L9

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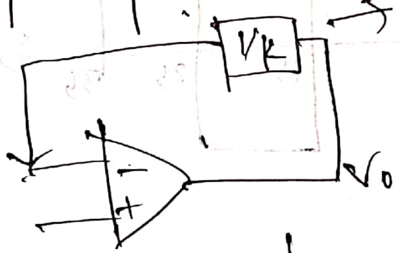
Now if we want to get stable output then we need negative Feedback.

-ve.

- This -ve feedback not only use for op-amp. it can be also used for any control device for proper control. [For example i.e. Line Following Robot]

so. how we provide negative Feedback in op-amp?



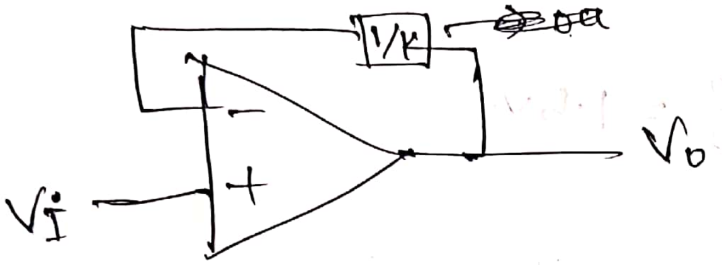
→ ~~oa~~ portion of output goes to inverting input.

→ this is called closed loop configuration.

- There's also positive Feedback (if its connect to V_+) that's also ~~called~~ used for pulse generator & ~~schimat~~ schimmit trigger

*

Ex of negative Feedback:



if $K = 10$ then $\frac{1}{10}$th of output is fed back to -ve input

lets Assume $A = 3$

if there were no feedback

$V_o = AV_i \rightarrow V_s^+$ | $V_i = 5\,V$, $\therefore V_d = +ve$

$\therefore V_o = V_s^+$

initially, $\boxed{V_o = 0V}$

$\therefore V_- = \frac{V_o}{10} = 0$

$\therefore V_d = V_+ - V_-$

$= 5 - 0 = 5$

$\therefore V_o = 5 \times 3 = 15V$

$\boxed{V_0 = 15}$

$\therefore V_- = \frac{V_0}{10} = \frac{15}{10} = 1.5V$

$\therefore V_d = V_+ - V_-$

$= 5 - 1.5 = 3.5V$ (decrease)

$\therefore \boxed{V_0 = 3 \times 3.5 = 10.5V}$

due to feed back now its gradually going down.

So negative feedback here increase output if it decrease and decrease output if it increases.

$\boxed{V_0 = 10.5V}$

$\therefore V_- = \frac{10.5}{10} = 1.05V$

$\therefore V_d = V_+ - V_- = 5 - 1.05 = 3.95$

$\therefore \boxed{V_0 = 3.95 \times 3} = 11.85V$ (increase)

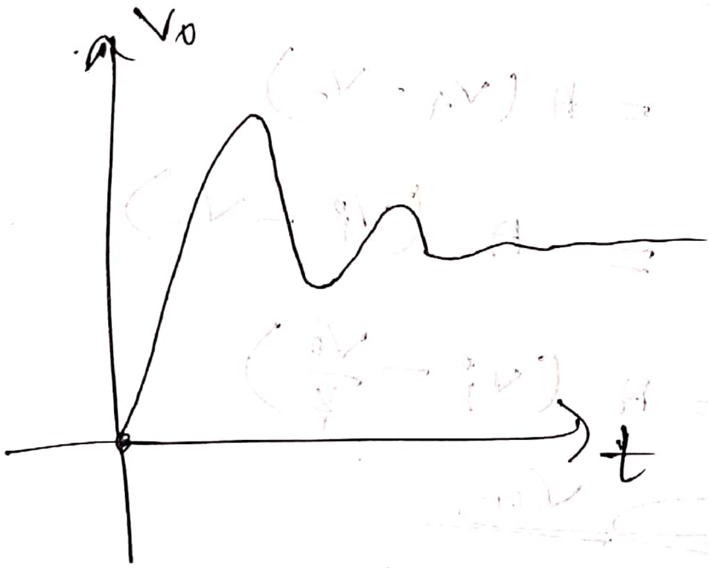
$\boxed{V_o = 11.85}$

$V_- = \frac{11.85}{10} = 1.185V$

$V_d = 5 - 1.185 = 3.815$

$\therefore V_o = 3 \times 3.815 = \boxed{11.445}$

so change ~~difference~~ gap decreasing gradually



this is graph of response of a feedback system. initially a overshoot then gradually get stabled

so it makes the op-amp stable.

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∴ whats the relation between V_o and V_i

$V_o = \boxed{2.31}\, V_i$

Gain

∴ $V_o = 2.31 \times 5$

$= 11.53$

if we repeat the previous equation ~~then~~ get this output

∴ $V_- = \frac{V_o}{K}$

$V_o = A\, V_d = A(V_+ - V_-)$

$\Rightarrow V_o = A(V_i - V_-)$

$\Rightarrow V_o = A\left(V_i - \frac{V_o}{K}\right)$

$\Rightarrow \cancel{A} = \cancel{\frac{V_o}{\ }}$

$\Rightarrow V_o\left(1 + \frac{A}{K}\right) = A\, V_i$

$\Rightarrow V_o = \boxed{\frac{A}{1 + \frac{A}{K}}}\, V_i$

Gain

For this ~~[illegible]~~ case Gain $= \frac{A}{1 + \frac{A}{K}} = \frac{3}{1 + \frac{3}{10}}$

$= 2.31$

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* Now if A = too large value.

  the Gain should be $\approx K$

  on that time. $\boxed{V_0 = K V_i}$

* So since here ~~gain~~ the internal gain of op-amp is ∞ (too large) we get finite gain of op-amp using negative feedback.

* And using this feedback property we can perform any mathematical operation.

Sub.: Lecture 4 (Rough)

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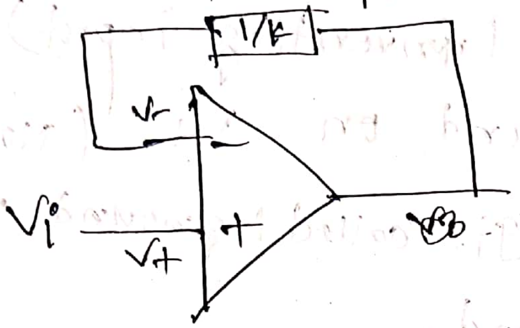
Feedback [closed loop configuration] (negative feedback)



∴ $V_o = \frac{A}{1+\frac{A}{K}} \times V_i$

if $A = \infty$

$V_o = K V_i$

⇒ provide stable output.

- Now V_o = stable

$V_o = A V_d$

∴ $V_d = \frac{V_o}{A}$

now if $V_o = 3V$, $A = \infty$

∴ $V_d = \frac{3}{\infty} = 0$

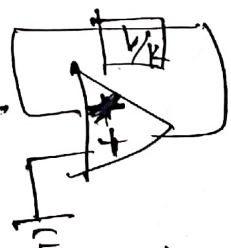
∴ In negative feedback $V_d = 0$

⇒ $V_+ - V_- = 0$

∴ $\boxed{V_+ = V_-}$

so if $V_+ = 0$

∴ $V_- = 0$



it also becomes zero.

And this is called virtual ground.

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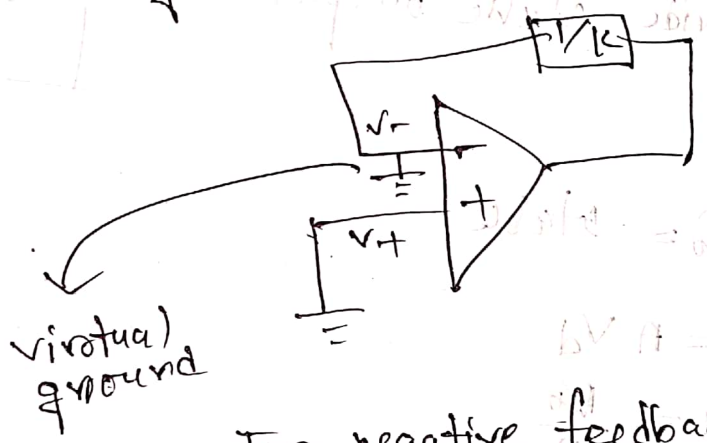
Therefore, when we get zero voltage on ground in V_- (inverting input) due to adding ground on V_+ (Non-inverting) input. ~~~~ ~~~~ It's called (ground on V_-) virtual ground.



For negative feedback

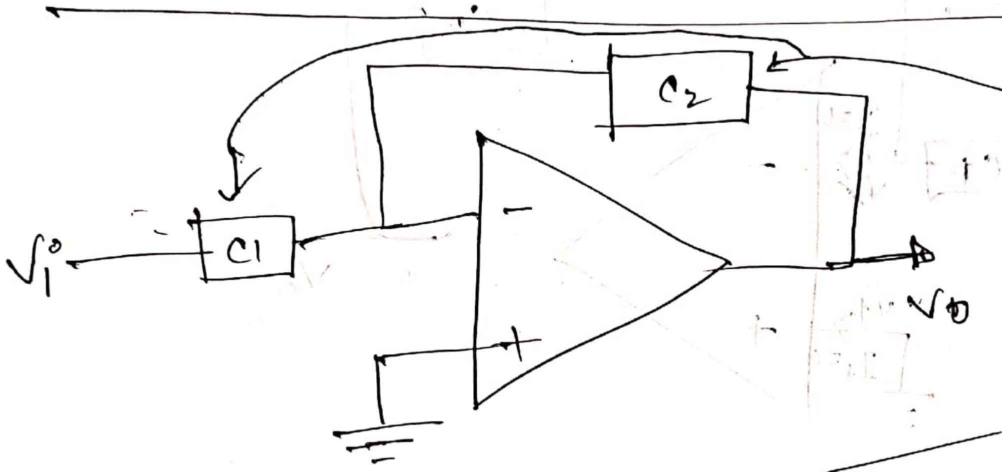
$V_d = 0$

$\therefore V_+ - V_- = 0$

$\boxed{V_+ = V_-}$

$\therefore I_+ = 0, \; I_- = 0$

* Basic structure of mathematical operation.



can be
1. capasitor
2. resistor
3. diod
4. inductor

[Here negative input because if we provide the input in positive ~~then~~ terminal the term 1+ something will come. ~~that~~ For preventing that we provide input in negative.]

→ Depending on the element the relation between input and output changes.

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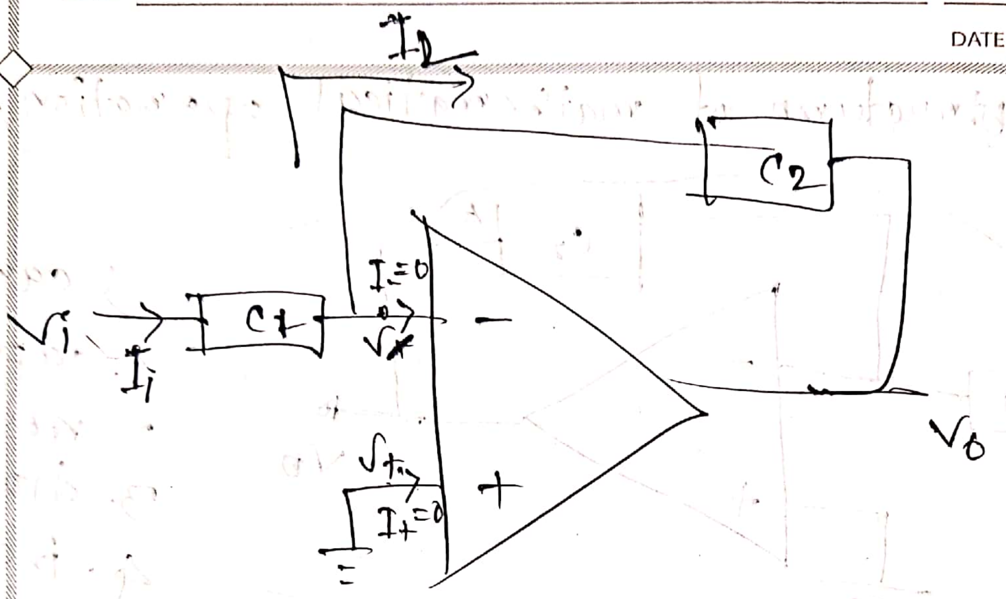

since $V_+=0$

$\therefore V_-=0$

since virtual ground

again $I_-=0$

$I_+=0$

* Have to remember for equation derivation:

step1. ① $V_d=0 \Rightarrow V_+=V_-=?$

② $I_1=?$

③ $I_2=I_1$ $\therefore$

④ $V_0=$ KVL/ohms law

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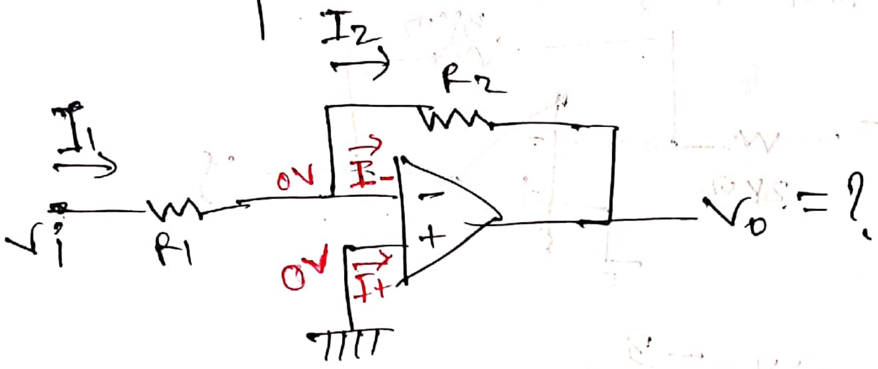
inverting amplifier:

if we replace C_1 and C_2 with resistance



$$\because I_1 = \frac{V_i - 0}{R_1} = \frac{V_i}{R_1}$$

now since $I_- = 0$

$$\therefore I_2 = I_1 = \frac{V_i}{R_1}$$

$$\therefore I_2 = \frac{0 - V_o}{R_2}$$

$$\Rightarrow V_o = -I_2 R_2$$

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

$$= \left(-\frac{R_2}{R_1}\right) V_i$$

$$\boxed{\therefore V_o = \left(-\frac{R_2}{R_1}\right) V_i}$$

amplification

since we are negative that's why inverting. Gain $= \frac{-R_2}{R_1}$

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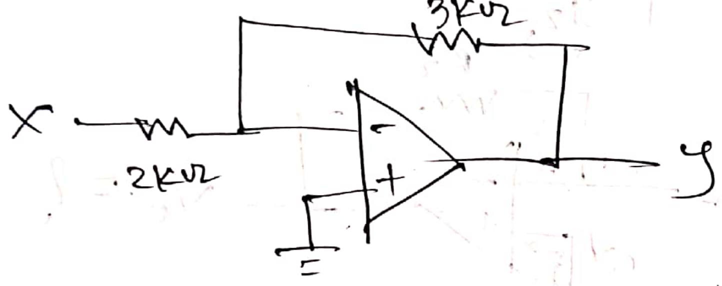
Q. Now what will be relation between x and y for this circuit.

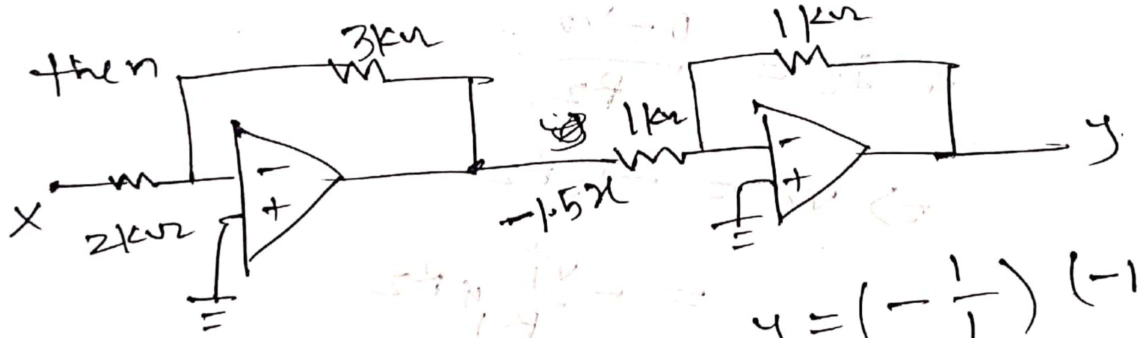


$\because y = \frac{-3}{2} x$

$\Rightarrow \boxed{y = -1.5x}$

Now what if I want $y = 1.5x$

then



$y = \left(-\frac{1}{1}\right)(-1.5x)$

$= 1.5x$

This is called cascading amplifier.

(provide one amplifier input to another amplifier)

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Sub.: $3x + 4y = 5$

I can achieve by inverting amplifier.

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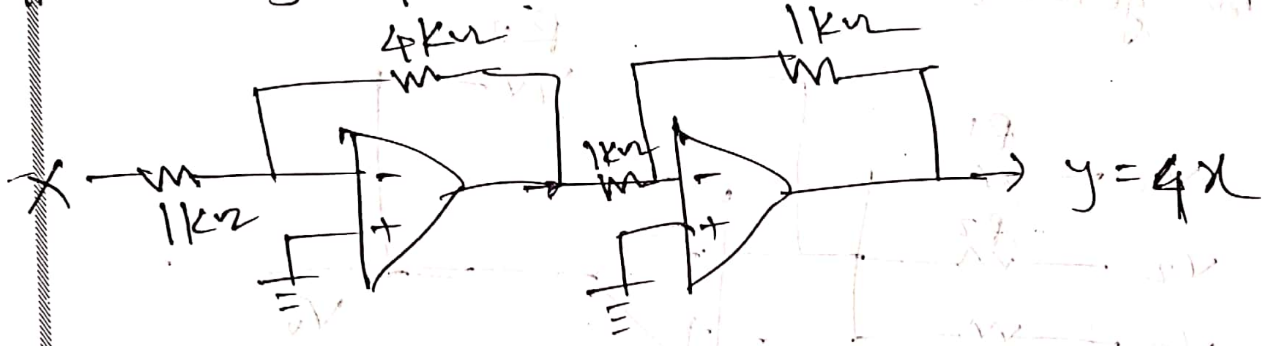
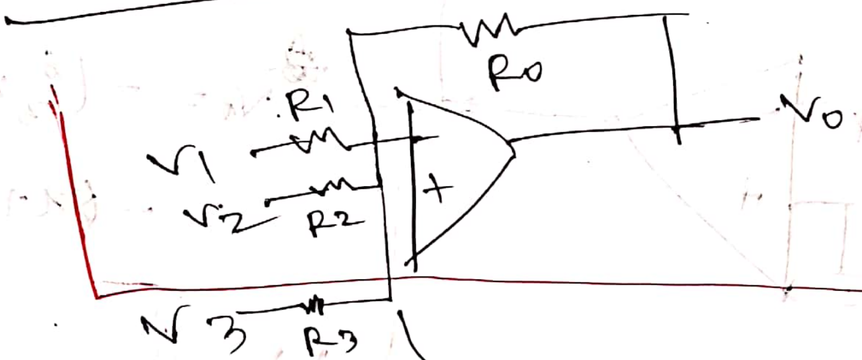
Do it $y = 4x$?



so inverting amplifier basically multiply a input ~~variable~~ with constant.

(2) # Inverting adder (summing amplifier):



$$\therefore V_o = -\frac{R_o}{R_1}V_1 - \frac{R_o}{R_2}V_2$$

it connect it

$$V_o = -\frac{R_o}{R_1}V_1 - \frac{R_o}{R_2}V_2 - \frac{R_o}{R_3}V_3$$

can use superposition theorem to get understanding

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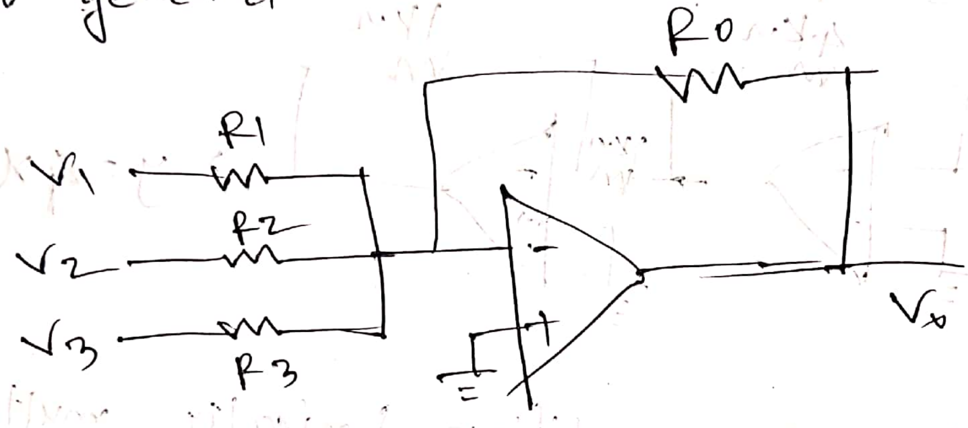
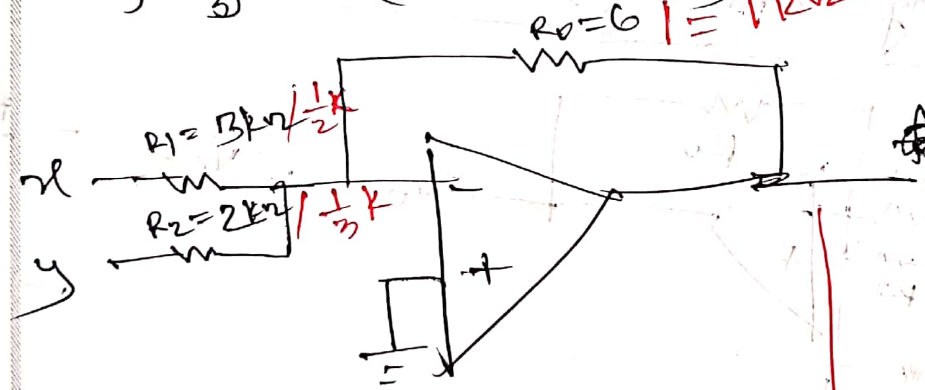
So general



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

For example: Ex 1:

$f\ y = -(2x + 3y)$



$$V_o = -\left(\frac{6}{3}x + \frac{6}{2}y\right)$$

$$= -(2x + 3y)$$

→ ~~Vo~~ put

$$V_o = -\left(\frac{1}{\frac{1}{2}}x + \frac{1}{\frac{1}{2}}y\right)$$

$$= -(2x + 3y)$$

same output

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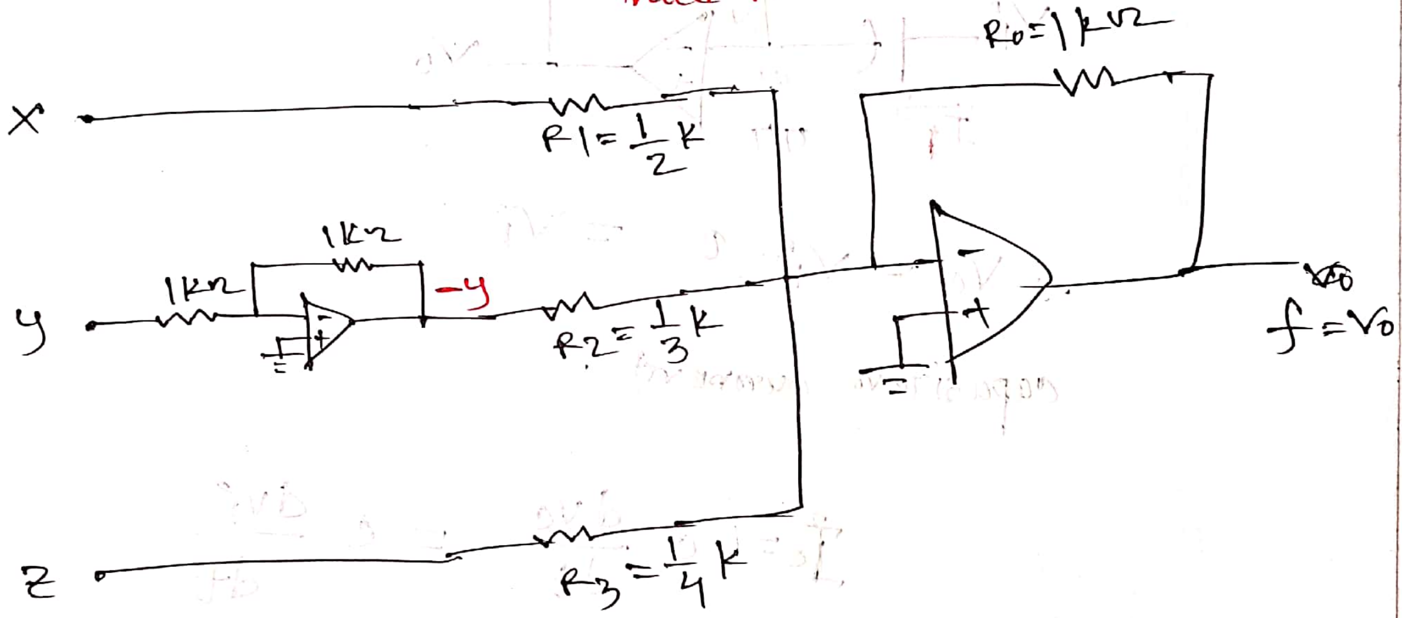
Ex 2:

$$f = -2x + 3y - 4z$$

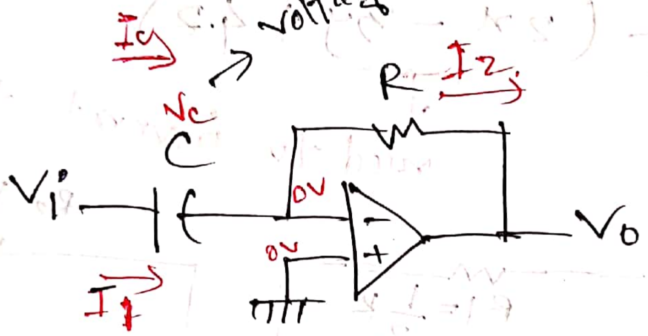
$$= -(2x - 3y + 4z)$$

need to invert this first



(3) Differentiation:

voltage across capasitor



$\therefore V_c = V_i - 0 = V_i$

capasitor current:

$$I_c = c\frac{dV_c}{dt} = c\frac{dv_i}{dt}$$

$\therefore I_2 = I_1$ since $I_+ = 0$, $I_- = 0$

$\therefore I_2 = I_1 = I_c$

$$\therefore I_2 = I_1 = I_c = c\frac{dv_i}{dt}$$

now $I_2 = \dfrac{0 - V_o}{R}$

$\therefore V_o = -I_2 R$

$$\therefore \boxed{V_o = -RC\frac{dv_i}{dt}}$$

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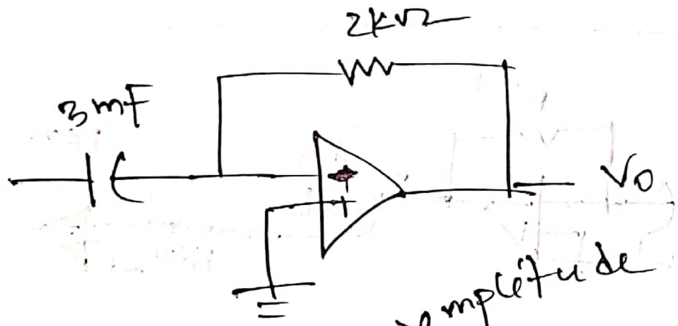
Now if $\frac{d}{dt}(\sin(100t)) = 100\cdot\cos 100t$

$\frac{d}{dt} e^{5t} = 5e^{5t}$

$\frac{d}{dt}\cos(t) = -\sin t$

Ex 1:



$v_i = \overset{\text{amplitude}}{10}\cos(2t)$

so output amplitude = ?

$\therefore V_o = ?$

$\therefore V_o = -RC\frac{dv_i}{dt}$

$= -\left(2000\times\frac{3}{1000}\right)\frac{d}{dt}(10\cos 2t)$

$= -6\times 10\left[\frac{d}{dt}\cos 2t\right]$

$= -6\times 10\times(-2\sin 2t)$

$= 120\sin 2t$ (Answer)

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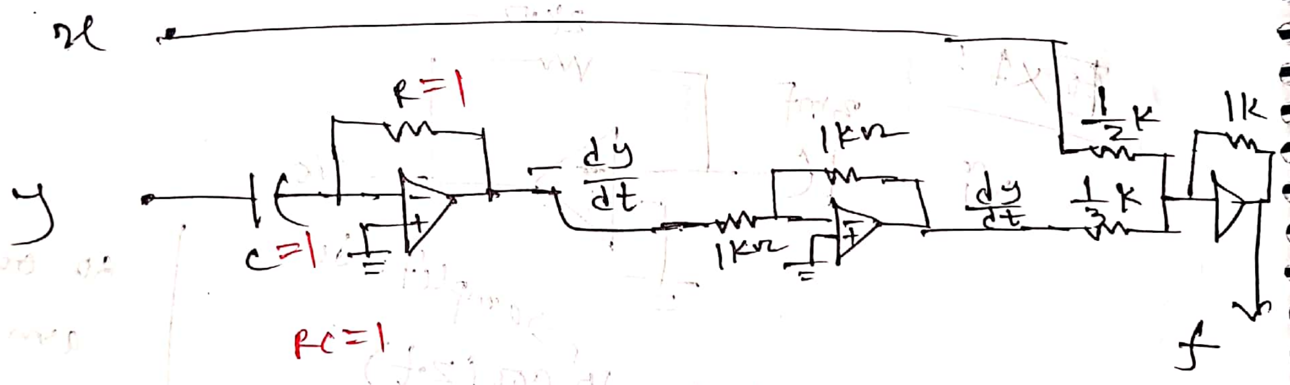
*Ques: Design a circuit such that

$$f = -2x - 3\frac{dy}{dt}$$

$$= -\left(2x + 3\frac{dy}{dt}\right)$$



$$\therefore V_0 = -\left(\frac{1}{1/2}x + \frac{1}{1/3}\frac{dy}{dt}\right)$$

$$= -\left(2x + 3\frac{dy}{dt}\right)$$

f.

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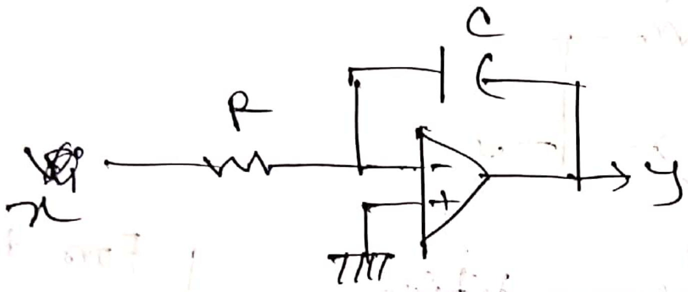
Integrator

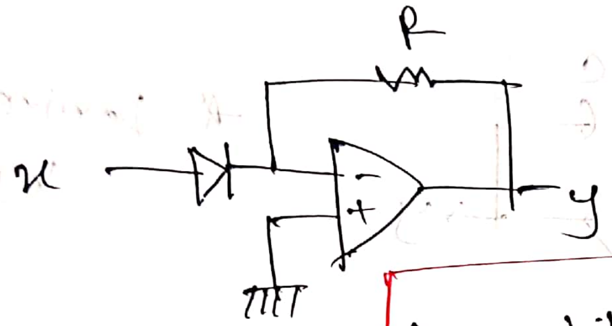


* Derive it by own

$$\boxed{y = -\frac{1}{RC}\int x\,dt}$$

~~Logarithm~~

Exponential



$y = -e^{x}$

condition

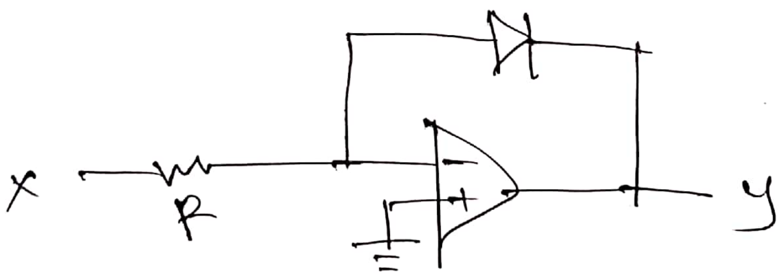
$I_S R = 1$

$V_T = 1$

For diod

$I_D = I_S \exp\left(\frac{V_o}{V_T}\right)$

Logarithom (Inverse of exponential)



$\therefore y = -\ln(x)$

condition same as exponential operation

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* so addition and substraction can be done ~~a~~ ~~a~~ inverting adder.

* And for multiplication and division we can use logarithm and exponential circuit.

For example:

(i) $\ln(\exp(a)) = a$ | $e^{\ln x} = x$

(ii) $\ln(ab) = \ln a + \ln b$

~~Now~~ for $f = xy$

$\therefore$ $x \longrightarrow \ln x$

$y \longrightarrow \ln y$ $\xRightarrow{\text{add}}$ $\ln x + \ln y \Longrightarrow \ln(xy)$

$\Downarrow \exp^{\ln(xy)}$

xy

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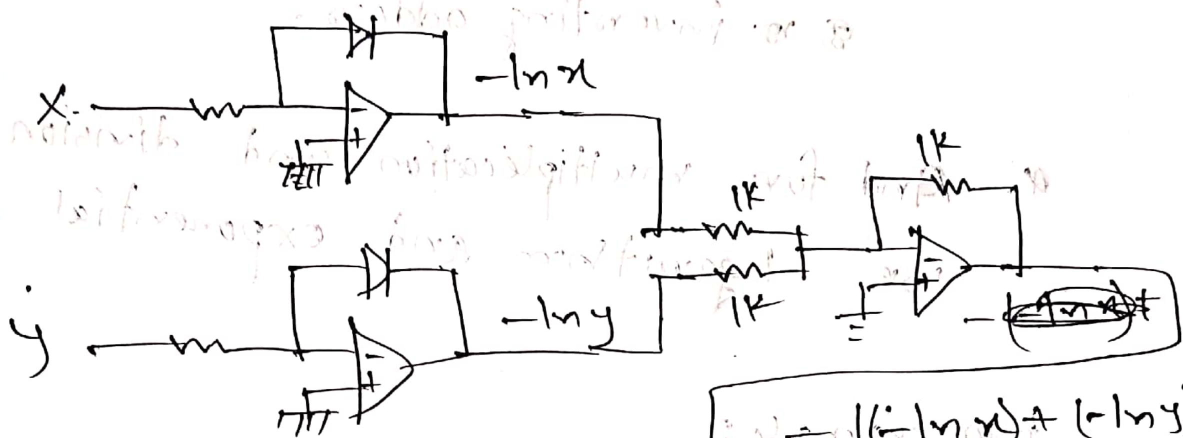
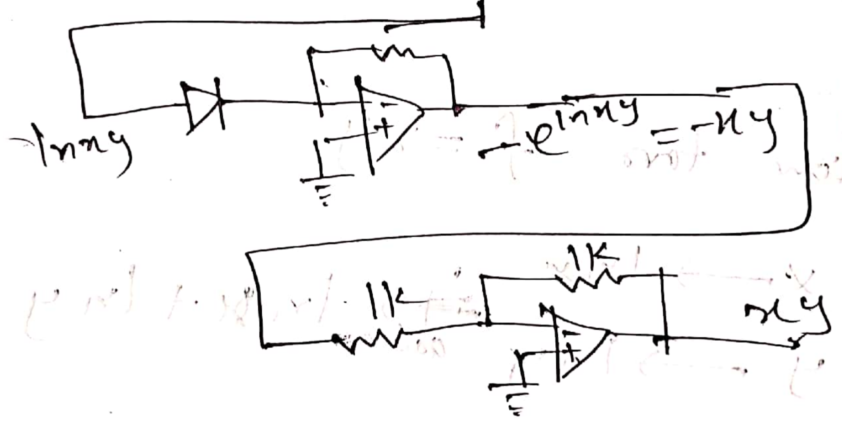


$= -((-\ln x) + (-\ln y))$

$= -(\ln x + \ln y)$

$= \cancel{-\ln(xy)}$

$= \ln xy$



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Homework:

~~① $f = -2x + \int$~~

① $f = -2x + \int y\,dt - e^z$

② $f = \dfrac{d}{dt}(x \ln x)$

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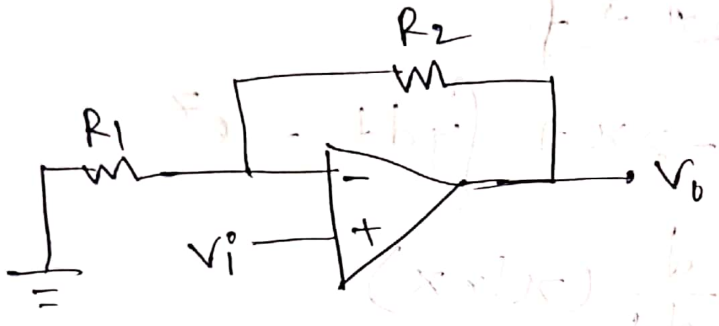
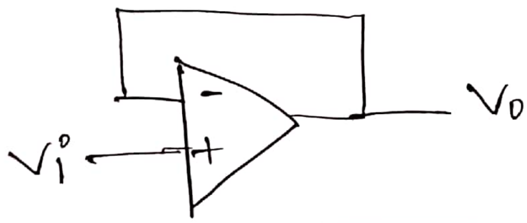
Non inverting amplifier:



$$\boxed{V_o = \underbrace{\left(1 + \frac{R_2}{R_1}\right)}_{\text{Gain}} V_i}$$

Voltage follower:



$$\boxed{V_o = V_i}$$

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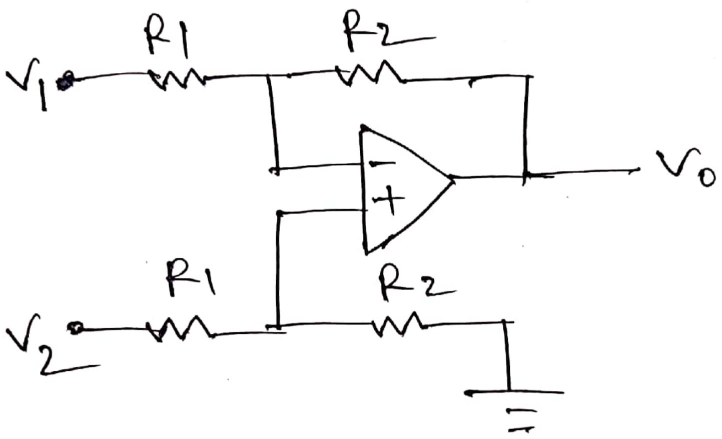
Difference amplifier:



$$\boxed{V_0 = \frac{R_2}{R_1}(V_2 - V_1)}$$