Quadrant II - Transcript

A warm welcome to all the students. I'm Mr. Narayan Bandodkar, Assistant Professor, Government College of Arts, Science and Commerce,Quepem-Goa. I will be discussing module number 8 MOSFET: Depletion mode that is Depletion type MOSFET from unit 2 Field Effect Transistors. In this module we are going to discuss the concept of MOSFET and its classification, construction and working principle of Depletion type MOSFET and its characteristics. After learning this module, the learner will be able to get introduced to Depletion type MOSFET, will be able to differentiate between FET and Depletion type MOSFET and will be able to understand the construction and working principle of Depletion type MOSFET. MOSFET is a Metal Oxide Semiconductor Field Effect Transistor having three main terminals, gate, drain and source, in which the current flow between drain and source is controlled by applying voltage to its gate terminal. Now these MOSFET's are basically classified into two types:Depletion type MOSFET and Enhancement type MOSFET. A Depletion type MOSFET has got a continuous n- channel existing between its drain and source terminals whereas a Enhancement type MOSFET there is no n-channel between its drain and source terminals and Depletion type MOSFET works for zero gate voltage, negative gate voltage and positive gate voltage whereas an Enhancement type MOSFET works only for positive gate voltage. These MOSFET's are further classified into n-channel and p-channel MOSFET. In this module we are going to study n- channel Depletion type MOSFET in detail. Let us now discuss the construction of n-channel Depletion type MOSFET. It basically consists of a lightly doped p-type Silicon substrate which acts as the base material for fabricating this device. In this lightly doped p-type substrate a lightly doped n-type semiconducting channel is diffused. The ends of the n-channel are heavily doped regions represented by N Plus. These are heavily doped regions because the metal contacts are to be formed for these regions.On the entire surface of N plus regions, n-channel and p-type substrate, a thin layer of Silicon dioxide that is SiO_2 is deposited and then selectively removing this SiO_2 layer, the metal contacts are formed for drain and source terminals for these N plus regions, a metal contact is also formed for gate terminal. Sometimes the substrate or bulk is internally connected to source at the time of fabricating the device. So let us now try to understand how this device represents a MOS device. M stands for Metal, O stands for Oxide and S stands for Semiconductor. So we have got a metal gate on one side, SiO_2 layer in between and we have got an n-type silicon channel on the other side. So this device represents a MOS device, Metal Oxide Semiconductor Field Effect Transistor and the input of this device that is at the gate side there is a formation of parallel plate capacitor with gate serving as one metal plate, SiO_2 layer in between serving as the dielectric material and n-type channel acting as the other plate of the capacitor. So due to the formation of a parallel plate capacitor at the input, the input resistance of this device is much much higher compared to an ordinary Field Effect Transistor. The symbol shows the bulk terminal or substrate terminal open or it can be shorted to source. A continuous n-channel is shown between drain and source. Gate is shown insulated from the n-channel and that's why this device is sometimes called Insulated Gate Field Effect Transistor or IGFET. So this arrow direction shows invards. Let us now discuss the working principle of Depletion type MOSFET under different voltage conditions when gate is given zero volts, when the gate is given negative voltage and when gate is given a positive voltage. So let us consider the first condition that the gate is given zero volts that is V_{GS} 0 volt. So gate is not given any voltage here. It is considered as 0 volt. Voltage between drain and source is applied by connecting positive terminal of the Voltage source to drain and negative terminal is connected to source which is grounded. Under this condition it is observed that there is a continuous n- channel existing between drain and source. As a result electrons can move from source to drain and as a result drain current flows under this condition. So there is a finite amount of drain current which flows under V_{GS} is equal to 0 volt condition for depletion type MOSFET. If you look at the drain characteristic curve under this condition it is similar to FET characteristics which shows that for lower values of drain to source voltages , the drain current increases linearly with the drain to source voltage in the linear region or channel ohmic region and for higher values of V_{DS} the drain current tries to remains almost constant in the saturation region or non-linear region. So for corresponding to V_{GS} equal to 0 volt condition, the maximum current obtained is I_{DSS}, I_{DSS} represents zero gate voltage drain current. Let us consider the second condition(voltage condition) when the gate is given a negative voltage. Let us say minus 1 volt. So we can apply negative voltage with the help of this voltage source by connecting the negative terminal of the source to the gate and positive terminal is connected to source which is grounded and voltage between drain and source is applied which is variable. Under this condition it is observed that the metal gate gets a negative charge and as a result positive charges are getting accumulated near the oxide channel interface just below the gate terminal. So positive charge gets induced in this area. This is a n- channel so it is already having negative charges in it. The positive charges and negative charges from the n-channel both recombine and deplete, the n- channel of majority charge carriers electrons. As a result the conductivity of n-channel decreases, thereby decreasing the drain current. So under this condition the drain current decreases. The drain characteristics for this condition is similar to FET characteristics for negative gate to source voltage which shows that for lower values of drain to source voltage, the drain current increases linearly with the drain to source voltage in the channel ohmic region or linear region and for higher V_{DS}, the drain current remains almost constant. There also exists a depletion region in this. So the width of the depletion region increases as the gate to source voltage is made more and more negative. As the gate to source voltage increases negatively and when the V_{GS} value reaches $V_{GS(off)}$ or pinch of voltage, the drain current is cut off. This working mode of the device where drain current decreases for negative gate to source voltage is called Depletion mode of operation. Let us now consider when the gate voltage is given positive. So we can apply a positive voltage with the help of a voltage source by connecting the positive terminal to the gate. Negative terminal is connected to the source which is grounded and the voltage between drain and source is applied which is variable. Under this condition it is observed that the metal gate gets a positive charge and as a result negative charges are getting induced in this area so that negative charge gets accumulated near the oxide channel interface just below the gate terminal. So as a result, the conductivity of this n- channel increases thereby increasing the drain current. So when V_{GS} is given positive voltage, the drain current increases above I_{DSS} that is shown in the drain characteristics corresponding to V_{GS} equal to +1 Volt, which shows that for lower values of drain to source voltages, drain current increases linearly and for higher values of V_{DS} the drain current tries to remain almost constant. The drain current which is flowing in non-linear region or saturation region is given by the equation I_D is equal to I_{DSS} times one minus V_{GS} upon V_P the whole square, I_{DSS} represents zero gate voltage drain current, V_{GS} is gate to source voltage, V_P is the pinch of voltage. So this working mode of the device is called Enhancement mode where the drain current increases with positive gate to source voltage. This diagram shows the transfer characteristic along with drain characteristics of depletion type MOSFET. The graph of drain current I_D versus gate to source voltage for constant V_{DS} represents transfer characteristic, which shows that when V_{GS} is 0 volts, there is a finite amount of drain current I_{DSS} and as V_{GS} is made negative the drain current starts decreasing. As V_{GS} approaches $V_{GS(off)}$ or pinch-off voltage, the drain current becomes zero. So the device is operating in Depletion mode where the current is decreasing and finally becoming zero at $V_{GS(off)}$. When V_{GS} is made positive, the drain current starts increasing above I_{DSS} and the device operates in the Enhancement mode. If you compare depletion type MOSFET with the ordinary field effect transistor, ordinary field effect transistors work for V_{GS} zero and negative voltages. Depletion type MOSFET also works for V_{GS} zero, negative voltages but it also works for positive gate to source voltage.