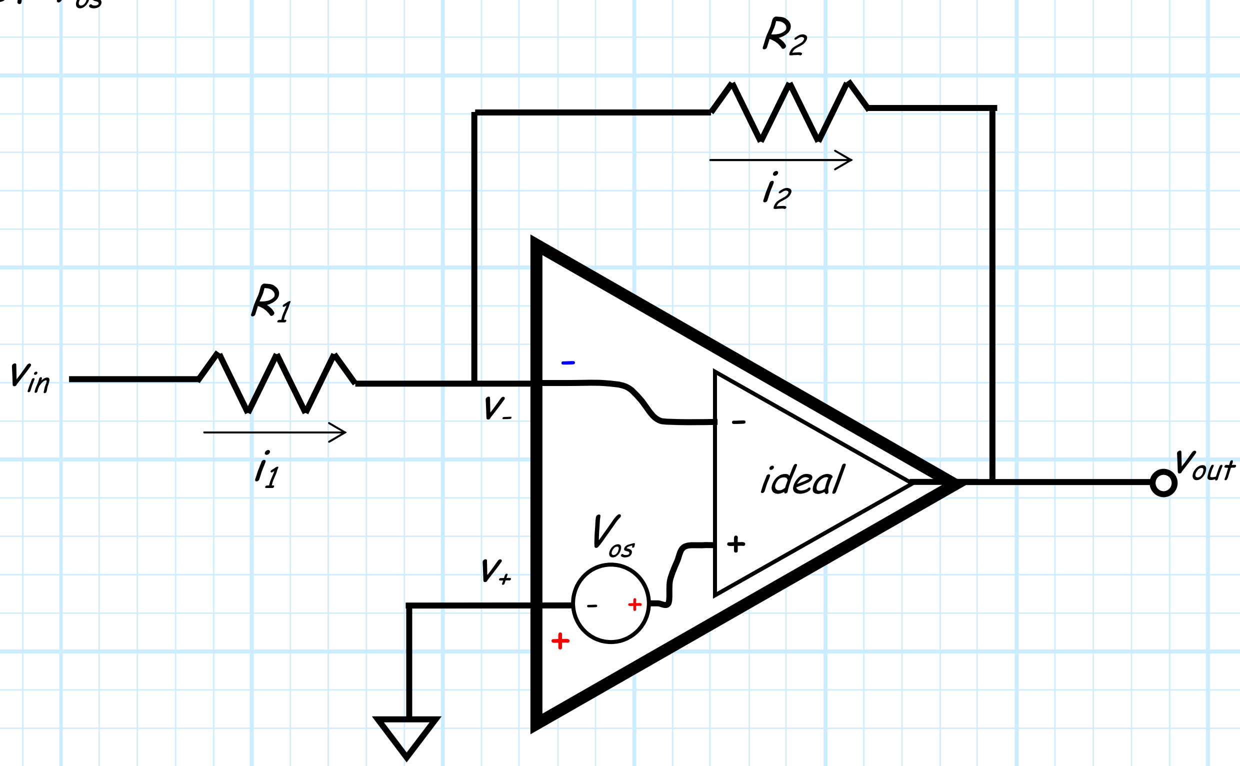
Example: The Input Offset Voltage

Consider an **inverting** amp constructed with an op-amp exhibiting an **input offset voltage** of V_{os}:



v_- not equal to v_+

We know that because of the input offset voltage:

$$v_- = v_+ + V_{os}$$

For the circuit above, the non-inverting terminal of the op-amp is connected to ground (i.e., $v_+ = 0$), and so the virtual "ground" is now described by:

$$v_- = V_{os}$$

The **current** into each terminal of the op-amp is still **zero**, so that from KCL:

$$i_1 = i_2$$

where form KCL and Ohm's Law:

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

and:

$$i_2 = \frac{v_- - v_{out}}{R_2} = \frac{V_{os} - v_{out}}{R_2}$$

The output has a DC offset!

Combining, we find:

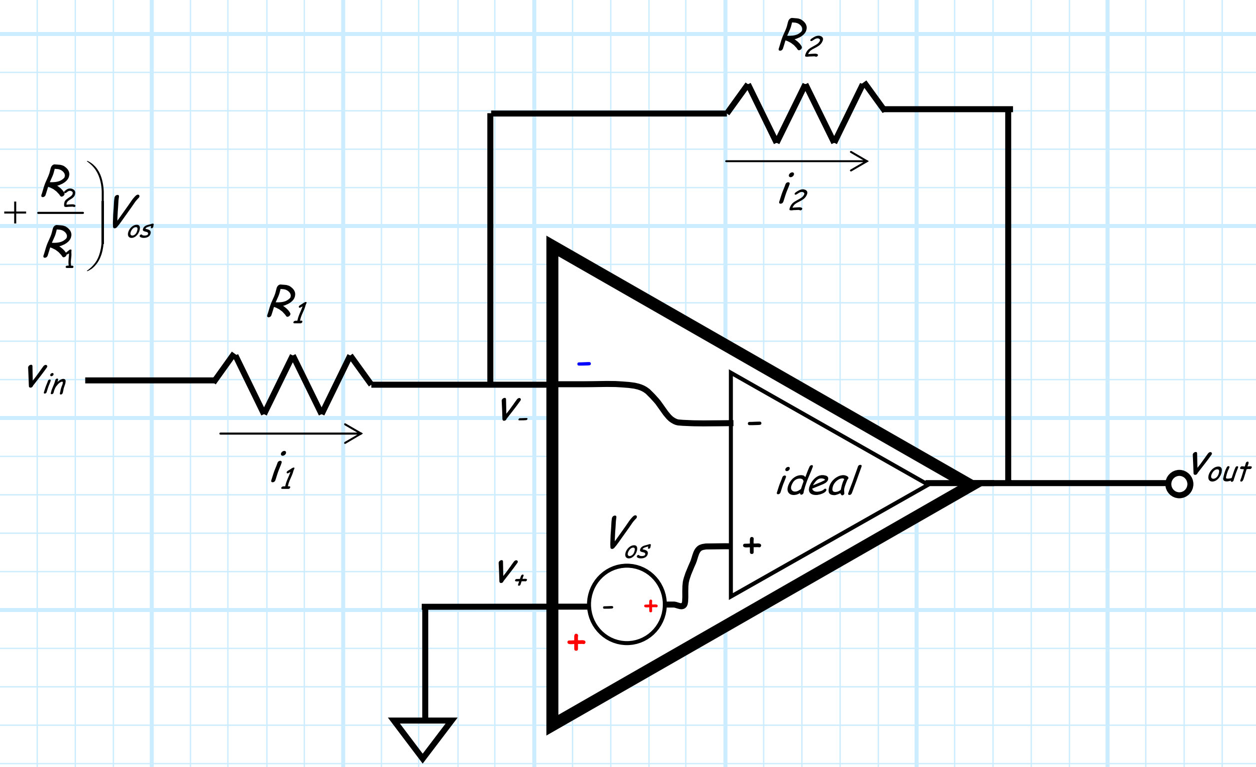
$$\frac{v_{in} - V_{os}}{R_1} = \frac{V_{os} - v_{out}}{R_2}$$

Performing a little algebra, we can solve this equation for **output voltage** v_{out}:

$$v_{out} = \frac{V_{os}R_1 + V_{os}R_2 - v_{in}R_2}{R_1}$$

and rearranging:

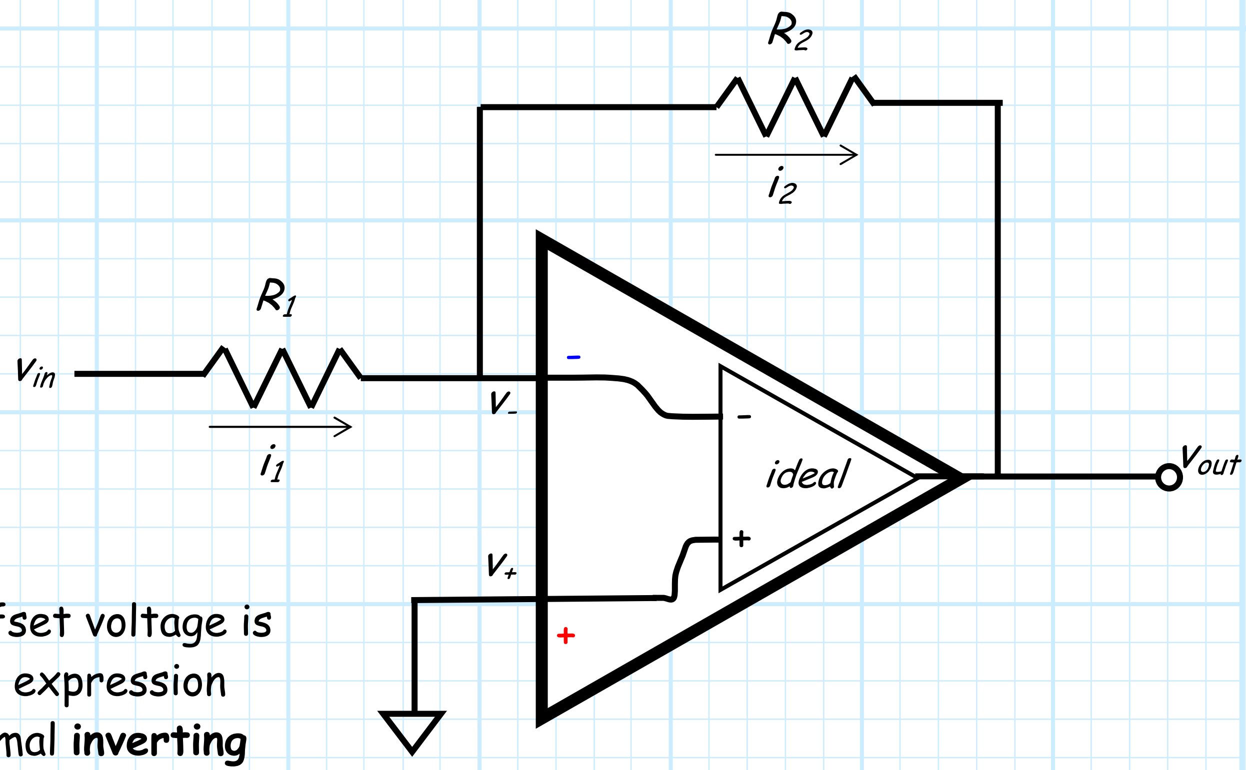
$$v_{out} = -\left(\frac{R_2}{R_1}\right)v_{in} + \left(1 + \frac{R_2}{R_1}\right)V_{os}$$



Superposition is your friend

Q: Hey! Couldn't we have easily found this result by applying **superposition**?

A: Absolutely!

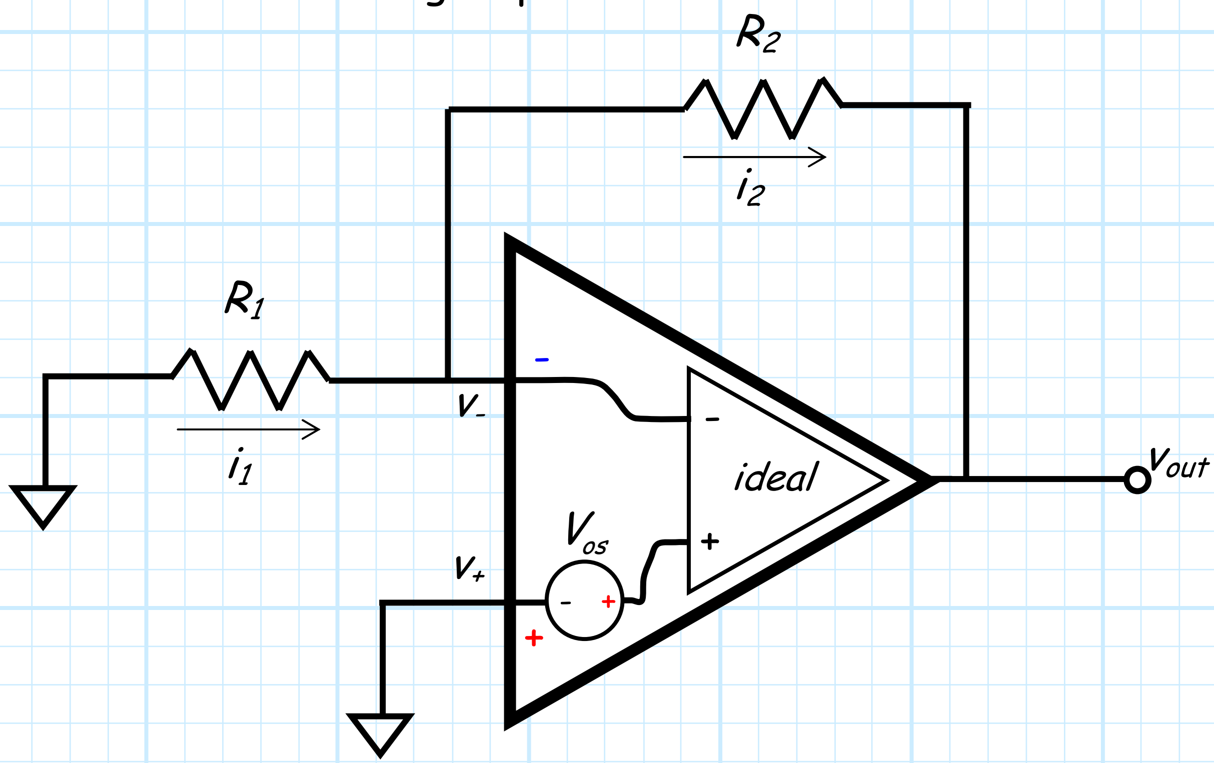


Note that **if** the input offset voltage is zero (its **ideal** value), this expression simply reduces to the normal **inverting amplifier** expression:

$$v_{out} = -\left(\frac{R_2}{R_1}\right) v_{in}$$

It's the non-inverting amplifier!

Likewise, if we set the input voltage source to ground potential (i.e., $v_{in} = 0$), it is evident that we have a non-inverting amplifier:



And so the output voltage is:

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

Look at the DC offset!

The sum of these two results provides our previous answer:

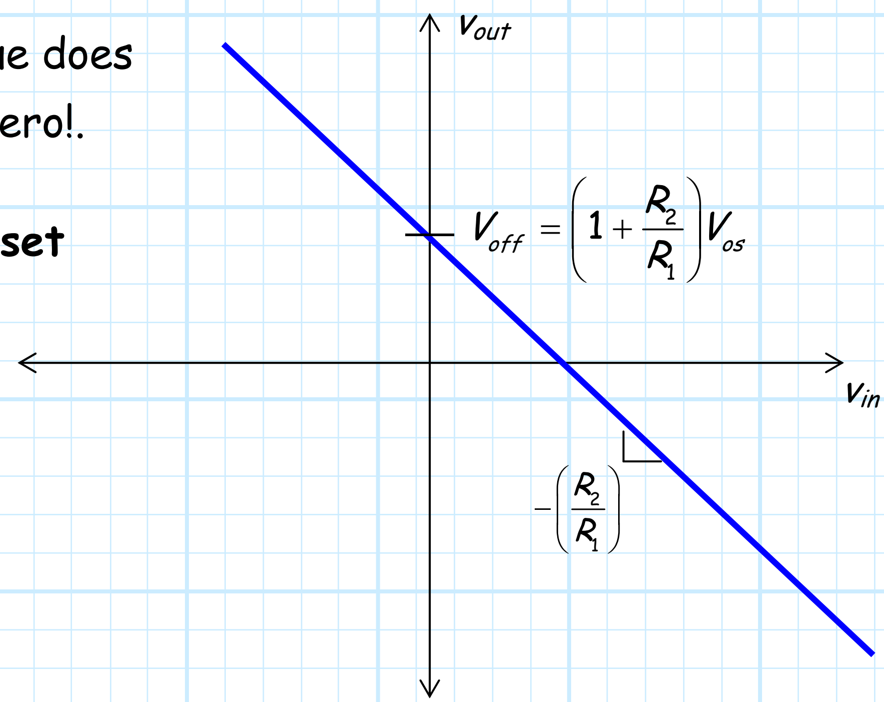
$$v_{out} = -\left(\frac{R_2}{R_1}\right)v_{in} + \left(1+\frac{R_2}{R_1}\right)V_{os}$$

Note the term:

$$\left(1+\frac{R_2}{R_1}\right)V_{os}$$

is a **constant** with respect to v_{in}—its value does not change, **even** if the input voltage is zero!.

Thus, the term represents an **output offset** voltage.



How do we define gain?

Q: *But what is the **gain** of this amplifier? The ratio v_{out}/v_{in} is not a constant!*

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

A: Remember, it is more accurate and more general to define gain in terms of the **derivative**:

$$A_{vo} \doteq \frac{d\,v_{out}}{d\,v_{in}}$$

Which for this case provides the **same result** for the inverting amplifier:

$$A_{vo} = -\left(\frac{R_2}{R_1}\right)$$