Price: $5.00

IGBT 2

IGBT

Insulated Gate Bipolar Transistor

DESIGNER'S MANUAL

International
IOR Rectifier

IGBT DESIGNER'S MANUAL IGBT-2

Insulated Gate Bipolar Transistors

IGBTs from International Rectifier

The Insulated Gate Bipolar Transistors (IGBTs) contained in this Designer's Manual represent International Rectifier's second generation of IGBT devices. Much progress has been made in our research and development labs, and the devices covered here represent the state of the art with regard to *any* IGBT available today. In creating the Generation-II process, International Rectifier has taken a quantum leap in IGBT technology—thus establishing the IGBT as a commercially viable power transistor—just as we did with our HEXFET power MOSFET more than a decade ago.

For designers who are new to IGBTs, these devices are voltage-controlled power transistors, similar to the power MOSFET in operation and in construction. While the IGBT is inherently faster than the power bipolar transistor, it is still not quite as fast as the power MOSFET (it is, however, getting closer). Because IGBTs have higher current densities (i.e. smaller die sizes) than equivalent high-voltage power MOSFETs, and offer far superior drive and output characteristics than bipolars, they are a more cost-effective solution in almost all high-voltage, high-current, moderate frequency applications.

International Rectifier is fully committed to its IGBT product line with expansions in voltage selections and package options in progress, as well as with the development of ancillary devices such as fast-recovery rectifiers and driver ICs to complement them.

You are invited to familiarize yourself with International Rectifier's present IGBT family by exploring this designer's manual. If you have any questions, please feel free to contact us directly. We will appreciate hearing from you, and look forward to filling your IGBT needs.

International
IOR Rectifier

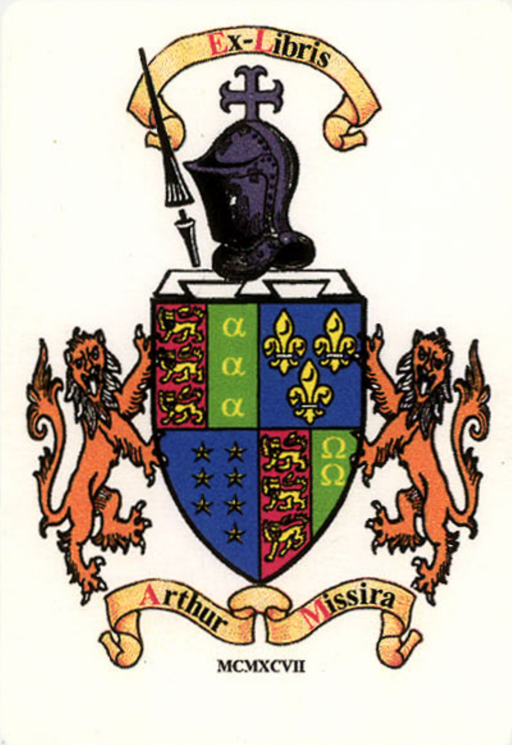
IGBT Designer's Manual

IGBT-2
Second Printing

PUBLISHED BY
INTERNATIONAL RECTIFIER, 233 KANSAS ST., EL SEGUNDO, CALIFORNIA 90245

Printed in U.S.A. 0191-M20

Insulated Gate Bipolar Transistors



The information presented in this publication is believed to be accurate and reliable. However, International Rectifier can assume no responsibility for its use nor any infringement of patents or other rights of third parties which may result from its use. No license is granted by implication or other use under any patent or patent rights of International Rectifier. No patent liability shall be incurred for use of the circuits or devices described herein.

International Rectifier does not recommend the use of its devices in life support applications wherein such use may directly threaten life or injuury due to device failure or malfunction. Users of International Rectifier devices in life support applications assume all risks of such use and indemnifies International Rectifier against all damages resulting from such use.

In the interest of product improvement, International Rectifier reserves the right to change specifications without notice.

Insulated Gate Bipolar Transistors

IGBTs

GENERAL INDEX

CONTENTS **PAGE**

Insulated Gate Bipolar Transistors

Discrete IGBTs

International Rectifier presently offers discrete IGBTs in the popular TO-220 and TO-247 (TO-3P) industry-standard packages. However, the performance of our IGBTs far surpasses present industry standard IGBTs. We offer IGBTs in different speeds which are optimized for your particular range of operating frequency.

Standard-Speed IGBTs.
These devices are optimized for the slowest range of operation, from dc to about 1 kHz. They are useful for many applications in line-frequency and pulse-type applications such as UPS systems and motor control circuits.

Fast-Speed IGBTs.
These devices are optimized for applications ranging in frequencies of about 3 to 10 kHz. They combine very low forward voltage drops with significantly lowered switching losses to provide the most efficient devices available for this frequency range. They find extreme usefulness in motor drives and general switching applications.

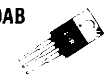
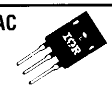
UltraFast™ IGBTs.
These devices minimize their overall switching losses in order to provide an IGBT which is useful in the range of 10 kHz to 100 kHz and beyond. No other IGBTs available possess E_{TS} (overall switching energy loss) values which are as low as IR's UltraFast series, and no other supplier measures switching losses as conservatively or as meaningfully to the designer as does IR.

These three families of IGBT devices offer the designer maximum flexibility and efficiency (cost and performance) for his or her design. (See page vi for more information on how to go about selecting the best device for your particular application).

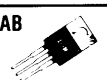
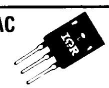
Insulated Gate Bipolar Transistors

PRODUCT SELECTOR GUIDE

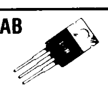
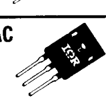
Standard-Speed IGBTs (< 1 kHz) Applications: High Voltage Motor Controls, UPS

Part Number	BV_{CES} Collector to Emitter Breakdown Voltage (V)	$V_{GE(th)}$ Gate to Emitter Threshold Voltage Min (V)	$V_{GE(th)}$ Gate to Emitter Threshold Voltage Max (V)	$V_{CE(on)}$ Collector to Emitter Saturation Voltage Max (V)	I_C Continuous Collector Current @ T_C = 25°C (A)	I_C Continuous Collector Current @ T_C = 100°C (A)	E_{ts} typ Total Switching Loss @ T_J = 150°C V_{CC} = 480V (mJ)	E_{ts} typ Total Switching Loss @ T_J = 150°C V_{CC} = 480V (A)	P_D Max. Power Dissip. (W)	Page Number	Case Style
IRGBC20S				2.0	19	10	4.1	10	60	7	**TO-220AB** 
IRGBC30S	600	3.0	5.5	1.9	34	18	7.1	18	100	25	
IRGBC40S				1.8	50	31	13	31	160	43	
IRGPC40S				1.8	60	31	13	31	160	61	**TO-247AC** (TO-3P) 
IRGPC50S				1.6	70	41	16	41	200	79	

Fast-Speed IGBTs (3 ~ 8 kHz) Applications: High Voltage UPS's, Motor Control, Industrial

Part Number	BV_{CES} Collector to Emitter Breakdown Voltage (V)	$V_{GE(th)}$ Gate to Emitter Threshold Voltage Min (V)	$V_{GE(th)}$ Gate to Emitter Threshold Voltage Max (V)	$V_{CE(on)}$ Collector to Emitter Saturation Voltage Max (V)	I_C Continuous Collector Current @ T_C = 25°C (A)	I_C Continuous Collector Current @ T_C = 100°C (A)	E_{ts} typ Total Switching Loss @ T_J = 150°C V_{CC} = 480V (mJ)	E_{ts} typ Total Switching Loss @ T_J = 150°C V_{CC} = 480V (A)	P_D Max. Power Dissip. (W)	Page Number	Case Style
IRGBC20F				2.8	16	9	1.8	9	60	1	**TO-220AB** 
IRGBC30F	600	3.0	5.5	2.1	31	17	2.5	17	100	19	
IRGBC40F				2.0	49	27	4.4	27	160	37	
IRGPC40F				2.0	49	47	4.4	27	160	55	**TO-247AC** (TO-3P) 
IRGPC50F				1.7	70	39	6.0	39	200	73	

UltraFast™ IGBTs (> 10 kHz) Applications: High Voltage SMPS's, Motor Controls, Robotics

Part Number	BV_{CES} Collector to Emitter Breakdown Voltage (V)	$V_{GE(th)}$ Gate to Emitter Threshold Voltage Min (V)	$V_{GE(th)}$ Gate to Emitter Threshold Voltage Max (V)	$V_{CE(on)}$ Collector to Emitter Saturation Voltage Max (V)	I_C Continuous Collector Current @ T_C = 25°C (A)	I_C Continuous Collector Current @ T_C = 100°C (A)	E_{ts} typ Total Switching Loss @ T_J = 150°C V_{CC} = 480V (mJ)	E_{ts} typ Total Switching Loss @ T_J = 150°C V_{CC} = 480V (A)	P_D Max. Power Dissip. (W)	Page Number	Case Style
IRGBC20U				3.0	13	6.5	0.35	6.5	60	13	**TO-220AB** 
IRGBC30U	600	3.0	5.5	3.0	23	12	0.59	12	100	31	
IRGBC40U				3.0	40	20	1.5	20	160	49	
IRGPC40U				3.0	40	20	1.5	20	160	67	**TO-247AC** (TO-3P) 
IRGPC50U				3.0	55	27	1.7	27	200	85	

Insulated Gate Bipolar Transistors

How to Select the Best IGBT for Your Applications

Follow 3 simple steps:

1. *What blocking voltage do you require?* At present, IR offers only 600V devices, so this question has limited significance for the moment; however, this question will become meaningful in the very near future as our 900V and 1200V devices are introduced (as well as a potential 250V family). Realize also that if you only require a 100 or 200-volt device, then our HEXFET power MOSFET will probably continue to be the most cost effective solution for your needs.

2. *What frequency will the device be operated at?* This will help you to decide whether to use "S", "F", or "U"-suffixed devices (for Standard, Fast, and UltraFast, respectively). If you are planning to operate in the overlap regions between families (i.e., ~1-3 kHz, or ~10 kHz), then we recommend that you try *both* of the closest family of devices, in order to see which one operates most efficiently in your application.

3. *What current will be required?* The current of the IGBT will determine the amount of power dissipated by the device, and will be a function of the operating temperature, the duty cycle, your particular drive circuit and/or PWM scheme, and other minor factors. However, the power dissipation can be simply approximated by plugging the anticipated current requirement into the following qualitative formula:

$$P_D = \left[I_C \cdot V_{CE}(I_C) \cdot \text{Duty Cycle} \right] + \left[E_{TS}(I_C) \cdot \text{Freq} \cdot \frac{V_{CE}}{V_{CE(meas)}} \right]$$

where P_D is the total power dissipated (limited by max junction temp and case temp), and V_{CE} and E_{TS} are both functions of I_C (the collector current). These values can be approximated by using the graphs provided in the data sheets.

This will result in a feeling for the power you will need to dissipate, and will tell you (for any given device size you have chosen) whether that device is likely to be able to handle your needs.

PD-9.686

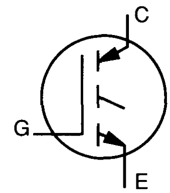
International Rectifier

IRGBC20F

INSULATED GATE BIPOLAR TRANSISTOR

Fast-Speed IGBT

- Latch-proof
- Simple gate-drive
- Fast operation 3kHz~8kHz
- Switching-Loss Rating includes all "tail" losses

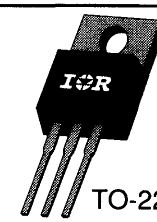


n-channel

V_{CEO} = 600 V
$I_{C(DC)}$ = 16 A
$V_{CE(sat)} \leq$ 2.8 V
$E_{TS} \leq$ 2.3 mJ

Description

Insulated Gate Bipolar Transistors (IGBTs) from International Rectifier have higher current densities than comparable bipolar transistors, while at the same time having simpler gate-drive requirements of the familiar power MOSFET. They provide substantial benefits to a host of higher-voltage, higher-current applications.



TO-220AB

Absolute Maximum Ratings

	Parameter	Max.	Units
I_C @ T_C = 25°C	Continuous Collector Current	16	A
I_C @ T_C = 100°C	Continuous Collector Current	9.0	
I_{CM}	Pulsed Collector Current ①	64	
V_{CE}	Collector-to-Emitter Breakdown Voltage	600	V
V_{GE}	Gate-to-Emitter Voltage	±20	
I_{LM}	Clamped Inductive Load Current ②	64	A
E_{ARV}	Reverse Voltage Avalanche Energy ③	5.0	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation	60	W
P_D @ T_C = 100°C	Maximum Power Dissipation	24	
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 3mm MA screw	10 in•lbs (11.5 kg•cm)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	---	---	2.1.	K/W ⑥
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	---	0.50	---	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	---	---	80	

Electrical Characteristic @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
BV_{CES}	Collector-to-Emitter Breakdown Voltage	600	---	---	V	V_{GE}=0V, I_C=250μA
BV_{ECS}	Emitter-to-Collector Breakdown Volt. ④	28	---	---	V	V_{GE}=0V, I_C=1.0A
$\Delta BV_{CES}/\Delta T_J$	Temp. Coeff. of Breakdown Voltage	---	0.72	---	V/°C	V_{GE}=0V, I_C =1.0mA
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	---	---	2.8	V	V_{GE}=15V, I_C=9.0A See fig 4.
		---	2.6	---		V_{GE}=15V, I_C=16A
		---	2.3	---		V_{CE}=15V, I_C=9.0A, T_J=150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	---	5.5	V	V_{CE}=V_{GE}, I_C=250μA
$\Delta BV_{GE(th)}/\Delta T_J$	Temp. Coeff. of Threshold Voltage	---	-11	---	mV/°C	V_{CE}=V_{GE}, I_C=250μA
g_{fe}	Forward Transconductance ⑤	2.9	---	7.2	S	V_{CE}=100V, I_C=9.0A
I_{CES}	Zero Gate Voltage Collector Current	---	---	250	μA	V_{GE}=0V, V_{CE}=600V, T_J=25°C
		---	---	1000		V_{GE}=0V, V_{CE}=600V, T_J=150°C
I_{GES}	Gate-to-Emitter Leakage Current	---	---	±500	nA	V_{GE}=±20V

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

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
Q_G	Total Gate Charge (turn-on)	11	---	21	nC	I_C=9.0A, V_{CC}=480V See Figure 6.
Q_{GE}	Gate - Emitter Charge (turn-on)	1.4	---	3.4		
Q_{GC}	Gate - Collector Charge (turn-on)	5.3	---	10		
$t_{d(on)}$	Turn-On Delay Time	---	24	---	ns	See test circuit, figure 13.
t_r	Rise Time	---	13	---		I_C=9.0A, V_{CC}=480V
$t_{d(off)}$	Turn-off Delay Time	---	---	270		T_J=25°C
t_f	Fall Time	---	---	600		V_{GE}=15V, R_G=50Ω
E_{on}	Turn-On Switching Loss	---	0.16	---	mJ	Energy losses include "tail".
E_{off}	Turn-Off Switching Loss	---	1.2	---		Also see figures 9, 10, & 11.
E_{ts}	Total Switching Loss	---	1.3	2.3		
$t_{d(on)}$	Turn-On Delay Time	---	25	---	ns	I_C=9.0A, V_{CC}=480V
t_r	Rise Time	---	18	---		T_J=150°C
$t_{d(off)}$	Turn-Off Delay Time	---	210	---		V_{GE}=15V
t_f	Fall Time	---	600	---		R_G=50Ω
E_{ts}	Total Switching Loss	---	1.8	---	mJ	
L_E	Internal Emitter Inductance	---	7.5	---	nH	Measured 5mm from package.
C_{iee}	Input Capacitance	---	340	---	pF	V_{GE}=0V
C_{oee}	Output Capacitance	---	63	---		V_{CC}=30V See fig 5.
C_{ree}	Reverse Transfer Capacitance	---	5.9	---		f = 1.0MHz

Notes:

① Repetitive rating; V_{GE}=20V, pulse width limited by max. junction temperature (See figure 12b).

② V_{CC}=80%(BV_{CES}), V_{GE}=20V, L=10μH, R_G=10Ω, (See figure 12a).

③ Repetitive rating; pulse width limited by maximum junction temperature.

④ Pulse width ≤ 80μs; duty factor ≤0.1%.

⑤ Pulse width ≤ 5μs, single shot.

⑥ K/W equivalent to °C/W.

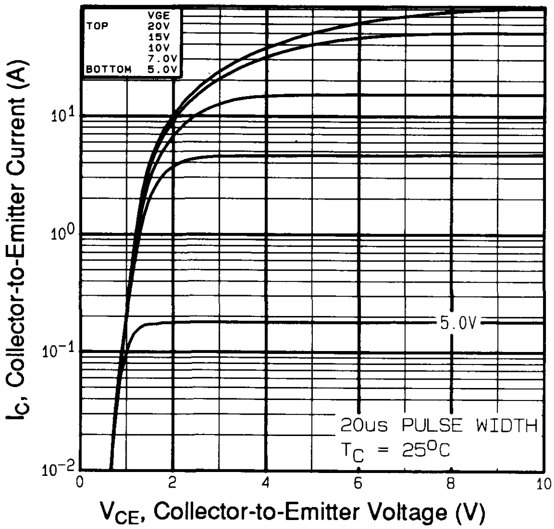


Fig 1. Typical Output Characteristics, $T_J = 25°C$

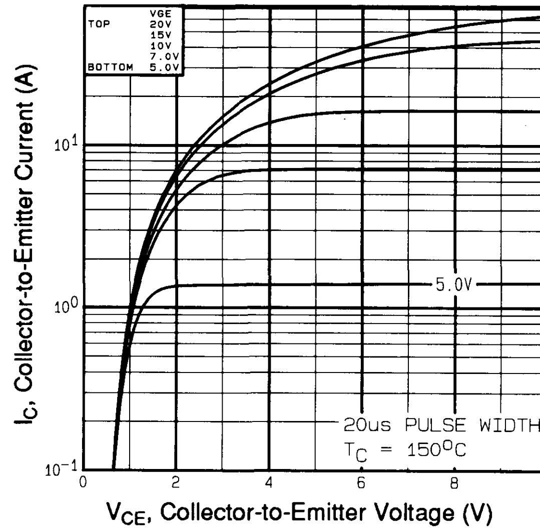


Fig 2. Typical Output Characteristics, $T_J = 150°C$

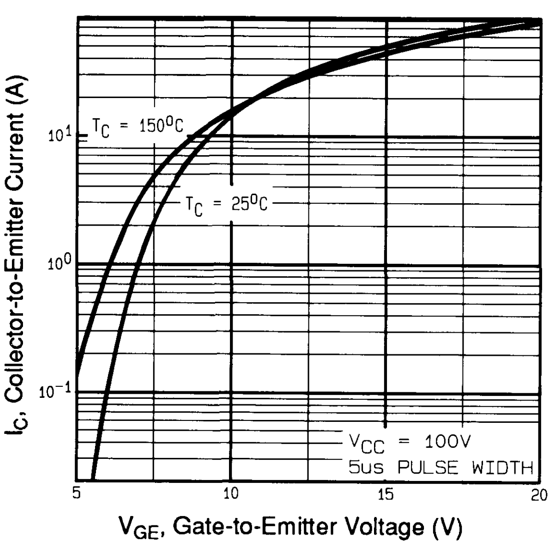


Fig 3. Typical Transfer Characteristics

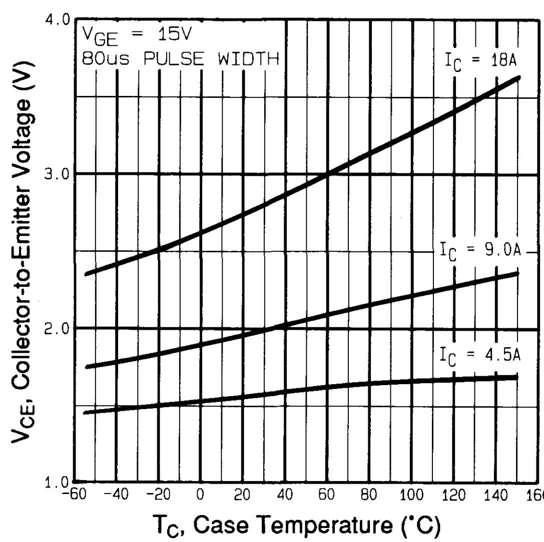


Fig 4. Collector-to-Emitter Saturation Voltage vs. Case Temperature

Graphs indicate performance of typical devices

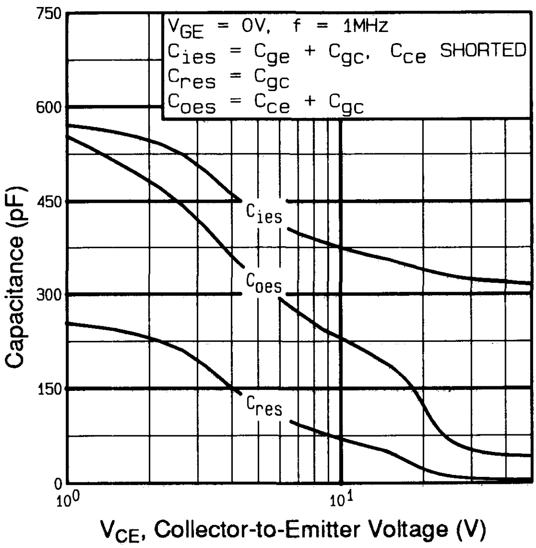


Fig 5. Typical Capacitance vs. Collector-to-Emitter Voltage

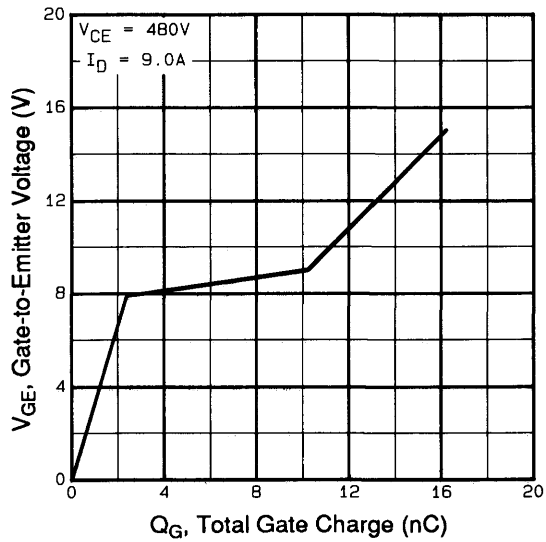


Fig 6. Typical Gate Charge vs. Gate-to-Emitter Voltage

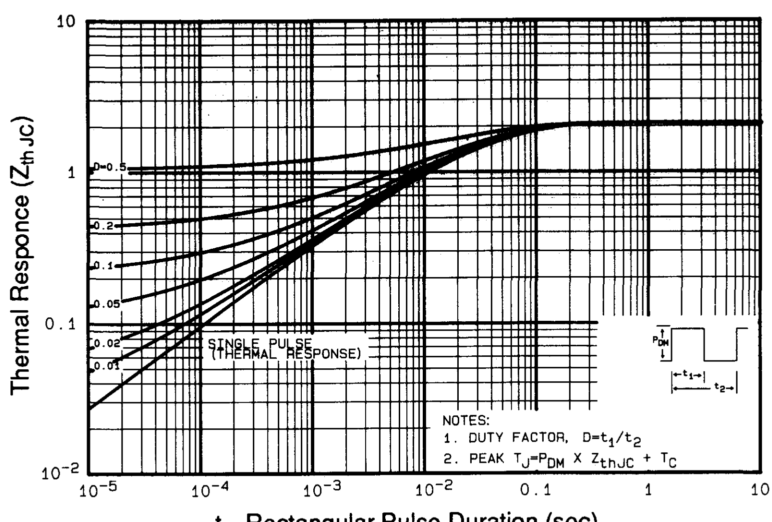


Fig 7. Maximum Effective Transient Thermal Impedance, Junction-to-Case

Graphs indicate performance of typical devices

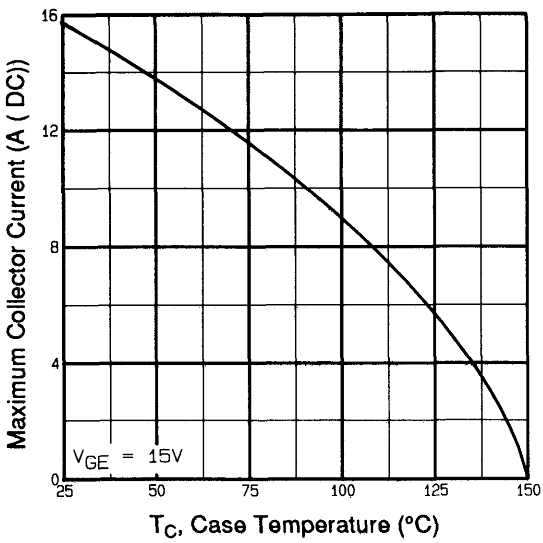


Fig 8. Maximum Collector Current vs. Case Temperature

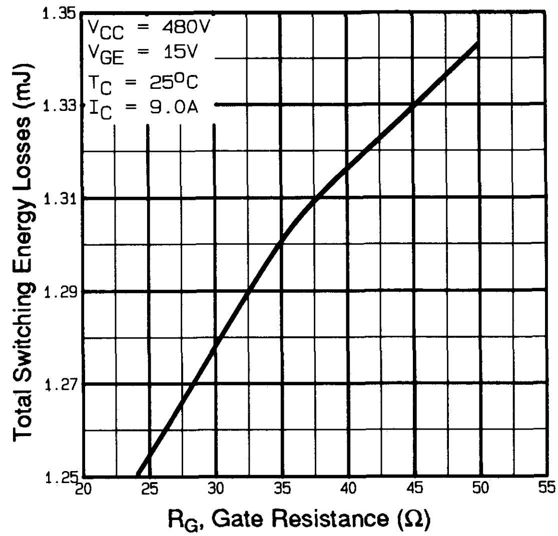


Fig 9. Typical Switching Losses vs. Gate Resistance

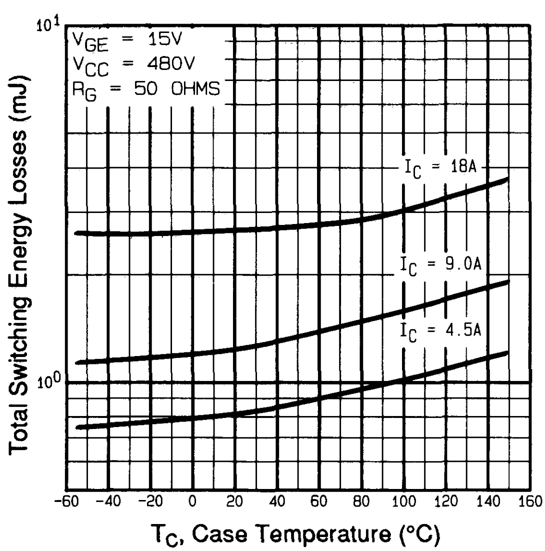


Fig 10. Typical Switching Losses vs. Case Temperature

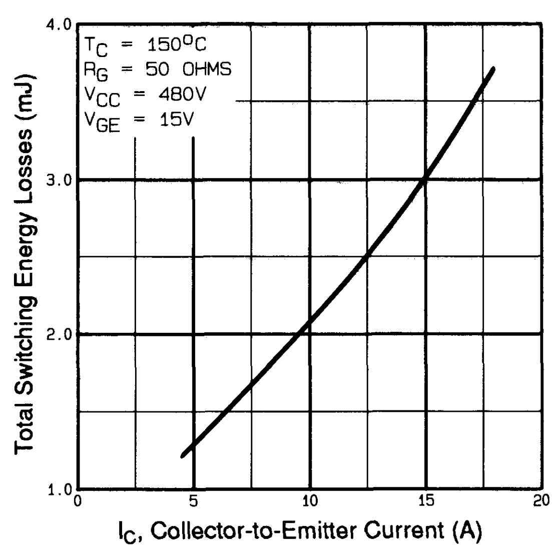


Fig 11. Typical Switching Losses vs. Collector-to-Emitter Current

Graphs indicate performance of typical devices

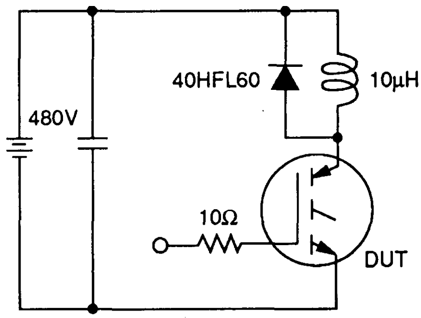


Fig 12a. Clamped Inductive Load Test Circuit

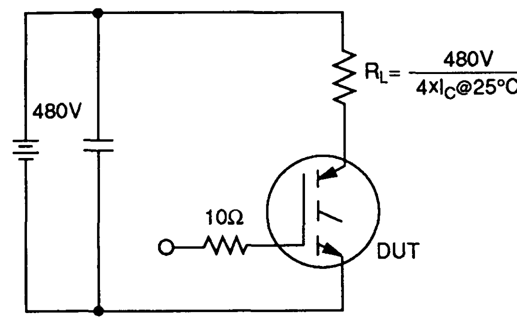


Fig 12b. Pulsed Collector Current Test Circuit

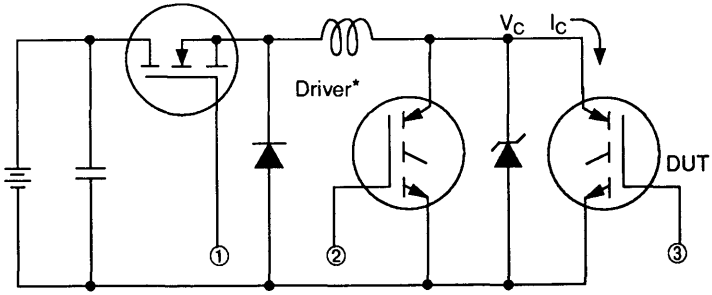


Fig 13a. Switching Loss Test Circuit

* Driver same type as DUT, V_C = 480V

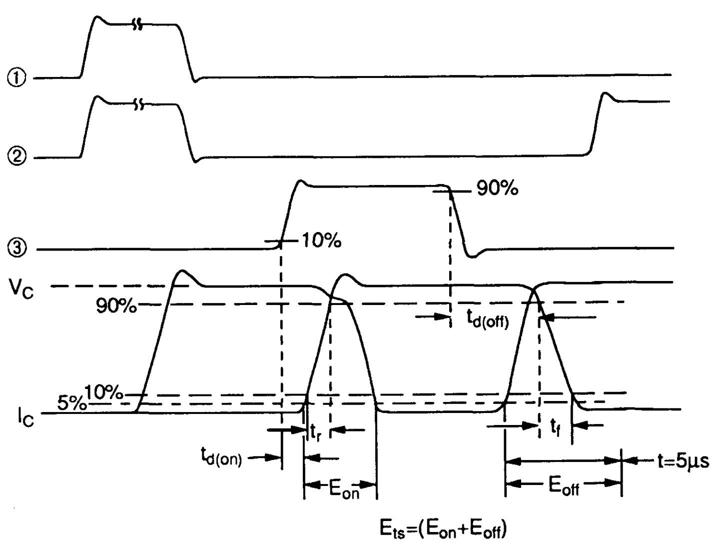


Fig 13b. Switching Loss Waveforms

International IOR Rectifier

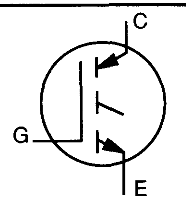
International
IOR Rectifier

IRGBC20S

INSULATED GATE BIPOLAR TRANSISTOR

Standard-Speed IGBT

- Latch-proof
- Simple gate-drive
- Standard operation < 1kHz
- Switching-Loss Rating includes all "tail" losses

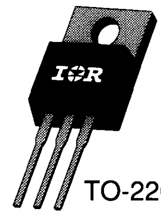


n-channel

V_{CEO} = 600 V
$I_{C(DC)}$ = 19 A
$V_{CE(sat)} \leq 2.4$ V
$E_{TS} \leq 6.0$ mJ

Description

Insulated Gate Bipolar Transistors (IGBTs) from International Rectifier have higher current densities than comparable bipolar transistors, while at the same time having simpler gate-drive requirements of the familiar power MOSFET. They provide substantial benefits to a host of higher-voltage, higher-current applications.



TO-220AB

Absolute Maximum Ratings

	Parameter	Max.	Units
I_C @ T_C = 25°C	Continuous Collector Current	19	A
I_C @ T_C = 100°C	Continuous Collector Current	10	
I_{CM}	Pulsed Collector Current ①	76	
V_{CE}	Collector-to-Emitter Breakdown Voltage	600	V
V_{GE}	Gate-to-Emitter Voltage	±20	
I_{LM}	Clamped Inductive Load Current ②	76	A
E_{ARV}	Reverse Voltage Avalanche Energy ③	5.0	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation	60	W
P_D @ T_C = 100°C	Maximum Power Dissipation	24	
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 3mm MA screw	10 in•lbs (11.5 kg•cm)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	---	---	2.1	K/W ⑥
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	---	0.50	---	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	---	---	80	

Electrical Characteristic @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
BV_{CES}	Collector-to-Emitter Breakdown Voltage	600	---	---	V	V_{GE}=0V, I_C=250µA
BV_{ECS}	Emitter-to-Collector Breakdown Volt. ④	15	---	---		V_{GE}=0V, I_C=1.0A
$\Delta BV_{CES}/\Delta T_J$	Temp. Coeff. of Breakdown Voltage	---	0.75	---	V/°C	V_{GE}=0V, I_C =1.0mA
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	---	---	2.0	V	V_{GE}=15V, I_C=10A See fig 4.
		---	2.4	---		V_{GE}=15V, I_C=19A
		---	1.9	---		V_{CE}=15V, I_C=10A, T_J=150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	---	5.5		V_{CE}=V_{GE}, I_C=250µA
$\Delta BV_{GE(th)}/\Delta T_J$	Temp. Coeff. of Threshold Voltage	---	-9.3	---	mV/°C	V_{CE}=V_{GE}, I_C=250µA
g_{fe}	Forward Transconductance ⑤	2.0	---	9.5	S	V_{CE}=100V, I_C=10A
I_{CES}	Zero Gate Voltage Collector Current	---	---	250	µA	V_{GE}=0V, V_{CE}=600V, T_J=25°C
		---	---	1000		V_{GE}=0V, V_{CE}=600V, T_J=150°C
I_{GES}	Gate-to-Emitter Leakage Current	---	---	±500	nA	V_{GE}=±20V

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

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
Q_G	Total Gate Charge (turn-on)	11	---	26	nC	I_C=10A, V_{CC}=480V
Q_{GE}	Gate - Emitter Charge (turn-on)	1.0	---	4.0		See Figure 6.
Q_{GC}	Gate - Collector Charge (turn-on)	4.0	---	12		
$t_{d(on)}$	Turn-On Delay Time	---	24	---	ns	See test circuit, figure 13.
t_r	Rise Time	---	23	---		I_C=10A, V_{CC}=480V
$t_{d(off)}$	Turn-off Delay Time	---	---	1200		T_J=25°C
t_f	Fall Time	---	---	1600		V_{GE}=15V, R_G=50Ω
E_{on}	Turn-On Switching Loss	---	0.24	---	mJ	Energy losses include "tail".
E_{off}	Turn-Off Switching Loss	---	3.9	---		Also see figures 9, 10, & 11.
E_{ts}	Total Switching Loss	---	4.1	6.0		
$t_{d(on)}$	Turn-On Delay Time	---	26	---	ns	I_C=10A, V_{CC}=480V
t_r	Rise Time	---	30	---		T_J=150°C
$t_{d(off)}$	Turn-Off Delay Time	---	1100	---		V_{GE}=15V
t_f	Fall Time	---	1800	---		R_G=50Ω
E_{ts}	Total Switching Loss	---	7.0	---	mJ	
L_E	Internal Emitter Inductance	---	7.5	---	nH	Measured 5mm from package.
C_{iee}	Input Capacitance	---	360	---	pF	V_{GE}=0V
C_{oee}	Output Capacitance	---	36	---		V_{CC}=30V See fig 5.
C_{ree}	Reverse Transfer Capacitance	---	5.2	---		f = 1.0MHz

Notes:

① Repetitive rating; V_{GE}=20V, pulse width limited by max. junction temperature (See figure 12b).

② V_{CC}=80%(BV_{CES}), V_{GE}=20V, L=10µH, R_G=10Ω, (See figure 12a).

③ Repetitive rating; pulse width limited by maximum junction temperature.

④ Pulse width ≤ 80µs; duty factor ≤0.1%.

⑤ Pulse width ≤ 5µs, single shot.

⑥ K/W equivalent to °C/W.

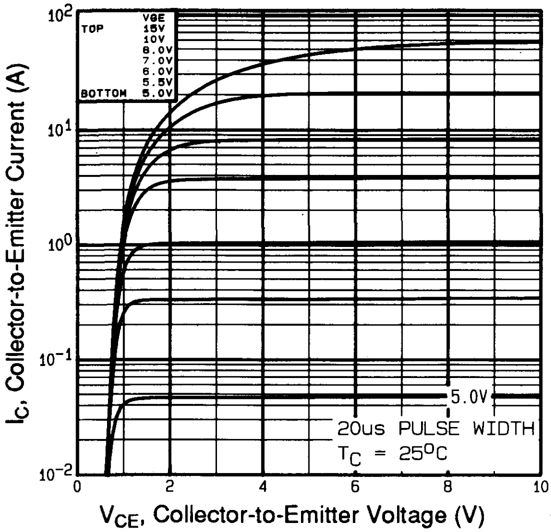


Fig 1. Typical Output Characteristics, $T_J = 25°C$

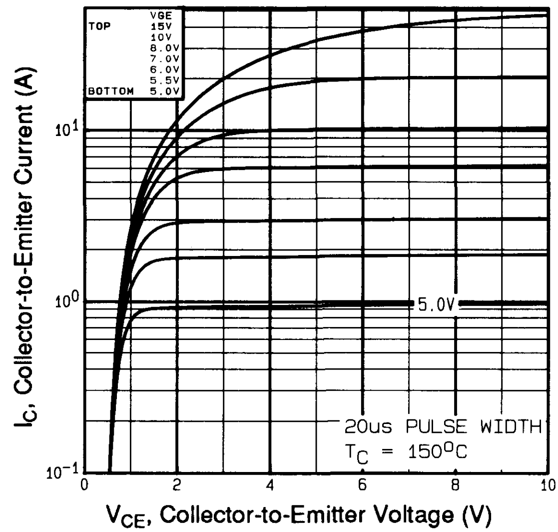


Fig 2. Typical Output Characteristics, $T_J = 150°C$

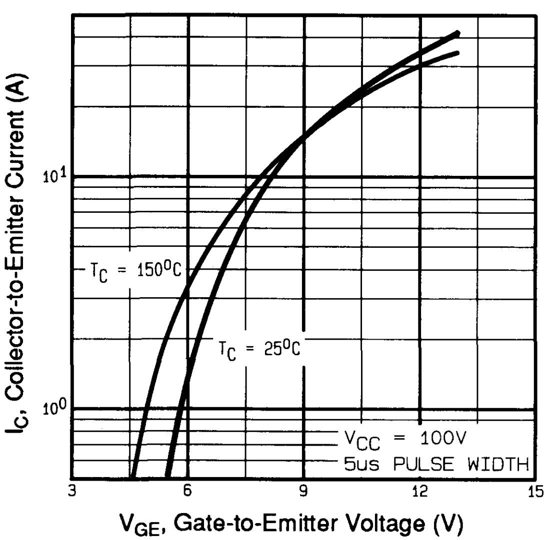


Fig 3. Typical Transfer Characteristics

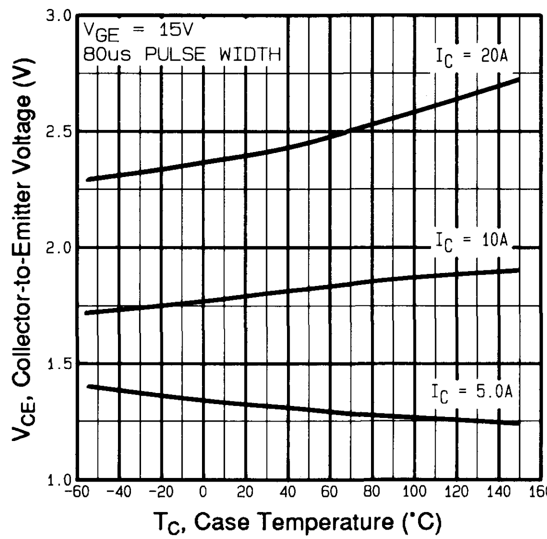


Fig 4. Collector-to-Emitter Saturation Voltage vs. Case Temperature

Graphs indicate performance of typical devices

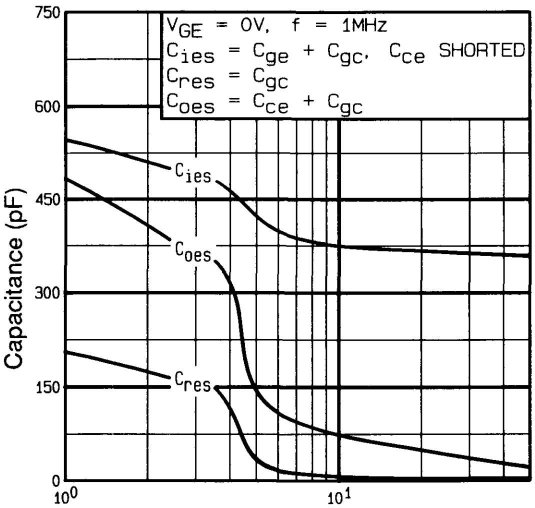


Fig 5. Typical Capacitance vs. Collector-to-Emitter Voltage

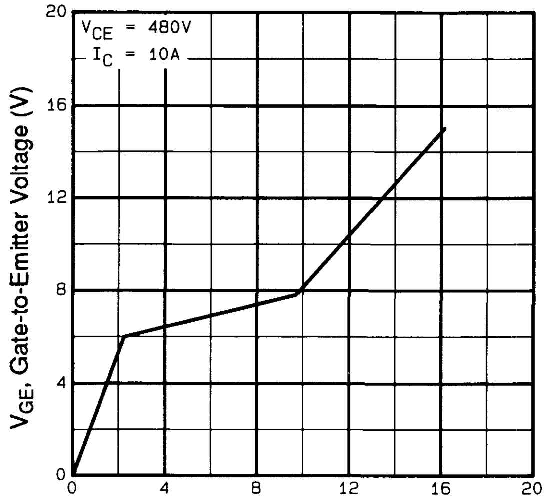


Fig 6. Typical Gate Charge vs. Gate-to-Emitter Voltage

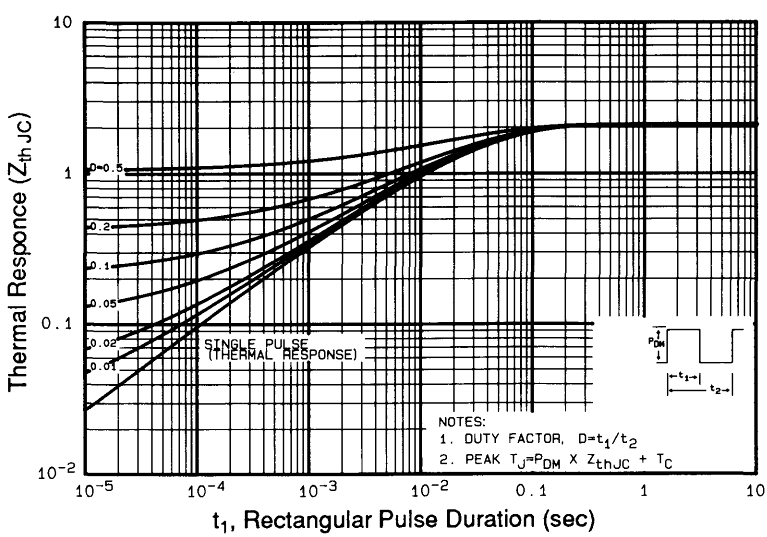


Fig 7. Maximum Effective Transient Thermal Impedance, Junction-to-Case

Graphs indicate performance of typical devices

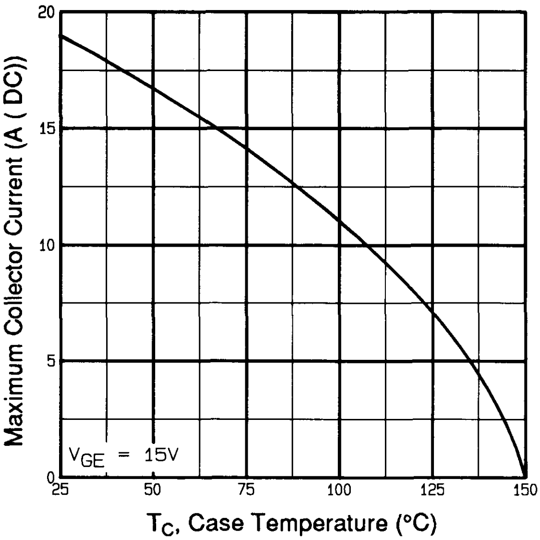


Fig 8. Maximum Collector Current vs. Case Temperature

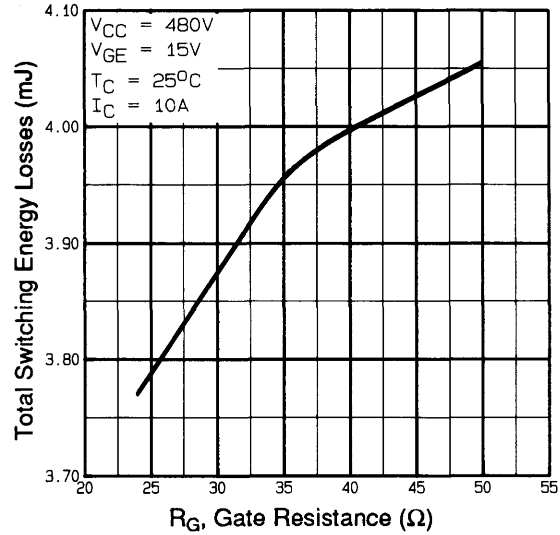


Fig 9. Typical Switching Losses vs. Gate Resistance

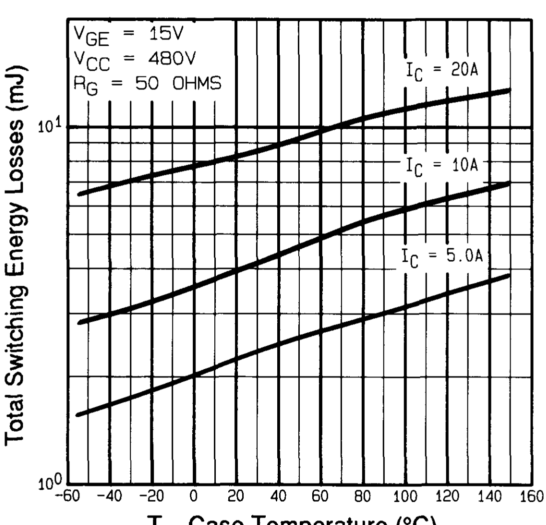


Fig 10. Typical Switching Losses vs. Case Temperature

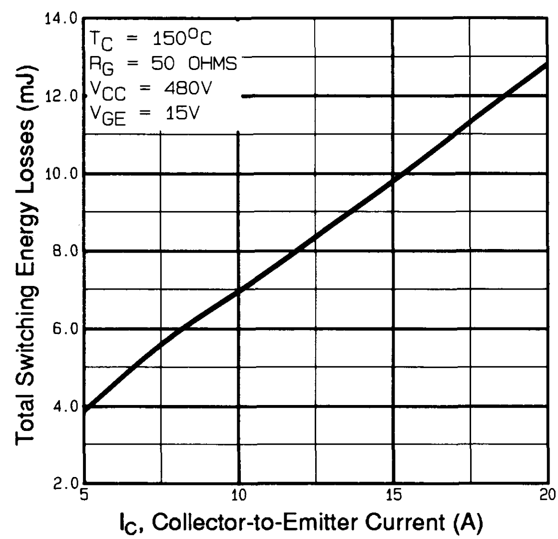


Fig 11. Typical Switching Losses vs. Collector-to-Emitter Current

Graphs indicate performance of typical devices

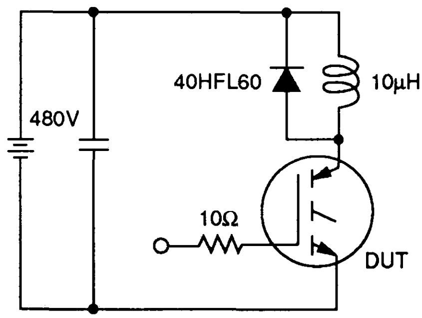


Fig 12a. Clamped Inductive Load Test Circuit

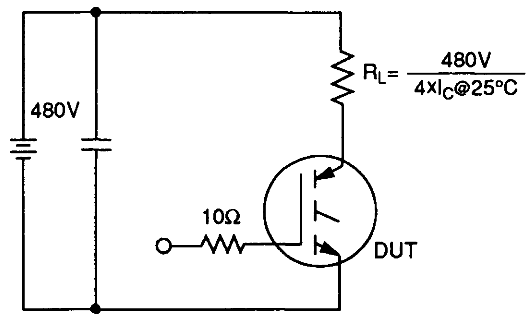


Fig 12b. Pulsed Collector Current Test Circuit

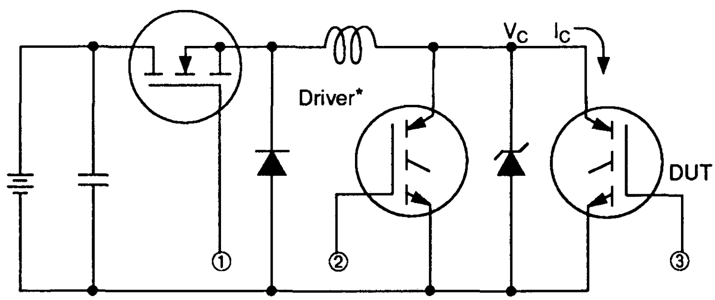


Fig 13a. Switching Loss Test Circuit

* Driver same type as DUT, V_C = 480V

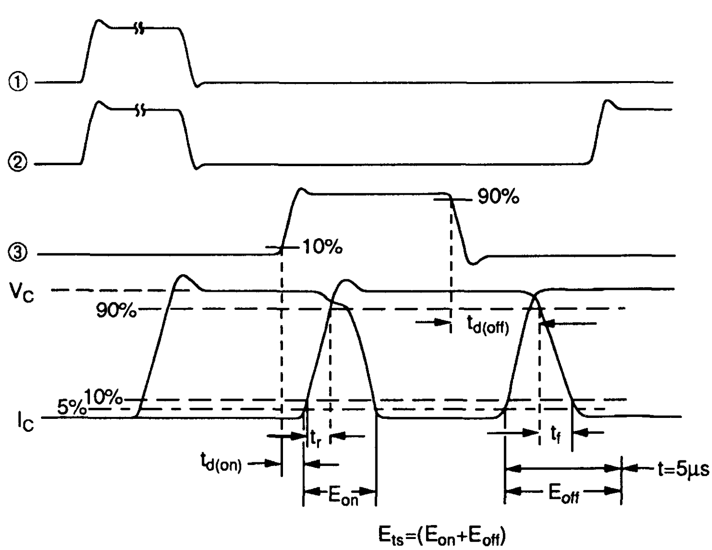


Fig 13b. Switching Loss Waveforms

International Rectifier

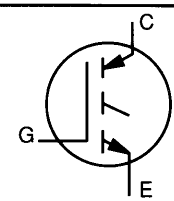
International
IOR Rectifier

IRGBC20U

INSULATED GATE BIPOLAR TRANSISTOR

UltraFast™ IGBT

- Latch-proof
- Simple gate-drive
- Ultra-fast operation > 10kHz
- Switching-Loss Rating includes all "tail" losses

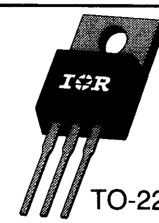


n-channel

V_{CEO} = 600 V
$I_{C(DC)}$ = 13 A
$V_{CE(sat)} \leq$ 3.0 V
$E_{TS} \leq$ 0.50 mJ

Description

Insulated Gate Bipolar Transistors (IGBTs) from International Rectifier have higher current densities than comparable bipolar transistors, while at the same time having simpler gate-drive requirements of the familiar power MOSFET. They provide substantial benefits to a host of higher-voltage, higher-current applications.



TO-220AB

Absolute Maximum Ratings

	Parameter	Max.	Units
I_C @ T_C = 25°C	Continuous Collector Current	13	A
I_C @ T_C = 100°C	Continuous Collector Current	6.5	
I_{CM}	Pulsed Collector Current ①	52	
V_{CE}	Collector-to-Emitter Breakdown Voltage	600	V
V_{GE}	Gate-to-Emitter Voltage	±20	
I_{LM}	Clamped Inductive Load Current ②	52	A
E_{ARV}	Reverse Voltage Avalanche Energy ③	5	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation	60	W
P_D @ T_C = 100°C	Maximum Power Dissipation	24	
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 3mm MA screw	10 in•lbs (11.5 kg•cm)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	---	---	2.1	K/W ⑥
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	---	0.50	---	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	---	---	80	

Electrical Characteristic @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
BV_{CES}	Collector-to-Emitter Breakdown Voltage	600	---	---	V	V_{GE}=0V, I_C=250µA
BV_{ECS}	Emitter-to-Collector Breakdown Volt. ④	15	---	---		V_{GE}=0V, I_C=1.0A
$\Delta BV_{CES}/\Delta T_J$	Temp. Coeff. of Breakdown Voltage	---	0.69	---	V/°C	V_{GE}=0V, I_C =1.0mA
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	---	---	3.0	V	V_{GE}=15V, I_C=6.5A See fig 4.
		---	2.8	---		V_{GE}=15V, I_C=13A
		---	2.5	---		V_{CE}=15V, I_C=6.5A, T_J=150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	---	5.5		V_{CE}=V_{GE}, I_C=250µA
$\Delta BV_{GE(th)}/\Delta T_J$	Temp. Coeff. of Threshold Voltage	---	-11	---	mV/°C	V_{CE}=V_{GE}, I_C=250µA
g_{fe}	Forward Transconductance ⑤	1.4	---	7.2	S	V_{CE}=100V, I_C=6.5A
I_{CES}	Zero Gate Voltage Collector Current	---	---	250	µA	V_{GE}=0V, V_{CE}=600V, T_J=25°C
		---	---	1000		V_{GE}=0V, V_{CE}=600V, T_J=150°C
I_{GES}	Gate-to-Emitter Leakage Current	---	---	±500	nA	V_{GE}=±20V

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

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
Q_G	Total Gate Charge (turn-on)	11	---	22	nC	I_C=6.5A, V_{CC}=480V
Q_{GE}	Gate - Emitter Charge (turn-on)	1.1	---	3.8		See Figure 6.
Q_{GC}	Gate - Collector Charge (turn-on)	2.6	---	13		
$t_{d(on)}$	Turn-On Delay Time	---	22	---	ns	See test circuit, figure 13.
t_r	Rise Time	---	12	---		I_C=6.5A, V_{CC}=480V
$t_{d(off)}$	Turn-off Delay Time	---	---	95		T_J=25°C
t_f	Fall Time	---	---	280		V_{GE}=15V, R_G=50Ω
E_{on}	Turn-On Switching Loss	---	0.09	---	mJ	Energy losses include "tail".
E_{off}	Turn-Off Switching Loss	---	0.26	---		Also see figures 9, 10, & 11.
E_{ts}	Total Switching Loss	---	0.35	.50		
$t_{d(on)}$	Turn-On Delay Time	---	23	---	ns	I_C=6.5A, V_{CC}=480V
t_r	Rise Time	---	13	---		T_J=150°C
$t_{d(off)}$	Turn-Off Delay Time	---	140	---		V_{GE}=15V
t_f	Fall Time	---	200	---		R_G=50Ω
E_{ts}	Total Switching Loss	---	0.55	---	mJ	
L_E	Internal Emitter Inductance	---	7.5	---	nH	Measured 5mm from package.
C_{ies}	Input Capacitance	---	330	---	pF	V_{GE}=0V
C_{oes}	Output Capacitance	---	65	---		V_{CC}=30V See fig 5.
C_{res}	Reverse Transfer Capacitance	---	6.0	---		f = 1.0MHz

Notes:

① Repetitive rating; V_{GE}=20V, pulse width limited by max. junction temperature (See figure 12b).

② V_{CC}=80%(BV_{CES}), V_{GE}=20V, L=10µH, R_G=10Ω, (See figure 12a).

③ Repetitive rating; pulse width limited by maximum junction temperature.

④ Pulse width ≤ 80µs; duty factor ≤0.1%.

⑤ Pulse width ≤ 5µs, single shot.

⑥ K/W equivalent to °C/W.

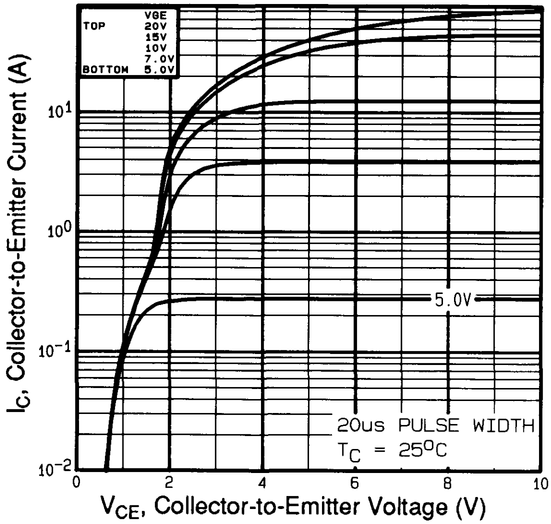


Fig 1. Typical Output Characteristics, $T_J = 25°C$

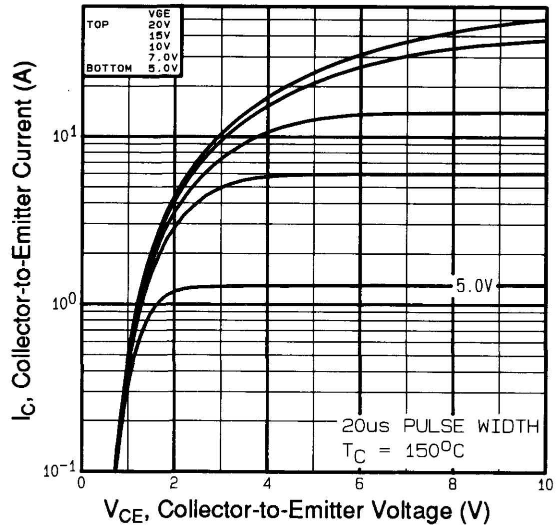


Fig 2. Typical Output Characteristics, $T_J = 150°C$

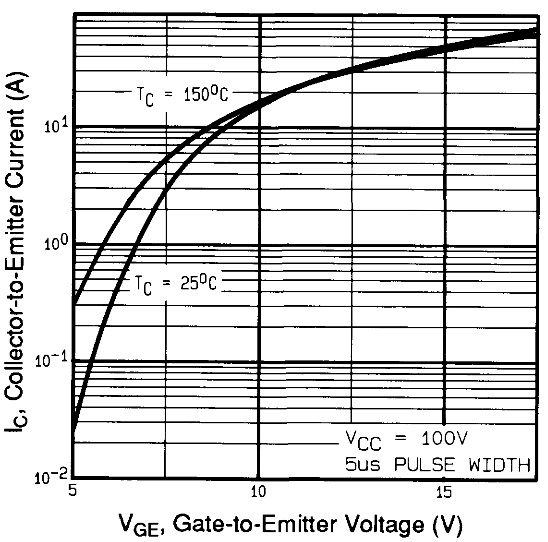


Fig 3. Typical Transfer Characteristics

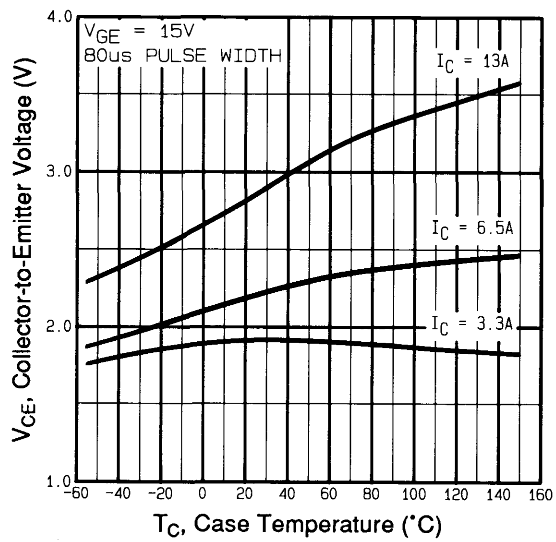


Fig 4. Collector-to-Emitter Saturation Voltage vs. Case Temperature

Graphs indicate performance of typical devices

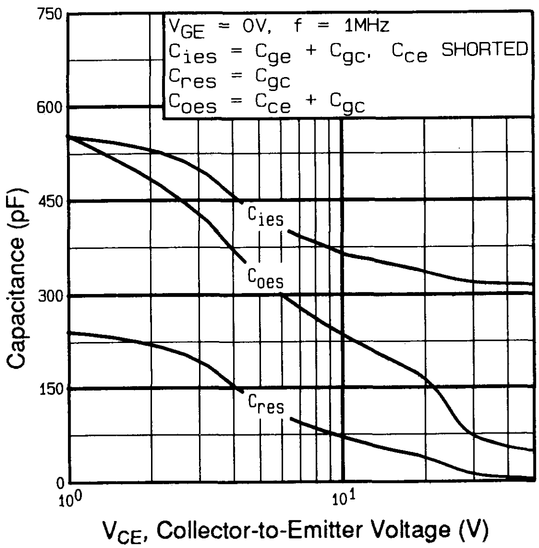


Fig 5. Typical Capacitance vs. Collector-to-Emitter Voltage

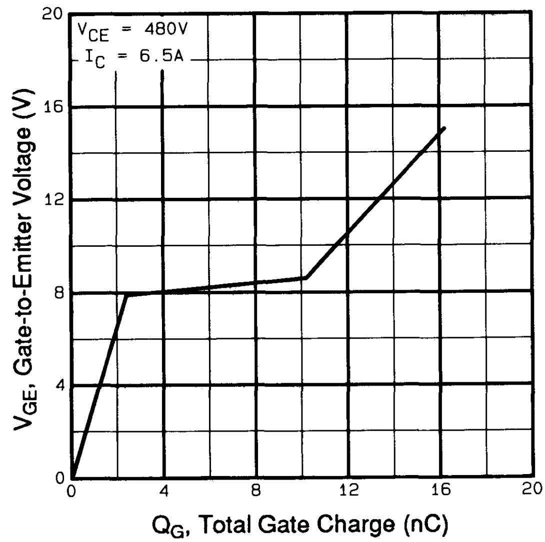


Fig 6. Typical Gate Charge vs. Gate-to-Emitter Voltage

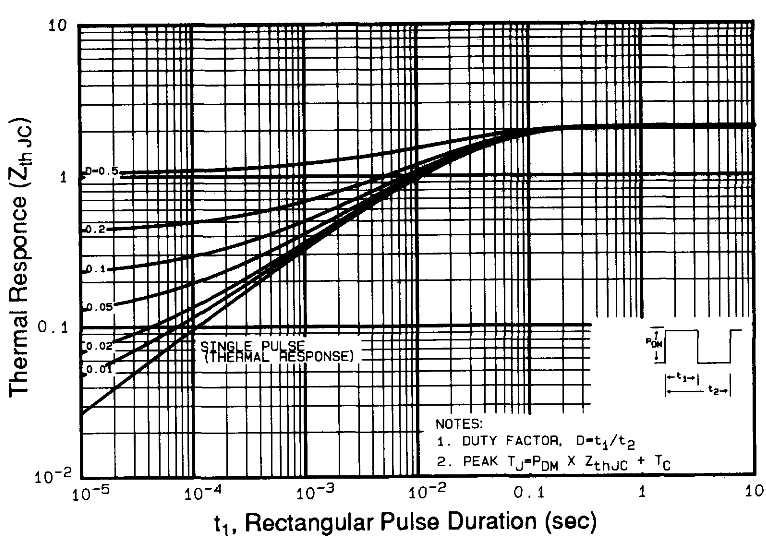


Fig 7. Maximum Effective Transient Thermal Impedance, Junction-to-Case

Graphs indicate performance of typical devices

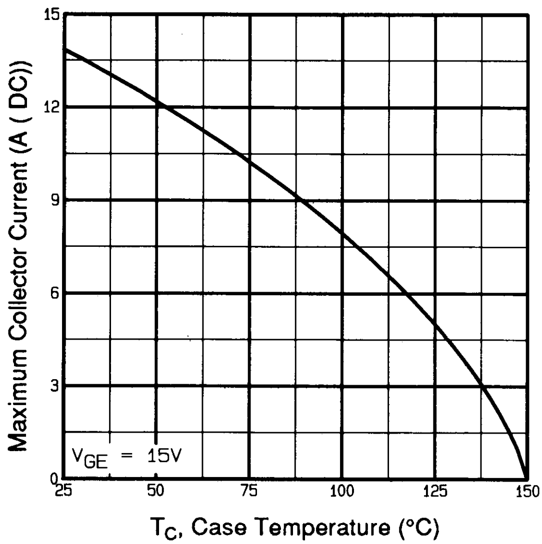


Fig 8. Maximum Collector Current vs. Case Temperature

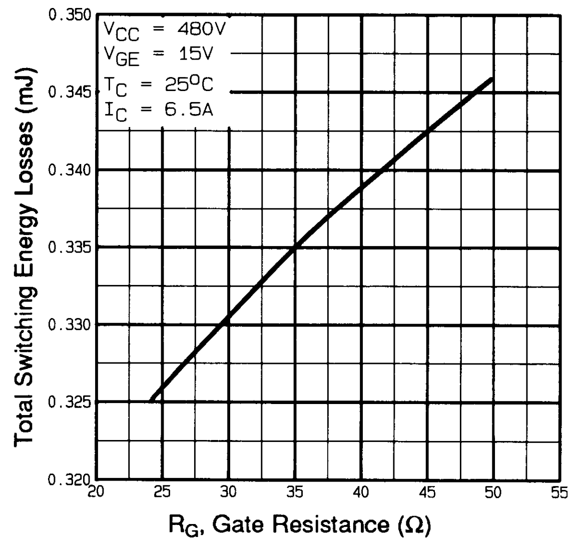


Fig 9. Typical Switching Losses vs. Gate Resistance

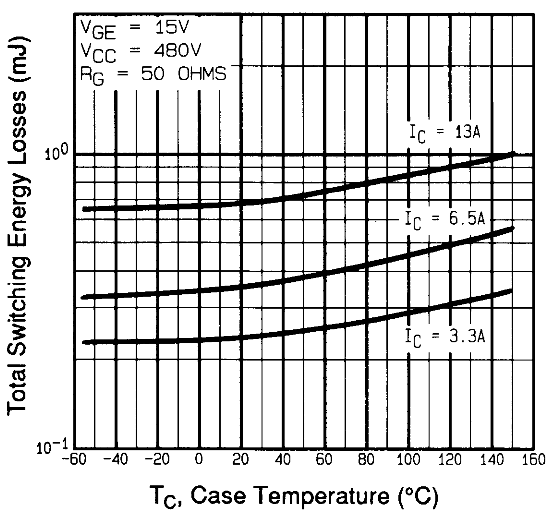


Fig 10. Typical Switching Losses vs. Case Temperature

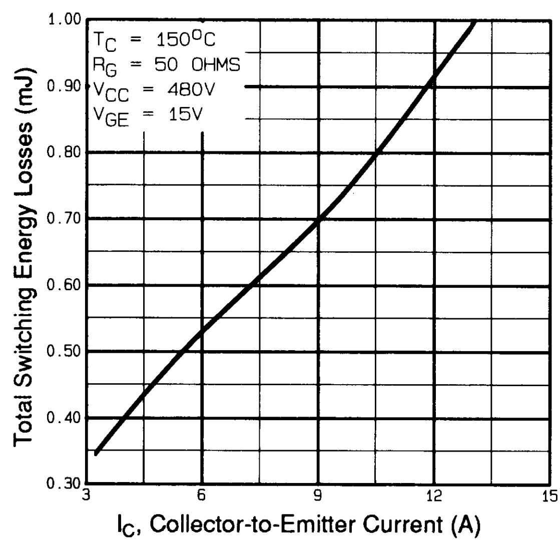


Fig 11. Typical Switching Losses vs. Collector-to-Emitter Current

Graphs indicate performance of typical devices

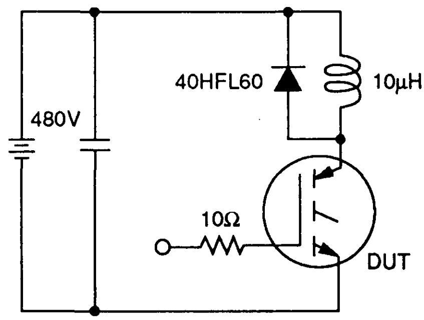


Fig 12a. Clamped Inductive Load Test Circuit

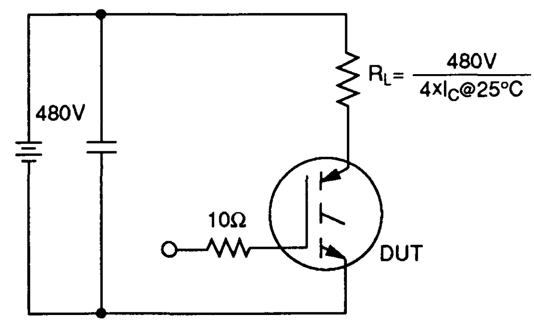


Fig 12b. Pulsed Collector Current Test Circuit

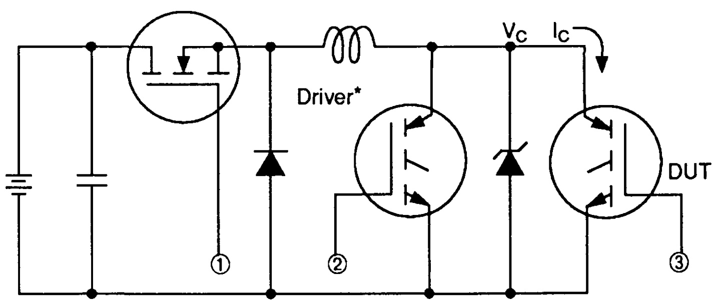


Fig 13a. Switching Loss Test Circuit

* Driver same type as DUT, V_C = 480V

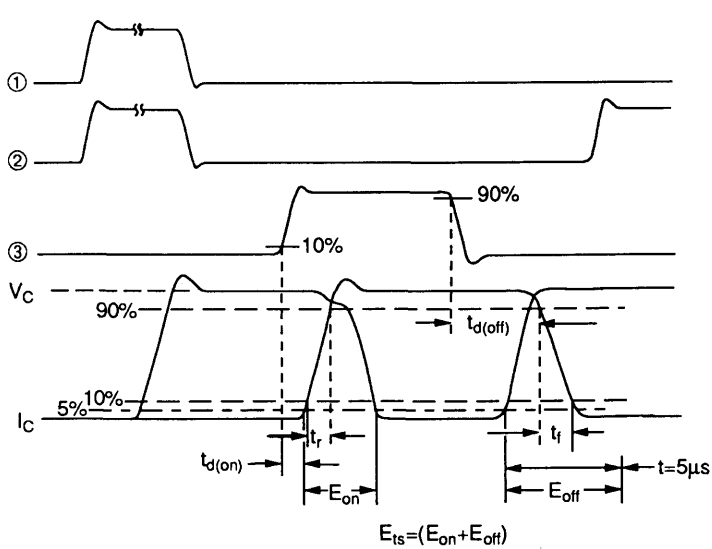


Fig 13b. Switching Loss Waveforms

International Rectifier

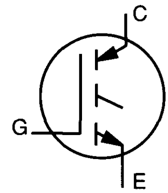
International
IOR Rectifier

IRGBC30F

INSULATED GATE BIPOLAR TRANSISTOR

Fast-Speed IGBT

- Latch-proof
- Simple gate-drive
- Fast operation 3kHz~8kHz
- Switching-Loss Rating includes all "tail" losses

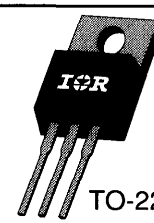


n-channel

$V_{CEO} = 600$ V
$I_{C(DC)} = 31$ A
$V_{CE(sat)} \leq 2.1$ V
$E_{TS} \leq 3.5$ mJ

Description

Insulated Gate Bipolar Transistors (IGBTs) from International Rectifier have higher current densities than comparable bipolar transistors, while at the same time having simpler gate-drive requirements of the familiar power MOSFET. They provide substantial benefits to a host of higher-voltage, higher-current applications.



TO-220AB

Absolute Maximum Ratings

	Parameter	Max.	Units
I_C @ T_C = 25°C	Continuous Collector Current	31	A
I_C @ T_C = 100°C	Continuous Collector Current	17	
I_{CM}	Pulsed Collector Current ①	120	
V_{CE}	Collector-to-Emitter Breakdown Voltage	600	V
V_{GE}	Gate-to-Emitter Voltage	±20	
I_{LM}	Clamped Inductive Load Current ②	120	A
E_{ARV}	Reverse Voltage Avalanche Energy ③	10	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation	100	W
P_D @ T_C = 100°C	Maximum Power Dissipation	42	
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 3mm MA screw	10 in•lbs (11.5 kg•cm)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	---	---	1.2	K/W ⑥
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	---	0.50	---	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	---	---	80	

Electrical Characteristic @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
BV_{CES}	Collector-to-Emitter Breakdown Voltage	600	---	---	V	V_{GE}=0V, I_C=250μA
BV_{ECS}	Emitter-to-Collector Breakdown Volt. ④	24	---	---	V	V_{GE}=0V, I_C=1.0A
$\Delta BV_{CES}/\Delta T_J$	Temp. Coeff. of Breakdown Voltage	---	0.69	---	V/°C	V_{GE}=0V, I_C =1.0mA
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	---	---	2.1	V	V_{GE}=15V, I_C=17A See fig 4.
		---	2.4	---		V_{GE}=15V, I_C=31A
		---	2.2	---		V_{CE}=15V, I_C=17A, T_J=150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	---	5.5	V	V_{CE}=V_{GE}, I_C=250μA
$\Delta BV_{GE(th)}/\Delta T_J$	Temp. Coeff. of Threshold Voltage	---	-11	---	mV/°C	V_{CE}=V_{GE}, I_C=250μA
g_{fe}	Forward Transconductance ⑤	6.1	---	15	S	V_{CE}=100V, I_C=17A
I_{CES}	Zero Gate Voltage Collector Current	---	---	250	μA	V_{GE}=0V, V_{CE}=600V, T_J=25°C
		---	---	1000		V_{GE}=0V, V_{CE}=600V, T_J=150°C
I_{GES}	Gate-to-Emitter Leakage Current	---	---	±500	nA	V_{GE}=±20V

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

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
Q_G	Total Gate Charge (turn-on)	23	---	30	nC	I_C=17A, V_{CC}=480V
Q_{GE}	Gate - Emitter Charge (turn-on)	2.4	---	5.9		See Figure 6.
Q_{GC}	Gate - Collector Charge (turn-on)	9.2	---	15		
$t_{d(on)}$	Turn-On Delay Time	---	25	---	ns	See test circuit, figure 13.
t_r	Rise Time	---	21	---		I_C=17A, V_{CC}=480V
$t_{d(off)}$	Turn-off Delay Time	---	---	320		T_J=25°C
t_f	Fall Time	---	---	500		V_{GE}=15V, R_G=23Ω
E_{on}	Turn-On Switching Loss	---	0.40	---	mJ	Energy losses include "tail".
E_{off}	Turn-Off Switching Loss	---	2.1	---		Also see figures 9, 10, & 11.
E_{ts}	Total Switching Loss	---	2.5	3.5		
$t_{d(on)}$	Turn-On Delay Time	---	25	---	ns	I_C=17A, V_{CC}=480V
t_r	Rise Time	---	21	---		T_J=150°C
$t_{d(off)}$	Turn-Off Delay Time	---	290	---		V_{GE}=15V
t_f	Fall Time	---	590	---		R_G=23Ω
E_{ts}	Total Switching Loss	---	4.0	---	mJ	
L_E	Internal Emitter Inductance	---	7.5	---	nH	Measured 5mm from package.
C_{ies}	Input Capacitance	---	670	---	pF	V_{GE}=0V
C_{oes}	Output Capacitance	---	100	---		V_{CC}=30V See fig 5.
C_{res}	Reverse Transfer Capacitance	---	10	---		f = 1.0MHz

Notes:

① Repetitive rating; V_{GE}=20V, pulse width limited by max. junction temperature (See figure 12b).

② V_{CC}=80%(BV_{CES}), V_{GE}=20V, L=μ10H, R_G=10Ω, (See figure 12a).

③ Repetitive rating; pulse width limited by maximum junction temperature.

④ Pulse width ≤ 80μs; duty factor ≤0.1%.

⑤ Pulse width ≤ 5μs, single shot.

⑥ K/W equivalent to °C/W.

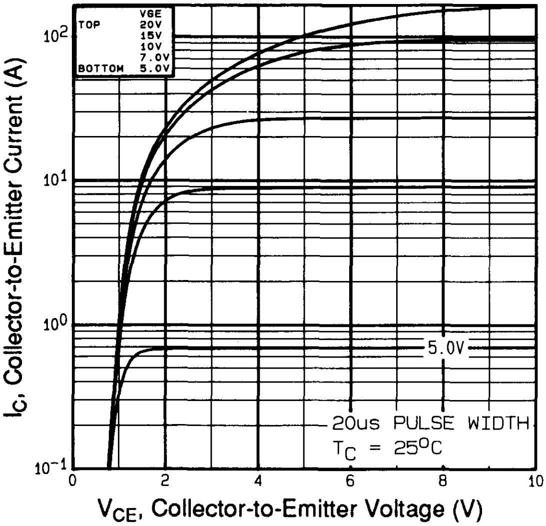


Fig 1. Typical Output Characteristics, $T_J = 25°C$

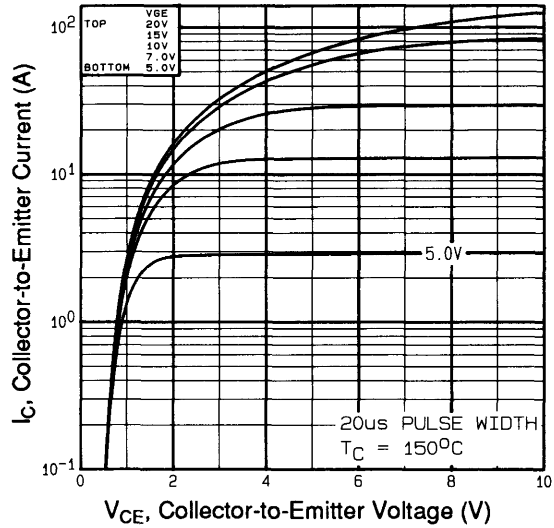


Fig 2. Typical Output Characteristics, $T_J = 150°C$

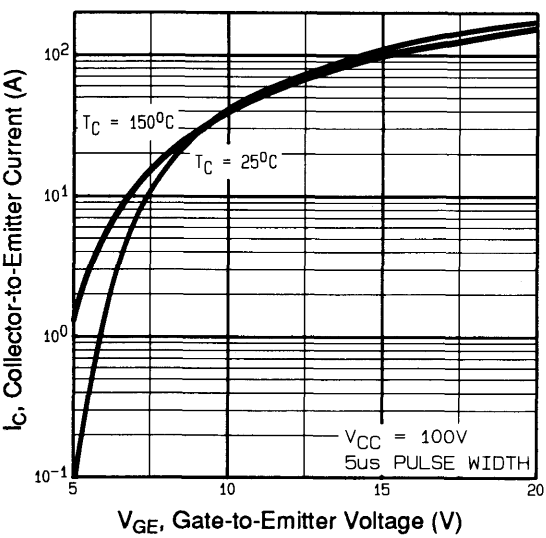


Fig 3. Typical Transfer Characteristics

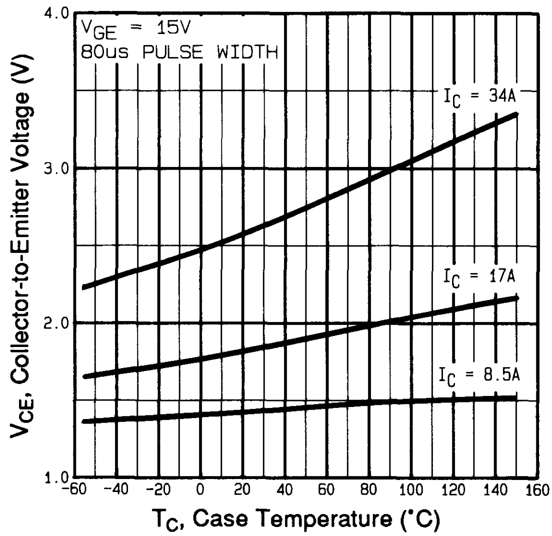


Fig 4. Collector-to-Emitter Saturation Voltage vs. Case Temperature

Graphs indicate performance of typical devices

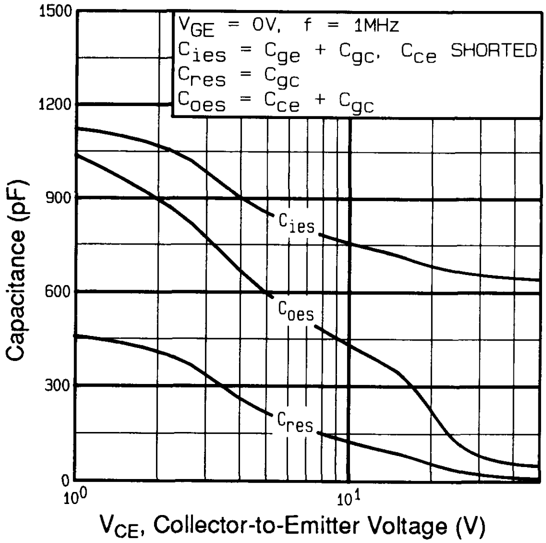


Fig 5. Typical Capacitance vs. Collector-to-Emitter Voltage

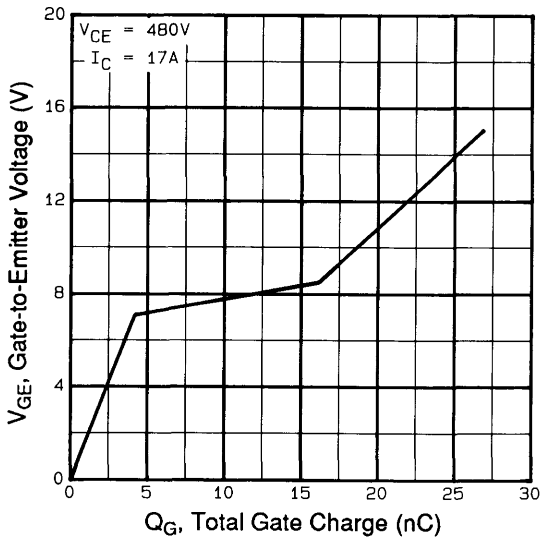


Fig 6. Typical Gate Charge vs. Gate-to-Emitter Voltage

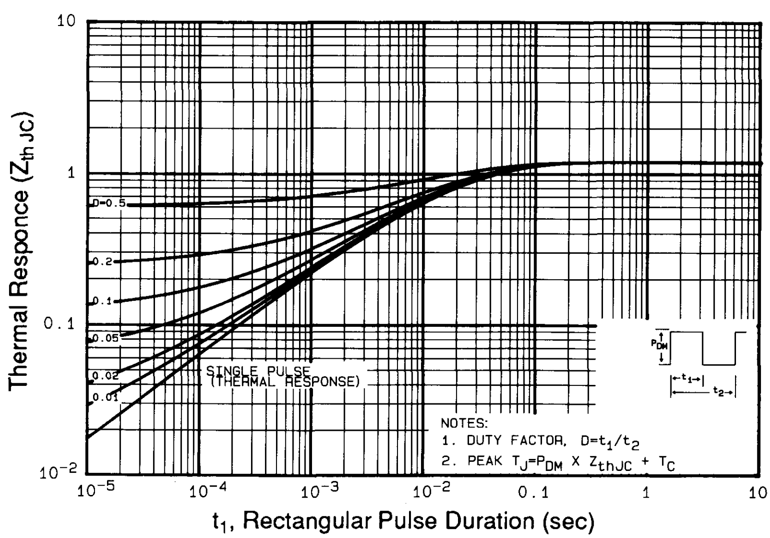


Fig 7. Maximum Effective Transient Thermal Impedance, Junction-to-Case

Graphs indicate performance of typical devices

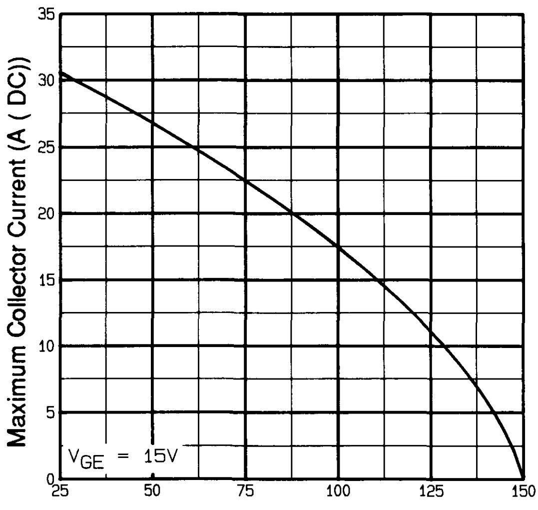


Fig 8. Maximum Collector Current vs. Case Temperature

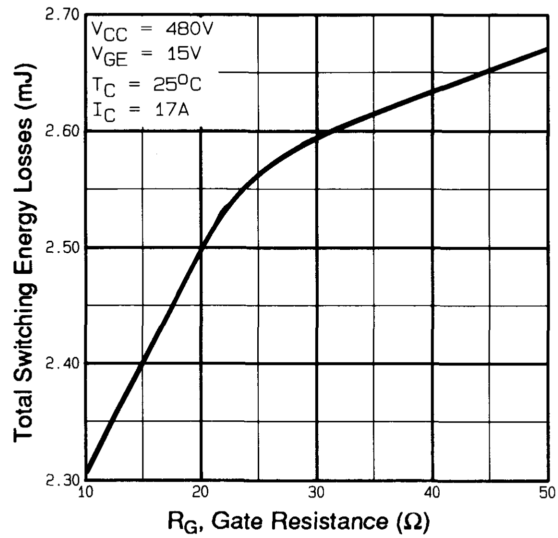


Fig 9. Typical Switching Losses vs. Gate Resistance

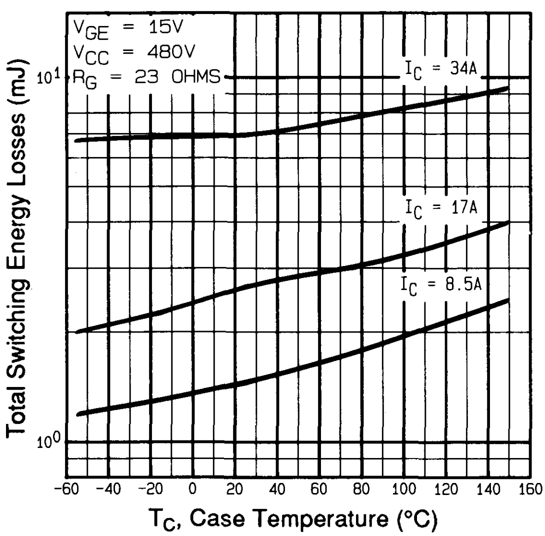


Fig 10. Typical Switching Losses vs. Case Temperature

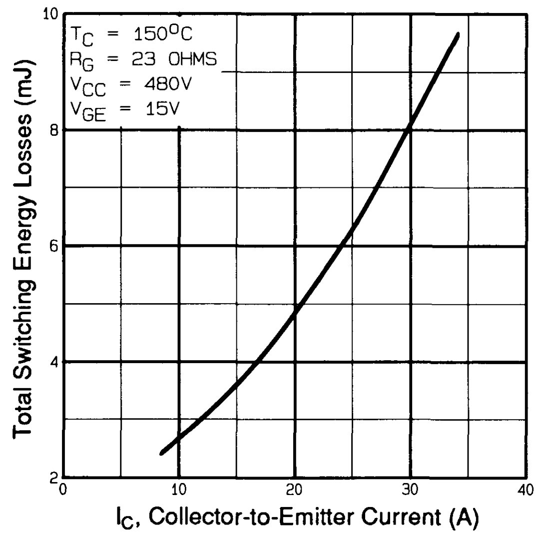


Fig 11. Typical Switching Losses vs. Collector-to-Emitter Current

Graphs indicate performance of typical devices

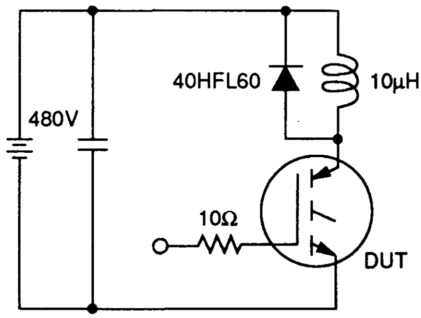


Fig 12a. Clamped Inductive Load Test Circuit

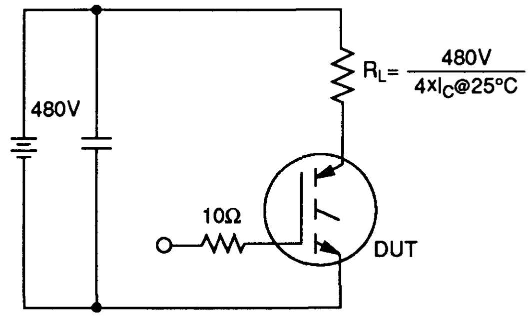


Fig 12b. Pulsed Collector Current Test Circuit

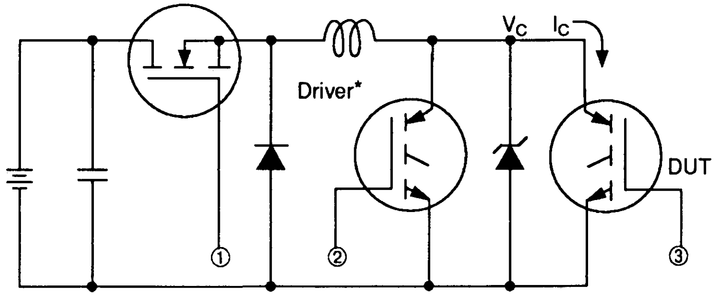


Fig 13a. Switching Loss Test Circuit

* Driver same type as DUT, V_C = 480V

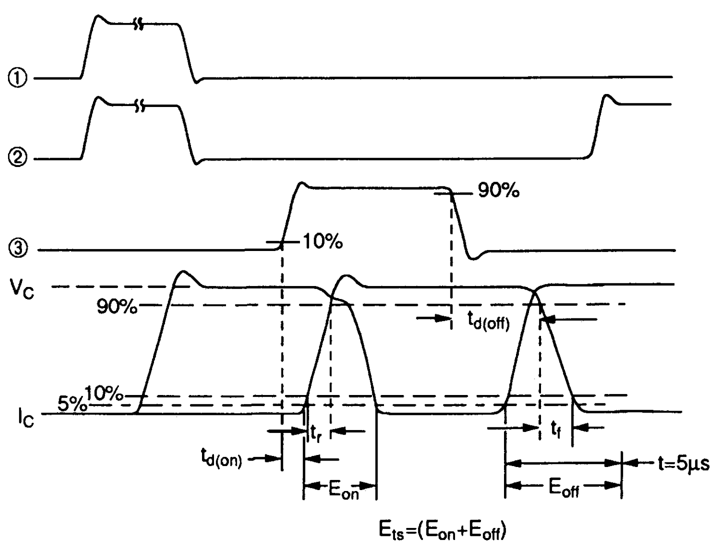


Fig 13b. Switching Loss Waveforms

International Rectifier

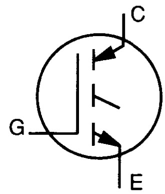
International Rectifier

IRGBC30S

INSULATED GATE BIPOLAR TRANSISTOR

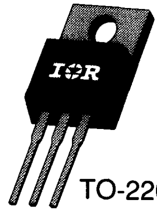
Standard-Speed IGBT

- Latch-proof
- Simple gate-drive
- Standard operation < 1kHz
- Switching-Loss Rating includes all "tail" losses



n-channel

$V_{CEO} = 600$ V
$I_{C(DC)} = 34$ A
$V_{CE(sat)} \leq 2.2$ V
$E_{TS} \leq 10$ mJ


TO-220AB

Description

Insulated Gate Bipolar Transistors (IGBTs) from International Rectifier have higher current densities than comparable bipolar transistors, while at the same time having simpler gate-drive requirements of the familiar power MOSFET. They provide substantial benefits to a host of higher-voltage, higher-current applications.

Absolute Maximum Ratings

	Parameter	Max.	Units
I_C @ T_C = 25°C	Continuous Collector Current	34	
I_C @ T_C = 100°C	Continuous Collector Current	18	A
I_{CM}	Pulsed Collector Current ①	136	
V_{CE}	Collector-to-Emitter Breakdown Voltage	600	V
V_{GE}	Gate-to-Emitter Voltage	±20	
I_{LM}	Clamped Inductive Load Current ②	136	A
E_{ARV}	Reverse Voltage Avalanche Energy ③	10	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation	100	W
P_D @ T_C = 100°C	Maximum Power Dissipation	42	
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 3mm MA screw	10 in•lbs (11.5 kg•cm)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	---	---	1.2	
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	---	0.50	---	K/W ⑥
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	---	---	80	

Electrical Characteristic @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
BV_{CES}	Collector-to-Emitter Breakdown Voltage	600	---	---	V	V_{GE}=0V, I_C=250µA
BV_{ECS}	Emitter-to-Collector Breakdown Volt. ④	15	---	---	V	V_{GE}=0V, I_C=1.0A
$\Delta BV_{CES}/\Delta T_J$	Temp. Coeff. of Breakdown Voltage	---	0.75	---	V/°C	V_{GE}=0V, I_C =1.0mA
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	---	---	1.9	V	V_{GE}=15V, I_C=18A See fig 4.
		---	2.4	---		V_{GE}=15V, I_C=34A
		---	1.9	---		V_{CE}=15V, I_C=18A, T_J=150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	---	5.5		V_{CE}=V_{GE}, I_C=250µA
$\Delta BV_{GE(th)}/\Delta T_J$	Temp. Coeff. of Threshold Voltage	---	-9.3	---	mV/°C	V_{CE}=V_{GE}, I_C=250µA
g_{fe}	Forward Transconductance ⑤	6.0	---	17	S	V_{CE}=100V, I_C=18A
I_{CES}	Zero Gate Voltage Collector Current	---	---	250	µA	V_{GE}=0V, V_{CE}=600V, T_J=25°C
		---	---	1000		V_{GE}=0V, V_{CE}=600V, T_J=150°C
I_{GES}	Gate-to-Emitter Leakage Current	---	---	±500	nA	V_{GE}=±20V

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

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
Q_G	Total Gate Charge (turn-on)	16	---	40	nC	I_C=18A, V_{CC}=480V See Figure 6.
Q_{GE}	Gate - Emitter Charge (turn-on)	3.0	---	8.0		
Q_{GC}	Gate - Collector Charge (turn-on)	6.0	---	20		
$t_{d(on)}$	Turn-On Delay Time	---	26	---	ns	See test circuit, figure 13.
t_r	Rise Time	---	32	---		I_C=18A, V_{CC}=480V
$t_{d(off)}$	Turn-off Delay Time	---	---	1100		T_J=25°C
t_f	Fall Time	---	---	1200		V_{GE}=15V, R_G=24Ω
E_{on}	Turn-On Switching Loss	---	0.51	---	mJ	Energy losses include "tail".
E_{off}	Turn-Off Switching Loss	---	6.6	---		Also see figures 9, 10, & 11.
E_{ts}	Total Switching Loss	---	7.1	10		
$t_{d(on)}$	Turn-On Delay Time	---	26	---	ns	I_C=18A, V_{CC}=480V T_J=150°C V_{GE}=15V R_G=24Ω
t_r	Rise Time	---	35	---		
$t_{d(off)}$	Turn-Off Delay Time	---	1200	---		
t_f	Fall Time	---	1500	---		
E_{ts}	Total Switching Loss	---	12	---	mJ	
L_E	Internal Emitter Inductance	---	7.5	---	nH	Measured 5mm from package.
C_{ies}	Input Capacitance	---	700	---	pF	V_{GE}=0V
C_{oes}	Output Capacitance	---	70	---		V_{CC}=30V See fig 5.
C_{res}	Reverse Transfer Capacitance	---	9.2	---		f = 1.0MHz

Notes:

① Repetitive rating; V_{GE}=20V, pulse width limited by max. junction temperature (See figure 12b).

② V_{CC}=80%(BV_{CES}), V_{GE}=20V, L=10µH, R_G=10Ω, (See figure 12a).

③ Repetitive rating; pulse width limited by maximum junction temperature.

④ Pulse width ≤ 80µs; duty factor ≤0.1%.

⑤ Pulse width ≤ 5µs, single shot.

⑥ K/W equivalent to °C/W.

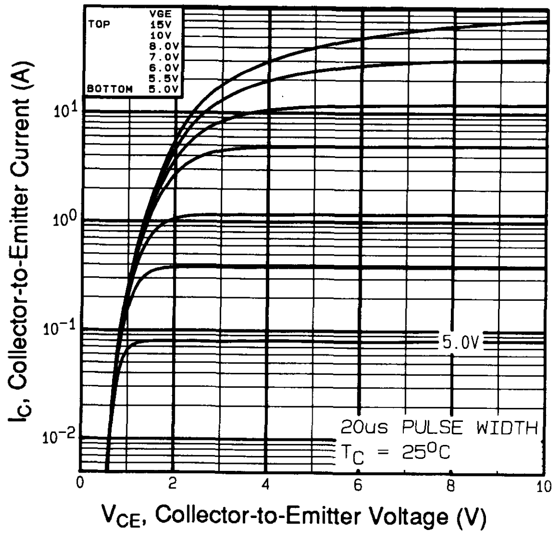


Fig 1. Typical Output Characteristics, $T_J = 25°C$

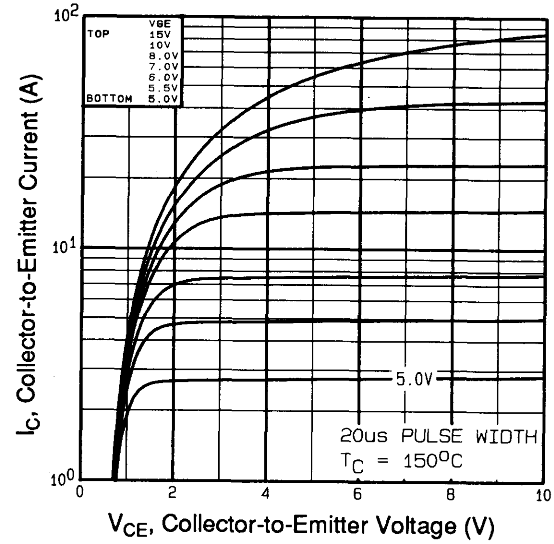


Fig 2. Typical Output Characteristics, $T_J = 150°C$

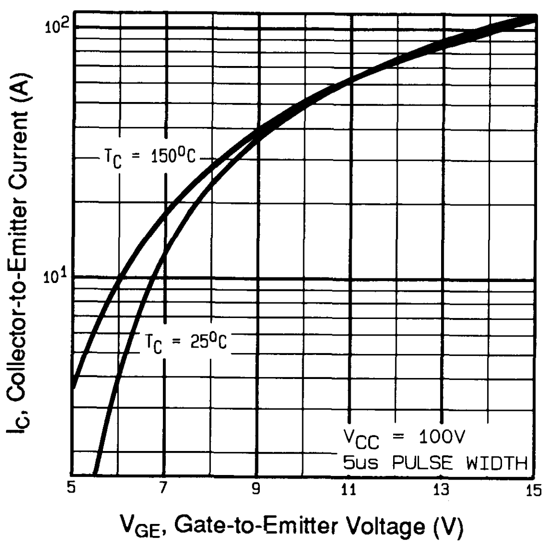


Fig 3. Typical Transfer Characteristics

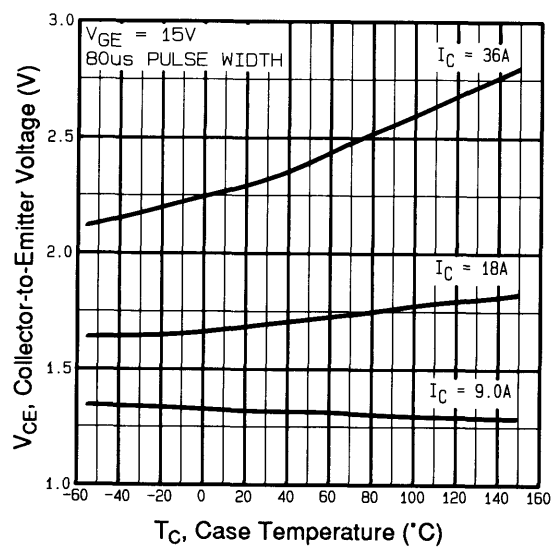


Fig 4. Collector-to-Emitter Saturation Voltage vs. Case Temperature

Graphs indicate performance of typical devices

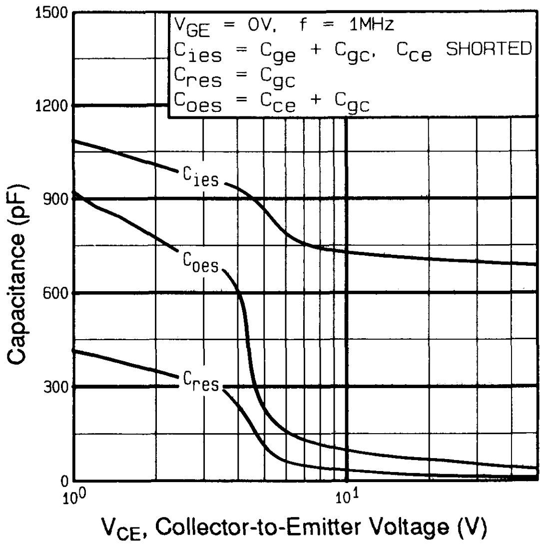


Fig 5. Typical Capacitance vs. Collector-to-Emitter Voltage

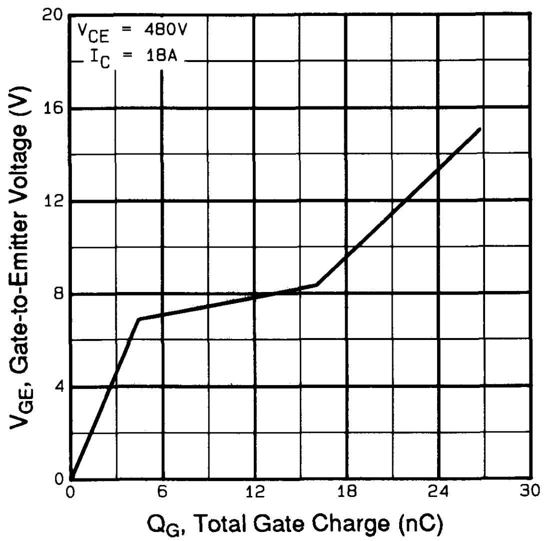


Fig 6. Typical Gate Charge vs. Gate-to-Emitter Voltage

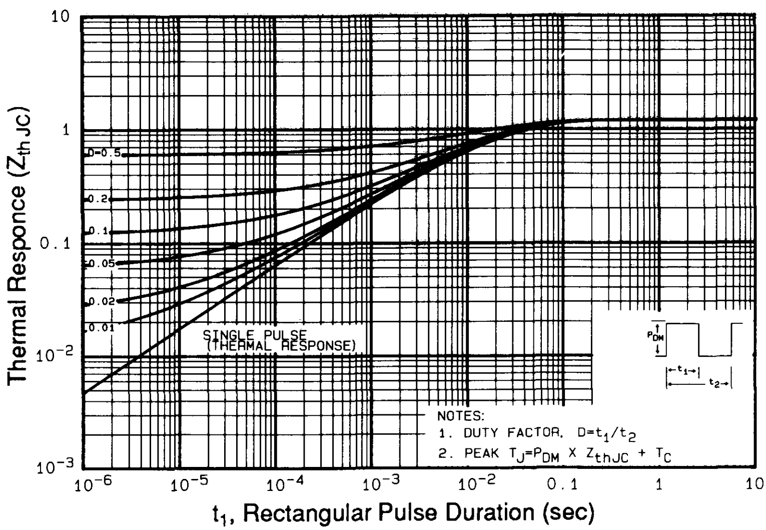


Fig 7. Maximum Effective Transient Thermal Impedance, Junction-to-Case

Graphs indicate performance of typical devices

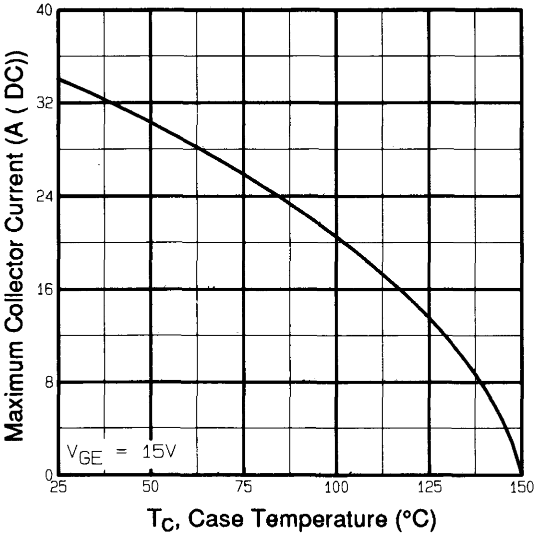


Fig 8. Maximum Collector Current vs. Case Temperature

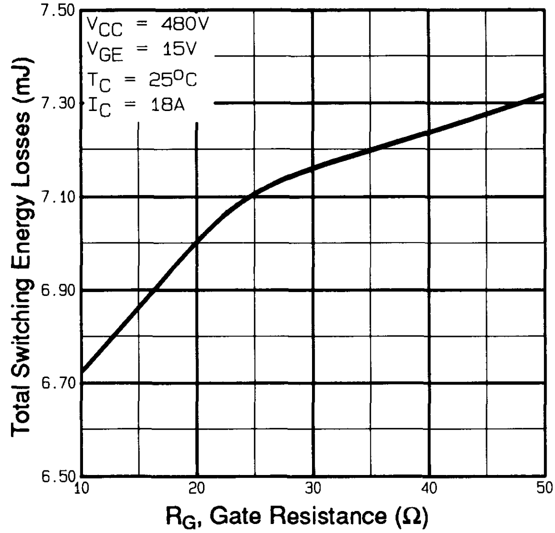


Fig 9. Typical Switching Losses vs. Gate Resistance

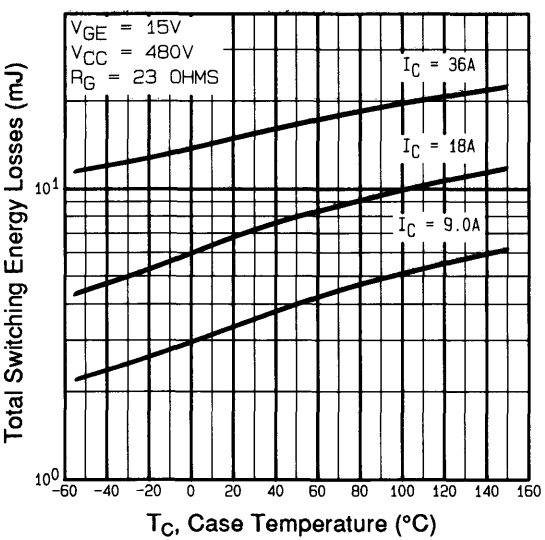


Fig 10. Typical Switching Losses vs. Case Temperature

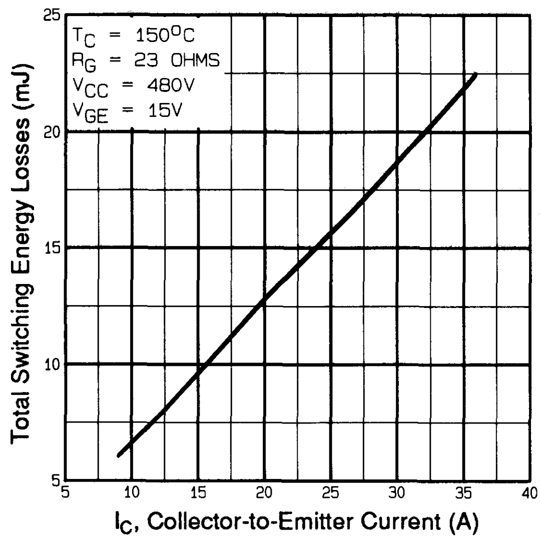


Fig 11. Typical Switching Losses vs. Collector-to-Emitter Current

Graphs indicate performance of typical devices

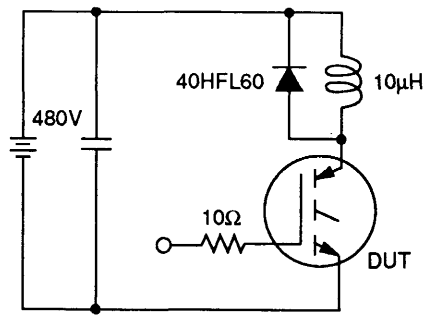


Fig 12a. Clamped Inductive Load Test Circuit

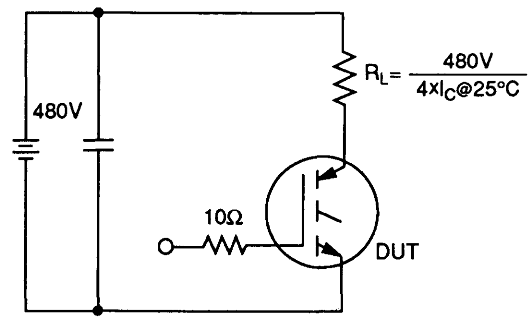


Fig 12b. Pulsed Collector Current Test Circuit

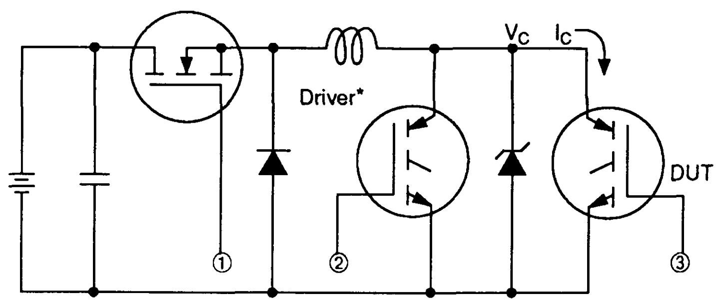


Fig 13a. Switching Loss Test Circuit

* Driver same type as DUT, V_C = 480V

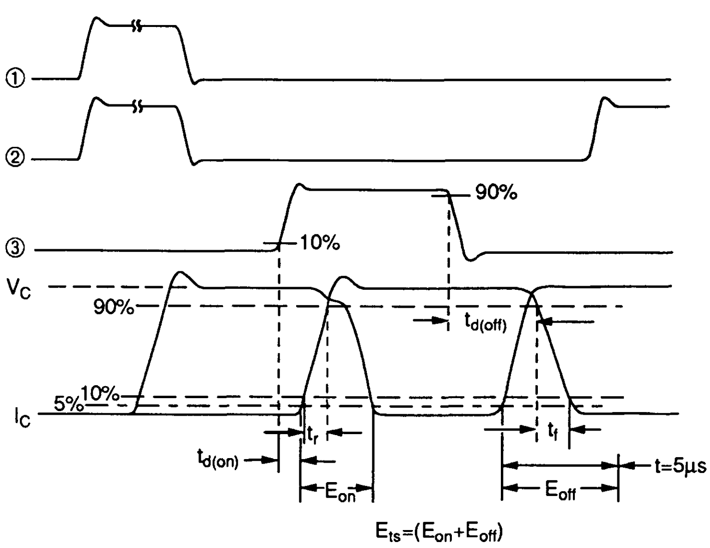


Fig 13b. Switching Loss Waveforms

International Rectifier

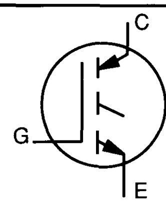
International
IOR Rectifier

IRGBC30U

INSULATED GATE BIPOLAR TRANSISTOR

UltraFast™ IGBT

- Latch-proof
- Simple gate-drive
- Ultra-fast operation > 10kHz
- Switching-Loss Rating includes all "tail" losses

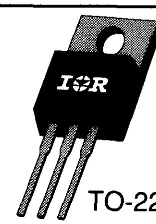


n-channel

$V_{CEO} = 600\ V$
$I_{C(DC)} = 23\ A$
$V_{CE(sat)} \leq 3.0\ V$
$E_{TS} \leq 1.2\ mJ$

Description

Insulated Gate Bipolar Transistors (IGBTs) from International Rectifier have higher current densities than comparable bipolar transistors, while at the same time having simpler gate-drive requirements of the familiar power MOSFET. They provide substantial benefits to a host of higher-voltage, higher-current applications.



TO-220AB

Absolute Maximum Ratings

	Parameter	Max.	Units
I_C @ T_C = 25°C	Continuous Collector Current	23	A
I_C @ T_C = 100°C	Continuous Collector Current	12	
I_{CM}	Pulsed Collector Current ①	92	
V_{CE}	Collector-to-Emitter Breakdown Voltage	600	V
V_{GE}	Gate-to-Emitter Voltage	±20	
I_{LM}	Clamped Inductive Load Current ②	92	A
E_{ARV}	Reverse Voltage Avalanche Energy ③	10	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation	100	W
P_D @ T_C = 100°C	Maximum Power Dissipation	42	
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 3mm MA screw	10 in•lbs (11.5 kg•cm)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	---	---	1.2	K/W ⑥
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	---	0.50	---	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	---	---	80	

Electrical Characteristic @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
BV_{CES}	Collector-to-Emitter Breakdown Voltage	600	---	---	V	V_{GE}=0V, I_C=250μA
BV_{ECS}	Emitter-to-Collector Breakdown Volt. ④	15	---	---		V_{GE}=0V, I_C=1.0A
$\Delta BV_{CES}/\Delta T_J$	Temp. Coeff. of Breakdown Voltage	---	0.63	---	V/°C	V_{GE}=0V, I_C =1.0mA
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	---	---	3.0	V	V_{GE}=15V, I_C=12A See fig 4.
		---	2.7	---		V_{GE}=15V, I_C=23A
		---	2.4	---		V_{CE}=15V, I_C=12A, T_J=150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	---	5.5		V_{CE}=V_{GE}, I_C=250μA
$\Delta BV_{GE(th)}/\Delta T_J$	Temp. Coeff. of Threshold Voltage	---	-11	---	mV/°C	V_{CE}=V_{GE}, I_C=250μA
g_{fe}	Forward Transconductance ⑤	3.1	---	14	S	V_{CE}=100V, I_C=12A
I_{CES}	Zero Gate Voltage Collector Current	---	---	250	μA	V_{GE}=0V, V_{CE}=600V, T_J=25°C
		---	---	1000		V_{GE}=0V, V_{CE}=600V, T_J=150°C
I_{GES}	Gate-to-Emitter Leakage Current	---	---	±500	nA	V_{GE}=±20V

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

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
Q_G	Total Gate Charge (turn-on)	21	---	36	nC	I_C=12A, V_{CC}=480V
Q_{GE}	Gate - Emitter Charge (turn-on)	2.8	---	6.8		See Figure 6.
Q_{GC}	Gate - Collector Charge (turn-on)	6.8	---	17		
$t_{d(on)}$	Turn-On Delay Time	---	24	---	ns	See test circuit, figure 13.
t_r	Rise Time	---	15	---		I_C=12A, V_{CC}=480V
$t_{d(off)}$	Turn-off Delay Time	---	---	200		T_J=25°C
t_f	Fall Time	---	---	190		V_{GE}=15V, R_G=23Ω
E_{on}	Turn-On Switching Loss	---	0.18	---	mJ	Energy losses include "tail".
E_{off}	Turn-Off Switching Loss	---	0.41	---		Also see figures 9, 10, & 11.
E_{ts}	Total Switching Loss	---	0.59	1.2		
$t_{d(on)}$	Turn-On Delay Time	---	24	---	ns	I_C=12A, V_{CC}=480V
t_r	Rise Time	---	15	---		T_J=150°C
$t_{d(off)}$	Turn-Off Delay Time	---	160	---		V_{GE}=15V
t_f	Fall Time	---	200	---		R_G=23Ω
E_{ts}	Total Switching Loss	---	1.2	---	mJ	
L_E	Internal Emitter Inductance	---	7.5	---	nH	Measured 5mm from package.
C_{ies}	Input Capacitance	---	660	---	pF	V_{GE}=0V
C_{oes}	Output Capacitance	---	100	---		V_{CC}=30V See fig 5.
C_{res}	Reverse Transfer Capacitance	---	11	---		f = 1.0MHz

Notes:

① Repetitive rating; V_{GE}=20V, pulse width limited by max. junction temperature (See figure 12b).

② V_{CC}=80%(BV_{CES}), V_{GE}=20V, L=10μH, R_G=10Ω, (See figure 12a).

③ Repetitive rating; pulse width limited by maximum junction temperature.

④ Pulse width ≤ 80μs; duty factor ≤0.1%.

⑤ Pulse width ≤ 5μs, single shot.

⑥ K/W equivalent to °C/W.

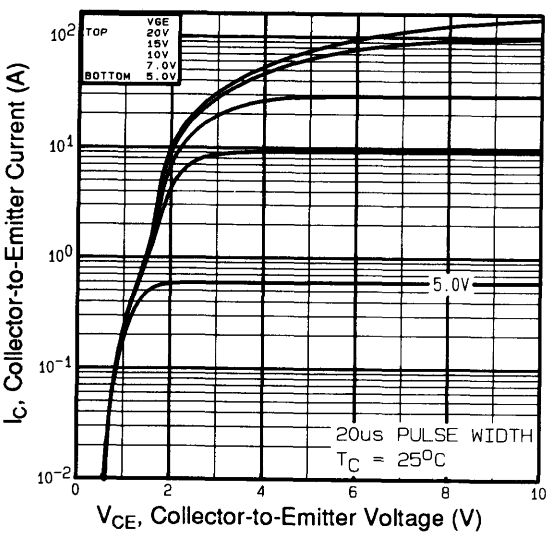


Fig 1. Typical Output Characteristics, $T_J = 25°C$

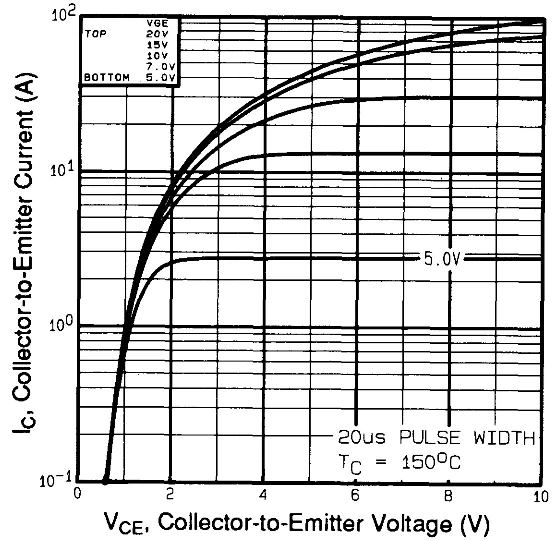


Fig 2. Typical Output Characteristics, $T_J = 150°C$

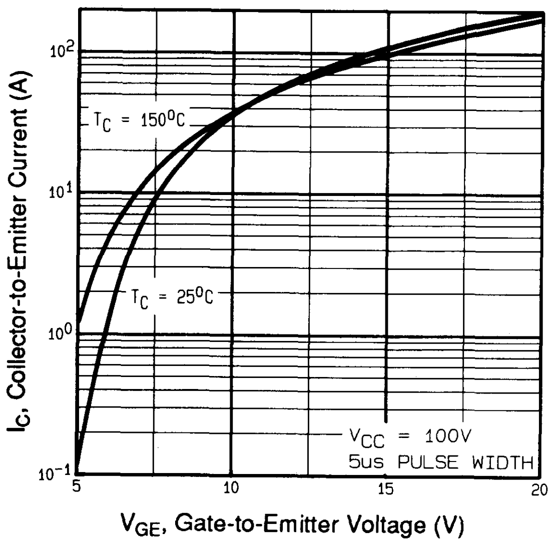


Fig 3. Typical Transfer Characteristics

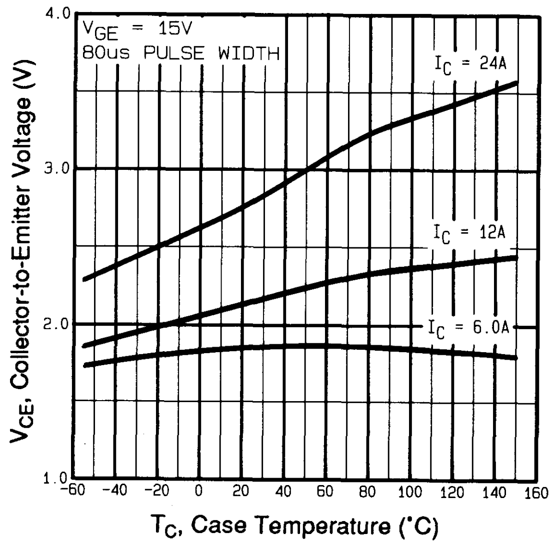


Fig 4. Collector-to-Emitter Saturation Voltage vs. Case Temperature

Graphs indicate performance of typical devices

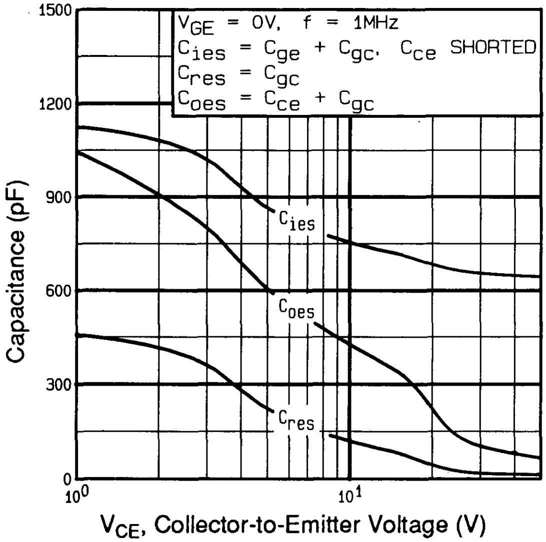


Fig 5. Typical Capacitance vs. Collector-to-Emitter Voltage

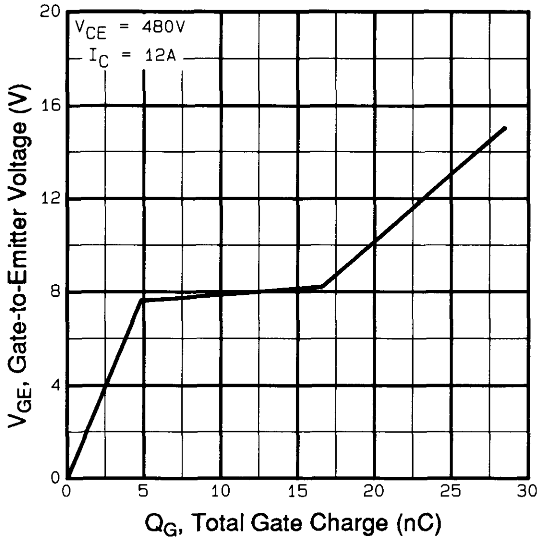


Fig 6. Typical Gate Charge vs. Gate-to-Emitter Voltage

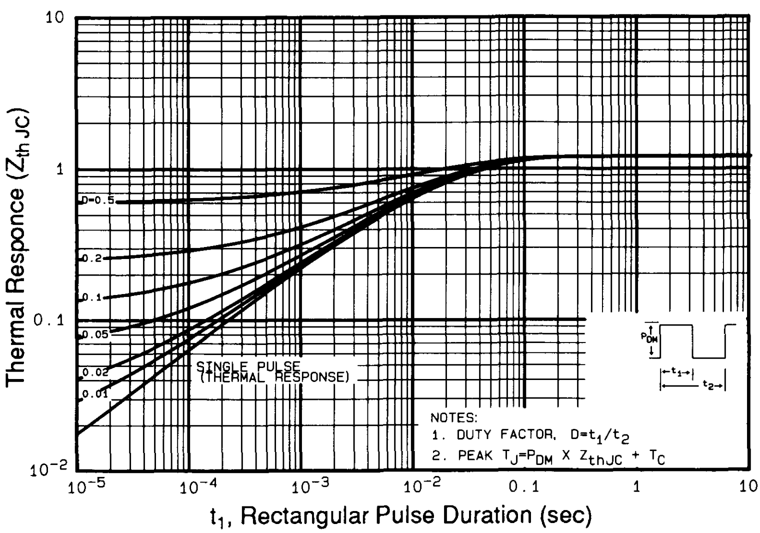


Fig 7. Maximum Effective Transient Thermal Impedance, Junction-to-Case

Graphs indicate performance of typical devices

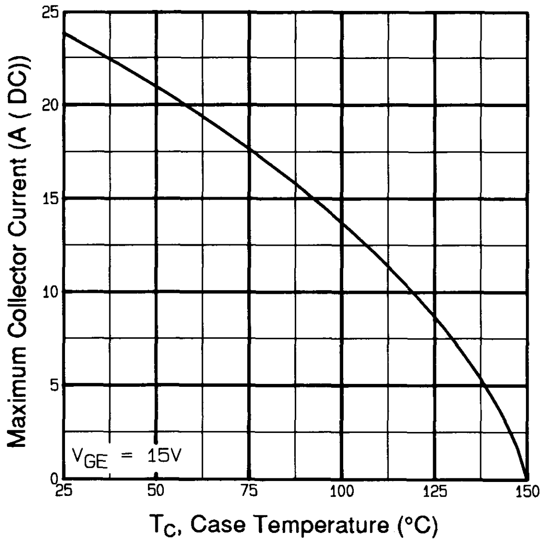


Fig 8. Maximum Collector Current vs. Case Temperature

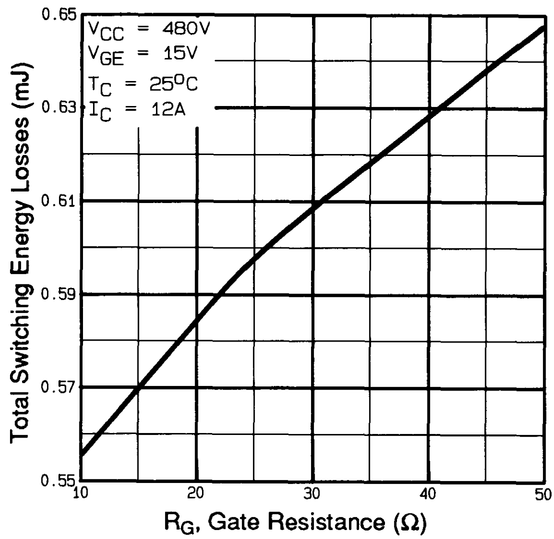


Fig 9. Typical Switching Losses vs. Gate Resistance

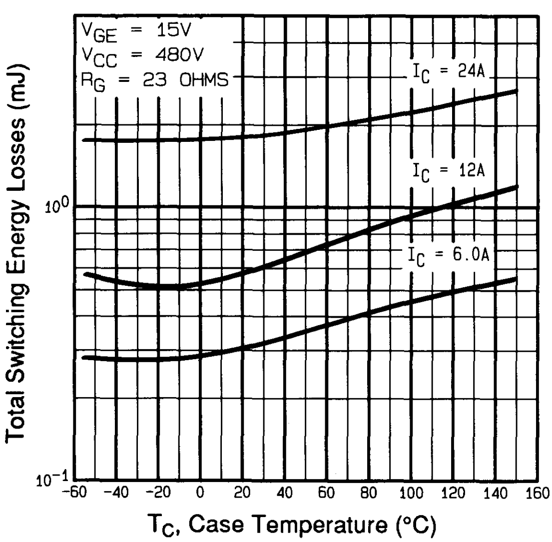


Fig 10. Typical Switching Losses vs. Case Temperature

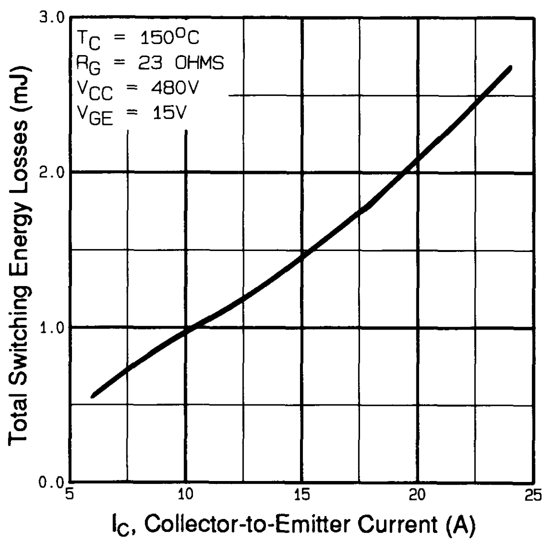


Fig 11. Typical Switching Losses vs. Collector-to-Emitter Current

Graphs indicate performance of typical devices

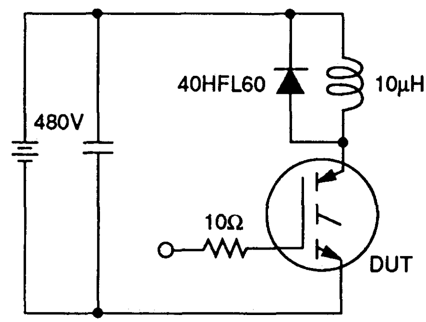


Fig 12a. Clamped Inductive Load Test Circuit

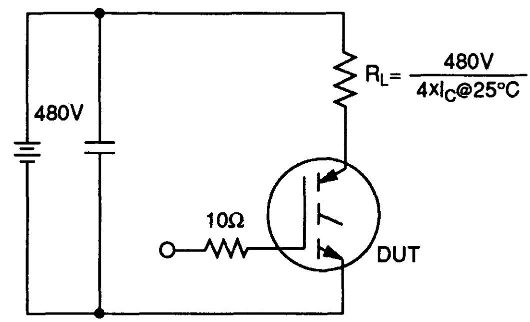


Fig 12b. Pulsed Collector Current Test Circuit

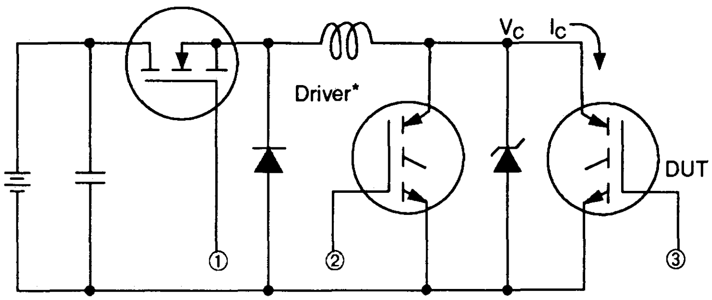


Fig 13a. Switching Loss Test Circuit

* Driver same type as DUT, V_C = 480V

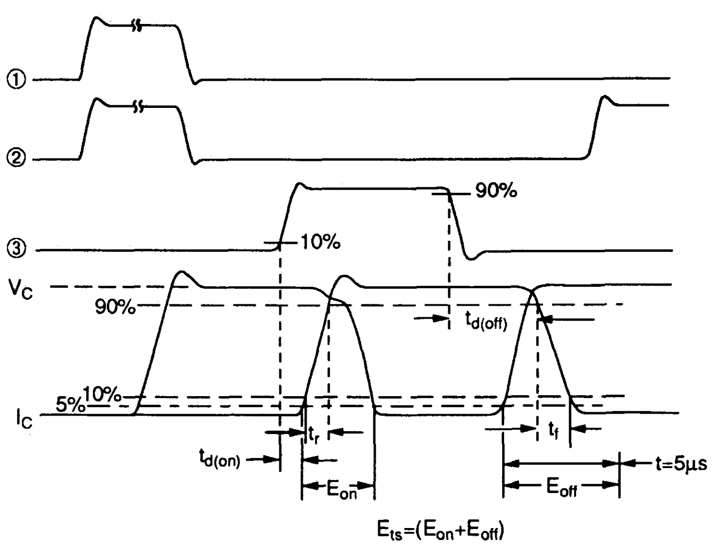


Fig 13b. Switching Loss Waveforms

International Rectifier

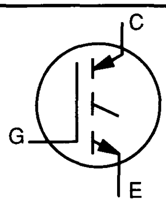
International
IOR Rectifier

IRGBC40F

INSULATED GATE BIPOLAR TRANSISTOR

Fast-Speed IGBT

- Latch-proof
- Simple gate-drive
- Fast Operation 3kHz~8kHz
- Switching-Loss Rating includes all "tail" losses

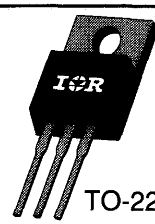


n-channel

V_{CEO} = 600 V
$I_{C(DC)}$ = 49 A
$V_{CE(sat)} \leq$ 2.0 V
$E_{TS} \leq$ 9.0 mJ

Description

Insulated Gate Bipolar Transistors (IGBTs) from International Rectifier have higher current densities than comparable bipolar transistors, while at the same time having simpler gate-drive requirements of the familiar power MOSFET. They provide substantial benefits to a host of higher-voltage, higher-current applications.



TO-220AB

Absolute Maximum Ratings

	Parameter	Max.	Units
I_C @ T_C = 25°C	Continuous Collector Current	49	A
I_C @ T_C = 100°C	Continuous Collector Current	27	
I_{CM}	Pulsed Collector Current ①	200	
V_{CE}	Collector-to-Emitter Breakdown Voltage	600	V
V_{GE}	Gate-to-Emitter Voltage	±20	
I_{LM}	Clamped Inductive Load Current ②	200	A
E_{ARV}	Reverse Voltage Avalanche Energy ③	15	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation	160	W
P_D @ T_C = 100°C	Maximum Power Dissipation	65	
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 3mm MA screw	10 in•lbs (11.5 kg•cm)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	---	---	0.77	K/W ⑥
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	---	0.50	---	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	---	---	80	

Electrical Characteristic @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
BV_{CES}	Collector-to-Emitter Breakdown Voltage	600	---	---	V	V_{GE}=0V, I_C=250µA
BV_{ECS}	Emitter-to-Collector Breakdown Volt. ④	24	---	---		V_{GE}=0V, I_C=1.0A
$\Delta BV_{CES}/\Delta T_J$	Temp. Coeff. of Breakdown Voltage	---	0.70	---	V/°C	V_{GE}=0V, I_C =1.0mA
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	---	---	2.0	V	V_{GE}=15V, I_C=27A See fig 4.
		---	2.2	---		V_{GE}=15V, I_C=49A
		---	1.9	---		V_{CE}=15V, I_C=27A, T_J=150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	---	5.5		V_{CE}=V_{GE}, I_C=250µA
$\Delta BV_{GE(th)}/\Delta T_J$	Temp. Coeff. of Threshold Voltage	---	-12	---	mV/°C	V_{CE}=V_{GE}, I_C=250µA
g_{fe}	Forward Transconductance ⑤	9.2	---	15	S	V_{CE}=100V, I_C=27A
I_{CES}	Zero Gate Voltage Collector Current	---	---	250	µA	V_{GE}=0V, V_{CE}=600V, T_J=25°C
		---	---	1000		V_{GE}=0V, V_{CE}=600V, T_J=150°C
I_{GES}	Gate-to-Emitter Leakage Current	---	---	±500	nA	V_{GE}=±20V

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

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
Q_G	Total Gate Charge (turn-on)	38	---	80	nC	I_C=27A, V_{CC}=480V
Q_{GE}	Gate - Emitter Charge (turn-on)	7.1	---	10		See Figure 6.
Q_{GC}	Gate - Collector Charge (turn-on)	7.7	---	42		
$t_{d(on)}$	Turn-On Delay Time	---	26	---	ns	See test circuit, figure 13.
t_r	Rise Time	---	37	---		I_C=27A, V_{CC}=480V
$t_{d(off)}$	Turn-off Delay Time	---	---	410		T_J=25°C
t_f	Fall Time	---	---	420		V_{GE}=15V, R_G=10Ω
E_{on}	Turn-On Switching Loss	---	0.60	---	mJ	Energy losses include "tail".
E_{off}	Turn-Off Switching Loss	---	3.8	---		Also see figures 9, 10, & 11.
E_{ts}	Total Switching Loss	---	4.4	9.0		
$t_{d(on)}$	Turn-On Delay Time	---	28	---	ns	I_C=27A, V_{CC}=480V
t_r	Rise Time	---	37	---		T_J=150°C
$t_{d(off)}$	Turn-Off Delay Time	---	380	---		V_{GE}=15V
t_f	Fall Time	---	460	---		R_G=10Ω
E_{ts}	Total Switching Loss	---	7.0	---	mJ	
L_E	Internal Emitter Inductance	---	7.5	---	nH	Measured 5mm from package.
C_{ies}	Input Capacitance	---	1500	---	pF	V_{GE}=0V
C_{oes}	Output Capacitance	---	190	---		V_{CC}=30V See fig 5.
C_{res}	Reverse Transfer Capacitance	---	20	---		f = 1.0MHz

Notes:

① Repetitive rating; V_{GE}=20V, pulse width limited by max. junction temperature (See figure 12b).

② V_{CC}=80%(BV_{CES}), V_{GE}=20V, L=10µH, R_G=10Ω, (See figure 12a).

③ Repetitive rating; pulse width limited by maximum junction temperature.

④ Pulse width ≤ 80µs; duty factor ≤0.1%.

⑤ Pulse width ≤ 5µs, single shot.

⑥ K/W equivalent to °C/W.

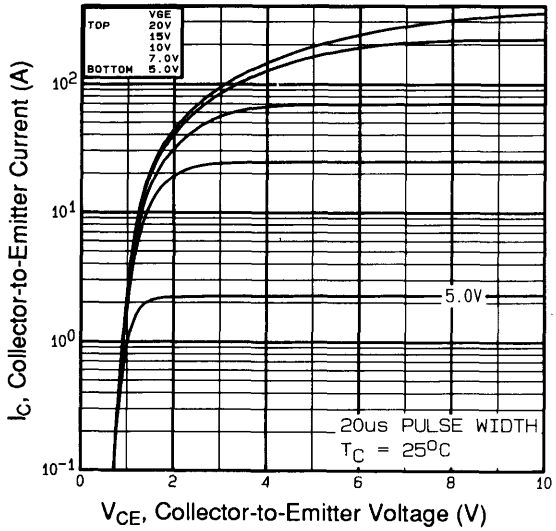


Fig 1. Typical Output Characteristics, $T_J = 25°C$

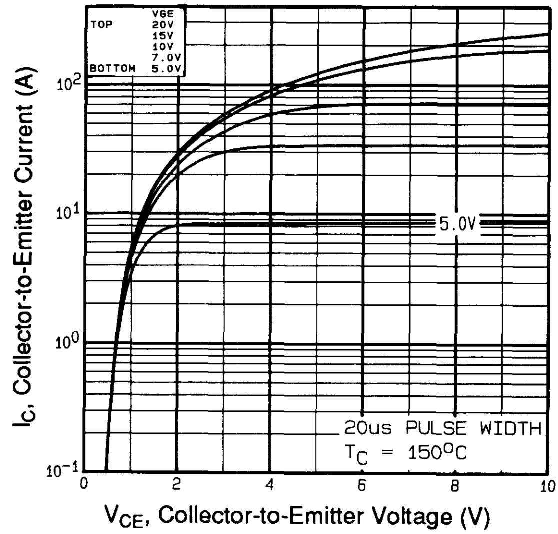


Fig 2. Typical Output Characteristics, $T_J = 150°C$

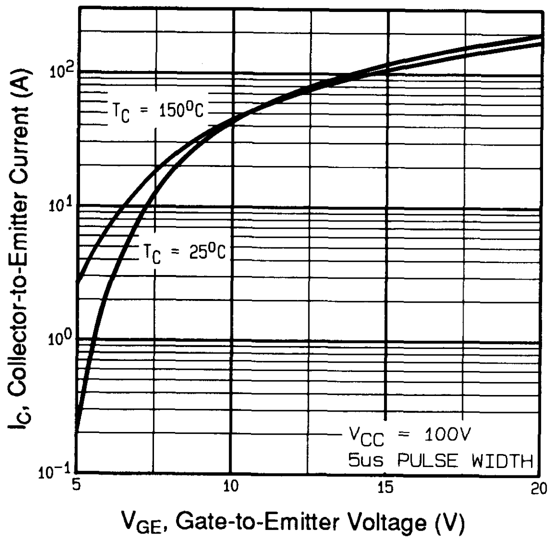


Fig 3. Typical Transfer Characteristics

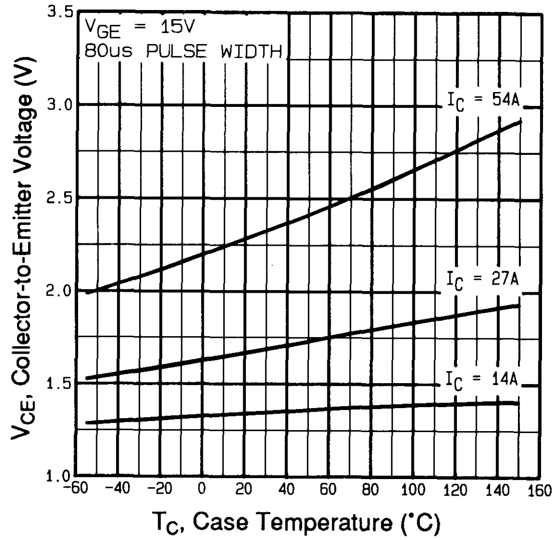


Fig 4. Collector-to-Emitter Saturation Voltage vs. Case Temperature

Graphs indicate performance of typical devices

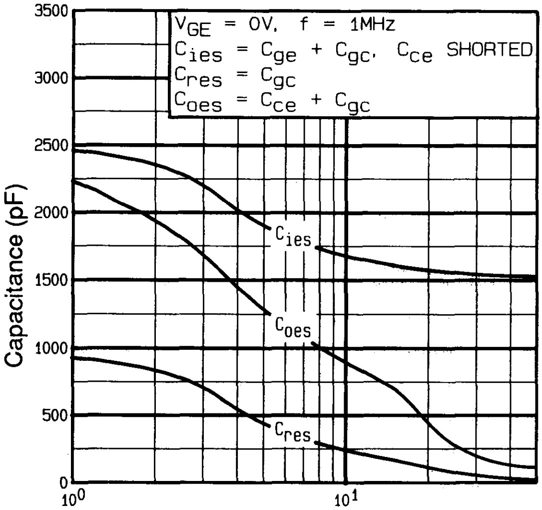


Fig 5. Typical Capacitance vs. Collector-to-Emitter Voltage

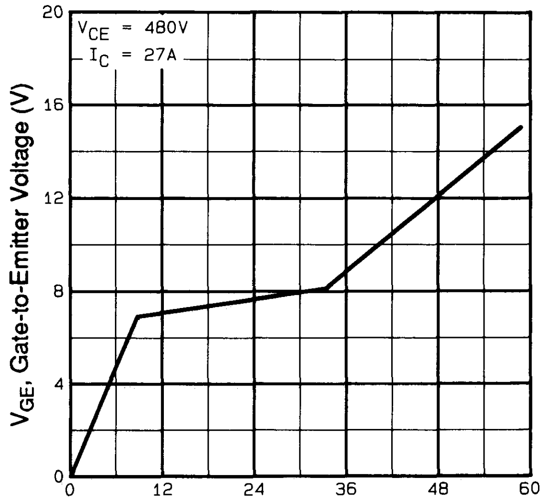


Fig 6. Typical Gate Charge vs. Gate-to-Emitter Voltage

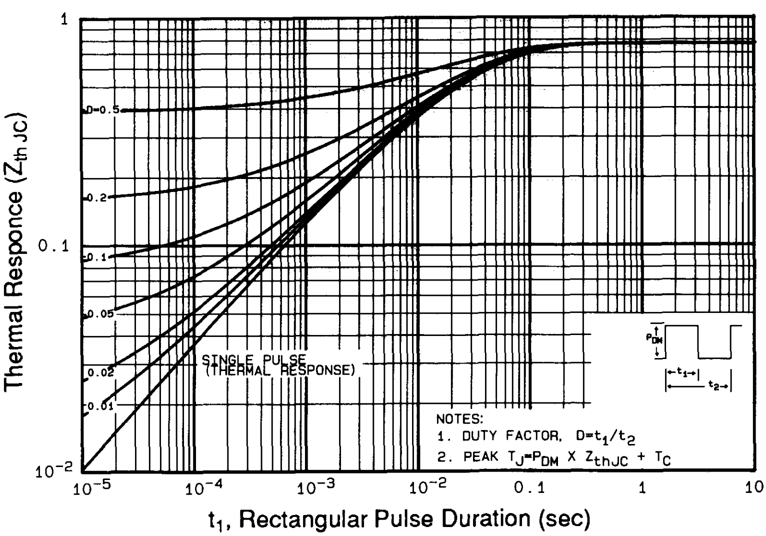


Fig 7. Maximum Effective Transient Thermal Impedance, Junction-to-Case

Graphs indicate performance of typical devices

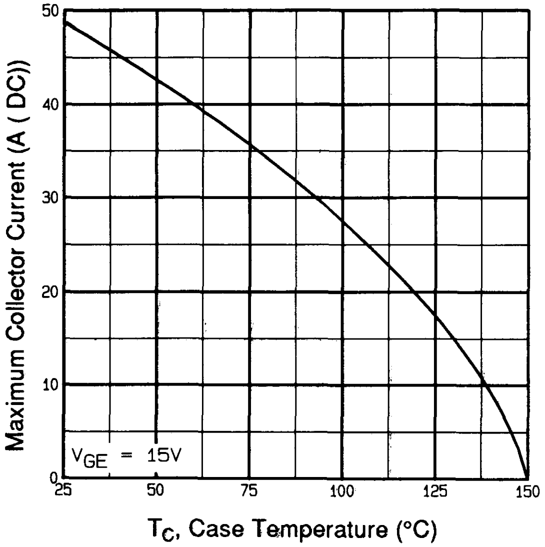


Fig 8. Maximum Collector Current vs. Case Temperature

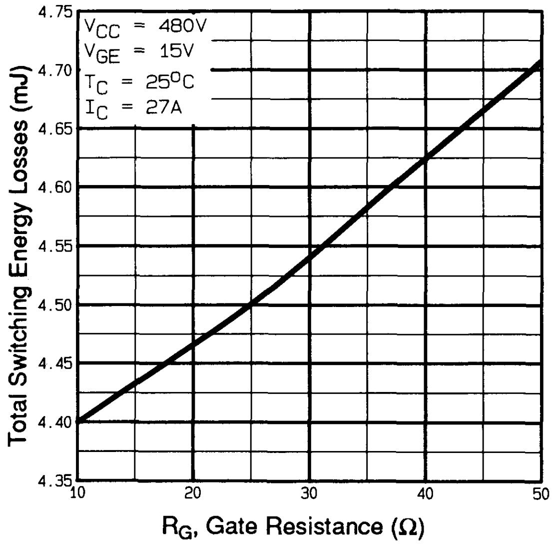


Fig 9. Typical Switching Losses vs. Gate Resistance

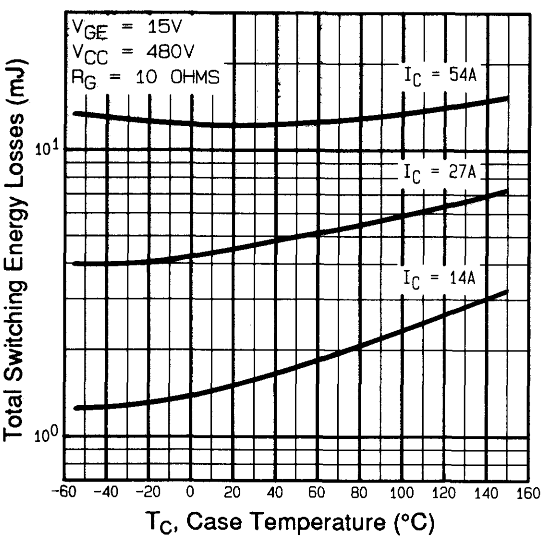


Fig 10. Typical Switching Losses vs. Case Temperature

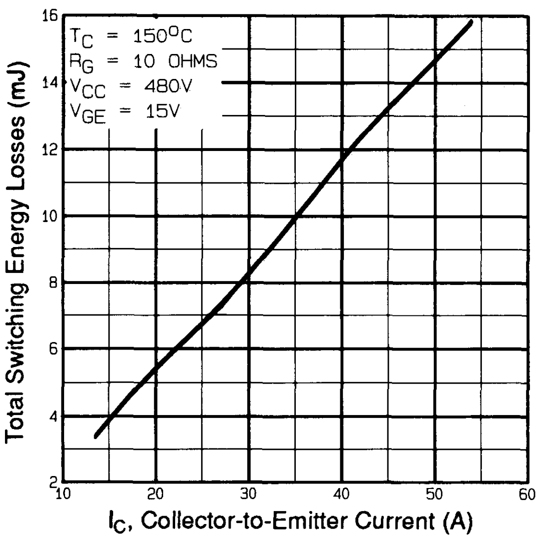


Fig 11. Typical Switching Losses vs. Collector-to-Emitter Current

Graphs indicate performance of typical devices

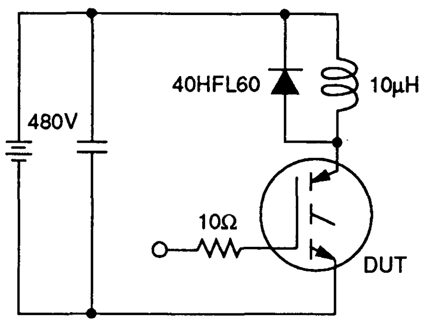


Fig 12a. Clamped Inductive Load Test Circuit

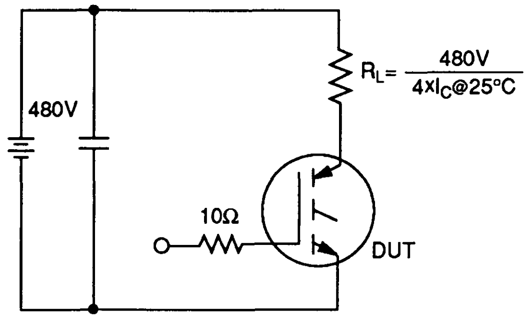


Fig 12b. Pulsed Collector Current Test Circuit

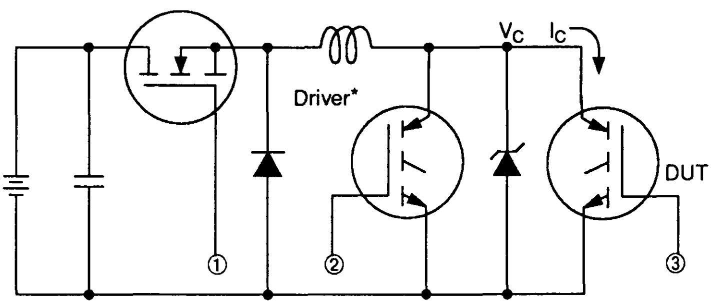


Fig 13a. Switching Loss Test Circuit

* Driver same type as DUT, V_C = 480V

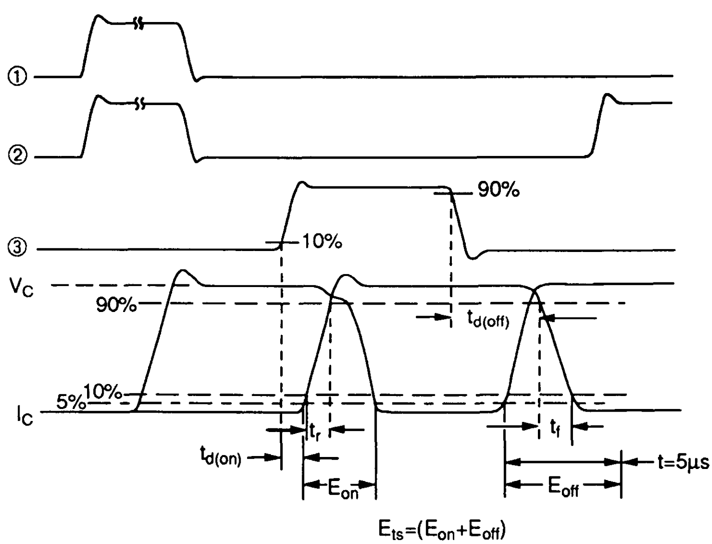


Fig 13b. Switching Loss Waveforms

International
IOR Rectifier

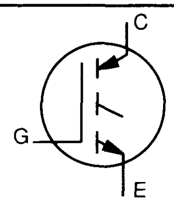
International Rectifier

IRGBC40S

INSULATED GATE BIPOLAR TRANSISTOR

Standard-Speed IGBT

- Latch-proof
- Simple gate-drive
- Standard operation < 1kHz
- Switching-Loss Rating includes all "tail" losses

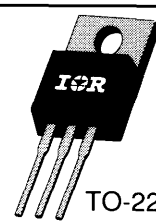


n-channel

V_{CEO} = 600 V
$I_{C(DC)}$ = 50 A
$V_{CE(sat)} \leq 1.8$ V
$E_{TS} \leq 20$ mJ

Description

Insulated Gate Bipolar Transistors (IGBTs) from International Rectifier have higher current densities than comparable bipolar transistors, while at the same time having simpler gate-drive requirements of the familiar power MOSFET. They provide substantial benefits to a host of higher-voltage, higher-current applications.


TO-220AB

Absolute Maximum Ratings

	Parameter	Max.	Units
I_C @ T_C = 25°C	Continuous Collector Current	50	A
I_C @ T_C = 100°C	Continuous Collector Current	31	
I_{CM}	Pulsed Collector Current ①	240	
V_{CE}	Collector-to-Emitter Breakdown Voltage	600	V
V_{GE}	Gate-to-Emitter Voltage	±20	
I_{LM}	Clamped Inductive Load Current ②	240	A
E_{ARV}	Reverse Voltage Avalanche Energy ③	15	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation	160	W
P_D @ T_C = 100°C	Maximum Power Dissipation	65	
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 3mm MA screw	10 in•lbs (11.5 kg•cm)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	---	---	0.77	K/W ⑥
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	---	0.50	---	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	---	---	80	

Electrical Characteristic @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
BV_{CES}	Collector-to-Emitter Breakdown Voltage	600	---	---	V	V_{GE}=0V, I_C=250µA
BV_{ECS}	Emitter-to-Collector Breakdown Volt. ④	15	---	---		V_{GE}=0V, I_C=1.0A
$\Delta BV_{CES}/\Delta T_J$	Temp. Coeff. of Breakdown Voltage	---	0.75	---	V/°C	V_{GE}=0V, I_C =1.0mA
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	---	---	1.8	V	V_{GE}=15V, I_C=31A See fig 4.
		---	2.2	---		V_{GE}=15V, I_C=60A
		---	1.7	---		V_{CE}=15V, I_C=31A, T_J=150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	---	5.5		V_{CE}=V_{GE}, I_C=250µA
$\Delta BV_{GE(th)}/\Delta T_J$	Temp. Coeff. of Threshold Voltage	---	-9.3	---	mV/°C	V_{CE}=V_{GE}, I_C=250µA
g_{fe}	Forward Transconductance ⑤	12	---	30	S	V_{CE}=100V, I_C=31A
I_{CES}	Zero Gate Voltage Collector Current	---	---	250	µA	V_{GE}=0V, V_{CE}=600V, T_J=25°C
		---	---	1000		V_{GE}=0V, V_{CE}=600V, T_J=150°C
I_{GES}	Gate-to-Emitter Leakage Current	---	---	±500	nA	V_{GE}=±20V

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

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
Q_G	Total Gate Charge (turn-on)	40	---	90	nC	I_C=31A, V_{CC}=480V
Q_{GE}	Gate - Emitter Charge (turn-on)	5.0	---	15		See Figure 6.
Q_{GC}	Gate - Collector Charge (turn-on)	13	---	40		
$t_{d(on)}$	Turn-On Delay Time	---	28	---	ns	See test circuit, figure 13.
t_r	Rise Time	---	50	---		I_C=31A, V_{CC}=480V
$t_{d(off)}$	Turn-off Delay Time	---	---	1500		T_J=25°C
t_f	Fall Time	---	---	1100		V_{GE}=15V, R_G=10Ω
E_{on}	Turn-On Switching Loss	---	1.0	---	mJ	Energy losses include "tail".
E_{off}	Turn-Off Switching Loss	---	12	---		Also see figures 9, 10, & 11.
E_{ts}	Total Switching Loss	---	13	20		
$t_{d(on)}$	Turn-On Delay Time	---	29	---	ns	I_C=31A, V_{CC}=480V
t_r	Rise Time	---	53	---		T_J=150°C
$t_{d(off)}$	Turn-Off Delay Time	---	1600	---		V_{GE}=15V
t_f	Fall Time	---	1200	---		R_G=10Ω
E_{ts}	Total Switching Loss	---	22	---	mJ	
L_E	Internal Emitter Inductance	---	7.5	---	nH	Measured 5mm from package.
C_{ies}	Input Capacitance	---	1600	---	pF	V_{GE}=0V
C_{oes}	Output Capacitance	---	140	---		V_{CC}=30V See fig 5.
C_{res}	Reverse Transfer Capacitance	---	20	---		f = 1.0MHz

Notes:

① Repetitive rating; V_{GE}=20V, pulse width limited by max. junction temperature (See figure 12b).

② V_{CC}=80%(BV_{CES}), V_{GE}=20V, L=10µH, R_G=10Ω, (See figure 12a).

③ Repetitive rating; pulse width limited by maximum junction temperature.

④ Pulse width ≤ 80µs; duty factor ≤0.1%.

⑤ Pulse width ≤ 5µs, single shot.

⑥ K/W equivalent to °C/W.

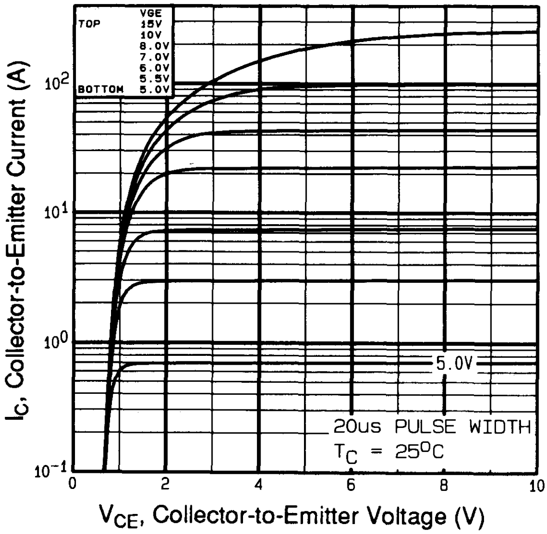


Fig 1. Typical Output Characteristics, $T_J = 25°C$

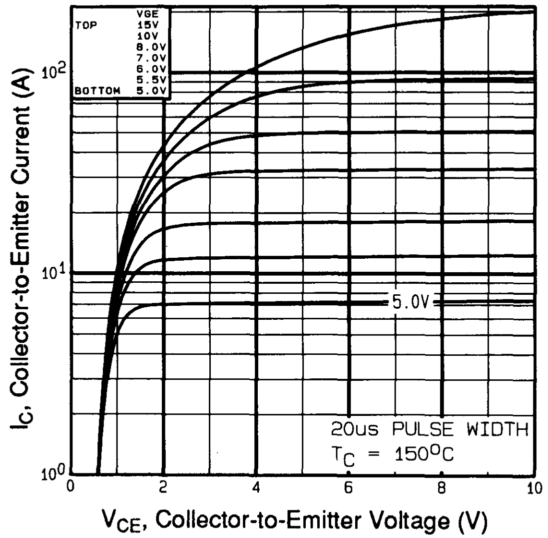


Fig 2. Typical Output Characteristics, $T_J = 150°C$

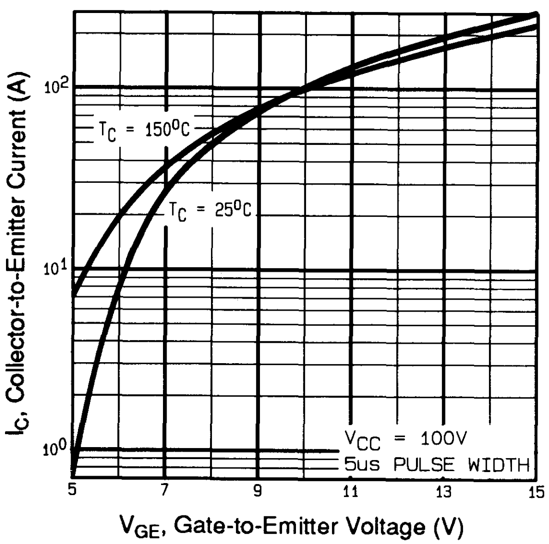


Fig 3. Typical Transfer Characteristics

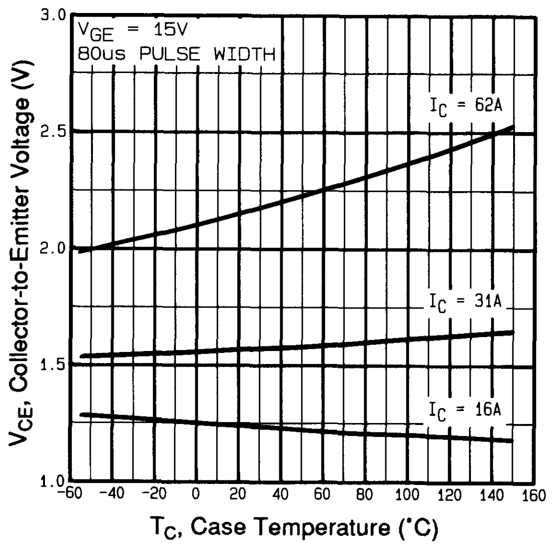


Fig 4. Collector-to-Emitter Saturation Voltage vs. Case Temperature

Graphs indicate performance of typical devices

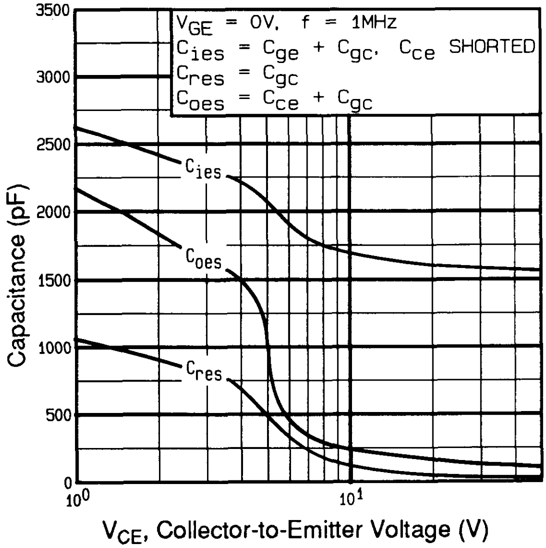


Fig 5. Typical Capacitance vs. Collector-to-Emitter Voltage

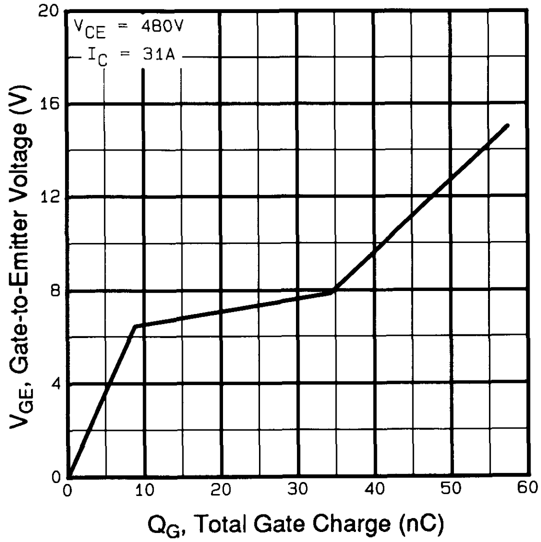


Fig 6. Typical Gate Charge vs. Gate-to-Emitter Voltage

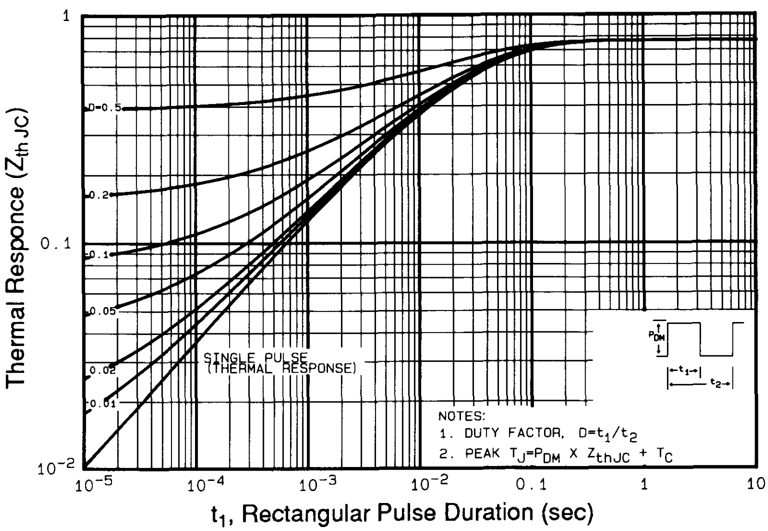


Fig 7. Maximum Effective Transient Thermal Impedance, Junction-to-Case

Graphs indicate performance of typical devices

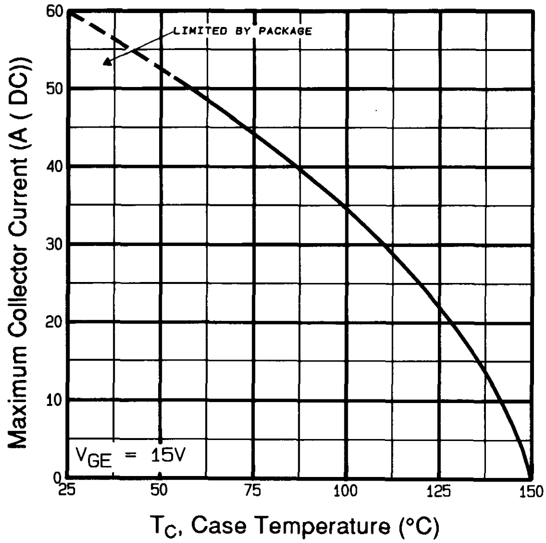


Fig 8. Maximum Collector Current vs. Case Temperature

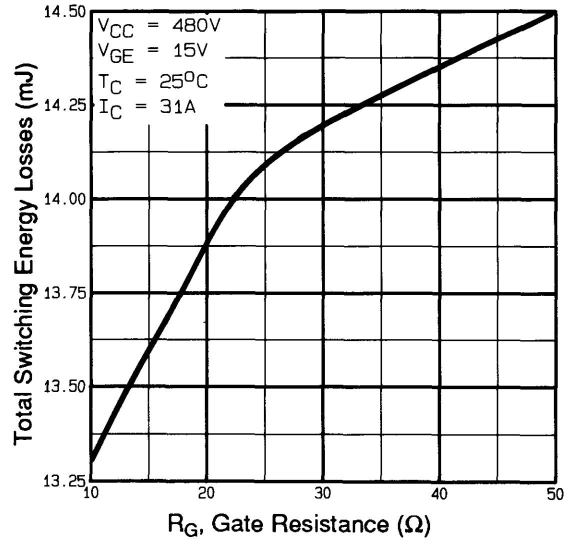


Fig 9. Typical Switching Losses vs. Gate Resistance

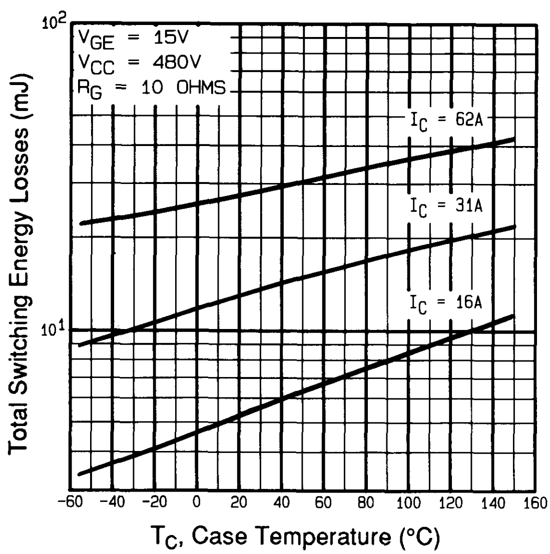


Fig 10. Typical Switching Losses vs. Case Temperature

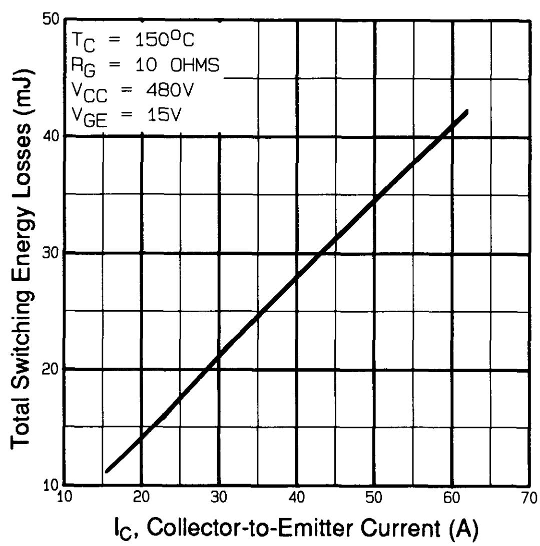


Fig 11. Typical Switching Losses vs. Collector-to-Emitter Current

Graphs indicate performance of typical devices

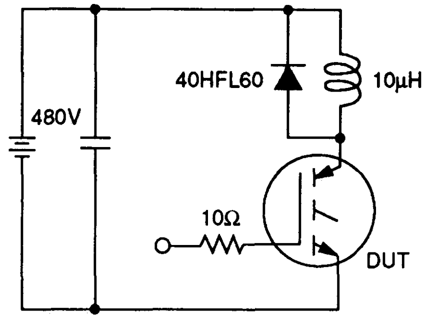


Fig 12a. Clamped Inductive Load Test Circuit

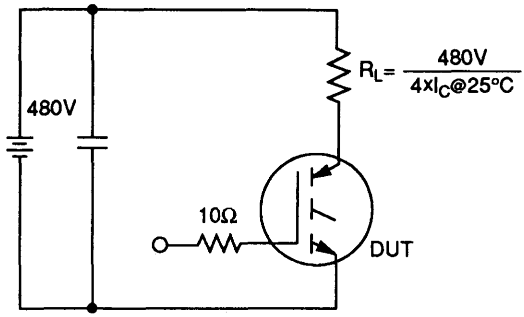


Fig 12b. Pulsed Collector Current Test Circuit

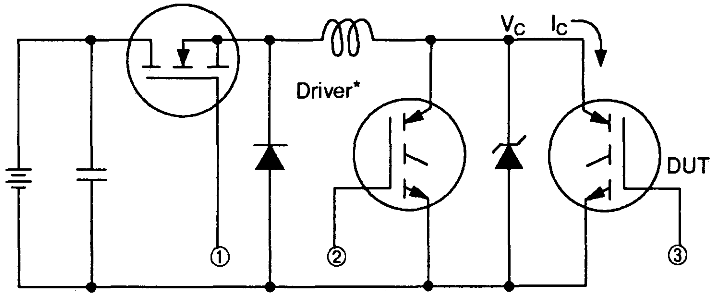


Fig 13a. Switching Loss Test Circuit

* Driver same type as DUT, V_C = 480V

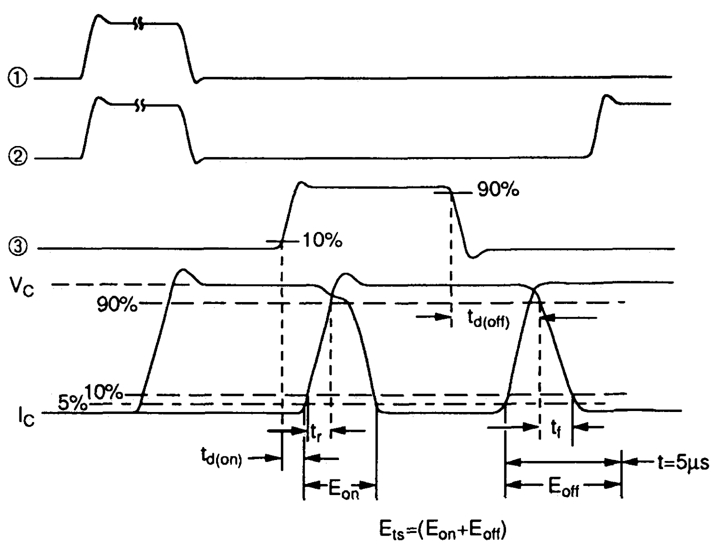


Fig 13b. Switching Loss Waveforms

International IOR Rectifier

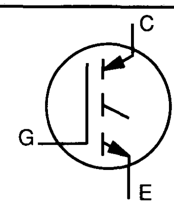
International
IOR Rectifier

IRGBC40U

INSULATED GATE BIPOLAR TRANSISTOR

UltraFast™ IGBT

- Latch-proof
- Simple gate-drive
- Ultra-fast operation > 10kHz
- Switching-Loss Rating includes all "tail" losses

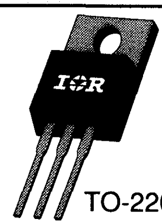


n-channel

V_{CEO} = 600 V
$I_{C(DC)}$ = 40 A
$V_{CE(sat)} \leq 3.0$ V
$E_{TS} \leq 2.0$ mJ

Description

Insulated Gate Bipolar Transistors (IGBTs) from International Rectifier have higher current densities than comparable bipolar transistors, while at the same time having simpler gate-drive requirements of the familiar power MOSFET. They provide substantial benefits to a host of higher-voltage, higher-current applications.



TO-220AB

Absolute Maximum Ratings

	Parameter	Max.	Units
I_C @ T_C = 25°C	Continuous Collector Current	40	A
I_C @ T_C = 100°C	Continuous Collector Current	20	
I_{CM}	Pulsed Collector Current ①	160	
V_{CE}	Collector-to-Emitter Breakdown Voltage	600	V
V_{GE}	Gate-to-Emitter Voltage	±20	
I_{LM}	Clamped Inductive Load Current ②	160	A
E_{ARV}	Reverse Voltage Avalanche Energy ③	15	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation	160	W
P_D @ T_C = 100°C	Maximum Power Dissipation	65	
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 3mm MA screw	10 in•lbs (11.5 kg•cm)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	---	---	0.77	
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	---	0.50	---	K/W ⑥
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	---	---	80	

Electrical Characteristic @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
BV_{CES}	Collector-to-Emitter Breakdown Voltage	600	---	---	V	V_{GE}=0V, I_C=250µA
BV_{ECS}	Emitter-to-Collector Breakdown Volt. ④	15	---	---	V	V_{GE}=0V, I_C=1.0A
$\Delta BV_{CES}/\Delta T_J$	Temp. Coeff. of Breakdown Voltage	---	0.63	---	V/°C	V_{GE}=0V, I_C =1.0mA
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	---	---	3.0	V	V_{GE}=15V, I_C=20A See fig 4.
		---	2.7	---		V_{GE}=15V, I_C=40A
		---	2.3	---		V_{CE}=15V, I_C=20A, T_J=150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	---	5.5		V_{CE}=V_{GE}, I_C=250µA
$\Delta BV_{GE(th)}/\Delta T_J$	Temp. Coeff. of Threshold Voltage	---	-13	---	mV/°C	V_{CE}=V_{GE}, I_C=250µA
g_{fe}	Forward Transconductance ⑤	11	---	24	S	V_{CE}=100V, I_C=20A
I_{CES}	Zero Gate Voltage Collector Current	---	---	250	µA	V_{GE}=0V, V_{CE}=600V, T_J=25°C
		---	---	1000		V_{GE}=0V, V_{CE}=600V, T_J=150°C
I_{GES}	Gate-to-Emitter Leakage Current	---	---	±500	nA	V_{GE}=±20V

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

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
Q_G	Total Gate Charge (turn-on)	35	---	67	nC	I_C=20A, V_{CC}=480V See Figure 6.
Q_{GE}	Gate - Emitter Charge (turn-on)	6.5	---	11		
Q_{GC}	Gate - Collector Charge (turn-on)	5.9	---	33		
$t_{d(on)}$	Turn-On Delay Time	---	25	---	ns	See test circuit, figure 13. I_C=20A, V_{CC}=480V T_J=25°C V_{GE}=15V, R_G=10Ω Energy losses include "tail". Also see figures 9, 10, & 11.
t_r	Rise Time	---	21	---		
$t_{d(off)}$	Turn-off Delay Time	---	---	190		
t_f	Fall Time	---	---	120		
E_{on}	Turn-On Switching Loss	---	0.18	---	mJ	
E_{off}	Turn-Off Switching Loss	---	1.3	---		
E_{ts}	Total Switching Loss	---	1.5	2.0		
$t_{d(on)}$	Turn-On Delay Time	---	25	---	ns	I_C=20A, V_{CC}=480V T_J=150°C V_{GE}=15V R_G=10Ω
t_r	Rise Time	---	23	---		
$t_{d(off)}$	Turn-Off Delay Time	---	174	---		
t_f	Fall Time	---	140	---		
E_{ts}	Total Switching Loss	---	2.4	---	mJ	
L_E	Internal Emitter Inductance	---	7.5	---	nH	Measured 5mm from package.
C_{ies}	Input Capacitance	---	1500	---	pF	V_{GE}=0V
C_{oes}	Output Capacitance	---	190	---		V_{CC}=30V See fig 5.
C_{res}	Reverse Transfer Capacitance	---	17	---		f = 1.0MHz

Notes:

① Repetitive rating; V_{GE}=20V, pulse width limited by max. junction temperature (See figure 12b).

② V_{CC}=80%(BV_{CES}), V_{GE}=20V, L=10µH, R_G=10Ω, (See figure 12a).

③ Repetitive rating; pulse width limited by maximum junction temperature.

④ Pulse width ≤ 80µs; duty factor ≤0.1%.

⑤ Pulse width ≤ 5µs, single shot.

⑥ K/W equivalent to °C/W.

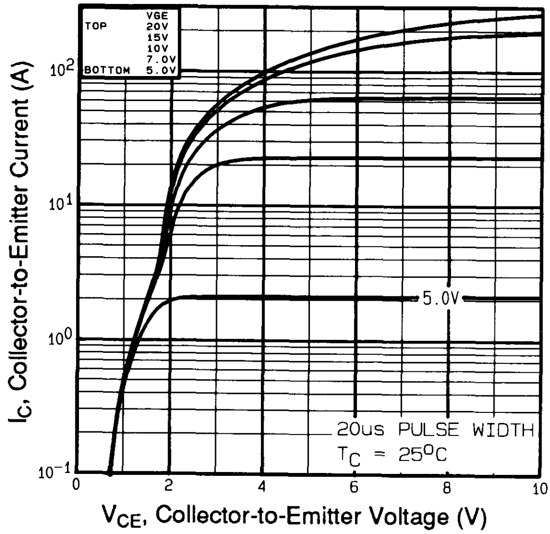


Fig 1. Typical Output Characteristics, $T_J = 25°C$

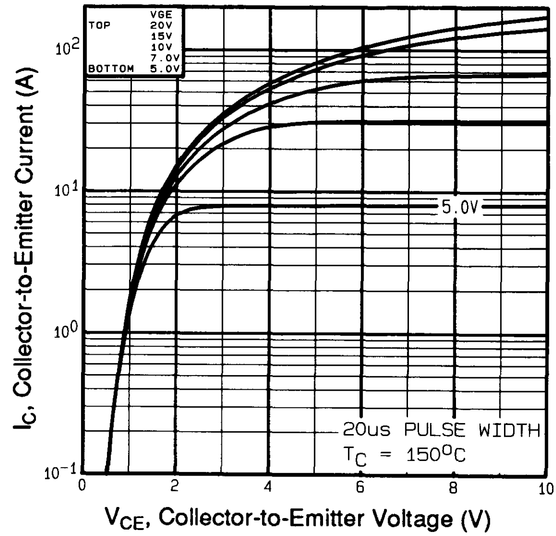


Fig 2. Typical Output Characteristics, $T_J = 150°C$

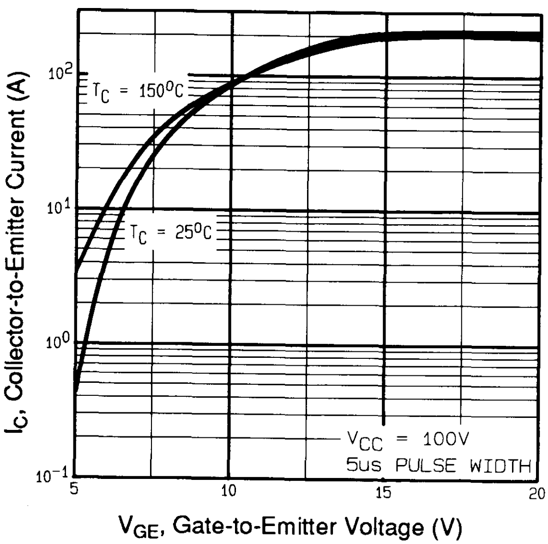


Fig 3. Typical Transfer Characteristics

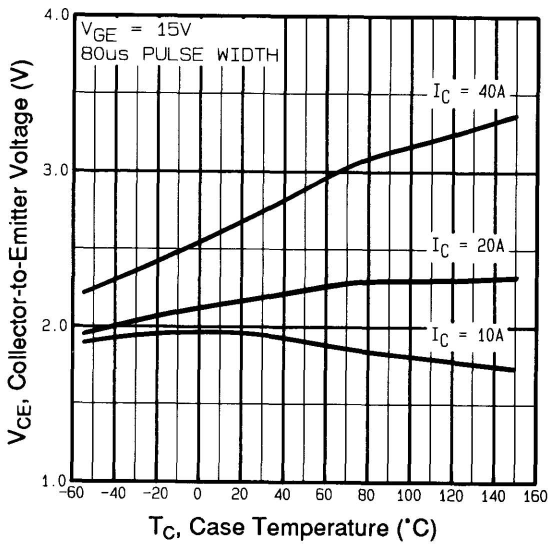


Fig 4. Collector-to-Emitter Saturation Voltage vs. Case Temperature

Graphs indicate performance of typical devices

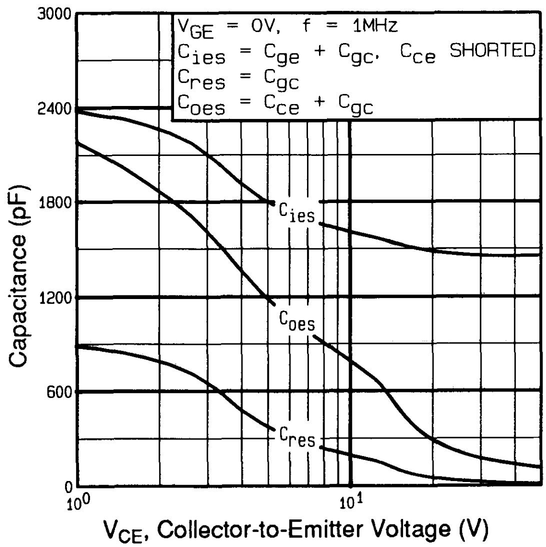


Fig 5. Typical Capacitance vs. Collector-to-Emitter Voltage

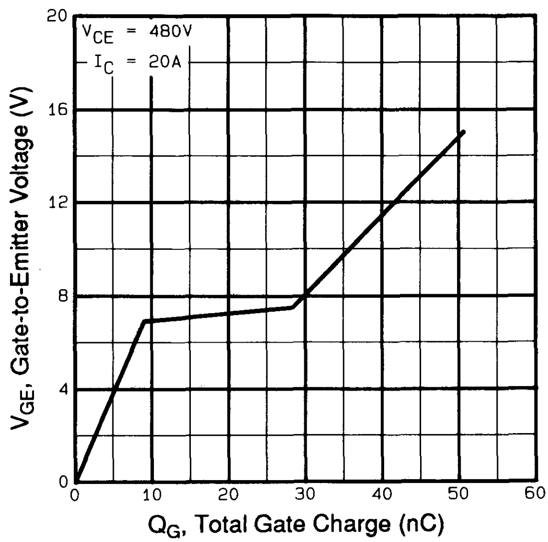


Fig 6. Typical Gate Charge vs. Gate-to-Emitter Voltage

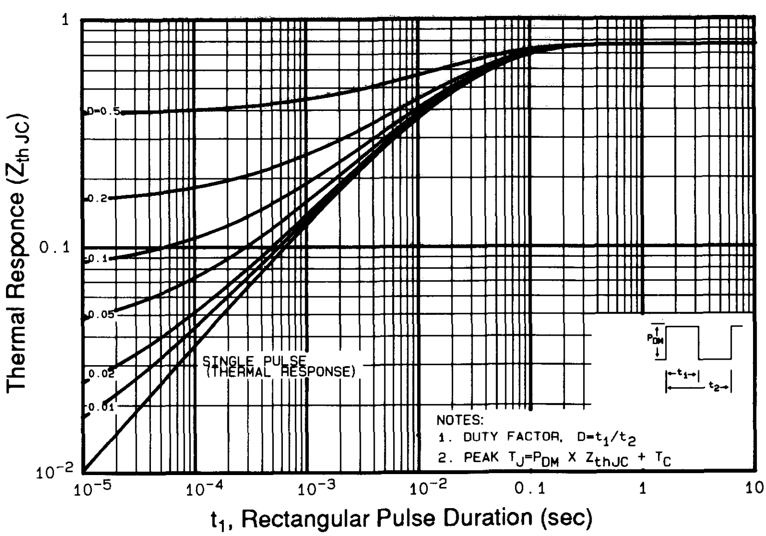


Fig 7. Maximum Effective Transient Thermal Impedance, Junction-to-Case

Graphs indicate performance of typical devices

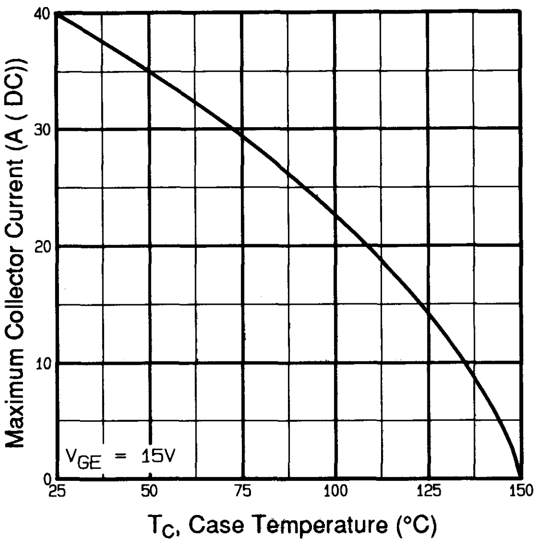


Fig 8. Maximum Collector Current vs. Case Temperature

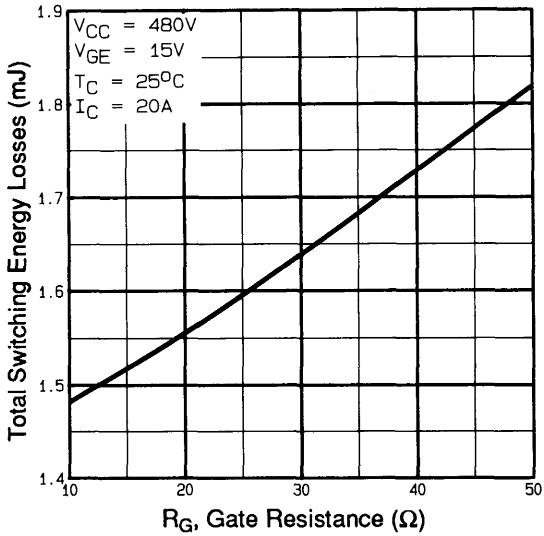


Fig 9. Typical Switching Losses vs. Gate Resistance

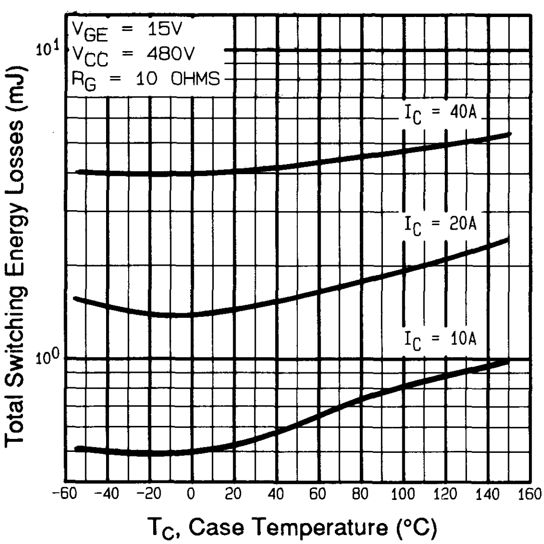


Fig 10. Typical Switching Losses vs. Case Temperature

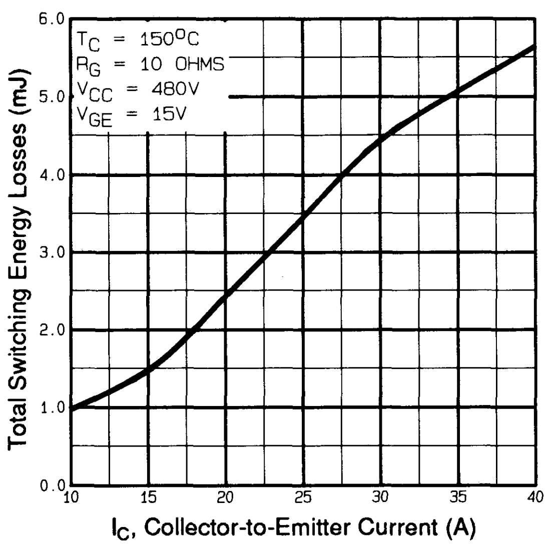


Fig 11. Typical Switching Losses vs. Collector-to-Emitter Current

Graphs indicate performance of typical devices

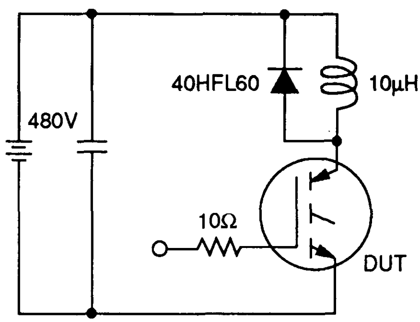


Fig 12a. Clamped Inductive Load Test Circuit

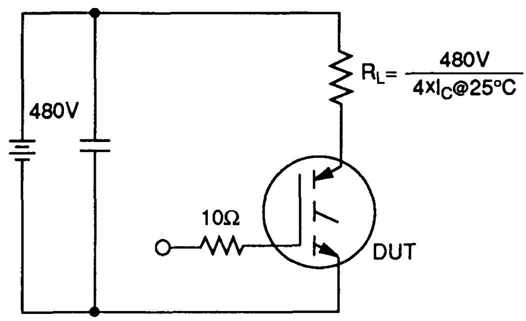


Fig 12b. Pulsed Collector Current Test Circuit

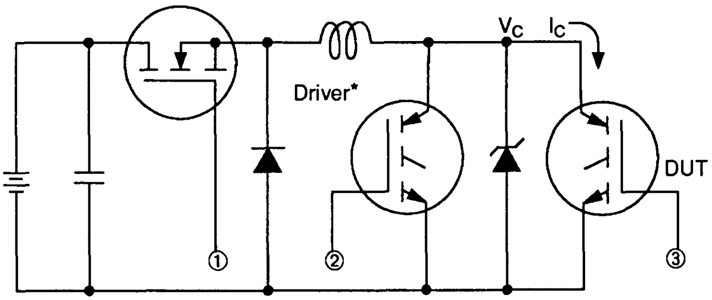


Fig 13a. Switching Loss Test Circuit

* Driver same type as DUT, V_C = 480V

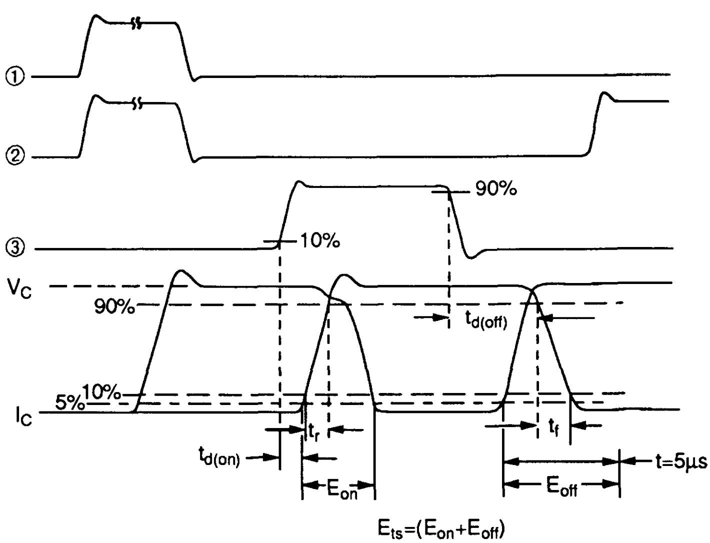


Fig 13b. Switching Loss Waveforms

International Rectifier

PD-9.693

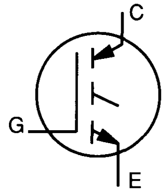
International Rectifier

IRGPC40F

INSULATED GATE BIPOLAR TRANSISTOR

Fast-Speed IGBT

- Latch-proof
- Simple gate-drive
- Fast operation 3kHz~8kHz
- Switching-Loss Rating includes all "tail" losses

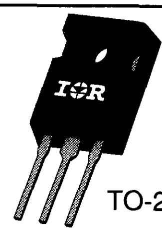


n-channel

$V_{CEO} = 600$ V
$I_{C(DC)} = 49$ A
$V_{CE(sat)} \leq 2.0$ V
$E_{TS} \leq 9.0$ mJ

Description

Insulated Gate Bipolar Transistors (IGBTs) from International Rectifier have higher current densities than comparable bipolar transistors, while at the same time having simpler gate-drive requirements of the familiar power MOSFET. They provide substantial benefits to a host of higher-voltage, higher-current applications.



TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
I_C @ $T_C = 25°C$	Continuous Collector Current	49	A
I_C @ $T_C = 100°C$	Continuous Collector Current	27	
I_{CM}	Pulsed Collector Current ①	200	
V_{CE}	Collector-to-Emitter Breakdown Voltage	600	V
V_{GE}	Gate-to-Emitter Voltage	±20	
I_{LM}	Clamped Inductive Load Current ②	200	A
E_{ARV}	Reverse Voltage Avalanche Energy ③	15	mJ
P_D @ $T_C = 25°C$	Maximum Power Dissipation	160	W
P_D @ $T_C = 100°C$	Maximum Power Dissipation	65	
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 3mm MA screw	10 in•lbs (11.5 kg•cm)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	---	---	0.77	K/W ⑥
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	---	0.24	---	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	---	---	40	

Electrical Characteristic @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
BV_{CES}	Collector-to-Emitter Breakdown Voltage	600	---	---	V	V_{GE}=0V, I_C=250µA
BV_{ECS}	Emitter-to-Collector Breakdown Volt. ④	24	---	---		V_{GE}=0V, I_C=1.0A
$\Delta BV_{CES}/\Delta T_J$	Temp. Coeff. of Breakdown Voltage	---	0.70	---	V/°C	V_{GE}=0V, I_C =1.0mA
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	---	---	2.0	V	V_{GE}=15V, I_C=27A See fig 4.
		---	2.2	---		V_{GE}=15V, I_C=49A
		---	1.9	---		V_{CE}=15V, I_C=27A, T_J=150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	---	5.5		V_{CE}=V_{GE}, I_C=250µA
$\Delta BV_{GE(th)}/\Delta T_J$	Temp. Coeff. of Threshold Voltage	---	-12	---	mV/°C	V_{CE}=V_{GE}, I_C=250µA
g_{fe}	Forward Transconductance ⑤	9.2	---	15	S	V_{CE}=100V, I_C=27A
I_{CES}	Zero Gate Voltage Collector Current	---	---	250	µA	V_{GE}=0V, V_{CE}=600V, T_J=25°C
		---	---	1000		V_{GE}=0V, V_{CE}=600V, T_J=150°C
I_{GES}	Gate-to-Emitter Leakage Current	---	---	±500	nA	V_{GE}=±20V

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

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
Q_G	Total Gate Charge (turn-on)	38	---	80	nC	I_C=27A, V_{CC}=480V
Q_{GE}	Gate - Emitter Charge (turn-on)	7.1	---	10		See Figure 6.
Q_{GC}	Gate - Collector Charge (turn-on)	7.7	---	42		
$t_{d(on)}$	Turn-On Delay Time	---	26	---	ns	See test circuit, figure 13.
t_r	Rise Time	---	37	---		I_C=27A, V_{CC}=480V
$t_{d(off)}$	Turn-off Delay Time	---	---	410		T_J=25°C
t_f	Fall Time	---	---	420		V_{GE}=15V, R_G=10Ω
E_{on}	Turn-On Switching Loss	---	0.60	---	mJ	Energy losses include "tail".
E_{off}	Turn-Off Switching Loss	---	3.8	---		Also see figures 9, 10, & 11.
E_{ts}	Total Switching Loss	---	4.4	9.0		
$t_{d(on)}$	Turn-On Delay Time	---	28	---	ns	I_C=27A, V_{CC}=480V
t_r	Rise Time	---	37	---		T_J=150°C
$t_{d(off)}$	Turn-Off Delay Time	---	380	---		V_{GE}=15V
t_f	Fall Time	---	460	---		R_G=10Ω
E_{ts}	Total Switching Loss	---	7.0	---	mJ	
L_E	Internal Emitter Inductance	---	13	---	nH	Measured 5mm from package.
C_{ies}	Input Capacitance	---	1500	---	pF	V_{GE}=0V
C_{oes}	Output Capacitance	---	190	---		V_{CC}=30V See fig 5.
C_{res}	Reverse Transfer Capacitance	---	20	---		f = 1.0MHz

Notes:

① Repetitive rating; V_{GE}=20V, pulse width limited by max. junction temperature (See figure 12b).

② V_{CC}=80%(BV_{CES}), V_{GE}=20V, L=10µH, R_G=10Ω, (See figure 12a).

③ Repetitive rating; pulse width limited by maximum junction temperature.

④ Pulse width ≤ 80µs; duty factor ≤0.1%.

⑤ Pulse width ≤ 5µs, single shot.

⑥ K/W equivalent to °C/W.

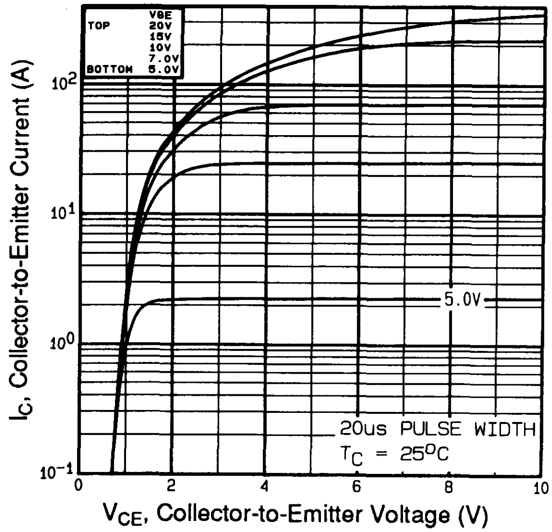


Fig 1. Typical Output Characteristics, $T_J = 25°C$

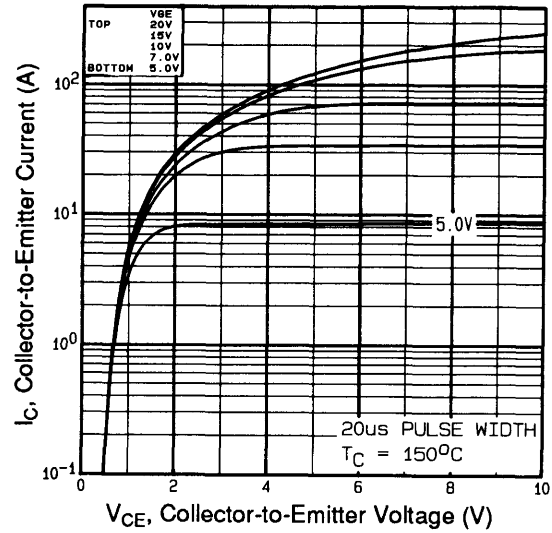


Fig 2. Typical Output Characteristics, $T_J = 150°C$

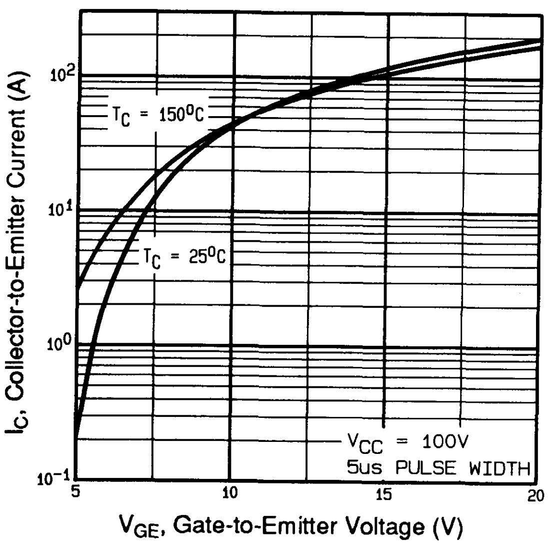


Fig 3. Typical Transfer Characteristics

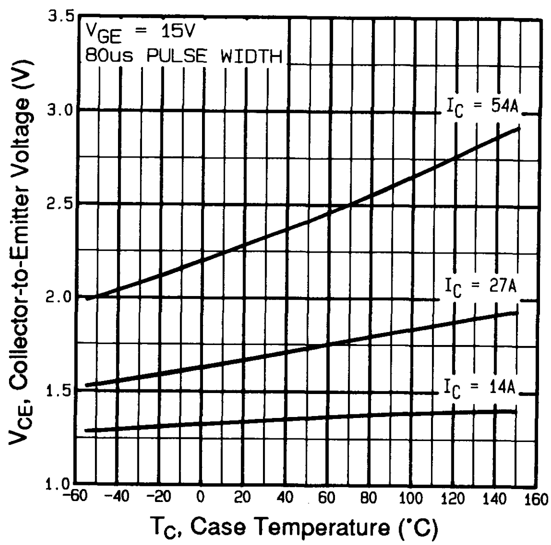


Fig 4. Collector-to-Emitter Saturation Voltage vs. Case Temperature

Graphs indicate performance of typical devices

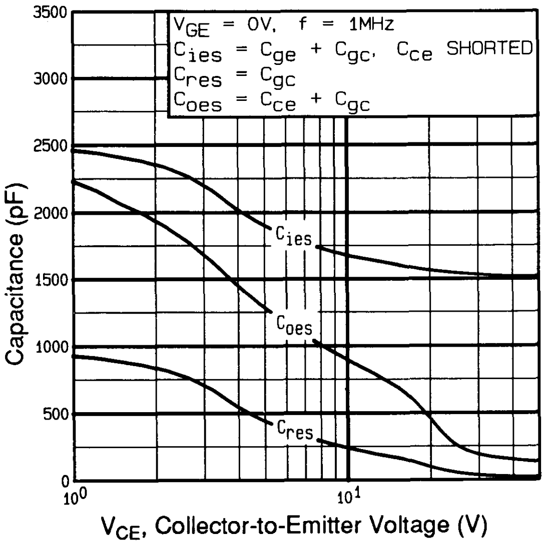


Fig 5. Typical Capacitance vs. Collector-to-Emitter Voltage

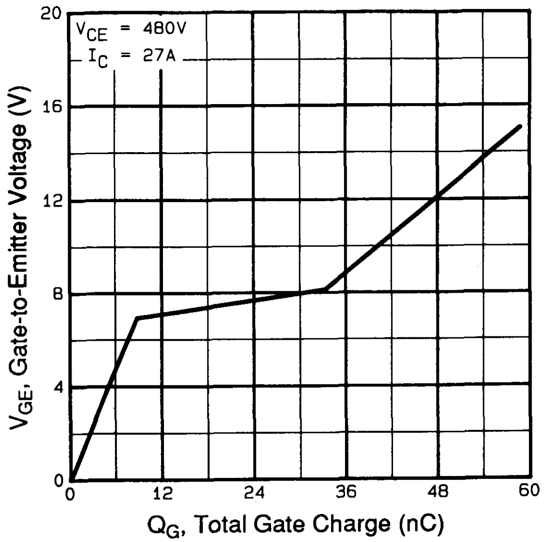


Fig 6. Typical Gate Charge vs. Gate-to-Emitter Voltage

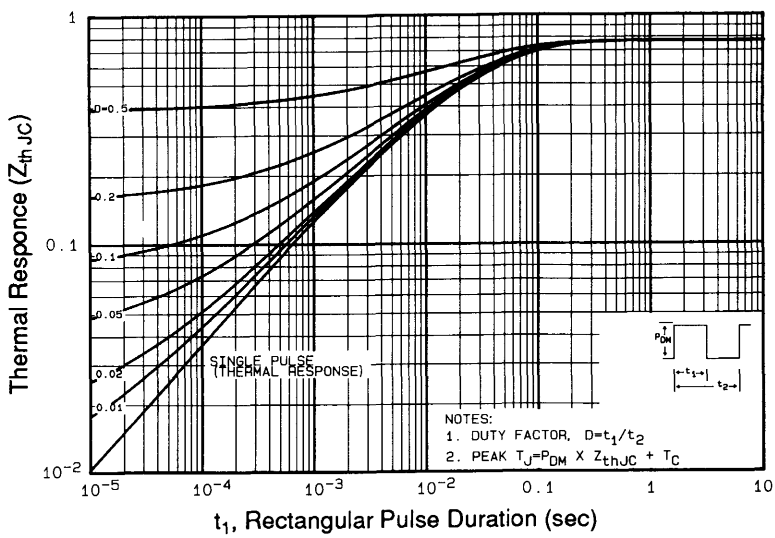


Fig 7. Maximum Effective Transient Thermal Impedance, Junction-to-Case

Graphs indicate performance of typical devices

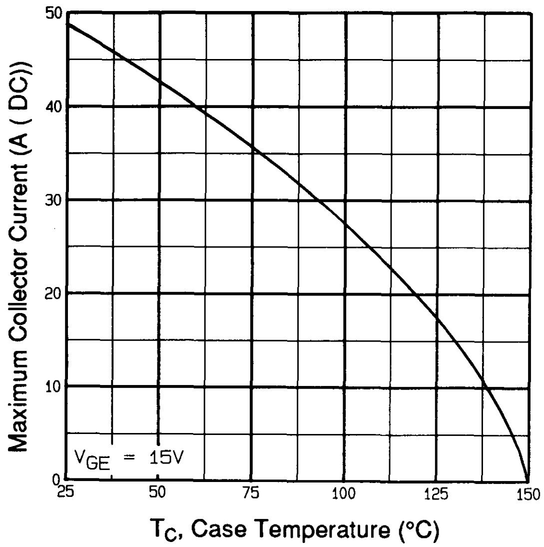


Fig 8. Maximum Collector Current vs. Case Temperature

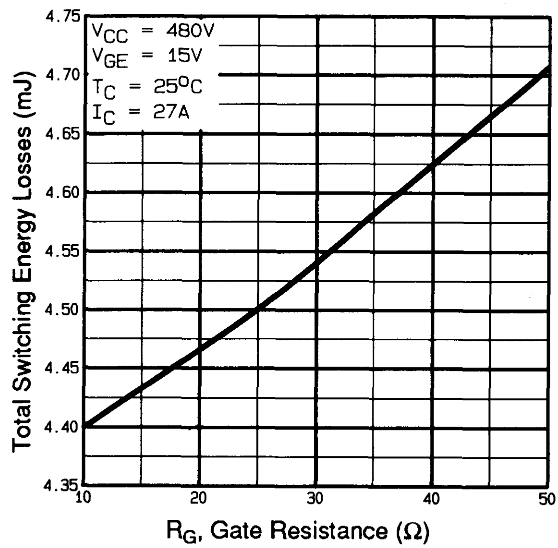


Fig 9. Typical Switching Losses vs. Gate Resistance

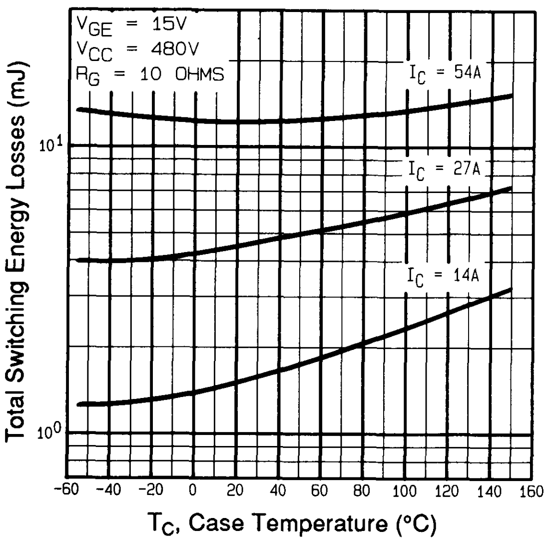


Fig 10. Typical Switching Losses vs. Case Temperature

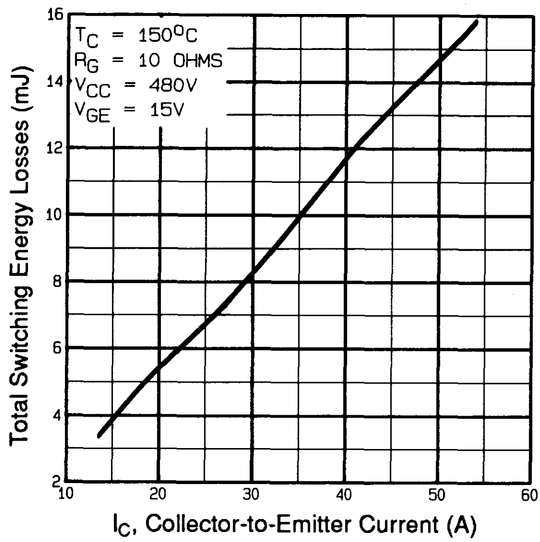


Fig 11. Typical Switching Losses vs. Collector-to-Emitter Current

Graphs indicate performance of typical devices

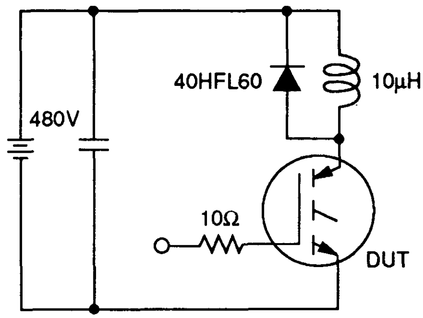


Fig 12a. Clamped Inductive Load Test Circuit

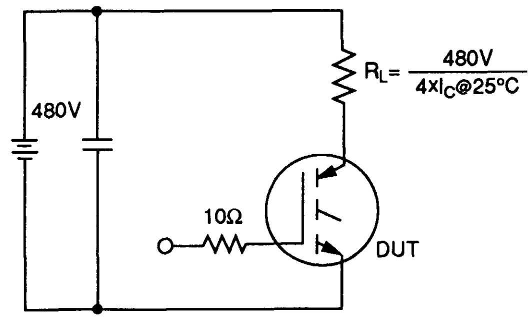


Fig 12b. Pulsed Collector Current Test Circuit

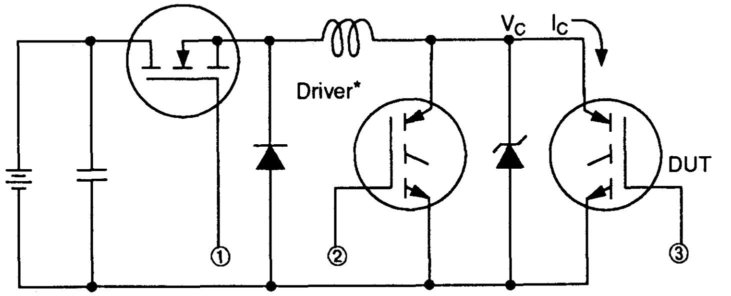
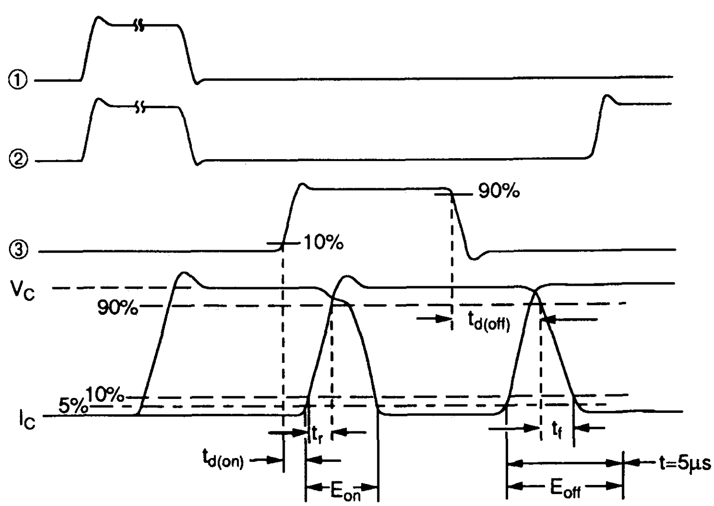


Fig 13a. Switching Loss Test Circuit

* Driver same type as DUT, V_C = 480V



$E_{ts}=(E_{on}+E_{off})$

Fig 13b. Switching Loss Waveforms

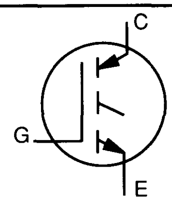
International
IOR Rectifier

IRGPC40S

INSULATED GATE BIPOLAR TRANSISTOR

Standard-Speed IGBT

- Latch-proof
- Simple gate-drive
- Standard Operation < 1kHz
- Switching-Loss Rating includes all "tail" losses

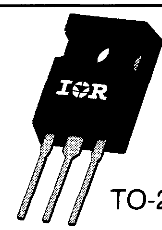


n-channel

$V_{CEO} = 600$ V
$I_{C(DC)} = 60$ A
$V_{CE(sat)} \leq 1.8$ V
$E_{TS} \leq 20$ mJ

Description

Insulated Gate Bipolar Transistors (IGBTs) from International Rectifier have higher current densities than comparable bipolar transistors, while at the same time having simpler gate-drive requirements of the familiar power MOSFET. They provide substantial benefits to a host of higher-voltage, higher-current applications.



TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
I_C @ T_C = 25°C	Continuous Collector Current	60	A
I_C @ T_C = 100°C	Continuous Collector Current	31	A
I_{CM}	Pulsed Collector Current ①	240	A
V_{CE}	Collector-to-Emitter Breakdown Voltage	600	V
V_{GE}	Gate-to-Emitter Voltage	±20	V
I_{LM}	Clamped Inductive Load Current ②	240	A
E_{ARV}	Reverse Voltage Avalanche Energy ③	15	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation	160	W
P_D @ T_C = 100°C	Maximum Power Dissipation	65	W
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)	°C
	Mounting Torque, 6-32 or 3mm MA screw	10 in•lbs (11.5 kg•cm)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	---	---	0.77	K/W ⑥
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	---	0.24	---	K/W ⑥
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	---	---	80	K/W ⑥

Electrical Characteristic @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
BV_{CES}	Collector-to-Emitter Breakdown Voltage	600	---	---	V	V_{GE}=0V, I_C=250μA
BV_{ECS}	Emitter-to-Collector Breakdown Volt. ④	15	---	---		V_{GE}=0V, I_C=1.0A
$\Delta BV_{CES}/\Delta T_J$	Temp. Coeff. of Breakdown Voltage	---	0.75	---	V/°C	V_{GE}=0V, I_C =1.0mA
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	---	---	1.8	V	V_{GE}=15V, I_C=31A See fig 4.
		---	2.2	---		V_{GE}=15V, I_C=60A
		---	1.7	---		V_{CE}=15V, I_C=31A, T_J=150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	---	5.5		V_{CE}=V_{GE}, I_C=250μA
$\Delta BV_{GE(th)}/\Delta T_J$	Temp. Coeff. of Threshold Voltage	---	-9.3	---	mV/°C	V_{CE}=V_{GE}, I_C=250μA
g_{fe}	Forward Transconductance ⑤	12	---	30	S	V_{CE}=100V, I_C=31A
I_{CES}	Zero Gate Voltage Collector Current	---	---	250	μA	V_{GE}=0V, V_{CE}=600V, T_J=25°C
		---	---	1000		V_{GE}=0V, V_{CE}=600V, T_J=150°C
I_{GES}	Gate-to-Emitter Leakage Current	---	---	±500	nA	V_{GE}=±20V

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

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
Q_G	Total Gate Charge (turn-on)	40	---	90	nC	I_C=31A, V_{CC}=480V
Q_{GE}	Gate - Emitter Charge (turn-on)	5.0	---	15		See Figure 6.
Q_{GC}	Gate - Collector Charge (turn-on)	13	---	40		
$t_{d(on)}$	Turn-On Delay Time	---	28	---	ns	See test circuit, figure 13.
t_r	Rise Time	---	50	---		I_C=31A, V_{CC}=480V
$t_{d(off)}$	Turn-off Delay Time	---	---	1500		T_J=25°C
t_f	Fall Time	---	---	1100		V_{GE}=15V, R_G=10Ω
E_{on}	Turn-On Switching Loss	---	1.0	---	mJ	Energy losses include "tail".
E_{off}	Turn-Off Switching Loss	---	12	---		Also see figures 9, 10, & 11.
E_{ts}	Total Switching Loss	---	13	20		
$t_{d(on)}$	Turn-On Delay Time	---	29	---	ns	I_C=31A, V_{CC}=480V
t_r	Rise Time	---	53	---		T_J=150°C
$t_{d(off)}$	Turn-Off Delay Time	---	1600	---		V_{GE}=15V
t_f	Fall Time	---	1200	---		R_G=10Ω
E_{ts}	Total Switching Loss	---	22	---	mJ	
L_E	Internal Emitter Inductance	---	13	---	nH	Measured 5mm from package.
C_{ies}	Input Capacitance	---	1600	---	pF	V_{GE}=0V
C_{oes}	Output Capacitance	---	140	---		V_{CC}=30V See fig 5.
C_{res}	Reverse Transfer Capacitance	---	20	---		f = 1.0MHz

Notes:

① Repetitive rating; V_{GE}=20V, pulse width limited by max. junction temperature (See figure 12b).

② V_{CC}=80%(BV_{CES}), V_{GE}=20V, L=10μH, R_G=10Ω, (See figure 12a).

③ Repetitive rating; pulse width limited by maximum junction temperature.

④ Pulse width ≤ 80μs; duty factor ≤0.1%.

⑤ Pulse width ≤ 5μs, single shot.

⑥ K/W equivalent to °C/W.

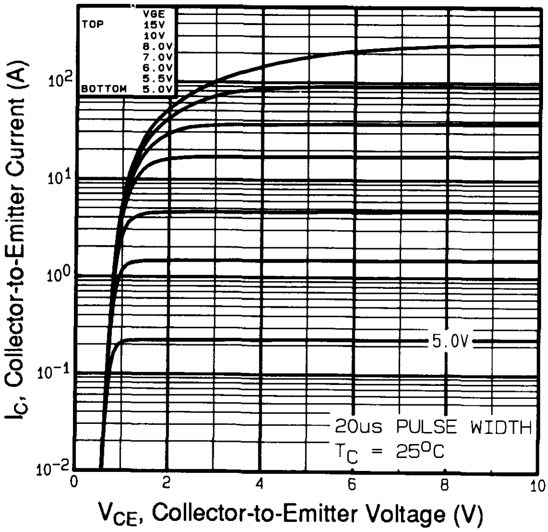


Fig 1. Typical Output Characteristics, $T_J = 25°C$

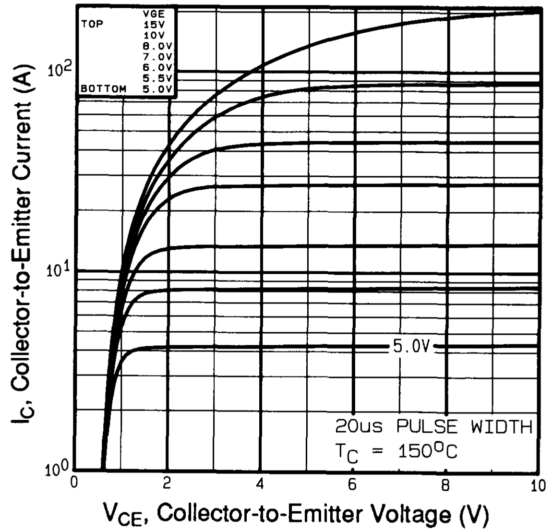


Fig 2. Typical Output Characteristics, $T_J = 150°C$

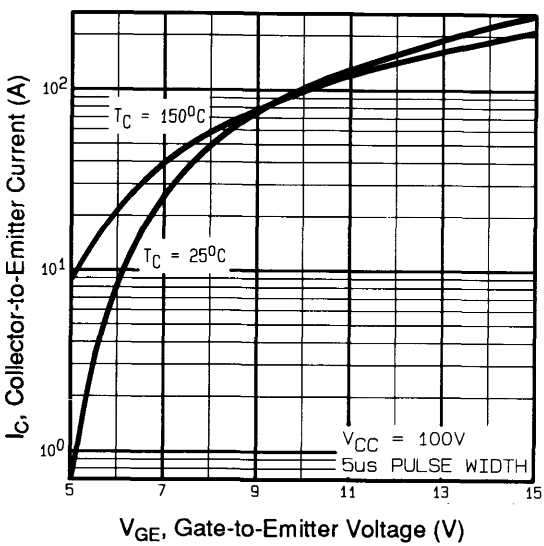


Fig 3. Typical Transfer Characteristics

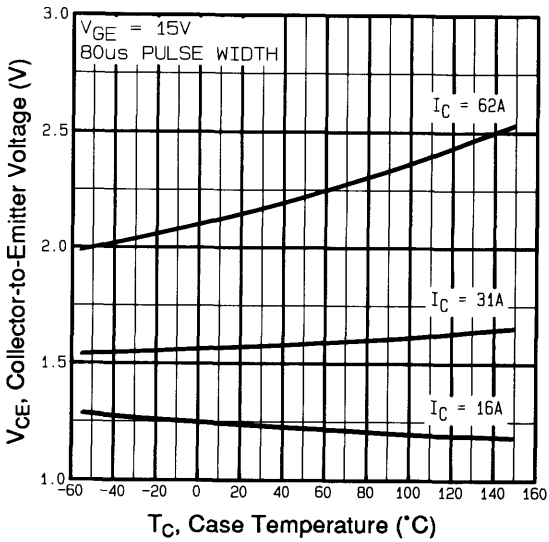


Fig 4. Collector-to-Emitter Saturation Voltage vs. Case Temperature

Graphs indicate performance of typical devices

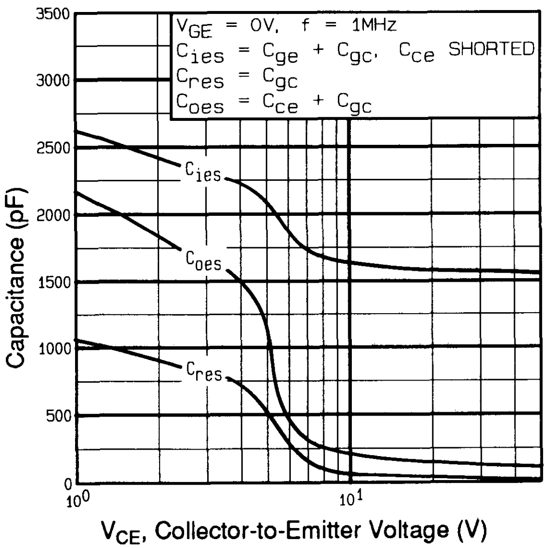


Fig 5. Typical Capacitance vs. Collector-to-Emitter Voltage

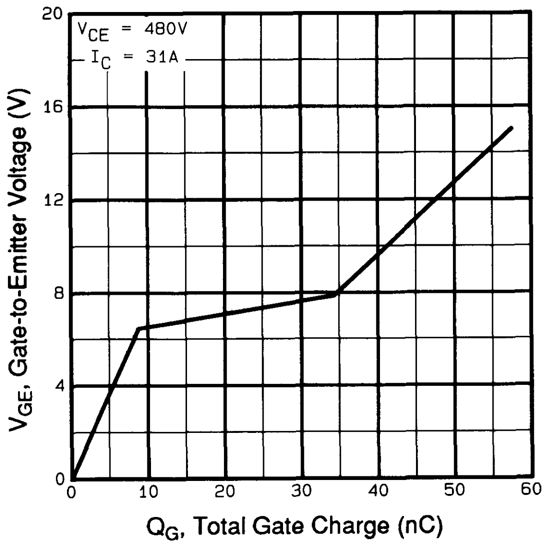


Fig 6. Typical Gate Charge vs. Gate-to-Emitter Voltage

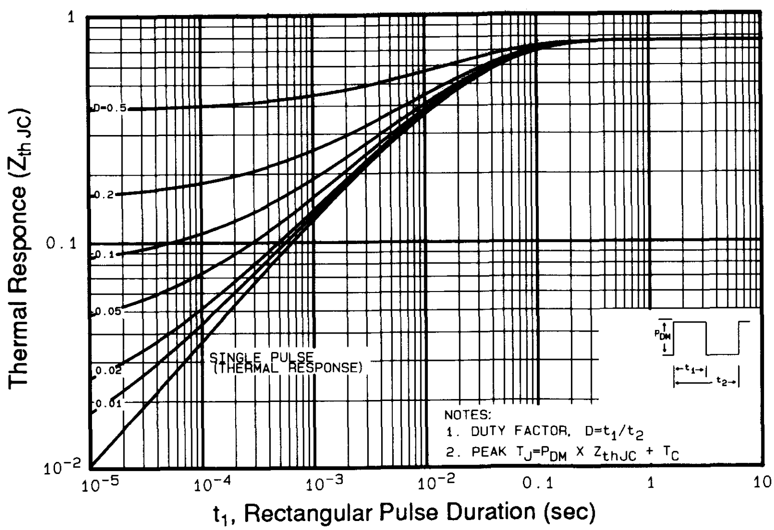


Fig 7. Maximum Effective Transient Thermal Impedance, Junction-to-Case

Graphs indicate performance of typical devices

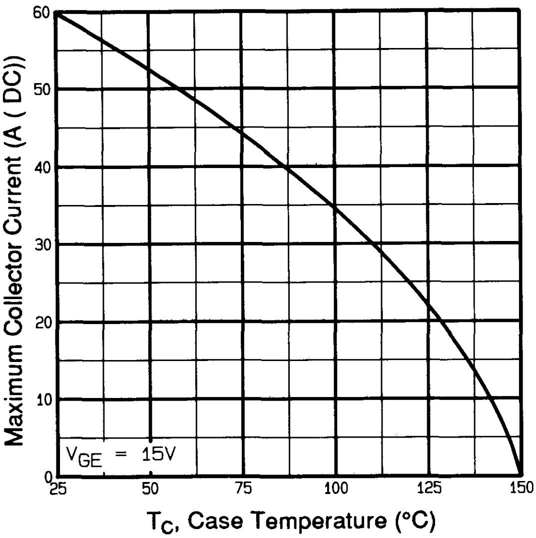


Fig 8. Maximum Collector Current vs. Case Temperature

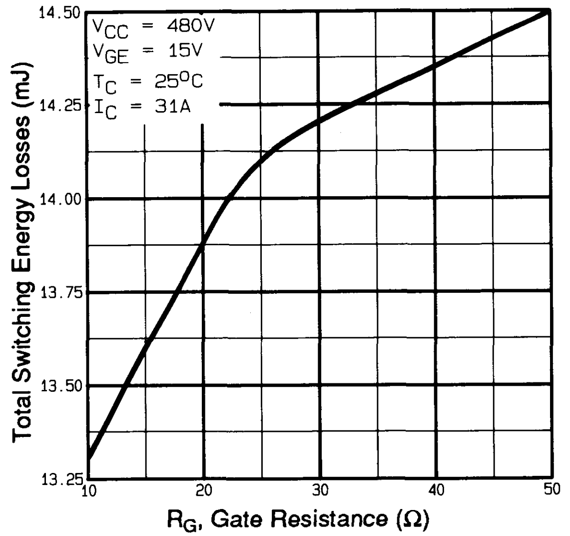


Fig 9. Typical Switching Losses vs. Gate Resistance

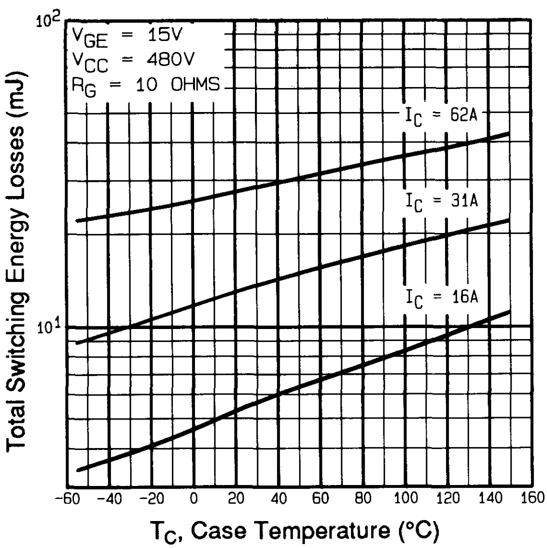


Fig 10. Typical Switching Losses vs. Case Temperature

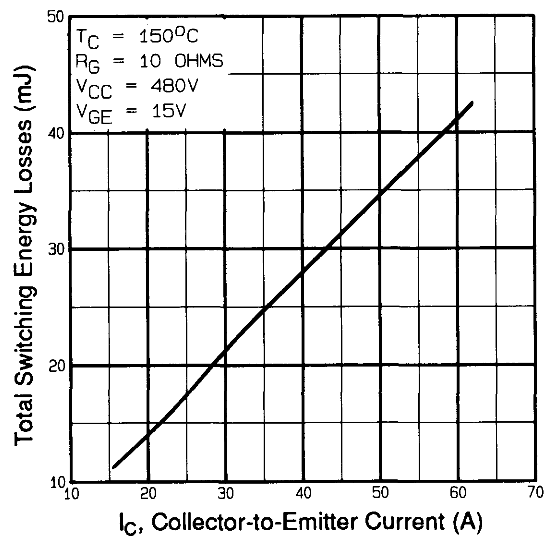


Fig 11. Typical Switching Losses vs. Collector-to-Emitter Current

Graphs indicate performance of typical devices

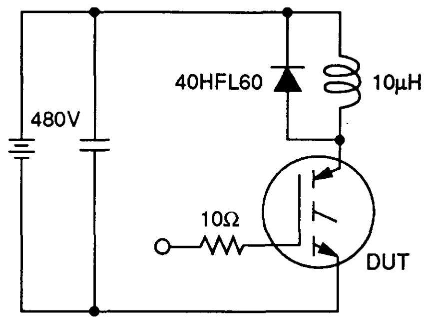


Fig 12a. Clamped Inductive Load Test Circuit

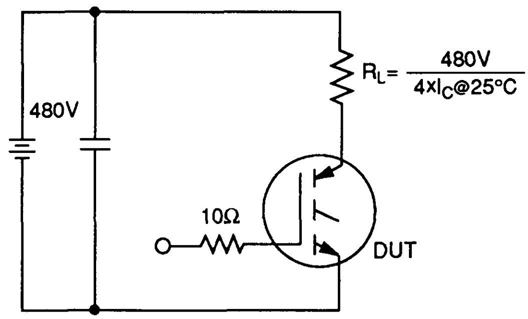


Fig 12b. Pulsed Collector Current Test Circuit

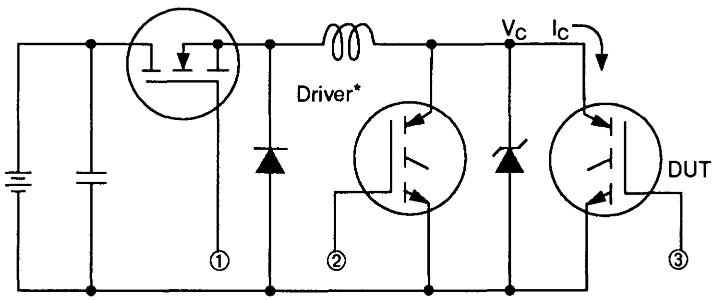


Fig 13a. Switching Loss Test Circuit

* Driver same type as DUT, V_C = 480V

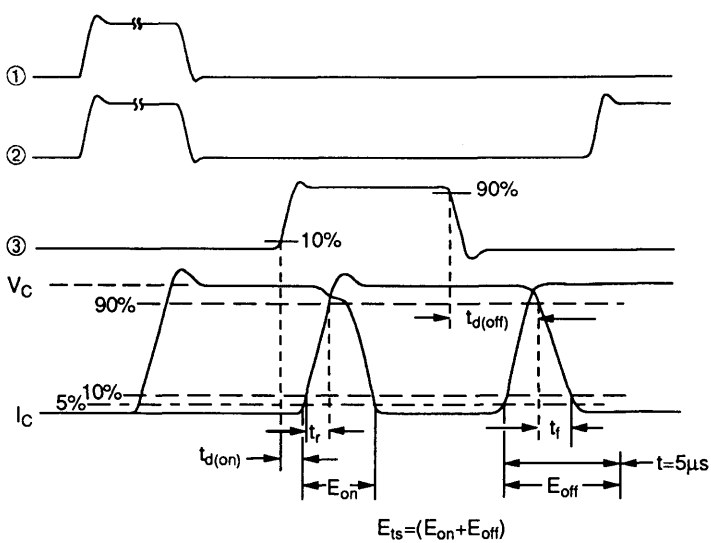


Fig 13b. Switching Loss Waveforms

International IOR Rectifier

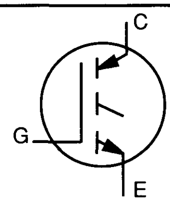
International
IOR Rectifier

IRGPC40U

INSULATED GATE BIPOLAR TRANSISTOR

UltraFast™ IGBT

- Latch-proof
- Simple gate-drive
- Ultra-fast operation > 10kHz
- Switching-Loss Rating includes all "tail" losses

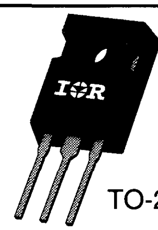


n-channel

V_{CEO} = 600 V
$I_{C(DC)}$ = 40 A
$V_{CE(sat)} \leq 3.0$ V
$E_{TS} \leq 2.0$ mJ

Description

Insulated Gate Bipolar Transistors (IGBTs) from International Rectifier have higher current densities than comparable bipolar transistors, while at the same time having simpler gate-drive requirements of the familiar power MOSFET. They provide substantial benefits to a host of higher-voltage, higher-current applications.


TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
I_C @ T_C = 25°C	Continuous Collector Current	40	A
I_C @ T_C = 100°C	Continuous Collector Current	20	
I_{CM}	Pulsed Collector Current ①	160	
V_{CE}	Collector-to-Emitter Breakdown Voltage	600	V
V_{GE}	Gate-to-Emitter Voltage	±20	
I_{LM}	Clamped Inductive Load Current ②	160	A
E_{ARV}	Reverse Voltage Avalanche Energy ③	15	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation	160	W
P_D @ T_C = 100°C	Maximum Power Dissipation	65	
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 3mm MA screw	10 in•lbs (11.5 kg•cm)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	---	---	0.77	K/W ⑥
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	---	0.24	---	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	---	---	40	

Electrical Characteristic @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
BV_{CES}	Collector-to-Emitter Breakdown Voltage	600	---	---	V	V_{GE}=0V, I_C=250μA
BV_{ECS}	Emitter-to-Collector Breakdown Volt. ④	15	---	---	V	V_{GE}=0V, I_C=1.0A
$\Delta BV_{CES}/\Delta T_J$	Temp. Coeff. of Breakdown Voltage	---	0.63	---	V/°C	V_{GE}=0V, I_C =1.0mA
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	---	---	3.0	V	V_{GE}=15V, I_C=20A See fig 4.
		---	2.7	---		V_{GE}=15V, I_C=40A
		---	2.3	---		V_{CE}=15V, I_C=20A, T_J=150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	---	5.5	V	V_{CE}=V_{GE}, I_C=250μA
$\Delta BV_{GE(th)}/\Delta T_J$	Temp. Coeff. of Threshold Voltage	---	-13	---	mV/°C	V_{CE}=V_{GE}, I_C=250μA
g_{fe}	Forward Transconductance ⑤	11	---	24	S	V_{CE}=100V, I_C=20A
I_{CES}	Zero Gate Voltage Collector Current	---	---	250	μA	V_{GE}=0V, V_{CE}=600V, T_J=25°C
		---	---	2500		V_{GE}=0V, V_{CE}=600V, T_J=150°C
I_{GES}	Gate-to-Emitter Leakage Current	---	---	±500	nA	V_{GE}=±20V

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

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
Q_G	Total Gate Charge (turn-on)	35	---	67	nC	I_C=20A, V_{CC}=480V See Figure 6.
Q_{GE}	Gate - Emitter Charge (turn-on)	6.5	---	11		
Q_{GC}	Gate - Collector Charge (turn-on)	5.9	---	33		
$t_{d(on)}$	Turn-On Delay Time	---	25	---	ns	See test circuit, figure 13.
t_r	Rise Time	---	21	---		I_C=20A, V_{CC}=480V
$t_{d(off)}$	Turn-off Delay Time	---	---	190		T_J=25°C
t_f	Fall Time	---	---	120		V_{GE}=15V, R_G=10Ω
E_{on}	Turn-On Switching Loss	---	0.18	---	mJ	Energy losses include "tail".
E_{off}	Turn-Off Switching Loss	---	1.3	---		Also see figures 9, 10, & 11.
E_{ts}	Total Switching Loss	---	1.5	2.0		
$t_{d(on)}$	Turn-On Delay Time	---	25	---	ns	I_C=20A, V_{CC}=480V
t_r	Rise Time	---	23	---		T_J=150°C
$t_{d(off)}$	Turn-Off Delay Time	---	174	---		V_{GE}=15V
t_f	Fall Time	---	140	---		R_G=10Ω
E_{ts}	Total Switching Loss	---	2.4	---	mJ	
L_E	Internal Emitter Inductance	---	13	---	nH	Measured 5mm from package.
C_{ies}	Input Capacitance	---	1500	---	pF	V_{GE}=0V
C_{oes}	Output Capacitance	---	190	---		V_{CC}=30V See fig 5.
C_{res}	Reverse Transfer Capacitance	---	17	---		f = 1.0MHz

Notes:

① Repetitive rating; V_{GE}=20V, pulse width limited by max. junction temperature (See figure 12b).

② V_{CC}=80%(BV_{CES}), V_{GE}=20V, L=10μH, R_G=10Ω, (See figure 12a).

③ Repetitive rating; pulse width limited by maximum junction temperature.

④ Pulse width ≤ 80μs; duty factor ≤0.1%.

⑤ Pulse width ≤ 5μs, single shot.

⑥ K/W equivalent to °C/W.

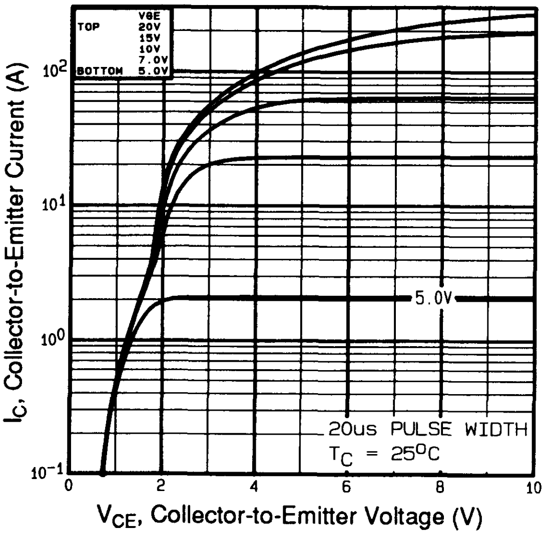


Fig 1. Typical Output Characteristics, $T_J = 25°C$

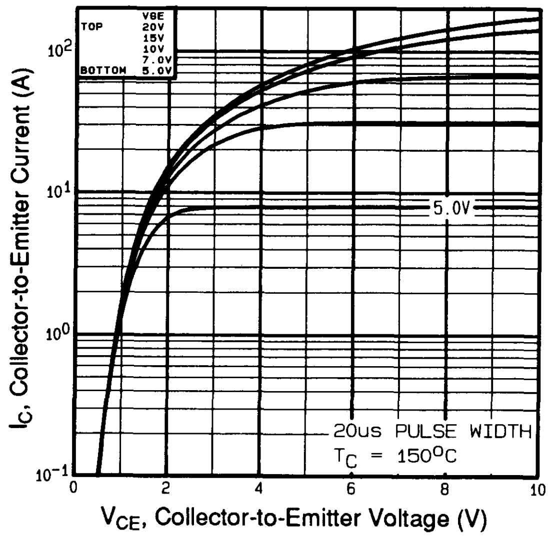


Fig 2. Typical Output Characteristics, $T_J = 150°C$

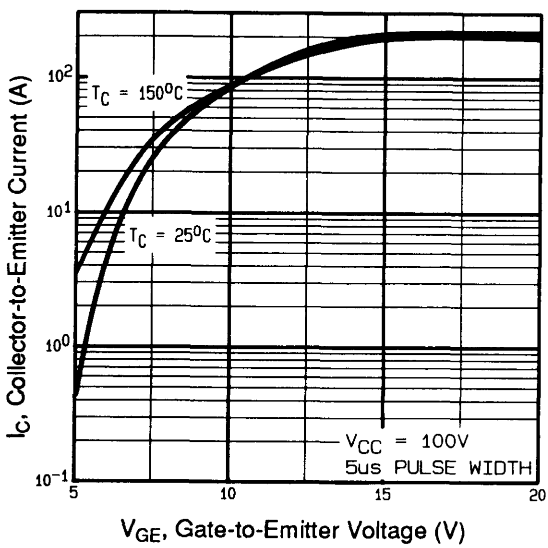


Fig 3. Typical Transfer Characteristics

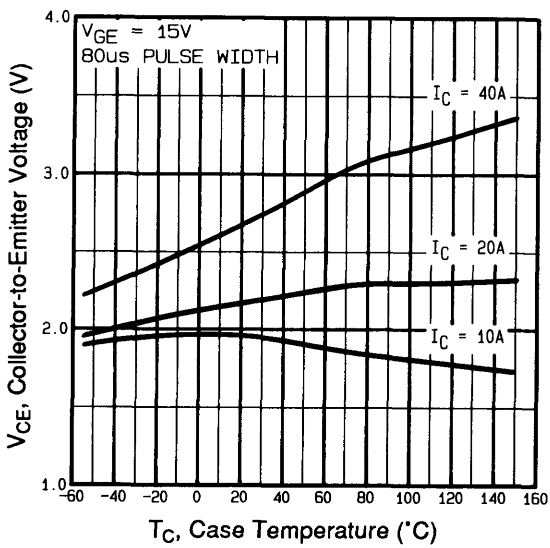


Fig 4. Collector-to-Emitter Saturation Voltage vs. Case Temperature

Graphs indicate performance of typical devices

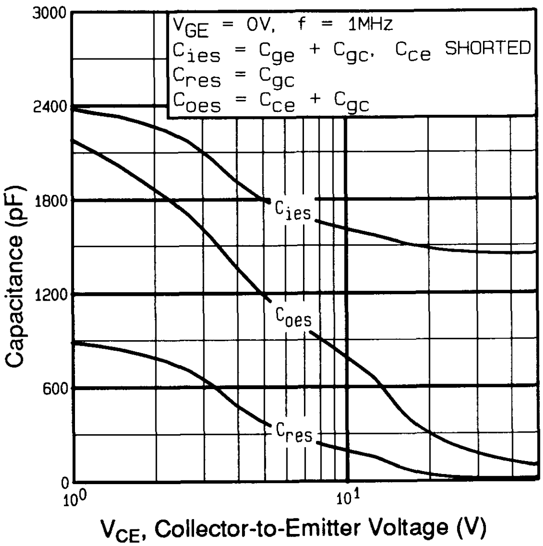


Fig 5. Typical Capacitance vs. Collector-to-Emitter Voltage

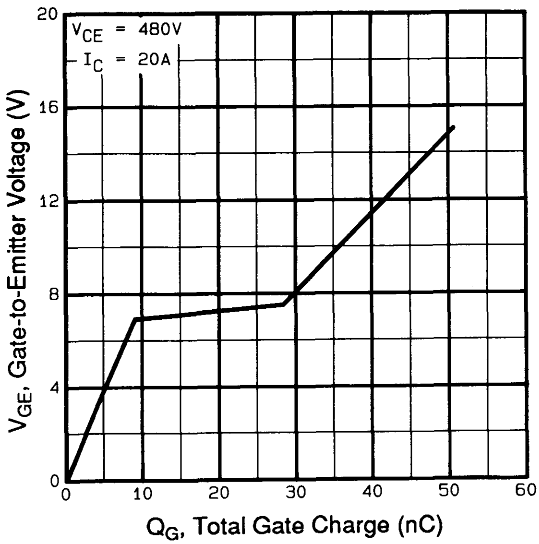


Fig 6. Typical Gate Charge vs. Gate-to-Emitter Voltage

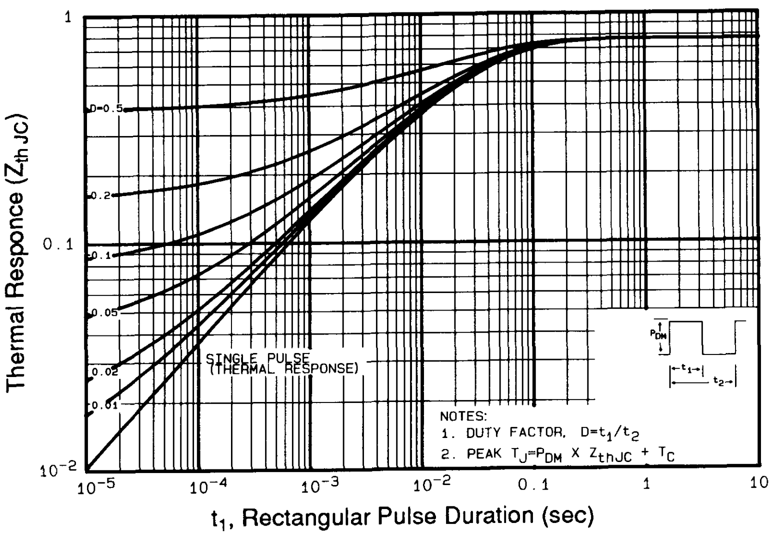


Fig 7. Maximum Effective Transient Thermal Impedance, Junction-to-Case

Graphs indicate performance of typical devices

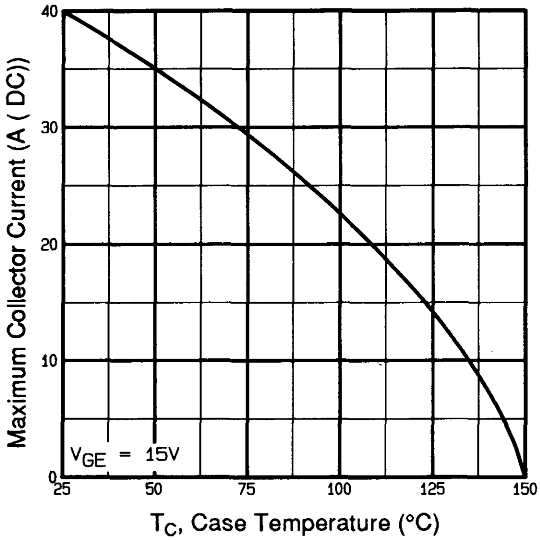


Fig 8. Maximum Collector Current vs. Case Temperature

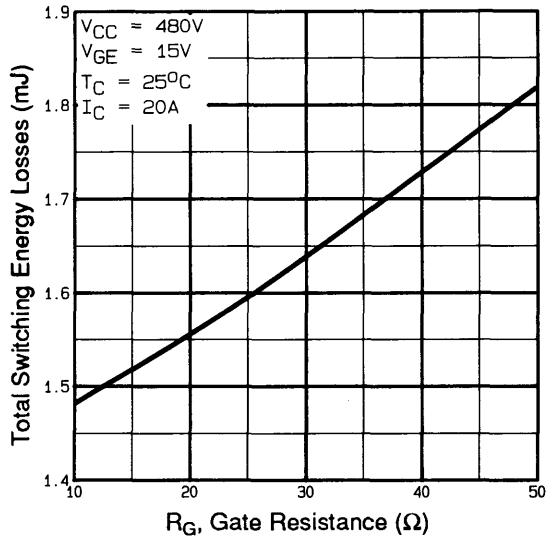


Fig 9. Typical Switching Losses vs. Gate Resistance

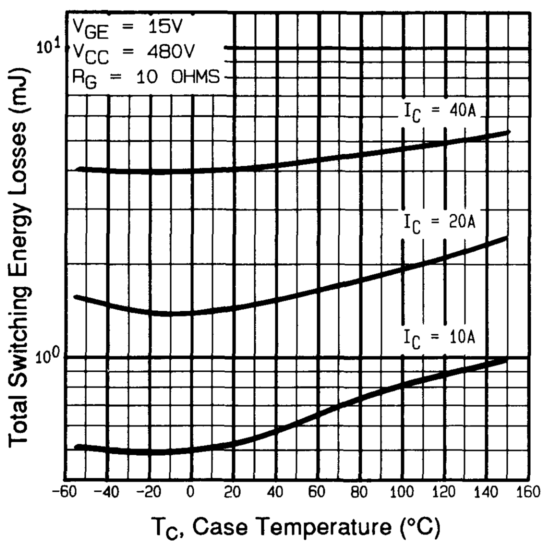


Fig 10. Typical Switching Losses vs. Case Temperature

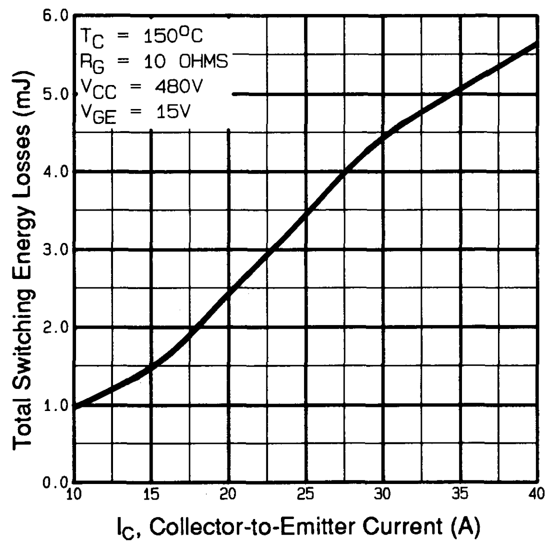


Fig 11. Typical Switching Losses vs. Collector-to-Emitter Current

Graphs indicate performance of typical devices

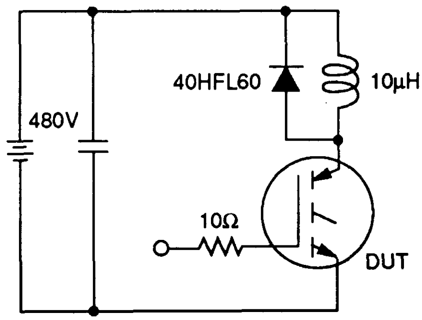


Fig 12a. Clamped Inductive Load Test Circuit

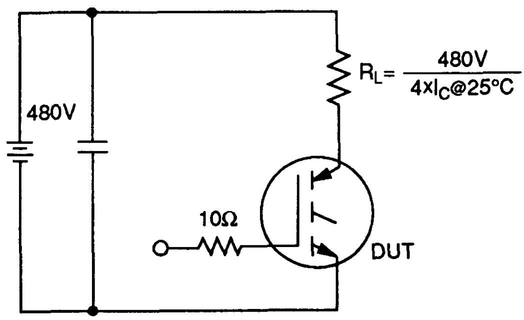


Fig 12b. Pulsed Collector Current Test Circuit

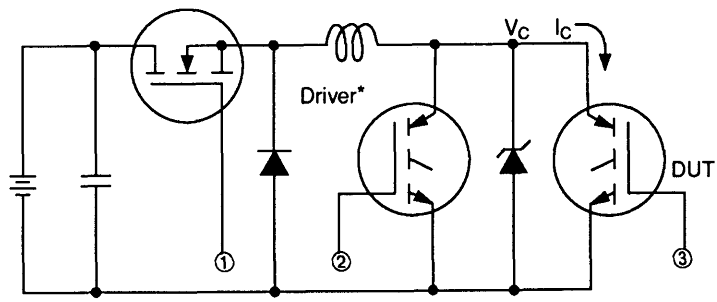


Fig 13a. Switching Loss Test Circuit

* Driver same type as DUT, V_C = 480V

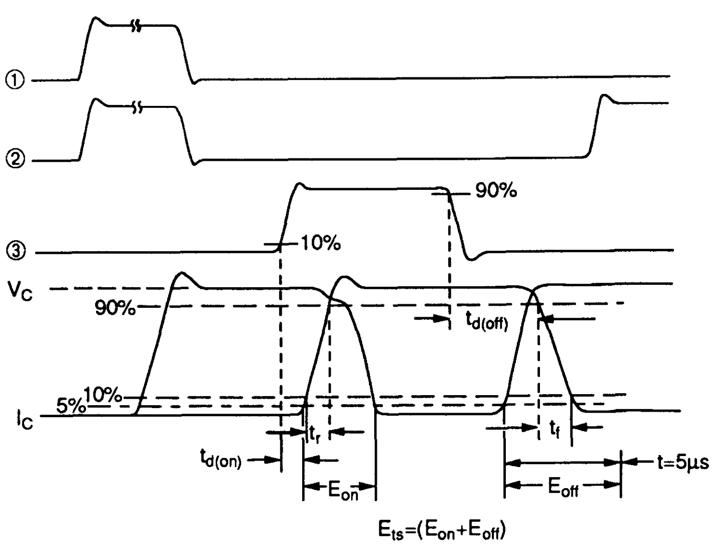


Fig 13b. Switching Loss Waveforms

International IOR Rectifier

PD-9.695

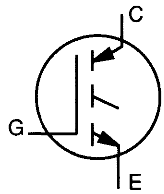
International
IOR Rectifier

IRGPC50F

INSULATED GATE BIPOLAR TRANSISTOR

Fast-Speed IGBT

- Latch-proof
- Simple gate-drive
- Fast operation 3kHz~8kHz
- Switching-Loss Rating includes all "tail" losses

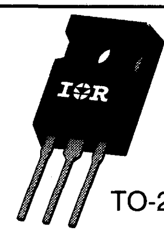


n-channel

V_{CEO} = 600 V
$I_{C(DC)}$ = 70 A
$V_{CE(sat)} \leq 1.7V$
$E_{TS} \leq$ 10 mJ

Description

Insulated Gate Bipolar Transistors (IGBTs) from International Rectifier have higher current densities than comparable bipolar transistors, while at the same time having simpler gate-drive requirements of the familiar power MOSFET. They provide substantial benefits to a host of higher-voltage, higher-current applications.


TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
I_C @ T_C = 25°C	Continuous Collector Current	70	A
I_C @ T_C = 100°C	Continuous Collector Current	39	
I_{CM}	Pulsed Collector Current ①	280	
V_{CE}	Collector-to-Emitter Breakdown Voltage	600	V
V_{GE}	Gate-to-Emitter Voltage	±20	
I_{LM}	Clamped Inductive Load Current ②	280	A
E_{ARV}	Reverse Voltage Avalanche Energy ③	20	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation	200	W
P_D @ T_C = 100°C	Maximum Power Dissipation	78	
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 3mm MA screw	10 in•lbs (11.5 kg•cm)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	---	---	0.64	K/W ⑥
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	---	0.24	---	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	---	---	40	

Electrical Characteristic @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
BV_{CES}	Collector-to-Emitter Breakdown Voltage	600	---	---	V	V_{GE}=0V, I_C=250μA
BV_{ECS}	Emitter-to-Collector Breakdown Volt. ④	25	---	---	V	V_{GE}=0V, I_C=1.0A
$\Delta BV_{CES}/\Delta T_J$	Temp. Coeff. of Breakdown Voltage	---	0.62	---	V/°C	V_{GE}=0V, I_C =1.0mA
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	---	---	1.7	V	V_{GE}=15V, I_C=39A See fig 4.
		---	2.0	---		V_{GE}=15V, I_C=70A
		---	1.7	---		V_{CE}=15V, I_C=39A, T_J=150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	---	5.5		V_{CE}=V_{GE}, I_C=250μA
$\Delta BV_{GE(th)}/\Delta T_J$	Temp. Coeff. of Threshold Voltage	---	-14	---	mV/°C	V_{CE}=V_{GE}, I_C=250μA
g_{fe}	Forward Transconductance ⑤	21	---	39	S	V_{CE}=100V, I_C=39A
I_{CES}	Zero Gate Voltage Collector Current	---	---	250	μA	V_{GE}=0V, V_{CE}=600V, T_J=25°C
		---	---	2000		V_{GE}=0V, V_{CE}=600V, T_J=150°C
I_{GES}	Gate-to-Emitter Leakage Current	---	---	±500	nA	V_{GE}=±20V

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

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
Q_G	Total Gate Charge (turn-on)	67	---	100	nC	I_C=39A, V_{CC}=480V See Figure 6.
Q_{GE}	Gate - Emitter Charge (turn-on)	14	---	25		
Q_{GC}	Gate - Collector Charge (turn-on)	35	---	67		
$t_{d(on)}$	Turn-On Delay Time	---	24	---	ns	See test circuit, figure 13.
t_r	Rise Time	---	50	---		I_C=39A, V_{CC}=480V
$t_{d(off)}$	Turn-off Delay Time	---	---	540		T_J=25°C
t_f	Fall Time	---	---	360		V_{GE}=15V, R_G=2.0Ω
E_{on}	Turn-On Switching Loss	---	0.20	---	mJ	Energy losses include "tail".
E_{off}	Turn-Off Switching Loss	---	5.8	---		Also see figures 9, 10, & 11.
E_{ts}	Total Switching Loss	---	6.0	10		
$t_{d(on)}$	Turn-On Delay Time	---	25	---	ns	I_C=39A, V_{CC}=480V
t_r	Rise Time	---	49	---		T_J=150°C
$t_{d(off)}$	Turn-Off Delay Time	---	440	---		V_{GE}=15V
t_f	Fall Time	---	410	---		R_G=2.0Ω
E_{ts}	Total Switching Loss	---	10	---	mJ	
L_E	Internal Emitter Inductance	---	13	---	nH	Measured 5mm from package.
C_{ies}	Input Capacitance	---	3000	---	pF	V_{GE}=0V
C_{oes}	Output Capacitance	---	340	---		V_{CC}=30V See fig 5.
C_{res}	Reverse Transfer Capacitance	---	40	---		f = 1.0MHz

Notes:

① Repetitive rating; V_{GE}=20V, pulse width limited by max. junction temperature (See figure 12b).

② V_{CC}=80%(BV_{CES}), V_{GE}=20V, L=10μH, R_G=10Ω, (See figure 12a).

③ Repetitive rating; pulse width limited by maximum junction temperature.

④ Pulse width ≤ 80μs; duty factor ≤0.1%.

⑤ Pulse width ≤ 5μs, single shot.

⑥ K/W equivalent to °C/W.

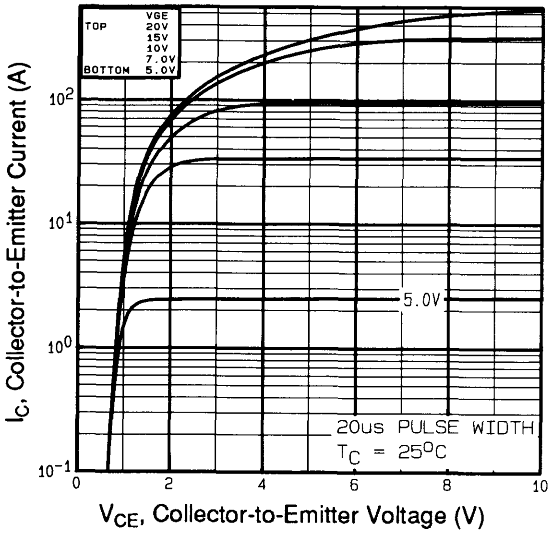


Fig 1. Typical Output Characteristics, $T_J = 25°C$

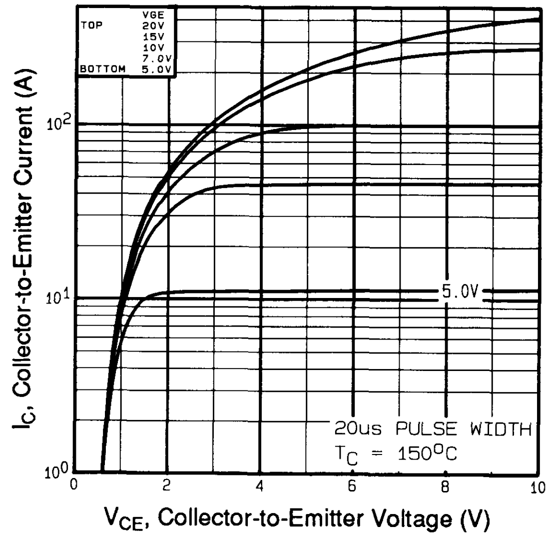


Fig 2. Typical Output Characteristics, $T_J = 150°C$

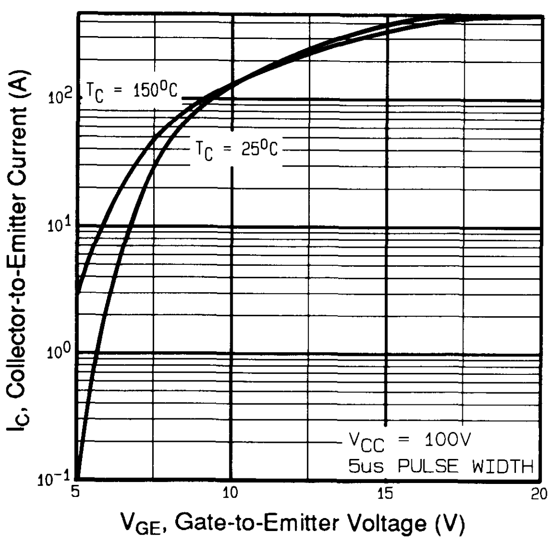


Fig 3. Typical Transfer Characteristics

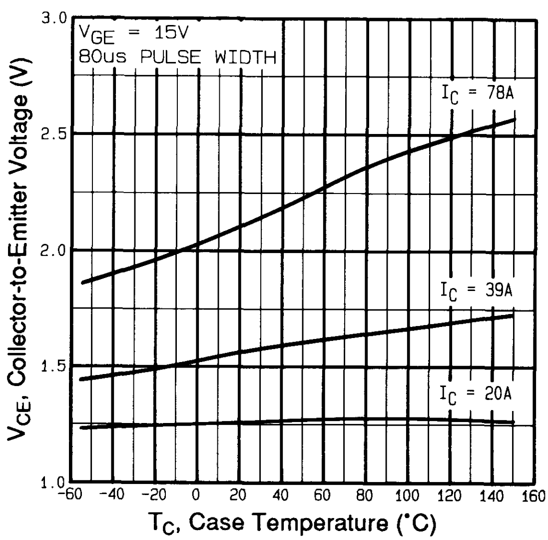


Fig 4. Collector-to-Emitter Saturation Voltage vs. Case Temperature

Graphs indicate performance of typical devices

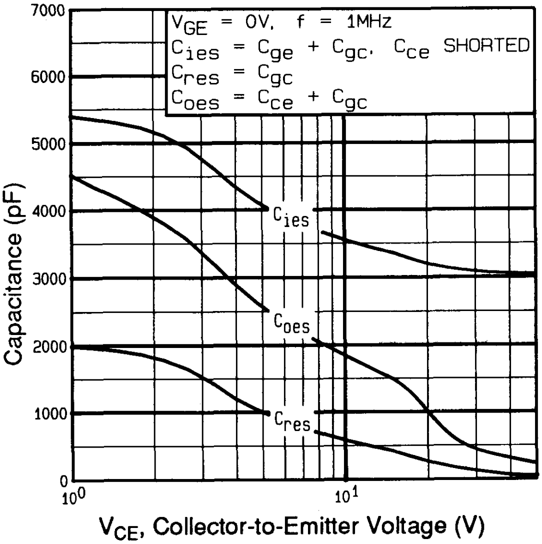


Fig 5. Typical Capacitance vs. Collector-to-Emitter Voltage

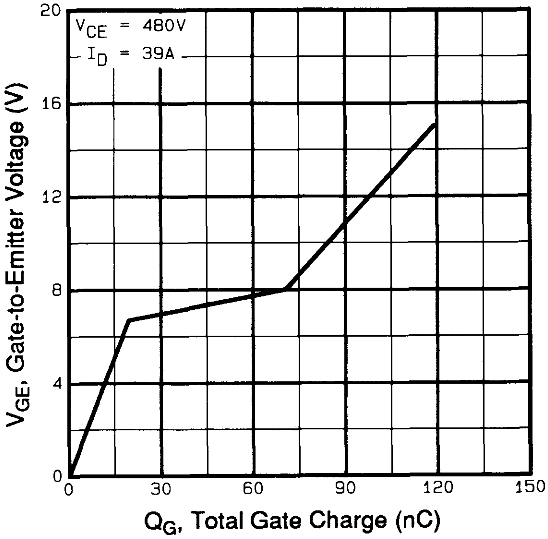


Fig 6. Typical Gate Charge vs. Gate-to-Emitter Voltage

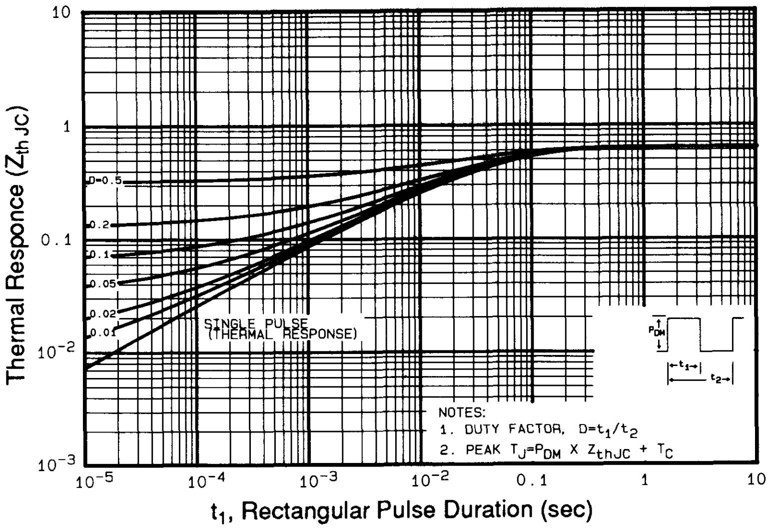


Fig 7. Maximum Effective Transient Thermal Impedance, Junction-to-Case

Graphs indicate performance of typical devices

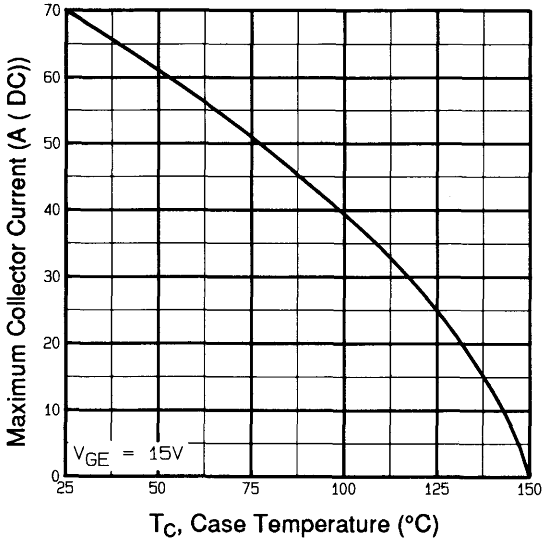


Fig 8. Maximum Collector Current vs. Case Temperature

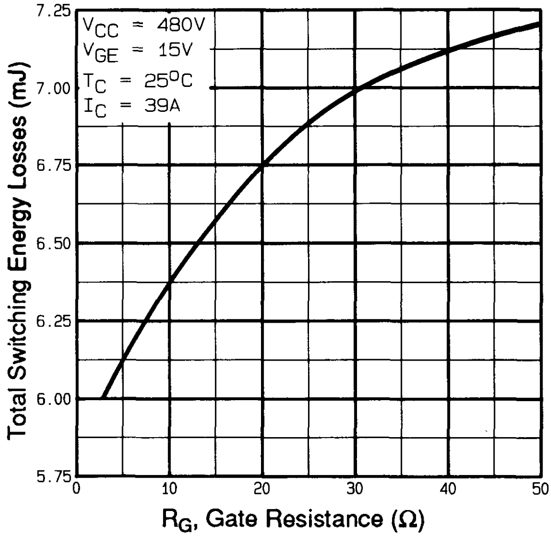


Fig 9. Typical Switching Losses vs. Gate Resistance

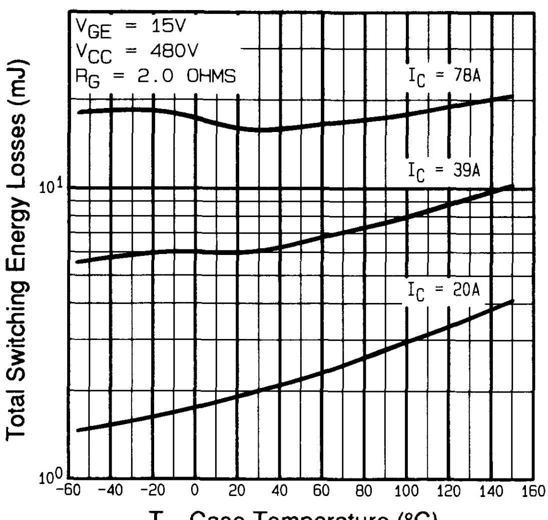


Fig 10. Typical Switching Losses vs. Case Temperature

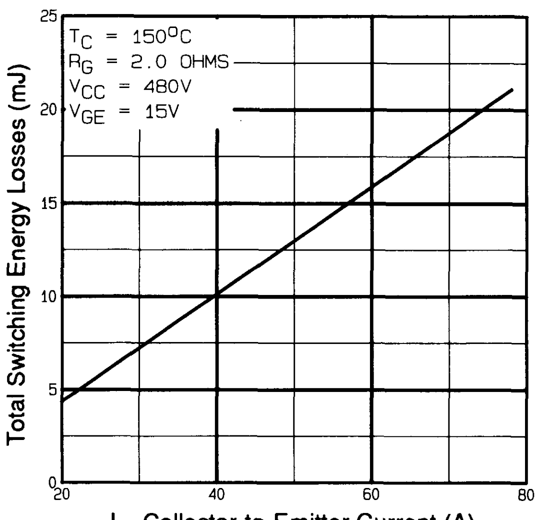


Fig 11. Typical Switching Losses vs. Collector-to-Emitter Current

Graphs indicate performance of typical devices

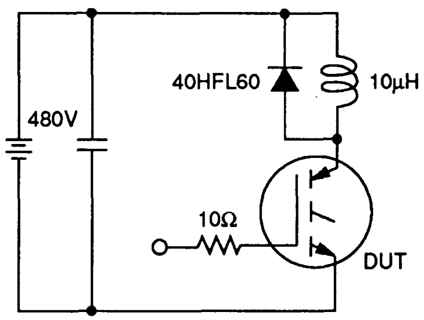


Fig 12a. Clamped Inductive Load Test Circuit

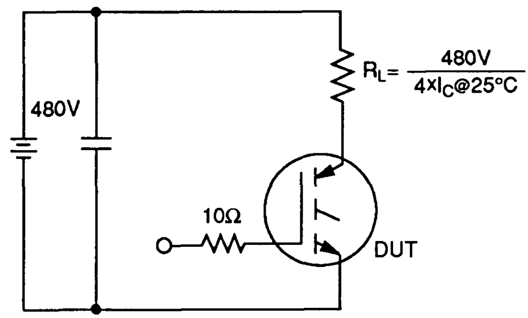


Fig 12b. Pulsed Collector Current Test Circuit

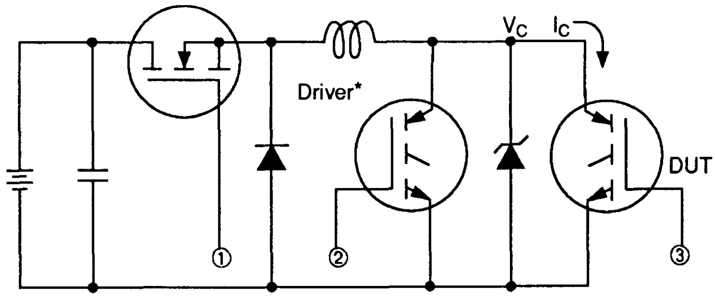


Fig 13a. Switching Loss Test Circuit

* Driver same type as DUT, $V_C = 480V$

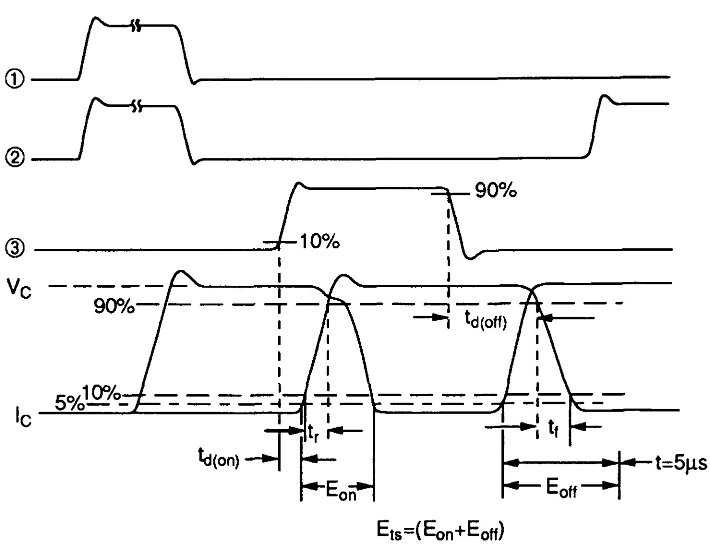


Fig 13b. Switching Loss Waveforms

International Rectifier

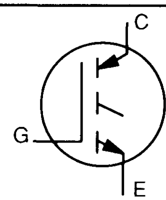
International Rectifier

IRGPC50S

INSULATED GATE BIPOLAR TRANSISTOR

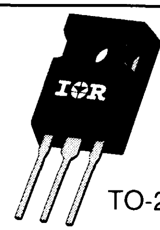
Standard-Speed IGBT

- Latch-proof
- Simple gate-drive
- Standard Operation < 1kHz
- Switching-Loss Rating includes all "tail" losses



n-channel

V_{CEO} = 600 V
$I_{C(DC)}$ = 70 A
$V_{CE(sat)} \leq$ 1.6 V
$E_{TS} \leq$ 22 mJ


TO-247AC

Description

Insulated Gate Bipolar Transistors (IGBTs) from International Rectifier have higher current densities than comparable bipolar transistors, while at the same time having simpler gate-drive requirements of the familiar power MOSFET. They provide substantial benefits to a host of higher-voltage, higher-current applications.

Absolute Maximum Ratings

	Parameter	Max.	Units
I_C @ T_C = 25°C	Continuous Collector Current	70	A
I_C @ T_C = 100°C	Continuous Collector Current	41	
I_{CM}	Pulsed Collector Current ①	320	
V_{CE}	Collector-to-Emitter Breakdown Voltage	600	V
V_{GE}	Gate-to-Emitter Voltage	±20	
I_{LM}	Clamped Inductive Load Current ②	320	A
E_{ARV}	Reverse Voltage Avalanche Energy ③	20	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation	200	W
P_D @ T_C = 100°C	Maximum Power Dissipation	78	
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 3mm MA screw	10 in•lbs (11.5 kg•cm)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	---	---	0.64	K/W ⑥
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	---	0.24	---	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	---	---	40	

Electrical Characteristic @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
BV_{CES}	Collector-to-Emitter Breakdown Voltage	600	---	---	V	V_{GE}=0V, I_C=250µA
BV_{ECS}	Emitter-to-Collector Breakdown Volt. ④	15	---	---	V	V_{GE}=0V, I_C=1.0A
$\Delta BV_{CES}/\Delta T_J$	Temp. Coeff. of Breakdown Voltage	---	0.75	---	V/°C	V_{GE}=0V, I_C =1.0mA
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	---	---	1.6	V	V_{GE}=15V, I_C=41A See fig 4.
		---	1.9	---		V_{GE}=15V, I_C=80A
		---	1.5	---		V_{CE}=15V, I_C=41A, T_J=150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	---	5.5	V	V_{CE}=V_{GE}, I_C=250µA
$\Delta BV_{GE(th)}/\Delta T_J$	Temp. Coeff. of Threshold Voltage	---	-9.3	---	mV/°C	V_{CE}=V_{GE}, I_C=250µA
g_{fe}	Forward Transconductance ⑤	17	---	50	S	V_{CE}=100V, I_C=41A
I_{CES}	Zero Gate Voltage Collector Current	---	---	250	µA	V_{GE}=0V, V_{CE}=600V, T_J=25°C
		---	---	1000		V_{GE}=0V, V_{CE}=600V, T_J=150°C
I_{GES}	Gate-to-Emitter Leakage Current	---	---	±500	nA	V_{GE}=±20V

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

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
Q_G	Total Gate Charge (turn-on)	84	---	150	nC	I_C=41A, V_{CC}=480V
Q_{GE}	Gate - Emitter Charge (turn-on)	8.0	---	23		See Figure 6.
Q_{GC}	Gate - Collector Charge (turn-on)	20	---	90		
$t_{d(on)}$	Turn-On Delay Time	---	25	---	ns	See test circuit, figure 13.
t_r	Rise Time	---	59	---		I_C=41A, V_{CC}=480V
$t_{d(off)}$	Turn-off Delay Time	---	---	1400		T_J=25°C
t_f	Fall Time	---	---	700		V_{GE}=15V, R_G=2.0Ω
E_{on}	Turn-On Switching Loss	---	0.35	---	mJ	Energy losses include "tail".
E_{off}	Turn-Off Switching Loss	---	15	---		Also see figures 9, 10, & 11.
E_{ts}	Total Switching Loss	---	16	22		
$t_{d(on)}$	Turn-On Delay Time	---	26	---	ns	I_C=41A, V_{CC}=480V
t_r	Rise Time	---	58	---		T_J=150°C
$t_{d(off)}$	Turn-Off Delay Time	---	2000	---		V_{GE}=15V
t_f	Fall Time	---	1100	---		R_G=2.0Ω
E_{ts}	Total Switching Loss	---	28	---	mJ	
L_E	Internal Emitter Inductance	---	13	---	nH	Measured 5mm from package.
C_{ies}	Input Capacitance	---	3100	---	pF	V_{GE}=0V
C_{oes}	Output Capacitance	---	240	---		V_{CC}=30V See fig 5.
C_{res}	Reverse Transfer Capacitance	---	37	---		f = 1.0MHz

Notes:

① Repetitive rating; V_{GE}=20V, pulse width limited by max. junction temperature (See figure 12b).

② V_{CC}=80%(BV_{CES}), V_{GE}=20V, L=10µH, R_G=10Ω, (See figure 12a).

③ Repetitive rating; pulse width limited by maximum junction temperature.

④ Pulse width ≤ 80µs; duty factor ≤0.1%.

⑤ Pulse width ≤ 5µs, single shot.

⑥ K/W equivalent to °C/W.

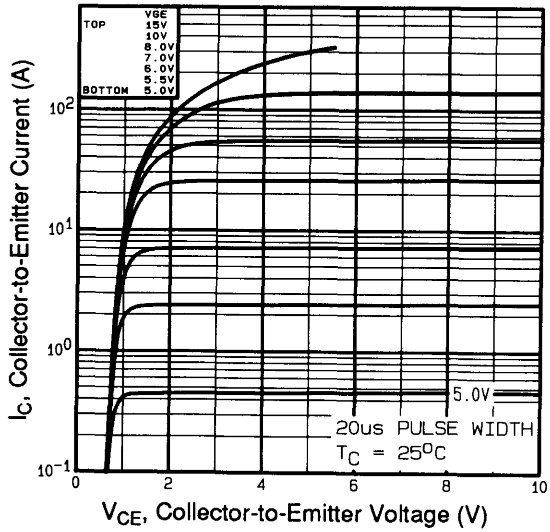


Fig 1. Typical Output Characteristics, $T_J = 25°C$

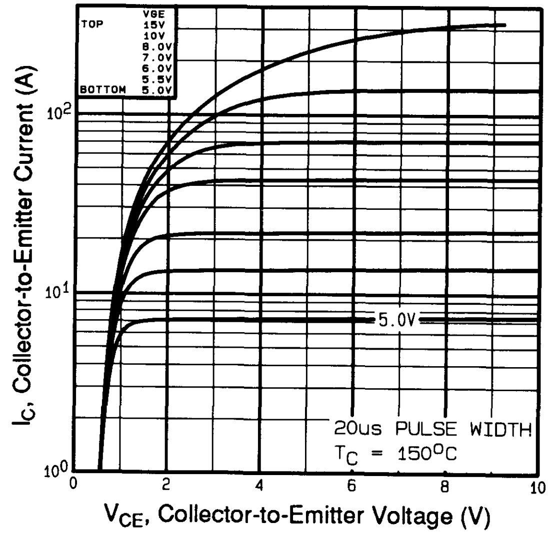


Fig 2. Typical Output Characteristics, $T_J = 150°C$

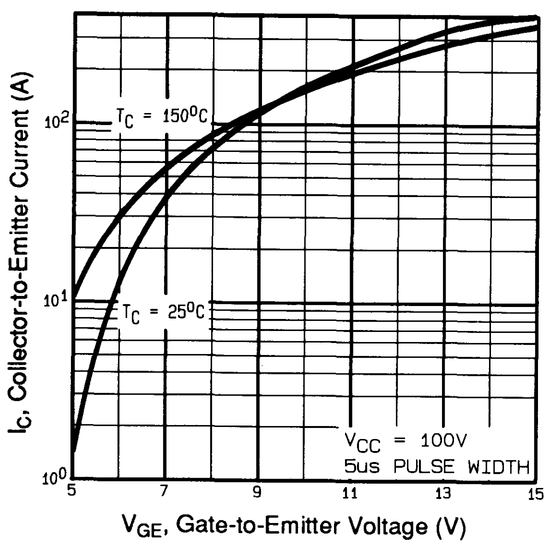


Fig 3. Typical Transfer Characteristics

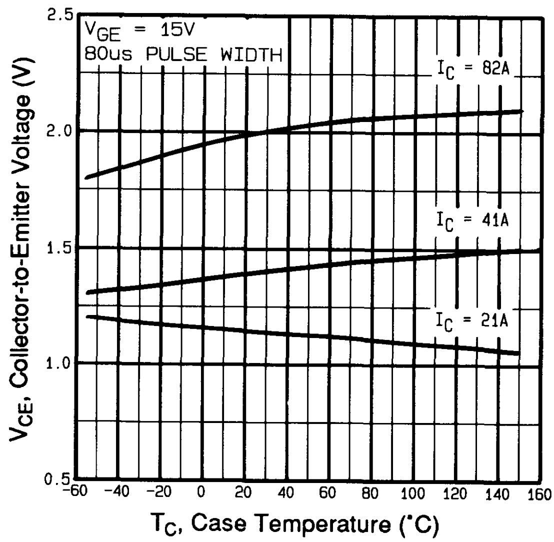


Fig 4. Collector-to-Emitter Saturation Voltage vs. Case Temperature

Graphs indicate performance of typical devices

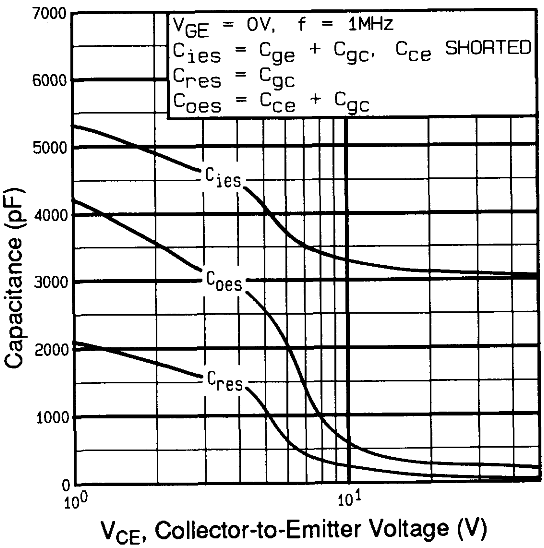


Fig 5. Typical Capacitance vs. Collector-to-Emitter Voltage

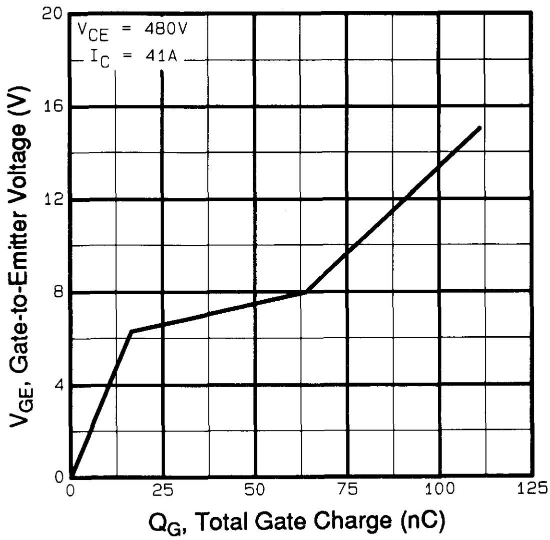


Fig 6. Typical Gate Charge vs. Gate-to-Emitter Voltage

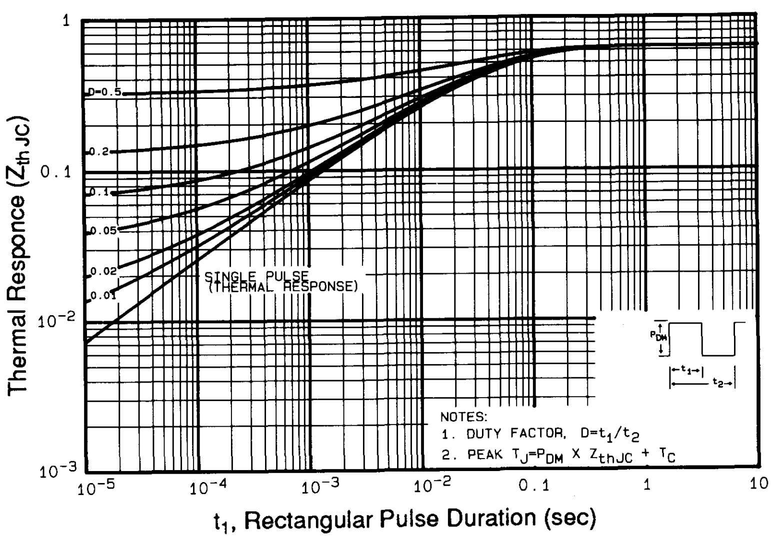


Fig 7. Maximum Effective Transient Thermal Impedance, Junction-to-Case

Graphs indicate performance of typical devices

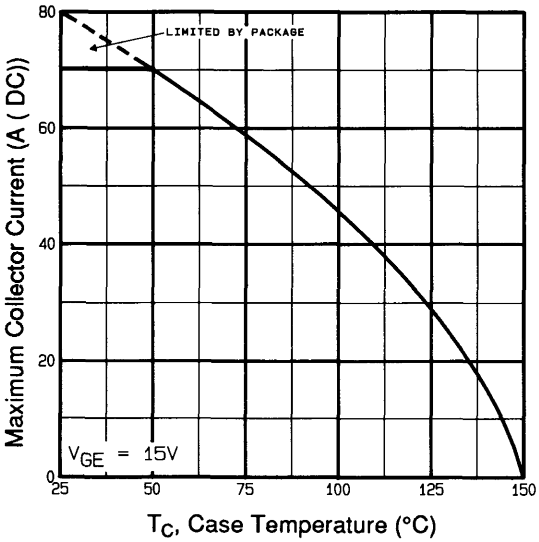


Fig 8. Maximum Collector Current vs. Case Temperature

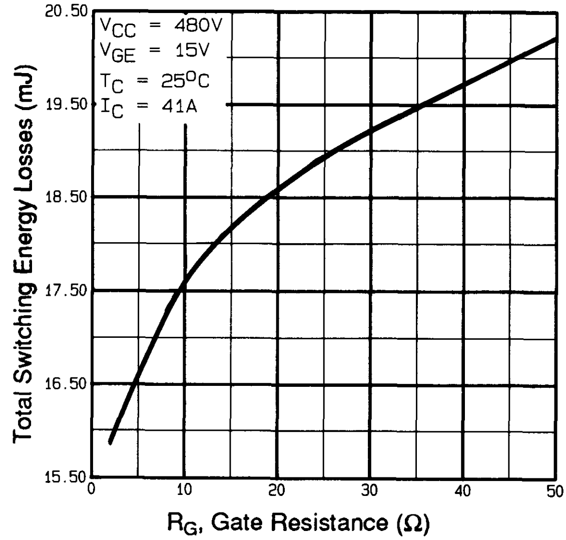


Fig 9. Typical Switching Losses vs. Gate Resistance

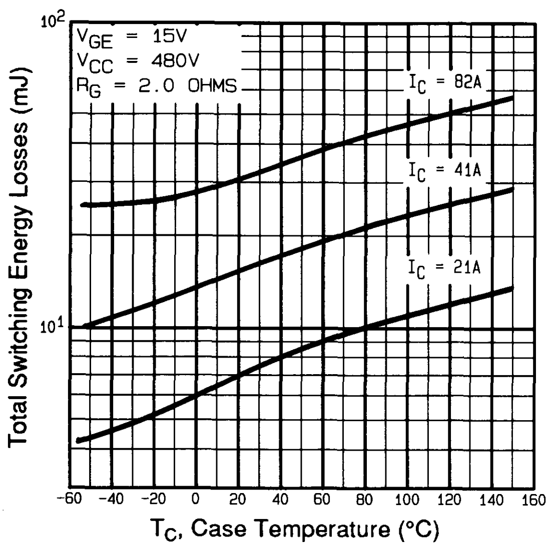


Fig 10. Typical Switching Losses vs. Case Temperature

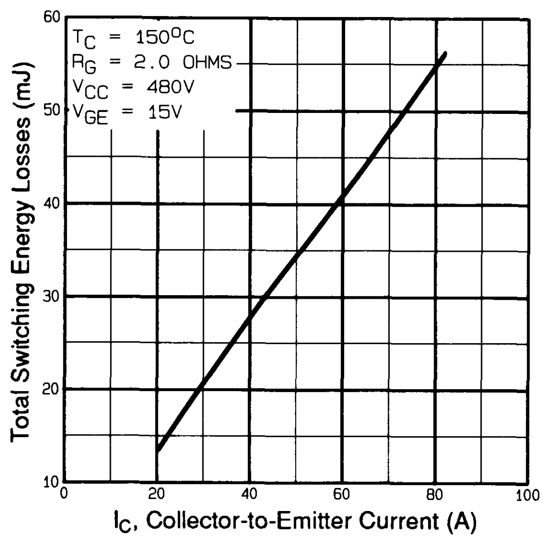


Fig 11. Typical Switching Losses vs. Collector-to-Emitter Current

Graphs indicate performance of typical devices

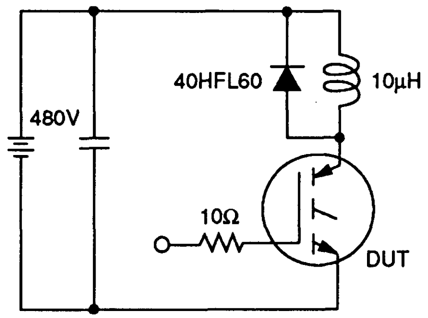


Fig 12a. Clamped Inductive Load Test Circuit

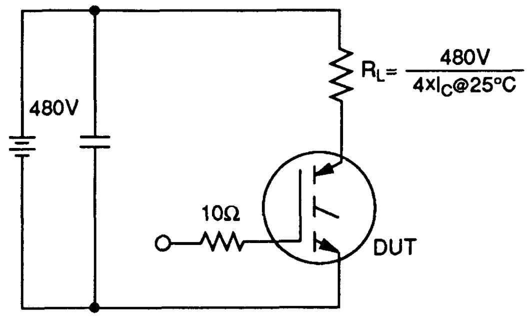


Fig 12b. Pulsed Collector Current Test Circuit

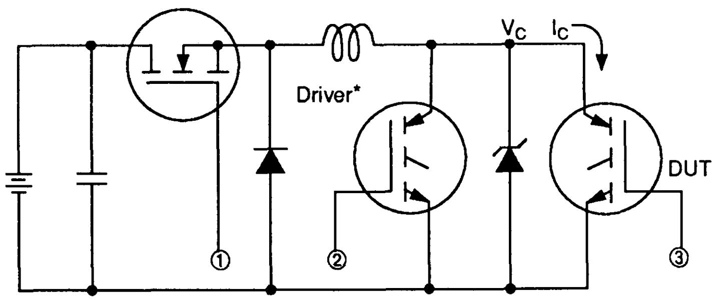


Fig 13a. Switching Loss Test Circuit

* Driver same type as DUT, V_C = 480V

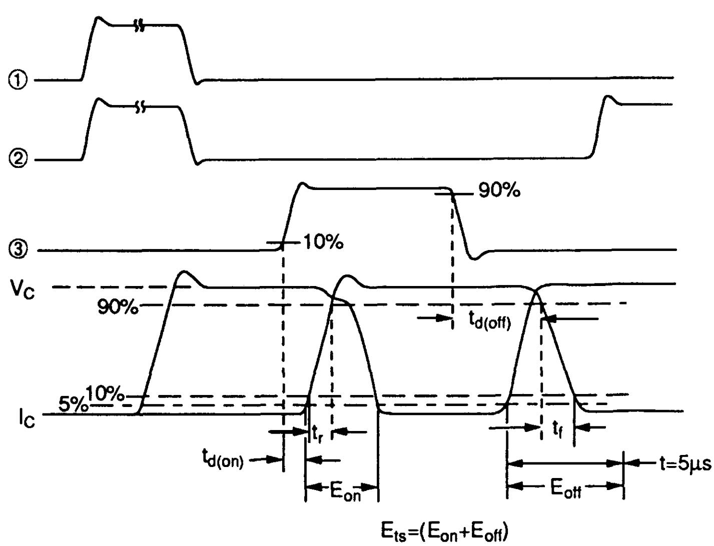


Fig 13b. Switching Loss Waveforms

International Rectifier

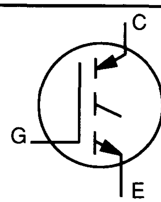
International
IOR Rectifier

IRGPC50U

INSULATED GATE BIPOLAR TRANSISTOR

UltraFast™ IGBT

- Latch-proof
- Simple gate-drive
- Ultra-fast operation > 10kHz
- Switching-Loss Rating includes all "tail" losses

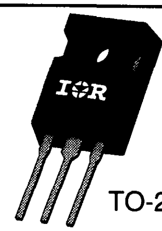


n-channel

V_{CEO} = 600 V
$I_{C(DC)}$ = 55 A
$V_{CE(sat)} \leq 3.0$ V
$E_{TS} \leq 2.8$ mJ

Description

Insulated Gate Bipolar Transistors (IGBTs) from International Rectifier have higher current densities than comparable bipolar transistors, while at the same time having simpler gate-drive requirements of the familiar power MOSFET. They provide substantial benefits to a host of higher-voltage, higher-current applications.


TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
I_C @ T_C = 25°C	Continuous Collector Current	55	A
I_C @ T_C = 100°C	Continuous Collector Current	27	
I_{CM}	Pulsed Collector Current ①	220	
V_{CE}	Collector-to-Emitter Breakdown Voltage	600	V
V_{GE}	Gate-to-Emitter Voltage	±20	
I_{LM}	Clamped Inductive Load Current ②	220	A
E_{ARV}	Reverse Voltage Avalanche Energy ③	20	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation	200	W
P_D @ T_C = 100°C	Maximum Power Dissipation	78	
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 3mm MA screw	10 in•lbs (11.5 kg•cm)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	---	---	0.64	K/W ⑥
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	---	0.24	---	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	---	---	40	

Electrical Characteristic @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
BV_{CES}	Collector-to-Emitter Breakdown Voltage	600	---	---	V	V_{GE}=0V, I_C=250µA
BV_{ECS}	Emitter-to-Collector Breakdown Volt. ④	23	---	---		V_{GE}=0V, I_C=1.0A
$\Delta BV_{CES}/\Delta T_J$	Temp. Coeff. of Breakdown Voltage	---	0.60	---	V/°C	V_{GE}=0V, I_C =1.0mA
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	---	---	3.0	V	V_{GE}=15V, I_C=27A See fig 4.
		---	2.4	---		V_{GE}=15V, I_C=55A
		---	1.9	---		V_{CE}=15V, I_C=27A, T_J=150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	---	5.5		V_{CE}=V_{GE}, I_C=250µA
$\Delta BV_{GE(th)}/\Delta T_J$	Temp. Coeff. of Threshold Voltage	---	-13	---	mV/°C	V_{CE}=V_{GE}, I_C=250µA
g_{fe}	Forward Transconductance ⑤	16	---	32	S	V_{CE}=100V, I_C=27A
I_{CES}	Zero Gate Voltage Collector Current	---	---	250	µA	V_{GE}=0V, V_{CE}=600V, T_J=25°C
		---	---	5000		V_{GE}=0V, V_{CE}=600V, T_J=150°C
I_{GES}	Gate-to-Emitter Leakage Current	---	---	±500	nA	V_{GE}=±20V

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

	Parameter	Min.	Typ.	Max.	Units	Test Conditions
Q_G	Total Gate Charge (turn-on)	77	---	140	nC	I_C=27A, V_{CC}=480V
Q_{GE}	Gate - Emitter Charge (turn-on)	13	---	21		See Figure 6.
Q_{GC}	Gate - Collector Charge (turn-on)	35	---	70		
$t_{d(on)}$	Turn-On Delay Time	---	23	---	ns	See test circuit, figure 13.
t_r	Rise Time	---	28	---		I_C=27A, V_{CC}=480V
$t_{d(off)}$	Turn-off Delay Time	---	---	200		T_J=25°C
t_f	Fall Time	---	---	140		V_{GE}=15V, R_G=2.0Ω
E_{on}	Turn-On Switching Loss	---	0.12	---	mJ	Energy losses include "tail".
E_{off}	Turn-Off Switching Loss	---	1.6	---		Also see figures 9, 10, & 11.
E_{ts}	Total Switching Loss	---	1.7	2.8		
$t_{d(on)}$	Turn-On Delay Time	---	24	---	ns	I_C=27A, V_{CC}=480V
t_r	Rise Time	---	27	---		T_J=150°C
$t_{d(off)}$	Turn-Off Delay Time	---	180	---		V_{GE}=15V
t_f	Fall Time	---	130	---		R_G=2.0Ω
E_{ts}	Total Switching Loss	---	2.7	---	mJ	
L_E	Internal Emitter Inductance	---	13	---	nH	Measured 5mm from package.
C_{ies}	Input Capacitance	---	2900	---	pF	V_{GE}=0V
C_{oes}	Output Capacitance	---	330	---		V_{CC}=30V See fig 5.
C_{res}	Reverse Transfer Capacitance	---	41	---		f = 1.0MHz

Notes:

① Repetitive rating; V_{GE}=20V, pulse width limited by max. junction temperature (See figure 12b).

② V_{CC}=80%(BV_{CES}), V_{GE}=20V, L=10µH, R_G=10Ω, (See figure 12a).

③ Repetitive rating; pulse width limited by maximum junction temperature.

④ Pulse width ≤ 80µs; duty factor ≤0.1%.

⑤ Pulse width ≤ 5µs, single shot.

⑥ K/W equivalent to °C/W.

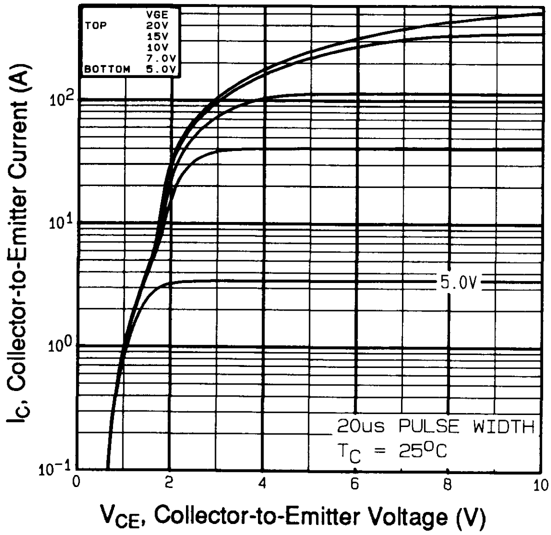


Fig 1. Typical Output Characteristics, $T_J = 25°C$

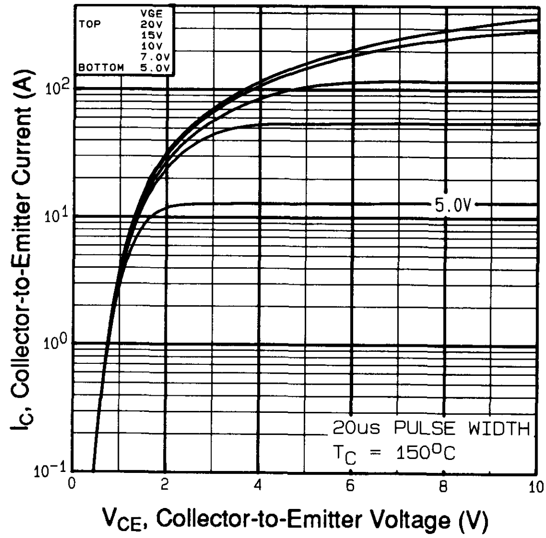


Fig 2. Typical Output Characteristics, $T_J = 150°C$

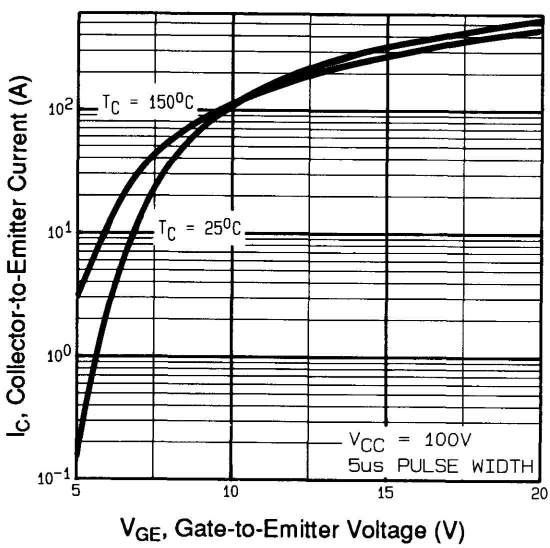


Fig 3. Typical Transfer Characteristics

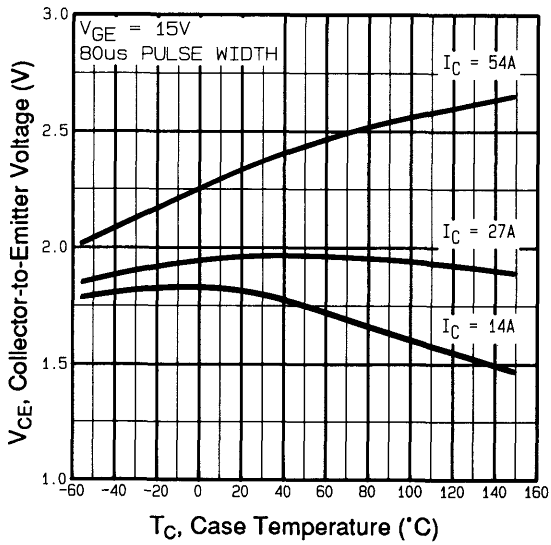


Fig 4. Collector-to-Emitter Saturation Voltage vs. Case Temperature

Graphs indicate performance of typical devices

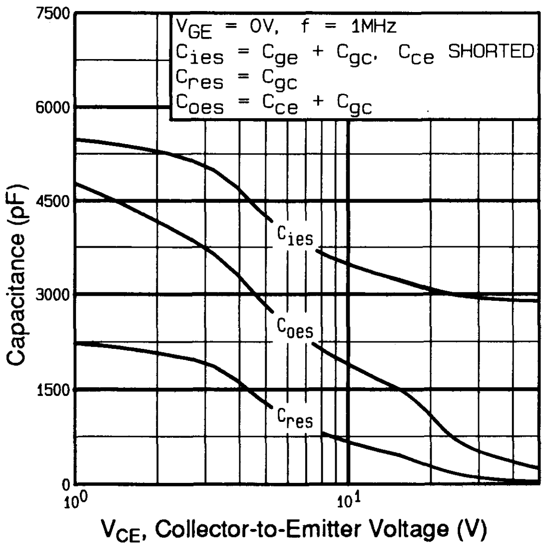


Fig 5. Typical Capacitance vs. Collector-to-Emitter Voltage

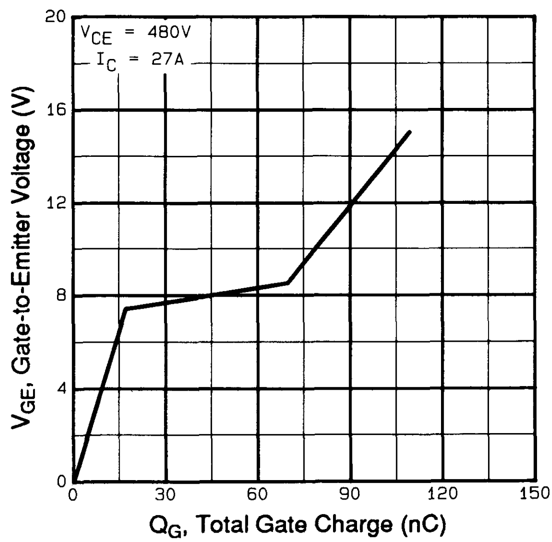


Fig 6. Typical Gate Charge vs. Gate-to-Emitter Voltage

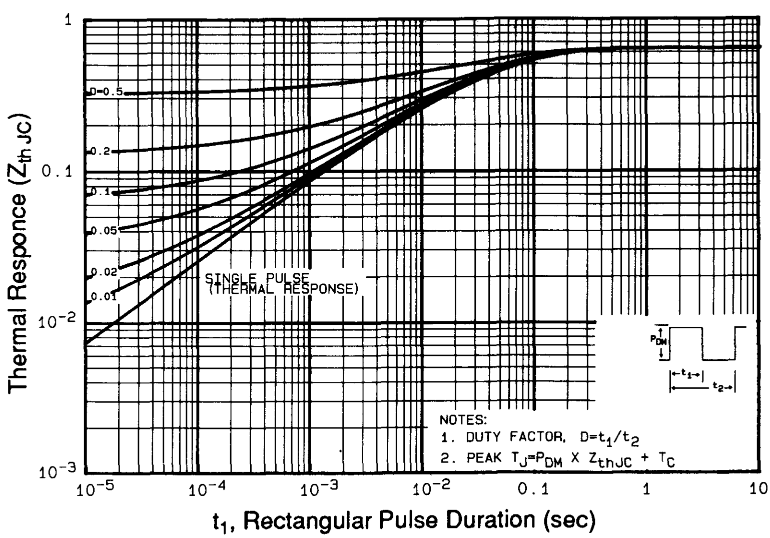


Fig 7. Maximum Effective Transient Thermal Impedance, Junction-to-Case

Graphs indicate performance of typical devices

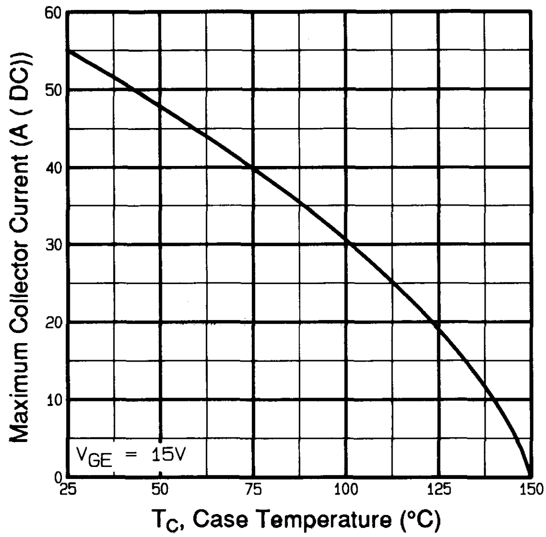


Fig 8. Maximum Collector Current vs. Case Temperature

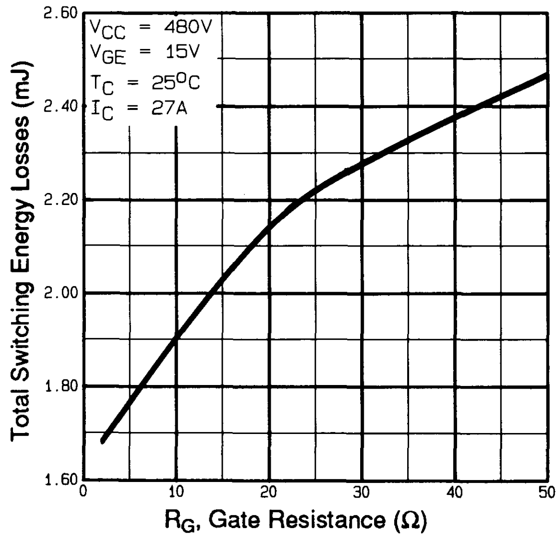


Fig 9. Typical Switching Losses vs. Gate Resistance

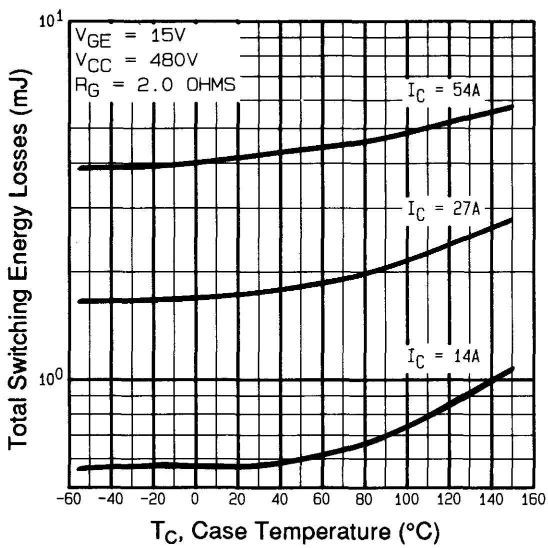


Fig 10. Typical Switching Losses vs. Case Temperature

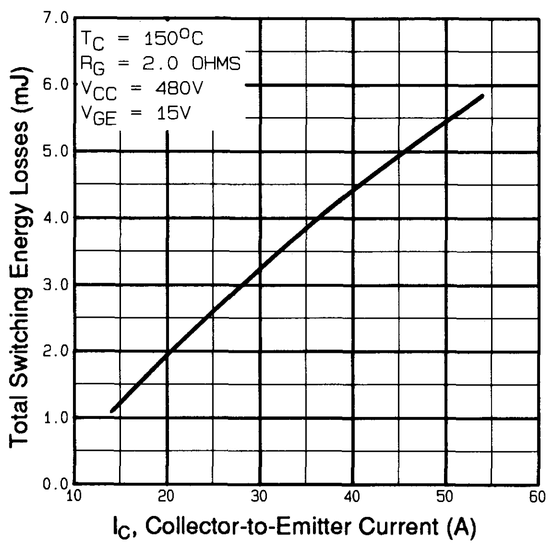


Fig 11. Typical Switching Losses vs. Collector-to-Emitter Current

Graphs indicate performance of typical devices

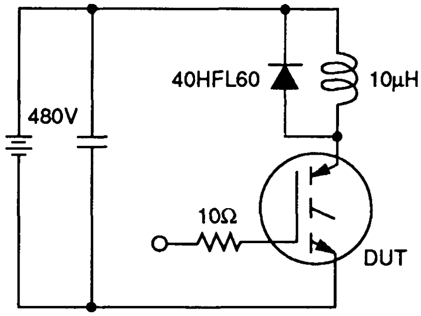


Fig 12a. Clamped Inductive Load Test Circuit

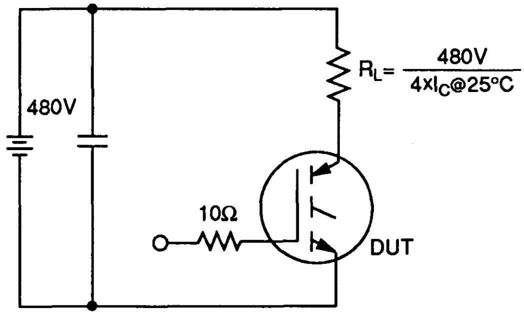


Fig 12b. Pulsed Collector Current Test Circuit

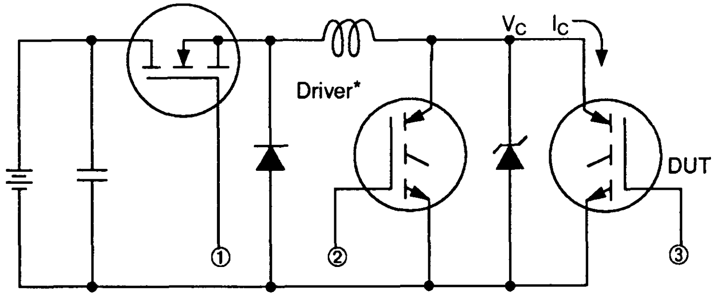


Fig 13a. Switching Loss Test Circuit

* Driver same type as DUT, V_C = 480V

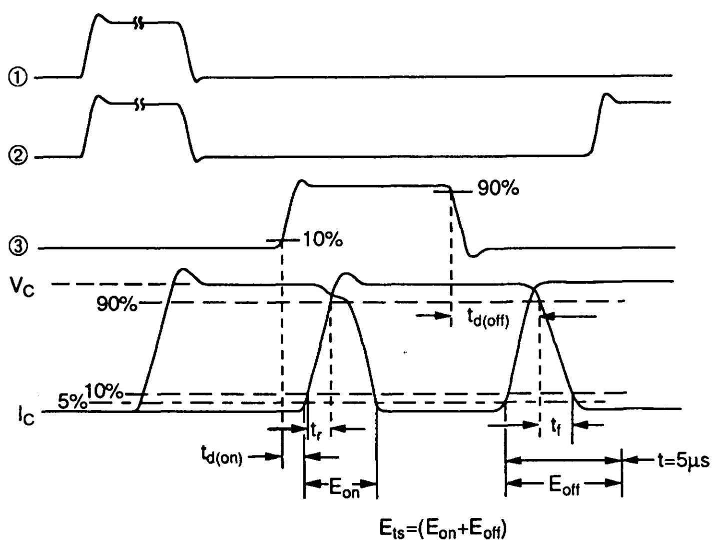


Fig 13b. Switching Loss Waveforms

International Rectifier

Application Notes

Insulated Gate Bipolar Transistors

IGBT Characteristics and Applications

(HEXFET is a trademark of International Rectifier)

by S. Clemente, A. Dubhashi, B. Pelly

Summary

This application note describes International Rectifier's Insulated Gate Bipolar Transistors (IGBTs).

Section I describes the characteristics of the device, its technology and the key trade-offs in its design, comparing it to MOSFETs and bipolar transistors.

Section II reviews the data sheet and explains the terms and test methods used to characterize the IGBT.

Section III contains an overview of the three families of IGBTs available from International Rectifier.

Section IV covers some application issues such as gate drive requirements, calculation of power losses, and thermal design.

Introduction

Switching speed, peak current capability, ease of drive, wide SOA, avalanche and dv/dt capability have made power MOSFETs the logical choice in new power electronic designs. These advantages, a natural consequence of being majority carrier devices, are partly mitigated by their conduction characteristics which are strongly dependent on temperature and voltage rating.

Furthermore, as the voltage rating goes up, the inherent reverse diode displays increasing Q_{rr} and T_{rr} which leads to increasing switching losses.

IGBTs on the other hand, being minority carrier devices, have superior conduction characteristics, while sharing many of the appealing features of power MOSFETs such as ease of drive, wide SOA, peak current capability and ruggedness. Generally speaking, the switching speed of an IGBT is inferior to that of power MOSFETs. However, as will be shown in Section III, a new line of IGBTs from International Rectifier has switching characteristics that are very close to those of power MOSFETs, without sacrificing the much superior conduction characteristics.

The absence of the integral reverse diode gives the user the flexibility of choosing an external fast recovery diode to match a specific requirement. This feature can be an advantage or a disadvantage, depending on the frequency of operation, cost of diodes, current requirement, etc.

The purpose of this application note is to provide the design engineer with a comprehensive understanding of this new class of devices, with special reference to those provided by International Rectifier.

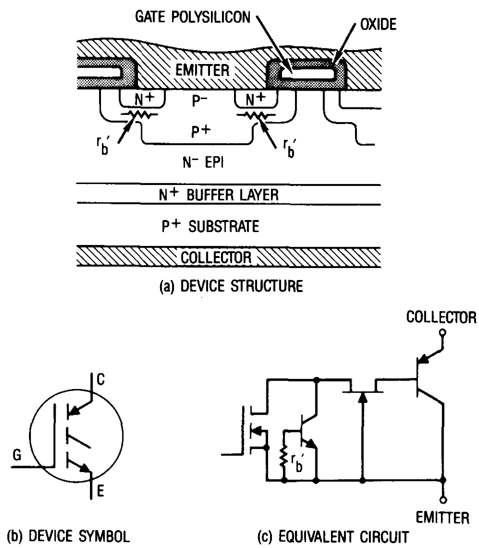


Figure 1. Silicon cross-section of an IGBT with its equivalent circuit and symbol (N-Channel, enhancement mode). The terminal called *collector* is, actually, the *emitter* of the PNP. In spite of its similarity to the cross-section of a power MOSFET, operation of the two transistors is fundamentally different, the IGBT being a minority carrier device.

Section I: The IGBT Technology and Characteristics

Except for the P+ substrate, the silicon cross-section of an IGBT (Figure 1) is virtually identical to that of a power MOSFET. Both devices share a similar polysilicon gate structure and P wells with N+ source contacts. In both devices the N- type material under the P wells is sized in thickness and resistivity to sustain the full voltage rating of the device.

However, in spite of the many similarities, the physical operation of the IGBT is closer to that of a bipolar transistor than to that of a power MOSFET. This is due to the P+ substrate which is responsible for the minority carrier injection into the N- region and the resulting conductivity modulation. In a power MOSFET, which does not benefit from conductivity modulation, a significant share of the conduction losses occur in the N- region, typically 70% in a 500V device.

As shown in the equivalent circuit of Figure 1, the IGBT consists of a PNP driven by an N-Channel MOSFET in a pseudo-Darlington configuration. The JFET supports most of the voltage and allows the MOSFET to be a low voltage type, and consequently have a low $R_{DS(on)}$.

The base region of the PNP is not brought out and the emitter-base PN junction, spanning the entire extension of the wafer cannot be terminated nor passivated. This influences the turn-off and reverse blocking behavior of the IGBT, as will be explained later. The breakdown voltage of this junction is about 20V and is shown in the IGBT symbol as an unconnected terminal (Figure 1).

A. Conduction Characteristics

As it is apparent from the equivalent circuit, the voltage drop across the IGBT is the sum of two components: a diode drop across the P-N junction and the voltage drop across the driving MOSFET. Thus, unlike the power MOSFET, the on-state voltage drop across an IGBT never goes below a diode threshold. The voltage drop across the driving MOSFET, on the other hand, has one characteristic that is typical of all low voltage MOSFETs: it is sensitive to gate drive voltage. This is apparent from Figures 12 and 13 where, for currents that are close to their rated value, an increase in gate voltage causes a reduction in collector-to-emitter voltage. This is due to the fact that, within its operating range, the gain of the PNP increases with current and an increase in gate voltage causes an increase in channel current, hence a reduction in voltage drop across the PNP. This is quite different from the behavior of a high voltage power MOSFET that is largely insensitive to gate voltage.

As the final stage of a pseudo-Darlington, the PNP is never in heavy saturation and its voltage drop is higher than what could be obtained from the same PNP in heavy saturation. It should be noted, however, that the emitter of an IGBT covers the entire area of the die, hence its injection efficiency and conduction drop are much superior to that of a bipolar transistor of the same size.

Two options are available to the device designer to decrease the conduction drop:

1. Reduce the on-resistance of the MOSFET. This can be done by increasing the die size and/or the packing density. Both have a negative impact on yield and cost.

2. Increase the gain of the PNP. As explained later, this option is limited by latch-up considerations.

International Rectifier has pursued the optimization of the MOSFET component of the IGBT to the point where its devices can be correctly referred to as a "conductivity modulated MOSFET" with its characteristic features of high speed, low voltage drop and efficient silicon utilization. Other semiconductor companies, on the other hand, have concentrated on the optimization of the bipolar part and the resulting product should be more correctly referred to as a "MOSFET-driven transistor" with a different set of characteristics.

The dramatic impact of conductivity modulation on voltage drop can be seen from Figure 2 which compares a HEXFET power MOSFET and an IGBT of the same die size. Temperature dependence, very significant in a power MOSFET, is minimal in an IGBT, just enough to ensure current sharing of paralleled devices at high current levels under steady state conditions, as shown in Figure 14 for the IRGBC20U. This same figure shows that the temperature dependence of the voltage drop is different

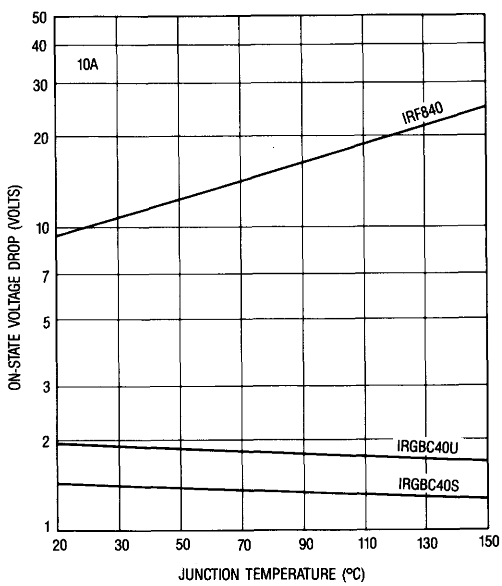


Figure 2. On-state voltage drop vs temperature of two IGBTs of different switching characteristics compared to those of a HEXFET of the same die size (IRGBC40S and IRGBC40U vs IRF840).
Conductivity modulation causes a dramatic improvement in the on-state voltage drop. To take the avalanche capability of the HEXFET into account, a 500V device is compared with 600V IGBTs.

at different current levels. This is because the diode component of this drop has a temperature coefficient that is initially negative becoming positive at higher current levels. The MOSFET component, on the other hand, is positive. The problem is made more complex by the fact that these two components are weighted differently at different current and temperatures.

In addition to reducing the voltage drop and its temperature coefficient, conductivity modulation virtually eliminates its dependence on the voltage rating. This is shown in Table I, where the conduction drops of four IGBTs of different voltage ratings are compared with those of HEXFETs at the same current density[1].

Table I: Dependence of Voltage Drop From Voltage Rating

Rated Voltage	IGBT	100	300	600	1200
	HEXFET	100	250	500	1000
Typical Voltage Drop @ 1.7A/mm^2, 100°C	IGBT	1.5	2.1	2.4	3.1
	HEXFET	2.0	11.2	26.7	100

The voltage rating of the HEXFET power MOSFETs used in this comparison are lower than the IGBTs to take into account their avalanche capability.

B. Switching Characteristics

The biggest limitation to the turn-off speed of an IGBT is the lifetime of the minority carriers in the N- epi, i.e., the base of the PNP. Since this base is not accessible, external drive circuitry cannot be used to improve the switching time. It should be remembered, though, that since the PNP is in a pseudo-Darlington connection, it has no storage time and its turn-off time is much better than the same PNP in heavy saturation. Even so, it may still be inadequate for many high frequency applications.

The charges stored in the base cause the characteristic "tail" in the current waveform of an IGBT at turn-off (Figure 3). As the MOSFET channel stops conducting, electron current ceases and the IGBT current drops rapidly to the level of the hole recombination current at the inception of the tail. This tail increases turn-off losses and requires an increase in the deadtime between the conduction of two devices in a half-bridge.

Traditional lifetime killing techniques and/or an N+ buffer layer to collect the minority charges at turn-off are commonly used to speed-up recombination time. Insofar as they reduce the gain of the PNP, these techniques increase the voltage drop. Pushed to the extreme, minority lifetime killing causes a quasi-saturation condition at turn-on, as shown in Figure 4, where the turn-on losses have become larger than the turn-off losses.

Thus, the gain of the PNP is constrained by conduction and turn-on losses on one hand, and by latching considerations on the other, as explained in the next section.

Like all minority carrier devices, the switching performance of an IGBT degrades with temperature. As can be seen in Figure 18, this phenomenon is less significant at high current levels.

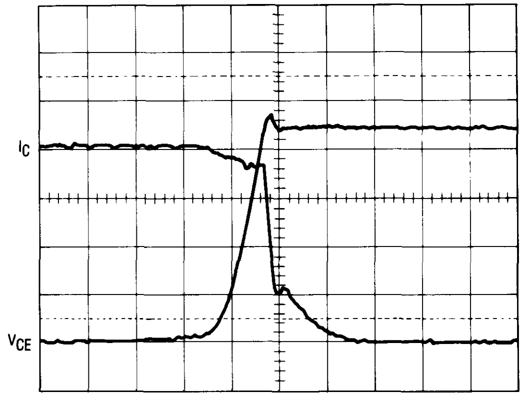


Figure 3. Turn-off waveform of a commercial IGBT at 25°C, rated current. Notice the clean break at the inception of the "tail". Switching circuit as in Figure 16.

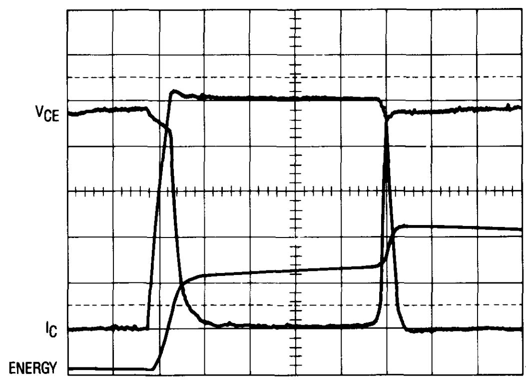


Figure 4. Switching waveforms of a commercially available IGBT with heavy lifetime killing.
It takes approximately 0.5 μs for the voltage to drop the last 50V. The energy plot shows that the losses at turn-on are twice as high as those at turn-off.
Switching circuit as in Figure 16.

[1]Several papers make reference to a voltage dependence of the $R_{DS(on)}$ of a power MOSFET of the following type:

$$R = R_O V^{\alpha}$$

with $\alpha = 2.5$, i.e., the on-resistance increases with the voltage rating at a higher rate than a square law. In reality, assuming that a power law is a true representation of the underlying physical phenomena, the correct value would be ≈ 1.6, as can be easily verified from the data sheets of any manufacturer. These data sheets will also contradict the common misconception that power MOSFETs have better silicon utilization at low voltage. In actual fact they achieve their highest power handling capability per unit area between 400V and 600V.

C. Latching

As shown in the cross-section of Figure 1, the IGBT is made of four alternate P-N-P-N layers. Given the necessary conditions ($\alpha_{NPN} + \alpha_{PNP} > 1$) the IGBT could latch-up like a thyristor.

The N+ buffer layer and the wide epi base reduce the gain of the PNP, while the gain of the NPN, which is the parasitic bipolar of the MOSFET, can be reduced with the same techniques [1] that are commonly employed to give HEXFETs their avalanche and dv/dt capability, mainly a drastic reduction of the r_b'. If this r_b' is not adequately reduced, "dynamic latching" could occur at turn-off when a high density of hole current flows in r_b', taking the gain of the parasitic NPN to much higher values.

Latching should not occur under any of the operating conditions of current, temperature and dv/dt that the device may see within its rated limits of operation. IGBTs from International Rectifier are guaranteed not to latch at the maximum current that can be sustained with $V_{gs} = 20V$, $T_j = 150°C$ and the highest dv/dt the device is capable of. At the same time, since a PNP with higher gain reduces conduction losses, International Rectifier has been careful not to reduce it beyond what is necessary for safe and reliable operation at the data sheet limits.

D. Safe Operating Area

The safe operating area (SOA) describes the capability of a transistor to withstand significant levels of voltage and current at the same time. The three main conditions that would subject an IGBT to this combined stress are the following:

1. Operation in short circuit. The current in the IGBT is limited by its gate voltage and transconductance and can reach values well in excess of 10 times its continuous rating. The level of hole current that flows underneath the N+ source contact can cause a drop across r_b', large enough to turn on the NPN parasitic bipolar with possible latching. This is normally prevented by a reduction in r_b', as mentioned in the previous section or by a reduction of the total device transconductance (essentially the gain of the PNP). This second technique increases conduction losses and reduces switching speed.

Lower power dissipation was deemed a more desirable feature than short circuit capability, particularly considering that simple protection circuitry can be added to the gate drive to protect the IGBT in those applications where a short circuit is a likely event.

2. Inductive turn-off, sometimes referred to as "clamped I_L." In an inductive turn-off the voltage swings from a few volts to the supply voltage with constant current and with no channel current. These conditions are different from those described in the previous section in so far as the load current is totally made up of holes flowing through r_b'. For this reason some manufacturers suggest the use of gate drive resistors to slow down the turn-off dv/dt and maintain some level of electron current, thereby avoiding a potential "dynamic latching" condition. IGBTs from International Rectifier can be operated at their maximum switching speed without any problem. Reasons to limit the switching speed should be external to the device (e.g., overshoots due to stray inductance), rather than internal.

3. Operation as a linear amplifier. Linear operation exercises the SOA of the IGBT in a combination of the two modes described above, but in a less severe fashion. A device that is designed to withstand those stresses will be more than suited to operate as a linear amplifier. No second breakdown has been observed in IGBTs from International Rectifier in any mode of operation within the data sheet limit.

E. Transconductance

The current handling capability of a semiconductor can be limited by thermal constraints or by gain/transconductance constraints. While the "headline current rating" of power semiconductors is based solely on thermal considerations, it is entirely possible, as is frequently the case with bipolar transistors, that the device cannot operate at the current level it is thermally capable of, because its gain has fallen to very low values. As shown in Figure 5, the transconductance of an IGBT tops out at current levels that are well beyond its thermal capability, while the gain of a bipolar of similar die size is on a steep downslope within its current operating range.

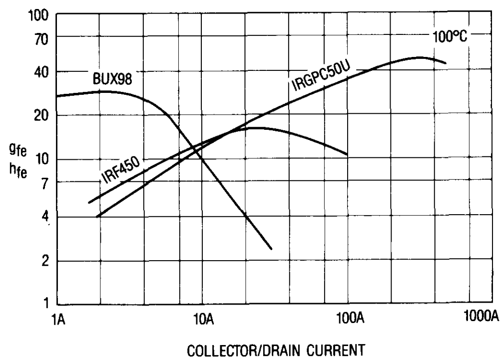


Figure 5. Current dependence of the transconductance of an IGBT compared to that of a HEXFET and to the gain of a bipolar of approximately the same die size.
The IGBT, like the power MOSFET, is not "gain limited."

The flattening out of transconductance occurs when the saturation effects in the MOSFET channel, that reduce the base current of the PNP, combine with the flattening of the gain of the PNP. Since temperature reduces the MOSFET channel current more than it increases the gain of the PNP, the saturation in transconductance occurs at lower current as the temperature increases.

Since lifetime killing reduces the gain of the PNP, the transconductance of fast IGBTs peaks at a lower level than those without lifetime killing. This, however, is a second order effect because the gain of the PNP is determined mainly by the N+ buffer layer.

The decrease in transconductance at very high current and its additional decrease with temperature helps protect the IGBT under short circuit conditions. With a gate voltage of 15V, the current density of a standard IGBT from International Rectifier reaches values of 10-20A/mm^2 in short circuit. This high transconductance is partly responsible for their superior switching and conduction characteristics.

Section II: The Data Sheet

International Rectifier prides itself on having one of the most comprehensive IGBT data sheets in the industry, with all the information required to operate the IGBT reliably. However, like all technical documents it requires a good understanding by the user of the different terms and conditions. These are briefly explained in the following sections.

A. The Headline Information

In addition to the mechanical layout, the front page gives the voltage and current ratings. The current rating is the industry standard dc current capability of the device with the case being maintained at 25°C.

The part number itself contains in coded form the key features of the IGBT. An explanation of the nomenclature is contained in Figure 6.

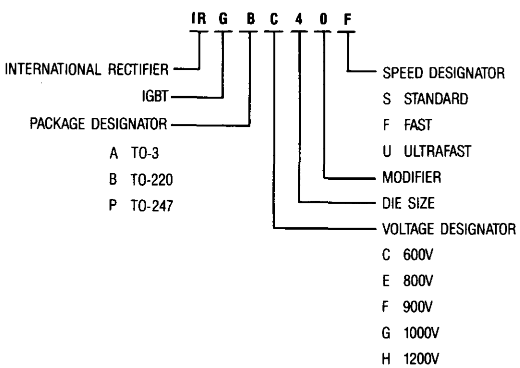


Figure 6. Simplified nomenclature code for commercial IGBTs from International Rectifier.

B. The Absolute Maximum Ratings

This table sets up a number of constraints on device operation that apply under any circumstance.

Continuous Collector Current @ T_C = 25°C and 100°C (I_C). This represents the dc current level that will take the junction to its rated temperature from the stipulated case temperature. It is calculated with the following formula:

$$I_C = \frac{\Delta T}{\theta_{j\text{-}c} \cdot I_C \cdot V_{CE(on)} \ @ \ I_C}$$

where ΔT is the temperature rise from the stipulated case temperature to the maximum junction temperature (150°C)[2].

It is clear, from this formula, that a current rating has no meaning without a corresponding junction and case temperature. Since in normal applications the case temperature is much higher than 25°C, the associated rating is of no practical value and is only reported because transistors have been traditionally rated in this way. Figure 7 shows how this rating changes with case temperature, with a junction temperature of 150°C, for a specific device.

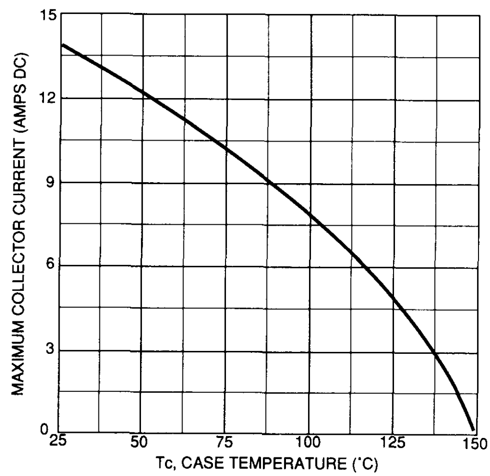


Figure 7. Maximum Collector Current vs. Case Temperature

Pulsed Collector Current (I_{CM}). Within its thermal limits, the IGBT can be used to a peak current well above the rated continuous DC current. The temperature rise during a high current transient can be calculated as indicated in Section IVC. The test circuit is shown in Figure 8.

Collector-to-Emitter Voltage (V_{CE}). Voltage across the IGBT should never exceed this rating, to prevent breakdown of the collector-emitter junction. The breakdown itself is guaranteed in the Table of Electrical Characteristics.

---

[2]Notice that $V_{CE(on)}$ @ I_C is not known because I_C is not known. It can be found with few iterations.

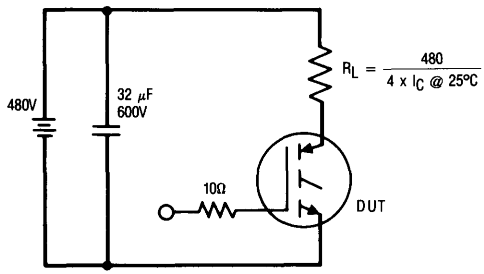


Figure 8. Pulsed Collector Current Test Circuit

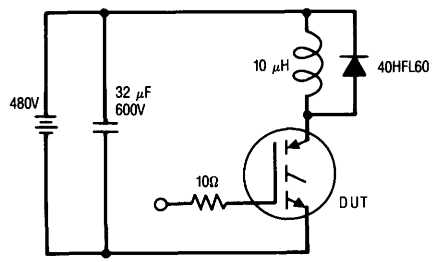


Figure 9. Clamped Inductive Load Test Circuit

Maximum Gate-to-Emitter Voltage (V_{GE}). The gate voltage is limited by the thickness and characteristics of the gate oxide layer. Though the gate dielectric breakdown is typically around 80 volts, the user is limited to 20V to limit current under fault conditions and to ensure long term reliability.

Clamped Inductive Load Current (I_{LM}). This rating guarantees that the device is able to repetitively turn off the specified current with a clamped inductive load, as encountered in most applications. In fact, the test circuit (Figure 9) exposes the IGBT to the peak recovery current of the free-wheeling diode, which adds a significant component to the turn-on losses (Figure 10).

This rating guarantees a square switching SOA, i.e., that the device can sustain high voltage and high current simultaneously. The I_{LM} rating is specified at 150°C, 80% of the rated voltage and at four times the rated current at T_C = 25°C. This is a simpler and more direct representation of the device capability than the traditional SOA curve that lends itself to many misunderstandings.

Reverse Avalanche Energy (E_{ARV}). This subject is covered in detail in the BV_{ECS} section of the electrical characteristics.

Maximum Power Dissipation @ 25°C and 100°C (P_D). It is calculated with the following formula:

$$P_D = \frac{\Delta T}{\theta_{j\text{-}c}}$$

The same comments that were made on the Continuous Collector Current apply to Power Dissipation.

Junction Temperature (T_J): the device can be operated in the industry standard range of -55°C to 150°C respectively.

C. Thermal Resistance

R_{thjc}, R_{thcs}, R_{thja} are needed for the thermal design, as explained in Section IV, C.

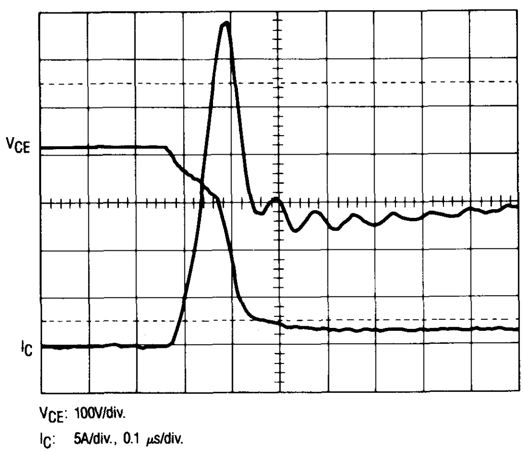


Figure 10a. Turn-on with a clamped inductive load and a fast recovery diode. Test circuit as in Figure 9.

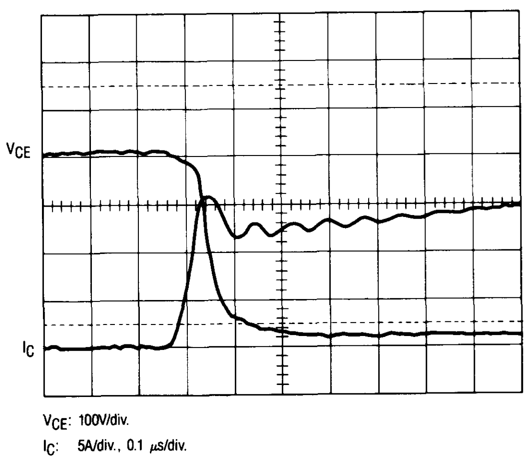


Figure 10b. Turn-on with an ideal diode (zener clamp). Test circuit as in Figure 16.

The reverse recovery is a significant contributor to turn-on losses. To discriminate between the losses that are intrinsic to the IGBT and those due to the diode reverse recovery, the test circuit shown in Figure 16 has been used to generate the data sheet values.

D. Electrical Characteristics

The purpose of this section is to provide a detailed characterization of the device so that the designer can predict with accuracy its behavior in a specific application.

Collector-to-Emitter Breakdown Voltage (BV_{CES}). This parameter guarantees the lower limit of the distribution in breakdown voltage. Breakdown is defined in terms of a specific leakage current and has a positive temperature coefficient (listed in the table as $BV_{CES}/\Delta T$) of about 0.63V/°C. This implies that a device with 600V breakdown at 25°C would have a breakdown voltage of 550V at -55°C.

Emitter-to-Collector Breakdown Voltage (BV_{ECS}). This rating characterizes the reverse breakdown of the unterminated collector-base junction of the PNP. The relevance of this specification and its associated reverse avalanche energy can be better understood with reference to Figure 11. When an IGBT turns off and current is transferred to the diode across the complementary device, the turn-off di/dt in the stray inductance that is in series with the diode generates a reverse voltage spike across the IGBT (i.e., the collector voltage goes negative with respect to the emitter). This reverse voltage is typically less than 10V, though higher voltages can result from very high di/dt or poor layout. Since this reverse voltage can cause avalanche in the junction, International Rectifier IGBTs have an energy rating, given in the Absolute Maximum Ratings table, that is more useful to the designer than a traditional diode characterization. This rating is typically an order of magnitude more than what would be required by the user.

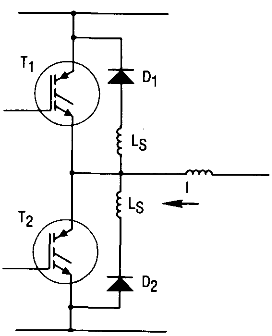


Figure 11. When T_2 goes off, load current flows into the diode in parallel with T_1. The reverse turn-off di/dt of T_2 develops a voltage across the stray inductance in series with D_1 which reverse biases T_1. IR's IGBTs have a specified reverse blocking capability (BV_{CES}) and an avalanche rating (E_{RV}).

Collector-to-Emitter Saturation Voltage ($V_{CE(on)}$). Being the key rating to calculate conduction losses, this value is supported by three figures that provide a detailed characterization in temperature, current and gate voltage (Figures 12, 13, and 14 for the IRBGC20U). The Table of Switching Characteristics lists three values at two currents and two temperatures.

Gate Threshold Voltage ($V_{GE(th)}$). This is the range of voltage on the gate at which collector current starts to flow.

The variation in gate threshold with temperature is also specified ($V_{GE(th)}/\Delta T_j$). Typically the coefficient is -11 mV/°C, leading to a reduction of about 1.4V in the threshold voltage at high temperatures.

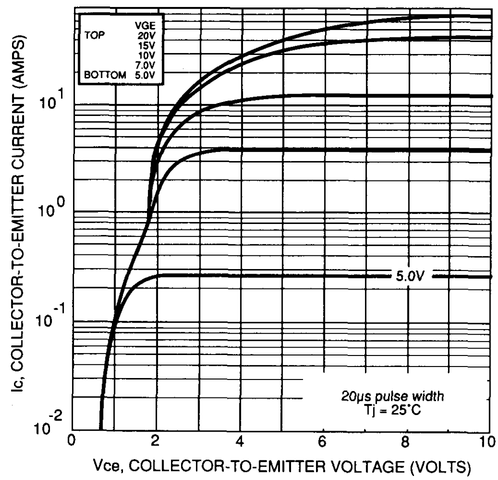


Figure 12. Typical Output Characteristics, T_C = 25°C

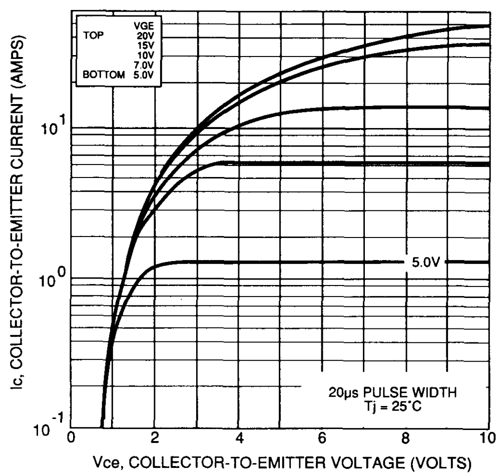


Figure 13. Typical Output Characteristics, T_C = 150°C

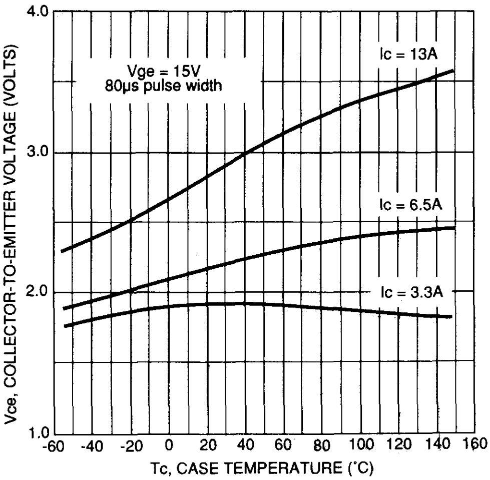


Figure 14. Collector-to-Emitter Saturation Voltage vs. Case Temperature

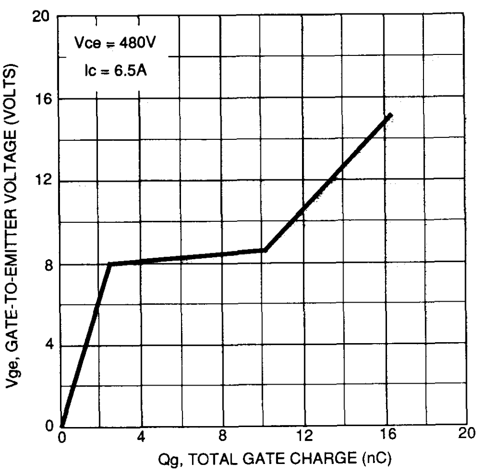


Figure 15. Typical Gate Charge vs. Gate-to-Emitter Voltage

Forward Transconductance (g_{FE}). This parameter is measured by superimposing a small variation on a gate bias that takes the IGBT to its 100°C rated current in "linear" mode. As mentioned in Section II, E, transconductance increases significantly with current so that the "current throughput" of an IGBT is not limited by gain, as a bipolar, but by thermal considerations.

Zero-Gate-Voltage Collector Current (I_{CES}). This parameter guarantees the upper limit of the leakage distribution at the rated voltage and two temperatures. It complements the BV_{CES} rating seen above.

E. Switching Characteristics

Gate Charge Parameters (Q_g, Q_{ge}, Q_{gc}). Gate charge values of an IGBT are useful to size the gate drive circuit and estimating gate drive losses. Unfortunately they cannot be used to predict switching times, as for a power MOSFET, because of the minority carrier nature of this device. The test method and the characteristics described in the application note AN-944 [3] for power MOSFETs are also applicable to IGBTs. Figure 15 gives the typical value of the total gate charge as a function of the voltage applied to the gate. The shape of the curve is explained in detail in AN-944.

Switching Times (t_d, t_r, t_f). The switching times are defined in a fairly conventional way (Figure 16):
- Turn-on delay time: 10% of gate voltage to 10% of collector current
- Rise time: 10 to 90% of collector current
- Turn-off delay time: 90% of gate voltage to 90% of collector voltage
- Fall time: 90 to 10% of collector current. The fall time definition is a problem with some IGBTs, because of the current tail, mentioned in Section IIB, a significant part of which may be below 10%. The voltage fall time, on the other hand, is not characterized in any way. Thus, two significant contributors to losses are not properly accounted for by the switching times and, for this reason, they should not be used to calculate switching losses.

Switching losses are fully characterized as such in the data sheet, as explained in the next paragraph.

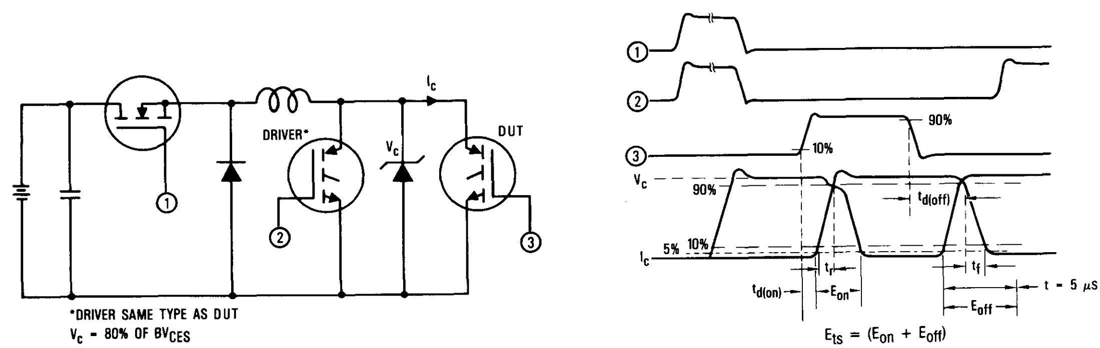


Figure 16. Switching Loss Test Circuit and Waveforms

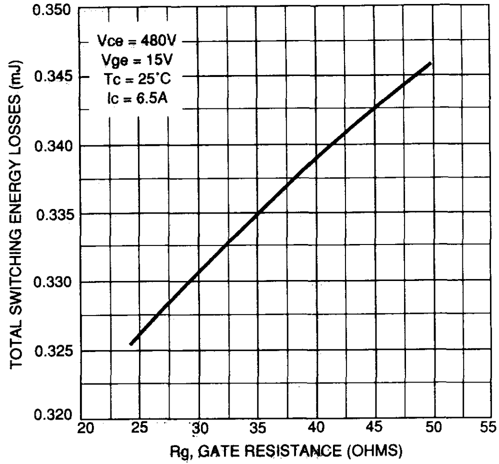


Figure 17. Typical Switching Losses vs. Gate Resistance

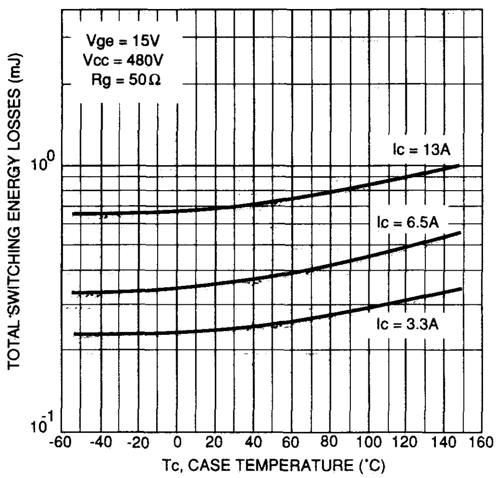


Figure 18. Typical Switching Losses vs. Case Temperature

It should be remembered that IGBTs, like power MOSFETs, do not have a storage time. The turn-off delay is due to the Miller effect, as explained in Section IVA.

Switching times provide a useful guideline to establish the appropriate deadtime between the turn-off and subsequent turn-on of complementary devices in a half bridge configuration and the minimum and maximum pulse widths.

Switching Energy (E_{on}, E_{off}, E_{ts}). IGBTs from International Rectifier have a guaranteed switching energy providing a full characterization in terms of temperature, collector current and gate resistance (Figures 17, 18 and 19 for the IRBGC20U). This allows the designer to calculate the switching losses, without worrying about the actual current and voltage waveshapes, the tail and the quasi-saturation.

Any test circuit for measuring switching losses has to satisfy two fundamental requirements:

1. It must simulate the switching conditions as they are encountered in a practical application, i.e., a clamped inductive load with continuous current flow.

2. It must reflect the losses that are attributable to the IGBT, and must be independent from those due to other circuit components, like the freewheeling diode.

The test *circuit* that meets these requirements is shown in Figure 16. Its operation is as follows:

The driver IGBT builds the test current in the inductor. When it is turned off, current flows in the zener. At this point the switching time and switching energy test begins, by turning on and off the device under test (DUT). The DUT will see the test current that was flowing into the inductor and the voltage across the zener, *without* any reverse recovery component from a free-wheeling diode. This test can exercise the IGBT to its full voltage and current without any spurious effect due to diode reverse recovery.

The test *method*, on the other hand, must account for all losses that occur because of the switching operation, including the quasi-saturation at turn-on and the tail at turn-off. To fulfill this requirement, the energy figures reported in the data sheet are defined as follows:

E_{on}: From 5% of test current to 5% of test voltage. We feel that 5% is a reasonable compromise between the resolution of the instrumentation and the need to account for the quasi-saturation that could occur in some devices.

E_{off}: This energy is measured over a period of time that starts with 5% of test voltage and goes on for 5 μsec. While the current tail of most IGBTs would be finished well before that time, it was felt that the contribution of the leakage loses to the total energy is minimal.

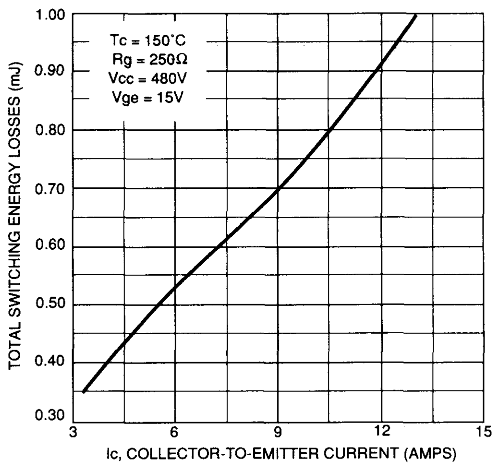


Figure 19. Typical Switching Losses vs. Collector Current

E_{ts}: This is the sum of the turn-on and turn-off losses.

As shown in Figure 19, switching energy for International Rectifier IGBTs is closely proportional to current. This is not necessarily true for IGBTs from other manufacturers.

Internal Emitter Inductance (L_E). This is the package inductance between the bonding pad on the die and the electrical connection at the lead. This inductance slows down the turn-on of the IGBT by an amount that is proportional to the di/dt of the collector current, just like the Miller effect slows it down by an amount that is proportional to the collector dv/dt. With a di/dt of 1000 A/μsec, the voltage developed across this inductance is in excess of 7V.

Device Capacitances (C_{iee}, C_{oee}, C_{ree}). The test circuit and a brief explanation of the test method can be found in Figure 20. The output capacitance has the typical voltage dependence of a P-N junction. The reverse transfer (Miller) capacitance is also strongly dependent on voltage (inversely proportional), but in a more complex way than the output capacitance. The input capacitance, which is the sum of the gate-to-emitter and of the Miller capacitance, shows the same voltage dependence of the Miller capacitance but in a very attenuated form since the gate-to-emitter capacitance is much larger and voltage independent.

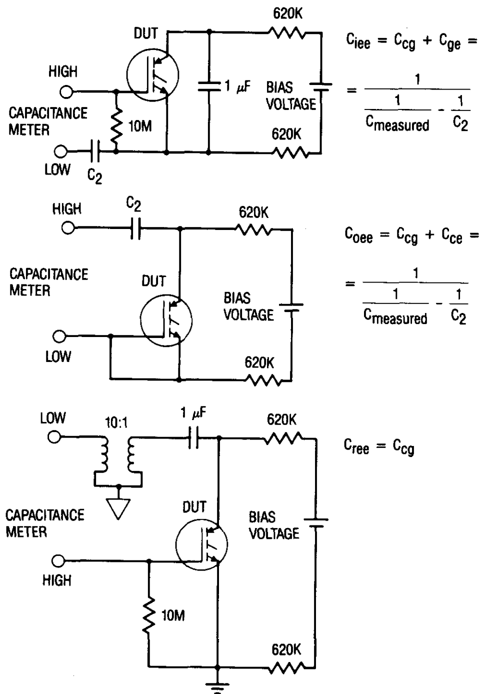


Figure 20. Capacitance test circuits.
The IGBT is biased with 25V between collector and emitter. Two of its terminals are ac shorted with a large value capacitor. Capacitance is measured between these two terminals and the third.

The Transfer Characteristic (Figure 21 for the IRGBC20U). This curve deviates from the traditional definition of transfer characteristic in one detail: the drain is not connected to the gate but to a fixed (100V) supply. When gate and drain are tied together, the curve is the boundary separating operation in full enhancement from operation in linear mode (sometimes referred to as "sat mode").

Figure 21 provides an indication of current when operated in short circuit. In the normal range of operation this curve shows a slight negative dependence on temperature and is largely independent from applied voltage.

Section III: The IGBT Families from IR

The discussion in Sections I and II can be summarized in a comparative table (Table II) that may be useful in placing different power transistors in the proper perspective. In general, the IGBT offers clear advantages in high voltage (>300V), high current (1-3 A/mm² of active area), and medium speed (to 10-20 kHz).

In a technological breakthrough, International Rectifier has developed a processing method that reduces the voltage drop per unit of current density to much lower values than are obtainable with state-of-the-art technology. This allows higher levels of minority lifetime killing and, consequently, much lower switching losses.

To maximize the value to the user of its technological breakthrough, International Rectifier has introduced three different families of devices with different crossover frequency: *Standard, Fast* and *UltraFast.*

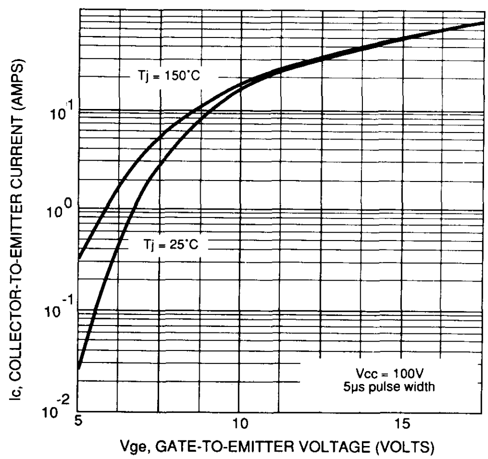


Figure 21. Typical Transfer Characteristics

Table II: Comparative Table of Power Transistor Characteristics

	Power MOSFETs	IGBTs	Bipolars	Darlingtons
Type of Drive	Voltage	Voltage	Current	Current
Drive Power	Minimal	Minimal	Large	Medium
Drive Complexity	Simple	Simple	High Large positive and negative currents are required	Medium
Current Density For Given Voltage Drop	High at low voltages Low at high voltages	Very High Small trade-off with switching speed	Medium Severe trade-off with switching speed	Low
Switching Losses	Very Low	Low to Medium depending on trade-off with conduction losses	Medium to High depending on trade-off with conduction losses	High

IR's *Standard* IGBTs have been optimized for voltage drop and conduction losses and have the lowest voltage drop per unit of current density that is presently available in the market.

IR's *UltraFast* IGBTs have been optimized for switching losses and have the lowest switching losses per unit of current density presently available in the market. As it is apparent from Figure 22, these devices have switching speeds that are comparable to those of power MOSFETs in practical applications. They can operate confortably at 50 kHz in PWM and significantly higher frequencies in resonant circuits.

IR's *Fast* devices offer a combination of low switching and low conduction losses that closely matches the switching characteristics of many popular bipolar transistors.

Table III shows the key features of the three families.

Section IV: Application Considerations

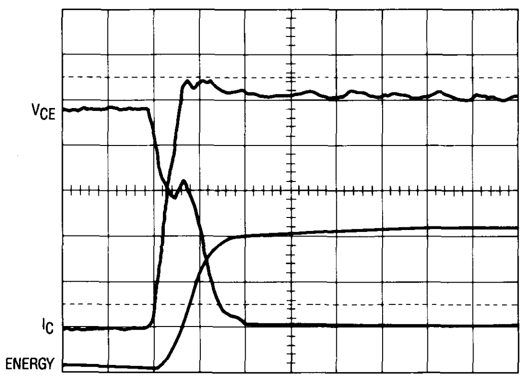
A. Gate Drive Requirements

The same general considerations that are normally made for power MOSFETs would apply to IGBTs [2] [3]. They can be summarized as follows:

- The lowest switching losses are obtained with the lowest drive impedance;

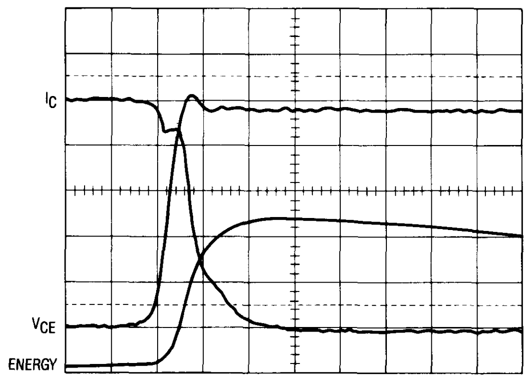
- To reduce the risk of dv/dt induced turn-on (see Note 3, page 12), the gate must be shorted to the emitter through a very low impedance;

- Gate charge is a good representation of the input characteristics of the IGBT, gate capacitance is not.



V_{CE}: 100V/div.
I_C: 10A/div.
E: 0.5 mJ/div., 0.1 μs/div.

Turn-on. Current rise time is approximately 50 ns with a turn-on energy of 1.5 mJ.



V_{CE}: 100V/div.
I_C: 10A/div.
E: 0.5 mJ/div., 0.1 μs/div.

Turn-off. Voltage rise time is approximately 50 ns with a current tail of 100 ns and a turn-off energy of 1.7 mJ. The tail contribution to these losses is 0.5 mJ. The drop in energy after the turn-off is due to the saturation of the current sensor.

Figure 22. IRGPC50U switching 50A at 480V, 125°C. Test circuit is as shown in Figure 16.

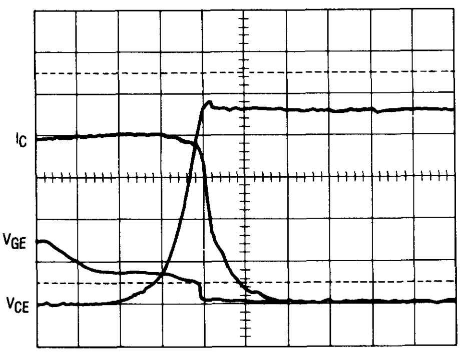
Table III: International Rectifier IGBT Families

Characteristic	Standard	Fast	Ultrafast
V_{CE}	1.3V	1.5V	1.9V
Switching Energy	0.54 mJ/A mm^2	0.16 mJ/A mm^2	0.055 mJ/A mm^2
Conduction Losses (50% dc)	0.625W	0.75W	0.95W

1A/mm^2, 100°C, Typical Values

The impedance of the gate drive circuit prolongs the Miller effect and causes a delay in the current fall time that is similar to a storage time. This delay is emphasized in Figure 23 with the addition of a 47Ω gate resistor. An explanation of this phenomenon can be found in Section 6 of Reference [6] and Section B of Reference [7].

In addition to the delay, the gate resistor has an impact on switching energy, as shown in Figure 17. As should be expected, total losses decreases as the gate resistor value goes down. The turn-on losses, being dominated by the MOSFET characteristics, are more sensitive to the gate drive impedence than the turn-off losses, which are largely dictated by minority carrier phenomena. For this reason, the impact of the gate drive impedance at turn-off is more prominent in the *UltraFast* devices, while the *Standard* devices are hardly affected.



V_{CE}: 100V/div.
I_C: 5A/div.
V_{GE}: 10V/div., 0.1 μs/div.

Figure 23. Turn-off waveform of an IRGBC40F with a 47Ω gate resistor. Notice the turn-off delay of the current waveform during the Miller effect.
Switching circuit as in Figure 16.

In spite of this, some manufacturers have suggested the use of gate resistors to reduce the possibility of "dynamic latching" (Section I, D). Although International Rectifier IGBTs do not have such requirement, there may be practical reasons to add them, mainly to reduce the current spike at turn-on due to reverse recovery of the diode. A more detailed analysis can be found in AN-978A, Section 3.b [4].

To reduce the risk of dv/dt induced turn-on a negative gate bias is frequently used. Unfortunately, this requires additional isolated supplies for the high side switches. As explained in [4], a better layout could be as effective in taking care of this problem as the negative bias. In many cases the effects of a contained amount of dv/dt induced turn-on, i.e., a small increase in power dissipation, can be an appealing alternative to the added complexity of the negative gate bias.

The gate terminal can be advantageously used to control the short-circuit withstanding capability of the IGBT. A decrease in gate drive voltage reduces the collector current and the power dissipation during short circuit. Simple circuits can be implemented to perform this function with a response time of less than 1 μsec.

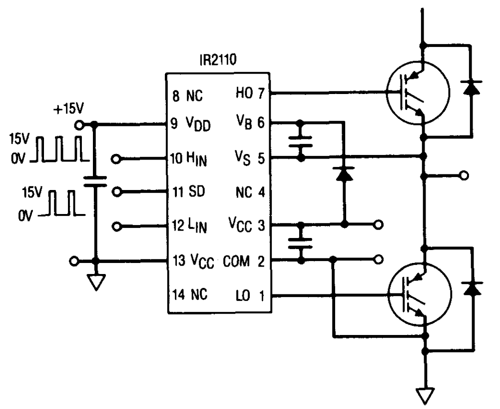


Figure 24. The IR2110 provides a simple, high performance, low cost solution to the problem of driving a Half-Bridge.

The circuit shown in Figure 24 provides a simple, low cost, high performance solution to the gate drive requirements of most applications. As explained in [4], a diode-resistor network in series with the gate may be needed in some applications.

[3]In a MOS-Gated transistor, any dv/dt that appears on the collector/drain is coupled to the gate through a capacitive divider made of the Miller capacitance and the gate-to-source/emitter capacitance. If the gate is not solidly clamped to the source/emitter, a large enough dv/dt will take the gate voltage beyond its threshold and the transistor would conduct. As it goes into conduction it clamps the dv/dt that is causing it to conduct so that the gate voltage never goes much beyond its threshold. The end result is a limited amount of "shoot-through" current, with an increase in power dissipation.

B. Calculation of losses

In any given interval, the energy dissipated in the device can be obtained with the following formula:

$$E = \int_0^{t_S} I(t)\ V(I)\ dt$$

Power is obtained by multiplying energy by frequency.

Losses are negligible when the transistor is off because $I(t) \approx 0$. For the sake of analytical expediency we divide the losses in two groups: conduction and switching. Again, for expediency's sake, the switching losses will be divided in two groups: losses when switching with an ideal diode and the contribution of reverse recovery.

1. *Conduction Losses*

If the current waveform during conduction is a rectangular pulse, the conduction energy is simply the product of the current times the voltage drop times the conduction time.

To obtain the maximum voltage drop at any current and temperature, from the data sheet supplied values, a two step procedure can be followed.

Firstly, a typical value is obtained by interpolating a curve in Figure 14 for the IRGBC20U at the desired current level. Then, to obtain a maximum value, the voltage drop read from this curve at the appropriate junction temperature is multiplied by the ratio between maximum and typical from the Table of Electrical Characteristics.[4]

An additional correction may be required if the gate drive voltage is not 15V. This can be interpolated from Figures 12 and 13.

If the current waveform is not a rectangular pulse, the conduction losses can only be found by calculating the integral. This requires a mathematical expression for the current waveform and one for the voltage drop. The expressions for the voltage drop as a function of current can be found in Table IV for the three families[5]. In many instances the integral can only be solved through numerical routines.

[4]This procedure assumes that the ratio between typical and maximum values measured at a given current and 25°C maintains over a wide range of current and temperature.

[5]The values in the model are expected to become more accurate as the knowledge of the device and its process grows.

2. *Switching Losses With Ideal Diode*

In this case, since the mathematical expressions for current and voltage are awkward and inaccurate, the option of an analytical calculation is not open and the data sheet supplied values provide the only recourse.

To obtain the total switching losses for any given current and temperature, a three step procedure should be followed, similar to the one for obtaining the on-state voltage drop. Firstly a typical value is obtained, either by interpolating a curve in Figure 18 in correspondence of the desired current, or by plotting another curve on Figure 19 for the appropriate temperature, from the values read from Figure 18.

From this typical value a max can be obtained by multiplying the typical by the ratio between maximum and typical that is in the Table of Switching Characteristics.

Finally, since the switching energy is proportional to voltage, the result is scaled by the ratio of the actual circuit voltage to the test voltage (normally 80% of device rated voltage).

An additional correction may be necessary to account for the gate resistor. This can be done with the help of Figure 17.

3. *The Contribution of the Diode Reverse Recovery*

In a typical clamped inductive load in continuous current mode, the turn-on of a switch causes a reverse recovery in the freewheeling diode and a large current spike in the device that is being turned on (Figure 10a) [5]. This causes additional losses in the IGBT, as well as in the diode. Here we are only concerned with the losses in the IGBT.

Table IV: Voltage Drop as a Function of Collector Current

General Expression: $V_{CE} = V_T + R\,I^{\beta}$

IGBT Family	IGBT-2			IGBT-3			IGBT-4			IGBT-5		
	V_T	R	β	V_T	R	β	V_T	R	β	V_T	R	β
Standard												
Typ.	0.75	0.077	1.13	0.75	0.054	1.07	0.75	0.022	1.08	0.75	0.0116	1.09
Max.	0.95	0.096	1.21	0.95	0.068	1.04	0.95	0.027	1.09	0.95	0.015	1.12
Fast												
Typ.	0.95	0.18	0.90	0.95	0.076	0.95	0.95	0.032	1.02	0.95	0.0166	1.03
Max.	1.23	0.23	0.93	1.23	0.10	0.98	1.23	0.42	1.02	1.23	0.022	1.03
Ultrafast												
Typ.	1.2	0.16	1.04	1.2	0.076	1.07	1.2	0.050	1.0	1.2	0.016	1.05
Max.	1.45	0.23	1.09	1.45	0.095	1.15	1.45	0.070	1.0	1.45	0.021	1.17

Rated Voltage: 600V $T_J = 150°C$ $V_{ge} = 15V$

As explained in Section II, C, the switching losses reported in the data sheet do not include the losses caused by the diode reverse recovery. These can be approximated by the following expression, that we supply without justification:

$$E_D = \frac{VI}{2}\left[\left(1 + \frac{I_{rr}}{I}\right) t_a - \left(1 - \frac{I_{rr}}{I}\right) \frac{t_b}{2}\right]$$

where V and I are supply voltage and load current. I_{rr} is the peak reverse recovery current and t_a and t_b are the two components of t_{rr}.

C. Thermal Design

It should be kept in mind that the IGBT, like the power MOSFET and the thyristor, is a thermally limited device. Hence, a good thermal design is the key to its cost effective utilization.

In general, the objective of the thermal design is the selection of the heatsink. Having calculated, with the help of the preceding section, the power dissipation, the maximum heatsink thermal resistance required to keep the junction temperature below a certain design limit can be calculated with the following formula:

$$R_{thS\text{-}A} = \frac{\Delta T_{j\text{-}a}}{P_d} - R_{thJ\text{-}C} - R_{thC\text{-}S}$$

The process of selecting the best device-heatsink combination may require an iterative use of the above formula.

In order to obtain a thermal resistance case-to-sink that is close to the data sheet value, the mounting torque should be close to what is specified. An excessive mounting torque causes the package to bow and may crack the die. An inadequate mounting torque, on the other hand, gives poor thermal performance.

The temperature rise due to pulses of short duration can be calculated with the transient thermal response curve. The section "Peak Current Rating" in application note AN-949A [6], originally written for International Rectifier HEXFET Power MOSFETs, describes the procedure in detail and is, in this respect, equally applicable to IGBTs. □

REFERENCES

[1] U.S. Patents No. 4,376,286 and 4,642,666

[2] AN-937A: Gate Drive Characteristics and Requirements

[3] AN-944: A New Gate Charge Factor

[4] AN-978: High Voltage Floating MOS-Gate Driver IC

[5] AN-967: PWM Motor Drive with HEXFET III

[6] Analysis and Characterization of Power MOSFET switching performance, by S.M. Clemente, A. Isidori, B.R. Pelly. Proceedings of Powercon 8, 1981, H2.

[7] AN-947 Understanding HEXFET Switching Performance

Protecting IGBTs Against Short Circuit

(HEXFET is a trademark of International Rectifier)

by G. Castino, A. Dubashi, S. Clemente, B. Pelly

Summary

Insulated Gate Bipolar Transistors (IGBTs) with the most rugged intrinsic short circuit performance generally have high saturation voltage and high operating losses, and vice versa.

This application note demonstrates that IGBTs with even modest intrinsic short-circuit capability can be fully protected against short circuit, allowing the most efficient, cost effective IGBTs to be used, without compromising ruggedness of the overall system.

Introduction

IGBTs are set to displace bipolar transistors and Darlingtons in applications such as variable speed motor controllers, uninterruptible power supplies, and high frequency welders. They generally offer comparable or lower power dissipation, higher operating frequency, and simplification of drive circuitry.

Systems using IGBTs offer greater compactness, greater efficiency, and superior dynamic performance than those with bipolar transistors.

The properties of the IGBT that make these advantages possible bring with them a new design consideration. An IGBT designed to maximize efficiency has a relatively high gain and this means a short-circuit current that is significantly greater than that obtained with a bipolar. The power density in the IGBT with an applied short circuit can therefore be much higher than that in a bipolar transistor.

An IGBT designed to minimize power dissipation under normal load conditions is unable to handle an unabated short circuit for as long as a bipolar transistor. The IGBT is not, therefore, as intrinsically fault-tolerant and will require a more "alert" protective circuit.

The purpose of this application note is to show how such a protective system can be implemented and to demonstrate that it can provide full short circuit protection, even for the most efficient high gain IGBT.

IGBT Short Circuit Characteristics

A test circuit for characterizing the short circuit capability of an IGBT is shown in Figure 1.

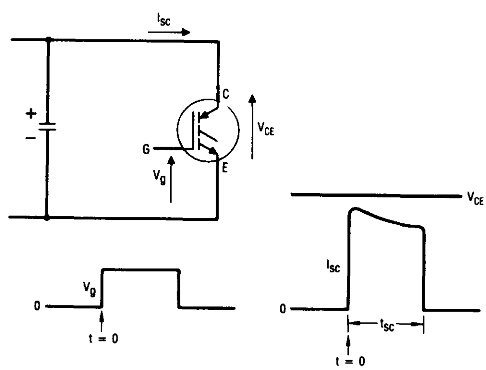


Figure 1. Typical short-circuit test for IGBT

A "stiff" voltage is applied from the reservoir capacitor, directly across the collector-emitter terminals of the device under test.

A pulse of voltage is applied to the gate (at a low repetition rate), and a pulse of "short-circuit" current flows. The short circuit time, t_{SC}, is gradually increased, until device failure occurs. The permissible short circuit time, for given values of collector-emitter voltage, gate voltage and starting temperature, can thus be determined.

This simple test circuit is useful for obtaining a first order assessment of the short circuit capability of an IGBT. It does not completely represent an actual application short-circuit condition because it does not apply dynamic dv/dt, which could induce the IGBT to latch-up. A more application-representative test circuit is described later.

This short circuit test will yield different results for IGBTs from the various manufacturers and different types. Generally, the higher the saturation voltage, $V_{CE(SAT)}$, of the IGBT the longer will be the permissible short circuit time.

Typical permissible short-circuit times, for different types of IGBTs, are shown in Figure 2. This data assumes that sufficient voltage is applied to the gate to keep the normal saturation voltage close to a practical minimum, and that this same gate drive voltage is maintained during the fault.

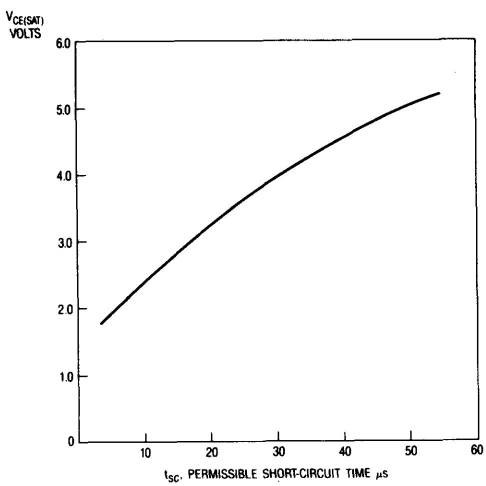


Figure 2. Typical IGBT short circuit time versus saturation voltage drop, $V_{CE(SAT)}$

Figure 2 indicates that an IGBT with a saturation voltage less than 2V typically has a permissible short circuit time of 5μS or less. An IGBT with a saturation voltage of 4 to 5V can have a short circuit time in the range of 30μS. (This is of the same order as for a typical bipolar transistor. But the saturation voltage is now higher than that of a bipolar).

Protecting Against Overcurrent - System Considerations

Different types of overcurrent condition will exist in a typical application. The most common type of overload is due to motor start-up, filter inrush current, step changes of load, and so on.

It is usually not feasible for the transistor (whatever type it is) to ride "brute force" through this type of situation, relying only upon its intrinsic short-circuit capability to carry it through. This type of overload typically lasts much longer than the transistor's intrinsic short-circuit time. The overload must be brought under proper control by other means.

A closed loop control is normally used that acts on the drive pulse timing signals to modify the switching instants and "hold back" the output current to a set level. The response of this control loop only has to keep pace with the rate of change of current that is naturally limited by motor or filter inductance.

This type of overload, when controlled as above, is not a threat to the integrity of the IGBT.

A second, more severe and more sudden type of overload is due to "mishaps," such as ground faults, or inadvertent terminal-to-terminal short circuits. Fault current now bypasses motor or filter inductance, and rises very rapidly in the transistor.

The regular PWM loop is powerless to protect against this type of fault. Protection must rely, in the first instance, upon the intrinsic short-circuit capability of the transistor, followed by rapid sensing of the fault and removal of the drive voltage, if the fault persists beyond the permitted short circuit period.

If the "fault" is a transient that clears itself before the permitted short-circuit period has expired, then the transistor should remain in conduction; turning it off would only constitute an unnecessary "nuisance" trip.

Diode reverse recovery current is an example of the type of transient overcurrent which should be ignored.

Referring to the characteristics of the IGBTs illustrated in Figure 2, the circuit designer's job is to provide an iron-clad protection circuit for an IGBT with the lowest $V_{CE(SAT)}$, and hence lowest t_{SC}, (but highest efficiency).

This circuit must provide reliable protection against real faults, yet be insensitive to spikes and "false alarms."

Stretching the IGBT's Short Circuit Time

The most-efficient IGBT, with the lowest saturation voltage drop, will typically have a short circuit time of less than 5μS. Allowing a suitable safety margin, the protection circuitry should react within 1 or 2μS maximum. One possibility is to remove the gate drive completely after 2μS, as represented by the waveforms in Figure 3(a). This would protect the IGBT, but a period of 1 or 2μS may generally be too short to distinguish properly between a real fault and a "false alarm." Nuisance trips could result as illustrated in Figure 3(b).

Possible Ways of Protecting the IGBT (Method 1)

- "Full" gate drive voltage for normal conduction
- Gate drive voltage rapidly removed in event of fault

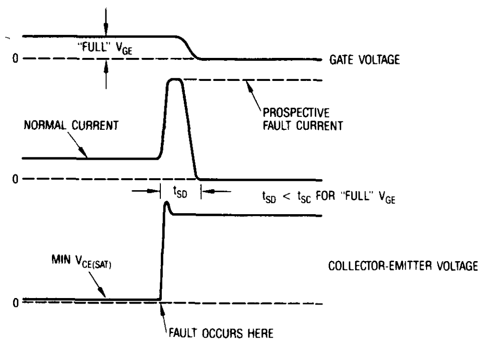


Figure 3a. Normal conduction losses minimized. Rapid fault shut-down.

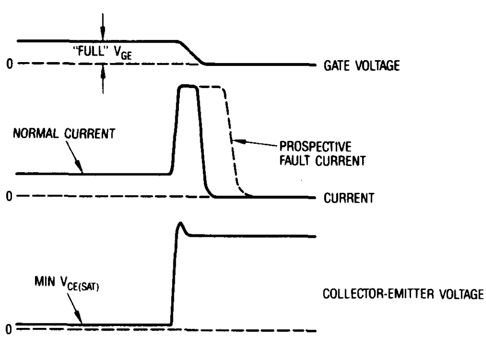


Figure 3b. Nuisance shut-down can occur under transient fault

The short circuit time can be stretched significantly by the simple expedient of reducing the gate voltage. Figure 4 illustrates that with reduced gate voltage, short circuit current is significantly reduced, and short circuit time is correspondingly increased.

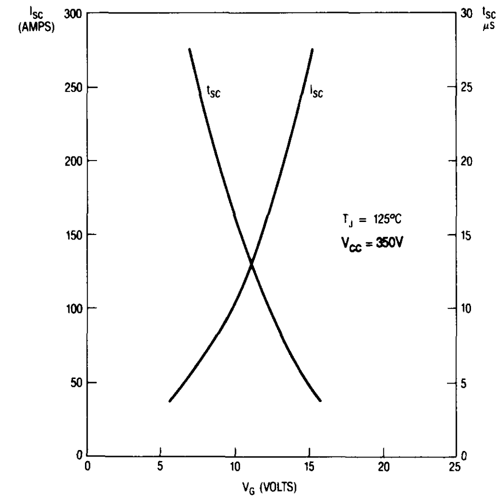


Figure 4. Typical relationships between gate voltage, V_G, short circuit current, I_{SC}, and permissible short-circuit time (IRGPC40F).

Reduction of the gate drive voltage, of course, increases $V_{CE(SAT)}$ which cannot be permitted for normal conduction.

The object is to reduce the gate drive voltage only when the "short circuit" occurs. This is illustrated by the operating waveforms in Figure 5(a, b). The short circuit period is now "stretched," prolonging the "fault inspection" period, at the end of which the IGBT must be turned off if the fault is still present.

The IGBT represented in Figure 3 has a short circuit time of about 5μS with full gate drive voltage of 15V, and about 15μS with gate drive voltage of 10V. Thus, if the gate voltage is reduced to 10V as soon as a fault is detected, the "fault inspection" period can be stretched to about 10μS (permitting a safety margin of about 5μS), allowing ample time for "rejection" of transient faults and false alarms. Operation is illustrated by the waveforms of Figure 5.

If the fault still persists after 10μS, the IGBT is turned off. If the fault disappears before that, full gate voltage is restored, and operation proceeds almost as if nothing had happened.

Possible Ways of Protecting the IGBT ***(Method 2)***

- "Full" gate drive voltage for normal conduction
- Gate drive voltage rapidly reduced in event of fault
- Gate drive voltage removed after delay, if fault persists

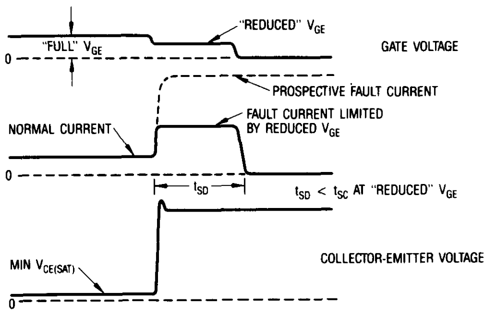


Figure 5a. Normal conduction losses minimized. Fault current reduced. Delayed fault shut-down.

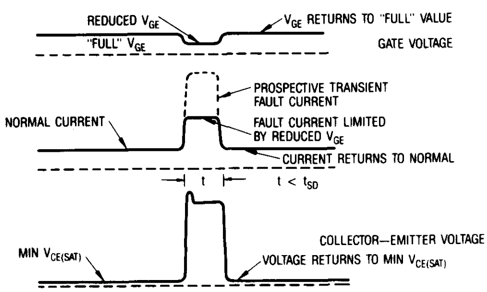


Figure 5b. Nuisance shut down avoided under transient fault

Protection Circuit Implementation

A functional schematic of a protection circuit is illustrated in Figure 6.

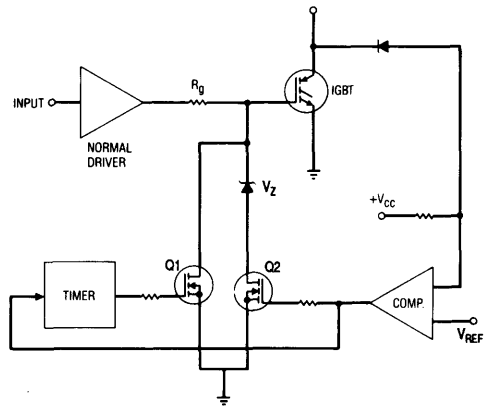


Figure 6. IGBT short circuit protection drive circuit schematic

During normal conduction, the saturation voltage of the IGBT is less than V_{ref}. The output of the comparator is low, and the small MOSFETs Q1 and Q2 are OFF. The IGBT's gate drive voltage is unmodified.

When an overload occurs, the collector-emitter voltage of the IGBT increases above V_{ref}, and the output of the comparator goes high. This initiates the timer; simultaneously Q2 is turned ON, reducing the IGBT's gate voltage to the zener voltage, V_Z.

If the fault disappears before the end of the timer period, the output of the comparator goes low, Q2 switches OFF, full gate drive voltage is restored, and normal operation proceeds.

If the fault is still present at the end of the timer period, the timer output goes high, Q1 switches ON and the IGBT's gate voltage is removed, turning it OFF.

Performance of Protection Circuit

Test circuit

The protection circuit shown in Figure 6 was tested in combination with International Rectifier's IGBT type IRFPC40F. This IGBT has a maximum permissible short circuit time, at V_{CC} = 350V and V_{GE} = 15V, of about 5μS, as illustrated in Figure 3.

The overall test circuit shown in Figure 7 was used to evaluate the operation of the protection circuit.

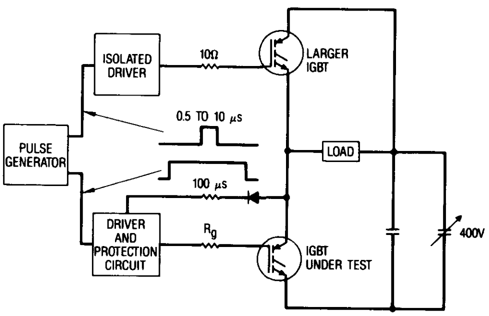


Figure 7. IGBT short-circuit test circuit

With reference to Figure 7, an input ON pulse of about 100µS is applied to the driver/protection circuit of the IGBT under test. About midway through this ON pulse, a drive pulse is applied to the larger IGBT, which short-circuits the load for a controlled period.

When this happens, it is the job of the protection circuit to immediately react by reducing the gate voltage of the device under test. It subsequently restores the full gate voltage, if the fault disappears before the end of the time-out period, or it removes the gate voltage at the end of the time-out period, if the fault still exists.

Test Results

The waveforms of Figures 8 through 13 illustrate the performance of the protection circuit.

Figure 8 shows a pulse of normal current of about 40A, with 110µS duration, and a superimposed short circuit of about 10µS duration occurring midway through the conduction period. The short circuit current initially rises to about 220A, but is quickly pulled back to about 60A by the action of the protection circuit. In this case, the gate voltage is pulled down to about 8V. After about 10µS, the short circuit is removed, the current returns to the normal load value, and full gate voltage is restored to the IGBT under test.

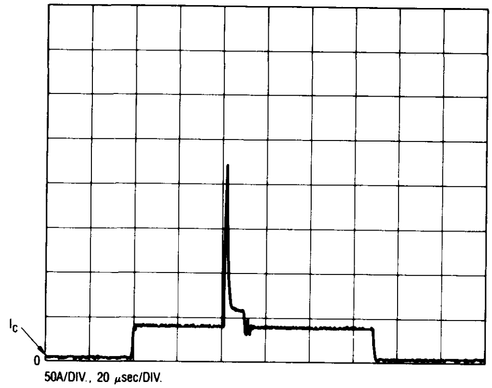


Figure 8. Load current with superimposed transient fault current. (IRFPC40F).

Figure 9 shows the collector-emitter voltage corresponding to the current waveform in Figure 8. The supply voltage is about 370V.

When the short circuit occurs, the voltage across the IGBT rises to the full supply voltage. When the fault is removed, the IGBT voltage falls back to the normal conduction voltage.

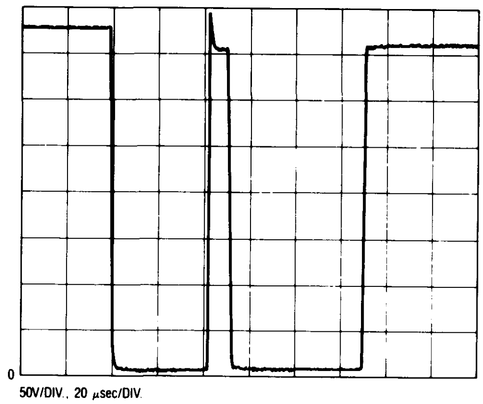


Figure 9. Collector-emitter voltage across device under test (IRGPC40F) with superimposed transient short-circuit.

Figure 10 shows the "prospective" short circuit current. This is the fault current through the IGBT when the protection circuit is disabled and 15V gate voltage is maintained during the fault.

The peak short circuit current is about 280A. Note that the time for which the short-circuit is applied has been reduced to about 5μS, so as not to exceed the capability of the IGBT with 15V gate voltage.

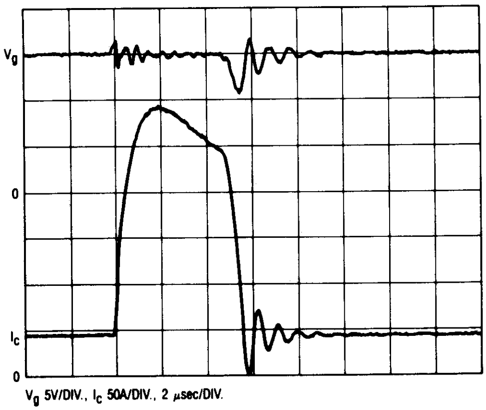


Figure 10. Prospective short-circuit current (i.e., without gate voltage reduction) under transient short circuit. (IRGPC40F)

Figure 11 shows the gate voltage and the collector current on an expanded time scale for approximately the same conditions as for Figures 8 and 9. Note the very effective current limiting action of the protection circuit relative to the prospective short circuit current.

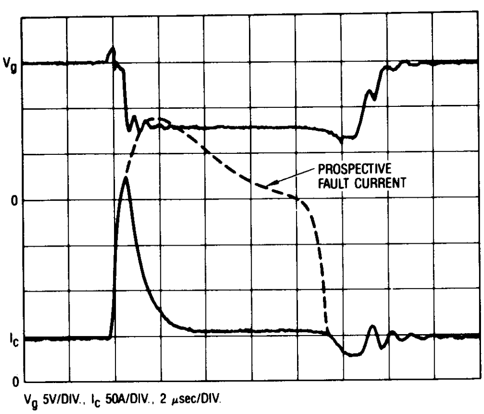


Figure 11. Actual fault current with gate voltage reduction from 15V to 8V under transient short-circuit, and superimposed prospective fault current with no gate voltage reduction. (IRGPC40F)

Figure 12 shows waveforms for a similar fault as for Figure 11, but with the gate voltage reduced to 10V during the fault.

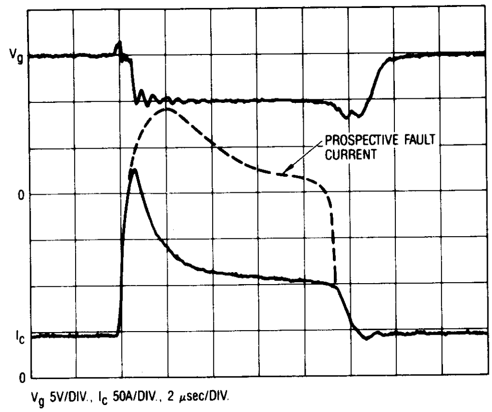


Figure 12. Actual fault current with gate voltage reduction from 15V to 10V under transient short circuit, and superimposed prospective fault current with no gate voltage reduction. (IRGPC40F).

Figure 13 shows the operation of the protection circuit when the duration of the short circuit exceeds the time-out period of the protection circuit. The gate voltage is removed at the end of the time-out period.

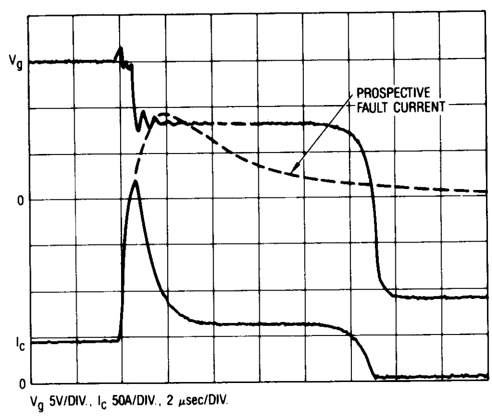


Figure 13. Actual fault current with gate voltage reduced from 15V to 8V under short-circuit, and superimposed prospective fault current with no gate voltage reduction. Short-circuit is permanent, and driver switches off after 10 μS (IRGPC40F).

Soft Turn-On

Peak diode reverse recovery current when turning on the IGBT into a diode-clamped inductive load can be limited by limiting the IGBT's gate drive voltage at turn-on.

This may sometimes be desirable, though use of this technique inevitably increases the total turn-on energy.

A test circuit for demonstrating the effect is shown in Figure 14. The gate drive circuit for the IGBT has the facility for limiting the drive voltage for the first 1 or 2μS at turn-on, prior to stepping up to full drive voltage.

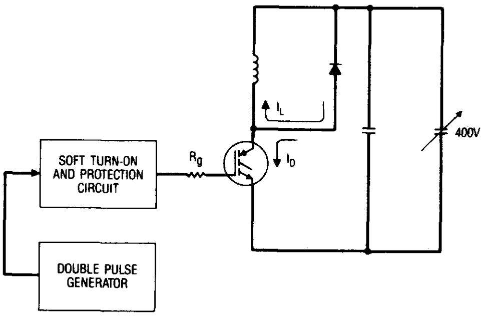


Figure 14. Soft turn-on test circuit.

Figure 15 shows oscillograms of IGBT voltage and current at turn-on, with 15V drive applied to the gate. The peak reverse recovery current of the diode is about 100A, and the total turn-on energy dissipated in the IGBT is about 22 mJ.

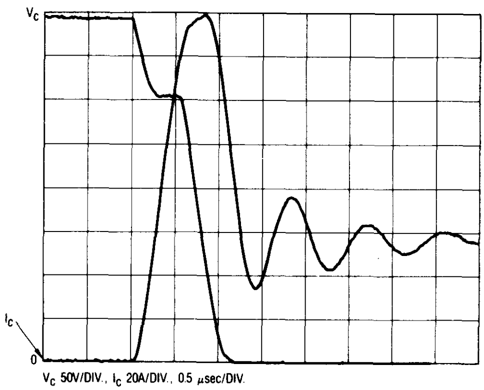


Figure 15. Collector voltage and current at turn-on with $V_{g(on)}$ = 15V. (IRGPC40F).

Figure 16 shows equivalent waveforms when the IGBT's gate drive voltage is held to 10V for the first 2μS before being stepped up to 15V. The peak reverse recovery current of the diode is reduced to about 30A. The total turn-on energy, however, increases more than twice, to about 52 mJ.

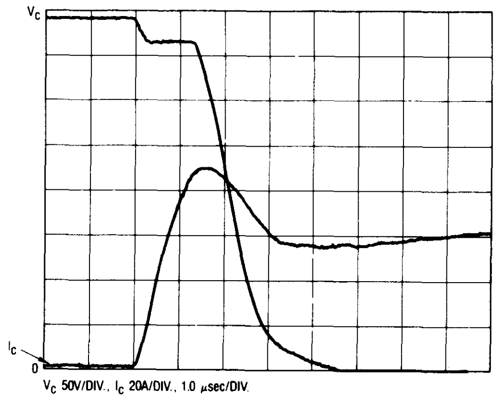


Figure 16. Collector voltage and current at turn-on with $V_{g(on)}$ = 10V. (IRGPC40F).

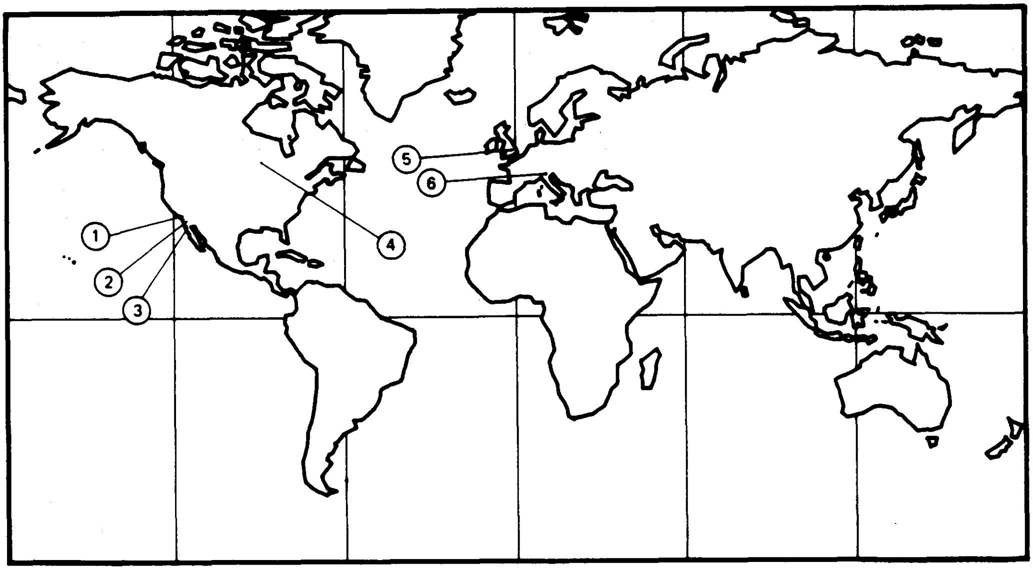
Conclusion

This application note demonstrates that it is possible to provide reliable short-circuit protection of an IGBT with modest intrinsic short-circuit capability, and correspondingly with low saturation voltage drop and high efficiency.

Thus the user is able to capitalize on the most efficient IGBTs without having to compromise overall system ruggedness. □

International Rectifier

...around-the-world manufacturing to serve worldwide needs.



① **El Segundo, California**
- 291,000 square feet
- Power MOSFETs, custom hybrids, rectifiers, thyristors, government/military/hi-rel devices, microelectronic relays

② **HEXFET America**
Rancho California, California
- 280,000 square feet
- Dedicated to power MOSFETs

③ **Tijuana, Mexico**
- 92,000 square feet
- Schottkys, thyristors, high power rectifiers

④ **Ontario, Canada**
- 20,000 square feet
- High voltage columns, open assemblies, heat sinks

⑤ **Oxted, England**
- 54,000 square feet
- Power MOSFETs, power modules, alloyed rectifiers

⑥ **Turin, Italy**
- 100,000 square feet
- Rectifiers, thyristors, diode bridges, power modules

INTERNATIONAL RECTIFIER, 233 KANSAS ST., EL SEGUNDO, CALIFORNIA 90245

International Rectifier

WORLDWIDE OPERATIONS

World Headquarters
El Segundo, CA 90245
233 Kansas Street
Tel: (213) 772-2000 Telex: 50-8104 FAX: (213) 772-9028

Canada
101 Bentley Street
Markham, Ontario, Canada L3R 3L1
Tel: (416) 475-1897 Telex: 069-66650 FAX: (416) 475-8801

California
Gilroy, CA 95020
8339 Church Street, Suite 204
Tel: (408) 848-8467 FAX: (408) 848-8501

El Segundo, CA 90245
200 Kansas Street
Tel: (213) 607-8885 FAX: (213) 607-8903

Florida
Kissimmee, FL 34743
800 Office Plaza Blvd., Suite 401
Tel: (407) 933-2383 FAX: (407) 933-2293

Illinois
Palatine, IL 60067
2401 Plum Grove Road, Suite 204
Tel: (708) 397-0002 FAX: (708) 397-0114

New Jersey
Palisades Park, NJ 07650
71 Grand Avenue
Tel: (201) 943-4554 FAX: (201) 943-5754

New York
Fishkill, NY 12524
2 Summit Court
Tel: (914) 896-4262 FAX: (914) 896-4277

North Carolina
Greensboro, NC 27407
2303 W. Meadowview Road, Suite 13
Tel: (919) 299-4762 FAX: (919) 292-6452

Ohio
Northfield, OH 44067
P.O. Box 687
Tel: (216) 467-0852 FAX: (216) 467-1865

Wisconsin
Brookfield, WI 53005
165 Bishops Way, Suite 122
Tel: (414) 784-2480 FAX: (414) 784-0744

European Headquarters
International Rectifier Company (Great Britain) Ltd.
Hurst Green, Oxted, Surrey RH8 9BB, England
Tel: (44) 883 713 215 Telex: 95219 FAX: (44) 883 714 234

France
123 rue de Petit Vaux
91360 Epinay sur Orge
Tel: (33) 164 548 329 Telex: 600943 FAX: (33) 164 548 330

Germany
Saalburgstrasse 157
D-6380 Bad Homburg
Tel: (49) 6172 37066 Telex: 410404 FAX: (49) 6172 37065

Hong Kong
202 Peter Building
60 Queens Road Central
Tel: (85) 252 36355 FAX: (85) 284 52908

Italy
Via Privata Liguria 49
10071 Borgaro, Turin
Tel: (39) 470 1484 Telex: 221257 FAX: (39) 470 4290

Via Zucca 8
20017 Rho Milano
Tel: (39) 02 9350 3650 FAX: (39) 02 9350 3655

Via Arno 1
40139 Bologna
Tel: (39) 051 49 3307 FAX: (39) 051 49 5480

India (Associate Company)
Ruttonsha-International Rectifier Private Ltd.
31 Greenacre, 5 Union Park
Khar (W), Bombay 400 052
Tel: (91) 22 535-026/533-779/540-242 Telex: 78064

Japan
K&H Building, 30-4 Nishi-Ikebukuro 3-Chome
Toshima-Ku, Tokyo 171
Tel: (81) 3983 0641 FAX: (81) 3983 0642

Singapore
HEX 10-01 Fortune Center
190 Middle Road, Singapore 0718
Tel: (65) 336-3922/2924, 338-5986 Telex: 35620 FAX: (65) 337 4692

Sweden
Box 86, S-162 12
Villingby 1, Stockholm
Tel: (46) 8 870035 Telex: 13164 FAX: (46) 887 4242

IGBT DESIGNER'S MANUAL IGBT-2

International
IOR Rectifier

WORLD HEADQUARTERS: 233 KANSAS ST., EL SEGUNDO, CA 90245, U.S.A. (213) 772-2000. TWX 910-348-6291. TELEX 472-0403
EUROPEAN HEADQUARTERS: HURST GREEN, OXTED, SURREY RH8, 9BB. ENGLAND TELEPHONE (0883) 713215. TELEX 95219