UNIT-3 MPHYECC-5

OP-AMP APPLICATIONS

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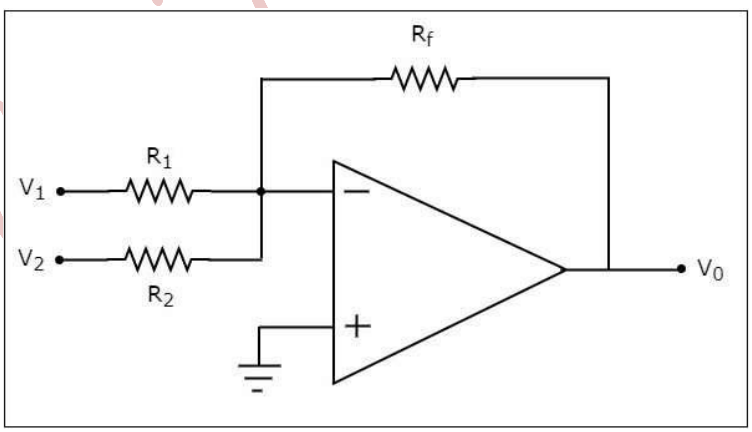
The electronic circuits, which perform arithmetic operations are known as **arithmetic circuits**. Using op-amps, we can build basic arithmetic circuits such as an **adder** and a **subtractor**. Here, you will learn about each of them in detail.

Adder

An adder is an electronic circuit that produces an output, which is equal to the sum of the applied inputs. This section discusses about the op-amp based adder circuit.

An op-amp based adder produces an output equal to the sum of the input voltages applied at its inverting terminal. It is also called as a summing amplifier, since the output is an amplified one. The circuit diagram of an op-amp based adder is shown in the following figure –



In the above circuit, the non-inverting input terminal of the op-amp is connected to ground. That means zero volts is applied at its non-inverting input terminal.

According to the virtual short concept, the voltage at the inverting input terminal of an op-amp is same as that of the voltage at its non-inverting input terminal. So, the voltage at the inverting input terminal of the op-amp will be zero volts.

The nodal equation at the inverting input terminal's node is

$$\frac{0 - V_i}{R_1} + \frac{0 - V_2}{R_2} + \frac{0 - V_0}{R_f} = 0$$

$$=> \frac{V_1}{R_1} - \frac{V_2}{R_2} = \frac{V_0}{R_f}$$

$$V_0 = R_f\,(\frac{V_1}{R_1} + \frac{V_2}{R_2})$$

If R_f=R_1=R_2=R, then the output voltage V_0 will be –

$$V_0 = -R(\frac{V_1}{R} + \frac{V_2}{R})$$

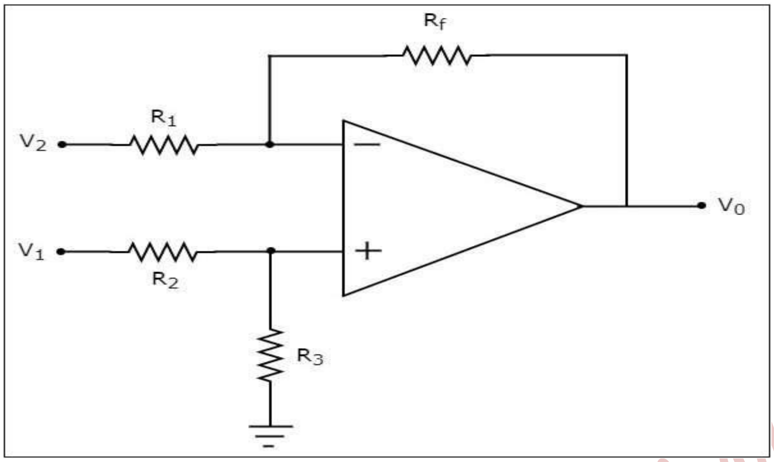
$$=> V_0 = -(V_1 + V_2)$$

Therefore, the op-amp based adder circuit discussed above will produce the sum of the two input voltages V_1 and V_2, as the output, when all the resistors present in the circuit are of same value. Note that the output voltage V_0 of an adder circuit is having a negative sign, which indicates that there exists a 180^o phase difference between the input and the output.

Subtractor

A subtractor is an electronic circuit that produces an output, which is equal to the difference of the applied inputs. This section discusses about the op-amp based subtractor circuit. An op-amp based subtractor produces an output equal to the difference of the input voltages applied at its inverting and non-inverting terminals. It is also called as a difference amplifier, since the output is an amplified one.

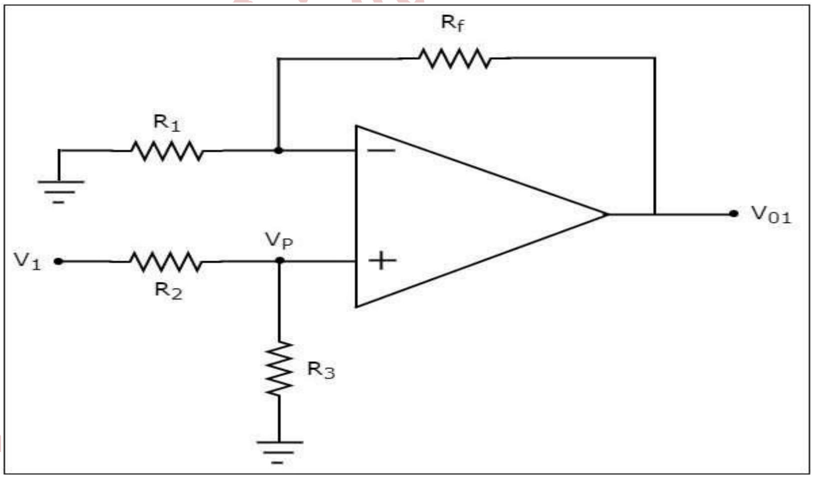
The circuit diagram of an op-amp based subtractor is shown in the following figure –



Now, let us find the expression for output voltage V_0 of the above circuit using superposition theorem using the following steps −

Step 1

Firstly, let us calculate the output voltage V_{01} by considering only V_1. For this, eliminate V_2 by making it short circuit. Then we obtain the modified circuit diagram as shown in the following figure –



Now, using the voltage division principle, calculate the voltage at the non-inverting input terminal of the op-amp.

$$=> V_p = V_1(\frac{R_3}{R_2 + R_3})$$

Now, the above circuit looks like a non-inverting amplifier having input voltage V_p. Therefore, the output voltage V_{01} of above circuit will be

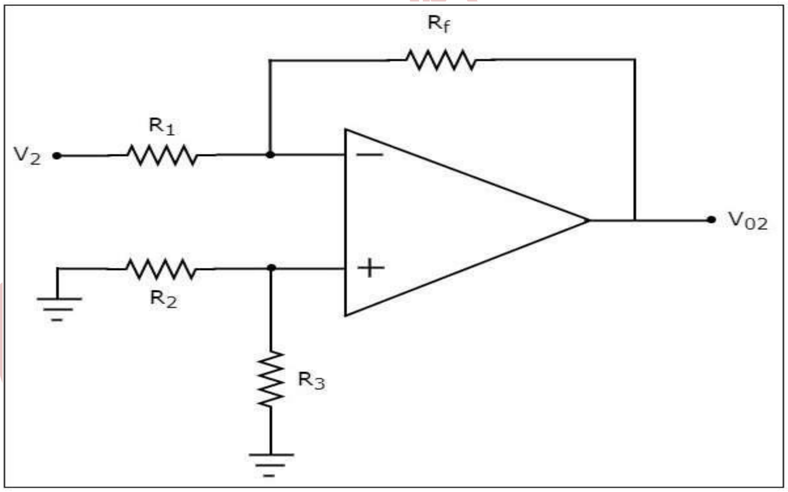
$$V_{01} = V_p \left(1 + \frac{R_f}{R_1}\right)$$

Substitute, the value of V_p in above equation, we obtain the output voltage V_{01} by considering only V_1, as –

$$V_{01} = V_1 \left(\frac{R_2}{R_2 + R_3}\right)\left(1 + \frac{R_f}{R_1}\right)$$

Step 2

In this step, let us find the output voltage, V_{02} by considering only V_2. Similar to that in the above step, eliminate V_1 by making it short circuit. The modified circuit diagram is shown in the following figure.



You can observe that the voltage at the non-inverting input terminal of the op-amp will be zero volts. It means, the above circuit is simply an inverting op-amp. Therefore, the output voltage V_{02} of above circuit will be –

$$V_{02} = -\left(\frac{R_f}{R_1}\right) V_2$$

Step 3

In this step, we will obtain the output voltage V_0 of the subtractor circuit by adding the output voltages obtained in Step1 and Step2. Mathematically, it can be written as

$$V_0 = V_{01} + V_{02}$$

Substituting the values of V_{01} and V_{02} in the above equation, we get –

$$V_0 = V_1 \left(\frac{R_3}{R_2 + R_3}\right)\left(1 + \frac{R_f}{R_1}\right) + \left(-\frac{R_f}{R_1}\right) V_2$$

$$=> V_0 = V_1 \left(\frac{R_3}{R_2 + R_3}\right)\left(1 + \frac{R_f}{R_1}\right) - \left(\frac{R_f}{R_1}\right) V_2$$

If $R_f=R_1=R_2=R_3=R$, then the output voltage V_0 will be

$$=> V_0 = V_1 \left(\frac{R}{R + R}\right)\left(1 + \frac{R}{R}\right) - \left(\frac{R}{R}\right) V_2$$

$$=> V_0 = V_1 \left(\frac{R}{2R}\right)(2) - (1)V_2$$

$$V_0 = V_1 - V_2$$

Thus, the op-amp based subtractor circuit discussed above will produce an output, which is the difference of two input voltages V_1 and V_2, when all the resistors present in the circuit are of same value.