

Univerza v Ljubljani

Fakulteta za elektrotehniko

Gašper Matič

Krmiljenje moči rezistivnega bremena

Seminarska naloga pri predmetu Elektronska vezja

Verd, 8.9.2009

1. Uvodna beseda

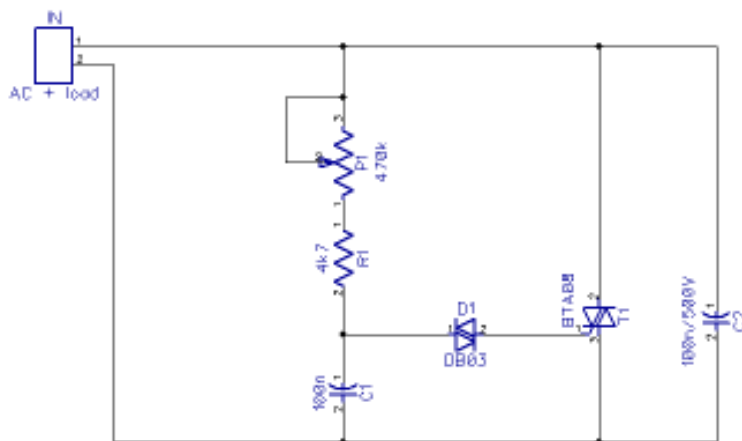
Priznati moram, da sem imel kar nekaj problemov z izbiro tematike moje seminarske naloge. V čem je bil problem? Bila sta pravzaprav kar dva. Prvi je bil v tem, da do sedaj s samim procesom izdelave elektronskih vezij praktično nisem imel nobenih izkušenj. Drugi pa je sledil iz prvega: večina projektov, ki bi me zanimali, so bili pa prezahtevni za začetnika. Tako sem se odločil napraviti nekakšen kompromis: izdelal sem zelo preprosto napravo, ki pa mi bo v nadaljne prišla prav v domači delavnici. Namenil sem se namreč izdelati preprost krmilnik moči, s katerim bi lahko nastavljal moč večjega spajkalnika, ki ga nameravam uporabljati za pospajkavanje vezij. Upam, da mi bo izdelana naprava dobro služila vsaj nekaj časa.



Starejši 150W »spenglerski« spajkalnik, produkt Jugoslavije. Izkazal se je kot zelo uporaben pri pospajkavanju vezij.

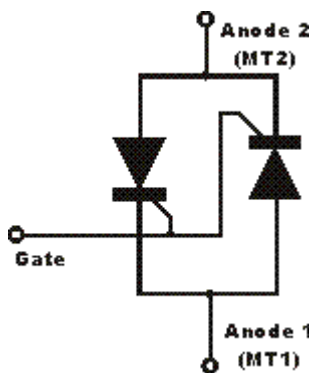
2. Opis delovanja vezja

Obstaja veliko principov regulacije moči. Ker pa moj primer ne zahteva posebno prefinjene metode (pravzaprav moramo le krmiliti moč na električnem grelcu, kar pomeni da je oblika signala na njem lahko zelo popačena) in ker je enostavnost pravzaprav zaželjena (enostavnejša montaža v priročno ohišje), sem se odločil da uporabim kar vezje, ki temelji na triaku – t.i. dimmer vezje, ki se uporablja s podobnim namenom za zatemnjevanje osvetljave z lučmi. Princip delovanja tega vezja je zelo enostaven: triak deluje kot nivojsko proženo stikalo, tj. ko na t.i. gate vhod pripeljemo dovolj visoko napetost (oz. ko v gate spustimo dovolj velik tokovni pulz), se stikalo sklene in triak prevaja vse dokler napetost čez stikalo (torej med anodama triaka) ne zamenja predznaka (triak je namreč nekakšna antiparalelna vezava dveh tiristorjev in tiristor prevaja tok le v eno smer). To stikalno sposobnost triaka pa nato uporabimo za krmiljenje toka skozi breme in s tem moči na bremenu. Potrebujemo le še vezje, ki bo poskrbelo za vklop triaka. Kot že vemo, se ob spremembi predznaka napetosti na anodah triaka le-ta zapre in ne prevaja. Iščemo vezje, ki ga bo ponovno (čez čas) odprlo. Besedna zveza »čez čas« nam da misliti, da to vezje opravlja nalogo zakasnjevalnika. Očitno res potrebujemo zakasnjevalnik, ki bo triak po določenem času spet prisilil v prevajanje. Kot zakasnjevalnik lahko uporabimo RC člen in vezje je že zelo blizu uporabnemu. Problem takega vezja bi bil v tem, da bi mu težje nastavili čas zakasnitve do ponovnega vklopa triaka. Zelo ugodno bi bilo, če bi se prevajanje triaka zgodilo skokoma. Zato se med RC člen in gate na triaku skoraj vedno doda še diac, ki pa s svojo vhodno karakteristiko poskrbi za hipen vžig triaka: dokler je napetost na triaku majhna, le ta ne prevaja toka, ko pa dosežemo t.i. vžigno napetost, pa se diac »odpre« in prevaja tok z majhno upornostjo (podobno kot »svečke«). In tako dobimo sledeče preprosto vezje:

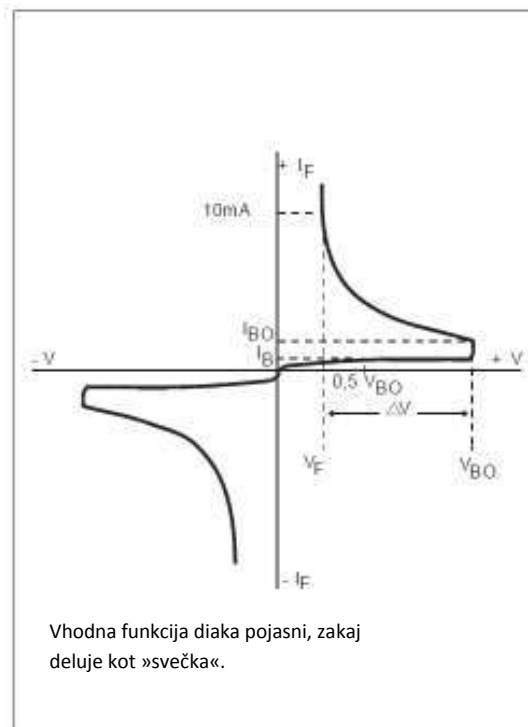


S spremenljivim uporom v RC členu dosežemo možnost nastavljanja zakasnitve do vžiga triaka in s tem možnost nastavljanja moči na bremenu. Krmilnik moči vežemo seveda zaporedno z napajanjem in bremenom. Na shemi vidimo še dodatni kondenzator C2. Njegova naloga pa je, da poreže

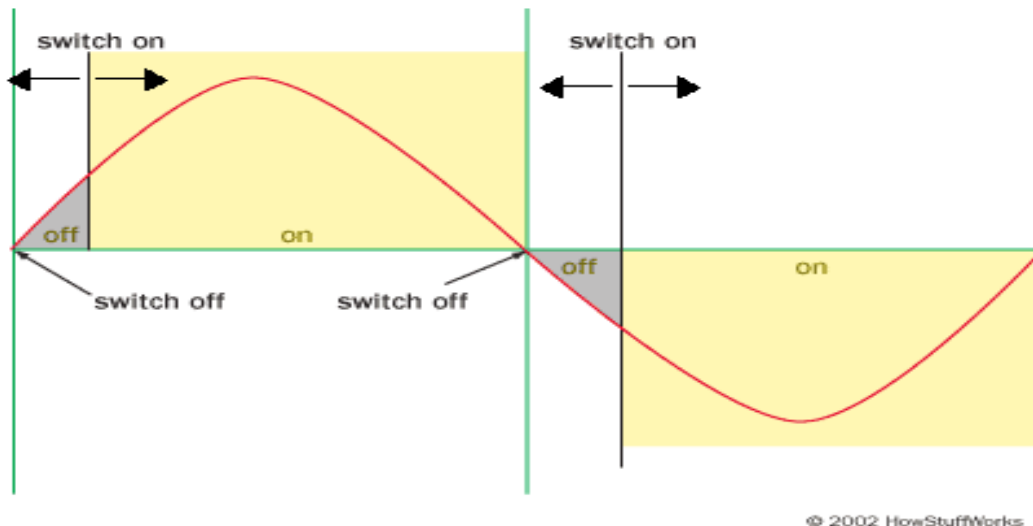
napetostne špice na triaku, do katerih pride ob hitrih spremembah toka skozi triak, saj se takrat na vseh induktivnih elementih inducira visoka, a kratkotrajna napetost. Morda lahko že kar na tem mestu dodam še možnost izboljšave vezja: vklapljanje in izklapljanje triaka povzroča precej skokovite spremembe električnih veličin, kar pa lahko povzroča probleme. Ker tako popačimo vhodni tok, lahko postanejo problematični višji harmoniki signala. Potrebno je torej filtriranje teh komponent. Del te naloge že opravlja kondenzator C2, še bolje bi pa bilo, če bi v serijo s triakom vezali še primerno veliko in zmogljivo tuljavo, ki bi pa poskrbela za to, da bi bili prehodi toka skozi triak (in zato breme in posledično iz omrežja) gladkejši in manj VF popačeni.



Triak kot vezava dveh antiparalelno vezanih tiristorjev. Eno polperiodo prevaja en tiristor, drugo pa drugi.



Princip stikalnega krmiljenja moči s triakom.



3. Izvedba vezja

Najprej le na kratko o izbiri elementov.

Triac je bil izbran tako, da skozenj lahko teče tak tok, kot sicer običajno teče skozi breme, torej spajkalnik. Iz nazivne moči spajkalnika lahko ob izmerjeni upornosti spajkalnika določimo efektivni tok skozi spajkalnik. In triac mora zdržati ta tok. No, izbrani triac je več kot očitno predimenzioniran, saj bo vezje izvedeno tako, da ga bo mogoče uporabljati še za druga bremena.

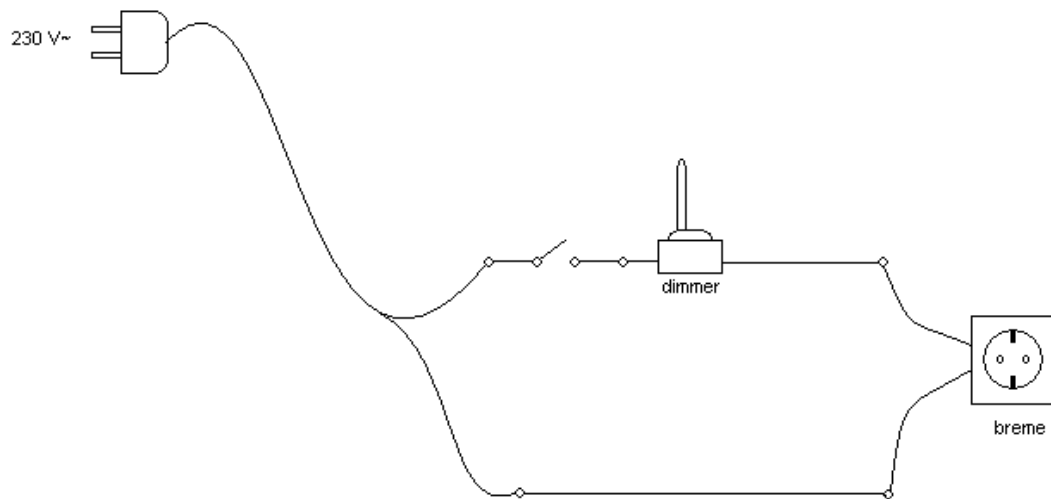
Pri diakih ni posebno velike izbire. Izbrani diak se vžge pri napetostih okoli 30 V.

Premislimo elemente RC člena: smiselno je, da napetost na kondenzatorju doseže vžigno napetost diaka znotraj ene polperiode vhodnega signala, saj le tako dobimo regulator moči. Torej se mora RC konstanta gibati v rangu od desetinke milisekunde do nekaj deset milisekund. Če izberemo kondenzator C1 kot tak, lahko hitro določimo še potreben razpon potenciometra.

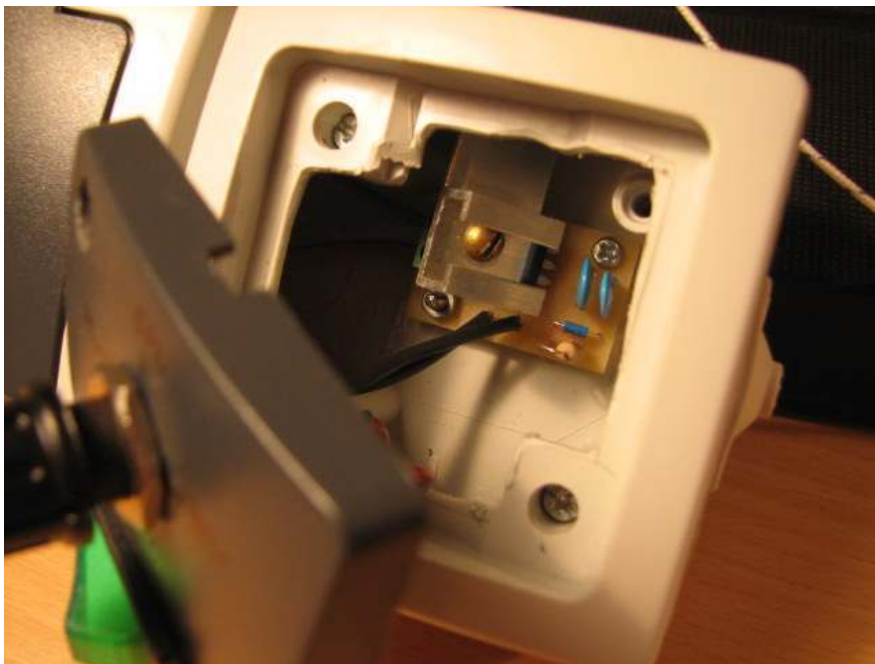
Kondenzator C2 filtrira napetostne špice na triaku, zato mora biti dimenzioniran za visoke napetosti (400 V ali več). Mora biti tudi primerno majhen, da premošča le hitre velike spremembe napetosti na stikalu.

Dodaten hladilnik na triaku je bil dodan »za vsak slučaj«. Namreč, za regulacijo moči na spajkalniku je tok skozenj manjši od 1A, kar pa v praksi pomeni, da dodaten hladilnik ni potreben. Vseeno pa sem dodal hladilno aluminijasto rebro. Velikost le-tega sem določil s primerjanjem s hladilnimi rebri podobnih vezij.

Vezje – krmilnik moči sem se odločil izvesti tako, da ga je mogoče uporabiti za različna manjša rezistivna bremena, ki se sicer napajajo iz omrežja. Ideja je bila sledeča:



Po vgradnji vezja

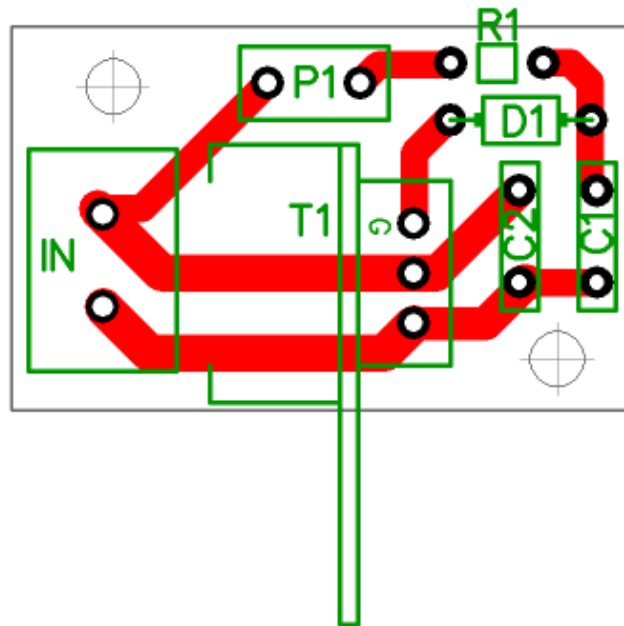


je tako nastala sledeča naprava



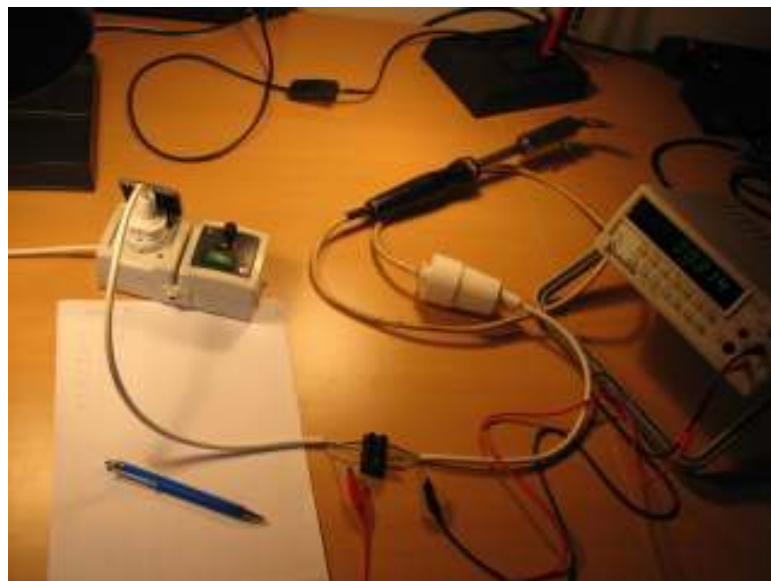
Nato sem montiral še gumbek ter vrisal relativno skalo.

Izvedba PCB. Vidi se obris hladilnega rebra.

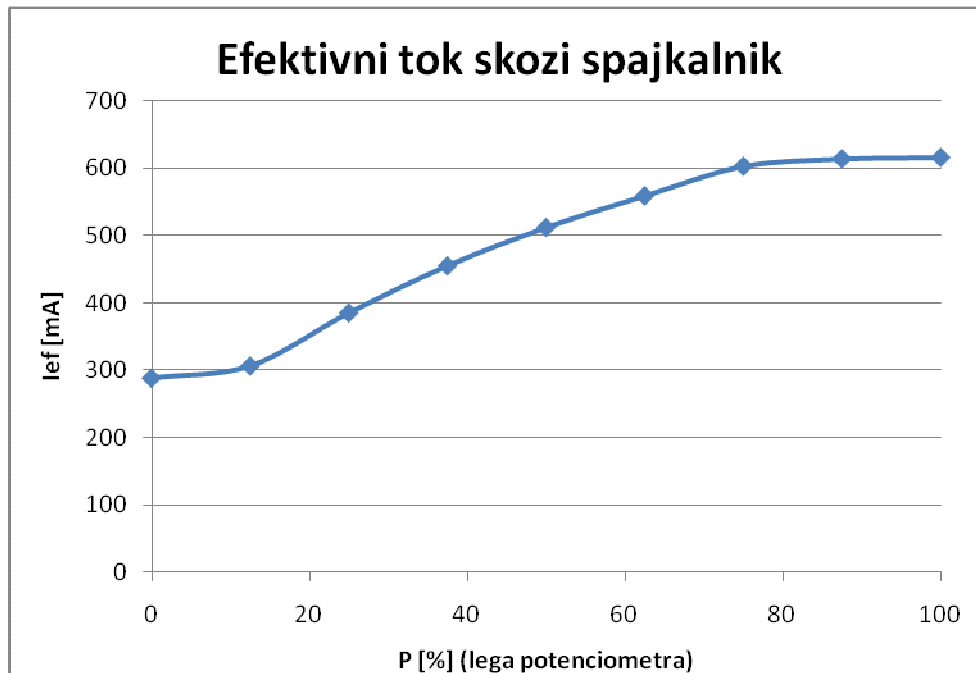


4. Meritve in umerjanje

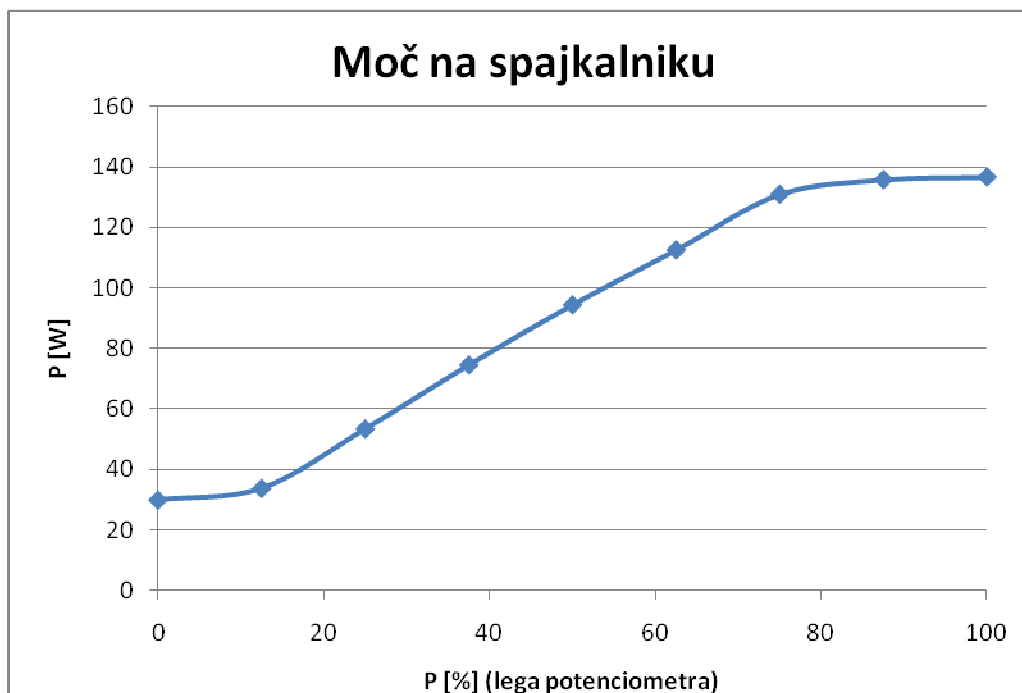
Ker je vezje precej preprosto, niti ni mogoče opraviti veliko »zgovornih« meritev. Tako sem opravil le meritve linearnosti (oz. nelinearnosti) krmiljenja moči – torej preveril sem odvisnost efektivnega toka (oz. moči na bremenu) od položaja krmilnega potenciometra.



Meritve efektivnega toka je bila opravljena z multimetrom GDM-8245



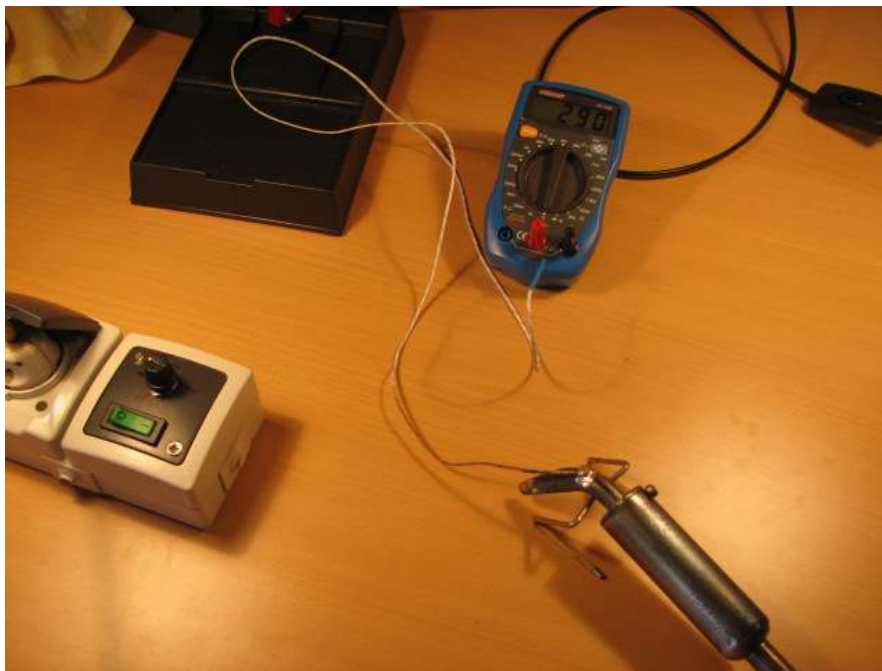
Presenetljivo dobimo v srednjem delu karakteristke še kar linearen potek toka. Kar je pa še bolj presenetljivo je pa to, da je potek moči še bolj linearen ($P = I_{ef}^2 \cdot R$; $R = 360 \text{ Ohm}$).



Smiselni bi bili še meritvi napetostnih/tokovnih špic in pa frekvenčne slike napetosti na bremenu. S tem bi ugotovil, kako dobro oz. slabo opravlja svojo nalogo filtrirni kondenzator C2 in kako nujno je potrebna zgoraj že omenjena dušilna tuljava. A zaradi pomankanja opreme te meritve nisem opravil.

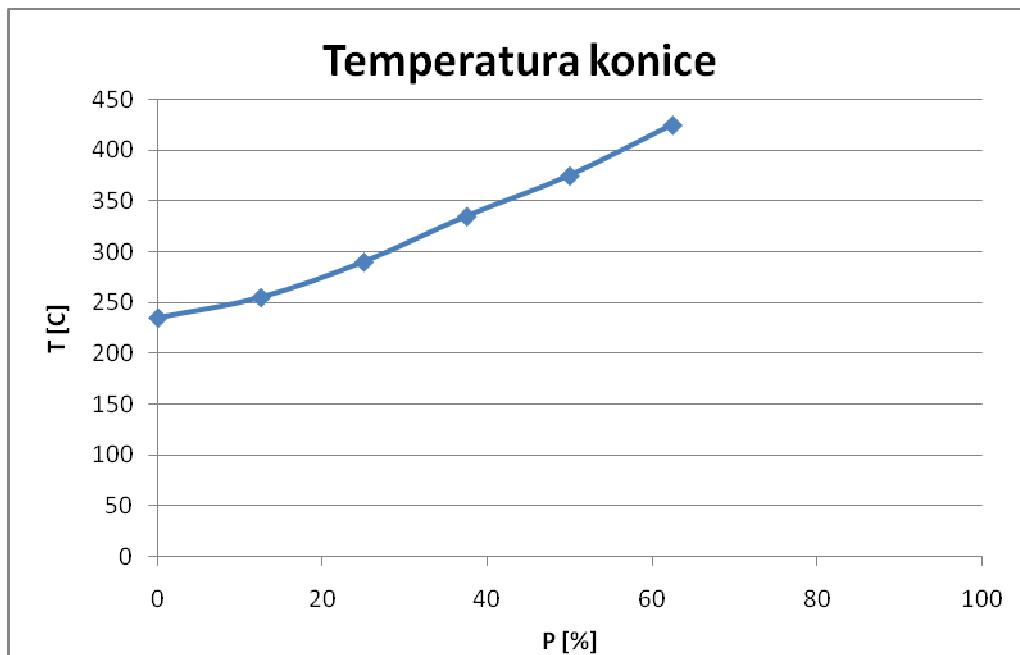
Zanimivo bi bilo še istočasno opazovati tok skozi triak/vhodno napetost in pa vžigno napetost na kondenzatorju C1.

Zamislil sem si pa še, da bi k potenciometru umeril temperaturno skalo s temperaturo konice spajkalnika. Meritev je potekala pri sobnih pogojih na sledeč način: potenciometer sem nastavil na določen položaj in počakal, da se je teperatura konice ustalila. Nato sem to temperaturo pripisal na skalo k potenciometru.



Meritev temperature konice je bila opravljena z multimetrom Voltcraft VC140.

Izkazalo se je, da tudi temperatura konice še kar linearna (pričakovano, saj moč v konico tudi raste linearno). Problem pa postajajo zelo dolgi prehodni časi potrebni, da se temperatura konice ustali.



5. Zaključek

Zaključim lahko, da naprava opravlja svojo funkcijo. Problem pa je mogoče v tem, kako dobro opravlja to funkcijo. Namreč, med njenim delovanjem je mogoče slišati brenčanje vezja. Do tega najbrž pride zaradi visokih špic in ostrih prehodov signalov. To bi morda popravila ustrezno dimenzionirana tuljava v seriji s triakom.

Izboljšav vezja je precej. Izmed vseh pa se mi zdi zelo smiselna vpeljava negativnega povratnega skopa kar bi krmiljenje moči spremenilo v regulacijo moči na spajkalniku. Ideja bi bila sledeča: na konico spajkalnika se pritrdi temperaturni senzor, katerega izhod pretvorimo v napetost. S to napetostjo in pa referenčno napetostjo (ki predstavlja željeno temperaturo konice) pa nato v neg. PS krmilimo triak tako, da dosežemo željeno temperaturo konice.

Negativni povratni sklop bi bil vsekakor smiselni tudi zato, ker bi precej zmanjšal prehodne čase potrebne, da se temperatura konice spajkalnika ustali. Problem krmiljenja moči v primeru segrevanja konice je v tem, da z njim zmanjšamo moč, ki jo dovajamo bremenu. S tem zmanjšamo tudi stacionarno temperaturo konice, prehodni čas je pa večji, kot bi lahko bil če bi vpeljali regulacijo: z regulacijo bi konico segrevali najprej z maksimalno močjo, ko pa bi prišli blizu željene temperature, bi pa moč primerno zmanjšali.

Mogoče bi bilo smiselno glede na krivuljo toka še povečati velikost potenciometra, kar bi še raztegnilo razpon moči, ki jo lahko krmilimo bremenu.

Naj pa dodam le še, da navkljub vsem možnim izboljšavam in brnenju vezja, se stari okorni spajkalnik v navezi z izdelanim vezjem odlično obnese pri pospajkavanju vezij.



Pospajkavanje vezij na ta način je zelo enostavno in hitro.

6. Viri

http://www.electronics-radio.com/articles/electronic_components/scr/what-is-a-triac.php

http://www.electronics-radio.com/articles/electronic_components/scr/what-is-a-thyristor.php

http://www.electronics-radio.com/articles/electronic_components/scr/what-is-a-diac.php

<http://home.howstuffworks.com/dimmer-switch2.htm>

<http://www.geocities.com/tomzi.geo/dimmer/dimmer.htm>



DB3 DB4 SMDB3

DIAC

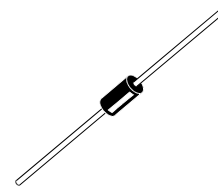
FEATURES

- V_{BO} : 32V and 40V
- LOW BREAKOVER CURRENT

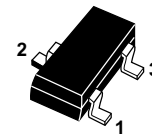
DESCRIPTION

Functioning as a trigger diode with a fixed voltage reference, the DB3/DB4 series can be used in conjunction with triacs for simplified gate control circuits or as a starting element in fluorescent lamp ballasts.

A new surface mount version is now available in SOT-23 package, providing reduced space and compatibility with automatic pick and place equipment.



DO-35
(DB3 and DB4)



SOT-23
(SMDB3)*
Pin 1 and 3 must be shorted together

ABSOLUTE MAXIMUM RATINGS (limiting values)

Symbol	Parameter	Value	Unit
I_{TRM}	Repetitive peak on-state current $t_p = 20 \mu s$ $F = 120 \text{ Hz}$	SMDB3	1.00
		DB3 / DB4	2.00
T_{stg} T_j	Storage temperature range Operating junction temperature range	- 40 to + 125	$^{\circ}C$

Note: * SMDB3 indicated as Preliminary spec as product is still in development stage.

DB3 DB4 SMDB3

ELECTRICAL CHARACTERISTICS (Tj = 25°C unless otherwise specified)

Symbol	Parameter	Test Conditions	SMDB3	DB3	DB4	Unit	
V _{BO}	Breakover voltage *	C = 22nF **	MIN.	28	28	35	V
			TYP.	32	32	40	
			MAX.	36	36	45	
V _{BO1} - V _{BO2}	Breakover voltage symmetry	C = 22nF **	MAX.	3		V	
ΔV	Dynamic breakover voltage *	V _{BO} and V _F at 10mA	MIN.	10	5	V	
V _O	Output voltage *	see diagram 2 (R=20Ω)	MIN.	10	5	V	
I _{BO}	Breakover current *	C = 22nF **	MAX.	10	50	μA	
t _r	Rise time *	see diagram 3	MAX.	0.50	2	μs	
I _R	Leakage current *	V _R = 0.5 V _{BO} max	MAX.	1	10	μA	
I _P	Peak current *	see diagram 2 (Gate)	MIN.	1	0.30	A	

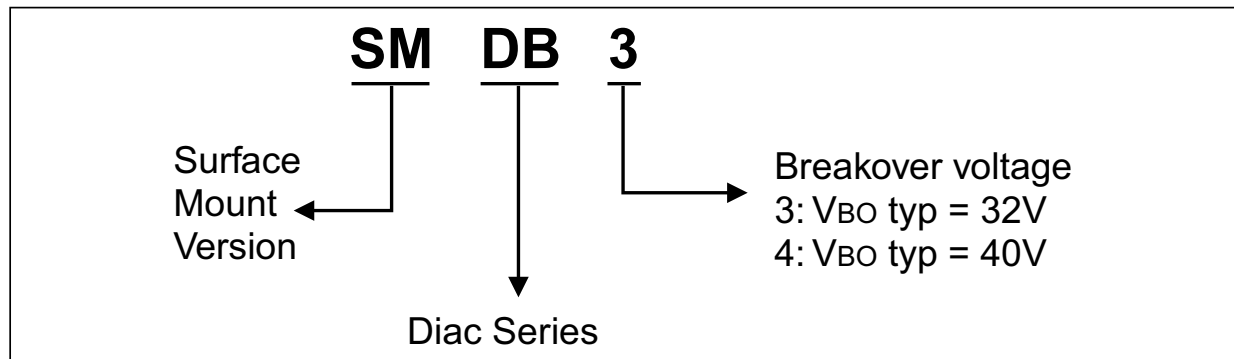
* Applicable to both forward and reverse directions.

** Connected in parallel to the device.

PRODUCT SELECTOR

Part Number	V _{BO}	Package
SMDB3	28 - 36	SOT-23
DB3	28 - 36	DO-35
DB4	35 - 45	DO-35

ORDERING INFORMATION



OTHER INFORMATION

Part Number	Marking	Weight	Base Quantity	Packing Mode
SMDB3	DB3	0.01 g	3000	Tape & Reel
DB3	DB3 (Blue Body Coat)	0.15 g	5000	Tape & Reel
DB4	DB4 (Blue Body Coat)	0.15 g	5000	Tape & Reel

Diagram 1: Voltage - current characteristic curve.

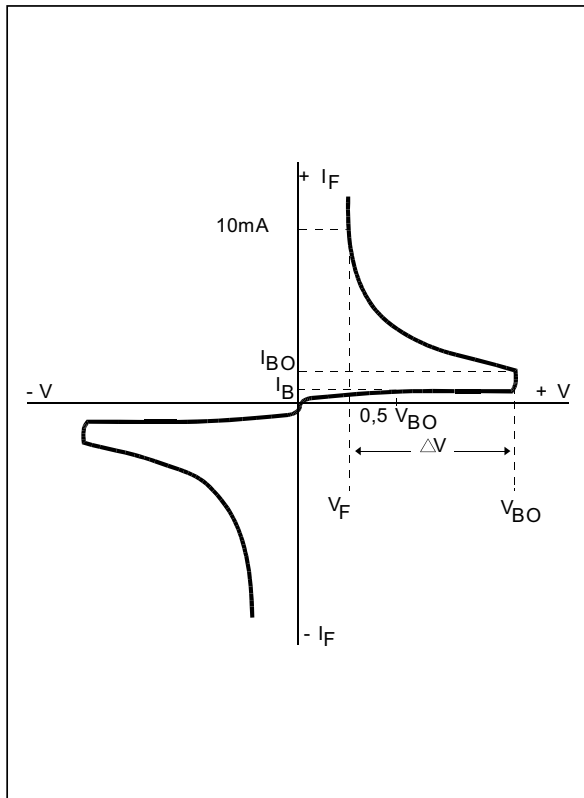


Diagram 2: Test circuit.

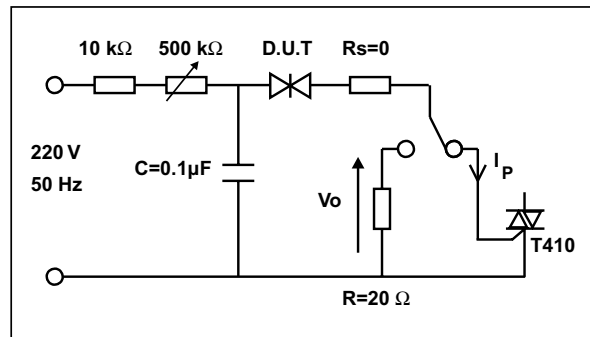


Diagram 3: Rise time measurement.

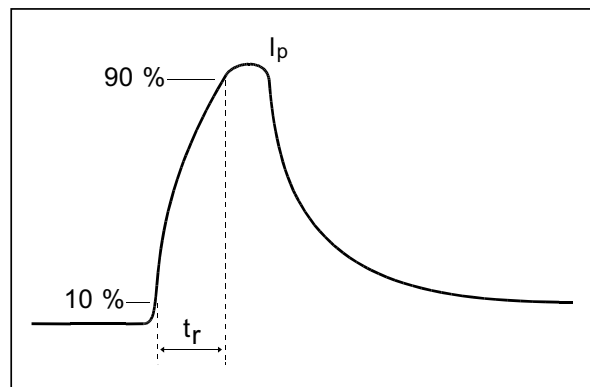


Fig. 1: Relative variation of VBO versus junction temperature (typical values).

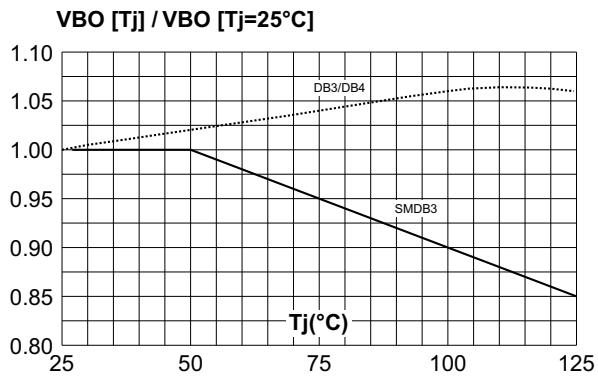


Fig. 2: Repetitive peak pulse current versus pulse duration (maximum values).

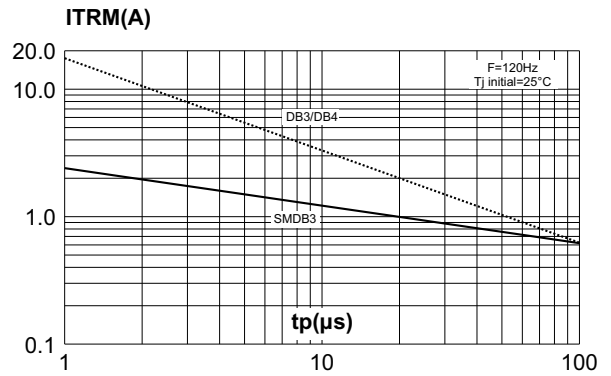
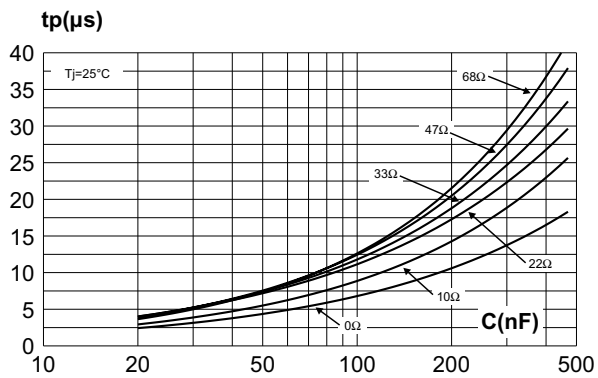
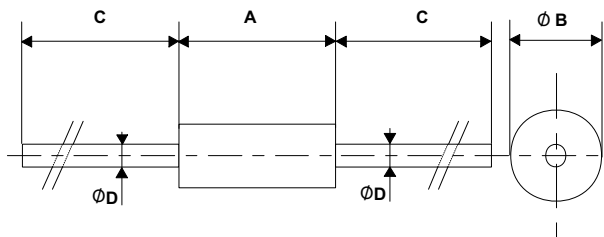


Fig. 3: Time duration while current pulse is higher 50mA versus C and Rs (typical values).



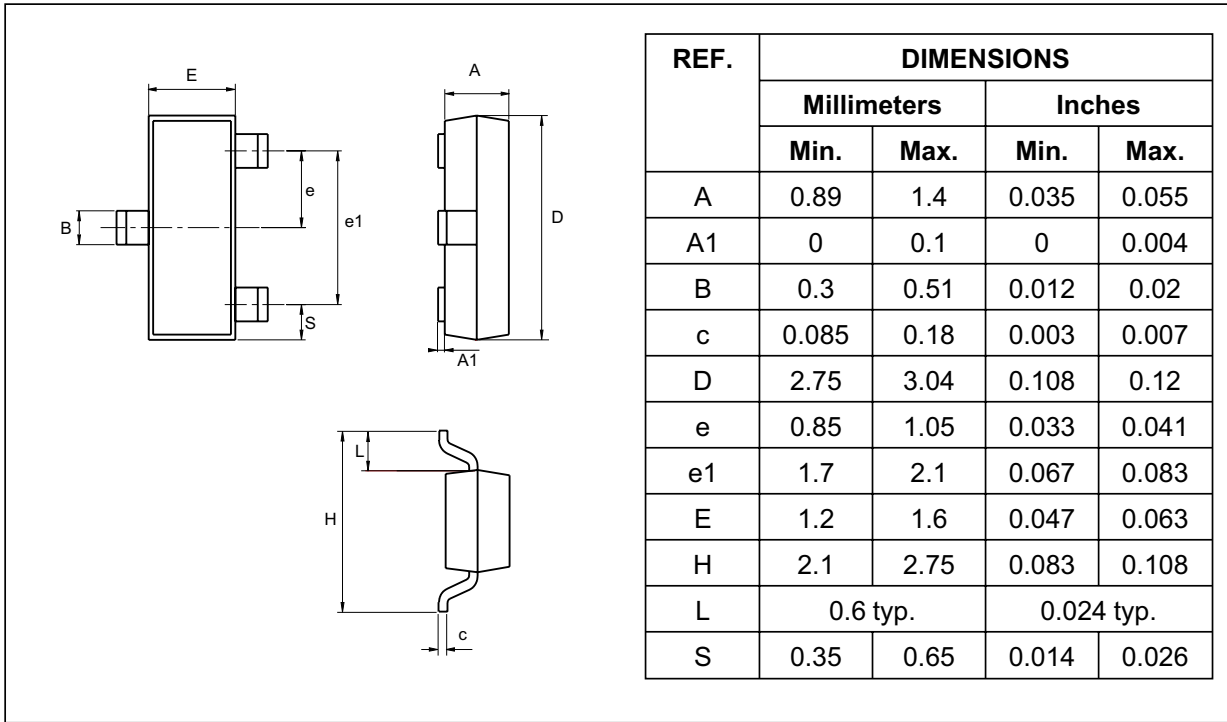
PACKAGE MECHANICAL DATA (in millimeters)
DO-35



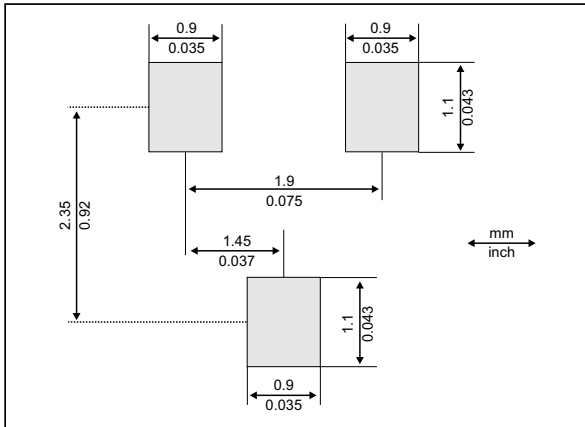
REF.	DIMENSIONS			
	Millimeters		Inches	
	Min.	Max.	Min.	Max.
A	3.05	4.50	0.120	0.177
B	1.53	2.00	0.060	0.079
C	28.00		1.102	
D	0.458	0.558	0.018	0.022

PACKAGE MECHANICAL DATA (in millimeters)

SOT-23



FOOTPRINT



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BTA/BTB08 and T8 Series

SNUBBERLESS™, LOGIC LEVEL & STANDARD

8A TRIACs

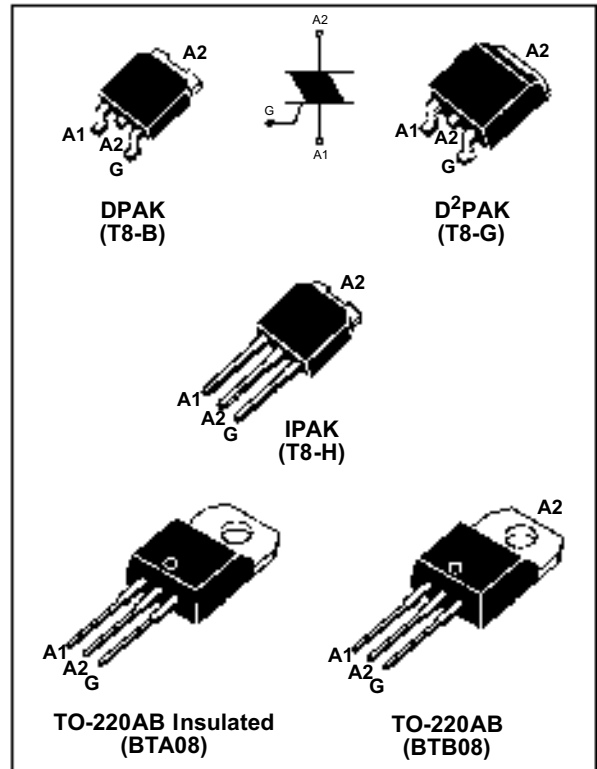
MAIN FEATURES:

Symbol	Value	Unit
$I_{T(RMS)}$	8	A
V_{DRM}/V_{RRM}	600 and 800	V
$I_{GT}(Q_1)$	5 to 50	mA

DESCRIPTION

Available either in through-hole or surface-mount packages, the BTA/BTB08 and T8 triac series is suitable for general purpose AC switching. They can be used as an ON/OFF function in applications such as static relays, heating regulation, induction motor starting circuits... or for phase control operation in light dimmers, motor speed controllers,...

The snubberless versions (BTA/BTB...W and T8 series) are specially recommended for use on inductive loads, thanks to their high commutation performances. By using an internal ceramic pad, the BTA series provides voltage insulated tab (rated at 2500V RMS) complying with UL standards (File ref.: E81734)



ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter		Value	Unit
$I_{T(RMS)}$	RMS on-state current (full sine wave)	DPAK / D PAK IPAK / TO-220AB $T_c = 110^\circ\text{C}$	8	A
		TO-220AB Ins. $T_c = 100^\circ\text{C}$		
I_{TSM}	Non repetitive surge peak on-state current (full cycle, T_j initial = 25°C)	F = 50 Hz t = 20 ms	80	A
		F = 60 Hz t = 16.7 ms	84	
I_t	I_t Value for fusing	tp = 10 ms	45	A s
dI/dt	Critical rate of rise of on-state current $I_G = 2 \times I_{GT}$, tr ≤ 100 ns	F = 120 Hz $T_j = 125^\circ\text{C}$	50	A/μs
I_{GM}	Peak gate current	tp = 20 μs $T_j = 125^\circ\text{C}$	4	A
$P_{G(AV)}$	Average gate power dissipation	$T_j = 125^\circ\text{C}$	1	W
T_{stg} T_j	Storage junction temperature range Operating junction temperature range		- 40 to + 150 - 40 to + 125	$^\circ\text{C}$

BTA/BTB08 and T8 Series

ELECTRICAL CHARACTERISTICS (T_j = 25°C, unless otherwise specified)

■ SNUBBERLESS™ and LOGIC LEVEL (3 Quadrants)

Symbol	Test Conditions	Quadrant		T8		BTA/BTB08				Unit
				T810	T835	TW	SW	CW	BW	
I _{GT} (1)	V _D = 12 V R _L = 30 Ω	I - II - III	MAX.	10	35	5	10	35	50	mA
V _{GT}			MAX.	1.3						
V _{GD}	V _D = V _{DRM} R _L = 3.3 kΩ T _j = 125°C	I - II - III	MIN.	0.2						V
I _H (2)	I _T = 100 mA	I - III	MAX.	15	35	10	15	35	50	mA
I _L	I _G = 1.2 I _{GT}		MAX.	25	50	10	25	50	70	
				30	60	15	30	60	80	
dV/dt (2)	V _D = 67 %V _{DRM} gate open T _j = 125°C		MIN.	40	400	20	40	400	1000	V/μs
(di/dt) _c (2)	(dV/dt) _c = 0.1 V/μs T _j = 125°C		MIN.	5.4	-	3.5	5.4	-	-	A/ms
	(dV/dt) _c = 10 V/μs T _j = 125°C			2.8	-	1.5	2.8	-	-	
	Without snubber T _j = 125°C			-	4.5	-	-	4.5	7	

■ STANDARD (4 Quadrants)

Symbol	Test Conditions	Quadrant		BTA/BTB08		Unit
				C	B	
I _{GT} (1)	V _D = 12 V R _L = 30 Ω	I - II - III IV	MAX.	25	50	mA
V _{GT}				50	100	
V _{GD}	V _D = V _{DRM} R _L = 3.3 kΩ T _j = 125°C	ALL	MIN.	0.2		V
I _H (2)	I _T = 500 mA		MAX.	25	50	mA
I _L	I _G = 1.2 I _{GT}	I - III - IV	MAX.	40	50	mA
		II		80	100	
dV/dt (2)	V _D = 67 %V _{DRM} gate open T _j = 125°C		MIN.	200	400	V/μs
(dV/dt) _c (2)	(di/dt) _c = 3.5 A/ms T _j = 125°C		MIN.	5	10	V/μs

STATIC CHARACTERISTICS

Symbol	Test Conditions			Value	Unit
V _{TM} (2)	I _{TM} = 11 A t _p = 380 μs	T _j = 25°C	MAX.	1.55	V
V _{to} (2)	Threshold voltage	T _j = 125°C	MAX.	0.85	V
R _d (2)	Dynamic resistance	T _j = 125°C	MAX.	50	mΩ
I _{DRM}	V _{DRM} = V _{RDM}	T _j = 25°C	MAX.	5	μA
I _{RDM}		T _j = 125°C		1	mA

Note 1: minimum I_{GT} is guaranteed at 5% of I_{GT} max.

Note 2: for both polarities of A2 referenced to A1

THERMAL RESISTANCES

Symbol	Parameter	Value	Unit	
$R_{th(j-c)}$	Junction to case (AC)	DPAK / D PAK IPAK / TO-220AB	1.6	°C/W
		TO-220AB Insulated	2.5	
$R_{th(j-a)}$	Junction to ambient	S = 1 cm D PAK	45	°C/W
		S = 0.5 cm DPAK	70	
		TO-220AB TO-220AB Insulated	60	
		IPAK	100	

S = Copper surface under tab

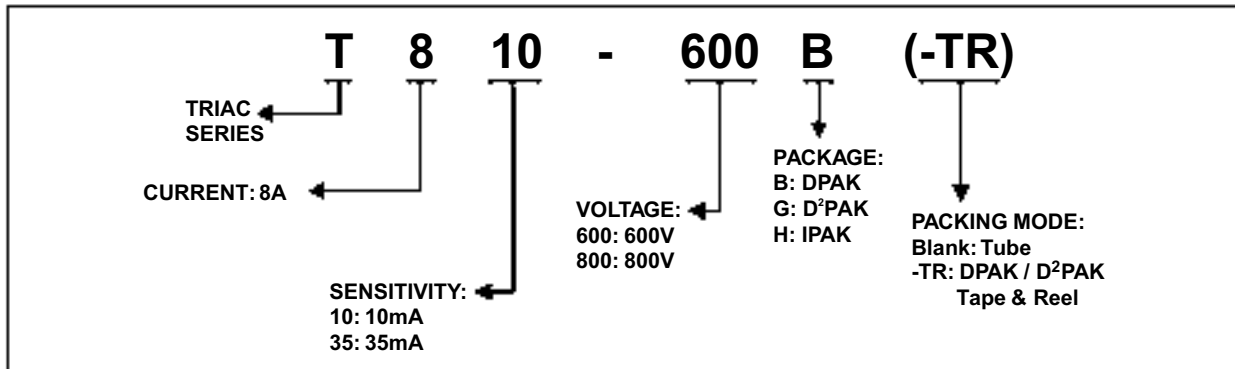
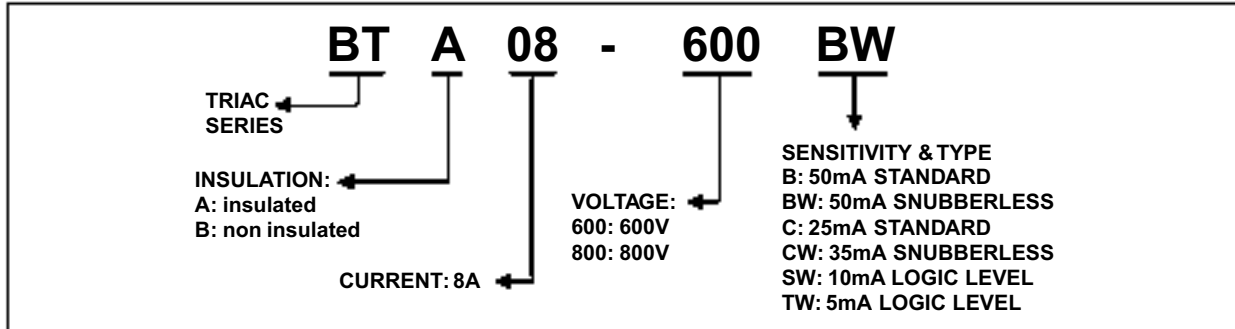
PRODUCT SELECTOR

Part Number	Voltage (xxx)		Sensitivity	Type	Package
	600 V	800 V			
BTA/BTB08-xxxB	X	X	50 mA	Standard	TO-220AB
BTA/BTB108-xxxBW	X	X	50 mA	Snubberless	TO-220AB
BTA/BTB08-xxxC	X	X	25 mA	Standard	TO-220AB
BTA/BTB08-xxxCW	X	X	35 mA	Snubberless	TO-220AB
BTA/BTB08-xxxSW	X	X	10 mA	Logic level	TO-220AB
BTA/BTB08-xxxTW	X	X	5 mA	Logic level	TO-220AB
T810-xxxB	X	X	10 mA	Logic level	DPAK
T810-xxxH	X	X	10 mA	Logic level	IPAK
T835-xxxB	X	X	35mA	Snubberless	DPAK
T835-xxxG	X	X	35 mA	Snubberless	D PAK
T835-xxxH	X	X	35 mA	Snubberless	IPAK

BTB: non insulated TO-220AB package

BTA/BTB08 and T8 Series

ORDERING INFORMATION



OTHER INFORMATION

Part Number	Marking	Weight	Base quantity	Packing mode
BTA/BTB08-xxxzy	BTA/BTB08xxxzy	2.3 g	250	Bulk
T8yy-xxxB	T8yyxxx	0.3 g	75	Tube
T8yy-xxxB-TR	T8yyxxx	0.3 g	2500	Tape & reel
T8yy-xxxH	T8yyxxx	0.4 g	75	Tube
T8yy-xxxG	T8yyxxx	1.5 g	50	Tube
T8yy-xxxG-TR	T8yyxxx	1.5 g	1000	Tape & reel

Note: xxx = voltage, yy = sensitivity, z = type

Fig. 1: Maximum power dissipation versus RMS on-state current (full cycle).

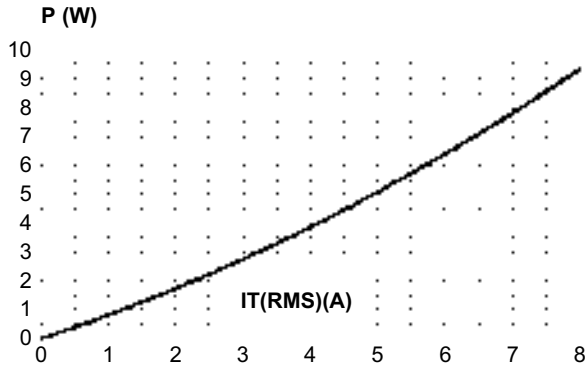


Fig. 2-1: RMS on-state current versus case temperature (full cycle).

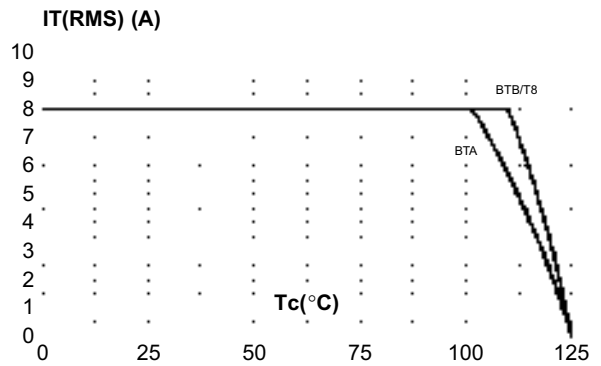


Fig. 2-2: RMS on-state current versus ambient temperature (printed circuit board FR4, copper thickness: 35µm), full cycle.

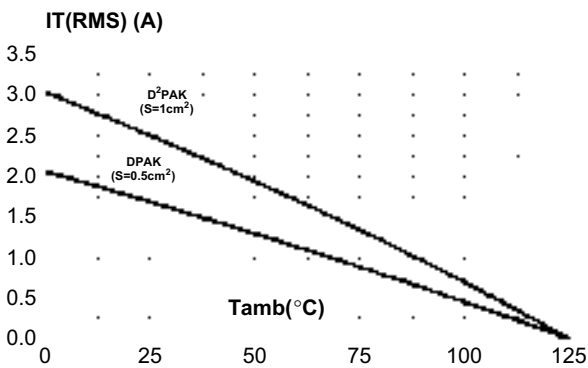


Fig. 3: Relative variation of thermal impedance versus pulse duration.

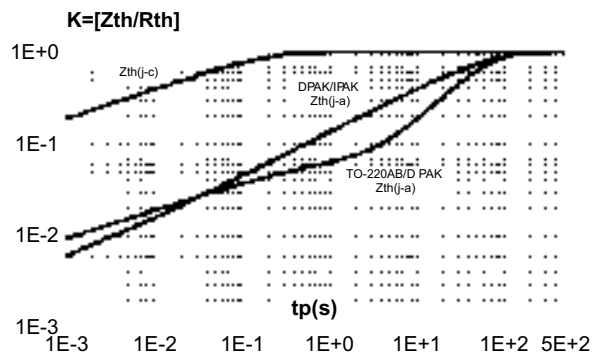


Fig. 4: On-state characteristics (maximum values).

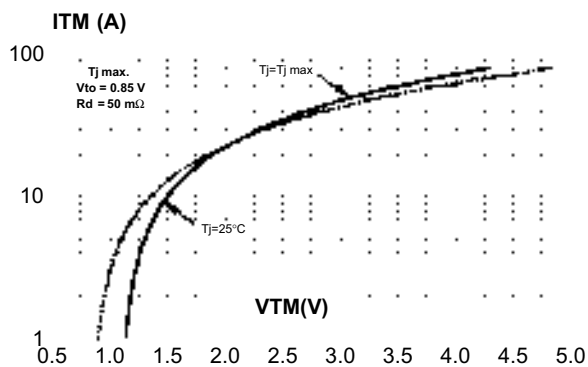


Fig. 5: Surge peak on-state current versus number of cycles.

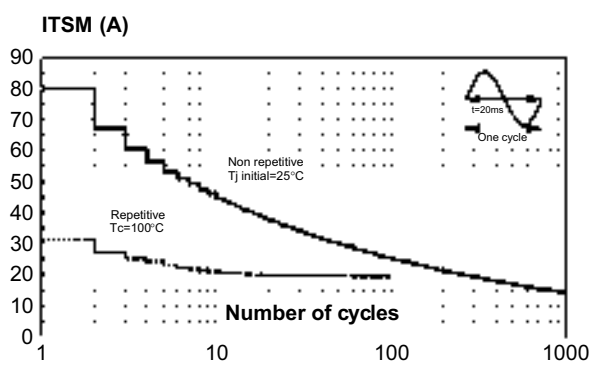


Fig. 6: Non-repetitive surge peak on-state current for a sinusoidal pulse with width $t_p < 10\text{ms}$, and corresponding value of I_t .

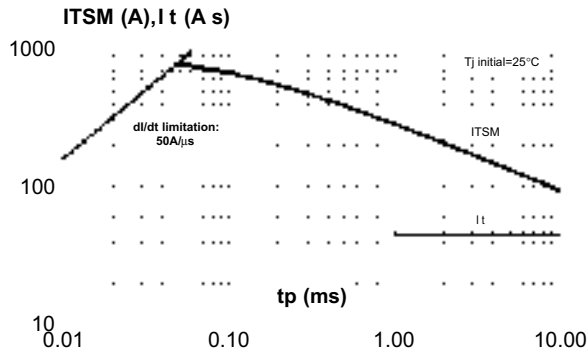


Fig. 8-1: Relative variation of critical rate of decrease of main current versus $(dV/dt)_c$ (typical values). Snubberless & Logic Level Types

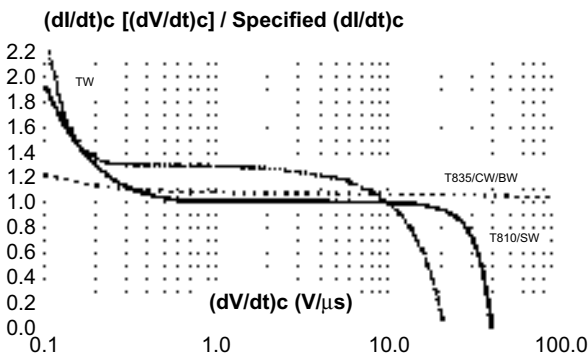


Fig. 9: Relative variation of critical rate of decrease of main current versus junction temperature.

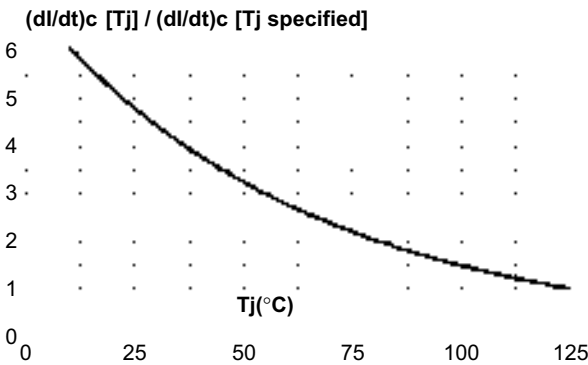


Fig. 7: Relative variation of gate trigger current, holding current and latching current versus junction temperature (typical values).

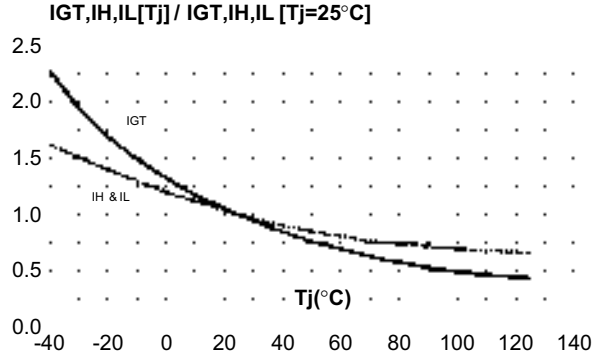


Fig. 8-2: Relative variation of critical rate of decrease of main current versus $(dV/dt)_c$ (typical values). Standard Types

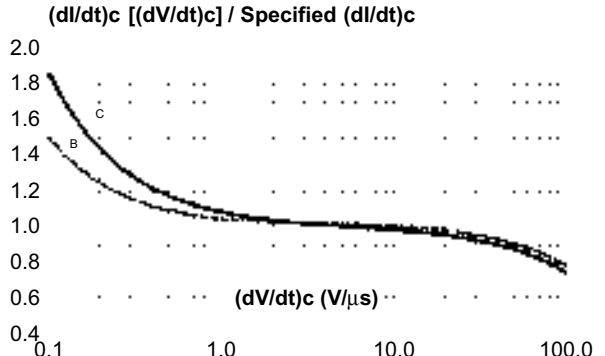
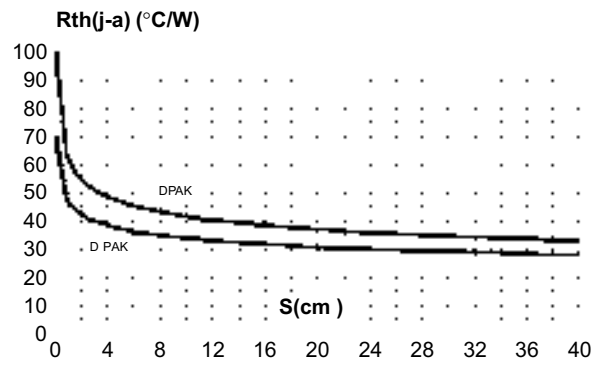
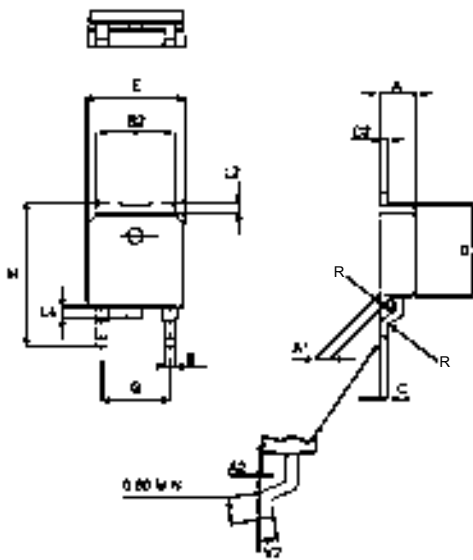


Fig. 10: DPAK and D²PAK Thermal resistance junction to ambient versus copper surface under tab (printed circuit board FR4, copper thickness: 35 μm).



PACKAGE MECHANICAL DATA

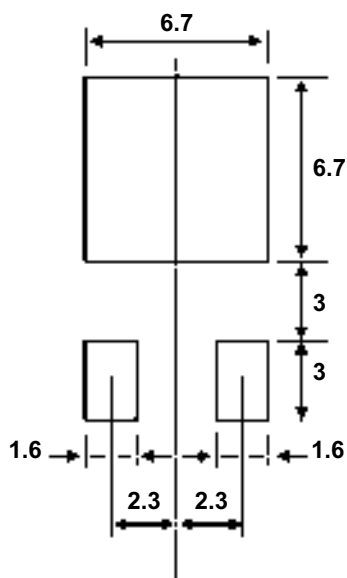
DPAK (Plastic)



REF.	DIMENSIONS			
	Millimeters		Inches	
	Min.	Max.	Min.	Max.
A	2.20	2.40	0.086	0.094
A1	0.90	1.10	0.035	0.043
A2	0.03	0.23	0.001	0.009
B	0.64	0.90	0.025	0.035
B2	5.20	5.40	0.204	0.212
C	0.45	0.60	0.017	0.023
C2	0.48	0.60	0.018	0.023
D	6.00	6.20	0.236	0.244
E	6.40	6.60	0.251	0.259
G	4.40	4.60	0.173	0.181
H	9.35	10.10	0.368	0.397
L2	0.80 typ.		0.031 typ.	
L4	0.60	1.00	0.023	0.039
R	0.2 typ.		0.007 typ.	
V2	0°	8°	0°	8°

FOOTPRINT DIMENSIONS (in millimeters)

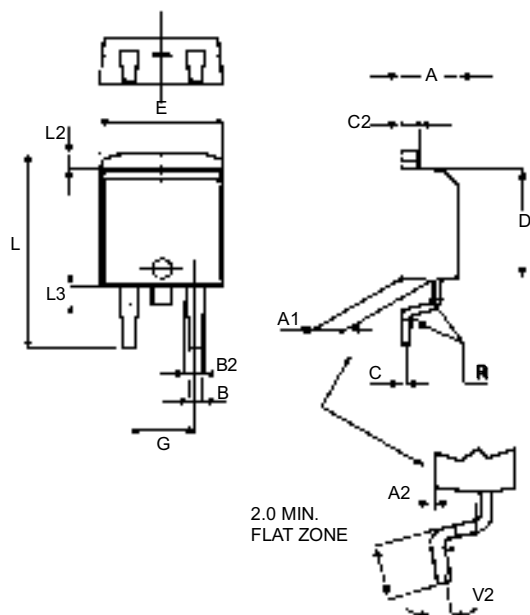
DPAK (Plastic)



BTA/BTB08 and T8 Series

PACKAGE MECHANICAL DATA

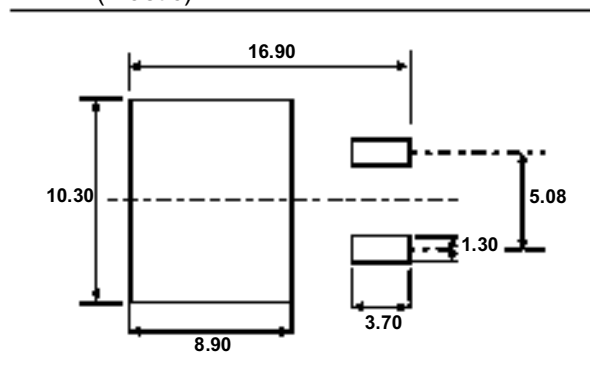
D PAK (Plastic)



REF.	DIMENSIONS					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	4.30		4.60	0.169		0.181
A1	2.49		2.69	0.098		0.106
A2	0.03		0.23	0.001		0.009
B	0.70		0.93	0.027		0.037
B2	1.25	1.40		0.048	0.055	
C	0.45		0.60	0.017		0.024
C2	1.21		1.36	0.047		0.054
D	8.95		9.35	0.352		0.368
E	10.00		10.28	0.393		0.405
G	4.88		5.28	0.192		0.208
L	15.00		15.85	0.590		0.624
L2	1.27		1.40	0.050		0.055
L3	1.40		1.75	0.055		0.069
R		0.40			0.016	
V2	0°		8°	0°		8°

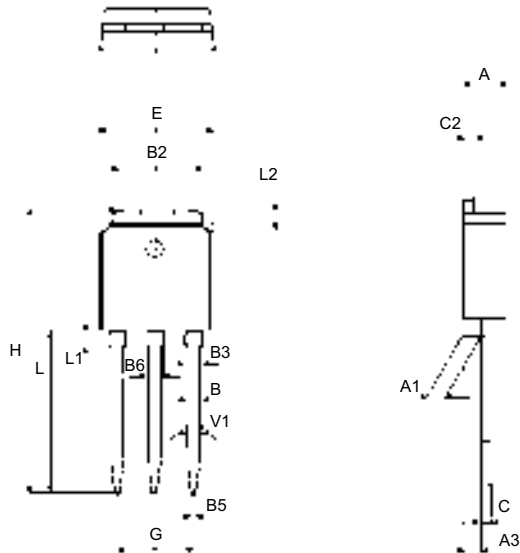
FOOTPRINT DIMENSIONS (in millimeters)

D PAK (Plastic)



PACKAGE MECHANICAL DATA

IPAK (Plastic)

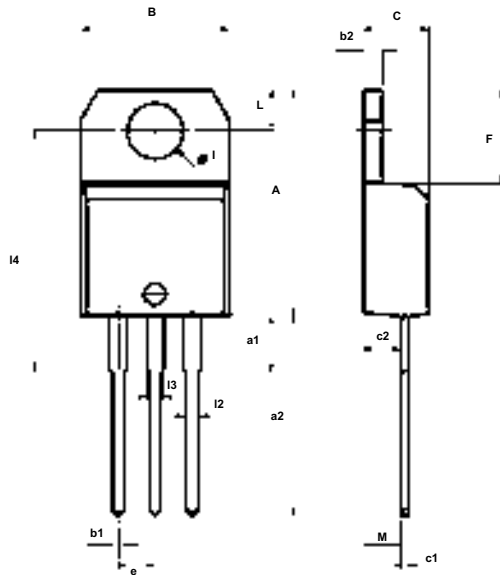


REF.	DIMENSIONS					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	2.2		2.4	0.086		0.094
A1	0.9		1.1	0.035		0.043
A3	0.7		1.3	0.027		0.051
B	0.64		0.9	0.025		0.035
B2	5.2		5.4	0.204		0.212
B3			0.85			0.033
B5		0.3			0.035	
B6			0.95			0.037
C	0.45		0.6	0.017		0.023
C2	0.48		0.6	0.019		0.023
D	6		6.2	0.236		0.244
E	6.4		6.6	0.252		0.260
G	4.4		4.6	0.173		0.181
H	15.9		16.3	0.626		0.641
L	9		9.4	0.354		0.370
L1	0.8		1.2	0.031		0.047
L2		0.8	1		0.031	0.039
V1		10°			10°	

BTA/BTB08 and T8 Series

PACKAGE MECHANICAL DATA

TO-220AB Ins.



REF.	DIMENSIONS					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	15.20		15.90	0.598		0.625
a1		3.75			0.147	
a2	13.00		14.00	0.511		0.551
B	10.00		10.40	0.393		0.409
b1	0.61		0.88	0.024		0.034
b2	1.23		1.32	0.048		0.051
C	4.40		4.60	0.173		0.181
c1	0.49		0.70	0.019		0.027
c2	2.40		2.72	0.094		0.107
e	2.40		2.70	0.094		0.106
F	6.20		6.60	0.244		0.259
I	3.75		3.85	0.147		0.151
I4	15.80	16.40	16.80	0.622	0.646	0.661
L	2.65		2.95	0.104		0.116
l2	1.14		1.70	0.044		0.066
l3	1.14		1.70	0.044		0.066
M		2.60			0.102	

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