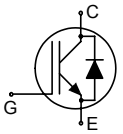
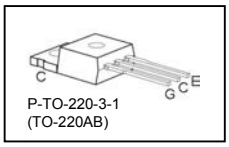
## Low Loss DuoPack : IGBT in Trench and Fieldstop technology with soft, fast recovery anti-parallel EmCon HE diode




P-TO-220-3-1
(TO-220AB)

- Very low $V_{CE(sat)}$ 1.5 V (typ.)
- Maximum Junction Temperature 175 °C
- Short circuit withstand time – 5µs
- Designed for :
  - Frequency Converters
  - Drives
- Trench and Fieldstop technology for 600 V applications offers :
  - very tight parameter distribution
  - high ruggedness, temperature stable behavior
  - very high switching speed
  - low $V_{CE(sat)}$
- Positive temperature coefficient in $V_{CE(sat)}$
- Low EMI
- Low Gate Charge
- Very soft, fast recovery anti-parallel EmCon HE diode
- Complete product spectrum and PSpice Models : http://www.infineon.com/igbt/

| Type | $V_{CE}$ | $I_C$ | $V_{CE(sat),Tj=25°C}$ | $T_{j,max}$ | Marking Code | Package | Ordering Code |
|---|---|---|---|---|---|---|---|
| IKP04N60T | 600 V | 4 A | 1.5 V | 175 °C | K04T60 | TO-220 | Q67040S4714 |

**Maximum Ratings**

| Parameter | Symbol | Value | Unit |
|---|---|---|---|
| Collector-emitter voltage | $V_{CE}$ | 600 | V |
| DC collector current, limited by $T_{jmax}$ | $I_C$ | | A |
| $T_C$ = 25°C | | 8 | |
| $T_C$ = 100°C | | 4 | |
| Pulsed collector current, $t_p$ limited by $T_{jmax}$ | $I_{Cpuls}$ | 12 | |
| Turn off safe operating area ($V_{CE} \le 600V$, $T_j \le 175°C$) | - | 12 | |
| Diode forward current, limited by $T_{jmax}$ | $I_F$ | | |
| $T_C$ = 25°C | | 4 | |
| $T_C$ = 100°C | | 8 | |
| Diode pulsed current, $t_p$ limited by $T_{jmax}$ | $I_{Fpuls}$ | 12 | |
| Gate-emitter voltage | $V_{GE}$ | ±20 | V |
| Short circuit withstand time[1)] | $t_{SC}$ | 5 | µs |
| $V_{GE}$ = 15V, $V_{CC} \le 400V$, $T_j \le 150°C$ | | | |
| Power dissipation $T_C$ = 25°C | $P_{tot}$ | 42 | W |
| Operating junction temperature | $T_j$ | -40...+175 | °C |
| Storage temperature | $T_{stg}$ | -55...+175 | |
| Soldering temperature, 1.6mm (0.063 in.) from case for 10s | - | 260 | |

[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 | $R_{thJC}$ | TO-220-3-1 | 3.5 | K/W |
| Diode thermal resistance, junction – case | $R_{thJCD}$ | TO-220-3-1 | 5 | |
| Thermal resistance, junction – ambient | $R_{thJA}$ | TO-220-3-1 | 62 | |

**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, $I_C$=0.2mA | 600 | - | - | V |
| Collector-emitter saturation voltage | $V_{CE(sat)}$ | $V_{GE}$ = 15V, $I_C$=4A | | | | |
| | | $T_j$=25°C | - | 1.5 | 2.05 | |
| | | $T_j$=175°C | - | 1.9 | - | |
| Diode forward voltage | $V_F$ | $V_{GE}$=0V, $I_F$=4A | | | | |
| | | $T_j$=25°C | - | 1.65 | 2.05 | |
| | | $T_j$=175°C | - | 1.6 | - | |
| Gate-emitter threshold voltage | $V_{GE(th)}$ | $I_C$= 60µA, $V_{CE}$=$V_{GE}$ | 4.1 | 4.9 | 5.7 | |
| Zero gate voltage collector current | $I_{CES}$ | $V_{CE}$=600V, $V_{GE}$=0V | | | | µA |
| | | $T_j$=25°C | - | - | 40 | |
| | | $T_j$=175°C | - | - | 1000 | |
| Gate-emitter leakage current | $I_{GES}$ | $V_{CE}$=0V, $V_{GE}$=20V | - | - | 100 | nA |
| Transconductance | $g_{fs}$ | $V_{CE}$=20V, $I_C$=4A | - | 2.2 | - | S |
| Integrated gate resistor | $R_{Gint}$ | | | - | | Ω |
| **Dynamic Characteristic** | | | | | | |
| Input capacitance | $C_{iss}$ | $V_{CE}$=25V, | - | 252 | - | pF |
| Output capacitance | $C_{oss}$ | $V_{GE}$=0V, | - | 20 | - | |
| Reverse transfer capacitance | $C_{rss}$ | $f$=1MHz | - | 7.5 | - | |
| Gate charge | $Q_{Gate}$ | $V_{CC}$=480V, $I_C$=4A $V_{GE}$=15V | - | 27 | - | nC |
| Internal emitter inductance measured 5mm (0.197 in.) from case | $L_E$ | TO-220-3-1 | - | 7 | - | nH |
| Short circuit collector current[1)] | $I_{C(SC)}$ | $V_{GE}$=15V, $t_{SC}$≤5µs $V_{CC}$ = 400V, $T_j$ ≤ 150°C | - | 36 | - | A |

[1)] 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, $I_C$=4A, $V_{GE}$=0/15V, $R_G$= 47 Ω, $L_\sigma$[1)]=150nH, $C_\sigma$[1)]=47pF Energy losses include "tail" and diode reverse recovery. | - | 14 | - | ns |
| Rise time | $t_r$ | | - | 7 | - | |
| Turn-off delay time | $t_{d(off)}$ | | - | 164 | - | |
| Fall time | $t_f$ | | - | 43 | - | |
| Turn-on energy | $E_{on}$ | | - | 61 | - | µJ |
| Turn-off energy | $E_{off}$ | | - | 84 | - | |
| Total switching energy | $E_{ts}$ | | - | 145 | - | |
| **Anti-Parallel Diode Characteristic** | | | | | | |
| Diode reverse recovery time | $t_{rr}$ | $T_j$=25°C, $V_R$=400V, $I_F$=4A, $di_F/dt$=610A/µs | - | 28 | - | ns |
| Diode reverse recovery charge | $Q_{rr}$ | | - | 79 | - | nC |
| Diode peak reverse recovery current | $I_{rrm}$ | | - | 5.3 | - | A |
| Diode peak rate of fall of reverse recovery current during $t_b$ | $di_{rr}/dt$ | | - | 346 | - | A/µs |

**Switching Characteristic, Inductive Load,** at $T_j$=175 °C

| Parameter | Symbol | Conditions | Value | | | Unit |
|---|---|---|---|---|---|---|
| | | | min. | Typ. | max. | |
| **IGBT Characteristic** | | | | | | |
| Turn-on delay time | $t_{d(on)}$ | $T_j$=175°C, $V_{CC}$=400V, $I_C$=4A, $V_{GE}$=0/15V, $R_G$= 47 Ω, $L_\sigma$[1)]=150nH, $C_\sigma$[1)]=47pF Energy losses include "tail" and diode reverse recovery. | - | 14 | - | ns |
| Rise time | $t_r$ | | - | 10 | - | |
| Turn-off delay time | $t_{d(off)}$ | | - | 185 | - | |
| Fall time | $t_f$ | | - | 83 | - | |
| Turn-on energy | $E_{on}$ | | - | 99 | - | µJ |
| Turn-off energy | $E_{off}$ | | - | 97 | - | |
| Total switching energy | $E_{ts}$ | | - | 196 | - | |
| **Anti-Parallel Diode Characteristic** | | | | | | |
| Diode reverse recovery time | $t_{rr}$ | $T_j$=175°C $V_R$=400V, $I_F$=4A, $di_F/dt$=610A/µs | - | 95 | - | ns |
| Diode reverse recovery charge | $Q_{rr}$ | | - | 291 | - | nC |
| Diode peak reverse recovery current | $I_{rrm}$ | | - | 6.6 | - | A |
| Diode peak rate of fall of reverse recovery current during $t_b$ | $di_{rr}/dt$ | | - | 253 | - | A/µs |

[1)] Leakage inductance $L_\sigma$ and Stray capacity $C_\sigma$ due to dynamic test circuit in Figure E.

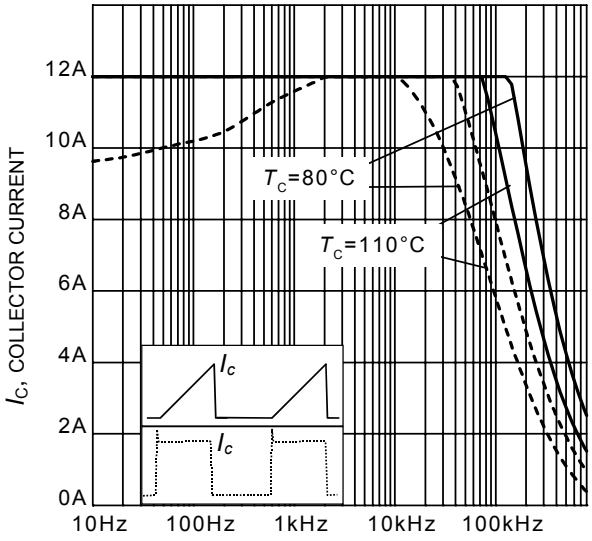



**Figure 1. Collector current as a function of switching frequency**
($T_j \le 175°C$, $D = 0.5$, $V_{CE} = 400V$, $V_{GE} = 0/+15V$, $R_G = 47\Omega$)

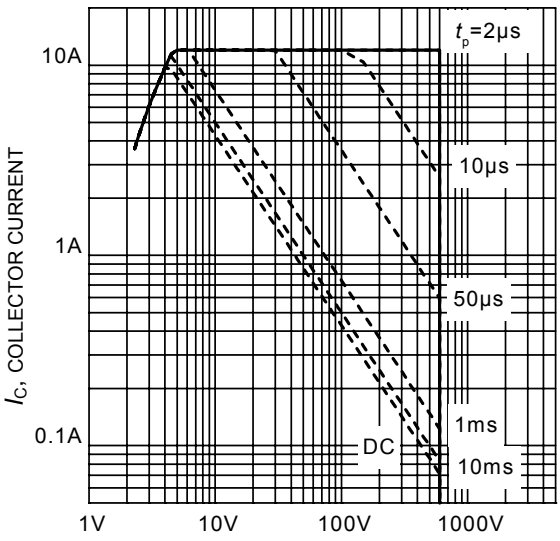



**Figure 2. Safe operating area**
($D = 0$, $T_C = 25°C$, $T_j \le 175°C$; $V_{GE}$=15V)

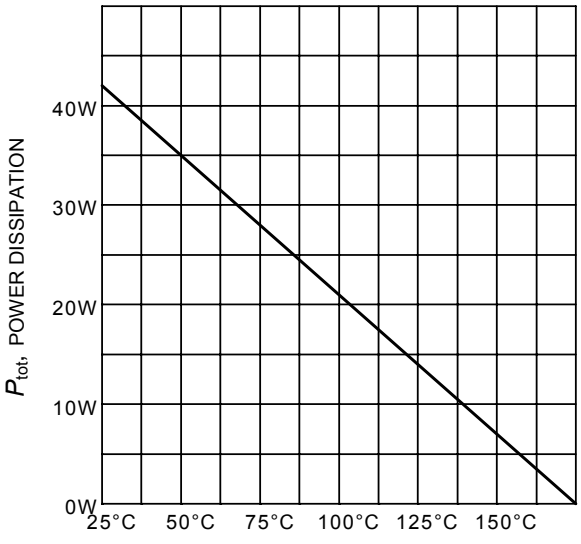



**Figure 3. Power dissipation as a function of case temperature**
($T_j \le 175°C$)

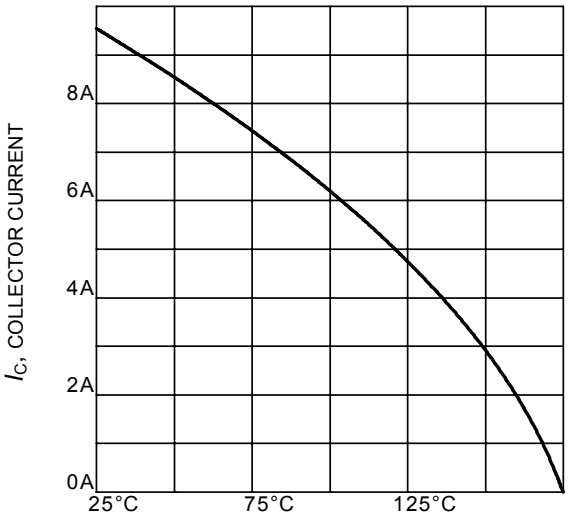



**Figure 4. Collector current as a function of case temperature**
($V_{GE} \ge 15V$, $T_j \le 175°C$)

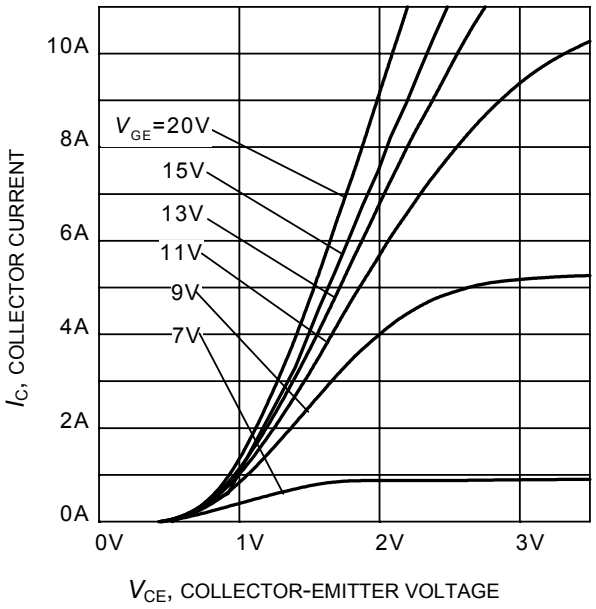



**Figure 5. Typical output characteristic**
($T_j$ = 25°C)

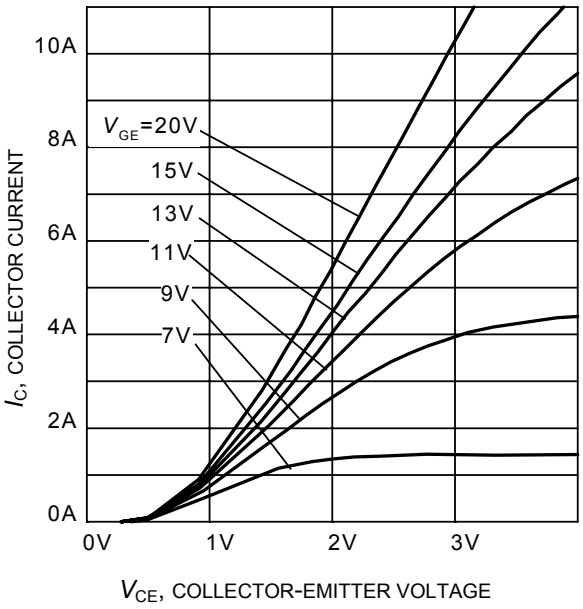



**Figure 6. Typical output characteristic**
($T_j$ = 175°C)

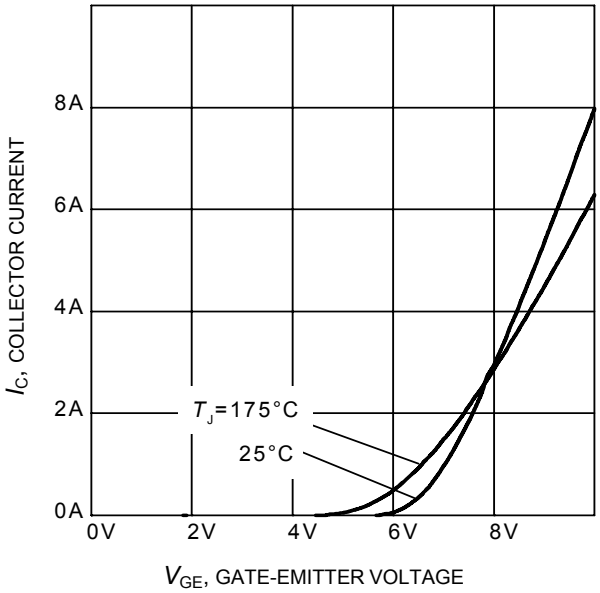



**Figure 7. Typical transfer characteristic**
($V_{CE}$=20V)

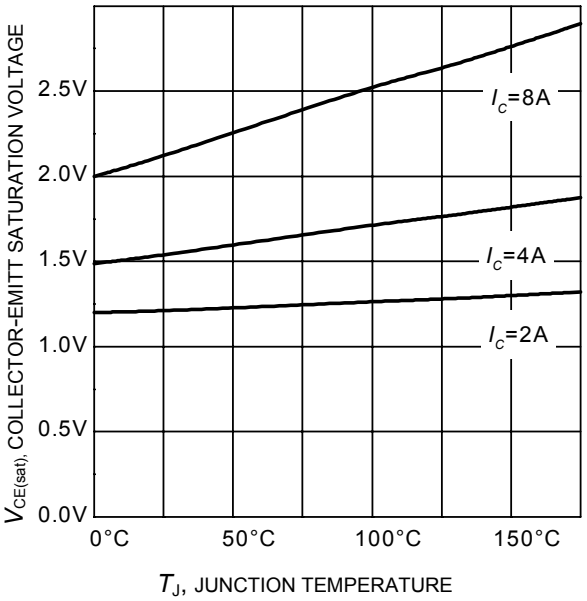



**Figure 8. Typical collector-emitter saturation voltage as a function of junction temperature**
($V_{GE}$ = 15V)

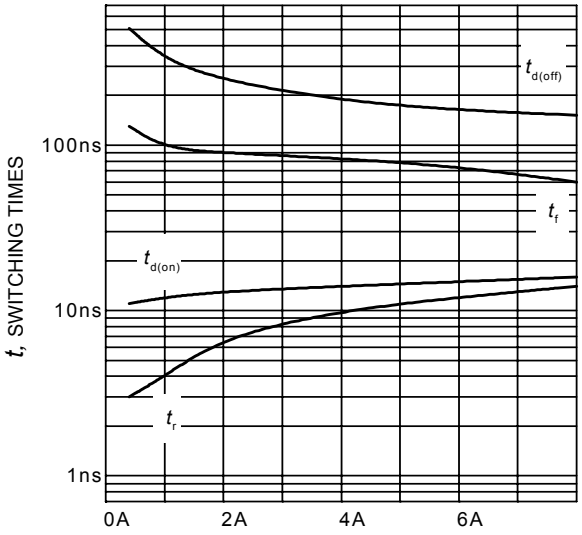



**Figure 9. Typical switching times as a function of collector current**
(inductive load, $T_J$=175°C, $V_{CE}$ = 400V, $V_{GE}$ = 0/15V, $R_G$ = 47Ω, Dynamic test circuit in Figure E)

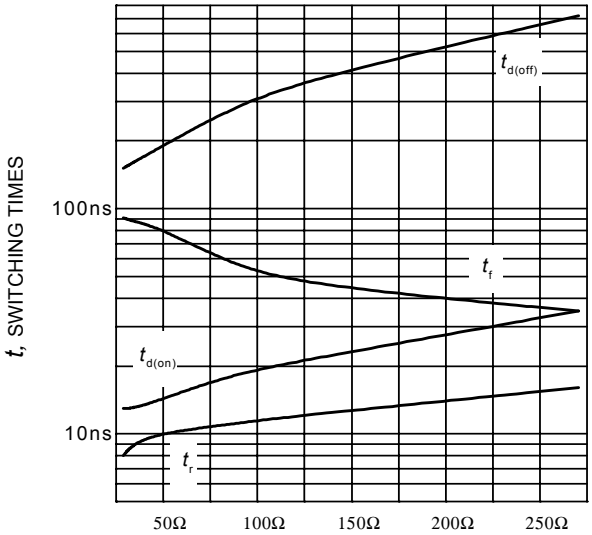



**Figure 10. Typical switching times as a function of gate resistor**
(inductive load, $T_J$ = 175°C, $V_{CE}$= 400V, $V_{GE}$ = 0/15V, $I_C$ = 4A, Dynamic test circuit in Figure E)

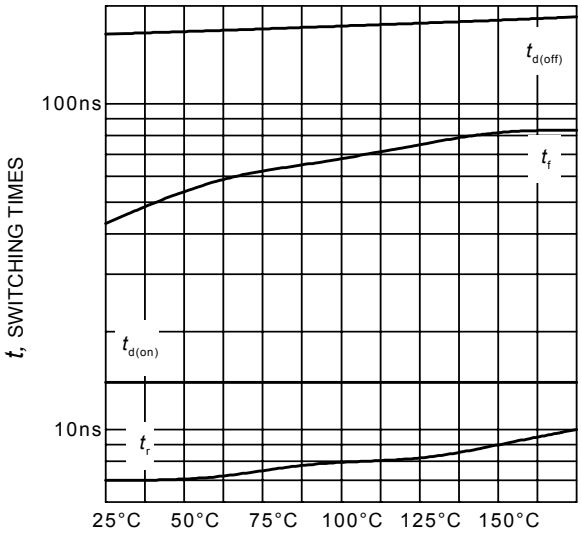



**Figure 11. Typical switching times as a function of junction temperature**
(inductive load, $V_{CE}$ = 400V, $V_{GE}$ = 0/15V, $I_C$ = 4A, $R_G$=47Ω, Dynamic test circuit in Figure E)

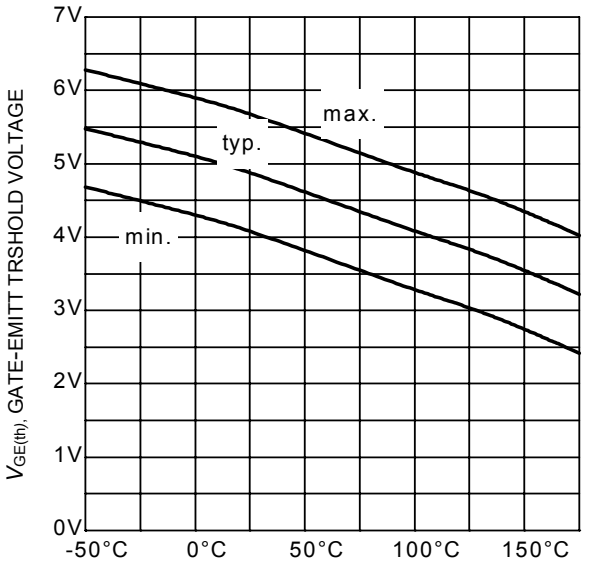



**Figure 12. Gate-emitter threshold voltage as a function of junction temperature**
($I_C$ = 60 µA)

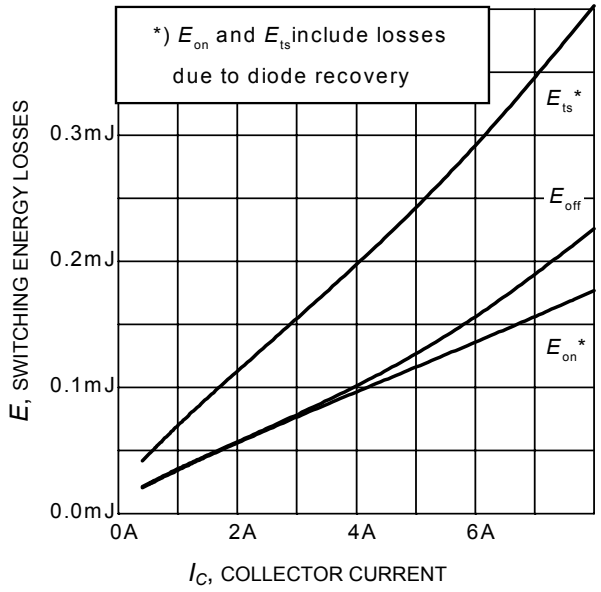



**Figure 13. Typical switching energy losses as a function of collector current**
(inductive load, $T_J$ = 175°C, $V_{CE}$ = 400V, $V_{GE}$ = 0/15V, $R_G$ = 47Ω, Dynamic test circuit in Figure E)

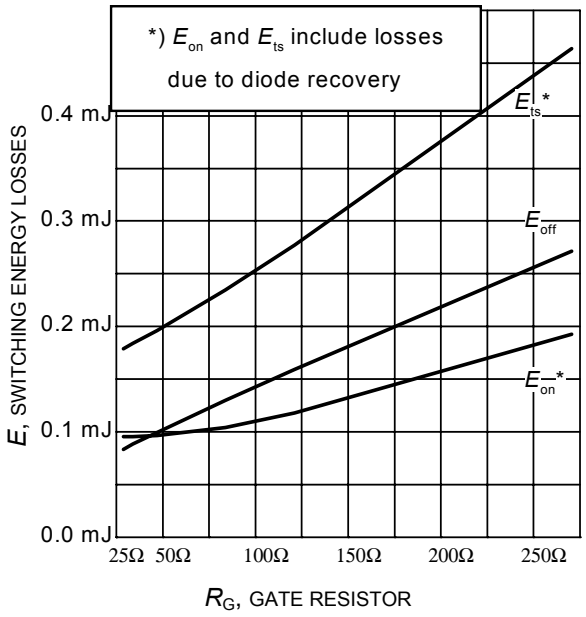



**Figure 14. Typical switching energy losses as a function of gate resistor**
(inductive load, $T_J$ = 175°C, $V_{CE}$ = 400V, $V_{GE}$ = 0/15V, $I_C$ = 4A, Dynamic test circuit in Figure E)

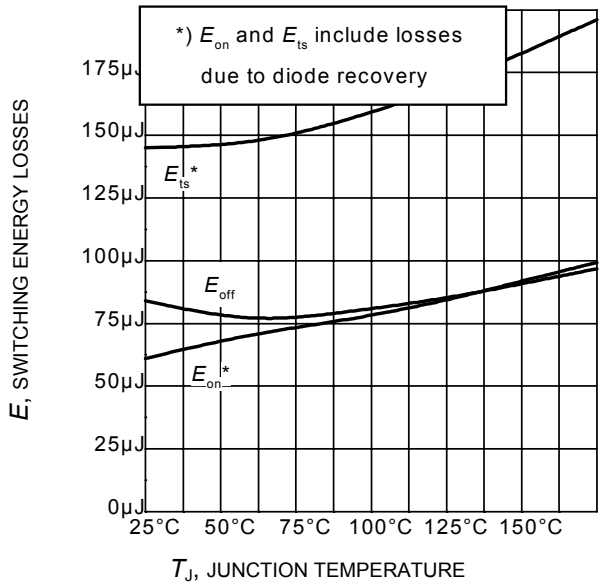



**Figure 15. Typical switching energy losses as a function of junction temperature**
(inductive load, $V_{CE}$ = 400V, $V_{GE}$ = 0/15V, $I_C$ = 4A, $R_G$ = 47Ω, Dynamic test circuit in Figure E)

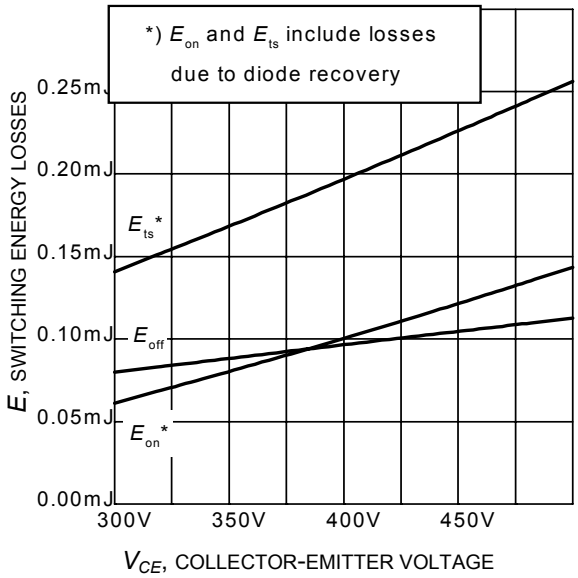



**Figure 16. Typical switching energy losses as a function of collector emitter voltage**
(inductive load, $T_J$ = 175°C, $V_{GE}$ = 0/15V, $I_C$ = 4A, $R_G$ = 47Ω, Dynamic test circuit in Figure E)

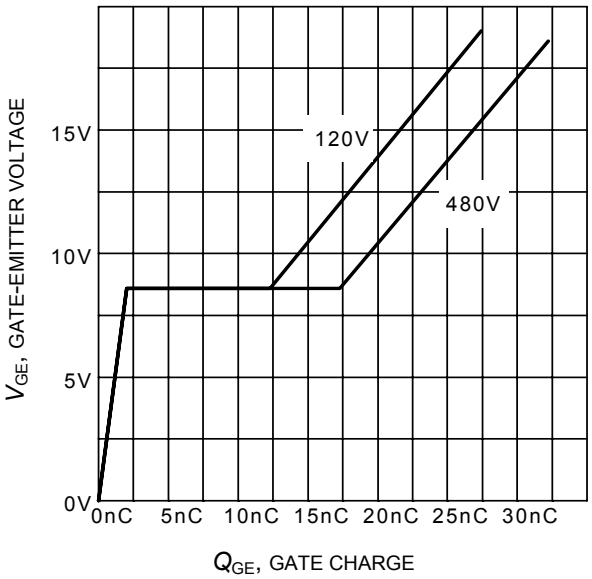



**Figure 17. Typical gate charge**
($I_C$=4 A)

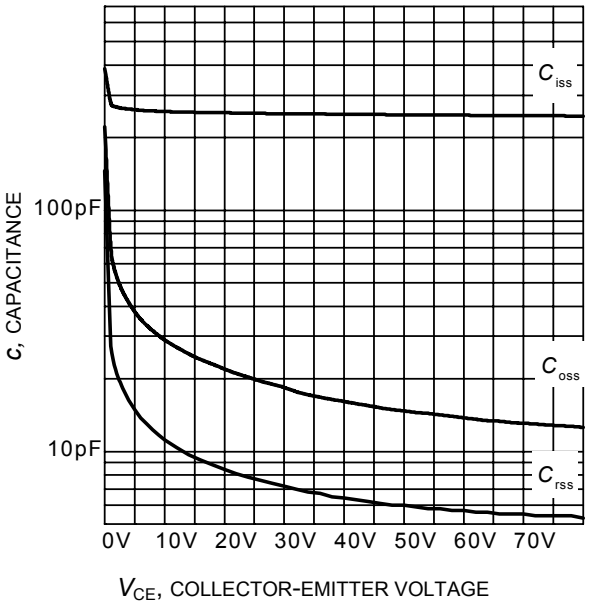



**Figure 18. Typical capacitance as a function of collector-emitter voltage**
($V_{GE}$=0V, *f* = 1 MHz)

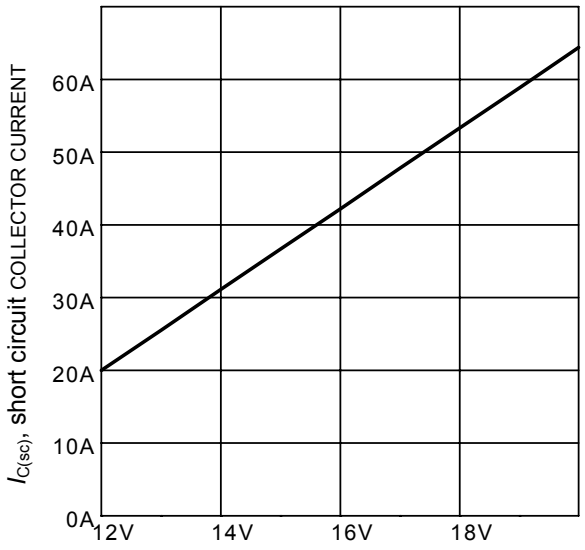



**Figure 19. Typical short circuit collector current as a function of gate-emitter voltage**
($V_{CE} \le 400V$, $T_j \le 150°C$)

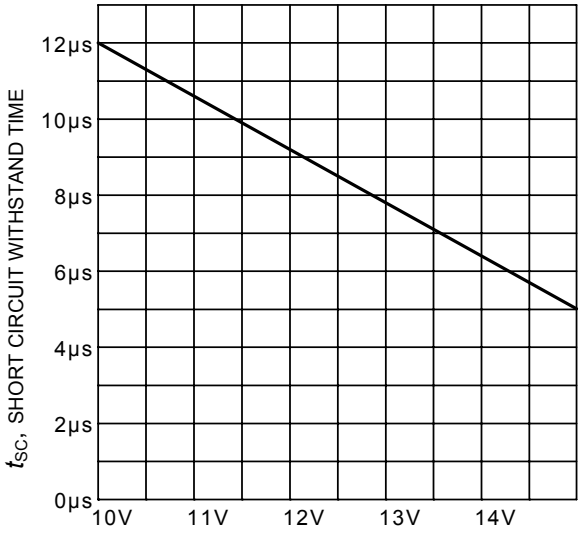



**Figure 20. Short circuit withstand time as a function of gate-emitter voltage**
($V_{CE}$=600V, start at $T_J$=25°C, $T_{Jmax}$<150°C)

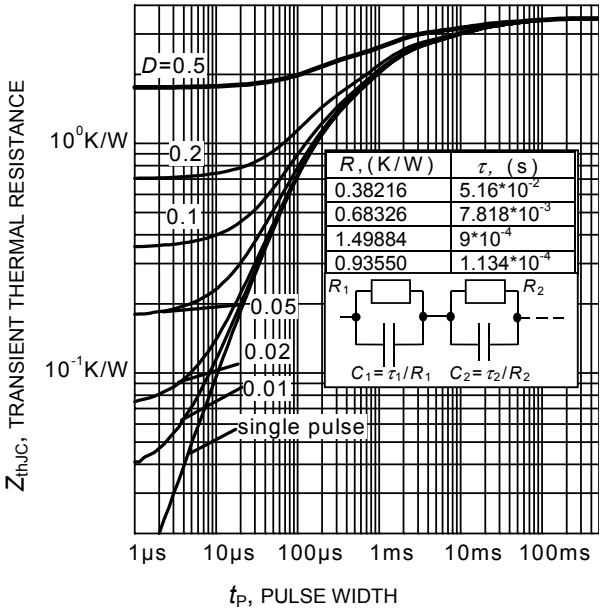



**Figure 21. IGBT transient thermal resistance**
($D = t_p / T$)

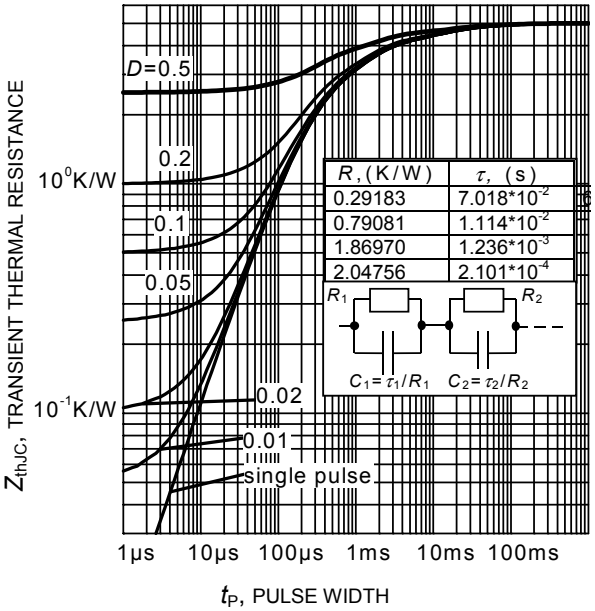



**Figure 22. Diode transient thermal impedance as a function of pulse width**
($D=t_P/T$)

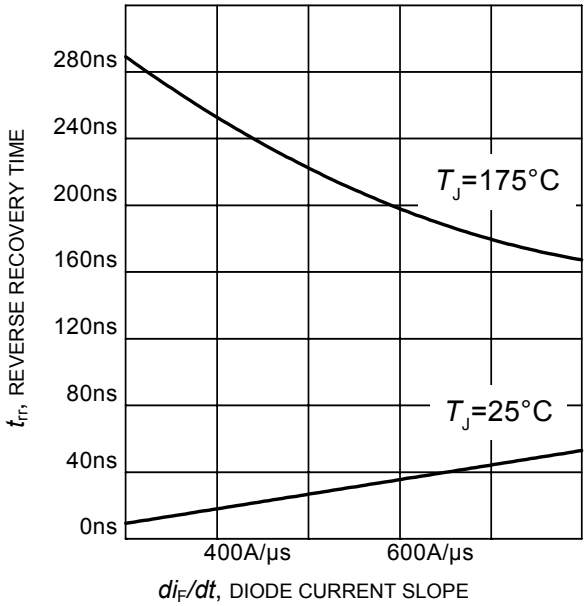



**Figure 23. Typical reverse recovery time as a function of diode current slope**
($V_R$=400V, $I_F$=4A,
Dynamic test circuit in Figure E)

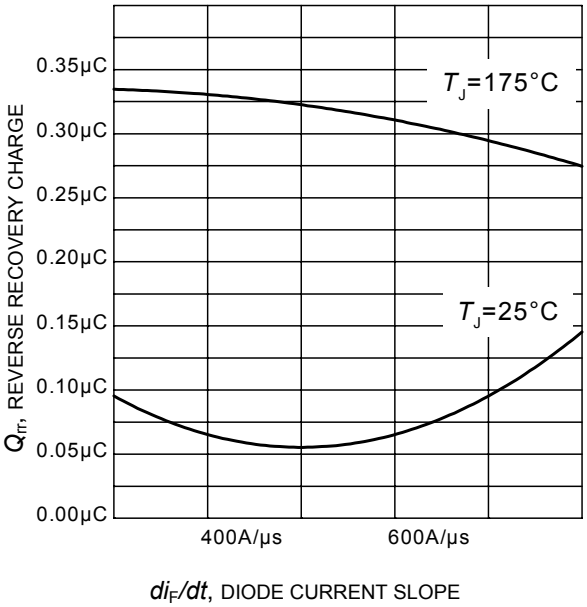



**Figure 24. Typical reverse recovery charge as a function of diode current slope**
($V_R$ = 400V, $I_F$ = 4A,
Dynamic test circuit in Figure E)

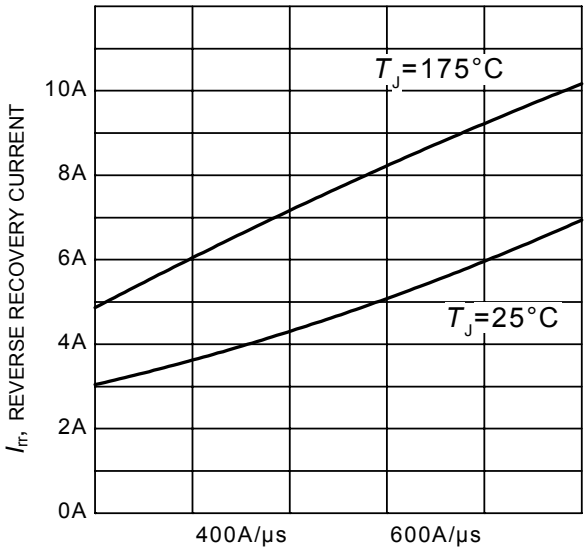



**Figure 25. Typical reverse recovery current as a function of diode current slope**
($V_R$ = 400V, $I_F$ = 4A,
Dynamic test circuit in Figure E)

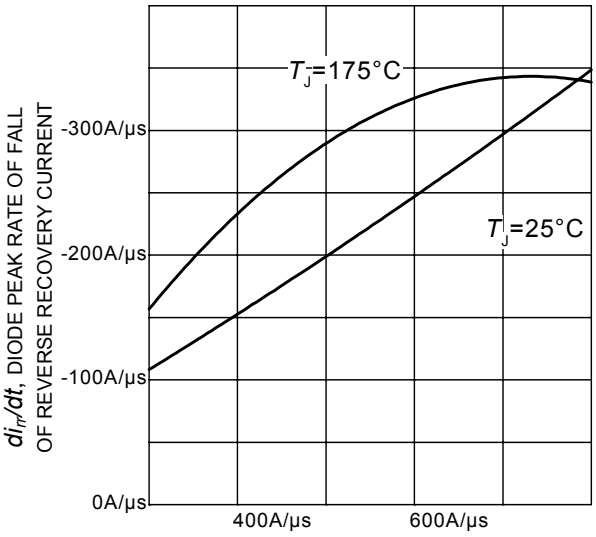



**Figure 26. Typical diode peak rate of fall of reverse recovery current as a function of diode current slope**
($V_R$=400V, $I_F$=4A,
Dynamic test circuit in Figure E)

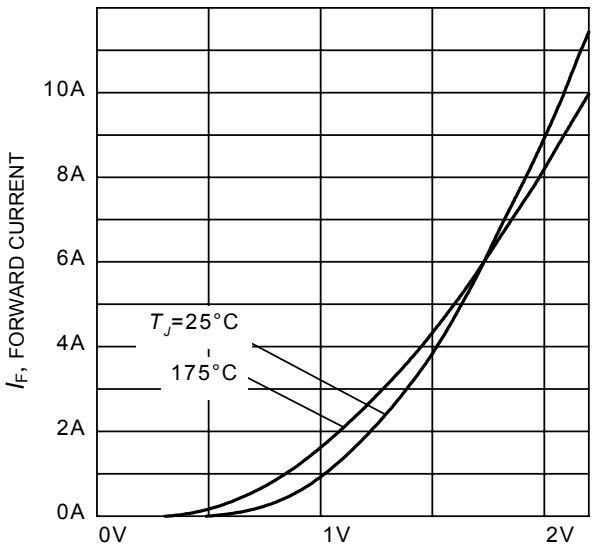



**Figure 27. Typical diode forward current as a function of forward voltage**

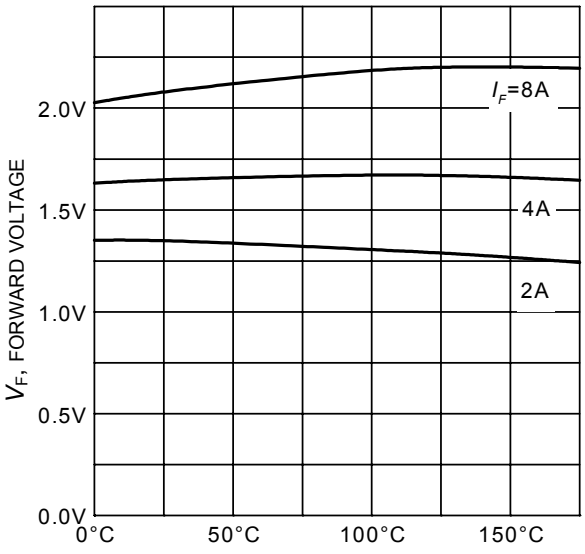
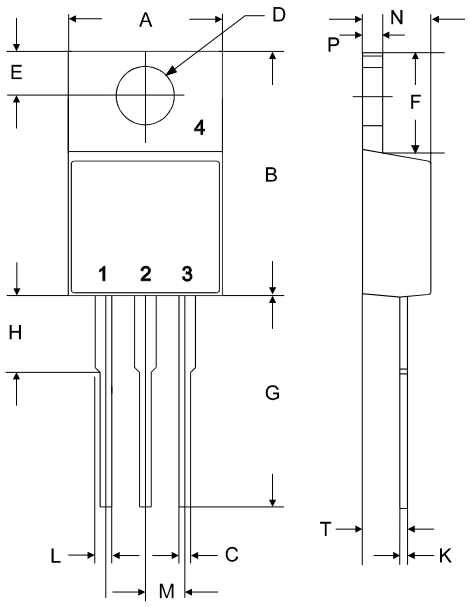



**Figure 28. Typical diode forward voltage as a function of junction temperature**

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 | 3.7 | 0.1398 | 0.1457 |
| 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 |

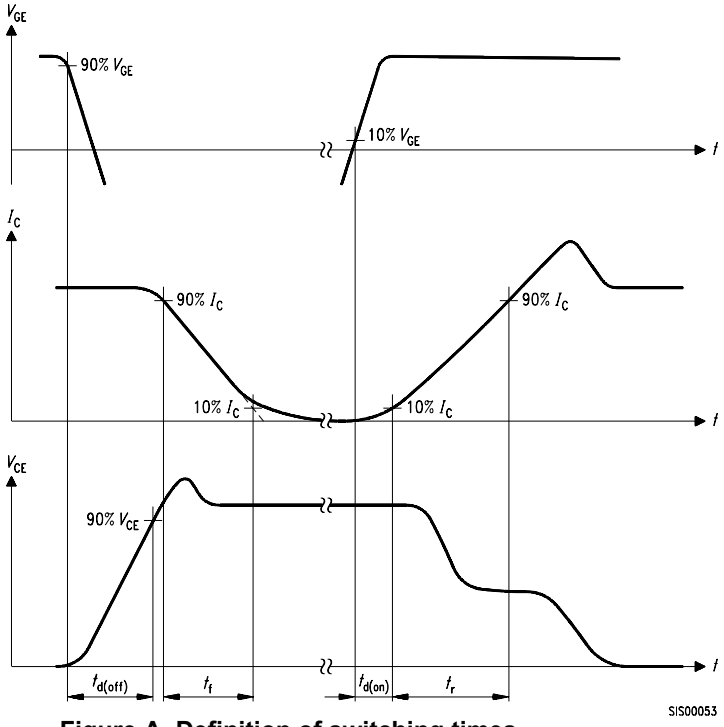



**Figure A. Definition of switching times**

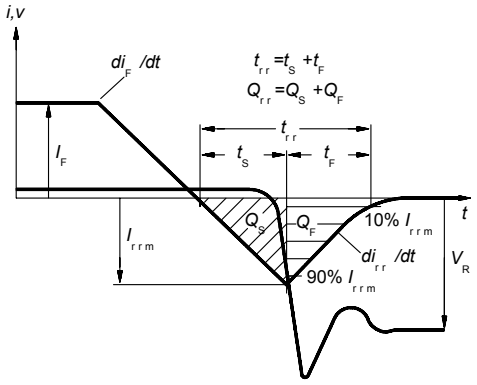



**Figure C. Definition of diodes switching characteristics**

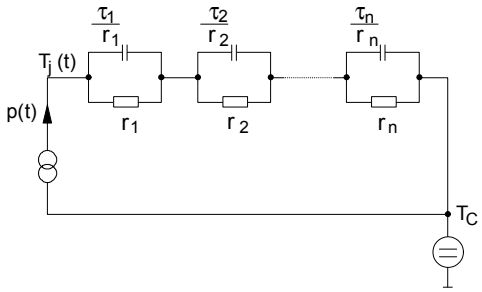



**Figure D. Thermal equivalent circuit**

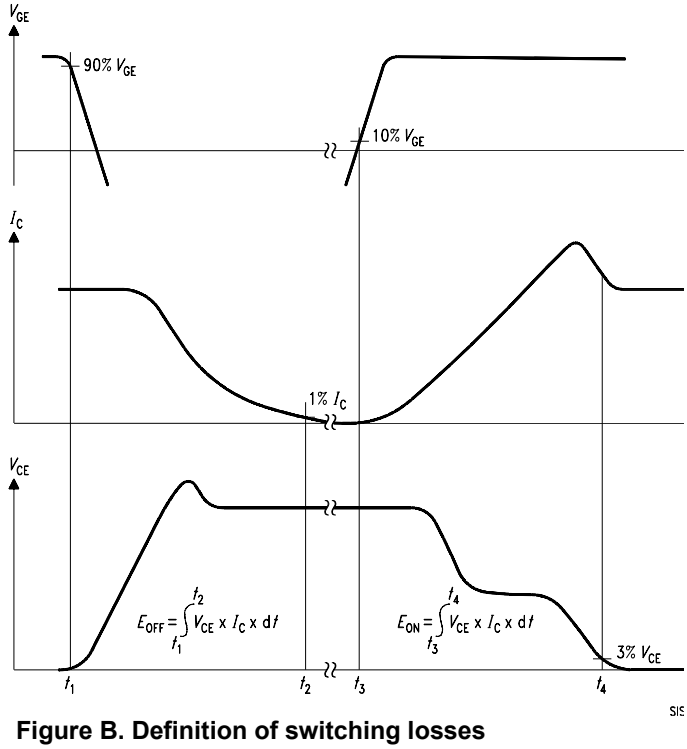



**Figure B. Definition of switching losses**

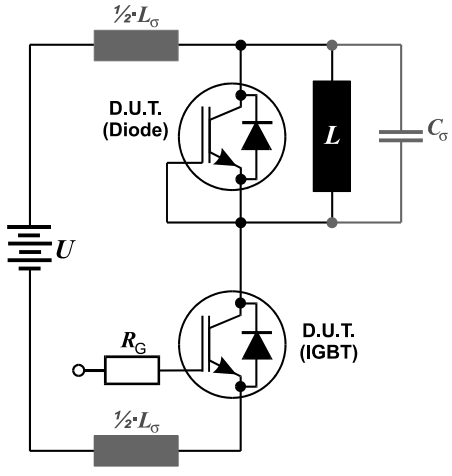



**Figure E. Dynamic test circuit**
Leakage inductance $L_\sigma$ =60nH
and Stray capacity $C_\sigma$ =40pF.

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