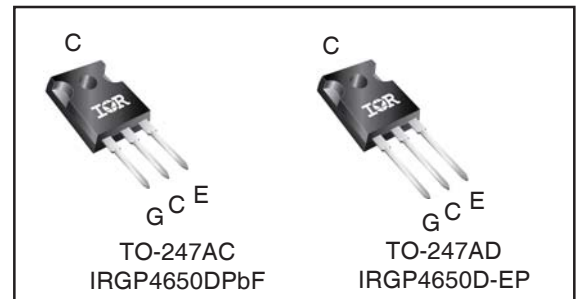
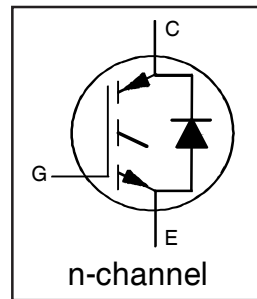


### INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE

$V_{CES} = 600V$
$I_C = 50A, T_C = 100^\circ C$
$t_{SC} \geq 5\mu s, T_{J(max)} = 175^\circ C$
$V_{CE(on)} \text{ typ.} = 1.60V @ I_C = 35A$



<b>G</b>	<b>C</b>	<b>E</b>
Gate	Collector	Emitter

#### Applications

- Industrial Motor Drive
- Inverters
- UPS
- Welding

Features	Benefits
Low $V_{CE(ON)}$ and Switching Losses	High efficiency in a wide range of applications and switching frequencies
Square RBSOA and Maximum Junction Temperature 175°C	Improved reliability due to rugged hard switching performance and higher power capability
Positive $V_{CE(ON)}$ Temperature Coefficient	Excellent current sharing in parallel operation
5μs short circuit SOA	Enables short circuit protection scheme
Lead-Free, RoHS compliant	Environmentally friendly

Base part number	Package Type	Standard Pack		Orderable part number
		Form	Quantity	
IRGP4650DPbF	TO-247AC	Tube	25	IRGP4650DPbF
IRGP4650D-EPbF	TO-247AD	Tube	25	IRGP4650D-EPbF

#### Absolute Maximum Ratings

Parameter	Max.	Units
$V_{CES}$ Collector-to-Emitter Voltage	600	V
$I_C @ T_C = 25^\circ C$ Continuous Collector Current	76	A
$I_C @ T_C = 100^\circ C$ Continuous Collector Current	50	
$I_{CM}$ Pulse Collector Current, $V_{GE} = 15V$	105	
$I_{LM}$ Clamped Inductive Load Current, $V_{GE} = 20V$ ①	140	
$I_F @ T_C = 25^\circ C$ Diode Continuous Forward Current	76	
$I_F @ T_C = 100^\circ C$ Diode Continuous Forward Current	50	V
$I_{FM}$ Diode Maximum Forward Current ④	140	
$V_{GE}$ Continuous Gate-to-Emitter Voltage	±20	
	±30	W
$P_D @ T_C = 25^\circ C$ Maximum Power Dissipation	268	
$P_D @ T_C = 100^\circ C$ Maximum Power Dissipation	134	°C
$T_J$ Operating Junction and	-55 to +175	
$T_{STG}$ 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) Junction-to-Case (IGBT) ②	—	—	0.56	°C/W
$R_{\theta JC}$ (Diode) Junction-to-Case (Diode) ②	—	—	1.0	
$R_{\theta CS}$ Case-to-Sink (flat, greased surface)	—	0.24	—	
$R_{\theta JA}$ Junction-to-Ambient (typical socket mount)	—	—	40	

**Electrical Characteristics @ T<sub>J</sub> = 25°C (unless otherwise specified)**

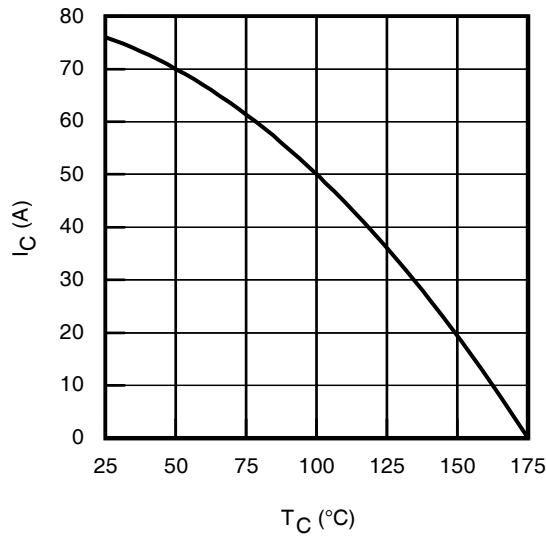
	Parameter	Min.	Typ.	Max.	Units	Conditions
V <sub>(BR)CES</sub>	Collector-to-Emitter Breakdown Voltage	600	—	—	V	V <sub>GE</sub> = 0V, I <sub>C</sub> = 100μA ③
ΔV <sub>(BR)CES</sub> /ΔT <sub>J</sub>	Temperature Coeff. of Breakdown Voltage	—	1.3	—	mV/°C	V <sub>GE</sub> = 0V, I <sub>C</sub> = 1mA (25°C-175°C)
V <sub>CE(on)</sub>	Collector-to-Emitter Saturation Voltage	—	1.60	1.90	V	I <sub>C</sub> = 35A, V <sub>GE</sub> = 15V, T <sub>J</sub> = 25°C
		—	1.90	—		I <sub>C</sub> = 35A, V <sub>GE</sub> = 15V, T <sub>J</sub> = 150°C
		—	2.00	—		I <sub>C</sub> = 35A, V <sub>GE</sub> = 15V, T <sub>J</sub> = 175°C
V <sub>GE(th)</sub>	Gate Threshold Voltage	4.0	—	6.5	V	V <sub>CE</sub> = V <sub>GE</sub> , I <sub>C</sub> = 1.0mA
ΔV <sub>GE(th)</sub> /ΔT <sub>J</sub>	Threshold Voltage temp. coefficient	—	-18	—	mV/°C	V <sub>CE</sub> = V <sub>GE</sub> , I <sub>C</sub> = 1.0mA (25°C - 175°C)
g <sub>f</sub> e	Forward Transconductance	—	25	—	S	V <sub>CE</sub> = 50V, I <sub>C</sub> = 35A, PW = 60μs
I <sub>CES</sub>	Collector-to-Emitter Leakage Current	—	1.0	70	μA	V <sub>GE</sub> = 0V, V <sub>CE</sub> = 600V
		—	770	—		V <sub>GE</sub> = 0V, V <sub>CE</sub> = 600V, T <sub>J</sub> = 175°C
V <sub>FM</sub>	Diode Forward Voltage Drop	—	2.0	3.0	V	I <sub>F</sub> = 35A
		—	1.4	—		I <sub>F</sub> = 35A, T <sub>J</sub> = 175°C
I <sub>GES</sub>	Gate-to-Emitter Leakage Current	—	—	±100	nA	V <sub>GE</sub> = ±20V

**Switching Characteristics @ T<sub>J</sub> = 25°C (unless otherwise specified)**

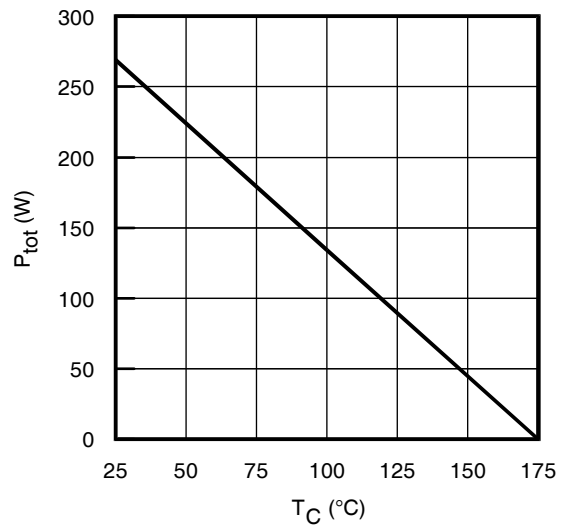
	Parameter	Min.	Typ.	Max.	Units	Conditions		
Q <sub>g</sub>	Total Gate Charge (turn-on)	—	69	104	nC	I <sub>C</sub> = 35A V <sub>GE</sub> = 15V V <sub>CC</sub> = 400V		
Q <sub>ge</sub>	Gate-to-Emitter Charge (turn-on)	—	18	27				
Q <sub>gc</sub>	Gate-to-Collector Charge (turn-on)	—	29	44				
E <sub>on</sub>	Turn-On Switching Loss	—	390	508	μJ	I <sub>C</sub> = 35A, V <sub>CC</sub> = 400V, V <sub>GE</sub> = 15V R <sub>G</sub> = 10Ω, L = 200μH, L <sub>S</sub> = 150nH, T <sub>J</sub> = 25°C Energy losses include tail & diode reverse recovery ⑤		
E <sub>off</sub>	Turn-Off Switching Loss	—	632	753				
E <sub>total</sub>	Total Switching Loss	—	1022	1261				
t <sub>d(on)</sub>	Turn-On delay time	—	46	56	ns	I <sub>C</sub> = 35A, V <sub>CC</sub> = 400V, V <sub>GE</sub> = 15V R <sub>G</sub> = 10Ω, L = 200μH, L <sub>S</sub> = 150nH, T <sub>J</sub> = 25°C		
t <sub>r</sub>	Rise time	—	33	42				
t <sub>d(off)</sub>	Turn-Off delay time	—	105	117				
t <sub>f</sub>	Fall time	—	44	54				
E <sub>on</sub>	Turn-On Switching Loss	—	1013	—			μJ	I <sub>C</sub> = 35A, V <sub>CC</sub> = 400V, V <sub>GE</sub> = 15V R <sub>G</sub> = 10Ω, L = 200μH, L <sub>S</sub> = 150nH, T <sub>J</sub> = 175°C Energy losses include tail & diode reverse recovery ⑤
E <sub>off</sub>	Turn-Off Switching Loss	—	929	—				
E <sub>total</sub>	Total Switching Loss	—	1942	—				
t <sub>d(on)</sub>	Turn-On delay time	—	43	—	ns	I <sub>C</sub> = 35A, V <sub>CC</sub> = 400V, V <sub>GE</sub> = 15V R <sub>G</sub> = 10Ω, L = 200μH, L <sub>S</sub> = 150nH T <sub>J</sub> = 175°C		
t <sub>r</sub>	Rise time	—	35	—				
t <sub>d(off)</sub>	Turn-Off delay time	—	127	—				
t <sub>f</sub>	Fall time	—	61	—				
C <sub>ies</sub>	Input Capacitance	—	2113	—	pF	V <sub>GE</sub> = 0V V <sub>CC</sub> = 30V f = 1.0Mhz		
C <sub>oes</sub>	Output Capacitance	—	197	—				
C <sub>res</sub>	Reverse Transfer Capacitance	—	65	—				
RBSOA	Reverse Bias Safe Operating Area	FULL SQUARE				T <sub>J</sub> = 175°C, I <sub>C</sub> = 140A V <sub>CC</sub> = 480V, V <sub>p</sub> ≤ 600V R <sub>G</sub> = 10Ω, V <sub>GE</sub> = +20V to 0V		
SCSOA	Short Circuit Safe Operating Area	5	—	—	μs	V <sub>CC</sub> = 400V, V <sub>p</sub> ≤ 600V R <sub>G</sub> = 10Ω, V <sub>GE</sub> = +15V to 0V		
E <sub>rec</sub>	Reverse Recovery Energy of the Diode	—	304	—	μJ	T <sub>J</sub> = 175°C		
t <sub>rr</sub>	Diode Reverse Recovery Time	—	120	—	ns	V <sub>CC</sub> = 400V, I <sub>F</sub> = 35A		
I <sub>rr</sub>	Peak Reverse Recovery Current	—	25	—	A	V <sub>GE</sub> = 15V, R <sub>G</sub> = 10Ω, L = 210μH, L <sub>S</sub> = 150nH		

**Notes:**

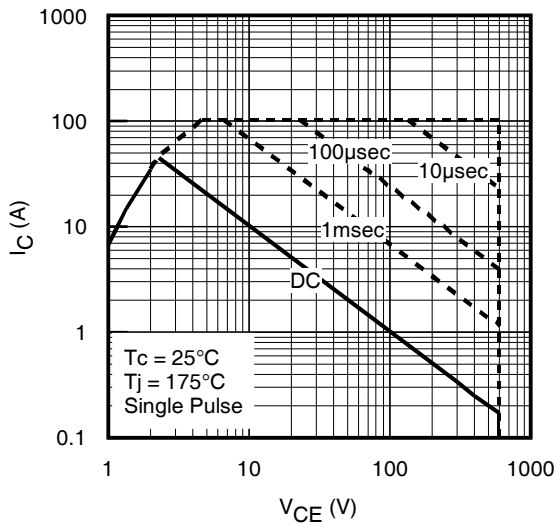
- ① V<sub>CC</sub> = 80% (V<sub>CES</sub>), V<sub>GE</sub> = 20V, L = 19μH, R<sub>G</sub> = 10Ω.
- ② R<sub>θ</sub> is measured at T<sub>J</sub> of approximately 90°C.
- ③ Refer to AN-1086 for guidelines for measuring V<sub>(BR)CES</sub> safely.
- ④ Pulse width limited by max. junction temperature.
- ⑤ Values influenced by parasitic L and C in measurement.



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



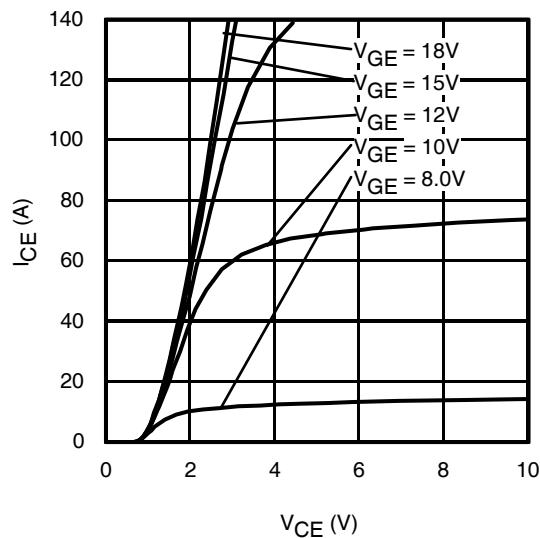
**Fig. 2 - Power Dissipation vs. Case Temperature**



**Fig. 3 - Forward SOA**  
 $T_C = 25^\circ\text{C}$ ,  $T_J \leq 175^\circ\text{C}$ ;  $V_{GE} = 15\text{V}$



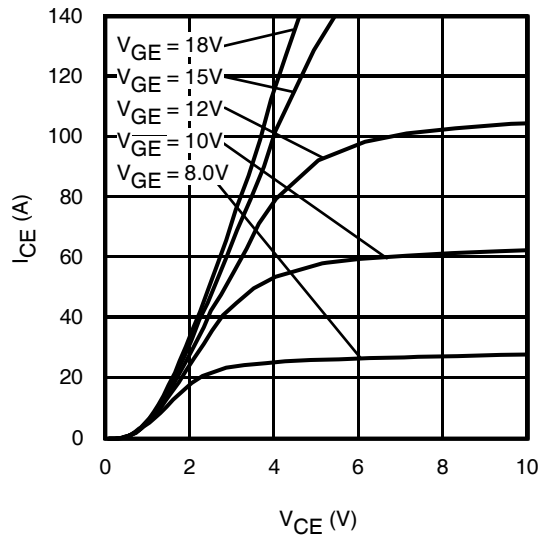
**Fig. 4 - Reverse Bias SOA**  
 $T_J = 175^\circ\text{C}$ ;  $V_{GE} = 20\text{V}$



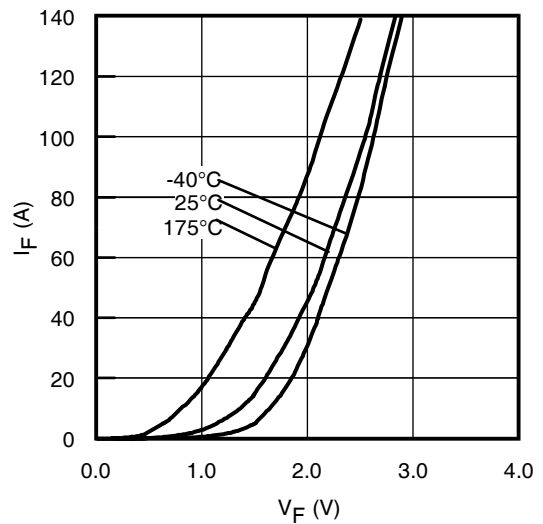
**Fig. 5 - Typ. IGBT Output Characteristics**  
 $T_J = -40^\circ\text{C}$ ;  $t_p \leq 60\mu\text{s}$



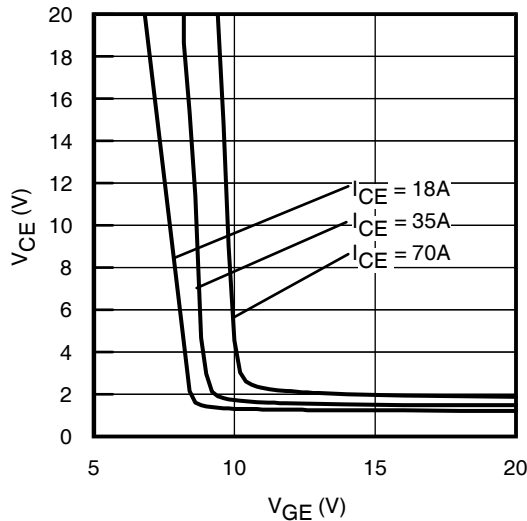
**Fig. 6 - Typ. IGBT Output Characteristics**  
 $T_J = 25^\circ\text{C}$ ;  $t_p \leq 60\mu\text{s}$



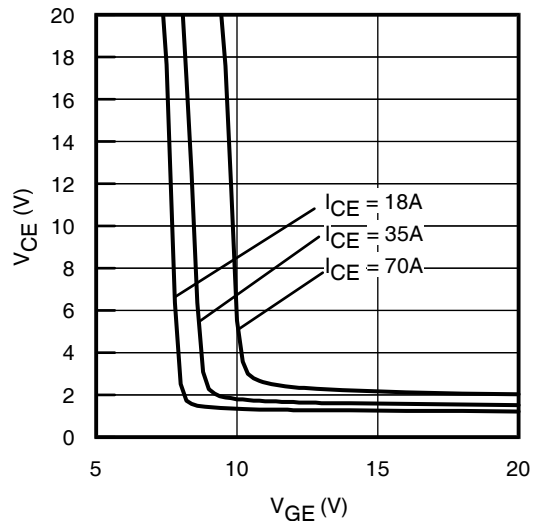
**Fig. 7 - Typ. IGBT Output Characteristics**  
 $T_J = 175^\circ\text{C}$ ;  $t_p = \leq 60\mu\text{s}$



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



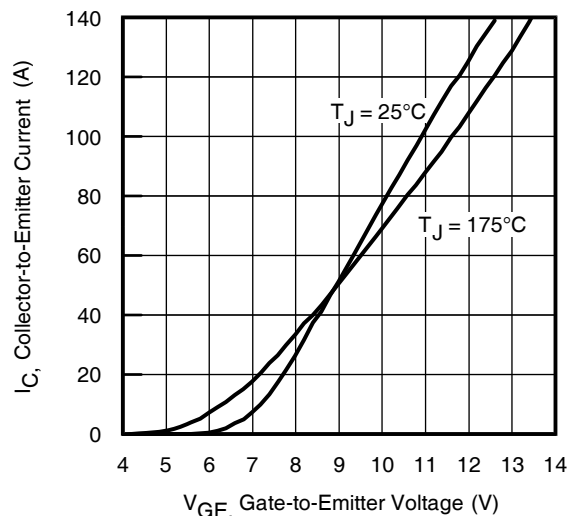
**Fig. 9 - Typical  $V_{CE}$  vs.  $V_{GE}$**   
 $T_J = -40^\circ\text{C}$



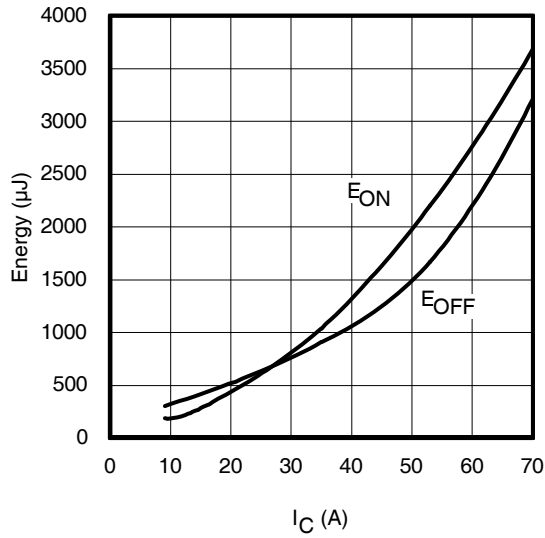
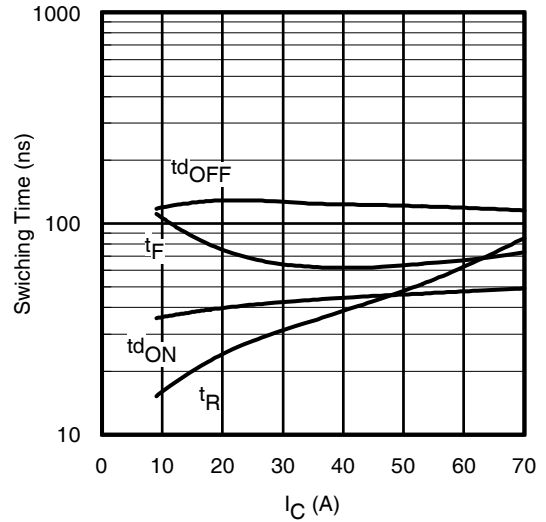
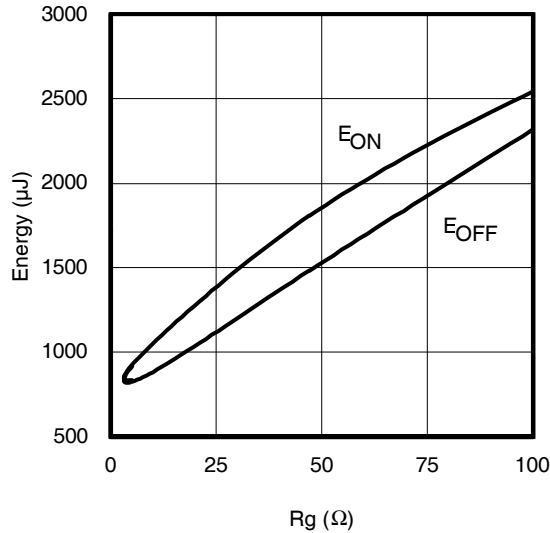
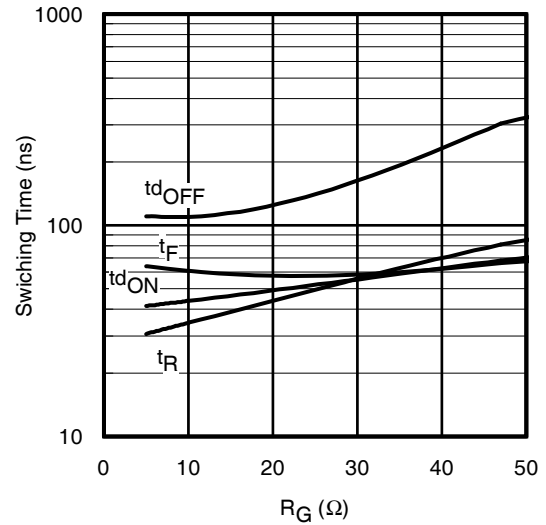
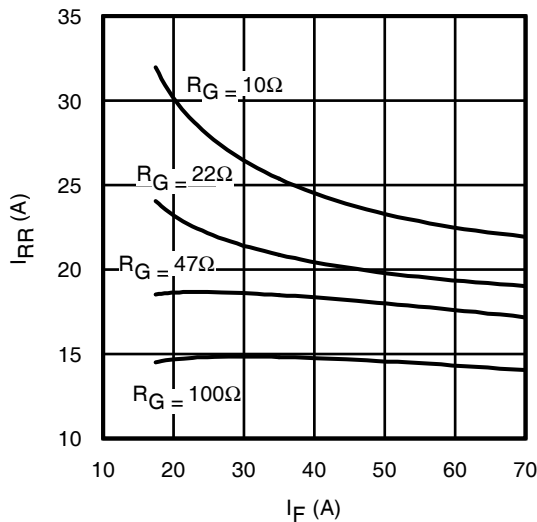
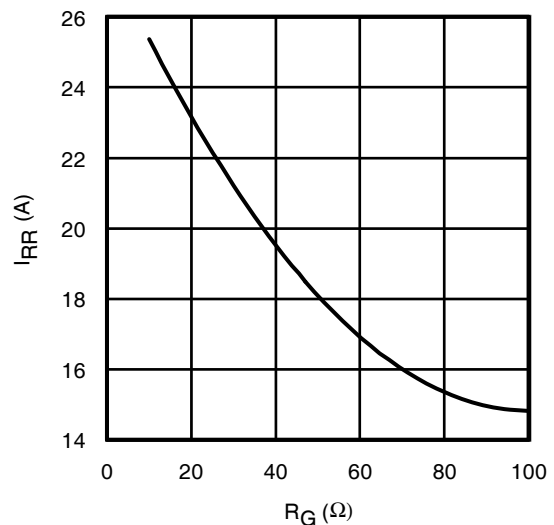
**Fig. 10 - Typical  $V_{CE}$  vs.  $V_{GE}$**   
 $T_J = 25^\circ\text{C}$



**Fig. 11 - Typical  $V_{CE}$  vs.  $V_{GE}$**   
 $T_J = 175^\circ\text{C}$

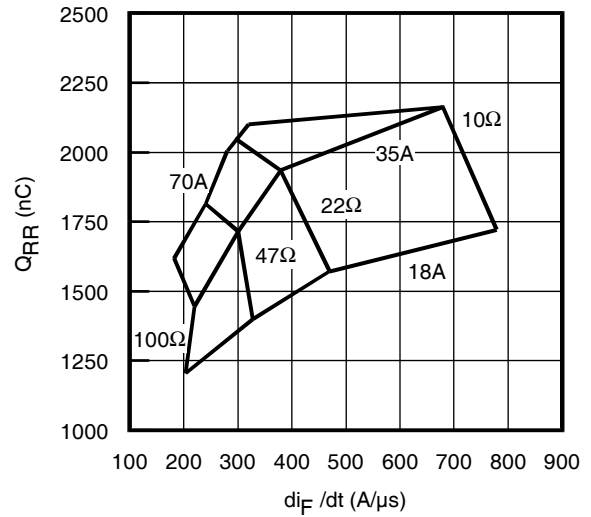


**Fig. 12 - Typ. Transfer Characteristics**  
 $V_{CE} = 50\text{V}$ ;  $t_p = 60\mu\text{s}$

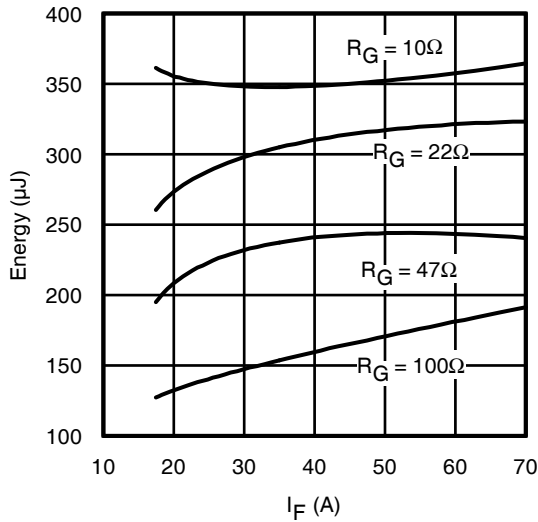

**Fig. 13 - Typ. Energy Loss vs.  $I_C$** 
 $T_J = 175^\circ\text{C}; L = 200\mu\text{H}; V_{CE} = 400\text{V}, R_G = 10\Omega; V_{GE} = 15\text{V}$ 

**Fig. 14 - Typ. Switching Time vs.  $I_C$** 
 $T_J = 175^\circ\text{C}; L = 200\mu\text{H}; V_{CE} = 400\text{V}, R_G = 10\Omega; V_{GE} = 15\text{V}$ 

**Fig. 15 - Typ. Energy Loss vs.  $R_G$** 
 $T_J = 175^\circ\text{C}; L = 210\mu\text{H}; V_{CE} = 400\text{V}, I_{CE} = 35\text{A}; V_{GE} = 15\text{V}$ 

**Fig. 16 - Typ. Switching Time vs.  $R_G$** 
 $T_J = 175^\circ\text{C}; L = 210\mu\text{H}; V_{CE} = 400\text{V}, I_{CE} = 35\text{A}; V_{GE} = 15\text{V}$ 

**Fig. 17 - Typ. Diode  $I_{RR}$  vs.  $I_F$** 
 $T_J = 175^\circ\text{C}$ 

**Fig. 18 - Typ. Diode  $I_{RR}$  vs.  $R_G$** 
 $T_J = 175^\circ\text{C}$



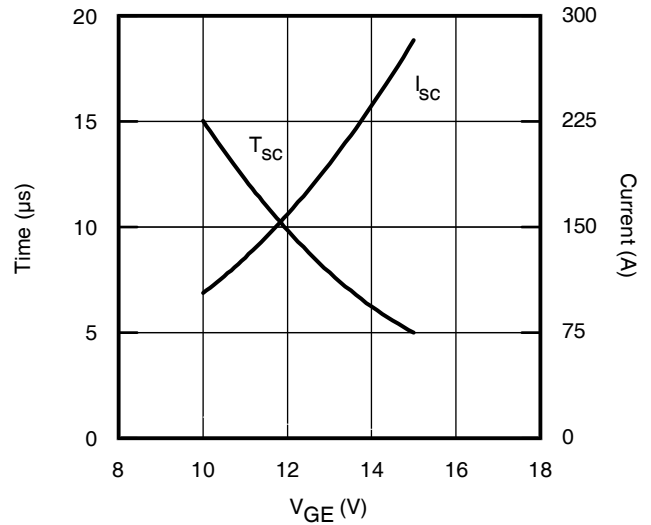
**Fig. 19** - Typ. Diode  $I_{RR}$  vs.  $di_F/dt$   
 $V_{CC} = 400V$ ;  $V_{GE} = 15V$ ;  $I_F = 35A$ ;  $T_J = 175^\circ C$



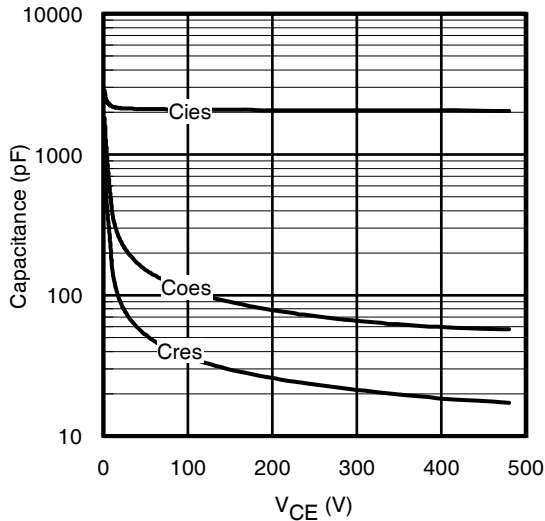
**Fig. 20** - Typ. Diode  $Q_{RR}$  vs.  $di_F/dt$   
 $V_{CC} = 400V$ ;  $V_{GE} = 15V$ ;  $T_J = 175^\circ C$



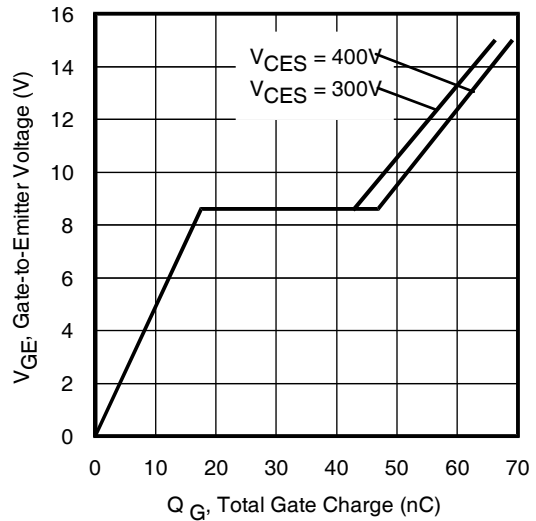
**Fig. 21** - Typ. Diode  $E_{RR}$  vs.  $I_F$   
 $T_J = 175^\circ C$



**Fig. 22** -  $V_{GE}$  vs. Short Circuit Time  
 $V_{CC} = 400V$ ;  $T_C = 25^\circ C$



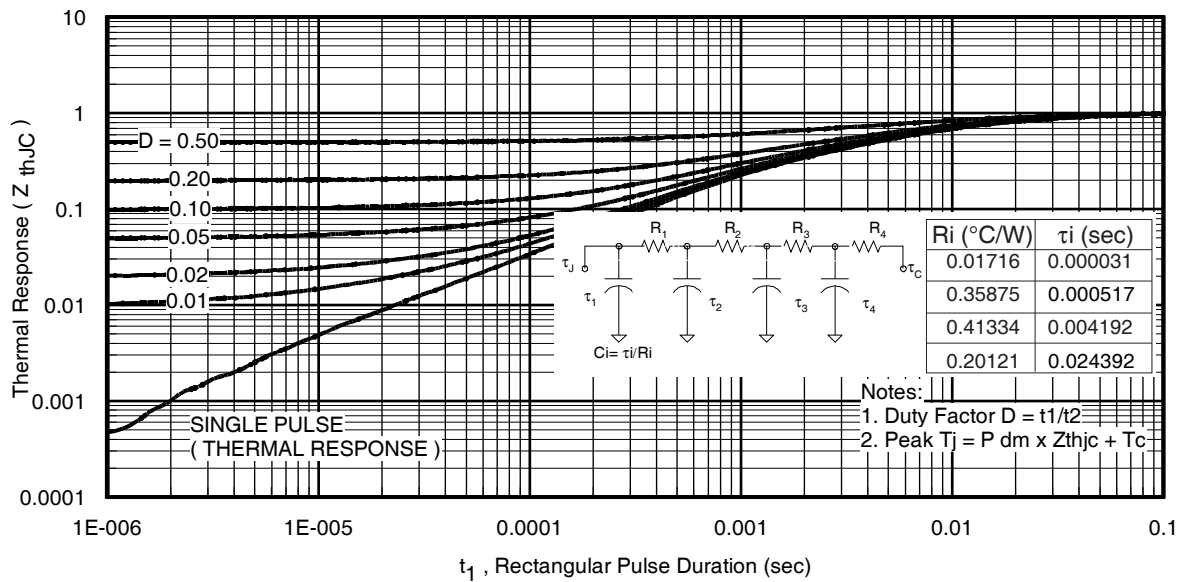
**Fig. 23** - Typ. Capacitance vs.  $V_{CE}$   
 $V_{GE} = 0V$ ;  $f = 1MHz$



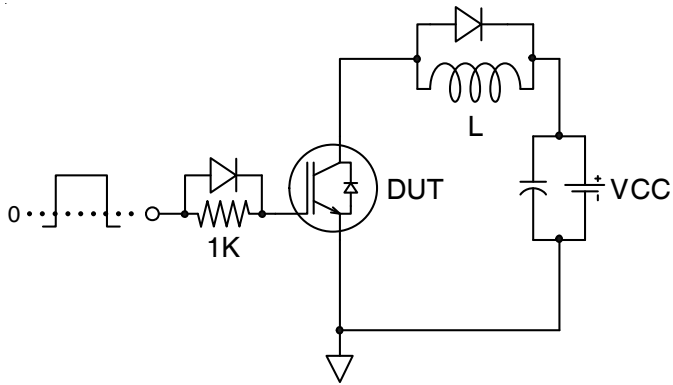
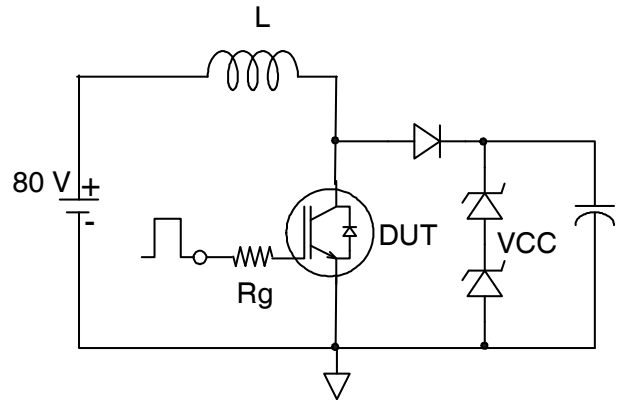
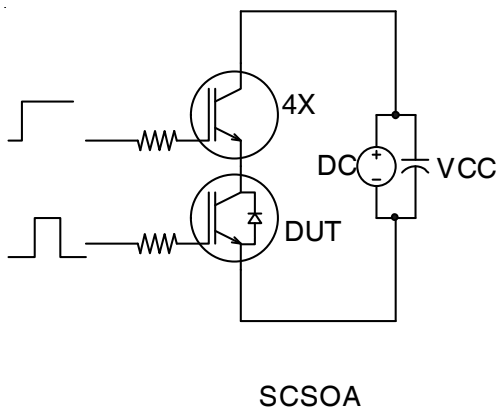
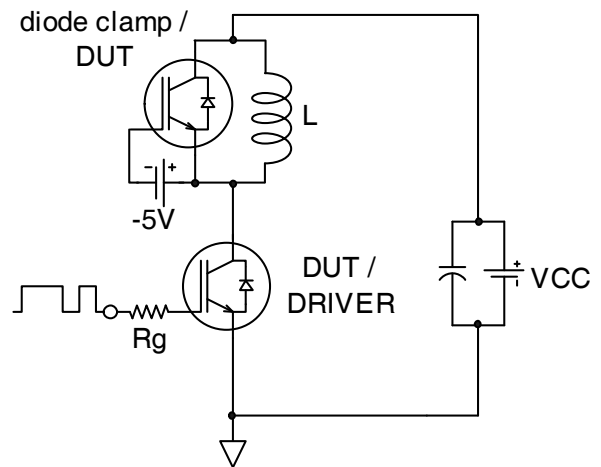
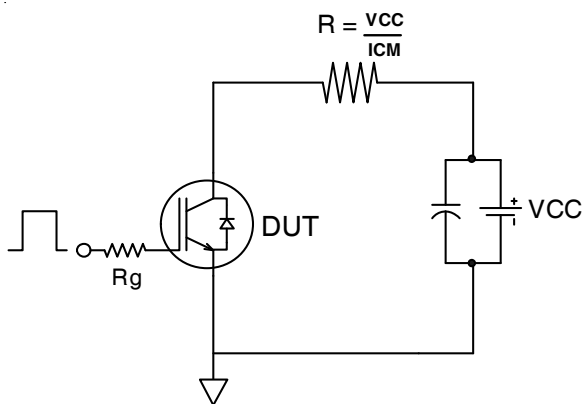
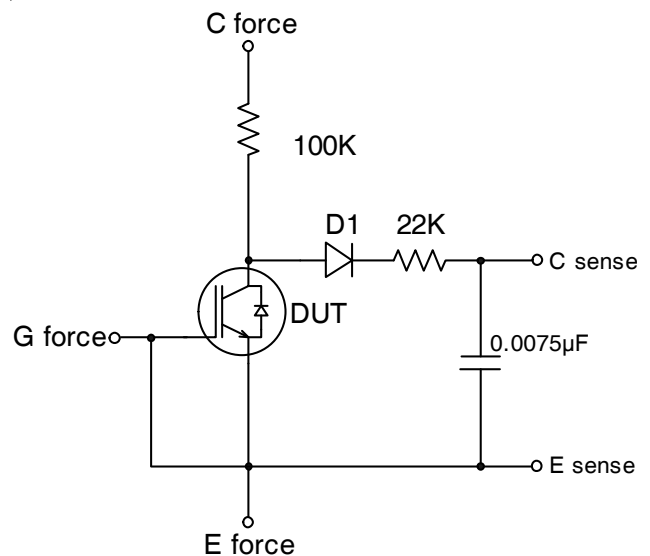
**Fig. 24** - Typical Gate Charge vs.  $V_{GE}$   
 $I_{CE} = 35A$ ;  $L = 740\mu H$



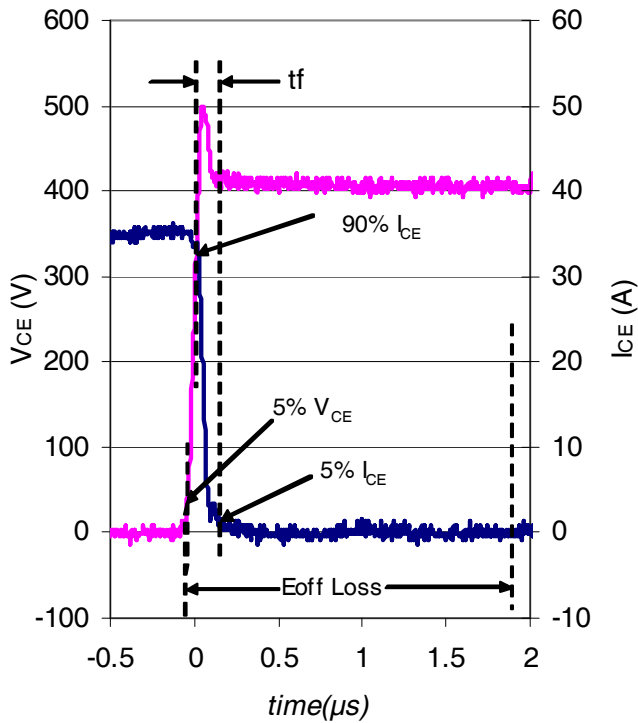
**Fig 25.** Maximum Transient Thermal Impedance, Junction-to-Case (IGBT)



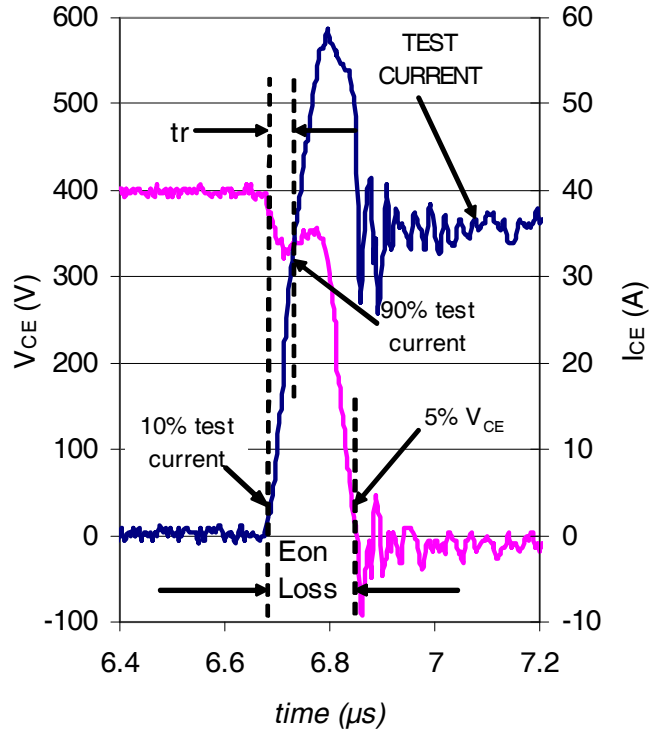
**Fig. 26.** Maximum Transient Thermal Impedance, Junction-to-Case (DIODE)


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

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

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

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

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

**Fig.C.T.6 - BVCES Filter Circuit**

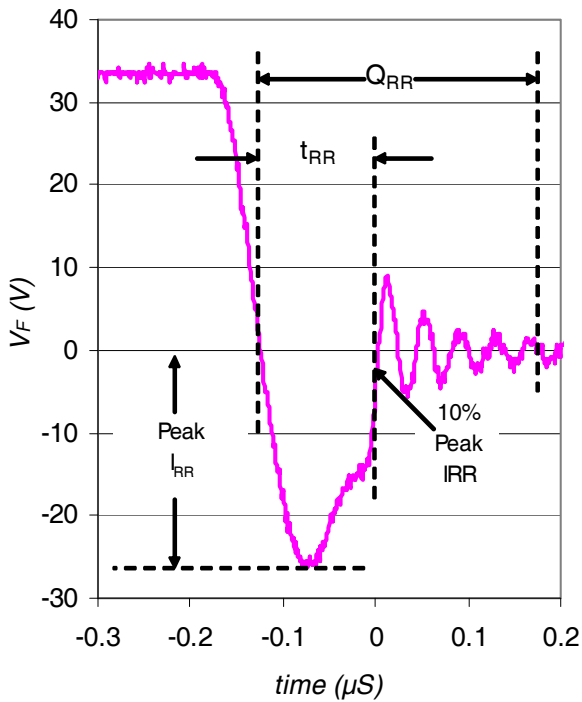




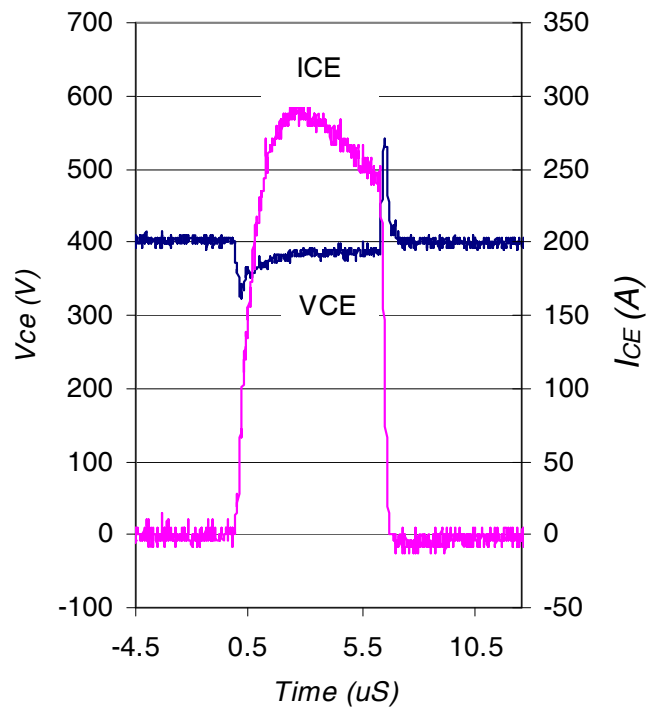
**Fig. WF1** - Typ. Turn-off Loss Waveform  
@  $T_J = 175^\circ\text{C}$  using Fig. CT.4



**Fig. WF2** - Typ. Turn-on Loss Waveform  
@  $T_J = 175^\circ\text{C}$  using Fig. CT.4



**Fig. WF3** - Typ. Diode Recovery Waveform  
@  $T_J = 175^\circ\text{C}$  using Fig. CT.4



**Fig. WF4** - Typ. S.C. Waveform  
@  $T_J = 25^\circ\text{C}$  using Fig. CT.3

## TO-247AC Package Outline

Dimensions are shown in millimeters (inches)



NOTES:

1. DIMENSIONING AND TOLERANCING AS PER ASME Y14.5M 1994.
2. DIMENSIONS ARE SHOWN IN INCHES.
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.  $\phi P$  TO HAVE A MAXIMUM DRAFT ANGLE OF 1.5 ° TO THE TOP OF THE PART WITH A MAXIMUM HOLE DIAMETER OF .154 INCH.
8. OUTLINE CONFORMS TO JEDEC OUTLINE TO-247AC .

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	2.34	
b4	.102	.135	2.59	3.43	
b5	.102	.133	2.59	3.38	
c	.015	.035	0.38	0.89	
c1	.015	.033	0.38	0.84	
D	.776	.815	19.71	20.70	4
D1	.515	-	13.08	-	5
D2	.020	.053	0.51	1.35	
E	.602	.625	15.29	15.87	4
E1	.530	-	13.46	-	
E2	.178	.216	4.52	5.49	
e	.215 BSC		5.46 BSC		
$\phi k$	.010		0.25		
L	.559	.634	14.20	16.10	
L1	.146	.169	3.71	4.29	
$\phi P$	.140	.144	3.56	3.66	
$\phi P1$	-	.291	-	7.39	
Q	.209	.224	5.31	5.69	
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

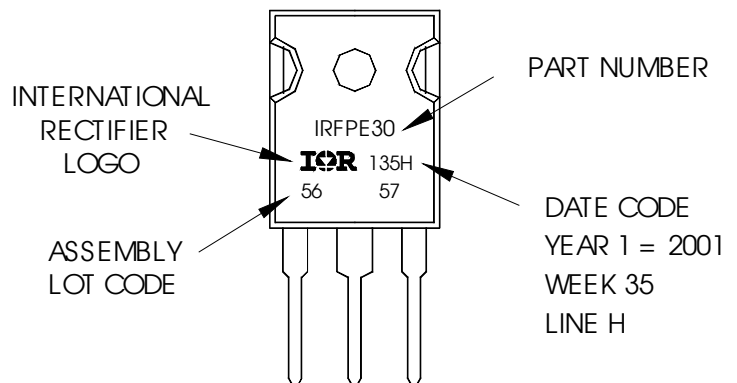
**DIODES**

- 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, 2001  
IN THE ASSEMBLY LINE "H"

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

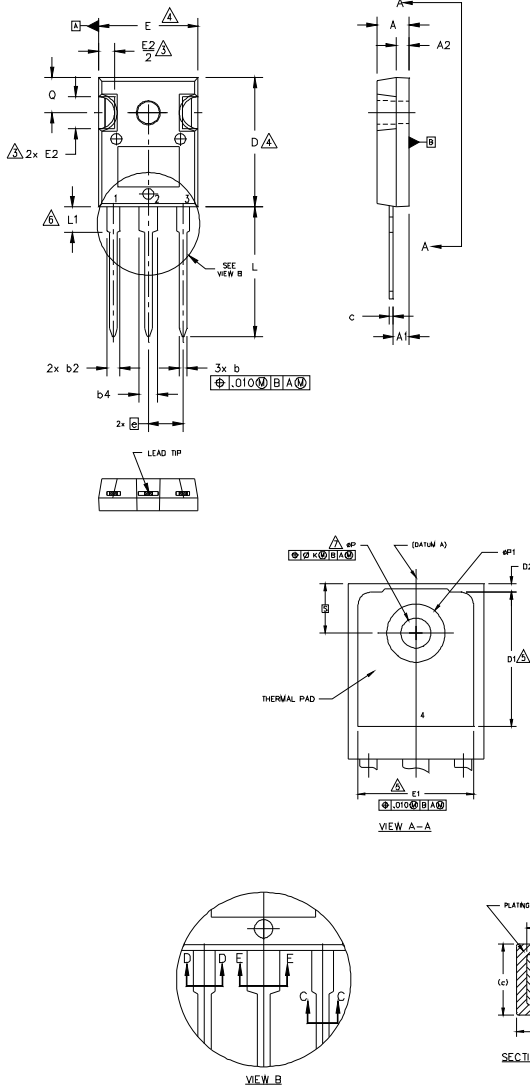


TO-247AC package is not recommended for Surface Mount Application.

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

## TO-247AD Package Outline

Dimensions are shown in millimeters (inches)



**NOTES:**

1. DIMENSIONING AND TOLERANCING AS PER ASME Y14.5M 1994.
2. DIMENSIONS ARE SHOWN IN INCHES.
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. ØP TO HAVE A MAXIMUM DRAFT ANGLE OF 1.5 ° TO THE TOP OF THE PART WITH A MAXIMUM HOLE DIAMETER OF .154 INCH.
8. OUTLINE CONFORMS TO JEDEC OUTLINE TO-247AD.

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	2.34	
b4	.102	.135	2.59	3.43	
b5	.102	.133	2.59	3.38	
c	.015	.035	0.38	0.89	
c1	.015	.033	0.38	0.84	
D	.776	.815	19.71	20.70	4
D1	.515	-	13.08	-	5
D2	.020	.053	0.51	1.35	
E	.602	.625	15.29	15.87	4
E1	.530	-	13.46	-	
E2	.178	.216	4.52	5.49	
e	.215 BSC		5.46 BSC		
Øk	.010		0.25		
L	.780	.827	19.57	21.00	
L1	.146	.169	3.71	4.29	
ØP	.140	.144	3.56	3.66	
ØP1	-	.291	-	7.39	
Q	.209	.224	5.31	5.69	
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

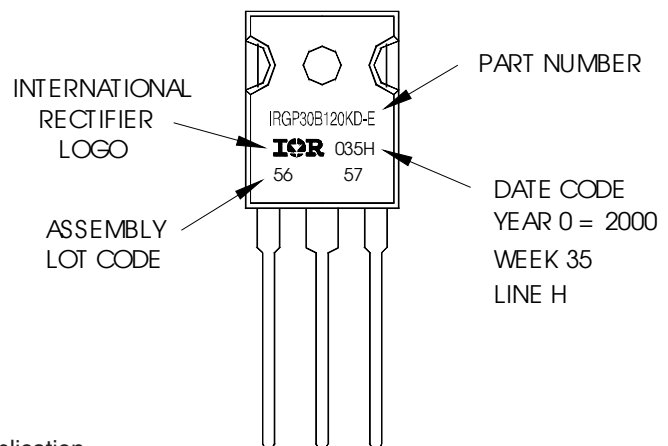
**DIODES**

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

## TO-247AD Part Marking Information

EXAMPLE: THIS IS AN IRGP30B120KD-E  
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-247AD package is not recommended for Surface Mount Application.

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

**Qualification Information<sup>†</sup>**

<b>Qualification Level</b>	Industrial (per International Rectifier's internal guidelines)	
<b>Moisture Sensitivity Level</b>	TO-247AC	N/A
	TO-247AD	N/A
<b>RoHS Compliant</b>	Yes	

† Qualification standards can be found at International Rectifier's web site: <http://www.irf.com/product-info/reliability>

†† Highest passing voltage.

**Revision History**

<b>Date</b>	<b>Comments</b>
11/17/2014	<ul style="list-style-type: none"> <li>• Added note ④ to I<sub>FM</sub> Diode Maximum Forward Current on page 1.</li> <li>• Added note ⑤ to switching losses test condition on page 2.</li> </ul>



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