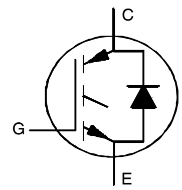
INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE

$V_{CES}$ = 600V

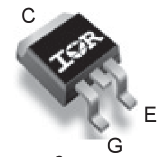
$I_C$ = 6.0A, $T_C$ = 100°C

$t_{sc}$ > 5μs, $T_{jmax}$ = 175°C

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



n-channel



$D^2$-Pak
IRGS4045DPbF

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

**Applications**
- Appliance Motor Drive
- Inverters
- SMPS

| Features → | Benefits |
|---|---|
| Low $V_{CE(ON)}$ and switching losses | High efficiency in a wide range of applications and switching frequencies |
| Square RBSOA and maximum junction temperature 175°C | Improved reliability due to rugged hard switching performance and higher power capability |
| Positive $V_{CE(ON)}$ temperature coefficient and tighter distribution of parameters | Excellent current sharing in parallel operation |
| 5μs short circuit SOA | Enables short circuit protection scheme |
| Ultra fast soft recovery copak diode | Performance optimized for motor drive operation |
| Lead-free, RoHS compliant | Environmentally friendly |

| Base part number | Package Type | Standard Pack | | Orderable Part Number |
|---|---|---|---|---|
| | | Form | Quantity | |
| IRGS4045DPbF | D2Pak | Tube | 50 | IRGS4045DPbF |
| | | Tape and Reel Left | 800 | IRGS4045DTRLPbF |
| | | Tape and Reel Right | 800 | IRGS4045DTRRPbF |

**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 | A |
| $I_C$@ $T_C$ = 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 | |
| $I_F$@$T_C$=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 | °C/W |
| $R_{\theta JC}$ | Junction-to-Case - Diode ③ | — | — | 6.3 | |
| $R_{\theta CS}$ | Case-to-Sink, Flat, Greased Surface | — | 0.5 | — | |
| $R_{\theta JA}$ | Junction-to-Ambient (PCB Mountet, steady-state) ⑤ | — | — | 40 | |

*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 |
|---|---|---|---|---|---|---|
| $V_{(BR)CES}$ | Collector-to-Emitter Breakdown Voltage | 600 | — | — | V | $V_{GE}$ = 0V, $I_c$ =100 μA ④ |
| $\Delta V_{(BR)CES}/\Delta T_J$ | 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 |
| | | — | 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 | 4.0 | — | 6.5 | V | $V_{CE}$ = $V_{GE}$, $I_C$ = 150μA |
| $\Delta V_{GE(th)}/\Delta TJ$ | 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 |
| | | — | — | 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 |
|---|---|---|---|---|---|---|
| $Q_g$ | Total Gate Charge (turn-on) | — | 13 | 19.5 | nC | $I_C$ = 6.0A |
| $Q_{ge}$ | Gate-to-Emitter Charge (turn-on) | — | 3.1 | 4.65 | | $V_{CC}$ = 400V |
| $Q_{gc}$ | 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 |
| $E_{off}$ | 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 |
| $t_r$ | 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 |
| $E_{off}$ | Turn-Off Switching Loss | — | 189 | — | | $R_G$ = 47Ω, L=1mH, $L_S$= 150nH, $T_J$ = 175°C |
| $E_{total}$ | Total Switching Loss | — | 329 | — | | Energy losses include tail and diode reverse recovery |
| $t_{d(on)}$ | Turn-On delay time | — | 26 | — | ns | $I_C$ = 6.0A, $V_{CC}$ = 400V |
| $t_r$ | Rise time | — | 12 | — | | $R_G$ = 47Ω, L=1mH, $L_S$= 150nH |
| $t_{d(off)}$ | Turn-Off delay time | — | 95 | — | | $T_J$ = 175°C |
| $t_f$ | Fall time | — | 32 | — | | |
| $C_{ies}$ | Input Capacitance | — | 350 | — | pF | $V_{GE}$ = 0V |
| $C_{oes}$ | 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 |
| SCSOA | Short Circuit Safe Operating Area | 5 | — | — | μs | $V_{CC}$ = 400V, Vp =600V<br>$R_G$ = 100Ω, $V_{GE}$ = +15V to 0V |
| Erec | Reverse recovery energy of the diode | — | 178 | — | μJ | $T_J$ = 175°C |
| trr | Diode Reverse recovery time | — | 74 | — | ns | $V_{CC}$ = 400V, $I_F$ = 6.0A |
| Irr | Peak Reverse Recovery Current | — | 12 | — | A | $V_{GE}$ = 15V, Rg = 47Ω, L=1mH, $L_S$=150nH |

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.

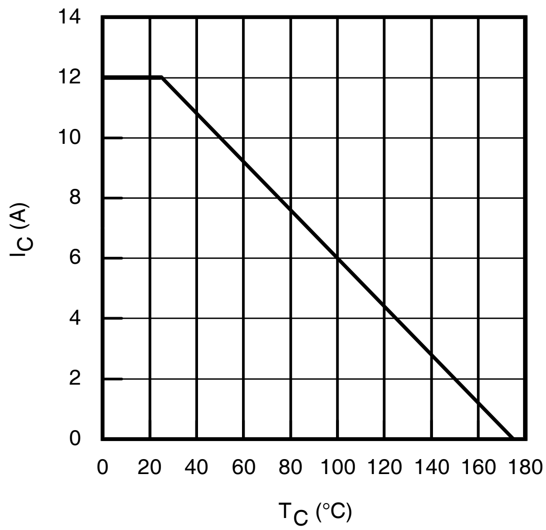



**Fig. 1** - Maximum DC Collector Current vs. Case Temperature

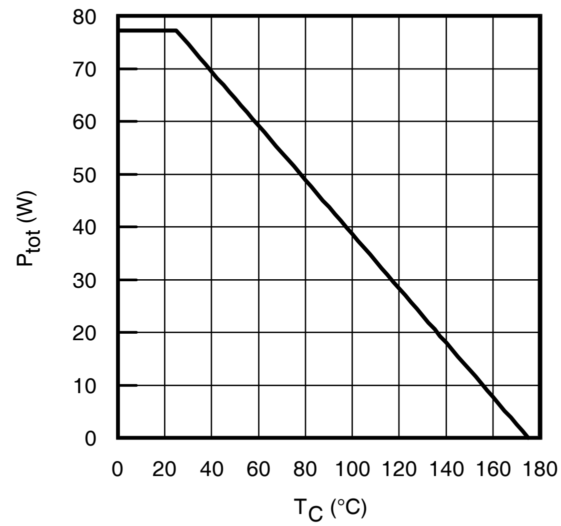



**Fig. 2** - Power Dissipation vs. Case Temperature

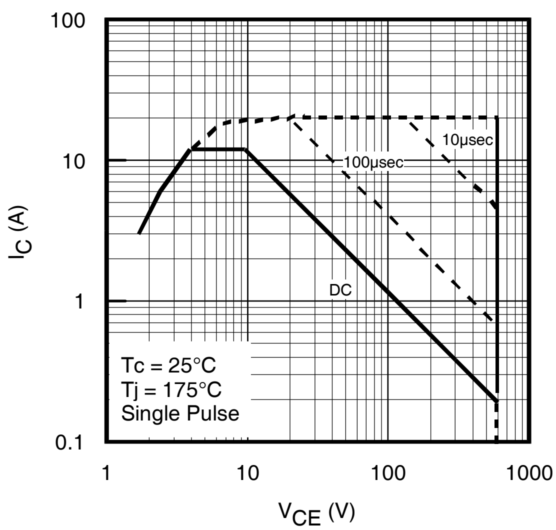



**Fig. 3** - Forward SOA, $T_C$ = 25°C, $T_J \leq$ 175°C, $V_{GE}$ = 15V

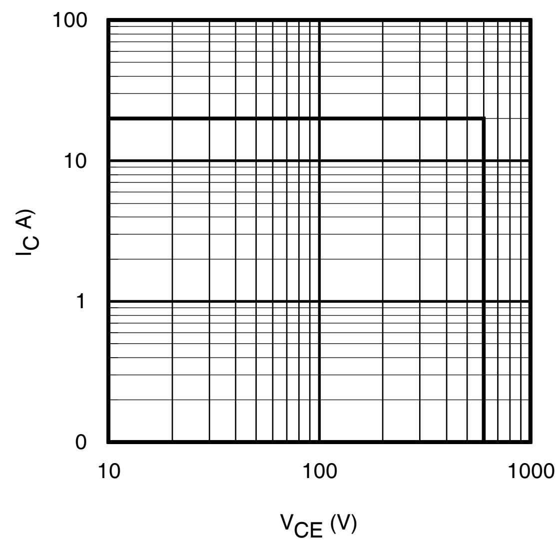



**Fig. 4** - Reverse Bias SOA $T_J$ = 175°C, $V_{GE}$ = 20V

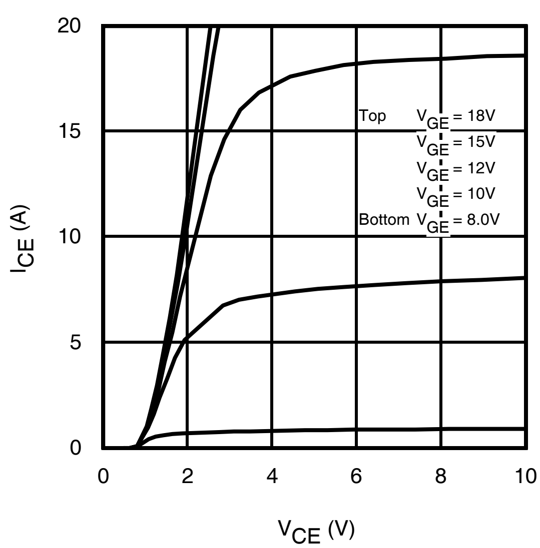



**Fig. 5** - Typ. IGBT Output Characteristics $T_J$ = -40°C; tp = 80µs

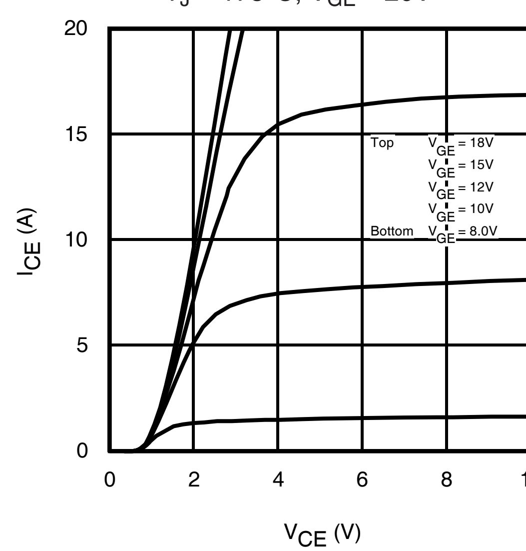



**Fig. 6** - Typ. IGBT Output Characteristics $T_J$ = 25°C; tp = 80µs

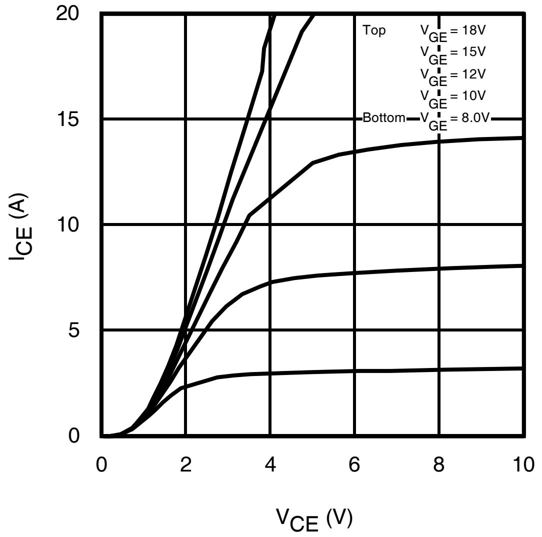



**Fig. 7** - Typ. IGBT Output Characteristics
$T_J$ = 175°C; tp = 80μs

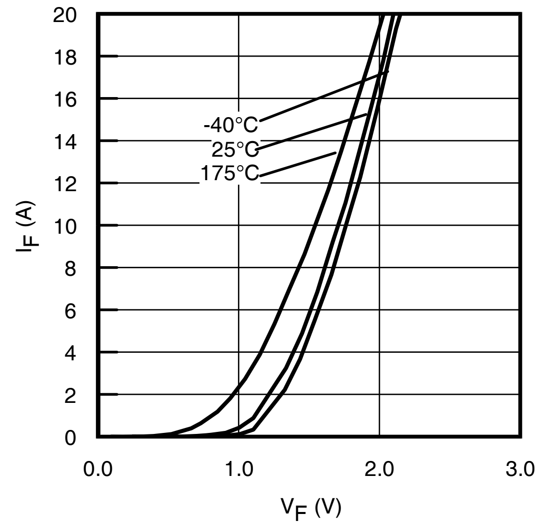



**Fig. 8** - Typ. Diode Forward Characteristics
tp = 80μs

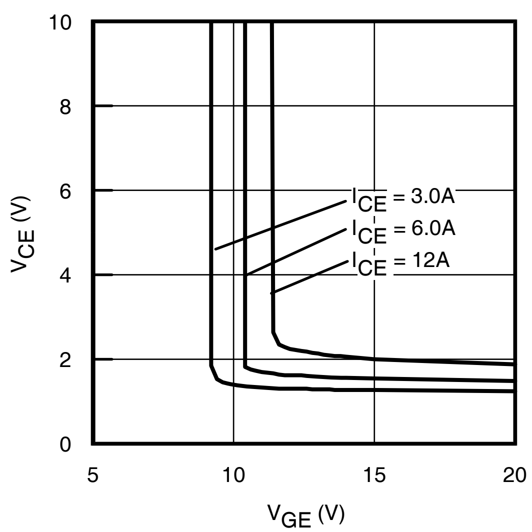



**Fig. 9** - Typical $V_{CE}$ vs. $V_{GE}$
$T_J$ = -40°C

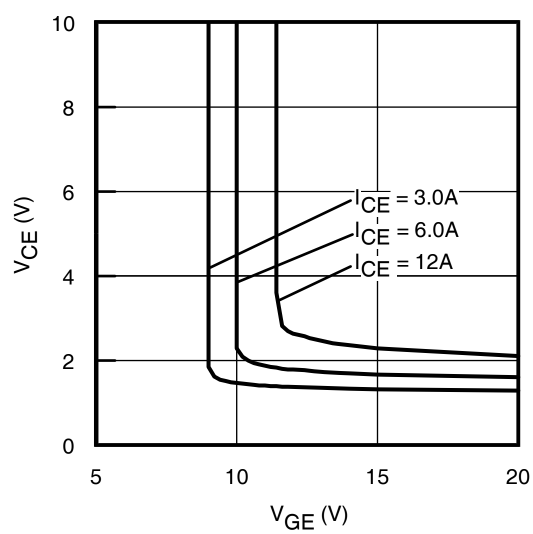



**Fig. 10** - Typical $V_{CE}$ vs. $V_{GE}$
$T_J$ = 25°C

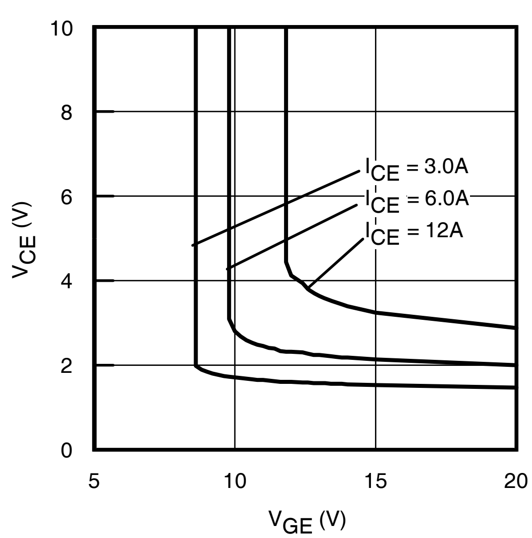



**Fig. 11** - Typical $V_{CE}$ vs. $V_{GE}$
$T_J$ = 175°C

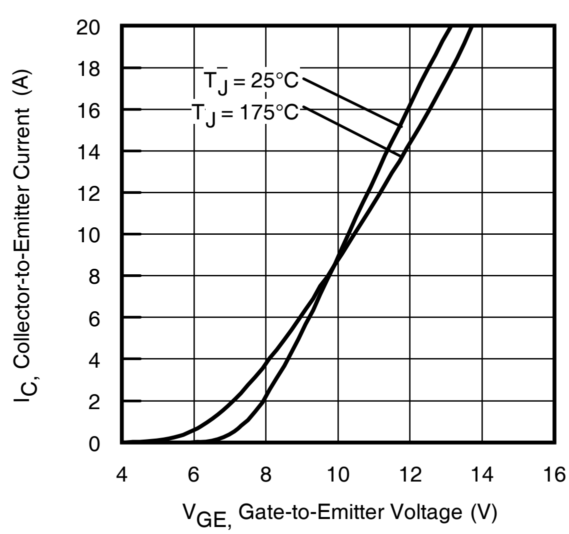



**Fig. 12** - Typ. Transfer Characteristics
$V_{CE}$ = 50V; tp = 10μs

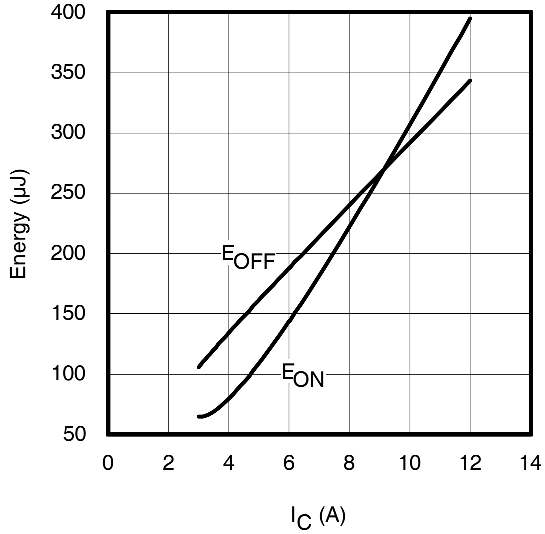



**Fig. 13** - Typ. Energy Loss vs. $I_C$
$T_J = 175°C$; L = 1mH; $V_{CE} = 400V$, $R_G = 47\Omega$; $V_{GE} = 15V$.

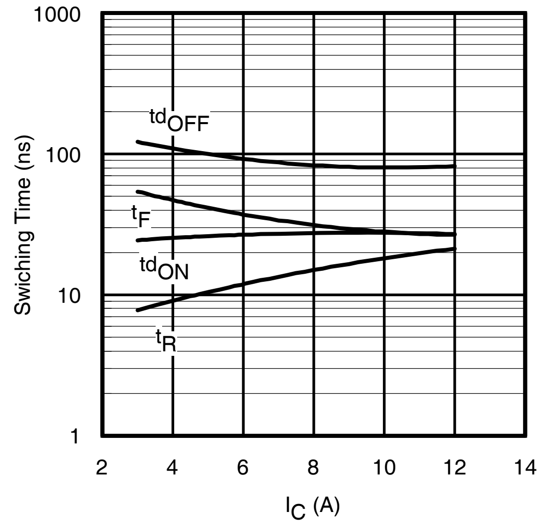



**Fig. 14** - Typ. Switching Time vs. $I_C$
$T_J = 175°C$; L=1mH; $V_{CE}$= 400V
$R_G$= 47Ω; $V_{GE}$= 15V

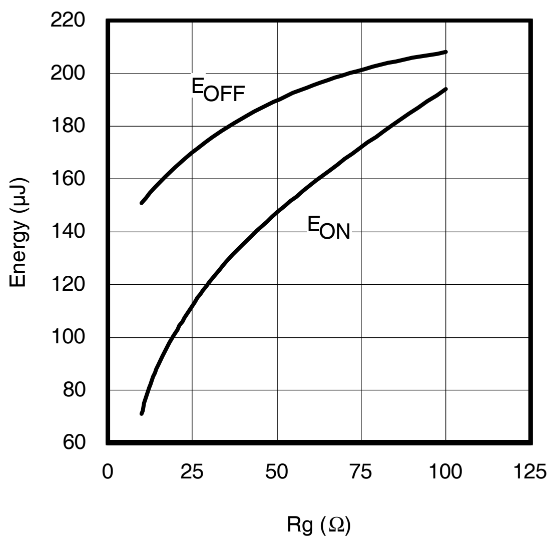



**Fig. 15** - Typ. Energy Loss vs. $R_G$
$T_J = 175°C$; L = 1mH; $V_{CE} = 400V$, $I_{CE} = 6.0A$; $V_{GE} = 15V$

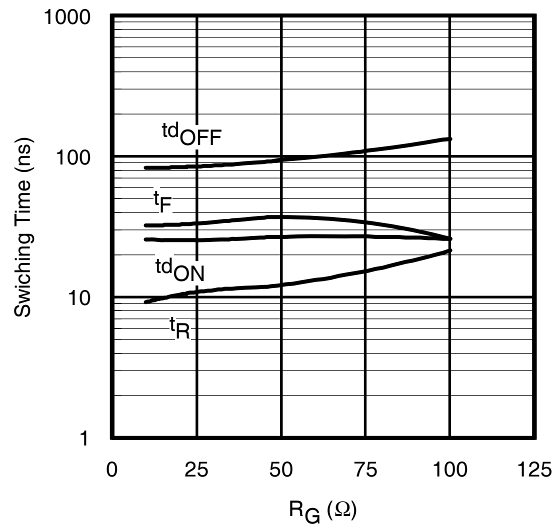



**Fig. 16**- Typ. Switching Time vs. $R_G$
$T_J = 175°C$; L=1mH; $V_{CE}$= 400V
$I_{CE}$= 6.0A; $V_{GE}$= 15V

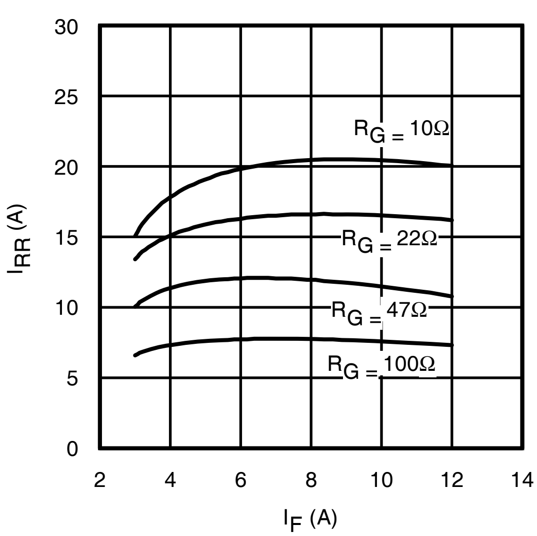



**Fig. 17** - Typical Diode $I_{RR}$ vs. $I_F$
$T_J = 175°C$

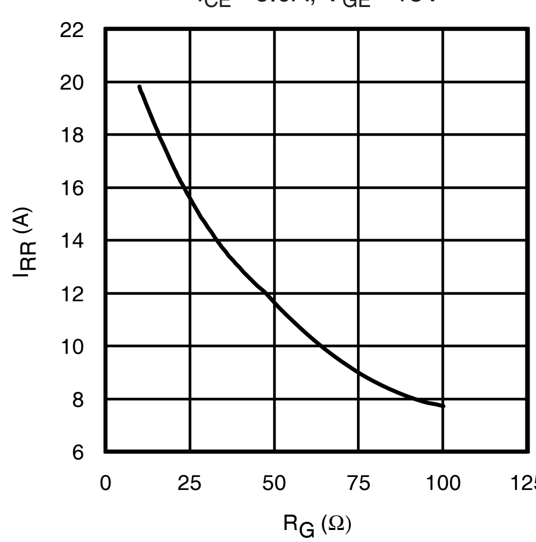



**Fig. 18** - Typical Diode $I_{RR}$ vs. $R_G$
$T_J = 175°C$; $I_F = 6.0A$

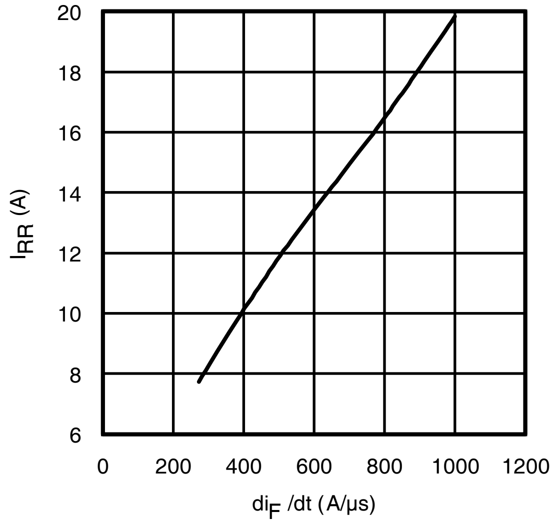



**Fig. 19**- Typical Diode $I_{RR}$ vs. $di_F/dt$
$V_{CC}$= 400V; $V_{GE}$= 15V;
$I_{CE}$= 6.0A; $T_J$ = 175°C

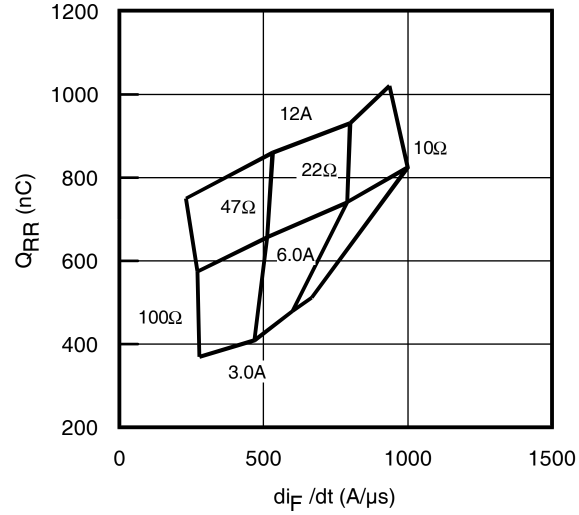



**Fig. 20** - Typical Diode $Q_{RR}$
$V_{CC}$= 400V; $V_{GE}$= 15V; $T_J$ = 175°C

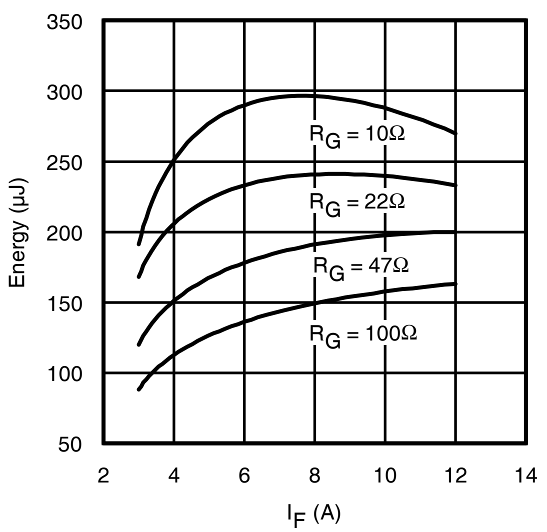



**Fig. 21** - Typical Diode $E_{RR}$ vs. $I_F$
$T_J$ = 175°C

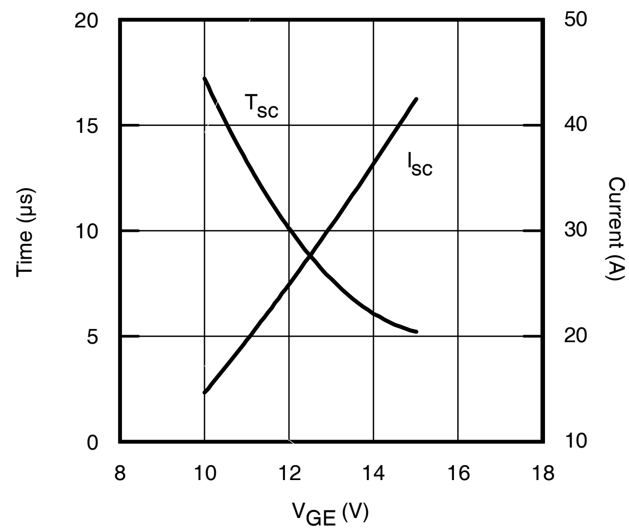



**Fig. 22**- Typ. $V_{GE}$ vs. Short Circuit Time
$V_{CC}$=400V, $T_C$ =25°C

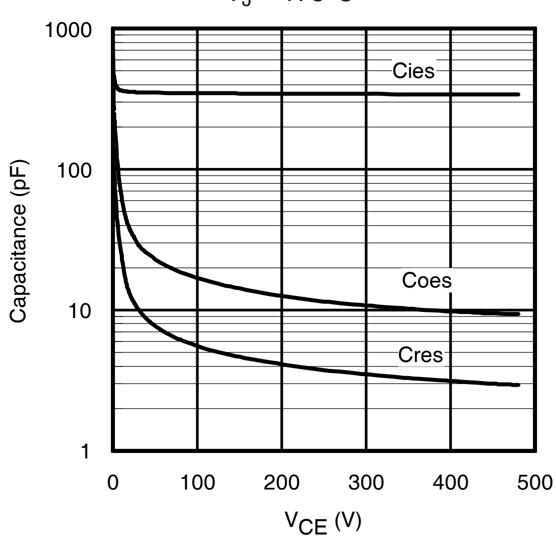



**Fig. 23**- Typ. Capacitance vs. $V_{CE}$
$V_{GE}$= 0V; f = 1MHz

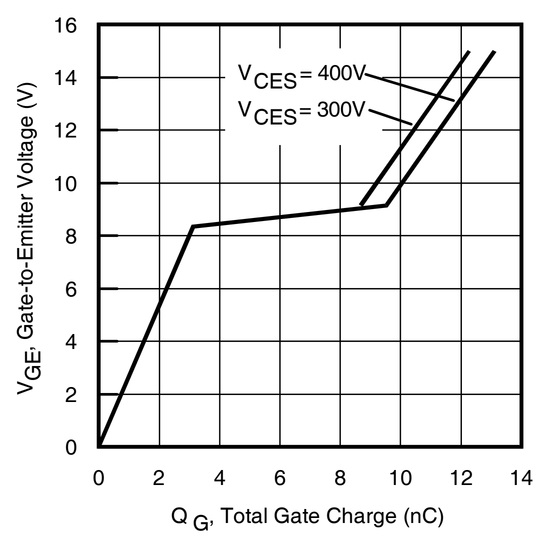
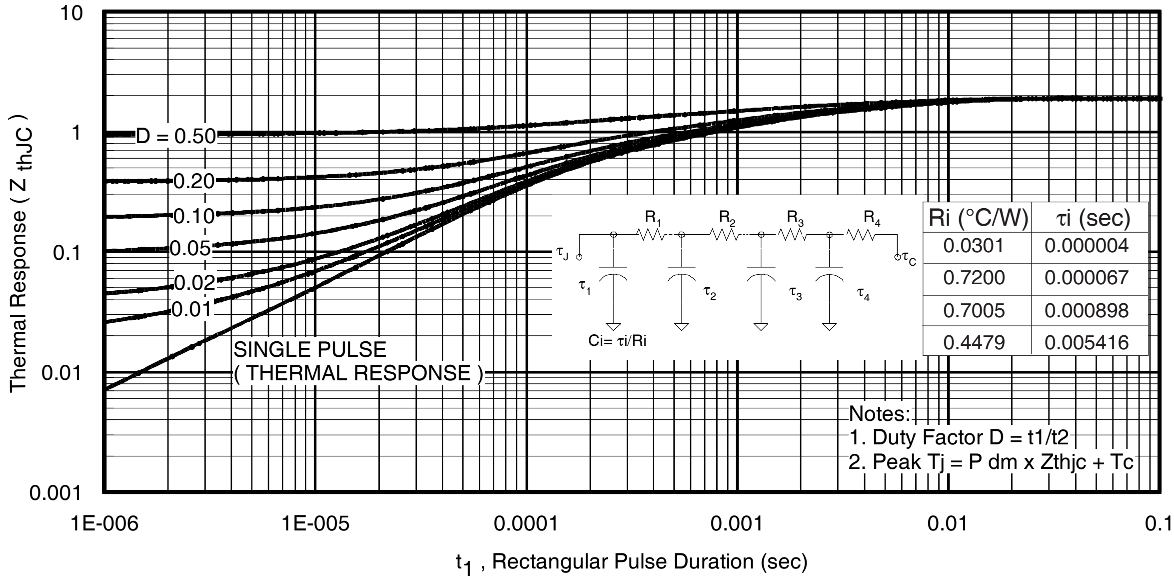


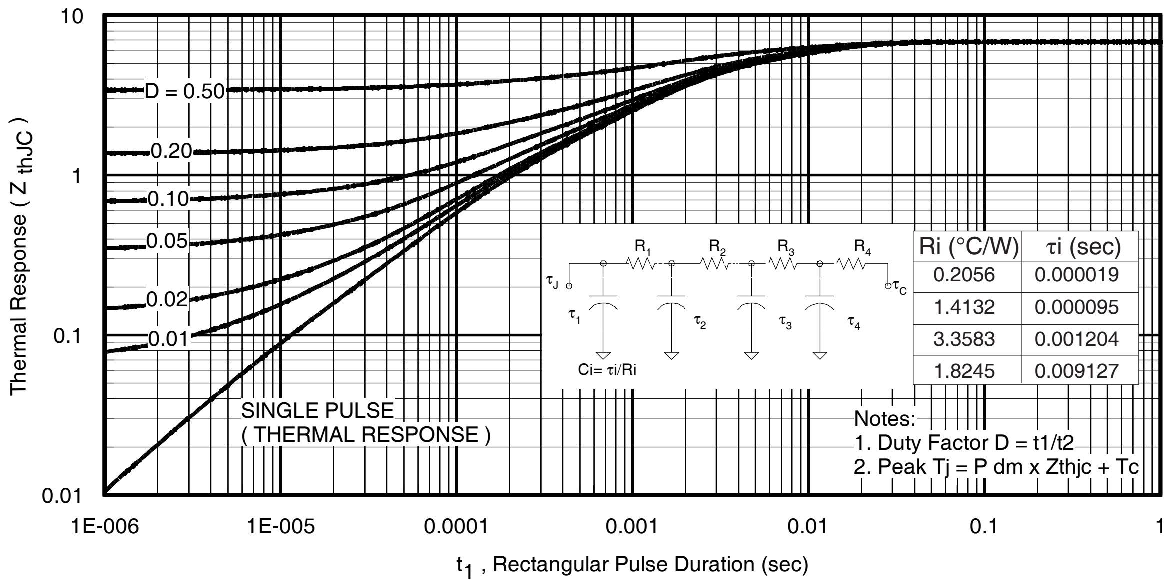

**Fig. 24** - Typical Gate Charge vs. $V_{GE}$
$I_{CE}$ = 6.0A, L=600µH




| Ri (°C/W) | τi (sec) |
|---|---|
| 0.0301 | 0.000004 |
| 0.7200 | 0.000067 |
| 0.7005 | 0.000898 |
| 0.4479 | 0.005416 |

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




| Ri (°C/W) | τi (sec) |
|---|---|
| 0.2056 | 0.000019 |
| 1.4132 | 0.000095 |
| 3.3583 | 0.001204 |
| 1.8245 | 0.009127 |

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

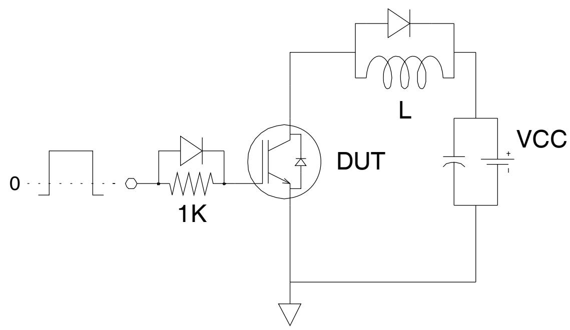



**Fig.C.T.1** - Gate Charge Circuit (turn-off)

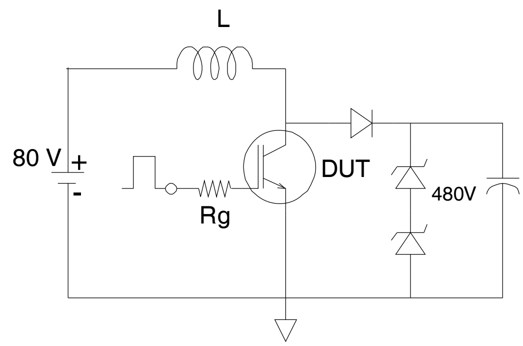



**Fig.C.T.2** - RBSOA Circuit

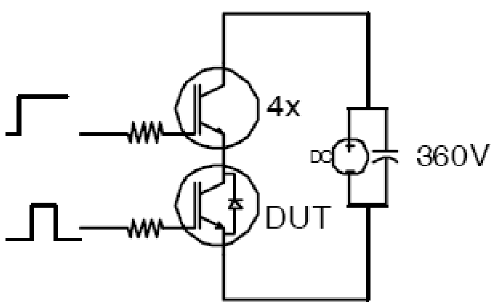



**Fig.C.T.3** - S.C.SOA Circuit

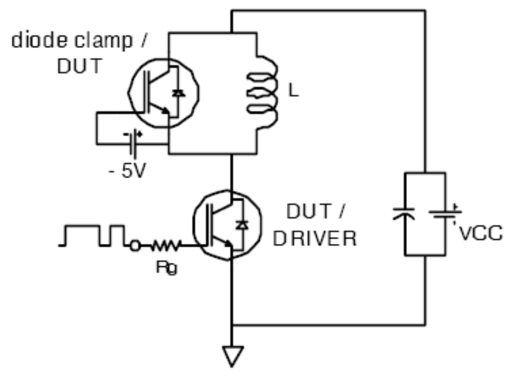



**Fig.C.T.4** - Switching Loss Circuit

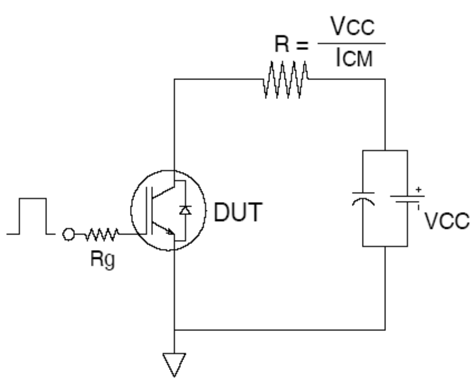



**Fig.C.T.5** - Resistive Load Circuit

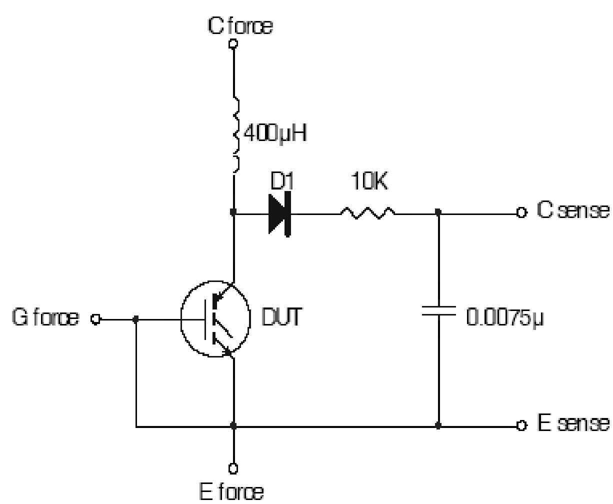



**Fig.C.T.6** - Typical Filter Circuit for $V_{(BR)CES}$ Measurement

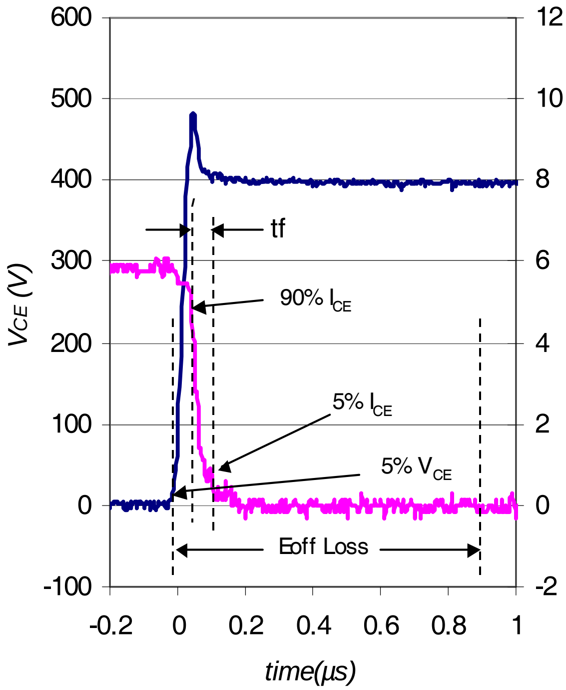



**Fig. WF1** - Typ. Turn-off Loss Waveform
@ $T_J$ = 175°C using Fig. CT.4

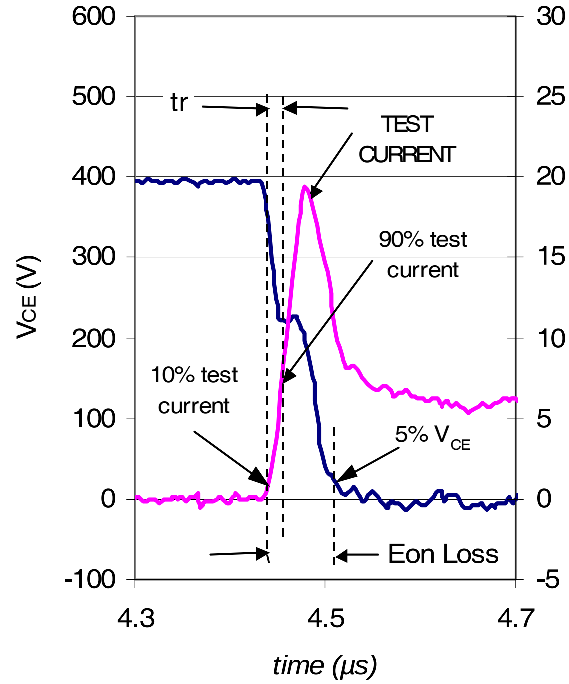
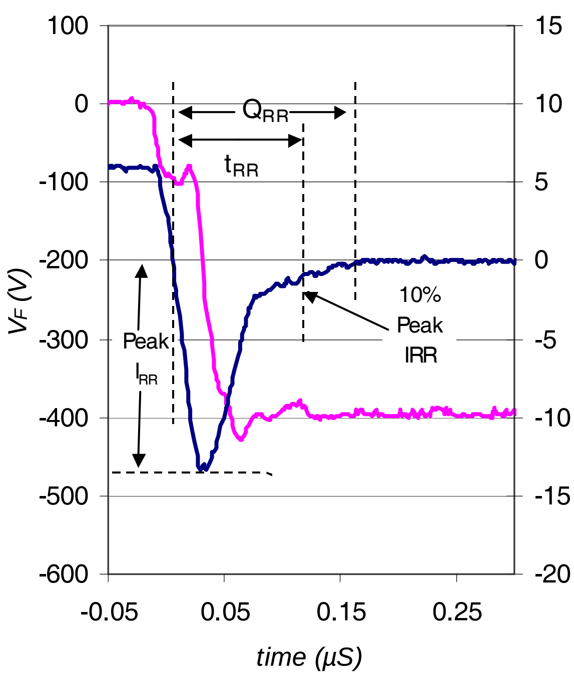
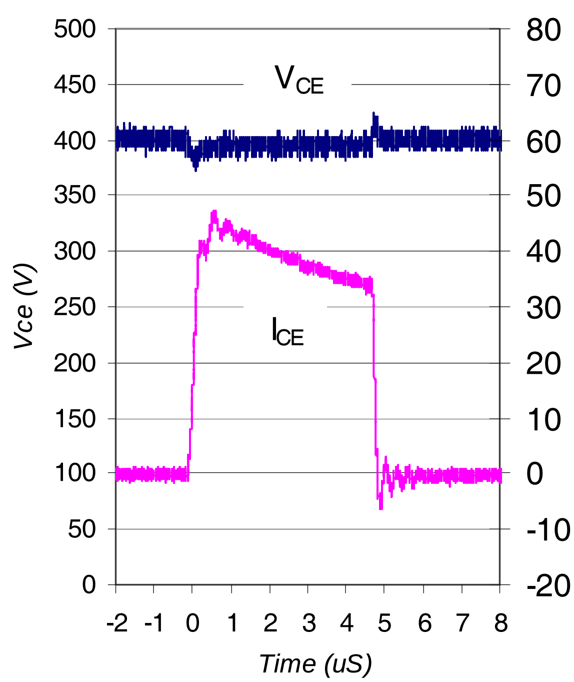



**Fig. WF2** - Typ. Turn-on Loss Waveform
@ $T_J$ = 175°C using Fig. CT.4




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

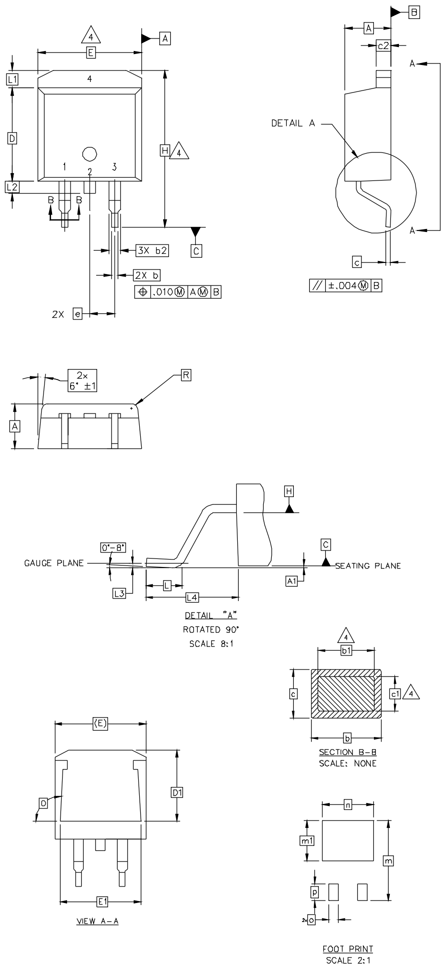



WF.4- Typ. Short Circuit Waveform
@ $T_J$ = 25°C using CT.3

# $D^2$Pak Package Outline

Dimensions are shown in millimeters (inches)



NOTES:

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994
2. DIMENSIONS ARE SHOWN IN MILLIMETERS [INCHES].
3. DIMENSION D & E DO NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.127 [.005"] PER SIDE. THESE DIMENSIONS ARE MEASURED AT THE OUTMOST EXTREMES OF THE PLASTIC BODY.
4. DIMENSION b1 AND c1 APPLY TO BASE METAL ONLY.
5. CONTROLLING DIMENSION: INCH.

| SYMBOL | DIMENSIONS | | | | NOTES |
|---|---|---|---|---|---|
| | MILLIMETERS | | INCHES | | |
| | MIN. | MAX. | MIN. | MAX. | |
| A | 4.06 | 4.83 | .160 | .190 | |
| A1 | 0.00 | 0.254 | .000 | .010 | |
| b | 0.51 | 0.99 | .020 | .039 | |
| b1 | 0.51 | 0.89 | .020 | .035 | 4 |
| b2 | 1.14 | 1.78 | .045 | .070 | |
| c | 0.38 | 0.74 | .015 | .029 | |
| c1 | 0.38 | 0.58 | .015 | .023 | 4 |
| c2 | 1.14 | 1.65 | .045 | .065 | |
| D | 8.51 | 9.65 | .335 | .380 | 3 |
| D1 | 6.86 | | .270 | | |
| E | 9.65 | 10.67 | .380 | .420 | 3 |
| E1 | 6.22 | | .245 | | |
| e | 2.54 BSC | | .100 BSC | | |
| H | 14.61 | 15.88 | .575 | .625 | |
| L | 1.78 | 2.79 | .070 | .110 | |
| L1 | | 1.65 | | .065 | |
| L2 | 1.27 | 1.78 | .050 | .070 | |
| L3 | 0.25 BSC | | .010 BSC | | |
| L4 | 4.78 | 5.28 | .188 | .208 | |
| m | 17.78 | | .700 | | |
| m1 | 8.89 | | .350 | | |
| n | 11.43 | | .450 | | |
| o | 2.08 | | .082 | | |
| p | 3.81 | | .150 | | |
| R | 0.51 | 0.71 | .020 | .028 | |
| θ | 90° | 93° | 90° | 93° | |

LEAD ASSIGNMENTS

HEXFET
1.- GATE
2, 4.- DRAIN
3.- SOURCE

IGBTs, CoPACK
1.- GATE
2, 4.- COLLECTOR
3.- EMITTER

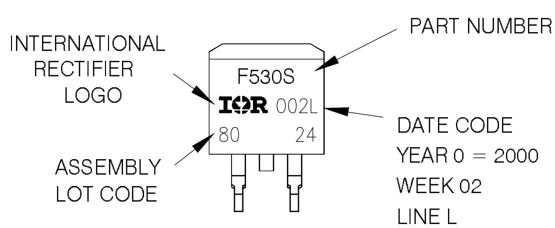
DIODES
1.- ANODE *
2, 4.- CATHODE
3.- ANODE

* PART DEPENDENT.

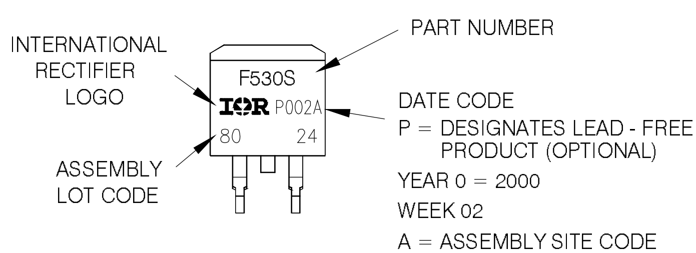
# $D^2$Pak Part Marking Information

EXAMPLE: THIS IS AN IRF530S WITH LOT CODE 8024 ASSEMBLED ON WW 02, 2000 IN THE ASSEMBLY LINE "L"

Note: "P" in assembly line position indicates "Lead - Free"



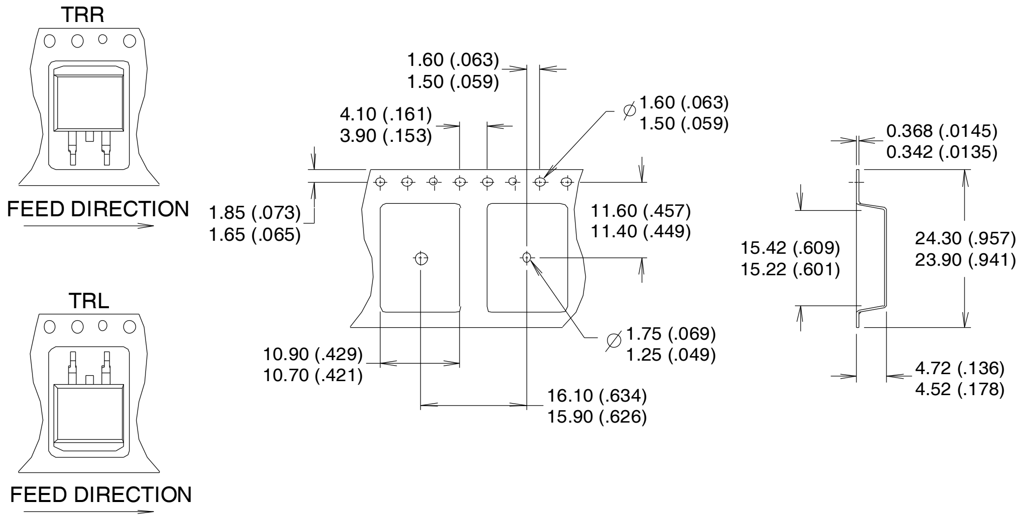

OR

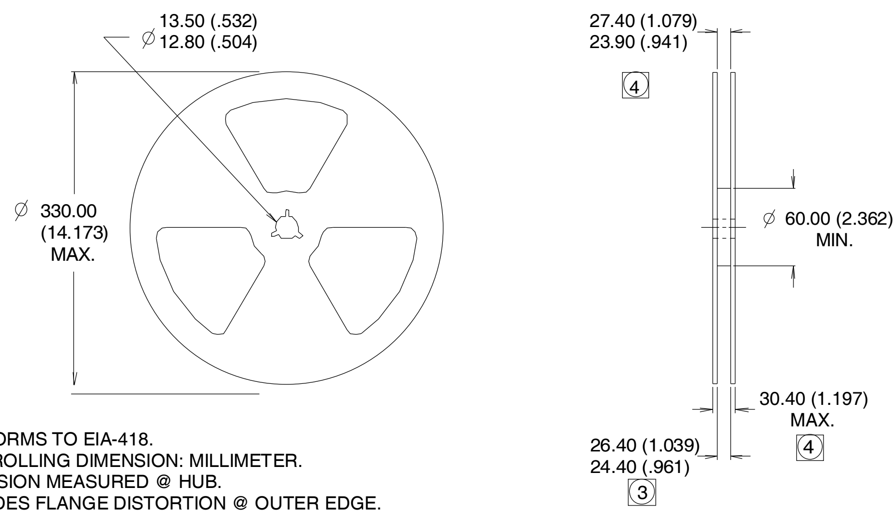



Note: For the most current drawing please refer to IR website at http://www.irf.com/package/

# D²Pak Tape & Reel Information

Dimensions are shown in millimeters (inches)




NOTES :
1. COMFORMS TO EIA-418.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION MEASURED @ HUB.
4. INCLUDES FLANGE DISTORTION @ OUTER EDGE.

**Qualification Information†**

<table>
<tr><td colspan="2">Qualification Level</td><td colspan="2">Industrial††<br>(per JEDEC JESD47F) †††</td></tr>
<tr><td colspan="2">Moisture Sensitivity Level</td><td>D2Pak</td><td>MSL1<br>(per JEDEC J-STD-020D)†††</td></tr>
<tr><td rowspan="3">ESD</td><td>Machine Model</td><td colspan="2">Class M2 (+/- 200V)†††<br>AEC-Q101-002</td></tr>
<tr><td>Human Body Model</td><td colspan="2">Class H1A (+/- 500V)†††<br>AEC-Q101-001</td></tr>
<tr><td>Charged Device Model</td><td colspan="2">Class C5 (+/- 1000V)†††<br>AEC-Q101-005</td></tr>
<tr><td colspan="2">RoHS Compliant</td><td colspan="2">Yes</td></tr>
</table>

† Qualification standards can be found at International Rectifier's web site: http://www.irf.com/product-info/reliability/

†† Higher qualification ratings may be available should the user have such requirements. Please contact your International Rectifier sales representative for further information: http:www.irf.com/whoto-call/salesrep/

††† Applicable version of JEDEC standard at the time of product release.

Data and specifications subject to change without notice.

International Rectifier

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