

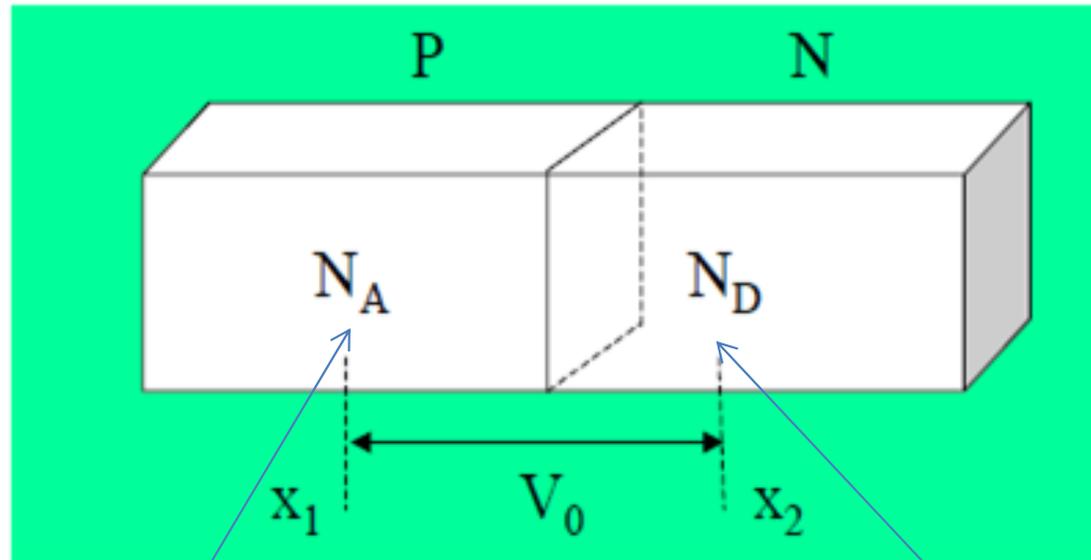
Tema 4: Unión PN (introducción, descripción cualitativa). Características I-V. Capacidad de la unión. Modelos para circuitos. Conmutación. Diodos especiales: diodos Schottky, Zéner, ...

Lecturas recomendadas:

“Electrónica Integrada” Cap.3- J.Millman y Ch.C.Halkias. Ed. Hispano Europea.

“Microelectrónica” Cap.2- J.Millman y A.Grabel. Ed. Hispano Europea

Potencial de contacto



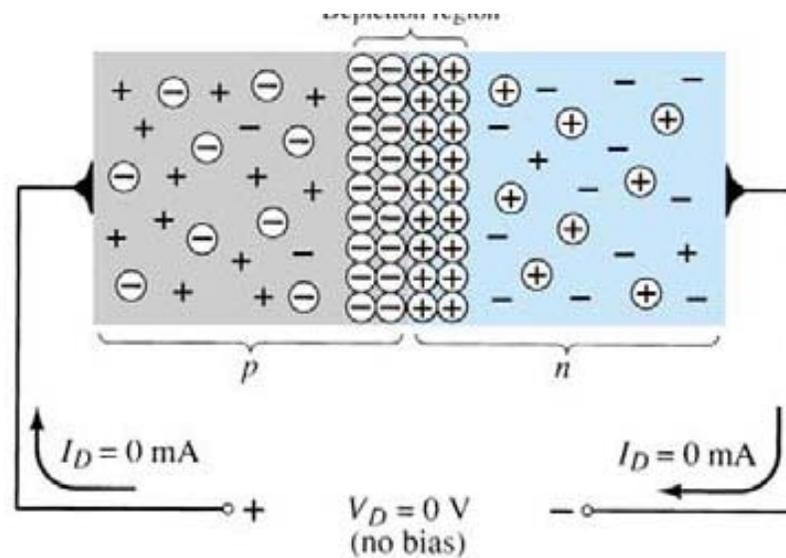
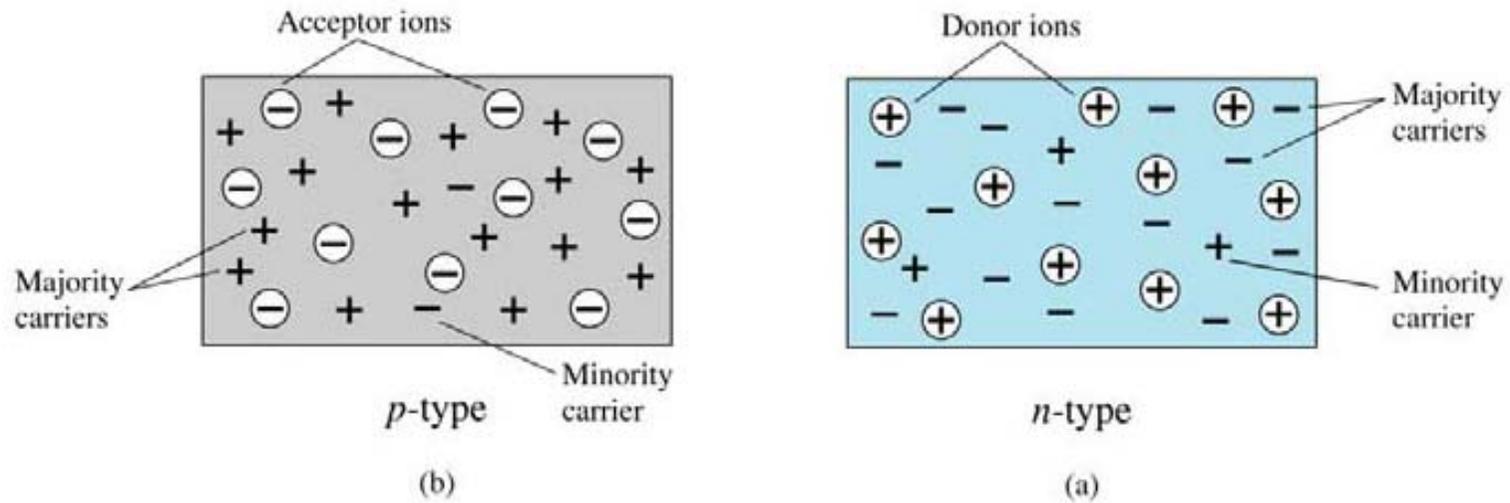
$$p_1 = p_{p0} = N_A$$

$$p_2 = p_{n0} = \frac{n_i^2}{N_D}$$

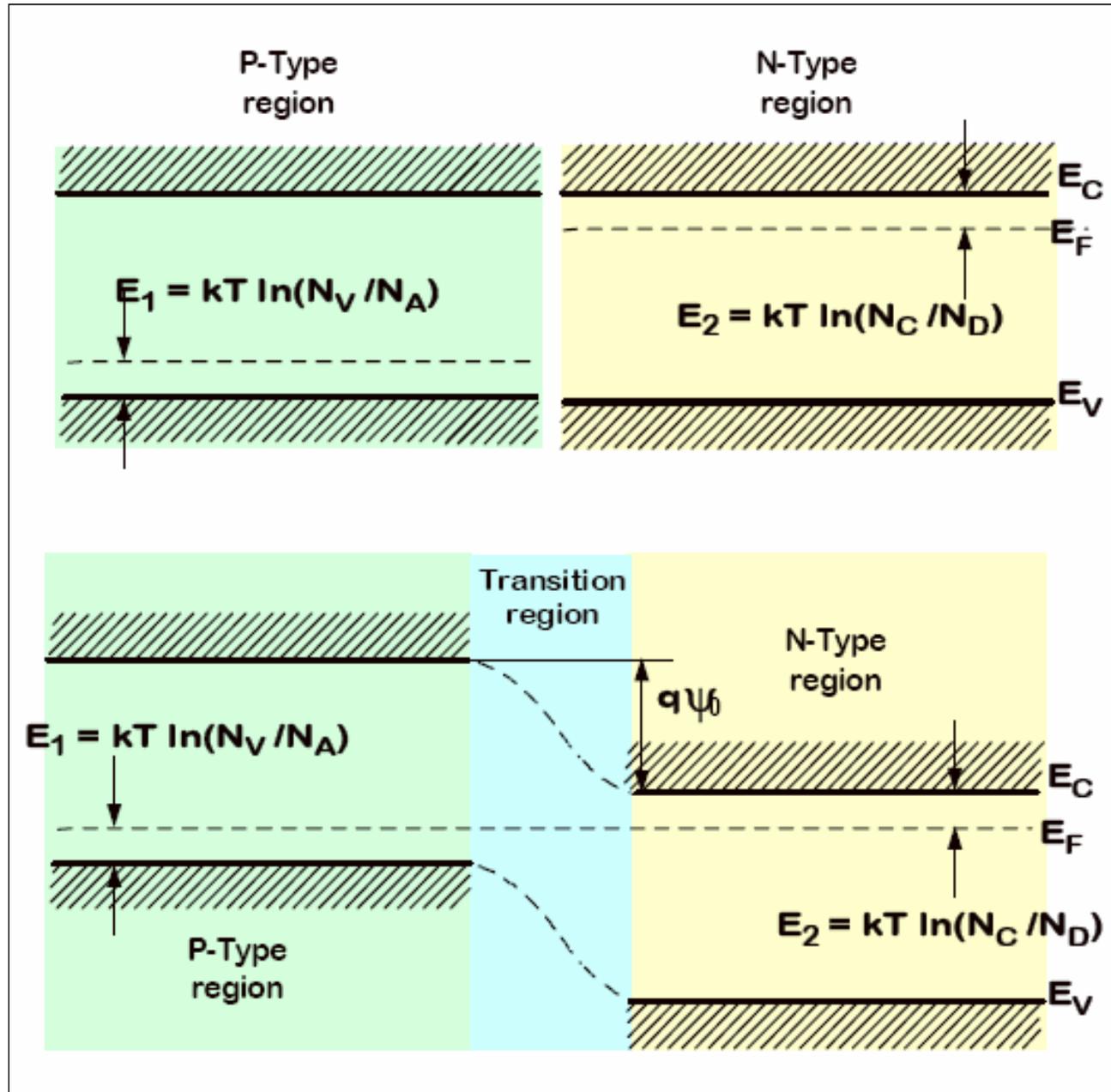
- Potencial de contacto (tensión en circuito abierto):

$$V_{21} = V_0 = V_T \cdot \ln\left(\frac{p_1}{p_2}\right) = V_T \cdot \ln\left(\frac{N_A N_D}{n_i^2}\right)$$

FORMACIÓN DE LA UNIÓN

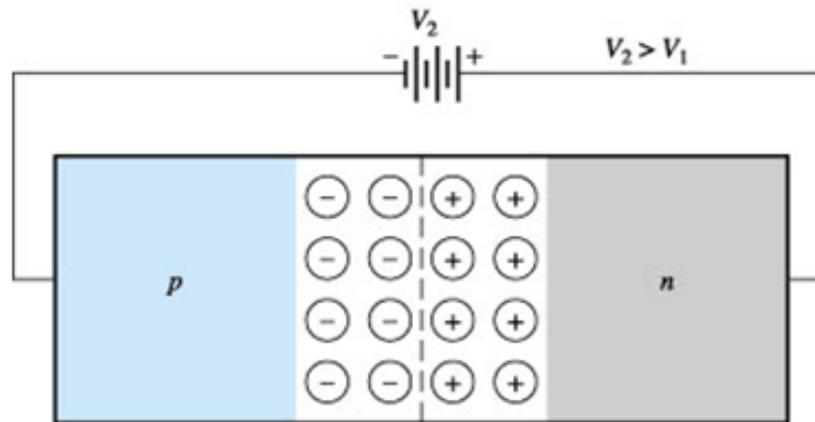
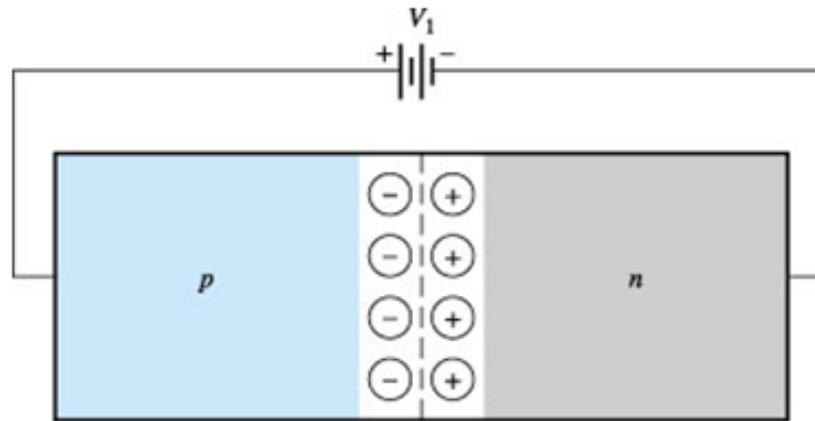


Potencial de contacto



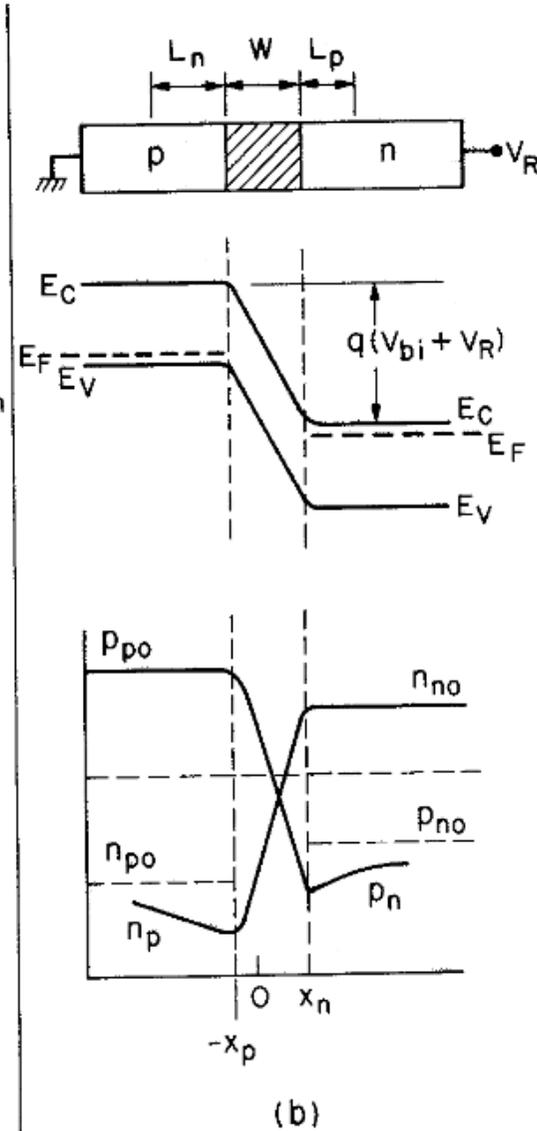
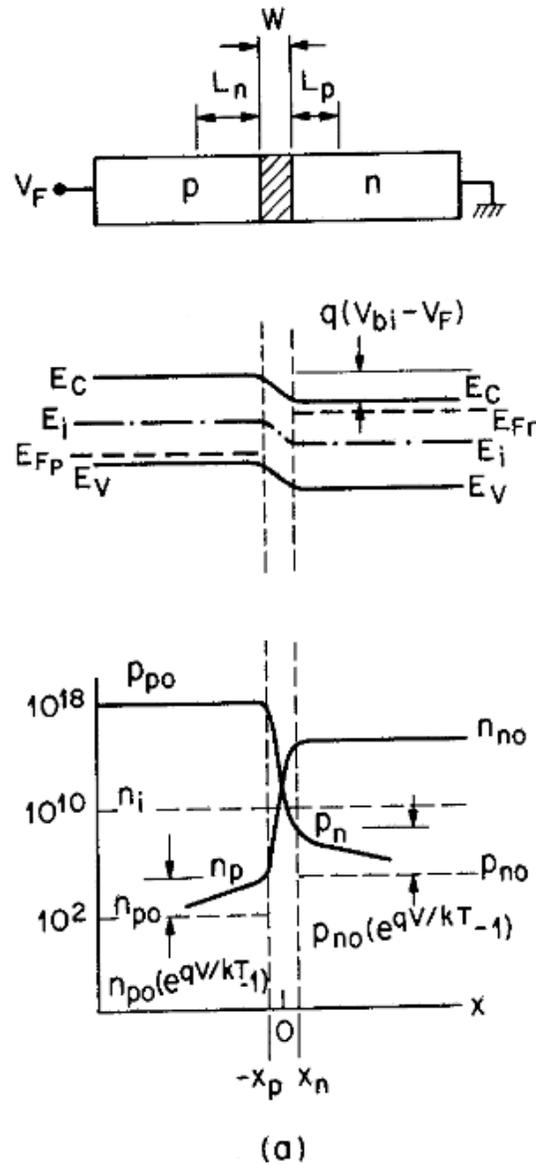
ZONA DE CARGA ESPACIAL

$V > 0$: polarización directa



$V < 0$: polarización inversa

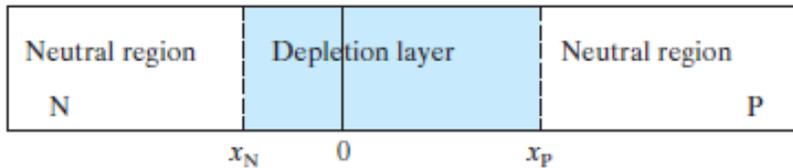
BARRERA DE POTENCIAL Y CONCENTRACIONES DE PORTADORES



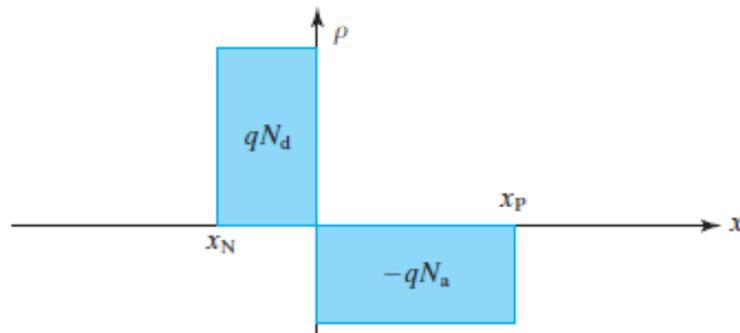
Zona de carga espacial

- Neutralidad de carga: $qN_A x_p = qN_D x_n$

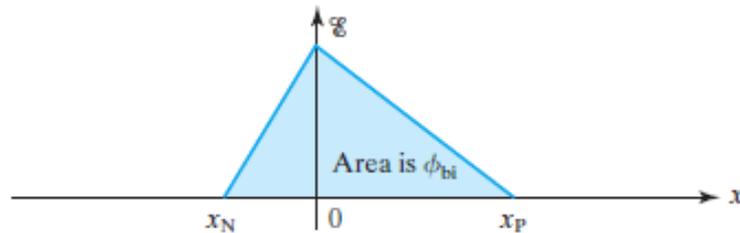
- Unión unilateral: $N_A \ll N_D ; x_n = \frac{N_A}{N_D} x_p \ll x_p \Rightarrow W = x_n + x_p \cong x_p$



(b)



(c)



(d)

- Ecuación de Poisson:

$$\frac{d^2V}{dx^2} = -\frac{\rho(x)}{\epsilon} ; \rho(x) = -qN_A$$

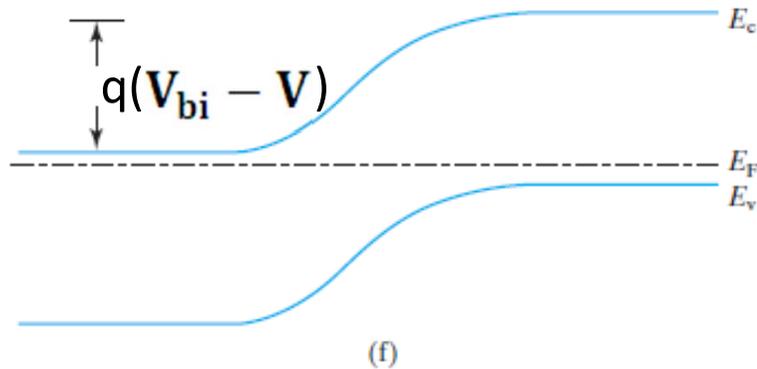
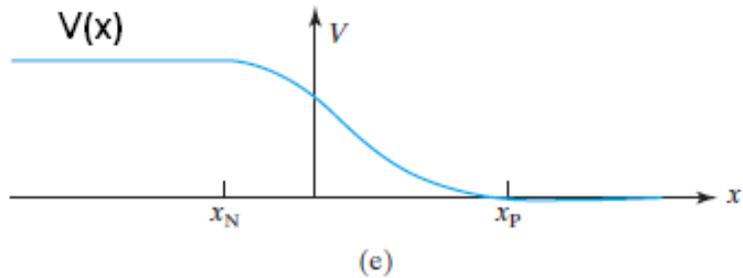
- Integrando entre x y W :

- Campo eléctrico: $\mathcal{E} = -\frac{qN_A}{\epsilon}(x - W)$

- Campo eléctrico máximo:

$$\mathcal{E}_m = \frac{qN_A W}{\epsilon}$$

Capacidad de transición



- Potencial:

$$V(x) = \frac{qN_A}{2\epsilon} (x - W)^2$$

- Diferencia de potencial:

$$V_j = V_{bi} - V = \frac{qN_A W^2}{2\epsilon}$$

- Anchura de la zona de carga:

$$W = \sqrt{\frac{2\epsilon}{qN_A} (V_{bi} - V)}$$

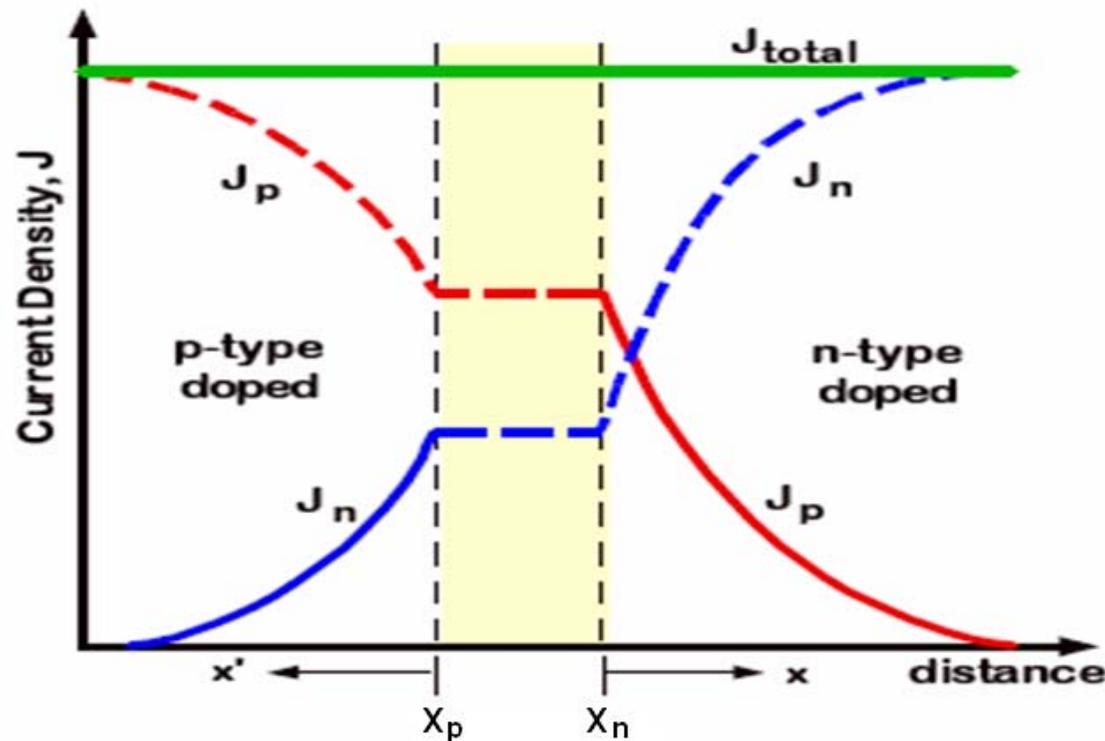
- Capacidad (diferencial) de transición:

$$C_T = \left| \frac{dQ}{dV} \right| = qAN_A \left| \frac{dW}{dV_j} \right| = \frac{\epsilon A}{W}$$

- Todas las propiedades de la unión dependen exclusivamente del lado menos dopado

CORRIENTES DE DIFUSIÓN Y ARRASTRE

Modelo de Shockley: no hay generación ni recombinación en la zona de carga

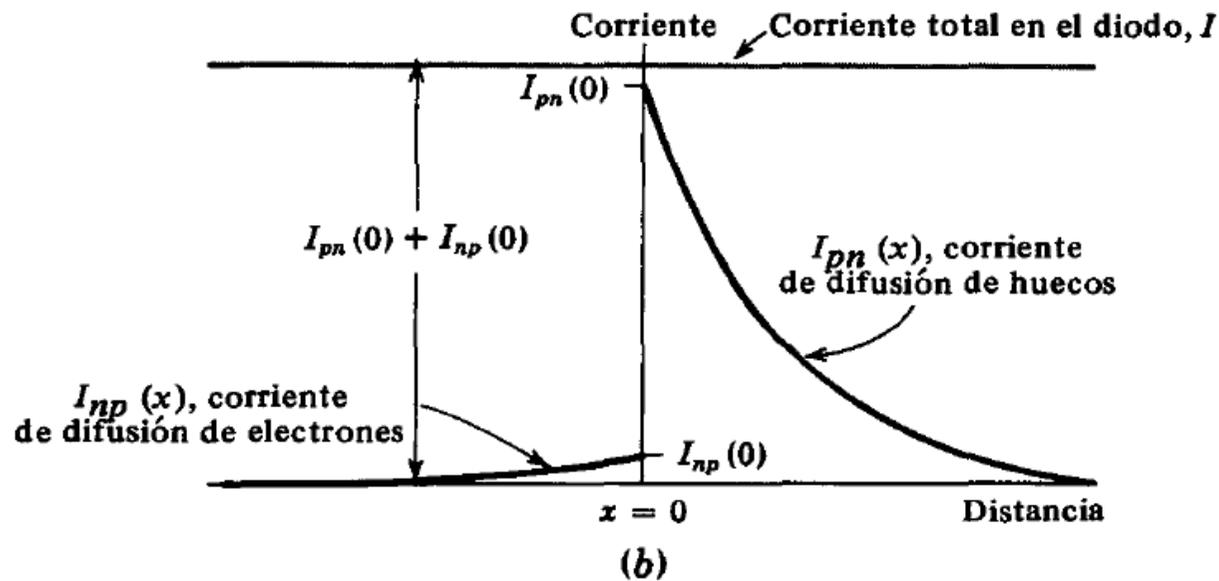
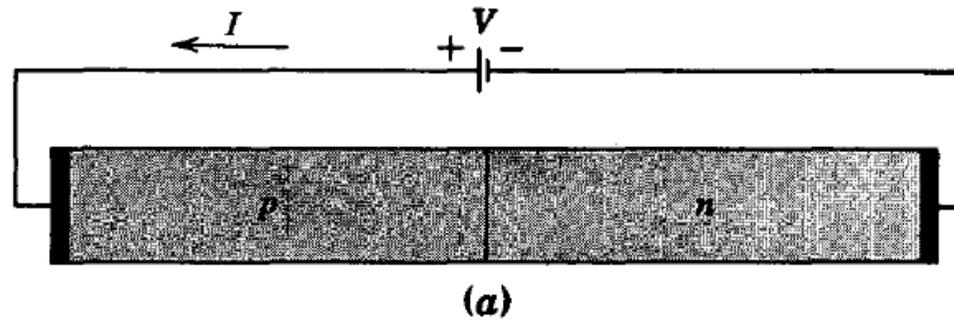


$$J \cong q\mu_p p \mathcal{E} + qD_n \frac{dn}{dx}$$

$$q\mu_p p \mathcal{E} \Big|_{x=W_p} = qD_p \frac{dp_n}{dx} \Big|_{x=W_n}$$

$$J = qD_p \frac{dp_n}{dx} \Big|_{x=W_n} + qD_n \frac{dn_p}{dx} \Big|_{x=W_p}$$

CORRIENTES DE DIFUSIÓN



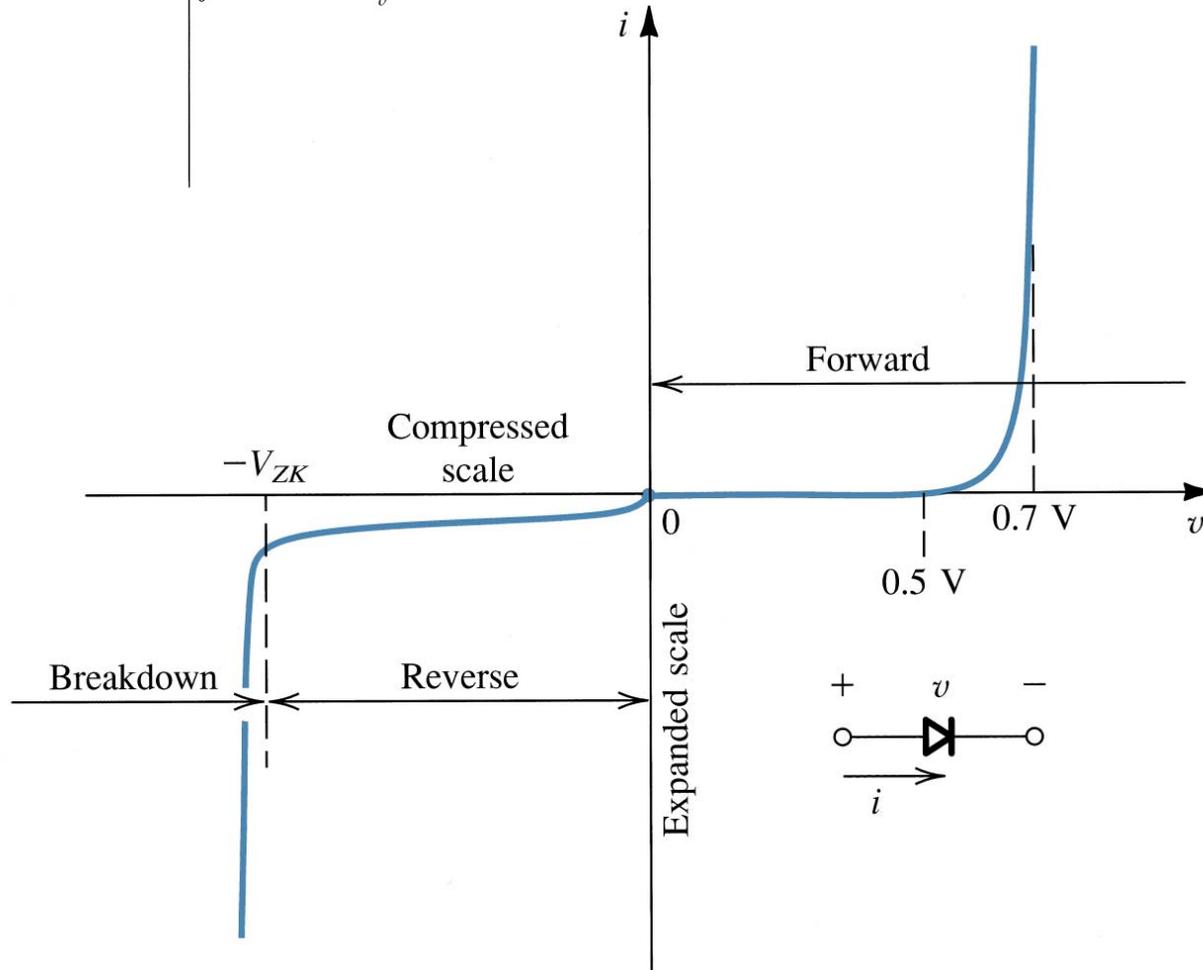
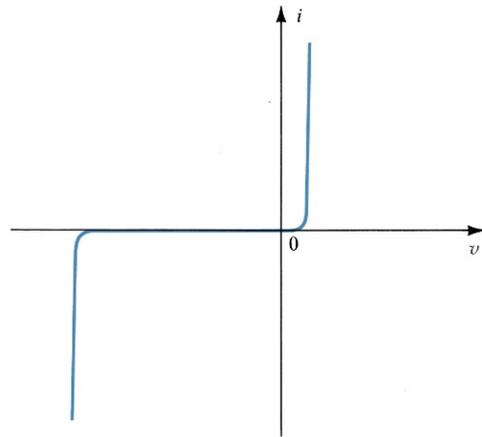
$$J_p = \frac{qD_p}{L_p} [p_n(0) - p_{n0}] e^{-x/L_p}$$

$$p_n(0) = p_{n0} e^{V/V_T}$$



$$J_p = \frac{qD_p p_{n0}}{L_p} (e^{V/V_T} - 1)$$

CARACTERISTICA I-V



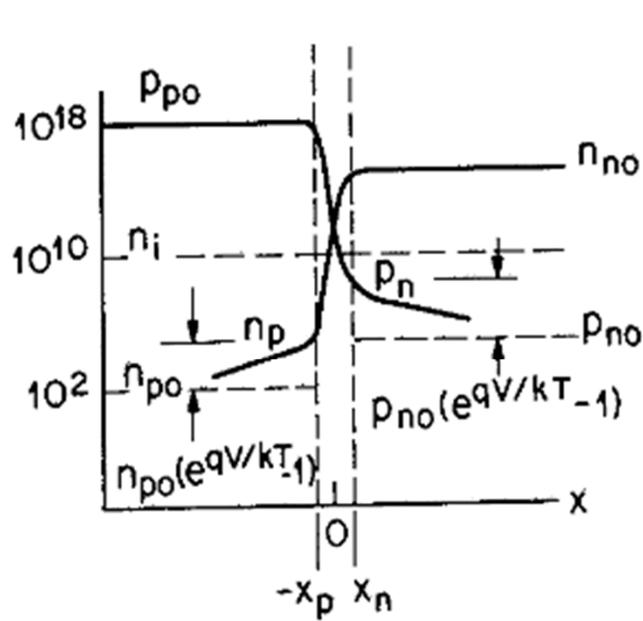
$$J = J_0(e^{v/v_T} - 1)$$

$$J_0 = \frac{qD_p p_{n0}}{L_p} + \frac{qD_n n_{p0}}{L_n}$$

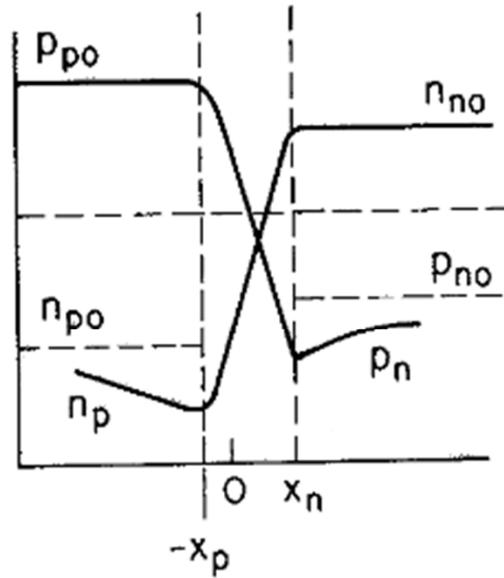
- Unión unilateral:
- $N_A \ll N_D$

- Las características dependen del lado menos dopado

CAPACIDAD DE DIFUSIÓN



(a)



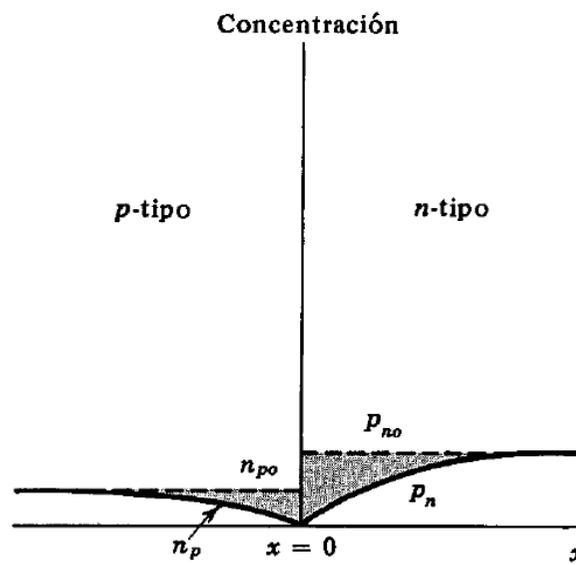
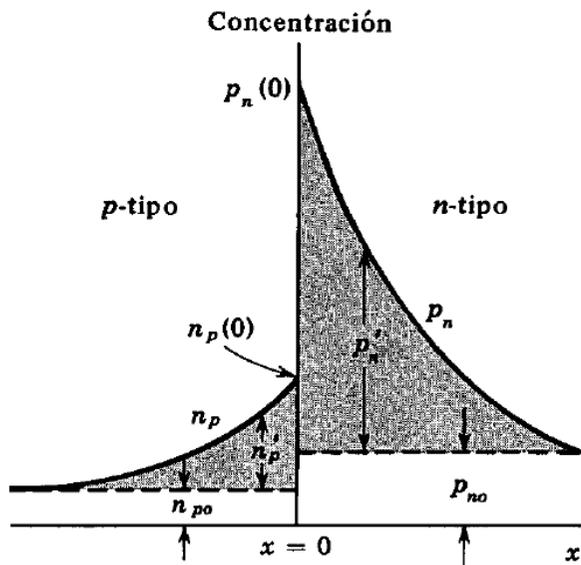
(b)

- Capacidad de difusión:

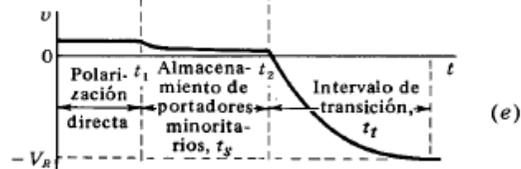
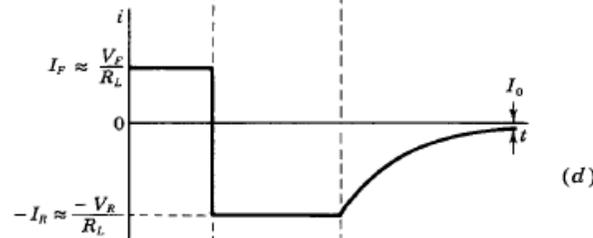
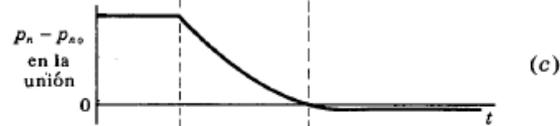
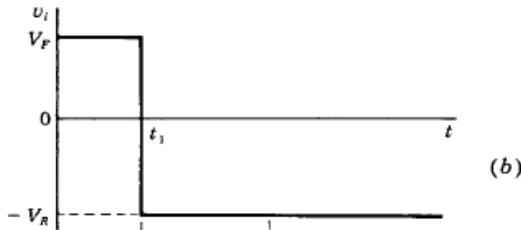
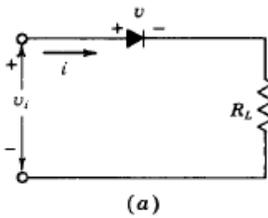
$$C_D = \frac{dQ}{dV} = \tau \frac{dI}{dV} = \frac{\tau}{r}$$

- Capacidad total:

$$C = C_T + C_D$$



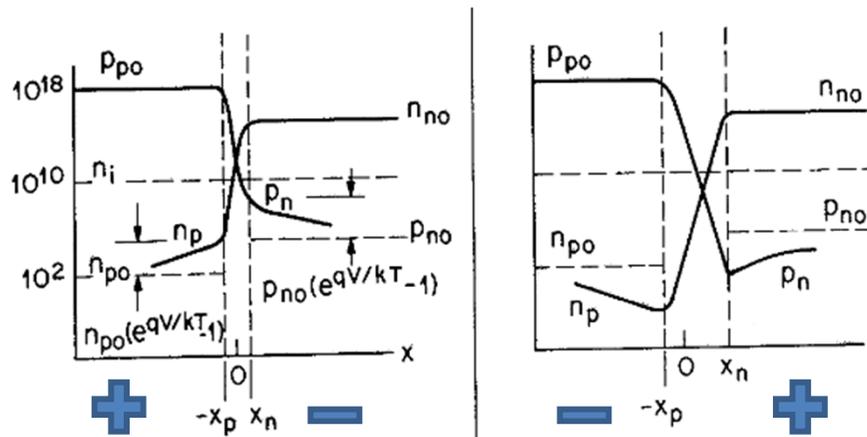
CONMUTACIÓN



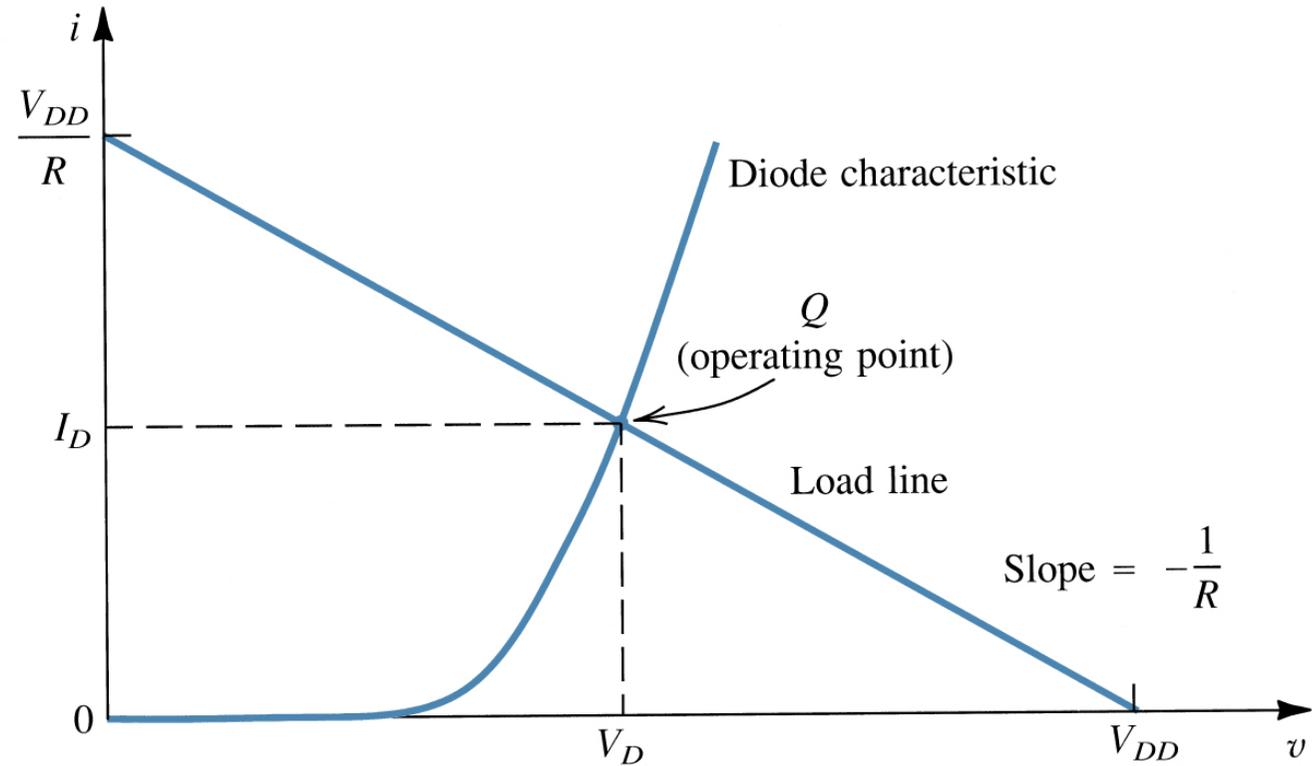
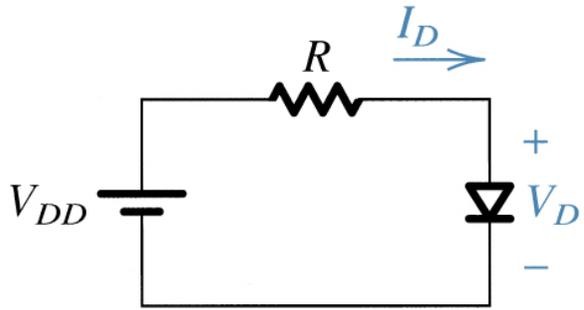
- Tiempo de tránsito

- Tiempo de recombinación

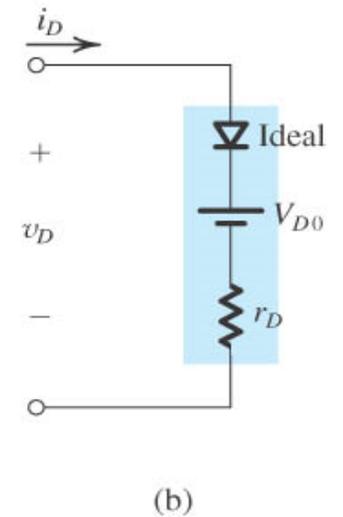
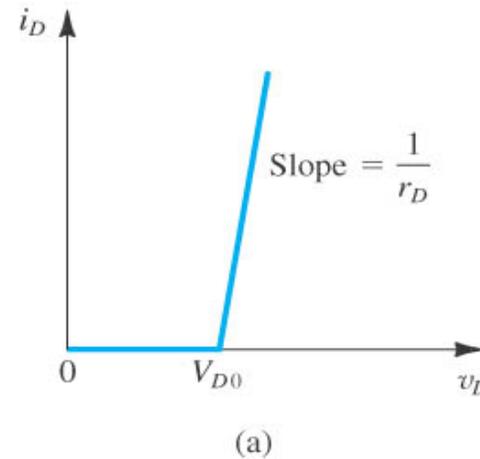
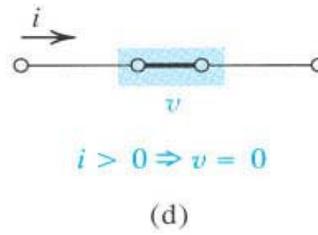
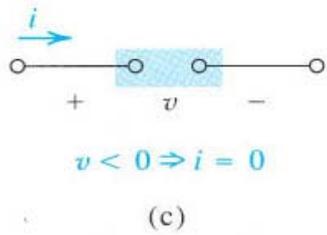
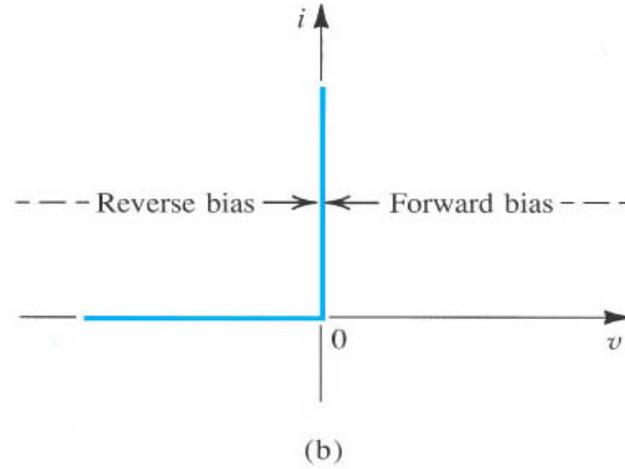
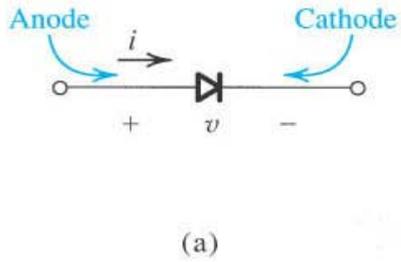
Tiempo de recuperación mayor o igual que la vida media: del orden de microsegundos



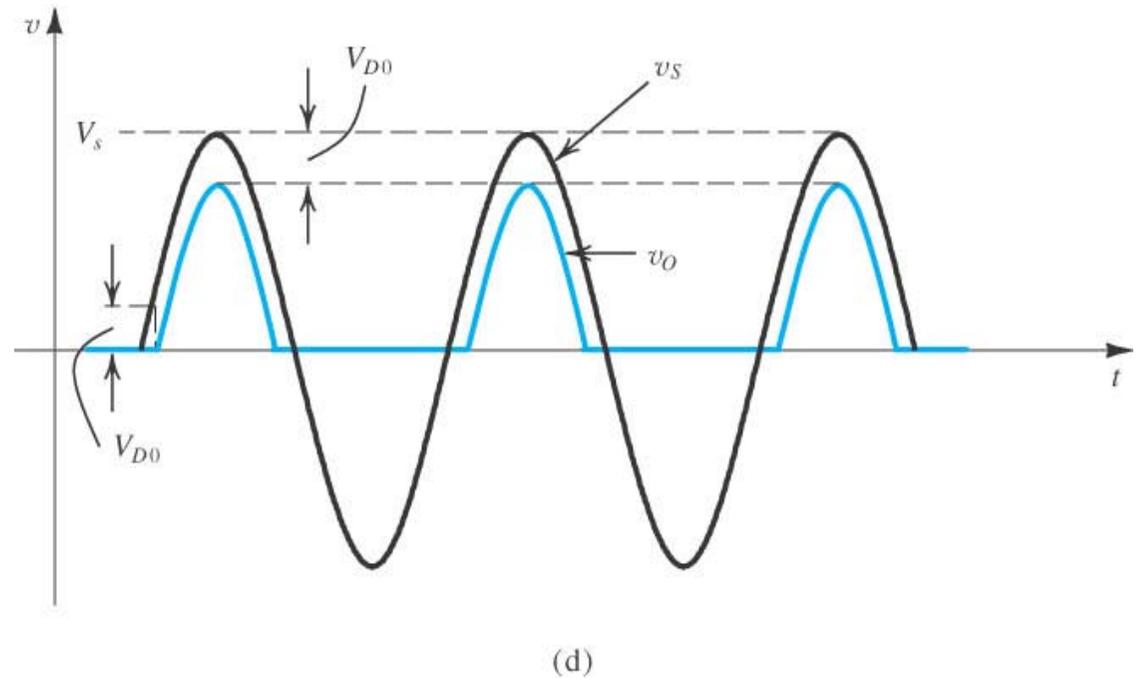
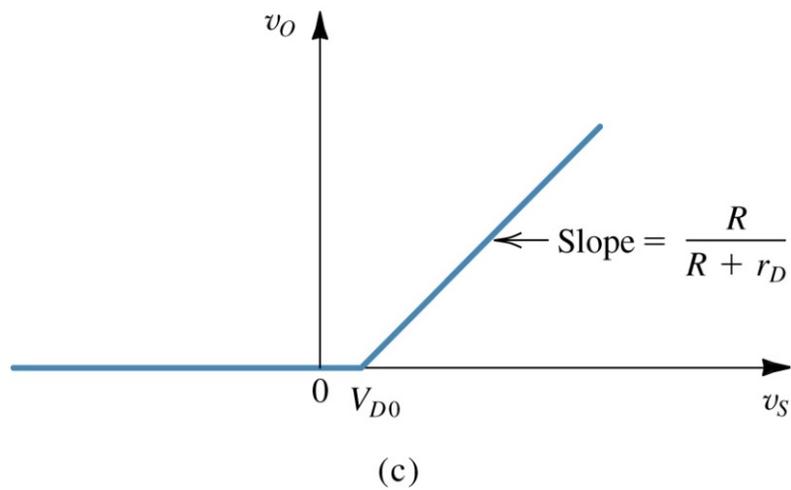
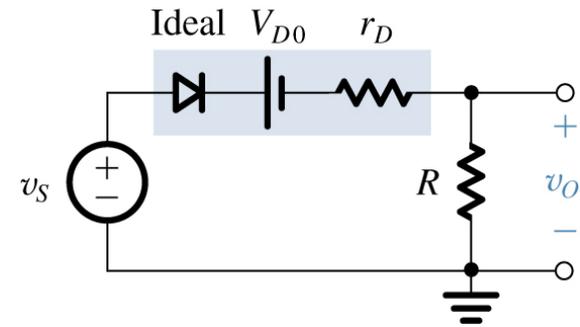
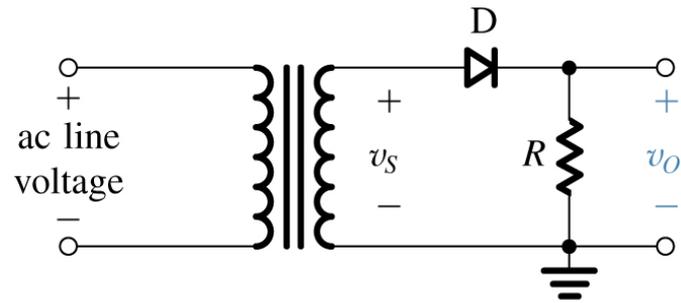
RECTA DE CARGA



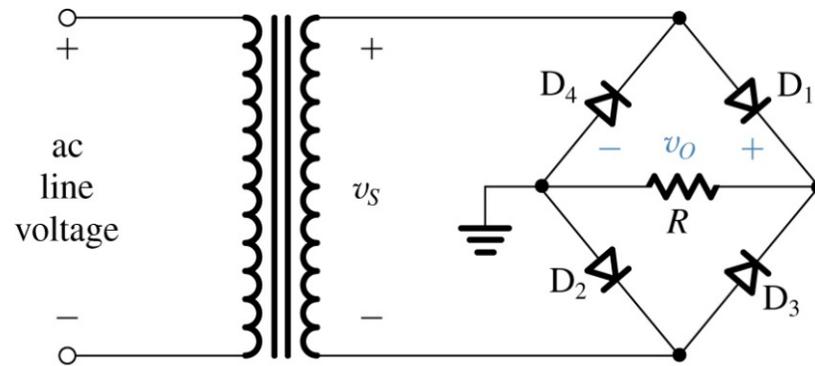
MODELOS DE CORRIENTE CONTINUA



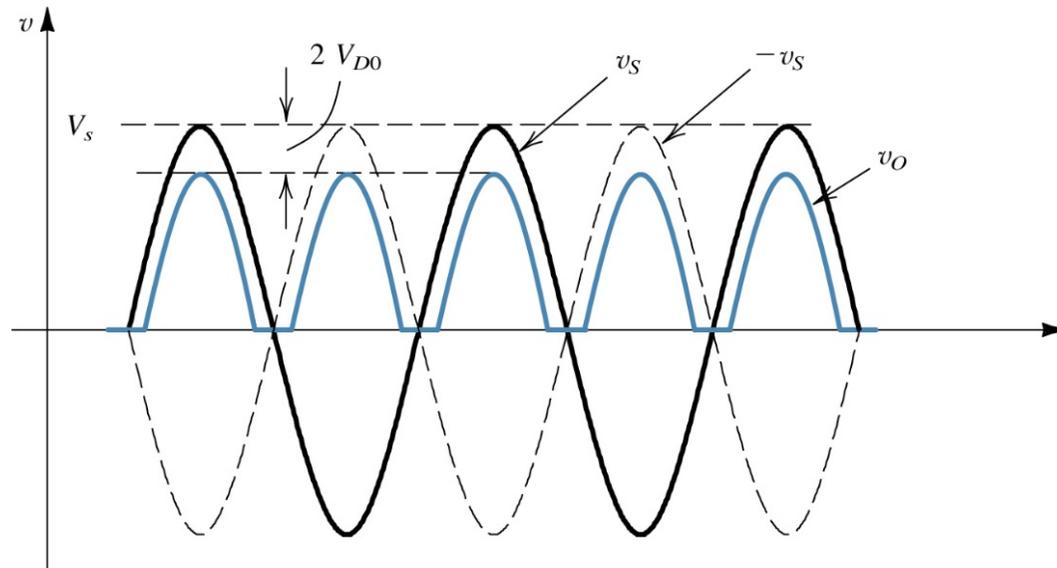
RECTIFICADOR DE MEDIA ONDA



CIRCUITO PUENTE: RECTIFICADOR DE ONDA COMPLETA

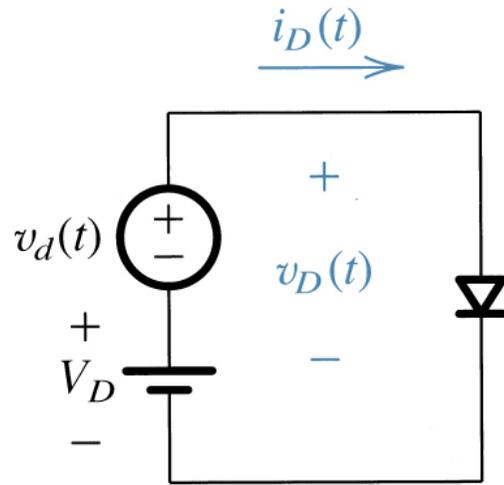


(a)

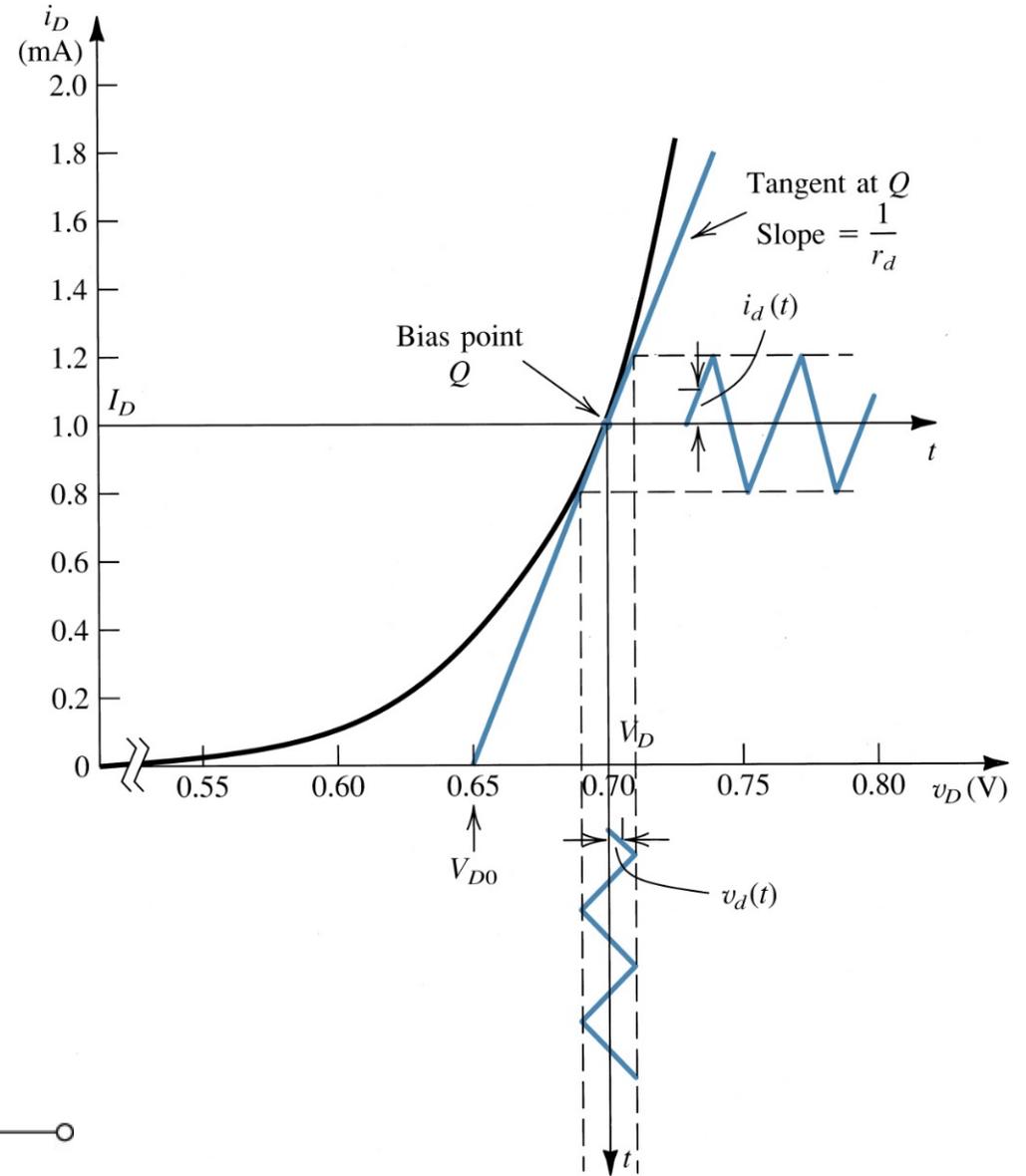


(b)

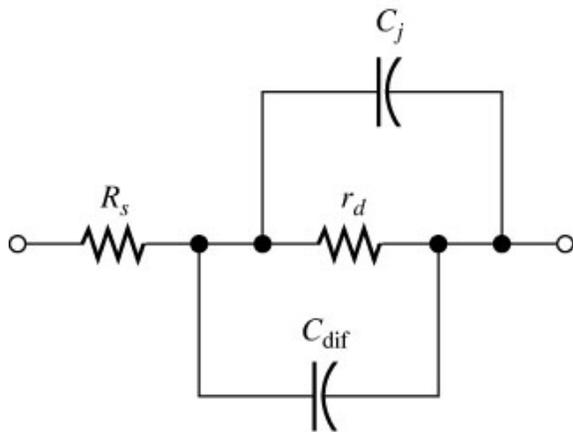
MODELO DE PEQUEÑA SEÑAL



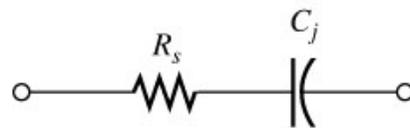
(a)



(b)

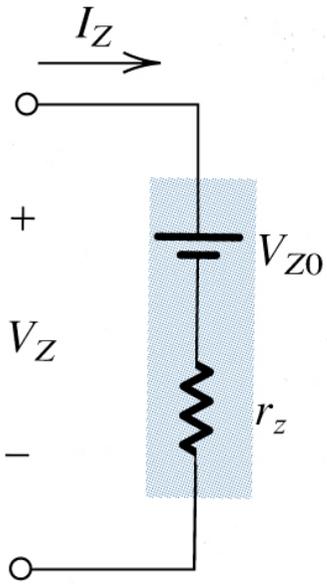
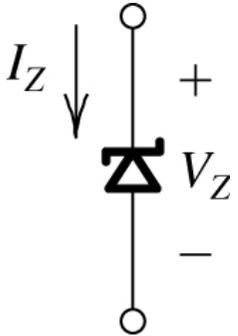
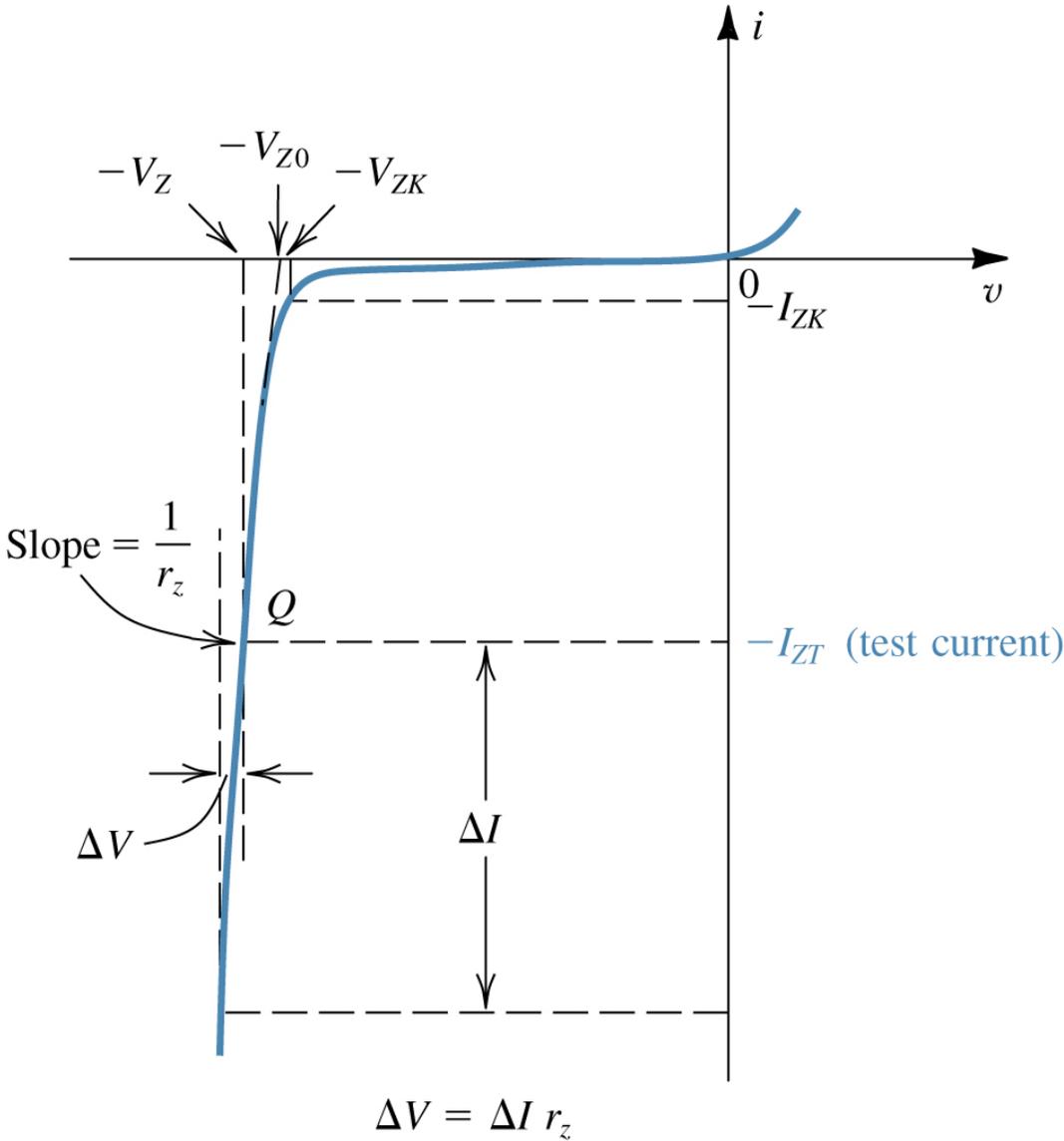


Polarización directa



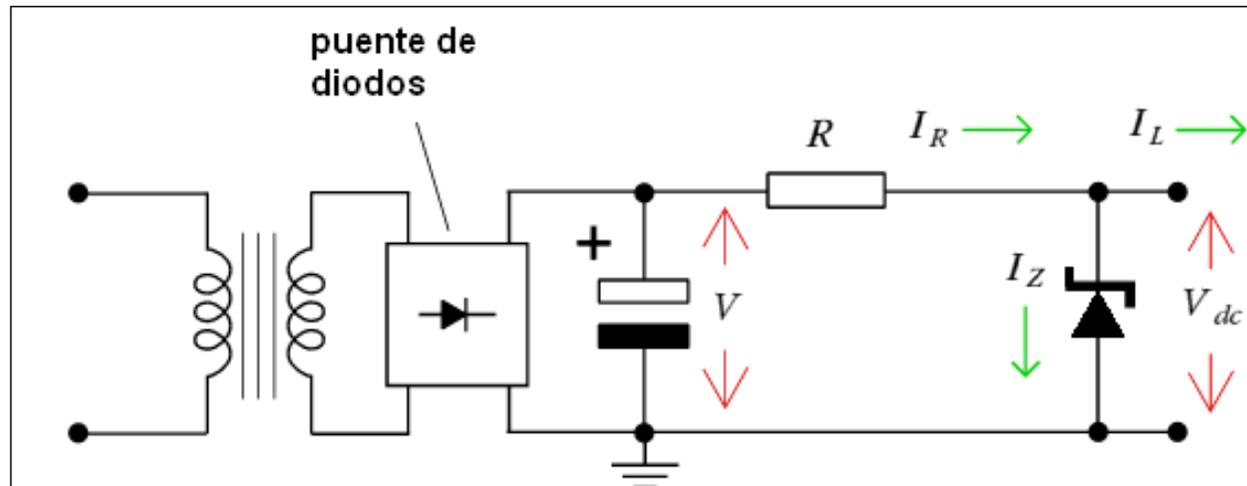
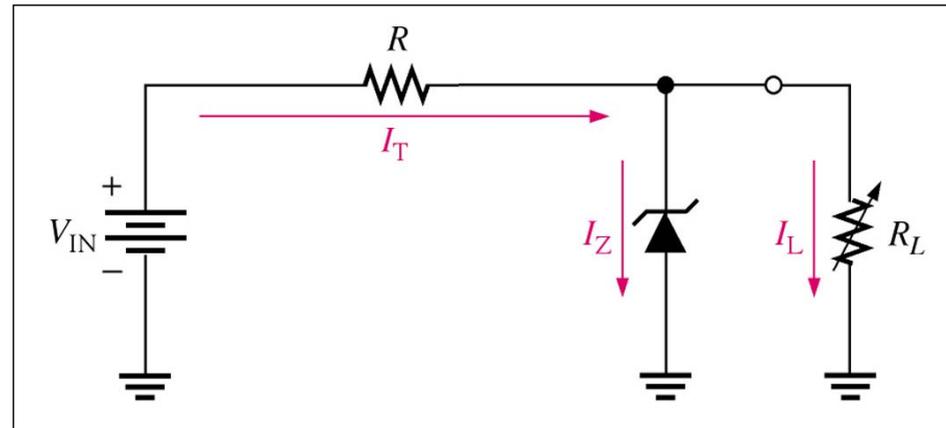
Polarización inversa

DIODO ZENER



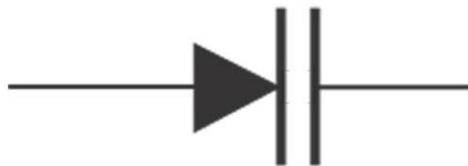
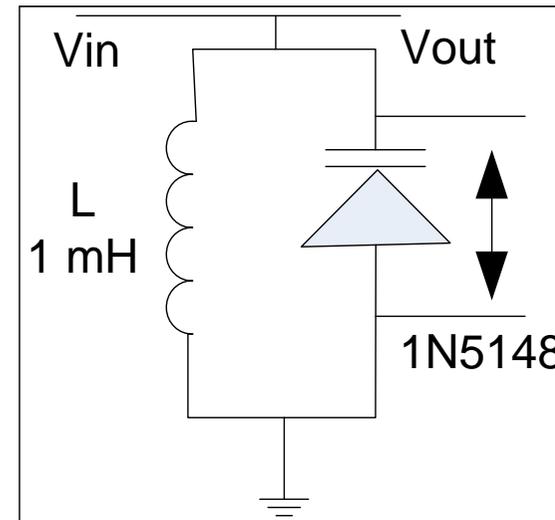
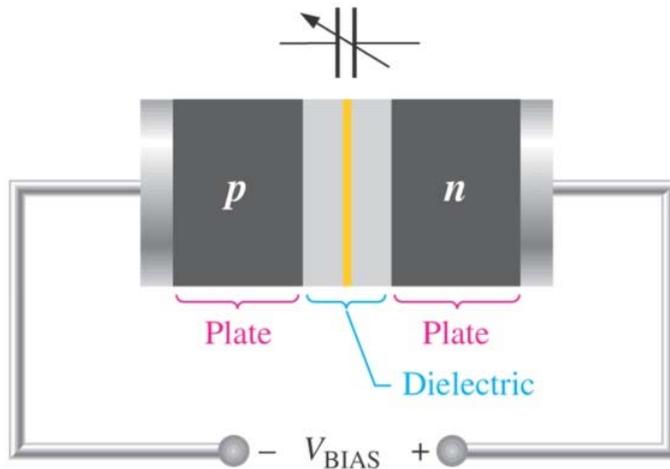
Aplicaciones del diodo Zener

- Establecer tensiones de referencia – reguladores de tensión



- Esquema de una fuente de alimentación de tensión constante

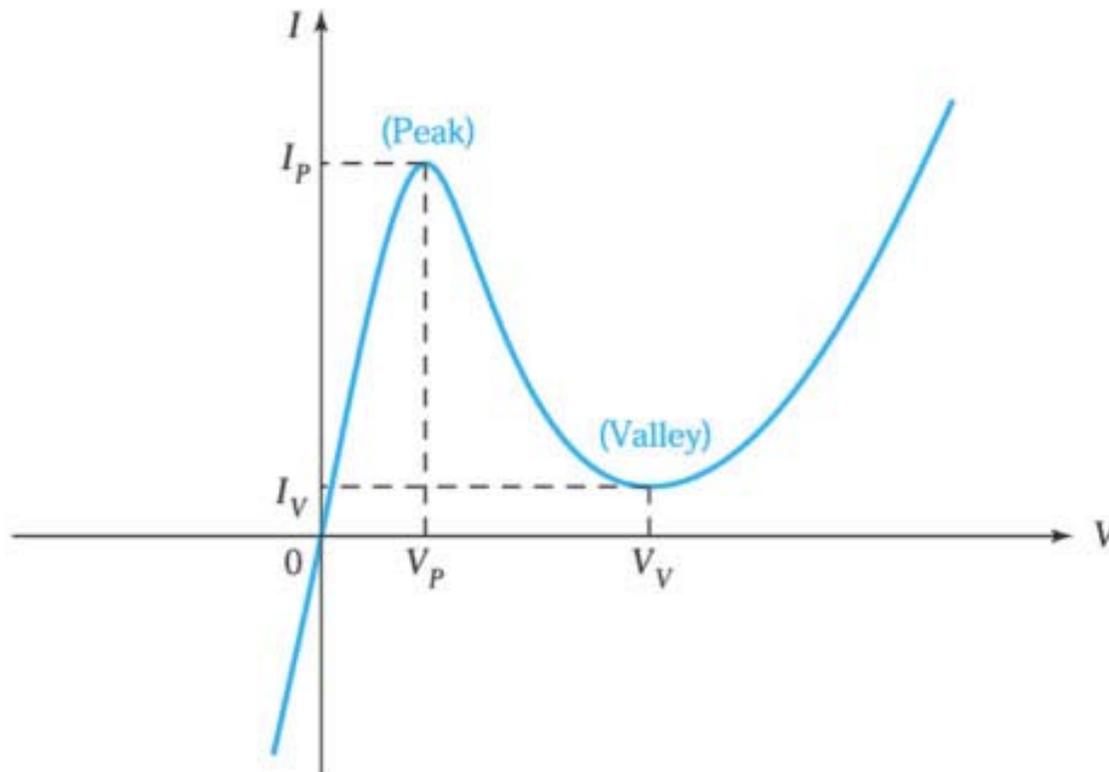
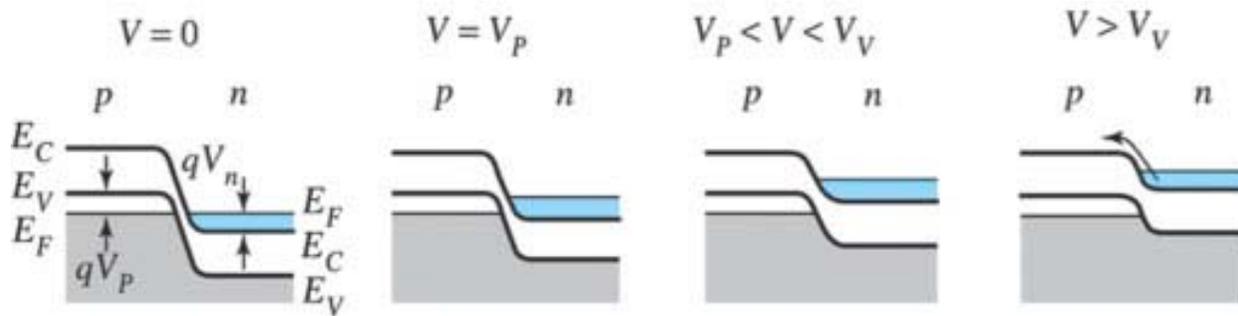
Varactores y filtros



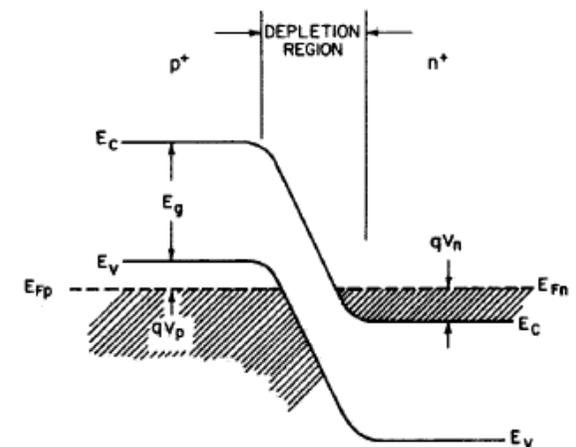
- Frecuencia de resonancia:

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

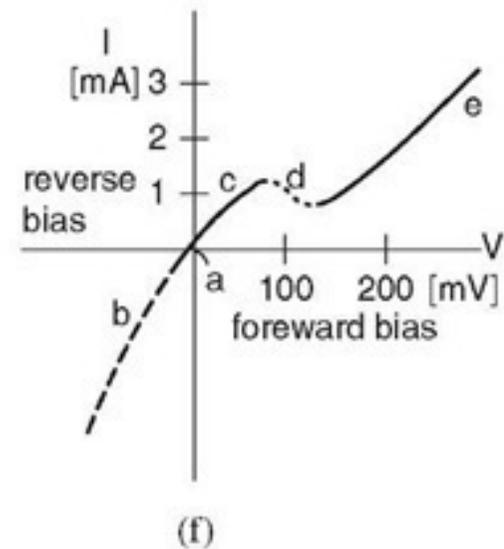
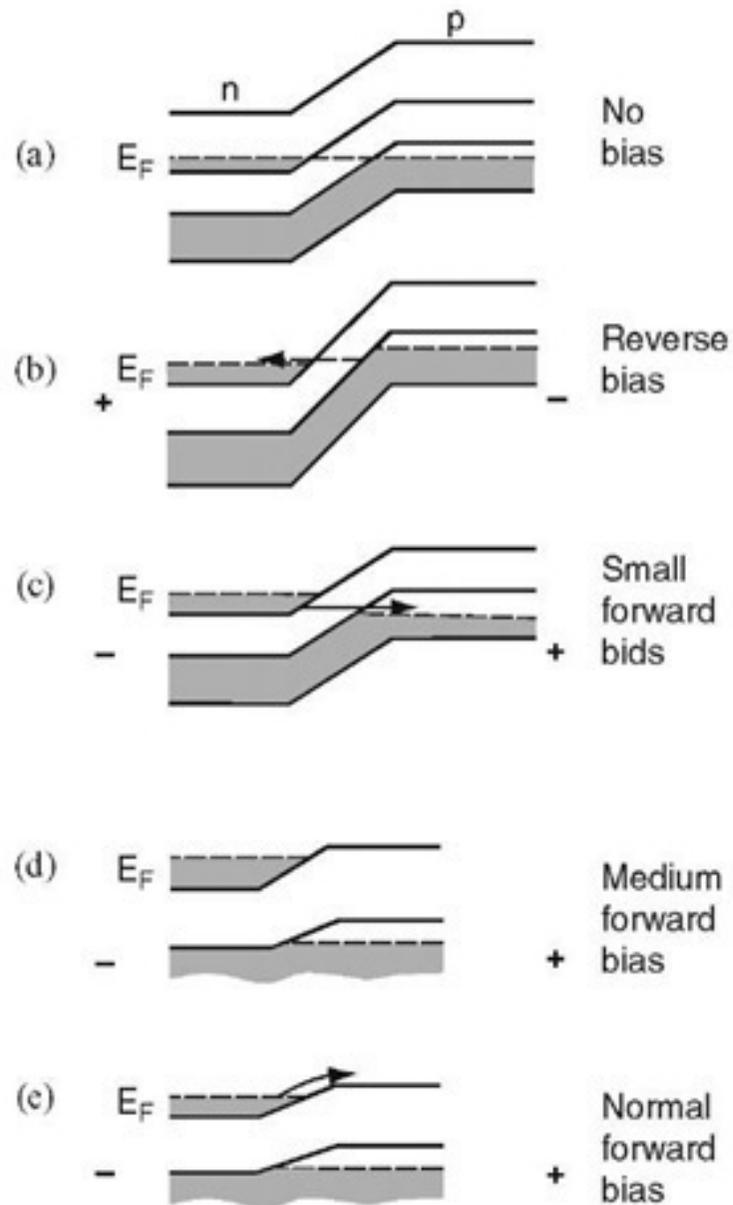
DIODO TÚNEL



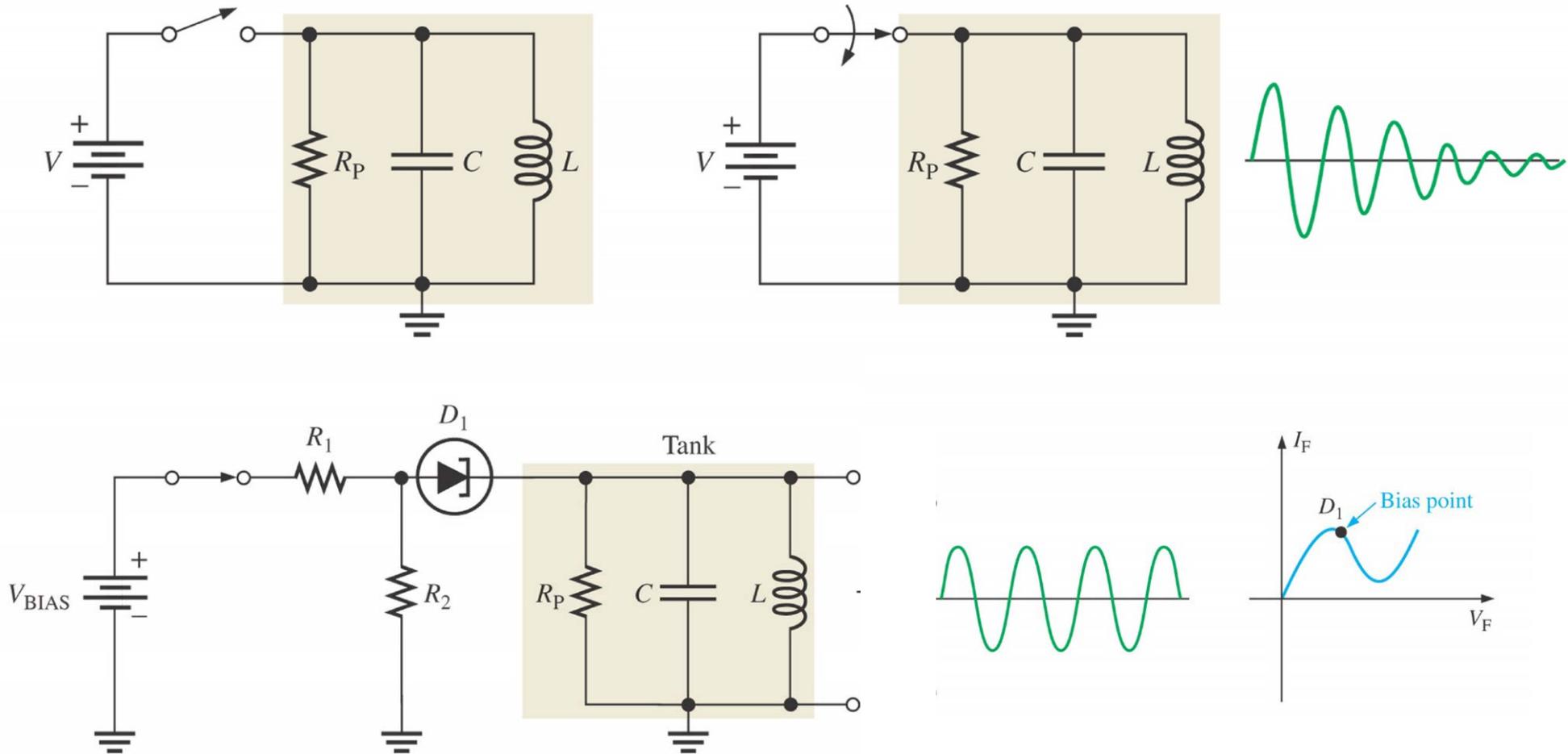
- En 1973 Leo Esaki recibió el Premio Nobel por el desarrollo (en 1959) de los dispositivos basados en efecto túnel



DIODO TÚNEL: CARACTERÍSTICAS I-V

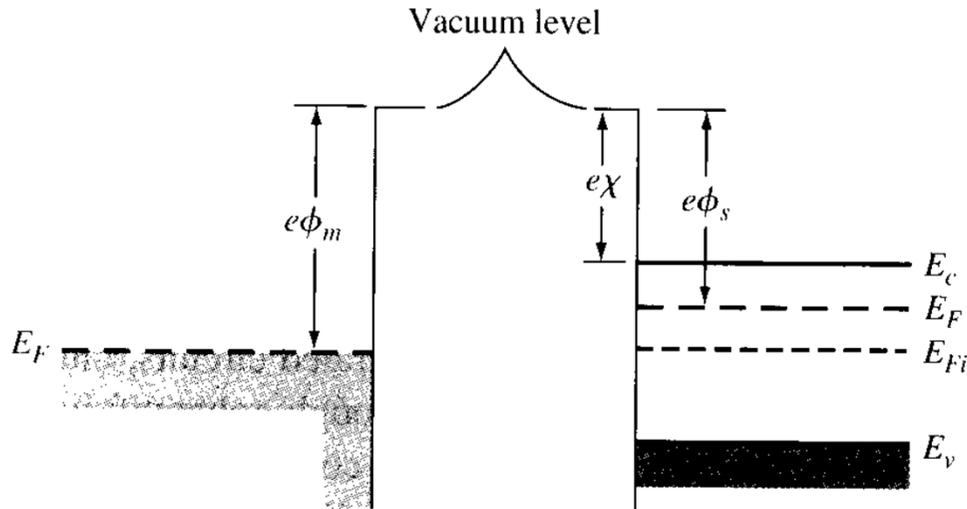


Osciladores y filtros con diodo túnel

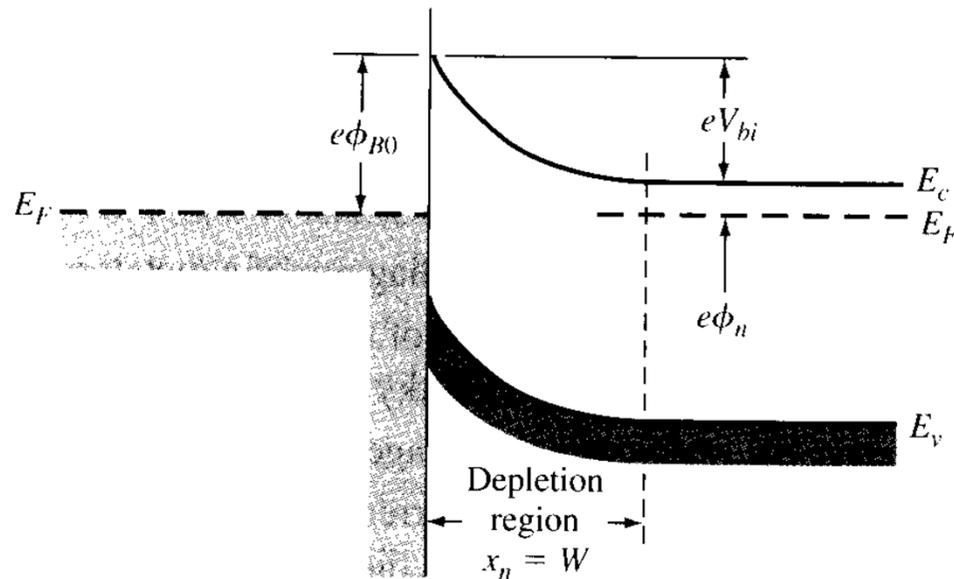


- La resistencia diferencial negativa del diodo tiende a disminuir la resistencia parásita del circuito resonante haciendo el ancho de banda más estrecho y reduciendo la atenuación

DIODOS SCHOTTKY



(a)



(b)

- Transporte por
mayoritarios

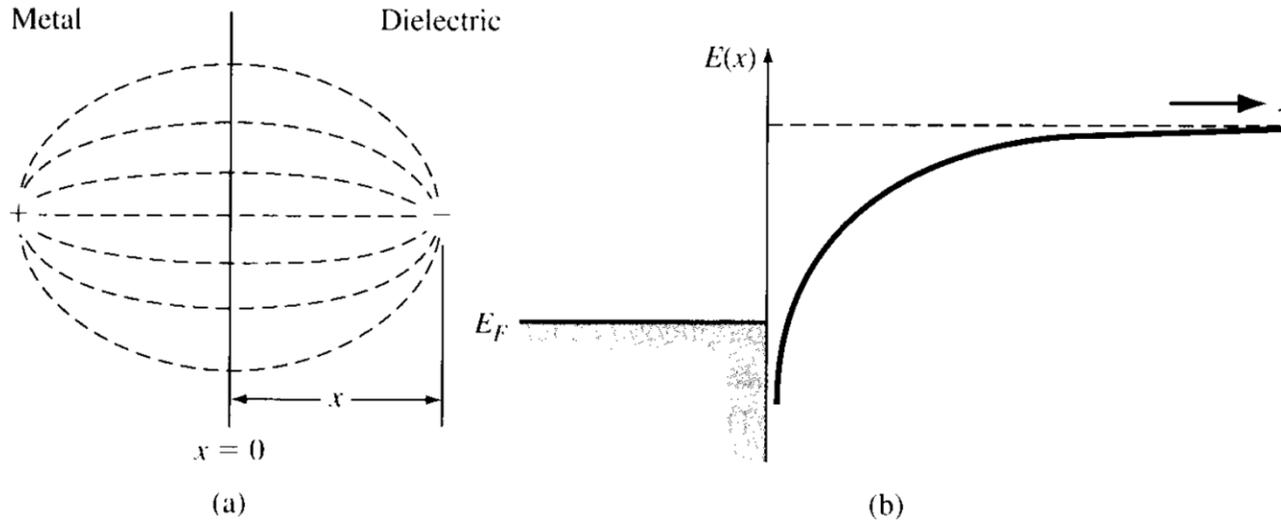
- Tiempo de
recuperación:

$$\tau = W/v_l$$

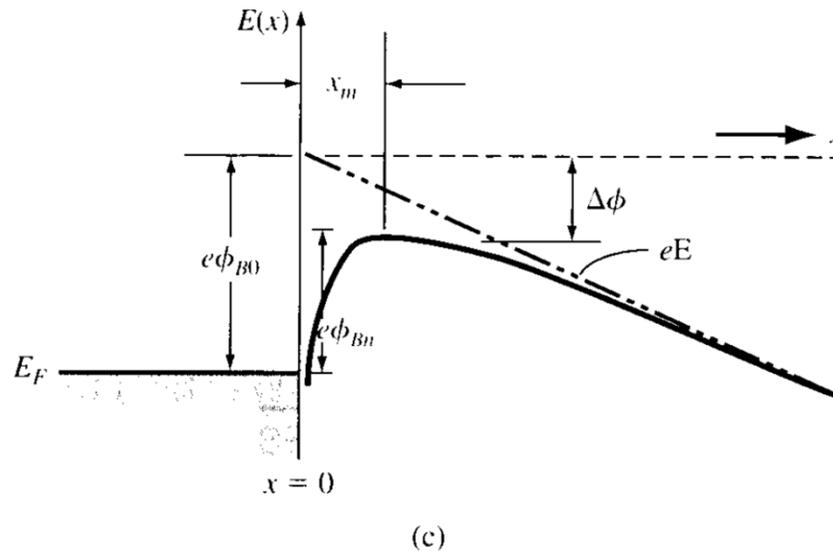
$$\sim 10^{-10} \text{ s}$$

EFFECTO DE LA FUERZA IMAGEN

- Fuerza imagen:



- Potencial inducido por la presencia cercana del metal



- Potencial combinado

DIODOS SCHOTTKY VERSUS P-N

