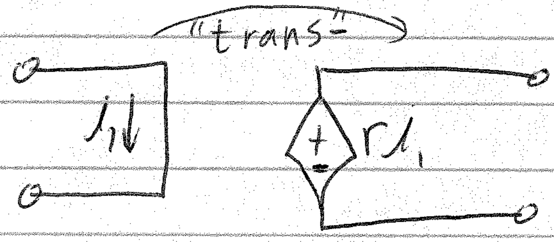
We will move on to Chapter 4 and talk about Active Ckts, which can take power from other places and inject it into a ckt, providing amplification or more power out than was put in.

Simplest Models: Dependent Sources

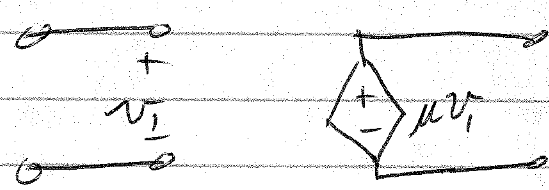
4 Types of Dependent Sources



CCVS

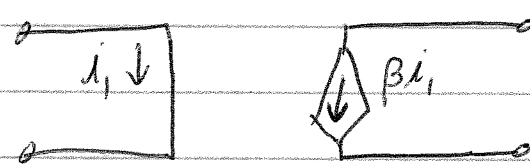
r = trans resistance

This device is a trans-resistor or transistor



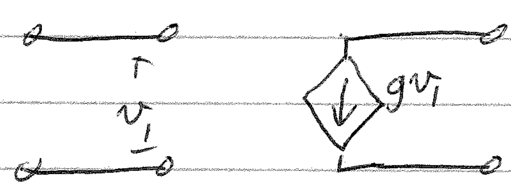
VCVS

μ = Voltage Gain



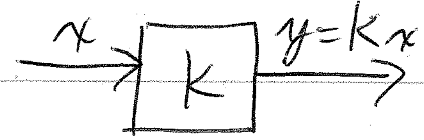
CCCS

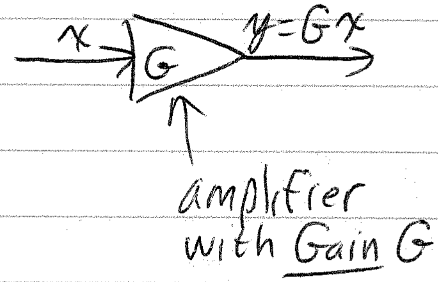
β = Current Gain



VCCS

g = trans conductance

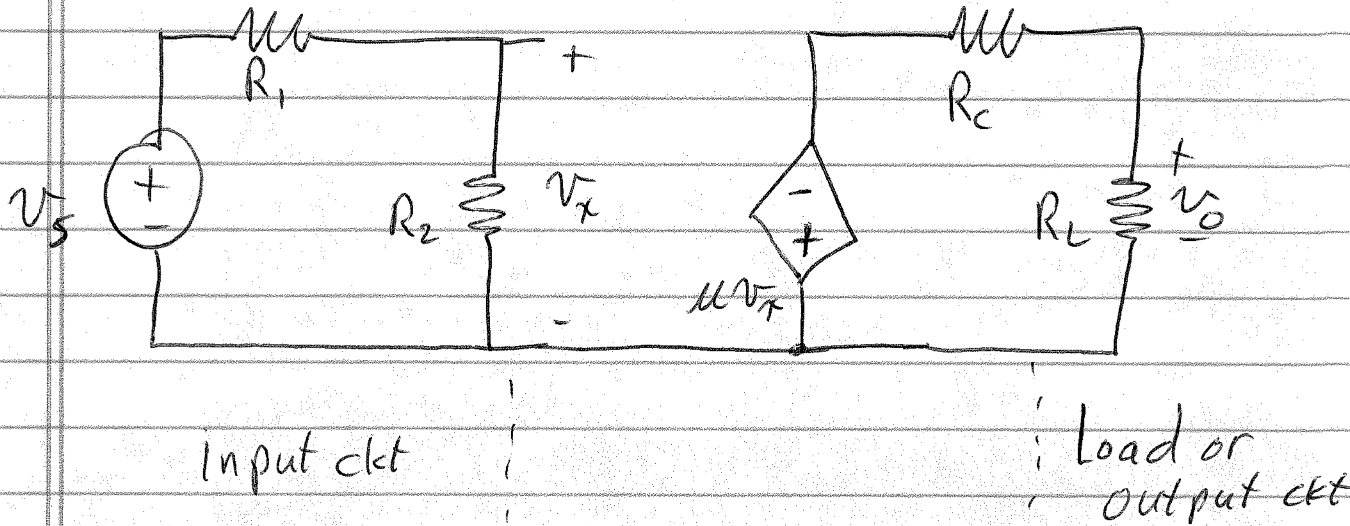
General: 

or 

We will use diamonds for dependent sources, not universal.

We analyse ckts w/ Dependent Src. just as we do with other elements, just remember that if you use superposition you always leave Dependent Sources turned on, or active.

Let's do a variation on an example in the text:



Good thing about Dep. Src, they can separate a ckt into 2 parts that pass a value but do not otherwise interact.

Voltage Division: $v_o = \frac{R_L}{R_c+R_L}(-\mu v_x)$

$$v_o = -\mu \frac{R_L}{R_c+R_L} v_x$$

Find v_x:

Voltage Division:

$$v_x = \frac{R_2}{R_1+R_2} v_s \longrightarrow v_o = \underbrace{-\mu\left(\frac{R_L}{R_c+R_L}\right)\left(\frac{R_2}{R_1+R_2}\right)}_{\text{Inverting, gain } G} v_s$$

$$v_o = \underset{\text{gain}}{G}\, v_s$$

Let all R's be $1\,k\Omega$ and $\mu = 100{,}000 = 10^5$ as in text:

$$v_o = -\mu\left(\frac{1}{2}\right)\left(\frac{1}{2}\right)v_s$$

$$= -10^5\left(\frac{1}{4}\right)v_s = -25{,}000\, v_s$$

"Input Power"

If $v_s = 100\,\mu V$, $P_2 = \dfrac{(50\,\mu V)^2}{1\,k\Omega} = \dfrac{25 \times 10^{-10}}{1 \times 10^3} W$

$$= 25 \times 10^{-7} W = \underline{2.5\,\mu W}$$

$$v_o = -25{,}000(10^{-4}) = -2.5V$$

output power

$$P_L = \frac{(-2.5V)^2}{1\,k\Omega} = \frac{6.25}{1}\,mW = 6.25\,mW$$

~~Power has increas~~ Output power is

$$\frac{6.25 \times 10^{-3} W}{2.5 \times 10^{-6} W} = 2500 \text{ times}$$

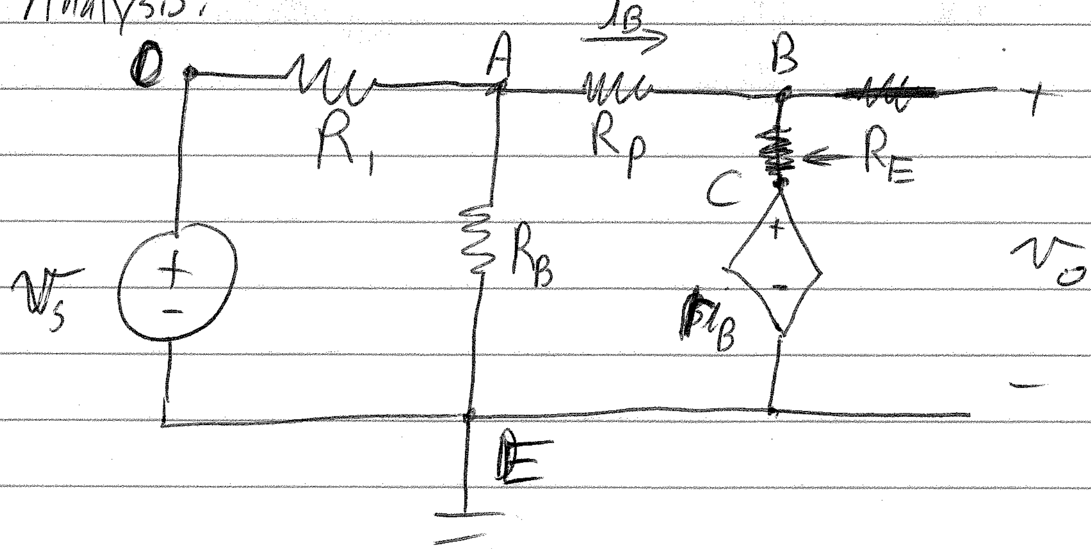
larger than the input power.

This power comes from the dependent src.

They are connected to batteries, the power grid, solar cells, an arc reactor, or something that provides power.

We insert Dependent Sources into Nodal Analysis or Mesh Analysis ~~just as we did~~ simply by substituting the Dependent Output instead of a constant as we do for Independent Sources. We may also have to write the Control Parameter in terms of our variables (Node Voltages or Mesh Currents.)

For example, find v_o in this ckt using Node-Voltage Analysis:



1.) Desired Output − $v_o = v_B$

2.) Control Parameter − $i_B = \dfrac{v_A - v_B}{R_p}$

Fixed Nodes? $v_D = v_S$

$$v_C = r\, i_B = \frac{r}{R_p}(v_A - v_B)$$

(A) $\dfrac{v_A - v_D}{R_1} + \dfrac{v_A}{R_B} + \dfrac{v_A - v_B}{R_p} = 0$

$$\left(\frac{1}{R_1} + \frac{1}{R_B} + \frac{1}{R_p}\right) v_A - \frac{1}{R_p} v_B = \frac{v_S}{R_1}$$

$$\frac{R_1R_p + R_BR_p + R_1R_B}{R_1R_BR_p} v_A - \frac{1}{R_p} v_B = \frac{v_S}{R_1} \longrightarrow (R_1R_p + R_BR_p + R_1R_B) v_A - R_1R_B v_B = R_BR_p v$$

(B) $\dfrac{v_B - v_A}{R_p} + \dfrac{v_B - v_C}{R_E} = 0$

$$-\frac{1}{R_p} v_A + \left(\frac{1}{R_p} + \frac{1}{R_E}\right) v_B - \frac{1}{R_E}\frac{r}{R_p}(v_A - v_B) = 0$$

$$\left(-\frac{1}{R_p} - \frac{r}{R_ER_p}\right) v_A + \left(\frac{1}{R_p} + \frac{1}{R_E} + \frac{r}{R_ER_p}\right) v_B = 0$$

$$-\left(\frac{R_E + r}{R_ER_p}\right) v_A + \left(\frac{R_E + R_p + r}{R_ER_p}\right) v_B = 0$$

$\times R_ER_p$: $\quad -(R_E + r) v_A + (R_E + R_p + r) v_B = 0$

Need v_B, so write $\quad v_A = \dfrac{R_E + R_p + r}{(R_E + r)} v_B$

Sub into (A) $\quad \dfrac{(R_1R_p + R_BR_p + R_1R_B)(R_E + R_p + r)}{R_E + r} v_B - \cancel{\dfrac{1}{R_p}} R_1R_B v_B = R_BR_p v_S$

$$\frac{(R_1R_p+R_BR_p+R_1R_B)(R_E+R_p+r)-R_1R_B(R_E+r)}{R_E+r}v_B = R_BR_p v_S$$

$$\text{Or } v_B = \frac{(R_E+r)(R_BR_p)}{(R_1R_p+R_BR_p+R_1R_B)(R_E+R_p+r)-R_1R_B(R_E+r)}v_S$$

$$v_B = \frac{\cancel{r}\left(\frac{R_E}{r}+1\right)(R_BR_p)}{\cancel{r}\left[(R_1R_p+R_BR_p+R_1R_B)\left(\frac{R_E}{r}+\frac{R_p}{r}+1\right)-R_1R_B\left(\frac{R_E}{r}+1\right)\right]}v_S$$

Very complicated

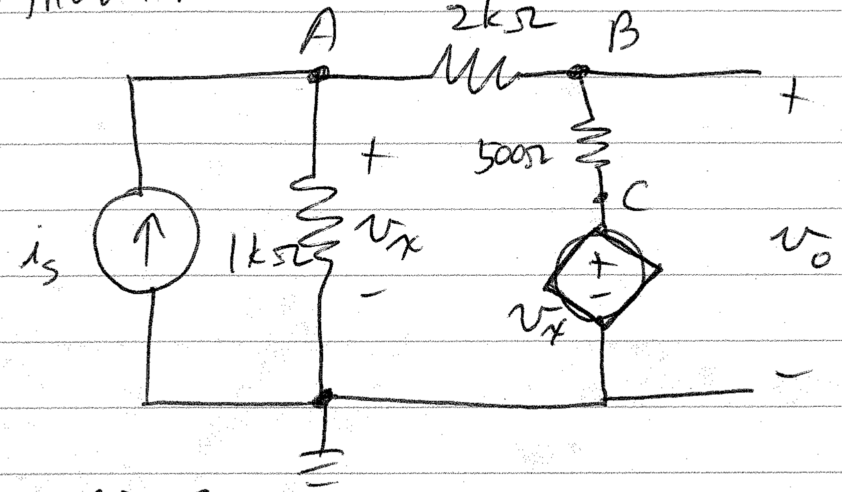
Take limit $r\to\infty$:

$$v_B = \frac{R_BR_p}{R_1R_p+R_BR_p}v_S$$

$$v_B = \frac{R_B}{R_1+R_B}v_S$$

less than 1!

Another:



$$v_o = v_B$$

$$v_c = v_x$$

$$v_x = \frac{v_A}{\cancel{4k\Omega}}$$

(A) $$-i_s + \frac{v_A}{1k\Omega} + \frac{v_A - v_B}{2k\Omega} = 0$$

$$(2+1)v_A - v_B = 2k\Omega\, i_s$$

$$3v_A - v_B = 2k\Omega\, i_s$$

(B) $$\frac{v_B - v_A}{2k\Omega} + \frac{v_B - v_C}{500\Omega} = 0$$

$$-\frac{1}{2k\Omega} v_A + \left(\frac{1}{2k\Omega} + \frac{1}{500\Omega}\right) v_B - \frac{1}{500\Omega}(v_A) = 0$$

$$-\left(\frac{1}{2k\Omega} + \frac{1}{500\Omega}\right) v_A + \left(\frac{1}{2k\Omega} + \frac{1}{500\Omega}\right) v_B = 0$$

$$v_A = v_B$$

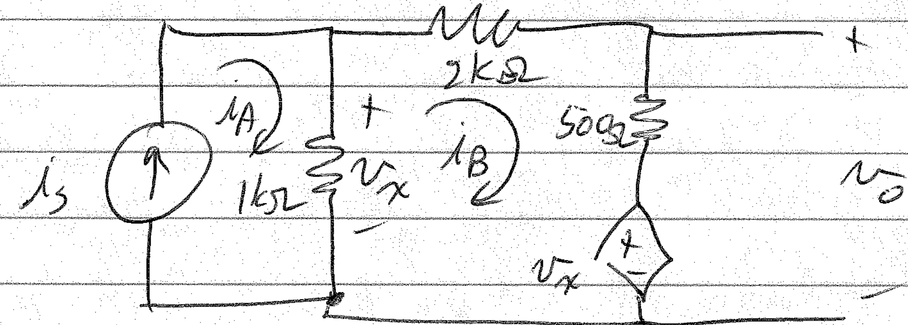
A $\Rightarrow$ $3v_B - v_B = 2k\Omega\, i_s$

$$2v_B = 2k\Omega\, i_s$$

$$v_B = v_o = \underline{1k\Omega\, i_s = 1000\Omega\, i_s}$$

In Mesh-Current Analysis we do similar things:

Analyze the same ckt using Mesh Currents:



1) D.O.

$$v_o - v_x - 500\Omega\, i_B = 0$$

$$\underline{v_o = v_x + 500\Omega\, i_B}$$

2) $v_x = 1k\Omega(i_A - i_B)$

(A) Current source on outer edge:

$$\underline{i_A = i_s}$$

(B) $2k\Omega\, i_B + 500\Omega\, i_B + v_x + 1k\Omega(i_B - i_A) = 0$

~~1kΩ iA~~

$$2500\Omega\, i_B + \cancel{1k\Omega(i_A - i_B)} + \cancel{1k\Omega(i_B - i_A)} = 0$$

$$\cancel{2500\Omega\, i_B + 2k\Omega(i_A - i_B) = 0}$$

$$2500\Omega\, i_B = 0$$

~~2kΩ iA +~~ $i_B = 0$

So $v_o = v_x + 500\Omega\, i_B = v_x$

$v_o = 1k\Omega\, i_A = \underline{\underline{1000\Omega\, i_s}}$ as before.