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 $V_{out} = A(V_+ - V_-)$ with the open-loop 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 Ω in practice).

The above properties require an external power source; in our analysis we have left out the power leads (typically ±15 V, each taken relative to the same common as used for the inputs and output).

**Case 1. Non-inverting buffer**

We have $V_{out} = A(V_+ - V_-)$ 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, $\frac{R_2}{R_1 + R_2} V_{out}$, is sensed. We have $V_{out} \xrightarrow{A \to \infty} \left(1 + \frac{R_1}{R_2}\right) V_+$.

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
\[ \frac{V_+ - V_{\text{out}}}{R} = I \quad \text{and} \quad V_{\text{out}} = A(V_+ - V_-) \]
so that
\[ V_{\text{out}} = \frac{A}{A+1} (V_+ - IR) \quad \text{or} \quad V_{\text{out}} \rightarrow A^{-\infty} V_+ - IR. \]
The input \( V_+ \) is either grounded or set to an offset voltage \( V_{\text{offset}} \).

It is instructive to calculate the input impedance seen by the current source. We take \( V_+ = 0 \) for simplicity and find the impedance is
\[ R_{\text{in}} = \frac{V_-}{I} = \frac{R}{1+A}. \]
Thus as the open-loop 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 \( R_{\text{in}} \approx R_f/A \). The current from input voltage \( V_i \) is \( V_i/R_i \), that from \( V_2 \) is \( V_2/R_2 \), etc. These current sum so that
\[ V_{\text{out}} \rightarrow A^{-\infty} V_+ - R_f \left( \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} \right). \]
The gain per input channel “i” is just
\[ G_i \rightarrow A^{-\infty} \frac{R_f}{R_i}. \]