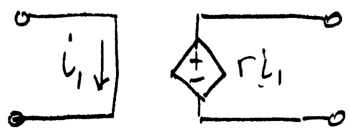
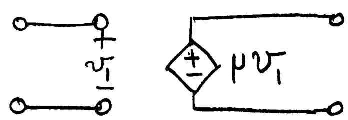
4.1 Linear Dependent Sources

- basis of the operational amplifier
- basis of feedback control

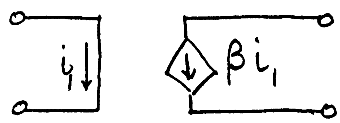
There are four basic types — these are all linear



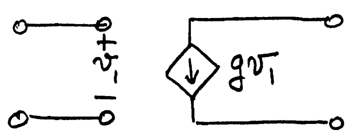
current controlled voltage source
r has units of ohms
transresistance



voltage controlled voltage source
μ is voltage gain



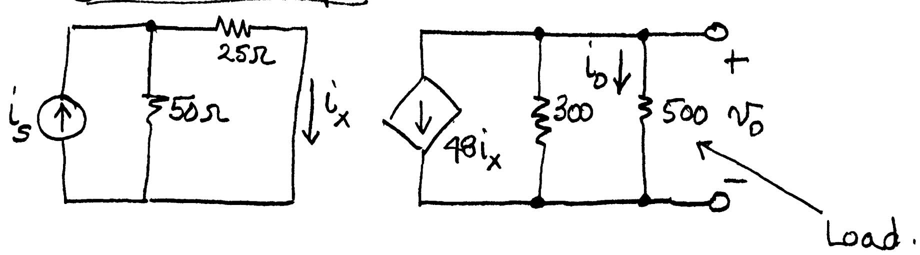
current controlled current source
β is current gain



voltage controlled current source
g has units of Siemens
transconductance

1. dependent sources are not in catalogs
2. can not be turned on/off individually — always a source and a <u>controlling</u> voltage/current

Figure 4-4 determine output



$$i_x = \frac{50}{50+25} i_s = \frac{2}{3} i_s$$

$$v_o = -\ 48 i_x \frac{(300)(500)}{(300+500)} = -48\left(\frac{2}{3} i_s\right)(187.5) = -6000\, i_s$$

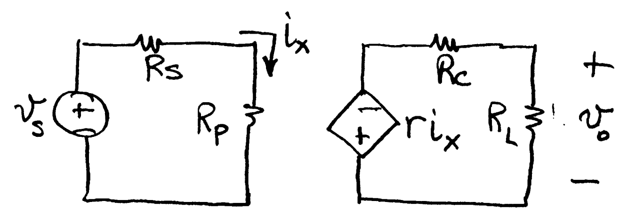
① can amplify very small currents

② signal is inverted. This is common in many amplifiers.

$$i_o = \frac{v_o}{R_L} = \frac{-6000\, i_s}{500} = -12 i_s$$

$$P_o = v_o i_o = (-6000 i_s)(-12 i_s) = 72{,}000\, i_s^2$$

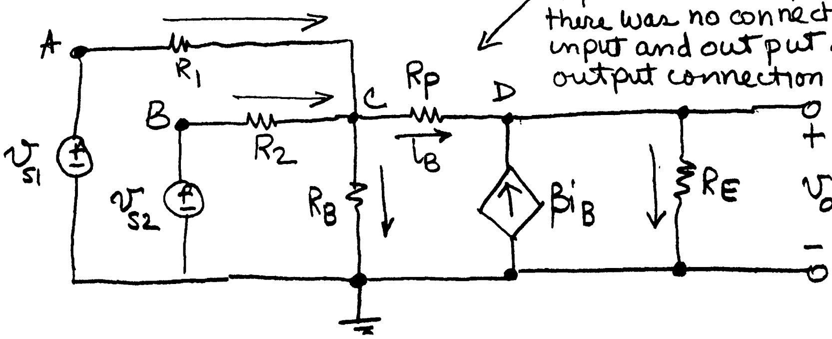
Exercise 4-1 determine output



$$i_x = \frac{v_s}{R_s + R_p}$$

$$v_o = \left(\frac{R_L}{R_L + R_c}\right)(-r i_x) = \left(\frac{R_L}{R_L + R_c}\right)\left(-\frac{r v_s}{R_s + R_p}\right)$$

Fig. 4-6



in previous examples there was no connection between input and output. This input output connection is called feedback.

v_A, v_B are known

find v_C, v_D using KCL

Procedure: solve without dependent source being explicit, then add control relationship

@ C $\Sigma i = 0$ + in

$$\frac{v_{S1} - v_C}{R_1} + \frac{v_{S2} - v_C}{R_2} - \frac{v_C}{R_B} - \frac{v_C - v_D}{R_p} = 0$$

@ D

$$\frac{v_C - v_D}{R_p} + \beta i_B - \frac{v_D}{R_E} = 0$$

Don't use i_B here

$$\left(-\frac{1}{R_1} - \frac{1}{R_2} - \frac{1}{R_B} - \frac{1}{R_p}\right) v_C + \left(\frac{1}{R_p}\right) v_D = \frac{v_{S1}}{R_1} + \frac{v_{S2}}{R_2} \qquad (1)$$

$$\left(\frac{1}{R_p}\right) v_C \quad \left(-\frac{1}{R_p} - \frac{1}{R_E}\right) v_D = -\beta i_B$$

Now use controlling connection $\dfrac{v_C - v_D}{R_p} = \beta i_B$

$$\left(\frac{1}{R_p}\right) (v_C) \quad \left(-\frac{1}{R_p} - \frac{1}{R_E}\right) v_D = -\frac{\beta}{R_p} v_C + \beta \frac{v_D}{R_p}$$

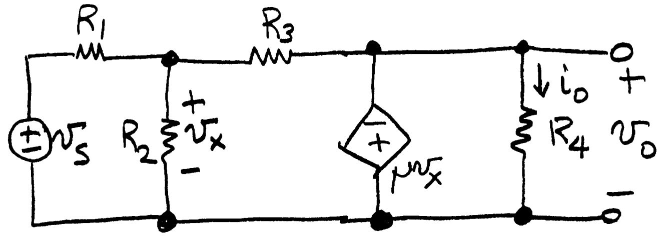
$$\left(\frac{1}{R_p} + \frac{\beta}{R_p}\right) v_C + \left(-\frac{1}{R_p} - \frac{\beta}{R_p} - \frac{1}{R_E}\right) v_D = 0$$

$$\frac{(\beta+1)}{R_p} v_C - \left(\frac{\beta+1}{R_p} + \frac{1}{R_E}\right) v_D = 0 \qquad (2)$$

Solve 1 & 2 simultaneously.

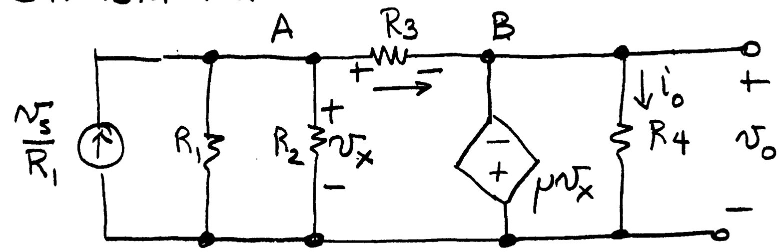
MAY WANT TO MENTION CAN'T SUPERIMPOSE.

Figure 4-7



simplified OP-AMP

do source transformation



ONLY ONE INDEPENDENT NODE ⇒ ONE EQUATION

$$\sum_{+in} i \ @ \quad +\frac{v_s}{R_1} - \frac{v_A}{R_1} - \frac{v_A}{R_2} - \frac{v_A - v_B}{R_3} = 0$$

control constraint $\quad v_A = v_x \ ; \ v_B = v_o$

$$-v_o = \mu v_x = \mu v_A \qquad v_A = v_x = -\frac{v_o}{\mu}$$

$$\frac{v_s}{R_1} - \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) v_A + \frac{v_B}{R_3} = 0$$

$$\frac{v_s}{R_1} - \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)\left(-\frac{v_o}{\mu}\right) + \frac{v_o}{R_3} = 0$$

$$\frac{v_s}{R_1} = -\left[\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)\frac{1}{\mu} + \frac{1}{R_3}\right] v_o$$

$$\frac{v_s}{v_o} = -\frac{\mu \frac{1}{R_1}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{(1+\mu)}{R_3}}$$

signal inversion

output independent of R_4

consider situation where $\mu \gg 1$

$$\frac{v_s}{v_o} \approx -\frac{\frac{1}{R_1}}{\frac{1}{R_3}} = -\frac{R_3}{R_1}$$