International IOR Rectifier

IRGP35B60PDPbF

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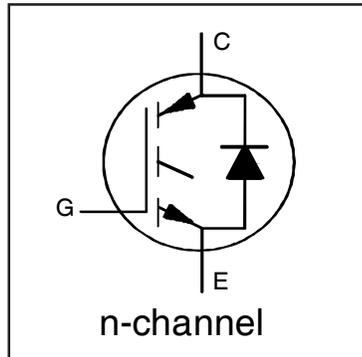ULTRAFAST SOFT RECOVERY DIODE**

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

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
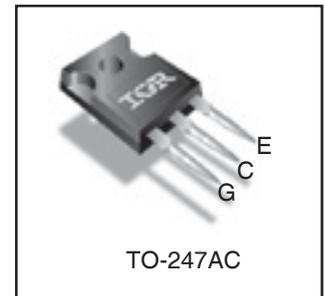- Higher Reliability

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

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

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

n-channel

TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	60	
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 Current ②	120	A
I_F @ T_C = 25°C	Diode Continous Forward Current	40	
I_F @ T_C = 100°C	Diode Continous Forward Current	15	
I_{FRM}	Maximum Repetitive Forward Current ③	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	Operating Junction and	-55 to +150	
T_{STG}	Storage Temperature Range		°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
$R_{θJC}$ (IGBT)	Thermal Resistance Junction-to-Case-(each IGBT)	——	——	0.41	°C/W
$R_{θJC}$ (Diode)	Thermal Resistance Junction-to-Case-(each Diode)	——	——	1.7	
$R_{θCS}$	Thermal Resistance, Case-to-Sink (flat, greased surface)	——	0.24	——	
$R_{θJA}$	Thermal Resistance, Junction-to-Ambient (typical socket mount)	——	——	40	
	Weight	——	6.0 (0.21)	——	g (oz)

6/2/04

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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	$V_{GE} = 0V$, $I_C = 500\mu A$	
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.78	—	V/°C	$V_{GE} = 0V$, $I_C = 1mA$ (25°C-125°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		$I_C = 22A$, $V_{GE} = 15V$, $T_J = 125°C$	
		—	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	$I_C = 250\mu A$	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	$I_F = 15A$, $V_{GE} = 0V$	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
Qg	Total Gate Charge (turn-on)	—	160	240		$I_C = 22A$	17
Q_{gc}	Gate-to-Collector Charge (turn-on)	—	55	83	nC	$V_{CC} = 400V$	CT1
Q_{ge}	Gate-to-Emitter Charge (turn-on)	—	21	32		$V_{GE} = 15V$	
E_{on}	Turn-On Switching Loss	—	220	270		$I_C = 22A$, $V_{CC} = 390V$	CT3
E_{off}	Turn-Off Switching Loss	—	215	265	μJ	$V_{GE} = +15V$, $R_G = 3.3Ω$, L = 200μH	
E_{total}	Total Switching Loss	—	435	535		$T_J = 25°C$ ④	
$t_{d(on)}$	Turn-On delay time	—	26	34		$I_C = 22A$, $V_{CC} = 390V$	CT3
t_r	Rise time	—	6.0	8.0	ns	$V_{GE} = +15V$, $R_G = 3.3Ω$, L = 200μH	
$t_{d(off)}$	Turn-Off delay time	—	110	122		$T_J = 25°C$ ④	
t_f	Fall time	—	8.0	10			
E_{on}	Turn-On Switching Loss	—	410	465		$I_C = 22A$, $V_{CC} = 390V$	CT3
E_{off}	Turn-Off Switching Loss	—	330	405	μJ	$V_{GE} = +15V$, $R_G = 3.3Ω$, L = 200μH	11,13
E_{total}	Total Switching Loss	—	740	870		$T_J = 125°C$ ④	WF1,WF2
$t_{d(on)}$	Turn-On delay time	—	26	34		$I_C = 22A$, $V_{CC} = 390V$	CT3
t_r	Rise time	—	8.0	11	ns	$V_{GE} = +15V$, $R_G = 3.3Ω$, L = 200μH	12,14
$t_{d(off)}$	Turn-Off delay time	—	130	150		$T_J = 125°C$ ④	WF1,WF2
t_f	Fall time	—	12	16			
C_{ies}	Input Capacitance	—	3715	—		$V_{GE} = 0V$	16
C_{oes}	Output Capacitance	—	265	—		$V_{CC} = 30V$	
C_{res}	Reverse Transfer Capacitance	—	47	—	pF	f = 1Mhz	
C_{oes} eff.	Effective Output Capacitance (Time Related) ⑤	—	135	—		$V_{GE} = 0V$, $V_{CE} = 0V$ to 480V	15
C_{oes} eff. (ER)	Effective Output Capacitance (Energy Related) ⑤	—	179	—			
RBSOA	Reverse Bias Safe Operating Area	FULL SQUARE				$T_J = 150°C$, $I_C = 120A$ $V_{CC} = 480V$, Vp =600V Rg = 22Ω, $V_{GE} = +15V$ to 0V	3 CT2
t_{rr}	Diode Reverse Recovery Time	—	42	60	ns	$T_J = 25°C$ $I_F = 15A$, $V_R = 200V$,	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	CT5

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.
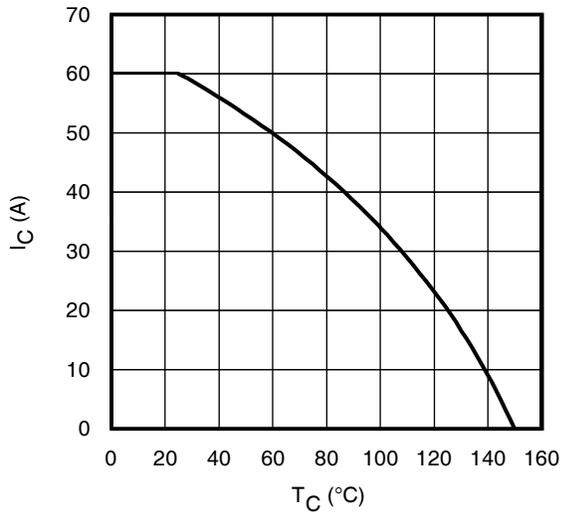
② $V_{CC} = 80%$ (V_{CES}), $V_{GE} = 15V$, L = 28 μH, $R_G = 22$ Ω.

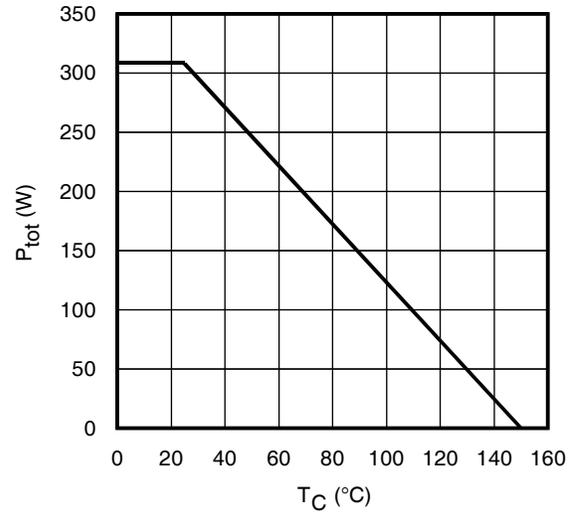③ Pulse width limited by max. junction temperature.

④ Energy losses include "tail" and diode reverse recovery, Data generated with use of Diode 30ETH06.

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}.
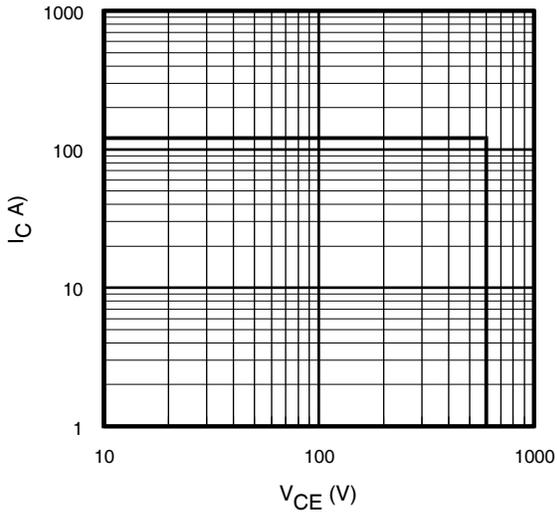C_{oes} eff.(ER) is a fixed capacitance that stores the same energy as C_{oes} while V_{CE} is rising from 0 to 80% V_{CES}.
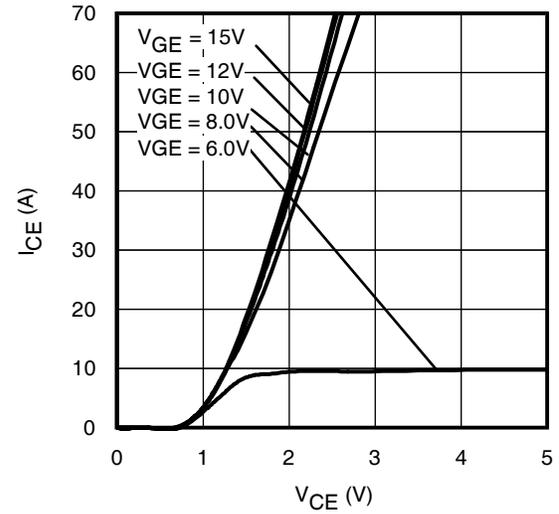
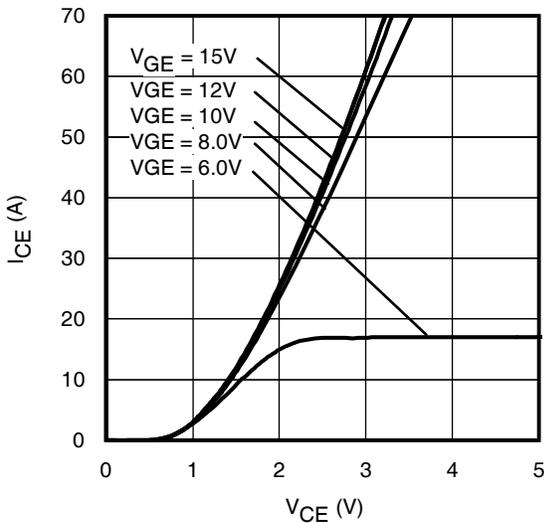**Fig. 1** - Maximum DC Collector Current vs. Case Temperature

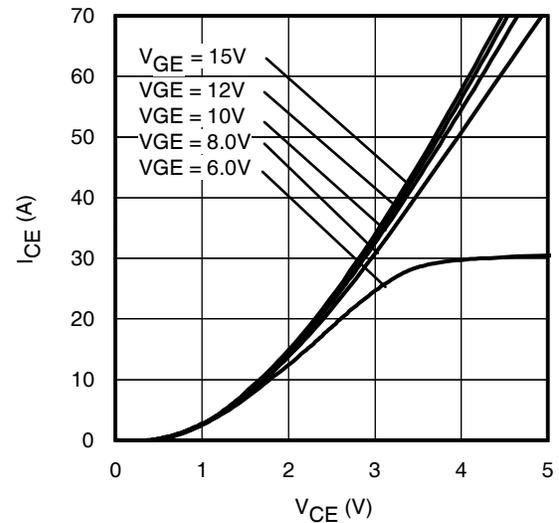

Fig. 2 - Power Dissipation vs. Case Temperature

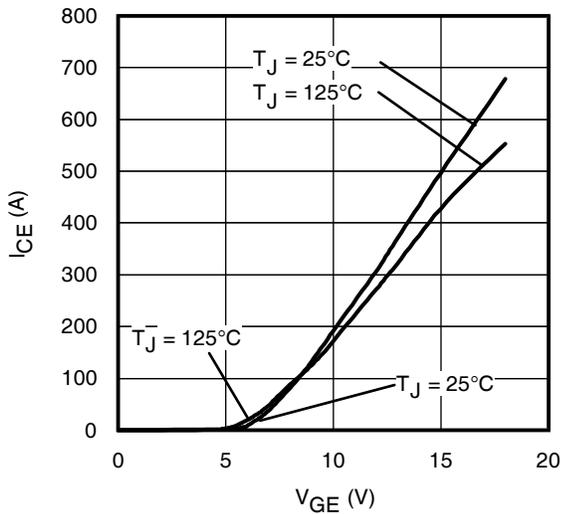**Fig. 3** - Reverse Bias SOA
T_J = 150°C; V_{GE} =15V
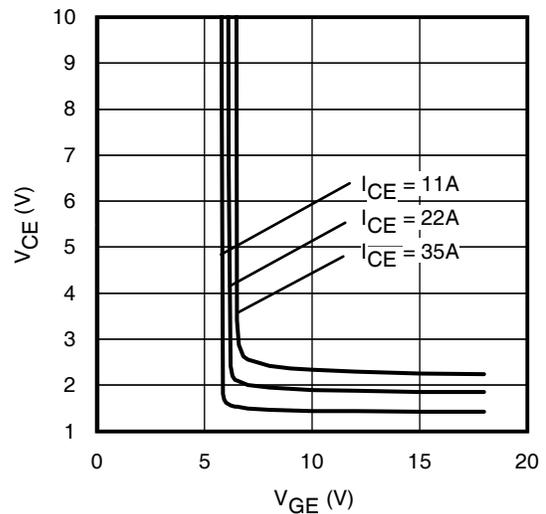

Fig. 4 - Typ. IGBT Output Characteristics
T_J = -40°C; tp = 80µs

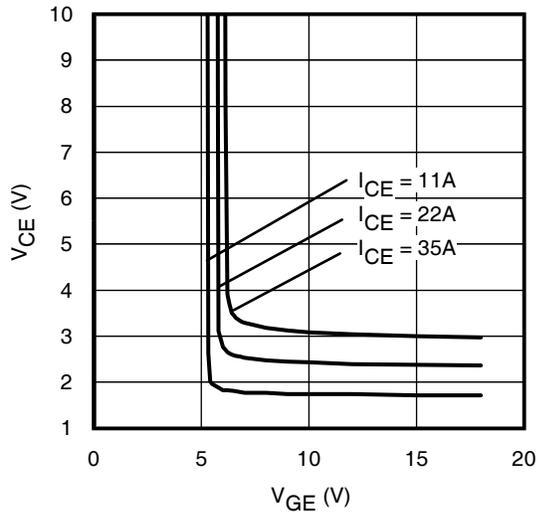**Fig. 5** - Typ. IGBT Output Characteristics
T_J = 25°C; tp = 80µs

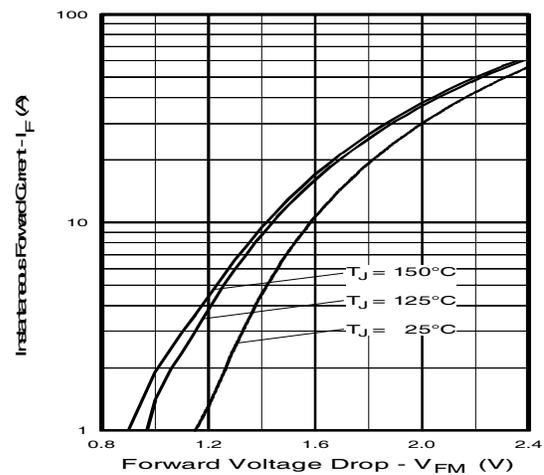**Fig. 6** - Typ. IGBT Output Characteristics
T_J = 125°C; tp = 80µs

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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; $V_{CE} = 390V$, $R_G = 3.3Ω$; $V_{GE} = 15V$.
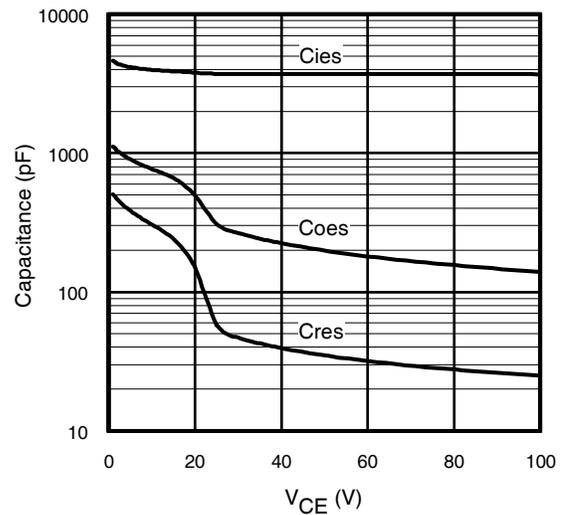Diode clamp used: 30ETH06 (See C.T.3)

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)

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

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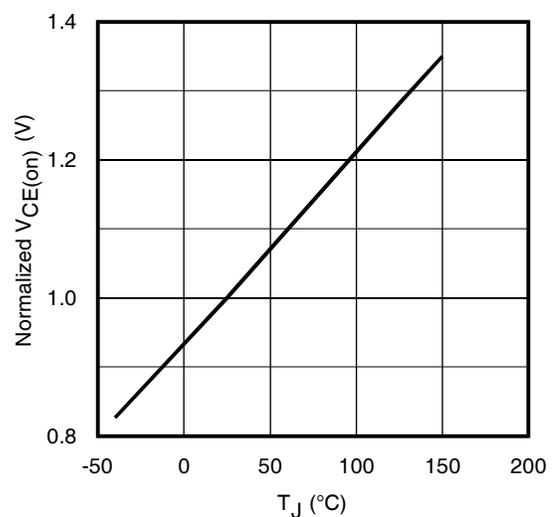Diode clamp used: 30ETH06 (See C.T.3)

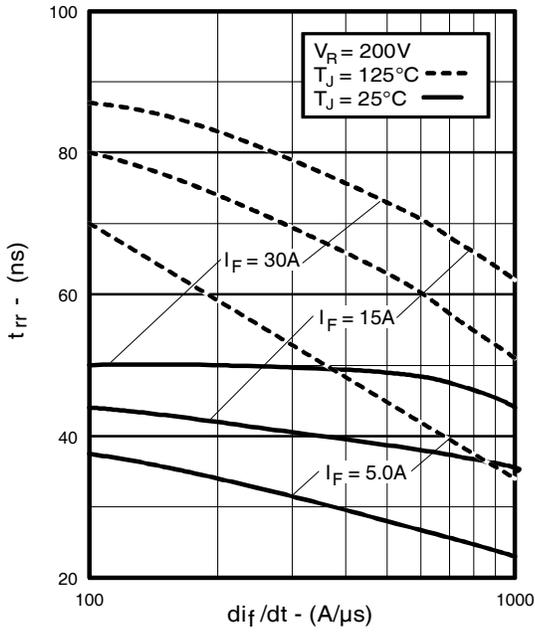**Fig. 15**- Typ. Output Capacitance
Stored Energy vs. V_{CE}

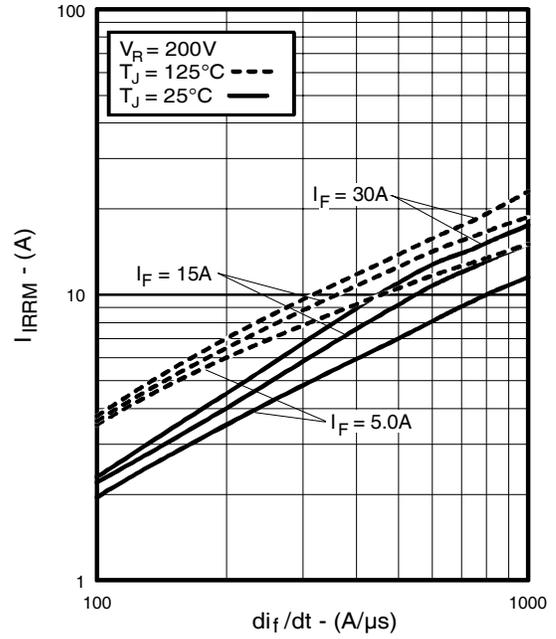**Fig. 16**- Typ. Capacitance vs. V_{CE}
$V_{GE} = 0V$; f = 1MHz

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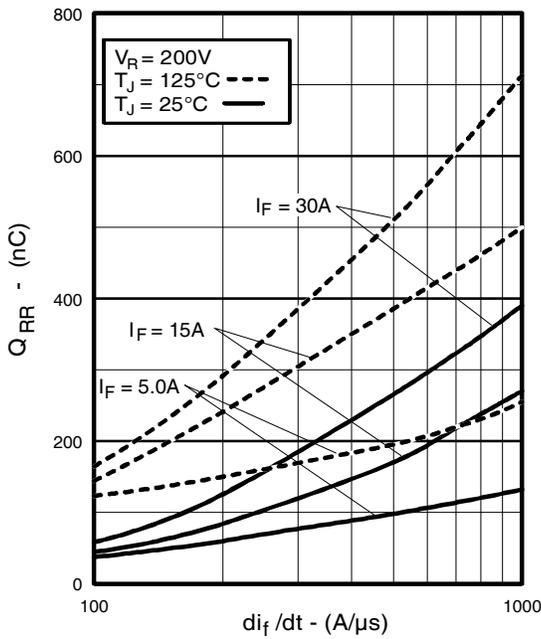

Fig. 18 - Normalized Typ. $V_{CE(on)}$
vs. Junction Temperature
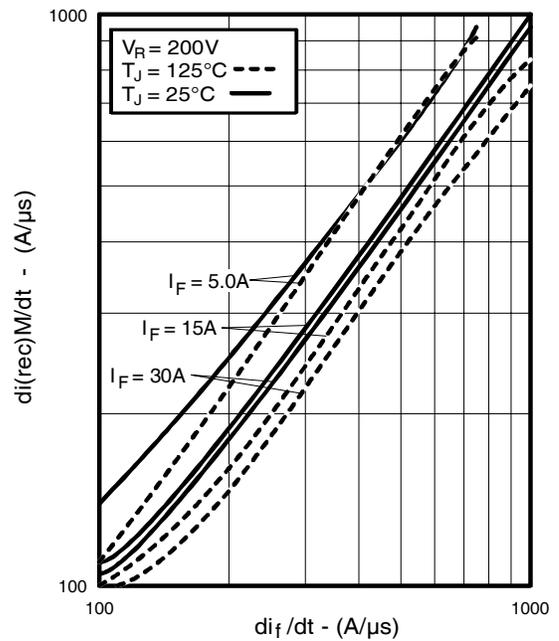$I_C = 22A$, $V_{GE} = 15V$

Fig. 19 - Typical Reverse Recovery vs. di$_f$/dt

Fig. 20 - Typical Recovery Current vs. di$_f$/dt

Fig. 21 - Typical Stored Charge vs. di$_f$/dt

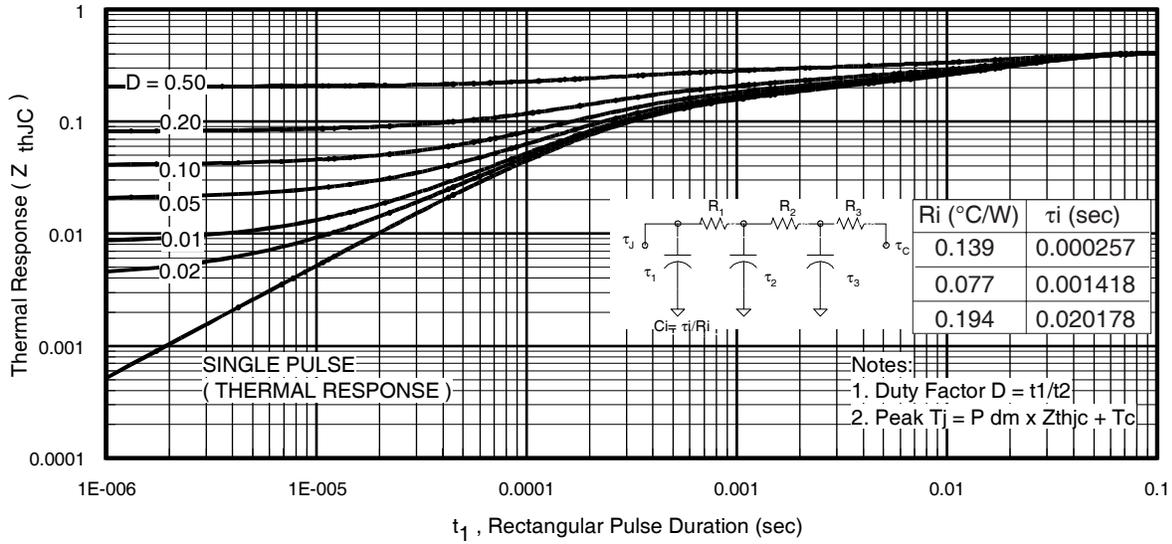**Fig. 22** - Typical di$_{(rec)M}$/dt vs. di$_f$/dt,
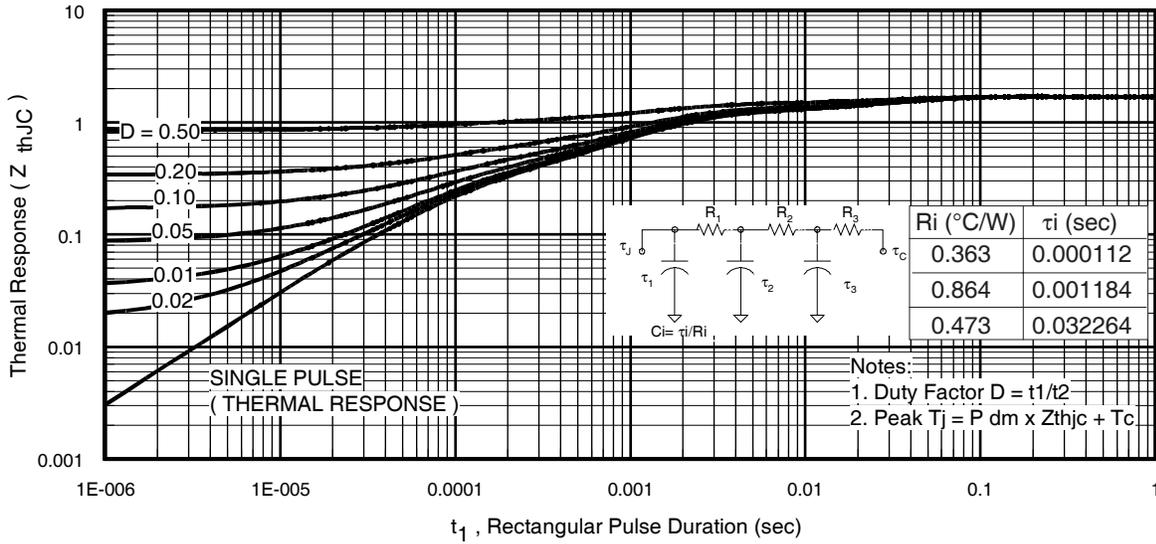
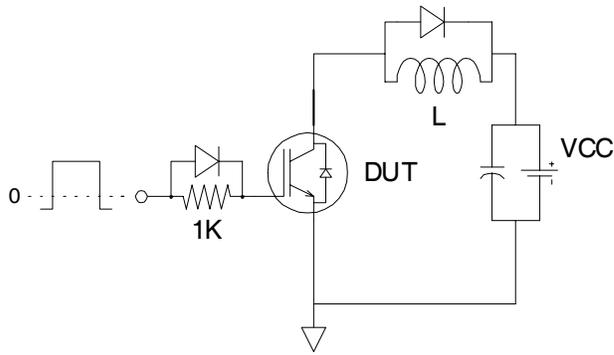**Fig 23.** Maximum Transient Thermal Impedance, Junction-to-Case (IGBT)
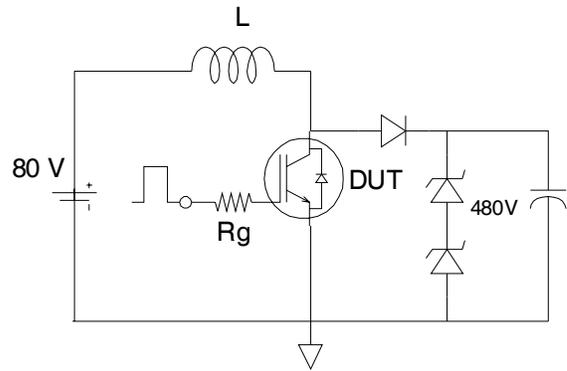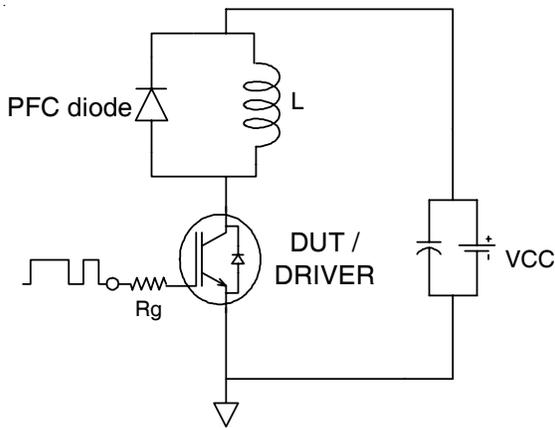

Fig. 24. Maximum Transient Thermal Impedance, Junction-to-Case (DIODE)
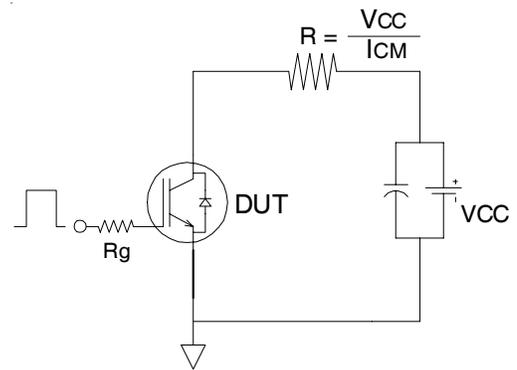
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Fig.C.T.1 - Gate Charge Circuit (turn-off)
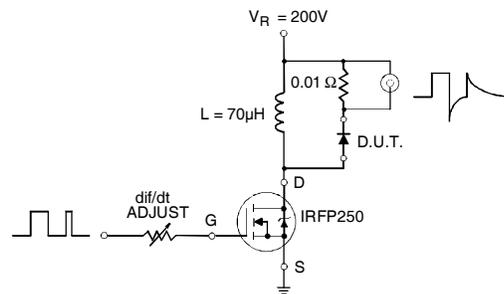

Fig.C.T.2 - RBSOA Circuit

Fig.C.T.3 - Switching Loss Circuit
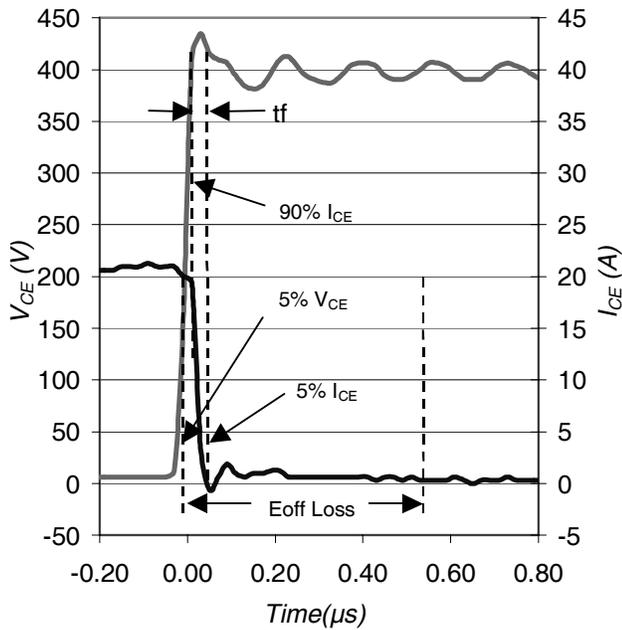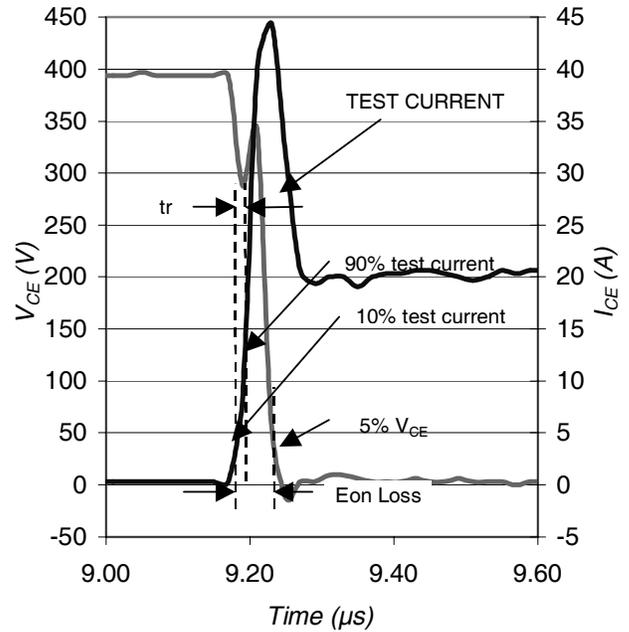

Fig.C.T.4 - Resistive Load Circuit

REVERSE RECOVERY CIRCUIT

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

Fig. WF1 - Typ. Turn-off Loss Waveform
@ T_J = 25°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. 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

International **IGR** Rectifier

TO-247AC Package Outline

Dimensions are shown in millimeters (inches)

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"

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

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.

International **IGR** Rectifier

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

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- Подбор аналогов;
- Консультации по применению компонента;
- Поставка образцов и прототипов;
- Техническая поддержка проекта;
- Защита от снятия компонента с производства.

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Факс: 8 (812) 320-02-42
Электронная почта: org@eplast1.ru
Адрес: 198099, г. Санкт-Петербург, ул. Калинина, дом 2, корпус 4, литера А.