9.18 Difference Amplifier or Subtractor APJAKTU : 2006-07, 2007-08, 2009-10

- The circuit diagram of subtractor is shown in the Fig. 9.18.1.

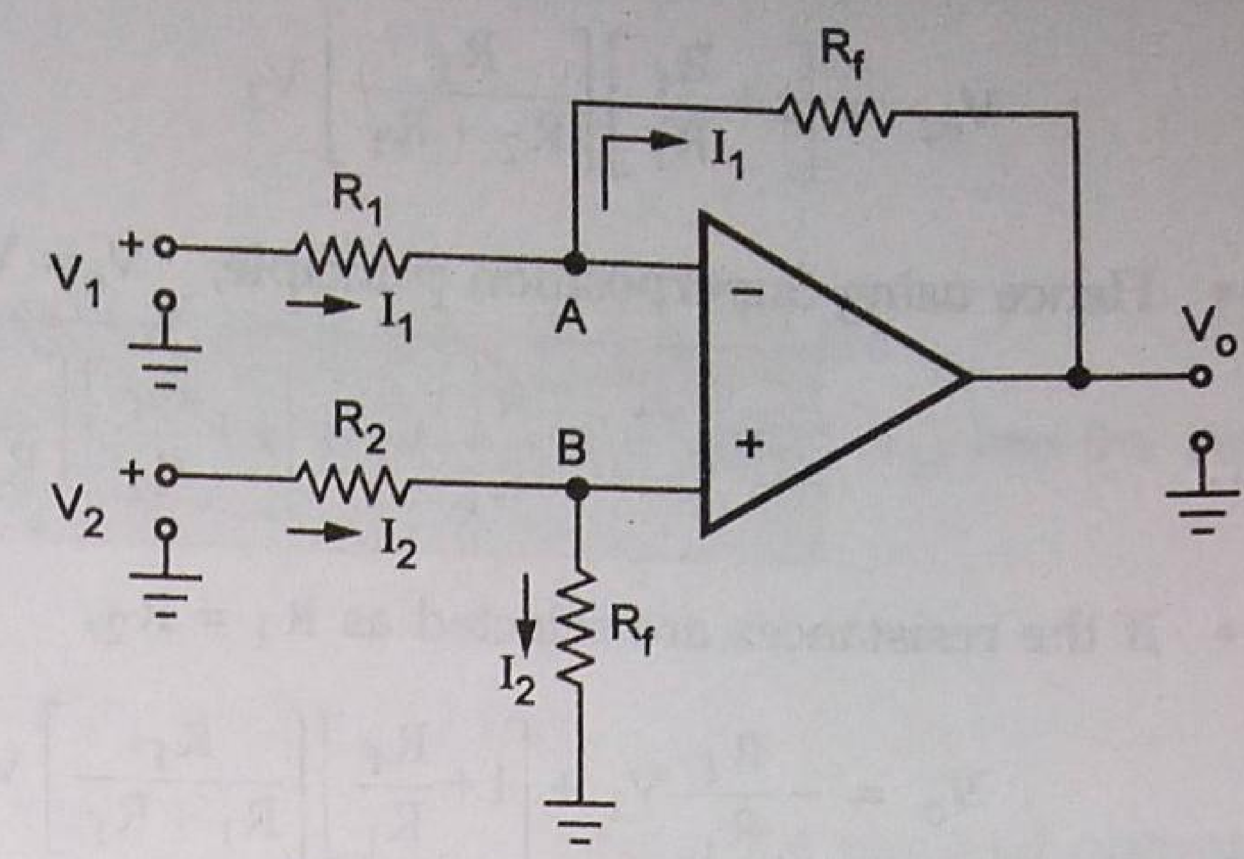

Fig. 9.18.1 Subtractor circuit

- To find the relation between the inputs and output let us use Superposition principle.
- Let V_{o1} be the output, with input V_1 acting alone, assuming V_2 to be zero. And V_{o2} be the output, with input V_2 acting, assuming V_1 to be zero.
- With V_2 zero, the circuit acts as an inverting amplifier as shown in the Fig. 9.18.2.
- Hence we can write,

$$V_{o1} = -\frac{R_f}{R_1} V_1 \qquad \dots (9.18.1)$$

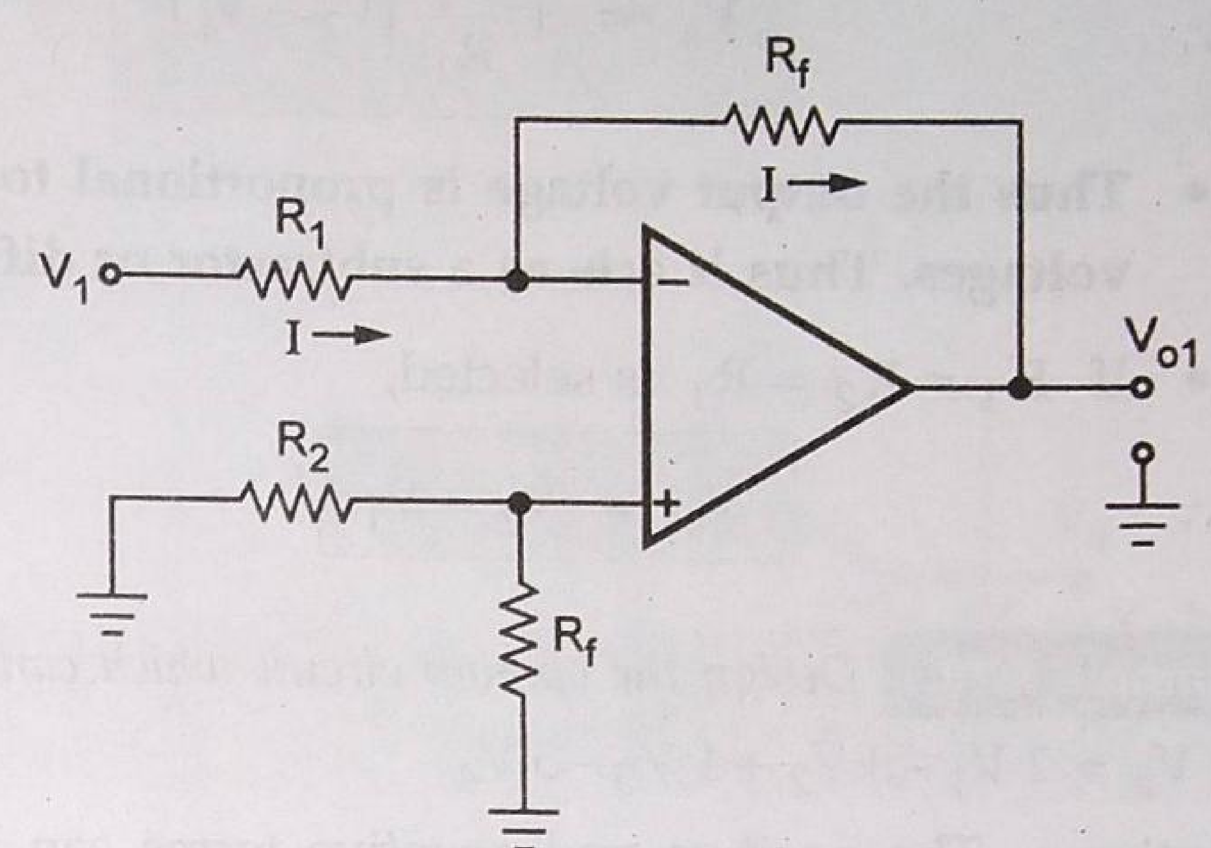

Fig. 9.18.2 V_1 acting, $V_2 = 0$

- While with V_1 as zero with V_2 acting, the circuit reduces to as shown in the Fig. 9.18.3.
- This circuit acts as a noninverting amplifier which amplifies the voltage at node B by the factor $\left(1+\frac{R_f}{R_1}\right)$.
- Let potential of node B be V_B.
- Applying voltage divider rule to the input V_2 loop,

$$V_B = \frac{R_f}{R_2 + R_f} V_2 \qquad \dots (9.18.2)$$

$$\therefore\ V_{o2} = \left[1+\frac{R_f}{R_1}\right] V_B \qquad \dots (9.18.3)$$

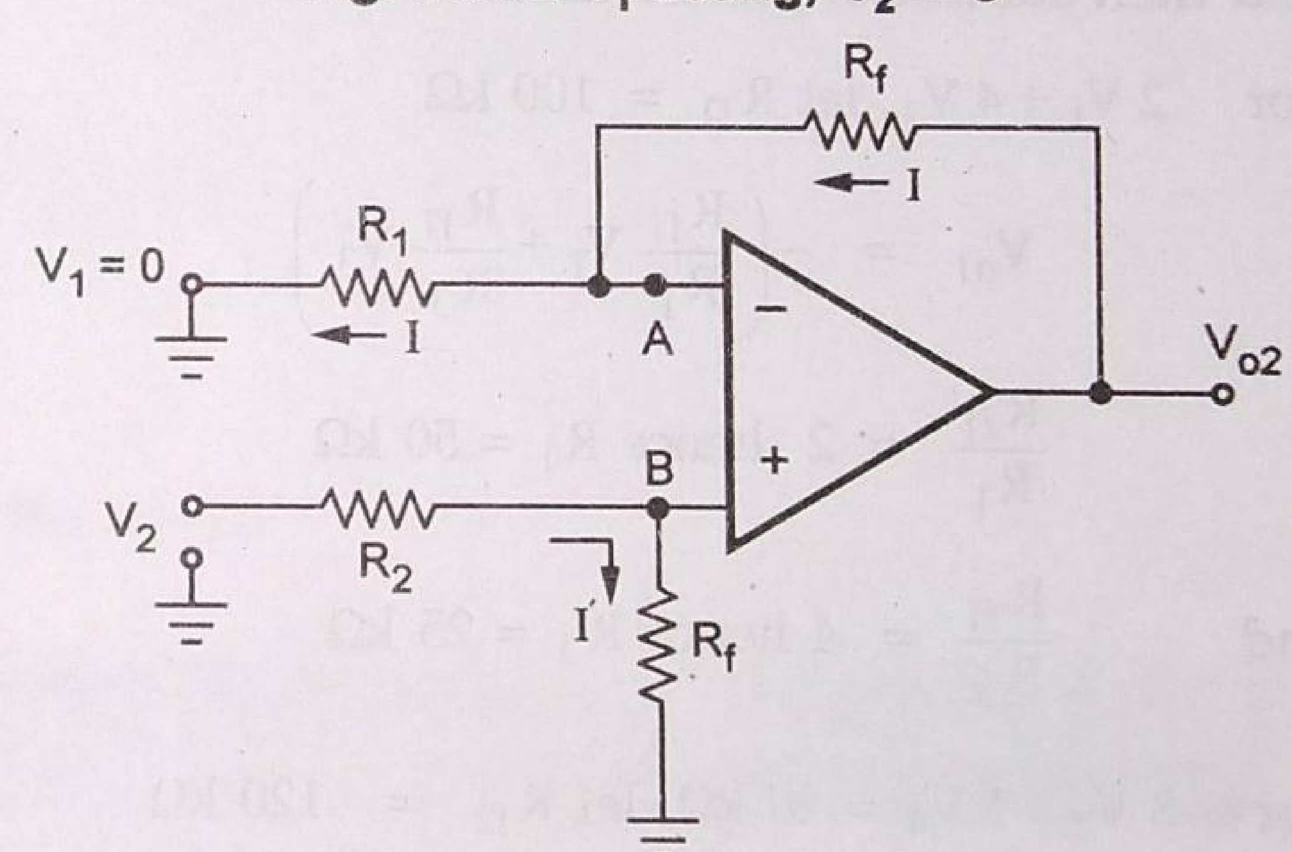

Fig. 9.18.3 V_2 acting, $V_1 = 0$

- Substituting V_B from (9.18.2) in (9.18.3) we get,

$$V_{o2} = \left[1+\frac{R_f}{R_1}\right]\left[\frac{R_f}{R_2+R_f}\right]V_2 \quad \text{... (9.18.4)}$$

- Hence using Superposition principle, $V_o = V_{o1} + V_{o2}$

$$\therefore \quad \boxed{V_o = -\frac{R_f}{R_1}V_1 + \left[1+\frac{R_f}{R_1}\right]\left[\frac{R_f}{R_2+R_f}\right]V_2} \quad \text{... (9.18.5)}$$

- If the resistances are selected as $R_1 = R_2$,

$$V_o = -\frac{R_f}{R_1}V_1 + \left[1+\frac{R_f}{R_1}\right]\left[\frac{R_f}{R_1+R_f}\right]V_2 = -\frac{R_f}{R_1}V_1 + \frac{R_f}{R_1}V_2$$

$$\therefore \quad \boxed{V_o = +\frac{R_f}{R_1}(V_2 - V_1)} \quad \text{... (9.18.6)}$$

- **Thus the output voltage is proportional to the difference between the two input voltages. Thus it acts as a subtractor or difference amplifier.**

- If $R_1 = R_2 = R_f$ is selected,

$$\therefore \quad \boxed{V_o = V_2 - V_1} \quad \text{... (9.18.7)}$$

Fig. 9.18.4

Example 9.18.2 *Find the output voltage of the following op-amp circuit shown in Fig. 9.18.5.*

APJAKTU : 2009-10, Marks 10

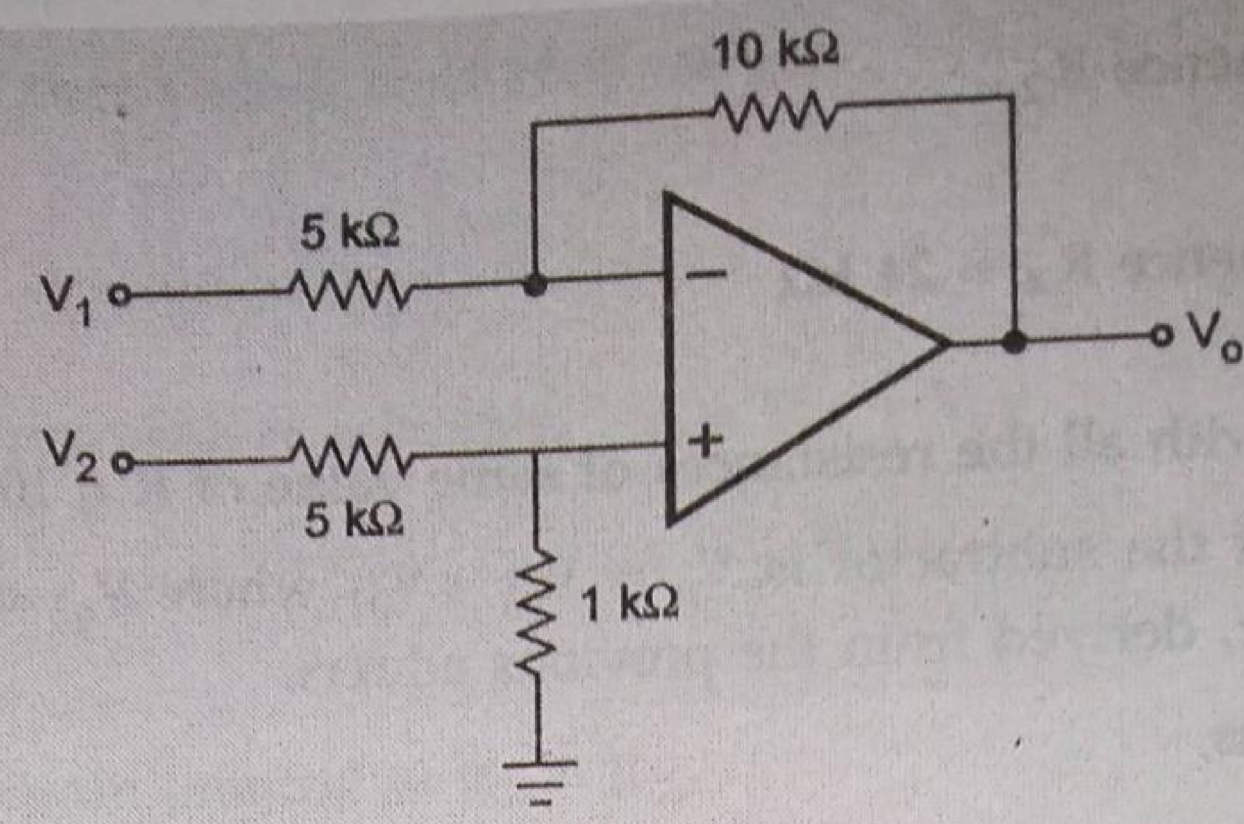

Fig. 9.18.5

Solution : Use Superposition principle.

Case 1 : Consider V_1 alone, V_2 is grounded.

The circuit acts as an inverting amplifier.

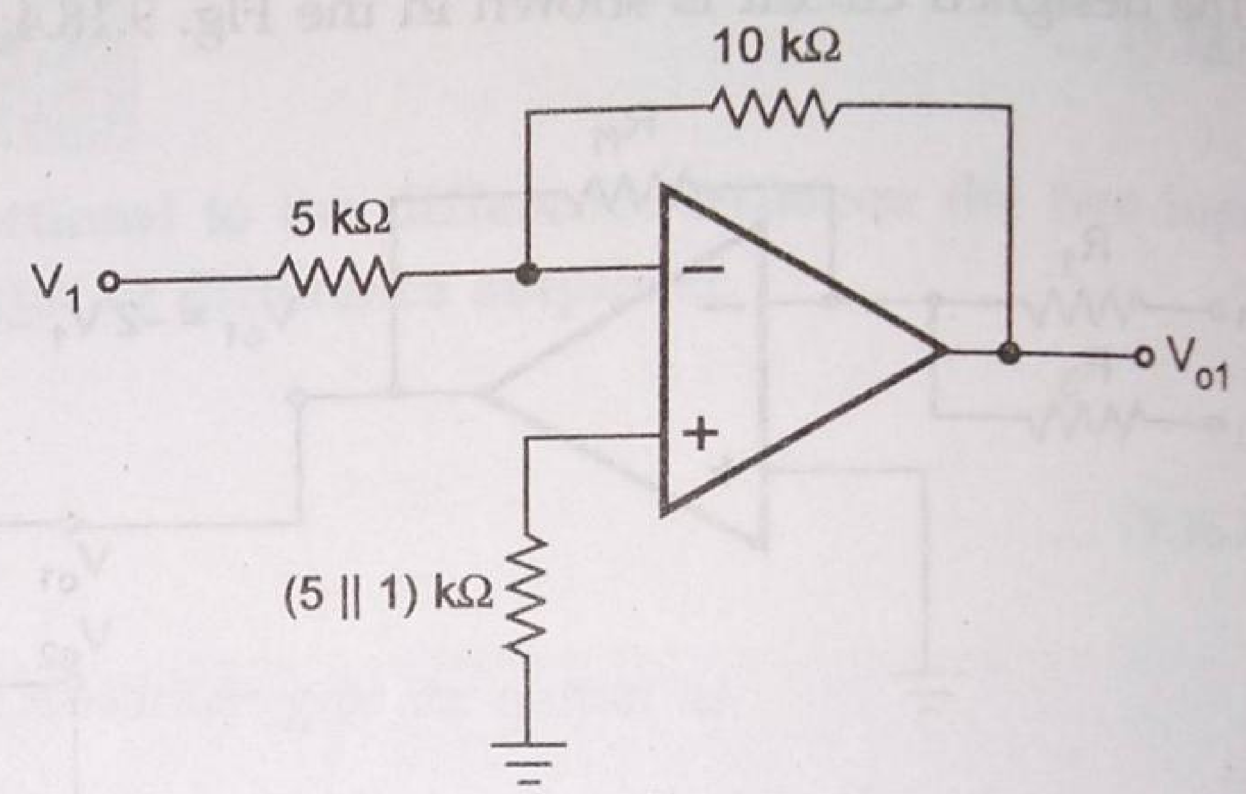

Fig. 9.18.5 (a)

$$\therefore \quad V_{o1} = -\frac{10\times10^3}{5\times10^3}\times V_1$$

$$= -2V_1$$

Case 2 : Consider V_2 alone, V_1 is grounded.

The circuit acts as non-inverting amplifier.

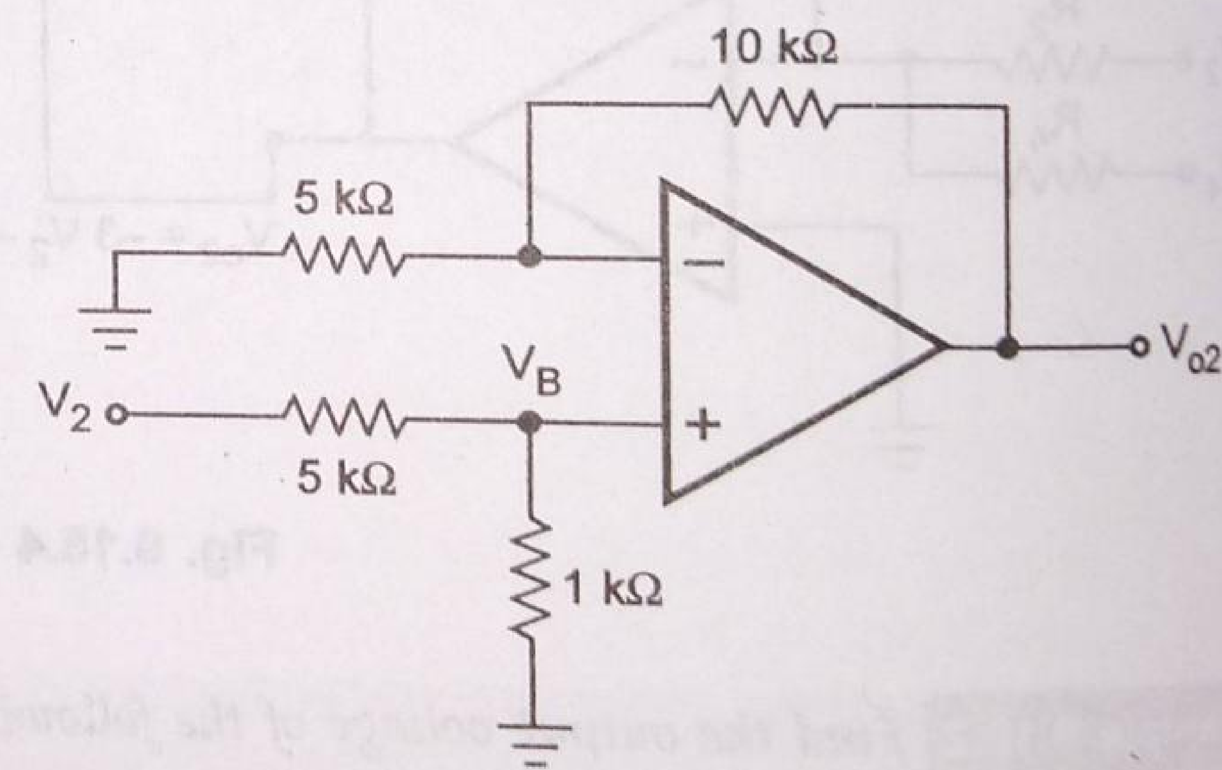

Fig. 9.18.5 (b)

$$\therefore \quad V_{o2} = \left(1+\frac{10\times10^3}{5\times10^3}\right)V_B$$

$$= 3\,V_B$$

$$\text{But} \quad V_B = \frac{V_2}{\left(5\times10^3+1\times10^3\right)}\times1\times10^3$$

$$= \frac{V_2}{6}$$

$$\therefore \quad V_{o2} = 3\times\frac{V_2}{6} = 0.5\,V_2$$

$$\therefore \quad V_o = V_{o1}+V_{o2} = -2\,V_1+0.5\,V_2$$