Lab Assignment 1

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Question 1

Question 2

a

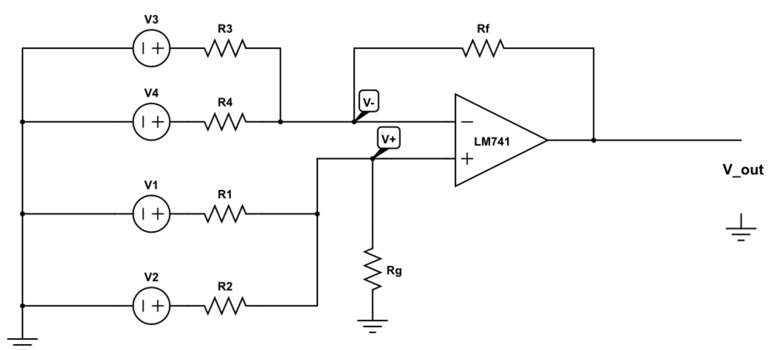

Figure 1: The required circuit diagram for question 2.

b

Circuit analysis:

At the non-inverting terminal, we effectively have a circuit represented by figure 2. We can use Kirchoff's voltage law along with the superposition theorem, we see:

$$\text{Voltage at } V^+ \text{ due to } V_1,\ V_1^+, \text{ is given by:}$$

$$V_1^+ = \frac{\frac{R_2 R_g}{R_2+R_g}}{R_1 + \frac{R_2 R_g}{R_2+R_g}}\ V_1$$

$$\therefore V_1^+ = \left(\frac{1}{\frac{R_1}{R_g} + \frac{R_1}{R_2} + 1}\right) V_1$$

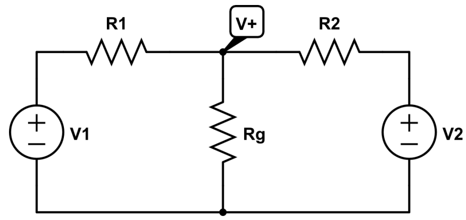

Figure 2: Equivalent circuit at the non-inverting terminal

Similarly, voltage at V^+ due to V_2, V_2^+, is given by:

$$V_2^+ = \frac{\frac{R_1 R_g}{R_1+R_g}}{R_2 + \frac{R_1 R_g}{R_1+R_g}} V_2$$

$$\therefore V_2^+ = \frac{1}{\frac{R_2}{R_g} + \frac{R_2}{R_1} + 1} V_2$$

Using the superposition theorem to recombine the values, we find that $V+$ is given by:

$$V^+ = V_1^+ + V_2^+$$

$$V^+ = \frac{1}{\frac{R_1}{R_g} + \frac{R_1}{R_2} + 1} V_1 + \frac{1}{\frac{R_2}{R_g} + \frac{R_2}{R_1} + 1} V_2$$

We can now move on to the inverting terminal of the op-amp. The corresponding equivalent circuit is shown in figure 3. Analyzing this circuit, we see that:

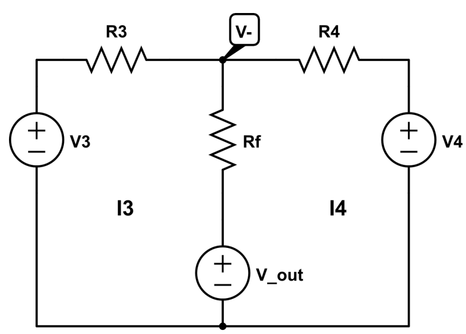

Figure 3: Equivalent circuit at the non-inverting terminal

$$I_3 R_3 = V_3 - V^-$$

$$I_4 R_4 = V_4 - V^-$$

$$V^- - V_{out} = (I_3 + I_4) R_f$$

Substituting from the above equations, we get:

$$V^- - V_{out} = \left(\frac{V_3 - V^-}{R_3} + \frac{V_4 - V^-}{R_4}\right) R_f$$

Reordering the terms, we get:

$$V_{out} = V^- - \left(\frac{V_3 - V^-}{R_3} + \frac{V_4 - V^-}{R_4}\right) R_f$$

$$\implies V_{out} = V^-\left(\frac{R_f}{R_3} + \frac{R_f}{R_4} + 1\right) - \left(\frac{R_f}{R_3}\right)V_3 - \left(\frac{R_f}{R_4}\right)V_4$$

We also know that for an ideal op-amp, $V^+ = V^-$, hence we get:

$$V_{out} = \left(\frac{R_f}{R_3} + \frac{R_f}{R_4} + 1\right)\left(\frac{1}{\frac{R_1}{R_g} + \frac{R_1}{R_2} + 1}\right)V_1 + \left(\frac{R_f}{R_3} + \frac{R_f}{R_4} + 1\right)\left(\frac{1}{\frac{R_2}{R_g} + \frac{R_2}{R_1} + 1}\right)V_2 - \left(\frac{R_f}{R_3}\right)V_3 - \left(\frac{R_f}{R_4}\right)V_4$$

This is equation is the mathematical representation of the required problem which was; $V_{out} = a_1V_1 + a_2V_2 - a_3V_3 - a_4V_4$, i.e. :

$$a_1 = \left(\frac{R_f}{R_3} + \frac{R_f}{R_4} + 1\right)\left(\frac{1}{\frac{R_1}{R_g} + \frac{R_1}{R_2} + 1}\right)$$

$$a_2 = \left(\frac{R_f}{R_3} + \frac{R_f}{R_4} + 1\right)\left(\frac{1}{\frac{R_2}{R_g} + \frac{R_2}{R_1} + 1}\right)$$

$$a_3 = \left(\frac{R_f}{R_3}\right)$$

$$a_4 = \left(\frac{R_f}{R_4}\right)$$

c