VLSI DESIGN

MOSFET

Metal-oxide-semiconductor field-effect transistor (MOSFET) became a practical reality in the 1970s. The MOSFET, compared to BJTs, can be made very small (that is, it occupies a very small area on an IC chip).

- In the MOSFET, the current is controlled by an electric field applied perpendicular to both the semiconductor surface and to the direction of current.

CONT..

The phenomenon used to control the current in a semiconductor, by applying an electric field perpendicular to the surface is called the **field effect.**

The basic transistor principle is that the voltage between two terminals controls the current through the third terminal.

Two-Terminal MOS Structure

The heart of the MOSFET is the metal-oxide-semiconductor capacitor shown in Figure.

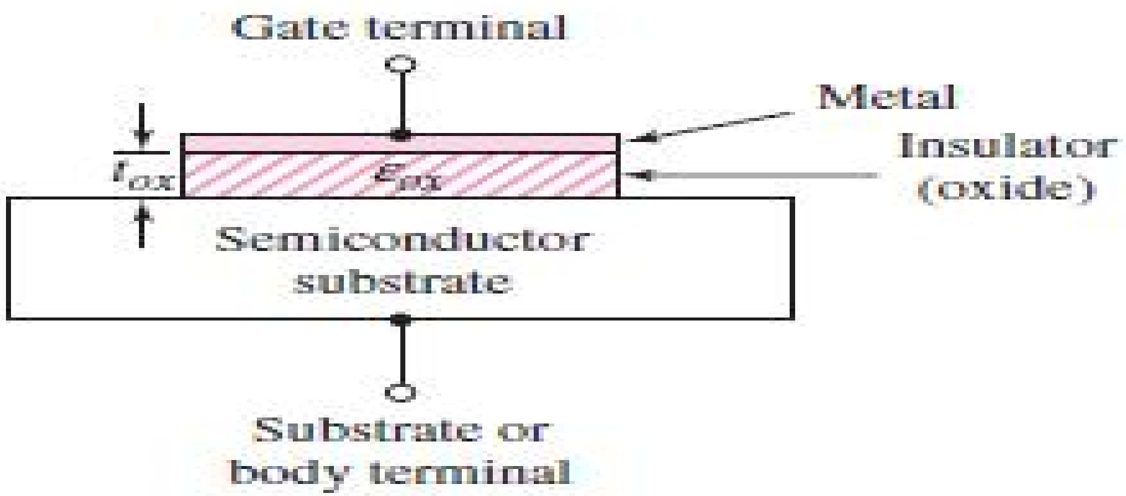
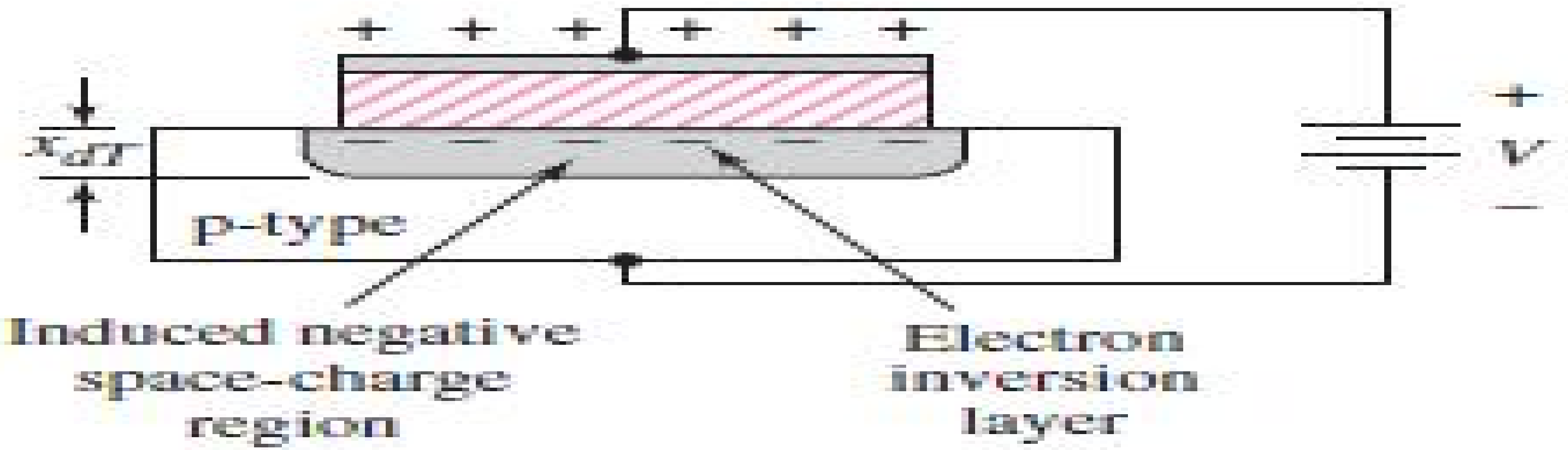


Figure 3.1 The basic MOS capacitor structure

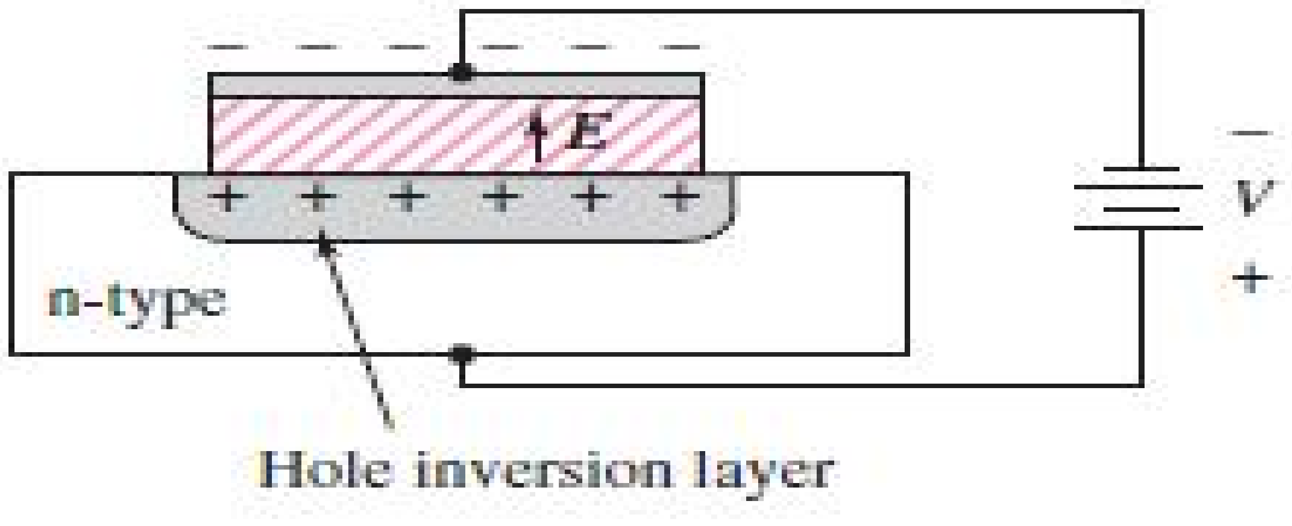
Cont..



When a larger positive voltage is applied to the gate, the magnitude of the induced electric field increases. Minority carrier electrons are attracted to the oxide semiconductor interface, as shown in Figure. This region of minority carrier electrons is called an **electron inversion layer.**

Cont..

When a larger negative voltage is applied, a region of positive charge is created at the oxide-semiconductor interface, as shown in Figure. This region of minority carrier holes is called a **hole inversion layer.**



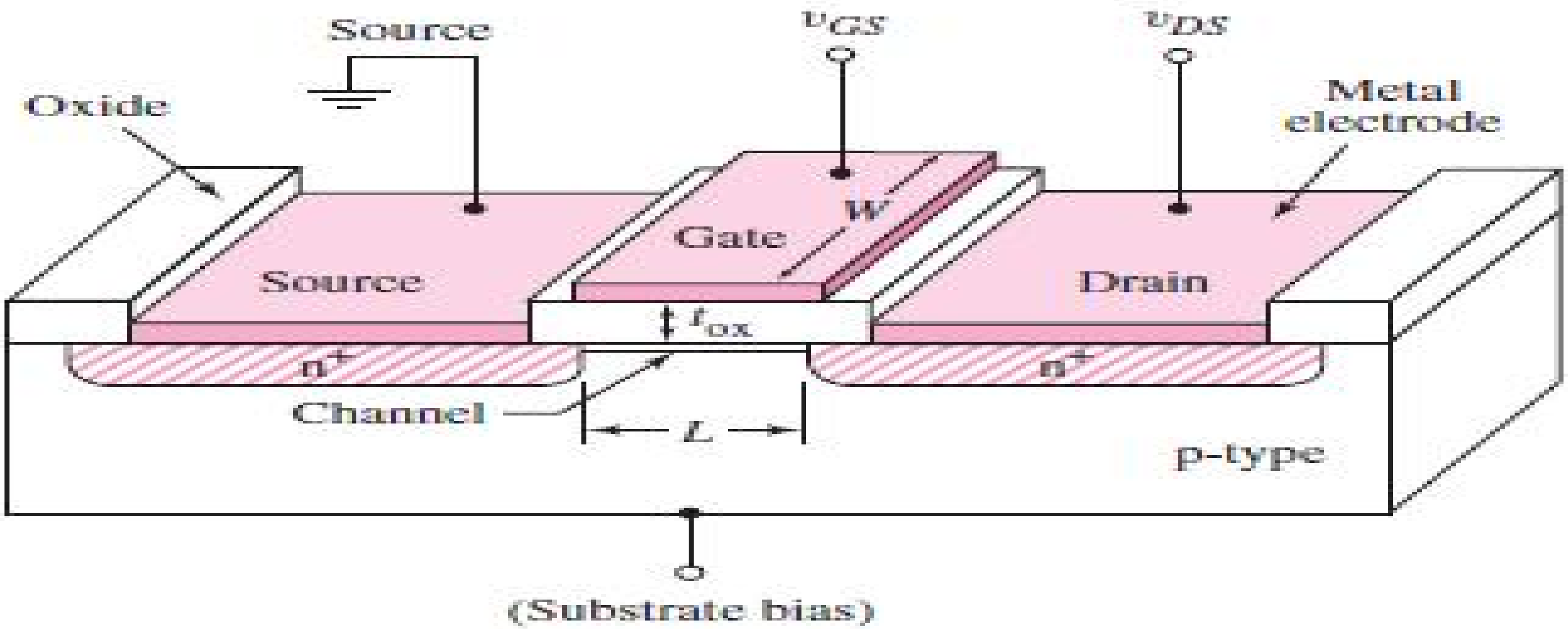
Cont..

The term **enhancement mode means that a voltage must be applied to the gate** to create an inversion layer. For the MOS capacitor with a p-type substrate, a positive gate voltage must be applied to create the electron inversion layer; for the MOS capacitor with an n-type substrate, a negative gate voltage must be applied to create the hole inversion layer.

n-Channel Enhancement-Mode MOSFET

We will now apply the concepts of an inversion layer charge in a MOS capacitor to create a transistor.

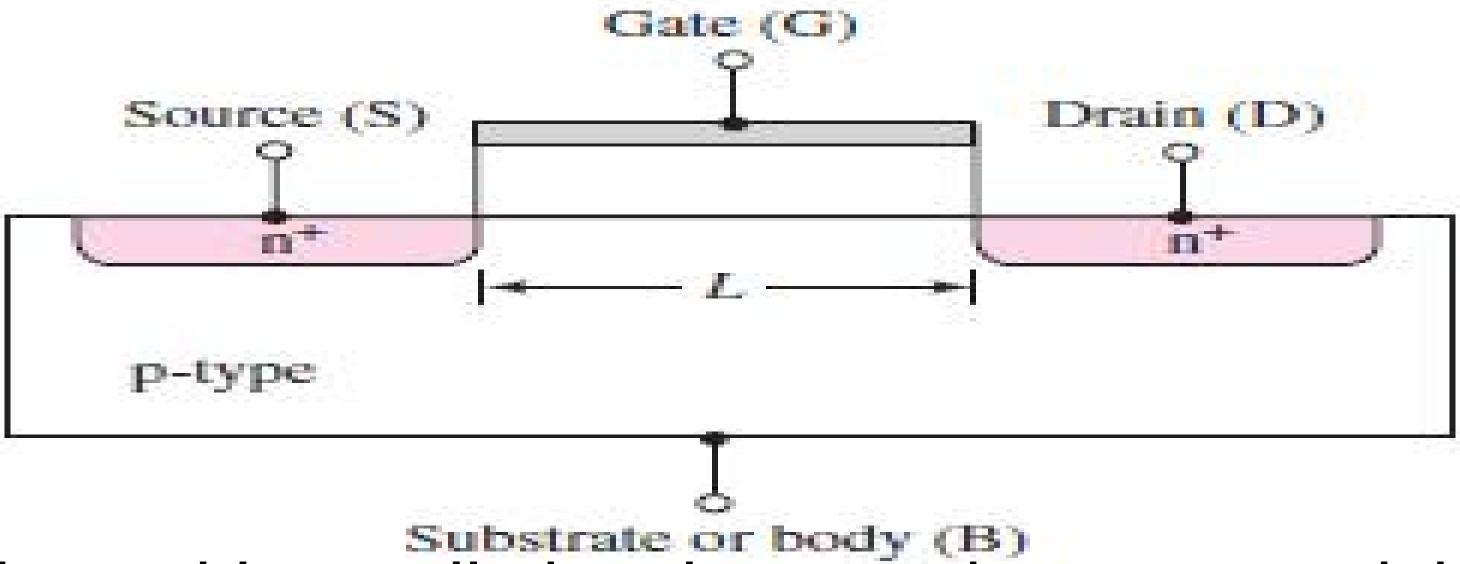
Transistor Structure:



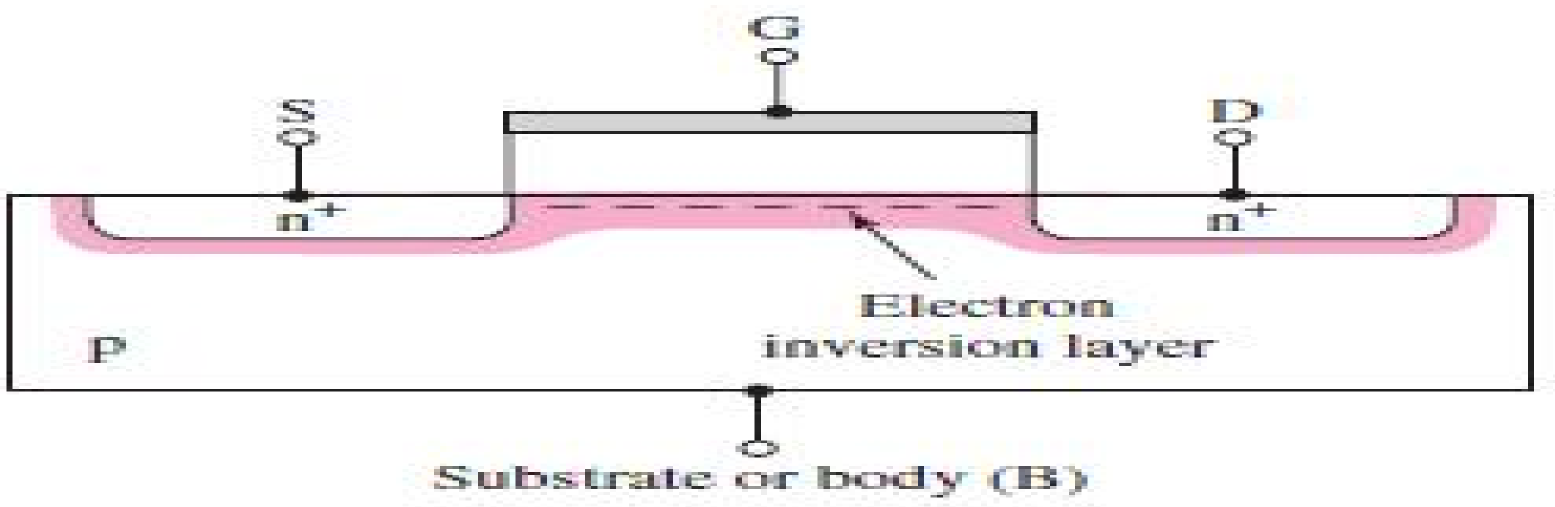
Cont..

Figure shows a simplified cross section of a MOS field-effect transistor. The gate, oxide, and p-type substrate regions are the same as those of a MOS capacitor. In addition, we now have two n-regions, called the **source terminal and drain terminal. The current in a MOSFET is the result of the flow of charge in the inversion** layer, also called the **channel region, adjacent to the oxide–semiconductor** interface.

Basic Transistor Operation



With zero bias applied to the gate, the source and drain terminals are separated by the p-region, as shown in Figure. The current in this case is essentially zero. If a large enough positive gate voltage is applied, an electron inversion layer is created at the oxide–semiconductor interface and this layer “connects” the n-source to the n-drain, as shown in Figure.



A current can then be generated between the source and drain terminals. Since a voltage must be applied to the gate to create the inversion charge, this transistor is called an **enhancement-mode MOSFET. Also, since the** carriers in the inversion layer are electrons, this device is also called an **n-channel MOSFET (NMOS).**

Cont..

- The source terminal supplies carriers that flow through the channel, and the drain terminal allows the carriers to drain from the channel. For the n-channel MOSFET, electrons flow from the source to the drain with an applied drain-to-source voltage.
- The magnitude of the current is a function of the amount of charge in the inversion layer, which in turn is a function of the applied gate voltage.