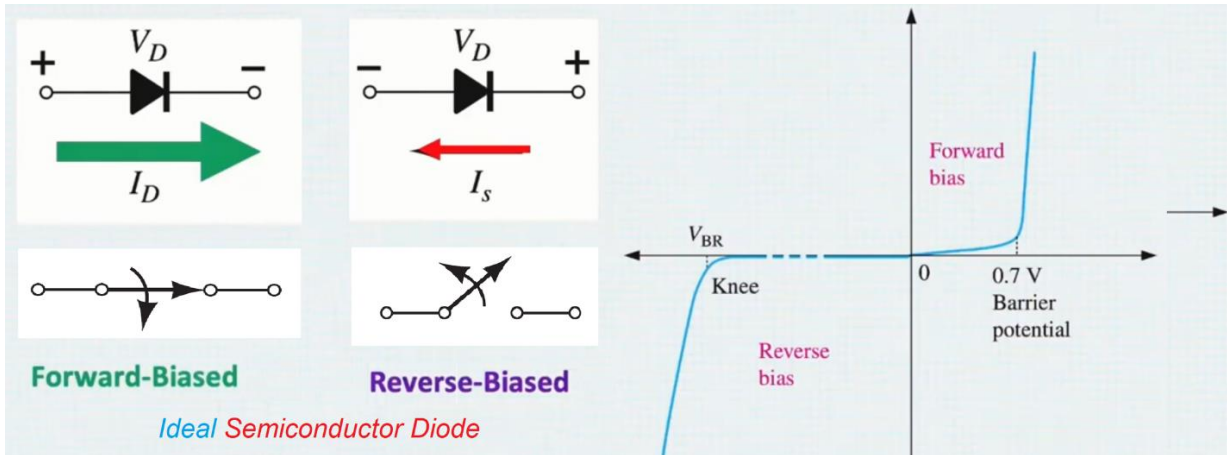


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|--|----------------------------------|
| كلية الهندسة | الكلية |
| قسم الهندسة الكهربائية | القسم |
| Fundamentals of Electronics I | المادة باللغة الانجليزية |
| أسس الإلكترونيك ١ | المادة باللغة العربية |
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| حامد ردام حسين | اسم التدريسي |
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| ثنائيات أشباه الموصلات | عنوان المحاضرة باللغة العربية |
| 5 | رقم المحاضرة |
| Electronic Devices and Circuit Theory 11 th Edition by Robert L. Boylestad, Louis Nashelsky | المصادر والمراجع |
| Electronic Devices 9th Edition by Thomas L. Floyd | |
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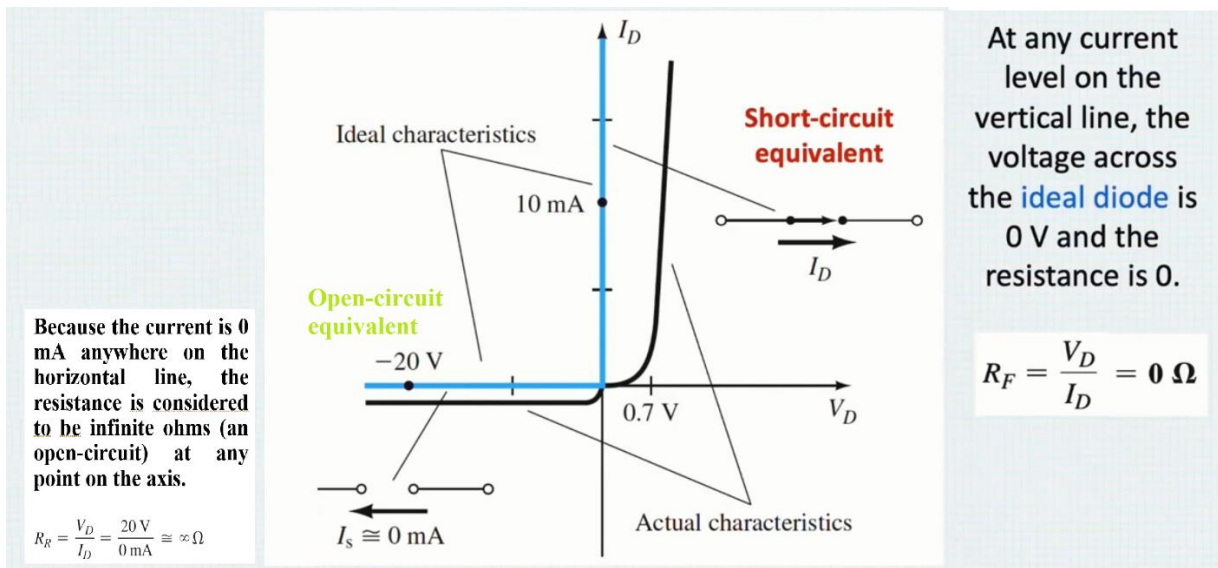
Lecture 4: Ideal VS Practical Diodes and resistance levels

1. Ideal Diode

- PN junction will permit a generous flow of charge when forward-biased and a very small level of current when reverse-biased.
- The semiconductor diode behaves in a manner like a mechanical switch.



2. Ideal Versus actual Diode Characteristic



3. Diode Resistance levels

- As the operating point of a diode moves from one region to another, the resistance of the diode will change due to the nonlinear shape of the characteristic curve.

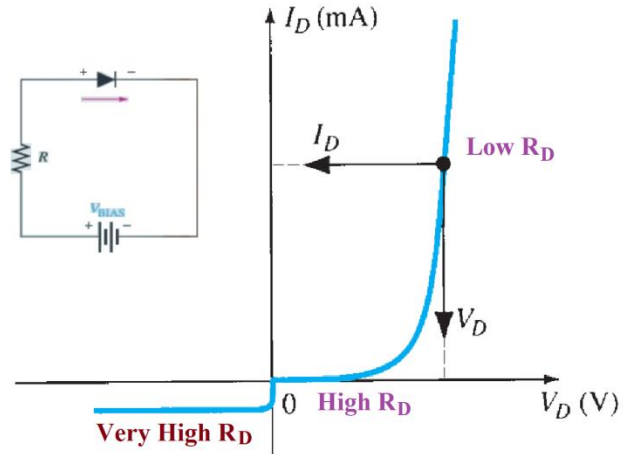


4. DC or static resistance

- The application of a **dc voltage** to a **diode** will result in an operating point on the characteristic curve that **will not change with time**.
- The **dc resistance** of the diode:

$$R_D = \frac{V_D}{I_D}$$

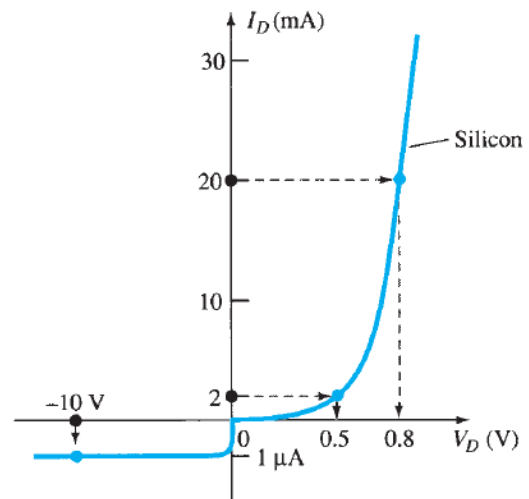
- Typically, the **dc resistance** of a diode in the **active** will range from about **10Ω to 80Ω**.



In general, the **higher** the **current** through a diode, the **lower** is the **dc resistance** level.

Example 1.3: Determine the **dc resistance levels** for the diode of figure below at:

- $I_D = 2 \text{ mA}$ (low level)
- $I_D = 20 \text{ mA}$ (high level)
- $V_D = -10 \text{ V}$ (reverse-biased)



Solution:

- a. At $I_D = 2 \text{ mA}$, from the curve, $V_D = 0.5 \text{ V}$

$$R_D = \frac{V_D}{I_D} = \frac{0.5 \text{ V}}{2 \text{ mA}} = 250 \Omega$$

- b. At $I_D = 20 \text{ mA}$, from the curve, $V_D = 0.8 \text{ V}$

$$R_D = \frac{V_D}{I_D} = \frac{0.8 \text{ V}}{20 \text{ mA}} = 40 \Omega$$

- c. At $V_D = -10 \text{ V}$, from the curve, $I_D = -I_S = -1 \mu\text{A}$

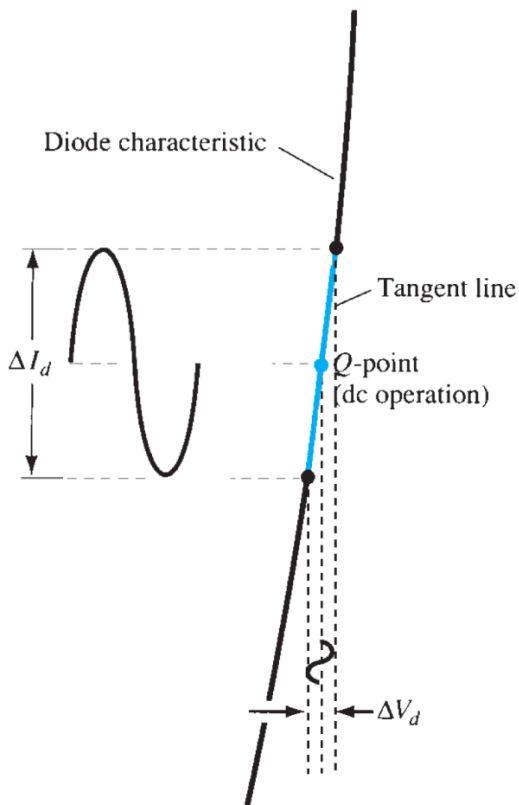
$$R_D = \frac{V_D}{I_D} = \frac{10 \text{ V}}{1 \mu\text{A}} = 10 \text{ M}\Omega$$

5. AC or Dynamic Resistance

- If a **sinusoidal voltage** is applied, the varying input will move, and the instantaneous **operating point** will change as well.
- The **dynamic resistance** r_d is given by:

$$r_d = \frac{\Delta V_d}{\Delta I_d}$$

- In general, the **lower the Q-point of operation** (smaller current or lower voltage), the **higher is the ac resistance**.



Defining the **dynamic** or **ac** resistance.

Example 1.4: For the characteristics of Figure:

- Determine the **ac resistance** at $I_D = 2 \text{ mA}$.
- Determine the **ac resistance** at $I_D = 25 \text{ mA}$.
- Compare the results of parts (a) and (b) to the **dc resistances** at each current level.

Solution:

a. For $I_D = 2 \text{ mA}$

$$\begin{aligned}\Delta I_d &= 4 \text{ mA} - 0 \text{ mA} = 4 \text{ mA} \\ \Delta V_d &= 0.76 \text{ V} - 0.65 \text{ V} = 0.11 \text{ V}\end{aligned}$$

The **ac resistance** is $r_d = \frac{\Delta V_d}{\Delta I_d} = \frac{0.11 \text{ V}}{4 \text{ mA}} = 27.5 \Omega$

b. For $I_D = 25 \text{ mA}$

$$\begin{aligned}\Delta I_d &= 30 \text{ mA} - 20 \text{ mA} = 10 \text{ mA} \\ \Delta V_d &= 0.8 \text{ V} - 0.78 \text{ V} = 0.02 \text{ V}\end{aligned}$$

The **ac resistance** is $r_d = \frac{\Delta V_d}{\Delta I_d} = \frac{0.02 \text{ V}}{10 \text{ mA}} = 2 \Omega$

c. For $I_D = 2 \text{ mA}$, $V_d = 0.7 \text{ V}$ the **dc resistance** is:

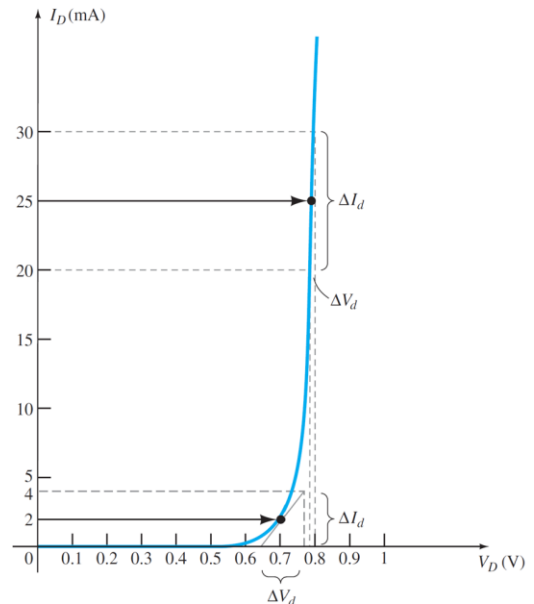
$$R_D = \frac{V_D}{I_D} = \frac{0.7 \text{ V}}{2 \text{ mA}} = 350 \Omega$$

Which far exceeds the r_d of 27.5Ω

For $I_D = 25 \text{ mA}$, $V_d = 0.79 \text{ V}$ the **dc resistance** is:

$$R_D = \frac{V_D}{I_D} = \frac{0.79 \text{ V}}{25 \text{ mA}} = 31.62 \Omega$$

Which far exceeds the r_d of 2Ω



The dynamic resistance (mathematically)

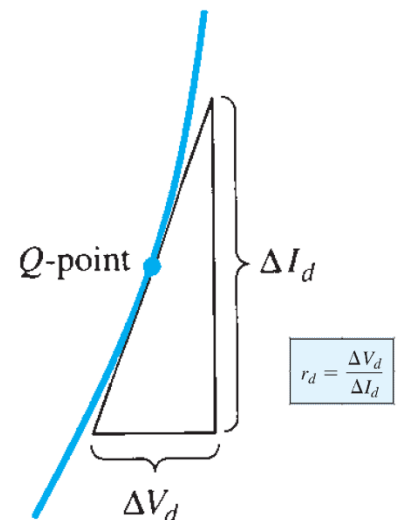
By taking the derivative of equation

$$I_D = I_S(e^{V_D/nV_T} - 1)$$

$$\frac{dV_D}{dI_D} = r_d = \frac{nV_T}{I_D}$$

Substituting $n = 1$ and $V_T = 26 \text{ mV}$

$$r_d = \frac{26 \text{ mV}}{I_D}$$

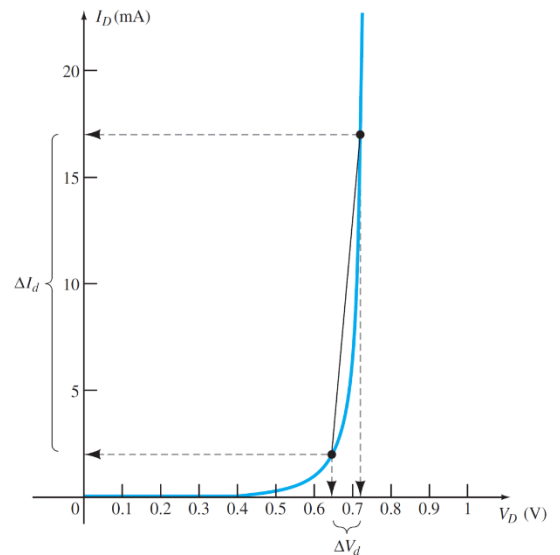


This equation is accurate only for values of I_D in the vertical-rise section of the curve.

6. Average AC Resistance

- If the **input signal is sufficiently large** to produce a broad swing, the resistance associated with the device for this region is called the **average ac resistance**.
- The **average ac resistance** is the resistance determined by a **straight line** drawn between the two intersections established by the **maximum** and **minimum** values of **input voltage**.

$$r_{av} = \left. \frac{\Delta V_d}{\Delta I_d} \right|_{\text{pt. to pt.}}$$



$$\Delta I_d = 17 \text{ mA} - 2 \text{ mA} = 15 \text{ mA}$$

$$\Delta V_d = 0.725 \text{ V} - 0.65 \text{ V} = 0.075 \text{ V}$$

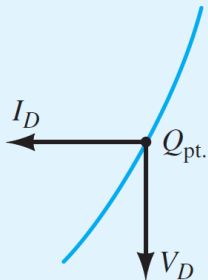
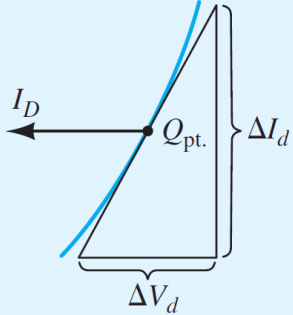
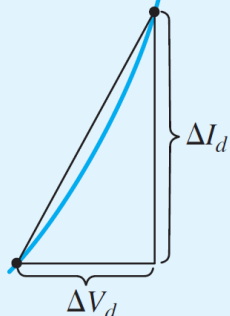
$$r_{av} = \frac{\Delta V_d}{\Delta I_d} = \frac{0.075 \text{ V}}{15 \text{ mA}} = 5 \Omega$$

$r_{av} = 5 \Omega$ defines a value that is considered the average of the ac values from 2 mA to 17 mA.

7. Summary Table

Table 1.6 was developed to reinforce the important conclusions of the last few pages and to emphasize the differences among the various resistance levels.

TABLE 1.6
Resistance Levels

| Type | Equation | Special Characteristics | Graphical Determination |
|---------------|---|--|---|
| DC or static | $R_D = \frac{V_D}{I_D}$ | Defined as a point on the characteristics |  |
| AC or dynamic | $r_d = \frac{\Delta V_d}{\Delta I_d} = \frac{26 \text{ mV}}{I_D}$ | Defined by a tangent line at the Q-point |  |
| Average ac | $r_{av} = \left. \frac{\Delta V_d}{\Delta I_d} \right _{\text{pt. to pt.}}$ | Defined by a straight line between limits of operation |  |

7. Problem to solve by yourself

In your textbook Solve Problems under sections

1.7 and 1.8

24 to 35 Pages 52 and 53