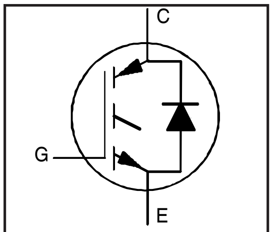
International
IOR Rectifier

PD - 95616A

# IRGB4B60KD1PbF
# IRGS4B60KD1PbF
# IRGSL4B60KD1PbF

INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE




n-channel

$V_{CES}$ = 600V

$I_C$ = 7.6A, $T_C$=100°C

$t_{sc}$ > 10µs, $T_J$=150°C

$V_{CE(on)}$ typ. = 2.1V

## Features

- Low VCE (on) Non Punch Through IGBT Technology.
- 10µs Short Circuit Capability.
- Square RBSOA.
- Positive VCE (on) Temperature Coefficient.
- Maximum Junction Temperature rated at 175°C.
- Lead-Free

## Benefits

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

| TO-220 | $D^2$Pak | TO-262 |
|---|---|---|
| IRGB4B60KD1 | IRGS4B60KD1 | IRGSL4B60KD1 |

## Absolute Maximum Ratings

| | Parameter | Max. | Units |
|---|---|---|---|
| $V_{CES}$ | Collector-to-Emitter Voltage | 600 | V |
| $I_C$ @ $T_C$ = 25°C | Continuous Collector Current | 11 | A |
| $I_C$ @ $T_C$ = 100°C | Continuous Collector Current | 7.6 | |
| $I_{CM}$ | Pulse Collector Current (Ref.Fig.C.T.5) | 22 | |
| $I_{LM}$ | Clamped Inductive Load current ① | 22 | |
| $I_F$ @ $T_C$ = 25°C | Diode Continuous Forward Current | 11 | |
| $I_F$ @ $T_C$ = 100°C | Diode Continuous Forward Current | 6.7 | |
| $I_{FM}$ | Diode Maximum Forward Current | 22 | |
| $V_{GE}$ | Gate-to-Emitter Voltage | ±20 | V |
| $P_D$ @ $T_C$ = 25°C | Maximum Power Dissipation | 63 | W |
| $P_D$ @ $T_C$ = 100°C | Maximum Power Dissipation | 31 | |
| $T_J$<br>$T_{STG}$ | Operating Junction and<br>Storage Temperature Range | -55 to +175 | °C |
| | Storage Temperature Range, for 10 sec. | 300 (0.063 in. (1.6mm) from case) | |

## Thermal / Mechanical Characteristics

| | Parameter | Min. | Typ. | Max. | Units |
|---|---|---|---|---|---|
| $R_{θJC}$ | Junction-to-Case- IGBT | --- | --- | 2.4 | °C/W |
| $R_{θJC}$ | Junction-to-Case- Diode | --- | --- | 6.1 | |
| $R_{θCS}$ | Case-to-Sink, flat, greased surface | --- | 0.50 | --- | |
| $R_{θJA}$ | Junction-to-Ambient | --- | --- | 62 | |
| $R_{θJA}$ | Junction-to-Ambient (PCB Mount, steady state)② | --- | --- | 40 | |
| Wt | Weight | --- | 1.44 | --- | g |




8/30/04

## 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, $I_C$ = 500μA | |
| $\Delta V_{(BR)CES}/\Delta T_J$ | Temperature Coeff. of Breakdown Voltage | — | 0.28 | — | V/°C | $V_{GE}$ = 0V, $I_C$ = 1mA (25°C-150°C) | |
| $V_{CE(on)}$ | Collector-to-Emitter Voltage | — | 2.1 | 2.5 | V | $I_C$ = 4.0A, $V_{GE}$ = 15V, $T_J$ = 25°C | 5,6,7 |
| | | — | 2.5 | 2.8 | | $I_C$ = 4.0A, $V_{GE}$ = 15V, $T_J$ = 150°C | 9,10,11 |
| | | — | 2.6 | 2.9 | | $I_C$ = 4.0A, $V_{GE}$ = 15V, $T_J$ = 175°C | |
| $V_{GE(th)}$ | Gate Threshold Voltage | 3.5 | 4.5 | 5.5 | V | $V_{CE}$ = $V_{GE}$, $I_C$ = 250μA | 9,10,11 |
| $\Delta V_{GE(th)}/\Delta T_J$ | Threshold Voltage temp. coefficient | — | -8.1 | — | mV/°C | $V_{CE}$ = $V_{GE}$, $I_C$ = 1mA (25°C-150°C) | 12 |
| gfe | Forward Transconductance | — | 1.7 | — | S | $V_{CE}$ = 50V, $I_C$ = 4.0A, PW = 80μs | |
| $I_{CES}$ | Zero Gate Voltage Collector Current | — | 1.0 | 150 | μA | $V_{GE}$ = 0V, $V_{CE}$ = 600V | |
| | | — | 136 | 600 | | $V_{GE}$ = 0V, $V_{CE}$ = 600V, $T_J$ = 150°C | |
| | | — | 722 | 2400 | | $V_{GE}$ = 0V, $V_{CE}$ = 600V, $T_J$ = 175°C | |
| $V_{FM}$ | Diode Forward Voltage Drop | — | 1.4 | 2.0 | V | $I_F$ = 4.0A | 8 |
| | | — | 1.3 | 1.8 | | $I_F$ = 4.0A, $T_J$ = 150°C | |
| | | — | 1.2 | 1.7 | | $I_F$ = 4.0A, $T_J$ = 175°C | |
| $I_{GES}$ | Gate-to-Emitter Leakage Current | — | — | ±100 | nA | $V_{GE}$ = ±20V | |

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

| | Parameter | Min. | Typ. | Max. | Units | Conditions | Ref.Fig. |
|---|---|---|---|---|---|---|---|
| $Q_g$ | Total Gate Charge (turn-on) | — | 12 | — | nC | $I_C$ = 4.0A | 23 |
| $Q_{ge}$ | Gate-to-Emitter Charge (turn-on) | — | 1.7 | — | | $V_{CC}$ = 400V | CT1 |
| $Q_{gc}$ | Gate-to-Collector Charge (turn-on) | — | 6.5 | — | | $V_{GE}$ = 15V | |
| $E_{on}$ | Turn-On Switching Loss | — | 73 | 80 | μJ | $I_C$ = 4.0A, $V_{CC}$ = 400V | CT4 |
| $E_{off}$ | Turn-Off Switching Loss | — | 47 | 53 | | $V_{GE}$ = 15V, $R_G$ = 100Ω, L = 2.5mH | |
| $E_{tot}$ | Total Switching Loss | — | 120 | 130 | | $T_J$ = 25°C ③ | |
| $t_{d(on)}$ | Turn-On delay time | — | 22 | 28 | ns | $I_C$ = 4.0A, $V_{CC}$ = 400V | |
| $t_r$ | Rise time | — | 18 | 23 | | $V_{GE}$ = 15V, $R_G$ = 100Ω, L = 2.5mH | CT4 |
| $t_{d(off)}$ | Turn-Off delay time | — | 100 | 110 | | $T_J$ = 25°C | |
| $t_f$ | Fall time | — | 66 | 80 | | | |
| $E_{on}$ | Turn-On Switching Loss | — | 130 | 150 | μJ | $I_C$ = 4.0A, $V_{CC}$ = 400V | CT4 |
| $E_{off}$ | Turn-Off Switching Loss | — | 83 | 140 | | $V_{GE}$ = 15V, $R_G$ = 100Ω, L = 2.5mH | 13,15 |
| $E_{tot}$ | Total Switching Loss | — | 220 | 280 | | $T_J$ = 150°C ③ | WF1,WF2 |
| $t_{d(on)}$ | Turn-On delay time | — | 22 | 27 | ns | $I_C$ = 4.0A, $V_{CC}$ = 400V | 14,16 |
| $t_r$ | Rise time | — | 18 | 22 | | $V_{GE}$ = 15V, $R_G$ = 100Ω, L = 2.5mH | CT4 |
| $t_{d(off)}$ | Turn-Off delay time | — | 120 | 130 | | $T_J$ = 150°C | WF1 |
| $t_f$ | Fall time | — | 79 | 89 | | | WF2 |
| $C_{ies}$ | Input Capacitance | — | 190 | — | pF | $V_{GE}$ = 0V | |
| $C_{oes}$ | Output Capacitance | — | 25 | — | | $V_{CC}$ = 30V | 22 |
| $C_{res}$ | Reverse Transfer Capacitance | — | 6.2 | — | | f = 1.0MHz | |
| RBSOA | Reverse Bias Safe Operating Area | FULL SQUARE | | | | $T_J$ = 150°C, $I_C$ = 22A, Vp = 600V | 4 |
| | | | | | | $V_{CC}$=500V,$V_{GE}$ = +15V to 0V,$R_G$ = 100Ω | CT2 |
| SCSOA | Short Circuit Safe Operating Area | 10 | — | — | μs | $T_J$ = 150°C, Vp = 600V, $R_G$ = 100Ω | CT3 |
| | | | | | | $V_{CC}$=360V,$V_{GE}$ = +15V to 0V | WF4 |
| $E_{rec}$ | Reverse Recovery Energy of the Diode | — | 81 | 100 | μJ | $T_J$ = 150°C | 17,18,19 |
| $t_{rr}$ | Diode Reverse Recovery Time | — | 93 | — | ns | $V_{CC}$ = 400V, $I_F$ = 4.0A, L = 2.5mH | 20,21 |
| $I_{rr}$ | Peak Reverse Recovery Current | — | 6.3 | 7.9 | A | $V_{GE}$ = 15V, $R_G$ = 100Ω | CT4,WF3 |

Note ① to ③ are on page 16

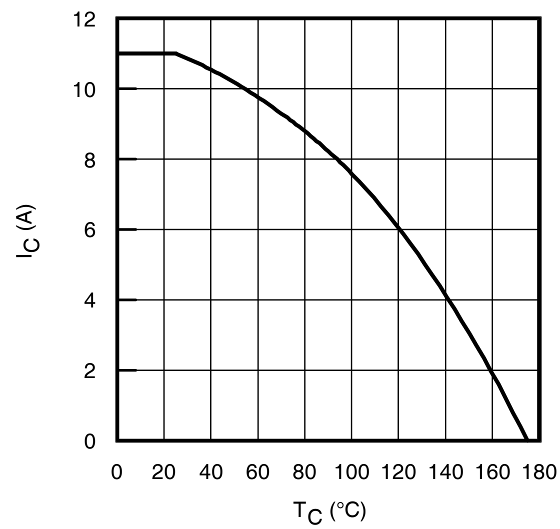



**Fig. 1** - Maximum DC Collector Current vs. Case Temperature

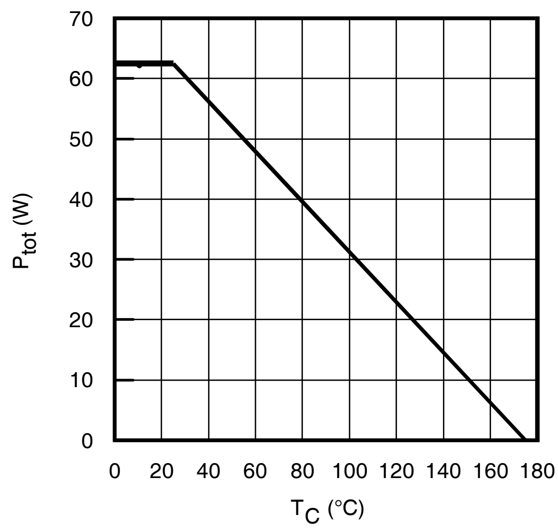



**Fig. 2** - Power Dissipation vs. Case Temperature

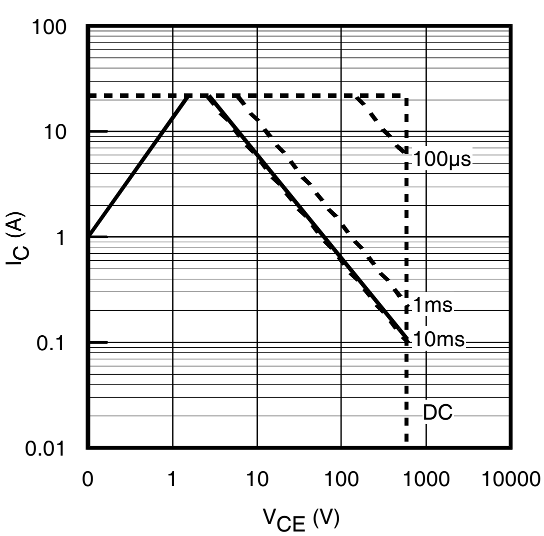



**Fig. 3** - Forward SOA
$T_C$ = 25°C; $T_J \leq$ 150°C

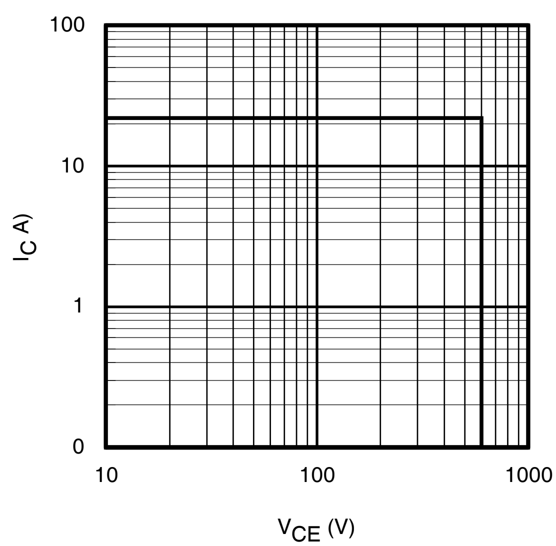



**Fig. 4** - Reverse Bias SOA
$T_J$ = 150°C; $V_{GE}$ =15V

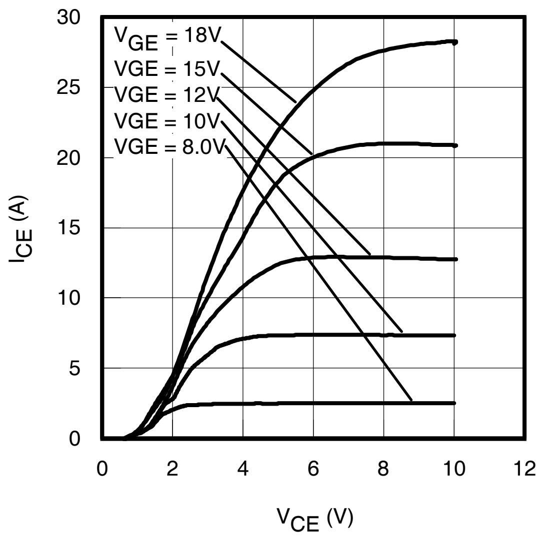



**Fig. 5** - Typ. IGBT Output Characteristics
$T_J$ = -40°C; tp = 80µs

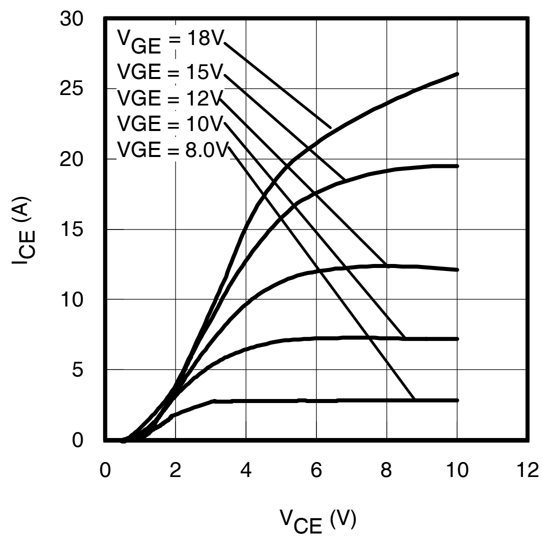



**Fig. 6** - Typ. IGBT Output Characteristics
$T_J$ = 25°C; tp = 80µs

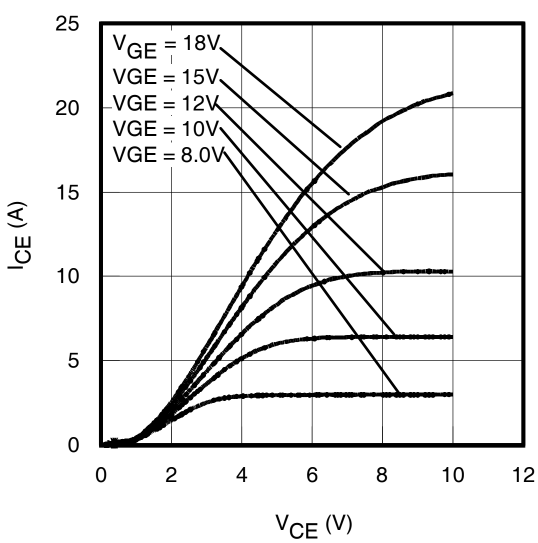



**Fig. 7** - Typ. IGBT Output Characteristics
$T_J$ = 150°C; tp = 80µs

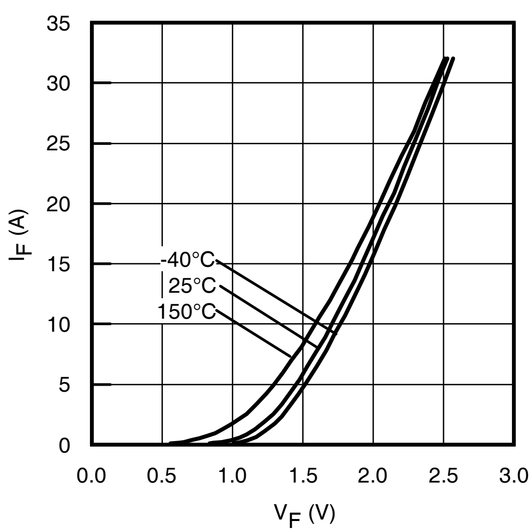



**Fig. 8** - Typ. Diode Forward Characteristics
tp = 80µs

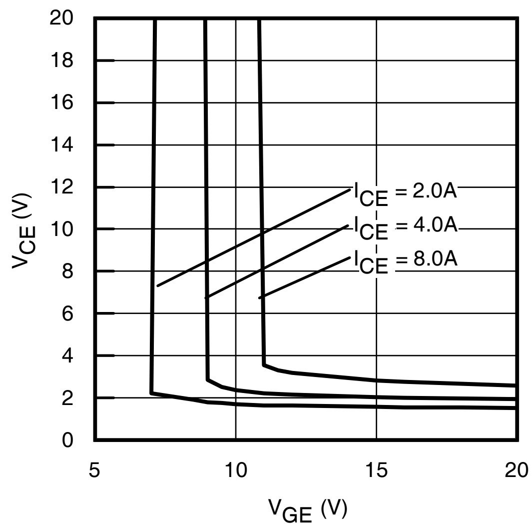



**Fig. 9** - Typical $V_{CE}$ vs. $V_{GE}$
$T_J$ = -40°C

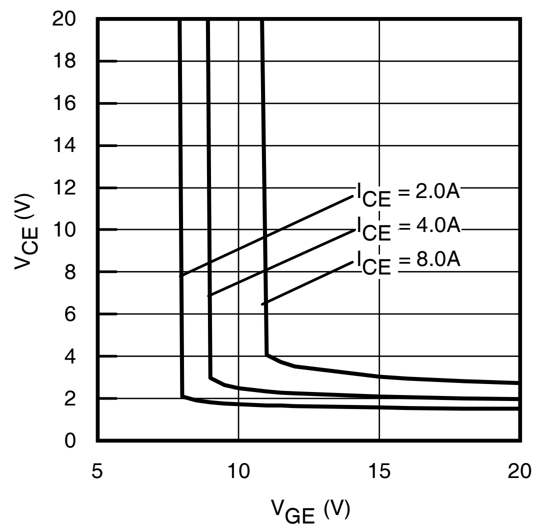



**Fig. 10** - Typical $V_{CE}$ vs. $V_{GE}$
$T_J$ = 25°C

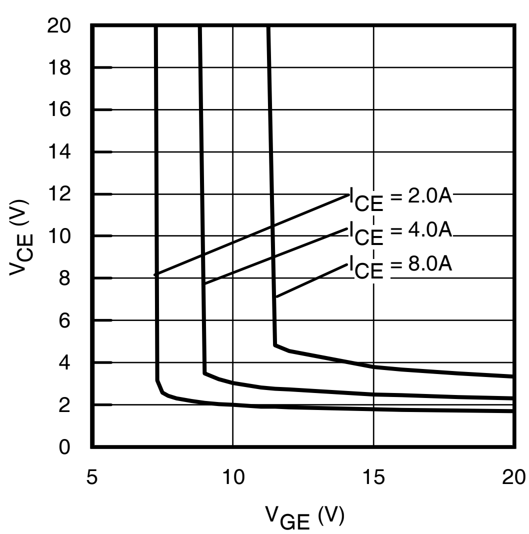



**Fig. 11** - Typical $V_{CE}$ vs. $V_{GE}$
$T_J$ = 150°C

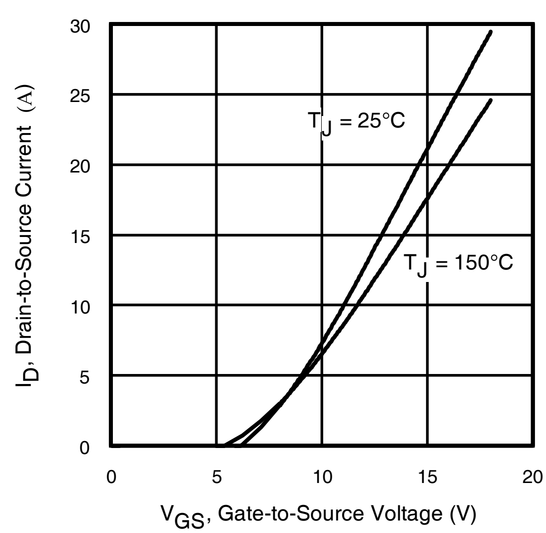



**Fig. 12** - Typ. Transfer Characteristics
$V_{CE}$ = 360V; tp = 10µs

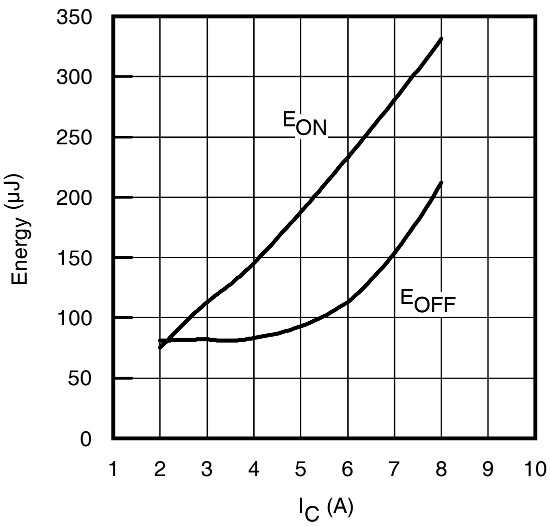



**Fig. 13** - Typ. Energy Loss vs. $I_C$
$T_J$ = 150°C; L=2.5mH; $V_{CE}$= 400V,
$R_G$= 100Ω; $V_{GE}$= 15V

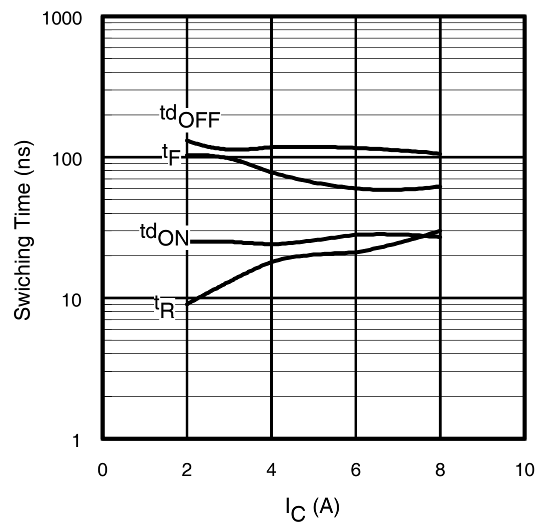



**Fig. 14** - Typ. Switching Time vs. $I_C$
$T_J$ = 150°C; L=2.5mH; $V_{CE}$= 400V
$R_G$= 100Ω; $V_{GE}$= 15V

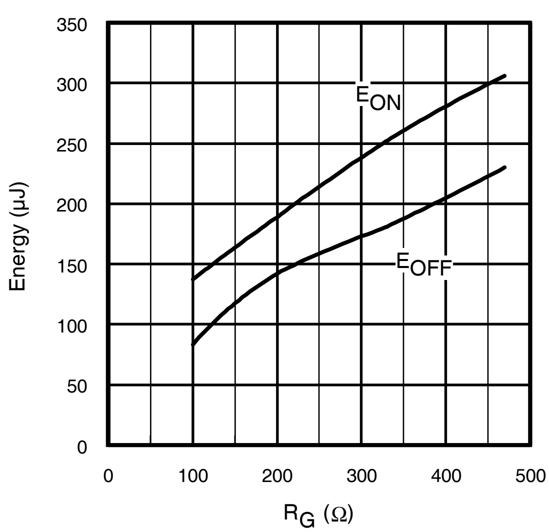



**Fig. 15** - Typ. Energy Loss vs. $R_G$
$T_J$ = 150°C; L=2.5mH; $V_{CE}$= 400V
$I_{CE}$= 4.0A; $V_{GE}$= 15V

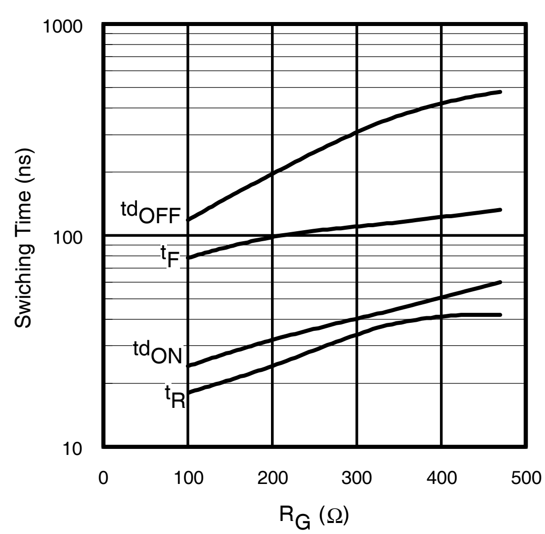



**Fig. 16** - Typ. Switching Time vs. $R_G$
$T_J$ = 150°C; L=2.5mH; $V_{CE}$= 400V
$I_{CE}$= 4.0A; $V_{GE}$= 15V

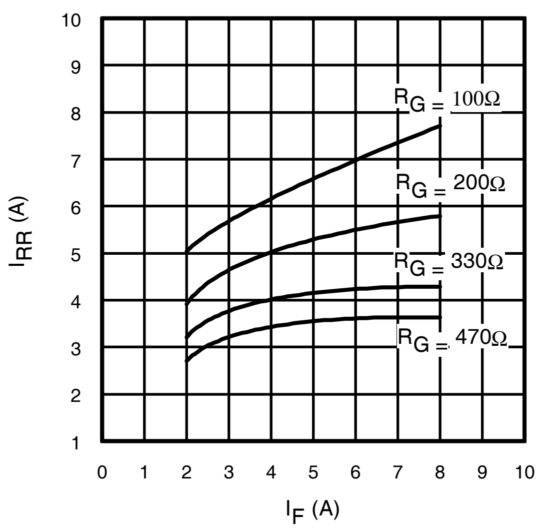



**Fig. 17** - Typical Diode $I_{RR}$ vs. $I_F$
$T_J$ = 150°C

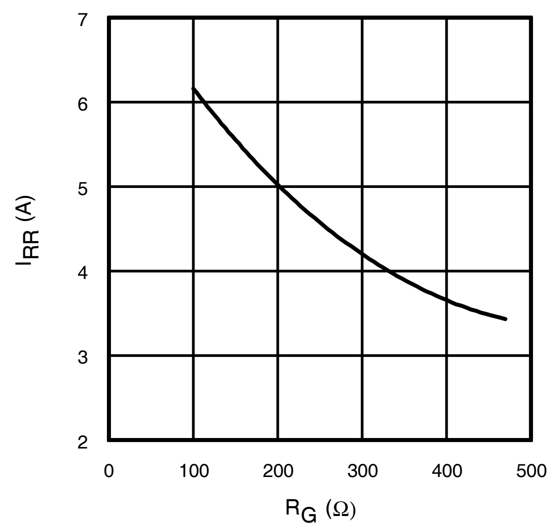



**Fig. 18** - Typical Diode $I_{RR}$ vs. $R_G$
$T_J$ = 150°C; $I_F$ = 4.0A

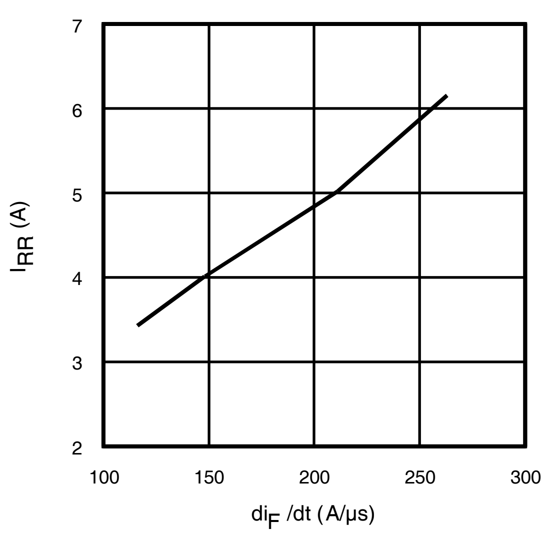



**Fig. 19**- Typical Diode $I_{RR}$ vs. $di_F/dt$
$V_{CC}$= 400V; $V_{GE}$= 15V;
$I_F$ = 4.0A; $T_J$ = 150°C

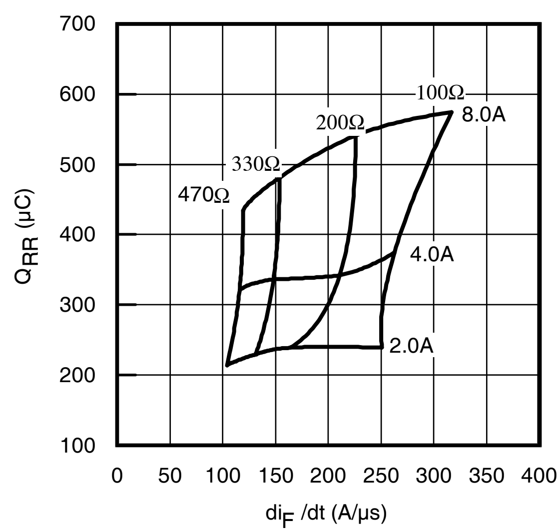



**Fig. 20** - Typical Diode $Q_{RR}$
$V_{CC}$= 400V; $V_{GE}$= 15V;$T_J$ = 150°C

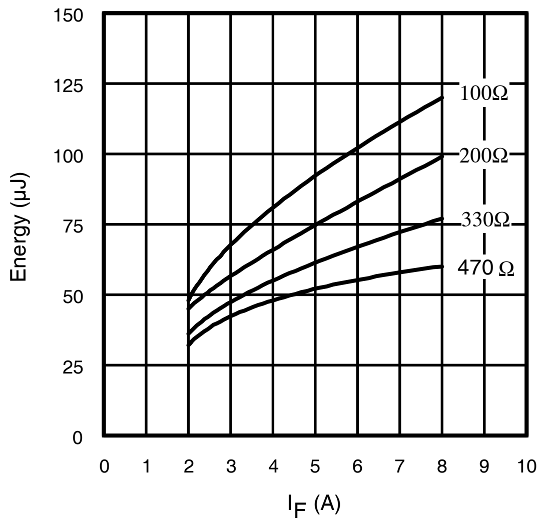



**Fig. 21** - Typical Diode $E_{RR}$ vs. $I_F$
$T_J$ = 150°C

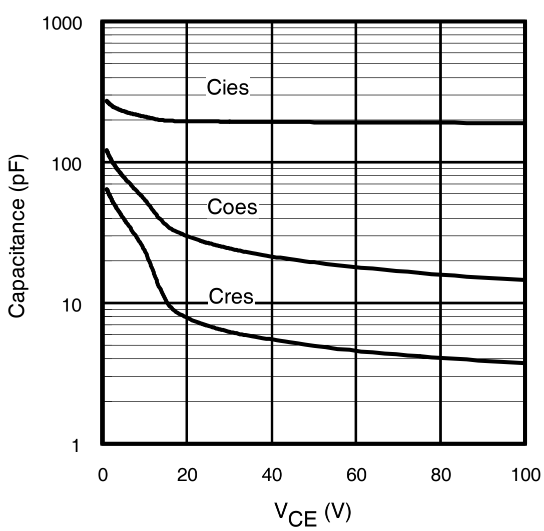



**Fig. 22**- Typ. Capacitance vs. $V_{CE}$
$V_{GE}$= 0V; f = 1MHz

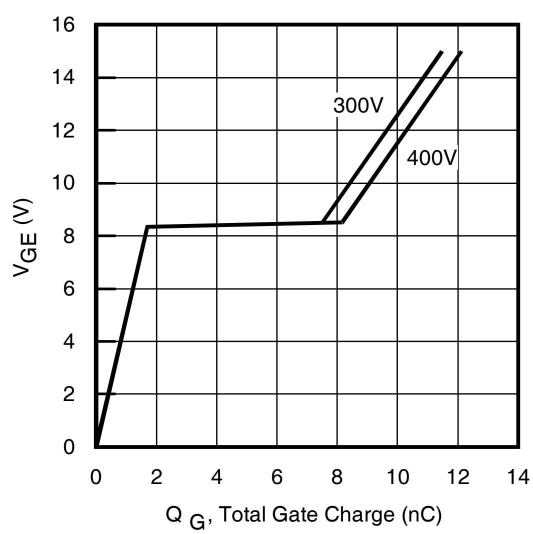



**Fig. 23** - Typical Gate Charge vs. $V_{GE}$
$I_{CE}$ = 4.0A; L = 3150µH

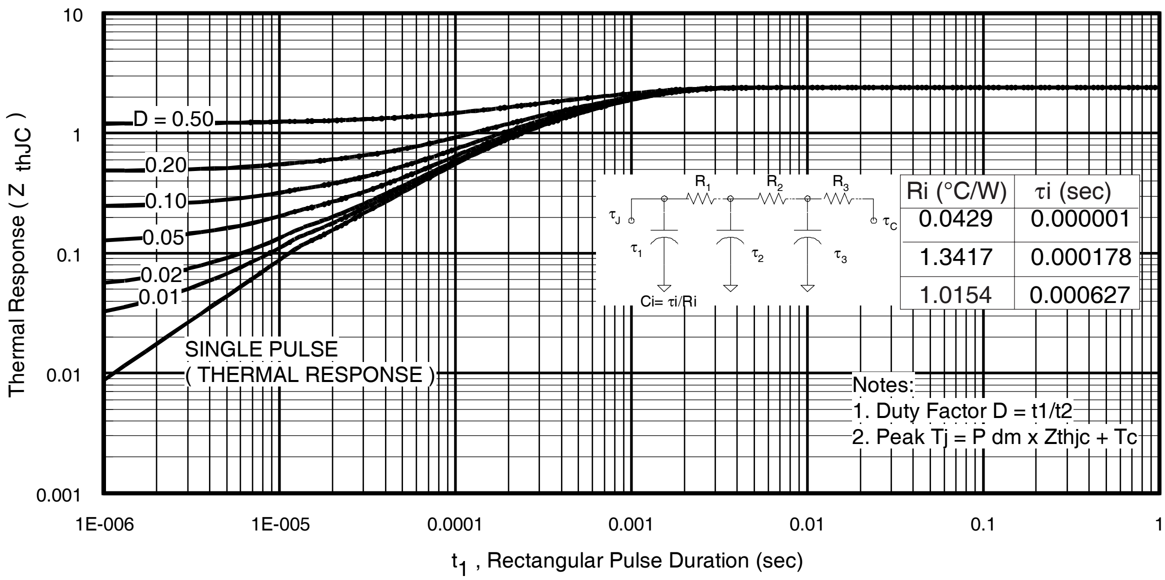



**Fig 24.** Maximum Transient Thermal Impedance, Junction-to-Case (IGBT)

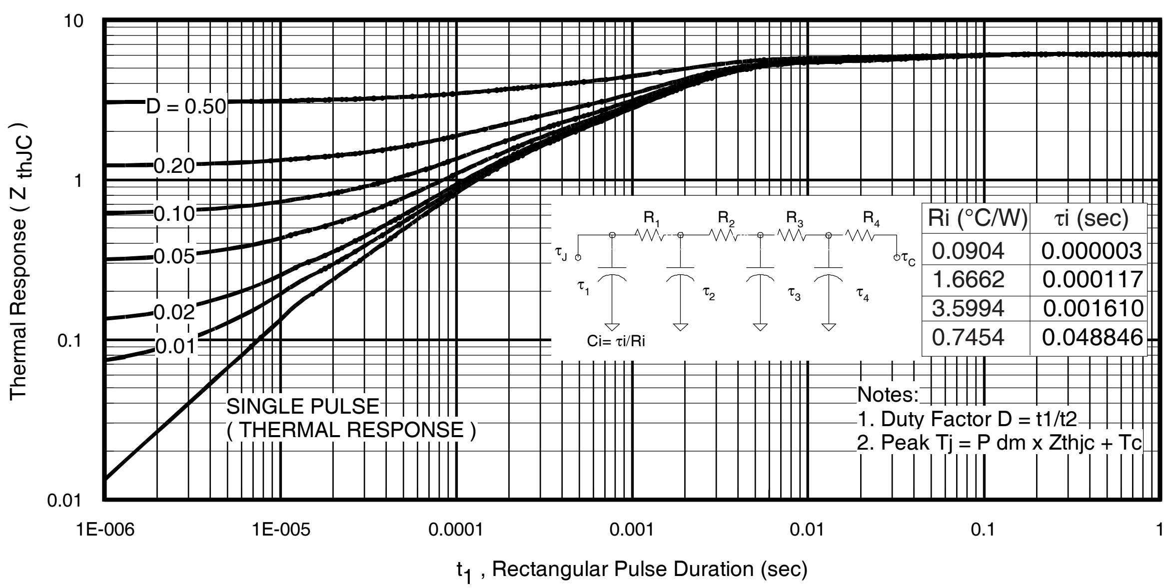



**Fig 25.** Maximum Transient Thermal Impedance, Junction-to-Case (DIODE)

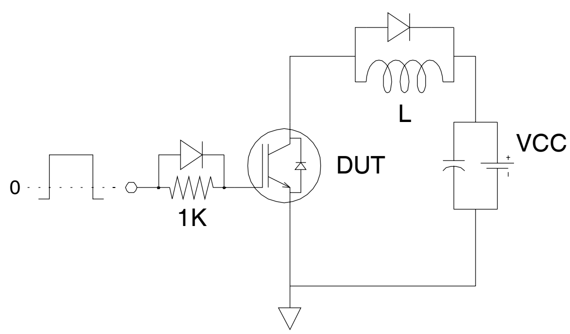



**Fig.C.T.1** - Gate Charge Circuit (turn-off)

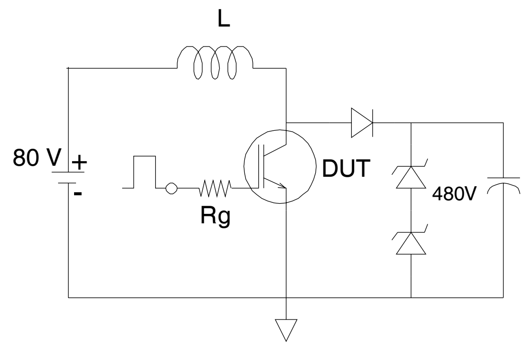



**Fig.C.T.2** - RBSOA Circuit

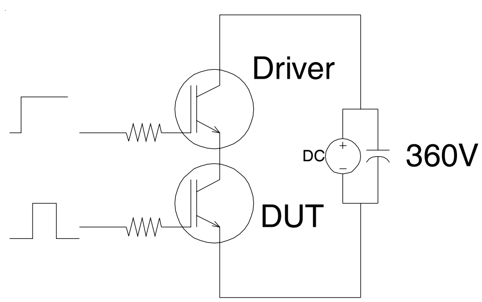



**Fig.C.T.3** - S.C.SOA Circuit

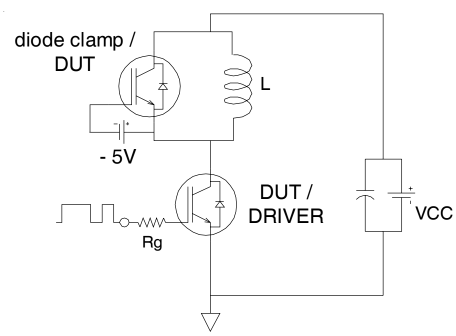



**Fig.C.T.4** - Switching Loss Circuit

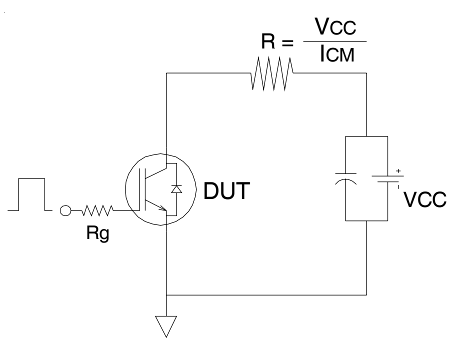



**Fig.C.T.5** - Resistive Load Circuit

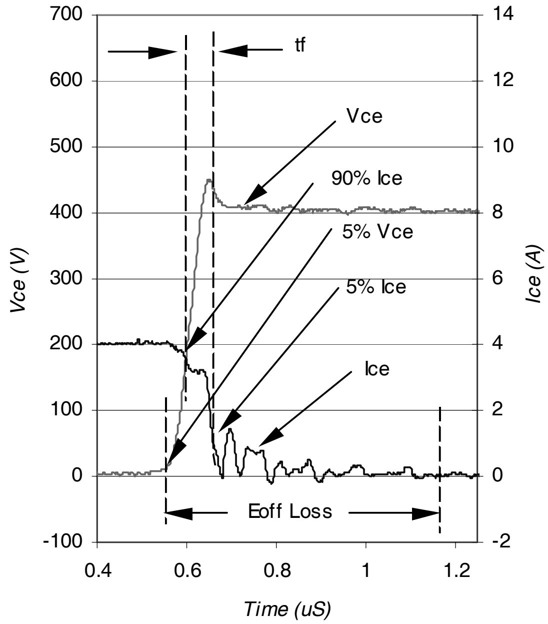



Fig. WF1- Typ. Turn-off Loss Waveform
@ $T_J$ = 150°C using Fig. CT.4

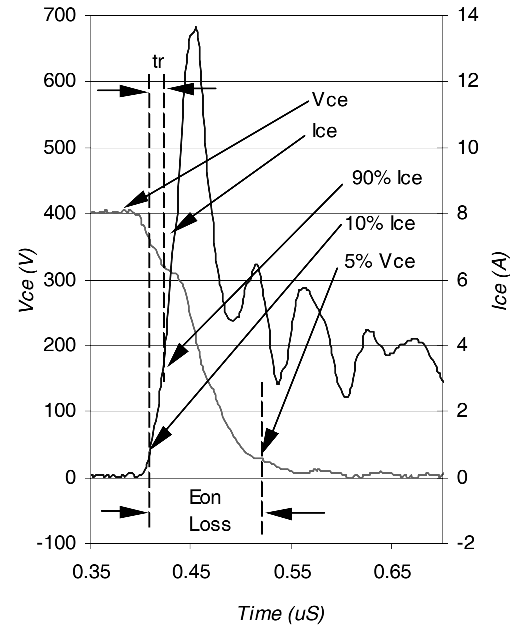



Fig. WF2- Typ. Turn-on Loss Waveform
@ $T_J$ = 150°C using Fig. CT.4

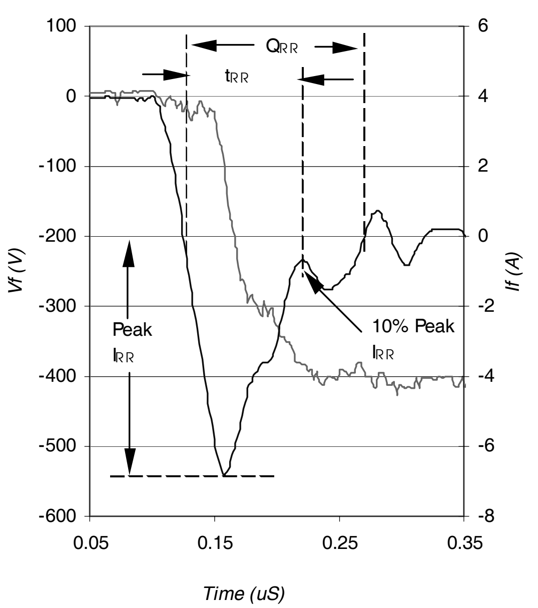



Fig. WF3- Typ. Diode Recovery Waveform
@ $T_J$ = 150°C using Fig. CT.4

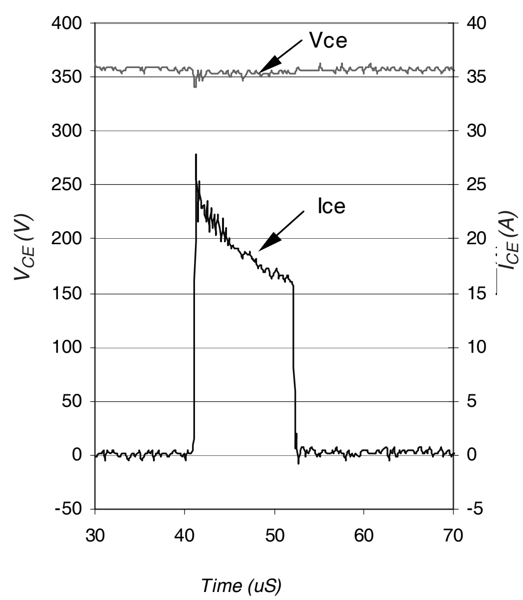
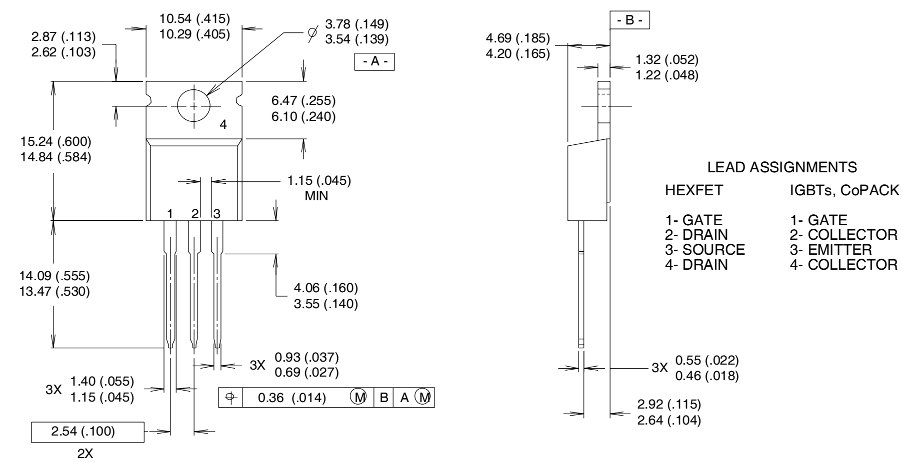



Fig. WF4- Typ. S.C Waveform
@ $T_C$ = 150°C using Fig. CT.3

## TO-220AB Package Outline

Dimensions are shown in millimeters (inches)



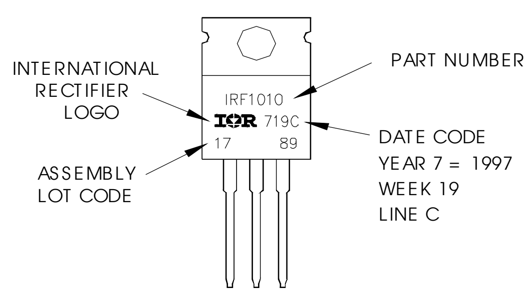

NOTES:

1 DIMENSIONING & TOLERANCING PER ANSI Y14.5M, 1982.
2 CONTROLLING DIMENSION : INCH
3 OUTLINE CONFORMS TO JEDEC OUTLINE TO-220AB.
4 HEATSINK & LEAD MEASUREMENTS DO NOT INCLUDE BURRS.

## TO-220AB Part Marking Information

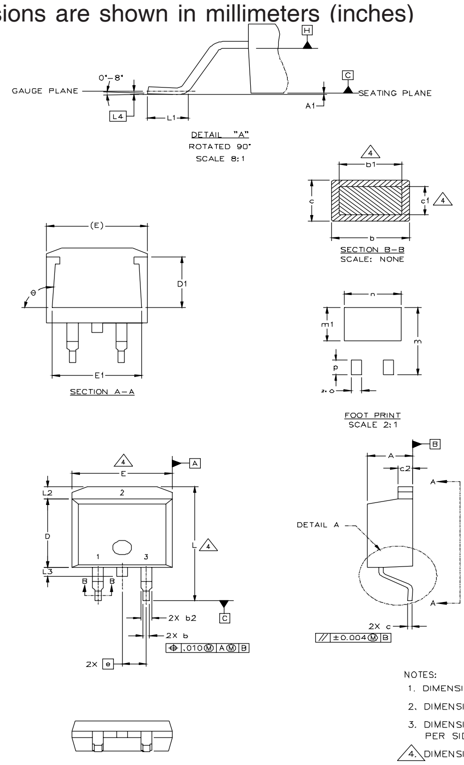
EXAMPLE: THIS IS AN IRF1010
LOT CODE 1789
ASSEMBLED ON WW 19, 1997
IN THE ASSEMBLY LINE "C"

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



## D2Pak Package Outline

Dimensions are shown in millimeters (inches)




| SYMBOL | DIMENSIONS | | | | NOTES |
|---|---|---|---|---|---|
| | MILLIMETERS | | INCHES | | |
| | MIN. | MAX. | MIN. | MAX. | |
| A | 4.06 | 4.83 | .160 | .190 | |
| A1 | | 0.127 | | .005 | |
| b | 0.51 | 0.99 | .020 | .039 | |
| b1 | 0.51 | 0.89 | .020 | .035 | 4 |
| b2 | 1.14 | 1.40 | .045 | .055 | |
| c | 0.43 | 0.63 | .017 | .025 | |
| c1 | 0.38 | 0.74 | .015 | .029 | 4 |
| c2 | 1.14 | 1.40 | .045 | .055 | |
| D | 8.51 | 9.65 | .335 | .380 | 3 |
| D1 | 5.33 | | .210 | | |
| E | 9.65 | 10.67 | .380 | .420 | 3 |
| E1 | 6.22 | | .245 | | |
| e | 2.54 BSC | | .100 BSC | | |
| L | 14.61 | 15.88 | .575 | .625 | |
| L1 | 1.78 | 2.79 | .070 | .110 | |
| L2 | | 1.65 | | .065 | |
| L3 | 1.27 | 1.78 | .050 | .070 | |
| L4 | 0.25 BSC | | .010 BSC | | |
| m | 17.78 | | .700 | | |
| m1 | 8.89 | | .350 | | |
| n | 11.43 | | .450 | | |
| o | 2.08 | | .082 | | |
| p | 3.81 | | .150 | | |
| θ | 90° | 93° | 90° | 93° | |

LEAD ASSIGNMENTS

| HEXFET | IGBTs, CoPACK | DIODES |
|---|---|---|
| 1.– GATE | 1.– GATE | 1.– ANODE * |
| 2.– DRAIN | 2.– COLLECTOR | 2.– CATHODE |
| 3.– SOURCE | 3.– EMITTER | 3.– ANODE |

* PART DEPENDENT.

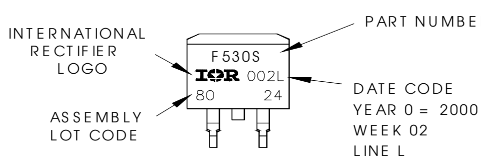
NOTES:

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.

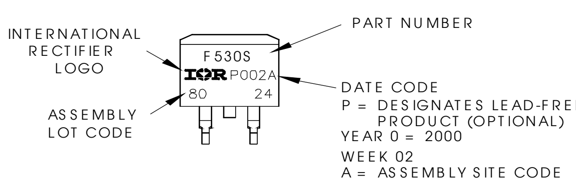
## D2Pak Part Marking Information (Lead-Free)

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

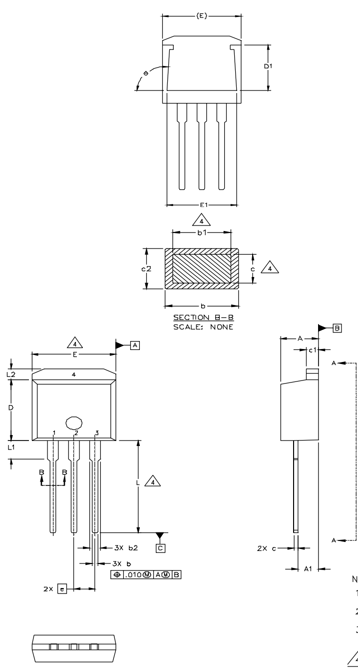
Note: "P" in assembly line position indicates "Lead-Free"




OR



## TO-262 Package Outline



| SYMBOL | DIMENSIONS | | | | NOTES |
|---|---|---|---|---|---|
| | MILLIMETERS | | INCHES | | |
| | MIN. | MAX. | MIN. | MAX. | |
| A | 4.06 | 4.83 | .160 | .190 | |
| A1 | 2.03 | 2.92 | .080 | .115 | |
| b | 0.51 | 0.99 | .020 | .039 | |
| b1 | 0.51 | 0.89 | .020 | .035 | 4 |
| b2 | 1.14 | 1.40 | .045 | .055 | |
| c | 0.38 | 0.63 | .015 | .025 | 4 |
| c1 | 1.14 | 1.40 | .045 | .055 | |
| c2 | 0.43 | .063 | .017 | .029 | |
| D | 8.51 | 9.65 | .335 | .380 | 3 |
| D1 | 5.33 | | .210 | | |
| E | 9.65 | 10.67 | .380 | .420 | 3 |
| E1 | 6.22 | | .245 | | |
| e | 2.54 BSC | | .100 BSC | | |
| L | 13.46 | 14.09 | .530 | .555 | |
| L1 | 3.56 | 3.71 | .140 | .146 | |
| L2 | | 1.65 | | .065 | |

LEAD ASSIGNMENTS

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

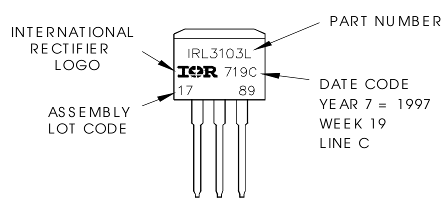
IGBT
1 - GATE
2 - COLLECTOR
3 - EMITTER

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.

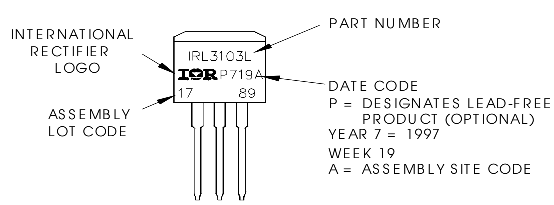
## TO-262 Part Marking Information

EXAMPLE: THIS IS AN IRL3103L
LOT CODE 1789
ASSEMBLED ON WW 19, 1997
IN THE ASSEMBLY LINE "C"

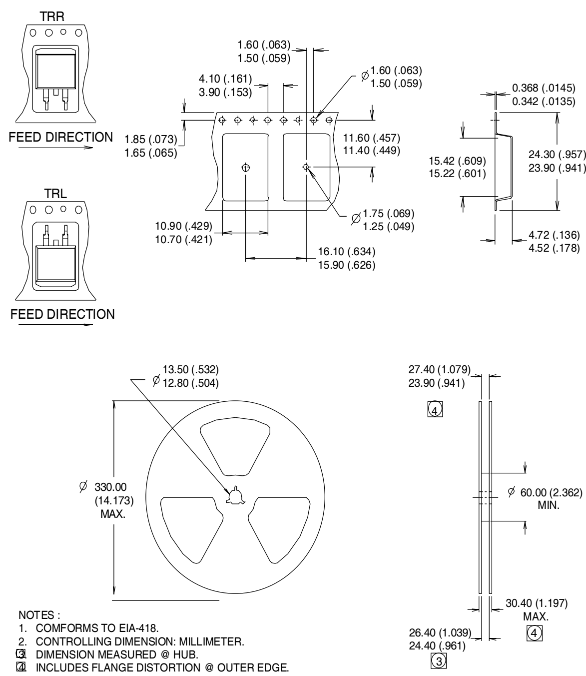
Note: "P" in assembly line position indicates "Lead-Free"




OR



## $D^2$Pak Tape & Reel Infomation




Notes:

① $V_{CC}$ = 80% ($V_{CES}$), $V_{GE}$ = 15V, L = 100µH, $R_G$ = 100Ω.

② When mounted on 1" square PCB ( FR-4 or G-10 Material ). For recommended footprint and soldering techniques refer to application note #AN-994.

③ Energy losses include "tail" and diode reverse recovery, using Diode FD059H06A5.

**TO-220AB package is not recommended for Surface Mount Application.**

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

International
IOR Rectifier

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Visit us at www.irf.com for sales contact information. 08/04

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