

## Cool MOS™ Power Transistor

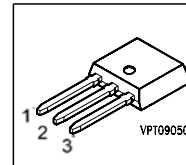
### Feature

- 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>
- Qualified according to JEDEC<sup>0)</sup> for target applications

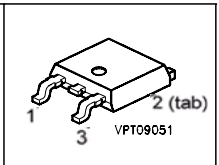


$V_{DS} @ T_{jmax}$	650	V
$R_{DS(on)}$	0.95	$\Omega$
$I_D$	4.5	A

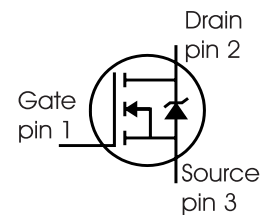
PG-TO251



PG-TO252



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



### Maximum Ratings

Parameter	Symbol	Value	Unit
Continuous drain current $T_C = 25\text{ }^\circ\text{C}$ $T_C = 100\text{ }^\circ\text{C}$	$I_D$	4.5 2.8	A
Pulsed drain current, $t_p$ limited by $T_{jmax}$	$I_{D\text{ puls}}$	13.5	
Avalanche energy, single pulse $I_D = 3.4\text{ A}$ , $V_{DD} = 50\text{ V}$	$E_{AS}$	130	mJ
Avalanche energy, repetitive $t_{AR}$ limited by $T_{jmax}$ <sup>1)</sup> $I_D = 4.5\text{ A}$ , $V_{DD} = 50\text{ V}$	$E_{AR}$	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

a) except PG-TO251, non-Halogen free (SPD04N60C3BT); Halogen free (SPD04N60C3AT)

**Maximum Ratings**

Parameter	Symbol	Value	Unit
Drain Source voltage slope $V_{DS} = 480 \text{ V}, I_D = 4.5 \text{ A}, T_j = 125 \text{ }^\circ\text{C}$	$dv/dt$	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	
SMD version, device on PCB: @ min. footprint @ 6 cm <sup>2</sup> cooling area <sup>2)</sup>	$R_{thJA}$	-	-	75 50	
Soldering temperature, *) 1.6 mm (0.063 in.) from case for 10s	$T_{sold}$	-	-	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	$I_{DSS}$	$V_{DS}=600\text{V}, V_{GS}=0\text{V},$ $T_j=25^\circ\text{C},$ $T_j=150^\circ\text{C}$	-	0.5	1 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	$R_{DS(on)}$	$V_{GS}=10\text{V}, I_D=2.8\text{A},$ $T_j=25^\circ\text{C}$ $T_j=150^\circ\text{C}$	-	0.85	0.95 -	$\Omega$
Gate input resistance	$R_G$	$f=1\text{MHz}, \text{open Drain}$	-	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	$g_{fs}$	$V_{DS} \geq 2 \cdot I_D \cdot R_{DS(on)max}$ , $I_D = 2.8\text{A}$	-	4.4	-	S
Input capacitance	$C_{iss}$	$V_{GS} = 0\text{V}$ , $V_{DS} = 25\text{V}$ , $f = 1\text{MHz}$	-	490	-	pF
Output capacitance	$C_{oss}$		-	160	-	
Reverse transfer capacitance	$C_{rss}$		-	15	-	
Effective output capacitance, <sup>3)</sup> energy related	$C_{o(er)}$	$V_{GS} = 0\text{V}$ , $V_{DS} = 0\text{V to } 480\text{V}$	-	20	-	pF
Effective output capacitance, <sup>4)</sup> time related	$C_{o(tr)}$		-	35	-	
Turn-on delay time	$t_{d(on)}$	$V_{DD} = 380\text{V}$ , $V_{GS} = 0/10\text{V}$ , $I_D = 4.5\text{A}$ , $R_G = 18\Omega$	-	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	$Q_g$	$V_{DD} = 480\text{V}$ , $I_D = 4.5\text{A}$ , $V_{GS} = 0\text{ to } 10\text{V}$	-	19	25	
Gate plateau voltage	$V_{(plateau)}$	$V_{DD} = 480\text{V}$ , $I_D = 4.5\text{A}$	-	5	-	V

<sup>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> $C_{o(er)}$  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> $I_{SD} \leq I_D$ ,  $di/dt \leq 400\text{A}/\mu\text{s}$ ,  $V_{DClink} = 400\text{V}$ ,  $V_{peak} < V_{BR, DSS}$ ,  $T_j < T_{j,max}$ .

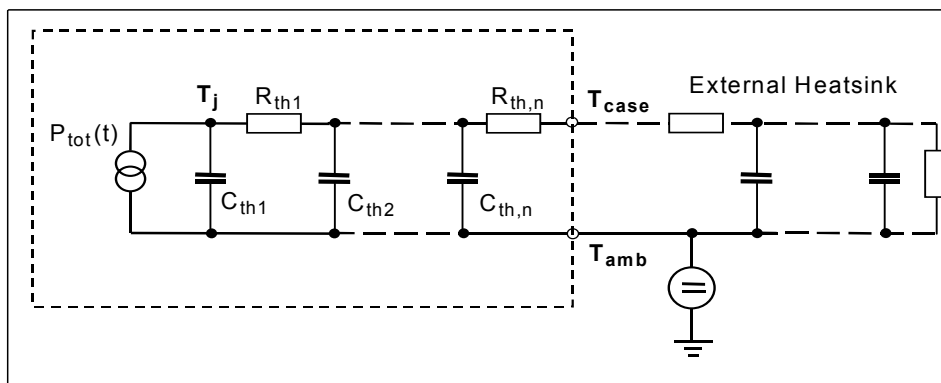
Identical low-side and high-side switch.

**Electrical Characteristics**, at  $T_j = 25\text{ }^\circ\text{C}$ , 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	$I_{SM}$		-	-	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	-	$\mu\text{C}$
Peak reverse recovery current	$I_{rrm}$		-	18	-	A
Peak rate of fall of reverse recovery current	$di_{rr}/dt$		-	-	900	$\text{A}/\mu\text{s}$

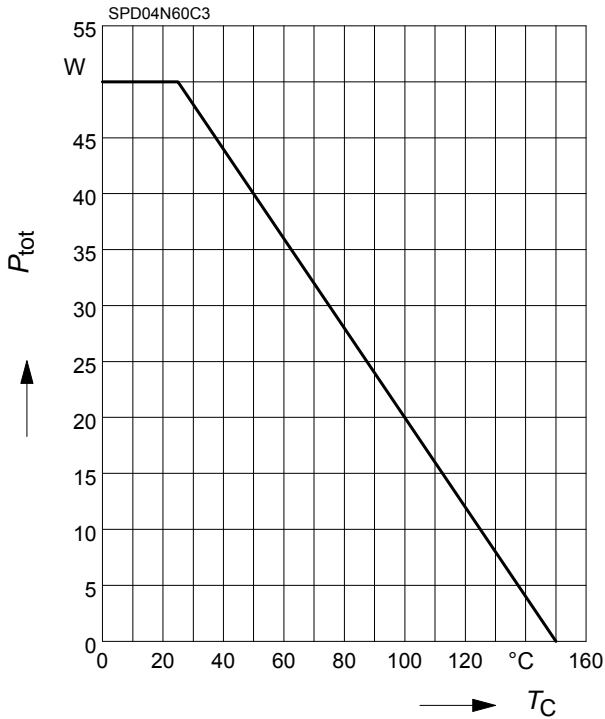
**Typical Transient Thermal Characteristics**

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

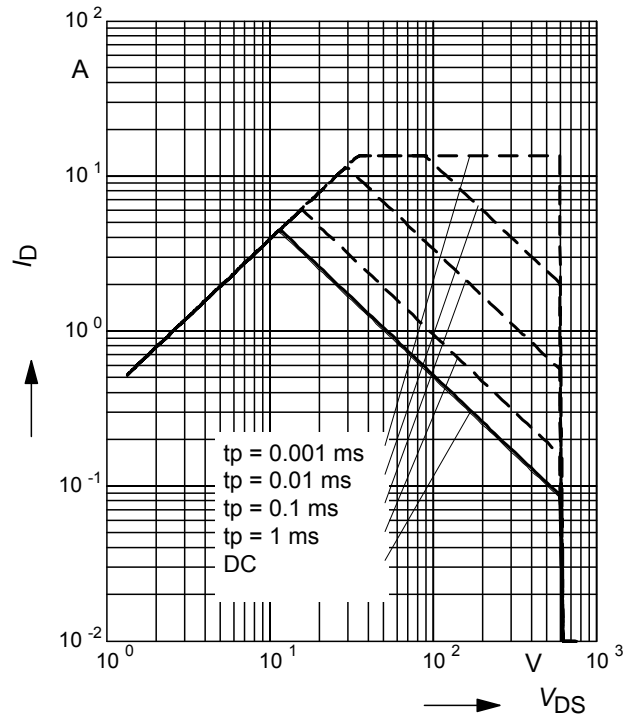
$$P_{tot} = f(T_C)$$



### 2 Safe operating area

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

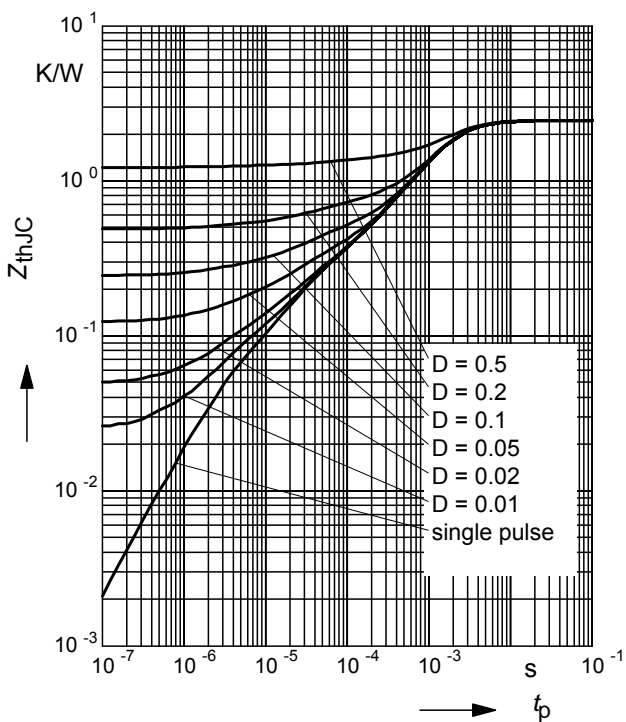
parameter :  $D = 0$  ,  $T_C = 25^{\circ}C$



### 3 Transient thermal impedance

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

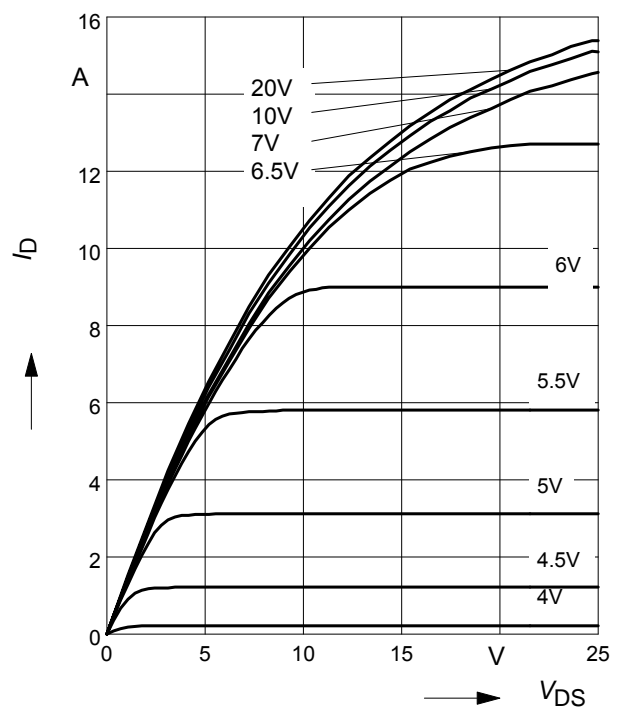
parameter:  $D = t_p/T$



### 4 Typ. output characteristic

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

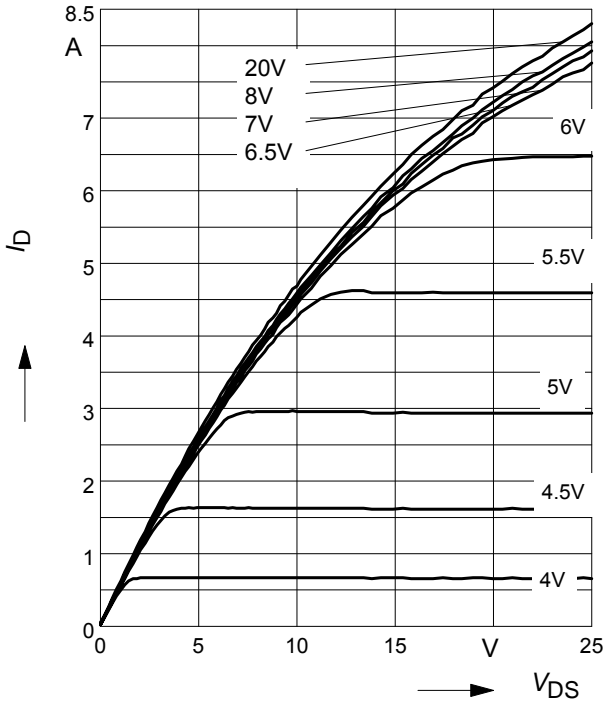
parameter:  $t_p = 10 \mu s$ ,  $V_{GS}$



**5 Typ. output characteristic**

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

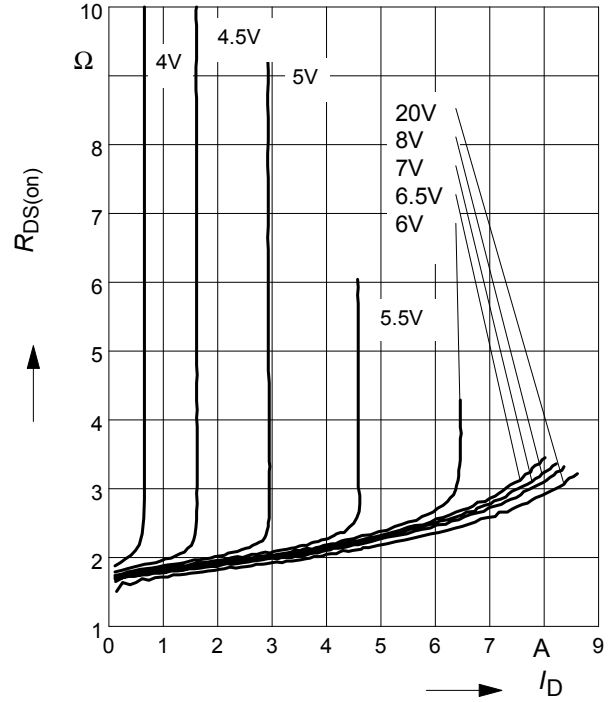
parameter:  $t_p = 10 \mu\text{s}, V_{GS}$



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

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

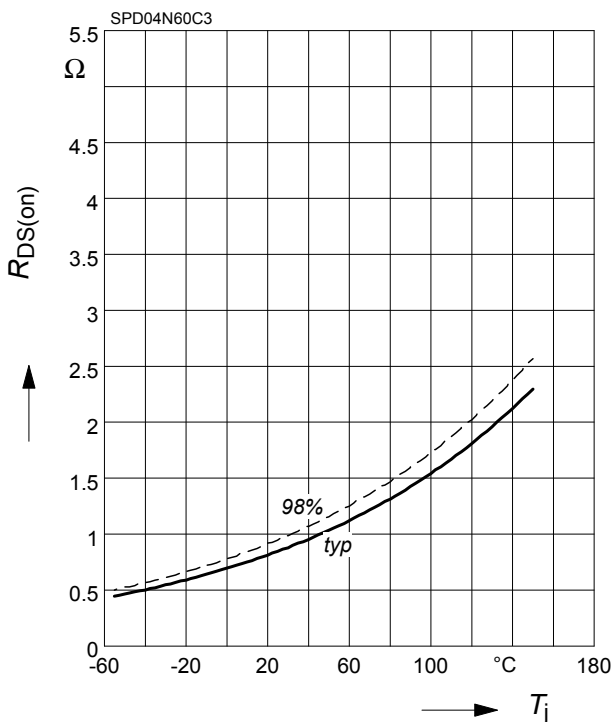
parameter:  $T_j = 150^\circ\text{C}, V_{GS}$



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

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

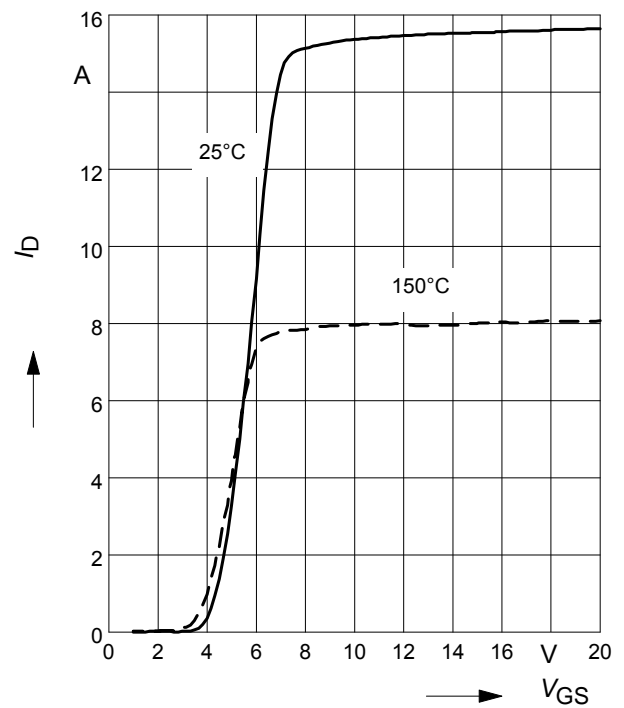
parameter:  $I_D = 2.8 \text{ A}, V_{GS} = 10 \text{ V}$



**8 Typ. transfer characteristics**

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

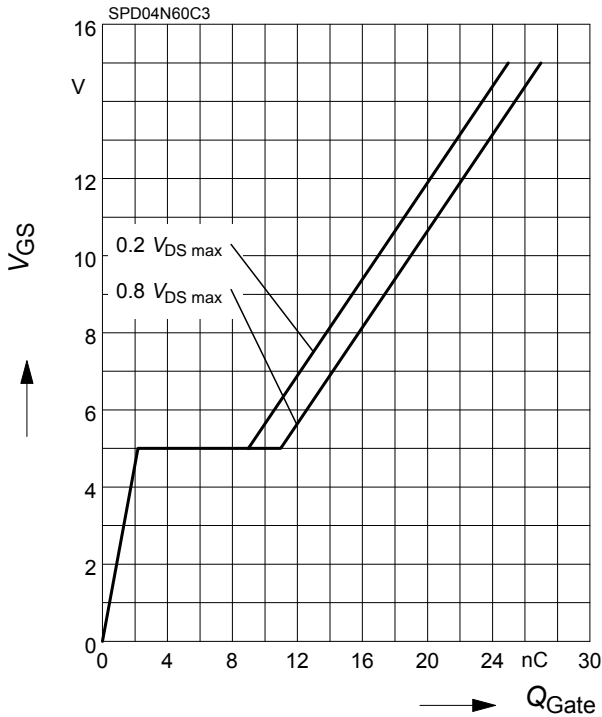
parameter:  $t_p = 10 \mu\text{s}$



### 9 Typ. gate charge

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

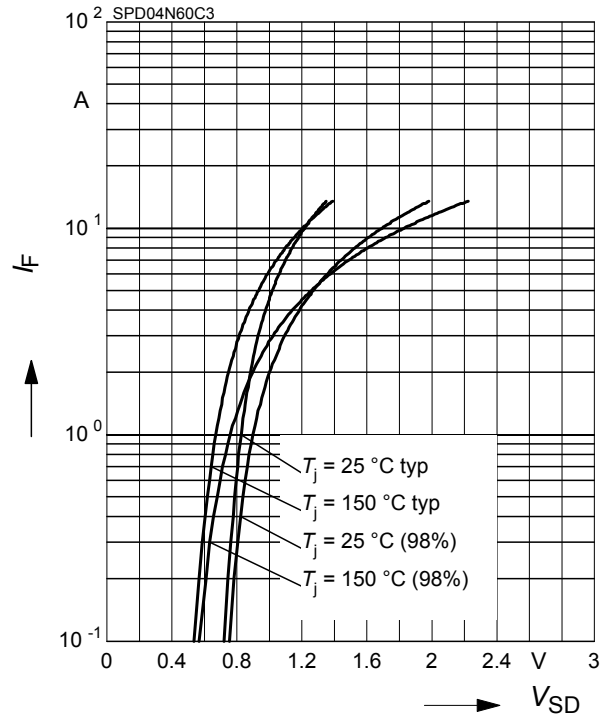
parameter:  $I_D = 4.5$  A pulsed



### 10 Forward characteristics of body diode

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

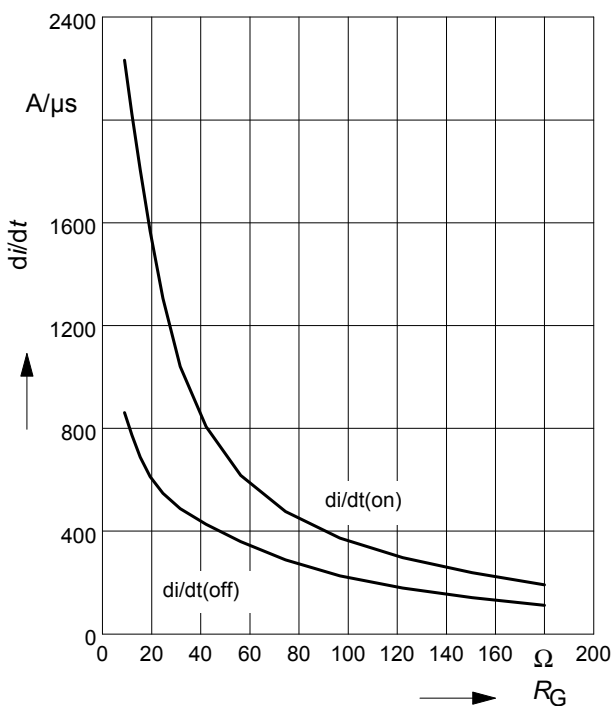
parameter:  $T_j$ ,  $t_p = 10$   $\mu$ s



### 11 Typ. drain current slope

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

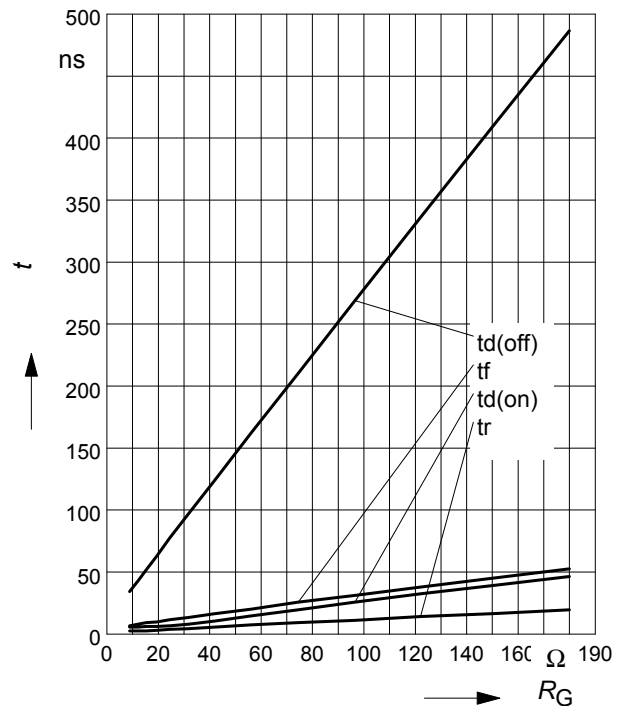
par.:  $V_{DS} = 380$  V,  $V_{GS} = 0/+13$  V,  $I_D = 4.5$  A



### 12 Typ. switching time

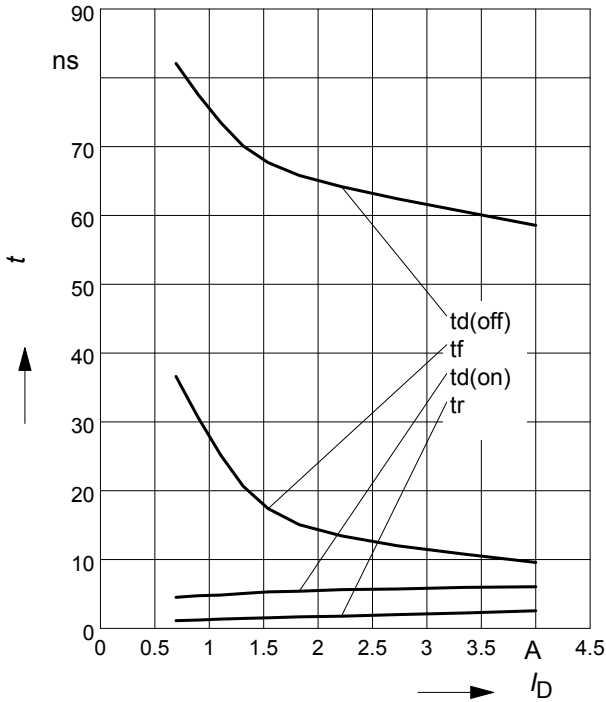
$$t = f(R_G), \text{ inductive load, } T_j = 125^\circ\text{C}$$

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



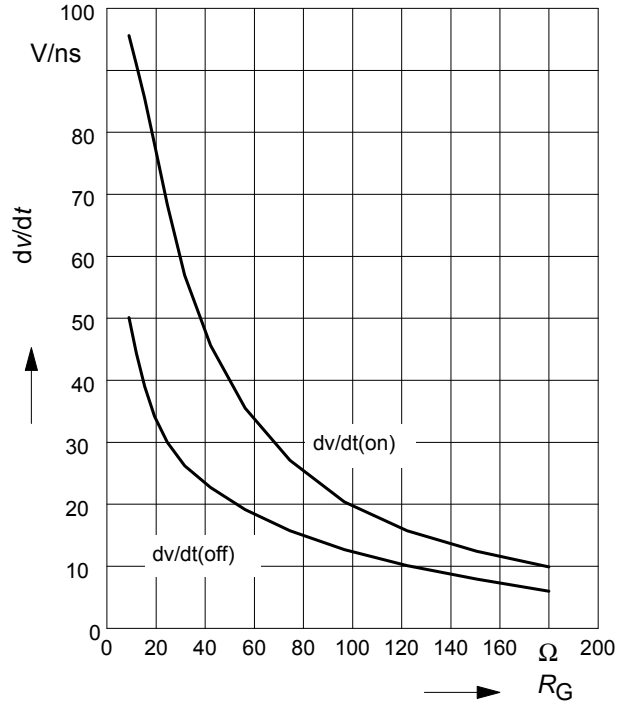
**13 Typ. switching time**

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



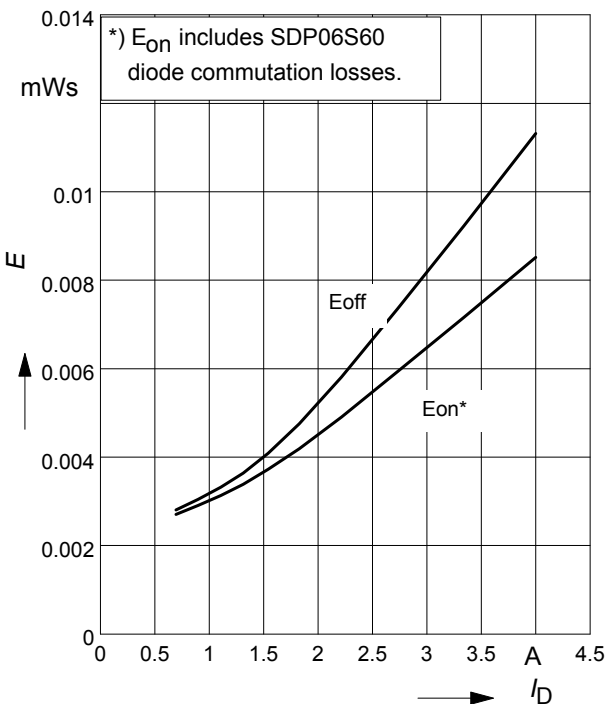
**14 Typ. drain source voltage slope**

$dv/dt = f(R_G)$ , inductive load,  $T_j = 125^\circ\text{C}$   
par.:  $V_{DS}=380\text{V}$ ,  $V_{GS}=0/+13\text{V}$ ,  $I_D=4.5\text{A}$



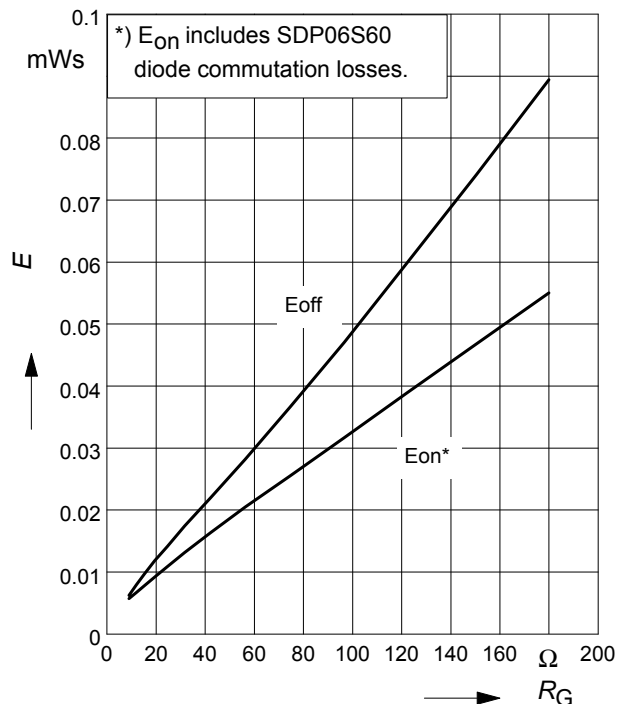
**15 Typ. switching losses**

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

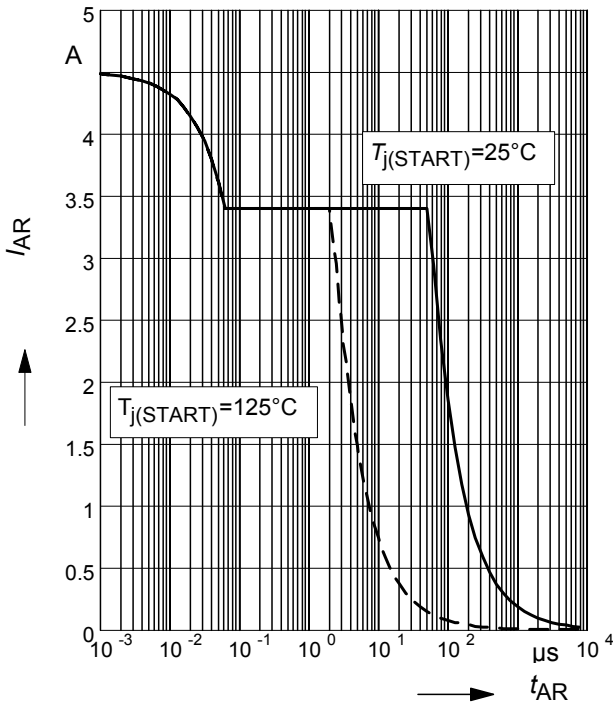




### 17 Avalanche SOA

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

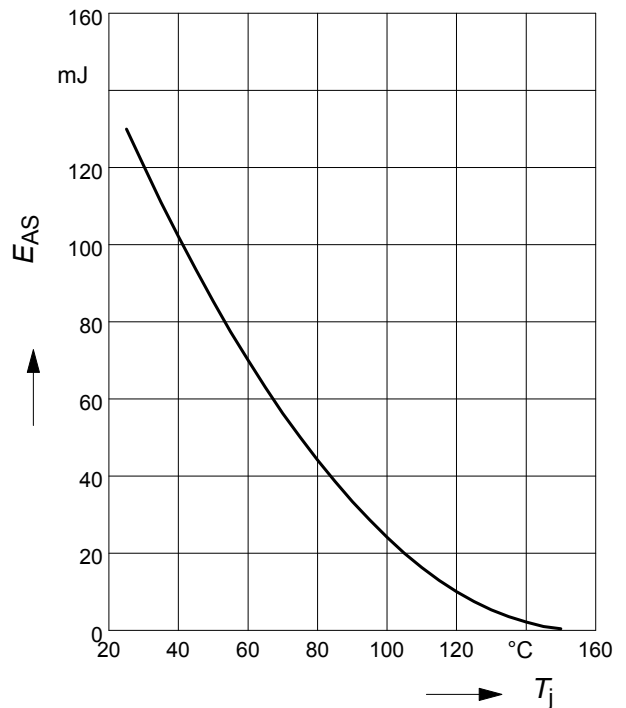
par.:  $T_j \leq 150\text{ }^\circ\text{C}$



### 18 Avalanche energy

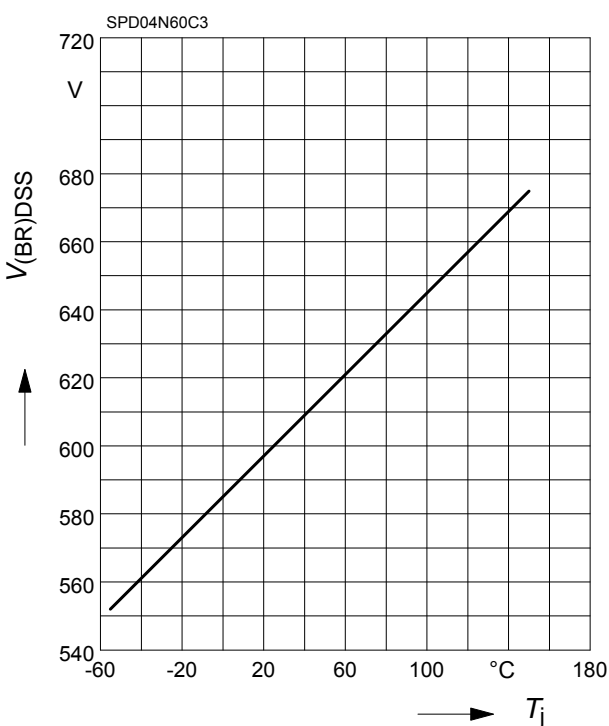
$$E_{AS} = f(T_j)$$

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



### 19 Drain-source breakdown voltage

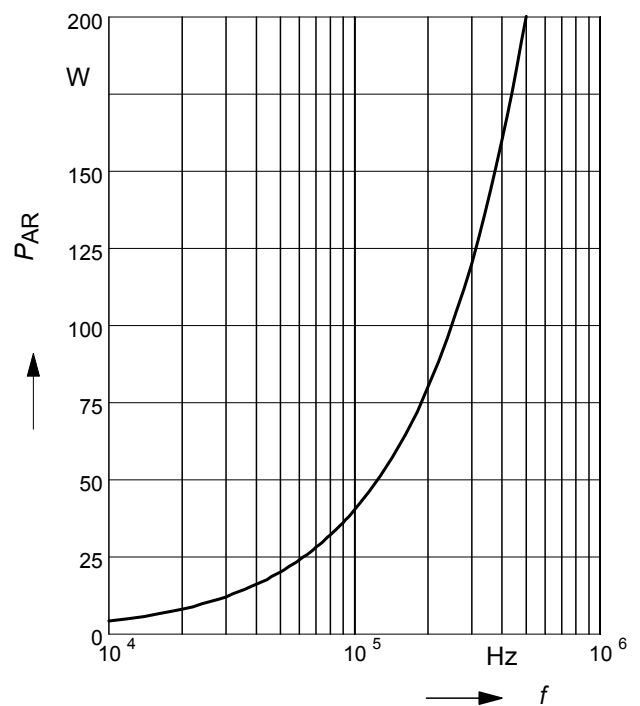
$$V_{(BR)DSS} = f(T_j)$$



### 20 Avalanche power losses

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

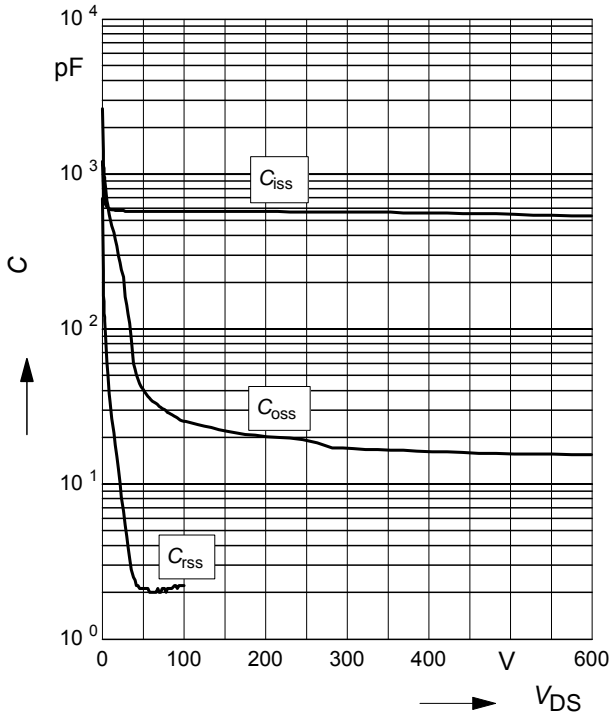
parameter:  $E_{AR} = 0.4\text{ mJ}$



**21 Typ. capacitances**

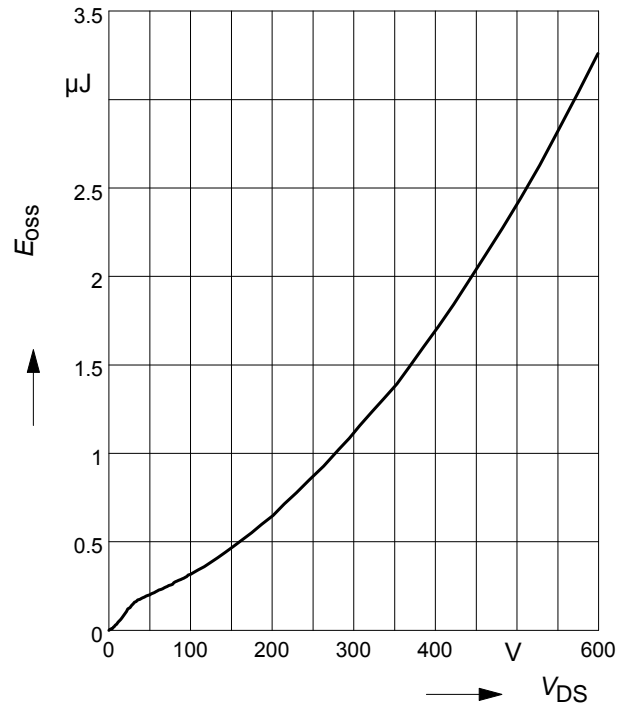
$C = f(V_{DS})$

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

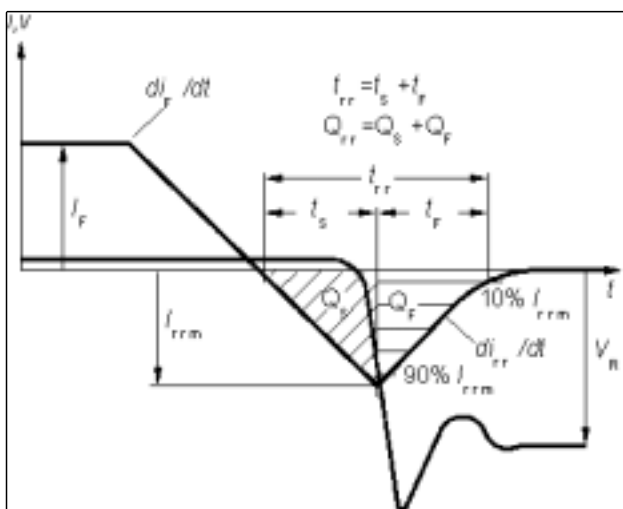


**22 Typ.  $C_{oss}$  stored energy**

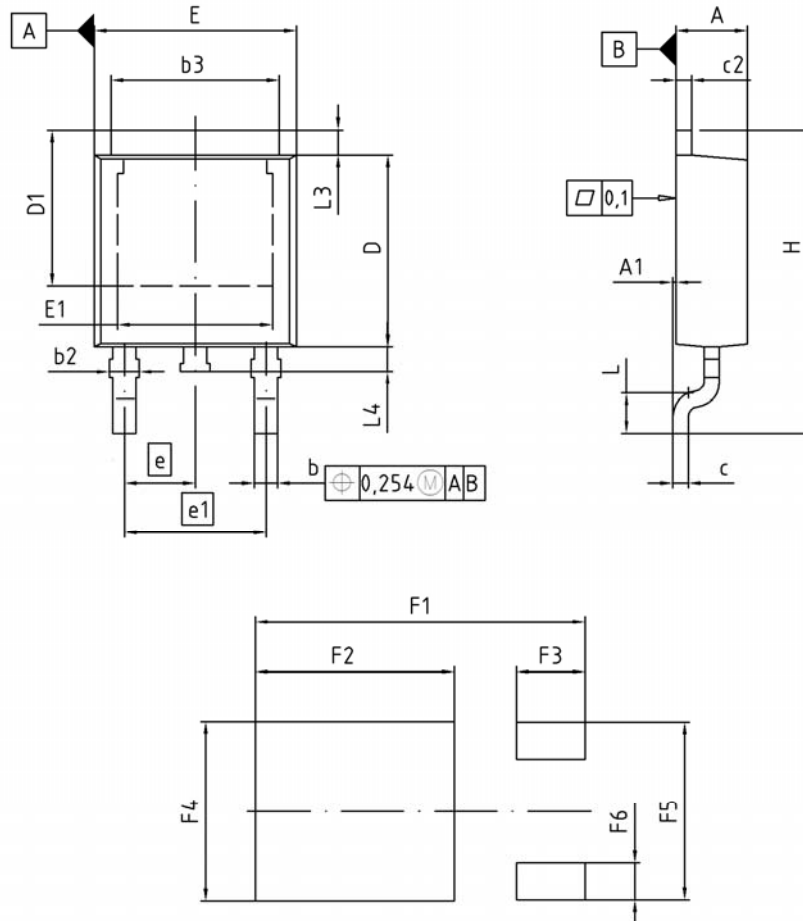
$E_{oss} = f(V_{DS})$



**Definition of diodes switching characteristics**



PG-TO252-3



DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	2.16	2.41	0.085	0.095
A1	0.00	0.15	0.000	0.006
b	0.64	0.89	0.025	0.035
b2	0.65	1.15	0.026	0.045
b3	5.00	5.50	0.197	0.217
c	0.46	0.60	0.018	0.024
c2	0.46	0.98	0.018	0.039
D	5.97	6.22	0.235	0.245
D1	5.02	5.84	0.198	0.230
E	6.40	6.73	0.252	0.265
E1	4.70	5.21	0.185	0.205
e	2.29		0.090	
e1	4.57		0.180	
N	3		3	
H	9.40	10.48	0.370	0.413
L	1.18	1.70	0.046	0.067
L3	0.90	1.25	0.035	0.049
L4	0.51	1.00	0.020	0.039
F1	10.50	10.70	0.413	0.421
F2	6.30	6.50	0.248	0.256
F3	2.10	2.30	0.083	0.091
F4	5.70	5.90	0.224	0.232
F5	5.66	5.86	0.223	0.231
F6	1.10	1.30	0.043	0.051

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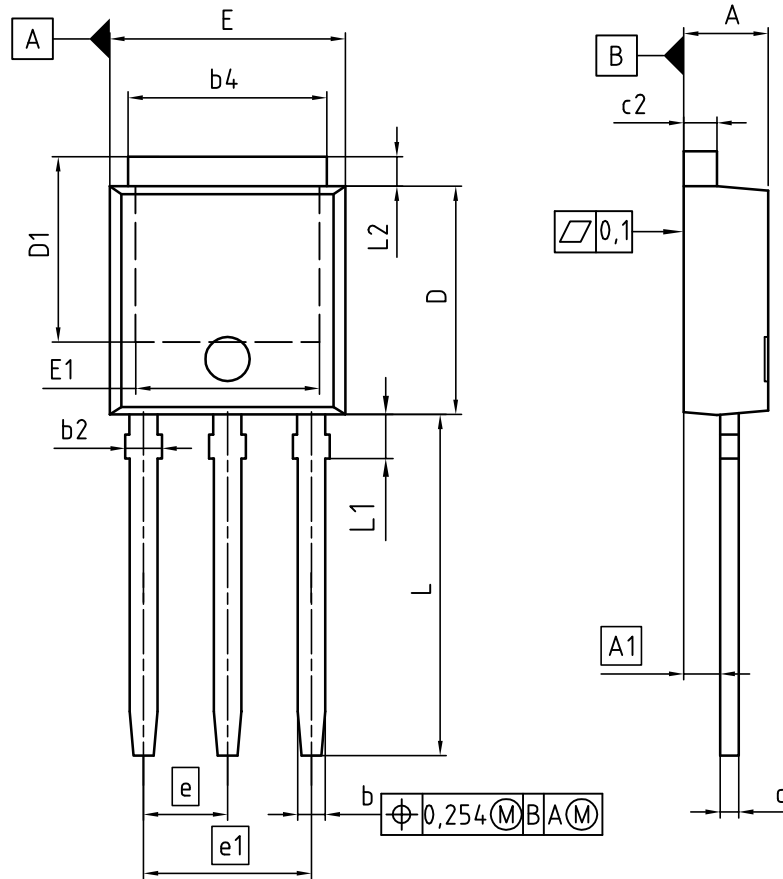
SCALE

0 2.0 4mm

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19-10-2007

REVISION  
03



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

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SCALE

EUROPEAN PROJECTION

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REVISION  
03

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