2. Define transconductance.

8.3 Enhancement MOSFET (E-MOSFET)

APJAKTU : 2015-16

- This type of MOSFET operates only in the enhancement mode and has no depletion mode. It differs in construction from the depletion MOSFET in that it has no physical channel.

8.3.1 Construction of n-Channel E-MOSFET

- The Fig. 8.3.1 shows the basic construction of n-channel enhancement type MOSFET.
- Like, depletion type MOSFET, two highly doped n-regions are diffused into a lightly doped p-type substrate.

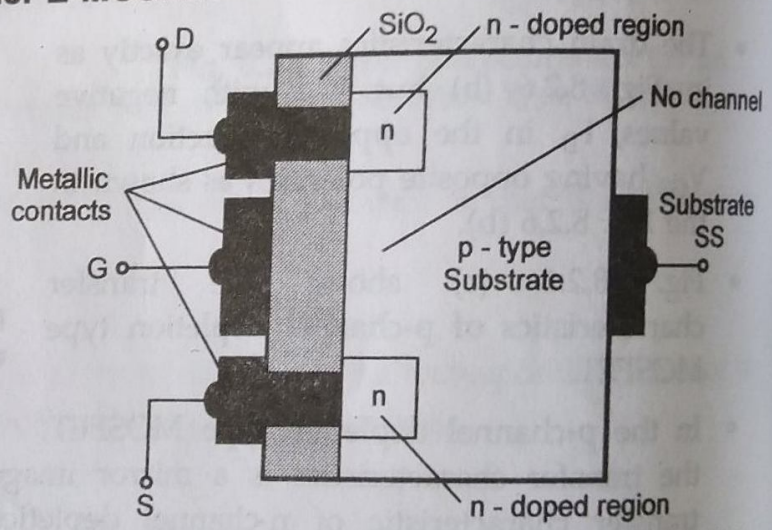

Fig. 8.3.1 n-channel enhancement type MOSFET

- The source and drain are taken out through metallic contacts to n-doped regions as shown in the Fig. 8.3.1.
- But the channel between two n-regions is absent in the enhancement type MOSFET.
- The SiO_2 layer is still present to isolate the gate metallic platform from the region between the drain and source, but now it is simply separated from a section of the p-type material.

8.3.2 Operation, Characteristics and Parameters of n-Channel E-MOSFET

- On application of drain to source voltage V_{DS} and keeping gate to source voltage (V_{GS}) zero by directly connecting gate terminal to the source terminal, practically zero current flows-quite different from the depletion type MOSFET and JFET.
- If we increase magnitude of V_{GS} in the positive direction, the concentration of electrons near the SiO_2 surface increases.

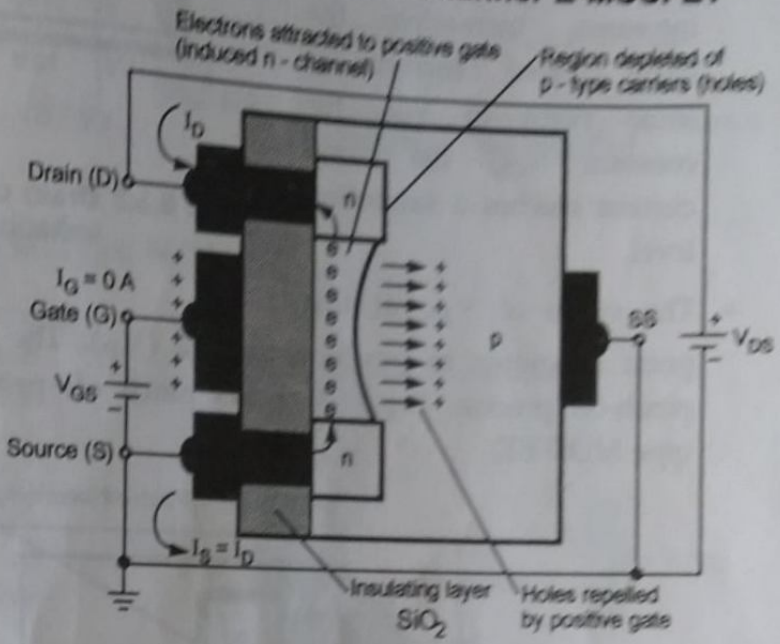

Fig. 8.3.2 Channel formation in the n-channel enhancement type MOSFET

- At a particular value of V_{GS} there is a measurable current flow between drain and source. This value of V_{GS} is called **threshold voltage** denoted by V_T.
- Thus, we can say that in an enhancement type n-channel MOSFET, a positive gate voltage above a threshold value induces a channel and hence the drain current by creating a thin layer of negative charges in the substrate region adjacent to the SiO_2 layer, as shown in the Fig. 8.3.2.
- The conductivity of the channel is enhanced by increasing the gate to source voltage and thus pulling more electrons into the channel.
- For any voltage below the threshold value, there is no channel.
- Since the channel does not exist with $V_{GS} = 0$ V and "enhanced" by the application of a positive gate to source voltage, this type of MOSFET is called an **enhancement type MOSFET.**

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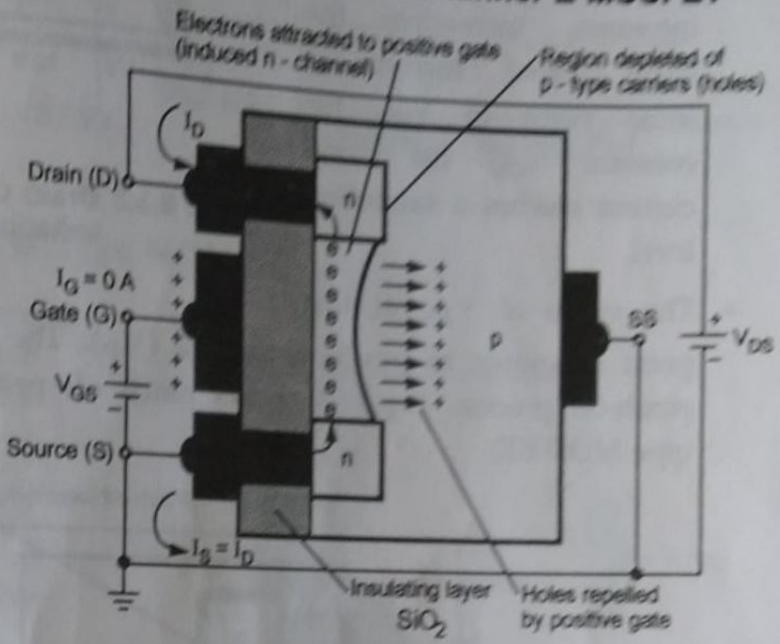

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- Fig. 8.3.3 shows the drain characteristics of an n-channel enhancement type MOSFET. Looking at Fig. 8.3.3 we can say that as V_{GS} increases beyond the threshold level, the density of free carriers (electrons) in the induced channel increases, increasing the drain current. However, at some point of V_{DS}, for constant V_{GS}, the drain current reaches a saturation level.

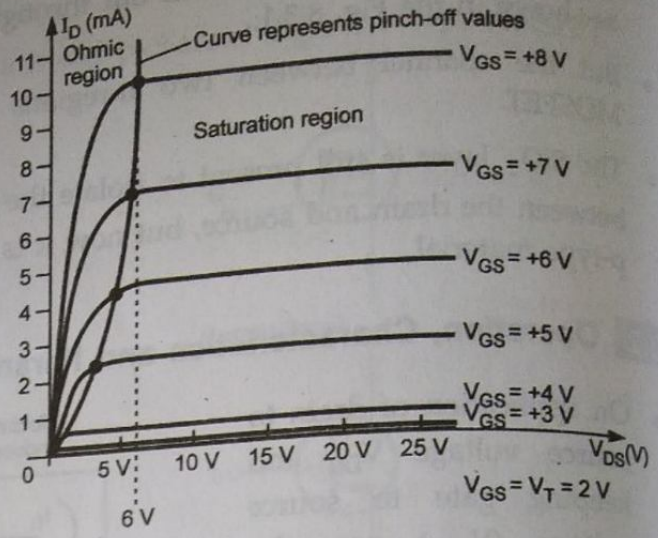


Fig. 8.3.3 Drain characteristics of an n-channel enhancement type MOSFET

- The value of V_{DS} at this point is known as pinch-off voltage (V_P). The levelling off of I_D is due to a pinch-off process. Fig. 8.3.4 shows pinch off process for n-channel enhancement type MOSFET.

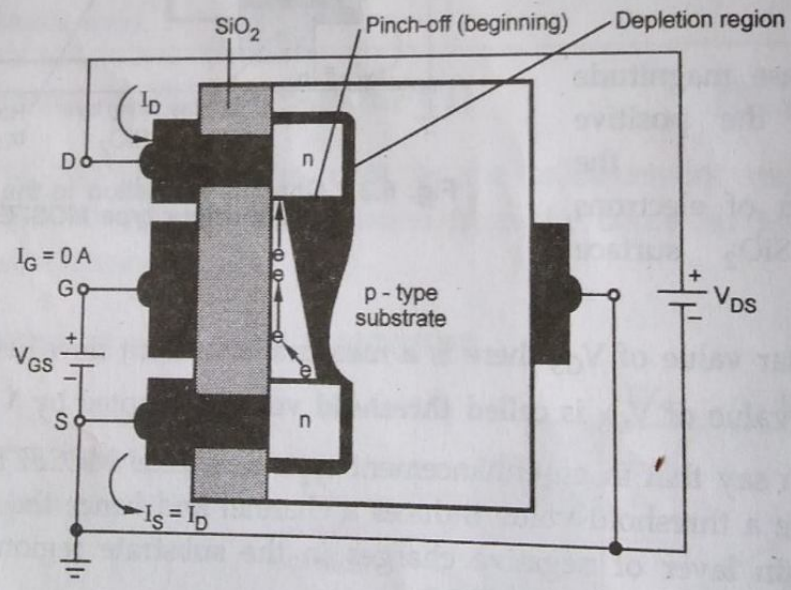


Fig. 8.3.4 Change in channel and depletion region with increasing level of V_{DS} for a fixed value of V_{GS}

- Fig. 8.3.5 shows the transfer characteristic for n-channel enhancement type MOSFET.
- This characteristic is quite different from characteristic that we obtained for JFET and depletion type MOSFET. For an n-channel enhancement type MOSFET it is

now totally in the positive V_{GS} region and as we know I_D does not flow until $V_{GS} = V_T$.

- For $V_{GS} > V_T$ the relationship between drain current and V_{GS} is nonlinear and it is given as

$$I_D = K(V_{GS} - V_T)^2 \quad \ldots (8.3.1)$$

- The K term is a constant that is a function of the construction of the device. The value of K can be determined from equation,

$$K = \frac{I_{D(ON)}}{(V_{GS(ON)} - V_T)^2} \quad \ldots (8.3.2)$$

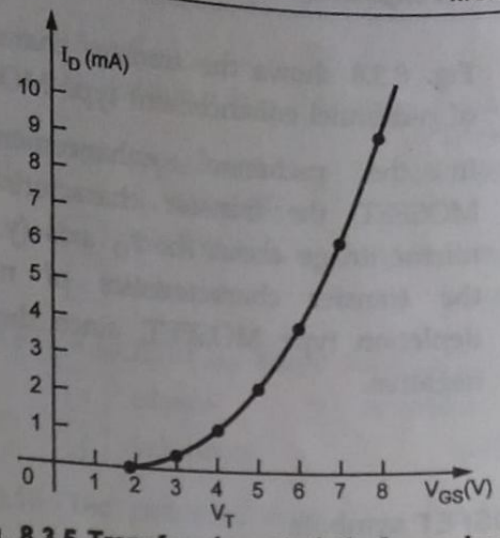


Fig. 8.3.5 Transfer characteristic for n-channel enhancement type MOSFET

8.3.3 p-Channel Enhancement Type MOSFET

- The construction of the p-channel enhancement type MOSFET is exactly opposite to that of n-channel enhancement type MOSFET. Here, the substrate is of n-type and regions are of p-type as shown in the Fig. 8.3.6.
- As shown in the Fig. 8.3.7 voltage polarities and current directions are reversed.
- The drain characteristics appear exactly as in the Fig. 8.3.7 but with V_{DS} with negative values, I_D in opposite direction and V_{GS} having opposite polarities as shown in the Fig. 8.3.7.
- Hence, drain current increases with increase in the negative gate to source (V_{GS}) voltage.

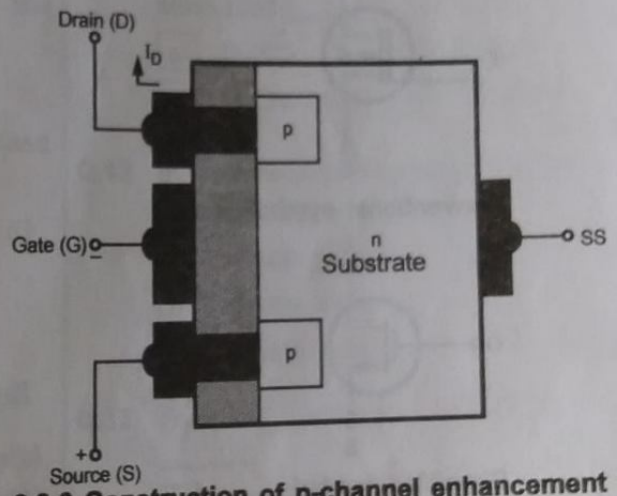


Fig. 8.3.6 Construction of p-channel enhancement type MOSFET

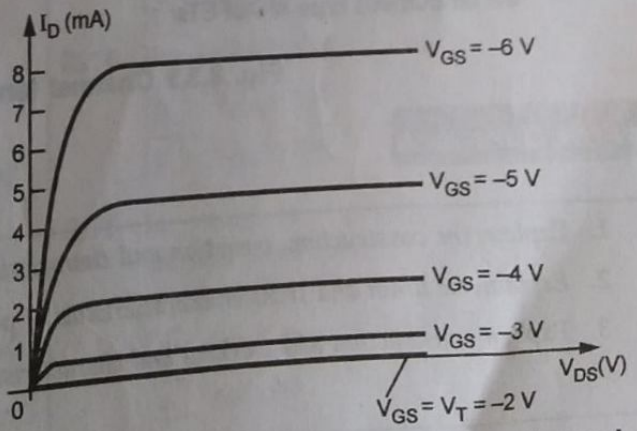


Fig. 8.3.7 Drain characteristics of p-channel enhancement MOSFET

- Fig. 8.3.8 shows the transfer characteristics of p-channel enhancement type MOSFET.
- In the p-channel enhancement type MOSFET, the transfer characteristic is a mirror image about the I_D axis (y axis) of the transfer characteristics of n-channel depletion type MOSFET, since the V_{GS} is negative.

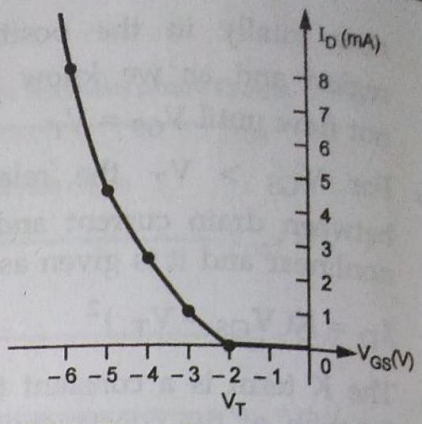
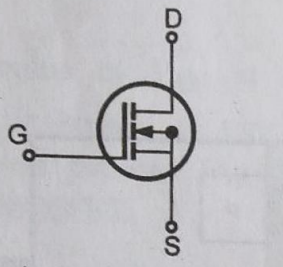


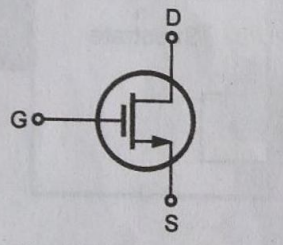
Fig. 8.3.8 Transfer characteristics of p-channel enhancement type

E-MOSFET symbols

Fig. 8.3.9 shows graphic symbols for n and p-channel enhancement type MOSFET.

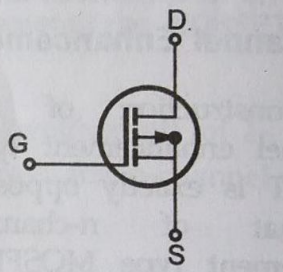


Conventional symbol

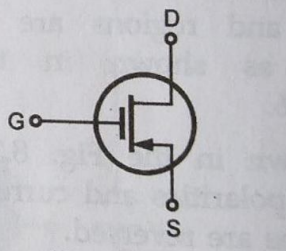


Simplified symbol

(a) Symbols for n-channel enhancement type MOSFETs



Conventional symbol



Simplified symbol

(b) Symbols for p-channel enhancement type MOSFETs

Fig. 8.3.9 Channel length modulation