International IƠR Rectifier

IRF1405PbF

HEXFET® Power MOSFET
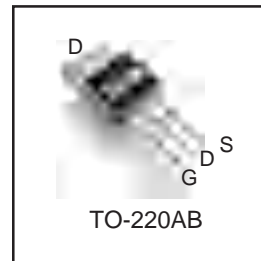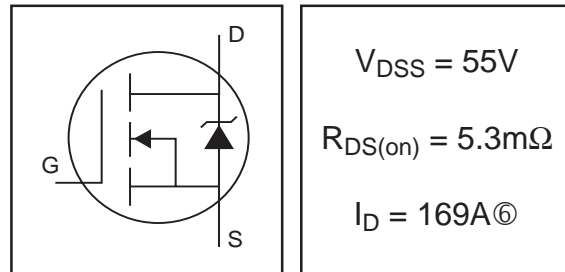
Typical Applications
- Industrial motor drive

Benefits
- Advanced Process Technology
- Ultra Low On-Resistance
- Dynamic dv/dt Rating
- 175°C Operating Temperature
- Fast Switching
- Repetitive Avalanche Allowed up to Tjmax
- Lead-Free

$V_{DSS} = 55V$

$R_{DS(on)} = 5.3m\Omega$

$I_D = 169A⑥$

TO-220AB

Description

This Stripe Planar design of HEXFET® Power MOSFETs utilizes the latest processing techniques to achieve extremely low on-resistance per silicon area. Additional features of this HEXFET power MOSFET are a 175°C junction operating temperature, fast switching speed and improved repetitive avalanche rating. These benefits combine to make this design an extremely efficient and reliable device for use in a wide variety of applications.
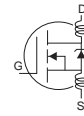
Absolute Maximum Ratings

	Parameter	Max.	Units
I_D @ T_C = 25°C	Continuous Drain Current, V_{GS} @ 10V	169⑥	A
I_D @ T_C = 100°C	Continuous Drain Current, V_{GS} @ 10V	118⑥	
I_{DM}	Pulsed Drain Current ①	680	
P_D @T_C = 25°C	Power Dissipation	330	W
	Linear Derating Factor	2.2	W/°C
V_{GS}	Gate-to-Source Voltage	± 20	V
E_{AS}	Single Pulse Avalanche Energy②	560	mJ
I_{AR}	Avalanche Current ①	See Fig.12a, 12b, 15, 16	A
E_{AR}	Repetitive Avalanche Energy ⑦		mJ
dv/dt	Peak Diode recovery dv/dt③	5.0	V/ns
T_J	Operating Junction and	-55 to + 175	
T_{STG}	Storage Temperature Range		°C
	Soldering Temperature, for 10 seconds	300 (1.6mm from case)	
	Mounting Torque, 6-32 or M3 screw	10 lbf•in (1.1N•m)	

Thermal Resistance

	Parameter	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	——	0.45	
$R_{\theta CS}$	Case-to-Sink, Flat, Greased Surface	0.50	——	°C/W
$R_{\theta JA}$	Junction-to-Ambient	——	62	

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Electrical Characteristics @ TJ = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)DSS}$	Drain-to-Source Breakdown Voltage	55	——	——	V	$V_{GS} = 0V$, $I_D = 250\mu A$
$\Delta V_{(BR)DSS}/\Delta T_J$	Breakdown Voltage Temp. Coefficient	——	0.057	——	V/°C	Reference to 25°C, $I_D = 1mA$
$R_{DS(on)}$	Static Drain-to-Source On-Resistance	——	4.6	5.3	mΩ	$V_{GS} = 10V$, $I_D = 101A$ ④
$V_{GS(th)}$	Gate Threshold Voltage	2.0	——	4.0	V	$V_{DS} = V_{GS}$, $I_D = 250\mu A$
gfs	Forward Transconductance	69	——	——	S	$V_{DS} = 25V$, $I_D = 101A$
I_{DSS}	Drain-to-Source Leakage Current	——	——	20	μA	$V_{DS} = 55V$, $V_{GS} = 0V$
		——	——	250		$V_{DS} = 44V$, $V_{GS} = 0V$, $T_J = 150°C$
I_{GSS}	Gate-to-Source Forward Leakage	——	——	200	nA	$V_{GS} = 20V$
	Gate-to-Source Reverse Leakage	——	——	-200		$V_{GS} = -20V$
Q_g	Total Gate Charge	——	170	260		$I_D = 101A$
Q_{gs}	Gate-to-Source Charge	——	44	66	nC	$V_{DS} = 44V$
Q_{gd}	Gate-to-Drain ("Miller") Charge	——	62	93		$V_{GS} = 10V$ ④
$t_{d(on)}$	Turn-On Delay Time	——	13	——		$V_{DD} = 38V$
t_r	Rise Time	——	190	——		$I_D = 101A$
$t_{d(off)}$	Turn-Off Delay Time	——	130	——	ns	$R_G = 1.1\ \Omega$
t_f	Fall Time	——	110	——		$V_{GS} = 10V$ ④
L_D	Internal Drain Inductance	——	4.5	——	nH	Between lead, 6mm (0.25in.) from package and center of die contact
L_S	Internal Source Inductance	——	7.5	——		
C_{iss}	Input Capacitance	——	5480	——		$V_{GS} = 0V$
C_{oss}	Output Capacitance	——	1210	——		$V_{DS} = 25V$
C_{rss}	Reverse Transfer Capacitance	——	280	——	pF	$f = 1.0MHz$, See Fig.5
C_{oss}	Output Capacitance	——	5210	——		$V_{GS} = 0V$, $V_{DS} = 1.0V$, $f = 1.0MHz$
C_{oss}	Output Capacitance	——	900	——		$V_{GS} = 0V$, $V_{DS} = 44V$, $f = 1.0MHz$
C_{oss} eff.	Effective Output Capacitance ⑤	——	1500	——		$V_{GS} = 0V$, $V_{DS} = 0V$ to 44V

Source-Drain Ratings and Characteristics

	Parameter	Min.	Typ.	Max.	Units	Conditions
I_S	Continuous Source Current (Body Diode)	——	——	169⑥	A	MOSFET symbol showing the integral reverse p-n junction diode.
I_{SM}	Pulsed Source Current (Body Diode) ①	——	——	680		
V_{SD}	Diode Forward Voltage	——	——	1.3	V	$T_J = 25°C$, $I_S = 101A$, $V_{GS} = 0V$ ④
t_{rr}	Reverse Recovery Time	——	88	130	ns	$T_J = 25°C$, $I_F = 101A$
Q_{rr}	Reverse Recovery Charge	——	250	380	nC	di/dt = 100A/μs ④
t_{on}	Forward Turn-On Time	Intrinsic turn-on time is negligible (turn-on is dominated by LS+LD)				

Notes:

① Repetitive rating; pulse width limited by max. junction temperature. (See fig. 11).

② Starting $T_J = 25°C$, L = 0.11mH $R_G = 25\Omega$, $I_{AS} = 101A$. (See Figure 12).

③ $I_{SD} \leq 101A$, di/dt $\leq 210A/\mu s$, $V_{DD} \leq V_{(BR)DSS}$, $T_J \leq 175°C$

④ Pulse width $\leq 400\mu s$; duty cycle $\leq 2\%$.

⑤ C_{oss} eff. is a fixed capacitance that gives the same charging time as C_{oss} while V_{DS} is rising from 0 to 80% V_{DSS}.

⑥ Calculated continuous current based on maximum allowable junction temperature. Package limitation current is 75A.

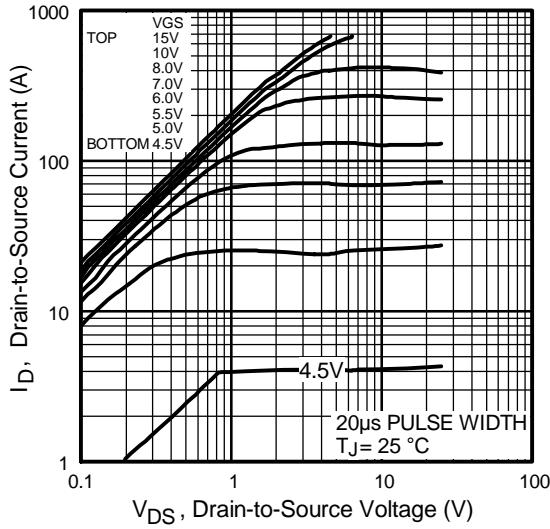⑦ Limited by T_{Jmax}, see Fig.12a, 12b, 15, 16 for typical repetitive avalanche performance.

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Fig 1. Typical Output Characteristics
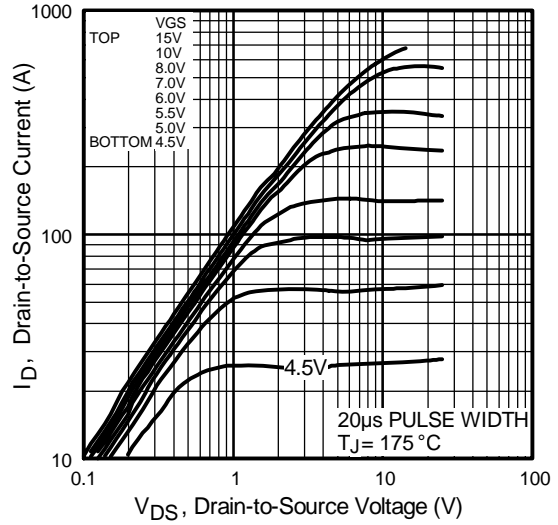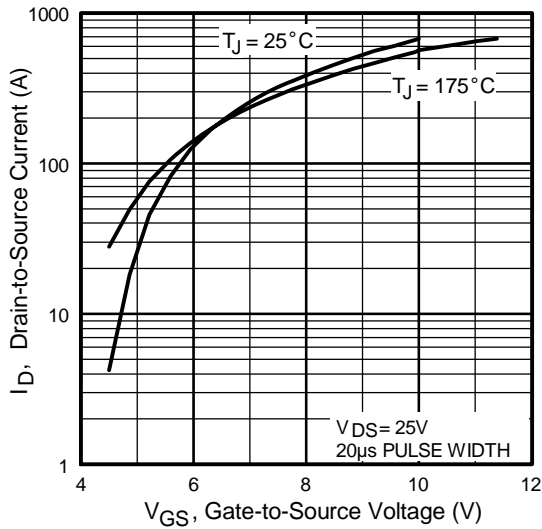

Fig 2. Typical Output Characteristics

Fig 3. Typical Transfer Characteristics

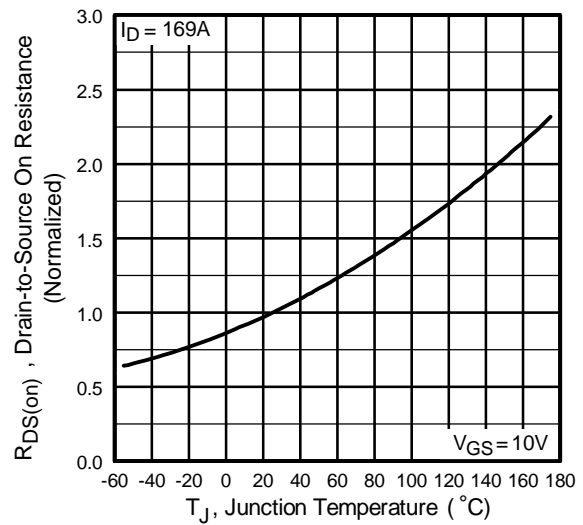**Fig 4.** Normalized On-Resistance
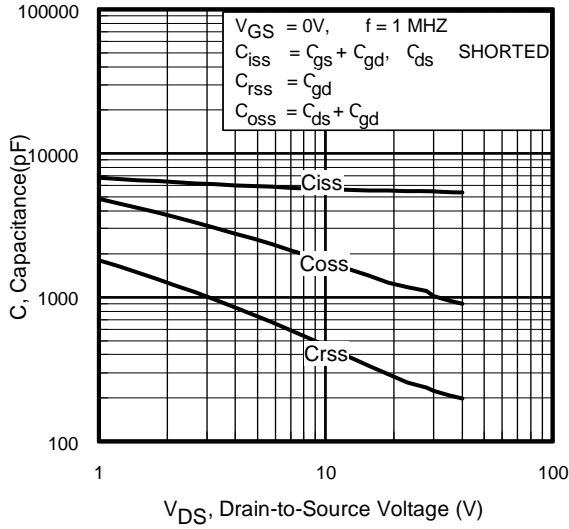Vs. Temperature

3

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Fig 5. Typical Capacitance Vs.
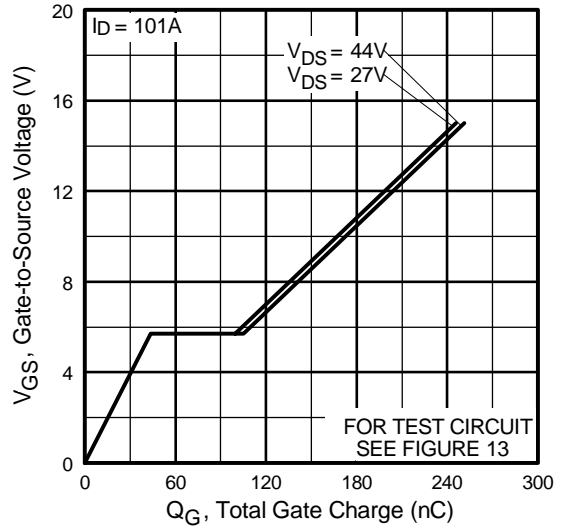Drain-to-Source Voltage

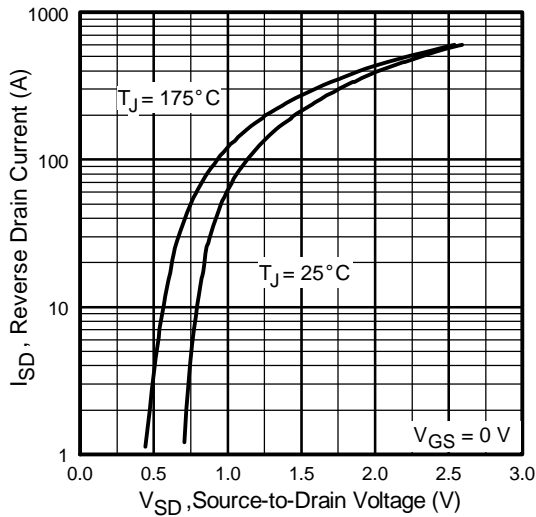

Fig 6. Typical Gate Charge Vs.
Gate-to-Source Voltage

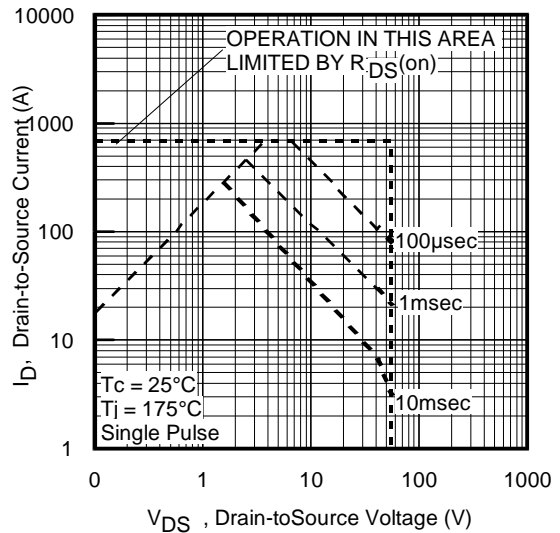**Fig 7.** Typical Source-Drain Diode
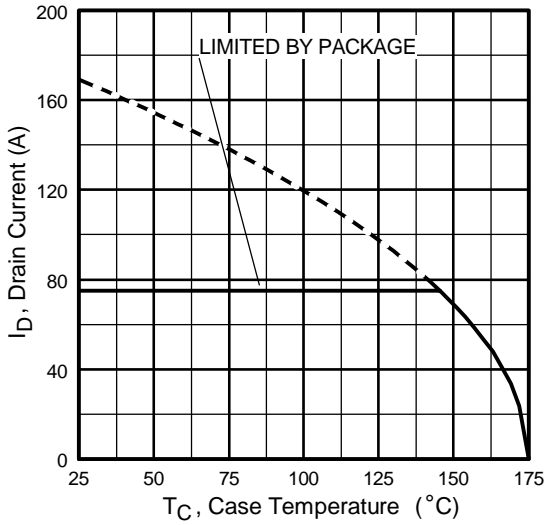Forward Voltage

Fig 8. Maximum Safe Operating Area

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Fig 9. Maximum Drain Current Vs.
Case Temperature

Fig 10a. Switching Time Test Circuit

Pulse Width ≤ 1 μs
Duty Factor ≤ 0.1 %

10V

Fig 10b. Switching Time Waveforms

SINGLE PULSE
(THERMAL RESPONSE)

Notes:
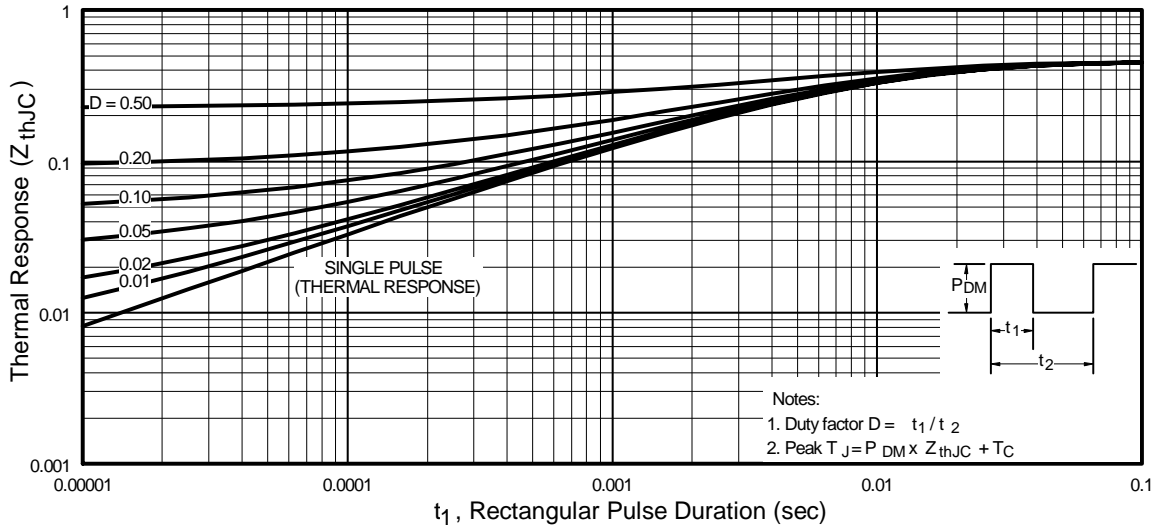1. Duty factor D = t_1 / t_2
2. Peak $T_J = P_{DM} \times Z_{thJC} + T_C$

Fig 11. Maximum Effective Transient Thermal Impedance, Junction-to-Case
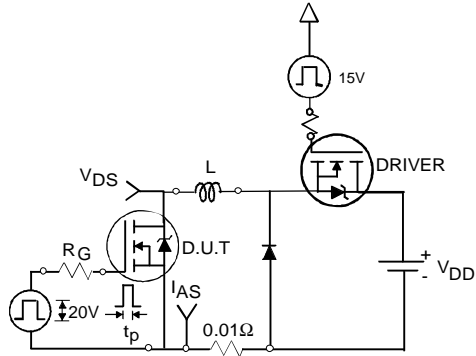
IRF1405PbF

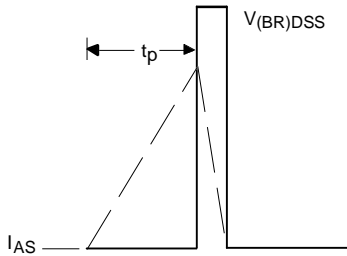**Fig 12a.** Unclamped Inductive Test Circuit

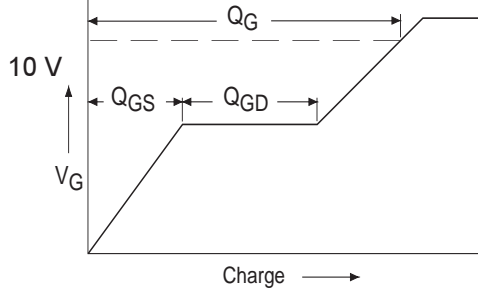**Fig 12b.** Unclamped Inductive Waveforms

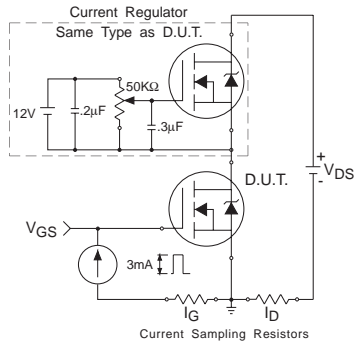**Fig 13a.** Basic Gate Charge Waveform
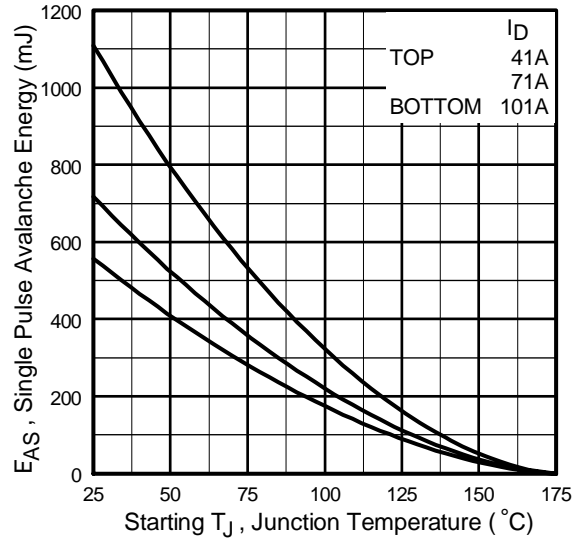

Fig 13b. Gate Charge Test Circuit

6

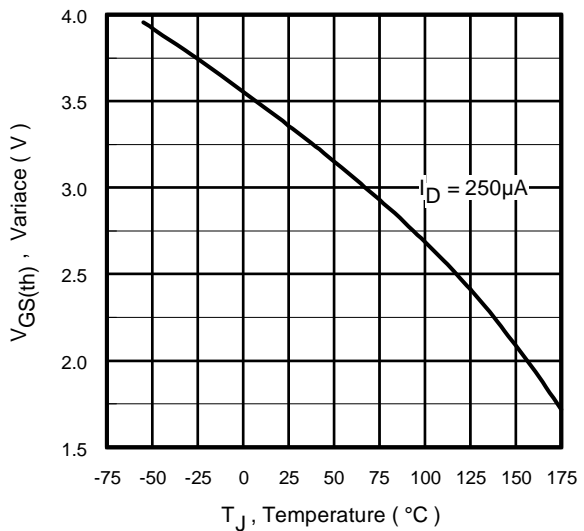**Fig 12c.** Maximum Avalanche Energy
Vs. Drain Current

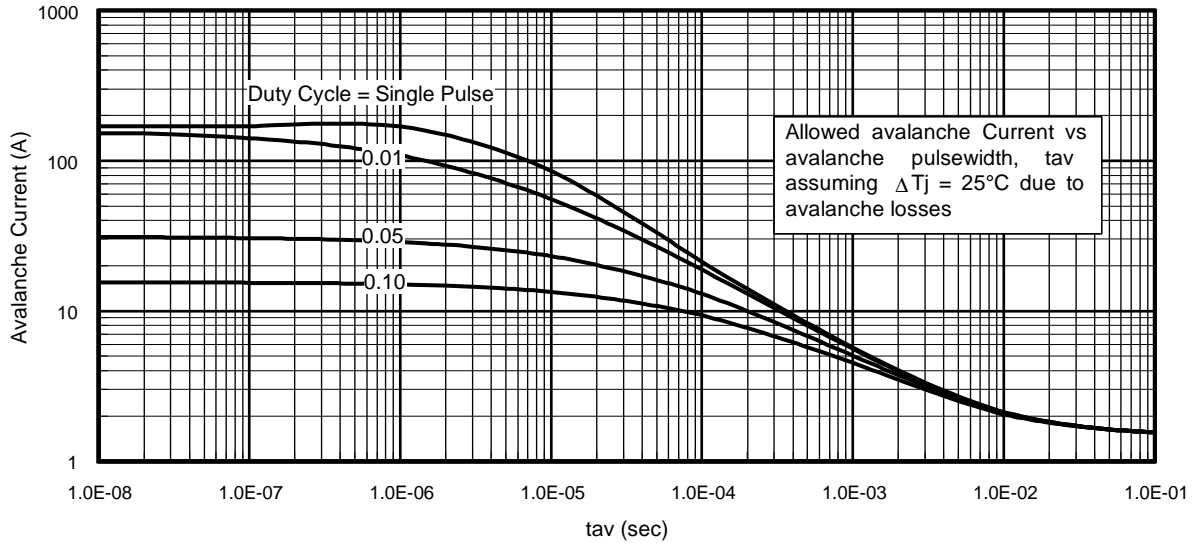
Fig 14. Threshold Voltage Vs. Temperature

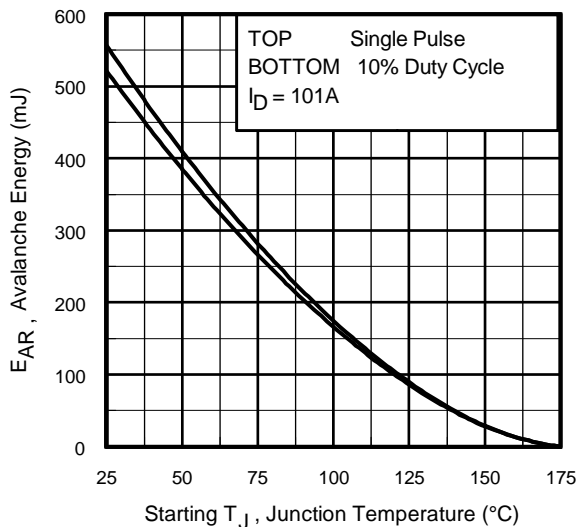**Fig 15.** Typical Avalanche Current Vs.Pulsewidth

Fig 16. Maximum Avalanche Energy Vs. Temperature

Notes on Repetitive Avalanche Curves , Figures 15, 16:
(For further info, see AN-1005 at www.irf.com)
1. Avalanche failures assumption:
   Purely a thermal phenomenon and failure occurs at a temperature far in excess of T_{jmax}. This is validated for every part type.
2. Safe operation in Avalanche is allowed as long as T_{jmax} is not exceeded.
3. Equation below based on circuit and waveforms shown in Figures 12a, 12b.
4. $P_{D\ (ave)}$ = Average power dissipation per single avalanche pulse.
5. BV = Rated breakdown voltage (1.3 factor accounts for voltage increase during avalanche).
6. I_{av} = Allowable avalanche current.
7. ΔT = Allowable rise in junction temperature, not to exceed T_{jmax} (assumed as 25°C in Figure 15, 16).
   t_{av} = Average time in avalanche.
   D = Duty cycle in avalanche = $t_{av} \cdot f$
   $Z_{thJC}(D, t_{av})$ = Transient thermal resistance, see figure 11)

$$P_{D\ (ave)} = 1/2\ (\ 1.3 \cdot BV \cdot I_{av}) = \Delta T/\ Z_{thJC}$$
$$I_{av} = 2\Delta T/\ [1.3 \cdot BV \cdot Z_{th}]$$
$$E_{AS\ (AR)} = P_{D\ (ave)} \cdot t_{av}$$

Peak Diode Recovery dv/dt Test Circuit

D.U.T*

Circuit Layout Considerations
- Low Stray Inductance
- Ground Plane
- Low Leakage Inductance
  Current Transformer

- dv/dt controlled by R_G
- I_{SD} controlled by Duty Factor "D"
- D.U.T. - Device Under Test

V_{DD}

V_{GS}

* Reverse Polarity of D.U.T for P-Channel

① Driver Gate Drive

P.W.

Period

$D = \dfrac{P.W.}{Period}$

$\left[V_{GS}=10V\right]$ ***

② D.U.T. I_{SD} Waveform

Reverse
Recovery
Current

Body Diode Forward
Current

di/dt

③ D.U.T. V_{DS} Waveform

Diode Recovery
dv/dt

$\left[V_{DD}\right]$

Re-Applied
Voltage

Body Diode   Forward Drop

④ Inductor Curent

Ripple ≤ 5%

$\left[I_{SD}\right]$

*** V_{GS} = 5.0V for Logic Level and 3V Drive Devices

Fig 17. For N-channel HEXFET® power MOSFETs

TO-220AB Package Outline

Dimensions are shown in millimeters (inches)

NOTES:
1.– DIMENSIONING AND TOLERANCING AS PER ASME Y14.5 M– 1994.
2.– DIMENSIONS ARE SHOWN IN INCHES [MILLIMETERS].
3.– LEAD DIMENSION AND FINISH UNCONTROLLED IN L1.
4.– DIMENSION D, D1 & 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.
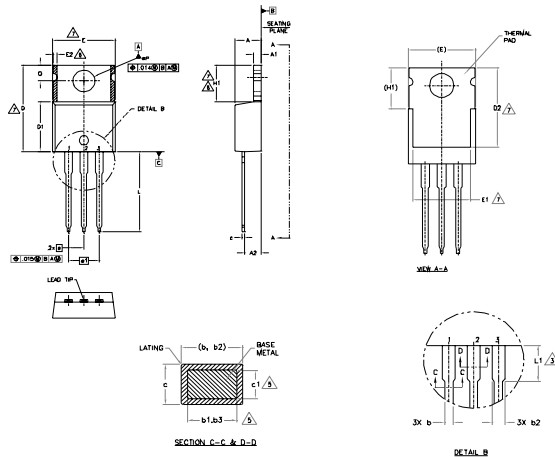5.– DIMENSION b1, b3 & c1 APPLY TO BASE METAL ONLY.
6.– CONTROLLING DIMENSION : INCHES.
7.– THERMAL PAD CONTOUR OPTIONAL WITHIN DIMENSIONS E,H1,D2 & E1
8.– DIMENSION E2 X H1 DEFINE A ZONE WHERE STAMPING AND SINGULATION IRREGULARITIES ARE ALLOWED.
9.– OUTLINE CONFORMS TO JEDEC TO–220, EXCEPT A2 (max.) AND D2 (min.) WHERE DIMENSIONS ARE DERIVED FROM THE ACTUAL PACKAGE OUTLINE.

SYMBOL	DIMENSIONS				
	MILLIMETERS		INCHES		
	MIN.	MAX.	MIN.	MAX.	NOTES
A	3.56	4.83	.140	.190	
A1	0.51	1.40	.020	.055	
A2	2.03	2.92	.080	.115	
b	0.38	1.01	.015	.040	
b1	0.38	0.97	.015	.038	5
b2	1.14	1.78	.045	.070	
b3	1.14	1.73	.045	.068	5
c	0.36	0.61	.014	.024	
c1	0.36	0.56	.014	.022	5
D	14.22	16.51	.560	.650	4
D1	8.38	9.02	.330	.355	
D2	11.68	12.88	.460	.507	7
E	9.65	10.67	.380	.420	4,7
E1	6.86	8.89	.270	.350	7
E2	–	2.54 BSC	–	.030	8
e	2.54 BSC		.100 BSC		
e1	5.08 BSC		.200 BSC		
H1	5.84	6.86	.230	.270	7,8
L	12.70	14.73	.500	.580	
L1	3.56	4.06	.140	.160	3
øP	3.54	4.08	.139	.161	
Q	2.54	3.42	.100	.135	

LEAD ASSIGNMENTS

HEXFET
1– GATE
2– DRAIN
3– SOURCE
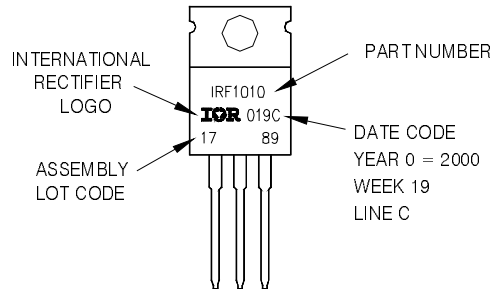
IGBTs, CoPACK
1– GATE
2– COLLECTOR
3– EMITTER

DIODES
1.– ANODE
2 – CATHODE
3.– ANODE

TO-220AB Part Marking Information

EXAMPLE: THIS IS AN IRF1010
LOT CODE 1789
ASSEMBLED ON WW 19, 2000
IN THE ASSEMBLY LINE "C"

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

INTERNATIONAL RECTIFIER LOGO

PART NUMBER

IRF1010
IOR 019C
17   89

DATE CODE
YEAR 0 = 2000
WEEK 19
LINE C

ASSEMBLY LOT CODE

TO-220AB packages are not recommended for Surface Mount Application.

Notes:
1. For an Automotive Qualified version of this part please see http://www.irf.com/product-info/auto/
2. For the most current drawing please refer to IR website at http://www.irf.com/package/

Data and specifications subject to change without notice.
This product has been designed and qualified for the Industrial market.
Qualification Standards can be found on IR's Web site.

International **IOR** Rectifier

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