

Tentti 10.1.2011, kello 9 ... 12, sali S1

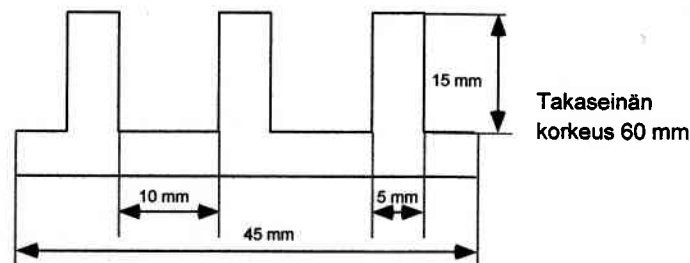
Papereihin

- sukunimi ja etunimet
- opiskelijanumero
- koulutusohjelma.

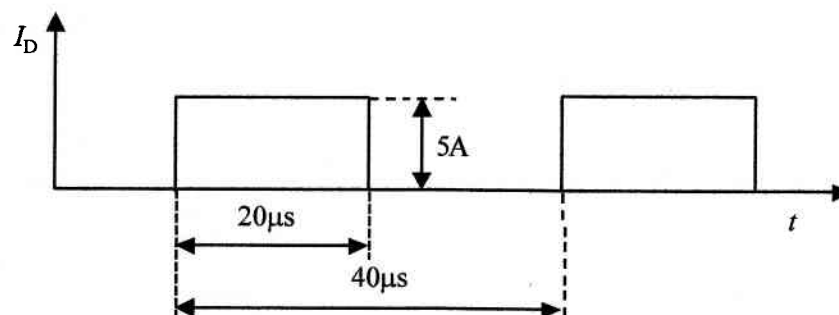
Tentissä sallitut apuvälineet

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

- Selvitä lyhyesti (max. 2...4 lausetta + mahdollinen kuva), mitä seuraavilla termeillä tarkoitetaan
 - neutronisäteilytys
 - muutoslämpövastuskäyrä
 - SOA
 - prospektiivinen oikosulkuvirta
 - Hall-anturi.
- Esittele IGBT:n rakenne, toimintaperiaate ja ominaisuudet.
- Minkälaisia kondensaattoreita käytetään tehoelektronikassa? Mitkä ovat niiden ominaisuudet?
- Erään laitteen hakkuriteholähteen tehopuolijohteiden jäädyttämiseksi luonnollisella tuuletuksella on aiottu muotoilla laitteen takaseinä oheisen kuvan mukaiseksi rivoitukseksi (vain yhden komponentin osuus esitetty). Kuinka suuri saa komponentin häviöteho korkeintaan olla, kun takaseinän sisäpinnan lämpötila ei saa ylittää 80 °C lämpötilaa ulkolämpötilan ollessa 50 °C? Käytä kaavaa $R_{th} = 11,7 A^{-0,7} P_H^{-0,15}$ jossa R_{th} on lämpövastus, yksikkö K/W, A on pinta-ala neliödesimetreissä ja P_H häviöteho watteina. Tehtävässä oletetaan, että laitteen sisällä ei ilma kierrä.



- Määrää IRG4BC20UPbF -IGBT:n vaatiman jäähdytysalueen lämpövastus, kun IGBT:n virta on oheisen kuvan mukainen. Jäähdytysilman lämpötila on 45 °C, $V_{GE} = 15$ V ja $R_G = 50$ Ω. IGBT:n yli oleva jännite on päällekytkennän aikana 360 V ja katkaisun aikana 500 V.



International IR Rectifier

INSULATED GATE BIPOLAR TRANSISTOR

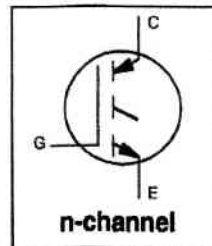
PD - 95445

IRG4BC20UPbF

UltraFast Speed IGBT

Features

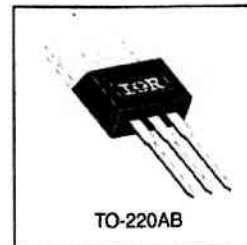
- UltraFast: optimized for high operating frequencies 8-40 kHz in hard switching, >200 kHz in resonant mode
- Generation 4 IGBT design provides tighter parameter distribution and higher efficiency than Generation 3
- Industry standard TO-220AB package
- Lead-Free



$V_{CES} = 600V$
$V_{CE(on) typ.} = 1.85V$
@ $V_{GE} = 15V, I_C = 6.5A$

Benefits

- Generation 4 IGBTs offer highest efficiency available
- IGBTs optimized for specified application conditions
- Designed to be a "drop-in" replacement for equivalent industry-standard Generation 3 IR IGBTs



Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Breakdown Voltage	600	V
$I_C @ T_C = 25^\circ C$	Continuous Collector Current	13	A
$I_C @ T_C = 100^\circ C$	Continuous Collector Current	6.5	
I_{CM}	Pulsed Collector Current Φ	52	
I_{LM}	Clamped Inductive Load Current Φ	52	
V_{GE}	Gate-to-Emitter Voltage	± 20	V
E_{ARV}	Reverse Voltage Avalanche Energy Φ	5.0	mJ
$P_D @ T_C = 25^\circ C$	Maximum Power Dissipation	60	W
$P_D @ T_C = 100^\circ C$	Maximum Power Dissipation	24	
T_J	Operating Junction and	-55 to + 150	°C
T_{STG}	Storage Temperature Range		
	Soldering Temperature, for 10 seconds	300 (0.063 in. (1.6mm from case))	
	Mounting torque, 6-32 or M3 screw.	10 lbf-in (1.1N-m)	

Thermal Resistance

	Parameter	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	—	2.1	°C/W
$R_{\theta CS}$	Case-to-Sink, Flat, Greased Surface	0.50	—	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	—	80	
W	Weight	2.0 (0.07)	—	g (oz)

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6/22/04

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IR RectifierElectrical Characteristics @ $T_J = 25^\circ\text{C}$ (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage	600	—	—	V	$V_{GE} = 0V, I_C = 250\mu A$
$V_{(BR)ECS}$	Emitter-to-Collector Breakdown Voltage ①	18	—	—	V	$V_{GE} = 0V, I_C = 1.0A$
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.69	—	V/°C	$V_{GE} = 0V, I_C = 1.0mA$
$V_{CE(ON)}$	Collector-to-Emitter Saturation Voltage	—	1.85	2.1	V	$I_C = 6.5A, V_{GE} = 15V$ See Fig. 2, 5
		—	2.27	—		
		—	1.87	—		
$V_{GE(th)}$	Gate Threshold Voltage	3.0	—	6.0		$I_C = 6.5A, T_J = 150^\circ\text{C}$
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	—	-11	—	mV/°C	$V_{CE} = V_{GE}, I_C = 250\mu A$
g_{fe}	Forward Transconductance ②	1.4	4.3	—	S	$V_{CE} = 100V, I_C = 6.5A$
I_{CES}	Zero Gate Voltage Collector Current	—	—	250	μA	$V_{GE} = 0V, V_{CE} = 600V$
		—	—	2.0		$V_{GE} = 0V, V_{CE} = 10V, T_J = 25^\circ\text{C}$
		—	—	1000		$V_{GE} = 0V, V_{CE} = 600V, T_J = 150^\circ\text{C}$
I_{GES}	Gate-to-Emitter Leakage Current	—	—	± 100	nA	$V_{GE} = \pm 20V$

Switching Characteristics @ $T_J = 25^\circ\text{C}$ (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions		
Q_g	Total Gate Charge (turn-on)	—	27	41	nC	$I_C = 6.5A$ $V_{CC} = 400V$ See Fig. 8 $V_{GE} = 15V$		
Q_{ge}	Gate - Emitter Charge (turn-on)	—	4.5	6.8				
Q_{gc}	Gate - Collector Charge (turn-on)	—	10	16				
$t_{d(on)}$	Turn-On Delay Time	—	21	—	ns	$T_J = 25^\circ\text{C}$ $I_C = 6.5A, V_{CC} = 480V$ $V_{GE} = 15V, R_G = 50\Omega$ Energy losses include "tail"		
t_r	Rise Time	—	13	—				
$t_{d(off)}$	Turn-Off Delay Time	—	86	130				
t_f	Fall Time	—	120	180				
E_{on}	Turn-On Switching Loss	—	0.10	—				
E_{off}	Turn-Off Switching Loss	—	0.12	—	mJ	See Fig. 10, 11, 13, 14		
E_{sw}	Total Switching Loss	—	0.22	0.4				
$t_{d(on)}$	Turn-On Delay Time	—	20	—	ns	$T_J = 150^\circ\text{C}$, $I_C = 6.5A, V_{CC} = 480V$ $V_{GE} = 15V, R_G = 50\Omega$ Energy losses include "tail"		
		t_r	Rise Time	—			14	—
		$t_{d(off)}$	Turn-Off Delay Time	—			190	—
		t_f	Fall Time	—			140	—
		E_{sw}	Total Switching Loss	—			0.42	—
L_E	Internal Emitter Inductance	—	7.5	—	nH	Measured 5mm from package		
C_{ies}	Input Capacitance	—	530	—	pF	$V_{GE} = 0V$ $V_{CC} = 30V$ See Fig. 7 $f = 1.0MHz$		
C_{oss}	Output Capacitance	—	39	—				
C_{res}	Reverse Transfer Capacitance	—	7.4	—				

Notes:

- ① Repetitive rating; $V_{GE} = 20V$, pulse width limited by max junction temperature. (See fig. 13b)
- ② $V_{CC} = 80\%(V_{CES})$, $V_{GE} = 20V$, $L = 10\mu H$, $R_G = 50\Omega$. (See fig. 13a)
- ③ Repetitive rating; pulse width limited by maximum junction temperature.
- ④ Pulse width $\leq 80\mu s$; duty factor $\leq 0.1\%$.
- ⑤ Pulse width $5.0\mu s$, single shot.

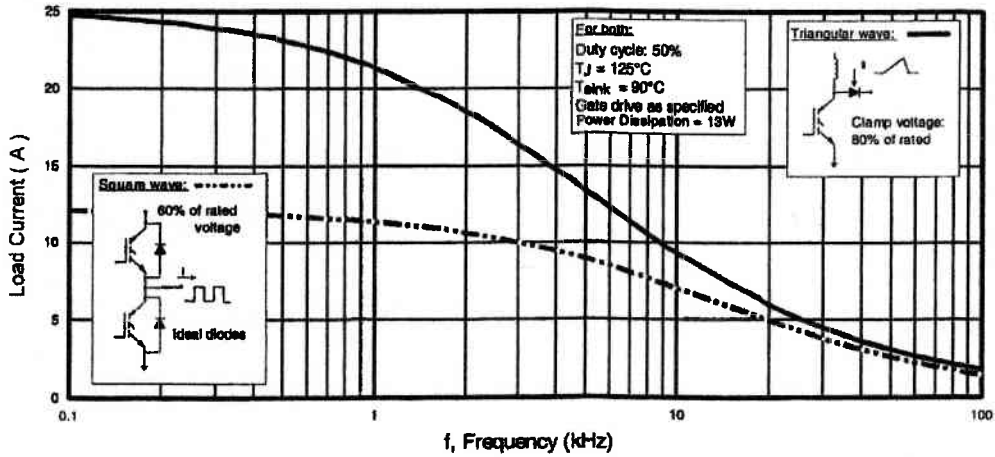


Fig. 1 - Typical Load Current vs. Frequency
(For square wave, $I = I_{RMS}$ of fundamental; for triangular wave, $I = I_{PK}$)

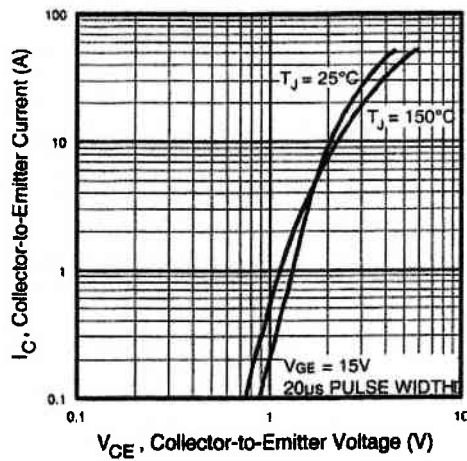


Fig. 2 - Typical Output Characteristics

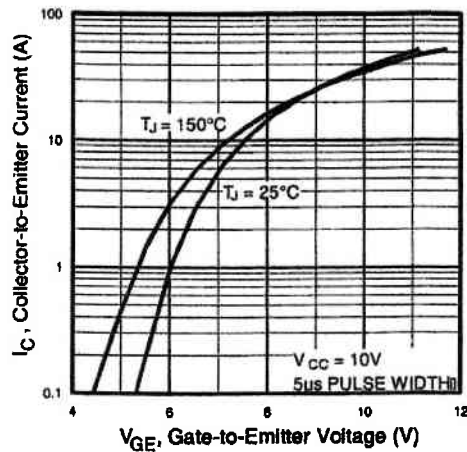


Fig. 3 - Typical Transfer Characteristics

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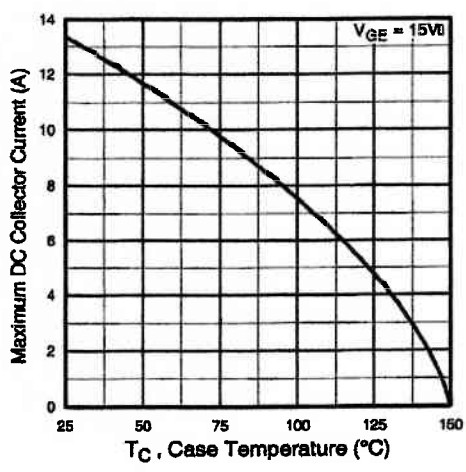


Fig. 4 - Maximum Collector Current vs. Case Temperature

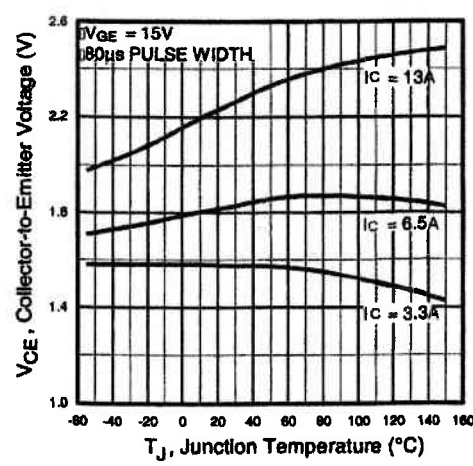


Fig. 5 - Collector-to-Emitter Voltage vs. Junction Temperature

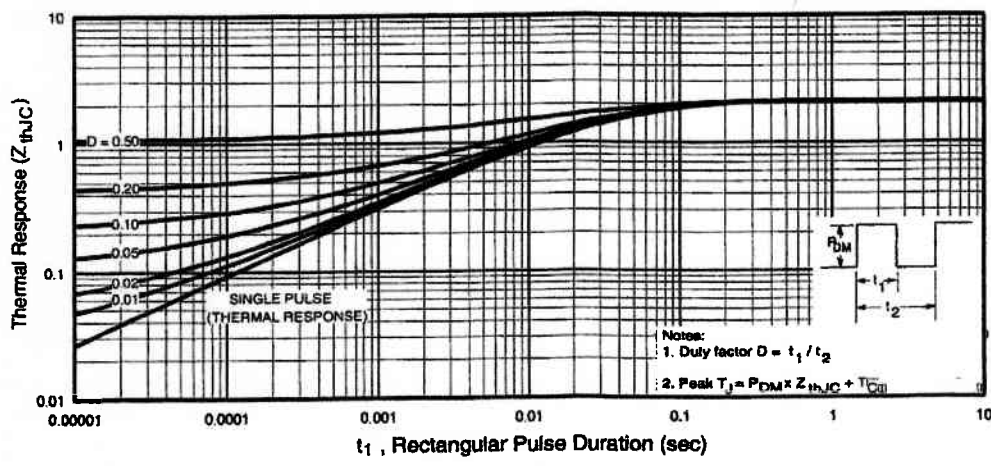


Fig. 6 - Maximum Effective Transient Thermal Impedance, Junction-to-Case

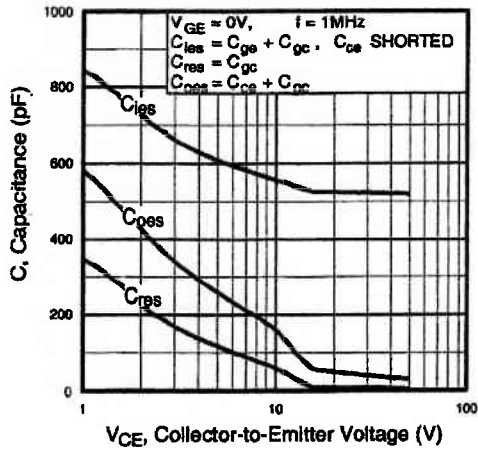


Fig. 7 - Typical Capacitance vs. Collector-to-Emitter Voltage

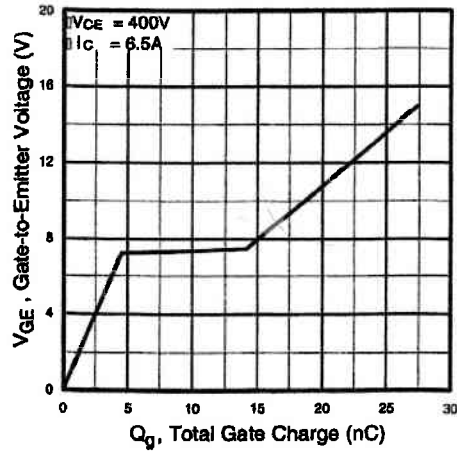


Fig. 8 - Typical Gate Charge vs. Gate-to-Emitter Voltage

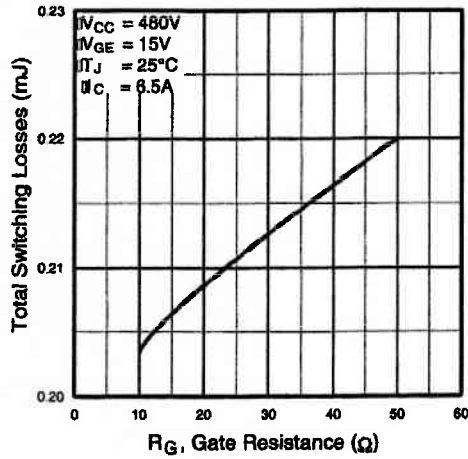


Fig. 9 - Typical Switching Losses vs. Gate Resistance

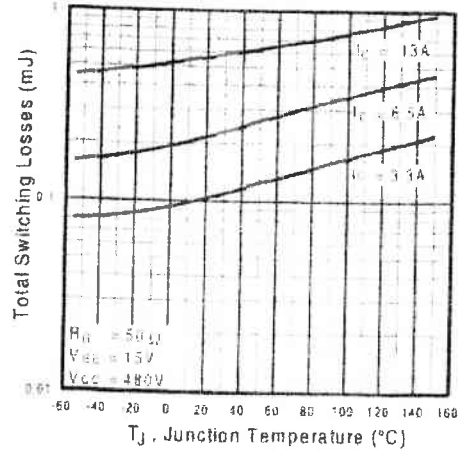


Fig. 10 - Typical Switching Losses vs. Junction Temperature

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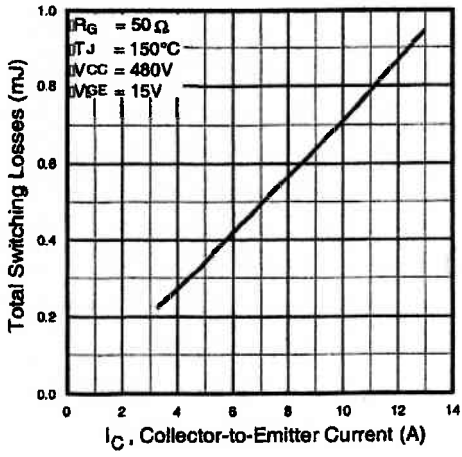


Fig. 11 - Typical Switching Losses vs. Collector-to-Emitter Current

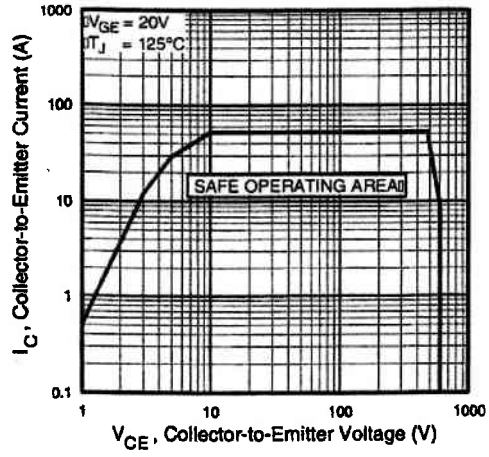
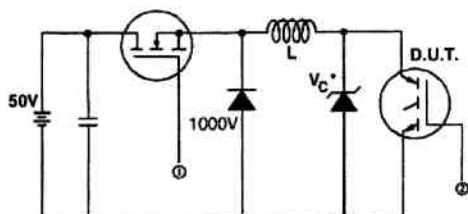


Fig. 12 - Turn-Off SOA



* Driver same type as D.U.T.; $V_c = 80\%$ of $V_{ce(max)}$
 * Note: Due to the 50V power supply, pulse width and inductor will increase to obtain rated I_d .

Fig. 13a - Clamped Inductive Load Test Circuit

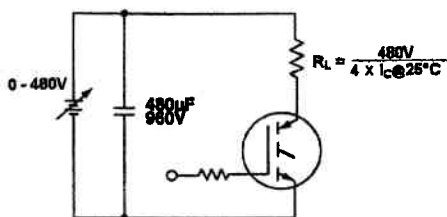


Fig. 13b - Pulsed Collector Current Test Circuit

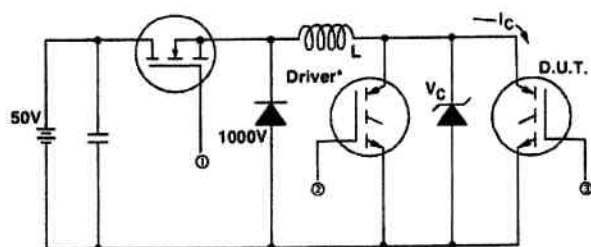


Fig. 14a - Switching Loss Test Circuit

* Driver same type as D.U.T., $V_c = 480V$

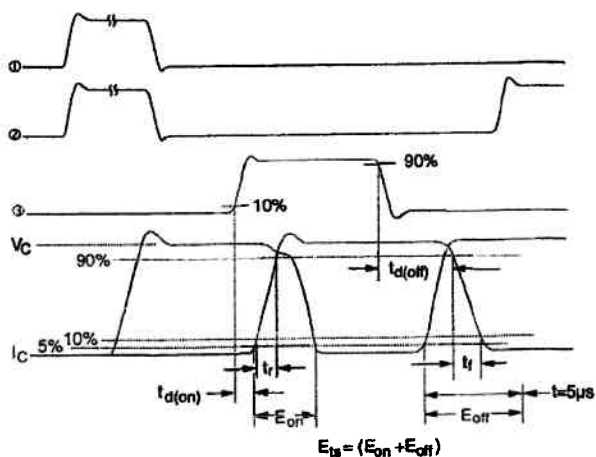


Fig. 14b - Switching Loss Waveforms

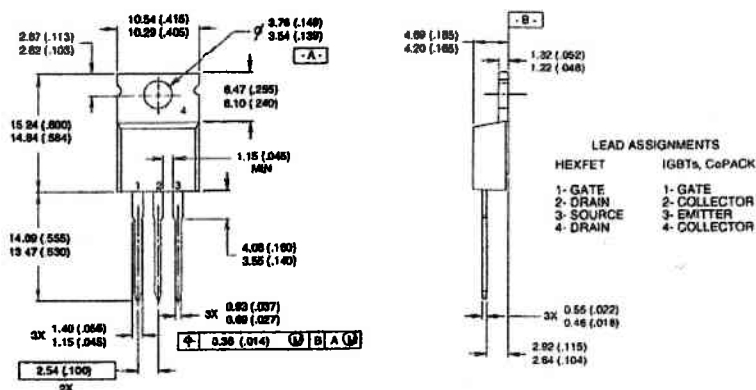
$$E_{ts} = (E_{on} + E_{off})$$

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TO-220AB Package Outline

Dimensions are shown in millimeters (inches)



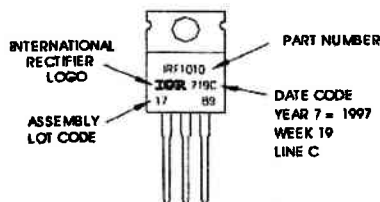
- NOTES:
- 1 DIMENSIONING & TOLERANCING PER ANSI Y14.5M, 1982
 - 2 CONTROLLING DIMENSION : INCH
 - 3 OUTLINE CONFORMS TO JEDEC OUTLINE TO-220AB
 - 4 HEAT-SINK & LEAD MEASUREMENTS DO NOT INCLUDE BURRS.

LEAD ASSIGNMENTS

HEXFET	IGBTs, CoPACK
1- GATE	1- GATE
2- DRAIN	2- COLLECTOR
3- SOURCE	3- EMITTER
4- DRAIN	4- COLLECTOR

TO-220AB Part Marking Information

EXAMPLE: THIS IS AN IRF1010
 LOT CODE 1789
 ASSEMBLED ON WW 19, 1997
 IN THE ASSEMBLY LINE "C"
 Note: "P" in assembly line
 position indicates "Lead-Free"



Data and specifications subject to change without notice.

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S-81,3120 Tehoelektroniikan komponentit
Tentti 10.1.2011 Ratkaisut

Tehtävät 1-3: Katso kirja

Tehtävä 4

$$R_{thsa} = 11,7 A^{-0,7} \cdot P_H^{-0,15} = \frac{T_s - T_A}{P_H}$$

$$\Rightarrow P_{Hmax}^{0,85} = \frac{T_s - T_A}{11,7 A^{-0,7}}$$

$$\Rightarrow P_{Hmax} = \left(\frac{T_s - T_A}{11,7 A^{-0,7}} \right)^{\frac{1}{0,85}}$$

Kotelon sisällä oletettiin ilmakierron olevan mitättömän \Rightarrow jäähdytys-elementti jäähtyy vain ulkopinnaltaan

$$\Rightarrow A = (45 \text{ mm} + 6 \cdot 15 \text{ mm}) \cdot 60 \text{ mm} = 8100 \text{ mm}^2 = 0,81 \text{ dm}^2$$

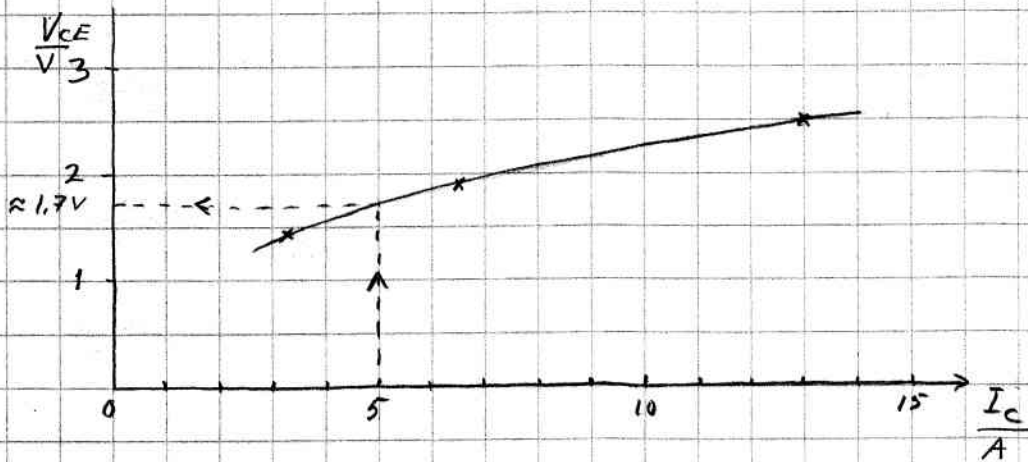
jos elementin ylä- ja alapintoja ei huomioida
(niiden pinta-ala = $6 \cdot 15 \cdot 5 \text{ mm} = 450 \text{ mm}^2 = 0,045 \text{ dm}^2$
 \Rightarrow pieni, lisäksi ilma ei niissä välttämättä liiku)

$$\Rightarrow P_{Hmax} \approx \left(\frac{80 - 50}{11,7 \cdot 0,81^{-0,7}} \right)^{\frac{1}{0,85}} = \underline{\underline{2,55 \text{ W}}}$$

Teht. 5

Johtohäviöt

Suoraan kuvasta 2: $V_{CE} = 14 \cdot 10 \frac{6\text{mm}}{26\text{mm}} \approx 1,7\text{V}$ tai
Kuva 5 aukipiirrettynä; kun $T_J = 150^\circ\text{C}$



Siten $V_{CE} \approx 1,7\text{V}$

$$E_{\text{HON}} = V_{CE} \cdot I_C \cdot t_{\text{ON}} = 1,7\text{V} \cdot 5\text{A} \cdot 20\mu\text{s} = 170\mu\text{J}$$

Kytkehäviöt

Kaikkina kuvissa 9, 10 ja 11 on päällekytkentä ja katkaisuhäviöiden summa 480V jännitteelle. Nyt päällekytkennän aikana jännite on 360V ja katkaisussa 500V. Numeroarvista nähdään (switching characteristics) että 25°C lämpötilassa suhde $E_{\text{on}}/E_{\text{off}} = 0,1\text{mJ}/0,12\text{mJ} \approx 0,833$. Oletetaan, että sama suhde pätee myös isommissa lämpötiloissa.

Tentti 10.1.2011 Ratk.

Teht. 5 jatkona

Kuvasta 11 saadaan 5 A virralla ja 480 V jännitteellä

$$E_{rs} \approx 340 \mu\text{J} \quad \text{joten} \quad E_{on} = \frac{0,1 \text{ ms}}{0,22 \text{ ms}} \cdot 340 \mu\text{J} \approx 155 \mu\text{J}$$

$$E_{off} = \frac{0,12 \text{ ms}}{0,22 \text{ ms}} \cdot 340 \mu\text{J} = 185 \mu\text{J}$$

Jos oletetaan häviön olevan verrannollinen jännitteeseen, ovat kytkentähäviöt

$$E_{on} \approx \frac{360 \text{ V}}{480 \text{ V}} \cdot 155 \mu\text{J} \approx 116 \mu\text{J}$$

$$E_{off} \approx \frac{500 \text{ V}}{480 \text{ V}} \cdot 185 \mu\text{J} = 193 \mu\text{J}$$

Siten

$$P_{H_{ave}} = \frac{1}{T} (E_{cond} + E_{on} + E_{off}) = \frac{1}{40 \mu\text{s}} (170 \mu\text{J} + 116 \mu\text{J} + 193 \mu\text{J})$$

$$= 12,0 \text{ W}$$

Määritetään kuoren lämpötila kuvan 6 perusteella

Keskimääräinen teho johtojalle laskettuna on

$$P_{DM} = \frac{T_1}{t_{on}} \cdot P_{H_{ave}} = \frac{40 \mu\text{s}}{20 \mu\text{s}} \cdot 12,0 \text{ W} = 24,0 \text{ W}$$

$$\text{Kuvasta 6 kun } D = \frac{t_{on}}{T} = \frac{20 \mu\text{s}}{40 \mu\text{s}} = 0,5 \quad \text{ja} \quad t_1 = t_{on} = 20 \mu\text{s}$$

$$Z_{thjc} \approx 1,1 \text{ }^\circ\text{C/W}$$

$$\Rightarrow T_c = T_J - P_{DM} \cdot Z_{thjc} = 150 \text{ }^\circ\text{C} - 24,0 \text{ W} \cdot 1,1 \frac{^\circ\text{C}}{\text{W}} = 124 \text{ }^\circ\text{C}$$

Jäähdytysalueen lämpövastuksen on siten oltava

$$\underline{R_{thSA}} \leq \frac{T_c - T_A}{P_{H_{ave}}} - R_{thCS} = \frac{124 \text{ }^\circ\text{C} - 45 \text{ }^\circ\text{C}}{12,0 \text{ W}} - 0,5 \text{ }^\circ\text{C/W}$$

$$\approx \underline{6,1 \text{ }^\circ\text{C/W}}$$