Operational Amplifiers (opamps)

Operational amplifiers are integrated circuits (ICs) that can be used in a variety of situations to perform mathematical operations.

The physical opamp is typically housed in an 8-pin DIP (dual-inline package). The schematic symbol is typically triangular and may or may not contain all pins corresponding to the physical package.

Ideal opamp assumptions

In the ideal opamp assumptions, we neglect the opamp power supply so that $V_{out}$ is not limited by those levels. In addition, we have the following three assumptions $V_{in}$:

\[ V_+ = V_- \quad I_+ = 0A, \quad I_- = 0A \]
All opamp circuits may be analyzed using these assumptions used in conjunction with KVL, KCL & Ohm’s Law. Here are some basic op-amp based amplifiers

**Inverting amplifier**

\[ \frac{V_{\text{out}}}{V_{\text{in}}} = -\frac{R_2}{R_1} \]

**Non-inverting amplifier**

\[ \frac{V_{\text{out}}}{V_{\text{in}}} = 1 + \frac{R_2}{R_1} \]

**Buffer / Unity-gain amplifier**

\[ \frac{V_{\text{out}}}{V_{\text{in}}} = 1 \]

**Inverting adder (summer) \text{ - can be expanded to have more inputs}**

\[ V_{\text{out}} = -\frac{R_f}{R_1} V_{\text{in1}} - \frac{R_f}{R_2} V_{\text{in2}} \]

\[ = -\left[ \frac{R_f}{R_1} V_{\text{in1}} + \frac{R_f}{R_2} V_{\text{in2}} \right] \]
Differential Amplifier

\[ V_{\text{out}} = \left( 1 + \frac{R_4}{R_3} \right) \left( \frac{R_1}{R_1 + R_2} \right) V_{\text{in1}} - \left( \frac{R_4}{R_3} \right) V_{\text{in2}} \]

- If \( R_1 = R_2 = R_3 = R_4 \), \( V_{\text{out}} = V_{\text{in1}} - V_{\text{in2}} \)
- If \( R_1 = R_3 \) & \( R_2 = R_4 \), \( V_{\text{out}} = \frac{R_1}{R_1} \left( V_{\text{in1}} - V_{\text{in2}} \right) \) or \( \frac{R_4}{R_3} \left( V_{\text{in1}} - V_{\text{in2}} \right) \)

**Example:** Determine the power dissipation in the resistors of the following opamp circuit.

\[ V_{\text{in}} = 5V \]