Tentti 17.3.2014, kello 16 ... 19, sali S4

Papereihin
- sukunimi ja etunimet
- opiskelijanumero
- koulutusohjelma.

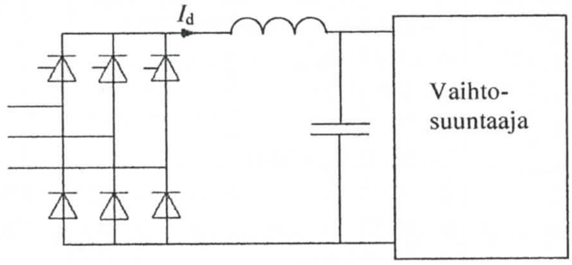
Tentissä sallitut apuvälineet
- kynät, kumit jne.
- taskulaskin
- lukion kaavakokoelma tms. + Laplace taulut

1. Selvitä lyhyesti (max. 2...4 lausetta + mahdollinen kuva), mitä seuraavilla termeillä tarkoitetaan
   - ioni-istutus
   - tyristorin toipumisaika
   - muutoslämpövastus
   - ESR
   - lähivaikutus.

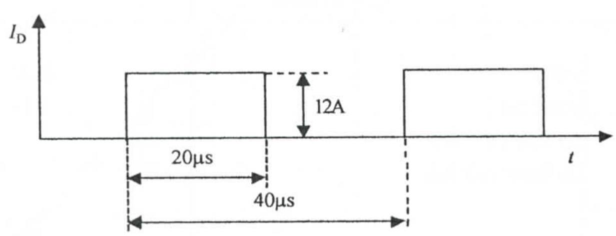
2. Esittele IGBT:n rakenne, toimintaperiaate ja ominaisuudet.

3. Selvitä, miten verkkotaajuiset ja suurtaajuiset muuntajat eroavat toisistaan. Kuvaile sanallisesti suurtaajuusmuuntajan (esim. 50 kHz, 100 W, 400 V/15 V) suunnittelun vaiheet ja kussakin vaiheessa huomioon otettavat seikat.

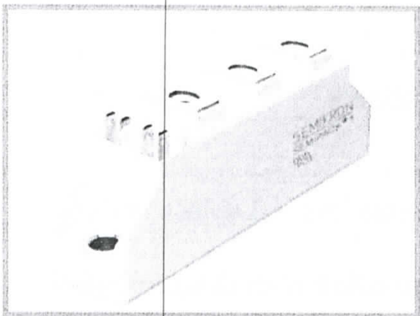
4. Kolmea tyristori/diodi -moduulia SKKH 57/16 E G6 (datalehti oheisena) käytetään allaolevassa kolmivaiheisessa tasasuuntaajasillassa. Mikä on moduulien yhteisen jäähdytyselementin lämpövastuksen $R_{th(s-a)}$ oltava, jotta silta kykenisi syöttämään 120 A tasavirran jäähdytysilman lämpötilan ollessa 65 °C?



5. Määrää IPP60R199CP -fetin vaatiman jäähdytyselementin lämpövastus, kun fetin virta on oheisen kuvan mukainen. Jäähdytysilman lämpötila on 45 °C ja V_{GS} = 10 V. Fetin yli oleva jännite on päällekytkennän aikana 360 V ja katkaisun aikana 500 V.



SKKH 57/16 E G6



SEMIPACK® 1

Thyristor / Diode Modules

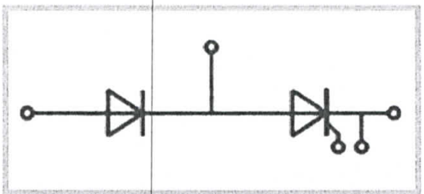
SKKH 57/16 E G6

Features

- Heat transfer through aluminium oxide ceramic isolated metal baseplate
- UL recognized, file no. E63532

Typical Applications

- DC motor control (e. g. for machine tools)
- AC motor soft starters
- Temperature control (e. g. for ovens, chemical processes)
- Professional light dimming (studios, theaters)



SKKH

Absolute Maximum Ratings				
Symbol	**Conditions**		**Values**	**Unit**
Chip				
$I_{T(AV)}$	sinus 180°	T_c = 85 °C	61	A
		T_c = 100 °C	45	A
I_{TSM}	10 ms	T_j = 25 °C	1500	A
		T_j = 130 °C	1200	A
i^2t	10 ms	T_j = 25 °C	11250	A^2s
		T_j = 130 °C	7200	A^2s
V_{RSM}			1700	V
V_{RRM}			1600	V
V_{DRM}			1600	V
$(di/dt)_{cr}$	T_j = 130 °C		140	A/µs
$(dv/dt)_{cr}$	T_j = 130 °C		1000	V/µs
T_j			-40 ... 130	°C
Module				
T_{stg}			-40 ... 125	°C
V_{isol}	a.c.; 50 Hz; r.m.s.	1 min	3000	V
		1 s	3600	V

Characteristics						
Symbol	**Conditions**		**min.**	**typ.**	**max.**	**Unit**
Chip						
V_T	T_j = 25 °C, I_T = 180 A			1.5	1.75	V
$V_{T(TO)}$	T_j = 130 °C			0.85	1	V
r_T	T_j = 130 °C			4.00	4.50	mΩ
I_{DD};I_{RD}	T_j = 130 °C, V_{DD} = V_{DRM}; V_{RD} = V_{RRM}				20	mA
t_{gd}	T_j = 25 °C, I_G = 1 A, di_G/dt = 1 A/µs			1		µs
t_{gr}	V_D = 0.67 * V_{DRM}			2		µs
t_q	T_j = 130 °C			170		µs
I_H	T_j = 25 °C			150	250	mA
I_L	T_j = 25 °C, R_G = 33 Ω			300	600	mA
V_{GT}	T_j = 25 °C, d.c.		2.5			V
I_{GT}	T_j = 25 °C, d.c.		100			mA
V_{GD}	T_j = 130 °C, d.c.				0.25	V
I_{GD}	T_j = 130 °C, d.c.				4	mA
$R_{th(j-c)}$	cont.	per chip			0.420	K/W
		per module			0.210	K/W
$R_{th(j-c)}$	sin. 180°	per chip			0.440	K/W
		per module			0.220	K/W
$R_{th(j-c)}$	rec. 120°	per chip			0.460	K/W
		per module			0.230	K/W
Module						
$R_{th(c-s)}$	chip			0.22		K/W
	module			0.11		K/W
M_s	to heatsink M5		4.25		5.75	Nm
M_t	to terminals M5		2.55		3.45	Nm
a					5 * 9,81	m/s^2
w				75		g

3

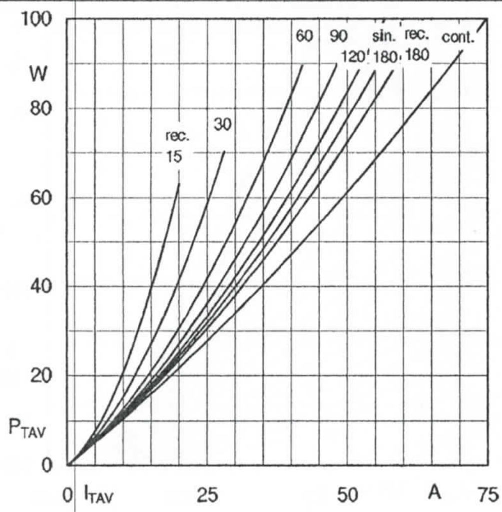


Fig. 1L: Power dissipation per thyristor/diode vs. on-state current

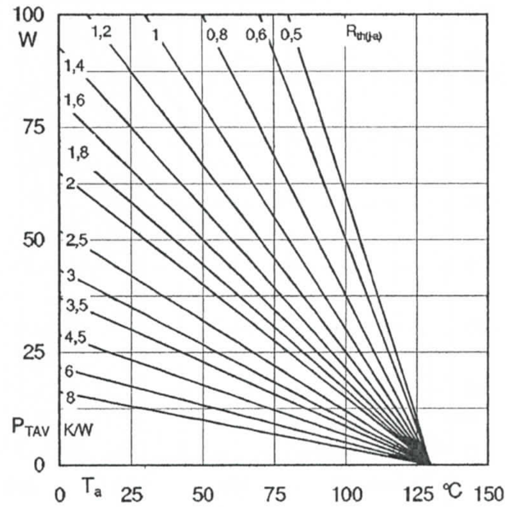


Fig. 1R: Max. power dissipation per chip vs. ambient temperature

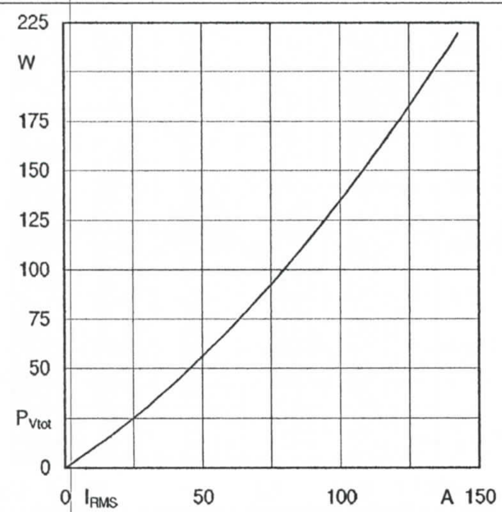


Fig. 2L: Max. power dissipation of one module vs. rms current

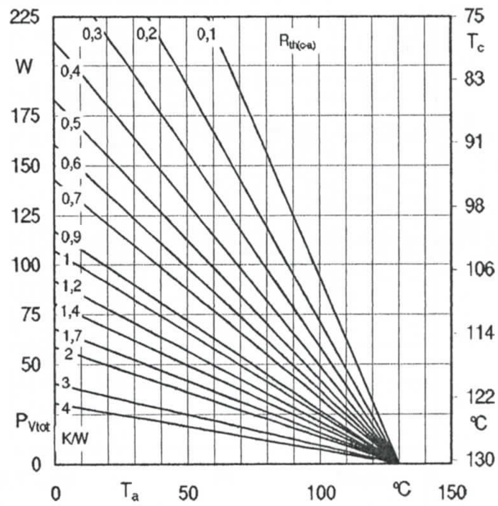


Fig. 2R: Max. power dissipation of one module vs. case temperature

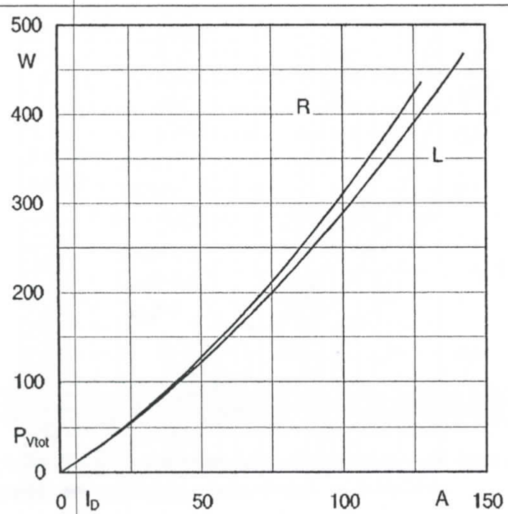


Fig. 3L: Max. power dissipation of two modules vs. direct current

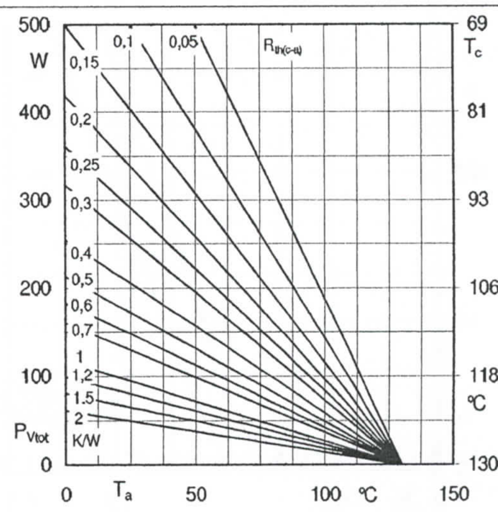


Fig. 3R: Max. power dissipation of two modules vs. case temperature

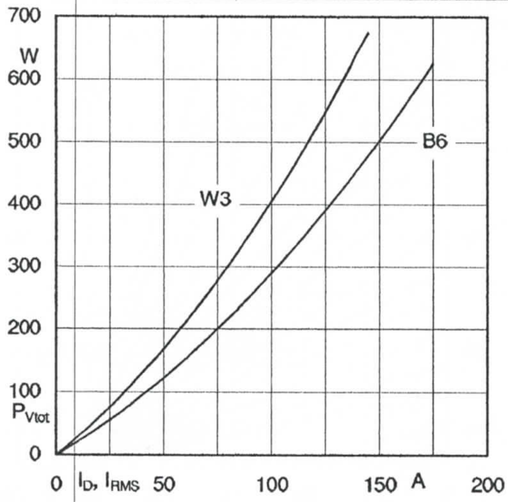


Fig. 4L: Max. power dissipation of three modules vs. direct current

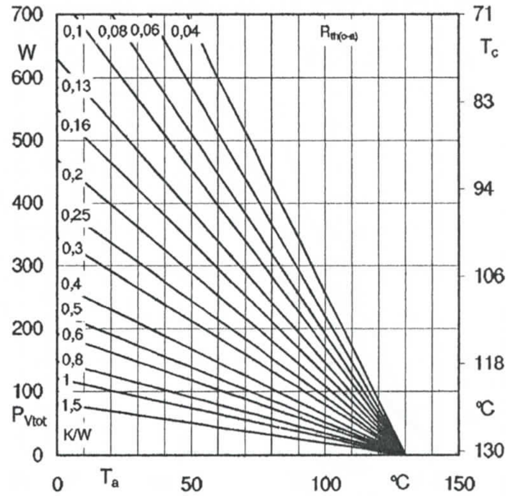


Fig. 4R: Max. power dissipation of three modules vs. case temperature

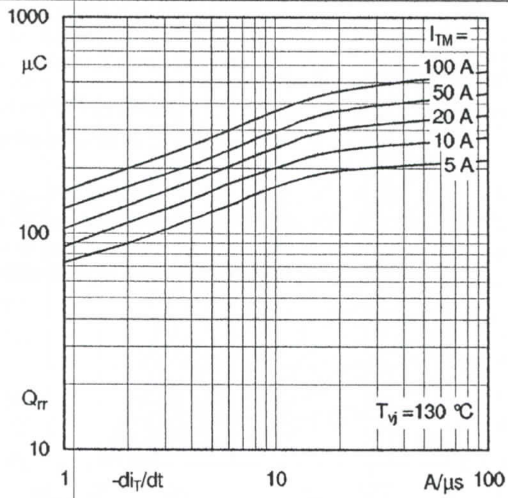


Fig. 5: Recovered charge vs. current decrease

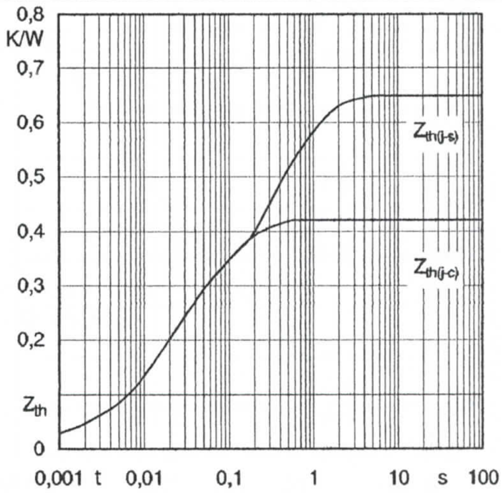


Fig. 6: Transient thermal impedance vs. time

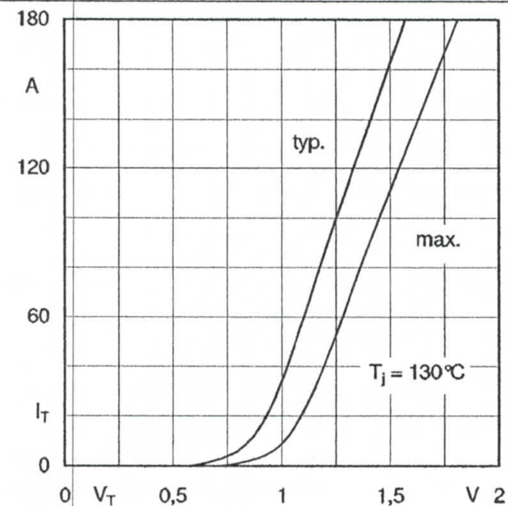


Fig. 7: On-state characteristics

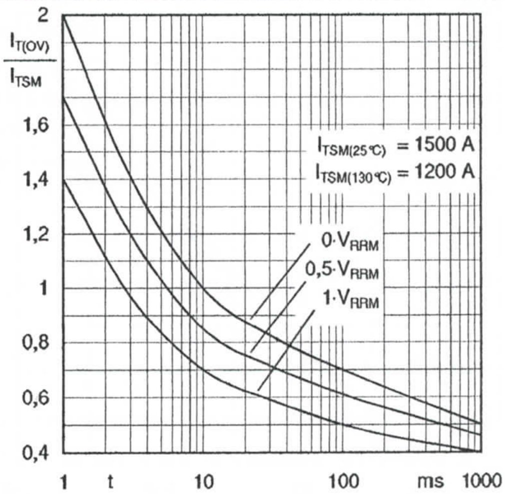


Fig. 8: Surge overload current vs. time

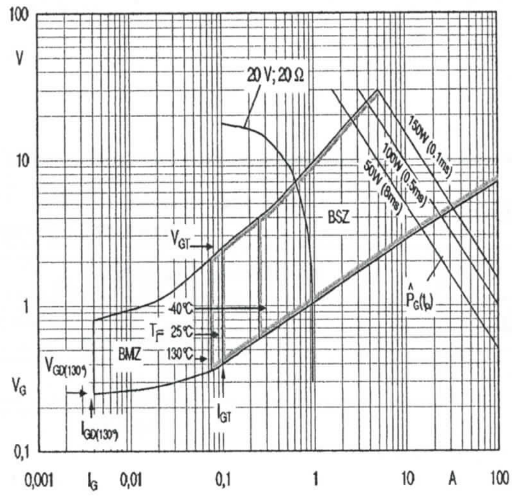
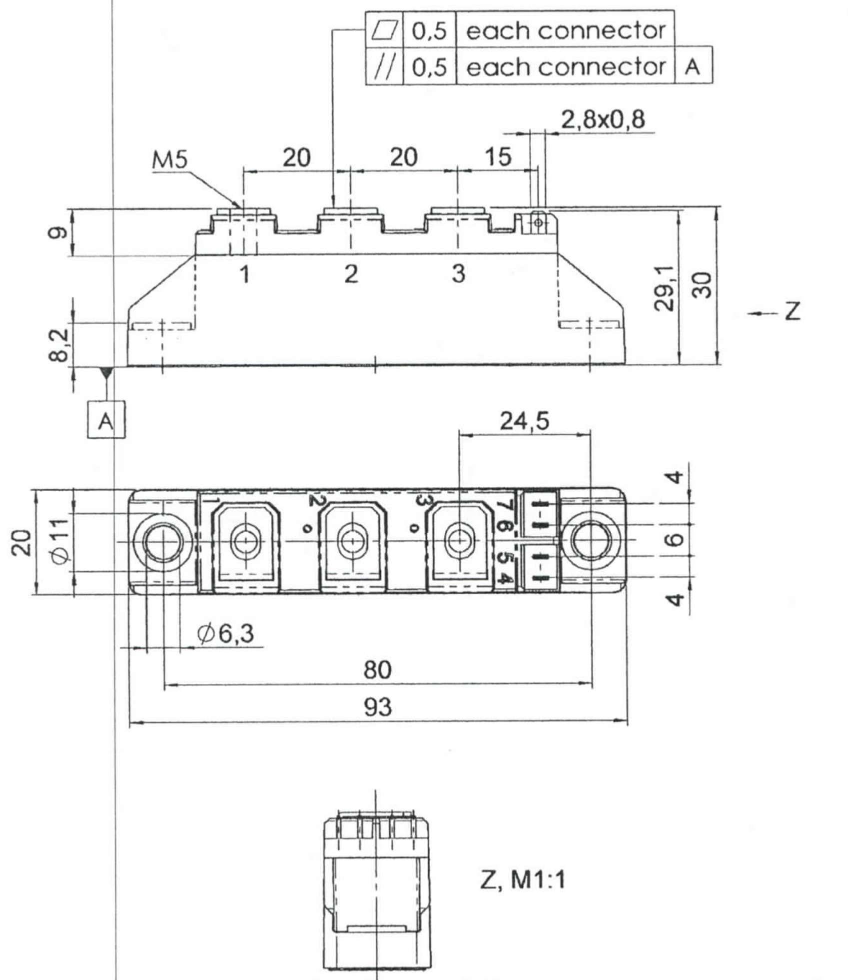
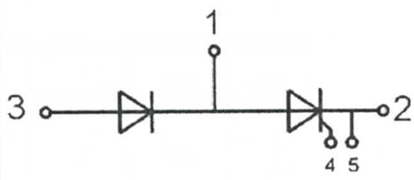


Fig. 9: Gate trigger characteristics



SEMIPACK 1



SKKH

CoolMOS® Power Transistor

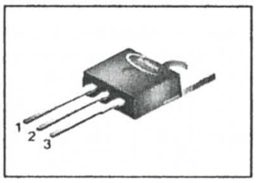
Product Summary

V_{DS} @ $T_{j,max}$	650	V
$R_{DS(on),max}$	0.199	Ω
$Q_{g,typ}$	32	nC

Features

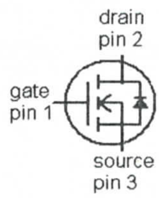
- Lowest figure-of-merit $R_{ON}xQ_g$
- Ultra low gate charge
- Extreme dv/dt rated
- High peak current capability
- Qualified according to JEDEC[1] for target applications
- Pb-free lead plating; RoHS compliant

PG-TO220



CoolMOS CP is specially designed for:

- Hard switching topologies, for Server and Telecom



Type	Package	Ordering Code	Marking
IPP60R199CP	PG-TO220	SP000084278	6R199P

Maximum ratings, at T_j=25 °C, unless otherwise specified

Parameter	Symbol	Conditions	Value	Unit
Continuous drain current	I_D	T_C=25 °C	16	A
		T_C=100 °C	10	
Pulsed drain current[2)]	$I_{D,pulse}$	T_C=25 °C	51	
Avalanche energy, single pulse	E_{AS}	I_D=6.6 A, V_{DD}=50 V	436	mJ
Avalanche energy, repetitive t_{AR}[2),3)]	E_{AR}	I_D=6.6 A, V_{DD}=50 V	0.66	
Avalanche current, repetitive t_{AR}[2),3)]	I_{AR}		6.6	A
MOSFET dv/dt ruggedness	dv/dt	V_{DS}=0...480 V	50	V/ns
Gate source voltage	V_{GS}	static	±20	V
		AC (f>1 Hz)	±30	
Power dissipation	P_{tot}	T_C=25 °C	139	W
Operating and storage temperature	T_j, T_{stg}		-55 ... 150	°C
Mounting torque		M3 and M3.5 screws	60	Ncm

Maximum ratings, at T_j=25 °C, unless otherwise specified

Parameter	Symbol	Conditions	Value	Unit
Continuous diode forward current	I_S	T_C=25 °C	9.9	A
Diode pulse current[2]	$I_{S,pulse}$		51	
Reverse diode dv/dt[4]	dv/dt		15	V/ns

Parameter	Symbol	Conditions	Values			Unit
			min.	typ.	max.	
Thermal characteristics						
Thermal resistance, junction - case	R_{thJC}		-	-	0.9	K/W
Thermal resistance, junction - ambient	R_{thJA}	leaded	-	-	62	
Soldering temperature, wavesoldering only allowed at leads	T_{sold}	1.6 mm (0.063 in.) from case for 10 s	-	-	260	°C
Electrical characteristics, at T_j=25 °C, unless otherwise specified						
Static characteristics						
Drain-source breakdown voltage	$V_{(BR)DSS}$	V_{GS}=0 V, I_D=250 µA	600	-	-	V
Gate threshold voltage	$V_{GS(th)}$	V_{DS}=V_{GS}, I_D=0.66 mA	2.5	3	3.5	
Zero gate voltage drain current	I_{DSS}	V_{DS}=600 V, V_{GS}=0 V, T_j=25 °C	-	-	1	µA
		V_{DS}=600 V, V_{GS}=0 V, T_j=150 °C	-	10	-	
Gate-source leakage current	I_{GSS}	V_{GS}=20 V, V_{DS}=0 V	-	-	100	nA
Drain-source on-state resistance	$R_{DS(on)}$	V_{GS}=10 V, I_D=9.9 A, T_j=25 °C	-	0.18	0.199	Ω
		V_{GS}=10 V, I_D=9.9 A, T_j=150 °C	-	0.49	-	
Gate resistance	R_G	f=1 MHz, open drain	-	2	-	Ω

Parameter	Symbol	Conditions	Values			Unit
			min.	typ.	max.	
Dynamic characteristics						
Input capacitance	C_{iss}	V_{GS}=0 V, V_{DS}=100 V, f=1 MHz	-	1520	-	pF
Output capacitance	C_{oss}		-	72	-	
Effective output capacitance, energy related[5)]	$C_{o(er)}$	V_{GS}=0 V, V_{DS}=0 V to 480 V	-	69	-	
Effective output capacitance, time related[6)]	$C_{o(tr)}$		-	180	-	
Turn-on delay time	$t_{d(on)}$	V_{DD}=400 V, V_{GS}=10 V, I_D=9.9 A, R_G=3.3 Ω	-	10	-	ns
Rise time	t_r		-	5	-	
Turn-off delay time	$t_{d(off)}$		-	50	-	
Fall time	t_f		-	5	-	
Gate Charge Characteristics						
Gate to source charge	Q_{gs}	V_{DD}=400 V, I_D=9.9 A, V_{GS}=0 to 10 V	-	8	-	nC
Gate to drain charge	Q_{gd}		-	11	-	
Gate charge total	Q_g		-	32	43	
Gate plateau voltage	$V_{plateau}$		-	5.0	-	V
Reverse Diode						
Diode forward voltage	V_{SD}	V_{GS}=0 V, I_F=9.9 A, T_j=25 °C	-	0.9	1.2	V
Reverse recovery time	t_{rr}	V_R=400 V, I_F=I_S, di_F/dt=100 A/µs	-	340	-	ns
Reverse recovery charge	Q_{rr}		-	5.5	-	µC
Peak reverse recovery current	I_{rrm}		-	33	-	A

1) J-STD20 and JESD22

2) Pulse width t_p limited by $T_{j,max}$

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

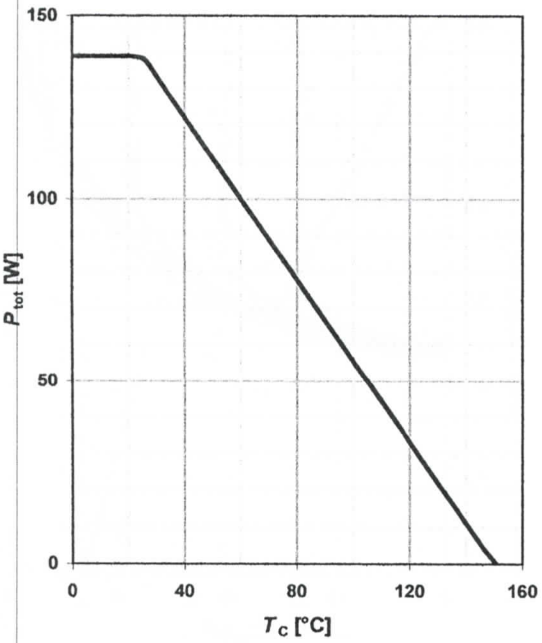
4) I_{SD}<=I_D, di/dt<=200A/µs, V_{DClink}=400V, V_{peak}<$V_{(BR)DSS}$, T_j<T_{jmax}, identical low side and high side switch.

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

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

1 Power dissipation

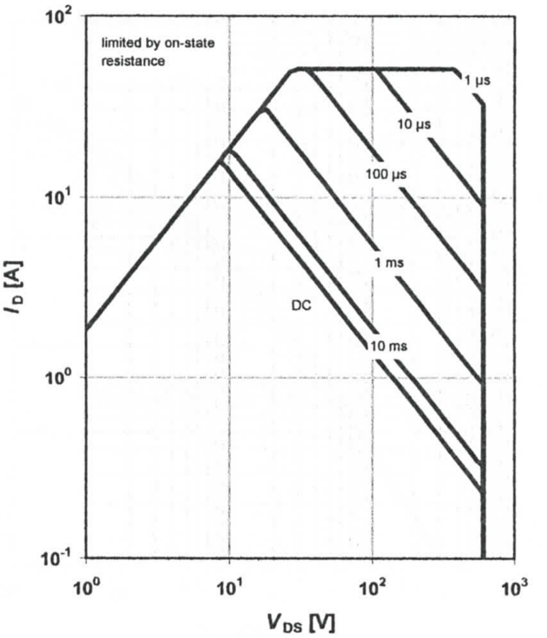
P_{tot}=f(T_C)



2 Safe operating area

I_D=f(V_{DS}); T_C=25 °C; D=0

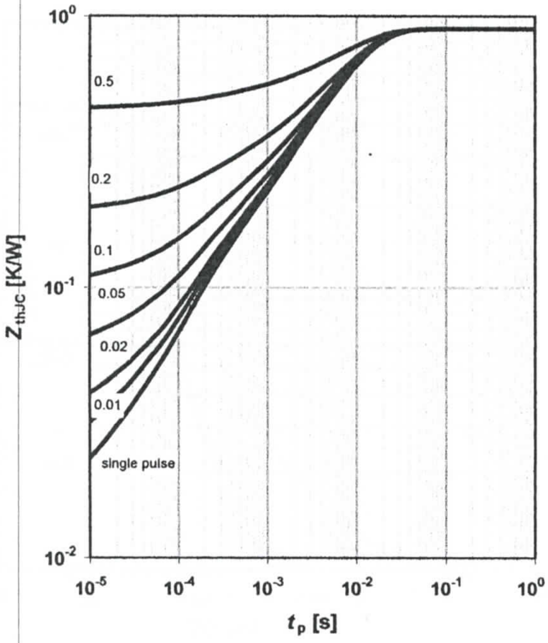
parameter: t_p



3 Max. transient thermal impedance

Z_{thJC}=f(t_P)

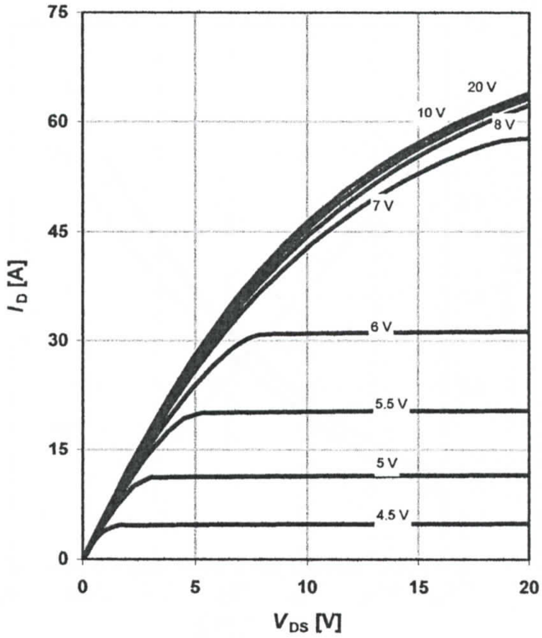
parameter: $D=t_p/T$



4 Typ. output characteristics

I_D=f(V_{DS}); T_j=25 °C

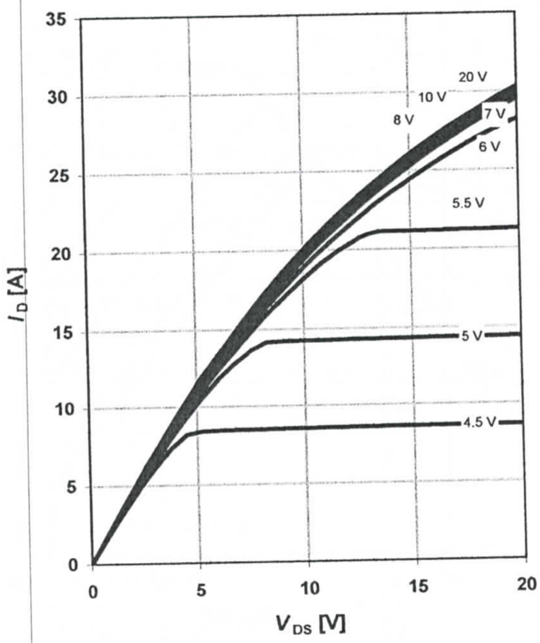
parameter: V_{GS}



5 Typ. output characteristics

I_D=f(V_{DS}); T_j=150 °C

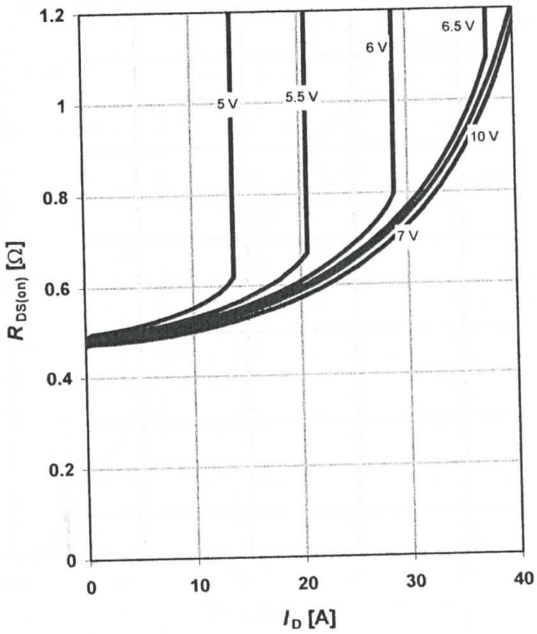
parameter: V_{GS}



6 Typ. drain-source on-state resistance

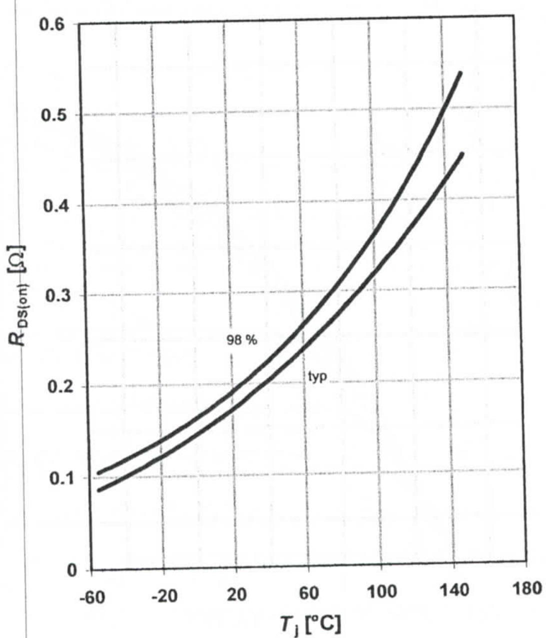
$R_{DS(on)}$=f(I_D); T_j=150 °C

parameter: V_{GS}



7 Drain-source on-state resistance

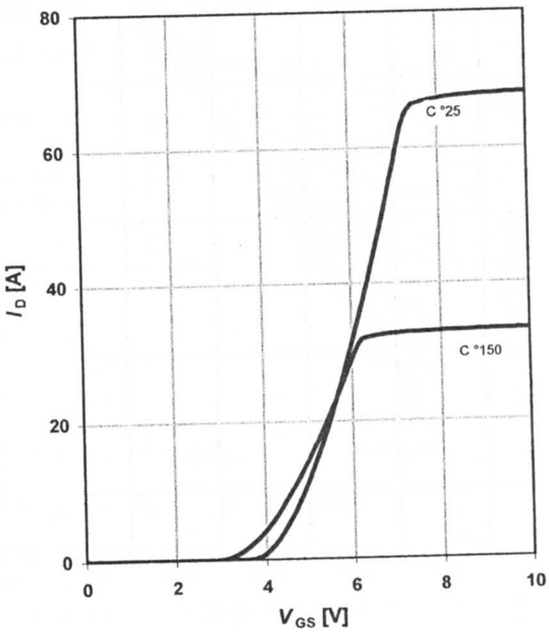
$R_{DS(on)}$=f(T_j); I_D=9.9 A; V_{GS}=10 V



8 Typ. transfer characteristics

I_D=f(V_{GS}); $|V_{DS}|>2|I_D|R_{DS(on)max}$

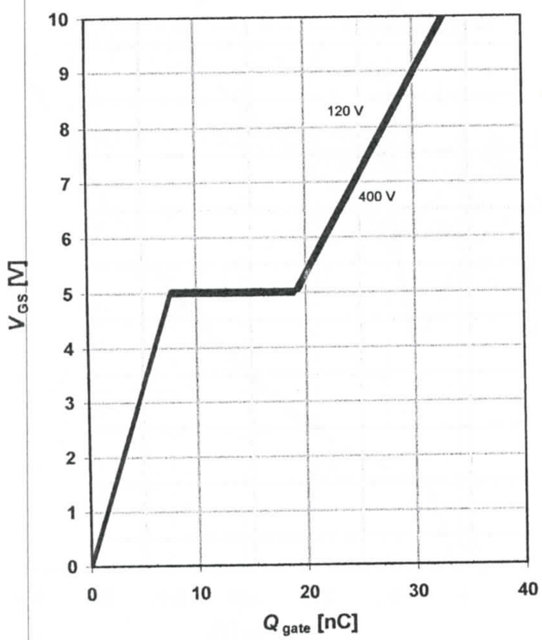
parameter: T_j



9 Typ. gate charge

V_{GS}=f(Q_{gate}); I_D=9.9 A pulsed

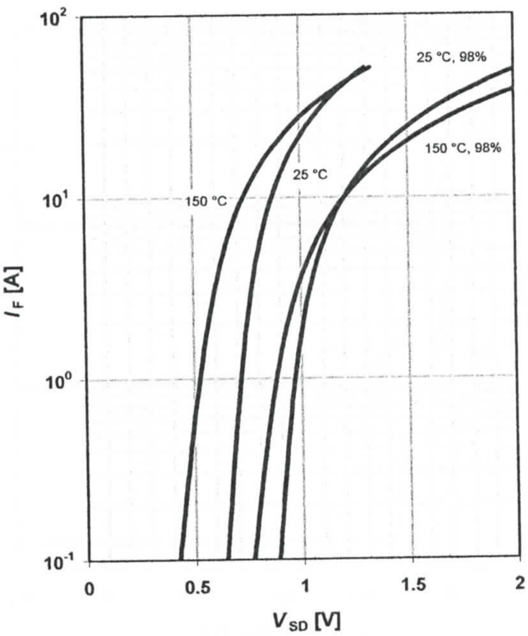
parameter: V_{DD}



10 Forward characteristics of reverse diode

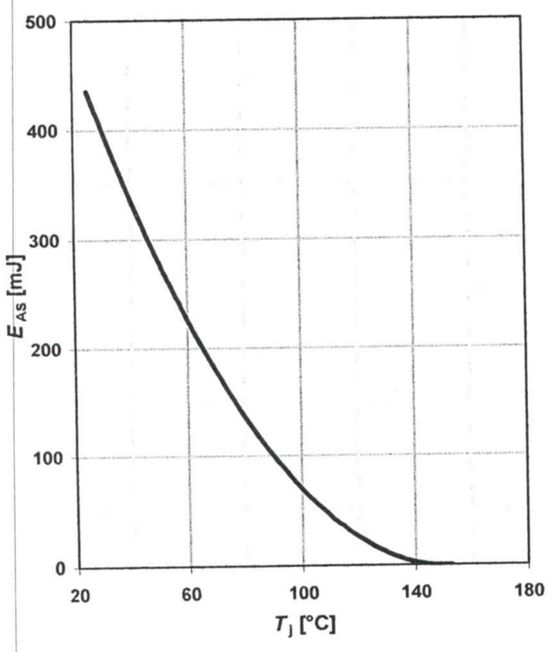
I_F=f(V_{SD})

parameter: T_j



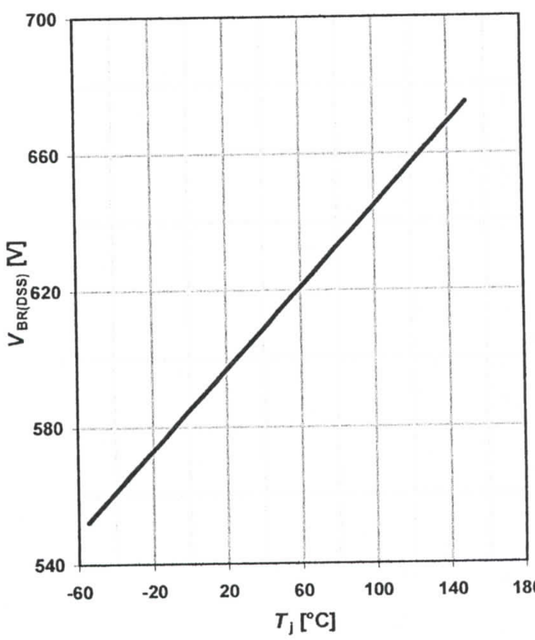
11 Avalanche energy

E_{AS}=f(T_j); I_D=6.6 A; V_{DD}=50 V



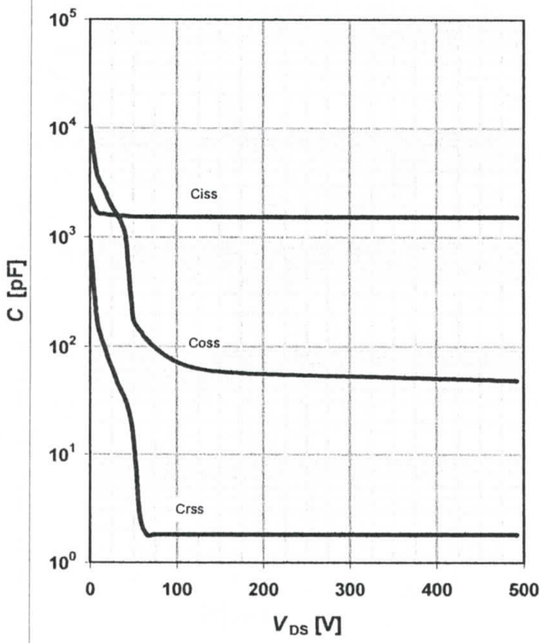
12 Drain-source breakdown voltage

$V_{BR(DSS)}$=f(T_j); I_D=0.25 mA



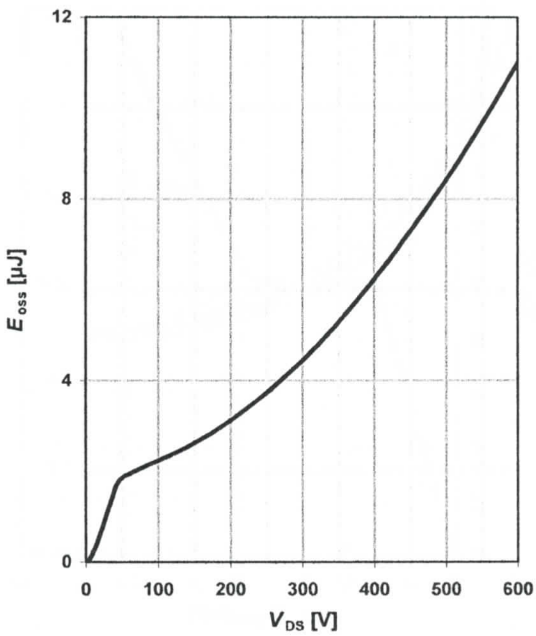
13 Typ. capacitances

$C = f(V_{DS})$; V_{GS}=0 V; f=1 MHz



14 Typ. Coss stored energy

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



Definition of diode switching characteristics