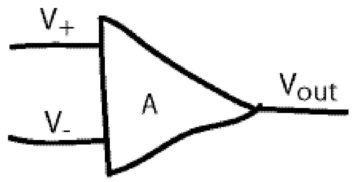
Physics 173 / BGGN 266 Primer on OpAmp Basics

David Kleinfeld, Spring 2008

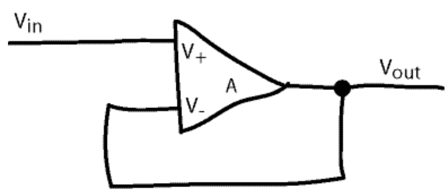
An Operation Amplifier may be considered as a block that takes the difference of two-signals and produces an output that is a high-gain version of this difference.



In the idealized case:

- The output is $V_{out} = A\left(V_+ - V_-\right)$ with the gain, A, tending to infinity (maybe 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 W in practice).

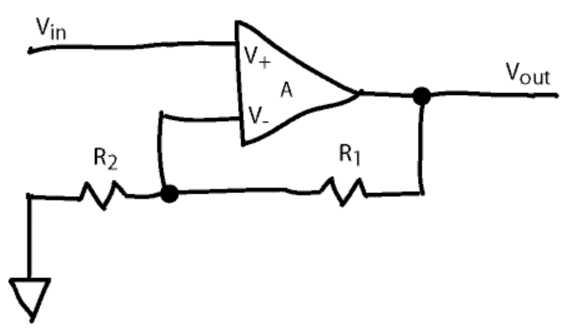
Case 1. Non-inverting buffer



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

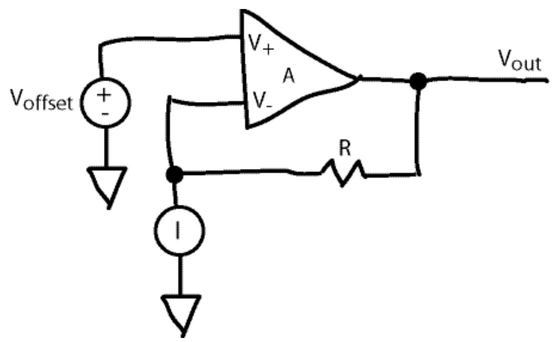
USE AS BUFFER FILTER EXERCISE

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



Here only a fraction of the output voltage, $\frac{R_2}{R_1 + R_2} V_{out}$, is sensed. We have $V_{out} \xrightarrow{A\to\infty} \left(1 + \frac{R_1}{R_2}\right) V_+$.

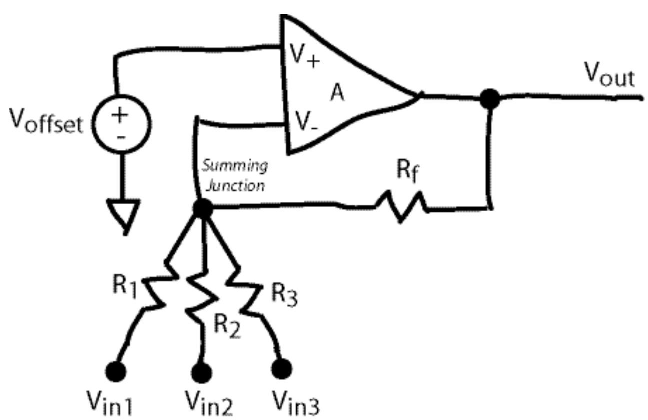
Case 3. Current-to-voltage converter (used as photodiode/photomultiplier tube amplifiers)



We have $\frac{(V_- - V_{out})}{R} = I$ and $V_{out} = A(V_+ - V_-)$ 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 oddest voltage V_{offset}.

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

Case 4. Summing Amplifier with gain.



Here we convert input voltages into 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 $R_{in} \approx R_f/A$. The current from input voltage V_1 is V_1/R_1, that from V_2 is V_2/R_2, etc. These current sum so that $V_{out} \xrightarrow{A\to\infty} V_+ - R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right)$.