ELECTRONIC SYSTEMS and TECHNOLOGIES

Master in Management Engineering

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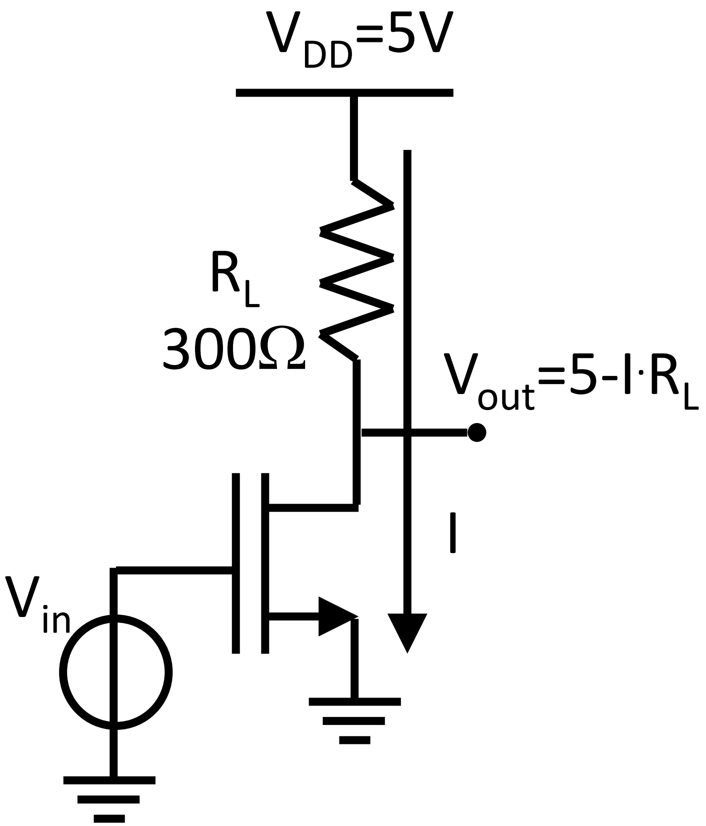
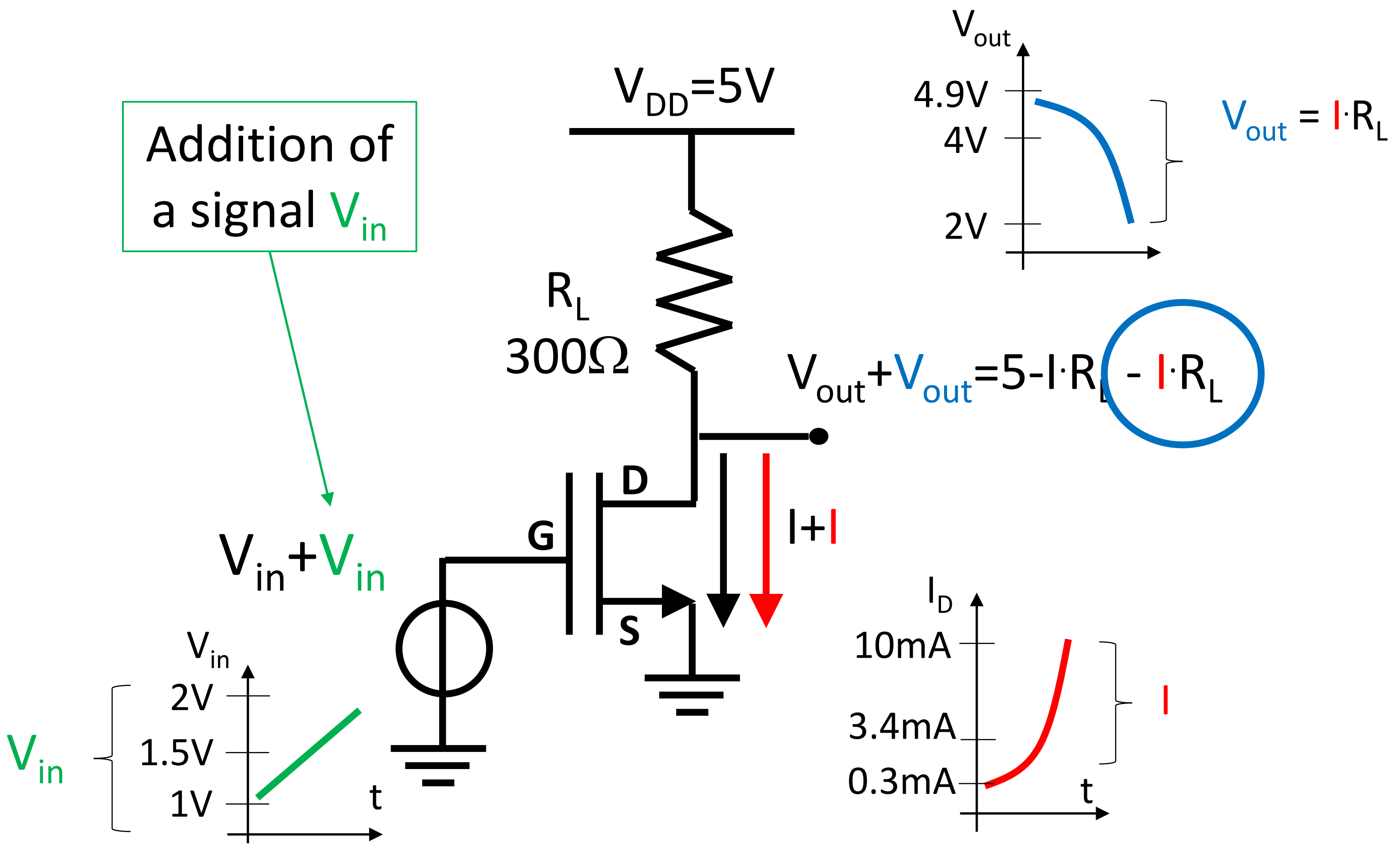
GROUND CONCEPTS ON ELECTRONICS

The idea of FEEDBACK

Polarisation and signal gain of an Amplifier

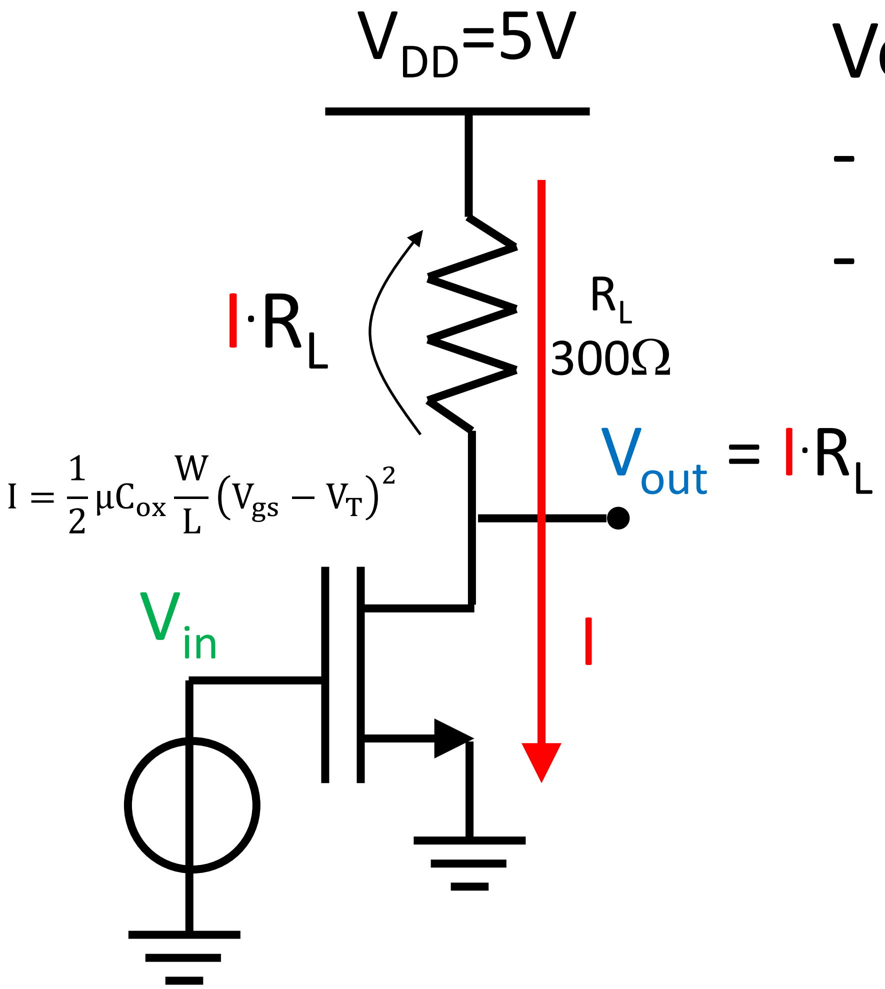


Starting condition
(Polarisation or Bias)



The information is contained in variations (color in the slide)
with respect to the initial steady situation (black)

Tuning of the Gain of an amplifier



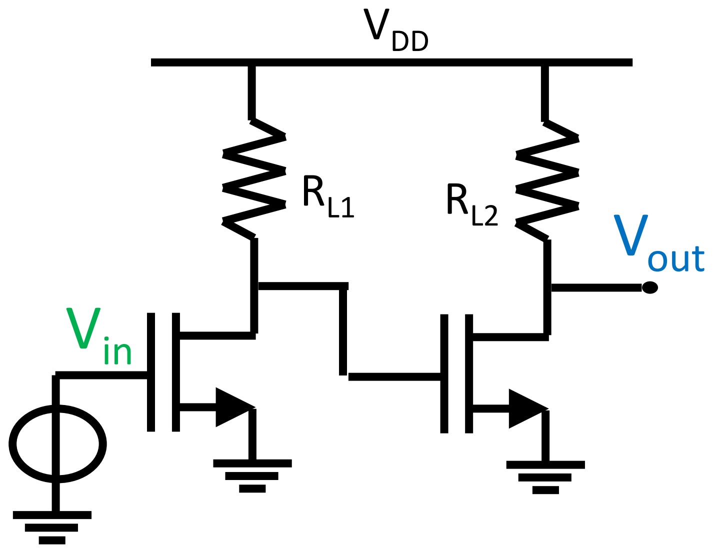
Voltage GAIN depends on :

- Transistor characteristics
- Value of R_L

Not very controllable (change with technology, with polarisation, with temperature, etc. …

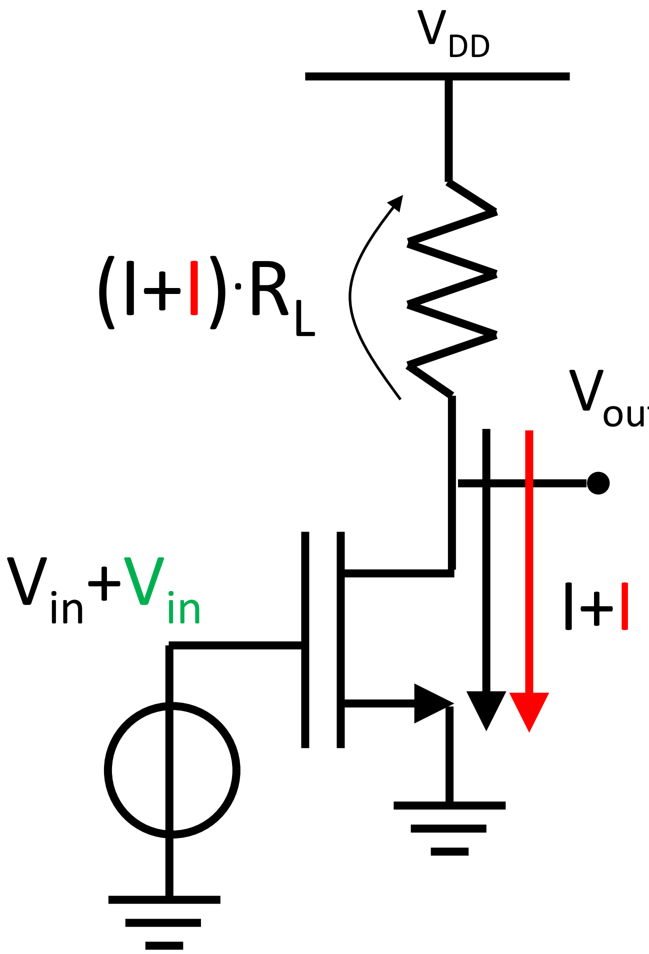
Multi-stage Amplifier

$G_{tot}=G_1 x G_2$



Very often the bias is not indicated (for simplicity)

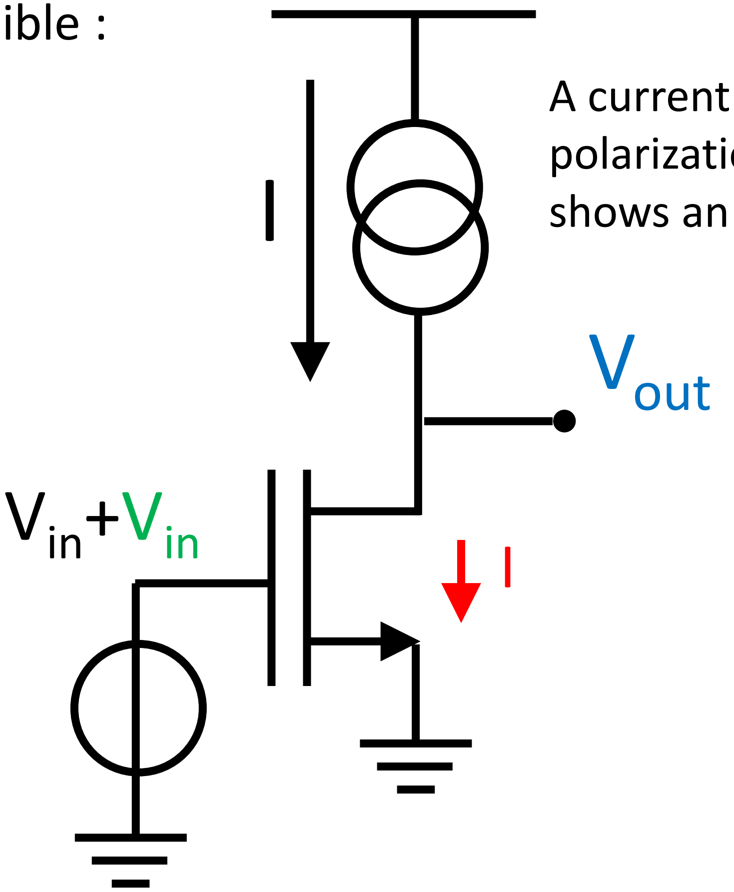
Amplifier with very high gain



Increase R_L not always possible :

Transistor out of operation point due to polarisation current I

$V_{out}+V_{out}=V_{DD}-I\cdot R_L - I\cdot R_L$



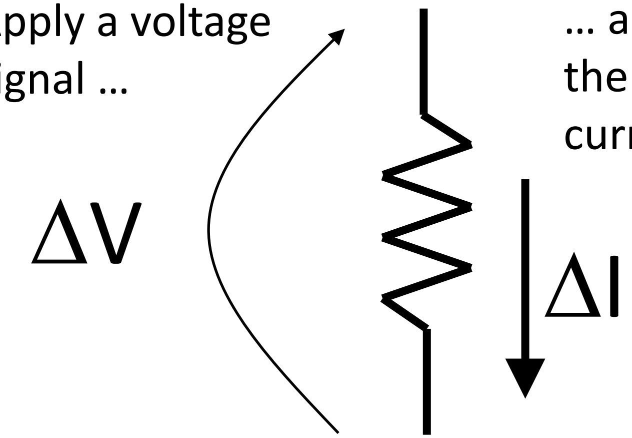
A current generator sets polarization current and shows an ∞ resistance

$G \cong -\infty$

Close look on resistance of a Current generator

How to measure a resistance ?

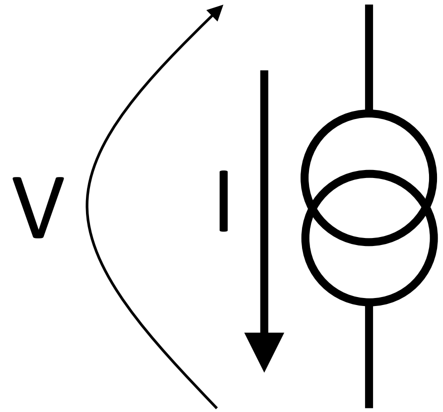
Apply a voltage signal …



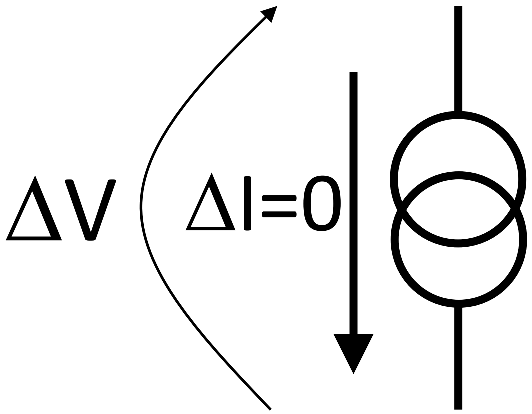
… and measure the corresponding current signal

The ratio between the two gives the Resistance

$$R = \frac{\Delta V}{\Delta I}$$

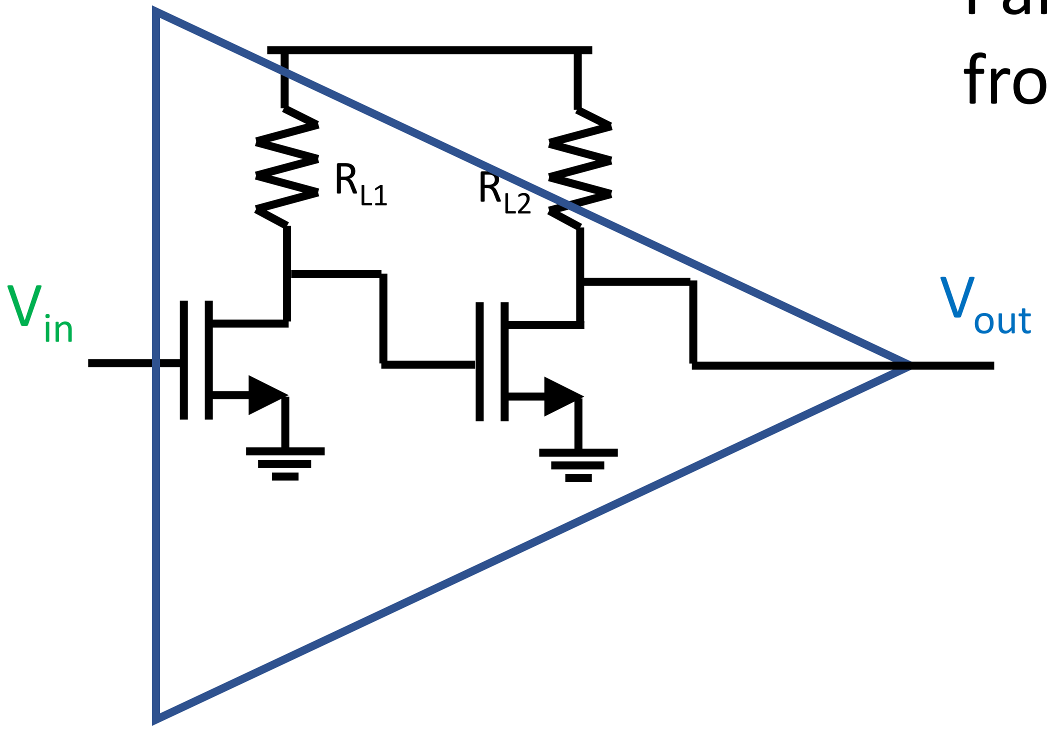


A current generator sets the Current **I** independently of the Voltage **V** across



$$R = \frac{\Delta V}{\Delta I} = \frac{\Delta V}{0} = \infty$$

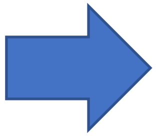
Compact symbol of an amplifier



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

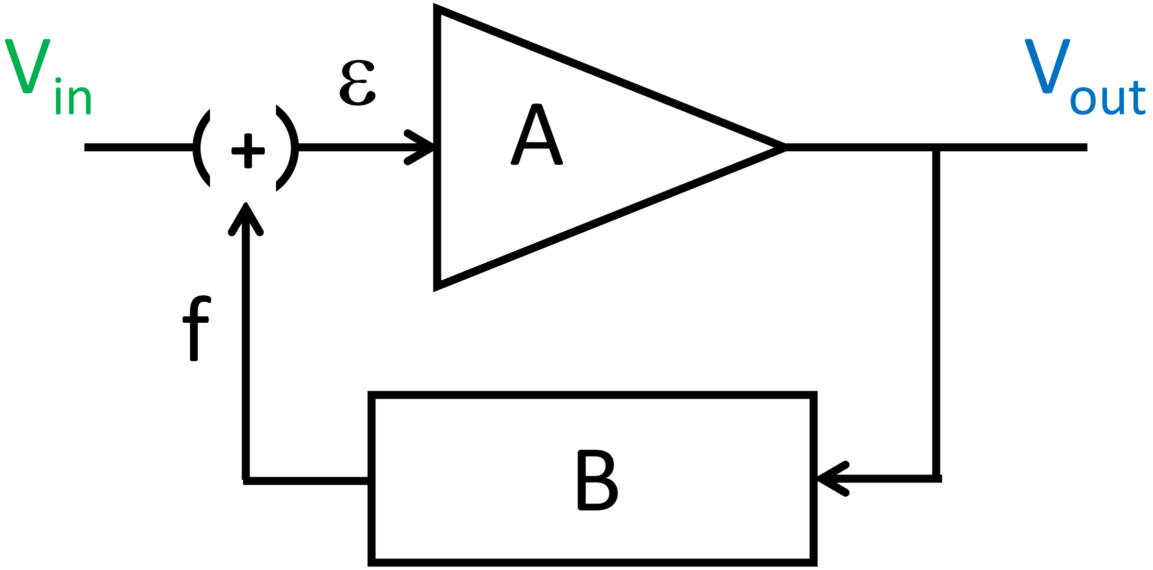
Gain changes
Distortion changes
Frequency response changes

Almost impossible to stabilize an amplifier by design



Need a Game changer !

The idea of the FEEDBACK



$$V_{out} = V_{in} \cdot A$$

Depends on the amplifier (BAD)

$$V_{out} = \varepsilon \cdot A$$

$$\varepsilon = V_{in} + V_{out} \cdot B$$

$$V_{out} = V_{in} \cdot A + V_{out} \cdot A \cdot B$$

$$\varepsilon = V_{in} + \varepsilon \cdot A \cdot B$$

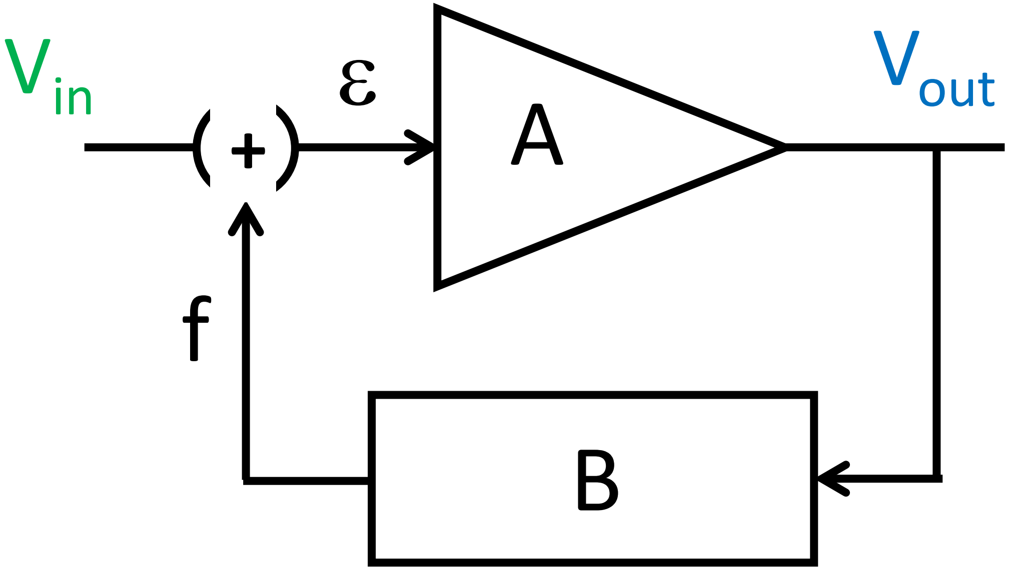
$$V_{in} \cdot \frac{1}{1 - A \cdot B} = V_{in} + f$$

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

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

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

A closer look to the FEEDBACK



The Gain does NOT depend on A (Very GOOD)

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

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

Practically no signal is applied to A (GOOD)

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

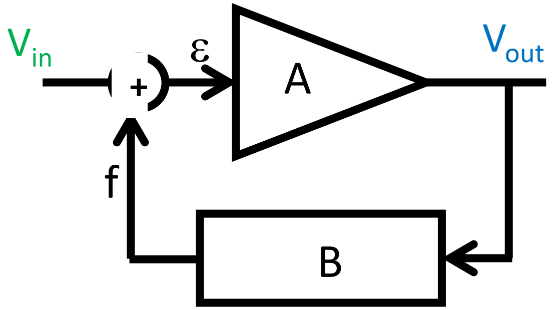
Suppose A=-∞ (we know we can !)

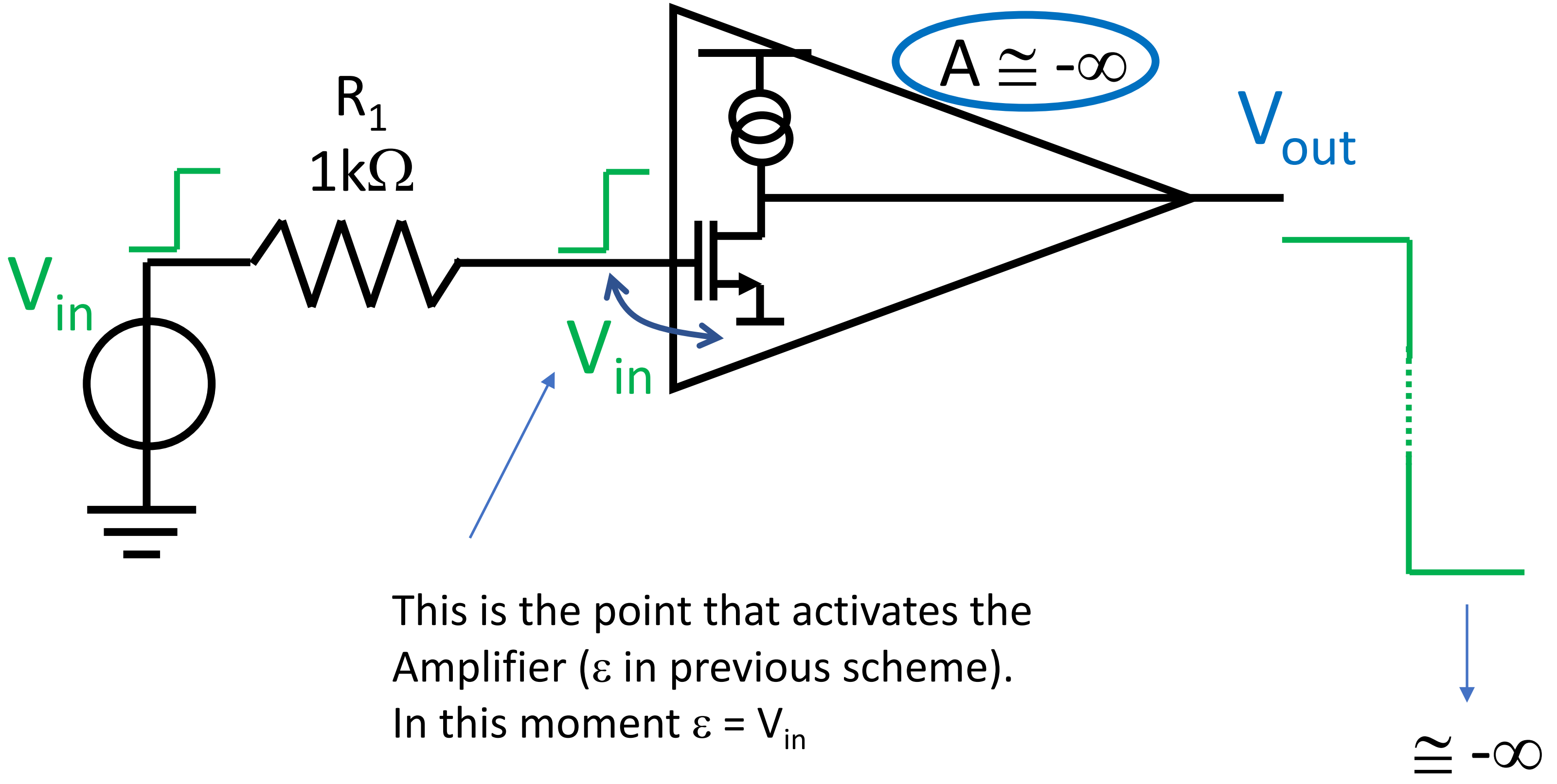
«A·B» is the Loop Gain

Practically all signal is available within the loop

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

A practical example of Feedback circuit (1)

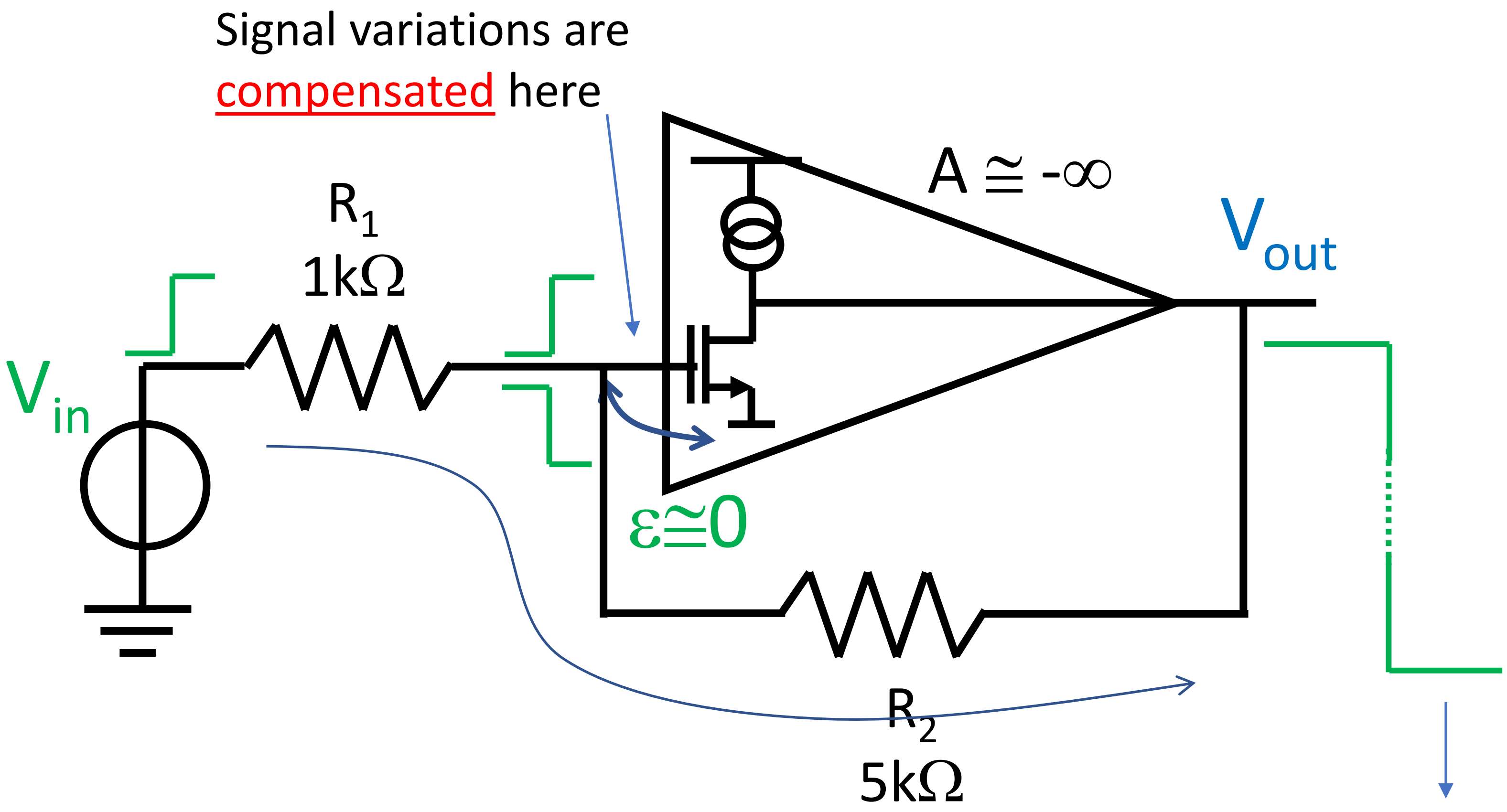


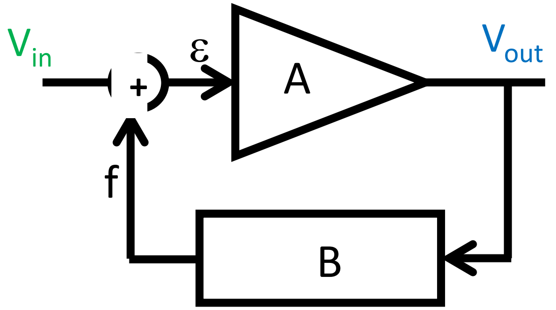


This is the point that activates the Amplifier (ε in previous scheme).
In this moment $\varepsilon = V_{in}$

We have to use the output to reduce the voltage variation of point ε (ideally to $\varepsilon \cong 0$)

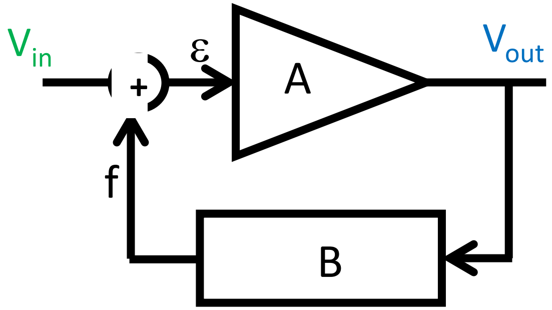
A practical example of Feedback circuit (2)



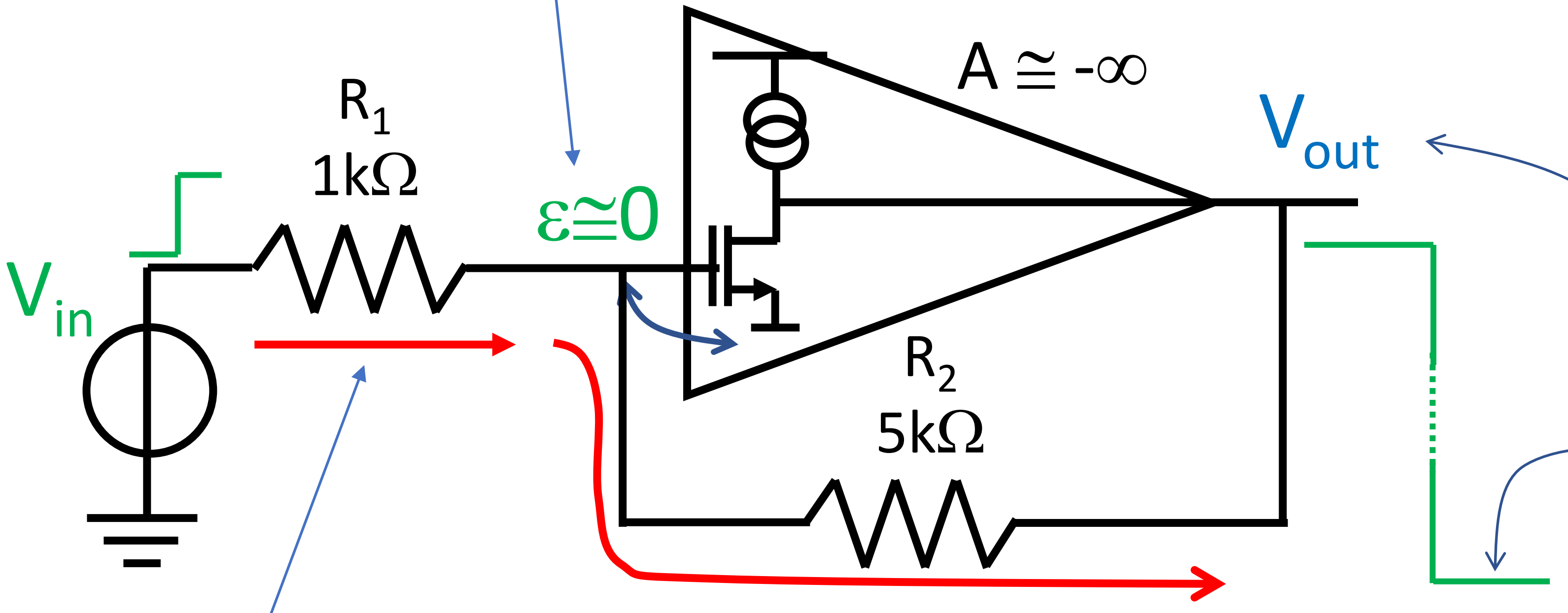


The output voltage pulls down the voltage at input of amplifier (GOOD) . The maximum pulling down is equal to the initial V_{in} , reducing the voltage variation of point ε ideally to $\varepsilon \cong 0$.

A practical example of Feedback circuit (3)



This point kept fixed in Voltage by the feedback



Current here is simply

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

The same current is flowing in R2 (remember f is equal to input signal !)

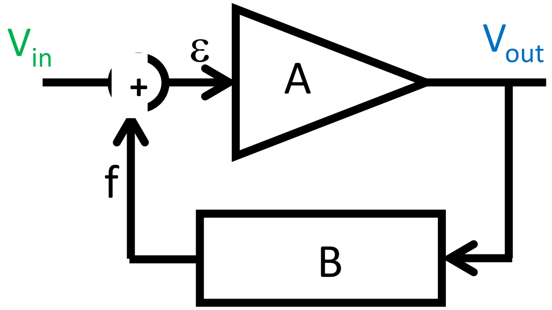
Output voltage is simply given by

$$V_{out} \cong -I \cdot R2$$

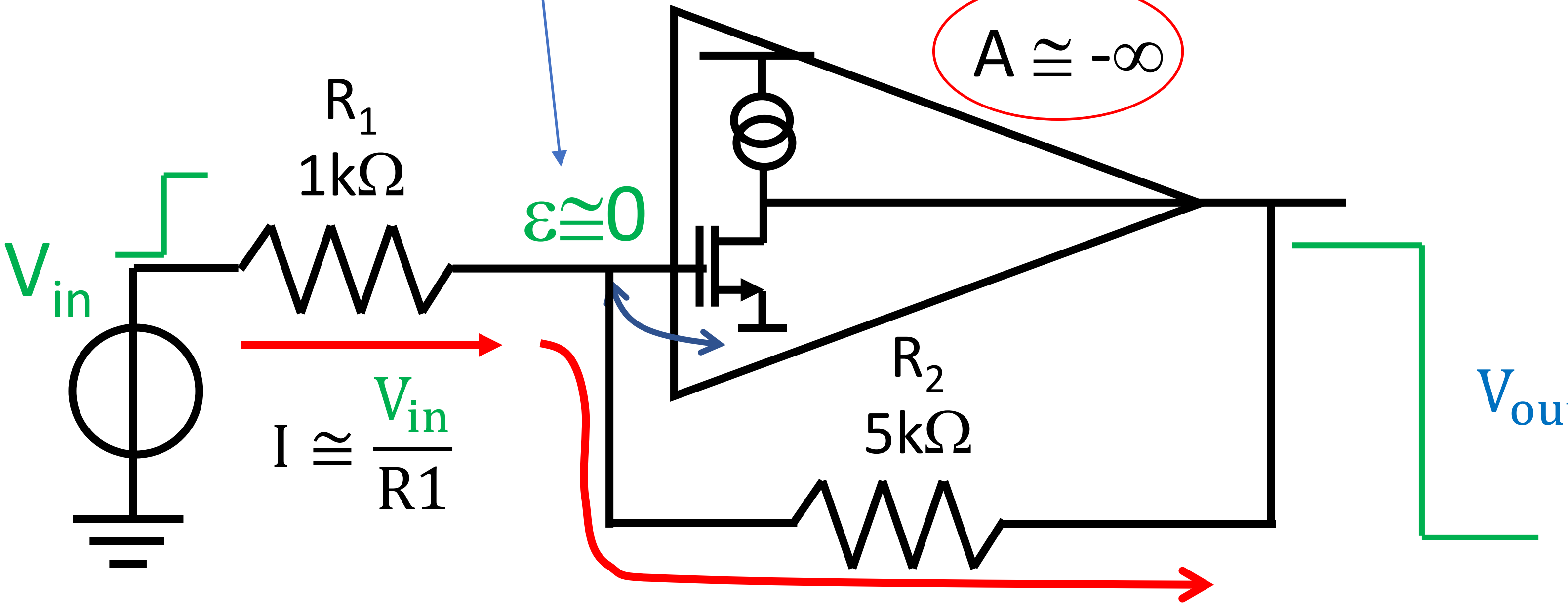
Amplifier A is NOT appearing in the Gain !

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

The ideal Gain of a Feedback circuit



This point kept fixed in Voltage by the feedback



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

The same current is flowing in R2

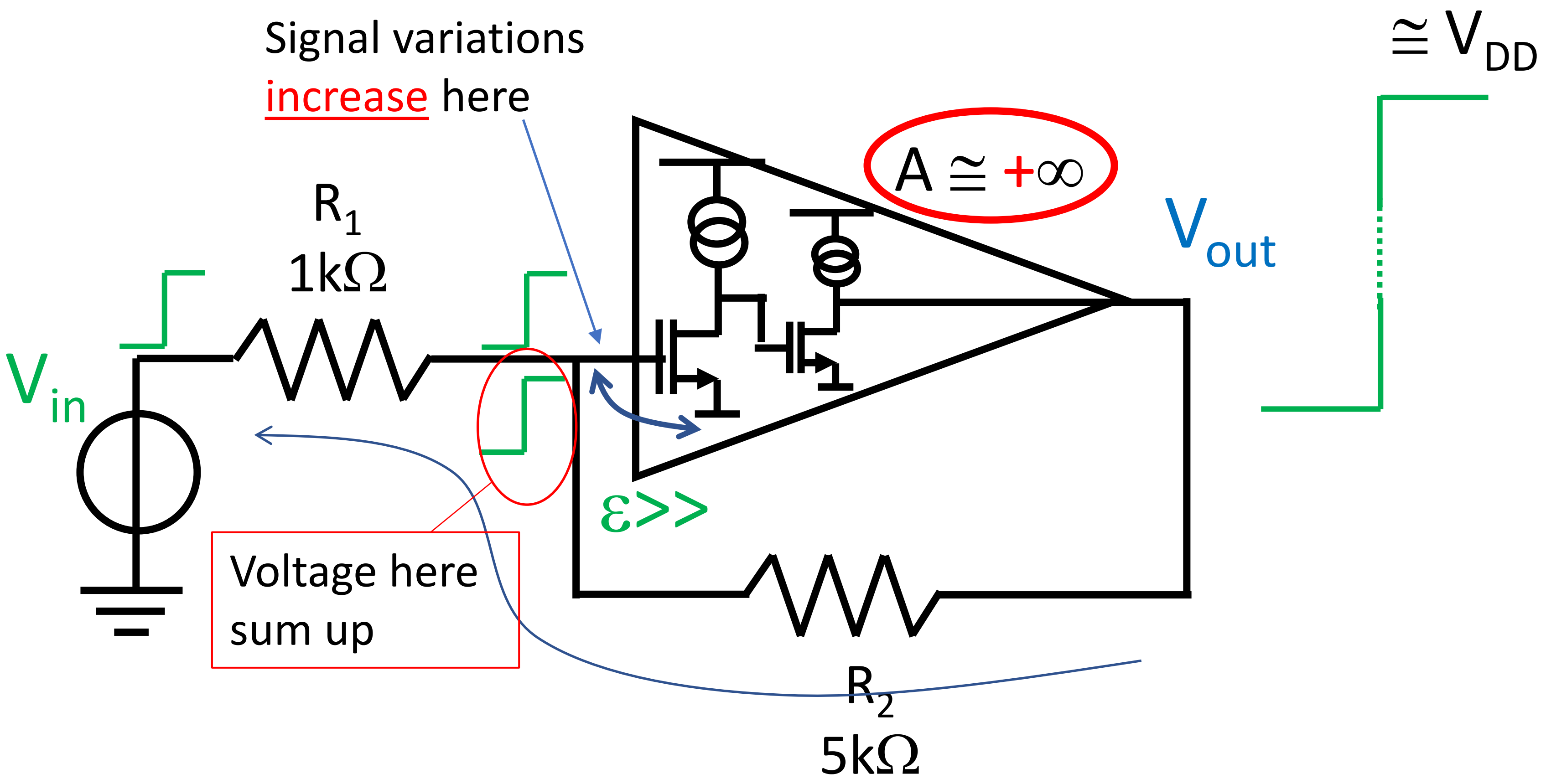
$$V_{out} = -\frac{V_{in}}{R1} \cdot R2$$

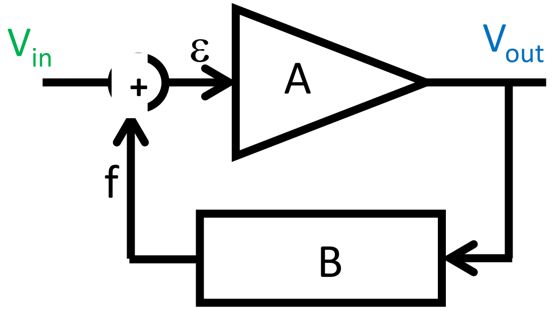
$$G_{id} = -\frac{R2}{R1} = -5$$

Ideal because A=∞

The GAIN only depend on RESISTANCES :
Stable and Linear !

Negative and Positive Feedback



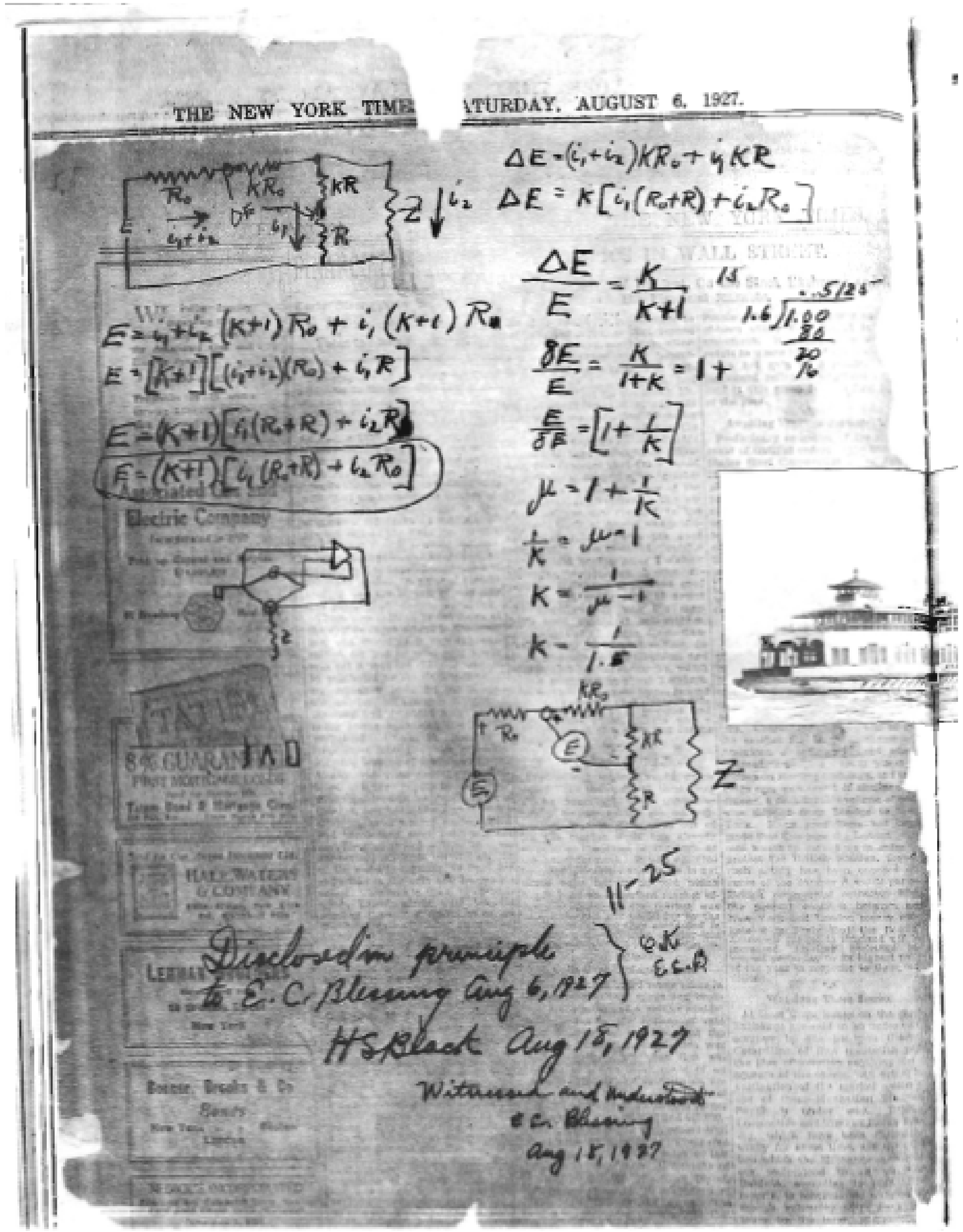


The output voltage pulls up the voltage at input of amplifier (ε increases, VERY BAD).

The output voltage will increase further. The system will only stop when V_{out} reaches V_{DD}. ➡ **POSITIVE FEEDBACK**

STABILITY is ensured only by NEGATIVE FEEDBACK

The inventor of the feedback : Harold S. Black



It was a day in August 1927 when Harold S. Black, while crossing Hudson river on the Lackawanna boat to go to work in Manhattan, got the idea of the Feedback control to stabilize gain variations and reduce non-linearities. He was 29 years old and was working since six years at Bell Telephone Laboratories, a telephone company.

End of the lesson