Non-idealities in an Op-Amp

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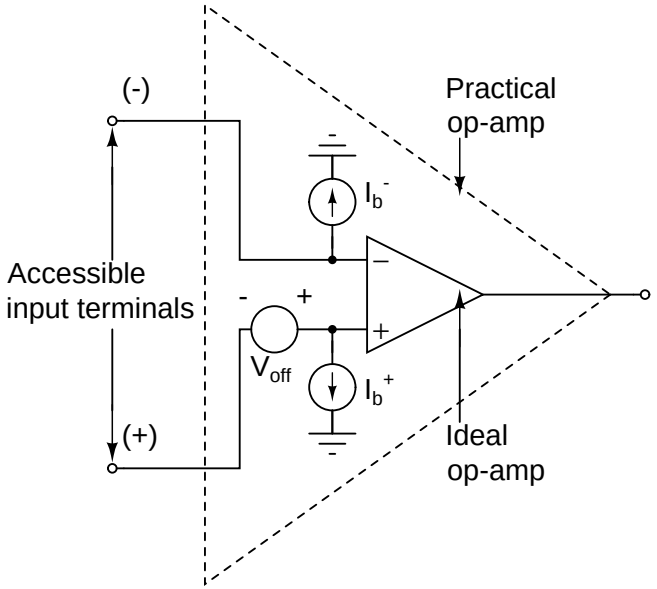
Non-ideal Characteristics in an Op-Amp

- Input offset voltage: A non-zero DC voltage present between the two input differential terminals which causes a DC shift in the output if the gain is sufficiently high. Occurs due to mismatch between the transistor bias voltages inside the op-amp.
- Input bias current: The non-zero current required to drive the base terminal of the input transistors of the op-amp. Can cause a DC shift in the output, depending on the circuit components.
- Finite gain: An ideal op-amp has infinite gain. However, the 3-4 stages inside the 741 op-amp are able to provide a gain of about 2×10^5, which becomes significant as the designed amplifier gain using the 741 is increased.
- Finite bandwidth: Due to internal parasitic capacitances, the output stage of the op-amp behaves like a low-pass R-C circuit, and hence the gain drops as the frequency is increased.
- Other parameters such as non-infinite input impedance, non-zero output impedance, common-mode rejection etc. are also important, though we will not be measuring these in the lab.

Representation of a Non-ideal Op-Amp

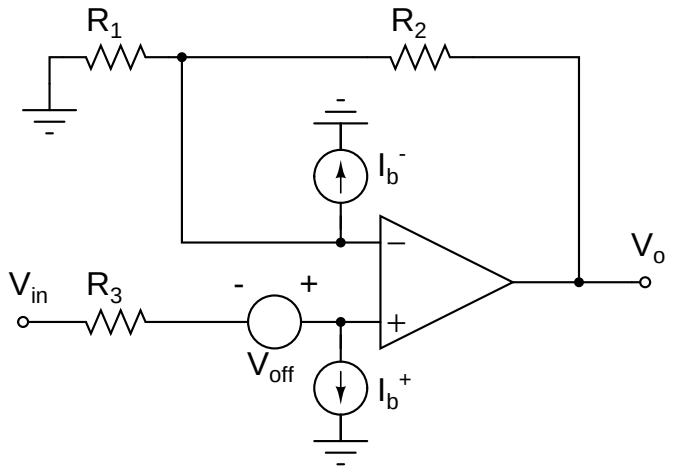
A practical, non-ideal op-amp is represented as an ideal op-amp, along with the input offset voltage and the input bias currents. This is a very simple model.



Here, V_{off} represents the input offset voltage, I_b^+ and I_b^- represent the input bias currents. V_{off} may even be shown on the inverting input, however, it is a common practice to show it on the non-inverting input.

Effects on a Circuit

Consider a simple non-inverting amplifier, along with the offset voltage and bias currents.



The DC error in the output voltage would be

$$V_{err} = V_{off}\left(1+\frac{R_2}{R_1}\right) + (-I_b^+ R_3)\left(1+\frac{R_2}{R_1}\right) + (-I_b^- R_2) \qquad (1)$$

This could be quite large, depending on R_1, R_2, R_3! Thus, DC error is due to both offset voltage and bias currents.

Minimizing the Effects of Bias Currents

Let us apply the superposition principle to ensure that the effects of the input bias currents are nullified. Assume that the bias currents are fairly well-matched, i.e. $|I_b^+| = |I_b^-|$. The voltages at the two input terminals are given by

$$V_n = \left(\frac{R_1}{R_1 + R_2}\right) V_0 - (R_1||R_2) I_b^-$$

$$V_p = I_b^+ R_3$$

To make $V_0 = 0$ and assuming that $|I_b^+| = |I_b^-| = |I_b|$,

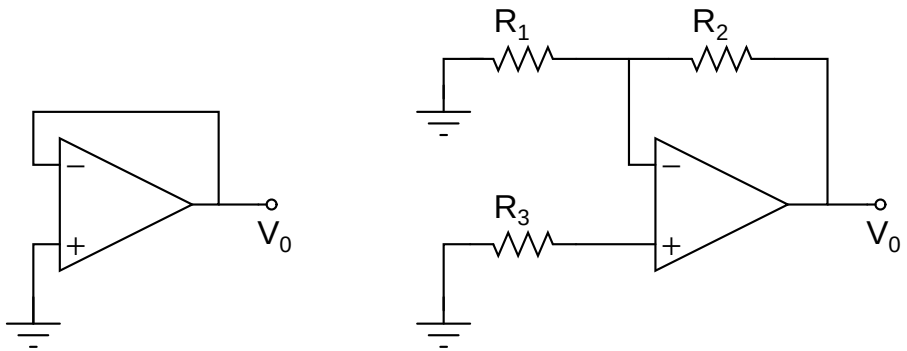
$$I_b R_3 = (R_1||R_2) I_b$$

$$\therefore R_3 = R_1||R_2 \tag{2}$$

Hence by placing a "dummy" resistor R_3 at the non-inverting input, bias current effect can be minimized (ONLY IF I_b^+ and I_b^- are fairly well matched!).

Measuring the Offset Voltage and Bias Currents

- Measuring one parameter requires you to minimize/consider the effects of the other. Let us first measure input offset voltage.
- You can use circuit (a) to measure the input offset voltage. Measure V_0 on a multimeter, which directly gives V_{off}.

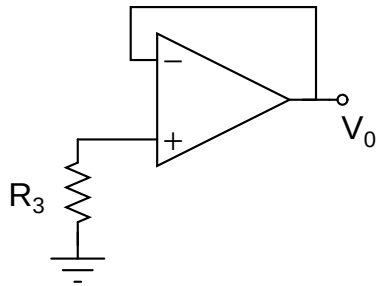


(a) (b)

- In case the V_{off} is too small to be read, use circuit (b) which provides a gain (you have to decide how much gain to provide). Make sure that $R_3 = R_1||R_2$.

Measuring the Offset Voltage and Bias Currents (cont'd...)

- Once the input offset voltage V_{off} is known, the bias currents I_b^+ and I_b^- can be found.
- Again, we minimize the effects of one to find the other. Say we wish to find I_b^+ first.
- You can use the circuit shown below.



- Here, the effect of I_b^- is minimized. Note down V_0 and substitute in eq. (1) to find I_b^+.
- Can you now devise a circuit to find I_b^-?