

WARP2 SERIES IGBT WITH
 ULTRAFAST SOFT RECOVERY DIODE

Applications

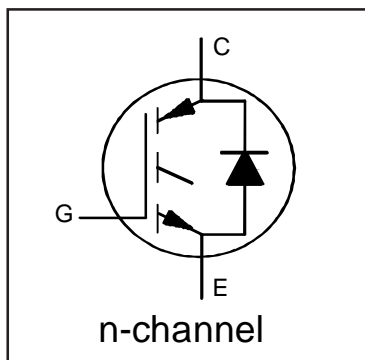
- Telecom and Server SMPS
- PFC and ZVS SMPS Circuits
- Uninterruptable Power Supplies
- Consumer Electronics Power Supplies

Features

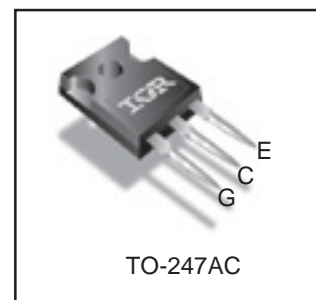
- NPT Technology, Positive Temperature Coefficient
- Lower $V_{CE(SAT)}$
- Lower Parasitic Capacitances
- Minimal Tail Current
- HEXFRED Ultra Fast Soft-Recovery Co-Pack Diode
- Tighter Distribution of Parameters
- Higher Reliability

Benefits

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



$V_{CES} = 600V$
$V_{CE(on)} \text{ typ.} = 1.85V$
@ $V_{GE} = 15V$ $I_C = 22A$
Equivalent MOSFET Parameters 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	± 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°C (unless otherwise specified)

Parameter	Min.	Typ.	Max.	Units	Conditions	Ref.Fig	
V _{(BR)CES}	600	—	—	V	V _{GE} = 0V, I _C = 500μA		
ΔV _{(BR)CES} /ΔT _J	—	0.78	—	V/°C	V _{GE} = 0V, I _C = 1mA (25°C-125°C)		
R _G	—	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)}	3.0	4.0	5.0	V	I _C = 250μA	7, 8, 9	
ΔV _{GE(th)} /ΔT _J	—	-10	—	mV/°C	V _{CE} = V _{GE} , I _C = 1.0mA		
g _{fe}	—	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	
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	μJ	I _C = 22A, V _{CC} = 390V	CT3	
E _{off}	—	215	265		V _{GE} = +15V, R _G = 3.3Ω, L = 200μH		
E _{total}	—	435	535		T _J = 25°C 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 = 3.3Ω, L = 200μH		
t _{d(off)}	—	110	122		T _J = 25°C ④		
t _f	—	8.0	10	μJ	I _C = 22A, V _{CC} = 390V	CT3	
E _{on}	—	410	465		V _{GE} = +15V, R _G = 3.3Ω, L = 200μH		
E _{off}	—	330	405		T _J = 125°C ④		
E _{total}	—	740	870	ns	I _C = 22A, V _{CC} = 390V	CT3	
t _{d(on)}	—	26	34		V _{GE} = +15V, R _G = 3.3Ω, L = 200μH		
t _r	—	8.0	11		T _J = 125°C ④		
t _{d(off)}	—	130	150	pF	I _C = 22A, V _{CC} = 390V	WF1, WF2	
t _f	—	12	16		V _{GE} = 0V		
C _{ies}	—	3715	—		V _{CC} = 30V		
C _{oes}	—	265	—	pF	f = 1Mhz	16	
C _{res}	—	47	—		V _{GE} = 0V		
C _{oes eff.}	—	135	—		V _{CC} = 30V		
C _{oes eff. (ER)}	—	179	—	pF	f = 1Mhz	15	
C _{oes eff. (ER)}	—	179	—		V _{GE} = 0V, V _{CE} = 0V to 480V		
C _{oes eff. (ER)}	—	179	—		V _{GE} = 0V, V _{CE} = 0V to 480V		
RBSOA	Reverse Bias Safe Operating Area	FULL SQUARE				T _J = 150°C, I _C = 120A V _{CC} = 480V, V _p = 600V R _g = 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,	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	

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 = 100 μH, R_G = 3.3Ω.
- 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}.

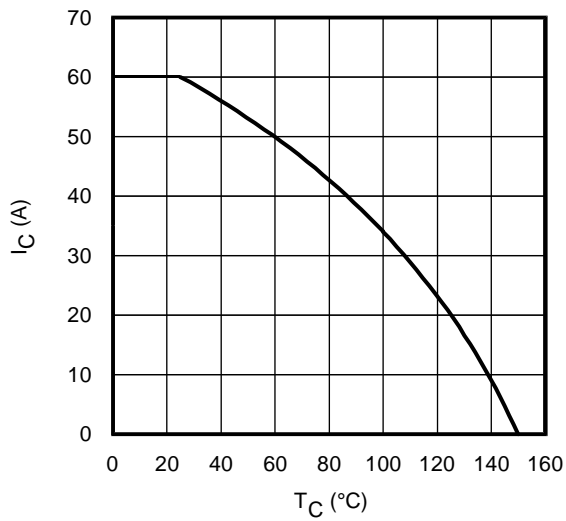


Fig. 1 - Maximum DC Collector Current vs. Case Temperature

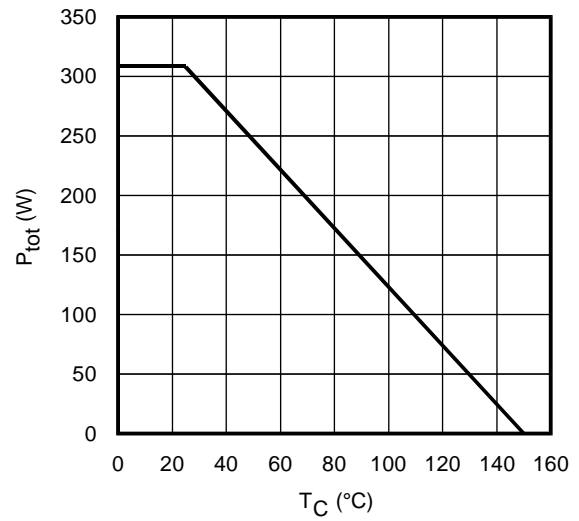


Fig. 2 - Power Dissipation vs. Case Temperature

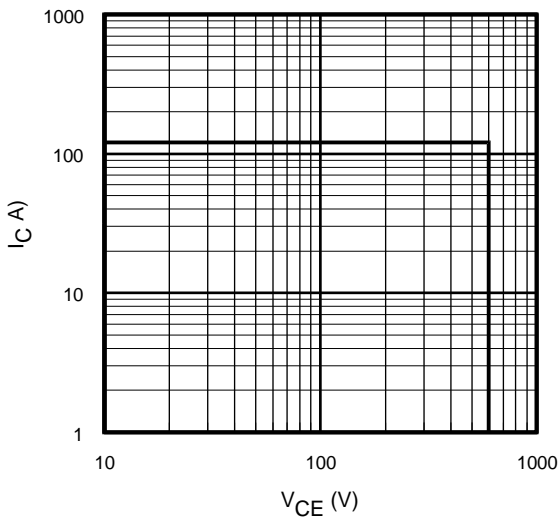


Fig. 3 - Reverse Bias SOA
 $T_J = 150^\circ\text{C}$; $V_{GE} = 15\text{V}$

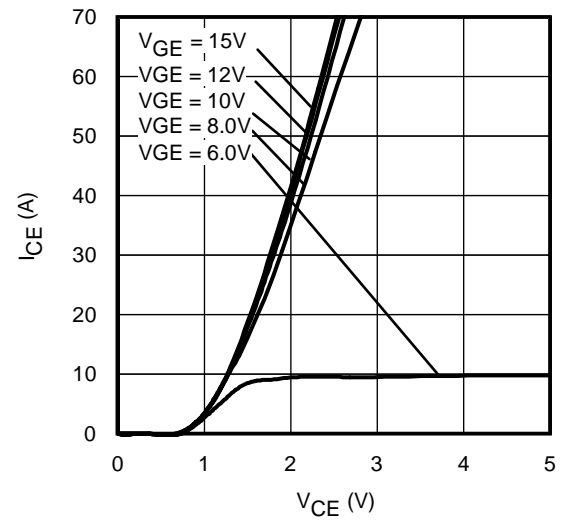


Fig. 4 - Typ. IGBT Output Characteristics
 $T_J = -40^\circ\text{C}$; $t_p = 80\mu\text{s}$

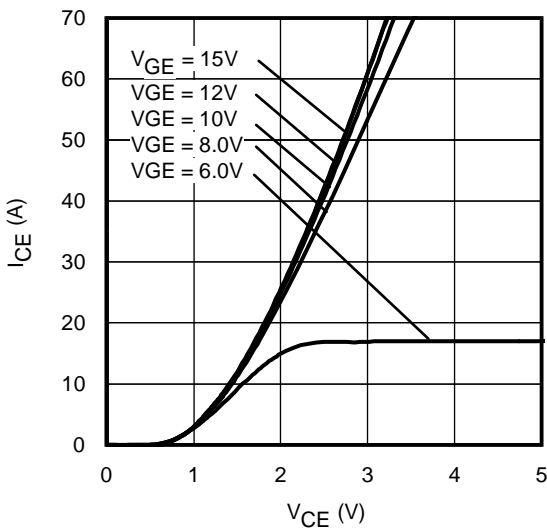


Fig. 5 - Typ. IGBT Output Characteristics
 $T_J = 25^\circ\text{C}$; $t_p = 80\mu\text{s}$

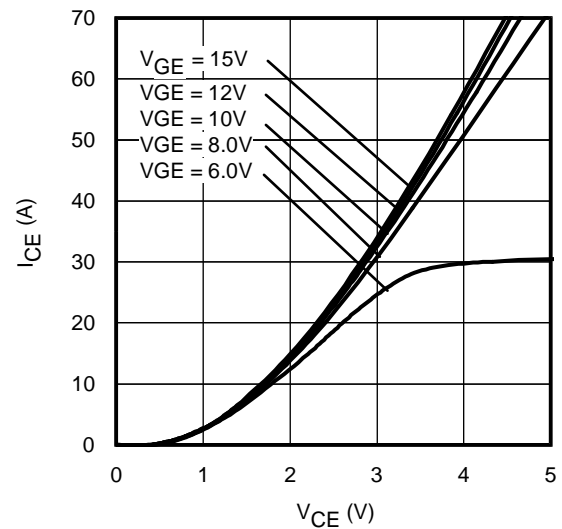


Fig. 6 - Typ. IGBT Output Characteristics
 $T_J = 125^\circ\text{C}$; $t_p = 80\mu\text{s}$

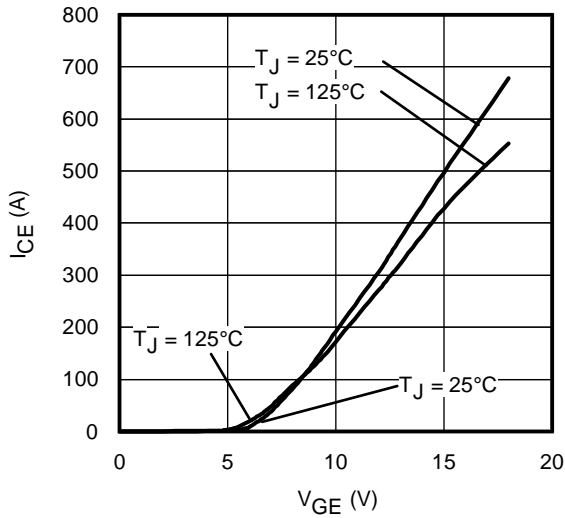


Fig. 7 - Typ. Transfer Characteristics
 $V_{CE} = 50V$; $t_p = 10\mu s$

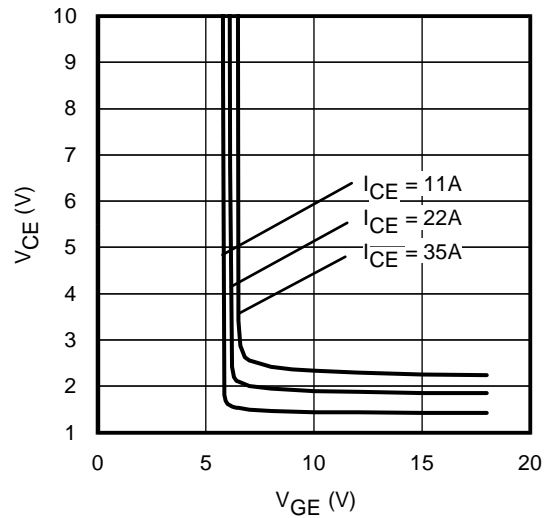


Fig. 8 - Typical V_{CE} vs. V_{GE}
 $T_J = 25^\circ C$

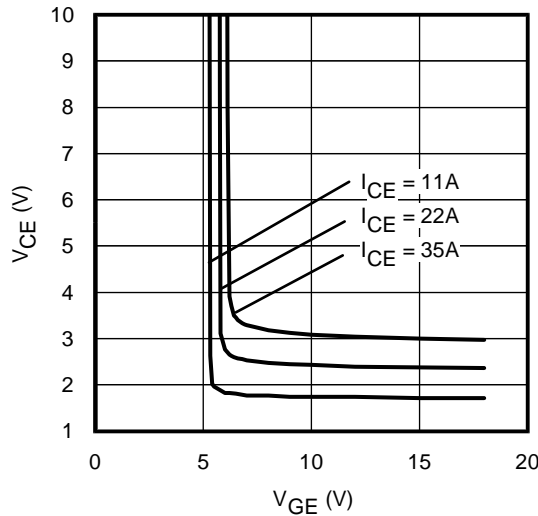


Fig. 9 - Typical V_{CE} vs. V_{GE}
 $T_J = 125^\circ C$

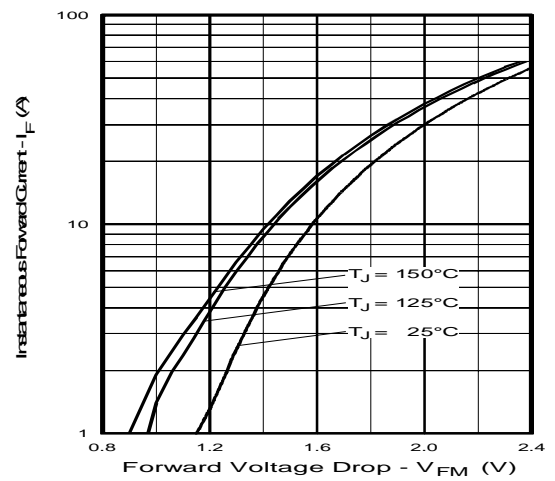


Fig. 10 - Typ. Diode Forward Characteristics
 $t_p = 80\mu s$

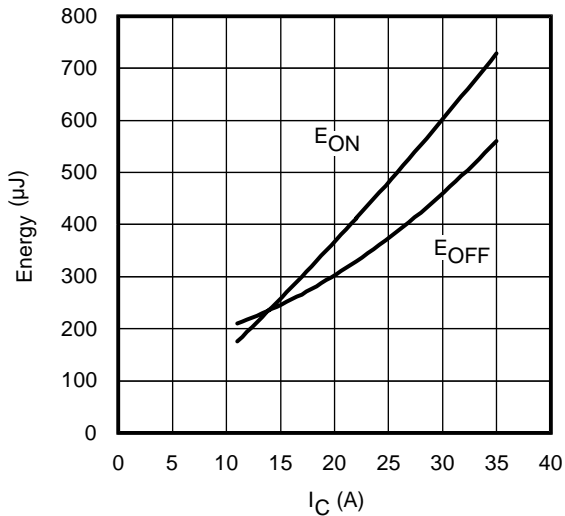


Fig. 11 - Typ. Energy Loss vs. I_C
 $T_J = 125^\circ C$; $L = 200\mu H$; $V_{CE} = 390V$, $R_G = 3.3\Omega$; $V_{GE} = 15V$.
Diode clamp used: 30ETH06 (See C.T.3)

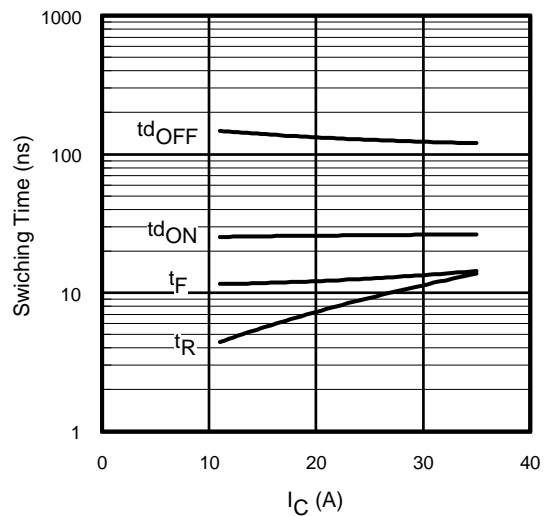


Fig. 12 - Typ. Switching Time vs. I_C
 $T_J = 125^\circ C$; $L = 200\mu H$; $V_{CE} = 390V$, $R_G = 3.3\Omega$; $V_{GE} = 15V$.
Diode clamp used: 30ETH06 (See C.T.3)

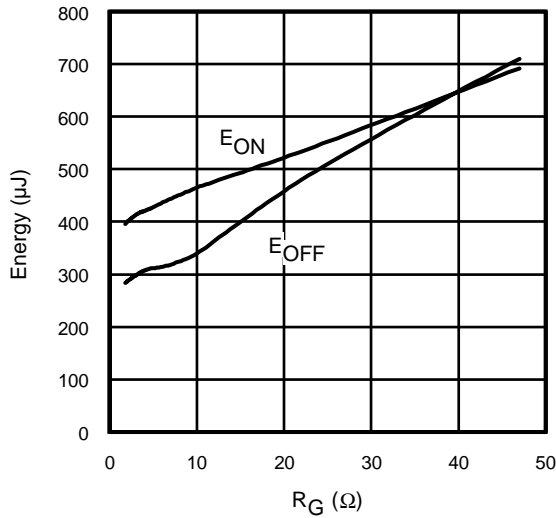


Fig. 13 - Typ. Energy Loss vs. R_G
 $T_J = 125^\circ\text{C}$; $L = 200\mu\text{H}$; $V_{CE} = 390\text{V}$; $I_{CE} = 22\text{A}$; $V_{GE} = 15\text{V}$
 Diode clamp used: 30ETH06 (See C.T.3)

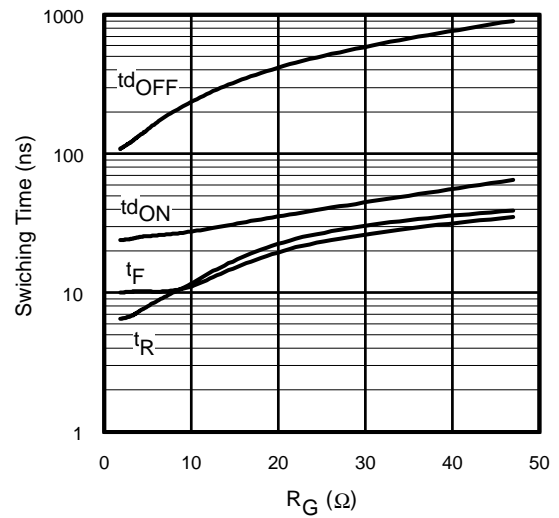
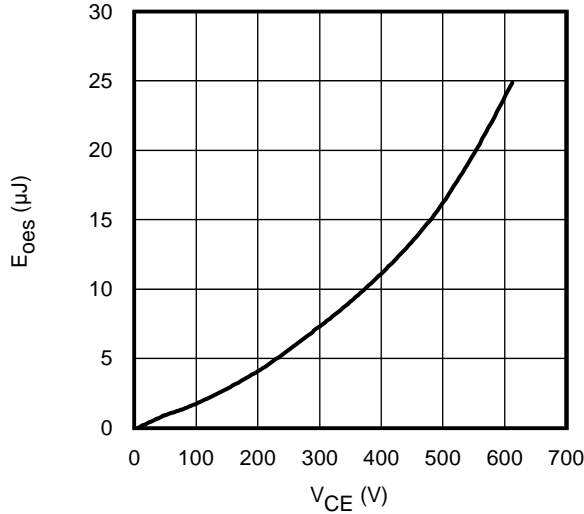


Fig. 14 - Typ. Switching Time vs. R_G
 $T_J = 125^\circ\text{C}$; $L = 200\mu\text{H}$; $V_{CE} = 390\text{V}$; $I_{CE} = 22\text{A}$; $V_{GE} = 15\text{V}$
 Diode clamp used: 30ETH06 (See C.T.3)



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

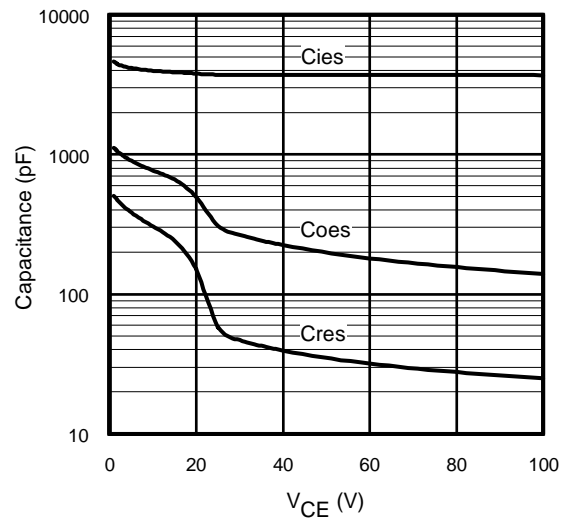


Fig. 16- Typ. Capacitance vs. V_{CE}
 $V_{GE} = 0\text{V}$; $f = 1\text{MHz}$

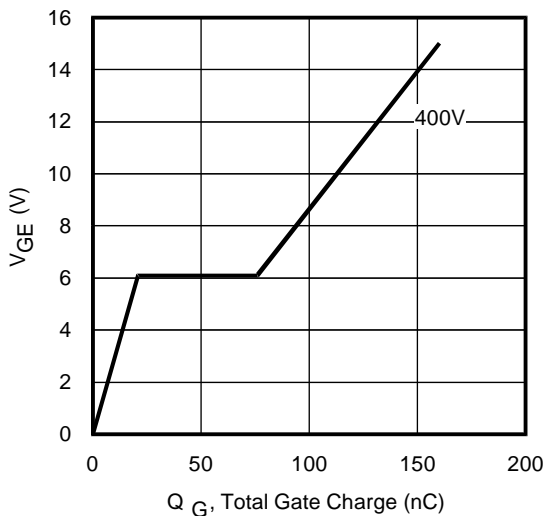
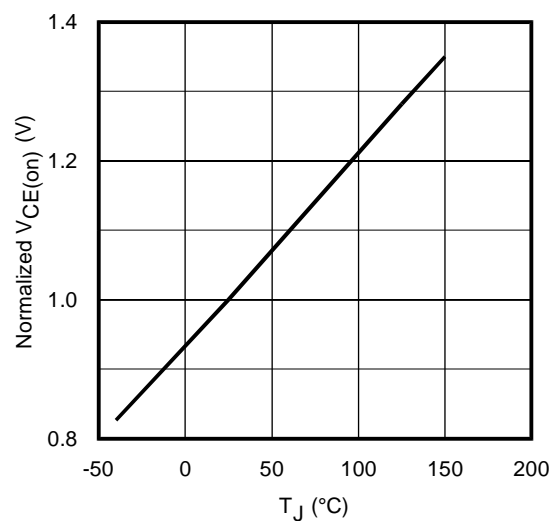


Fig. 17 - Typical Gate Charge vs. V_{GE}
 $I_{CE} = 22\text{A}$



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

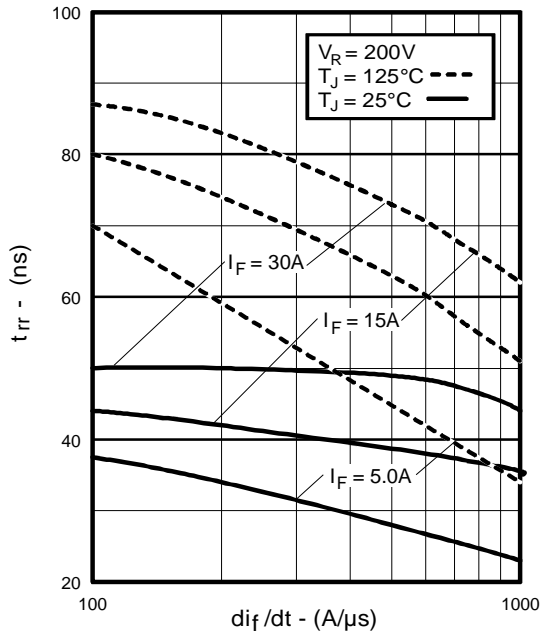


Fig. 19 - Typical Reverse Recovery vs. di_f/dt

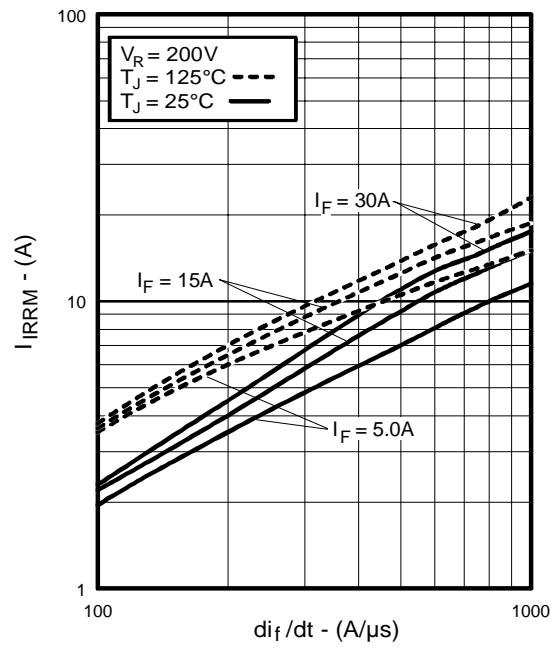


Fig. 20 - Typical Recovery Current vs. di_f/dt

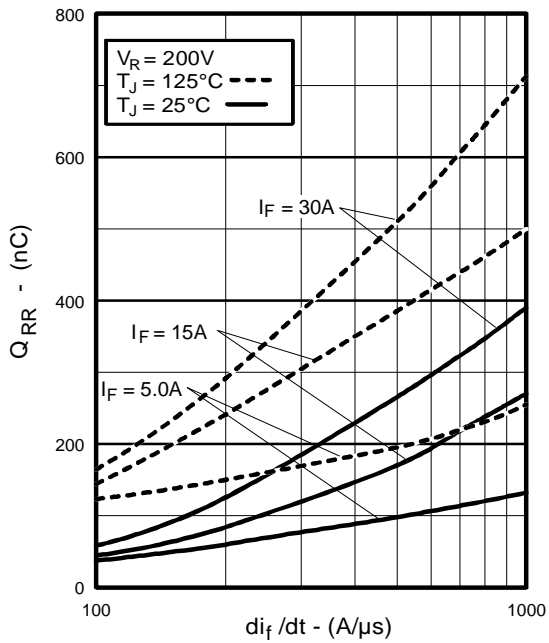


Fig. 21 - Typical Stored Charge vs. di_f/dt

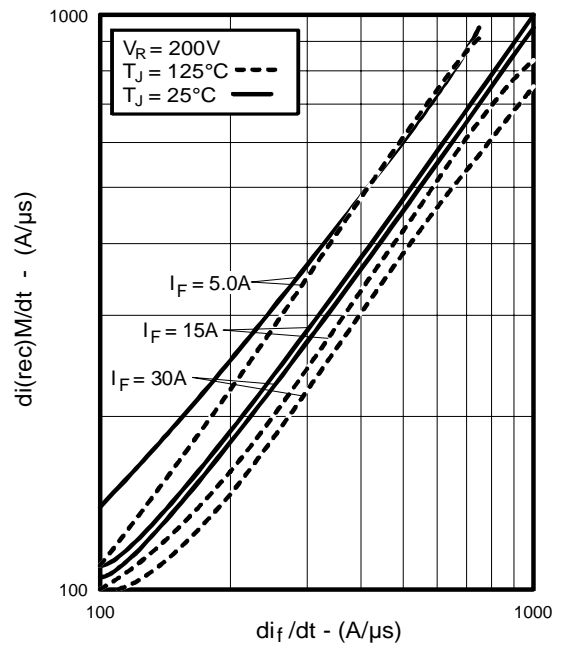


Fig. 22 - Typical $di_{(rec)M}/dt$ vs. di_f/dt

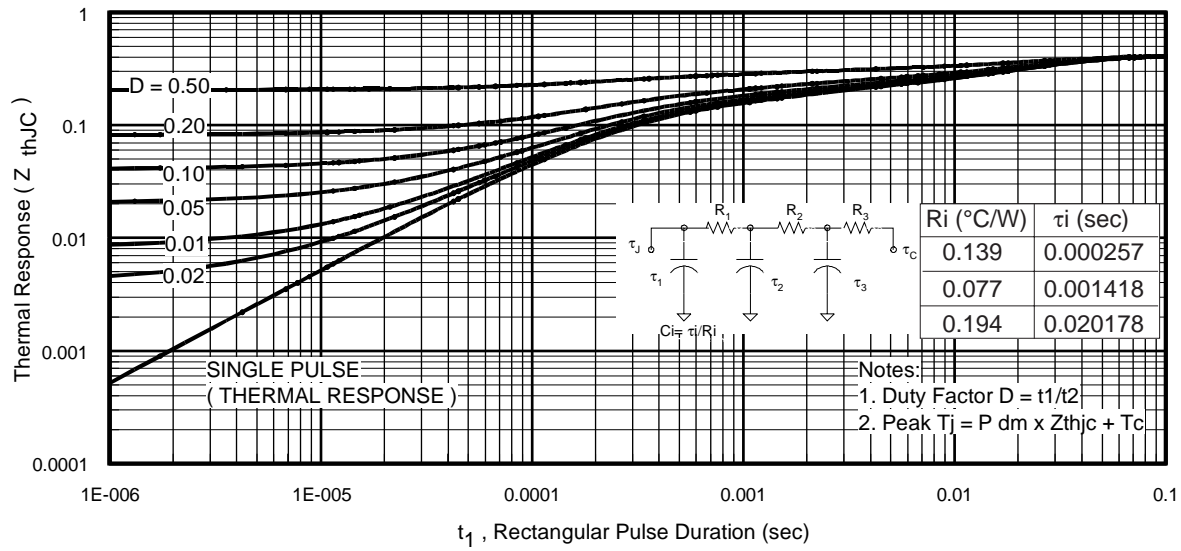


Fig 23. Maximum Transient Thermal Impedance, Junction-to-Case (IGBT)

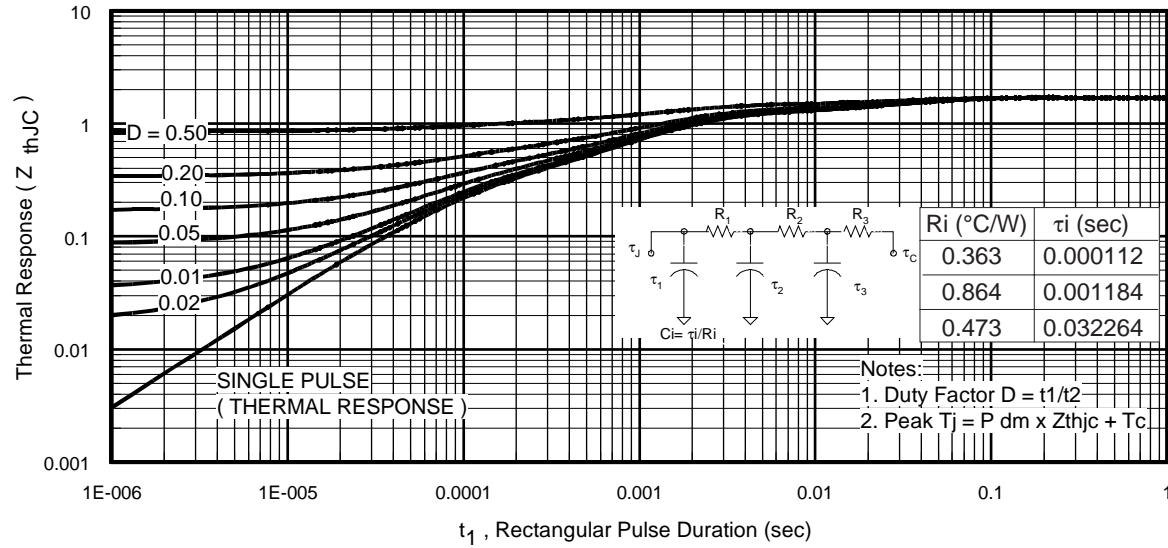


Fig. 24. Maximum Transient Thermal Impedance, Junction-to-Case (DIODE)

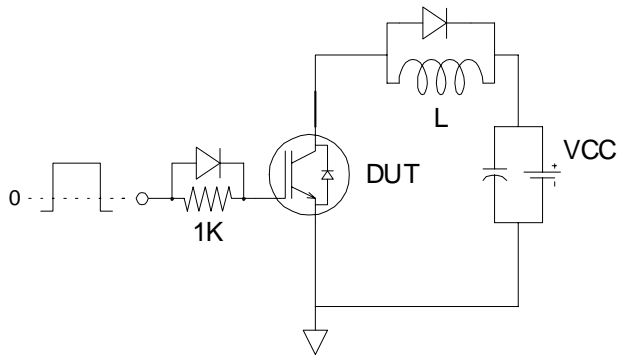


Fig.C.T.1 - Gate Charge Circuit (turn-off)

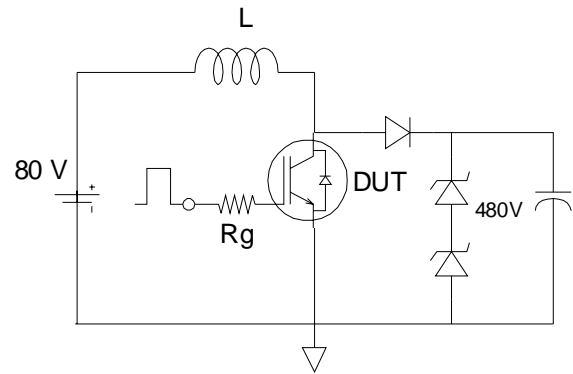


Fig.C.T.2 - RBSOA Circuit

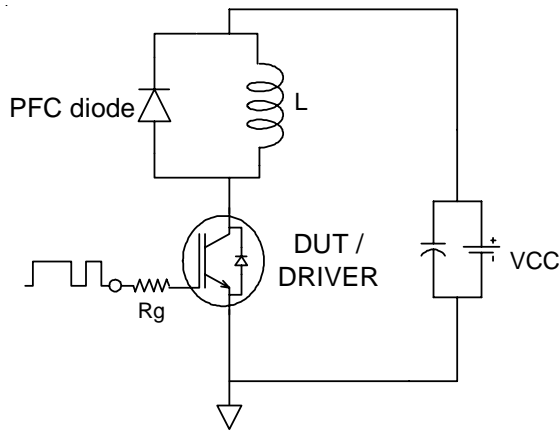


Fig.C.T.3 - Switching Loss Circuit

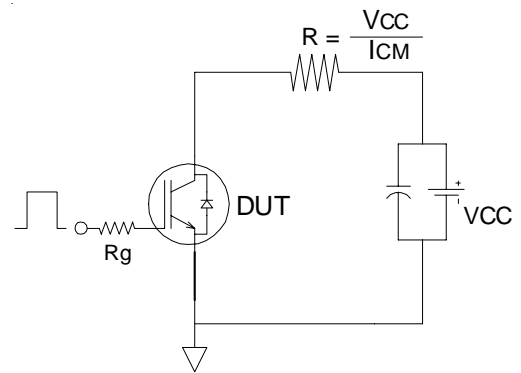


Fig.C.T.4 - Resistive Load Circuit

REVERSE RECOVERY CIRCUIT

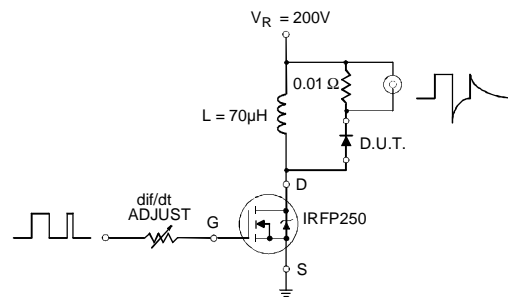


Fig. C.T.5 - Reverse Recovery Parameter Test Circuit

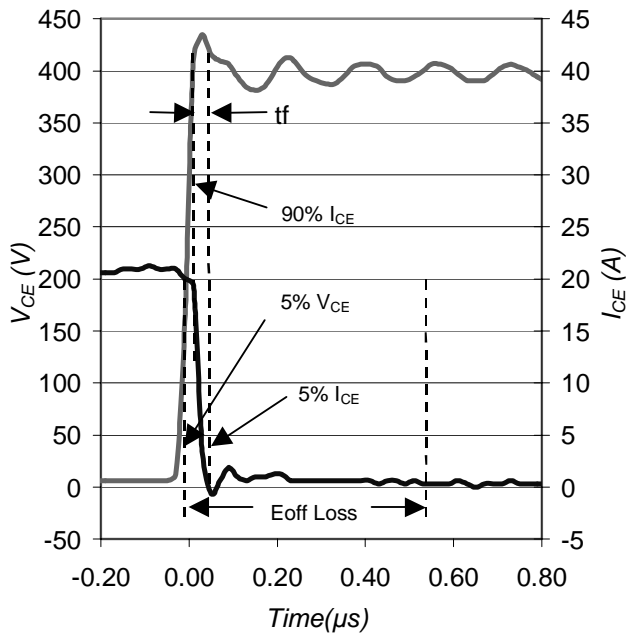


Fig. WF1 - Typ. Turn-off Loss Waveform
@ $T_J = 25^\circ\text{C}$ using Fig. CT.3

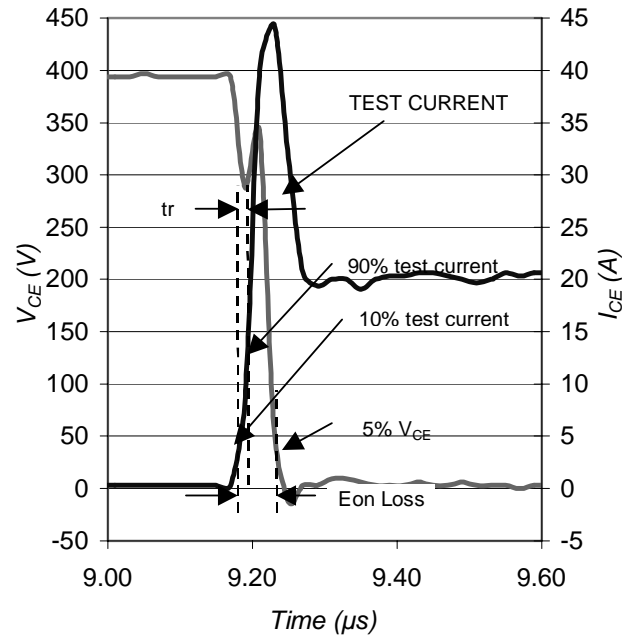
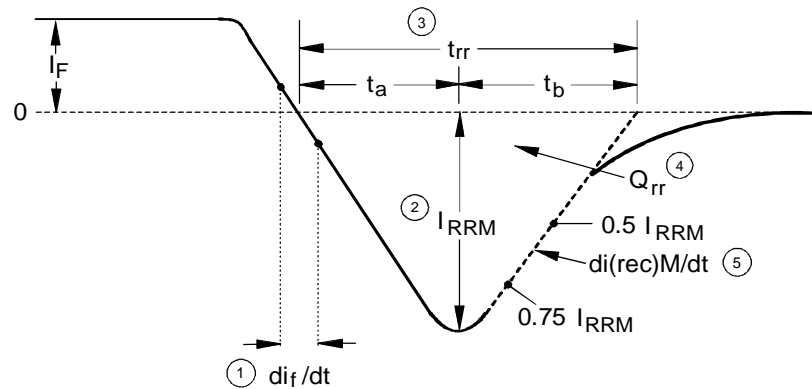


Fig. WF2 - Typ. Turn-on Loss Waveform
@ $T_J = 25^\circ\text{C}$ using Fig. CT.3

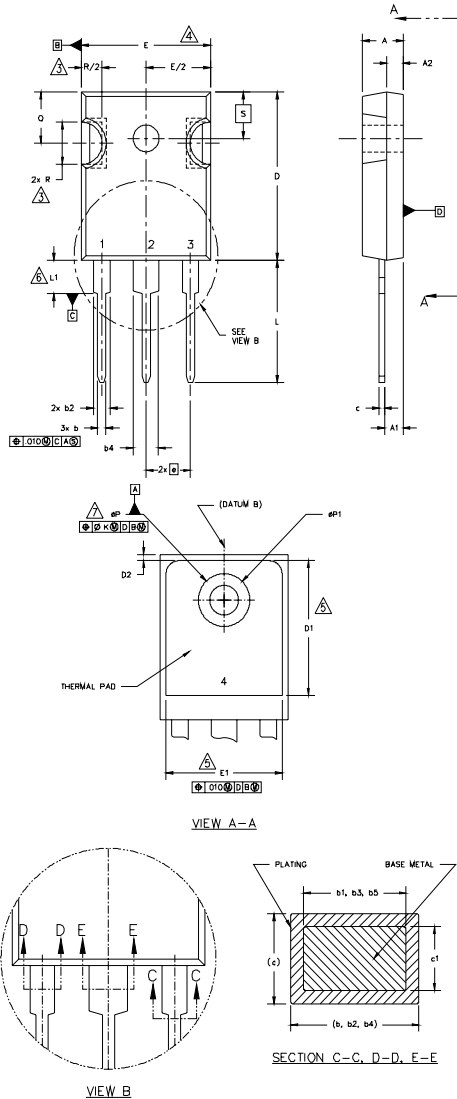


1. di_f/dt - Rate of change of current through zero crossing
2. I_{RRM} - Peak reverse recovery current
3. t_{rr} - Reverse recovery time measured from zero crossing point of negative going I_F to point where a line passing through $0.75 I_{RRM}$ and $0.50 I_{RRM}$ extrapolated to zero current
4. Q_{rr} - 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:
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 DIMENSIONS D1 & E1.
 6. LEAD FINISH UNCONTROLLED IN L1.
 7. ϕP 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		
ϕk	.010		2.54		
L	.559	.634	14.20	16.10	
L1	.146	.169	3.71	4.29	
N	3		7.62 BSC		
ϕP	.140	.144	3.56	3.66	
$\phi P1$	-	.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

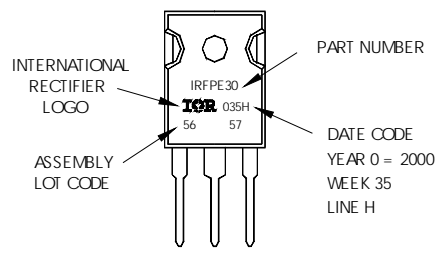
- 1.- GATE
- 2.- COLLECTOR
- 3.- EMITTER
- 4.- COLLECTOR

DIODES

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

TO-247AC Part Marking Information

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.