

Cool MOS™ Power Transistor



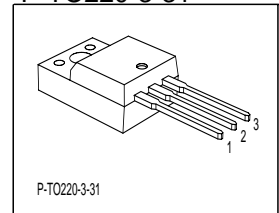
Feature

- New revolutionary high voltage technology
- Worldwide best $R_{DS(on)}$ in TO 220
- Ultra low gate charge
- Periodic avalanche rated
- Extreme dv/dt rated
- High peak current capability
- Improved transconductance
- 150 °C operating temperature

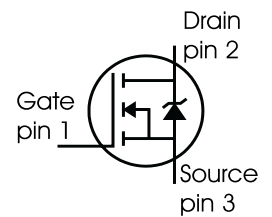
Product Summary

| | | |
|---------------------|------|----------|
| $V_{DS} @ T_{jmax}$ | 650 | V |
| $R_{DS(on)}$ | 0.95 | Ω |
| I_D | 3.3 | A |

P-TO220-3-31



| Type | Package | Ordering Code | Marking |
|------------|--------------|---------------|---------|
| SPA04N60C3 | P-TO220-3-31 | Q67040-S4413 | 04N60C3 |



Maximum Ratings, at $T_j = 25\text{ °C}$, unless otherwise specified

| Parameter | Symbol | Value | Unit |
|---|---------------------|-------------|------|
| Continuous drain current $T_C = 25\text{ °C}$ $T_C = 100\text{ °C}$ | I_D | 3.3 2.1 | A |
| Pulsed drain current, t_p limited by T_{jmax} | $I_{D\text{ puls}}$ | 13.5 | |
| Avalanche energy, single pulse $I_D=2.3\text{A}, V_{DD}=50\text{V}$ | E_{AS} | 130 | mJ |
| Avalanche energy, repetitive t_{AR} limited by T_{jmax} ¹⁾ $I_D=4.5\text{A}, V_{DD}=50\text{V}$ | E_{AR} | 0.4 | |
| Avalanche current, repetitive t_{AR} limited by T_{jmax} | I_{AR} | 4.5 | A |
| Reverse diode dv/dt $I_S=3.3\text{A}, V_{DS} < V_{DD}, di/dt=100\text{A}/\mu\text{s}, T_{jmax}=150\text{°C}$ | dv/dt | 6 | V/ns |
| Gate source voltage static | V_{GS} | ± 20 | V |
| Gate source voltage dynamic | V_{GS} | ± 30 | |
| Power dissipation, $T_C = 25\text{°C}$ | P_{tot} | 31 | W |
| Operating and storage temperature | T_j, T_{stg} | -55... +150 | °C |

Thermal Characteristics

| Parameter | Symbol | Values | | | Unit |
|--|------------|--------|------|------|------|
| | | min. | typ. | max. | |
| Characteristics | | | | | |
| Thermal resistance, junction - case | R_{thJC} | - | - | 4 | K/W |
| Thermal resistance, junction - ambient, leaded | R_{thJA} | - | - | 80 | |
| Linear derating factor | | - | - | 0.25 | W/K |
| Soldering temperature, 1.6 mm (0.063 in.) from case for 10s | T_{sold} | - | - | 260 | °C |

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

Static Characteristics

| | | | | | |
|--|---------------|-----|------|------|----------|
| Drain-source breakdown voltage $V_{GS}=0V, I_D=0.25mA$ | $V_{(BR)DSS}$ | 600 | - | - | V |
| Drain-source avalanche breakdown voltage $V_{GS}=0V, I_D=4.5A$ | $V_{(BR)DS}$ | - | 700 | - | |
| Gate threshold voltage, $V_{GS} = V_{DS}$ $I_D = 200\ \mu A$ | $V_{GS(th)}$ | 2.1 | 3 | 3.9 | |
| Zero gate voltage drain current $V_{DS} = 600\ V, V_{GS} = 0\ V, T_j = 25\text{ °C}$ $V_{DS} = 600\ V, V_{GS} = 0\ V, T_j = 150\text{ °C}$ | I_{DSS} | - | 0.5 | 1 | μA |
| | | - | - | 50 | |
| Gate-source leakage current $V_{GS}=20V, V_{DS}=0V$ | I_{GSS} | - | - | 100 | nA |
| Drain-source on-state resistance $V_{GS}=10V, I_D=2.1A, T_j=25\text{ °C}$ $V_{GS}=10V, I_D=2.1A, T_j=150\text{ °C}$ | $R_{DS(on)}$ | - | 0.85 | 0.95 | Ω |
| | | - | 2.35 | 2.62 | |
| Gate input resistance $f = 1\text{ MHz}$, open drain | R_G | - | 0.95 | - | |

¹ Repetitive avalanche causes additional power losses that can be calculated as $P_{AV} = E_{AR} * f$.

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

| Parameter | Symbol | Conditions | Values | | | Unit |
|--|--------------|--|--------|------|------|------|
| | | | min. | typ. | max. | |
| Characteristics | | | | | | |
| Transconductance | g_{fs} | $V_{DS} \geq 2 \cdot I_D \cdot R_{DS(on)max}$, $I_D = 2.1\text{A}$ | - | 4.4 | - | S |
| Input capacitance | C_{iss} | $V_{GS} = 0\text{V}$, $V_{DS} = 25\text{V}$, | - | 580 | - | pF |
| Output capacitance | C_{oss} | $f = 1\text{MHz}$ | - | 220 | - | |
| Reverse transfer capacitance | C_{rss} | | - | 7 | - | |
| Effective output capacitance, 1) energy related | $C_{o(er)}$ | $V_{GS} = 0\text{V}$, $V_{DS} = 0\text{V to } 480\text{V}$ | - | 20 | - | pF |
| Effective output capacitance, 2) time related | $C_{o(tr)}$ | | - | 35 | - | |
| Turn-on delay time | $t_{d(on)}$ | $V_{DD} = 380\text{V}$, $V_{GS} = 0/10\text{V}$, | - | 6 | - | ns |
| Rise time | t_r | $I_D = 3.3\text{A}$, $R_G = 18\Omega$ | - | 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} | $V_{DD} = 480\text{V}$, $I_D = 3.3\text{A}$ | - | 2.2 | - | nC |
| Gate to drain charge | Q_{gd} | | - | 8.8 | - | |
| Gate charge total | Q_g | $V_{DD} = 480\text{V}$, $I_D = 3.3\text{A}$, $V_{GS} = 0\text{ to } 10\text{V}$ | - | 19 | 25 | |
| Gate plateau voltage | $V_{(plateau)}$ | $V_{DD} = 480\text{V}$, $I_D = 3.3\text{A}$ | - | 5 | - | V |

¹ $C_{o(er)}$ is a fixed capacitance that gives the same stored energy as C_{oss} while V_{DS} is rising from 0 to 80% V_{DSS} .

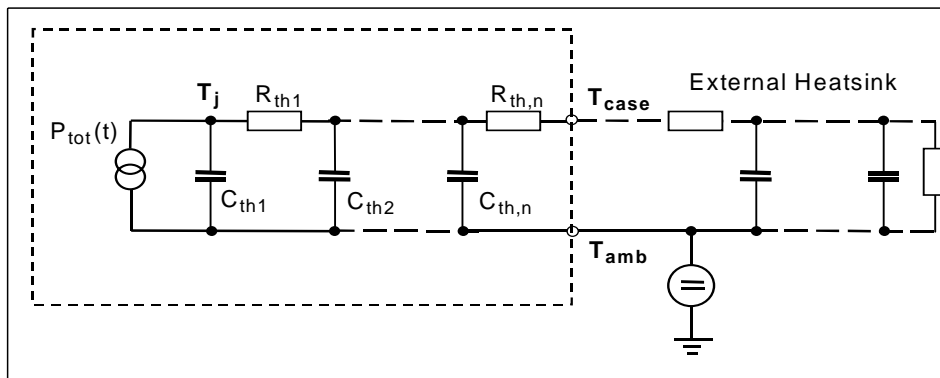
² $C_{o(tr)}$ is a fixed capacitance that gives the same charging time as C_{oss} while V_{DS} is rising from 0 to 80% V_{DSS} .

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

| Parameter | Symbol | Conditions | Values | | | Unit |
|---|--------------|-----------------------------------|--------|------|------|------------------------|
| | | | min. | typ. | max. | |
| Characteristics | | | | | | |
| Inverse diode continuous forward current | I_S | $T_C=25^\circ\text{C}$ | - | - | 3.3 | 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} | $V_R=480\text{V}, I_F=I_S,$ | - | 300 | 500 | ns |
| Reverse recovery charge | Q_{rr} | $di_F/dt=100\text{A}/\mu\text{s}$ | - | 2.6 | - | μC |
| Peak reverse recovery current | I_{rrm} | | - | 18 | - | A |
| Peak rate of fall of reverse recovery current | di_{rr}/dt | | - | - | 900 | $\text{A}/\mu\text{s}$ |

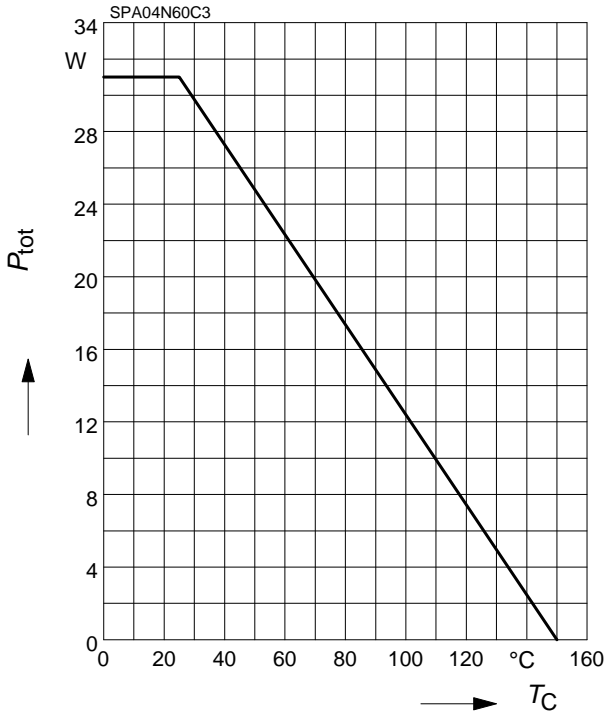
Transient Thermal Characteristics

| Symbol | Value | Unit | Symbol | Value | Unit |
|--------------------|-------|------|---------------------|-----------|------|
| | typ. | | | typ. | |
| Thermal resistance | | | Thermal capacitance | | |
| R_{th1} | 0.039 | K/W | C_{th1} | 0.0000734 | Ws/K |
| R_{th2} | 0.075 | | C_{th2} | 0.000282 | |
| R_{th3} | 0.102 | | C_{th3} | 0.000401 | |
| R_{th4} | 0.27 | | C_{th4} | 0.000736 | |
| R_{th5} | 0.594 | | C_{th5} | 0.00501 | |
| R_{th6} | 2.536 | | C_{th6} | 0.412 | |



1 Power dissipation

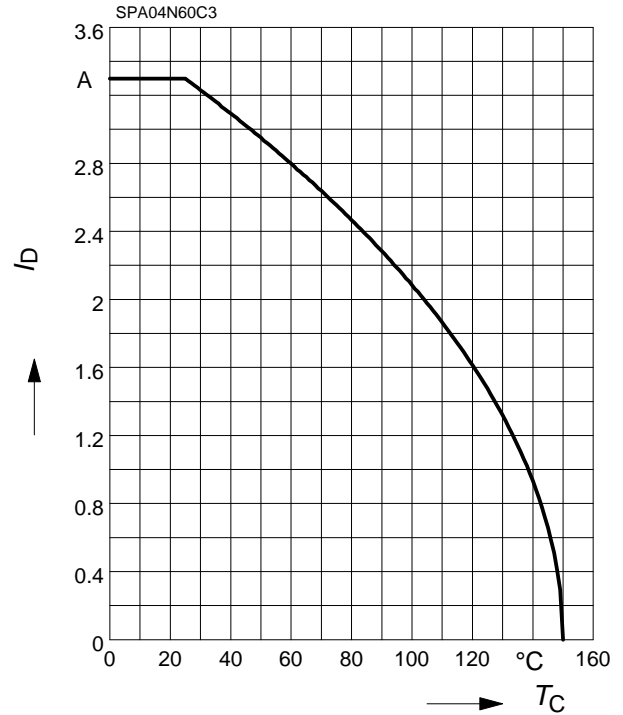
$$P_{\text{tot}} = f(T_C)$$



2 Drain current

$$I_D = f(T_C)$$

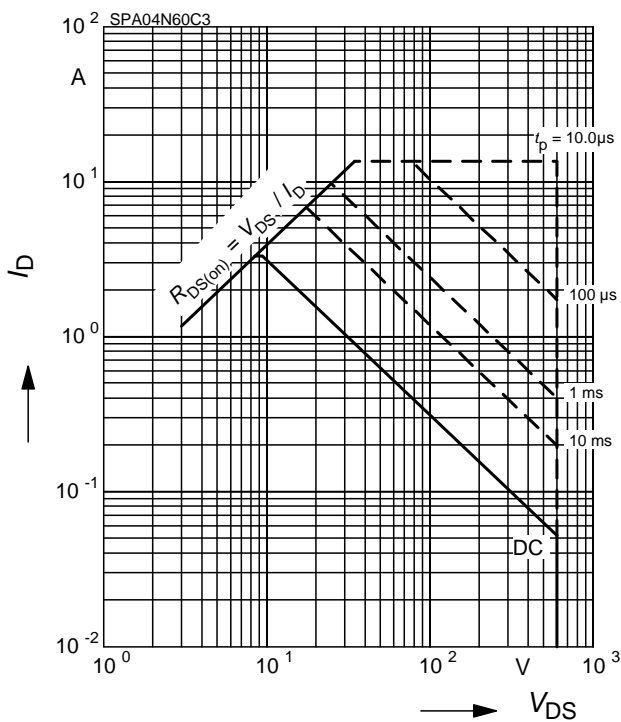
parameter: $V_{GS} \geq 10 \text{ V}$



3 Safe operating area

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

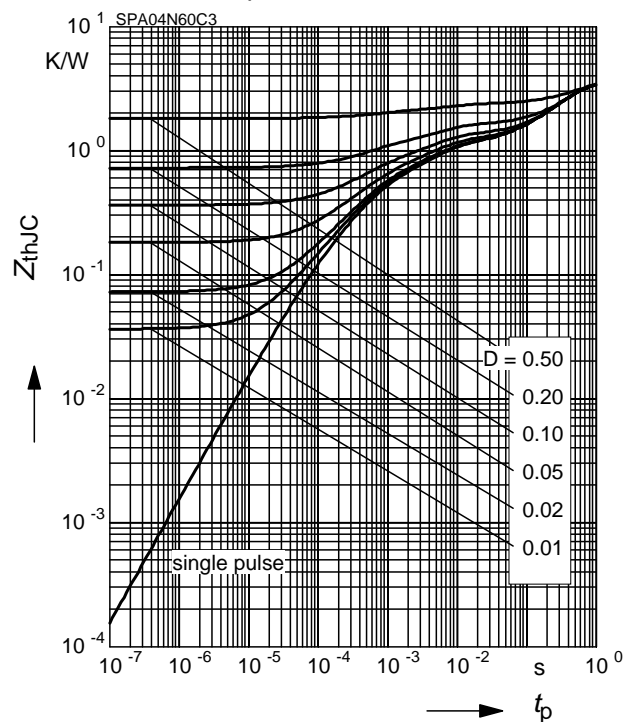
parameter: $D = 0$, $T_C = 25^\circ\text{C}$



4 Transient thermal impedance

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

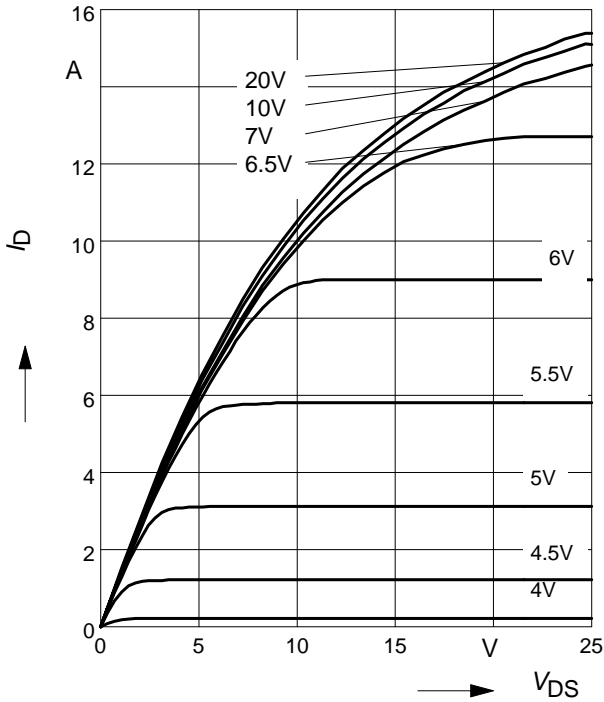
parameter: $D = t_p/T$



5 Typ. output characteristic

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

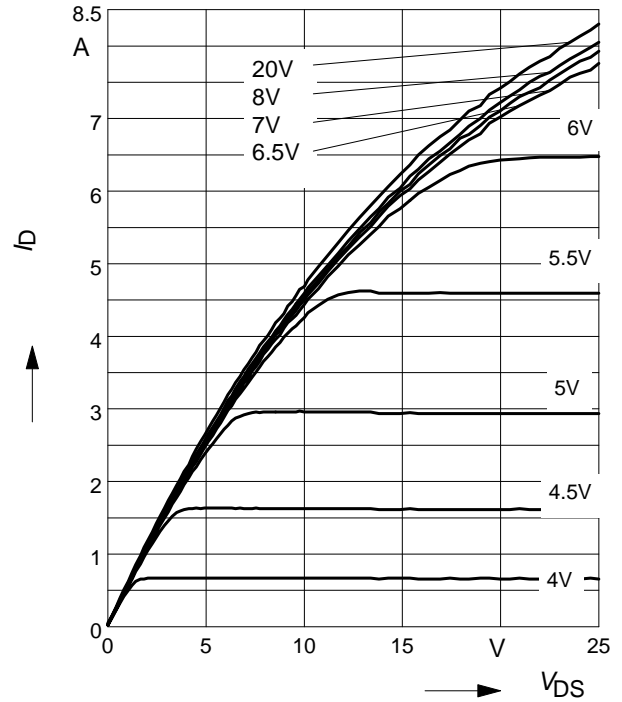
parameter: $t_p = 10 \mu\text{s}, V_{GS}$



6 Typ. output characteristic

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

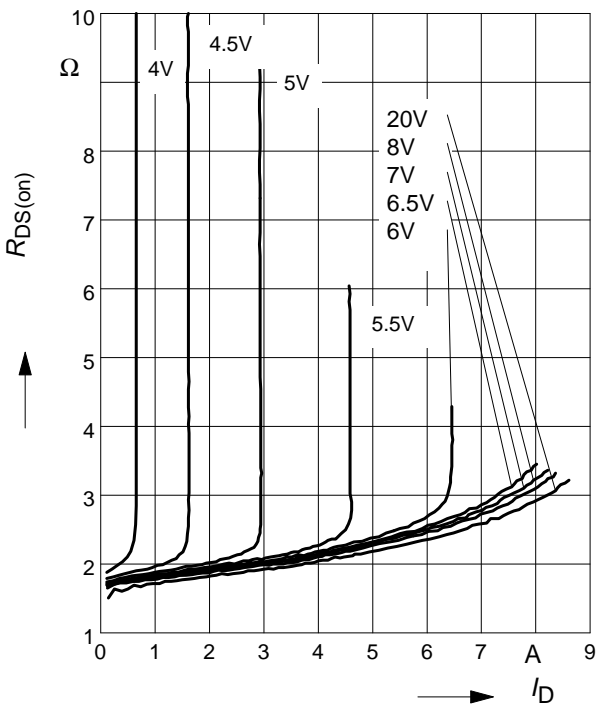
parameter: $t_p = 10 \mu\text{s}, V_{GS}$



7 Typ. drain-source on resistance

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

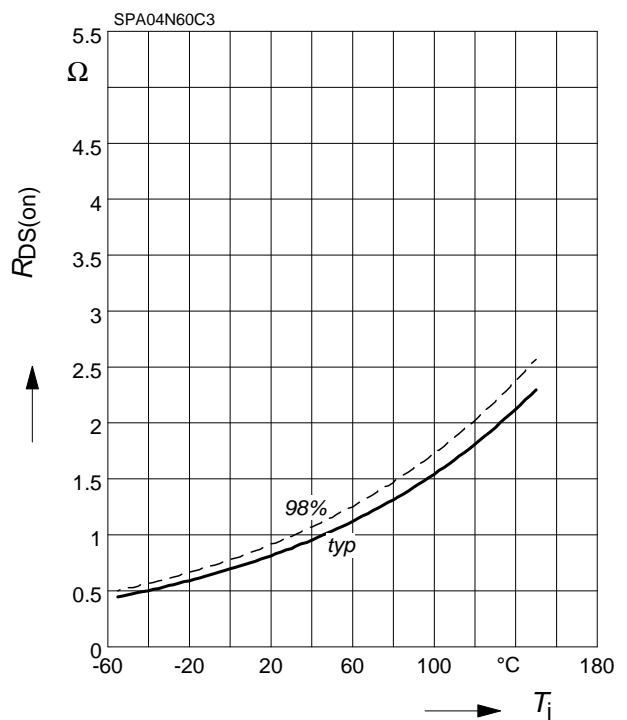
parameter: $T_j = 150^\circ\text{C}, V_{GS}$



8 Drain-source on-state resistance

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

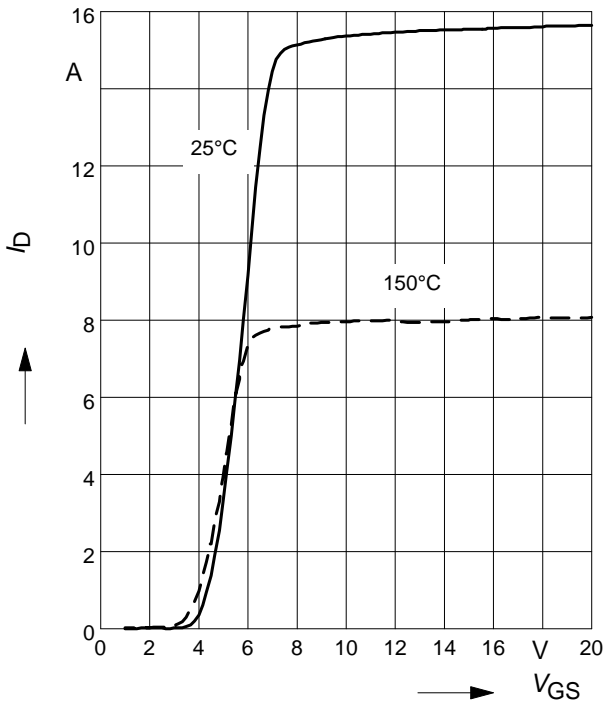
parameter: $I_D = 2.1 \text{ A}, V_{GS} = 10 \text{ V}$



9 Typ. transfer characteristics

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

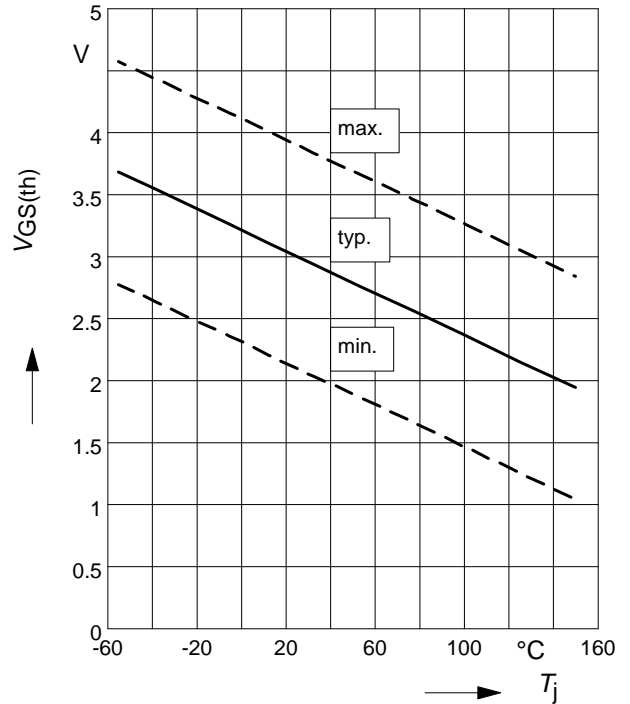
parameter: $t_p = 10 \mu s$



10 Gate threshold voltage

$V_{GS(th)} = f(T_j)$

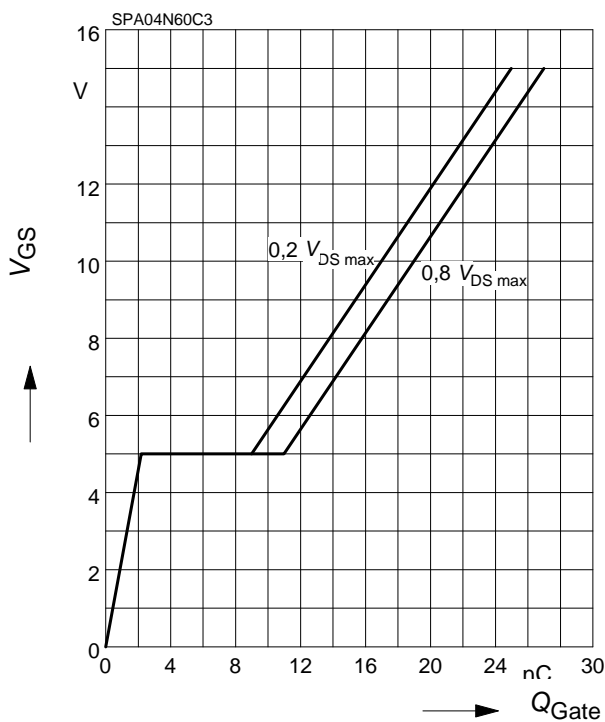
parameter: $V_{GS} = V_{DS}$, $I_D = 200 \mu A$



11 Typ. gate charge

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

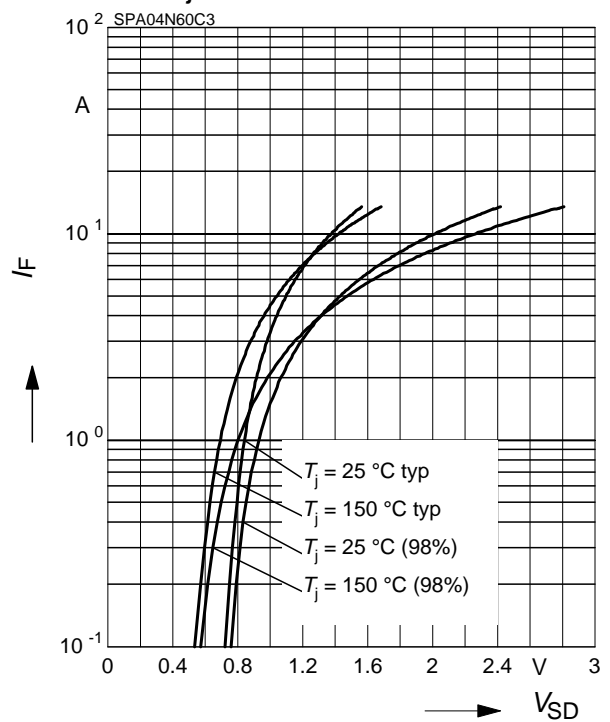
parameter: $I_D = 3.3 A$ pulsed



12 Forward characteristics of body diode

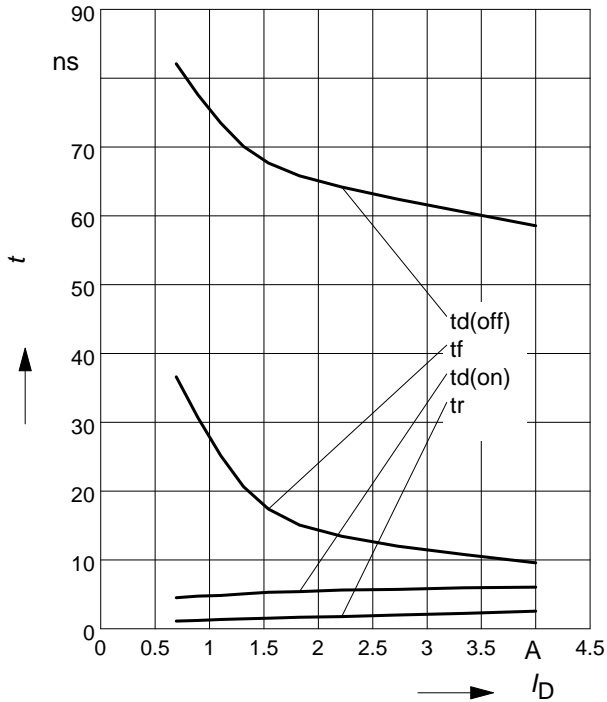
$I_F = f(V_{SD})$

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



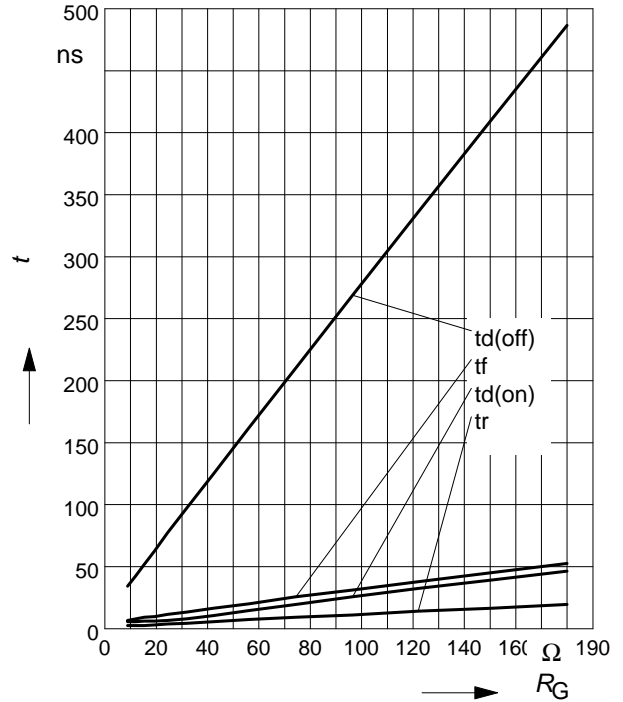
18 Typ. switching time

$t = f(I_D)$, inductive load, $T_j = 125^\circ\text{C}$
 par.: $V_{DS} = 380\text{V}$, $V_{GS} = 0/+13\text{V}$, $R_G = 18\Omega$



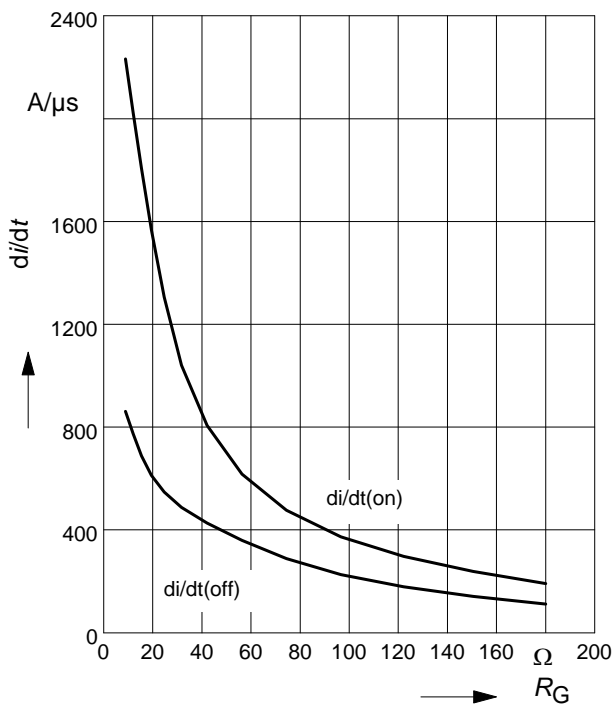
13 Typ. switching time

$t = f(R_G)$, inductive load, $T_j = 125^\circ\text{C}$
 par.: $V_{DS} = 380\text{V}$, $V_{GS} = 0/+13\text{V}$, $I_D = 3.3\text{A}$



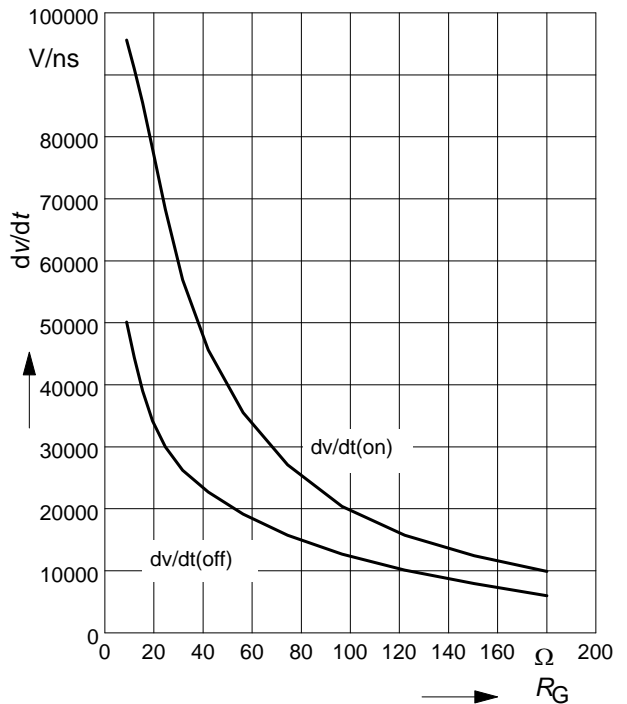
14 Typ. drain current slope

$di/dt = f(R_G)$, inductive load, $T_j = 125^\circ\text{C}$
 par.: $V_{DS} = 380\text{V}$, $V_{GS} = 0/+13\text{V}$, $I_D = 3.3\text{A}$



15 Typ. drain source voltage slope

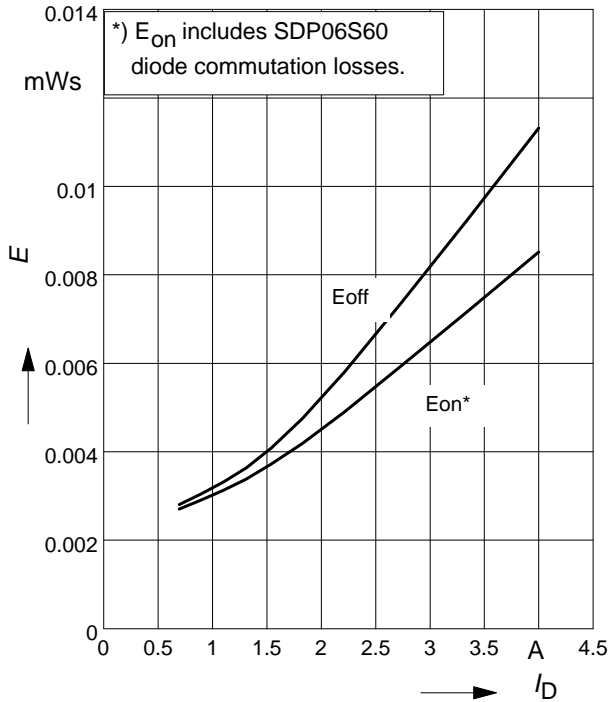
$dv/dt = f(R_G)$, inductive load, $T_j = 125^\circ\text{C}$
 par.: $V_{DS} = 380\text{V}$, $V_{GS} = 0/+13\text{V}$, $I_D = 3.3\text{A}$



16 Typ. switching losses

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

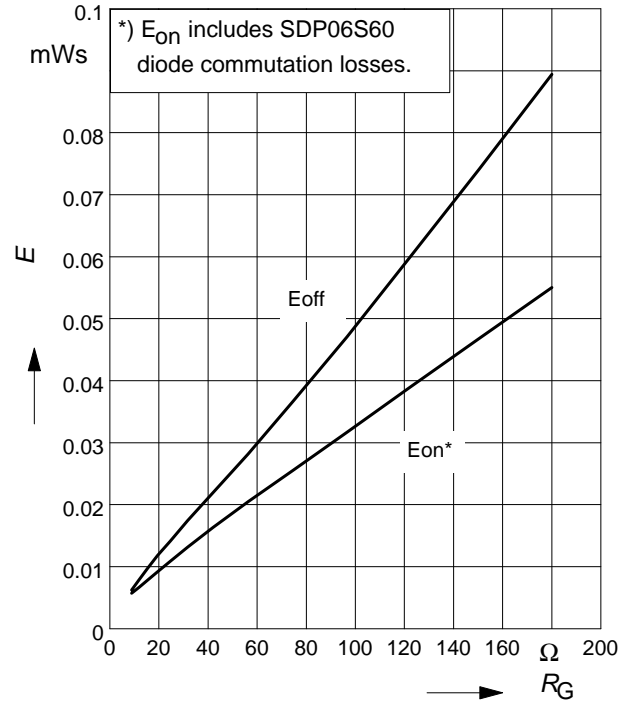
par.: $V_{DS} = 380\text{V}$, $V_{GS} = 0/+13\text{V}$, $R_G = 18\Omega$



17 Typ. switching losses

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

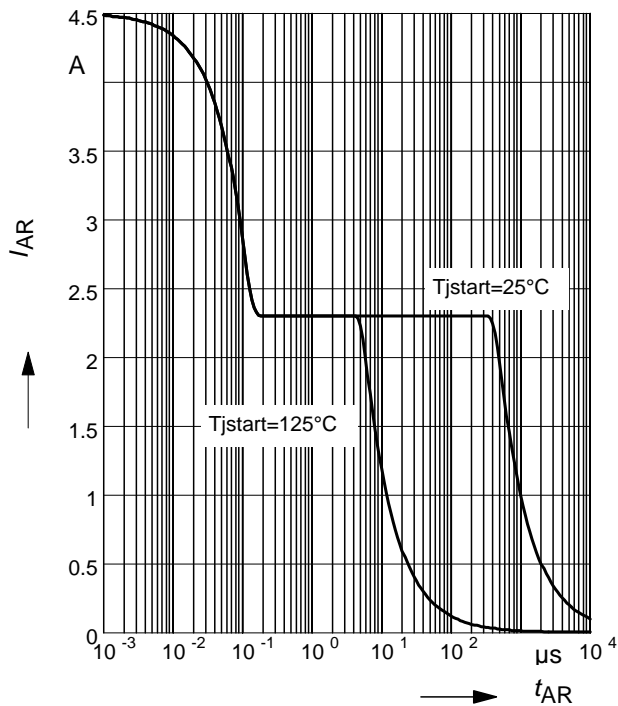
par.: $V_{DS} = 380\text{V}$, $V_{GS} = 0/+13\text{V}$, $I_D = 3.3\text{A}$



18 Avalanche SOA

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

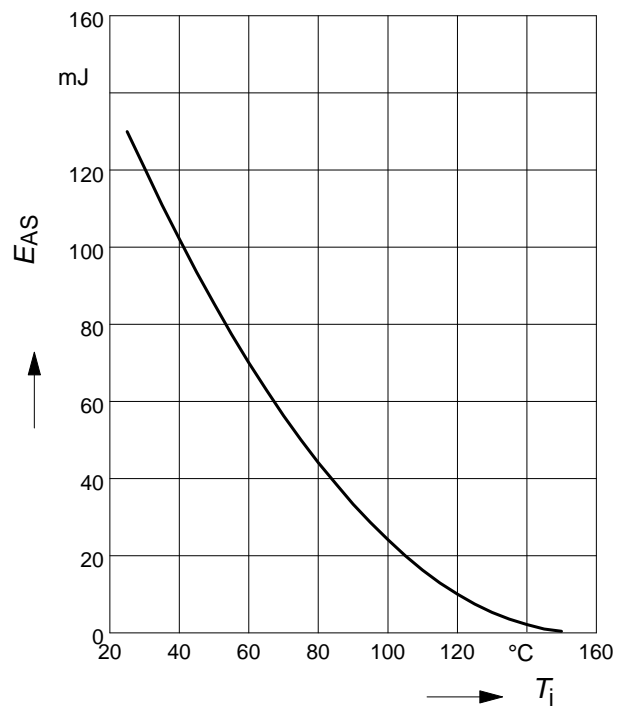
par.: $T_j \leq 150^\circ\text{C}$



19 Avalanche energy

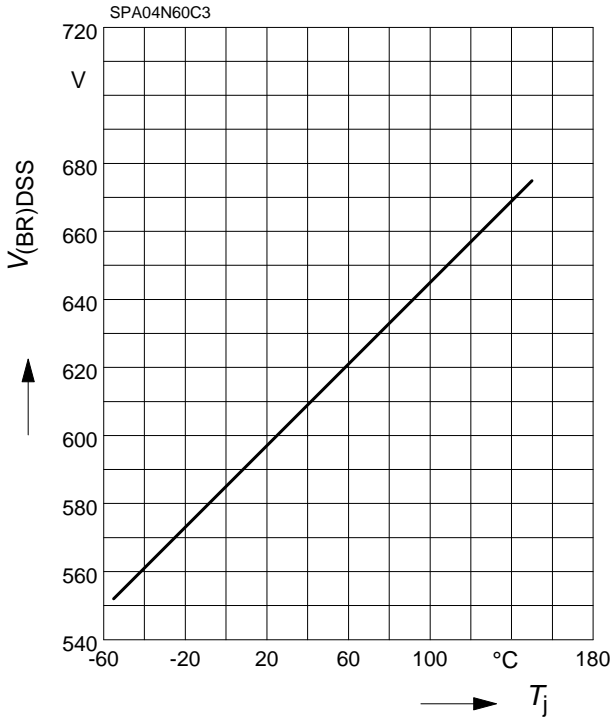
$E_{AS} = f(T_j)$

par.: $I_D = 2.3\text{A}$, $V_{DD} = 50\text{V}$



20 Drain-source breakdown voltage

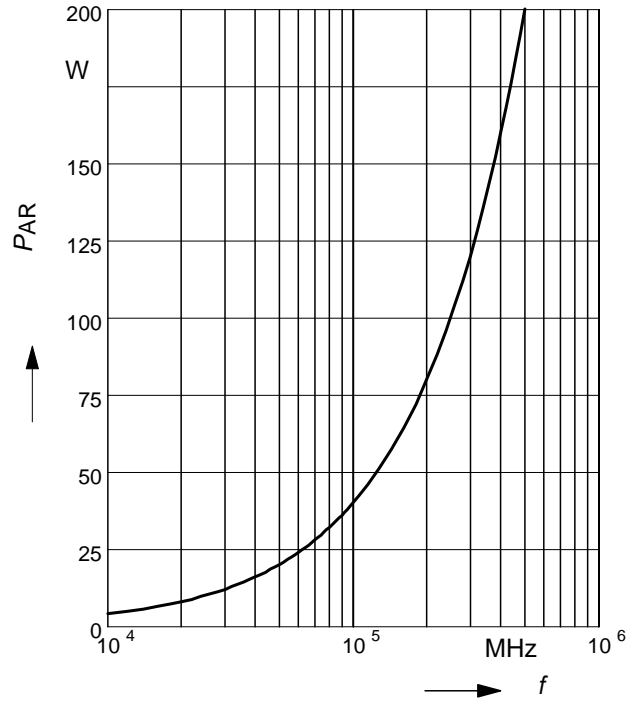
$$V_{(BR)DSS} = f(T_j)$$



21 Avalanche power losses

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

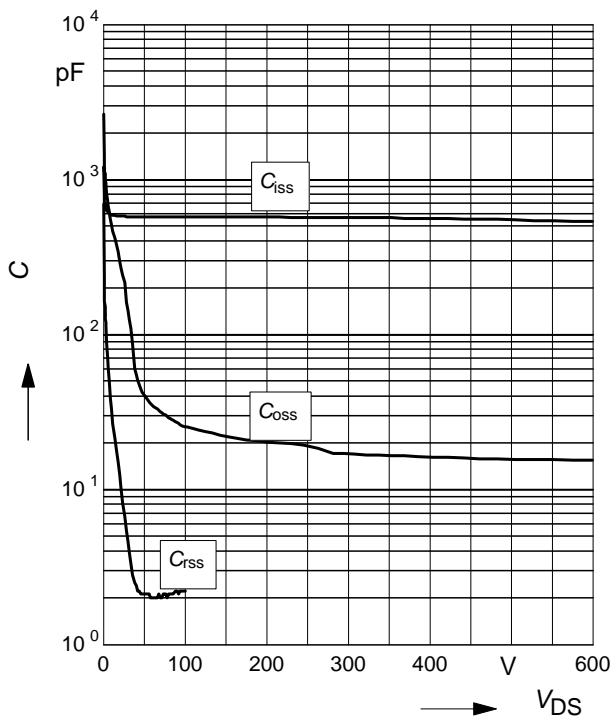
parameter: $E_{AR}=0.4mJ$



22 Typ. capacitances

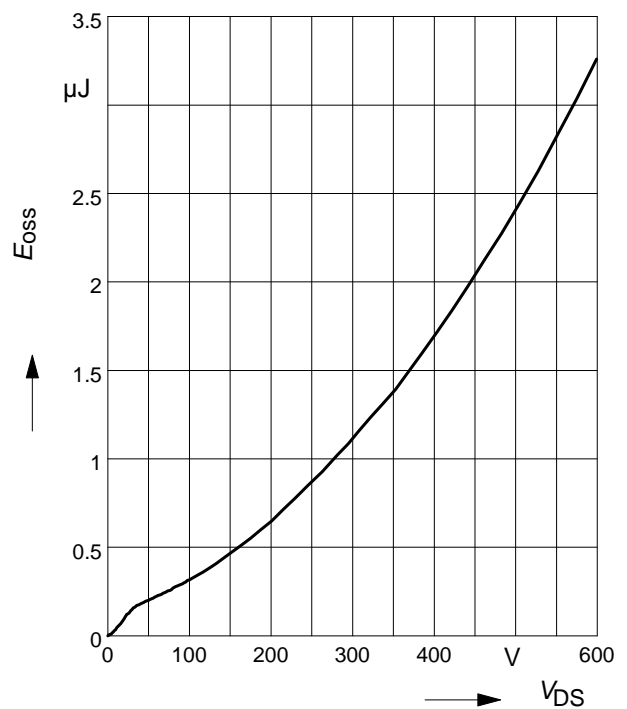
$$C = f(V_{DS})$$

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

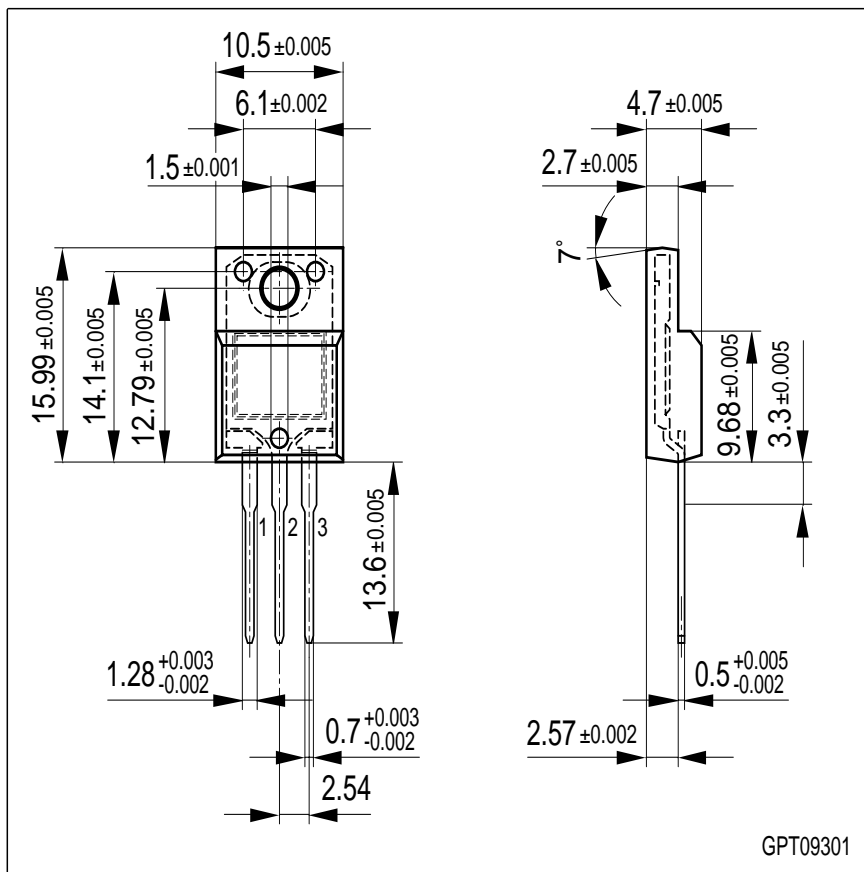
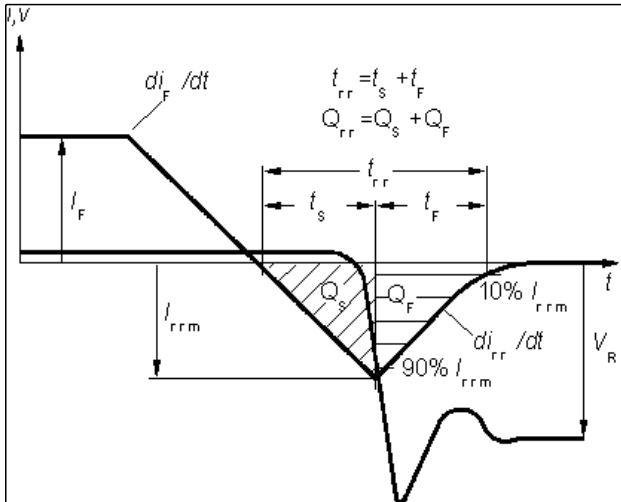


23 Typ. C_{oss} stored energy

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



Definition of diodes switching characteristics



Please refer to mounting instructions (application note AN-TO220-3-31-01)

Published by
Infineon Technologies AG,
Bereichs Kommunikation
St.-Martin-Strasse 53,
D-81541 München
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