Ideal OP AMP Model

Open-loop gain   : $\mu \Rightarrow \propto$
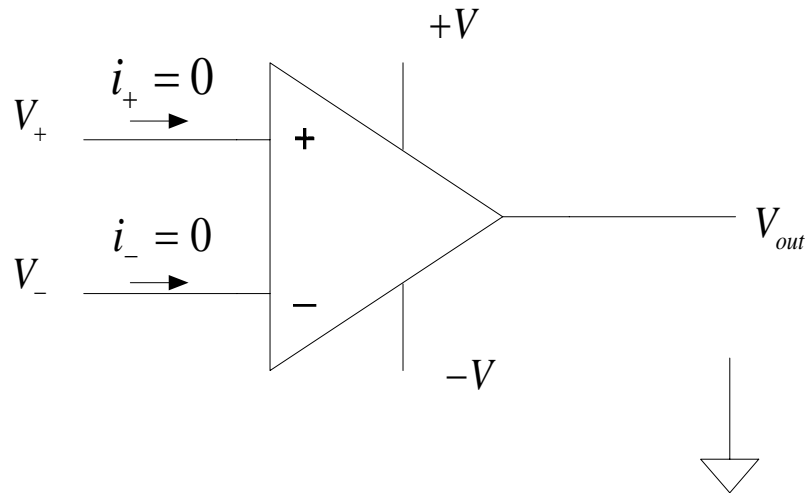
Input impedance   : $R_I \Rightarrow \propto \Omega$

Output impedance : $R_O \Rightarrow 0 \, \Omega$

Two assumptions:

1.   No current flowing in and out of the input terminals of the op-amp (high input impedance of op-amp).

2.   If the output is not in saturation, the voltage between the inverting and non-inverting input terminals is zero.
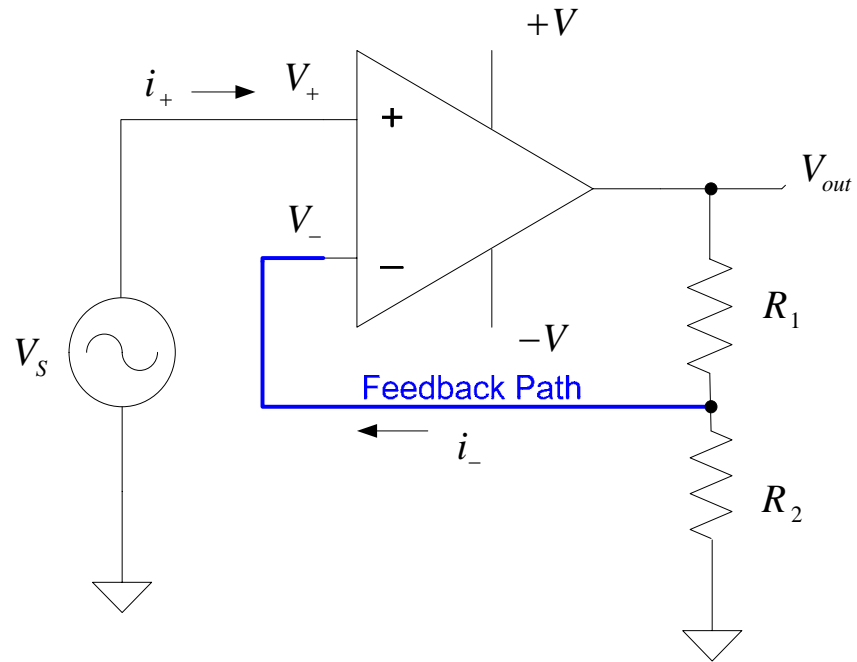
Ideal OP AMP Model

$$V_+ = V_- \quad \text{and} \quad i_+ = i_- = 0$$

The current in or out of either input is negligible.

If the output is not in saturation, the voltage between the two input terminals is zero.

Non-inverting Amplifier

$$V_- = \frac{R_2}{R_1 + R_2} V_{out}$$

Non-inverting Amplifier

The voltage at the inverting input, V_- can be determined by voltage division:
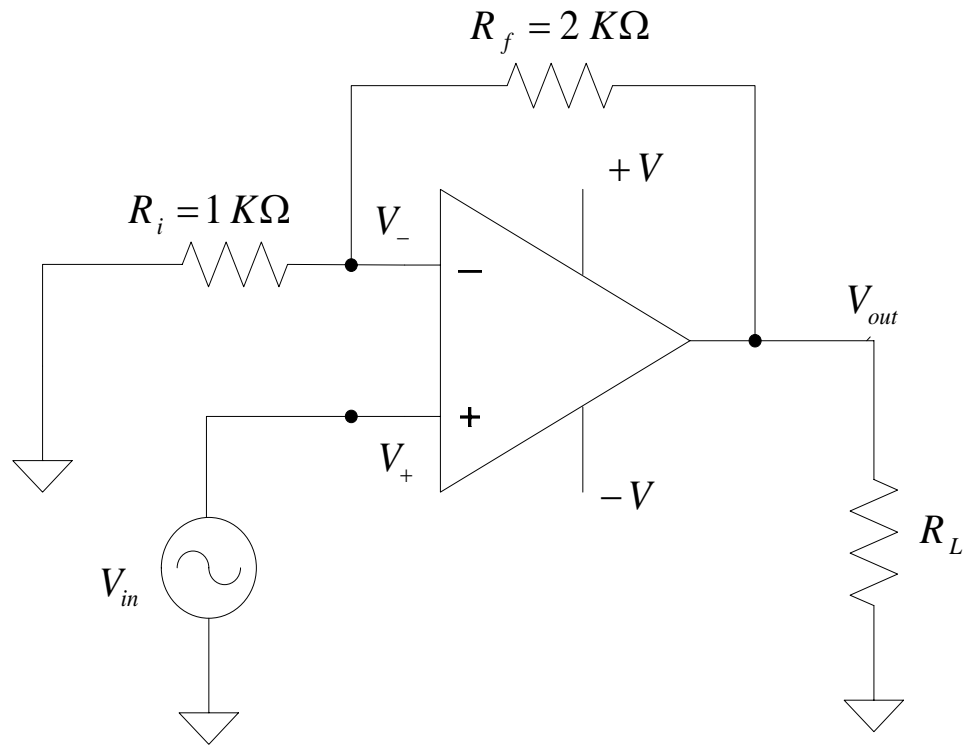
$$V_- = \frac{R_2}{R_1 + R_2} V_O$$

The input-output relationship of the overall circuit:

$$V_{out} = \frac{R_1 + R_2}{R_2} V_S \quad \Rightarrow \quad K = \frac{R_1 + R_2}{R_2}$$

Where K is the closed-loop gain.

Non-inverting Amplifier

Non-inverting Amplifier

If there is +1V present at the non-inverting input, there is also +1V at the inverting input. Positive one volt at the inverting input causes 1 mA through R_i (1 KΩ). The current flowing in or out of the input of the op-amp is essentially zero, so the current flowing through resistor R_i is forced to flow through R_f (2 KΩ). The 1 mA flowing through R_f causes the output to be two volts more positive (1 mA × 2 KΩ) than the inverting input, so the output is equal to three volts. The voltage gain of the circuit is equal to three.

Voltage gain, $A_v = V_{out} / V_{in} = 3\,V / 1\,V = 3$

Non-inverting Amplifier

$$V_{out} = V_{R_i} + V_{R_f}$$

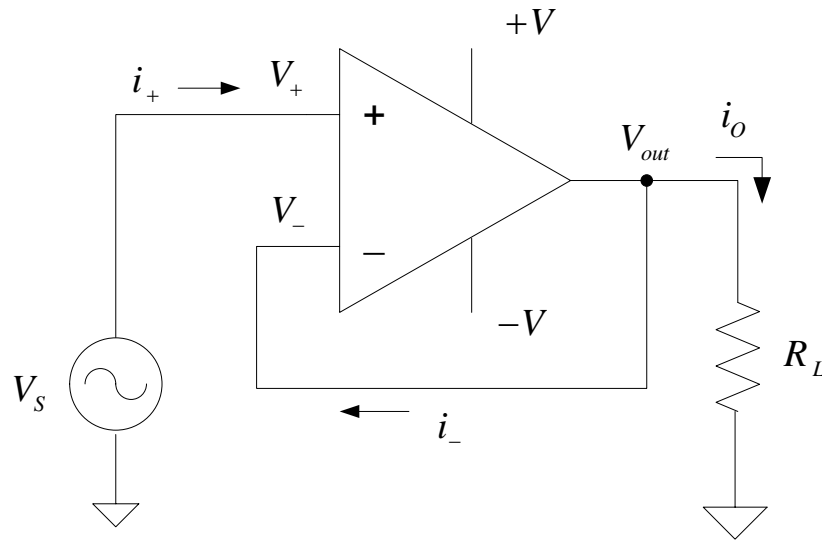R_i and R_f form an unloaded voltage divider.

$$V_{in} = V_{R_i}$$

Voltage on the inverting input equals voltage on the non-inverting input.

$$A_v = V_{out} / V_{in} = (V_{R_i} + V_{R_f}) / V_{R_i} = 1 + \left(V_{R_f} / V_{R_i} \right)$$

The same current flows through R_i and R_f .

$$A_v = V_{out} / V_{in} = 1 + \left(V_{R_f} / V_{R_i} \right) = 1 + \left(R_f / R_i \right)$$

Voltage Follower or Buffer

Assuming the output of the voltage follower is not in saturation, the voltage between the two input terminals is zero. The input signal voltage present on the non-inverting input is also present on the inverting input. The inverting input is connected to the output; therefore, the voltage at the output is the same as the input.

Voltage Follower or Buffer

The current delivered to the load, R_L:

$$i_o = V_{out} / R_L$$

Since $V_o = V_S$, the output current, $i_o = V_S / R_L$

$$i_- = i_O$$

For the ideal model, $i_- = 0$, but the output current comes from the power supply and not from the input.