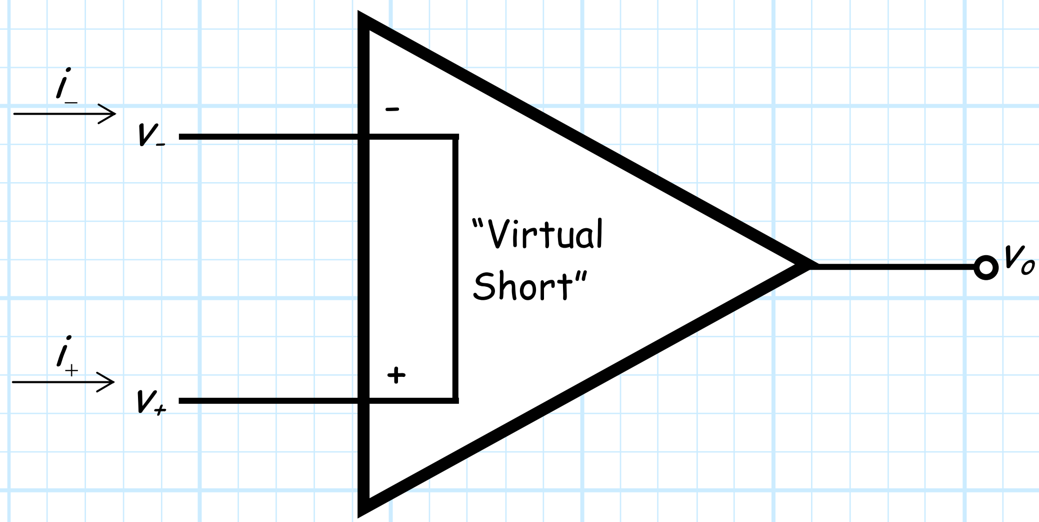
The Virtual Short

For **feedback** amplifiers constructed with op-amps, we have found (and will continue to find) that the two op-amp terminals will always be **approximately equal** ($v_- \approx v_+$).

Of course, this must be true in order to avoid saturation, as the gain of an op-amp is ideally **infinitely** large.

Since $v_- \approx v_+$ for feedback applications, it **appears** that the two op-amp terminals are **shorted** together!

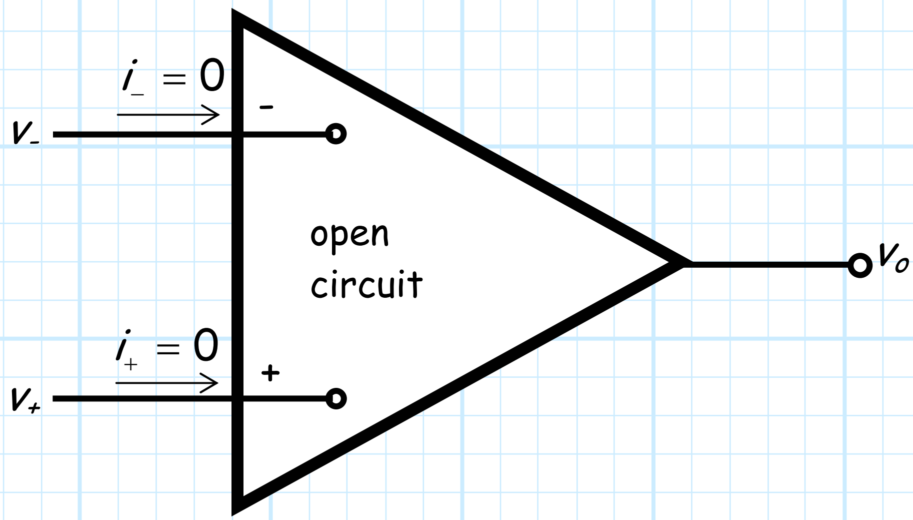


There is no short inside the op-amp!

The condition in op-amp feedback amplifiers where $v_1 = v_2$ is known as the "**virtual short**".

Remember, although the two input terminal **appear** to be shorted together, they are most certainly **not**!

If a **true** short **were** present, then **current** could flow from one terminal to the other (i.e., $i_- = -i_+$). However, we know that the input resistance of an op-amp is ideally **infinite**, and thus we know that the input current into an op-amp is **zero**.

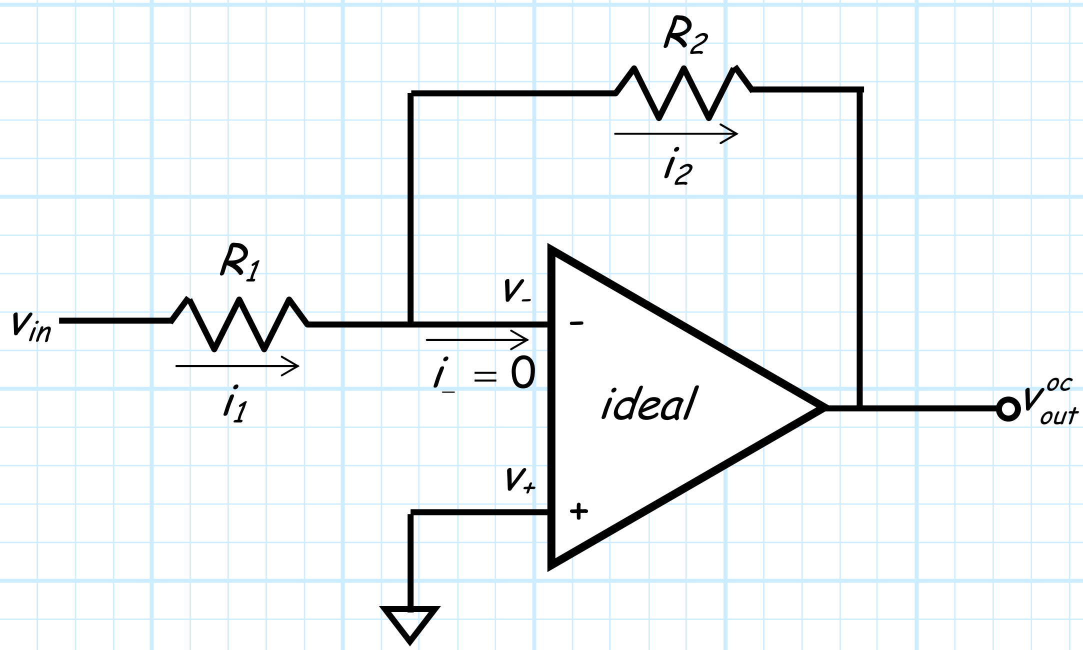


Therefore, it is **not** the op-amp that enforces the condition $v_1 = v_2$, it is the **feedback** that makes this so!

The virtual short: your new BFF

Applying the concept of a **virtual short** can greatly **simplify** the analysis of an op-amp feedback amplifier.

For example, consider **again** the **inverting amplifier**:



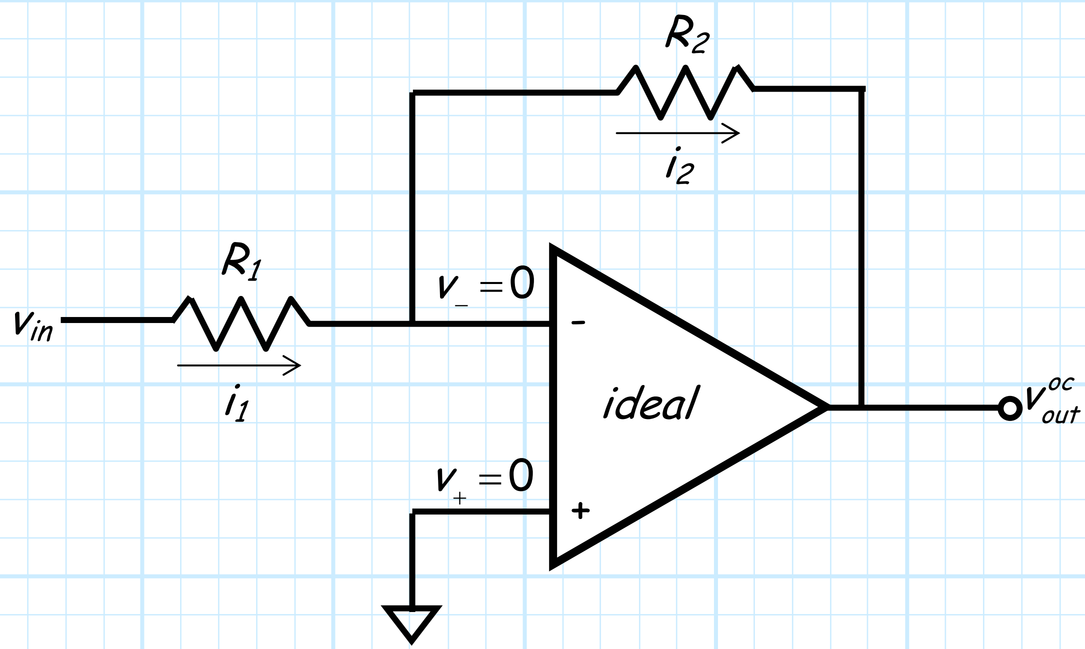
The virtual ground

This time, we **begin** the analysis by applying the **virtual short** condition:

$$v_- \cong v_+$$

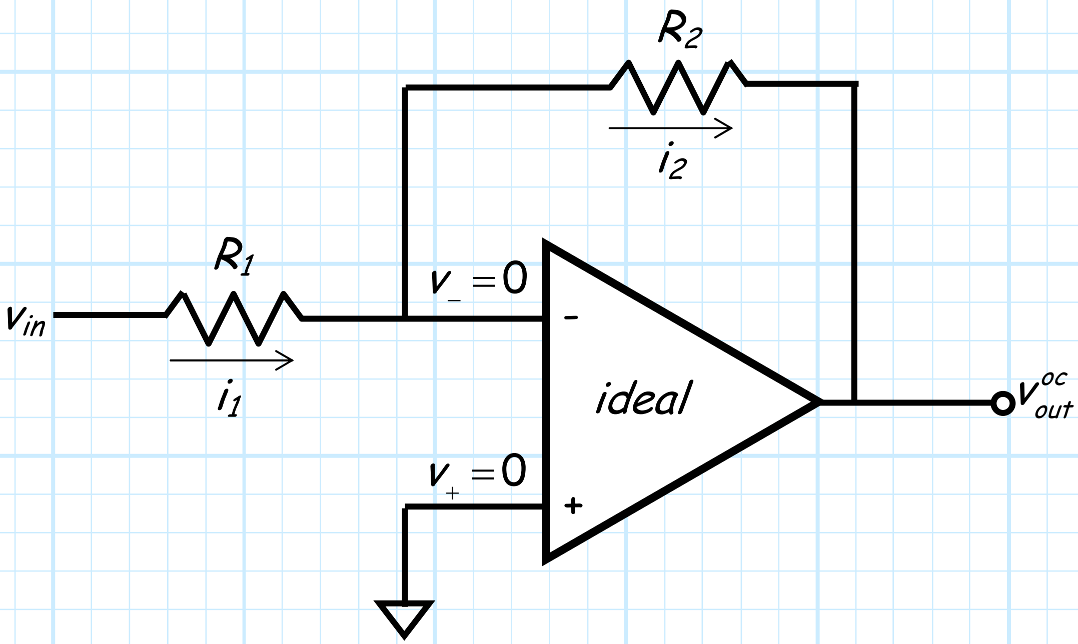
Since the non-inverting terminal is **grounded** ($v_+ = 0$), the virtual short means that the non-inverting terminal is **likewise** at zero potential ($v_- = 0$)!

We refer to this condition as a **virtual ground**.



Isn't this simpler?

Analyzing the remainder of the **circuit**, we find:



$$i_- = 0$$

$$i_1 = i_2 + i_- = i_2$$

$$i_1 = \frac{v_{in} - v_-}{R_1} = \frac{v_{in}}{R_1}$$

$$i_2 = \frac{v_- - v_{out}^{oc}}{R_2} = \frac{-v_{out}^{oc}}{R_2}$$

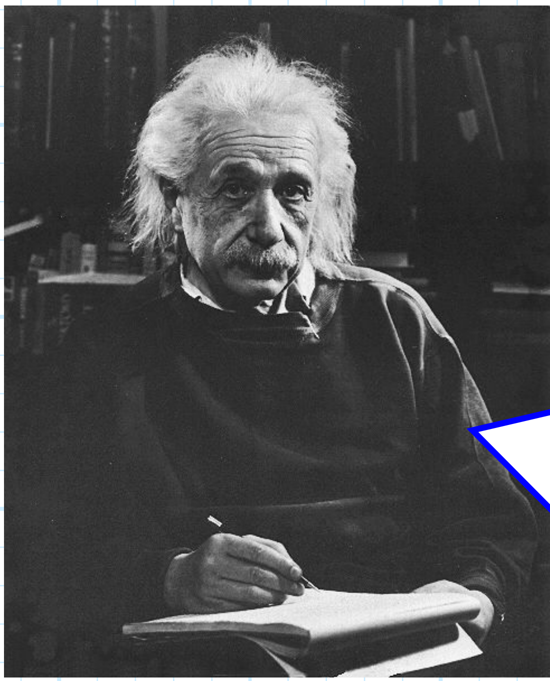
Combining, we find:

$$\frac{v_{in}}{R_1} = \frac{-v_{out}^{oc}}{R_2}$$

Rearranging, we again find the **open-circuit**, **closed-loop** voltage gain:

$$A_{vo} = \frac{v_{out}^{oc}}{v_{in}} = \frac{-R_2}{R_1}$$

Your TA is even smarter than this guy!



*Note this is **exactly** the result we found before, yet in this case we **never** considered the op-amp equation:*

$$v_{out}^{oc} = A_{op}\left(v_+ - v_-\right)$$

*The virtual short equation ($v_+ = v_-$) **replaced** the op-amp equation in our analysis of this **feedback amplifier**.*

*Eeffectively, the two equations say the **same** thing (provided A_{op} is infinitely **large**, and we have **negative feedback** in the circuit).*