Op-amp circuits (`EC_opamp_1.sqproj`)

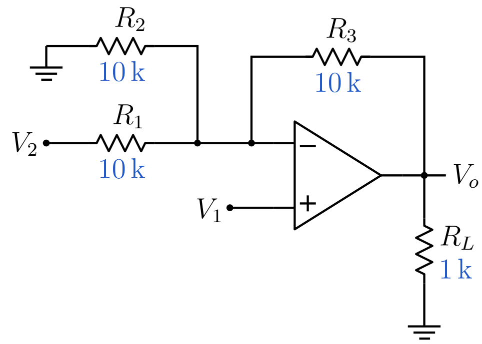

Figure 1: Op-amp circuit example.

Question: In the circuit shown in Fig. 1, assume that the op-amp is operating in the linear region.

(a) Obtain an expression for V_o in terms of V_1 and V_2.

(b) If $V_1 = 0.5 \sin \omega t$ and $V_2 = 0.8 \sin \omega t$ (Volts), what is the output voltage?

Solution:

Method 1:

Since the op-amp is operating in the linear region, V_+ and V_- are nearly equal, i.e., $V_- = V_+ = V_1$. KCL at the inverting input terminal of the op-amp gives

$$\frac{V_2 - V_-}{R_1} - \frac{V_- - 0}{R_2} - \frac{V_- - V_o}{R_3} = 0, \tag{1}$$

where the op-amp input current, which is negligibly small, has been ignored. Using $V_- = V_1$, we get

$$\frac{V_2 - V_1}{R_1} - \frac{V_1}{R_2} - \frac{V_1 - V_o}{R_3} = 0 \;\rightarrow\; V_o = \left[1 + \left(\frac{1}{R_1} + \frac{1}{R_2}\right) R_3\right] V_1 - \frac{R_3}{R_1} V_2. \tag{2}$$

Method 2:

Since the op-amp is operating in the linear region, we can use superposition to obtain V_o.

1. Only V_1 active (see Fig. 2 (a)): In this case, we have a non-inverting amplifier configuration with input voltage V_1. The output is

$$V_o^{(1)} = \left(1 + \frac{R_3}{R_1 \parallel R_2}\right) V_1. \tag{3}$$

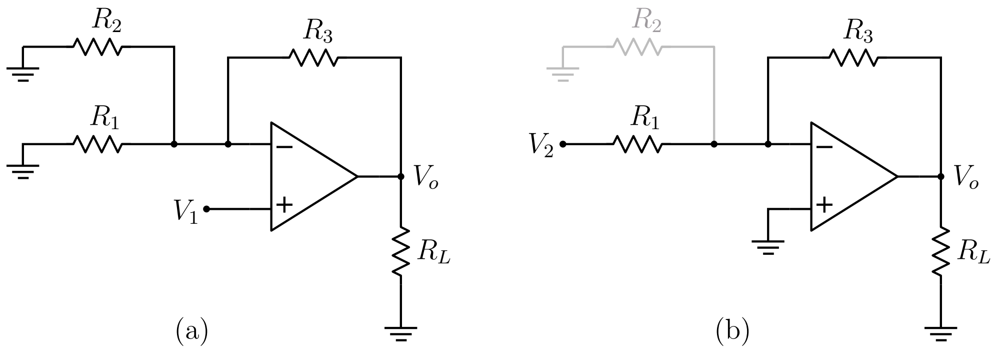

Figure 2: Use of superposition for the circuit of Fig. 1: (a) Only V_1 active, (b) Only V_2 active.

2. Only V_2 active (see Fig. 2 (b)): In this case, note that the current through R_2 is zero since its one end is at real ground and the other end is at virtual ground. In effect, we can therefore remove R_2 from the circuit, and then we are left with an inverting amplifier configuration. The output is

$$V_o^{(2)} = -\frac{R_3}{R_1} V_2. \tag{4}$$

The net output voltage is

$$V_o = V_o^{(1)} + V_o^{(2)} = \left(1 + \frac{R_3}{R_1 \parallel R_2}\right) V_1 - \frac{R_3}{R_1} V_2, \tag{5}$$

which is the same as our earlier expression (Eq. 2).

Substituting $V_1 = 0.5 \sin \omega t$ and $V_2 = 0.8 \sin \omega t$ in Eq. 5, we obtain $V_0 = 0.7 \sin \omega t$.

SequelApp Exercises: Assuming that the input voltages $V_1(t)$, $V_2(t)$, and the other circuit parameters remain the same as before,

1. Find R_3 which will give $V_o(t) = 0.6 \sin \omega t$.
2. Find R_2 which will give $V_o(t) = 1.45 \sin \omega t$.

Verify your answers using SequelApp.