IGBT Report

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IGBT Definition

The **Insulated Gate Bipolar Transistor** also called an **IGBT** for short, is something of a cross between a conventional **Bipolar Junction Transistor**, (**BJT**) and a **Field Effect Transistor, (MOSFET)** making it ideal as a semiconductor switching device.

The **IGBT** *Transistor* takes the best parts of these two types of common transistors, the **high input impedance** and **high switching speeds** of a **MOSFET** with the low saturation voltage of a bipolar transistor, and combines them together to produce another type of transistor switching device that is capable of handling large collector-emitter currents with virtually zero gate current drive.

The **Insulated Gate Bipolar Transistor**, (**IGBT**) combines the insulated gate (hence the first part of its name) technology of the **MOSFET** with the output performance characteristics of a conventional bipolar transistor, (hence the second part of its name).

The result of this hybrid combination is that the "**IGBT Transistor**" has the output switching and conduction characteristics of a bipolar transistor but is voltage-controlled like a **MOSFET**.

IGBTs are mainly used in power electronics applications, such as inverters, converters and power supplies, were the demands of the solid state switching device are not fully met by power bipolars and power **MOSFET**s. High-current and high-voltage bipolars are available, but their switching speeds are slow, while power **MOSFET**s may have higher switching speeds, but high-voltage and high-current devices are expensive and hard to achieve.

The advantage gained by the insulated gate bipolar transistor device over a **BJT** or **MOSFET** is that it offers greater power gain than the standard bipolar type transistor combined with the higher voltage operation and lower input losses of the **MOSFET**. In effect it is an **FET** integrated with a bipolar transistor in a form of Darlington type configuration as shown

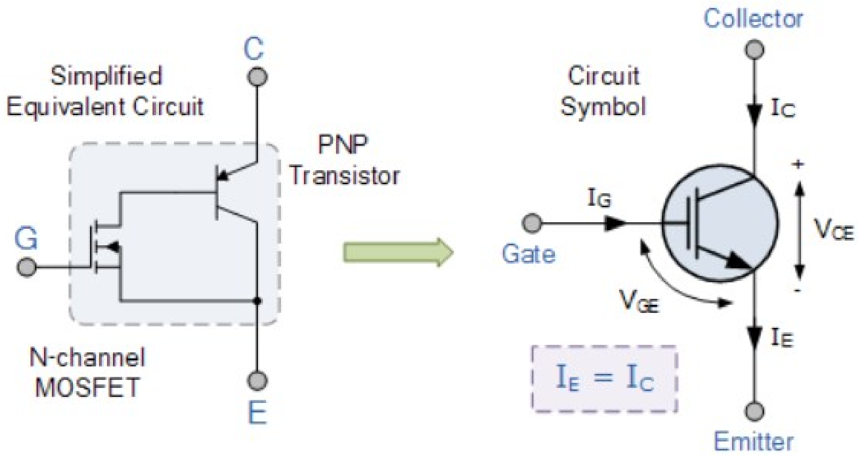

Figure 1 IGBT Symbol

We can see that the insulated gate bipolar transistor is a three terminal, transconductance device that combines an insulated gate N-channel **MOSFET** input with a **PNP** bipolar transistor output connected in a type of Darlington configuration.

As a result, the terminals are labelled as: **Collector, Emitter and Gate**. Two of its terminals (**C-E**) are associated with the conductance path which passes current, while its third terminal (**G**) controls the device.

Operating Regions

Cut-off Region

Characteristics:

- The gate-emitter voltage (**VGE**) is less than the threshold voltage (**Vth**), typically around 4 to 8 volts, depending on the specific **IGBT**.
- In this region, the **IGBT** is **turned off**, and it does not conduct any significant collector current (**IC**). The collector-emitter path behaves like an open circuit.

- The collector-emitter voltage (**VCE**) is high as the **IGBT** is blocking the voltage.

Applications:

- The cut-off region is used when the **IGBT** is intended to **stop** the current flow in a circuit, such as when a power switch is turned off.

Important Considerations:

- Ensuring that **VGE** is sufficiently **low** to prevent unintended turn-on due to noise or voltage spikes.

Active (Saturation) Region

Characteristics:

- The gate-emitter voltage (**VGE**) is above the threshold voltage, **fully turning on the IGBT**.
- The **IGBT** acts as a **closed switch** with a low collector-emitter voltage (**VCE**), allowing a large collector current (**IC**) to flow through.
- This region is **analogous to the saturation region** of a bipolar junction transistor (**BJT**).

Applications:

- The active region is where the **IGBT** is used as a switch in power converters, motor drives, and other applications that require high efficiency and fast switching.

Important Considerations:

- Power losses in this region are primarily due to the on-state voltage drop and switching losses during transitions between the on and off states.

Linear (Active Forward) Region

Characteristics:

- In the linear region, the **IGBT** is **partially on**, and the gate-emitter voltage is just above the threshold.
- The collector-emitter voltage (**VCE**) is moderate, and the **IGBT** conducts current but not at its maximum capacity.
- The **IGBT**'s current conduction is controlled by the gate voltage, offering a proportional relationship between **VGE** and **IC**.

Applications:

- This region is generally **avoided in switching applica**tions because it results in higher power dissipation due to a higher voltage drop across the **IGBT**.
- It may be used in **analog applications** where linear current control is needed, but such usage is rare.

Important Considerations:

- Operating in the linear region can lead to thermal issues and reduced efficiency due to increased power dissipation.

Breakdown Region

Characteristics:

- The breakdown region occurs when the collector-emitter voltage **exceeds** the breakdown voltage of the **IGBT**.
- In this region, a significant increase in collector current occurs, leading to potentially destructive consequences.

Applications:

- The breakdown region is an **undesirable operating condition**. It is crucial to design circuits to avoid entering this region.

Important Considerations:

- Operating in the **breakdown region** can cause **permanent damage** to the **IGBT** due to excessive heat and electrical stress. Designers must ensure that the voltage ratings are not exceeded during normal operation or transient conditions.

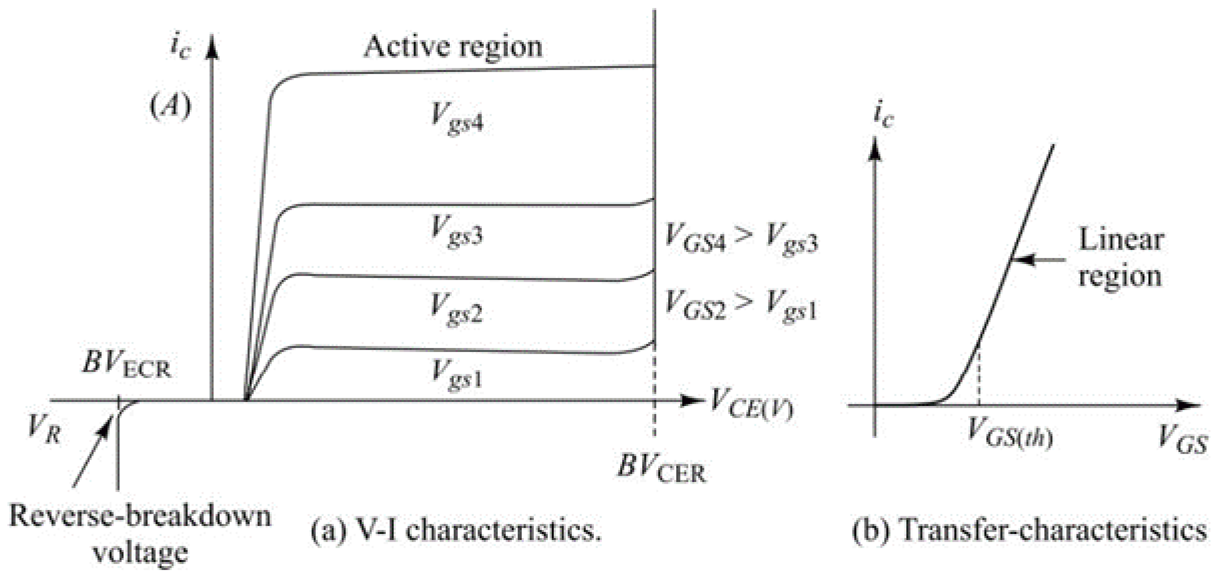

Figure 2 Characteristics

Key Parameters:

Collector-Emitter Voltage (VCE):

- **Maximum Voltage (VCEmax):** Highest voltage the **IGBT** can withstand without breakdown.
- **Saturation Voltage (VCEsat):** Voltage across the **collector-emitter** when fully on; lower values indicate lower power losses.

Collector Current (IC):

- **Maximum Current (ICmax):** Highest continuous current the IGBT can handle.
- **Peak Current (ICM):** Maximum current for **short durations without damage.**

Gate-Emitter Voltage (VGE):

- **Threshold Voltage (VGEth):** Minimum voltage required to turn on the **IGBT**.
- **Maximum Voltage (VGEmax):** Highest voltage the gate can safely handle.

Switching Characteristics:

Turn-On/Off Times

- Time required for the **IGBT** to switch between on and off states, affecting switching frequency and efficiency.

Power Dissipation (PDmax):

- Maximum power the **IGBT** can dissipate as heat without exceeding its temperature limits.

Junction Temperature (TJ):

- **Maximum Temperature (TJmax):** Highest temperature the **IGBT** can operate at without damage.

Thermal Resistance (Rth):

- Measures heat dissipation capability; lower values indicate better heat management.

Safe Operating Area (SOA):

- Defines the voltage and current combinations that the **IGBT** can safely handle.

Short-Circuit Withstand Time:

- Duration the **IGBT** can endure a short-circuit condition without failing.

Input Capacitance (Cies):

- Affects the gate drive requirements and switching speed; higher capacitance requires a stronger gate drive.