Operational Amplifiers

Using the Ideal Op Amp Model
Operational Amplifier (Op Amp)

- Non-inverting or positive input
- Inverting or negative input
- Output terminal

\[ + \quad R_i \quad - \]

\[ \text{U}_d \quad R_o \quad \text{U}_o \]
Determine the output voltage if we use include the input and output resistors, $R_i$ and $R_o$, in the op amp model.

The analysis assumes that the power supplies $V^+ = \infty$ and $V^- = -\infty$ V.

The circuit does not have a feedback resistor between the negative input terminal and the output terminal of the op amp.
Substituting in the op amp model into the circuit, we obtain:

There are now two circuits that are coupled by the dependent voltage source in the circuit on the right. We can calculate the voltage across $R_i$ in the circuit on the left and then determine the output voltage of the op amp using the circuit on the right.
In this circuit, the 5 nA current flowing into the op amp is significantly smaller than the current through the other 1 kW resistor, which is 5 mA. This is the reason why we say that no current flows into the op amp input terminals in an ideal op amp.

\[
U_d = \frac{1M_u}{1M_u + 1k\Omega} S mV = 4.99 S mV = S mV
\]

\[
i_+ = \frac{S mV}{1M_u} = S nA
\]
This large of an output voltage is unrealistically large; the output voltage would be limited by $V^+$ ($v_o = V^+$) if we used the almost ideal op amp model.
Example 2

\[ R_i = 10 \text{M} \Omega \]
\[ R_o = 1 \Omega \]
\[ A_{oL} = 10^6 \]

\[ V_d = (V_+ - V_-) = -10 \text{mV} \]
Note that a load resistor can be connected to the output of the op amp. Since the output resistor of the op amp, \( R_o \), is so small, almost all of the \(-10^4\)V would be dropped across the output resistor as long as it was much larger than 1\( \Omega \). Since most resistors used in circuits are in the k\( \Omega \) range, we usually neglect the output resistor when analyzing op amp circuits.

\[
V_o = A_{ol} V_d \\
= 10^6 \times (-10mV) \\
= -10^4V
\]