AL-Mustaqbal University College

Department of Medical Physics

The Second Stage

Semiconductors

M.SC.Gufran hadi

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قسم الفيزياء الطبية
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Lecture .7

What is Junction Breakdown ?

In the *ideal PN junction* device, when a reverse bias voltage is applied, a small reverse bias current flow through the device. This reverse current remains very small until a critical voltage is reached, at which point the current suddenly increases. This sudden increase in current is referred to as the junction breakdown

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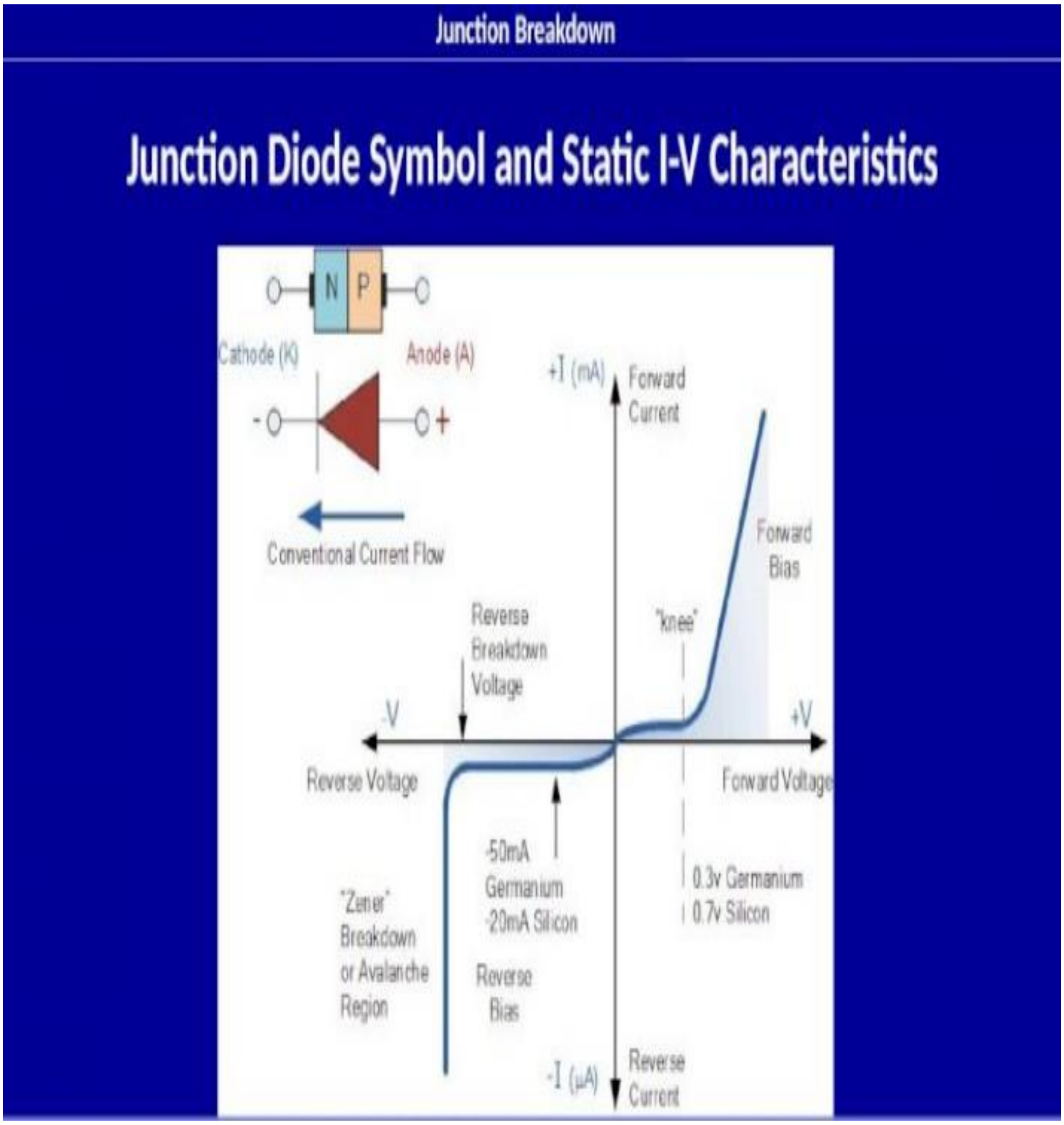

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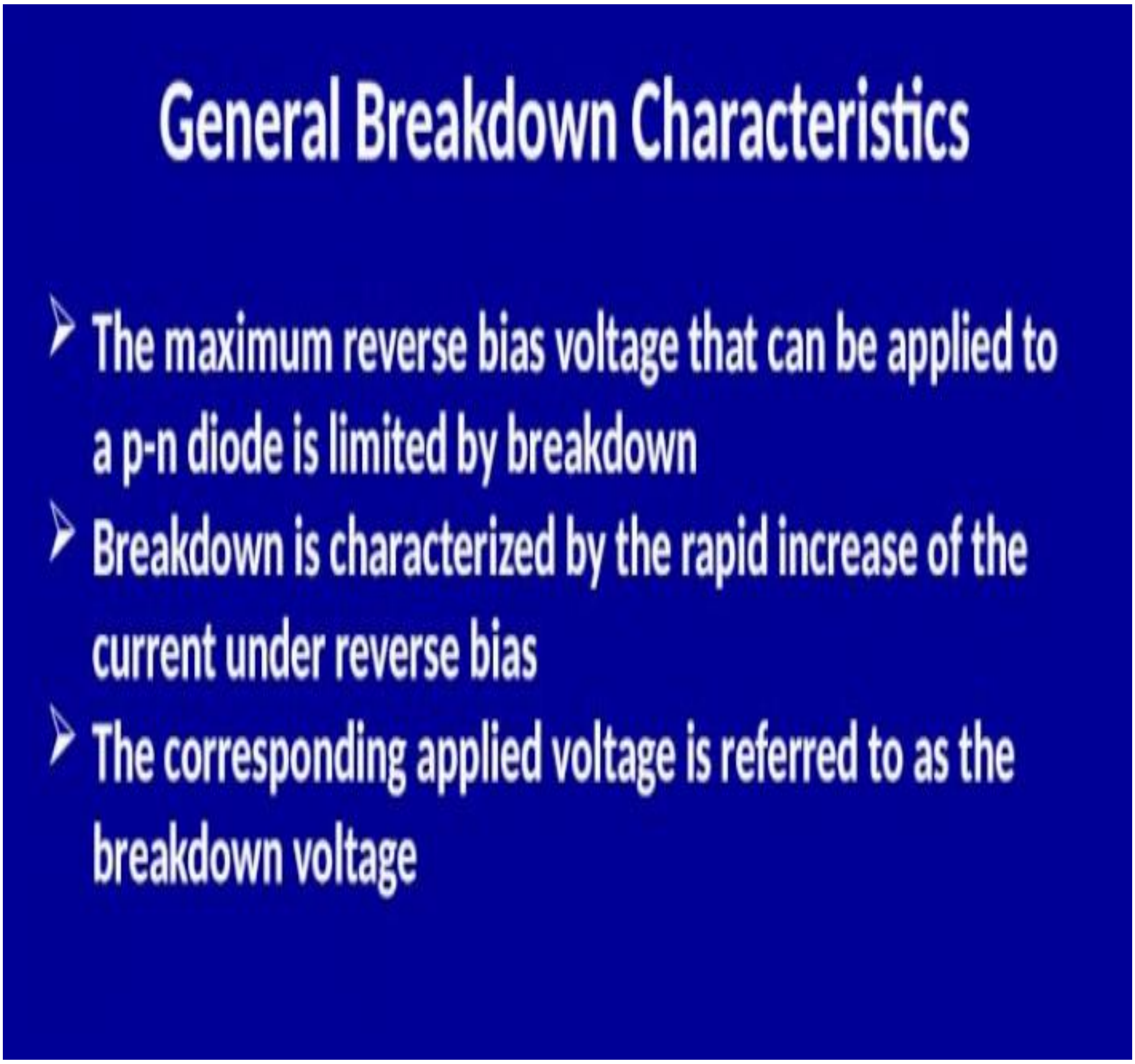

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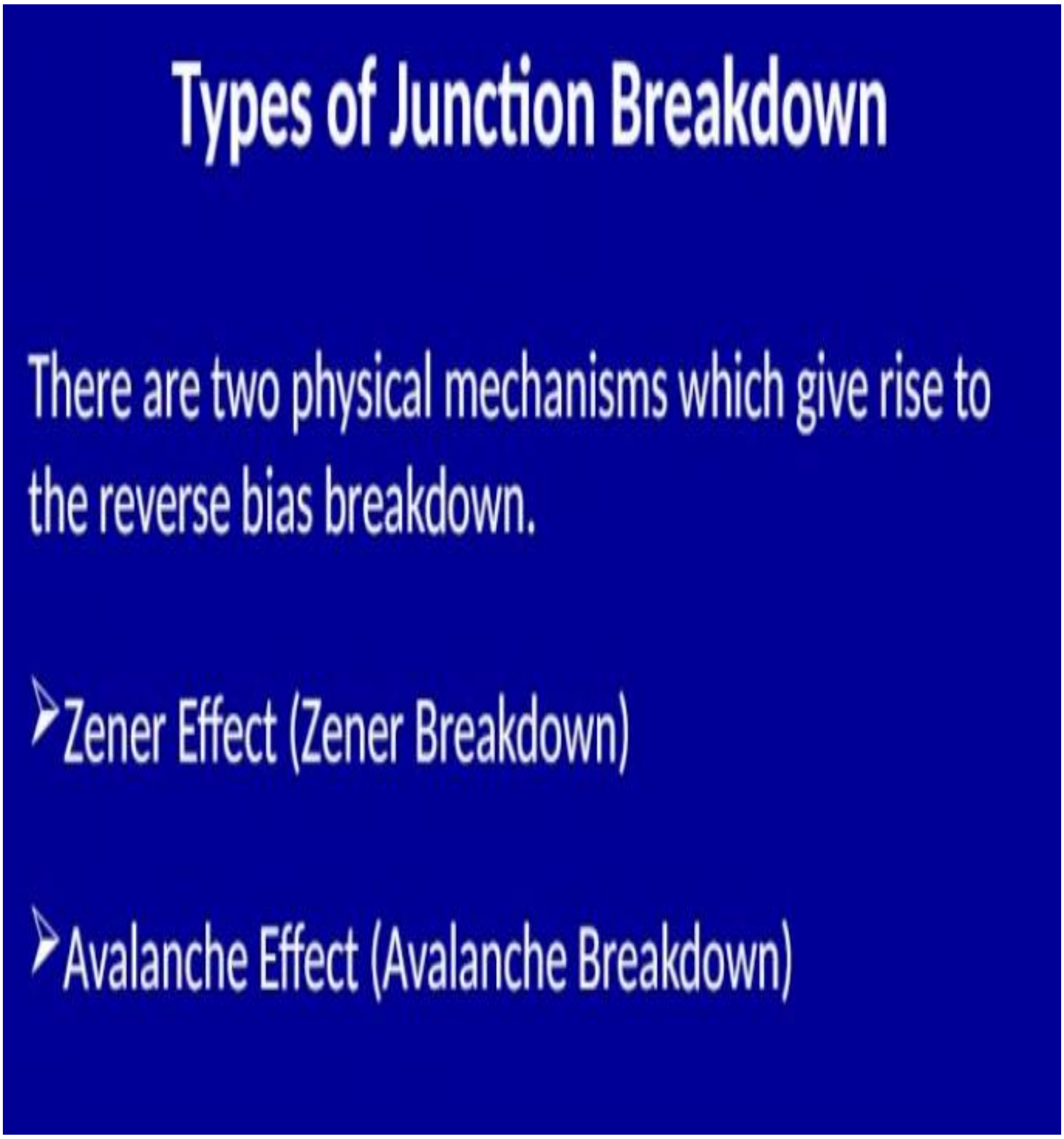

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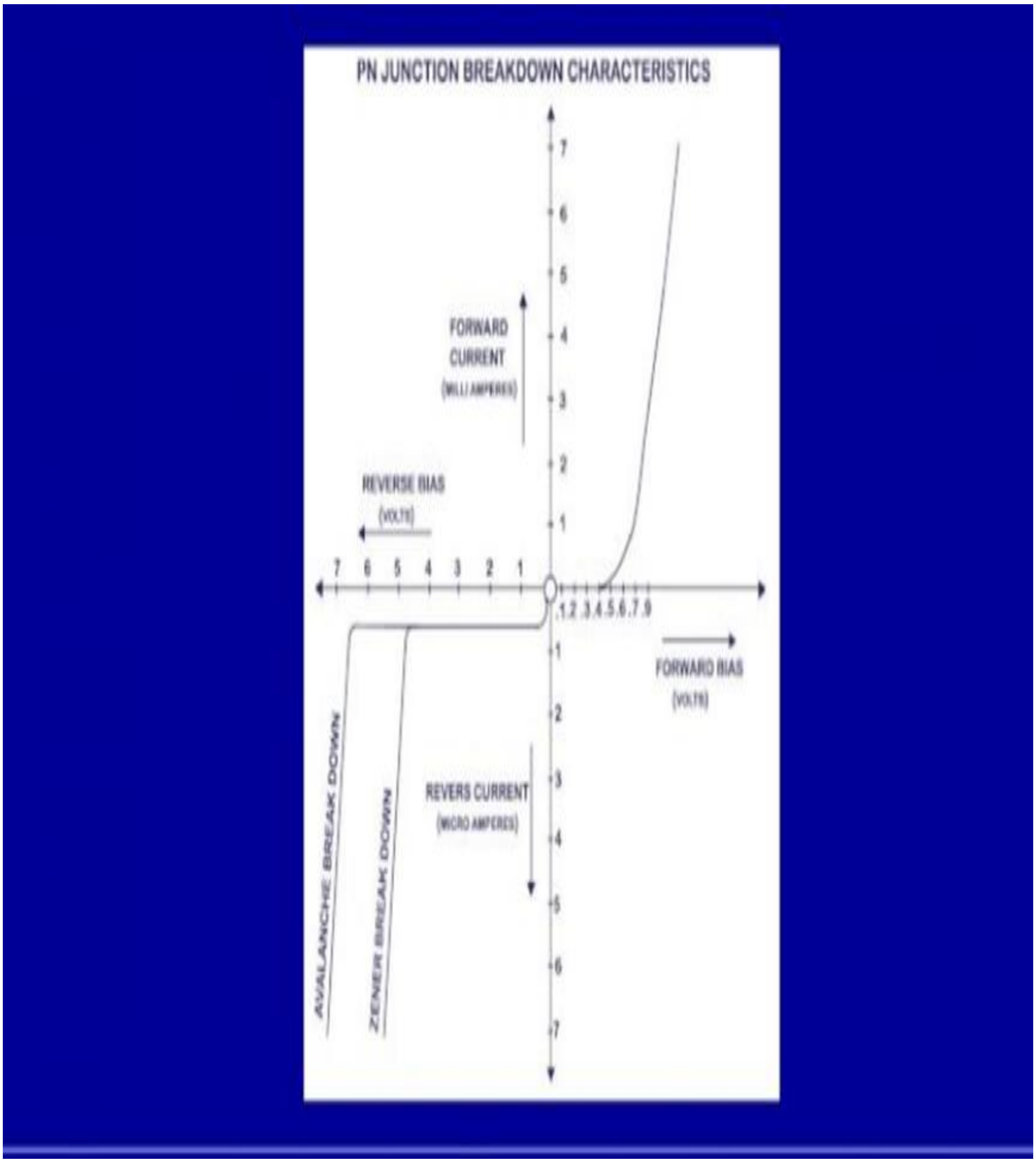

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Ideal Diode Equation

- Empirical fit for both the negative and positive I-V of a diode when the magnitude of the applied voltage is reasonably small.

$$I_D = I_S\left(e^{\frac{qV_D}{nkT}} - 1\right)$$

Ideal Diode Equation

Where

I_D and V_D are the diode current and voltage, respectively
q is the charge on the electron
n is the ideality factor: n = 1 for indirect semiconductors (Si, Ge, etc.)
n = 2 for direct semiconductors (GaAs, InP, etc.)
k is Boltzmann's constant
T is temperature in Kelvin

kT/q is also known as V_{th}, the thermal voltage. At 300K (room temperature), kT/q = 25.9mV

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Simplification

- When V_D is negative

$$I_D \sim -I_S$$

- When V_D is positive

$$I_D \sim I_S e^{\frac{qV_D}{nkT}}$$

Large signal model (Charge control model)

The charge

control model of a bipolar transistor is an extension of the charge control model of a p-n diode.

$$I_E = \frac{\Delta Q_{p,E}}{t_{r,E}} + \frac{\Delta Q_{n,B,f}}{t_{r,B}} - \frac{\Delta Q_{n,B,r}}{t_{r,B}} + \frac{\Delta Q_{n,B,r}}{\tau_{n,B}}$$

$$I_B = \frac{\Delta Q_{p,E}}{t_{r,E}} + \frac{\Delta Q_{n,B,f}}{\tau_{n,B}} + \frac{\Delta Q_{p,C}}{t_{r,C}} + \frac{\Delta Q_{n,B,r}}{\tau_{n,B}}$$

$$I_C = -\frac{\Delta Q_{p,C}}{t_{r,C}} - \frac{\Delta Q_{n,B,r}}{t_{r,B}} + \frac{\Delta Q_{n,B,f}}{t_{r,B}} - \frac{\Delta Q_{n,B,f}}{\tau_{n,B}}$$

Under forward active mode of operation, this model can be simplified since the reverse mode components can be ignored. A transient model can be obtained by adding the rate of change of the charges over time. To further simplify the model, we also ignore the minority carrier charge in the emitter. This results in the following equations:

$$I_E = \frac{\Delta Q_{n,B,f}}{\tau_B} + \frac{dQ_{n,B,f}}{dt}$$

$$I_B = \frac{\Delta Q_{n,B,f}}{\tau_{n,B}} + \frac{1}{\beta_F}\frac{dQ_{n,B,f}}{dt}$$

$$I_C = \frac{\beta_F}{\beta_F + 1}\Delta Q_{n,B,f} + \frac{dQ_{n,B,f}}{dt}$$

As an example we now apply this charge control model to the abrupt switching of a bipolar transistor. Consider a simple circuit as shown in Figure 5.6.2. As one applies a positive voltage to the base, the base-emitter junction will become forward biased so that the collector current will start to rise. The input is then connected to a negative supply voltage, VR. This reverses the base current and the base-emitter junction capacitance is discharged. After this transient, the transistor is eventually turned off and the collector current reduces back to zero. A full analysis would require solving the charge control model equations simultaneously, while adding the external circuit equations. Such approach requires numeric simulation tools. To simplify this analysis and provide insight, we now assume that the base current is constant before and after switching. This approximation is very good under forward bias since the baseemitter voltage is almost constant. Under reverse bias, the base current will vary as the baseemitter voltage varies, but conceivably one could design a circuit that does provide a constant reverse current. The turn-on of the BJT consists of an initial delay time, td,1, during which the base-emitter junction capacitance is charged. This delay is followed by the increase of the collector current,

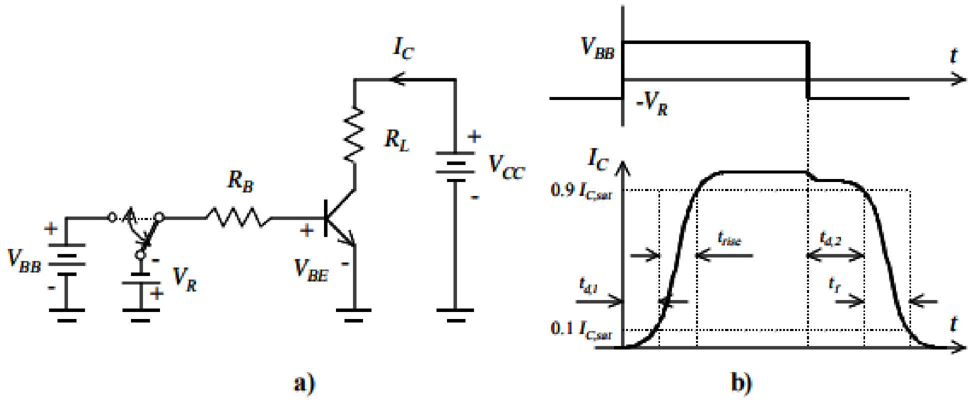

Figure 5.6.2 Switching behavior of a BJT: a) bias circuit used to explain the switching behavior. b) Applied voltage and resulting collector current.