

## Low Loss Duopack: IGBT 7 with Trench and Fieldstop technology

### Features

- $V_{CE} = 650\text{ V}$
- $I_C = 75\text{ A}$
- Very Low  $V_{CEsat}$
- Low turn-off losses
- Short tail current
- Reduced EMI
- Humidity robust design
- Very soft, fast recovery antiparallel diode
- Maximum junction temperature  $T_{vjmax} = 175^\circ\text{C}$
- Qualified according to JEDEC for target applications
- Pb-free lead plating; RoHS compliant
- Complete product spectrum and PSpice Models: <http://www.infineon.com/igbt7/>

### Potential applications

- Servo Drives
- General Purpose Drives (GPD)
- Industrial UPS
- Industrial SMPS
- Solar Optimizer
- Solar String Inverter

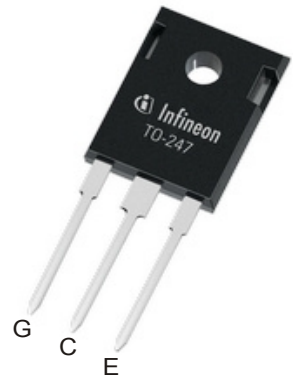
### Product validation

- Product Validation: Qualified for industrial applications according to the relevant tests of JEDEC47/20/22

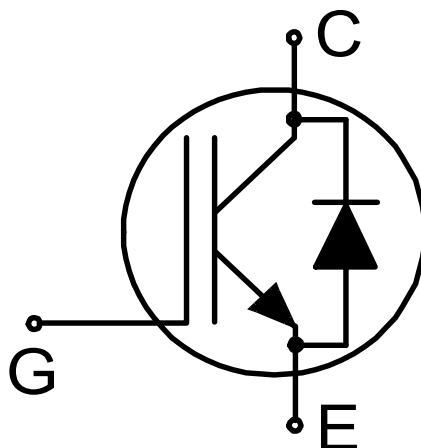
### Description

Package pin definition:

- Pin C & backside - Collector
- Pin E - Emitter
- Pin G - Gate



-  Lead-Free
-  Green
-  Halogen-Free
-  RoHS



Type	Package	Marking
IKW75N65ET7	PG-TO247-3	K75EET7

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## 1 Package

**Table 1** Characteristic values

Parameter	Symbol	Note or test condition	Values			Unit
			Min.	Typ.	Max.	
Internal emitter inductance measured 5 mm (0.197 in) from case	$L_E$			13.0		nH
Storage temperature	$T_{stg}$		-55		150	°C
Soldering temperature		wave soldering 1.6 mm (0.063 in.) from case for 10 s			260	°C
Mounting torque, M3 screw Maximum of mounting processes: 3	$M$				0.6	Nm
Thermal resistance, junction-ambient	$R_{th(j-a)}$				40	K/W

## 2 IGBT

**Table 2** Maximum rated values

Parameter	Symbol	Note or test condition	Values	Unit	
Collector-emitter voltage	$V_{CE}$	$T_{vj} \geq 25\text{ °C}$	650	V	
DC collector current, limited by $T_{vjmax}$	$I_C$	limited by bondwire	$T_C = 25\text{ °C}$	80	A
			$T_C = 100\text{ °C}$	78.5	
Pulsed collector current, $t_p$ limited by $T_{vjmax}$ <sup>1)</sup>	$I_{Cpuls}$		225	A	
Turn-off safe operating area <sup>2)</sup>		$V_{CE} \leq 650\text{ V}$ , $t_p = 1\text{ }\mu\text{s}$ , $T_{vj} \leq 175\text{ °C}$	225	A	
Gate-emitter voltage	$V_{GE}$		$\pm 20$	V	
Transient gate-emitter voltage	$V_{GE}$	$t_p \leq 10\text{ }\mu\text{s}$ , $D < 0.010$	$\pm 30$	V	
Short circuit withstand time	$t_{SC}$	$V_{GE} = 15\text{ V}$ , Allowed number of short circuits < 1000, Time between short circuits $\geq 1.0\text{ s}$	$V_{CC} \leq 330\text{ V}$ , $T_{vj} = 100\text{ °C}$	5	$\mu\text{s}$
			$V_{CC} \leq 400\text{ V}$ , $T_{vj} = 150\text{ °C}$	3	
Power dissipation	$P_{tot}$		$T_C = 25\text{ °C}$	333	W
			$T_C = 100\text{ °C}$	167	

1) Defined by design. Not subject to production test.

2) Clamped inductive load current test for each device,  $I_C=225\text{ A}$ ,  $V_{CC}=400\text{ V}$ ,  $T_C=25\text{ °C}$ ,  $V_{GE}=20\text{ V}$ ,  $L=80\text{ }\mu\text{H}$ ,  $R_G=10\text{ }\Omega$

**Table 3** Characteristic values

Parameter	Symbol	Note or test condition	Values			Unit	
			Min.	Typ.	Max.		
Collector-emitter saturation voltage	$V_{CE\ sat}$	$I_C = 75.0\ A, V_{GE} = 15\ V$	$T_{vj} = 25\ ^\circ C$		1.35	1.65	V
			$T_{vj} = 125\ ^\circ C$		1.50		
			$T_{vj} = 175\ ^\circ C$		1.60		
Gate-emitter threshold voltage	$V_{GEth}$	$I_C = 0.75\ mA, V_{CE} = V_{GE}$	4.30	5.00	5.70	V	
Zero gate voltage collector current	$I_{CES}$	$V_{CE} = 650\ V, V_{GE} = 0\ V$	$T_{vj} = 25\ ^\circ C$		40	$\mu A$	
			$T_{vj} = 175\ ^\circ C$		1200		
Gate-emitter leakage current	$I_{GES}$	$V_{CE} = 0\ V, V_{GE} = 20\ V$			100	nA	
Transconductance	$g_{fs}$	$I_C = 75.0\ A, V_{CE} = 20\ V$		40		S	
Short circuit collector current	$I_{SC}$	$V_{GE} = 15\ V, t_{SC} \leq 3\ \mu s$ , Allowed number of short circuits < 1000 , Time between short circuits $\geq 1.0\ s$		350		A	
Input capacitance	$C_{ies}$	$V_{CE} = 25\ V, V_{GE} = 0\ V, f = 1000\ kHz$		4460		pF	
Output capacitance	$C_{oes}$	$V_{CE} = 25\ V, V_{GE} = 0\ V, f = 1000\ kHz$		135		pF	
Reverse transfer capacitance	$C_{res}$	$V_{CE} = 25\ V, V_{GE} = 0\ V, f = 1000\ kHz$		46		pF	
Gate charge	$Q_G$	$I_C = 75.0\ A, V_{GE} = 15\ V, V_{CE} = 520\ V$		435		nC	
Turn-on delay time	$t_{don}$	$V_{CE} = 400\ V, V_{GE} = 15\ V,$ $R_{Gon} = 4.7\ \Omega,$ $R_{Goff} = 4.7\ \Omega, L_\sigma = 32\ nH,$ $C_\sigma = 30\ pF$	$T_{vj} = 25\ ^\circ C,$ $I_C = 75.0\ A$		28	ns	
			$T_{vj} = 25\ ^\circ C,$ $I_C = 37.5\ A$		26		
			$T_{vj} = 175\ ^\circ C,$ $I_C = 75.0\ A$		31		
			$T_{vj} = 175\ ^\circ C,$ $I_C = 37.5\ A$		28		
Rise time (inductive load)	$t_r$	$V_{CE} = 400\ V, V_{GE} = 15\ V,$ $R_{Gon} = 4.7\ \Omega,$ $R_{Goff} = 4.7\ \Omega, L_\sigma = 32\ nH,$ $C_\sigma = 30\ pF$	$T_{vj} = 25\ ^\circ C,$ $I_C = 75.0\ A$		25	ns	
			$T_{vj} = 25\ ^\circ C,$ $I_C = 37.5\ A$		13		
			$T_{vj} = 175\ ^\circ C,$ $I_C = 75.0\ A$		30		
			$T_{vj} = 175\ ^\circ C,$ $I_C = 37.5\ A$		18		

**Table 3** Characteristic values (continued)

Parameter	Symbol	Note or test condition	Values			Unit
			Min.	Typ.	Max.	
Turn-off delay time	$t_{\text{doff}}$	$V_{\text{CE}} = 400 \text{ V}, V_{\text{GE}} = 15 \text{ V},$ $R_{\text{Gon}} = 4.7 \text{ } \Omega,$ $R_{\text{Goff}} = 4.7 \text{ } \Omega, L_{\sigma} = 32 \text{ nH},$ $C_{\sigma} = 30 \text{ pF}$	$T_{\text{vj}} = 25 \text{ } ^\circ\text{C},$ $I_{\text{C}} = 75.0 \text{ A}$	310		ns
			$T_{\text{vj}} = 25 \text{ } ^\circ\text{C},$ $I_{\text{C}} = 37.5 \text{ A}$	330		
			$T_{\text{vj}} = 175 \text{ } ^\circ\text{C},$ $I_{\text{C}} = 75.0 \text{ A}$	365		
			$T_{\text{vj}} = 175 \text{ } ^\circ\text{C},$ $I_{\text{C}} = 37.5 \text{ A}$	415		
Fall time (inductive load)	$t_{\text{f}}$	$V_{\text{CE}} = 400 \text{ V}, V_{\text{GE}} = 15 \text{ V},$ $R_{\text{Gon}} = 4.7 \text{ } \Omega,$ $R_{\text{Goff}} = 4.7 \text{ } \Omega, L_{\sigma} = 32 \text{ nH},$ $C_{\sigma} = 30 \text{ pF}$	$T_{\text{vj}} = 25 \text{ } ^\circ\text{C},$ $I_{\text{C}} = 75.0 \text{ A}$	15		ns
			$T_{\text{vj}} = 25 \text{ } ^\circ\text{C},$ $I_{\text{C}} = 37.5 \text{ A}$	11		
			$T_{\text{vj}} = 175 \text{ } ^\circ\text{C},$ $I_{\text{C}} = 75.0 \text{ A}$	25		
			$T_{\text{vj}} = 175 \text{ } ^\circ\text{C},$ $I_{\text{C}} = 37.5 \text{ A}$	20		
Turn-on energy	$E_{\text{on}}$	$V_{\text{CE}} = 400 \text{ V}, V_{\text{GE}} = 15 \text{ V},$ $R_{\text{Gon}} = 4.7 \text{ } \Omega,$ $R_{\text{Goff}} = 4.7 \text{ } \Omega, L_{\sigma} = 32 \text{ nH},$ $C_{\sigma} = 30 \text{ pF}$	$T_{\text{vj}} = 25 \text{ } ^\circ\text{C},$ $I_{\text{C}} = 75.0 \text{ A}$	2.17		mJ
			$T_{\text{vj}} = 25 \text{ } ^\circ\text{C},$ $I_{\text{C}} = 37.5 \text{ A}$	0.79		
			$T_{\text{vj}} = 175 \text{ } ^\circ\text{C},$ $I_{\text{C}} = 75.0 \text{ A}$	3.45		
			$T_{\text{vj}} = 175 \text{ } ^\circ\text{C},$ $I_{\text{C}} = 37.5 \text{ A}$	1.52		
Turn-off energy	$E_{\text{off}}$	$V_{\text{CE}} = 400 \text{ V}, V_{\text{GE}} = 15 \text{ V},$ $R_{\text{Gon}} = 4.7 \text{ } \Omega,$ $R_{\text{Goff}} = 4.7 \text{ } \Omega, L_{\sigma} = 32 \text{ nH},$ $C_{\sigma} = 30 \text{ pF}$	$T_{\text{vj}} = 25 \text{ } ^\circ\text{C},$ $I_{\text{C}} = 75.0 \text{ A}$	1.23		mJ
			$T_{\text{vj}} = 25 \text{ } ^\circ\text{C},$ $I_{\text{C}} = 37.5 \text{ A}$	0.56		
			$T_{\text{vj}} = 175 \text{ } ^\circ\text{C},$ $I_{\text{C}} = 75.0 \text{ A}$	2.05		
			$T_{\text{vj}} = 175 \text{ } ^\circ\text{C},$ $I_{\text{C}} = 37.5 \text{ A}$	1.11		

**Table 3** Characteristic values (continued)

Parameter	Symbol	Note or test condition	Values			Unit	
			Min.	Typ.	Max.		
Total switching energy	$E_{ts}$	$V_{CE} = 400\text{ V}, V_{GE} = 15\text{ V},$ $R_{Gon} = 4.7\ \Omega,$ $R_{Goff} = 4.7\ \Omega, L_{\sigma} = 32\text{ nH},$ $C_{\sigma} = 30\text{ pF}$	$T_{vj} = 25\text{ }^{\circ}\text{C},$ $I_C = 75.0\text{ A}$		3.40		mJ
			$T_{vj} = 25\text{ }^{\circ}\text{C},$ $I_C = 37.5\text{ A}$		1.35		
			$T_{vj} = 175\text{ }^{\circ}\text{C},$ $I_C = 75.0\text{ A}$		5.50		
			$T_{vj} = 175\text{ }^{\circ}\text{C},$ $I_C = 37.5\text{ A}$		2.63		
IGBT thermal resistance, junction-case	$R_{thjc}$				0.45	K/W	
Operating junction temperature	$T_{vj}$		-40		175	$^{\circ}\text{C}$	

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

### 3 Diode

**Table 4** Maximum rated values

Parameter	Symbol	Note or test condition	Values	Unit	
Repetitive peak reverse voltage	$V_{RRM}$	$T_{vj} \geq 25\text{ }^{\circ}\text{C}$	650	V	
Diode forward current, limited by $T_{vjmax}$	$I_F$	limited by bondwire	$T_C = 25\text{ }^{\circ}\text{C}$	80	A
			$T_C = 100\text{ }^{\circ}\text{C}$	74	
Diode pulsed current, limited by $T_{vjmax}$ <sup>1)</sup>	$I_{Fpuls}$		225	A	

1) Defined by design. Not subject to production test.

**Table 5** Characteristic values

Parameter	Symbol	Note or test condition	Values			Unit
			Min.	Typ.	Max.	
Diode forward voltage	$V_F$	$I_F = 75.0\text{ A}$	$T_{vj} = 25\text{ }^{\circ}\text{C}$	1.65	2.00	V
			$T_{vj} = 125\text{ }^{\circ}\text{C}$	1.60		
			$T_{vj} = 175\text{ }^{\circ}\text{C}$	1.55		
Reverse leakage current	$I_R$	$V_R = 650\text{ V}$	$T_{vj} = 25\text{ }^{\circ}\text{C}$		40	$\mu\text{A}$
			$T_{vj} = 175\text{ }^{\circ}\text{C}$	1200		

**Table 5** Characteristic values (continued)

Parameter	Symbol	Note or test condition	Values			Unit	
			Min.	Typ.	Max.		
Diode reverse recovery time	$t_{rr}$	$V_R = 400\text{ V}$	$T_{vj} = 25\text{ °C}$ , $I_F = 75.0\text{ A}$ , $-di_F/dt = 1650\text{ A}/\mu\text{s}$		100		ns
			$T_{vj} = 25\text{ °C}$ , $I_F = 37.5\text{ A}$ , $-di_F/dt = 2725\text{ A}/\mu\text{s}$		70		
			$T_{vj} = 175\text{ °C}$ , $I_F = 75.0\text{ A}$ , $-di_F/dt = 1650\text{ A}/\mu\text{s}$		155		
			$T_{vj} = 175\text{ °C}$ , $I_F = 37.5\text{ A}$ , $-di_F/dt = 2260\text{ A}/\mu\text{s}$		125		
Diode reverse recovery charge	$Q_{rr}$	$V_R = 400\text{ V}$	$T_{vj} = 25\text{ °C}$ , $I_F = 75.0\text{ A}$ , $-di_F/dt = 1650\text{ A}/\mu\text{s}$		1.50		$\mu\text{C}$
			$T_{vj} = 25\text{ °C}$ , $I_F = 37.5\text{ A}$ , $-di_F/dt = 2725\text{ A}/\mu\text{s}$		1.15		
			$T_{vj} = 175\text{ °C}$ , $I_F = 75.0\text{ A}$ , $-di_F/dt = 1650\text{ A}/\mu\text{s}$		4.40		
			$T_{vj} = 175\text{ °C}$ , $I_F = 37.5\text{ A}$ , $-di_F/dt = 2260\text{ A}/\mu\text{s}$		3.36		
Diode peak reverse recovery current	$I_{rrm}$	$V_R = 400\text{ V}$	$T_{vj} = 25\text{ °C}$ , $I_F = 75.0\text{ A}$ , $-di_F/dt = 1650\text{ A}/\mu\text{s}$		22.0		A
			$T_{vj} = 25\text{ °C}$ , $I_F = 37.5\text{ A}$ , $-di_F/dt = 2725\text{ A}/\mu\text{s}$		34.0		
			$T_{vj} = 175\text{ °C}$ , $I_F = 75.0\text{ A}$ , $-di_F/dt = 1650\text{ A}/\mu\text{s}$		41.0		
			$T_{vj} = 175\text{ °C}$ , $I_F = 37.5\text{ A}$ , $-di_F/dt = 2260\text{ A}/\mu\text{s}$		43.0		

**Table 5**                    **Characteristic values (continued)**

Parameter	Symbol	Note or test condition	Values			Unit	
			Min.	Typ.	Max.		
Diode peak rate off fall of reverse recovery current	$di_{rr}/dt$	$V_R = 400 \text{ V}$	$T_{vj} = 25 \text{ }^\circ\text{C}$ , $I_F = 75.0 \text{ A}$ , $-di_F/dt = 1650 \text{ A}/\mu\text{s}$		-480		A/ $\mu\text{s}$
			$T_{vj} = 25 \text{ }^\circ\text{C}$ , $I_F = 37.5 \text{ A}$ , $-di_F/dt = 2725 \text{ A}/\mu\text{s}$		-600		
			$T_{vj} = 175 \text{ }^\circ\text{C}$ , $I_F = 75.0 \text{ A}$ , $-di_F/dt = 1650 \text{ A}/\mu\text{s}$		-590		
			$T_{vj} = 175 \text{ }^\circ\text{C}$ , $I_F = 37.5 \text{ A}$ , $-di_F/dt = 2260 \text{ A}/\mu\text{s}$		-500		
Diode thermal resistance, junction-case	$R_{thjc}$				0.60	K/W	
Operating junction temperature	$T_{vj}$		-40		175	$^\circ\text{C}$	

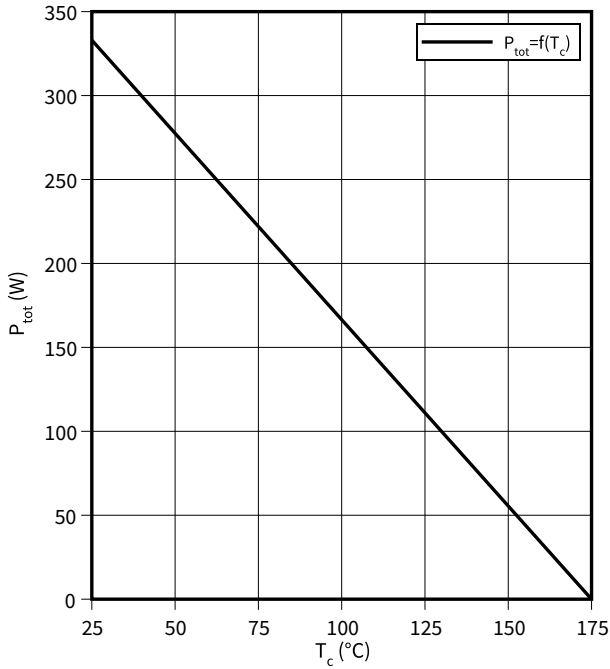
*Note: For optimum lifetime and reliability, Infineon recommends operating conditions that do not exceed 80% of the maximum ratings stated in this datasheet.*



## 4 Characteristics diagrams

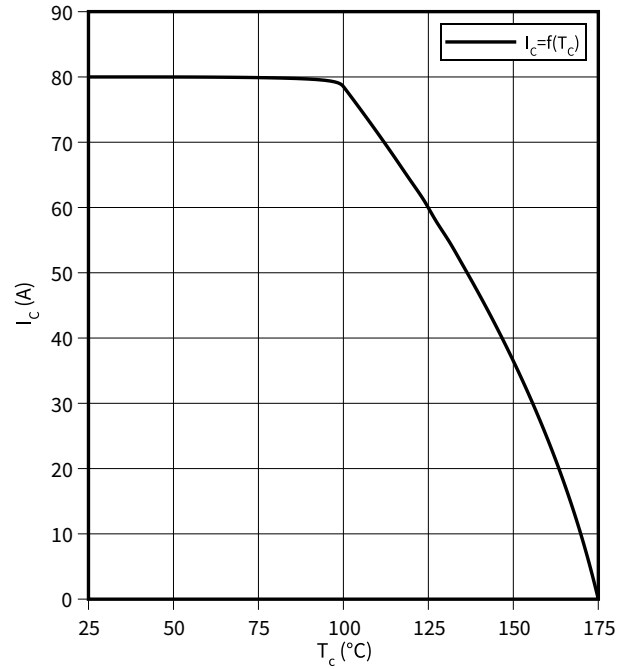
**Power dissipation as a function of case temperature, IGBT**

$P_{tot} = f(T_c)$   
 $T_{vj} \leq 175\text{ °C}$



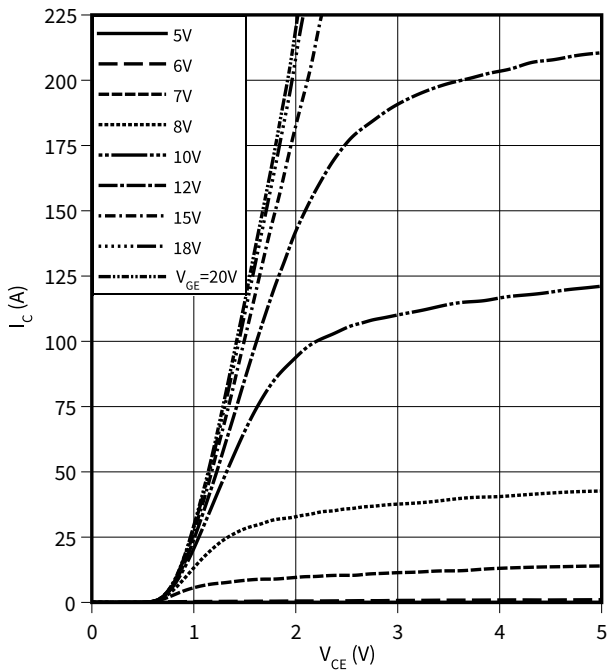
**Collector current as a function of case temperature, IGBT**

$I_c = f(T_c)$   
 $T_{vj} \leq 175\text{ °C}, V_{GE} \geq 15\text{ V}$



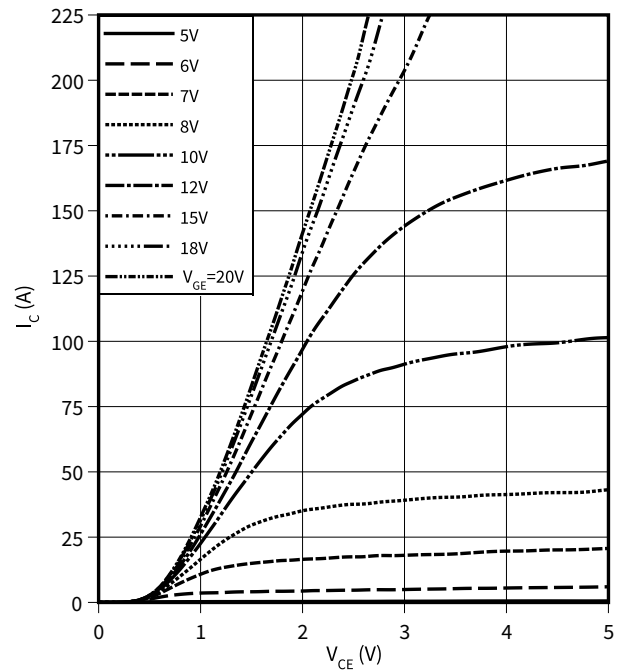
**Typical output characteristic, IGBT**

$I_c = f(V_{CE})$   
 $T_{vj} = 25\text{ °C}$



**Typical output characteristic, IGBT**

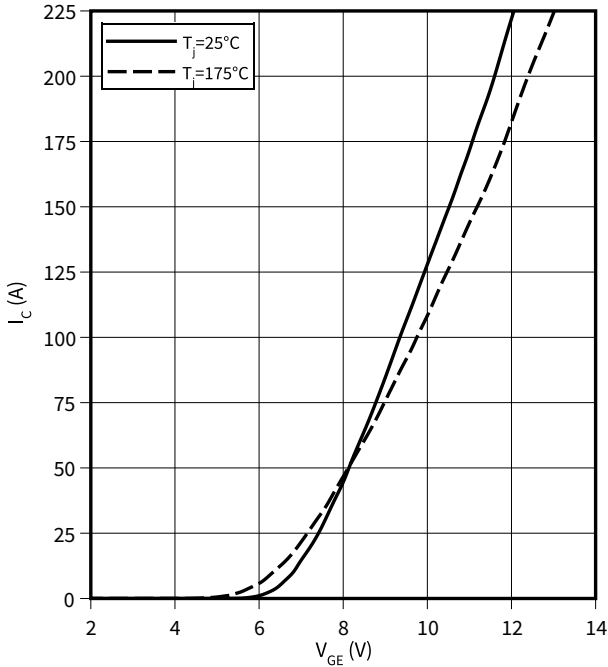
$I_c = f(V_{CE})$   
 $T_{vj} = 175\text{ °C}$



4 Characteristics diagrams

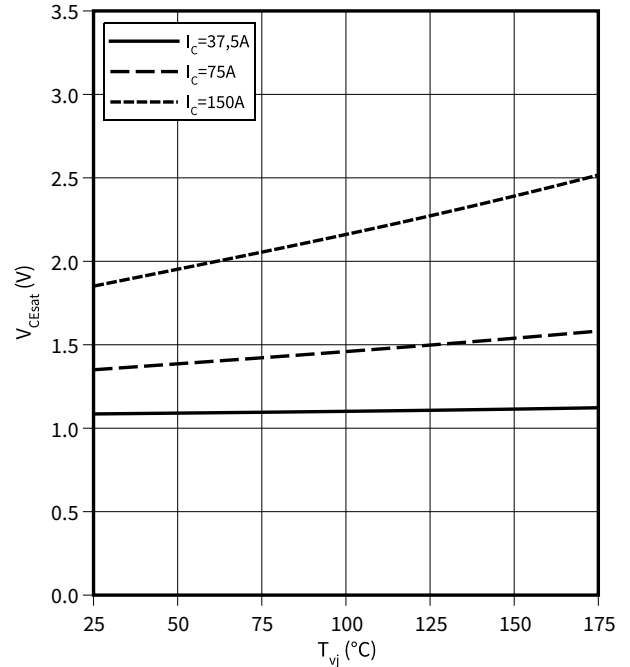
**Typical transfer characteristic, IGBT**

$I_C = f(V_{GE})$   
 $V_{CE} = 20\text{ V}$



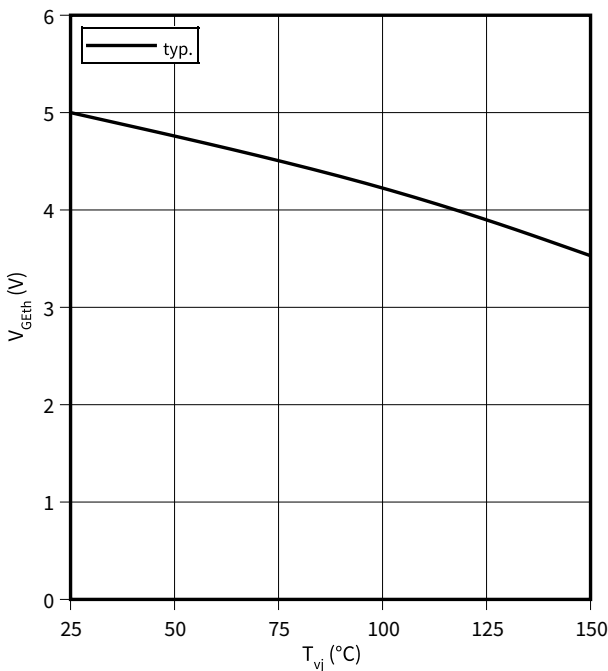
**Typical collector-emitter saturation voltage as a function of junction temperature, IGBT**

$V_{CEsat} = f(T_{vj})$   
 $V_{GE} = 15\text{ V}$



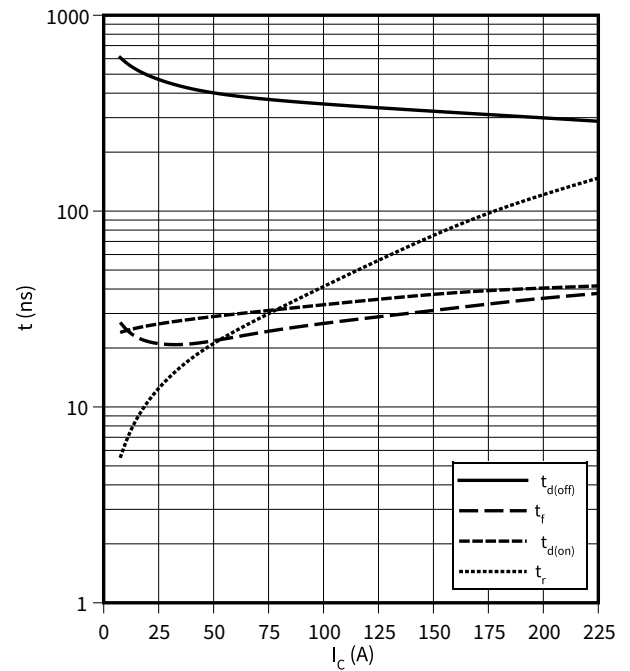
**Gate-emitter threshold voltage as a function of junction temperature, IGBT**

$V_{GEth} = f(T_{vj})$   
 $I_C = 0.75\text{ mA}$



**Typical switching times as a function of collector current, IGBT**

$t = f(I_C)$   
 $V_{CE} = 400\text{ V}, T_{vj} = 175^\circ\text{C}, V_{GE} = 0/15\text{ V}, R_G = 4.7\ \Omega$

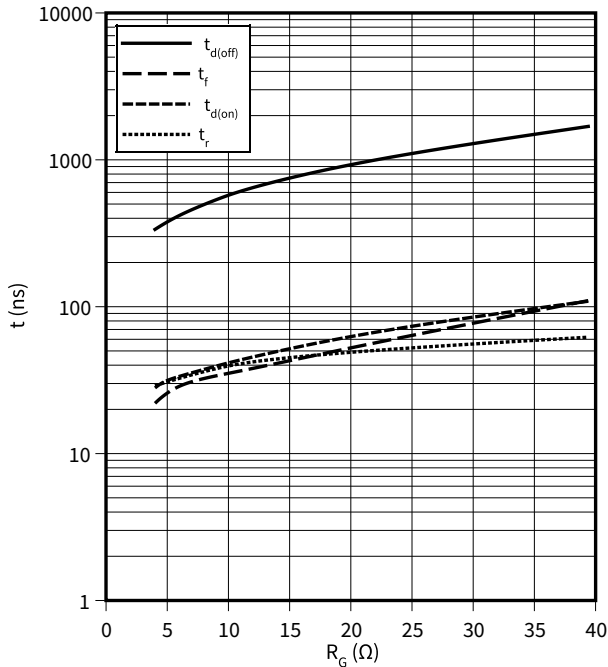


4 Characteristics diagrams

**Typical switching times as a function of gate resistor, IGBT**

$t = f(R_G)$

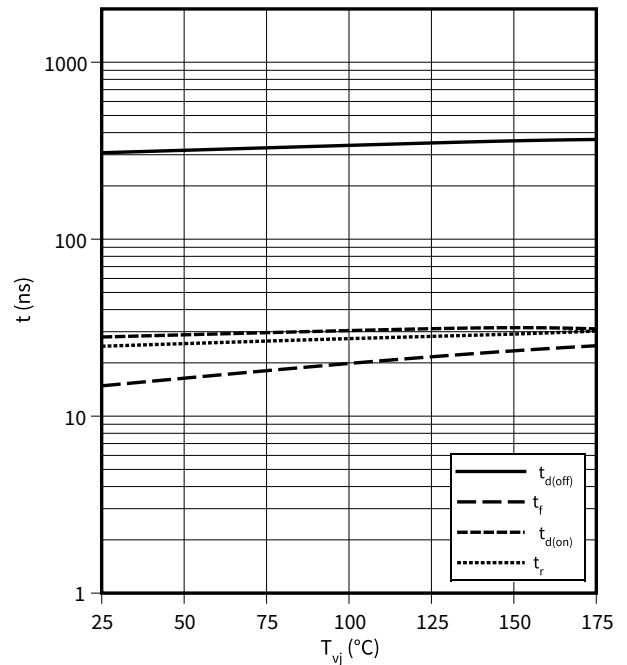
$I_C = 75.0 \text{ A}$ ,  $V_{CE} = 400 \text{ V}$ ,  $T_{vj} = 175 \text{ }^\circ\text{C}$ ,  $V_{GE} = 0/15 \text{ V}$



**Typical switching times as a function of junction temperature, IGBT**

$t = f(T_{vj})$

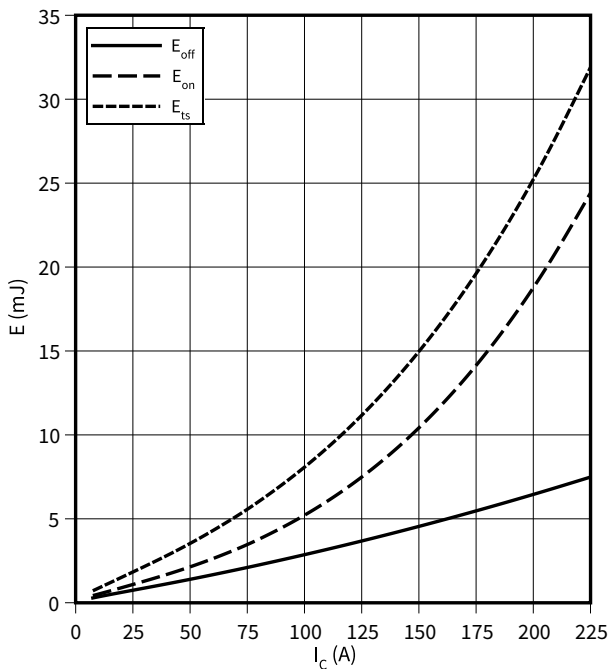
$I_C = 75.0 \text{ A}$ ,  $V_{CE} = 400 \text{ V}$ ,  $V_{GE} = 0/15 \text{ V}$ ,  $R_G = 4.7 \text{ } \Omega$



**Typical switching energy losses as a function of collector current, IGBT**

$E = f(I_C)$

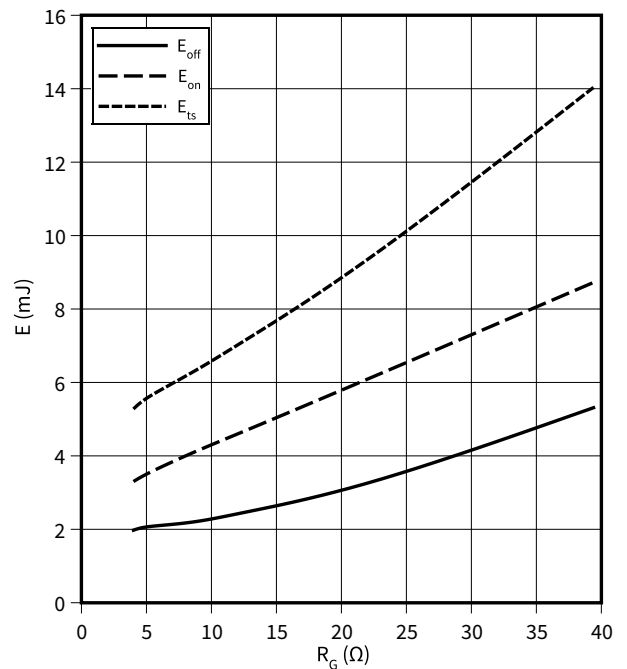
$V_{CE} = 400 \text{ V}$ ,  $T_{vj} = 175 \text{ }^\circ\text{C}$ ,  $V_{GE} = 0/15 \text{ V}$ ,  $R_G = 4.7 \text{ } \Omega$



**Typical switching energy losses as a function of gate resistor, IGBT**

$E = f(R_G)$

$I_C = 75.0 \text{ A}$ ,  $V_{CE} = 400 \text{ V}$ ,  $T_{vj} = 175 \text{ }^\circ\text{C}$ ,  $V_{GE} = 0/15 \text{ V}$

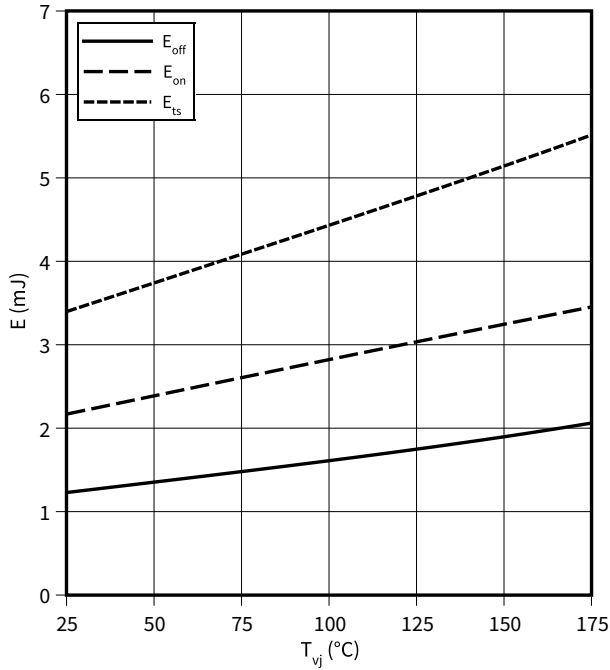


4 Characteristics diagrams

**Typical switching energy losses as a function of junction temperature, IGBT**

$E = f(T_{vj})$

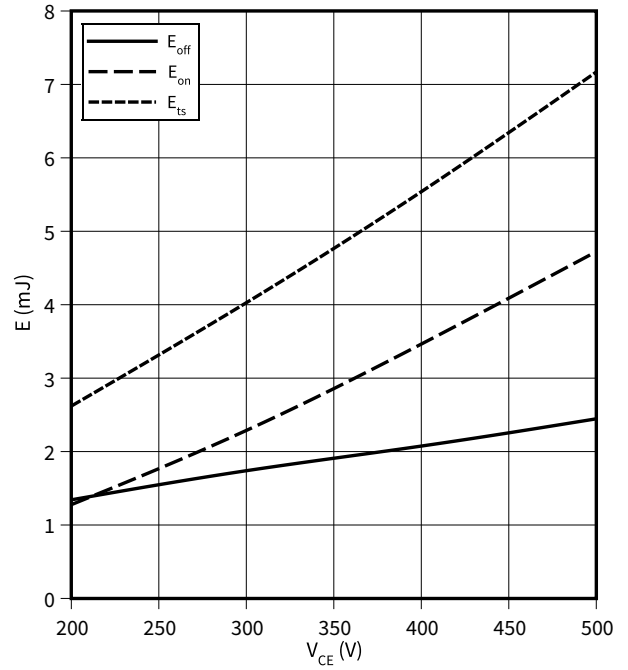
$I_C = 75.0 \text{ A}$ ,  $V_{CE} = 400 \text{ V}$ ,  $V_{GE} = 0/15 \text{ V}$ ,  $R_G = 4.7 \text{ } \Omega$



**Typical switching energy losses as a function of collector emitter voltage, IGBT**

$E = f(V_{CE})$

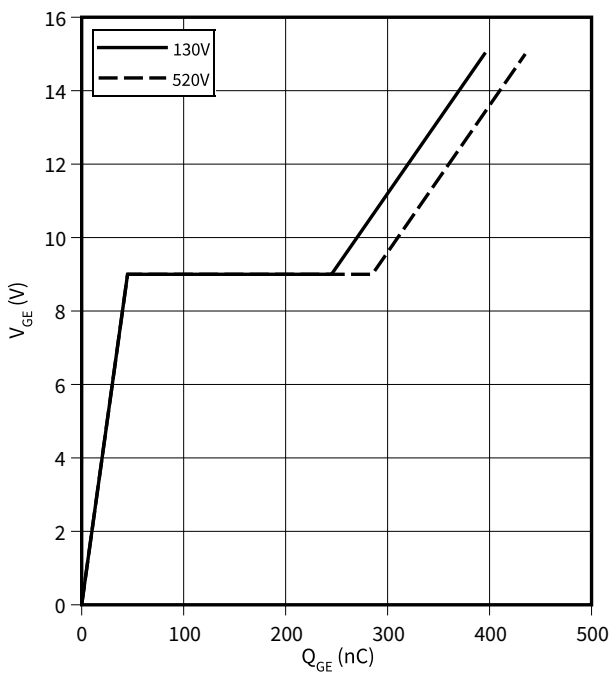
$I_C = 75.0 \text{ A}$ ,  $T_{vj} = 175 \text{ } ^\circ\text{C}$ ,  $V_{GE} = 0/15 \text{ V}$ ,  $R_G = 4.7 \text{ } \Omega$



**Typical gate charge, IGBT**

$V_{GE} = f(Q_{GE})$

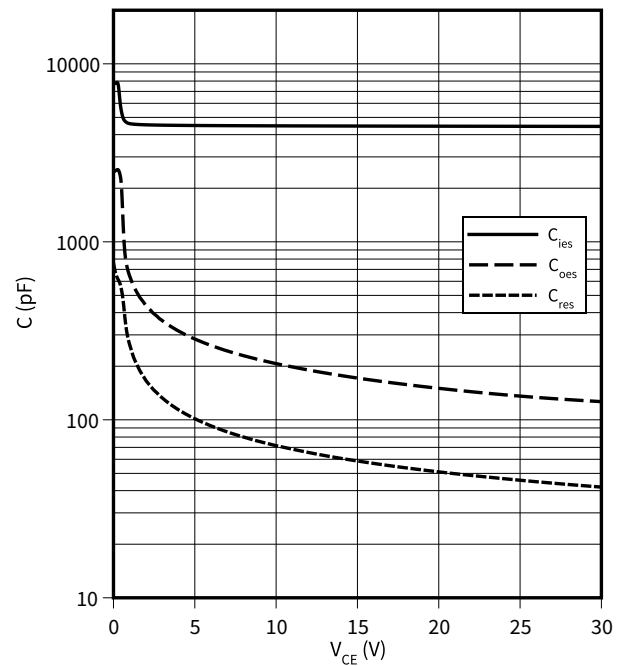
$I_C = 75.0 \text{ A}$



**Typical capacitance as a function of collector-emitter voltage, IGBT**

$C = f(V_{CE})$

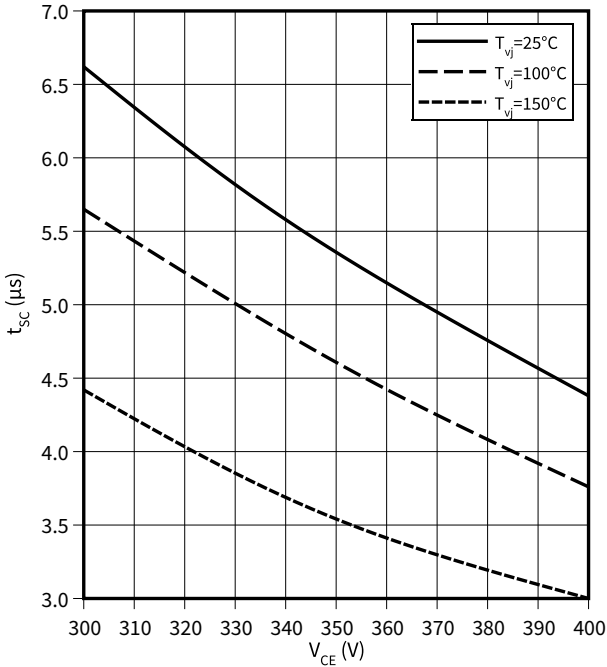
$f = 1000 \text{ kHz}$ ,  $V_{GE} = 0 \text{ V}$



4 Characteristics diagrams

**Typical short circuit safe operating range as a function of collector-emitter voltage, IGBT**

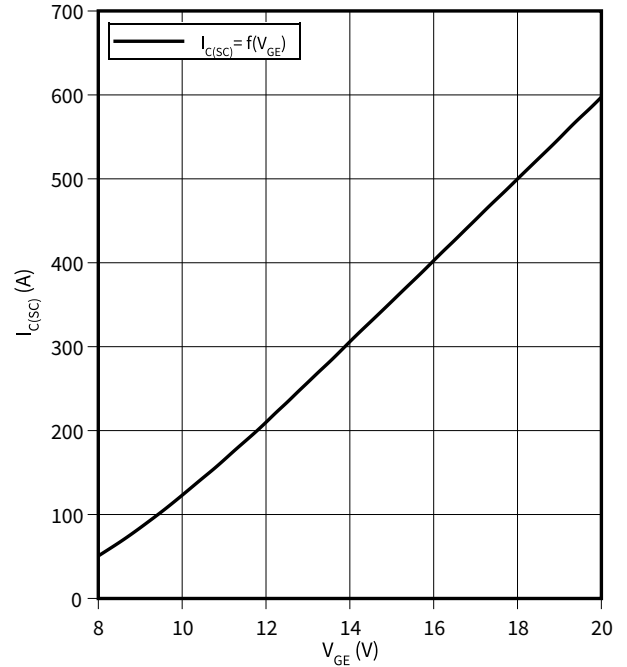
$t_{SC} = f(V_{CE})$



**Typical short circuit collector current as a function of gate-emitter voltage, IGBT**

$I_{C(SC)} = f(V_{GE})$

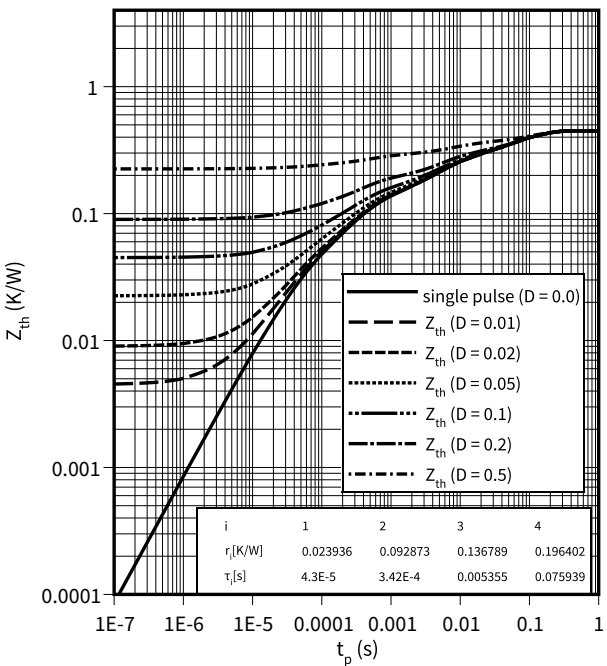
$V_{CE} = 400\text{ V}, T_{vj} = 150^{\circ}C$



**IGBT transient thermal resistance, IGBT**

$Z_{th} = f(t_p)$

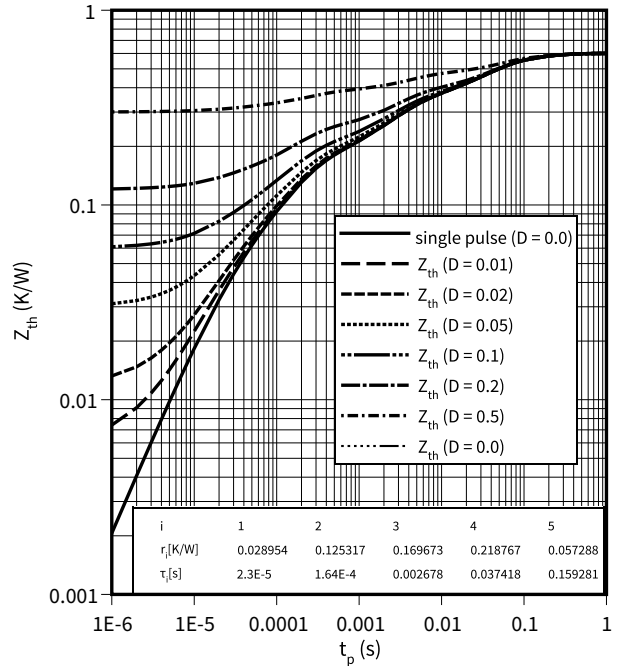
$D = t_p/T$



**Diode transient thermal impedance as a function of pulse width, Diode**

$Z_{th} = f(t_p)$

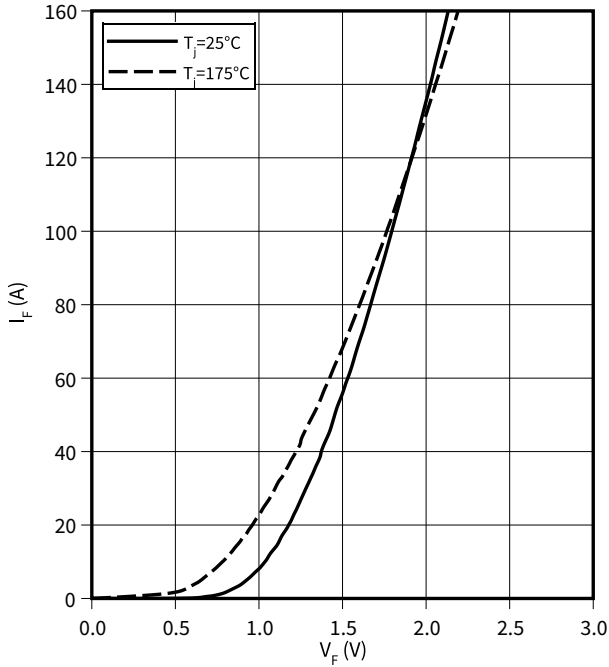
$D = t_p/T$



4 Characteristics diagrams

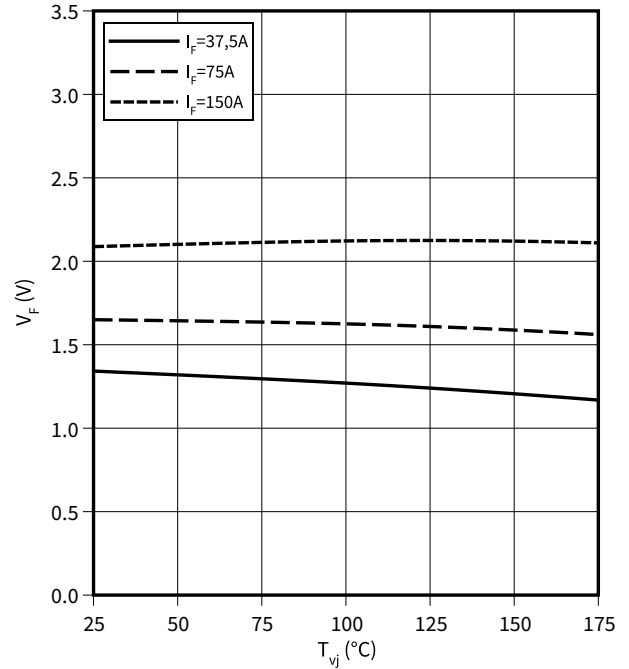
**Typical diode forward current as a function of forward voltage, Diode**

$I_F = f(V_F)$



**Typical diode forward voltage as a function of junction temperature, Diode**

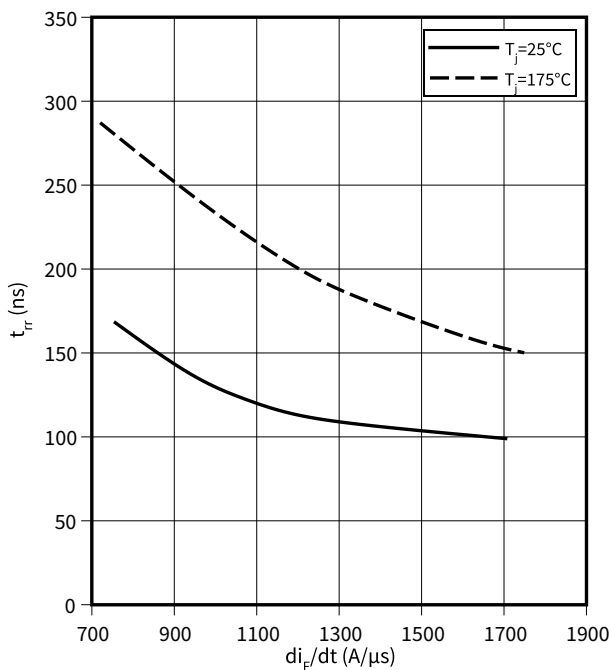
$V_F = f(T_{vj})$



**Typical reverse recovery time as a function of diode current slope, Diode**

$t_{rr} = f(di_F/dt)$

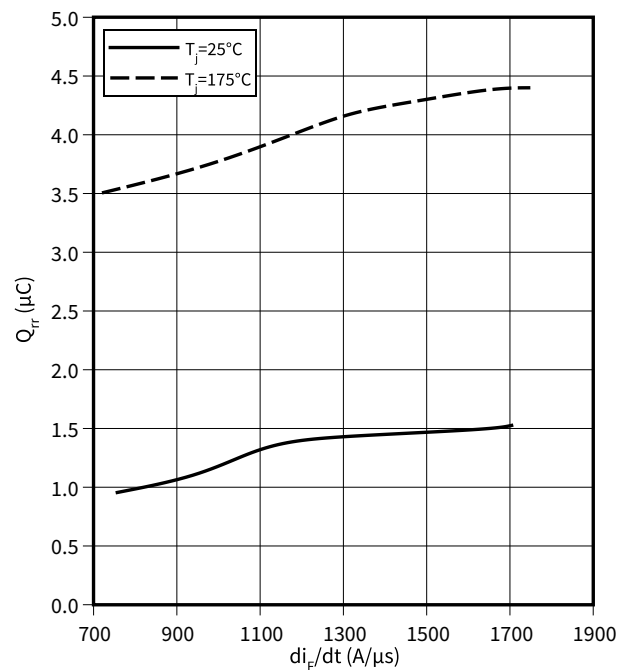
$V_R = 400\text{ V}, I_F = 75\text{ A}$



**Typical reverse recovery charge as a function of diode current slope, Diode**

$Q_{rr} = f(di_F/dt)$

$V_R = 400\text{ V}, I_F = 75\text{ A}$

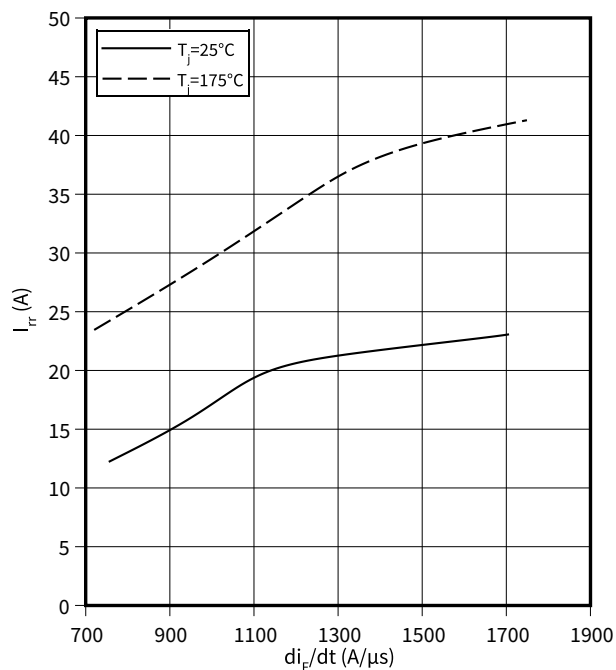


4 Characteristics diagrams

**Typical reverse recovery current as a function of diode current slope, Diode**

$I_{rr} = f(di_F/dt)$

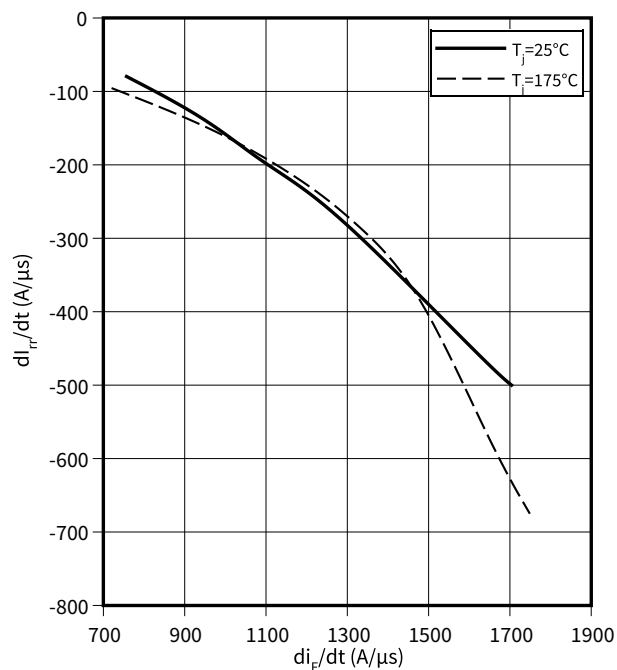
$V_R = 400\text{ V}, I_F = 75\text{ A}$



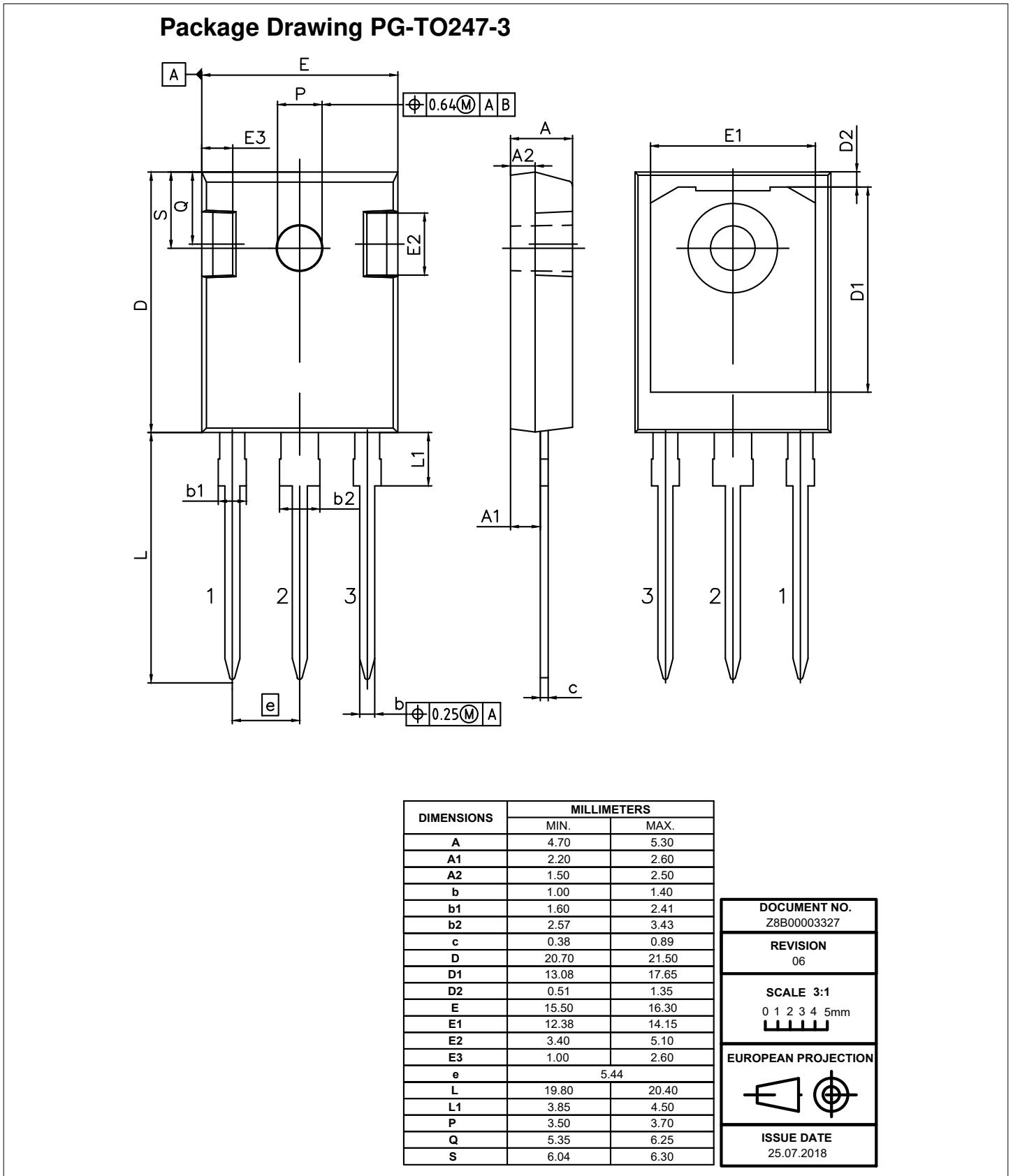
**Typical diode peak rate of fall of reverse recovery current as a function of diode current slope, Diode**

$di_{rr}/dt = f(di_F/dt)$

$V_R = 400\text{ V}, I_F = 75\text{ A}$



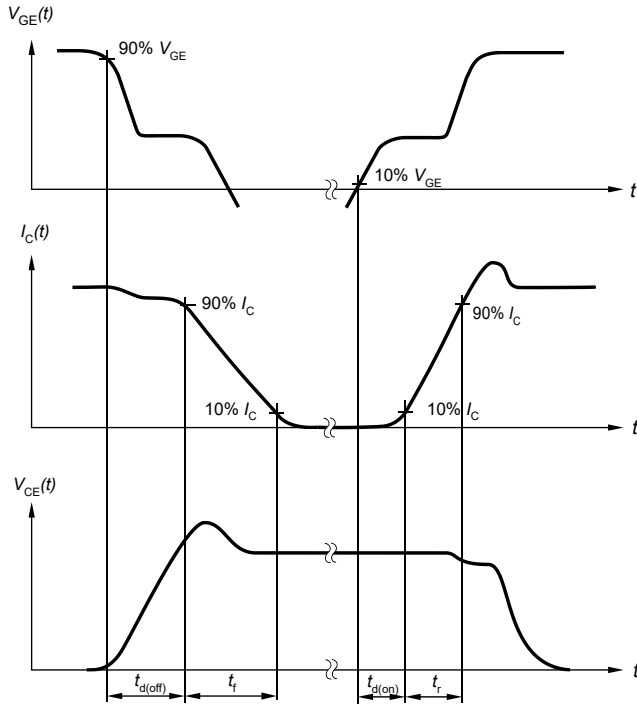
**5 Package outlines**



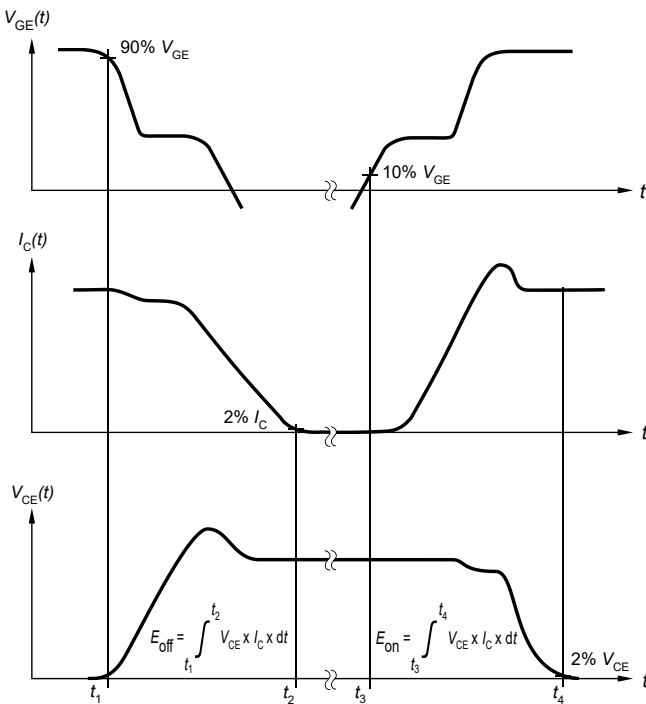
**Figure 6**



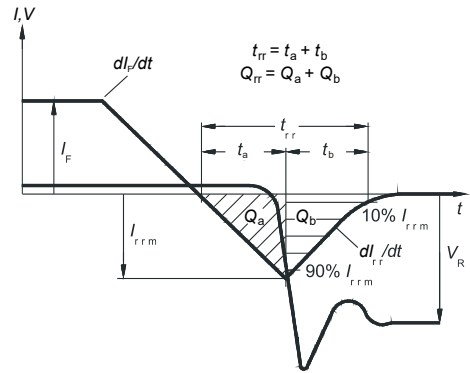
**6 Testing conditions**



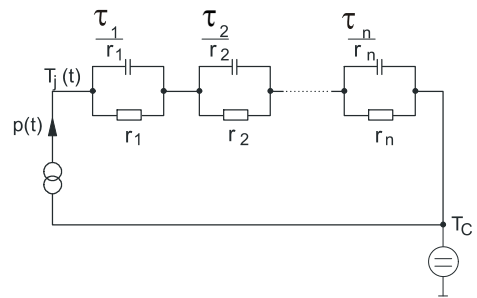
**Figure A. Definition of switching times**



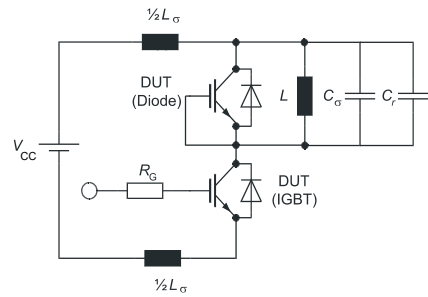
**Figure B. Definition of switching losses**



**Figure C. Definition of diode 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)

**Figure 7**

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Revision history

## Revision history

Document revision	Date of release	Description of changes
V0.1	2019-10-25	Target Data Sheet
V1.1	2020-04-20	Preliminary data sheet
V2.1	2020-05-12	Final data sheet
1.00	2021-06-29	Change of potential applications and new diagram added ( $t_{SC}$ as function of $V_{CE}$ )

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**Email: [erratum@infineon.com](mailto:erratum@infineon.com)**

**Document reference**

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