Video#28: Electronic Basics #28: IGBT and when to use them

Understanding IGBTs and MOSFETs in Power Electronics

Introduction to Power Switching Devices

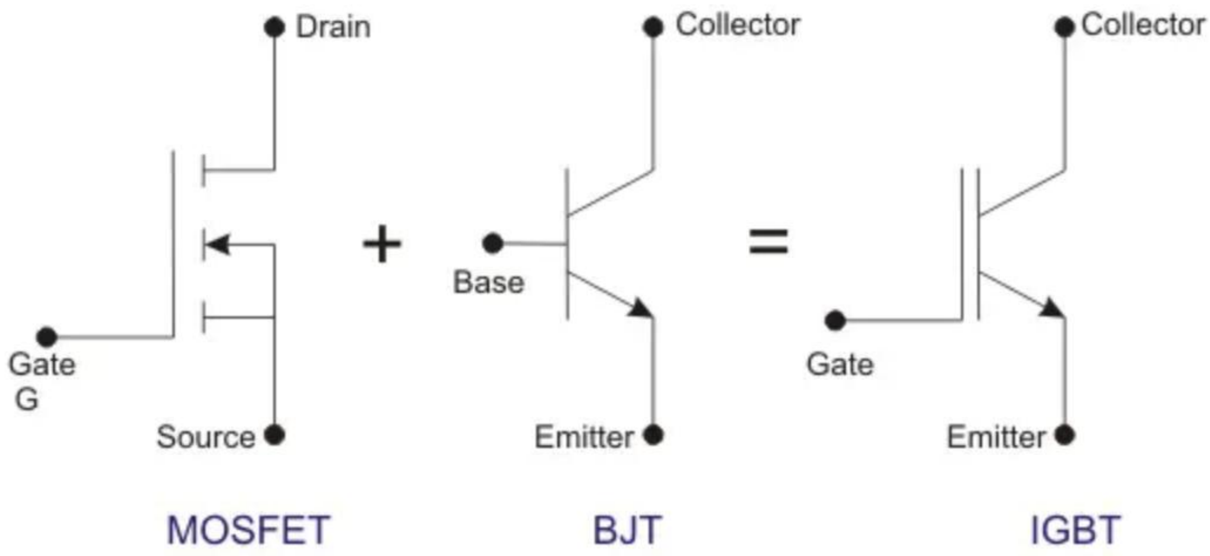
Power electronic circuits commonly utilize semiconductor switching devices like MOSFETs (Metal-Oxide-Semiconductor Field-Effect Transistors) and IGBTs (Insulated-Gate Bipolar Transistors) to control the flow of electrical energy efficiently. These devices are used in applications such as inverters, motor drives, and solid-state Tesla coils. Choosing between MOSFETs and IGBTs depends on the application requirements, particularly frequency, voltage, and current handling capabilities.

MOSFETs and Their Characteristics

MOSFETs are available in two types: N-channel and P-channel. However, P-channel MOSFETs exhibit inferior characteristics, making them less common in practical applications. The MOSFET is characterized by three terminals: Gate (G), Drain (D), and Source (S). MOSFETs operate by controlling the gate voltage, which in turn regulates current flow between the drain and source. They exhibit fast switching speeds, making them suitable for high-frequency applications.

Introduction to IGBTs

IGBTs combine the characteristics of MOSFETs and BJTs (Bipolar Junction Transistors). They feature three terminals: Gate (G), Collector (C), and Emitter (E). Internally, an IGBT is a combination of an N-channel MOSFET and a PNP BJT. This hybrid structure allows IGBTs to handle high voltages and currents efficiently while being driven by a MOSFET-like gate.



IGBT Switching Characteristics

In a basic switching circuit, the emitter of an IGBT is connected to the ground, while the load is placed between the supply voltage and the collector. Applying a gate voltage higher than the threshold voltage turns the IGBT on. IGBTs require proper gate drive management to ensure efficient operation. When the gate voltage is removed, the IGBT remains conductive unless the gate charge is actively discharged, typically using a pull-down resistor (e.g., 10 kΩ) or a dedicated driver IC.

Gate Drive Requirements

To switch IGBTs efficiently, a dedicated driver IC, such as the TC4420, is recommended. This IC provides proper gate drive voltage, ensuring the device turns on and off efficiently. Additionally, high-frequency applications (above 20 kHz) benefit from driver ICs like the IR2113, which supports bootstrap operation to drive high-side switching devices.

Switching Speed Comparison

MOSFETs switch significantly faster than IGBTs. A typical MOSFET has turn-on and turn-off times around 32 ns and 160 ns, respectively, whereas an IGBT exhibits delay and rise times of approximately 145 ns and 240 ns. Due to this, MOSFETs are preferred for applications above 200 kHz, while IGBTs are suitable for lower frequency applications.

Power Loss Considerations

MOSFETs exhibit lower power losses due to their linear voltage drop, behaving like a constant resistance in their ohmic region. For example, a MOSFET with a drain-to-source resistance of 0.024 Ω at 1.7 A results in a power loss of only 0.04 W. In contrast, an IGBT with a collector-to-emitter voltage drop of 0.79 V at 1.65 A results in a power loss of 1.3 W, which is significantly higher. However, IGBTs are more efficient at higher current levels.

Voltage and Current Handling Capabilities

IGBTs are advantageous in medium-frequency, high-voltage, high-current applications. They typically have higher collector-emitter breakdown voltages than MOSFETs, which enhances their ability to withstand higher voltages. This makes them ideal for power conversion applications, including solid-state Tesla coils.

MOSFETs and IGBTs each have their respective strengths and are chosen based on application requirements. MOSFETs are preferred for high-frequency applications due to their fast switching times and lower conduction losses, while IGBTs excel in high-power, medium-frequency applications where their higher current handling capability is beneficial. Selecting the appropriate switching device ensures efficiency and reliability in power electronic circuits.