Tema 4: Diodos.

Contenidos

4.1 Estructura

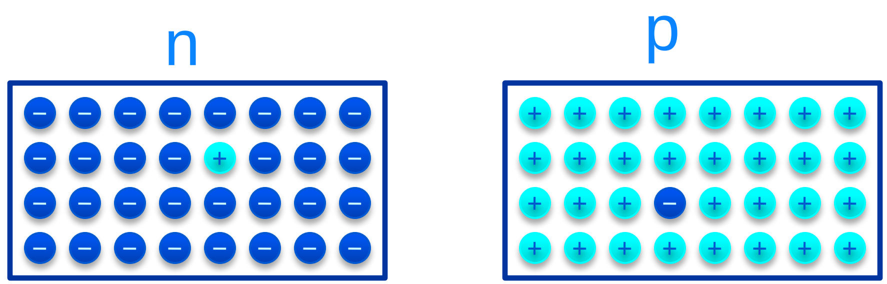
4.2 Modelos

4.3 Limitadores

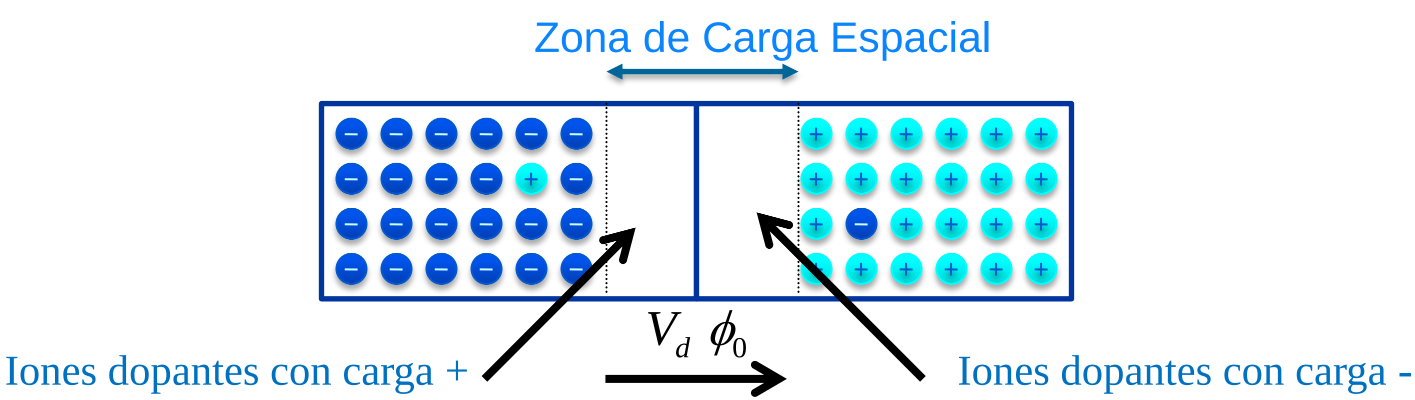
4.4 Rectificadores

4.1 Estructura

Semiconductores Separados

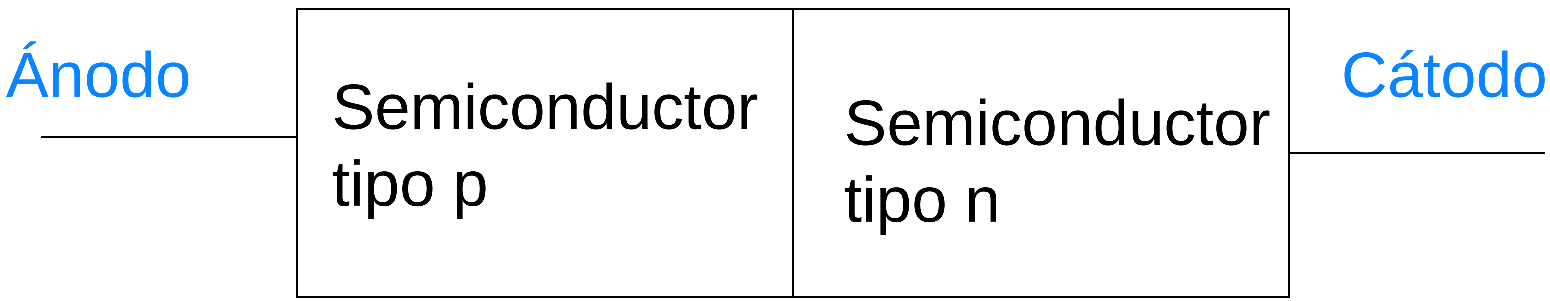


Unión de los semiconductores

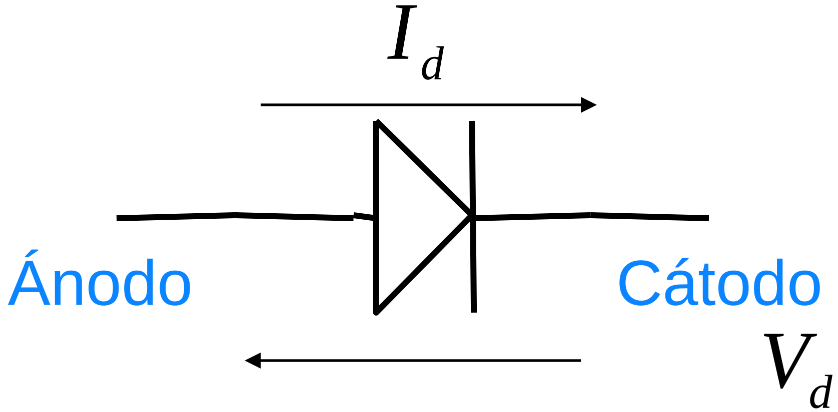


4.1 Estructura

Diodo: Dispositivo formado por dos uniones semiconductoras de tipo p y tipo n o la unión de un semiconductor y un metal

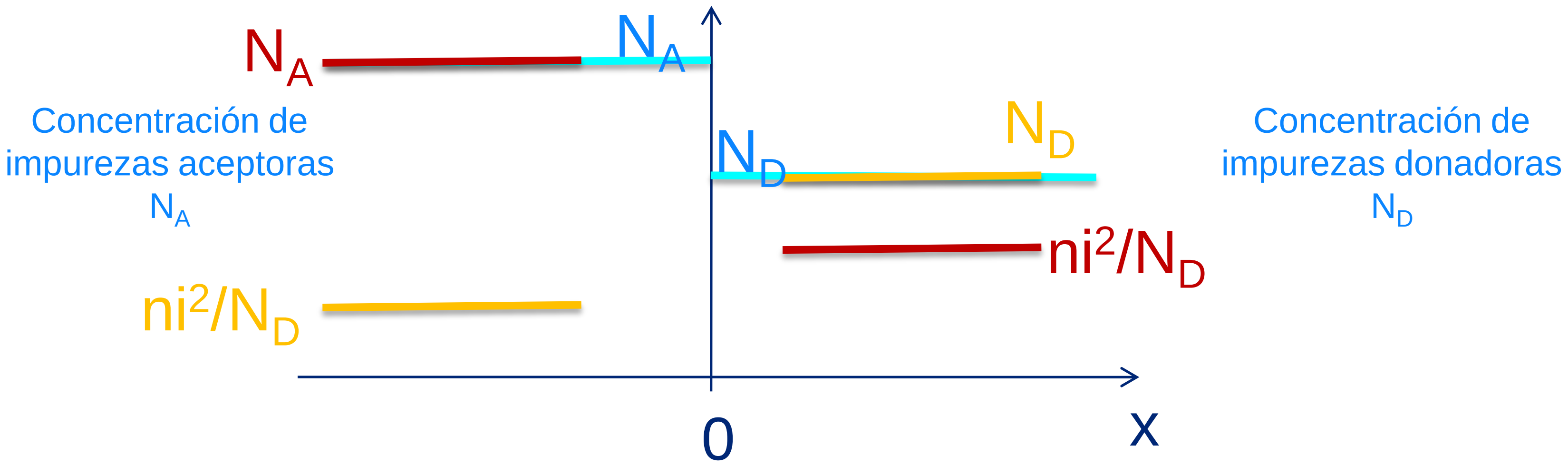


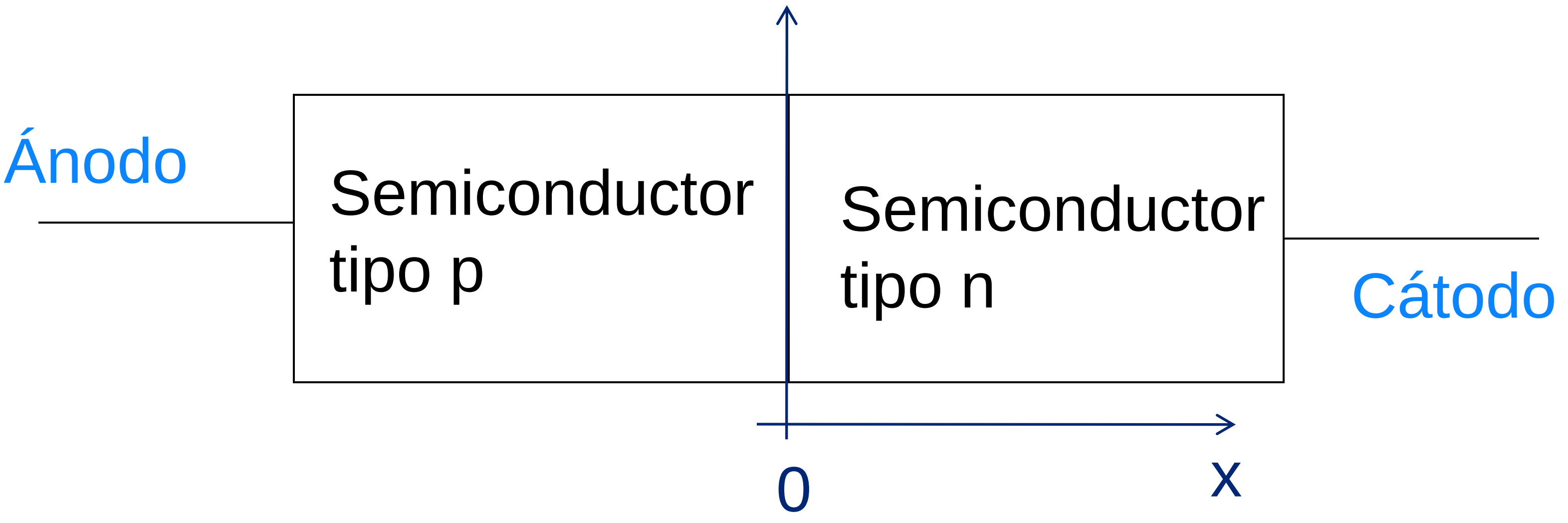
Símbolo



4.1 Estructura

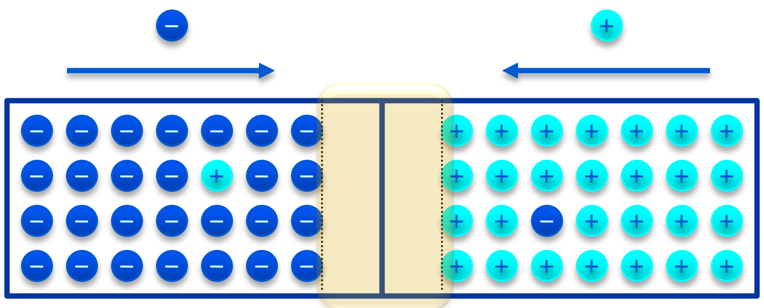
Concentración de Impurezas





4.1 Estructura

Condensadores en el Diodo:



$$C_j = \frac{Cjo}{\left[1 - \frac{V}{\phi_o}\right]^m} \quad [F]$$

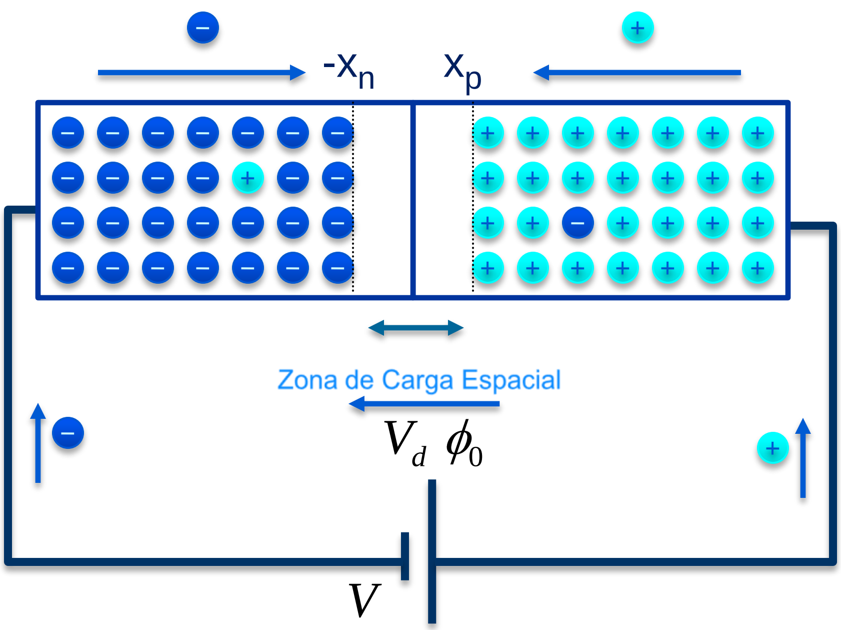
$$Cjo \equiv A \cdot \sqrt{\frac{q\varepsilon_{Si}}{2} \frac{N_A N_D}{N_A + N_D}} \quad [F/m^2]$$

$$Ceq = \frac{C_{jo}\phi_o}{(V_2 - V_1)(1-m)}\left[\left(1 - \frac{V_2}{\phi_o}\right)^{1-m} - \left(1 - \frac{V_1}{\phi_o}\right)^{1-m}\right]$$

Capacidad equivalente de gran señal

4.1 Estructura

Funcionamiento en Polarización:



$$p_1 = p_2 e^{V_{21}/V_{Te}}$$

$$n_1 = n_2 e^{-V_{21}/V_{Te}}$$

$$p_{no} = p_{po} e^{-\phi_0/V_{Te}}$$

$$n_{po} = n_{no} e^{-\phi_0/V_{Te}}$$

Ley de Boltzman:

$$p_n(-x_n) = p_p(x_p) e^{-(\phi_0 - V)/V_{Te}} \approx p_{p0} e^{-(\phi_0 - V)/V_{Te}} = p_{n0} e^{V/V_{Te}}$$

$$n_p(x_p) = n_n(-x_n) e^{-(\phi_0 - V)/V_{Te}} \approx n_{n0} e^{-(\phi_0 - V)/V_{Te}} = n_{p0} e^{V/V_{Te}}$$

Ley de la Unión:

4.1 Estructura

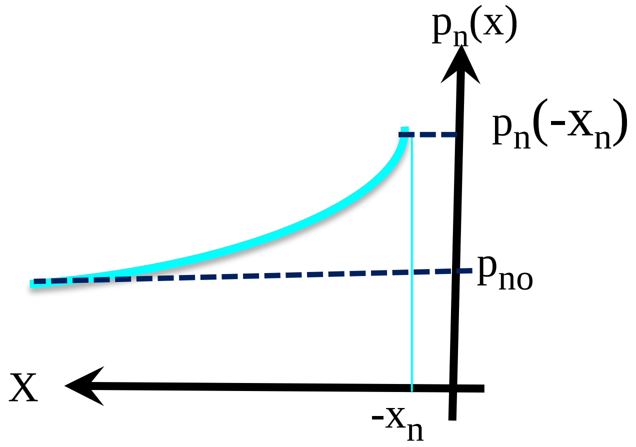
Funcionamiento en Polarización:

Aplicación de V>0 (**Zona Directa**)

$$p_n(-x_n) = p_{p0} e^{-(\phi_0 - V)/V_{Te}} = p_{no} e^{V/V_{Te}}$$

$$n_p(x_p) = n_{n0} e^{-(\phi_0 - V)/V_{Te}} = n_{po} e^{V/V_{Te}}$$

Inyección de portadores



Sólo tenemos corriente de difusión

$$J_{dp} = -qD_p \left. \frac{dp}{dx} \right|_{x=-x_n}$$

$$p_n'(x) = p_n'(-x_n) e^{\frac{-(x+x_n)}{L_p}} = [p_n(-x_n) - p_{n0}] e^{\frac{-(x+x_n)}{L_p}} = p_{n0}(e^{V/V_{Te}} - 1) e^{\frac{-(x+x_n)}{L_p}}$$

$$J_{dp}(-x_n) = \frac{qD_p p_{n0}}{L_p}(e^{V/V_{Te}} - 1)$$

$$J_{dn}(x_p) = \frac{qD_n n_{p0}}{L_n}(e^{V/V_{Te}} - 1)$$

4.1 Estructura

Funcionamiento en Polarización:

Aplicación de V>0 (**Zona Directa**)

$$I = qA\left[\frac{D_p p_{n0}}{L_p} + \frac{D_n n_{p0}}{L_n}\right](e^{V/V_{Te}} - 1)$$

(Es válida también para V < 0)

$$I = I_S\,(e^{V/V_{Te}} - 1)$$

⌂ I_S ≡ **Corriente Inversa de Saturación**

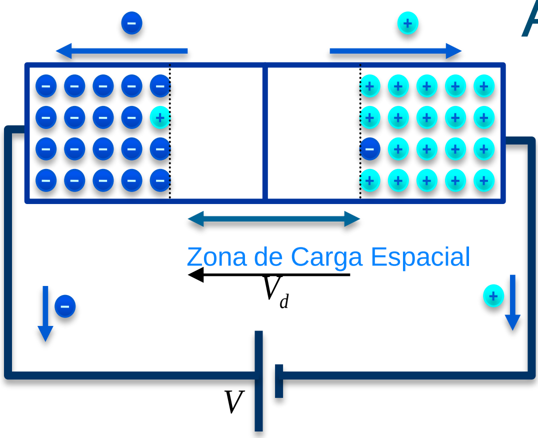
$$I_s = qA\left[\frac{D_p p_{n0}}{L_p} + \frac{D_n n_{p0}}{L_n}\right] = qAn_i^2\left[\frac{D_p}{L_p N_D} + \frac{D_n}{L_n N_A}\right]$$

¡¡¡ I_S es muy pequeña !!!

4.1 Estructura

Funcionamiento en Inversa:

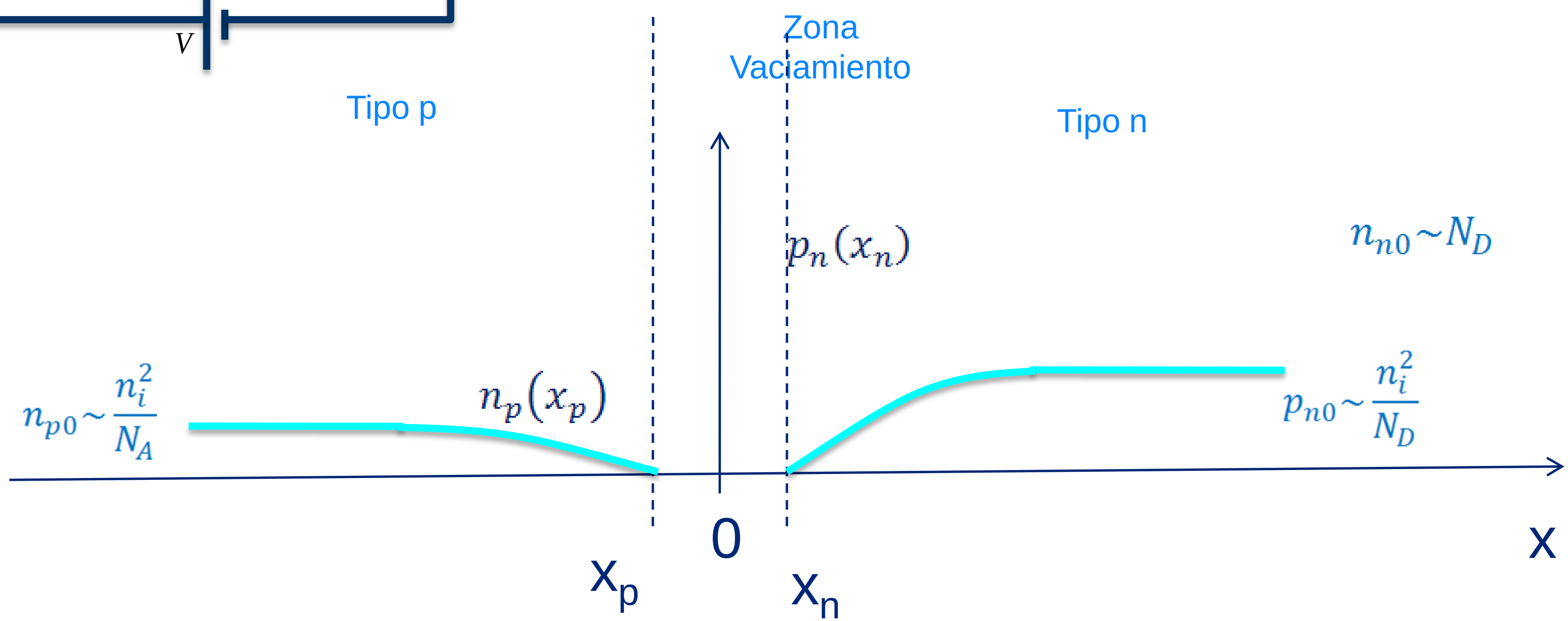
Aplicación de V<0



$$I \approx -I_s$$

$$p_n(-x_n) = p_{n0} e^{V/V_{Te}}$$

$$n_p(x_p) = n_{p0} e^{V/V_{Te}}$$

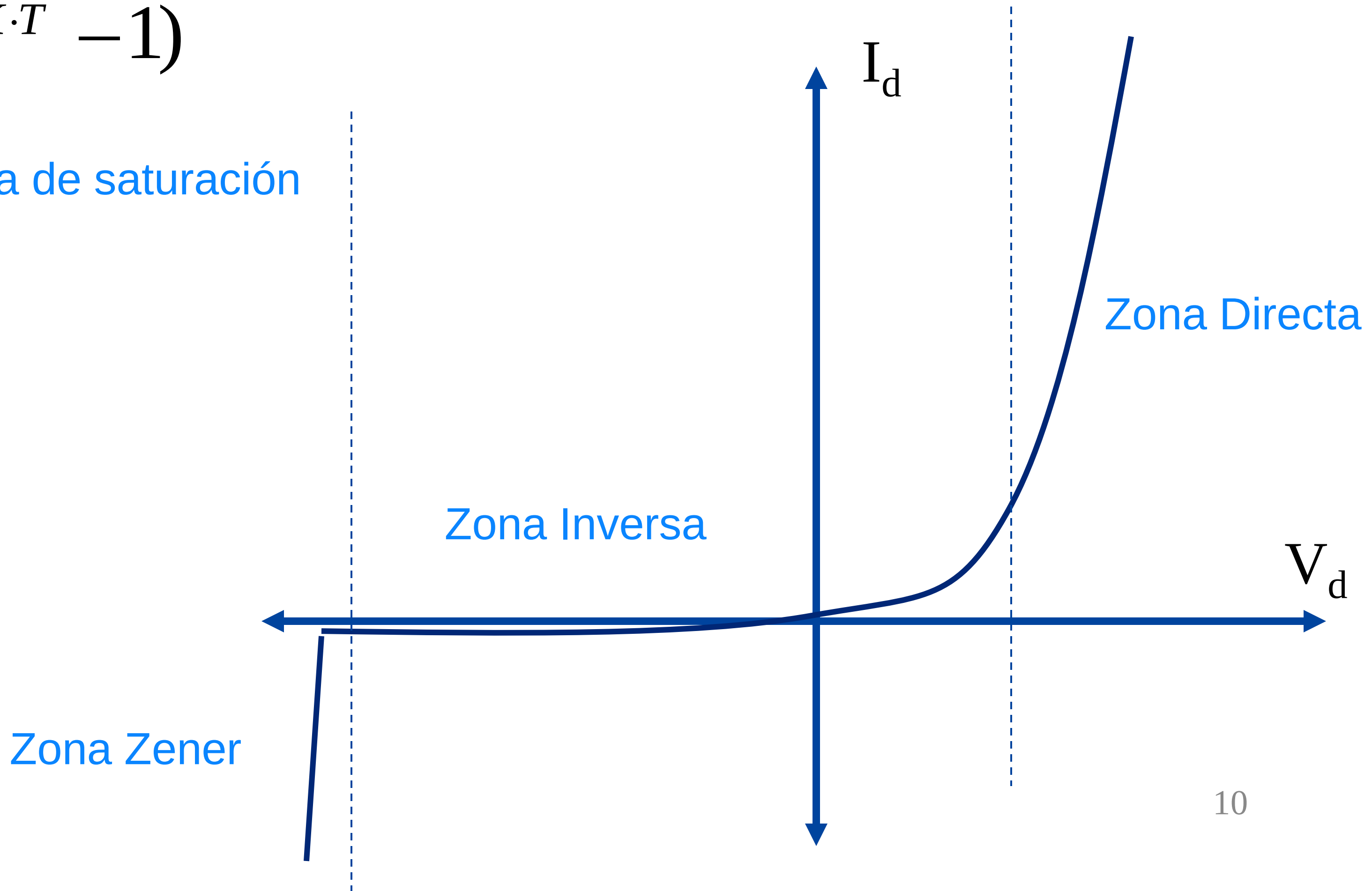


4.2 Modelos

Modelo (Z. Directa y Z. Inversa)

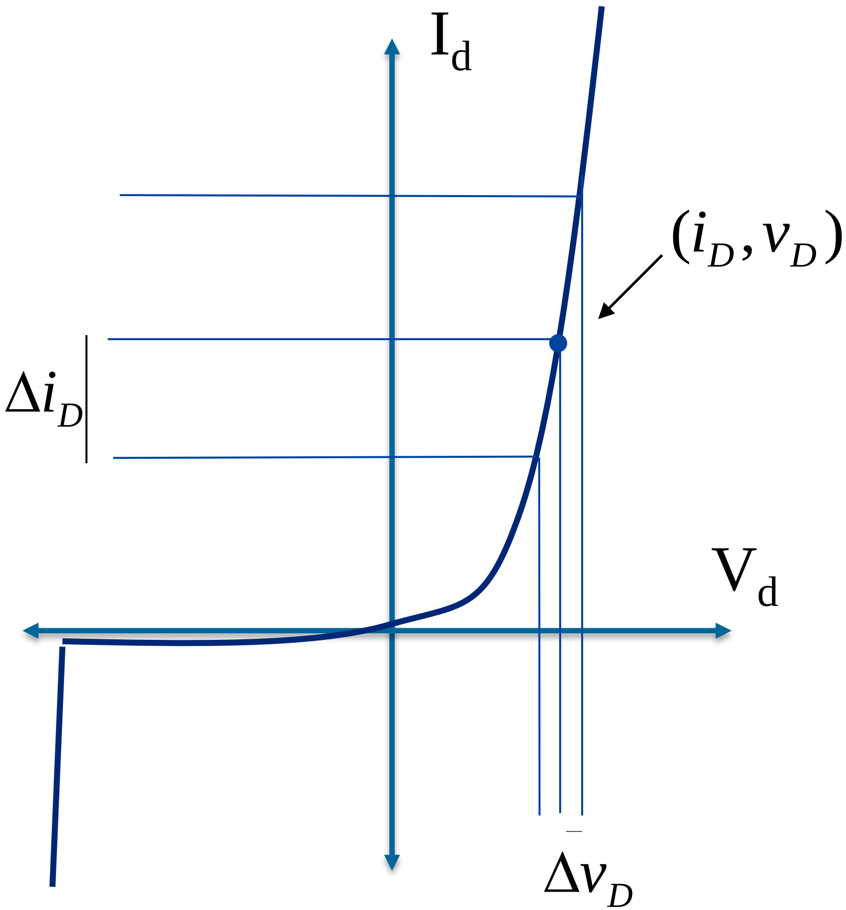
$$I_d = I_S \cdot (e^{\frac{q \cdot V_d}{K \cdot T}} - 1)$$

I_S: Corriente inversa de saturación



4.2 Modelos

Análisis de Circuitos como dispositivos no-lineales



$$I_d = i_D + \Delta i_d$$

$$V_d = v_D + \Delta v_d$$

Análisis del punto de trabajo: Polarización

i_D

v_D

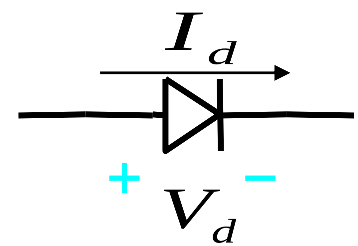
Análisis de Pequeña Señal

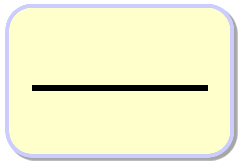
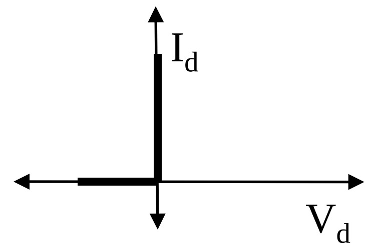
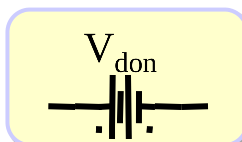
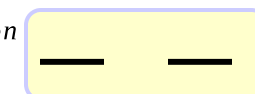
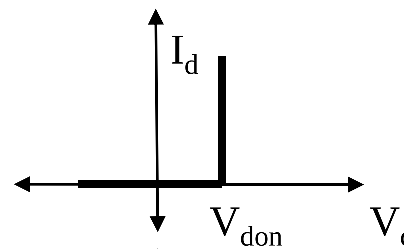
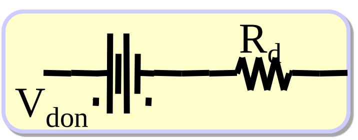
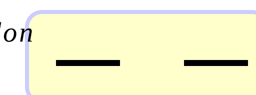
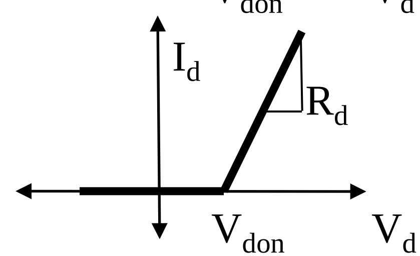
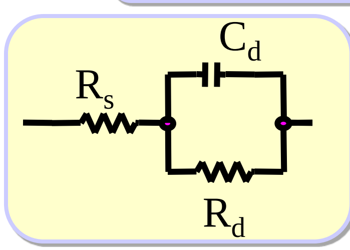
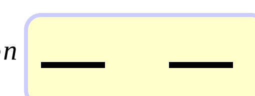
Δi_D

Δv_D

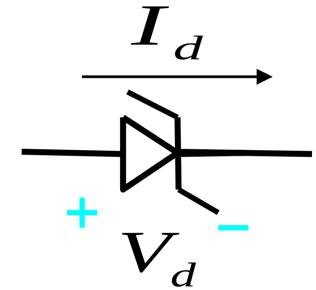
4.2 Modelos

Diodo

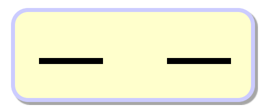
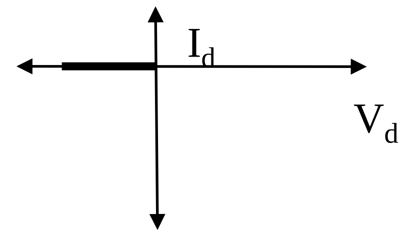
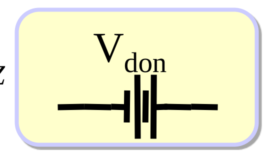
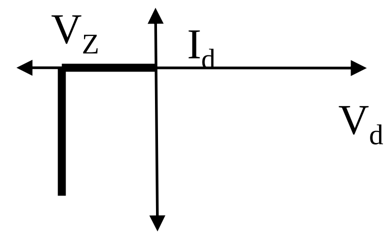
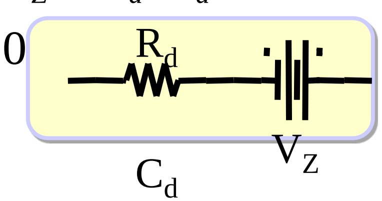
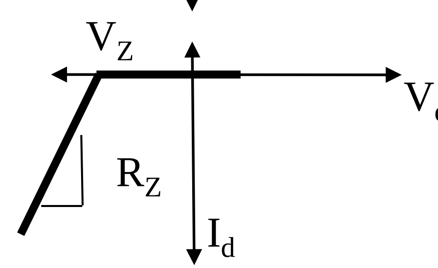
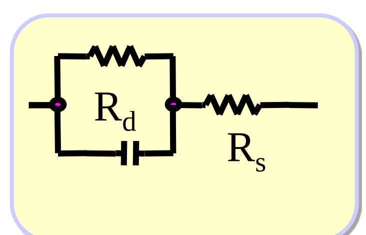


Modelos	Directa		Inversa		Gráfica
Modelo Idealizado	$V_d = 0$ $I_d > 0$		$V_d < 0$ $I_d = 0$		
Modelo Idealizado con tensión umbral	$V_d = V_{don}$ $I_d > 0$		$V_d < V_{don}$ $I_d = 0$		
Modelo Linealizado	$V_d = V_{don} + R_d \cdot I_d$ $I_d > 0$		$V_d < V_{don}$ $I_d = 0$		
Modelo de pequeña señal			$V_d < V_{don}$ $I_d = 0$		$R_d = \dfrac{\partial V_d}{\partial I_d}$

4.2 Modelos

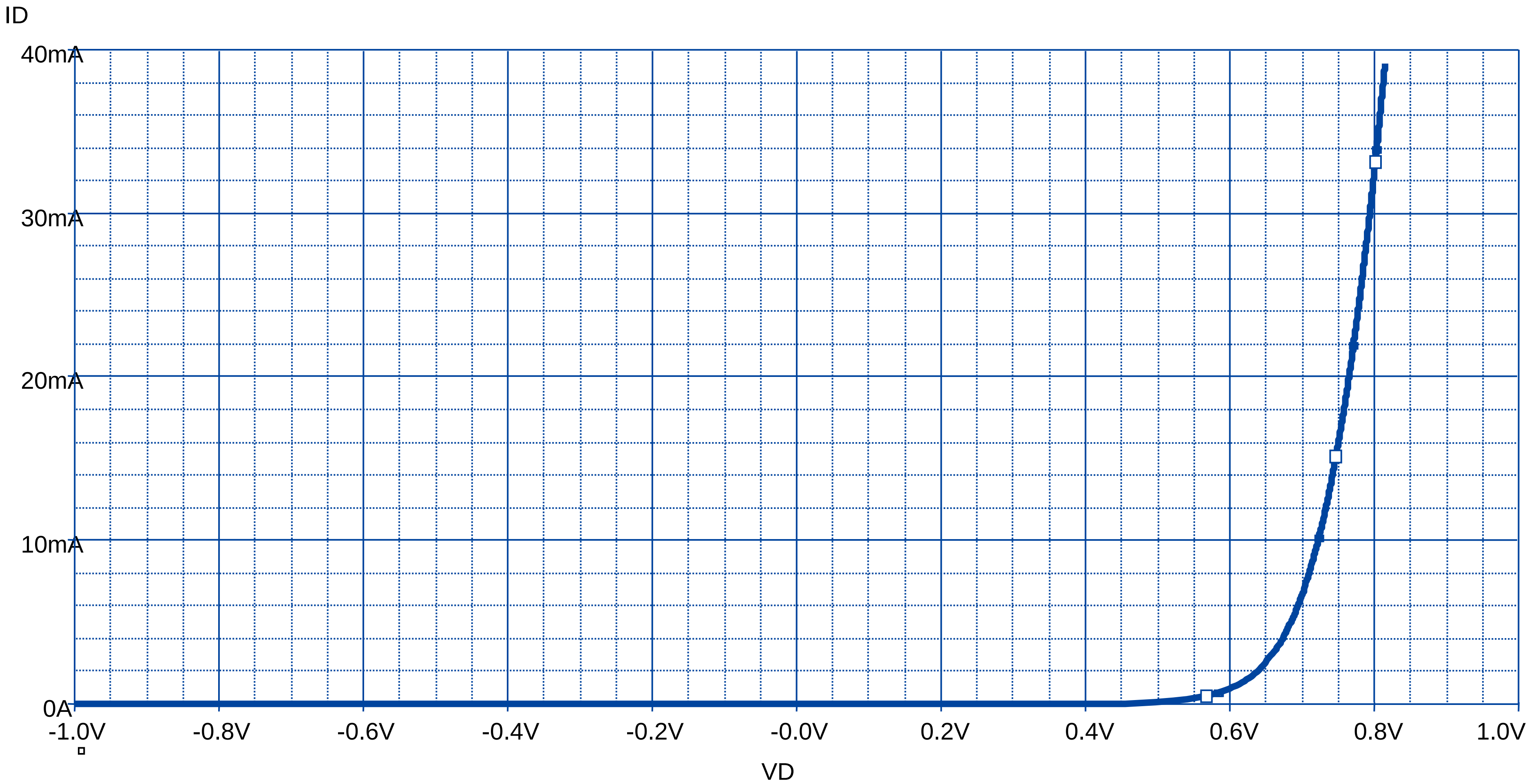


Diodo Zener

Modelos	Directa	Inversa		Gráfica
Modelo Idealizado		$V_d < 0$ $I_d = 0$ $V_d > -V_Z$		
Modelo Idealizado con tensión umbral		$V_d = -V_Z$ $I_d < 0$	 	
Modelo Linealizado		$V_d = V_Z + R_d \cdot I_d$ $I_d < 0$	 	
Modelo de pequeña señal			 	$R_Z = \dfrac{\partial V_d}{\partial I_d}$

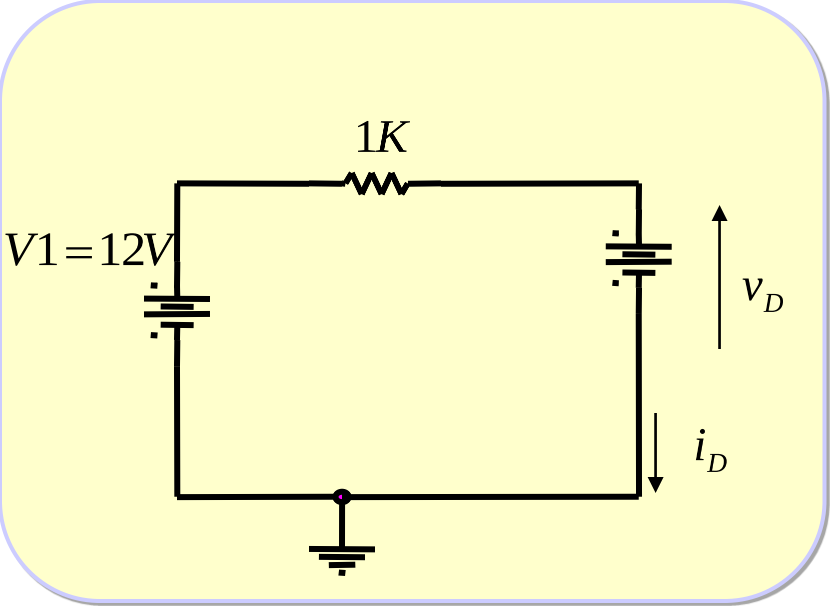
4.2 Modelo

Curva del diodo (D1N4148)



4.2 Modelo

Circuito sencillo con Diodo



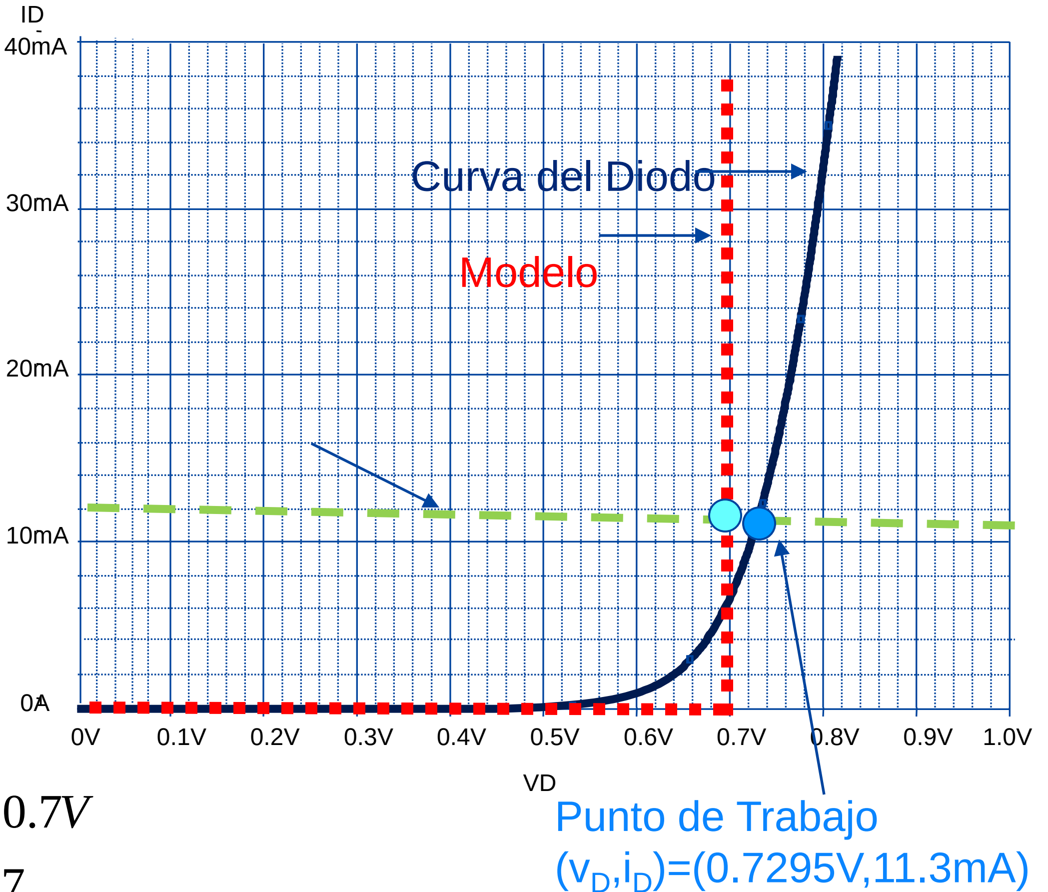
$$i_D = \frac{V1 - v_D}{1K}$$

$$i_D(v_D = 0) = \frac{12 - 0}{1K} = 12mA$$

$$i_D(v_D = 1) = \frac{12 - 1}{1K} = 11mA$$

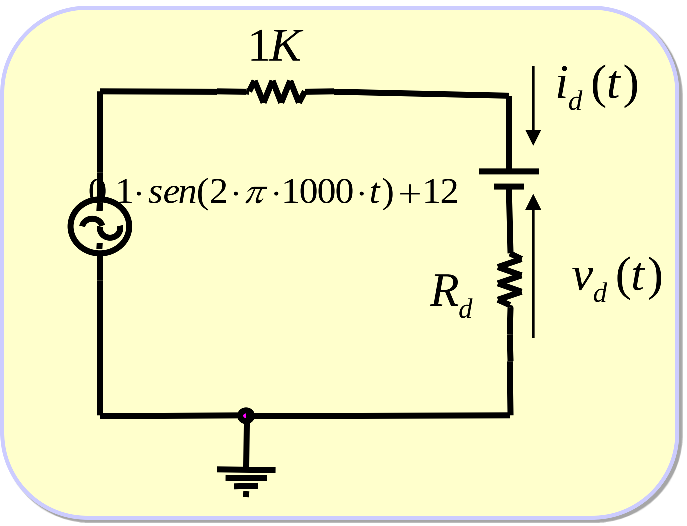
$$v_D = v_{don} \approx 0.7V$$

$$i_D = \frac{12 - 0.7}{1K} = 11.3mA$$



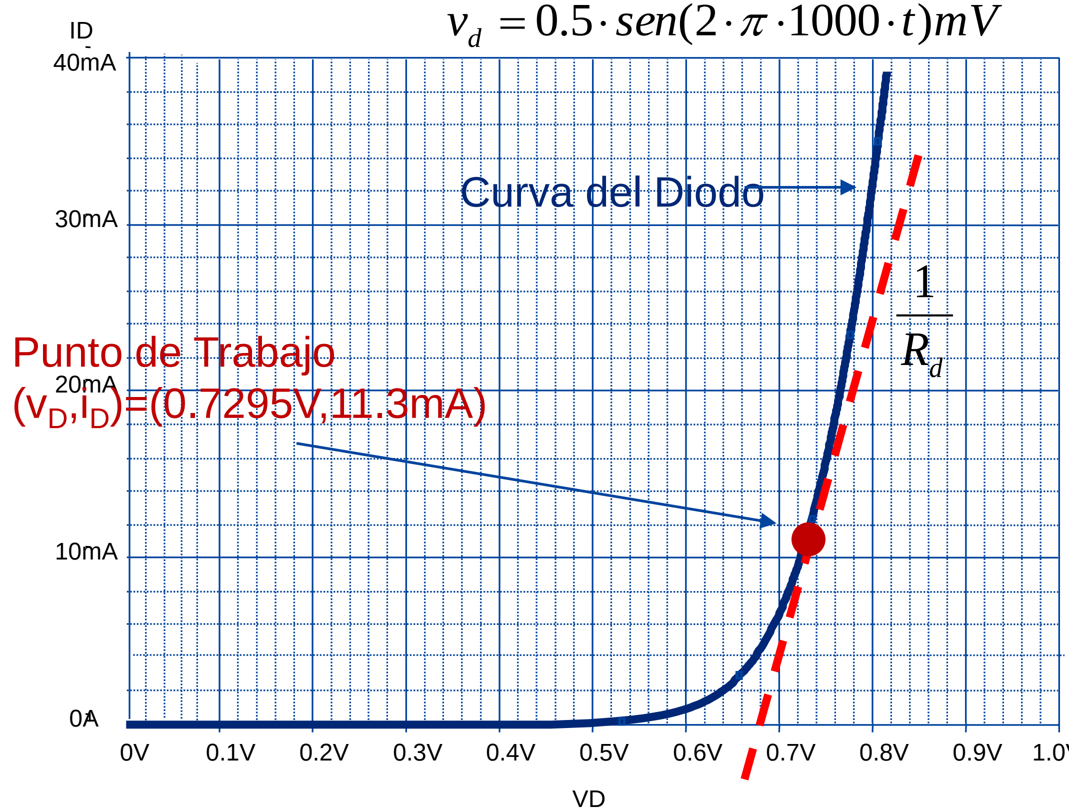
4.2 Modelo

Circuito sencillo con Diodo



$$i_d = 0.1 \cdot sen(2 \cdot \pi \cdot 1000 \cdot t) mA$$

$$v_d = 0.5 \cdot sen(2 \cdot \pi \cdot 1000 \cdot t) mV$$



$$i_d = \frac{V2 - v_d}{1K} = \frac{V2 - v_{don} - R_d \cdot i_d}{1K}$$

$$i_d = \frac{V2}{1K + R_d}$$

$$R_d = \left.\frac{\partial v_d}{\partial i_d}\right|_{(v_D, i_D)}$$

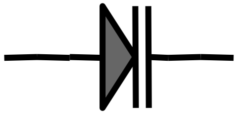
$$\frac{1}{R_d} = \left.\frac{\partial i_d}{\partial v_d}\right|_{(0.73, 11.3mA)} = \left.\frac{\partial \left(I_S \cdot \left(-1 + e^{\frac{v_d}{K \cdot T / q}}\right)\right)}{\partial v_d}\right|_{(0.73, 11.3mA)}$$

$$\approx \left.\frac{I_D}{K \cdot T / q}\right|_{(0.73, 11.3mA)} = \frac{11.3mA}{26mV} = 0.43$$

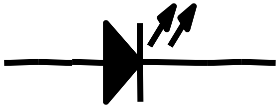
4.2 Modelo

Diodo: (Otros tipos de diodos)

Diodo Varicap: Diodos con alta capacidad parásita variable dependiente de la tensión inversa aplicada



Diodo LED: Diodos capaces de emitir luz cuando están polarizados en directa



Fotodiodos: Diodos preparados para conducir en inversa una corriente eléctrica proporcional a la luz con la que son iluminados