Experiment 03: Study of Operational Amplifiers

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1 Aim

- Study of op-Amp as inverting and non-inverting amplifiers.
- Study of application of op-Amp as adder and subtractor.

2 Theory

op-Amp as Inverting Amplifier:

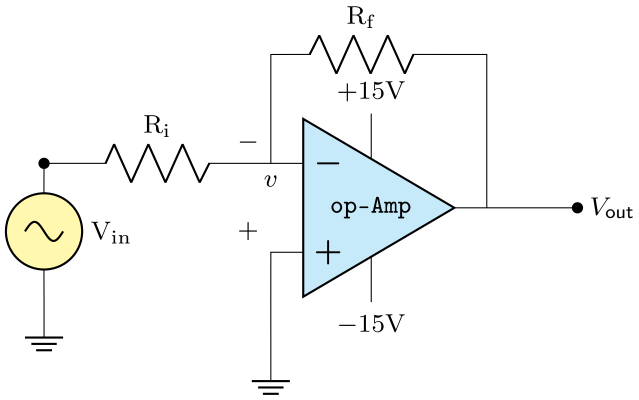

Figure 1: Circuit diagram for an inverting op-Amp

Since current through op-Amp due to high resistance is almost negligible, from Kirchoff current law at the junction, we get:

$$\frac{\mathrm{V_{in}} - \mathrm{v}}{\mathrm{R_i}} = \frac{\mathrm{v} - \mathrm{V_{out}}}{\mathrm{R_f}}$$

From virtual ground condition, $\mathrm{v} \approx 0$ Hence we obtain an expression for the gain $\mathcal{A}$ as:

$$\mathrm{V_{out}} = -\left(\frac{\mathrm{R_f}}{\mathrm{R_i}}\right)\mathrm{V_{in}} \implies \boxed{\mathcal{A} = \frac{\mathrm{V_{out}}}{\mathrm{V_{in}}} = -\left(\frac{\mathrm{R_f}}{\mathrm{R_i}}\right)}$$

op-Amp as Non-Inverting Amplifier:

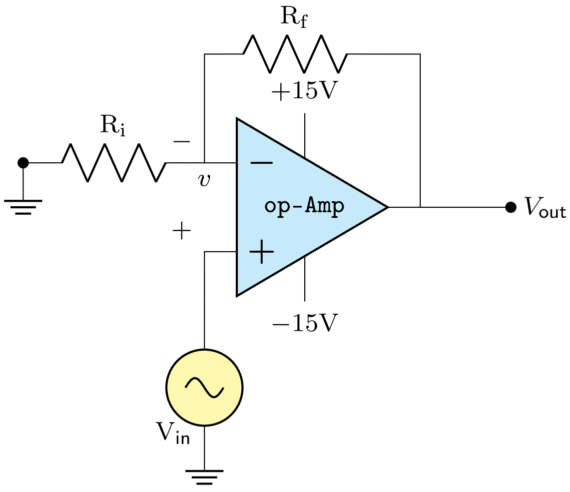

Figure 2: Circuit diagram for an non-inverting op-Amp

Since current through op-Amp due to high resistance is almost negligible, from Kirchoff current law at the junction, we get:

$$\frac{-\mathrm{v}}{\mathrm{R_i}} = \frac{\mathrm{v} - \mathrm{V_{out}}}{\mathrm{R_f}} \implies \mathrm{V_{out}} = \mathrm{v}\left(1 + \frac{\mathrm{R_f}}{\mathrm{R_i}}\right)$$

From virtual ground condition, $\mathrm{v} \approx \mathrm{V_{in}}$, hence we get an expression for the gain $\mathcal{A}$ as:

$$\mathrm{V_{out}} = \mathrm{V_{in}}\left(1 + \frac{\mathrm{R_f}}{\mathrm{R_i}}\right) \implies \boxed{\mathcal{A} = \frac{\mathrm{V_{out}}}{\mathrm{V_{in}}} = 1 + \frac{\mathrm{R_f}}{\mathrm{R_i}}}$$

op-Amp as Adder:

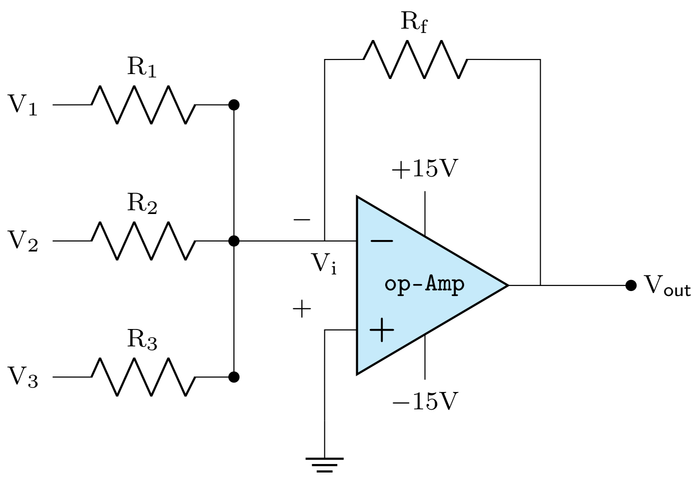

Figure 3: Circuit for op-Amp as an adder

For the circuit shown above, the current through op-Amp is negligible, hence the total current through the three resistors $\mathrm{R_1}$, $\mathrm{R_2}$, $\mathrm{R_3}$ goes through $\mathrm{R_f}$. Applying Kirchoff's current law at the junction, we get:

$$\frac{\mathrm{V_{out}} - \mathrm{V_i}}{\mathrm{R_f}} = \frac{\mathrm{V_i} - \mathrm{V_1}}{\mathrm{R_1}} + \frac{\mathrm{V_i} - \mathrm{V_2}}{\mathrm{R_2}} + \frac{\mathrm{V_i} - \mathrm{V_3}}{\mathrm{R_3}}$$

From the virtual ground condition, $V_i \approx 0$, hence:

$$\mathrm{V_{out}} = -\mathrm{R_f}\left(\frac{\mathrm{V_1}}{\mathrm{R_1}} + \frac{\mathrm{V_2}}{\mathrm{R_2}} + \frac{\mathrm{V_3}}{\mathrm{R_3}}\right)$$

If we take $R_f = R_1 = R_2 = R_3$, then:

$$\boxed{V_{out} = -(V_1 + V_2 + V_3)}$$

Hence, the circuit acts as an adder, that is, it adds the individual input voltages.
op-Amp as Subtractor:

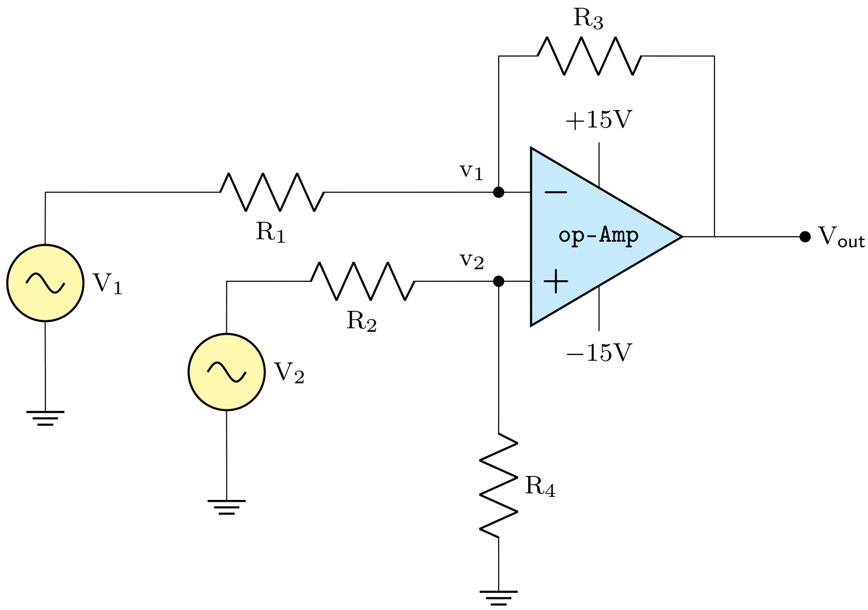

Figure 4: Circuit diagram for op-Amp as a subtractor

For the circuit shown above, the current through op-Amp is negligible. Thus, using Kirchoff's current law at the junctions, we get:

$$\frac{V_1 - v_1}{R_1} = \frac{v_1 - V_{out}}{R_3} = \frac{V_1 - V_{out}}{R_1 + R_3} \implies v_1 = \frac{R_3}{R_1 + R_3}(V_1 - V_{out}) + V_{out}$$

$$\frac{V_2 - v_2}{R_2} = \frac{v_2 - 0}{R_4} = \frac{V_2}{R_2 + R_4} \implies v_2 = \frac{R_4}{R_2 + R_4}V_2$$

From the virtual ground condition, $v_1 \approx v_2$, hence:

$$\frac{R_3}{R_1 + R_3}V_1 + \frac{R_1}{R_1 + R_3}V_{out} = \frac{R_4}{R_2 + R_4}V_2 \implies V_{out} = \frac{R_4(R_1 + R_3)}{(R_4 + R_2)R_1}V_1 - \frac{R_3}{R_1}V_2$$

If we take $R_1 = R_2 = R_3 = R_4$, then:

$$\boxed{V_{out} = -(V_2 - V_1)}$$

Hence, the circuit acts as a subtractor, that is, it subtracts the individual input voltages.

3 Data and Calculation

4 Sources of Error

5 Discussion and Conclusion