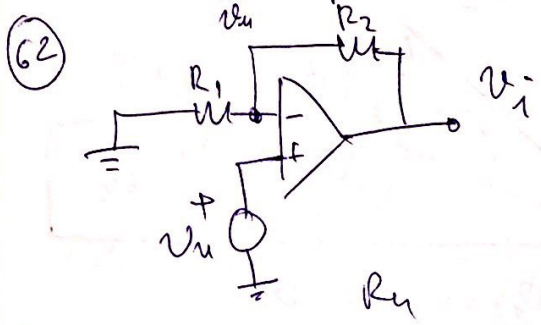


$$\frac{V_m}{R_1} = i \quad 0 - V_i = \frac{V_m}{R_1} \cdot R_2$$

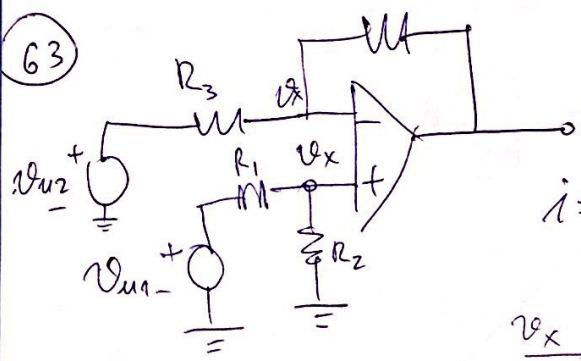
$$\boxed{V_i = -\frac{R_2}{R_1} V_m}$$



$$i = -\frac{V_m}{R_1}$$

$$V_m - V_i = -\frac{R_2}{R_1} V_m$$

$$\boxed{V_i = \left(1 + \frac{R_2}{R_1}\right) V_m}$$



$$i = \frac{V_{m2} - V_x}{R_3} \quad V_x = \frac{R_2}{R_1 + R_2} V_{m1}$$

$$\frac{V_x + V_i}{R_4} = \frac{V_{m2} - V_x}{R_3}$$

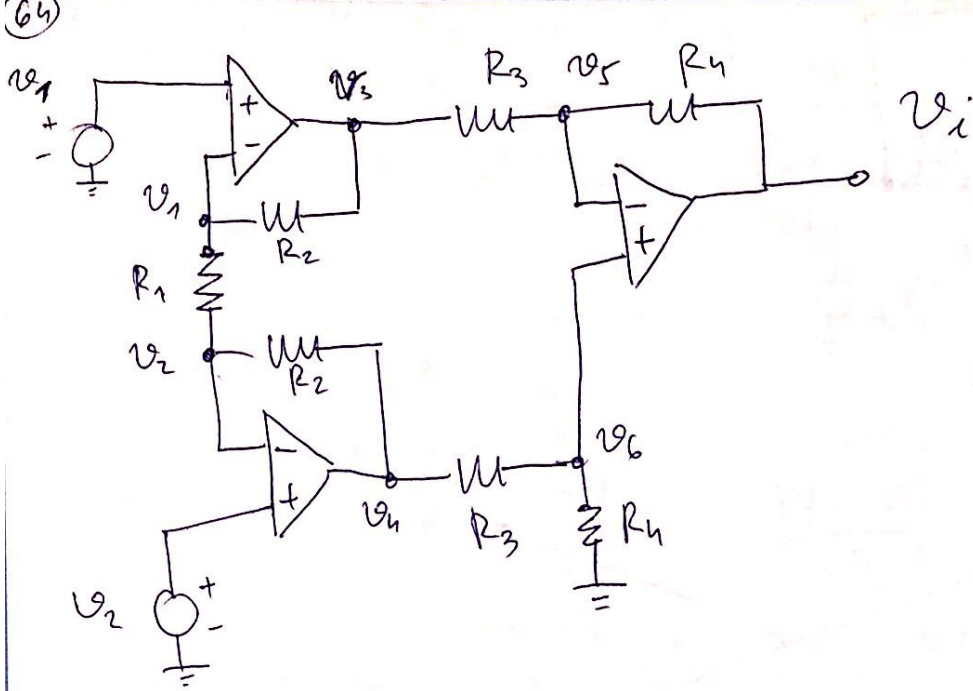
$$V_x R_3 - V_i R_3 = V_{m2} R_4 - V_x R_4$$

$$V_i = \frac{V_x (R_3 + R_4)}{R_3} - \frac{V_{m2} R_4}{R_3}$$

$$\frac{V_i - V_x}{R_4} = \frac{V_x - V_{m2}}{R_3}$$

$$V_i = \frac{R_4}{R_3} (V_x - V_{m2}) + V_x = V_x \left(1 + \frac{R_4}{R_3}\right) - \frac{R_4}{R_3} V_{m2} =$$

$$= \frac{R}{R_1 + R_2} \left(1 + \frac{R_4}{R_3}\right) V_{m1} - \frac{R_4}{R_3} V_{m2}$$

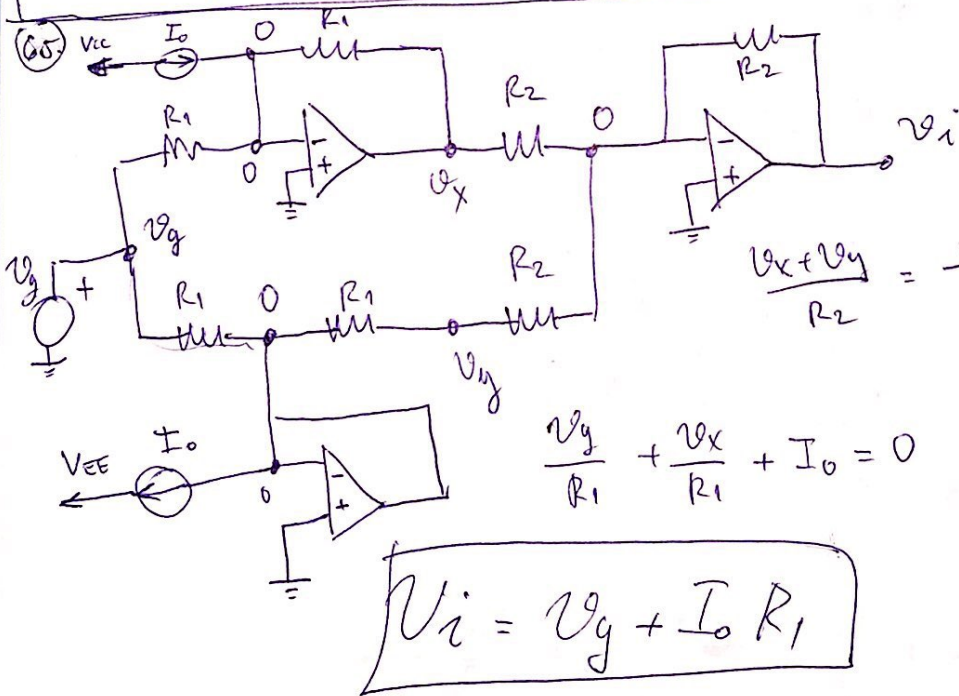


$$\frac{v_3 - v_1}{R_2} = \frac{v_2 - v_4}{R_2} = \frac{v_1 - v_2}{R_1} = I$$

$$v_3 = \left(1 + \frac{R_2}{R_1}\right)v_1 - \frac{R_2}{R_1}v_2 \quad v_4 = \left(1 + \frac{R_2}{R_1}\right)v_2 - \frac{R_2}{R_1}v_1$$

$$v_i = \frac{R_4}{R_3}(v_4 - v_3) = \frac{R_4}{R_3} \left(\left(1 + \frac{R_2}{R_1}\right)(v_2 - v_1) + \frac{R_2}{R_1}(v_2 - v_1) \right) =$$

$$v_i = \frac{R_4}{R_3} \left(1 + \frac{2R_2}{R_1}\right)(v_2 - v_1)$$

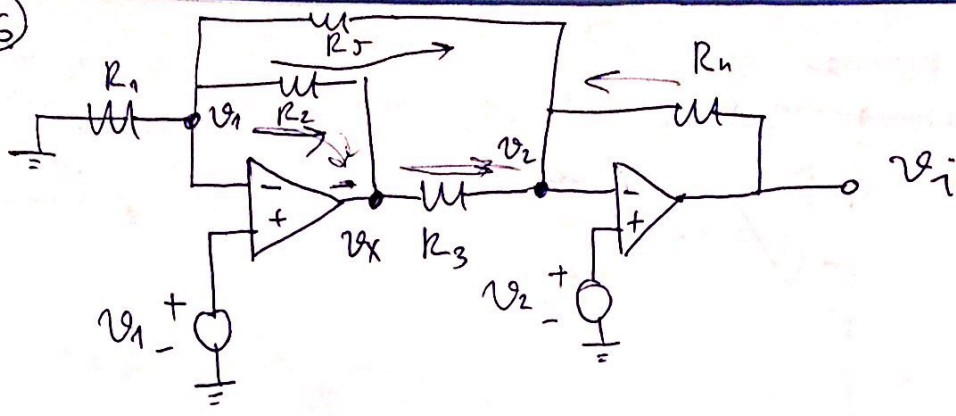


$$\frac{v_x + v_y}{R_2} = -\frac{v_i}{R_2} \quad v_i = -(v_x + v_y)$$

$$\frac{v_y}{R_1} + \frac{v_x}{R_1} + I_0 = 0 \quad v_x = -v_y - I_0 R_1$$

$$v_i = v_y + I_0 R_1$$

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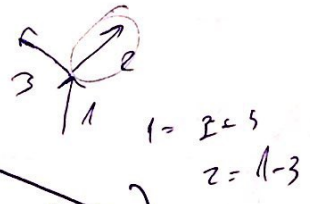


~~$$\frac{(v_1 - v_2)}{R_2 + R_3} + \frac{v_2 - v_2}{R_5} = \frac{v_2 - v_i}{R_4}$$~~

~~$$(v_1 - v_2) \left(\frac{1}{R_2 + R_3} + \frac{1}{R_5} \right) R_4 = v_2 - v_i$$~~

~~$$v_i = v_2 - (v_1 - v_2) \left(\frac{R_4}{R_2 + R_3} + \frac{R_4}{R_5} \right)$$

$$= v_2 \left(1 + \frac{R_4}{R_2 + R_3} + \frac{R_4}{R_5} \right) - v_1 \left(\frac{R_4}{R_2 + R_3} + \frac{R_4}{R_5} \right)$$~~



~~$$-\frac{v_1}{R_1} = \frac{v_1 - v_2}{R_5} + \frac{v_1 - v_x}{R_2} + \frac{v_x - v_2}{R_3}$$~~

~~$$\frac{v_1 - v_2}{R_5} + \frac{v_1}{R_1} = \frac{v_1 - v_x}{R_2} = -\frac{v_1}{R_1} - \frac{v_1 - v_2}{R_5}$$~~

$$\frac{v_x}{R_2} = \frac{v_1}{R_2} + \frac{v_1}{R_1} + \frac{v_1 - v_2}{R_5}$$

$$v_x = v_1 \left(1 + \frac{R_2}{R_1} \right) + v_1 \cdot \frac{R_2}{R_5} - \frac{R_2}{R_5} v_2 =$$

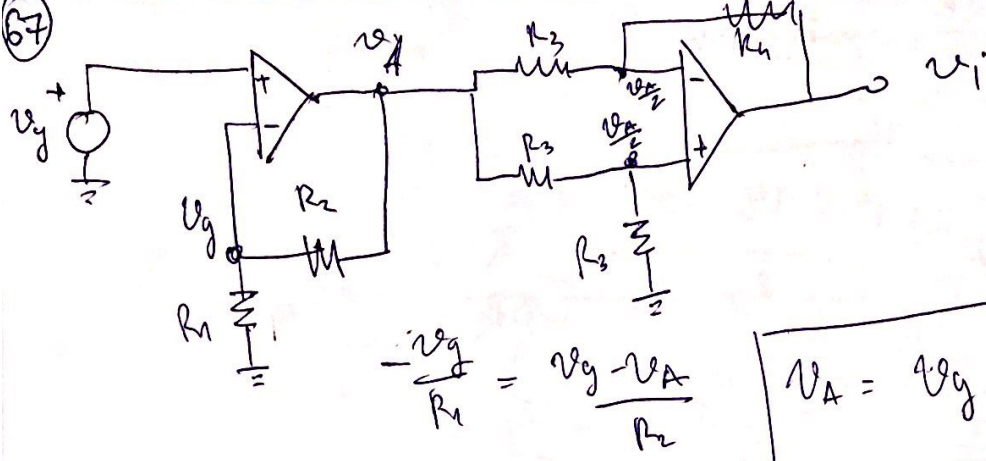
$$v_x = v_1 \left(1 + \frac{R_2}{R_1} + \frac{R_2}{R_5} \right) - \frac{R_2}{R_5} v_2$$

$$\frac{v_i - v_2}{R_4} = -\frac{v_x - v_2}{R_3} \Rightarrow \frac{v_i - v_2}{R_4} = \frac{v_1 - v_2}{R_5}$$

$$v_i = \frac{v_2}{R_4} \left(R_4 + \frac{R_4 R_2}{R_3} \right) + \frac{R_4}{R_3} v_x = \frac{R_4}{R_5} v_1 + \frac{R_4}{R_5} v_2 =$$

$$= v_2 \left(1 + \frac{R_2 R_4}{R_3 R_5} + \frac{R_4}{R_3} \left(\frac{R_4}{R_5} + \frac{R_2 R_4}{R_1 R_3} + \frac{R_2 R_4}{R_5 R_3} \right) \right) - v_1 \left(\frac{R_4}{R_5} + \frac{R_4}{R_3} + \frac{R_2 R_4}{R_1 R_3} + \frac{R_2 R_4}{R_5 R_3} \right)$$

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$$-\frac{v_A}{R_1} = \frac{v_g - v_A}{R_2}$$

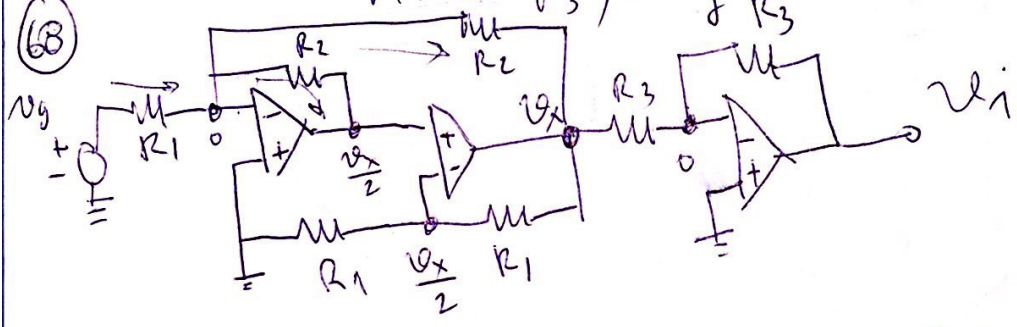
$$v_A = v_g \left(1 + \frac{R_2}{R_1}\right)$$

$$-\frac{v_A}{2R_3} = \frac{v_A}{2} - v_i$$

$$v_i = \frac{v_A}{2R_3} - \frac{v_A}{2} = \frac{v_A}{2} \left(\frac{1}{R_3} - 1 \right) = \frac{1}{2} v_A \left(1 - \frac{R_4}{R_3} \right)$$

$$v_i = \frac{1}{2} \left(1 + \frac{R_2}{R_1} \right) \left(1 - \frac{R_4}{R_3} \right) \cdot v_g$$

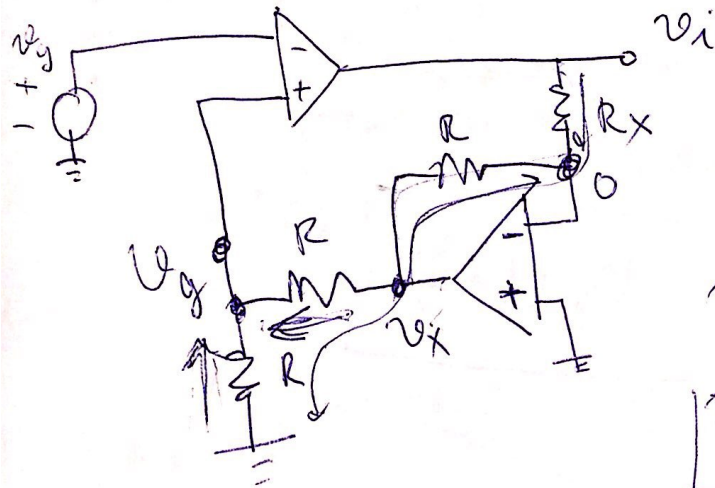
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$$\frac{v_x}{R_1} = -\frac{v_x}{2R_2} - \frac{v_x}{2R_2} = -\frac{3}{2} \frac{v_x}{R_2} \quad v_x = -\frac{2}{3} \frac{R_2}{R_1} v_g$$

$$\frac{v_x}{R_3} = -\frac{v_i}{R_3} \quad \boxed{v_i = \frac{2}{3} \frac{R_2}{R_1} v_g}$$

(69) $R_1 = R_2 = R_3$ $a = \frac{v_i}{v_g} = -2$ | $R_x = ?$



$$\frac{v_i}{R_x} = - \frac{v_x}{R}$$

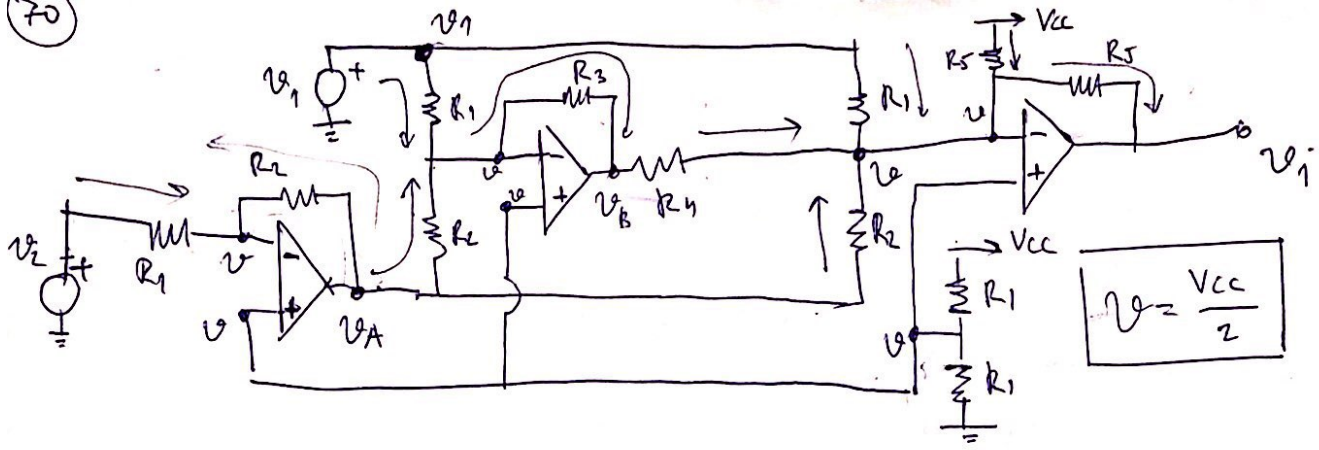
$$\frac{v_x - v_g}{R} = + \frac{v_g}{R}$$

$$v_x = 2v_g$$

$$\frac{v_i}{v_g} = -2 = - \frac{R_x}{R} \cdot \frac{2v_g}{v_g}$$

$$R_x = R$$

$$\frac{v_i}{R_x} = - \frac{v_x}{R} \quad v_i = - \frac{R_x}{R} 2v_g$$



$$\frac{v_1 - v_A}{R_2} + \frac{v_1 - v}{R_2} + \frac{v - v_A}{R_2} = 0 \quad \boxed{v_1 = v_A}$$

$$\frac{-v_2 + v}{R_1} = \frac{v_A - v}{R_2} \quad \boxed{v_A = \left(1 + \frac{R_2}{R_1}\right)v - \frac{R_2}{R_1}v_2}$$

$$\frac{v_1 - v}{R_1} + \frac{v_A - v}{R_2} = \frac{v - v_B}{R_3}$$

$$v_B = v - \frac{R_3}{R_1}v_1 + \frac{R_3}{R_1}v - \frac{R_3}{R_2}v_A + \frac{R_3}{R_2}v$$

$$v_B = v \left(1 + \frac{R_3}{R_1} + \frac{R_3}{R_2}\right) - \frac{R_3}{R_1}v_1 - \frac{R_3}{R_2}v_A =$$

$$= v \left(1 + \frac{R_3}{R_1} + \frac{R_3}{R_2}\right) - \frac{R_3}{R_1}v_1 - \frac{R_3}{R_2} \left(1 + \frac{R_2}{R_1}\right)v + \frac{R_3}{R_2} \frac{R_2}{R_1}v_2$$

$$= v \left(1 + \frac{R_3}{R_1} + \frac{R_3}{R_2} - \frac{R_3}{R_2} - \frac{R_3}{R_1}\right) - \frac{R_3}{R_1}(v_1 - v_2) =$$

$$= v - \frac{R_3}{R_1}(v_1 - v_2)$$

$$\frac{v_i - v}{R_5} = \frac{V_{cc} - v}{R_5} + \frac{v_1 - v}{R_1} + \frac{v_B - v}{R_4} + \frac{v_A - v}{R_2}$$

$$v_i = v + V_{cc} - v + \frac{R_5}{R_1}v_1 - \frac{R_5}{R_4}v + \frac{R_5}{R_4}(v_B - v) + \frac{R_5}{R_2}(v_A - v)$$

$$= V_{cc} + \frac{R_5}{R_1}v_1 - \frac{R_5}{R_4}v + \frac{R_5}{R_4} \left(v - \frac{R_3}{R_1}(v_1 - v_2) - v\right) + \frac{R_5}{R_2} \left(\frac{R_2}{R_1}v - \frac{R_2}{R_1}v_2\right) =$$

$$= V_{cc} + \frac{R_5}{R_1}v_1 - \frac{R_5}{R_4}v - \frac{R_5 R_3}{R_1 R_4}(v_1 - v_2) + \frac{R_5}{R_2}v - \frac{R_5}{R_1}v_2 =$$

$$= V_{cc} + R_5 \left(\frac{R_3}{R_1 R_4} - \frac{1}{R_1}\right)(v_1 - v_2)$$

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$$\frac{v_2 - v}{R_1} = \frac{v - v_A}{R_2}$$

$$v - v_A = \frac{R_2}{R_1} v_2 - \frac{R_2}{R_1} v$$

$$v_A = \left(1 + \frac{R_2}{R_1}\right)v - \frac{R_2}{R_1} v_2$$

$$\frac{v - v_B}{R_3} = \frac{v_1 - v}{R_1} + \frac{v_A - v}{R_2}$$

$$v_B = v - \frac{R_3}{R_1} v_1 + \frac{R_3}{R_1} v - \frac{R_3}{R_2} v_A + \frac{R_3}{R_2} v$$

$$v_B = v - \frac{R_3}{R_1} v_1 + \frac{R_3}{R_1} v - \frac{R_3}{R_2} \left(\left(1 + \frac{R_2}{R_1}\right)v - \frac{R_2}{R_1} v_2 \right) + \frac{R_3}{R_2} v =$$

$$= v - \frac{R_3}{R_1} v_1 + \frac{R_3}{R_1} v - \frac{R_3}{R_2} v - \frac{R_3}{R_1} v + \frac{R_3}{R_1} v_2 + \frac{R_3}{R_2} v$$

$$v_B = v - \frac{R_3}{R_1} (v_1 - v_2)$$

$$\frac{v_1 - v}{R_1} + \frac{v_B - v}{R_4} + \frac{v_A - v}{R_2} + \frac{v - v_i}{R_5} = \frac{v - v_i}{R_5}$$

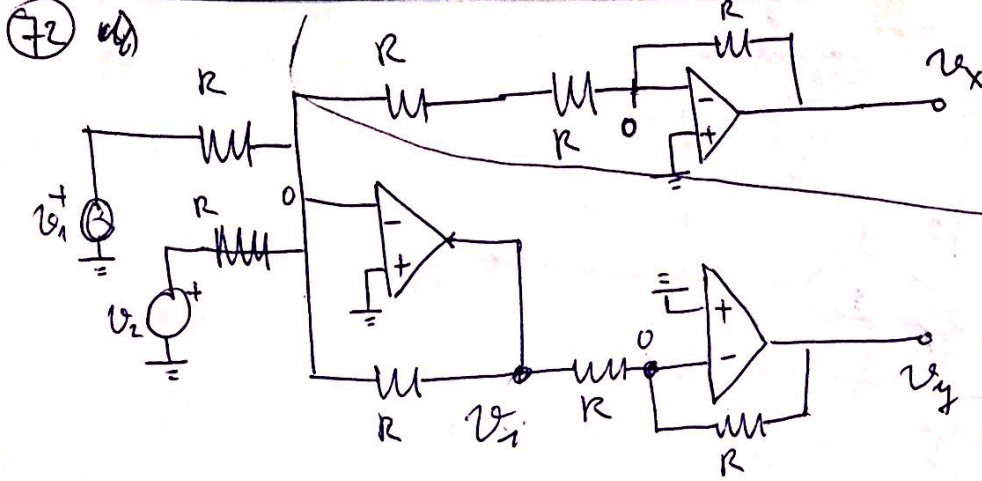
$$\frac{R_5}{R_1} v_1 - \frac{R_5}{R_1} v + \frac{R_5}{R_4} \left(v - \frac{R_3}{R_1} (v_1 - v_2) \right) + \frac{R_5}{R_2} \left(\left(1 + \frac{R_2}{R_1}\right)v - \frac{R_2}{R_1} v_2 \right) + v - v_i = v - v_i$$

$$-v_i = \frac{R_5}{R_1} v_1 - \frac{R_5}{R_1} v + \frac{R_5}{R_4} v - \frac{R_5 R_3}{R_4 R_1} (v_1 - v_2) + \frac{R_5}{R_2} v - \frac{R_5}{R_1} v_2$$

$$-v_i = \frac{R_5}{R_1} (v_1 - v_2) - \frac{R_5 R_3}{R_4 R_1} (v_1 - v_2) = (v_1 - v_2) R_5 \left(\frac{1}{R_1} - \frac{R_3}{R_4 R_1} \right)$$

$$v_i = R_5 \left(\frac{R_3}{R_1 R_4} - \frac{1}{R_1} \right) (v_1 - v_2)$$

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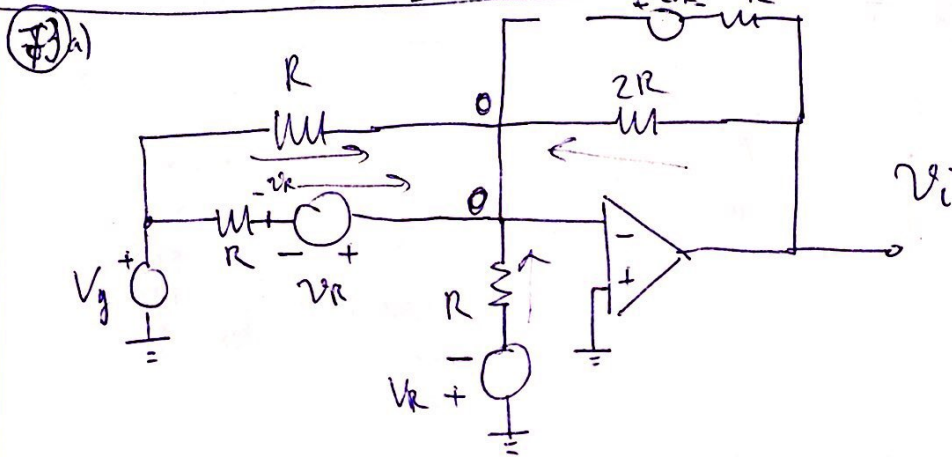


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 $v_x = 0$

$$\frac{v_1}{R} + \frac{v_2}{R} = -\frac{v_i}{R} \quad v_i = -(v_1 + v_2)$$

$$\frac{v_i}{R} = -\frac{v_y}{R}$$

$$v_y = -v_i = v_1 + v_2$$



$$\frac{v_i}{2R} + \frac{v_y}{R} + \frac{v_y + v_1}{R} + \frac{-v_1}{R} = 0$$

$$v_i = -4v_y$$

