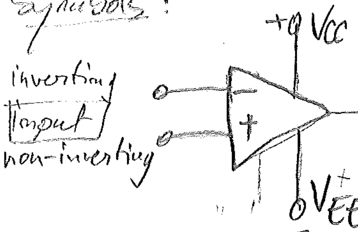
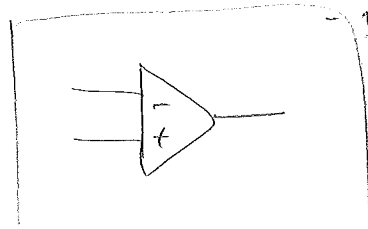
The Operational Amplifier (OpAmp) (OA)

tell about the R_{eq} techniques
- $\frac{v_T}{i_T}$ always applicable
- $\frac{v_{oc}}{i_{sc}}$ applicable when $v_{oc} \neq 0$, $i_{sc} \neq 0$.

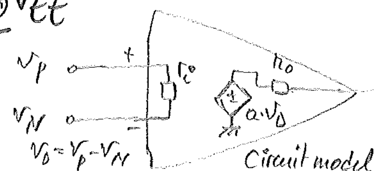
Symbols:





we'll use this

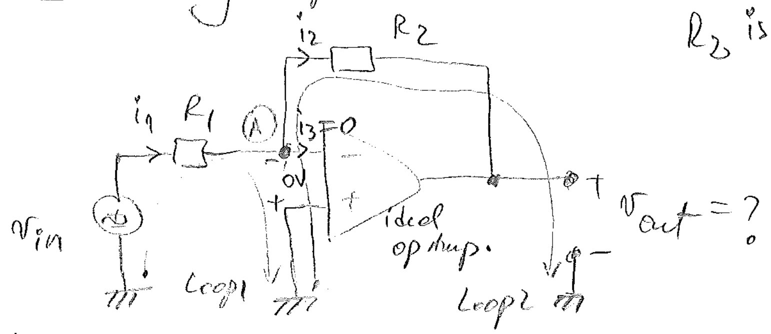
Terminology:



a = unloaded voltage gain ; eg: 200,000 V/V
r_i, r_o = input, output resistances
v_D = differential input voltage

The ideal OpAmp: $a \to \infty$, $r_i \to \infty$, $r_o \to 0$
- no current flows into the inputs!
- there is no voltage difference between the two input terminals
- $r_i \to \infty$, $r_o \to 0$, $a \to \infty$

(a) The inverting amplifier



R_2 is the feedback resistance (negative)

KVL:

Loop1: $v_{in} - R_1 i_1 + 0 = 0$

Loop2: $v_{out} + R_2 i_2 + 0 = 0$

KCL

Node (A): $i_1 = i_2 + \underbrace{i_3}_{=0} = i_2$

$\Rightarrow i_1 = i_2 = \frac{v_{in}}{R_1} \Rightarrow v_{out} + R_2 \cdot \frac{v_{in}}{R_1} = 0$

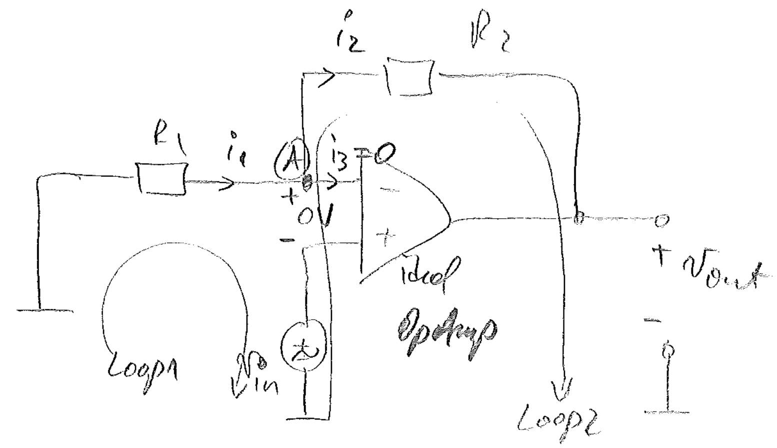
$$\Rightarrow \boxed{v_{out} = -\frac{R_2}{R_1} \cdot v_{in}} \quad (1)$$

"inverting" amplifier.

the gain!

if
- $R_2 > R_1 \Rightarrow$ gain is an amplification.
- $R_2 < R_1 \Rightarrow$ attenuation.
- $R_1 = R_2 \Rightarrow$ gain is 1 ; inverted.

(b) Noninverting amplifier



Loop 1: $+R_1 i_1 + v_{in} = 0$

Loop 2: $-v_{in} + R_2 i_2 + v_{out} = 0$

KCL A: $i_1 = i_2 - \underbrace{i_3}_{=0} = i_2$

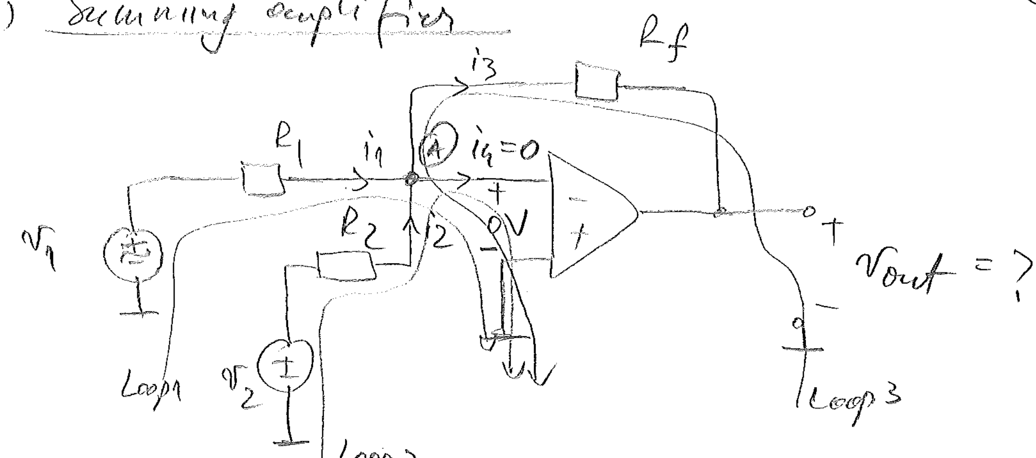
$\Rightarrow \begin{cases} R_1 i_1 = -v_{in} \Rightarrow i_1 = -\dfrac{v_{in}}{R_1} \\ -v_{in} + R_2 i_1 + v_{out} = 0 \end{cases}$

$$-v_{in} - \frac{v_{in}}{R_1} \cdot R_2 + v_{out} = 0$$

$$\boxed{v_{out} = \underbrace{\left(1 + \frac{R_2}{R_1}\right)}_{\text{gain.}} \cdot v_{in}} \quad (2) \quad \text{non-inverting!}$$

Gain: $\dfrac{v_{out}}{v_{in}} = \boxed{1 + \dfrac{R_2}{R_1}}$

(c) Summing amplifier



$R_1 = R_2$

Method 1:

Loop 1: $v_1 - R_1 i_1 = 0 \Rightarrow i_1 = \dfrac{v_1}{R_1}$

Loop 2: $v_2 - R_2 i_2 = 0 \Rightarrow i_2 = \dfrac{v_2}{R_2}$

Loop 3: $v_{out} + R_f i_3 = 0 \Rightarrow i_3 = -\dfrac{v_{out}}{R_f}$

$\boxed{\text{KCL}}$ $i_1 + i_2 = i_3$

$$\frac{v_1}{R_1} + \frac{v_2}{R_2} = -\frac{v_{out}}{R_f}$$

$$\boxed{v_{out} = -\frac{R_f}{R_1} v_1 + \frac{R_f}{R_2} v_2} \quad (3)!$$

see verso

Method 2: use super-position.