IGBT

1. Introduction

An Insulated Gate Bipolar Transistor (IGBT) is a three terminal device that combines the MOSFET's advantages of high input impedance and high switching speed with BJT's advantages of high conductivity characteristics i.e. low saturation voltage.

Its name additionally indicates that they are merged.

2. IGBT definition

The term "insulated gate" describes a MOSFET's very high input impedance input part. It operates on the voltage at its gate terminal instead of drawing any input current.

"Bipolar" describes the output part of the PNP BJT that is bipolar, meaning that both kinds of charge carriers contribute to the current flow. It enables it to use low voltage signals to handle large currents and voltages. Because of its hybrid design, the IGBT is a voltage-controlled device.

A thin silicon oxide layer insulates this gate so this how it has a gate like MOSFET and a collector & an emitter like a BJT.

As shown in the following figure this is the IGBT equivalent structure.

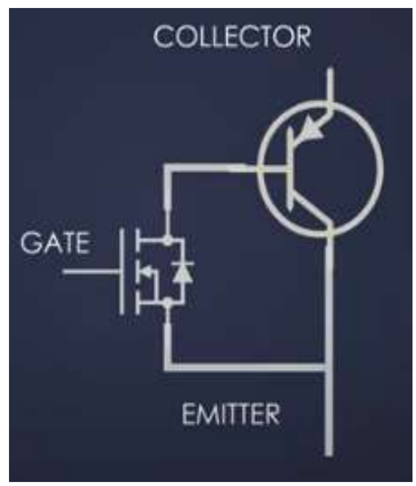

Figure2.1

3. Key parameters

3.1 Absolute maximum rating

The following parameters are usually specified at 25-degree Celsius ambient temperature

3.1.1 Collector-emitter voltage

In the absence of a gate voltage, it is the maximum voltage that can be applied between the emitter and collector. So, the input voltage must be lower than V_{CE}.

3.1.2 Gate-emitter voltage

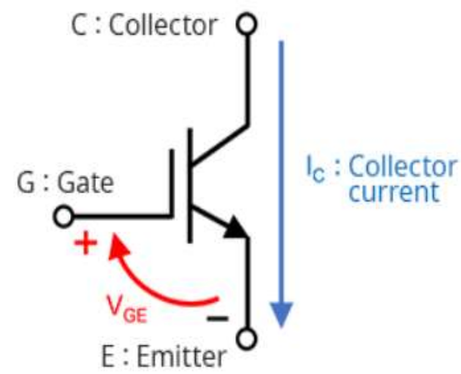

Figure 3.1

V_{GE} is required to turn on IGBT and it should be at least more than the threshold voltage then the IGBT will turn on.

More voltage applied to the gate IGBT will cause it to turn on and operate faster. Conversely, a higher negative gate voltage will cause the IGBT to turn off faster. However, if the driver goes beyond the V_{GE} range, oxide breakdown and dielectric rupture may cause permanent device destruction.

3.1.3 Collector current I_C

Collector current is the electric current flowing from the collector to the emitter of an IGBT. It can be determined using Ohm's Law also. Here, Vce represents the collector-emitter voltage, and Rl is the load resistance.

$I_c = V_{ce} / R_l$.

It is the maximum continuous current which an IGBT can carry when it is on

3.1.4 Thermal Resistance

It relates to the heat conduction properties of the device.

There are different thermal resistance quantities of any device, which are:

1) The thermal resistance from the device junction to the device case is the $R_{TH(JC)}$
2) The contact thermal resistance between the device keys and the heatsink is $R_{TH(CH)}$
3) The thermal resistance between the heat sink to the ambient is $R_{TH(HA)}$

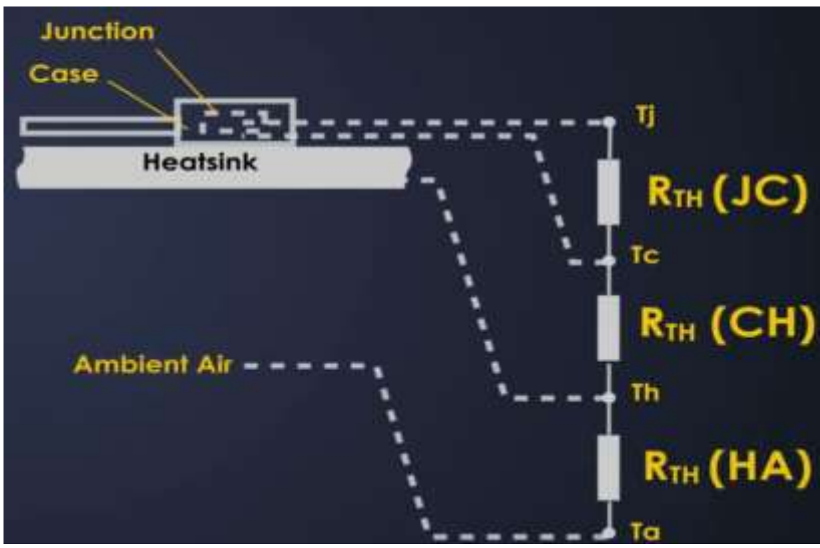

Figure 3.2

By summing them all to get the thermal resistance between the junction to ambient $R_{TH(JA)}$

$R_{TH(JA)} = R_{TH(JC)} + R_{TH(CH)} + R_{TH(HA)}$

So that, for calculating temperature rise, this formula can be used:

$(R_{TH(JA)} \times P_D) + T_{ambient} = T_J$

P_D: The total power dissipation across IGBT

The calculated junction temperature should not exceed the maximum limit of IGBT

3.1.5 Safe Operating Area (SOA)

The region on the datasheet for the IGBT that specifies the highest combinations of voltage and current that are safe to use.

For IGBT, the area is defined by the maximum collector-emitter

voltage VCE and collector current IC within which the IGBT

operation must be confined to protect it from damage.

•The IGBT has the following types of SOA operations:

- forward-biased safe operating area (FBSOA)
- reverse-biased safe operating area (RBSOA)
- short-circuit safe operating area (SCSOA)

3.2 Static characteristics

3.2.1 Collector-Emitter Saturation Voltage $V_{CE(SAT)}$

It represents the IGBT power dissipation during the conduction.

It depends on the collector current, gate-emitter voltage, and junction temperature.

$V_{GE} \uparrow$ Channel Conductivity $\uparrow$ $V_{CE(SAT)} \uparrow$

$I_C \uparrow$ $V_{CE(SAT)} \uparrow$

The conduction power loss = $V_{CE(SAT)} \times I_C$

3.2.2 Forward Voltage Drop Vf

The forward voltage drop is the voltage across the IGBT when it is in the conducting state

$V_F = V_{CE} + V_{CE(SAT)}$

3.2.3 The Collector Cut off Current (I_{CES})

It is also a collector to emitter current at $V_{GE} = 0$.

Even when the IGBT is turned off I_{CES} allows a small amount of current to flow through it

3.3 Dynamic characteristics

4. Operating regions

4.1 Cut Off Region

When the gate to emitter voltage, VGE = 0, the device is in an OFF state and there is no flow of current between the collector and emitter

4.2 Active Region

When the VGE is increased beyond the threshold voltage the device goes into the active region and the current starts flowing through the device. The flow of current will increase with an increase in the voltage VGE as shown in the graph below

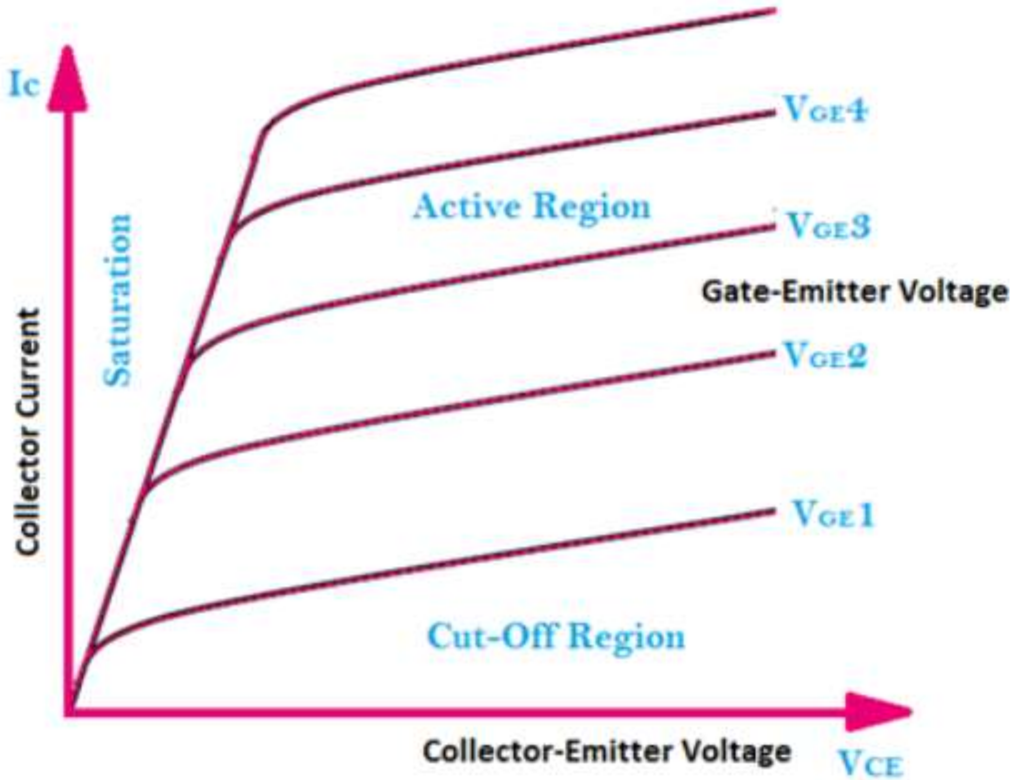

Figure 4.1

4.3 Saturation Region

In this region, the IGBT is fully turned on, and maximum current flows between the collector and emitter terminals with minimal voltage drop.

- ✓ **References**

- ✓ https://www.geeksforgeeks.org/igbt/#what-is-an-insulated-gate-bipolar-transistor
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