

Tentti 12.03.2010, kello 9 ... 12, sali S3

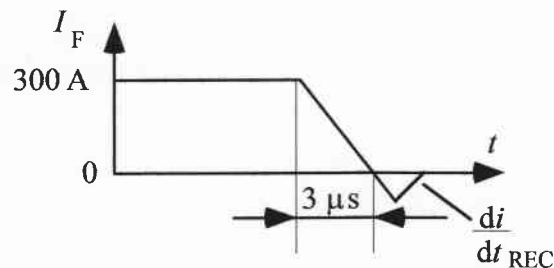
Papereihin

- sukunimi ja etunimet
- opiskelijanumero
- koulutusohjelma.

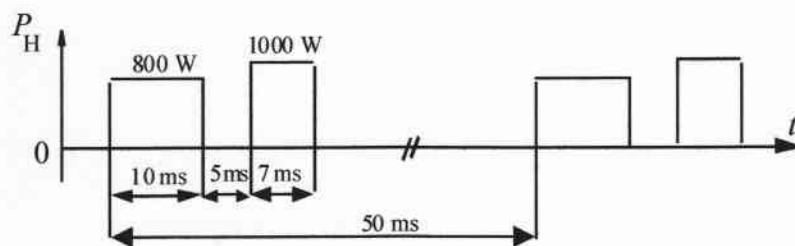
Tentissä sallitut apuvälineet

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

1. Selvitä lyhyesti (max. 2...4 lausetta + mahdollinen kuva), mitä seuraavilla termeillä tarkoitetaan
 - SiC
 - muutoslämpövastus
 - darlington-transistori
 - heat-pipe
 - lähivaikutus.
2. Esittele IGBT:n rakenne, toimintaperiaate ja ominaisuudet.
3. Minkälaisia kondensaattoreita käytetään tehoelektroniikassa? Mitkä ovat niiden ominaisuudet?
4. a) Johda lauseke diodin vaimennusaikaiselle takavirran derivaatalle di/dt_{REC} , kun tunnetaan virran derivaatta di/dt estoviiveen aikana, takavirran varaus Q_{RR} ja takavirran huippuarvo I_{RRM} sekä oletetaan takavirran muuttuvan lineaarisesti vaimennusaikana.
b) Mikä on di/dt_{REC} diodilla SKN 420 F, kun virran käyrämuoto on oheisen kuvan mukainen?



5. Viimeisellä sivulla on esitetty IGBT-moduulin SKM 300 GB 123 D muutoslämpövastuskäyrästä. Laske kiihdytettyä superpositiomenetelmää käyttäen transistorin maksimilämpenemä koteloon nähden kun transistorin häviöteho on seuraavan kuvan mukainen:



Fast Recovery Rectifier Diodes

SKN 420 F



Features

- Small recovered charge
- Soft recovery
- Up to 2500 V reverse voltage
- Hermetic capsule type metal cases with ceramic insulators

Typical Applications

- Inverse diodes for GTO and asymmetric thyristors
- Inverters and choppers
- A. C. motor control
- Uninterruptible power supplies

V_{RSM} V_{RRM} V	I_{FAV} (sin. 180; $T_{case} = 85^\circ C$) 420 A
1800	SKN 420 F 18
2000	SKN 420 F 20
2200	SKN 420 F 22
2500	SKN 420 F 25

Symbol	Conditions	SKN 420 F	Units
I_{FAV}	sin. 180; DSC; $T_{case} = 85^\circ C$; 500 Hz	420	A
I_{FSM}	$T_{vj} = 25^\circ C$; 10 ms $T_{vj} = 125^\circ C$; 10 ms	7500 7000	A A
i^2t	$T_{vj} = 25^\circ C$; 8,3... 10 ms $T_{vj} = 125^\circ C$; 8,3... 10 ms	281 000 245 000	A ² s A ² s
Q_{rr}	$T_{vj} = 125^\circ C$; $I_{FM} = 300 A$; $\frac{dI}{dt} = 100 \frac{A}{\mu s}$	550	μC
I_{RM}	$T_{vj} = 125^\circ C$; $I_{FM} = 500 A$; $\frac{dI}{dt} = 100 \frac{A}{\mu s}$	245	A
I_R	$T_{vj} = 25^\circ C$; $V_R = V_{RRM}$ $T_{vj} = 125^\circ C$; $V_R = V_{RRM}$	4 60	mA mA
V_F	$T_{vj} = 25^\circ C$; $I_F = 1500 A$; max.	2,4	V
$V_{(TO)}$	$T_{vj} = 125^\circ C$	1,2	V
r_T	$T_{vj} = 125^\circ C$	0,8	m Ω
R_{thjc}	DSC/SSC (Double-sided cooling/ single-sided cooling)	0,045/0,092	$^\circ C/W$
R_{thch}		0,012/0,024	$^\circ C/W$
T_{vj}		-40... + 125	$^\circ C$
T_{sig}		-40... + 125	$^\circ C$
F	SI units	5,2...8	kN
W	US units	1200...1800 95	lbs. g
Case		E 30	

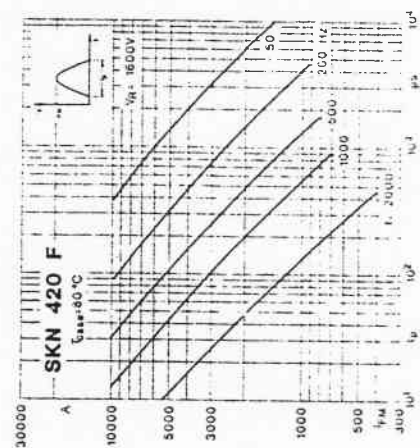


Fig. 1 a Rated sinusoidal peak forward current

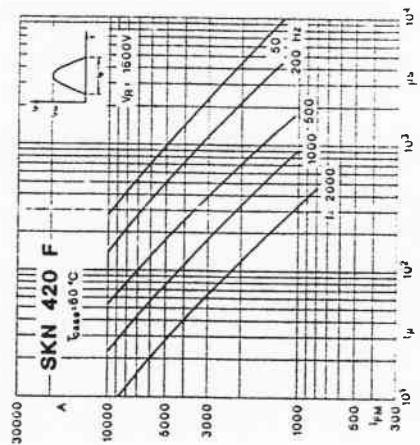


Fig. 1 b Rated sinusoidal peak forward current

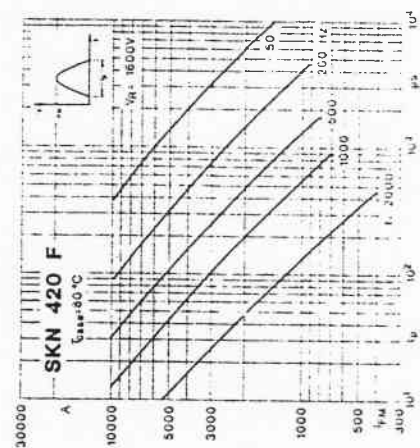


Fig. 1 c Rated sinusoidal peak forward current

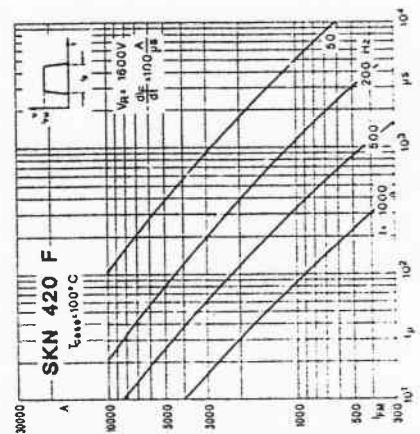


Fig. 2 Forward energy dissipation, sinusoidal

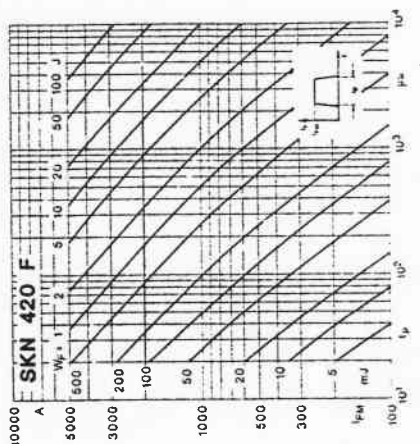


Fig. 3 Forward energy dissipation, rectangular

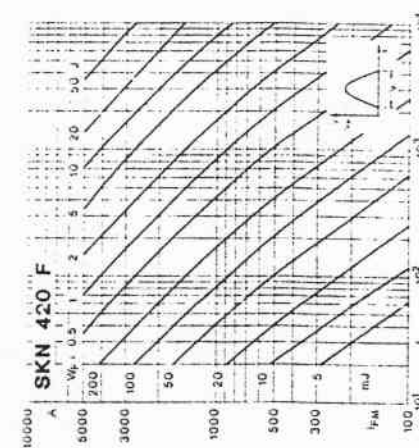


Fig. 4 Rated rectangular peak forward current

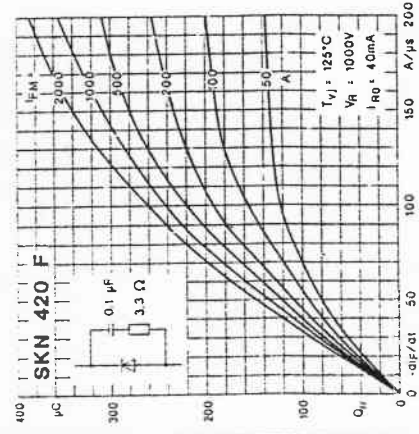


Fig. 5 Recovered charge

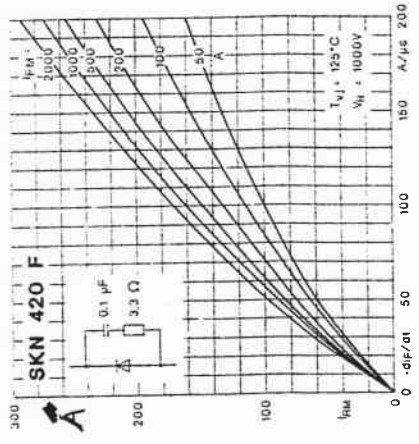


Fig. 6 Peak reverse recovery current

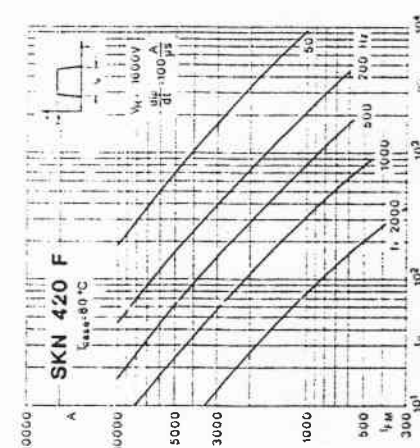


Fig. 7 Transient thermal impedance

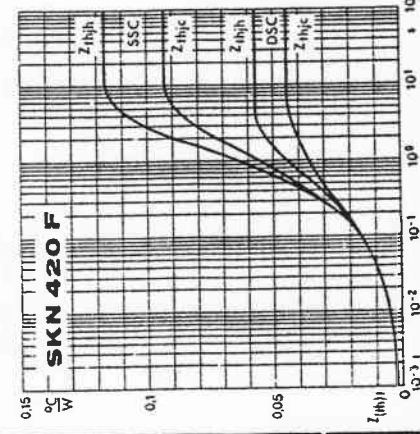


Fig. 8 Forward characteristics

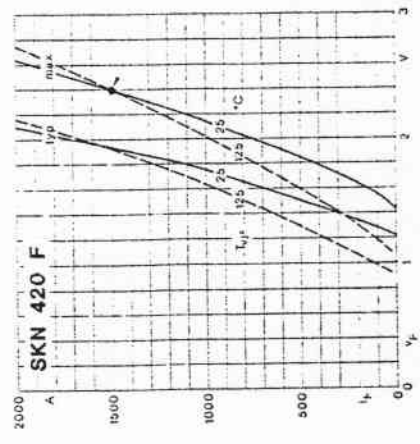


Fig. 9 Rated rectangular peak forward current

174

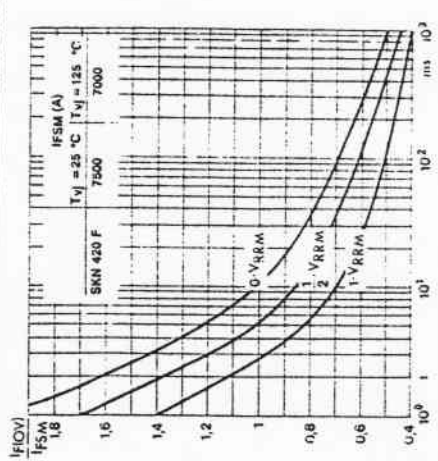
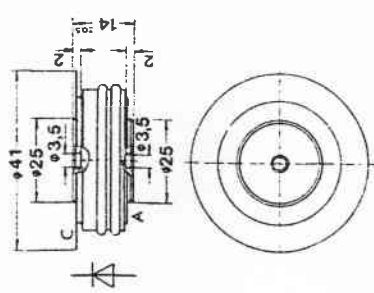


Fig. 9 Rated surge overload current

SKN 420 F

Case E 30

DIN 41 814: 152 A 2
JEDEC: DO-200 AB



Dimensions in mm

V_{RSM}	
V_{RRM}	V
	800
	1200
	1400
	1600
	1800

Symbol	SI	US
I_{FAV}		
I_{FSM}		
$i^2 t$		
Q_{rr}		
I_{RM}		
I_R		
T_c		
T_v		
T_v		
V_f		
$V_{(FO)}$		
η		
R_{thjc}		
R_{thch}		
T_{vj}		
T_{sig}		
F	SI	US
w		
Case		

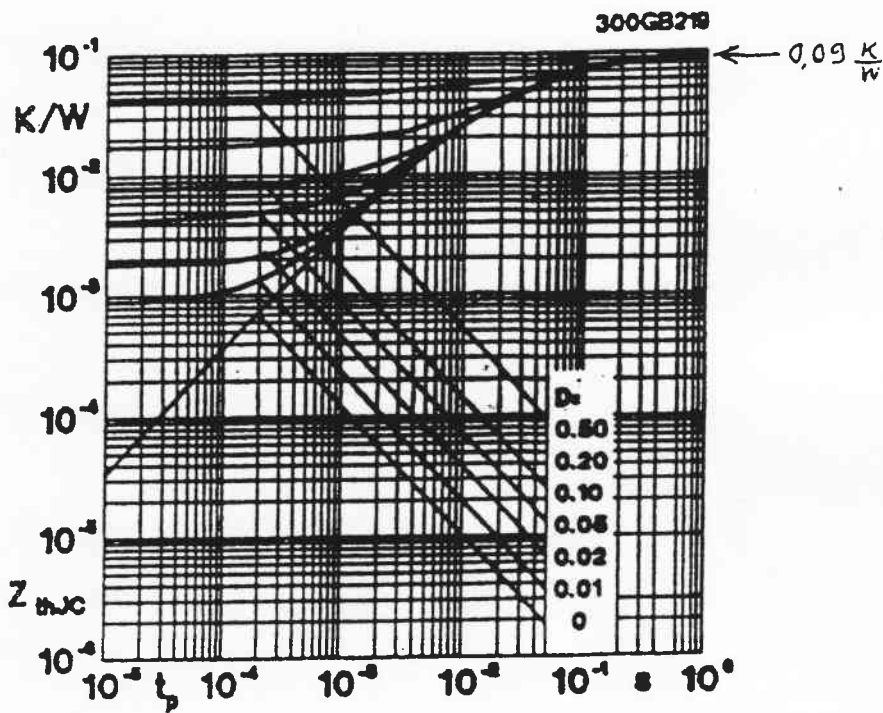


Fig. 19 Transient thermal impedance of IGBT $Z_{thJC} = f(t_p)$; $D = t_p / t_c = t_p \cdot f$

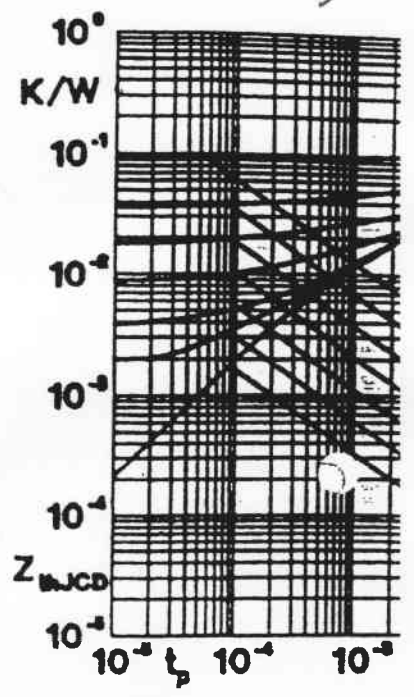


Fig. 20 Transient thermal impedance of inverse CAL diode

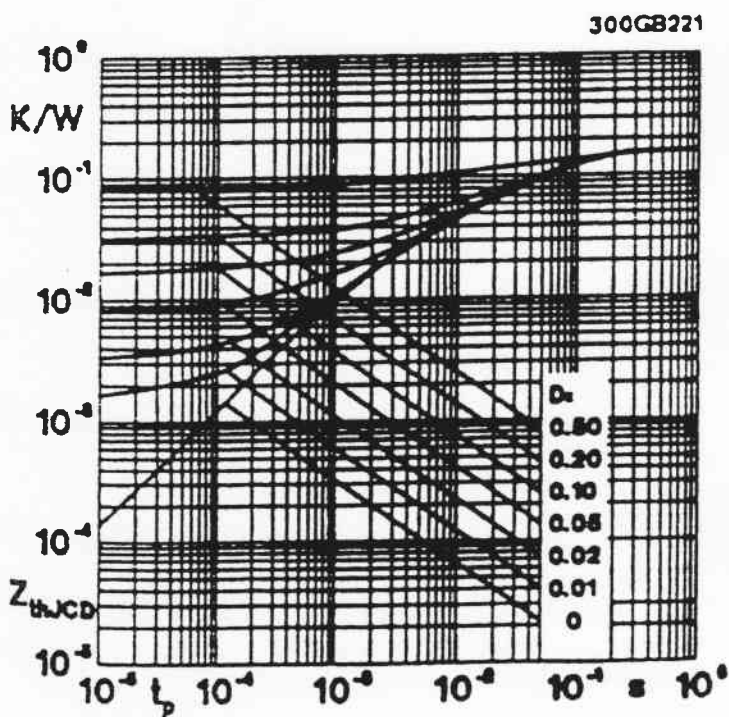


Fig. 21 Transient thermal impedance of the freewheeling diode $Z_{thJC} \rightarrow$ B 6 - 95, rem. 6)

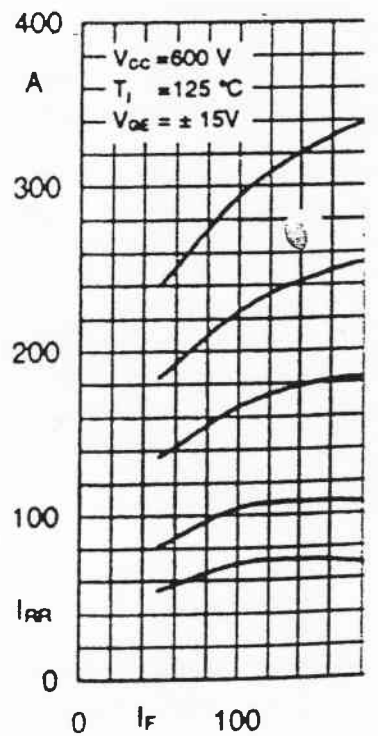
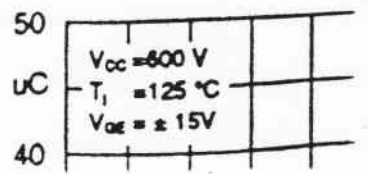
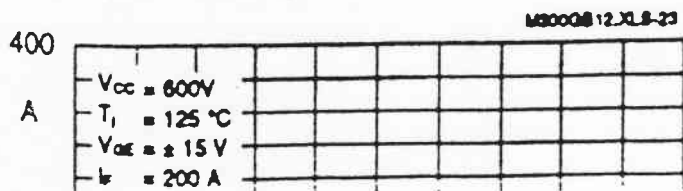


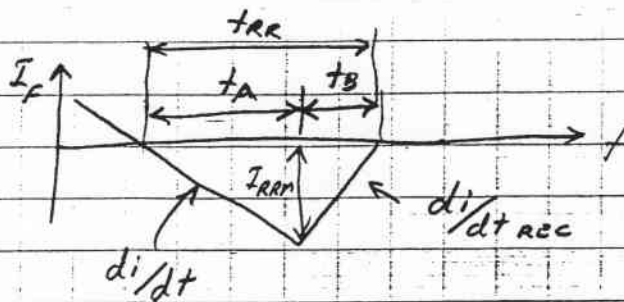
Fig. 22 Typ CAL diode reverse current $I_{RR} = f(I_f)$



Teht. 1, 3 : Katso kirja

Teht. 4:

a)



$$Q_{RR} = \frac{I_{IRM} t_{RR}}{2}$$

$$I_{IRM} = \frac{di}{dt} \cdot t_A = \frac{di}{dt_{REC}} t_B$$

$$\Rightarrow t_A = \frac{I_{IRM}}{\frac{di}{dt}}$$

$$t_{RR} = t_A + t_B = \frac{I_{IRM}}{\frac{di}{dt}} + t_B$$

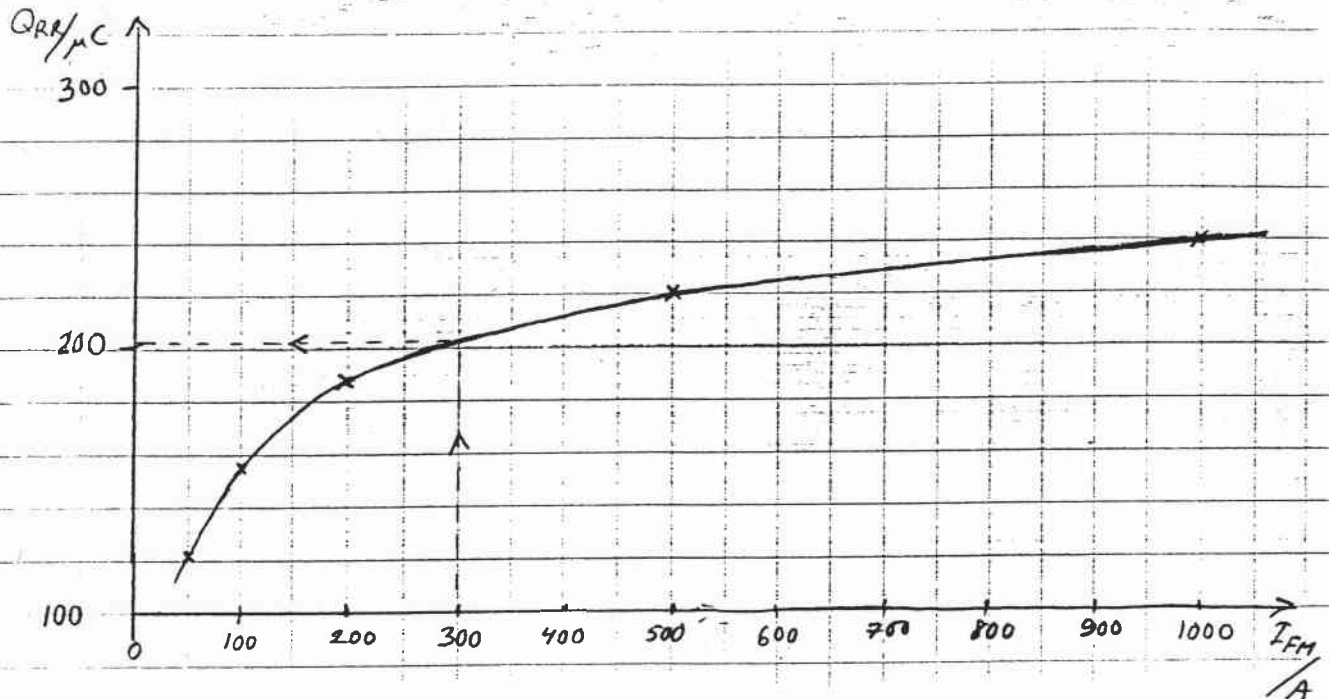
$$\Rightarrow t_B = t_{RR} - \frac{I_{IRM}}{\frac{di}{dt}} = \frac{2Q_{RR}}{I_{IRM}} - \frac{I_{IRM}}{\frac{di}{dt}}$$

$$\Rightarrow \frac{di}{dt_{REC}} = \frac{I_{IRM}}{t_B} = \frac{I_{IRM}}{\frac{2Q_{RR}}{I_{IRM}} - \frac{I_{IRM}}{\frac{di}{dt}}}$$

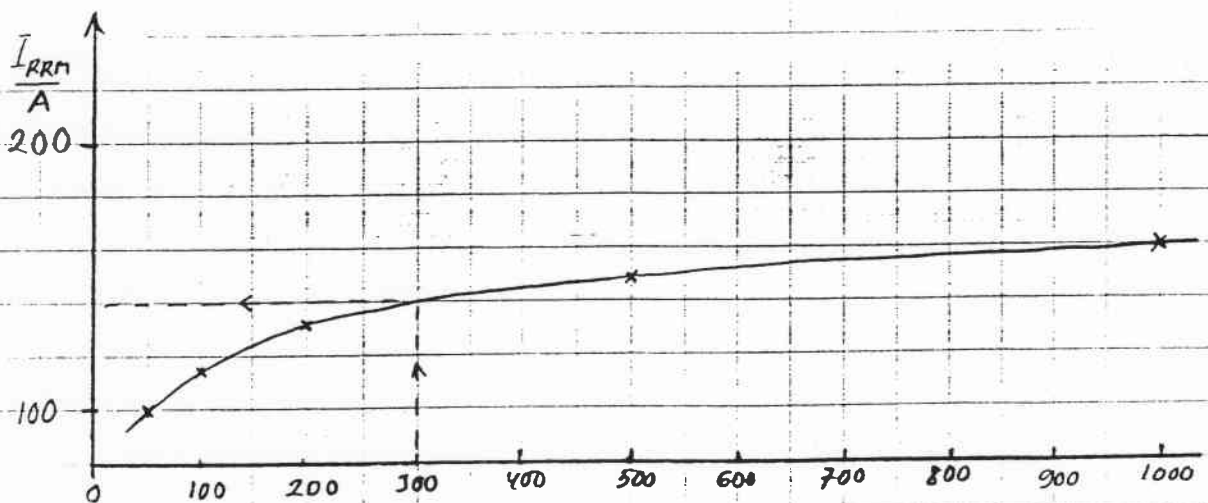
b)

$$\frac{di}{dt} = \frac{300A}{3\mu s} = 100 A/\mu s$$

lehd. 4 jatkoa

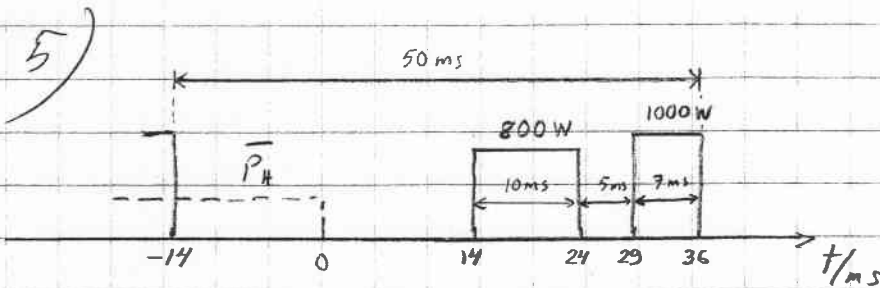
Piirretään kuva 5 auki 100 μs kshdella

$\Rightarrow Q_{RR} \approx 202 \mu\text{C}$ (Huom! Tämä on tyypillinen arvo, numeroarvoissa annettu max 550 μC)

Piirretään kuva 6 auki 100 μs kshdella

$\Rightarrow I_{RRM} \approx 140 \text{ A}$

$$\Rightarrow \frac{di}{dt}_{REC} = \frac{140 \text{ A}}{2 \cdot 202 \mu\text{C}} = \frac{140 \text{ A}}{404 \mu\text{C}} \approx 94 \frac{\text{A}}{\mu\text{s}}$$



Keskimääräinen teho:

$$\bar{P}_H = \frac{800 \text{ W} \cdot 10 \text{ ms} + 1000 \text{ W} \cdot 7 \text{ ms}}{50 \text{ ms}} = 300 \text{ W}$$

Keskimääräinen lämpenemä (\approx lämpenemä hetkellä $t=0$)

$$\bar{\Delta T}_{JC} = \bar{P}_H Z_{thJC}(\infty) = 300 \text{ W} \cdot 0,09 \frac{\text{K}}{\text{W}} = 27 \text{ K}$$

Lämpenemä 800 W pulssin lopussa ($Z(t)$ luetaan käyrältä $D=0$!)

$$\begin{aligned} \Delta T_{JC}(24 \text{ ms}) &= \bar{\Delta T}_{JC} - Z_{thJC}(24 \text{ ms}) \cdot \bar{P}_H + Z_{th}(10 \text{ ms}) \cdot P_1 \\ &= 27 \text{ K} - 0,043 \frac{\text{K}}{\text{W}} \cdot 300 \text{ W} + 0,026 \frac{\text{K}}{\text{W}} \cdot 800 \text{ W} \\ &\approx \underline{35 \text{ K}} \end{aligned}$$

ja 1000 W pulssin lopussa:

$$\begin{aligned} \Delta T_{JC}(36 \text{ ms}) &= \bar{\Delta T}_{JC} - Z_{thJC}(36 \text{ ms}) \cdot \bar{P}_H + (Z_{th}(22 \text{ ms}) - Z_{th}(12 \text{ ms})) P_1 \\ &\quad + Z_{th}(7 \text{ ms}) \cdot P_2 \\ &= 27 \text{ K} - 0,05 \frac{\text{K}}{\text{W}} \cdot 300 \text{ W} + (0,04 \frac{\text{K}}{\text{W}} - 0,028 \frac{\text{K}}{\text{W}}) \cdot 800 \text{ W} \\ &\quad + 0,02 \frac{\text{K}}{\text{W}} \cdot 1000 \text{ W} \\ &\approx \underline{42 \text{ K}} \end{aligned}$$

Siis maksimilämpenemä on noin 42 K