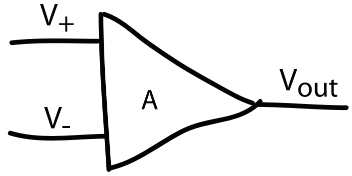
Notes on Op Amp Configurations; Physics 120: David Kleinfeld, Spring 2017

An Operation Amplifier is constructed from circuit elements - transistors, etc. - yet may be considered as a functional device that takes the difference of two-signals and produces an output that is a high-gain version of this difference.

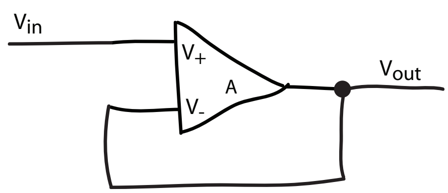


In the idealized case:

- The output is $V_{out} = A\left(V_+ - V_-\right)$ with the open-loop gain, A, tending to infinity (easily 10^6 in practice).
- The inputs have infinite impedance (as much as 10^{12} Ω in practice).
- The output has zero impedance (as low as 10 Ω in practice).

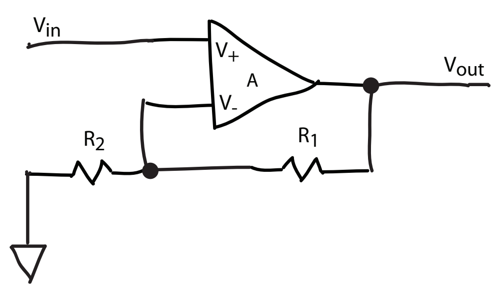
The Operation Amplifier is an active device that require an external power source; in our analysis we have left out the power leads (typically both +15 V and -15 V, each taken relative to the same common as used for the inputs and output).

Case 1. Non-inverting buffer



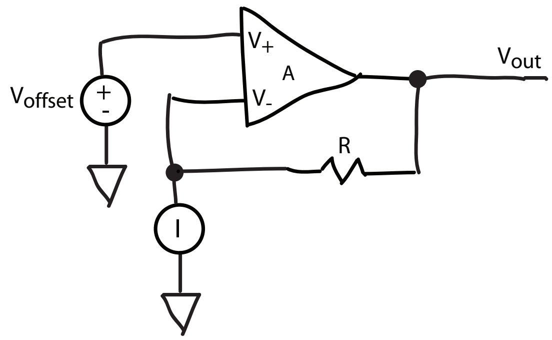
We have $V_{out} = A\left(V_+ - V_{out}\right)$ or $V_{out} = \frac{A}{A+1}V_+$ or $V_{out} \xrightarrow{A\to\infty} V_+$. The gain is $G = \frac{A}{A+1} \xrightarrow{A\to\infty} 1$

Case 2. Non-inverting buffer with gain (used in extracellular/intracellular amps)



Only a fraction of the output voltage, $V_- = \frac{R_2}{R_1+R_2}V_{out}$, is sensed. This forces the output voltage to be proportionally greater, so have $V_{out} \xrightarrow{A\to\infty} \left(1+\frac{R_1}{R_2}\right)V_+$. The gain is $G \xrightarrow{A\to\infty} 1+\frac{R_1}{R_2}$.

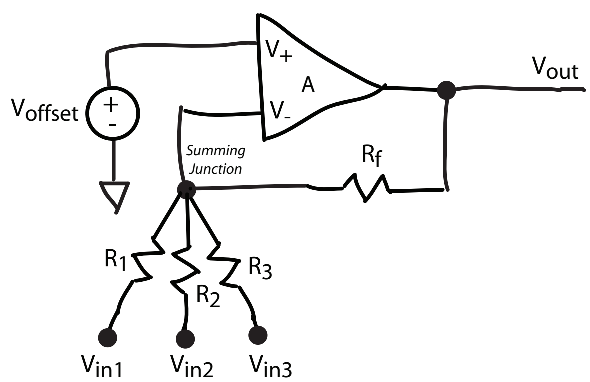
Case 3. Current-to-voltage converter (used as photodiode/photomultiplier tube amplifiers)



We have the node equation $\frac{(V_- - V_{out})}{R} = I$ as well as $V_{out} = A(V_+ - V_-)$, so that $V_{out} = \frac{A}{A+1}(V_+ - IR)$ or $V_{out} \xrightarrow{A\to\infty} V_+ - IR$. The input V_+ is either grounded or set to an offset voltage V_{offset}.

It is instructive to calculate the input impedance seen by the current source *I*. We take $V_+ = 0$ for simplicity and find the impedance is $R_{in} = \frac{V_-}{I} = \frac{R}{1+A}$. Thus as the open-loop gain, A, goes to infinity, the input to the current measurement goes to zero.

Case 4. Summing amplifier with gain.



Here we convert input voltages into input currents by passing them through a resistor, and sum these currents with the above circuit. The summing junction makes use of the effective low input impedance to the current-to-voltage converter, $R_{in} \approx R_f/A$. The current from input voltage V_1 is V_1/R_1, that from V_2 is V_2/R_2, etc. These currents sum so that $V_{out} \xrightarrow{A\to\infty} V_+ - R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right)$.

The gain per input channel "*i*" is just $G_i \xrightarrow{A\to\infty} -\frac{R_f}{R_i}$.