DIODE CHARACTERISTICS

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DIODE STRUCTURE AND SYMBOLS:

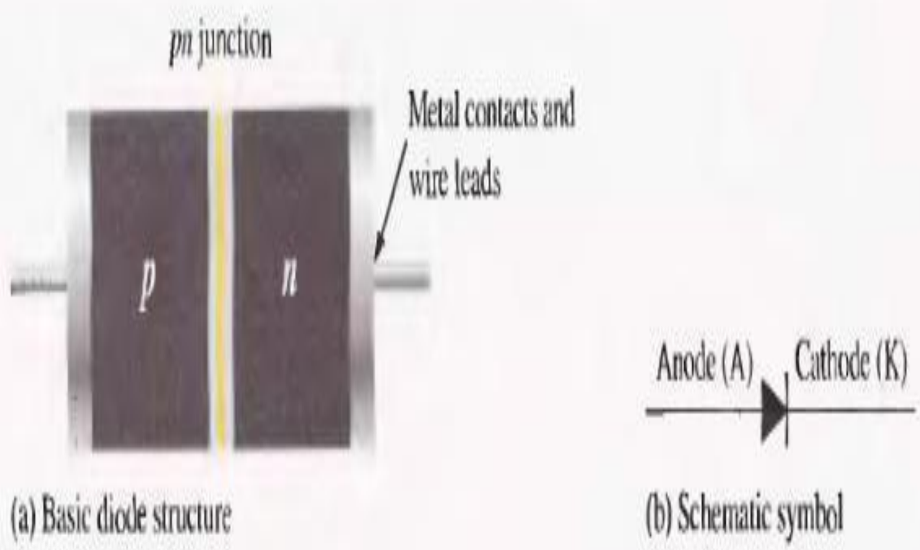


FIGURE 1-31

Diode structure and schematic symbol.

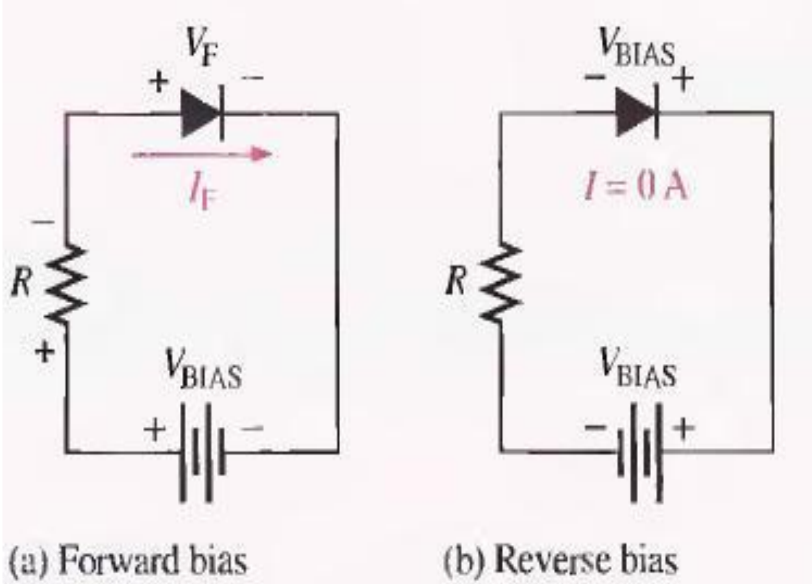


FIGURE 1-32

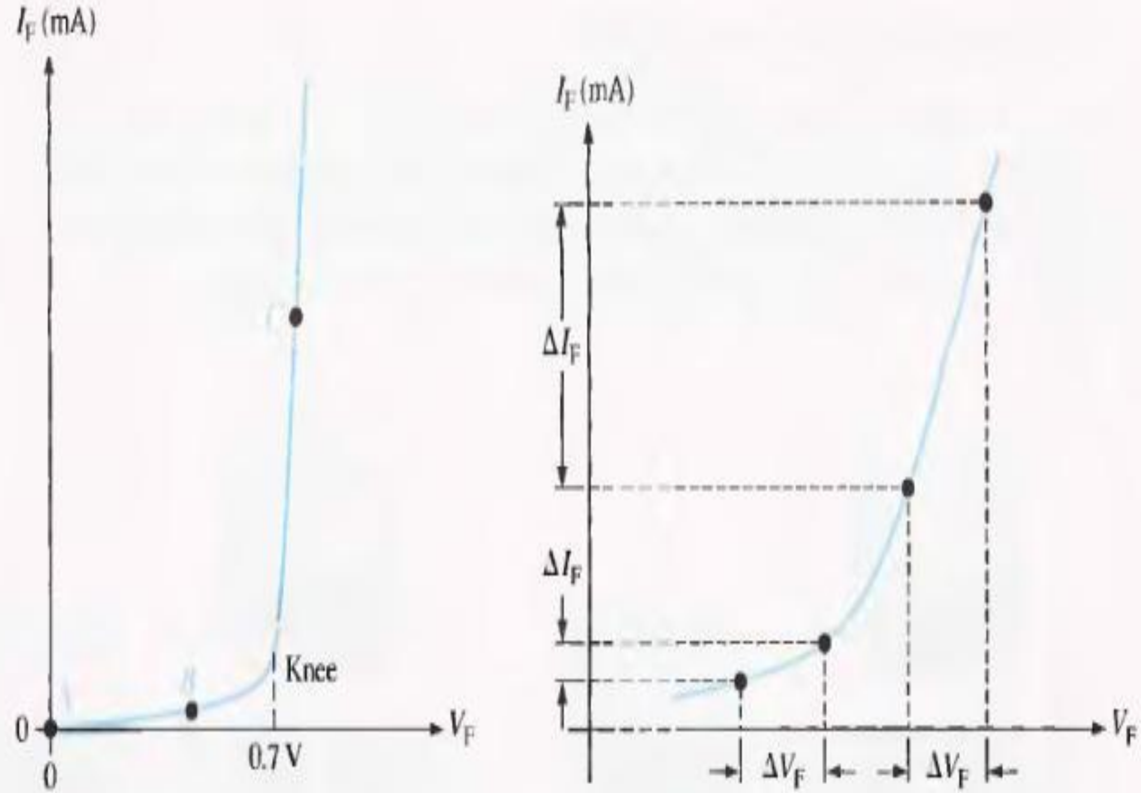
Forward-bias and reverse-bias connections showing the diode symbol.

VOLTAGE-CURRENT CHARACTERISTICS OF A DIODE:

V-I Characteristics for Forward Bias:

FIGURE 1–27

Relationship of voltage and current in a forward-biased diode.



(a) *V-I* characteristic curve for forward bias.

(b) Expanded view of a portion of the curve in part (a). The dynamic resistance r'_d decreases as you move up the curve, as indicated by the decrease in the value of $\Delta V_F / \Delta I_F$.

V-I Characteristics for Reverse Bias:

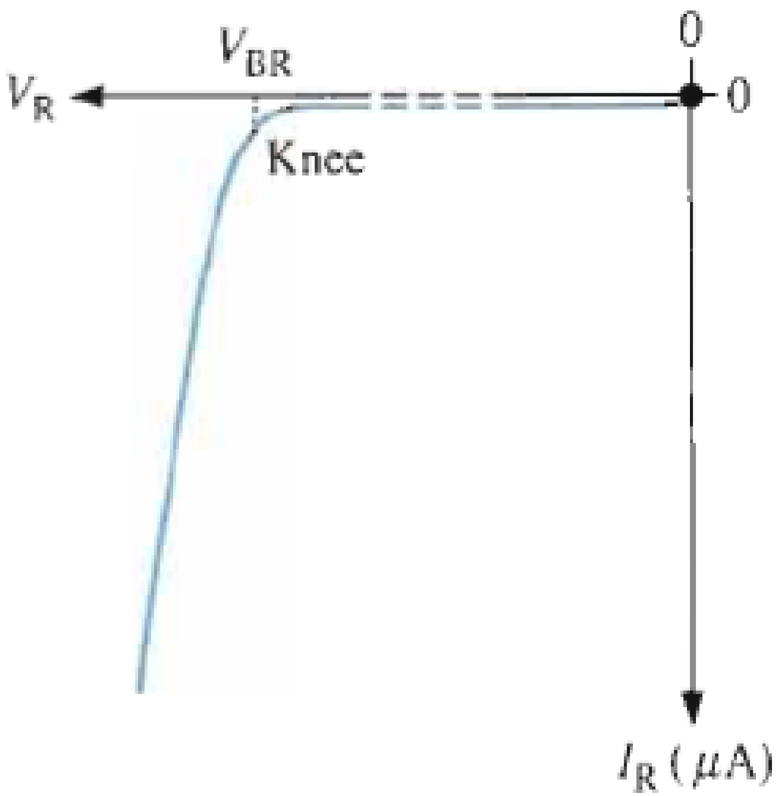


FIGURE 1–28

V-I characteristic curve for a reverse-biased diode.

The Complete V-I Characteristic Curve:

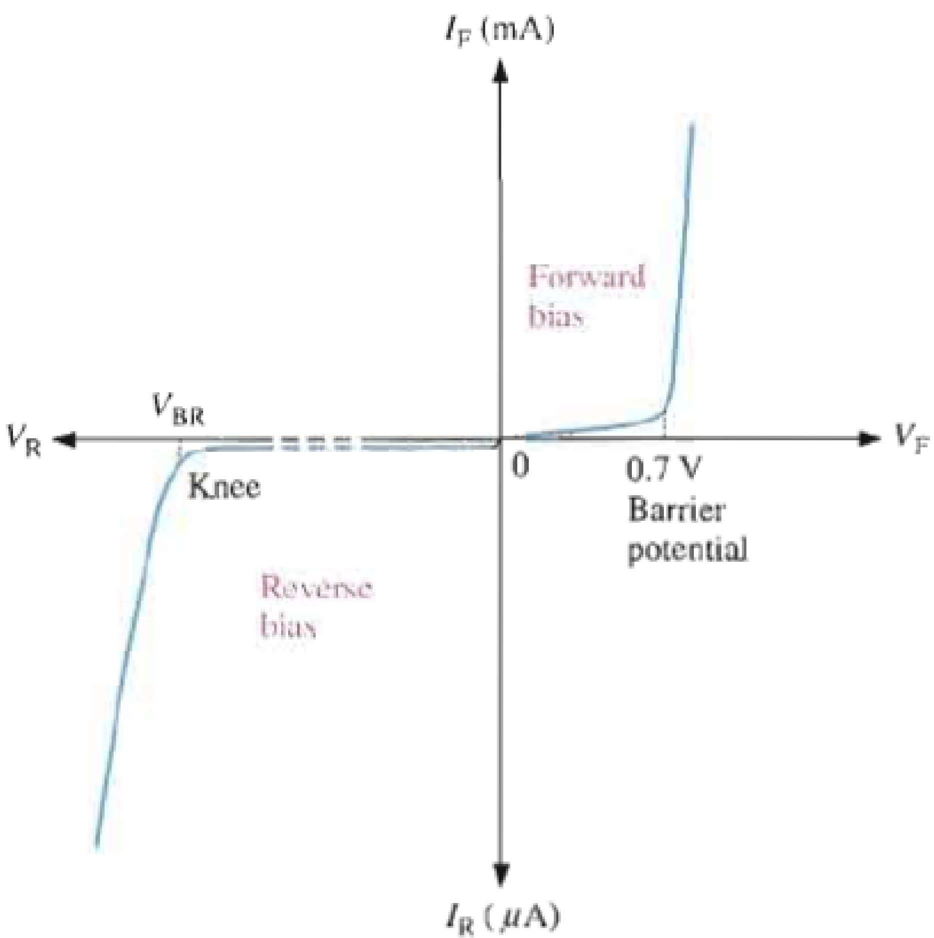


FIGURE 1–29

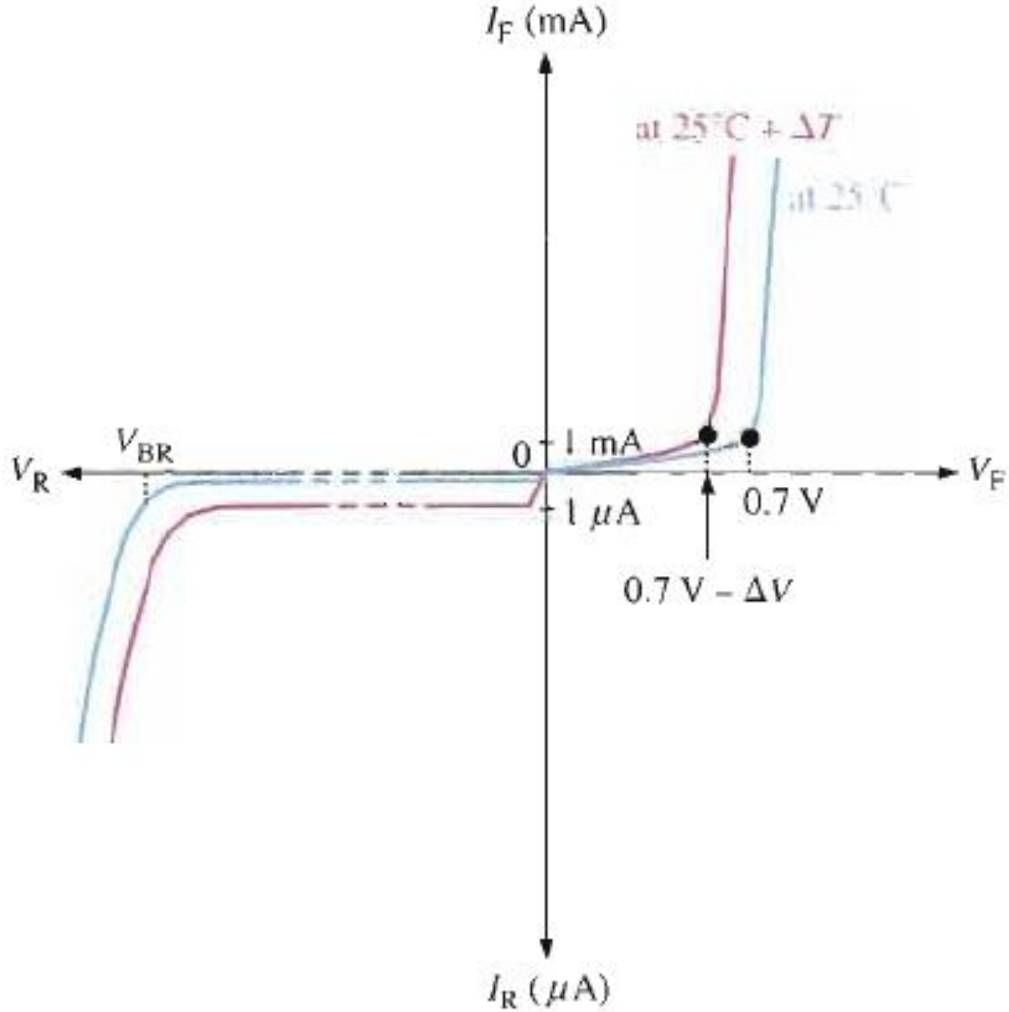
The complete *V-I* characteristic curve for a diode.

Temperature Effects For a forward-biased diode, as temperature is increased, the forward current increases for a given value of forward voltage. Also, for a given value of forward current, the forward voltage decreases. This is shown with the *V-I* characteristic curves in Figure 1–30. The blue curve is at room temperature (25°C) and the red curve is at an elevated temperature (25°C + ΔT). Notice that the barrier potential decreases as temperature increases.

For a reverse-biased diode, as temperature is increased, the reverse current increases. The difference in the two curves is exaggerated on the graph in Figure 1–30 for illustration. Keep in mind that the reverse current below breakdown remains extremely small and can usually be neglected.

FIGURE 1–30

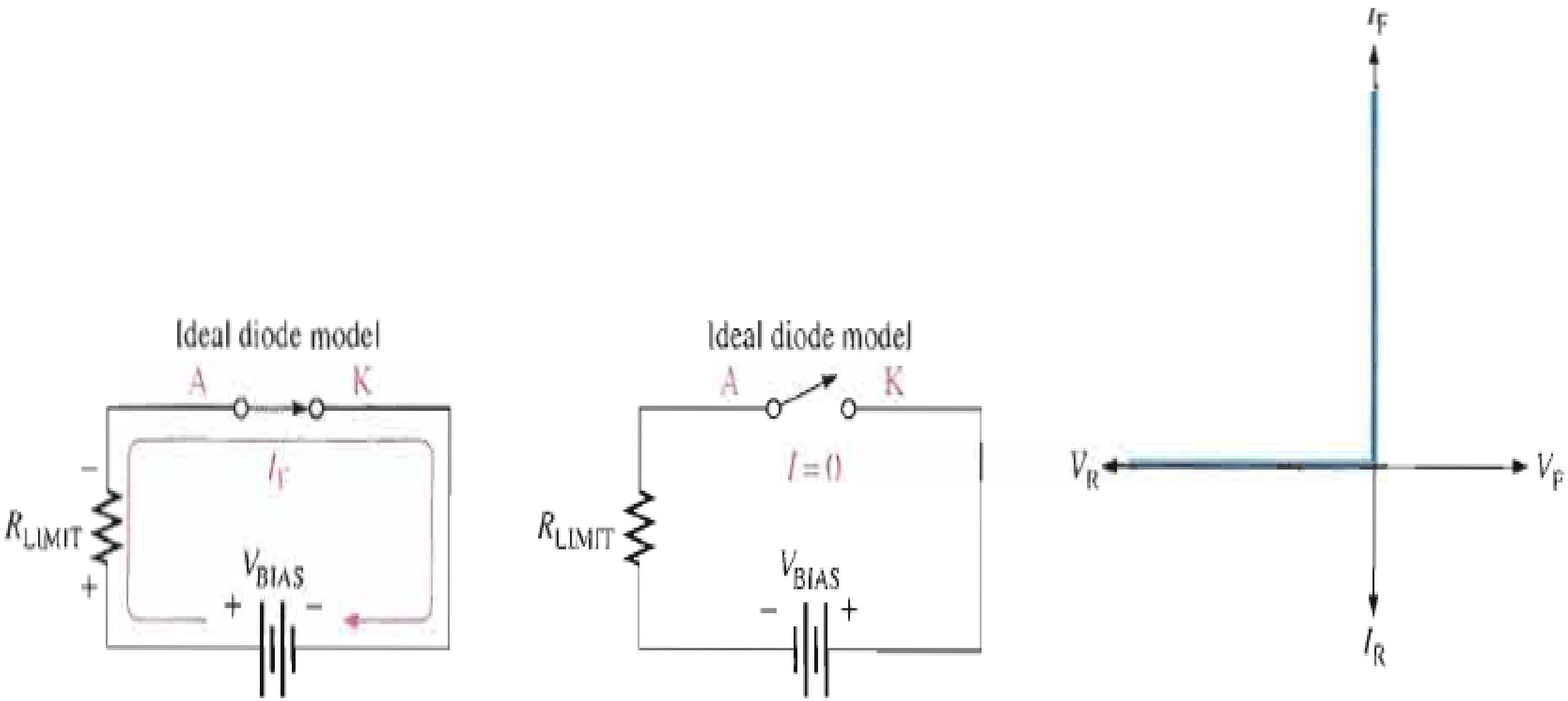
Temperature effect on the diode *V-I* characteristic. The 1 mA and 1 μA marks on the vertical axis are given as a basis for a relative comparison of the current scales.



DIODE APPROXIMATION MODELS:

The Ideal Diode Model

The ideal model of a diode is a simple switch. When the diode is forward-biased, it acts like a closed (on) switch, as shown in Figure 1–33(a). When the diode is reverse-biased, it acts like an open (off) switch, as shown in part (b). The barrier potential, the forward dynamic resistance, and the reverse current are all neglected.



(a) Forward bias (b) Reverse bias (c) Ideal characteristic curve (blue)

In Figure 1–33(c), the ideal *V-I* characteristic curve graphically depicts the ideal diode operation. Since the barrier potential and the forward dynamic resistance are neglected, the diode is assumed to have a zero voltage across it when forward-biased, as indicated by the portion of the curve on the positive vertical axis.

$$V_F = 0 \text{ V}$$

The forward current is determined by the bias voltage and the limiting resistor using Ohm's law.

$$I_F = \frac{V_{BIAS}}{R_{LIMIT}}$$

Since the reverse current is neglected, its value is assumed to be zero, as indicated in Figure 1–33(c) by the portion of the curve on the negative horizontal axis.

$$I_R = 0 \text{ A}$$

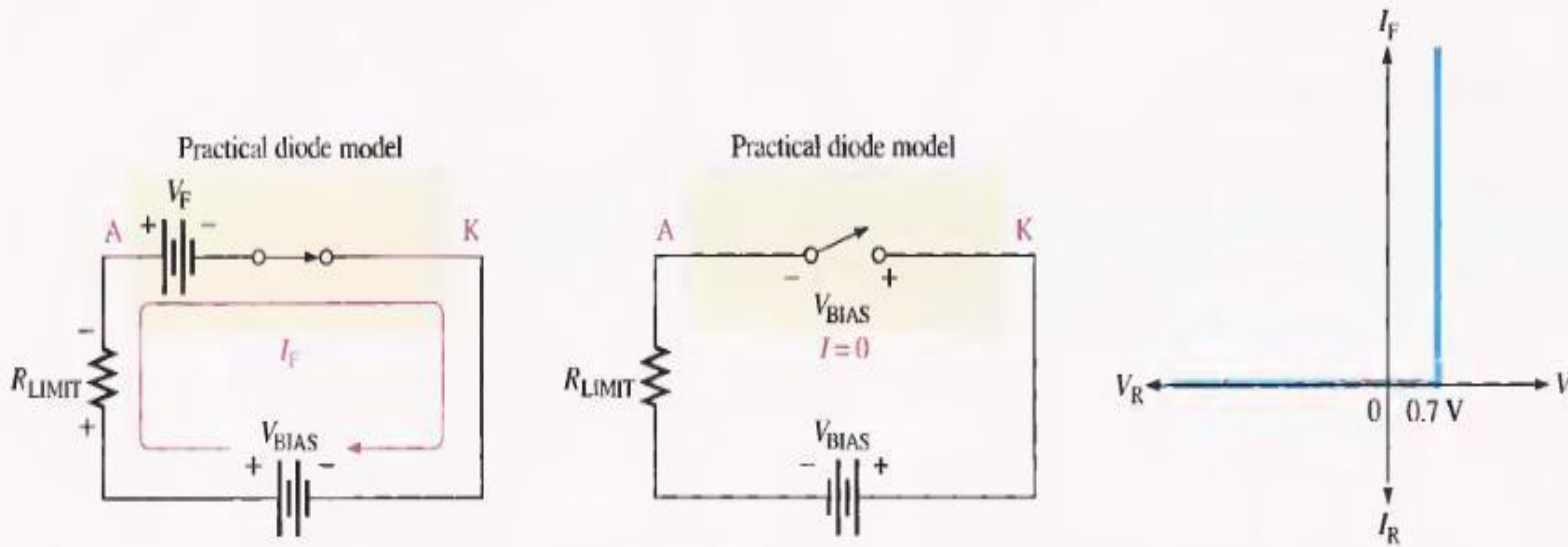
The reverse voltage equals the bias voltage.

$$V_R = V_{BIAS}$$

You may want to use the ideal model when you are troubleshooting or trying to figure out the operation of a circuit and are not concerned with more exact values of voltage or current.

The Practical Diode Model

The practical model adds the barrier potential to the ideal switch model. When the diode is forward-biased, it is equivalent to a closed switch in series with a small equivalent voltage source equal to the barrier potential (0.7 V) with the positive side toward the anode, as indicated in Figure 1–34(a). This equivalent voltage source represents the fixed voltage drop (V_F) produced across the forward-biased *pn* junction of the diode and is not an active source of voltage.



(a) Forward bias (b) Reverse bias (c) Characteristic curve (silicon)

FIGURE 1–34

The practical model of a diode.

$V_F = 0.7$ V

The forward current is determined as follows by first applying Kirchhoff's voltage law to Figure 1–34(a):

$$V_{BIAS} - V_F - V_{R_{LIMIT}} = 0$$
$$V_{R_{LIMIT}} = I_F R_{LIMIT}$$

Substituting and solving for I_F,

$$I_F = \frac{V_{BIAS} - V_F}{R_{LIMIT}}$$

The diode is assumed to have zero reverse current, as indicated by the portion of the curve on the negative horizontal axis.

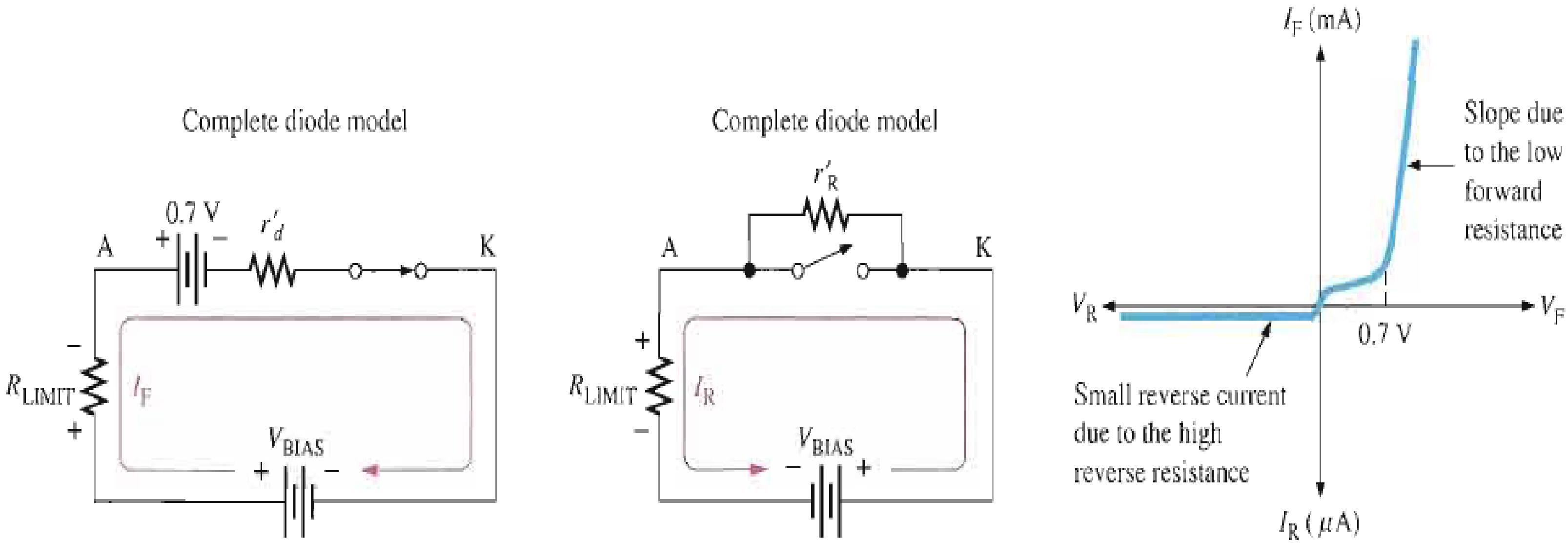
$$I_R = 0 \text{ A}$$
$$V_R = V_{BIAS}$$

NOTE: This Practical Diode Model is also known as First Approximation.

The Complete Diode Model

The complete model of a diode consists of the barrier potential, the small forward dynamic resistance (r'_d), and the large internal reverse resistance (r'_R). The reverse resistance is taken into account because it provides a path for the reverse current, which is included in this diode model.

When the diode is forward-biased, it acts as a closed switch in series with the barrier potential voltage and the small forward dynamic resistance (r'_d), as indicated in Figure 1–35(a). When the diode is reverse-biased, it acts as an open switch in parallel with the large internal reverse resistance (r'_R), as shown in Figure 1–35(b). The barrier potential does not affect reverse bias, so it is not a factor.



(a) Forward bias (b) Reverse bias (c) Characteristic curve (silicon)

FIGURE 1–35

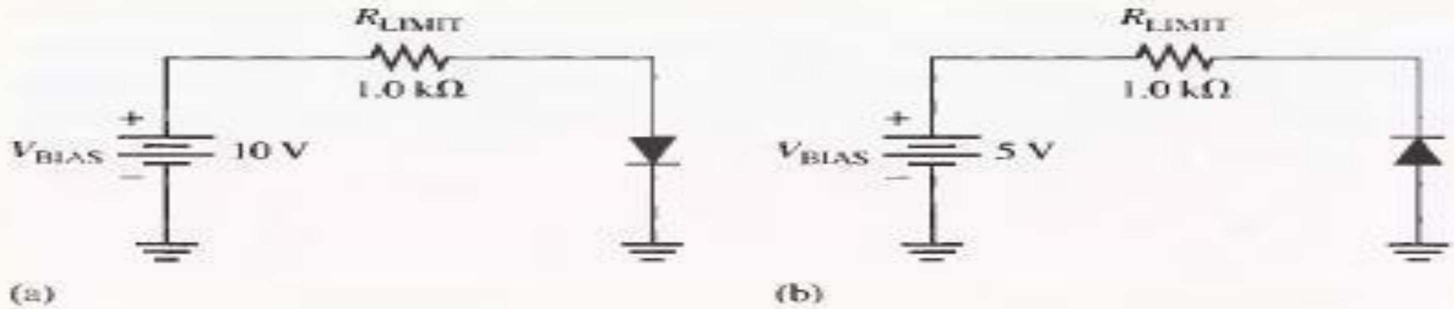
The complete model of a diode.

$$V_F = 0.7\ \text{V} + I_F r'_d$$

$$I_F = \frac{V_{\text{BIAS}} - 0.7\ \text{V}}{R_{\text{LIMIT}} + r'_d}$$

NOTE: Complete Diode Model is also known as Second Approximation.

An Example of Diode Approximations:



Ideal model:

$$V_F = 0\text{ V}$$

$$I_F = \frac{V_{BIAS}}{R_{LIMIT}} = \frac{10\text{ V}}{1.0\text{ k}\Omega} = 10\text{ mA}$$

$$V_{R_{LIMIT}} = I_F R_{LIMIT} = (10\text{ mA})(1.0\text{ k}\Omega) = 10\text{ V}$$

Practical model:

$$V_F = 0.7\text{ V}$$

$$I_F = \frac{V_{BIAS} - V_F}{R_{LIMIT}} = \frac{10\text{ V} - 0.7\text{ V}}{1.0\text{ k}\Omega} = \frac{9.3\text{ V}}{1.0\text{ k}\Omega} = 9.3\text{ mA}$$

$$V_{R_{LIMIT}} = I_F R_{LIMIT} = (9.3\text{ mA})(1.0\text{ k}\Omega) = 9.3\text{ V}$$

Complete model:

$$I_F = \frac{V_{BIAS} - 0.7\text{ V}}{R_{LIMIT} + r'_d} = \frac{10\text{ V} - 0.7\text{ V}}{1.0\text{ k}\Omega + 10\ \Omega} = \frac{9.3\text{ V}}{1010\ \Omega} = 9.21\text{ mA}$$

$$V_F = 0.7\text{ V} + I_F r'_d = 0.7\text{ V} + (9.21\text{ mA})(10\ \Omega) = 792\text{ mV}$$

$$V_{R_{LIMIT}} = I_F R_{LIMIT} = (9.21\text{ mA})(1.0\text{ k}\Omega) = 9.21\text{ V}$$