

**QUIZ NO. 3 - SOLUTION**

(Average score = xx/10 of those taking the quiz.)

The differential amplifier below uses an ideal op amp. Find the values of  $R_1$ ,  $R_2$ ,  $R_3$  and  $R_4$  if the single-ended input resistances,  $R_{in1}$  and  $R_{in2}$  are to be  $100\text{k}\Omega$  and the output voltage is to be  $v_{out} = 10(v_1 - v_2)$ .

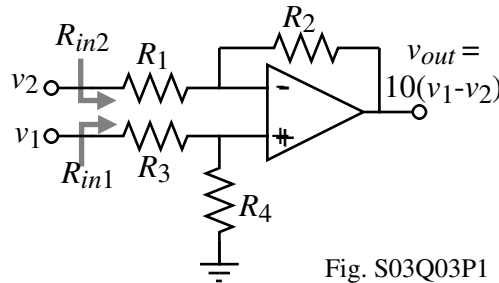


Fig. S03Q03P1

Solution

The first step is to find  $v_{out}$  as a function of  $v_1$  and  $v_2$  and to find  $R_{in1}$  and  $R_{in2}$ .

The output voltage can be found by using superposition applied to the inputs  $v_1$  and  $v_2$ .

The result is,

$$v_{out} = \left( \frac{v_{out}}{v_1} \right)_{v_2=0} + \left( \frac{v_{out}}{v_2} \right)_{v_1=0} = \left( \frac{R_1+R_2}{R_1} \right) \left( \frac{R_4}{R_3+R_4} \right) v_1 - \left( \frac{R_2}{R_1} \right) v_2$$

$$R_{in1} = R_3 + R_4 \text{ (remember to set } v_2 \text{ to zero in this calculation – only one excitation at a time)}$$

$$R_{in2} = R_1 \text{ (remember to set } v_1 \text{ to zero in this calculation – only one excitation at a time)}$$

From the input resistance results, we can write that,

$$R_3 + R_4 = 100\text{k}\Omega \text{ and } \underline{R_1 = 100\text{k}\Omega}$$

Substituting these values in the voltage gain expression gives,

$$v_{out} = \left( \frac{R_1+R_2}{100\text{k}\Omega} \right) \left( \frac{R_4}{100\text{k}\Omega} \right) v_1 - \left( \frac{R_2}{100\text{k}\Omega} \right) v_2 = 10(v_1 - v_2)$$

This gives us  $\underline{R_2 = 1\text{M}\Omega}$ . Substituting this back into the voltage gain expression gives,

$$v_{out} = \left( \frac{1100\text{k}\Omega}{100\text{k}\Omega} \right) \left( \frac{R_4}{100\text{k}\Omega} \right) v_1 - 10 v_2 = 10(v_1 - v_2) \rightarrow R_4 = \frac{1000\text{k}\Omega}{11} = \underline{90.9\text{k}\Omega}$$

Since the sum of  $R_3$  and  $R_4$  must equal  $100\text{k}\Omega$ , we get

$$R_3 = 100\text{k}\Omega - 90.9\text{k}\Omega = \underline{9.1\text{k}\Omega}$$

Substituting these values back into the top three equations satisfies the requirements.

