      | $I_S$        | $T_C=25^{\circ}\text{C}$                                    | -      | -    | 4.5  | A                      |
| Inverse diode direct current, pulsed          | $I_{SM}$     |                                                             | -      | -    | 13.5 |                        |
| Inverse diode forward voltage                 | $V_{SD}$     | $V_{GS}=0\text{V}, I_F=I_S$                                 | -      | 1    | 1.2  | V                      |
| Reverse recovery time                         | $t_{rr}$     | $V_R=480\text{V}, I_F=I_S, di_F/dt=100\text{A}/\mu\text{s}$ | -      | 300  | 500  | ns                     |
| Reverse recovery charge                       | $Q_{rr}$     |                                                             | -      | 2.6  | -    | $\mu\text{C}$          |
| Peak reverse recovery current                 | $I_{rrm}$    |                                                             | -      | 18   | -    | A                      |
| Peak rate of fall of reverse recovery current | $di_{rr}/dt$ | $T_j=25^{\circ}\text{C}$                                    | -      | 900  | -    | $\text{A}/\mu\text{s}$ |

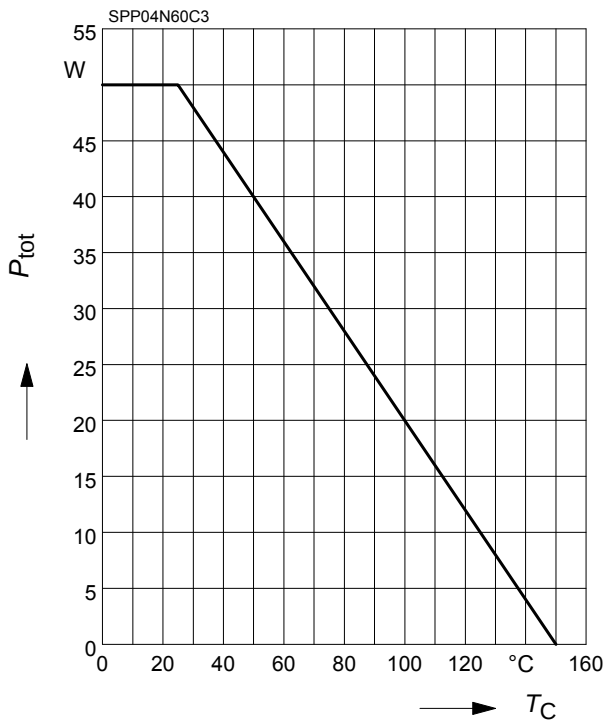
### Typical Transient Thermal Characteristics

| Symbol    | Value |       | Unit | Symbol    | Value      |            | Unit |
|-----------|-------|-------|------|-----------|------------|------------|------|
|           | SPP   | SPA   |      |           | SPP        | SPA        |      |
| $R_{th1}$ | 0.039 | 0.039 | K/W  | $C_{th1}$ | 0.00007347 | 0.00007347 | Ws/K |
| $R_{th2}$ | 0.074 | 0.074 |      | $C_{th2}$ | 0.0002831  | 0.0002831  |      |
| $R_{th3}$ | 0.132 | 0.132 |      | $C_{th3}$ | 0.0004062  | 0.0004062  |      |
| $R_{th4}$ | 0.555 | 0.272 |      | $C_{th4}$ | 0.001215   | 0.001215   |      |
| $R_{th5}$ | 0.529 | 0.559 |      | $C_{th5}$ | 0.00276    | 0.005633   |      |
| $R_{th6}$ | 0.169 | 2.523 |      | $C_{th6}$ | 0.029      | 0.412      |      |



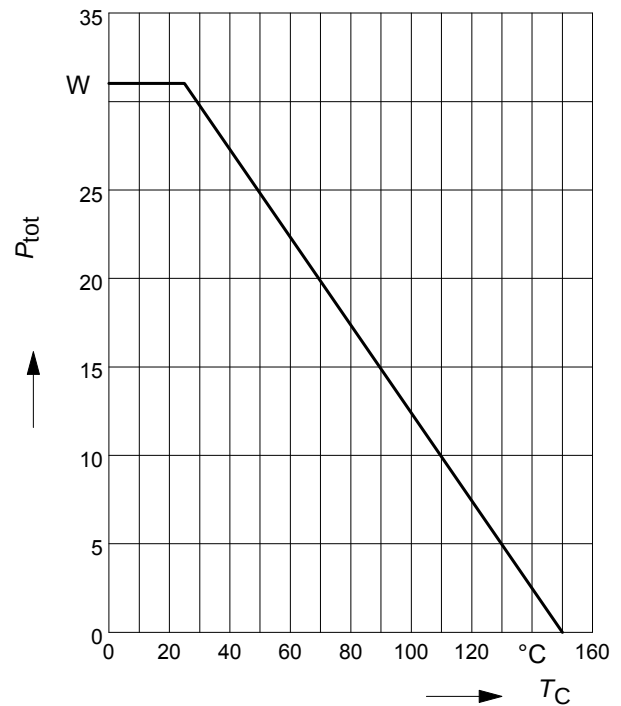
### 1 Power dissipation

$$P_{\text{tot}} = f(T_C)$$



### 2 Power dissipation FullPAK

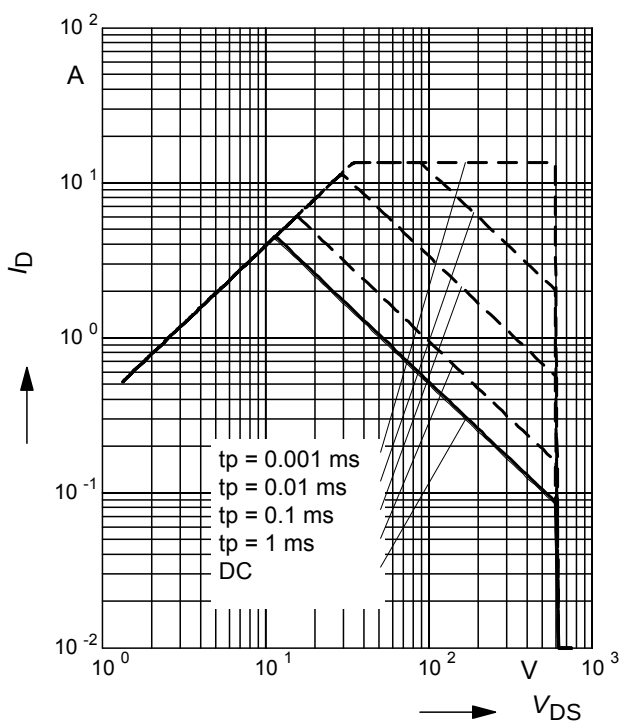
$$P_{\text{tot}} = f(T_C)$$



### 3 Safe operating area

$$I_D = f(V_{DS})$$

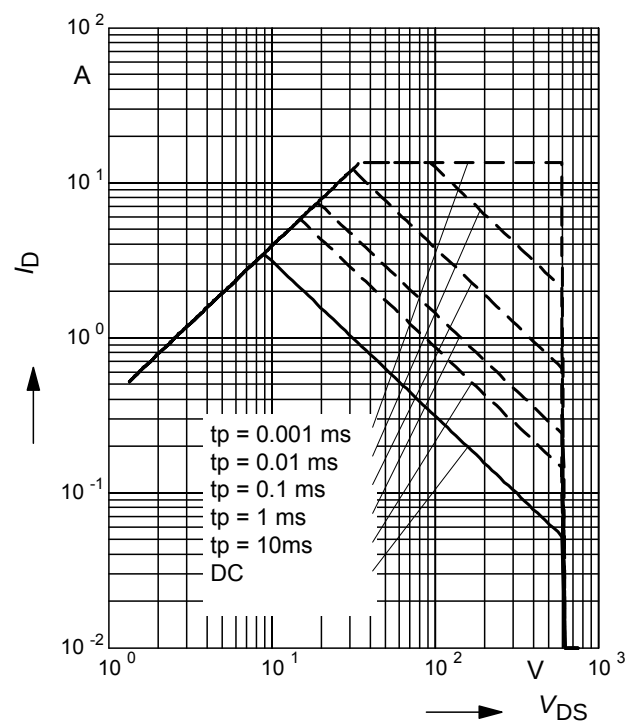
parameter :  $D = 0$  ,  $T_C = 25^\circ\text{C}$



### 4 Safe operating area FullPAK

$$I_D = f(V_{DS})$$

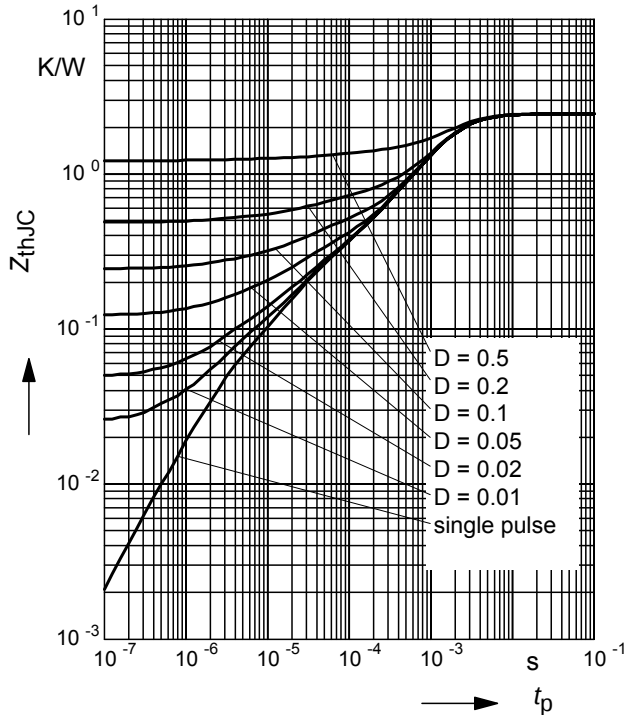
parameter:  $D = 0$  ,  $T_C = 25^\circ\text{C}$



## 5 Transient thermal impedance

$$Z_{thJC} = f(t_p)$$

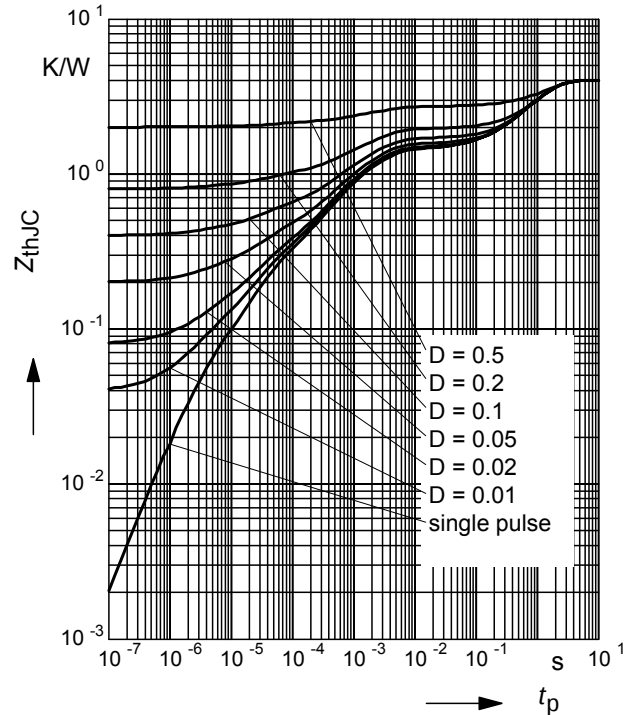
parameter:  $D = t_p/T$



## 6 Transient thermal impedance FullPAK

$$Z_{thJC} = f(t_p)$$

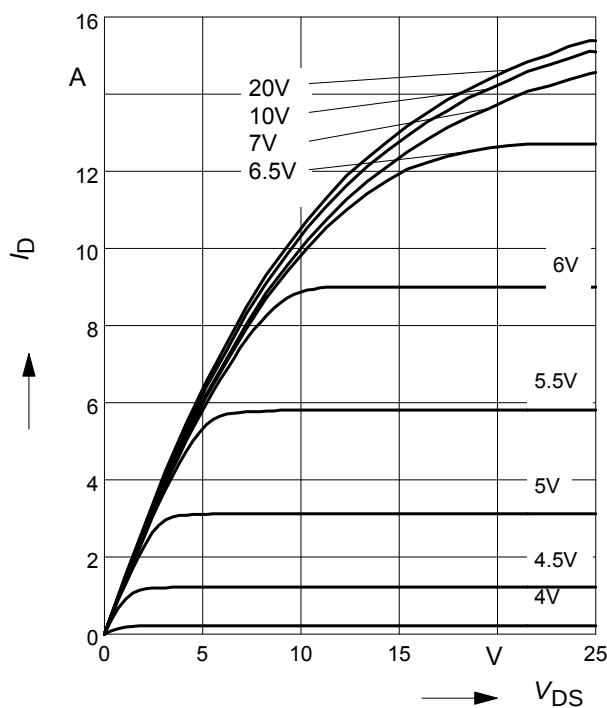
parameter:  $D = t_p/t$



## 7 Typ. output characteristic

$$I_D = f(V_{DS}); T_j = 25^\circ\text{C}$$

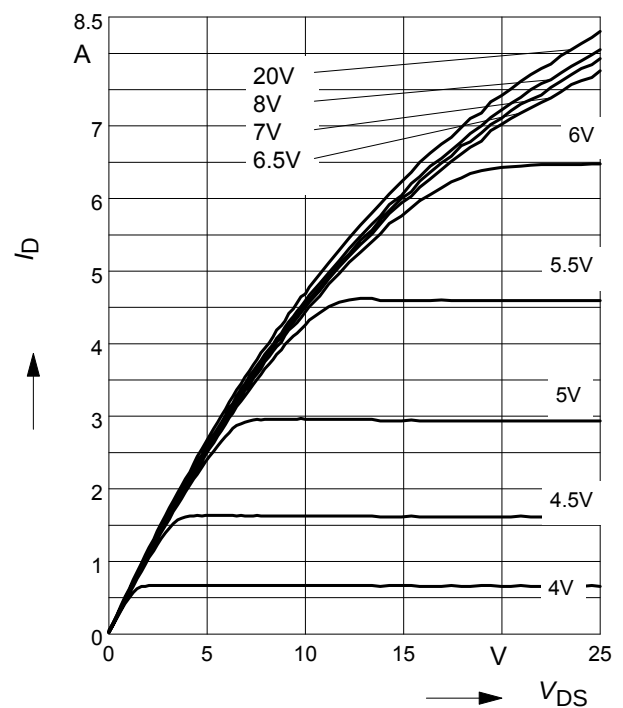
parameter:  $t_p = 10 \mu\text{s}, V_{GS}$



## 8 Typ. output characteristic

$$I_D = f(V_{DS}); T_j = 150^\circ\text{C}$$

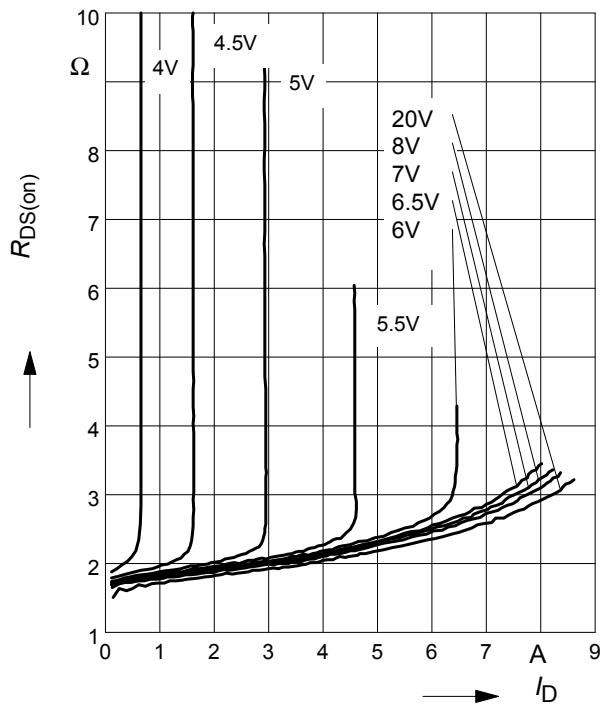
parameter:  $t_p = 10 \mu\text{s}, V_{GS}$



### 9 Typ. drain-source on resistance

$$R_{DS(on)} = f(I_D)$$

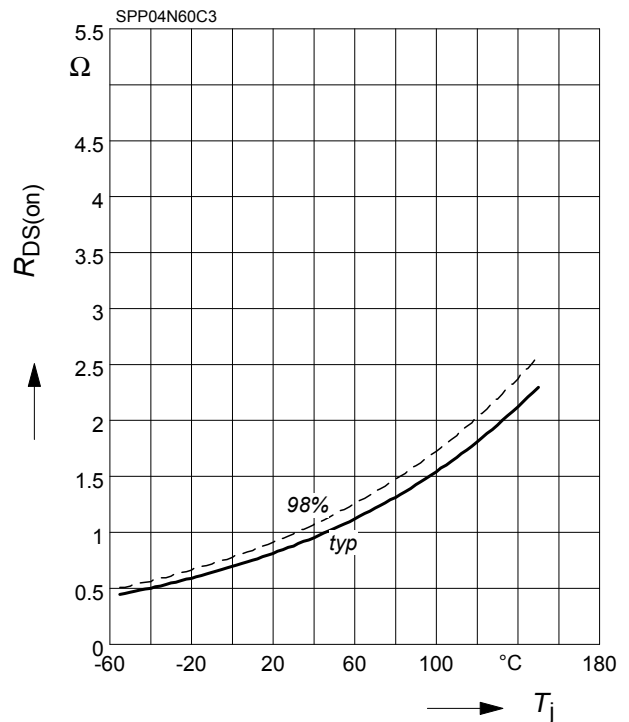
parameter:  $T_j = 150^\circ\text{C}$ ,  $V_{GS}$



### 10 Drain-source on-state resistance

$$R_{DS(on)} = f(T_j)$$

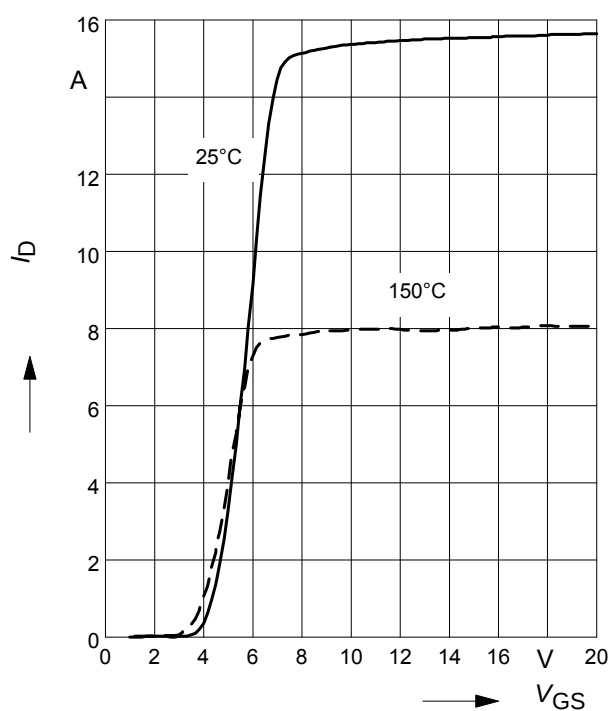
parameter:  $I_D = 2.8\text{ A}$ ,  $V_{GS} = 10\text{ V}$



### 11 Typ. transfer characteristics

$$I_D = f(V_{GS}); V_{DS} \geq 2 \times I_D \times R_{DS(on)max}$$

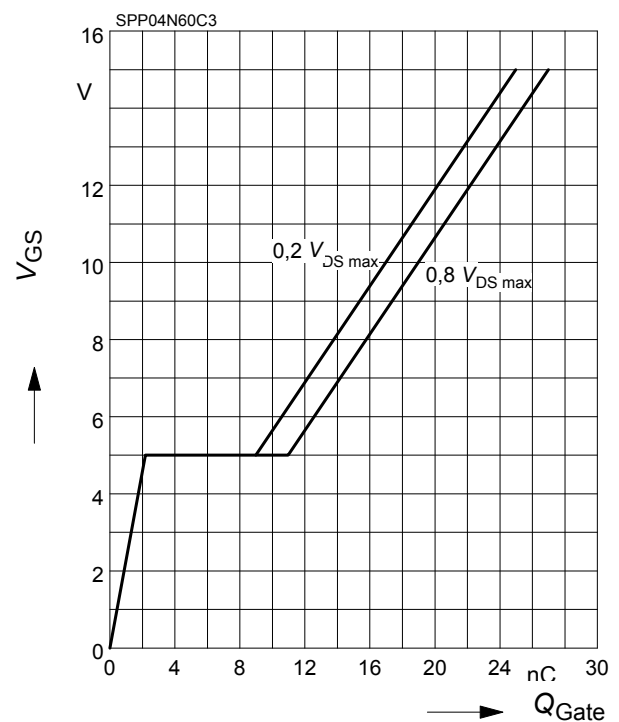
parameter:  $t_p = 10\text{ }\mu\text{s}$



### 12 Typ. gate charge

$$V_{GS} = f(Q_{Gate})$$

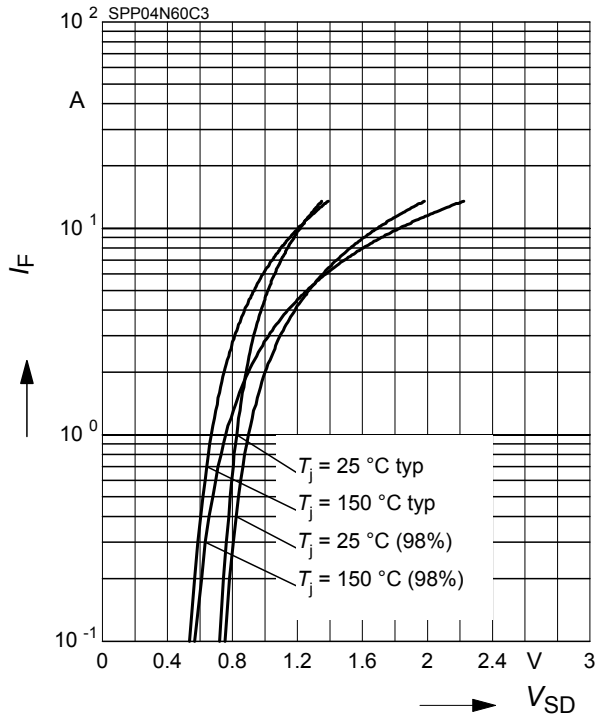
parameter:  $I_D = 4.5\text{ A}$  pulsed



### 13 Forward characteristics of body diode

$$I_F = f(V_{SD})$$

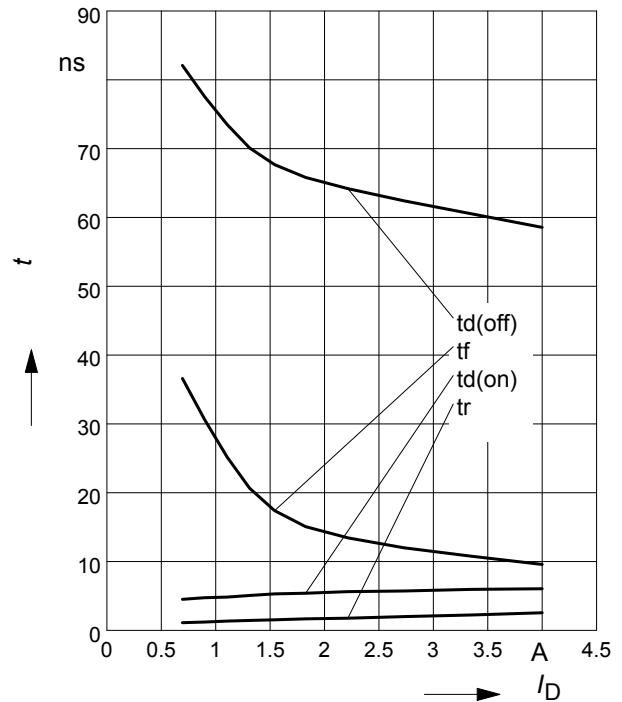
parameter:  $T_j$ ,  $t_p = 10 \mu s$



### 14 Typ. switching time

$$t = f(I_D), \text{ inductive load, } T_j = 125^\circ C$$

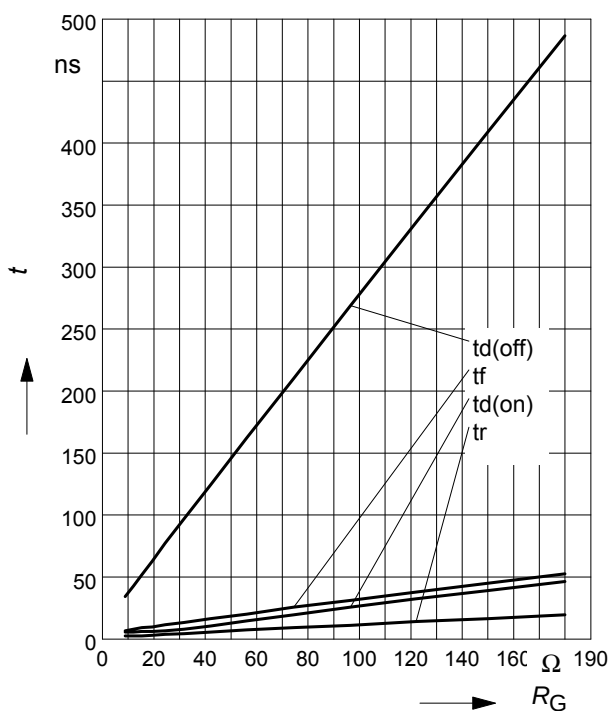
par.:  $V_{DS} = 380V$ ,  $V_{GS} = 0/+13V$ ,  $R_G = 18\Omega$



### 15 Typ. switching time

$$t = f(R_G), \text{ inductive load, } T_j = 125^\circ C$$

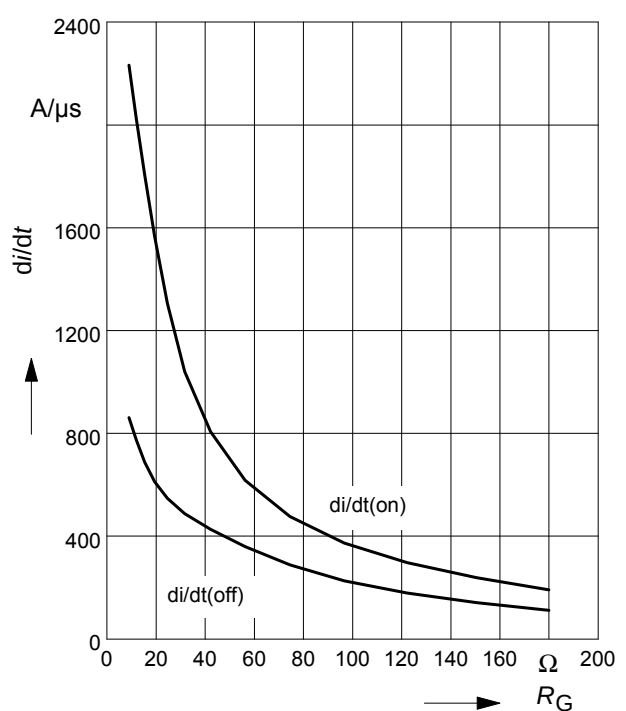
par.:  $V_{DS} = 380V$ ,  $V_{GS} = 0/+13V$ ,  $I_D = 4.5 A$



### 16 Typ. drain current slope

$$di/dt = f(R_G), \text{ inductive load, } T_j = 125^\circ C$$

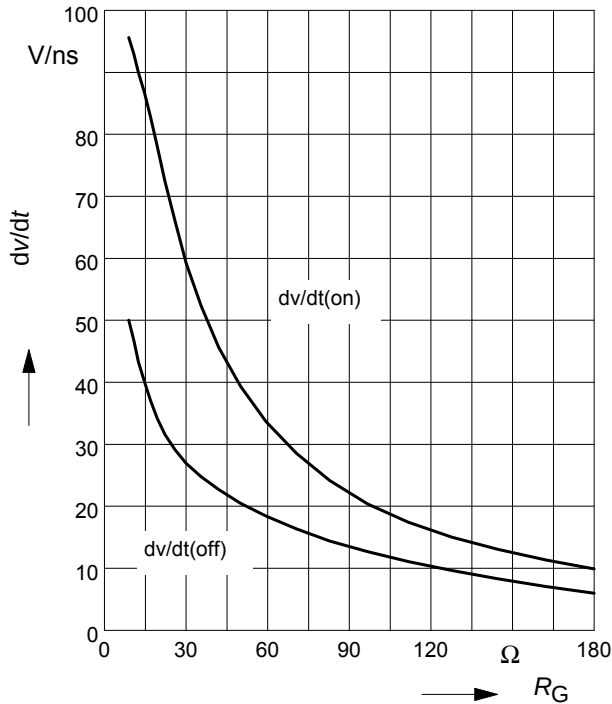
par.:  $V_{DS} = 380V$ ,  $V_{GS} = 0/+13V$ ,  $I_D = 4.5A$



### 17 Typ. drain source voltage slope

$dv/dt = f(R_G)$ , inductive load,  $T_j = 125^\circ\text{C}$

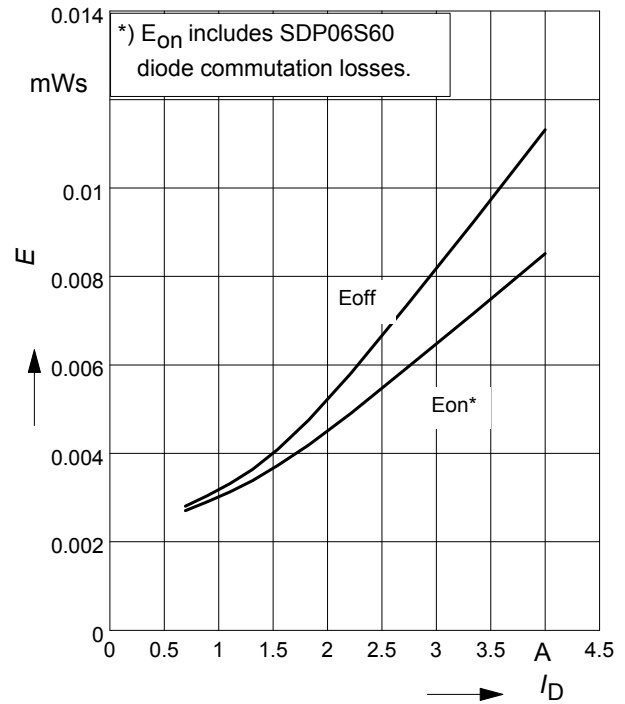
par.:  $V_{DS}=380\text{V}$ ,  $V_{GS}=0/+13\text{V}$ ,  $I_D=4.5\text{A}$



### 18 Typ. switching losses

$E = f(I_D)$ , inductive load,  $T_j=125^\circ\text{C}$

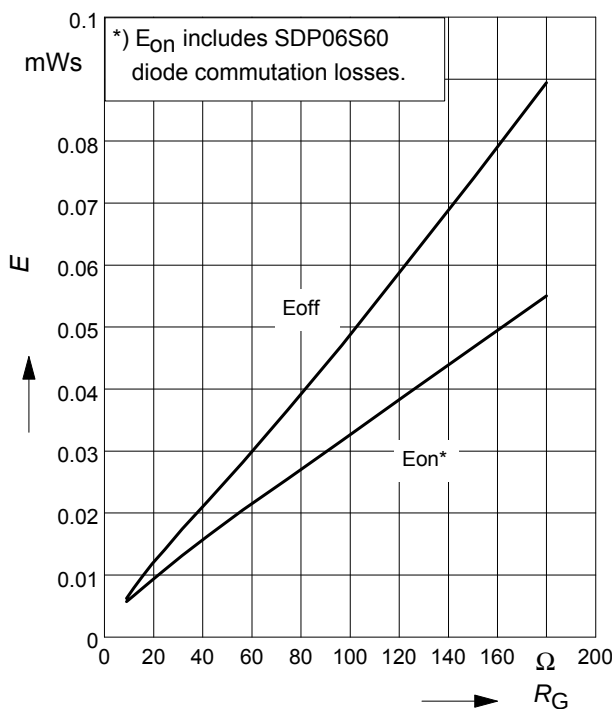
par.:  $V_{DS}=380\text{V}$ ,  $V_{GS}=0/+13\text{V}$ ,  $R_G=18\Omega$



### 19 Typ. switching losses

$E = f(R_G)$ , inductive load,  $T_j=125^\circ\text{C}$

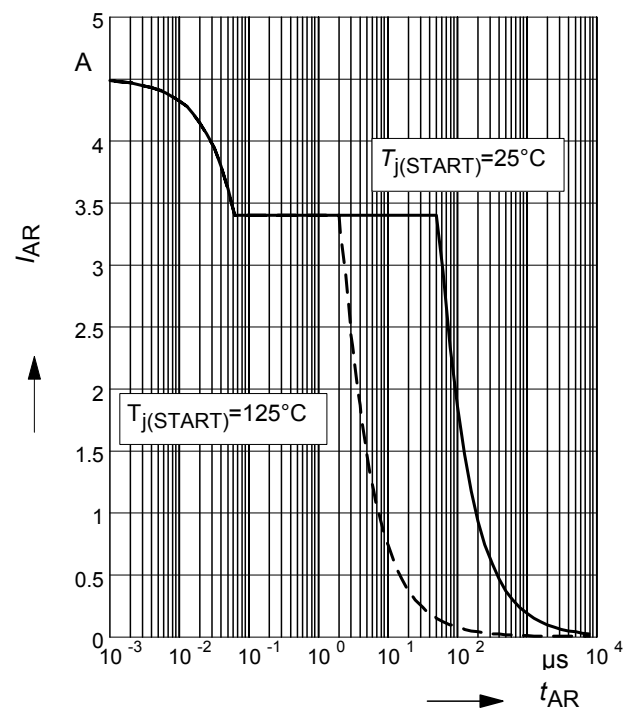
par.:  $V_{DS}=380\text{V}$ ,  $V_{GS}=0/+13\text{V}$ ,  $I_D=4.5\text{A}$



### 20 Avalanche SOA

$I_{AR} = f(t_{AR})$

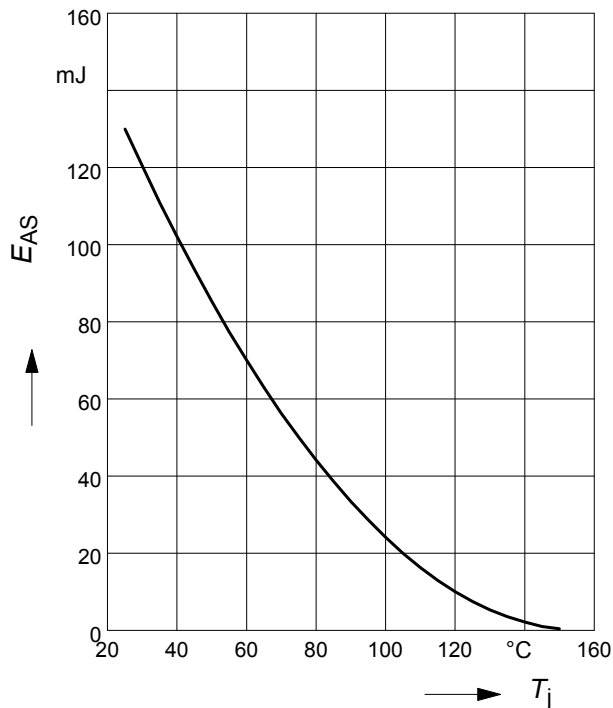
par.:  $T_j \leq 150^\circ\text{C}$



## 21 Avalanche energy

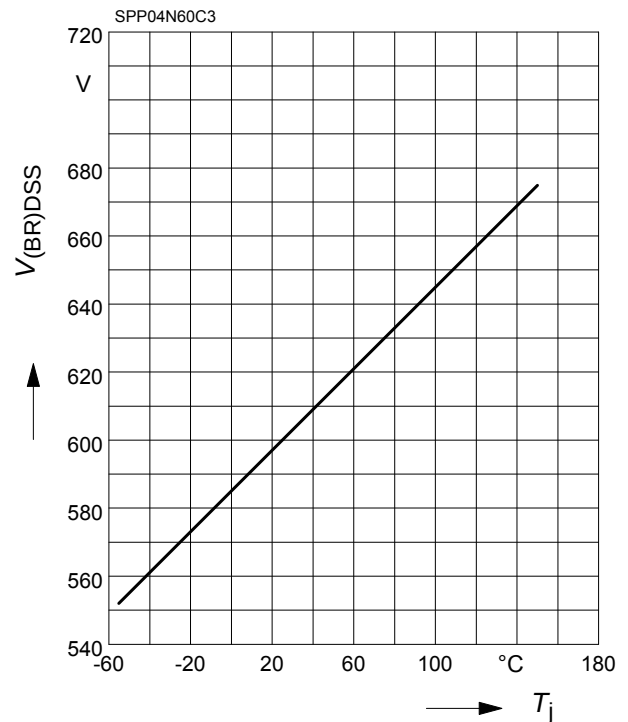
$$E_{AS} = f(T_j)$$

par.:  $I_D = 3.4$ ,  $V_{DD} = 50$  V



## 22 Drain-source breakdown voltage

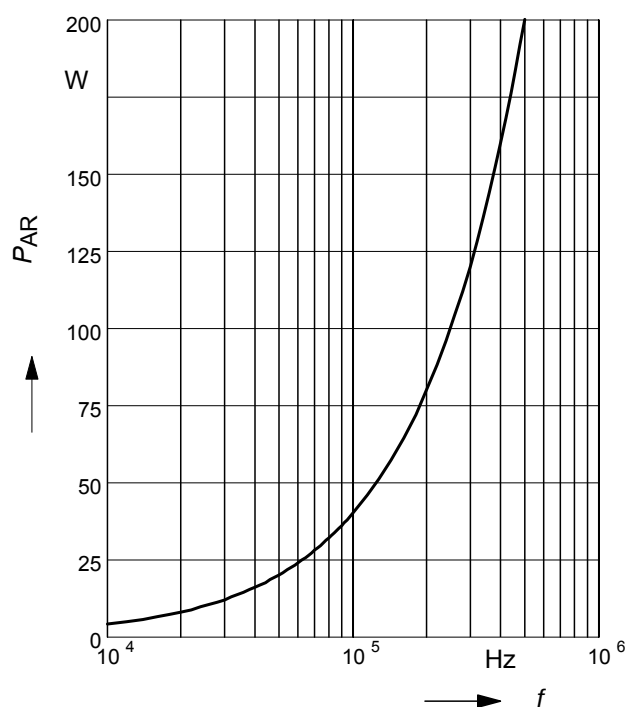
$$V_{(BR)DSS} = f(T_j)$$



## 23 Avalanche power losses

$$P_{AR} = f(f)$$

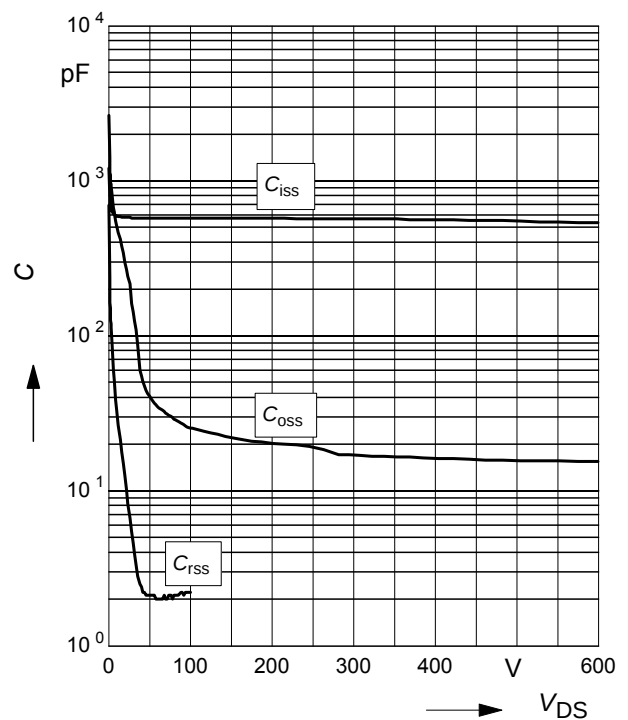
parameter:  $E_{AR} = 0.4$  mJ



## 24 Typ. capacitances

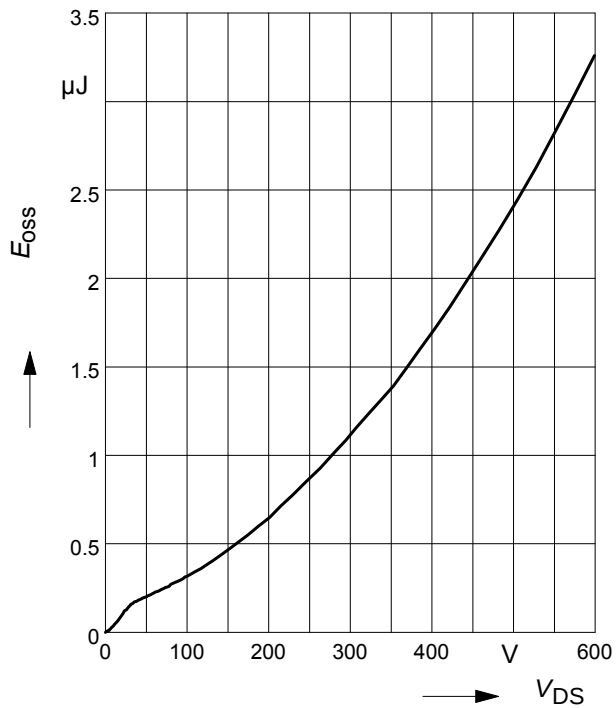
$$C = f(V_{DS})$$

parameter:  $V_{GS} = 0$  V,  $f = 1$  MHz

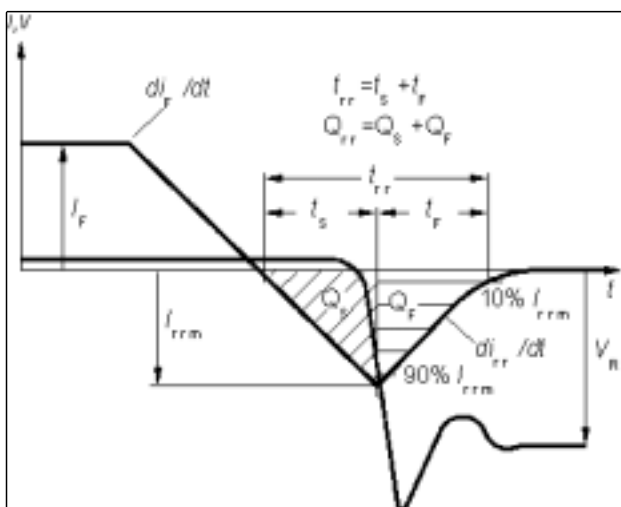


## 25 Typ. $C_{oss}$ stored energy

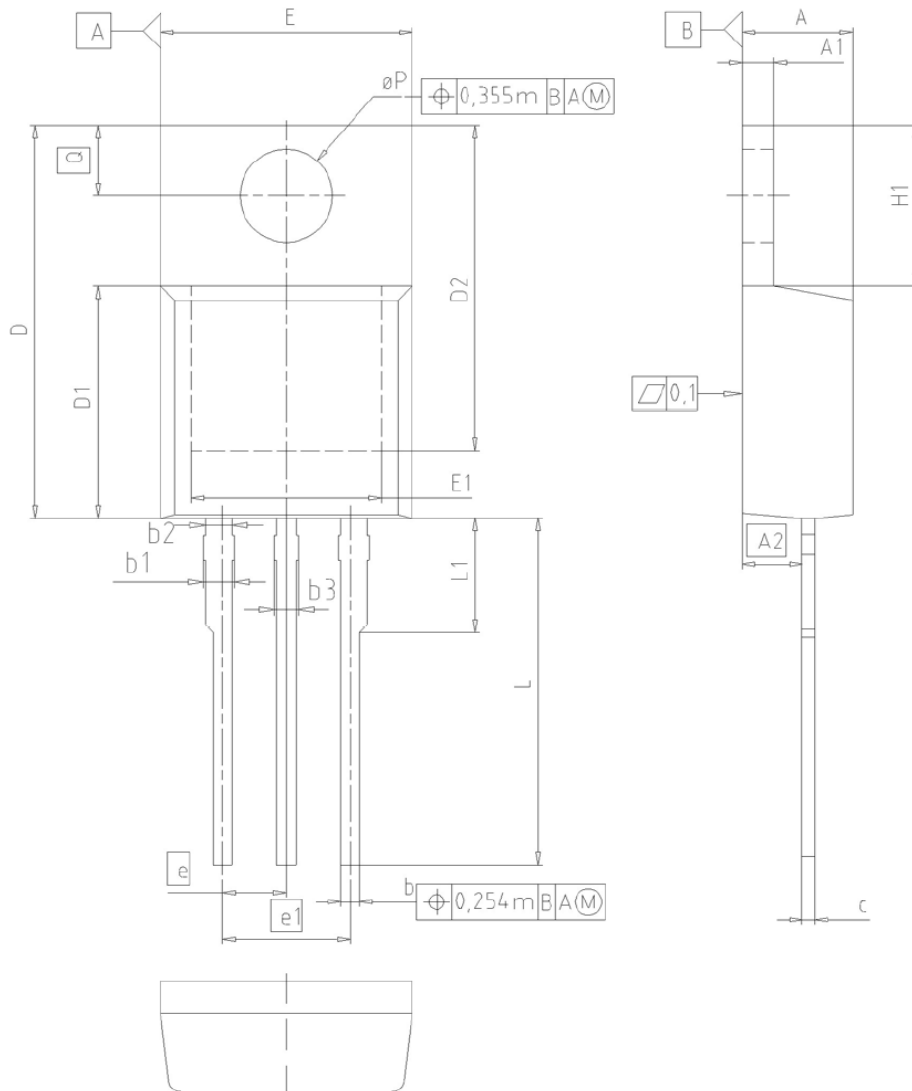
$$E_{oss} = f(V_{DS})$$



## Definition of diodes switching characteristics



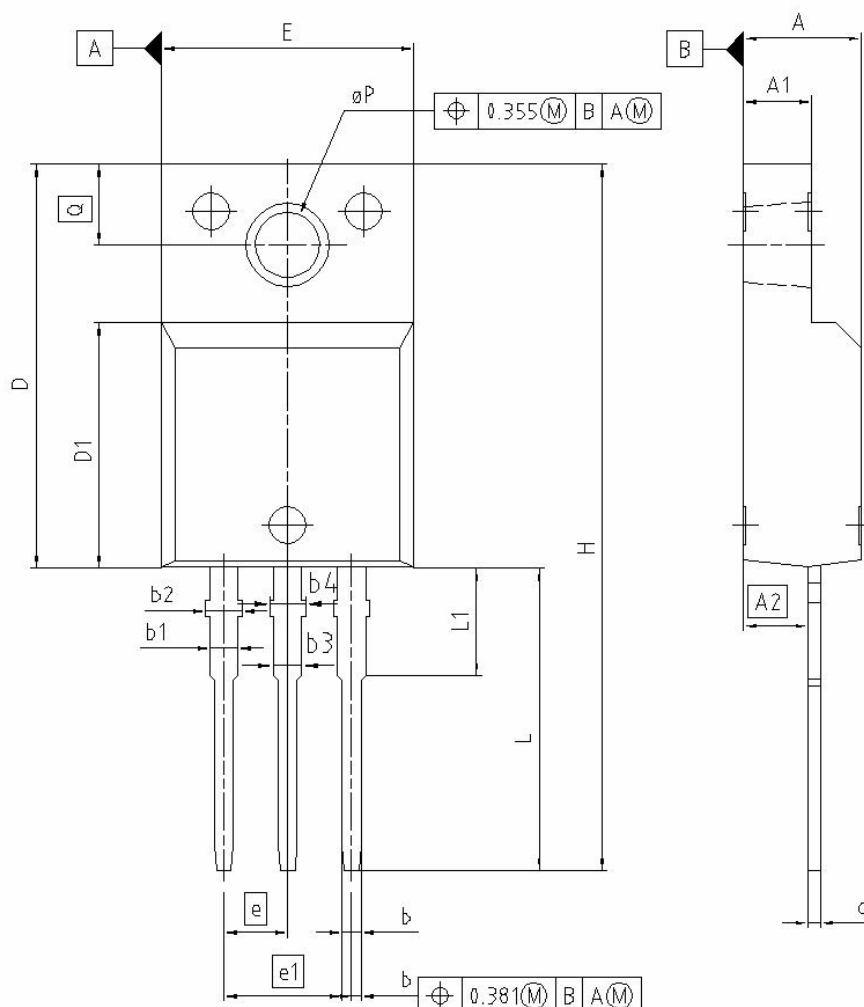
PG-TO220-3-1, PG-TO220-3-21 : Outline



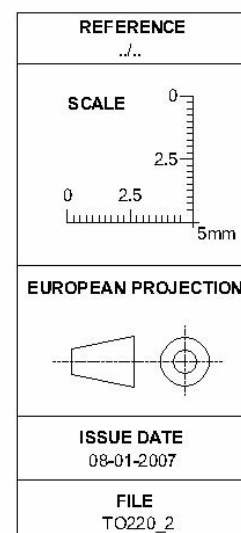
| DIM | MILLIMETERS |       | INCHES |       |
|-----|-------------|-------|--------|-------|
|     | MIN         | MAX   | MIN    | MAX   |
| A   | 4.30        | 4.57  | 0.169  | 0.180 |
| A1  | 1.17        | 1.40  | 0.046  | 0.055 |
| A2  | 2.15        | 2.72  | 0.085  | 0.107 |
| b   | 0.65        | 0.86  | 0.026  | 0.034 |
| b1  | 0.95        | 1.40  | 0.037  | 0.055 |
| b2  | 0.95        | 1.15  | 0.037  | 0.045 |
| b3  | 0.65        | 1.15  | 0.026  | 0.045 |
| c   | 0.33        | 0.80  | 0.013  | 0.024 |
| D   | 14.81       | 15.95 | 0.583  | 0.628 |
| D1  | 8.51        | 9.45  | 0.335  | 0.372 |
| D2  | 12.19       | 13.10 | 0.480  | 0.516 |
| E   | 9.70        | 10.36 | 0.382  | 0.408 |
| E1  | 6.50        | 8.60  | 0.256  | 0.339 |
| e   | 2.54        |       | 0.100  |       |
| e1  | 5.08        |       | 0.200  |       |
| N   | 3           |       | 3      |       |
| H1  | 5.90        | 6.90  | 0.232  | 0.272 |
| L   | 13.00       | 14.00 | 0.512  | 0.551 |
| L1  | -           | 4.80  | -      | 0.189 |
| øP  | 3.60        | 3.89  | 0.142  | 0.153 |
| Q   | 2.60        | 3.00  | 0.102  | 0.118 |

|                                                                                                                     |
|---------------------------------------------------------------------------------------------------------------------|
| <b>DOCUMENT NO.</b><br>Z8B00003318                                                                                  |
| <b>SCALE</b><br>0 2.5 5mm                                                                                           |
| <b>EUROPEAN PROJECTION</b><br> |
| <b>ISSUE DATE</b><br>23-08-2007                                                                                     |
| <b>REVISION</b><br>05                                                                                               |

PG-TO220-3-31/3-111 Fully isolated package (2500VAC; 1 minute)



| DIM | MILLIMETERS |       | INCHES |       |
|-----|-------------|-------|--------|-------|
|     | MIN         | MAX   | MIN    | MAX   |
| A   | 4.55        | 4.85  | 0.179  | 0.191 |
| A1  | 2.55        | 2.85  | 0.100  | 0.112 |
| A2  | 2.42        | 2.72  | 0.095  | 0.107 |
| b   | 0.65        | 0.85  | 0.026  | 0.033 |
| b1  | 0.95        | 1.33  | 0.037  | 0.052 |
| b2  | 0.95        | 1.51  | 0.037  | 0.059 |
| b3  | 0.65        | 1.33  | 0.026  | 0.052 |
| b4  | 0.65        | 1.51  | 0.026  | 0.059 |
| c   | 0.40        | 0.63  | 0.016  | 0.025 |
| D   | 15.85       | 16.15 | 0.624  | 0.636 |
| D1  | 9.53        | 9.83  | 0.375  | 0.387 |
| E   | 10.35       | 10.65 | 0.407  | 0.419 |
| e   | 2.54        |       | 0.100  |       |
| e1  | 5.08        |       | 0.200  |       |
| N   | 3           |       | 3      |       |
| H   | 29.45       | 29.75 | 1.159  | 1.171 |
| L   | 13.45       | 13.75 | 0.530  | 0.541 |
| L1  | 3.15        | 3.45  | 0.124  | 0.136 |
| øP  | 2.95        | 3.20  | 0.116  | 0.126 |
| Q   | 3.15        | 3.50  | 0.124  | 0.138 |



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