

**6.7****CHAPTER SUMMARY**

- A voltage-dependent current source can form an amplifier along with a load resistor. MOSFETs are electronic devices that can operate as voltage-dependent current sources.
- A MOSFET consists of a conductive plate (the “gate”) atop a semiconductor substrate and two junctions (“source” and “drain”) in the substrate. The gate controls the current flow from the source to the drain. The gate draws nearly zero current because an insulating layer separates it from the substrate.

- As the gate voltage rises, a depletion region is formed in the substrate under the gate area. Beyond a certain gate-source voltage (the “threshold voltage”), mobile carriers are attracted to the oxide-silicon interface and a channel is formed.
- If the drain-source voltage is small, the device operates a voltage-dependent resistor.
- As the drain voltage rises, the charge density near the drain falls. If the drain voltage reaches one threshold below the gate voltage, the channel ceases to exist near the drain, leading to “pinch-off.”
- MOSFETs operate in the “triode” region if the drain voltage is more than one threshold below the gate voltage. In this region, the drain current is a function of  $V_{GS}$  and  $V_{DS}$ . The current is also proportional to the device aspect ratio,  $W/L$ .
- MOSFETs enter the “saturation region” if channel pinch-off occurs, i.e., the drain voltage is less than one threshold below the gate voltage. In this region, the drain current is proportional to  $(V_{GS} - V_{TH})^2$ .
- MOSFETs operating in the saturation region behave as current sources and find wide application in microelectronic circuits.
- As the drain voltage exceeds  $V_{GS} - V_{TH}$  and pinch-off occurs, the drain end of the channel begins to move toward the source, reducing the effective length of the device. Called “channel-length modulation,” this effect leads to variation of drain current in the saturation region. That is, the device is not an ideal current source.
- A measure of the small-signal performance of voltage-dependent current sources is the “transconductance,” defined as the change in the output current divided by the change in the input voltage. The transconductance of MOSFETs can be expressed by one of three equations in terms of the bias voltages and currents.
- Operation across different regions and/or with large swings exemplifies “large-signal behavior.” If the signal swings are sufficiently small, the MOSFET can be represented by a small-signal model consisting of a *linear* voltage-dependent current source and an output resistance.
- The small-signal model is derived by making a small change in the voltage difference between two terminals while the other voltages remain constant.
- The small-signal models of NMOS and PMOS devices are identical.
- NMOS and PMOS transistors are fabricated on the same substrate to create CMOS technology.