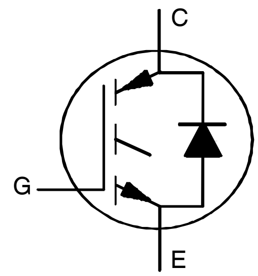
International
IOR Rectifier

**SMPS IGBT**

PD - 95329

# IRGP35B60PDPbF

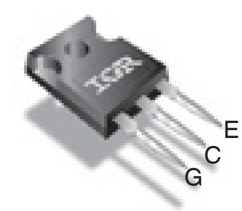
## WARP2 SERIES IGBT WITH ULTRAFAST SOFT RECOVERY DIODE




n-channel

$V_{CES}$ = 600V
$V_{CE(on)}$ typ. = 1.85V
@ $V_{GE}$ = 15V $I_C$ = 22A

**Equivalent MOSFET Parameters**①
$R_{CE(on)}$ typ. = 84mΩ
$I_D$ (FET equivalent) = 35A




TO-247AC

### Applications
- Telecom and Server SMPS
- PFC and ZVS SMPS Circuits
- Uninterruptable Power Supplies
- Consumer Electronics Power Supplies
- Lead-Free

### Features
- NPT Technology, Positive Temperature Coefficient
- Lower $V_{CE}$(SAT)
- Lower Parasitic Capacitances
- Minimal Tail Current
- HEXFRED Ultra Fast Soft-Recovery Co-Pack Diode
- Tighter Distribution of Parameters
- Higher Reliability

### Benefits
- Parallel Operation for Higher Current Applications
- Lower Conduction Losses and Switching Losses
- Higher Switching Frequency up to 150kHz

### Absolute Maximum Ratings

| | Parameter | Max. | Units |
|---|---|---|---|
| $V_{CES}$ | Collector-to-Emitter Voltage | 600 | V |
| $I_C$ @ $T_C$ = 25°C | Continuous Collector Current | 60 | A |
| $I_C$ @ $T_C$ = 100°C | Continuous Collector Current | 34 | |
| $I_{CM}$ | Pulse Collector Current (Ref. Fig. C.T.4) | 120 | |
| $I_{LM}$ | Clamped Inductive Load Current ② | 120 | |
| $I_F$ @ $T_C$ = 25°C | Diode Continous Forward Current | 40 | |
| $I_F$ @ $T_C$ = 100°C | Diode Continous Forward Current | 15 | |
| $I_{FRM}$ | Maximum Repetitive Forward Current ③ | 60 | |
| $V_{GE}$ | Gate-to-Emitter Voltage | ±20 | V |
| $P_D$ @ $T_C$ = 25°C | Maximum Power Dissipation | 308 | W |
| $P_D$ @ $T_C$ = 100°C | Maximum Power Dissipation | 123 | |
| $T_J$<br>$T_{STG}$ | Operating Junction and<br>Storage Temperature Range | -55 to +150 | °C |
| | Soldering Temperature for 10 sec. | 300 (0.063 in. (1.6mm) from case) | |
| | Mounting Torque, 6-32 or M3 Screw | 10 lbf·in (1.1 N·m) | |

### Thermal Resistance

| | Parameter | Min. | Typ. | Max. | Units |
|---|---|---|---|---|---|
| $R_{\theta JC}$ (IGBT) | Thermal Resistance Junction-to-Case-(each IGBT) | —— | —— | 0.41 | °C/W |
| $R_{\theta JC}$ (Diode) | Thermal Resistance Junction-to-Case-(each Diode) | —— | —— | 1.7 | |
| $R_{\theta CS}$ | Thermal Resistance, Case-to-Sink (flat, greased surface) | —— | 0.24 | —— | |
| $R_{\theta JA}$ | Thermal Resistance, Junction-to-Ambient (typical socket mount) | —— | —— | 40 | |
| | Weight | —— | 6.0 (0.21) | —— | g (oz) |

### 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 | — | 0.78 | — | V/°C | $V_{GE}$ = 0V, $I_C$ = 1mA (25°C-125°C) | |
| $R_G$ | Internal Gate Resistance | — | 1.7 | — | Ω | 1MHz, Open Collector | |
| $V_{CE(on)}$ | Collector-to-Emitter Saturation Voltage | — | 1.85 | 2.15 | V | $I_C$ = 22A, $V_{GE}$ = 15V | 4, 5,6,8,9 |
| | | — | 2.25 | 2.55 | | $I_C$ = 35A, $V_{GE}$ = 15V | |
| | | — | 2.37 | 2.80 | | $I_C$ = 22A, $V_{GE}$ = 15V, $T_J$ = 125°C | |
| | | — | 3.00 | 3.45 | | $I_C$ = 35A, $V_{GE}$ = 15V, $T_J$ = 125°C | |
| $V_{GE(th)}$ | Gate Threshold Voltage | 3.0 | 4.0 | 5.0 | V | $I_C$ = 250μA | 7,8,9 |
| $\Delta V_{GE(th)}/\Delta TJ$ | Threshold Voltage temp. coefficient | — | -10 | — | mV/°C | $V_{CE}$ = $V_{GE}$, $I_C$ = 1.0mA | |
| gfe | Forward Transconductance | — | 36 | — | S | $V_{CE}$ = 50V, $I_C$ = 22A, PW = 80μs | |
| $I_{CES}$ | Collector-to-Emitter Leakage Current | — | 3.0 | 375 | μA | $V_{GE}$ = 0V, $V_{CE}$ = 600V | |
| | | — | 0.35 | — | mA | $V_{GE}$ = 0V, $V_{CE}$ = 600V, $T_J$ = 125°C | |
| $V_{FM}$ | Diode Forward Voltage Drop | — | 1.30 | 1.70 | V | $I_F$ = 15A, $V_{GE}$ = 0V | 10 |
| | | — | 1.20 | 1.60 | | $I_F$ = 15A, $V_{GE}$ = 0V, $T_J$ = 125°C | |
| $I_{GES}$ | Gate-to-Emitter Leakage Current | — | — | ±100 | nA | $V_{GE}$ = ±20V, $V_{CE}$ = 0V | |

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

| | Parameter | Min. | Typ. | Max. | Units | Conditions | Ref.Fig |
|---|---|---|---|---|---|---|---|
| Qg | Total Gate Charge (turn-on) | — | 160 | 240 | nC | $I_C$ = 22A | 17 |
| $Q_{gc}$ | Gate-to-Collector Charge (turn-on) | — | 55 | 83 | | $V_{CC}$ = 400V | CT1 |
| $Q_{ge}$ | Gate-to-Emitter Charge (turn-on) | — | 21 | 32 | | $V_{GE}$ = 15V | |
| $E_{on}$ | Turn-On Switching Loss | — | 220 | 270 | μJ | $I_C$ = 22A, $V_{CC}$ = 390V | CT3 |
| $E_{off}$ | Turn-Off Switching Loss | — | 215 | 265 | | $V_{GE}$ = +15V, $R_G$ = 3.3Ω, L = 200μH | |
| $E_{total}$ | Total Switching Loss | — | 435 | 535 | | $T_J$ = 25°C ④ | |
| $t_{d(on)}$ | Turn-On delay time | — | 26 | 34 | ns | $I_C$ = 22A, $V_{CC}$ = 390V | CT3 |
| $t_r$ | Rise time | — | 6.0 | 8.0 | | $V_{GE}$ = +15V, $R_G$ = 3.3Ω, L = 200μH | |
| $t_{d(off)}$ | Turn-Off delay time | — | 110 | 122 | | $T_J$ = 25°C ④ | |
| $t_f$ | Fall time | — | 8.0 | 10 | | | |
| $E_{on}$ | Turn-On Switching Loss | — | 410 | 465 | μJ | $I_C$ = 22A, $V_{CC}$ = 390V | CT3 |
| $E_{off}$ | Turn-Off Switching Loss | — | 330 | 405 | | $V_{GE}$ = +15V, $R_G$ = 3.3Ω, L = 200μH | 11,13 |
| $E_{total}$ | Total Switching Loss | — | 740 | 870 | | $T_J$ = 125°C ④ | WF1,WF2 |
| $t_{d(on)}$ | Turn-On delay time | — | 26 | 34 | ns | $I_C$ = 22A, $V_{CC}$ = 390V | CT3 |
| $t_r$ | Rise time | — | 8.0 | 11 | | $V_{GE}$ = +15V, $R_G$ = 3.3Ω, L = 200μH | 12,14 |
| $t_{d(off)}$ | Turn-Off delay time | — | 130 | 150 | | $T_J$ = 125°C ④ | WF1,WF2 |
| $t_f$ | Fall time | — | 12 | 16 | | | |
| $C_{ies}$ | Input Capacitance | — | 3715 | — | pF | $V_{GE}$ = 0V | 16 |
| $C_{oes}$ | Output Capacitance | — | 265 | — | | $V_{CC}$ = 30V | |
| $C_{res}$ | Reverse Transfer Capacitance | — | 47 | — | | f = 1Mhz | |
| $C_{oes}$ eff. | Effective Output Capacitance (Time Related) ⑤ | — | 135 | — | | $V_{GE}$ = 0V, $V_{CE}$ = 0V to 480V | 15 |
| $C_{oes}$ eff. (ER) | Effective Output Capacitance (Energy Related) ⑤ | — | 179 | — | | | |
| RBSOA | Reverse Bias Safe Operating Area | FULL SQUARE | | | | $T_J$ = 150°C, $I_C$ = 120A<br>$V_{CC}$ = 480V, Vp =600V<br>Rg = 22Ω, $V_{GE}$ = +15V to 0V | 3<br>CT2 |
| $t_{rr}$ | Diode Reverse Recovery Time | — | 42 | 60 | ns | $T_J$ = 25°C $I_F$ = 15A, $V_R$ = 200V, | 19 |
| | | — | 74 | 120 | | $T_J$ = 125°C di/dt = 200A/μs | |
| $Q_{rr}$ | Diode Reverse Recovery Charge | — | 80 | 180 | nC | $T_J$ = 25°C $I_F$ = 15A, $V_R$ = 200V, | 21 |
| | | — | 220 | 600 | | $T_J$ = 125°C di/dt = 200A/μs | |
| $I_{rr}$ | Peak Reverse Recovery Current | — | 4.0 | 6.0 | A | $T_J$ = 25°C $I_F$ = 15A, $V_R$ = 200V, | 19,20,21,22 |
| | | — | 6.5 | 10 | | $T_J$ = 125°C di/dt = 200A/μs | CT5 |

Notes:

① $R_{CE(on)}$ typ. = equivalent on-resistance = $V_{CE(on)}$ typ./ $I_C$, where $V_{CE(on)}$ typ.= 1.85V and $I_C$ =22A. $I_D$ (FET Equivalent) is the equivalent MOSFET $I_D$ rating @ 25°C for applications up to 150kHz. These are provided for comparison purposes (only) with equivalent MOSFET solutions.

② $V_{CC}$ = 80% ($V_{CES}$), $V_{GE}$ = 15V, L = 28 μH, $R_G$ = 22 Ω.

③ Pulse width limited by max. junction temperature.

④ Energy losses include "tail" and diode reverse recovery, Data generated with use of Diode 30ETH06.

⑤ $C_{oes}$ eff. is a fixed capacitance that gives the same charging time as $C_{oes}$ while $V_{CE}$ is rising from 0 to 80% $V_{CES}$.
$C_{oes}$ eff.(ER) is a fixed capacitance that stores the same energy as $C_{oes}$ while $V_{CE}$ is rising from 0 to 80% $V_{CES}$.

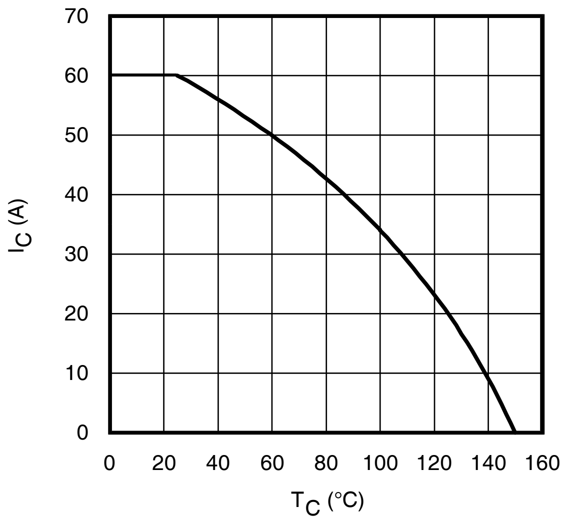



**Fig. 1** - Maximum DC Collector Current vs. Case Temperature

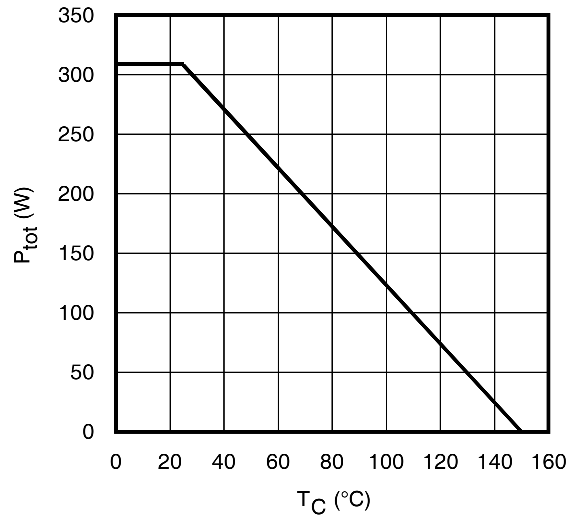



**Fig. 2** - Power Dissipation vs. Case Temperature

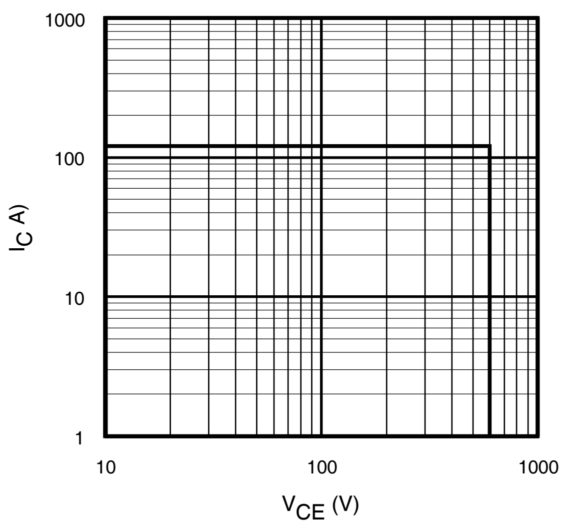



**Fig. 3** - Reverse Bias SOA
$T_J$ = 150°C; $V_{GE}$ =15V

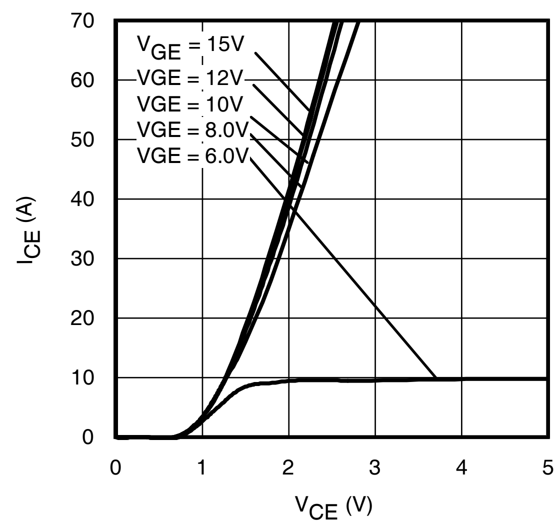



**Fig. 4** - Typ. IGBT Output Characteristics
$T_J$ = -40°C; tp = 80µs

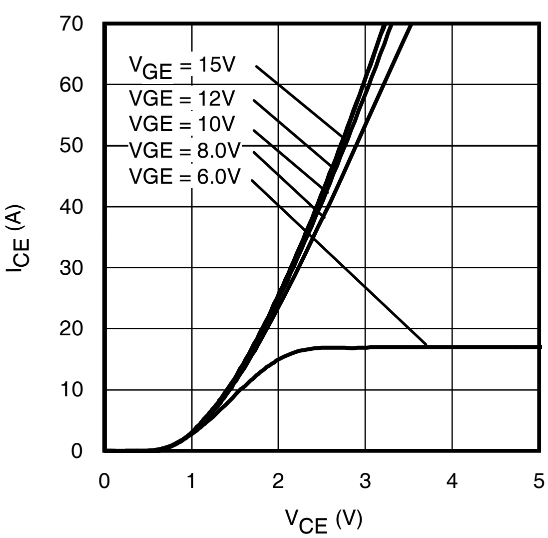



**Fig. 5** - Typ. IGBT Output Characteristics
$T_J$ = 25°C; tp = 80µs

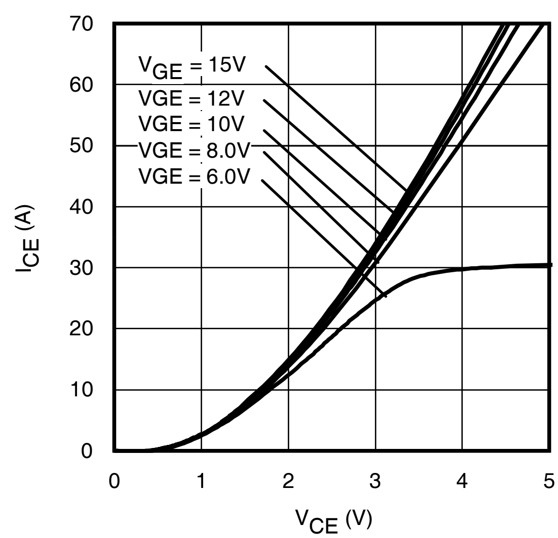



**Fig. 6** - Typ. IGBT Output Characteristics
$T_J$ = 125°C; tp = 80µs

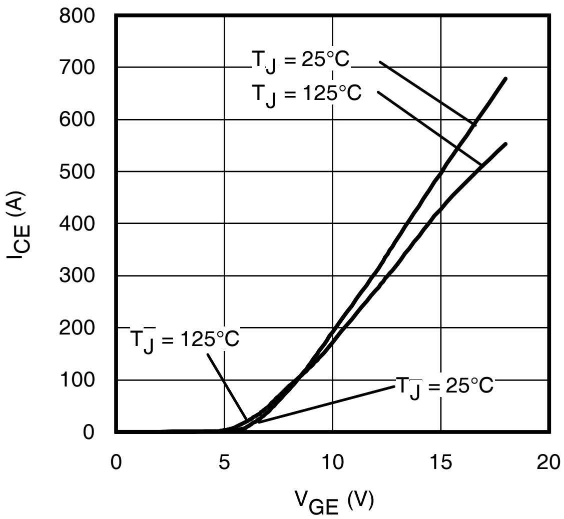



**Fig. 7** - Typ. Transfer Characteristics
$V_{CE}$ = 50V; tp = 10µs

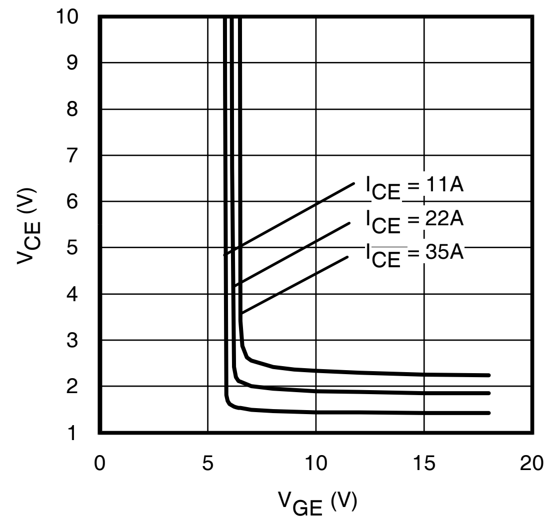



**Fig. 8** - Typical $V_{CE}$ vs. $V_{GE}$
$T_J$ = 25°C

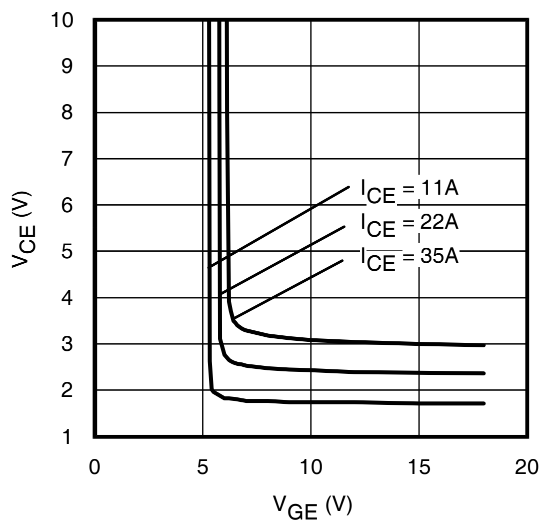



**Fig. 9** - Typical $V_{CE}$ vs. $V_{GE}$
$T_J$ = 125°C

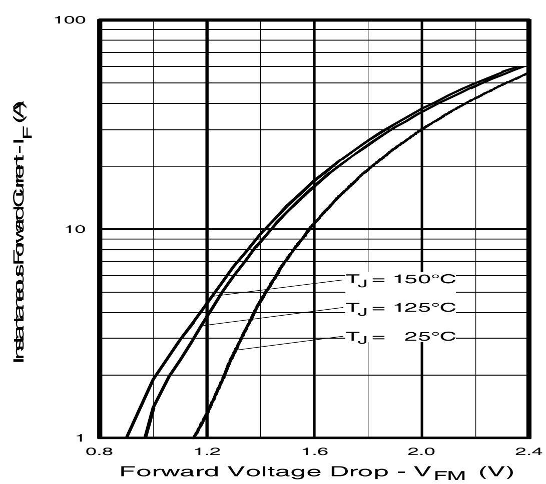



**Fig. 10** - Typ. Diode Forward Characteristics
tp = 80µs

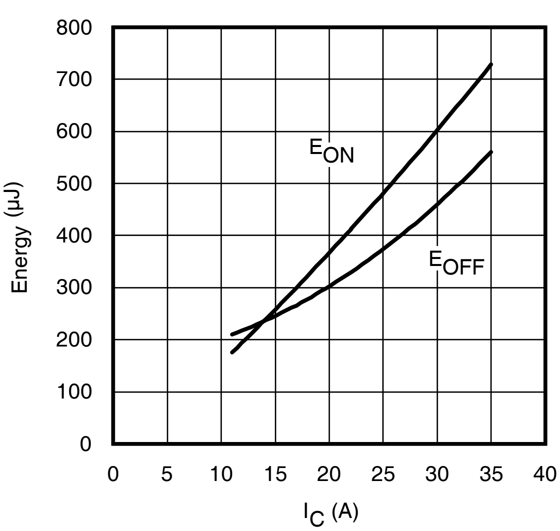



**Fig. 11** - Typ. Energy Loss vs. $I_C$
$T_J$ = 125°C; L = 200µH; $V_{CE}$ = 390V, $R_G$ = 3.3Ω; $V_{GE}$ = 15V.
Diode clamp used: 30ETH06 (See C.T.3)

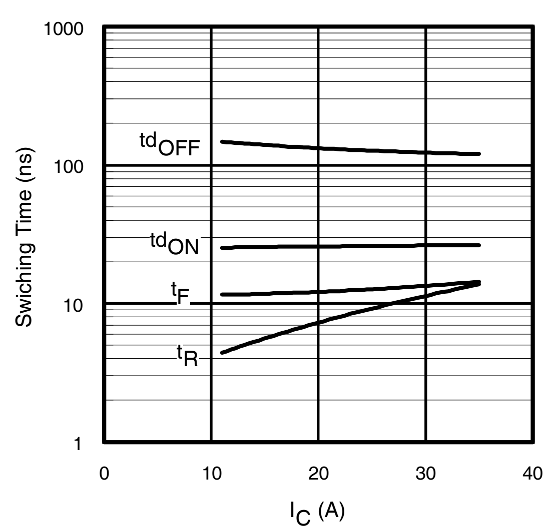



**Fig. 12** - Typ. Switching Time vs. $I_C$
$T_J$ = 125°C; L = 200µH; $V_{CE}$ = 390V, $R_G$ = 3.3Ω; $V_{GE}$ = 15V.
Diode clamp used: 30ETH06 (See C.T.3)

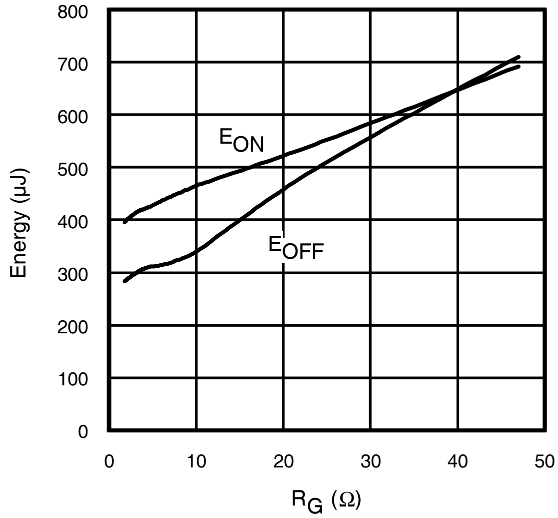



**Fig. 13** - Typ. Energy Loss vs. $R_G$
$T_J$ = 125°C; L = 200µH; $V_{CE}$ = 390V, $I_{CE}$ = 22A; $V_{GE}$ = 15V
Diode clamp used: 30ETH06 (See C.T.3)

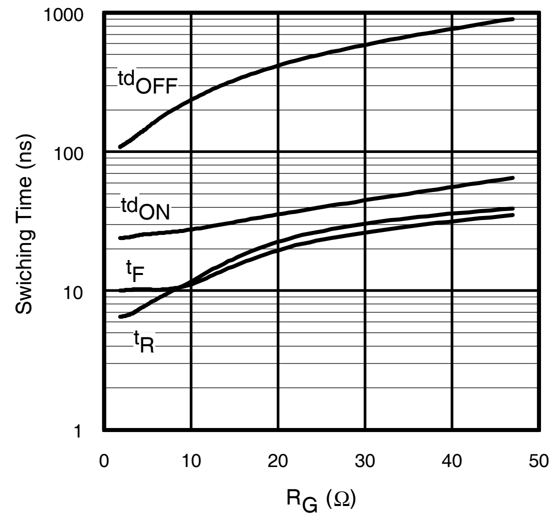



**Fig. 14** - Typ. Switching Time vs. $R_G$
$T_J$ = 125°C; L = 200µH; $V_{CE}$ = 390V, $I_{CE}$ = 22A; $V_{GE}$ = 15V
Diode clamp used: 30ETH06 (See C.T.3)

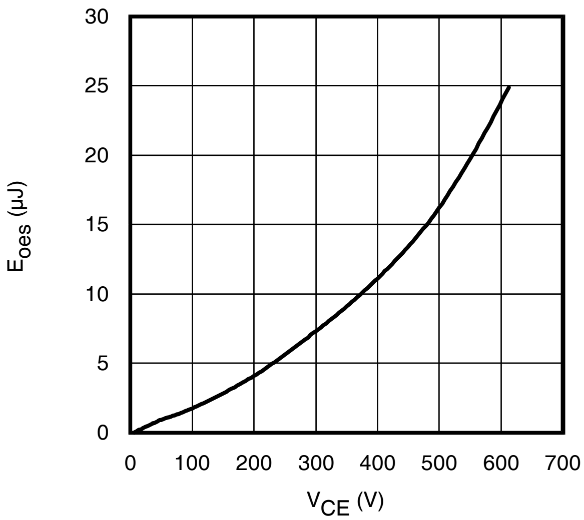



**Fig. 15**- Typ. Output Capacitance
Stored Energy vs. $V_{CE}$

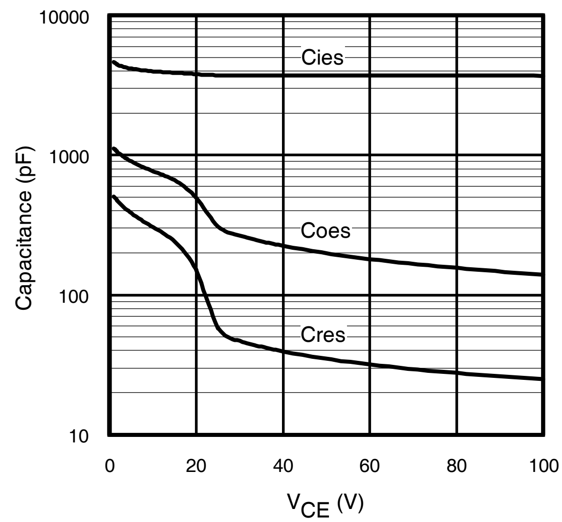



**Fig. 16**- Typ. Capacitance vs. $V_{CE}$
$V_{GE}$= 0V; f = 1MHz

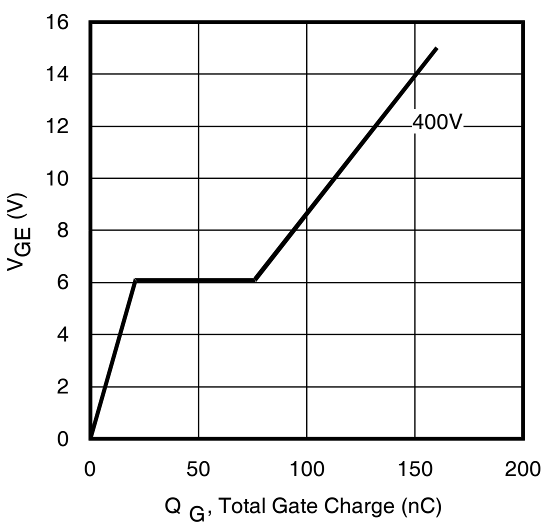



**Fig. 17** - Typical Gate Charge vs. $V_{GE}$
$I_{CE}$ = 22A

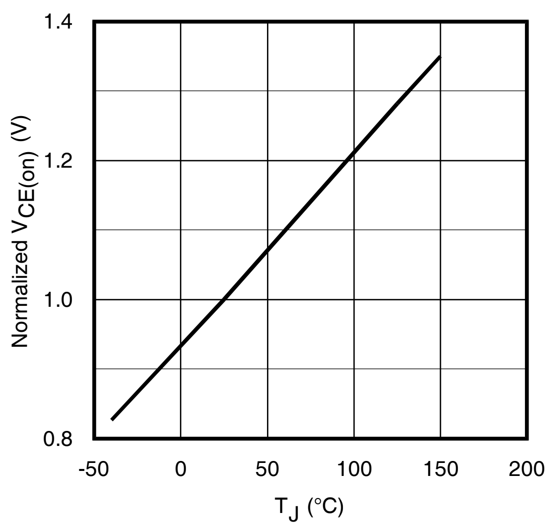



**Fig. 18** - Normalized Typ. $V_{CE(on)}$
vs. Junction Temperature
$I_C$ = 22A, $V_{GE}$= 15V

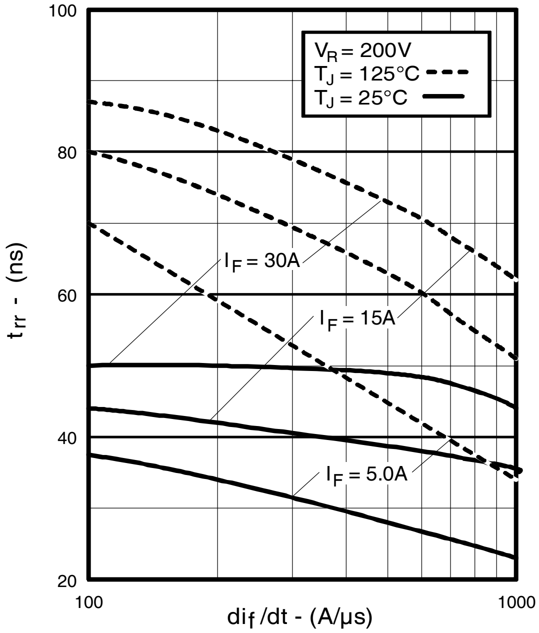



**Fig. 19 -** Typical Reverse Recovery vs. $di_f/dt$

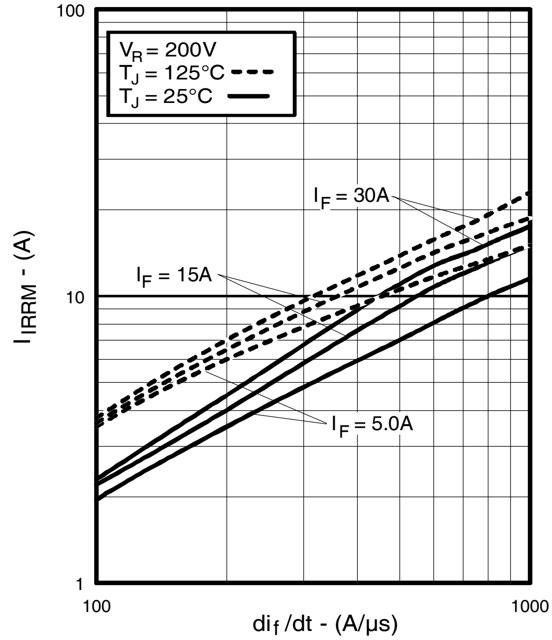



**Fig. 20 -** Typical Recovery Current vs. $di_f/dt$

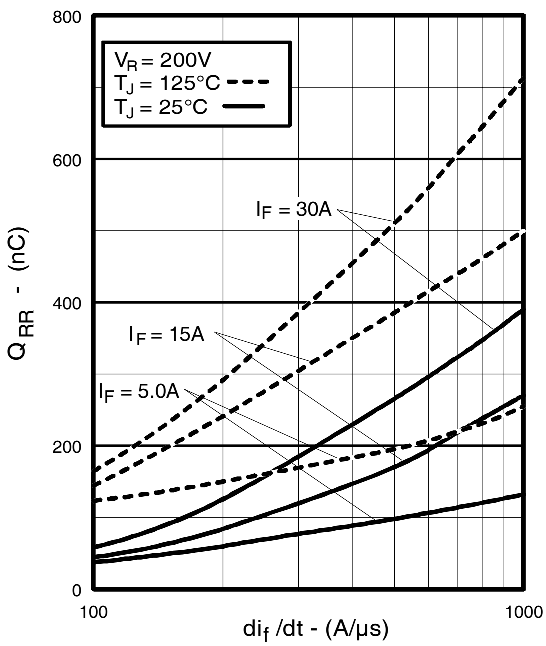



**Fig. 21 -** Typical Stored Charge vs. $di_f/dt$

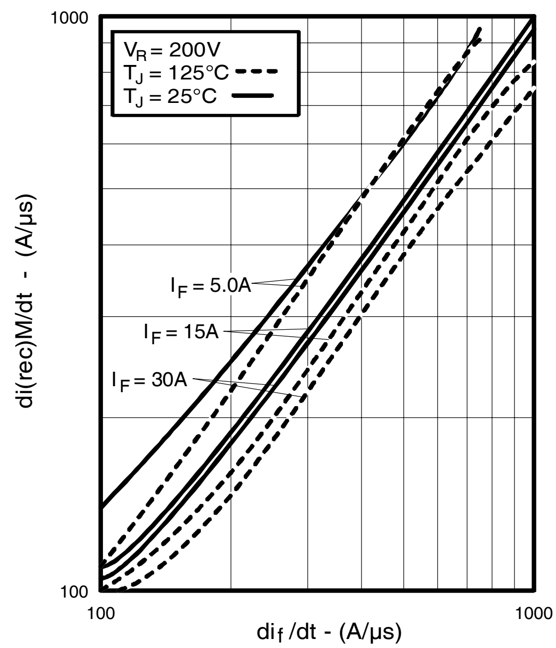



**Fig. 22 -** Typical $di_{(rec)M}/dt$ vs. $di_f/dt$,

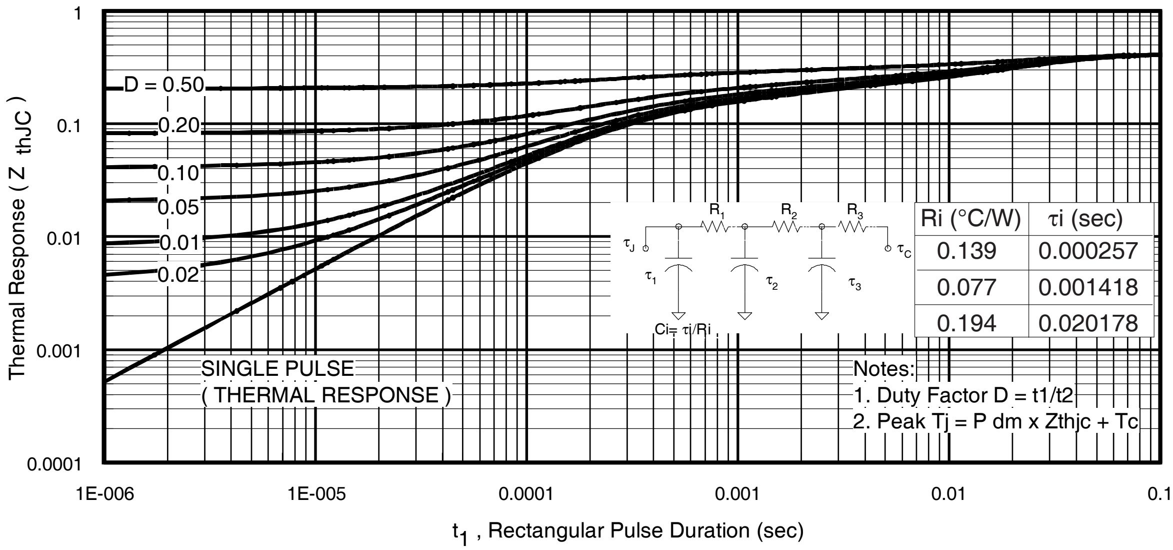



**Fig 23.** Maximum Transient Thermal Impedance, Junction-to-Case (IGBT)

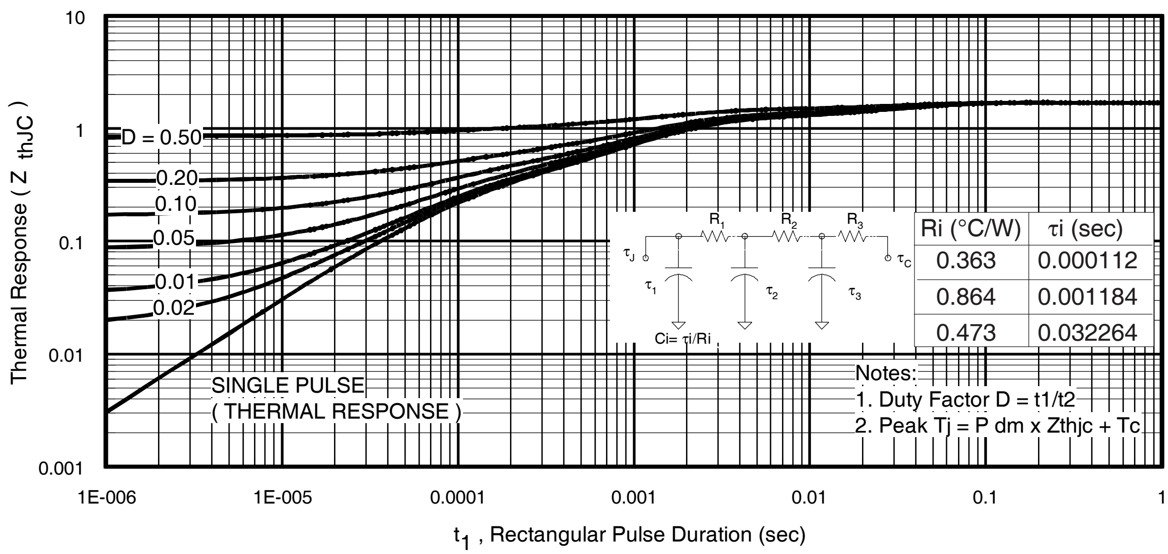



**Fig. 24.** Maximum Transient Thermal Impedance, Junction-to-Case (DIODE)

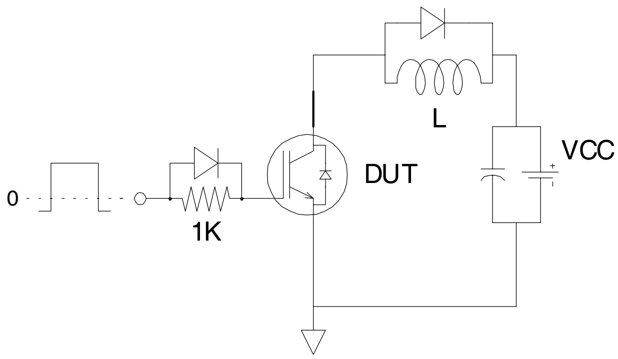



Fig.C.T.1 - Gate Charge Circuit (turn-off)

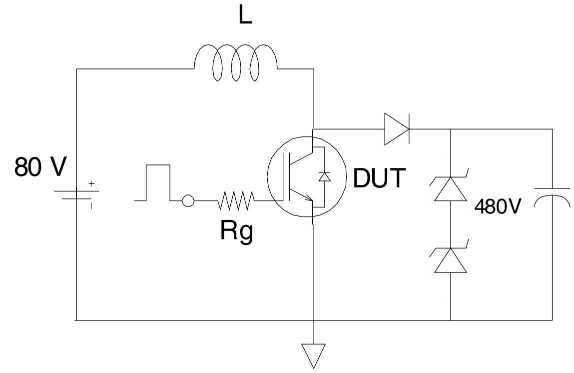



Fig.C.T.2 - RBSOA Circuit

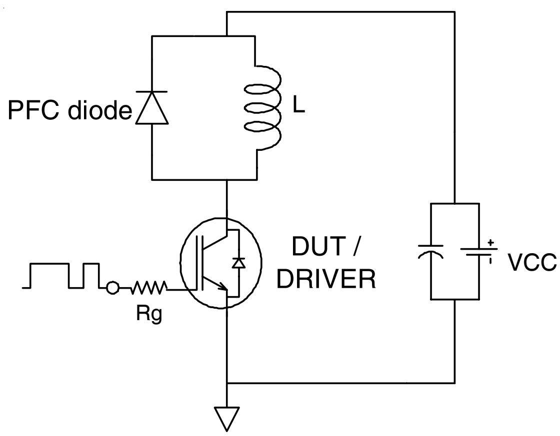



Fig.C.T.3 - Switching Loss Circuit

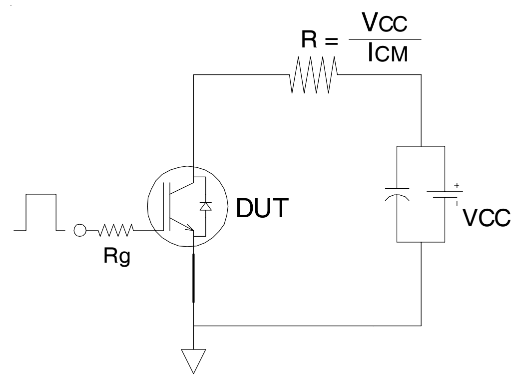



Fig.C.T.4 - Resistive Load Circuit

REVERSE RECOVERY CIRCUIT

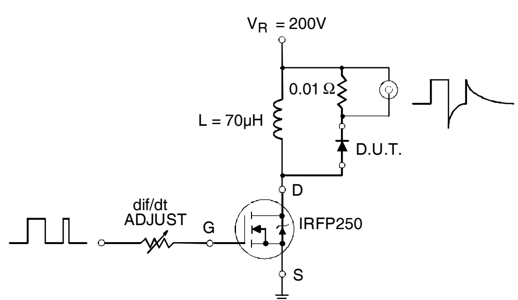



Fig. C.T.5 - Reverse Recovery Parameter Test Circuit

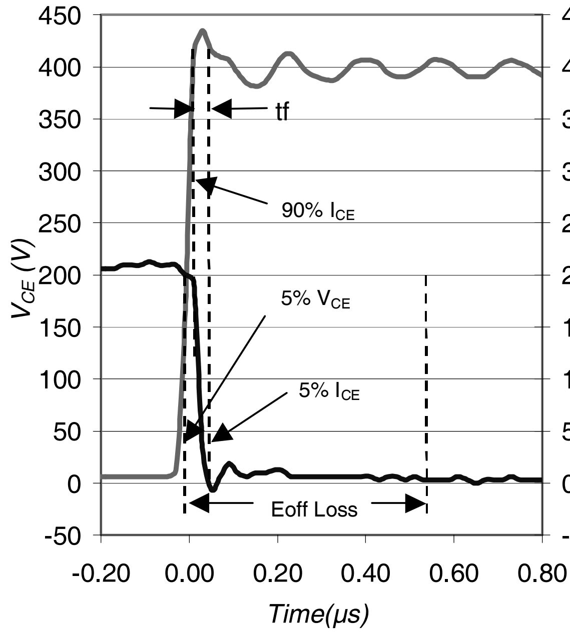



**Fig. WF1** - Typ. Turn-off Loss Waveform
@ $T_J$ = 25°C using Fig. CT.3

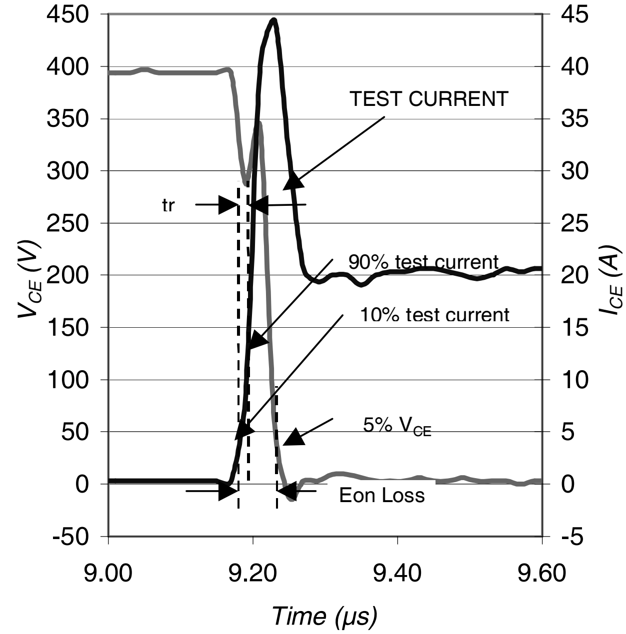
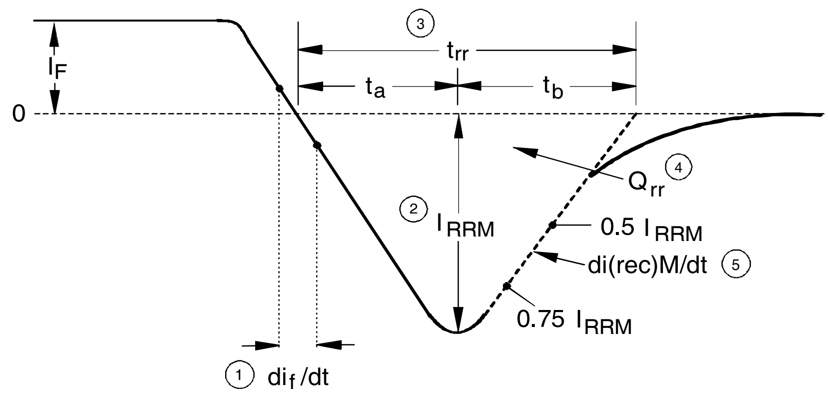



**Fig. WF2** - Typ. Turn-on Loss Waveform
@ $T_J$ = 25°C using Fig. CT.3




1. $di_f/dt$ - Rate of change of current through zero crossing
2. $I_{RRM}$ - Peak reverse recovery current
3. trr - Reverse recovery time measured from zero crossing point of negative going $I_F$ to point where a line passing through 0.75 $I_{RRM}$ and 0.50 $I_{RRM}$ extrapolated to zero current
4. $Q_{rr}$ - Area under curve defined by $t_{rr}$ and $I_{RRM}$

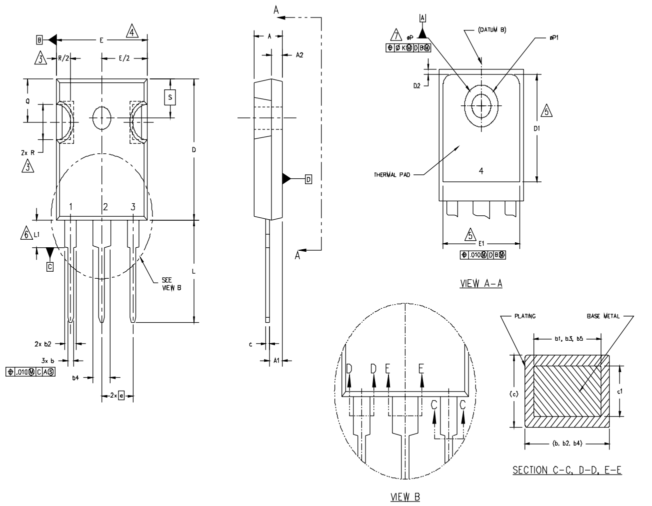
$$Q_{rr} = \frac{t_{rr} \times I_{RRM}}{2}$$

5. $di_{(rec)M}/dt$ - Peak rate of change of current during $t_b$ portion of $t_{rr}$

**Fig. WF3** - Reverse Recovery Waveform and Definitions

## TO-247AC Package Outline

Dimensions are shown in millimeters (inches)




NOTES:

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M 1994.
2. DIMENSIONS ARE SHOWN IN INCHES [MILLIMETERS]
3. CONTOUR OF SLOT OPTIONAL.
4. DIMENSION D & E DO NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED .005" (0.127) PER SIDE. THESE DIMENSIONS ARE MEASURED AT THE OUTERMOST EXTREMES OF THE PLASTIC BODY.
5. THERMAL PAD CONTOUR OPTIONAL WITHIN DIMENISONS D1 & E1.
6. LEAD FINISH UNCONTROLLED IN L1.
7. øP TO HAVE A MAXIMUM DRAFT ANGLE OF 1.5 ° TO THE TOP OF THE PART WITH A MAXIMUM HOLE DIAMETER OF .154" [3.91].
8. OUTLINE CONFORMS TO JEDEC OUTLINE TO-247 WITH THE EXCEPTION OF DIMENSION c.

| SYMBOL | DIMENSIONS | | | | NOTES |
|---|---|---|---|---|---|
| | INCHES | | MILLIMETERS | | |
| | MIN. | MAX. | MIN. | MAX. | |
| A | .183 | .209 | 4.65 | 5.31 | |
| A1 | .087 | .102 | 2.21 | 2.59 | |
| A2 | .059 | .098 | 1.50 | 2.49 | |
| b | .039 | .055 | 0.99 | 1.40 | |
| b1 | .039 | .053 | 0.99 | 1.35 | |
| b2 | .065 | .094 | 1.65 | 2.39 | |
| b3 | .065 | .092 | 1.65 | 2.37 | |
| b4 | .102 | .135 | 2.59 | 3.43 | |
| b5 | .102 | .133 | 2.59 | 3.38 | |
| c | .015 | .034 | 0.38 | 0.86 | |
| c1 | .015 | .030 | 0.38 | 0.76 | |
| D | .776 | .815 | 19.71 | 20.70 | 4 |
| D1 | .515 | - | 13.08 | - | 5 |
| D2 | .020 | .030 | 0.51 | 0.76 | |
| E | .602 | .625 | 15.29 | 15.87 | 4 |
| E1 | .540 | - | 15.72 | - | |
| e | .215 BSC | | 5.46 BSC | | |
| øk | .010 | | 2.54 | | |
| L | .559 | .634 | 14.20 | 16.10 | |
| L1 | .146 | .169 | 3.71 | 4.29 | |
| N | 3 | | 7.62 BSC | | |
| øP | .140 | .144 | 3.56 | 3.66 | |
| øP1 | - | .275 | - | 6.98 | |
| Q | .209 | .224 | 5.31 | 5.69 | |
| R | .178 | .216 | 4.52 | 5.49 | |
| S | .217 BSC | | 5.51 BSC | | |

LEAD ASSIGNMENTS

HEXFET

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

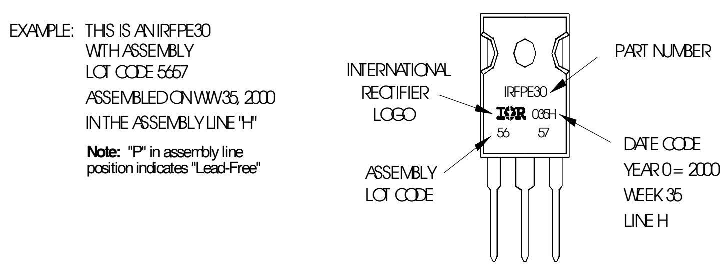
IGBTs, CoPACK

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

DIODES

1.- ANODE/OPEN
2.- CATHODE
3.- ANODE

## TO-247AC Part Marking Information




**TO-247AC 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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Note:  For the most current drawings please refer to the IR website at:
http://www.irf.com/package/