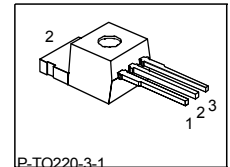


**Cool MOS™ Power Transistor**
**Feature**

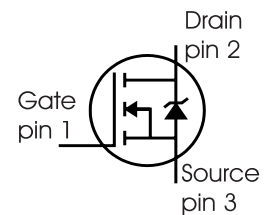
- New revolutionary high voltage technology
- Ultra low gate charge
- Periodic avalanche rated
- Extreme  $dv/dt$  rated
- Ultra low effective capacitances
- Improved transconductance
- Pb-free lead plating; RoHS compliant
- Qualified according to JEDEC<sup>0)</sup> for target applications

|              |      |          |
|--------------|------|----------|
| $V_{DS}$     | 600  | V        |
| $R_{DS(on)}$ | 0.95 | $\Omega$ |
| $I_D$        | 4.5  | A        |

PG-TO220



| Type       | Package  | Ordering Code | Marking |
|------------|----------|---------------|---------|
| SPP04N60S5 | PG-TO220 | Q67040-S4200  | 04N60S5 |


**Maximum Ratings**

| Parameter  | Symbol              | Value       | Unit               |
|--|---------------------|-------------|--------------------|
| Continuous drain current<br>$T_C = 25\text{ °C}$<br>$T_C = 100\text{ °C}$  | $I_D$               | 4.5<br>2.8  | A                  |
| Pulsed drain current, $t_p$ limited by $T_{jmax}$  | $I_{D\text{ puls}}$ | 9           |                    |
| 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  | $V_{GS}$            | $\pm 20$    | V                  |
| Gate source voltage AC ( $f > 1\text{ Hz}$ )   | $V_{GS}$            | $\pm 30$    |                    |
| Power dissipation, $T_C = 25\text{ °C}$  | $P_{tot}$           | 50          | W                  |
| Operating and storage temperature  | $T_j, T_{stg}$      | -55... +150 | $^{\circ}\text{C}$ |

**Maximum Ratings**

| Parameter   | Symbol  | Value | Unit |
|---|---------|-------|------|
| Drain Source voltage slope<br>$V_{DS} = 480 \text{ V}$ , $I_D = 4.5 \text{ A}$ , $T_j = 125 \text{ }^\circ\text{C}$ | $dv/dt$ | 20    | 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  | $R_{thJA}$ | -      | -    | 62   |      |
| SMD version, device on PCB:<br>@ min. footprint<br>@ 6 cm <sup>2</sup> cooling area <sup>2)</sup> | $R_{thJA}$ | -      | -    | 62   |      |
| Soldering temperature, wavesoldering<br>1.6 mm (0.063 in.) from case for 10s <sup>3)</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<br>breakdown voltage | $V_{(BR)DS}$  | $V_{GS}=0\text{V}$ , $I_D=4.5\text{A}$   | -      | 700  | -    |               |
| Gate threshold voltage                      | $V_{GS(th)}$  | $I_D=200\mu\text{A}$ , $V_{GS}=V_{DS}$   | 3.5    | 4.5  | 5.5  |               |
| 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>$T_j=150^\circ\text{C}$ | -      | 0.5  | 1    | $\mu\text{A}$ |
| Gate-source leakage current                 | $I_{GSS}$     | $V_{GS}=20\text{V}$ , $V_{DS}=0\text{V}$   | -      | -    | 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>$T_j=150^\circ\text{C}$     | -      | 0.85 | 0.95 | $\Omega$      |
| Gate input resistance                       | $R_G$         | $f=1\text{MHz}$ , open Drain   | -      | 20   | -    |               |

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

| Parameter   | Symbol       | Conditions   | Values |      |      | Unit |
|---|--------------|--|--------|------|------|------|
|   |              |  | min.   | typ. | max. |      |
| <b>Characteristics</b>  |              |  |        |      |      |      |
| Transconductance  | $g_{fs}$     | $V_{DS} \geq 2 \cdot I_D \cdot R_{DS(on)max}$ ,<br>$I_D = 2.8\text{A}$                       | -      | 2.5  | -    | S    |
| Input capacitance   | $C_{iss}$    | $V_{GS} = 0\text{V}$ , $V_{DS} = 25\text{V}$ ,<br>$f = 1\text{MHz}$                          | -      | 580  | -    | pF   |
| Output capacitance  | $C_{oss}$    |  | -      | 220  | -    |      |
| Reverse transfer capacitance                                  | $C_{rss}$    |  | -      | 7    | -    |      |
| Effective output capacitance, <sup>4)</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>5)</sup><br>time related   | $C_{o(tr)}$  |  | -      | 35   | -    |      |
| Turn-on delay time  | $t_{d(on)}$  | $V_{DD} = 350\text{V}$ , $V_{GS} = 0/10\text{V}$ ,<br>$I_D = 4.5\text{A}$ , $R_G = 18\Omega$ | -      | 55   | -    | ns   |
| Rise time   | $t_r$        | $V_{DD} = 350\text{V}$ , $V_{GS} = 0/10\text{V}$ ,<br>$I_D = 4.5\text{A}$ , $R_G = 18$       | -      | 30   | -    |      |
| Turn-off delay time   | $t_{d(off)}$ | $V_{DD} = 350\text{V}$ , $V_{GS} = 0/10\text{V}$ ,<br>$I_D = 4.5\text{A}$ , $R_G = 18\Omega$ | -      | 60   | 90   |      |
| Fall time   | $t_f$        |  | -      | 15   | 22.5 |      |

**Gate Charge Characteristics**

|                       |                 |  |   |      |      |    |
|-----------------------|-----------------|--|---|------|------|----|
| Gate to source charge | $Q_{gs}$        | $V_{DD} = 350\text{V}$ , $I_D = 4.5\text{A}$   | - | 4.5  | -    | nC |
| Gate to drain charge  | $Q_{gd}$        |  | - | 11   | -    |    |
| Gate charge total     | $Q_g$           | $V_{DD} = 350\text{V}$ , $I_D = 4.5\text{A}$ ,<br>$V_{GS} = 0\text{ to } 10\text{V}$ | - | 17.6 | 22.9 |    |
| Gate plateau voltage  | $V_{(plateau)}$ | $V_{DD} = 350\text{V}$ , $I_D = 4.5\text{A}$   | - | 8    | -    | V  |

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

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

<sup>4</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%  $V_{DSS}$ .

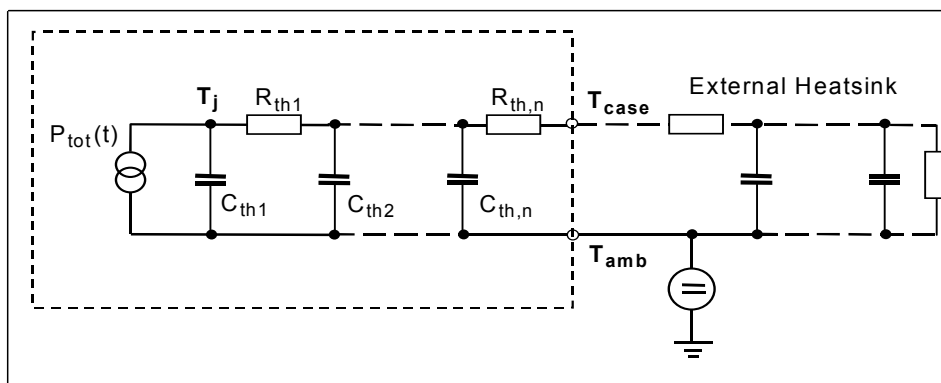
<sup>5</sup> $C_{o(tr)}$  is a fixed capacitance that gives the same charging time as  $C_{oss}$  while  $V_{DS}$  is rising from 0 to 80%  $V_{DSS}$ .

**Electrical Characteristics**, at  $T_j = 25\text{ }^\circ\text{C}$ , 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     | $I_{SM}$ |                                   | -      | -    | 9    |               |
| Inverse diode forward voltage            | $V_{SD}$ | $V_{GS}=0\text{V}, I_F=I_S$       | -      | 1    | 1.2  | V             |
| Reverse recovery time                    | $t_{rr}$ | $V_R=350\text{V}, I_F=I_S,$       | -      | 900  | 1530 | ns            |
| Reverse recovery charge                  | $Q_{rr}$ | $di_F/dt=100\text{A}/\mu\text{s}$ | -      | 3.2  | -    | $\mu\text{C}$ |

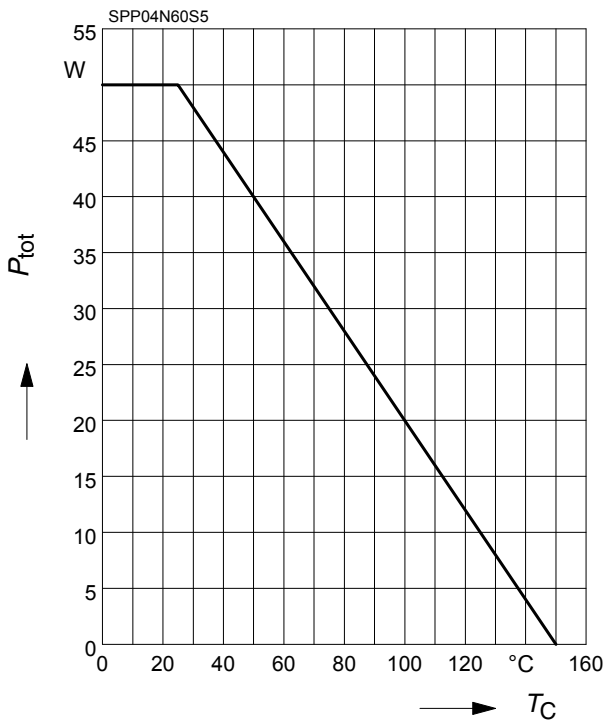
**Typical Transient Thermal Characteristics**

| 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

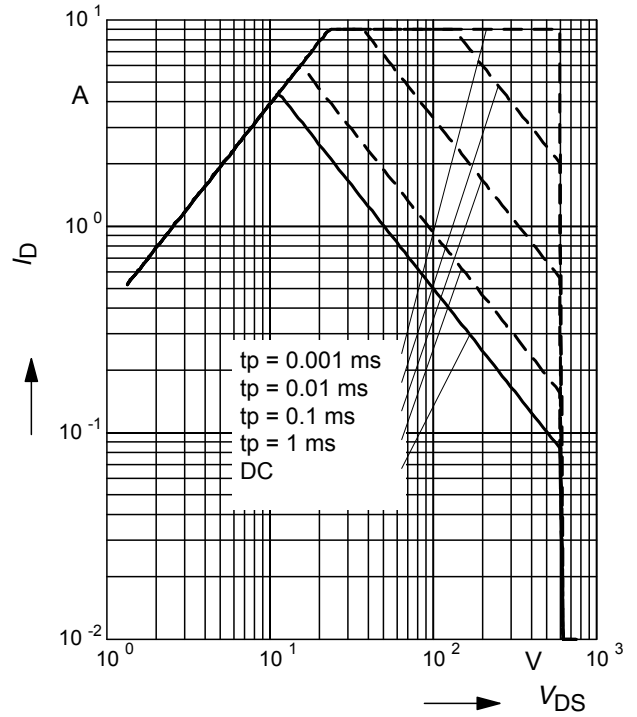
$$P_{tot} = f(T_C)$$



### 2 Safe operating area

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

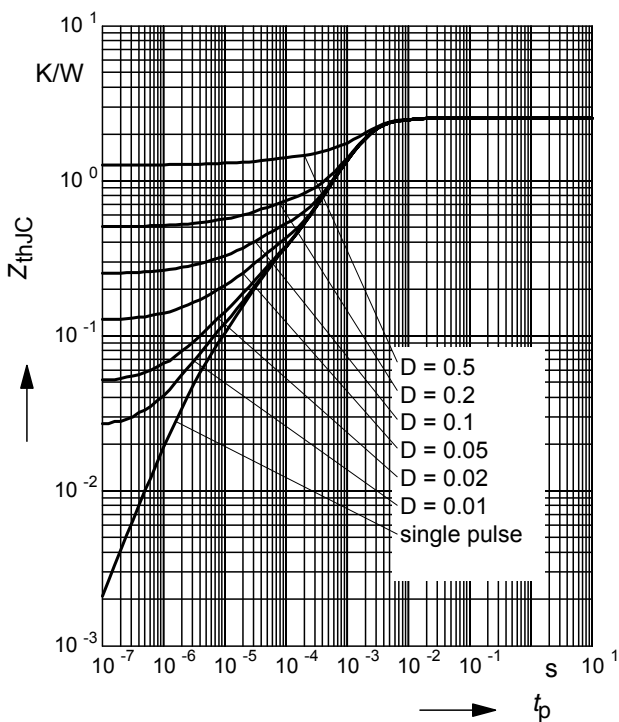
parameter :  $D = 0$  ,  $T_C = 25^\circ\text{C}$



### 3 Transient thermal impedance

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

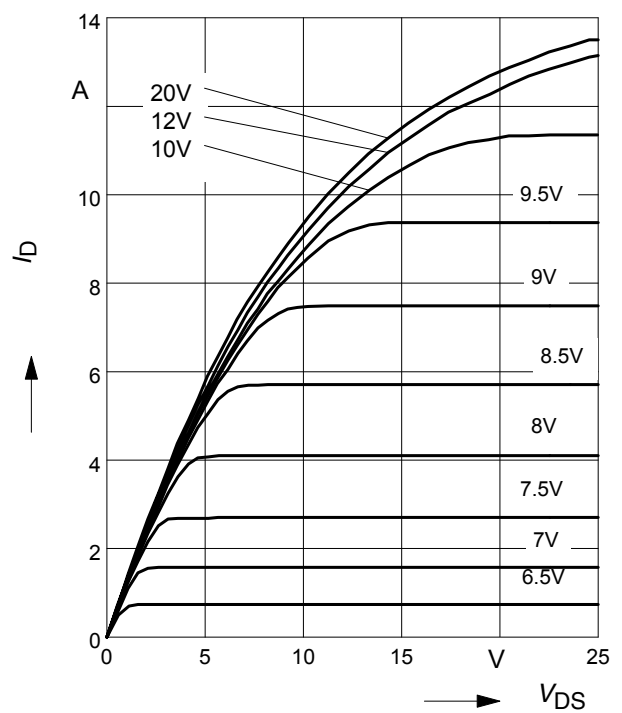
parameter:  $D = t_p/T$



### 4 Typ. output characteristic

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

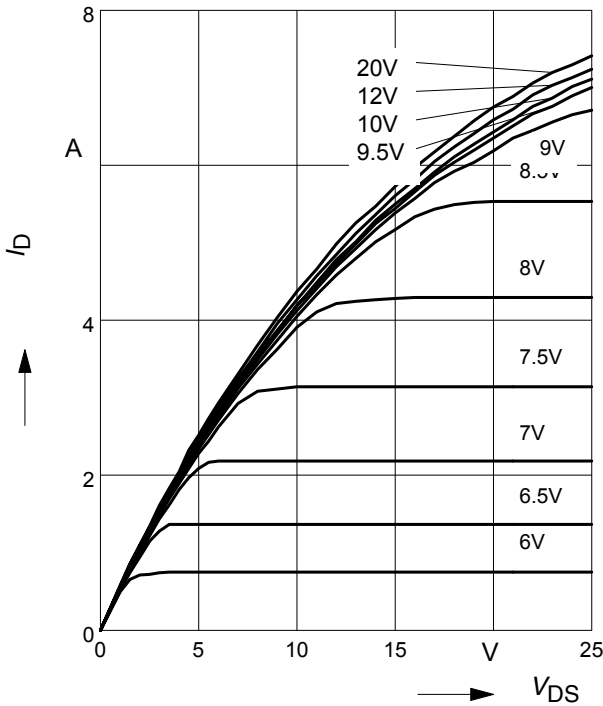
parameter:  $t_p = 10 \mu\text{s}$  ,  $V_{GS}$



**5 Typ. output characteristic**

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

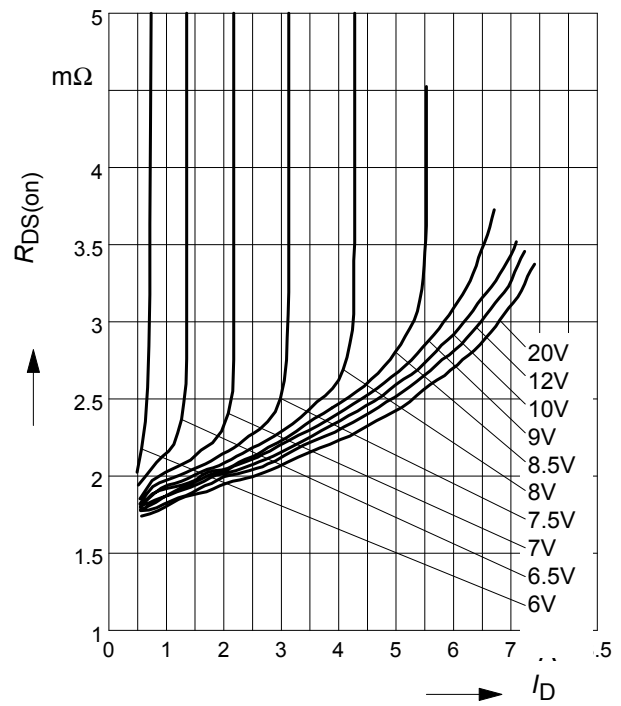
parameter:  $t_p = 10 \mu\text{s}, V_{GS}$



**6 Typ. drain-source on resistance**

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

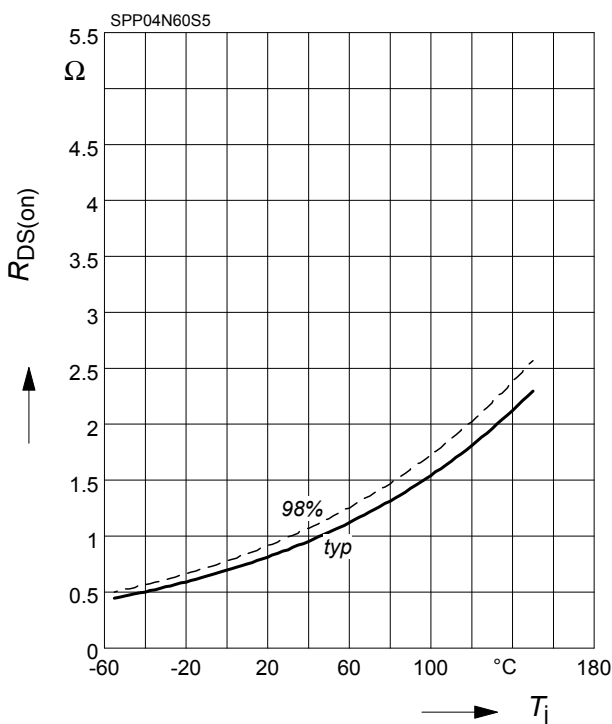
parameter:  $T_j = 150^\circ\text{C}, V_{GS}$



**7 Drain-source on-state resistance**

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

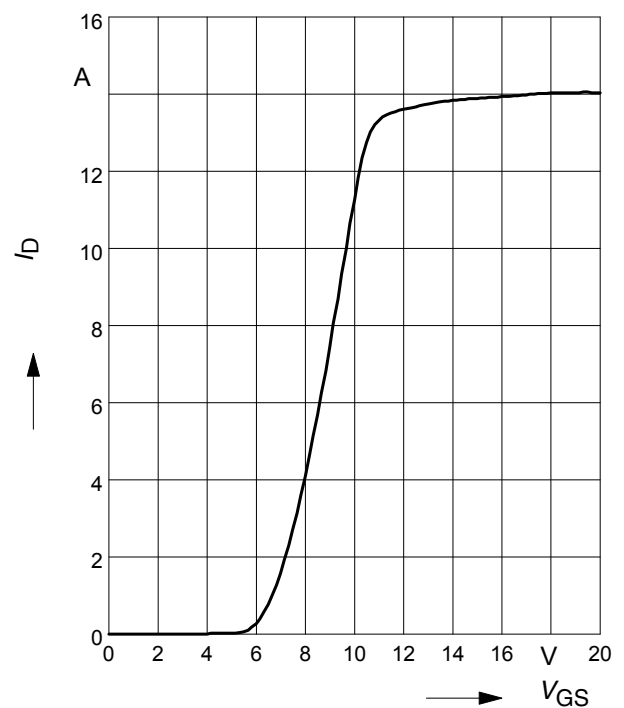
parameter:  $I_D = 2.8 \text{ A}, V_{GS} = 10 \text{ V}$



**8 Typ. transfer characteristics**

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

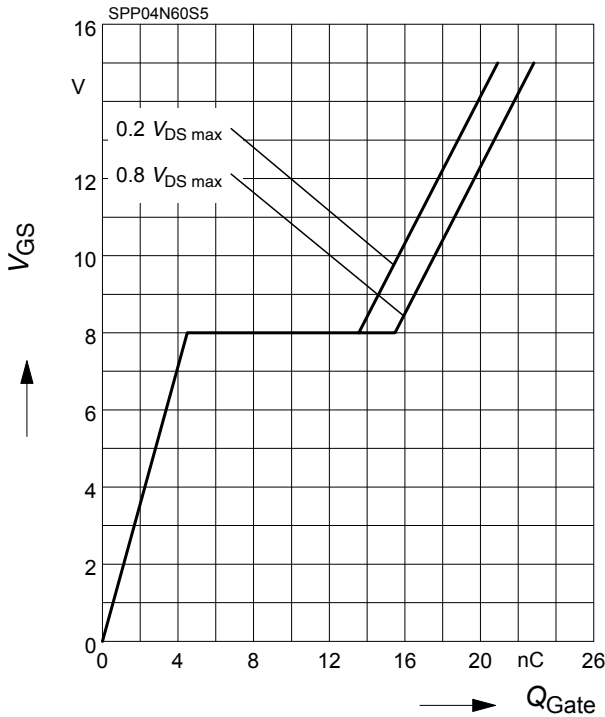
parameter:  $t_p = 10 \mu\text{s}$



### 9 Typ. gate charge

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

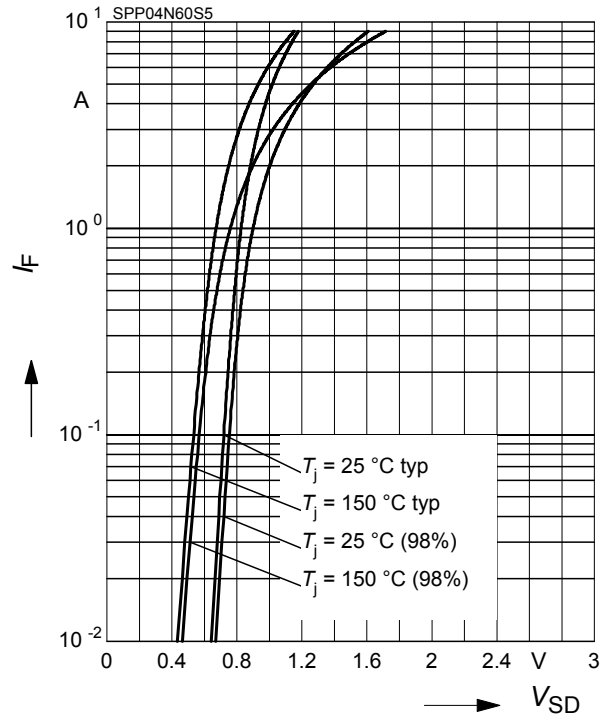
parameter:  $I_D = 4.5 \text{ A}$  pulsed



### 10 Forward characteristics of body diode

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

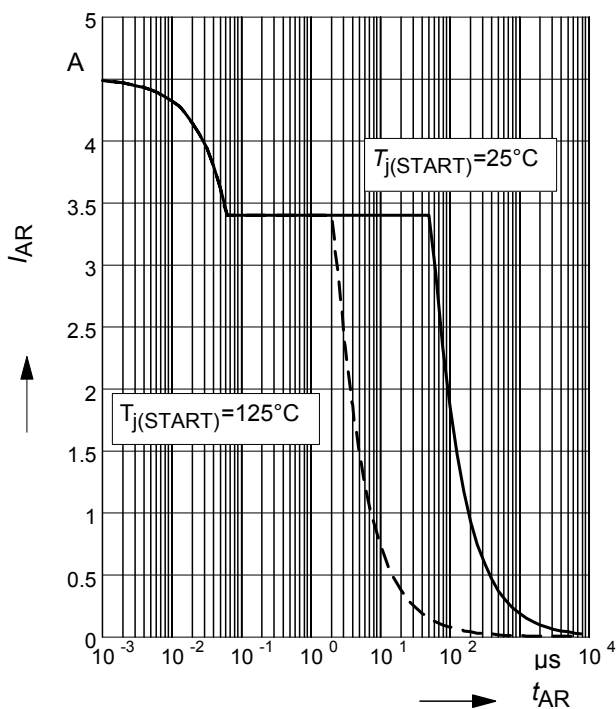
parameter:  $T_j$ ,  $t_p = 10 \mu\text{s}$



### 11 Avalanche SOA

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

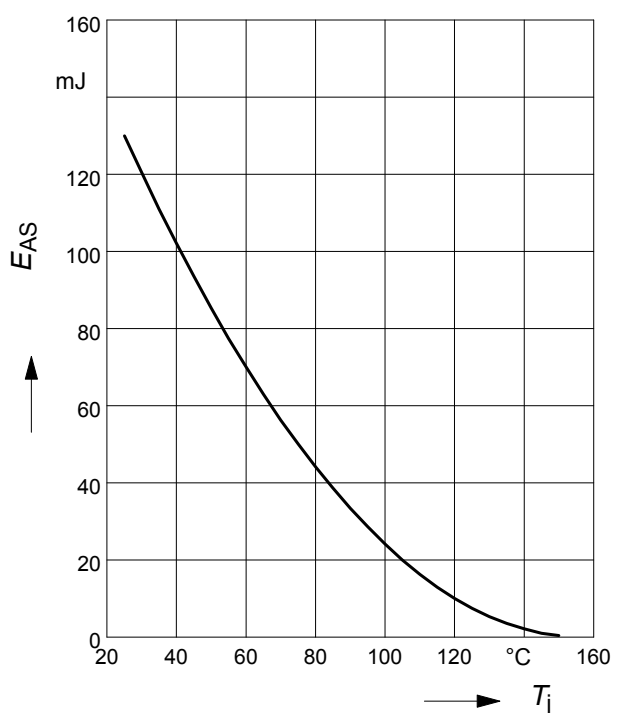
par.:  $T_j \leq 150 \text{ °C}$



### 12 Avalanche energy

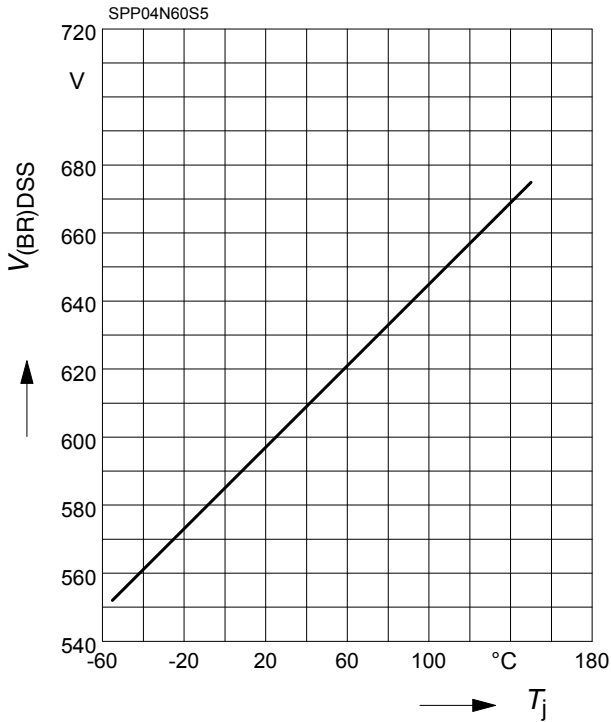
$$E_{AS} = f(T_j)$$

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



**13 Drain-source breakdown voltage**

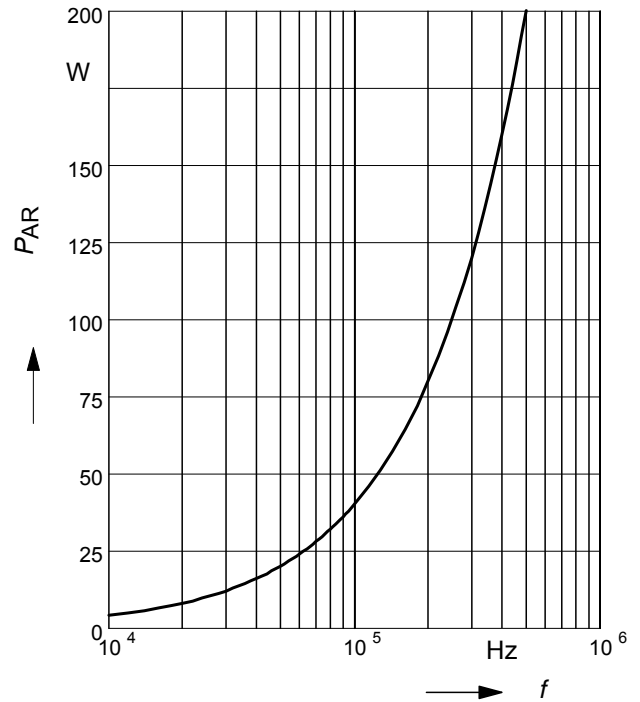
$$V_{(BR)DSS} = f(T_j)$$



**14 Avalanche power losses**

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

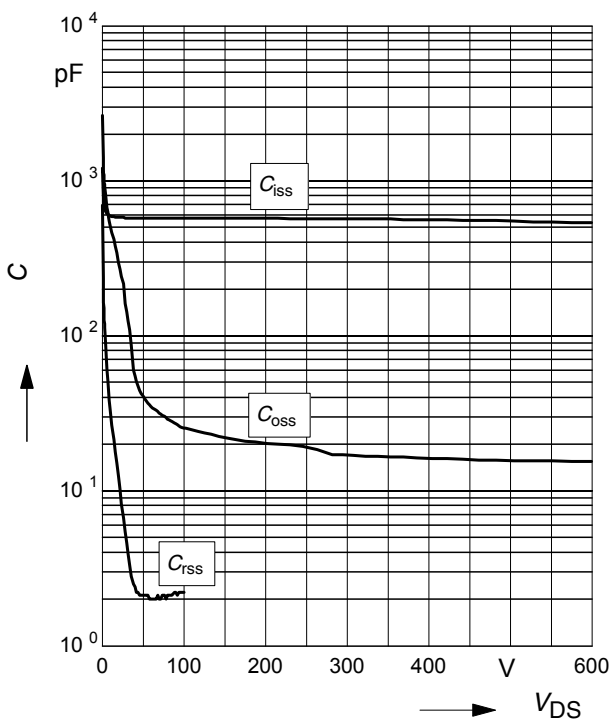
parameter:  $E_{AR}=0.4mJ$



**15 Typ. capacitances**

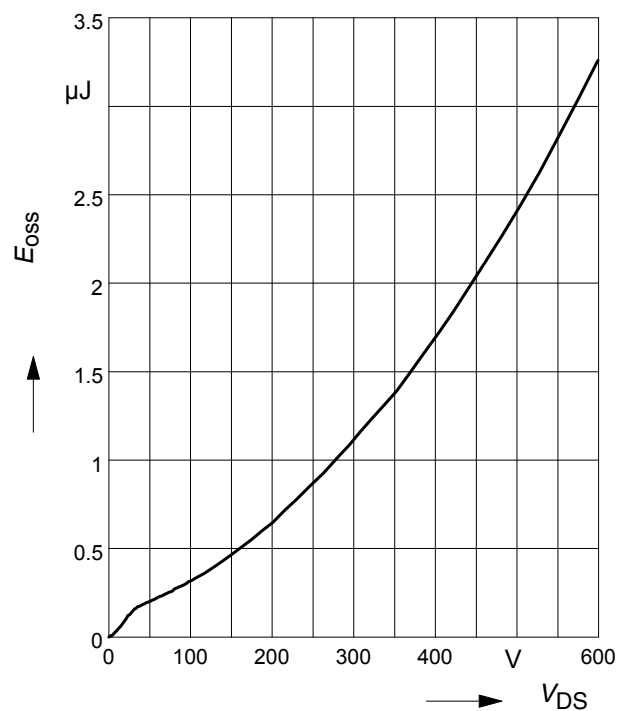
$$C = f(V_{DS})$$

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



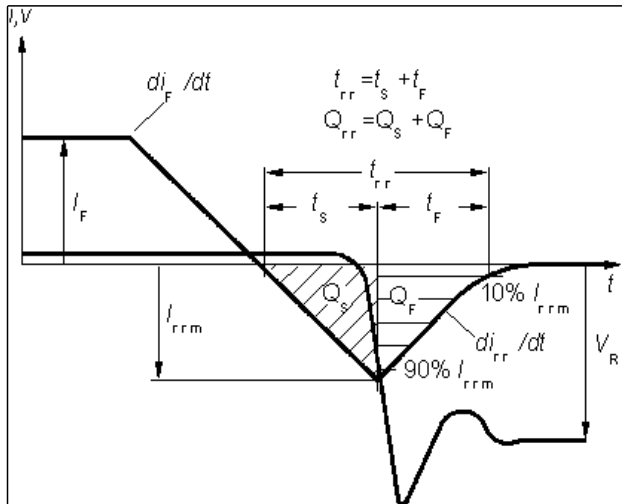
**16 Typ.  $C_{OSS}$  stored energy**

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

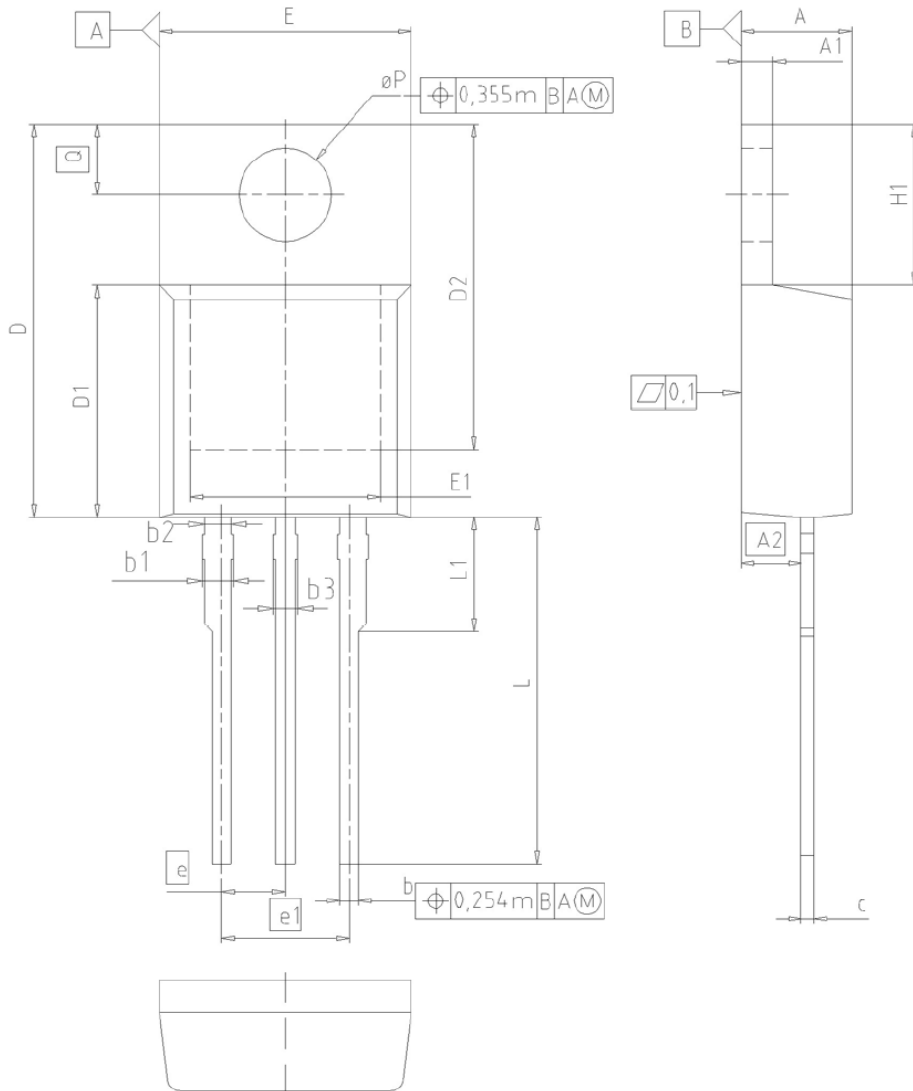




Definition of diodes switching characteristics



PG-TO220-3-1, PG-TO220-3-21



| 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        | 0.60  | 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 |

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