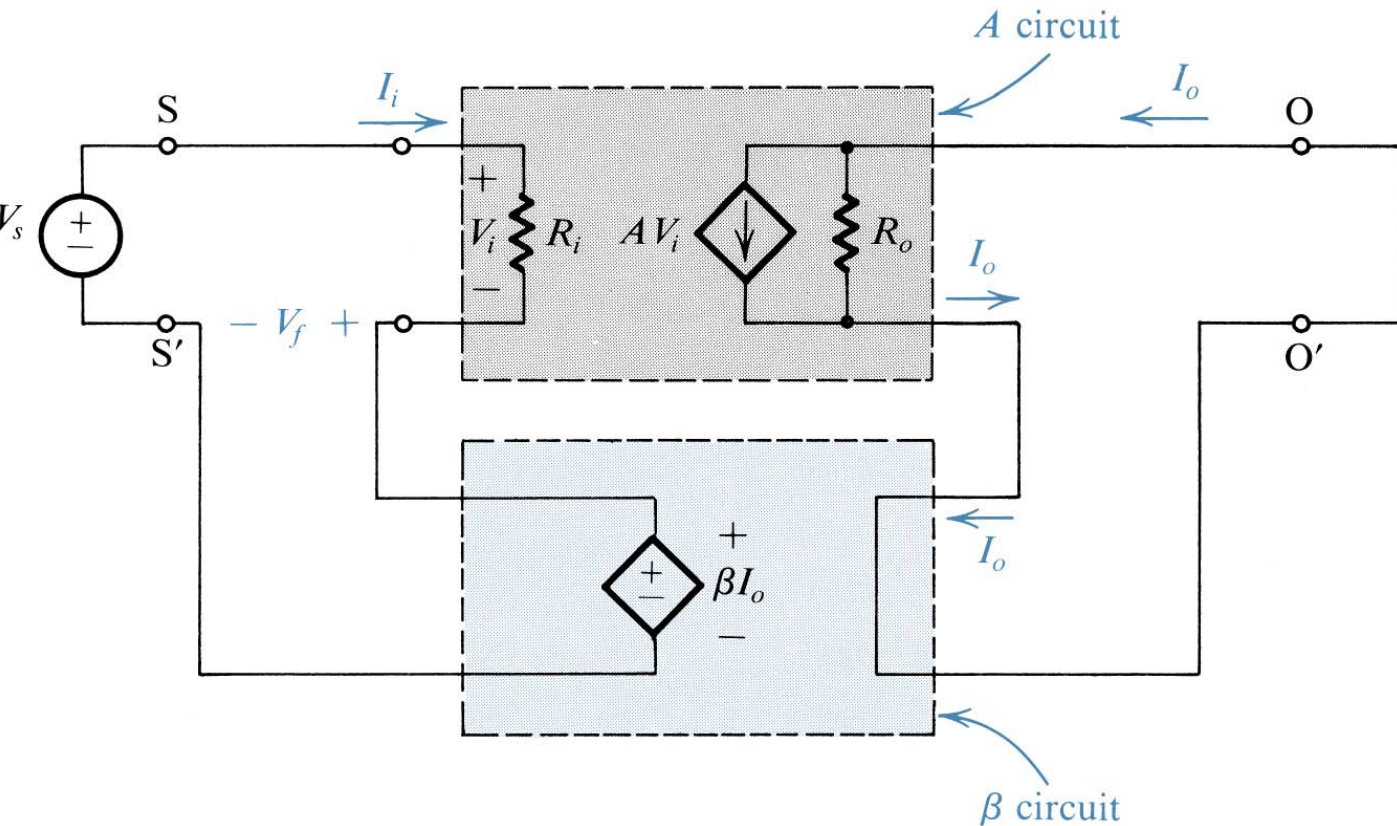

Retroalimentación Negativa

(2a. parte)

Algunas de las figuras de esta presentación fueron tomadas de la página de internet de los autores del texto:

A.S. Sedra and K.C. Smith, *Microelectronic Circuits*. New York, NY: Oxford University Press, 1998.

Amp. con Retroalimentación S-S (Caso Ideal)



A_f :

$$I_o = AV_i$$

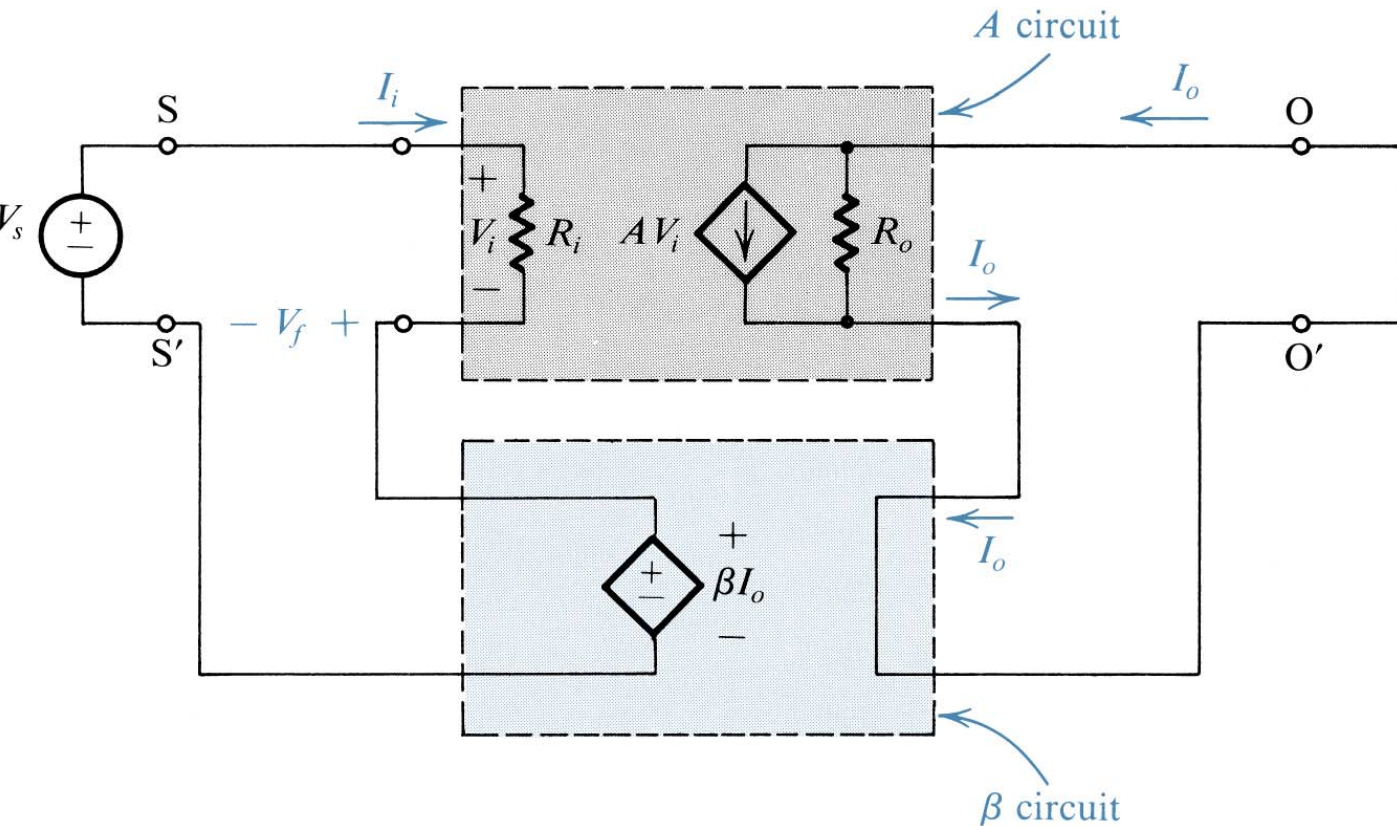
$$V_i = V_s - V_f$$

$$V_i = V_s - \beta I_o$$

$$I_o = A(V_s - \beta I_o)$$

$$A_f = \frac{I_o}{V_s} = \frac{A}{1 + A\beta}$$

Amp. con Retroalimentación S-S (Caso Ideal)



$R_{if} :$

$$R_{if} = \frac{V_s}{I_i}$$

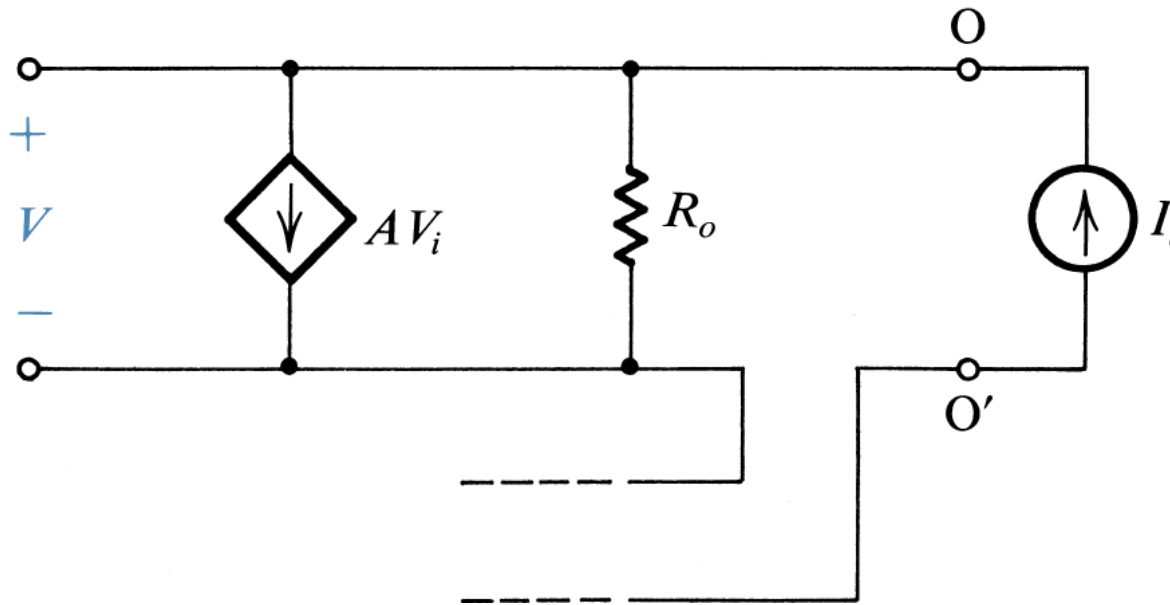
$$R_{if} = \frac{V_s}{V_i / R_i}$$

$$V_i = V_s - \beta I_o$$

$$V_i = V_s - A\beta V_i$$

$$R_{if} = R_i(1 + A\beta)$$

Amp. con Retroalimentación S-S (Caso Ideal)



$R_{of} :$

$$R_{of} = \left. \frac{V}{I_t} \right|_{V_s=0}$$

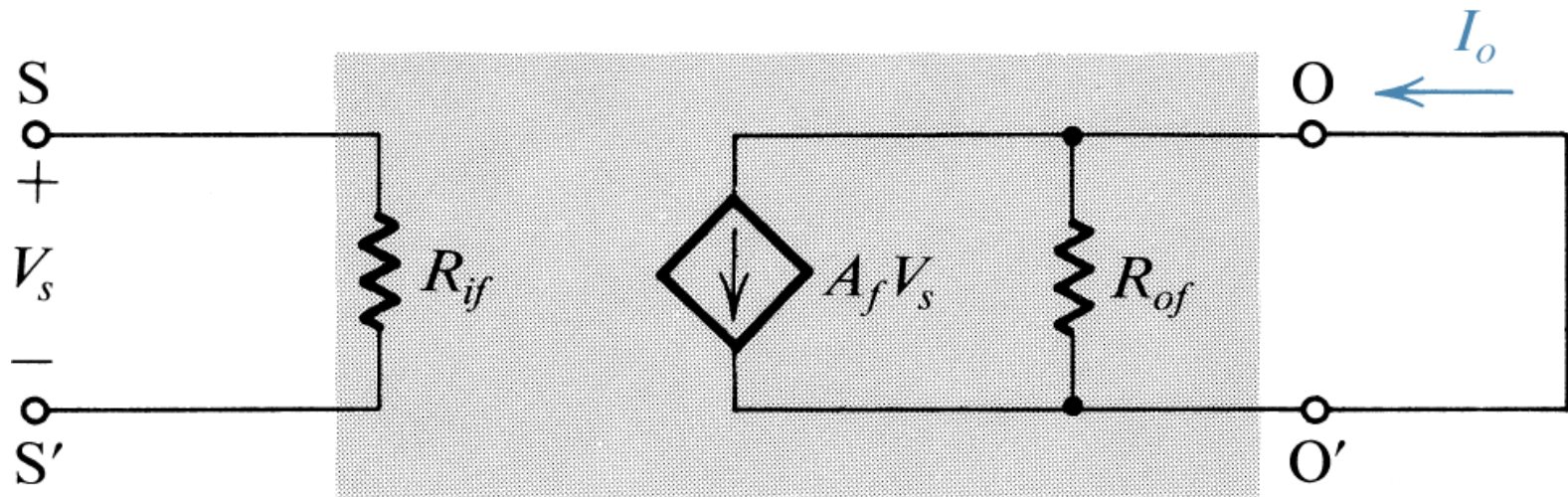
$$V = (I_t - AV_i)R_o$$

$$V_i = -\beta I_o = -\beta I_t$$

$$V = (I_t + A\beta I_t)R_o$$

$$R_{of} = (1 + A\beta)R_o$$

Amp. con Retroalimentación S-S (Caso Ideal)

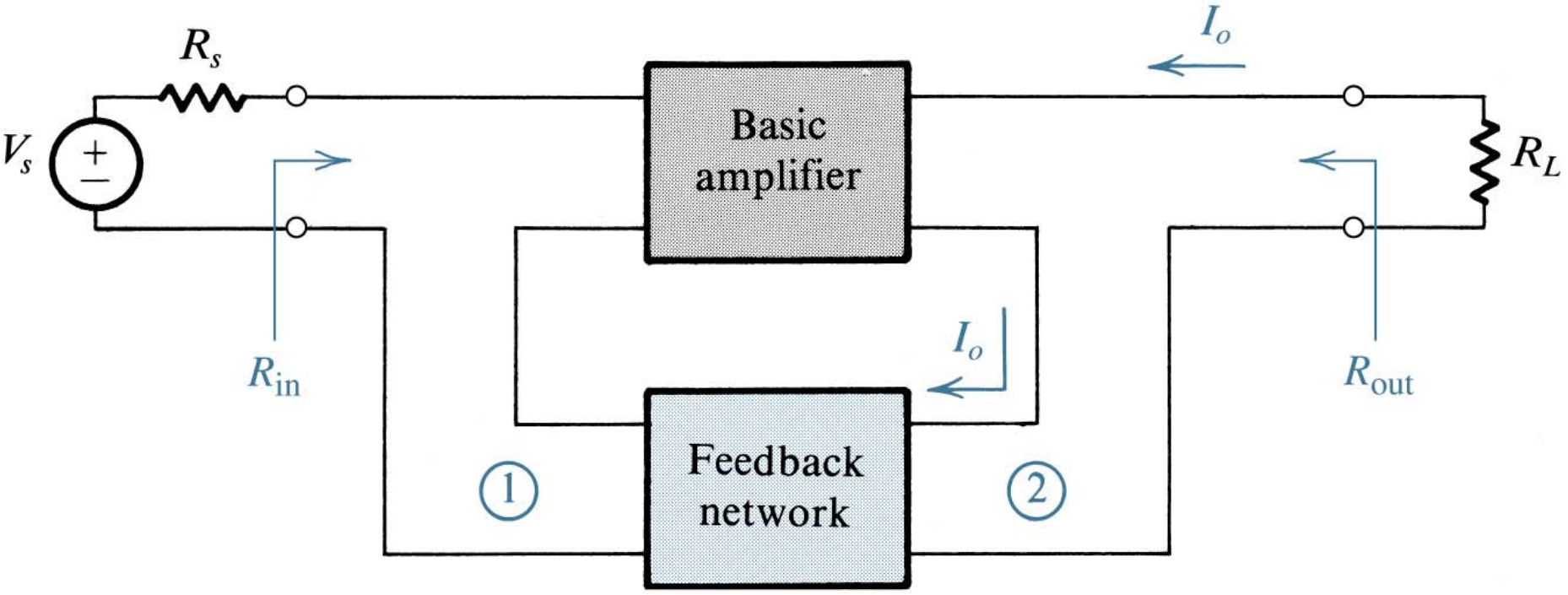


$$A_f = \frac{I_o}{V_s} = \frac{A}{1 + A\beta}$$

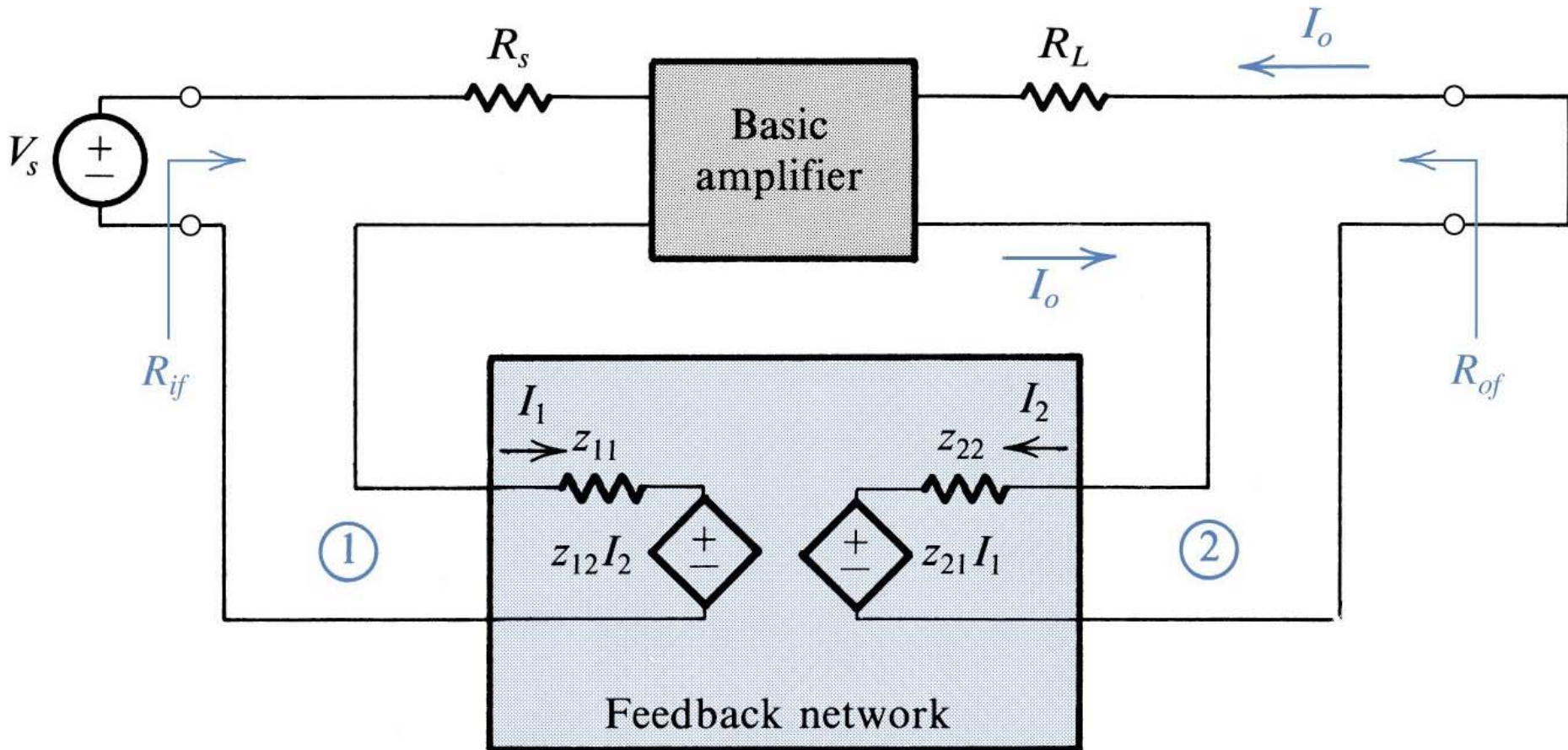
$$R_{if} = R_i(1 + A\beta)$$

$$R_{of} = (1 + A\beta)R_o$$

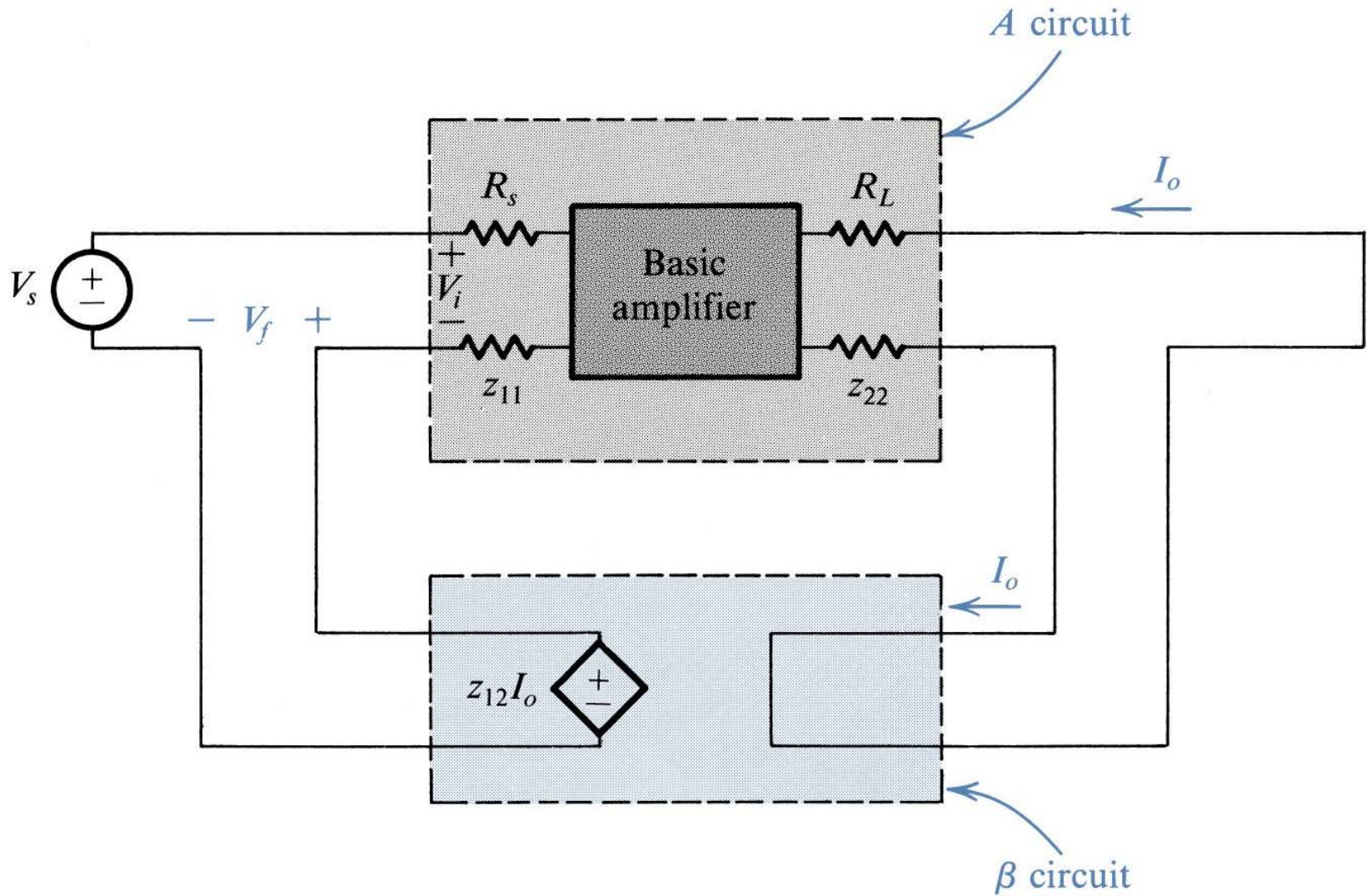
Amp. con Retroalimentación S-S (Caso Real)



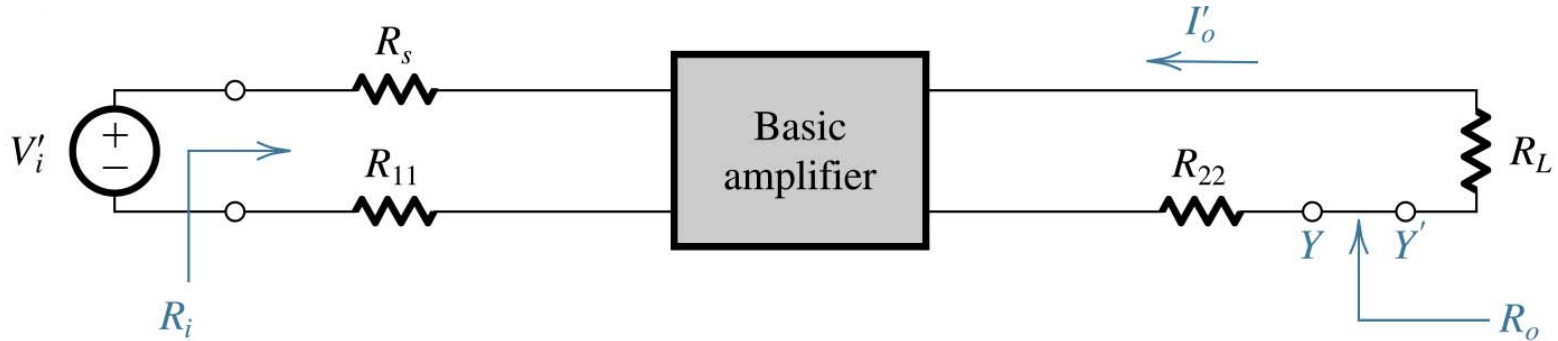
Amp. con Retroalimentación S-S (Caso Real)



Amp. con Retroalimentación S-S (Caso Real)

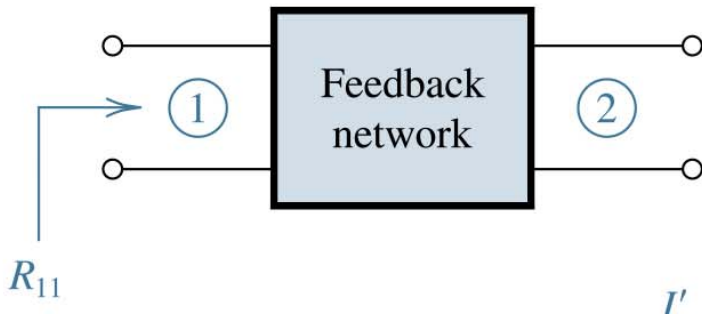


Calculando A y β para el caso S-S

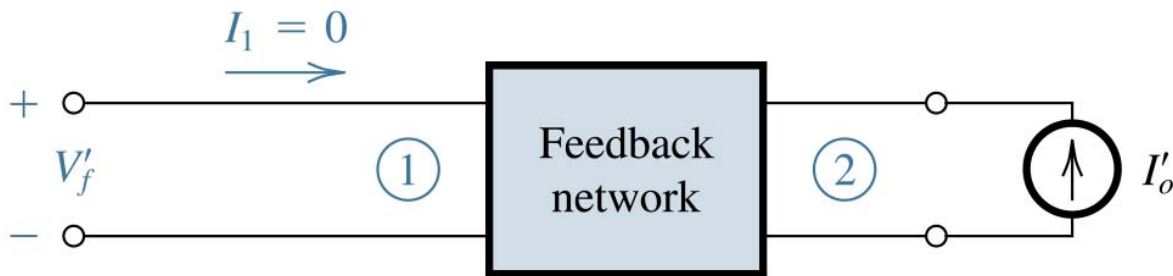
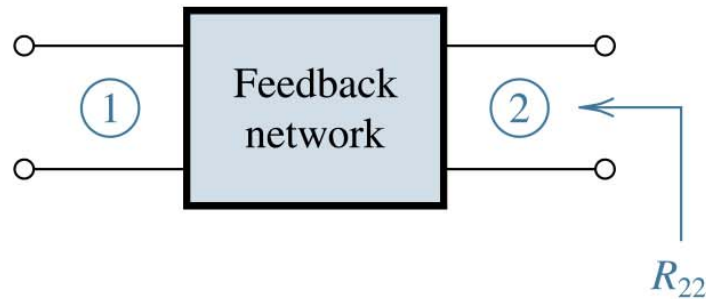


$$A = \frac{I_o'}{V_i'}$$

where R_{11} is obtained from



and R_{22} is obtained from



$$\beta = \left. \frac{V_f'}{I_o'} \right|_{I_1=0}$$

Validez del Método para Calcular de A y β (S-S)

Z_a Parámetros de impedancia del amplificador A

Z_β Parámetros de impedancia de la red β

El método propuesto es exacto siempre que

$$Z_{12a} \ll Z_{12\beta}$$

$$Z_{21a} \gg Z_{21\beta}$$

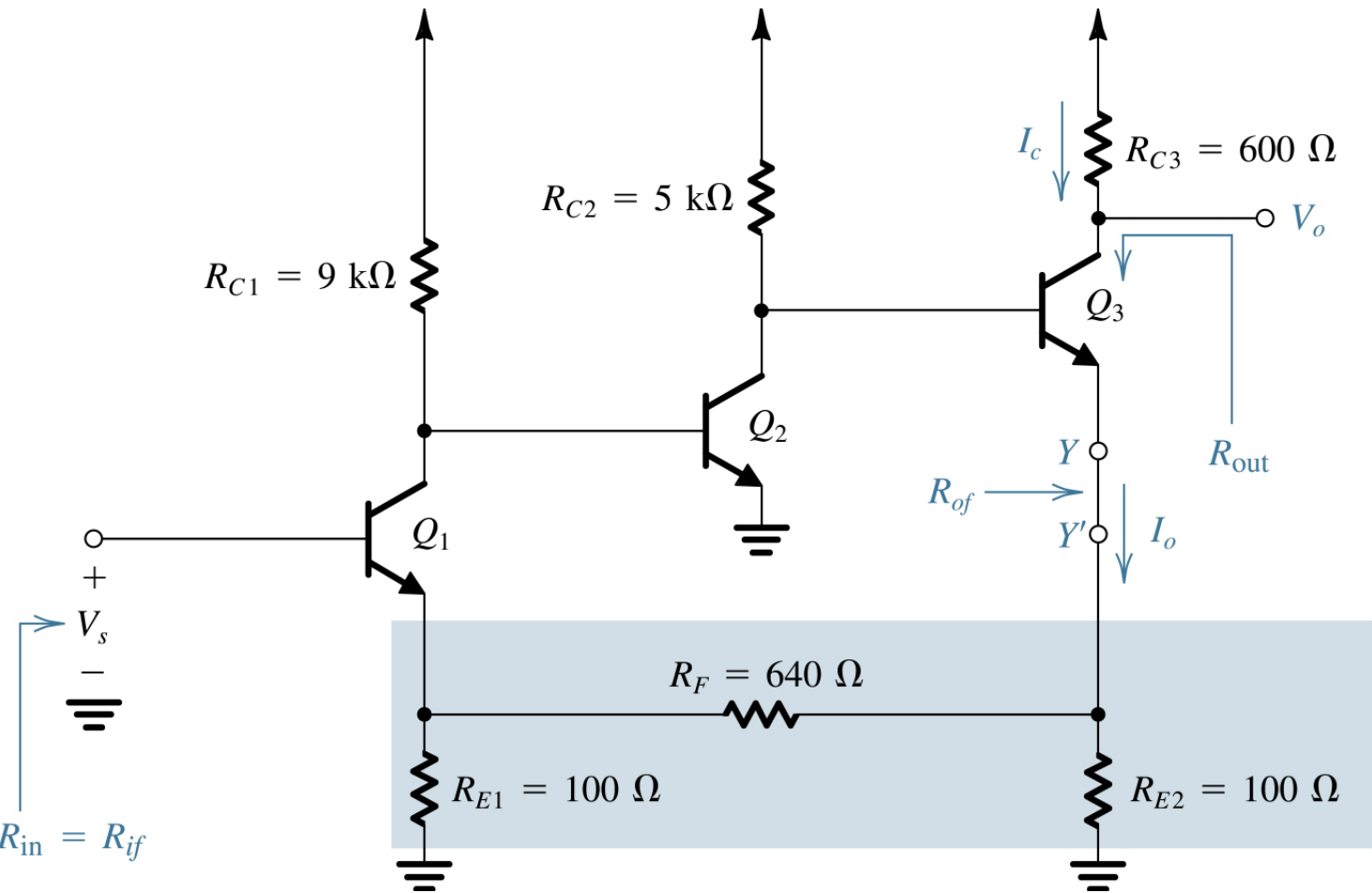
Una vez calculadas A y β siguiendo el método propuesto,

$$A_f = \frac{I_o}{V_s} = \frac{A}{1 + A\beta}$$

$$R_{if} = R_i(1 + A\beta)$$

$$R_{of} = (1 + A\beta)R_o$$

Ejemplo de Retroalimentación S-S



Suponer

$$I_{C1} = 0.6 \text{ mA}$$

$$I_{C2} = 1 \text{ mA}$$

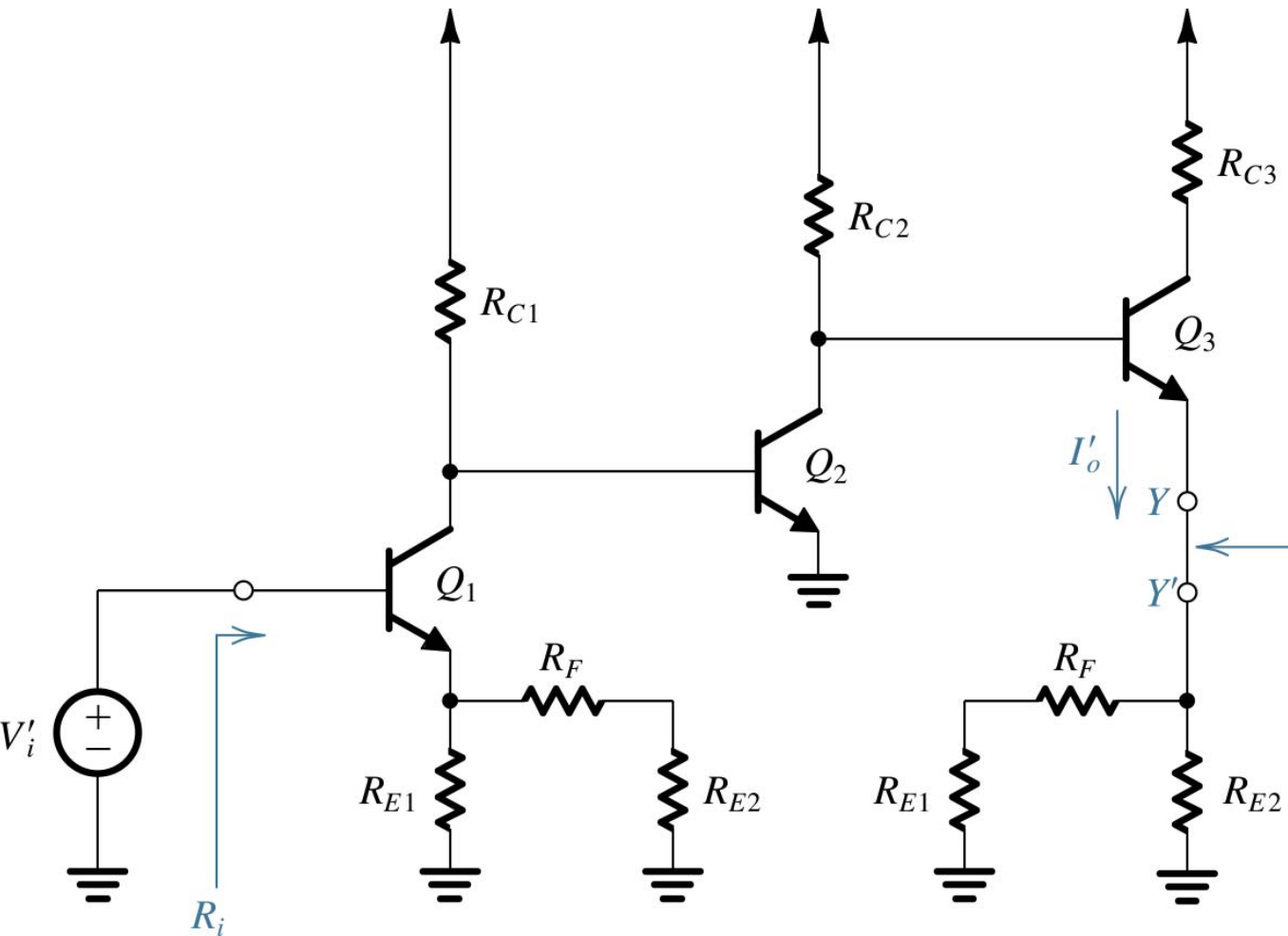
$$I_{C3} = 4 \text{ mA}$$

$$h_{fe} = 100$$

$$V_{A3} = 100 \text{ V}$$

Ejemplo de Retroalimentación S-S (cont.)

Para calcular A ...



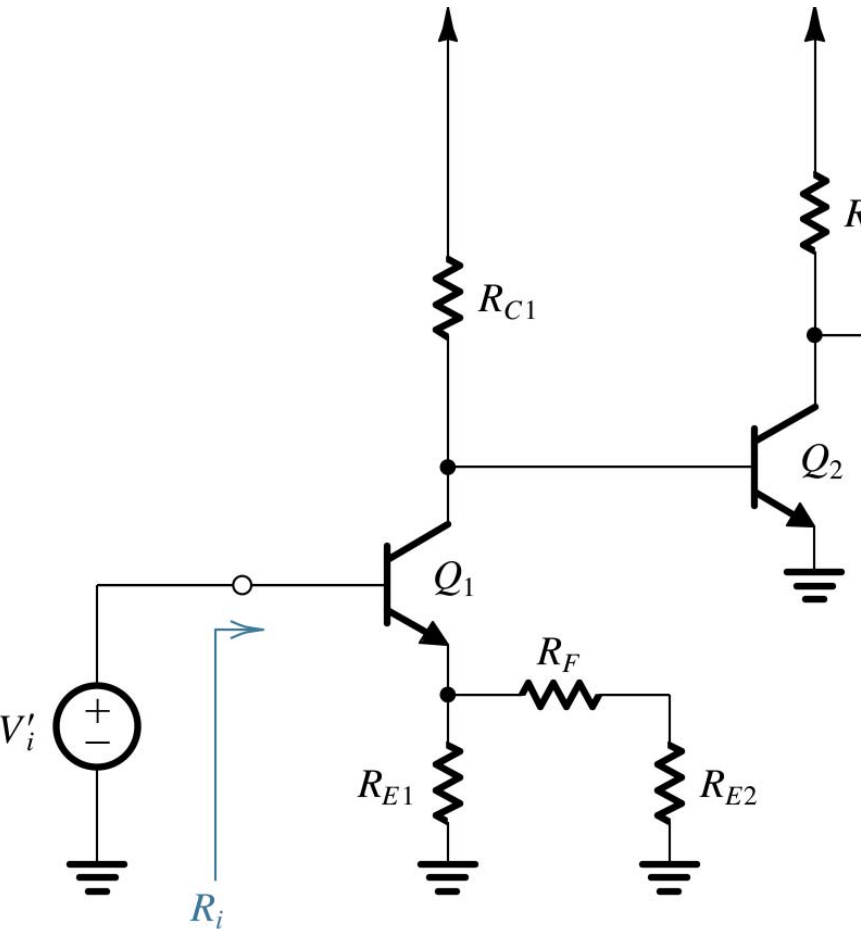
$$A = \frac{I_o'}{V_i'}$$

$$\frac{V_{c3}}{V_i'} = \frac{V_{c1}}{V_i'} \frac{V_{c2}}{V_{c1}} \frac{V_{c3}}{V_{c2}}$$

$$V_{c3} \approx -I_o' R_{C3}$$

$$A = \frac{-1}{R_{C3}} \frac{V_{c1}}{V_i'} \frac{V_{c2}}{V_{c1}} \frac{V_{c3}}{V_{c2}}$$

Ejemplo de Retroalimentación S-S (cont.)



$$\frac{V_{c1}}{V_i'} = \frac{-g_{m1}(R_{C1} \parallel r_{\pi 2})}{1 + g_{m1}[R_{E1} \parallel (R_F + R_{E2})]}$$

$$g_{m1} = \frac{0.6\text{mA}}{25\text{mV}} = 24\text{m}\Omega^{-1}$$

$$g_{m2} = \frac{1\text{mA}}{25\text{mV}} = 40\text{m}\Omega^{-1}$$

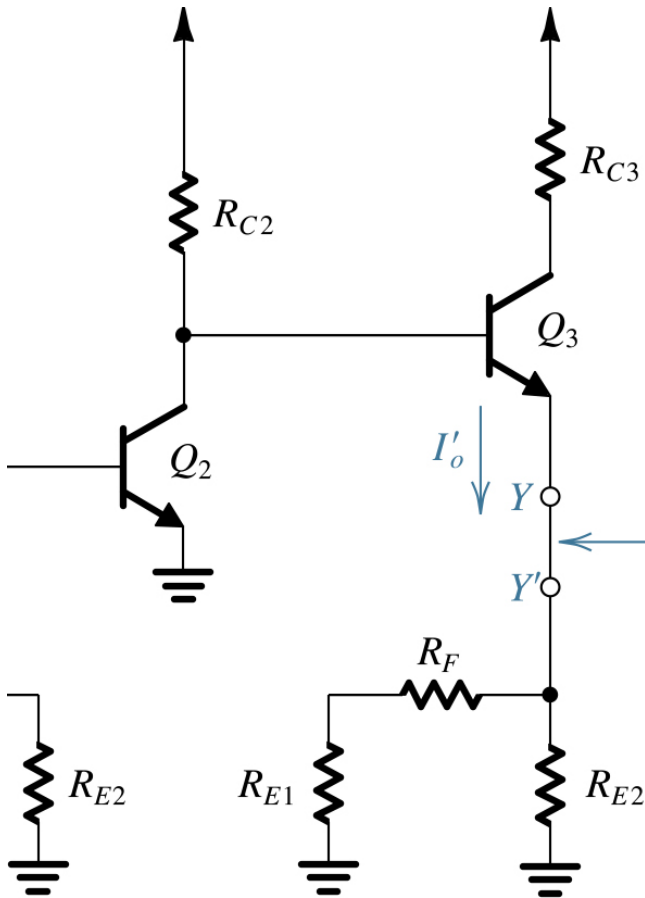
$$r_{\pi 2} = \frac{h_{fe}}{g_{m2}} = 2.5\text{K}\Omega$$

$$R_{C1} \parallel r_{\pi 2} = 1.96\text{K}\Omega$$

$$R_{E1} \parallel (R_F + R_{E2}) = 88.09\Omega$$

$$\frac{V_{c1}}{V_i'} = -15.1$$

Ejemplo de Retroalimentación S-S (cont.)



$$\frac{V_{c2}}{V_{c1}} = -g_{m2}(R_{C2} \parallel R_{i3})$$

$$R_{i3} = r_{\pi3} + (1 + h_{fe})[R_{E2} \parallel (R_F + R_{E1})]$$

$$g_{m3} = \frac{4\text{mA}}{25\text{mV}} = 160\text{m}\Omega^{-1}$$

$$r_{\pi3} = \frac{h_{fe}}{g_{m3}} = \frac{100}{160\text{m}\Omega^{-1}} = 625\Omega$$

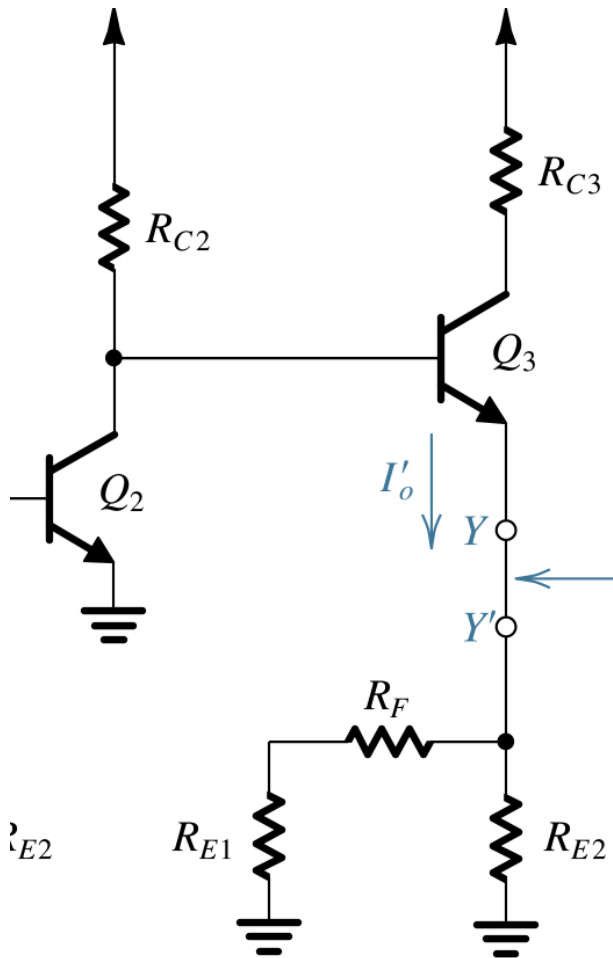
$$R_{E2} \parallel (R_F + R_{E1}) = 88.09\Omega$$

$$R_{i3} = 9.52\text{K}\Omega$$

$$R_{C2} \parallel R_{i3} = 3.28\text{K}\Omega$$

$$\frac{V_{c1}}{V_i} = -131.13$$

Ejemplo de Retroalimentación S-S (cont.)



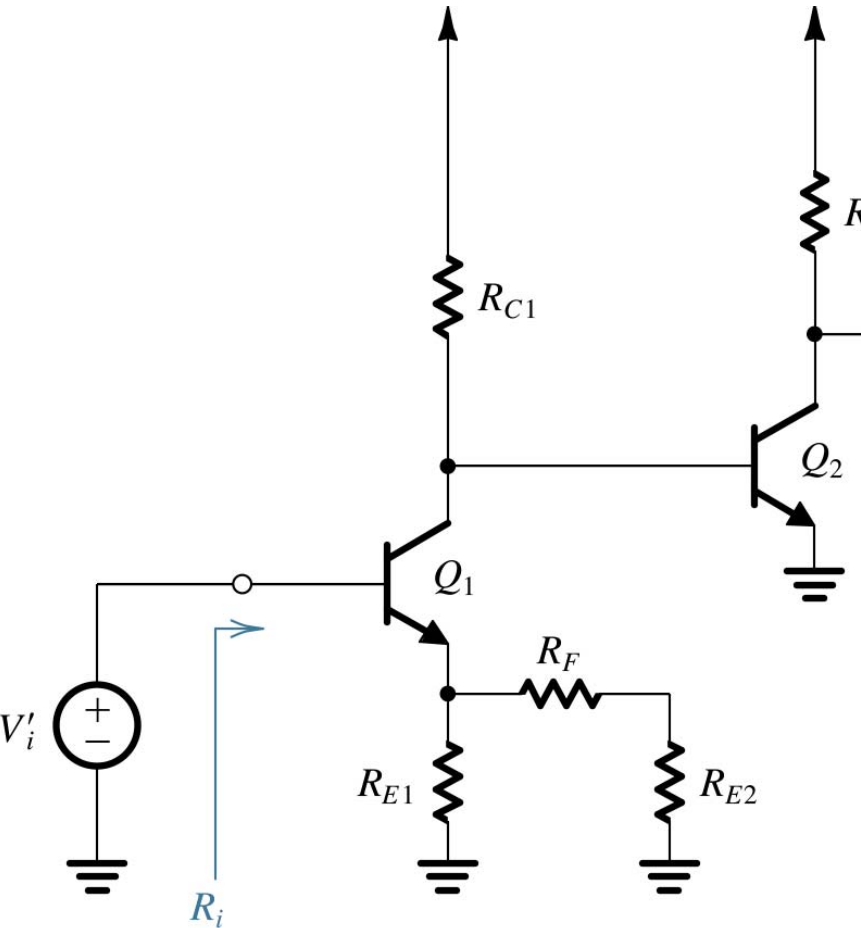
$$\frac{V_{c3}}{V_{c2}} = \frac{-g_{m3}R_{C3}}{1 + g_{m3}[R_{E2} \parallel (R_F + R_{E1})]}$$

$$\frac{V_{c3}}{V_{c2}} = -6.36$$

$$A = \frac{I_o'}{V_i'} = \frac{-1}{R_{C3}} \frac{V_{c1}}{V_i'} \frac{V_{c2}}{V_{c1}} \frac{V_{c3}}{V_{c2}}$$

$$A = \frac{-1}{600} (-15.1)(-131.13)(-6.36) = 20.99 \Omega^{-1}$$

Ejemplo de Retroalimentación S-S (cont.)



Para calcular R_i ...

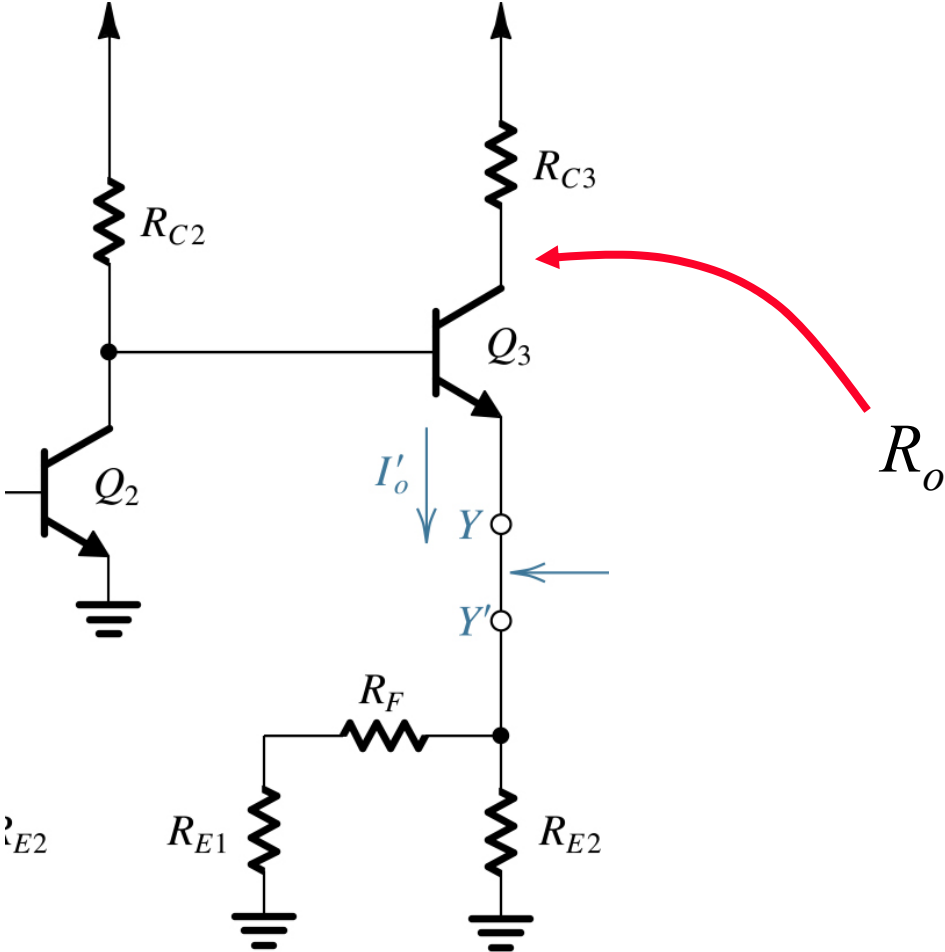
$$R_i = r_{\pi 1} + (1 + h_{fe})[R_{E1} \parallel (R_F + R_{E2})]$$

$$r_{\pi 1} = \frac{h_{fe}}{g_{m1}} = \frac{100}{24\text{m}\Omega^{-1}} = 4.17\text{K}\Omega$$

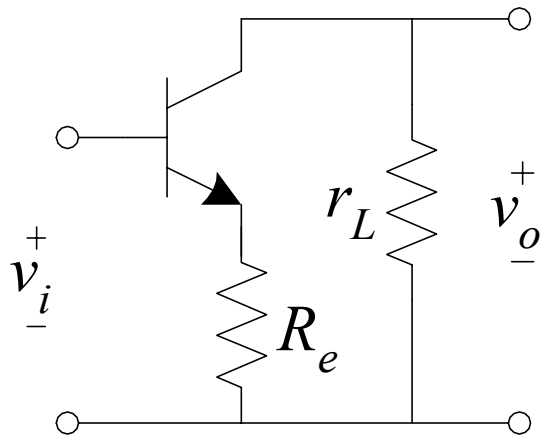
$$R_i = 13.07\text{K}\Omega$$

Ejemplo de Retroalimentación S-S (cont.)

Para calcular R_o ...



Degeneración de Emisor – Señal Peq. (repass)



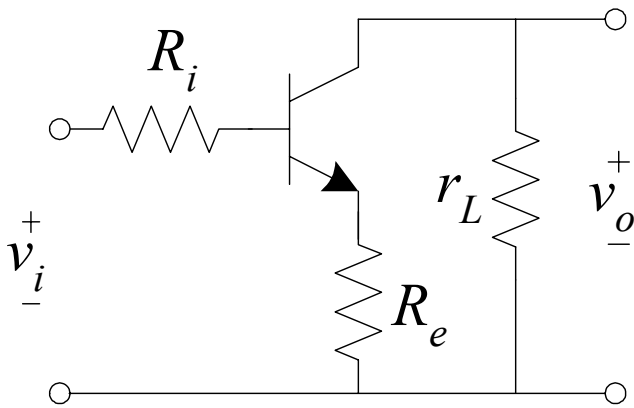
$$A_v = \frac{v_o}{v_i} = \frac{-g_m r_L}{1 + g_m R_e}$$

$$Z_{in} = \frac{v_i}{i_i} = r_\pi + \beta R_e$$

$$A_i = \frac{i_L}{i_i} = -g_m r_\pi = -\beta$$

$$Z_o \approx r_o [1 + g_m (r_\pi \parallel R_e)]$$

R_o del Degeneración de Emisor (con R_i)



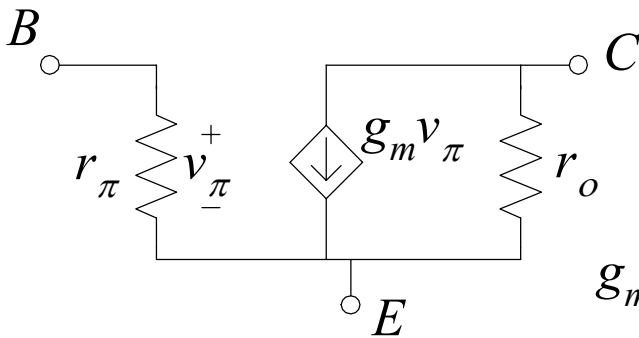
$$Z_o = \left. \frac{v_o}{-i_o} \right|_{v_i=0}$$

$$v_o = (-i_o - g_m v_\pi) r_o + v_e$$

$$v_e = -i_o [(r_\pi + R_i) \parallel R_e]$$

$$v_\pi = \frac{-v_e r_\pi}{r_\pi + R_i} = \left(\frac{r_\pi}{r_\pi + R_i} \right) i_o [(r_\pi + R_i) \parallel R_e]$$

$$Z_o = r_o + [R_e \parallel (r_\pi + R_i)] \left[1 + g_m r_o \left(\frac{r_\pi}{r_\pi + R_i} \right) \right]$$



$$Z_o \approx r_o \left[1 + g_m [R_e \parallel (r_\pi + R_i)] \left(\frac{r_\pi}{r_\pi + R_i} \right) \right]$$

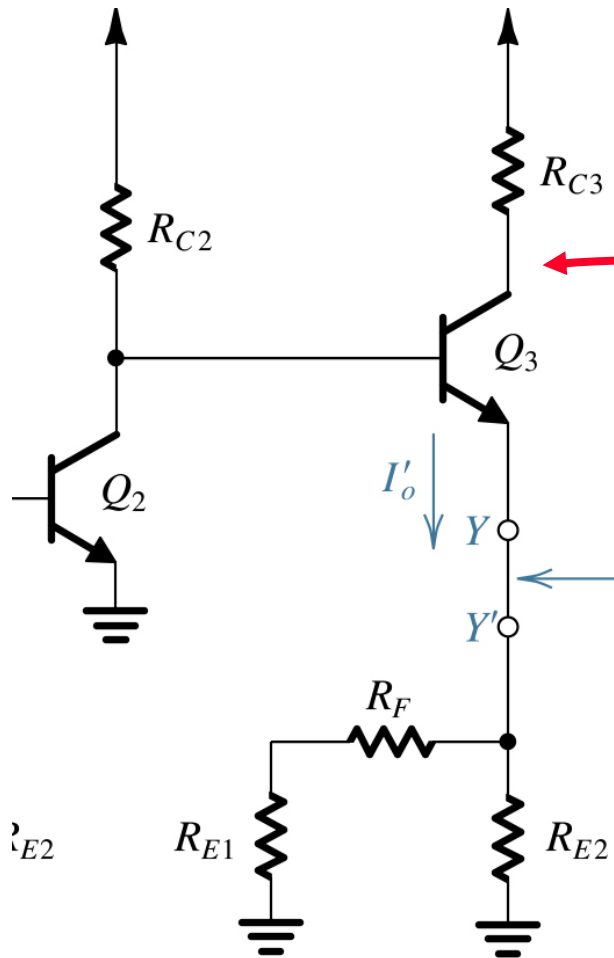
$$g_m = I_C / V_T$$

$$r_\pi = \beta / g_m$$

$$r_o = V_A / I_C$$

Ejemplo de Retroalimentación S-S (cont.)

Para calcular R_o ...



$$R_o = r_{o3} \left[1 + g_{m3} [R_e \parallel (r_{\pi3} + R_i)] \left(\frac{r_{\pi3}}{r_{\pi3} + R_i} \right) \right]$$

$$g_{m3} = 160 \text{m}\Omega^{-1} \quad r_{\pi3} = 625 \Omega$$

$$R_e = R_{E2} \parallel (R_F + R_{E1}) = 88.09 \Omega$$

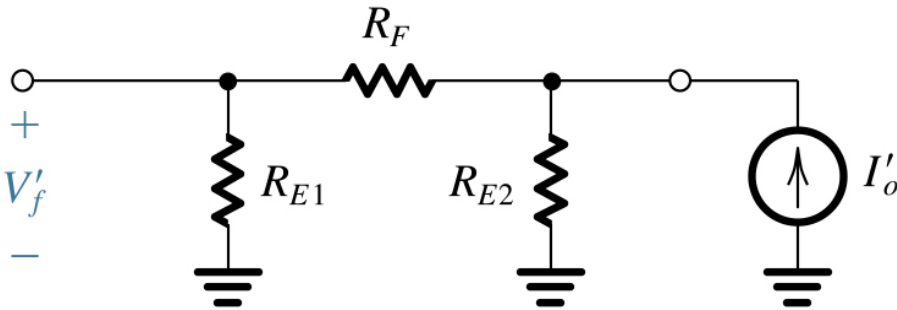
$$R_i \approx R_{C2} = 5 \text{K}\Omega$$

$$r_{o3} = \frac{V_{A3}}{I_{CQ3}} = \frac{100 \text{V}}{4 \text{mA}} = 25 \text{K}\Omega$$

$$R_o = 63.55 \text{K}\Omega$$

Ejemplo de Retroalimentación S-S (cont.)

Para calcular β ...



$$\beta = \frac{V_f'}{I_o'}$$

$$V_f' = \frac{I_o' R_{E2}}{R_{E2} + R_F + R_{E1}} R_{E1}$$

$$\beta = \frac{R_{E2} R_{E1}}{R_{E2} + R_F + R_{E1}} = \frac{(100)(100)}{100 + 640 + 100} = 11.9\Omega$$

Ejemplo de Retroalimentación S-S (cont.)

$$A_f = \frac{I_o}{V_s} = \frac{A}{1 + A\beta} = \frac{20.99}{1 + (20.99)(11.9)} = \frac{20.99}{250.78} = 83.7\text{mA/V}$$

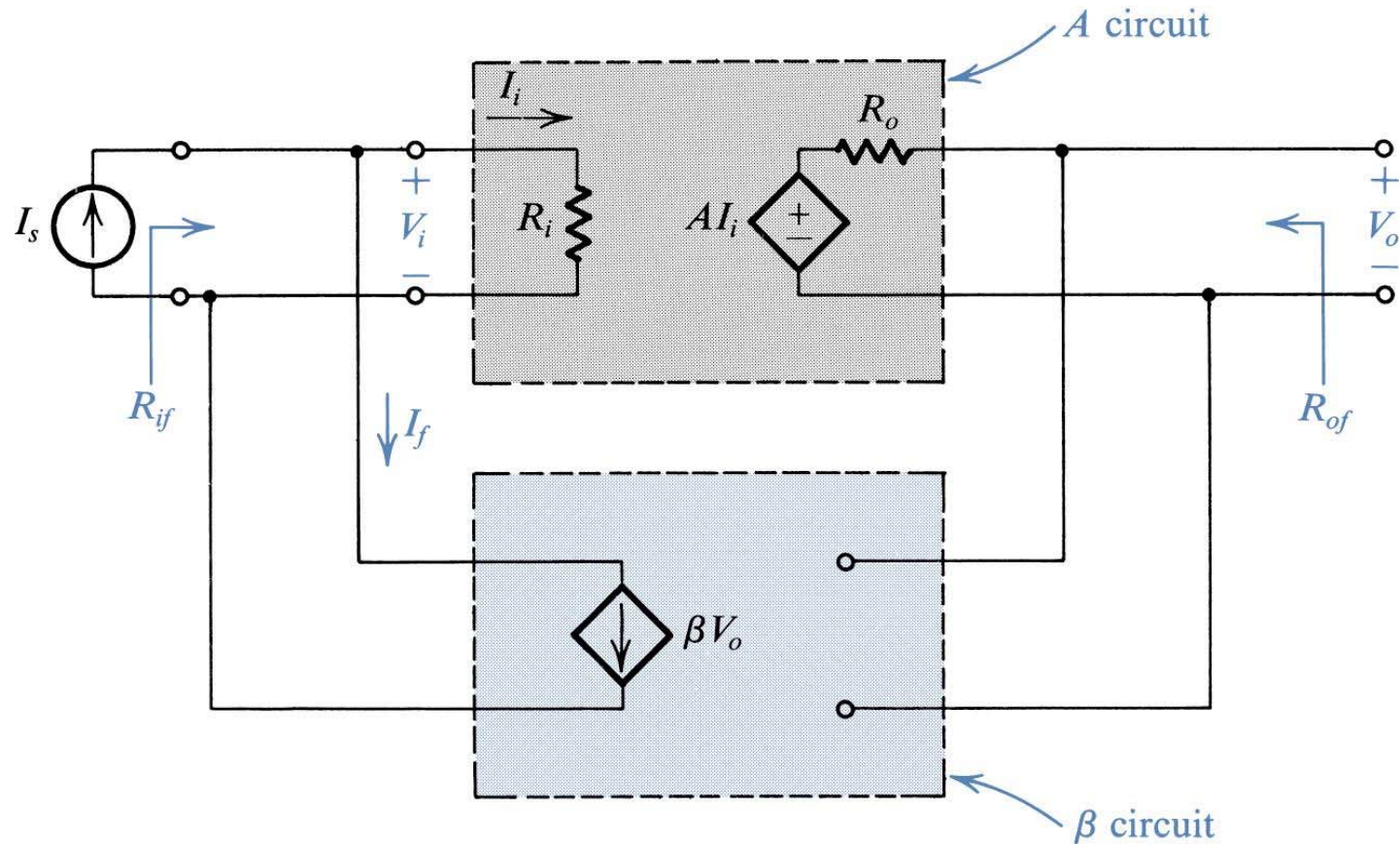
$$A_f = \frac{I_o}{V_s} \approx \frac{1}{\beta} = 84\text{mA/V}$$

$$R_{if} = R_i(1 + A\beta) = 13.07\text{K}\Omega(250.78) = 3.28\text{M}\Omega$$

$$R_{of} = R_o(1 + A\beta) = 63.55\text{K}\Omega(250.78) = 15.94\text{M}\Omega$$

$$A_V = \frac{V_o}{V_s} \approx -A_f R_{C3} = -(83.7\text{mA/V})(600) = -50.22$$

Amp. con Retroalimentación P-P (Caso Ideal)

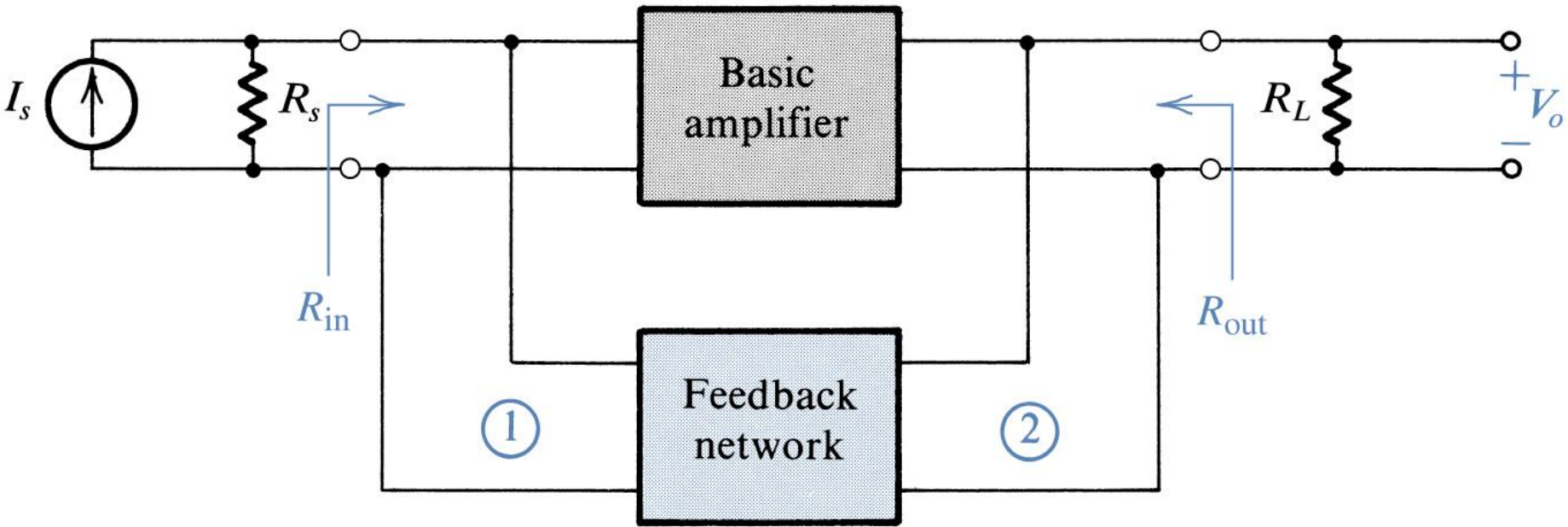


$$A_f = \frac{V_o}{I_s} = \frac{A}{1 + A\beta}$$

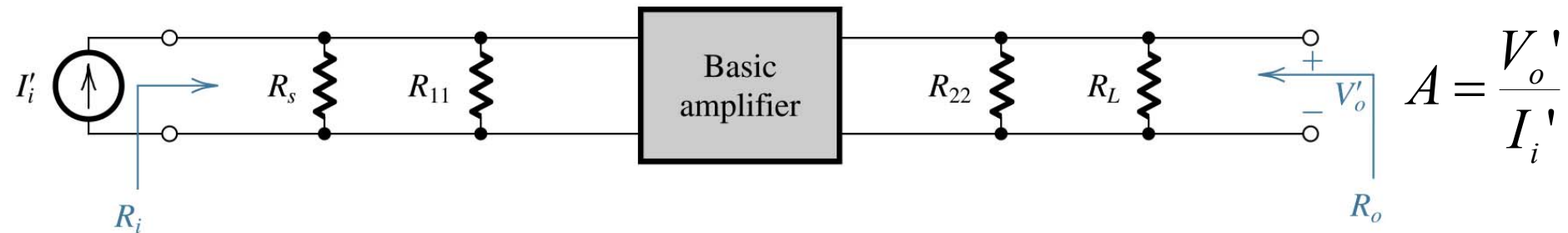
$$R_{if} = \frac{R_i}{1 + A\beta}$$

$$R_{of} = \frac{R_o}{1 + A\beta}$$

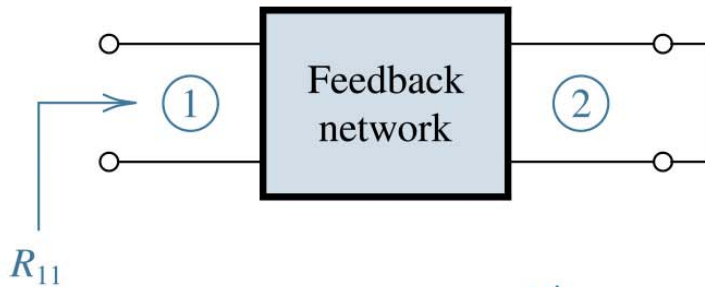
Amp. con Retroalimentación P-P (Caso Real)



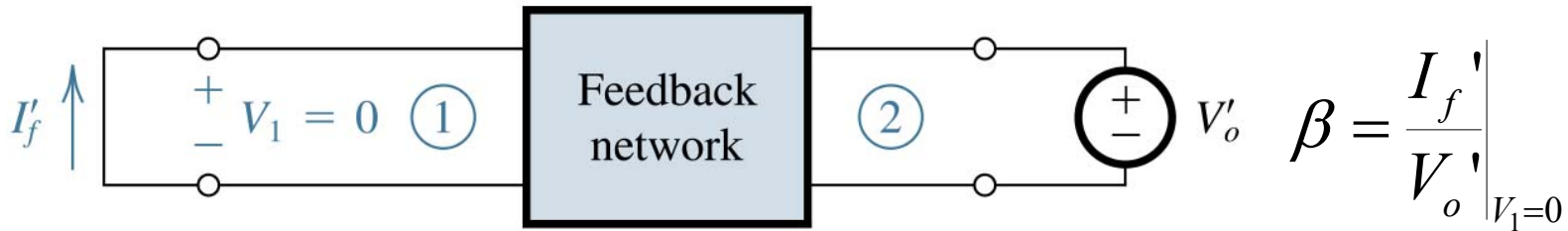
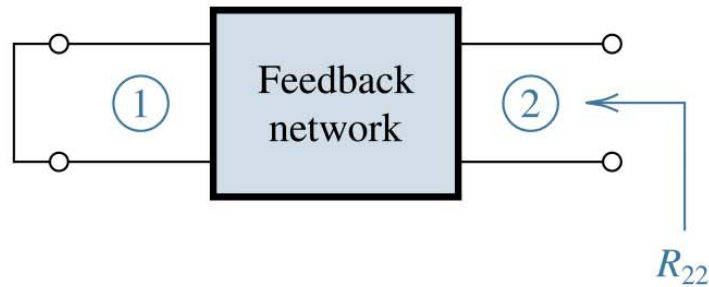
Calculando A y β para el caso P-P



where R_{11} is obtained from



and R_{22} is obtained from



Validez del Método para Calcular de A y β (P-P)

Y_a Parámetros de admitancia del amplificador A

Y_β Parámetros de admitancia de la red β

El método propuesto es exacto siempre que

$$y_{12a} \ll y_{12\beta}$$

$$y_{21a} \gg y_{21\beta}$$

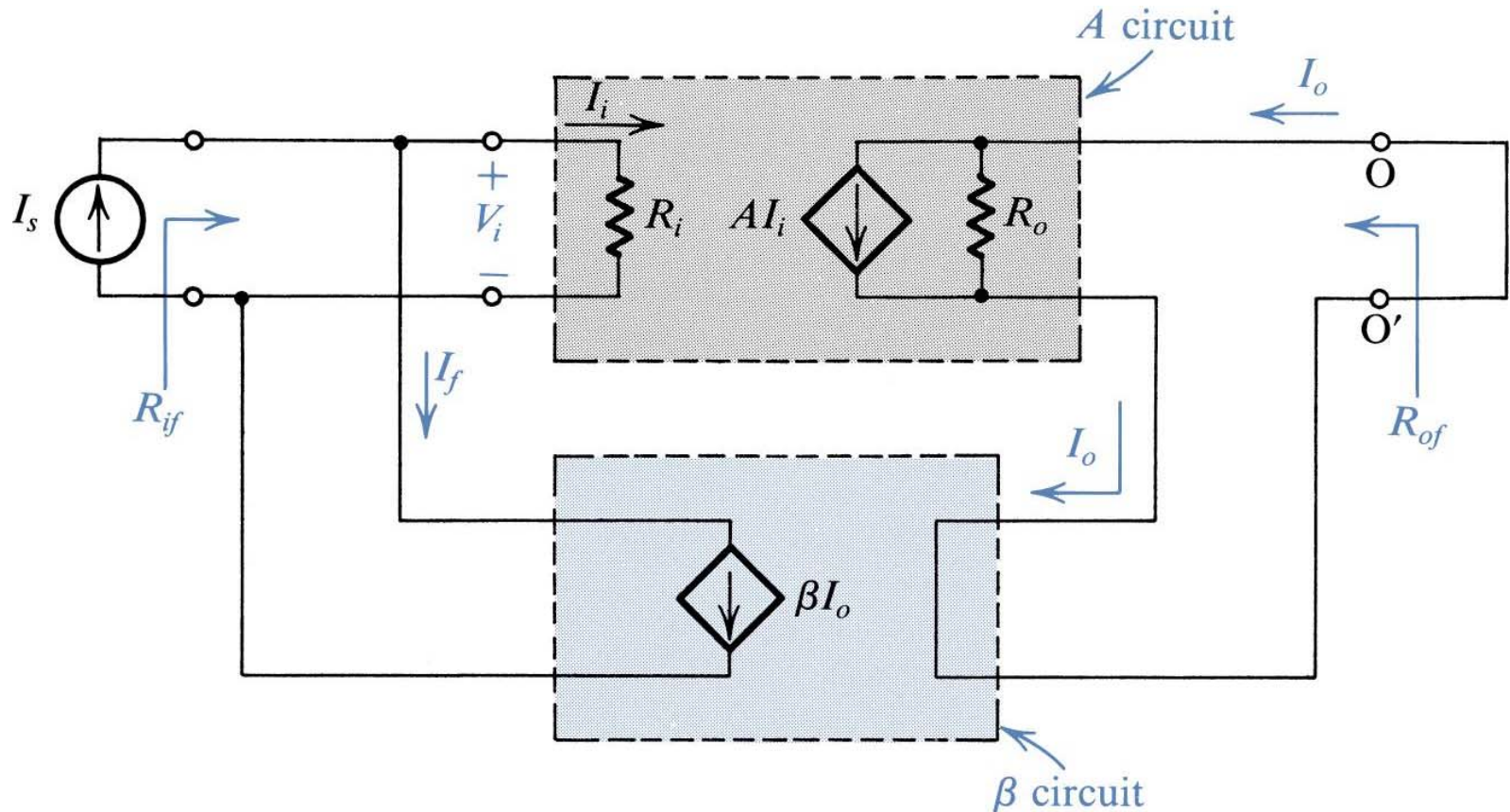
Una vez calculadas A y β siguiendo el método propuesto,

$$A_f = \frac{V_o}{I_s} = \frac{A}{1 + A\beta}$$

$$R_{if} = \frac{R_i}{1 + A\beta}$$

$$R_{of} = \frac{R_o}{1 + A\beta}$$

Amp. con Retroalimentación P-S (Caso Ideal)

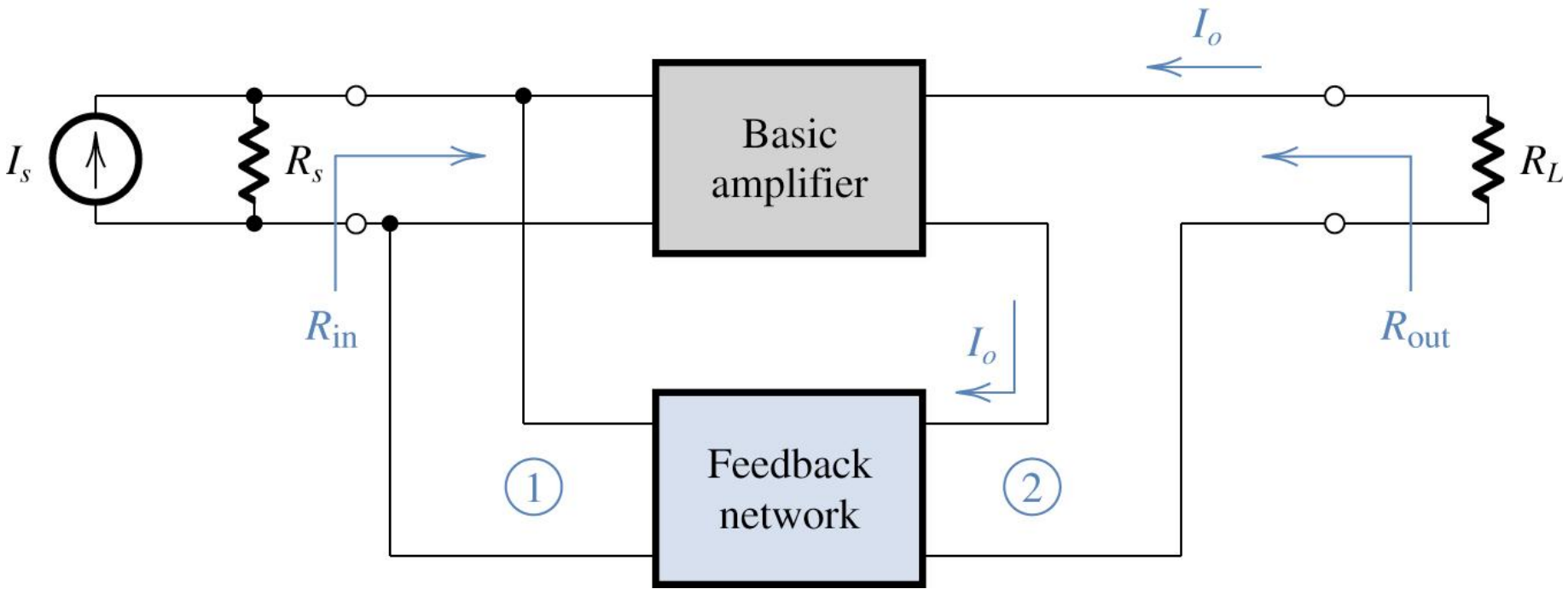


$$A_f = \frac{I_o}{I_s} = \frac{A}{1 + A\beta}$$

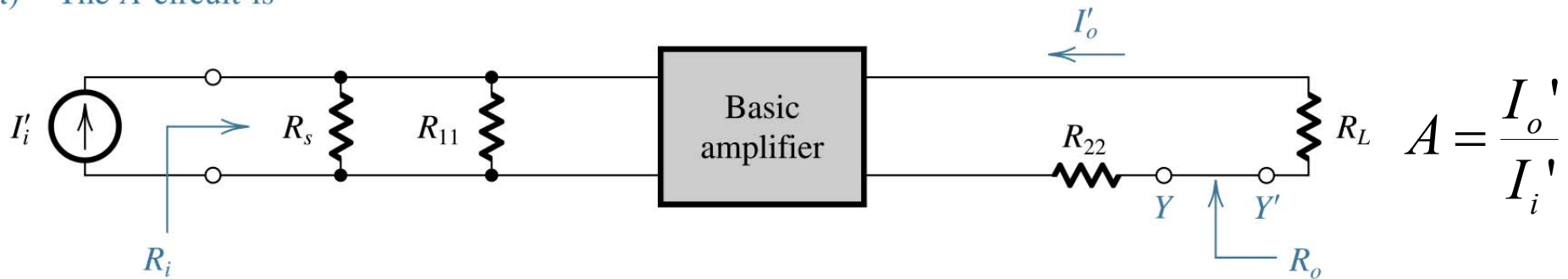
$$R_{if} = \frac{R_i}{1 + A\beta}$$

$$R_{of} = R_o(1 + A\beta)$$

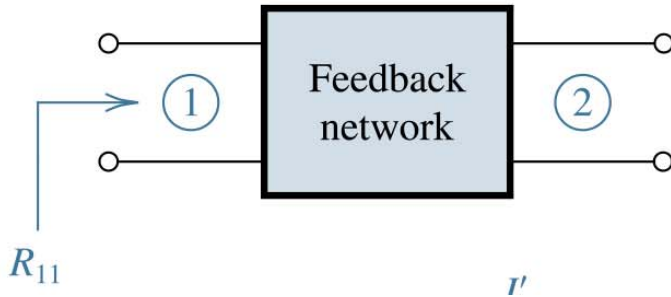
Amp. con Retroalimentación P-S (Caso Real)



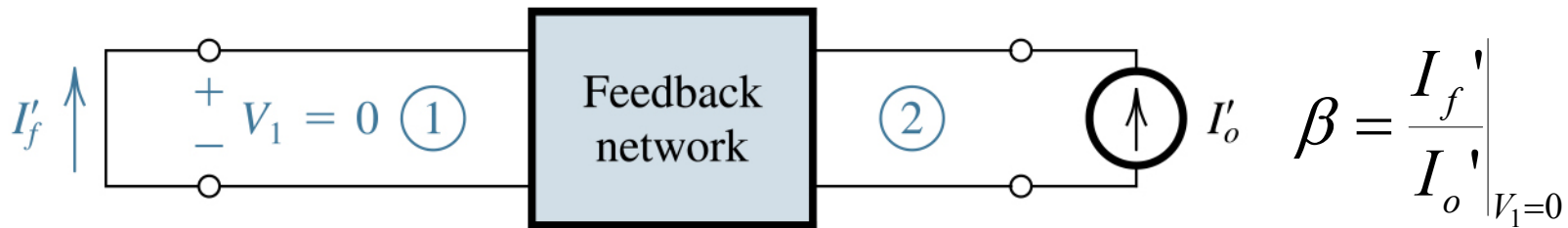
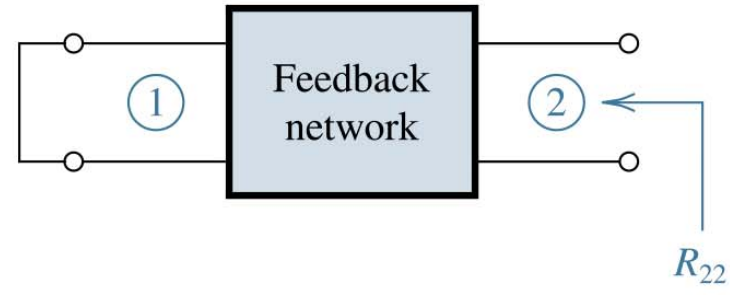
Calculando A y β para el caso P-S



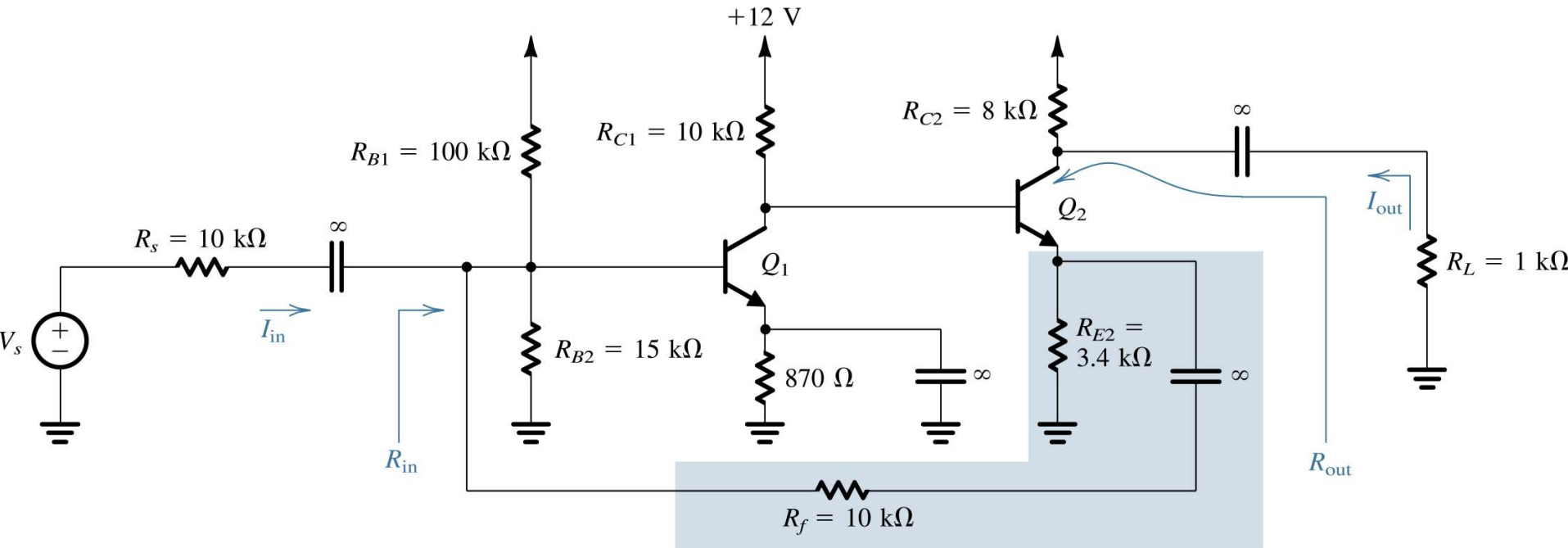
where R_{11} is obtained from



and R_{22} is obtained from



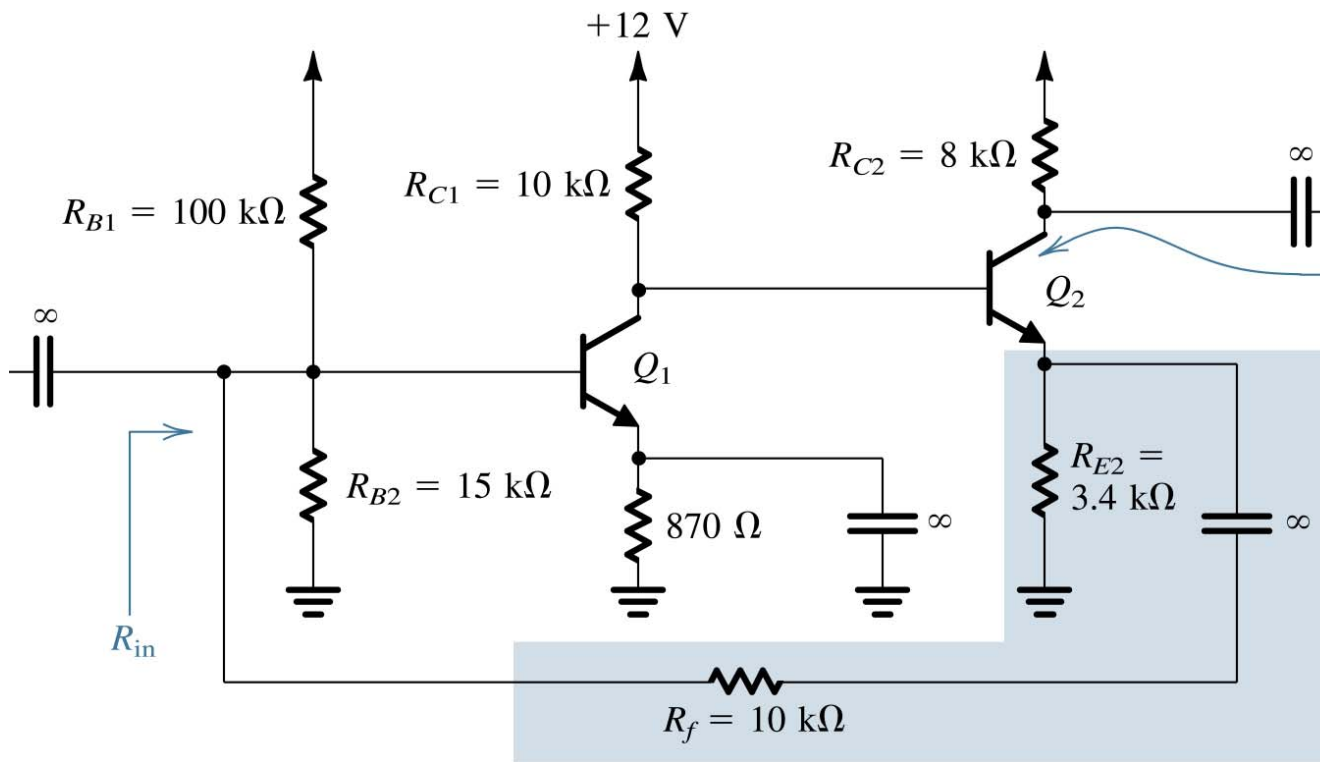
Ejemplo de Retroalimentación P-S



Suponer $h_{fe} = 100$ y $V_A = 75\text{ V}$

Ejemplo de Retroalimentación P-S (cont.)

Análisis de C.D.



$$V_{B1} \approx \frac{12R_{B2}}{R_{B1} + R_{B2}}$$

$$V_{B1} \approx 1.57V$$

$$I_{C1} \approx \frac{V_{B1} - 0.7}{870}$$

$$I_{C1} \approx 1mA$$

$$V_{C1} \approx 12 - I_{C1}R_{C1}$$

$$V_{C1} \approx 2V$$

$$I_{C2} \approx \frac{V_{C1} - 0.7}{R_{E2}} = 0.4mA$$

$$V_{C2} \approx 12 - I_{C2}R_{C2} = 8.8V$$

Ejemplo de Retroalimentación P-S (cont.)

Calculando parámetros internos de los BJTs

$$I_{C1} = 1\text{mA}$$

$$g_{m1} = \frac{1\text{mA}}{25\text{mV}} = 40\text{m}\Omega^{-1}$$

$$r_{\pi 1} = \frac{h_{fe}}{g_{m1}} = \frac{100}{40\text{m}\Omega^{-1}} = 2.5\text{K}\Omega$$

$$r_{o1} = \frac{V_A}{I_{C1}} = \frac{75\text{V}}{1\text{mA}} = 75\text{K}\Omega$$

$$I_{C2} = 0.4\text{mA}$$

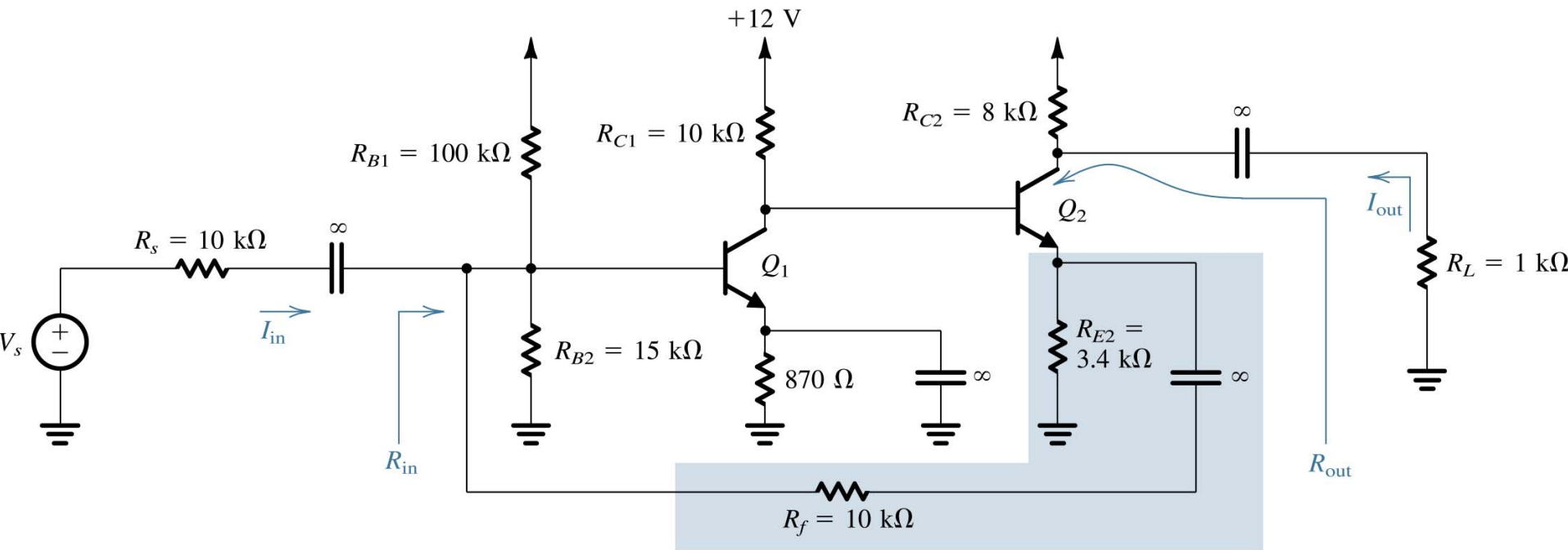
$$g_{m2} = \frac{0.4\text{mA}}{25\text{mV}} = 16\text{m}\Omega^{-1}$$

$$r_{\pi 2} = \frac{h_{fe}}{g_{m2}} = \frac{100}{16\text{m}\Omega^{-1}} = 6.25\text{K}\Omega$$

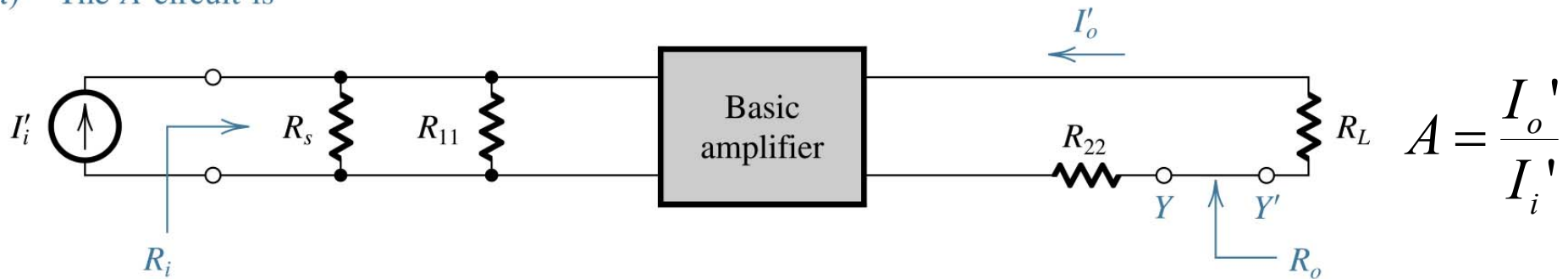
$$r_{o2} = \frac{V_A}{I_{C2}} = \frac{75\text{V}}{0.4\text{mA}} = 187.5\text{K}\Omega$$

Ejemplo de Retroalimentación P-S (cont.)

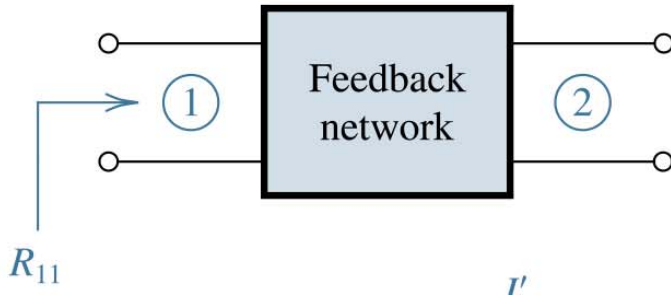
Calculando $A...$



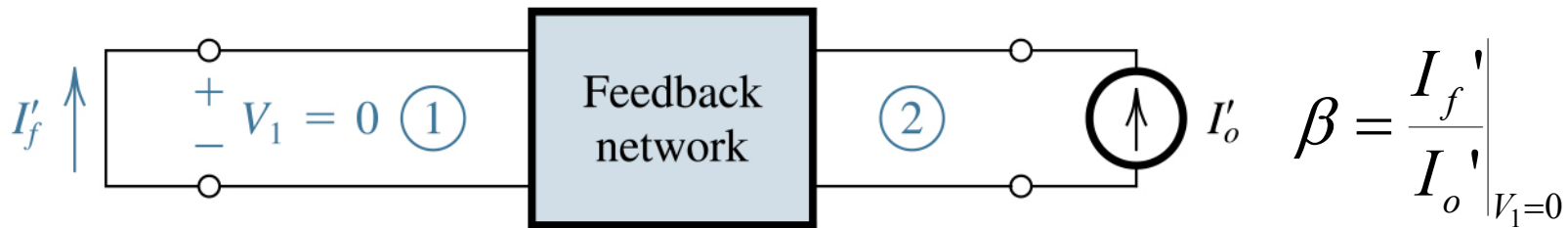
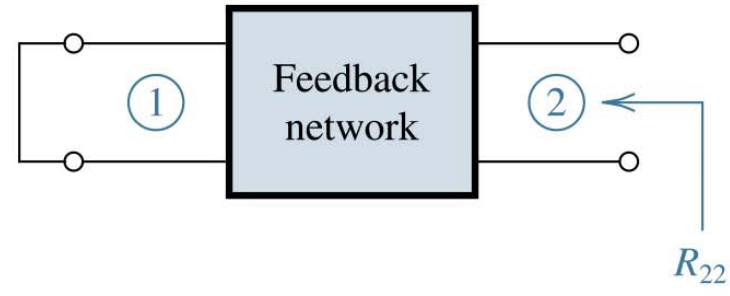
Calculando A y β para el caso P-S



where R_{11} is obtained from

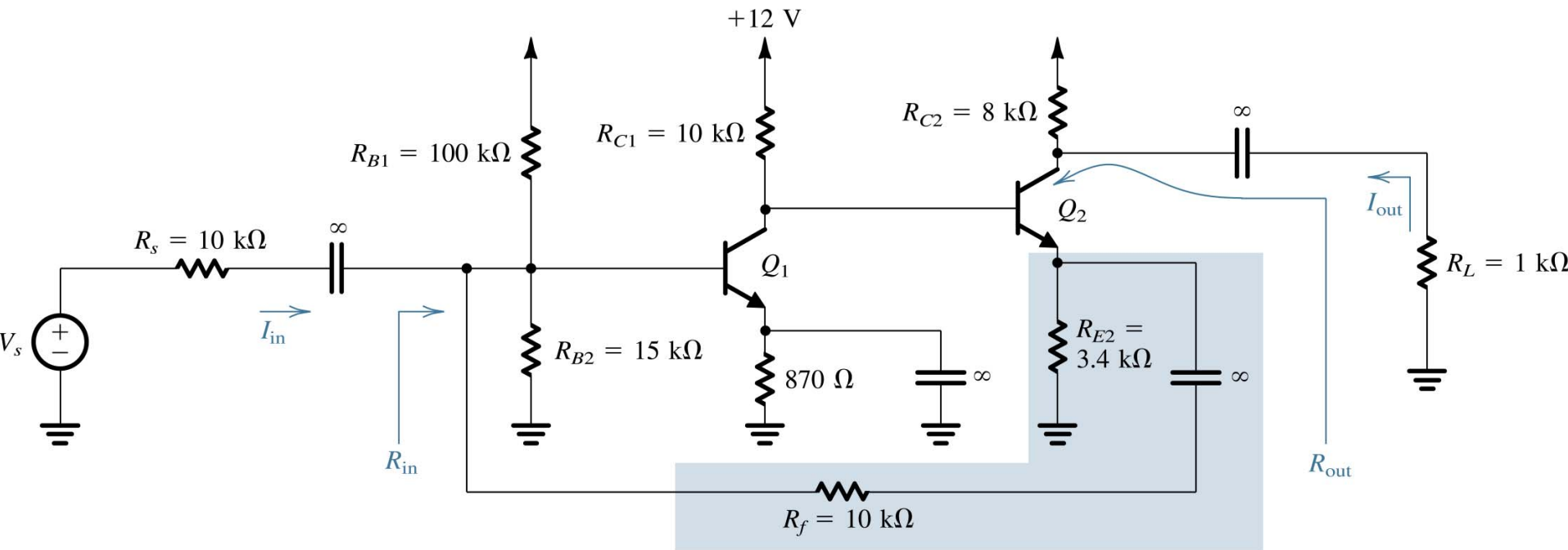


and R_{22} is obtained from



Ejemplo de Retroalimentación P-S (cont.)

Calculando A ...



$$\frac{v_{c2}}{v_{b1}} = \frac{v_{c1}}{v_{b1}} \frac{v_{c2}}{v_{c1}}$$

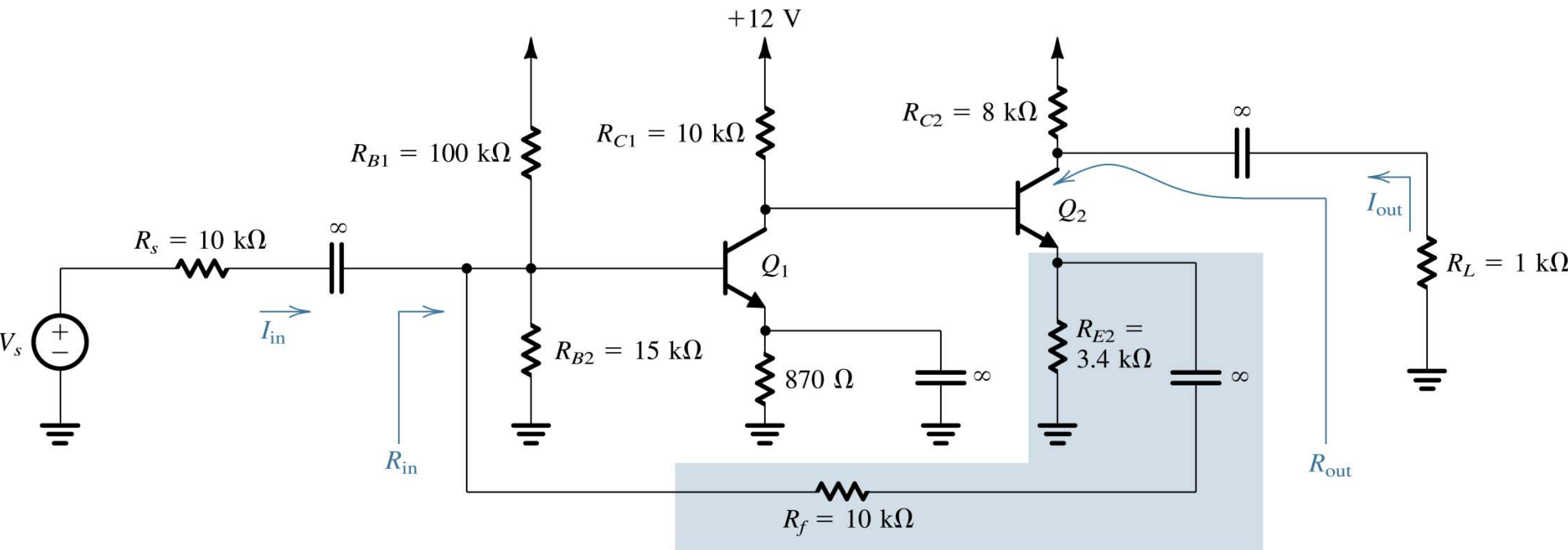
$$i_i' = \frac{v_{b1}}{R_{i1}}$$

$$i_o' = \frac{-v_{c2}}{R_{C2} \parallel R_L}$$

$$A = \frac{i_o'}{i_i'} = \frac{-R_{i1}}{(R_{C2} \parallel R_L)} \frac{v_{c2}}{v_{b1}}$$

Ejemplo de Retroalimentación P-S (cont.)

Calculando $A...$



$$\frac{v_{c1}}{v_{b1}} = -g_{m1} (R_{c1} \parallel r_{o1} \parallel R_{i2})$$

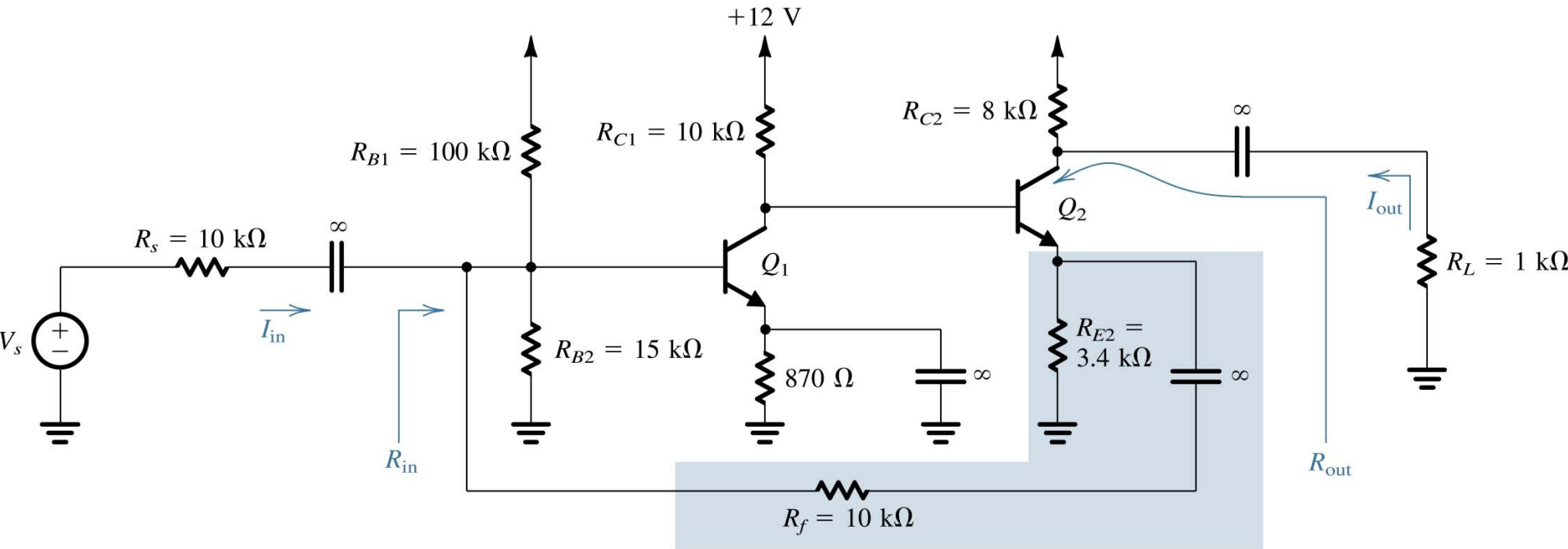
$$R_{i2} = r_{\pi 2} + (1 + h_{fe})(R_{E2} \parallel R_f) = 262.79 \text{ k}\Omega$$

$$\frac{v_{c1}}{v_{b1}} = -341.48$$

$$v_{b1}$$

Ejemplo de Retroalimentación P-S (cont.)

Calculando $A...$

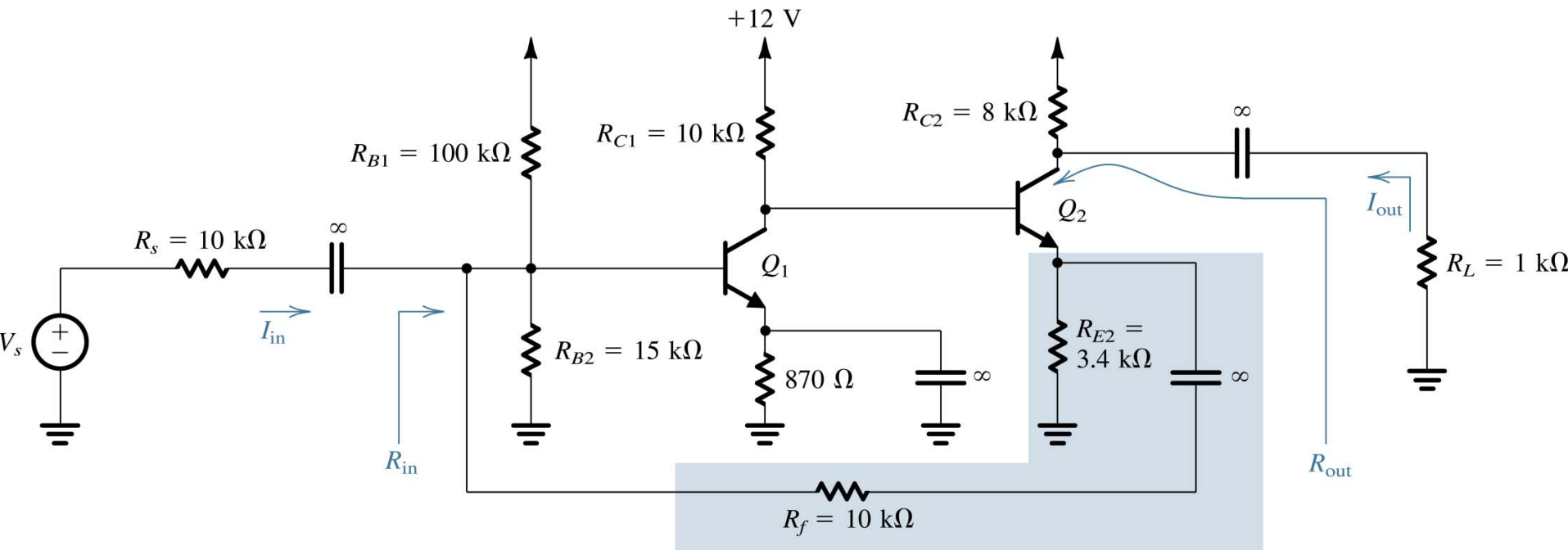


$$\frac{v_{c2}}{v_{c1}} = \frac{-g_{m2}(R_{c2} \parallel R_L)}{1 + g_{m2}(R_{E2} \parallel R_f)}$$

$$\frac{v_{c2}}{v_{c1}} = -0.3415$$

Ejemplo de Retroalimentación P-S (cont.)

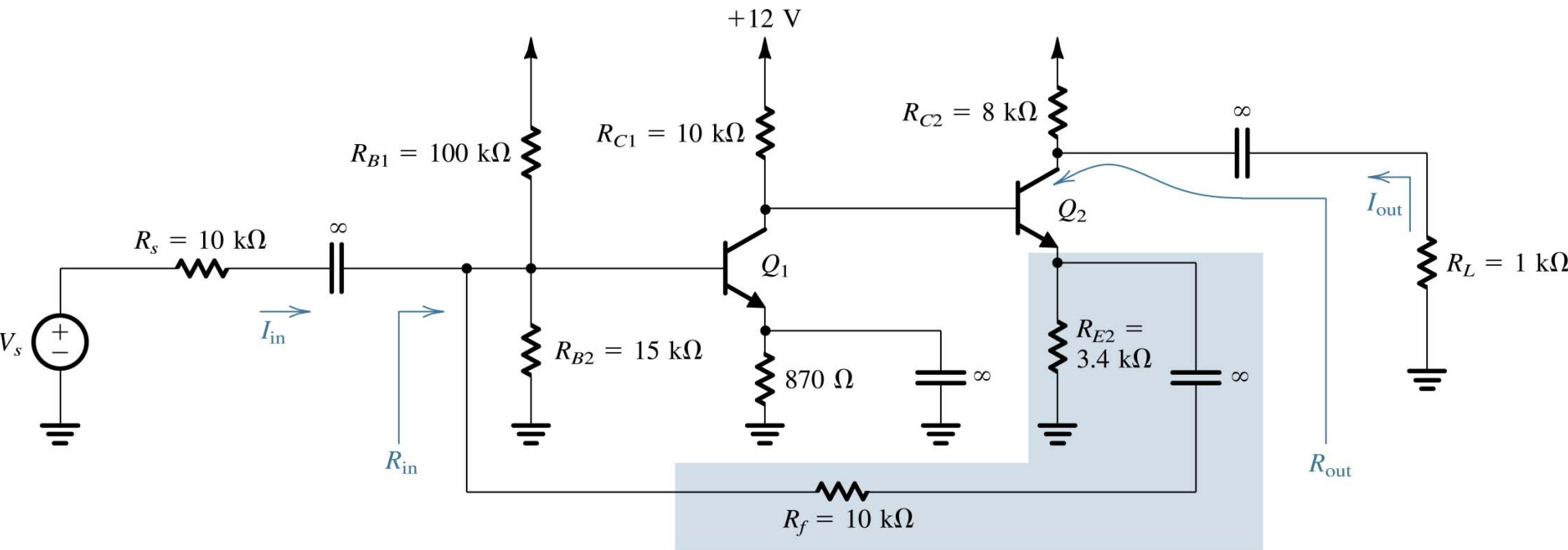
Calculando $A...$



$$R_{i1} = (R_f + R_{E2}) \parallel R_{B1} \parallel R_{B2} \parallel r_{\pi1} = 1.814 \text{ k}\Omega$$

Ejemplo de Retroalimentación P-S (cont.)

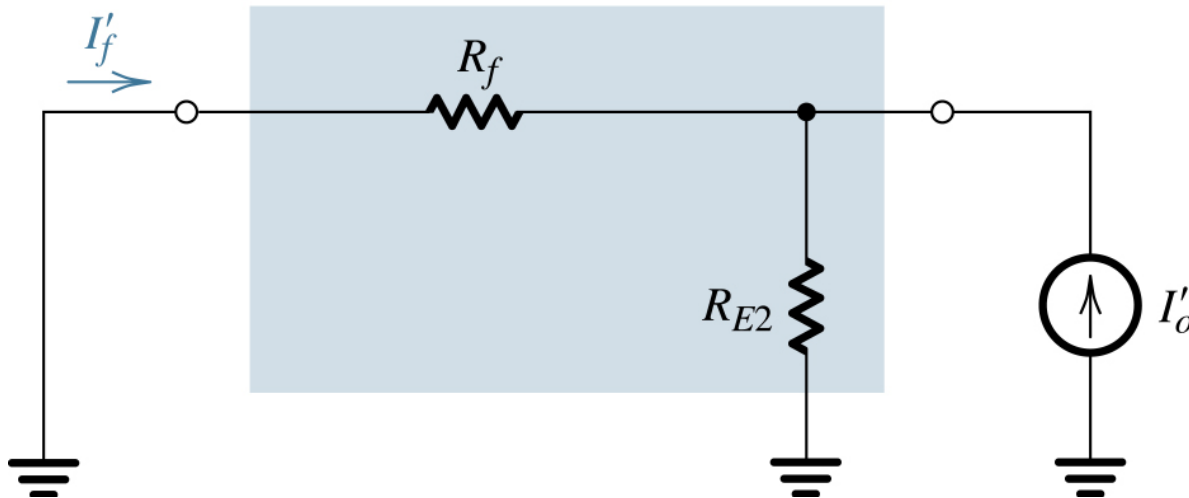
Calculando A ...



$$A = \frac{i_o'}{i_i'} = \frac{-R_{i1}}{(R_{C2} \parallel R_L)} \frac{v_{c2}}{v_{b1}} = \frac{-1.814\text{K}\Omega}{889\Omega} (-341.48)(-0.3415) = -237.95$$

Ejemplo de Retroalimentación P-S (cont.)

Calculando β ...



$$\beta = \frac{i_f'}{i_o'}$$

$$\beta = \frac{i_f'}{i_o'} = \frac{-R_{E2}}{R_{E2} + R_f}$$

$$\beta = -0.254$$

Ejemplo de Retroalimentación P-S (cont.)

$$A_f = \frac{I_o}{I_s} = \frac{A}{1 + A\beta} = \frac{-237.95}{1 + (-237.95)(-0.254)} = \frac{-237.95}{61.44} = -3.87$$

$$A_f = \frac{I_o}{I_s} \approx \frac{1}{\beta} = -3.94$$

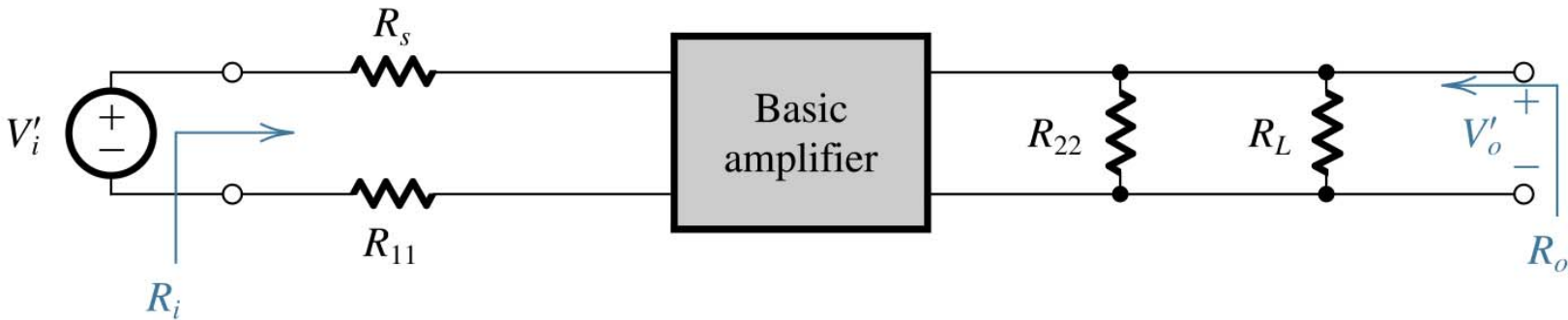
$$R_{if} = R_i / (1 + A\beta) = 1.814\text{K}\Omega / 61.44 = 29.52\Omega$$

$$R_{of} = R_o (1 + A\beta)$$

$$R_o = (R_{E2} \parallel R_f) + \frac{r_{\pi 2} + R_{C1} \parallel r_{o1}}{1 + h_{fe}} = 2.69\text{K}\Omega$$

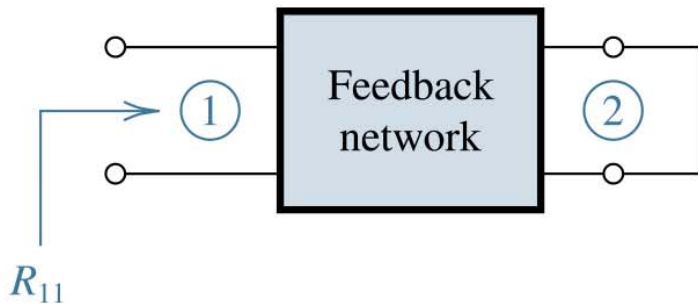
$$R_{of} = 165.23\text{K}\Omega$$

Calculando A y β para el caso S-P

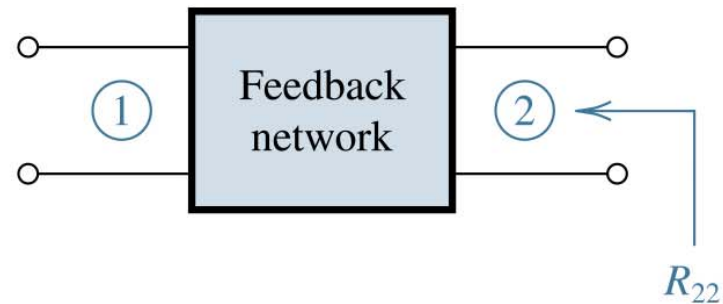


$$A = \frac{V_o'}{V_i'}$$

where R_{11} is obtained from

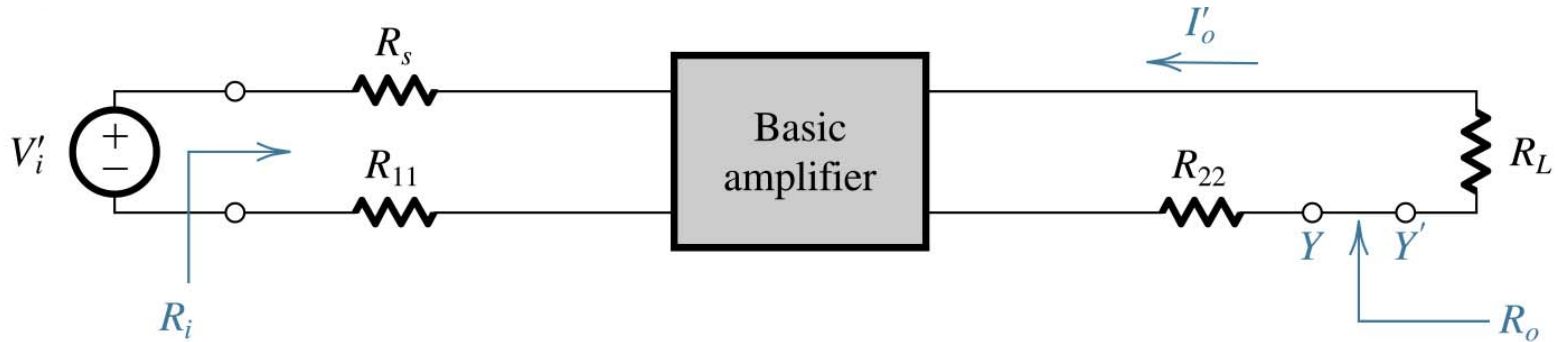


and R_{22} is obtained from



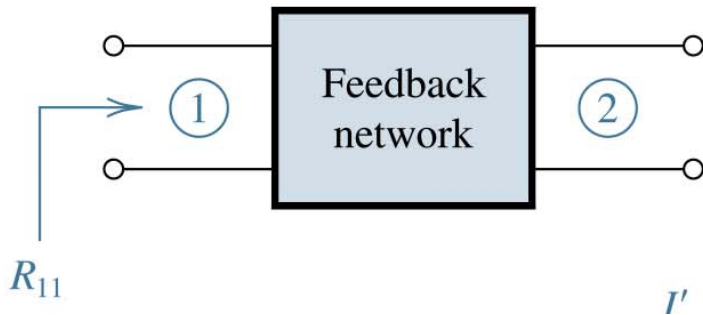
$$\beta = \left. \frac{V_f'}{V_o'} \right|_{I_1=0}$$

Calculando A y β para el caso S-S

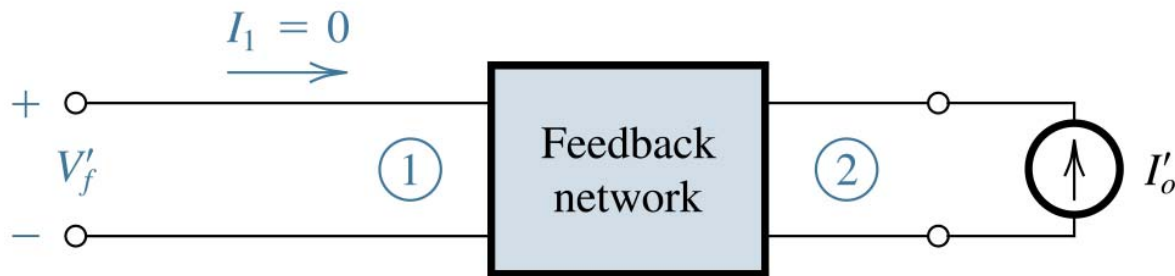
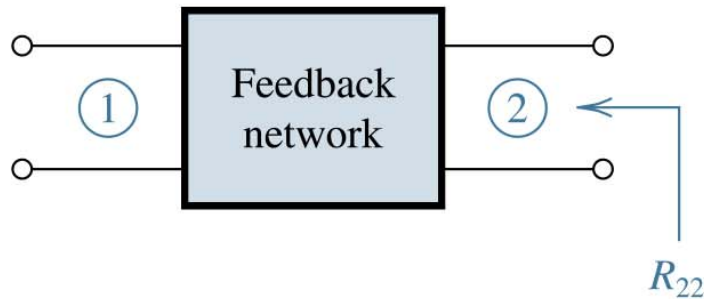


$$A = \frac{I_o'}{V_i'}$$

where R_{11} is obtained from

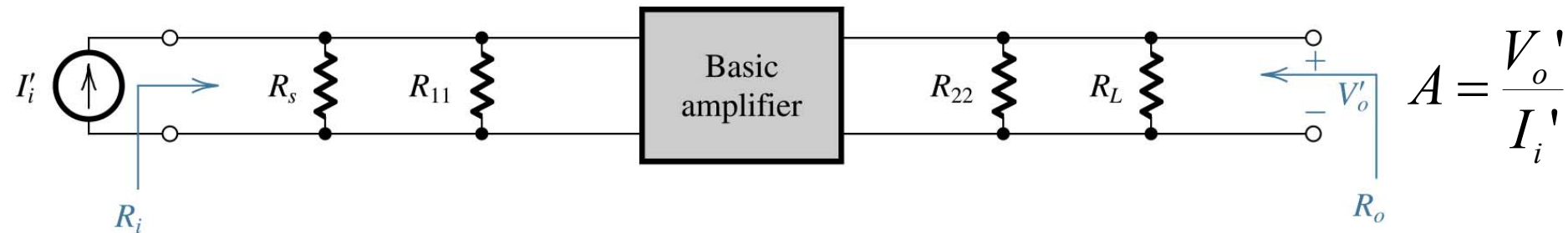


and R_{22} is obtained from

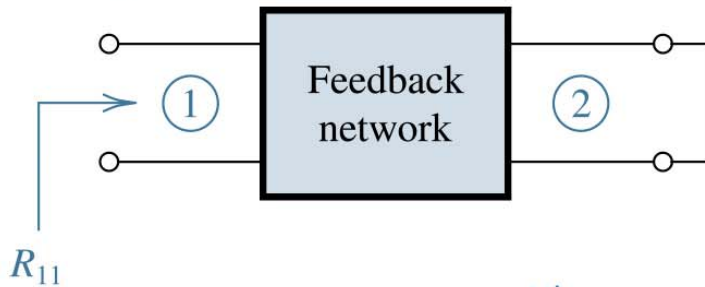


$$\beta = \left. \frac{V_f'}{I_o'} \right|_{I_1=0}$$

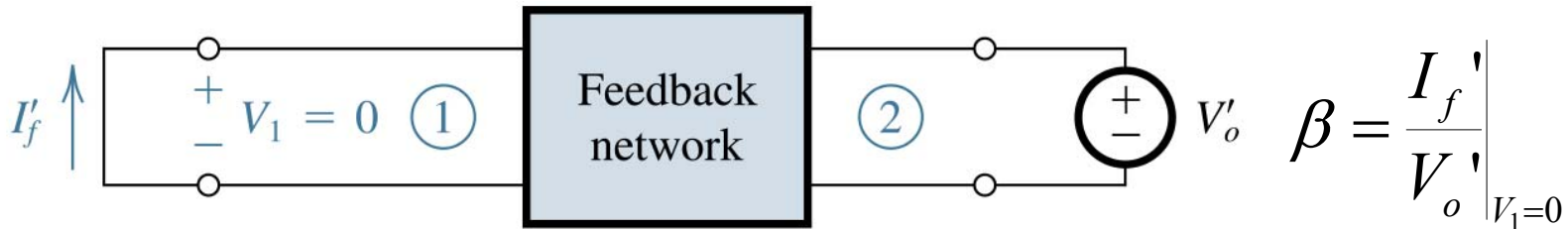
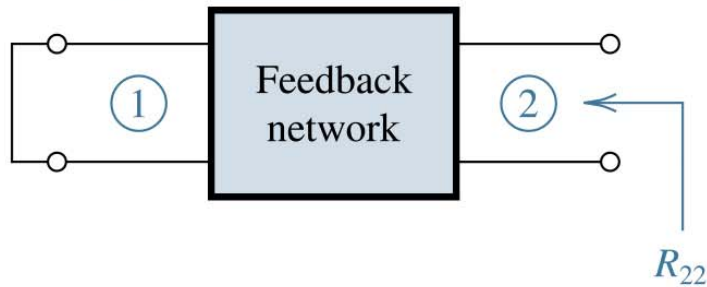
Calculando A y β para el caso P-P



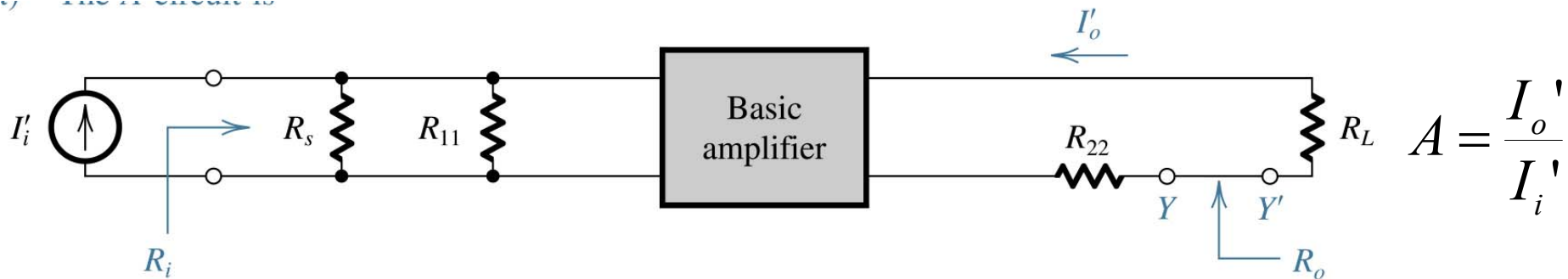
where R_{11} is obtained from



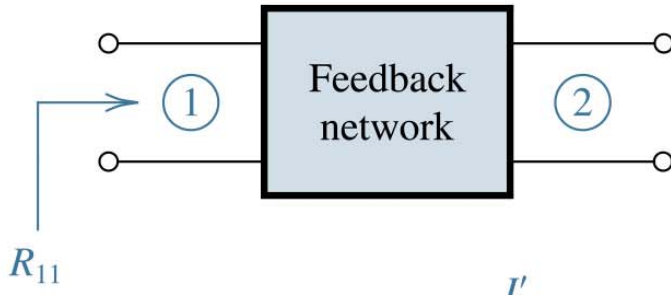
and R_{22} is obtained from



Calculando A y β para el caso P-S



where R_{11} is obtained from



and R_{22} is obtained from

