

International

**IR** Rectifier

INSULATED GATE BIPOLAR TRANSISTOR WITH  
ULTRAFAST SOFT RECOVERY DIODE

PD-94576A

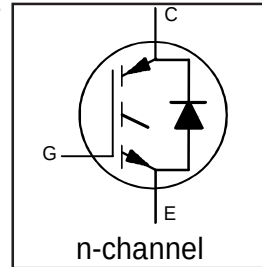
**IRGIB10B60KD1**

### Features

- Low VCE (on) Non Punch Through IGBT Technology.
- Low Diode VF.
- 10μs Short Circuit Capability.
- Square RBSOA.
- Ultrasoft Diode Reverse Recovery Characteristics.
- Positive VCE (on) Temperature Coefficient.
- Maximum Junction Temperature Rated at 175°C

### Benefits

- Benchmark Efficiency for Motor Control.
- Rugged Transient Performance.
- Low EMI.
- Excellent Current Sharing in Parallel Operation.



$V_{CES} = 600V$

$I_C = 10A, T_C = 100^\circ C$

$t_{sc} > 10\mu s, T_J = 150^\circ C$

$V_{CE(on)} \text{ typ.} = 1.7V$



TO-220  
Full-Pak

### Absolute Maximum Ratings

|                           | Parameter                                                    | Max.                              | Units      |
|---------------------------|--------------------------------------------------------------|-----------------------------------|------------|
| $V_{CES}$                 | Collector-to-Emitter Voltage                                 | 600                               | V          |
| $I_C @ T_C = 25^\circ C$  | Continuous Collector Current                                 | 16                                | A          |
| $I_C @ T_C = 100^\circ C$ | Continuous Collector Current                                 | 10                                |            |
| $I_{CM}$                  | Pulse Collector Current (Ref.Fig.C.T.5)                      | 32                                |            |
| $I_{LM}$                  | Clamped Inductive Load current ①                             | 32                                |            |
| $I_F @ T_C = 25^\circ C$  | Diode Continuous Forward Current                             | 16                                |            |
| $I_F @ T_C = 100^\circ C$ | Diode Continuous Forward Current                             | 10                                |            |
| $I_{FM}$                  | Diode Maximum Forward Current                                | 32                                | V          |
| $V_{ISOL}$                | RMS Isolation Voltage, Terminal to Case, $t = 1 \text{ min}$ | 2500                              |            |
| $V_{GE}$                  | Gate-to-Emitter Voltage                                      | $\pm 20$                          | W          |
| $P_D @ T_C = 25^\circ C$  | Maximum Power Dissipation                                    | 44                                |            |
| $P_D @ T_C = 100^\circ C$ | Maximum Power Dissipation                                    | 22                                | $^\circ C$ |
| $T_J$                     | Operating Junction and                                       | -55 to +175                       |            |
| $T_{STG}$                 | Storage Temperature Range                                    |                                   |            |
|                           | Soldering Temperature for 10 sec.                            | 300 (0.063 in. (1.6mm) from case) |            |
|                           | Mounting Torque, 6-32 or M3 Screw                            | 10 lbf.in (1.1N.m)                |            |

### Thermal / Mechanical Characteristics

|                 | Parameter                                 | Min. | Typ. | Max. | Units        |
|-----------------|-------------------------------------------|------|------|------|--------------|
| $R_{\theta JC}$ | Junction-to-Case- IGBT                    | —    | —    | 3.4  | $^\circ C/W$ |
| $R_{\theta JC}$ | Junction-to-Case- Diode                   | —    | —    | 5.3  |              |
| $R_{\theta CS}$ | Case-to-Sink, flat, greased surface       | —    | 0.50 | —    |              |
| $R_{\theta JA}$ | Junction-to-Ambient, typical socket mount | —    | —    | 62   |              |
| Wt              | Weight                                    | —    | 2.0  | —    | g            |

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2/27/04

# IRGIB10B60KD1

Electrical Characteristics @ T<sub>J</sub> = 25°C (unless otherwise specified)

International  
IR Rectifier

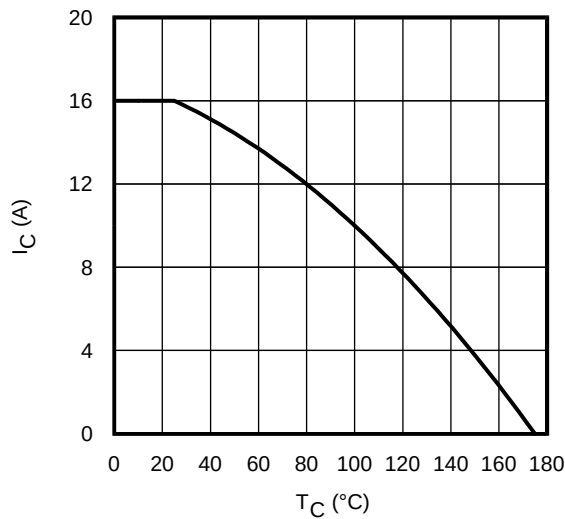
|                                        | Parameter                               | Min. | Typ. | Max. | Units | Conditions                                                            |
|----------------------------------------|-----------------------------------------|------|------|------|-------|-----------------------------------------------------------------------|
| V <sub>(BR)CES</sub>                   | Collector-to-Emitter Breakdown Voltage  | 600  | —    | —    | V     | V <sub>GE</sub> = 0V, I <sub>C</sub> = 500μA                          |
| ΔV <sub>(BR)CES</sub> /ΔT <sub>J</sub> | Temperature Coeff. of Breakdown Voltage | —    | 0.99 | —    | V/°C  | V <sub>GE</sub> = 0V, I <sub>C</sub> = 1mA (25°C-150°C)               |
| V <sub>CE(on)</sub>                    | Collector-to-Emitter Voltage            | 1.50 | 1.70 | 2.10 | V     | I <sub>C</sub> = 10A, V <sub>GE</sub> = 15V, T <sub>J</sub> = 25°C    |
|                                        |                                         | —    | 2.05 | 2.35 |       | I <sub>C</sub> = 10A, V <sub>GE</sub> = 15V, T <sub>J</sub> = 150°C   |
|                                        |                                         | —    | 2.06 | 2.35 |       | I <sub>C</sub> = 10A, V <sub>GE</sub> = 15V, T <sub>J</sub> = 175°C   |
| V <sub>GE(th)</sub>                    | Gate Threshold Voltage                  | 3.5  | 4.5  | 5.5  | V     | V <sub>CE</sub> = V <sub>GE</sub> , I <sub>C</sub> = 250μA            |
| ΔV <sub>GE(th)</sub> /ΔT <sub>J</sub>  | Threshold Voltage temp. coefficient     | —    | -10  | —    | mV/°C | V <sub>CE</sub> = V <sub>GE</sub> , I <sub>C</sub> = 1mA (25°C-150°C) |
| g <sub>fe</sub>                        | Forward Transconductance                | —    | 5.0  | —    | S     | V <sub>CE</sub> = 50V, I <sub>C</sub> = 10A, PW = 80μs                |
| I <sub>CES</sub>                       | Zero Gate Voltage Collector Current     | —    | 1.0  | 150  | μA    | V <sub>GE</sub> = 0V, V <sub>CE</sub> = 600V                          |
|                                        |                                         | —    | 90   | 250  |       | V <sub>GE</sub> = 0V, V <sub>CE</sub> = 600V, T <sub>J</sub> = 150°C  |
|                                        |                                         | —    | 150  | 400  |       | V <sub>GE</sub> = 0V, V <sub>CE</sub> = 600V, T <sub>J</sub> = 175°C  |
| V <sub>FM</sub>                        | Diode Forward Voltage Drop              | —    | 1.80 | 2.40 | V     | I <sub>F</sub> = 5.0A, V <sub>GE</sub> = 0V                           |
|                                        |                                         | —    | 1.32 | 1.74 |       | I <sub>F</sub> = 5.0A, V <sub>GE</sub> = 0V, T <sub>J</sub> = 150°C   |
|                                        |                                         | —    | 1.23 | 1.62 |       | I <sub>F</sub> = 5.0A, V <sub>GE</sub> = 0V, T <sub>J</sub> = 175°C   |
| I <sub>GES</sub>                       | Gate-to-Emitter Leakage Current         | —    | —    | ±100 | nA    | V <sub>GE</sub> = ±20V, V <sub>CE</sub> = 0V                          |

Switching Characteristics @ T<sub>J</sub> = 25°C (unless otherwise specified)

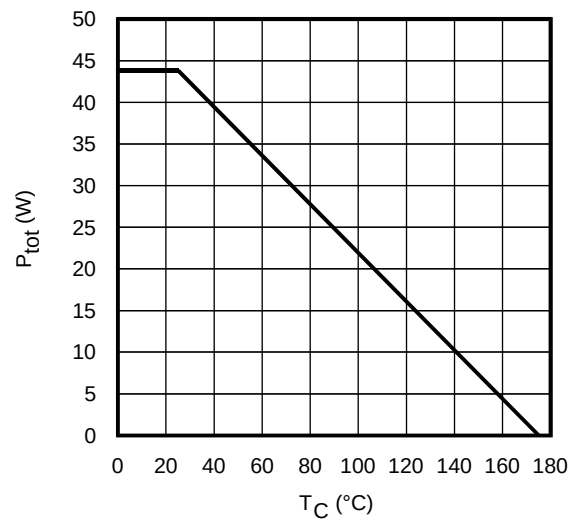
|                        | Parameter                            | Min.        | Typ. | Max. | Units | Conditions                                                                                                                                                  |
|------------------------|--------------------------------------|-------------|------|------|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Q <sub>g</sub>         | Total Gate Charge (turn-on)          | —           | 41   | 62   | nC    | I <sub>C</sub> = 10A<br>V <sub>CC</sub> = 400V<br>V <sub>GE</sub> = 15V                                                                                     |
| Q <sub>ge</sub>        | Gate-to-Emitter Charge (turn-on)     | —           | 4.6  | 6.9  |       |                                                                                                                                                             |
| Q <sub>gc</sub>        | Gate-to-Collector Charge (turn-on)   | —           | 19   | 29   |       |                                                                                                                                                             |
| E <sub>on</sub>        | Turn-On Switching Loss               | —           | 156  | 264  | μJ    | I <sub>C</sub> = 10A, V <sub>CC</sub> = 400V<br>V <sub>GE</sub> = 15V, R <sub>G</sub> = 50Ω, L = 1.07mH<br>L <sub>S</sub> = 150nH, T <sub>J</sub> = 25°C ②  |
| E <sub>off</sub>       | Turn-Off Switching Loss              | —           | 165  | 273  |       |                                                                                                                                                             |
| E <sub>tot</sub>       | Total Switching Loss                 | —           | 321  | 434  |       |                                                                                                                                                             |
| t <sub>d(on)</sub>     | Turn-On delay time                   | —           | 25   | 33   | ns    | I <sub>C</sub> = 10A, V <sub>CC</sub> = 400V<br>V <sub>GE</sub> = 15V, R <sub>G</sub> = 50Ω, L = 1.1mH<br>L <sub>S</sub> = 150nH, T <sub>J</sub> = 25°C     |
| t <sub>r</sub>         | Rise time                            | —           | 24   | 34   |       |                                                                                                                                                             |
| t <sub>d(off)</sub>    | Turn-Off delay time                  | —           | 180  | 250  |       |                                                                                                                                                             |
| t <sub>f</sub>         | Fall time                            | —           | 62   | 87   | μJ    | I <sub>C</sub> = 10A, V <sub>CC</sub> = 400V<br>V <sub>GE</sub> = 15V, R <sub>G</sub> = 50Ω, L = 1.07mH<br>L <sub>S</sub> = 150nH, T <sub>J</sub> = 150°C ② |
| E <sub>on</sub>        | Turn-On Switching Loss               | —           | 261  | 372  |       |                                                                                                                                                             |
| E <sub>off</sub>       | Turn-Off Switching Loss              | —           | 313  | 425  |       |                                                                                                                                                             |
| E <sub>tot</sub>       | Total Switching Loss                 | —           | 574  | 694  | ns    | I <sub>C</sub> = 8.0A, V <sub>CC</sub> = 400V<br>V <sub>GE</sub> = 15V, R <sub>G</sub> = 50Ω, L = 1.07mH<br>L <sub>S</sub> = 150nH, T <sub>J</sub> = 150°C  |
| t <sub>d(on)</sub>     | Turn-On delay time                   | —           | 22   | 31   |       |                                                                                                                                                             |
| t <sub>r</sub>         | Rise time                            | —           | 24   | 34   |       |                                                                                                                                                             |
| t <sub>d(off)</sub>    | Turn-Off delay time                  | —           | 240  | 340  | nH    | Measured 5 mm from package                                                                                                                                  |
| t <sub>f</sub>         | Fall time                            | —           | 48   | 67   |       |                                                                                                                                                             |
| L <sub>E</sub>         | Internal Emitter Inductance          | —           | 7.5  | —    |       |                                                                                                                                                             |
| C <sub>ies</sub>       | Input Capacitance                    | —           | 610  | 915  | pF    | V <sub>GE</sub> = 0V<br>V <sub>CC</sub> = 30V<br>f = 1.0MHz                                                                                                 |
| C <sub>oes</sub>       | Output Capacitance                   | —           | 66   | 99   |       |                                                                                                                                                             |
| C <sub>res</sub>       | Reverse Transfer Capacitance         | —           | 23   | 35   |       |                                                                                                                                                             |
| RBSOA                  | Reverse Bias Safe Operating Area     | FULL SQUARE |      |      |       | T <sub>J</sub> = 150°C, I <sub>C</sub> = 32A, V <sub>p</sub> = 600V<br>V <sub>CC</sub> = 500V, V <sub>GE</sub> = +15V to 0V, R <sub>G</sub> = 50Ω           |
| SCSOA                  | Short Circuit Safe Operating Area    | 10          | —    | —    | μs    | T <sub>J</sub> = 150°C, V <sub>p</sub> = 600V, R <sub>G</sub> = 50Ω<br>V <sub>CC</sub> = 360V, V <sub>GE</sub> = +15V to 0V                                 |
| I <sub>SC (PEAK)</sub> | Peak Short Circuit Collector Current | —           | 100  | —    | A     |                                                                                                                                                             |
| E <sub>rec</sub>       | Reverse Recovery Energy of the Diode | —           | 99   | 128  | μJ    | T <sub>J</sub> = 150°C                                                                                                                                      |
| t <sub>rr</sub>        | Diode Reverse Recovery Time          | —           | 79   | 103  | ns    | V <sub>CC</sub> = 400V, I <sub>F</sub> = 10A, L = 1.07mH                                                                                                    |
| I <sub>rr</sub>        | Peak Reverse Recovery Current        | —           | 14   | 18   | A     | V <sub>GE</sub> = 15V, R <sub>G</sub> = 50Ω                                                                                                                 |
| Q <sub>rr</sub>        | Diode Reverse Recovery Charge        | —           | 553  | 719  | nC    | di/dt = 500A/μs                                                                                                                                             |

① V<sub>CC</sub> = 80% (V<sub>CES</sub>), V<sub>GE</sub> = 20V, L = 100μH, R<sub>G</sub> = 50Ω.

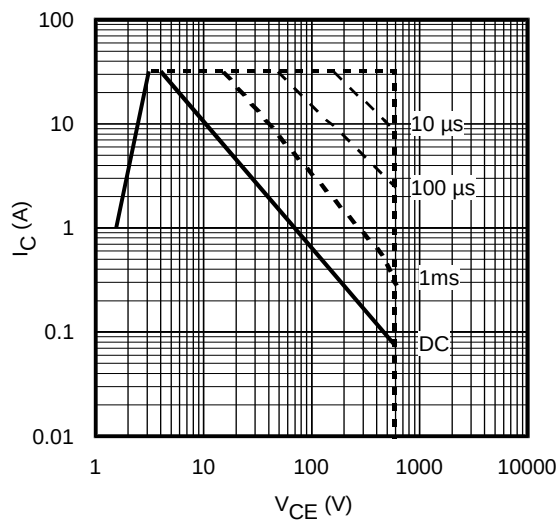
② Energy losses include "tail" and diode reverse recovery.



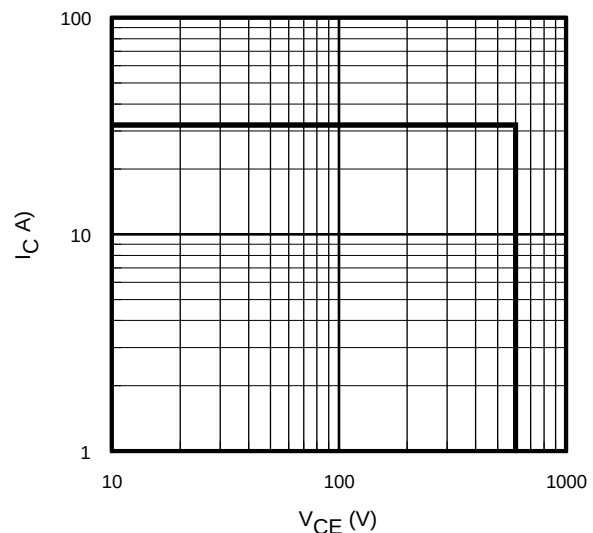
**Fig. 1** - Maximum DC Collector Current vs. Case Temperature



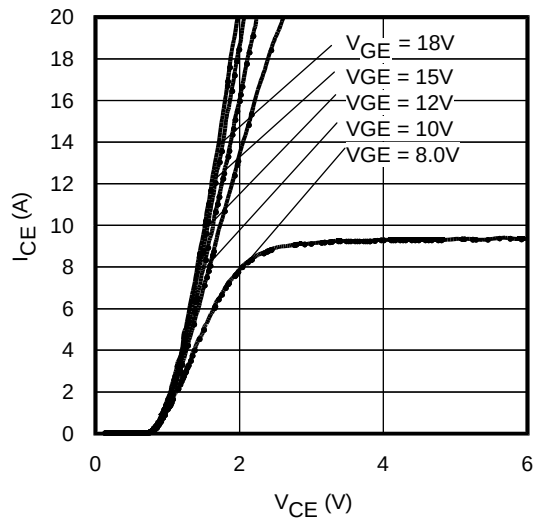
**Fig. 2** - Power Dissipation vs. Case Temperature



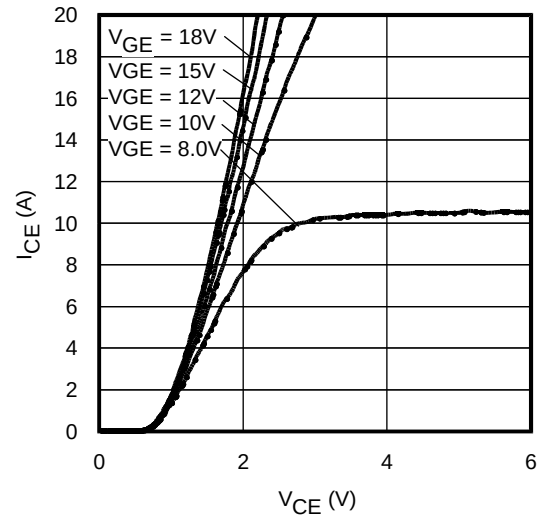
**Fig. 3** - Forward SOA  
 $T_C = 25^\circ\text{C}$ ;  $T_J \leq 175^\circ\text{C}$



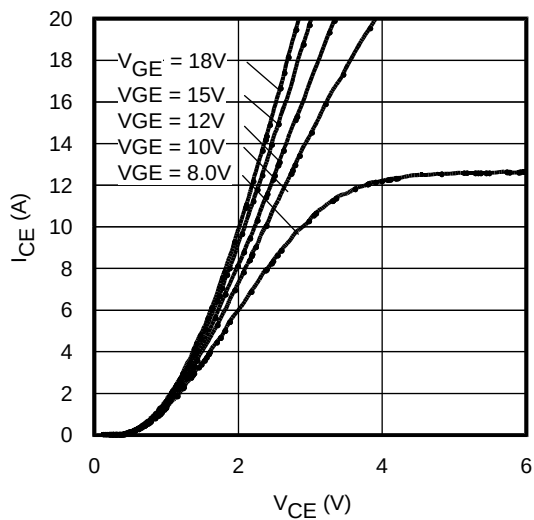
**Fig. 4** - Reverse Bias SOA  
 $T_J = 150^\circ\text{C}$ ;  $V_{GE} = 15\text{V}$



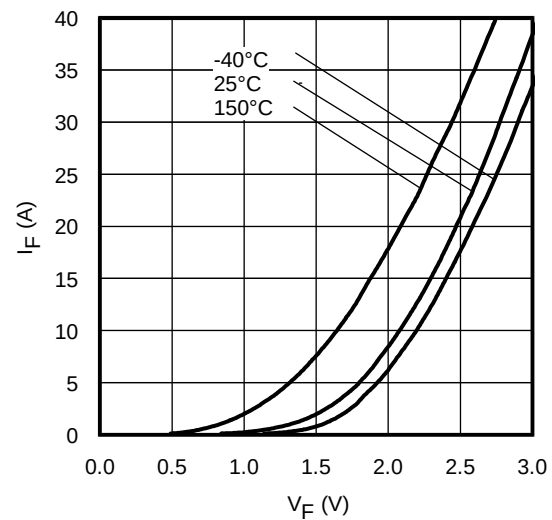
**Fig. 5** - Typ. IGBT Output Characteristics  
 $T_j = -40^\circ\text{C}$ ;  $t_p = 80\mu\text{s}$



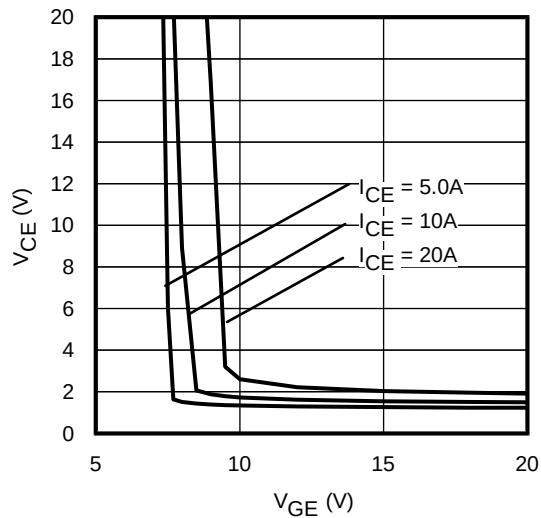
**Fig. 6** - Typ. IGBT Output Characteristics  
 $T_j = 25^\circ\text{C}$ ;  $t_p = 80\mu\text{s}$



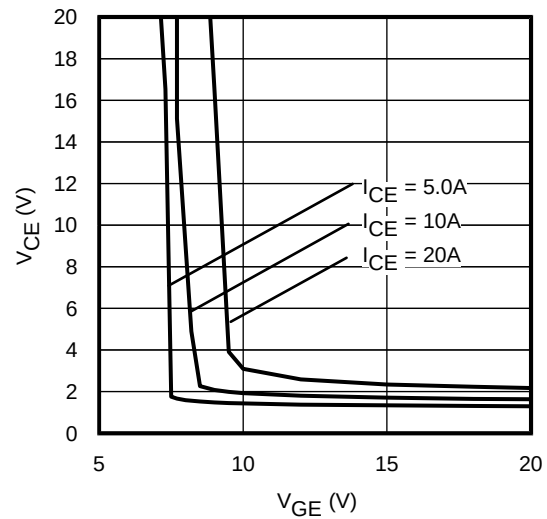
**Fig. 7** - Typ. IGBT Output Characteristics  
 $T_j = 150^\circ\text{C}$ ;  $t_p = 80\mu\text{s}$



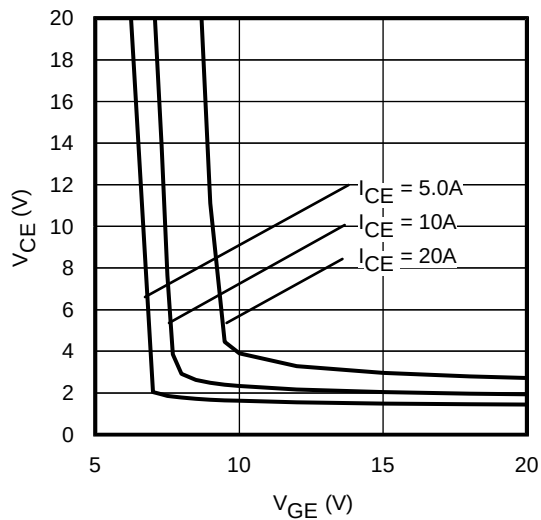
**Fig. 8** - Typ. Diode Forward Characteristics  
 $t_p = 80\mu\text{s}$



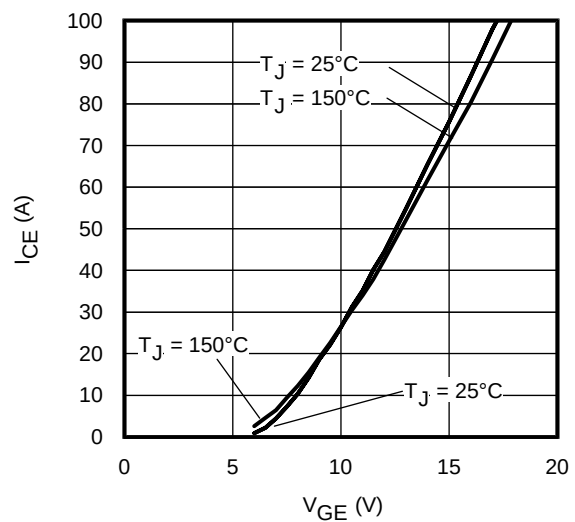
**Fig. 9** - Typical  $V_{CE}$  vs.  $V_{GE}$   
 $T_J = -40^\circ\text{C}$



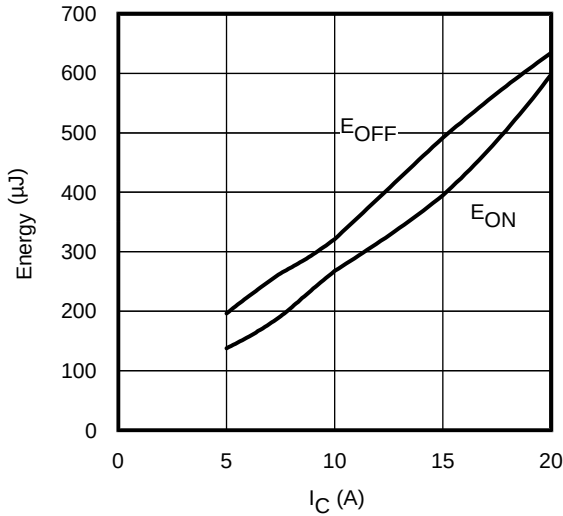
**Fig. 10** - Typical  $V_{CE}$  vs.  $V_{GE}$   
 $T_J = 25^\circ\text{C}$



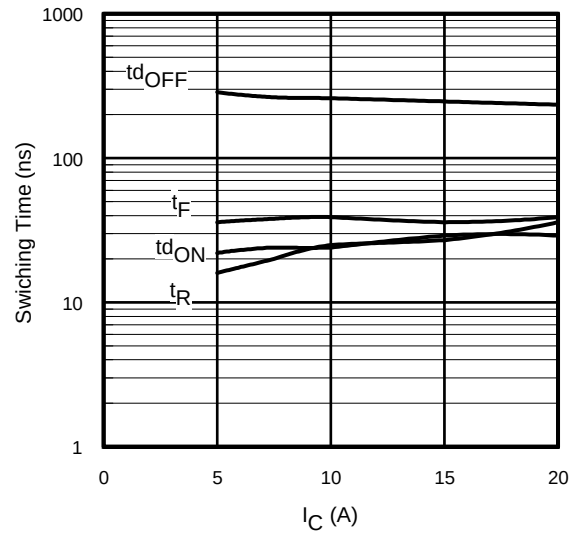
**Fig. 11** - Typical  $V_{CE}$  vs.  $V_{GE}$   
 $T_J = 150^\circ\text{C}$



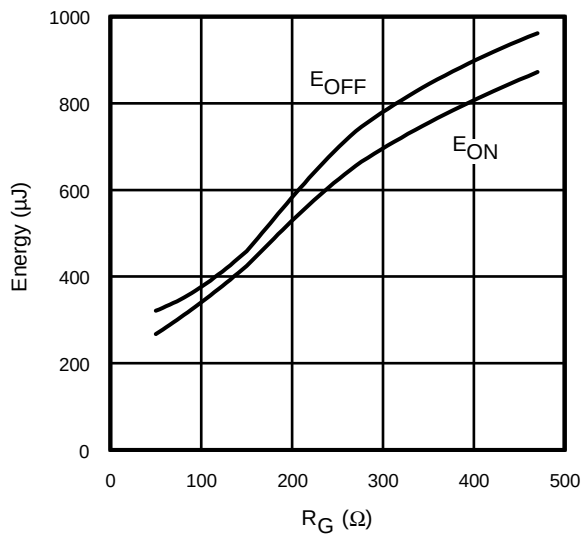
**Fig. 12** - Typ. Transfer Characteristics  
 $V_{CE} = 50\text{V}$ ;  $t_p = 10\mu\text{s}$



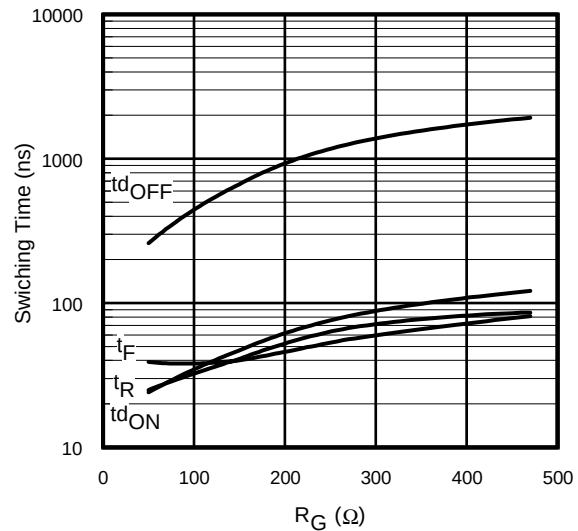
**Fig. 13** - Typ. Energy Loss vs.  $I_C$   
 $T_J = 150^\circ\text{C}$ ;  $L = 1.07\text{mH}$ ;  $V_{CE} = 400\text{V}$   
 $R_G = 50\Omega$ ;  $V_{GE} = 15\text{V}$



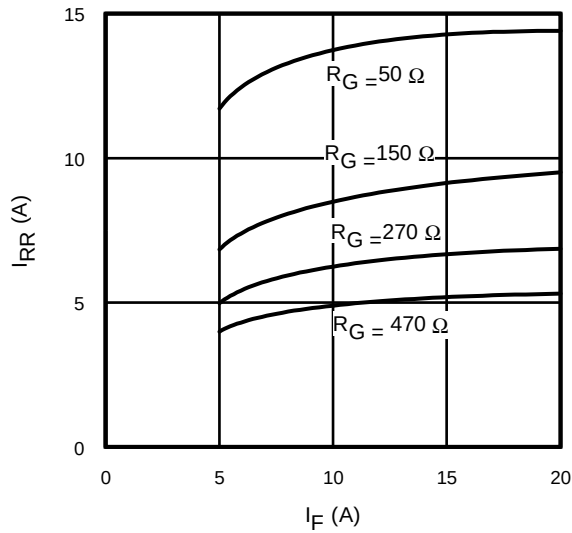
**Fig. 14** - Typ. Switching Time vs.  $I_C$   
 $T_J = 150^\circ\text{C}$ ;  $L = 1.07\text{mH}$ ;  $V_{CE} = 400\text{V}$   
 $R_G = 50\Omega$ ;  $V_{GE} = 15\text{V}$



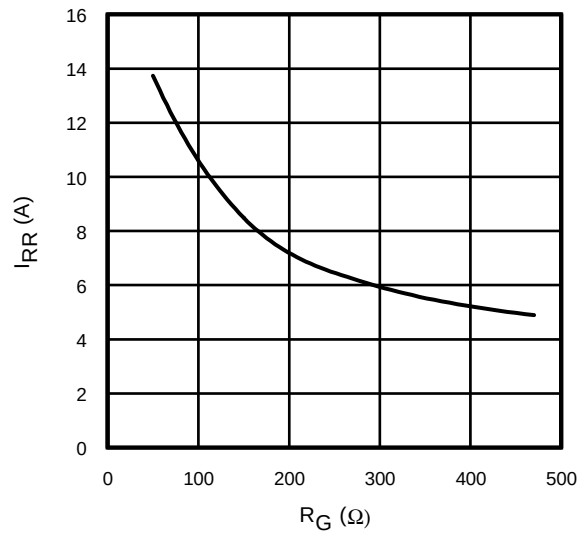
**Fig. 15** - Typ. Energy Loss vs.  $R_G$   
 $T_J = 150^\circ\text{C}$ ;  $L = 1.07\text{mH}$ ;  $V_{CE} = 400\text{V}$   
 $I_{CE} = 10\text{A}$ ;  $V_{GE} = 15\text{V}$



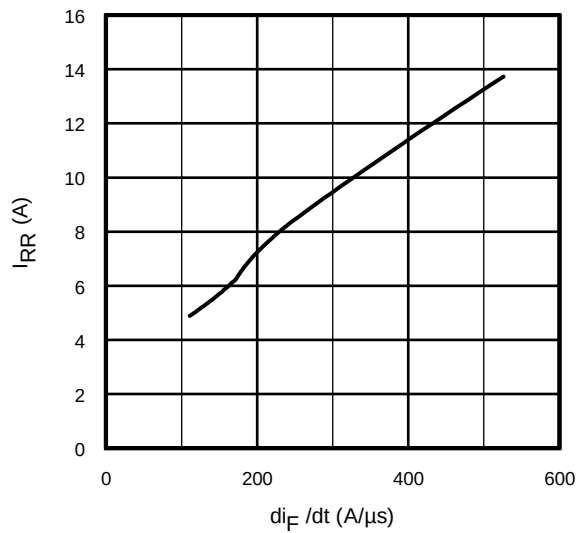
**Fig. 16** - Typ. Switching Time vs.  $R_G$   
 $T_J = 150^\circ\text{C}$ ;  $L = 1.07\text{mH}$ ;  $V_{CE} = 400\text{V}$   
 $I_{CE} = 10\text{A}$ ;  $V_{GE} = 15\text{V}$



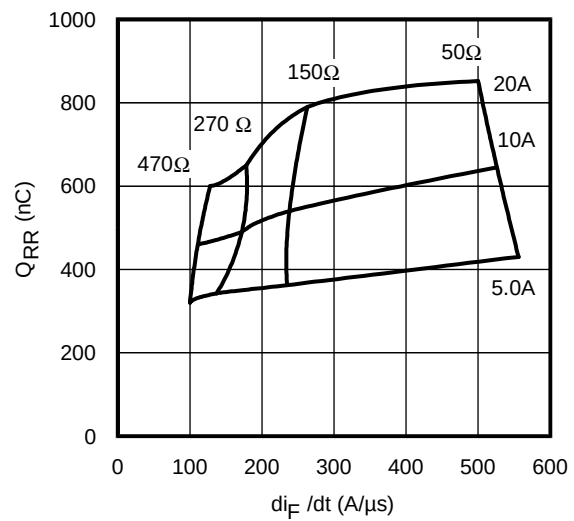
**Fig. 17** - Typical Diode  $I_{RR}$  vs.  $I_F$   
 $T_J = 150^\circ\text{C}$



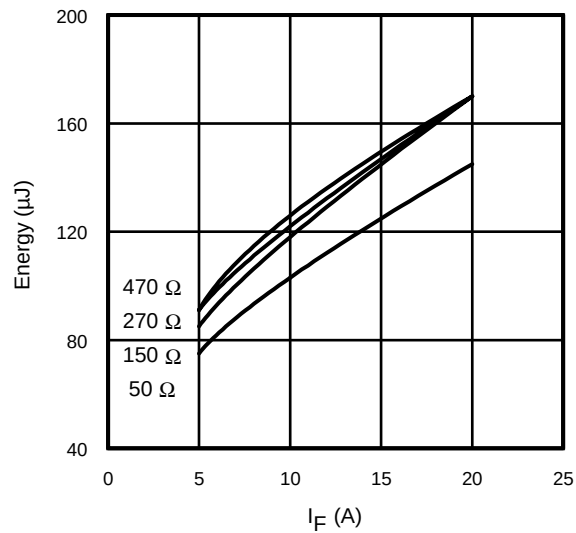
**Fig. 18** - Typical Diode  $I_{RR}$  vs.  $R_G$   
 $T_J = 150^\circ\text{C}$ ;  $I_F = 10\text{A}$



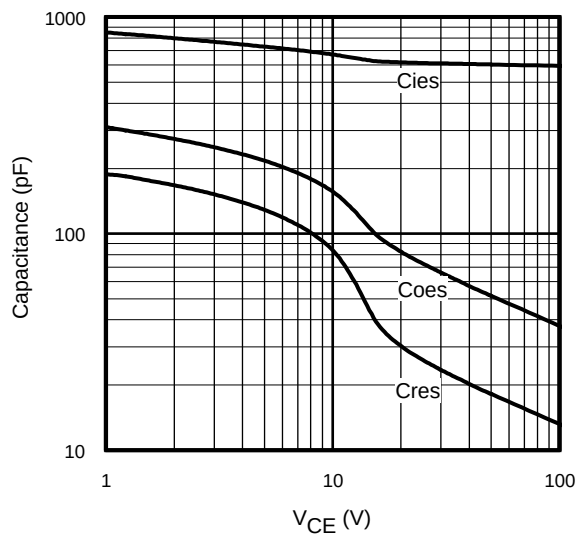
**Fig. 19** - Typical Diode  $I_{RR}$  vs.  $di_F/dt$   
 $V_{CC} = 400\text{V}$ ;  $V_{GE} = 15\text{V}$ ;  
 $I_{CE} = 10\text{A}$ ;  $T_J = 150^\circ\text{C}$



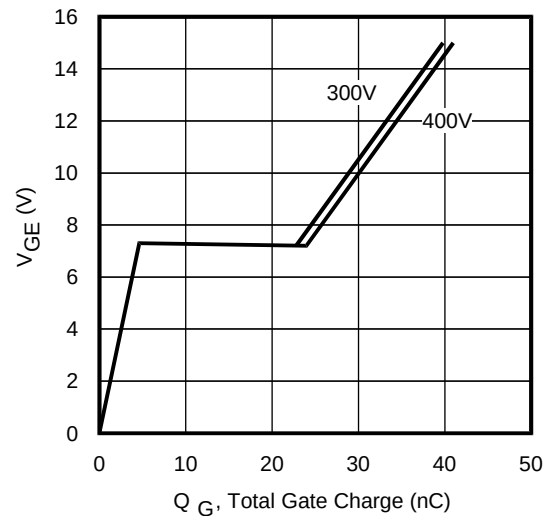
**Fig. 20** - Typical Diode  $Q_{RR}$   
 $V_{CC} = 400\text{V}$ ;  $V_{GE} = 15\text{V}$ ;  $T_J = 150^\circ\text{C}$



**Fig. 21** - Typical Diode  $E_{RR}$  vs.  $I_F$   
 $T_J = 150^\circ\text{C}$

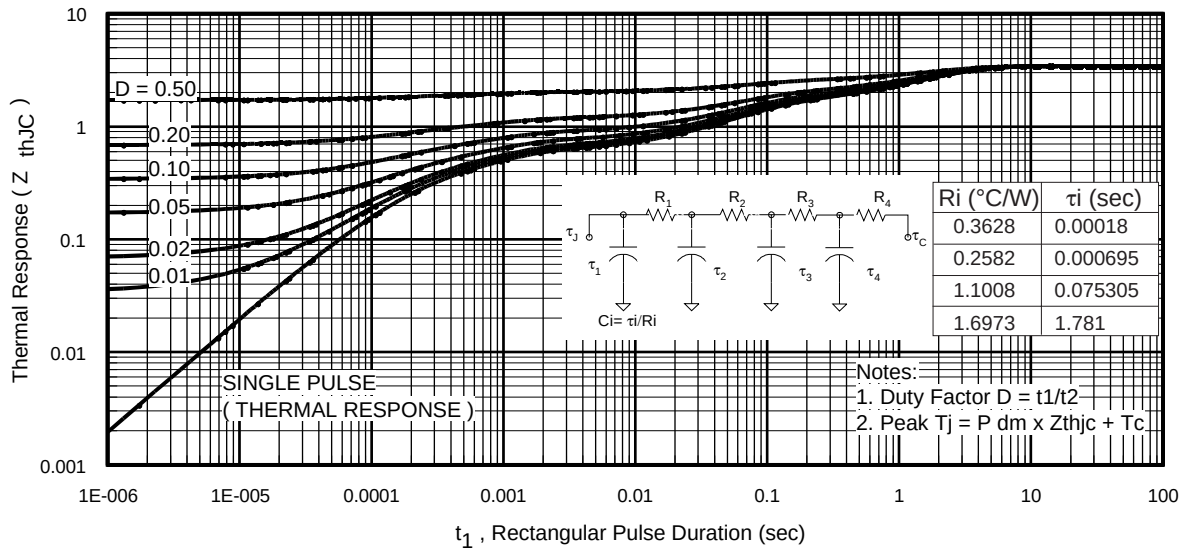


**Fig. 22**- Typ. Capacitance vs.  $V_{CE}$   
 $V_{GE} = 0\text{V}$ ;  $f = 1\text{MHz}$

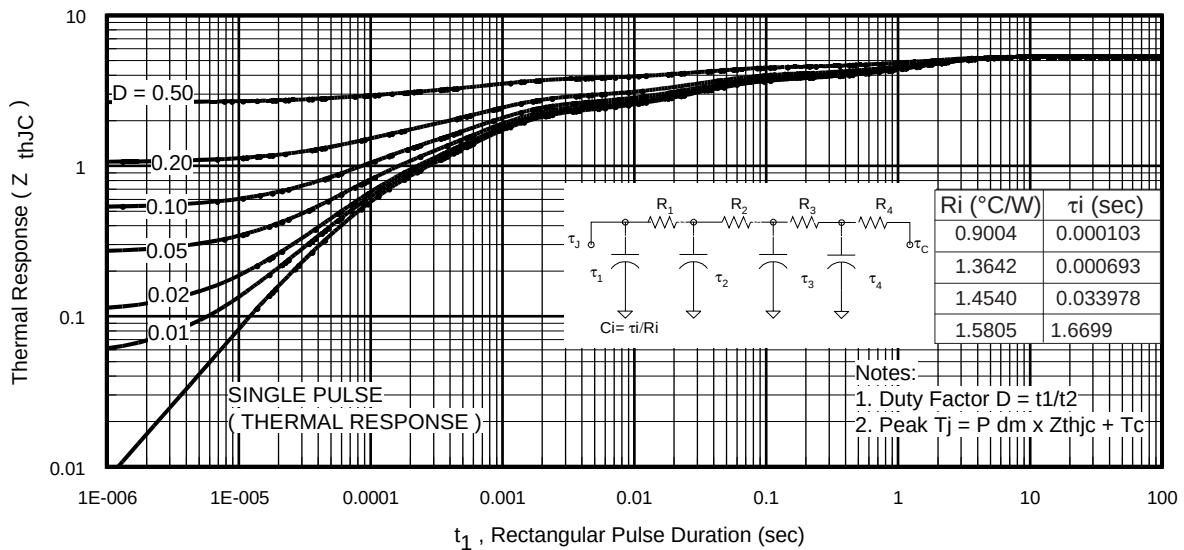


**Fig. 23** - Typical Gate Charge vs.  $V_{GE}$   
 $I_{CE} = 10\text{A}$ ;  $L = 2500\mu\text{H}$





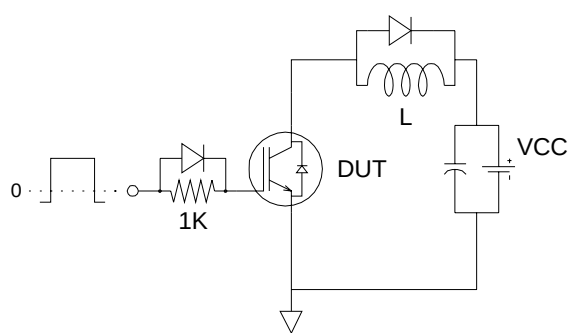
**Fig 24.** Maximum Transient Thermal Impedance, Junction-to-Case (IGBT)



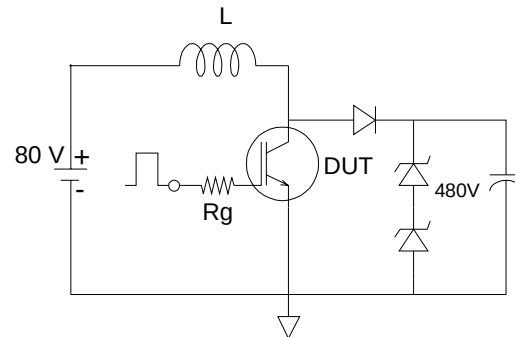
**Fig 25.** Maximum Transient Thermal Impedance, Junction-to-Case (DIODE)

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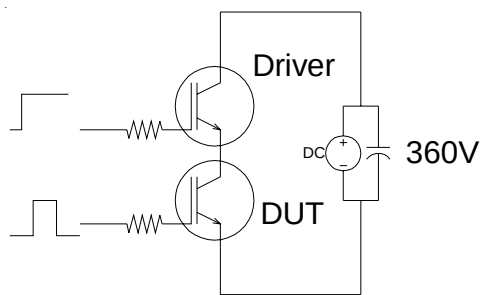
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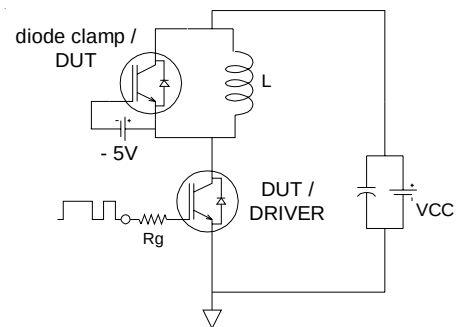
**Fig.C.T.1 - Gate Charge Circuit (turn-off)**



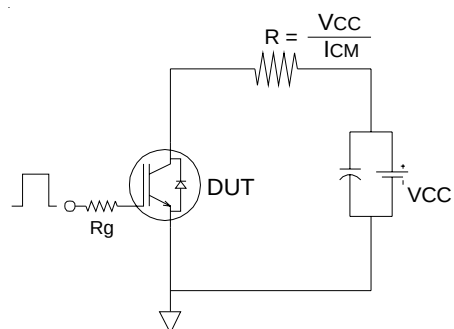
**Fig.C.T.2 - RBSOA Circuit**



**Fig.C.T.3 - S.C.SOA Circuit**



**Fig.C.T.4 - Switching Loss Circuit**



**Fig.C.T.5 - Resistive Load Circuit**

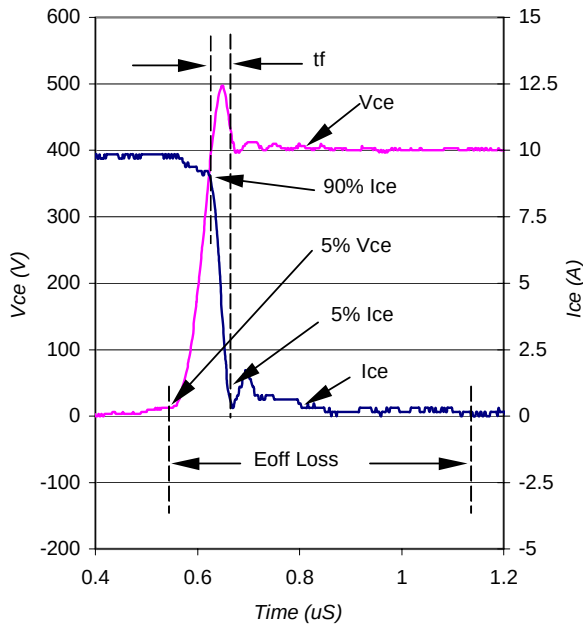


Fig. WF1- Typ. Turn-off Loss Waveform  
@  $T_J = 150^{\circ}\text{C}$  using Fig. CT.4

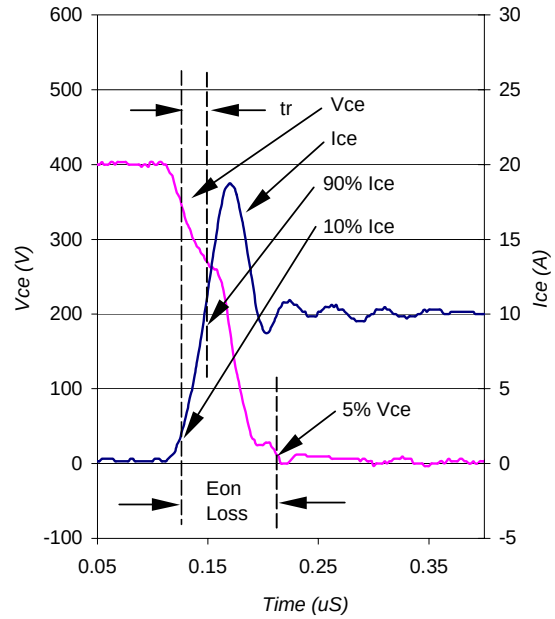


Fig. WF2- Typ. Turn-on Loss Waveform  
@  $T_J = 150^{\circ}\text{C}$  using Fig. CT.4

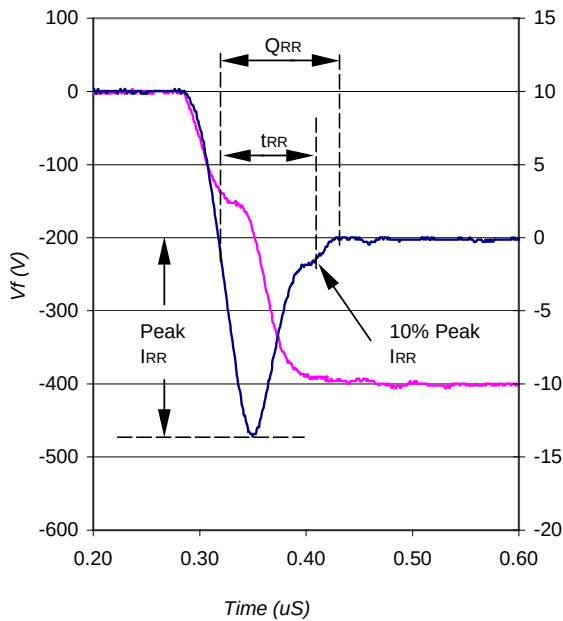


Fig. WF3- Typ. Diode Recovery Waveform  
@  $T_J = 150^{\circ}\text{C}$  using Fig. CT.4

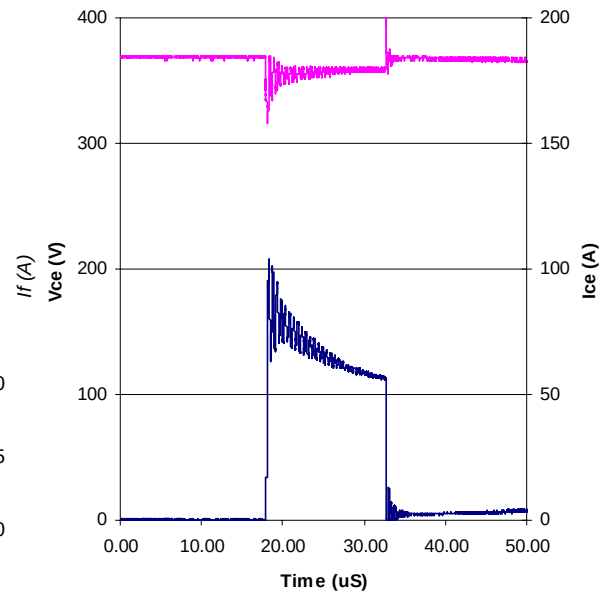


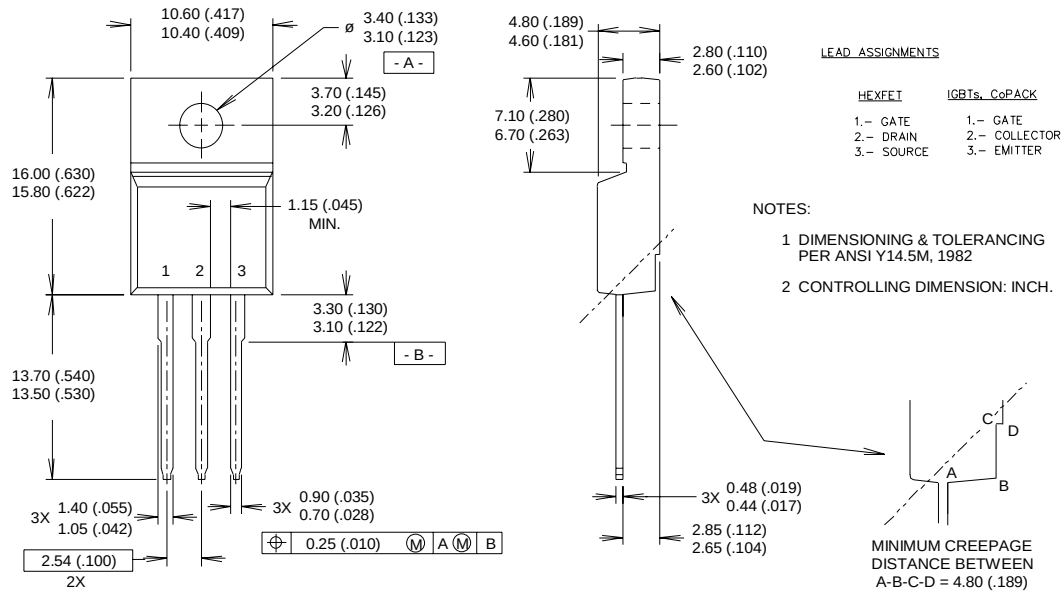
Fig. WF4- Typ. S.C Waveform  
@  $T_C = 150^{\circ}\text{C}$  using Fig. CT.3

# IRGIB10B60KD1

International  
**IR** Rectifier

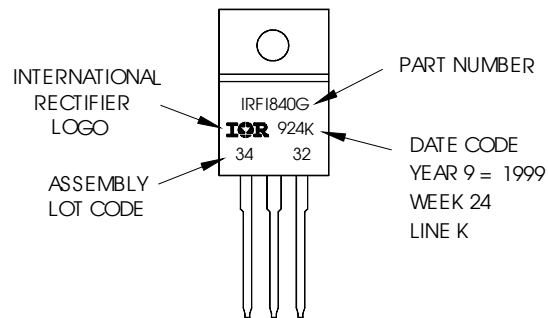
## TO-220 Full-Pak Package Outline

Dimensions are shown in millimeters (inches)



## TO-220 Full-Pak Part Marking Information

EXAMPLE: THIS IS AN IRF1840G  
WITH ASSEMBLY  
LOT CODE 3432  
ASSEMBLED ON WW 24 1999  
IN THE ASSEMBLY LINE "K"



TO-220 Full-Pak package is not recommended for Surface Mount Application

Data and specifications subject to change without notice.  
This product has been designed and qualified for the Industrial market.  
Qualification Standards can be found on IR's Web site.

International  
**IR** Rectifier

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Visit us at [www.irf.com](http://www.irf.com) for sales contact information.2/04

[www.irf.com](http://www.irf.com)

Note: For the most current drawings please refer to the IR website at:  
<http://www.irf.com/package/>