Determination of output characteristics of IGBT

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Abstract

In the modern era IGBTs are pervasively and more extensively used power semiconductor device used in power electronics domain. It finds use in wide range of applications due to its dynamic and fast switching characteristics. Therefore, IGBT devices are widely used in electronics sector owing to its high efficiency switching. The research presented in this paper is determination of output characteristics of IGBT. The findings of the experiment reveal that IGBT devices are voltage controlled and their switching behavior is determined by the voltage applied to the gate terminal. The output characteristic curve of IGBT exhibits the relationship between collector emitter voltage V_{CE} ad collector current I_C under different gate emitter voltages V_{GE}.

Keywords: *IGBT, Power semiconductor device, fast switching characteristics, gate terminal voltage controlled.*

1. Introduction

IGBT in the field of power electronics has a wide range of application scenarios. The basic operating principles of IGBTs and its design is of vital importance and needs studied thoroughly [1], [2]. Insulated Gate Bipolar transistors (IGBTs) are three terminal power semiconductor devices having positive attributes of both Bipolar junction transistors (BJTs) and Metal oxide semiconductor field effect transistors (MOSFETs). IGBTs offer faster switching times and possess high input impedance similar to that of MOSFETs and lower ON state voltages and larger blocking voltages similar to that of BJTs. IGBTs are used in high efficiency and fast switching applications like switched mode power supplies, traction motor control and induction heating as well as medium power applications such as DC and AC motor drives, power supplies, solid state relays and contractors [3], [4]. The salient features of IGBT device are enumerated below

- Controlled turn on and controlled turn off.
- Continuous gate signal requirement.
- Unidirectional current capability.
- Unipolar voltage withstanding capability.

2. IGBT overview

2.1 IGBT structure

Figure 1 shows the cross section view of an N-channel IGBT device. The three terminals of IGBT are gate, collector and emitter. The construction of IGBT is very similar to Power MOSFET with the only difference that the N+ drain is replaced by the P+ collector layer, thus forming a vertical PNP transistor [5].

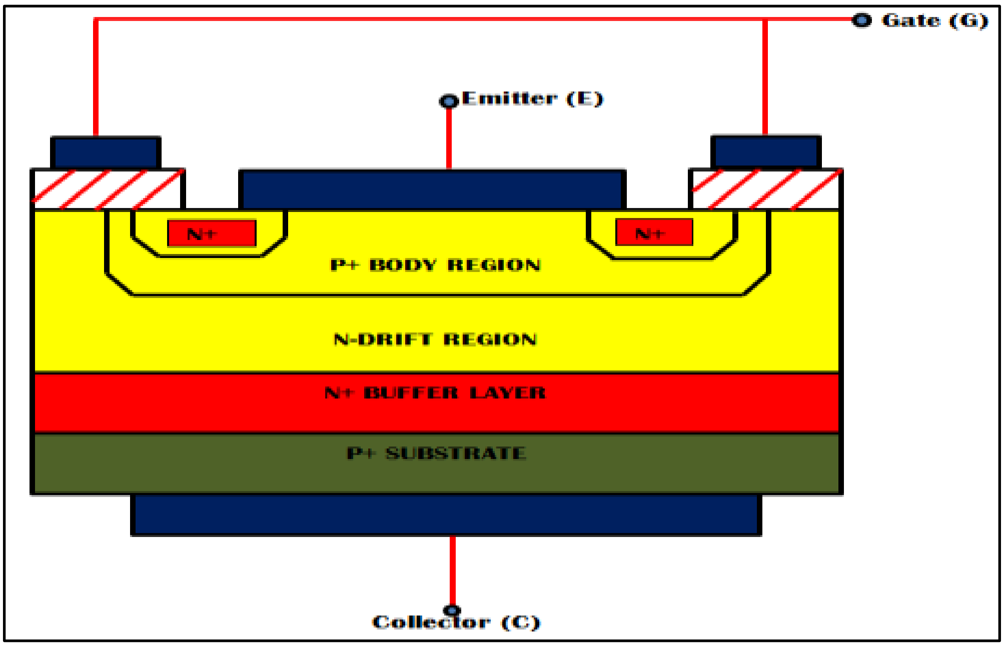

Figure 1 Cross section of N-channel IGBT

Figure 2 illustrates the simplified equivalent circuit for the N-channel IGBT. The equivalent circuit shows a N-channel power MOSFET driving a wide base PNP transistor in a Darlington configuration.

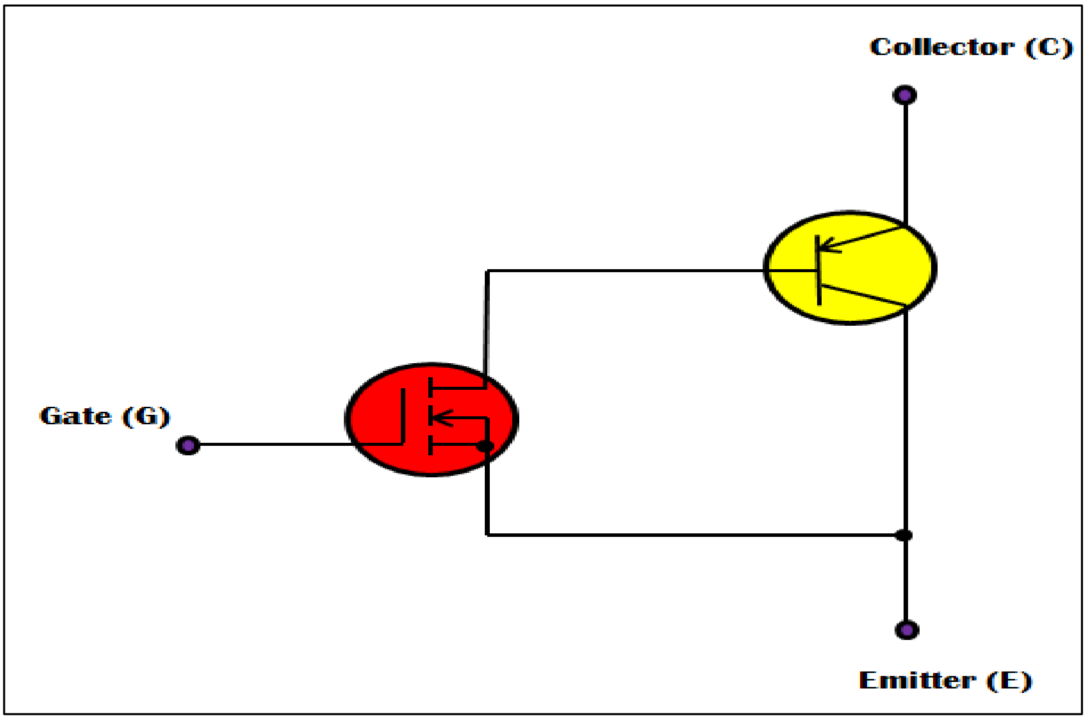

Figure 2 Simplified equivalent circuit of an N-channel IGBT

2.2 IGBT working

The ON/OFF state of the device is controlled by the applied gate voltage with respect to the emitter voltage. If the gate emitter voltage is less than the threshold voltage (V_{TH}) of the MOSFET, no inversion layer is created and the device is in the OFF state. When the gate-emitter voltage is above the threshold voltage (V_{TH}), enough electrons will be drawn towards the gate to form a conductive channel across the body region, leading to the flow of current between the collector and the emitter terminals [6], [7].

IGBTS offer slower switching speeds especially during turn-off. Turn-Off in the case of IGBTs is achieved by decreasing the gate- emitter voltage below the threshold voltage. The electron flow in an IGBT as in the case of N-channel E-MOSFET stops abruptly. However, in an IGBT holes are left in the drift region and they can only be removed by the process of recombination or by applying a voltage gradient. This result in a tail current in IGBTs during turn- OFF till all the holes is removed. An N+ buffer layer is added in some IGBTs to control the rate of recombination of holes by absorbing trapped holes during turn-off. IGBTs with N+ buffer layer are called Punch through IGBTs (PT-IGBTs) and those without N+ buffer layer are called Non-punch through IGBTs (NPT-IGBTs). PT-IGBTs are also referred to as asymmetrical IGBTs and NPT-IGBTs as symmetrical IGBTs [8].

2.3 Characteristic curves

The typical output characteristics of an N-channel IGBT device is depicted in figure 3. These characteristics are quite similar to the output characteristics of an N-channel E-

MOSFET. A typical feature of the output characteristics of IGBT is the offset of approximately 0.7 volt from the origin and the steep slope of the rising portion of the characteristics. The offset is due to the fact that the ON state voltage across the IGBT is one diode drop higher than that of N-channel E-MOSFET. The steep slope of the characteristics is attributed to the fact that the current flow in an IGBT is due to the flow of both electrons and holes as compared to an N-channel E-MOSFET where the current flow is due to the flow of electrons only. This reduces the effective resistance to the current flow in the drift region. The resulting reduction in the ON-state voltage is the noteworthy and important advantage of IGBTs as compared to power MOSFETs [7], [8], [9], [10].

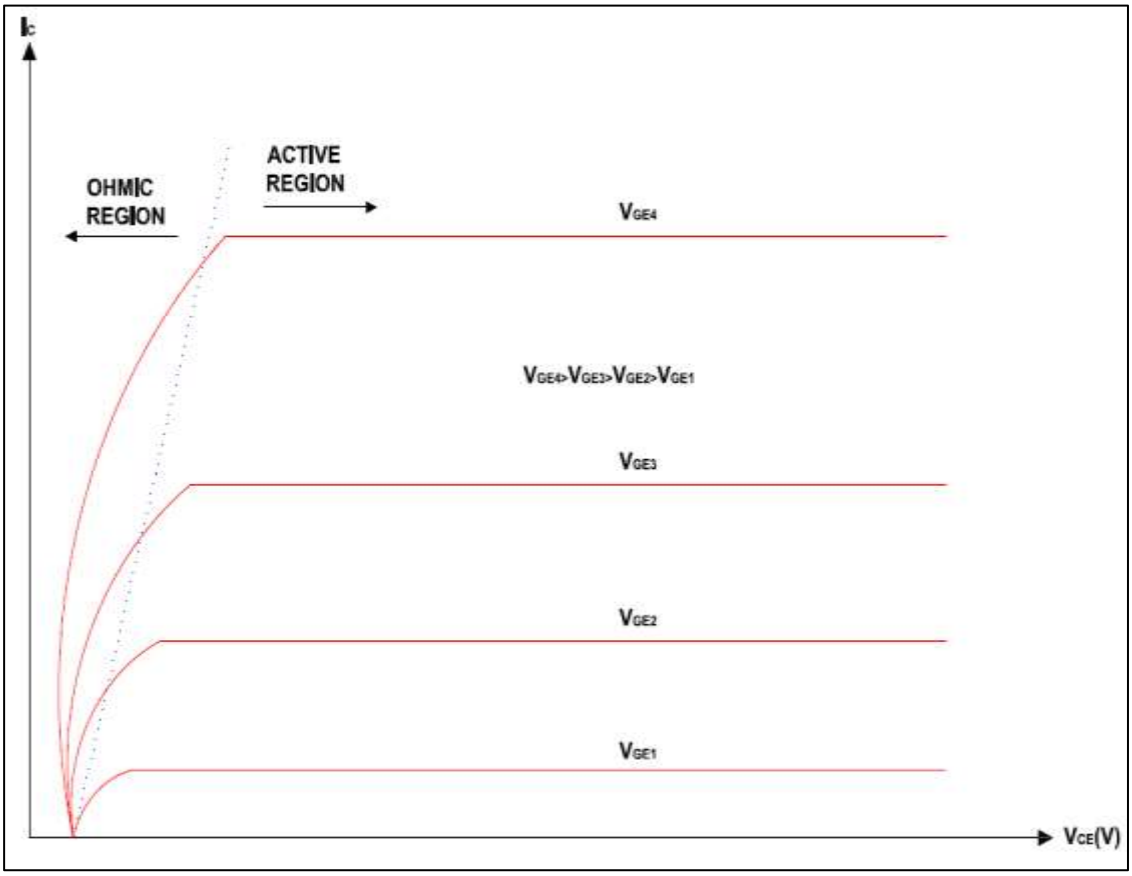

Figure 3 Output characteristics of an N-channel IGBT.

3. Proposed System Design

3.1 Hardware design

Based on the hardware design the circuit schematic for the system is shown in figure 4.

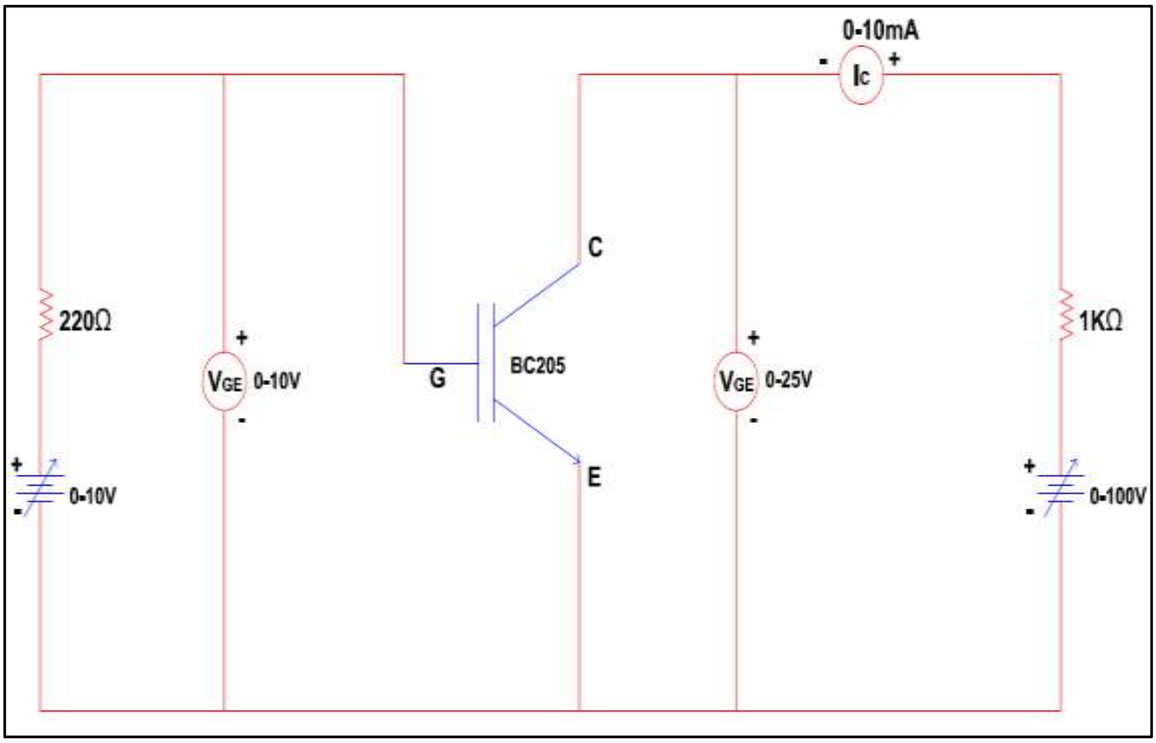

Figure 4 Circuit schematic

3.2 System specifications

Table 1 illustrates the system specifications

Table 1. System Specifications

Sl. No	Component
1.	Domain: Power Electronics, Electronic circuits.
2.	Power electronics device: IGBT
3.	Breadboard
4.	Resistors: 220Ω, 1KΩ.
5.	DC power supply Battery.
6.	Multimeters: Voltmeters (0-25V) and (0-10V), Ammeter (0-10mA).
7.	Connecting wires, connecting probes.
8.	Crocodile clips
9.	Software tool: MATLAB

3.3 System set up

The experimental set up was done in Power electronics laboratory. According to the hardware design the required components were taken and the resistor values were checked using a multimeter. The system was rigged up as per the circuit schematic on a breadboard and the IGBT device with its three terminals gate, collector and emitter was carefully placed on the breadboard. The IGBT device used in the study is shown in figure 5.

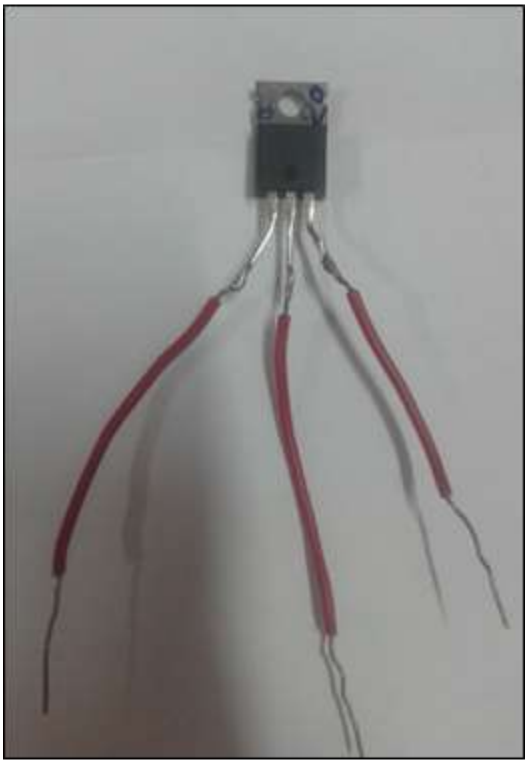

Figure 5: IGBT device implemented for the study

The supply voltage was provided using a DC regulated power supply. Special care was taken in connecting the voltmeters and ammeters according to the polarity as per the circuit schematic. The DC regulated power supply which is used in the system set up is having two voltage sources in the form of a dual battery namely V_1 and V_2. Figure 6 and 7 respectively shows the DC regulated power supply and the photographic view of the system set up.

Figure 6 Photographic view of DC regulated power supply

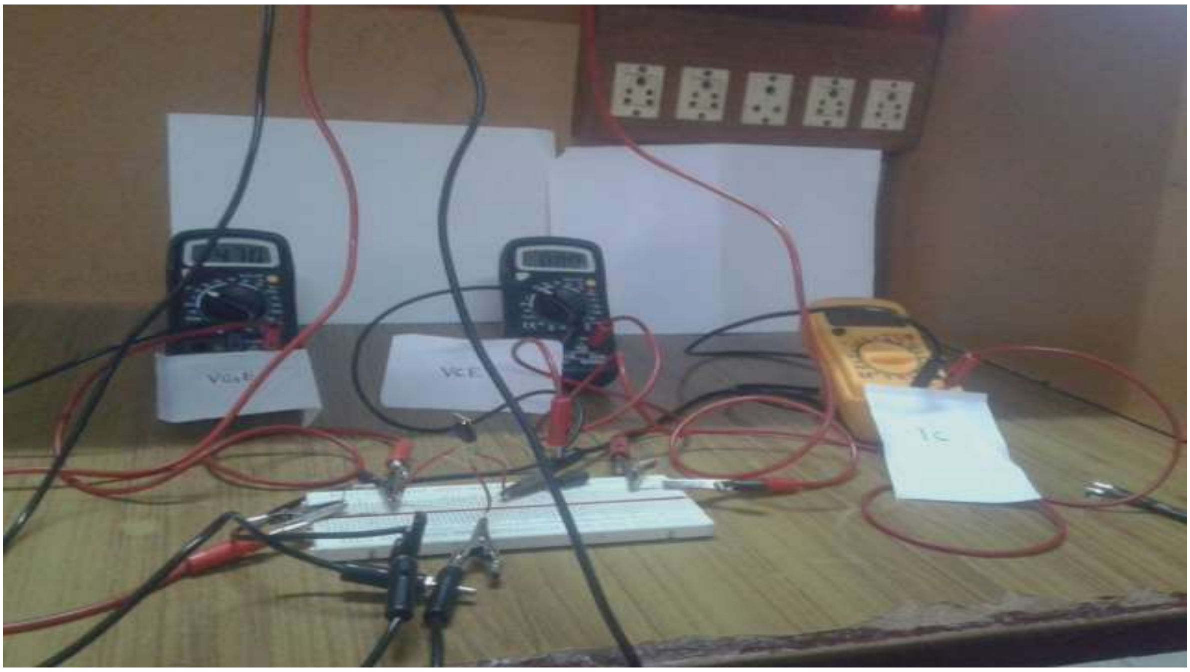

Figure 7 Photographic view of the System set up

4. Experimental Results

Using the DC regulated power supply initially $V_1 = V_{GE}$ was set to 4.70V. Voltage V_2 was slowly varied and the corresponding collector current I_C was noted down along with the corresponding values of collector emitter voltage V_{CE}. The same procedure was repeated for another set of values of gate emitter voltage (4.80 and 4.90 respectively) and the current I_C was noted down along with the corresponding values of V_{CE}. The results obtained for parameters such as collector emitter voltage V_{CE} and collector current I_C for the set values of gate emitter voltage V_{GE} are tabulated in table 2.

Table 2 Variations of V_{CE} and I_C

Sl. No	**V_{GE} = 4.70 Volts**		**V_{GE} = 4.80 Volts**		**V_{GE} = 4.90 Volts**	
	V_{CE} in volts	**I_C in mili amps**	**V_{CE} in volts**	**I_C in mili amps**	**V_{CE} in volts**	**I_C in mili amps**
1.	0.0	0.00	0.0	0.00	0.0	0.00
2.	0.1	0.00	0.1	0.00	0.1	0.00
3.	0.2	0.03	0.2	0.04	0.2	0.03
4.	0.3	0.04	0.3	0.08	0.3	0.14
5.	0.4	0.10	0.4	0.20	0.4	0.21
6.	0.5	0.12	0.5	0.23	0.5	0.44
7.	0.6	0.12	0.6	0.25	0.6	0.44
8.	0.8	0.12	0.7	0.25	0.7	0.45
9.	0.9	0.12	0.8	0.25	0.8	0.45
10.	1.0	0.12	0.9	0.25	0.9	0.45
11.	1.1	0.12	1.1	0.25	1.0	0.45
12.	1.3	0.12	1.2	0.25	1.1	0.45
13.	1.5	0.12	1.3	0.25	1.3	0.45
14.	1.6	0.12	1.4	0.25	1.5	0.45
15.	1.7	0.12	1.7	0.25	1.7	0.45

The figures 8 and 9 shows the photographic view of results for one of the values of V_{CE} and I_C when V_{GE} set to 4.70V.

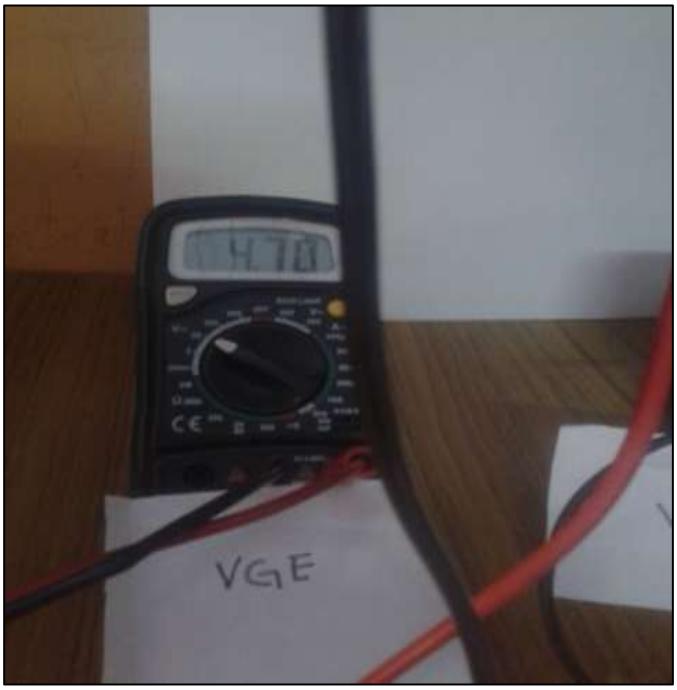

Figure 8 Gate to emitter voltage $V_{GE=}$ 4.70V

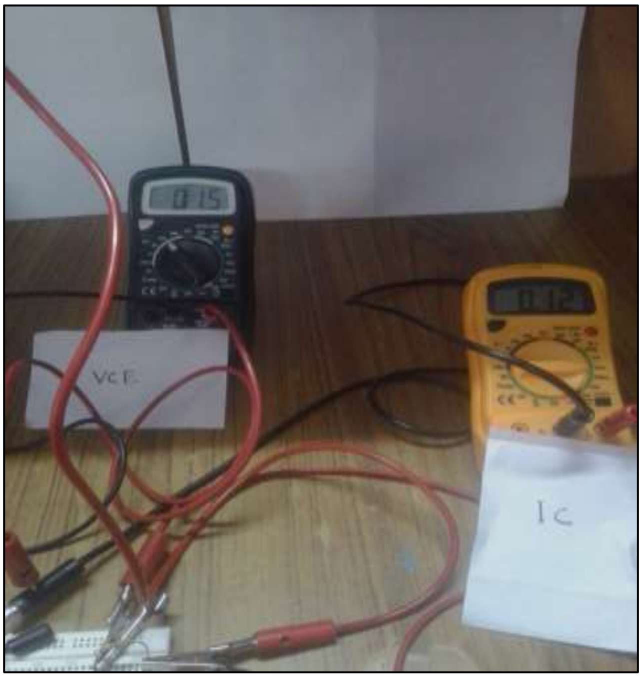

Figure 9 V_{CE} and I_C for $V_{GE=}$ 4.70V

Figures 10 and 11 illustrate the photographic view of results for one of the values of V_{CE} and I_C when V_{GE} set to 4.90V.

Figure 10 Gate to emitter voltage $V_{GE=}$ 4.90V

Figure 11 V_{CE} and I_C for $V_{GE=}$ 4.90V

Based on the readings obtained from the experimental results tabulated in table 2 the output characteristics were plotted for various values of collector emitter voltage V_{CE} versus the collector current I_C for the set values of gate emitter voltage V_{GE} for the three set of readings. MATLAB software tool was used for plotting the result in graphical form as illustrated in figure 12.

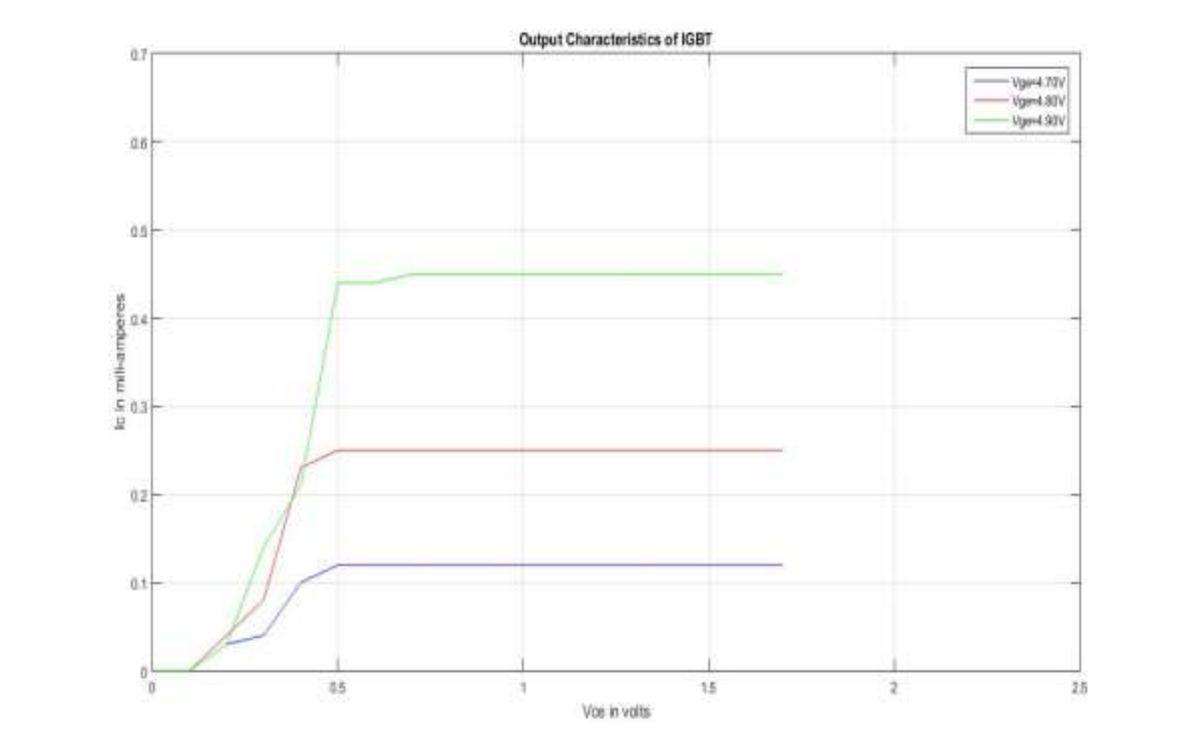

Figure 12 Graphical representation of output characteristics of IGBT.

4. Conclusion

The circuit for obtaining the output characteristics for IGBT was designed and implemented. From the experimental results it can be concluded that keeping the gate emitter voltage fixed, as the collector emitter voltage was increased steadily there was a rise in collector current and after a certain increase in the value of gate emitter voltage the collector current was saturated. This is evident from the results displayed in the tabular column. Lastly, the output characteristics were plotted. The circuit which is used to determine the output characteristics is quite simple, easy to design requiring few components and requires less cost. Furthermore the designed system is very stable and reliable and easy to use and implement.

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