14–1 The Depletion-Mode MOSFET

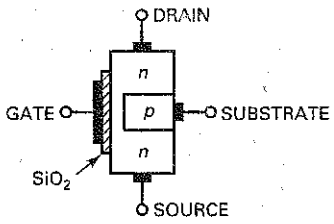
Figure 14-1 shows a **depletion-mode MOSFET,** a piece of n material with an insulated gate on the left and a p region on the right. The p region is called the **substrate.** Electrons flowing from source to drain must pass through the narrow channel between the gate and the p substrate.

A thin layer of silicon dioxide (SiO_2) is deposited on the left side of the channel. Silicon dioxide is the same as glass, which is an insulator. In a MOSFET, the gate is metallic. Because the metallic gate is insulated from the channel, negligible gate current flows even when the gate voltage is positive.

Figure 14-2*a* shows a depletion-mode MOSFET with a negative gate voltage. The V_{DD} supply forces free electrons to flow from source to drain. These electrons flow through the narrow channel on the left of the p substrate. As with a JFET, the gate voltage controls the width of the channel. The more negative the gate voltage, the smaller the drain current. When the gate voltage is negative enough, the drain current is cut off. Therefore, the operation of a depletion-mode MOSFET is similar to that of a JFET when V_{GS} is negative.

Since the gate is insulated, we can also use a positive input voltage, as shown in Fig. 14-2*b*. The positive gate voltage increases the number of free electrons flowing through the channel. The more positive the gate voltage, the greater the conduction from source to drain.

Figure 14–1 Depletion-mode MOSFET.



GOOD TO KNOW

Like a JFET, a depletion-mode MOSFET is considered a normally on device. This is because both devices have drain current when $V_{GS} = 0$ V. Recall that for a JFET, I_{DSS} is the maximum possible drain current. With a depletion-mode MOSFET, the drain current can exceed I_{DSS} if the gate voltage is of the correct polarity to increase the number of charge carriers in the channel. For an n-channel D-MOSFET, I_D is greater than I_{DSS} when V_{GS} is positive.

14–2 D-MOSFET Curves

Figure 14-3*a* shows the set of drain curves for a typical n-channel, depletion-mode MOSFET. Notice that the curves above $V_{GS} = 0$ are positive and the curves below $V_{GS} = 0$ are negative. As with a JFET, the bottom curve is for $V_{GS} = V_{GS(off)}$ and the drain current will be approximately zero. As shown, when $V_{GS} = 0$ V, the drain current will equal I_{DSS}. This demonstrates that the depletion-mode MOSFET, or D-MOSFET, is a *normally on* device. When V_{GS} is made negative, the drain current will be reduced. In contrast to an n-channel JFET, the n-channel D-MOSFET can have V_{GS} made positive and still function properly. This is because there is no pn junction to become forward biased. When V_{GS} becomes positive, I_D will increase following the square-law equation

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)^2 \tag{14-1}$$

Figure 14–2 (*a*) D-MOSFET with negative gate; (*b*) D-MOSFET with positive gate.