

1.4 Semiconductor devices:

Semiconductor diode and its characteristics

A semiconductor diode is a two-terminal electronic device made from a p-n junction, where one side is doped with acceptor atoms (p-type) and the other with donor atoms (n-type). This configuration allows current to flow primarily in one direction, making it a key component in rectification processes. The diode exhibits distinct characteristics:

Forward Bias: When the p-side is connected to the positive terminal of a voltage source and the n-side to the negative terminal, the diode allows current flow. The voltage required to overcome the barrier potential is typically 0.7 V for silicon and 0.3 V for germanium.

Reverse Bias: When the polarity is reversed, the diode blocks current flow except for a negligible leakage current. However, beyond a certain reverse voltage, known as the breakdown voltage, the diode conducts heavily, which may damage it unless it is designed for such conditions (e.g., Zener diodes).

Semiconductor diodes are fundamental in power conversion, signal demodulation, and protection circuits.

BJT Configuration and biasing

The bipolar junction transistor (BJT) is a three-layer semiconductor device consisting of two p-n junctions. BJTs are classified as either NPN or PNP types, depending on the arrangement of the layers. BJTs operate in three regions: active, saturation, and cutoff. They are configured in three common modes:

Common Emitter: Provides high gain and is widely used in amplification.

Common Base: Offers low input impedance and high-frequency operation.

Common Collector (Emitter Follower): Used for impedance matching due to high input and low output impedance.

Proper biasing is critical to ensure that the BJT operates in the desired region. This involves applying a DC voltage or current to the base terminal relative to the emitter and collector. Biasing methods include fixed bias, voltage-divider bias, and emitter bias, each suited for specific applications to stabilize the transistor's operation.

Small and large signal model

The small-signal model of a BJT simplifies the analysis of its behavior in amplifying weak signals. It uses equivalent circuit parameters, such as transconductance and output resistance, to represent the transistor's linear region of operation. The large-signal model, on the other hand, is used to analyze the transistor's behavior when significant variations in current and voltage occur, such as in switching applications. These models are indispensable in designing and analyzing amplifiers, oscillators, and other analog circuits.

Working principle of MOSFET

The metal-oxide-semiconductor field-effect transistor (MOSFET) is a voltage-controlled device widely used in analog and digital circuits. It consists of four terminals: gate, source, drain, and body. The MOSFET operates by controlling the flow of current between the drain and source terminals through an electric field induced by the voltage applied to the gate terminal. The device operates in three regions: cutoff, linear, and saturation. In the cutoff region, the MOSFET is off, and no current flows. In the linear region, it acts as a variable resistor. In the saturation region, it operates as a current source. MOSFETs are characterized by high input impedance, fast switching, and low power consumption.

Working principle of CMOS

Complementary metal-oxide-semiconductor (CMOS) technology combines NMOS and PMOS transistors in a complementary arrangement to form logic gates and other circuits. The principle of operation relies on the complementary switching

behavior of NMOS and PMOS transistors. When one transistor is on, the other is off, ensuring minimal power consumption. This characteristic makes CMOS the preferred technology for integrated circuits, particularly in digital applications. The low static power dissipation and high noise immunity of CMOS circuits contribute to their widespread adoption in microprocessors, memory devices, and application-specific integrated circuits.

Application of MOSFET

MOSFETs are versatile devices with a broad range of applications, including power electronics, signal amplification, and switching. In power applications, MOSFETs are used in DC-DC converters, inverters, and motor control circuits due to their high efficiency and fast switching capabilities. In analog circuits, they serve as amplifiers and variable resistors, while in digital circuits, MOSFETs act as the building blocks of logic gates and memory cells.

Application of CMOS

CMOS technology is integral to modern electronics, finding applications in both digital and analog domains. In digital circuits, CMOS is used in microprocessors, microcontrollers, and digital signal processors due to its low power consumption and high integration density. Analog CMOS circuits are employed in mixed-signal applications, such as data converters, operational amplifiers, and filters. The combination of low cost, high efficiency, and scalability makes CMOS a cornerstone of semiconductor technology.