Ministry of Higher Education and Scientific Research

Al-Mustaqbal University College

Department of Medical Physics

Analog Electronics

Lecture 8

Metal Oxide Semiconductor Field Effect Transistor (MOSFET)

By

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MOSFET

The MOSFET (Metal Oxide Semiconductor Field Effect Transistor) transistor is a semiconductor device that is widely used for switching purposes and for the amplification of electronic signals in electronic devices.

A MOSFET is a four-terminal device having source(S), gate (G), drain (D) and body (B) terminals. In general, the body of the MOSFET is in connection with the source terminal thus forming a three-terminal device such as a field-effect transistor. MOSFET is generally considered as a transistor and employed in both the analog and digital circuits. And the general structure of this device is as below:

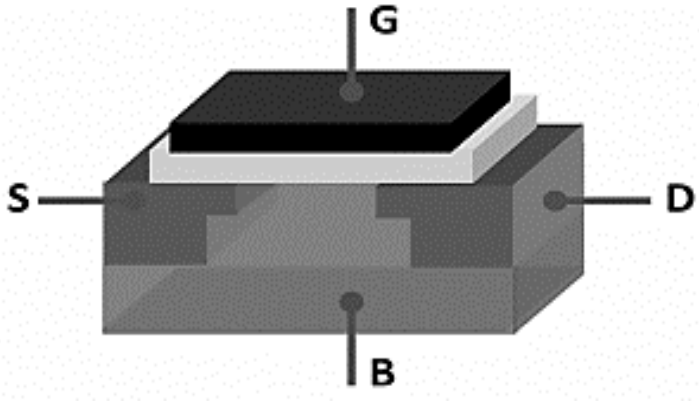

Figure (48) MOSFET.

From the above MOSFET structure, the functionality of MOSFET depends on the electrical variations happening in the channel width along with the flow of carriers (either holes or electrons). The charge carriers enter into the channel through the source terminal and exit via the drain.

A MOSFET can function in two ways:

- Depletion Mode.
- Enhancement Mode.

Depletion Mode

When there is no voltage across the gate terminal, the channel shows its maximum conductance. Whereas when the voltage across the gate terminal is either positive or negative, then the channel conductivity decreases.

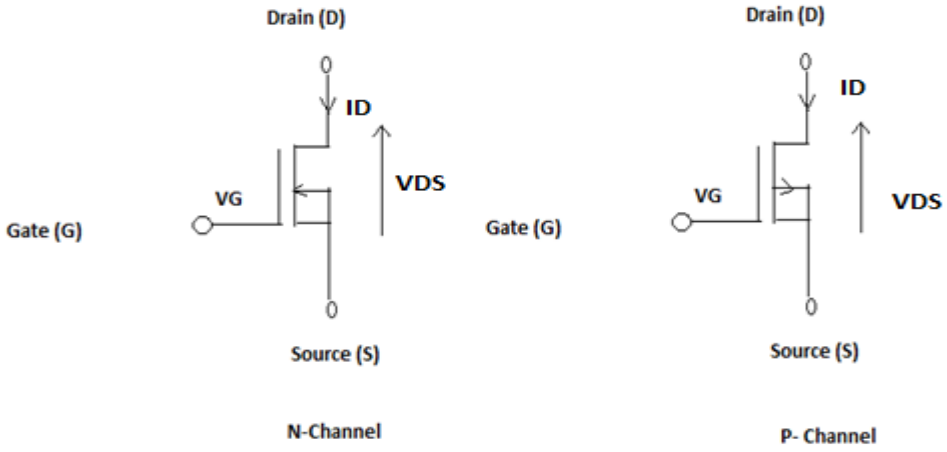

Figure (49) Depletion Mode of N-Channel, and P-Channel.

Enhancement Mode

When there is no voltage across the gate terminal, then the device does not conduct. When there is the maximum voltage across the gate terminal, then the device shows enhanced conductivity.

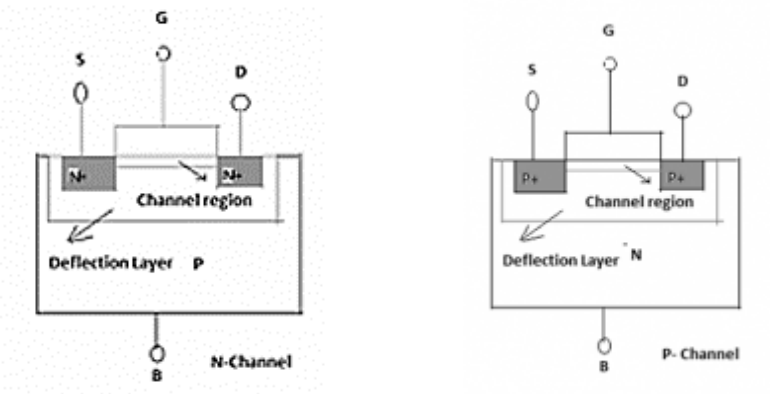

Figure (50) Enhancement Mode of N-Channel and P-Channel.

P-Channel MOSFET

The P-Channel MOSFET has a P-Channel region located in between the source and drain terminals. It is a four-terminal device having the terminals as gate, drain, source, and body. The drain and source are heavily doped p+ region and the body or substrate is of n-type. The flow of current is in the direction of positively charged holes.

When we apply the negative voltage with repulsive force at the gate terminal, then the electrons present under the oxide layer are pushed downwards into the substrate. The depletion region populated by the bound positive charges which are associated with the donor atoms. The negative gate voltage also attracts holes from the p+ source and drain region into the channel region.

N- Channel MOSFET

The N-Channel MOSFET has an N- channel region located in between the source and drain terminals. It is a four-terminal device having the terminals as gate, drain, source, body. In this type of Field Effect Transistor, the drain and source are heavily doped n+ region and the substrate or body are of P-type.

The current flow in this type of MOSFET happens because of negatively charged electrons. When we apply the positive voltage with repulsive force at the gate terminal then the holes present under the oxide layer are pushed downward into the substrate. The depletion region is populated by the bound negative charges which are associated with the acceptor atoms.

MOSFET Regions of Operation

The operation of this device happens mainly in three regions and those are as follows:

- **Cut-off Region:** It is the region where the device will be in the OFF condition and there zero amount of current flow through it. Here, the device functions as a basic switch and is so employed as when they are necessary to operate as electrical switches.
- **Saturation Region:** In this region, the devices will have their drain to source current value as constant without considering the enhancement in the voltage across the drain to source. This happens only once when the voltage across the drain to source terminal increases more than the pinch-off voltage value.
- **Linear/Ohmic Region:** It is the region where the current across the drain to source terminal enhances with the increment in the voltage across the drain to source path. When the MOSFET devices function in this linear region, they perform amplifier functionality.

Ideal Switch Characteristics

When a MOSFET is supposed to function as an ideal switch, it should hold the below properties and those are:

- In the ON condition, there has to be the current limitation that it carries.
- In the OFF condition, blocking voltage levels should not hold any kind of limitations.
- When the device functions in ON state, the voltage drop value should be null.
- The resistance in OFF state should be infinite.

- There should be no restrictions on the speed of operation.

Practical Switch Characteristics

- In the ON condition, the power managing abilities should be limited which means that the flow of conduction current has to be restricted.
- In the OFF state, blocking voltage levels should not be limited.
- Turning ON and OFF for finite times restricts the limiting speed of the device and even limits the functional frequency.
- In the ON condition of the MOSFET device, there will be minimal resistance values where this results in the voltage drop in forwarding bias. Also, there exists finite OFF state resistance that delivers reverse leakage current.
- When the device is performing in practical characteristics, it loses power ON and OFF conditions. This happens even in the transition states too.

Advantages

- It generates enhanced efficiency even when functioning at minimal voltage levels.
- There is no presence of gate current this creates more input impedance which further provides increased switching speed for the device.
- These devices can function at minimal power levels and uses minimal current.

Disadvantages

- When these devices are functioned at overload voltage levels, it creates instability of the device.
- As because the devices have a thin oxide layer, this may create damage to the device when stimulated by the electrostatic charges.

Applications

- Amplifiers made of MOSFET are extremely employed in extensive frequency applications.
- The regulation for DC motors are provided by these devices.
- As because these have enhanced switching speeds, it acts as perfect for the construction of chopper amplifiers.
- Functions as a passive component for various electronic elements.