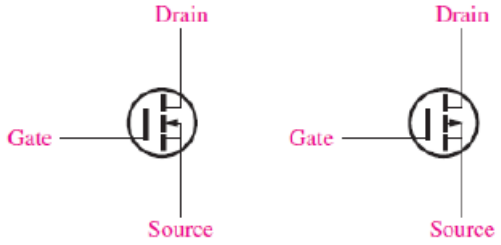
Subject : Basic electrical engineering

Question : MOSFET operation and characteristics

Answer :

MOSFET (Metal Oxide Semiconductor Field-Effect Transistor):

- MOSFET (metal oxide semiconductor field-effect transistor) is another category of field-effect transistor. The MOSFET is different from the JFET and has no pn junction structure instead, the gate of the MOSFET is insulated from the channel by a silicon dioxide (SiO2) layer
- The two basic types of MOSFETs are enhancement (E) and depletion (D)
- Since polycrystalline silicon is used for the gate material instead of metal, these devices are sometimes called IGFETs (insulated-gate FETs)
- The schematic symbols for the n-channel and p-channel E-MOSFETs are shown below



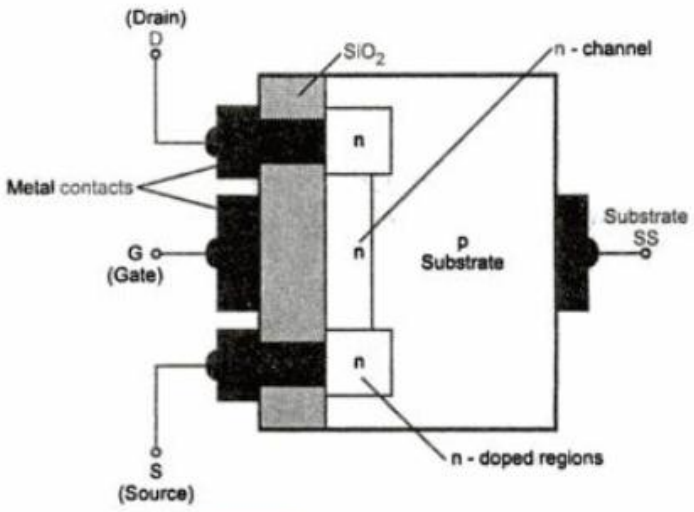
n channel E-MOSFET p channel E-MOSFET

- The broken lines symbolize the absence of a physical channel. An inward pointing substrate arrow denotes n channel, and an outward-pointing arrow denoted p channel

Depletion Mode MOSFET

Construction of n-channel MOSFET

- The below figure shows the basic construction of n channel depletion type MOSFET

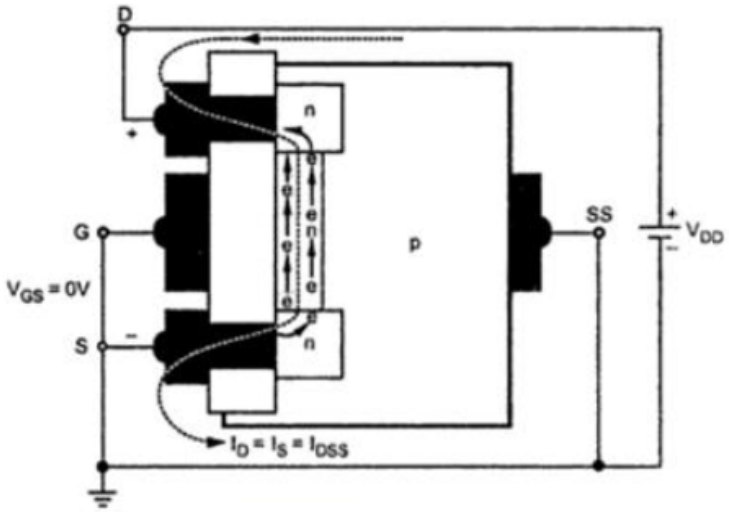


n-channel depletion type MOSFET

- Two highly doped n-regions are diffused into a lightly doped p-type substrate. These two highly doped n-regions represent source and drain. In some cases substrate is internally connected to the source terminal
- The source and drain terminals are connected through metallic contacts to n-doped regions linked by an n-channel
- 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

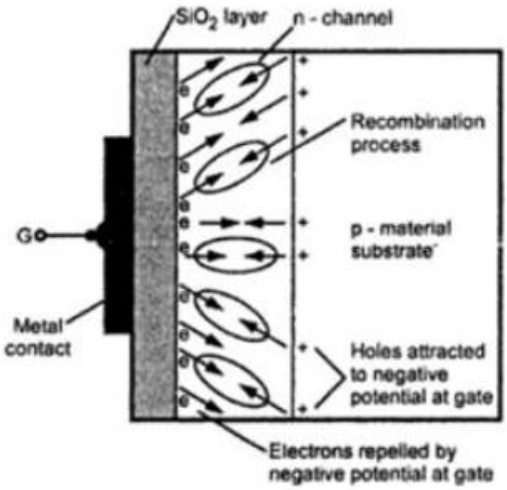
Operation, Characteristics and Parameters of n-channel MOSFET

- 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* $V_{GS} = 0V$, as shown in the below figure



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

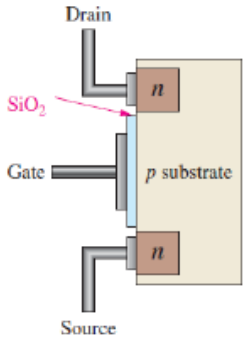
- If we apply negative gate voltage, the negative charges on the gate on the gate repel conduction electrons from the channel, and attract holes from the p-type substrate
- This initiates recombination of repelled electrons and attracted holes as shown in the below figure



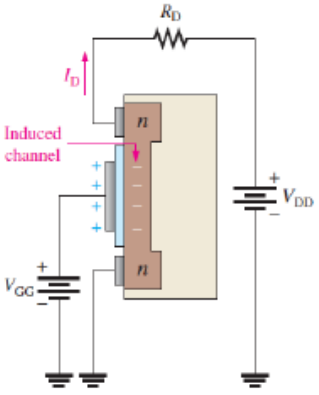
Reduction in free electrons in the n-channel due to negative potential at the gate terminal

- The level of recombination between electrons and holes depends on the magnitude of the negative applied at the gate
- This recombination reduces the number of free electrons in the n-channel for the conduction, reducing the drain current

Enhancement MOSFET (E-MOSFET):



- The E-MOSFET operates only in the enhancement mode and has no depletion mode
- For an n-channel device, a positive gate voltage above a threshold value induces a channel by creating a thin layer of negative charges in the substrate region adjacent to the SiO2 layer
- The conductivity of the channel is enhanced by increasing the gate-to-source voltage and thus pulling more electrons into the channel area
- For any gate voltage below the threshold value, there is no channel

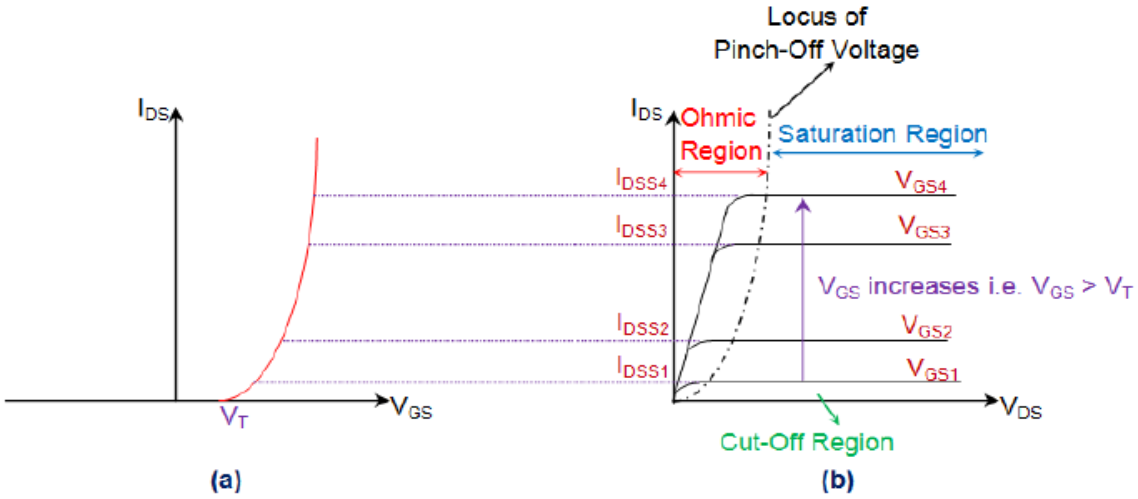


Induced channel (*VGS*>*VGS*(th))

Characteristics of MOSFET:

Based on, voltage applied to the gate, the flow of current has been controlled between the Drain and source terminal.

Based on this control the MOSFET will act in three regions



1. Cut-Off Region:

Cut-off region is a region in which the MOSFET will be OFF as there will be no current flow through it. In this region, MOSFET behaves like an open switch and is thus used when they are required to function as electronic switches.

2. Ohmic or Linear Region:

Ohmic or linear region is a region where in the current I_{DS} increases with an increase in the value of V_{DS}. When MOSFETs are made to operate in this region, they can be used as amplifiers.

3. Saturation Region:

In saturation region, the MOSFETs have their IDS constant in spite of an increase in VDS and occur once VDS exceeds the value of pinch-off voltage VP. Under this condition, the device will act like a closed switch through which a saturated value of IDS flows. As a result, this operating region is chosen whenever MOSFETs are required to perform switching operations.