Tutorial - 6

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① What will be gain factor for a non-invert closed loop op amp.

→ $$A_{(v)} = \frac{V_{out}}{V_{in}}$$

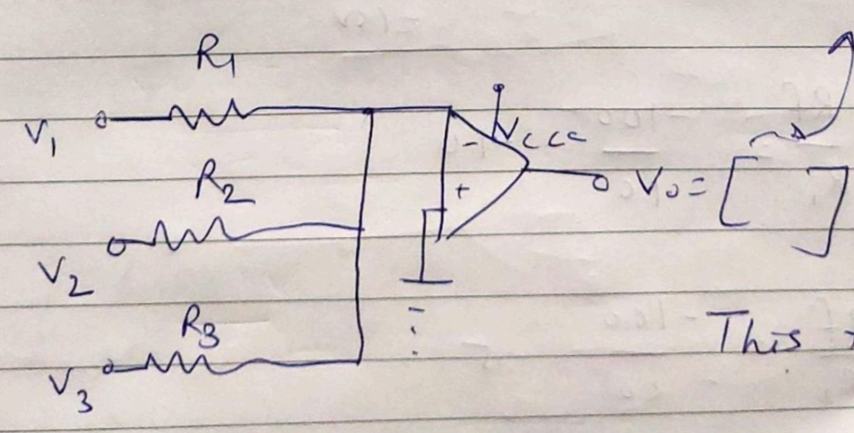
$$= \frac{R_2 + Rf}{R_2}$$

$$= 1 + \frac{Rf}{R_2}$$

→ from the equation we can see that gain factor is always greater but never less than one (unity), its positive in nature and determined by the ratio of Rf and R_2

② How many op-amps are required to implement this equation.

→ $$V_o = -\left(\frac{Rf}{R_1}V_1 + \frac{Rf}{R_2}V_2 + \frac{Rf}{R_3}V_3\right)$$



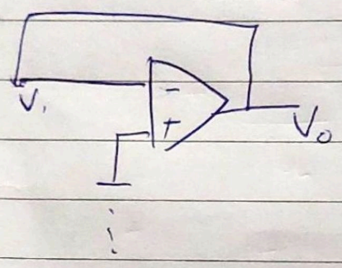
This topology

→ So basically only one op-amp is required.

(3) How many op-amps are required to implement this equation $V_o = V_i$

→ $V_o = V_i$

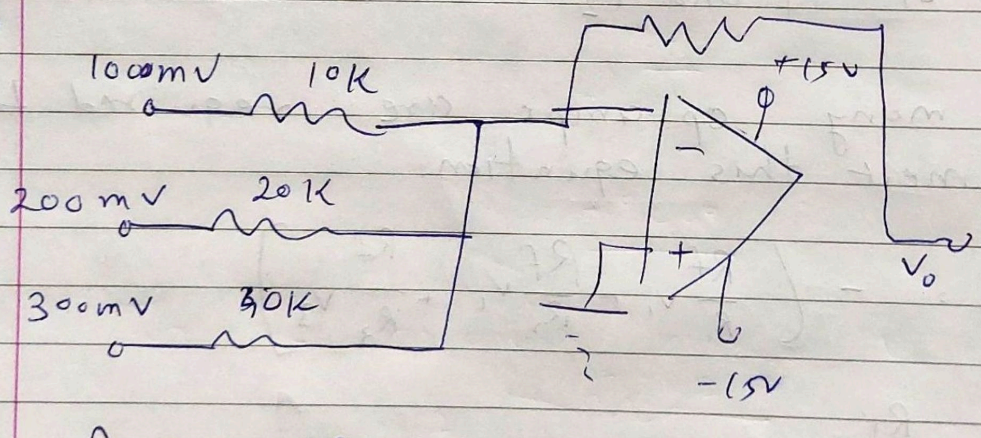
– Basically Voltage follower



→ So, Only one op-amp is required for $V_o = V_i$ too.

(4) The loop gain that is considered as closed loop gain can be calculated as.

→



$$A_1 = \frac{-R_f}{R_1} = \frac{-100}{10} = -10$$

$$A_2 = \frac{-R_f}{R_2} = \frac{-100}{20} = -5$$

$$A_3 = \frac{-R_f}{R_3}$$

$$= \frac{-100}{40}$$

$$= -2.5$$

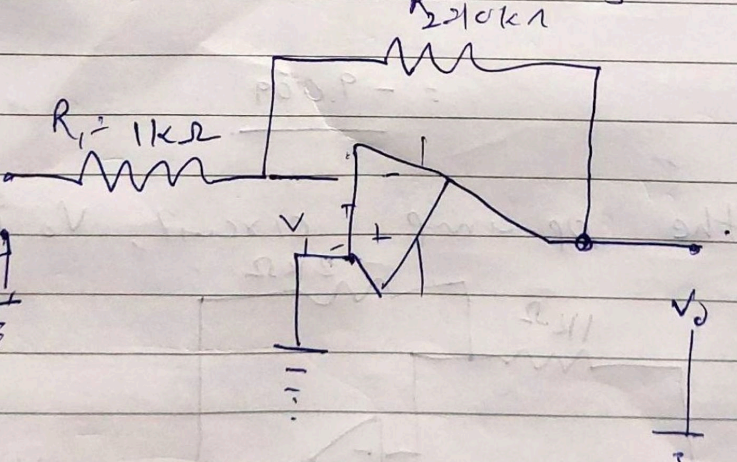
$$V_{out} = -\left[A_1 V_1 + A_2 V_2 + A_3 V_3 \right]$$

$$= -10(0.1) + -5(0.2) + -2.5(0.3)$$

$$= -1 - 1 - 0.75$$

$$= -2.75 \text{ Volt}$$

6) The inverting op-amp shown, loop gain = 100
The closed loop gain $\frac{V_o}{V_s}$ is



$R_1 = 1k\Omega$
$R_2 = 10\ k\Omega$

$A_{OL} = 100$

It's Inverting op-amp, So

Closed loop gain $A_v = \frac{V_o}{V_s}$

$$= \frac{-\frac{R_2}{R_1}}{1 + \frac{\left(1 + \frac{R_2}{R_1}\right)}{A_{OL}}}$$

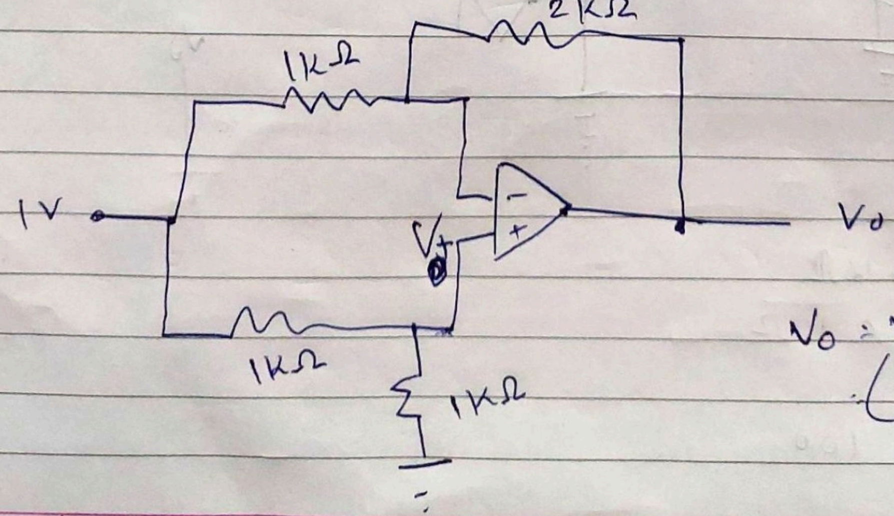
$$\frac{V_o}{V_s} = \frac{-\frac{10}{1}}{1 + \frac{\left(1 + \frac{10}{1}\right)}{100}}$$

$$= \frac{-10}{1 + \frac{11}{100}} = \frac{-1000}{100 + 11}$$

$$= \frac{-1000}{111}$$

$$= \underline{-9.009}$$

(6) For the op-amp circuit, V_o is



$V_o = V_{o1} + V_{o2}$
(due to v) (due V_+)

$\rightarrow$ $V_{o1} = \left(-\dfrac{R_2}{R_1}\right) V_{in}$ (Inverting)

$= \dfrac{-2}{1} \times 1$

$= -2$ Volts

$\rightarrow$ $V_{o2} = \left(1 + \dfrac{R_2}{R_1}\right) V$. (Non-Inverting)

$= \left(1 + \dfrac{R_2}{R_1}\right) V_{+}$

$= \left(1 + \dfrac{R_2}{R_1}\right)\left(\dfrac{R_4}{R_4 + R_3}\right) V \rightarrow (1)$

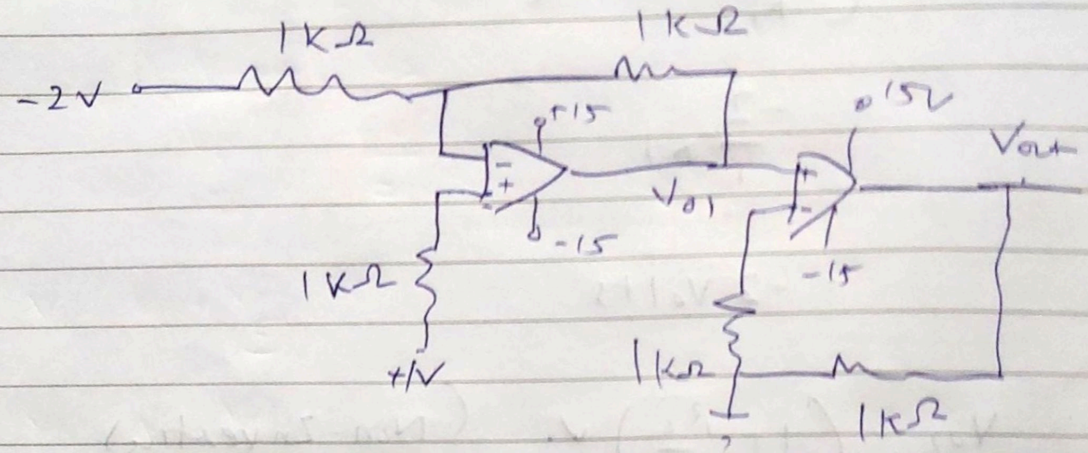
$= \left(1 + \dfrac{2}{1}\right)\left(\dfrac{1}{1+1}\right)(1)$

$= 3 \cdot \dfrac{1}{2}$

$= 1.5$ Volts

$\therefore$ $V_o = 1.5 + (-2) = -0.5$ Volts

(7) In this circuit show, V_{out}



→ W.r.t op-amp-2
Non Inverting op-am

$$V_{out} = \left(1 + \frac{R_f}{R_1}\right) V_{o1}$$

$$V_{out} = \left(1 + \frac{1}{1}\right) V_{o1}$$

$$V_{out} = 2V_{o1} \quad - (1)$$

→ V_{o1} → $V_{o1} = V_{o1_{-2}} + V_{o_{+1}}$ (Superposition).

V_{o1} due to -2 Volt

op-amp act as Inverting op-amp

$$V_{o1_{-2}} = -\frac{R_f}{R_1} \cdot V_{in} = (-1)(-2) = 2 \text{ Volt}.$$

V_{o1} due to +1

→ Non Inverting op-amp.

$$V_{o1+1} = \left(1 + \frac{R_f}{R_1}\right) V_{i1}$$

$$= (2)(1)$$

$$= 2$$

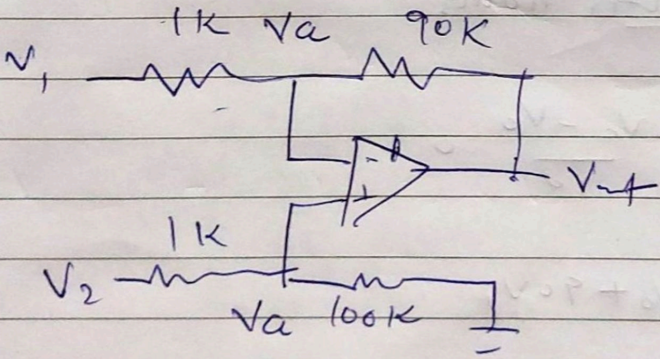
∴ $V_{o1} = 2 + 2$
$= 4\ V$

∴ $V_{out} = 2V_{o1}$

$= 2(4)$

$= \underline{8\ \text{Volt}}$

(8) Calculate CMRR.



→ ~~Ad~~ $CMRR = \frac{A_d}{A_c}$

$V_o = A_d V_d + A_c V_c$

$\Rightarrow V_d = V_1 - V_2$

$V_c = \frac{V_1 + V_2}{2}$

$$\boxed{\begin{aligned} V_1 &= V_c + \frac{V_d}{2} \\ V_2 &= V_c - \frac{V_d}{2} \end{aligned}}$$

→ V_o Interms of V_1 & V_2

KCL at Non Invertin node,

$$\frac{V_a - V_2}{1} + \frac{V_a}{100} = 0$$

$$\therefore V_a = \frac{100}{101} V_2 \quad -(1)$$

KCL at Invertin node

$$\frac{V_a - V_1}{1} + \frac{V_a - V_o}{90} = 0$$

$$91 V_a = V_o + 90 V_1$$

$$91\left(\frac{100}{101} V_2\right) = V_o + 90 V_1$$

$$91\left(\frac{100}{101}\left(V_c - \frac{V_d}{2}\right)\right) = V_o + 90\left(V_c + \frac{V_d}{2}\right)$$

$$\therefore V_o = \left(\frac{91(100)}{101} - 90\right)V_c - \left(\frac{91\cancel{(100)}^{50}}{\cancel{(101)}(2)} - 45\right)V_d$$

$$\therefore \left(\frac{9100-9090}{101}\right)V_c - \left(\cancel{9100}/29\ \frac{91(50)-45(101)}{101}\right)$$

$$= \left(\frac{10}{101}\right)V_c + \left(\frac{-9095}{101}\right)V_d$$

$$\therefore V_o = A_d V_d + A_c V_c$$

$$\therefore A_d = \frac{-9095}{101}$$

$$\therefore A_c = \frac{10}{101}$$

$$\therefore CMRR = \left|\frac{A_d}{A_c}\right|$$

$$= \left|\frac{\frac{-9095}{101}}{\frac{10}{101}}\right|$$

$$= \underline{909.5}$$

(9) AN OPAMP has slew rate of $5 V/\mu s$. The largest sine wave o/p voltage possible at 1MHz

→ $$\text{Slew-rate} = \frac{2 \times \pi \times f \times V_m}{10^6} \ V/\mu s$$

$S.R = 5 \ V/\mu s$

$f = 1 MHz$

∴ $$SR = \frac{2\pi f V_m}{10^6}$$

∴ $$5 = \frac{2 \times \pi \times 1 \times \cancel{10^6} \times V_m}{\cancel{10^6}}$$

∴ $$V_m = \frac{5}{2\pi} \text{ Volts}$$

$= \underline{0.79577}$ Volts.