

## IGBT

IGBT with integrated diode in packages offering space saving advantage

### IKD06N60R

600V TRENCHSTOP™ RC-Series for hard switching applications

Data sheet

## TRENCHSTOP™ RC-Series for hard switching applications

## IGBT with integrated diode in packages offering space saving advantage

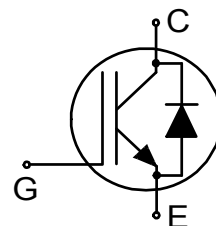
**Features:**

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 JEDEC for target applications
- 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:**

- Consumer motor drives

**Key Performance and Package Parameters**

| Type      | $V_{CE}$ | $I_C$ | $V_{CEsat}$ , $T_{vj}=25^\circ\text{C}$ | $T_{vjmax}$ | Marking | Package    |
|-----------|----------|-------|-----------------------------------------|-------------|---------|------------|
| IKD06N60R | 600V     | 6A    | 1.65V                                   | 175°C       | K06R60  | PG-TO252-3 |

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## TRENCHSTOP™ RC-Series for hard switching applications

## Maximum Ratings

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

| Parameter                                                                                                                                                                                                           | Symbol      | Value            | Unit               |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|------------------|--------------------|
| Collector-emitter voltage, $T_{vj} \geq 25^{\circ}\text{C}$                                                                                                                                                         | $V_{CE}$    | 600              | V                  |
| DC collector current, limited by $T_{vjmax}$<br>$T_c = 25^{\circ}\text{C}$<br>$T_c = 100^{\circ}\text{C}$                                                                                                           | $I_C$       | 12.0<br>6.0      | A                  |
| Pulsed collector current, $t_p$ limited by $T_{vjmax}$                                                                                                                                                              | $I_{Cpuls}$ | 18.0             | A                  |
| Turn off safe operating area<br>$V_{CE} \leq 600\text{V}$ , $T_{vj} \leq 175^{\circ}\text{C}$ , $t_p = 1\mu\text{s}$                                                                                                | -           | 18.0             | A                  |
| Diode forward current, limited by $T_{vjmax}$<br>$T_c = 25^{\circ}\text{C}$<br>$T_c = 100^{\circ}\text{C}$                                                                                                          | $I_F$       | 12.0<br>6.0      | A                  |
| Diode pulsed current, $t_p$ limited by $T_{vjmax}$                                                                                                                                                                  | $I_{Fpuls}$ | 18.0             | A                  |
| Gate-emitter voltage                                                                                                                                                                                                | $V_{GE}$    | $\pm 20$         | V                  |
| Short circuit withstand time<br>$V_{GE} = 15.0\text{V}$ , $V_{CC} \leq 400\text{V}$<br>Allowed number of short circuits < 1000<br>Time between short circuits: $\geq 1.0\text{s}$<br>$T_{vj} = 150^{\circ}\text{C}$ | $t_{SC}$    | 5                | $\mu\text{s}$      |
| Power dissipation $T_c = 25^{\circ}\text{C}$                                                                                                                                                                        | $P_{tot}$   | 100.0            | W                  |
| Operating junction temperature                                                                                                                                                                                      | $T_{vj}$    | $-40 \dots +175$ | $^{\circ}\text{C}$ |
| Storage temperature                                                                                                                                                                                                 | $T_{stg}$   | $-55 \dots +150$ | $^{\circ}\text{C}$ |
| Soldering temperature,<br>reflow soldering (MSL1 according to JEDEC J-STA-020)                                                                                                                                      |             | 260              | $^{\circ}\text{C}$ |

## Thermal Resistance

| Parameter                                                               | Symbol               | Conditions | Value |      |      | Unit |
|-------------------------------------------------------------------------|----------------------|------------|-------|------|------|------|
|                                                                         |                      |            | min.  | typ. | max. |      |
| R <sub>th</sub> Characteristics                                         |                      |            |       |      |      |      |
| IGBT thermal resistance, <sup>1)</sup><br>junction - case               | R <sub>th(j-c)</sub> |            | -     | -    | 1.50 | K/W  |
| Diode thermal resistance, <sup>2)</sup><br>junction - case              | R <sub>th(j-c)</sub> |            | -     | -    | 3.60 | K/W  |
| Thermal resistance, min. footprint<br>junction - ambient                | R <sub>th(j-a)</sub> |            | -     | -    | 75   | K/W  |
| Thermal resistance, 6cm <sup>2</sup> Cu on<br>PCB<br>junction - ambient | R <sub>th(j-a)</sub> |            | -     | -    | 50   | K/W  |

<sup>1)</sup> R<sub>th</sub>/Z<sub>th</sub> based on single cooling pulse. Please be aware that a correct R<sub>th</sub> measurement of the IGBT, is not possible using a thermocouple.

<sup>2)</sup> R<sub>th</sub>/Z<sub>th</sub> based on single cooling pulse. Please be aware that a correct R<sub>th</sub> measurement of the Diode, is not possible using a thermocouple.

## TRENCHSTOP™ RC-Series for hard switching applications

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

| Parameter                                         | Symbol        | Conditions                                                                        | Value  |              |            | Unit     |
|---------------------------------------------------|---------------|-----------------------------------------------------------------------------------|--------|--------------|------------|----------|
|                                                   |               |                                                                                   | min.   | typ.         | max.       |          |
| Static Characteristic                             |               |                                                                                   |        |              |            |          |
| Collector-emitter breakdown voltage               | $V_{(BR)CES}$ | $V_{GE} = 0V, I_C = 0.20mA$                                                       | 600    | -            | -          | V        |
| Collector-emitter saturation voltage              | $V_{CEsat}$   | $V_{GE} = 15.0V, I_C = 6.0A$<br>$T_{vj} = 25^{\circ}C$<br>$T_{vj} = 175^{\circ}C$ | -<br>- | 1.65<br>1.85 | 2.10<br>-  | V        |
| Diode forward voltage                             | $V_F$         | $V_{GE} = 0V, I_F = 6.0A$<br>$T_{vj} = 25^{\circ}C$<br>$T_{vj} = 175^{\circ}C$    | -<br>- | 1.70<br>1.70 | 2.10<br>-  | V        |
| Gate-emitter threshold voltage                    | $V_{GE(th)}$  | $I_C = 0.11mA, V_{CE} = V_{GE}$                                                   | 4.3    | 5.0          | 5.7        | V        |
| Zero gate voltage collector current <sup>1)</sup> | $I_{CES}$     | $V_{CE} = 600V, V_{GE} = 0V$<br>$T_{vj} = 25^{\circ}C$<br>$T_{vj} = 175^{\circ}C$ | -<br>- | -<br>-       | 40<br>1000 | $\mu A$  |
| Gate-emitter leakage current                      | $I_{GES}$     | $V_{CE} = 0V, V_{GE} = 20V$                                                       | -      | -            | 100        | nA       |
| Transconductance                                  | $g_{fs}$      | $V_{CE} = 20V, I_C = 6.0A$                                                        | -      | 3.4          | -          | 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. |      |
| Dynamic Characteristic                                                                             |                    |                                                                                                     |       |      |      |      |
| Input capacitance                                                                                  | C <sub>ies</sub>   | V <sub>CE</sub> = 25V, V <sub>GE</sub> = 0V, f = 1MHz                                               | -     | 470  | -    | pF   |
| Output capacitance                                                                                 | C <sub>oes</sub>   |                                                                                                     | -     | 24   | -    |      |
| Reverse transfer capacitance                                                                       | C <sub>res</sub>   |                                                                                                     | -     | 14   | -    |      |
| Gate charge                                                                                        | Q <sub>G</sub>     | V <sub>CC</sub> = 480V, I <sub>C</sub> = 6.0A,<br>V <sub>GE</sub> = 15V                             | -     | 48.0 | -    | nC   |
| Short circuit collector current<br>Max. 1000 short circuits<br>Time between short circuits: ≥ 1.0s | I <sub>C(SC)</sub> | V <sub>GE</sub> = 15.0V, V <sub>CC</sub> ≤ 400V,<br>t <sub>SC</sub> ≤ 5μs<br>T <sub>vj</sub> = 25°C | -     | 46   | -    | A    |

## Switching Characteristic, Inductive Load

| Parameter                                             | Symbol              | Conditions                                                                                                                                                                                                                                                           | Value |      |      | Unit |
|-------------------------------------------------------|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|------|------|------|
|                                                       |                     |                                                                                                                                                                                                                                                                      | min.  | typ. | max. |      |
| IGBT Characteristic, at $T_{vj} = 25^{\circ}\text{C}$ |                     |                                                                                                                                                                                                                                                                      |       |      |      |      |
| Turn-on delay time                                    | $t_{d(\text{on})}$  | $T_{vj} = 25^{\circ}\text{C},$<br>$V_{CC} = 400\text{V}, I_C = 6.0\text{A},$<br>$V_{GE} = 0.0/15.0\text{V},$<br>$R_{G(\text{on})} = 23.0\Omega, R_{G(\text{off})} = 23.0\Omega,$<br>$L\sigma = 60\text{nH}, C\sigma = 40\text{pF}$<br>$L\sigma, C\sigma$ from Fig. E | -     | 12   | -    | ns   |
| Rise time                                             | $t_r$               |                                                                                                                                                                                                                                                                      | -     | 7    | -    | ns   |
| Turn-off delay time                                   | $t_{d(\text{off})}$ |                                                                                                                                                                                                                                                                      | -     | 127  | -    | ns   |
| Fall time                                             | $t_f$               |                                                                                                                                                                                                                                                                      | -     | 152  | -    | ns   |
| Turn-on energy                                        | $E_{\text{on}}$     |                                                                                                                                                                                                                                                                      | -     | 0.11 | -    | mJ   |
| Turn-off energy                                       | $E_{\text{off}}$    |                                                                                                                                                                                                                                                                      | -     | 0.22 | -    | mJ   |
| Total switching energy                                | $E_{\text{ts}}$     |                                                                                                                                                                                                                                                                      | -     | 0.33 | -    | mJ   |

<sup>1)</sup> Not subject to production test - verified by design/characterization

## TRENCHSTOP™ RC-Series for hard switching applications

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

|                                                                  |              |                                                                                                                       |   |      |   |                        |
|------------------------------------------------------------------|--------------|-----------------------------------------------------------------------------------------------------------------------|---|------|---|------------------------|
| Diode reverse recovery time                                      | $t_{rr}$     | $T_{vj} = 25^{\circ}\text{C},$<br>$V_R = 400\text{V},$<br>$I_F = 6.0\text{A},$<br>$di_F/dt = 800\text{A}/\mu\text{s}$ | - | 68   | - | ns                     |
| Diode reverse recovery charge                                    | $Q_{rr}$     |                                                                                                                       | - | 0.37 | - | $\mu\text{C}$          |
| Diode peak reverse recovery current                              | $I_{rrm}$    |                                                                                                                       | - | 12.0 | - | A                      |
| Diode peak rate of fall of reverse recovery current during $t_b$ | $di_{rr}/dt$ |                                                                                                                       | - | -211 | - | $\text{A}/\mu\text{s}$ |

## 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     | $t_{d(on)}$  | $T_{vj} = 175^{\circ}\text{C},$<br>$V_{CC} = 400\text{V}, I_C = 6.0\text{A},$<br>$V_{GE} = 0.0/15.0\text{V},$<br>$R_{G(on)} = 23.0\Omega, R_{G(off)} = 23.0\Omega,$<br>$L\sigma = 60\text{nH}, C\sigma = 40\text{pF}$<br>$L\sigma, C\sigma$ from Fig. E | - | 12   | - | ns |
| Rise time              | $t_r$        |                                                                                                                                                                                                                                                         | - | 10   | - | ns |
| Turn-off delay time    | $t_{d(off)}$ |                                                                                                                                                                                                                                                         | - | 164  | - | ns |
| Fall time              | $t_f$        |                                                                                                                                                                                                                                                         | - | 171  | - | ns |
| Turn-on energy         | $E_{on}$     |                                                                                                                                                                                                                                                         | - | 0.20 | - | mJ |
| Turn-off energy        | $E_{off}$    |                                                                                                                                                                                                                                                         | - | 0.36 | - | mJ |
| Total switching energy | $E_{ts}$     |                                                                                                                                                                                                                                                         | - | 0.56 | - | mJ |

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

|                                                                  |              |                                                                                                                        |   |      |   |                        |
|------------------------------------------------------------------|--------------|------------------------------------------------------------------------------------------------------------------------|---|------|---|------------------------|
| Diode reverse recovery time                                      | $t_{rr}$     | $T_{vj} = 175^{\circ}\text{C},$<br>$V_R = 400\text{V},$<br>$I_F = 6.0\text{A},$<br>$di_F/dt = 800\text{A}/\mu\text{s}$ | - | 74   | - | ns                     |
| Diode reverse recovery charge                                    | $Q_{rr}$     |                                                                                                                        | - | 0.80 | - | $\mu\text{C}$          |
| Diode peak reverse recovery current                              | $I_{rrm}$    |                                                                                                                        | - | 17.0 | - | A                      |
| Diode peak rate of fall of reverse recovery current during $t_b$ | $di_{rr}/dt$ |                                                                                                                        | - | -237 | - | $\text{A}/\mu\text{s}$ |

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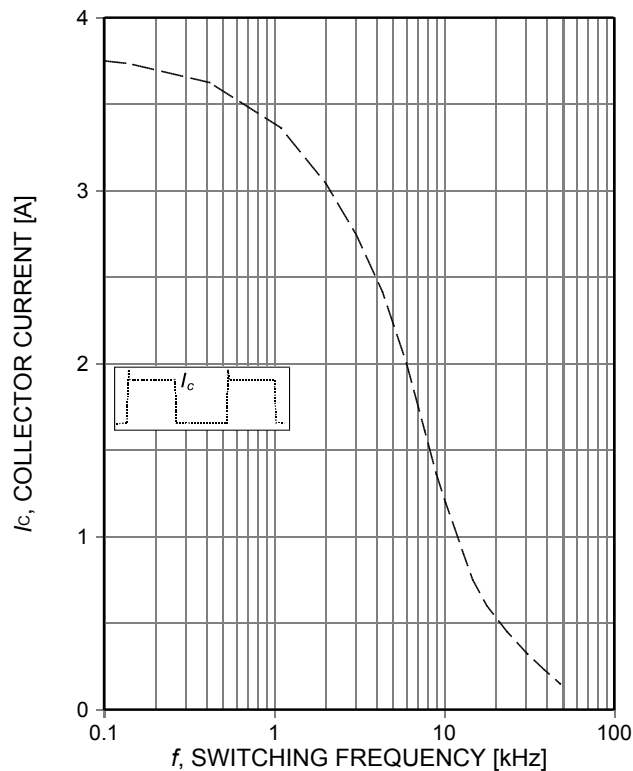


Figure 1. **Collector current as a function of switching frequency**  
 $(T_{vj} \leq 175^\circ\text{C}, T_a = 55^\circ\text{C}, D = 0.5, V_{CE} = 400\text{V}, V_{GE} = 15/0\text{V}, r_G = 23\Omega, \text{PCB mounting, } 6\text{cm}^2 \text{ Cu, } P_{tot} = 2.4\text{W})$

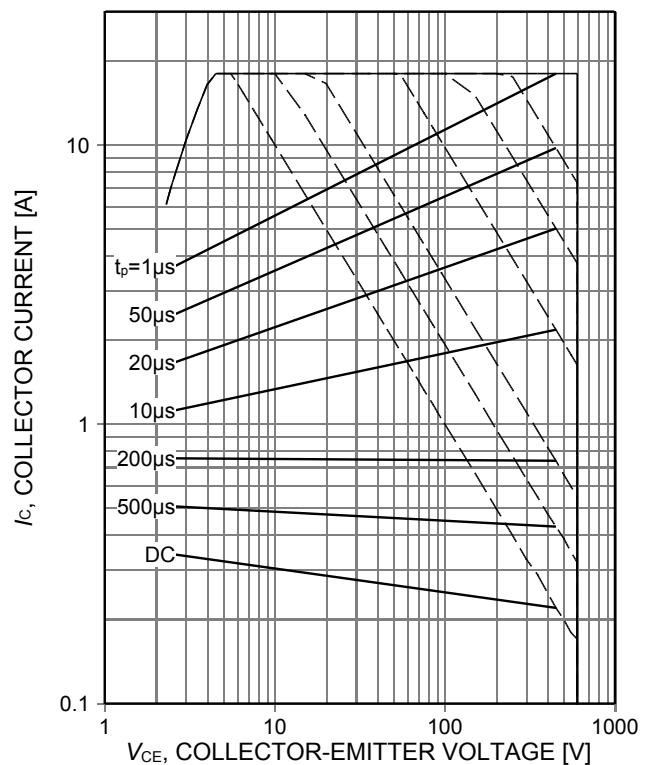


Figure 2. **Forward bias safe operating area**  
 $(D = 0, T_C = 25^\circ\text{C}, T_{vj} \leq 175^\circ\text{C}; V_{GE} = 15\text{V})$

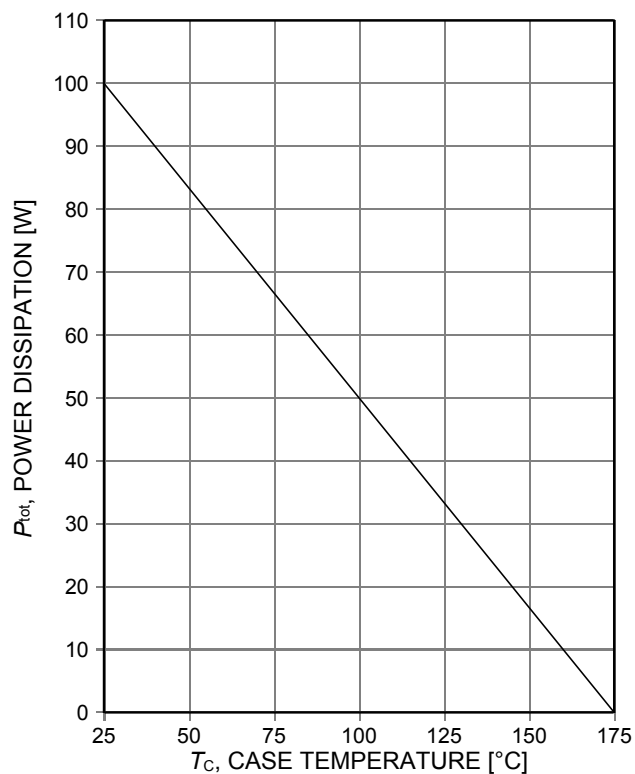


Figure 3. **Power dissipation as a function of case temperature**  
 $(T_{vj} \leq 175^\circ\text{C})$

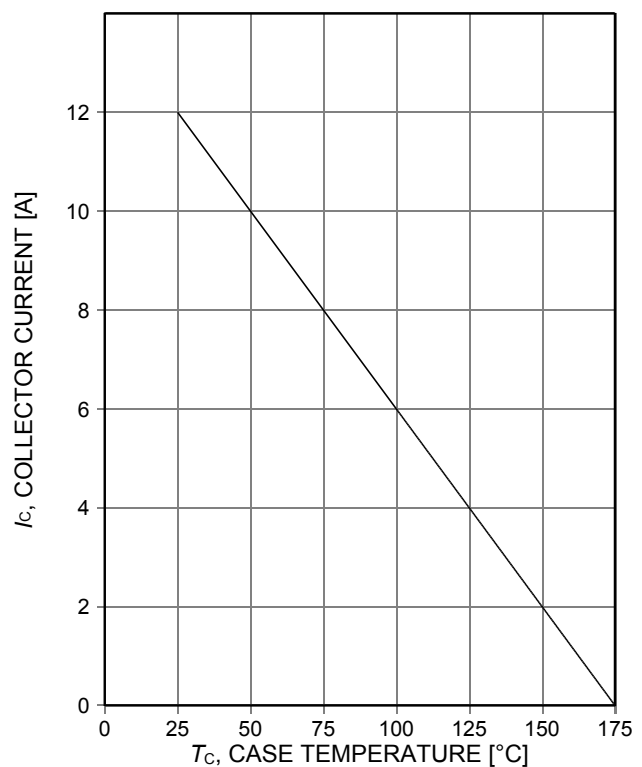


Figure 4. **Collector current as a function of case temperature**  
 $(V_{GE} \geq 15\text{V}, T_{vj} \leq 175^\circ\text{C})$

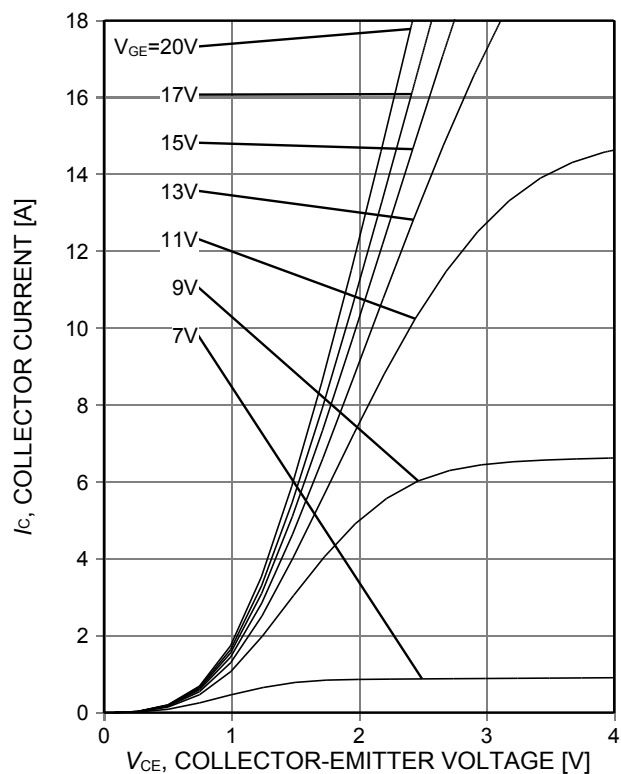


Figure 5. **Typical output characteristic**  
( $T_j = 25^\circ\text{C}$ )

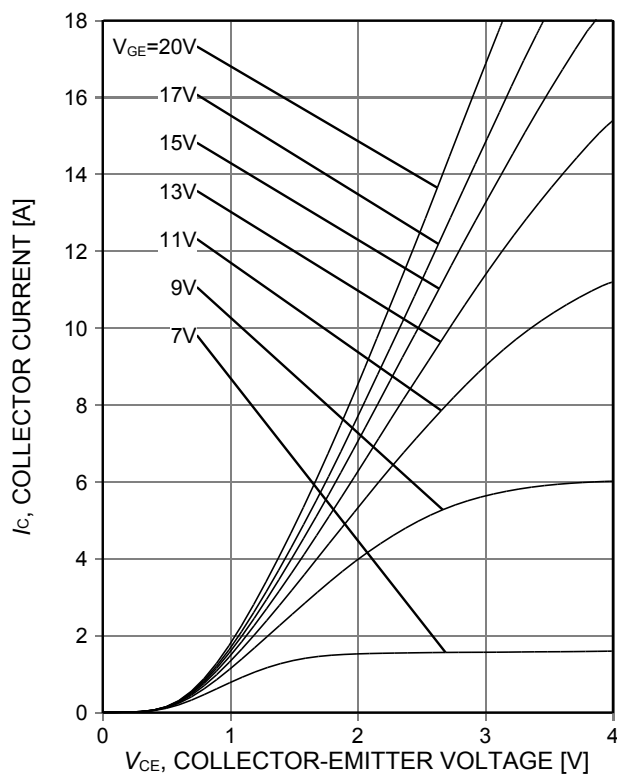


Figure 6. **Typical output characteristic**  
( $T_j = 175^\circ\text{C}$ )

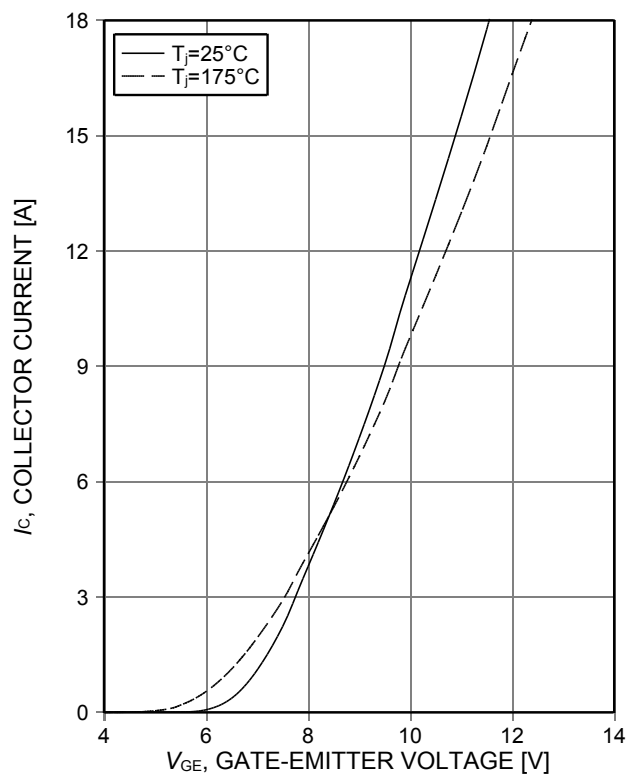


Figure 7. **Typical transfer characteristic**  
( $V_{CE} = 10\text{V}$ )

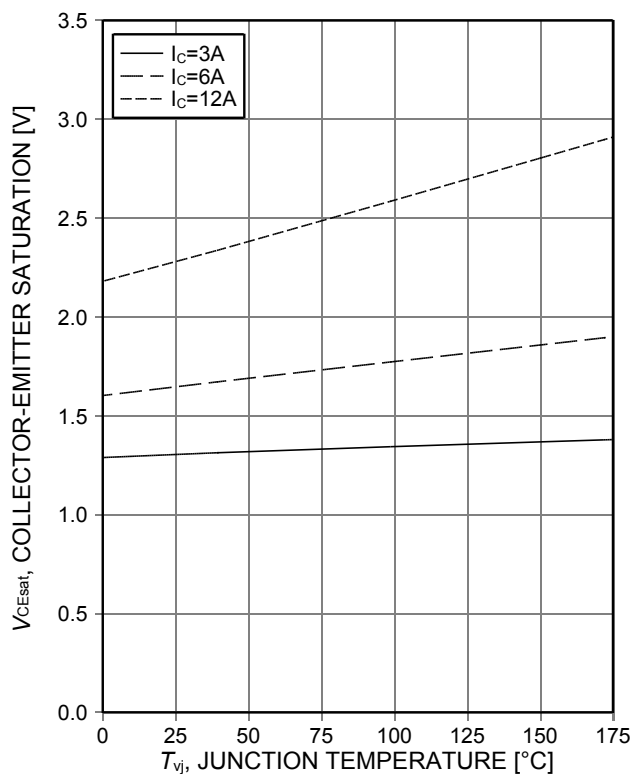


Figure 8. **Typical collector-emitter saturation voltage as a function of junction temperature**  
( $V_{GE} = 15\text{V}$ )

## TRENCHSTOP™ RC-Series for hard switching applications

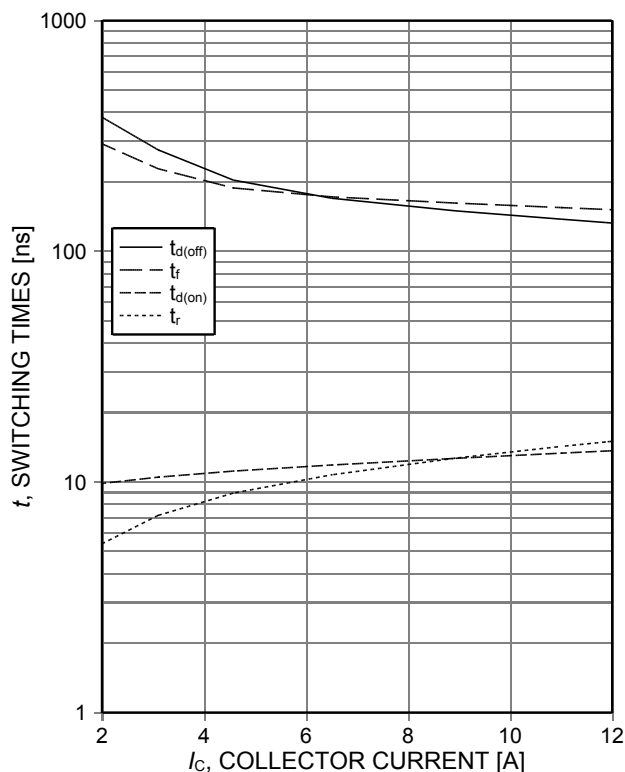


Figure 9. **Typical switching times as a function of collector current**  
(inductive load,  $T_{vj}=175^{\circ}\text{C}$ ,  $V_{CE}=400\text{V}$ ,  $V_{GE}=15/0\text{V}$ ,  $r_G=23\Omega$ , Dynamic test circuit in Figure E)

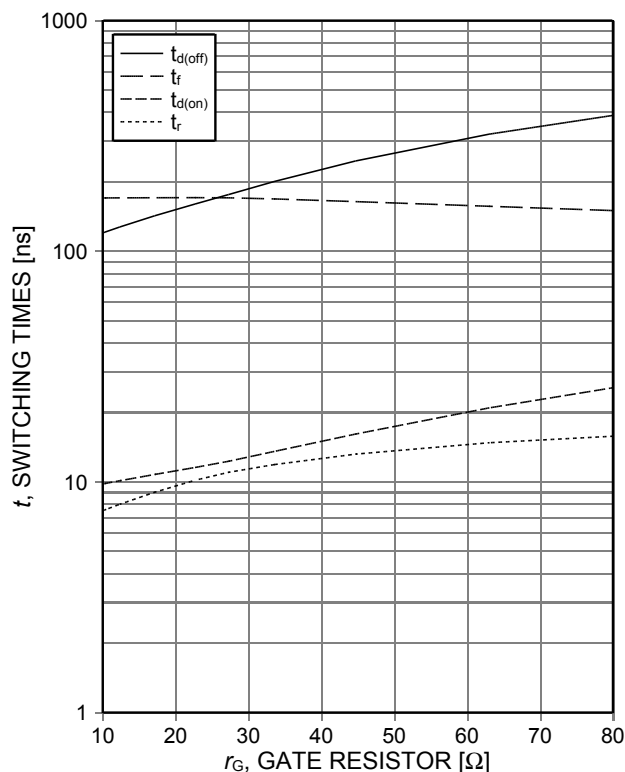


Figure 10. **Typical switching times as a function of gate resistor**  
(inductive load,  $T_{vj}=175^{\circ}\text{C}$ ,  $V_{CE}=400\text{V}$ ,  $V_{GE}=15/0\text{V}$ ,  $I_C=6\text{A}$ , Dynamic test circuit in Figure E)

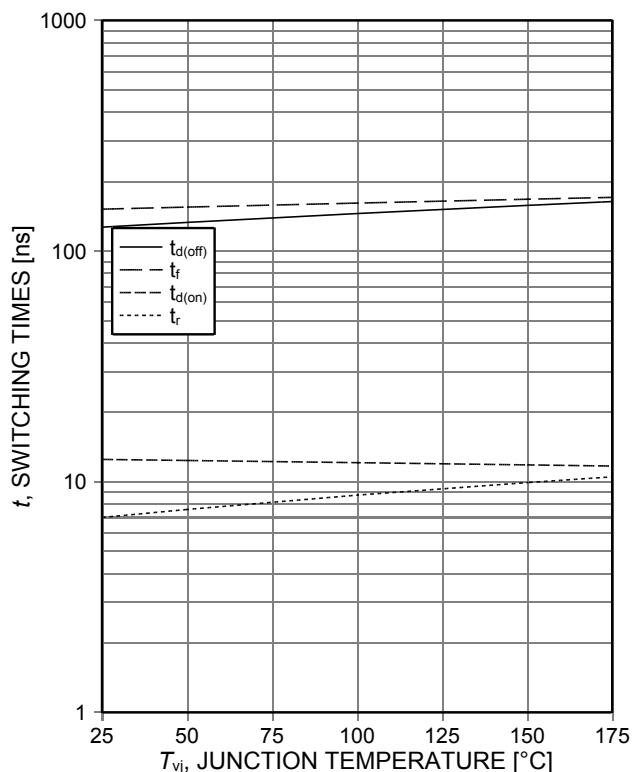


Figure 11. **Typical switching times as a function of junction temperature**  
(inductive load,  $V_{CE}=400\text{V}$ ,  $V_{GE}=15/0\text{V}$ ,  $I_C=6\text{A}$ ,  $r_G=23\Omega$ , Dynamic test circuit in Figure E)

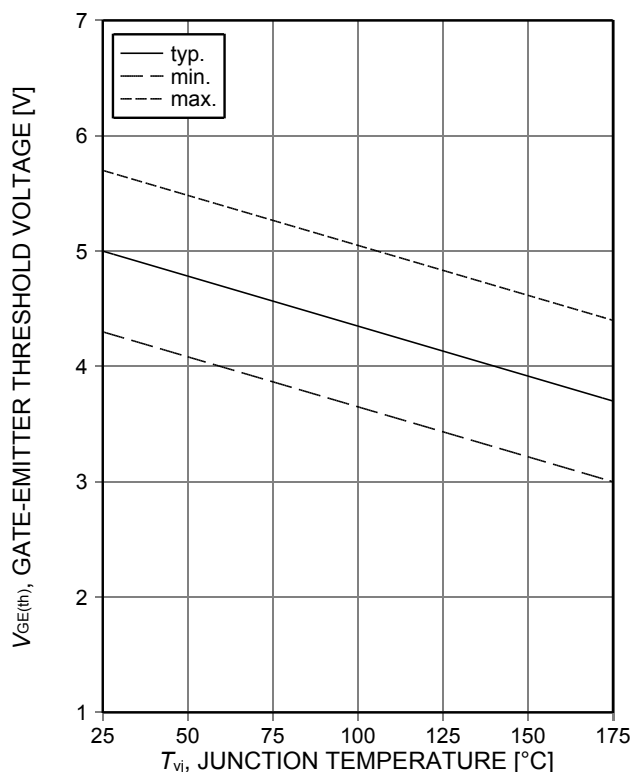


Figure 12. **Gate-emitter threshold voltage as a function of junction temperature**  
( $I_C=0.11\text{mA}$ )

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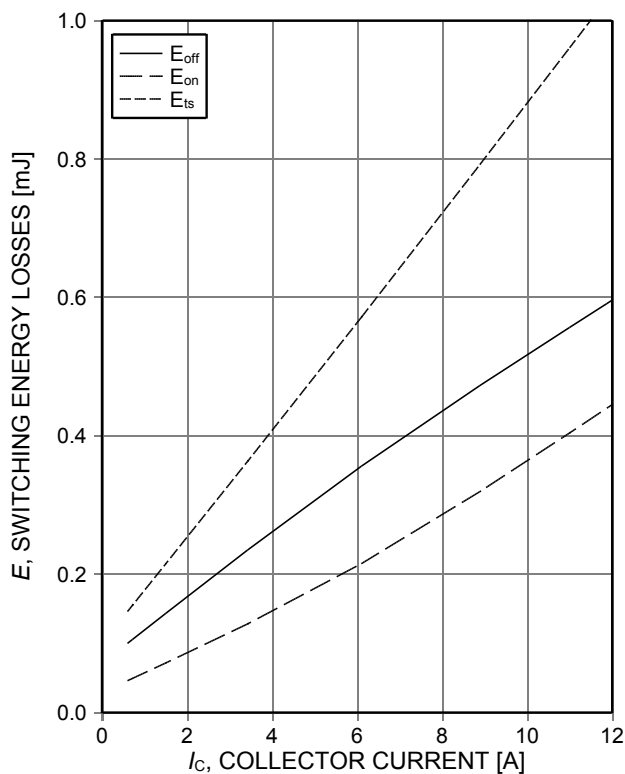


Figure 13. **Typical switching energy losses as a function of collector current**  
(inductive load,  $T_{vj}=175^{\circ}\text{C}$ ,  $V_{CE}=400\text{V}$ ,  $V_{GE}=15/0\text{V}$ ,  $r_G=23\Omega$ , Dynamic test circuit in Figure E)

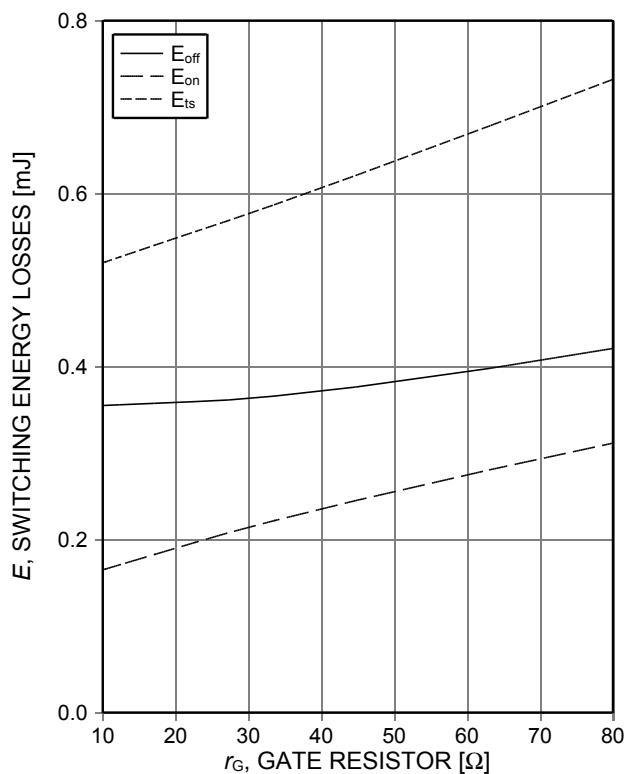


Figure 14. **Typical switching energy losses as a function of gate resistor**  
(inductive load,  $T_{vj}=175^{\circ}\text{C}$ ,  $V_{CE}=400\text{V}$ ,  $V_{GE}=15/0\text{V}$ ,  $I_C=6\text{A}$ , Dynamic test circuit in Figure E)

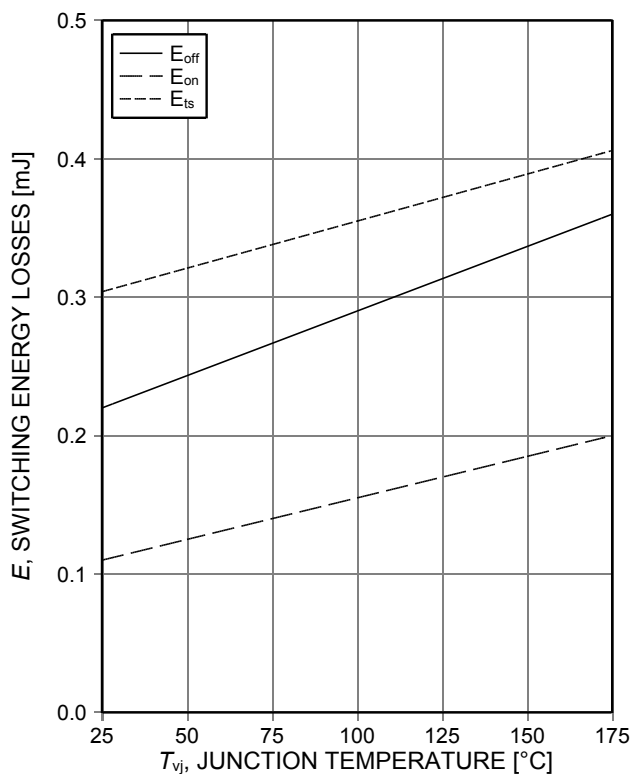


Figure 15. **Typical switching energy losses as a function of junction temperature**  
(inductive load,  $V_{CE}=400\text{V}$ ,  $V_{GE}=15/0\text{V}$ ,  $I_C=6\text{A}$ ,  $r_G=23\Omega$ , Dynamic test circuit in Figure E)

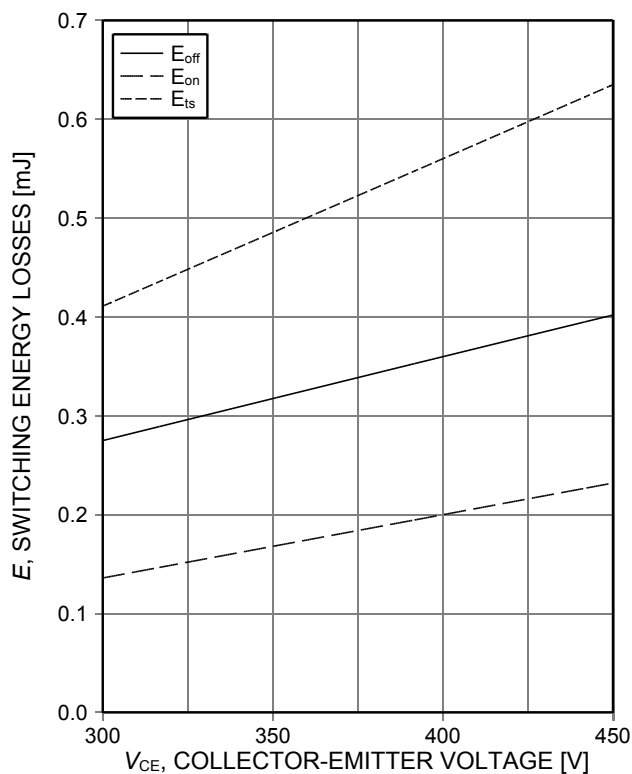


Figure 16. **Typical switching energy losses as a function of collector emitter voltage**  
(inductive load,  $T_{vj}=175^{\circ}\text{C}$ ,  $V_{GE}=15/0\text{V}$ ,  $I_C=6\text{A}$ ,  $r_G=23\Omega$ , Dynamic test circuit in Figure E)

## TRENCHSTOP™ RC-Series for hard switching applications

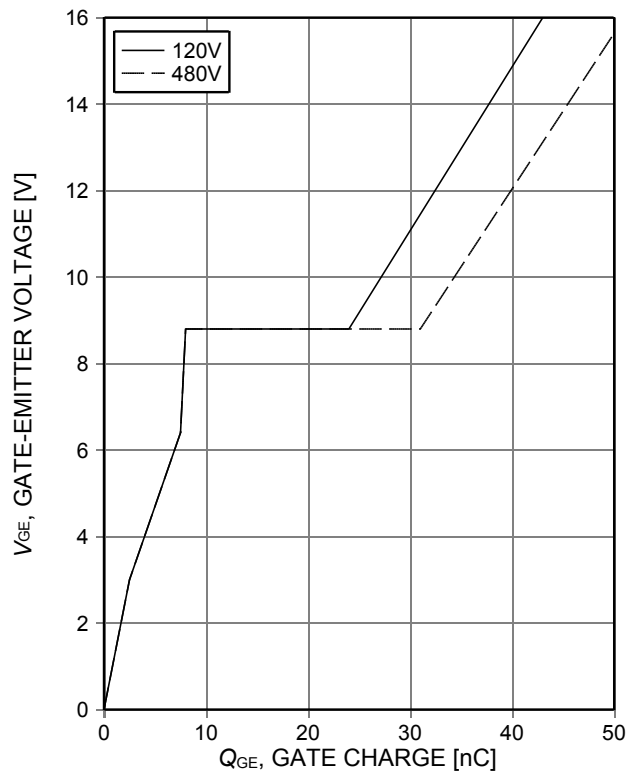


Figure 17. **Typical gate charge**  
( $I_C=6A$ )

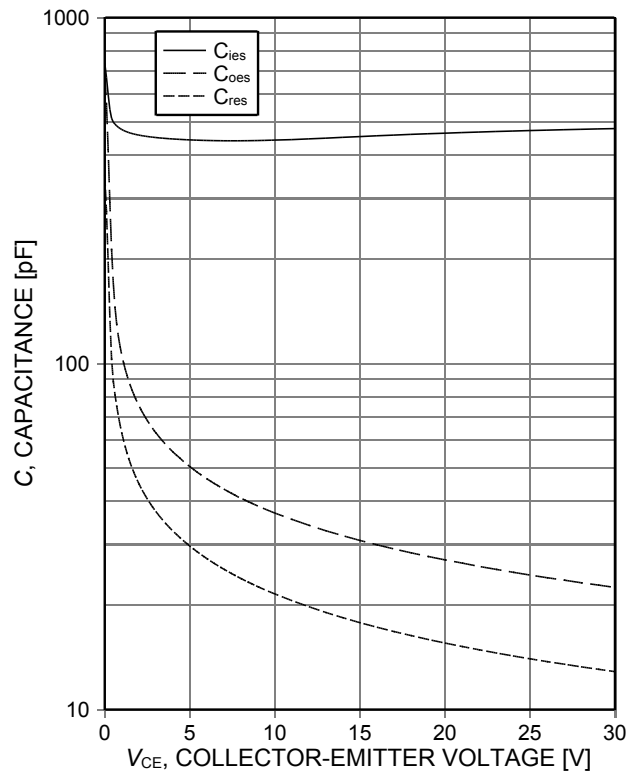


Figure 18. **Typical capacitance as a function of collector-emitter voltage**  
( $V_{GE}=0V$ ,  $f=1MHz$ )

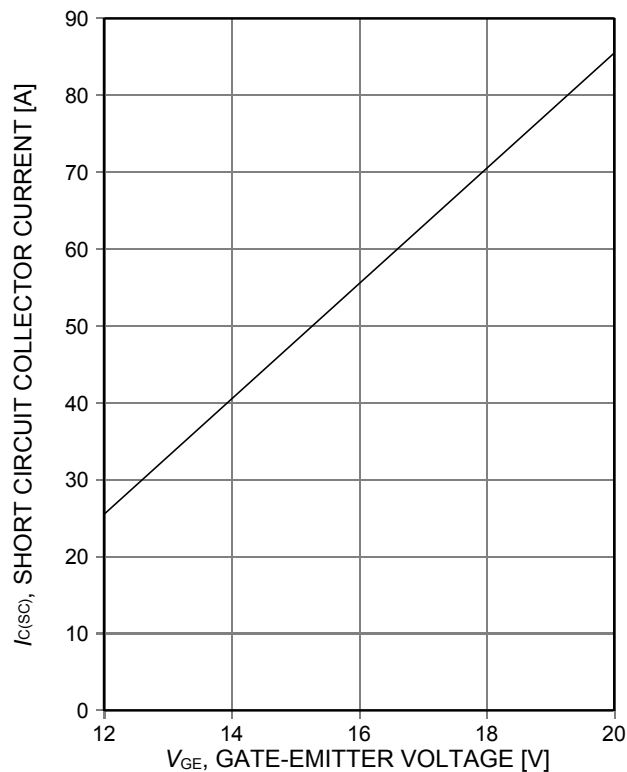


Figure 19. **Typical short circuit collector current as a function of gate-emitter voltage**  
( $V_{CE} \leq 400V$ , start at  $T_{vj}=25^\circ C$ )

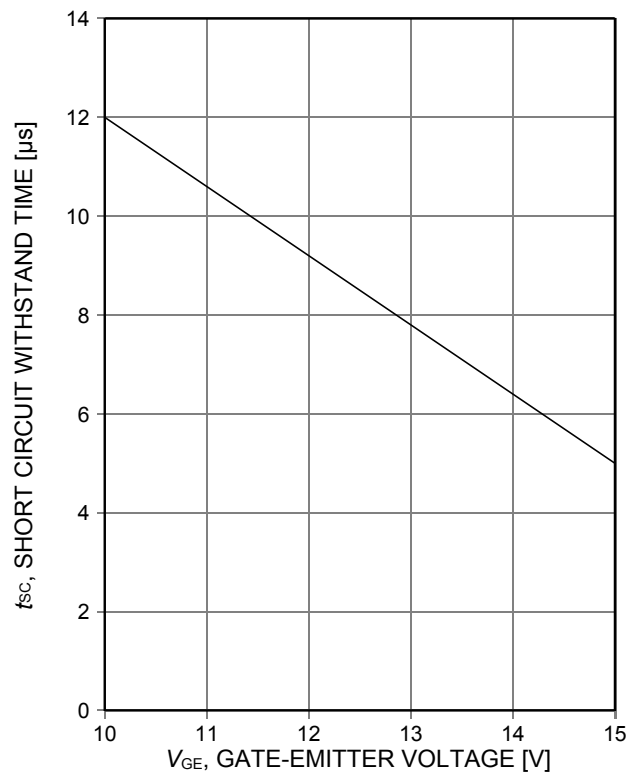


Figure 20. **Short circuit withstand time as a function of gate-emitter voltage**  
( $V_{CE} \leq 400V$ , start at  $T_{vj} \leq 150^\circ C$ )

## TRENCHSTOP™ RC-Series for hard switching applications

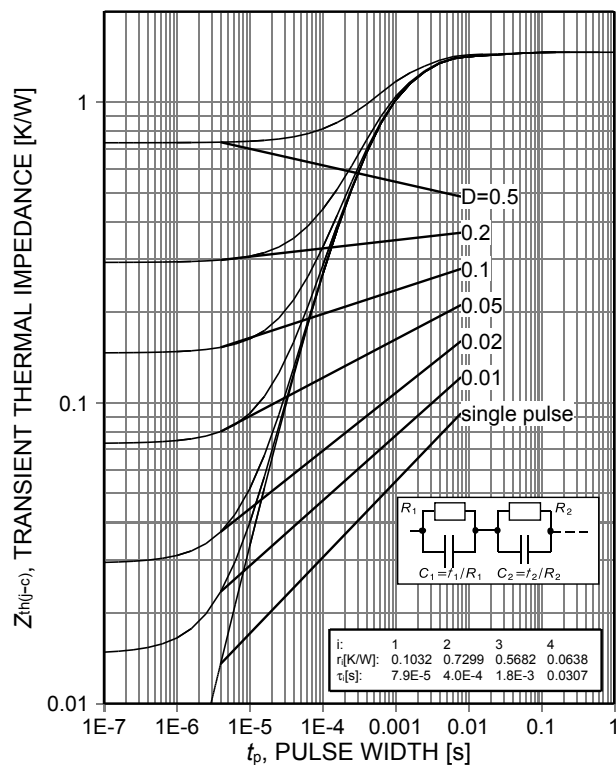


Figure 21. IGBT transient thermal impedance as a function of pulse width <sup>1)</sup> (see page 4)  
( $D = t_p/T$ )

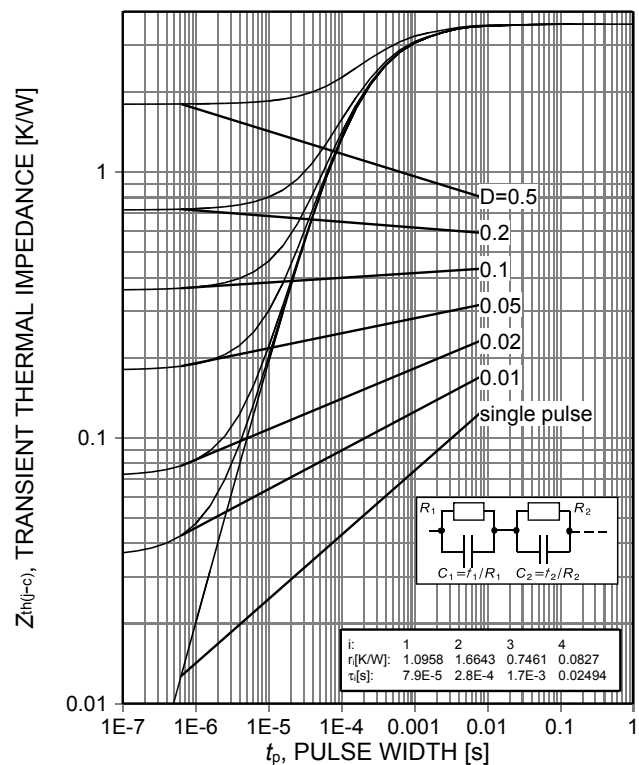


Figure 22. Diode transient thermal impedance as a function of pulse width <sup>2)</sup> (see page 4)  
( $D = t_p/T$ )

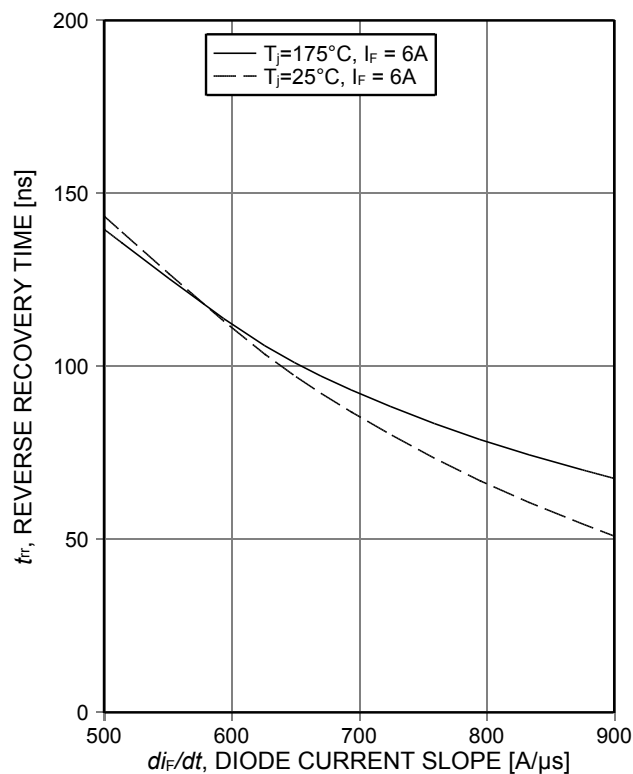


Figure 23. Typical reverse recovery time as a function of diode current slope  
( $V_R = 400V$ )

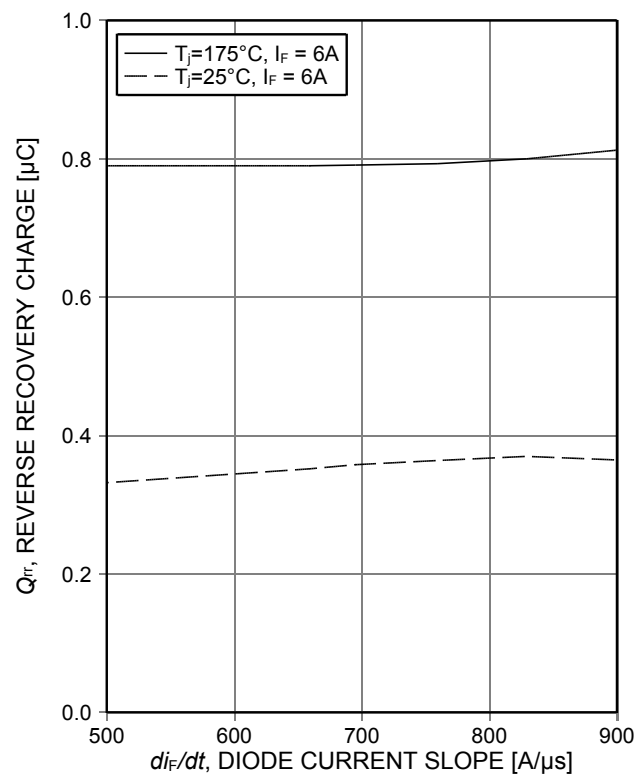


Figure 24. Typical reverse recovery charge as a function of diode current slope  
( $V_R = 400V$ )

## TRENCHSTOP™ RC-Series for hard switching applications

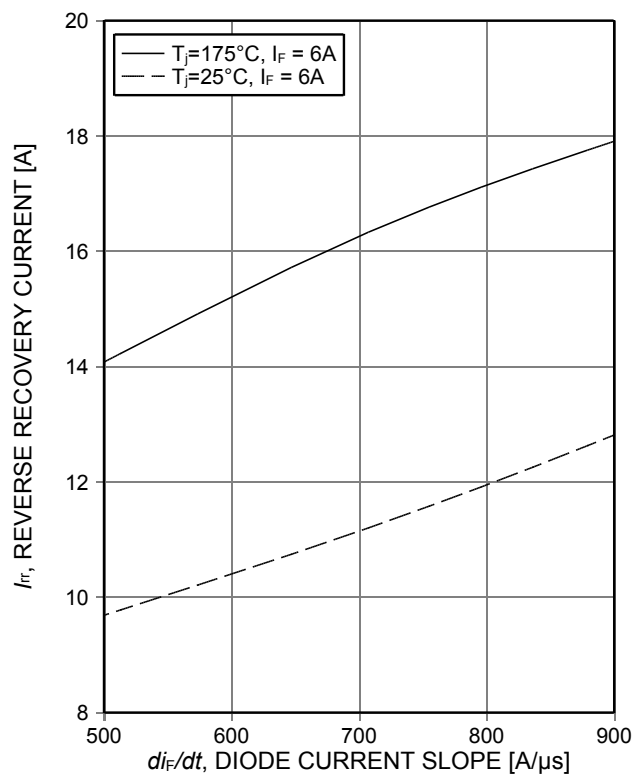


Figure 25. **Typical reverse recovery current as a function of diode current slope**  
( $V_R=400V$ )

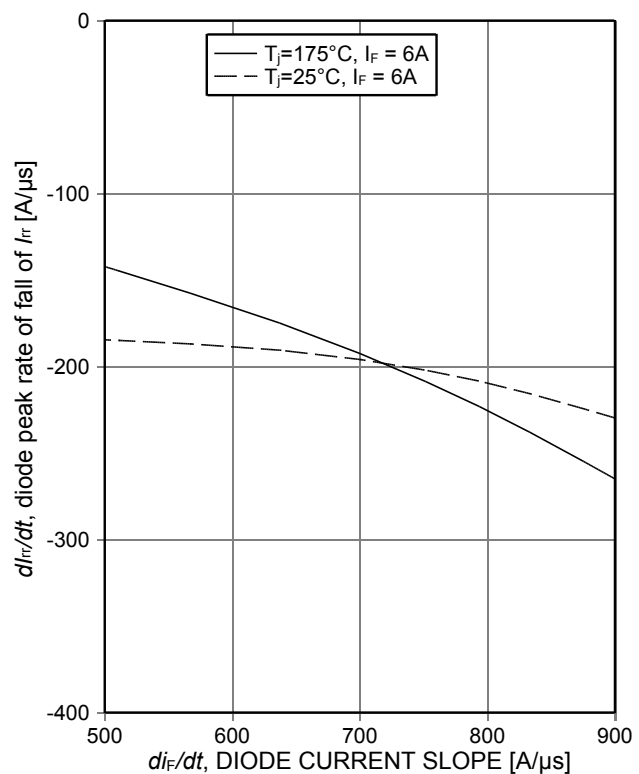


Figure 26. **Typical diode peak rate of fall of reverse recovery current as a function of diode current slope**  
( $V_R=400V$ )

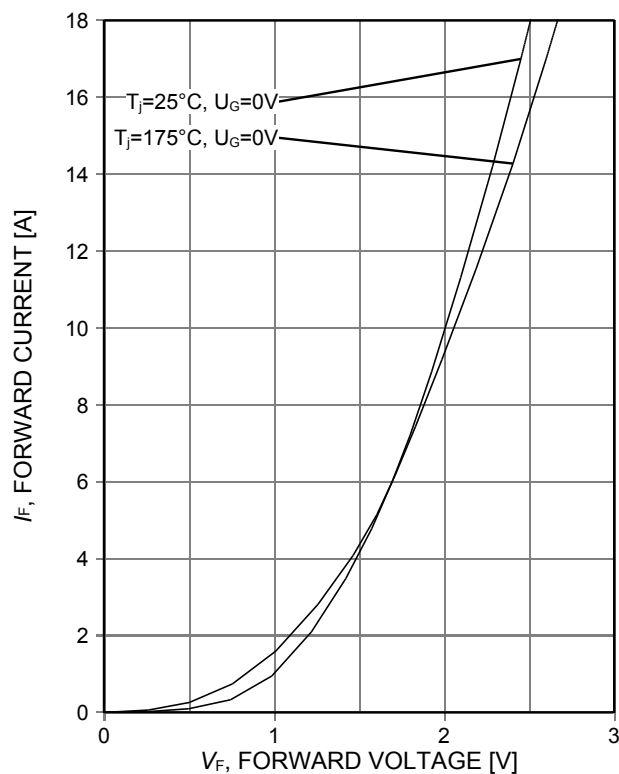


Figure 27. **Typical diode forward current as a function of forward voltage**

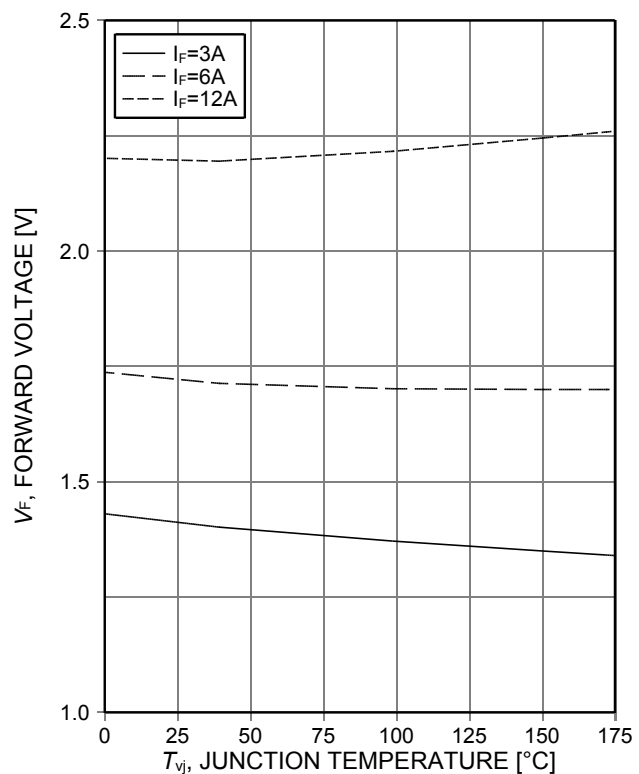


Figure 28. **Typical diode forward voltage as a function of junction temperature**

## TRENCHSTOP™ RC-Series for hard switching applications

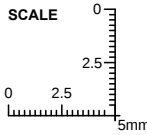
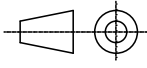
## Package Drawing PG-TO252-3



## NOTES:

1. ALL DIMENSIONS REFER TO JEDEC STANDARD TO-252 DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.

| DIM | MILLIMETERS |       |
|-----|-------------|-------|
|     | MIN         | MAX   |
| A   | 2.16        | 2.41  |
| A1  | 0.00        | 0.15  |
| b   | 0.64        | 0.89  |
| b2  | 0.65        | 1.15  |
| b3  | 4.95        | 5.50  |
| c   | 0.46        | 0.61  |
| c2  | 0.40        | 0.98  |
| D   | 5.97        | 6.22  |
| D1  | 5.02        | 5.84  |
| E   | 6.35        | 6.73  |
| E1  | 4.32        | 5.21  |
| e   | 2.29 (BSC)  |       |
| e1  | 4.57 (BSC)  |       |
| N   | 3           |       |
| H   | 9.40        | 10.48 |
| L   | 1.18        | 1.78  |
| L3  | 0.89        | 1.27  |
| L4  | 0.51        | 1.02  |

|                                                                                                                     |
|---------------------------------------------------------------------------------------------------------------------|
| <b>DOCUMENT NO.</b><br>Z8B00003328                                                                                  |
| <b>SCALE</b><br>               |
| <b>EUROPEAN PROJECTION</b><br> |
| <b>ISSUE DATE</b><br>05-02-2016                                                                                     |
| <b>REVISION</b><br>06                                                                                               |

## Testing Conditions

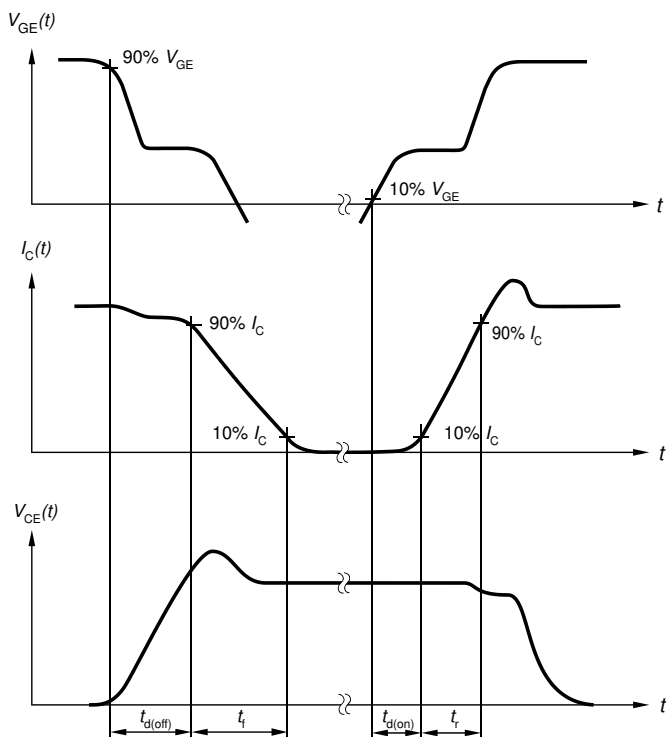


Figure A. Definition of switching times

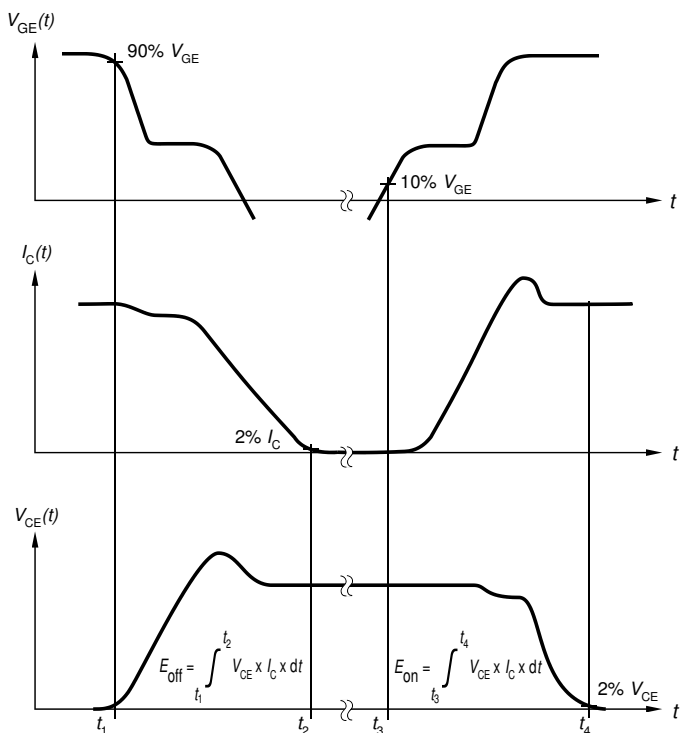


Figure B. Definition of switching losses

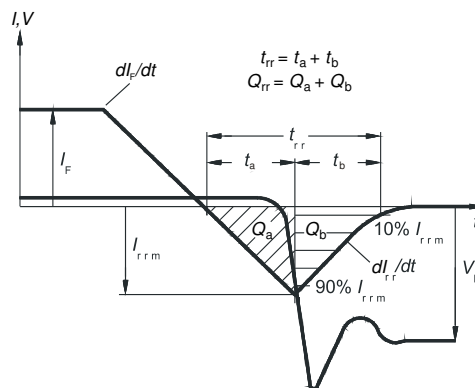


Figure C. Definition of diode switching characteristics

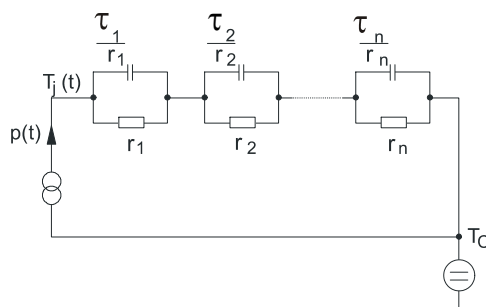


Figure D. Thermal equivalent circuit

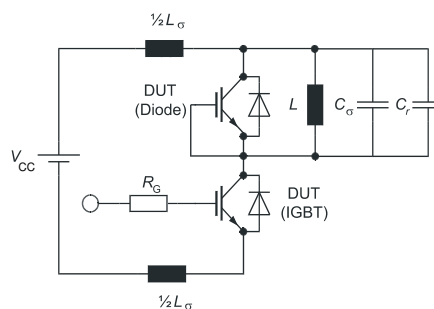


Figure E. **Dynamic test circuit**  
Parasitic inductance  $L_\sigma$ ,  
parasitic capacitor  $C_\sigma$ ,  
relief capacitor  $C_r$ ,  
(only for ZVT switching)

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TRENCHSTOP™ RC-Series for hard switching applications

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**Revision History**

IKD06N60R

**Revision: 2014-03-12, Rev. 2.5**

## Previous Revision

| Revision | Date       | Subjects (major changes since last revision) |
|----------|------------|----------------------------------------------|
| 1.2      | 2010-01-12 | -                                            |
| 2.1      | 2011-01-17 | Release of final datasheet                   |
| 2.2      | 2013-02-19 | Change package                               |
| 2.3      | 2013-12-10 | Neu value ICES max limit at 175°C            |
| 2.4      | 2014-02-26 | Without PB free logo                         |
| 2.5      | 2014-03-12 | Storage temp -55...+150°C                    |

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