8.1 Introduction

- MOSFET (metal oxide semiconductor field effect transistor) is a second category of field effect transistor. The MOSFETs, compared to BJTs, can be made very small and hence can be used to design high density VLSI circuits.
- The MOSFET has no pn junction structure; instead, the gate of the MOSFET is insulated from the channel by a silicon dioxide (SiO_2) layer. Due to this the input resistance of MOSFET is very high.
- Because of the insulated gate, MOSFETs are also called **IGFETs. The** two basic types of MOSFETs are : depletion (D) MOSFET and enhancement (E) MOSFET.

8.2 Depletion MOSFET (D-MOSFET)

8.2.1 Construction of n-Channel MOSFET

- The Fig. 8.2.1 shows the basic construction of n-channel depletion type MOSFET.
- Two highly doped n-regions are diffused into a lightly doped p-type substrate.
- These two highly doped n-regions represent source and drain. Usually substrate is internally connected to the source terminal.

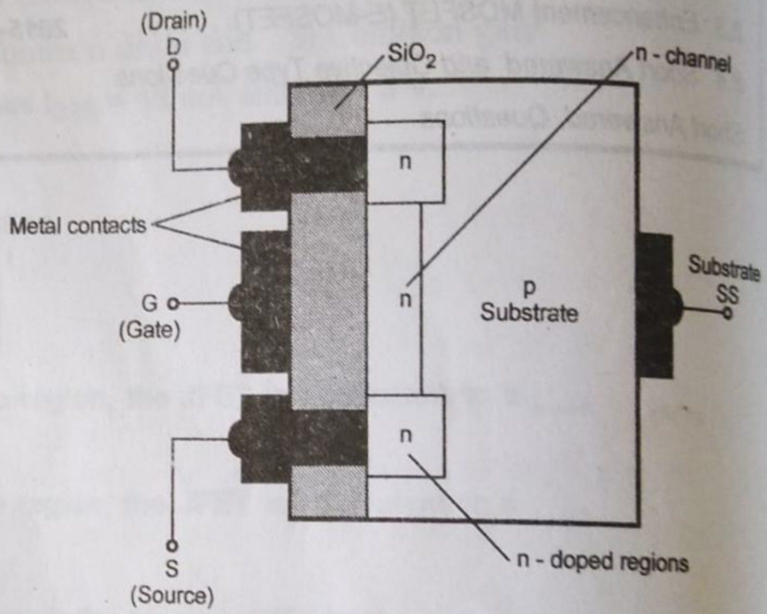


Fig. 8.2.1 n-channel depletion-type MOSFET

- The source and drain terminals are connected through metallic contacts to n-doped regions linked by an n-channel as shown in the Fig. 8.2.1.
- The gate is also connected to a metal contact surface but remains insulated from the n-channel by a very thin layer of dielectric material, silicon dioxide (SiO_2).
- Thus, there is no direct electrical connection between the gate terminal and the channel of a MOSFET, increasing the input impedance of the device.

8.2.2 Operation, Characteristics and Parameters of n-Channel MOSFET

- On the application of drain to source voltage, V_{DS} and keeping gate to source voltage to zero by directly connecting gate terminal to the source terminal, free electrons from the n-channel are attracted towards positive potential of drain terminal.
- This establishes current through the channel to be denoted as I_{DSS} at $V_{GS} = 0$ V, as shown in the Fig. 8.2.2.

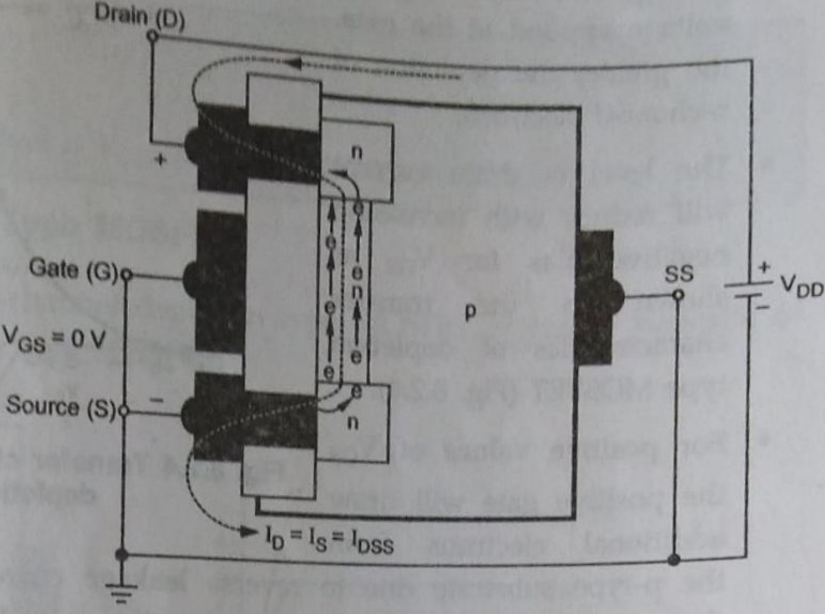


Fig. 8.2.2 n-channel depletion type MOSFET with $V_{GS} = 0$ V and an applied voltage V_{DD}

- If we apply negative gate voltage, the negative charges on the gate repel conduction electrons from the channel, and attract holes from the p-type substrate.
- This initiates recombination of repelled electrons and attracted holes as shown in the Fig. 8.2.3.

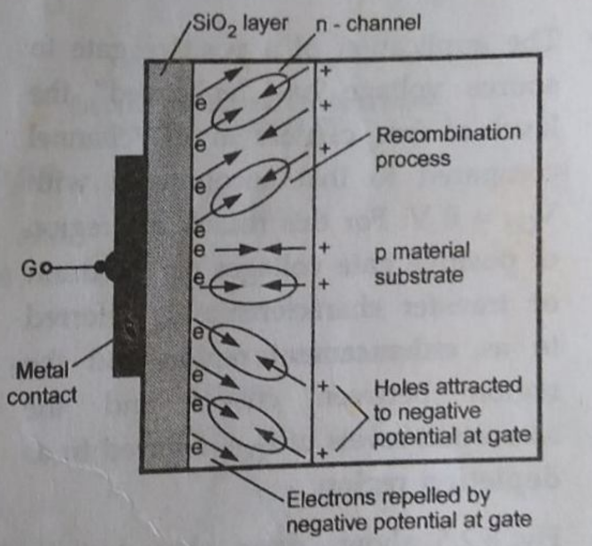


Fig. 8.2.3 Reduction in free electrons in the n-channel due to negative potential at the gate

- The level of recombination between electrons and holes depends on the magnitude of the negative voltage applied at the gate.
- This recombination reduces the number of free electrons in the n-channel for the conduction, reducing the drain current.
- In other words we can say that, due to recombinations, n-channel is depleted of some of its electrons, thus decreasing the channel conductivity.

- The greater the negative voltage applied at the gate, the greater the depletion of n-channel electrons.
- The level of drain current will reduce with increasing negative bias for V_{GS} as shown in the transfer characteristics of depletion type MOSFET (Fig. 8.2.4).

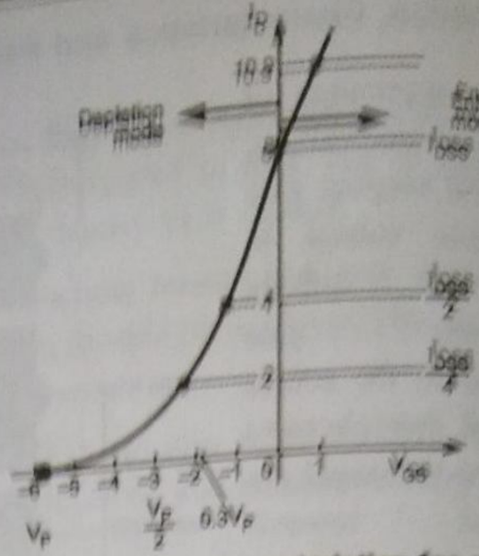


Fig. 8.2.4 Transfer characteristics for an n-channel depletion type MOSFET

- For positive values of V_{GS} the positive gate will draw additional electrons from the p-type substrate due to reverse leakage current and establish new carriers through the collisions between accelerating particles. Because of this, as gate to source voltage increases in positive direction, the drain current also increases as shown in the Fig. 8.2.4.

- The application of a positive gate to source voltage has "enhanced" the level of free carriers in the channel compared to that encountered with $V_{GS} = 0$ V. For this reason the region of positive gate voltages on the drain or transfer characteristics is referred to as **enhancement region** and the region between cut-off and the saturation levels of I_{DSS} referred to as **depletion region**.

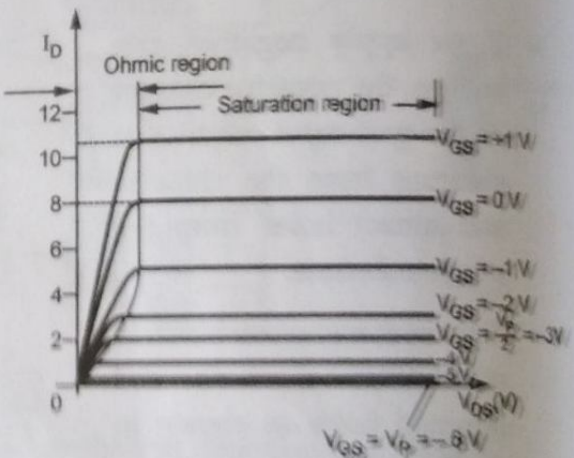


Fig. 8.2.5 Drain characteristics for an n-channel depletion type MOSFET

- Fig. 8.2.5 shows drain characteristics for an n-channel depletion type MOSFET. It is similar to that of JFET. The only difference is that it has positive part of V_{GS}.

Transconductance (g_m)

- It is defined as the ratio of change in drain current to the corresponding change in gate to source voltage, at a constant of drain to source voltage

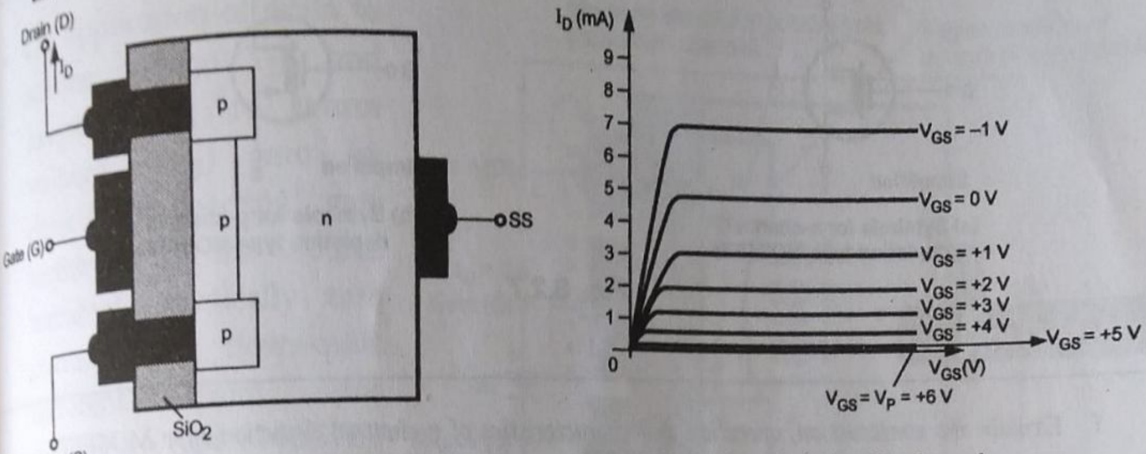
$$g_m = \left. \frac{\Delta I_D}{\Delta V_{GS}} \right|_{\text{constant } V_{DS}}$$

Important Concept

1. $I_D = 0$ corresponds to $V_{GS(off)}$, $V_{GS(off)} = -V_p$.
2. $V_{GS} = 0$ corresponds to I_{DSS}.
3. Both positive and negative values of V_{GS} can be used to bias D-MOSFET.

8.2.3 p-Channel Depletion Type MOSFET

- The construction of the p-channel depletion type MOSFET is exactly opposite of that of n-channel depletion type MOSFET.



(a) p-channel depletion type MOSFET

(b) Drain characteristics of p-channel depletion type MOSFET

Fig. 8.2.6

- Here, the substrate is of n-type, and regions and channels are of p-type as shown in the Fig. 8.2.6 (a).
- As shown in the Fig. 8.2.6 (a) voltage polarities and current directions are reversed.
- The drain characteristics appear exactly as in Fig. 8.2.6 (b) but V_{DS} with negative values, I_D in the opposite direction and V_{GS} having opposite polarities as shown in the Fig. 8.2.6 (b).
- Fig. 8.2.6 (c) shows the transfer characteristics of p-channel depletion type MOSFET.

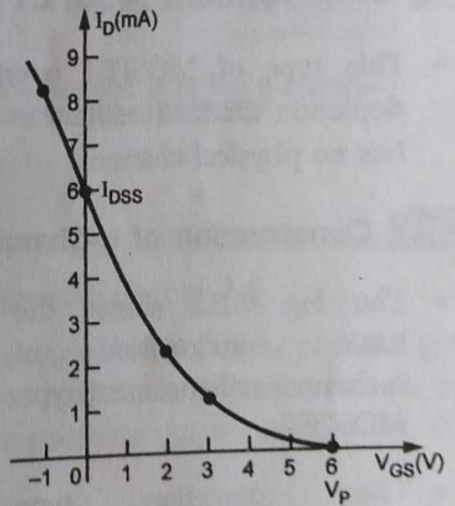


Fig. 8.2.6 (c) Transfer characteristics of p-channel depletion type MOSFET

- In the p-channel depletion type MOSFET, the transfer characteristics is a mirror image about the I_D axis (Y axis) of the transfer characteristic of n-channel depletion type MOSFET, since the V_{GS} is positive in p-channel depletion region.

8.2.4 D-MOSFET Symbols

Fig. 8.2.7 shows graphic symbols for a n and p-channel depletion type MOSFET.

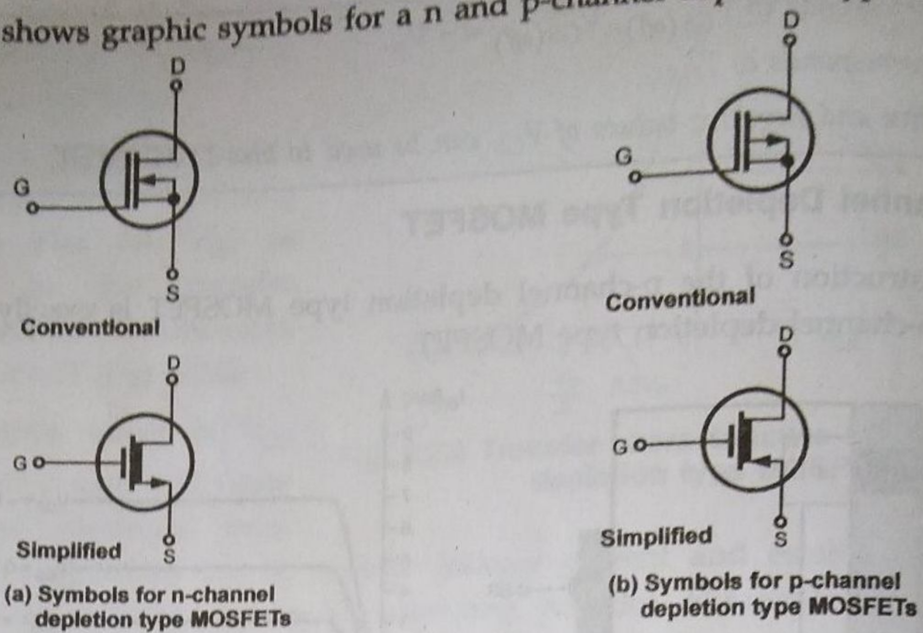


Fig. 8.2.7

Review Questions