Lecture 9 – Module 2

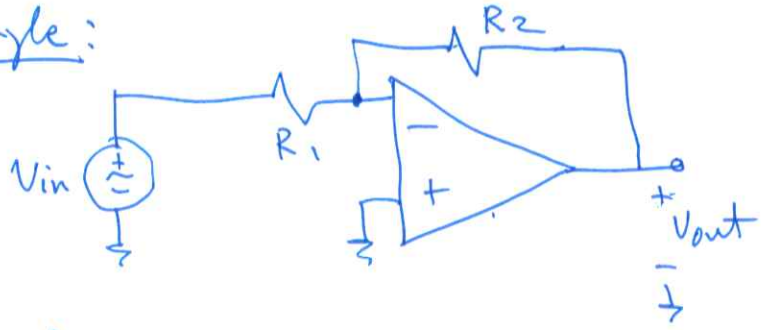
Today:
Note 19

* NFB inspection
* Summing op-amp / Neuron
* Cascading ckt blocks (building large functions)

Determining the polarity of NFB:

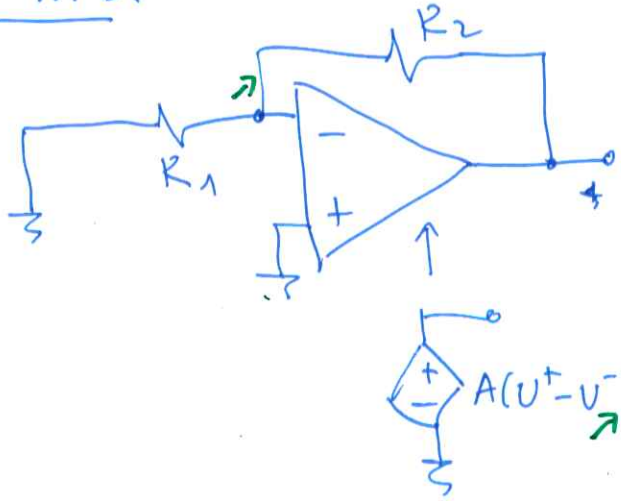
1. Turn-off independent sources
2. Apply a disturbance at the output & follow the feedback to see it suppressed at the output

example:



check for NFB:

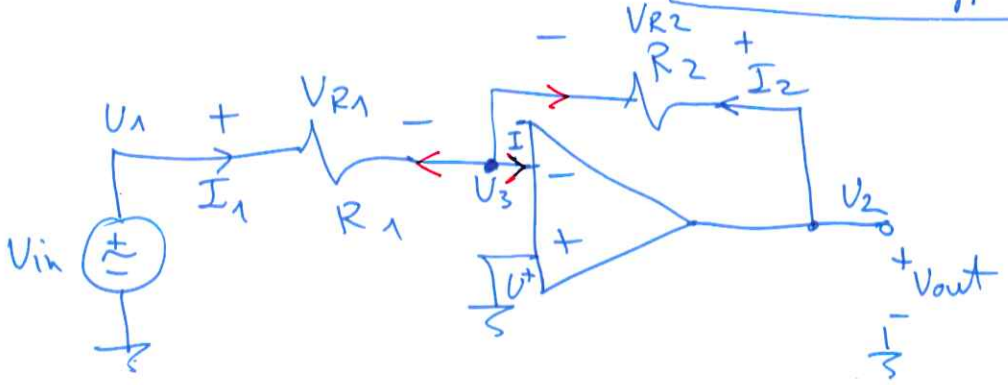
step 1: Null the source



step 2: Apply disturbance (NFB) ☺

(l2) Solve:

NFB $\Rightarrow$ GR #2 applies $U^+ = U^-$



$U_1 = V_{in}$

$U_2 = V_{out}$

$U_3 = 0$ (ckt in NFB $\Rightarrow$ GR2 applies $U^+ = U^-$)

also know $U^+ = 0 \underset{GR2}{\Rightarrow} U^- = 0$

$U^- = U_3 \Rightarrow U_3 = 0$

$V_{R1} = I_1 R_1$

$V_{R2} = I_2 R_2$ } elem. def.

$V_{R1} = U_1 - \cancel{U_3}^{\,0} = U_1 = V_{in}$

$V_{R2} = U_2 - \cancel{U_3}^{\,0} = U_2 = V_{out}$

(KCL) $I_1 + I_2 = \cancel{I}^{\,0}$ (GR #1)

$V_{in} = I_1 R_1$, $V_{out} = I_2 R_2$

$\underbrace{\frac{V_{in}}{R_1}}_{I_1} + \underbrace{\frac{V_{out}}{R_2}}_{I_2} = 0 \Rightarrow V_{out} = -\frac{R_2}{R_1} \cdot V_{in}$

$$A_V = \frac{V_{out}}{V_{in}} = -\frac{R_2}{R_1}$$

inverting amplifier

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A faster way:

GR2: $V^+ = V^-$, $V_3 = V^-$

$V^+ = 0$ $\Rightarrow$ $V_3 = 0$

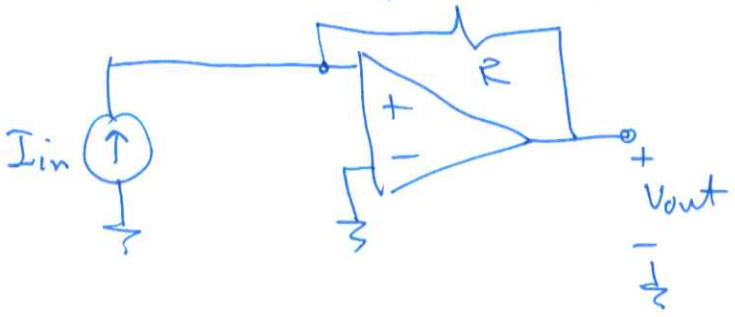
GR1 & KCL:

$$\frac{\cancel{V_3}^{\,0} - V_{in}}{R_1} + \frac{\cancel{V_3}^{\,0} - V_{out}}{R_2} + \cancel{I}^{\,0} = 0$$

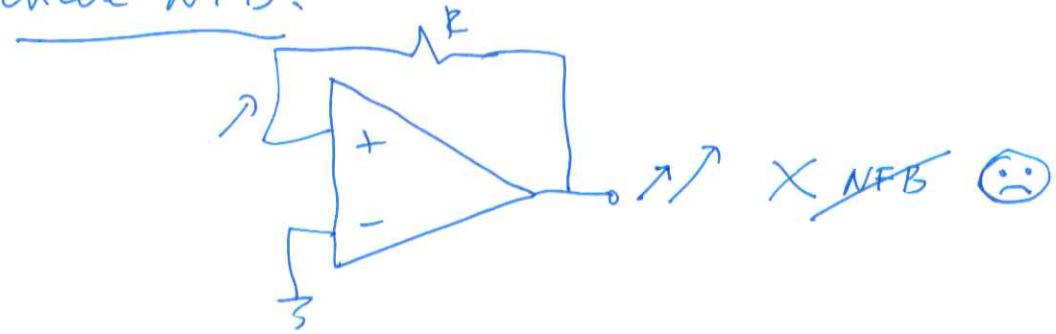
$$-\frac{V_{in}}{R_1} - \frac{V_{out}}{R_2} = 0$$

$$\boxed{V_{out} = -\frac{R_2}{R_1} V_{in}}$$

Another example: (trans-resistance amplifier)

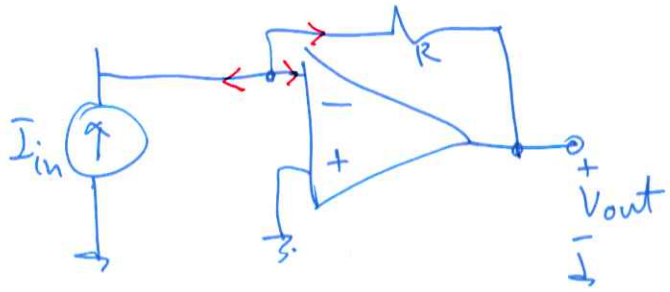


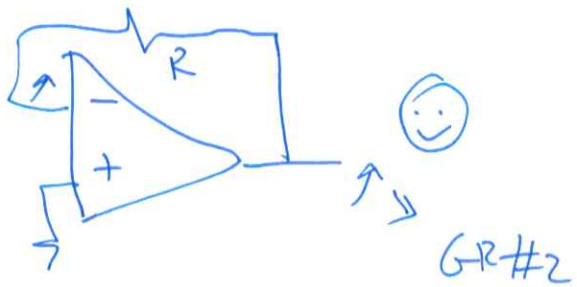
check NFB:



(24)

Flip - the polarity:





✓ NFB: $U^+ = U^-$ $\quad U^+ = 0$

$\rightarrow U^- = 0$

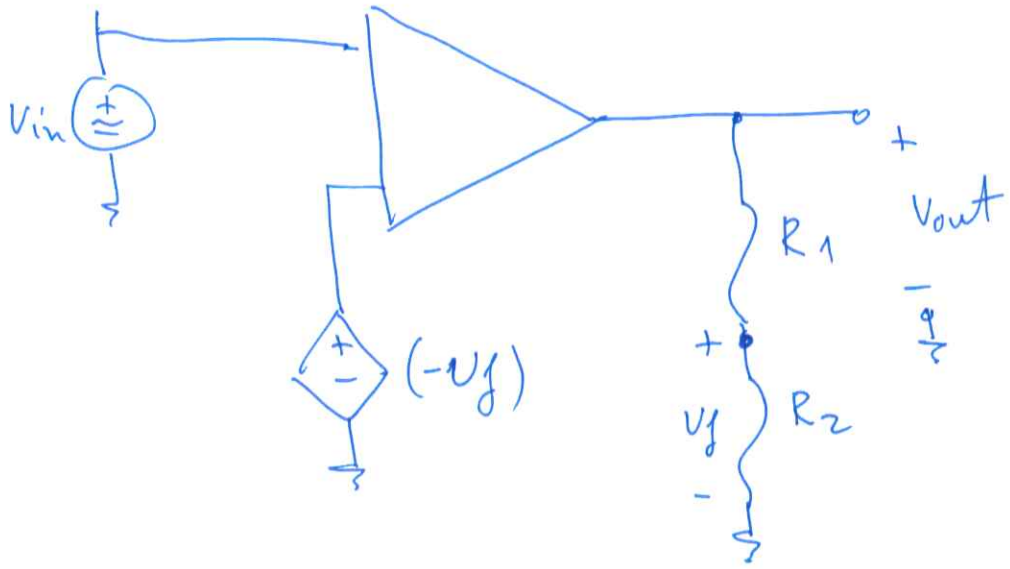
GR#2 $\dfrac{U^- - V_{out}}{R} + (-I_{in}) + \underbrace{I^-}_{\text{GR\#1}} = 0$

$V_{out} = -I_{in} \cdot R$

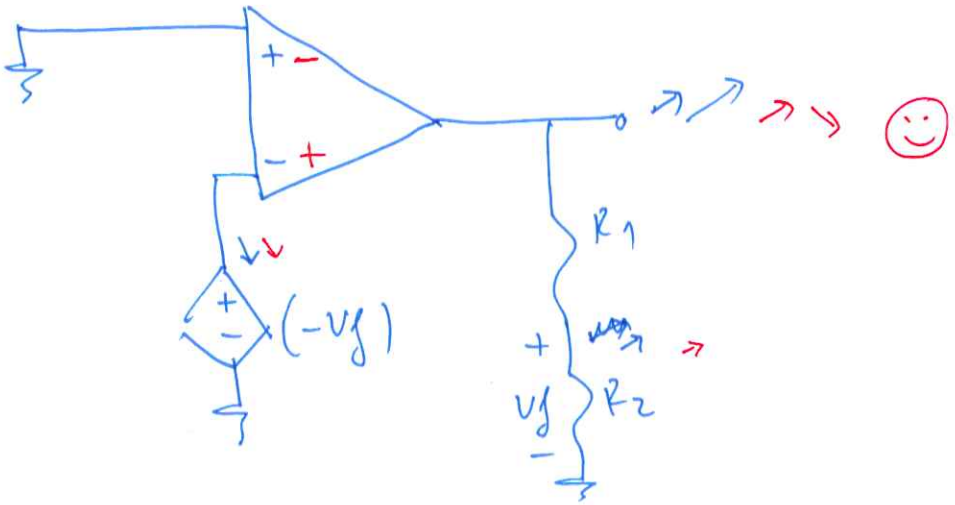
$$\boxed{\frac{V_{out}}{I_{in}} = -R}$$

(15)

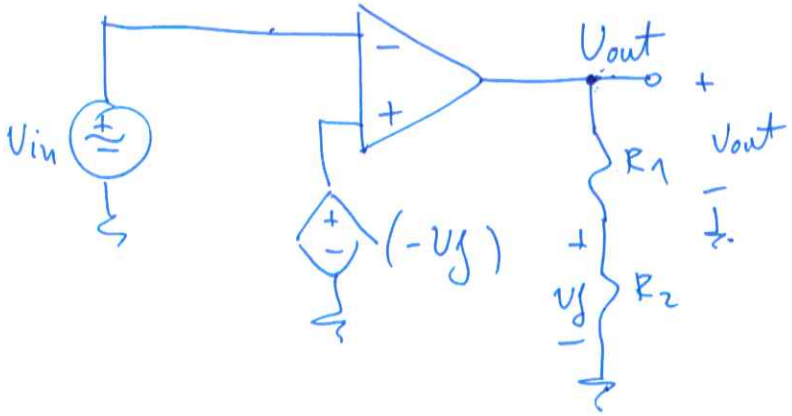
Another example:



Check NFB:



solve:



voltage divider:

$$V_f = \frac{V_{out} \cdot R_2}{R_1 + R_2}$$

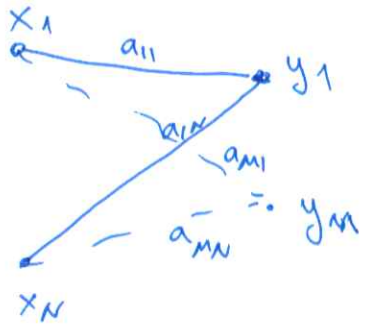
NFB (GE #2)

$$V_{in} = -V_f$$

($V^- \rightarrow V_{in} = -V_f \leftarrow V^+$)

$$V_{in} = -\frac{R_2}{R_1+R_2} V_{out} \Rightarrow \boxed{A_v = \frac{V_{out}}{V_{in}} = -\left(1 + \frac{R_1}{R_2}\right)}$$

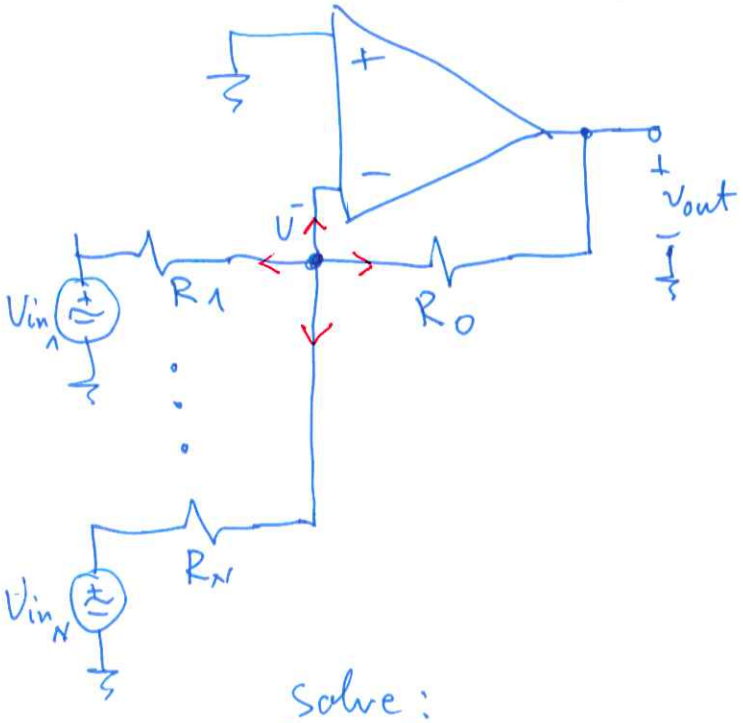
(l6) Building energy-efficient deep neural networks



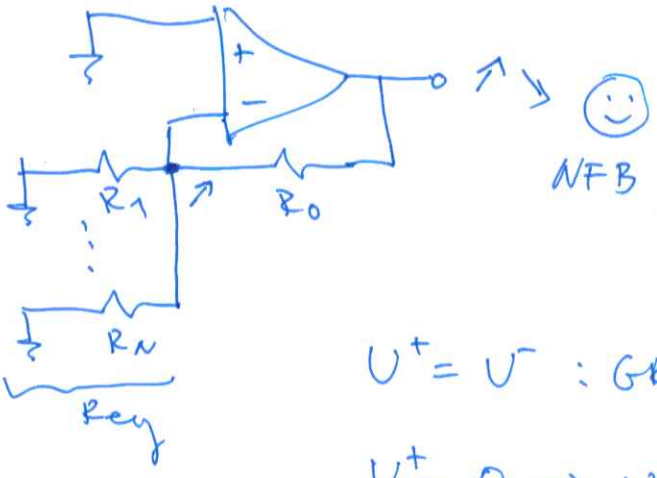
$$\vec{y} = A\vec{x}$$

$$\begin{bmatrix} y_1 \\ \vdots \\ y_M \end{bmatrix} = \begin{bmatrix} a_{11} & \cdots & a_{1N} \\ \vdots & & \vdots \\ a_{M1} & \cdots & a_{MN} \end{bmatrix} \begin{bmatrix} x_1 \\ \vdots \\ x_N \end{bmatrix}$$

(inverting summer)



check for NFB:



$U^+ = U^-$: GR2

$U^+ = 0 \Rightarrow U^- = 0$

Solve:

KCL:

$$\frac{\cancel{U^-} - V_{in_1}}{R_1} + \ldots + \frac{\cancel{U^-} - V_{in_N}}{R_N} + \frac{\cancel{U^-} - V_{out}}{R_0} + \cancel{I} = 0$$

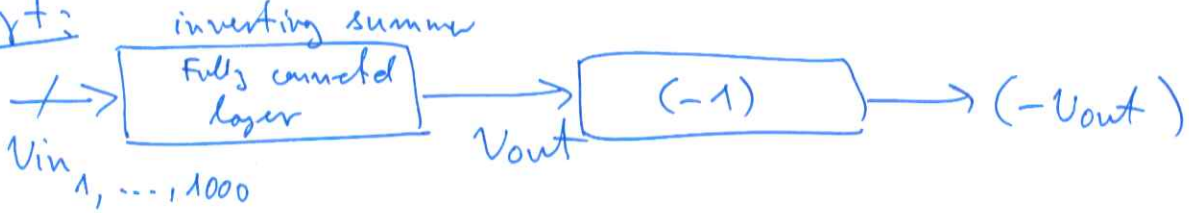
$$V_{out} = -\frac{R_0}{R_1} V_{in_1} + \ldots + \left(-\frac{R_0}{R_N}\right) V_{in_N}$$

y_1 ; a_{11} ; x_1 ; a_{1N} ; x_N

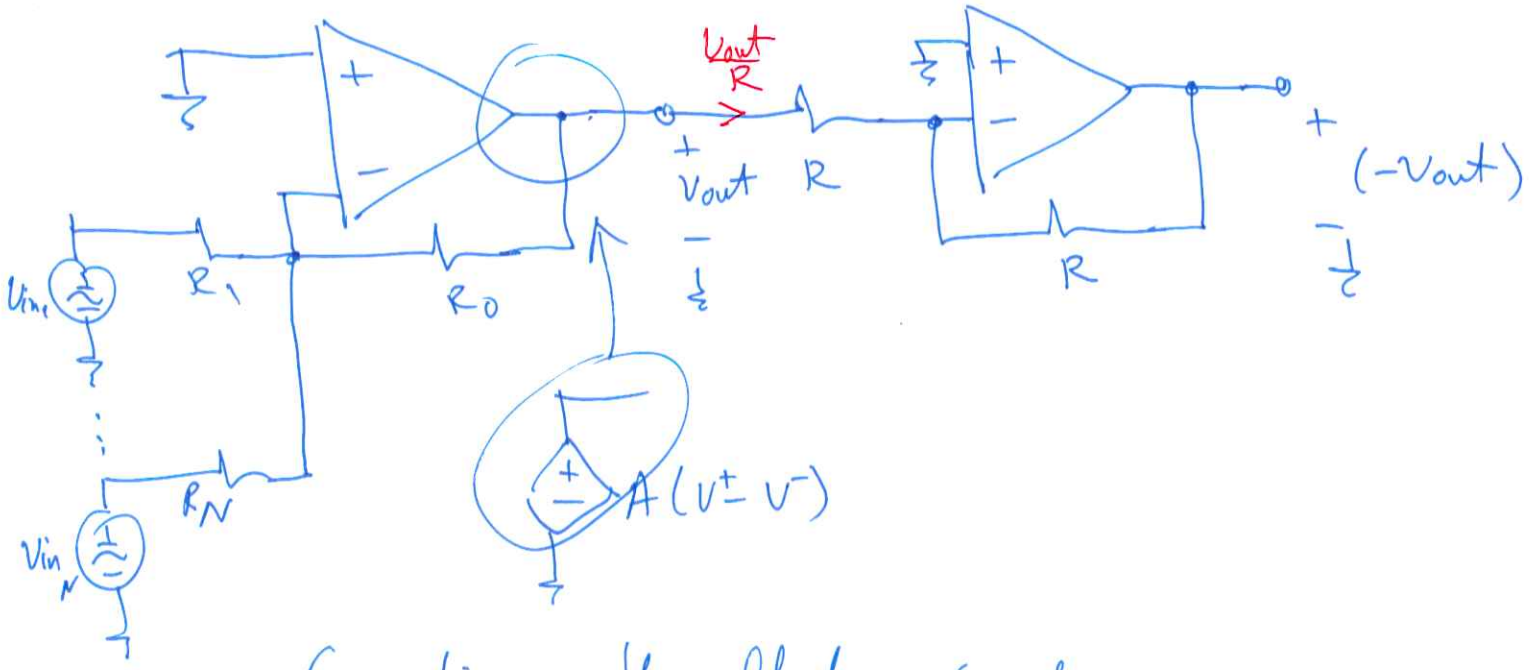
(L7)

Think in block diagrams:

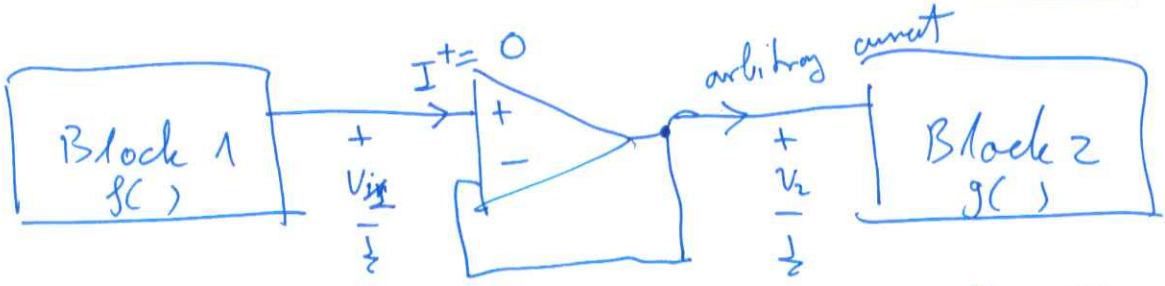
Concept:



Implementation:



Cascading the blocks (safe way):



$V_1 = V_2$

NFB:

$V^+ = V^-$

$V_{in} = V_{out}$

(Unity gain buffer)