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AUIRGP35B60PD-E

WARP2 SERIES IGBT WITH ULTRAFAST SOFT RECOVERY DIODE

Features

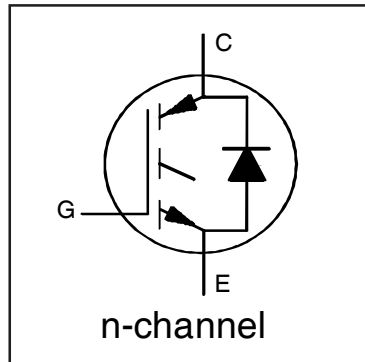
- NPT Technology, Positive Temperature Coefficient
- Lower $V_{CE(SAT)}$
- Lower Parasitic Capacitances
- Minimal Tail Current
- HEXFRED Ultra Fast Soft-Recovery Co-Pack Diode
- Tighter Distribution of Parameters
- Higher Reliability
- Lead-Free, RoHS Compliant
- Automotive Qualified*

Applications

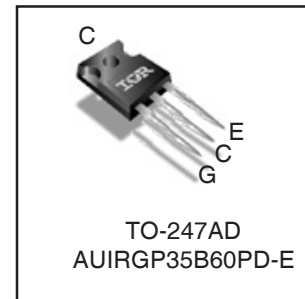
- PFC and ZVS SMPS Circuits
- DC/DC Converter Charger

Benefits

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



| |
|---|
| $V_{CES} = 600V$ |
| $V_{CE(on)} \text{ typ.} = 1.85V$ |
| @ $V_{GE} = 15V$ $I_C = 22A$ |
| Equivalent MOSFET Parameters^① |
| $R_{CE(on)} \text{ typ.} = 84m\Omega$ |
| I_D (FET equivalent) = 35A |



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

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 |
| $I_C @ T_C = 25^\circ C$ | Continuous Collector Current | 60 | A |
| $I_C @ T_C = 100^\circ C$ | Continuous Collector Current | 34 | |
| I_{CM} | Pulse Collector Current (Ref. Fig. C.T.4) | 120 | |
| I_{LM} | Clamped Inductive Load Current ^② | 120 | |
| $I_F @ T_C = 25^\circ C$ | Diode Continuous Forward Current | 40 | |
| $I_F @ T_C = 100^\circ C$ | Diode Continuous Forward Current | 15 | |
| I_{FRM} | Maximum Repetitive Forward Current ^③ | 60 | |
| V_{GE} | Gate-to-Emitter Voltage | ±20 | V |
| $P_D @ T_C = 25^\circ C$ | Maximum Power Dissipation | 308 | W |
| $P_D @ T_C = 100^\circ C$ | Maximum Power Dissipation | 123 | |
| T_J T_{STG} | Operating Junction and 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 <http://www.irf.com/>

AUIRGP35B60PD-E

Electrical Characteristics @ $T_J = 25^\circ\text{C}$ (unless otherwise specified)

| | Parameter | Min. | Typ. | Max. | Units | Conditions | Ref.Fig |
|---------------------------------|---|------|------|-----------|----------|---|---------------|
| $V_{(BR)CES}$ | Collector-to-Emitter Breakdown Voltage | 600 | — | — | V | $V_{GE} = 0V, I_C = 500\mu A$ | |
| $\Delta V_{(BR)CES}/\Delta T_J$ | Temperature Coeff. of Breakdown Voltage | — | 0.78 | — | V/°C | $V_{GE} = 0V, I_C = 1mA (25^\circ\text{C}-125^\circ\text{C})$ | |
| 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 | | $I_C = 22A, V_{GE} = 15V, T_J = 125^\circ\text{C}$ | |
| | | — | 3.00 | 3.45 | | $I_C = 35A, V_{GE} = 15V, T_J = 125^\circ\text{C}$ | |
| $V_{GE(th)}$ | Gate Threshold Voltage | 3.0 | 4.0 | 5.0 | V | $I_C = 250\mu A$ | 7, 8, 9 |
| $\Delta V_{GE(th)}/\Delta T_J$ | Threshold Voltage temp. coefficient | — | -10 | — | mV/°C | $V_{CE} = V_{GE}, I_C = 1.0mA$ | |
| g_{fe} | Forward Transconductance | — | 36 | — | S | $V_{CE} = 50V, I_C = 22A, PW = 80\mu s$ | |
| I_{CES} | Collector-to-Emitter Leakage Current | — | 3.0 | 375 | μA | $V_{GE} = 0V, V_{CE} = 600V$ | |
| | | — | 0.35 | — | mA | $V_{GE} = 0V, V_{CE} = 600V, T_J = 125^\circ\text{C}$ | |
| V_{FM} | Diode Forward Voltage Drop | — | 1.30 | 1.70 | V | $I_F = 15A, V_{GE} = 0V$ | 10 |
| | | — | 1.20 | 1.60 | | $I_F = 15A, V_{GE} = 0V, T_J = 125^\circ\text{C}$ | |
| I_{GES} | Gate-to-Emitter Leakage Current | — | — | ± 100 | nA | $V_{GE} = \pm 20V, V_{CE} = 0V$ | |

Switching Characteristics @ $T_J = 25^\circ\text{C}$ (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_{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 | | $V_{GE} = +15V, R_G = 3.3\Omega, L = 200\mu H$ | |
| E_{total} | Total Switching Loss | — | 435 | 535 | | $T_J = 25^\circ\text{C} \text{ (4)}$ | |
| $t_{d(on)}$ | Turn-On delay time | — | 26 | 34 | ns | $I_C = 22A, V_{CC} = 390V$ | CT3 |
| t_r | Rise time | — | 6.0 | 8.0 | | $V_{GE} = +15V, R_G = 3.3\Omega, L = 200\mu H$ | |
| $t_{d(off)}$ | Turn-Off delay time | — | 110 | 122 | | $T_J = 25^\circ\text{C} \text{ (4)}$ | |
| 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 | | $V_{GE} = +15V, R_G = 3.3\Omega, L = 200\mu H$ | 11, 13 |
| E_{total} | Total Switching Loss | — | 740 | 870 | | $T_J = 125^\circ\text{C} \text{ (4)}$ | 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 | | $V_{GE} = +15V, R_G = 3.3\Omega, L = 200\mu H$ | 12, 14 |
| $t_{d(off)}$ | Turn-Off delay time | — | 130 | 150 | | $T_J = 125^\circ\text{C} \text{ (4)}$ | 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 | — | | $V_{GE} = 0V, V_{CE} = 0V \text{ to } 480V$ | 15 |
| $C_{oes\ eff. (ER)}$ | Effective Output Capacitance (Energy Related) (5) | — | 179 | — | | | |
| RBSOA | Reverse Bias Safe Operating Area | FULL SQUARE | | | | $T_J = 150^\circ\text{C}, I_C = 120A$ $V_{CC} = 480V, V_p = 600V$ $R_g = 22\Omega, V_{GE} = +15V \text{ to } 0V$ | 3 CT2 |
| t_{rr} | Diode Reverse Recovery Time | — | 42 | 60 | ns | $T_J = 25^\circ\text{C} \quad I_F = 15A, V_R = 200V,$ | 19 |
| | | — | 74 | 120 | | $T_J = 125^\circ\text{C} \quad di/dt = 200A/\mu s$ | |
| Q_{rr} | Diode Reverse Recovery Charge | — | 80 | 180 | nC | $T_J = 25^\circ\text{C} \quad I_F = 15A, V_R = 200V,$ | 21 |
| | | — | 220 | 600 | | $T_J = 125^\circ\text{C} \quad di/dt = 200A/\mu s$ | |
| I_{rr} | Peak Reverse Recovery Current | — | 4.0 | 6.0 | A | $T_J = 25^\circ\text{C} \quad I_F = 15A, V_R = 200V,$ | 19, 20, 21, 22 |
| | | — | 6.5 | 10 | | $T_J = 125^\circ\text{C} \quad di/dt = 200A/\mu s$ | |

Notes:

- $R_{CE(on)}$ 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.
- $V_{CC} = 80\% (V_{CES}), V_{GE} = 20V, L = 28 \mu H, R_G = 22 \Omega$.
- Pulse width limited by max. junction temperature.
- Energy losses include "tail" and diode reverse recovery, Data generated with use of Diode 30ETH06.
- $C_{oes\ eff.}$ 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} .

Qualification Information[†]

| | | | |
|-----------------------------------|----------------------|---|------|
| Qualification Level | | Automotive (per AEC-Q101) ^{††} | |
| | | Comments: This part number(s) passed Automotive qualification. IR's Industrial and Consumer qualification level is granted by extension of the higher Automotive level. | |
| Moisture Sensitivity Level | | TO-247 | MSL1 |
| ESD | Machine Model | Class M4 (425V) ^{†††} AEC-Q101-002 | |
| | Human Body Model | Class H2 (4000V) ^{†††} AEC-Q101-001 | |
| | Charged Device Model | Class C5 (1125V) ^{†††} AEC-Q101-005 | |
| RoHS Compliant | | Yes | |

† Qualification standards can be found at International Rectifier's web site: <http://www.irf.com/>

†† Exceptions to AEC-Q101 requirements are noted in the qualification report.

††† Highest passing voltage

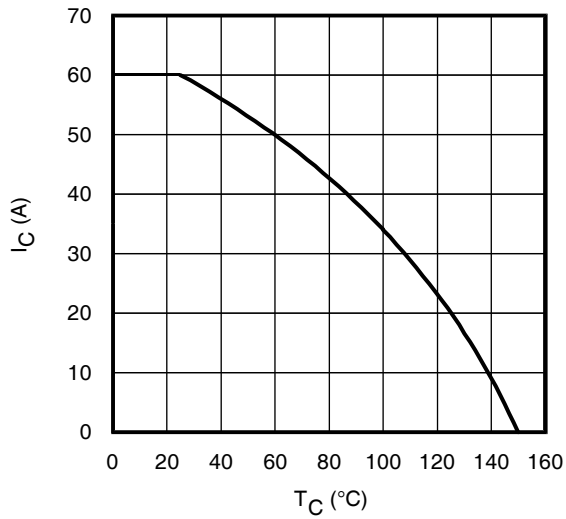


Fig. 1 - Maximum DC Collector Current vs. Case Temperature

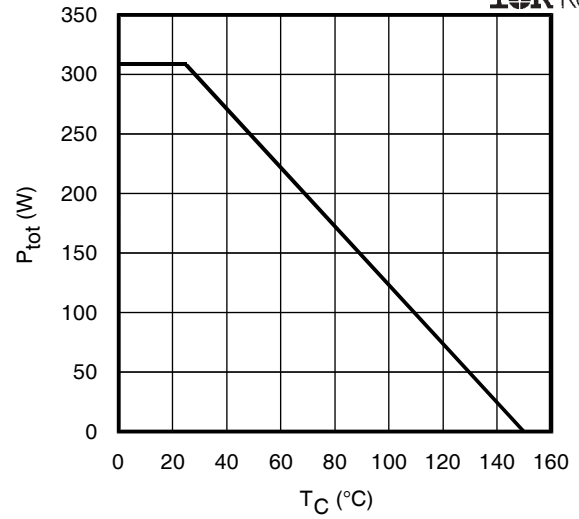


Fig. 2 - Power Dissipation vs. Case Temperature

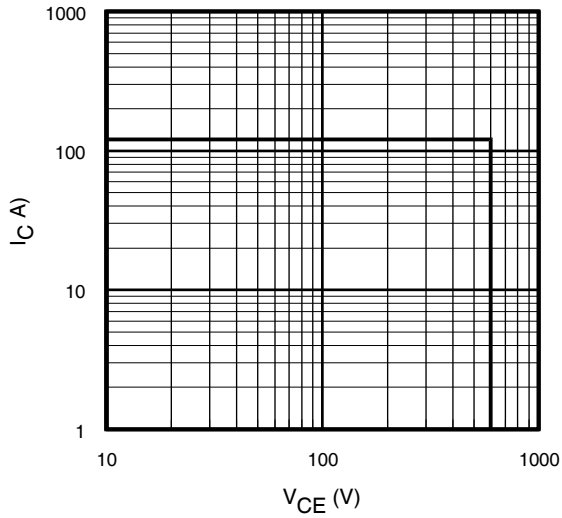


Fig. 3 - Reverse Bias SOA
 $T_J = 150^{\circ}C$; $V_{GE} = 15V$

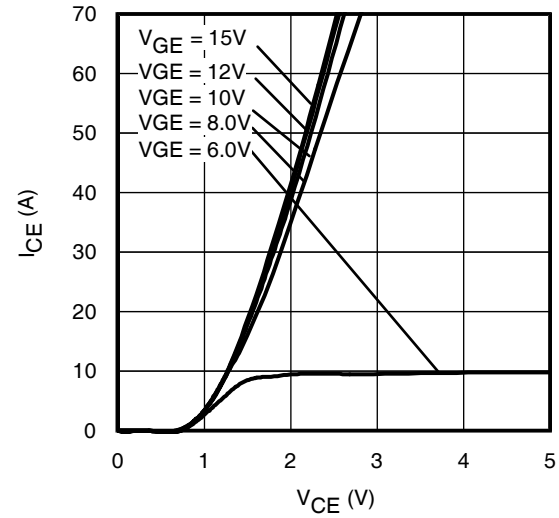


Fig. 4 - Typ. IGBT Output Characteristics
 $T_J = -40^{\circ}C$; $t_p = 80\mu s$

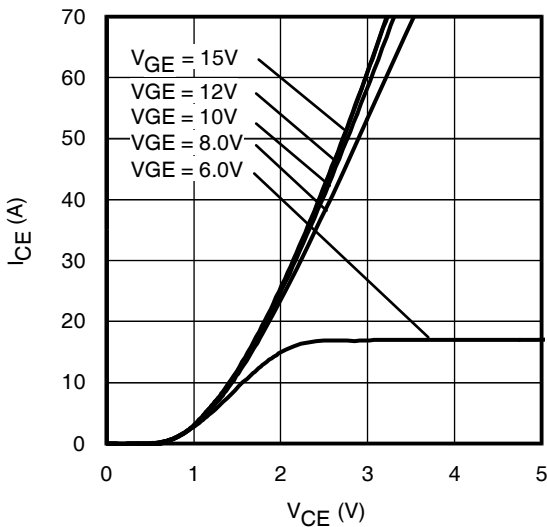


Fig. 5 - Typ. IGBT Output Characteristics
 $T_J = 25^{\circ}C$; $t_p = 80\mu s$

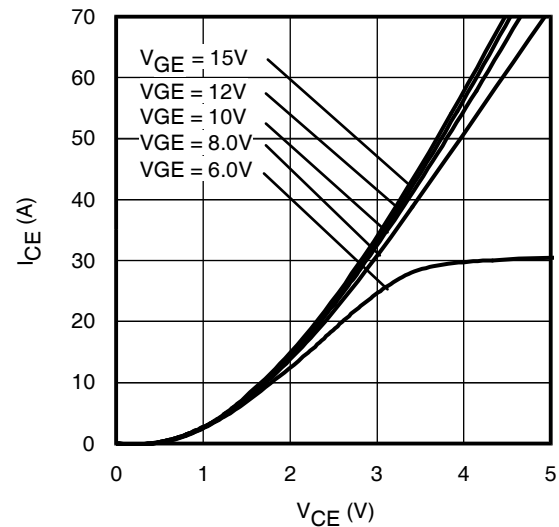


Fig. 6 - Typ. IGBT Output Characteristics
 $T_J = 125^{\circ}C$; $t_p = 80\mu s$

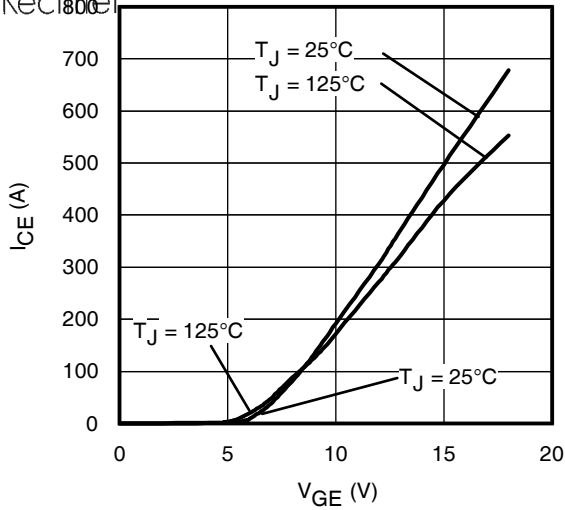


Fig. 7 - Typ. Transfer Characteristics
 $V_{CE} = 50V$; $t_p = 10\mu s$

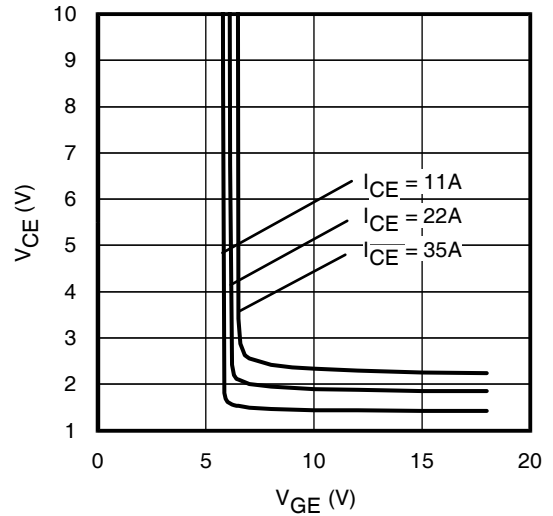


Fig. 8 - Typical V_{CE} vs. V_{GE}
 $T_J = 25^\circ C$

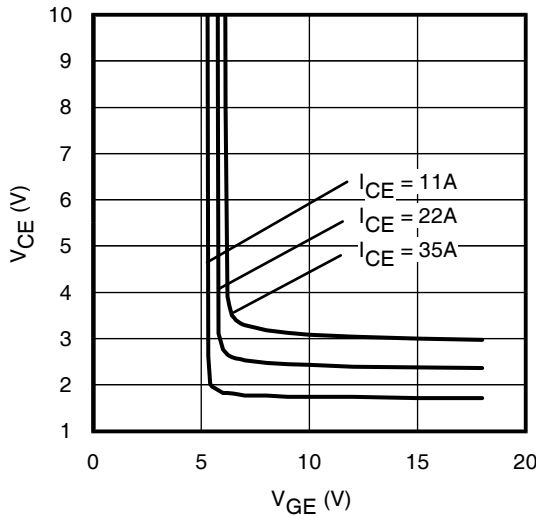


Fig. 9 - Typical V_{CE} vs. V_{GE}
 $T_J = 125^\circ C$

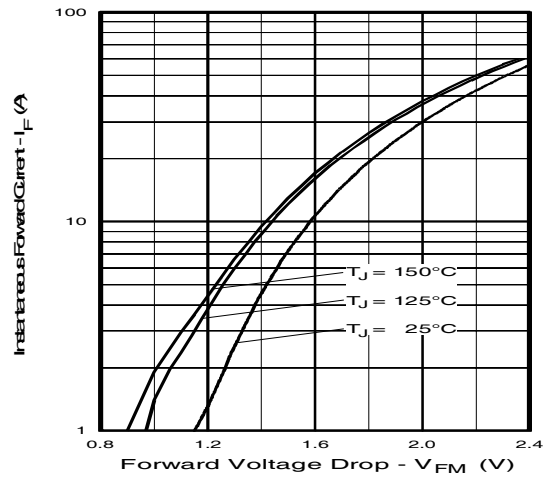


Fig. 10 - Typ. Diode Forward Characteristics
 $t_p = 80\mu s$

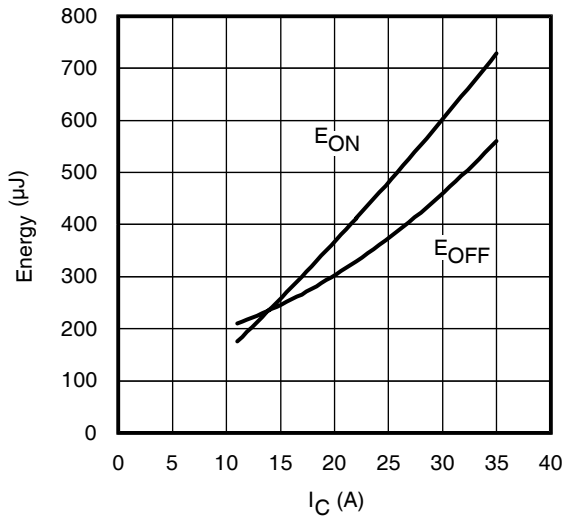


Fig. 11 - Typ. Energy Loss vs. I_C

$T_J = 125^\circ C$; $L = 200\mu H$; $V_{CE} = 390V$; $R_G = 3.3\Omega$; $V_{GE} = 15V$.
 Diode clamp used: 30ETH06 (See C.T.3)

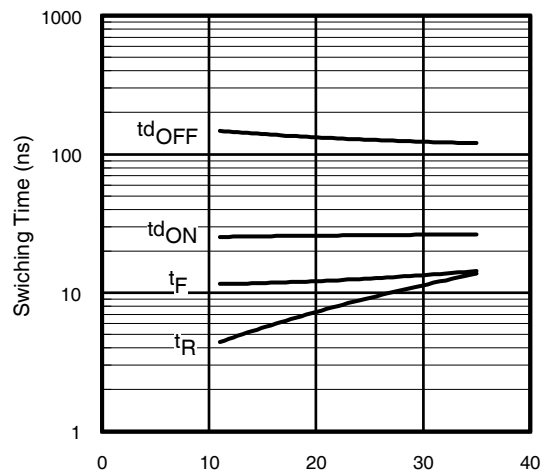


Fig. 12 - Typ. Switching Time vs. I_C
 $T_J = 125^\circ C$; $L = 200\mu H$; $V_{CE} = 390V$; $R_G = 3.3\Omega$; $V_{GE} = 15V$.
 Diode clamp used: 30ETH06 (See C.T.3)

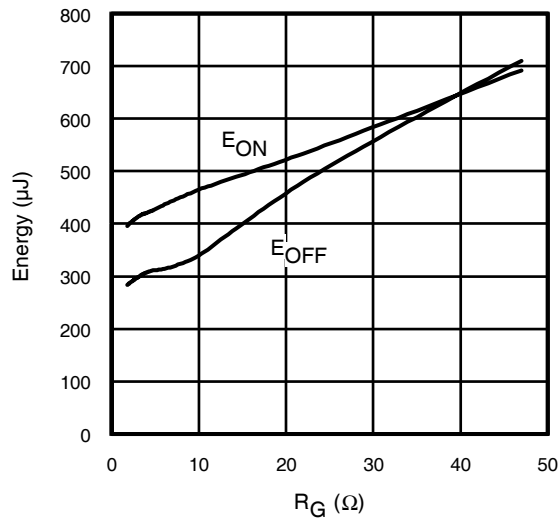


Fig. 13 - Typ. Energy Loss vs. R_G

$T_J = 125^\circ\text{C}$; $L = 200\mu\text{H}$; $V_{CE} = 390\text{V}$; $I_{CE} = 22\text{A}$; $V_{GE} = 15\text{V}$
Diode clamp used: 30ETH06 (See C.T.3)

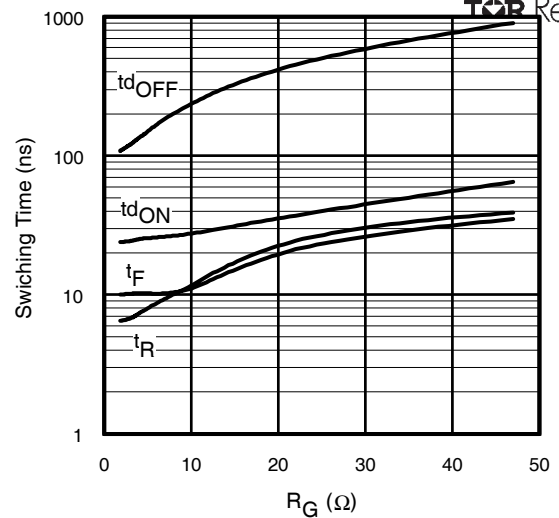
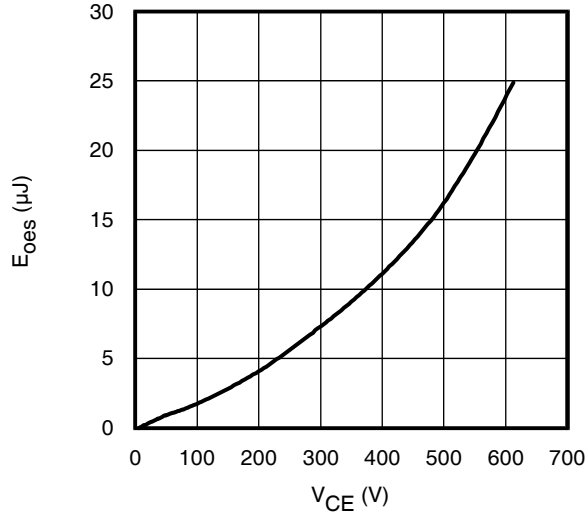


Fig. 14 - Typ. Switching Time vs. R_G

$T_J = 125^\circ\text{C}$; $L = 200\mu\text{H}$; $V_{CE} = 390\text{V}$; $I_{CE} = 22\text{A}$; $V_{GE} = 15\text{V}$
Diode clamp used: 30ETH06 (See C.T.3)



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

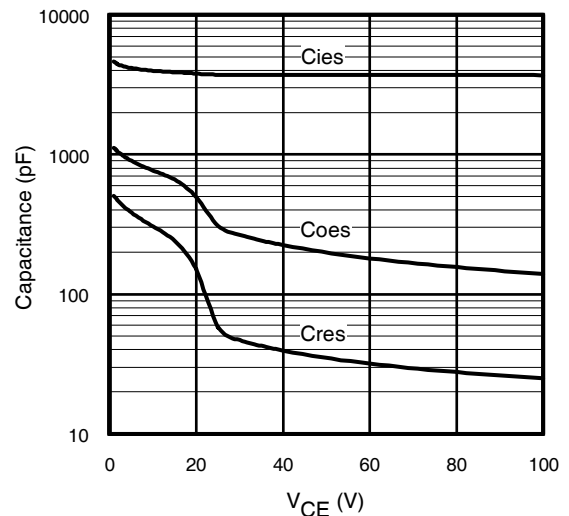


Fig. 16- Typ. Capacitance vs. V_{CE}
 $V_{GE} = 0\text{V}$; $f = 1\text{MHz}$

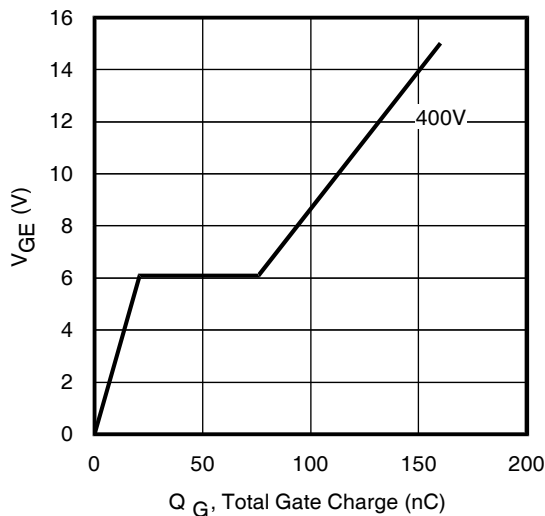
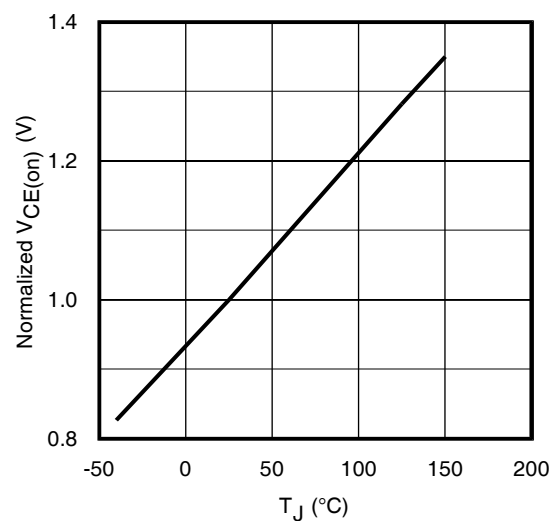


Fig. 17 - Typical Gate Charge vs. V_{GE}
 $I_{CE} = 22\text{A}$



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

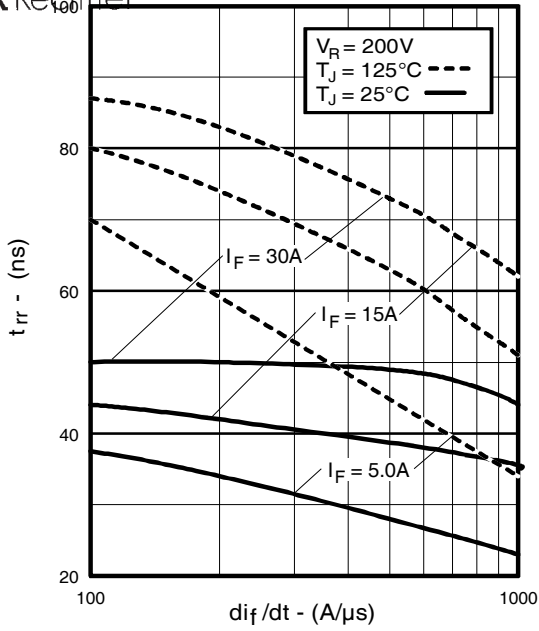


Fig. 19 - Typical Reverse Recovery vs. di_f/dt

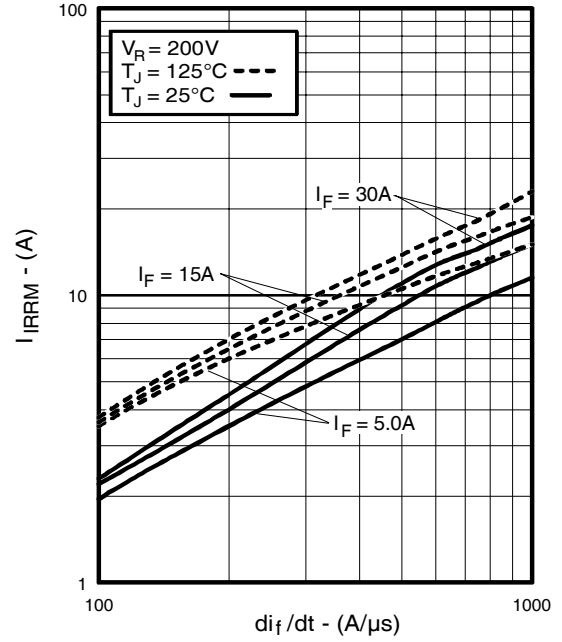


Fig. 20 - Typical Recovery Current vs. di_f/dt

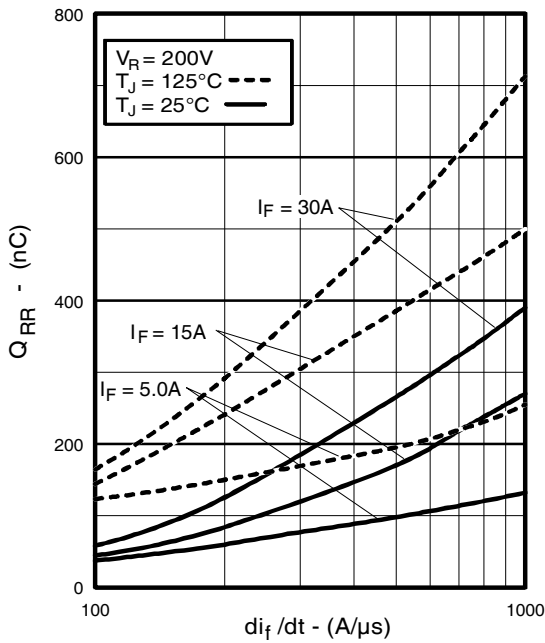


Fig. 21 - Typical Stored Charge vs. di_f/dt

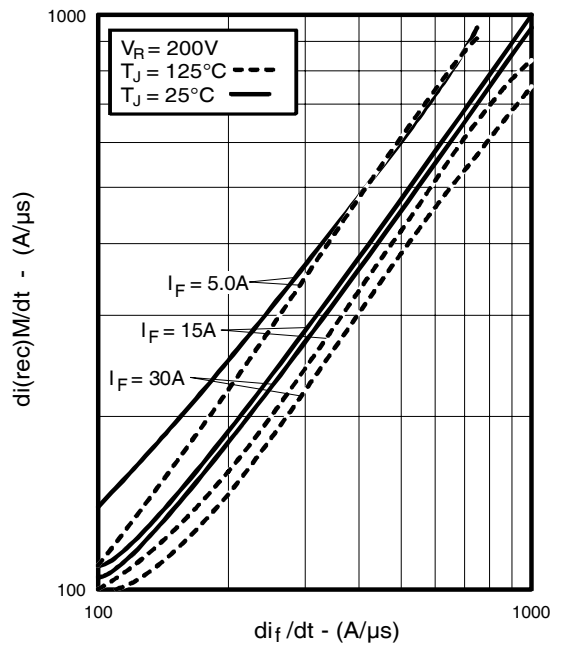


Fig. 22 - Typical $di_{(rec)M}/dt$ vs. di_f/dt

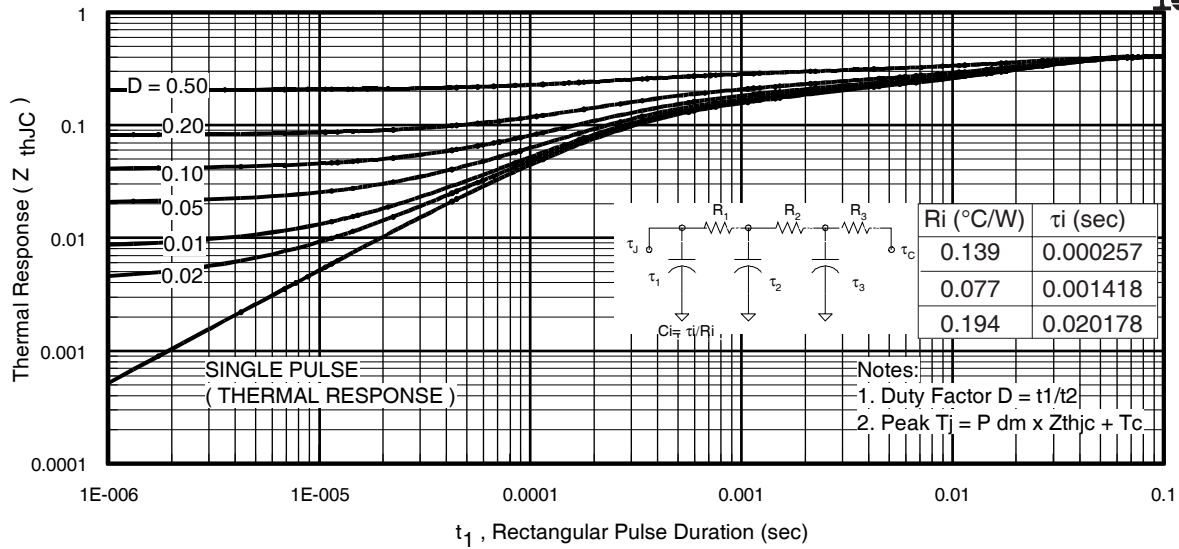


Fig 23. Maximum Transient Thermal Impedance, Junction-to-Case (IGBT)

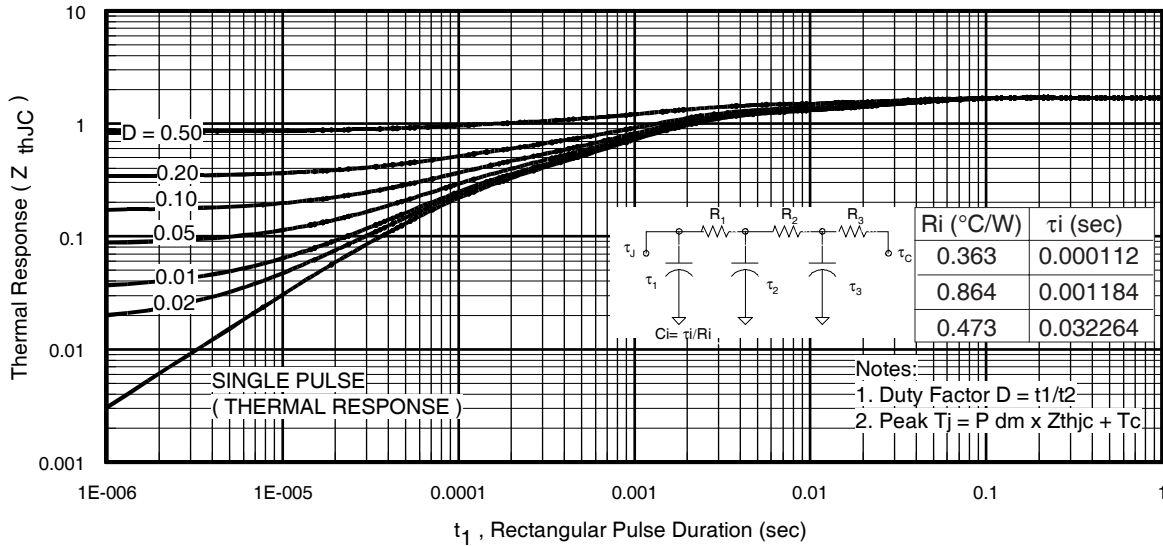


Fig. 24. Maximum Transient Thermal Impedance, Junction-to-Case (DIODE)

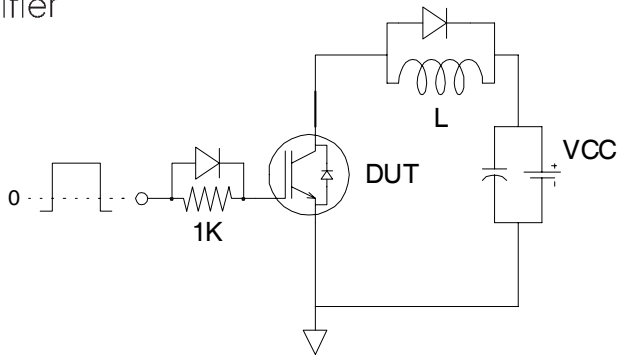


Fig.C.T.1 - Gate Charge Circuit (turn-off)

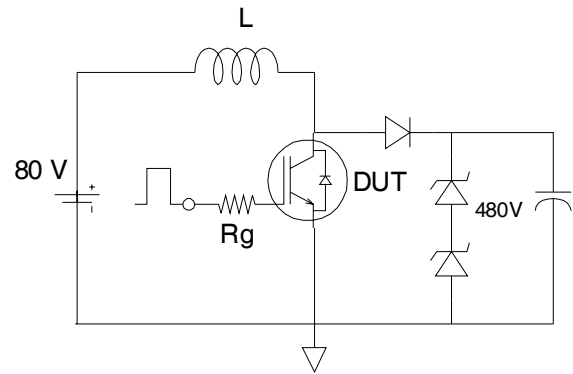


Fig.C.T.2 - RBSOA Circuit

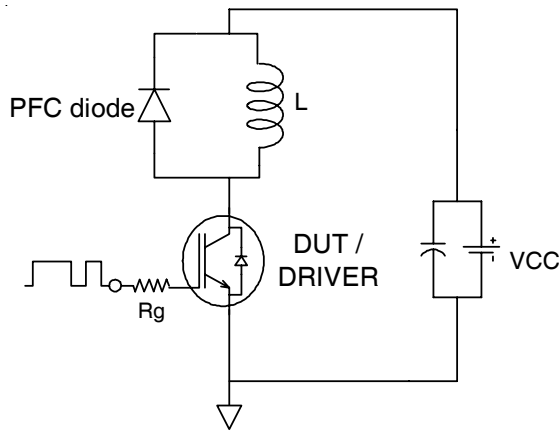


Fig.C.T.3 - Switching Loss Circuit

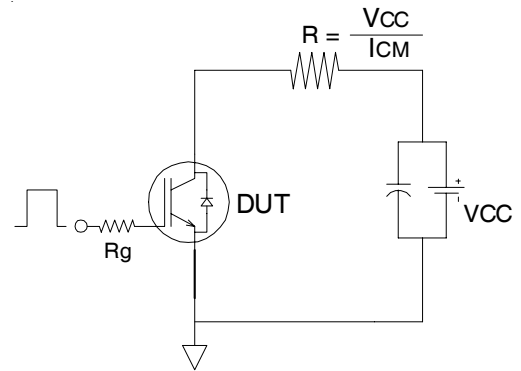


Fig.C.T.4 - Resistive Load Circuit

REVERSE RECOVERY CIRCUIT

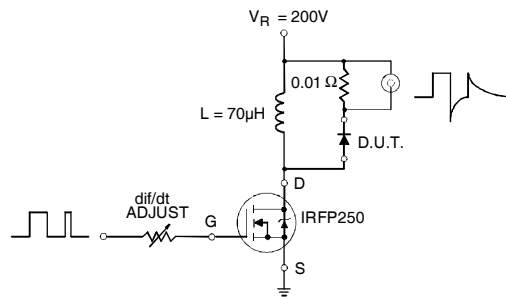


Fig. C.T.5 - Reverse Recovery Parameter Test Circuit

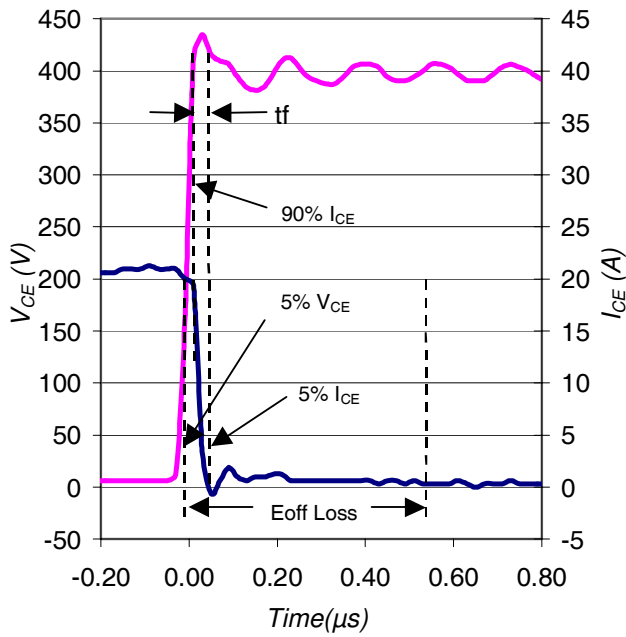


Fig. WF1 - Typ. Turn-off Loss Waveform
 @ $T_J = 25^\circ\text{C}$ using Fig. CT.3

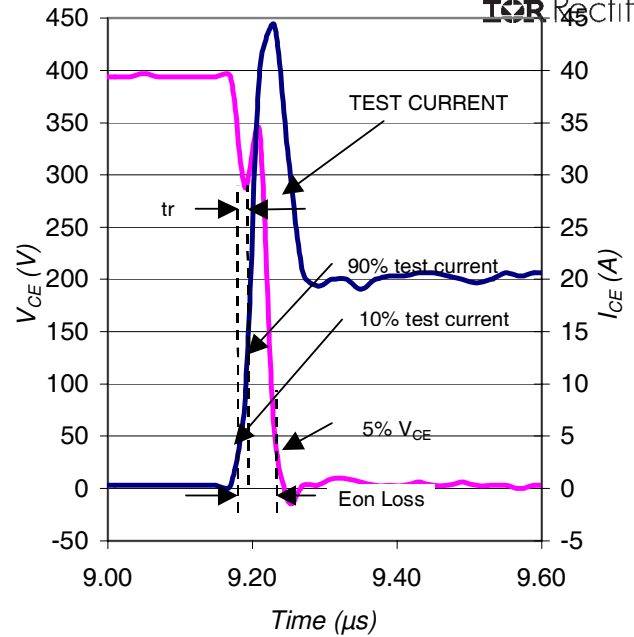
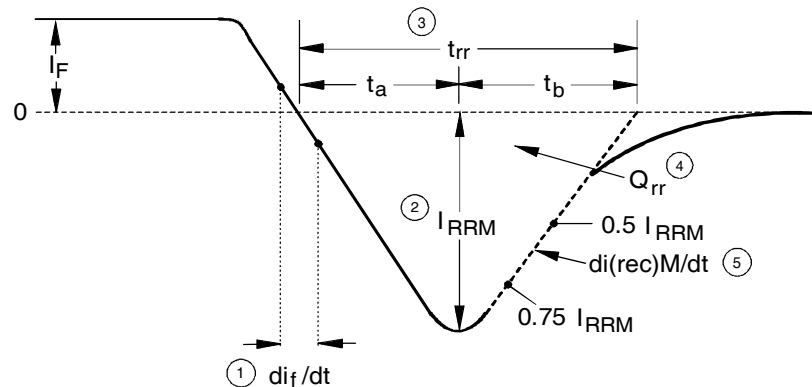


Fig. WF2 - Typ. Turn-on Loss Waveform
 @ $T_J = 25^\circ\text{C}$ using Fig. CT.3



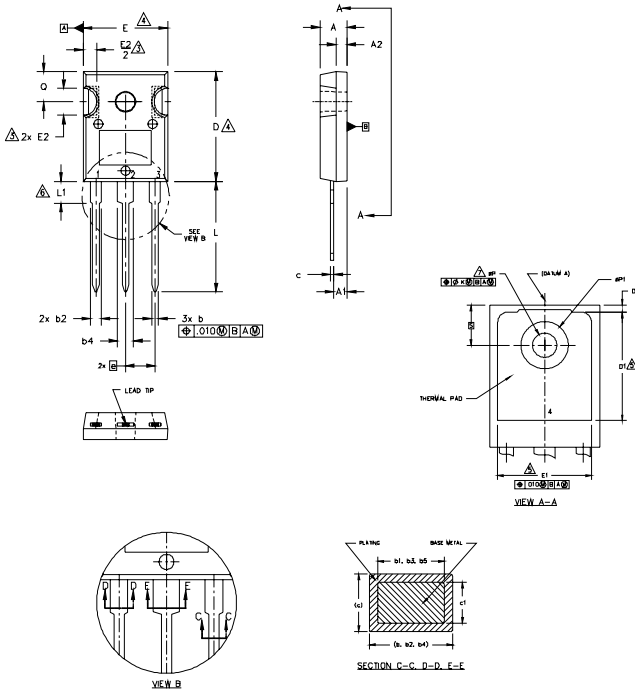
1. di_f/dt - Rate of change of current through zero crossing
2. I_{RRM} - Peak reverse recovery current
3. t_{rr} - Reverse recovery time measured from zero crossing point of negative going I_F to point where a line passing through $0.75 I_{RRM}$ and $0.50 I_{RRM}$ extrapolated to zero current
4. Q_{rr} - 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 | .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 | 2.34 | |
| 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

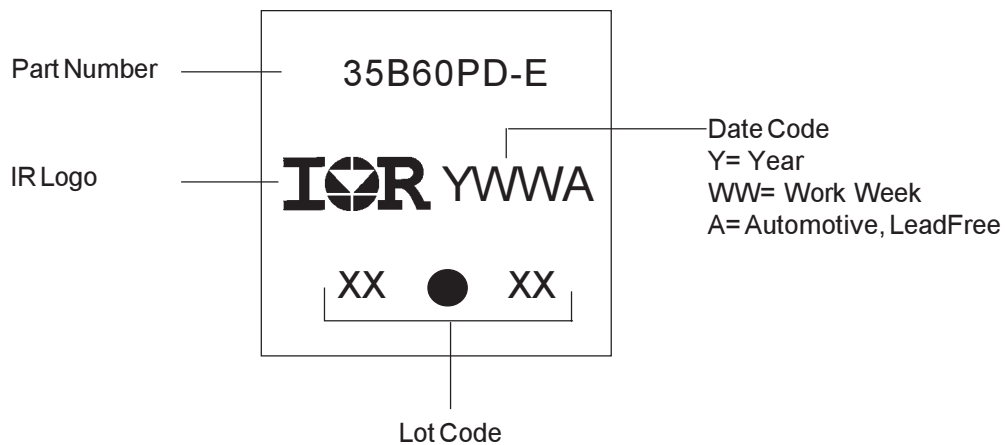
IGBTs, CoPACK

- 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.

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

Ordering Information

| Base part number | Package Type | Standard Pack | | Complete Part Number |
|------------------|--------------|---------------|----------|----------------------|
| | | Form | Quantity | |
| AUIRGP35B60PD-E | TO-247 | Tube | 25 | AUIRGP35B60PD-E |
| | | | | |

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