

## Cool MOS™ Power Transistor

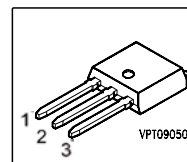
### Feature

- New revolutionary high voltage technology
- Ultra low gate charge
- Periodic avalanche rated
- Extreme dv/dt rated
- High peak current capability
- Improved transconductance
- Pb-free lead plating; RoHS compliant, available in Halogen free mold compound<sup>a)</sup>
- Fully qualified according to JEDEC for Industrial Applications

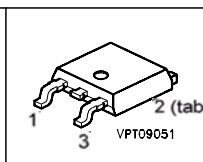


|                     |      |          |
|---------------------|------|----------|
| $V_{DS} @ T_{jmax}$ | 650  | V        |
| $R_{DS(on)}$        | 0.95 | $\Omega$ |
| $I_D$               | 4.5  | A        |

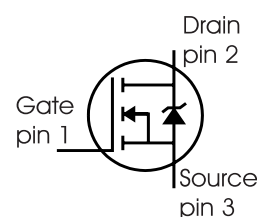
PG-TO251



PG-TO252



| Type       | Package  | Marking |
|------------|----------|---------|
| SPD04N60C3 | PG-TO252 | 04N60C3 |
| SPU04N60C3 | PG-TO251 | 04N60C3 |



### Maximum Ratings

| Parameter                                                                                                                 | Symbol              | Value       | Unit             |
|---------------------------------------------------------------------------------------------------------------------------|---------------------|-------------|------------------|
| Continuous drain current<br>$T_C = 25\text{ }^\circ\text{C}$<br>$T_C = 100\text{ }^\circ\text{C}$                         | $I_D$               | 4.5<br>2.8  | A                |
| Pulsed drain current, $t_p$ limited by $T_{jmax}$                                                                         | $I_{D\text{ puls}}$ | 13.5        |                  |
| Avalanche energy, single pulse<br>$I_D = 3.4\text{ A}$ , $V_{DD} = 50\text{ V}$                                           | $E_{AS}$            | 130         | mJ               |
| Avalanche energy, repetitive $t_{AR}$ limited by $T_{jmax}$ <sup>1</sup><br>$I_D = 4.5\text{ A}$ , $V_{DD} = 50\text{ V}$ | $E_{AR}$            | 0.4         |                  |
| Avalanche current, repetitive $t_{AR}$ limited by $T_{jmax}$                                                              | $I_{AR}$            | 4.5         | A                |
| Gate source voltage static                                                                                                | $V_{GS}$            | $\pm 20$    | V                |
| Gate source voltage AC ( $f > 1\text{ Hz}$ )                                                                              | $V_{GS}$            | $\pm 30$    |                  |
| Power dissipation, $T_C = 25\text{ }^\circ\text{C}$                                                                       | $P_{tot}$           | 50          | W                |
| Operating and storage temperature                                                                                         | $T_j, T_{stg}$      | -55... +150 | $^\circ\text{C}$ |
| Reverse diode dv/dt <sup>5)</sup>                                                                                         | dv/dt               | 15          | V/ns             |

<sup>a)</sup> non-Halogen free (OPN: SPD04N60C3BT), Halogen free (OPN: SPD04N60C3AT)

**Maximum Ratings**

| Parameter                                                                                                           | Symbol  | Value | Unit |
|---------------------------------------------------------------------------------------------------------------------|---------|-------|------|
| Drain Source voltage slope<br>$V_{DS} = 480 \text{ V}$ , $I_D = 4.5 \text{ A}$ , $T_j = 125 \text{ }^\circ\text{C}$ | $dv/dt$ | 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 - ambient, leaded                    | $R_{thJA}$ | -      | -    | 75   | K/W              |
| SMD version, device on PCB:<br>@ min. footprint                   | $R_{thJA}$ | -      | -    | 75   |                  |
| @ 6 cm <sup>2</sup> cooling area <sup>2)</sup>                    |            | -      | -    | 50   |                  |
| Soldering temperature, *)<br>1.6 mm (0.063 in.) from case for 10s | $T_{sold}$ | -      | -    | 260  | $^\circ\text{C}$ |

**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<br>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>$T_j=25^\circ\text{C}$ ,<br>$T_j=150^\circ\text{C}$ | -<br>- | 0.5<br>-    | 1<br>50   | $\mu\text{A}$ |
| Gate-source leakage current                 | $I_{GSS}$     | $V_{GS}=30\text{V}$ , $V_{DS}=0\text{V}$                                                           | -      | -           | 100       |               |
| Drain-source on-state resistance            | $R_{DS(on)}$  | $V_{GS}=10\text{V}$ , $I_D=2.8\text{A}$ ,<br>$T_j=25^\circ\text{C}$<br>$T_j=150^\circ\text{C}$     | -<br>- | 0.85<br>2.3 | 0.95<br>- | $\Omega$      |
| Gate input resistance                       | $R_G$         | $f=1\text{MHz}$ , open Drain                                                                       | -      | 0.95        | -         |               |

\*) TO252: reflow soldering, MSL1; TO251: wavesoldering

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

| Parameter                                                     | Symbol       | Conditions                                                                                   | Values |      |      | Unit |
|---------------------------------------------------------------|--------------|----------------------------------------------------------------------------------------------|--------|------|------|------|
|                                                               |              |                                                                                              | min.   | typ. | max. |      |
| Transconductance                                              | $g_{fs}$     | $V_{DS} \geq 2 \cdot I_D \cdot R_{DS(on)max}$ ,<br>$I_D = 2.8\text{A}$                       | -      | 4.4  | -    | S    |
| Input capacitance                                             | $C_{iss}$    | $V_{GS} = 0\text{V}$ , $V_{DS} = 25\text{V}$ ,<br>$f = 1\text{MHz}$                          | -      | 490  | -    | pF   |
| Output capacitance                                            | $C_{oss}$    |                                                                                              | -      | 160  | -    |      |
| Reverse transfer capacitance                                  | $C_{rss}$    |                                                                                              | -      | 15   | -    |      |
| Effective output capacitance, <sup>3)</sup><br>energy related | $C_{o(er)}$  | $V_{GS} = 0\text{V}$ ,<br>$V_{DS} = 0\text{V to } 480\text{V}$                               | -      | 20   | -    | pF   |
| Effective output capacitance, <sup>4)</sup><br>time related   | $C_{o(tr)}$  |                                                                                              | -      | 35   | -    |      |
| Turn-on delay time                                            | $t_{d(on)}$  | $V_{DD} = 380\text{V}$ , $V_{GS} = 0/10\text{V}$ ,<br>$I_D = 4.5\text{A}$ , $R_G = 18\Omega$ | -      | 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 | $Q_{gs}$        | $V_{DD} = 480\text{V}$ , $I_D = 4.5\text{A}$                                         | - | 2.2 | -  | nC |
| Gate to drain charge  | $Q_{gd}$        |                                                                                      | - | 8.8 | -  |    |
| Gate charge total     | $Q_g$           | $V_{DD} = 480\text{V}$ , $I_D = 4.5\text{A}$ ,<br>$V_{GS} = 0\text{ to } 10\text{V}$ | - | 19  | 25 |    |
| Gate plateau voltage  | $V_{(plateau)}$ | $V_{DD} = 480\text{V}$ , $I_D = 4.5\text{A}$                                         | - | 5   | -  | V  |

<sup>1</sup> Repetitive avalanche causes additional power losses that can be calculated as  $P_{AV} = E_{AR} \cdot f$ .

<sup>2</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>3</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>4</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>5</sup>  $I_{SD} \leq I_D$ ,  $di/dt \leq 400\text{A}/\mu\text{s}$ ,  $V_{DClamp} = 400\text{V}$ ,  $V_{peak} < V_{BR, DSS}$ ,  $T_j < T_{j,max}$ .

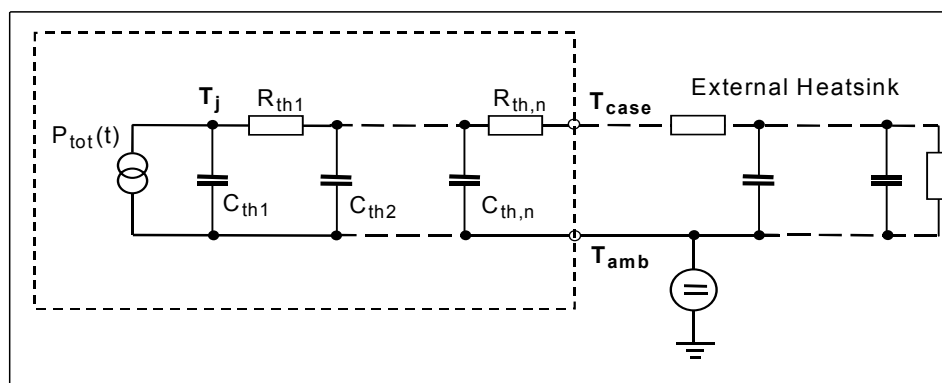
Identical low-side and high-side switch.

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

| 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 | $di_{rr}/dt$ |                                                             | -      | -    | 900  | $\text{A}/\mu\text{s}$ |

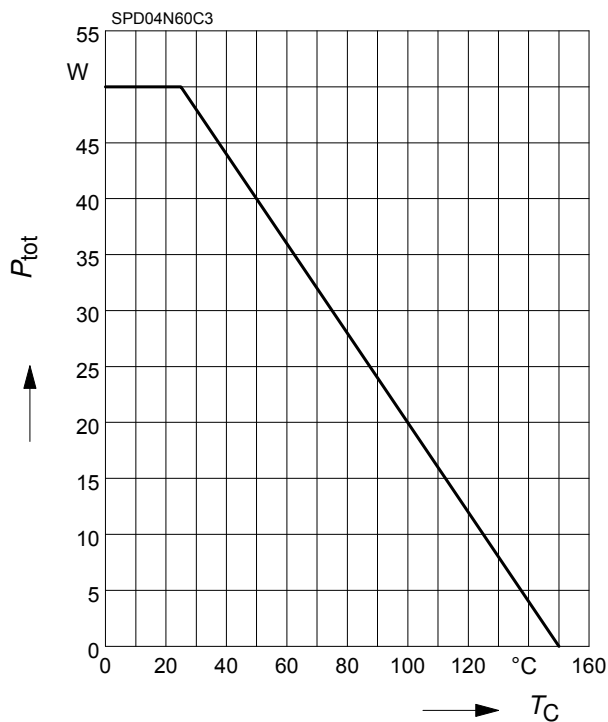
### Typical Transient Thermal Characteristics

| Symbol             | Value | Unit | Symbol              | Value      | Unit |
|--------------------|-------|------|---------------------|------------|------|
|                    | typ.  |      |                     | typ.       |      |
| Thermal resistance |       |      | Thermal capacitance |            |      |
| $R_{th1}$          | 0.039 | K/W  | $C_{th1}$           | 0.00007347 | Ws/K |
| $R_{th2}$          | 0.074 |      | $C_{th2}$           | 0.0002831  |      |
| $R_{th3}$          | 0.132 |      | $C_{th3}$           | 0.0004062  |      |
| $R_{th4}$          | 0.555 |      | $C_{th4}$           | 0.001215   |      |
| $R_{th5}$          | 0.529 |      | $C_{th5}$           | 0.00276    |      |
| $R_{th6}$          | 0.169 |      | $C_{th6}$           | 0.029      |      |



### 1 Power dissipation

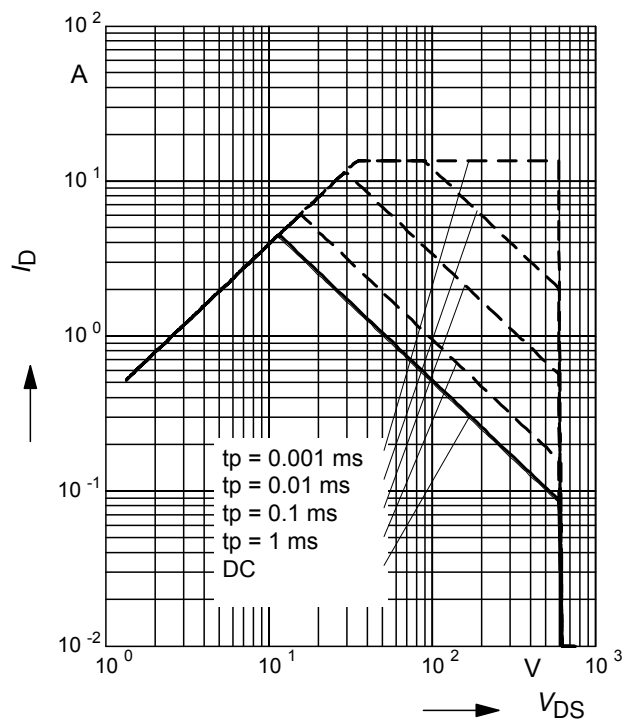
$$P_{\text{tot}} = f(T_C)$$



### 2 Safe operating area

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

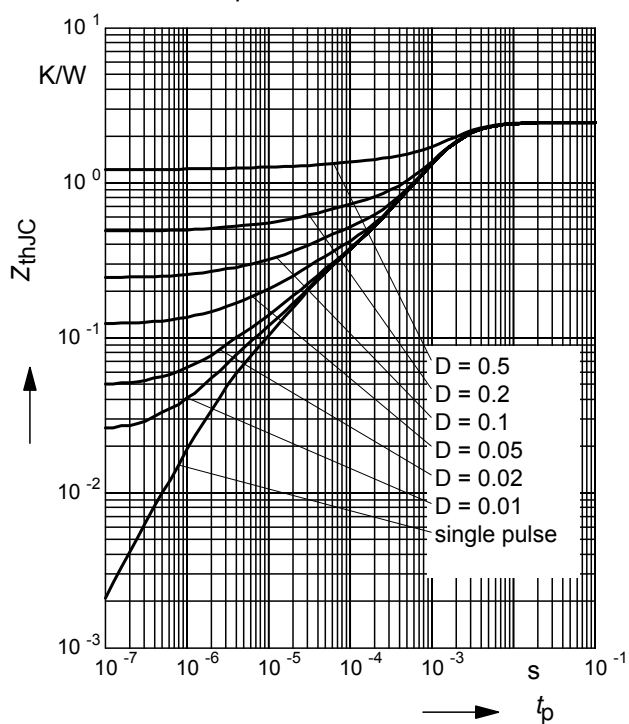
parameter :  $D = 0$  ,  $T_C = 25^\circ\text{C}$



### 3 Transient thermal impedance

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

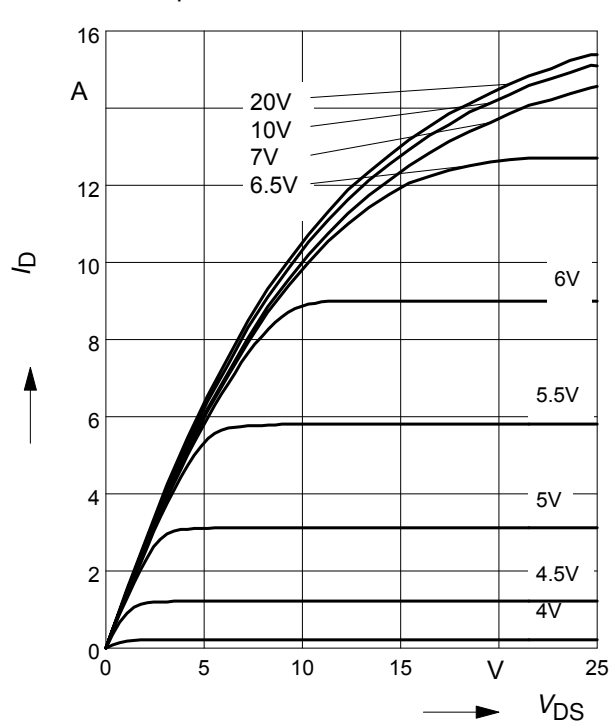
parameter:  $D = t_p/T$



### 4 Typ. output characteristic

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

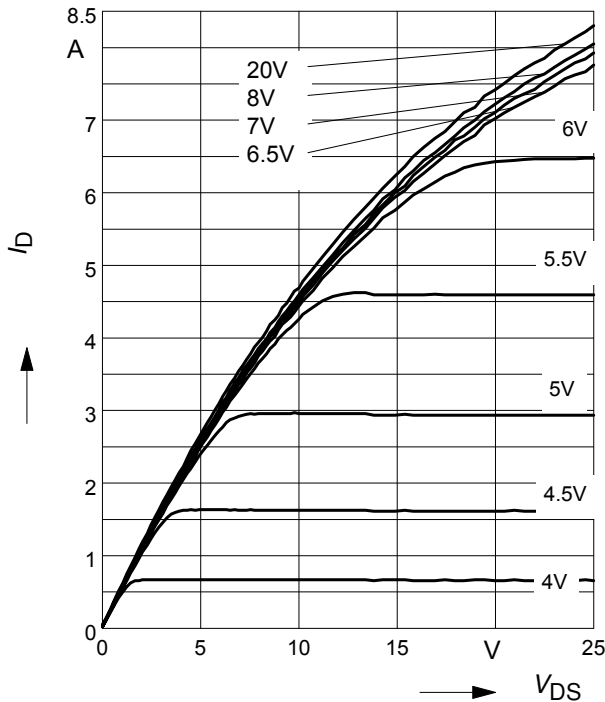
parameter:  $t_p = 10 \mu\text{s}$ ,  $V_{GS}$



### 5 Typ. output characteristic

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

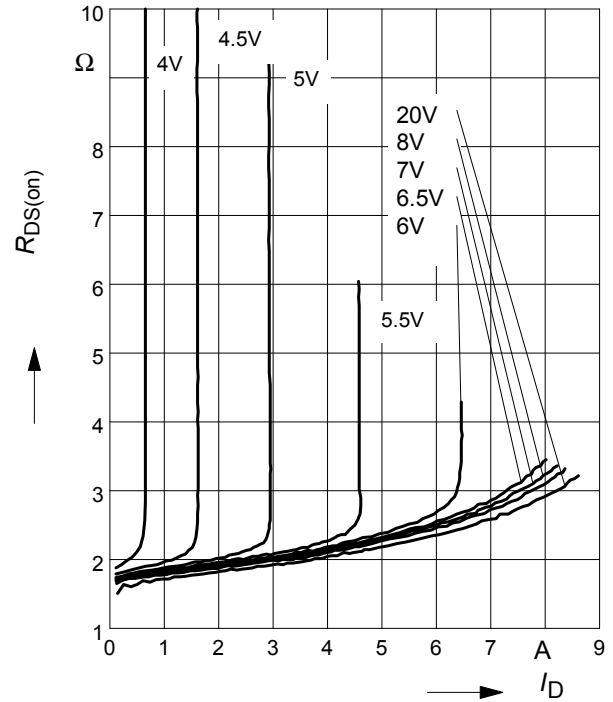
parameter:  $t_p = 10 \mu\text{s}$ ,  $V_{GS}$



### 6 Typ. drain-source on resistance

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

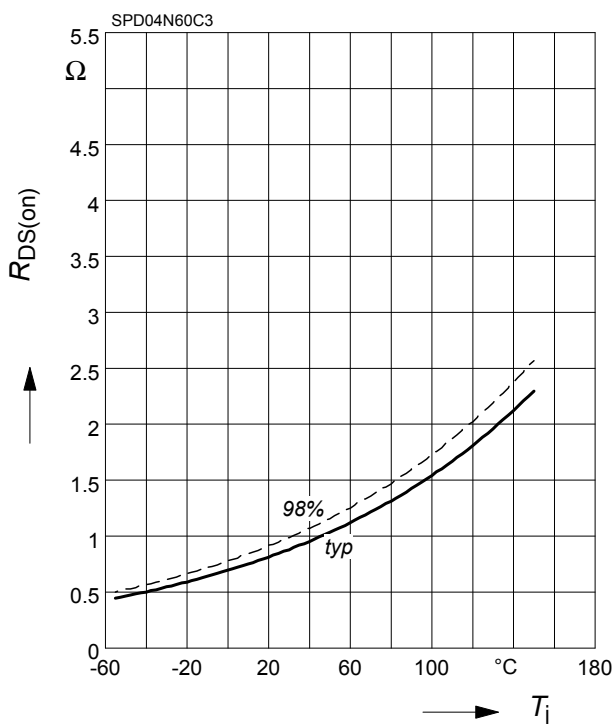
parameter:  $T_j = 150^\circ\text{C}$ ,  $V_{GS}$



### 7 Drain-source on-state resistance

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

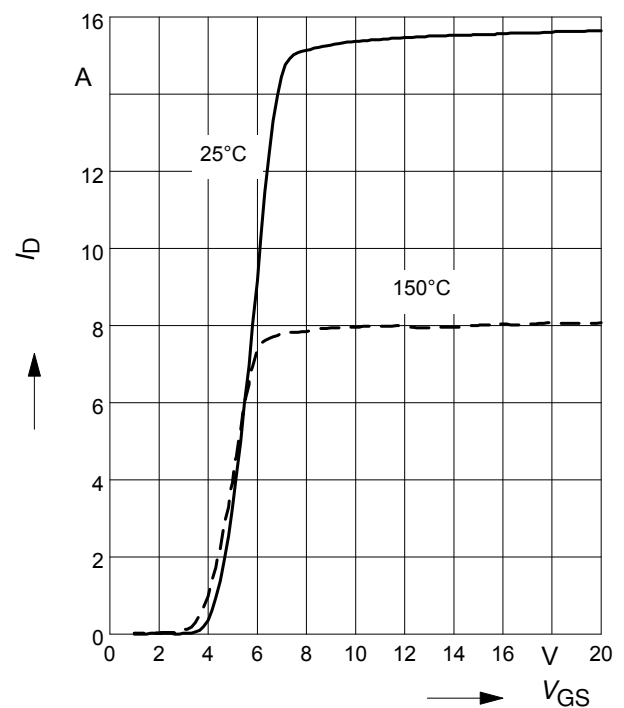
parameter:  $I_D = 2.8 \text{ A}$ ,  $V_{GS} = 10 \text{ V}$



### 8 Typ. transfer characteristics

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

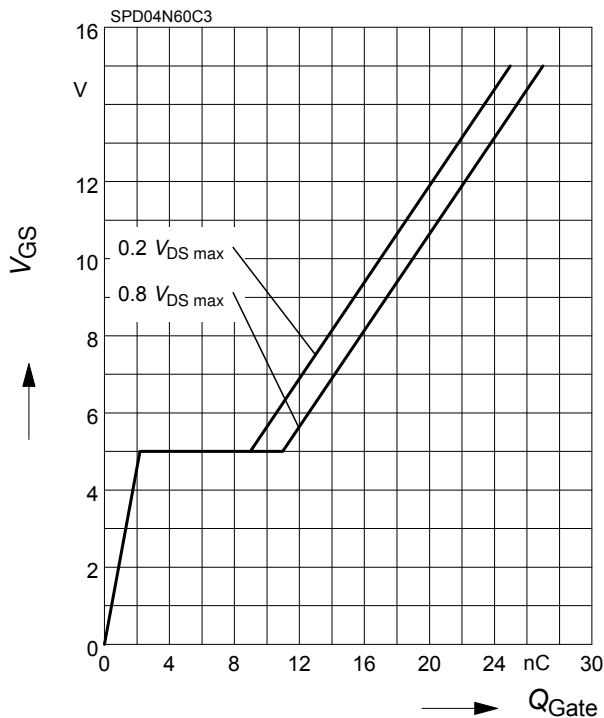
parameter:  $t_p = 10 \mu\text{s}$



### 9 Typ. gate charge

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

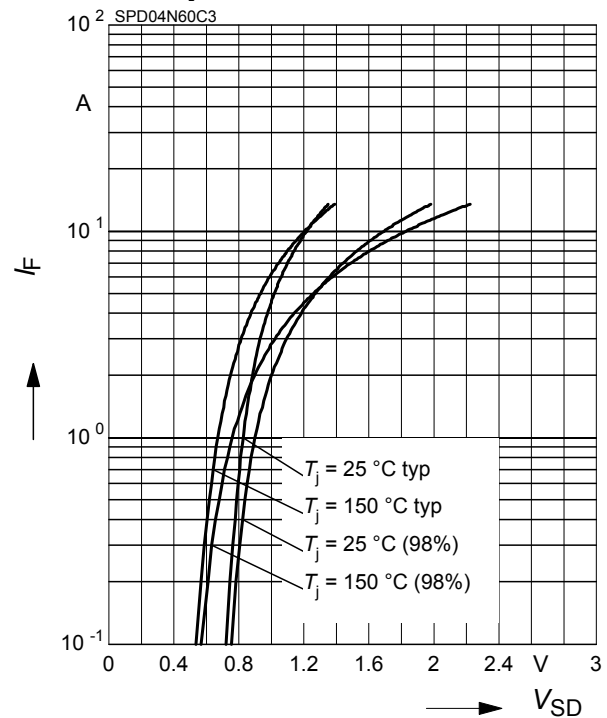
parameter:  $I_D = 4.5$  A pulsed



### 10 Forward characteristics of body diode

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

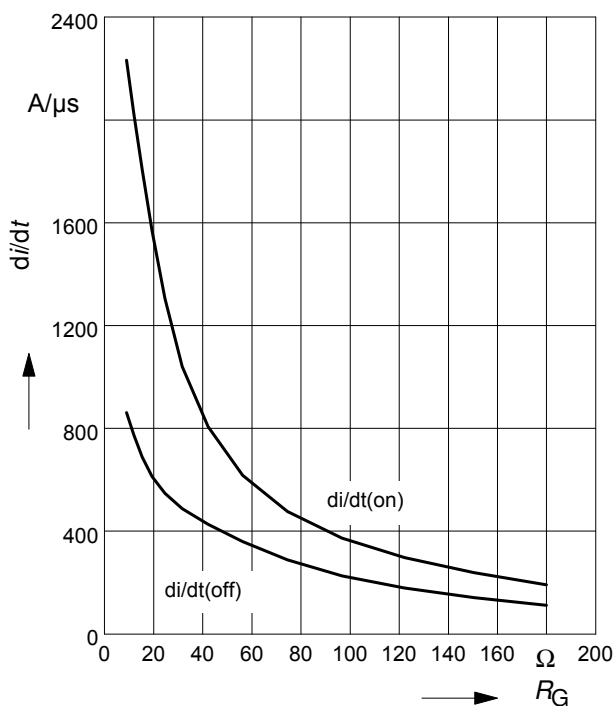
parameter:  $T_j$ ,  $t_p = 10$   $\mu$ s



### 11 Typ. drain current slope

$di/dt = f(R_G)$ , inductive load,  $T_j = 125$  °C

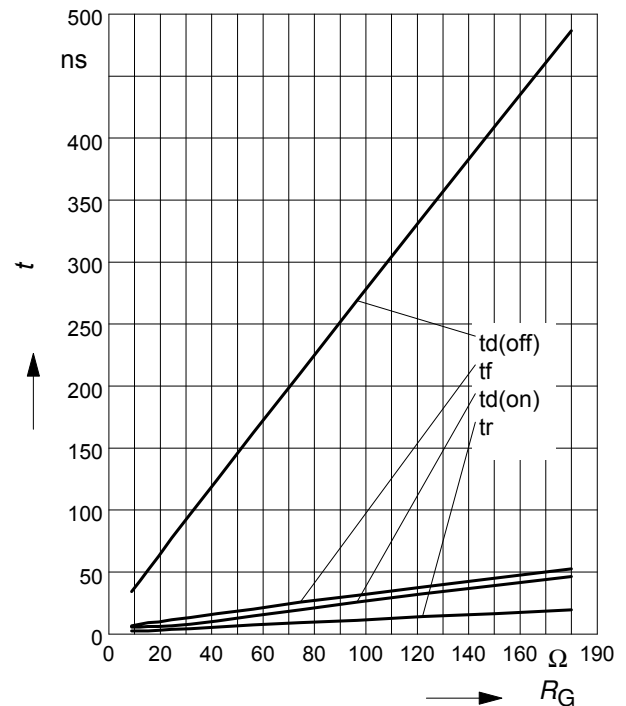
par.:  $V_{DS} = 380$  V,  $V_{GS} = 0/+13$  V,  $I_D = 4.5$  A



### 12 Typ. switching time

$t = f(R_G)$ , inductive load,  $T_j = 125$  °C

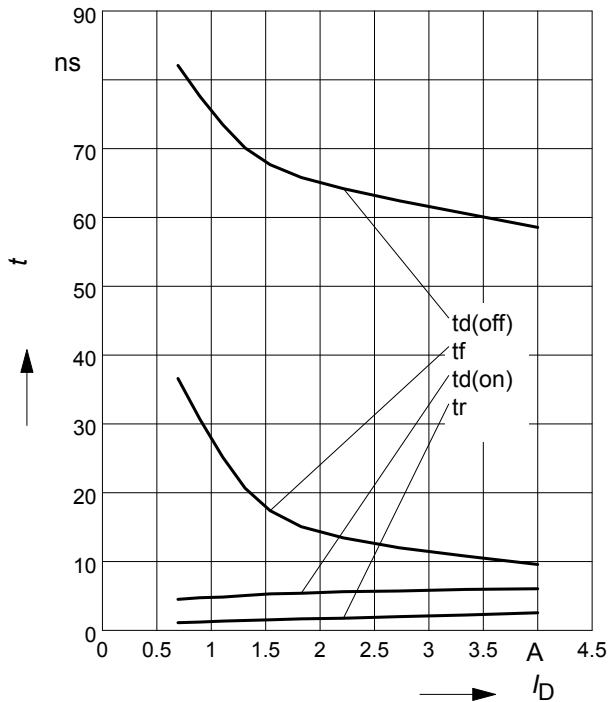
par.:  $V_{DS} = 380$  V,  $V_{GS} = 0/+13$  V,  $I_D = 4.5$  A



### 13 Typ. switching time

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

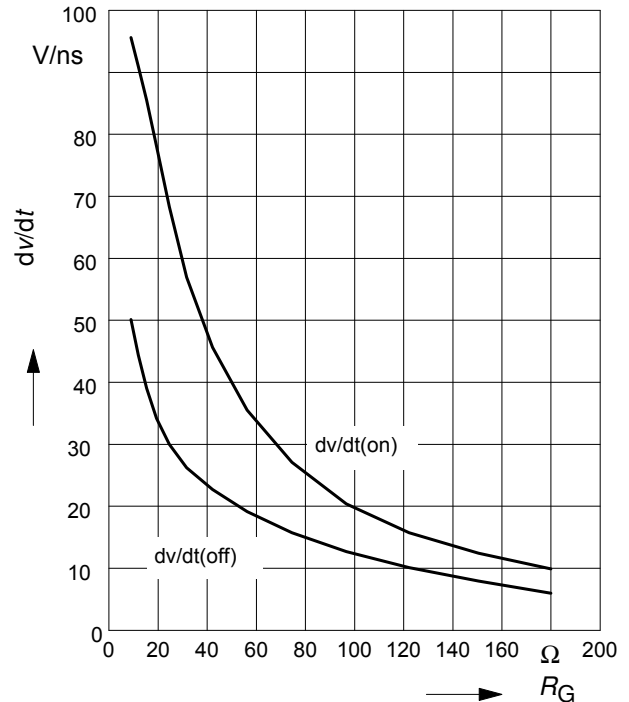
par.:  $V_{DS} = 380\text{V}$ ,  $V_{GS} = 0/+13\text{V}$ ,  $R_G = 18\Omega$



### 14 Typ. drain source voltage slope

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

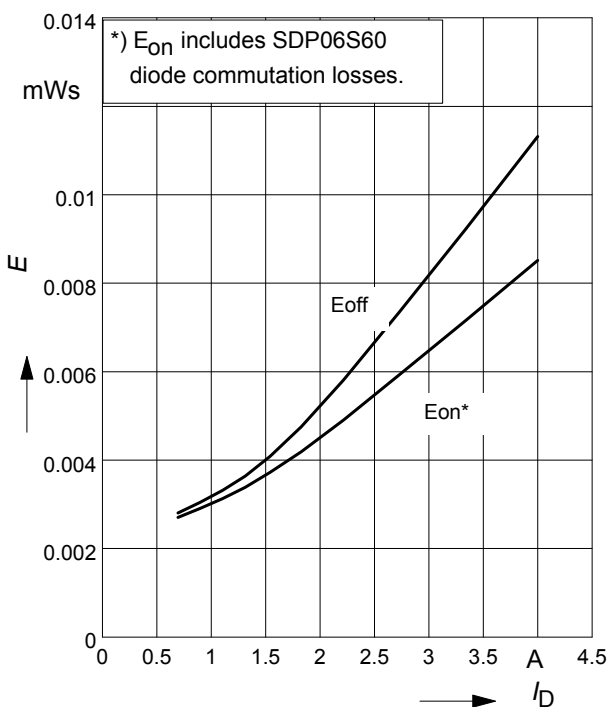
par.:  $V_{DS} = 380\text{V}$ ,  $V_{GS} = 0/+13\text{V}$ ,  $I_D = 4.5\text{A}$



### 15 Typ. switching losses

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

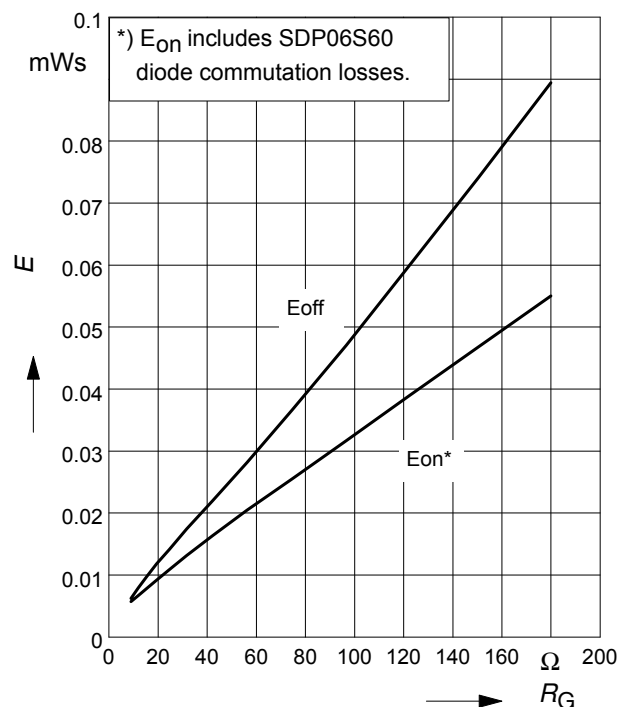
par.:  $V_{DS} = 380\text{V}$ ,  $V_{GS} = 0/+13\text{V}$ ,  $R_G = 18\Omega$



### 16 Typ. switching losses

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

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

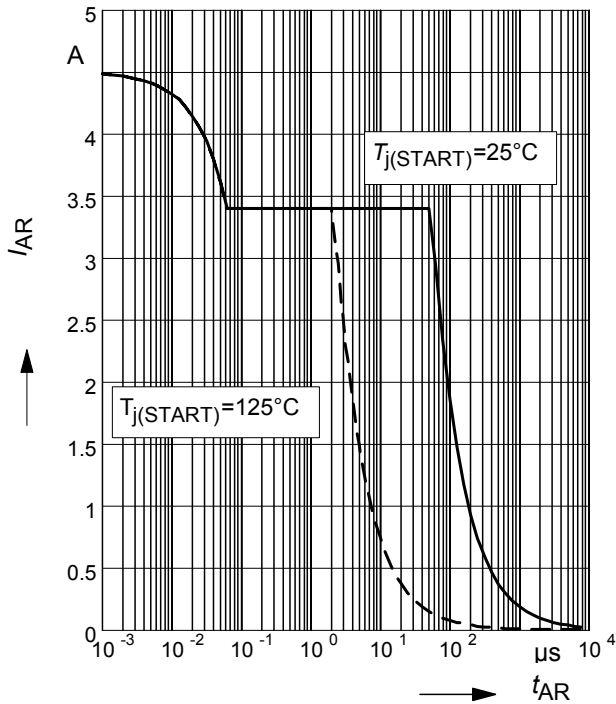




### 17 Avalanche SOA

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

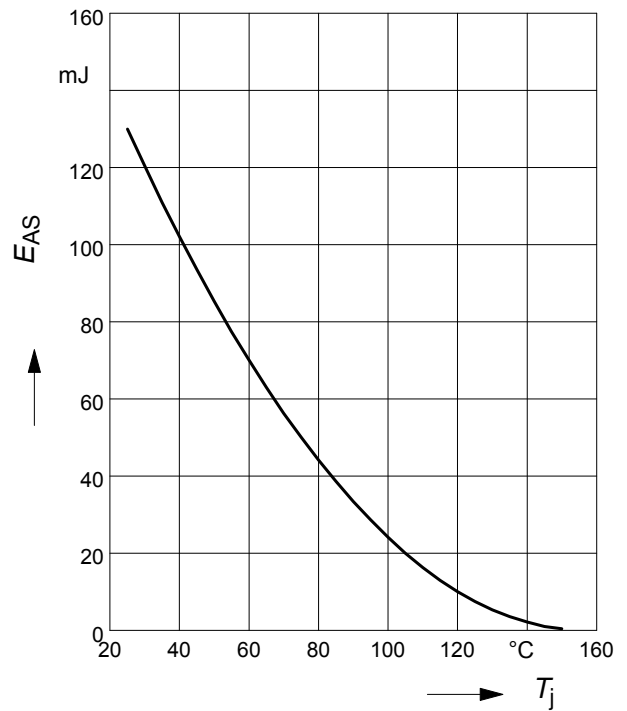
par.:  $T_j \leq 150^\circ\text{C}$



### 18 Avalanche energy

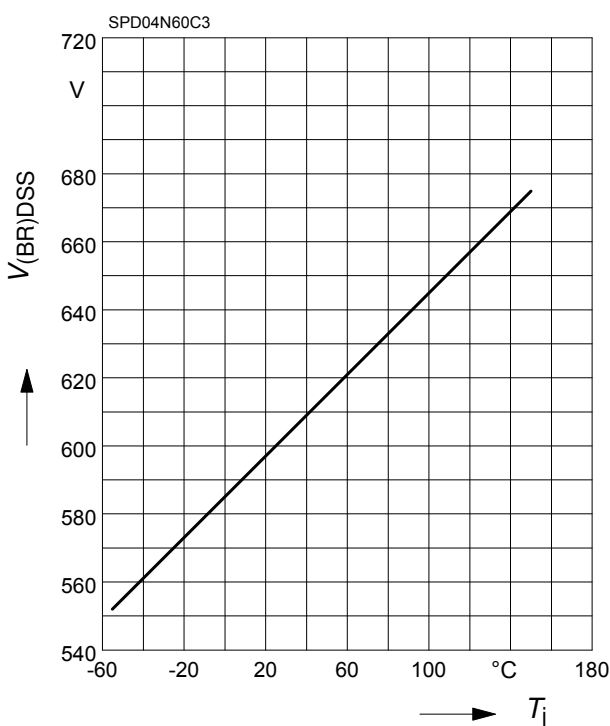
$$E_{AS} = f(T_j)$$

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



### 19 Drain-source breakdown voltage

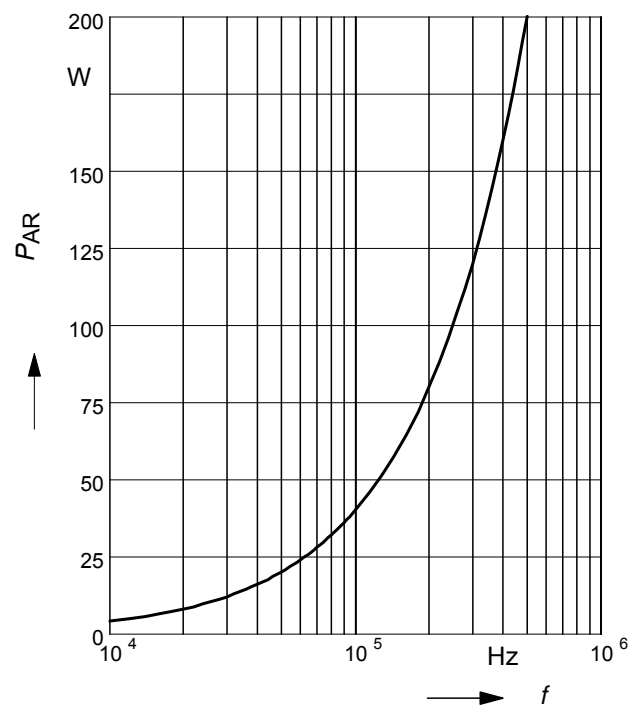
$$V_{(BR)DSS} = f(T_j)$$



### 20 Avalanche power losses

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

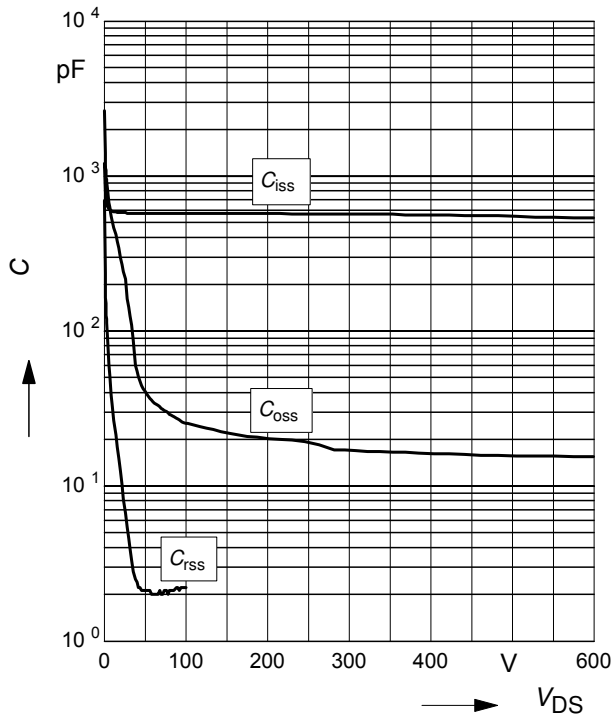
parameter:  $E_{AR} = 0.4\text{ mJ}$



## 21 Typ. capacitances

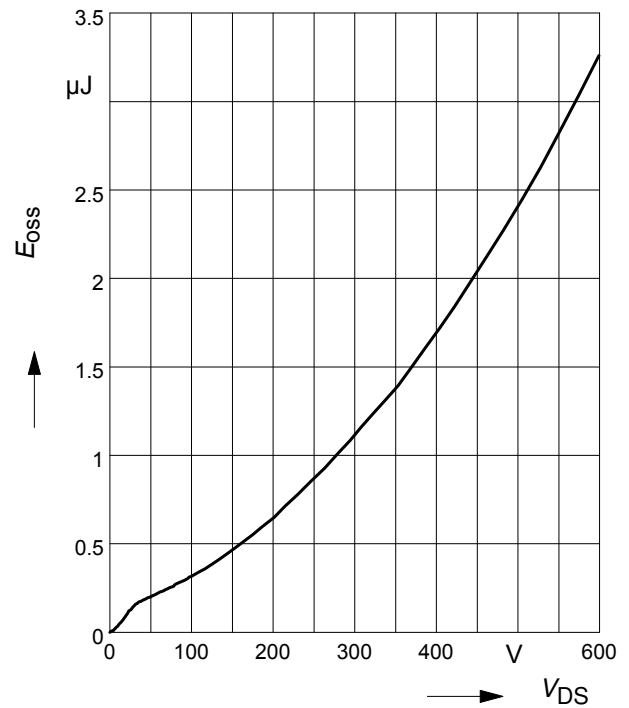
$$C = f(V_{DS})$$

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

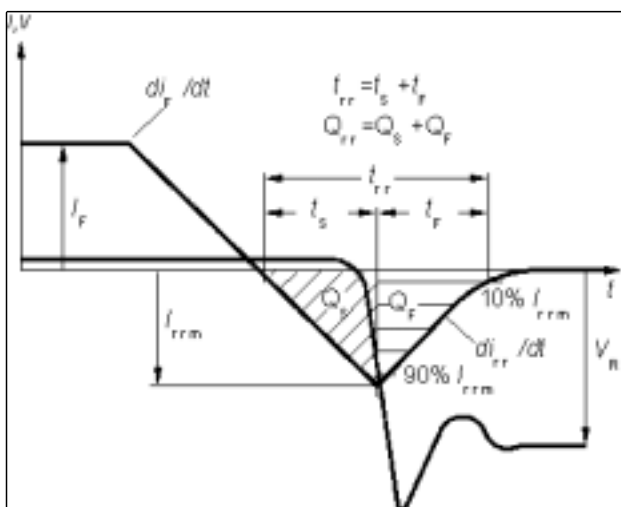


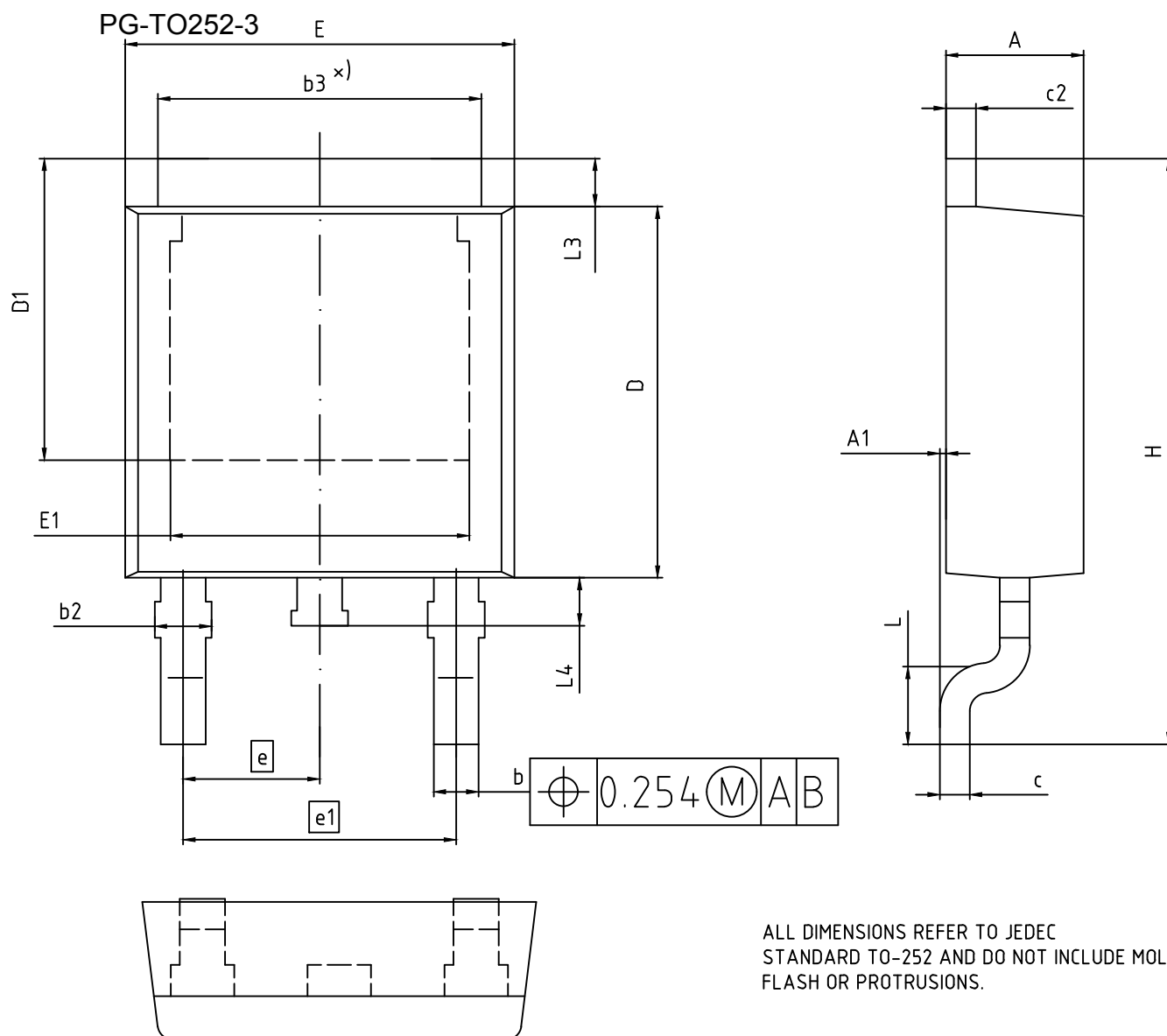
## 22 Typ. $C_{oss}$ stored energy

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

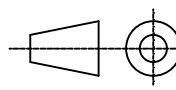


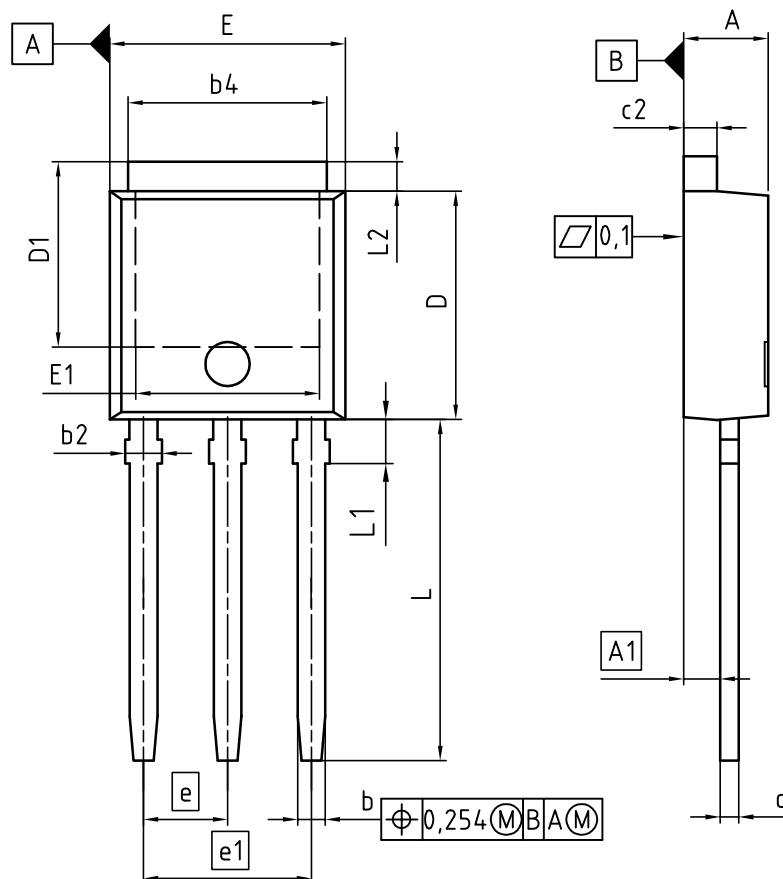
## Definition of diodes switching characteristics



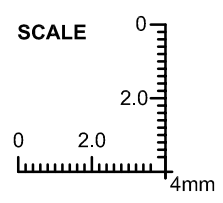
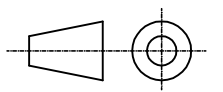


| DIMENSION | MILLIMETERS |       |
|-----------|-------------|-------|
|           | MIN.        | MAX.  |
| A         | 2.16        | 2.41  |
| A1        | 0.00        | 0.15  |
| b         | 0.64        | 0.89  |
| b2        | 0.65        | 1.15  |
| b3        | 4.95        | 5.50  |
| c         | 0.46        | 0.61  |
| c2        | 0.40        | 0.98  |
| D         | 5.97        | 6.22  |
| D1        | 5.02        | 5.84  |
| E         | 6.35        | 6.73  |
| E1        | 4.32        | 5.50  |
| e         | 2.29        |       |
| e1        | 4.57        |       |
| N         | 3           |       |
| H         | 9.40        | 10.48 |
| L         | 1.18        | 1.78  |
| L3        | 0.89        | 1.27  |
| L4        | 0.51        | 1.02  |

|                                                                                                                           |
|---------------------------------------------------------------------------------------------------------------------------|
| <b>DOCUMENT NO.</b><br>Z8B00003328                                                                                        |
| <b>REVISION</b><br>07                                                                                                     |
| <b>SCALE:</b><br>10:1<br>0 1 2mm<br> |
| <b>EUROPEAN PROJECTION</b><br>       |
| <b>ISSUE DATE</b><br>01.04.2020                                                                                           |



| DIM | MILLIMETERS |      | INCHES |       |
|-----|-------------|------|--------|-------|
|     | MIN         | MAX  | MIN    | MAX   |
| A   | 2.16        | 2.41 | 0.085  | 0.095 |
| A1  | 0.90        | 1.14 | 0.035  | 0.045 |
| b   | 0.64        | 0.89 | 0.025  | 0.035 |
| b2  | 0.65        | 1.15 | 0.026  | 0.045 |
| b4  | 4.95        | 5.50 | 0.195  | 0.217 |
| c   | 0.46        | 0.60 | 0.018  | 0.024 |
| c2  | 0.46        | 0.89 | 0.018  | 0.035 |
| D   | 5.97        | 6.22 | 0.235  | 0.245 |
| D1  | 5.04        | 5.77 | 0.198  | 0.227 |
| E   | 6.35        | 6.73 | 0.250  | 0.265 |
| E1  | 4.70        | 5.21 | 0.185  | 0.205 |
| e   | 2.29        |      | 0.090  |       |
| e1  | 4.57        |      | 0.180  |       |
| N   | 3           |      | 3      |       |
| L   | 8.89        | 9.65 | 0.350  | 0.380 |
| L1  | 1.90        | 2.29 | 0.075  | 0.090 |
| L2  | 0.89        | 1.37 | 0.035  | 0.054 |

|                                                                                                                     |
|---------------------------------------------------------------------------------------------------------------------|
| <b>DOCUMENT NO.</b><br>DZ80000310                                                                                   |
| <b>SCALE</b><br>               |
| <b>EUROPEAN PROJECTION</b><br> |
| <b>ISSUE DATE</b><br>19-03-2008                                                                                     |
| <b>REVISION</b><br>03                                                                                               |

## Revision History

SPD04N60C3

**Revision: 2020-05-26, Rev. 2.6**

Previous Revision

| Revision | Date       | Subjects (major changes since last revision) |
|----------|------------|----------------------------------------------|
| 2.6      | 2020-05-26 | Update package outline                       |

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