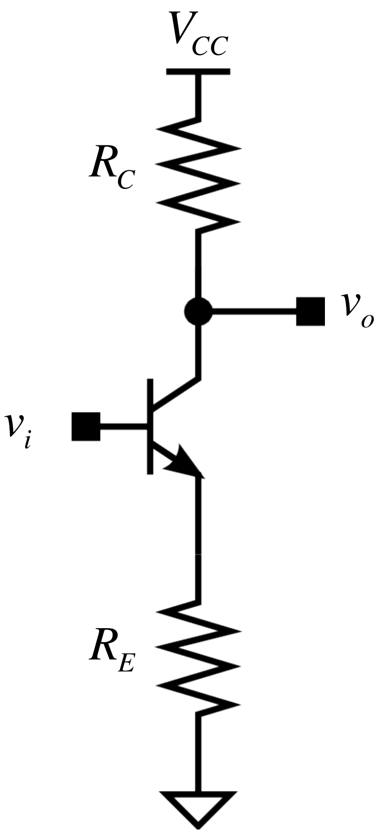
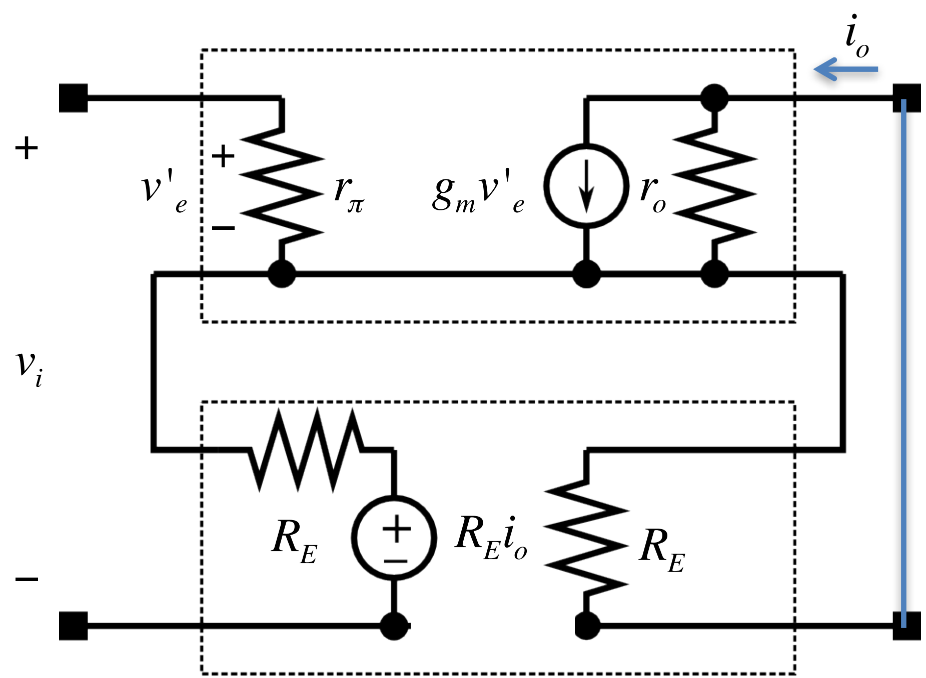
EEE 51: Second Semester 2017 - 2018

Lecture 19

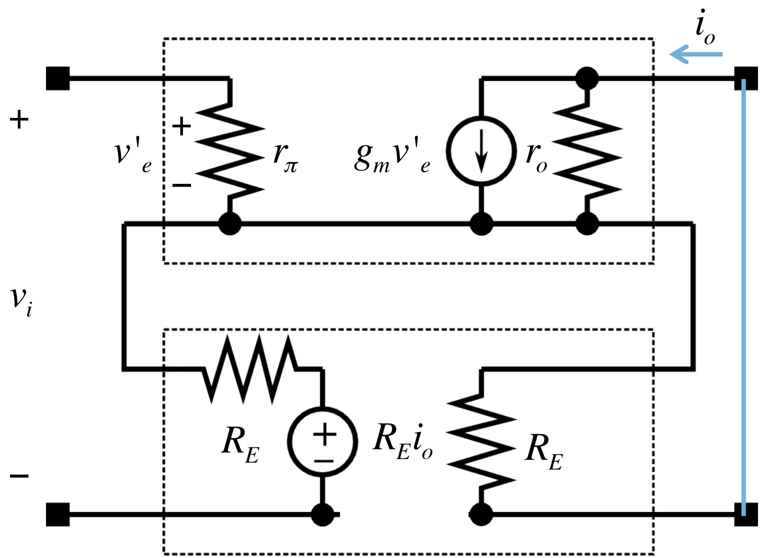
Feedback

Example: CE with Emitter Degeneration





Example: CE with Emitter Degeneration



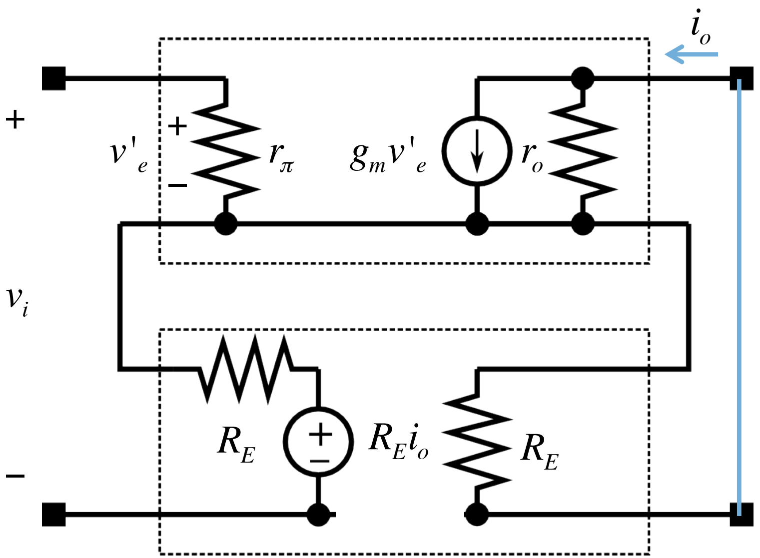
$$v'_e = \underbrace{\left(v_i - R_E i_o\right)}_{v_e} \frac{r_\pi}{r_\pi + R_E}$$

$$i_o = g_m v'_e \frac{r_o}{r_o + R_E}$$

$$= g_m v_e \frac{r_\pi}{r_\pi + R_E} \cdot \frac{r_o}{r_o + R_E}$$

$$G_m = g'_m = \frac{i_o}{v_e} = g_m \cdot \frac{r_\pi}{r_\pi + R_E} \cdot \frac{r_o}{r_o + R_E}$$

Example: CE with Emitter Degeneration



$$v'_e = \underbrace{\left(v_i - R_E i_o\right)}_{v_e} \frac{r_\pi}{r_\pi + R_E}$$

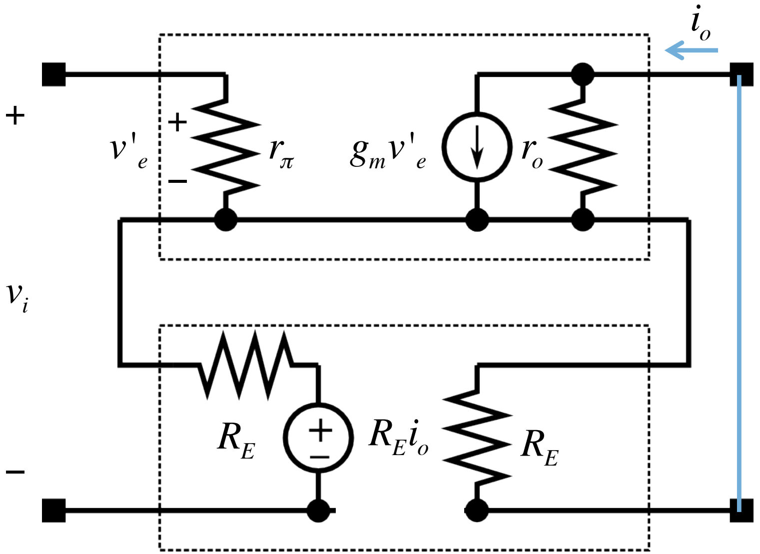
$$i_o = g_m \frac{r_o}{r_o + R_E} v'_e$$

$$= g_m \frac{r_o}{r_o + R_E} v_e \frac{r_\pi}{r_\pi + R_E}$$

$$G_m = \frac{i_o}{v_e} = g_m \cdot \frac{r_\pi}{r_\pi + R_E} \cdot \frac{r_o}{r_o + R_E} \qquad T = G_m F = g_m R_E \cdot \frac{r_\pi}{r_\pi + R_E} \cdot \frac{r_o}{r_o + R_E}$$

$$F = R_E$$

Example: CE with Emitter Degeneration



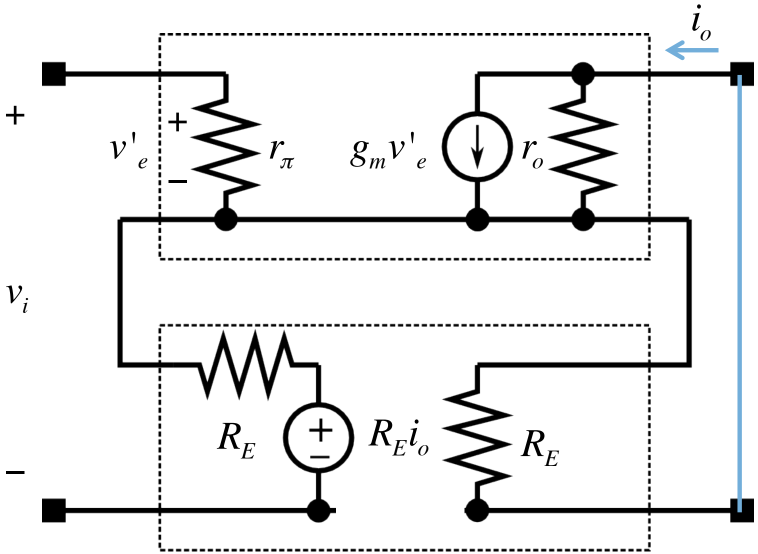
$$v'_e = \underbrace{\left(v_i - R_E i_o\right)}_{v_e} \frac{r_\pi}{r_\pi + R_E}$$

$$i_o = g_m \frac{r_o}{r_o + R_E} v'_e$$

$$= g_m \frac{r_o}{r_o + R_E} v_e \frac{r_\pi}{r_\pi + R_E}$$

$$G_{m,CL} = \frac{i_o}{v_i} = \frac{G_m}{1+T} = \frac{g_m \cdot \frac{r_\pi}{r_\pi + R_E} \cdot \frac{r_o}{r_o + R_E}}{1 + g_m R_E \cdot \frac{r_\pi}{r_\pi + R_E} \cdot \frac{r_o}{r_o + R_E}}$$

Example: CE with Emitter Degeneration R_o:



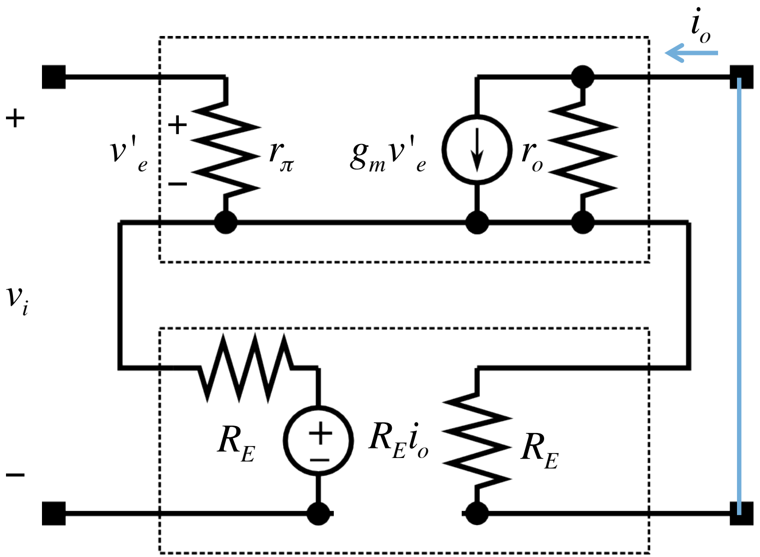
$$R_{o,CL} = (r_o + R_E)(1+T)$$

$$T = G_m F = g_m R_E \cdot \frac{r_\pi}{r_\pi + R_E} \cdot \frac{r_o}{r_o + R_E}$$

$$v_o = \left[i_o - g_m \left(-R_E \frac{r_\pi}{r_\pi + R_E} \cdot i_o \right) \right] r_o + R_E i_o = i_o \left(r_o + g_m r_o R_E \frac{r_\pi}{r_\pi + R_E} + R_E \right)$$

$$= i_o \left[(r_o + R_E) \left(1 + g_m R_E \frac{r_\pi}{r_\pi + R_E} \frac{r_o}{r_o + R_E} \right) \right] = i_o \left[(r_o + R_E)(1+T) \right]$$

Example: CE with Emitter Degeneration



$$v'_e = \underbrace{(v_i - R_E i_o)}_{v_e} \frac{r_\pi}{r_\pi + R_E}$$

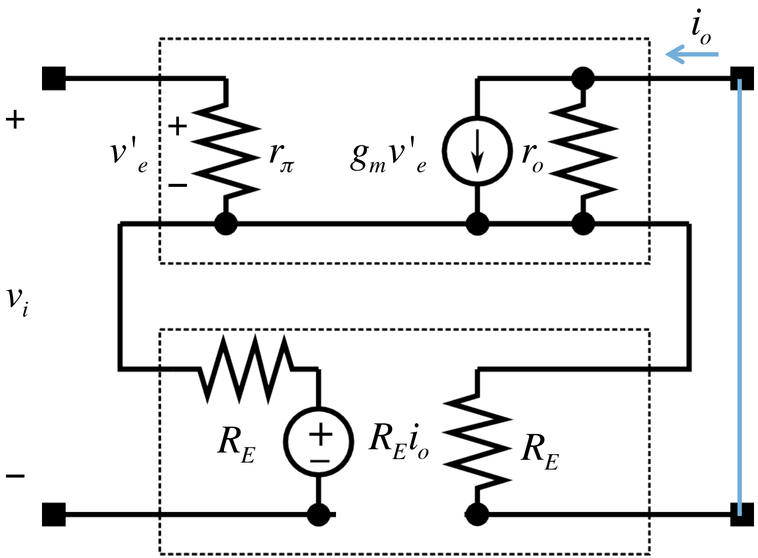
$$i_o = g_m \frac{r_o}{r_o + R_E} v'_e$$

$$= g_m \frac{r_o}{r_o + R_E} v_e \frac{r_\pi}{r_\pi + R_E}$$

$$A_v = \frac{v_o}{v_i} = -G_{m,CL} R_{o,CL}$$

$$= -\frac{g_m \cdot \frac{r_\pi}{r_\pi + R_E} \cdot \frac{r_o}{r_o + R_E}}{1 + g_m R_E \cdot \frac{r_\pi}{r_\pi + R_E} \cdot \frac{r_o}{r_o + R_E}} \cdot \left(\left[(r_o + R_E) \left(1 + g_m R_E \frac{r_\pi}{r_\pi + R_E} \frac{r_o}{r_o + R_E} \right) \right] \parallel R_C \right)$$

Example: CE with Emitter Degeneration R_i:

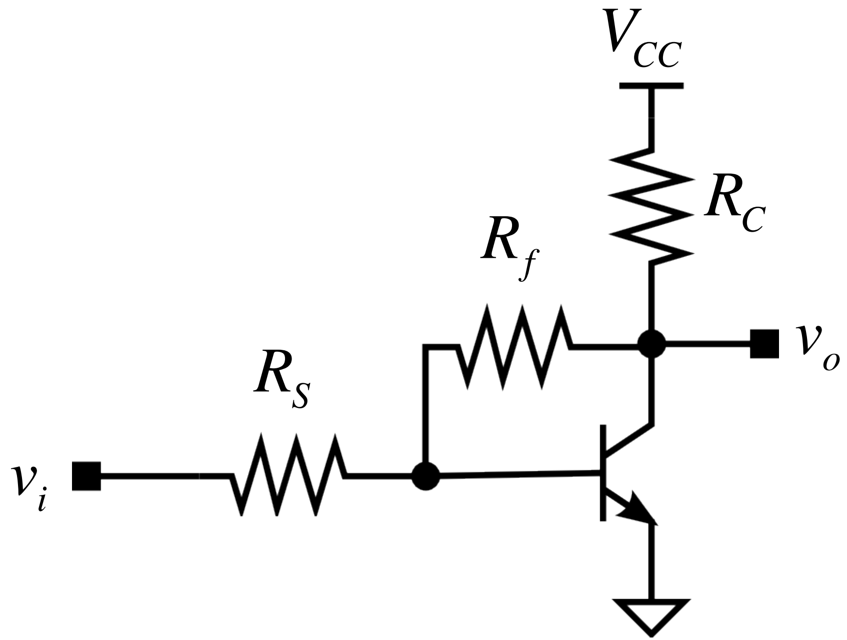


$$R_{i,CL} = \left(r_\pi + R_E\right)\left(1 + T\right)$$

$$T = G_m F = g_m R_E \cdot \frac{r_\pi}{r_\pi + R_E} \cdot \frac{r_o}{r_o + R_E}$$

$$i_i = \frac{v_e}{r_\pi + R_E} = \frac{\left(v_i - R_E \cdot i_o\right)}{r_\pi + R_E} = \left(v_i - R_E \frac{G_m}{1+T} v_i\right)\frac{1}{r_\pi + R_E} = \frac{v_i}{\left(1+T\right)\left(r_\pi + R_E\right)}$$

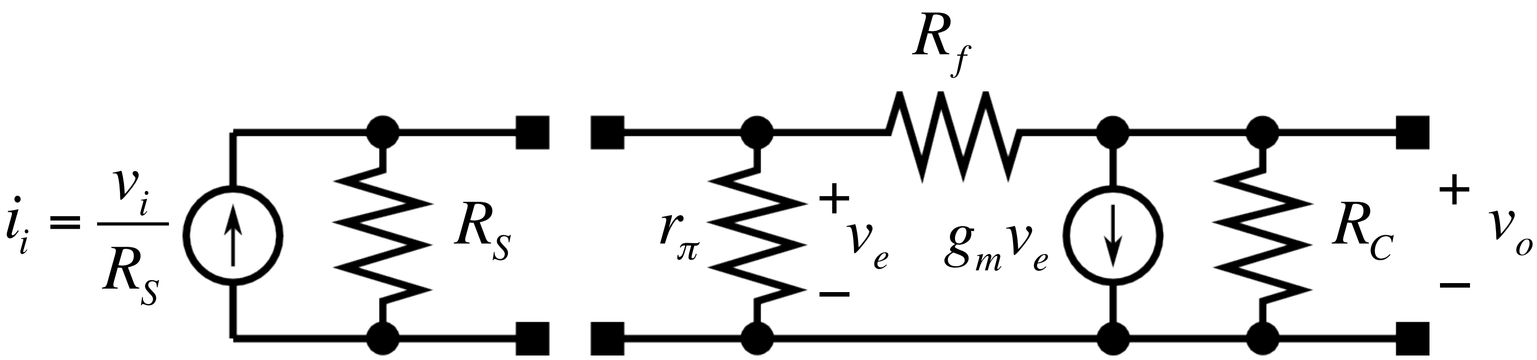
Feedback Example



What feedback topology is used?

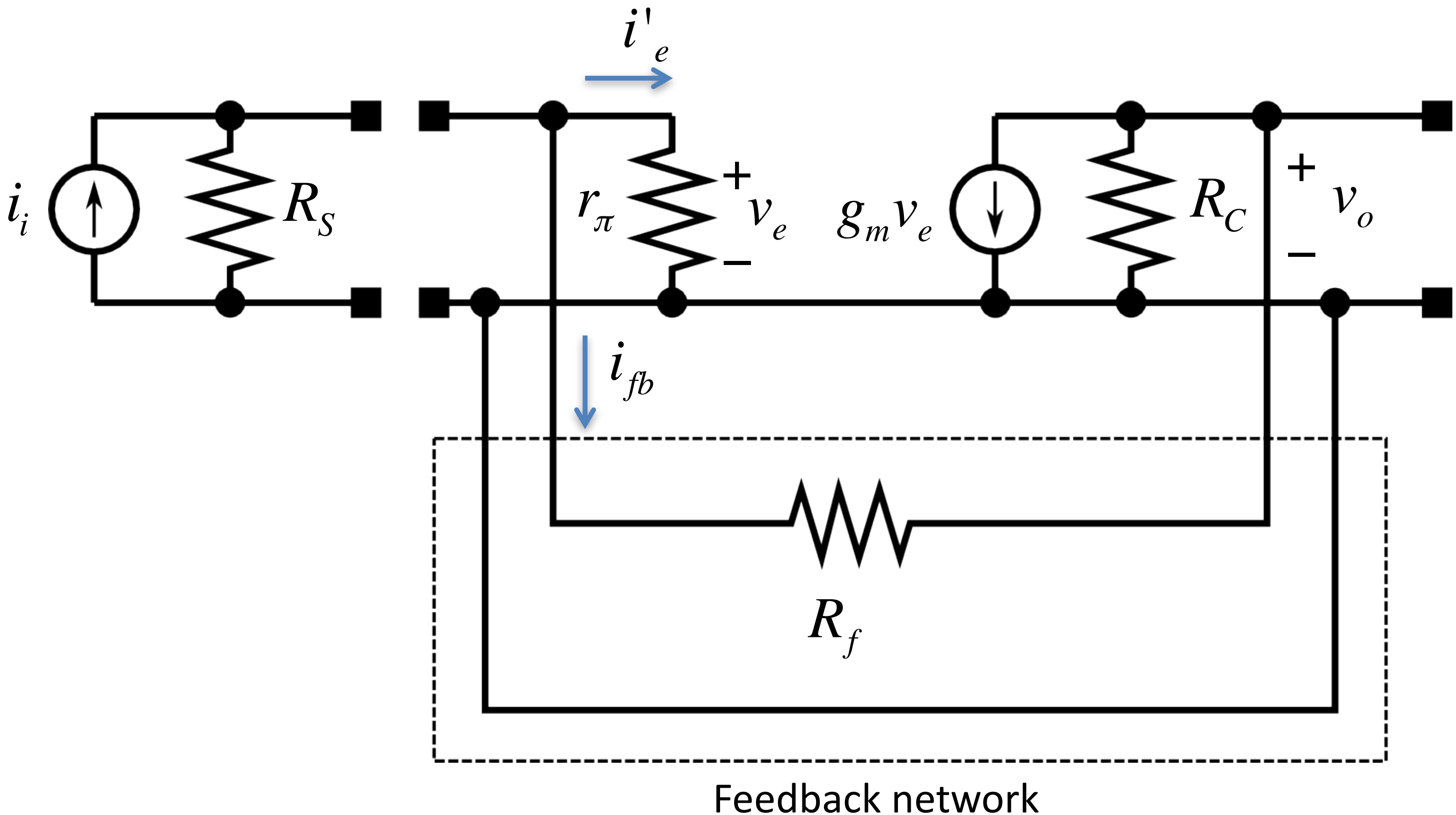
Small Signal Model

- Replace the voltage input with the Norton equivalent circuit:

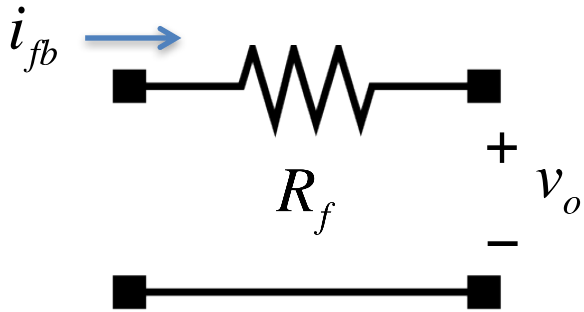


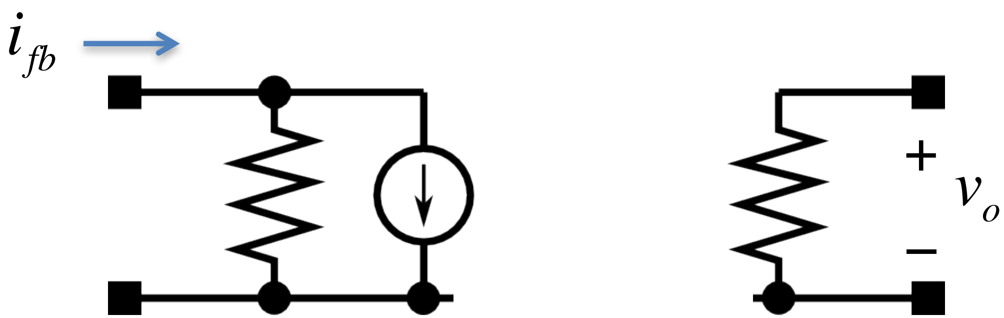
Where is the summing node?

Small Signal Model

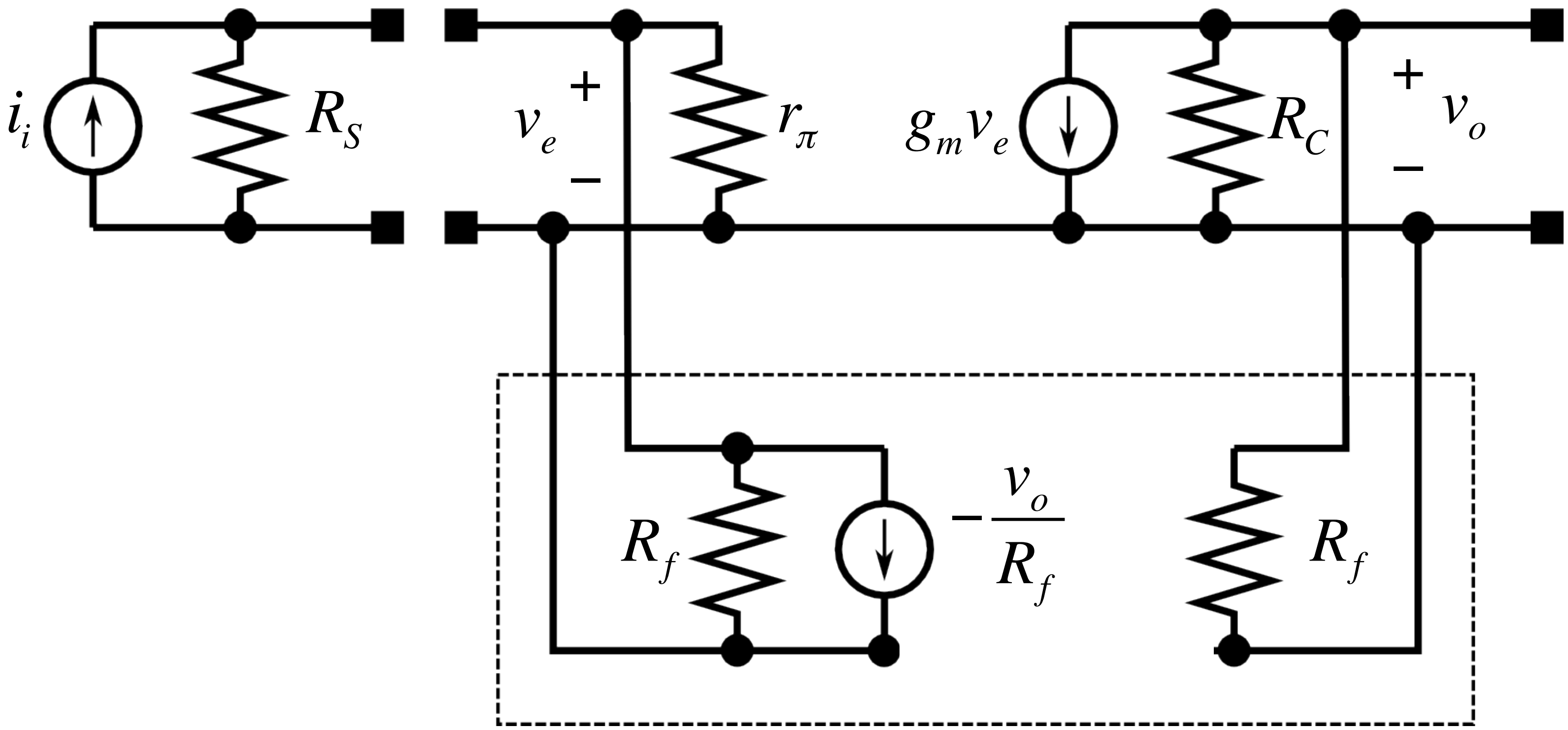


Modeling the Feedback Network



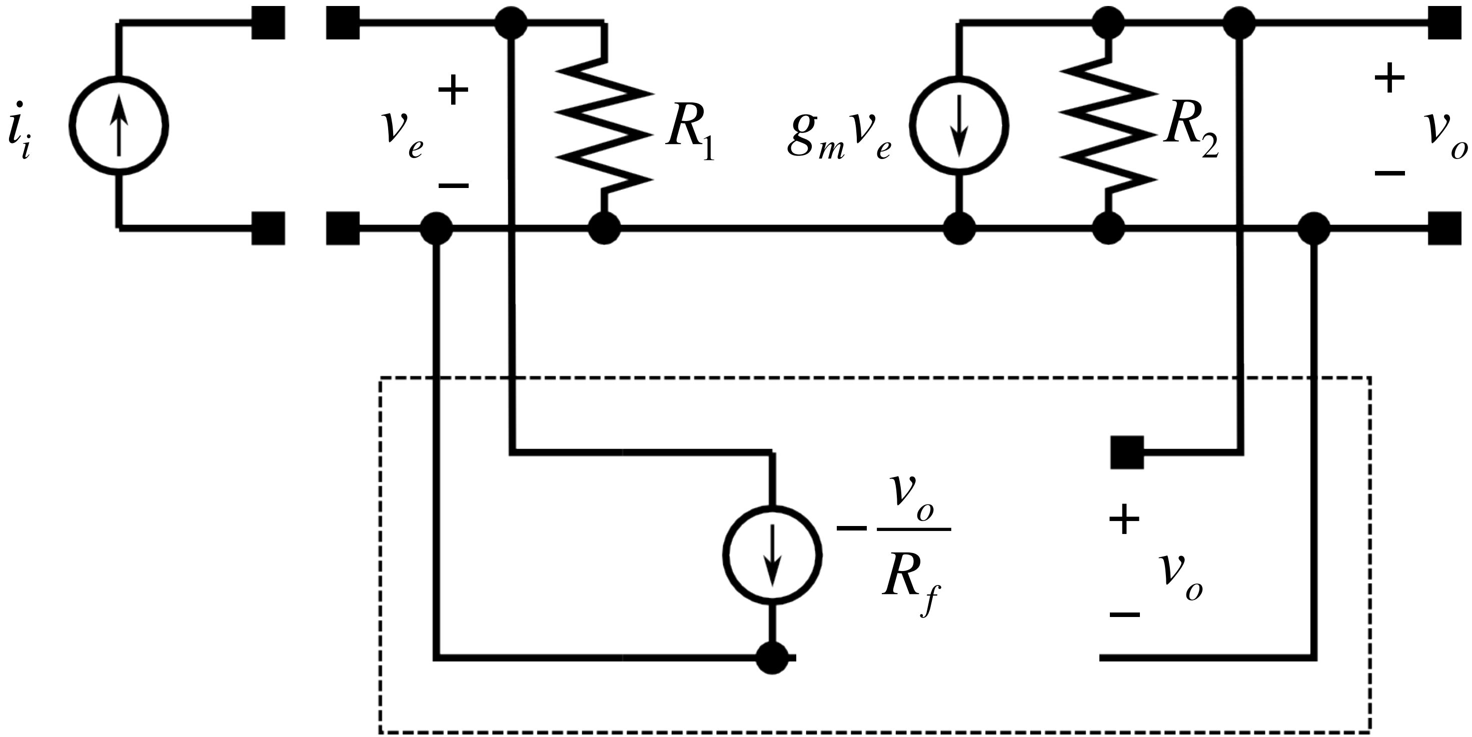


Equivalent Feedback Topology



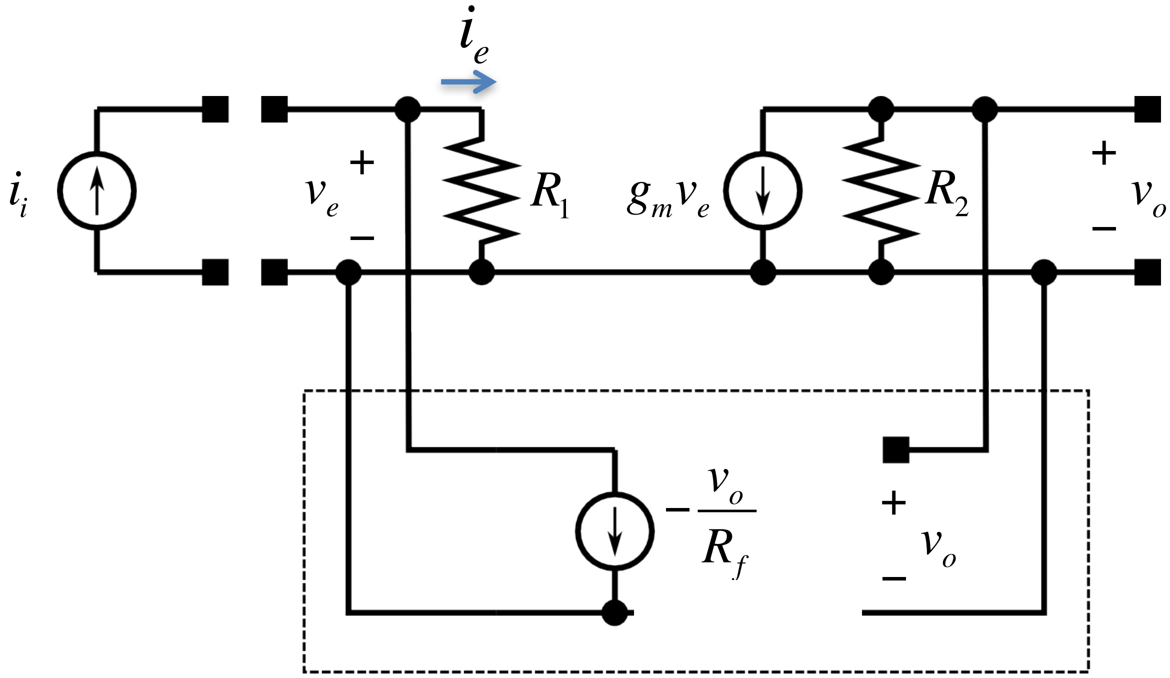
Next step?

Taking Loading Into Account



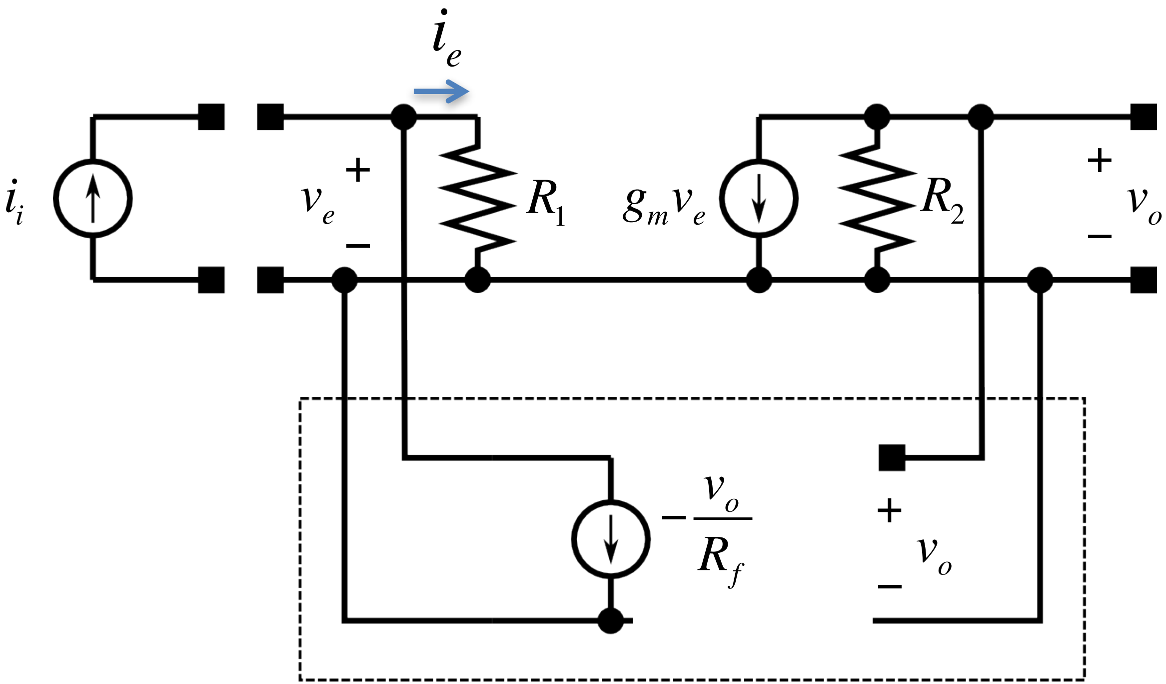
$R_1 = R_S \parallel R_f \parallel r_\pi$ $R_2 = R_C \parallel R_f$

Forward Gain



$R_1 = R_S \parallel R_f \parallel r_\pi \qquad R_2 = R_C \parallel R_f$

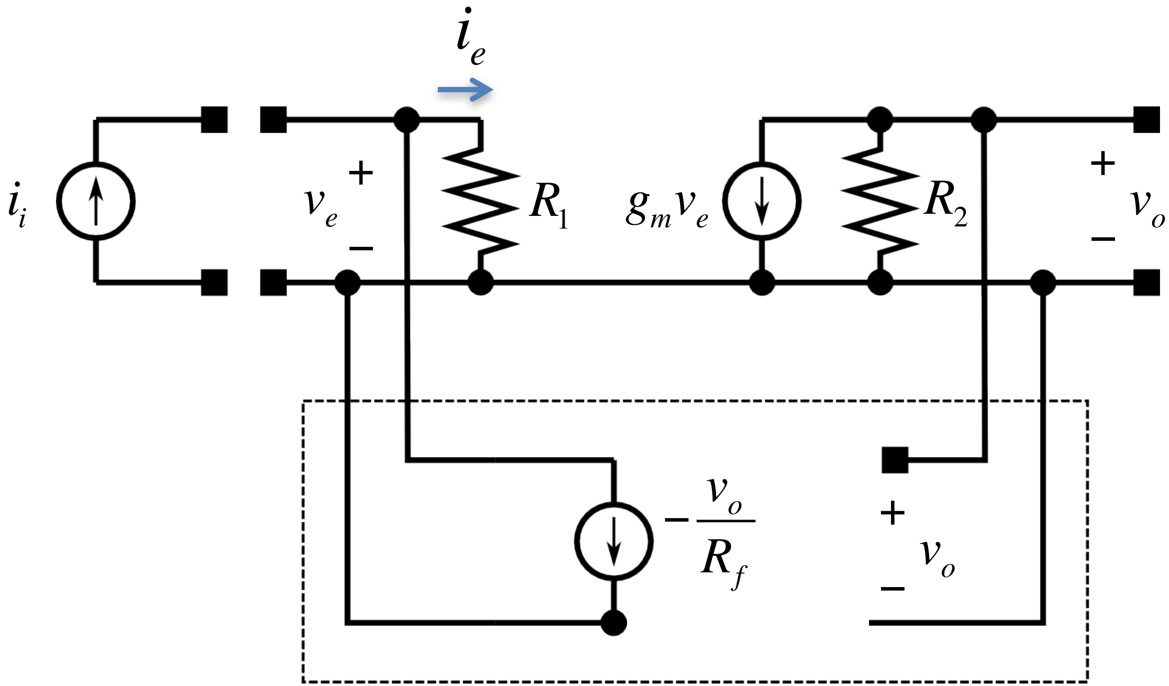
$$\frac{v_o}{i_e} = -g_m R_1 R_2 \qquad f = -\frac{1}{R_f} \qquad T = \frac{g_m}{R_f} R_1 R_2$$



$R_1 = R_S \parallel R_f \parallel r_\pi$ $\quad$ $R_2 = R_C \parallel R_f$

$$\frac{v_o}{i_i} = -\frac{g_m R_1 R_2}{1 + \frac{g_m}{R_f} R_1 R_1}$$

$$= -R_f \frac{\frac{g_m}{R_f} R_1 R_2}{1 + \frac{g_m}{R_f} R_1 R_1}$$

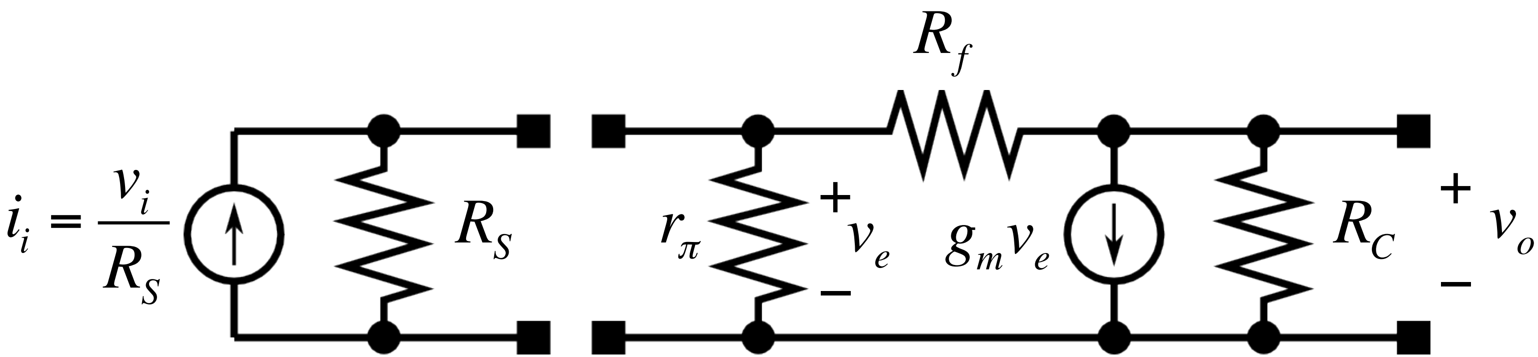


$R_1 = R_S \parallel R_f \parallel r_\pi$ $\qquad$ $R_2 = R_C \parallel R_f$

$$\frac{v_o}{v_i} = \frac{v_o}{i_i}\frac{1}{R_S} = -\frac{1}{R_S}\left[\frac{g_m R_1 R_2}{1 + \frac{g_m}{R_f} R_1 R_1}\right]$$

$$= -\frac{R_f}{R_S}\left[\frac{\frac{g_m}{R_f} R_1 R_2}{1 + \frac{g_m}{R_f} R_1 R_1}\right]$$

Direct Solution



$$\frac{v_o}{v_i} = -\frac{R_f}{R_S}\left[\frac{\frac{1}{R_f}\left(g_m - \frac{1}{R_f}\right)R_1R_2}{1 + \frac{1}{R_f}\left(g_m - \frac{1}{R_f}\right)R_1R_1}\right]$$

Why not use the direct solution all the time?

Next Meeting

- Feedback Amplifiers