

WARP2 SERIES IGBT WITH  
 ULTRAFAST SOFT RECOVERY DIODE

**Applications**

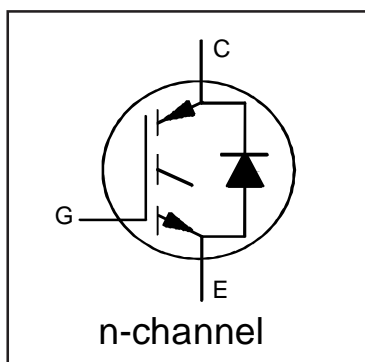
- Telecom and Server SMPS
- PFC and ZVS SMPS Circuits
- Uninterruptable Power Supplies
- Consumer Electronics Power Supplies

**Features**

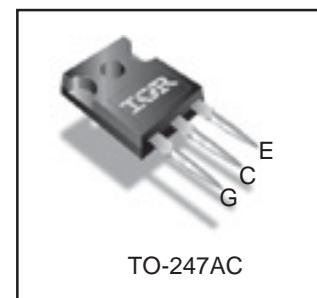
- NPT Technology, Positive Temperature Coefficient
- Lower  $V_{CE(SAT)}$
- Lower Parasitic Capacitances
- Minimal Tail Current
- HEXFRED Ultra Fast Soft-Recovery Co-Pack Diode
- Tighter Distribution of Parameters
- Higher Reliability

**Benefits**

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



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

**Absolute Maximum Ratings**

	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	$\pm 20$	
$P_D @ T_C = 25^\circ C$	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.		
	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)	—	0.24	—	
$R_{\theta JA}$	Thermal Resistance, Junction-to-Ambient (typical socket mount)	—	—	40	
	Weight	—	6.0 (0.21)	—	g (oz)

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

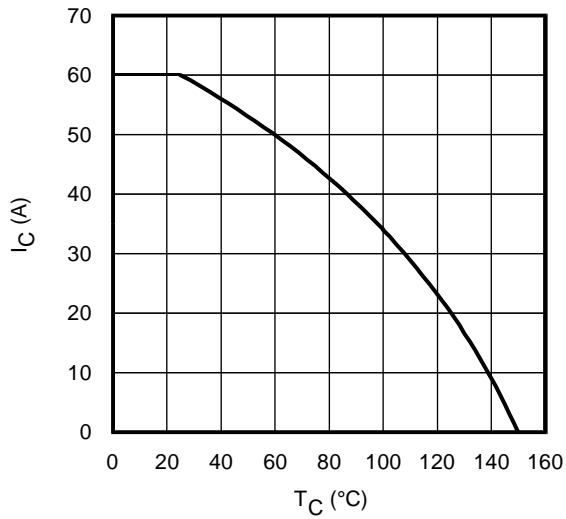
Parameter	Min.	Typ.	Max.	Units	Conditions	Ref.Fig	
$V_{(BR)CES}$	600	—	—	V	$V_{GE} = 0V, I_C = 500\mu A$		
$\Delta V_{(BR)CES}/\Delta T_J$	—	0.78	—	$V/^\circ\text{C}$	$V_{GE} = 0V, I_C = 1mA (25^\circ\text{C}-125^\circ\text{C})$		
$R_G$	—	1.7	—	$\Omega$	1MHz, Open Collector		
$V_{CE(on)}$	Collector-to-Emitter 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		$I_C = 35A, V_{GE} = 15V, T_J = 125^\circ\text{C}$	
$V_{GE(th)}$	3.0	4.0	5.0	V	$I_C = 250\mu A$	7, 8, 9	
$\Delta V_{GE(th)}/\Delta T_J$	—	-10	—	$mV/^\circ\text{C}$	$V_{CE} = V_{GE}, I_C = 1.0mA$		
$g_{fe}$	—	36	—	S	$V_{CE} = 50V, I_C = 22A, PW = 80\mu s$		
$I_{CES}$	Collector-to-Emitter Leakage Current	—	3.0	375	$\mu A$	$V_{GE} = 0V, V_{CE} = 600V$	
		—	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	—	—	$\pm 100$	nA	$V_{GE} = \pm 20V, V_{CE} = 0V$	

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

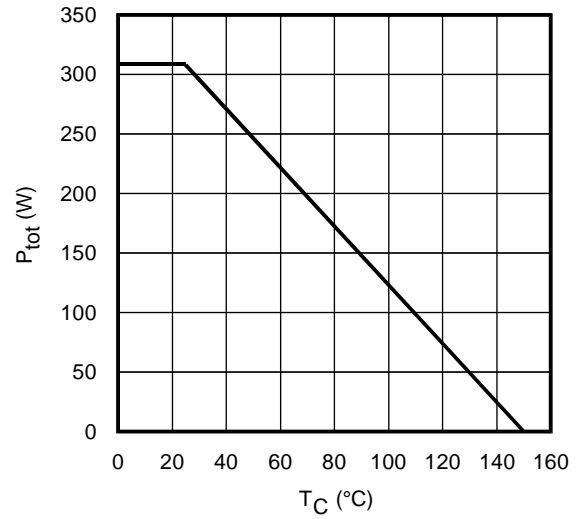
Parameter	Min.	Typ.	Max.	Units	Conditions	Ref.Fig	
$Q_g$	—	160	240	nC	$I_C = 22A$	17	
$Q_{gc}$	—	55	83		$V_{CC} = 400V$	CT1	
$Q_{ge}$	—	21	32		$V_{GE} = 15V$		
$E_{on}$	—	220	270	$\mu J$	$I_C = 22A, V_{CC} = 390V$	CT3	
$E_{off}$	—	215	265		$V_{GE} = +15V, R_G = 3.3\Omega, L = 200\mu H$		
$E_{total}$	—	435	535		$T_J = 25^\circ\text{C} \text{ ④}$		
$t_{d(on)}$	—	26	34	ns	$I_C = 22A, V_{CC} = 390V$	CT3	
$t_r$	—	6.0	8.0		$V_{GE} = +15V, R_G = 3.3\Omega, L = 200\mu H$		
$t_{d(off)}$	—	110	122		$T_J = 25^\circ\text{C} \text{ ④}$		
$t_f$	—	8.0	10	$\mu J$	$I_C = 22A, V_{CC} = 390V$	CT3	
$E_{on}$	—	410	465		$V_{GE} = +15V, R_G = 3.3\Omega, L = 200\mu H$	11, 13	
$E_{off}$	—	330	405		$T_J = 125^\circ\text{C} \text{ ④}$	WF1, WF2	
$E_{total}$	—	740	870	ns	$I_C = 22A, V_{CC} = 390V$	CT3	
$t_{d(on)}$	—	26	34		$V_{GE} = +15V, R_G = 3.3\Omega, L = 200\mu H$	12, 14	
$t_r$	—	8.0	11		$T_J = 125^\circ\text{C} \text{ ④}$	WF1, WF2	
$t_{d(off)}$	—	130	150	pF	$V_{GE} = 0V$	16	
$t_f$	—	12	16		$V_{CC} = 30V$		
$C_{ies}$	—	3715	—		$f = 1MHz$		
$C_{oes}$	—	265	—	pF	$V_{GE} = 0V, V_{CE} = 0V \text{ to } 480V$	15	
$C_{res}$	—	47	—				
$C_{oes \text{ eff.}}$	—	135	—				
$C_{oes \text{ eff. (ER)}}$	—	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	$T_J = 25^\circ\text{C}$ $I_F = 15A, V_R = 200V,$	19
		—	74	120		$T_J = 125^\circ\text{C}$ $di/dt = 200A/\mu s$	
$Q_{rr}$	Diode Reverse Recovery Charge	—	80	180	nC	$T_J = 25^\circ\text{C}$ $I_F = 15A, V_R = 200V,$	21
		—	220	600		$T_J = 125^\circ\text{C}$ $di/dt = 200A/\mu s$	
$I_{rr}$	Peak Reverse Recovery Current	—	4.0	6.0	A	$T_J = 25^\circ\text{C}$ $I_F = 15A, V_R = 200V,$	19, 20, 21, 22
		—	6.5	10		$T_J = 125^\circ\text{C}$ $di/dt = 200A/\mu s$	

## Notes:

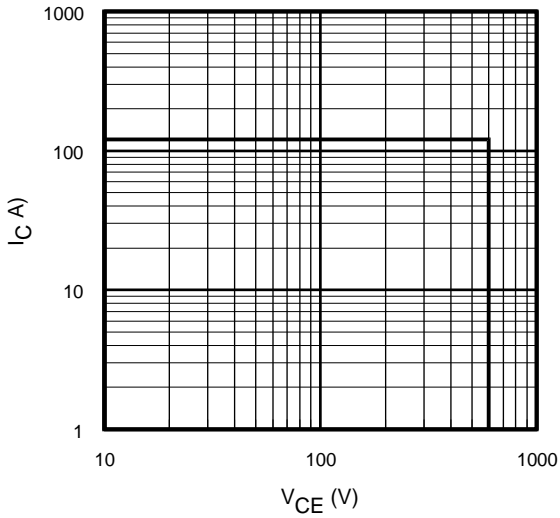
- $R_{CE(on)}$  typ. = equivalent on-resistance =  $V_{CE(on)}$  typ. /  $I_C$ , where  $V_{CE(on)}$  typ. = 1.85V and  $I_C = 22A$ .  $I_D$  (FET Equivalent) is the equivalent MOSFET  $I_D$  rating @  $25^\circ\text{C}$  for applications up to 150kHz. These are provided for comparison purposes (only) with equivalent MOSFET solutions.
- $V_{CC} = 80\% (V_{CES}), V_{GE} = 20V, L = 100 \mu H, R_G = 3.3\Omega$ .
- Pulse width limited by max. junction temperature.
- Energy losses include "tail" and diode reverse recovery, Data generated with use of Diode 30ETH06.
- $C_{oes \text{ eff.}}$  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%  $V_{CES}$ .



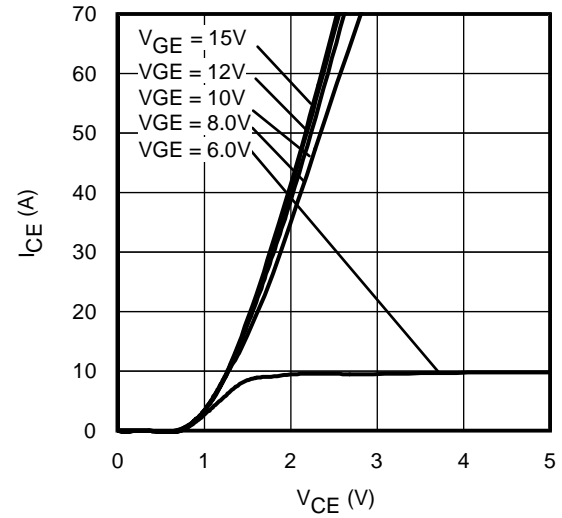
**Fig. 1** - Maximum DC Collector Current vs. Case Temperature



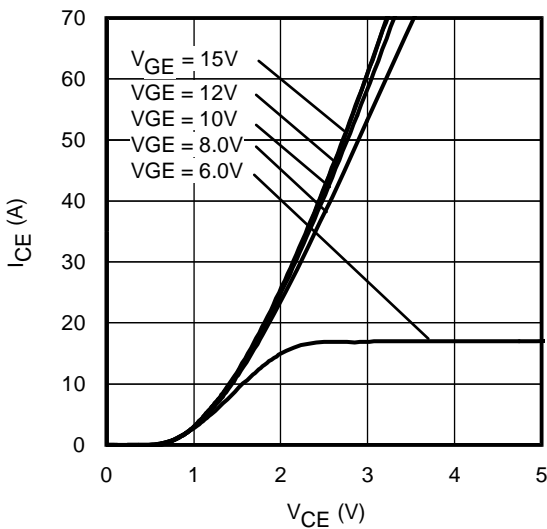
**Fig. 2** - Power Dissipation vs. Case Temperature



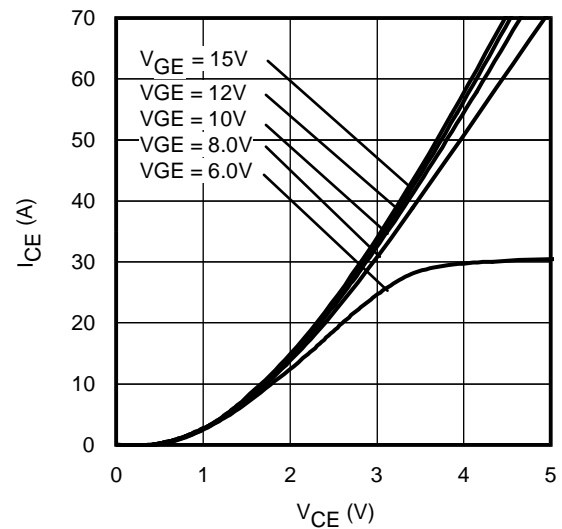
**Fig. 3** - Reverse Bias SOA  
 $T_J = 150^{\circ}C$ ;  $V_{GE} = 15V$



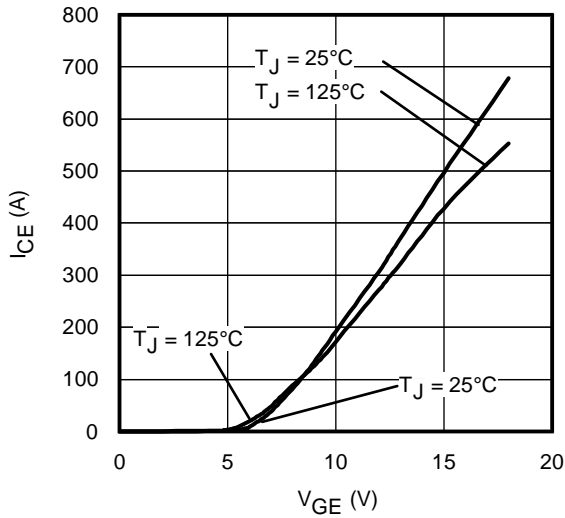
**Fig. 4** - Typ. IGBT Output Characteristics  
 $T_J = -40^{\circ}C$ ;  $t_p = 80\mu s$



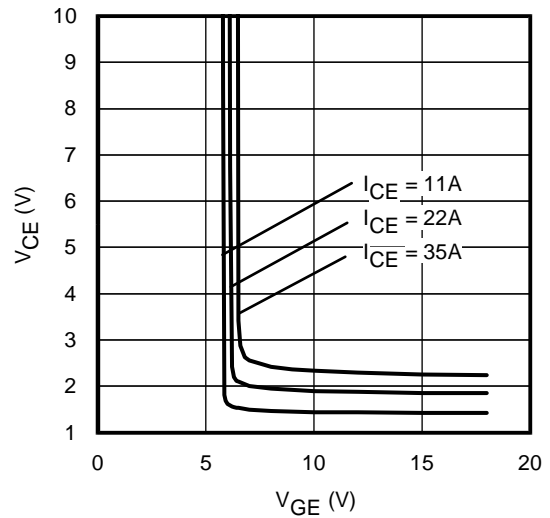
**Fig. 5** - Typ. IGBT Output Characteristics  
 $T_J = 25^{\circ}C$ ;  $t_p = 80\mu s$



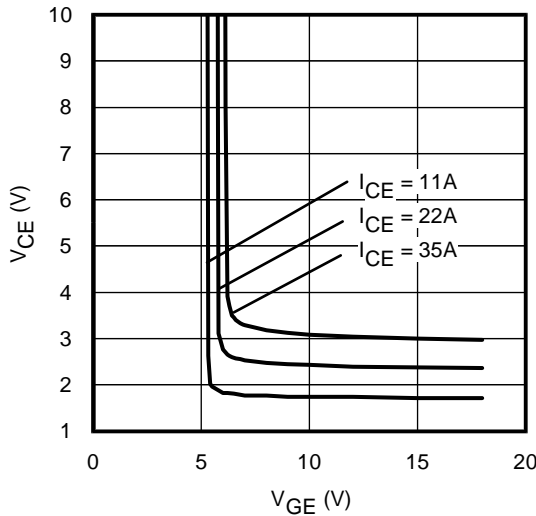
**Fig. 6** - Typ. IGBT Output Characteristics  
 $T_J = 125^{\circ}C$ ;  $t_p = 80\mu s$



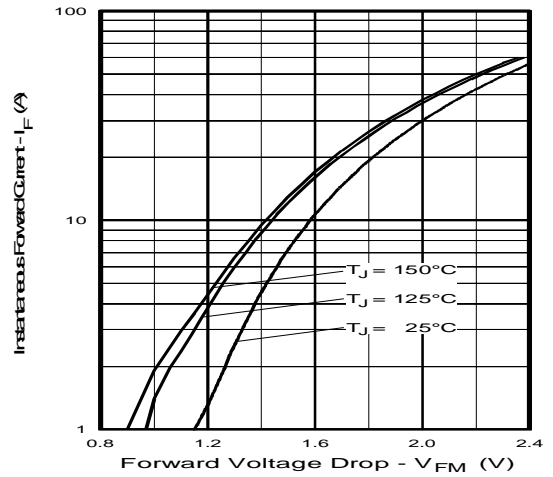
**Fig. 7 - Typ. Transfer Characteristics**  
 $V_{CE} = 50V$ ;  $t_p = 10\mu s$



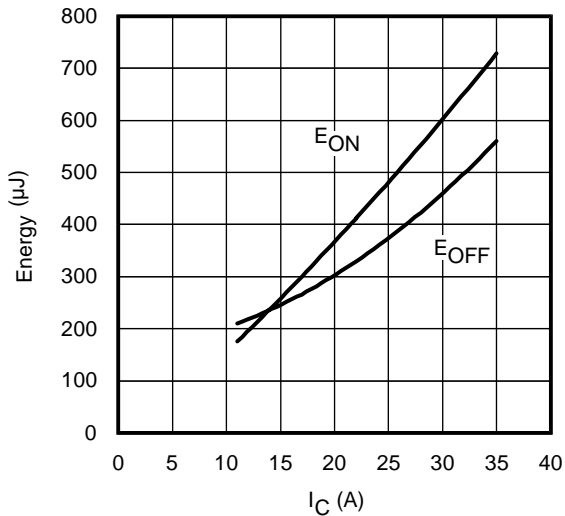
**Fig. 8 - Typical  $V_{CE}$  vs.  $V_{GE}$**   
 $T_J = 25^\circ C$



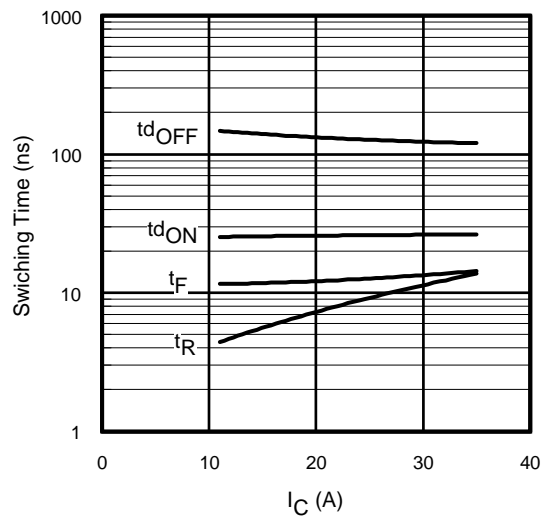
**Fig. 9 - Typical  $V_{CE}$  vs.  $V_{GE}$**   
 $T_J = 125^\circ C$



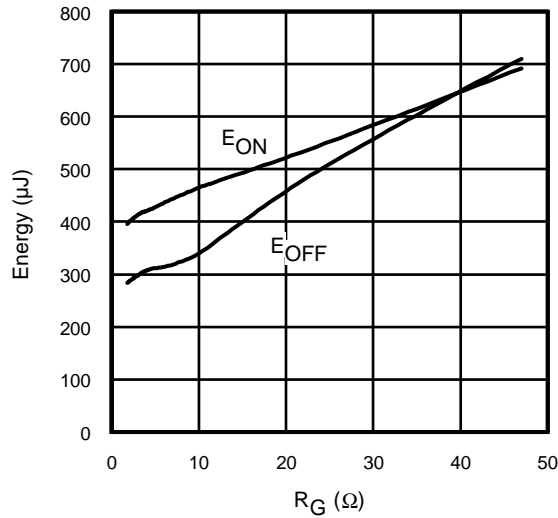
**Fig. 10 - Typ. Diode Forward Characteristics**  
 $t_p = 80\mu s$



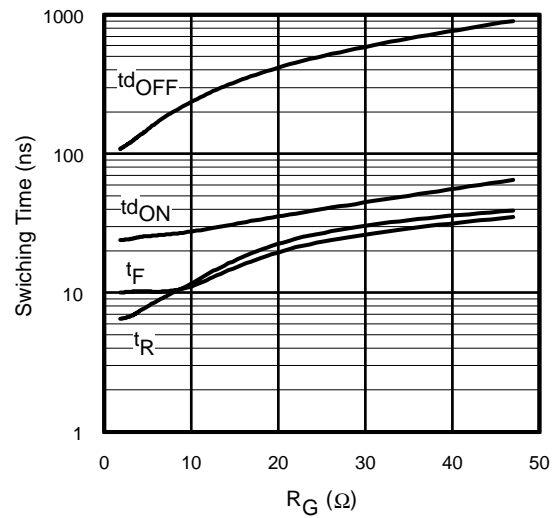
**Fig. 11 - Typ. Energy Loss vs.  $I_C$**   
 $T_J = 125^\circ C$ ;  $L = 200\mu H$ ;  $V_{CE} = 390V$ ,  $R_G = 3.3\Omega$ ;  $V_{GE} = 15V$ .  
Diode clamp used: 30ETH06 (See C.T.3)



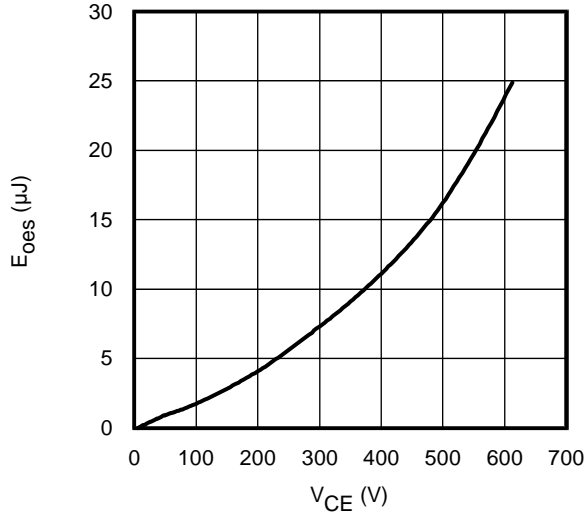
**Fig. 12 - Typ. Switching Time vs.  $I_C$**   
 $T_J = 125^\circ C$ ;  $L = 200\mu H$ ;  $V_{CE} = 390V$ ,  $R_G = 3.3\Omega$ ;  $V_{GE} = 15V$ .  
Diode clamp used: 30ETH06 (See C.T.3)



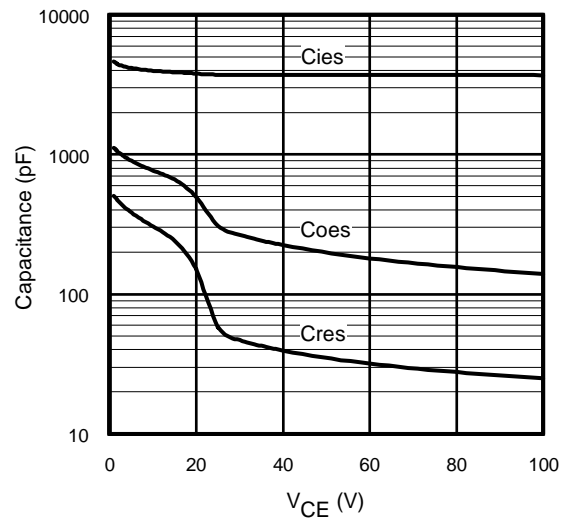
**Fig. 13 - Typ. Energy Loss vs.  $R_G$**   
 $T_J = 125^\circ\text{C}$ ;  $L = 200\mu\text{H}$ ;  $V_{CE} = 390\text{V}$ ;  $I_{CE} = 22\text{A}$ ;  $V_{GE} = 15\text{V}$   
 Diode clamp used: 30ETH06 (See C.T.3)



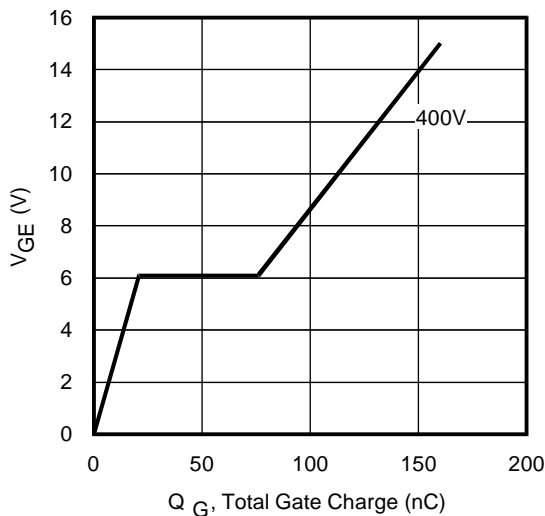
**Fig. 14 - Typ. Switching Time vs.  $R_G$**   
 $T_J = 125^\circ\text{C}$ ;  $L = 200\mu\text{H}$ ;  $V_{CE} = 390\text{V}$ ;  $I_{CE} = 22\text{A}$ ;  $V_{GE} = 15\text{V}$   
 Diode clamp used: 30ETH06 (See C.T.3)



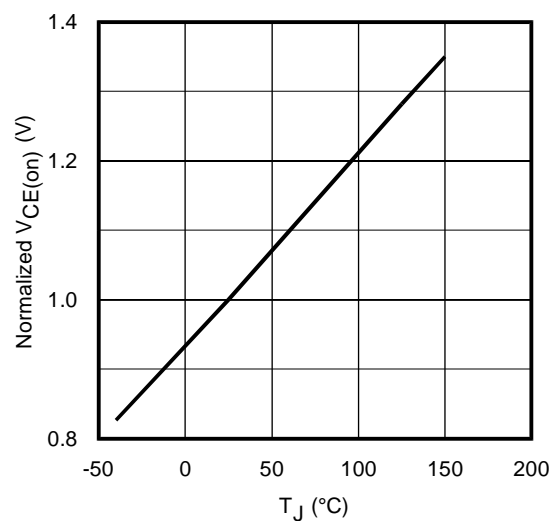
**Fig. 15- Typ. Output Capacitance  
 Stored Energy vs.  $V_{CE}$**



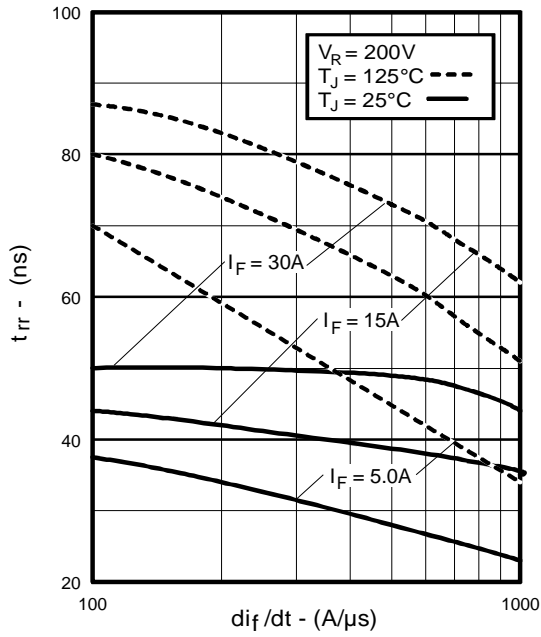
**Fig. 16- Typ. Capacitance vs.  $V_{CE}$**   
 $V_{GE} = 0\text{V}$ ;  $f = 1\text{MHz}$



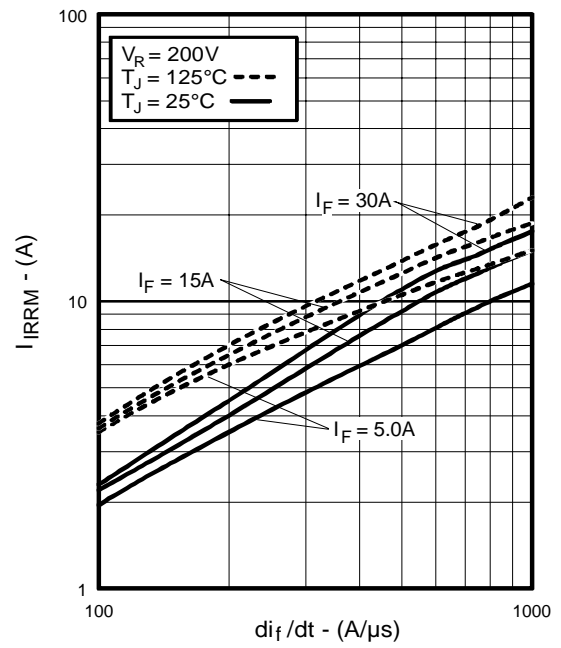
**Fig. 17 - Typical Gate Charge vs.  $V_{GE}$**   
 $I_{CE} = 22\text{A}$



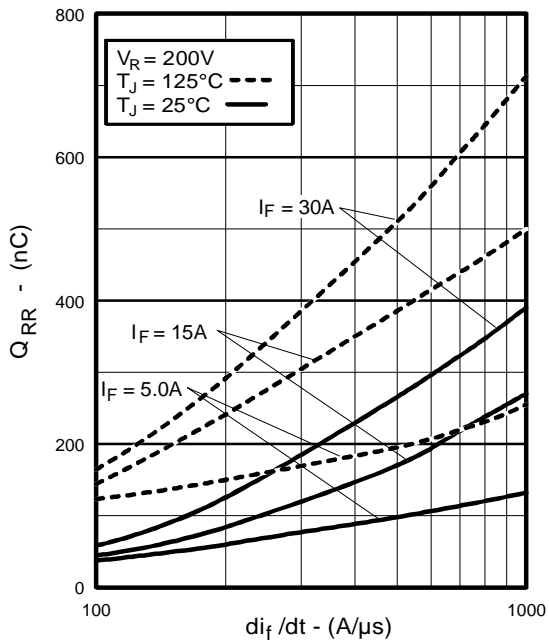
**Fig. 18 - Normalized Typ.  $V_{CE(on)}$   
 vs. Junction Temperature**  
 $I_C = 22\text{A}$ ,  $V_{GE} = 15\text{V}$



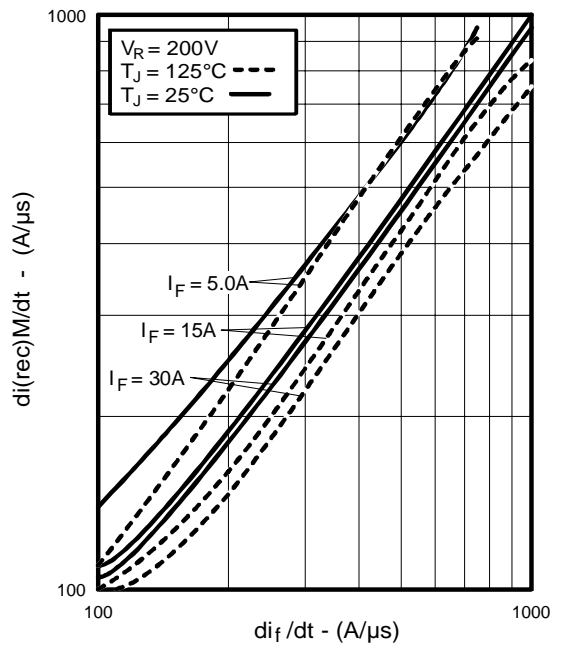
**Fig. 19** - Typical Reverse Recovery vs.  $di_f/dt$



**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.  $di_f/dt$

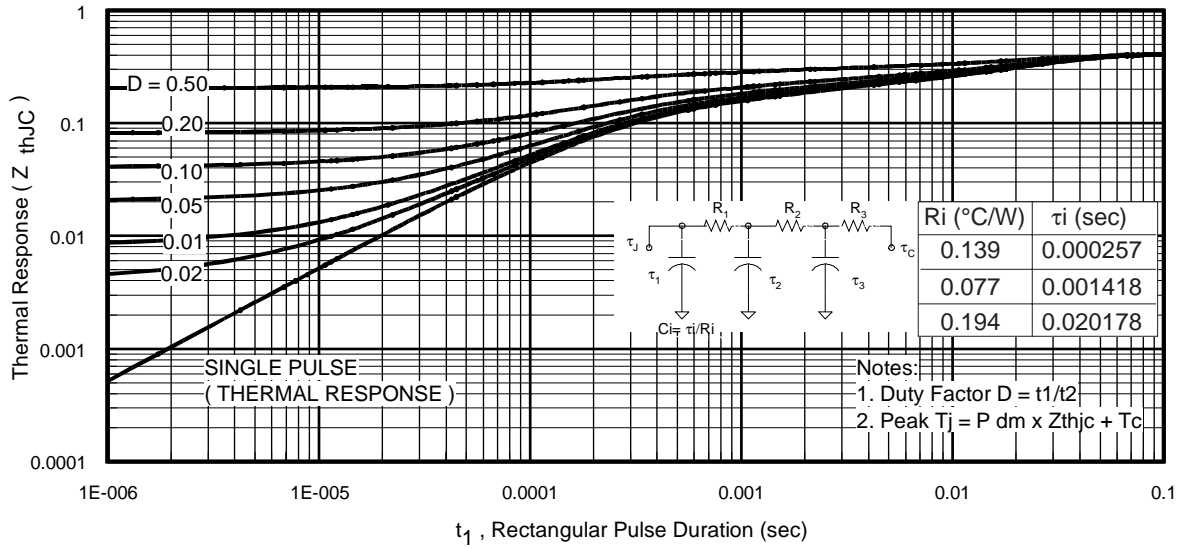


Fig 23. Maximum Transient Thermal Impedance, Junction-to-Case (IGBT)

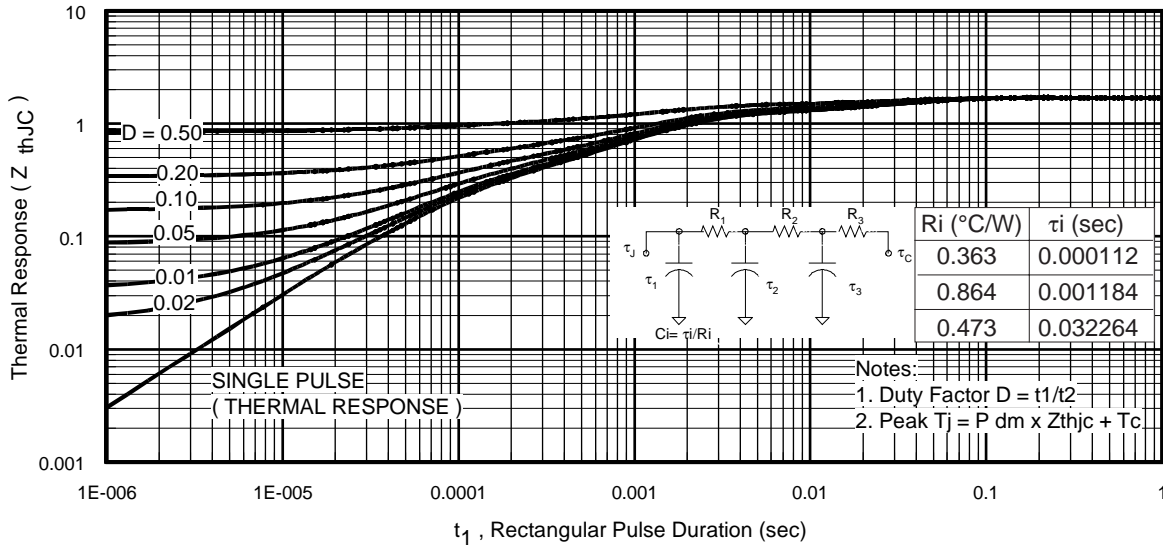
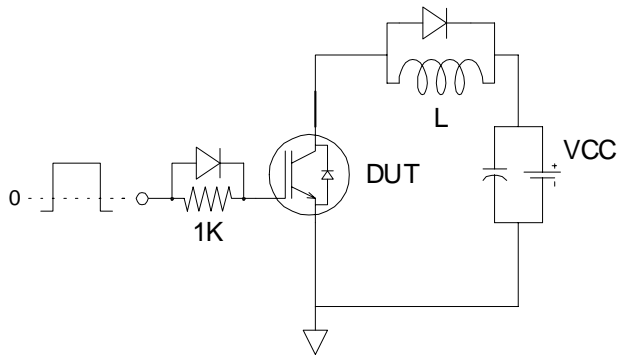
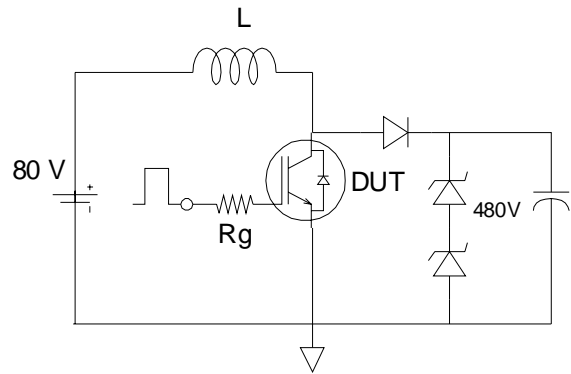


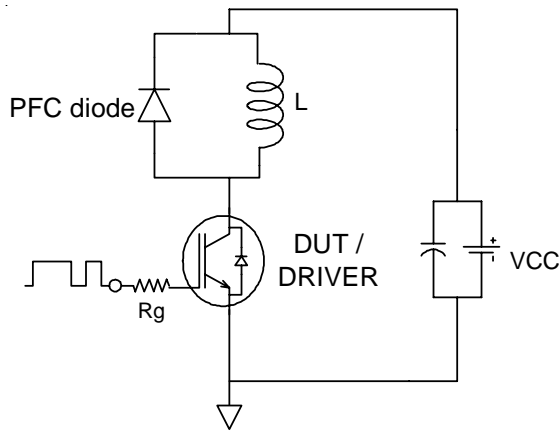
Fig. 24. Maximum Transient Thermal Impedance, Junction-to-Case (DIODE)



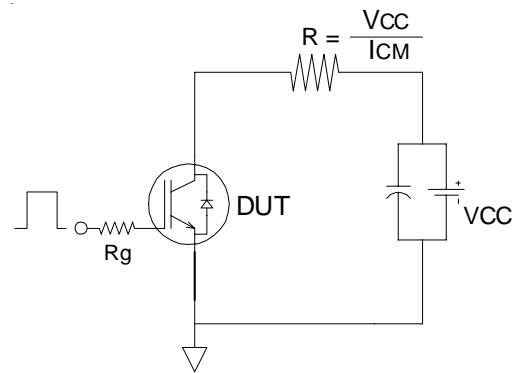
**Fig.C.T.1** - Gate Charge Circuit (turn-off)



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

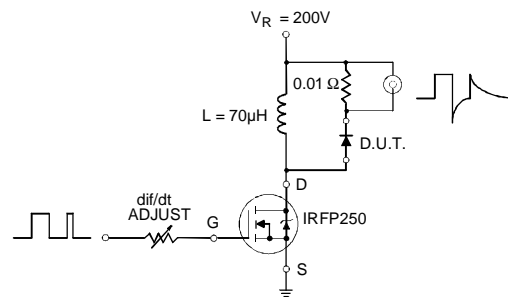


**Fig.C.T.3** - Switching Loss Circuit



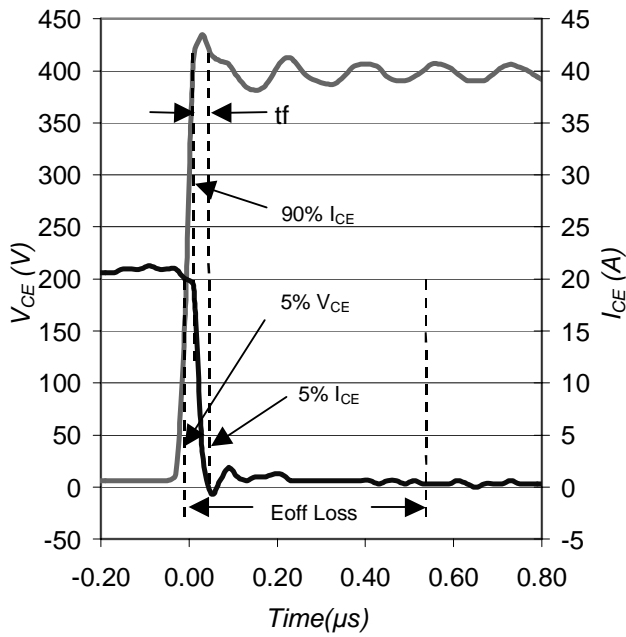
**Fig.C.T.4** - Resistive Load Circuit

### REVERSE RECOVERY CIRCUIT

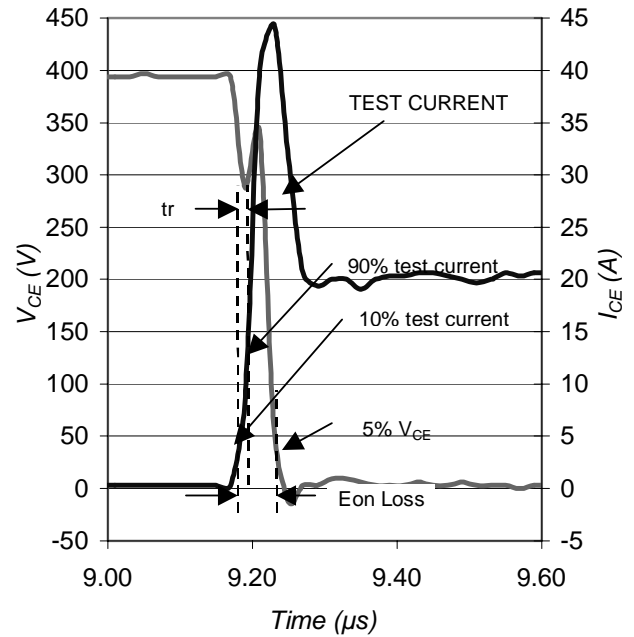


**Fig. C.T.5** - Reverse Recovery Parameter Test Circuit

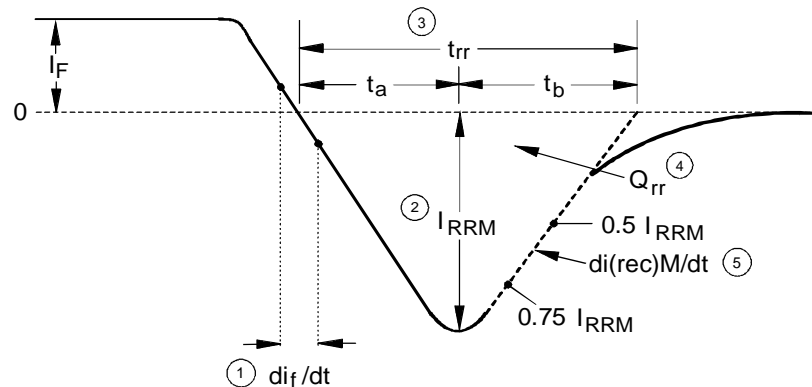




**Fig. WF1** - Typ. Turn-off Loss Waveform  
@  $T_J = 25^\circ\text{C}$  using Fig. CT.3



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

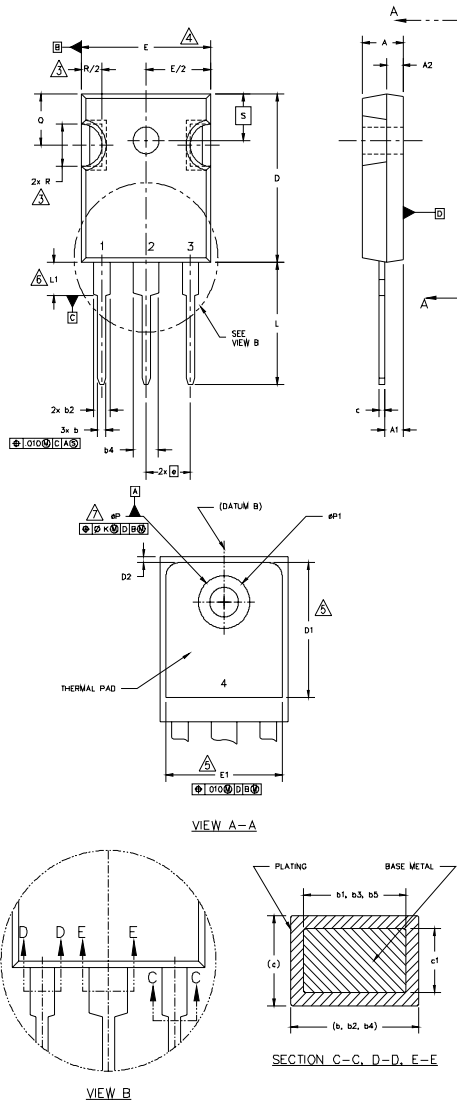


1.  $di_f/dt$  - Rate of change of current through zero crossing
2.  $I_{RRM}$  - Peak reverse recovery current
3.  $t_{rr}$  - Reverse recovery time measured from zero crossing point of negative going  $I_F$  to point where a line passing through  $0.75 I_{RRM}$  and  $0.50 I_{RRM}$  extrapolated to 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-247AC Package Outline Dimensions are shown in millimeters (inches)



NOTES:

- DIMENSIONING AND TOLERANCING PER ASME Y14.5M 1994.
- DIMENSIONS ARE SHOWN IN INCHES [MILLIMETERS]
- CONTOUR OF SLOT OPTIONAL.
- DIMENSION D & E DO NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED .005" (.127) PER SIDE. THESE DIMENSIONS ARE MEASURED AT THE OUTERMOST EXTREMES OF THE PLASTIC BODY.
- THERMAL PAD CONTOUR OPTIONAL WITHIN DIMENSIONS D1 & E1.
- LEAD FINISH UNCONTROLLED IN L1.
- 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].
- 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		4
E	.602	.625	15.29	15.87		
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**

- GATE
- DRAIN
- SOURCE
- DRAIN

**IGBTs, CoPACK**

- GATE
- COLLECTOR
- EMITTER
- COLLECTOR

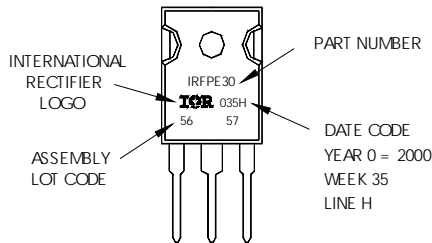
**DIODES**

- ANODE/OPEN
- CATHODE
- ANODE

## TO-247AC Part Marking Information

EXAMPLE: THIS IS AN IRFPE30 WITH ASSEMBLY LOT CODE 5657 ASSEMBLED ON WW 35, 2000 IN THE ASSEMBLY LINE "H"

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



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.