Bulk-Charge Theory Lesson

Lesson Topic: Bulk-Charge Theory

Objective of Lesson: To understand the limitations of the two I_D-V_D-V_G relationships, bulk-charge theory and square-law theory.

Reading Assignment: Section 17.2.3

Homework: None

Discussion Questions:

1. How are square-law and bulk-charge theories different?

What do you need to know for the exam? None

Summary
There are many models of increasing complexity, accuracy, and applicability for the I_D-V_D-V_G of a MOSFET. This lesson discusses the bulk-charge theory approach and its place among the other models or approaches.

Bulk-Charge Theory
The previous model for I_D-V_D-V_G of a MOSFET, the square-law theory, had its limitations and inaccuracies because we were trying to obtain a closed-form solution—an equation. The neat thing is that the derivation result really works well for long-channel transistors. Both the square-law theory and the bulk-charge theory—to be discussed in this lesson—have inherent limitations, especially involving charge. The charge in the channel does not disappear for voltages below threshold and then magically appear for voltages above threshold. The other issue is that they are not “self-saturating.” What that means is that we have to state, “Well, the current stays the same after pinch-off.” Why? Because we said so! In other words, the saturation is not built into the equation that is used “pre-“ saturation. There are two more theories/approaches discussed in the text, but we are running out of time in the semester so we will stop with the first two. Remember that all of these, more or less, are replaced by sophisticated computer models for modern devices.

Let’s talk about the bulk-charge theory now.

The bulk-charge theory tries to address the issue of the simplification of the charge distribution approach used for the square-law theory. The text mentions that an implicit assumption is that the depletion region is the same width all along the channel. You can see that this is not true by referring again to the demo/animation on MOSFETs—at the point where the animation allows the user to step through increasing values of the drain voltage. The depletion region is represented by a broken line. This means the capacitance is not uniform across the channel so the estimate

for the capacitance will be overestimated. Including the width of the depletion region in the analysis gives a more accurate estimate of the charge, and this is the difference between the two models.

Figure 17.9 from the text shows plots of the I_D-V_D-V_G characteristics from the bulk-charge theory and square-law theory for a particular set of parameter values. The figure shows that the two models produce results that are similar but clearly different. The presumption is that the bulk-charge model more accurately predicts device behavior. It should also be better at modeling short-channel devices.

Links:
MOSFETs demo