The Threshold Voltage Lesson

Lesson Topic: The Threshold Voltage

Objective of Lesson: To learn some details about the threshold voltage for a metal oxide semiconductor capacitor (MOS-C).

Reading Assignment: Section 18.3

Homework: None

Discussion Questions:

1. List everything that impacts the threshold voltage.

What do you need to know for the exam?

1. All the parameters one can use to design the threshold voltage of a MOS-C or MOSFET.
2. The two “mode” types of MOSFET.
3. How to compute threshold voltage.

Summary The threshold voltage,VT, is really important. It is a critical parameter of the most fabricated device on the planet. It determines more than any other parameter how a MOSFET will perform. The effects we call non-idealities are actually powerful tools for designing a MOSFET to operate in a manner consistent with engineering desires. The designer-controllable parameters are discussed in this lesson.

The Threshold Voltage
The threshold voltage,V_T, is really important. It is a critical parameter of the most fabricated device on the planet. It determines more than any other parameter how a MOSFET will perform. The text presents the threshold as the following,

$$\mathbf{V_T = V'_T + \text{Non-idealities}}$$

So V'_T is what the threshold voltage would have been if it were an ideal device. As there is no such thing as an ideal MOS-C, one must always consider the impact of the non-idealities. The mathematical equation is,

$\mathbf{V_T = V'_T + V_{FB}}$, where

$$V'_T = 2\phi_F \pm \frac{K_s}{K_o} x_o \sqrt{\frac{4qN_B}{K_s \varepsilon_o}(\pm\phi_F)}$$

and

$$V_{FB} = \phi_{MS} - \frac{Q_M}{C_o} - \frac{Q_M \gamma_M}{C_o} - \frac{Q_{IT}}{C_o}$$

.

N_B is the doping in the semiconductor. The rest you have seen before recently.

These equations lay it out very clearly in terms of how varies with the many parameters. Many of these parameters are controllable by designers much to their advantage.

Increasing the doping in the semiconductor increases not only N_B of course but also, both of which increase V_T . Changing x_o changed V_T as well. Well, you can see the rest of the parameters and how they impact V_T . We'll finish by making a list of what the designer can use to control the threshold voltage:

1. Semiconductor doping
2. Semiconductor doping type
3. Metal-semiconductor work function difference (by controlling doping and dopant or the gate material).
4. Thickness of oxide (note that that also impacts C_o).

Controlling these quantities allow the device designer to control the threshold voltage. One can design a MOSFET that is normally "on," and that type of transistor is called a "depletion mode" device. A MOSFET that is normally "off" is called an "enhancement mode" device.

Definitions:

Enhancement: raised up, with improved features.

Depletion: to empty out.