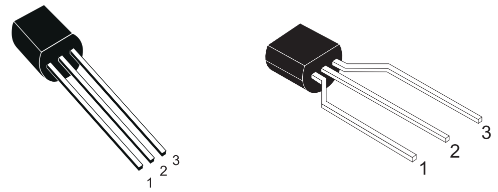
2N3904

SMALL SIGNAL NPN TRANSISTOR

PRELIMINARY DATA

Ordering Code	Marking	Package / Shipment
2N3904	2N3904	TO-92 / Bulk
2N3904-AP	2N3904	TO-92 / Ammopack

- SILICON EPITAXIAL PLANAR NPN TRANSISTOR
- TO-92 PACKAGE SUITABLE FOR THROUGH-HOLE PCB ASSEMBLY
- THE PNP COMPLEMENTARY TYPE IS 2N3906

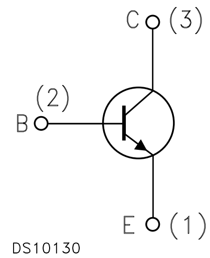


TO-92 Bulk **TO-92 Ammopack**

APPLICATIONS

- WELL SUITABLE FOR TV AND HOME APPLIANCE EQUIPMENT
- SMALL LOAD SWITCH TRANSISTOR WITH HIGH GAIN AND LOW SATURATION VOLTAGE

INTERNAL SCHEMATIC DIAGRAM



ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value	Unit
V_{CBO}	Collector-Base Voltage ($I_E = 0$)	60	V
V_{CEO}	Collector-Emitter Voltage ($I_B = 0$)	40	V
V_{EBO}	Emitter-Base Voltage ($I_C = 0$)	6	V
I_C	Collector Current	200	mA
P_{tot}	Total Dissipation at $T_C = 25\ ^oC$	625	mW
T_{stg}	Storage Temperature	-65 to 150	^oC
T_j	Max. Operating Junction Temperature	150	^oC

THERMAL DATA

$R_{thj\text{-}amb}$ •	Thermal Resistance Junction-Ambient	Max	200	$^oC/W$
$R_{thj\text{-}case}$ •	Thermal Resistance Junction-Case	Max	83.3	$^oC/W$

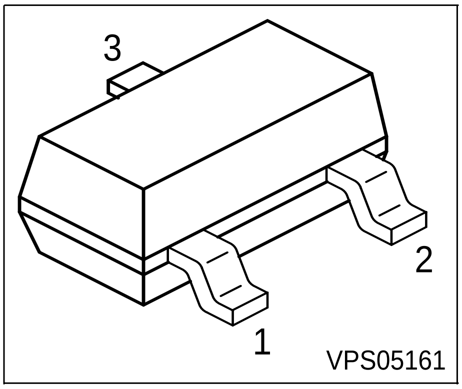
ELECTRICAL CHARACTERISTICS (T_{case} = 25 ^oC unless otherwise specified)

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
I_{CEX}	Collector Cut-off Current (V_{BE} = -3 V)	V_{CE} = 30 V			50	nA
I_{BEX}	Base Cut-off Current (V_{BE} = -3 V)	V_{CE} = 30 V			50	nA
$V_{(BR)CEO}$∗	Collector-Emitter Breakdown Voltage (I_B = 0)	I_C = 1 mA	40			V
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage (I_E = 0)	I_C = 10 µA	60			V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage (I_C = 0)	I_E = 10 µA	6			V
$V_{CE(sat)}$∗	Collector-Emitter Saturation Voltage	I_C = 10 mA I_B = 1 mA I_C = 50 mA I_B = 5 mA			0.2 0.2	V V
$V_{BE(sat)}$∗	Base-Emitter Saturation Voltage	I_C = 10 mA I_B = 1 mA I_C = 50 mA I_B = 5 mA	 0.65		0.85 0.95	V V
h_{FE}∗	DC Current Gain	I_C = 0.1 mA V_{CE} = 1 V I_C = 1 mA V_{CE} = 1 V I_C = 10 mA V_{CE} = 1 V I_C = 50 mA V_{CE} = 1 V I_C = 100 mA V_{CE} = 1 V	60 80 100 60 30		 300	
f_T	Transition Frequency	I_C = 10 mA V_{CE} = 20 V f = 100 MHz	250	270		MHz
C_{CBO}	Collector-Base Capacitance	I_E = 0 V_{CB} = 10 V f = 1 MHz		4		pF
C_{EBO}	Emitter-Base Capacitance	I_C = 0 V_{EB} = 0.5 V f = 1 MHz		18		pF
NF	Noise Figure	V_{CE} = 5 V I_C = 0.1 mA f = 10 Hz to 15.7 KHz R_G = 1 KΩ		5		dB
t_d t_r	Delay Time Rise Time	I_C = 10 mA I_B = 1 mA V_{CC} = 30 V			35 35	ns ns
t_s t_f	Storage Time Fall Time	I_C = 10 mA I_{B1} = $-I_{B2}$ = 1 mA V_{CC} = 30 V			200 50	ns ns

∗ Pulsed: Pulse duration = 300 µs, duty cycle ≤ 2 %

NPN Silicon Switching Transistors

- High DC current gain: 0.1mA to 500 mA
- Low collector-emitter saturation voltage
- Complementary types: BSS80, BSS82 (PNP)



Type	Marking	Pin Configuration			Package
BSS79B	CEs	1 = B	2 = E	3 = C	SOT23
BSS79C	CFs	1 = B	2 = E	3 = C	SOT23
BSS81B	CDs	1 = B	2 = E	3 = C	SOT23
BSS81C	CGs	1 = B	2 = E	3 = C	SOT23

Maximum Ratings

Parameter	Symbol	BSS79	BSS81	Unit
Collector-emitter voltage	V_{CEO}	40	35	V
Collector-base voltage	V_{CBO}	75		V
Emitter-base voltage	V_{EBO}	6		
DC collector current	I_C	800		mA
Peak collector current	I_{CM}	1		A
Base current	I_B	100		mA
Peak base current	I_{BM}	200		
Total power dissipation, T_S = 77 °C	P_{tot}	330		mW
Junction temperature	T_j	150		°C
Storage temperature	T_{stg}	-65 ... 150		

Thermal Resistance

Junction - soldering point[1)]	R_{thJS}	≤220	K/W

[1] For calculation of R_{thJA} please refer to Application Note Thermal Resistance

Electrical Characteristics at T_A = 25°C, unless otherwise specified.

Parameter		Symbol	Values			Unit
			min.	typ.	max.	
DC Characteristics						
Collector-emitter breakdown voltage		$V_{(BR)CEO}$				V
I_C = 10 mA, I_B = 0	BSS79		40	-	-	
	BSS81		35	-	-	
Collector-base breakdown voltage I_C = 10 µA, I_E = 0		$V_{(BR)CBO}$	75	-	-	
Emitter-base breakdown voltage I_E = 10 µA, I_C = 0		$V_{(BR)EBO}$	6	-	-	
Collector cutoff current V_{CB} = 60 V, I_E = 0		I_{CBO}	-	-	10	nA
Collector cutoff current V_{CB} = 60 V, I_E = 0 , T_A = 150 °C		I_{CBO}	-	-	10	µA
Emitter cutoff current V_{EB} = 3 V, I_C = 0		I_{EBO}	-	-	10	nA
DC current gain 1)		h_{FE}				-
I_C = 100 µA, V_{CE} = 10 V	BSS79/81B		20	-	-	
	BSS79/81C		35	-	-	
I_C = 1 mA, V_{CE} = 10 V	BSS79/81B		25	-	-	
	BSS79/81C		50	-	-	
I_C = 10 mA, V_{CE} = 10 V	BSS79/81B		35	-	-	
	BSS79/81C		75	-	-	
I_C = 150 mA, V_{CE} = 10 V	BSS79/81B		40	-	120	
	BSS79/81C		100	-	300	
I_C = 500 mA, V_{CE} = 10 V	BSS79/81B		25	-	-	
	BSS79/82C		40	-	-	
Collector-emitter saturation voltage1)		V_{CEsat}				V
I_C = 150 mA, I_B = 15 mA			-	-	0.3	
I_C = 500 mA, I_B = 50 mA			-	-	1.3	
Base-emitter saturation voltage 1)		V_{BEsat}				
I_C = 150 mA, I_B = 15 mA			-	-	1.2	
I_C = 500 mA, I_B = 50 mA			-	-	2.0	

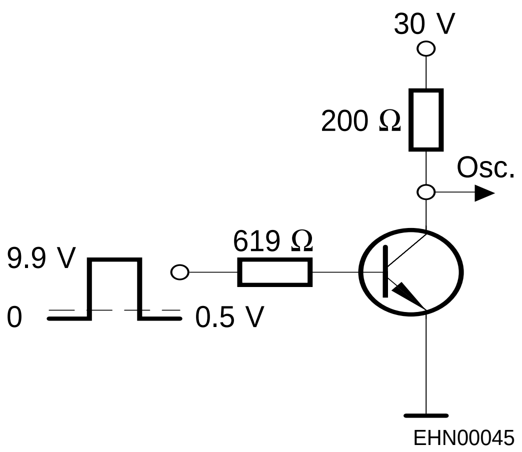
1) Pulse test: t ≤ 300µs, D = 2%

Electrical Characteristics at T_A = 25°C, unless otherwise specified.

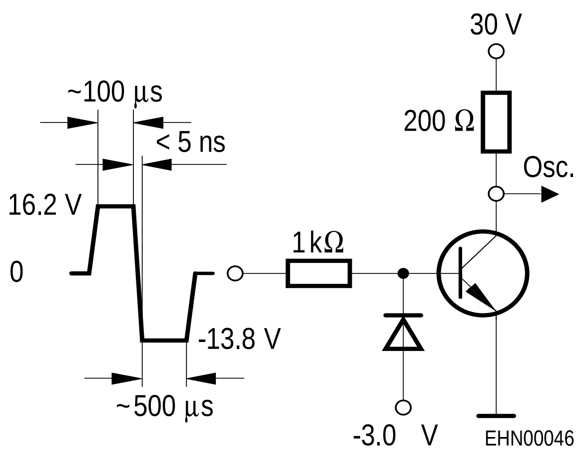
Parameter	Symbol	Values			Unit
		min.	typ.	max.	
AC Characteristics					
Transition frequency I_C = 20 mA, V_{CE} = 20 V, f = 100 MHz	f_T	-	250	-	MHz
Collector-base capacitance V_{CB} = 10 V, f = 1 MHz	C_{cb}	-	6	-	pF
Delay time V_{CC} = 30 V, I_C = 150 mA, I_{B1} = 15 mA, $V_{BE(off)}$ = 0.5 V	t_d	-	-	10	ns
Rise time V_{CC} = 30 V, I_C = 150 mA, I_{B1} = 15 mA, $V_{BE(off)}$ = 0.5 V	t_r	-	-	25	
Storage time V_{CC} = 30 V, I_C = 150 mA, I_{B1}=I_{B2} = 15mA	t_{stg}	-	-	250	
Fall time V_{CC} = 30 V, I_C = 150 mA, I_{B1}=I_{B2} = 15mA	t_f	-	-	60	

Test circuits

Delay and rise time

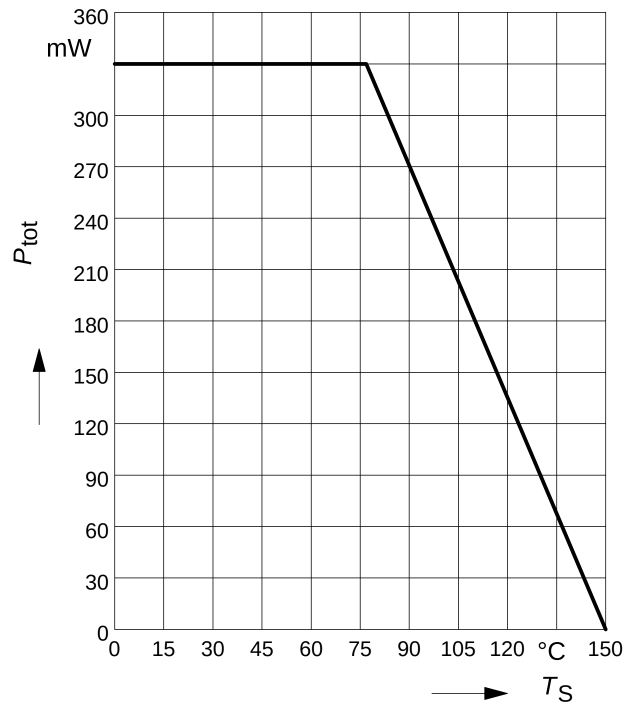


Storage and fall time



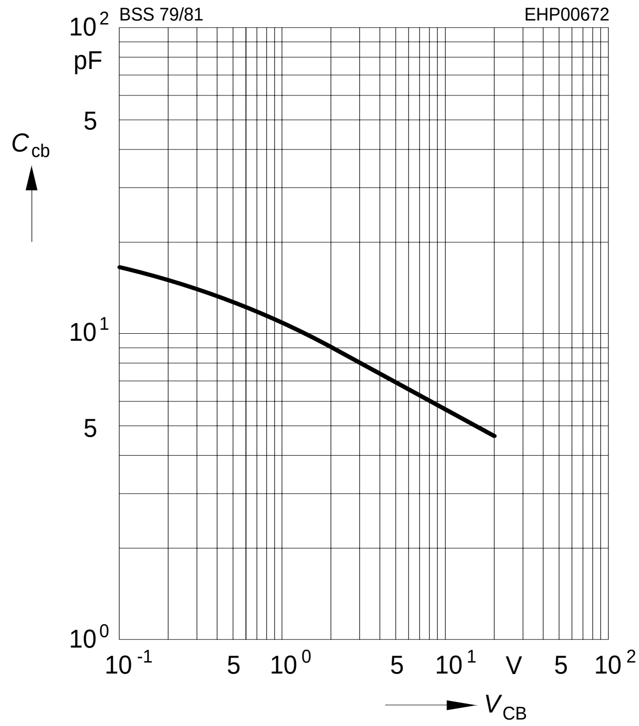
Oscillograph: R > 100kΩ
C < 12pF
t_r < 5ns

Total power dissipation $P_{tot} = f(T_S)$



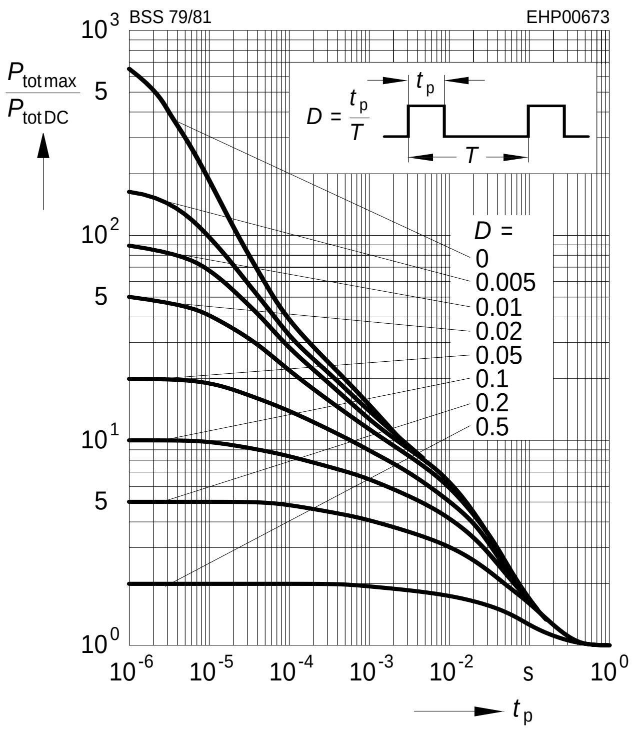
Collector-base capacitance $C_{CB} = f\ (V_{CB})$

f = 1MHz



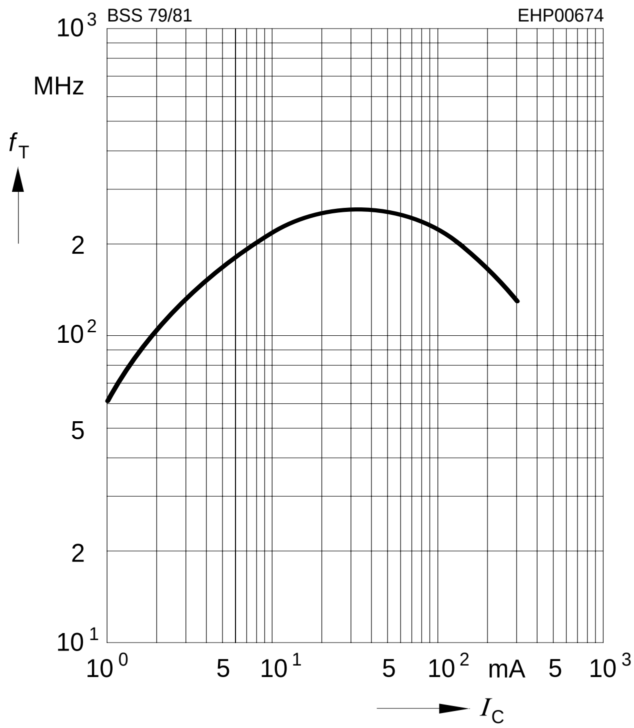
Permissible pulse load

$P_{totmax}\ /\ P_{totDC} = f\ (t_p)$



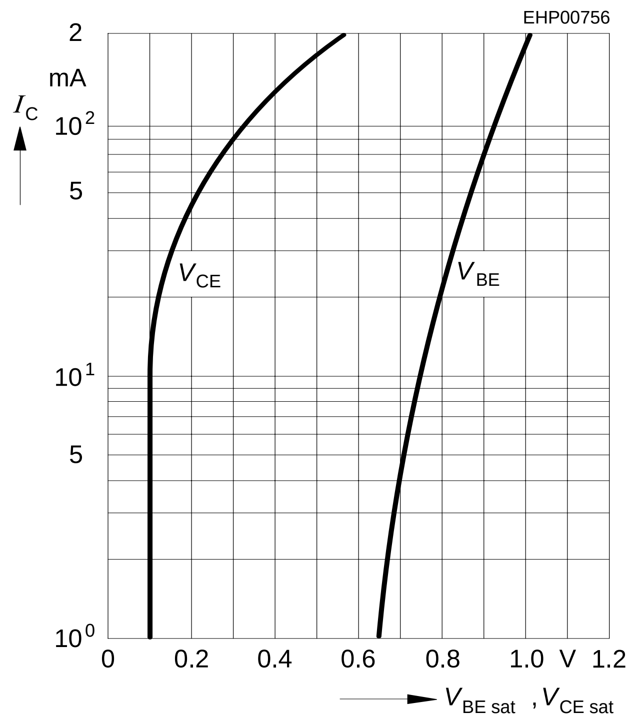
Transition frequency $f_T = f\ (I_C)$

V_{CE} = 20V



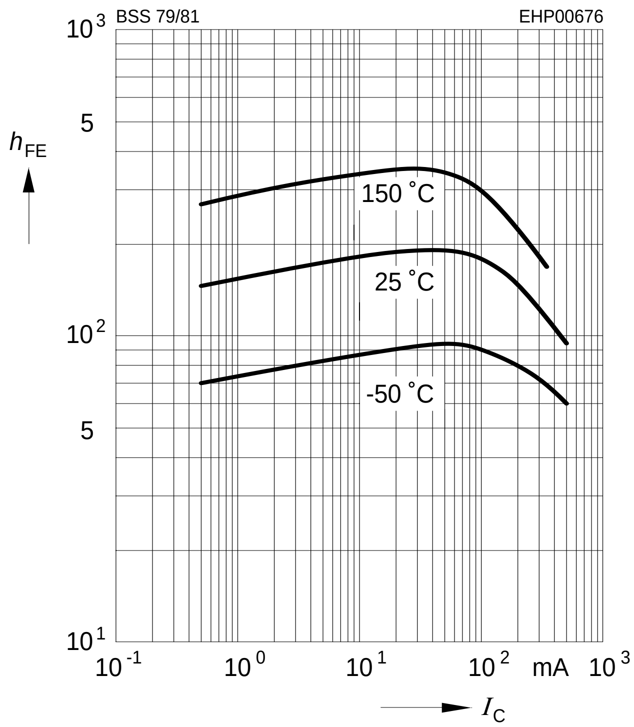
Saturation voltage $I_C = f(V_{BEsat}, V_{CEsat})$

$h_{FE} = 10$



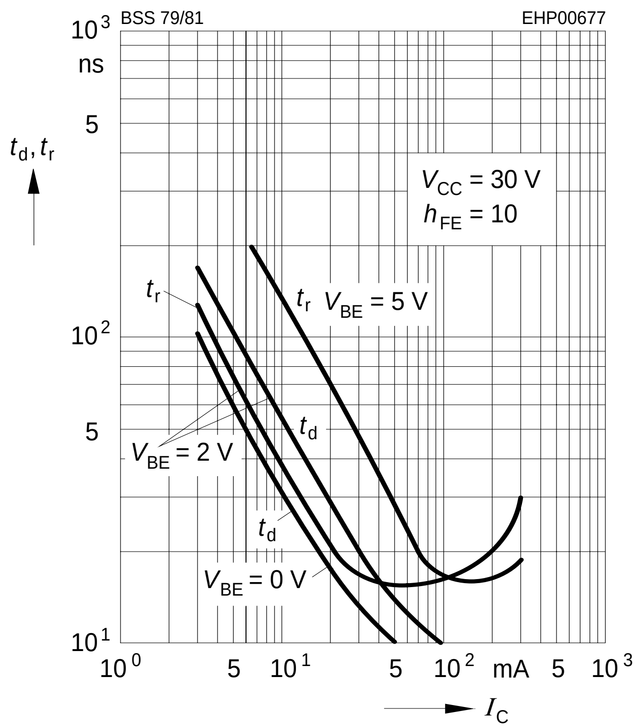
DC current gain $h_{FE} = f(I_C)$

$V_{CE} = 10V$



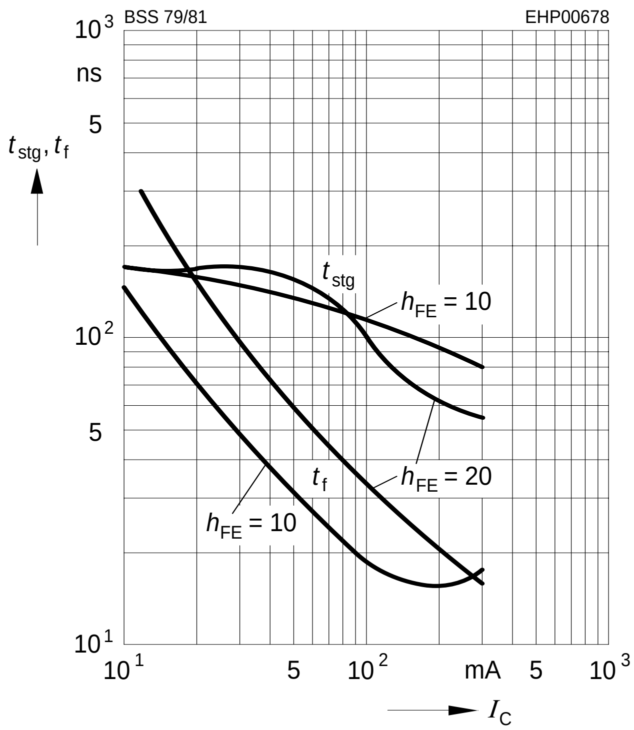
Delay time $t_d = f(I_C)$

Rise time $t_r = f(I_C)$



Storage time $t_{stg} = f(I_C)$

Fall time $t_f = f(I_C)$



Silicon diffused power transistors | BUT12; BUT12A

DESCRIPTION

High-voltage, high-speed, glass-passivated NPN power transistor in a TO-220AB package.

APPLICATIONS

- Converters
- Inverters
- Switching regulators
- Motor control systems.

PINNING

PIN	DESCRIPTION
1	base
2	collector; connected to mounting base
3	emitter

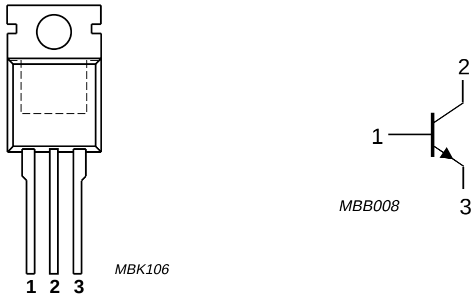


Fig.1 Simplified outline (TO-220AB) and symbol.

QUICK REFERENCE DATA

SYMBOL	PARAMETER	CONDITIONS	MAX.	UNIT
V_{CESM}	collector-emitter peak voltage	$V_{BE} = 0$		
	BUT12		850	V
	BUT12A		1000	V
V_{CEO}	collector-emitter voltage	open base		
	BUT12		400	V
	BUT12A		450	V
V_{CEsat}	collector-emitter saturation voltage	see Fig.8	1.5	V
I_{Csat}	collector saturation current			
	BUT12		6	A
	BUT12A		5	A
I_C	collector current (DC)	see Figs 3 and 4	8	A
I_{CM}	collector current (peak value)	see Fig. 4	20	A
P_{tot}	total power dissipation	$T_{mb} \leq 25$ °C; see Fig.2	125	W
t_f	fall time	resistive load; see Figs 12 and 13	0.8	µs

THERMAL CHARACTERISTICS

SYMBOL	PARAMETER	VALUE	UNIT
$R_{th\ j\text{-}mb}$	thermal resistance from junction to mounting base	1	K/W

LIMITING VALUES

In accordance with the Absolute Maximum Rating System (IEC 134).

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_{CESM}	collector-emitter peak voltage	V_{BE} = 0			
	BUT12		–	850	V
	BUT12A		–	1000	V
V_{CEO}	collector-emitter voltage	open base			
	BUT12		–	400	V
	BUT12A		–	450	V
I_{Csat}	collector saturation current				
	BUT12		–	6	A
	BUT12A		–	5	A
I_C	collector current (DC)	see Figs 3 and 4	–	8	A
I_{CM}	collector current (peak value)	see Fig. 4	–	20	A
I_B	base current (DC)		–	4	A
I_{BM}	base current (peak value)		–	6	A
P_{tot}	total power dissipation	T_{mb} ≤ 25 °C; see Fig.2	–	125	W
T_{stg}	storage temperature		–65	+150	°C
T_j	junction temperature		–	150	°C

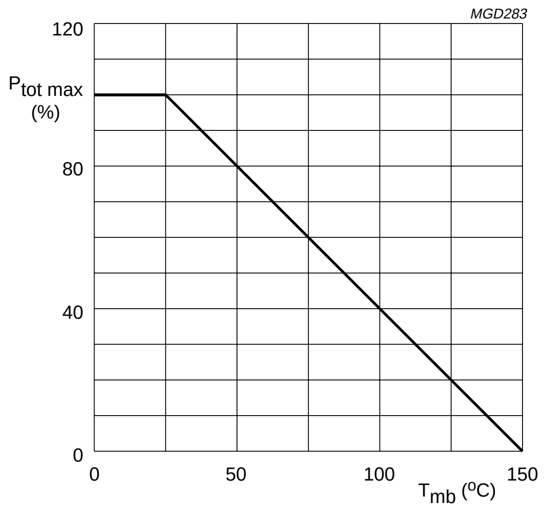
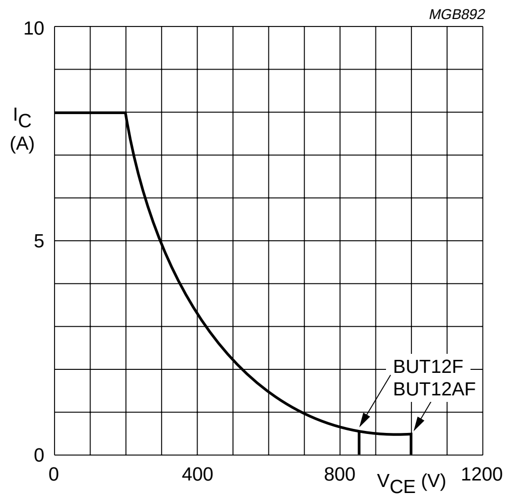


Fig.2 Power derating curve.



V_{BE} = –1 to –5 V; T_c = 100 °C.

Fig.3 Reverse bias SOAR.

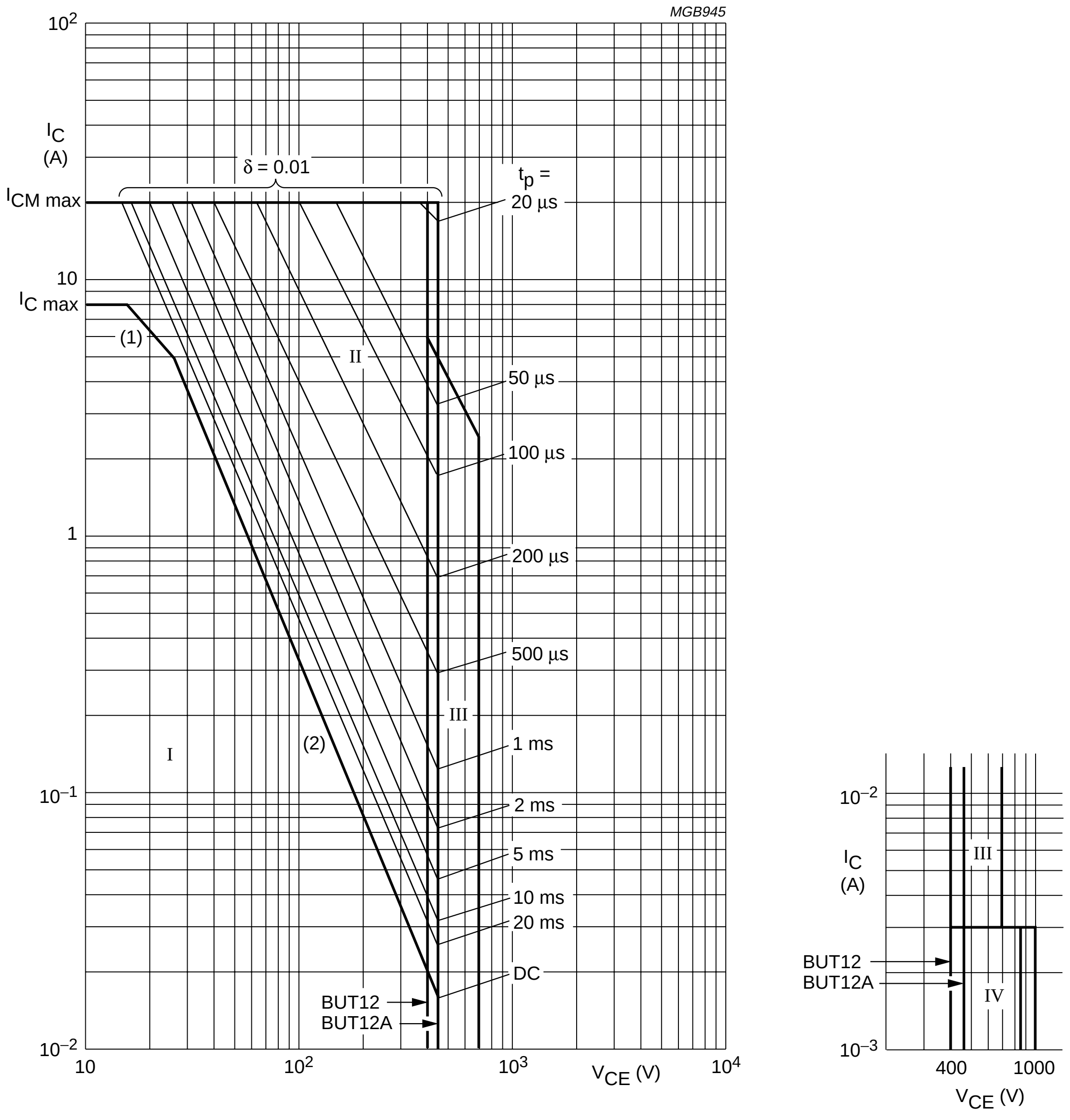
CHARACTERISTICS

T_j = 25 °C unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
$V_{CEOsust}$	collector-emitter sustaining voltage	I_C = 100 mA; I_{Boff} = 0; L = 25 mH; see Figs 6 and 7				
	BUT12		400	–	–	V
	BUT12A		450	–	–	V
V_{CEsat}	collector-emitter saturation voltage					
	BUT12	I_C = 6 A; I_B = 1.2 A; see Figs 8 and 10	–	–	1.5	V
	BUT12A	I_C = 5 A; I_B = 1 A; see Figs 8 and 10	–	–	1.5	V
V_{BEsat}	base-emitter saturation voltage					
	BUT12	I_C = 6 A; I_B = 1.2 A; see Fig.8	–	–	1.5	V
	BUT12A	I_C = 5 A; I_B = 1 A; see Fig.8	–	–	1.5	V
I_{CES}	collector-emitter cut-off current	$V_{CE} = V_{CESmax}$; V_{BE} = 0; note 1	–	–	1	mA
		$V_{CE} = V_{CESmax}$; V_{BE} = 0; T_j = 125 °C; note 1	–	–	3	mA
I_{EBO}	emitter-base cut-off current	V_{EB} = 9 V; I_C = 0	–	–	10	mA
h_{FE}	DC current gain	V_{CE} = 5 V; I_C = 10 mA; see Fig.11	10	18	35	
		V_{CE} = 5 V; I_C = 1 A; see Fig.11	10	20	35	
Switching times resistive load (see Figs 12 and 13)						
t_{on}	turn-on time					
	BUT12	I_{Con} = 6 A; $I_{Bon} = -I_{Boff}$ = 1.2 A	–	–	1	µs
	BUT12A	I_{Con} = 5 A; $I_{Bon} = -I_{Boff}$ = 1 A	–	–	1	µs
t_s	storage time					
	BUT12	I_{Con} = 6 A; $I_{Bon} = -I_{Boff}$ = 1.2 A	–	–	4	µs
	BUT12A	I_{Con} = 5 A; $I_{Bon} = -I_{Boff}$ = 1 A	–	–	4	µs
t_f	fall time					
	BUT12	I_{Con} = 6 A; $I_{Bon} = -I_{Boff}$ = 1.2 A	–	–	0.8	µs
	BUT12A	I_{Con} = 5 A; $I_{Bon} = -I_{Boff}$ = 1 A	–	–	0.8	µs
Switching times inductive load (see Figs 14 and 15)						
t_s	storage time					
	BUT12	I_{Con} = 6 A; I_{Bon} = 1.2 A; V_{CL} = 250 V; T_c = 100 °C	–	1.9	2.5	µs
	BUT12A	I_{Con} = 5 A; I_{Bon} = 1 A; V_{CL} = 300 V; T_c = 100 °C	–	1.9	2.5	µs
t_f	fall time					
	BUT12	I_{Con} = 6 A; I_{Bon} = 1.2 A; V_{CL} = 250 V; T_c = 100 °C	–	200	300	ns
	BUT12A	I_{Con} = 5 A; I_{Bon} = 1 A; V_{CL} = 300 V; T_c = 100 °C	–	200	300	ns

Note

1. Measured with a half-sinewave voltage (curve tracer).



T_{mb} < 25 °C.

I - Region of permissible DC operation.

II - Permissible extension for repetitive pulse operation.

(1) $P_{tot\,max}$ and $P_{tot\,peak\,max}$ lines.

(2) Second breakdown limits.

Fig.4 Forward bias SOAR.

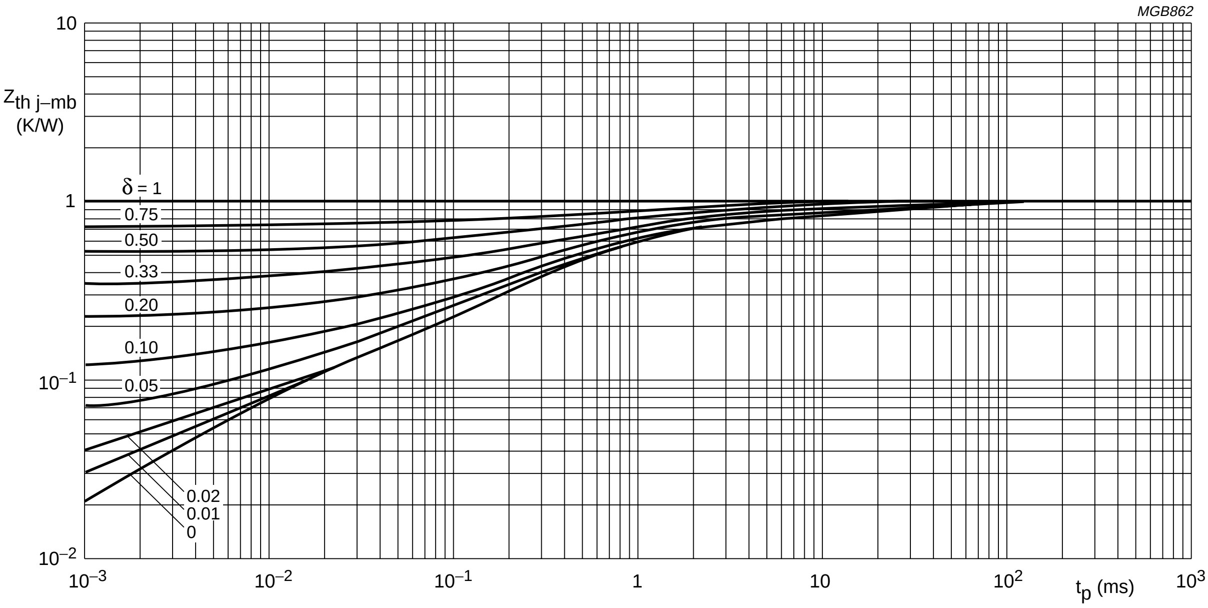


Fig.5 Transient thermal impedance.

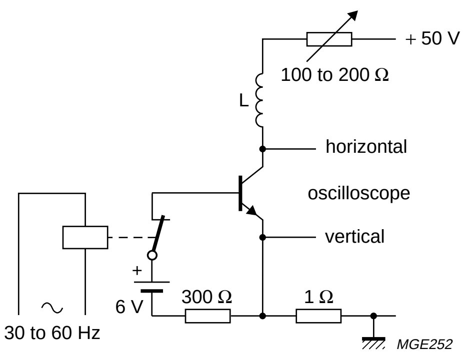


Fig.6 Test circuit for collector-emitter sustaining voltage.

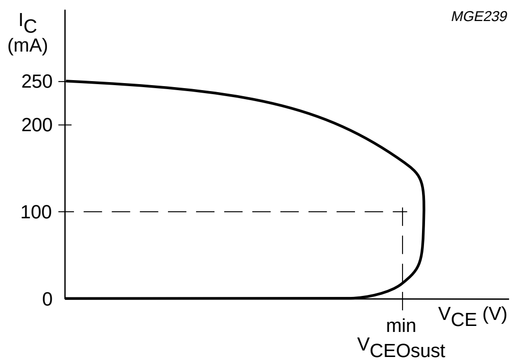
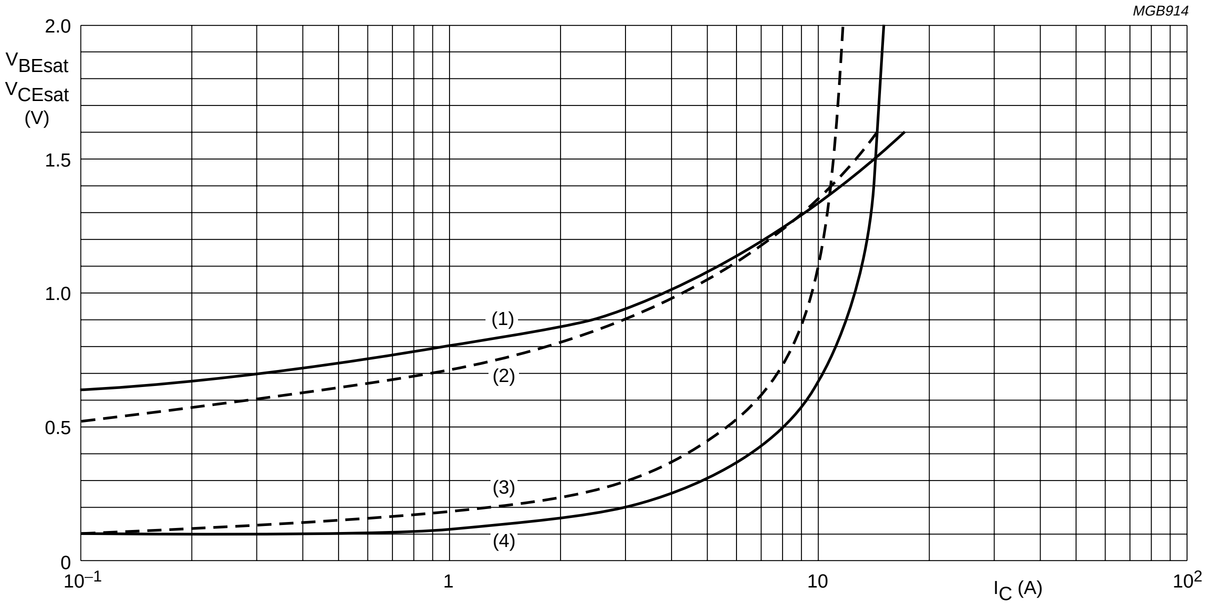


Fig.7 Oscilloscope display for collector-emitter sustaining voltage.



$I_C/I_B = 5$.

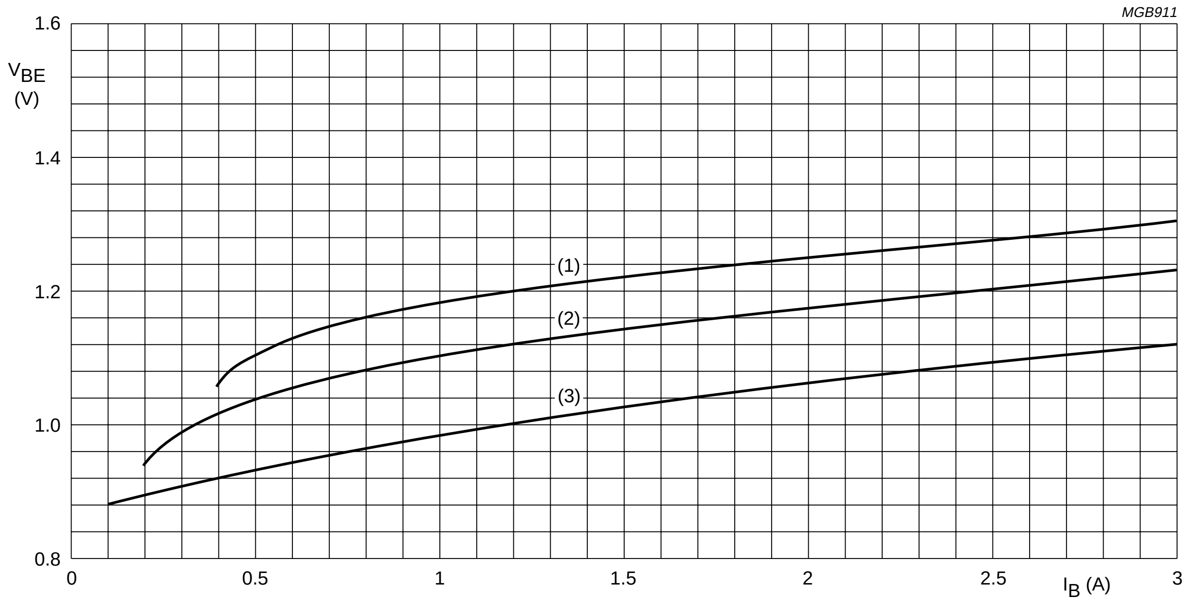
(1) V_{BE}; $T_j = 25$ °C.

(2) V_{BE}; $T_j = 100$ °C.

(3) V_{CE}; $T_j = 100$ °C.

(4) V_{CE}; $T_j = 25$ °C.

Fig.8 Base-emitter and collector-emitter saturation voltages as functions of collector current; typical values.



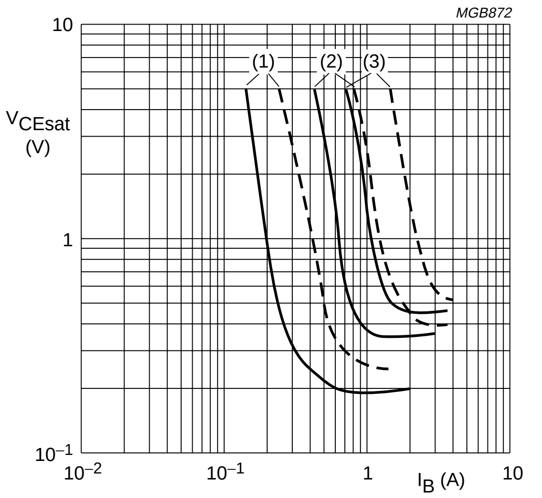
$T_j = 25$ °C.

(1) $I_C = 8$ A.

(2) $I_C = 6$ A.

(3) $I_C = 3$ A.

Fig.9 Base-emitter voltage as a function of base current; typical values.



(1) I_C = 3 A.
(2) I_C = 6 A.
(3) I_C = 8 A.
T_j = 25 °C; solid line: typical values; dotted line: maximum values.

Fig.10 Collector-emitter saturation voltage as a function of base current.

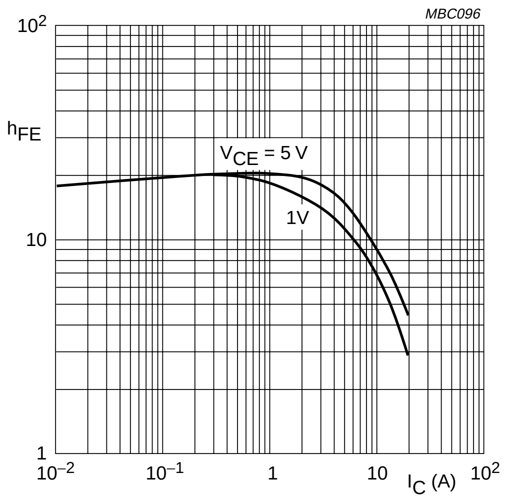
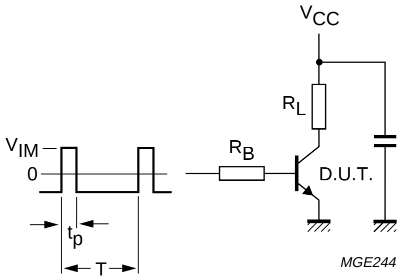
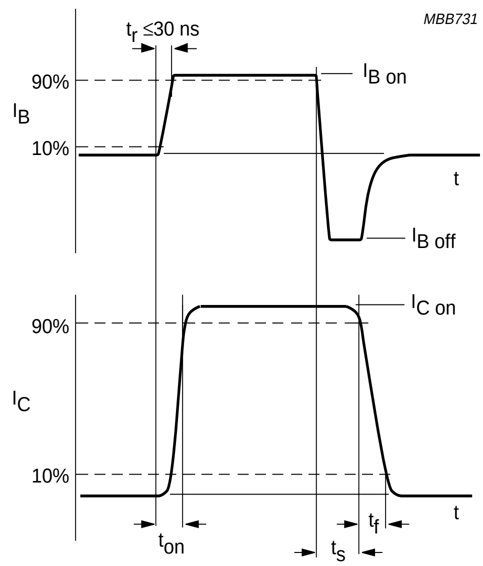


Fig.11 DC current gain; typical values.



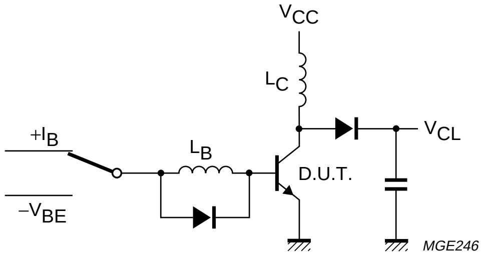
V_{CC} = 250 V; t_p = 20 µs; V_{IM} = –6 to +8 V; t_p/T = 0.01.
The values of R_B and R_L are selected in accordance with I_{Con} and I_{Bon} requirements.

Fig.12 Test circuit resistive load.



t_r ≤ 20 ns.

Fig.13 Switching time waveforms with resistive load.



V_{CL} = up to 1000 V; V_{CC} = 30 V; V_{BE} = –1 to –5 V; L_B = 1 µH; L_C = 200 µH.

Fig.14 Test circuit inductive load and reverse bias SOAR.

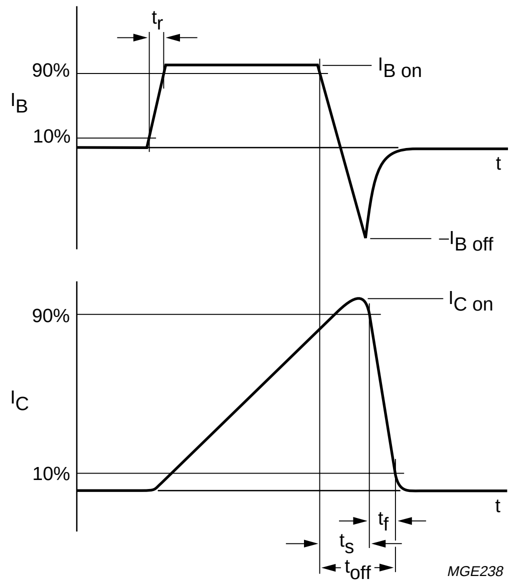
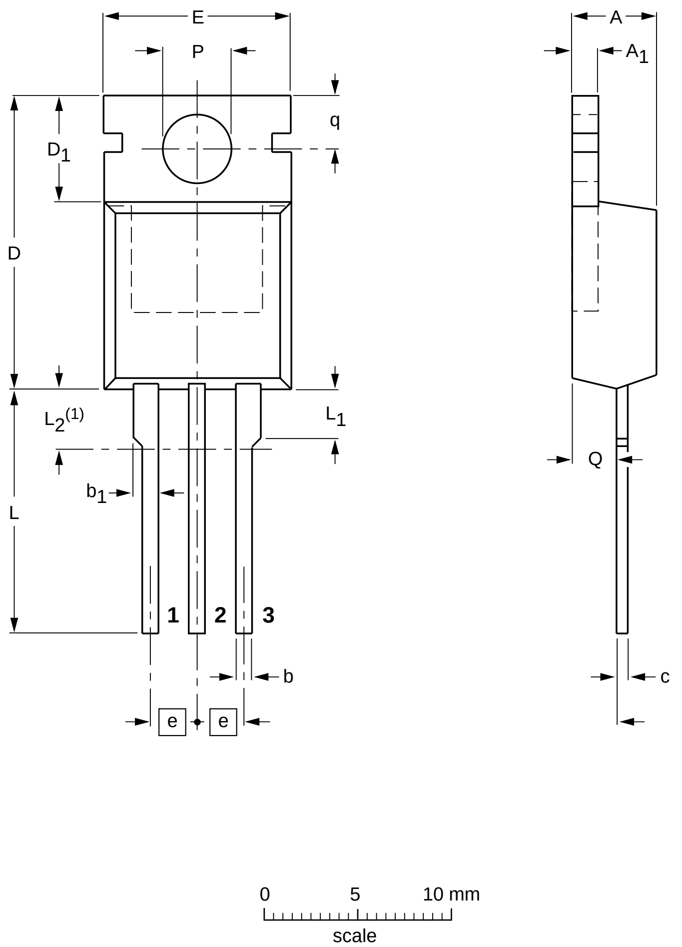


Fig.15 Switching time waveforms with inductive load.

PACKAGE OUTLINE

Plastic single-ended package; heatsink mounted; 1 mounting hole; 3-lead TO-220 **SOT78**



DIMENSIONS (mm are the original dimensions)

UNIT	A	A_1	b	b_1	c	D	D_1	E	e	L	L_1	$L_2^{(1)}$ max.	P	q	Q
mm	4.5 4.1	1.39 1.27	0.9 0.7	1.3 1.0	0.7 0.4	15.8 15.2	6.4 5.9	10.3 9.7	2.54	15.0 13.5	3.30 2.79	3.0	3.8 3.6	3.0 2.7	2.6 2.2

Note

1. Terminals in this zone are not tinned.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT78		TO-220				97-06-11

FAIRCHILD
SEMICONDUCTOR®

December 2006

FRFET™

FQP10N50CF / FQPF10N50CF
500V N-Channel MOSFET

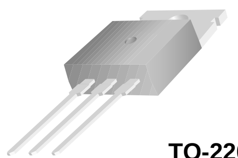
Features

- 10A, 500V, $R_{DS(on)}$ = 0.61 Ω @V_{GS} = 10 V
- Low gate charge (typical 43 nC)
- Low Crss (typical 16pF)
- Fast switching
- 100% avalanche tested
- Improved dv/dt capability
- Fast recovery body diode

Description

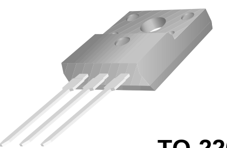
These N-Channel enhancement mode power field effect transistors are produced using Fairchild's proprietary, planar stripe, DMOS technology.

This advanced technology has been especially tailored to minimize on-state resistance, provide superior switching performance, and withstand high energy pulse in the avalanche and commutation mode. These devices are well suited for high efficient switched mode power supplies and active power factor correction.



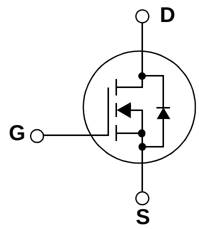
G D S

TO-220
FQP Series



G D S

TO-220F
FQPF Series



Absolute Maximum Ratings

Symbol	Parameter	FQP10N50CF	FQPF10N50CF	Unit
V_{DSS}	Drain-Source Voltage	500		V
I_D	Drain Current - Continuous (T_C = 25°C)	10	10*	A
	- Continuous (T_C = 100°C)	6.35	6.35*	A
I_{DM}	Drain Current - Pulsed (Note 1)	40	40*	A
V_{GSS}	Gate-Source voltage	± 30		V
E_{AS}	Single Pulsed Avalanche Energy (Note 2)	388		mJ
I_{AR}	Avalanche Current (Note 1)	10		A
E_{AR}	Repetitive Avalanche Energy (Note 1)	14.3		mJ
dv/dt	Peak Diode Recovery dv/dt (Note 3)	4.5		V/ns
P_D	Power Dissipation (T_C = 25°C)	143	48	W
	- Derate above 25°C	1.14	0.38	W/°C
T_J, T_{STG}	Operating and Storage Temperature Range	-55 to +150		°C
T_L	Maximum Lead Temperature for Soldering Purpose, 1/8" from Case for 5 Seconds	300		°C

*Drain current limited by maximum junction temperature

Thermal Characteristics

Symbol	Parameter	FQP10N50CF	FQPF10N50CF	Unit
$R_{\theta JC}$	Thermal Resistance, Junction-to-Case	0.87	2.58	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction-to-Ambient	62.5	62.5	°C/W

Package Marking and Ordering Information

Device Marking	Device	Package	Reel Size	Tape Width	Quantity
FQP10N50CF	FQP10N50CF	TO-220	-	-	50
FQPF10N50CF	FQPF10N50CF	TO-220F	-	-	50

Electrical Characteristics T_C = 25°C unless otherwise noted

Symbol	Parameter	Conditions	Min	Typ	Max	Units
Off Characteristics						
BV_{DSS}	Drain-Source Breakdown Voltage	V_{GS} = 0V, I_D = 250µA, T_J = 25°C	500	--	--	V
ΔBV_{DSS} / ΔT_J	Breakdown Voltage Temperature Coefficient	I_D = 250µA, Referenced to 25°C	--	0.5	--	V/°C
I_{DSS}	Zero Gate Voltage Drain Current	V_{DS} = 500V, V_{GS} = 0V	--	--	10	µA
		V_{DS} = 400V, T_C = 125°C	--	--	100	µA
I_{GSSF}	Gate-Body Leakage Current, Forward	V_{GS} = 30V, V_{DS} = 0V	--	--	100	nA
I_{GSSR}	Gate-Body Leakage Current, Reverse	V_{GS} = -30V, V_{DS} = 0V	--	--	-100	nA
On Characteristics						
$V_{GS(th)}$	Gate Threshold Voltage	V_{DS} = V_{GS}, I_D = 250µA	2.0	--	4.0	V
$R_{DS(on)}$	Static Drain-Source On-Resistance	V_{GS} = 10V, I_D = 5A	--	0.5	0.61	Ω
g_{FS}	Forward Transconductance	V_{DS} = 40V, I_D = 5A (Note 4)	--	15	--	S
Dynamic Characteristics						
C_{iss}	Input Capacitance	V_{DS} = 25V, V_{GS} = 0V, f = 1.0MHz	--	1610	2096	pF
C_{oss}	Output Capacitance		--	177	230	pF
C_{rss}	Reverse Transfer Capacitance		--	16	24	pF
Switching Characteristics						
$t_{d(on)}$	Turn-On Delay Time	V_{DD} = 250V, I_D = 10A, R_G = 25Ω (Note 4, 5)	--	29	67	ns
t_r	Turn-On Rise Time		--	80	170	ns
$t_{d(off)}$	Turn-Off Delay Time		--	141	290	ns
t_f	Turn-Off Fall Time		--	80	165	ns
Q_g	Total Gate Charge	V_{DS} = 400V, I_D = 10A, V_{GS} = 10V (Note 4, 5)	--	43	56	nC
Q_{gs}	Gate-Source Charge		--	7.5	--	nC
Q_{gd}	Gate-Drain Charge		--	18.5	--	nC
Drain-Source Diode Characteristics and Maximum Ratings						
I_S	Maximum Continuous Drain-Source Diode Forward Current		--	--	10	A
I_{SM}	Maximum Pulsed Drain-Source Diode Forward Current		--	--	40	A
V_{SD}	Drain-Source Diode Forward Voltage	V_{GS} = 0V, I_S = 10A	--	--	1.4	V
t_{rr}	Reverse Recovery Time	V_{GS} = 0V, I_S = 10A, dI_F/dt =100A/µs (Note 4)	--	50		ns
Q_{rr}	Reverse Recovery Charge		--	0.1	--	µC

Notes:

1. Repetitive Rating: Pulse width limited by maximum junction temperature
2. L = 7mH, I_{AS} = 10A, V_{DD} = 50V, R_G = 25 Ω, Starting T_J = 25°C
3. I_{SD} ≤ 10A, di/dt ≤ 200A/µs, V_{DD} ≤ $BV_{DSS,}$ Starting T_J = 25°C
4. Pulse Test: Pulse width ≤ 300µs, Duty Cycle ≤ 2%
5. Essentially Independent of Operating Temperature Typical Characteristics

Typical Performance Characteristics

Figure 1. On-Region Characteristics

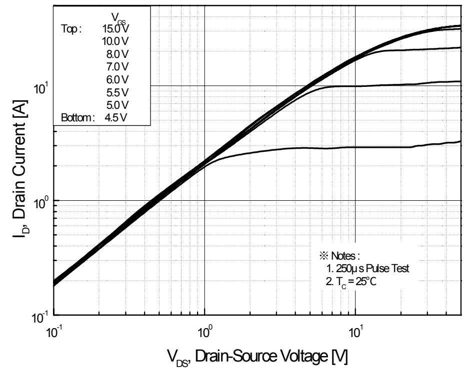


Figure 2. Transfer Characteristics

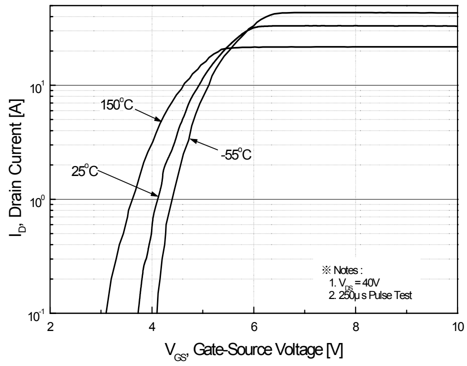


Figure 3. On-Resistance Variation vs. Drain Current and Gate Voltage

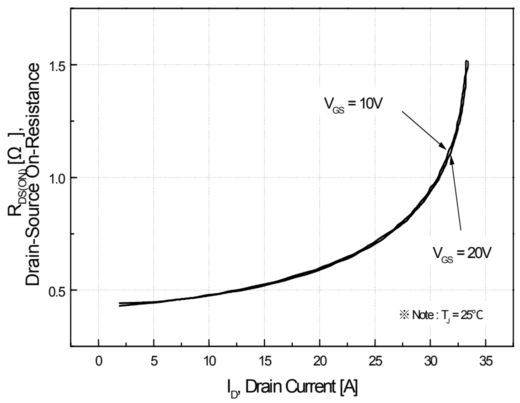


Figure 4. Body Diode Forward Voltage Variation vs. Source Current and Temperatue

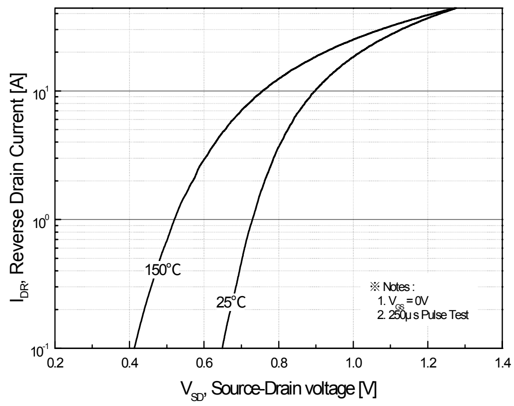


Figure 5. Capacitance Characteristics

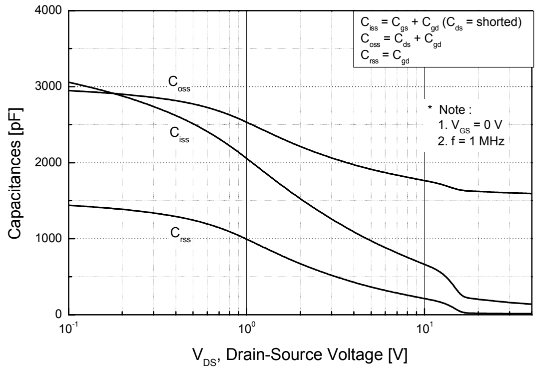
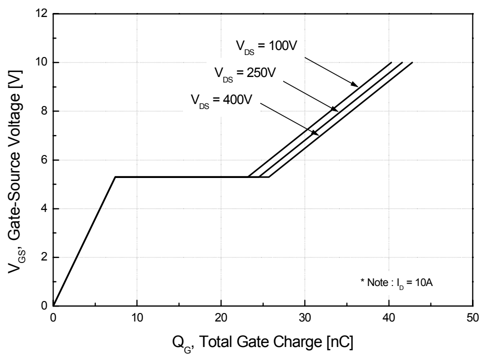


Figure 6. Gate Charge Characteristics



Typical Performance Characteristics (Continued)

Figure 7. Breakdown Voltage Variation vs. Temperature

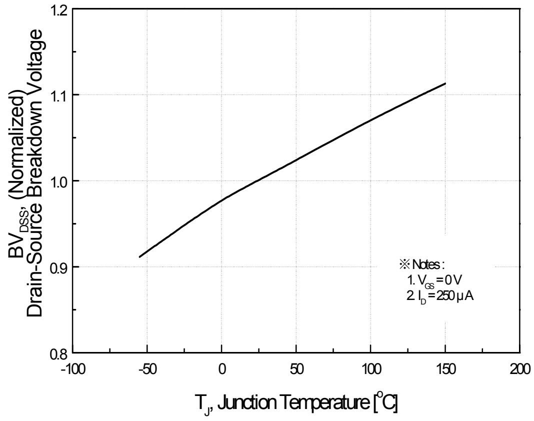


Figure 8. On-Resistance Variation vs. Temperature

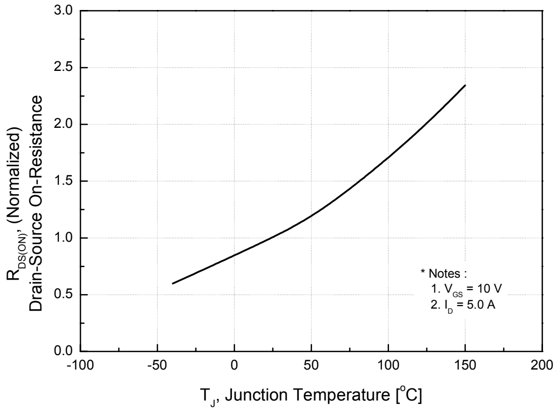


Figure 9-1. Maximum Safe Operating Area for FQP10N50CF

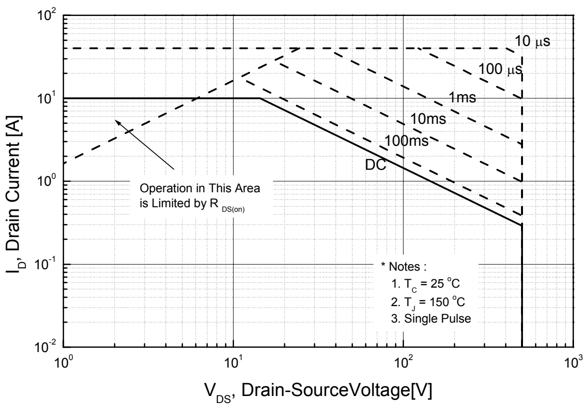


Figure 9-2. Maximum Safe Operating Area for FQPF10N50CF

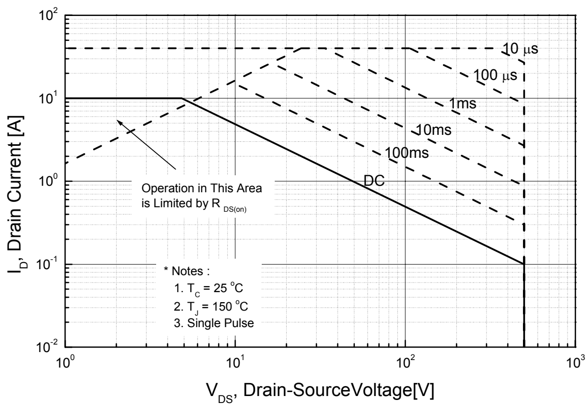
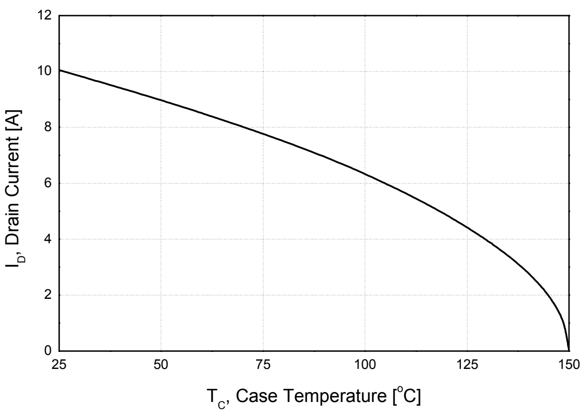


Figure 10. Maximum Drain Current vs. Case Temperature



Typical Performance Characteristics (Continued)

Figure 11-1. Transient Thermal Response Curve for FQP10N50CF

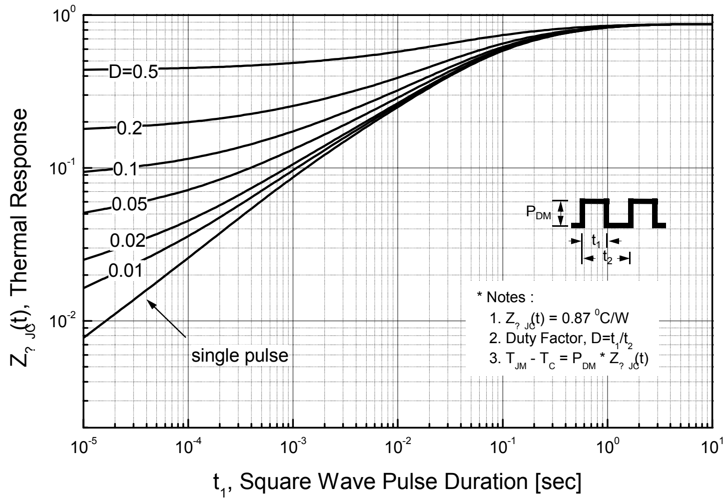
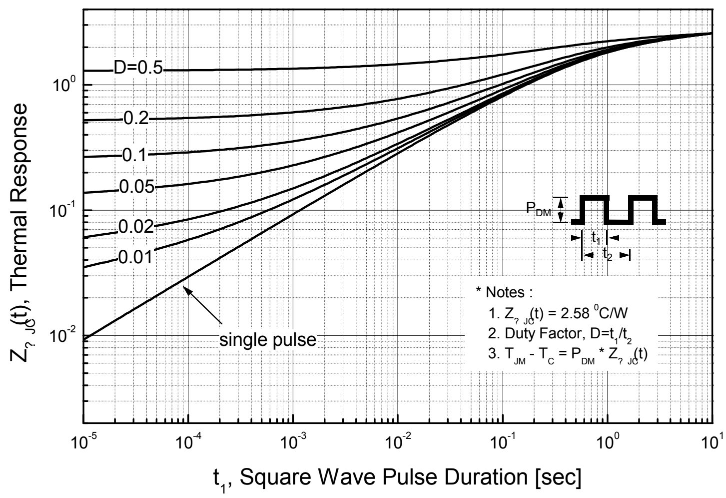
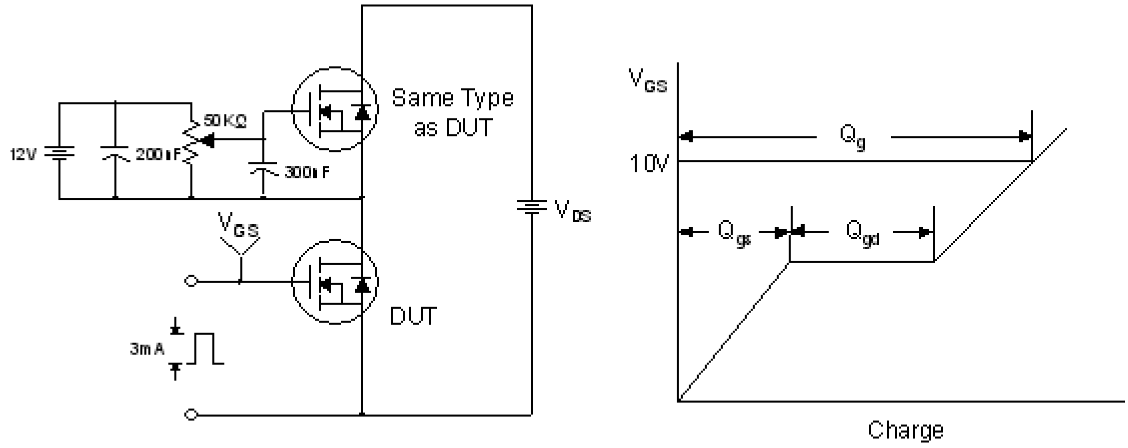


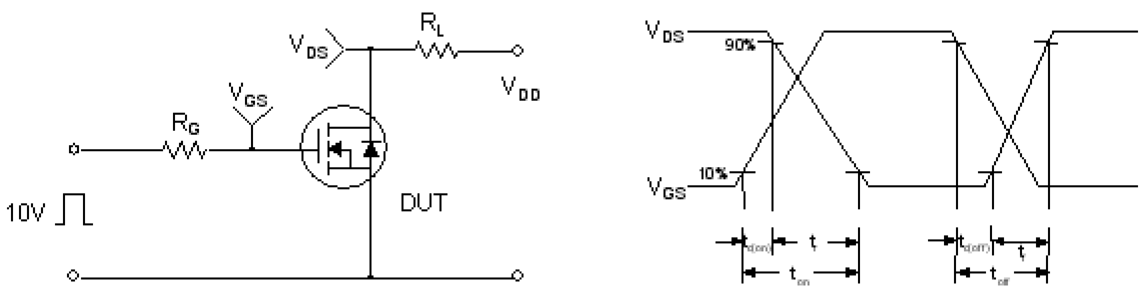
Figure 11-2. Transient Thermal Response Curve for FQPF10N50CF



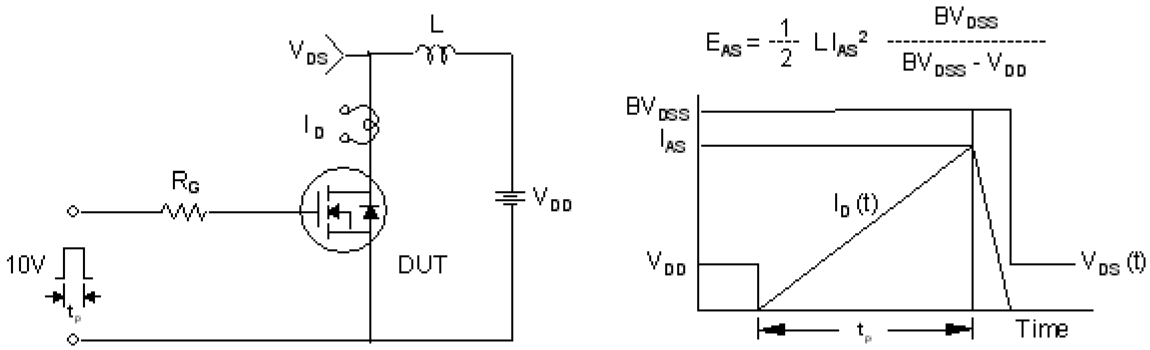
Gate Charge Test Circuit & Waveform



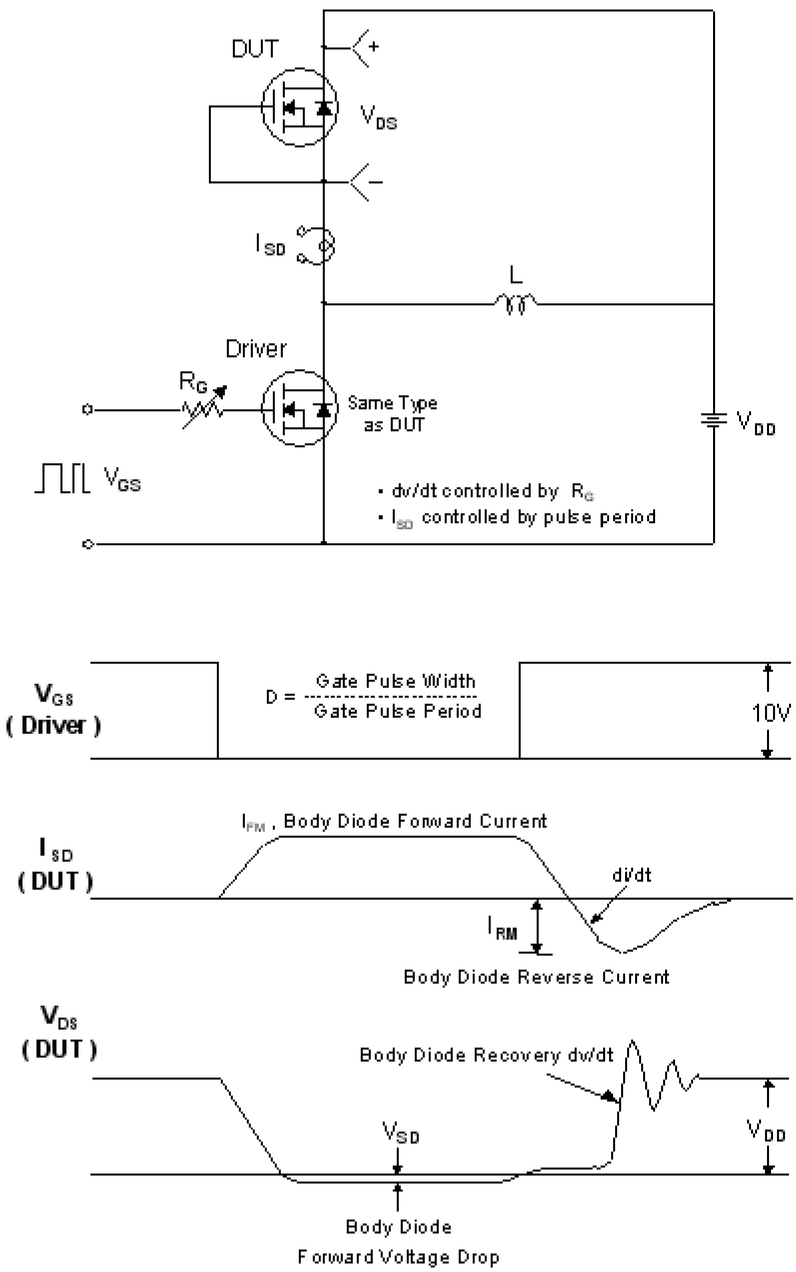
Resistive Switching Test Circuit & Waveforms



Unclamped Inductive Switching Test Circuit & Waveforms

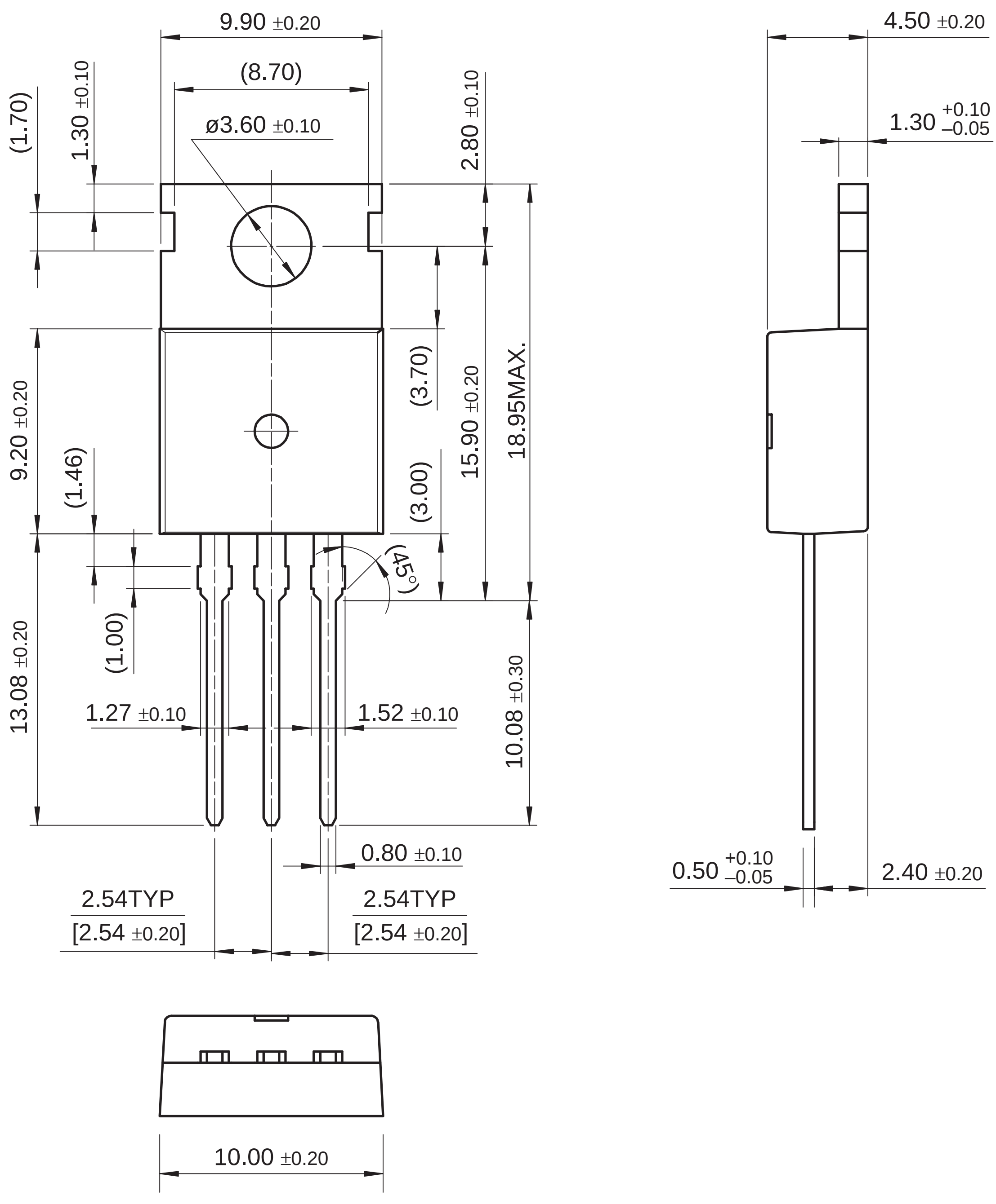


Peak Diode Recovery dv/dt Test Circuit & Waveforms



Mechanical Dimensions

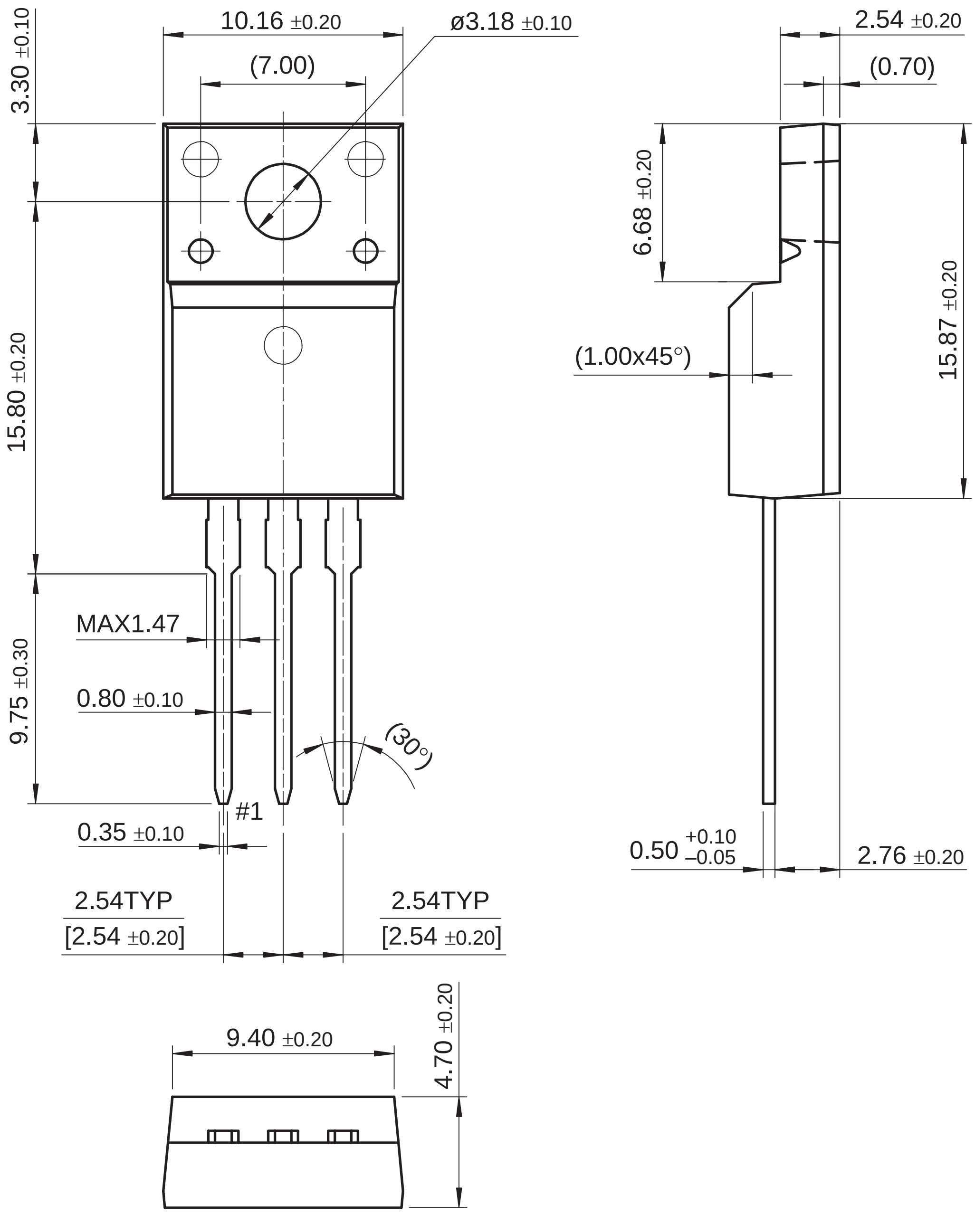
TO-220



Dimensions in Millimeters

Mechanical Dimensions (Continued)

TO-220F



Dimensions in Millimeters

TRADEMARKS

The following are registered and unregistered trademarks Fairchild Semiconductor owns or is authorized to use and is not intended to be an exhaustive list of all such trademarks.

ACEx™
ActiveArray™
Bottomless™
Build it Now™
CoolFET™
CROSSVOLT™
DOME™
EcoSPARK™
E^2CMOS™
EnSigna™
FACT™
FAST®
FASTr™
FPS™
FRFET™
FACT Quiet Series™
GlobalOptoisolator™
GTO™
HiSeC™
I^2C™
i-Lo™
ImpliedDisconnect™
IntelliMAX™
ISOPLANAR™
LittleFET™
MICROCOUPLER™
MicroFET™
MicroPak™
MICROWIRE™
MSX™
MSXPro™
Across the board. Around the world.™
The Power Franchise®
Programmable Active Droop™
OCX™
OCXPro™
OPTOLOGIC®
OPTOPLANAR™
PACMAN™
POP™
Power247™
PowerEdge™
PowerSaver™
PowerTrench®
QFET®
QS™
QT Optoelectronics™
Quiet Series™
RapidConfigure™
RapidConnect™
µSerDes™
ScalarPump™
SILENT SWITCHER®
SMART START™
SPM™
Stealth™
SuperFET™
SuperSOT™-3
SuperSOT™-6
SuperSOT™-8
SyncFET™
TCM™
TinyBoost™
TinyBuck™
TinyPWM™
TinyPower™
TinyLogic®
TINYOPTO™
TruTranslation™
UHC™
UniFET™
UltraFET®
VCX™
Wire™

DISCLAIMER

FAIRCHILD SEMICONDUCTOR RESERVES THE RIGHT TO MAKE CHANGES WITHOUT FURTHER NOTICE TO ANY PRODUCTS HEREIN TO IMPROVE RELIABILITY, FUNCTION OR DESIGN. FAIRCHILD DOES NOT ASSUME ANY LIABILITY ARISING OUT OF THE APPLICATION OR USE OF ANY PRODUCT OR CIRCUIT DESCRIBED HEREIN; NEITHER DOES IT CONVEY ANY LICENSE UNDER ITS PATENT RIGHTS, NOR THE RIGHTS OF OTHERS. THESE SPECIFICATIONS DO NOT EXPAND THE TERMS OF FAIRCHILD'S WORLDWIDE TERMS AND CONDITIONS, SPECIFICALLY THE WARRANTY THEREIN, WHICH COVERS THESE PRODUCTS.

LIFE SUPPORT POLICY

FAIRCHILD'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF FAIRCHILD SEMICONDUCTOR CORPORATION.

As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, or (c) whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in significant injury to the user.

2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

PRODUCT STATUS DEFINITIONS

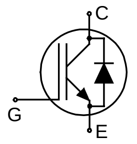
Definition of Terms

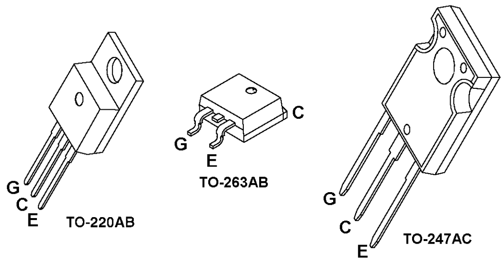
Datasheet Identification	Product Status	Definition
Advance Information	Formative or In Design	This datasheet contains the design specifications for product development. Specifications may change in any manner without notice.
Preliminary	First Production	This datasheet contains preliminary data, and supplementary data will be published at a later date. Fairchild Semiconductor reserves the right to make changes at any time without notice in order to improve design.
No Identification Needed	Full Production	This datasheet contains final specifications. Fairchild Semiconductor reserves the right to make changes at any time without notice in order to improve design.
Obsolete	Not In Production	This datasheet contains specifications on a product that has been discontinued by Fairchild semiconductor. The datasheet is printed for reference information only.

Rev. I20

Fast S-IGBT in NPT-technology with soft, fast recovery anti-parallel EmCon diode

- 75% lower E_{off} compared to previous generation combined with low conduction losses
- Short circuit withstand time – 10 µs
- Designed for:
  - Motor controls
  - Inverter
- NPT-Technology for 600V applications offers:
  - very tight parameter distribution
  - high ruggedness, temperature stable behaviour
  - parallel switching capability
- Very soft, fast recovery anti-parallel EmCon diode





Type	V_{CE}	I_C	$V_{CE(sat)}$	T_j	Package	Ordering Code
SKP10N60	600V	10A	2.2V	150°C	TO-220AB	Q67040-S4217
SKB10N60					TO-263AB	Q67040-S4218
SKW10N60					TO-247AC	Q67040-S4241

Maximum Ratings

Parameter	Symbol	Value	Unit
Collector-emitter voltage	V_{CE}	600	V
DC collector current $T_C = 25°C$ $T_C = 100°C$	I_C	 21 10.9	A
Pulsed collector current, t_p limited by T_{jmax}	I_{Cpuls}	42	
Turn off safe operating area $V_{CE} \leq 600V$, $T_j \leq 150°C$	-	42	
Diode forward current $T_C = 25°C$ $T_C = 100°C$	I_F	 21 10	
Diode pulsed current, t_p limited by T_{jmax}	I_{Fpuls}	42	
Gate-emitter voltage	V_{GE}	±20	V
Short circuit withstand time[1)] $V_{GE} = 15V$, $V_{CC} \leq 600V$, $T_j \leq 150°C$	t_{SC}	10	µs
Power dissipation $T_C = 25°C$	P_{tot}	104	W
Operating junction and storage temperature	T_j , T_{stg}	-55...+150	°C

[1)] Allowed number of short circuits: <1000; time between short circuits: >1s.

Thermal Resistance

Parameter	Symbol	Conditions	Max. Value	Unit
Characteristic				
IGBT thermal resistance, junction – case	R_{thJC}		1.2	K/W
Diode thermal resistance, junction – case	R_{thJCD}		2.4	
Thermal resistance, junction – ambient	R_{thJA}	TO-220AB TO-247AC	62 40	
SMD version, device on PCB[1)]	R_{thJA}	TO-263AB	40	

Electrical Characteristic, at T_j = 25 °C, unless otherwise specified

Parameter	Symbol	Conditions	Value			Unit
			min.	Typ.	max.	
Static Characteristic						
Collector-emitter breakdown voltage	$V_{(BR)CES}$	V_{GE}=0V, I_C=500µA	600	-	-	V
Collector-emitter saturation voltage	$V_{CE(sat)}$	V_{GE} = 15V, I_C=10A T_j=25°C T_j=150°C	 1.7 -	 2 2.2	 2.4 2.7	
Diode forward voltage	V_F	V_{GE}=0V, I_F=10A T_j=25°C T_j=150°C	 1.2 -	 1.4 1.25	 1.8 1.65	
Gate-emitter threshold voltage	$V_{GE(th)}$	I_C=300µA,V_{CE}=V_{GE}	3	4	5	
Zero gate voltage collector current	I_{CES}	V_{CE}=600V,V_{GE}=0V T_j=25°C T_j=150°C	 - -	 - -	 40 1500	µA
Gate-emitter leakage current	I_{GES}	V_{CE}=0V,V_{GE}=20V	-	-	100	nA
Transconductance	g_{fs}	V_{CE}=20V, I_C=10A	-	6.7	-	S
Dynamic Characteristic						
Input capacitance	C_{iss}	V_{CE}=25V,	-	580	696	pF
Output capacitance	C_{oss}	V_{GE}=0V,	-	70	84	
Reverse transfer capacitance	C_{rss}	f=1MHz	-	50	60	
Gate charge	Q_{Gate}	V_{CC}=480V, I_C=10A V_{GE}=15V	-	64	83	nC
Internal emitter inductance measured 5mm (0.197 in.) from case	L_E	TO-220AB TO-247AC	- -	7 13	- -	nH
Short circuit collector current[2)]	$I_{C(SC)}$	V_{GE}=15V,t_{SC}≤10µs V_{CC} ≤ 600V, T_j ≤ 150°C	-	100	-	A

[1)] Device on 50mm*50mm*1.5mm epoxy PCB FR4 with 6cm^2 (one layer, 70µm thick) copper area for collector connection. PCB is vertical without blown air.
[2)] Allowed number of short circuits: <1000; time between short circuits: >1s.

Switching Characteristic, Inductive Load, at T_j=25 °C

Parameter	Symbol	Conditions	Value			Unit
			min.	typ.	max.	
IGBT Characteristic						
Turn-on delay time	$t_{d(on)}$	T_j=25°C, V_{CC}=400V, I_C=10A, V_{GE}=0/15V, R_G=25Ω, Energy losses include "tail" and diode reverse recovery.	-	29	35	ns
Rise time	t_r		-	21	25	
Turn-off delay time	$t_{d(off)}$		-	233	280	
Fall time	t_f		-	49	59	
Turn-on energy	E_{on}		-	0.20	0.230	mJ
Turn-off energy	E_{off}		-	0.17	0.221	
Total switching energy	E_{ts}		-	0.370	0.451	
Anti-Parallel Diode Characteristic						
Diode reverse recovery time	t_{rr} t_S t_F	T_j=25°C, V_R=200V, I_F=10A, di_F/dt=200A/µs	- - -	220 20 200	- - -	ns
Diode reverse recovery charge	Q_{rr}		-	310	-	nC
Diode peak reverse recovery current	I_{rrm}		-	4.5	-	A
Diode peak rate of fall of reverse recovery current during t_b	di_{rr}/dt		-	180	-	A/µs

Switching Characteristic, Inductive Load, at T_j=150 °C

Parameter	Symbol	Conditions	Value			Unit
			min.	typ.	max.	
IGBT Characteristic						
Turn-on delay time	$t_{d(on)}$	T_j=150°C V_{CC}=400V, I_C=10A, V_{GE}=0/15V, R_G=25Ω Energy losses include "tail" and diode reverse recovery.	-	29	35	ns
Rise time	t_r		-	21	25	
Turn-off delay time	$t_{d(off)}$		-	266	319	
Fall time	t_f		-	63	76	
Turn-on energy	E_{on}		-	0.297	0.342	mJ
Turn-off energy	E_{off}		-	0.28	0.364	
Total switching energy	E_{ts}		-	0.577	0.706	
Anti-Parallel Diode Characteristic						
Diode reverse recovery time	t_{rr} t_S t_F	T_j=150°C V_R=200V, I_F=10A, di_F/dt=200A/µs	- - -	350 36 314	- - -	ns
Diode reverse recovery charge	Q_{rr}		-	690	-	nC
Diode peak reverse recovery current	I_{rrm}		-	6.3	-	A
Diode peak rate of fall of reverse recovery current during t_b	di_{rr}/dt		-	200	-	A/µs

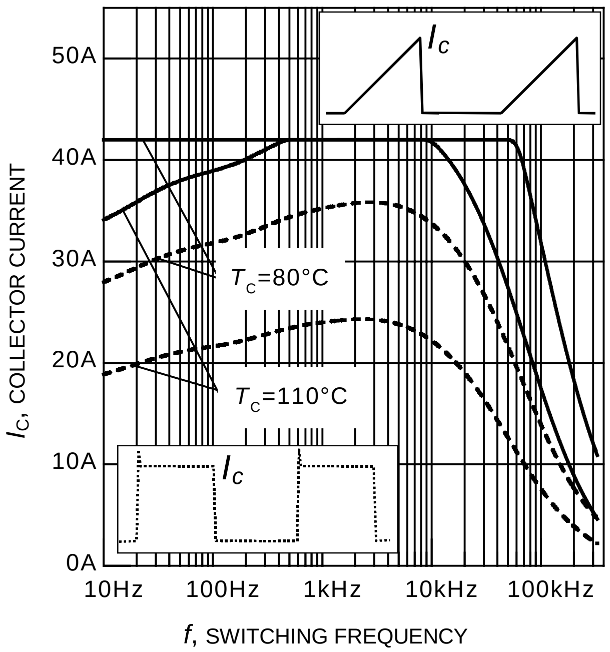


Figure 1. Collector current as a function of switching frequency
($T_j \leq 150°C$, $D = 0.5$, $V_{CE} = 400V$,
$V_{GE} = 0/+15V$, $R_G = 25\Omega$)

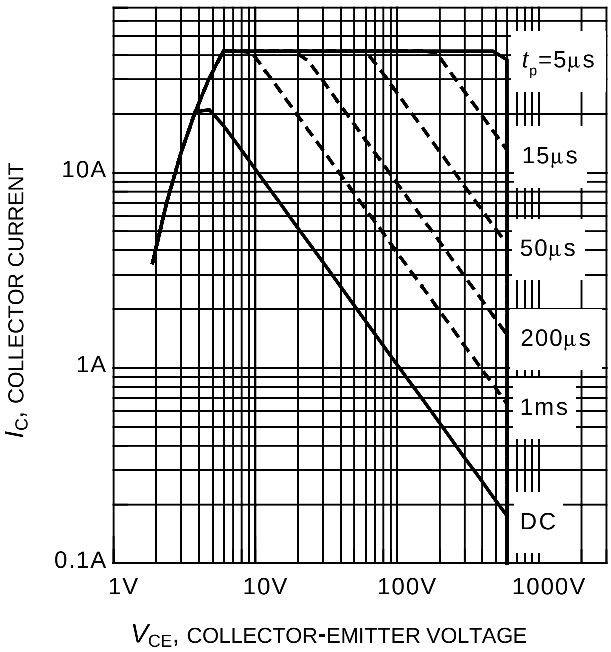


Figure 2. Safe operating area
($D = 0$, $T_C = 25°C$, $T_j \leq 150°C$)

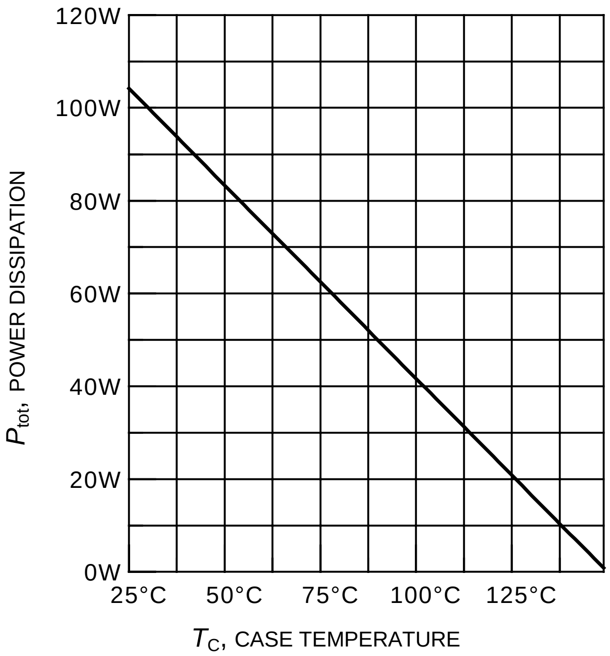


Figure 3. Power dissipation as a function of case temperature
($T_j \leq 150°C$)

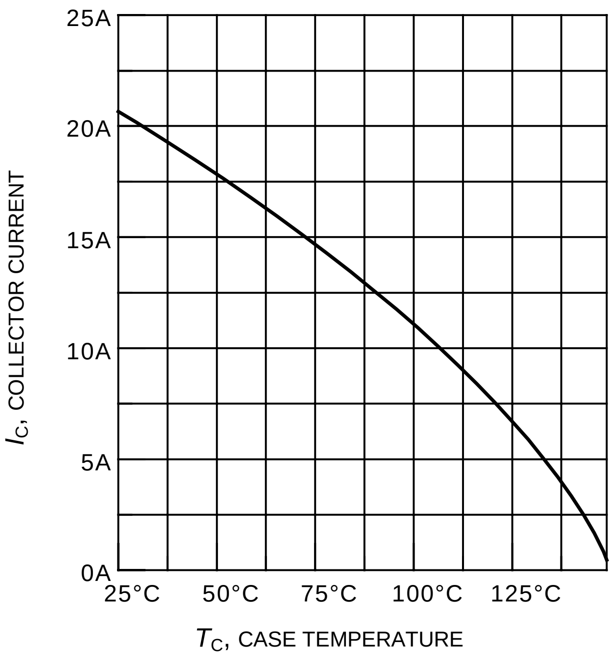


Figure 4. Collector current as a function of case temperature
($V_{GE} \leq 15V$, $T_j \leq 150°C$)

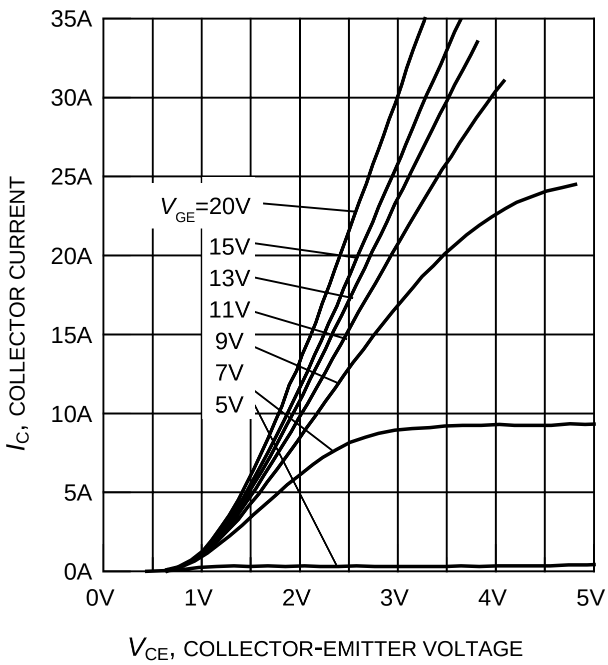


Figure 5. Typical output characteristics
(T_j = 25°C)

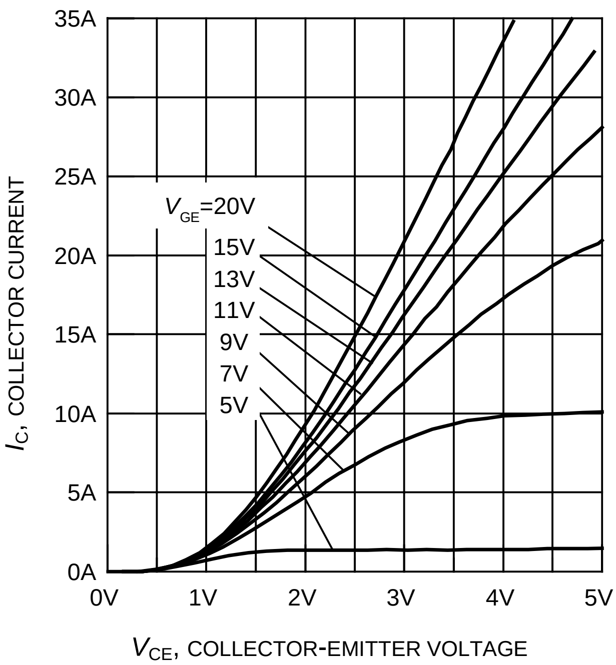


Figure 6. Typical output characteristics
(T_j = 150°C)

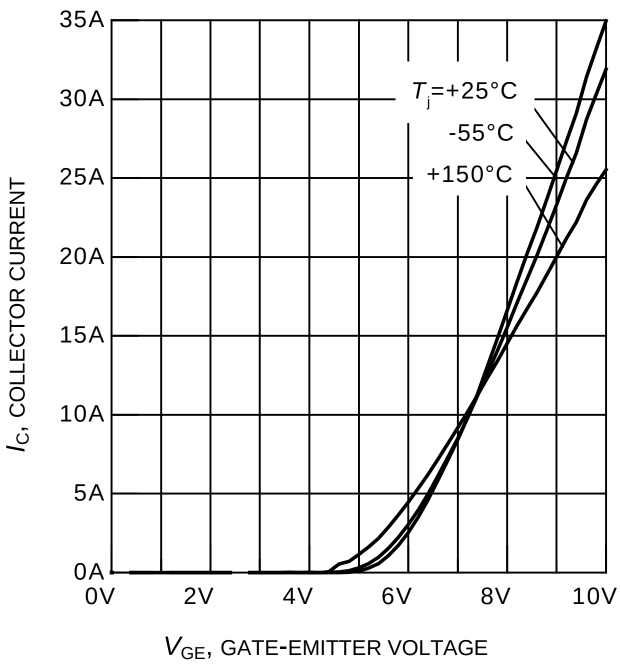


Figure 7. Typical transfer characteristics
(V_{CE} = 10V)

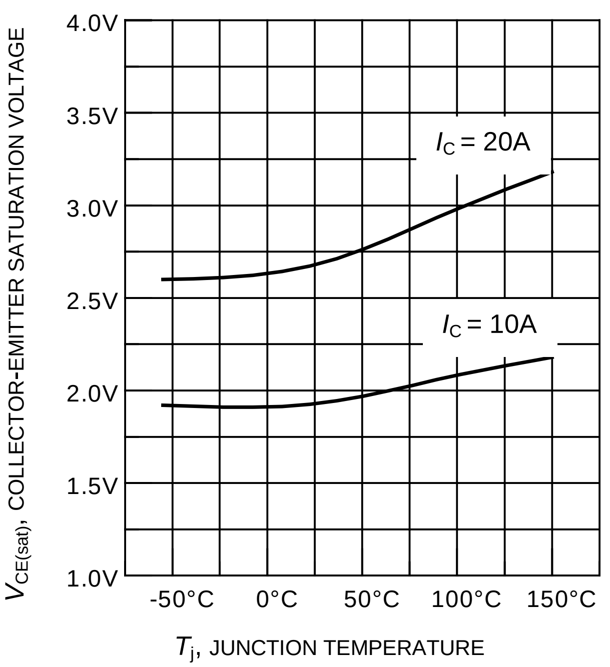


Figure 8. Typical collector-emitter saturation voltage as a function of junction temperature
(V_{GE} = 15V)

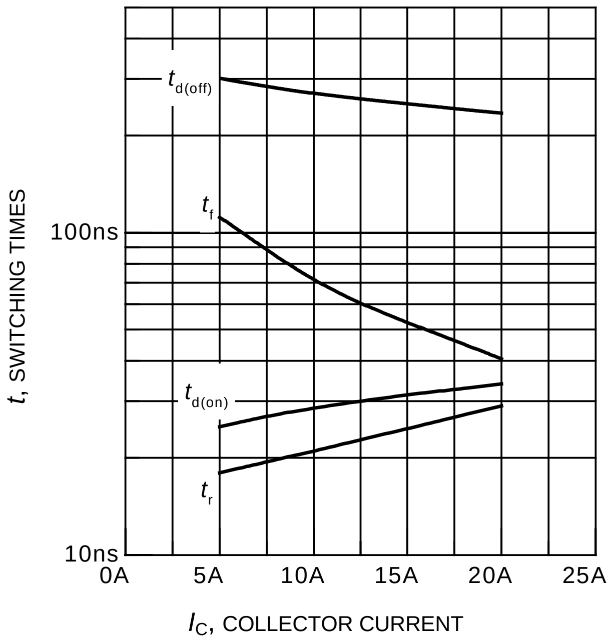


Figure 9. Typical switching times as a function of collector current
(inductive load, T_j = 150°C, V_{CE} = 400V, V_{GE} = 0/+15V, R_G = 25Ω)

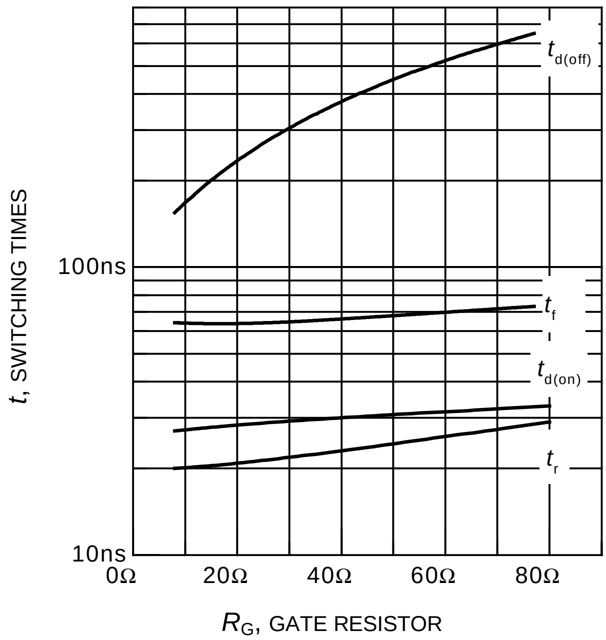


Figure 10. Typical switching times as a function of gate resistor
(inductive load, T_j = 150°C, V_{CE} = 400V, V_{GE} = 0/+15V, I_C = 10A)

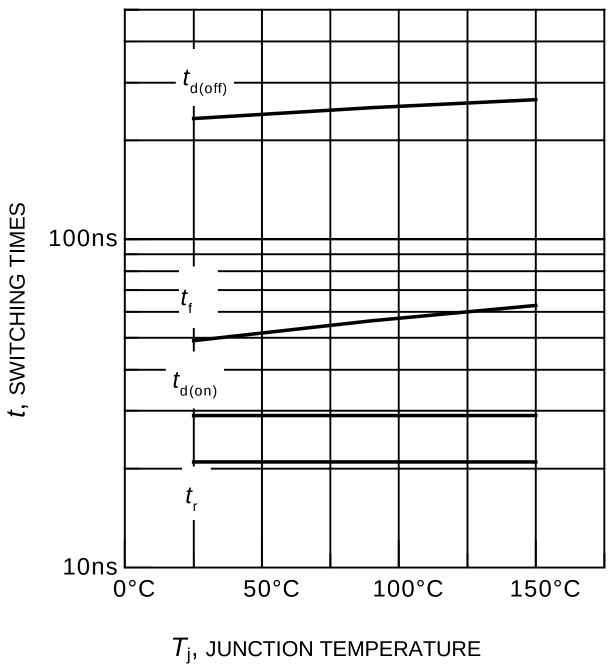


Figure 11. Typical switching times as a function of junction temperature
(inductive load, V_{CE} = 400V, V_{GE} = 0/+15V, I_C = 10A, R_G = 25Ω)

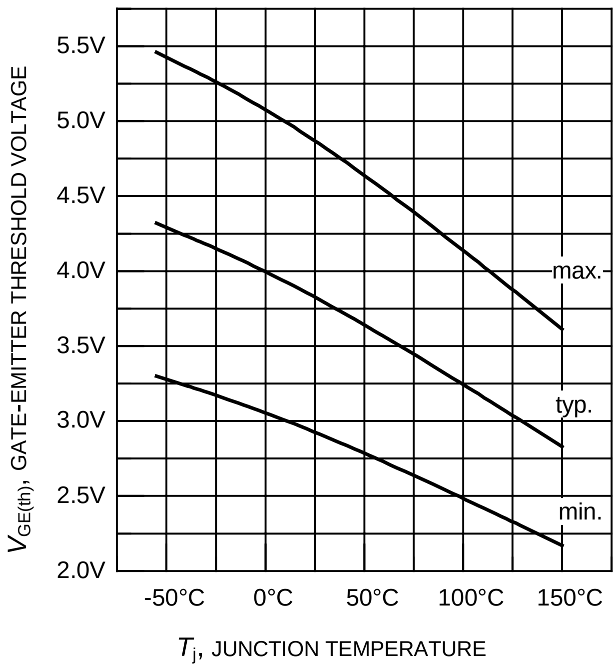


Figure 12. Gate-emitter threshold voltage as a function of junction temperature
(I_C = 0.3mA)

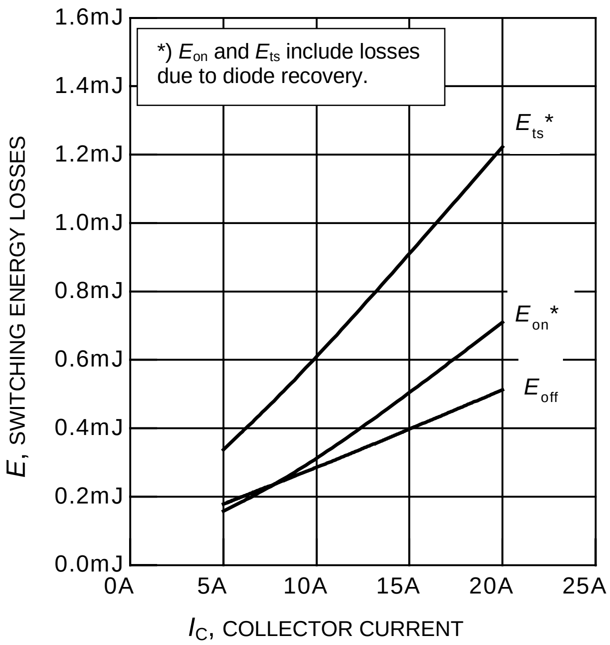


Figure 13. Typical switching energy losses as a function of collector current
(inductive load, T_j = 150°C, V_{CE} = 400V, V_{GE} = 0/+15V, R_G = 25Ω)

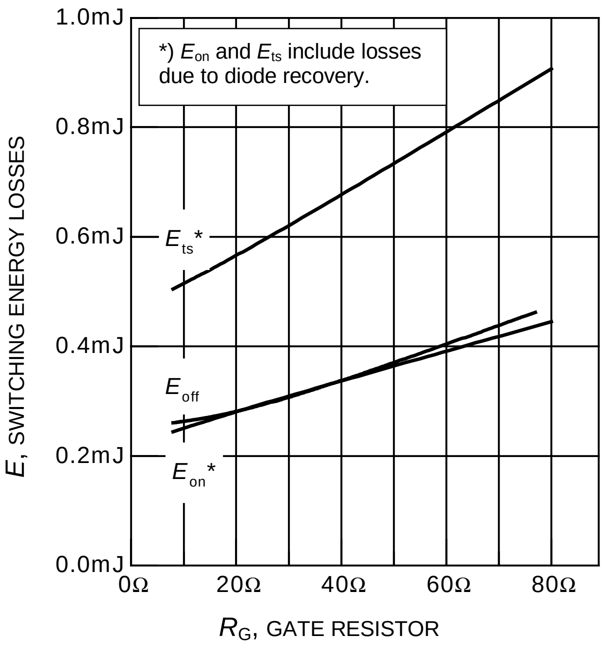


Figure 14. Typical switching energy losses as a function of gate resistor
(inductive load, T_j = 150°C, V_{CE} = 400V, V_{GE} = 0/+15V, I_C = 10A)

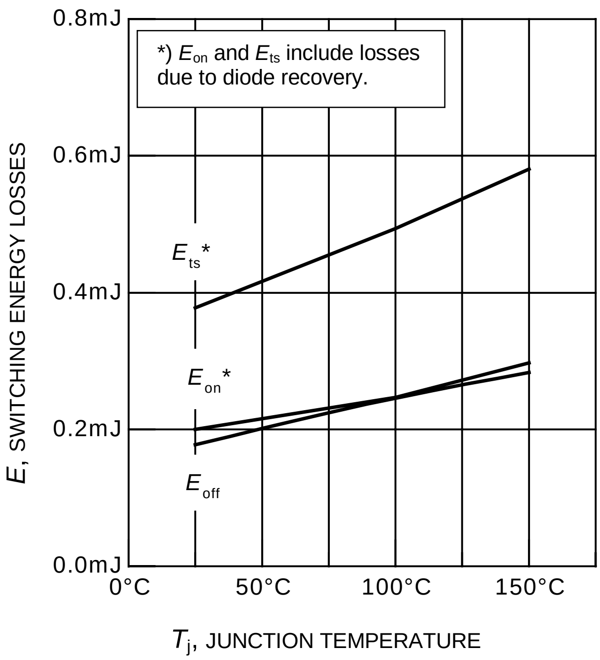


Figure 15. Typical switching energy losses as a function of junction temperature
(inductive load, V_{CE} = 400V, V_{GE} = 0/+15V, I_C = 10A, R_G = 25Ω)

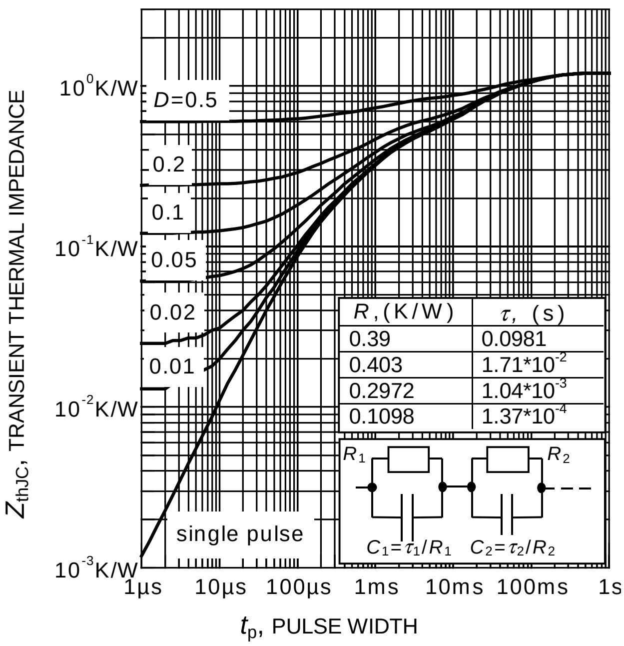


Figure 16. IGBT transient thermal impedance as a function of pulse width
($D = t_p / T$)

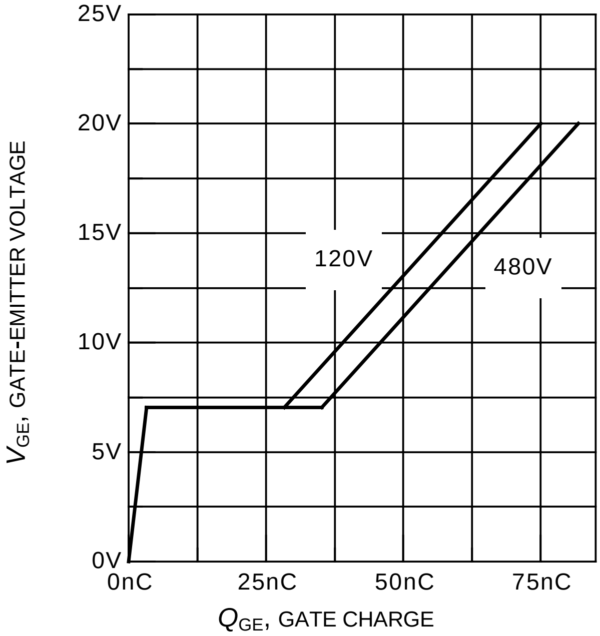


Figure 17. Typical gate charge
(I_C = 10A)

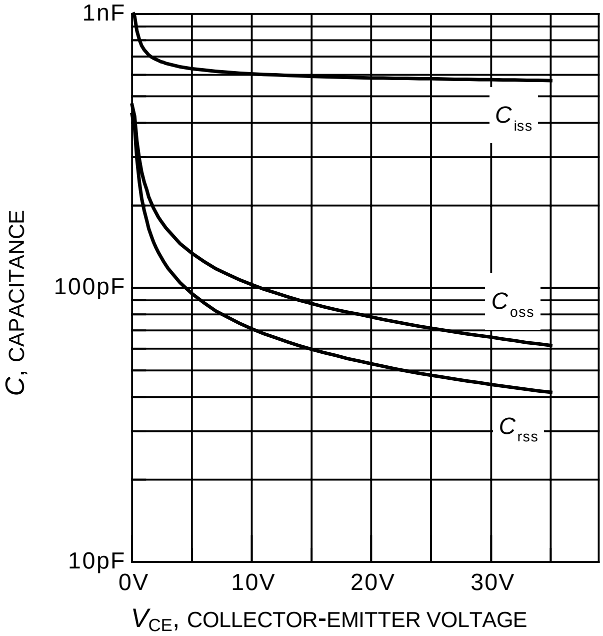


Figure 18. Typical capacitance as a function of collector-emitter voltage
(V_{GE} = 0V, f = 1MHz)

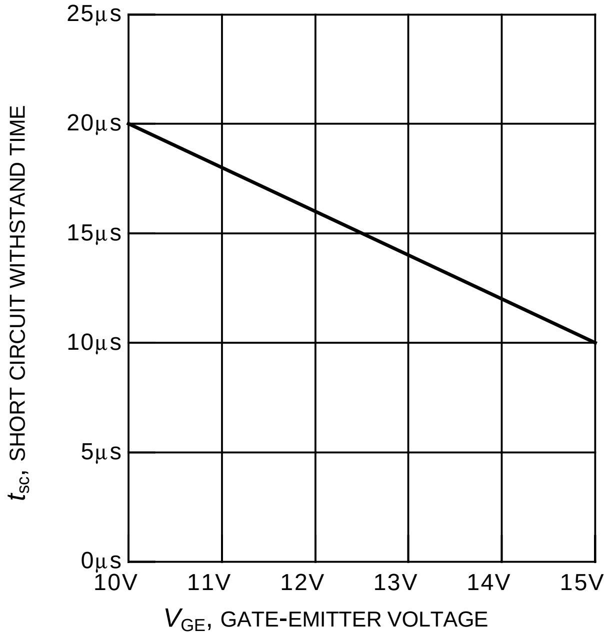


Figure 19. Short circuit withstand time as a function of gate-emitter voltage
(V_{CE} = 600V, start at T_j = 25°C)

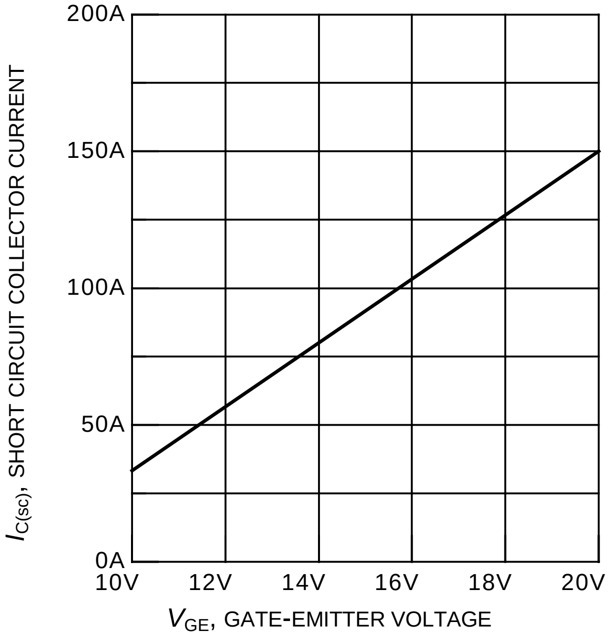


Figure 20. Typical short circuit collector current as a function of gate-emitter voltage
($V_{CE} \leq$ 600V, T_j = 150°C)

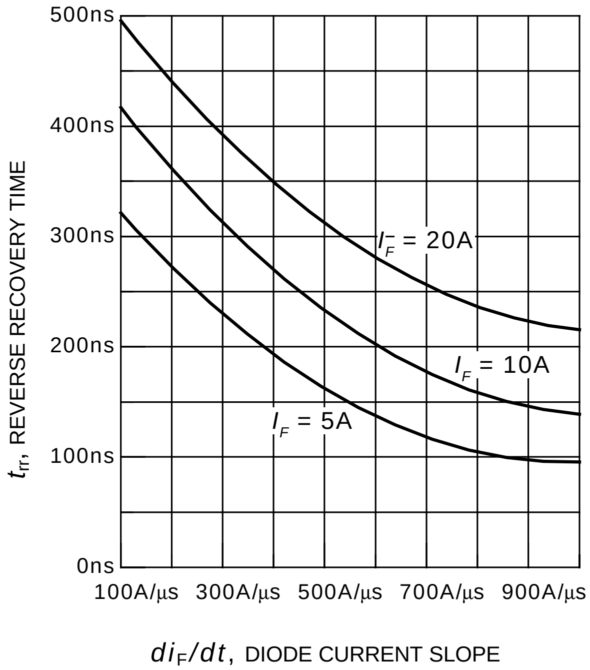


Figure 21. Typical reverse recovery time as a function of diode current slope
(V_R = 200V, T_j = 125°C)

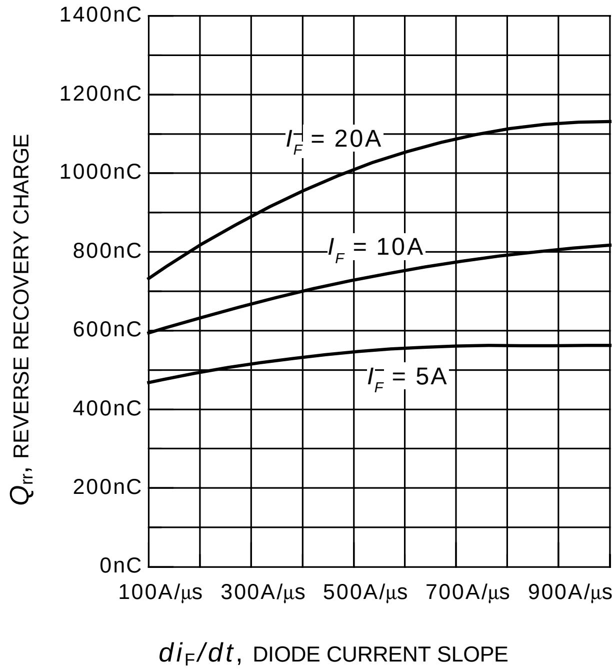


Figure 22. Typical reverse recovery charge as a function of diode current slope
(V_R = 200V, T_j = 125°C)

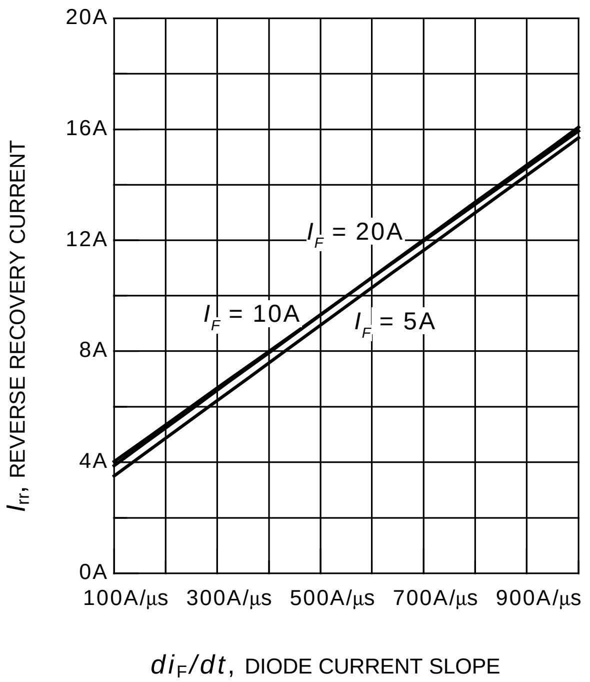


Figure 23. Typical reverse recovery current as a function of diode current slope
(V_R = 200V, T_j = 125°C)

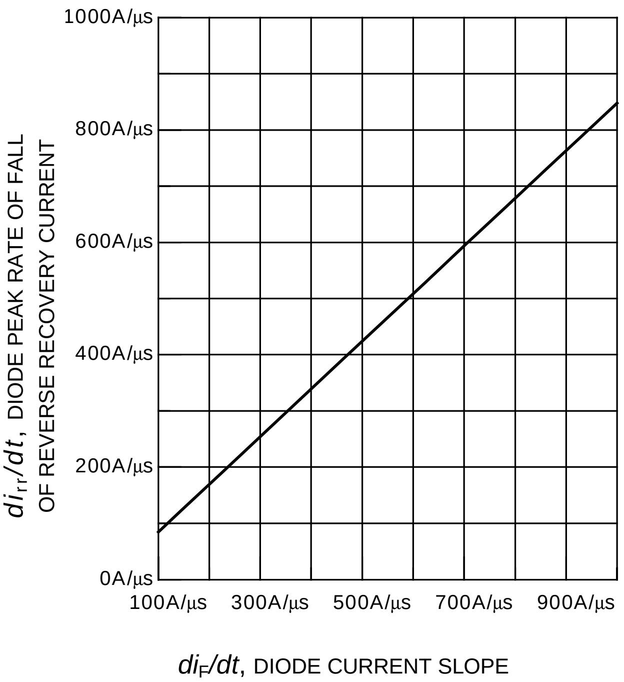


Figure 24. Typical diode peak rate of fall of reverse recovery current as a function of diode current slope
(V_R = 200V, T_j = 125°C)

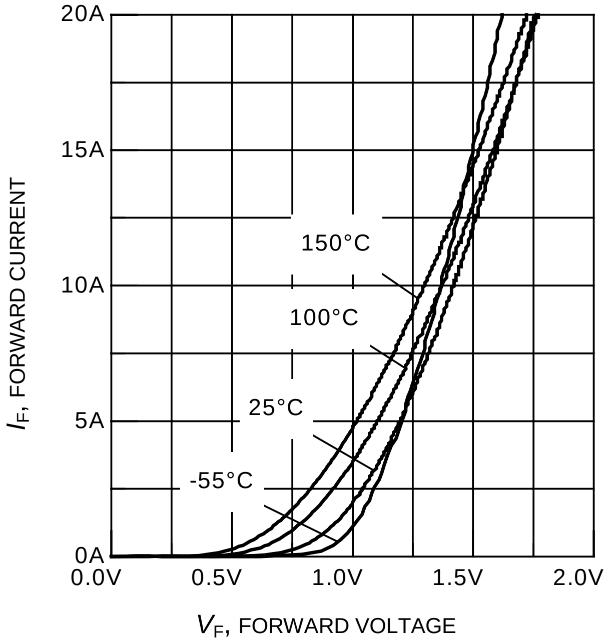


Figure 25. Typical diode forward current as a function of forward voltage

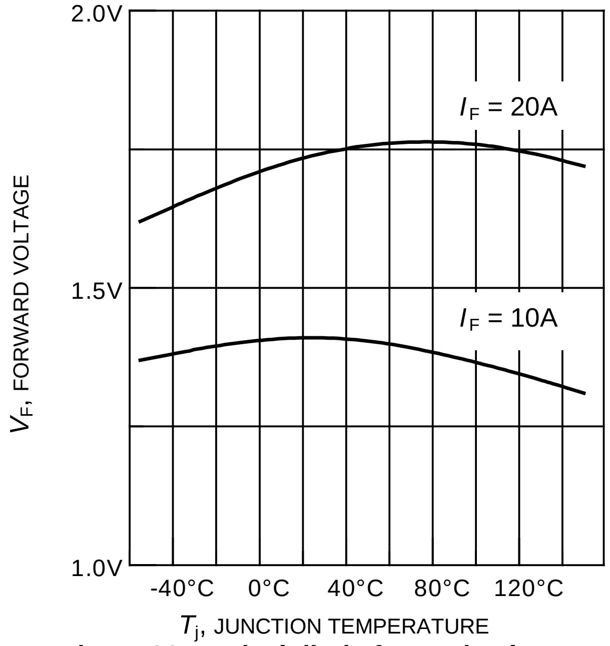


Figure 26. Typical diode forward voltage as a function of junction temperature

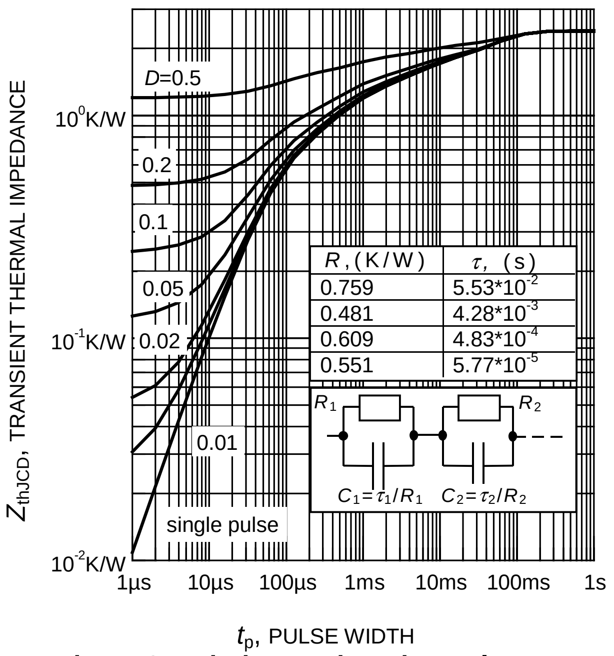
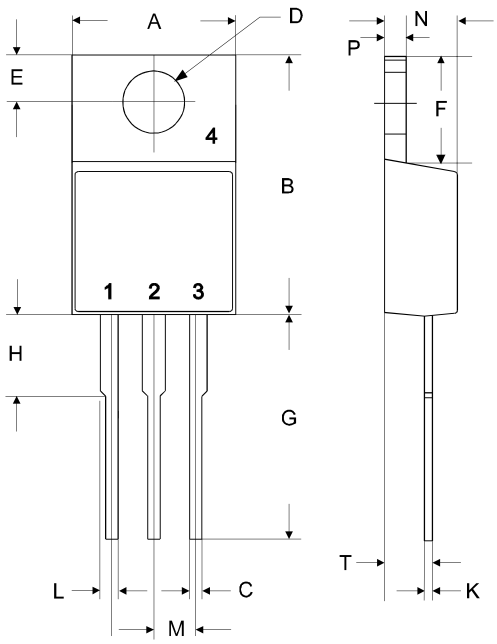


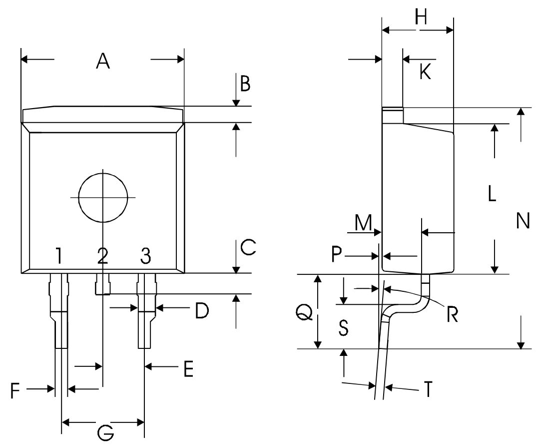
Figure 27. Diode transient thermal impedance as a function of pulse width
($D = t_p / T$)

TO-220AB

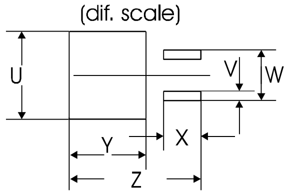


symbol	dimensions			
	[mm]		[inch]	
	min	max	min	max
A	9.70	10.30	0.3819	0.4055
B	14.88	15.95	0.5858	0.6280
C	0.65	0.86	0.0256	0.0339
D	3.55	3.89	0.1398	0.1531
E	2.60	3.00	0.1024	0.1181
F	6.00	6.80	0.2362	0.2677
G	13.00	14.00	0.5118	0.5512
H	4.35	4.75	0.1713	0.1870
K	0.38	0.65	0.0150	0.0256
L	0.95	1.32	0.0374	0.0520
M	2.54 typ.		0.1 typ.	
N	4.30	4.50	0.1693	0.1772
P	1.17	1.40	0.0461	0.0551
T	2.30	2.72	0.0906	0.1071

TO-263AB (D^2Pak)

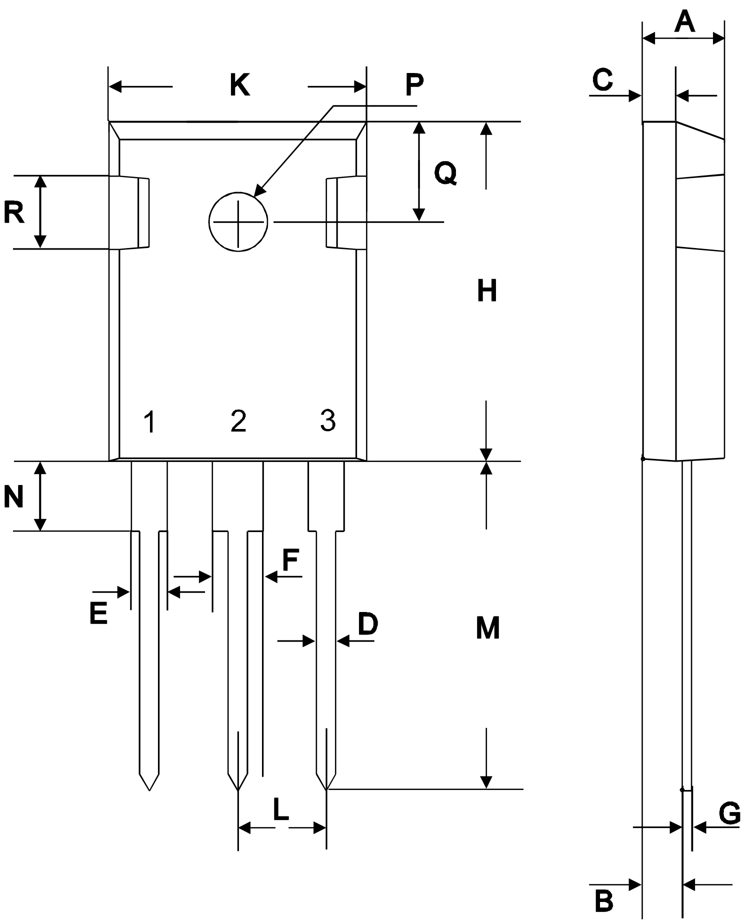


Footprint
(dif. scale)



symbol	dimensions			
	[mm]		[inch]	
	min	max	min	max
A	9.80	10.20	0.3858	0.4016
B	0.70	1.30	0.0276	0.0512
C	1.00	1.60	0.0394	0.0630
D	1.03	1.07	0.0406	0.0421
E	2.54 typ.		0.1 typ.	
F	0.65	0.85	0.0256	0.0335
G	5.08 typ.		0.2 typ.	
H	4.30	4.50	0.1693	0.1772
K	1.17	1.37	0.0461	0.0539
L	9.05	9.45	0.3563	0.3720
M	2.30	2.50	0.0906	0.0984
N	15 typ.		0.5906 typ.	
P	0.00	0.20	0.0000	0.0079
Q	4.20	5.20	0.1654	0.2047
R	8° max		8° max	
S	2.40	3.00	0.0945	0.1181
T	0.40	0.60	0.0157	0.0236
U	10.80		0.4252	
V	1.15		0.0453	
W	6.23		0.2453	
X	4.60		0.1811	
Y	9.40		0.3701	
Z	16.15		0.6358	

TO-247AC



symbol	dimensions			
	[mm]		[inch]	
	min	max	min	max
A	4.78	5.28	0.1882	0.2079
B	2.29	2.51	0.0902	0.0988
C	1.78	2.29	0.0701	0.0902
D	1.09	1.32	0.0429	0.0520
E	1.73	2.06	0.0681	0.0811
F	2.67	3.18	0.1051	0.1252
G	0.76 max		0.0299 max	
H	20.80	21.16	0.8189	0.8331
K	15.65	16.15	0.6161	0.6358
L	5.21	5.72	0.2051	0.2252
M	19.81	20.68	0.7799	0.8142
N	3.560	4.930	0.1402	0.1941
∅P	3.61		0.1421	
Q	6.12	6.22	0.2409	0.2449

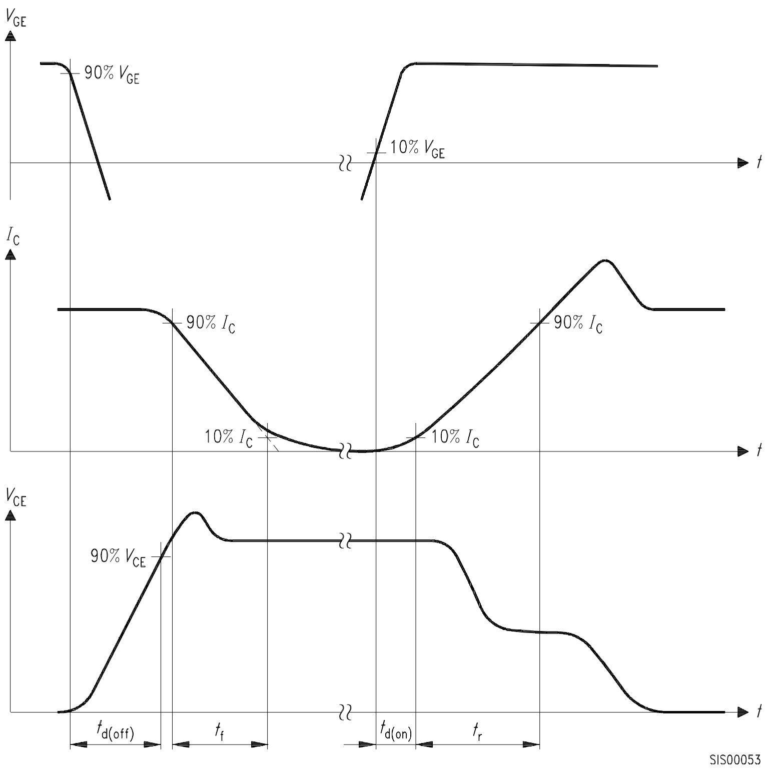


Figure A. Definition of switching times

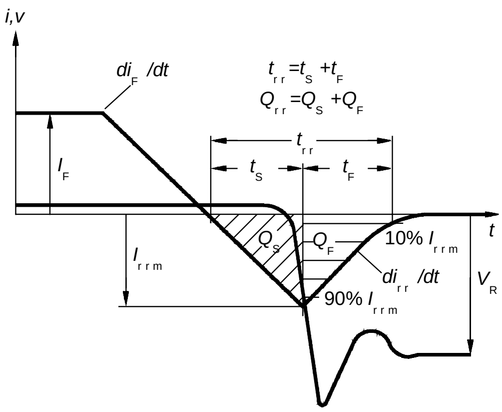


Figure C. Definition of diodes switching characteristics

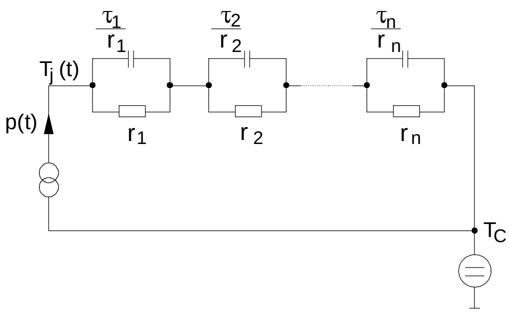


Figure D. Thermal equivalent circuit

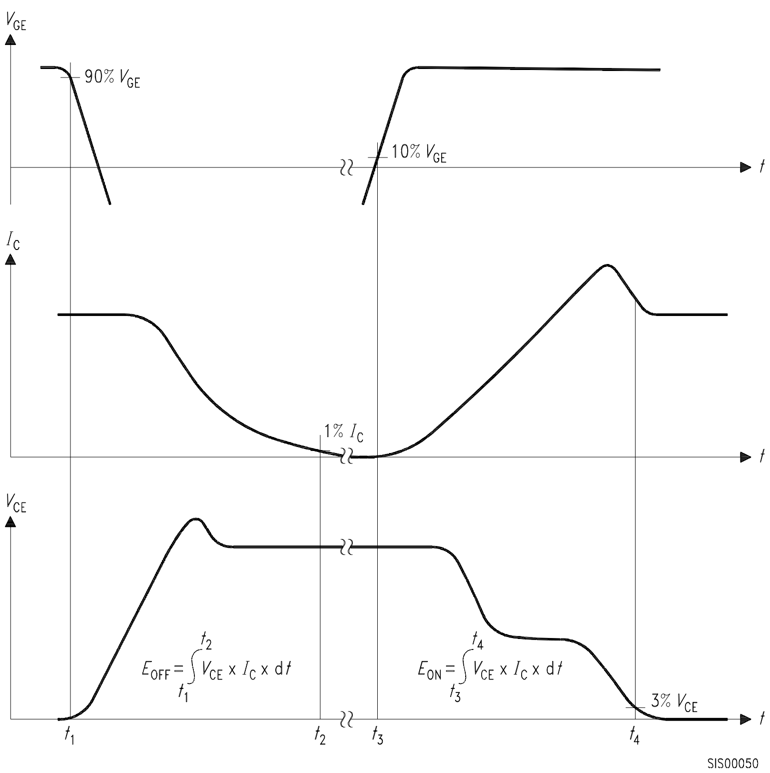


Figure B. Definition of switching losses

Published by
Infineon Technologies AG,
Bereich Kommunikation
St.-Martin-Strasse 53,
D-81541 München

Attention please!

The information herein is given to describe certain components and shall not be considered as warranted characteristics.

Terms of delivery and rights to technical change reserved.

We hereby disclaim any and all warranties, including but not limited to warranties of non-infringement, regarding circuits, descriptions and charts stated herein.

Infineon Technologies is an approved CECC manufacturer.

Information

For further information on technology, delivery terms and conditions and prices please contact your nearest Infineon Technologies Office in Germany or our Infineon Technologies Representatives worldwide (see address list).

Warnings

Due to technical requirements components may contain dangerous substances. For information on the types in question please contact your nearest Infineon Technologies Office.

Infineon Technologies Components may only be used in life-support devices or systems with the express written approval of Infineon Technologies, if a failure of such components can reasonably be expected to cause the failure of that life-support device or system, or to affect the safety or effectiveness of that device or system. Life support devices or systems are intended to be implanted in the human body, or to support and/or maintain and sustain and/or protect human life. If they fail, it is reasonable to assume that the health of the user or other persons may be endangered.