Introduction:

Power electronics is a critical technology for modern society, and it is used in everything from our homes and businesses to our transportation systems and communication networks. So, we call it power electronics because it is about controlling the flow of electric power, which is essential for many different applications.

Power electronics uses semiconductor devices to control the flow of electricity, which allows us to modify the voltage, current, and frequency of electric power. This is essential for a wide range of applications, including:

Motor drives: Power electronics is used to control the speed and torque of electric motors in everything from industrial robots to electric vehicles.

Power supplies: Power electronics is used to convert AC power from the grid to DC power for use in electronic devices.

Renewable energy: Power electronics is used to convert the intermittent power output of solar and wind power plants into a form that can be used by the grid.

High-voltage direct current transmission: Power electronics is used to transmit electricity over long distances at high voltages, which reduces losses.

1-Types of power electronics circuit

Diode rectifiers are electronic devices that convert alternating current (AC) to direct current (DC). They do this by allowing current to flow in one direction only. Diode rectifiers are the most basic type of rectifier, and they are used in a wide variety of applications, including power supplies, motor drives, and renewable energy systems.

DC-DC converters, also known as DC choppers, are electronic devices that convert a constant DC voltage to a variable DC voltage. They do this by switching the DC voltage on and off at a high

frequency. This creates a pulsating DC voltage, which can then be filtered to produce a smooth DC voltage of the desired output voltage.

AC-AC converters are electronic devices that convert one AC voltage waveform to another AC voltage waveform. AC-AC converters are used in a variety of applications, including:

- Frequency conversion: AC-AC converters can be used to convert one AC frequency to another. This is useful for applications such as variable-speed motor drives and renewable energy systems.
- Voltage regulation: AC-AC converters can be used to regulate the voltage of an AC waveform. This is useful for applications such as uninterruptible power supplies (UPSs) and power quality conditioners.

Inverters are electronic devices that convert direct current (DC) to alternating current (AC). They do this by switching the DC voltage on and off at a high frequency. This creates an AC waveform that can be used to power AC loads.

2-Power electronic switches:

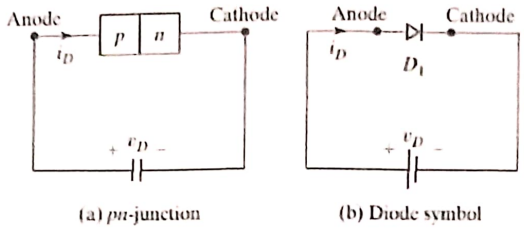
- Power electronic switches are typically made from silicon, but newer devices are being developed using wide bandgap materials such as gallium nitride (GaN) and silicon carbide (SiC). These materials offer several advantages over silicon, including higher switching speeds, lower losses, and higher operating temperatures. Power electronic switches can be operated in two main modes: ON mode and OFF mode.

- ON mode: In the ON mode, the switch is fully conducting and current can flow freely through it.
- OFF mode: In the OFF mode, the switch is fully blocking and current cannot flow through it.

The switching between the ON and OFF modes is controlled by the gate voltage of the switch. When the gate voltage is high enough, the switch turns on and current can flow. When the gate voltage is low, the switch turns off and current is blocked

Some of the most common types of power electronic switches include:

Diode; A diode is a semiconductor made up of two PN junctions, and it conducts in the anode-cathode direction when it is forward biased. This means that current can flow through the diode from the anode to the cathode, but it cannot flow in the opposite direction.



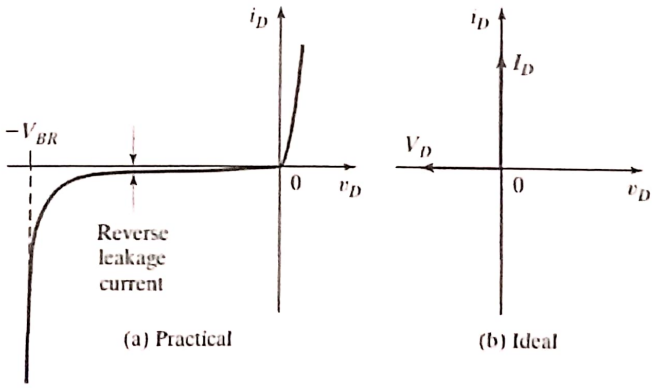
(a) *pn*-junction (b) Diode symbol

When a diode is forward biased, the PN junction is forward biased and the potential barrier at the junction is reduced. This allows electrons to flow across the junction from the n-type semiconductor to the p-type semiconductor. The electrons then flow through the p-type semiconductor to the cathode.

When a diode is reverse biased, the PN junction is reverse biased and the potential barrier at the junction is increased. This prevents electrons from flowing across the junction. As a result, current cannot flow through the diode in the reverse direction.

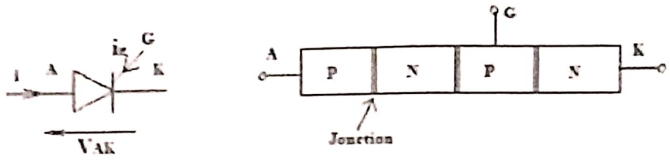
If $v_D > 0$, forward direction, the diode conducts (passing).
If $v_D < 0$, reverse direction, the diode does not conduct (blocked).

The theoretical static characteristic of the diode is:



(a) Practical (b) Ideal

Thyristors: is a four-layer semiconductor device that can be used to control the flow of current in a circuit. It is made up of three PN junctions that are connected in a series. It has three terminals: the anode, the cathode, and the gate. Where the gate is the terminal that is used to control the thyristor.

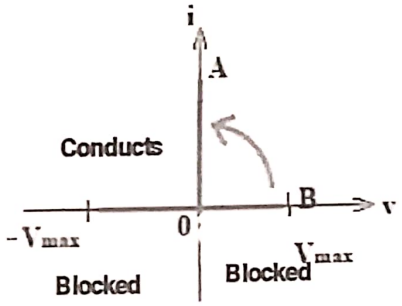


If $v_{AK} < 0$ becomes the thyristors is blocked (does not conduct)

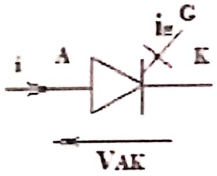
If $v_{AK} > 0$ becomes positive, it remains blocked.

If $v_{AK} > 0$ plus a positive pulse of gate current, the thyristor becomes conducting (conducts).

When the thyristor is conducting, it behaves like a diode.



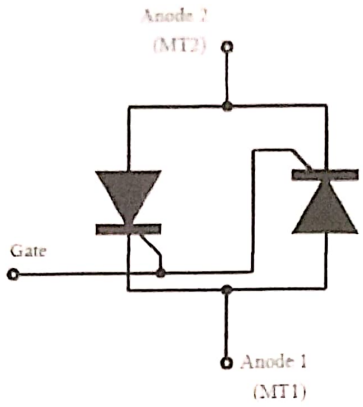
Thyristor « GTO » A GTO thyristor is a type of thyristor that can be turned on and off by applying a pulse of current to the gate.where The gate current is a pulse of current that is applied to the gate of the GTO thyristor to turn it on or off.



If $v_{AK} < 0$ the thyristor is blocked (does not conduct)

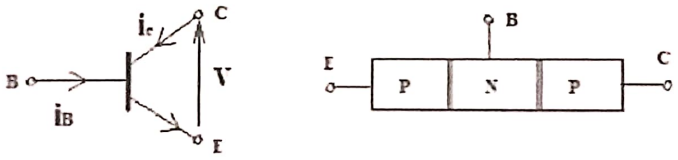
If $v_{AK} > 0$ plus a positive pulse of gate current, the thyristor becomes conducting (conducts), it only turns off when the circuit current i is zero. A strong negative pulse of gate current allows it to be opened

TRIAC A TRIAC is a three-terminal semiconductor device that can be used to control the flow of current in both directions. TRIACs are similar to thyristors, but they have the ability to conduct current in both directions.



Triac equivalent circuit

Transistor: is a semiconductor device that can be used to amplify or switch current. The BJT has three terminals: the base, the emitter, and the collector. bipolar junction transistor (BJT) is controlled by the base current i_B injected into the B-E circuit. It is equivalent to a diode. The base current i_B is necessary to achieve saturation, and it represents a significant fraction of the controlled current i.



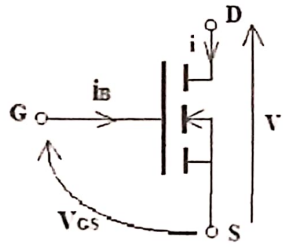
- Base: The base is the terminal that is used to control the BJT.
- Emitter: The emitter is the terminal where the current flows into the BJT.
- Collector: The collector is the terminal where the current flows out of the BJT.

Here is a more detailed explanation of the operation of a BJT in terms of its I-V characteristics:

- **Cutoff state:** When the base current i_B is zero or negative, the BJT is in the cutoff state. In this state, the base-emitter junction is reverse biased and no current flows through it.
- **Saturation state:** When the base current i_B is sufficiently large, the BJT is in the saturation state. In this state, the base-emitter junction is forward biased and the BJT allows current to flow from the emitter to the collector with minimal resistance.

Transistor MOSFET:

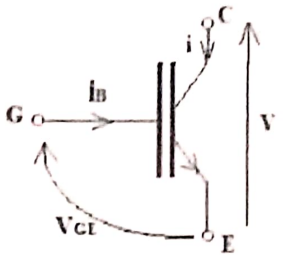
A MOSFET (metal-oxide-semiconductor field-effect transistor) is a type of transistor that can be used to amplify or switch electronic signals. it's able to controls the flow of current through the semiconductor material.



MOSFETs have several advantages over other types of transistors, including:

- Fast switching: MOSFETs can switch very quickly, making them ideal for high-frequency applications.
- High current carrying capacity: MOSFETs can carry high currents, making them ideal for applications where high power levels are required.
- Low power consumption: MOSFETs consume very little power when they are idle, making them ideal for battery-powered devices.

Transistor IGBT: An IGBT (insulated-gate bipolar transistor) is a type of transistor that combines the advantages of MOSFETs and BJTs. The IGBT is a bipolar junction transistor with field effect control.The IGBT combines the advantages of bipolar junction transistors (BJTs) and metal-oxide-semiconductor field-effect transistors (MOSFETs).



BJT advantages: Low voltage drop in the on state and high blocking voltage

MOSFET advantages: Voltage control

- High switching speed