9.17 Summing Amplifier or Adder Circuit

APJAKTU : 2005-06, 2006-07, 2007-08, 2009-10, 2013-14

- As the input impedance of an op-amp is extremely large, more than one input signal can be applied to the inverting amplifier. Such circuit amplifies the addition of the applied signals at the output. Hence it is called **summing amplifier** or adder circuit.
- Depending upon the sign of the output, the summer circuits are classified as inverting summer and non-inverting summer.

9.17.1 Inverting Summing Amplifier

- In this circuit, all the input signals to be added are applied to the inverting input terminal of the op-amp.
- The circuit with three inputs is shown in the Fig. 9.17.1.
- As point B is grounded, due to virtual ground concept, node A is also grounded hence $V_A = V_B = 0$.

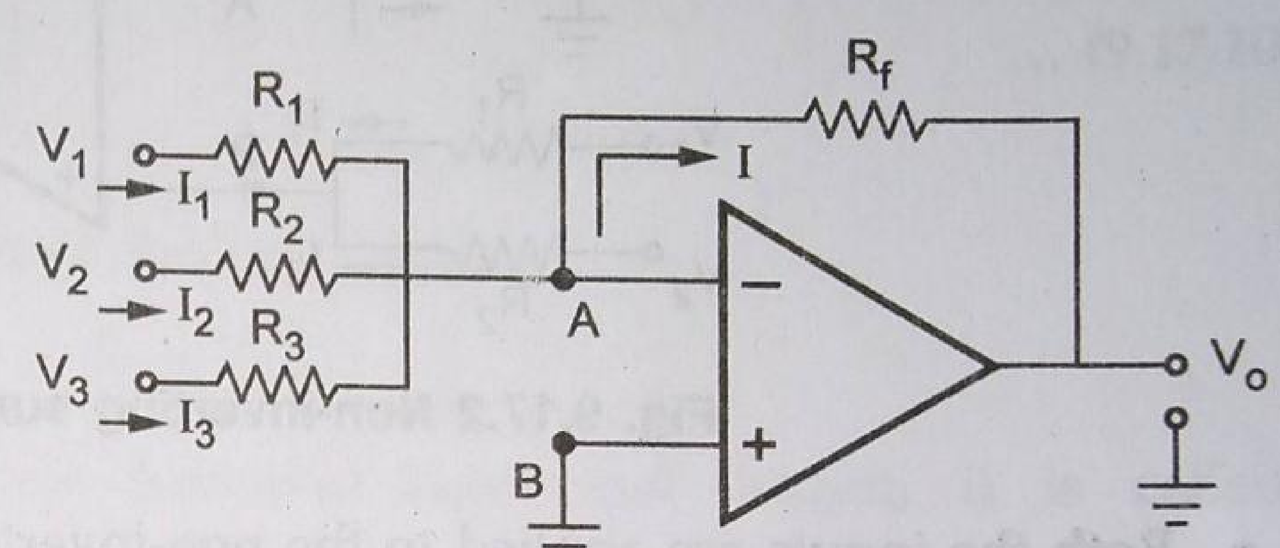

Fig. 9.17.1 Inverting summer

- From input side, $I_1 = \frac{V_1 - V_A}{R_1} = \frac{V_1}{R_1}$, $I_2 = \frac{V_2}{R_2}$, $I_3 = \frac{V_3}{R_3}$.
- Applying KCL at node A, $I = I_1 + I_2 + I_3$.
- As op-amp input current is zero, the entire current I passes through R_f.
- From output side, $I = \frac{V_A - V_o}{R_f} = -\frac{V_o}{R_f}$

$$\therefore \quad I_1 + I_2 + I_3 = -\frac{V_o}{R_f} \quad \text{i.e.} \quad \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} = -\frac{V_o}{R_f}$$

$$\therefore \quad \boxed{V_o = -\left[\frac{R_f}{R_1} V_1 + \frac{R_f}{R_2} V_2 + \frac{R_f}{R_3} V_3\right]} \quad \ldots (9.17.1)$$

- Thus the circuit amplifies the sum of the inputs in an inverting mode.
- If $R_1 = R_2 = R_3 = R$ then $V_o = -\frac{R_f}{R}[V_1 + V_2 + V_3]$
- If $R_1 = R_2 = R_3 = R_f = R$ then $V_o = -[V_1 + V_2 + V_3]$

- Due to the negative sign, there exists phase difference of 180° between input and output hence circuit is called inverting summing amplifier.

9.17.2 Non-inverting Summing Amplifier

- A summer circuit that gives amplification of non-inverted sum of the input signals is called **non-inverting summing amplifier.**
- The circuit with two input voltages is shown in the Fig. 9.17.2.

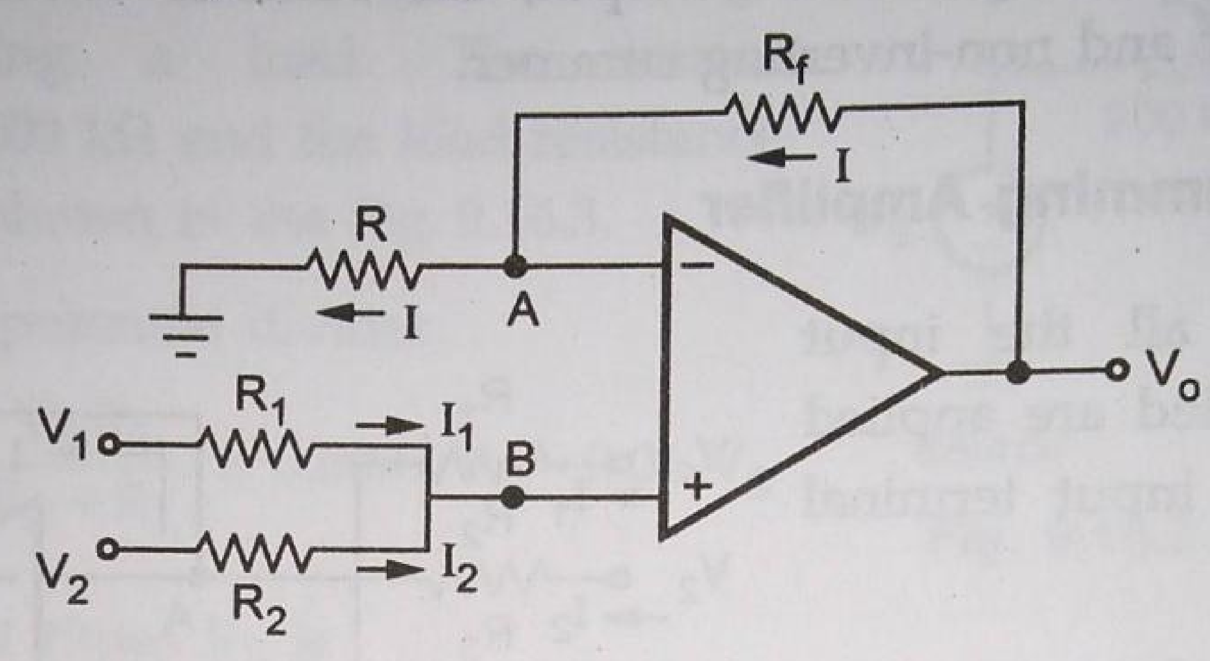

Fig. 9.17.2 Non-inverting summing amplifier

- Both the inputs are applied to the non-inverting terminal of the op-amp.
- Let the voltage of node B is V_B.
- Now the node A is at the same potential as that of B i.e. $V_A = V_B$ ... (9.17.2)
- From the input side, $I_1 = \frac{V_1 - V_B}{R_1}$ and $I_2 = \frac{V_2 - V_B}{R_2}$ ... (9.17.3)
- But as the input current of op-amp is zero, $I_1 + I_2 = 0$ ...(9.17.4)

$$\therefore \quad \frac{V_1 - V_B}{R_1} + \frac{V_2 - V_B}{R_2} = 0 \qquad \text{... Substituting (9.17.3) in (9.17.4)}$$

$$\therefore \quad \frac{V_1}{R_1} + \frac{V_2}{R_2} = V_B\left[\frac{1}{R_1} + \frac{1}{R_2}\right] \quad \text{i.e.} \quad V_B = \frac{(R_2 V_1 + R_1 V_2)}{(R_1 + R_2)} \qquad \text{...(9.17.5)}$$

- Now at node A, $I = \frac{V_A}{R} = \frac{V_B}{R}$ (as $V_B = V_A$) ...(9.17.6)

and

$$I = \frac{V_o - V_A}{R_f} = \frac{V_o - V_B}{R_f} \qquad \text{...(9.17.7)}$$

- Equating the two equations (9.17.6) and (9.17.7),

$$\frac{V_B}{R} = \frac{V_o - V_B}{R_f} \quad \text{i.e.} \quad \frac{V_o}{R_f} = V_B\left[\frac{1}{R} + \frac{1}{R_f}\right]$$

$$\therefore \quad V_o = V_B \frac{[R + R_f]}{R} \quad \ldots (9.17.8)$$

- Substituting equations (9.17.5) in (9.17.8) we get,

$$V_o = \frac{(R_2 V_1 + R_1 V_2)[R + R_f]}{R(R_1 + R_2)}$$

i.e.

$$\boxed{V_o = \frac{R_2 (R + R_f)}{R(R_1 + R_2)} V_1 + \frac{R_1 (R + R_f)}{R(R_1 + R_2)} V_2} \quad \ldots (9.17.9)$$

- If the two resistances R_1 and R_2 are selected equal i.e. $R_1 = R_2$ then,

$$\boxed{V_o = \frac{R + R_f}{2R} (V_1 + V_2)} \quad \ldots (9.17.10)$$

- Thus circuit amplifies the addition of the two inputs.
- If $R_1 = R_2 = R = R_f$ we get, $V_o = V_1 + V_2$.
- As there is no **phase difference between input and output,** it is called non-inverting summer amplifier.

9.17.3 Average Circuit

- If in the inverting summer circuit, the values of resistance are selected as,

$$R_1 = R_2 = R_3 = R \text{ and } R_f = \frac{R}{3} \quad \text{then from the equation (9.17.1) we get,}$$

$$V_o = -\left[\frac{R/3}{R} V_1 + \frac{R/3}{R} V_2 + \frac{R/3}{R} V_3\right] = -\frac{(V_1 + V_2 + V_3)}{3} \quad \ldots (9.17.11)$$

- Thus the magnitude of the output voltage is the average of the two input voltages. So circuit acts like an **averager.**
- Similarly average of n inputs can be obtained by selecting,

$$\boxed{R_1 = R_2 = R_3 = \ldots = R_n = R \quad \text{and} \quad R_f = \frac{R}{n}} \quad \ldots (9.17.12)$$

Example 9.17.2 *Calculate output voltage for the circuit shown in Fig. 9.17.4.*

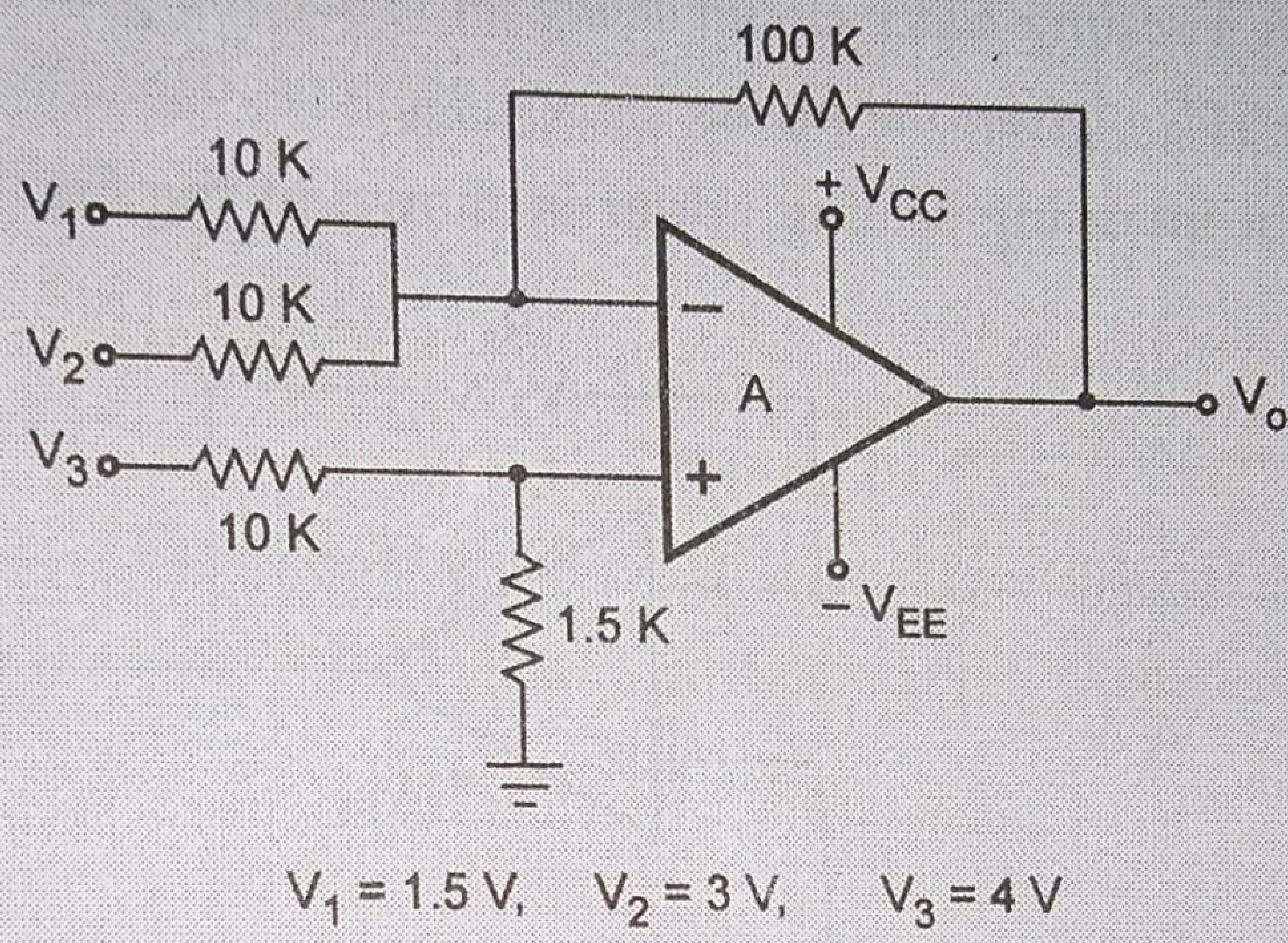

Fig. 9.17.4

Solution : Use superposition principle,

Case 1 : V_1 acting, $V_2 = V_3 = 0$

$$\therefore \quad V_{o1} = -\frac{R_f}{R_1} V_1 = \frac{-100\times10^3}{10\times10^3}\times1.5 = -15 \text{ V}$$

Case 2 : V_2 acting, $V_1 = V_3 = 0$

$$\therefore \quad V_{o2} = -\frac{R_f}{R_2} V_2 = \frac{-100\times10^3}{10\times10^3}\times3 = -30 \text{ V}$$

Case 3 : V_3 acting, $V_1 = V_2 = 0$

The circuit reduces as shown in the Fig. 9.17.4 (a).

The circuit amplifies V_B by $\left(1+\frac{R_f}{R_1}\right)$ times

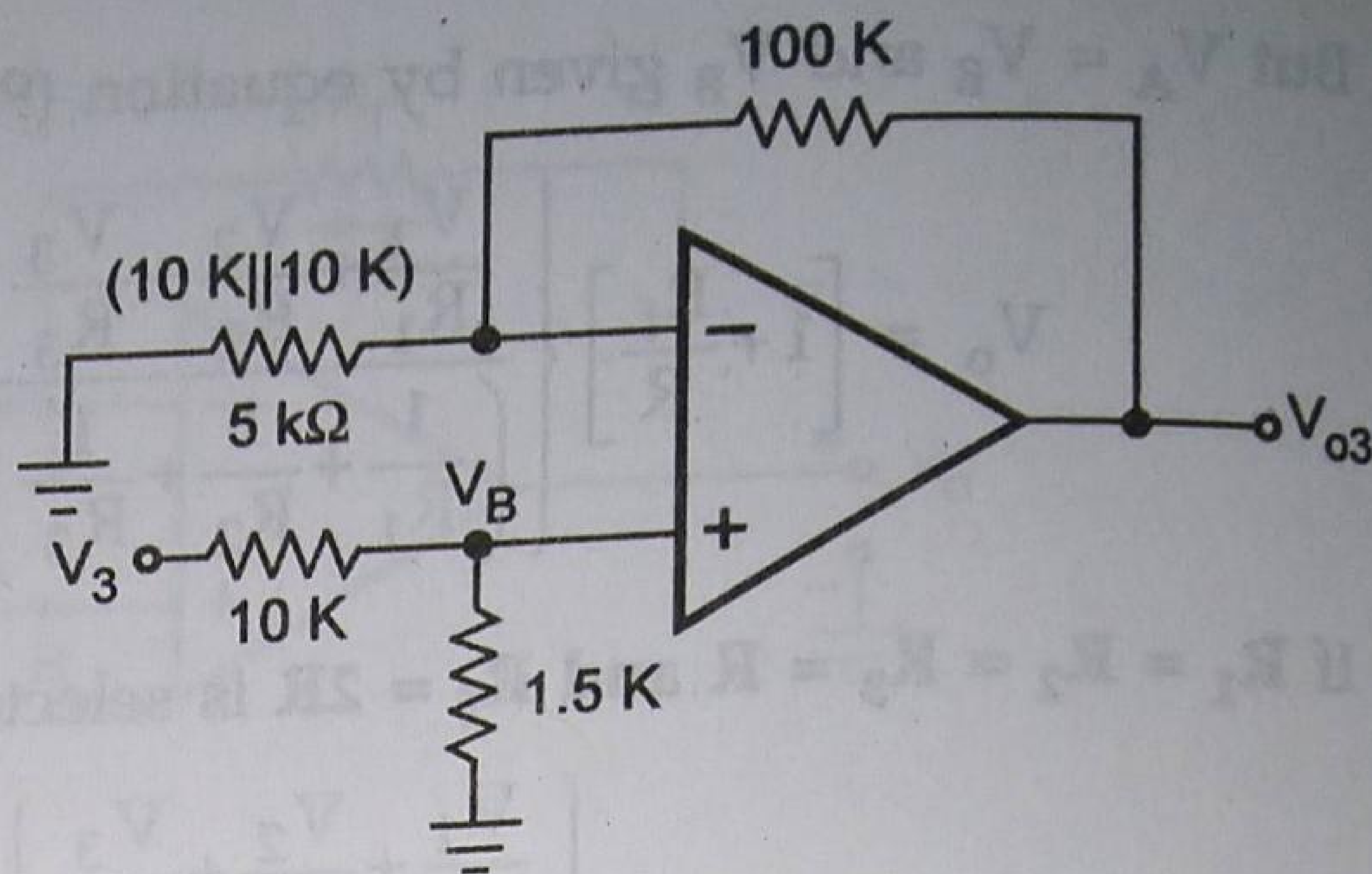

Fig. 9.17.4 (a)

where $R_1 = (10\text{ K} \,||\, 10\text{ K}) = 5\text{ k}\Omega$

$$V_B = \frac{V_3}{(10\text{ K}+1.5\text{ K})} \times 1.5\text{ K}$$

$$\therefore \quad V_{o3} = \left(1+\frac{100}{5}\right)\left(\frac{1.5}{10+1.5}\right)V_3$$

$$= 21 \times 0.1304 \times 4$$

$$= 10.9565\text{ V}$$

$$\therefore \quad V_o = V_{o1} + V_{o2} + V_{o3} = -15 - 30 + 10.9565 = -\mathbf{34.043\text{ V}}$$