

## IGBT

IGBT with integrated diode in packages offering space saving advantage

## IKD04N60RA

600V TRENCHSTOP™ RC-Series for hard switching applications

Data sheet

IGBT with integrated diode in packages offering space saving advantage

**Features:**

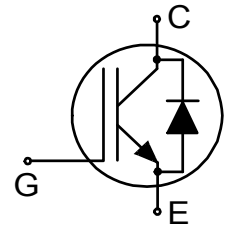
TRENCHSTOP™ Reverse Conducting (RC) technology for 600V applications offering

- Optimised  $V_{CEsat}$  and  $V_F$  for low conduction losses
- Smooth switching performance leading to low EMI levels
- Very tight parameter distribution
- Operating range of 1 to 20kHz
- Maximum junction temperature 175°C
- Short circuit capability of 5µs
- Best in class current versus package size performance
- Qualified according to AECQ101
- Pb-free lead plating; RoHS compliant (for PG-TO252: solder temperature 260°C, MSL1)

Complete product spectrum and PSpice Models:  
<http://www.infineon.com/igbt/>

**Applications:**

- HID lighting
- Piezo injection



**Key Performance and Package Parameters**

Type	$V_{CE}$	$I_C$	$V_{CEsat}, T_{vj}=25^\circ\text{C}$	$T_{vjmax}$	Marking	Package
IKD04N60RA	600V	4A	1.65V	175°C	K04R60A	PG-TO252-3



**Table of Contents**

Description ..... 2

Table of Contents ..... 3

Maximum ratings ..... 4

Thermal Resistance ..... 4

Electrical Characteristics ..... 5

Electrical Characteristics diagrams ..... 7

Package Drawing .....14

Testing Conditions .....15

Revision History .....16

Disclaimer .....16

**Maximum ratings**

Parameter	Symbol	Value	Unit
Collector-emitter voltage	$V_{CE}$	600	V
DC collector current, limited by $T_{vjmax}$ $T_C = 25^\circ\text{C}$ $T_C = 100^\circ\text{C}$	$I_C$	8.0 4.0	A
Pulsed collector current, $t_p$ limited by $T_{vjmax}$	$I_{Cpuls}$	12.0	A
Turn off safe operating area $V_{CE} \leq 600\text{V}$ , $T_{vj} \leq 175^\circ\text{C}$	-	12.0	A
Diode forward current, limited by $T_{vjmax}$ $T_C = 25^\circ\text{C}$ $T_C = 100^\circ\text{C}$	$I_F$	8.0 4.0	A
Diode pulsed current, $t_p$ limited by $T_{vjmax}$	$I_{Fpuls}$	12.0	A
Gate-emitter voltage	$V_{GE}$	$\pm 20$	V
Short circuit withstand time $V_{GE} = 15.0\text{V}$ , $V_{CC} \leq 400\text{V}$ Allowed number of short circuits < 1000 Time between short circuits: $\geq 1.0\text{s}$ $T_{vj} = 150^\circ\text{C}$	$t_{SC}$	5	$\mu\text{s}$
Power dissipation $T_C = 25^\circ\text{C}$	$P_{tot}$	75.0	W
Operating junction temperature	$T_{vj}$	-40...+175	$^\circ\text{C}$
Storage temperature	$T_{stg}$	-55...+175	$^\circ\text{C}$
Soldering temperature, reflow soldering (MSL1 according to JEDEC J-STA-020)		260	$^\circ\text{C}$

**Thermal Resistance**

Parameter	Symbol	Conditions	Max. Value	Unit
<b>Characteristic</b>				
IGBT thermal resistance, junction - case	$R_{th(j-c)}$		2.00	K/W
Diode thermal resistance, junction - case	$R_{th(j-c)}$		4.50	K/W
Thermal resistance, min. footprint junction - ambient	$R_{th(j-a)}$		75	K/W
Thermal resistance, 6cm <sup>2</sup> Cu on PCB junction - ambient	$R_{th(j-a)}$		50	K/W

**Electrical Characteristic, at  $T_{vj} = 25^{\circ}\text{C}$ , unless otherwise specified**

Parameter	Symbol	Conditions	Value			Unit
			min.	typ.	max.	
<b>Static Characteristic</b>						
Collector-emitter breakdown voltage	$V_{(BR)CES}$	$V_{GE} = 0\text{V}, I_C = 0.20\text{mA}$	600	-	-	V
Collector-emitter saturation voltage	$V_{CESat}$	$V_{GE} = 15.0\text{V}, I_C = 4.0\text{A}$ $T_{vj} = 25^{\circ}\text{C}$ $T_{vj} = 175^{\circ}\text{C}$	- -	1.65 1.85	2.10 -	V
Diode forward voltage	$V_F$	$V_{GE} = 0\text{V}, I_F = 4.0\text{A}$ $T_{vj} = 25^{\circ}\text{C}$ $T_{vj} = 175^{\circ}\text{C}$	- -	1.70 1.70	2.10 -	V
Gate-emitter threshold voltage	$V_{GE(th)}$	$I_C = 0.07\text{mA}, V_{CE} = V_{GE}$	4.3	5.0	5.7	V
Zero gate voltage collector current	$I_{CES}$	$V_{CE} = 600\text{V}, V_{GE} = 0\text{V}$ $T_{vj} = 25^{\circ}\text{C}$ $T_{vj} = 175^{\circ}\text{C}$	- -	- -	40.0 1000.0	$\mu\text{A}$
Gate-emitter leakage current	$I_{GES}$	$V_{CE} = 0\text{V}, V_{GE} = 20\text{V}$	-	-	100	nA
Transconductance	$g_{fs}$	$V_{CE} = 20\text{V}, I_C = 4.0\text{A}$	-	2.2	-	S
Integrated gate resistor	$r_G$			none		$\Omega$

**Electrical Characteristic, at  $T_{vj} = 25^{\circ}\text{C}$ , unless otherwise specified**

Parameter	Symbol	Conditions	Value			Unit
			min.	typ.	max.	
<b>Dynamic Characteristic</b>						
Input capacitance	$C_{ies}$		-	305	-	pF
Output capacitance	$C_{oes}$	$V_{CE} = 25\text{V}, V_{GE} = 0\text{V}, f = 1\text{MHz}$	-	18	-	
Reverse transfer capacitance	$C_{res}$		-	9	-	
Gate charge	$Q_G$	$V_{CC} = 480\text{V}, I_C = 4.0\text{A},$ $V_{GE} = 15\text{V}$	-	27.0	-	nC
Short circuit collector current Max. 1000 short circuits Time between short circuits: $\geq 1.0\text{s}$	$I_{C(SC)}$	$V_{GE} = 15.0\text{V}, V_{CC} \leq 400\text{V},$ $t_{SC} \leq 5\mu\text{s}$ $T_{vj} = 25^{\circ}\text{C}$	-	31	-	A

**Switching Characteristic, Inductive Load**

Parameter	Symbol	Conditions	Value			Unit
			min.	typ.	max.	
<b>IGBT Characteristic, at <math>T_{vj} = 25^{\circ}\text{C}</math></b>						
Turn-on delay time	$t_{d(on)}$	$T_{vj} = 25^{\circ}\text{C},$ $V_{CC} = 400\text{V}, I_C = 4.0\text{A},$ $V_{GE} = 0.0/15.0\text{V},$ $r_G = 43.0\Omega, L\sigma = 60\text{nH},$ $C\sigma = 40\text{pF}$ $L\sigma, C\sigma$ from Fig. E	-	14	-	ns
Rise time	$t_r$		-	8	-	ns
Turn-off delay time	$t_{d(off)}$		-	146	-	ns
Fall time	$t_f$		-	171	-	ns
Turn-on energy	$E_{on}$		-	0.09	-	mJ
Turn-off energy	$E_{off}$		-	0.15	-	mJ
Total switching energy	$E_{ts}$		-	0.24	-	mJ

**Diode Characteristic, at  $T_{vj} = 25^{\circ}\text{C}$** 

Diode reverse recovery time	$t_{rr}$	$T_{vj} = 25^{\circ}\text{C},$ $V_R = 400\text{V},$ $I_F = 4.0\text{A},$ $di_F/dt = 600\text{A}/\mu\text{s}$	-	43	-	ns
Diode reverse recovery charge	$Q_{rr}$		-	0.22	-	$\mu\text{C}$
Diode peak reverse recovery current	$I_{rrm}$		-	7.6	-	A
Diode peak rate of fall of reverse recovery current during $t_b$	$di_{rr}/dt$		-	-330	-	$\text{A}/\mu\text{s}$

**Switching Characteristic, Inductive Load**

Parameter	Symbol	Conditions	Value			Unit
			min.	typ.	max.	

**IGBT Characteristic, at  $T_{vj} = 175^{\circ}\text{C}$** 

Turn-on delay time	$t_{d(\text{on})}$	$T_{vj} = 175^{\circ}\text{C},$ $V_{CC} = 400\text{V}, I_C = 4.0\text{A},$ $V_{GE} = 0.0/15.0\text{V},$ $r_G = 43.0\Omega, L\sigma = 60\text{nH},$ $C\sigma = 40\text{pF}$ $L\sigma, C\sigma$ from Fig. E	-	12	-	ns
Rise time	$t_r$		-	8	-	ns
Turn-off delay time	$t_{d(\text{off})}$		-	177	-	ns
Fall time	$t_f$		-	165	-	ns
Turn-on energy	$E_{\text{on}}$		-	0.16	-	mJ
Turn-off energy	$E_{\text{off}}$		-	0.24	-	mJ
Total switching energy	$E_{\text{ts}}$		-	0.40	-	mJ

**Diode Characteristic, at  $T_{vj} = 175^{\circ}\text{C}$** 

Diode reverse recovery time	$t_{rr}$	$T_{vj} = 175^{\circ}\text{C},$ $V_R = 400\text{V},$ $I_F = 4.0\text{A},$ $di_F/dt = 600\text{A}/\mu\text{s}$	-	98	-	ns
Diode reverse recovery charge	$Q_{rr}$		-	0.52	-	$\mu\text{C}$
Diode peak reverse recovery current	$I_{rrm}$		-	11.0	-	A
Diode peak rate of fall of reverse recovery current during $t_b$	$di_{rr}/dt$		-	-200	-	$\text{A}/\mu\text{s}$

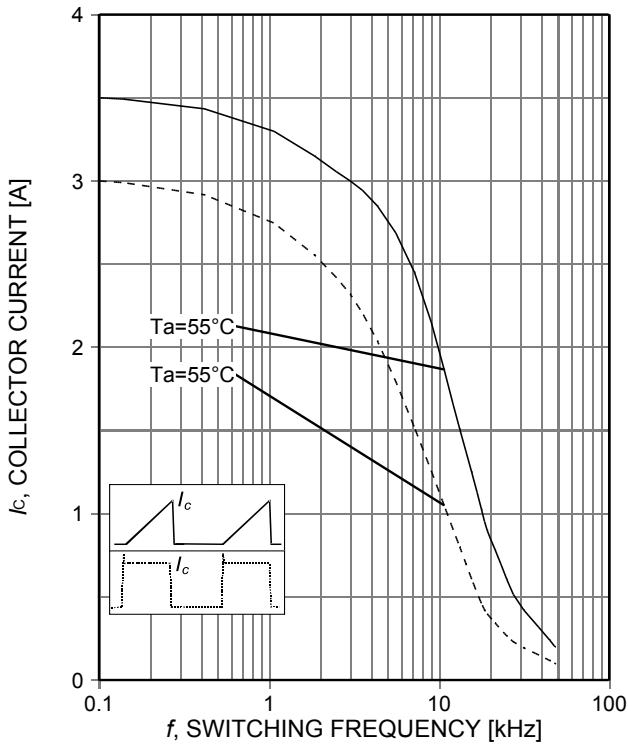


Figure 1. **Collector current as a function of switching frequency**  
 ( $T_{vj} \leq 175^\circ\text{C}$ ,  $D=0,5$ ,  $V_{CE}=400\text{V}$ ,  $V_{GE}=15/0\text{V}$ ,  $r_G=43\Omega$ , PCB Mounting,  $6\text{cm}^2$  Cu,  $P_{tot}=2,4\text{W}$ , for further information see Appnote: [www.infineon.com/igbt](http://www.infineon.com/igbt))

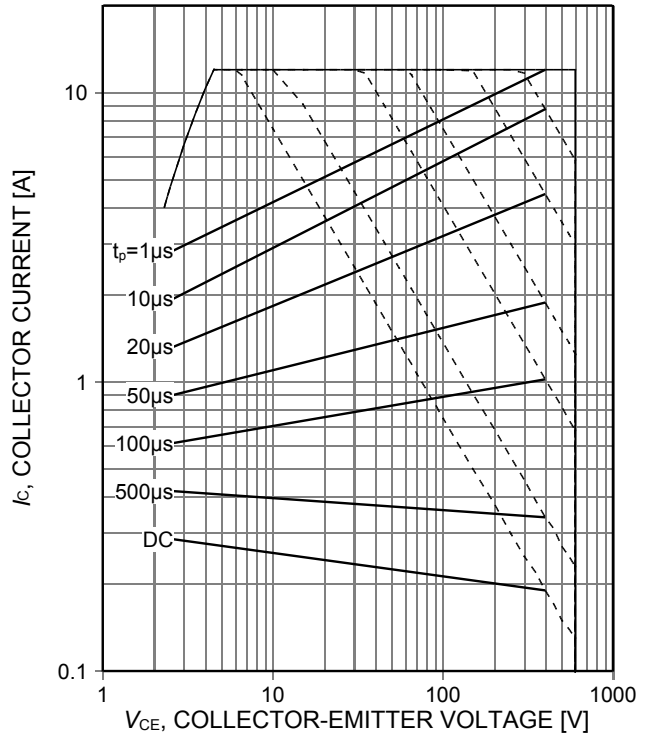


Figure 2. **Forward bias safe operating area**  
 ( $D=0$ ,  $T_C=25^\circ\text{C}$ ,  $T_{vj} \leq 175^\circ\text{C}$ ;  $V_{GE}=15\text{V}$ )

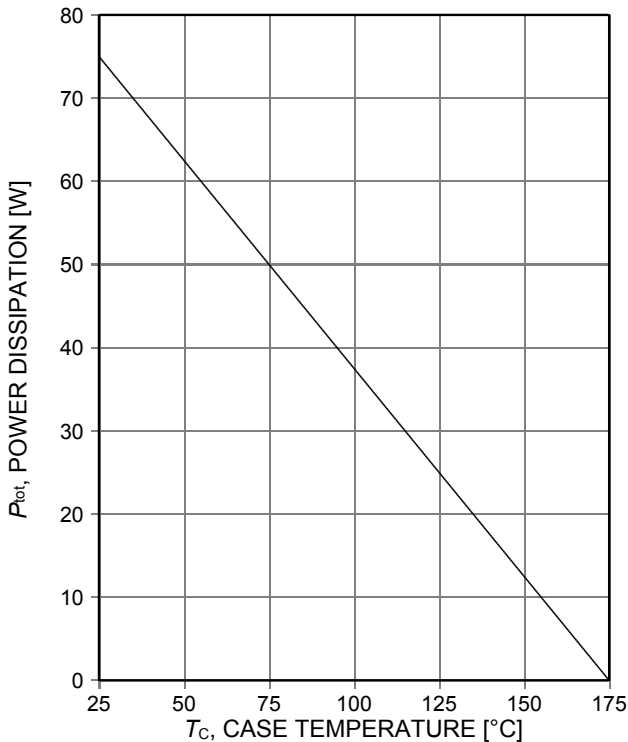


Figure 3. **Power dissipation as a function of case temperature**  
 ( $T_{vj} \leq 175^\circ\text{C}$ )

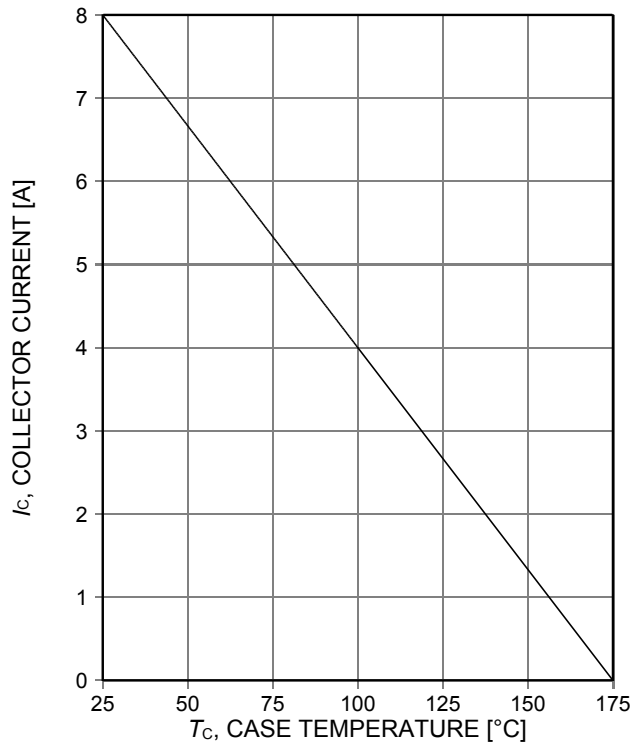


Figure 4. **Collector current as a function of case temperature**  
 ( $V_{GE} \geq 15\text{V}$ ,  $T_{vj} \leq 175^\circ\text{C}$ )

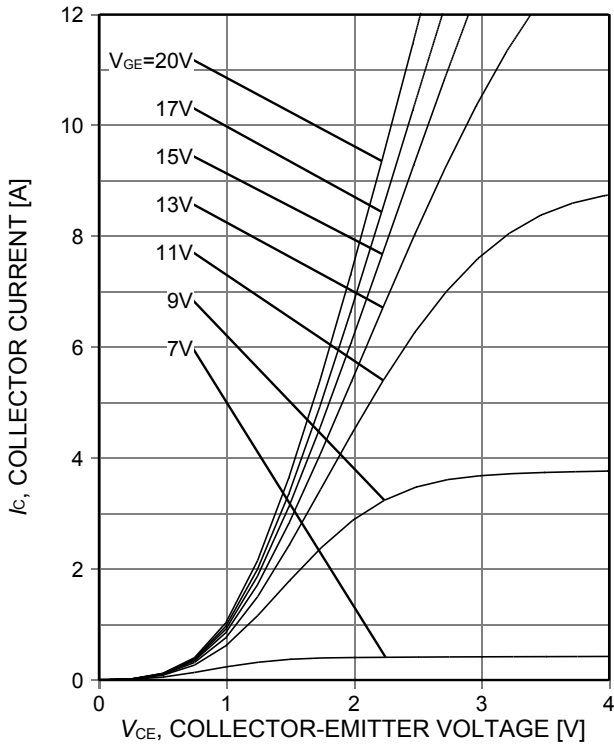


Figure 5. **Typical output characteristic**  
( $T_{vj}=25^{\circ}\text{C}$ )

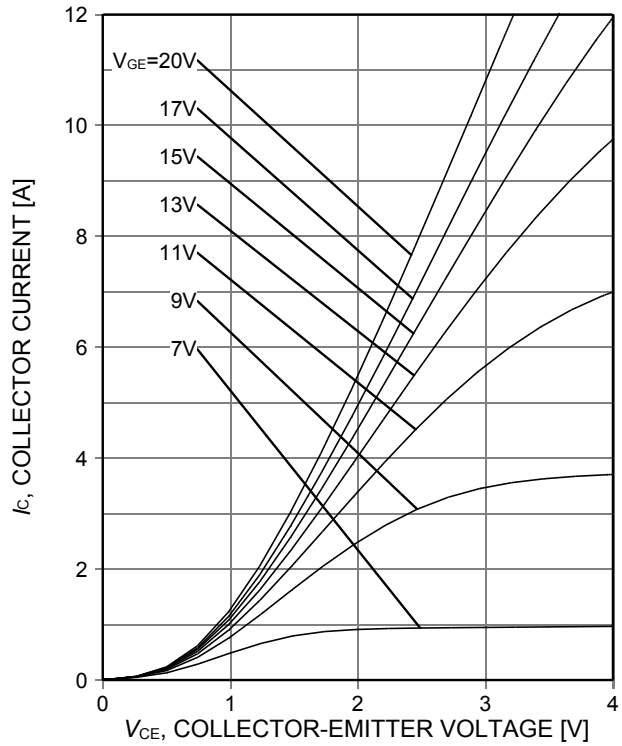


Figure 6. **Typical output characteristic**  
( $T_{vj}=175^{\circ}\text{C}$ )

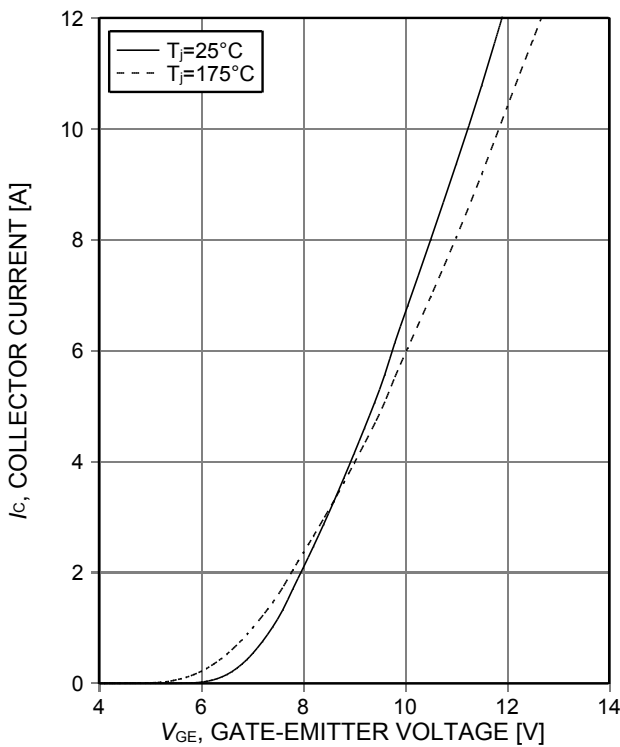


Figure 7. **Typical transfer characteristic**  
( $V_{ce}=10\text{V}$ )

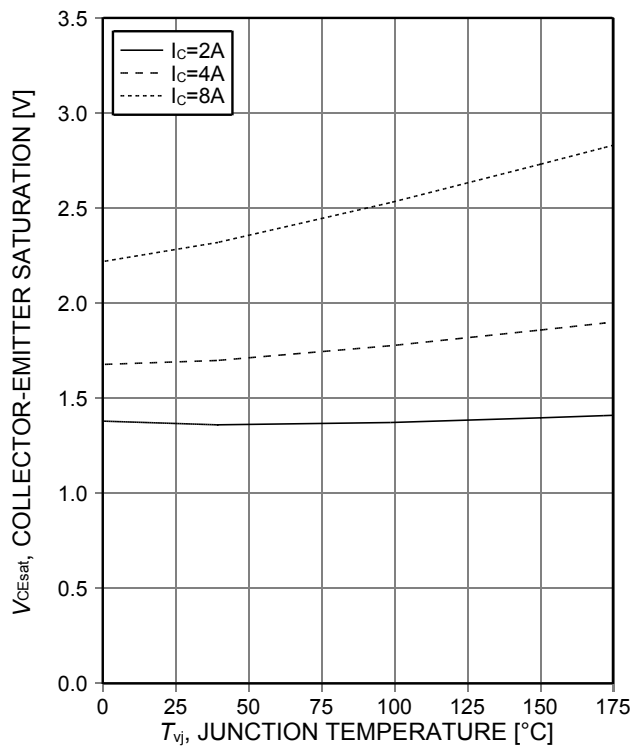


Figure 8. **Typical collector-emitter saturation voltage as a function of junction temperature**  
( $V_{ge}=15\text{V}$ )



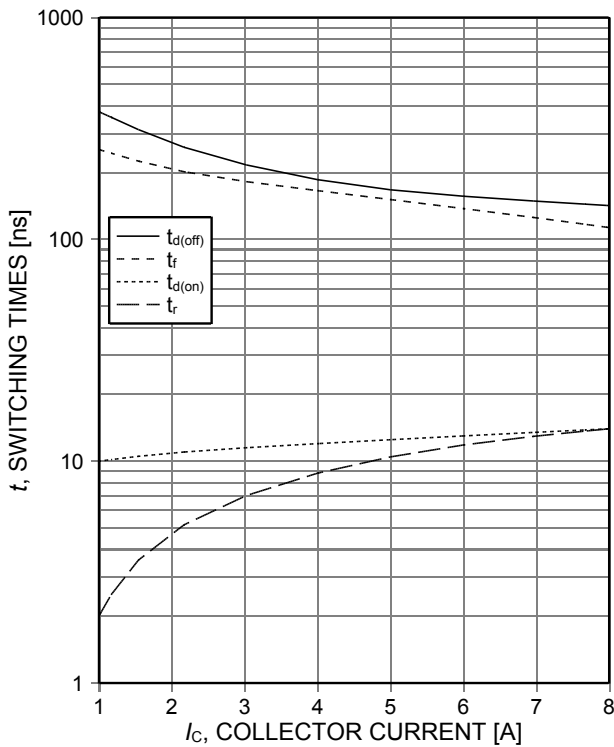


Figure 9. **Typical switching times as a function of collector current**  
 (inductive load,  $T_{vj}=175^{\circ}\text{C}$ ,  $V_{ce}=400\text{V}$ ,  $V_{ge}=15/0\text{V}$ ,  $r_g=43\Omega$ , Dynamic test circuit in Figure E)

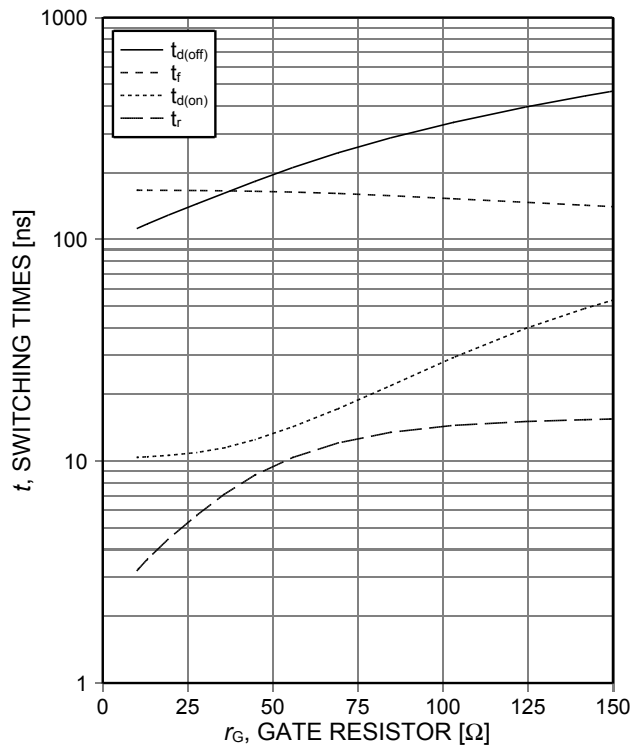


Figure 10. **Typical switching times as a function of gate resistor**  
 (inductive load,  $T_{vj}=175^{\circ}\text{C}$ ,  $V_{ce}=400\text{V}$ ,  $V_{ge}=15/0\text{V}$ ,  $I_c=4\text{A}$ , Dynamic test circuit in Figure E)

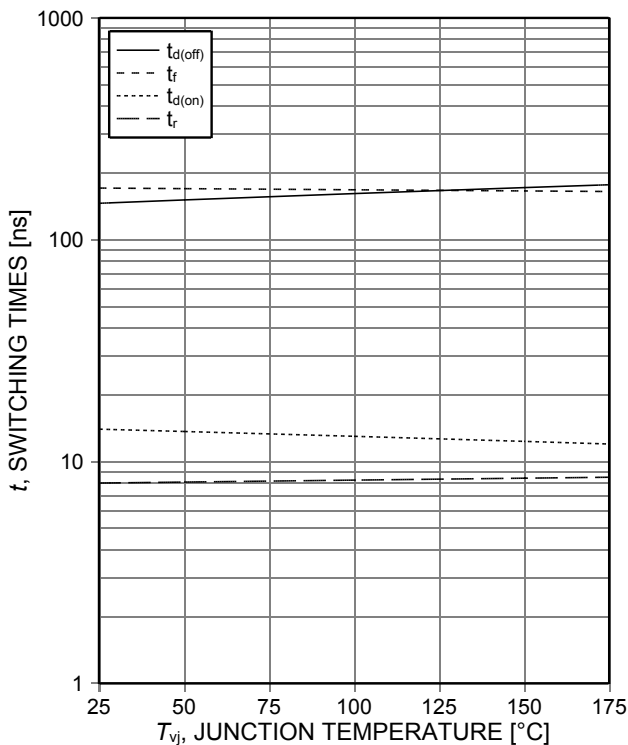


Figure 11. **Typical switching times as a function of junction temperature**  
 (inductive load,  $V_{ce}=400\text{V}$ ,  $V_{ge}=15/0\text{V}$ ,  $I_c=4\text{A}$ ,  $r_g=43\Omega$ , Dynamic test circuit in Figure E)

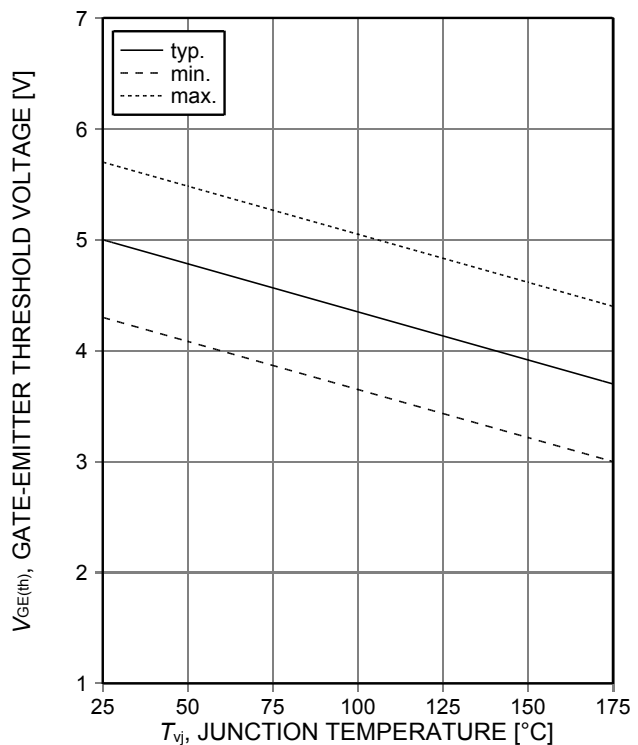


Figure 12. **Gate-emitter threshold voltage as a function of junction temperature**  
 ( $I_c=0,07\text{mA}$ )

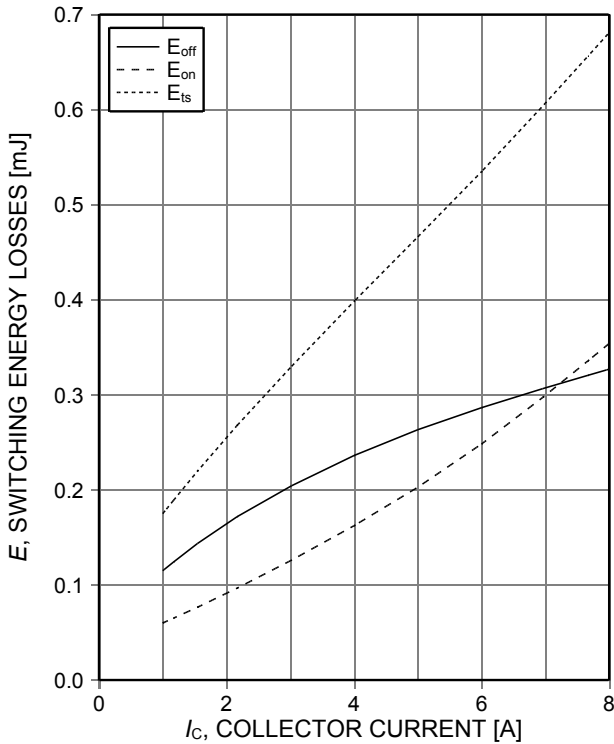


Figure 13. **Typical switching energy losses as a function of collector current**  
 (inductive load,  $T_{vj}=175^{\circ}\text{C}$ ,  $V_{CE}=400\text{V}$ ,  $V_{GE}=15/0\text{V}$ ,  $r_G=43\Omega$ , Dynamic test circuit in Figure E)

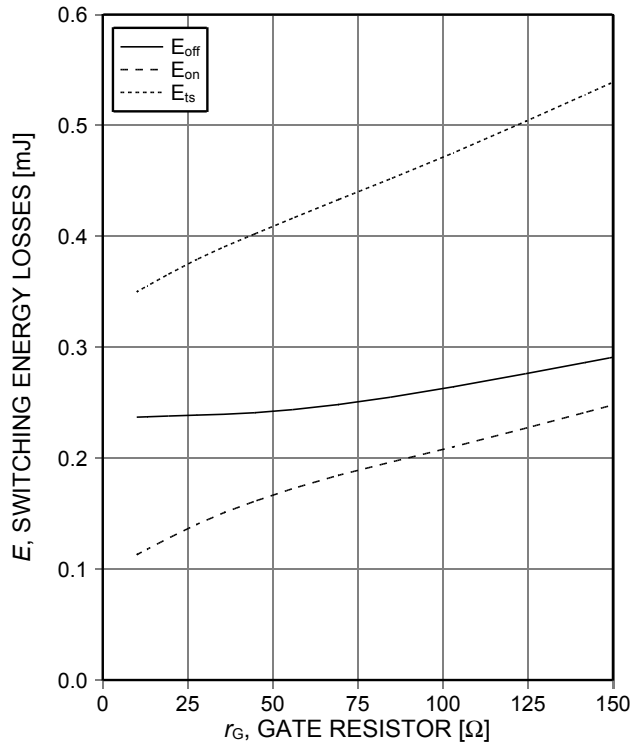


Figure 14. **Typical switching energy losses as a function of gate resistor**  
 (inductive load,  $T_{vj}=175^{\circ}\text{C}$ ,  $V_{CE}=400\text{V}$ ,  $V_{GE}=15/0\text{V}$ ,  $I_C=4\text{A}$ , Dynamic test circuit in Figure E)

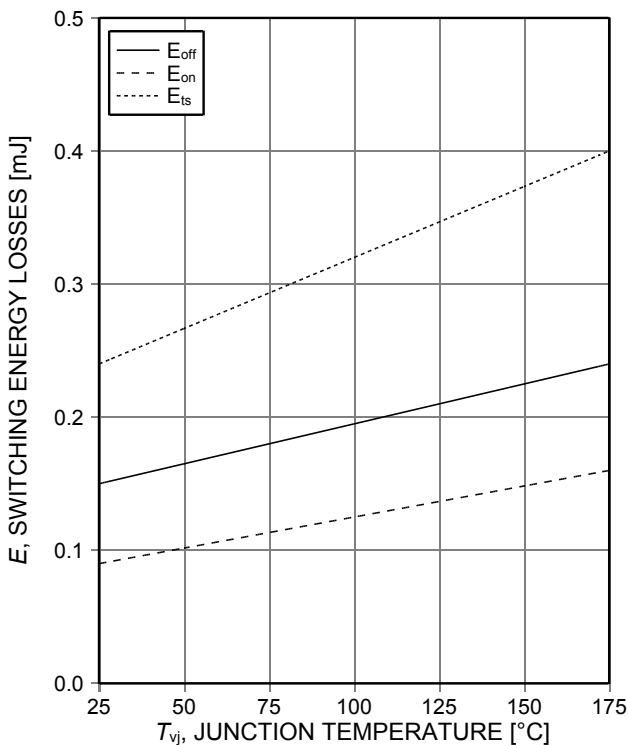


Figure 15. **Typical switching energy losses as a function of junction temperature**  
 (inductive load,  $V_{CE}=400\text{V}$ ,  $V_{GE}=15/0\text{V}$ ,  $I_C=4\text{A}$ ,  $r_G=43\Omega$ , Dynamic test circuit in Figure E)

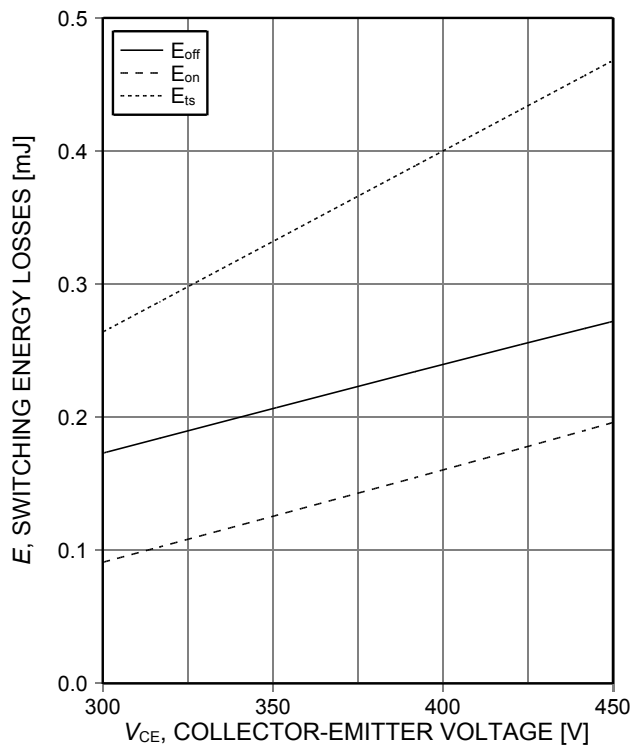


Figure 16. **Typical switching energy losses as a function of collector emitter voltage**  
 (inductive load,  $T_{vj}=175^{\circ}\text{C}$ ,  $V_{GE}=15/0\text{V}$ ,  $I_C=4\text{A}$ ,  $r_G=43\Omega$ , Dynamic test circuit in Figure E)

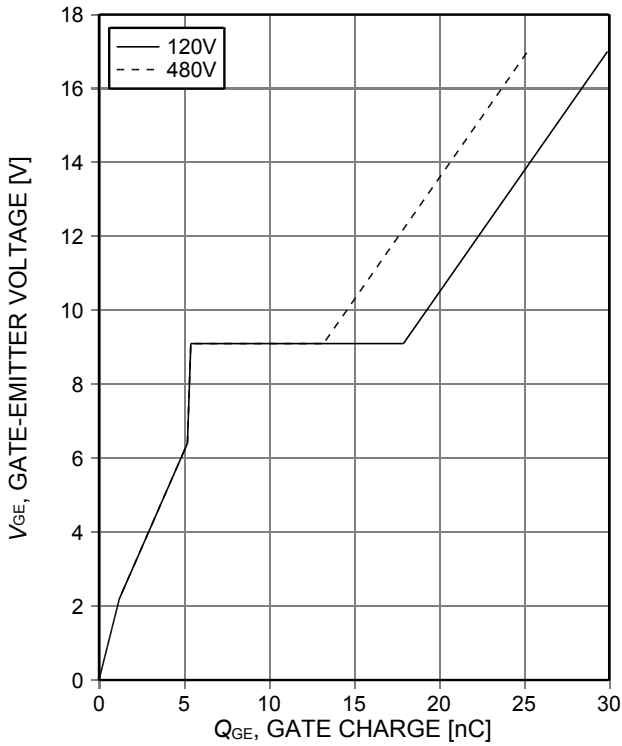


Figure 17. **Typical gate charge**  
( $I_C=4A$ )

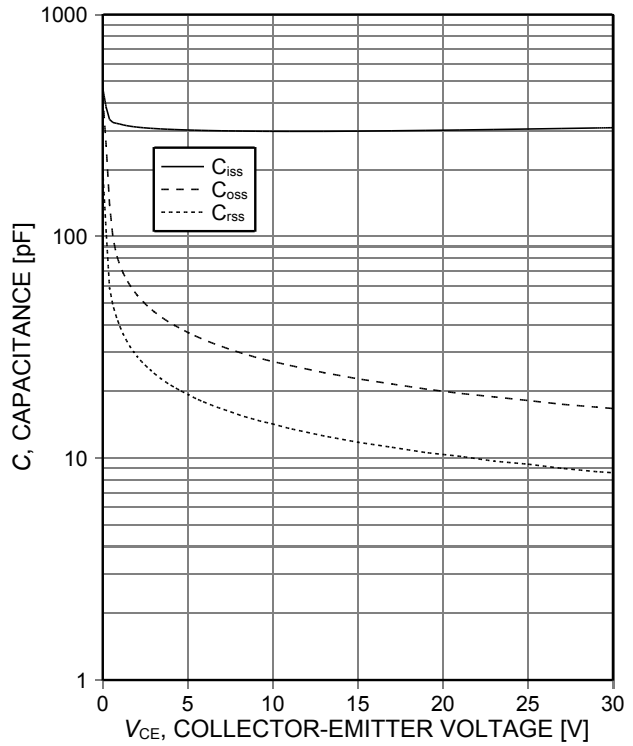


Figure 18. **Typical capacitance as a function of collector-emitter voltage**  
( $V_{GE}=0V$ ,  $f=1MHz$ )

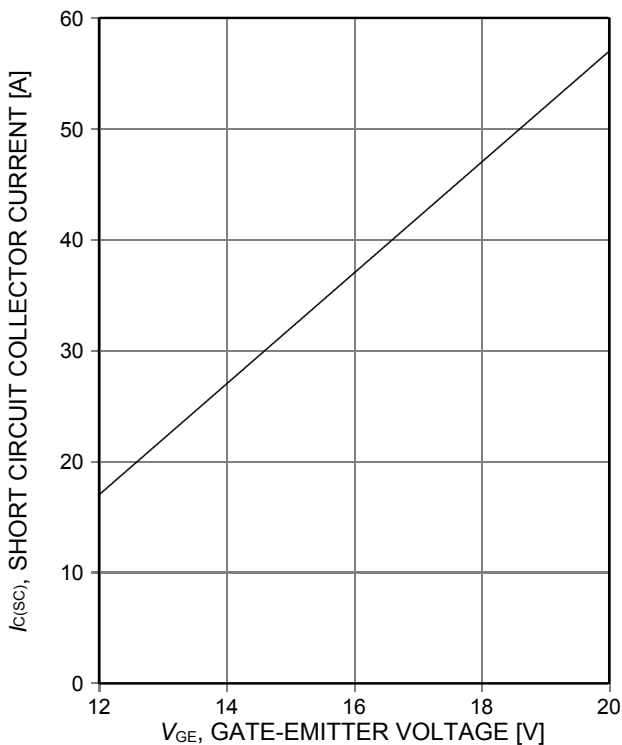


Figure 19. **Typical short circuit collector current as a function of gate-emitter voltage**  
( $V_{CE}\leq 400V$ , start at  $T_{vj}=25^\circ C$ )

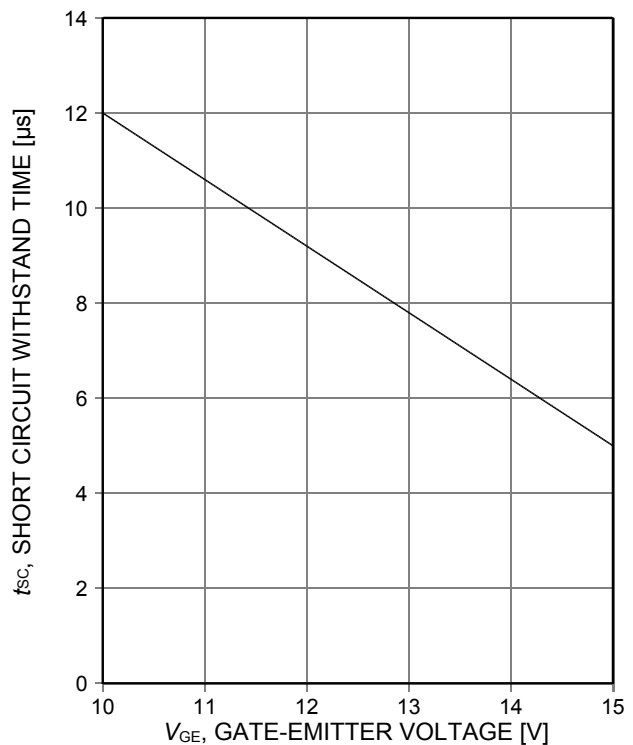


Figure 20. **Short circuit withstand time as a function of gate-emitter voltage**  
( $V_{CE}\leq 400V$ , start at  $T_{vj}=150^\circ C$ )

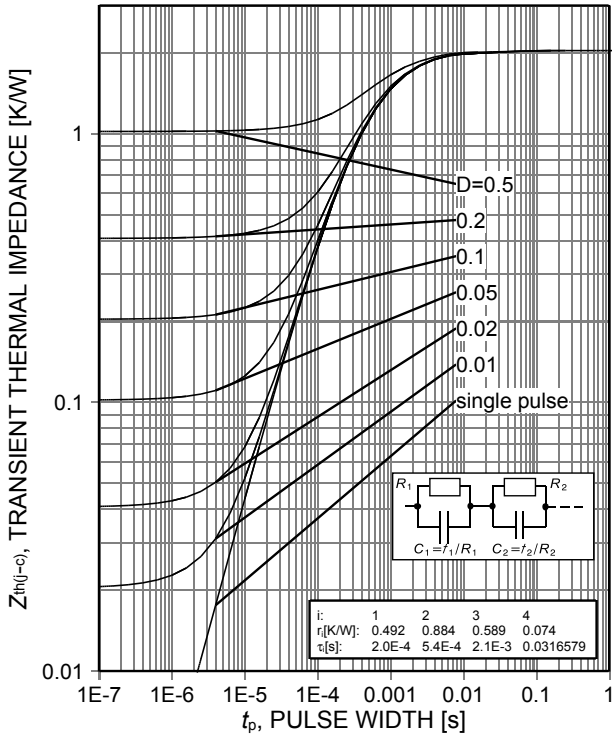


Figure 21. IGBT transient thermal impedance <sup>1)</sup>  
( $D=t_p/T$ )

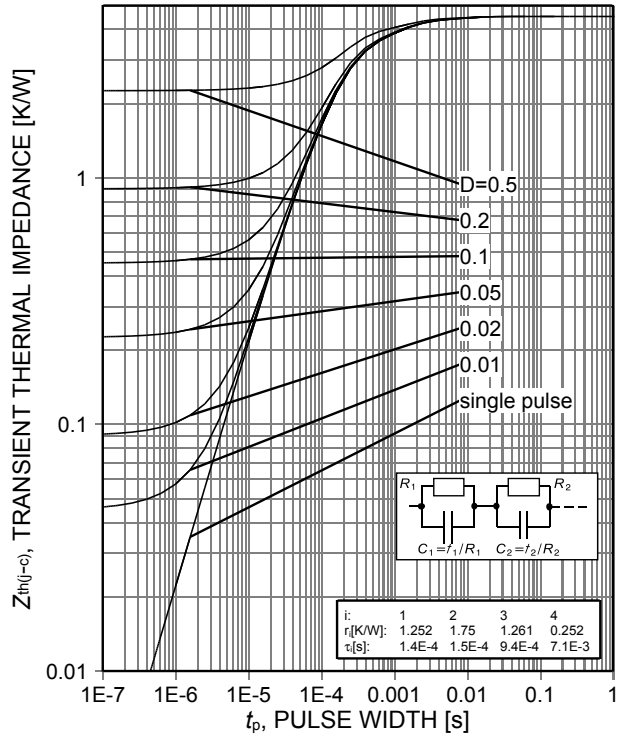


Figure 22. Diode transient thermal impedance as a function of pulse width <sup>1)</sup>  
( $D=t_p/T$ )

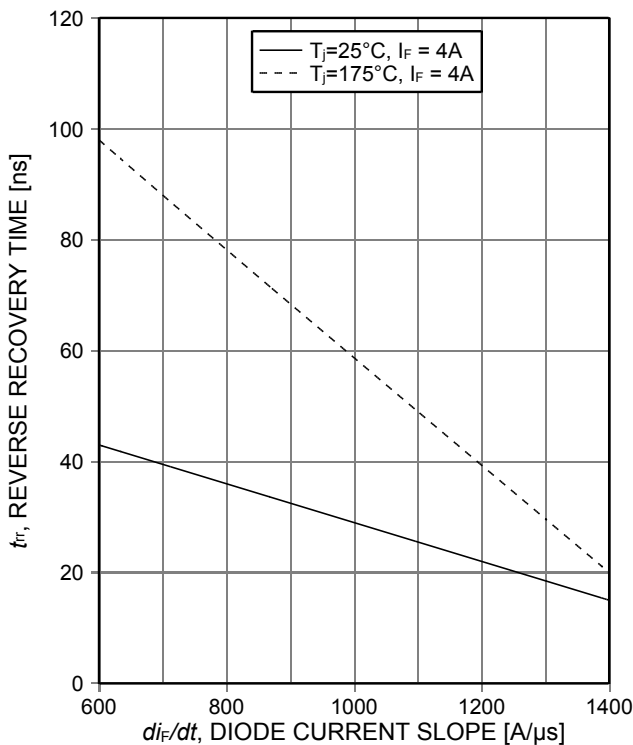


Figure 23. Typical reverse recovery time as a function of diode current slope  
( $V_R=400V$ )

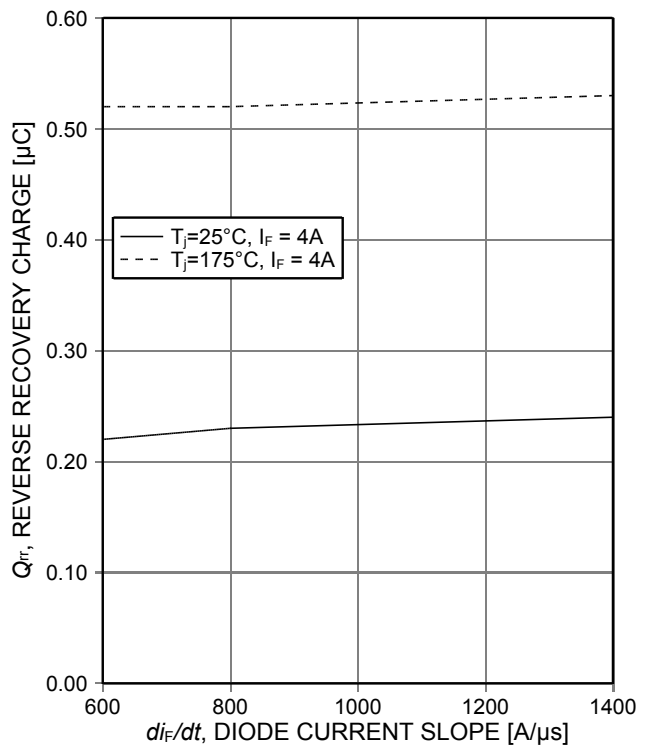


Figure 24. Typical reverse recovery charge as a function of diode current slope  
( $V_R=400V$ )

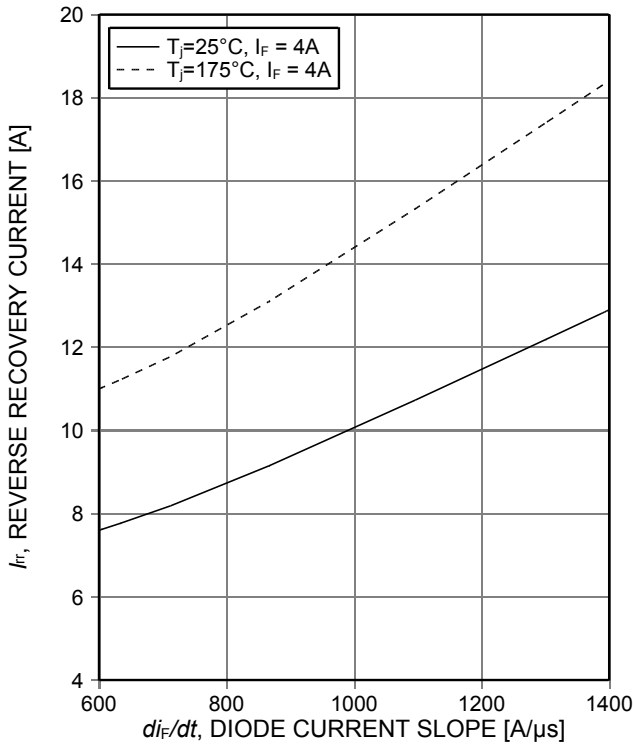


Figure 25. Typical reverse recovery current as a function of diode current slope ( $V_R=400V$ )

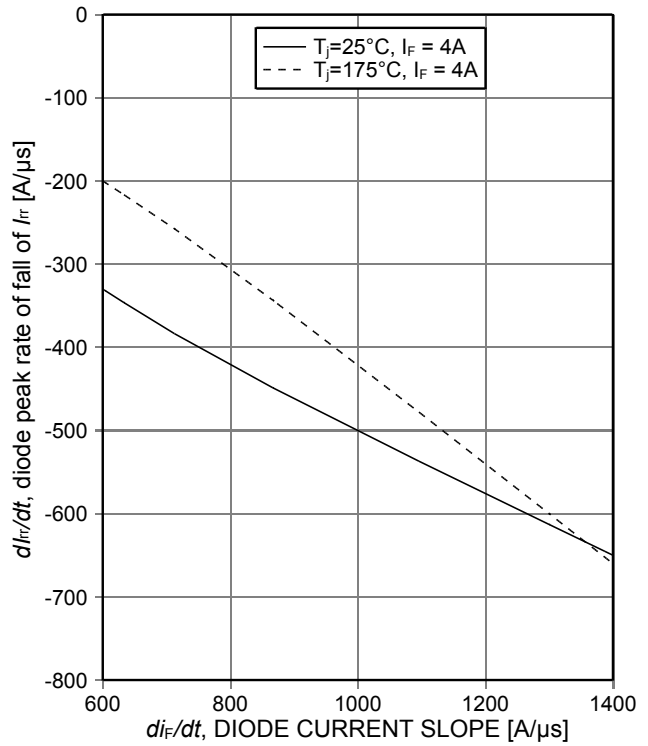


Figure 26. Typical diode peak rate of fall of reverse recovery current as a function of diode current slope ( $V_R=400V$ )

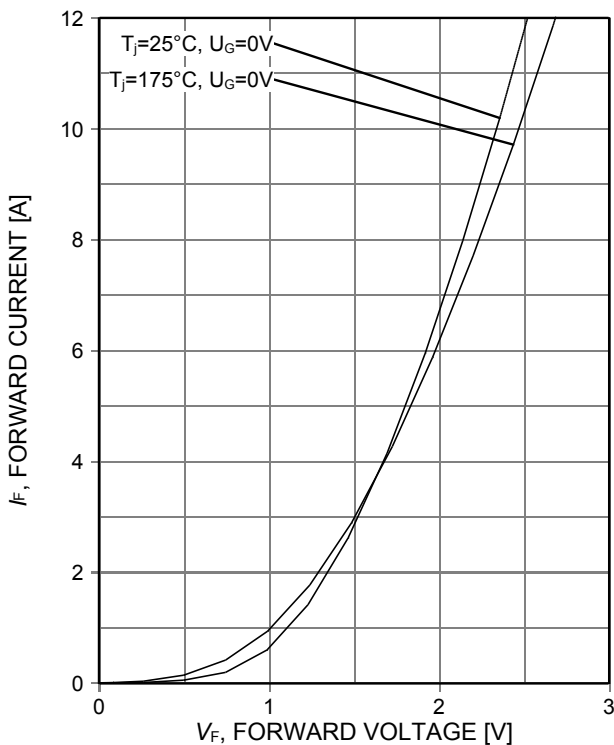


Figure 27. Typical diode forward current as a function of forward voltage

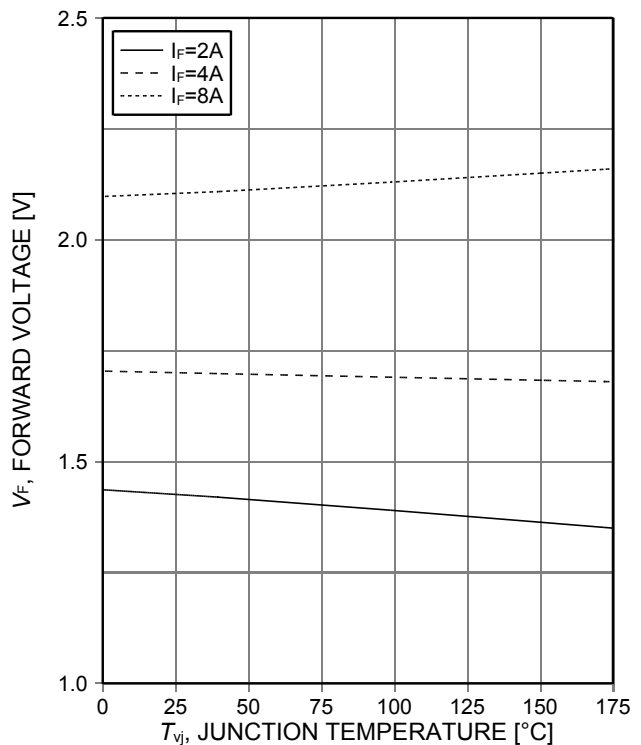
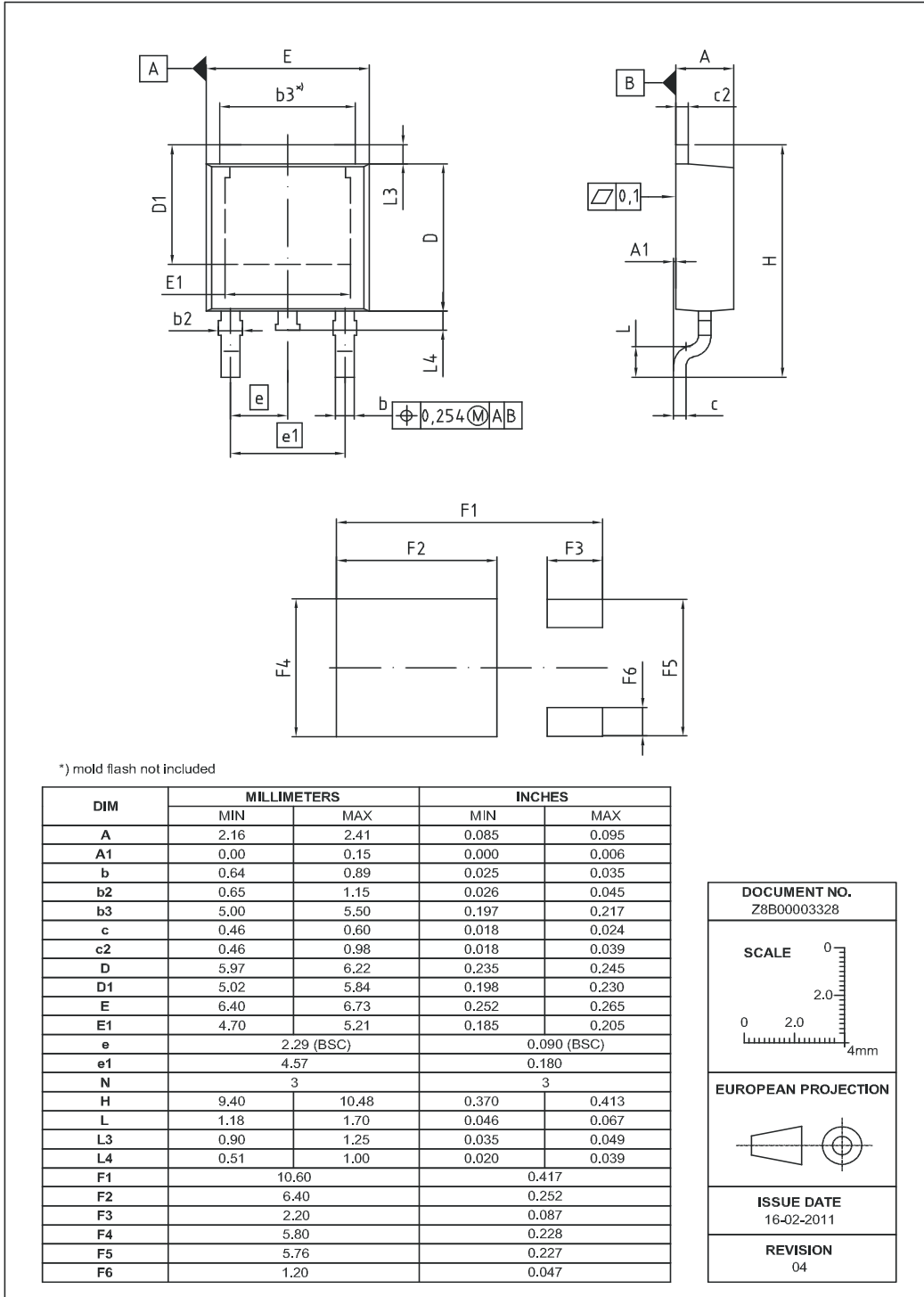


Figure 28. Typical diode forward voltage as a function of junction temperature

PG-TO252 -3



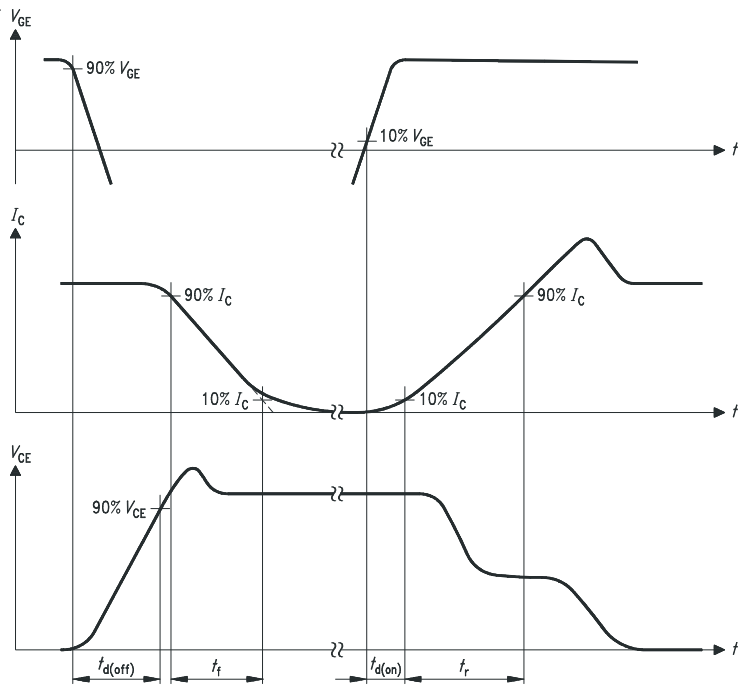


Figure A. Definition of switching times

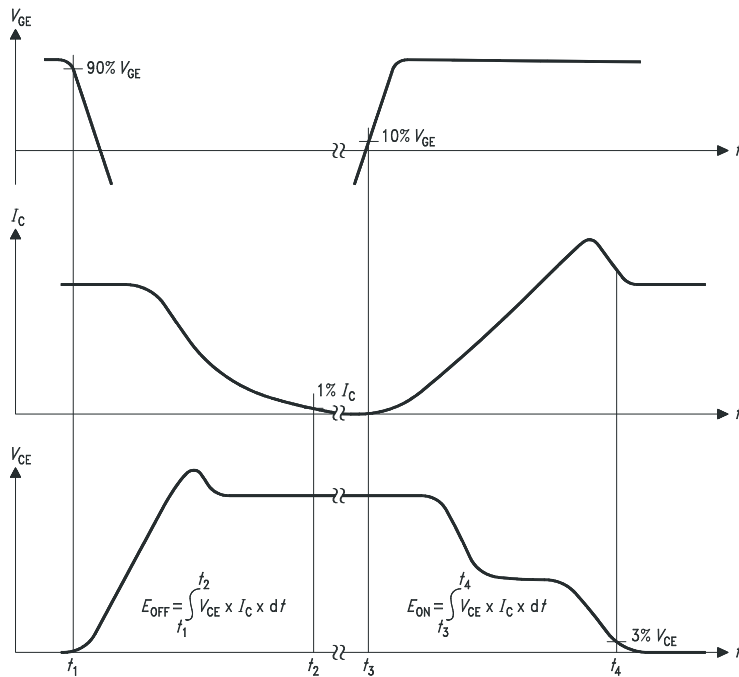


Figure B. Definition of switching losses

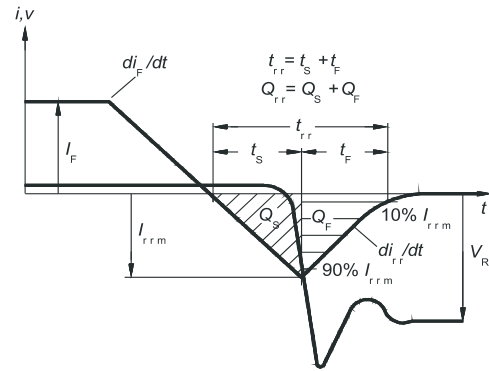


Figure C. Definition of diodes switching characteristics

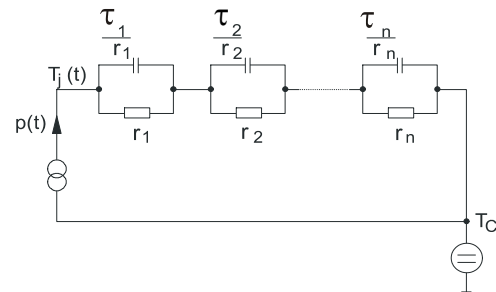


Figure D. Thermal equivalent circuit

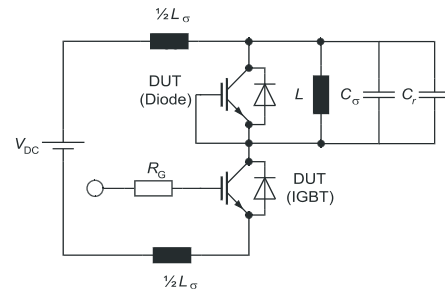


Figure E. Dynamic test circuit  
Parasitic inductance  $L_\sigma$ ,  
Parasitic capacitor  $C_\sigma$ ,  
Relief capacitor  $C_r$   
(only for ZVT switching)

**Revision History**

IKD04N60RA

**Revision: 2013-02-15, Rev. 2.1**

Previous Revision

Revision	Date	Subjects (major changes since last revision)
2.1	2013-02-15	Final data sheet

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