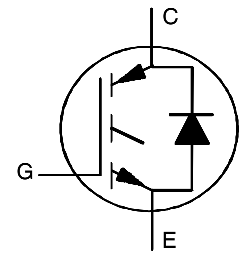
# IRGR4045DPbF

INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE




n-channel

$V_{CES}$ = 600V

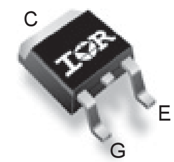
$I_C$ = 6.0A, $T_C$ = 100°C

$T_{jmax}$ = 175°C

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

### Features

- Low $V_{CE\ (on)}$ Trench IGBT Technology
- Low Switching Losses
- Maximum Junction temperature 175 °C
- 5μs SCSOA
- Square RBSOA
- 100% of the parts tested for $I_{LM}$ ①
- Positive $V_{CE\ (on)}$ Temperature Coefficient.
- Ultra Fast Soft Recovery Co-pak Diode
- Tighter Distribution of Parameters
- Lead-Free, RoHS Compliant




D-Pak
IRGR4045DPbF

| G | C | E |
|---|---|---|
| Gate | Colletor | Emitter |

### Benefits

- High Efficiency in a Wide Range of Applications
- Suitable for a Wide Range of Switching Frequencies due to Low $V_{CE\ (ON)}$ and Low Switching Losses
- Rugged Transient Performance for Increased Reliability
- Excellent Current Sharing in Parallel Operation
- Low EMI

## Absolute Maximum Ratings

| | Parameter | Max. | Units |
|---|---|---|---|
| $V_{CES}$ | Collector-to-Emitter Breakdown Voltage | 600 | V |
| $I_C$ @ $T_C$ = 25°C | Continuous Collector Current | 12 | |
| $I_C$ @ $T_C$ = 100°C | Continuous Collector Current | 6.0 | |
| $I_{CM}$ | Pulsed Collector Current, $V_{GE}$ = 15V | 18 | |
| $I_{LM}$ | Clamped Inductive Load Current, $V_{GE}$ = 20V ① | 24 | A |
| $I_F$@$T_C$=25°C | Diode Continuous Forward Current | 8.0 | |
| $I_F$@$T_C$=100°C | Diode Continuous Forward Current | 4.0 | |
| $I_{FM}$ | Diode Maximum Forward Current ② | 24 | |
| $V_{GE}$ | Continuous Gate-to-Emitter Voltage | ± 20 | V |
| | Transient Gate-to-Emitter Voltage | ± 30 | |
| $P_D$ @ $T_C$ =25° | Maximum Power Dissipation | 77 | W |
| $P_D$ @ $T_C$ =100° | Maximum Power Dissipation | 39 | |
| $T_J$<br>$T_{STG}$ | Operating Junction and<br>Storage Temperature Range | -55 to + 175 | °C |
| | Soldering Temperature, for 10 seconds | 300 (0.063 in. (1.6mm) from case) | |

## Thermal Resistance

| | Parameter | Min. | Typ. | Max. | Units |
|---|---|---|---|---|---|
| $R_{\theta JC}$ | Junction-to-Case - IGBT ③ | ––– | ––– | 1.9 | |
| $R_{\theta JC}$ | Junction-to-Case - Diode ③ | ––– | ––– | 6.8 | °C/W |
| $R_{\theta JA}$ | Junction-to-Ambient (PCB Mount) ⑤ | ––– | ––– | 50 | |
| $R_{\theta JA}$ | Junction-to-Ambient | ––– | ––– | 110 | |

*Qualification standards can be found at http://www.irf.com/

### Electrical Characteristics @ $T_J$ = 25°C (unless otherwise specified)

| | Parameter | Min. | Typ. | Max. | Units | Conditions | Ref.Fig |
|---|---|---|---|---|---|---|---|
| $V_{(BR)CES}$ | Collector-to-Emitter Breakdown Voltage | 600 | — | — | V | $V_{GE}$ = 0V, $I_c$ =100 μA ④ | CT 6 |
| $\Delta V_{(BR)CES}/\Delta T_J$ | Temperature Coeff. of Breakdown Voltage | — | 0.36 | — | V/°C | $V_{GE}$ = 0V, $I_c$ = 250μA ( 25 -175 °C ) ④ | |
| $V_{CE(on)}$ | Collector-to-Emitter Saturation Voltage | — | 1.7 | 2.0 | V | $I_C$ = 6.0A, $V_{GE}$ = 15V, $T_J$ = 25°C | 5,6,7,9, 10 ,11 |
| | | — | 2.07 | — | | $I_C$ = 6.0A, $V_{GE}$ = 15V, $T_J$ = 150°C | |
| | | — | 2.14 | — | | $I_C$ = 6.0A, $V_{GE}$ = 15V, $T_J$ = 175°C | |
| $V_{GE(th)}$ | Gate Threshold Voltage | 3.5 | — | 6.5 | V | $V_{CE}$ = $V_{GE}$, $I_C$ = 150μA | 9,10,11,12 |
| $\Delta V_{GE(th)}/\Delta TJ$ | Threshold Voltage temp. coefficient | — | -13 | — | mV/°C | $V_{CE}$ = $V_{GE}$, $I_C$ = 250μA ( 25 -175 °C ) | |
| gfe | Forward Transconductance | — | 5.8 | — | S | $V_{CE}$ = 25V, $I_C$ = 6.0A, PW =80μs | |
| $I_{CES}$ | Collector-to-Emitter Leakage Current | — | — | 25 | μA | $V_{GE}$ = 0V, $V_{CE}$ = 600V | 8 |
| | | — | — | 250 | | $V_{GE}$ = 0V, $V_{CE}$ = 600V, $T_J$ =175°C | |
| $V_{FM}$ | Diode Forward Voltage Drop | — | 1.60 | 2.30 | V | $I_F$ = 6.0A | |
| | | — | 1.30 | — | | $I_F$ = 6.0A, $T_J$ = 175°C | |
| $I_{GES}$ | Gate-to-Emitter Leakage Current | — | — | ±100 | nA | $V_{GE}$ = ± 20 V | |

### Switching Characteristics @ $T_J$ = 25°C (unless otherwise specified)

| | Parameter | Min. | Typ. | Max.⑥ | Units | Conditions | Ref.Fig |
|---|---|---|---|---|---|---|---|
| $Q_g$ | Total Gate Charge (turn-on) | — | 13 | 19.5 | nC | $I_C$ = 6.0A | 24 |
| $Q_{ge}$ | Gate-to-Emitter Charge (turn-on) | — | 3.1 | 4.65 | | $V_{CC}$ = 400V | CT 1 |
| $Q_{gc}$ | Gate-to-Collector Charge (turn-on) | — | 6.4 | 9.6 | | $V_{GE}$ = 15V | |
| $E_{on}$ | Turn-On Switching Loss | — | 56 | 86 | μJ | $I_C$ = 6.0A, $V_{CC}$ = 400V, $V_{GE}$ = 15V | CT 4 |
| $E_{off}$ | Turn-Off Switching Loss | — | 122 | 143 | | $R_G$ = 47Ω, L=1mH, $L_S$= 150nH, $T_J$ = 25°C | |
| $E_{total}$ | Total Switching Loss | — | 178 | 229 | | Energy losses include tail and diode reverse recovery | |
| $t_{d(on)}$ | Turn-On delay time | — | 27 | 35 | ns | $I_C$ = 6.0A, $V_{CC}$ = 400V | CT 4 |
| $t_r$ | Rise time | — | 11 | 15 | | $R_G$ = 47Ω, L=1mH, $L_S$= 150nH | |
| $t_{d(off)}$ | Turn-Off delay time | — | 75 | 93 | | $T_J$ = 25°C | |
| $t_f$ | Fall time | — | 17 | 22 | | | |
| $E_{on}$ | Turn-On Switching Loss | — | 140 | — | μJ | $I_C$ = 6.0A, $V_{CC}$ = 400V, $V_{GE}$ = 15V | 13,15 |
| $E_{off}$ | Turn-Off Switching Loss | — | 189 | — | | $R_G$ = 47Ω, L=1mH, $L_S$= 150nH, $T_J$ = 175°C | CT 4 |
| $E_{total}$ | Total Switching Loss | — | 329 | — | | Energy losses include tail and diode reverse recovery | WF 1,WF 2 |
| $t_{d(on)}$ | Turn-On delay time | — | 26 | — | ns | $I_C$ = 6.0A, $V_{CC}$ = 400V | 14,16 |
| $t_r$ | Rise time | — | 12 | — | | $R_G$ = 47Ω, L=1mH, $L_S$= 150nH | CT 4 |
| $t_{d(off)}$ | Turn-Off delay time | — | 95 | — | | $T_J$ = 175°C | WF 1,WF 2 |
| $t_f$ | Fall time | — | 32 | — | | | |
| $C_{ies}$ | Input Capacitance | — | 350 | — | pF | $V_{GE}$ = 0V | 23 |
| $C_{oes}$ | Output Capacitance | — | 29 | — | | $V_{CC}$ = 30V | |
| $C_{res}$ | Reverse Transfer Capacitance | — | 10 | — | | f = 1Mhz | |
| RBSOA | Reverse Bias Safe Operating Area | FULL SQUARE | | | | $T_J$ = 175°C, $I_C$ = 24A<br>$V_{CC}$ = 500V, Vp =600V<br>$R_G$ = 100Ω, $V_{GE}$ = +20V to 0V | 4<br>CT 2 |
| SCSOA | Short Circuit Safe Operating Area | — | 5 | — | μs | $V_{CC}$ = 400V, Vp =600V<br>$R_G$ = 100Ω, $V_{GE}$ = +15V to 0V | 22<br>CT 3, WF 4 |
| Erec | Reverse recovery energy of the diode | — | 178 | — | μJ | $T_J$ = 175°C | 17,18,19 |
| trr | Diode Reverse recovery time | — | 74 | — | ns | $V_{CC}$ = 400V, $I_F$ = 6.0A | 20,21 |
| Irr | Peak Reverse Recovery Current | — | 12 | — | A | $V_{GE}$ = 15V, Rg = 47Ω, L=1mH, $L_S$=150nH | WF 3 |

Notes:

① $V_{CC}$ = 80% ($V_{CES}$), $V_{GE}$ = 15V, L = 1.0mH, $R_G$ = 47Ω.
② Pulse width limited by max. junction temperature.
③ $R_\theta$ is measured at $T_J$ approximately 90°C.
④ Refer to AN-1086 for guidelines for measuring $V_{(BR)CES}$ safely.
⑤ When mounted on 1" square PCB (FR-4 or G-10 Material). For recommended footprint and soldering techniques refer to application note #AN-994.
⑥ Maximum limits are based on statistical sample size characterization.

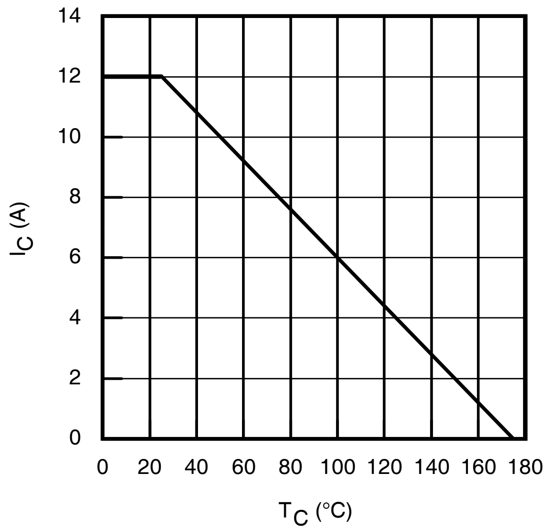



**Fig. 1** - Maximum DC Collector Current vs. Case Temperature

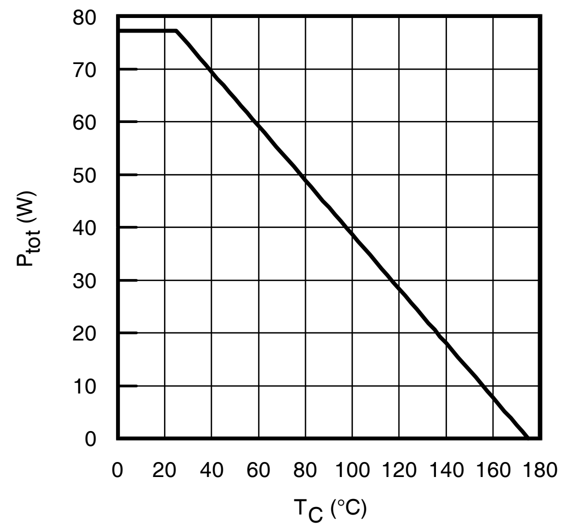



**Fig. 2** - Power Dissipation vs. Case Temperature

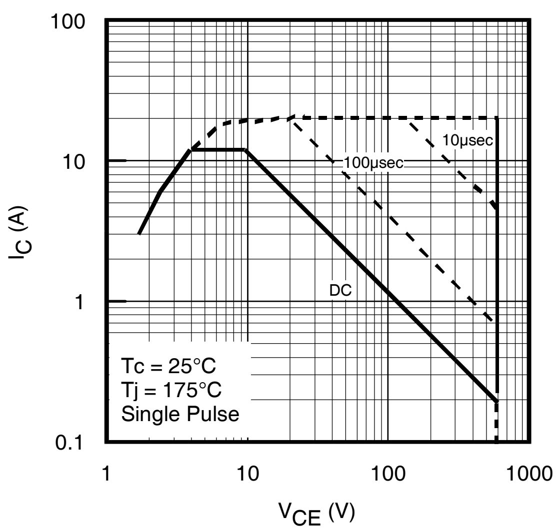



**Fig. 3** - Forward SOA, $T_C = 25°C$, $T_J \leq 175°C$, $V_{GE} = 15V$

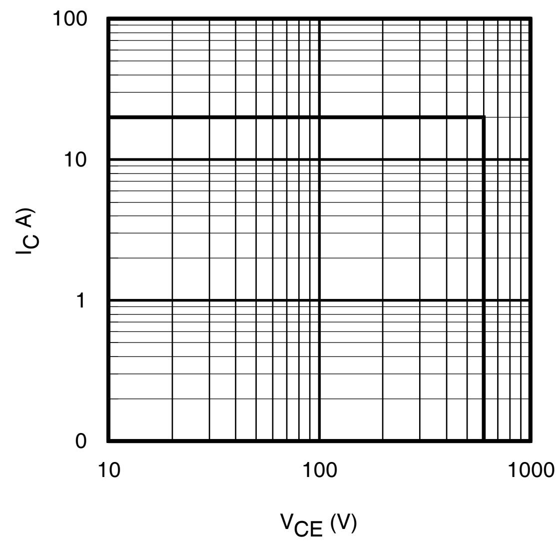



**Fig. 4** - Reverse Bias SOA $T_J = 175°C$, $V_{GE} = 20V$

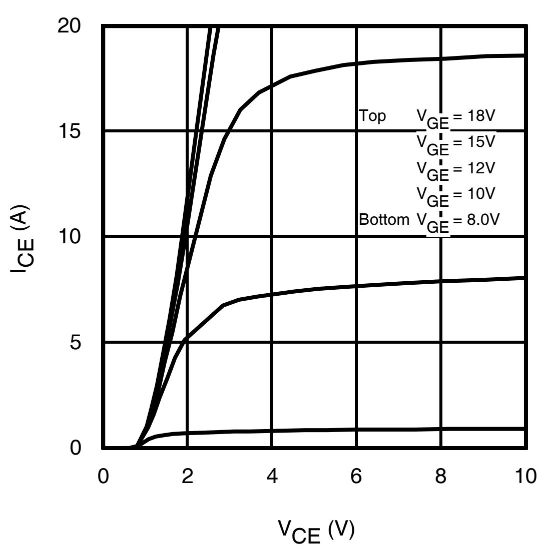



**Fig. 5** - Typ. IGBT Output Characteristics $T_J = -40°C$; tp = 80µs

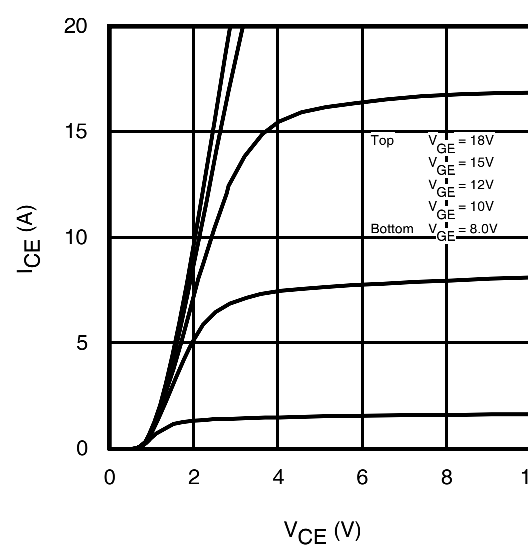



**Fig. 6** - Typ. IGBT Output Characteristics $T_J = 25°C$; tp = 80µs

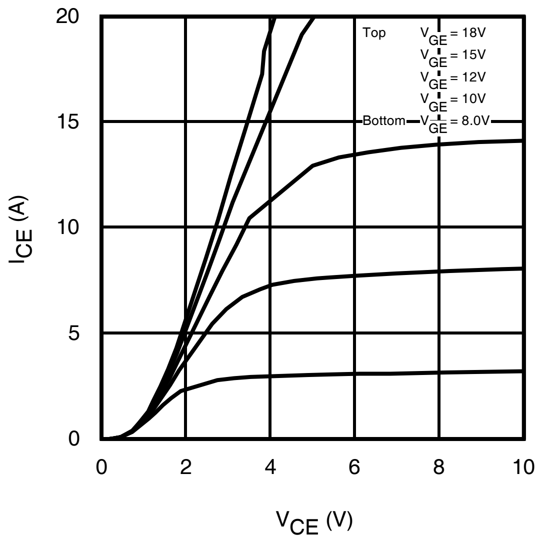



**Fig. 7** - Typ. IGBT Output Characteristics
$T_J$ = 175°C; tp = 80µs

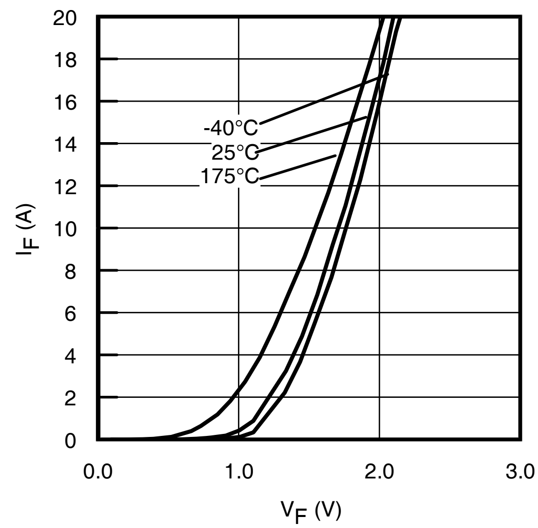



**Fig. 8** - Typ. Diode Forward Characteristics
tp = 80µs

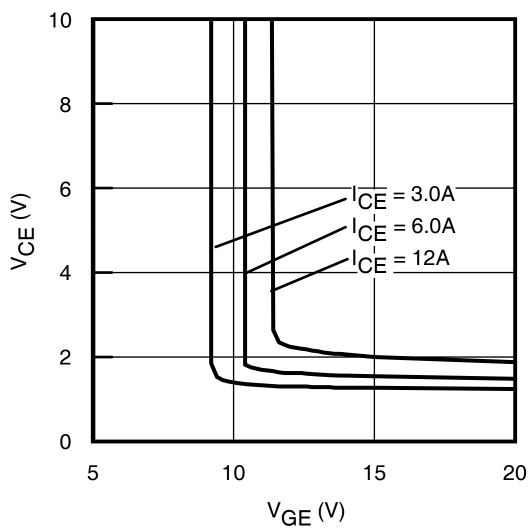



**Fig. 9** - Typical $V_{CE}$ vs. $V_{GE}$
$T_J$ = -40°C

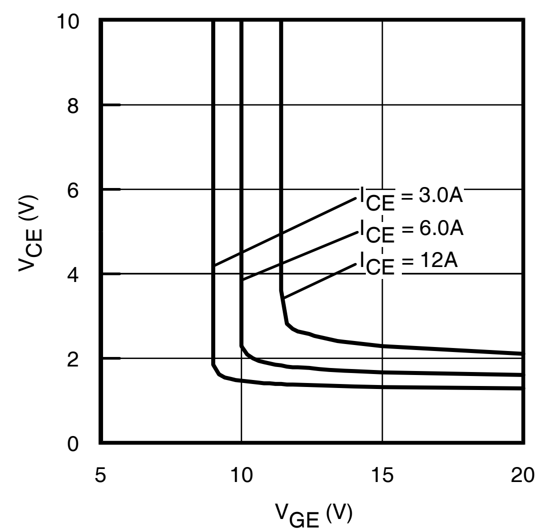



**Fig. 10** - Typical $V_{CE}$ vs. $V_{GE}$
$T_J$ = 25°C

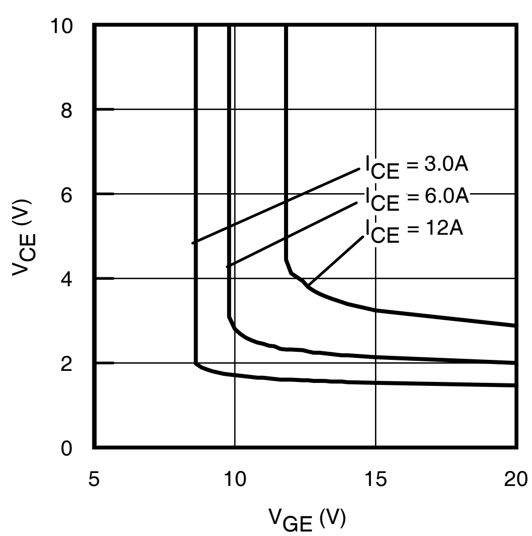



**Fig. 11** - Typical $V_{CE}$ vs. $V_{GE}$
$T_J$ = 175°C

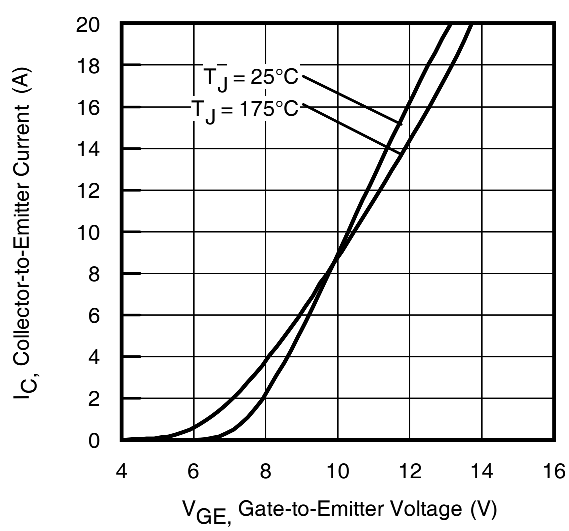



**Fig. 12** - Typ. Transfer Characteristics
$V_{CE}$ = 50V; tp = 10µs

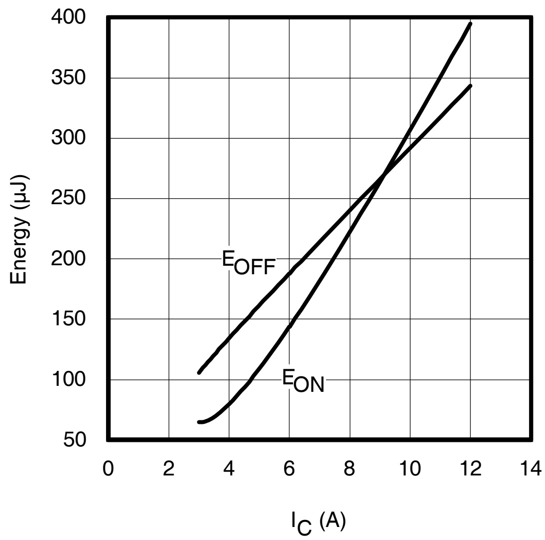



**Fig. 13** - Typ. Energy Loss vs. $I_C$
$T_J = 175°C$; L = 1mH; $V_{CE} = 400V$, $R_G = 47\Omega$; $V_{GE} = 15V$.

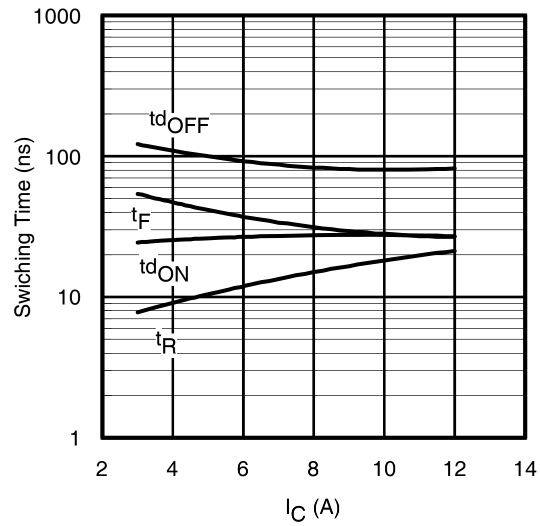



**Fig. 14** - Typ. Switching Time vs. $I_C$
$T_J = 175°C$; L=1mH; $V_{CE}= 400V$
$R_G= 47\Omega$; $V_{GE}= 15V$

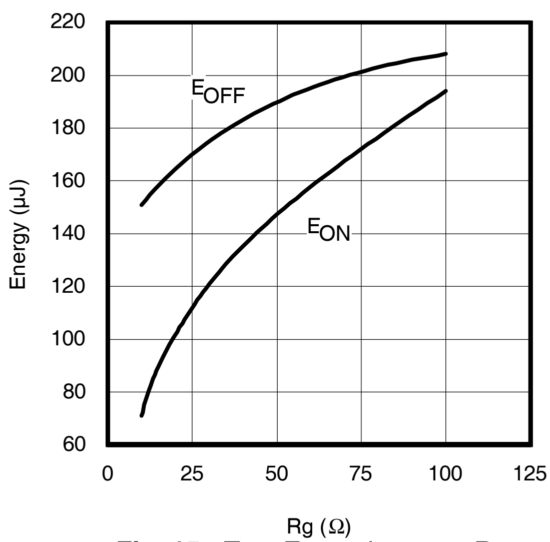



**Fig. 15** - Typ. Energy Loss vs. $R_G$
$T_J = 175°C$; L = 1mH; $V_{CE} = 400V$, $I_{CE} = 6.0A$; $V_{GE} = 15V$

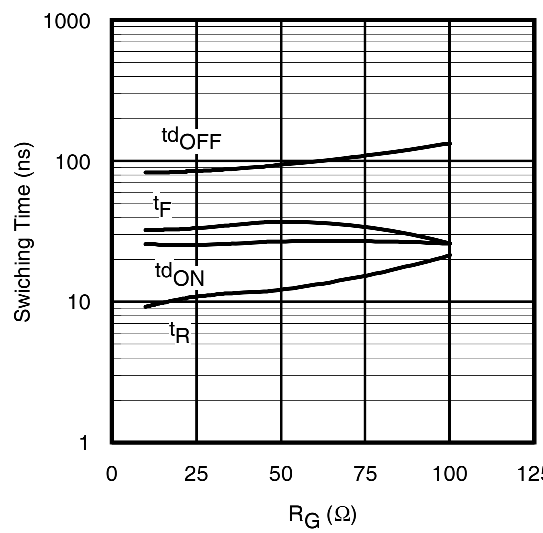



**Fig. 16**- Typ. Switching Time vs. $R_G$
$T_J = 175°C$; L=1mH; $V_{CE}= 400V$
$I_{CE}= 6.0A$; $V_{GE}= 15V$

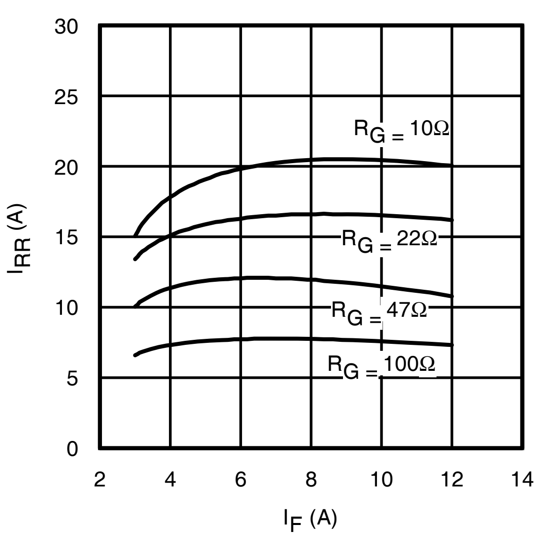



**Fig. 17** - Typical Diode $I_{RR}$ vs. $I_F$
$T_J = 175°C$

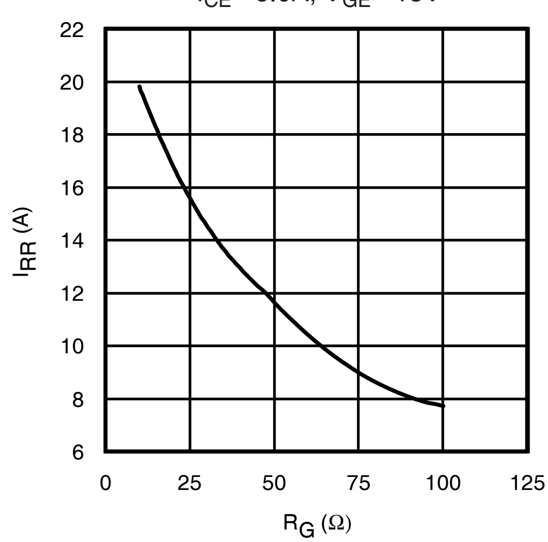



**Fig. 18** - Typical Diode $I_{RR}$ vs. $R_G$
$T_J = 175°C$; $I_F = 6.0A$

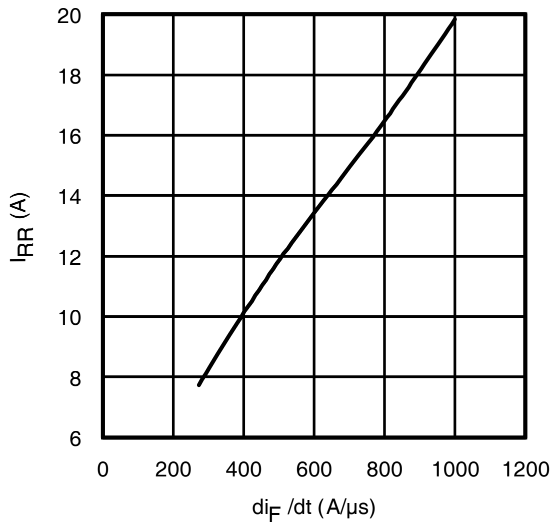



**Fig. 19**- Typical Diode $I_{RR}$ vs. $di_F/dt$
$V_{CC}$= 400V; $V_{GE}$= 15V;
$I_{CE}$= 6.0A; $T_J$ = 175°C

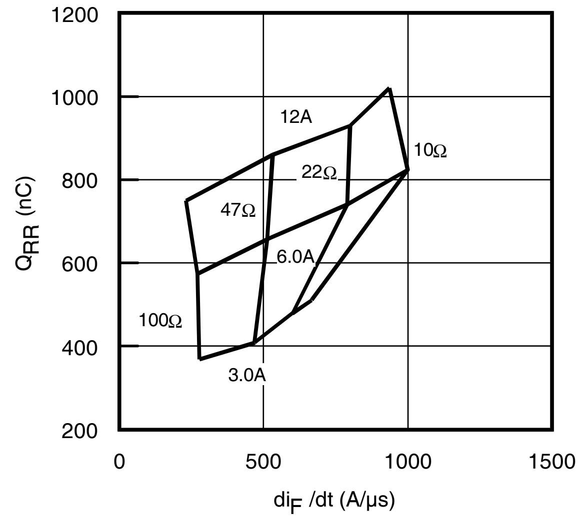



**Fig. 20** - Typical Diode $Q_{RR}$
$V_{CC}$= 400V; $V_{GE}$= 15V; $T_J$ = 175°C

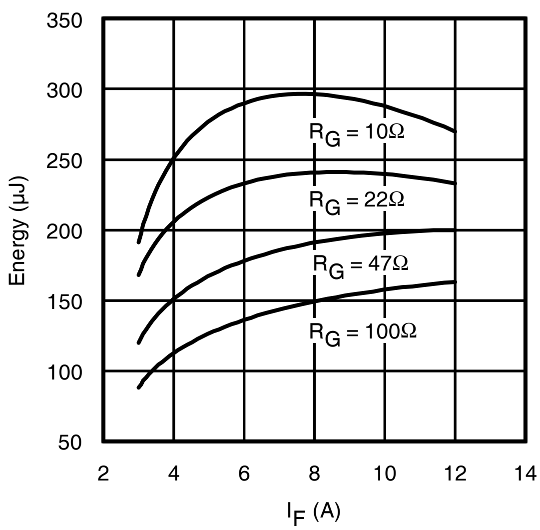



**Fig. 21** - Typical Diode $E_{RR}$ vs. $I_F$
$T_J$ = 175°C

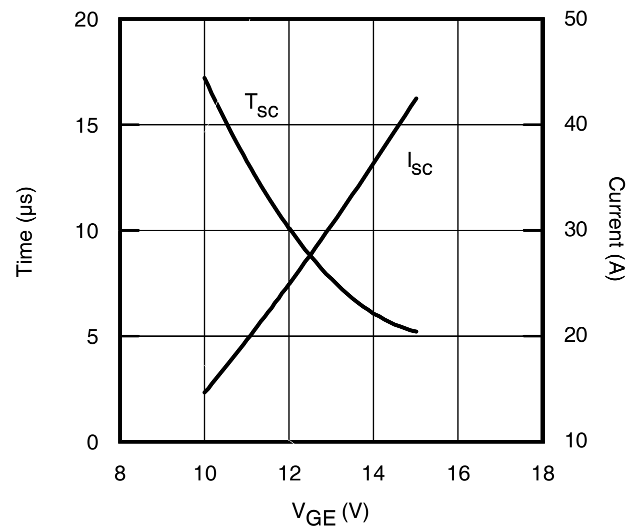



**Fig. 22**- Typ. $V_{GE}$ vs. Short Circuit Time
$V_{CC}$=400V, $T_C$ =25°C

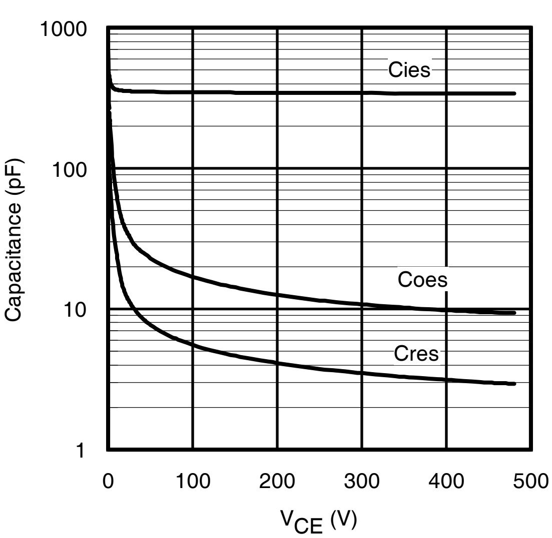



**Fig. 23**- Typ. Capacitance vs. $V_{CE}$
$V_{GE}$= 0V; f = 1MHz

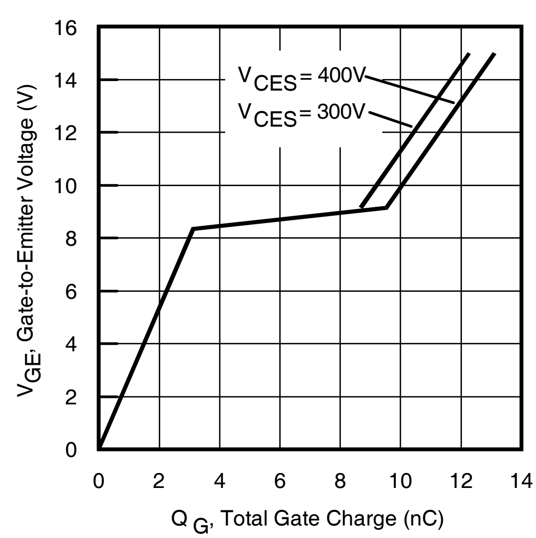



**Fig. 24** - Typical Gate Charge vs. $V_{GE}$
$I_{CE}$ = 6.0A, L=600µH

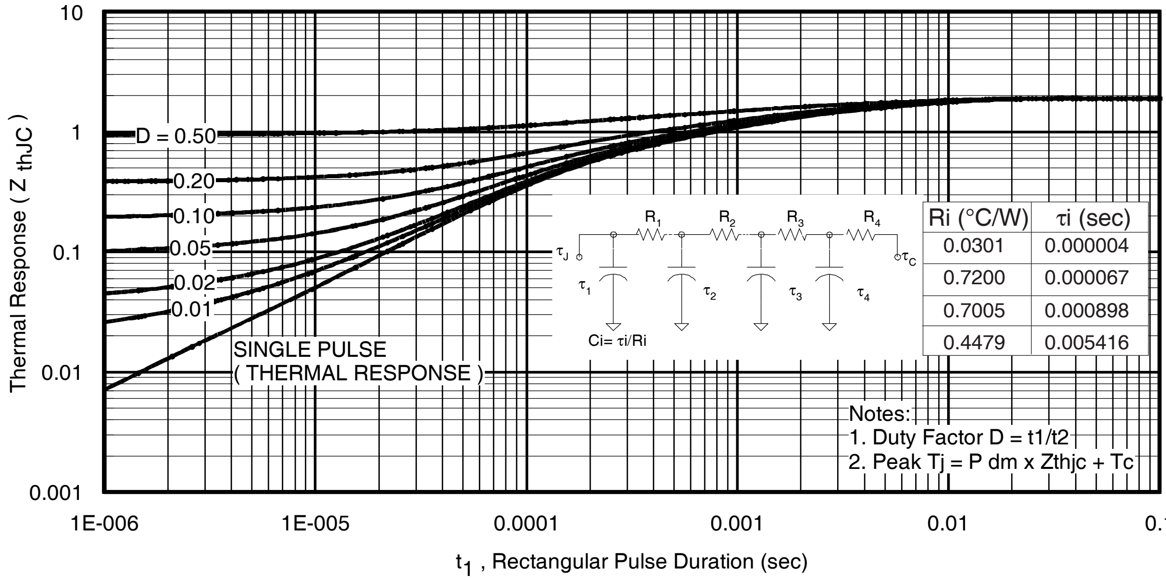



**Fig 25.** Maximum Transient Thermal Impedance, Junction-to-Case (IGBT)

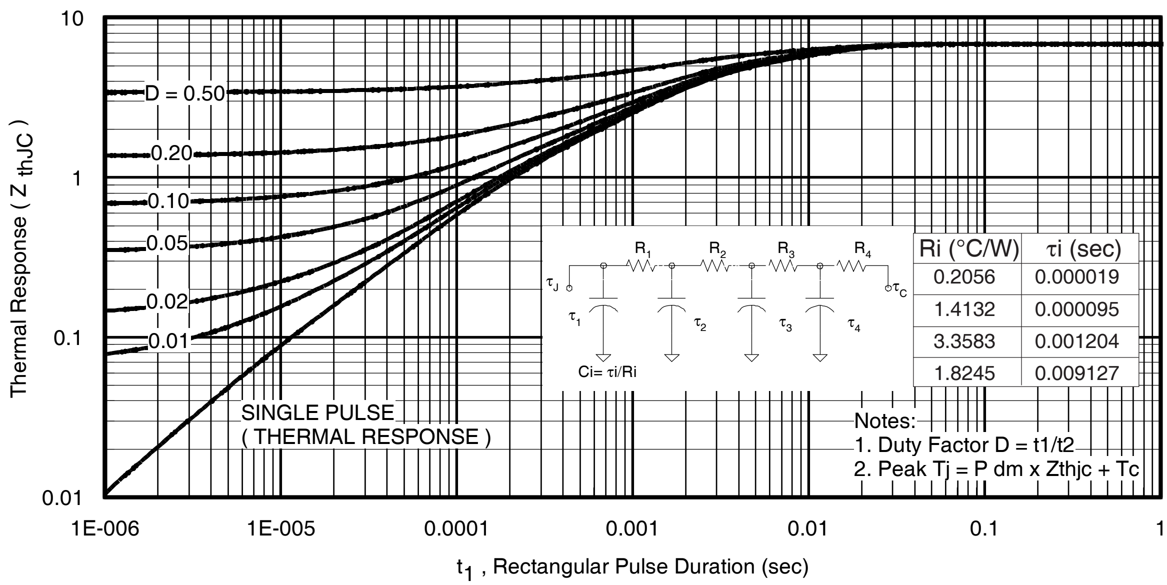



**Fig. 26.** Maximum Transient Thermal Impedance, Junction-to-Case (DIODE)

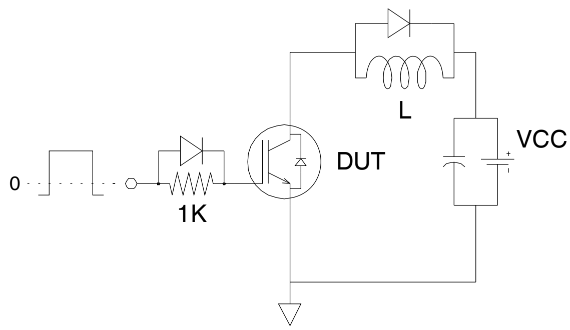



**Fig.C.T.1** - Gate Charge Circuit (turn-off)

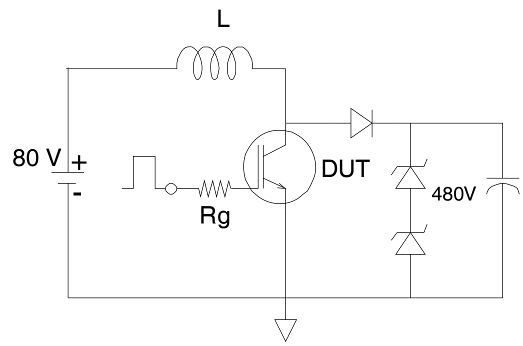



**Fig.C.T.2** - RBSOA Circuit

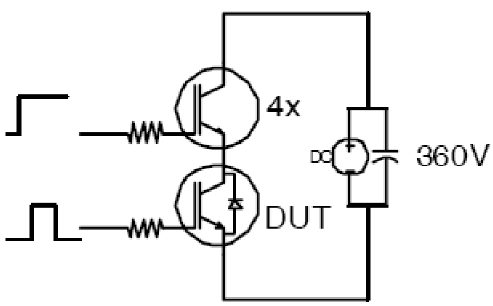



**Fig.C.T.3** - S.C.SOA Circuit

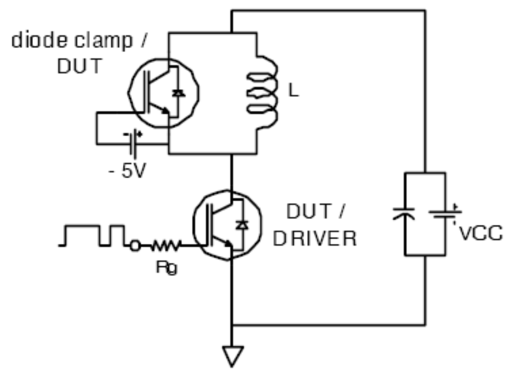



**Fig.C.T.4** - Switching Loss Circuit

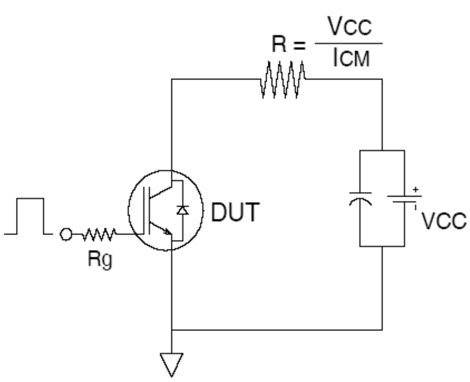



**Fig.C.T.5** - Resistive Load Circuit

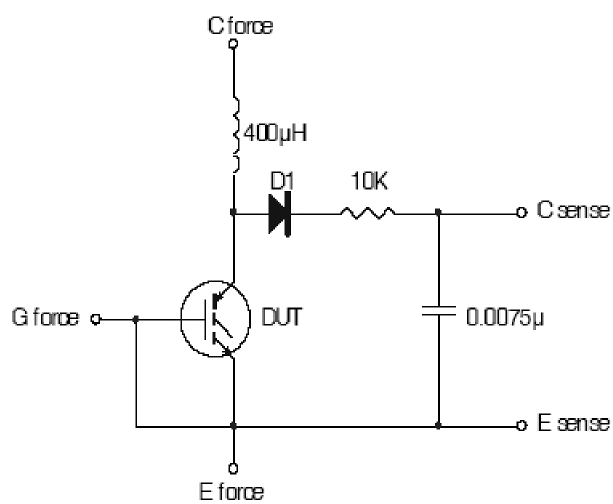



**Fig.C.T.6** - Typical Filter Circuit for $V_{(BR)CES}$ Measurement

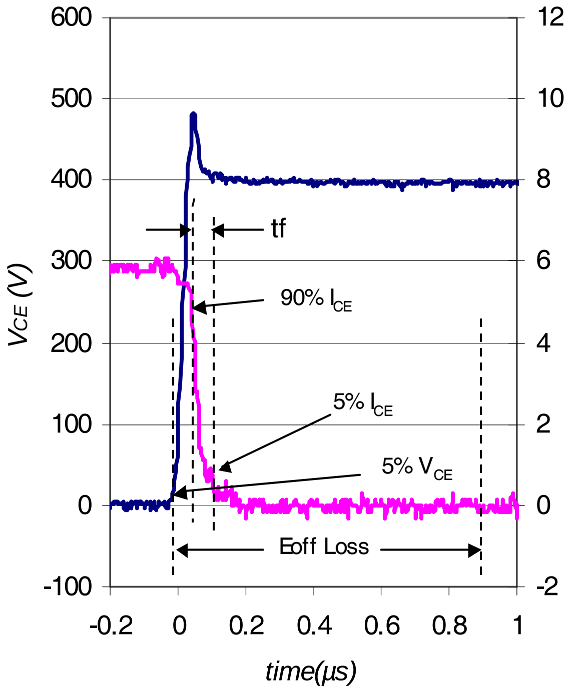



**Fig. WF1** - Typ. Turn-off Loss Waveform
@ $T_J$ = 175°C using Fig. CT.4

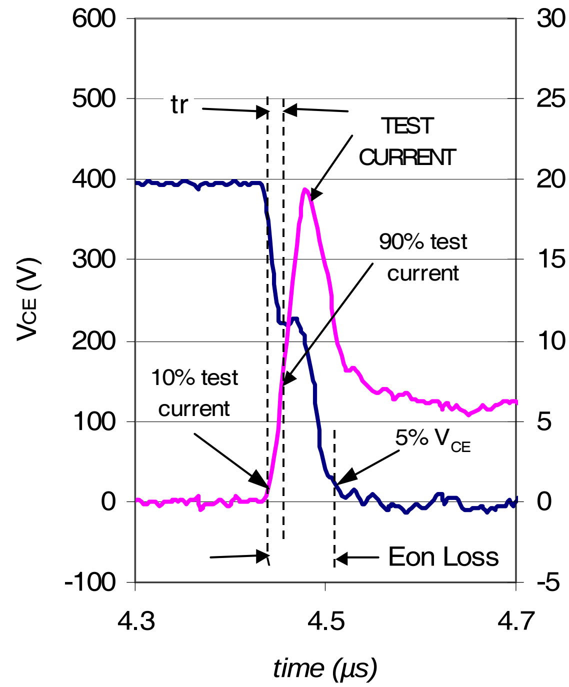
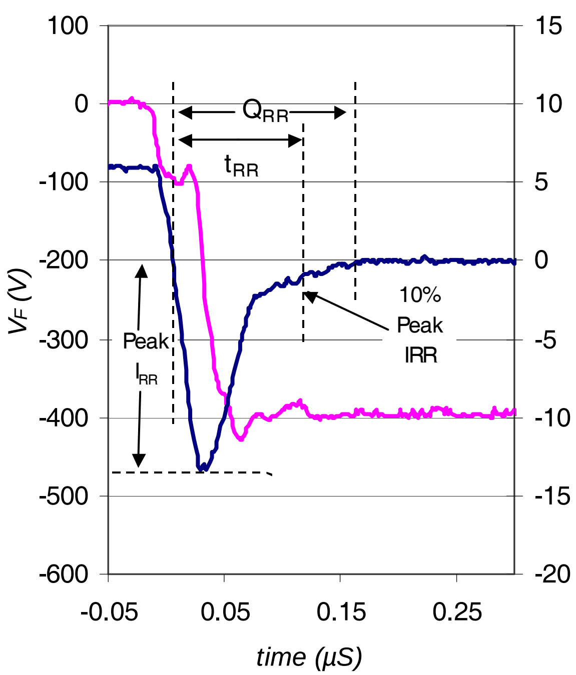
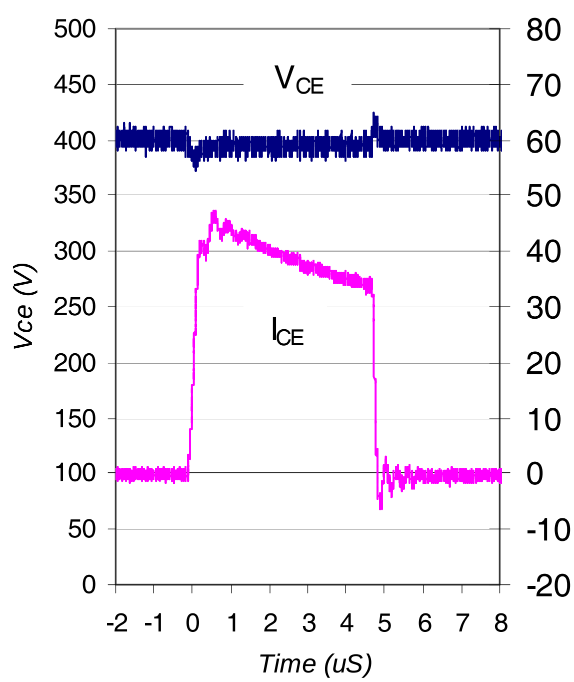



**Fig. WF2** - Typ. Turn-on Loss Waveform
@ $T_J$ = 175°C using Fig. CT.4



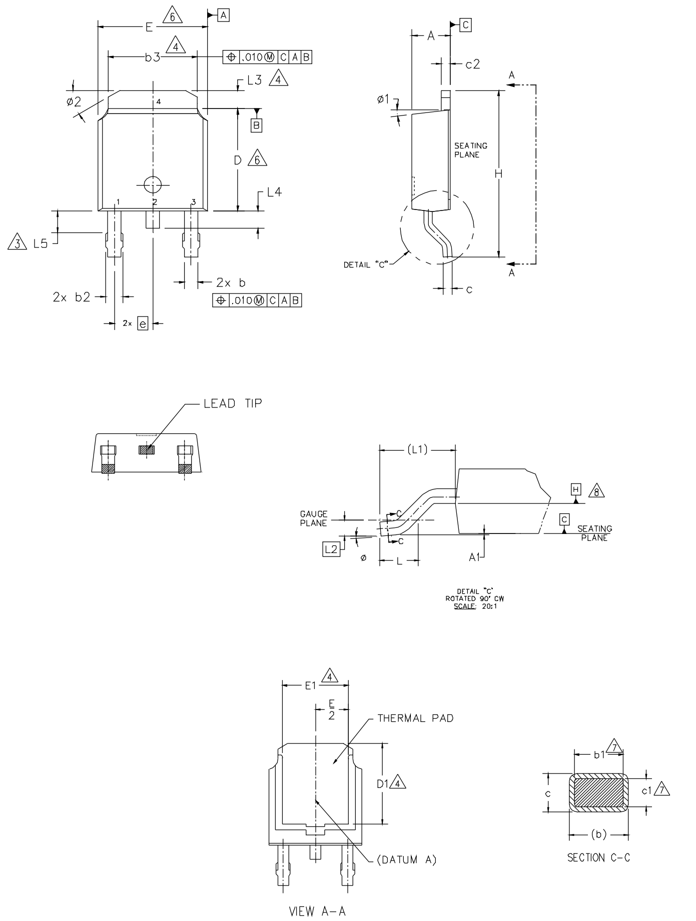

WF.3- Typ. Diode Recovery Waveform
@ $T_J$ = 175°C using CT.4




WF.4- Typ. Short Circuit Waveform
@ $T_J$ = 25°C using CT.3

## D-Pak (TO-252AA) Package Outline

Dimensions are shown in millimeters (inches)




NOTES:

1.– DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994
2.– DIMENSION ARE SHOWN IN INCHES [MILLIMETERS].
3.– LEAD DIMENSION UNCONTROLLED IN L5.
4.– DIMENSION D1, E1, L3 & b3 ESTABLISH A MINIMUM MOUNTING SURFACE FOR THERMAL PAD.
5.– SECTION C-C DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN .005 AND 0.10 [0.13 AND 0.25] FROM THE LEAD TIP.
6.– DIMENSION D & E DO NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED .005 [0.13] PER SIDE. THESE DIMENSIONS ARE MEASURED AT THE OUTMOST EXTREMES OF THE PLASTIC BODY.
7.– DIMENSION b1 & c1 APPLIED TO BASE METAL ONLY.
8.– DATUM A & B TO BE DETERMINED AT DATUM PLANE H.
9.– OUTLINE CONFORMS TO JEDEC OUTLINE TO-252AA.

| SYMBOL | DIMENSIONS | | | | NOTES |
|---|---|---|---|---|---|
| | MILLIMETERS | | INCHES | | |
| | MIN. | MAX. | MIN. | MAX. | |
| A | 2.18 | 2.39 | .086 | .094 | |
| A1 | – | 0.13 | – | .005 | |
| b | 0.64 | 0.89 | .025 | .035 | |
| b1 | 0.65 | 0.79 | .025 | .031 | 7 |
| b2 | 0.76 | 1.14 | .030 | .045 | |
| b3 | 4.95 | 5.46 | .195 | .215 | 4 |
| c | 0.46 | 0.61 | .018 | .024 | |
| c1 | 0.41 | 0.56 | .016 | .022 | 7 |
| c2 | 0.46 | 0.89 | .018 | .035 | |
| D | 5.97 | 6.22 | .235 | .245 | 6 |
| D1 | 5.21 | – | .205 | – | 4 |
| E | 6.35 | 6.73 | .250 | .265 | 6 |
| E1 | 4.32 | – | .170 | – | 4 |
| e | 2.29 BSC | | .090 BSC | | |
| H | 9.40 | 10.41 | .370 | .410 | |
| L | 1.40 | 1.78 | .055 | .070 | |
| L1 | 2.74 BSC | | .108 REF. | | |
| L2 | 0.51 BSC | | .020 BSC | | |
| L3 | 0.89 | 1.27 | .035 | .050 | 4 |
| L4 | – | 1.02 | – | .040 | |
| L5 | 1.14 | 1.52 | .045 | .060 | 3 |
| ø | 0° | 10° | 0° | 10° | |
| ø1 | 0° | 15° | 0° | 15° | |
| ø2 | 25° | 35° | 25° | 35° | |

LEAD ASSIGNMENTS

HEXFET

1.– GATE
2.– DRAIN
3.– SOURCE
4.– DRAIN

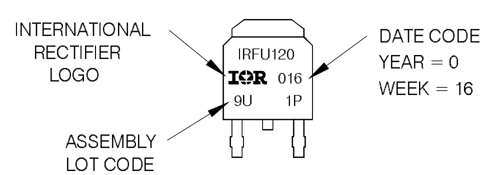
IGBT & CoPAK

1.– GATE
2.– COLLECTOR
3.– EMITTER
4.– COLLECTOR

## D-Pak (TO-252AA) Part Marking Information

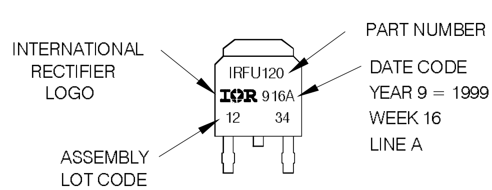
Notes: This part marking information applies to devices produced before 02/26/2001

EXAMPLE: THIS IS AN IRFR120
WITH ASSEMBLY
LOT CODE 9U1P




Notes: This part marking information applies to devices produced after 02/26/2001

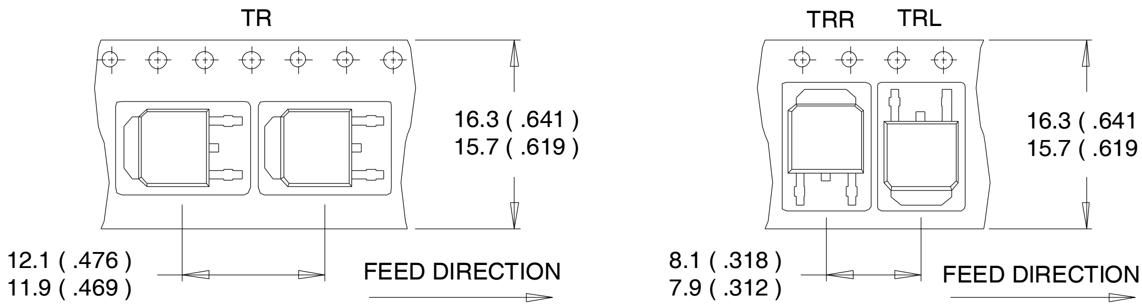
EXAMPLE: THIS IS AN IRFR120
WITH ASSEMBLY
LOT CODE 1234
ASSEMBLED ON WW 16, 1999
IN THE ASSEMBLY LINE "A"



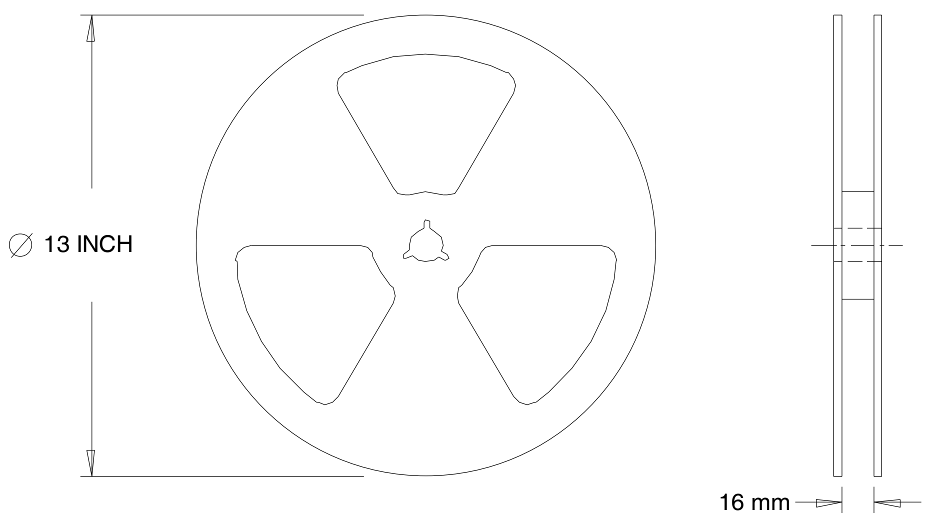

Note: For the most current drawing please refer to IR website at http://www.irf.com/package/

## D-Pak (TO-252AA) Tape & Reel Information

Dimensions are shown in millimeters (inches)




NOTES :
1. CONTROLLING DIMENSION : MILLIMETER.
2. ALL DIMENSIONS ARE SHOWN IN MILLIMETERS ( INCHES ).
3. OUTLINE CONFORMS TO EIA-481 & EIA-541.




NOTES :
1. OUTLINE CONFORMS TO EIA-481.

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
IOR Rectifier

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