International IOR Rectifier

SMPS IGBT   # IRGB20B60PD1

## 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
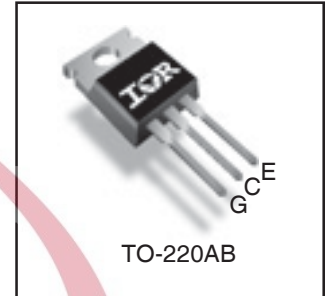- Tighter Distribution of Parameters
- Higher Reliability

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

C

G

E

n-channel
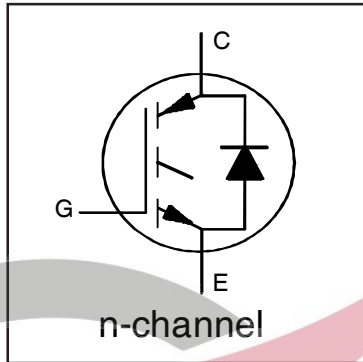
$V_{CES} = 600V$
$V_{CE(on)}$ typ. $= 2.05V$
@ $V_{GE} = 15V$ $I_C = 13.0A$

Equivalent MOSFET Parameters ①
$R_{CE(on)}$ typ. $= 158m\Omega$
I_D (FET equivalent) $= 20A$

E
C
G

TO-220AB

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	40	A
I_C @ T_C = 100°C	Continuous Collector Current	22	
I_{CM}	Pulse Collector Current (Ref. Fig. C.T.4)	80	
I_{LM}	Clamped Inductive Load Current ②	80	
I_F @ T_C = 25°C	Diode Continous Forward Current	10	
I_F @ T_C = 100°C	Diode Continous Forward Current	4	
I_{FRM}	Maximum Repetitive Forward Current ③	16	
V_{GE}	Gate-to-Emitter Voltage	±20	V
P_D @ T_C = 25°C	Maximum Power Dissipation	215	W
P_D @ T_C = 100°C	Maximum Power Dissipation	86	
T_J	Operating Junction and	-55 to +150	°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)	——	——	0.58	°C/W
$R_{\theta JC}$ (Diode)	Thermal Resistance Junction-to-Case-(each Diode)	——	——	5.0	
$R_{\theta CS}$	Thermal Resistance, Case-to-Sink (flat, greased surface)	——	0.50	——	
$R_{\theta JA}$	Thermal Resistance, Junction-to-Ambient (typical socket mount)	——	——	80	
	Weight	——	2 (0.07)	——	g (oz)

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12/10/03

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 = 500µA	
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.32	—	V/°C	V_{GE} = 0V, I_C = 1mA (25°C-125°C)	
R_G	Internal Gate Resistance	—	4.3	—	Ω	1MHz, Open Collector	
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	—	2.05	2.35	V	I_C = 13A, V_{GE} = 15V	4, 5,6,8,9
		—	2.50	2.80		I_C = 20A, V_{GE} = 15V	
		—	2.65	3.00		I_C = 13A, V_{GE} = 15V, T_J = 125°C	
		—	3.30	3.70		I_C = 20A, V_{GE} = 15V, T_J = 125°C	
$V_{GE(th)}$	Gate Threshold Voltage	3.0	4.0	5.0	V	I_C = 250µA	7,8,9
$\Delta V_{GE(th)}/\Delta TJ$	Threshold Voltage temp. coefficient	—	-11	—	mV/°C	V_{CE} = V_{GE}, I_C = 1.0mA	
gfe	Forward Transconductance	—	19	—	S	V_{CE} = 50V, I_C = 40A, PW = 80µs	
I_{CES}	Collector-to-Emitter Leakage Current	—	1.0	250	µA	V_{GE} = 0V, V_{CE} = 600V	
		—	0.1	—	mA	V_{GE} = 0V, V_{CE} = 600V, T_J = 125°C	
V_{FM}	Diode Forward Voltage Drop	—	1.5	1.8	V	I_F = 4.0A, V_{GE} = 0V	10
		—	1.4	1.7		I_F = 4.0A, 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)	—	68	102		I_C = 13A	17
Q_{gc}	Gate-to-Collector Charge (turn-on)	—	24	36	nC	V_{CC} = 400V	CT1
Q_{ge}	Gate-to-Emitter Charge (turn-on)	—	10	15		V_{GE} = 15V	
E_{on}	Turn-On Switching Loss	—	95	140		I_C = 13A, V_{CC} = 390V	CT3
E_{off}	Turn-Off Switching Loss	—	100	145	µJ	V_{GE} = +15V, R_G = 10Ω, L = 200µH	
E_{total}	Total Switching Loss	—	195	285		T_J = 25°C ④	
$t_{d(on)}$	Turn-On delay time	—	20	26		I_C = 13A, V_{CC} = 390V	CT3
t_r	Rise time	—	5.0	7.0	ns	V_{GE} = +15V, R_G = 10Ω, L = 200µH	
$t_{d(off)}$	Turn-Off delay time	—	115	135		T_J = 25°C ④	
t_f	Fall time	—	6.0	8.0			
E_{on}	Turn-On Switching Loss	—	165	215		I_C = 13A, V_{CC} = 390V	CT3
E_{off}	Turn-Off Switching Loss	—	150	195	µJ	V_{GE} = +15V, R_G = 10Ω, L = 200µH	11,13
E_{total}	Total Switching Loss	—	315	410		T_J = 125°C ④	WF1,WF2
$t_{d(on)}$	Turn-On delay time	—	19	25		I_C = 13A, V_{CC} = 390V	CT3
t_r	Rise time	—	6.0	8.0	ns	V_{GE} = +15V, R_G = 10Ω, L = 200µH	12,14
$t_{d(off)}$	Turn-Off delay time	—	125	140		T_J = 125°C ④	WF1,WF2
t_f	Fall time	—	13	17			
C_{ies}	Input Capacitance	—	1560	—		V_{GE} = 0V	16
C_{oes}	Output Capacitance	—	95			V_{CC} = 30V	
C_{res}	Reverse Transfer Capacitance	—	20	—	pF	f = 1Mhz	
C_{oes} eff.	Effective Output Capacitance (Time Related) ⑤	—	83			V_{GE} = 0V, V_{CE} = 0V to 480V	15
C_{oes} eff. (ER)	Effective Output Capacitance (Energy Related) ⑤	—	61				
RBSOA	Reverse Bias Safe Operating Area		FULL SQUARE			T_J = 150°C, I_C = 80A V_{CC} = 480V, Vp =600V Rg = 22Ω, V_{GE} = +15V to 0V	3 CT2
t_{rr}	Diode Reverse Recovery Time	—	28	42	ns	T_J = 25°C, I_F = 4.0A, V_R = 200V,	19
		—	38	57		T_J = 125°C, di/dt = 200A/µs	
Q_{rr}	Diode Reverse Recovery Charge	—	40	60	nC	T_J = 25°C, I_F = 4.0A, V_R = 200V,	21
		—	70	105		T_J = 125°C, di/dt = 200A/µs	
I_{rr}	Peak Reverse Recovery Current	—	2.9	5.2	A	T_J = 25°C, I_F = 4.0A, V_R = 200V,	19,20,21,22
		—	3.7	6.7		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. = 2.05V and I_C = 13A. 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 = 28µH, R_G = 22Ω.

③ Pulse width limited by max. junction temperature.

④ Energy losses include "tail" and diode reverse recovery. Data generated with use of Diode 8ETH06.

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}.

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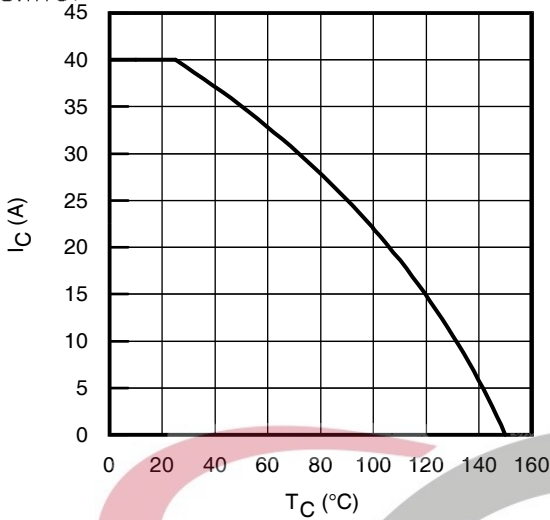
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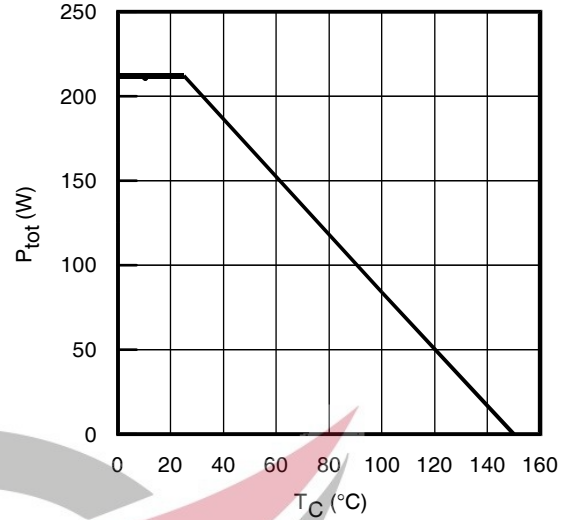**Fig. 1** - Maximum DC Collector Current vs. Case Temperature

Fig. 2 - Power Dissipation vs. Case Temperature
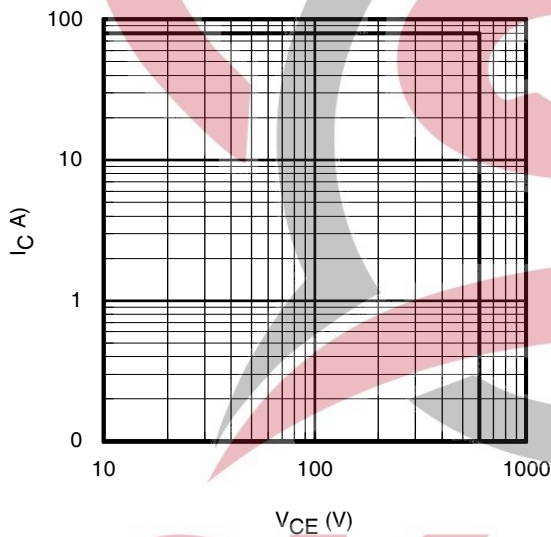
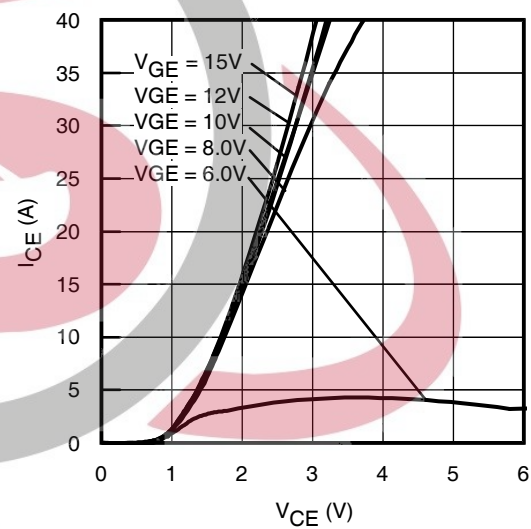**Fig. 3** - Reverse Bias SOA
$T_J = 150°C$; $V_{GE} = 15V$

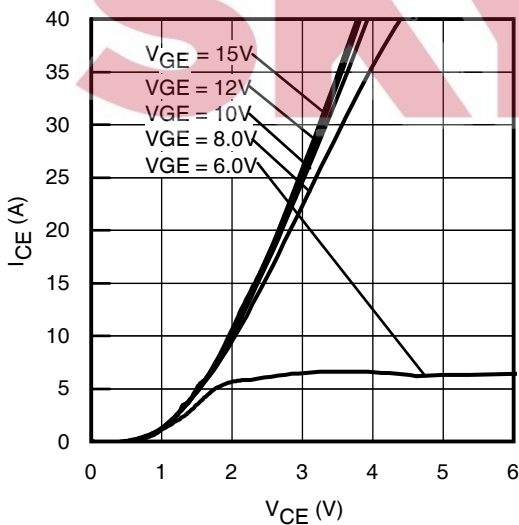**Fig. 4** - Typ. IGBT Output Characteristics
$T_J = -40°C$; $tp = 80\mu s$

Fig. 5 - Typ. IGBT Output Characteristics
$T_J = 25°C$; $tp = 80\mu s$
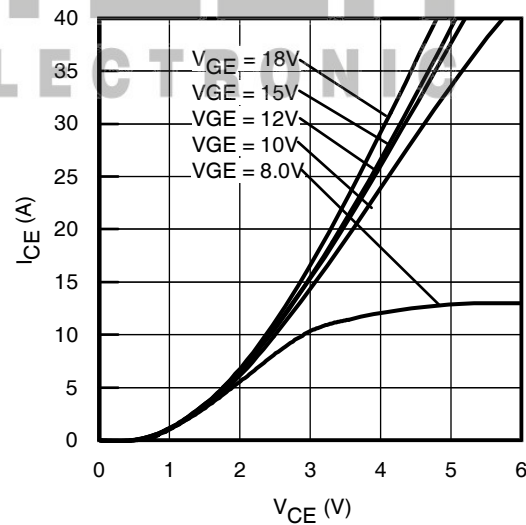
Fig. 6 - Typ. IGBT Output Characteristics
$T_J = 125°C$; $tp = 80\mu s$

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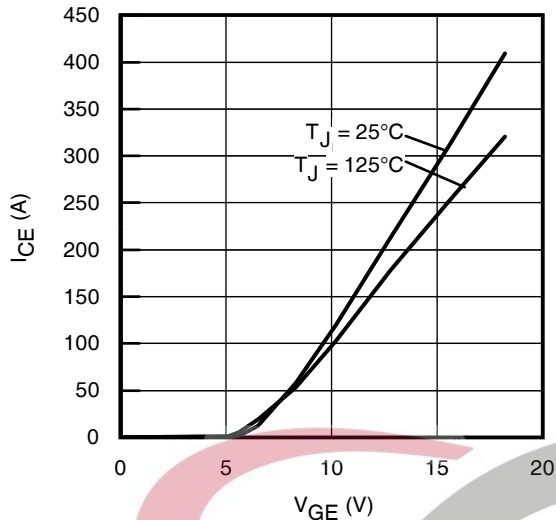
Fig. 7 - Typ. Transfer Characteristics
$V_{CE} = 50V$; tp = 10µs
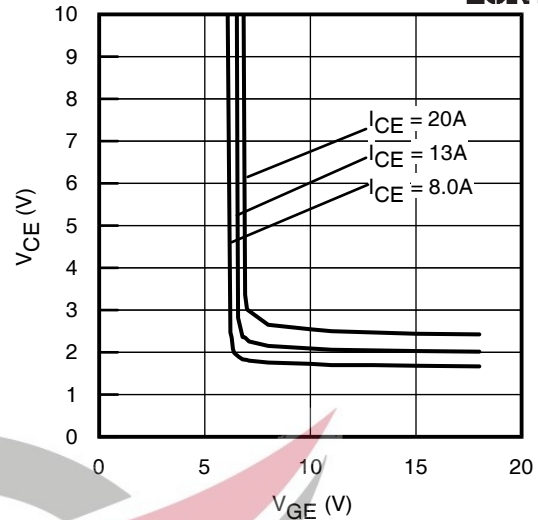
Fig. 8 - Typical V_{CE} vs. V_{GE}
$T_J = 25°C$
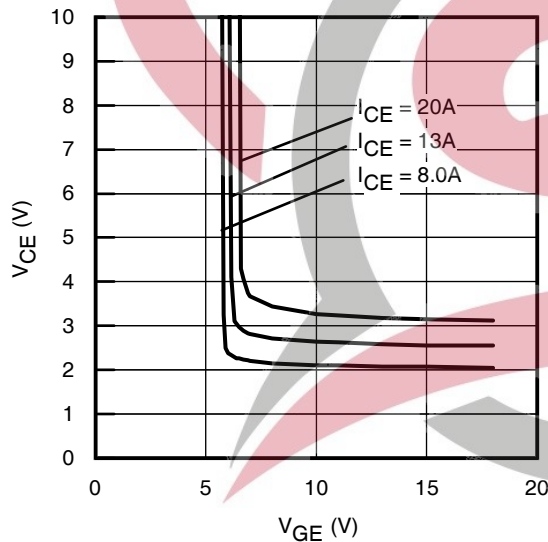
Fig. 9 - Typical V_{CE} vs. V_{GE}
$T_J = 125°C$
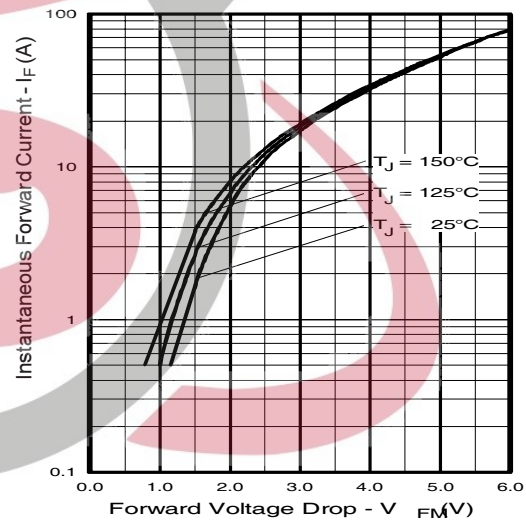
Fig. 10 - Typ. Diode Forward Characteristics
tp = 80µs
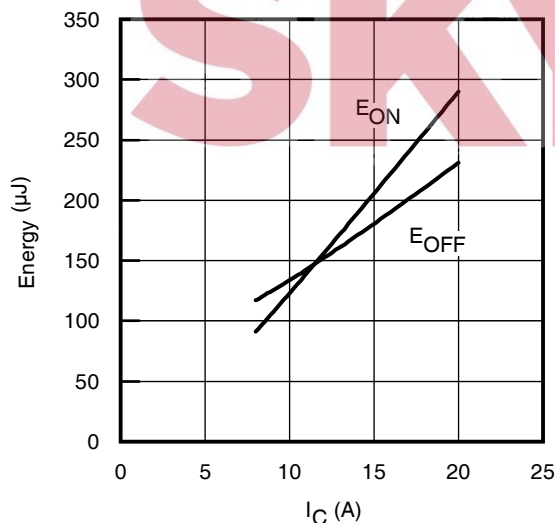
Fig. 11 - Typ. Energy Loss vs. I_C
$T_J = 125°C$; L = 200µH; $V_{CE} = 390V$; $R_G = 10Ω$; $V_{GE} = 15V$.
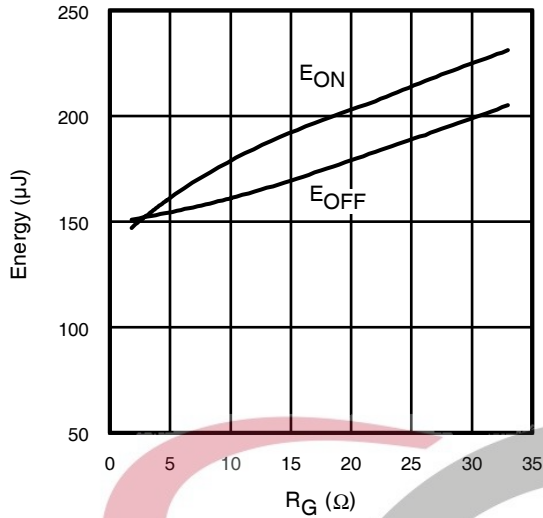Diode clamp used: 8ETH06 (See C.T.3)
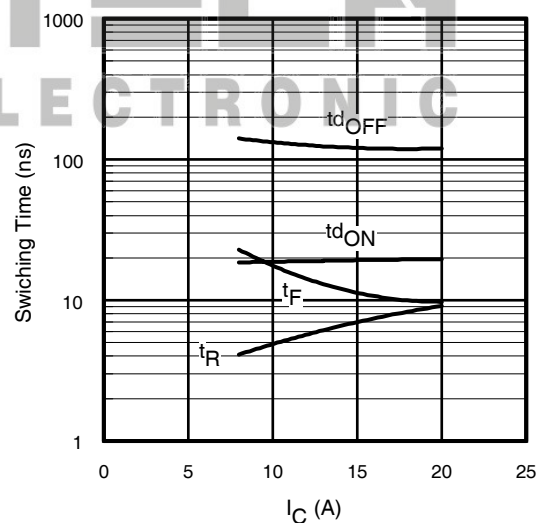
Fig. 12 - Typ. Switching Time vs. I_C
$T_J = 125°C$; L = 200µH; $V_{CE} = 390V$; $R_G = 10Ω$; $V_{GE} = 15V$.
Diode clamp used: 8ETH06 (See C.T.3)

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Fig. 13 - Typ. Energy Loss vs. R_G
$T_J = 125°C$; $L = 200\mu H$; $V_{CE} = 390V$, $I_{CE} = 13A$; $V_{GE} = 15V$
Diode clamp used: 8ETH06 (See C.T.3)
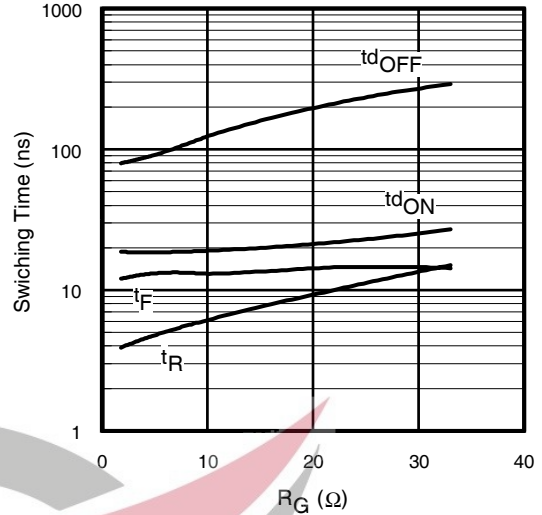
Fig. 14 - Typ. Switching Time vs. R_G
$T_J = 125°C$; $L = 200\mu H$; $V_{CE} = 390V$, $I_{CE} = 13A$; $V_{GE} = 15V$
Diode clamp used: 8ETH06 (See C.T.3)
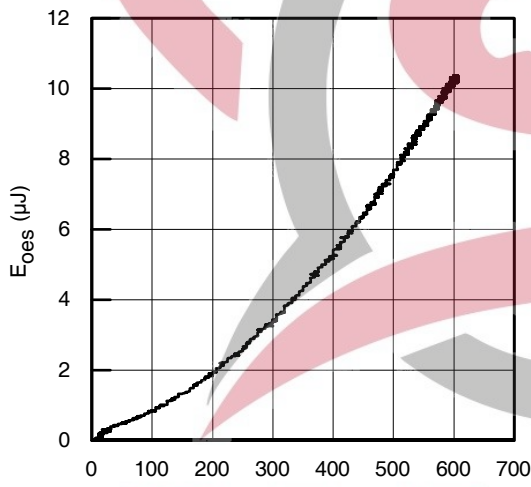
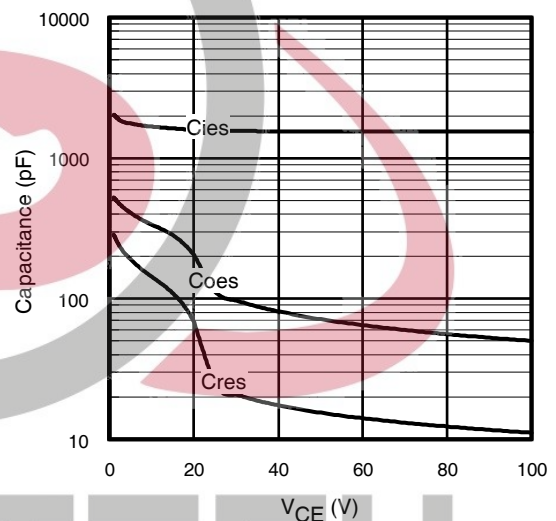**Fig. 15**- Typ. Output Capacitance
Stored Energy vs. V_{CE}

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

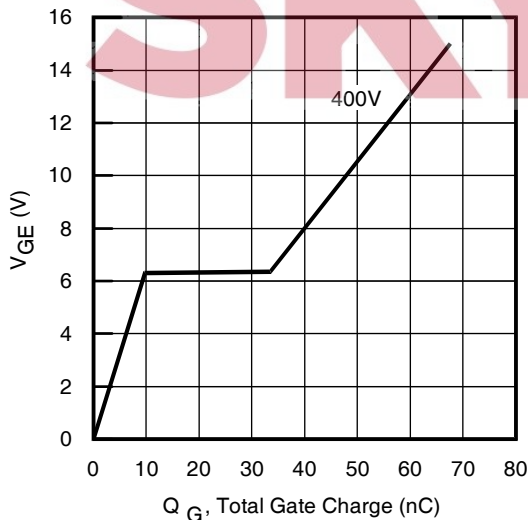**Fig. 17** - Typical Gate Charge vs. V_{GE}
$I_{CE} = 13A$

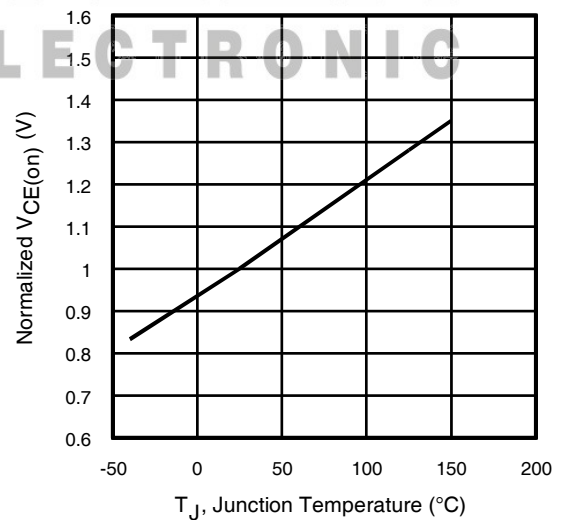**Fig. 18** - Normalized Typical $V_{CE(on)}$ vs.
Junction Temperature
$I_{CE} = 13A$; $V_{GE} = 15V$
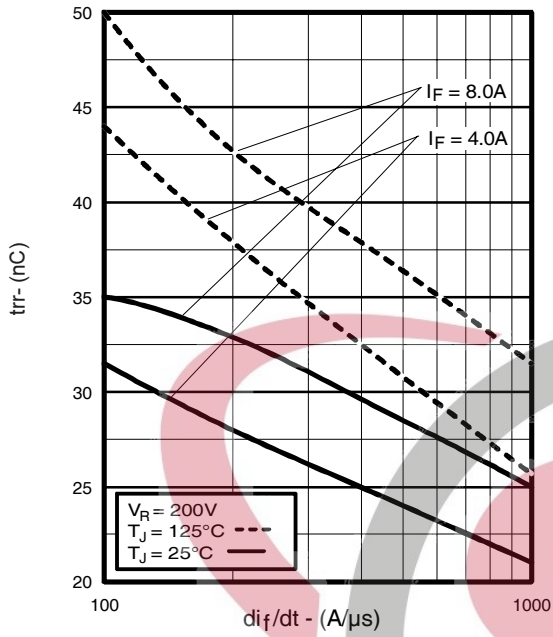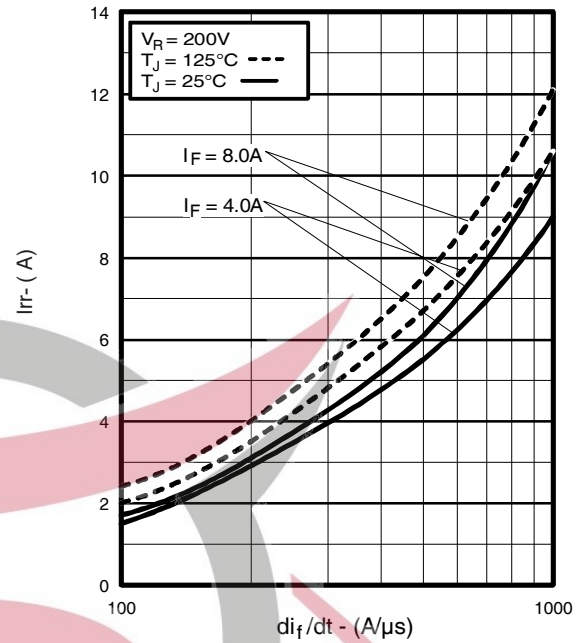
Fig. 19 - Typical Reverse Recovery vs. di$_f$/dt

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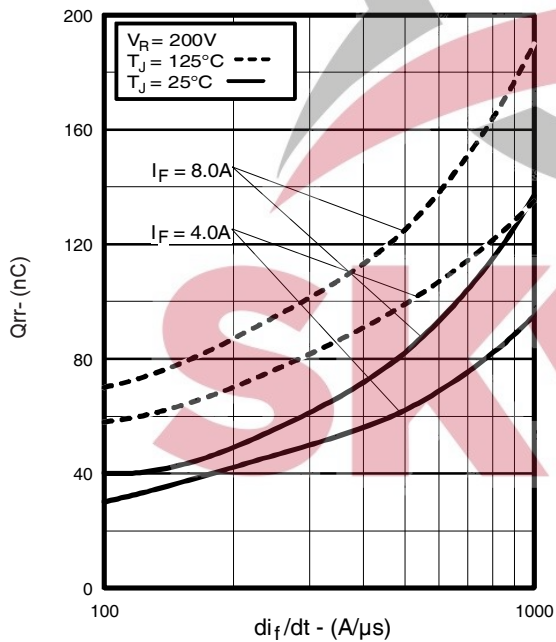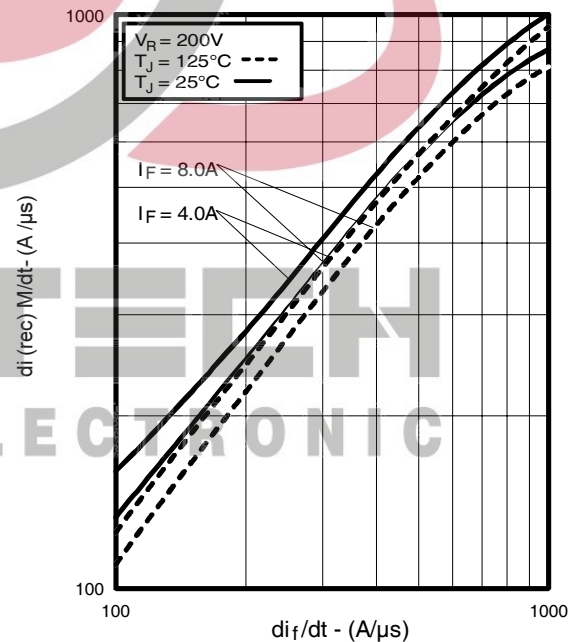

Fig. 21 - Typical Stored Charge vs. di$_f$/dt
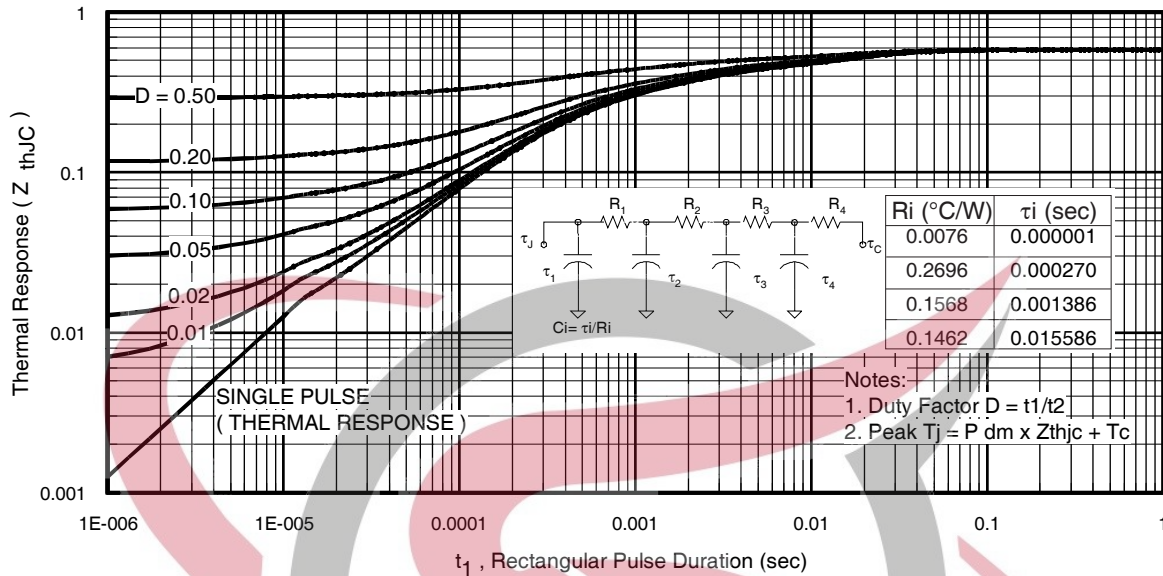

Fig. 22 - Typical di$_{(rec)M}$/dt vs. di$_f$/dt,

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Ri (°C/W)	τi (sec)
0.0076	0.000001
0.2696	0.000270
0.1568	0.001386
0.1462	0.015586

$C_i = \tau_i / R_i$

Notes:
1. Duty Factor D = t1/t2
2. Peak Tj = P dm x Zthjc + Tc

SINGLE PULSE
(THERMAL RESPONSE)

Thermal Response (Z_{thJC})

D = 0.50
0.20
0.10
0.05
0.02
0.01

t_1 , Rectangular Pulse Duration (sec)

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

Ri (°C/W)	τi (sec)
1.779	0.000226
3.223	0.001883

$C_i = \tau_i / R_i$

Notes:
1. Duty Factor D = t1/t2
2. Peak Tj = P dm x Zthjc + Tc

SINGLE PULSE
(THERMAL RESPONSE)

Thermal Response (Z_{thJC})

D = 0.50
0.20
0.10
0.05
0.02
0.01

t_1 , Rectangular Pulse Duration (sec)
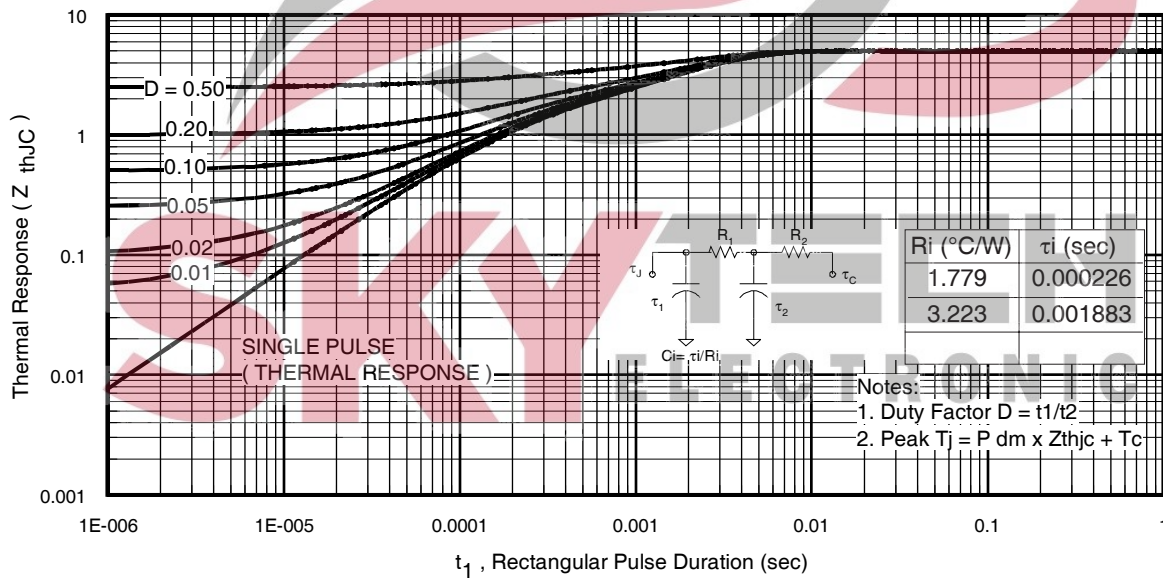
Fig. 24. Maximum Transient Thermal Impedance, Junction-to-Case (DIODE)
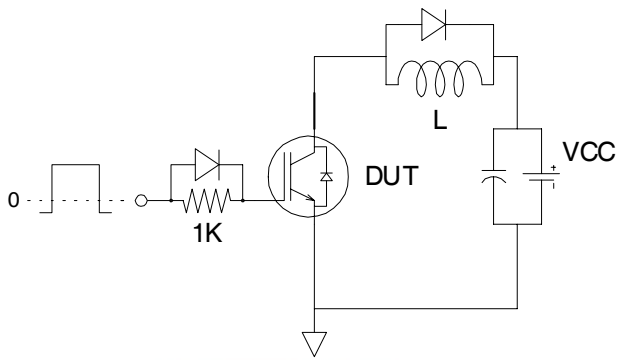
International
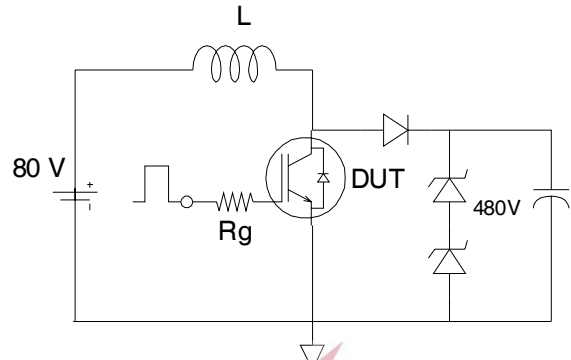**IƏR** Rectifier

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

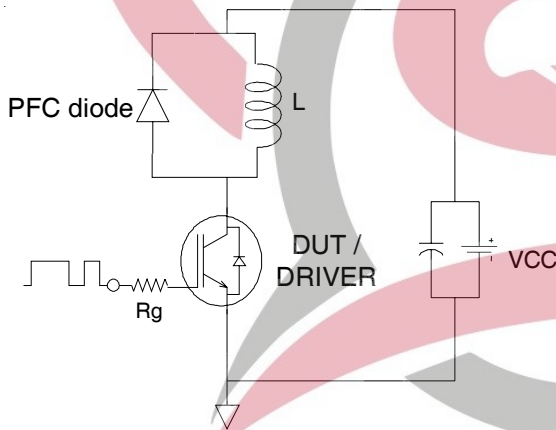**Fig.C.T.2** - RBSOA Circuit

Fig.C.T.3 - Switching Loss Circuit
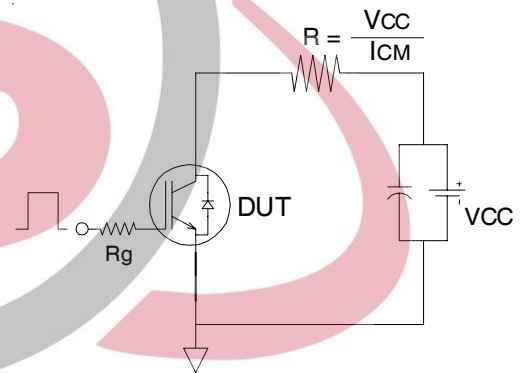
Fig.C.T.4 - Resistive Load Circuit
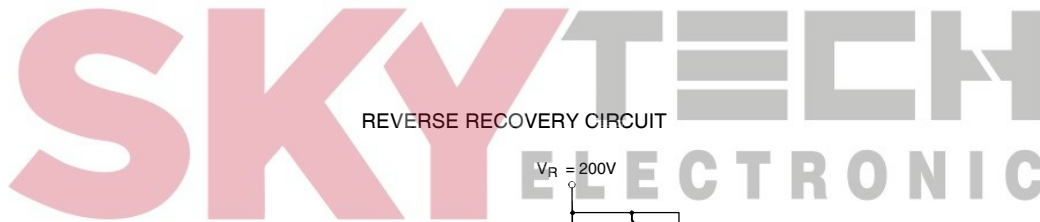
REVERSE RECOVERY CIRCUIT

$V_R = 200V$

$0.01\ \Omega$

$L = 70\mu H$

D.U.T.
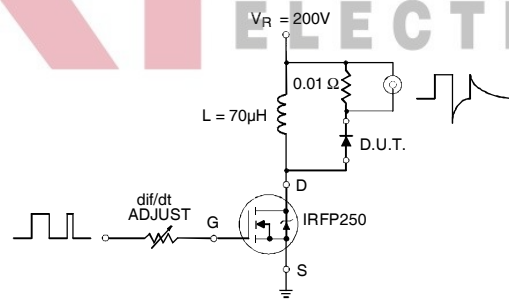
dif/dt ADJUST

IRFP250
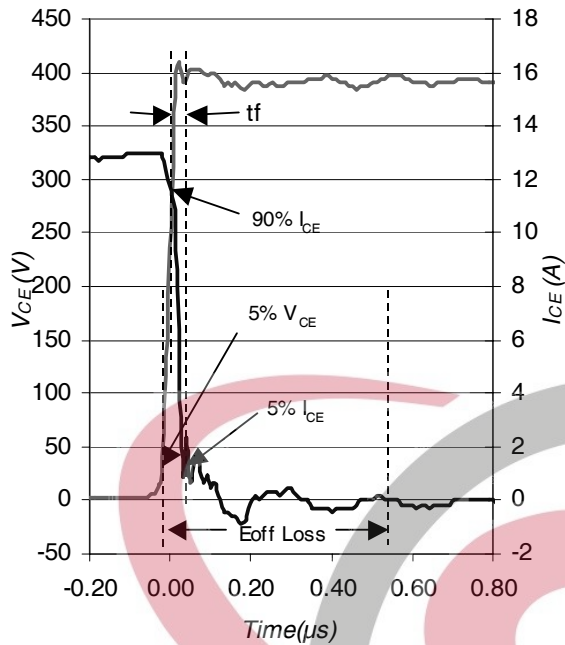
Fig. C.T.5 - Reverse Recovery Parameter
Test Circuit

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Fig. WF1 - Typ. Turn-off Loss Waveform
@ T_J = 125°C using Fig. CT.3
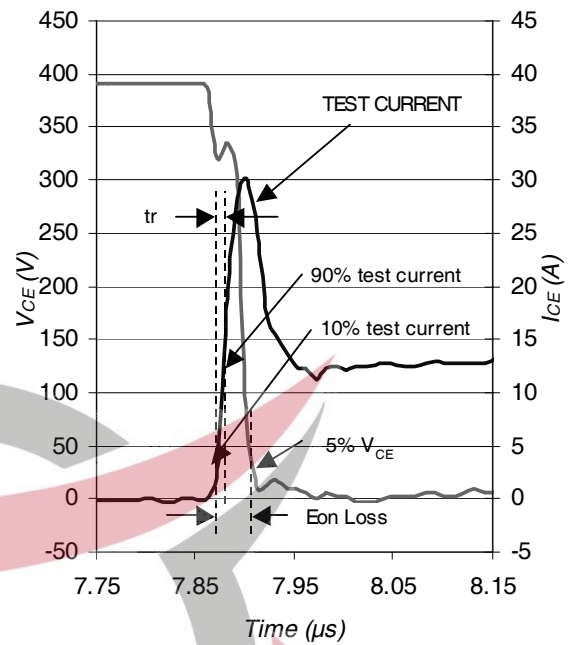
Fig. WF2 - Typ. Turn-on Loss Waveform
@ T_J = 125°C using Fig. CT.3

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

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TO-220AB Package Outline

Dimensions are shown in millimeters (inches)

2.87 (.113)
2.62 (.103)
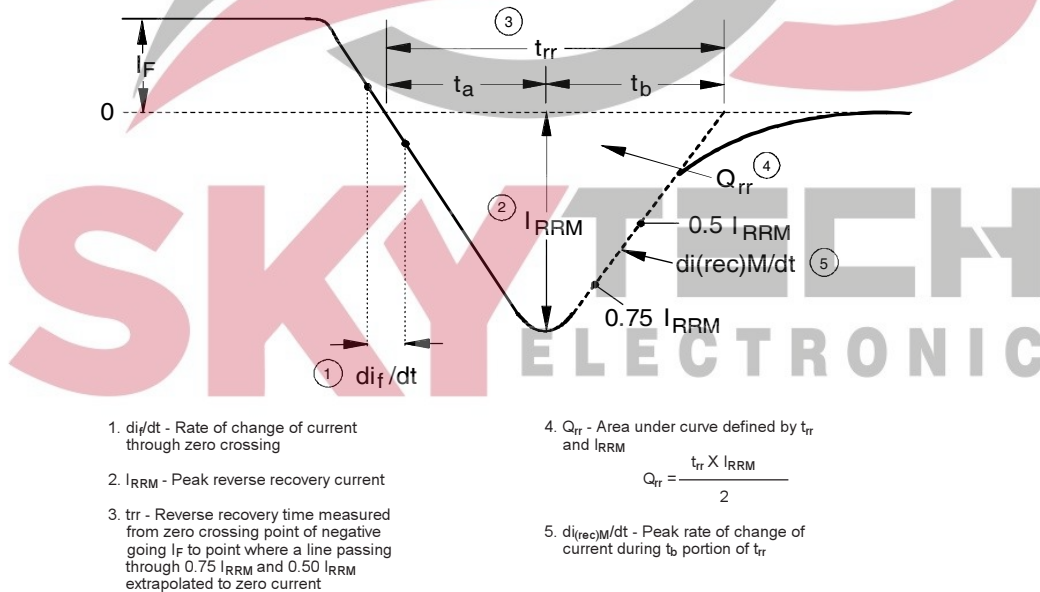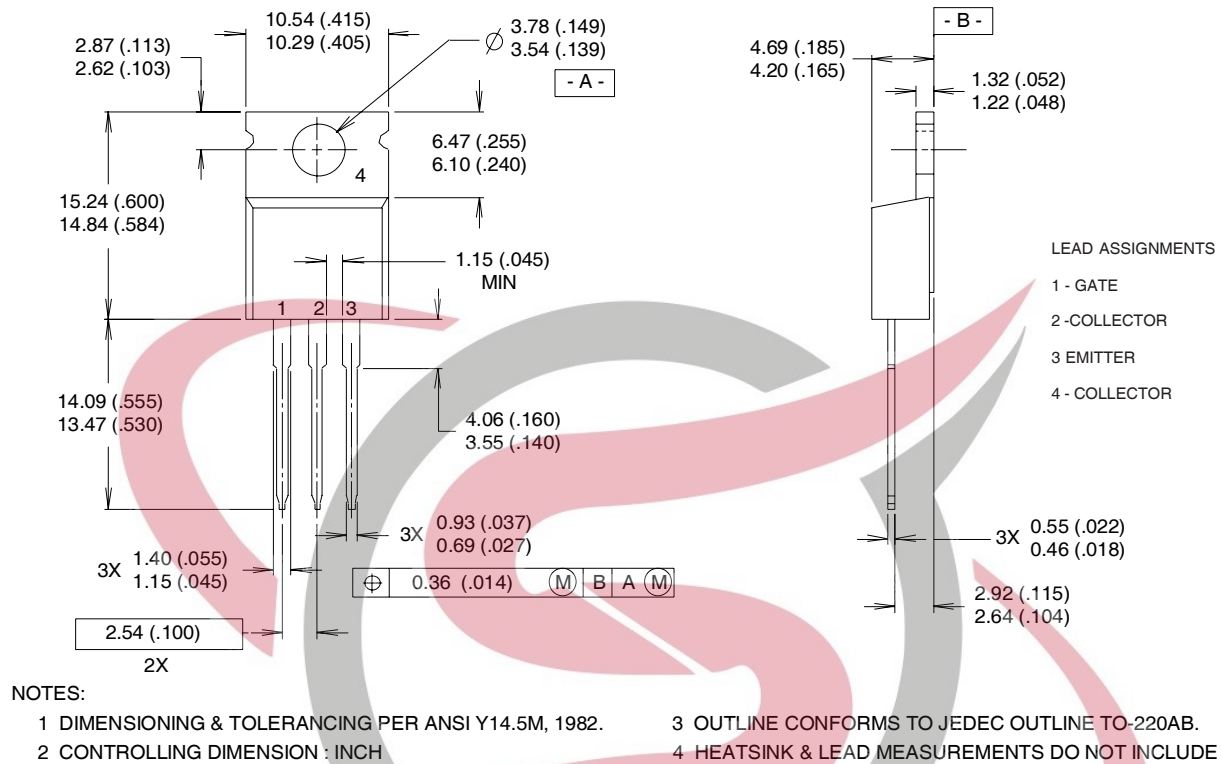
10.54 (.415)
10.29 (.405)

∅ 3.78 (.149)
3.54 (.139)

- A -

4.69 (.185)
4.20 (.165)

- B -

1.32 (.052)
1.22 (.048)

6.47 (.255)
6.10 (.240)

4

15.24 (.600)
14.84 (.584)

1.15 (.045)
MIN

1 2 3

14.09 (.555)
13.47 (.530)

4.06 (.160)
3.55 (.140)

LEAD ASSIGNMENTS

1 - GATE

2 -COLLECTOR

3 EMITTER

4 - COLLECTOR

3X 0.93 (.037)
0.69 (.027)

3X 1.40 (.055)
1.15 (.045)

⊕ 0.36 (.014) Ⓜ B A Ⓜ

3X 0.55 (.022)
0.46 (.018)

2.92 (.115)
2.64 (.104)

2.54 (.100)
2X

NOTES:
1 DIMENSIONING & TOLERANCING PER ANSI Y14.5M, 1982.
2 CONTROLLING DIMENSION : INCH
3 OUTLINE CONFORMS TO JEDEC OUTLINE TO-220AB.
4 HEATSINK & LEAD MEASUREMENTS DO NOT INCLUDE BURRS.

TO-220AB Part Marking Information

EXAMPLE: THIS IS AN IRF1010
LOT CODE 1789
ASSEMBLED ON WW 19, 1997
IN THE ASSEMBLY LINE "C"

INTERNATIONAL
RECTIFIER
LOGO

PART NUMBER

IRF1010
IƏR 719C
17   89

ASSEMBLY
LOT CODE

DATE CODE
YEAR 7 = 1997
WEEK 19
LINE C
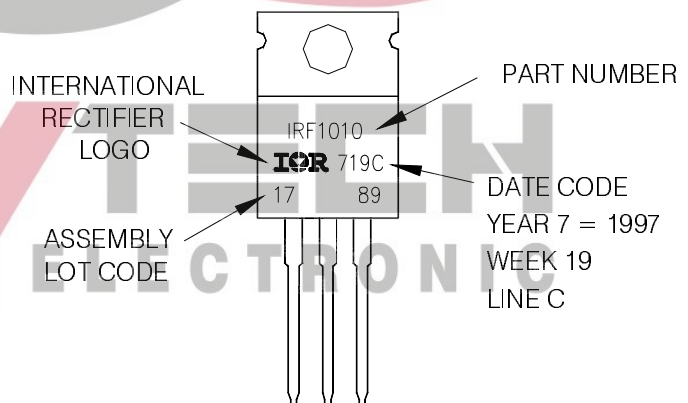
TO-220AB package is not recommended for Surface Mount Application.

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