Real Op-Amp Input and Output Resistances

The **input** resistances of real op-amps are **very large**, but of course **not** infinite!

Typical values of input resistances range from several hundred **K** Ohms to tens of **Mega** Ohms.

As a result, there is a **small** amount of current flowing into **input** terminals of a real op-amp.

Q: *Well of course! We **just studied** this topic.*

*We already know that there is a **bias current** I_B flowing into (or out of) real op-amp terminals!*

A: This is true! However, there is an **additional** amount of current flowing into the input terminals. This current is **not** a constant bias current, but instead is directly **proportional** to the input terminal voltage.

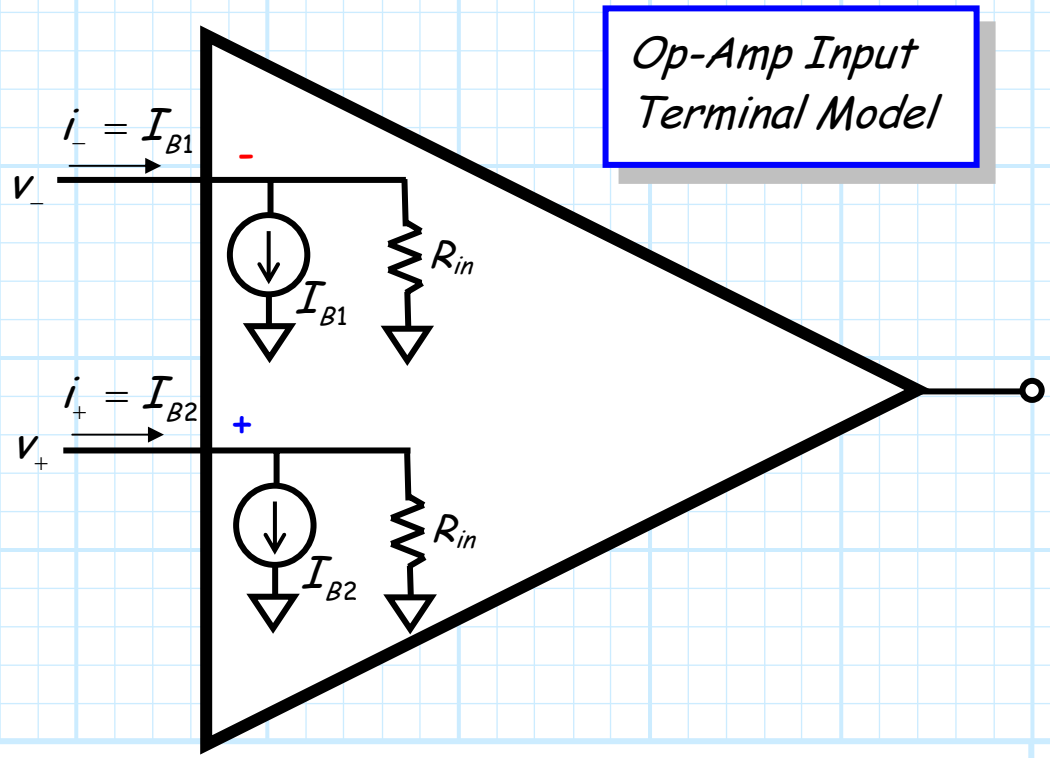
The input resistance is large, but finite

Because the **input resistance** is finite, the **total** current into real op-amp terminals are:

$$i_+ = I_{B2} + v_+ / R_{in}$$

$$i_- = I_{B1} + v_- / R_{in}$$

As such, our input terminal **circuit model** is:



Don't use resistors that are too large!

We find that the input current v_-/R_{in} or v_+/R_{in} will be **insignificant** (i.e., we can ignore its effect), provided that **all** other resistors used in an op-amp circuit are significantly **less** than the op-amp input resistance R_{in}.

Q: *But this would imply that we should* ***never*** *use resistor values greater than* ***100K*** *in our op-amp circuits!*

A: That's **exactly** right!

If the resistor values that **you** use in your op-circuit design are of the order of R_{in}, you may find that **your** circuit behaves quite **differently** from what you expected!

Worse even than finding haggis on the menu

Now let's examine the real values of op-amp **output** resistance.

Instead of the ideal value of zero, we find that the output resistances of real op-amps are **non-zero** (i.e., $R_{out}^{op} > 0$)!

Recall that the output resistance of **both** the inverting and non-inverting configurations is approximately equal to the op-amp output resistance (i.e., $R_{out} = R_{out}^{op}$).

Thus, we find that the **output resistance** of real inverting and non-inverting amplifiers are likewise **non-zero**!

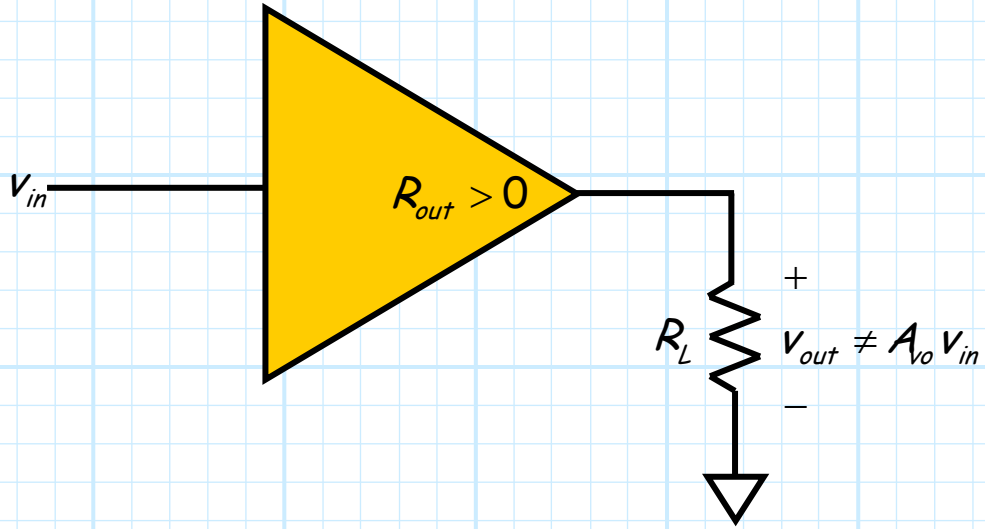
Q: **NO!** *The amplifier output resistance is* ***not*** *zero?!?*

This means that the amplifier output will ***not*** *be equal to the* ***open-circuit*** *voltage if a finite* ***load*** *is attached!*

A: This is absolutely correct!

Still, R_{out} is usually pretty darn small

Remember, the output voltage of an amplifier is equal to the input voltage times the **open-circuit** voltage gain **only** when the amplifier output is connected to an **open circuit**.



But, recall that the output voltage will be **approximately equal** to the open-circuit voltage **if** the output resistance is much **smaller** than the load resistance. I.E.,:

$$v_{out} \simeq A_{vo} v_{in} \quad \text{if} \quad R_{out} \ll R_L$$

Typical values of real op-amp output resistances are **less than 5 Ohms**!