Op-amp circuits (`EC_opamp_2.sqproj`)

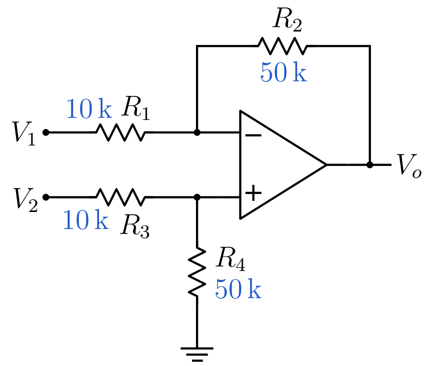

Figure 1: Difference amplifier circuit.

Question: In the difference amplifier shown in Fig. 1, $V_1 = V_C + V_m \sin\omega t$, $V_2 = V_C - V_m \sin\omega t$, with $V_C = 1$,V and $V_m = 0.5\,\text{mV}$. The nominal values of the resistances are shown in the figure.

(a) Find $V_o(t)$.

(b) If R_1 is larger than its nominal value by 1%, how will $V_o(t)$ change?

Solution:

By superposition, the output voltage is given by

$$V_o = -\frac{R_2}{R_1}V_1 + \left(\frac{R_4}{R_3+R_4}V_2\right) \times \left(1 + \frac{R_2}{R_1}\right). \tag{1}$$

If $\dfrac{R_2}{R_1}$ is exactly equal to $\dfrac{R_4}{R_3}$, the circuit works as an ideal difference amplifier, with

$$V_o = \frac{R_2}{R_1}\left(V_2 - V_1\right). \tag{2}$$

With the help of the above equations, we can now answer the above questions.

(a) In this case, we can use Eq. 2 and obtain

$$\begin{aligned} V_o &= \frac{50\,\text{k}}{10\,\text{k}} \times (-2\,V_m \sin\omega t) && (3)\\ &= -(5\,\text{mV})\sin\omega t. && (4)\end{aligned}$$

(b) Since the resistances are not matched in this case, we need to use Eq. 2. Substituting component values in Eq. 2, we get

$$V_o = -\frac{50\,\text{k}}{10.1\,\text{k}}\,(V_C + V_m \sin\omega t) + \left(\frac{50\,\text{k}}{60\,\text{k}}\right)\left(1 + \frac{50\,\text{k}}{10.1\,\text{k}}\right)(V_C - V_m \sin\omega t) \tag{5}$$

$$= 8.25\,\text{mV} - (4.95\,\text{mV})\sin\omega t. \tag{6}$$

SequelApp Exercises:

1. Find the output voltage in the following cases, assuming that the input voltages $V_1(t)$, $V_2(t)$, and the other circuit parameters remain the same as before.

   (a) R_3 is changed to 10.1 k.

   (b) R_2 is changed to 50.1 k.

2. For $V_1 = V_2 = 1\,\text{V}$ and R_2, R_3, R_4 equal to their nominal values, find R_1 for which $V_o = -12\,\text{mV}$.

Verify your answers using SequelApp.