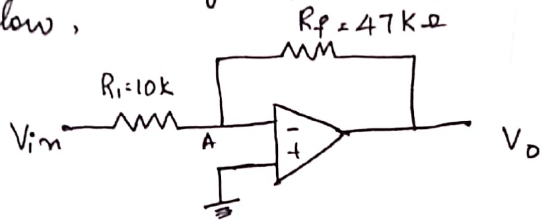
Problems :-

Operational Amplifiers :-

1) Determine the voltage gain of the op-amp circuit shown below.



Soln:- The above circuit represents an inverting amplifier.

$$\text{gain } A_f = -\frac{\cancel{0} \cdot R_f}{R_1} = \frac{-47K}{10K} = -4.7$$

$$\boxed{A_f = -4.7}$$

2) A sine wave of 0.5V peak voltage is applied to an inverting amplifier using $R_1 = 10K\Omega$ and $R_f = 50k\Omega$. It uses the supply voltage of $\pm 12V$. Determine output.

If the amplitude of input sinewave is increased to 5V, what will be the possible output ?

Soln: for inverting amplifier

$$\text{gain} = -\frac{R_f}{R_1} = -\frac{50K}{10K} = -5$$

if $V_{in} = 0.5V \Rightarrow V_o = V_{in} \times \text{Gain} = 0.5 \times 5 = 12.5V$ peak.

→ o/p is inverted wrt. i/p

if $V_{in} = 5V$

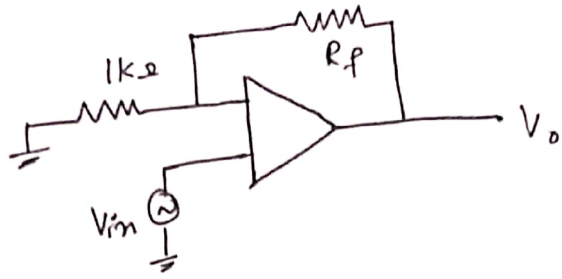
$V_o = V_{in} \times \text{gain} = 5 \times 5 = 25V$ peak

But practically o/p saturates at ±12 V

hence portion above +12 and below −12 will be clipped.

o/p 180° out of phase wrt i/p

3) For the op-amp shown the gain = 61. Determine the appropriate value of feedback resistance R_f



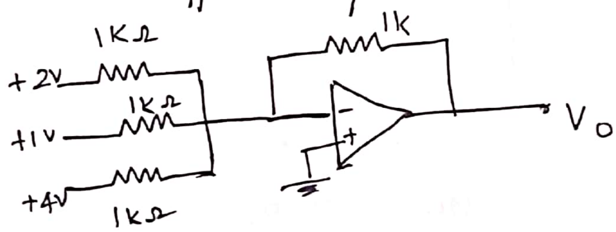
$$\text{Gain} = \frac{V_o}{V_{in}} = 1 + \frac{R_f}{R_1}$$

$$61 = 1 + \frac{R_f}{R_1}$$

$$\therefore R_f = 60 \times R_1$$

$$R_f = 60\,k\Omega$$

4) Determine the o/p voltage in the below figure.



$$V_{out} = -(V_{in1} + V_{in2} + V_{in3}) \frac{R_f}{R_1}$$

$$V_{out} = -(2 + 1 + 4) \frac{\cancel{1K}}{\cancel{1K}}$$

$$\boxed{V_{out} = -7V}$$

5) Design a scaling adder circuit using an op-amp to give the output $V_o = -(3V_1 + 4V_2 + 5V_3)$

Soln:- for an inverting summer

$$V_o = -\left[\frac{R_f}{R_1} V_1 + \frac{R_f}{R_2} V_2 + \frac{R_f}{R_3} V_3\right]$$

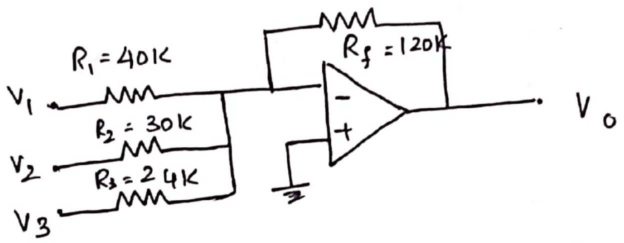
let $R_f = 120k\Omega$

$$\frac{R_f}{R_1} = 3 \Rightarrow R_1 = \frac{120}{3} = 40k\Omega$$

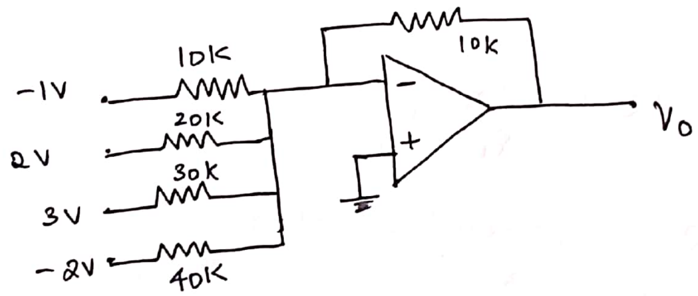
$$\frac{R_f}{R_2} = 4 \Rightarrow R_2 = \frac{120}{4} = 30k\Omega$$

$$\frac{R_f}{R_3} = 5 \Rightarrow R_3 = \frac{120}{5} = 24k\Omega$$

∴ the summer circuit is as shown in the figure below,



6) For the circuit shown determine the output



$$V_o = -\left[\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2 + \frac{R_f}{R_3}V_3 + \frac{R_f}{R_4}V_4\right]$$

$$V_o = -\left[\frac{10\times10^3}{10\times10^3}\times(-1) + \frac{10\times10^3}{20\times10^3}\times(2) + \frac{10\times10^3}{30\times10^3}\times(3) + \frac{10\times10^3}{40\times10^3}\times(-2)\right]$$

$$V_o = -\left[-1 + 1 + 1 - 0.5\right]$$

$$\boxed{V_o = -0.5\,V}$$

7) Design the op-amp circuit which can give output as

$$V_o = 2V_1 - 3V_2 + 4V_3 - 5V_4$$

Soln: The positive and -ve terms can be added separately using two adders ie, $2V_1 - 3V_2 + 4V_3 - 5V_4 = (2V_1 + 4V_3) - (3V_2 + 5V_4)$

consider $2V_1 + 4V_3$

let $R_f = 100k$ then $V_{o1} = -\left[\frac{R_{f1}}{R_1} V_1 + \frac{R_{f1}}{R_2} V_3\right]$

$$\frac{R_{f1}}{R_1} = 2 \Rightarrow \frac{100 \times 10^3}{R_1} = 2 \quad \underline{R_1 = 50k\Omega}$$

$$\frac{R_{f3}}{R_3} = 4 \Rightarrow R_2 = \frac{\cancel{100}^{25} \times 10^3}{\cancel{4}} = \underline{25k\Omega}$$

consider $3V_2 + 5V_4$ let $R_{f2} = 120k\Omega$

$$V_{o2} = -\left[\frac{R_{f2}}{R_2} V_2 + \frac{R_{f2}}{R_4} V_4\right]$$

$$\frac{R_{f2}}{R_2} = 3 \Rightarrow R_2 = \frac{\cancel{120}^{60} \times 10^3}{\cancel{3}} = 60k\Omega.$$

$$\frac{R_{f2}}{R_4} = 5 \Rightarrow R_4 = \frac{R_{f2}}{5} = \frac{120 \times 10^3}{5} = \underline{24k\Omega}$$

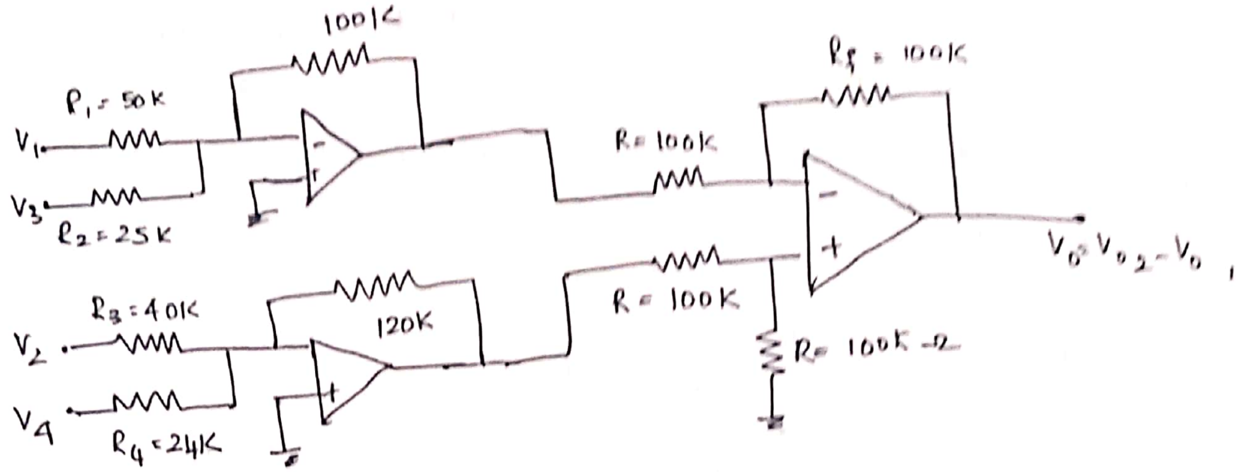
a subtractor with all resistances of $R = 100k\Omega$ as can be used,

therefore o/p of subtractor $V_2 - V_1 = V_{o2} - V_{o1}$

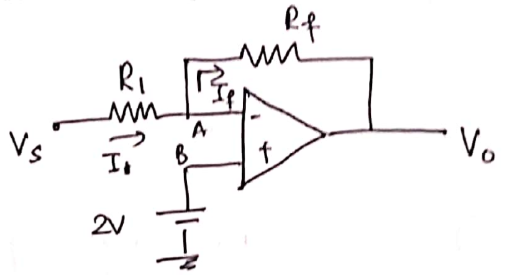
$$V_o = V_{o2} - V_{o1} = -3V_2 - 5V_4 - (-2V_1 - 4V_3)$$

$$V_o = 2V_1 - 3V_2 + 4V_3 - 5V_4$$

$$\therefore \boxed{V_o = 2V_1 - 3V_2 + 4V_3 - 5V_4}$$



8) Consider an ideal op-amp shown in below circuit given $R_1 = 10k\,\Omega$ $R_f = 30k\Omega$ $V_S = 4V$ find V_o



from virtual gnd $V_A = V_B = 2V$

$$I = \frac{V_S - V_A}{R_1} = \frac{4 - 2}{10 \times 10^3} = \frac{2}{\underset{5}{\cancel{10}} \times 10^3}$$

$$I = 0.2mA$$

$$I_f = \frac{V_A - V_o}{R_f} = \frac{2 - V_o}{30K}.$$

wkt $I_f = I$

$$2 - 0.2 \times 10^{-3} \times 30K = V_o$$

$$\boxed{V_o = -4V}$$

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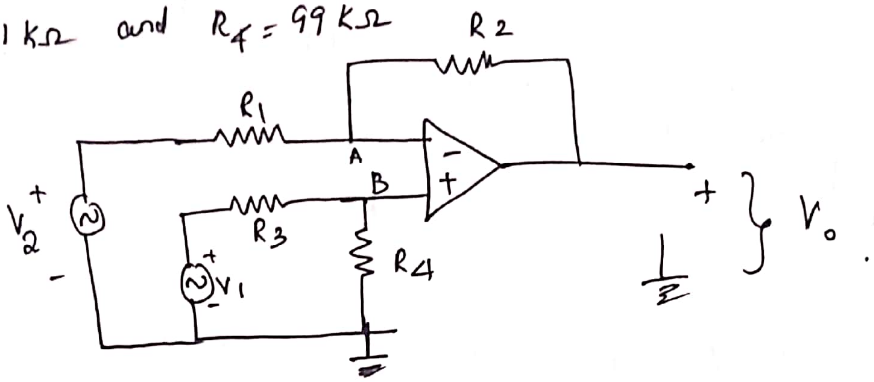
9) Consider the operational amplifier circuit shown in figure below, Assuming it to be ideal the output voltage is given by $V_0 = A_1 V_1 + A_2 V_2$. Find the values of A_1 and A_2 for resistor combination $R_1 = 10\,k\Omega$, $R_2 = 100\,k\Omega$, $R_3 = 10.1\,k\Omega$ and $R_4 = 99\,k\Omega$



Soln:- using super position theorem, V_0 can be ~~detemed~~ determined.

let $V_1 = 0$ the o/p is due to i/p V_2

$$\therefore V_{02} = V_2\left[\frac{-R_2}{R_1}\right] \longrightarrow \text{inverting amplifier.}$$

let $V_2 = 0$, the o/p is only due to i/p V_1 → non inverting amplifier.

$$\cancel{V_B = V_1\left(1+\frac{R_f}{R_1}\right)}$$

$$\cancel{V_B = V_1\left[1+\frac{R_2}{R_1}\right]} = V_1$$

the potential at point B ie., V_B is given by.

$$V_B = \frac{V_1 R_4}{R_3 + R_4}$$

$$\therefore V_{01} = V_B\left[1 + \frac{R_2}{R_1}\right] = \frac{V_1 R_4}{R_3 + R_4}\left[1 + \frac{R_2}{R_1}\right].$$

combining both,

$$V_0 = V_{01} + V_{02} = \frac{V_1 R_4}{R_3 + R_4} + \frac{V_1 R_4}{(R_3 + R_4) R_1} + V_2\left[\frac{-R_3}{R_1}\right].$$

$$v_o = v_1\left[\frac{R_4}{R_3+R_4} + \frac{R_2 R_4}{(R_3+R_4)R_1}\right] + V_2\left[\frac{-R_2}{R_1}\right]$$

$$v_o = V_1 \frac{R_4}{R_3+R_4}\left[1 + \frac{R_2}{R_1}\right] + V_2\left[\frac{-R_2}{R_1}\right]$$

By comparing the above Eqn with given Eqn,

$$v_o = V_1 A_1 + V_2 A_2$$

we get, $A_1 = \frac{R_4}{R_3+R_4}\left[1 + \frac{R_2}{R_1}\right]$

$$A_1 = \frac{99\times\cancel{10^3}}{109.1\times\cancel{10^3}}\left[1 + \frac{100\times\cancel{10^3}}{10\times\cancel{10^3}}\right]$$

$$A_1 = \frac{99}{109.1}\left[\frac{11\cancel{0}}{1\cancel{0}}\right]$$

$$\underline{\underline{A_1 = 9.9817}}$$

$$A_2 = -\frac{R_2}{R_1} = -10$$

10) A differential amplifier has a typical common mode gain of 35dB and CMRR of 72 dB. Find the output voltage (V_o) when input voltages are 0.16mV and 0.18mV.

Soln: $CMRR = \frac{A_d}{A_c}$

$20\log A_c = 35\,dB$

$A_c = 10^{\left(\frac{35}{20}\right)}$

$\underline{\underline{A_c = 56.23}}$

$A_c = 56.23$.

$CMRR = 72dB \Rightarrow 20\log x = 72dB$

$x = 3981 = CMRR$.

$Ad = CMRR \times A_c = 3981 \times 56.23 = 223855$

$= 2.24\times10^5$

V_c = common mode signal

$$V_c = \frac{V_1 + V_2}{2} = \frac{1}{2}\left[0.18 + 0.16\right] \times 10^{-3}$$

$$V_c = 0.17 mV$$

V_d = difference mode signal

$V_d = (0.18V - 0.16V) = 0.02 mV$

$V_d = 0.02 mV$

$V_o = A_c V_c + A_d V_d = (56.23)(0.17 mV) + (0.02 m)(2.23 \times 10^5)$

$$\underline{\underline{V_o = 4.47 V}}$$

An amplifier has mid band gain of 125 and BW of 250kHz i) If 4% negative feedback is introduced find the new bandwidth & gain. ii) If BW is restricted to 1MHz find feedback ratio.

Soln: Given $A_v = 125$ $B_W = 250K$ $\beta = 0.04$

$$A_{vf} = \frac{A}{1+\beta A} = \frac{125}{1+0.04 \times 125} = 20.83$$

$$B_{wf} = B_W(1+AB) = 250 \times 10^3 (1+0.04 \times 125)$$

$$= 1.5 MHz$$

$$B_W = 1MHz$$

$$1 \times 10^6 = B_W(1+AB).$$

$$= 250 \times 10^3 (1+125 \times \beta)$$

$$\beta = 0.024$$