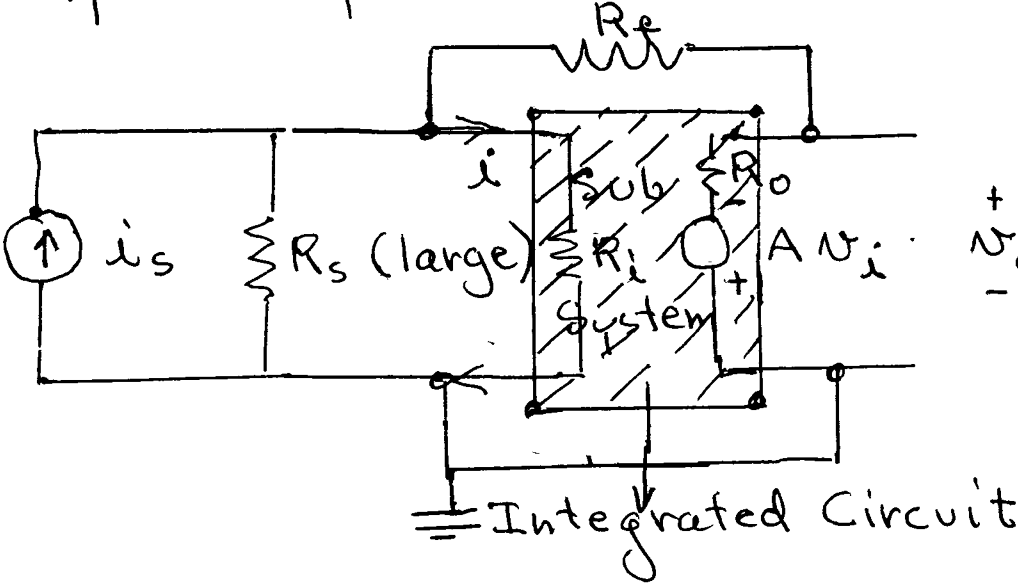
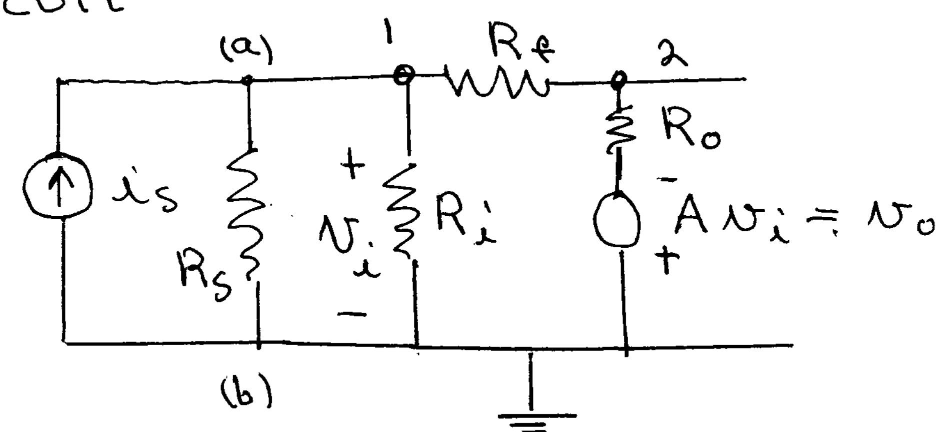
Many of the book exercises are exercises in algebra.

Many applications minimize algebra because one wishes to isolate the influence of one part of an overall circuit on another. The analysis can be broken into sub-analysis which are much simpler.

Example Dependent Source Analysis



Circuit



Ans ? $v_o \simeq - R_f i_s$

The sub-circuit disappears

Node (1)

(1) $$v_i\left(\frac{1}{R_i}+\frac{1}{R_s}\right)+\frac{v_i-v_o}{R_f}=+i_s$$

Node (2)

(2) $$\frac{v_o+Av_i}{R_o}+\frac{v_o-v_i}{R_f}=0$$

(1) $$v_i\left(\frac{1}{R_i}+\frac{1}{R_s}+\frac{1}{R_f}\right)=+i_s+\frac{v_o}{R_f}$$

sub in (2)

$$v_o\left(\frac{1}{R_o}+\frac{1}{R_f}\right)+\left(\frac{A}{R_o}-\frac{1}{R_f}\right)\frac{\left(+i_s+\frac{v_o}{R_f}\right)}{\frac{1}{R_i}+\frac{1}{R_s}+\frac{1}{R_f}}$$

$$=0$$

$$v_o\left(\frac{1}{R_o}+\frac{1}{R_f}+\frac{1}{R_f}\left(\frac{A}{R_o}-\frac{1}{R_f}\right)\frac{1}{\frac{1}{R_i}+\frac{1}{R_s}+\frac{1}{R_f}}\right)+\left(\frac{A}{R_o}-\frac{1}{R_f}\right)\frac{i_s}{\left(\frac{1}{R_i}+\frac{1}{R_s}+\frac{1}{R_f}\right)}$$

$$=0$$

When $A \to \infty$ $\boxed{\frac{v_o}{R_f}=-i_s}$ as above

"Feedback" Picture with Flow Graphs

Two node equations are:

$$\frac{v_o + A v_i}{R_o} + \frac{v_o - v_i}{R_f} = 0$$

$$\frac{v_i}{R_i} + \frac{v_i}{R_s} - i_s + \frac{v_i - v_o}{R_f} = 0$$

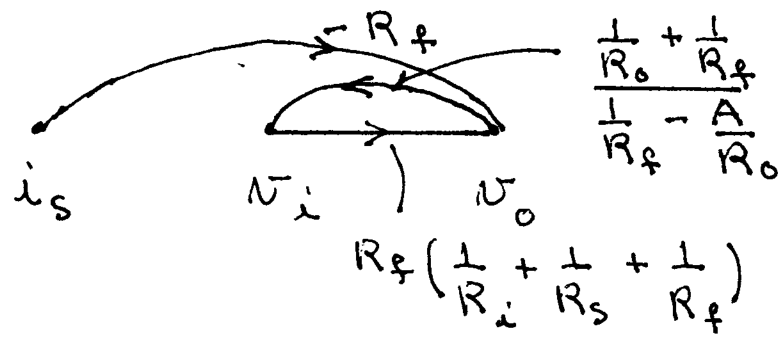
Unknowns v_i and v_o known i_s

rewrite these as

$$v_i = \frac{\left(\frac{1}{R_o} + \frac{1}{R_f}\right)}{\frac{1}{R_f} - A/R_o} v_o$$

$$v_o = R_f\left(\frac{1}{R_i} + \frac{1}{R_s} + \frac{1}{R_f}\right) v_i - R_f i_s$$

Graph



$$v_o = \frac{-R_f i_s}{\underbrace{1 - \frac{R_f\left(1/R_o + 1/R_f\right)}{\frac{1}{R_f} - \frac{A}{R_o}}\left(\frac{1}{R_i} + \frac{1}{R_s} + \frac{1}{R_f}\right)}_{1 \,-\, \text{"Feedback"}}} \qquad 1$$

Ideal Operational Amplifier Conditions

① Input Resistance $R_i \to \infty$ (gigaohms can be realized in practice)

② $A \to \infty$ A in excess of 10^6 can be realized

③ Virtual short ($v_i \to 0$). Note, however since $R_i \to \infty$ the current is very small

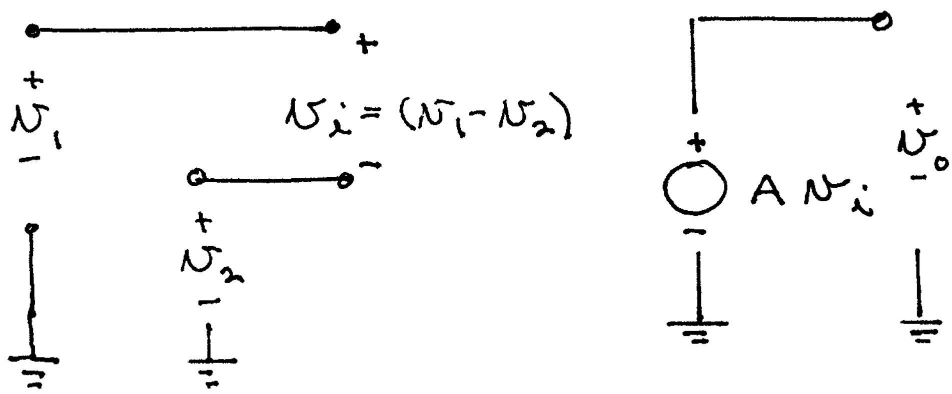
The argument for $v_i \to 0$

We showed that when $A \to \infty$

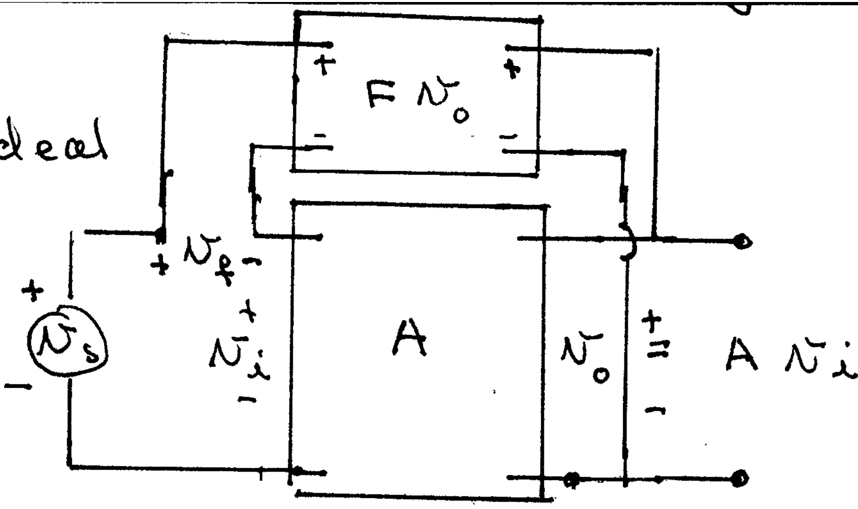
$$v_o/R_f = -i_s$$

so $v_i = v_o/A = -i_s R_f/A \to 0$ (Summing Point Constraint)

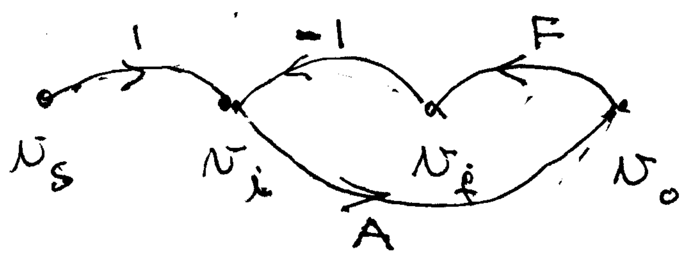
Results in Ideal Op-Amp picture of Fig 14.2



Ideal



$$v_i = v_s - v_f$$
$$v_f = F v_o$$
$$v_o = A v_i = A(v_s - v_f)$$

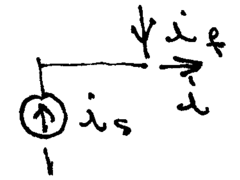


$$v_o = \frac{A v_s}{1 + AF}$$

Negative Feedback

v_f in opposition to v_s

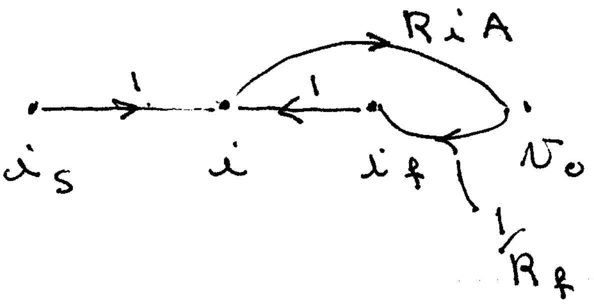
Curren Feedback



$i = i_s + i_f$

$v_o = A(R_i\, i) = (A R_i)\, i$

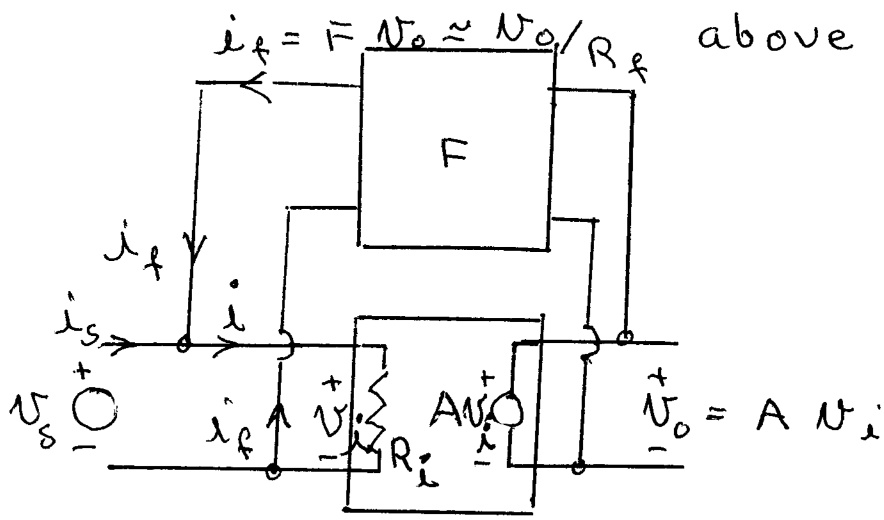
$i_f \cong v_o / R_f$



$\therefore\ v_o = \dfrac{R_i A}{1 - \dfrac{R_i A}{R_f}}$ ← feed back equation

positive feedback

Ideal Picture



above