Insulated Gate
Bipolar Transistor (IGBT)
ST2701

Learning Material
Ver 1.1

An ISO 9001:2008 company
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Standard: **ISO 9001:2008**

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Insulated Gate Bipolar Transistor

ST2701
Table of Contents

Introduction

Insulated Gate Bipolar Transistor (IGBT) is a compact, ready to use experimenalt board. This is useful for students for the study of the characteristics of IGBT and to understand its different operating regions. It can be used as a stand alone unit with external DC power supply.

Theory

The insulated gate bipolar transistor (IGBT) combines the positive attributes of BJTs and MOSFETs. BJTs have lower conduction losses in the ‘On’-state, especially in devices with larger blocking voltages, but have longer switching times, especially at turn-‘Off’ while MOSFETs can be turned on and off much faster, but their on-state conduction losses are larger, especially in devices rated for higher blocking voltages. Hence, IGBTs have lower on-state voltage drop with high blocking voltage capabilities in addition to fast switching speeds and has become the most favored power device in Industrial application.

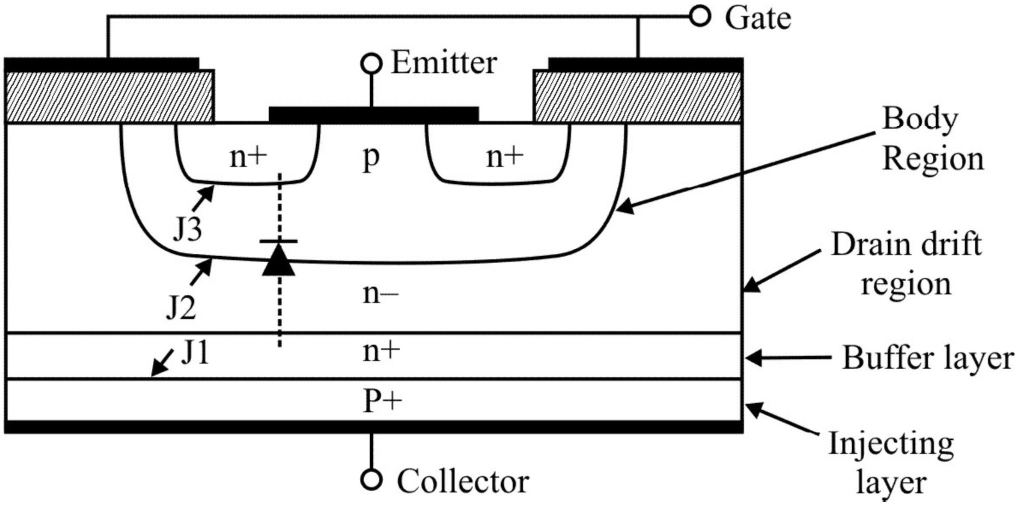
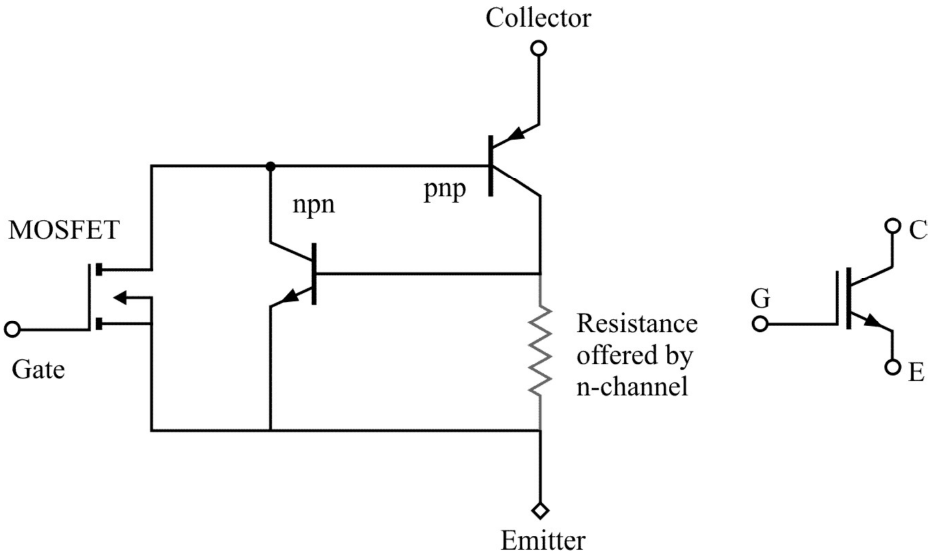


Figure 1

The vertical cross sectional structure of an IGBT is shown in Figure 1 having four alternate p-n-p-n layers with three terminals Emitter, Collector and Gate. A heavily doped p+ substrate has a lightly doped n-type drift region grown on to it by epitaxial process. Then the p-type emitter is diffused with two subsequent n-type layers over doping windows. Two silicon dioxide layers are then deposited, and deposition of the metal forms an interconnected gate as shown in Figure 2

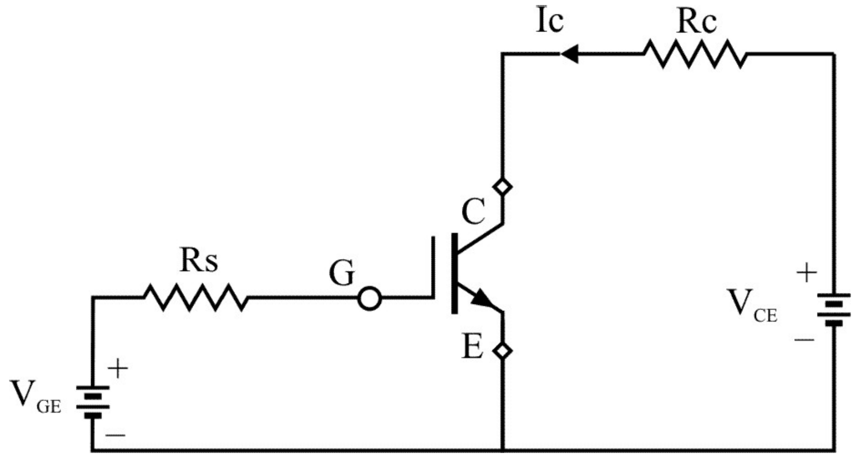
The performance of an IGBT is closer to that of a BJT rather than a MOSFET. The circuit symbol of an IGBT are shown in the below Figure 2. When the gate is positive with respect to the emitter and this voltage is beyond the threshold value, an n-channel is induced in the p-region of a MOSFET. These charge carriers forward bias the base-emitter junction of the p-n-p transistor and holes are injected into the n-type drift region.



(a) Equivalent Circuit **(b) Circuit Symbol of IGBT**

Figure 2

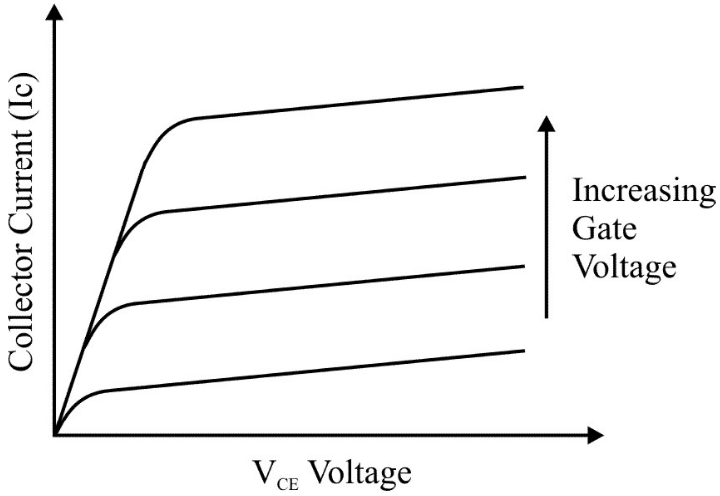
These injected holes cross the reverse biased collector junction of the p-n-p transistor and constitute the collector current. This collector current is the base current for the n-p-n transistor, which is properly biased in the active region. This amplifying collector current flows from the n-p-n transistor to the base of the p-n-p transistor, hence a positive feedback exits and the device turns ON.



Basic circuit

Figure 3

When a positive voltage is applied to the collector terminal with the gate short circuited (V_{GE} = 0) to the emitter terminal, the upper junction (J2) becomes reverse biased and the device operates in forward blocking mode i.e. there is no current flow between collector and emitter. If we set a positive voltage to V_{GE} & V_{CE} then a current (Ic) will flow in collector terminal. For a value less then the threshold level the collector current of an IGBT is 0mA.If we hold V_{GE} constant and increasing the V_{CE} then Ic will reach a saturation level. So with increase in V_{CE} and keeping the V_{GE} to the threshold value the collector current (Ic) will reach the saturation level. Further increase in Gate voltage the value of collector current will increase. The V-I characteristics of the IGBT is given below.



Output V-I Characteristics of IGBT

Figure 4

Experiment

Objective :

Study of the characteristics of IGBT

Equipments Needed :

1. Power Electronics board **ST2701**.
2. Digital Multi-meter.
3. 2 mm patch cords.

Circuit diagram :

Circuit used to plot the characteristics of an IGBT is shown in Figure 5.

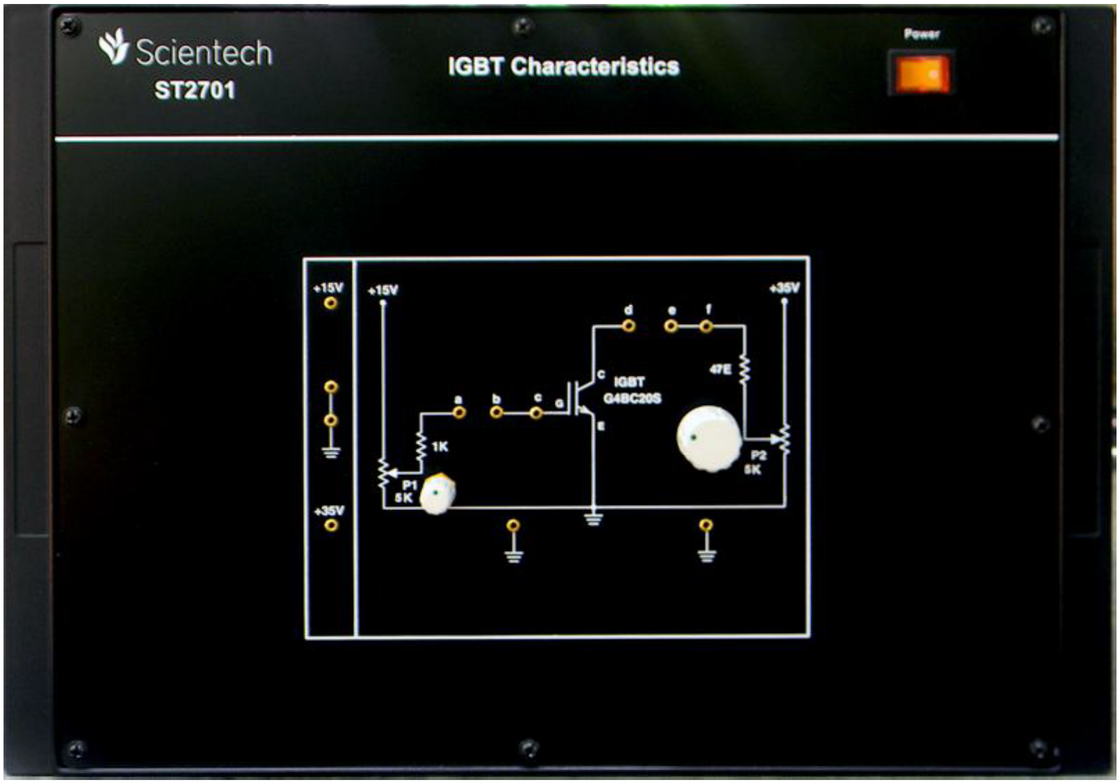


Figure 5

Procedure :

1. Rotate the potentiometer ‘P1’ fully in clockwise direction and ‘P2’ fully in counter clockwise direction.
2. Connect Ammeter between point d and e to measure collector current Ic (mA).
3. Connect a 2mm patch cord between point ‘a’ and ‘b’.
4. Connect voltmeter between point c and ground to measure the Gate voltage V_{GE} and between point f and ground.
5. Switch ‘On’ the power supply.
6. Vary the potentiometer ‘P_{1}’ in counterclockwise direction to set the gate voltage V_{GE} (between 4.8V and 5.6V).
7. Vary the potentiometer ‘P2’ in clockwise direction so as to increase the value of collector-emitter voltage V_{CE} from 0 to 35V in step and measure the corresponding values of collector current Ic for different constant value of gate voltage V_{GE} in an Observation Table 1.
8. Rotate the potentiometer ‘P2’ fully in the counterclockwise direction and potentiometer ‘P1’ fully in clockwise direction.
9. Repeat the procedure from step 6 for different sets of gate voltage VGE.
10. Plot a curve between collector-emitter voltage current (V_{CE}) and Collector current Ic using suitable scale with the help of observation Table 1. This curve is the required collector characteristic.

Observation Table 1 :

S.No.	Collector Voltage V_{CE}	Collector Current Ic (mA) at constant value of Gate Voltage V_{GE} (volt)		
		$V_{GE =}$ V	$V_{GE =}$ V	$V_{GE =}$ V
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				

Data Sheet

International
IOR Rectifier

PD - 91597A

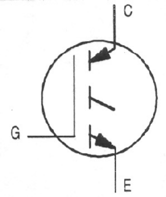
IRG4BC20S

INSULATED GATE BIPOLAR TRANSISTOR

Standard Speed IGBT

Features

- Standard: optimized for minimum saturation voltage and low operating frequencies (< 1kHz)
- Generation 4 IGBT design provides tighter parameter distribution and higher efficiency than Generation 3
- Industry standard TO-220AB package



n-channel

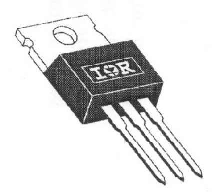
V_{CES} = 600V

$V_{CE(on)\ typ.}$ = 1.4V

@V_{GE} = 15V, I_C = 10A

Benefits

- Generation 4 IGBTs offer highest efficiency available
- IGBTs optimized for specified application conditions
- Designed to be a "drop-in" replacement for equivalent industry-standard Generation 3 IR IGBTs



TO-220AB

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Breakdown Voltage	600	V
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	38	
I_{LM}	Clamped Inductive Load Current ②	38	
V_{GE}	Gate-to-Emitter Voltage	± 20	V
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 seconds	300 (0.063 in. (1.6mm) from case)	
	Mounting torque, 6-32 or M3 screw.	10 lbf•in (1.1N•m)	

Thermal Resistance

	Parameter	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	—	2.1	°C/W
$R_{\theta CS}$	Case-to-Sink, Flat, Greased Surface	0.50	—	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	—	80	
Wt	Weight	2.0 (0.07)	—	g (oz)

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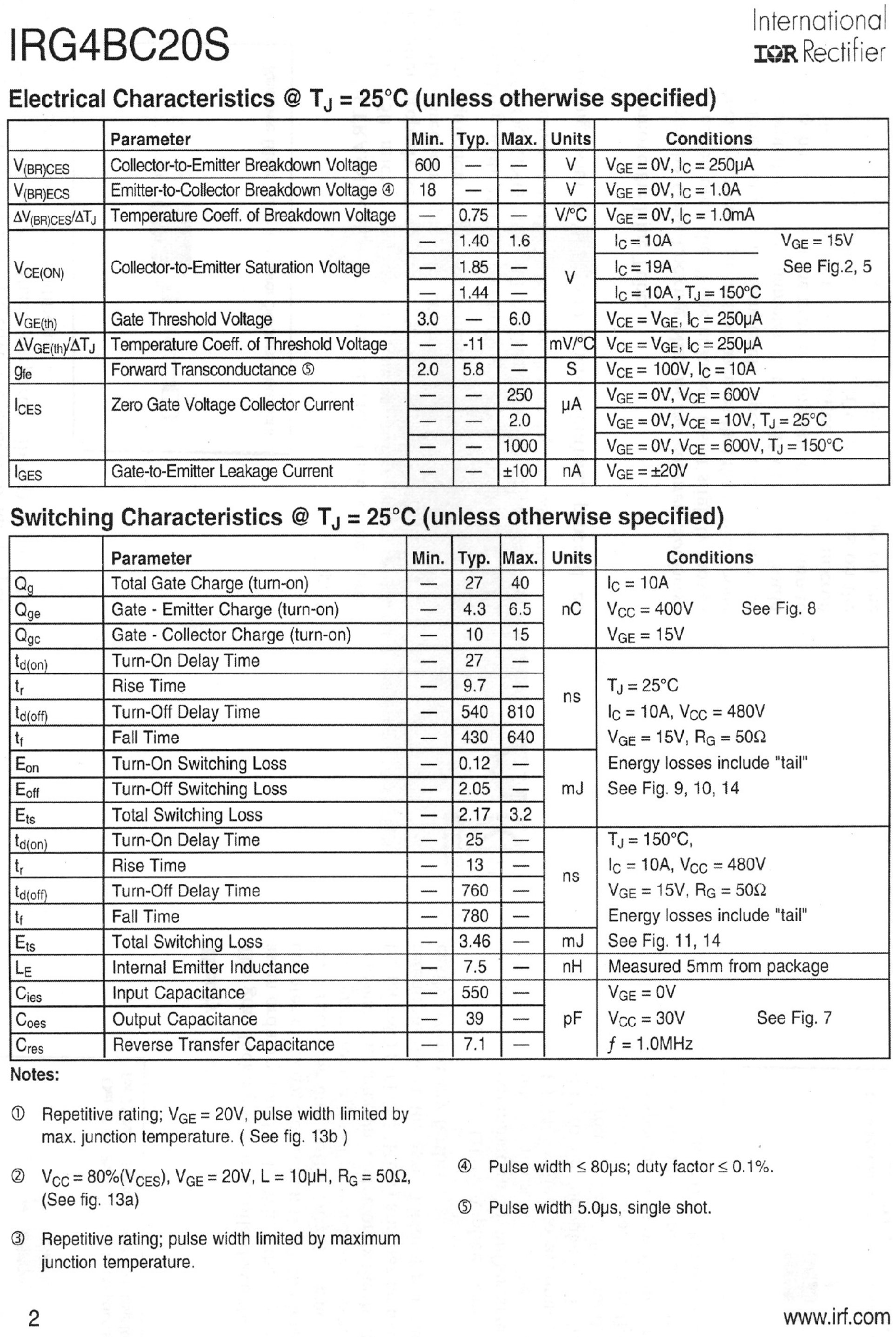

IRG4BC20S

International IOR Rectifier

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

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage	600	—	—	V	V_{GE} = 0V, I_C = 250μA
$V_{(BR)ECS}$	Emitter-to-Collector Breakdown Voltage ④	18	—	—	V	V_{GE} = 0V, I_C = 1.0A
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.75	—	V/°C	V_{GE} = 0V, I_C = 1.0mA
$V_{CE(ON)}$	Collector-to-Emitter Saturation Voltage	—	1.40	1.6	V	I_C = 10A V_{GE} = 15V
		—	1.85	—		I_C = 19A See Fig.2, 5
		—	1.44	—		I_C = 10A , T_J = 150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	—	6.0		V_{CE} = V_{GE}, I_C = 250μA
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	—	-11	—	mV/°C	V_{CE} = V_{GE}, I_C = 250μA
g_{fe}	Forward Transconductance ⑤	2.0	5.8	—	S	V_{CE} = 100V, I_C = 10A
I_{CES}	Zero Gate Voltage Collector Current	—	—	250	μA	V_{GE} = 0V, V_{CE} = 600V
		—	—	2.0		V_{GE} = 0V, V_{CE} = 10V, T_J = 25°C
		—	—	1000		V_{GE} = 0V, V_{CE} = 600V, T_J = 150°C
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V

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

	Parameter	Min.	Typ.	Max.	Units	Conditions
Q_g	Total Gate Charge (turn-on)	—	27	40	nC	I_C = 10A
Q_{ge}	Gate - Emitter Charge (turn-on)	—	4.3	6.5		V_{CC} = 400V See Fig. 8
Q_{gc}	Gate - Collector Charge (turn-on)	—	10	15		V_{GE} = 15V
$t_{d(on)}$	Turn-On Delay Time	—	27	—	ns	
t_r	Rise Time	—	9.7	—		T_J = 25°C
$t_{d(off)}$	Turn-Off Delay Time	—	540	810		I_C = 10A, V_{CC} = 480V
t_f	Fall Time	—	430	640		V_{GE} = 15V, R_G = 50Ω
E_{on}	Turn-On Switching Loss	—	0.12	—	mJ	Energy losses include "tail"
E_{off}	Turn-Off Switching Loss	—	2.05	—		See Fig. 9, 10, 14
E_{ts}	Total Switching Loss	—	2.17	3.2		
$t_{d(on)}$	Turn-On Delay Time	—	25	—	ns	T_J = 150°C,
t_r	Rise Time	—	13	—		I_C = 10A, V_{CC} = 480V
$t_{d(off)}$	Turn-Off Delay Time	—	760	—		V_{GE} = 15V, R_G = 50Ω
t_f	Fall Time	—	780	—		Energy losses include "tail"
E_{ts}	Total Switching Loss	—	3.46	—	mJ	See Fig. 11, 14
L_E	Internal Emitter Inductance	—	7.5	—	nH	Measured 5mm from package
C_{ies}	Input Capacitance	—	550	—	pF	V_{GE} = 0V
C_{oes}	Output Capacitance	—	39	—		V_{CC} = 30V See Fig. 7
C_{res}	Reverse Transfer Capacitance	—	7.1	—		f = 1.0MHz

Notes:

① Repetitive rating; V_{GE} = 20V, pulse width limited by max. junction temperature. (See fig. 13b)

② V_{CC} = 80%(V_{CES}), V_{GE} = 20V, L = 10μH, R_G = 50Ω, (See fig. 13a)

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

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

⑤ Pulse width 5.0μs, single shot.

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