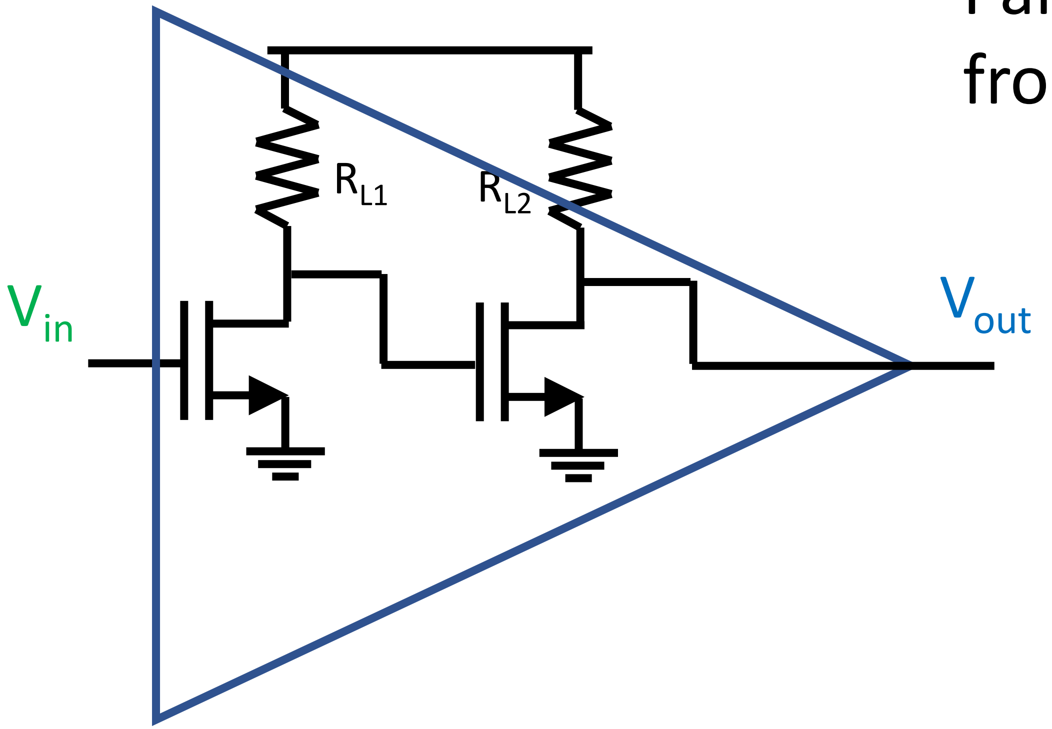
Recap : Open loop amplifiers very unpredictable

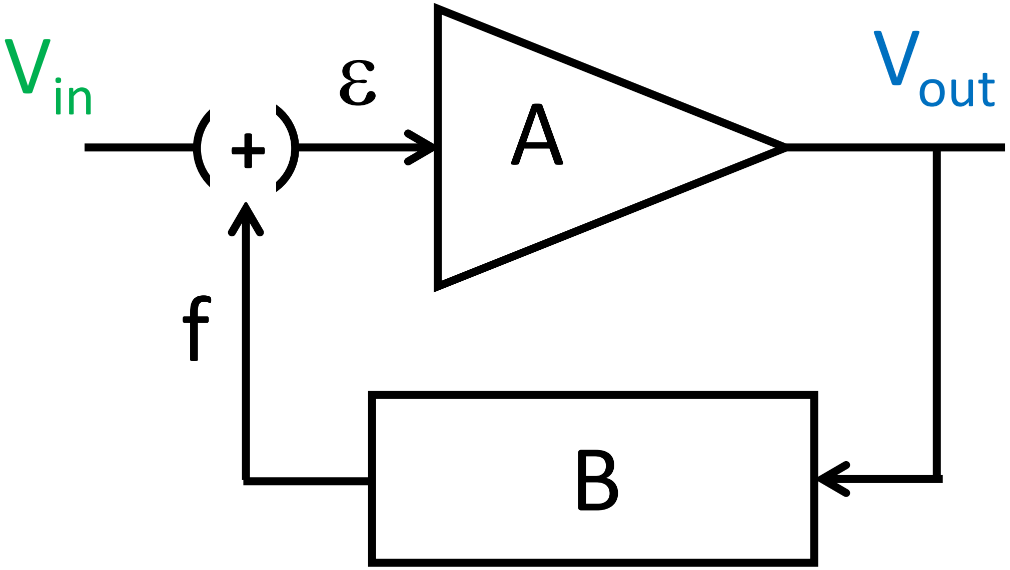


Parameters of amplifiers may <u>change a lot</u> from sample to sample (few % to 100 % !)

Gain changes
Distortion changes
Frequency response changes

Almost impossible to stabilize an amplifier by design → Need a Game changer !

Recap : the FEEDBACK concept



«A·B» is the Loop Gain

Suppose A=-∞
(we know we can !)

The output does NOT depend on A (Very GOOD)

$$V_{out} = V_{in}\cdot\frac{A}{1-A\cdot B} \longrightarrow V_{out} = V_{in}\cdot\frac{1}{-B}$$

If B is stable and linear, also the Gain will be stable and linear (Very GOOD)

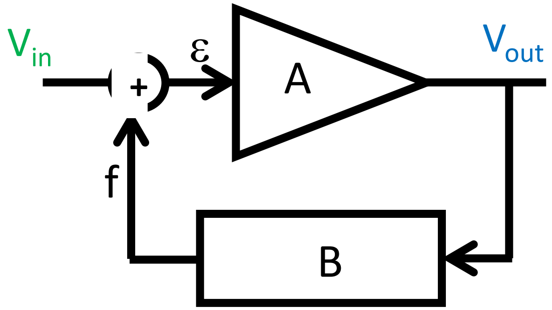
Practically no signal is applied to A (Important)

$$\varepsilon = V_{in}\cdot\frac{1}{1-A\cdot B} \longrightarrow \varepsilon \cong 0$$

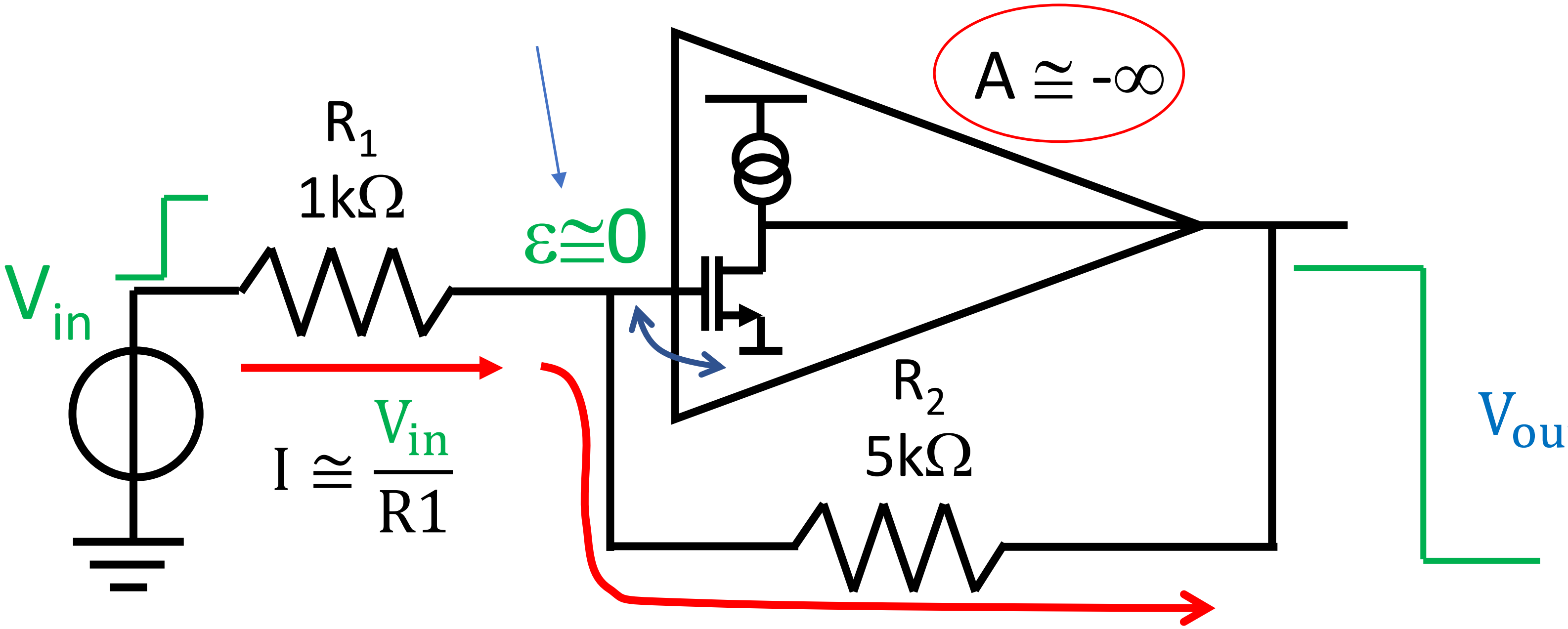
Practically all signal is available within the loop

$$f = V_{in}\cdot\frac{A\cdot B}{1-A\cdot B} \longrightarrow f \cong -V_{in}$$

Recap : the FEEDBACK in practice



This point is contrasted in its initial movement up,
by the feedback that pull it down.
At best it is NOT moving.



The same current is flowing in R2

$$V_{out} = -\frac{V_{in}}{R1} \cdot R2$$

$$G_{id} = -\frac{R2}{R1} = -5$$

Ideal because A=-∞

GAIN only depends on RESISTANCES : Stable and Linear !

ELECTRONIC SYSTEMS and TECHNOLOGIES

Master in Management Engineering

Prof. Marco Sampietro

GROUND CONCEPTS ON ELECTRONICS

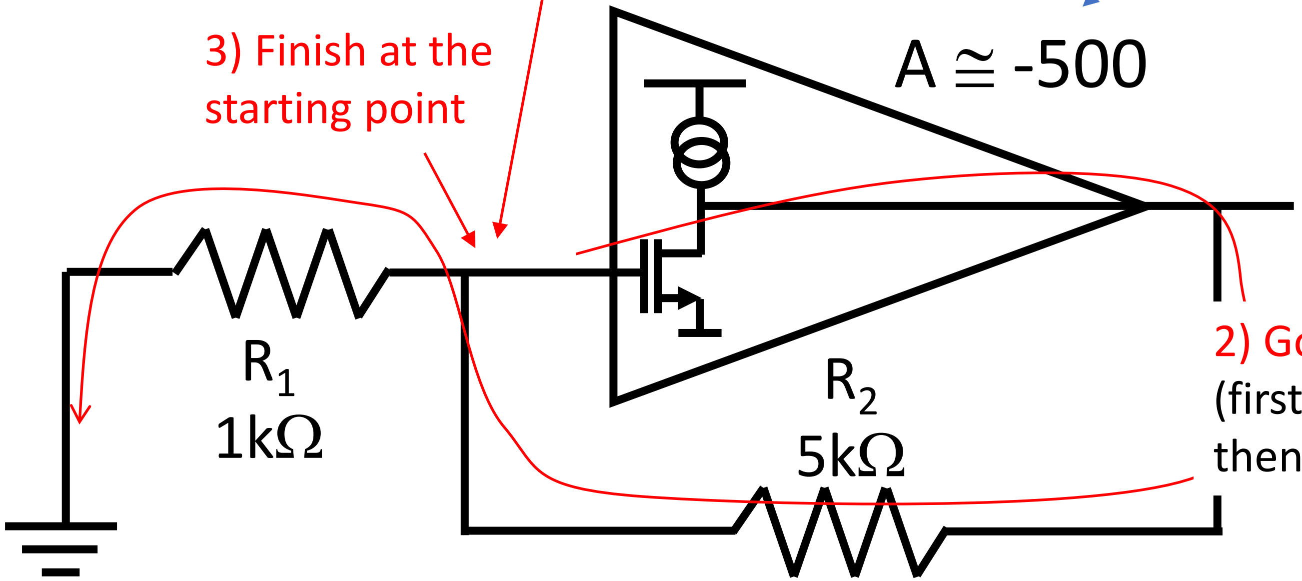
Feedback with Operational Amplifiers

About the Loop Gain

1) Start from one point

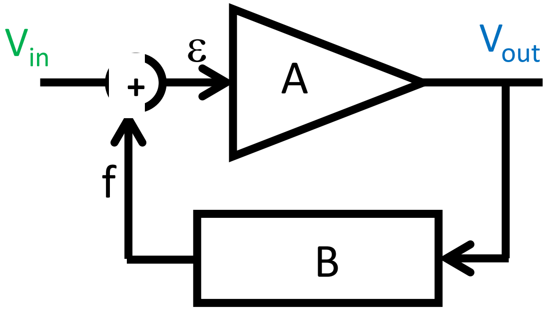
Let us suppose a given value of A

3) Finish at the starting point



A ≅ -500

2) Go around the loop (first through the Amplifier then through the feedback)



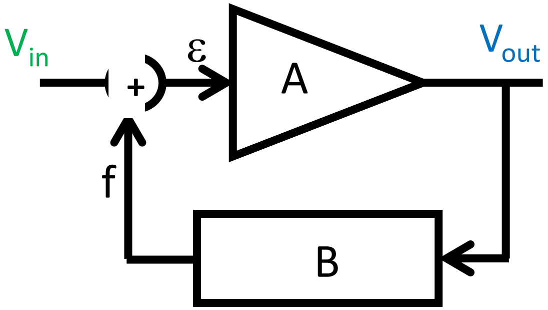
$$V_{out} = V_{in} \cdot \frac{A}{1 - \boxed{A \cdot B}}$$

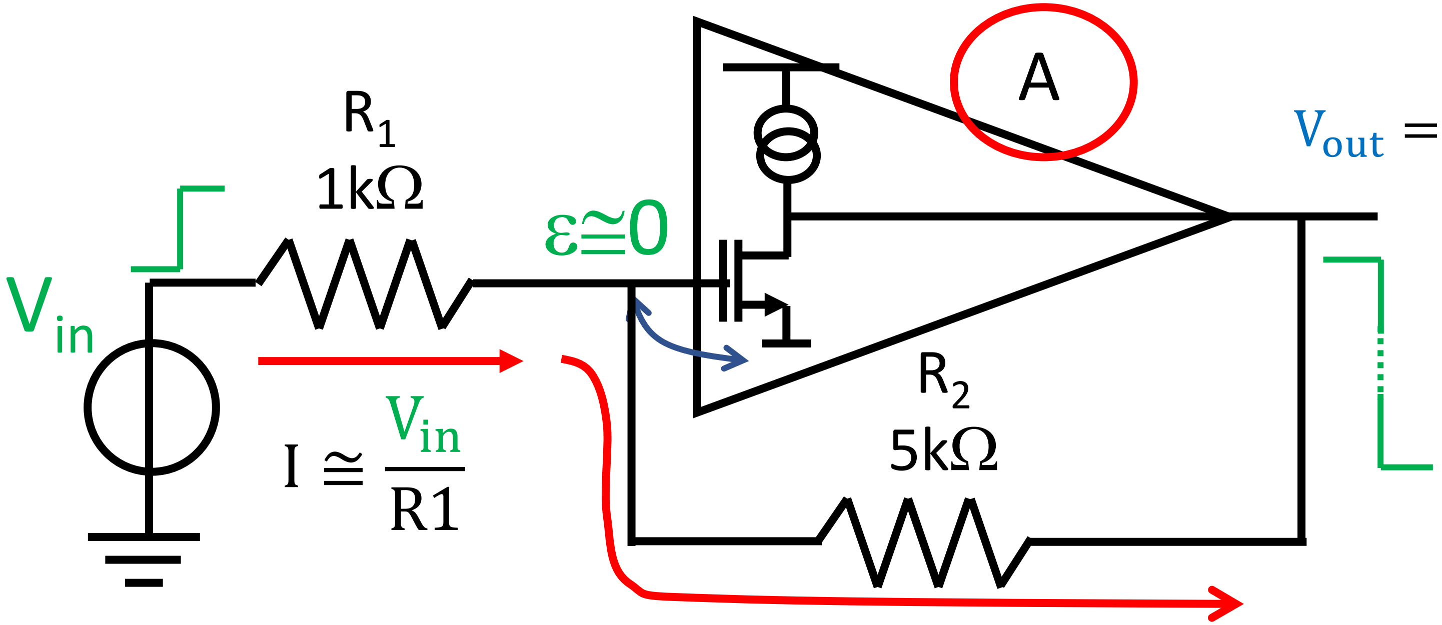
Loop Gain

$$G_{loop} = -500 \frac{R1}{R1 + R2} \cong -83$$

In negative Feedback circuits, the Loop Gain result negative (because the feedback always contrasts the initial variation !)

Ideal Gain and Real Gain





$$V_{out} = V_{in} \cdot \frac{A}{1 - A \cdot B}$$

The same current I is flowing in R2

If A ≅ -∞ → $V_{out} = V_{in} \cdot (-)\frac{1}{B}$

$$G_{id} = \frac{V_{out}}{V_{in}} = -\frac{1}{B} = -5$$

If A ≅ -500 → $V_{out} = V_{in} \cdot \frac{A}{1 - A \cdot B} \cdot \frac{B}{B} = V_{in} \cdot (-)\frac{1}{B} \cdot \frac{-A \cdot B}{1 - A \cdot B}$

$$G_{real} = \frac{V_{out}}{V_{in}} = G_{id} \cdot \frac{-G_{loop}}{1 - G_{loop}} = -5 \cdot \frac{83}{84} = -4.94$$

Only G_{id} and G_{loop} are necessary

Gain robustness

Given $G = \frac{\mathrm{V_{out}}}{\mathrm{V_{in}}} = \frac{\mathrm{A}}{1 - \mathrm{A} \cdot \mathrm{B}}$ how is the variation of G when A varies ?

(We know that A is unpredictable !)

$$\frac{\partial G}{\partial A} = \frac{1}{1 - \mathrm{A} \cdot \mathrm{B}} + \frac{\mathrm{AB}}{(1 - \mathrm{A} \cdot \mathrm{B})^2} = \frac{1}{(1 - \mathrm{A} \cdot \mathrm{B})^2} = \frac{1}{1 - \mathrm{A} \cdot \mathrm{B}} \cdot \frac{\mathrm{A}}{1 - \mathrm{A} \cdot \mathrm{B}} \cdot \frac{1}{A} = \frac{1}{1 - \mathrm{A} \cdot \mathrm{B}} \cdot G \cdot \frac{1}{A}$$

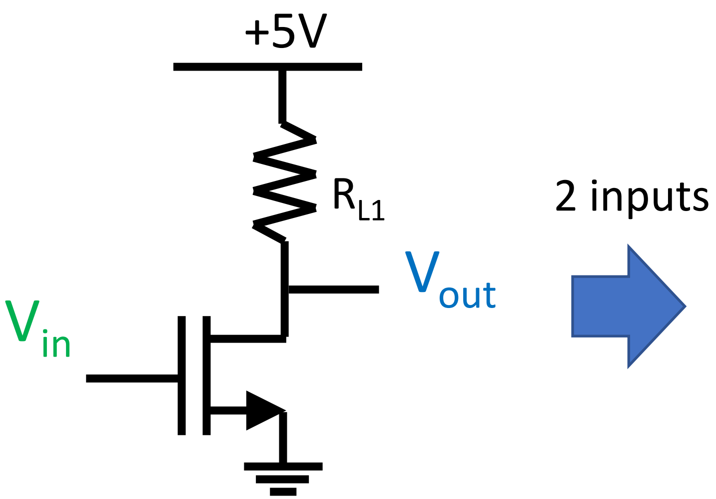
$$\frac{\partial G}{G} = \frac{\partial A}{A} \cdot \frac{1}{1 - \mathrm{A} \cdot \mathrm{B}}$$

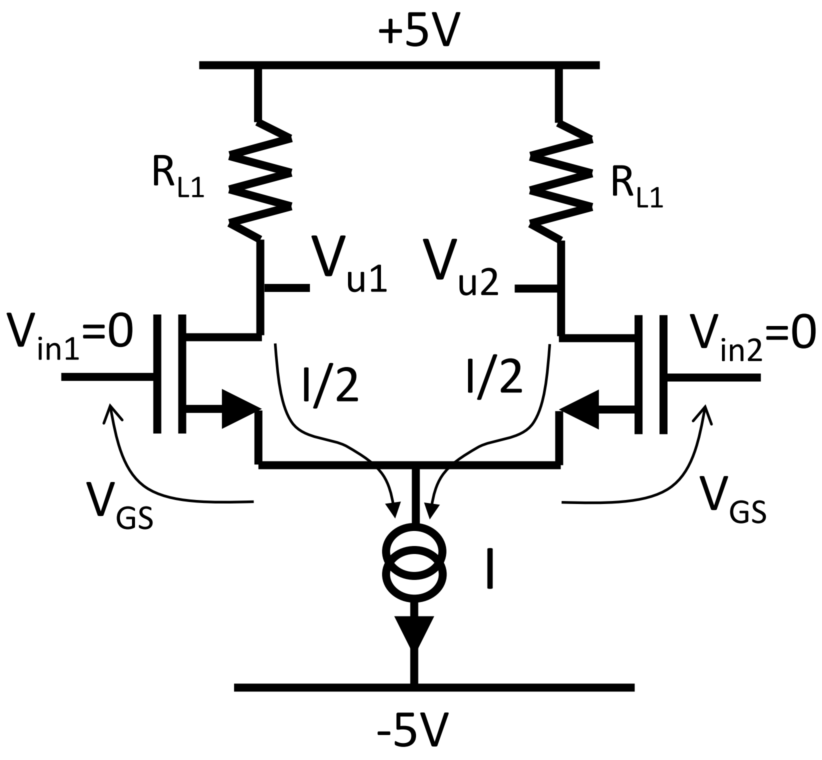
If A varies 50% and $\mathrm{G_{loop}}$=-100 $\longrightarrow$ $\frac{\partial G}{G} = 0.5\%$

If A varies 50% and $\mathrm{G_{loop}}$=-10 $\longrightarrow$ $\frac{\partial G}{G} = 5\%$

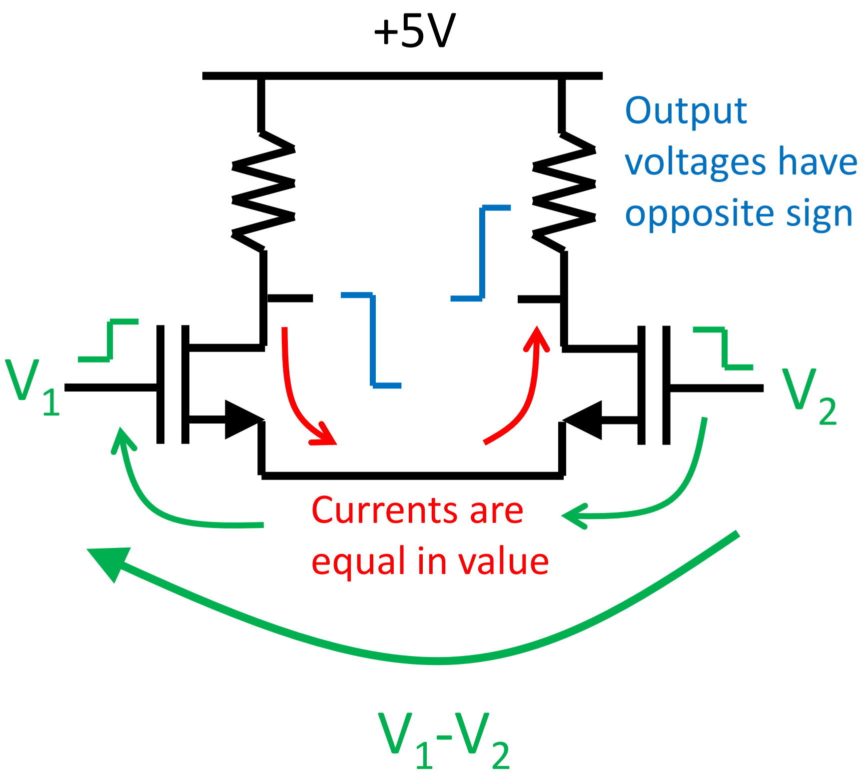
It is important to have big $\mathrm{G_{loop}}$ in order to be insensitive to variations of the gain of the amplifier A

Amplifiers with 2 inputs : leveraging the difference





Example of Bias

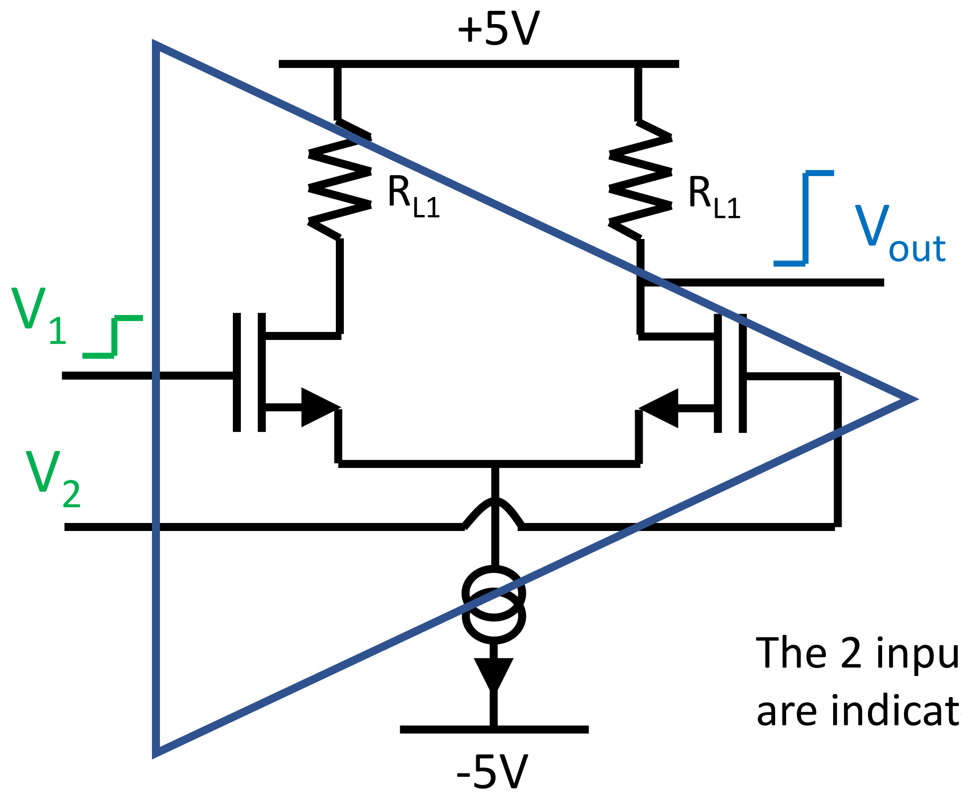


Output voltages have opposite sign

Currents are equal in value

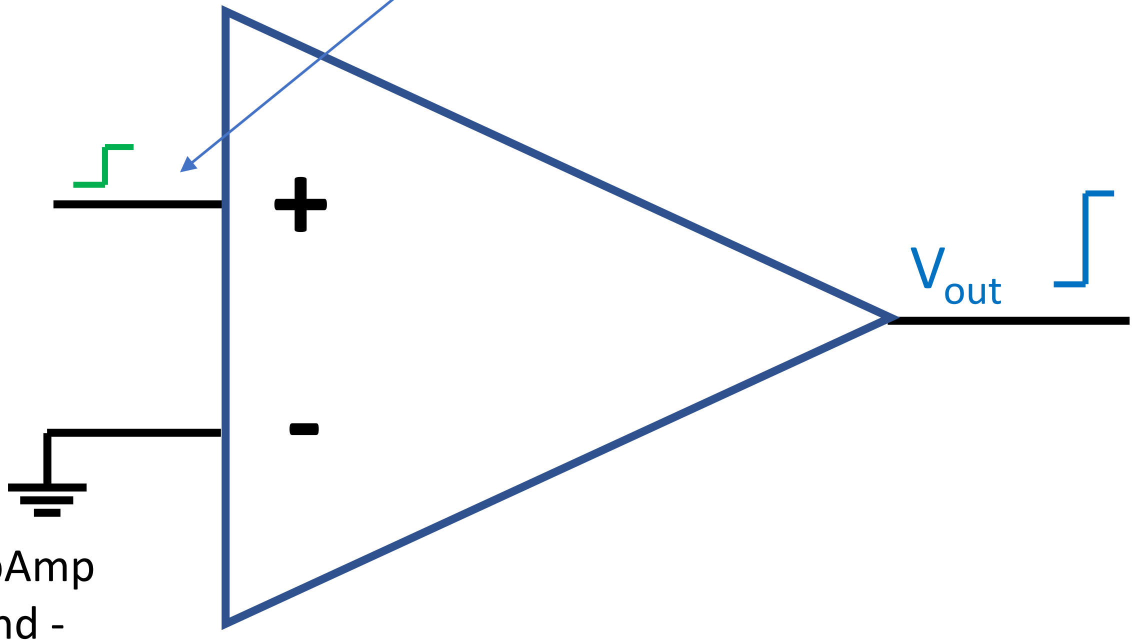
Behaviour with signal applied
(only the signal is indicated)

The Operational Amplifier – OpAmp (1)

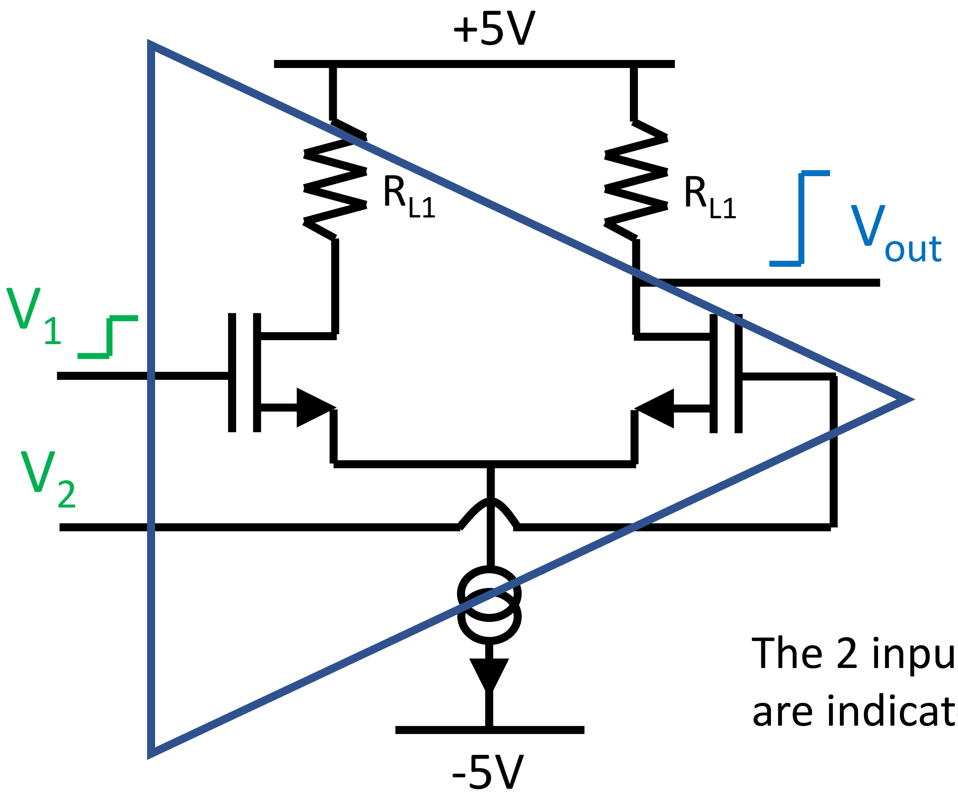


The 2 inputs of the OpAmp are indicated with + and -

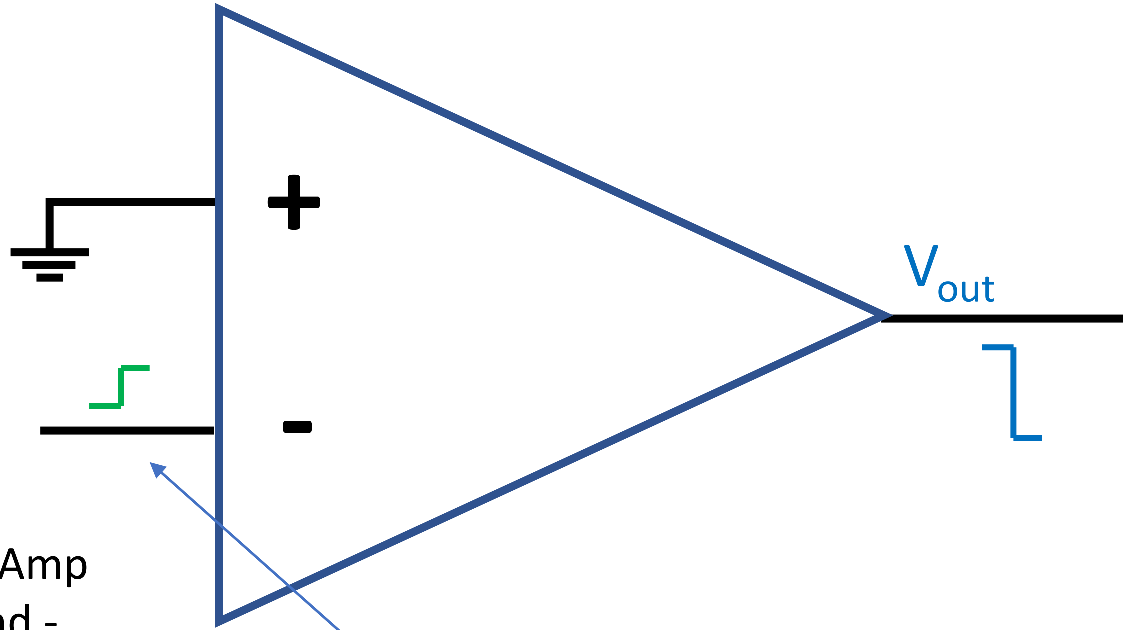
NON inverting input, i.e. a positive signal applied here give a positive output



The Operational Amplifier – OpAmp (2)

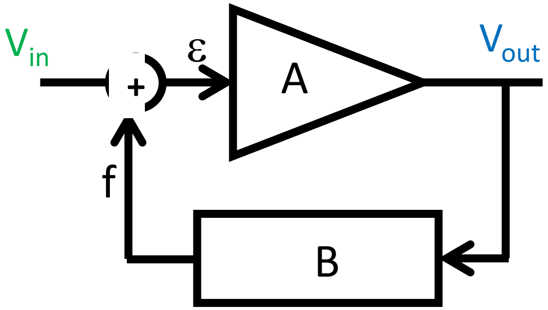


The 2 inputs of the OpAmp are indicated with + and -



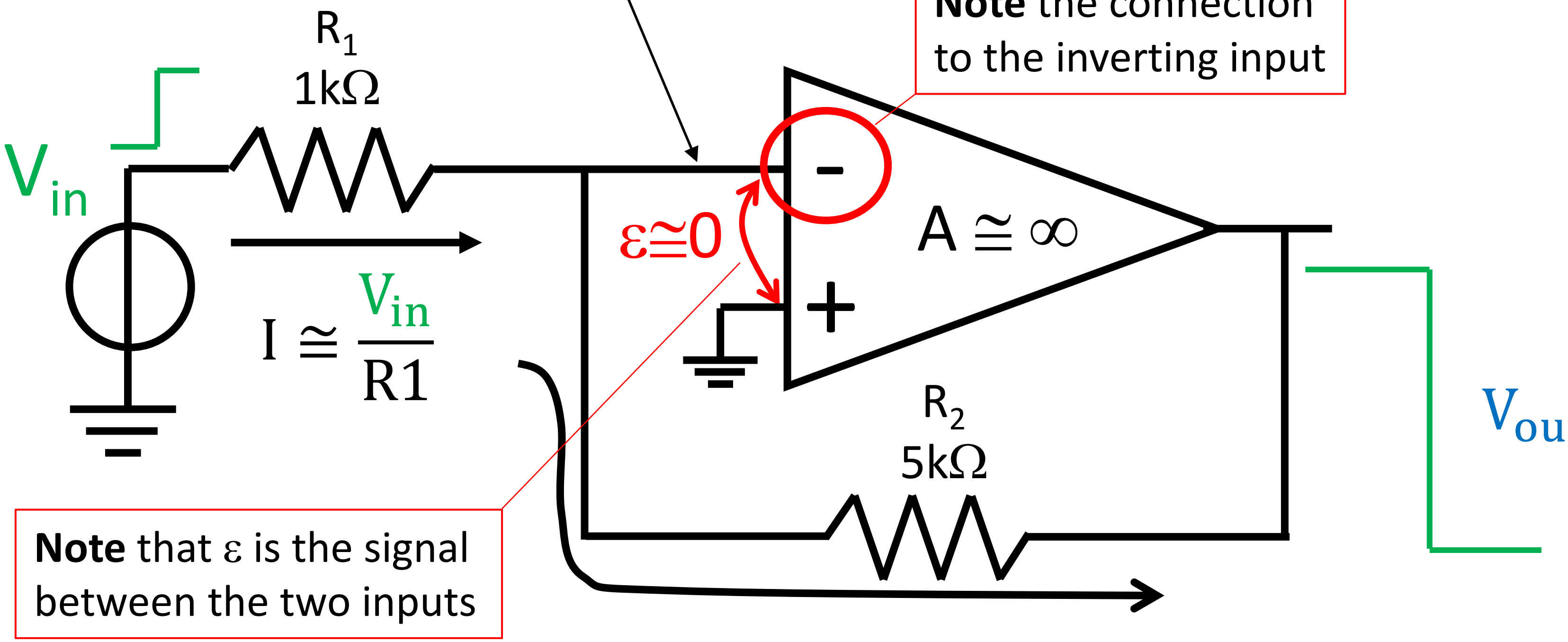
Inverting input, i.e. a positive signal applied here give a negative output

FEEDBACK using an OpAmp - review



This point is contrasted in its movement up by the feedback that pull it down. At best, it is kept fixed to the same voltage of the other input of the OpAmp (in this case to ground)

Note the connection to the inverting input



$$I \cong \frac{V_{in}}{R1}$$

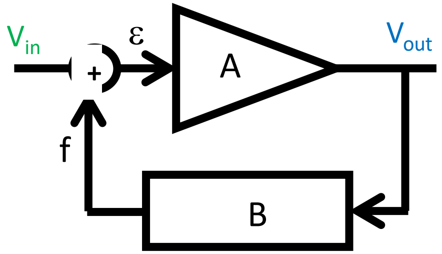
Note that ε is the signal between the two inputs

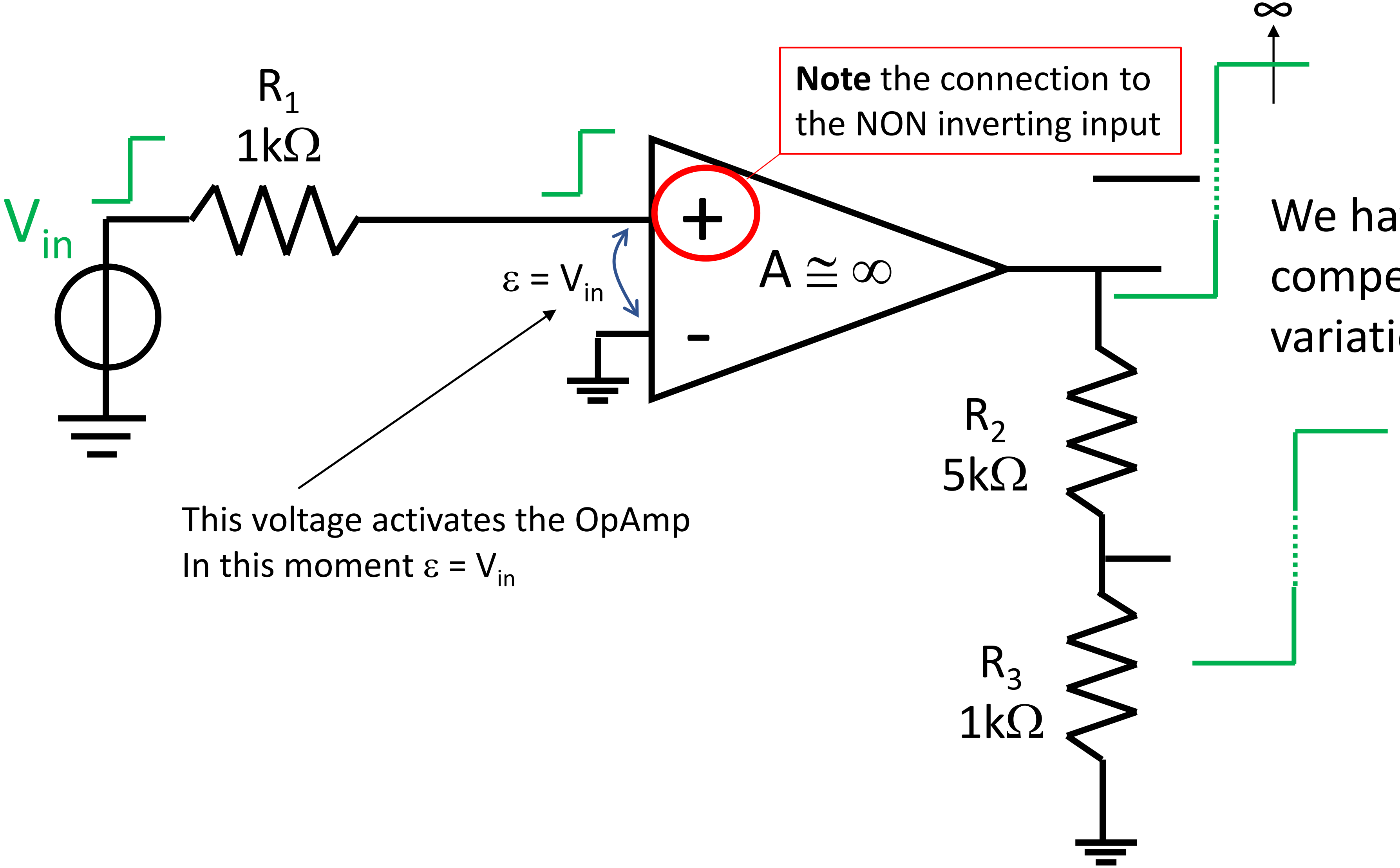
The same current is flowing in R2

$$V_{out} = -\frac{V_{in}}{R1} \cdot R2$$

$$G_{id} = -\frac{R2}{R1} = -5$$

Exercise on Feedback with OpAmp (1)



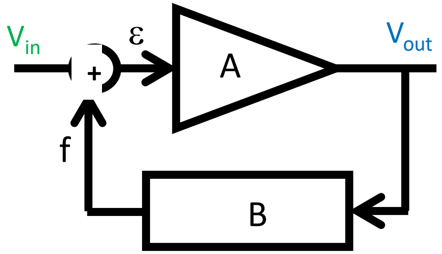


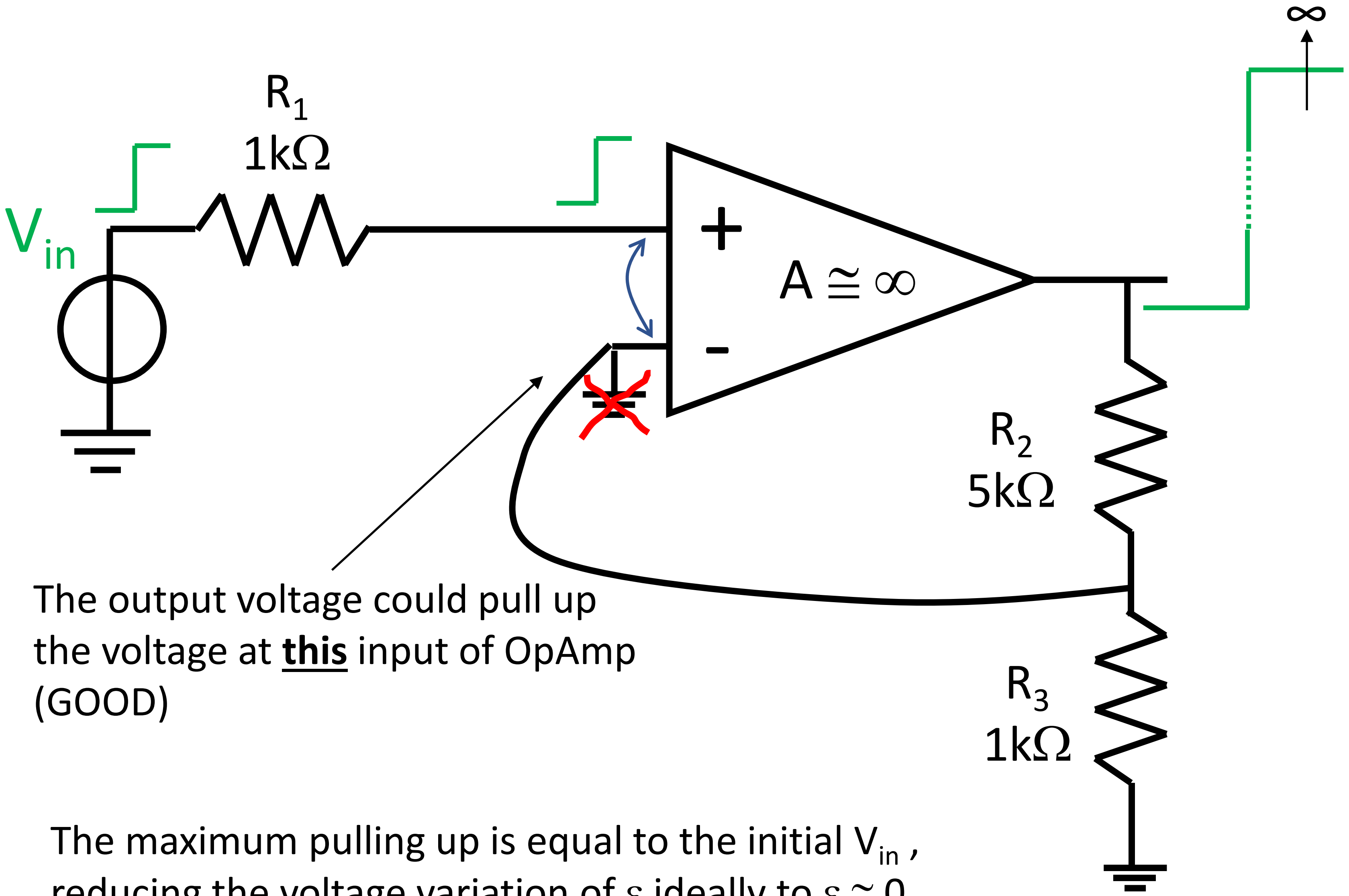
Note the connection to the NON inverting input

We have to use the output to compensate the voltage variation of ε (ideally to ε ≅ 0)

This voltage activates the OpAmp
In this moment $\varepsilon = V_{in}$

Exercise on Feedback with OpAmp (2)

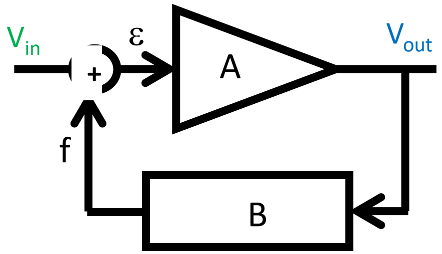


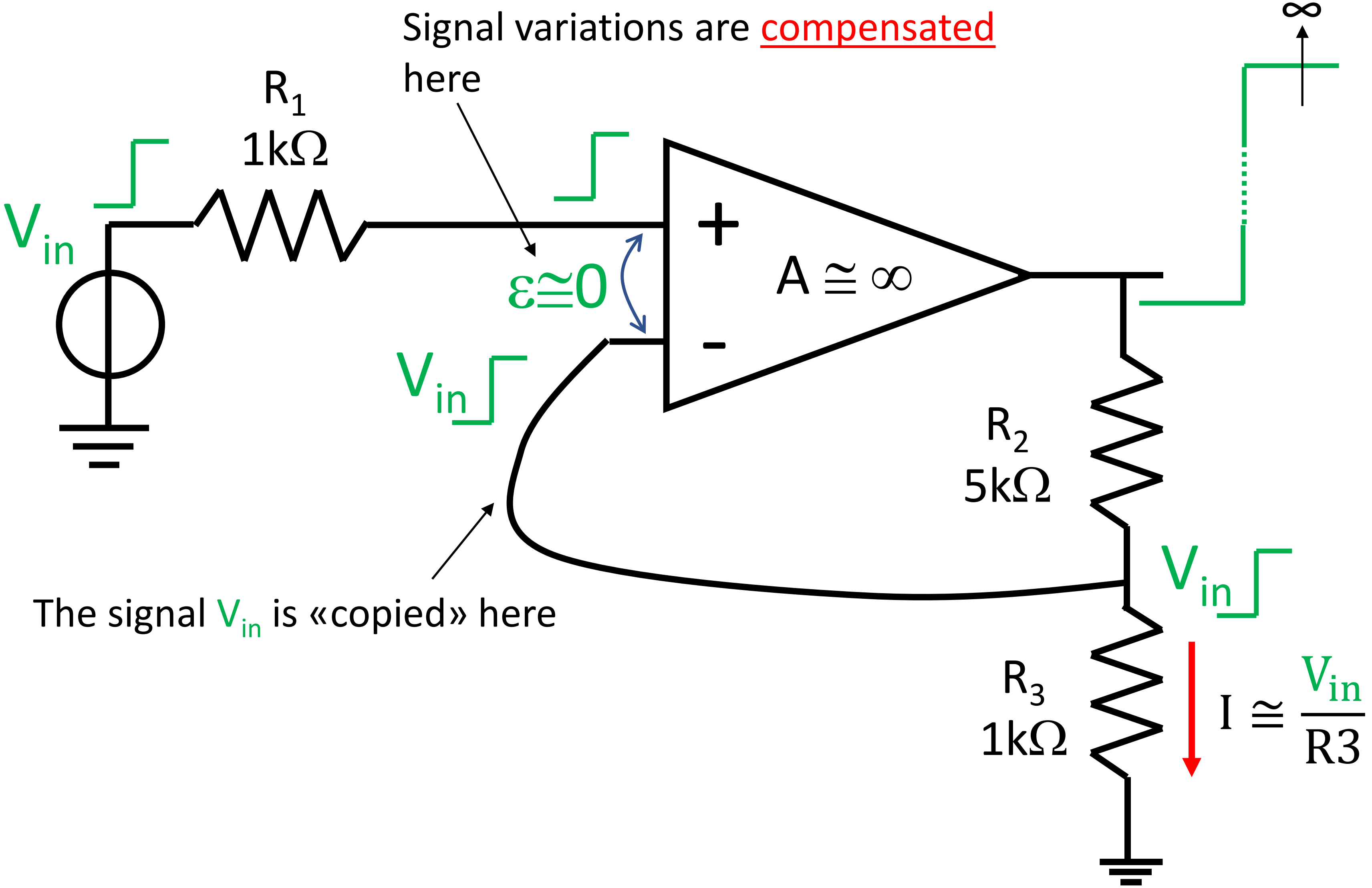


The output voltage could pull up the voltage at **this** input of OpAmp (GOOD)

The maximum pulling up is equal to the initial V_{in} , reducing the voltage variation of ε ideally to $\varepsilon \cong 0$.

Exercise on Feedback with OpAmp (3)



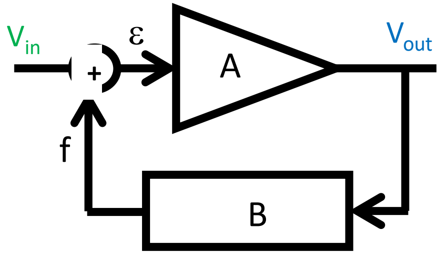


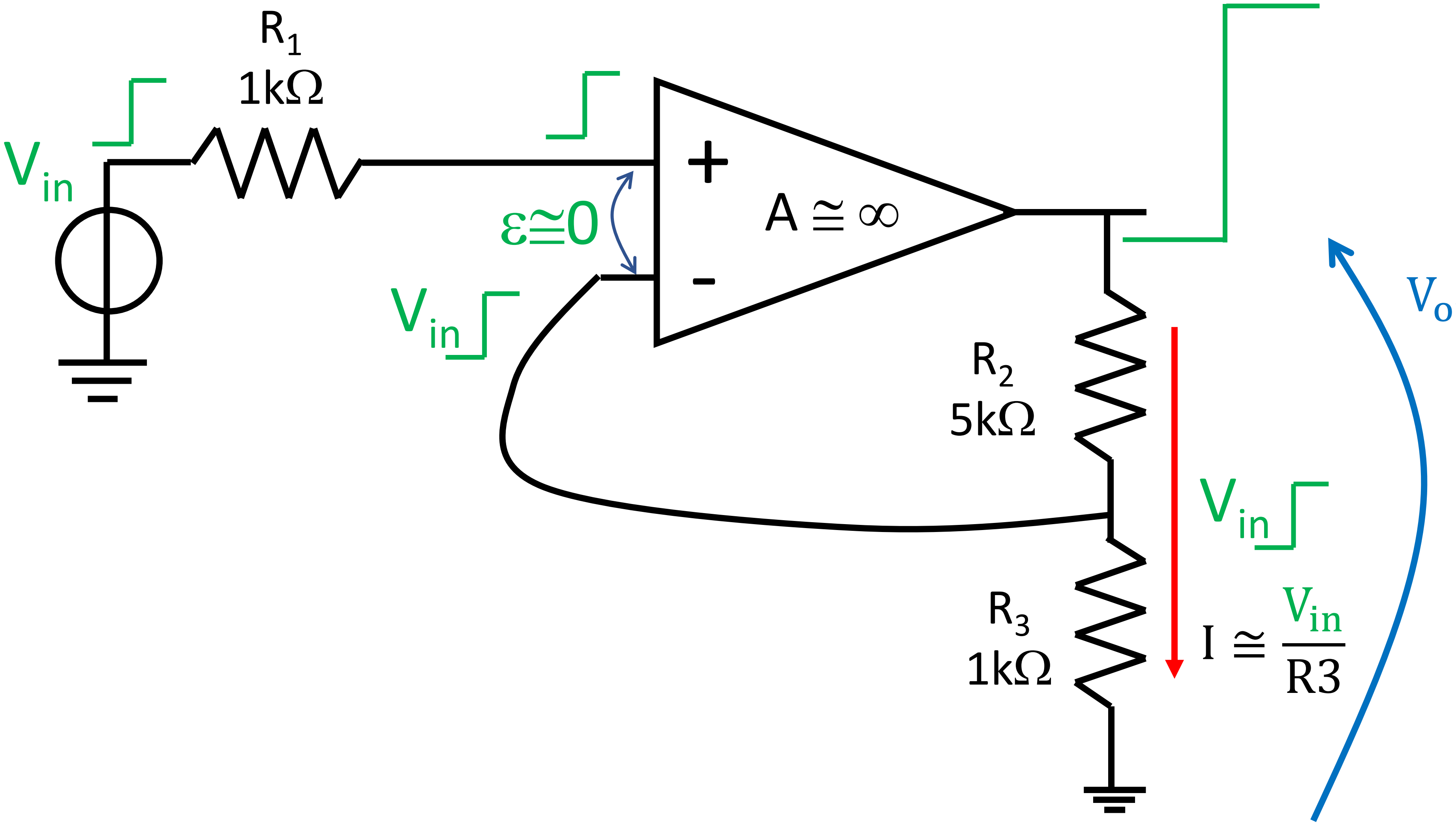
Signal variations are compensated here

The signal V_{in} is «copied» here

If this point moves up by V_{in} the current in R3 is defined

Exercise on Feedback with OpAmp (4)





$$I \cong \frac{V_{in}}{R3}$$

$$V_{out} \cong \frac{V_{in}}{R3} \cdot (R2 + R3)$$

$$\boxed{G_{id} = \frac{R2 + R3}{R3} = 6}$$

End of the lesson