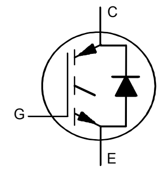
***WARP2 SERIES IGBT WITH ULTRAFAST SOFT RECOVERY DIODE***




n-channel

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

**Equivalent MOSFET Parameters①**
$R_{CE(on)}$ typ. = 84mΩ
$I_D$ (FET equivalent) = 35A

## Features

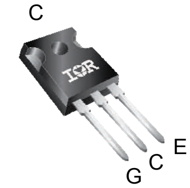
- NPT Technology, Positive Temperature Coefficient
- Lower $V_{CE}$(SAT)
- Lower Parasitic Capacitances
- Minimal Tail Current
- HEXFRED Ultra Fast Soft-Recovery Co-Pack Diode
- Tighter Distribution of Parameters
- Higher Reliability
- Lead-Free, RoHS Compliant
- Automotive Qualified *

## Applications

- PFC and ZVS SMPS Circuits
- DC/DC Converter Charger

## Benefits

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




TO-247AD
AUIRGP35B60PD-E

| G | C | E |
|---|---|---|
| Gate | Collector | Emitter |

| Base Part Number | Package Type | Standard Pack | | Orderable Part Number |
|---|---|---|---|---|
| | | Form | Quantity | |
| AUIRGP35B60PD-E | TO-247AD | Tube | 25 | AUIRGP35B60PD-E |

## Absolute Maximum Ratings

Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only; and functional operation of the device at these or any other condition beyond those indicated in the specifications is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability. The thermal resistance and power dissipation ratings are measured under board mounted and still air conditions. Ambient temperature ($T_A$) is 25°C, unless otherwise specified.

| | 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 Current② | 120 | |
| $I_F$ @ $T_C$ = 25°C | Diode Continuous Forward Current | 40 | |
| $I_F$ @ $T_C$ = 100°C | Diode Continuous Forward Current | 15 | |
| $I_{FSM}$ | Maximum Repetitive Forward Current | 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) | —— | 0.50 | —— | |
| $R_{\theta JA}$ | Thermal Resistance, Junction-to-Ambient (typical socket mount) | —— | —— | 40 | |
| | Weight | —— | 6.0(0.21) | —— | g(oz) |

* Qualification standards can be found at www.infineon.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, $I_C$ = 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 | 4,5,6,8,9 |
| $V_{CE(on)}$ | Collector-to-Emitter Saturation Voltage | — | 1.85 | 2.15 | V | $I_C$ = 22A, $V_{GE}$ = 15V | |
| | | — | 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 | 10 |
| | | — | 1.20 | 1.60 | | $I_F$ = 15A, $T_J$ = 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. |
|---|---|---|---|---|---|---|---|
| $Q_g$ | Total Gate Charge (turn-on) | — | 160 | 240 | nC | $I_C$ = 22A | 17 |
| $Q_{ge}$ | Gate-to-Emitter Charge (turn-on) | — | 55 | 83 | | $V_{GE}$ = 15V | CT1 |
| $Q_{gc}$ | Gate-to-Collector Charge (turn-on) | — | 21 | 32 | | $V_{CC}$ = 400V | |
| $E_{on}$ | Turn-On Switching Loss | — | 220 | 270 | μJ | $I_C$ = 22A, $V_{CC}$ = 390V, $V_{GE}$ = +15V, $R_G$ = 3.3Ω, L = 200μH, $T_J$ = 25°C ④ | CT3 |
| $E_{off}$ | Turn-Off Switching Loss | — | 215 | 265 | | | |
| $E_{total}$ | Total Switching Loss | — | 435 | 535 | | | |
| $t_{d(on)}$ | Turn-On delay time | — | 26 | 34 | ns | | |
| $t_r$ | Rise time | — | 6.0 | 8.0 | | | |
| $t_{d(off)}$ | Turn-Off delay time | — | 110 | 122 | | | |
| $t_f$ | Fall time | — | 8.0 | 10 | | | |
| $E_{on}$ | Turn-On Switching Loss | — | 410 | 465 | μJ | $I_C$ = 22A, $V_{CC}$ = 390V, $V_{GE}$ = +15V, $R_G$ = 3.3Ω, L = 200μH, $T_J$ = 125°C ④ | CT3 11,13 WF1,WF2 |
| $E_{off}$ | Turn-Off Switching Loss | — | 330 | 405 | | | |
| $E_{total}$ | Total Switching Loss | — | 740 | 870 | | | |
| $t_{d(on)}$ | Turn-On delay time | — | 26 | 34 | ns | | CT3 12,14 WF1,WF2 |
| $t_r$ | Rise time | — | 8.0 | 11 | | | |
| $t_{d(off)}$ | Turn-Off delay time | — | 130 | 150 | | | |
| $t_f$ | Fall time | — | 12 | 16 | | | |
| $C_{ies}$ | Input Capacitance | — | 3715 | — | pF | $V_{GE}$ = 0V, $V_{CC}$ = 30V, f = 1.0Mhz | 16 |
| $C_{oes}$ | Output Capacitance | — | 265 | — | | | |
| $C_{res}$ | Reverse Transfer Capacitance | — | 47 | — | | | |
| $C_{oes\ eff.}$ | Effective Output Capacitance (Time Related) | — | 135 | — | | $V_{GE}$ = 0V, $V_{CE}$ = 0V to 480V | 15 |
| $C_{oes\ eff.\ (ER)}$ | Effective Output Capacitance (Energy Related) | — | 179 | — | | | |
| RBSOA | Reverse Bias Safe Operating Area | FULL SQUARE | | | | $T_J$ = 150°C, $I_C$ = 120A, $V_{CC}$ = 480V, Vp ≤ 600V, Rg = 22Ω, $V_{GE}$ = +15V to 0V | 3 CT2 |
| $t_{rr}$ | Diode Reverse Recovery Time | — | 42 | 60 | ns | $T_J$ = 25°C; $I_F$ = 15A, $V_R$ = 200V, di/dt = 200A/μs | 19 |
| | | — | 74 | 120 | | $T_J$ = 125°C | |
| $Q_{rr}$ | Diode Reverse Recovery Charge | — | 80 | 180 | nC | $T_J$ = 25°C | 21 |
| | | — | 220 | 600 | | $T_J$ = 125°C | |
| $I_{rr}$ | Peak Reverse Recovery Current | — | 4.0 | 6.0 | A | $T_J$ = 25°C | 19,20,21,22 CT5 |
| | | — | 6.5 | 10 | | $T_J$ = 125°C | |

**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% ($V_{CES}$), $V_{GE}$ = 20V, 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.

⑥ $C_{oes}$ 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% $V_{CES}$.

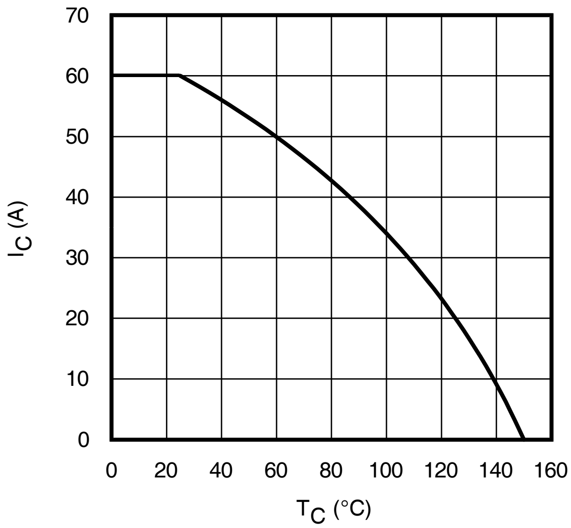



**Fig. 1** - Maximum DC Collector Current vs. Case Temperature

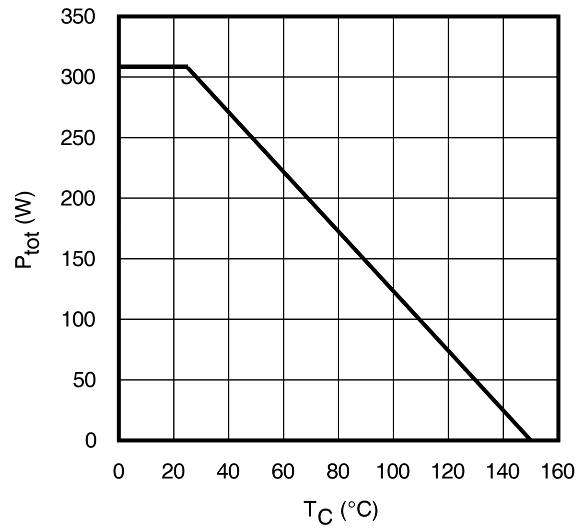



**Fig. 2** - Power Dissipation vs. Case Temperature

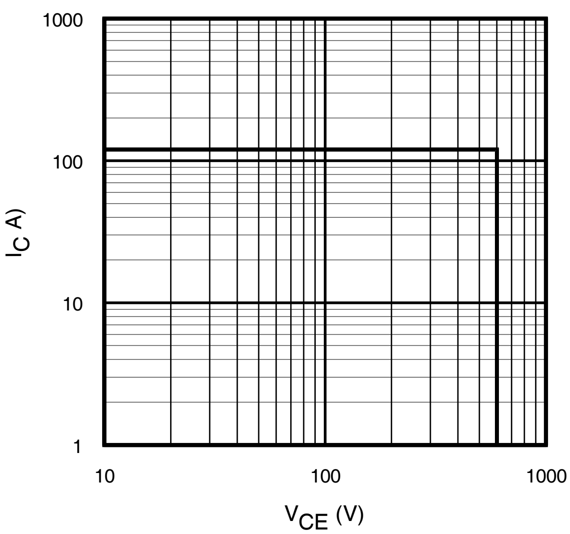



**Fig. 3** - Reverse Bias SOA
$T_J$ = 150°C; $V_{GE}$ = 15V

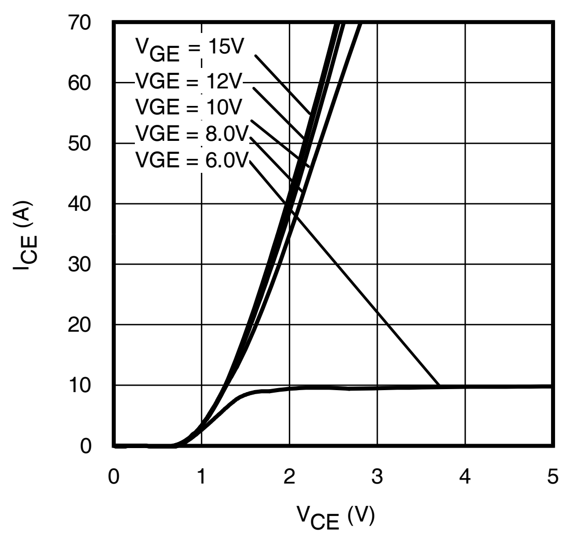



**Fig. 4** - Typ. IGBT Output Characteristics
$T_J$ = -40°C; tp = 80µs

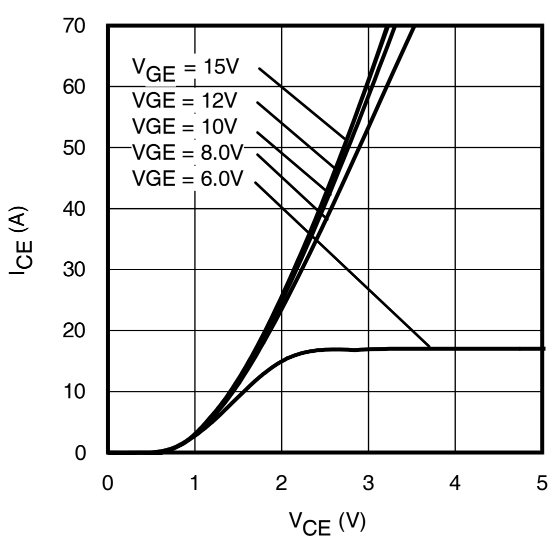



**Fig. 5** - Typ. IGBT Output Characteristics
$T_J$ = 25°C; tp = 80µs

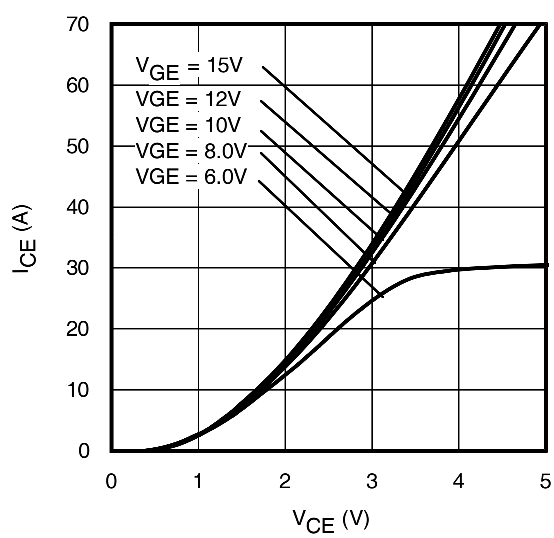



**Fig. 6** - Typ. IGBT Output Characteristics
$T_J$ = 125°C; tp = 80µs

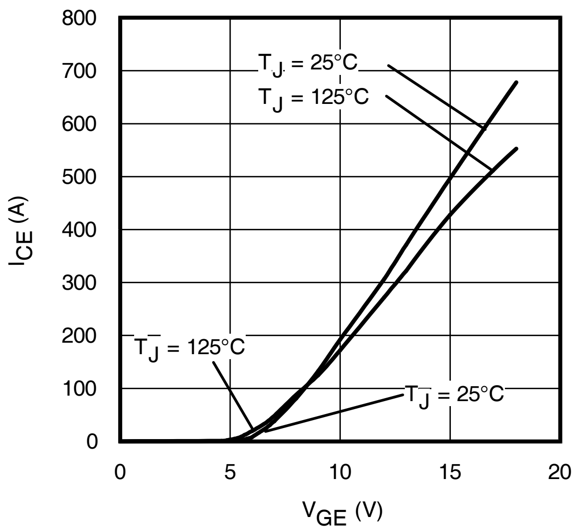



**Fig. 7** - Typ. Transfer Characteristics
$V_{CE}$ = 50V; tp = 10µs

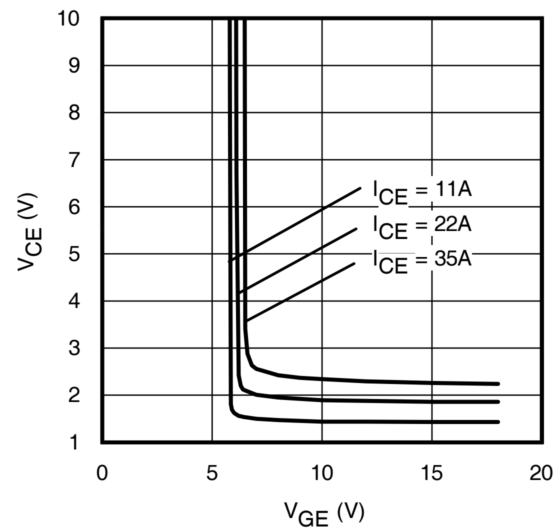



**Fig. 8** - Typical $V_{CE}$ vs. $V_{GE}$
$T_J$ = 25°C

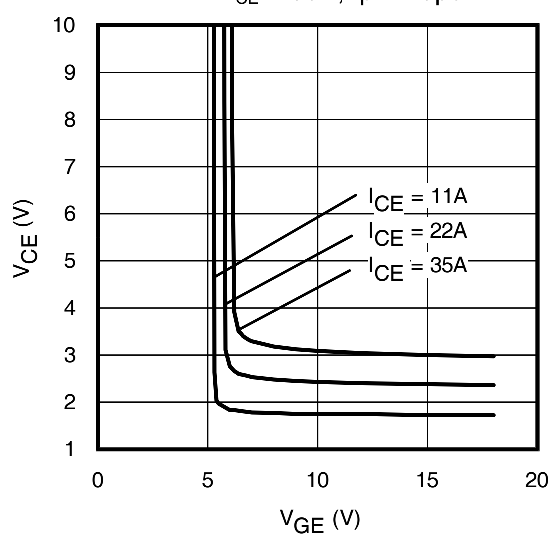



**Fig. 9** - Typical $V_{CE}$ vs. $V_{GE}$
$T_J$ = 125°C

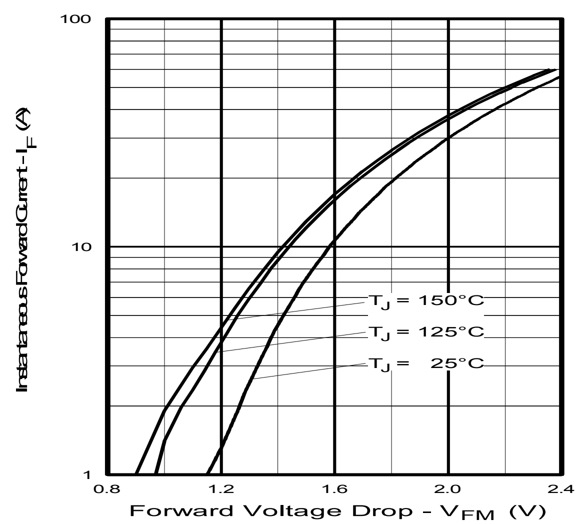



**Fig. 10** - Typ. Diode Forward Characteristics
tp = 80µs

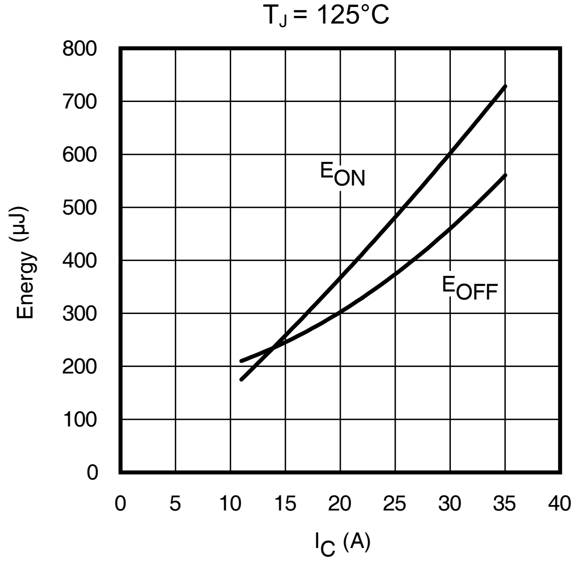



**Fig. 11** - Typ. Energy Loss vs. $I_C$
$T_J$ = 125°C; L = 200µH; $V_{CE}$ = 390V, $R_G$ = 3.3Ω; $V_{GE}$ = 15V.
Diode clamp used: 30ETH06 (See C.T.3)

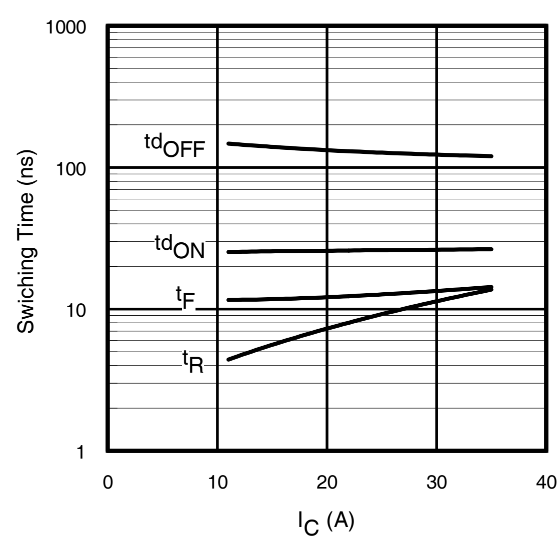



**Fig. 12** - Typ. Switching Time vs. $I_C$
$T_J$ = 125°C; L = 200µH; $V_{CE}$ = 390V, $R_G$ = 3.3Ω; $V_{GE}$ = 15V.
Diode clamp used: 30ETH06 (See C.T.3)

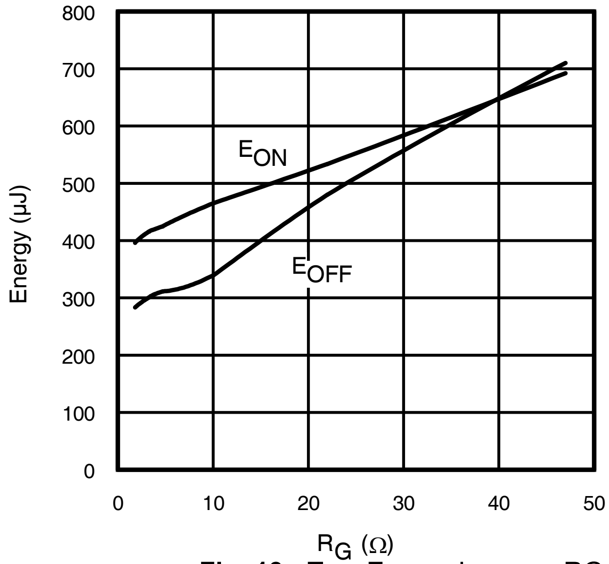



**Fig. 13** - Typ. Energy Loss vs. RG
$T_J$ = 125°C; L = 200µH; $V_{CE}$ = 390V, $I_{CE}$ = 22A; $V_{GE}$ = 15V
Diode clamp used: 30ETH06 (See C.T.3)

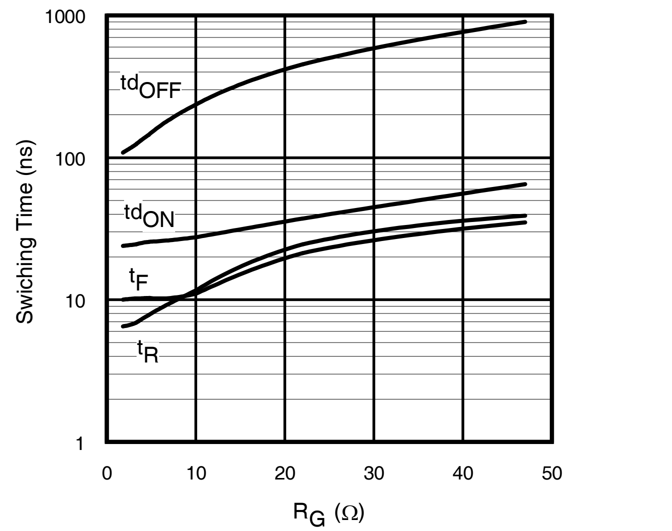



**Fig. 14** - Typ. Switching Time vs. $R_G$
$T_J$ = 125°C; L = 200µH; $V_{CE}$ = 390V, $I_{CE}$ = 22A; $V_{GE}$ = 15V
Diode clamp used: 30ETH06 (See C.T.3)

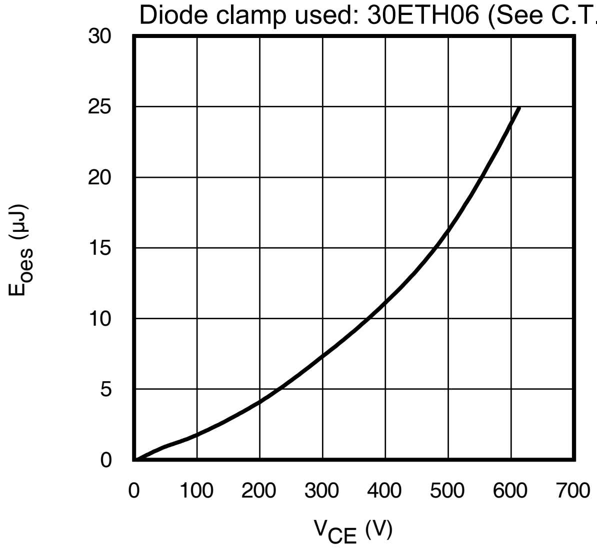



**Fig. 15** - Typ. Output Capacitance Stored Energy vs. $V_{CE}$

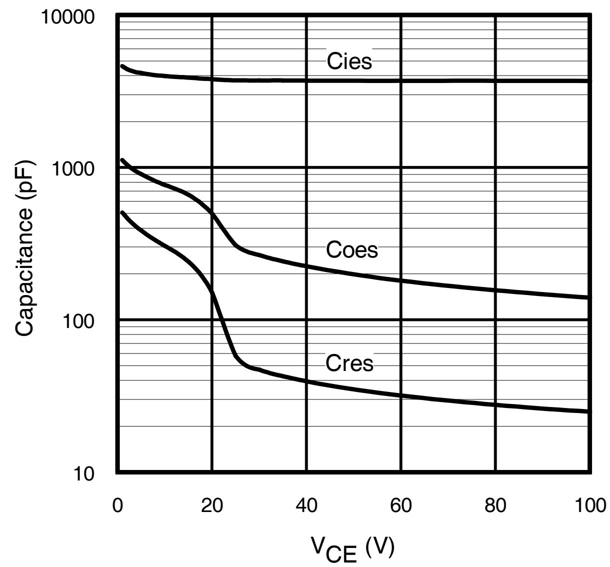



**Fig. 16** - Typ. Capacitance vs. $V_{CE}$
$V_{GE}$= 0V; f = 1MHz

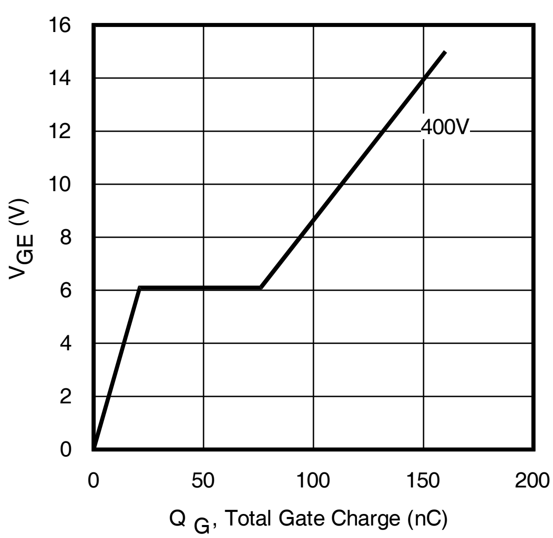



**Fig. 17** - Typical Gate Charge vs. $V_{GE}$
$I_{CE}$ = 22A

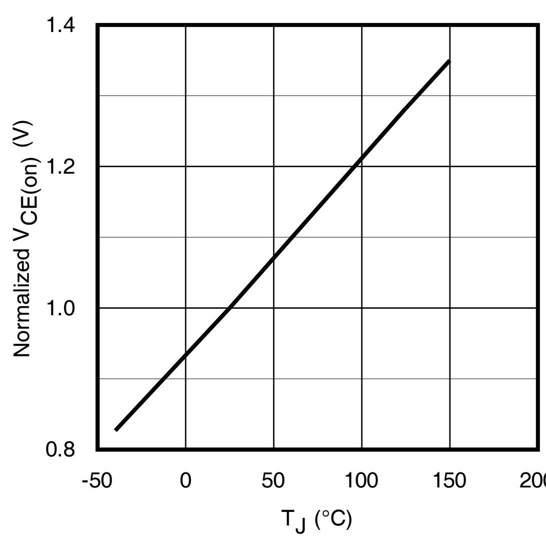



**Fig. 18** Normalized Typ. $V_{CE(on)}$ vs. Junction Temperature
$I_C$ = 22A, $V_{GE}$= 15V

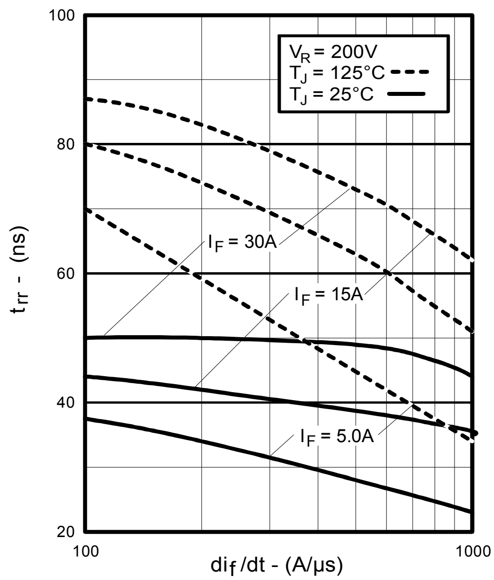



**Fig. 19** - Typical Reverse Recovery vs. dif/dt

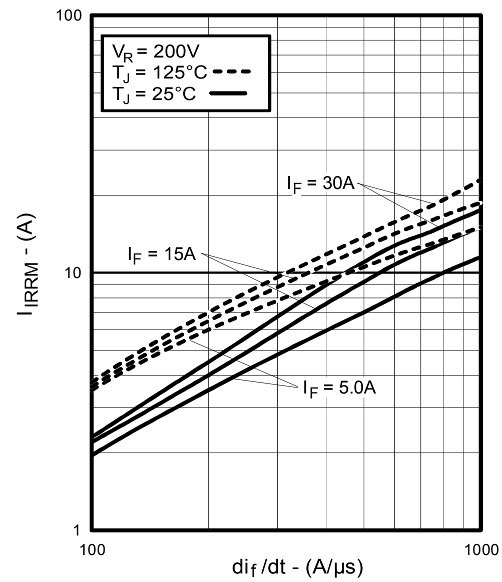



**Fig. 20** - Typical Recovery Current vs. dif/dt

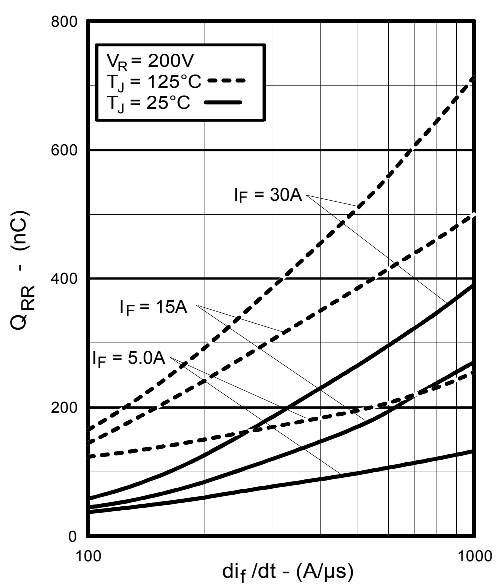



**Fig. 21** - Typical Stored Charge vs. dif/dt

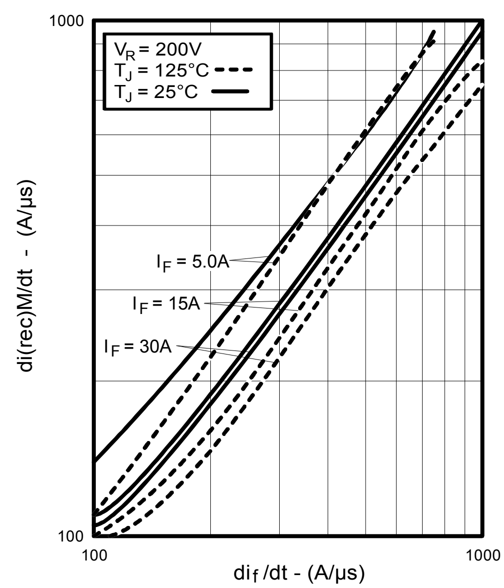



**Fig. 22** - Typical di(rec)M/dt vs. dif/dt,

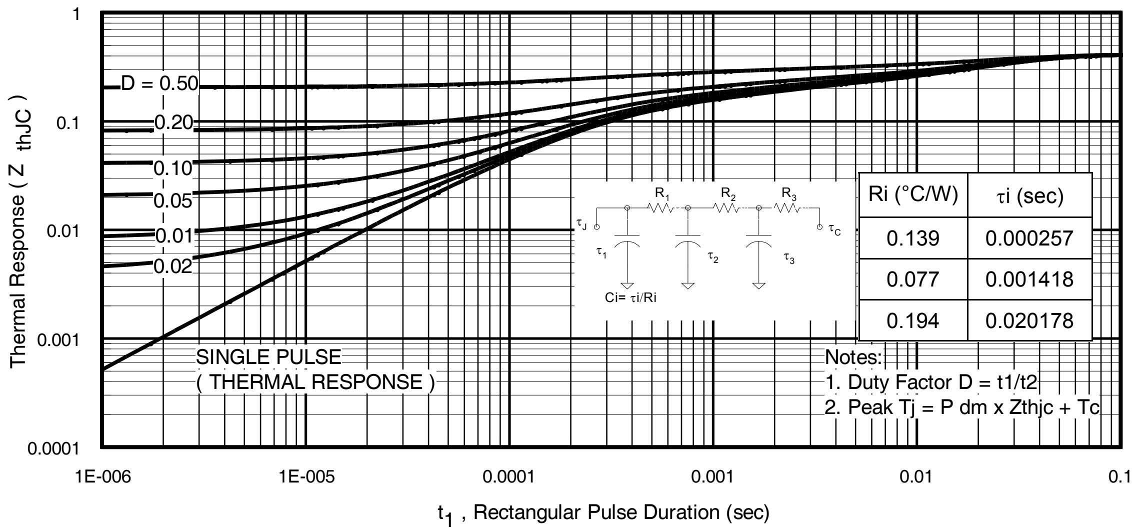



**Fig 25.** Maximum Transient Thermal Impedance, Junction-to-Case (IGBT)

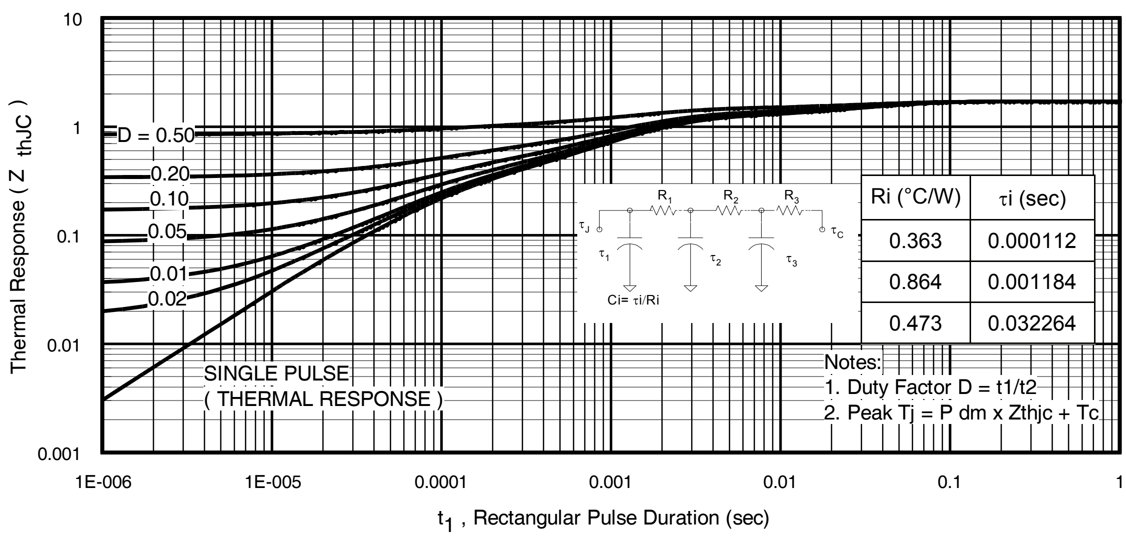



**Fig 26.** Maximum Transient Thermal Impedance, Junction-to-Case (DIODE)

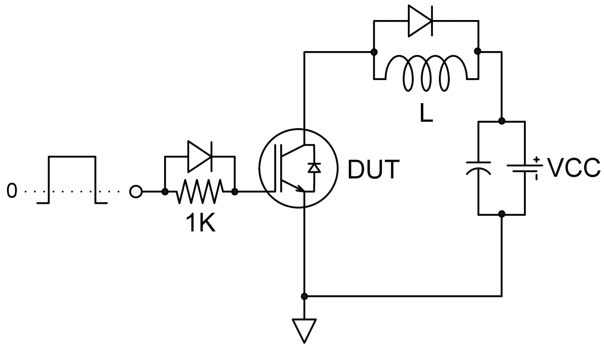



**Fig.C.T.1** - Gate Charge Circuit (turn-off)

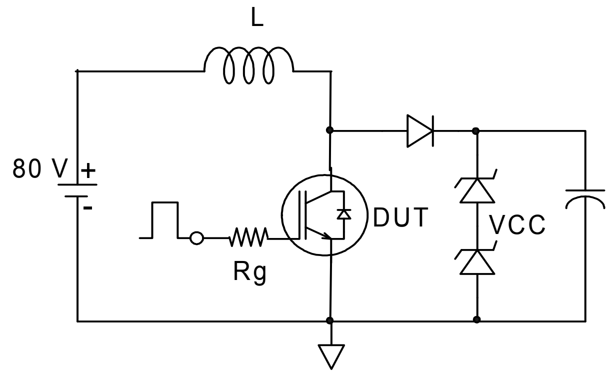



**Fig.C.T.2** - RBSOA Circuit

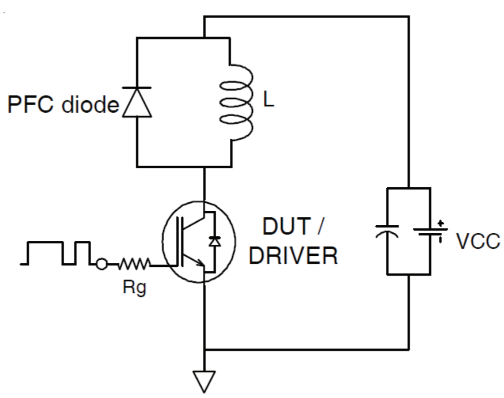



**Fig.C.T.3** - Switching Loss Circuit

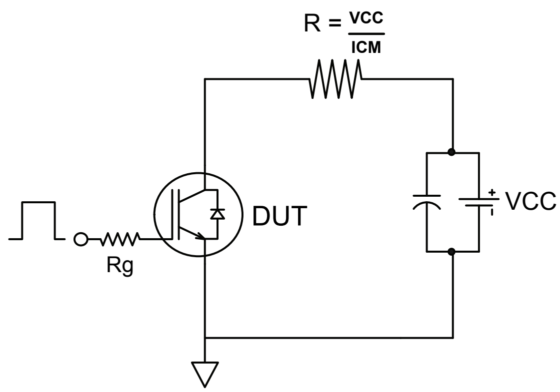



**Fig.C.T.4** - Resistive Load Circuit

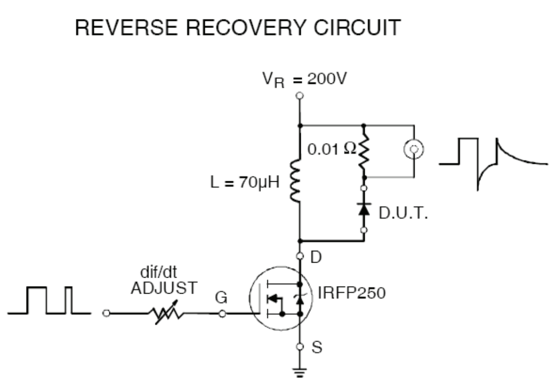



**Fig.C.T.5** - Reverse Recovery Parameter Test Circuit

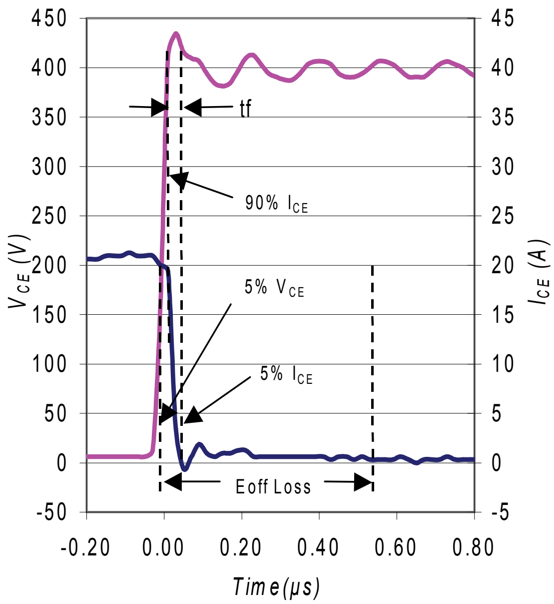



**Fig. WF1** - Typ. Turn-off Loss Waveform @ $T_J$ = 25°C using Fig. CT.3

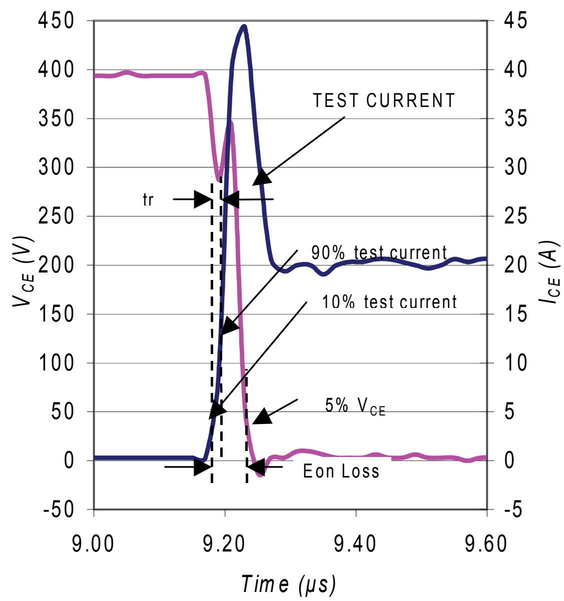
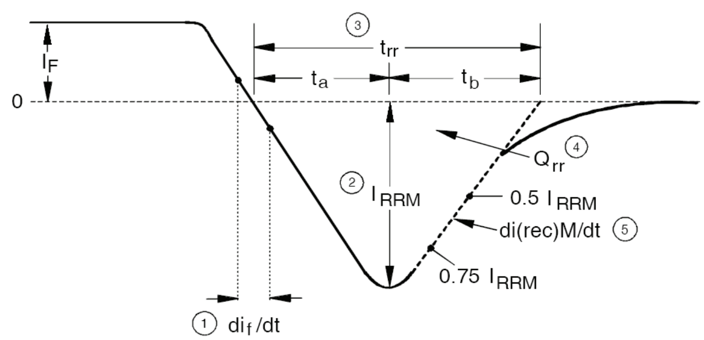



**Fig. WF2** - Typ. Turn-on Loss Waveform @ $T_J$ = 25°C using Fig. CT.3




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 $I_{RRM}$

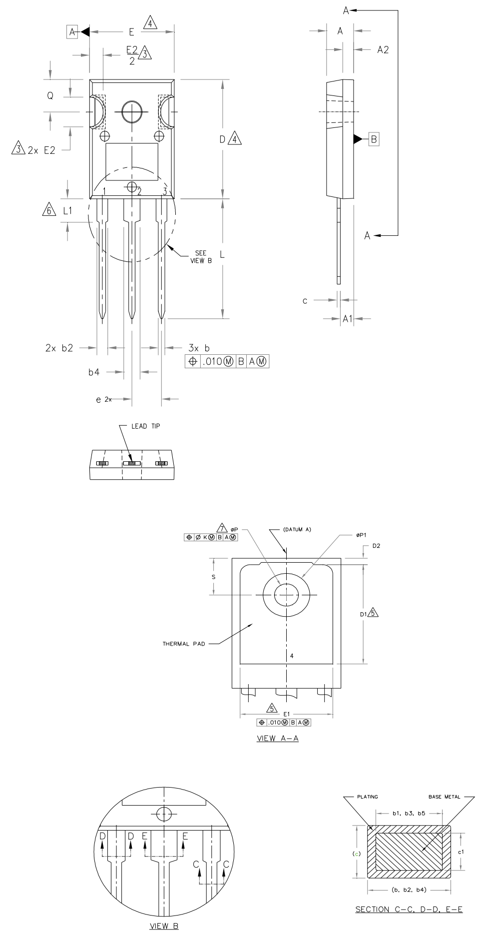
$$Q_{rr} = \frac{t_{rr} \times I_{RRM}}{2}$$

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-247AD Package Outline

(Dimensions are shown in millimeters (inches))




NOTES:

1. DIMENSIONING AND TOLERANCING AS PER ASME Y14.5M 1994.
2. DIMENSIONS ARE SHOWN IN INCHES.
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 DIMENSIONS 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 INCH.
8. OUTLINE CONFORMS TO JEDEC OUTLINE TO-247AD.

| SYMBOL | DIMENSIONS | | | | NOTES |
|---|---|---|---|---|---|
| | INCHES | | MILLIMETERS | | |
| | MIN. | MAX. | MIN. | MAX. | |
| A | .190 | .203 | 4.83 | 5.13 | |
| 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 | 2.34 | |
| b4 | .102 | .135 | 2.59 | 3.43 | |
| b5 | .102 | .133 | 2.59 | 3.38 | |
| c | .015 | .035 | 0.38 | 0.89 | |
| c1 | .015 | .033 | 0.38 | 0.84 | |
| D | .776 | .815 | 19.71 | 20.70 | 4 |
| D1 | .515 | – | 13.08 | – | 5 |
| D2 | .020 | .053 | 0.51 | 1.35 | |
| E | .602 | .625 | 15.29 | 15.87 | 4 |
| E1 | .530 | – | 13.46 | – | |
| E2 | .178 | .216 | 4.52 | 5.49 | |
| e | .215 BSC | | 5.46 BSC | | |
| øk | .010 | | 0.25 | | |
| L | .780 | .827 | 19.57 | 21.00 | |
| L1 | .146 | .169 | 3.71 | 4.29 | |
| øP | .140 | .144 | 3.56 | 3.66 | |
| øP1 | – | .291 | – | 7.39 | |
| Q | .209 | .224 | 5.31 | 5.69 | |
| S | .217 BSC | | 5.51 BSC | | |

LEAD ASSIGNMENTS

HEXFET

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

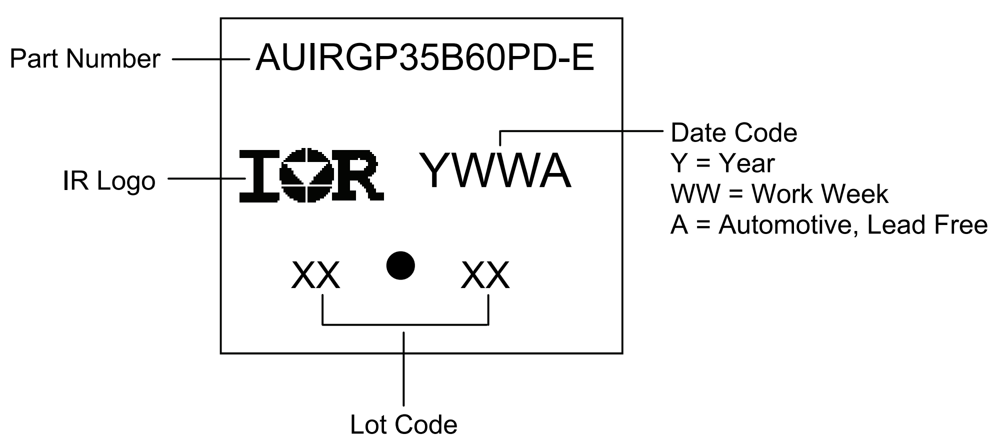
IGBTs, CoPACK

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

DIODES

1.– ANODE/OPEN
2.– CATHODE
3.– ANODE

# TO-247AD Part Marking Information




TO-247AD package is not recommended for Surface Mount Application.

### Qualification Information

| | | | |
|---|---|---|---|
| **Qualification Level** | | Automotive<br>(per AEC-Q101) | |
| | | This part number(s) passed Automotive qualification. Infineon's Industrial and Consumer qualification level is granted by extension of the higher Automotive level. | |
| **Moisture Sensitivity Level** | | TO-247AD | N/A |
| **ESD** | Machine Model | Class M4(+/- 425V)†<br>AEC-Q101-002 | |
| | Human Body Model | Class H2(+/- 4000V)†<br>AEC-Q101-001 | |
| | Charged Device Model | Class C5 (+/- 1125V)†<br>AEC-Q101-005 | |
| **RoHS Compliant** | | Yes | |

† Highest passing voltage.

### Revision History

| Date | Comments |
|---|---|
| 8/24/2017 | • Updated datasheet with corporate template<br>• Corrected typo Qual table -Moisture Sensitivity Level-from "MSL1" to N/A-page 11<br>• Corrected part marking on pages 10 |

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