S-81.3120 Tehoelektroniikan komponentit

J. Niiranen

Tentti 11.12.2014, kello 16 ... 19, sali E110

Papereihin
- sukunimi ja etunimet
- opiskelijanumero
- koulutusohjelma.

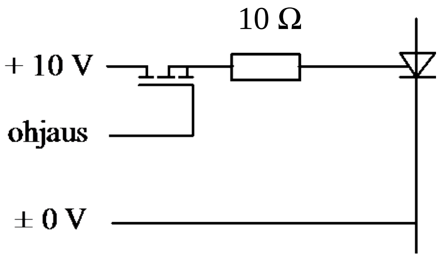
Tentissä sallitut apuvälineet
- kynät, kumit jne.
- taskulaskin
- lukion kaavakokoelma tms. + Laplace taulut

1. Selvitä lyhyesti (max. 2...4 lausetta + mahdollinen kuva), mitä seuraavilla termeillä tarkoitetaan
   - neutronisäteilytys
   - takavirta
   - triak
   - ESR
   - ferriitti.

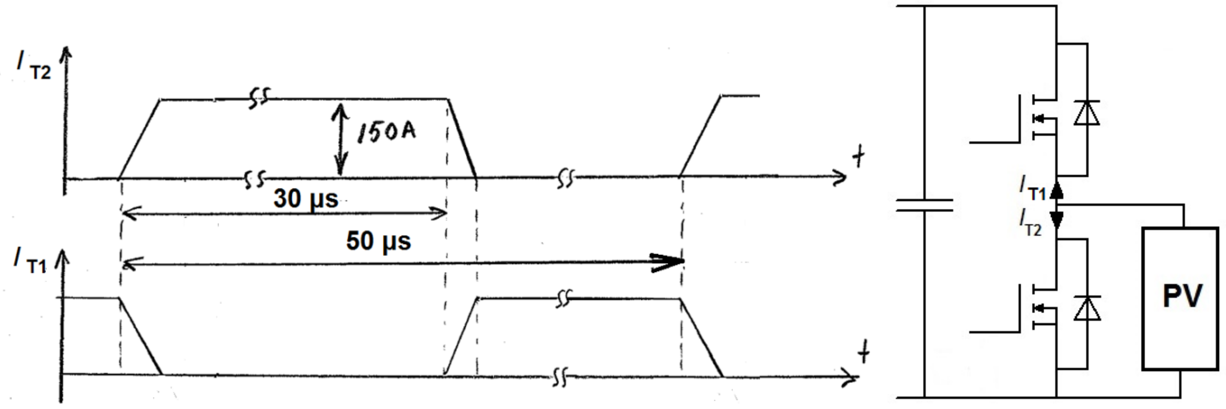
2. Esittele IGBT:n rakenne, toimintaperiaate ja ominaisuudet.

3. Selvitä, mitä vaikeuksia on puolijohdetehokomponenttien rinnankytkennässä ja mitä menetelmiä on käytettävissä niiden voittamiseen. Miten diodien sekä MOSFET- ja IGBT-komponenttien ominaisuudet vaikuttavat niiden toimintaan rinnankytkennässä?

4. Tyristorin SKKT 71 hilapulssi vahvistetaan kuvan mukaisella piirillä. MOSFET-transistorin sisäinen vastus R_{DS} on 1Ω. Onko tyristorin syttyminen varmaa − 40 ˚C lämpötilassa? Mikä on suurin mahdollinen tyristorin hilahäviöteho, jonka kytkentä voi saada aikaan?



5. Aurinkopaneelin DC/DC katkojan SiC MOSFET moduuli CAS300M17BM2 (datalehti oheisena) sisältää kaksi MOSFET transistoria diodeineen. Yläpuolen fet (3. kvadrantissa, eli myös kanava johtaa, ei pelkkä ~~siis~~ diodi) ja alapuolen fet johtavat alla olevan kuvan mukaisesti vuorotellen paneelista tulevaa virtaa. Jäähdytyselementin ja rajapinnan yhteislämpövastus R_{thCA} on 0,08 °C/W ja jäähdytysilman lämpötila on 45 °C. Mitkä ovat fettien liitoslämpötilat, kun fettien hilasyötön resistanssi on 2.5 Ω ja jännite + 20 V fettien johtoaikana ja − 5 V muulloin? Tasasähkökondensaattorin jännite on 1000 V.



S-81.3120 Components of power electronics

J. Niiranen

Examination Dec 11, 2014, at 16:00 ... 19:00, room E110

Write in all papers
- your full name
- your student number
- department.

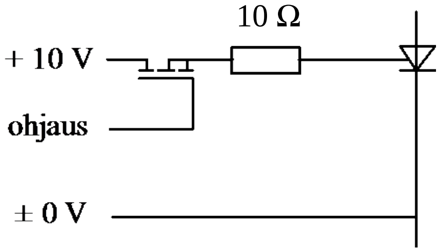
Items allowed in the exam:
- pens, eraser, etc
- calculator
- Book of math. formulas & Laplace tables

1. Give a short definition (max. 2...4 sentences + possible figure), what the following terms mean
   - neutron transmutation doping
   - reverse recovery
   - triac
   - ESR
   - ferrite.

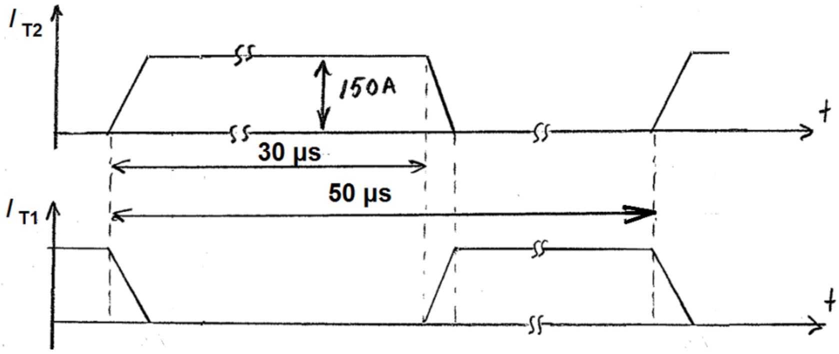
2. Describe in detail the structure, operation principle and properties of an IGBT.

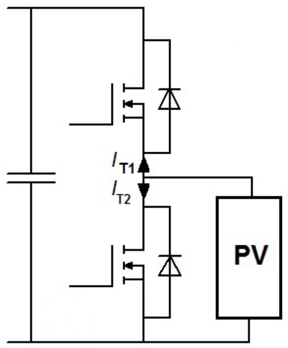
3. Describe the difficulties of parallel operation of power devices and what means there are to overcome these. How the properties of diodes, MOSFETs and IGBTs affect their parallel operation?

4. Gate current pulse of the thyristor SKKT 71 is produced by the circuit shown below. The internal resistance of the driving MOSFET is $R_{DS} = 1\Omega$. Is the firing of the thyristor certain at − 40 ˚C temperature? What is the worst case (that is, maximum) power loss caused by the driver in the thyristor?



5. The SiC MOSFET module CAS300M17BM2 (datasheet attached) of a photovoltaic converter's DC/DC chopper contains two MOSFET transistors with their diodes. The upper fet (operating in 3rd quadrant, that is, the fet's channel conducts too, not only the diode) and the lower fet conducts the solar panel current in turns according the figure below. The combined thermal resistance of the heatsink and the interface of the module R_{thCA} is 0,08 °C/W and the temperature of cooling air is 45 °C. The gate driver's resistance is 2.5 Ω and voltage is + 20 V when fets conduct and − 5 V when they are off. The voltage of the intermediate circuit's capacitor is 1000 V. Calculate the junction temperatures of the fets.



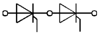


V_{RSM} V	V_{RRM} V_{DRM} V	(dv/dt)cr V/µs	I_{TRMS} (maximum value for continuous operation) 125 A I_{TAV} (sin. 180; T_{case} = 78 °C) 80 A			
700	600	500	**SKKT 71/06 D**	–	–	**SKKH 72/06 D**
900	800	500	**SKKT 71/08 D**	**SKKT 72/08 D**1)	**SKKH 71/08 D**	**SKKH 72/08 D**
1300	1200	500	**SKKT 71/12 D**	–	**SKKH 71/12 D**	–
1300	1200	1000	**SKKT 71/12 E**	**SKKT 72/12 E**1)	–	**SKKH 72/12 E**
1500	1400	1000	**SKKT 71/14 E**	**SKKT 72/14 E**1)	**SKKH 71/14 E**	**SKKH 72/14 E**
1700	1600	1000	**SKKT 71/16 E**	**SKKT 72/16 E**1)	**SKKH 71/16 E**	**SKKH 72/16 E**
1900	1800	1000	**SKKT 71/18 E**	**SKKT 72/18 E**1)	**SKKH 71/18 E**	**SKKH 72/18 E**
2100	2000	1000	**SKKT 71/20 E**	**SKKT 72/20 E**1)	–	**SKKH 72/20 E**
2300	2200	1000	**SKKT 71/22 E**	**SKKT 72/22 E**1)	–	**SKKH 72/22 E**

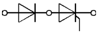
Symbol	**Conditions**	**SKKT 71** **SKKH 71**	**SKKT 72** **SKKT 72B** **SKKH 72**
I_{TAV}	sin. 180; T_{case} = 78 °C	80 A	
	T_{case} = 85 °C	70 A	
I_D	B2/B6 T_{amb} = 45 °C; P 3/180	62 A/75 A	
	T_{amb} = 35 °C; P 3/180 F	115 A/145 A	
I_{RMS}	W1/W3 T_{amb} = 35 °C; P 3/180 F	155 A/3 x 115 A	
I_{TSM}	T_{vj} = 25 °C; 10 ms	1 600 A	
	T_{vj} = 125 °C; 10 ms	1 450 A	
i^2t	T_{vj} = 25 °C; 8,3 ... 10 ms	13 000 A^2s	
	T_{vj} = 125 °C; 8,3 ... 10 ms	10 500 A^2s	
t_{gd}	T_{vj} = 25 °C; I_G = 1 A; di_G/dt = 1 A/µs	1 µs	
t_{gr}	$V_D = 0{,}67 \cdot V_{DRM}$	2 µs	
$(di/dt)_{cr}$	T_{vj} = 125 °C	150 A/µs	
t_q	T_{vj} = 125 °C	typ. 80 µs	
I_H	T_{vj} = 25 °C;	typ.150 mA; max. 250 mA	
I_L	T_{vj} = 25 °C; R_G = 33 Ω	typ.300 mA; max. 600 mA	
V_T	T_{vj} = 25 °C; I_T = 300 A	max. 1,9 V	
$V_{T(TO)}$	T_{vj} = 125 °C	0,9 V	
r_T	T_{vj} = 125 °C	3,5 mΩ	
I_{DD}; I_{RD}	T_{vj} = 125 °C; $V_{DD} = V_{DRM}$; $V_{RD} = V_{RRM}$	max. 20 mA3)	
V_{GT}	T_{vj} = 25 °C; d. c.	3 V	
I_{GT}	T_{vj} = 25 °C; d. c.	150 mA	
V_{GD}	T_{vj} = 125 °C; d. c.	0,25 V	
I_{GD}	T_{vj} = 125 °C; d. c.	6 mA	
R_{thjc}	cont. } per thyristor/per module	0,35 °C/W / 0,18 °C/W	
	sin. 180	0,37 °C/W / 0,19 °C/W	
	rec.120	0,39 °C/W / 0,20 °C/W	
R_{thch}		0,2 °C/W / 0,1 °C/W	
T_{vj}, T_{stg}		– 40 ... +125 °C	
V_{isol}	a. c. 50 Hz; r.m.s.; 1 s/1 min	3600 V~ / 3000 V~	
M_1	to heatsink } SI units/ US units	5 Nm/44 lb. in. ± 15 %2)	
M_2	to terminals	3 Nm/26 lb. in. ± 15 %	
a		$5 \cdot 9{,}81$ m/s^2	
w	approx.	120 g	
Case	→ page B 1 – 93	SKKT 71: A 5 SKKH 71: A 6	SKKT 72: A 46 SKKT 72B: A 48 SKKH 72: A 47

SEMIPACK® 1
Thyristor/ Diode Modules

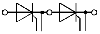
SKKT 71 **SKKH 71**
SKKT 72 **SKKH 72**
SKKT 72B



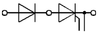
SKKT 71



SKKH 71



SKKT 72



SKKH 72

Features

- Heat transfer through aluminium oxide ceramic isolated metal baseplate
- Hard soldered joints for high reliability
- UL recognized, file no. E 63 532

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)

1) Also available in SKKT 72 B configuration (case A 48)

2) See the assembly instructions

3) /20 E, /22 E max. 30 mA

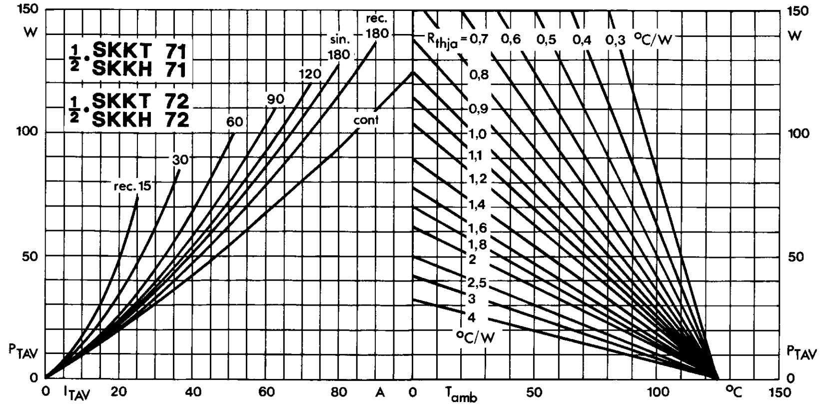


Fig. 1 Power dissipation per thyristor vs. on-state current and ambient temperature

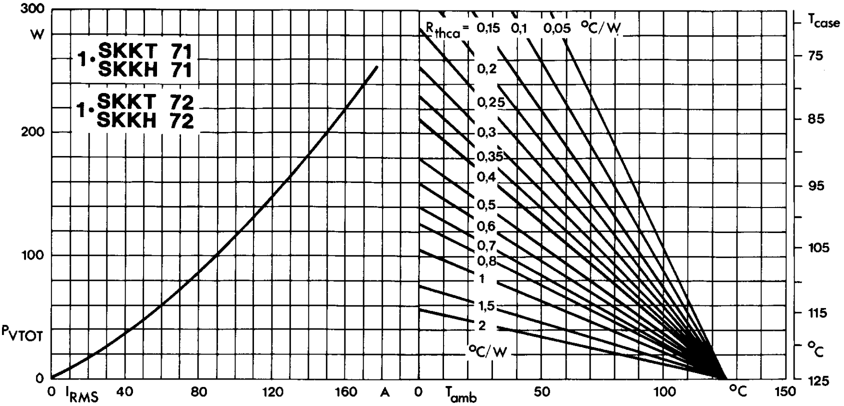


Fig. 2 Power dissipation per module vs. rms current and case temperature

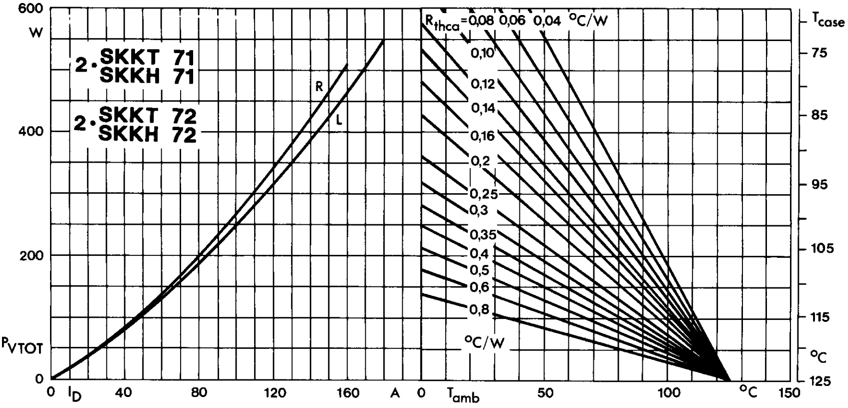


Fig. 3 Power dissipation of two modules vs. direct current and case temperature

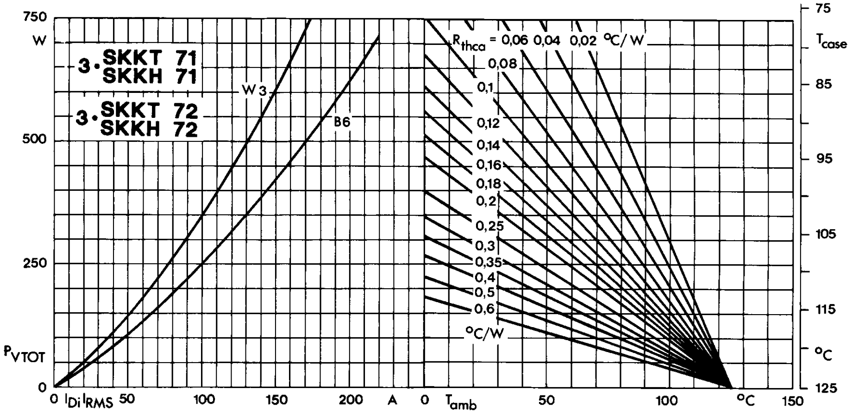


Fig. 4 Power dissipation of three modules vs. direct and rms current and case temperature

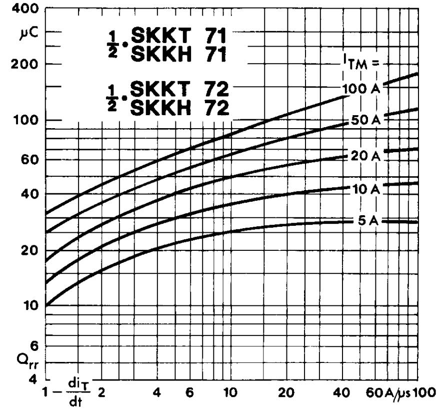


Fig. 5 Recovered charge vs. current decrease

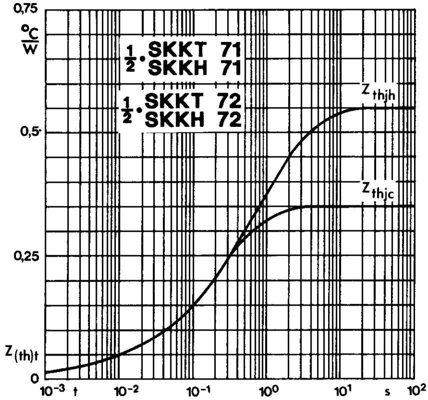


Fig. 6 Transient thermal impedance vs. time

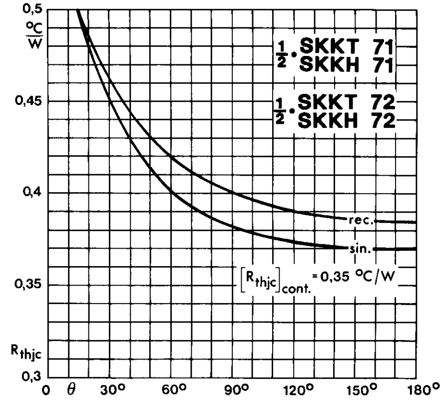


Fig. 7 Thermal resistance vs. conduction angle

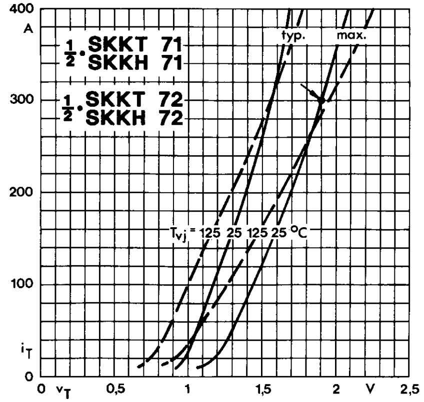


Fig. 8 On-state characteristics

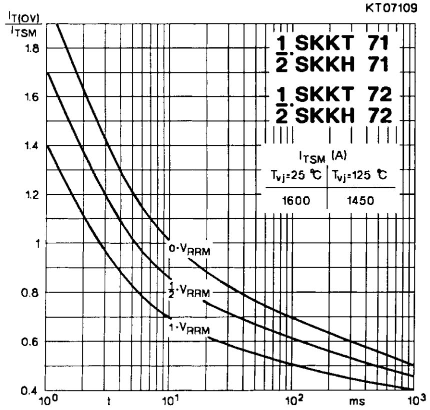


Fig. 9 Surge overload current vs. time

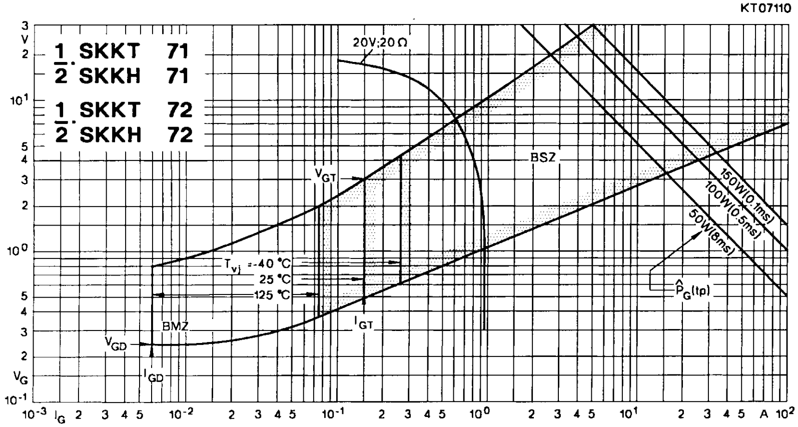


Fig. 10 Gate trigger characteristics

CAS300M17BM2

1.7kV, 8.0 mΩ All-Silicon Carbide Half-Bridge Module

C2M MOSFET and Z-Rec® Diode

V_{DS}	1.7 kV
$E_{sw,\ Total\ @\ 300A,\ 150\ ^\circ C}$	23.7 mJ
$R_{DS(on)}$	8.0 mΩ

Features

- Ultra Low Loss
- High-Frequency Operation
- Zero Reverse Recovery Current from Diode
- Zero Turn-off Tail Current from MOSFET
- Normally-off, Fail-safe Device Operation
- Ease of Paralleling
- Copper Baseplate and Aluminum Nitride Insulator

Package 62mm x 106mm x 30mm

System Benefits

- Enables Compact and Lightweight Systems
- High Efficiency Operation
- Mitigates Over-voltage Protection
- Reduced Thermal Requirements
- Reduced System Cost

Applications

- HF Resonant Converters/Inverters
- Solar and Wind Inverters
- UPS and SMPS
- Motor Drive
- Traction

Part Number	Package	Marking
CAS300M17BM2	Half-Bridge Module	CAS300M17BM2

Maximum Ratings ($T_C = 25^\circ C$ unless otherwise specified)

Symbol	Parameter	Value	Unit	Test Conditions	Notes
V_{DSmax}	Drain - Source Voltage	1.7	kV		
V_{GSmax}	Gate - Source Voltage	-10/+25	V	Absolute maximum values	
V_{GSop}	Gate - Source Voltage	-5/20	V	Recommended operational values	
I_D	Continuous MOSFET Drain Current	325	A	V_{GS} = 20 V, T_C = 25 °C	Fig. 26
		225		V_{GS} = 20 V, T_C = 90 °C	
$I_{D(pulse)}$	Pulsed Drain Current	900	A	Pulse width tp limited by $T_{J(max)}$	
I_F	Continuous Diode Forward Current	556	A	V_{GS} = -5 V, T_C = 25 °C	Fig. 27
		353		V_{GS} = -5 V, T_C = 90 °C	
T_{Jmax}	Junction Temperature	-40 to +150	°C		
T_C ,T_{STG}	Case and Storage Temperature Range	-40 to +125	°C		
V_{isol}	Case Isolation Voltage	4.5	kV	AC, 50 Hz , 1 min	
L_{Stray}	Stray Inductance	15	nH	Measured between terminals 2 and 3	
P_D	Power Dissipation	1760	W	T_C = 25 °C, T_J = 150 °C	Fig. 25

Electrical Characteristics (T_C = 25 °C unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit	Test Conditions	Note
$V_{(BR)DSS}$	Drain - Source Breakdown Voltage	1.7			kV	$V_{GS,}$ = 0 V, I_D = 1 mA	
$V_{GS(th)}$	Gate Threshold Voltage	1.8	2.3		V	V_{DS} = 10 V, I_D = 15 mA	Fig. 7
I_{DSS}	Zero Gate Voltage Drain Current		500	1000	μA	V_{DS} = 1.7 kV, V_{GS} = 0V	
			1500	3000	μA	V_{DS} = 1.7 kV,V_{GS} = 0V, T_J = 150 °C	
I_{GSS}	Gate-Source Leakage Current		1	600	nA	V_{GS} = 20 V, V_{DS} = 0V	
$R_{DS(on)}$	On State Resistance		8.0	10	mΩ	V_{GS} = 20 V, I_{DS} = 225 A	Fig. 4, 5, 6
			16.2	20		V_{GS} = 20V, I_{DS} = 225 A,T_J = 150 °C	
g_{fs}	Transconductance		95		S	V_{DS} = 20 V, I_{DS} = 225 A	Fig. 8
			82			V_{DS} = 20 V, I_D = 225 A, T_J = 150 °C	
C_{iss}	Input Capacitance		20		nF	V_{DS} = 1 kV, f = 200 kHz, V_{AC} = 25 mV	Fig. 16, 17
C_{oss}	Output Capacitance		2.5				
C_{rss}	Reverse Transfer Capacitance		0.08				
E_{on}	Turn-On Switching Energy		13.0		mJ	V_{DD} = 900 V, V_{GS} = -5V/+20V I_D = 300 A, $R_{G(ext)}$ = 2.5 Ω Load = 77 μH, T_J = 150 °C Note: IEC 60747-8-4 Definitions	Fig. 19
E_{Off}	Turn-Off Switching Energy		10.0		mJ		
$R_{G\ (int)}$	Internal Gate Resistance		3.7		Ω	f = 1 MHz, V_{AC} = 25 mV	
Q_{GS}	Gate-Source Charge		273		nC	V_{DD}= 900 V, V_{GS} = -5V/+20V, I_D= 300 A, Per JEDEC24 pg 27	Fig. 15
Q_{GD}	Gate-Drain Charge		324				
Q_G	Total Gate Charge		1076				
$t_{d(on)}$	Turn-on delay time		105		ns	V_{DD} = 900V, V_{GS} = -5/+20V, I_D = 300 A, $R_{G(ext)}$ = 2.5 Ω, Timing relative to V_{DS} Note: IEC 60747-8-4, pg 83 Inductive load	Fig. 24
t_r	Rise Time		72		ns		
$t_{d(off)}$	Turn-off delay time		211		ns		
t_f	Fall Time		56		ns		
V_{SD}	Diode Forward Voltage		1.7	2.0	V	I_F = 300 A, V_{GS} = 0	Fig. 10
			2.2	2.5		I_F = 300 A, V_{GS} = 0 , T_J = 150 °C	Fig. 11
Q_C	Total Capacitive Charge		4.4		μC	I_{SD} = 300 A, V_{DS} = 900 V, T_J = 25°C, di_{SD}/dt = 9 kA/μs, V_{GS} = -5 V	

Thermal Characteristics

Symbol	Parameter	Min.	Typ.	Max.	Unit	Test Conditions	Note
R_{thJCM}	Thermal Resistance Juction-to-Case for MOSFET		0.067	0.071	°C/W		Fig. 27
R_{thJCD}	Thermal Resistance Juction-to-Case for Diode		0.060	0.065			Fig. 28

Additional Module Data

Symbol	Parameter	Max.	Unit	Test Condtion
W	Weight	300	g	
M	Mounting Torque	5	Nm	To heatsink and terminals
	Clearance Distance	9	mm	Terminal to terminal
	Creepage Distance	30	mm	Terminal to terminal
		40	mm	Terminal to baseplate

Typical Performance

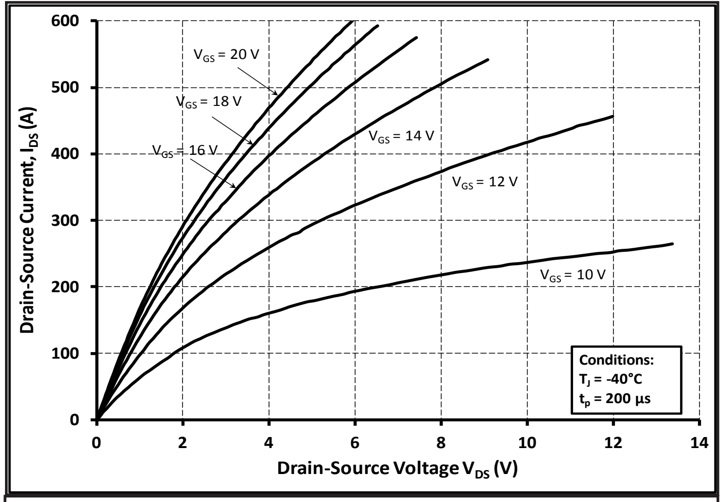


Figure 1. Output Characteristics T_J = -40 °C

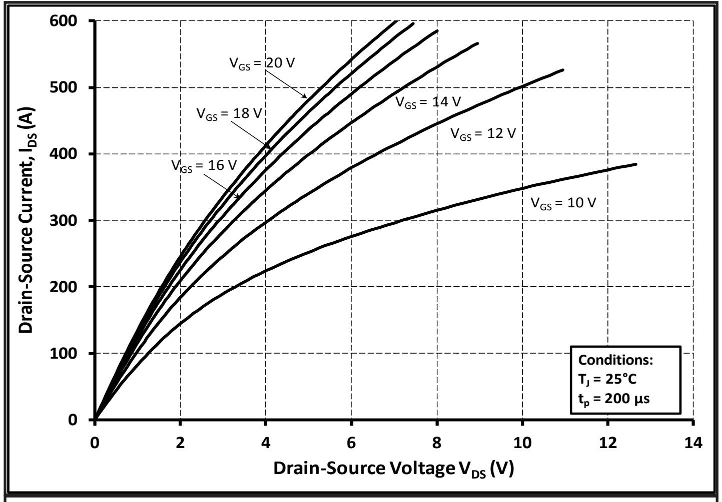


Figure 2. Output Characteristics T_J = 25 °C

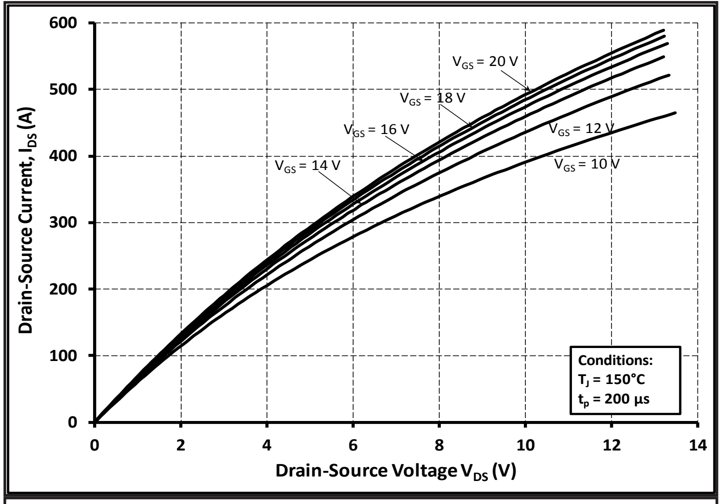


Figure 3. Output Characteristics T_J = 150 °C

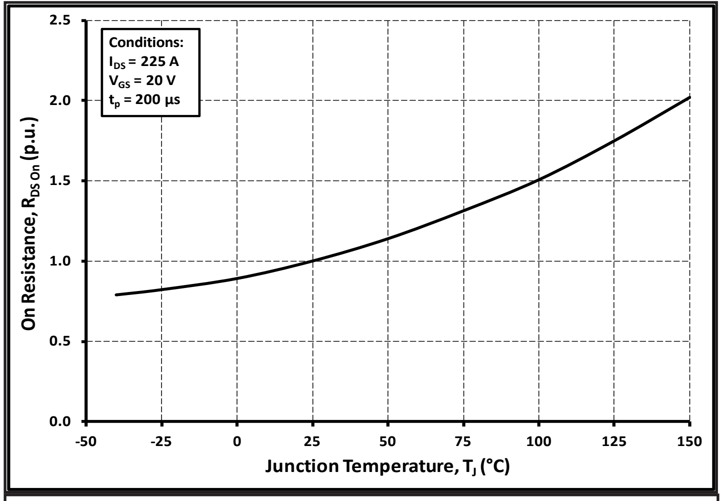


Figure 4. Normalized On-Resistance vs. Temperature

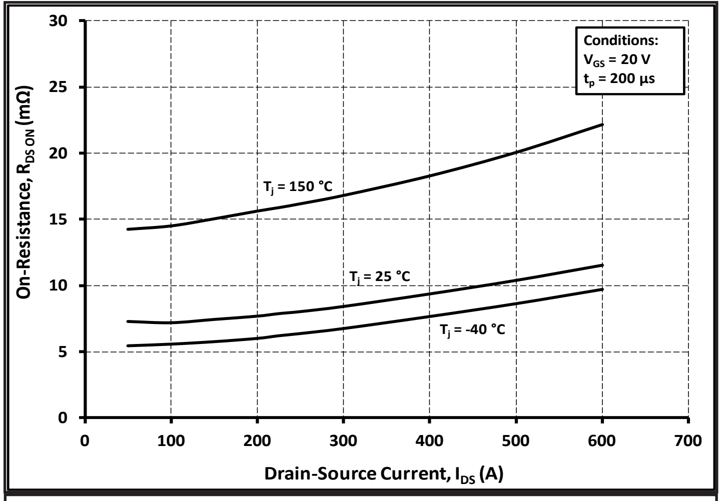


Figure 5. On-Resistance vs. Drain Current For Various Temperatures

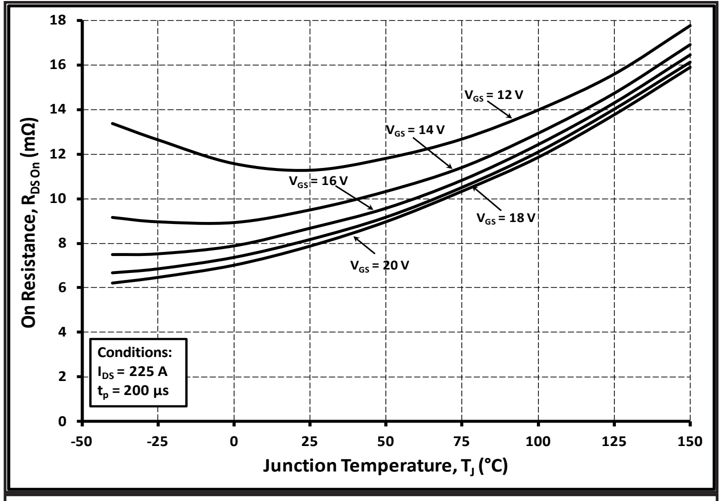


Figure 6. On-Resistance vs. Temperature for Various Gate-Source Voltage

Typical Performance

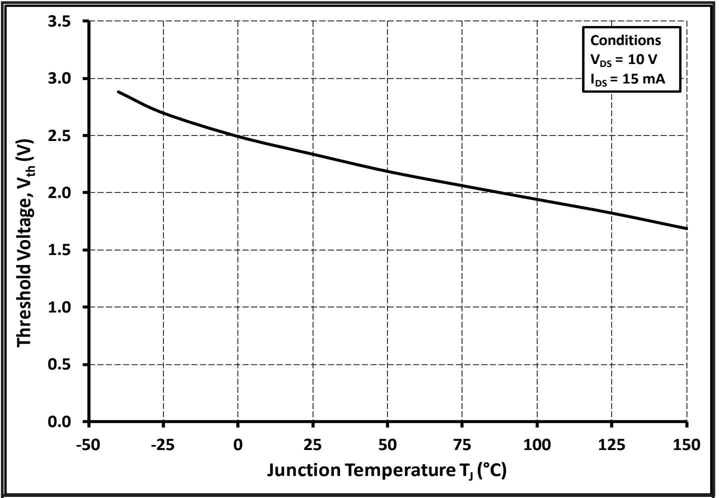


Figure 7. Threshold Voltage vs. Temperature

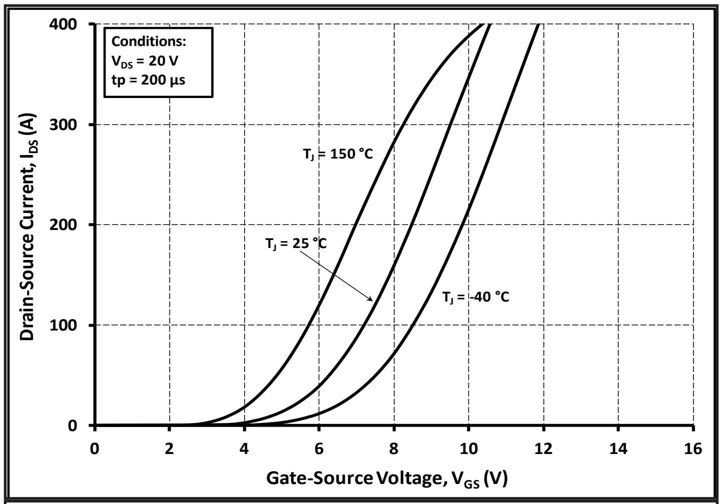


Figure 8. Transfer Characteristic for Various Junction Temperatures

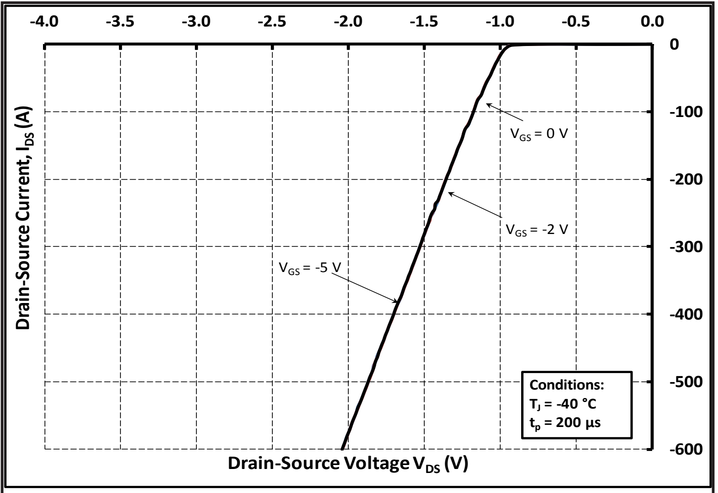


Figure 9. Diode Characteristic at -40 °C

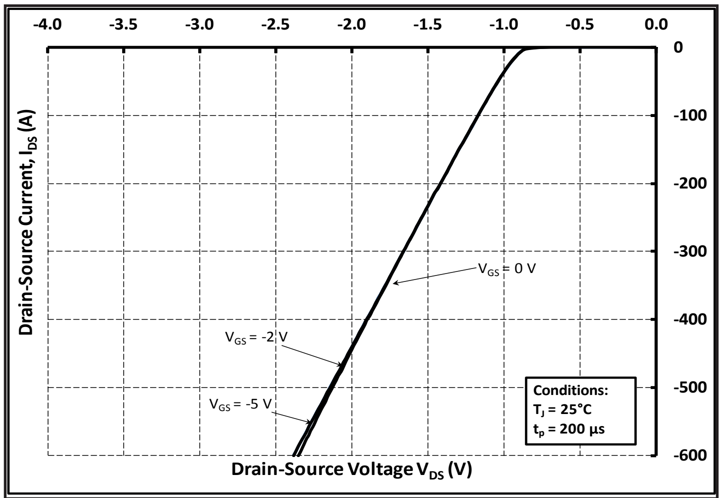


Figure 10. Diode Characteristic at 25 °C

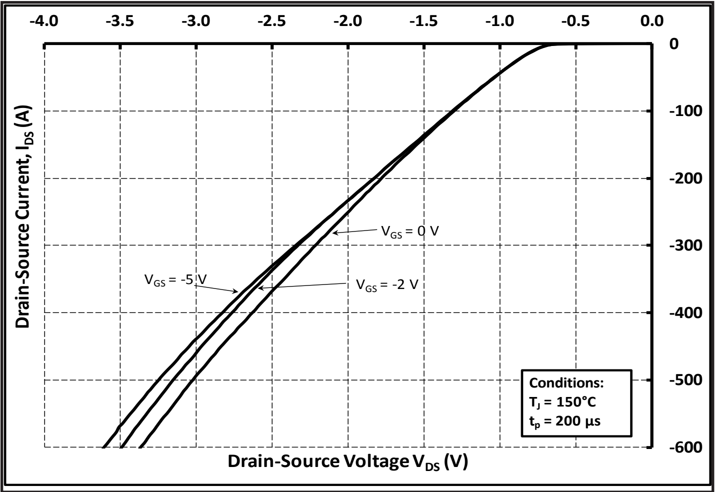


Figure 11. Diode Characteristic at 150 °C

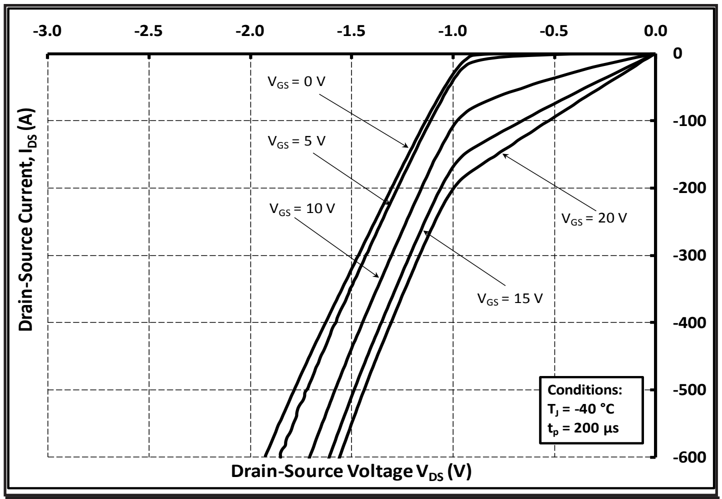


Figure 12. 3rd Quadrant Characteristic at -40 °C

Typical Performance

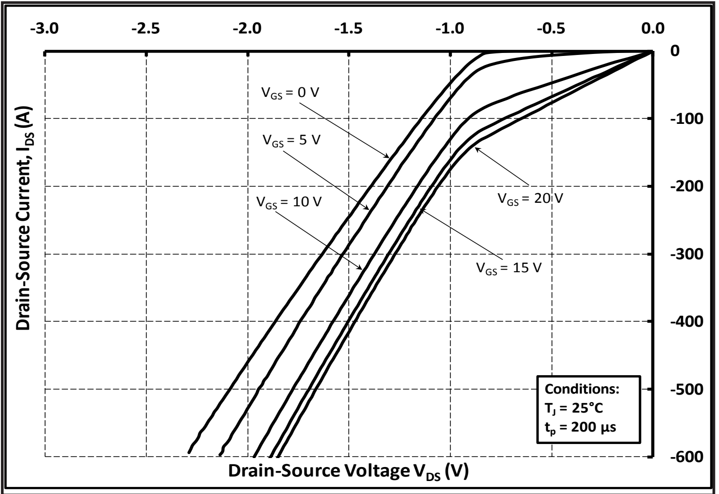


Figure 13. 3rd Quadrant Characteristic at 25 °C

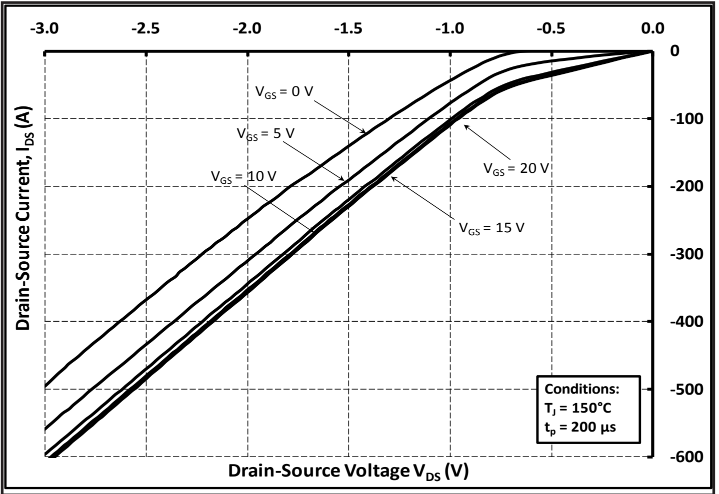


Figure 14. 3rd Quadrant Characteristic at 150 °C

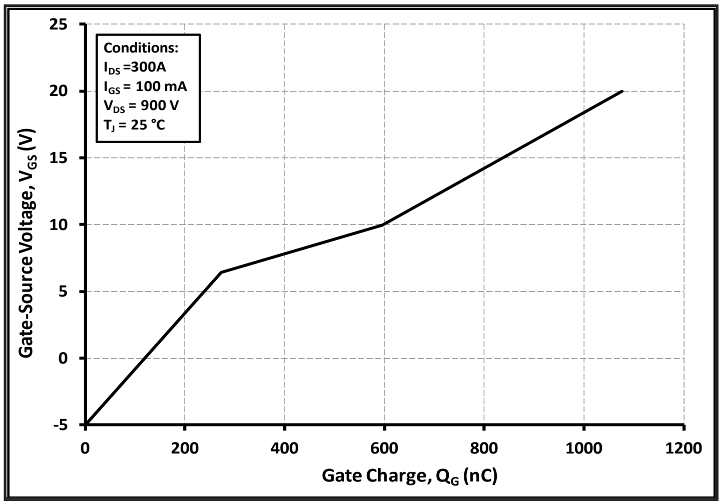


Figure 15. Gate Charge Characteristics

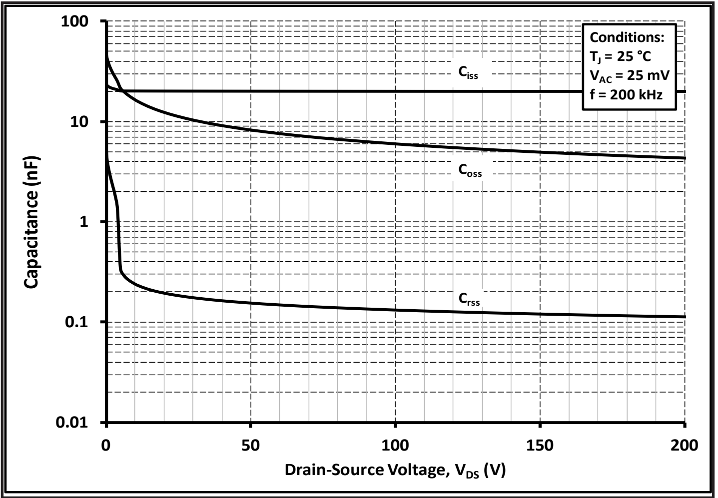


Figure 16. Capacitances vs. Drain-Source Voltage (0 - 200 V)

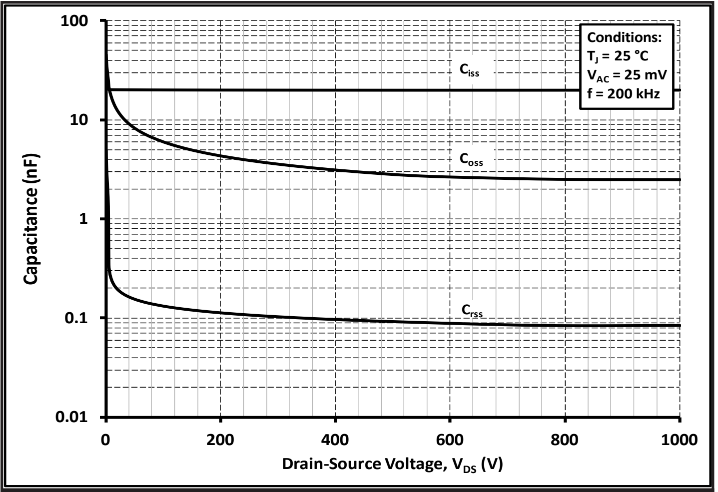


Figure 17. Capacitances vs. Drain-Source Voltage (0 - 1 kV)

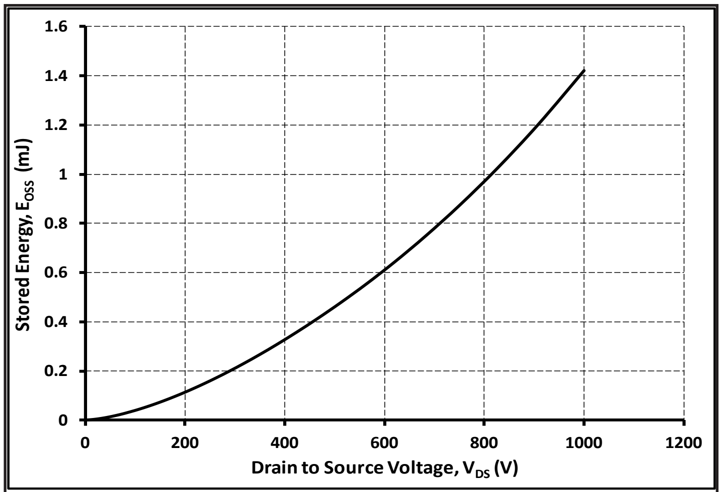


Figure 18. Output Capacitor Stored Energy

Typical Performance

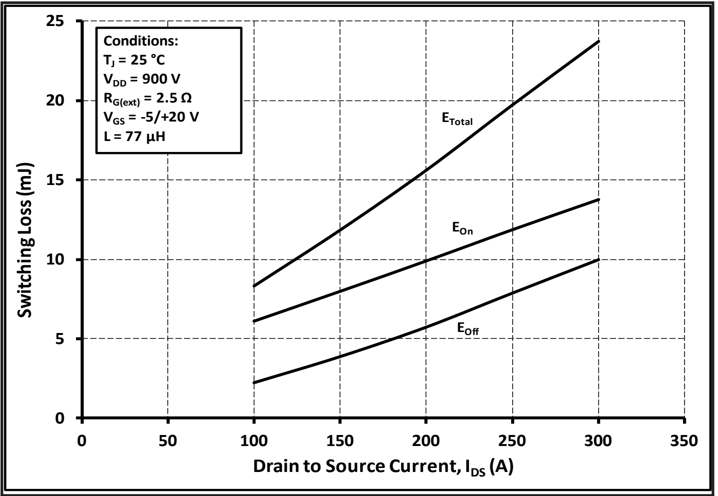


Figure 19. Inductive Switching Energy vs. Drain Current For V_{DS} = 900V, R_G = 2.5 Ω

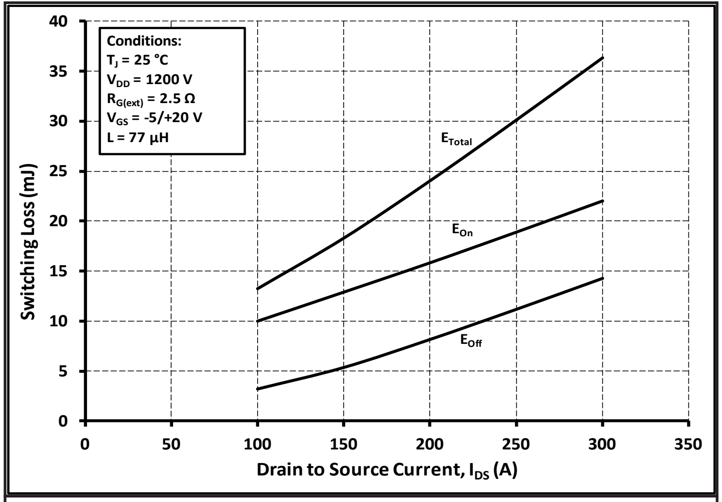


Figure 20. Inductive Switching Energy vs. Drain Current For V_{DS} = 1200 V, R_G = 2.5 Ω

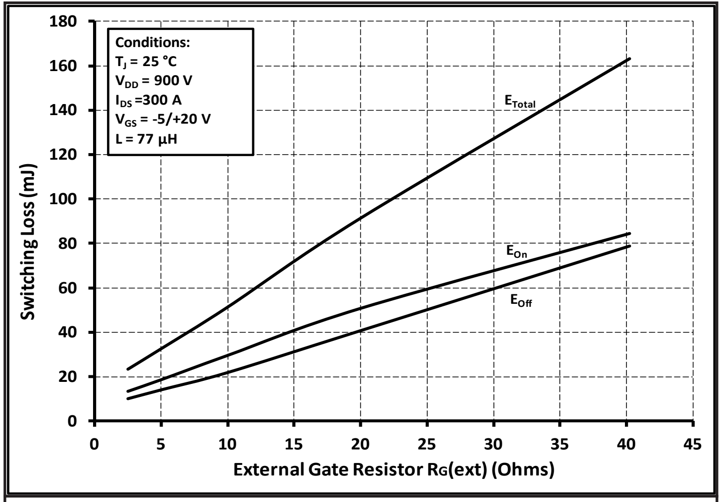


Figure 21. Inductive Switching Energy vs. $R_{G(ext)}$

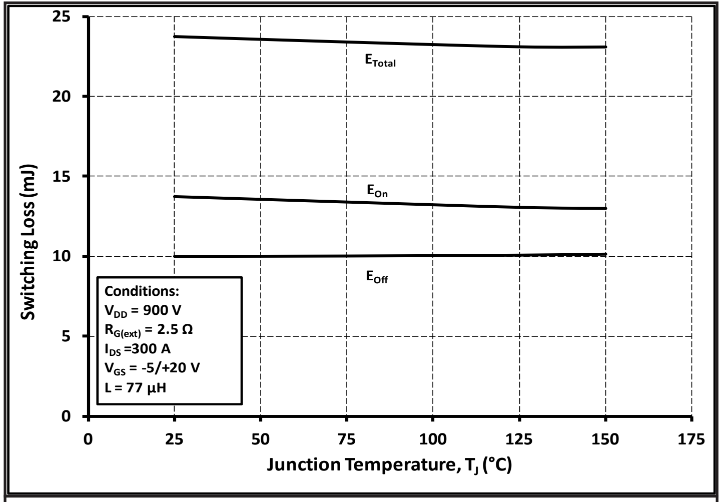


Figure 22. Inductive Switching Energy vs. Temperature

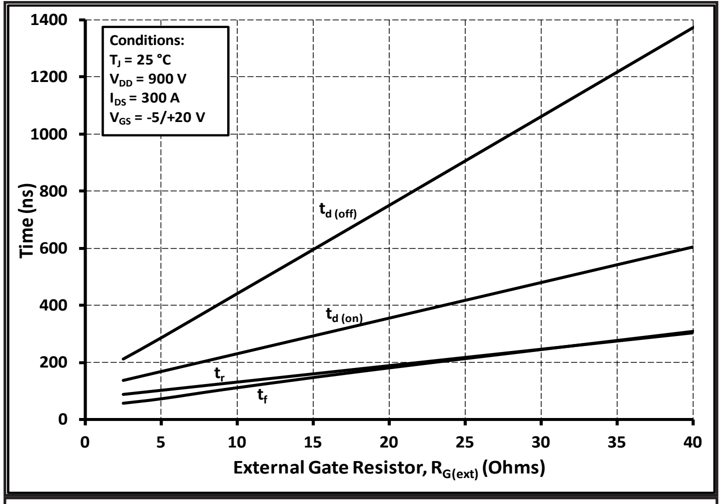


Figure 23. Timing vs. $R_{G(ext)}$

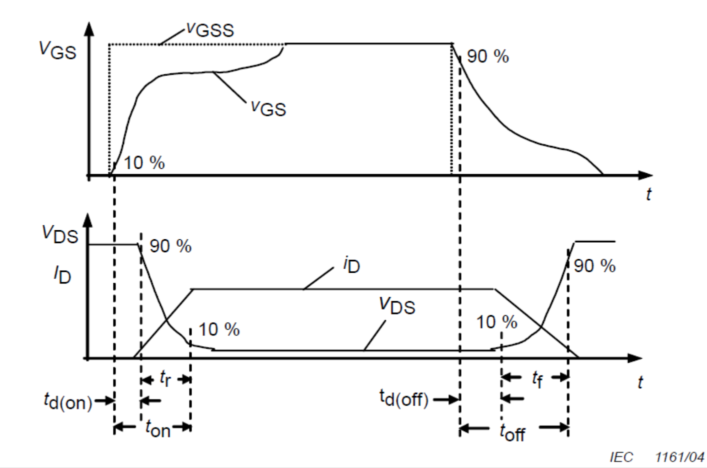


Figure 24. Resistive Switching Time Description

Typical Performance

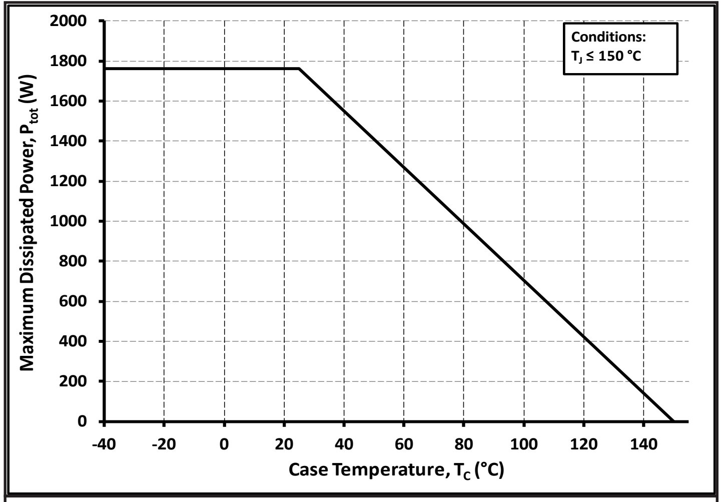


Figure 25. Maximum Power Dissipation (MOSFET) Derating vs. Case Temperature

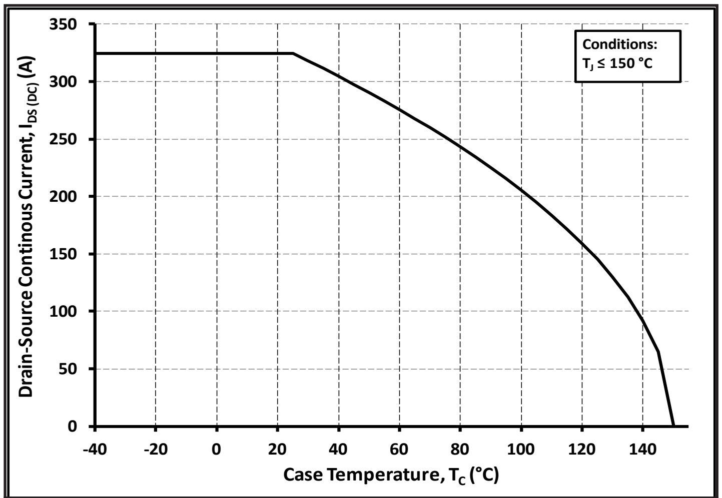


Figure 26. Continous Drain Current Derating vs Case Temperature

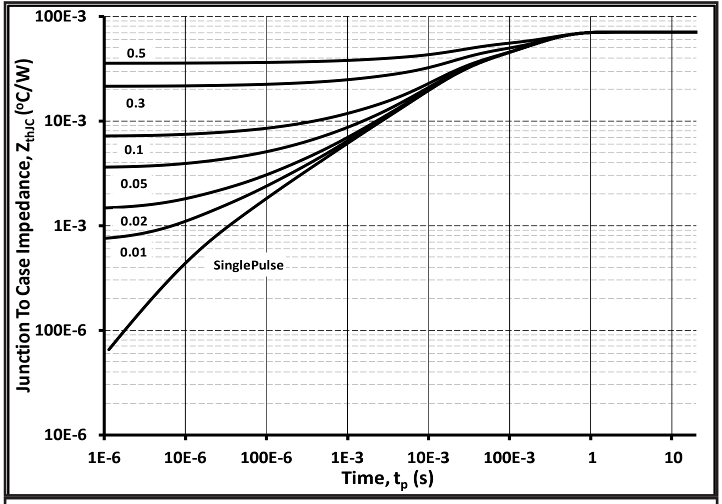


Figure 27. MOSFET Junction to Case Thermal Impedance

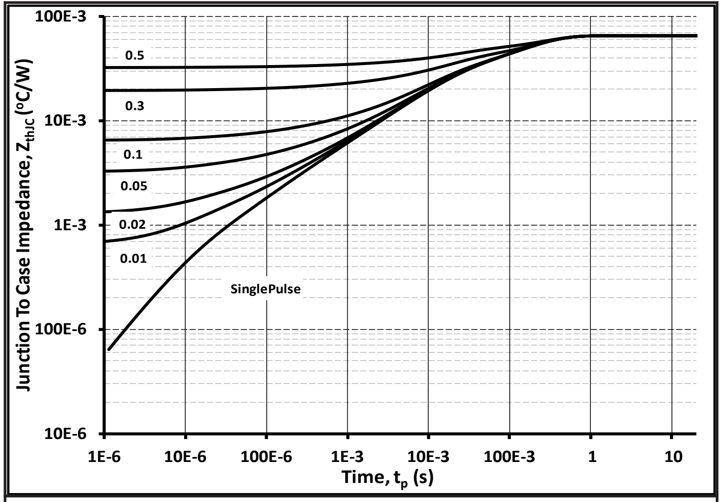


Figure 28. Diode Junction to Case Thermal Impedance

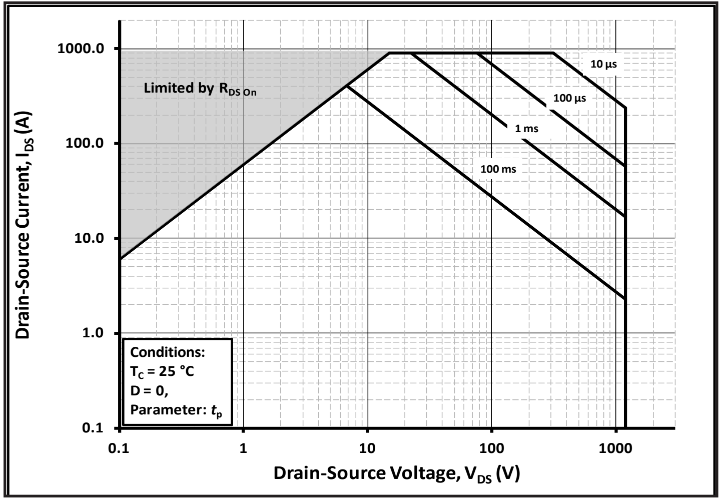
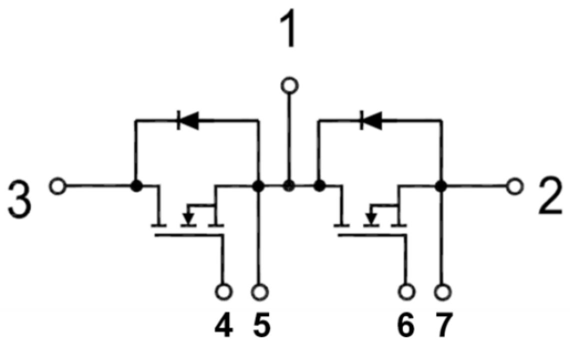
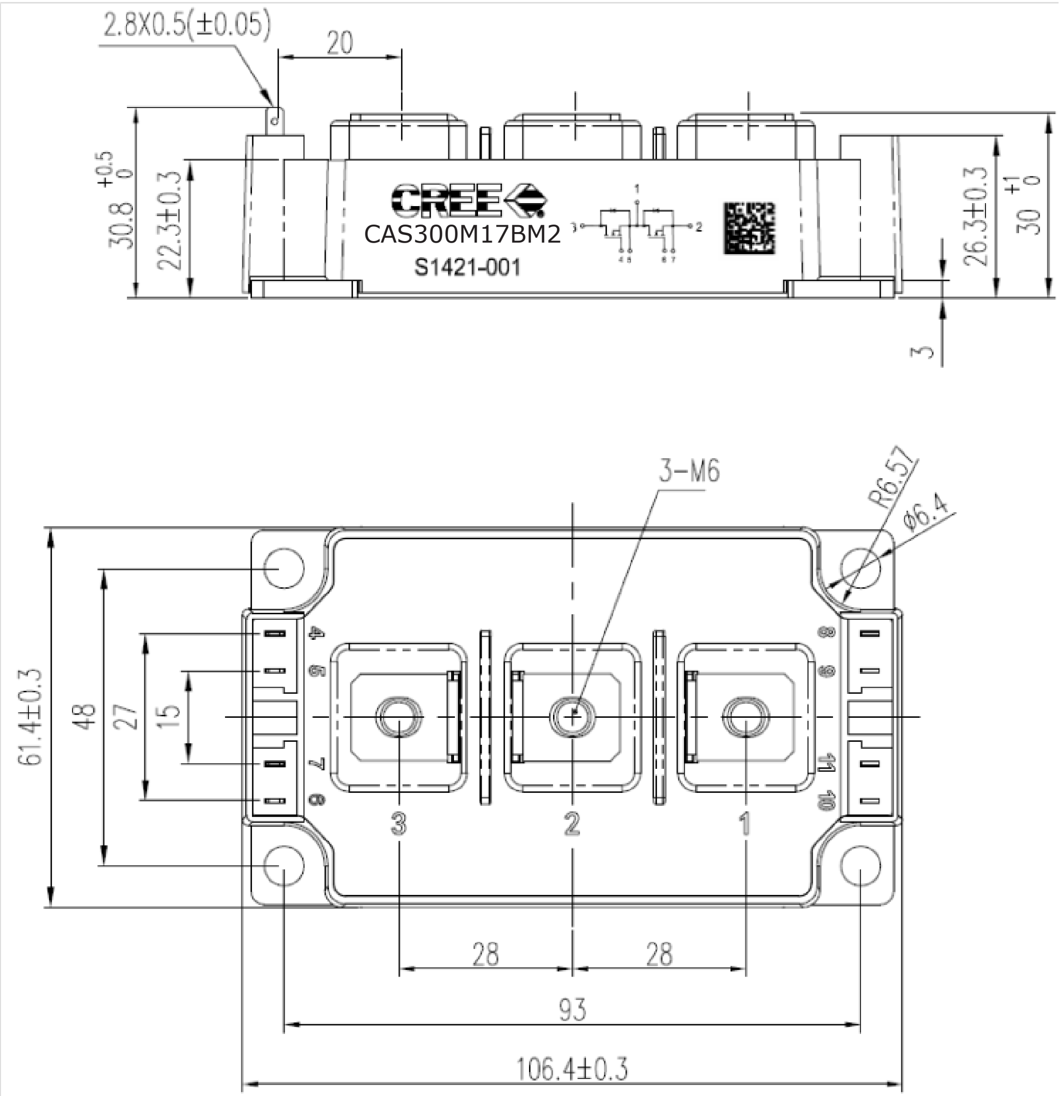


Figure 29. Maximum Power Dissipation (MOSFET) Derating vs. Case Temperature

Schematic



Package Dimensions (mm)



Notes

- **RoHS Compliance**
  The levels of RoHS restricted materials in this product are below the maximum concentration values (also referred to as the threshold limits) permitted for such substances, or are used in an exempted application, in accordance with EU Directive 2011/65/EC (RoHS2), as implemented January 2, 2013. RoHS Declarations for this product can be obtained from your Cree representative or from the Product Documentation sections of www.cree.com.

- **REACh Compliance**
  REACh substances of high concern (SVHCs) information is available for this product. Since the European Chemical Agency (ECHA) has published notice of their intent to frequently revise the SVHC listing for the foreseeable future,please contact a Cree representative to insure you get the most up-to-date REACh SVHC Declaration. REACh banned substance information (REACh Article 67) is also available upon request.

- This product has not been designed or tested for use in, and is not intended for use in, applications implanted into the human body nor in applications in which failure of the product could lead to death, personal injury or property damage, including but not limited to equipment used in the operation of nuclear facilities, life-support machines, cardiac defibrillators or similar emergency medical equipment, aircraft navigation or communication or control systems, air traffic control systems.

Module Application Note:

The SiC MOSFET module switches at speeds beyond what is customarily associated with IGBT based modules. Therefore, special precautions are required to realize the best performance. The interconnection between the gate driver and module housing needs to be as short as possible. This will afford the best switching time and avoid the potential for device oscillation. Also, great care is required to insure minimum inductance between the module and link capacitors to avoid excessive V_{DS} overshoots.

Please Refer to application note: Design Considerations when using Cree SiC Modules Part 1 and Part 2.
[CPWR-AN12, CPWR-AN13]

S-81.3120 Tehoelektroniikan komponentit
Tentti 11.12.2014

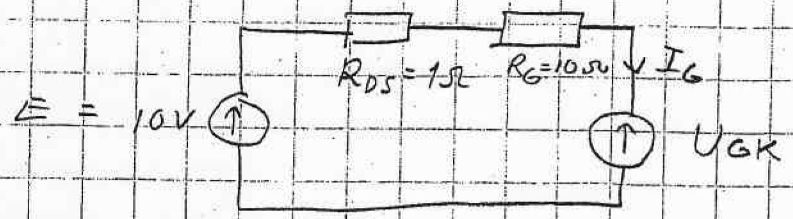
RATKAISUT

Teht. 1...3: katso moniste

Teht. 4

(vrt. LH3 teht. 3)

Sijaiskytkentä



$$E = (R_{DS} + R_G) I_G + U_{GK}$$

Taulukoidaan hilapiirin ominaiskäyrä:

$$U_{GK} = E - (R_{DS} + R_G) I_G = 10V - 11\Omega\, I_G$$

I_G/A	U_{GK}/V
0,1	8,9
0,2	7,8
0,3	6,7
0,4	5,6
0,5	4,5
0,7	2,3
0,9	0,1

Piirretään datalehden kuvaan 10

⇒ Toimii −40°C lämpötilassa, koska valmistajan ilmoittaman hilapiirin vaihteluvälin sisällä ollaan −40°C rajan ulkopuolella

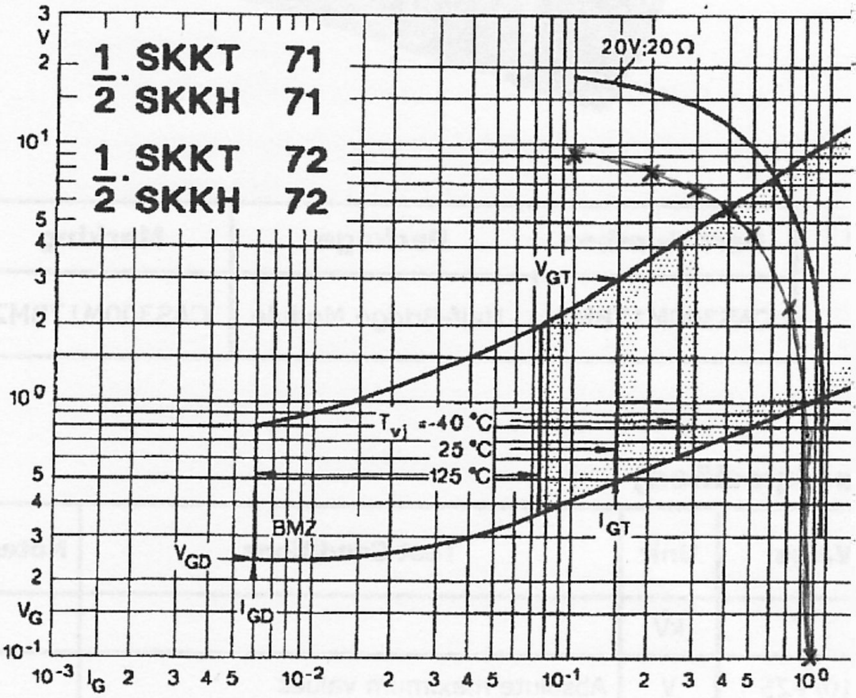


Fig. 10 Gate trigger characteristics

Teht. 4 jatkoa

Maksimiteho kun hilan impedanssi on syöttävän lähteen resistanssin suuruinen, el.

$$\frac{U_{GK}}{I_G} = R_G + R_{DS}$$

$$\Rightarrow \quad E = 2(R_G + R_{DS})\, I_G$$

$$\Rightarrow \quad I_G = \frac{E}{2(R_G + R_{DS})}$$

$$\Rightarrow \quad P_{G\,max} = (R_G + R_{DS})\, I_G^2 = \frac{E^2}{4(R_G + R_{DS})} = \frac{(10\,V)^2}{4 \cdot 11\,\Omega}$$

$$\underline{\underline{\approx 2{,}3\ W}}$$

S-81.3120 Tehoelektroniikan komponentit

Tentti 11.12.2014 Rath

Teht. 5

Mosfetin T_2 häviöenergiat pulssia kohden

Kuvat 19 ja 20 pätevät kun $R_G = 2{,}5\,\Omega$ ja ohjaus on +20/−5 V kuten tehtävässä on.

Siten 150 A virralla

$E_{HTON} \approx 7{,}9\text{ mJ}$ ja $E_{HTOFF} \approx 3{,}7\text{ mJ}$ kun $V_{DS} = 900\text{V}$

$E_{HTON} \approx 12{,}6\text{ mJ}$ ja $E_{HTOFF} \approx 5{,}2\text{ mJ}$ kun $V_{DS} = 1200\text{V}$

Lineaarisella interpolaatiolla saadaan 1000 V jännitteelle

$$E_{HTON} \approx \frac{7{,}9\text{mJ} - 12{,}6\text{mJ}}{900\text{V} - 1200\text{V}}\left(1000\text{V} - 1200\text{V}\right) + 12{,}6\text{mJ}$$

$$\approx 9{,}5\text{ mJ}$$

$$E_{HTOFF} \approx \frac{3{,}7\text{mJ} - 5{,}2\text{mJ}}{900\text{V} - 1200\text{V}}\left(1000\text{V} - 1200\text{V}\right) + 5{,}2\text{mJ}$$

$$\approx 4{,}2\text{mJ}$$

Johtohäviöt saadaan laskettua kuvan 3 jännitteellä

$U_{DS} \approx 2{,}2\text{V}$ kun $V_{GS} = 20\text{ V}$ ja $I_{DS} = 150\text{ A}$

sekä $T_J = 150\,°\text{C}$

Siten

$$E_{HCOND} = U_{DS} \cdot I_{DS} \cdot t_{ON} \approx 2{,}2\text{V} \cdot 150\text{A} \cdot 30\mu\text{s}$$

$$\approx 9{,}9\text{ mJ}$$

(kytkentäajat t_r ja t_f ovat $\approx 0{,}1\mu\text{s}$ joten ne voi unohtaa)

Teht. 5 jatkoa

Siten Mosfet T_2:n kokonaishäviö on

$$P_{HT2} = f\,(E_{HTON} + E_{HTOFF} + E_{HCOND})$$

$$\approx \frac{1}{50\mu s}\left(12.6\,mJ + 5{,}2\,mJ + 9{,}9\,mJ\right) \approx 554\,W$$

Mosfet T_1:n ja sen diodin häviöt

3. kvadrantissa virta kulkee osittain fetin kanavassa ja vain kytkentänetkillä pelkästään diodissa.

Koska myös diodi on SiC-materiaalista tehty "zero recovery" eli ilmeisesti Schottky-tyyppinen, ovat sen virran katkaisuhäviöt pieniä ja koostuvat lähinnä liitoskapasitanssin latautumis- ja purkaushäviöistä

Kuvasta 18 nähdään, että 1000 V jännitteellä kapasitanssiin on varautunut 1,4 mJ

Jos oletetaan (pahin tapaus) että tämä energia muuttuu lämmöksi diodissa sekä päällekytkennässä että virran katkaisussa niin

$$E_{HDTON+TOFF} = 2 \cdot 1{,}4\,mJ = 2{,}8\,mJ$$

Johtohäviöissä täytyy huomioida virran jako Mosfetin kanavan ja Schottkydiodin välillä. Kuvasta 14 nähdään että jännitehäviö on noin 1,2 V 150 A virralla kun $T_J = 150\,°C$ ja $V_{GS} = 20\,V$. Edelleen kuvasta nähdään, että kun $V_{GS} = 0$ eli fet ei johda, diodi johtaa kyseisellä 1,2 V jännitteellä noin 77 A. Siitä voi päätellä, että fetin virta on noin 150 A − 77 A = 73 A

Siten Mosfetin johtohäviä on

$$E_{ONT1} \approx 1{,}2V \cdot 73A \cdot 20\mu s \approx 1{,}8\,mJ$$

Ja diodilla $E_{OND1} \approx 1{,}2V \cdot 77A \cdot 20\mu s \approx 1{,}8\,mJ$

S-81.3120 Tehoelektroniikan komponentit

Tentti 11.12.2014 Ratkaisut

Teht. 5 jatkoa

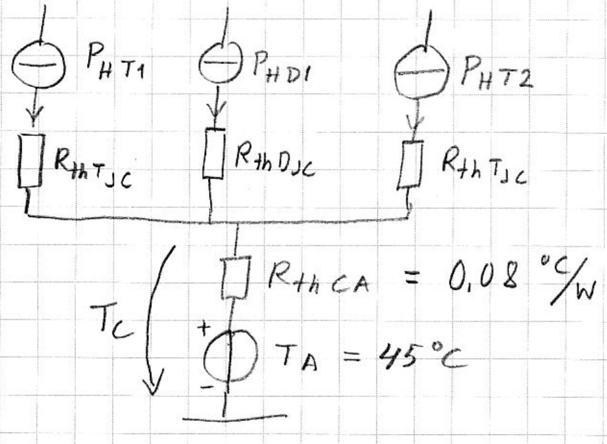
Siten T_1:n diodin kokonaishäviöteho on

$$P_{HD1} \approx \frac{1}{50\mu s}\left(2{,}8\,mJ + 1{,}8\,mJ\right) \approx 92\,W$$

Ja Mosfet T_1 itsensä osuus, eli pelkät johtohäviöt rinnalla olevan diodin takia

$$P_{HT1} \approx \frac{1}{50\mu s}\cdot 1{,}8\,mJ \approx 36\,W$$

Terminen sijaiskytkentä



$R_{thTJC} = 0{,}071\,\frac{°C}{W}$ } max.

$R_{thDJC} = 0{,}065\,\frac{°C}{W}$ }

Moduulin pohjan lämpötila

$$T_C = \left(P_{HT2} + P_{HT1} + P_{HD1}\right)\cdot R_{thCA} + T_A$$
$$\approx \left(554\,W + 36\,W + 92\,W\right)\cdot 0{,}08\,\frac{°C}{W} + 45\,°C$$
$$\approx 100\,°C$$

Siten $T_{JT1} = P_{HT1}\cdot R_{thTJC} + T_C \approx 36\,W\cdot 0{,}071\,\frac{°C}{W} + 100\,°C$

$\approx \underline{\underline{103\,°C}}$

$T_{JT2} \approx P_{HT2}\cdot R_{thTJC} + T_C \approx 554\,W\ 0{,}071\,\frac{°C}{W} + 100\,°C$

$\approx \underline{\underline{140\,°C}}$

(Ja diodilla, vaikkei kysytty $T_{JD1} \approx 92\,W\cdot 0{,}065\,\frac{°C}{W} + 100\,°C \approx 106\,°C$)