

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

Features

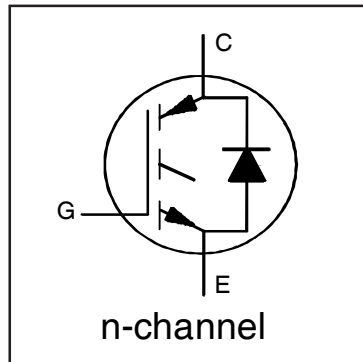
- NPT Technology, Positive Temperature Coefficient
- Lower $V_{CE(SAT)}$
- Lower Parasitic Capacitances
- Minimal Tail Current
- HEXFRED Ultra Fast Soft-Recovery Co-Pack Diode
- Tighter Distribution of Parameters
- Higher Reliability
- Lead-Free, RoHS Compliant
- Automotive Qualified*

Applications

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

Benefits

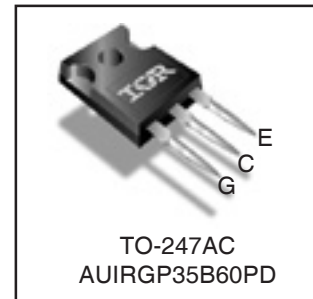
- Parallel Operation for Higher Current Applications
- Lower Conduction Losses and Switching Losses
- Higher Switching Frequency up to 150kHz



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

**Equivalent MOSFET
Parameters^①**

$R_{CE(on)} \text{ typ.} = 84m\Omega$
 $I_D \text{ (FET equivalent)} = 35A$



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
V_{GE}	Gate-to-Emitter Voltage	± 20	
$P_D @ T_C = 25^\circ C$	Maximum Power Dissipation	308	W
$P_D @ T_C = 100^\circ C$	Maximum Power Dissipation	123	
T_J	Operating Junction and	-55 to +150	$^\circ C$
T_{STG}	Storage Temperature Range		
	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	$^\circ C/W$
$R_{\theta JC}$ (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/>

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/ $^\circ\text{C}$	$V_{GE} = 0V, I_C = 1mA (25^\circ\text{C}-125^\circ\text{C})$	
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/ $^\circ\text{C}$	$V_{CE} = V_{GE}, I_C = 1.0mA$	
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 CT1
Q_{gc}	Gate-to-Collector Charge (turn-on)	—	55	83		$V_{CC} = 400V$	
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 11, 13 WF1, WF2
E_{off}	Turn-Off Switching Loss	—	330	405		$V_{GE} = +15V, R_G = 3.3\Omega, L = 200\mu H$	
E_{total}	Total Switching Loss	—	740	870		$T_J = 125^\circ\text{C} \text{ ④}$	
$t_{d(on)}$	Turn-On delay time	—	26	34	ns	$I_C = 22A, V_{CC} = 390V$	CT3 12, 14 WF1, WF2
t_r	Rise time	—	8.0	11		$V_{GE} = +15V, R_G = 3.3\Omega, L = 200\mu H$	
$t_{d(off)}$	Turn-Off delay time	—	130	150		$T_J = 125^\circ\text{C} \text{ ④}$	
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	—		$f = 1MHz$	
$C_{oes \text{ eff.}}$	Effective Output Capacitance (Time Related) ⑤	—	135	—		$V_{GE} = 0V, V_{CE} = 0V \text{ to } 480V$	15
$C_{oes \text{ eff. (ER)}}$	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	$T_J = 25^\circ\text{C}$	19
		—	74	120		$T_J = 125^\circ\text{C}$	
Q_{rr}	Diode Reverse Recovery Charge	—	80	180	nC	$T_J = 25^\circ\text{C}$	21
		—	220	600		$T_J = 125^\circ\text{C}$	
I_{rr}	Peak Reverse Recovery Current	—	4.0	6.0	A	$T_J = 25^\circ\text{C}$	19, 20, 21, 22 CT5
		—	6.5	10		$T_J = 125^\circ\text{C}$	

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 $V_{CC} = 80\% (V_{CES})$, $V_{GE} = 20V$, $L = 28\mu H$, $R_G = 22\Omega$.

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 $C_{oes \text{ eff.}}$ is a fixed capacitance that gives the same charging time as C_{oes} while V_{CE} is rising from 0 to 80% V_{CES} .

$C_{oes \text{ eff. (ER)}}$ 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.

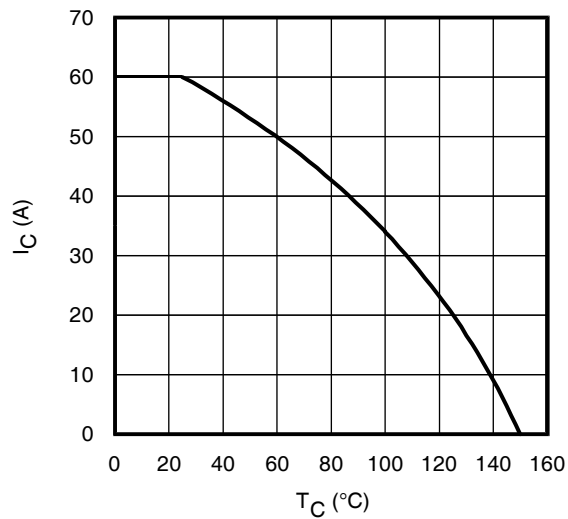


Fig. 1 - Maximum DC Collector Current vs. Case Temperature

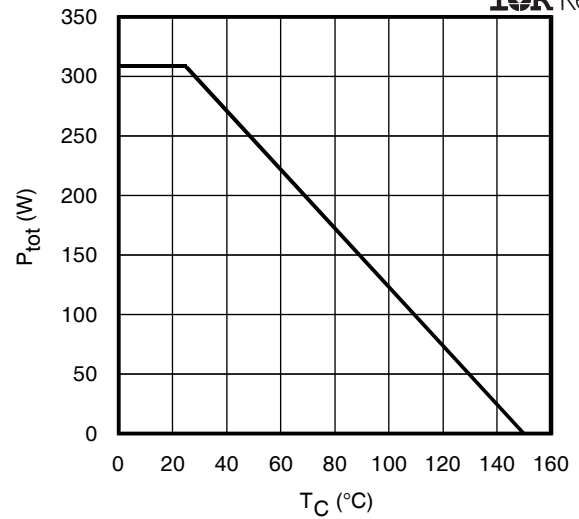


Fig. 2 - Power Dissipation vs. Case Temperature

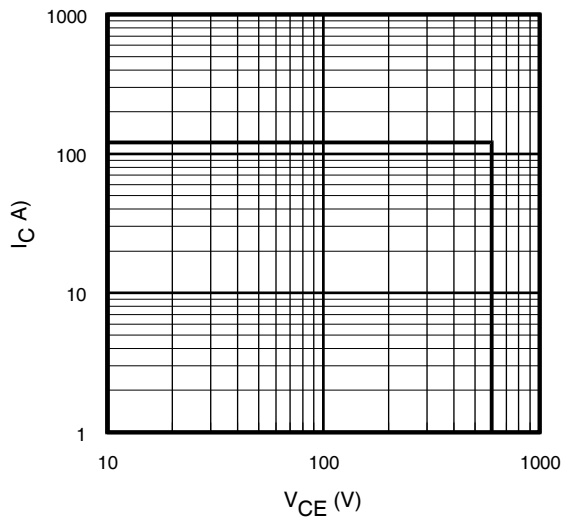


Fig. 3 - Reverse Bias SOA
 $T_J = 150^\circ\text{C}$; $V_{GE} = 15\text{V}$

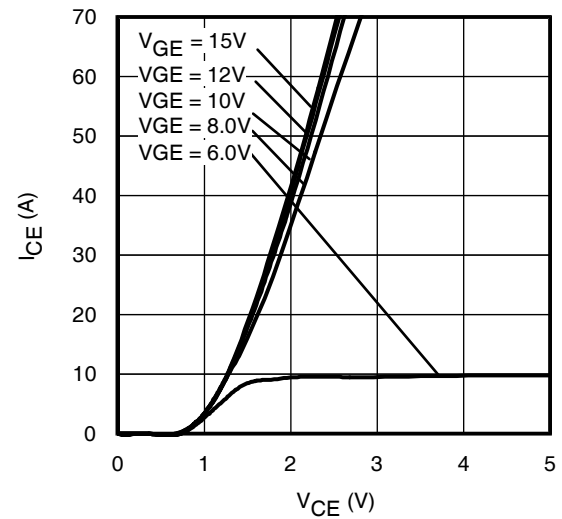


Fig. 4 - Typ. IGBT Output Characteristics
 $T_J = -40^\circ\text{C}$; $t_p = 80\mu\text{s}$

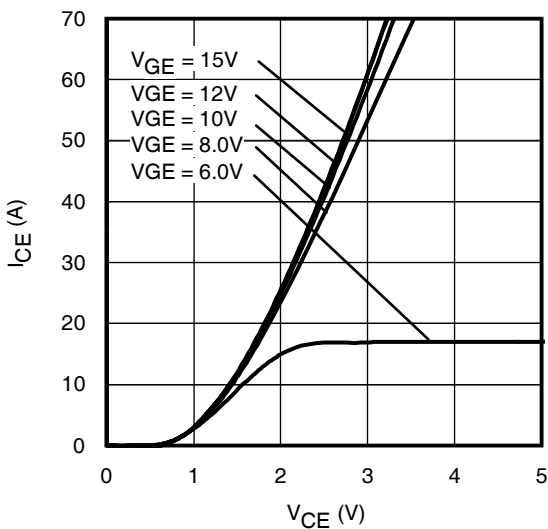


Fig. 5 - Typ. IGBT Output Characteristics
 $T_J = 25^\circ\text{C}$; $t_p = 80\mu\text{s}$

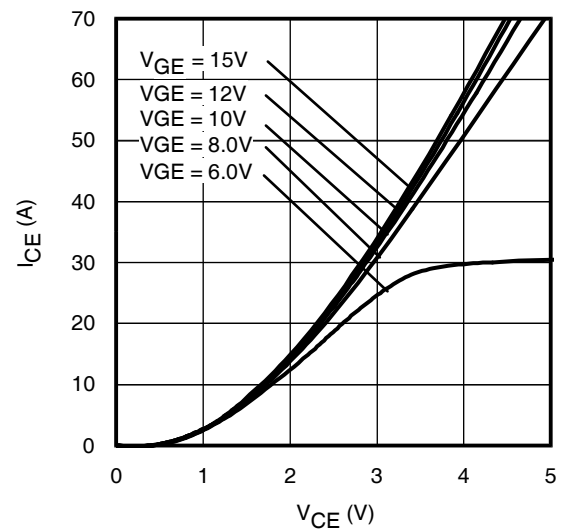


Fig. 6 - Typ. IGBT Output Characteristics
 $T_J = 125^\circ\text{C}$; $t_p = 80\mu\text{s}$

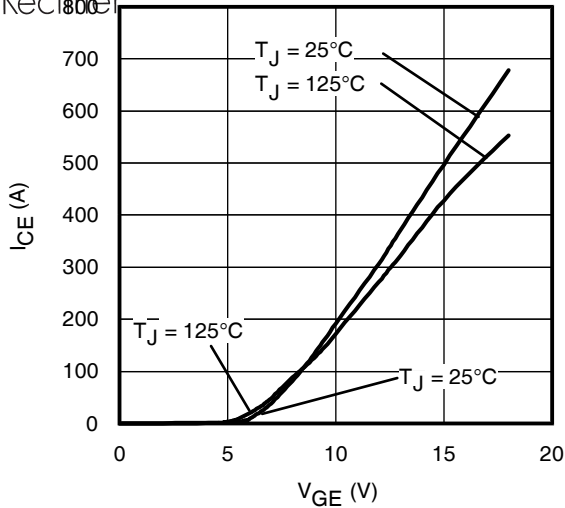


Fig. 7 - Typ. Transfer Characteristics
 $V_{CE} = 50V$; $t_p = 10\mu s$

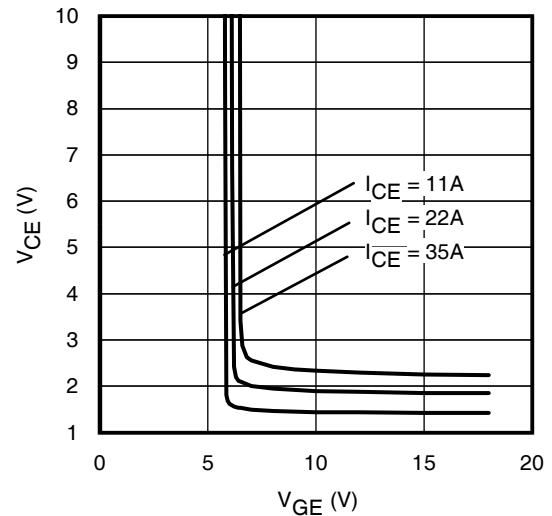


Fig. 8 - Typical V_{CE} vs. V_{GE}
 $T_J = 25^\circ C$

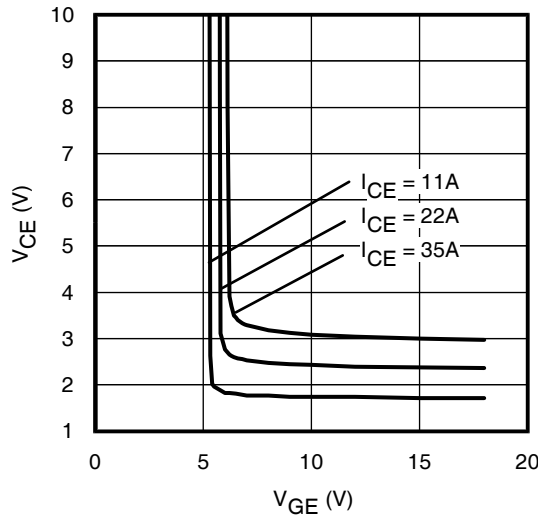


Fig. 9 - Typical V_{CE} vs. V_{GE}
 $T_J = 125^\circ C$

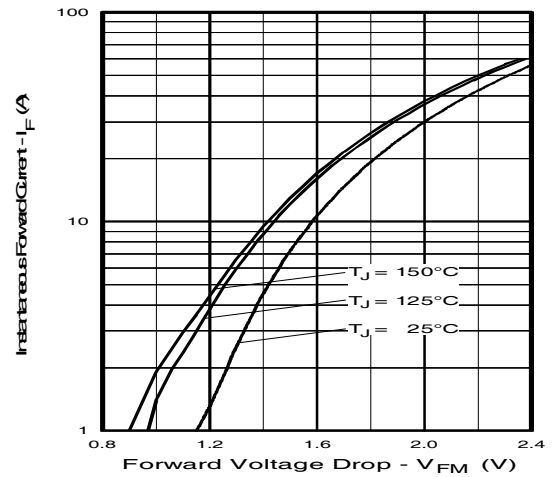


Fig. 10 - Typ. Diode Forward Characteristics
 $t_p = 80\mu s$

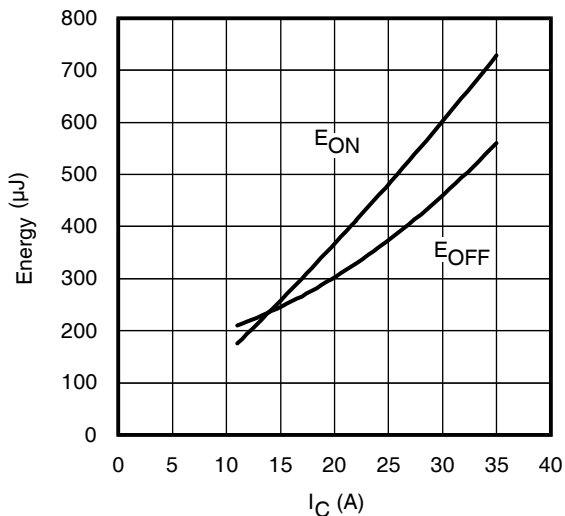


Fig. 11 - Typ. Energy Loss vs. I_C

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

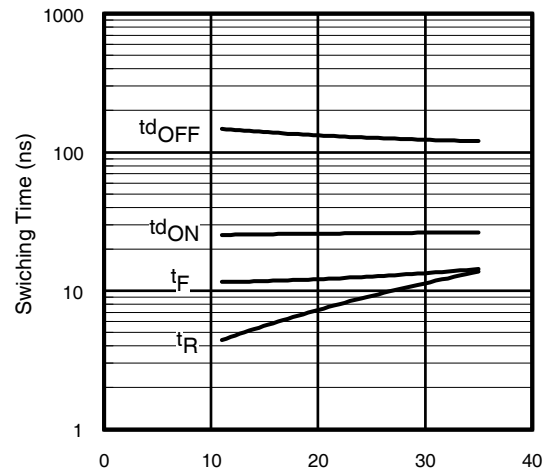


Fig. 12 - Typ. Switching Time vs. I_C
 $T_J = 125^\circ C$; $L = 200\mu H$; $V_{CE} = 390V$; $R_G = 3.3\Omega$; $V_{GE} = 15V$.
Diode clamp used: 30ETH06 (See C.T.3)

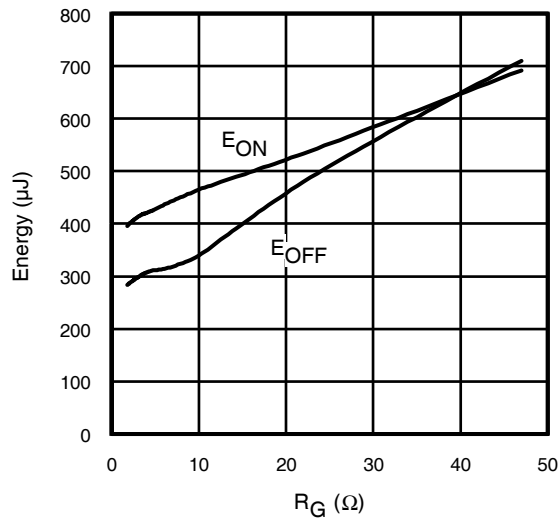


Fig. 13 - Typ. Energy Loss vs. R_G
 $T_J = 125^\circ\text{C}$; $L = 200\mu\text{H}$; $V_{CE} = 390\text{V}$; $I_{CE} = 22\text{A}$; $V_{GE} = 15\text{V}$
 Diode clamp used: 30ETH06 (See C.T.3)

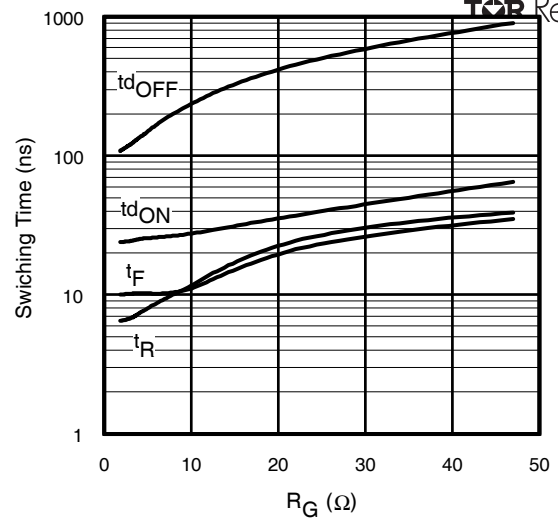


Fig. 14 - Typ. Switching Time vs. R_G
 $T_J = 125^\circ\text{C}$; $L = 200\mu\text{H}$; $V_{CE} = 390\text{V}$; $I_{CE} = 22\text{A}$; $V_{GE} = 15\text{V}$
 Diode clamp used: 30ETH06 (See C.T.3)

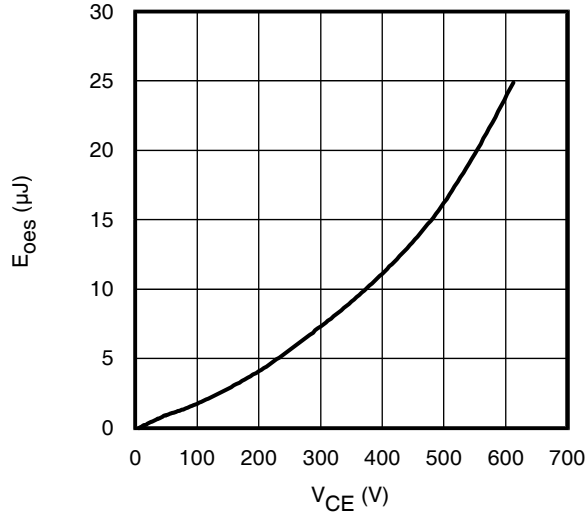


**Fig. 15- Typ. Output Capacitance
Stored Energy vs. V_{CE}**

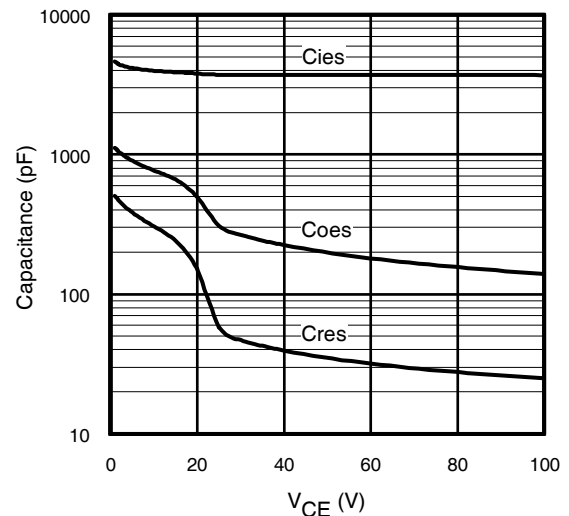


Fig. 16- Typ. Capacitance vs. V_{CE}
 $V_{GE} = 0\text{V}$; $f = 1\text{MHz}$

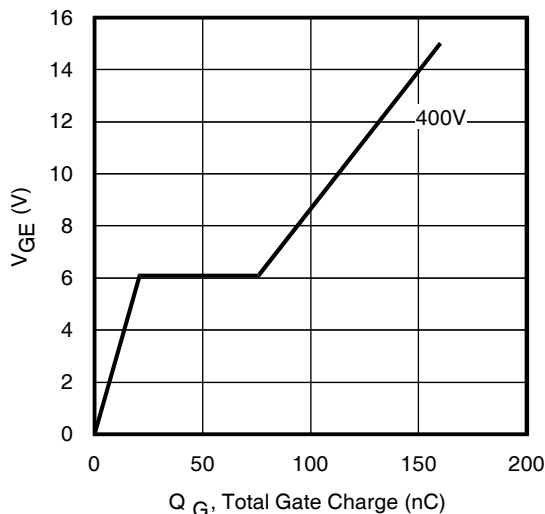


Fig. 17 - Typical Gate Charge vs. V_{GE}
 $I_{CE} = 22\text{A}$

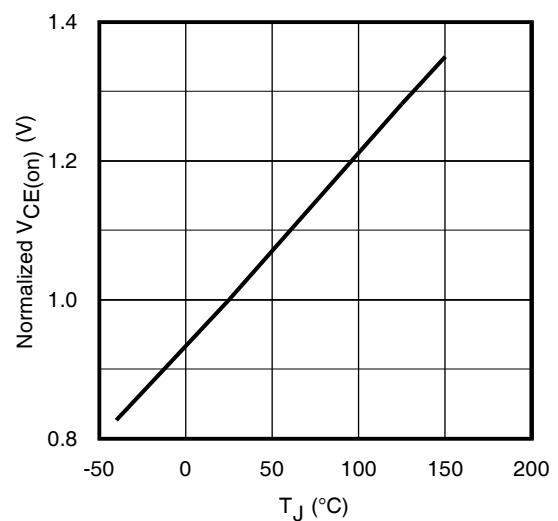


**Fig. 18 - Normalized Typ. $V_{CE(on)}$
vs. Junction Temperature**
 $I_C = 22\text{A}$, $V_{GE} = 15\text{V}$

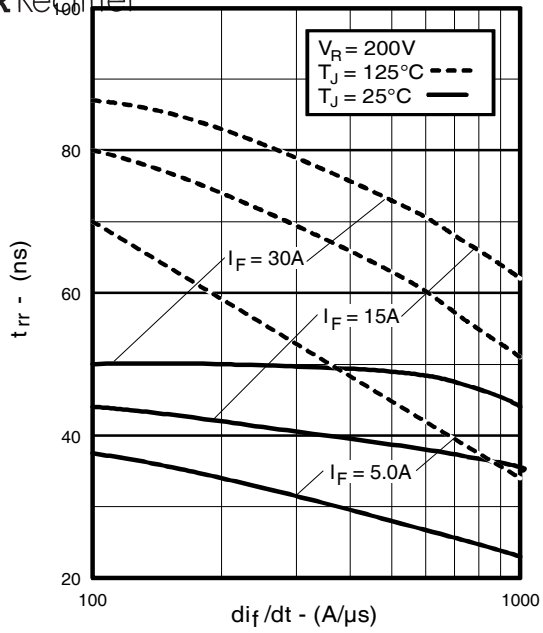


Fig. 19 - Typical Reverse Recovery vs. di_f/dt

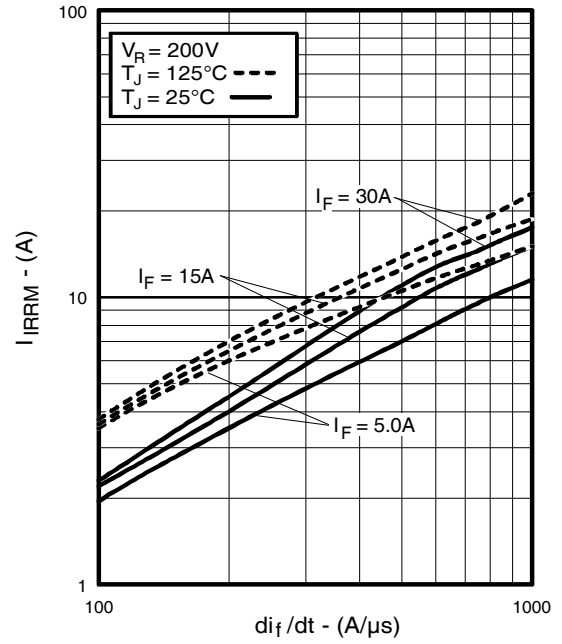


Fig. 20 - Typical Recovery Current vs. di_f/dt

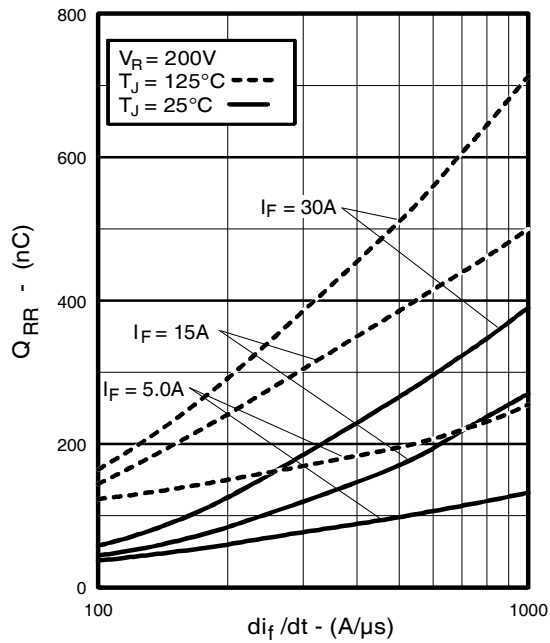


Fig. 21 - Typical Stored Charge vs. di_f/dt

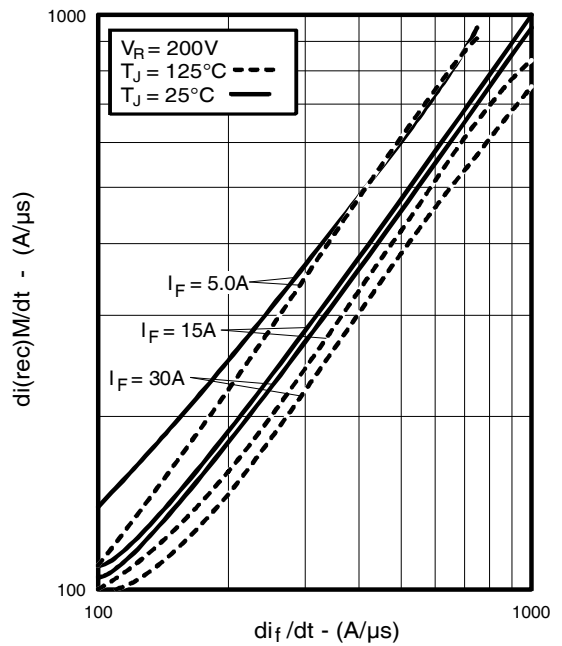


Fig. 22 - Typical $di_{(rec)M}/dt$ vs. di_f/dt

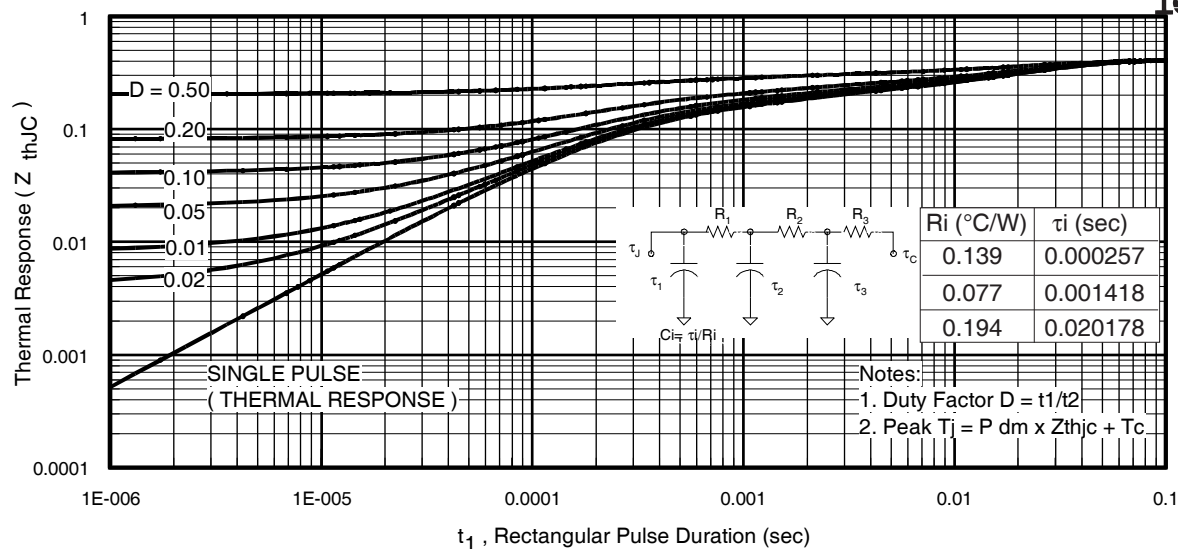


Fig 23. Maximum Transient Thermal Impedance, Junction-to-Case (IGBT)

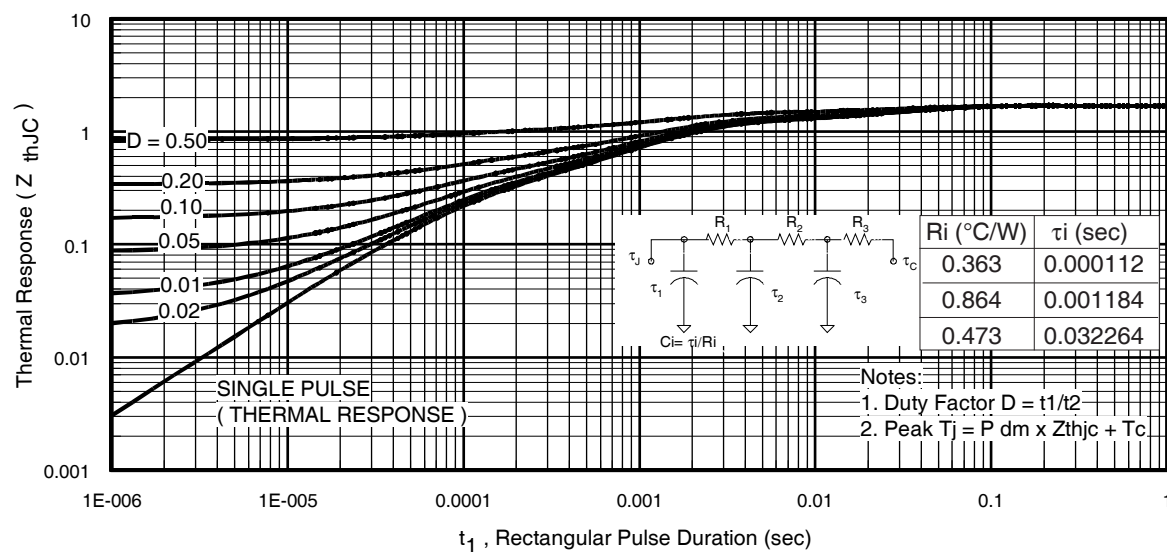


Fig. 24. Maximum Transient Thermal Impedance, Junction-to-Case (DIODE)

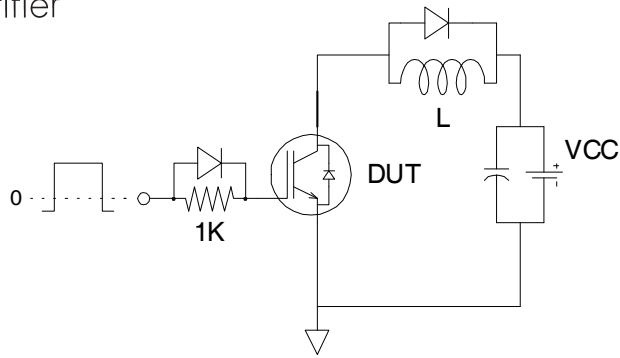


Fig.C.T.1 - Gate Charge Circuit (turn-off)

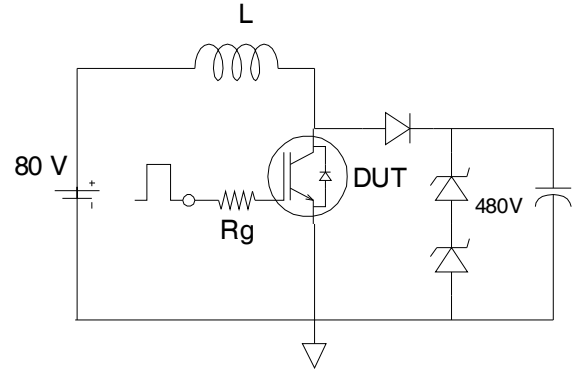


Fig.C.T.2 - RBSOA Circuit

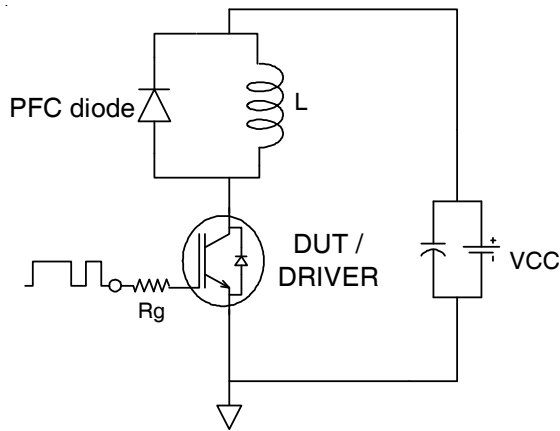


Fig.C.T.3 - Switching Loss Circuit

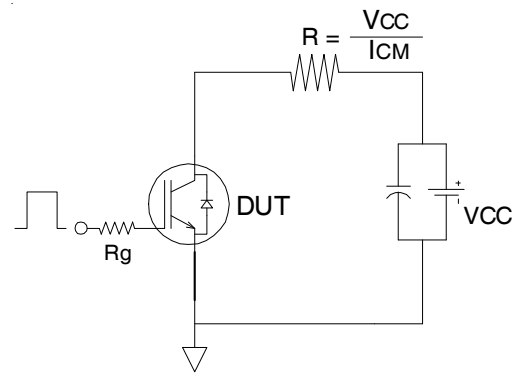


Fig.C.T.4 - Resistive Load Circuit

REVERSE RECOVERY CIRCUIT

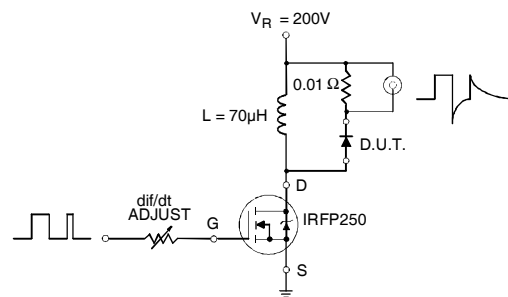


Fig. C.T.5 - Reverse Recovery Parameter Test Circuit

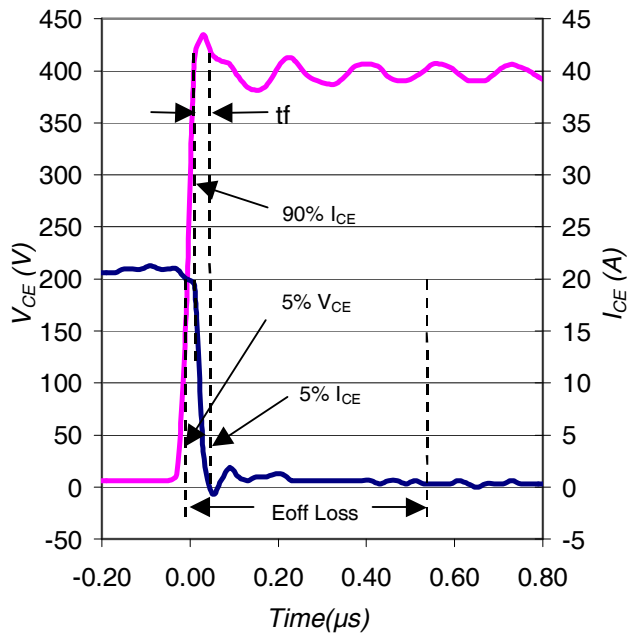


Fig. WF1 - Typ. Turn-off Loss Waveform
@ $T_J = 25^\circ\text{C}$ using Fig. CT.3

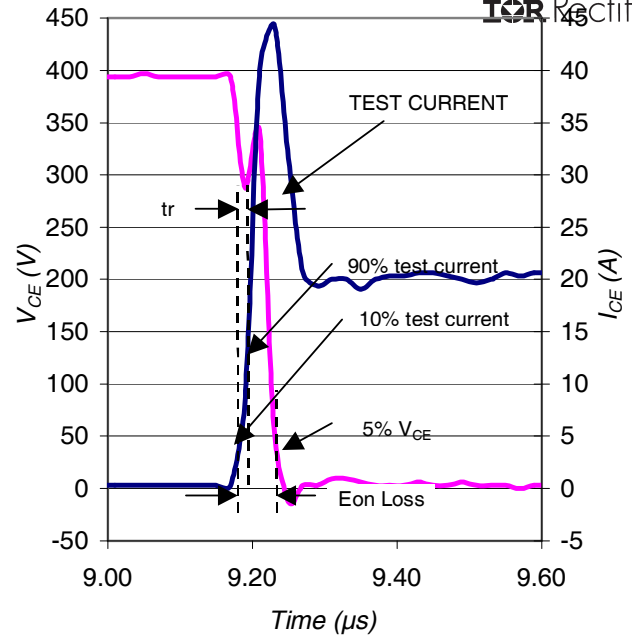


Fig. WF2 - Typ. Turn-on Loss Waveform
@ $T_J = 25^\circ\text{C}$ using Fig. CT.3

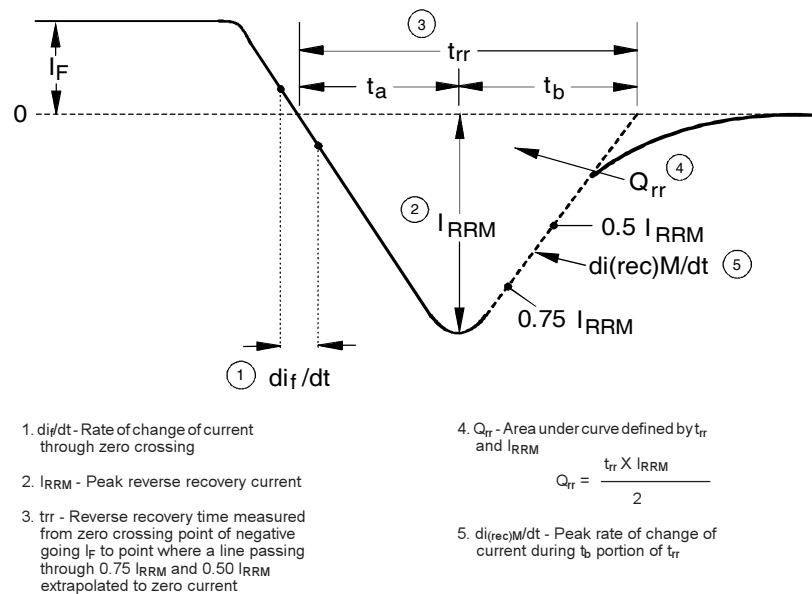
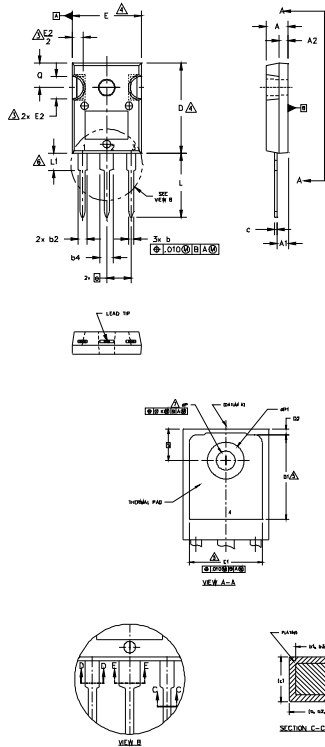


Fig. WF3 - Reverse Recovery Waveform and Definitions

TO-247AC 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-247AC .

SYMBOL	DIMENSIONS				NOTE
	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		
ek	0.0		0.25		
L	.559	.634	14.20	16.10	
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

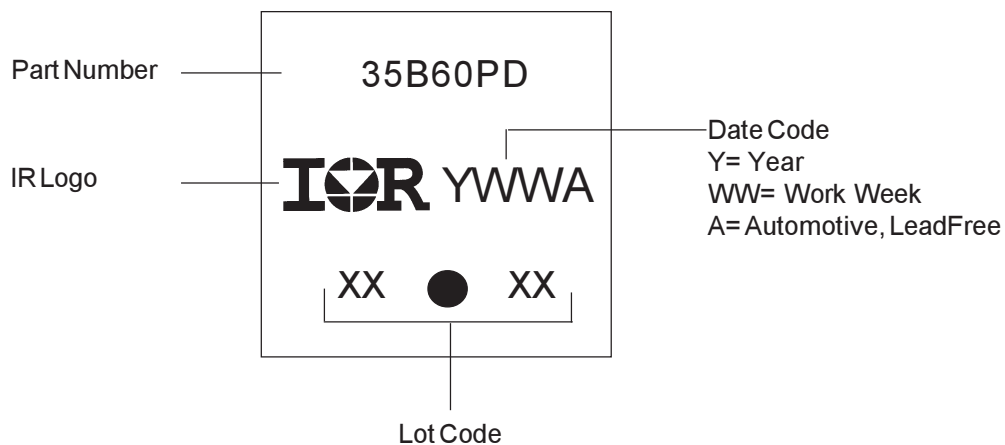
IGBTs CoPACK

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

DIODES

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

TO-247AC Part Marking Information



TO-247AC 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/>
www.irf.com

Ordering Information

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

IMPORTANT NOTICE

Unless specifically designated for the automotive market, International Rectifier Corporation and its subsidiaries (IR) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or services without notice. Part numbers designated with the “AU” prefix follow automotive industry and / or customer specific requirements with regards to product discontinuance and process change notification. All products are sold subject to IR’s terms and conditions of sale supplied at the time of order acknowledgment.

IR warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with IR’s standard warranty. Testing and other quality control techniques are used to the extent IR deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

IR assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using IR components. To minimize the risks with customer products and applications, customers should provide adequate design and operating safeguards.

Reproduction of IR information in IR data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alterations is an unfair and deceptive business practice. IR is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of IR products or serviced with statements different from or beyond the parameters stated by IR for that product or service voids all express and any implied warranties for the associated IR product or service and is an unfair and deceptive business practice. IR is not responsible or liable for any such statements.

IR products are not designed, intended, or authorized for use as components in systems intended for surgical implant into the body, or in other applications intended to support or sustain life, or in any other application in which the failure of the IR product could create a situation where personal injury or death may occur. Should Buyer purchase or use IR products for any such unintended or unauthorized application, Buyer shall indemnify and hold International Rectifier and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that IR was negligent regarding the design or manufacture of the product.

Only products certified as military grade by the Defense Logistics Agency (DLA) of the US Department of Defense, are designed and manufactured to meet DLA military specifications required by certain military, aerospace or other applications. Buyers acknowledge and agree that any use of IR products not certified by DLA as military-grade, in applications requiring military grade products, is solely at the Buyer’s own risk and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

IR products are neither designed nor intended for use in automotive applications or environments unless the specific IR products are designated by IR as compliant with ISO/TS 16949 requirements and bear a part number including the designation “AU”. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, IR will not be responsible for any failure to meet such requirements.

For technical support, please contact IR’s Technical Assistance Center
<http://www.irf.com/technical-info/>

WORLDHEADQUARTERS:

101 N. Sepulveda Blvd., El Segundo, California 90245
Tel: (310) 252-7105