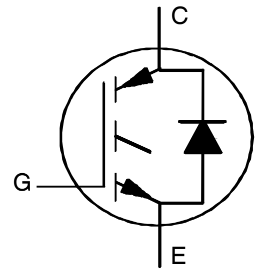
International
IOR Rectifier

AUTOMOTIVE GRADE

PD - 96306A

AUIRGP50B60PD1
AUIRGP50B60PD1E

WARP2 SERIES IGBT WITH
ULTRAFAST SOFT RECOVERY DIODE



n-channel

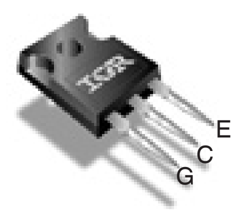
V_{CES} = 600V
$V_{CE(on)}$ typ. = 2.00V
@ V_{GE} = 15V I_C = 33A

Equivalent MOSFET Parameters①
$R_{CE(on)}$ typ. = 61mΩ
I_D (FET equivalent) = 50A

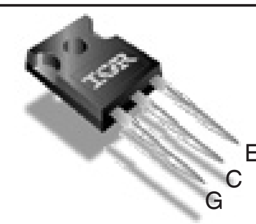
Applications
- Automotive HEV and EV
- PFC and ZVS SMPS Circuits

Features
- Low $V_{CE(ON)}$ NPT Technology, Positive Temperature Coefficient
- Lower Parasitic Capacitances
- Minimal Tail Current
- HEXFRED Ultra Fast Soft-Recovery Co-Pack Diode
- Tighter Distribution of Parameters
- Lead-Free, RoHS Compliant
- Automotive Qualified *

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



TO-247AC
AUIRGP50B60PD1



TO-247AD
AUIRGP50B60PD1E

G	C	E
Gate	Collector	Emitter

Absolute Maximum Ratings
Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only; and functional operation of the device at these or any other condition beyond those indicated in the specifications is not implied.Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability. The thermal resistance and power dissipation ratings are measured under board mounted and still air conditions. Ambient temperature (T_A) is 25°C, unless otherwise specified.

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	75 ⑥	A
I_C @ T_C = 100°C	Continuous Collector Current	45	
I_{CM}	Pulse Collector Current (Ref. Fig. C.T.4)	150	
I_{LM}	Clamped Inductive Load Current ②	150	
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	390	W
P_D @ T_C = 100°C	Maximum Power Dissipation	156	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°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)	–––	–––	0.32	°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)

*Qualification standards can be found at http://www.irf.com/

Dynamic 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	—	0.31	—	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	—	2.00	2.35	V	I_C = 33A, V_{GE} = 15V	4, 5,6,8,9
		—	2.45	2.85		I_C = 50A, V_{GE} = 15V	
		—	2.60	2.95		I_C = 33A, V_{GE} = 15V, T_J = 125°C	
		—	3.20	3.60		I_C = 50A, 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	—	-10	—	mV/°C	V_{CE} = V_{GE}, I_C = 1.0mA	
gfe	Forward Transconductance	—	41	—	S	V_{CE} = 50V, I_C = 33A, PW = 80μs	
I_{CES}	Collector-to-Emitter Leakage Current	—	5.0	500	μA	V_{GE} = 0V, V_{CE} = 600V	
		—	1.0	—	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	

Static or Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	Ref.Fig
Q_g	Total Gate Charge (turn-on)	—	205	308	nC	I_C = 33A	17
Q_{gc}	Gate-to-Collector Charge (turn-on)	—	70	105		V_{CC} = 400V	CT1
Q_{ge}	Gate-to-Emitter Charge (turn-on)	—	30	45		V_{GE} = 15V	
E_{on}	Turn-On Switching Loss	—	255	305	μJ	I_C = 33A, V_{CC} = 390V	CT3
E_{off}	Turn-Off Switching Loss	—	375	445		V_{GE} = +15V, R_G = 3.3Ω, L = 200μH	
E_{total}	Total Switching Loss	—	630	750		TJ = 25°C ④	
$t_{d(on)}$	Turn-On delay time	—	30	40	ns	I_C = 33A, V_{CC} = 390V	CT3
t_r	Rise time	—	10	15		V_{GE} = +15V, R_G = 3.3Ω, L = 200μH	
$t_{d(off)}$	Turn-Off delay time	—	130	150		T_J = 25°C ④	
t_f	Fall time	—	11	15			
E_{on}	Turn-On Switching Loss	—	580	700	μJ	I_C = 33A, V_{CC} = 390V	CT3
E_{off}	Turn-Off Switching Loss	—	480	550		V_{GE} = +15V, R_G = 3.3Ω, L = 200μH	11,13
E_{total}	Total Switching Loss	—	1060	1250		T_J = 125°C ④	WF1,WF2
$t_{d(on)}$	Turn-On delay time	—	26	35	ns	I_C = 33A, V_{CC} = 390V	CT3
t_r	Rise time	—	13	20		V_{GE} = +15V, R_G = 3.3Ω, L = 200μH	12,14
$t_{d(off)}$	Turn-Off delay time	—	146	165		T_J = 125°C ④	WF1,WF2
t_f	Fall time	—	15	20			
C_{ies}	Input Capacitance	—	3648	—	pF	V_{GE} = 0V	16
C_{oes}	Output Capacitance	—	322	—		V_{CC} = 30V	
C_{res}	Reverse Transfer Capacitance	—	56	—		f = 1Mhz	
C_{oes} eff.	Effective Output Capacitance (Time Related) ⑤	—	215	—		V_{GE} = 0V, V_{CE} = 0V to 480V	15
C_{oes} eff. (ER)	Effective Output Capacitance (Energy Related) ⑤	—	163	—			
RBSOA	Reverse Bias Safe Operating Area	FULL SQUARE				T_J = 150°C, I_C = 150A 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.= 2.00V and I_C =33A. 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}.

⑥ Calculated continuous current based on maximum allowable junction temperature. Package current limit is 60A. Note that current limitations arising from heating of the device leads may occur with some lead mounting arrangements.

Qualification Information†

Qualification Level		Automotive (per AEC-Q101) ††	
		Comments: This part number(s) passed Automotive qualification. IR's Industrial and Consumer qualification level is granted by extension of the higher Automotive level.	
Moisture Sensitivity Level		TO-247AC	N/A
		TO-247AD	
ESD	Machine Model	Class M4 (+/-450V) AEC-Q101-002	
	Human Body Model	Class H2 (+/-4500V) AEC-Q101-001	
	Charged Device Model	Class C5 (+/-1100V) AEC-Q101-005	
RoHS Compliant		Yes	

† Qualification standards can be found at International Rectifier's web site: http//www.irf.com/

†† Exceptions to AEC-Q101 requirements are noted in the qualification report.

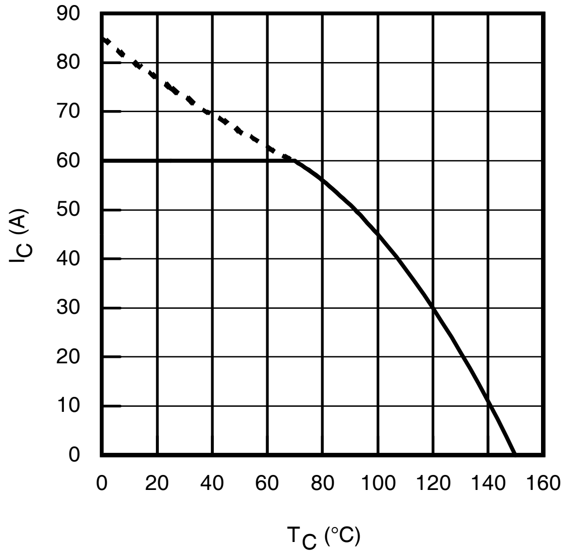


Fig. 1 - Maximum DC Collector Current vs. Case Temperature

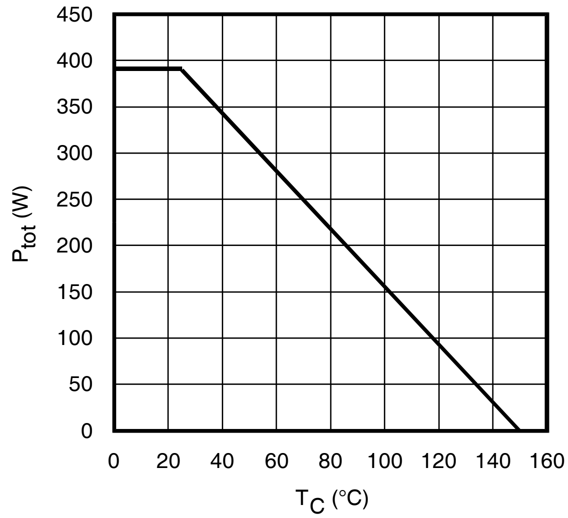


Fig. 2 - Power Dissipation vs. Case Temperature

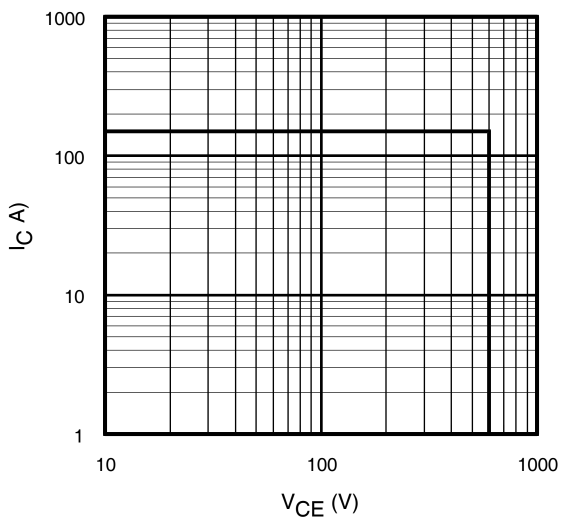


Fig. 3 - Reverse Bias SOA
T_J = 150°C; V_{GE} =15V

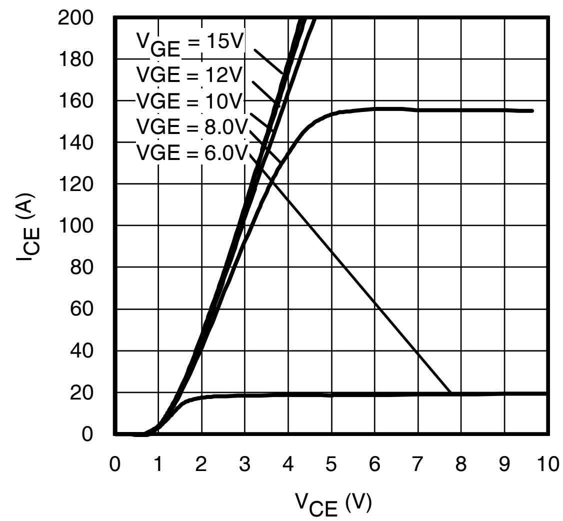


Fig. 4 - Typ. IGBT Output Characteristics
T_J = -40°C; tp = 80μs

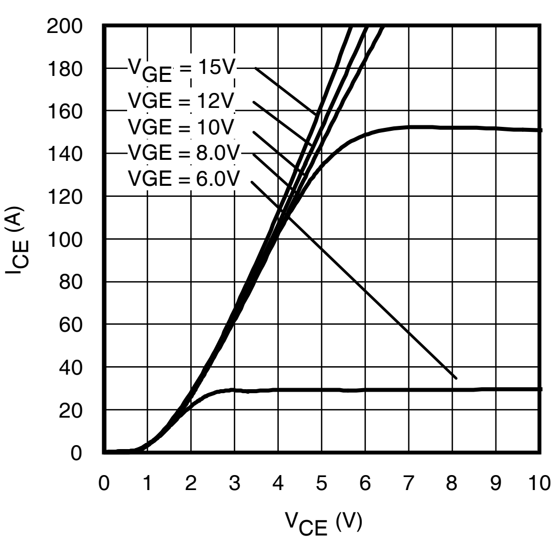


Fig. 5 - Typ. IGBT Output Characteristics
T_J = 25°C; tp = 80μs

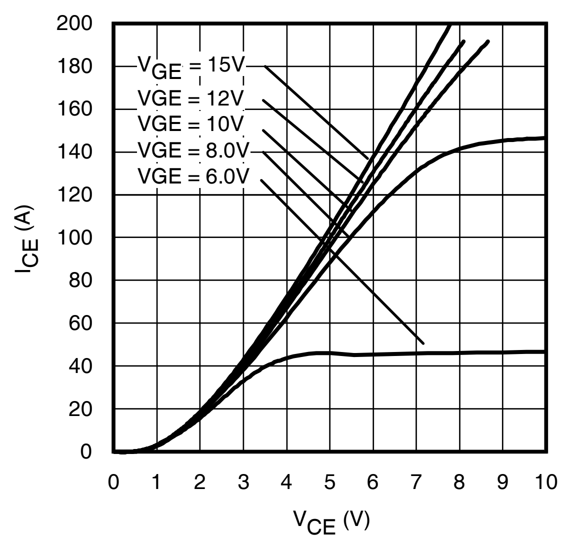


Fig. 6 - Typ. IGBT Output Characteristics
T_J = 125°C; tp = 80μs

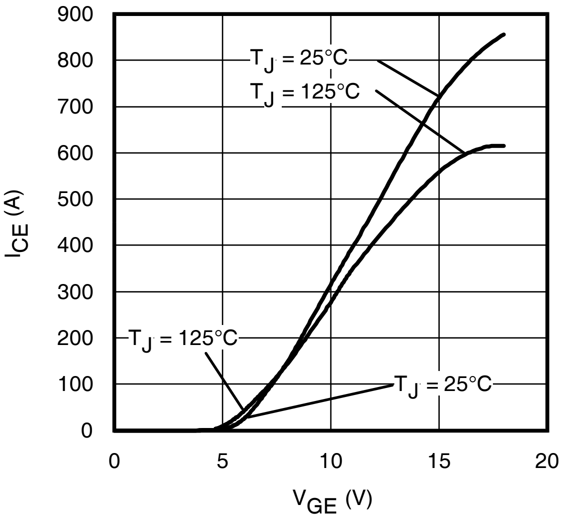


Fig. 7 - Typ. Transfer Characteristics
V_{CE} = 50V; tp = 10µs

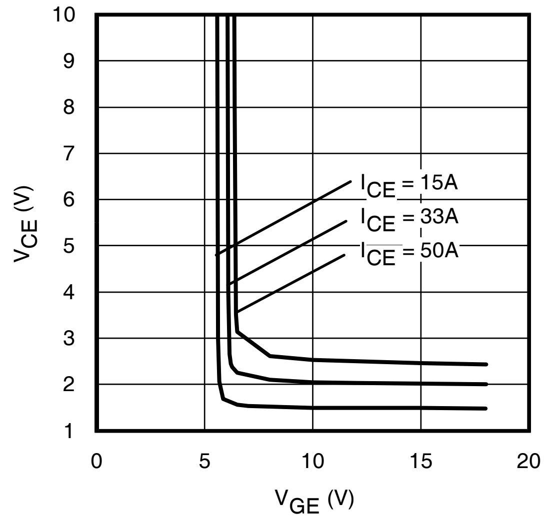


Fig. 8 - Typical V_{CE} vs. V_{GE}
T_J = 25°C

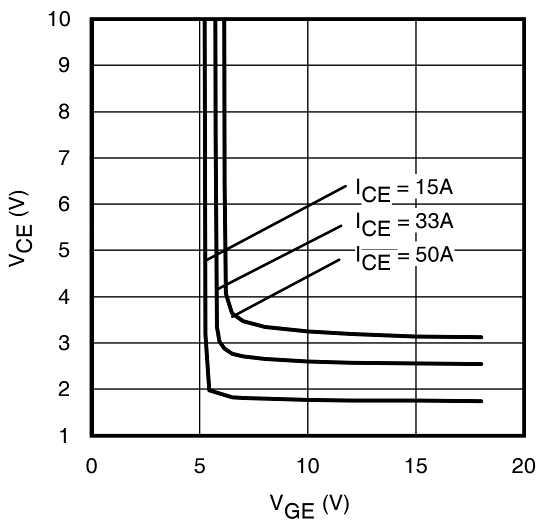


Fig. 9 - Typical V_{CE} vs. V_{GE}
T_J = 125°C

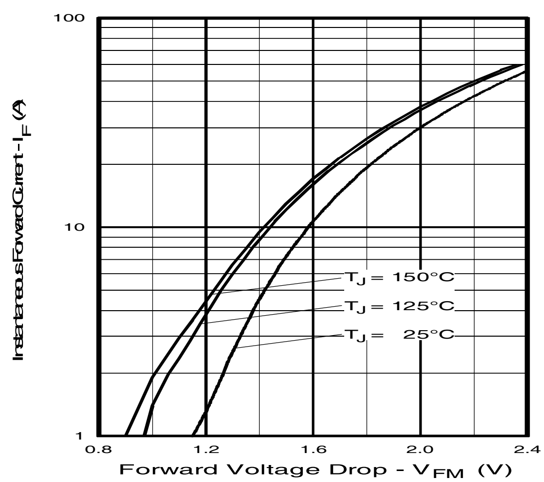


Fig. 10 - Typ. Diode Forward Characteristics
tp = 80µs

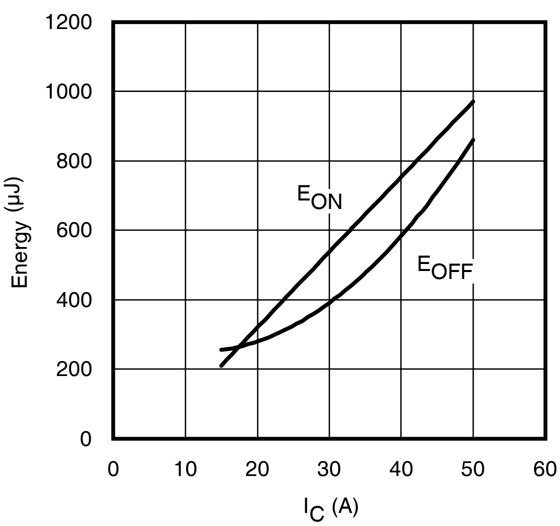


Fig. 11 - Typ. Energy Loss vs. I_C
T_J = 125°C; L = 200µH; V_{CE} = 390V, R_G = 3.3Ω; V_{GE} = 15V.
Diode clamp used: 30ETH06 (See C.T.3)

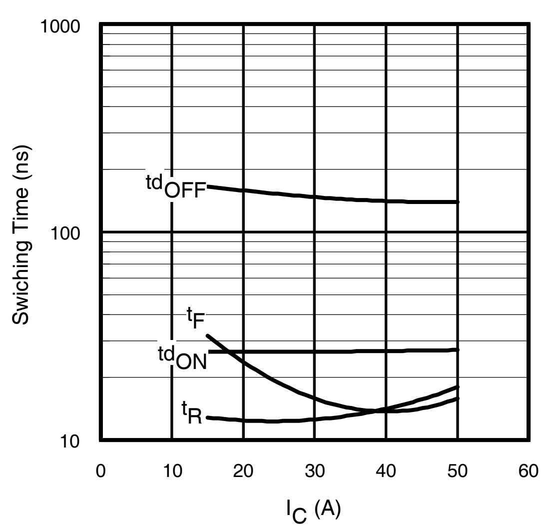


Fig. 12 - Typ. Switching Time vs. I_C
T_J = 125°C; L = 200µH; V_{CE} = 390V, R_G = 3.3Ω; V_{GE} = 15V.
Diode clamp used: 30ETH06 (See C.T.3)

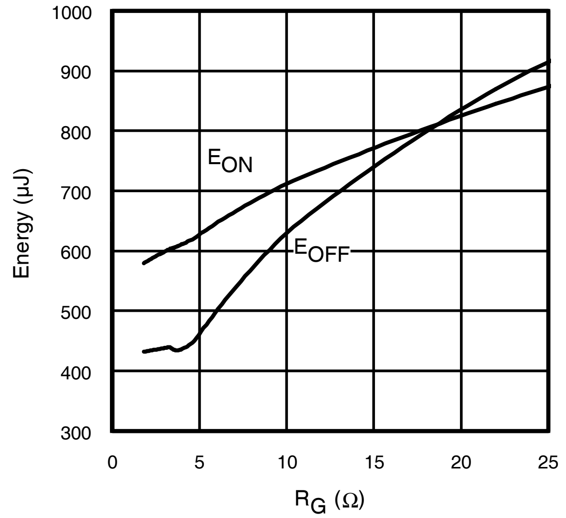


Fig. 13 - Typ. Energy Loss vs. R_G
T_J = 125°C; L = 200µH; V_{CE} = 390V, I_{CE} = 33A; V_{GE} = 15V
Diode clamp used: 30ETH06 (See C.T.3)

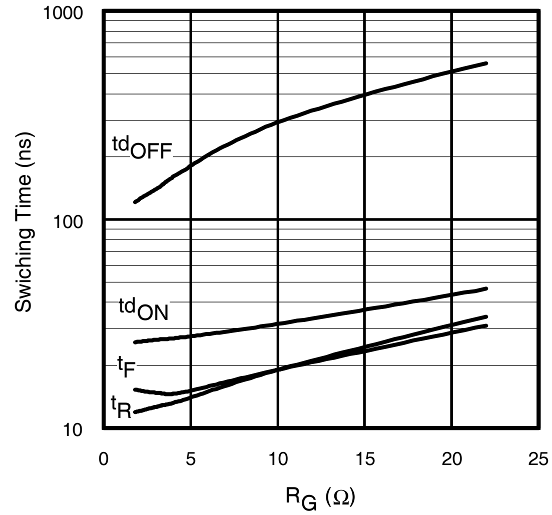


Fig. 14 - Typ. Switching Time vs. R_G
T_J = 125°C; L = 200µH; V_{CE} = 390V, I_{CE} = 33A; V_{GE} = 15V
Diode clamp used: 30ETH06 (See C.T.3)

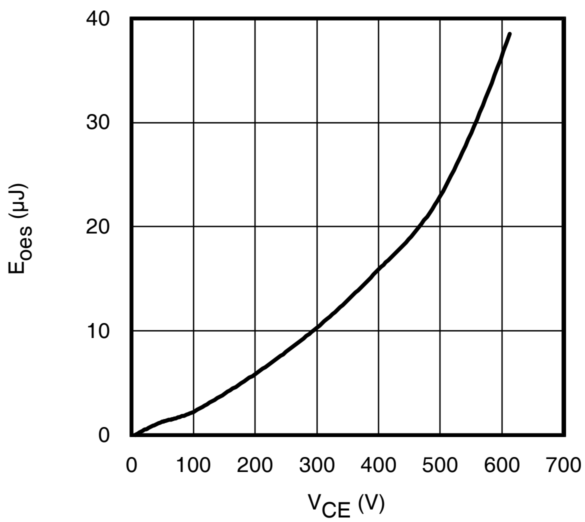


Fig. 15- Typ. Output Capacitance Stored Energy vs. V_{CE}

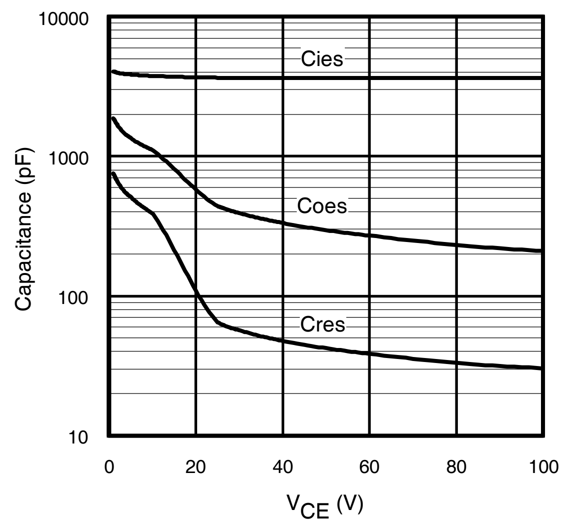


Fig. 16- Typ. Capacitance vs. V_{CE}
V_{GE}= 0V; f = 1MHz

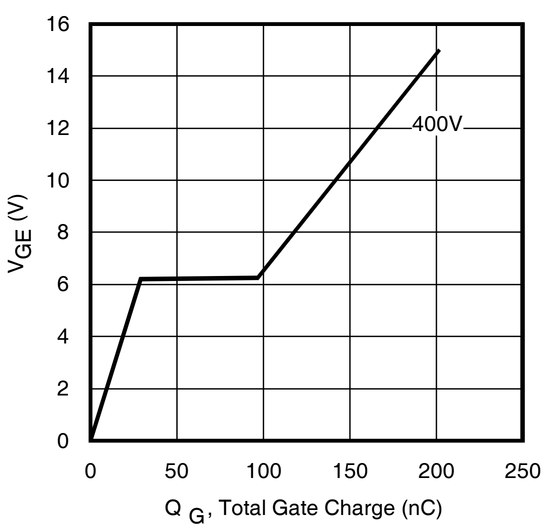


Fig. 17 - Typical Gate Charge vs. V_{GE}
I_{CE} = 33A

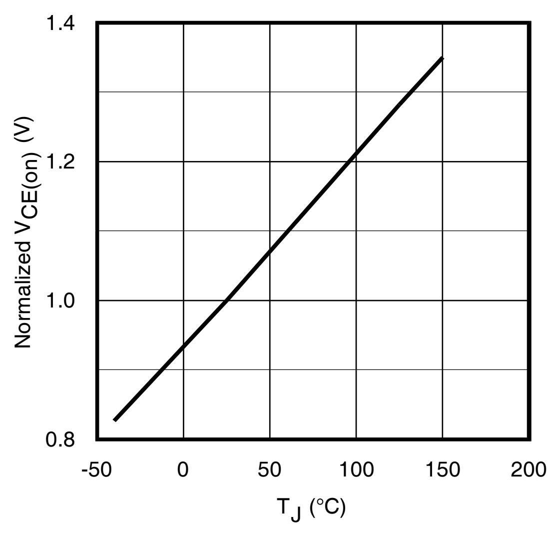


Fig. 18 - Normalized Typ. $V_{CE(on)}$ vs. Junction Temperature
I_C = 33A, V_{GE}= 15V

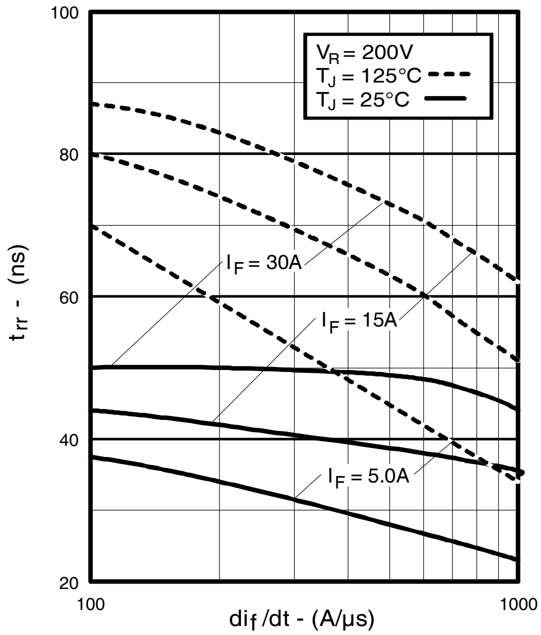


Fig. 19 - Typical Reverse Recovery vs. di_f/dt

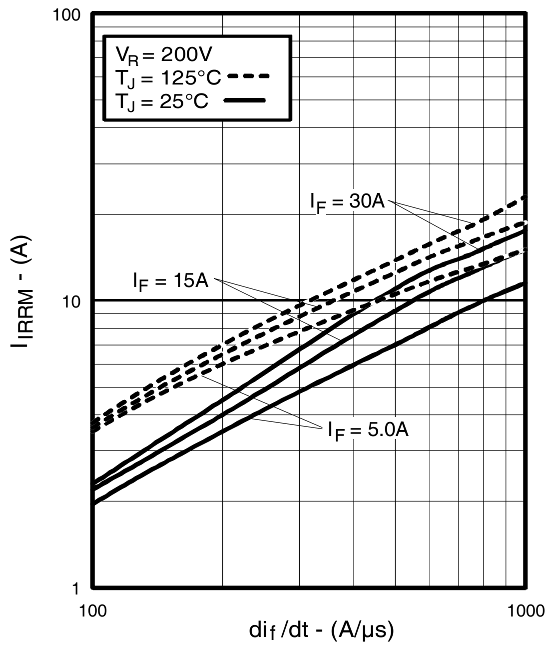


Fig. 20 - Typical Recovery Current vs. di_f/dt

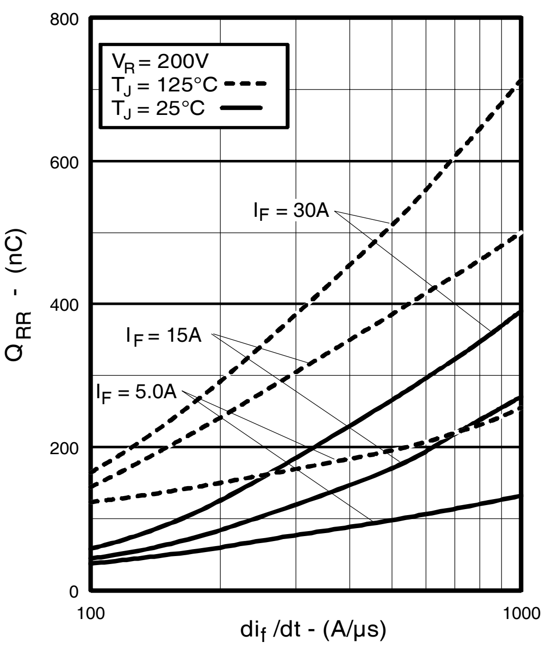


Fig. 21 - Typical Stored Charge vs. di_f/dt

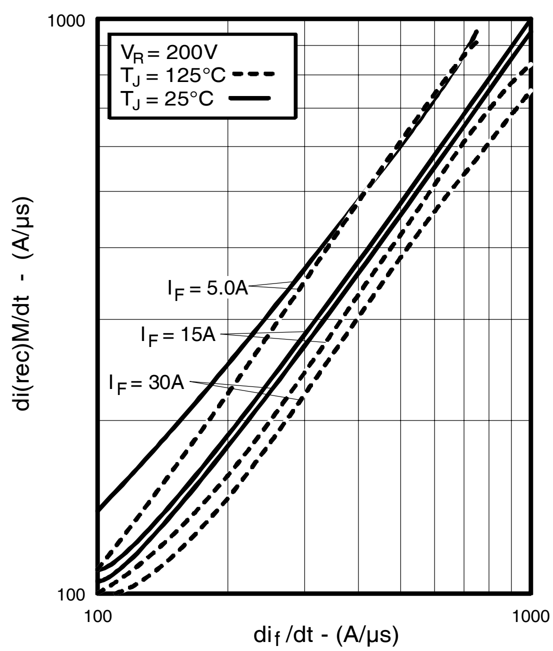


Fig. 22 - Typical $di_{(rec)M}/dt$ vs. di_f/dt,

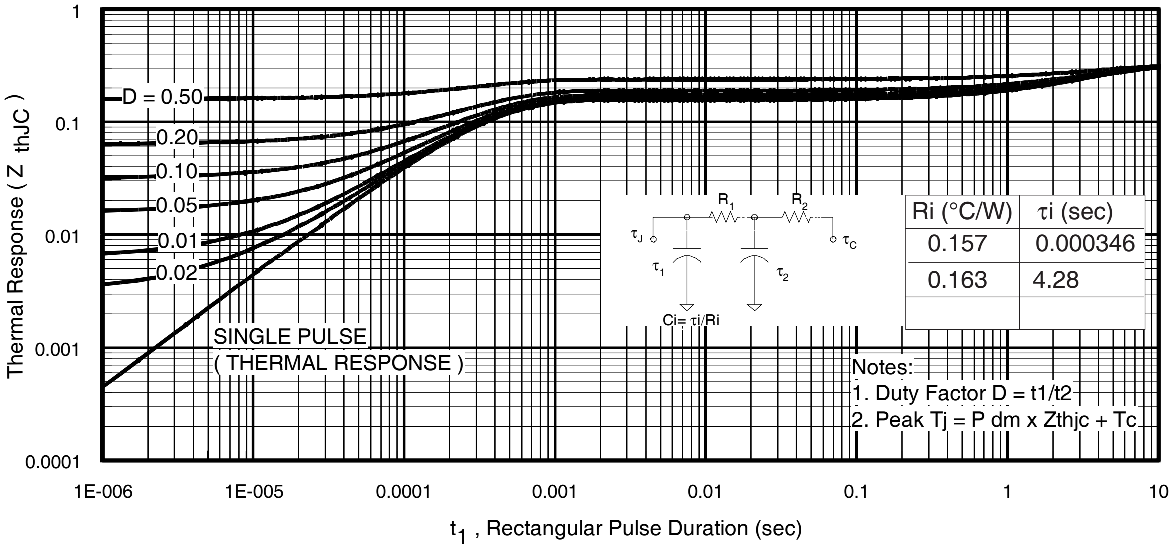


Fig 23. Maximum Transient Thermal Impedance, Junction-to-Case (IGBT)

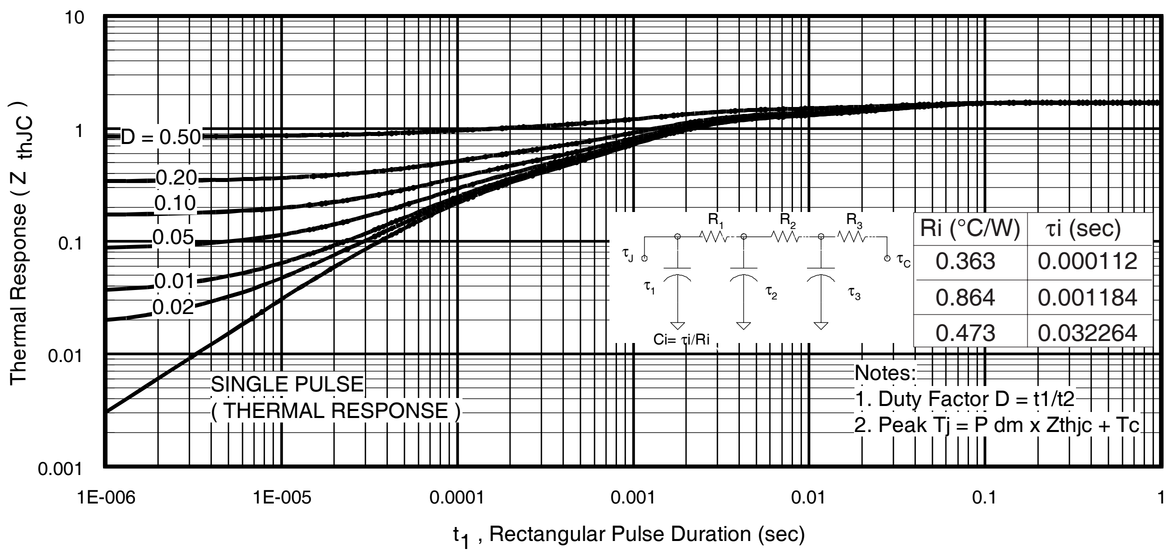


Fig. 24. Maximum Transient Thermal Impedance, Junction-to-Case (DIODE)

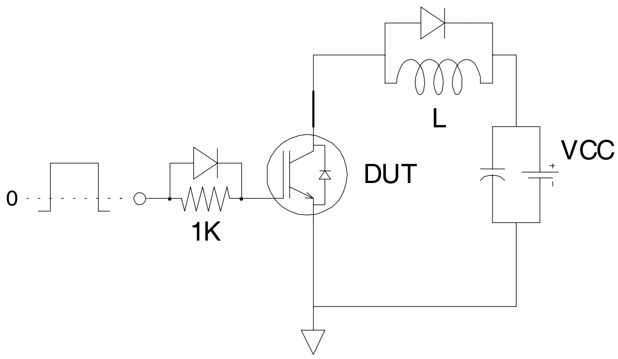


Fig.C.T.1 - Gate Charge Circuit (turn-off)

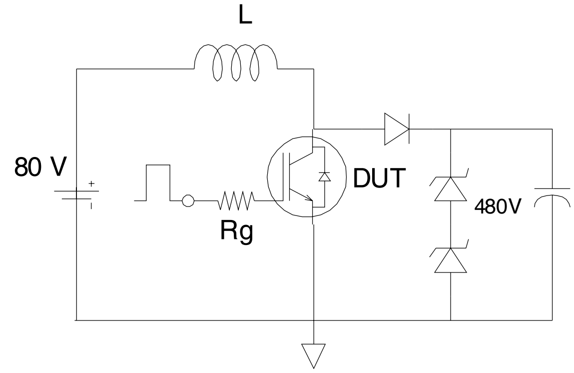


Fig.C.T.2 - RBSOA Circuit

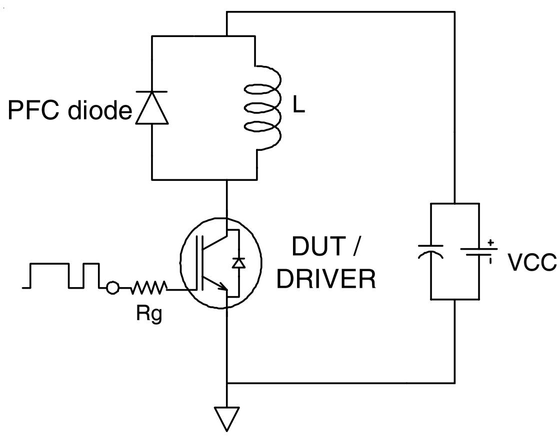


Fig.C.T.3 - Switching Loss Circuit

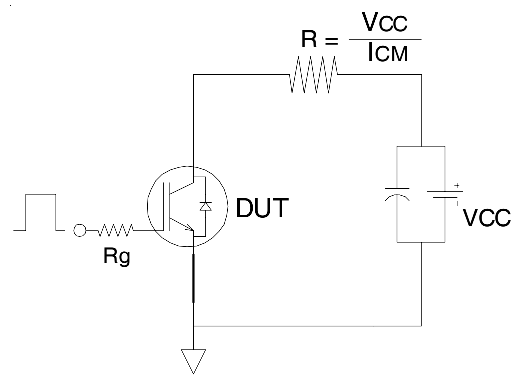


Fig.C.T.4 - Resistive Load Circuit

REVERSE RECOVERY CIRCUIT

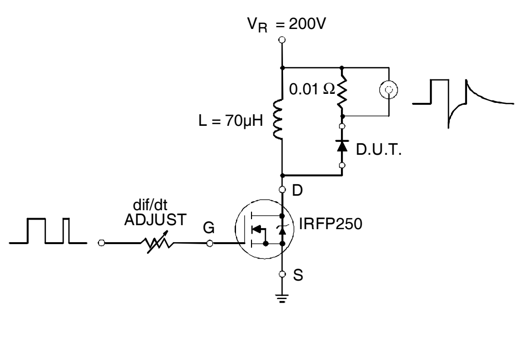


Fig. C.T.5 - Reverse Recovery Parameter Test Circuit

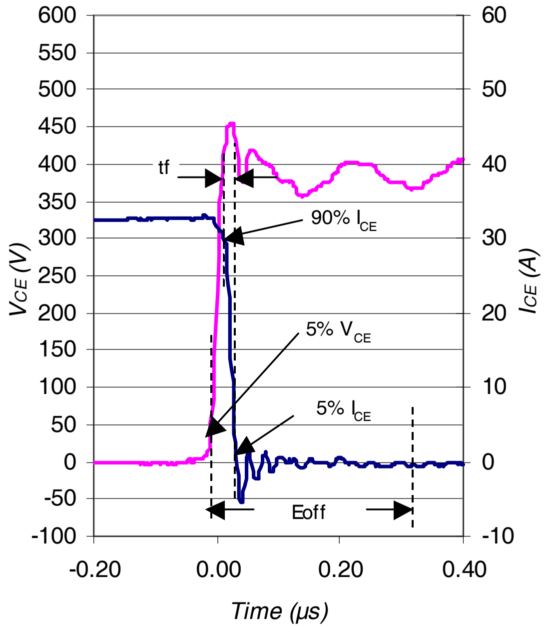


Fig. WF1 - Typ. Turn-off Loss Waveform
@ T_J = 25°C using Fig. CT.3

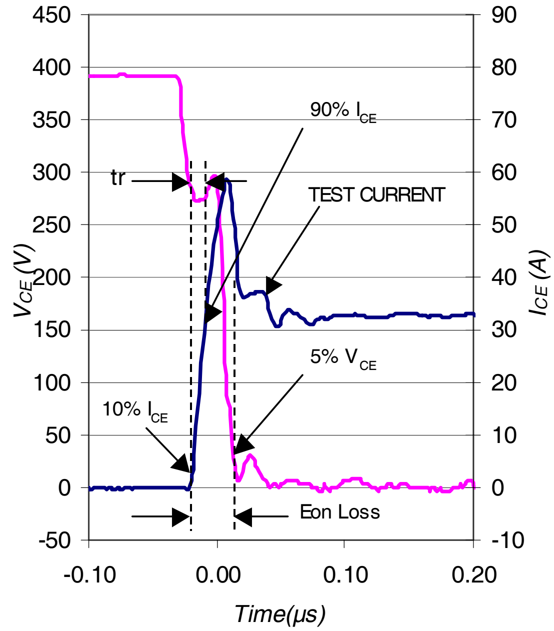
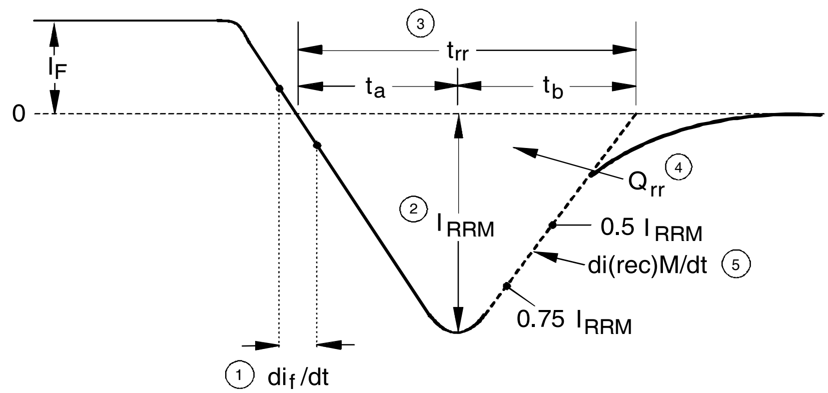


Fig. WF2 - Typ. Turn-on Loss Waveform
@ T_J = 25°C using Fig. CT.3



1. di_f/dt - Rate of change of current through zero crossing
2. I_{RRM} - Peak reverse recovery current
3. trr - 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}

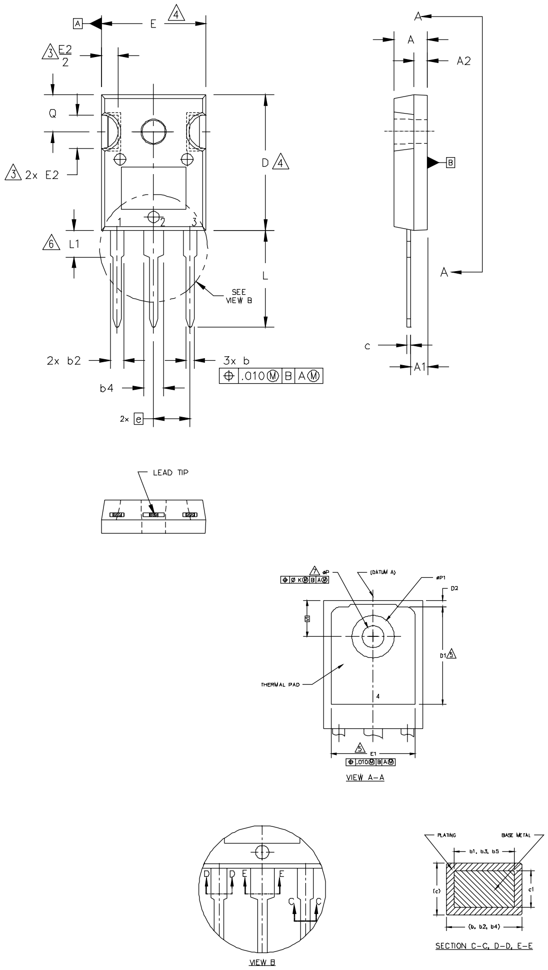
$$Q_{rr} = \frac{t_{rr} \times I_{RRM}}{2}$$

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

TO-247AC Package Outline

Dimensions are shown in milimeters (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-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		
Øk	.010		0.25		
L	.559	.634	14.20	16.10	
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

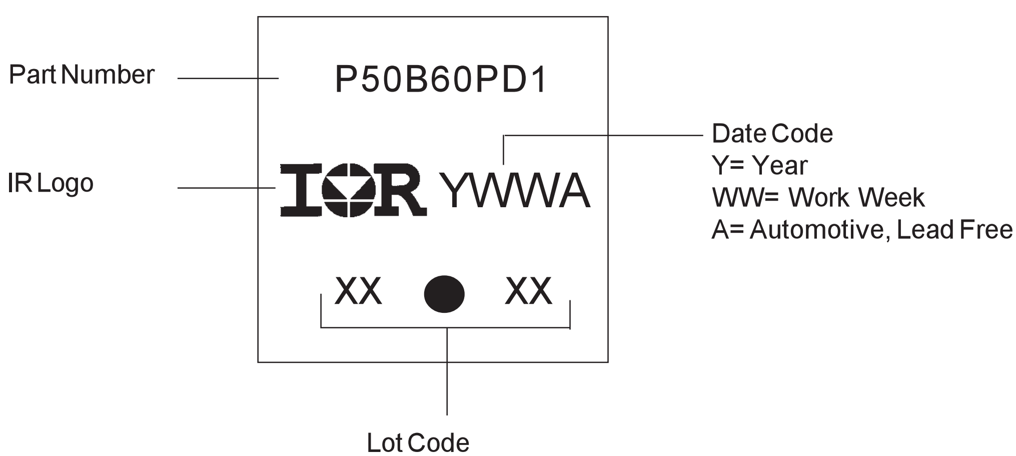
IGBTs, CoPACK

1.- GATE
2.- COLLECTOR
3.- EMITTER
4.- COLLECTOR

DIODES

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

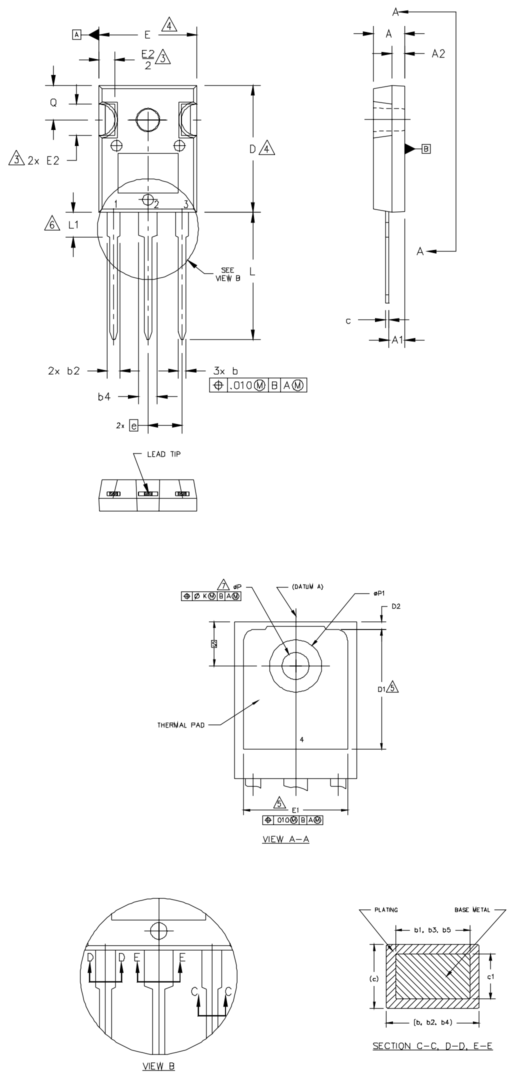
TO-247AC Part Marking Information



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.
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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

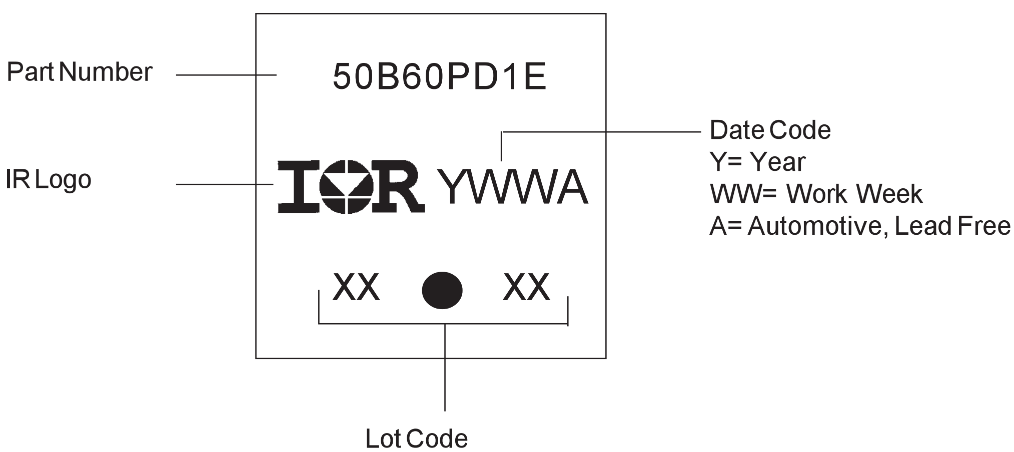
IGBTs, CoPACK

1.– GATE
2.– COLLECTOR
3.– EMITTER
4.– COLLECTOR

DIODES

1.– ANODE/OPEN
2.– CATHODE
3.– ANODE

TO-247AD Part Marking Information



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

Ordering Information

Base part number	Package Type	Standard Pack		Complete Part Number
		Form	Quantity	
AUIRGP50B60PD1	TO-247AC	Tube	25	AUIRGP50B60PD1
AUIRGP50B60PD1E	TO-247AD	Tube	25	AUIRGP50B60PD1E

IMPORTANT NOTICE

For technical support, please contact IR’s Technical Assistance Center
http://www.irf.com/technical-info/

WORLD HEADQUARTERS:

233 Kansas St., El Segundo, California 90245

Tel: (310) 252-7105