

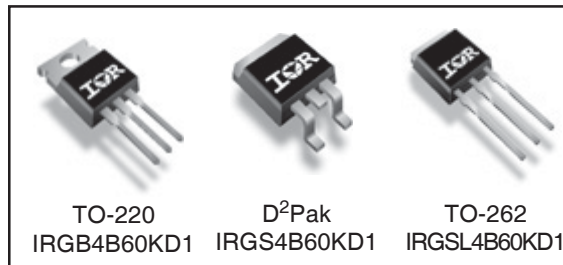
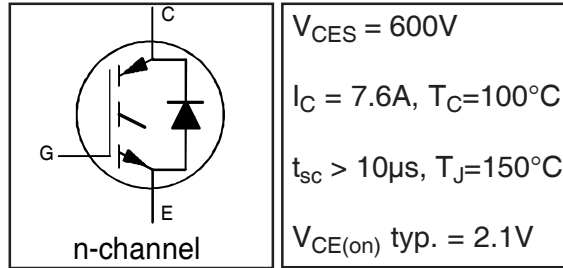
INSULATED GATE BIPOLAR TRANSISTOR WITH  
ULTRAFAST SOFT RECOVERY DIODE

**Features**

- Low VCE (on) Non Punch Through IGBT Technology.
- 10µs Short Circuit Capability.
- Square RBSOA.
- Positive VCE (on) Temperature Coefficient.
- Maximum Junction Temperature rated at 175°C.
- Lead-Free

**Benefits**

- Benchmark Efficiency for Motor Control.
- Rugged Transient Performance.
- Low EMI.
- Excellent Current Sharing in Parallel Operation.



**Absolute Maximum Ratings**

	Parameter	Max.	Units
$V_{CES}$	Collector-to-Emitter Voltage	600	V
$I_C @ T_C = 25^\circ C$	Continuous Collector Current	11	A
$I_C @ T_C = 100^\circ C$	Continuous Collector Current	7.6	
$I_{CM}$	Pulse Collector Current (Ref.Fig.C.T.5)	22	
$I_{LM}$	Clamped Inductive Load current ①	22	
$I_F @ T_C = 25^\circ C$	Diode Continuous Forward Current	11	
$I_F @ T_C = 100^\circ C$	Diode Continuous Forward Current	6.7	
$I_{FM}$	Diode Maximum Forward Current	22	V
$V_{GE}$	Gate-to-Emitter Voltage	±20	
$P_D @ T_C = 25^\circ C$	Maximum Power Dissipation	63	W
$P_D @ T_C = 100^\circ C$	Maximum Power Dissipation	31	
$T_J$	Operating Junction and	-55 to +175	°C
$T_{STG}$	Storage Temperature Range		
	Storage Temperature Range, for 10 sec.	300 (0.063 in. (1.6mm) from case)	

**Thermal / Mechanical Characteristics**

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case- IGBT	—	—	2.4	°C/W
$R_{\theta JC}$	Junction-to-Case- Diode	—	—	6.1	
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	—	0.50	—	
$R_{\theta JA}$	Junction-to-Ambient	—	—	62	
$R_{\theta JA}$	Junction-to-Ambient (PCB Mount, steady state)②	—	—	40	
Wt	Weight	—	1.44	—	g

# IRGB/S/SL4B60KD1PbF

International  
IR Rectifier

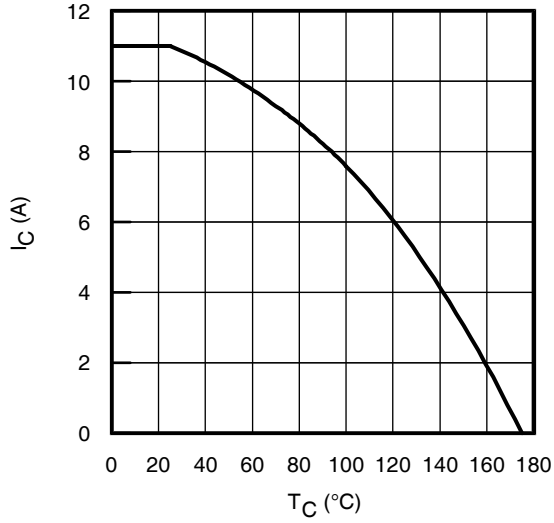
## Electrical Characteristics @ $T_J = 25^\circ\text{C}$ (unless otherwise specified)

	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	—	0.28	—	V/ $^\circ\text{C}$	$V_{GE} = 0V, I_C = 1mA (25^\circ\text{C}-150^\circ\text{C})$	
$V_{CE(on)}$	Collector-to-Emitter Voltage	—	2.1	2.5	V	$I_C = 4.0A, V_{GE} = 15V, T_J = 25^\circ\text{C}$	5,6,7
		—	2.5	2.8		$I_C = 4.0A, V_{GE} = 15V, T_J = 150^\circ\text{C}$	9,10,11
		—	2.6	2.9		$I_C = 4.0A, V_{GE} = 15V, T_J = 175^\circ\text{C}$	
$V_{GE(th)}$	Gate Threshold Voltage	3.5	4.5	5.5	V	$V_{CE} = V_{GE}, I_C = 250\mu A$	9,10,11
$\Delta V_{GE(th)}/\Delta T_J$	Threshold Voltage temp. coefficient	—	-8.1	—	mV/ $^\circ\text{C}$	$V_{CE} = V_{GE}, I_C = 1mA (25^\circ\text{C}-150^\circ\text{C})$	12
$g_{fe}$	Forward Transconductance	—	1.7	—	S	$V_{CE} = 50V, I_C = 4.0A, PW = 80\mu s$	
$I_{CES}$	Zero Gate Voltage Collector Current	—	1.0	150	$\mu A$	$V_{GE} = 0V, V_{CE} = 600V$	
		—	136	600		$V_{GE} = 0V, V_{CE} = 600V, T_J = 150^\circ\text{C}$	
		—	722	2400		$V_{GE} = 0V, V_{CE} = 600V, T_J = 175^\circ\text{C}$	
$V_{FM}$	Diode Forward Voltage Drop	—	1.4	2.0	V	$I_F = 4.0A$	8
		—	1.3	1.8		$I_F = 4.0A, T_J = 150^\circ\text{C}$	
		—	1.2	1.7		$I_F = 4.0A, T_J = 175^\circ\text{C}$	
$I_{GES}$	Gate-to-Emitter Leakage Current	—	—	$\pm 100$	nA	$V_{GE} = \pm 20V$	

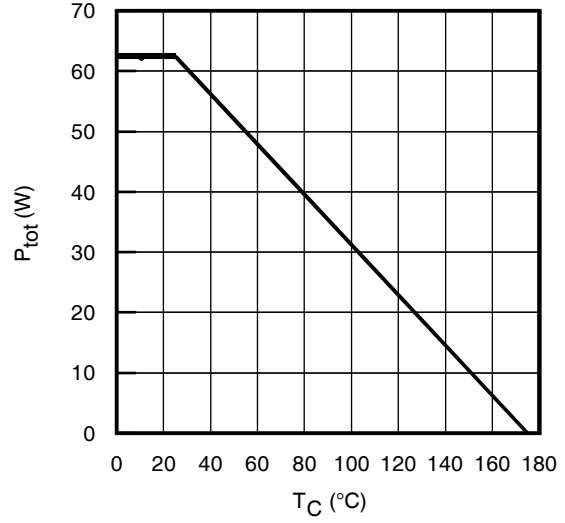
## Switching Characteristics @ $T_J = 25^\circ\text{C}$ (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	Ref.Fig.
$Q_g$	Total Gate Charge (turn-on)	—	12	—	nC	$I_C = 4.0A$	23
$Q_{ge}$	Gate-to-Emitter Charge (turn-on)	—	1.7	—		$V_{CC} = 400V$	CT1
$Q_{gc}$	Gate-to-Collector Charge (turn-on)	—	6.5	—		$V_{GE} = 15V$	
$E_{on}$	Turn-On Switching Loss	—	73	80	$\mu J$	$I_C = 4.0A, V_{CC} = 400V$	CT4
$E_{off}$	Turn-Off Switching Loss	—	47	53		$V_{GE} = 15V, R_G = 100\Omega, L = 2.5mH$	
$E_{tot}$	Total Switching Loss	—	120	130		$T_J = 25^\circ\text{C}$ ③	
$t_{d(on)}$	Turn-On delay time	—	22	28	ns	$I_C = 4.0A, V_{CC} = 400V$	CT4
$t_r$	Rise time	—	18	23		$V_{GE} = 15V, R_G = 100\Omega, L = 2.5mH$	
$t_{d(off)}$	Turn-Off delay time	—	100	110		$T_J = 25^\circ\text{C}$	
$t_f$	Fall time	—	66	80			
$E_{on}$	Turn-On Switching Loss	—	130	150	$\mu J$	$I_C = 4.0A, V_{CC} = 400V$	CT4
$E_{off}$	Turn-Off Switching Loss	—	83	140		$V_{GE} = 15V, R_G = 100\Omega, L = 2.5mH$	
$E_{tot}$	Total Switching Loss	—	220	280		$T_J = 150^\circ\text{C}$ ③	
$t_{d(on)}$	Turn-On delay time	—	22	27	ns	$I_C = 4.0A, V_{CC} = 400V$	14,16
$t_r$	Rise time	—	18	22		$V_{GE} = 15V, R_G = 100\Omega, L = 2.5mH$	
$t_{d(off)}$	Turn-Off delay time	—	120	130		$T_J = 150^\circ\text{C}$	
$t_f$	Fall time	—	79	89			
$C_{ies}$	Input Capacitance	—	190	—	pF	$V_{GE} = 0V$	22
$C_{oes}$	Output Capacitance	—	25	—		$V_{CC} = 30V$	
$C_{res}$	Reverse Transfer Capacitance	—	6.2	—		$f = 1.0MHz$	
RBSOA	Reverse Bias Safe Operating Area	FULL SQUARE				$T_J = 150^\circ\text{C}, I_C = 22A, V_p = 600V$ $V_{CC}=500V, V_{GE} = +15V \text{ to } 0V, R_G = 100\Omega$	4 CT2
SCSOA	Short Circuit Safe Operating Area	10	—	—	$\mu s$	$T_J = 150^\circ\text{C}, V_p = 600V, R_G = 100\Omega$ $V_{CC}=360V, V_{GE} = +15V \text{ to } 0V$	CT3 WF4
$E_{rec}$	Reverse Recovery Energy of the Diode	—	81	100	$\mu J$	$T_J = 150^\circ\text{C}$	17,18,19
$t_{rr}$	Diode Reverse Recovery Time	—	93	—	ns	$V_{CC} = 400V, I_F = 4.0A, L = 2.5mH$	20,21
$I_{rr}$	Peak Reverse Recovery Current	—	6.3	7.9	A	$V_{GE} = 15V, R_G = 100\Omega$	CT4,WF3

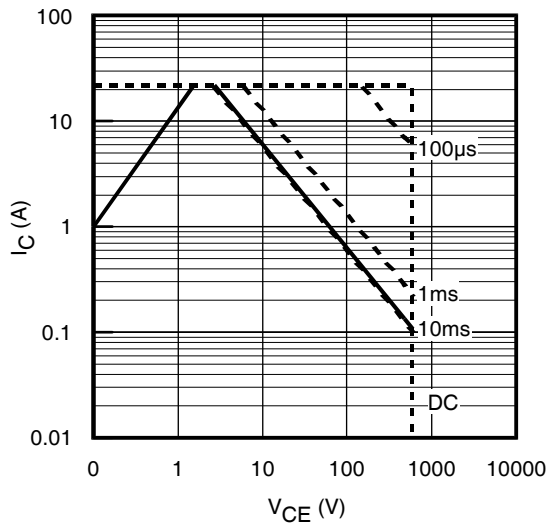
Note ① to ③ are on page 16



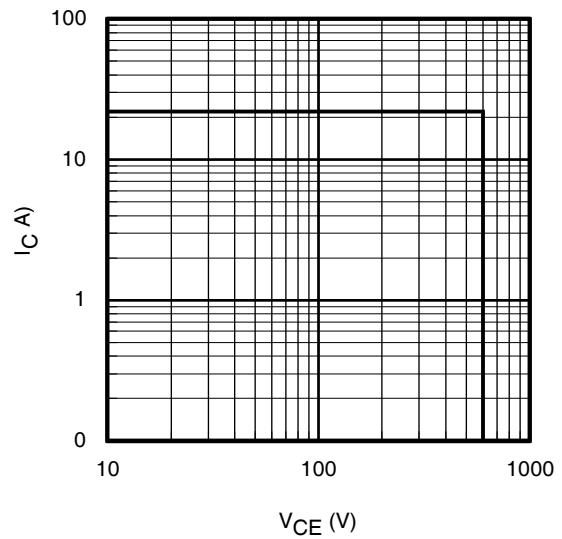
**Fig. 1** - Maximum DC Collector Current vs. Case Temperature



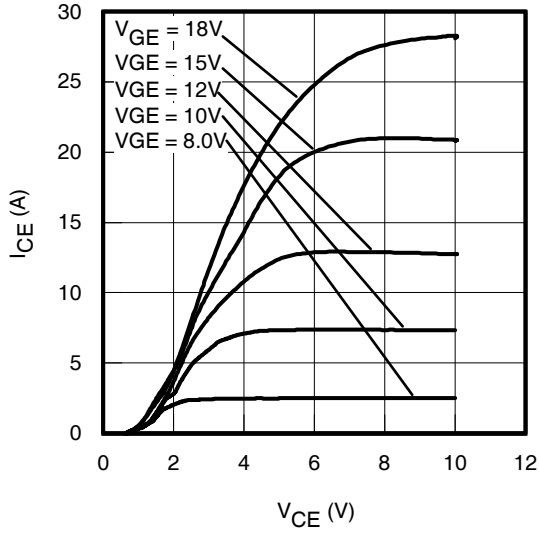
**Fig. 2** - Power Dissipation vs. Case Temperature



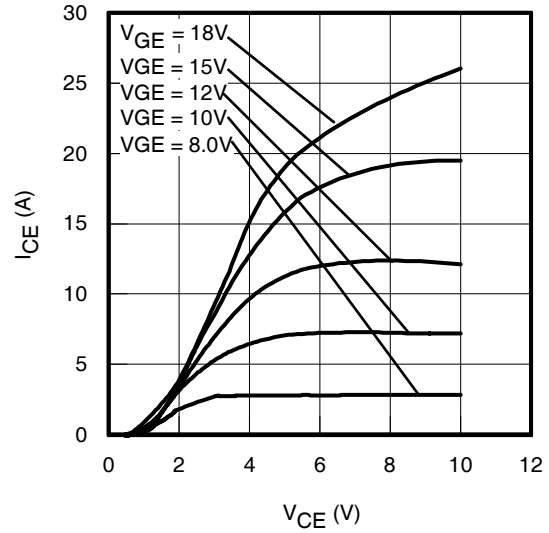
**Fig. 3** - Forward SOA  
 $T_C = 25^{\circ}C$ ;  $T_J \leq 150^{\circ}C$



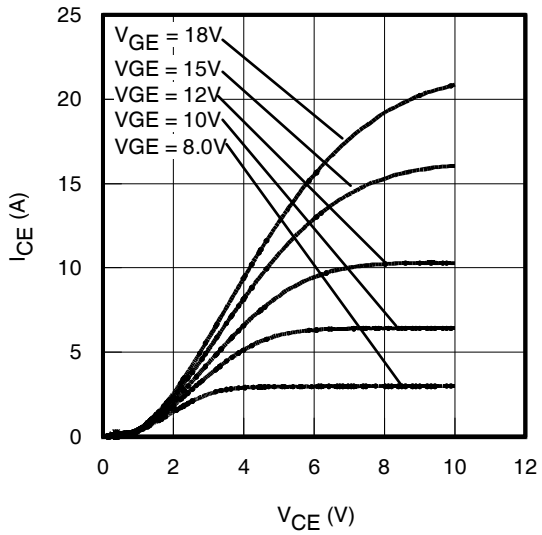
**Fig. 4** - Reverse Bias SOA  
 $T_J = 150^{\circ}C$ ;  $V_{GE} = 15V$



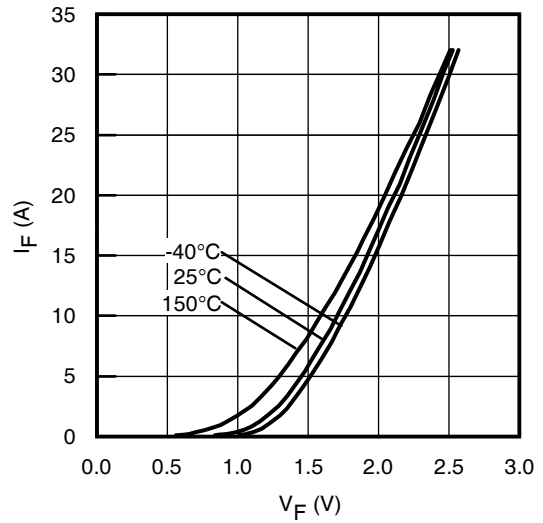
**Fig. 5** - Typ. IGBT Output Characteristics  
 $T_J = -40^\circ\text{C}$ ;  $t_p = 80\mu\text{s}$



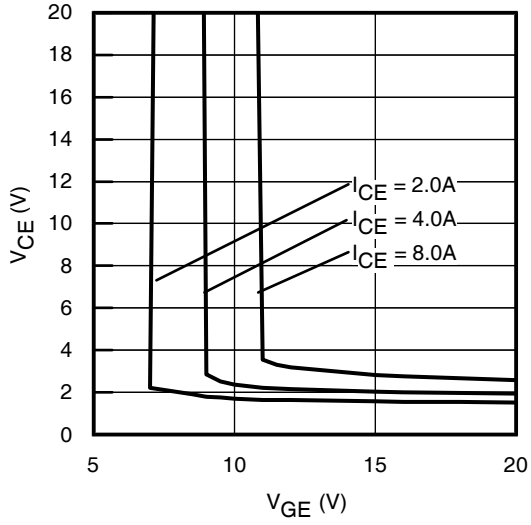
**Fig. 6** - Typ. IGBT Output Characteristics  
 $T_J = 25^\circ\text{C}$ ;  $t_p = 80\mu\text{s}$



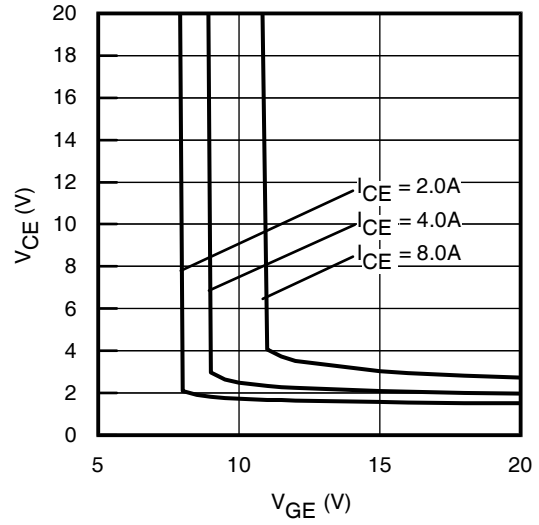
**Fig. 7** - Typ. IGBT Output Characteristics  
 $T_J = 150^\circ\text{C}$ ;  $t_p = 80\mu\text{s}$



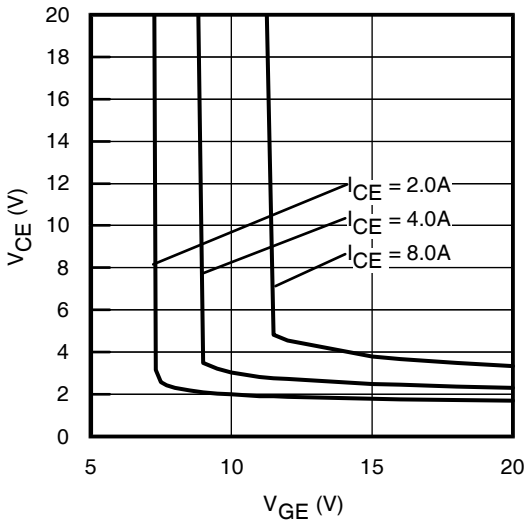
**Fig. 8** - Typ. Diode Forward Characteristics  
 $t_p = 80\mu\text{s}$



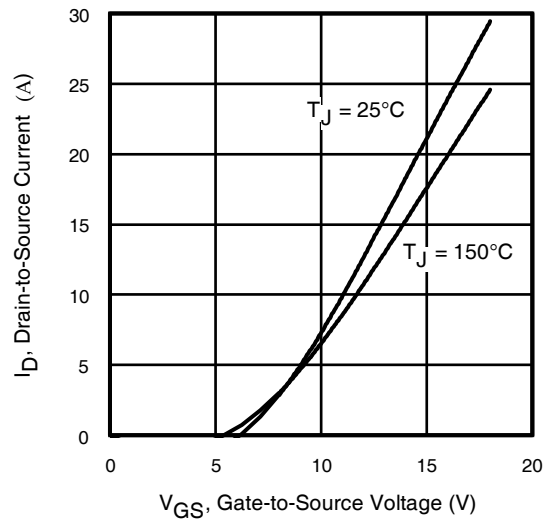
**Fig. 9** - Typical  $V_{CE}$  vs.  $V_{GE}$   
 $T_J = -40^\circ\text{C}$



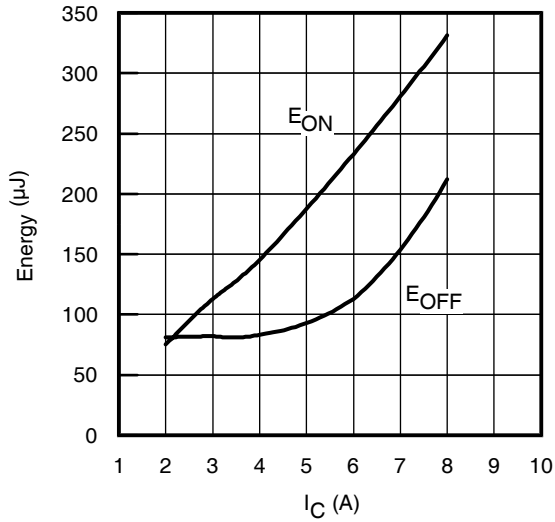
**Fig. 10** - Typical  $V_{CE}$  vs.  $V_{GE}$   
 $T_J = 25^\circ\text{C}$



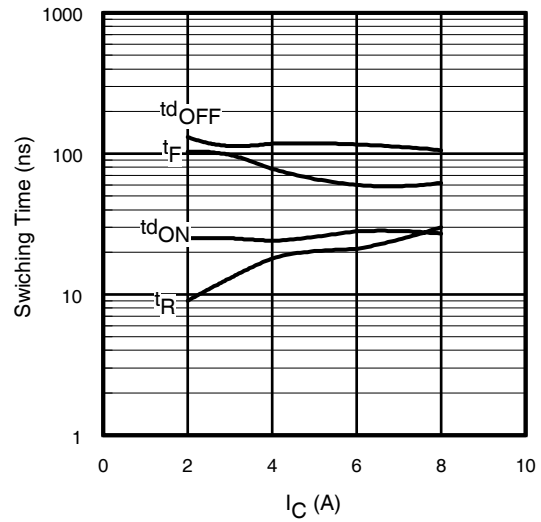
**Fig. 11** - Typical  $V_{CE}$  vs.  $V_{GE}$   
 $T_J = 150^\circ\text{C}$



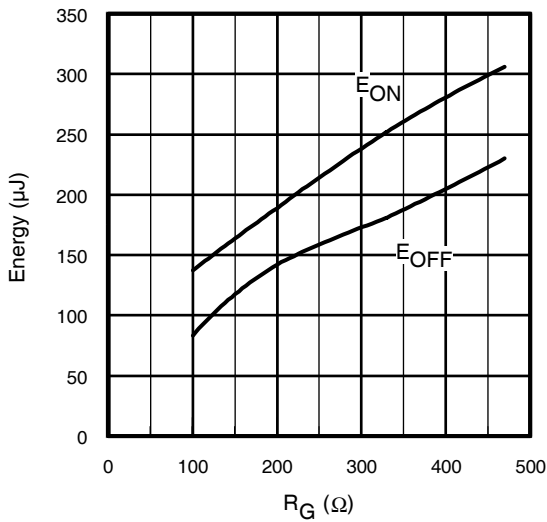
**Fig. 12** - Typ. Transfer Characteristics  
 $V_{CE} = 360\text{V}$ ;  $t_p = 10\mu\text{s}$



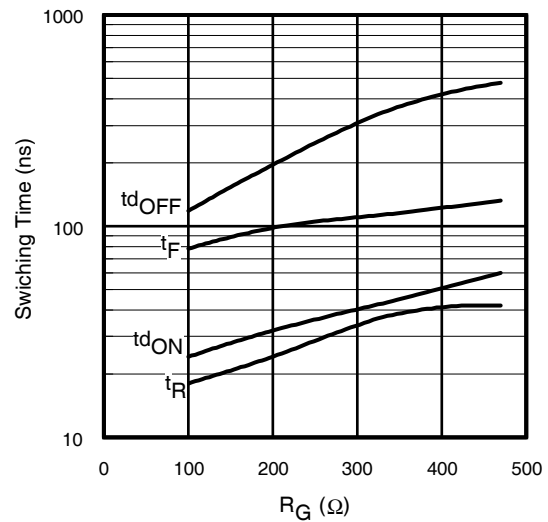
**Fig. 13** - Typ. Energy Loss vs. I<sub>C</sub>  
T<sub>J</sub> = 150°C; L=2.5mH; V<sub>CE</sub>= 400V,  
R<sub>G</sub>= 100Ω; V<sub>GE</sub>= 15V



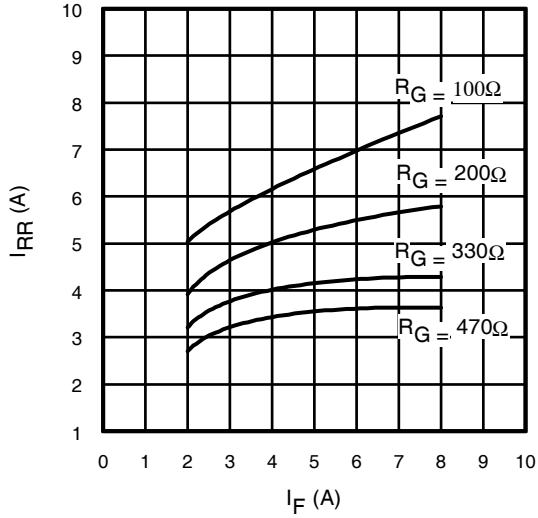
**Fig. 14** - Typ. Switching Time vs. I<sub>C</sub>  
T<sub>J</sub> = 150°C; L=2.5mH; V<sub>CE</sub>= 400V  
R<sub>G</sub>= 100Ω; V<sub>GE</sub>= 15V



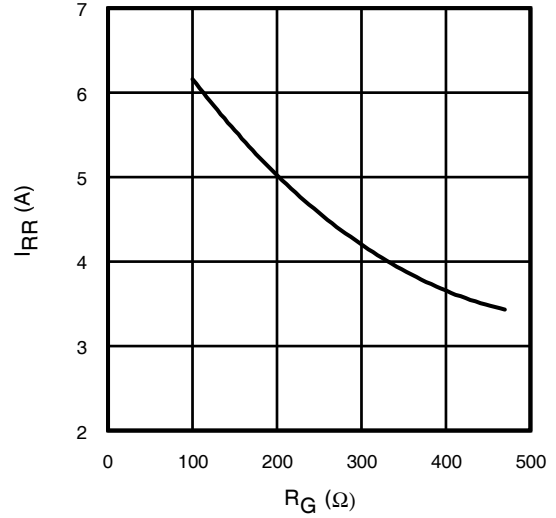
**Fig. 15** - Typ. Energy Loss vs. R<sub>G</sub>  
T<sub>J</sub> = 150°C; L=2.5mH; V<sub>CE</sub>= 400V  
I<sub>CE</sub>= 4.0A; V<sub>GE</sub>= 15V



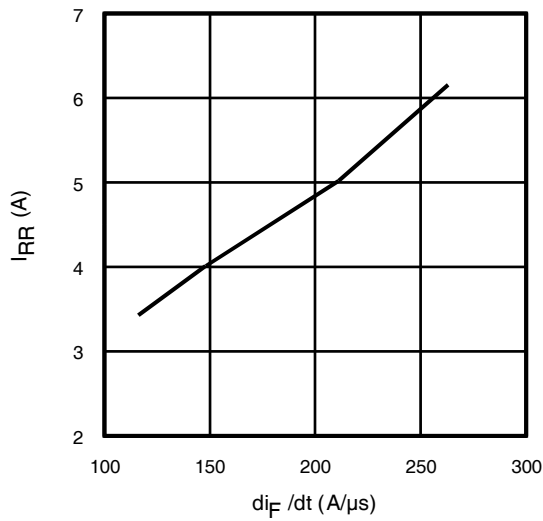
**Fig. 16** - Typ. Switching Time vs. R<sub>G</sub>  
T<sub>J</sub> = 150°C; L=2.5mH; V<sub>CE</sub>= 400V  
I<sub>CE</sub>= 4.0A; V<sub>GE</sub>= 15V



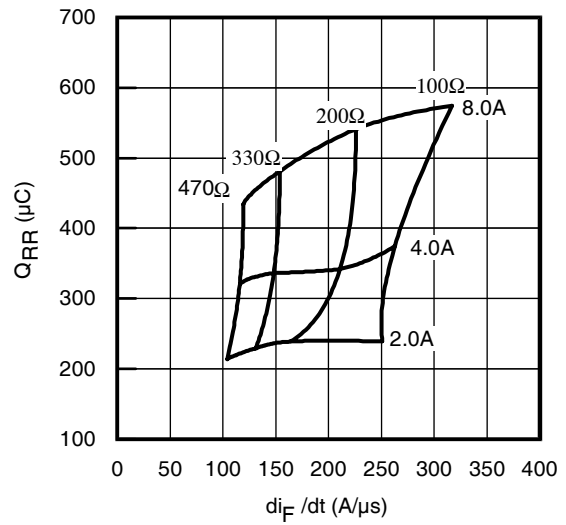
**Fig. 17** - Typical Diode  $I_{RR}$  vs.  $I_F$   
 $T_J = 150^\circ\text{C}$



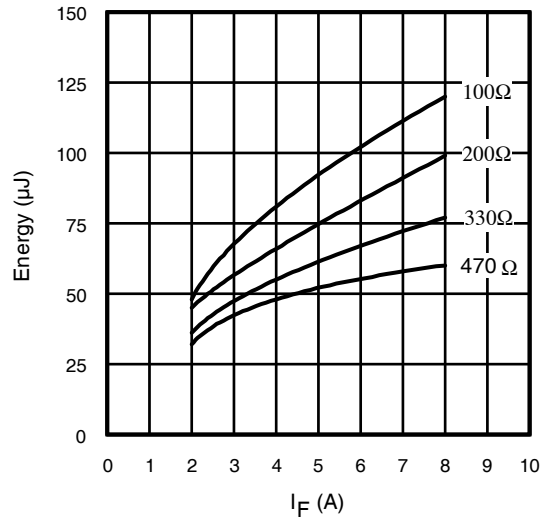
**Fig. 18** - Typical Diode  $I_{RR}$  vs.  $R_G$   
 $T_J = 150^\circ\text{C}$ ;  $I_F = 4.0\text{A}$



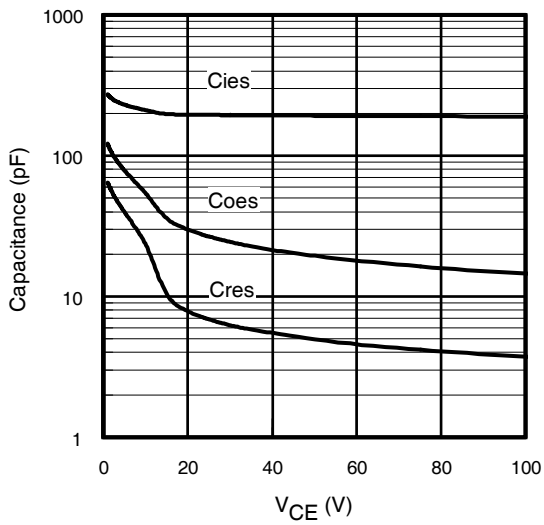
**Fig. 19**- Typical Diode  $I_{RR}$  vs. di/dt  
 $V_{CC} = 400\text{V}$ ;  $V_{GE} = 15\text{V}$ ;  
 $I_F = 4.0\text{A}$ ;  $T_J = 150^\circ\text{C}$



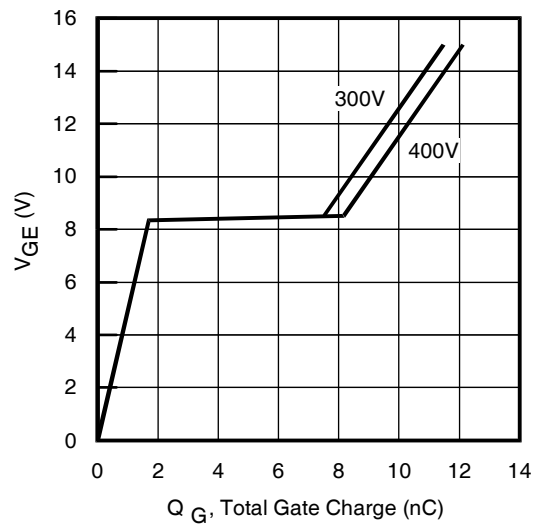
**Fig. 20** - Typical Diode  $Q_{RR}$   
 $V_{CC} = 400\text{V}$ ;  $V_{GE} = 15\text{V}$ ;  $T_J = 150^\circ\text{C}$



**Fig. 21** - Typical Diode  $E_{RR}$  vs.  $I_F$   
 $T_J = 150^\circ\text{C}$



**Fig. 22**- Typ. Capacitance vs.  $V_{CE}$   
 $V_{GE} = 0\text{V}$ ;  $f = 1\text{MHz}$



**Fig. 23** - Typical Gate Charge vs.  $V_{GE}$   
 $I_{CE} = 4.0\text{A}$ ;  $L = 3150\mu\text{H}$



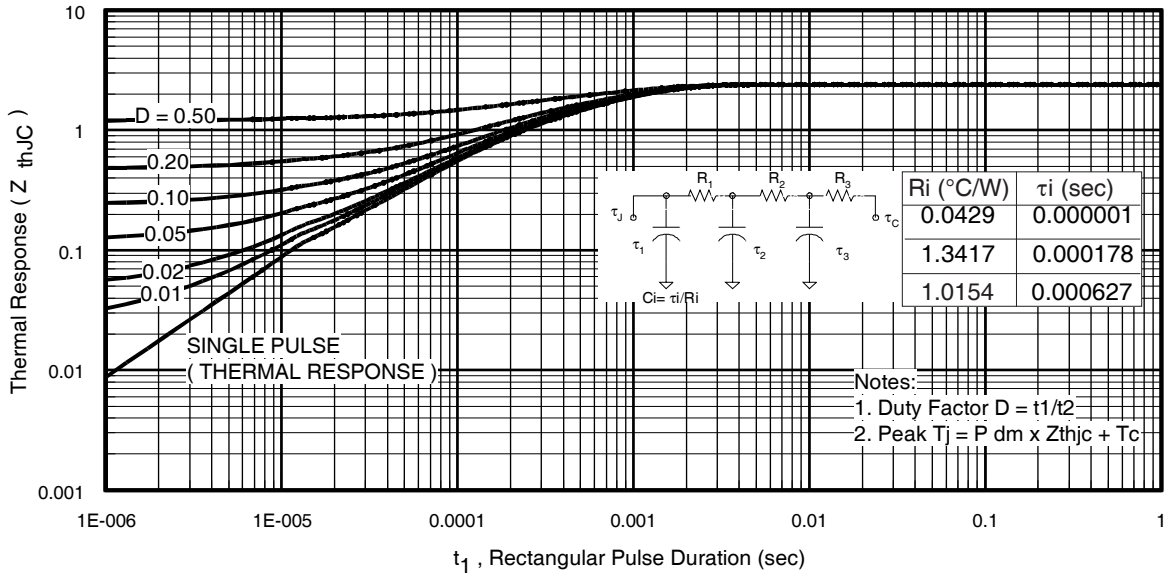


Fig 24. Maximum Transient Thermal Impedance, Junction-to-Case (IGBT)

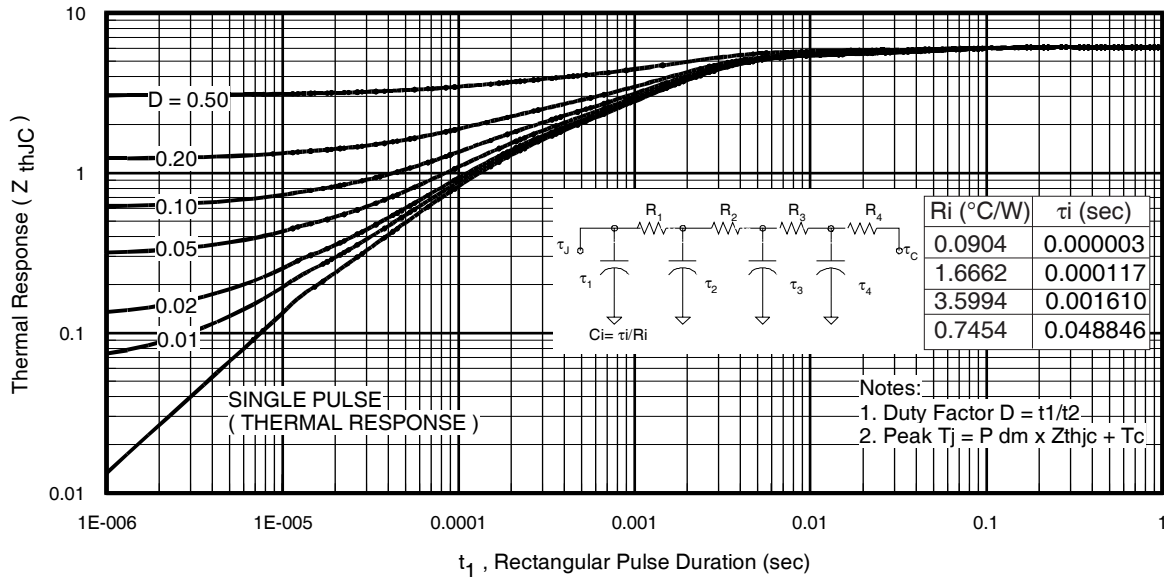
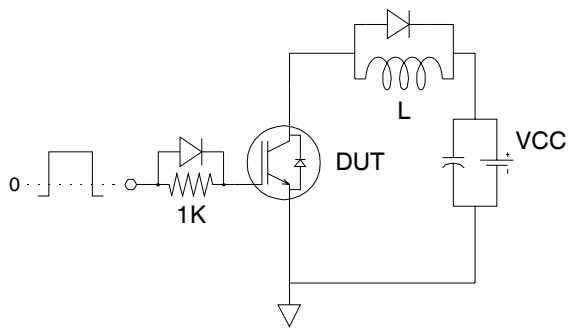
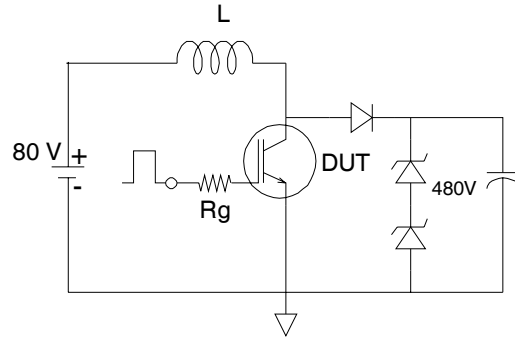


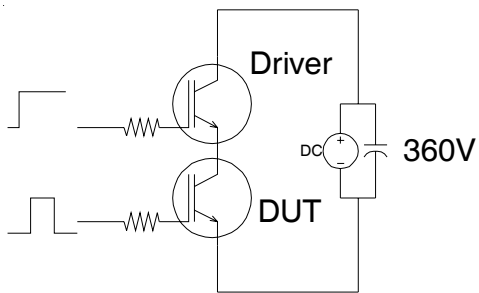
Fig 25. Maximum Transient Thermal Impedance, Junction-to-Case (DIODE)



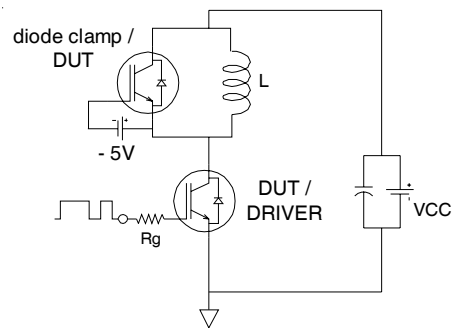
**Fig.C.T.1** - Gate Charge Circuit (turn-off)



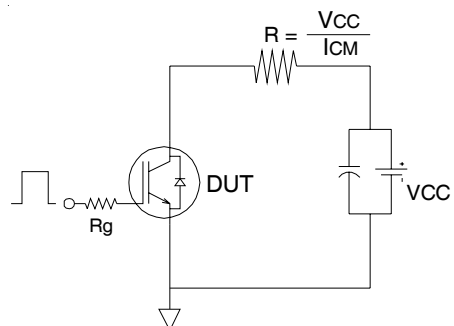
**Fig.C.T.2** - RBSOA Circuit



**Fig.C.T.3** - S.C.SOA Circuit



**Fig.C.T.4** - Switching Loss Circuit



**Fig.C.T.5** - Resistive Load Circuit

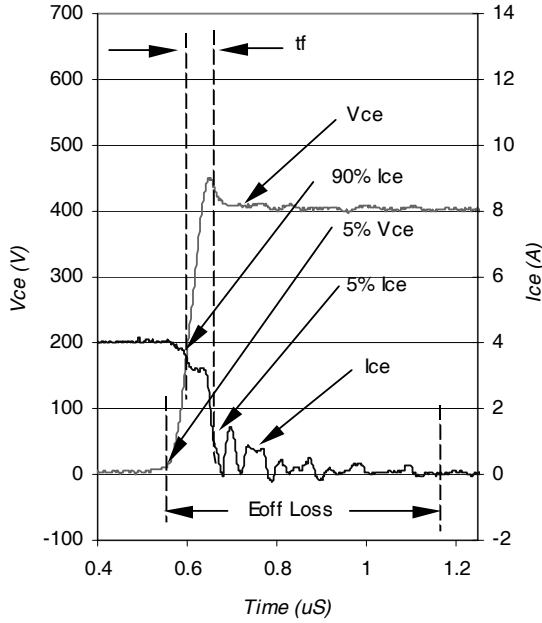


Fig. WF1- Typ. Turn-off Loss Waveform  
@  $T_J = 150^\circ\text{C}$  using Fig. CT.4

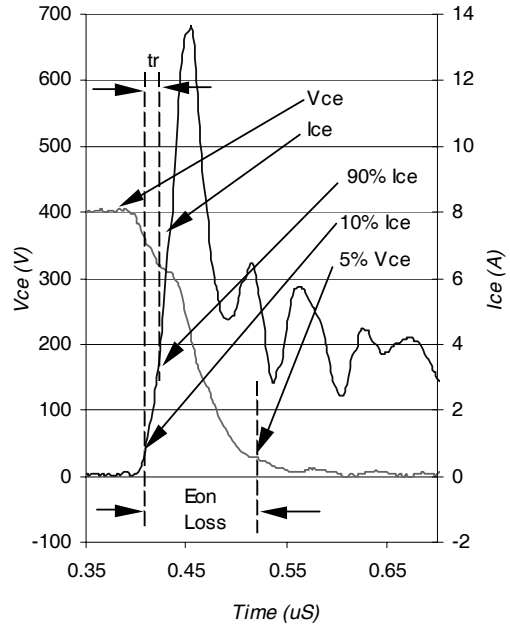


Fig. WF2- Typ. Turn-on Loss Waveform  
@  $T_J = 150^\circ\text{C}$  using Fig. CT.4

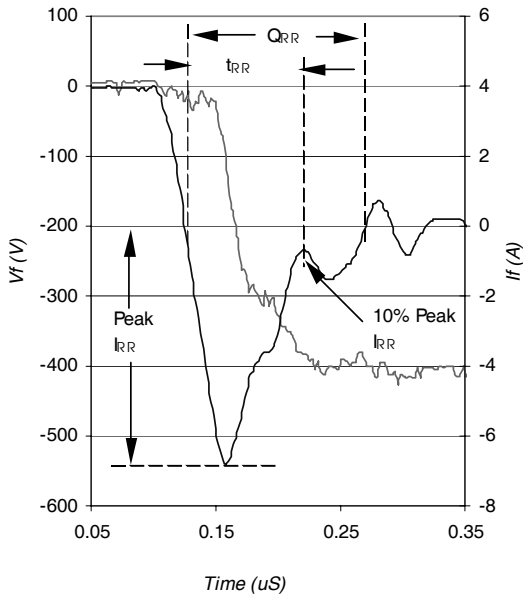


Fig. WF3- Typ. Diode Recovery Waveform  
@  $T_J = 150^\circ\text{C}$  using Fig. CT.4

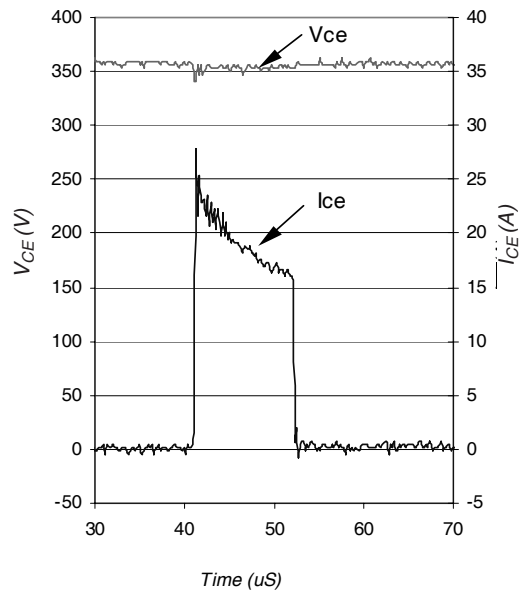
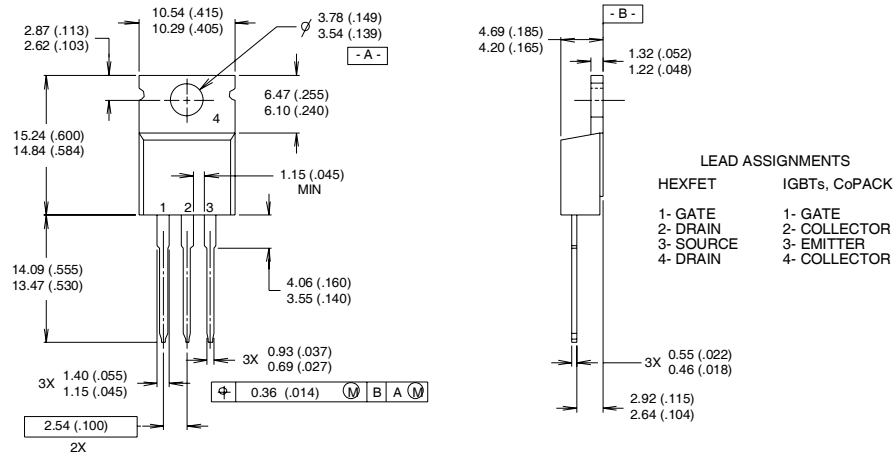


Fig. WF4- Typ. S.C Waveform  
@  $T_C = 150^\circ\text{C}$  using Fig. CT.3

# IRGB/S/SL4B60KD1PbF

## TO-220AB Package Outline

Dimensions are shown in millimeters (inches)



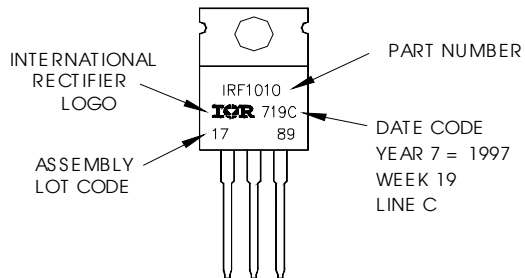
**NOTES:**

- 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.

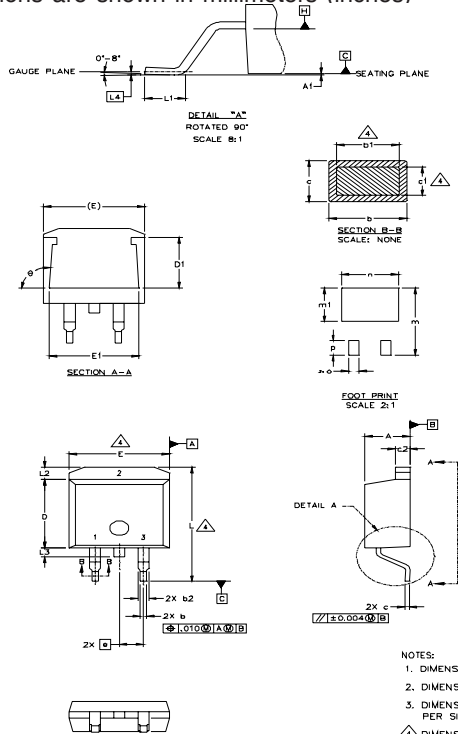
## TO-220AB Part Marking Information

EXAMPLE: THIS IS AN IRF1010  
 LOT CODE 1789  
 ASSEMBLED ON WW 19, 1997  
 IN THE ASSEMBLY LINE "C"  
**Note:** "P" in assembly line  
 position indicates "Lead-Free"



## D<sup>2</sup>Pak Package Outline

Dimensions are shown in millimeters (inches)



SYMBOL	DIMENSIONS				NOTES
	MILLIMETERS		INCHES		
	MIN.	MAX.	MIN.	MAX.	
A	4.06	4.83	.160	.190	4
A1		0.127		.005	
b	0.51	0.99	.020	.039	
b1	0.51	0.89	.020	.035	
b2	1.14	1.40	.045	.055	4
c	0.43	0.63	.017	.025	
c1	0.38	0.74	.015	.029	
c2	1.14	1.40	.045	.055	3
D	8.51	9.65	.335	.380	
D1	5.33		.210		3
E	9.65	10.67	.380	.420	
E1	6.22		.245		
e	2.54 BSC		.100 BSC		
L	14.61	15.88	.575	.625	
L1	1.78	2.79	.070	.110	
L2		1.65		.065	
L3	1.27	1.78	.050	.070	
L4	0.25 BSC		.010 BSC		
m	17.78		.700		
m1	8.89		.350		
n	11.43		.450		
o	2.08		.082		
p	3.81		.150		
θ	90°	93°	90°	93°	

### LEAD ASSIGNMENTS

HEXFET	IGBTs - CoPACK	DIODES
1 - GATE	1 - GATE	1 - ANODE +
2 - DRAIN	2 - COLLECTOR	2 - CATHODE
3 - SOURCE	3 - EMITTER	3 - ANODE

\* PART DEPENDENT.

### NOTES:

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994
2. DIMENSIONS ARE SHOWN IN MILLIMETERS [INCHES].
3. DIMENSION D & E DO NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.127 [0.005"] PER SIDE. THESE DIMENSIONS ARE MEASURED AT THE OUTMOST EXTREMES OF THE PLASTIC BODY.
4. DIMENSION b1 AND c1 APPLY TO BASE METAL ONLY.
5. CONTROLLING DIMENSION: INCH.

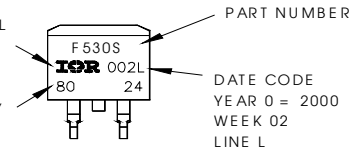
## D<sup>2</sup>Pak Part Marking Information (Lead-Free)

EXAMPLE: THIS IS AN IRF530S WITH  
LOT CODE 8024  
ASSEMBLED ON WW 02, 2000  
IN THE ASSEMBLY LINE "L"

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

INTERNATIONAL  
RECTIFIER  
LOGO

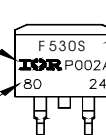
ASSEMBLY  
LOT CODE



**OR**

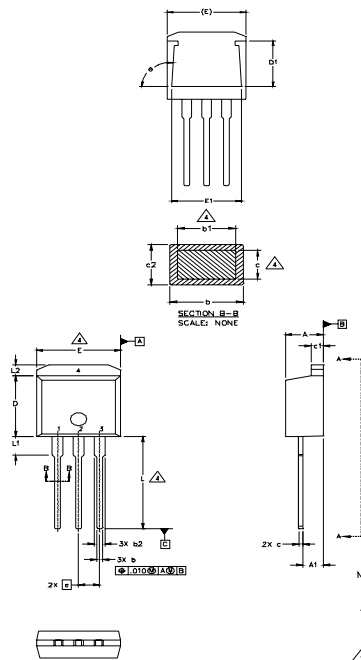
INTERNATIONAL  
RECTIFIER  
LOGO

ASSEMBLY  
LOT CODE



# IRGB/S/SL4B60KD1PbF

## TO-262 Package Outline



SYMBOL	DIMENSIONS				NOTES
	MILLIMETERS		INCHES		
	MIN.	MAX.	MIN.	MAX.	
A	4.06	4.83	.160	.190	
A1	2.03	2.92	.080	.115	
b	0.51	0.99	.020	.039	
b1	0.51	0.89	.020	.035	4
b2	1.14	1.40	.045	.055	
c	0.38	0.63	.015	.025	4
c1	1.14	1.40	.045	.055	
c2	0.43	.063	.017	.029	
D	8.51	9.65	.335	.380	3
D1	5.33		.210		
E	9.65	10.67	.380	.420	3
E1	6.22		.245		
e	2.54 BSC		.100 BSC		
L	13.46	14.09	.530	.555	
L1	3.56	3.71	.140	.146	
L2		1.65		.065	

### LEAD ASSIGNMENTS

#### HEXFET

- 1. - GATE
- 2. - DRAIN
- 3. - SOURCE
- 4. - DRAIN

#### IGBT

- 1 - GATE
- 2 - COLLECTOR
- 3 - EMITTER

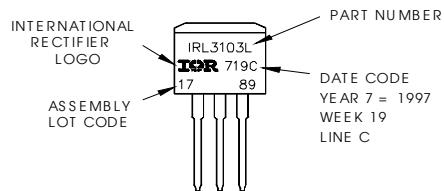
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4. DIMENSION b1 AND c1 APPLY TO BASE METAL ONLY.
5. CONTROLLING DIMENSION: INCH.

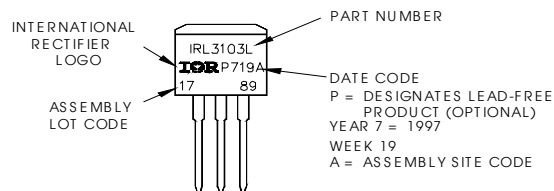
## TO-262 Part Marking Information

EXAMPLE: THIS IS AN IRL3103L  
LOT CODE 1789  
ASSEMBLED ON WW 19, 1997  
IN THE ASSEMBLY LINE "C"

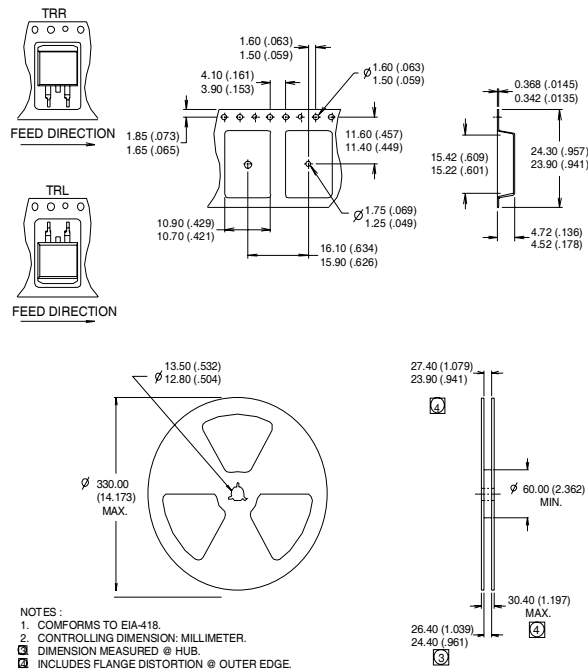
Note: "P" in assembly line position indicates "Lead-Free"



**OR**



## D<sup>2</sup>Pak Tape & Reel Infomation



### Notes:

- ①  $V_{CC} = 80\% (V_{CES})$ ,  $V_{GE} = 15V$ ,  $L = 100\mu H$ ,  $R_G = 100\Omega$ .
- ② When mounted on 1" square PCB (FR-4 or G-10 Material). For recommended footprint and soldering techniques refer to application note #AN-994.
- ③ Energy losses include "tail" and diode reverse recovery, using Diode FD059H06A5.

**TO-220AB 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  
**IR** Rectifier

**IR WORLD HEADQUARTERS:** 233 Kansas St., El Segundo, California 90245, USA Tel: (310) 252-7105  
 TAC Fax: (310) 252-7903

Visit us at [www.irf.com](http://www.irf.com) for sales contact information. 08/04

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