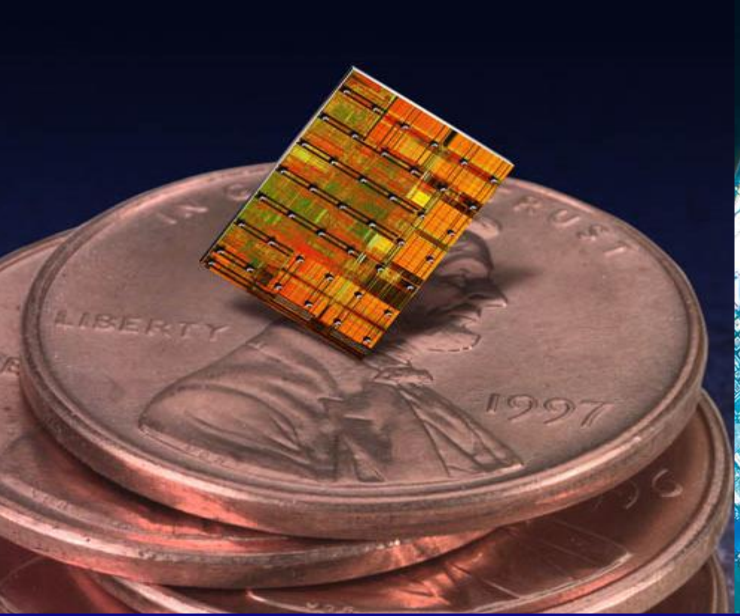
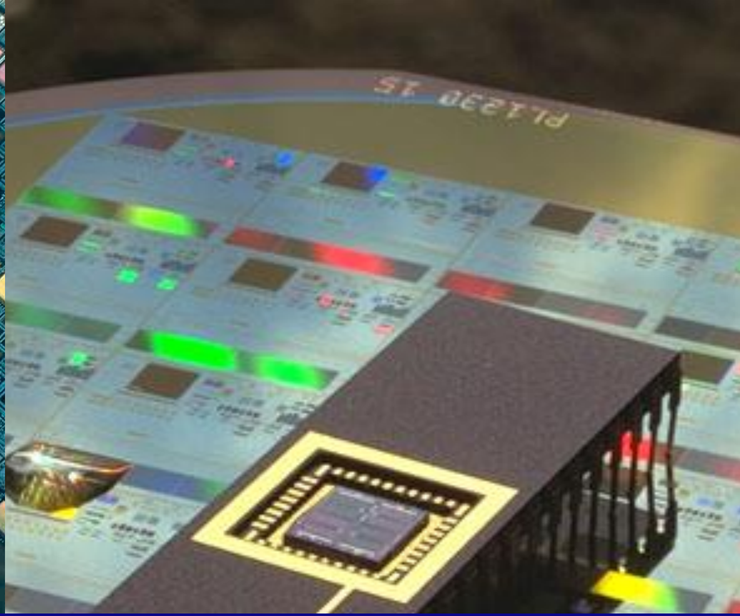
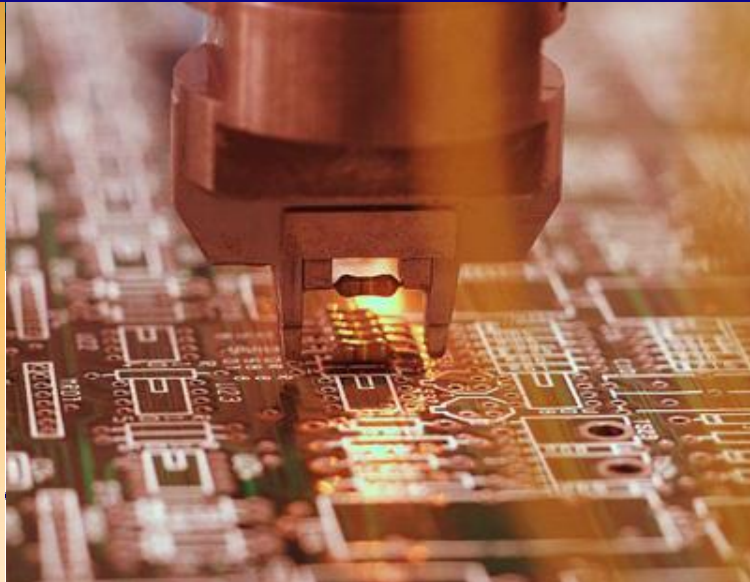


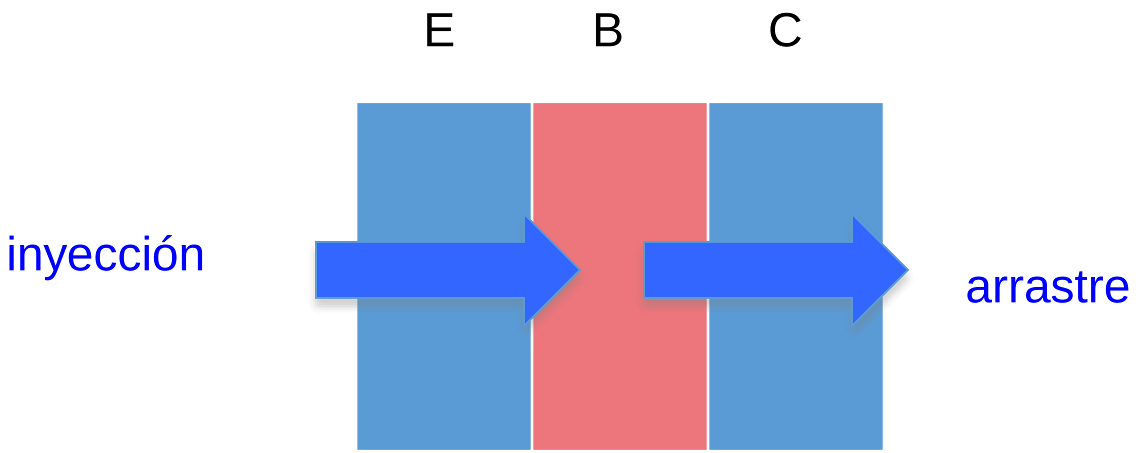



ELEMENTOS ACTIVOS
Transistor BJT

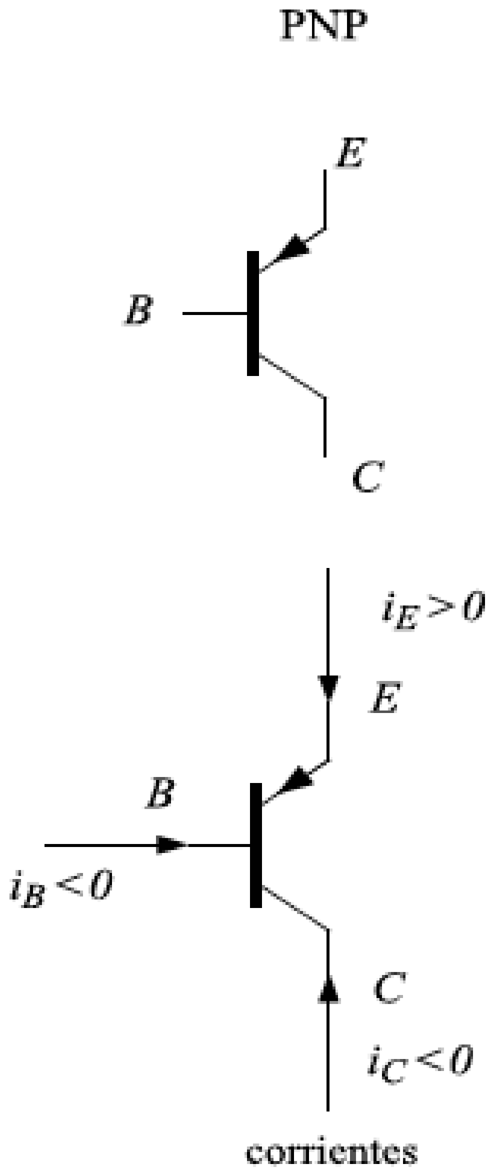
Descripción cualitativa

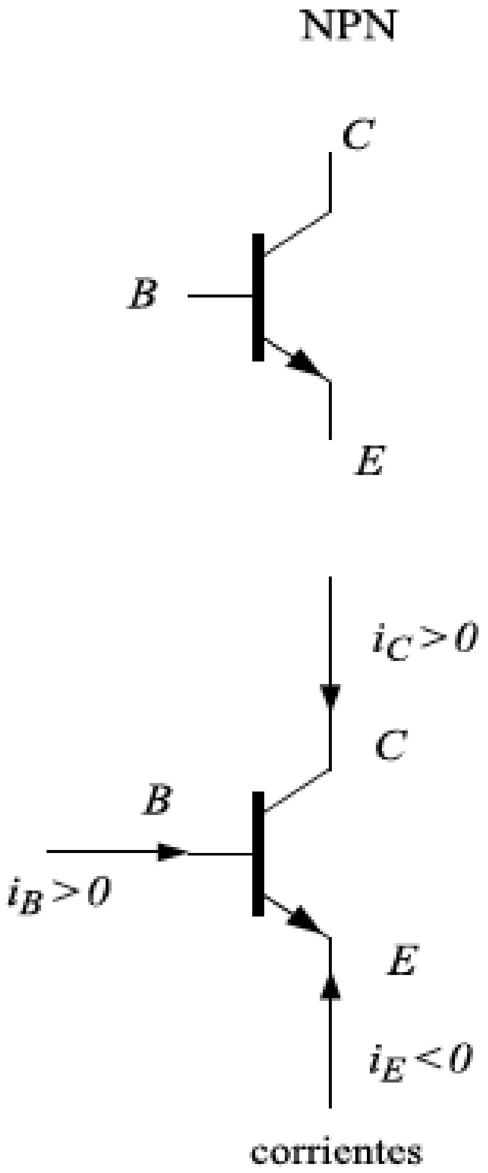
- Se alternan materiales: NPN ó PNP
  - Se designan como Emisor, Base y Colector
  - La juntura EB directa; juntura BC inversa



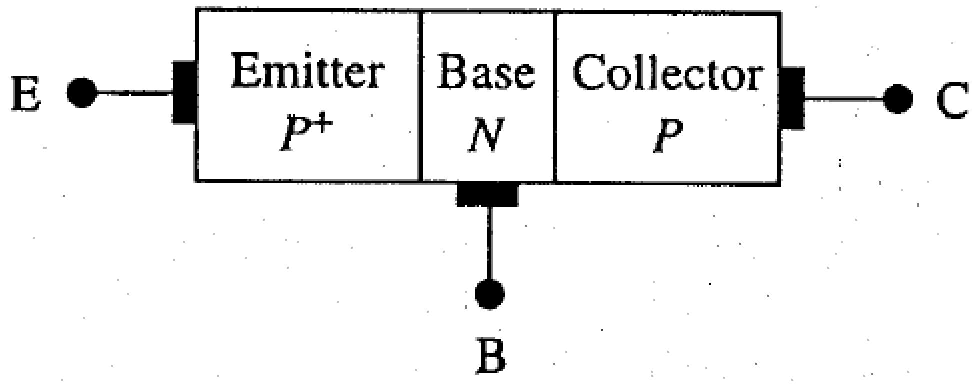
Los portadores mayoritarios de E se inyectan en B, y el campo de la juntura BC los lleva a C

Símbolos

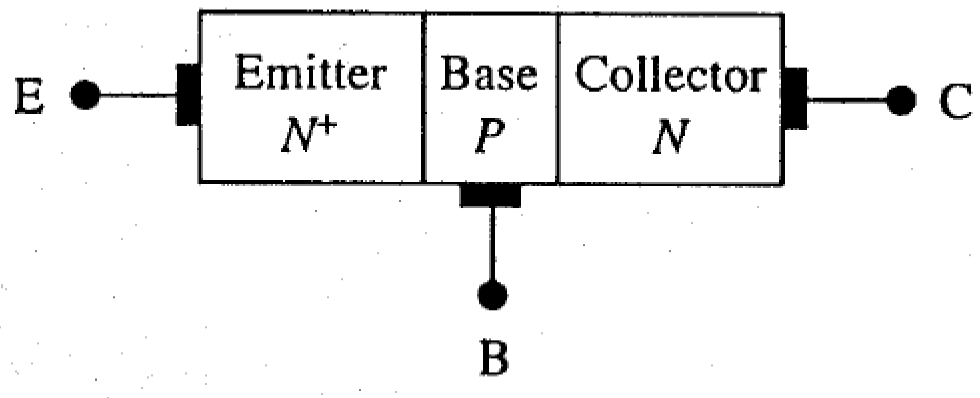

PNP
E
B
C
$i_E > 0$
E
B
$i_B < 0$
C
$i_C < 0$
corrientes


NPN
C
B
E
$i_C > 0$
C
B
$i_B > 0$
E
$i_E < 0$
corrientes

Representación esquemática(Regiones, terminales)



(a) *pnp*



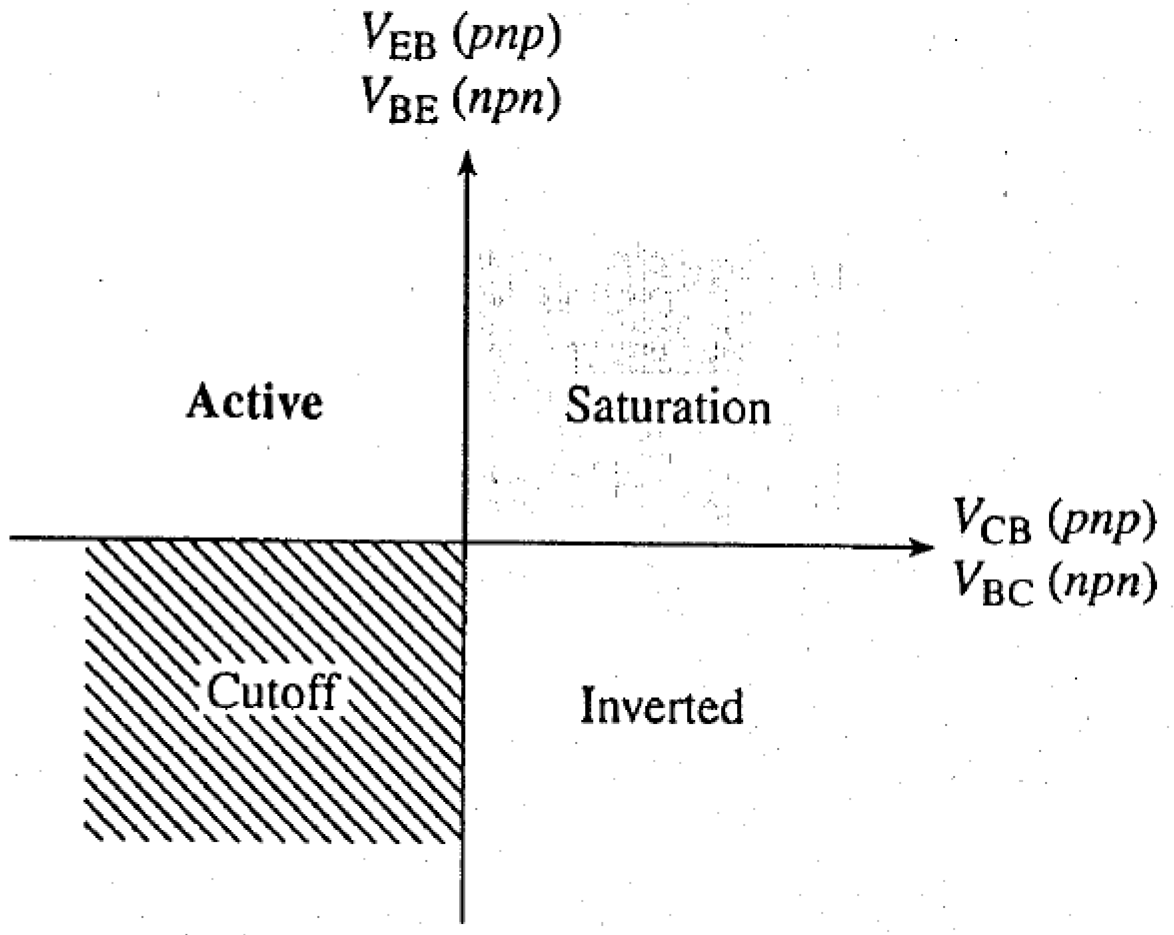
(b) *npn*

Modos de operación

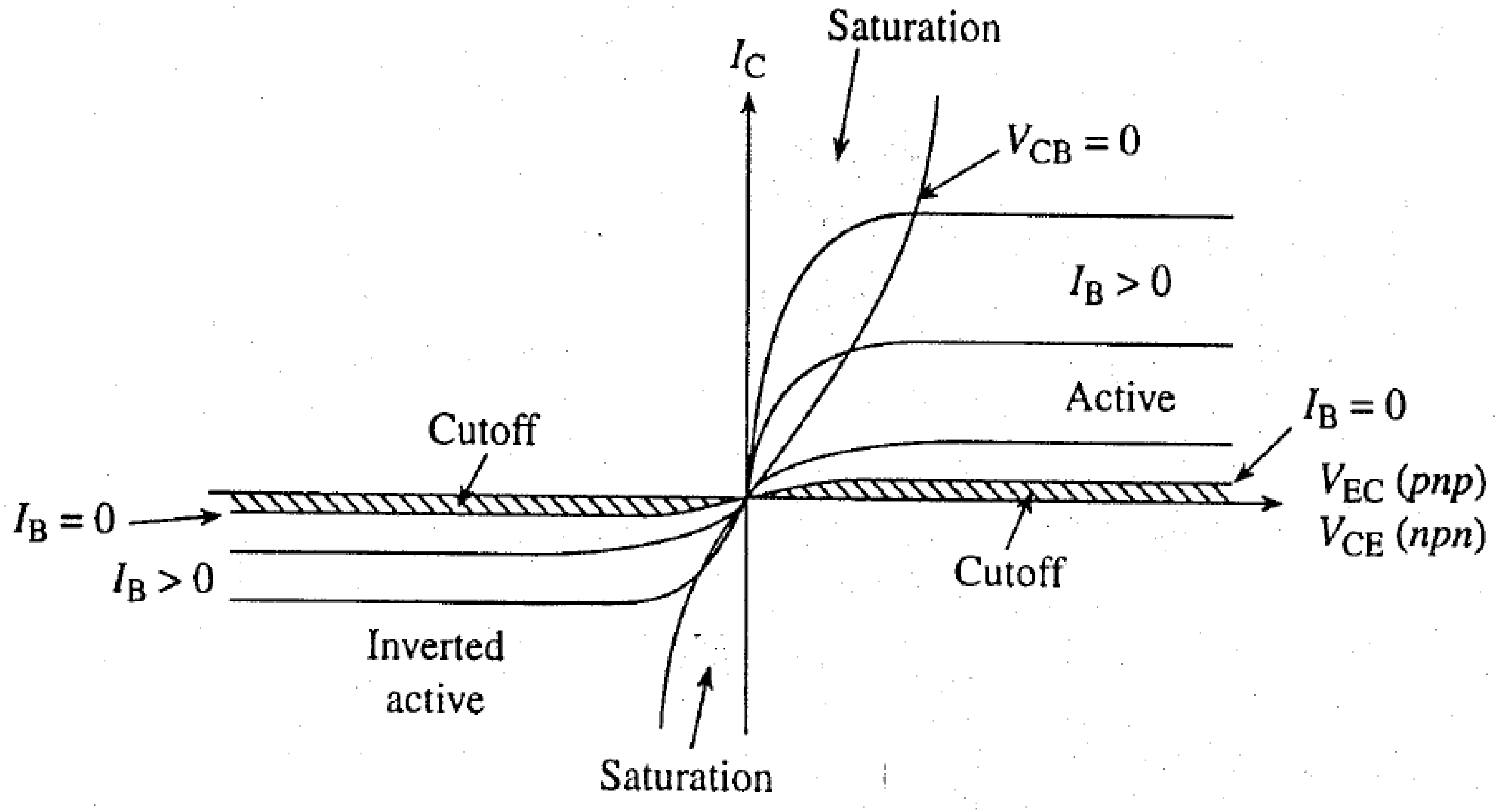
Table 10.1 Biasing Modes.

Biasing Mode	*Biasing Polarity E–B Junction*	*Biasing Polarity C–B Junction*
Saturation	Forward	Forward
Active	**Forward**	**Reverse**
Inverted	Reverse	Forward
Cutoff	Reverse	Reverse

Modos de operación: tensiones de E-S

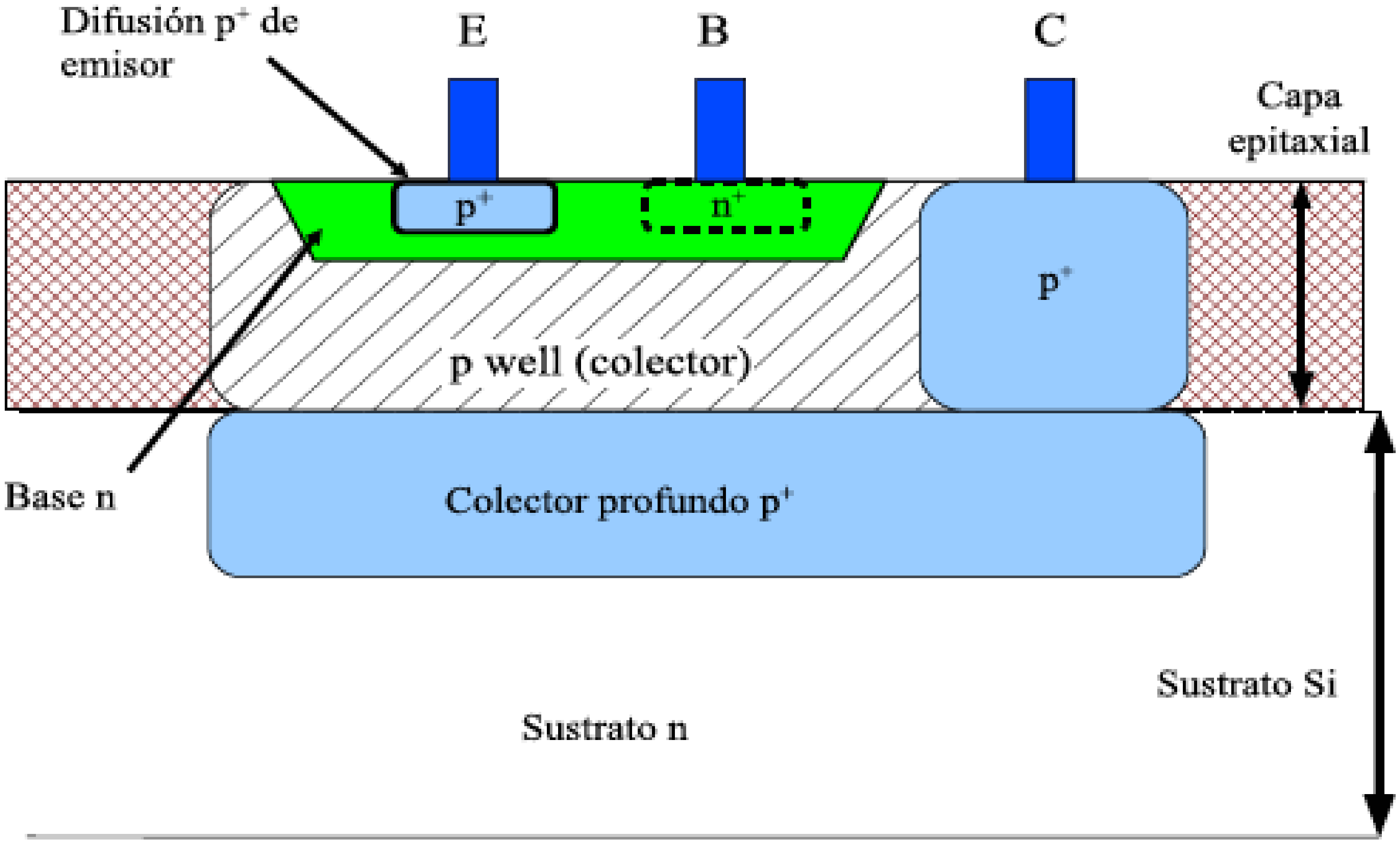


Modos de operación: Configuración emisor común



Modelo DC: PNP

- Construcción



Región activa directa

- Corrientes

$v_{EB} > 0 \quad v_{CB} < 0$

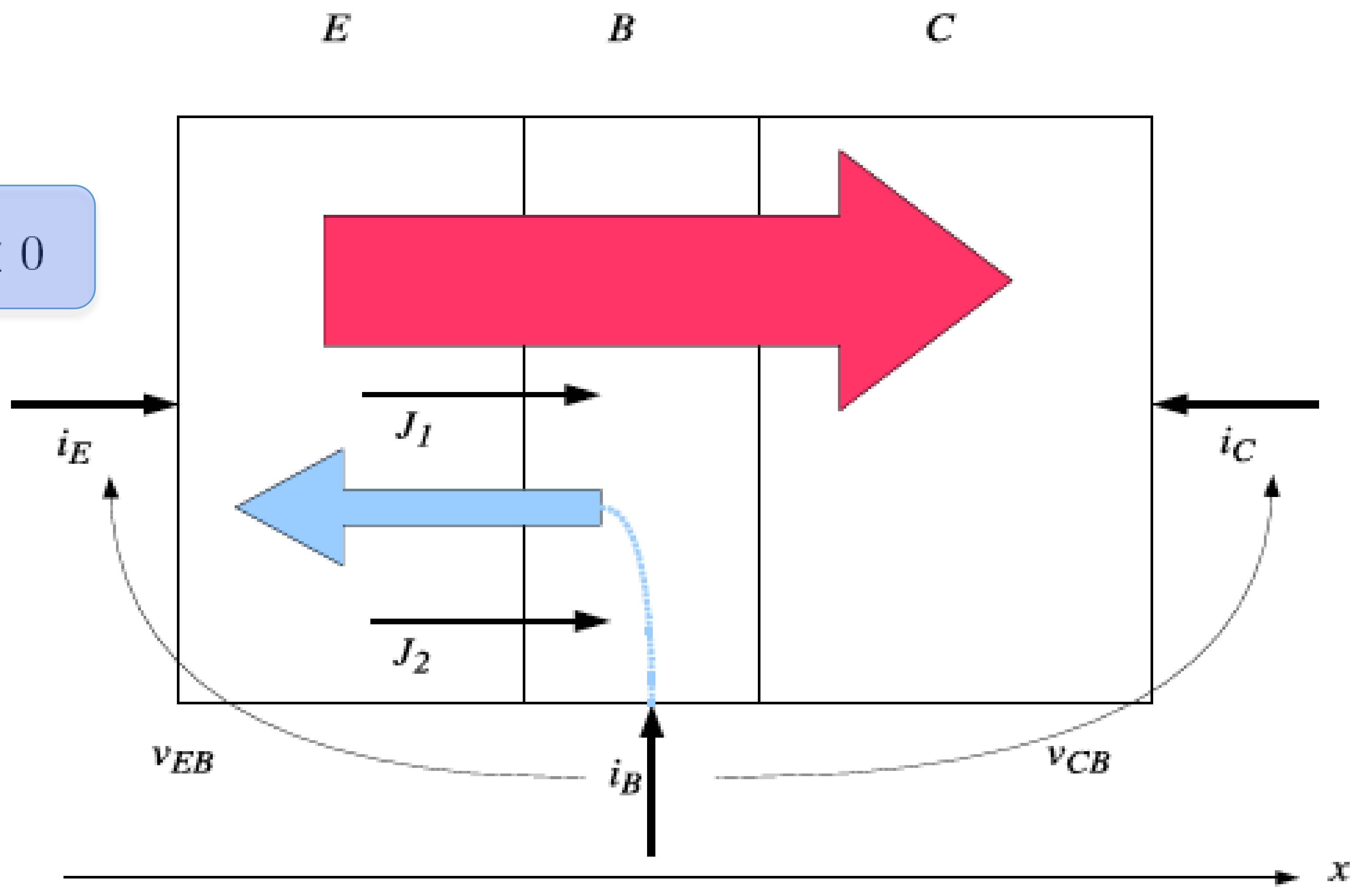
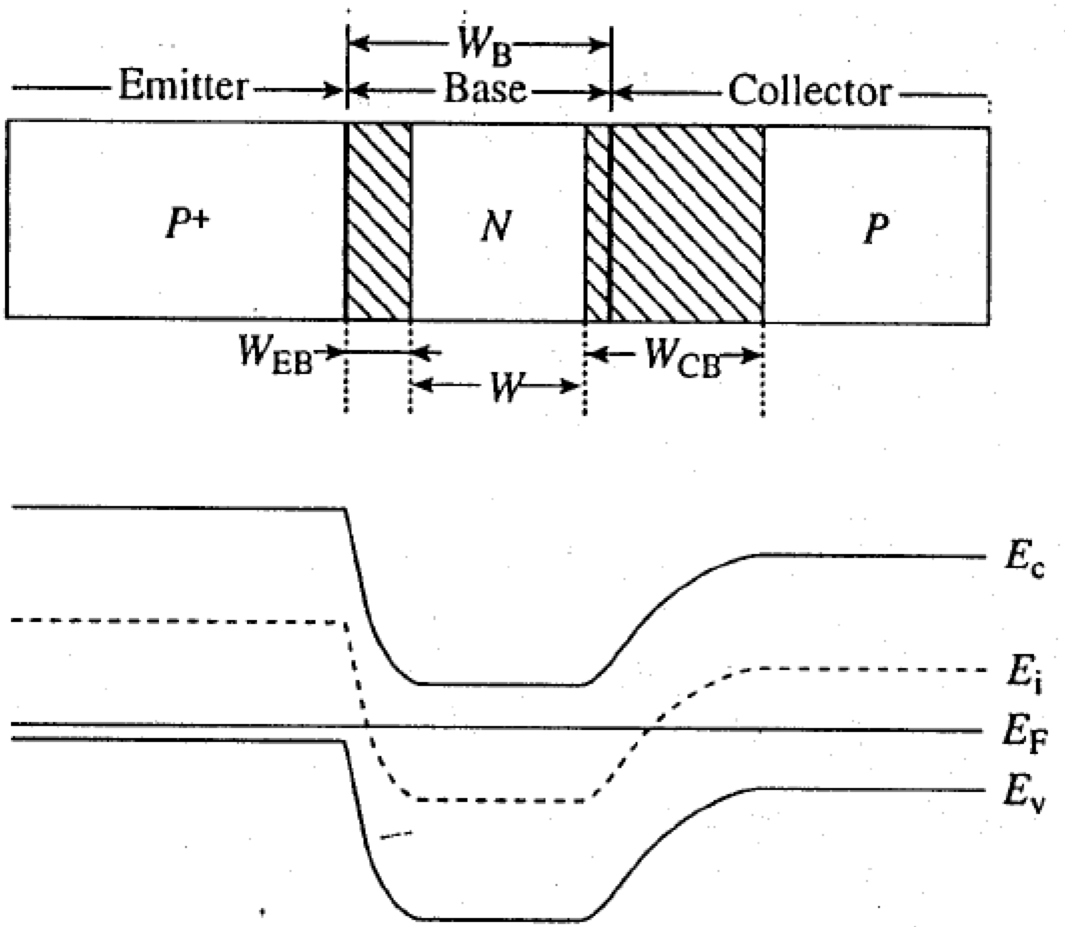
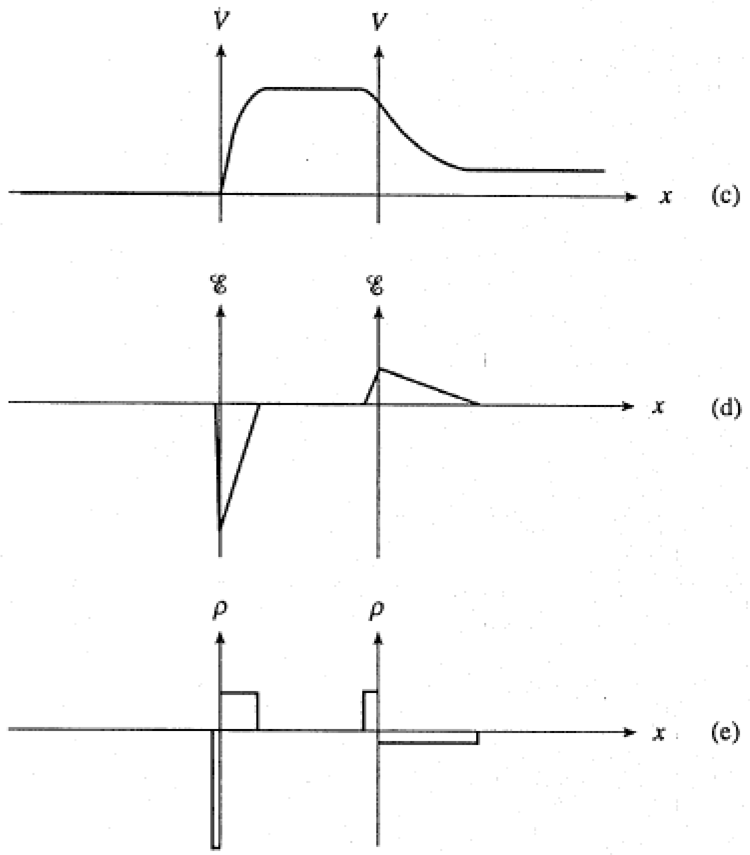


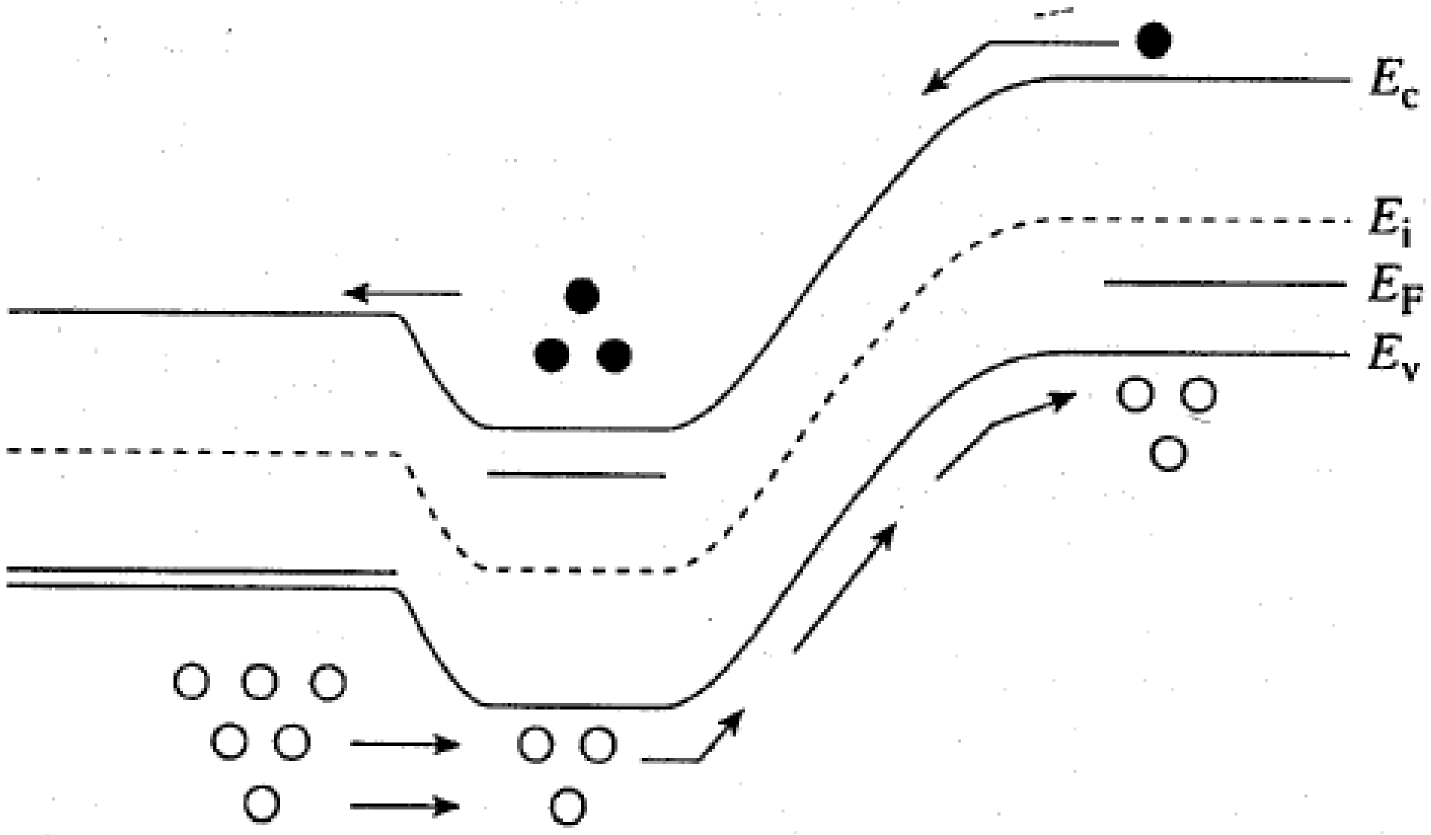
Diagrama de bandas de energía



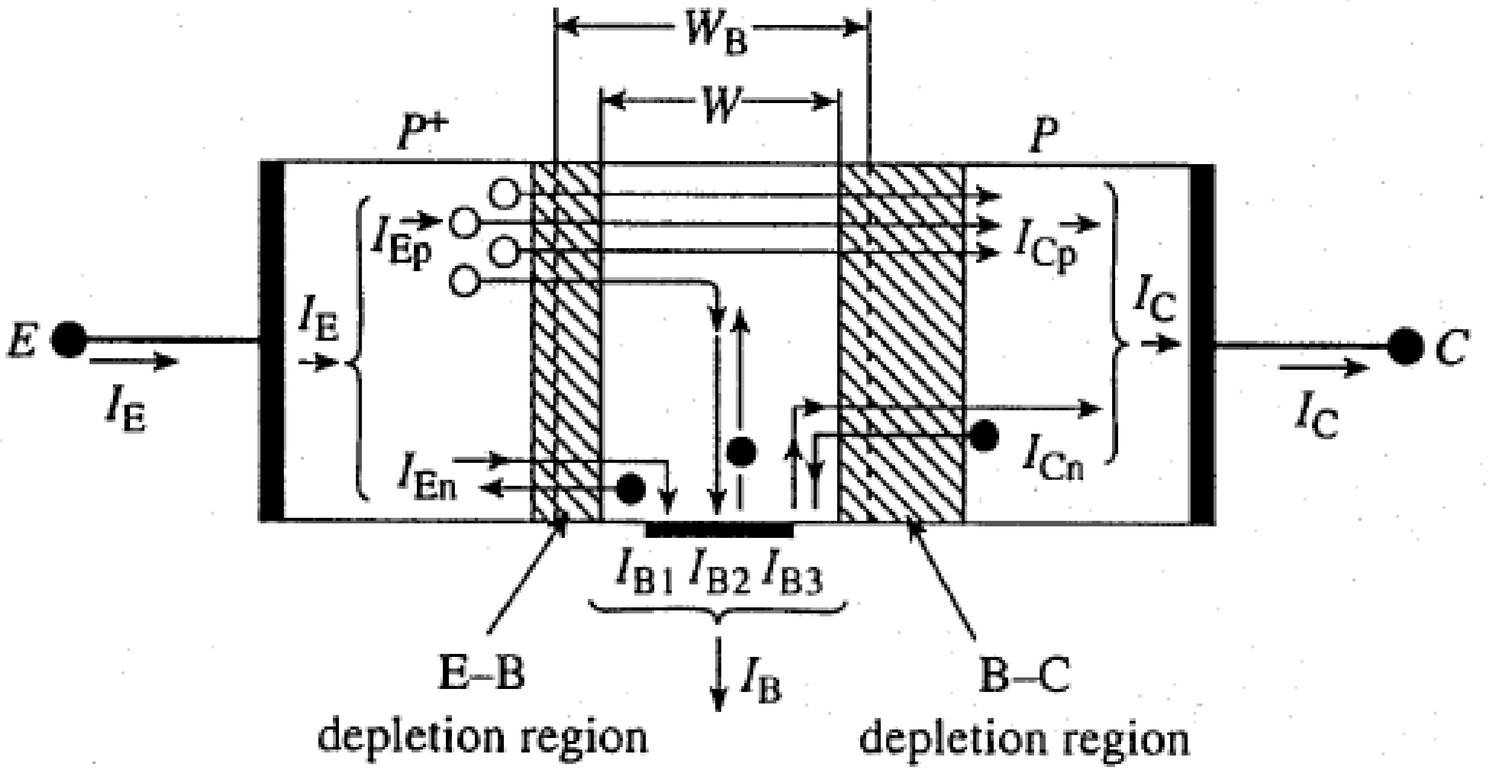
Variables electrostáticas



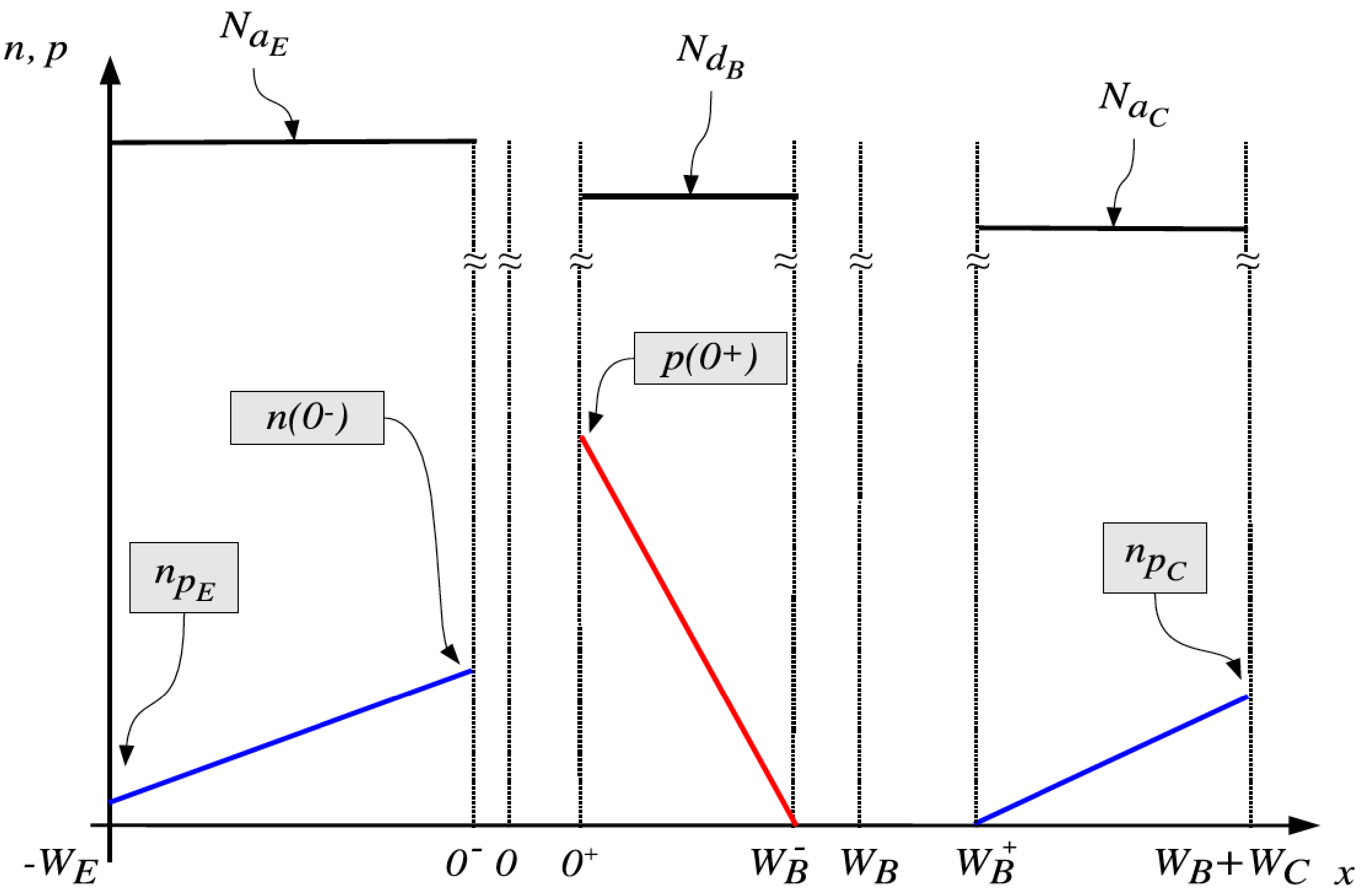
Condiciones de operación



Condiciones de operación



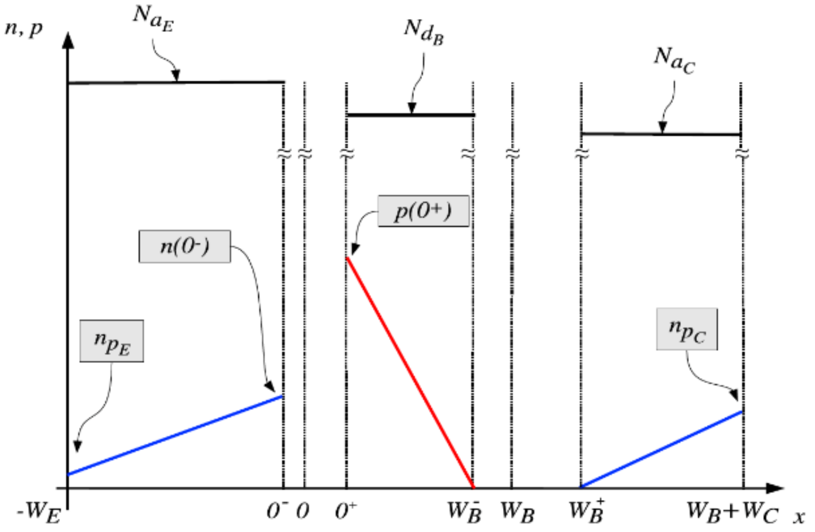
Región activa directa



Región activa directa

- Corrientes

$$J_1 = -qD_p \frac{p(W_B^-) - p(0^+)}{W_B}$$



$$p(W_B^-) = 0$$

$$\phi J_{EB} = \phi B_{EB} - v_{EB},\ y\ p_{N_B} = N_{a_E} e^{-\phi B_{EB}/U_T}$$

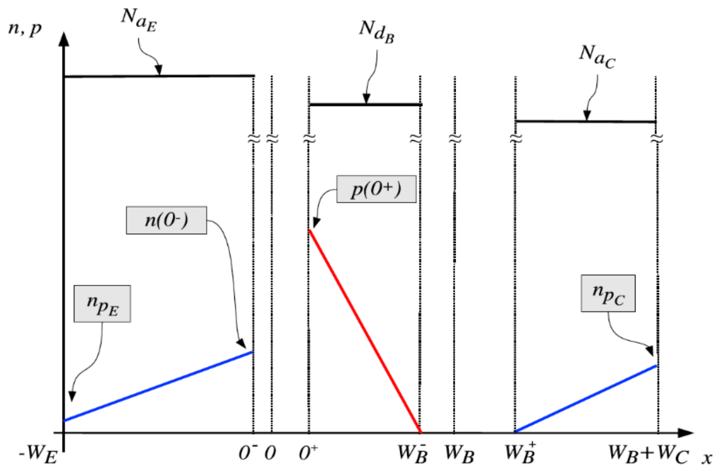
$$p(0^+) = N_{a_E} e^{-\phi J_{EB}/U_T} = p_{N_B} e^{v_{EB}/U_T}$$

$$\boxed{J_1 = qD_p \frac{p_{N_B} e^{v_{EB}/U_T}}{W_B}}$$

Región activa directa

- Corrientes

$$J_2 = qD_n \frac{n(0^-) - n(-W_E)}{W_E}$$



$$n(0^-) = N_{d_B} e^{-\phi_{J_{EB}}/U_T} = n_{P_E} e^{v_{EB}/U_T}$$

$$n(-W_E) = n_{P_E}$$

$$J_2 = qD_n \frac{n_{P_E} e^{v_{EB}/U_T} - n_{P_E}}{W_E} = qD_n \frac{n_{P_E}\left(e^{v_{EB}/U_T} - 1\right)}{W_E}$$

Corrientes externas

- Nodos

$$\begin{cases} i_E &= A(J_1 + J_2) \\ i_B &= -AJ_2 \\ i_C &= -AJ_1 \end{cases}$$

$$\boxed{i_E = A\left(\frac{qD_p p_{N_B}}{W_B} + \frac{qD_n n_{P_E}}{W_E}\right) e^{v_{EB}/U_T}}$$

$$\boxed{i_B = -A\frac{qD_n n_{P_E}}{W_E}\left(e^{v_{EB}/U_T} - 1\right)}$$

$$\boxed{i_C = -A\frac{qD_p p_{N_B}}{W_B} e^{v_{EB}/U_T}}$$

Relaciones de corriente

- Ic vs Ie

$$\alpha_F \triangleq -\frac{i_C}{i_E} = \frac{\left(\frac{qD_p p_{N_B}}{W_B}\right)}{\left(\frac{qD_p p_{N_B}}{W_B}\right) + \left(\frac{qD_n n_{P_E}}{W_E}\right)}$$

$$\boxed{\alpha_F = \frac{1}{1 + \frac{D_n N_{d_B} W_B}{D_p N_{a_E} W_E}}}$$

$$N_{a_E} = 10^{18} cm^{-3},\ N_{d_B} = 10^{16} cm^{-3}, \text{ y } W_B \approx W_E, \qquad D_p \approx 1{,}8 D_n,$$

$$\alpha_F = \frac{1}{1 + \frac{1}{1{,}8 \times 100 \times 1}} = 0{,}9945$$

Relaciones de corrientes

- Ic vs Ib

$$\beta_F \triangleq \frac{i_C}{i_B} = \frac{i_C}{-i_C - i_E} = \frac{\alpha_F}{1-\alpha_F}$$

$$= \frac{D_p p_{N_B} W_E}{D_n n_{P_E} W_B}$$

$$\boxed{\beta_F = \frac{D_p N_{a_E} W_E}{D_n N_{d_B} W_B}}$$

Aspectos constructivos

- Para maximizar la ganancia de I
  - Dopar el emisor más que la base

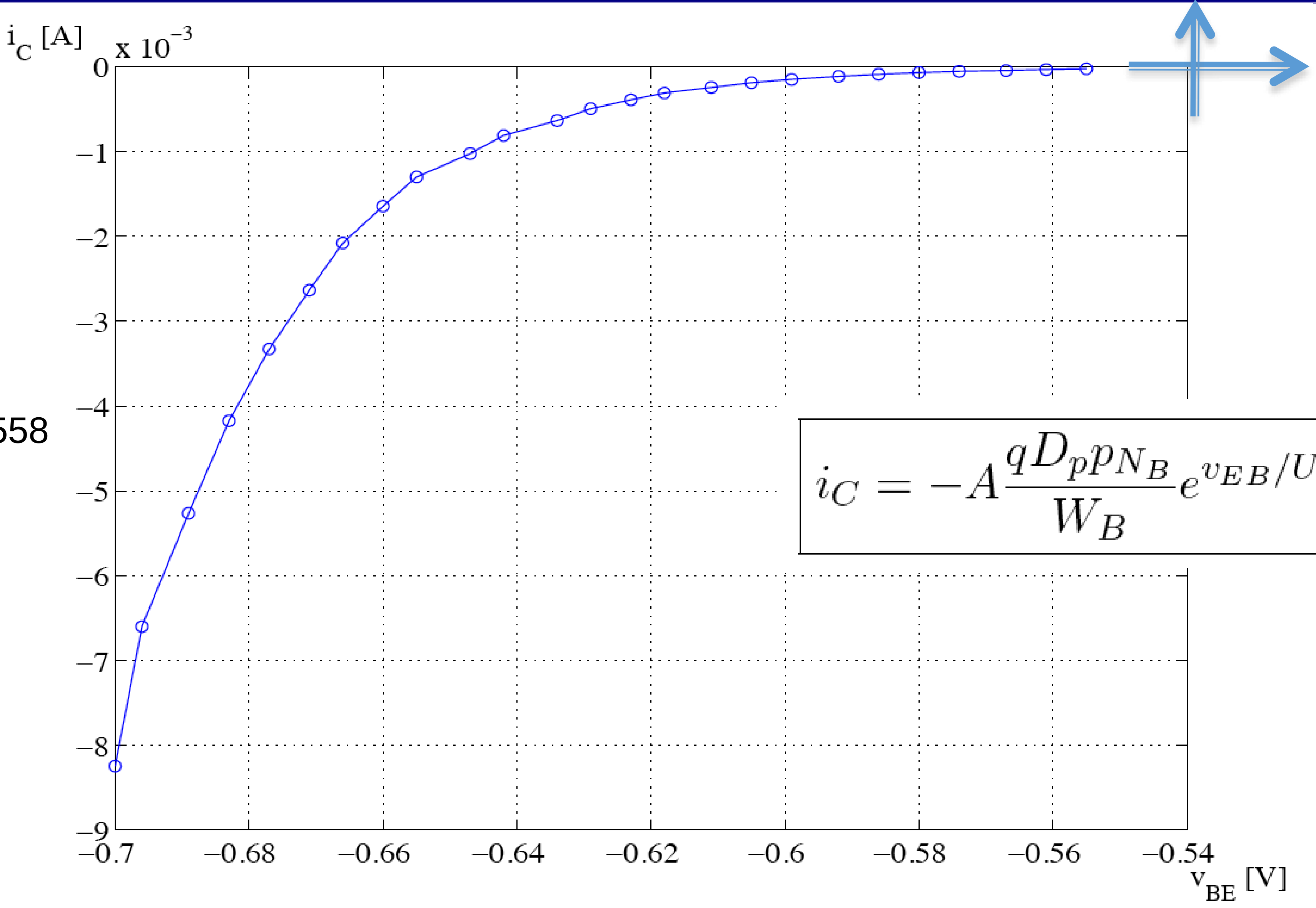
$$N_{a_E} \gg N_{d_B}$$

  - Hacer la base angosta

$$W_B \ll W_E$$

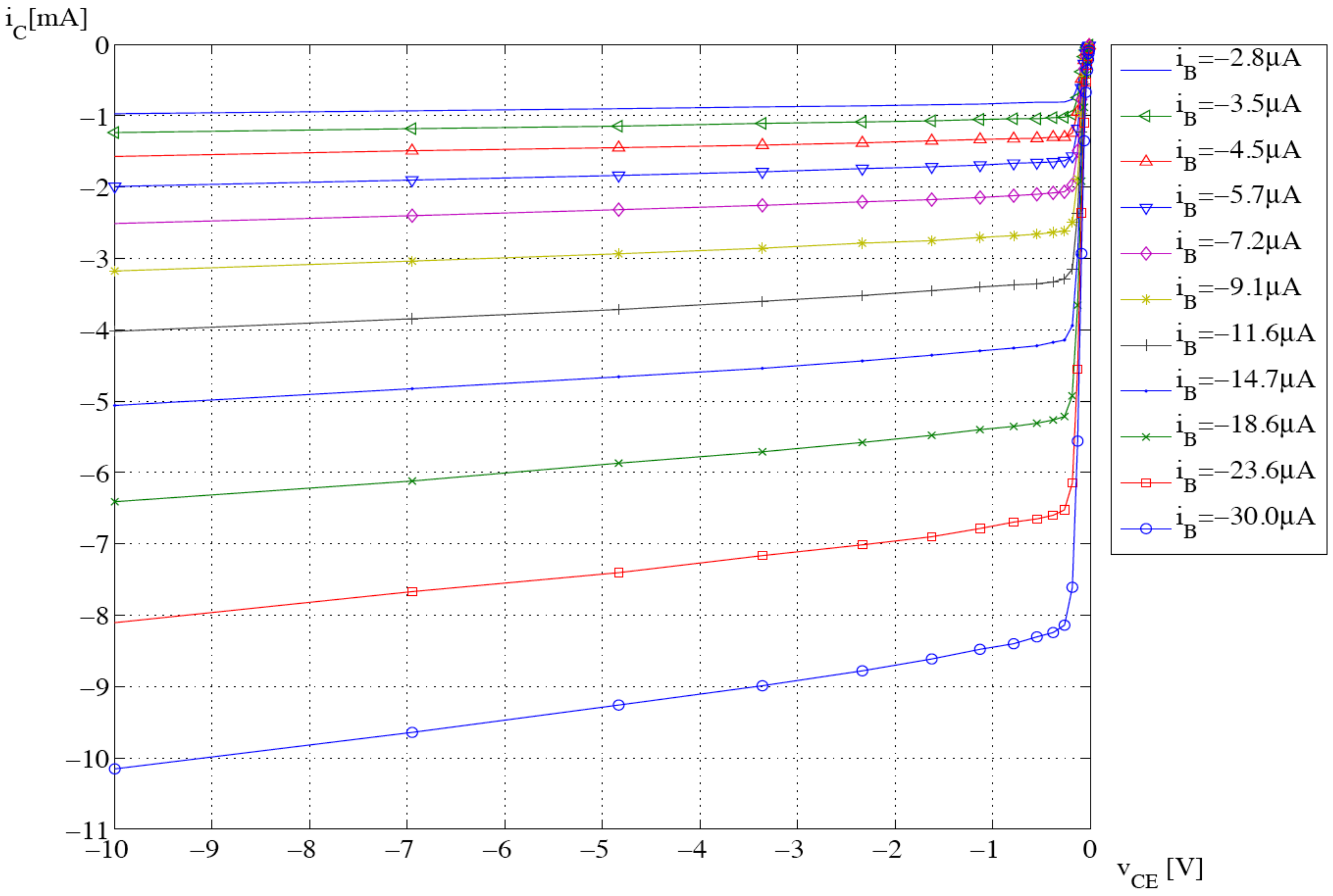
Curva de transferencia

PNP BC558



$$i_C = -A\frac{qD_p p_{N_B}}{W_B}e^{v_{EB}/U_T}$$

Curvas de salida



Tensión de Early

- Pendiente de las curvas de corriente
  - Angostamiento de la base:

$$i_C = \beta i_B \left(1 + \frac{v_{CE} - V_{CE(sat)}}{V_A}\right)$$

  - Longitud regiones de vaciamiento

$$x_{nB} = \sqrt{\frac{2\varepsilon_{Si}(\phi_B - v_{CB})}{q}}\sqrt{\frac{N_{aC}}{N_{dB}(N_{aC} + N_{dB})}} \qquad x_{pC} = \sqrt{\frac{2\varepsilon_{Si}(\phi_B - v_{CB})}{q}}\sqrt{\frac{N_{dB}}{N_{aC}(N_{aC} + N_{dB})}}$$

$$\frac{x_{nB}}{x_{pC}} = \sqrt{\frac{N_{aC}^2}{N_{dB}^2}} = \frac{N_{aC}}{N_{dB}} \Longrightarrow N_{aC} \ll N_{dB}$$

Minimizar la variación de la base