(L1) EE16A

Lecture 9 - Module 2

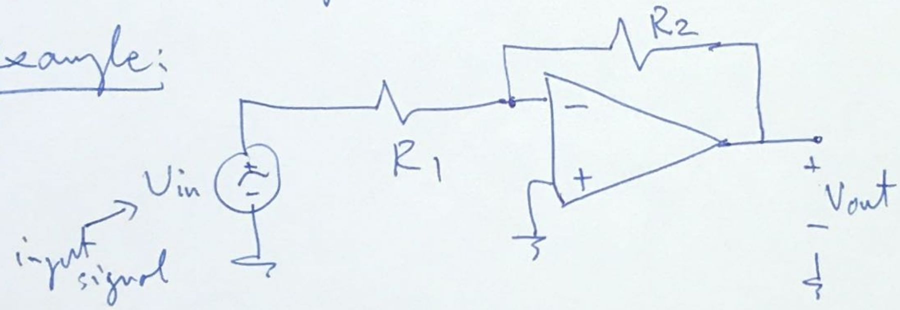
Today:
Note 19

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

Determining the polarity of the NFB:

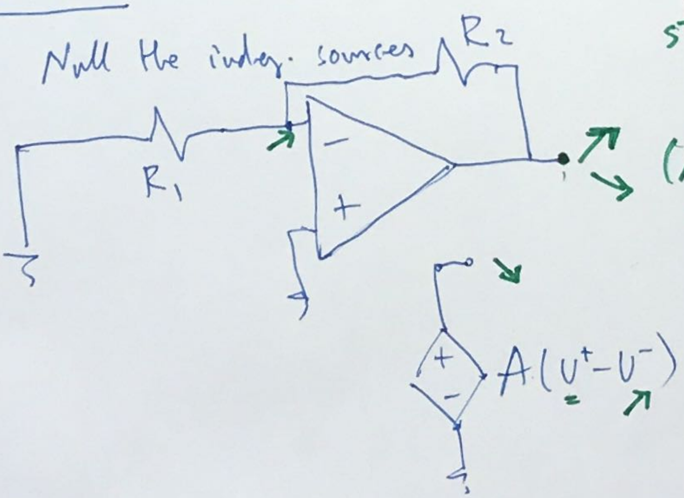
1. Turn-off all independent sources
2. Apply a disturbance at the output & follow the path through the feedback to see if the disturbance is suppressed at the output.

example:



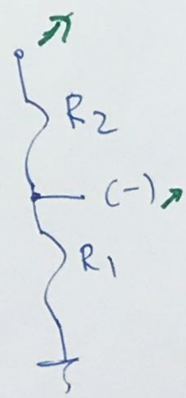
check for NFB:

step 1: Null the indep. sources



step 2: Apply disturbance to output

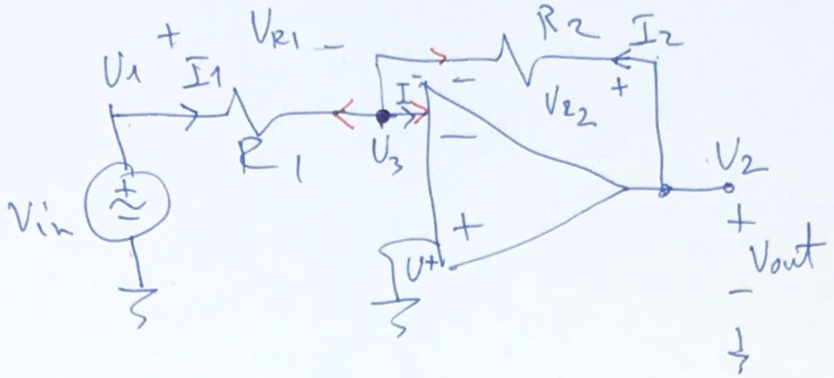
(NFB) ✓



Since NFB ⇒ can apply GR#2 ⇒ $v^- = v^+$

(2)

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



solve for V_{out} as a fn. of V_{in}.

$U_1 = V_{in}$

$U_2 = V_{out}$

$U_3 = 0$ (ckt is in NFB $\Rightarrow$ GR#2 applies $U^+ = U^-$)

also $U^+ = 0$ (in this ckt) $\Rightarrow$ $U^- = 0$

$U_3 = U^-$

$\left.\begin{array}{l} V_{R1} = I_1 R_1 \\ V_{R2} = I_2 R_2 \end{array}\right\}$ (elem. equations)

$V_{R1} = \cancel{U_1}^{V_{in}} - \cancel{U_3}^{0} = V_{in}$ (voltage def)

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

(KCL) $-I_1 + (-I_2) + I^- = 0$ also $I_1 + I_2 = I^-$

GR#1: $I^- = 0$ $\Rightarrow$ $\boxed{I_1 + I_2 = 0}$

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

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

$$A_V = \frac{V_{out}}{V_{in}} = -\frac{R_2}{R_1} \quad \text{(inverting amplifier)}$$

$\uparrow$ voltage gain of the amplifier in NFB

(l3)

A faster way:

GR2: $U^+ = U^-$ since in NFB, $U_3 = U^-$, $U^+ = 0$ $\Rightarrow U_3 = 0$

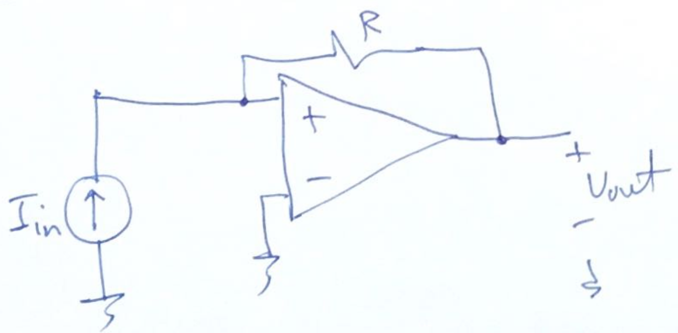
GR1 & KCL:

$$\frac{\overset{0\,(GR2)}{\cancel{U_3}} - \overset{V_{in}}{\cancel{U_1}}}{R_1} + \frac{\overset{0}{\cancel{U_3}} - \overset{V_{out}}{\cancel{U_2}}}{R_2} + \overset{0\,(GR\#1)}{\cancel{I^-}} = 0$$

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

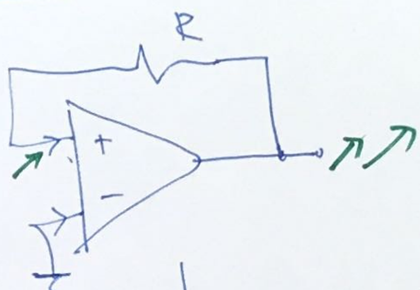
$$\boxed{V_{out} = -\frac{R_2}{R_1} V_{in}}$$

Another example: (trans-resistance amplifier)

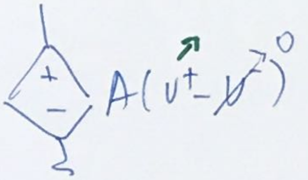


GR#1: $I^+ = 0$, $I^- = 0$ always

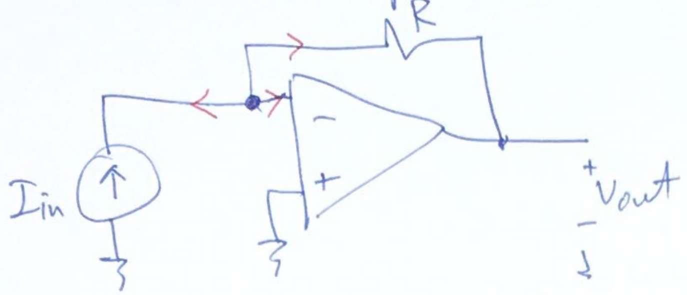
check NFB:

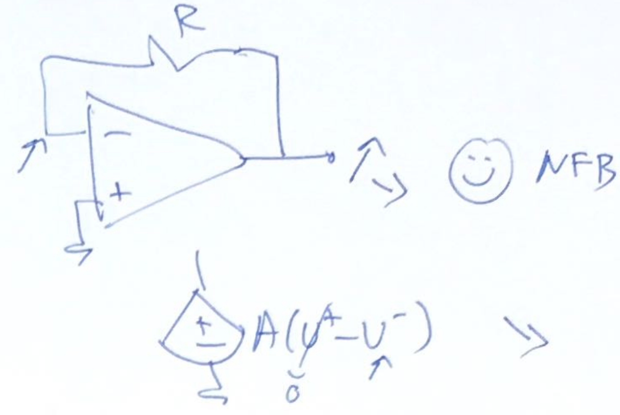


× NFB ☹



(L4) Flip the polarity:





$$\checkmark \text{NFB}: \left.\begin{array}{l} V^+ = V^- \\ V^+ = 0 \end{array}\right\} \Rightarrow V^- = 0$$

$$(-I_{in}) + \frac{\overset{0}{\cancel{V^-}} - V_{out}}{R} + \overset{0 \ \text{GR\#1}}{\cancel{I}} = 0$$

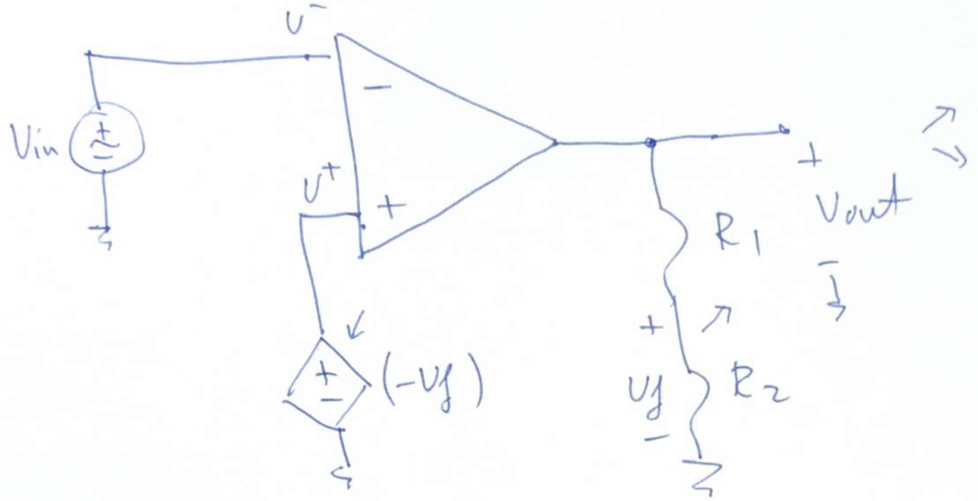
$$-\frac{V_{out}}{R} = I_{in}$$

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

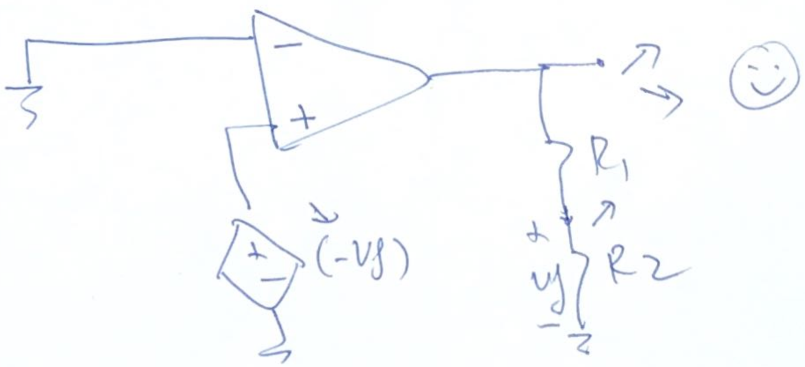
or

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

(L5) Another example:



check NFB:



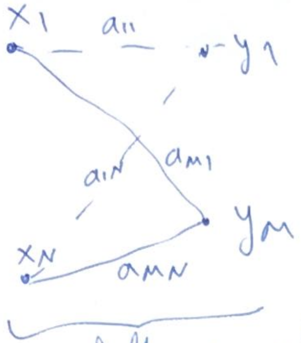
solve: NFB: $v^+ = v^- \Rightarrow \left.\begin{array}{l} v^+ = -v_f \\ v^- = V_{in} \end{array}\right\}$ $\underline{-v_f = V_{in}}$

$$\underline{v_f = \frac{R_2}{R_1+R_2} V_{out}} \longrightarrow -V_{in} = \frac{R_2}{R_1+R_2} V_{out}$$

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

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

(L6) Building energy-efficient deep neural network:

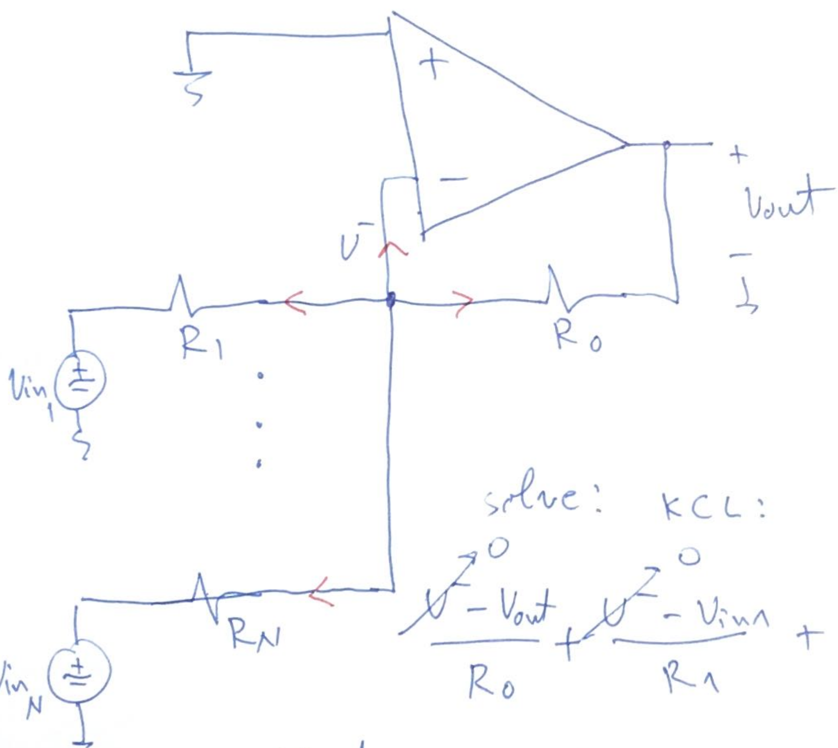


fully-connected layer

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

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

(inverting summer)



$$V_{out} = -\frac{R_0}{R_1} V_{in1} - \dots - \frac{R_0}{R_N} V_{inN}$$

solve: KCL:

$$\frac{\overset{0}{\cancel{v^-}} - V_{out}}{R_0} + \frac{\overset{0}{\cancel{v^-}} - V_{in1}}{R_1} + \dots + \frac{\overset{0\ (GR\#2\ v^+ = v^-)}{\cancel{v^-}} - V_{inN}}{R_N} + \overset{0}{\cancel{I}} = 0$$

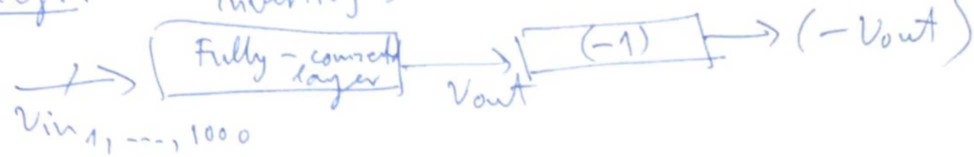
$$\frac{V_{out}}{R_0} = -\frac{1}{R_1} V_{in1} + \dots + \left(-\frac{1}{R_N}\right) V_{inN}$$

$$\boxed{\underset{y_1}{V_{out}} = \Big(\underset{a_{11}}{-\frac{R_0}{R_1}}\Big) \underset{x_1}{V_{in1}} + \dots + \Big(\underset{a_{1N}}{-\frac{R_0}{R_N}}\Big) \underset{x_N}{V_{inN}}}$$

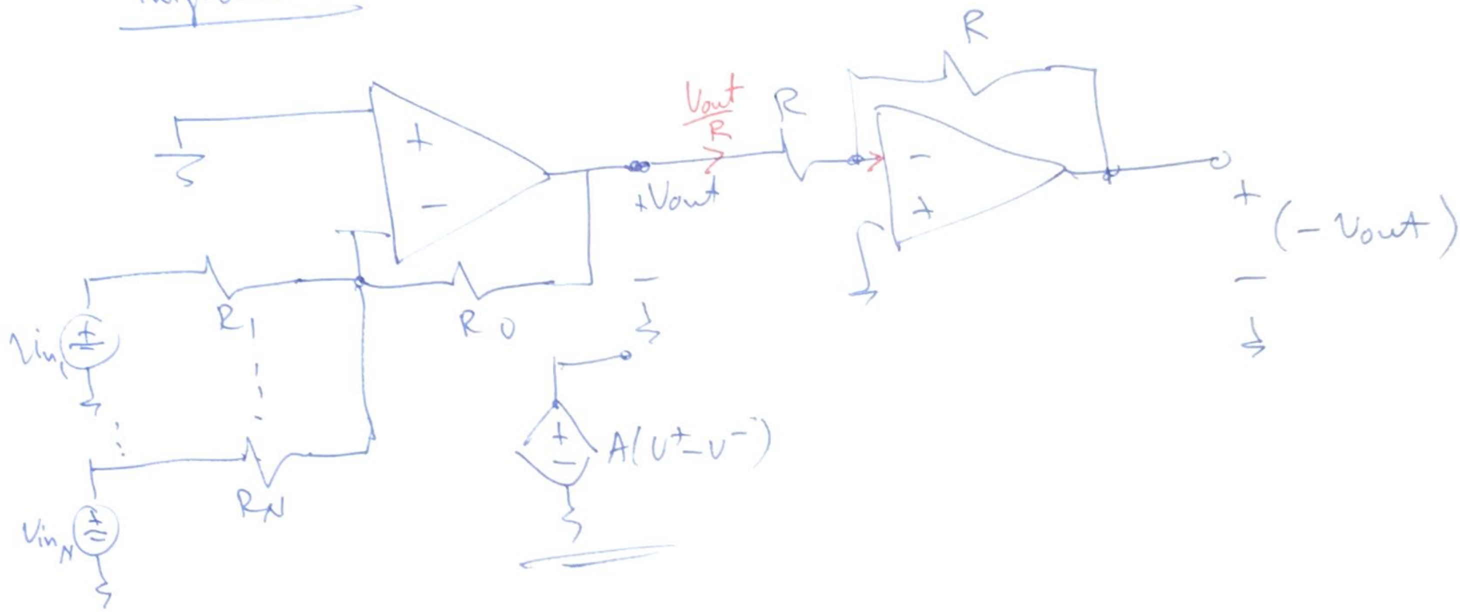
(27)

Think in block diagrams:

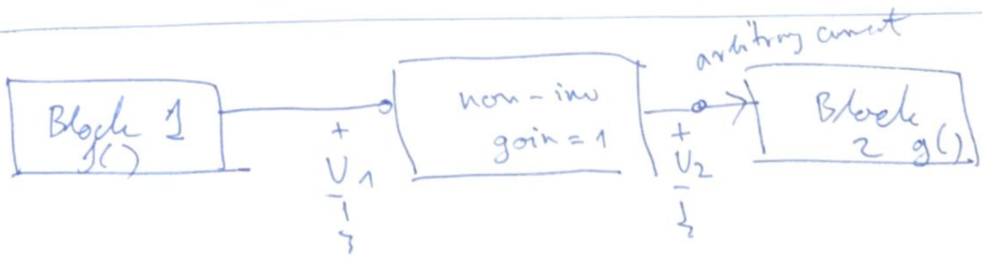
Concept:

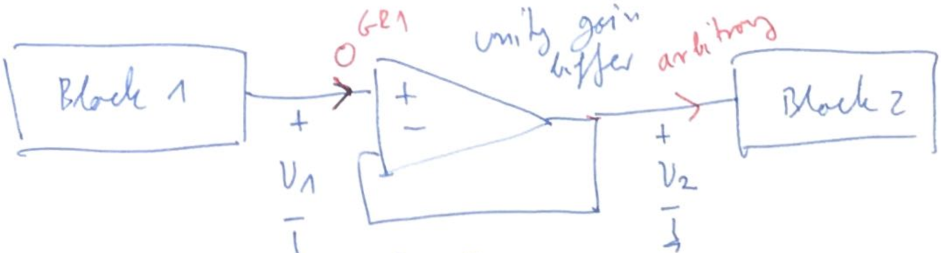


Implement:



Cascading the blocks (sof way):





$$\underset{NFB}{U^+ = U^-} \Rightarrow U_1 = U_2$$