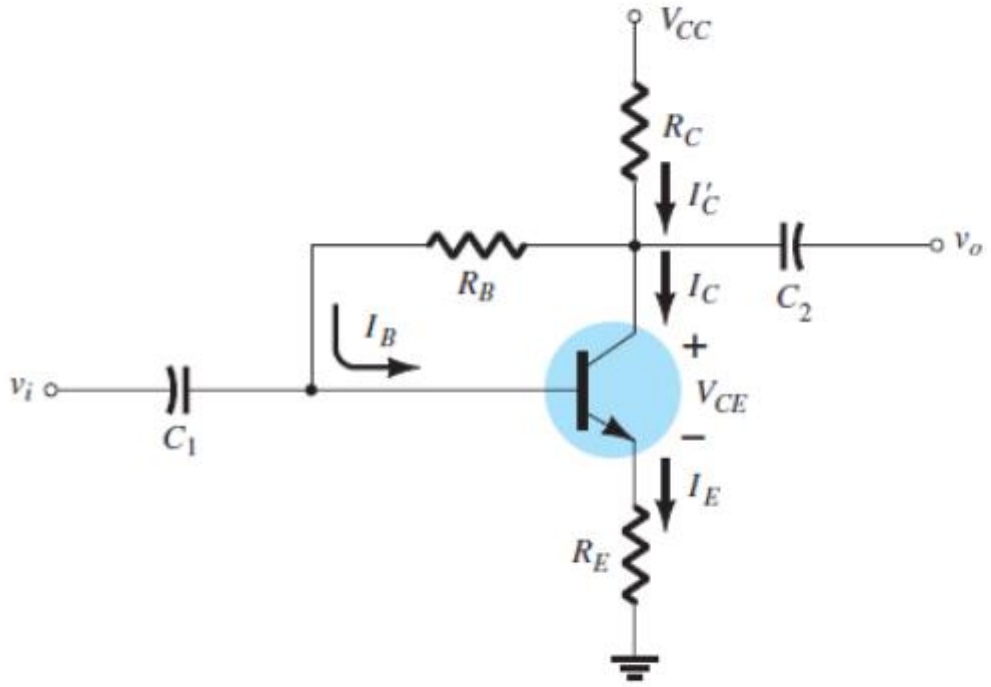
Transistor Unión Bipolar BJT

Configuraciones

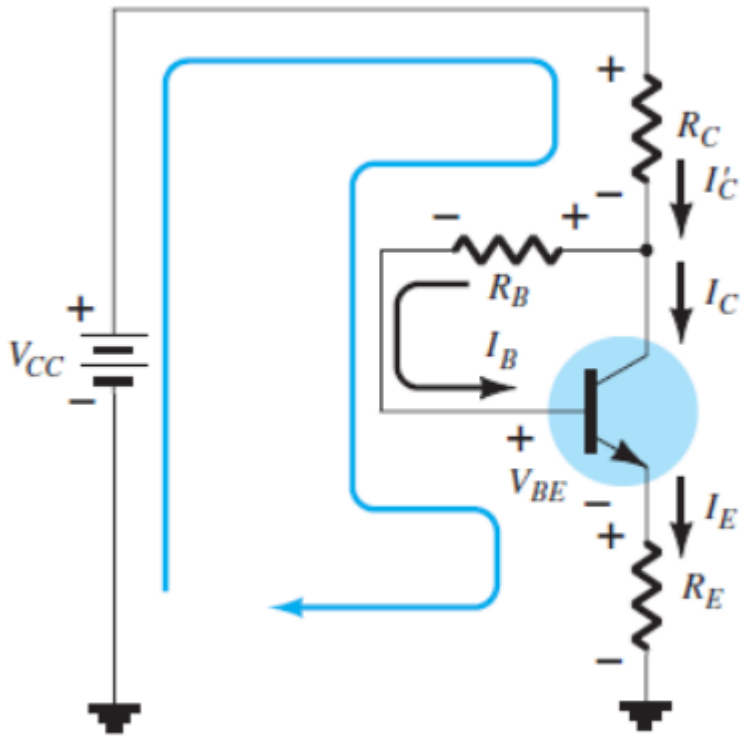
Configuración Realimentación del Colector



$$I_B = \frac{V_{CC} - V_{BE}}{R_B + \beta(R_C + R_E)}$$

$$V_{CE} = V_{CC} - I_C(R_C + R_E)$$

Configuración Realimentación del Colector
Malla base-emisor



$$V_{CC} - I'_C R_C - I_B R_B - V_{BE} - I_E R_E = 0$$

$$I'_C \cong I_C = \beta I_B \text{ y } I_E \cong I_C$$

$$V_{CC} - \beta I_B R_C - I_B R_B - V_{BE} - \beta I_B R_E = 0$$

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + \beta(R_C + R_E)}$$

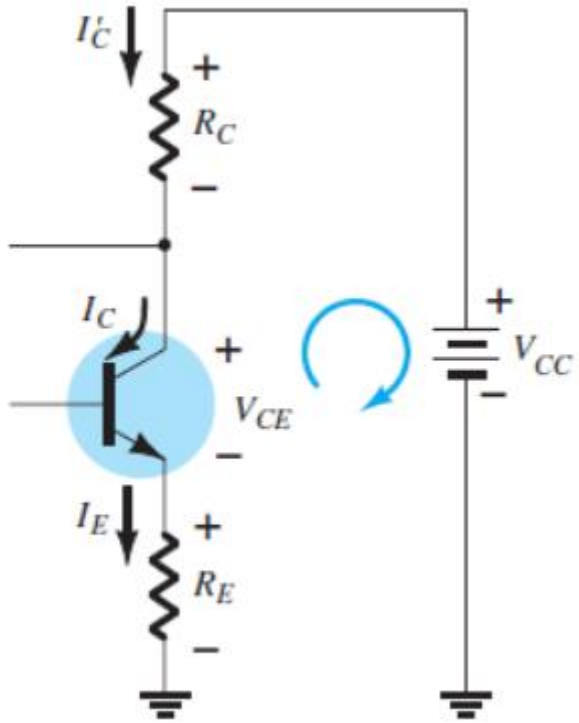
Configuración Realimentación del Colector
Malla colector – emisor

$$I_E R_E + V_{CE} + I'_C R_C - V_{CC} = 0$$

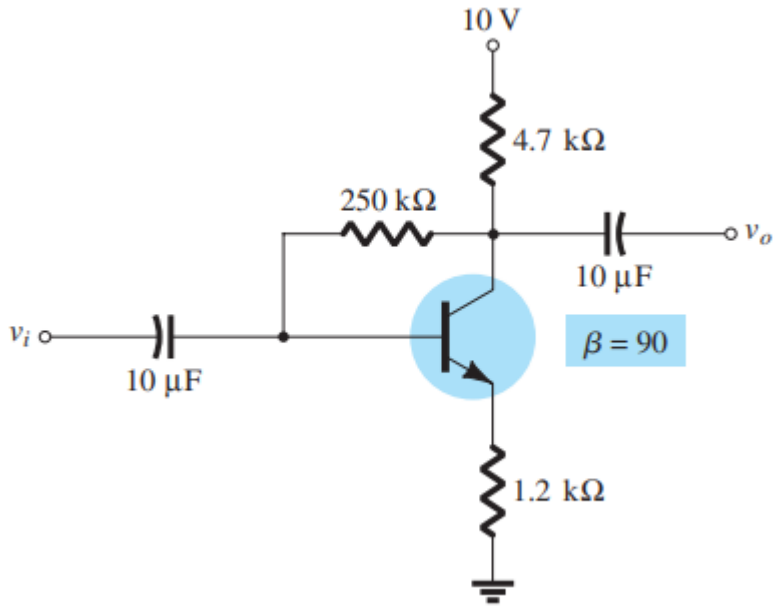
Como $I'_C \cong I_C$ e $I_E \cong I_C$, tenemos

$$I_C(R_C + R_E) + V_{CE} - V_{CC} = 0$$

$$\boxed{V_{CE} = V_{CC} - I_C(R_C + R_E)}$$



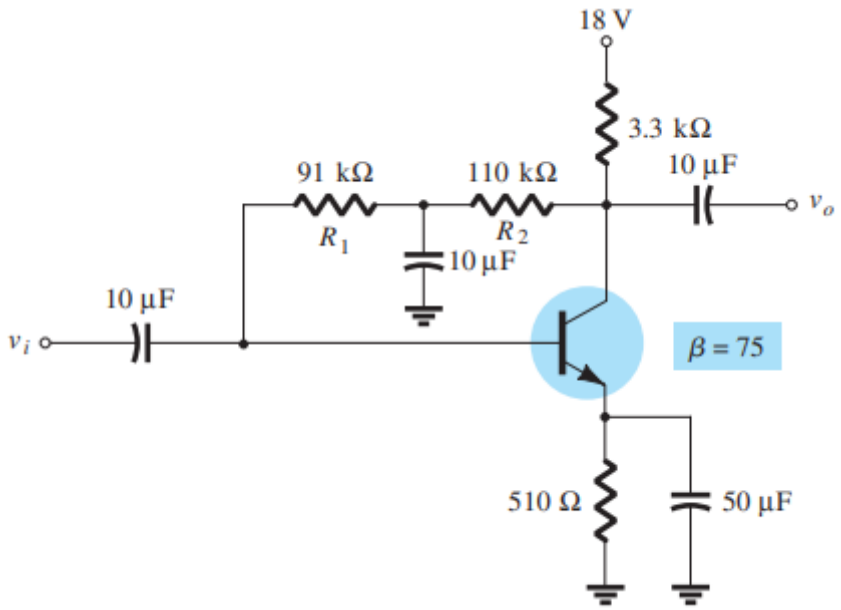
Ejemplo



$$I_B = \frac{V_{CC} - V_{BE}}{R_B + \beta(R_C + R_E)}$$
$$= \frac{10\,\text{V} - 0.7\,\text{V}}{250\,\text{k}\Omega + (90)(4.7\,\text{k}\Omega + 1.2\,\text{k}\Omega)}$$
$$= \frac{9.3\,\text{V}}{250\,\text{k}\Omega + 531\,\text{k}\Omega} = \frac{9.3\,\text{V}}{781\,\text{k}\Omega}$$
$$= 11.91\,\mu\text{A}$$

$$I_{C_Q} = \beta I_B = (90)(11.91\,\mu\text{A})$$
$$= \mathbf{1.07\,mA}$$
$$V_{CE_Q} = V_{CC} - I_C(R_C + R_E)$$
$$= 10\,\text{V} - (1.07\,\text{mA})(4.7\,\text{k}\Omega + 1.2\,\text{k}\Omega)$$
$$= 10\,\text{V} - 6.31\,\text{V}$$
$$= \mathbf{3.69\,V}$$

Ejemplo



$$I_B = \frac{V_{CC} - V_{BE}}{R_B + \beta(R_C + R_E)}$$

$$= \frac{18\,\text{V} - 0.7\,\text{V}}{(91\,\text{k}\Omega + 110\,\text{k}\Omega) + (75)(3.3\,\text{k}\Omega + 0.51\,\text{k}\Omega)}$$

$$= \frac{17.3\,\text{V}}{201\,\text{k}\Omega + 285.75\,\text{k}\Omega} = \frac{17.3\,\text{V}}{486.75\,\text{k}\Omega}$$

$$= \mathbf{35.5\ \mu A}$$

$$I_C = \beta I_B$$

$$= (75)(35.5\,\mu\text{A})$$

$$= 2.66\,\text{mA}$$

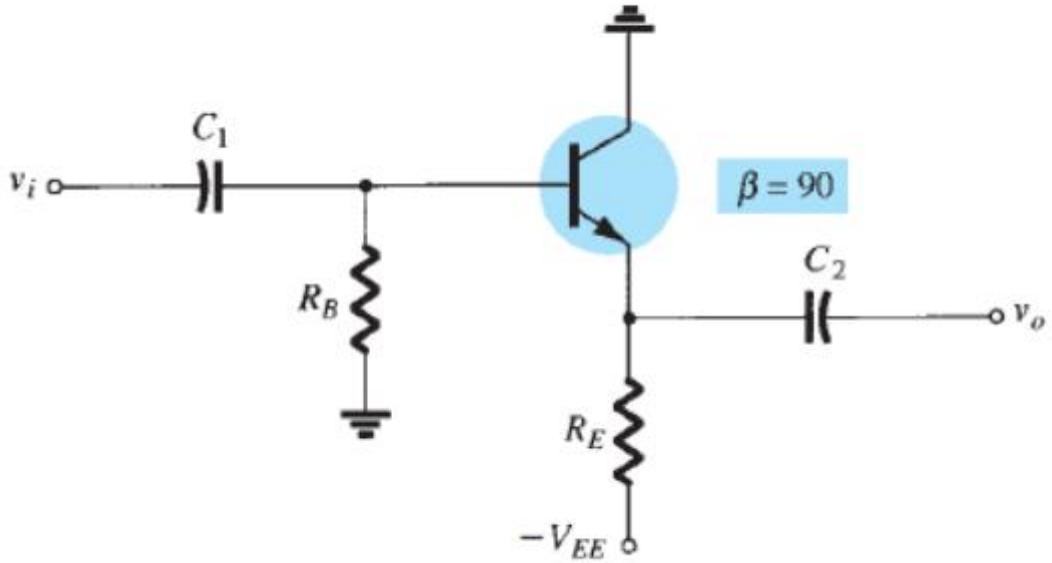
$$V_C = V_{CC} - I'_C R_C \cong V_{CC} - I_C R_C$$

$$= 18\,\text{V} - (2.66\,\text{mA})(3.3\,\text{k}\Omega)$$

$$= 18\,\text{V} - 8.78\,\text{V}$$

$$= \mathbf{9.22\ V}$$

Configuración en Emisor Seguidor



$$-I_B R_B - V_{BE} - I_E R_E + V_{EE} = 0$$

$$I_E = (\beta + 1) I_B$$

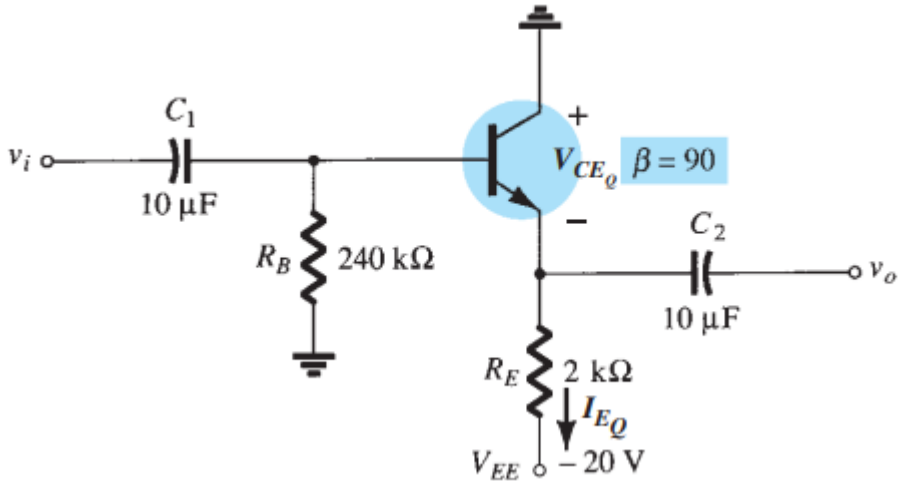
$$I_B R_B + (\beta + 1) I_B R_E = V_{EE} - V_{BE}$$

$$\boxed{I_B = \frac{V_{EE} - V_{BE}}{R_B + (\beta + 1) R_E}}$$

$$-V_{CE} - I_E R_E + V_{EE} = 0$$

$$\boxed{V_{CE} = V_{EE} - I_E R_E}$$

Ejemplo



$$I_B = \frac{V_{EE} - V_{BE}}{R_B + (\beta + 1)R_E}$$

$$= \frac{20\text{ V} - 0.7\text{ V}}{240\text{ k}\Omega + (90 + 1)2\text{ k}\Omega} = \frac{19.3\text{ V}}{240\text{ k}\Omega + 182\text{ k}\Omega}$$

$$= \frac{19.3\text{ V}}{422\text{ k}\Omega} = 45.73\ \mu\text{A}$$

$$V_{CE_Q} = V_{EE} - I_E R_E$$

$$= V_{EE} - (\beta + 1)I_B R_E$$

$$= 20\text{ V} - (90 + 1)(45.73\ \mu\text{A})(2\text{ k}\Omega)$$

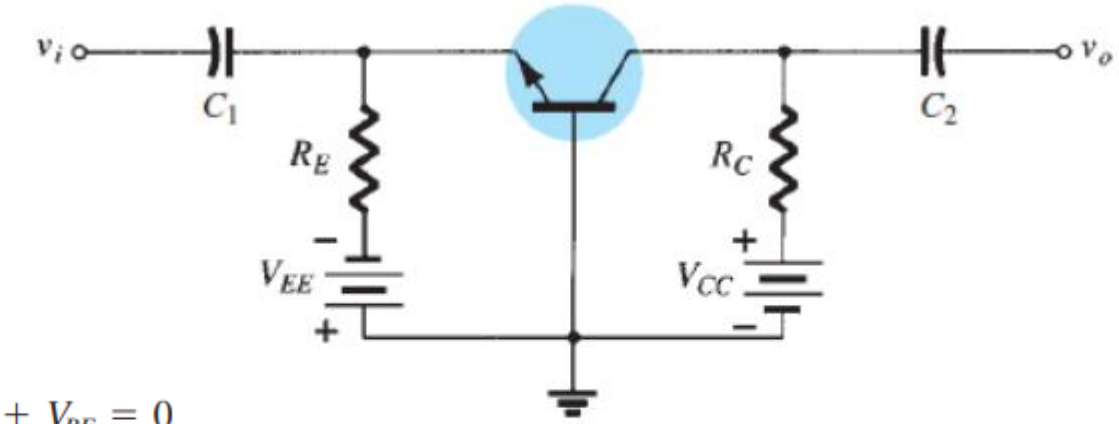
$$= 20\text{ V} - 8.32\text{ V}$$

$$= \mathbf{11.68}\text{ V}$$

$$I_{E_Q} = (\beta + 1)I_B = (91)(45.73\ \mu\text{A})$$

$$= 4.16\text{ mA}$$

Configuración Base Común



$$-V_{EE} + I_E R_E + V_{BE} = 0$$

$$I_E = \frac{V_{EE} - V_{BE}}{R_E}$$

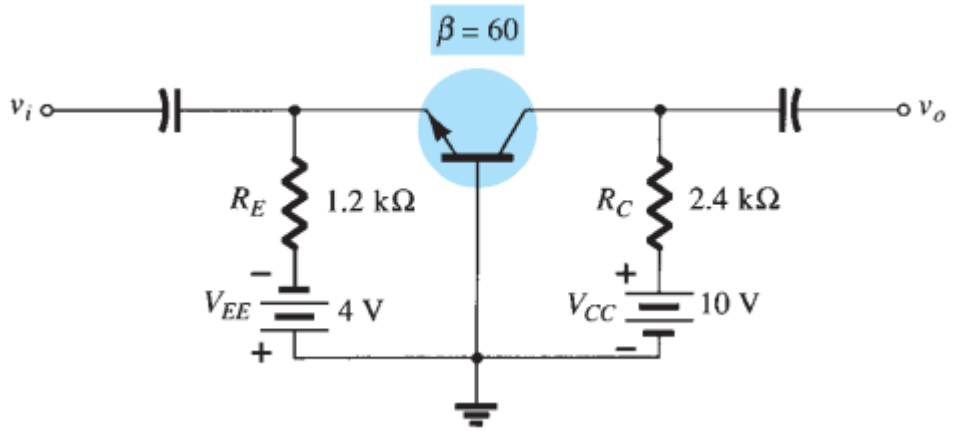
$$V_{CE} = V_{EE} + V_{CC} - I_E(R_C + R_E)$$

$$-V_{EE} + I_E R_E + V_{CE} + I_C R_C - V_{CC} = 0$$
$$V_{CE} = V_{EE} + V_{CC} - I_E R_E - I_C R_C$$
$$I_E \cong I_C$$

$$V_{CB} + I_C R_C - V_{CC} = 0$$
$$V_{CB} = V_{CC} - I_C R_C$$
$$I_C \cong I_E$$

$$V_{CB} = V_{CC} - I_C R_C$$

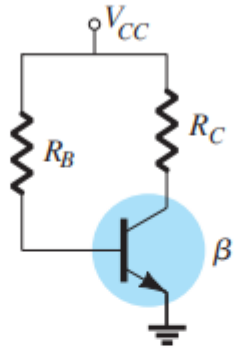
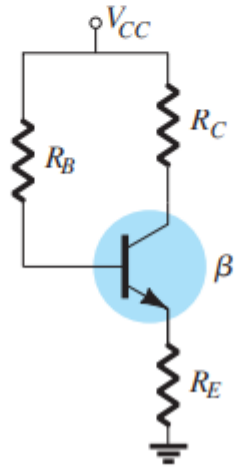
Ejemplo



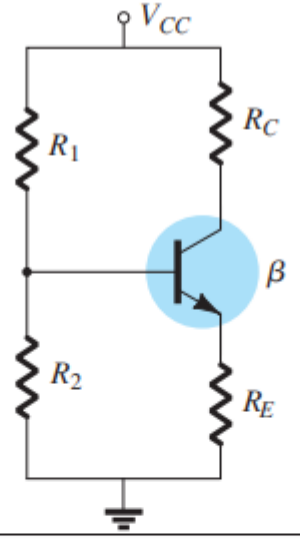
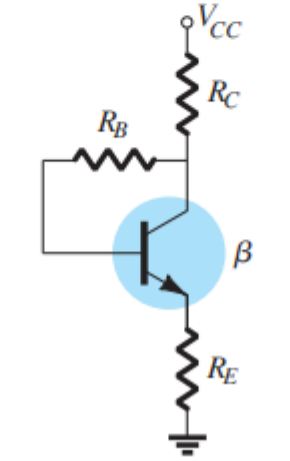
$$I_E = \frac{V_{EE} - V_{BE}}{R_E}$$
$$= \frac{4\text{ V} - 0.7\text{ V}}{1.2\text{ k}\Omega} = \mathbf{2.75\text{ mA}}$$
$$I_B = \frac{I_E}{\beta + 1} = \frac{2.75\text{ mA}}{60 + 1} = \frac{2.75\text{ mA}}{61}$$
$$= \mathbf{45.08\ \mu A}$$

$$V_{CE} = V_{EE} + V_{CC} - I_E(R_C + R_E)$$
$$= 4\text{ V} + 10\text{ V} - (2.75\text{ mA})(2.4\text{ k}\Omega + 1.2\text{ k}\Omega)$$
$$= 14\text{ V} - (2.75\text{ mA})(3.6\text{ k}\Omega)$$
$$= 14\text{ V} - 9.9\text{ V}$$
$$= \mathbf{4.1\text{ V}}$$
$$V_{CB} = V_{CC} - I_C R_C = V_{CC} - \beta I_B R_C$$
$$= 10\text{ V} - (60)(45.08\ \mu\text{A})(24\text{ k}\Omega)$$
$$= 10\text{ V} - 6.49\text{ V}$$
$$= \mathbf{3.51\text{ V}}$$

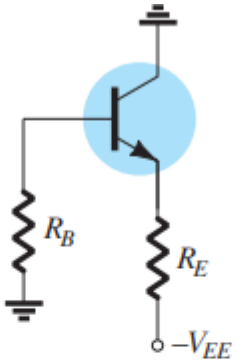
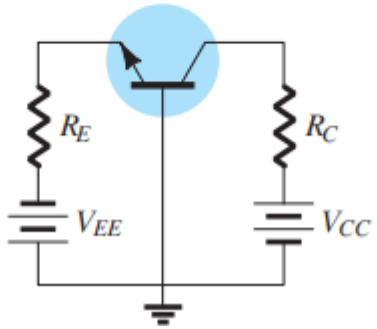
Configuración polarización BJT

Tipo	Configuración	Ecuaciones correspondientes
Polarización fija		$I_B = \frac{V_{CC} - V_{BE}}{R_B}$ $I_C = \beta I_B, I_E = (\beta + 1)I_B$ $V_{CE} = V_{CC} - I_C R_C$
Polarización de emisor		$I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta + 1)R_E}$ $I_C = \beta I_B, I_E = (\beta + 1)I_B$ $R_i = (\beta + 1)R_E$ $V_{CE} = V_{CC} - I_C (R_C + R_E)$

Configuración polarización BJT

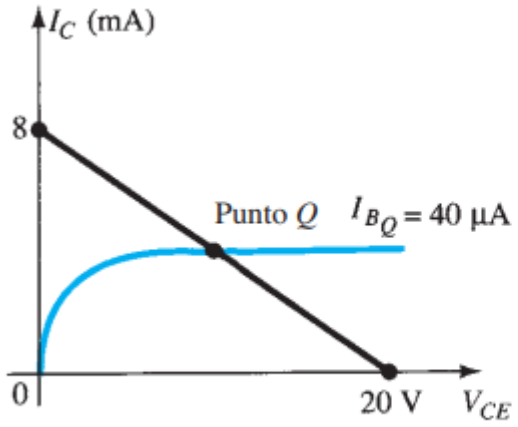
Tipo	Configuración	Ecuaciones correspondientes
Polarización por medio del divisor de voltaje		EXACTA: $R_{Th} = R_1 \| R_2$, $E_{Th} = \frac{R_2 V_{CC}}{R_1 + R_2}$ $I_B = \frac{E_{Th} - V_{BE}}{R_{Th} + (\beta + 1)R_E}$ $I_C = \beta I_B$, $I_E = (\beta + 1)I_B$ $V_{CE} = V_{CC} - I_C(R_C + R_E)$ APROXIMADA: $\beta R_E \geq 10R_2$ $V_B = \frac{R_2 V_{CC}}{R_1 + R_2}$, $V_E = V_B - V_{BE}$ $I_E = \frac{V_E}{R_E}$, $I_B = \frac{I_E}{\beta + 1}$ $V_{CE} = V_{CC} - I_C(R_C + R_E)$
Realimentación de colector		$I_B = \frac{V_{CC} - V_{BE}}{R_B + \beta(R_C + R_E)}$ $I_C = \beta I_B$, $I_E = (\beta + 1)I_B$ $V_{CE} = V_{CC} - I_C(R_C + R_E)$

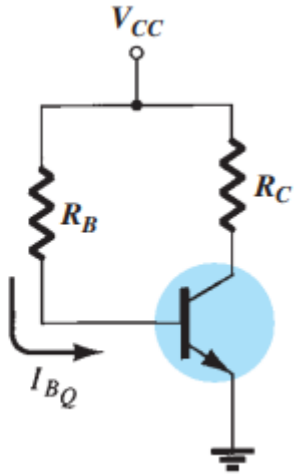
Configuración polarización BJT

Tipo	Configuración	Ecuaciones correspondientes
Emisor seguidor		$I_B = \frac{V_{EE} - V_{BE}}{R_B + (\beta + 1)}$ $I_C = \beta I_B, I_E = (\beta + 1) I_B$ $V_{CE} = V_{EE} - I_E R_E$
Base común		$I_E = \frac{V_{EE} - V_{BE}}{R_E}$ $I_B = \frac{I_E}{\beta + 1}, I_C = \beta I_B$ $V_{CE} = V_{EE} + V_{CC} - I_E (R_C + R_E)$ $V_{CB} = V_{CC} - I_C R_C$

Diseño

- Determine VCC, RB y RC para la configuración de polarización fija





A partir de la línea de carga

$$V_{CC} = \mathbf{20\ V}$$

$$I_C = \left.\frac{V_{CC}}{R_C}\right|_{V_{CE}=0\ V}$$

$$R_C = \frac{V_{CC}}{I_C} = \frac{20\ V}{8\ mA} = \mathbf{2.5\ k\Omega}$$

$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

$$R_B = \frac{V_{CC} - V_{BE}}{I_B}$$

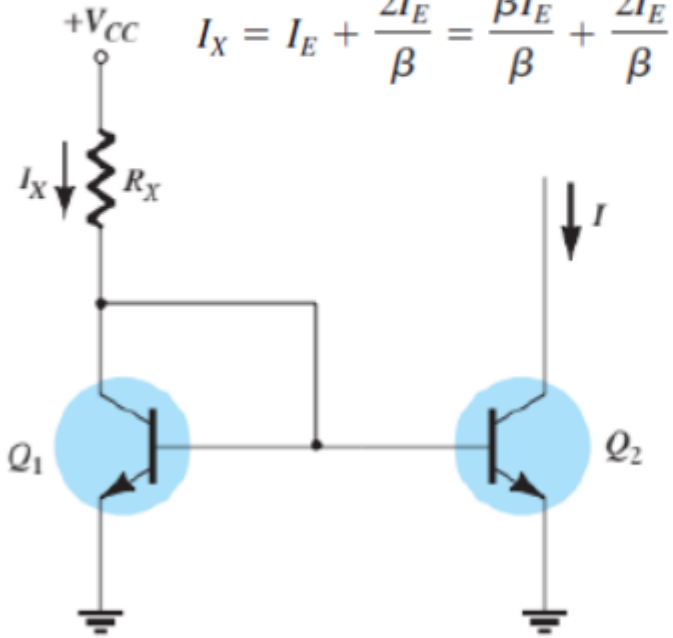
$$= \frac{20\ V - 0.7\ V}{40\ \mu A} = \frac{19.3\ V}{40\ \mu A}$$

$$= \mathbf{482.5\ k\Omega}$$

Circuitos Espejos de corriente

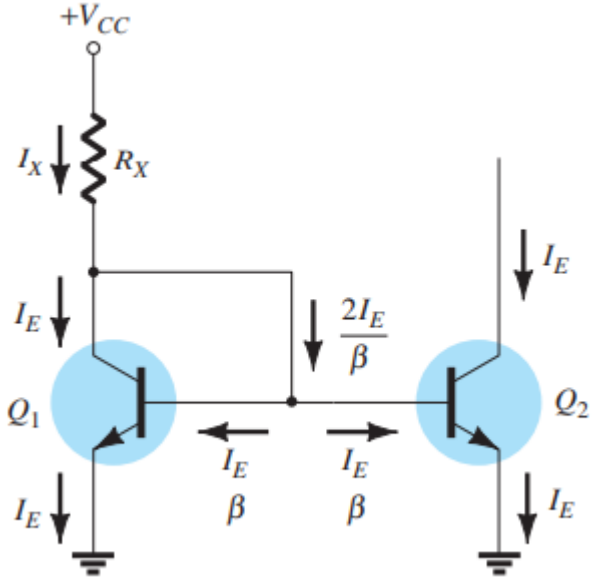
Este tipo de circuitos producen una corriente constante y se utilizan principalmente en circuitos integrados, donde se es posible obtener transistores con características aproximadas.

$$I_X = I_E + \frac{2I_E}{\beta} = \frac{\beta I_E}{\beta} + \frac{2I_E}{\beta} = \frac{\beta + 2}{\beta} I_E \approx I_E$$

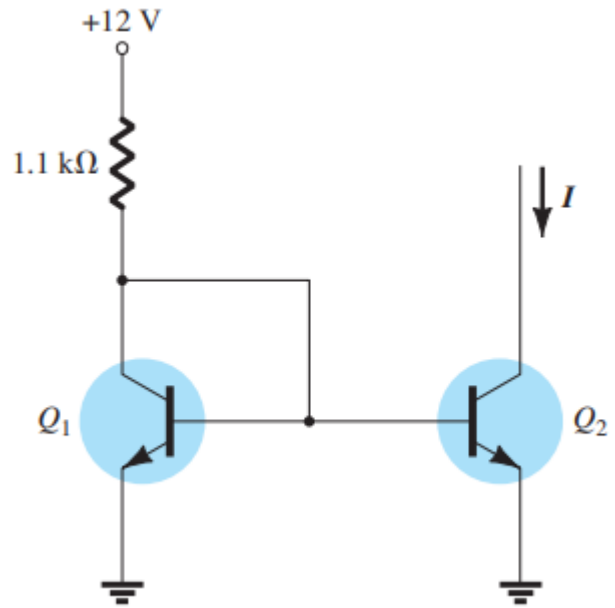


$$I_X = \frac{V_{CC} - V_{BE}}{R_X}$$

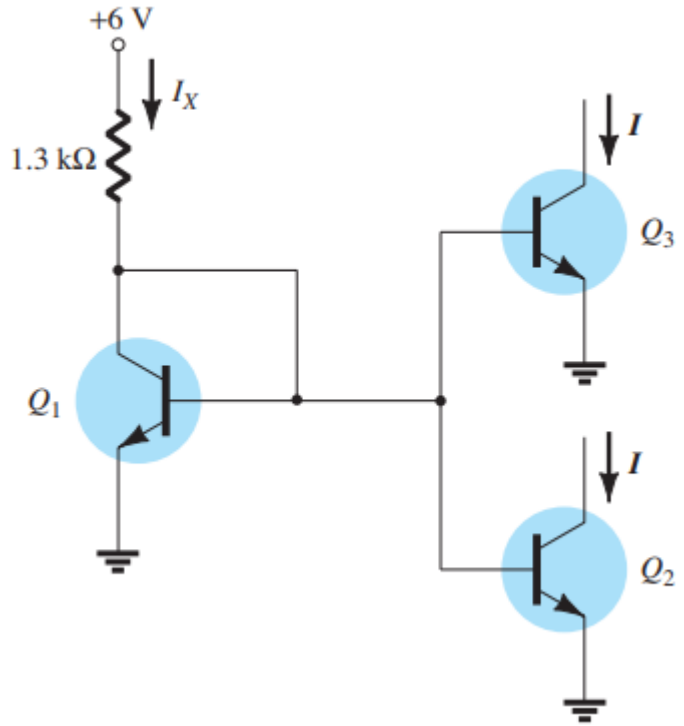
$$I_X = I_c + \frac{2I_C}{\beta}$$



Ejemplo



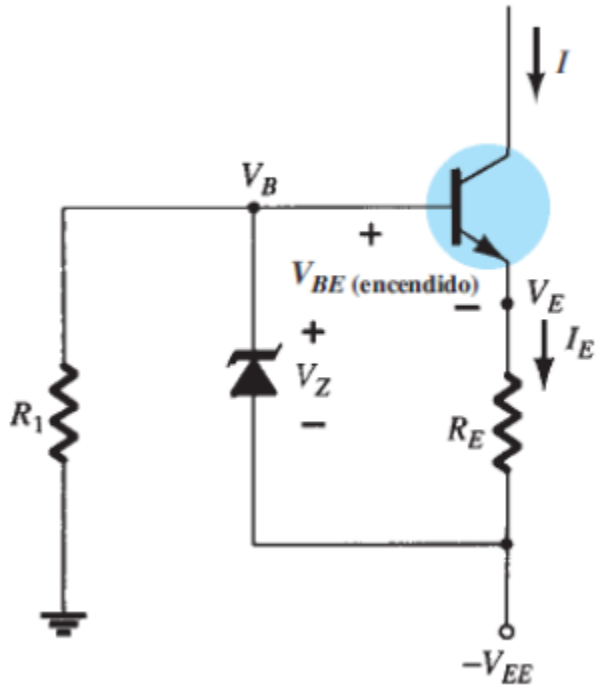
$$I = I_X = \frac{V_{CC} - V_{BE}}{R_X} = \frac{12\,\text{V} - 0.7\,\text{V}}{1.1\,\text{k}\Omega} = \mathbf{10.27\,mA}$$



$$I_X = I_E + \frac{3I_E}{\beta} = \frac{\beta + 3}{\beta} I_E \approx I_E$$

$$I \approx I_X = \frac{V_{CC} - V_{BE}}{R_X} = \frac{6\,\text{V} - 0.7\,\text{V}}{1.3\,\text{k}\Omega} = \mathbf{4.08\,mA}$$

Fuentes de Corriente Constante



$$I \approx I_E = \frac{V_Z - V_{BE}}{R_E}$$

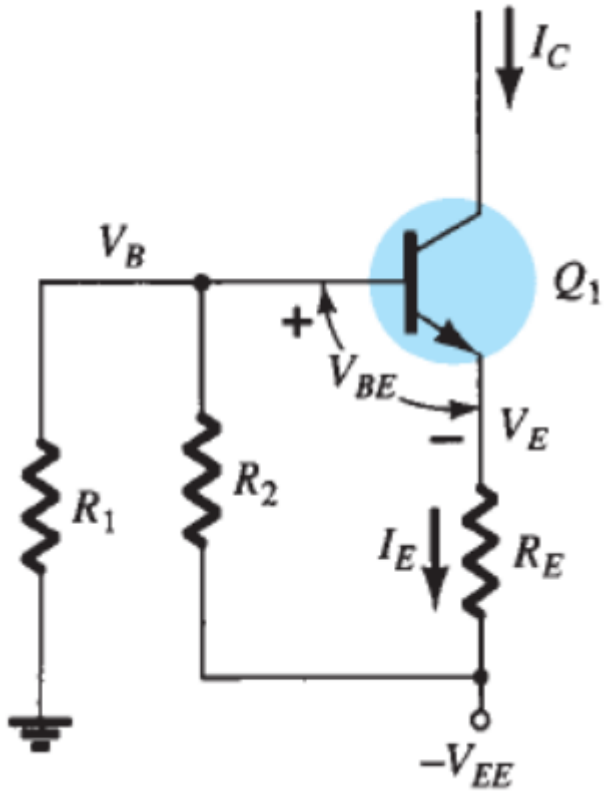
Fuentes de corriente constante

$$V_B = \frac{R_1}{R_1 + R_2}(-V_{EE})$$

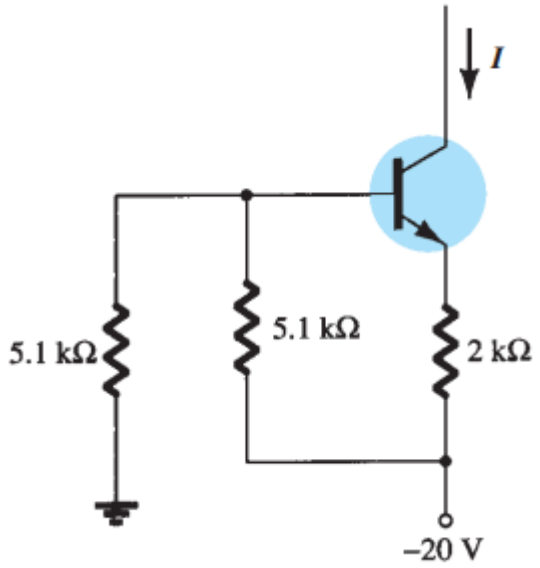
$$V_E = V_B - 0.7\,\text{V}$$

$$I_E = \frac{V_E - (-V_{EE})}{R_E} \approx I_C$$

donde I_C es la corriente constante



Ejemplo



$$V_B = \frac{R_1}{R_1 + R_2}(-V_{EE}) = \frac{5.1\,\text{k}\Omega}{5.1\,\text{k}\Omega + 5.1\,\text{k}\Omega}(-20\,\text{V}) = -10\,\text{V}$$

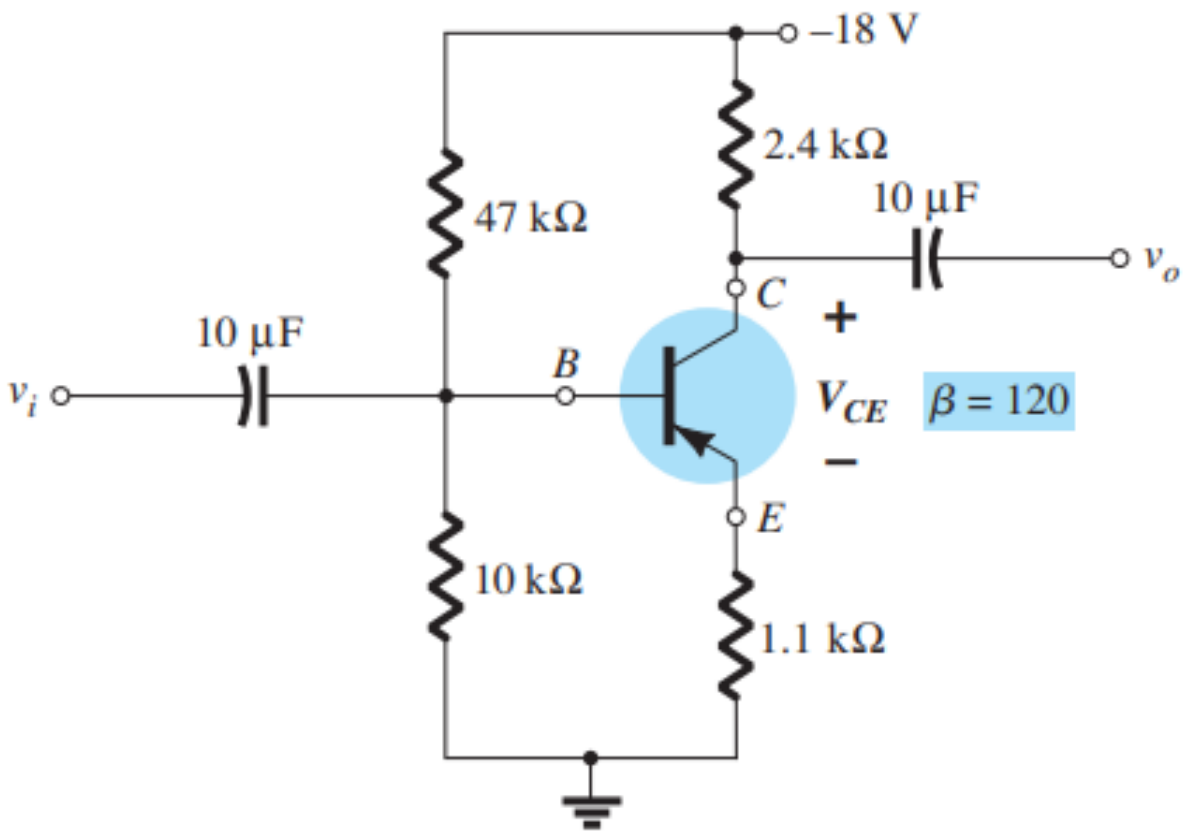
$$V_E = V_B - 0.7\,\text{V} = -10\,\text{V} - 0.7\,\text{V} = -10.7\,\text{V}$$

$$I = I_E = \frac{V_E - (-V_{EE})}{R_E} = \frac{-10.7\,\text{V} - (-20\,V)}{2\,\text{k}\Omega}$$

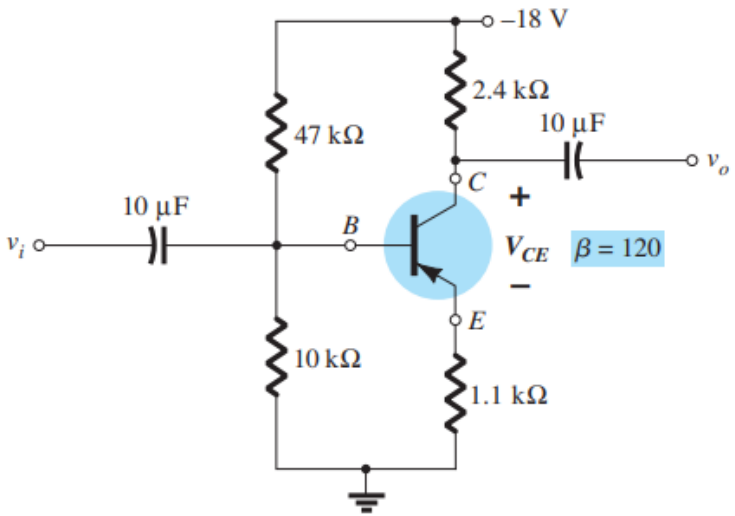
$$= \frac{9.3\,\text{V}}{2\,\text{k}\Omega} = \mathbf{4.65\,mA}$$

Ejercicio

- Determine VCE



Solución



$$V_B = \frac{R_2 V_{CC}}{R_1 + R_2} = \frac{(10\,\text{k}\Omega)(-18\,\text{V})}{47\,\text{k}\Omega + 10\,\text{k}\Omega} = -3.16\,\text{V}$$

$$+V_B - V_{BE} - V_E = 0$$
$$V_E = V_B - V_{BE}$$

$$V_E = -3.16\,\text{V} - (-0.7\,\text{V})$$
$$= -3.16\,\text{V} + 0.7\,\text{V}$$
$$= -2.46\,\text{V}$$

$$I_E = \frac{V_E}{R_E} = \frac{2.46\,\text{V}}{1.1\,\text{k}\Omega} = 2.24\,\text{mA}$$

$$\beta R_E \geq 10 R_2$$

$$(120)(1.1\,\text{k}\Omega) \geq 10(10\,\text{k}\Omega)$$
$$132\,\text{k}\Omega \geq 100\,\text{k}\Omega \quad (\textit{satisfecha})$$

$$-I_E R_E + V_{CE} - I_C R_C + V_{CC} = 0$$
$$V_{CE} = -V_{CC} + I_C(R_C + R_E)$$

$$V_{CE} = -18\,\text{V} + (2.24\,\text{mA})(2.4\,\text{k}\Omega + 1.1\,\text{k}\Omega)$$
$$= -18\,\text{V} + 7.84\,\text{V}$$
$$= \mathbf{-10.16\,V}$$