Sub.: Lec3 Lecture 3

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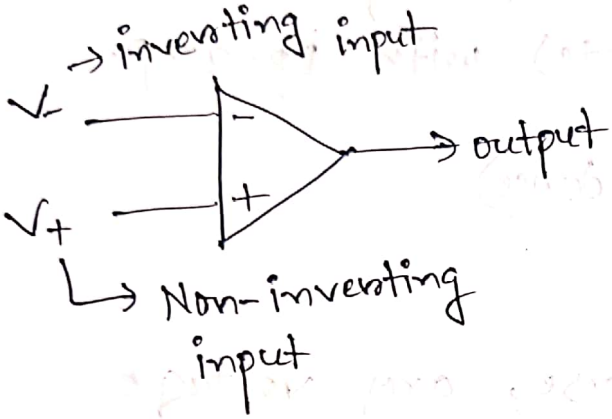
(op-amp) Rough

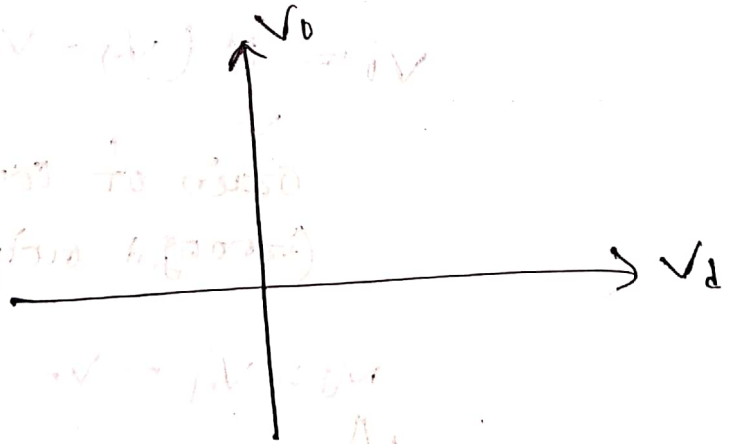
operational amplifier:



Differential amplifier ⇒ amplifier difference.

$$V_0 = A(V_+ - V_-)$$

$$\boxed{V_0 = AV_d}$$ where $[V_d = V_+ - V_-]$



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why operational?

→ cause we can perform any mathematical operation (+, −, *, / etc) with Op-amp.

op-amp (3 terminal device)

inverting input cause, any voltage provide in V_- terminal will be multiplied by −1.

why differential? because it doesn't amplify particular voltage rather it amplify voltage difference. $(V_+ - V_-)$

$$V_0 = A(V_+ - V_-)$$

↓

Gain of amplifier.

(output)

$$V_d = V_+ - V_-$$

↑

voltage difference.

$$\therefore V_0 = A V_d$$

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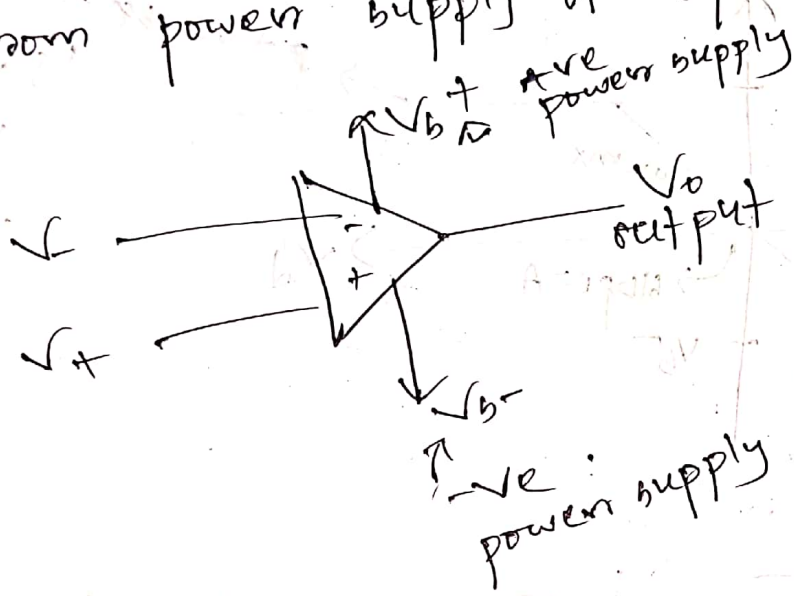
Now from where this output amplification come?

from power supply of op-amp. [V_S^+ and V_S^-]



↑ two power supply

there need power supply because output voltage ~~difference~~ should be higher than input voltage difference.

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* lab's op-amp usually $V_5^+ = 15V$ and $V_5^- = -15V$

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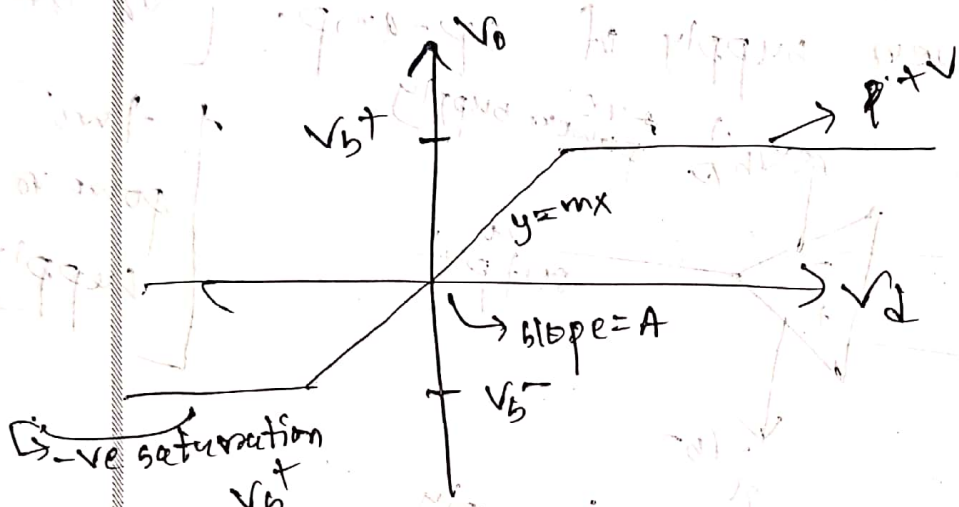
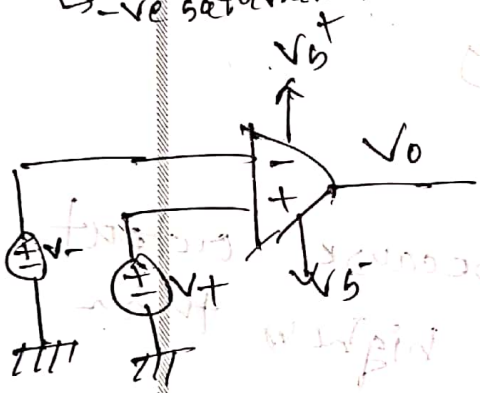
Transfer characteristics of op-amp:



↳ when V_d crosses valid input range then V_o = saturation



Example:

$A = 100$

$V_5^+ = 10V$

$V_5^- = -10V$

① $V_+ = 1.01V$, $V_- = 1V$

$V_d = ?$ $V_o = ?$

$V_d = V_+ - V_- = 0.01V$

$V_o = 100 * 0.01 = 1V$

② $V_d = 0.02V$

$\therefore V_o = 2V$

③ $V_d = 0.1V$

$V_o = 10V$

④ $V_d = 0.2V$

$V_o = 20V$? NO

$\therefore V_o = 10V$

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CamScanner

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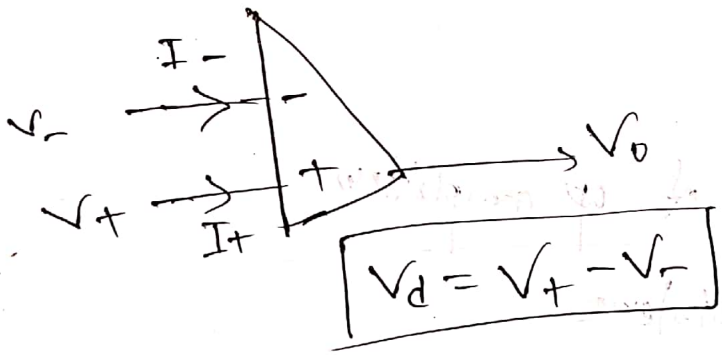
∴ For this case valid input range is

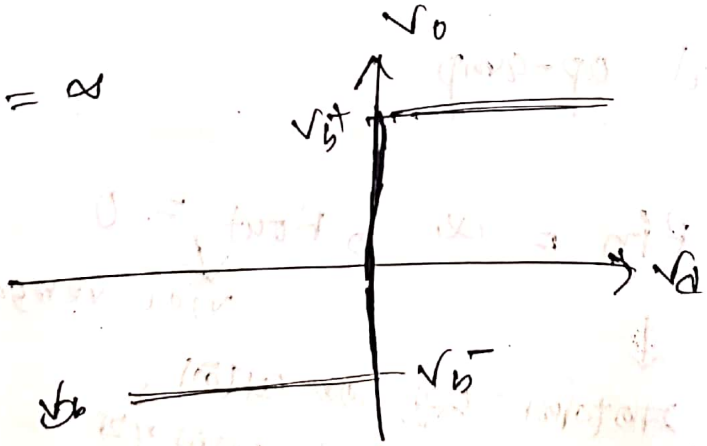
$-0.1 < V_d < 0.1$

Ideal op-amp



$V_d = V_+ - V_-$

∴ A = ∞



Normal op-amp

Gain A = 100, 200

but ~~practical~~ real life ideal op-amp has A = ∞ (too large)

practical op-amp

$A = 10^6 \sim 10^7$

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Now whats the valid input range for ideal op-amp? (from transfer characteristic)

$V_d = 0V$

$\therefore A = \infty$: if $V_d > 0 \Rightarrow V_o = V_b^+$

and $V_d < 0 \Rightarrow V_o = V_b^-$

properties of ideal op-amp ⇒

Other properties of op amplifier:

1. input resistance
2. output "

For ideal op-amp

preferable $R_{in} = \infty$, $R_{out} = 0$ (vice versa)

↓

সাধারণত হয় এর বেলা, loading effect কম হয়

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∴ For this case $I_- = 0$, $I_+ = 0$] ideal op-amp.

Note that ***

For ideal op-amp:

1. $A = \infty$
2. $R_{in} = \infty$, $R_o = 0$
3. $I_- = 0$, $I_+ = 0$

but the behaviour $V_d > 0 \Rightarrow V_o = V_s^+$

$V_d < 0 \Rightarrow V_o = V_s^-$

like comparator.

that is

$V_+ > V_-$] $V_o = V_s^+$

and $V_+ < V_-$] $V_o = V_s^-$

so we can say which is greater of two voltage without measuring the voltage.

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Sub.: Exam question use case to design circuit

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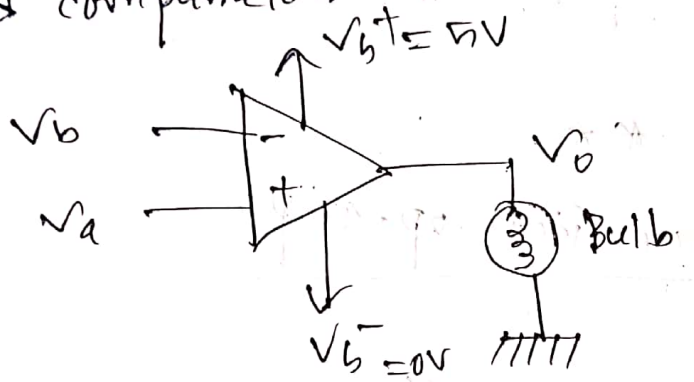
→ Q. use case of ideal op-amp :-

(1) comparator



$V_d = V_a - V_b$

$\therefore V_d > 0$ means $V_a > V_b$

and $V_d < 0$ " $V_a < V_b$

$\therefore$ if $V_a > V_b \Rightarrow V_o = 5V$ so bulb on

and if $V_a < V_b \Rightarrow V_o = 0V$ " " OFF

* if multiple voltage then ~~bab~~ compare ~~two~~ voltage pairs and pick one from them for next test.

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(2) Turn ON AC automatically.

Temp sensor → V_T

$V_T \propto$ Temp

set temp: 23°, $V_T = 1V$

ideal → 24°, $V_T = 2V$

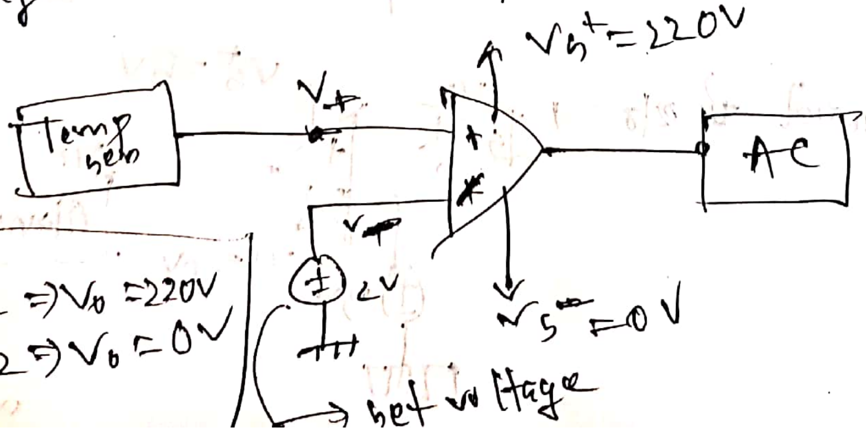
25°, $V_T = 3V$

if Temp > 24° AC ON

if Temp < 24° AC OFF

Design করার সময় সামান্য রাখতে হবে কারণ positive এ থাকে বোতাম negative এ থাকে।

so here we cant measure temparature, we can compare the voltage only. so we compare the voltage with ideal temp. so



$V_T > 2 \Rightarrow V_0 = 220V$

$V_T < 2 \Rightarrow V_0 = 0V$

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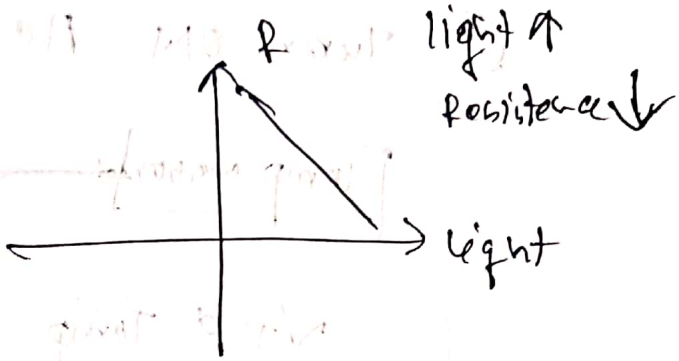
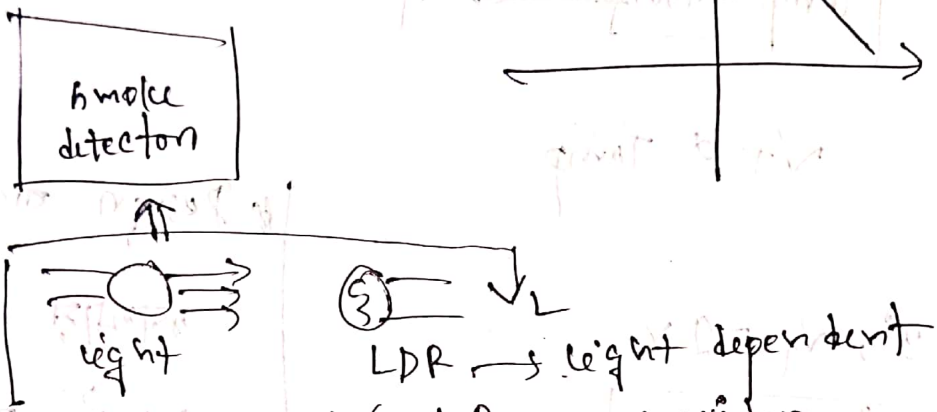
(3) smoke detector :



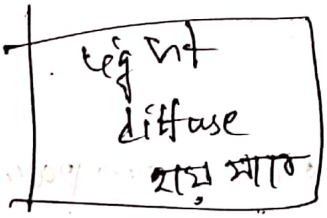


LDR → light dependent resistor.

$V_L \propto R$

* No smoke V_L = small = 2V (assume) → intermediate voltage

smoke V_L = high = 4V (assume



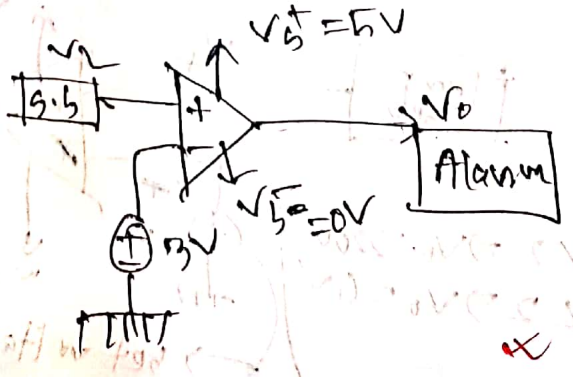
So we want

if $V_L > 3V$ ⇒ Alarm ON

$V_L < 3V$ ⇒ is OFF

↓ positive ↓ negative

∴ circuit की तरह !



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Sub.: Op-amp (here using open loop configuration) L3

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(4) Because here no physicall connection between output and input.

So if it is said that you have to use to solve the use case using open loop configuration of op-amp. Then it should be comparator problem.

So it should think which voltage should be V+ and which voltage should be V−.

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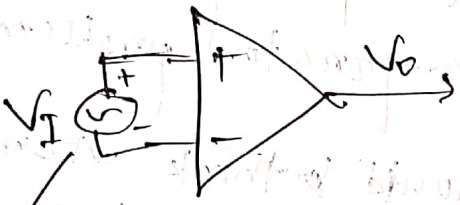
④ Pulse generators :

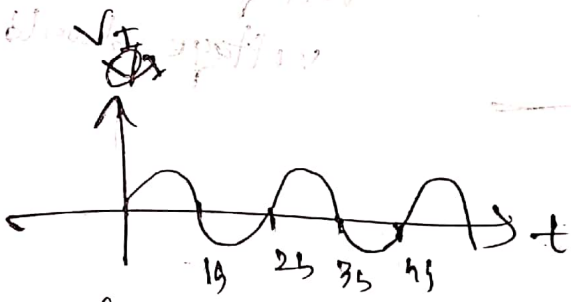
$V_{I,+} = V_+ \quad | \quad V_{I,-} = V_-$

$\therefore V_d = V_+ - V_-$

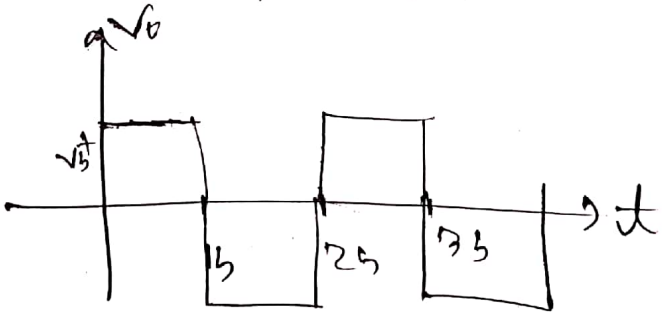
$= V_I$



AC source



input sign wave



square wave

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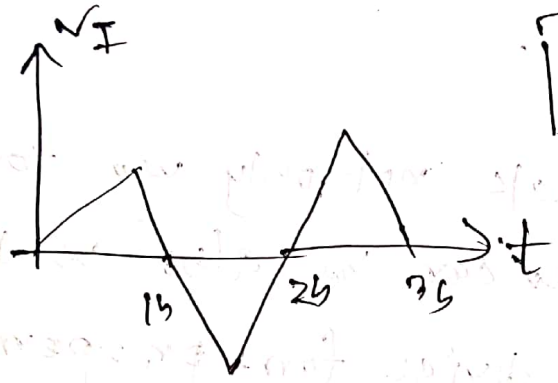
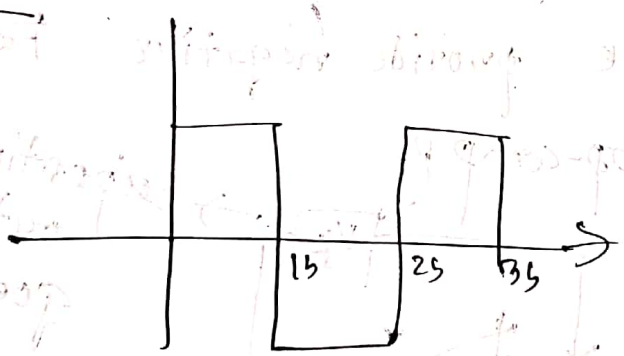
now : if input :



input triangle

output :



output square wave

(iv) Till now everything is op-amps open loop configuration.

[∵ No connection between output and input] Hence output is unstable. ∵ because of ideal op-amp has infinity gain.

Sub.: Nodal analysis / KCL / KVL / on op-amp

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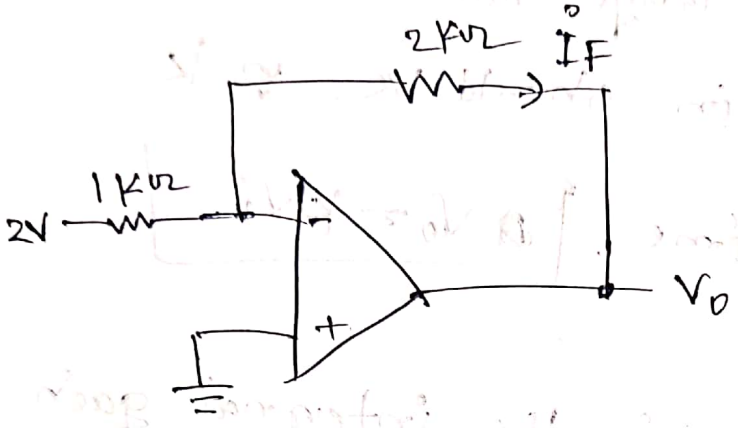
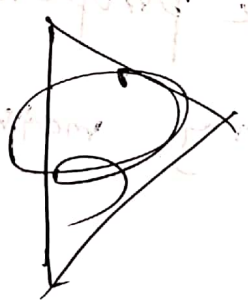


Question find I_F and V_o

Soln: The equivalent circuit:



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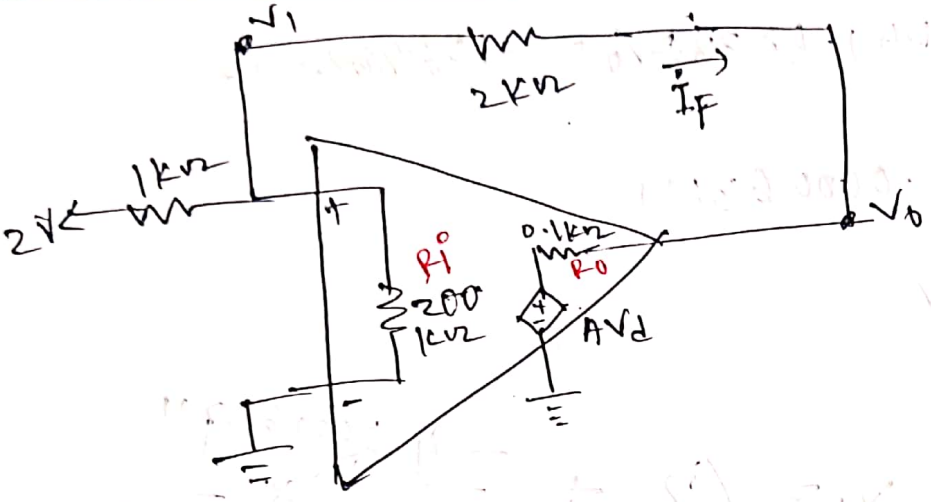

Here,

$V_d = V_+ - V_-$

$= V_1 - 0$

$\therefore A V_d = A V_1$

Using node analysis.

$$V_1\left(\frac{1}{1}+\frac{1}{200}+\frac{1}{2}\right)-\frac{2}{1}-\frac{0}{200}-\frac{V_0}{2}=0$$

$$\Rightarrow V_1 \times 1.505 - 2 - \frac{V_0}{2} = 0 \quad \text{--- (1)}$$

$$\Rightarrow V_1 = \left(2+\frac{V_0}{2}\right)\times\frac{1}{1.505}$$

$$V_0\left(\frac{1}{2}+\frac{1}{0.1}\right)-\frac{V_1}{2}-\frac{AV_1}{0.1}=0$$

$$\Rightarrow -V_0 * 10.5 - \frac{V_1}{2} - \frac{2\times10^5 V_1}{0.1} = 0$$

$$\Rightarrow 10.5V_0 - \frac{V_1}{2} - 2\times10^6 \times V_1 = 0 \quad \text{--- (2)}$$

$$\Rightarrow 10.5V_0 - \frac{1}{2}\left(\frac{2}{1.505}+\frac{V_0}{2\times1.505}\right) - 2\times10^6\times\left(\frac{2}{1.505}+\frac{V_0}{2\times1.505}\right)=0$$

$$\Rightarrow 10.5V_0 - \frac{1}{1.505} - \frac{V_0\times50.}{301} - 2653080.309 - 664451.8272V_0 = 0$$

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$\Rightarrow -66444.4033 V_0 = 26582.973$

$\Rightarrow V_0 = 4.0000\,63211$

$= -4\ V$

Now, $V_1 = \left(2 + \frac{-4.00006\,3211}{2}\right) \times \frac{1}{1.505}$

$= -6.2545 \times 10^{-6}\ V$

≈ 0

$\therefore$ $2 \times I_F = \Delta V$

$\Rightarrow 2 I_F = V_1 - V_0$

$\Rightarrow 2 I_F = 0 - (-4)$

$\Rightarrow 2 I_F = 4$

$\therefore I_F = 2\ mA$ (Ans)

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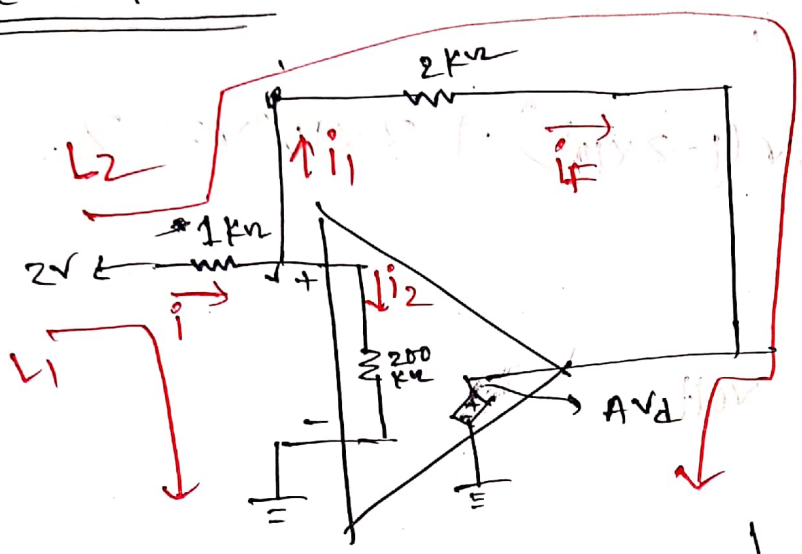
KCL KVL



KCL

$$i = i_1 + i_2$$
$$= i_2 + i_F$$

KVL along L1 :

$$i + 200 i_2 = 2 - 0$$
$$\Rightarrow 2 = i + 200 i_2 \quad \text{---(1)}$$

KVL along L2 :

$$i + 2 i_F + AV_d = 2 - 0$$
$$\Rightarrow i + 2 i_F + 2 \times 10^5 V_d = 2 \quad \text{---(2)}$$

ohms law

$$V - 0 = i_2 \times 200$$
$$\Rightarrow V = 200 \times i_2$$

Again

$$V - AV_d = 2 i_F$$

Also

$$\Rightarrow V(1 - 2 \times 10^5) = 2 i_F$$
$$\Rightarrow i_F = \frac{V(1 - 2 \times 10^5)}{2}$$

∴ From (1)

$$i = 2 - 200 i_2$$
$$= 2 - 200 \times \frac{V}{200}$$
$$= 2 - V$$

ohms law

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Now from (2),

$2 - V = V(1 - 2\times10^{5}) + 2\times10^{5}V = 2$

$\Rightarrow V = 0$ Volt

$\therefore i = 2$ mA