SISTEMAS ELECTRÓNICOS DE ALIMENTACIÓN

BLOQUE TEMÁTICO I
ELEMENTOS DE UN CONVERTIDOR DE ENERGÍA

TEMA 2

COMPONENTES DE POTENCIA

Componentes Electrónicos de Potencia

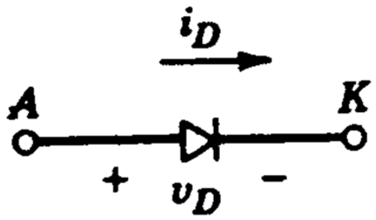
- Componentes semiconductores de potencia: diodos y transistores
- Potencia disipada en conmutación
- Cálculo de disipadores

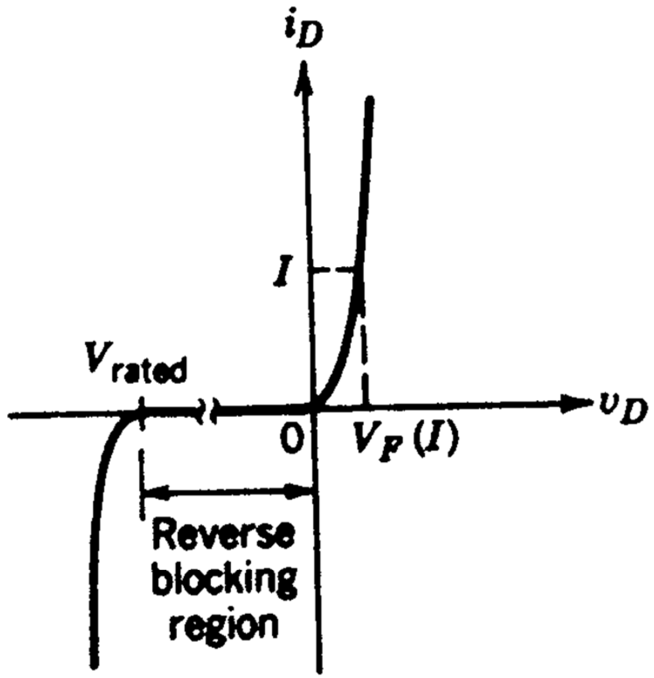
Bibliografía de consulta

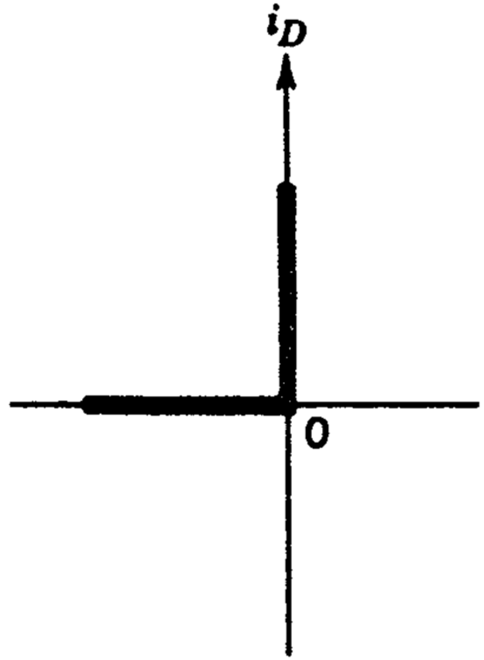
- POWER ELECTRONICS: CONVERTERS, APPLICATIONS AND DESIGN. (Third Edition). Ned Mohan, Tore M. Undeland, William P. Robbins. Editorial: John Wiley. 2003.

✓ Páginas: 16-17, 20-26, 29-30, 535,
567 (SOA BJT), 591(SOA MOSFET),
696-703(Drivers), 730-739 (Disipación).

DIODOS DE POTENCIA



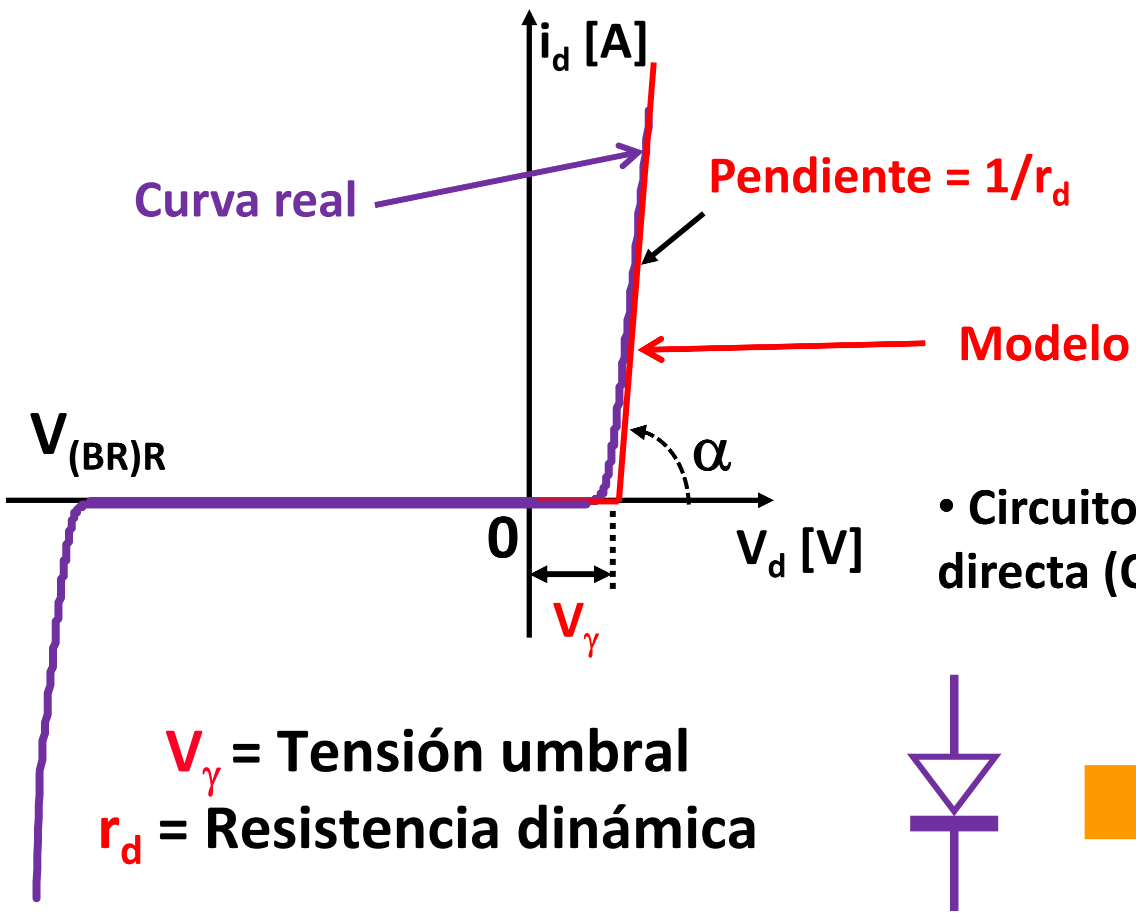


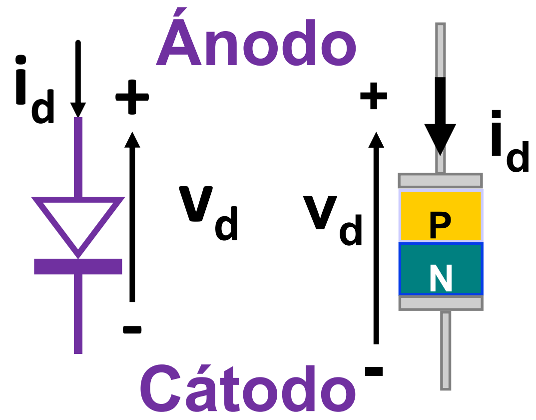


SÍMBOLO DEL DIODO **CURVA CARACTERÍSTICA** **CURVA IDEALIZADA**

Ec. Shockley: $i_D = I_S \cdot (e^{v_D/V_T} - 1)$, $V_T = kT/q$ (≈ 26 mV a 300 K),
I_s es la corriente inversa de saturación (≈10^{-14} A).

Modelo estático (asintótico) del diodo

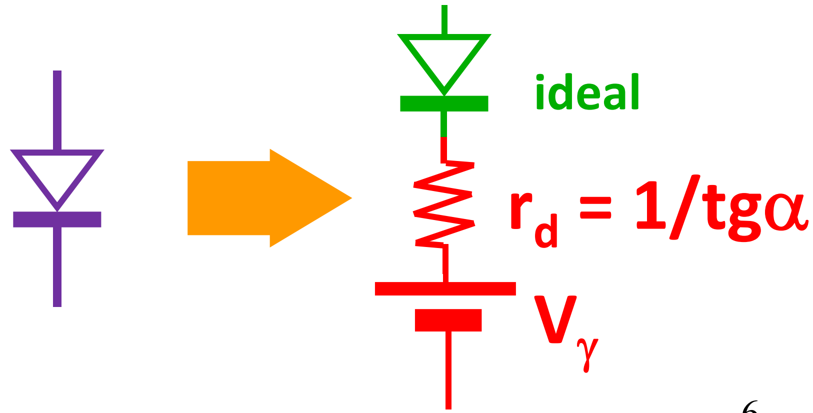


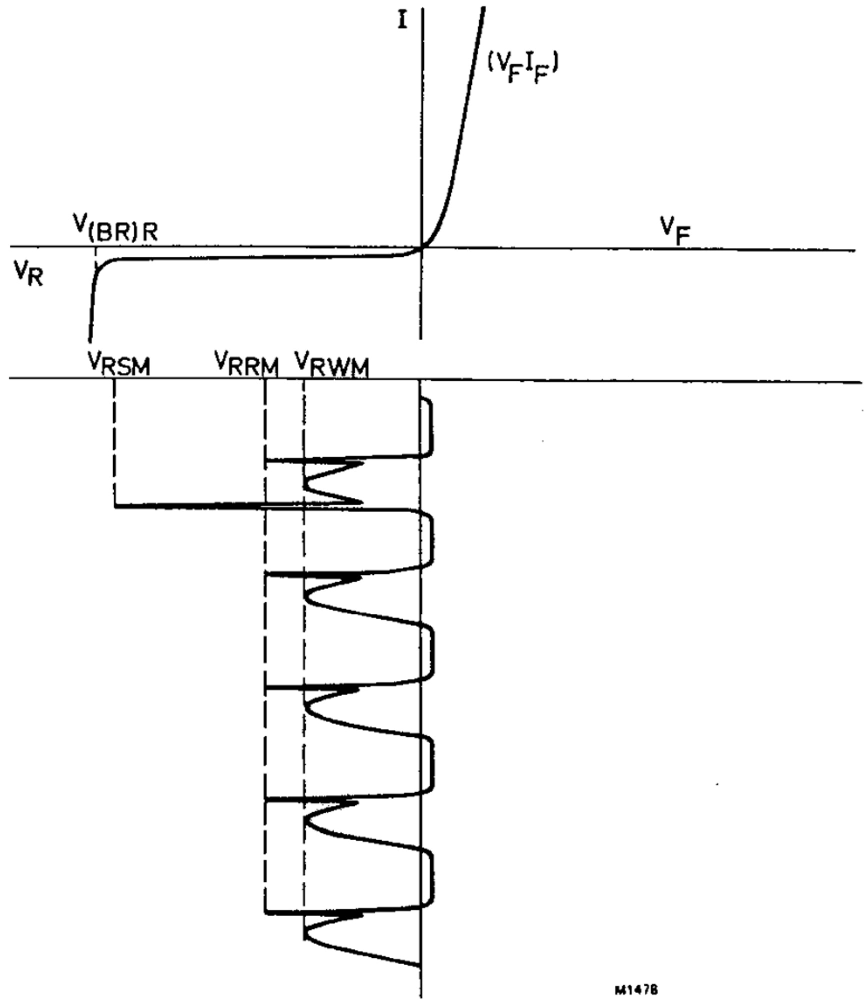


V_γ = Tensión umbral

r_d = Resistencia dinámica

- Circuito equivalente en conducción directa (ON)





CARACTERISTICA DE UN DIODO RECTIFICADOR, EJEMPLO DE TENSION ANODO-CATODO Y NOMENCLATURA

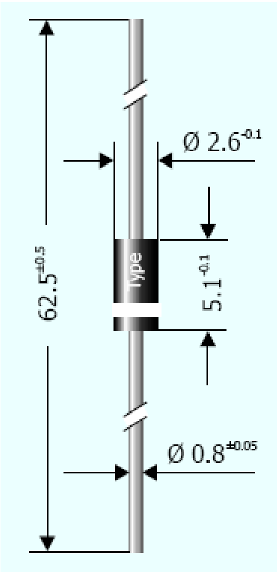
DIODOS RECTIFICADORES DE PROPÓSITO GENERAL

IO: Corriente directa media rectificada (A), Corriente de salida en c.c.

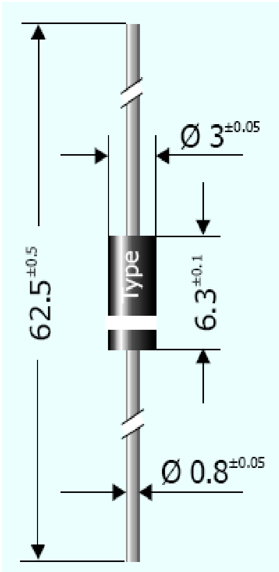
	1.0	1.5	3.0			6.0	25	35
	59-03 (DO-41)	59-04 (DO-15)	60 Metal	267 Plástico		194-04 Plástico	309A-03	309A-02
								
VRRM (Voltios)	Plástico	Plástico						
50	1N4001	1N5391	1N4719	MR500	1N5400	MR750	MDA2500	MDA3500
100	1N4002	1N5392	1N4720	MR501	1N5401	MR751	MDA2501	MDA3501
200	1N4003	1N5393 MR5059	1N4721	MR502	1N5402	MR752	MDA2502	MDA3502
400	1N4004	1N5395 MR5060	1N4722	MR504	1N5404	MR754	MDA2504	MDA3504
600	1N4005	1N5397 MR5061	1N4723	MR506	1N5406	MR756	MDA2506	MDA3506
800	1N4006	1N5398	1N4724	MR508		MR758		MDA3508
1000	1N4007	1N5399	1N4725	MR510		MR760		MDA3510

Encapsulados (I)

Axial (baja potencia)

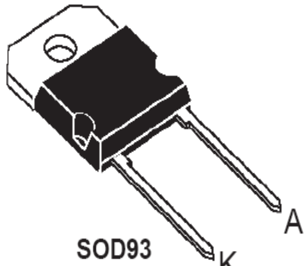


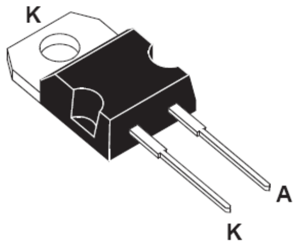
DO 41

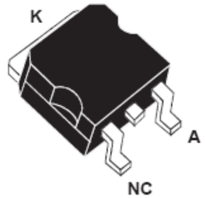


DO 15

Para usar con disipador

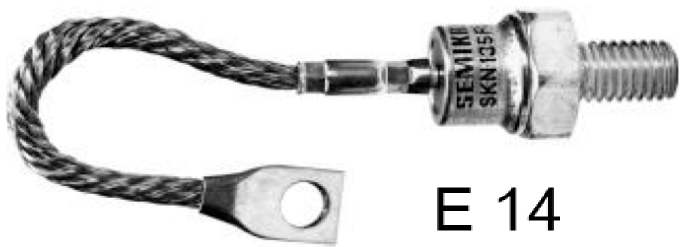






Para mayor potencia

DO 5



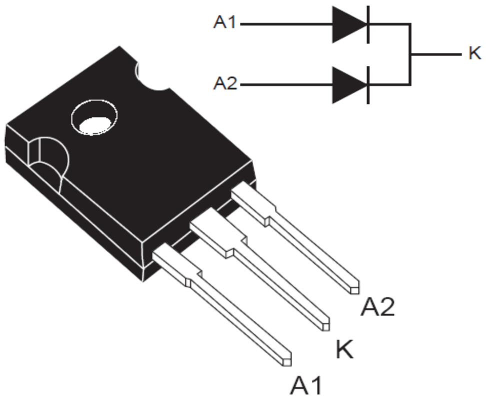
E 14

B 44

E 35

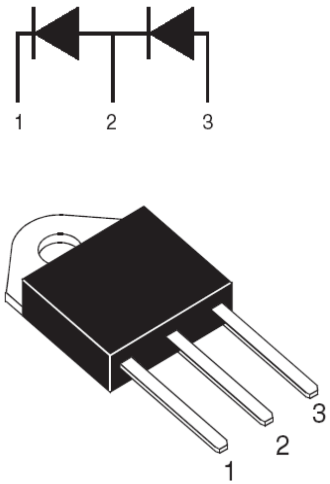
Encapsulados (II)

Conjuntos de dos diodos



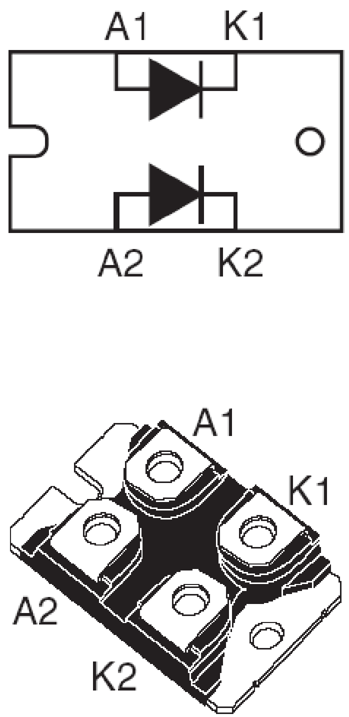
TO-247

Cátodo común (Dual center tap Diodes)

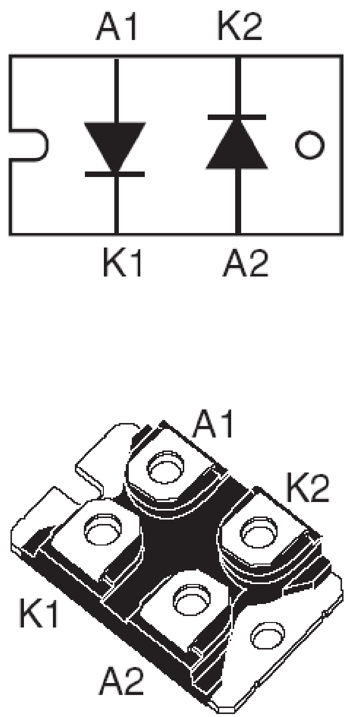


TOP-3 (Insulated)

Doblador (2 diodos en serie)



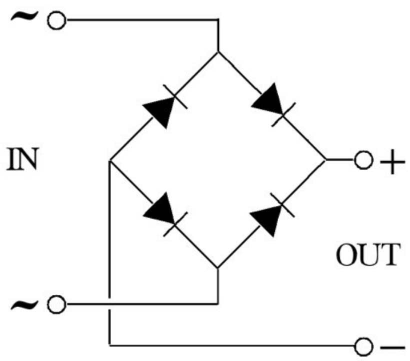
ISOTOP
STTH12010TV1

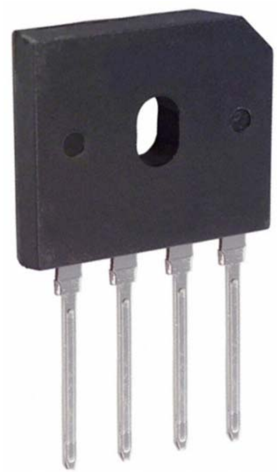


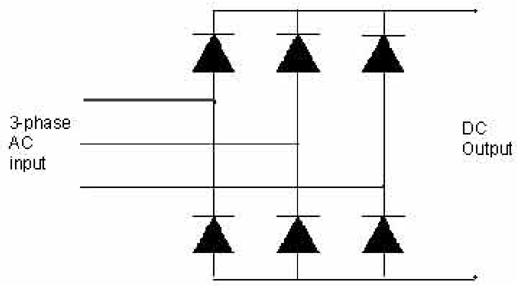
ISOTOP
STTH12010TV2

Encapsulados (III)

Puentes rectificadores

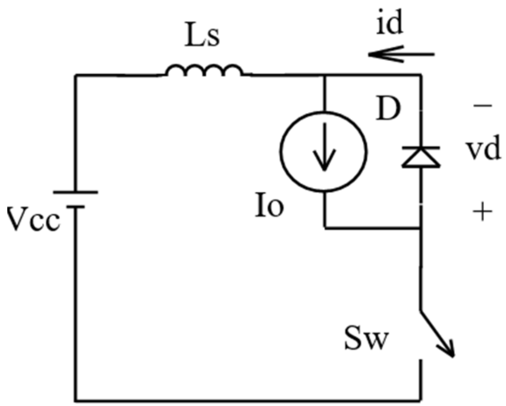




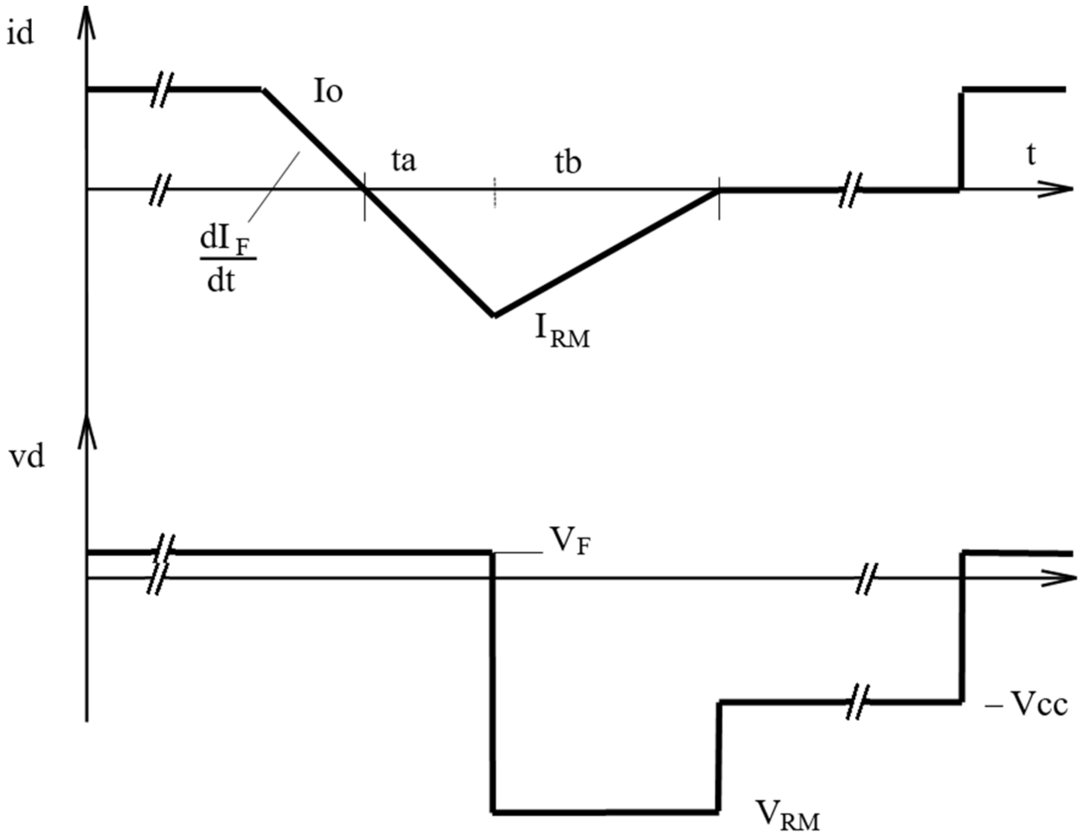


Puente rectificador trifásico

Transistor genérico ideal (Sw) en conmutación con carga fuertemente inductiva (Io) y diodo de libre circulación

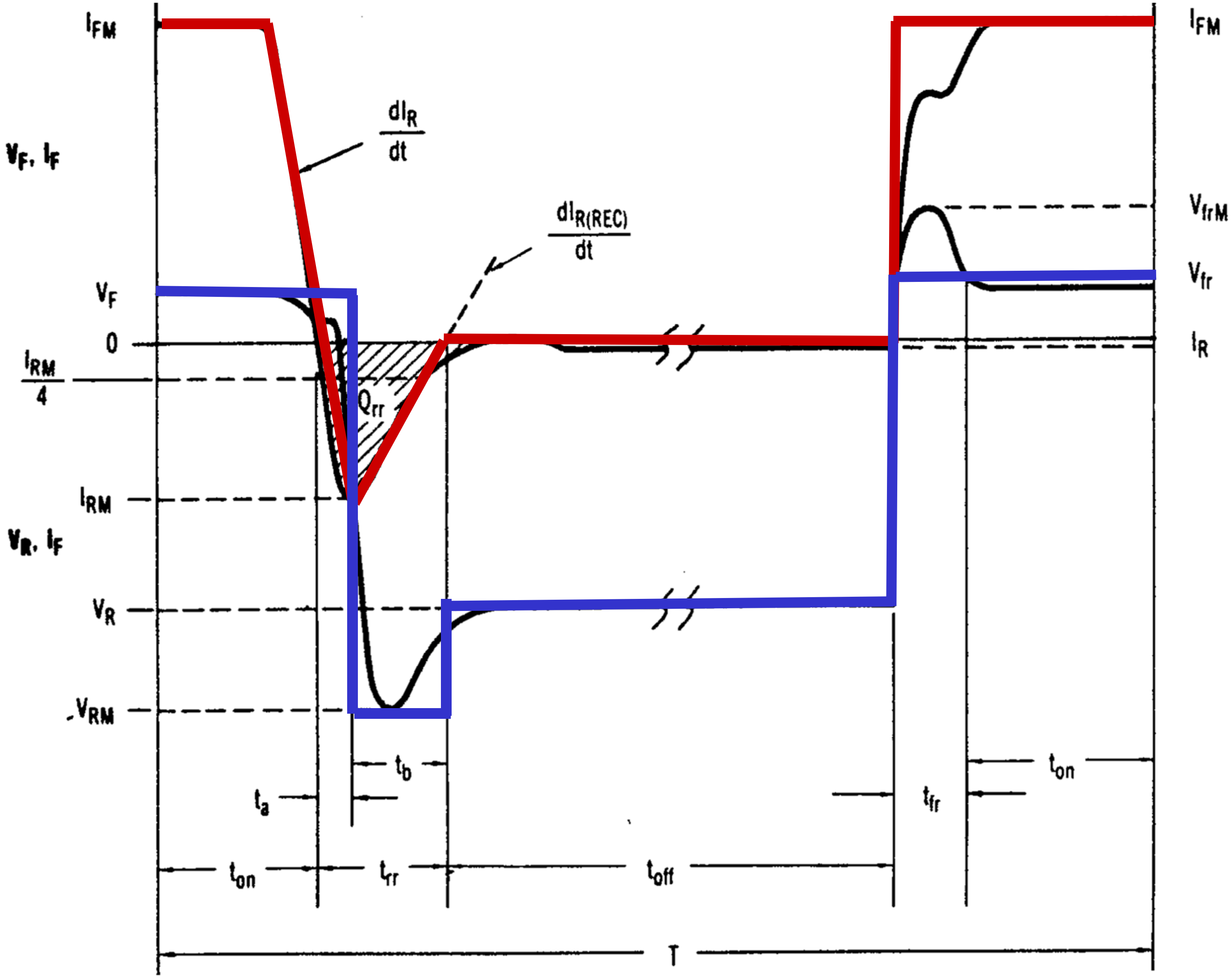


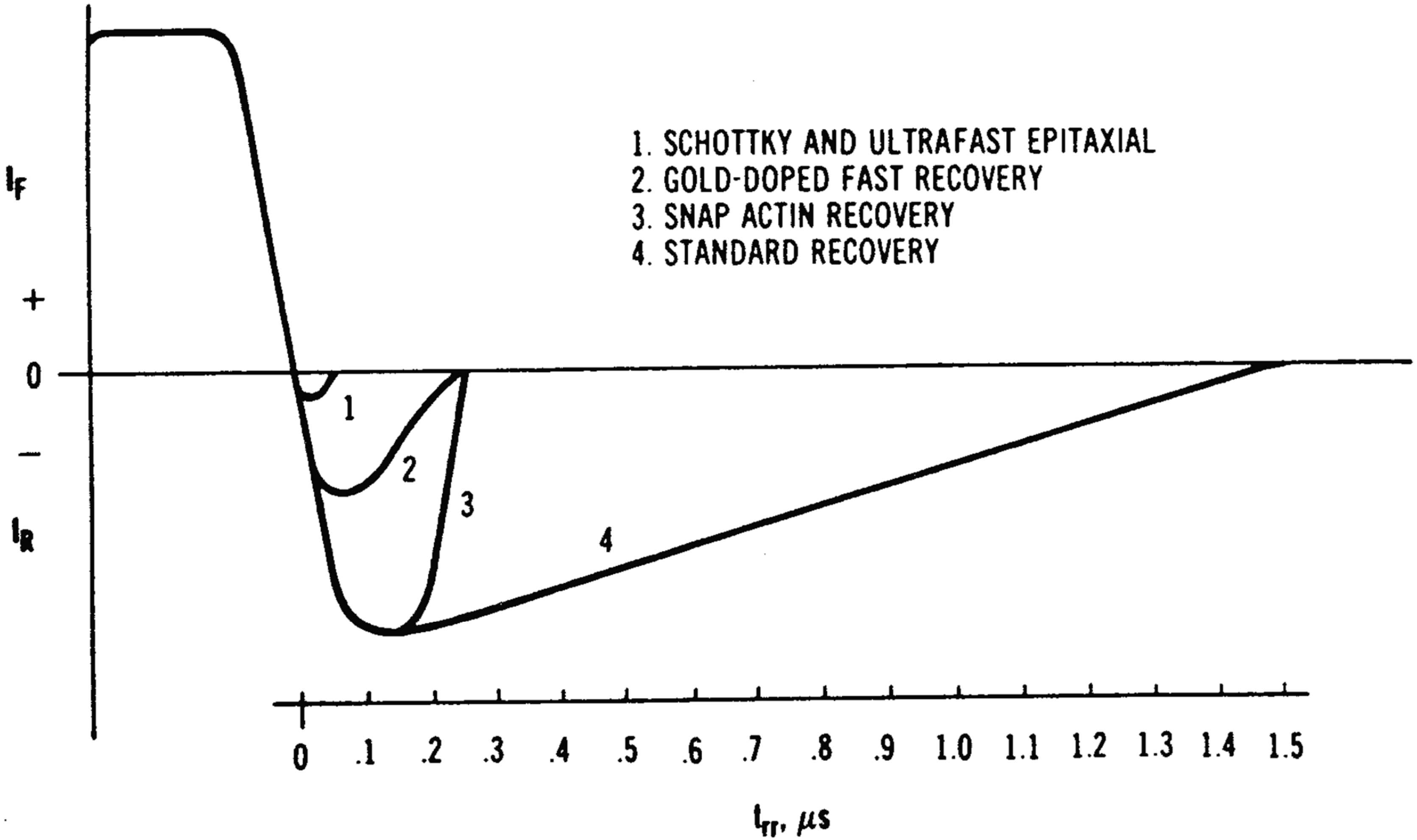
Circuito



Formas de onda

CONMUTACIÓN EN UN DIODO DE POTENCIA





TIPOS DE DIODOS SEGUN SU trr

Clasificación de los diodos de potencia

DIODOS	t_{rr}	I_o (A)	V_{RRM}	Observaciones
Propósito general	25 µs (típ.)	1-7000	50V-5kV	Baja frecuencia-1kHz.
Rápidos (Fast Recovery)	100ns.-750ns.	1-1150	50V-3kV	Hasta 40 kHz.
Ultrarápidos (Ultrafast Recovery)	25ns.-100ns.	1-1150	Hasta 600V	Hasta 250kHz.
Schottky	10 ns.	1-300	Hasta 200V	V_F 0,3-0,4V.

* En diodos Schottky de silicio con $V_{RRM} < 200$ V la tensión en directa (V_F) es inferior a la de los diodos de Si de similares características, sin embargo, las características dinámicas (t_{rr}) siempre serán mejores en los Schottky.

Según su tiempo de recuperación inversa:

Softness factor

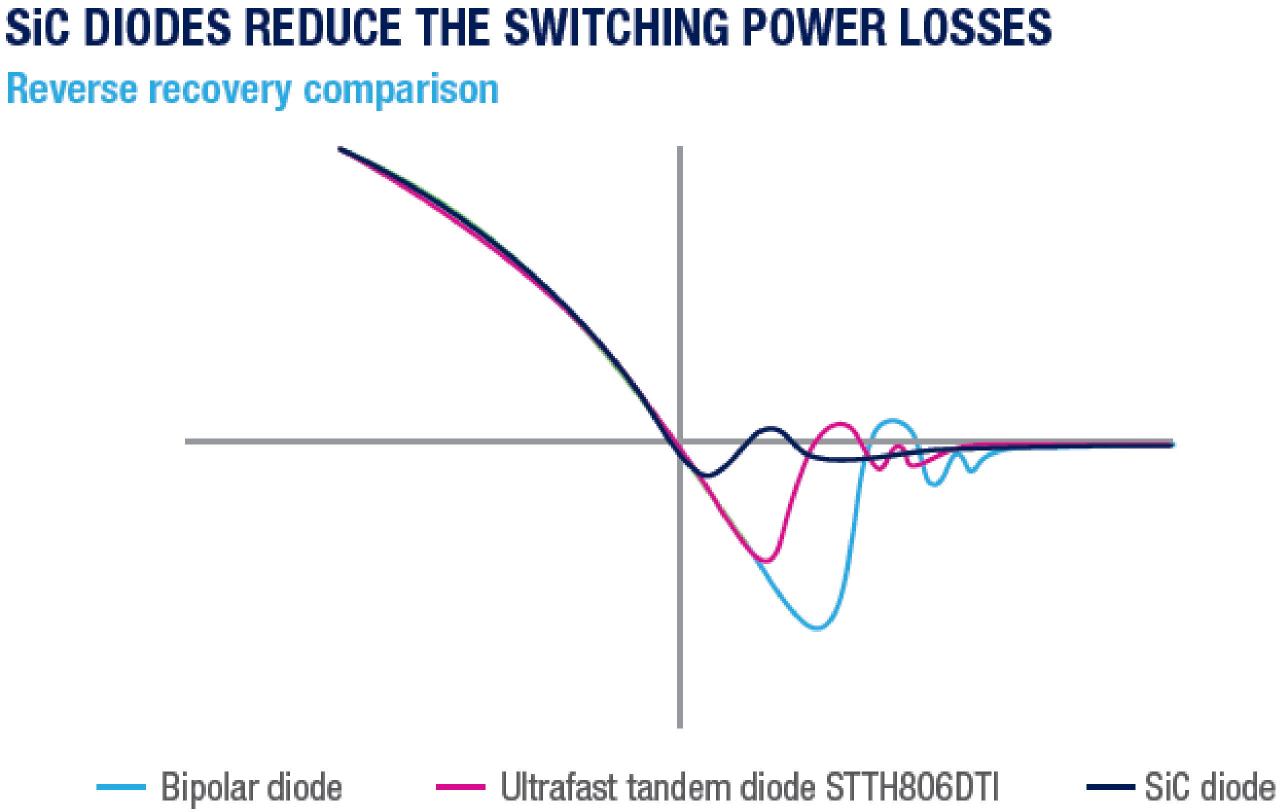
$$S_f = \frac{t_b}{t_a}$$

Soft Recovery	$t_b \cong t_a$
Standard Recovery	$t_b >> t_a$
Abrupt Recovery	$t_b << t_a$

Diodos Schottky de SiC (Carburo de Silicio)

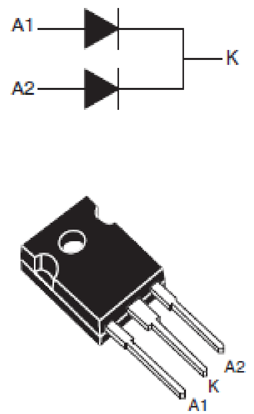
SiC diodes are high-performance power Schottky diodes that feature a silicon-carbide substrate. This wide bandgap material enables the design of high-voltage Schottky diodes, and ST offers rectifiers up to 1200 V. They present negligible reverse recovery at turn-off and minimal capacitive turn-off behavior which is independent of temperature.

The 1st generation of 600 V diodes offers the best forward and switching characteristics. The 2nd generation of 650 V diodes offers more surge robustness for optimal use in circuits featuring current spikes. The 1200 V diode range is especially suited for use in 3-phase circuits.



Diodos Schottky de SiC (Carburo de Silicio)

600 V generation 1				650 V generation 2				1200 V		
Part number	Forward current $I_{F(AV)}$ (A)	Maximum reverse voltage V_{RRM} (V)	Packages	Part number	Forward current $I_{F(AV)}$ (A)	Maximum reverse voltage V_{RRM} (V)	Packages	Part number	Forward current $I_{F(AV)}$ (A)	Packages
STPSC406	4	600	TO-220AC, DPAK	STPSC4H065	4	650	TO-220AC, DPAK	STPSC6H12	6	DPAK
STPSC606	6	600	TO-220AC, D²PAK	STPSC6H065	6	650	TO-220AC, DPAK, D²PAK	Range extension by Q2-2014		
STPSC806	8	600	TO-220AC, D²PAK			650	TO-220AC, D²PAK			
STPSC1006	10	600	TO-220AC, D²PAK			650	TO-220AB			
STPSC1206	12	600	TO-220AC			650	TO-220AC, DPAK, D²PAK			
STPSC2006C	2 x 10	600	TO-247			650	TO-220AC			
						650	TO-220AB			
						650	TO-220AB			
						650	TO-220AB, TO-247			
						2 x 650	TO-220 ins			
						2 x 650	TO-220 ins			
						2 x 650	TO-220 ins			



TO-247
STPSC2006CW

Note: (*) Product in development. Available end of Q1-2014.

FAIRCHILD SEMICONDUCTOR®

RURP3060

Data Sheet **January 2002**

30A, 600V Ultrafast Diode

The RURP3060 is an ultrafast diode (t_{rr} < 55ns) with soft recovery characteristics. It has a low forward voltage drop and is of planar, silicon nitride passivated, ion-implanted, epitaxial construction.

This device is intended for use as an energy steering/clamping diode and rectifier in a variety of switching power supplies and other power switching applications. Its low stored charge and ultrafast recovery with soft recovery characteristics minimize ringing and electrical noise in many power switching circuits, thus reducing power loss in the switching transistor.

Formerly developmental type TA09903.

Ordering Information

PART NUMBER	PACKAGE	BRAND
RURP3060	TO-220AC	RURP3060

NOTE: When ordering, use the entire part number.

Symbol

Features

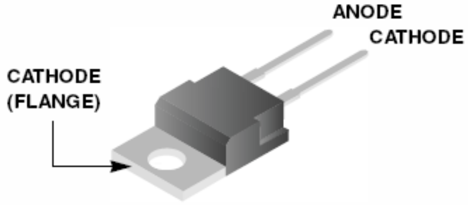
- Ultrafast with Soft Recovery. . . . .< 55ns
- Operating Temperature . . . . 175°C
- Reverse Voltage 600V
- Avalanche Energy Rated
- Planar Construction

Applications

- Switching Power Supply
- Power Switching Circuits
- General Purpose

Packaging

JEDEC TO-220AC



Absolute Maximum Ratings $T_C = 25^oC$, Unless Otherwise Specified

		RURP3060	UNITS
Peak Repetitive Reverse Voltage	V_{RRM}	600	V
Working Peak Reverse Voltage	V_{RWM}	600	V
DC Blocking Voltage	V_R	600	V
Average Rectified Forward Current ($T_C = 130^oC$)	$I_{F(AV)}$	30	A
Repetitive Peak Surge Current (Square Wave, 20kHz)	I_{FRM}	70	A
Nonrepetitive Peak Surge Current (Halfwave 1 Phase 60Hz)	I_{FSM}	325	A
Maximum Power Dissipation	P_D	125	W
Avalanche Energy (See Figures 7 and 8)	E_{AVL}	20	mJ
Operating and Storage Temperature	T_{STG}, T_J	-55 to 175	^oC

Electrical Specifications

$T_C = 25^oC$, Unless Otherwise Specified

SYMBOL	TEST CONDITION	MIN	TYP	MAX	UNITS
V_F	$I_F = 30A$	-	-	1.5	V
	$I_F = 30A$, $T_C = 150^oC$	-	-	1.3	V
I_R	$V_R = 600V$	-	-	250	µA
	$V_R = 600V$, $T_C = 150^oC$	-	-	1	mA
t_{rr}	$I_F = 1A$, $dI_F/dt = 100A/\mu s$	-	-	55	ns
	$I_F = 30A$, $dI_F/dt = 100A/\mu s$	-	-	60	ns
t_a	$I_F = 30A$, $dI_F/dt = 100A/\mu s$	-	30	-	ns
t_b	$I_F = 30A$, $dI_F/dt = 100A/\mu s$	-	20	-	ns
$R_{\theta JC}$		-	-	1.2	$^oC/W$

DEFINITIONS

V_F = Instantaneous forward voltage (pw = 300µs, D = 2%).

I_R = Instantaneous reverse current.

t_{rr} = Reverse recovery time at dI_F/dt = 100A/µs (See Figure 6), summation of $t_a + t_b$.

t_a = Time to reach peak reverse current at dI_F/dt = 100A/µs (See Figure 6).

t_b = Time from peak I_{RM} to projected zero crossing of I_{RM} based on a straight line from peak I_{RM} through 25% of I_{RM} (See Figure 6).

$R_{\theta JC}$ = Thermal resistance junction to case.

pw = Pulse width.

D = Duty cycle.

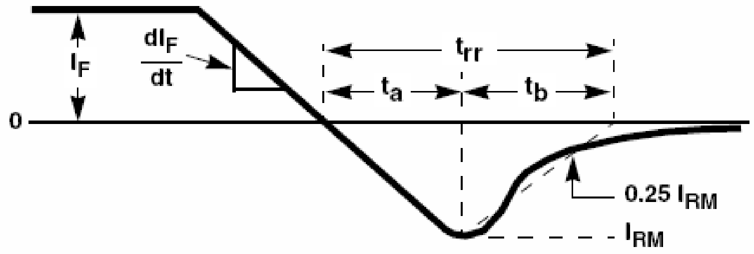


FIGURE 6. t_{rr} WAVEFORMS AND DEFINITIONS

Typical Performance Curves

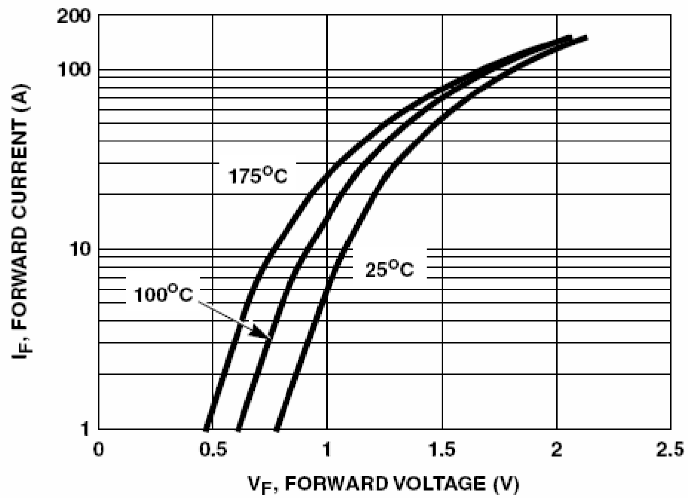


FIGURE 1. FORWARD CURRENT vs FORWARD VOLTAGE

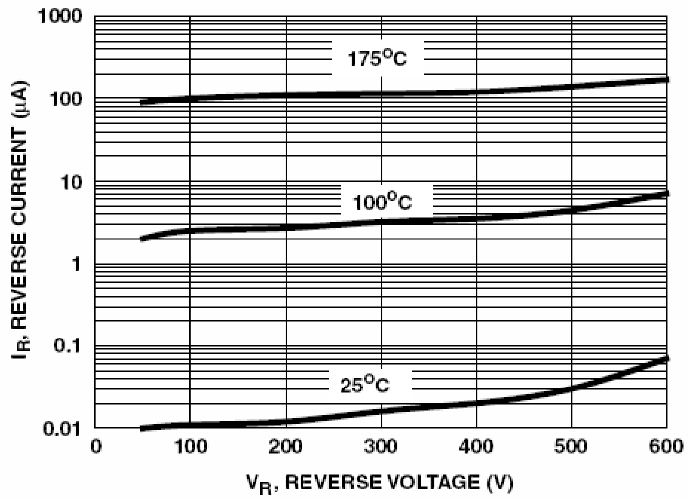


FIGURE 2. REVERSE CURRENT vs REVERSE VOLTAGE

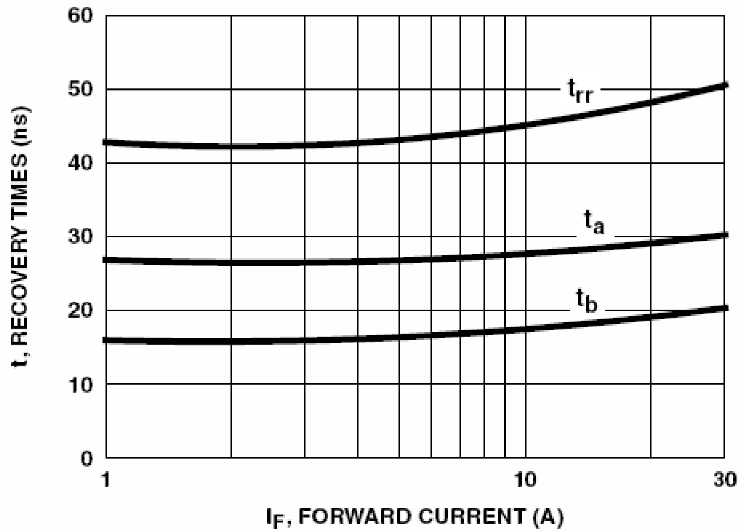
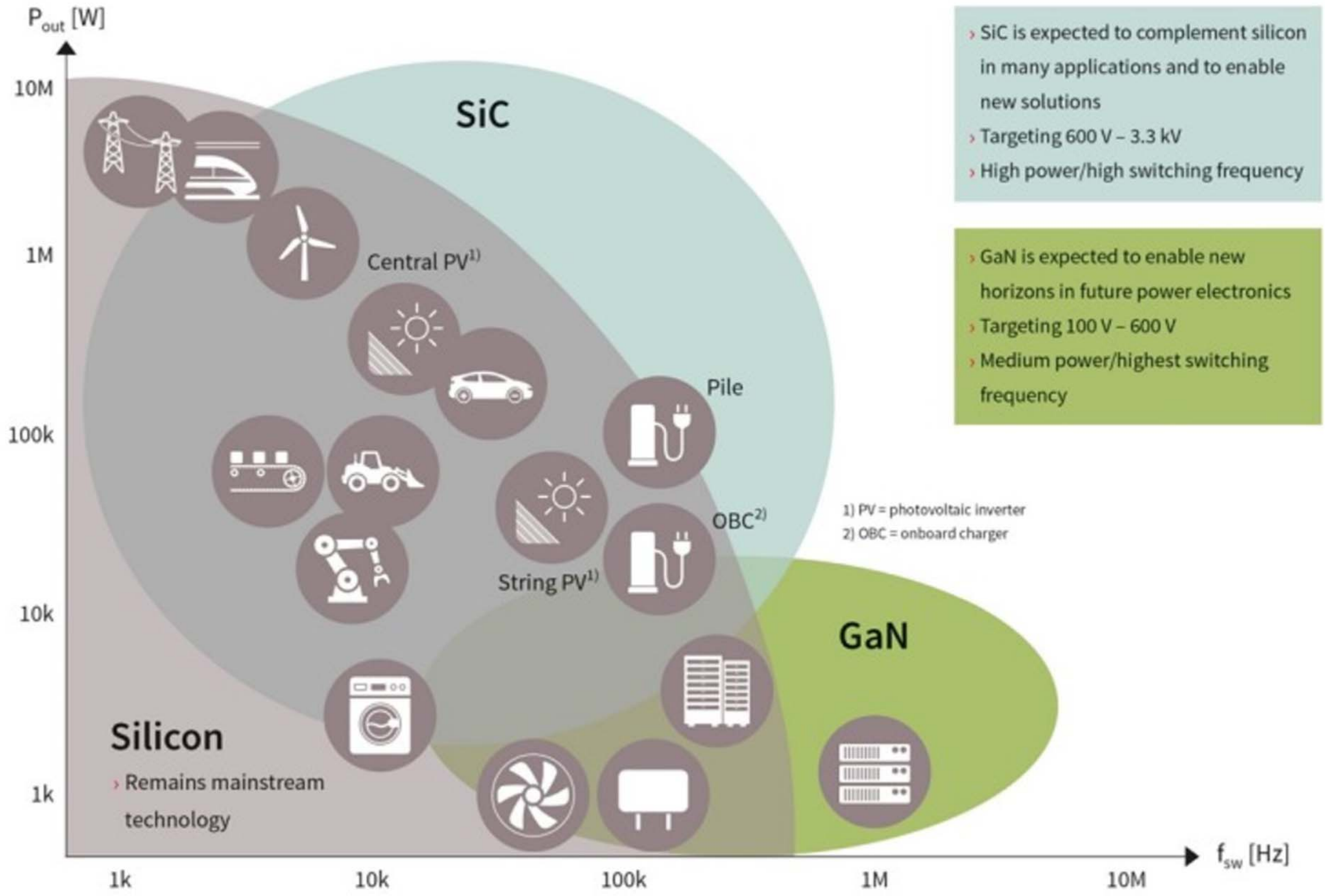


FIGURE 3. t_{rr}, t_a AND t_b CURVES vs FORWARD CURRENT

TRANSISTORES DE POTENCIA



P_{out} [W]
10M
1M
100k
10k
1k
SiC
Central PV1)
Pile
OBC2)
String PV1)
GaN
Silicon
› Remains mainstream technology
1k
10k
100k
1M
10M
f_{sw} [Hz]
1) PV = photovoltaic inverter
2) OBC = onboard charger
› SiC is expected to complement silicon in many applications and to enable new solutions
› Targeting 600 V – 3.3 kV
› High power/high switching frequency
› GaN is expected to enable new horizons in future power electronics
› Targeting 100 V – 600 V
› Medium power/highest switching frequency

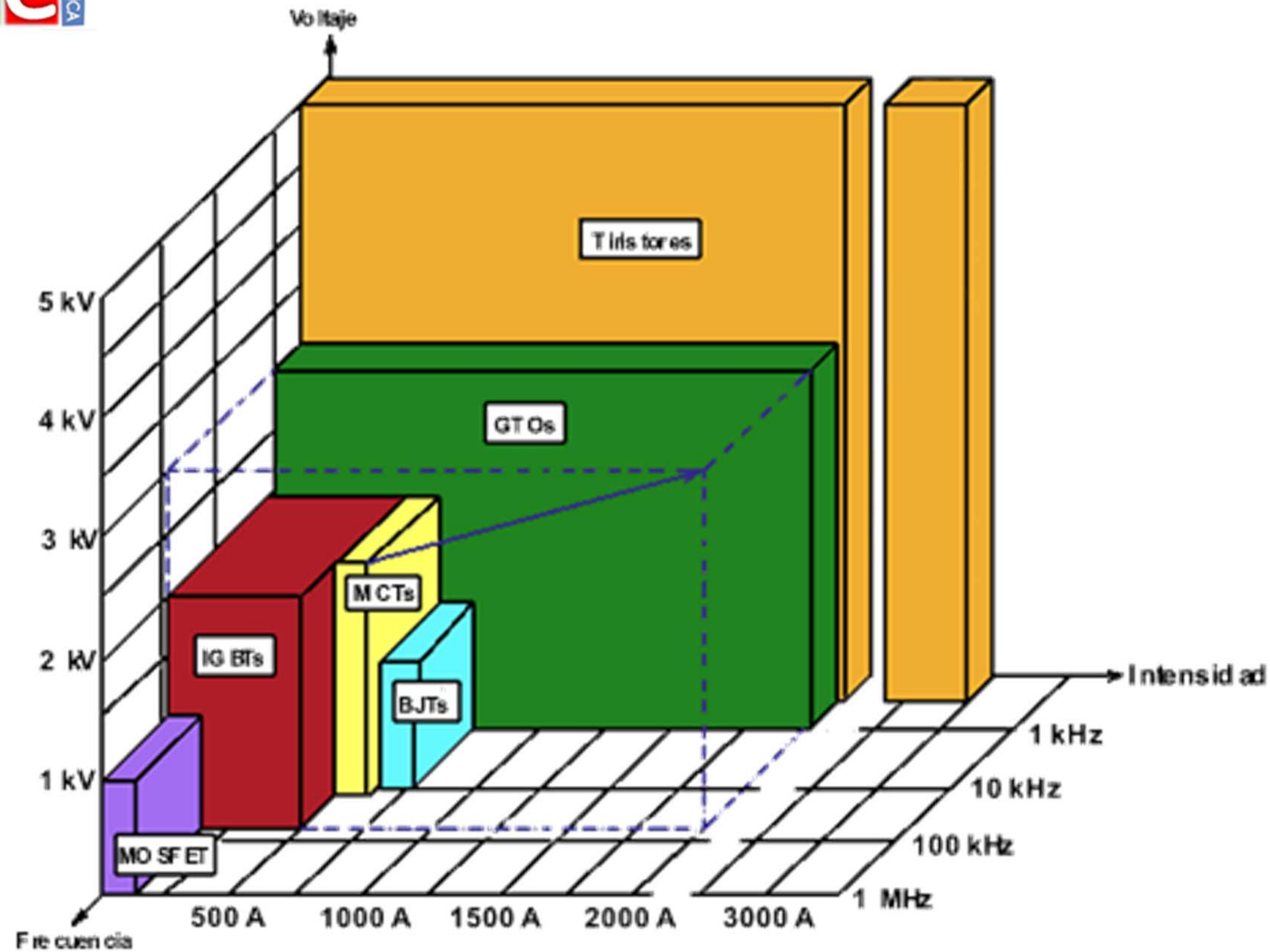
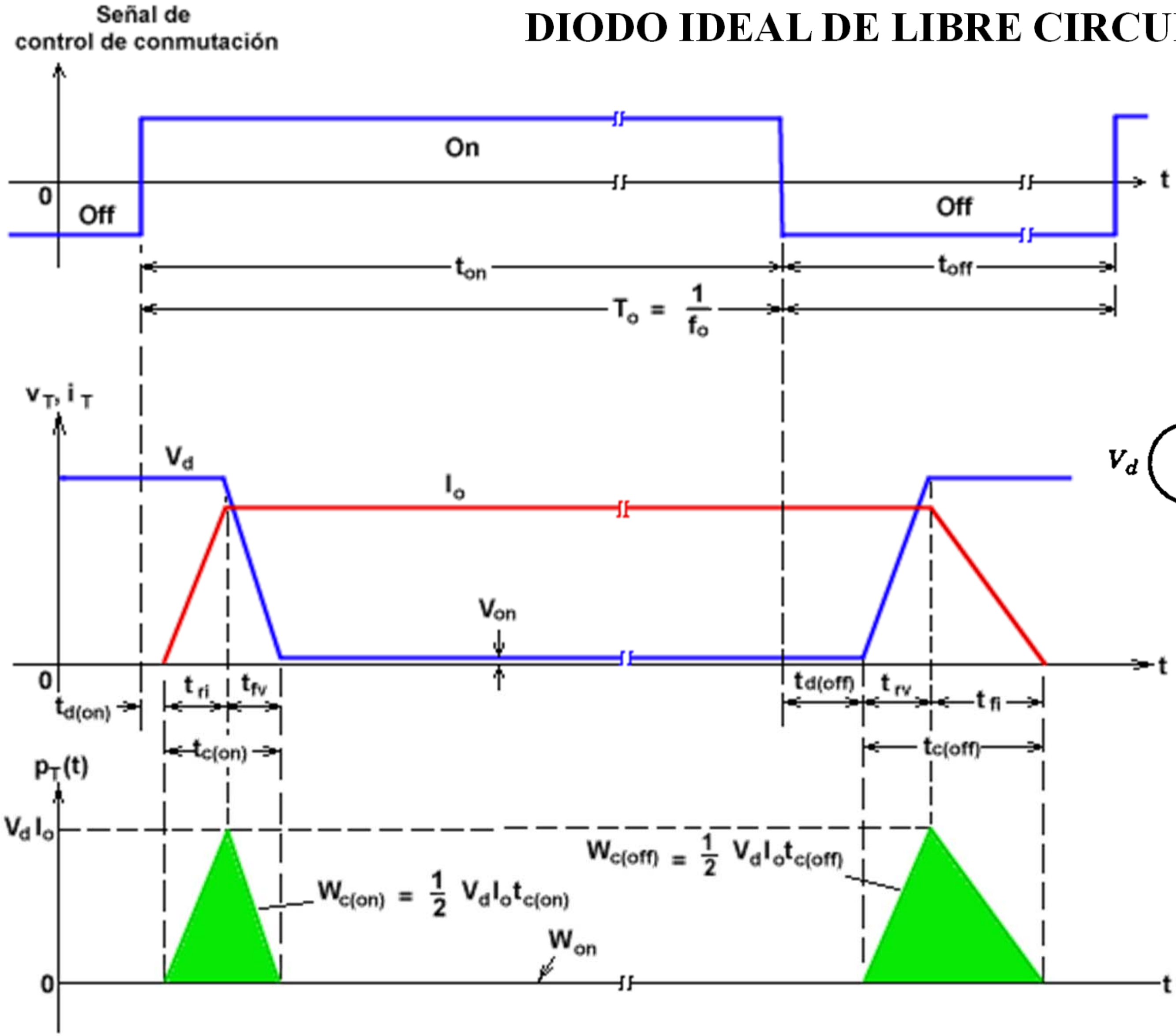
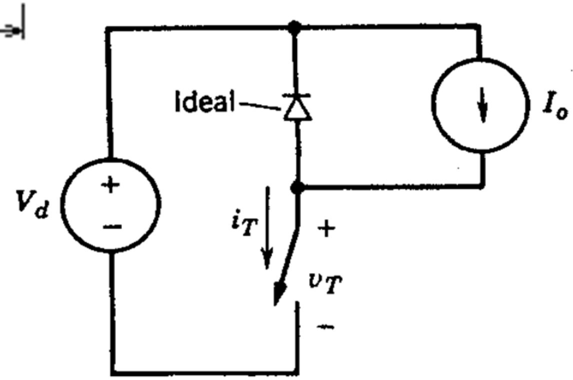


Gráfico comparativo de semiconductores de potencia

CARACTERÍSTICAS LINEALIZADAS DE UN CONMUTADOR GENÉRICO CON CARGA FUERTEMENTE INDUCTIVA Y DIODO IDEAL DE LIBRE CIRCULACIÓN





TRANSISTORES BIPOLARES DE POTENCIA

DATA SHEET
www.onsemi.com

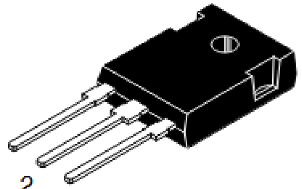
October, 2024 − Rev. 4

NPN Silicon Power Transistors High Voltage Planar

MJW18020

The MJW18020 planar High Voltage Power Transistor is specifically Designed for motor control applications, high power supplies and UPS's for which the high reproducibility of DC and Switching parameters minimizes the dead time in bridge configurations.

30 AMPERES
1000 VOLTS BV_{CES}
450 VOLTS BV_{CEO}, 250 WATTS



1
2
3

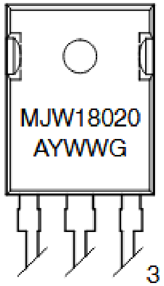
TO−247
CASE 340L

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector−Emitter Sustaining Voltage	V_{CEO}	450	Vdc
Collector−Base Breakdown Voltage	V_{CES}	1000	Vdc
Collector−Base Voltage	V_{CBO}	1000	Vdc
Emitter−Base Voltage	V_{EBO}	9.0	Vdc
Collector Current − Continuous − Peak (Note 1)	I_C	30 45	Adc
Base Current − Continuous − Peak (Note 1)	I_B	6.0 10	Adc
Total Power Dissipation @ T_C = 25°C Derate Above 25°C	P_D	250 2.0	W W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	−65 to +150	°C

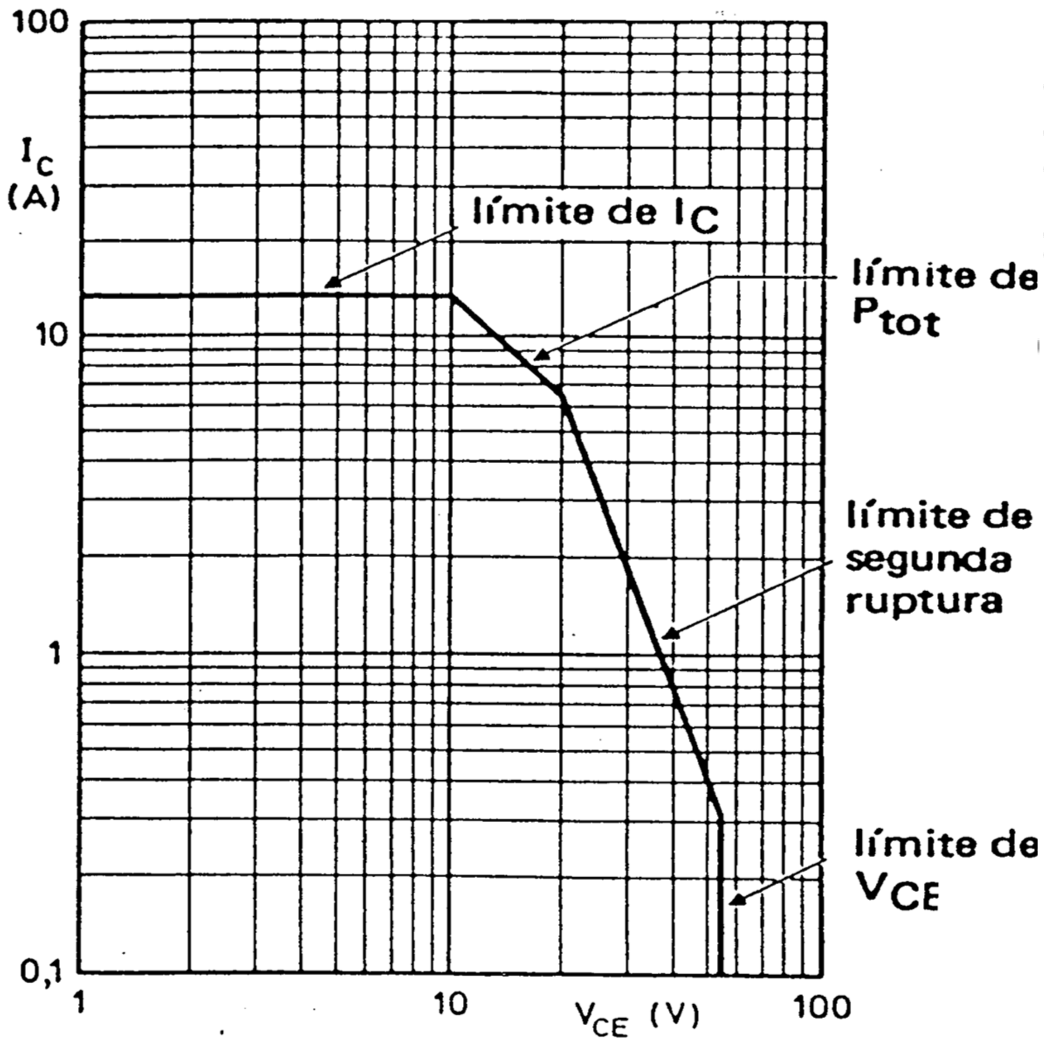
1. Pulse Test: Pulse Width = 5 μs, Duty Cycle ≤ 10%.

MARKING DIAGRAM



1 BASE
3 EMITTER
2 COLLECTOR

A = Assembly Location
Y = Year
WW = Work Week
G = Pb−Free Package



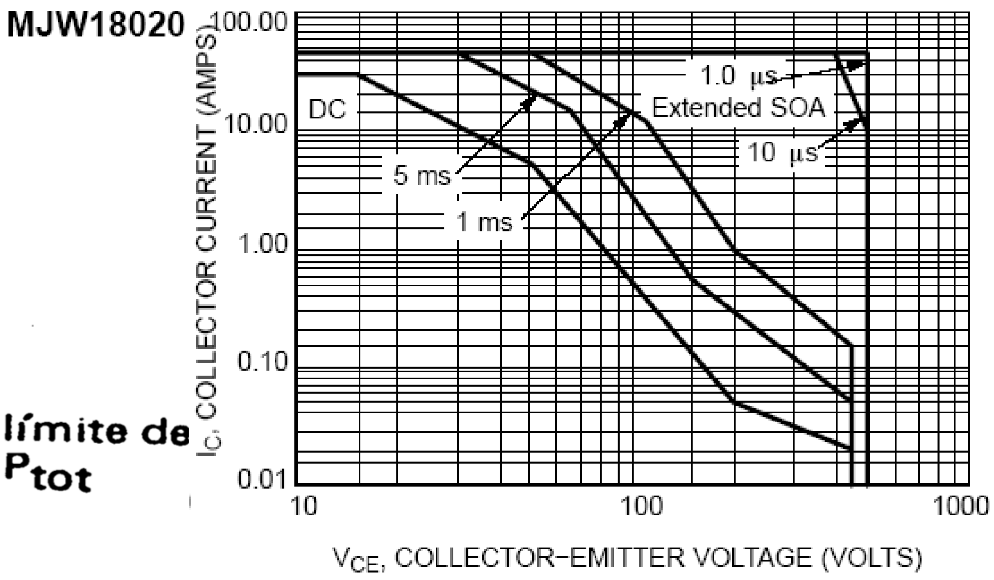


Figure 8. Forward Bias Safe Operating Area

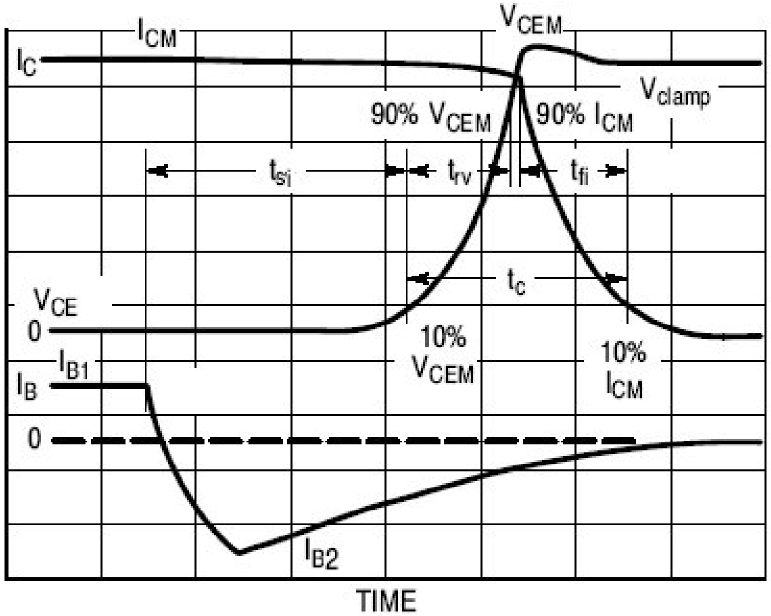
ÁREA DE FUNCIONAMIENTO SEGURO CON POLARIZACIÓN DIRECTA DE BASE, $I_B=I_{B1}$ (FBSOA: FORWARD BIAS SAFE OPERATING AREA)

ON CHARACTERISTICS

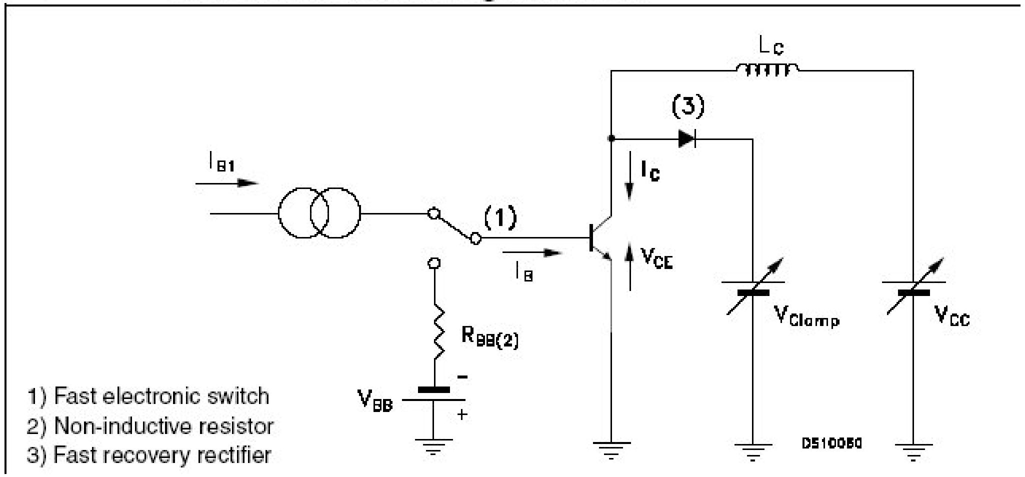
		Symbol	Min	Typ	Max	Unit
DC Current Gain	(I_C = 3 Adc, V_{CE} = 5 Vdc)	h_{FE}	14		34	
	(T_C = 125°C)		–	30	–	
	(I_C = 10 Adc V_{CE} = 2 Vdc)		8	16		
	(T_C = 125°C)		5	14	–	
	(I_C = 20 Adc V_{CE} = 2 Vdc)		5.5	9	–	
	(T_C = 125°C)		4	7	–	
	(I_C = 10 mAdc V_{CE} = 5 Vdc)		14	25	–	

SWITCHING CHARACTERISTICS: Inductive Load (V_{clamp}= 300 V , Vcc = 15 V, L = 200 μH)

		Symbol	Min	Typ	Max	Unit
Fall Time	(I_C = 10 Adc, I_{B1} = I_{B2} = 2 Adc)	t_{fi}	–	142	250	ns
Storage Time		t_{si}	–	4.75	6	μs
Crossover Time		t_c	–	320	500	ns
Fall Time	(I_C = 20 Adc, I_{B1} = I_{B2} = 4 Adc)	t_{fi}	–	350	500	ns
Storage Time		t_{si}	–	3.0	3.5	μs
Crossover Time		t_c	–	500	750	ns



Inductive load switching test circuit



CÁLCULO DEL PUNTO DE TRABAJO EN SATURACIÓN

$\beta_F=5$

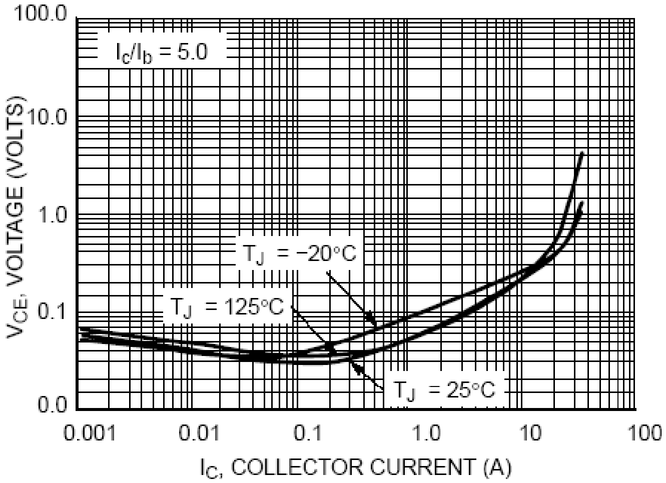


Figure 3. Typical Collector−Emitter Saturation Voltage, I_C/I_B = 5.0

$\beta_F=10$

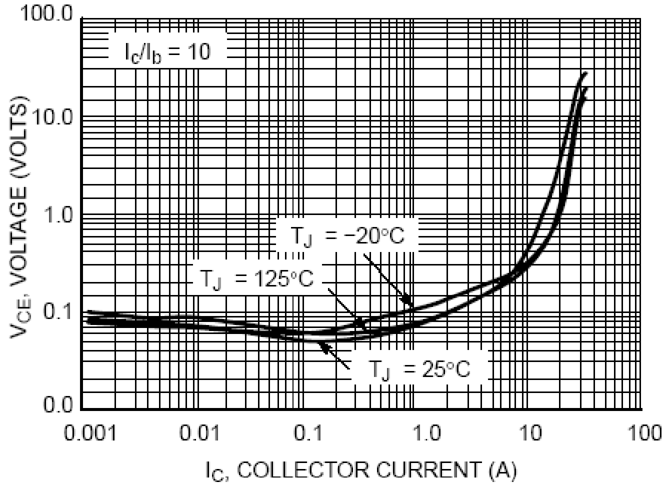


Figure 4. Typical Collector−Emitter Saturation Voltage, I_C/I_B = 10

$\beta_F=5$

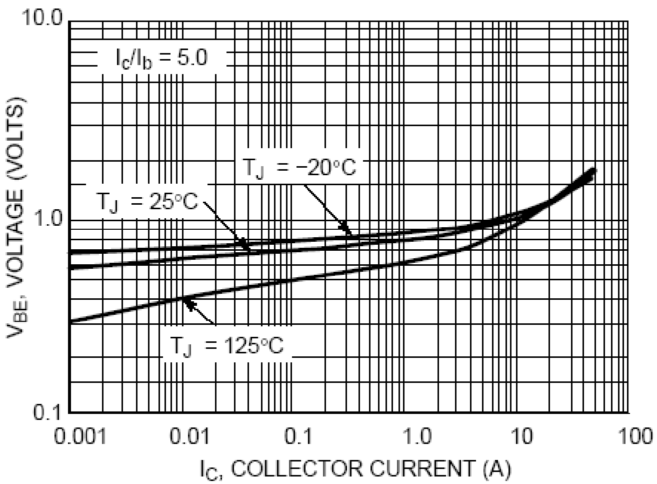


Figure 5. Typical Base−Emitter Saturation Voltage, I_C/I_B = 5.0

$\beta_F=10$

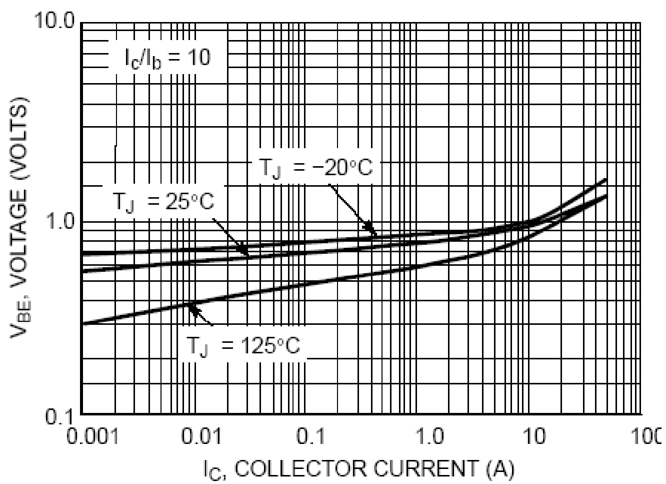
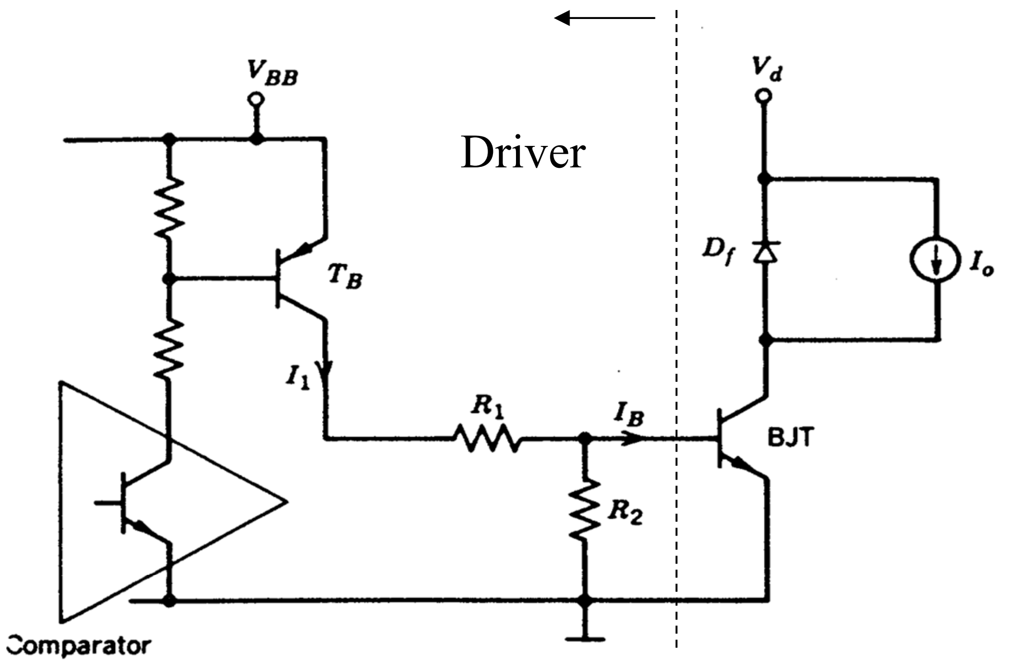
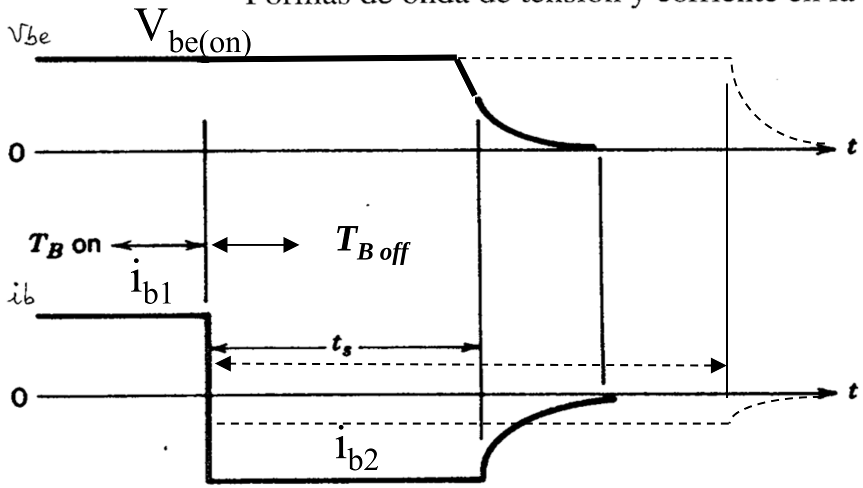


Figure 6. Typical Base−Emitter Saturation Voltage, I_C/I_B = 10

Excitador para BJT, con tensión de alimentación sencilla.



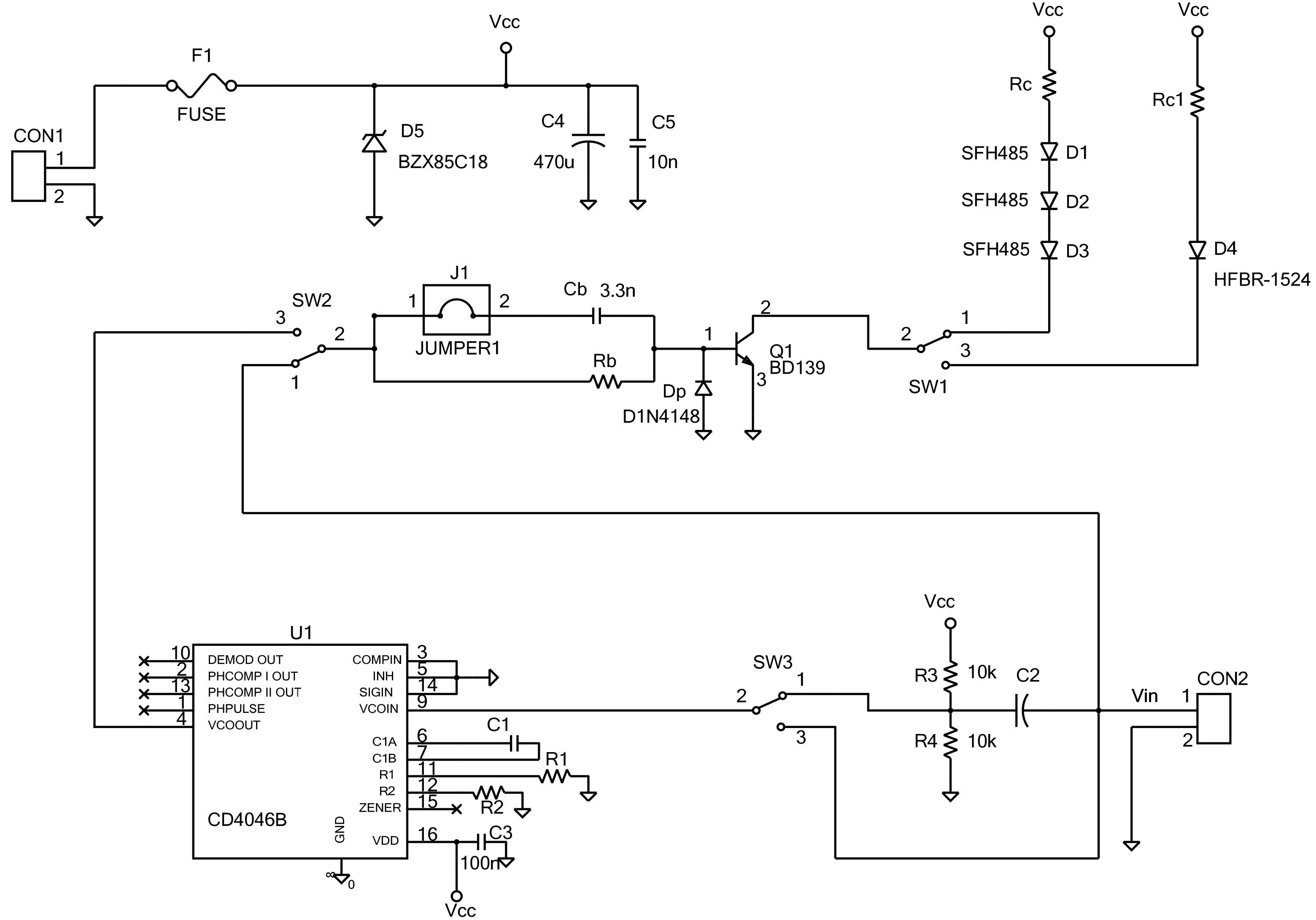
Formas de onda de tensión y corriente en la base.

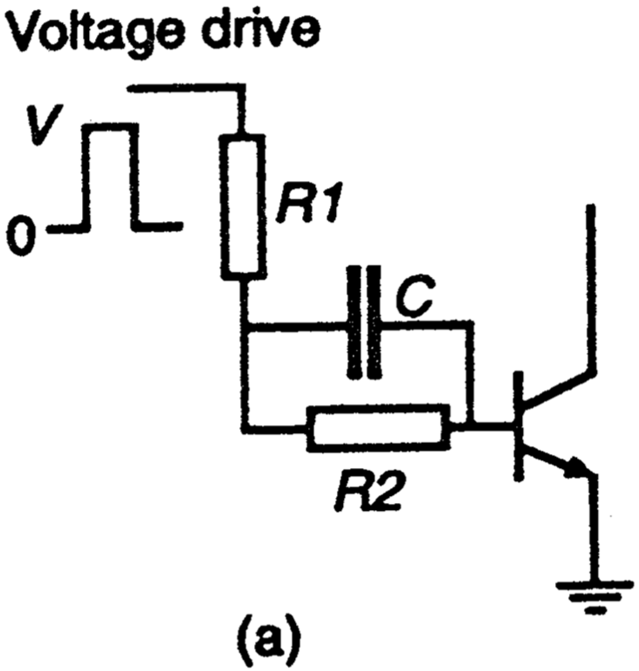


$R_2\uparrow \rightarrow t_s \uparrow$

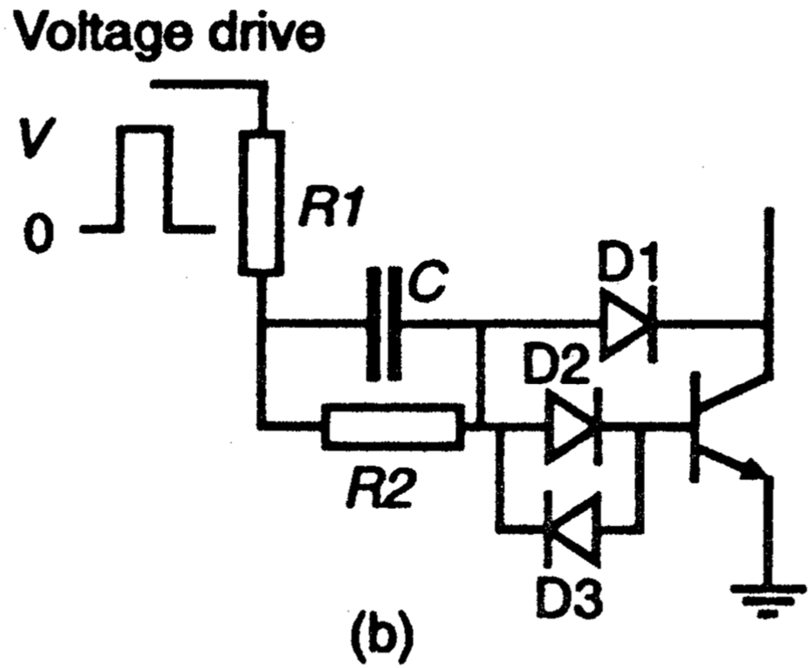
$$i_{b2} \approx \frac{V_{be(on)}}{R_2}$$

Práctica II (1ª parte). Electrónica Analógica II



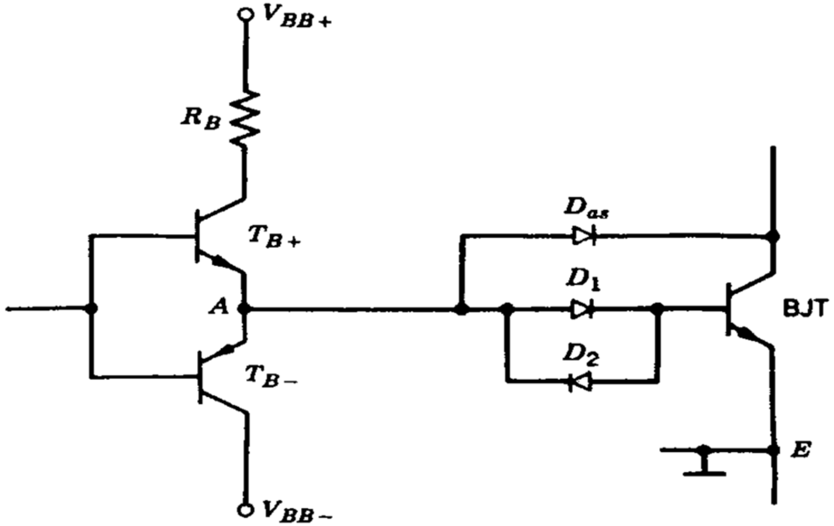


Condensador de aceleración de paso al corte.



Empleo de diodos anti-saturación.

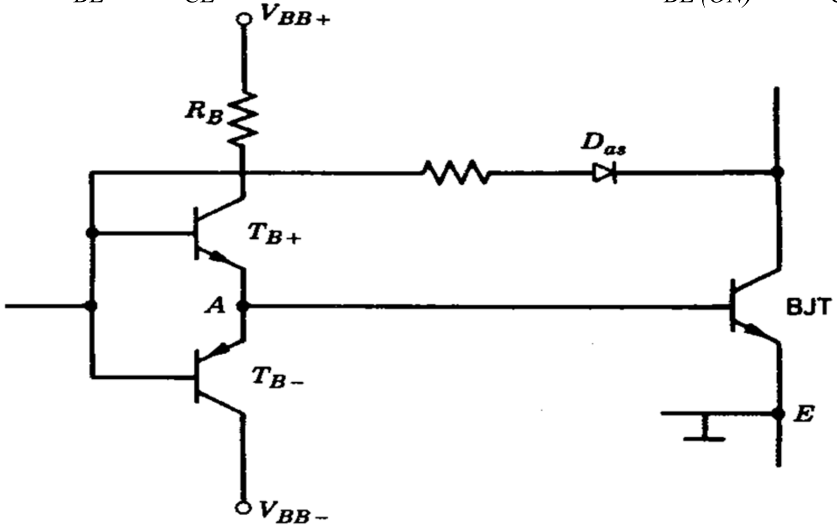
Excitación bipolar y diodos anti-saturación



(a)

Activa

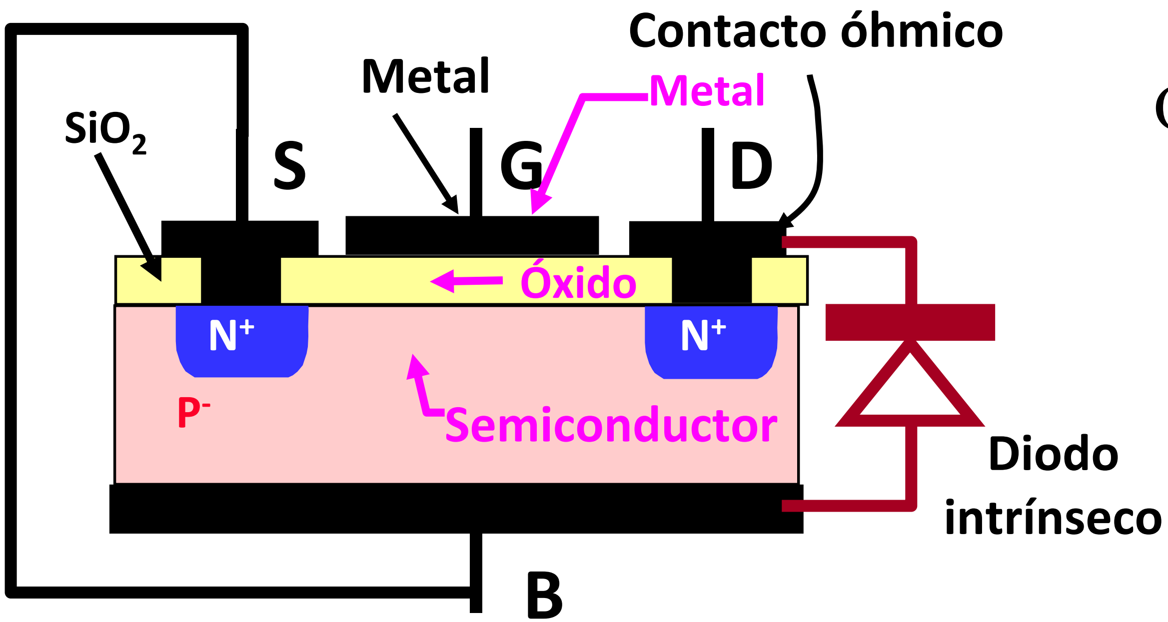
$$\left.\begin{array}{l} V_{CB} > 0 \rightarrow BC_{off} \\ V_{BE} > 0 \rightarrow BE_{on} \\ V_{CB} = V_{CE} - V_{BE} \end{array}\right\} \rightarrow V_{BE} \leq \mathrm{V}_{CE} \xrightarrow{\text{límite entre activa y saturación}} V_{BE\,(ON)} = \mathrm{V}_{CE}$$



TRANSISTORES MOSFET DE POTENCIA

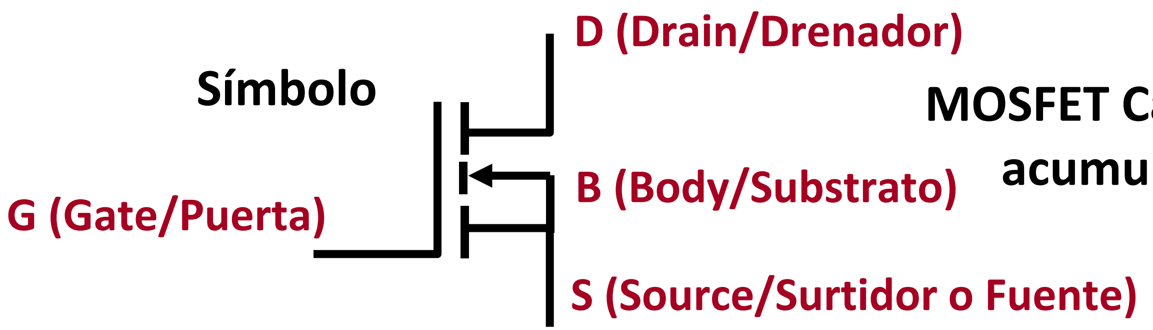
Estructura transistor MOSFET

Estructura

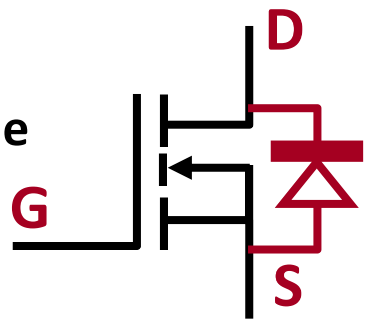


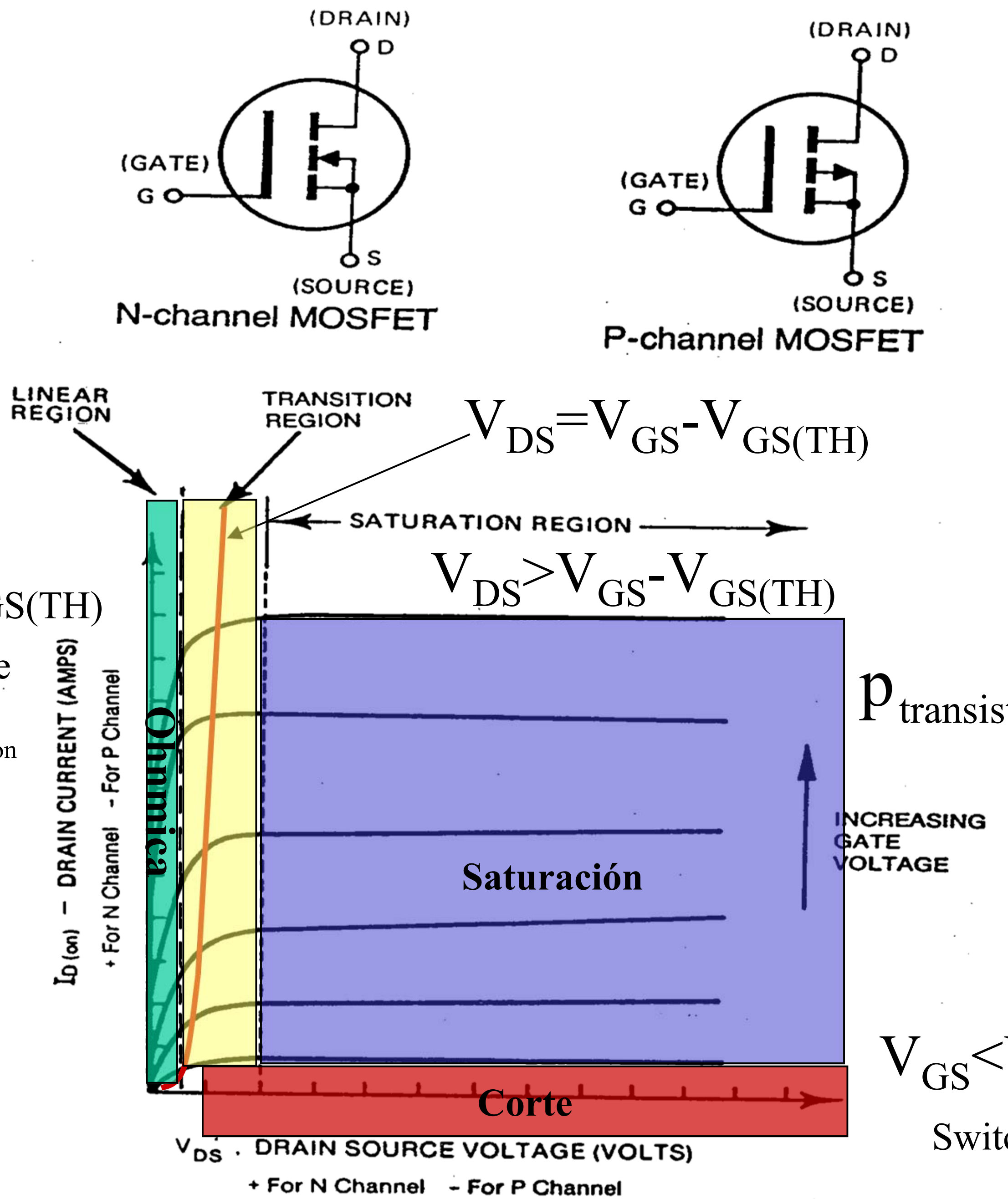
MOSFET = Metal Oxide Semiconductor Field Effect Transistor/Transistor de Efecto de Campo Metal Óxido Semiconductor

Símbolo



MOSFET Canal N de acumulación





$V_{DS}=V_{GS}-V_{GS(TH)}$

$V_{DS}<V_{GS}-V_{GS(TH)}$

Switch ON, en serie

con resistencia $r_{DS,on}$

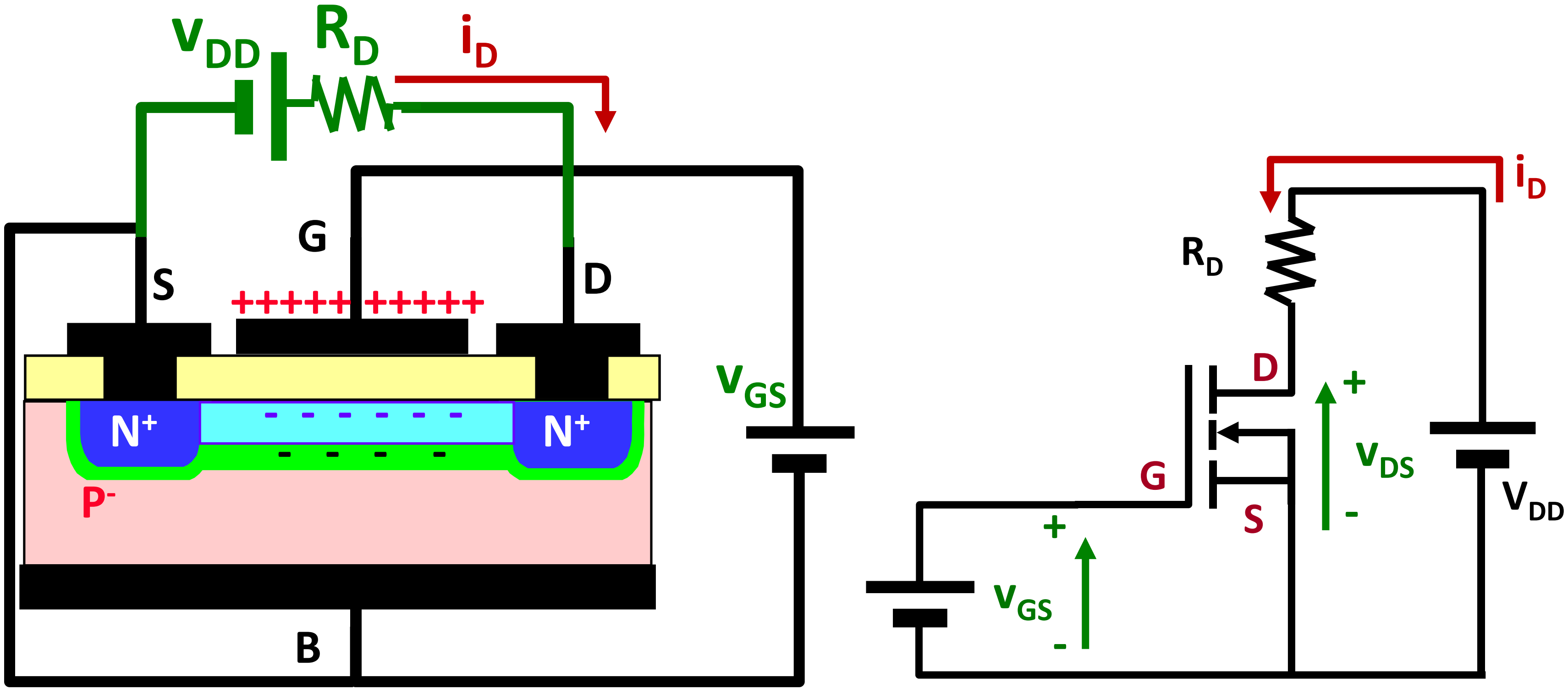
$V_{DS}>V_{GS}-V_{GS(TH)}$

$p_{transistor} \approx i_D \cdot v_{DS}$

$V_{GS}<V_{GS(TH)}$

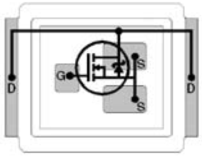
Switch OFF

Polarización



$$V_{GS} > V_{GS(TH)}$$

Encapsulados



DirectFET™ ISOMETRIC

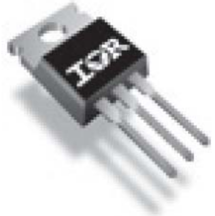
IRF6648

$R_{DS(on)}$ = 5.5 mΩ, I_D = 86 A

SO-8

IRF7855PbF

$R_{DS(on)}$ = 9.4 mΩ, I_D = 12 A



TO-220AB

IRFZ44VZPbF

D²Pak

IRFZ44VZSPbF

TO-262

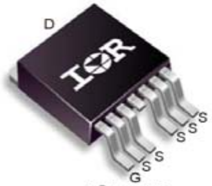
IRFZ44VZLPbF

$R_{DS(on)}$ = 12 mΩ, I_D = 57 A

TO-247AC

IRFP054VPbF

$R_{DS(on)}$ = 9 mΩ, I_D = 93 A



D²Pak 7 Pin

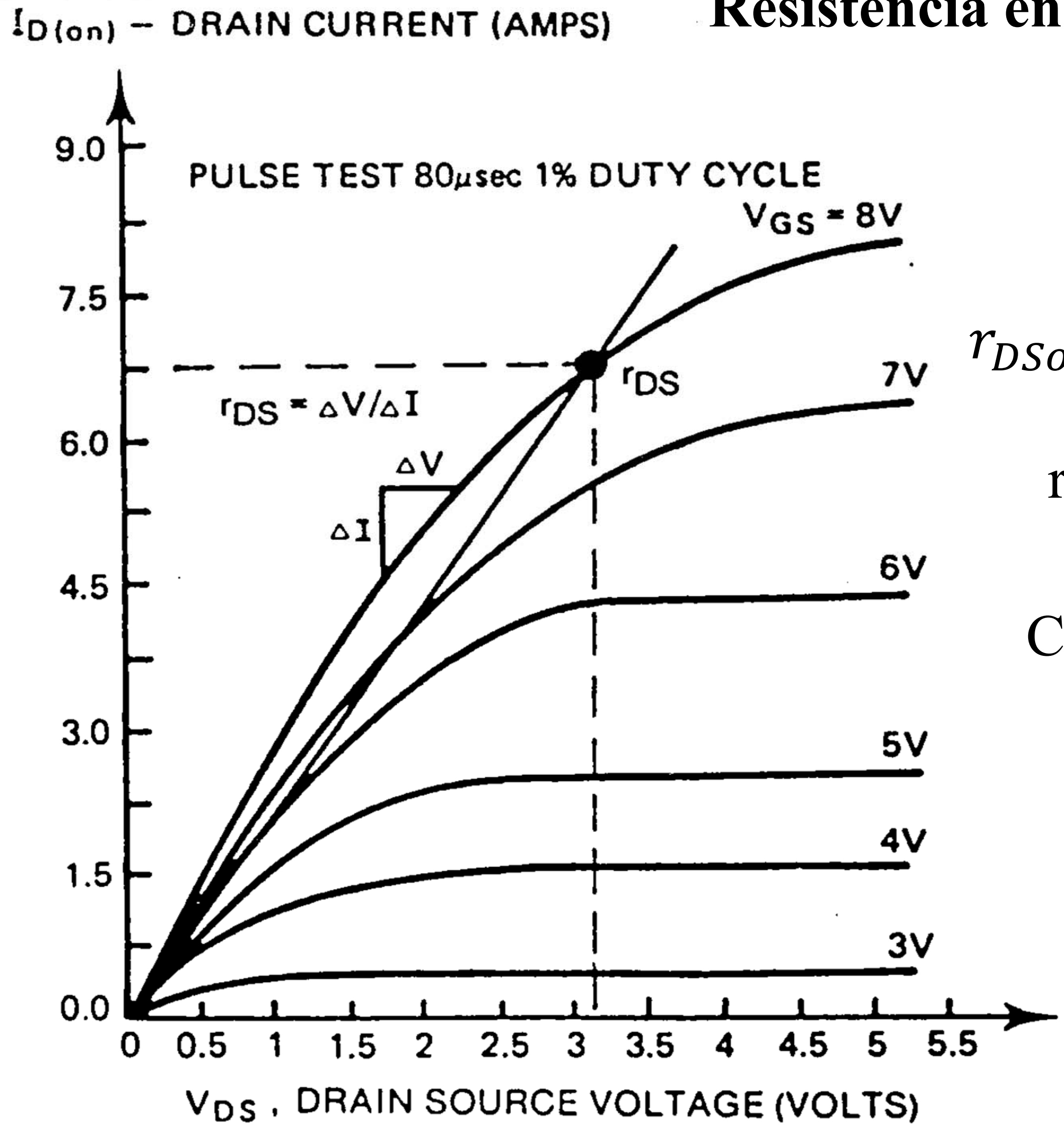
IRFS3006-7PPbF

$R_{DS(on)}$ = 1.5 mΩ, I_D = 240 A

Type	IPB034N06L3 G	IPI037N06L3 G	IPP037N06L3 G
			
Package	PG-TO-263-3	PG-TO-262-3	PG-TO-220-3
Marking	034N06L	037N06L	037N06L

$R_{DS(on)}$ = 3.4 mΩ, I_D = 90 A

Resistencia en zona óhmica



Cuanto más pequeña mejor

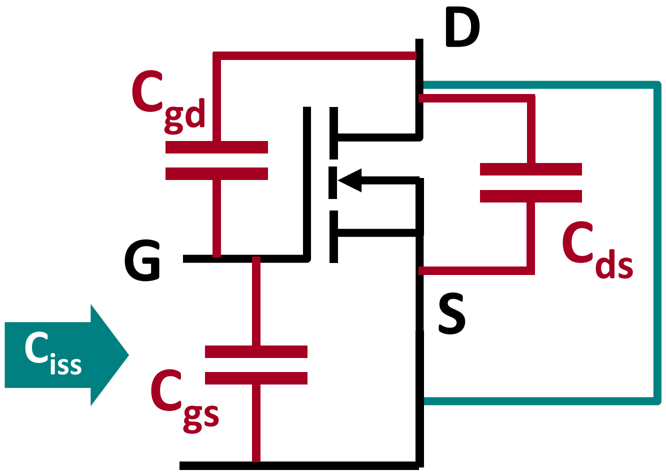
$$r_{DSon} \sim (K_1 \bullet BV_{DSS})^{2,5-2,7}$$

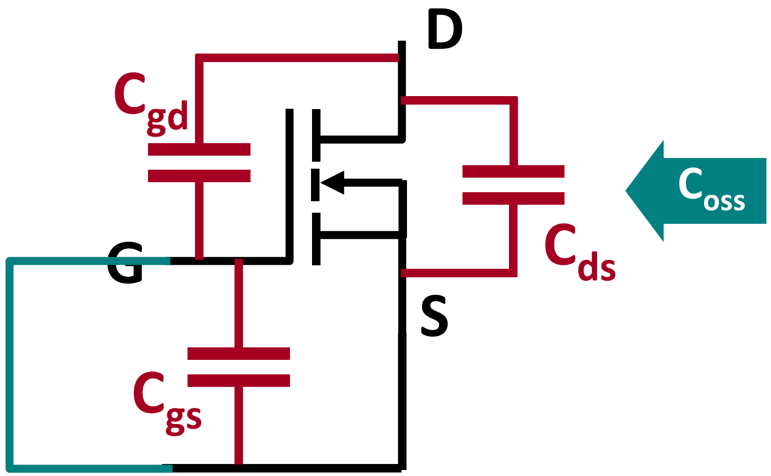
$$r_{DSon} = f(T^a, V_{GS})$$

$$\text{C.T.: } \frac{\partial r_{DSon}}{\partial T^{\underline{a}}} > 0$$

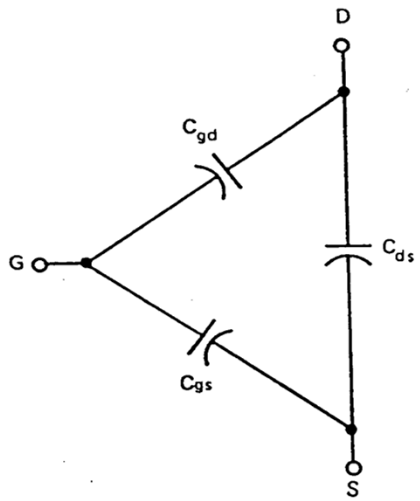
Al ser positivo el C.T., se facilita la conexión en paralelo de varios MOSFET

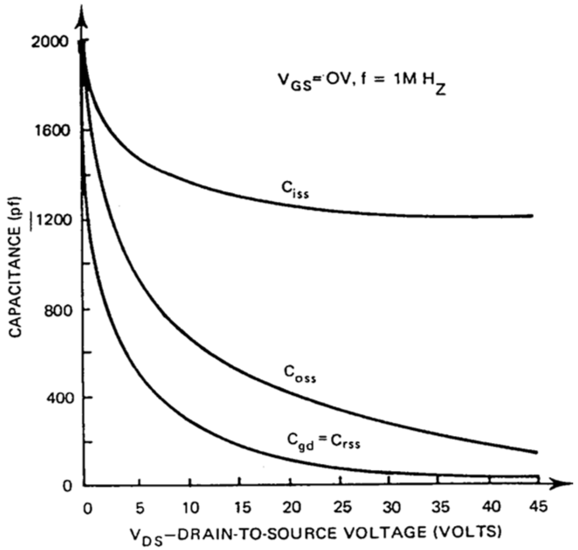
Capacidades parásitas





$C_{ISS} = C_{GD} // C_{GS}$ $\quad$ $C_{OSS} = C_{DS} // C_{GD}$ $\quad$ $C_{RSS} = C_{GD}$





International
IOR Rectifier

7/20/04 PD - 95531

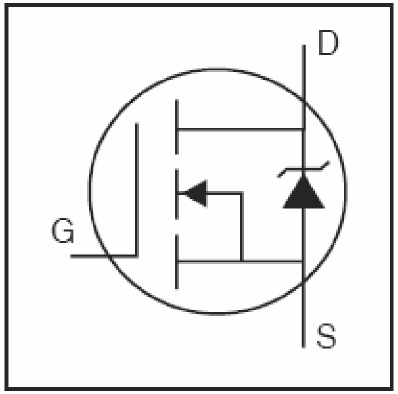
AUTOMOTIVE MOSFET

IRF540ZPbF
IRF540ZSPbF
IRF540ZLPbF

HEXFET® Power MOSFET

Features

- Advanced Process Technology
- Ultra Low On-Resistance
- 175°C Operating Temperature
- Fast Switching
- Repetitive Avalanche Allowed up to Tjmax
- Lead-Free



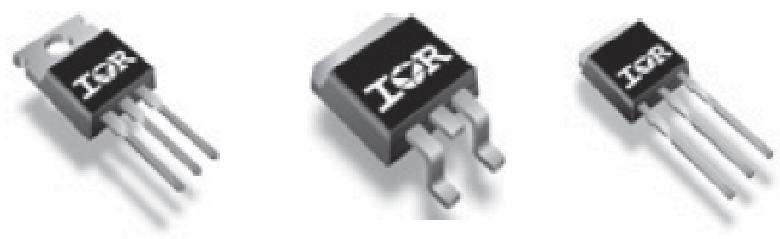
$V_{DSS} = 100V$

$R_{DS(on)} = 26.5m\Omega$

$I_D = 36A$

Description

Specifically designed for Automotive applications, this HEXFET® Power MOSFET utilizes the latest processing techniques to achieve extremely low on-resistance per silicon area. Additional features of this design are a 175°C junction operating temperature, fast switching speed and improved repetitive avalanche rating . These features combine to make this design an extremely efficient and reliable device for use in Automotive applications and a wide variety of other applications.



TO-220AB IRF540Z	D²Pak IRF540ZS	TO-262 IRF540ZL

Absolute Maximum Ratings

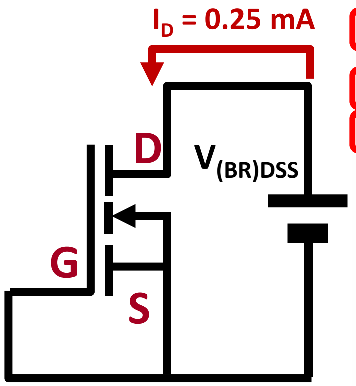
	Parameter	Max.	Units
I_D @ T_C = 25°C	Continuous Drain Current, V_{GS} @ 10V (Silicon Limited)	36	A
I_D @ T_C = 100°C	Continuous Drain Current, V_{GS} @ 10V	25	
I_{DM}	Pulsed Drain Current ①	140	
P_D @T_C = 25°C	Power Dissipation	92	W
	Linear Derating Factor	0.61	W/°C
V_{GS}	Gate-to-Source Voltage	± 20	V
E_{AS} (Thermally limited)	Single Pulse Avalanche Energy②	83	mJ
E_{AS} (Tested)	Single Pulse Avalanche Energy Tested Value ⑥	120	
I_{AR}	Avalanche Current ①	See Fig.12a, 12b, 15, 16	A
E_{AR}	Repetitive Avalanche Energy ⑤		mJ
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to + 175	°C
	Soldering Temperature, for 10 seconds	300 (1.6mm from case)	
	Mounting Torque, 6-32 or M3 screw ⑦	10 lbf•in (1.1N•m)	

Thermal Resistance

	Parameter	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	–––	1.64	°C/W
$R_{\theta CS}$	Case-to-Sink, Flat Greased Surface ⑦	0.50	–––	
$R_{\theta JA}$	Junction-to-Ambient ⑦	–––	62	
$R_{\theta JA}$	Junction-to-Ambient (PCB Mount) ⑧	–––	40	

⑦ This is only applied to TO-220AB pakcage.

⑧ This is applied to D^{2}Pak, when mounted on 1" square PCB (FR-4 or G-10 Material). For recommended footprint and soldering techniques refer to application note #AN-994.



Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)DSS}$	Drain-to-Source Breakdown Voltage	100	---	---	V	V_{GS} = 0V, I_D = 250μA
$\Delta V_{(BR)DSS}/\Delta T_J$	Breakdown Voltage Temp. Coefficient	---	0.093	---	V/°C	Reference to 25°C, I_D = 1mA
$R_{DS(on)}$	Static Drain-to-Source On-Resistance	---	21	26.5	mΩ	V_{GS} = 10V, I_D = 22A ③
$V_{GS(th)}$	Gate Threshold Voltage	2.0	---	4.0	V	V_{DS} = V_{GS}, I_D = 250μA
gfs	Forward Transconductance	36	---	---	~~V~~ Ω^{-1}	...2A
I_{DSS}	Drain-to-Source Leakage Current	---	---	20	μA	... = 0V
		---	---	250		... = 0V, T_J = 125°C
I_{GSS}	Gate-to-Source Forward Leakage	---	---	200	nA	V_{GS} = 20V
	Gate-to-Source Reverse Leakage	---	---	-200		V_{GS} = -20V
Q_g	Total Gate Charge	---	42	63	nC	I_D = 22A
Q_{gs}	Gate-to-Source Charge	---	9.7	---		V_{DS} = 80V
Q_{gd}	Gate-to-Drain ("Miller") Charge	---	15	---		V_{GS} = 10V ③
$t_{d(on)}$	Turn-On Delay Time	---	15	---	ns	V_{DD} = 50V
t_r	Rise Time	---	51	---		I_D = 22A
$t_{d(off)}$	Turn-Off Delay Time	---	43	---		R_G = 12 Ω
t_f	Fall Time	---	39	---		V_{GS} = 10V ③
L_D	Internal Drain Inductance	---	4.5	---	nH	Between lead, 6mm (0.25in.)
L_S	Internal Source Inductance	---	7.5	---		from package and center of die contact
C_{iss}	Input Capacitance	---	1770	---	pF	V_{GS} = 0V
C_{oss}	Output Capacitance	---	180	---		V_{DS} = 25V
C_{rss}	Reverse Transfer Capacitance	---	100	---		f = 1.0MHz
C_{oss}	Output Capacitance	---	730	---		V_{GS} = 0V, V_{DS} = 1.0V, f = 1.0MHz
C_{oss}	Output Capacitance	---	110	---		V_{GS} = 0V, V_{DS} = 80V, f = 1.0MHz
C_{oss} eff.	Effective Output Capacitance	---	170	---		V_{GS} = 0V, V_{DS} = 0V to 80V ④

Source-Drain Ratings and Characteristics

	Parameter	Min.	Typ.	Max.	Units	Conditions
I_S	Continuous Source Current (Body Diode)	---	---	36	A	MOSFET symbol showing the
I_{SM}	Pulsed Source Current (Body Diode) ①	---	---	140		integral reverse p-n junction diode.
V_{SD}	Diode Forward Voltage	---	---	1.3	V	T_J = 25°C, I_S = 22A, V_{GS} = 0V ③
t_{rr}	Reverse Recovery Time	---	33	50	ns	T_J = 25°C, I_F = 22A, V_{DD} = 50V
Q_{rr}	Reverse Recovery Charge	---	41	62	nC	di/dt = 100A/μs ③
t_{on}	Forward Turn-On Time	Intrinsic turn-on time is negligible (turn-on is dominated by LS+LD)				

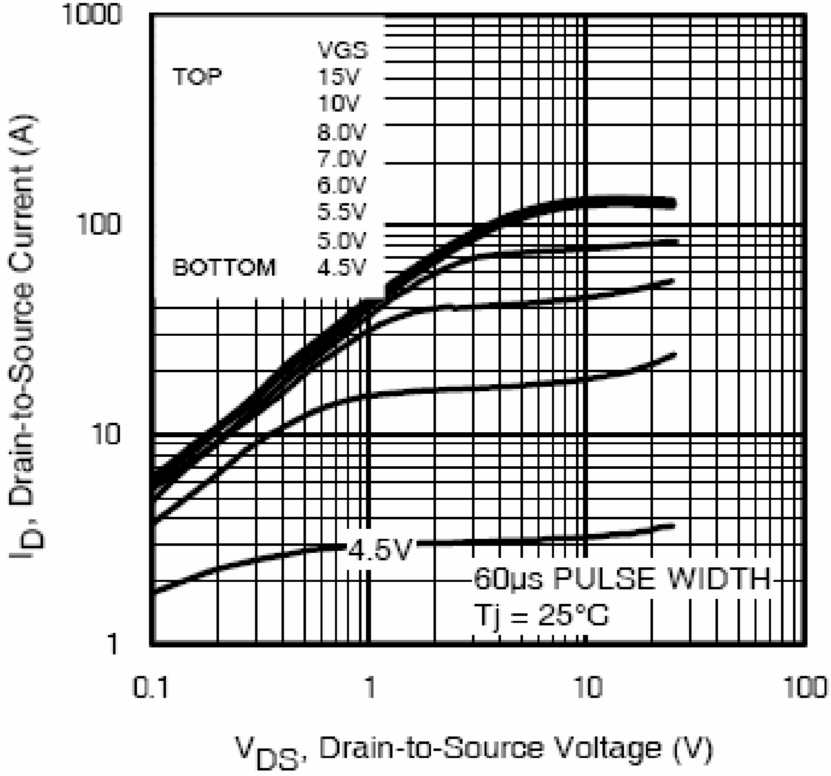


Fig 1. Typical Output Characteristics

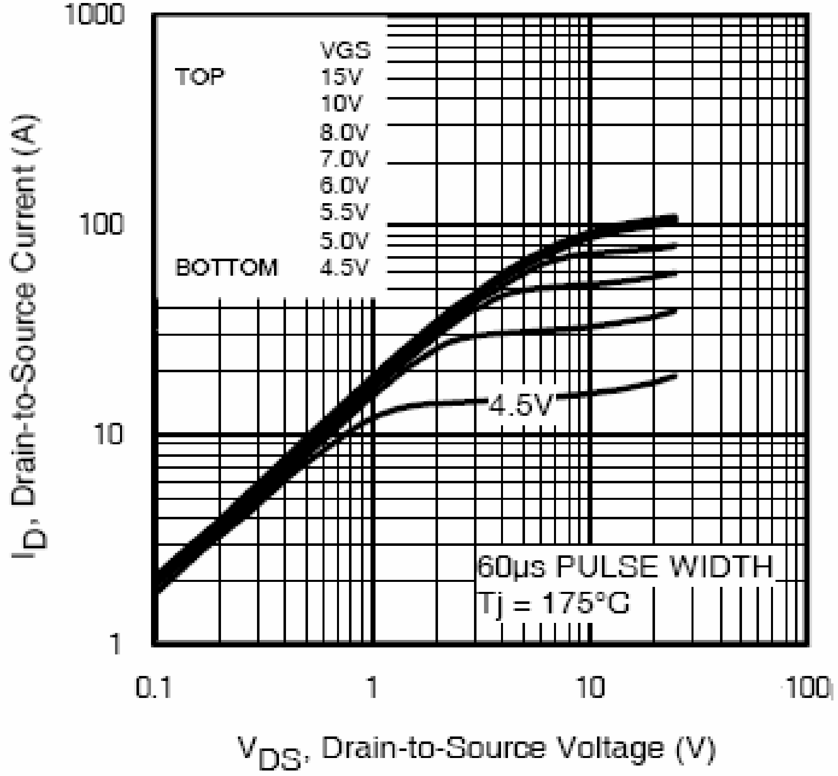


Fig 2. Typical Output Characteristics

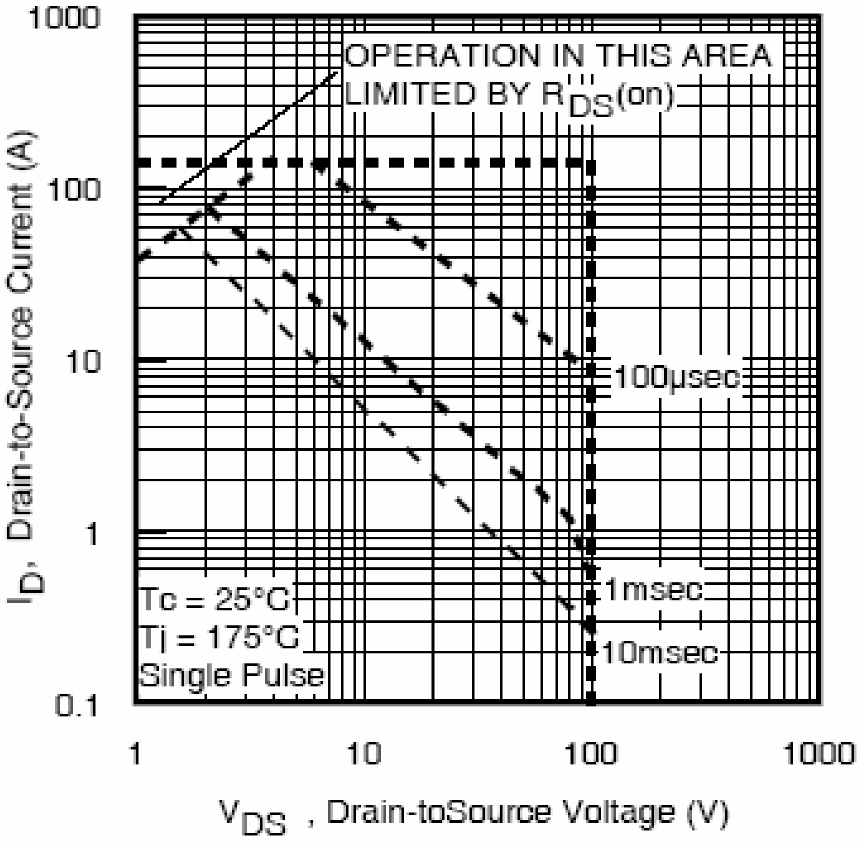


Fig 8. Maximum Safe Operating Area

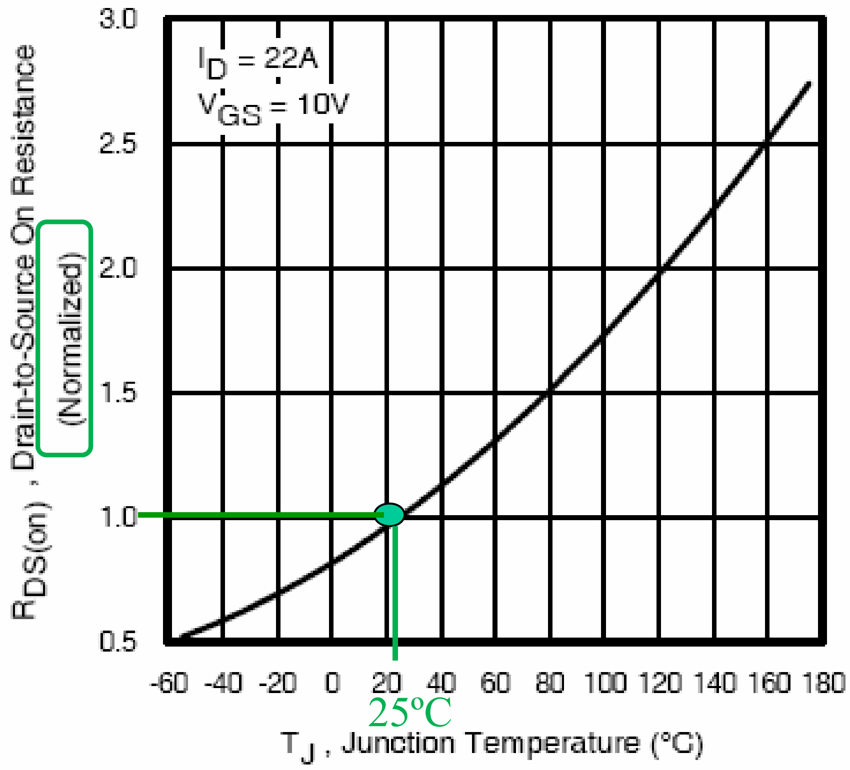


Fig 10. Normalized On-Resistance Vs. Temperature

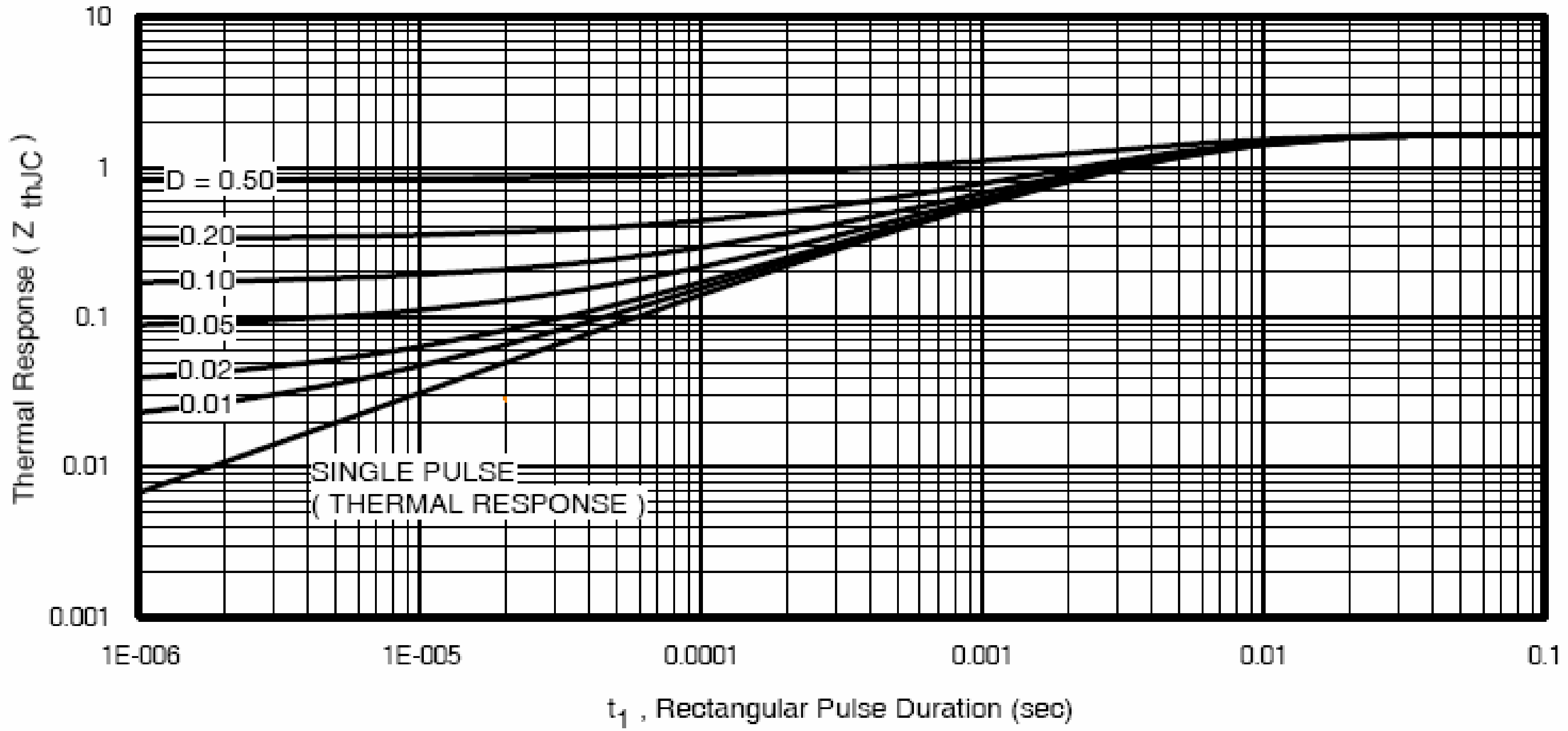
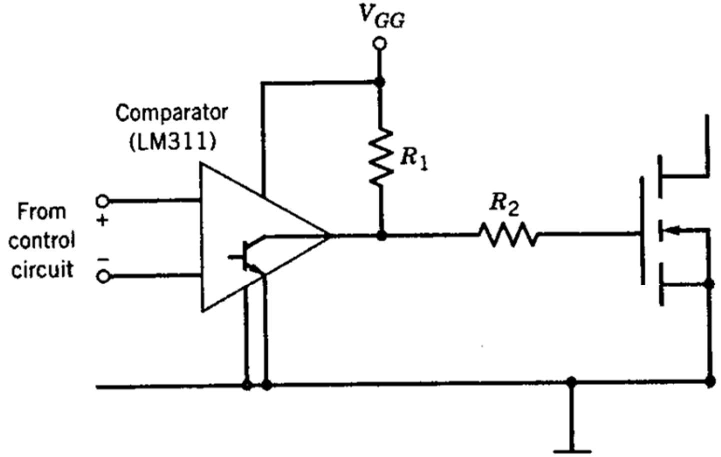
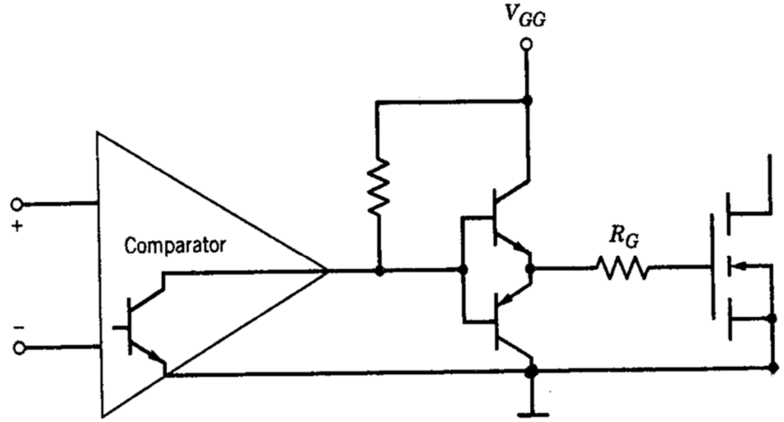


Fig 11. Maximum Effective Transient Thermal Impedance, Junction-to-Case

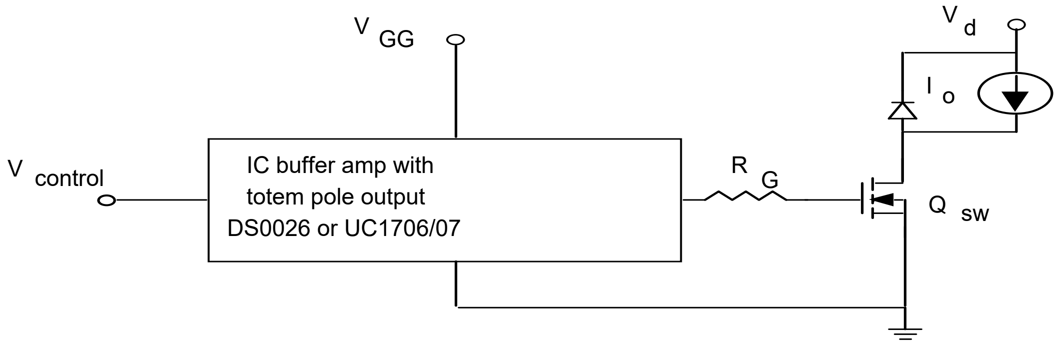
Excitación unipolar



Excitador sencillo para MOSFET.

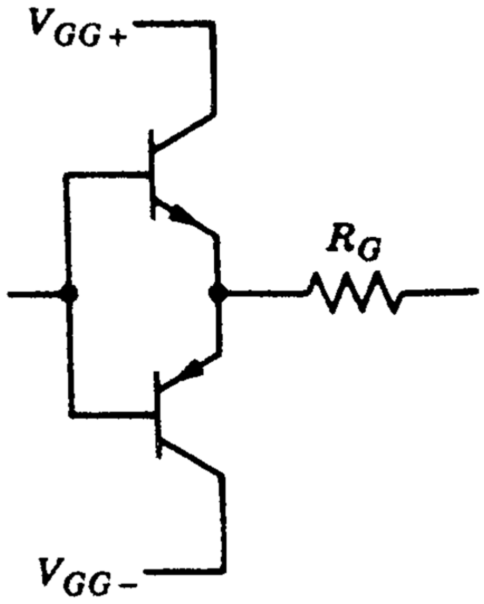


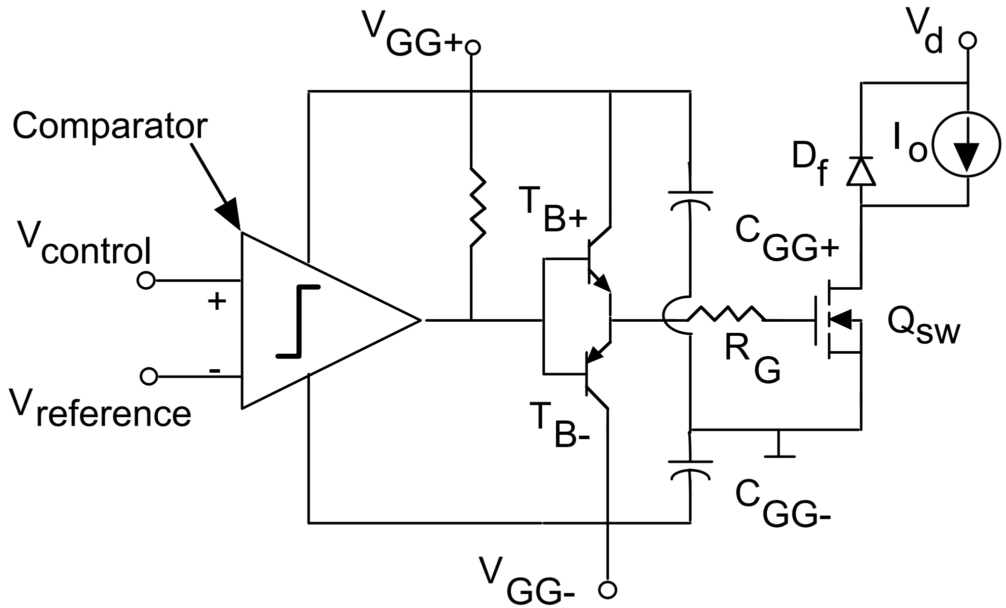
Excitador con par complementario.

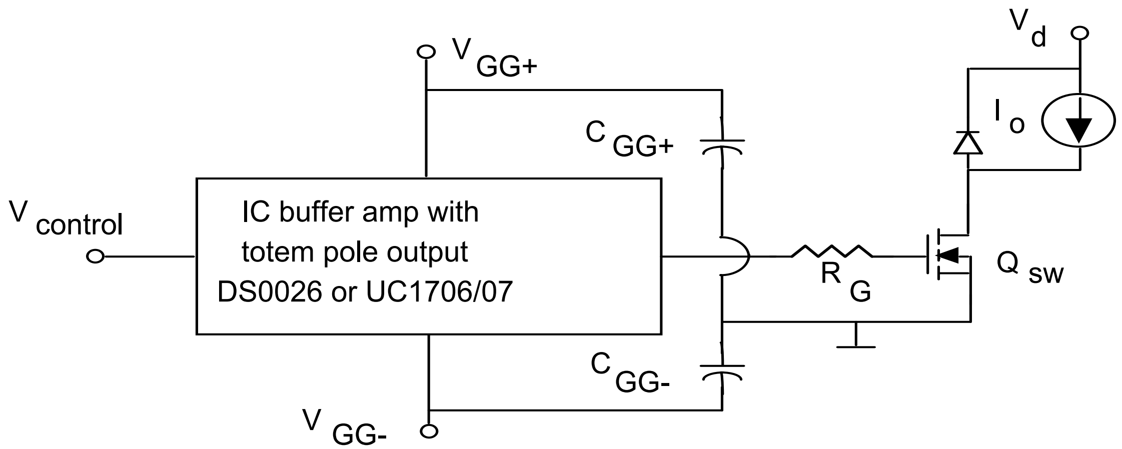


Driver con C.I. específico

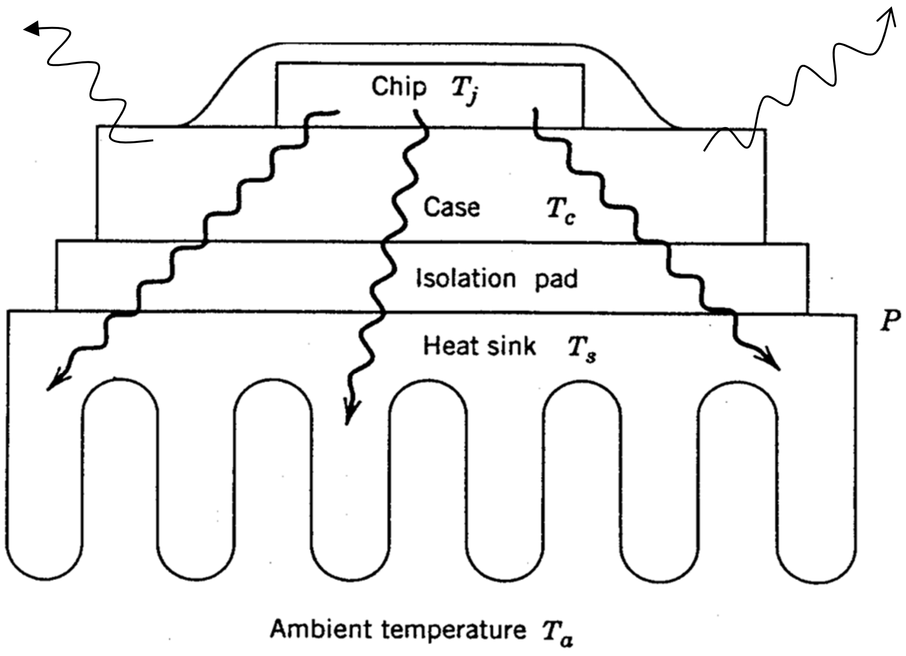
Excitadores con alimentación bipolar



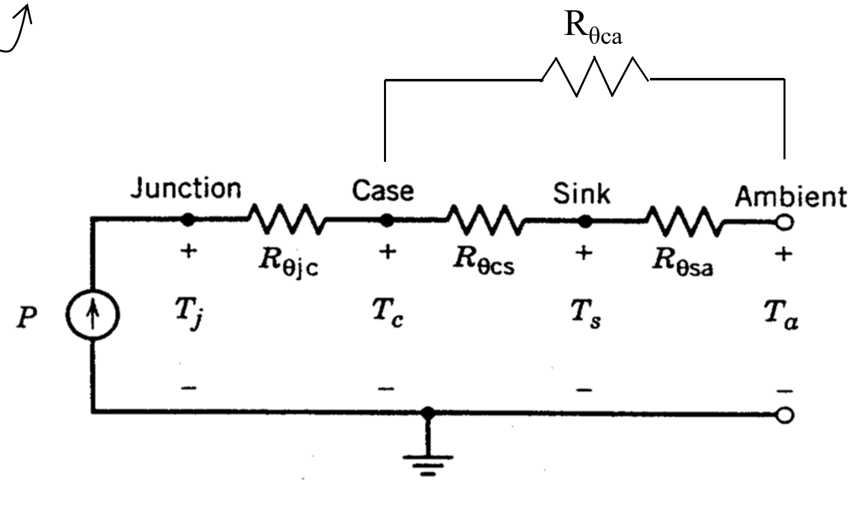




DISIPACIÓN TÉRMICA



(a)



(b)

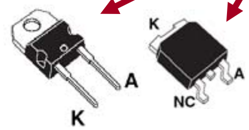
a) Semiconductor montado sobre radiador.

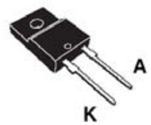
b) Circuito equivalente al térmico.

R_{thjc}

Table 2. Thermal parameters — STTH512 — *$I_{F(AV)}$ = 5A, V_{RRM} = 1200V*

Symbol	Parameter		Value	Unit
$R_{th(j-c)}$	Junction to case	TO-220AC / DPAK	2.5	°C/W
		TO-220FPAC	5.8	



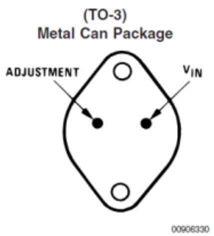


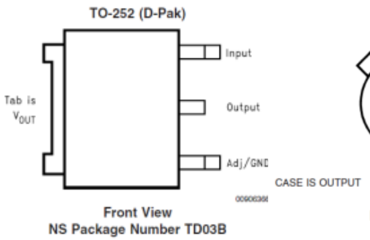
National Semiconductor — **LM117/LM317A/LM317 3-Terminal Adjustable Regulator**

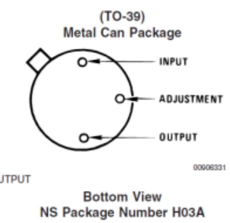
Parameter	Conditions	LM317A			LM317			Units
		Min	Typ	Max	Min	Typ	Max	
Thermal Resistance, Junction-to-Case	K Package					2.3	3	°C/W
	MDT Package					5		°C/W
	H Package		12	15		12	15	°C/W
	T Package		4	5		4		°C/W
	MP Package		23.5			23.5		°C/W

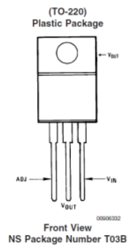
LM117 Series Packages

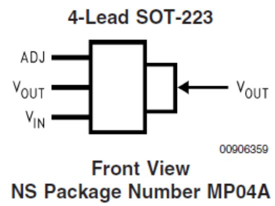
Part Number Suffix	Package	Design Load Current
K	TO-3	1.5A
H	**TO-39**	**0.5A**
T	TO-220	1.5A
E	**LCC**	**0.5A**
S	TO-263	1.5A
EMP	SOT-223	1A
MDT	**TO-252**	**0.5A**











R_{thCA}

- Información en catálogos: R_{thJC} y frecuentemente R_{thJA}
- R_{thJA} depende del encapsulado
- $R_{thJA} = R_{thJC} + R_{thCA}$, por tanto se deduce su valor: $R_{thCA} = R_{thJA} - R_{thJC}$

International
IOR Rectifier

AUTOMOTIVE MOSFET

7/20/04 PD - 95531

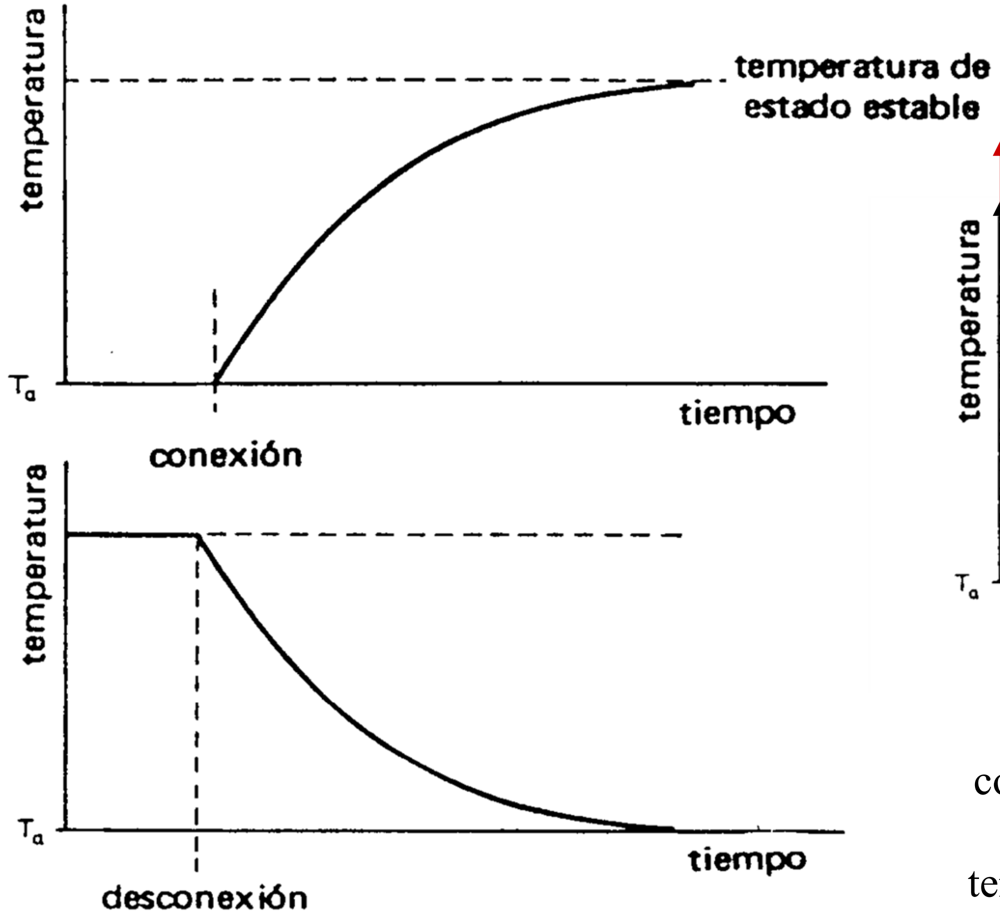
IRF540ZPbF
IRF540ZSPbF
IRF540ZLPbF

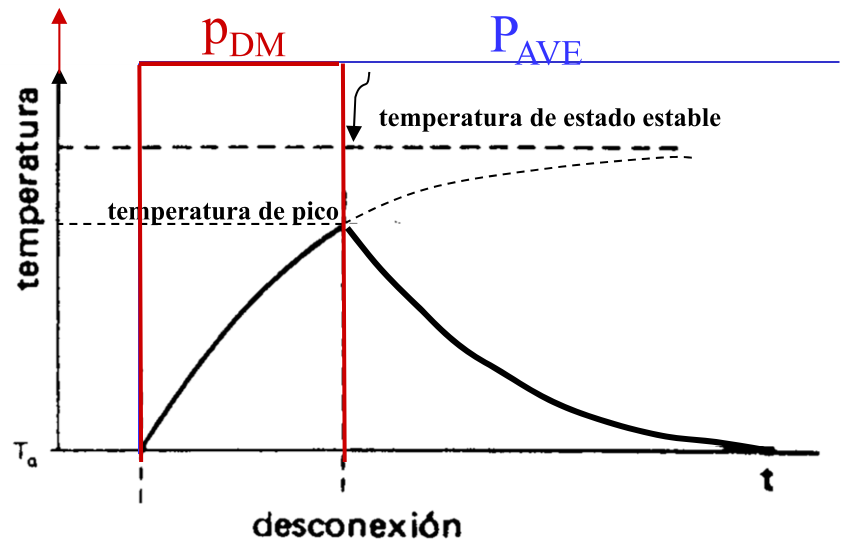
Thermal Resistance

	Parameter	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	–––	1.64	°C/W
$R_{\theta CS}$	Case-to-Sink, Flat Greased Surface ⑦	0.50	–––	
$R_{\theta JA}$	Junction-to-Ambient ⑦	–––	62	
$R_{\theta JA}$	Junction-to-Ambient (PCB Mount) ⑧	–––	40	

⑦ This is only applied to TO-220AB pakcage.
⑧ This is applied to D^2Pak, when mounted on 1" square PCB (FR-4 or G-10 Material). For recommended footprint and soldering techniques refer to application note #AN-994.

Pulsos de potencia

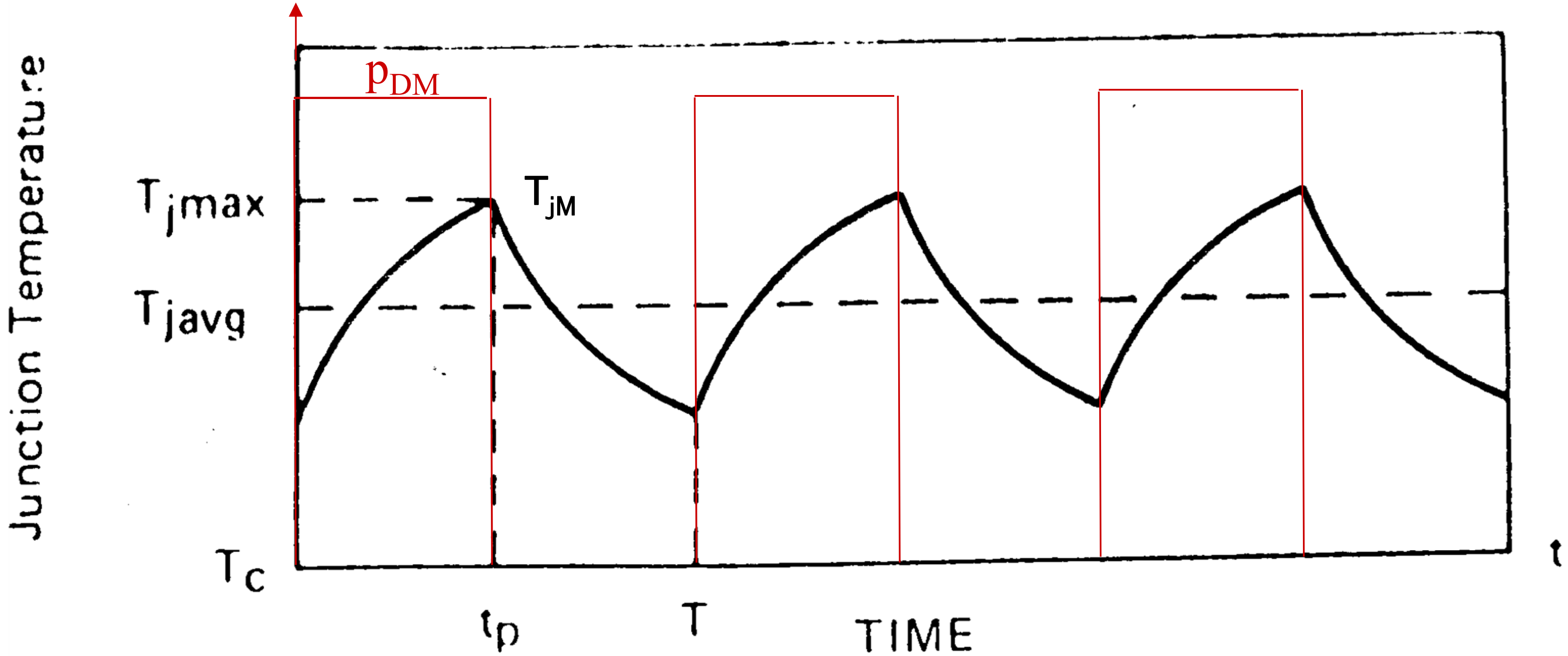




La temperatura de pico adquirida en el componente de potencia, debida a un impulso de potencia corto, será menor que la temperatura adquirida en el componente si esa misma potencia se aplica de forma estable

El calentamiento (subida) y el enfriamiento (bajada) siguen la misma ley.

Pulsos de potencia



Thermal Response to Repetitive Power Pulses

Influencia de la frecuencia de los pulsos de potencia aplicados en el valor de la temperatura de la unión.

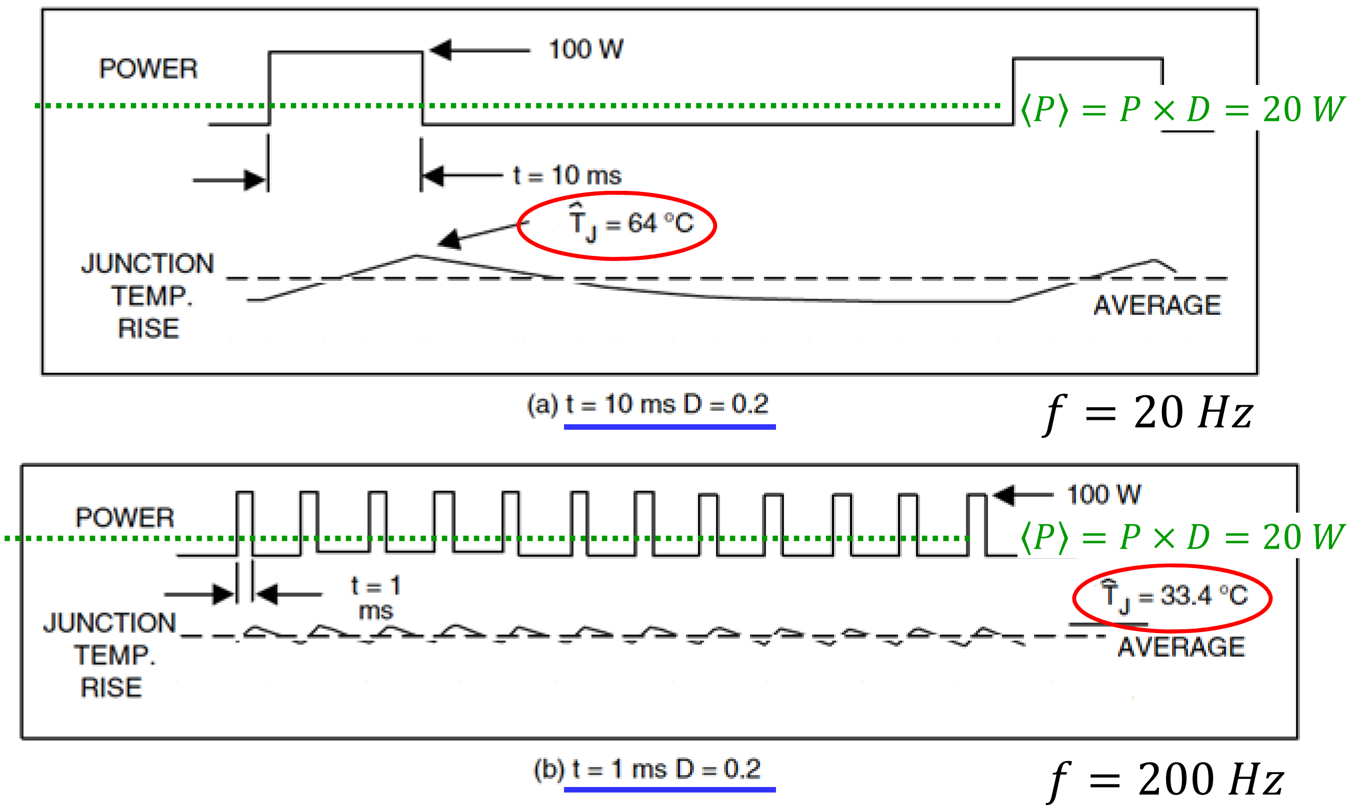
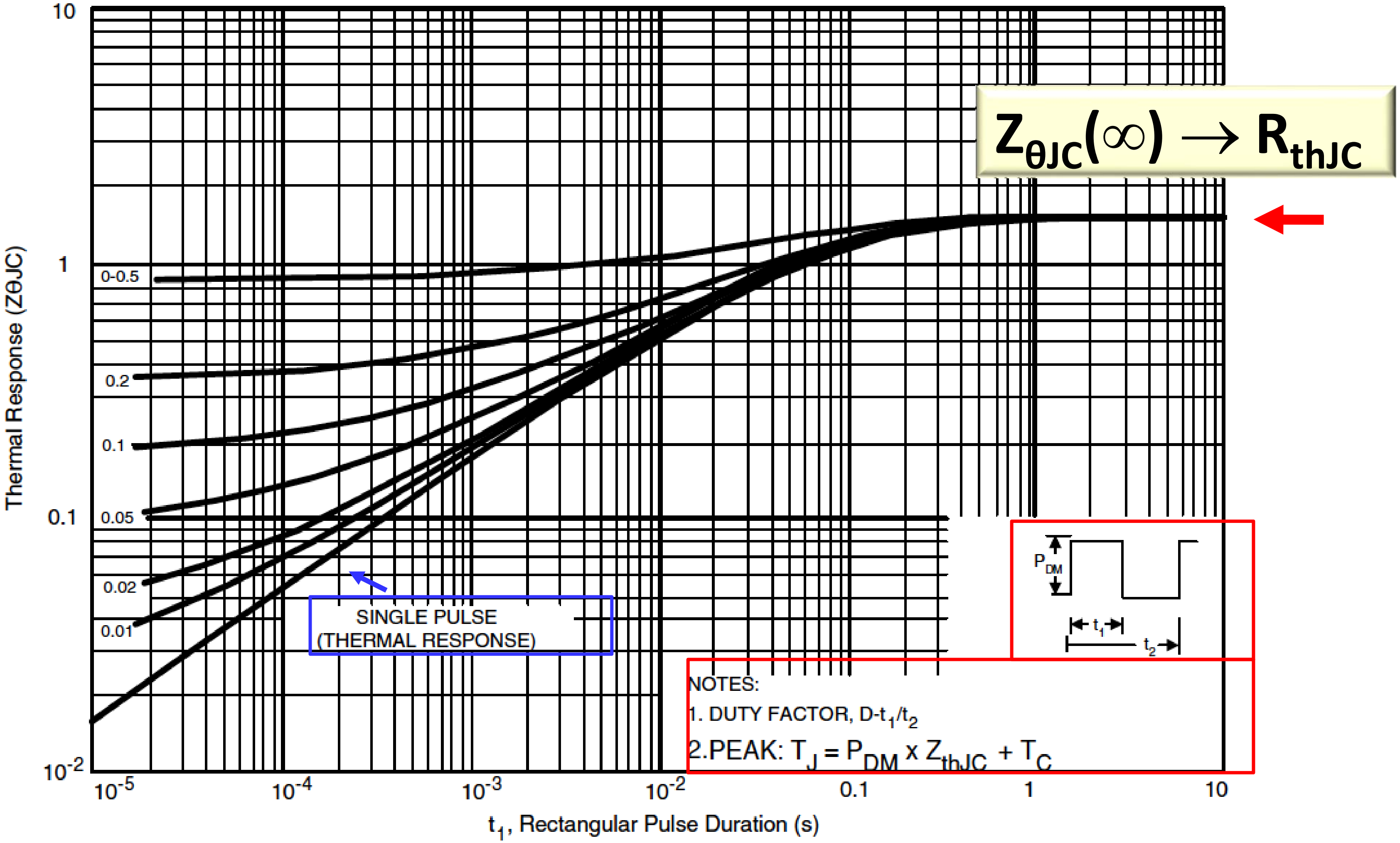


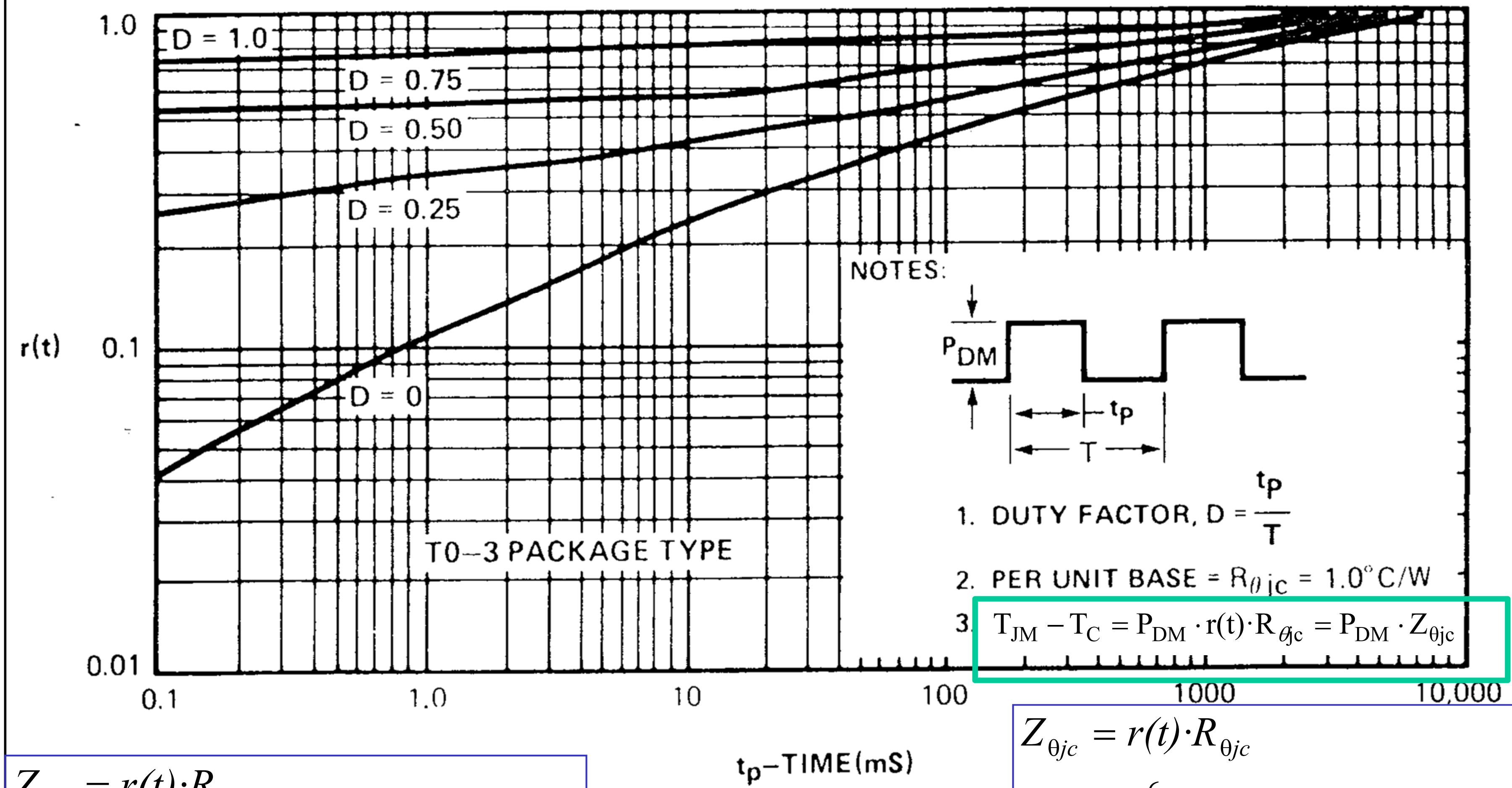
Fig. 3 - Waveforms of Power and Junction Temperature for Repetitive Operation, showing that Peak Junction Temperature is function of Operating Frequency.

Gráfica de impedancia térmica transitoria.



$$T_{J\_max} = T_C + P_{DM} \cdot Z_{\theta JC}(t)$$

Gráfica de impedancia térmica transitoria normalizada.



$$Z_{\theta jc} = r(t) \cdot R_{\theta jc}$$

$$t_p \downarrow \Rightarrow r(t) \rightarrow D$$

$$T_{JM} - T_C = p_{DM} \cdot D \cdot R_{\theta jc} = P_D \cdot R_{\theta jc}$$

$$5Hz \leq f \leq 5kHz$$

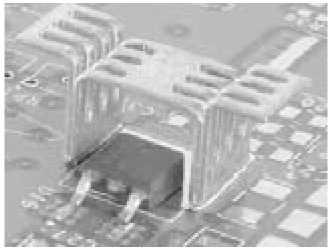
(más o menos)

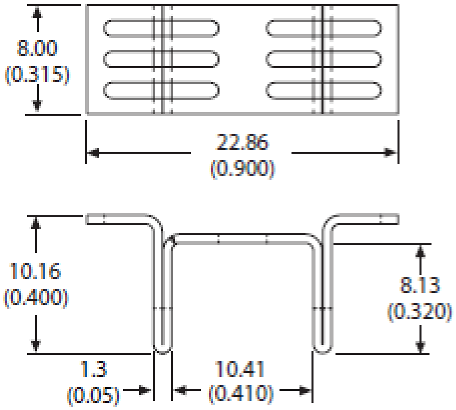
$$Z_{\theta jc} = r(t) \cdot R_{\theta jc}$$

$$t_p \uparrow \Rightarrow \begin{cases} r(t) \approx 1 \Rightarrow Z_{\theta jc} = R_{\theta jc} \\ tiempo\ estable \end{cases}$$

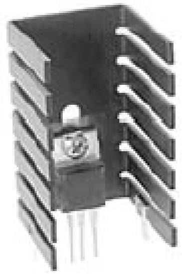
$$T_{JM} - T_C = p_{DM} \cdot 1 \cdot R_{\theta jc} = P_D \cdot R_{\theta jc}$$

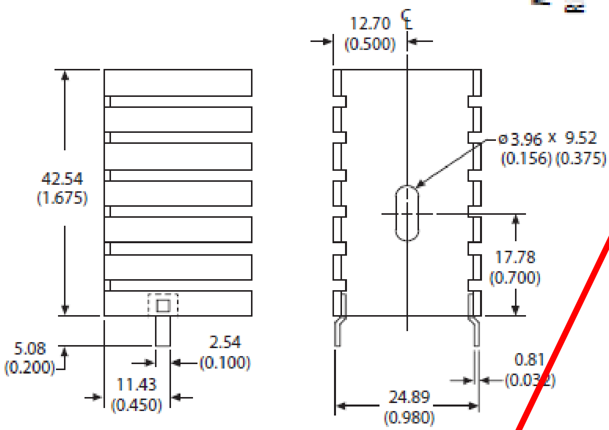
D-PACK



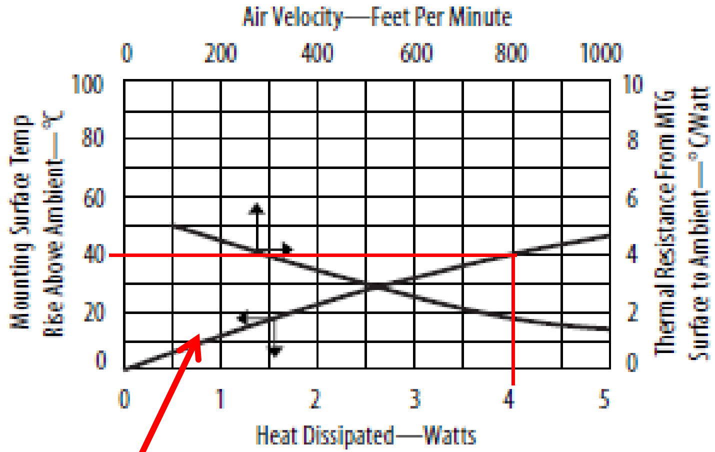


TO-220



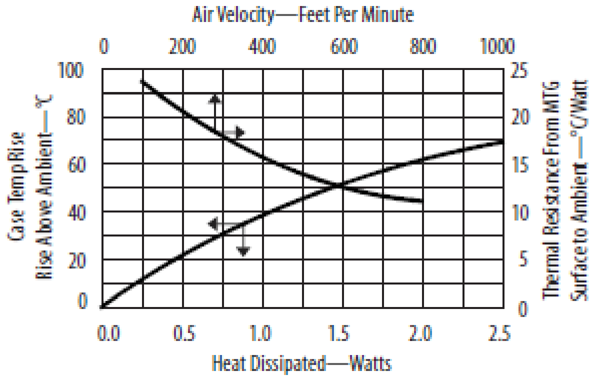


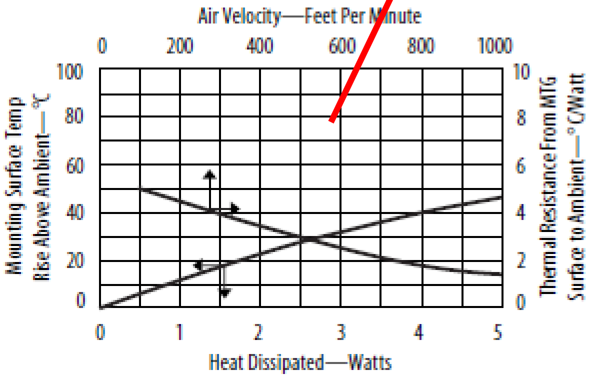
Material: 1.27 (0.050) Thick Aluminum
Finish: Black Anodize



Valor de la $R_{\theta sa}$

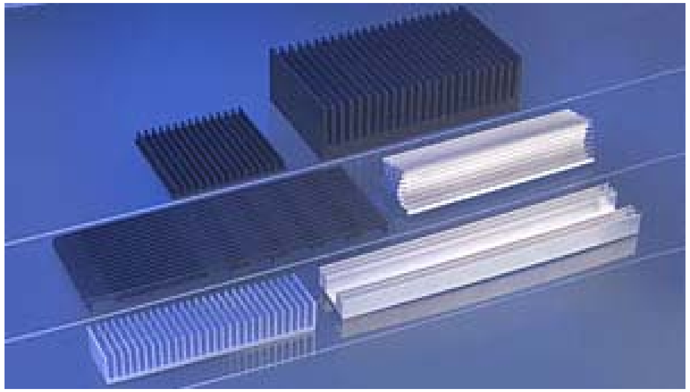
$$R_{\theta sa} = 40/4 = 10\ ºC/W$$

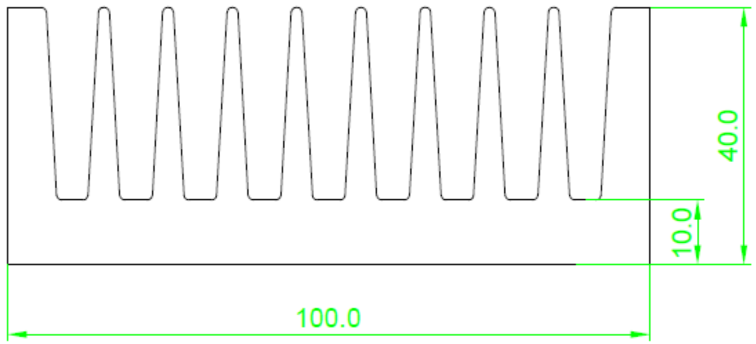


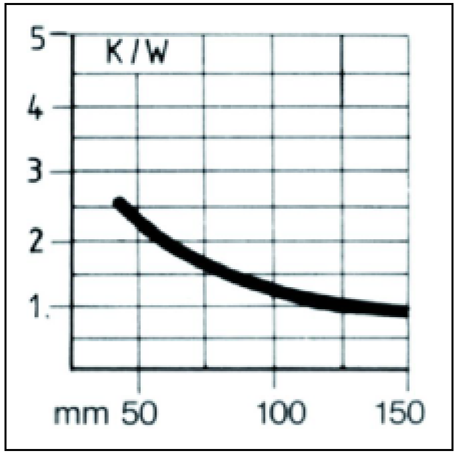


AAVID THERMALLOY
www.aavidthermalloy.com

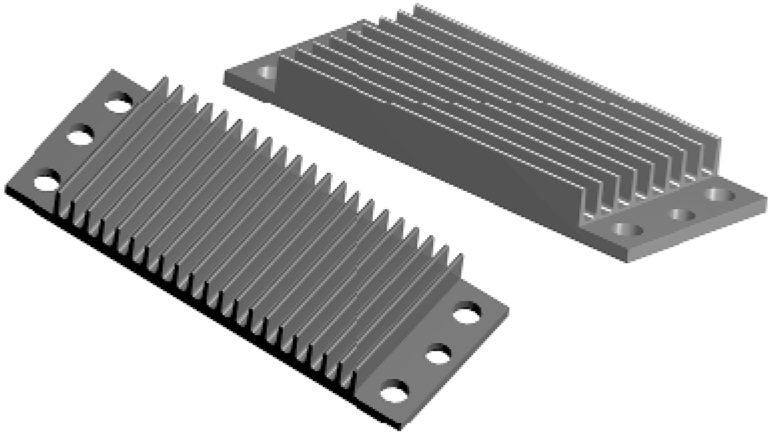
Perfiles

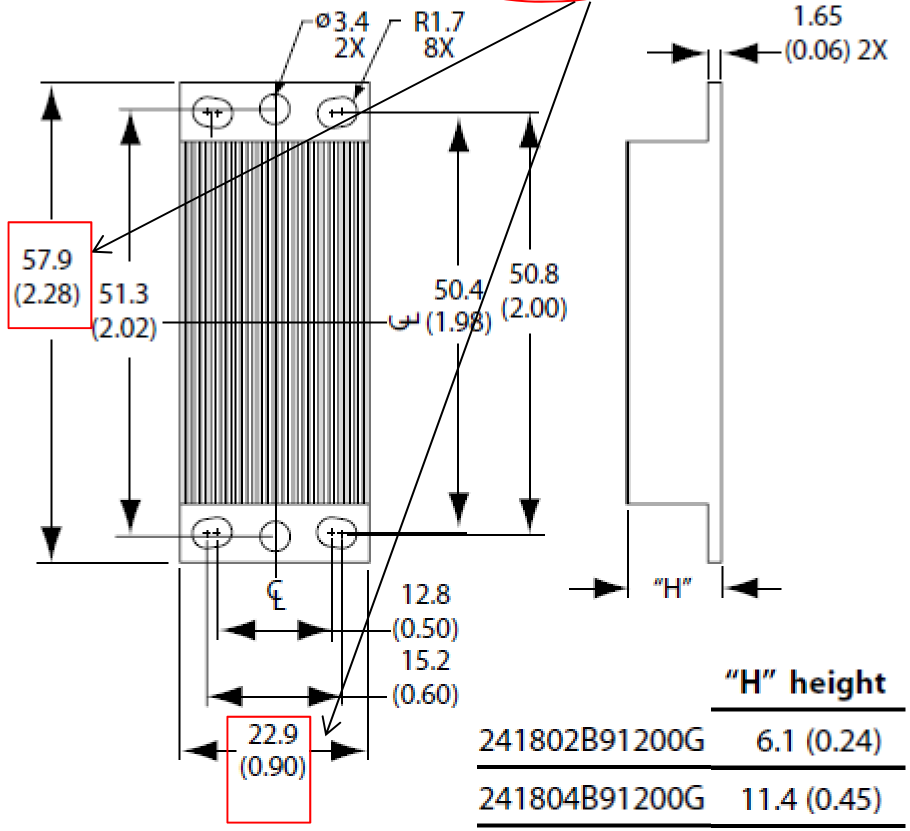




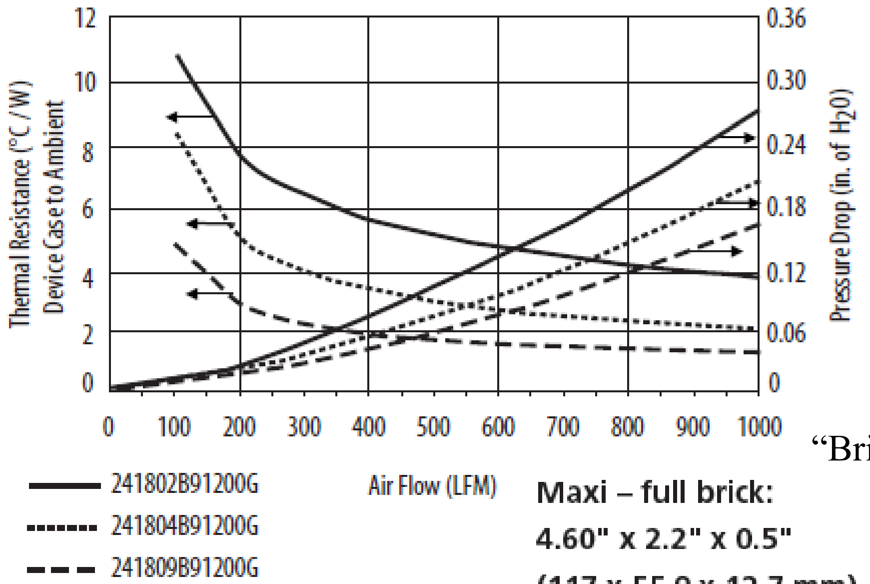


Disipadores para convertidores DC/DC de 1/8 brick





	"H" height
241802B91200G	6.1 (0.24)
241804B91200G	11.4 (0.45)
241809B91200G	22.9 (0.90)

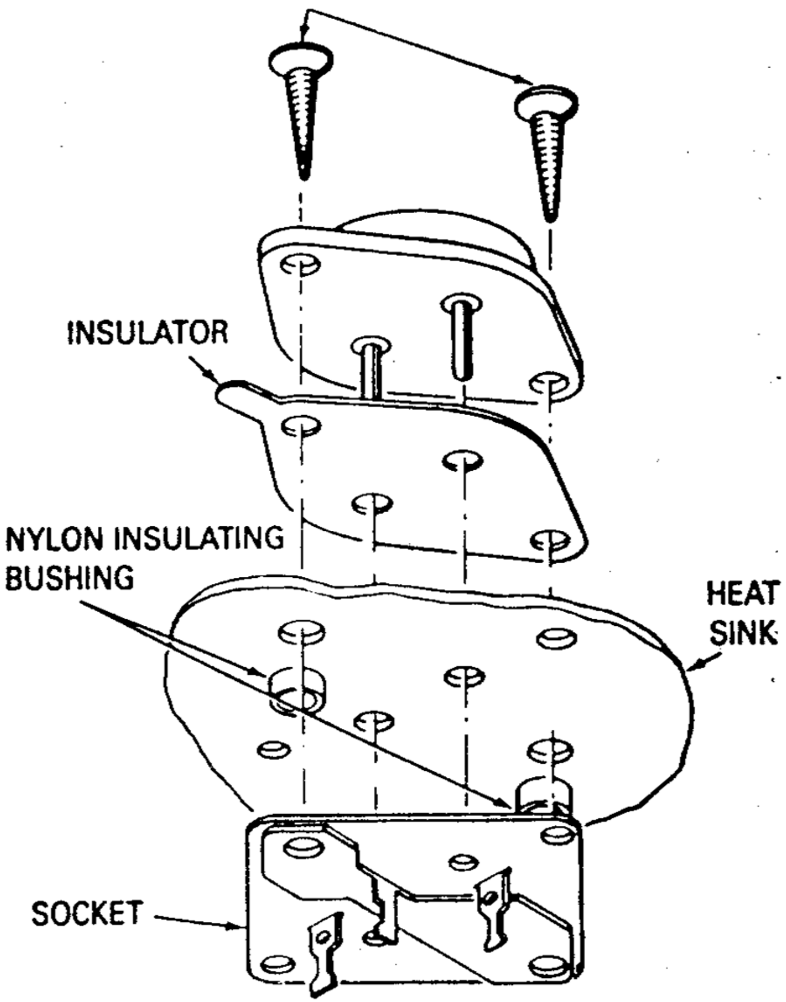


"Brick" se refiere a dimensión estandarizada en módulos DC/DC

Maxi – full brick:
4.60" x 2.2" x 0.5"
(117 x 55,9 x 12,7 mm)

Mini – half brick:
2.28" x 2.2" x 0.5"
(57,9 x 55,9 x 12,7 mm)

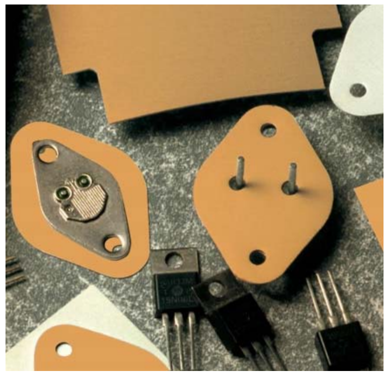
Micro – quarter brick:
2.28" x 1.45" x 0.5"
(57,9 x 36,8 x 12,7 mm)



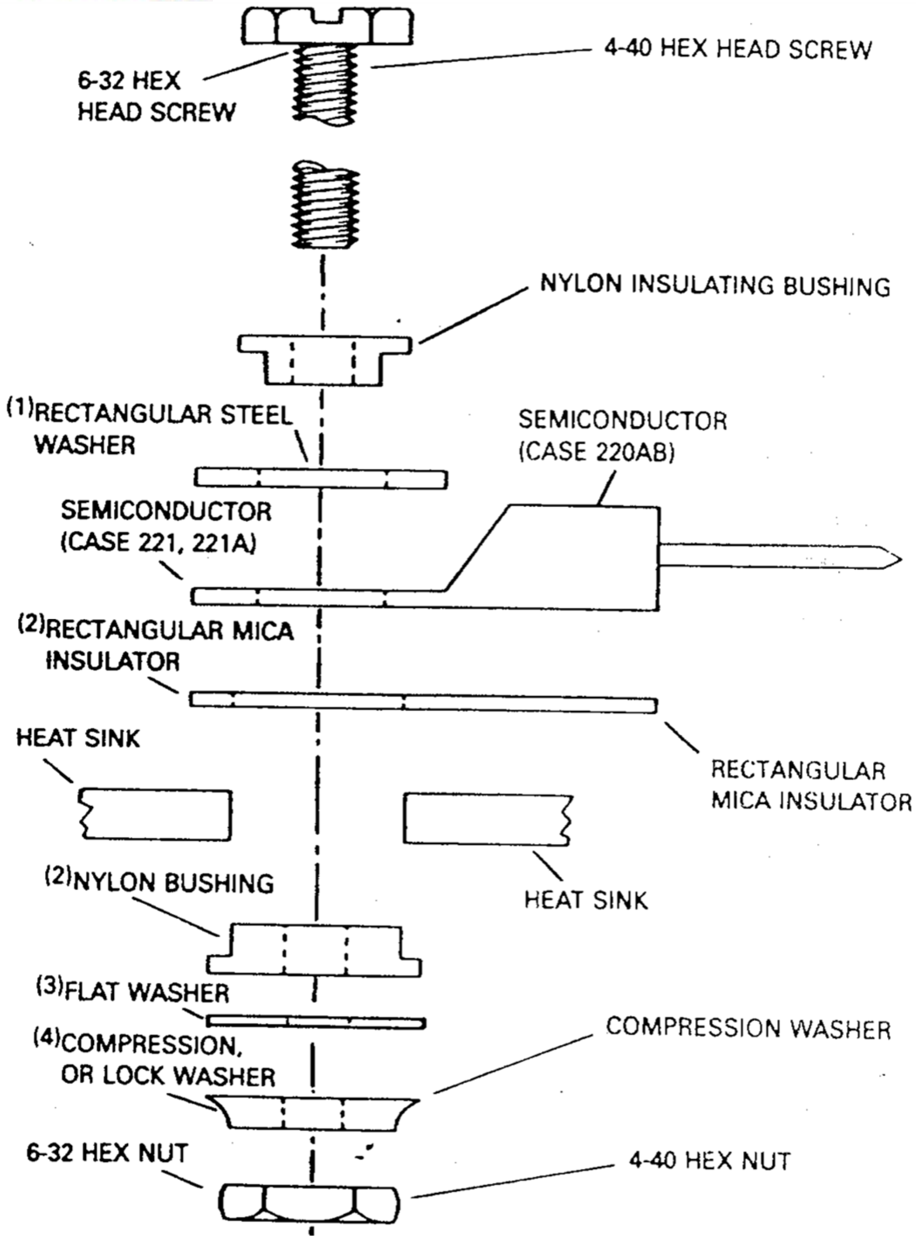
Mounting Details for Flat-Base Mounted Semiconductors (TO-204AE Shown)

Aislantes eléctricos (aumentan la resistencia térmica)

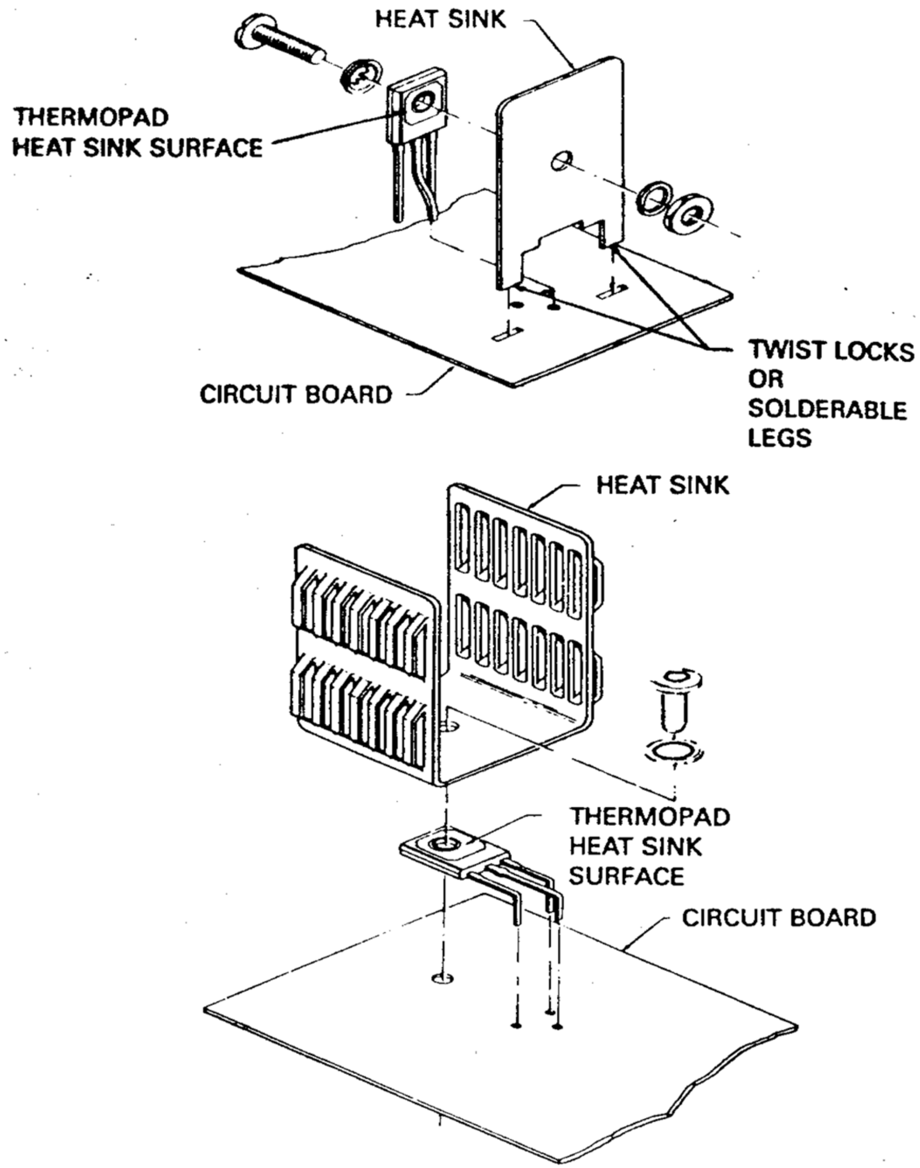
Hoja de mica



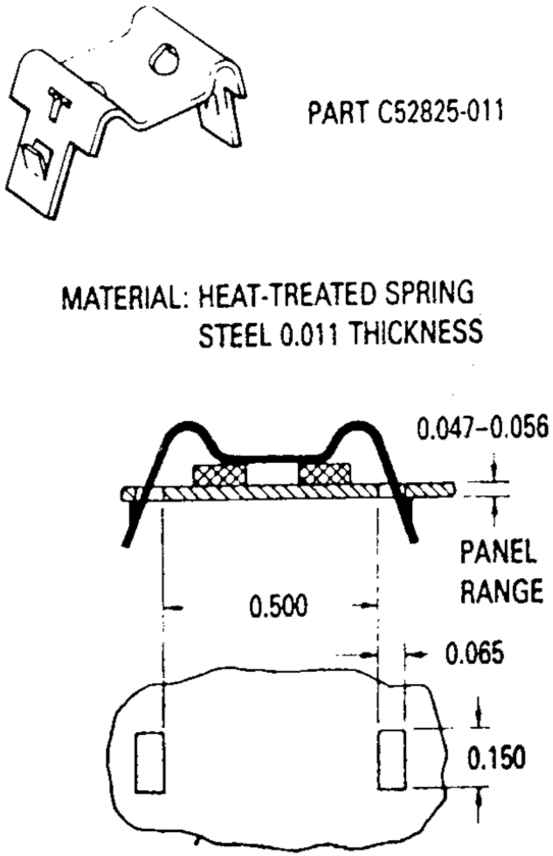
Film



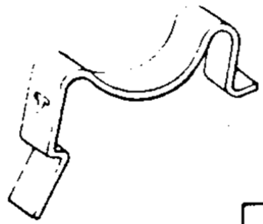
(1) Used with thin chassis and/or large hole
(2) Used when isolation is required
(3) Required when nylon bushing and lock washer are used
(4) Compression washer preferred when plastic insulating material is used



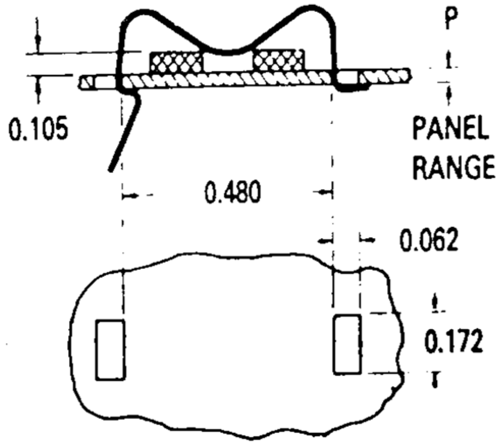
Methods of Using Small Heat Sinks with Plastic Semiconductor Packages



TO-225AB Clip



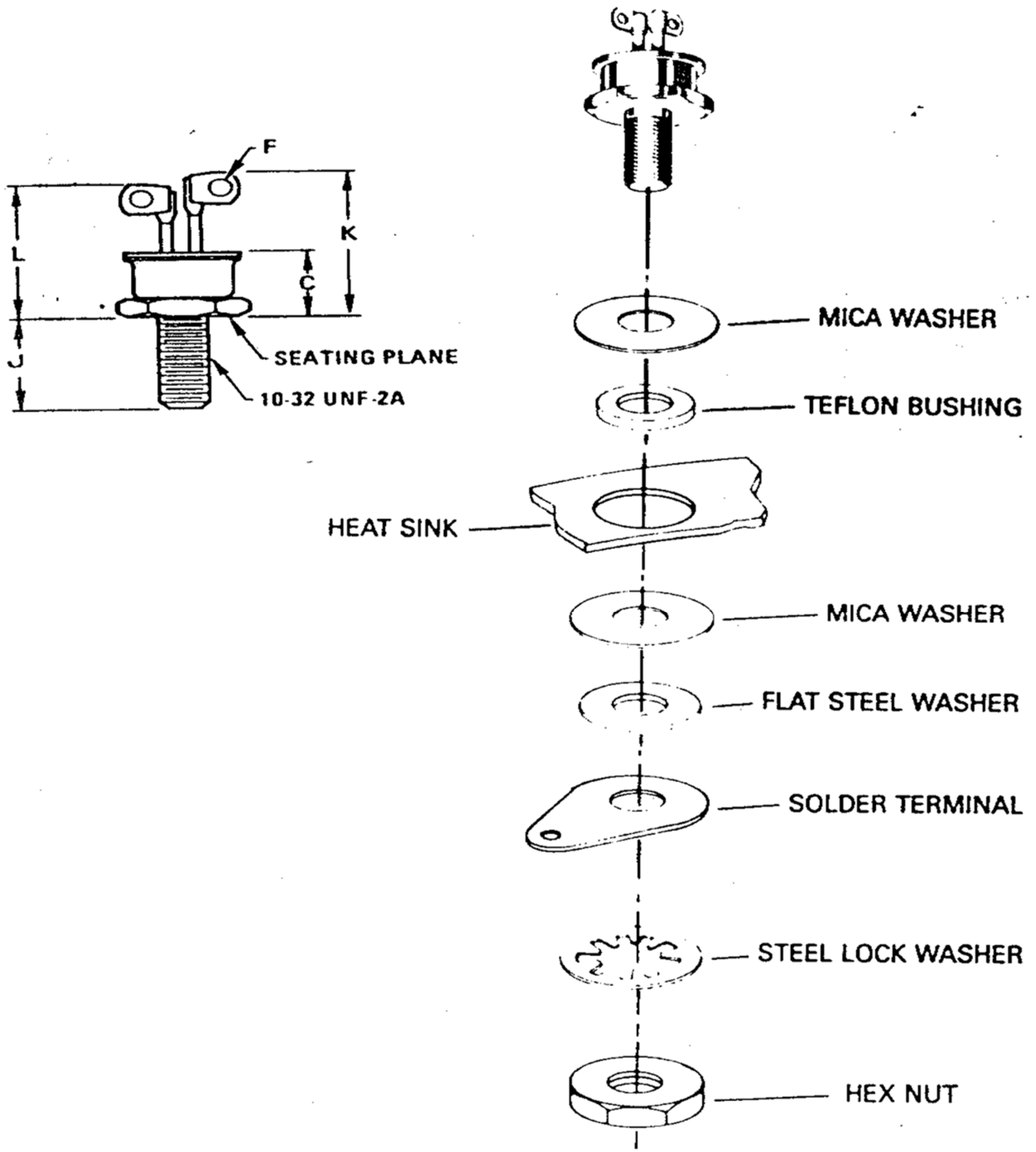
Part	P
C50272-011 C51451-011	0.046–0.055 0.030–0.034



TO-225AA Clip

Tinnerman Clips (Eaton Corp.)

Mounting Arrangements for TO-225AA and TO-225AB



Mounting Details for Stud-Mounted Semiconductors

SEMICONDUCTOR THERMAL AND PHYSICAL PARAMETERS

JEDEC CASE TYPE	*PRESS-PAK CASE TYPE*	θ_{j-c} °C/W	θ_{c-s}[1] °C/W	θ_{j-a} °C/W	*MOUNTING TORQUE in-lb*	*MOUNTING FORCE lb*	*STUD SIZE*
			RECTIFIERS				
DO-41				75[2]			(AXIAL)
DO-15,27				70[2]			(AXIAL)
DO-4		2-3	.5		12-15		10-32
DO-5,203		.8-1.2	.3		25-30		1/4-28
DO-8		.35-.4	.15		75-125		3/8-24
DO-9		.15-.2	.075		300-350		3/4-16
DO-200AA	½" Thick	.095	.06			1000	
DO-200AB	1" Thick	.055	.03			2200	
DO-200AC	1" Thick, 2.9" Dia.	.023	.0075			5000	
			THYRISTORS				
TO-92		75		200			
TO-5,39		5		150			
TO-64		3-3.5	.5		12-15		10-32
TO-48		1.3-1.7	.3		25-30		1/4-28
TO-83,94		.3-.4	.12		120-130		1/2-20
TO-93		.13-.15	.075		300-350		3/4-16
TO-200AB	½" Thick	.08-.12	.06			1000	
TO-200AC	1" Thick	.04-.06	.03			2200	
	1" Thick, 2.9" Dia.	.023	.0075			5000	
			TRANSISTORS				
TO-92		75-125		200-350			
TO-18,46		100		300			
TO-5,39		18-35		150-175			
TO-202		10-20		70-80			
TO-8		6-7		75-100			
TO-59[3],111		3.3-5	1	85-90	12-15		10-32
TO-66		2.3-7	.5-.8	60-70	4-6		
TO-220		1.6-3.1	.8-1	65-70	4-6		
TO-3.219		.8-1.5	.05-.1	30	6-8		
TO-36(Ge)		.8	.4	25	6-8		
TO-63,82		.5-.75	.4		30-50		5/16-24
TO-61[3]		1-1.5	.3		25-30		¼-28
TO-114			.12				½-20

1. With Thermal Compound, No Insulator
2. Typical Printed Circuit Board Mount
3. Isolated Collector

SEMICONDUCTOR THERMAL INTERFACE PARAMETERS

THERMAL RESISTANCE, θ_{c-s} (°C/W)

JEDEC	*METAL-TO-METAL*		*MICA INSULATOR*		*FILM INSULATOR*		*BeO INSULATOR*	
CASE TYPE	*DRY**	*COMPOUND*	*DRY**	*COMPOUND*	*DRY**	*COMPOUND*	*DRY**	*COMPOUND*
DO-4, TO-64	.7	.5	3	2.5			1.5	.5
DO-5, TO-48	.5	.2	2.2	1.8			.6	.3
TO-220	1.2	.9	3.5	1.6	4.5	2.5		
TO-66	1	.7	2	.34	2	1.5	.9	.3
TO-3[1]	.3	.1	.45	.35	.8	.54	.6	.15
TO-36	.4	.2		.9			.6	.3
TO-63	.5	.3		.9			.6	.4
TO-83, -94	.2	.1	1.5	1.2				

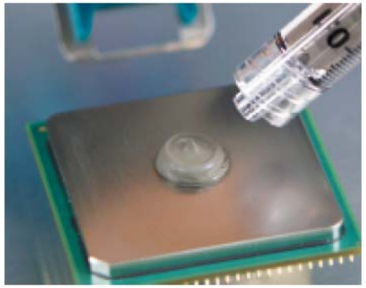
*Shown for effect. Thermal compound is recommended.

[1]With silicone rubber, θ_{c-s} = .65 dry, = .45 with compound

With anodized or coated aluminum, θ_{c-s} = 1.1 dry, = .35 with compound

THERMAL RESISTANCE OF INSULATORS WITH RECOMMENDED MOUNTING TORQUE

Insulator	*°C/W per square inch of area*
.0025″ Mica	.34
.002″ Film	.47
.007″ Silicone Rubber	.35
.06″ BeO	.009
.02″ Anodized Aluminum	.004



Thermal Compound

Disminuye la resistencia térmica

TABLE 2. Plastic Package Thermal Data

Package Type	Mkt Dwg	JEDEC Spec	Typical Thermal Data					
			Die Size (Sq mils)	θ_{JA}(°C/W) (Note 1) Flow—LFM (Linear Feet/Minute)				θ_{JC} (°C/W)
				0	225	500	1000	
Small Outline Transistor (SOT-23)	M03A	TO-236-AA	900	405	353	325	294	140
	M03B	TO-236-AB	900	405	353	325	294	140
Small Outline Package, JEDEC (SOP)	M08A	MS-012-AA	3600	172	138	123	115	35
	M14A	MS-012-AB	1672	137	108	98	90	30
	M14B	MS-013-AF	3900	114	89	80	72	27
	M16A	MS-012-AC	2115	130	107	97	89	29
	M16B	MS-013-AA	14762	95	76	66	60	20
	M20B	MS-013-AC	10900	84	60	55	51	19
	M24B	MS-013-AD	17800	78	56	51	47	17
	M28B	MS-013-AE	14762	69	55	48	42	15
Small Outline Package, EIAJ (SOP)	M14D	None	1722	143	120	110	101	52
	M16D	None	3360	130	109	98	91	45
	M20D	None	3717	111	97	90	81	39
Shrink Small Outline Package, JEDEC (SSOP)	MQA20	MO-137-AD	Data Not Available at This Time					
	MQA24	MO-137-AE	Data Not Available at This Time					
	MS48A	MO-118-AA	16000	92	71	62	54	20
	MS56	MO-118-AB	16000	81	63	55	47	17
Shrink Small Outline Package, EIAJ (SSOP)	MSA20	None	Data Not Available at This Time					
	MSA24	None	Data Not Available at This Time					
	MS40A	None	17000	71	56	49	42	15
Very Small Outline Package (VSOP)	M40A	None	Data Not Available at This Time					
Thin Small Outline Package, EIAJ (TSOP)	MBH32A	Pending	84375	99	Data Not Available at This Time			
Thin Shrink Small Outline Package, EIAJ (TSSOP)	MTA20	None	Data Not Available at This Time					
Molded Dual In-Line Package (MDIP)	N08E	MO-001-AB	3600	107	85	70	60	37
	N14A	MO-001-AC	6290	79	60	51	47	30
	N16A	MO-001-AL	14606	63	45	36	28	20
	N16E	MO-001-AA	9048	75	56	48	44	27
	N16G	MO-001-AL	14606	52	39	36	29	18
	N18A	MS-001-AD	10000	70	53	45	41	24
	N20A	MS-001-AE	15388	65	49	42	39	21

Package Type	Mkt Dwg	JEDEC Spec	Typical Thermal Data					
			Die Size (Sq mils)	θ_{JA}(°C/W) (Note 1) Flow—LFM (Linear Feet/Minute)				θ_{JC} (°C/W)
				0	225	500	1000	
Plastic Pin Grid Array (PPGA)	UP124A	None	48840	74	63	54	48	26
	UP159A	None	48840	26	19	14	11	7
	UP175A	None	48840	26	19	14	11	7
Plastic Leaded Chip Carrier (PLCC)	V20A	MO-047-AA	2444	90	68	60	51	32
	V28A	MO-047-AB	14762	79	60	51	40	20
	V32A	MO-052-AE	Data Not Available at This Time					
	V44A	MO-047-AC	23864	56	43	37	31	15
	V52A	MO-047-AD	23864	50	38	33	28	14
	V68A	MO-047-AE	23864	43	32	28	24	14
	V84A	MO-047-AF	40000	37	30	25	22	12
Plastic Quad Flatpack (PQFP)	VEF44A		59048	62	51	44	39	15
	VBG48A		59048	119	110	90	80	32
	VHG80A	Pending	55900	53	40	33	28	14
	VCC80A		71316	51	43	37	32	13
	VJE80A	MO-108-BE	59048	45	38	33	30	13
	VCE100A	MO-108-CC	59048	42	37	32	28	10
	VLJ100A		59048	42	37	32	28	10
	VJG100A	Pending	59048	42	37	32	28	10
	VNG144A		124608	42	34	29	26	9
	VUL160A	Pending	108264	36	29	26	23	7
	VQL160A		108264	36	29	26	23	7
	VUW208A	Pending	108264	36	29	26	23	7
	VF132A	MO-069-AE	14762	44	38	37	29	10
	VF196A	MO-069-AG	Data Not Available at This Time					
TO-92	Z03A	TO-226-AA	225	250	210	180	160	125
	Z03B	TO-226-AA	225	250	210	180	160	125
	Z03C	TO-226-AB	961	208	180	160	150	125
	Z03D	None	961	208	180	160	150	125
	Z03E	None	961	208	180	160	150	125
	Z03G	None	961	208	180	160	150	125
	Z03H	None	961	208	180	160	150	125
	Z03J	None	961	208	180	160	150	125
TO-202	P03A	TO-202-AB	900	63	47	41	37	13
TO-237	R03A	TO-237-AA	900	125	95	85	75	50
TO-226	RC03A	TO-226AE	2025	125	100	90	85	63
TO-220	TA02A	TO-220-AC	8000	83	44	33	24	3
	T02D	TO-220-AA	8000	83	44	33	24	3
	T03B	TO-220-AB	8000	83	44	33	24	3
	TA11B	TO-220	59048	43	22	16	12	1
	P03H	None	900	63	47	41	37	13
	P03J	None	900	63	47	41	37	13
	P04A	None	900	65	45	39	35	11
	P11A	None	30000	55	35	25	20	10