16/11/2025

CSE - 223

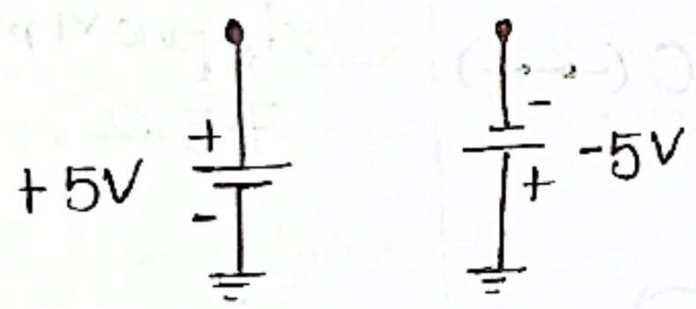
Lecture - 01

Op - amp
(Operational Amplifier)

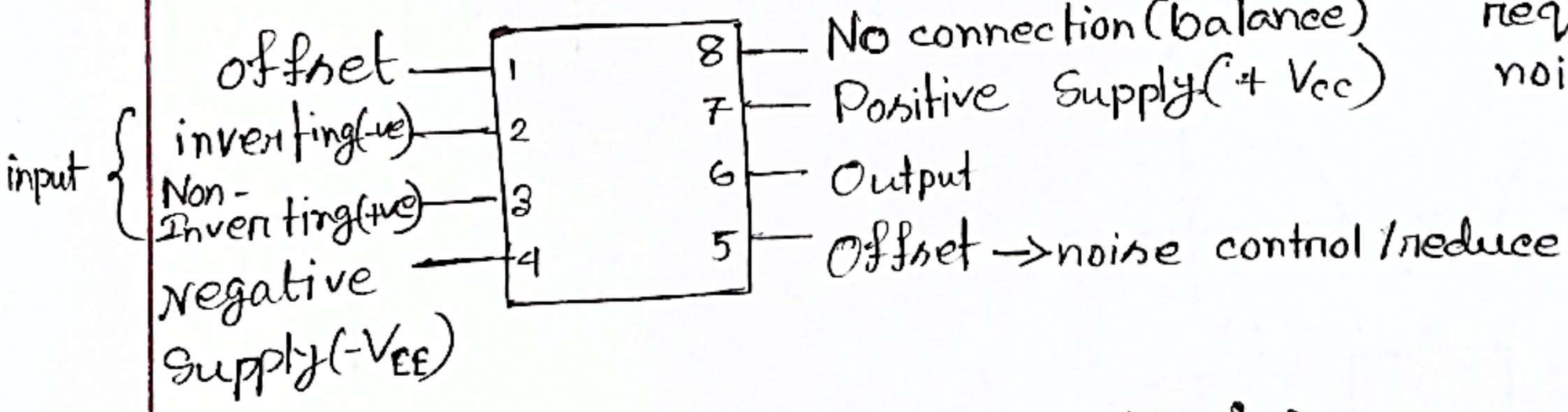
⇒ Op-amp = IC, works as an comparator & amplifier.

⇒ Different mathmetical operation (SUB, MUL, Add, Integ./Differ.)

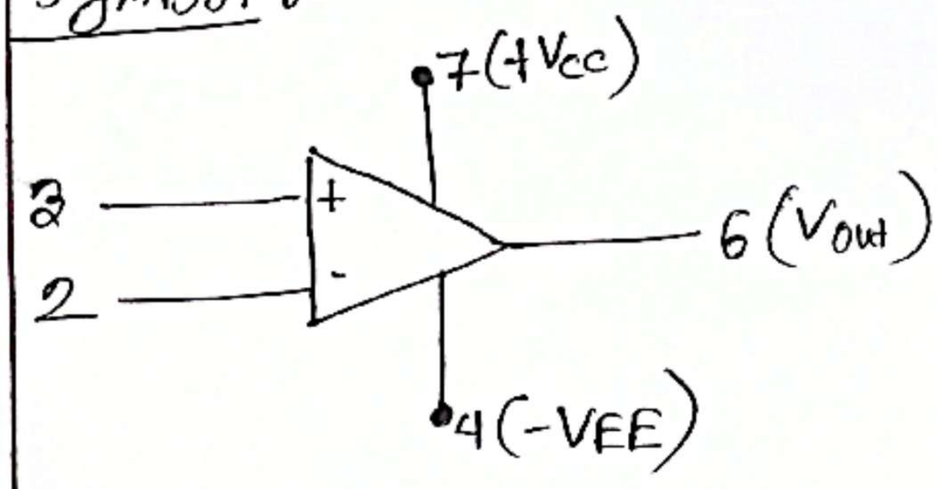
⇒ 2 input pin, 1 output pin.



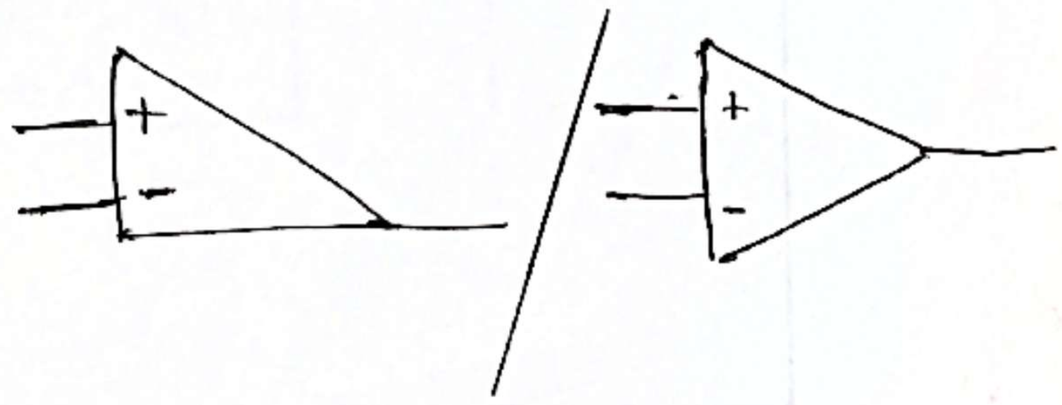
IC Pin Diagram: op-amp → dual power supply (+ve/-ve)
Amplifier problem: Noise, so 2 offset pin required for reduce noise.



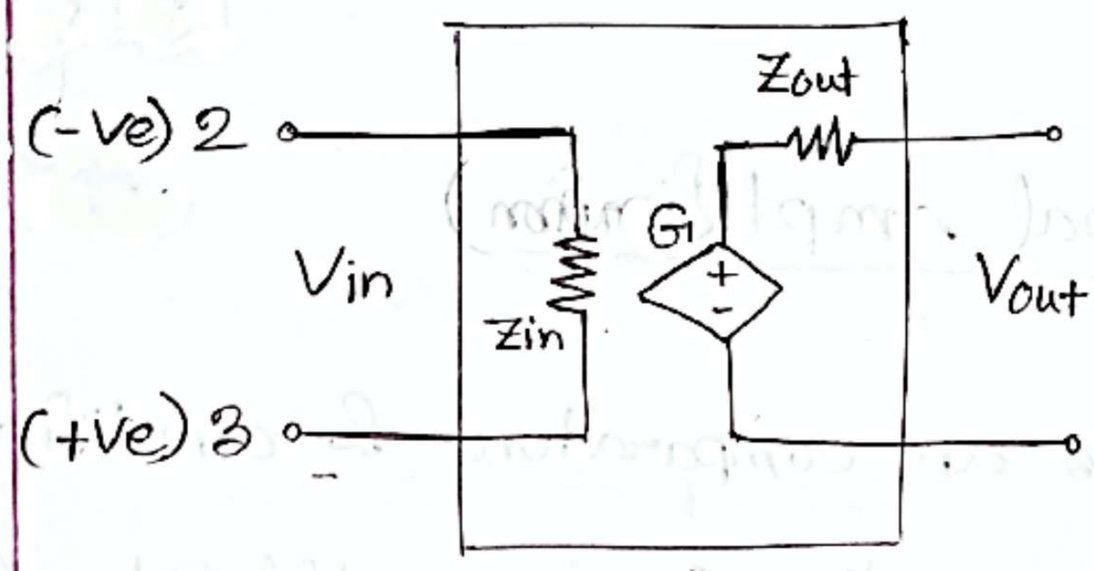
Symbol:



Use:



Internal Structure:



Zin → Impedence

→ Input কে amplify করবে

G → কতগুন amplify করতে পারবে (10x, 20x, 100x) সেটাই G.

2 & 3 no. pin-এ multimeter দিয়ে measure করলে, যে বাঁধা পাব কোনো বাঁধা থাকবে না

Characteristics of Op-amp:

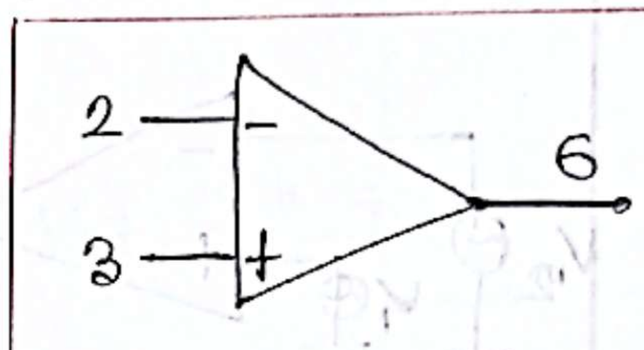
	Ideal	Practical
① Input Impedence: (Zin)	∞ (—/—) → no elec. flow	MΩ range $100 \times 10^6 = 10^8$
② Output Impedence: (Zout)	0 (—o—o—)	Approximately 75Ω
③ Gain (G):	∞ (main focus চাইলেই (0/1/100) করতে পারি)	800M↑
④ Bandwidth (Bw):	∞	Wide

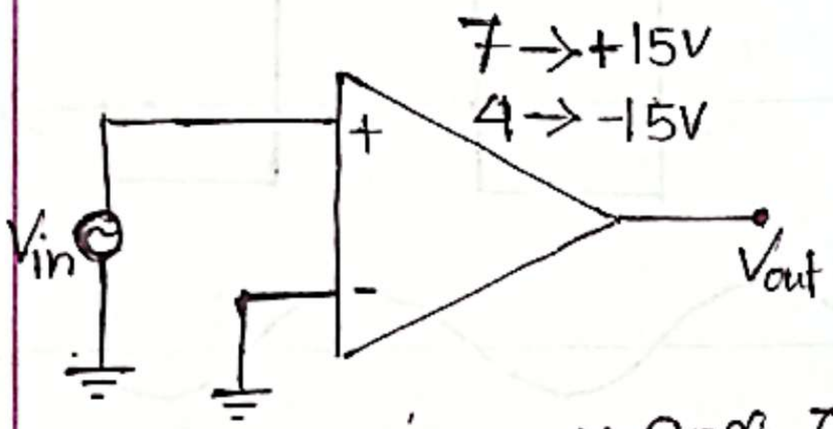
Input Modes:

• 2 input → 4 combination

① Single Ended Mode: → 2-inp, 3-none(ground)
→ 2-none, 3-inp.

ⓘ Non-Inverting Input: → 2-inp, 3-inp
→ 2, 3-short

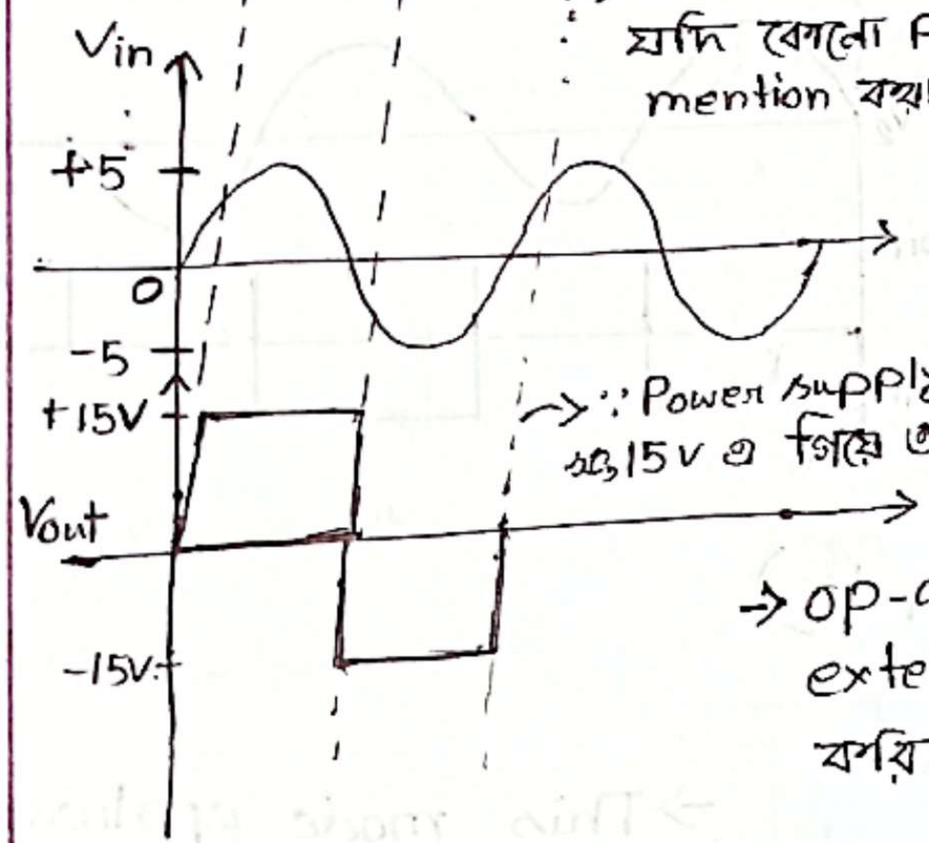




$V_{in} - 0 = V_{in}$

$V_{in} \times G = +$ result,

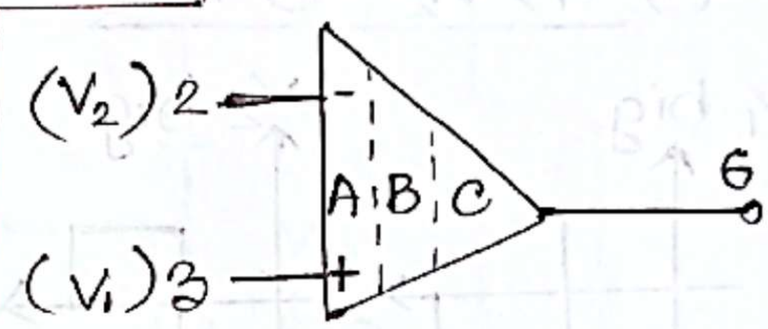
→ G = ∞ যেতে থাকবে Vout এ যদি কোনো power supply mention করা না থাকে



→ ∵ Power supply 15V এর 15V এ গিয়ে আটকে যাবে

→ op-amp এ যদি কোনো external circuit add না করি, input এ যেকোনো signal wave এর জন্য output এ square wave পাব

Stage:



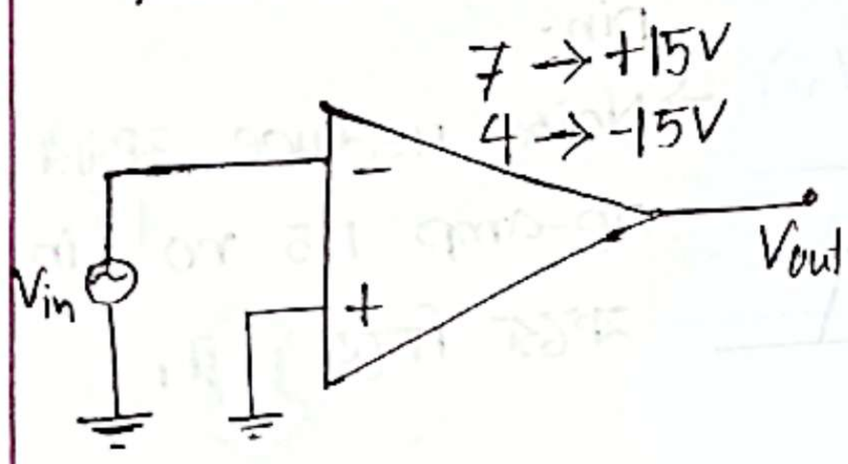
$V_1 - V_2$ এর value amp হবে

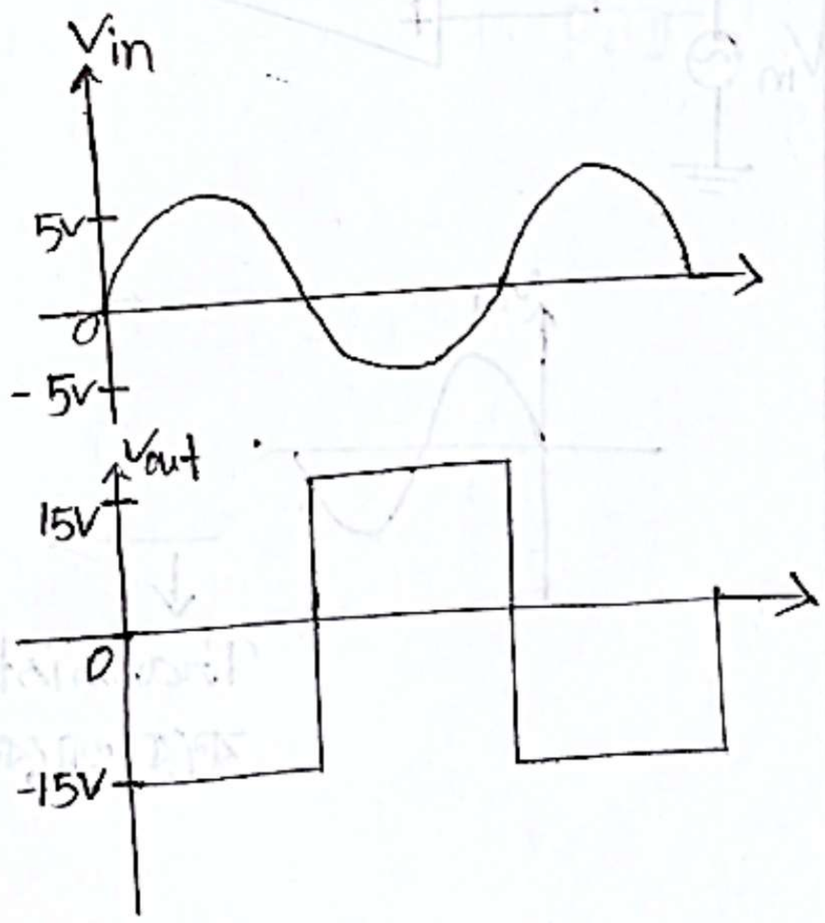
A → Differential Stage ($V_1 - V_2$)

B → Amplification Stage

C → Output Stage

ⓘⓘ Inverting Input:

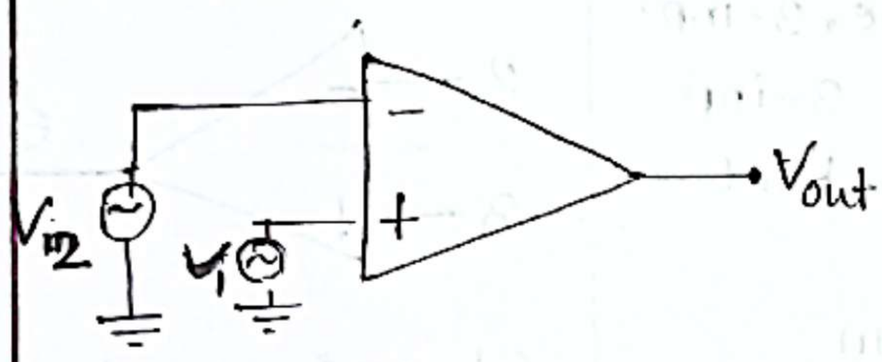




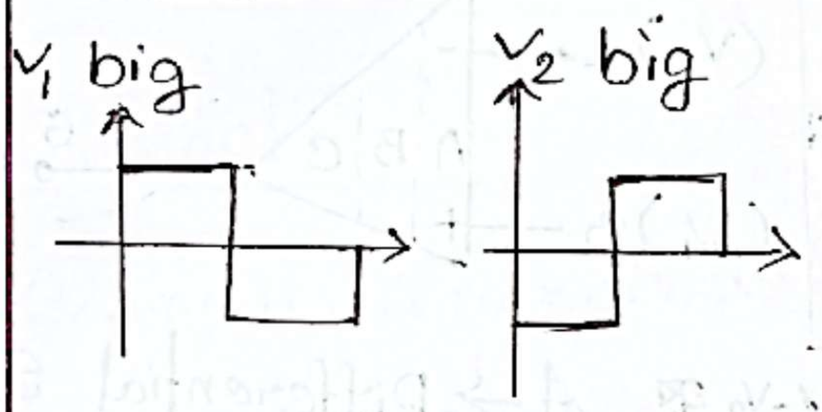
Vout Graph এর জন্য → $(0 - V_{in})$
$= -V_{in}$

$-V_{in} \times G$
$= -$ আসবে, কিন্তু power supply দেয়া থাকায় কারণে limited হয়ে যাবে

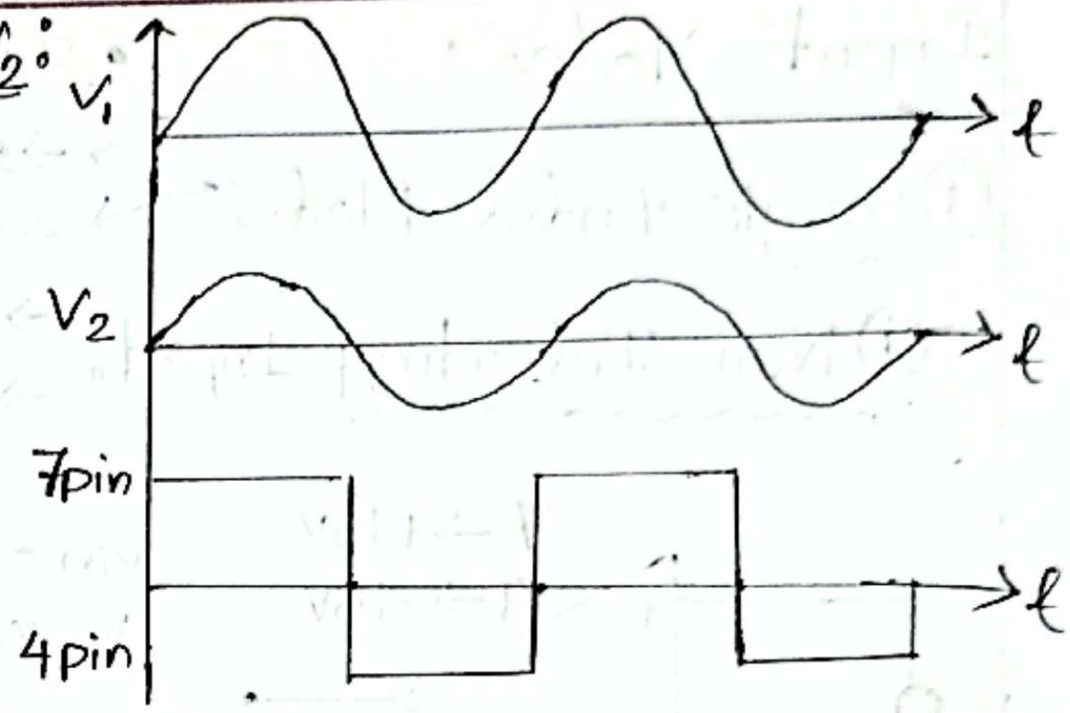
② Differential Mode:



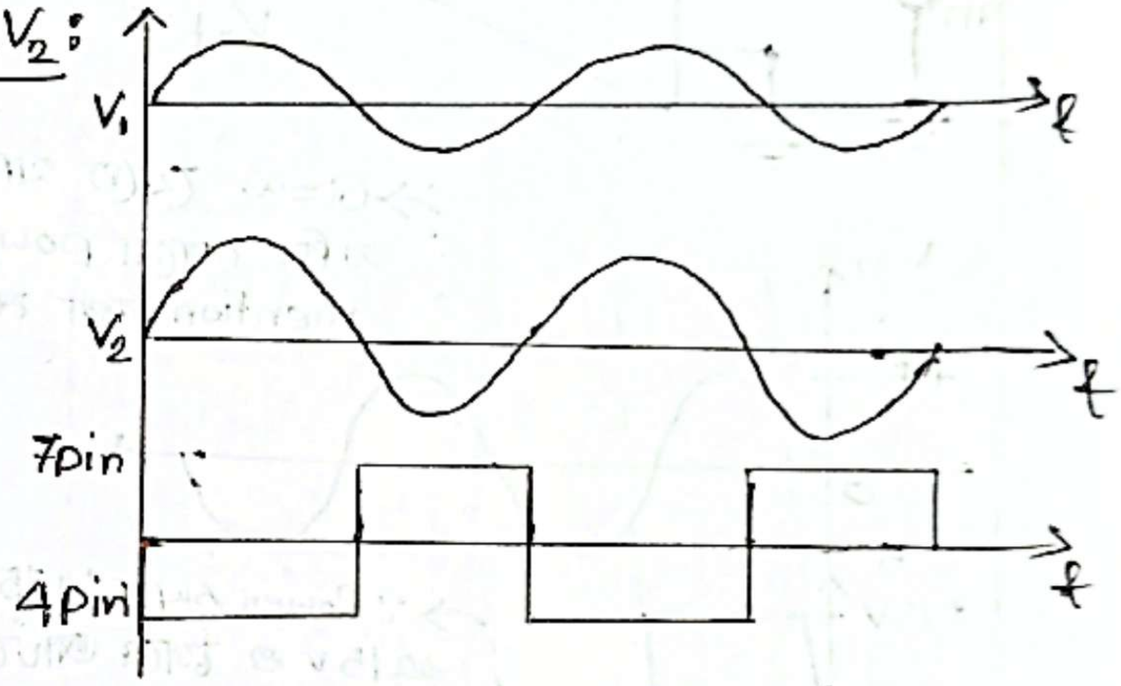
① $V_1 > V_2$ ⑪ $V_1 < V_2$



① $V_1 > V_2$:

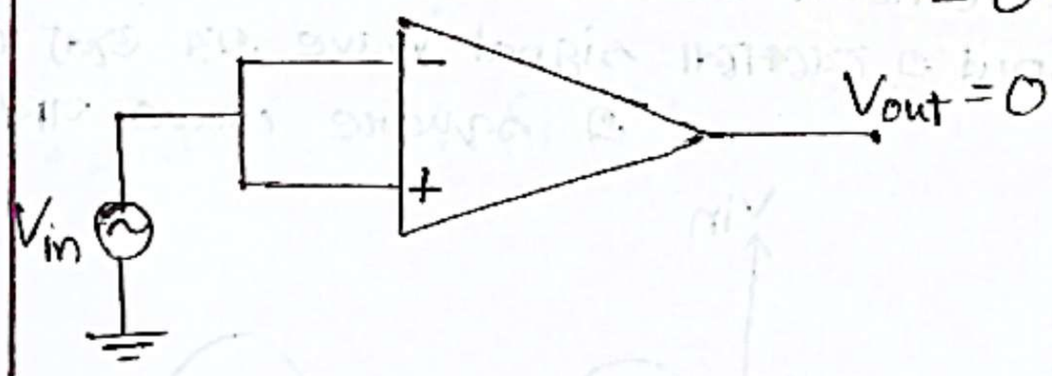


⑪ $V_1 < V_2$:



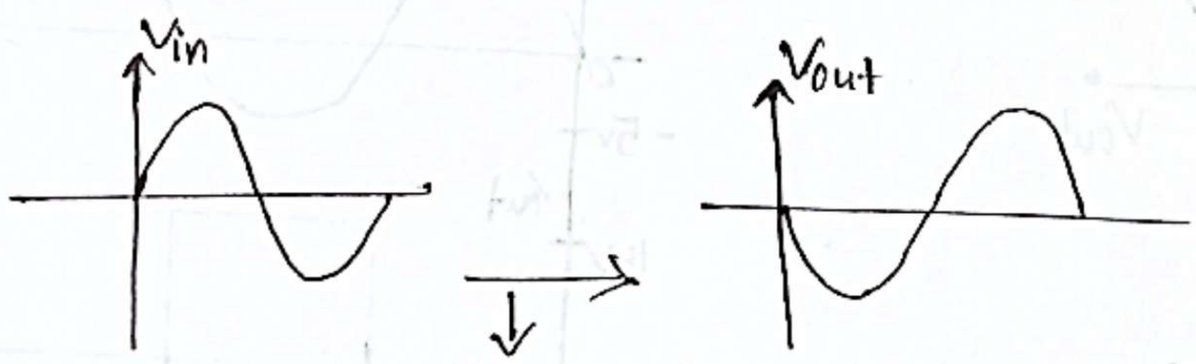
③ Common Mode:

$\boxed{V_1 = V_2}$ $\therefore V_{out} = G(V_1 - V_2)$
$= 0$



→ This mode applicable for op-amp 1,5 no offset pin.

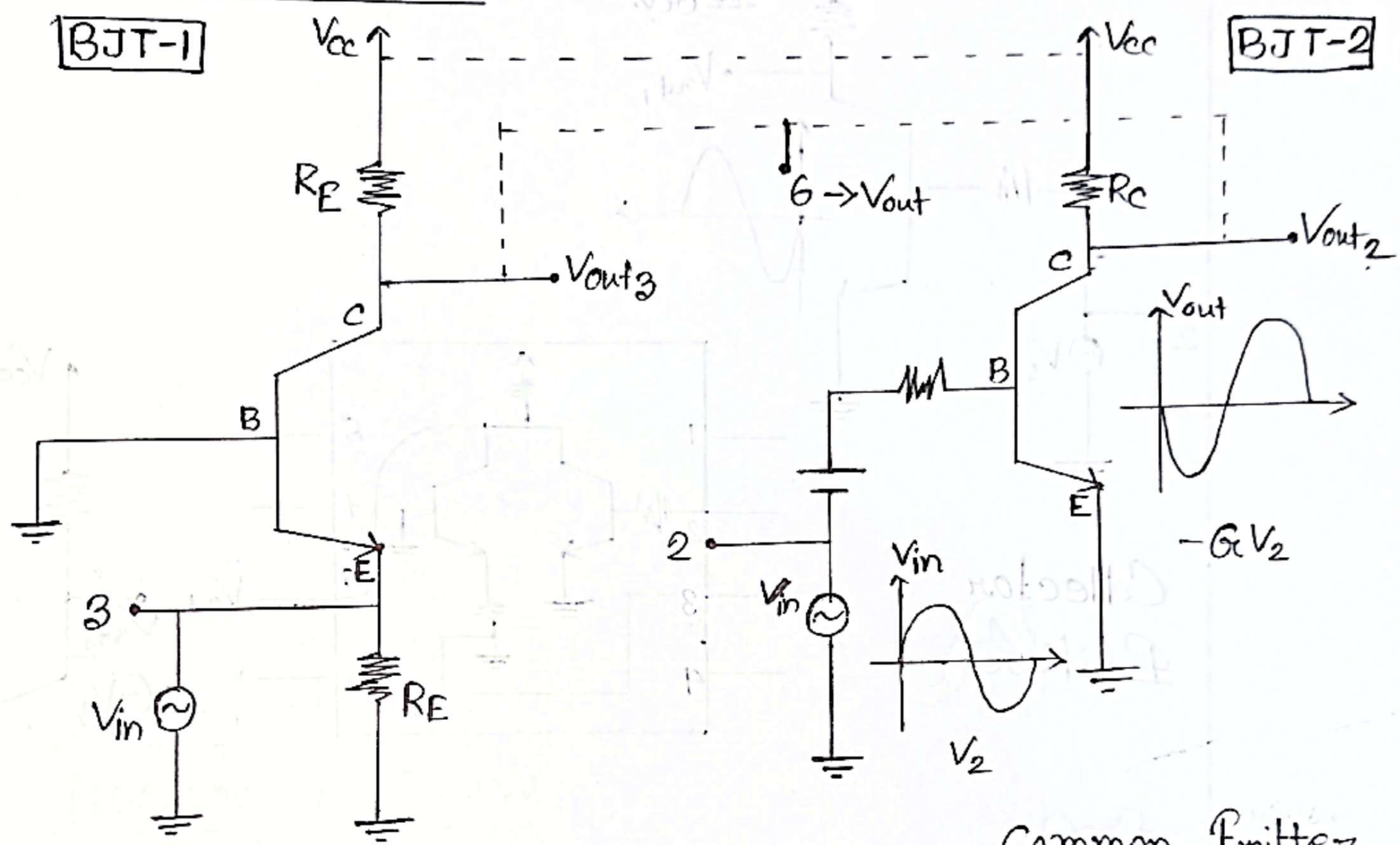
→ Noise reduce করার জন্য op-amp 1,5 no pin short করে দিতে হয়।



↓
Transistor করে থাকে

Exam-2 লাগবে না

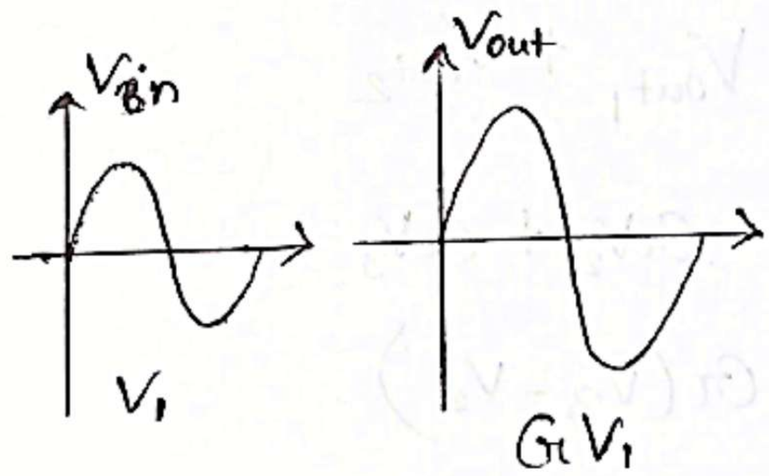
Op-amp internal circuit:



Common Base

3 number input

→ Reason: signal invert করার দরকার নাই,



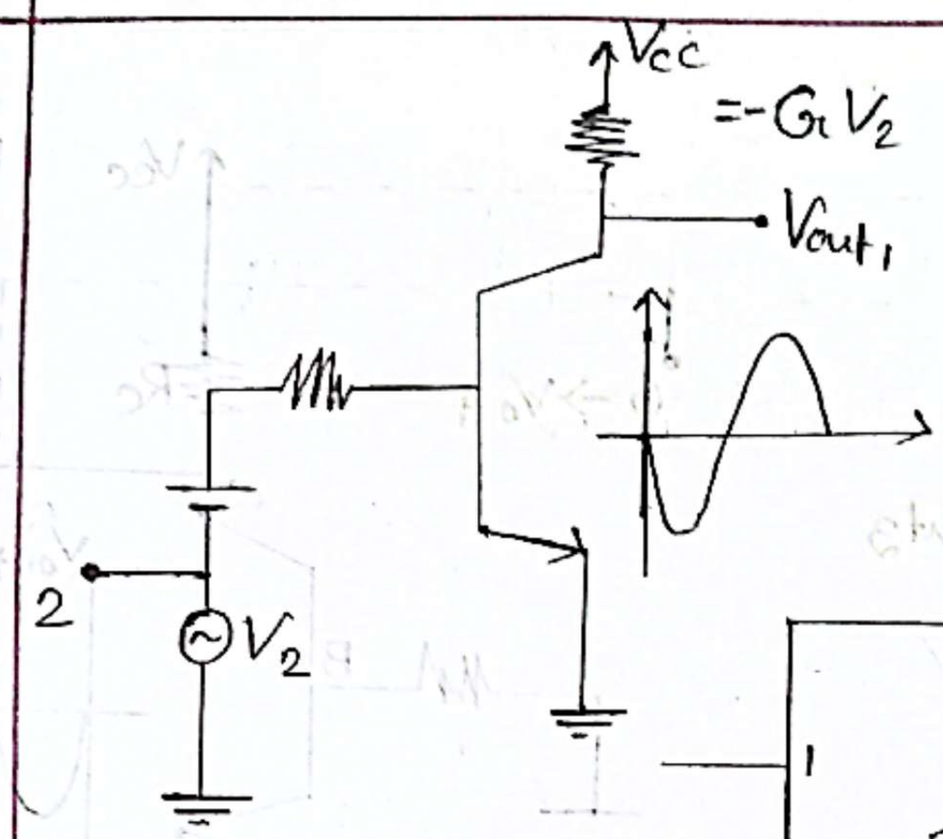
Common Emitter

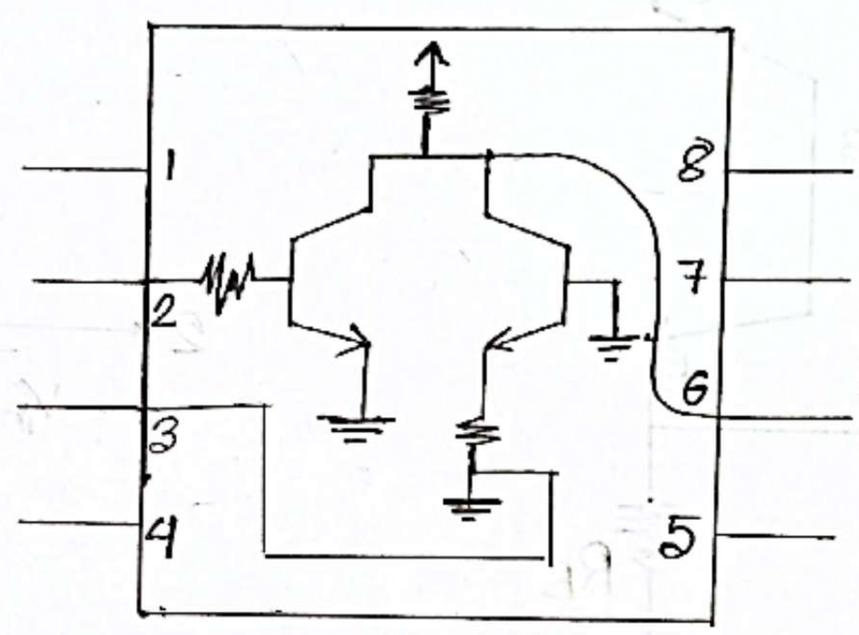
2 number input

→ Reason: signal inverted করার জন্য,

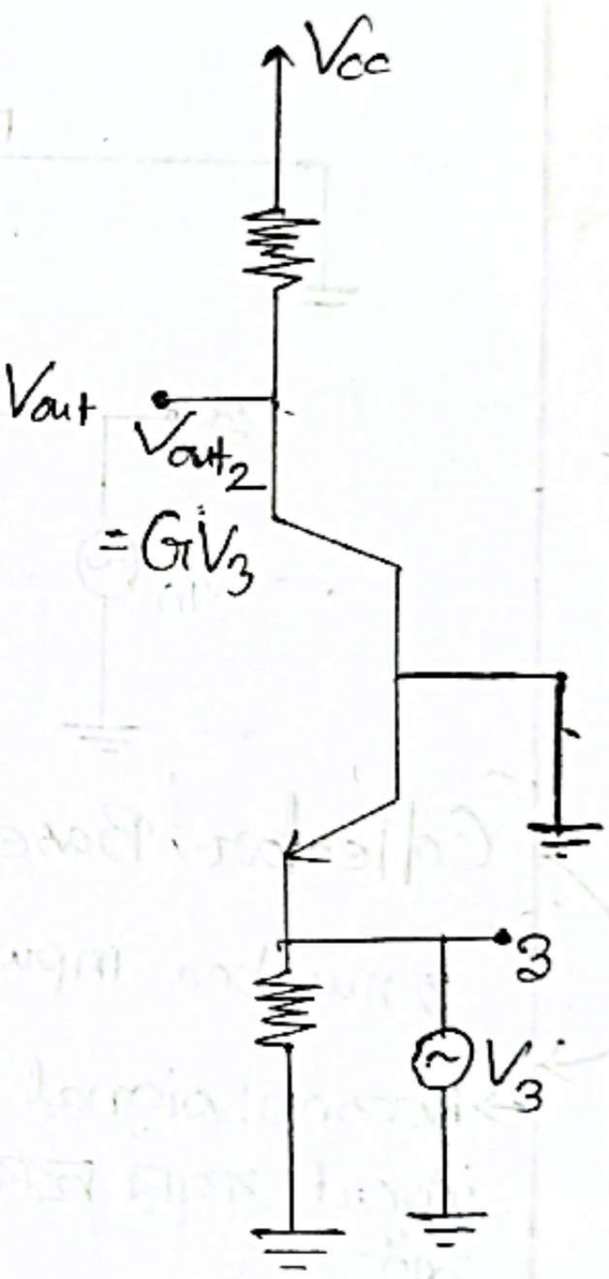
$$V_{out} = GV_1 - GV_2$$

$$\boxed{= G(V_1 - V_2)}$$





Common Emitter



Common Base

$$V_{out} = V_{out_1} + V_{out_2}$$

$$= -GV_2 + GV_3$$

$$= G(V_3 - V_2)$$

22/11/2025

Lecture-02

Basic Definitions

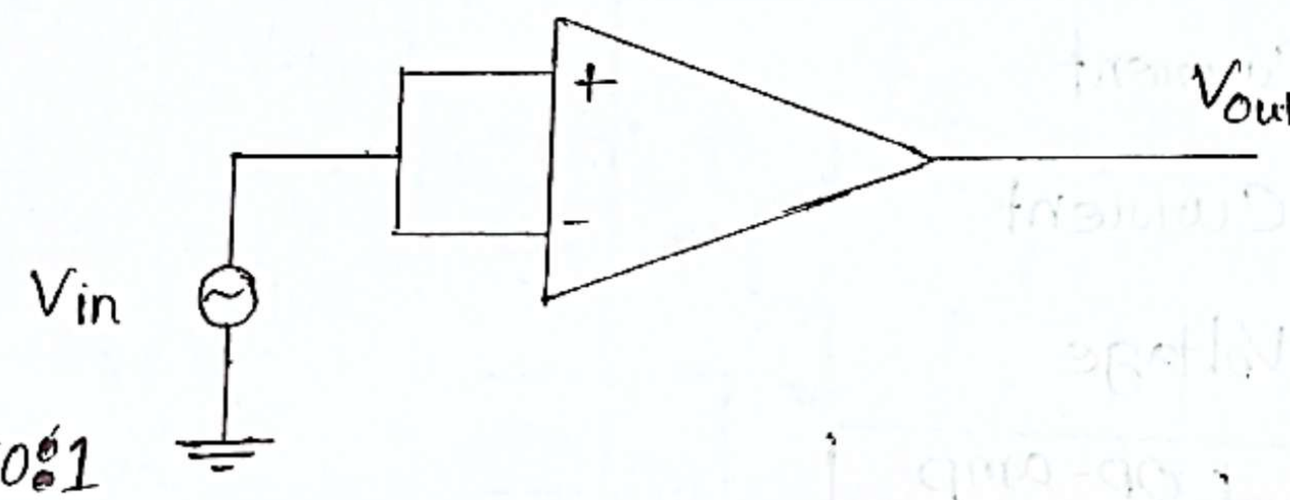
- CMRR
- Slew Rate
- Input Bias Current
- Input Offset Current
- Input Offset Voltage

	Op-amp ①	Op-amp ②
CMRR	100,000	150,000
Slew Rate	0.7 V/μs	0.9 V/μs
Input Bias C.	1×10^{-14} A	1×10^{-17} A
Input Offset C.	0.2	0.1
Input Offset Voltage	0.01	0.05

CMRR:

→ Common Mode Rejection Ratio

→ The ability of an op-amp to reject CMS common mode signal is known as CMRR.



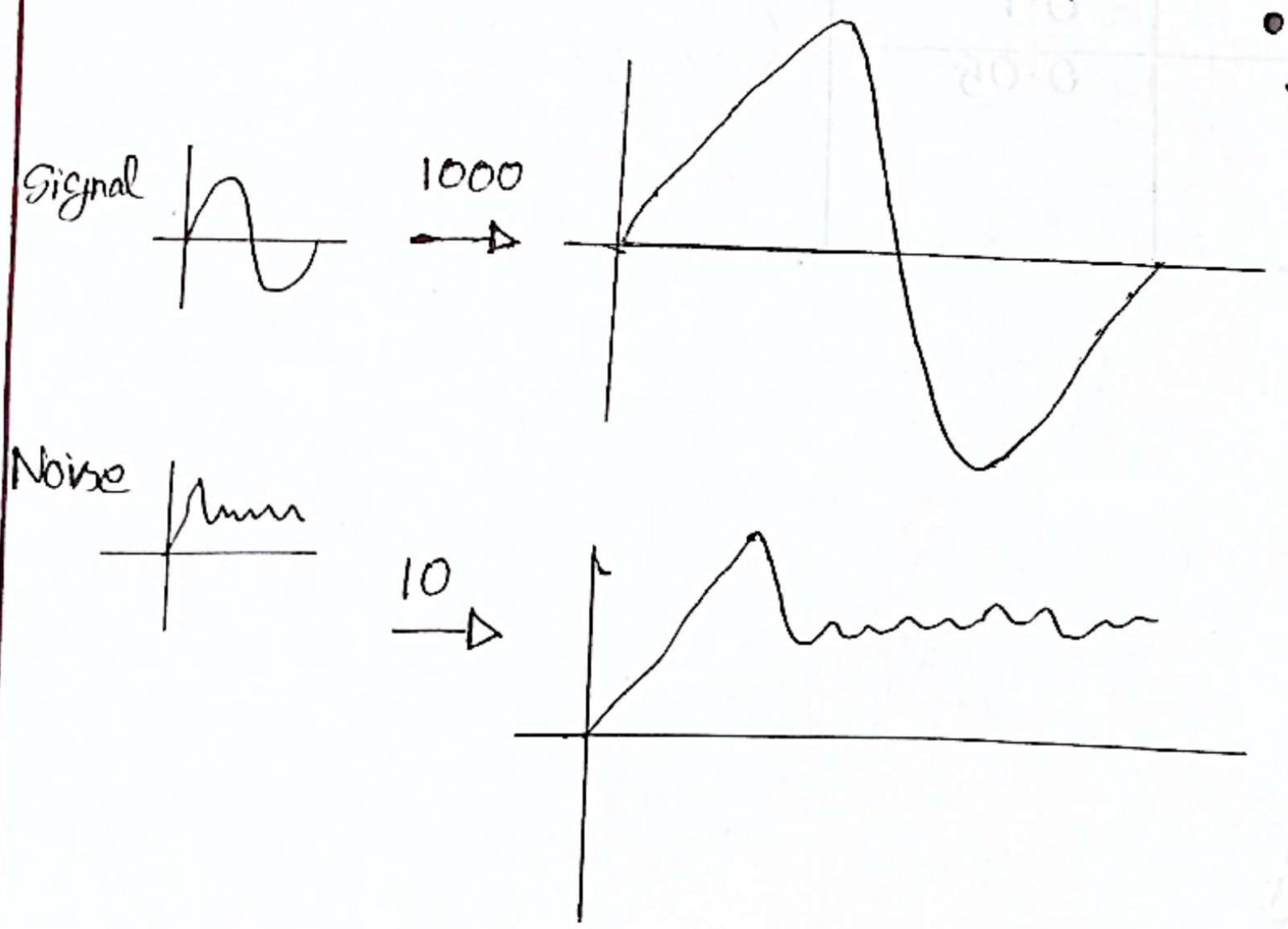
$V_{out} = 0$ (theoritically)
but practically একটা value চলে আ
0 এর কাছাকাছি

50=50:1

Signal(2/3) $\xrightarrow{A_{OL}}$ $V_{out}|signal$

\+   +

Noise $\xrightarrow{A_{CM}}$ $V_{out}|Noise$



- Signal amplification factor / noise এর amp factor এর ratio-টা CMRR, ability to reject noise.
- Ratio যত বেশি হবে, তত ভালো, কারণ signal এর তুলনায় noise এর পরিমান অনেক কম হবে।

amplifier হিসেবে

->CMRR ratio যত বেশি হবে op-amp তত ভালো কাজ করবে

Open Loop Gain, A_{OL}

Common Mode Gain, A_{CM}

$$\text{Gain} = \frac{\text{output}}{\text{input}}$$

$$CMRR = \frac{A_{OL}}{A_{CM}}$$

1V signal + A_{OL} = 1,00,000

1V Noise + A_{CM} = 0.1

$$\therefore CMRR = \frac{100,000}{0.1}$$

$$= 10,00000$$

(Power এর logarithm unit Bel)

$$dB = 10 \log_{10}(P)$$

B

$$P = \frac{V^2}{R}$$

$$(A_{OL})^2 = \left(\frac{V_{out}}{V_{in}}\right)^2$$

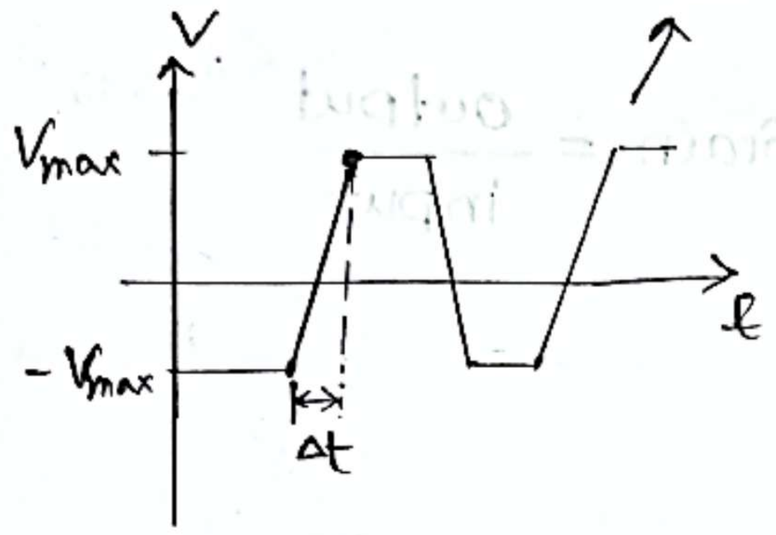
$$CMRR|_{log\ scale} = \left(\frac{A_{OL}}{A_{CM}}\right)^2$$

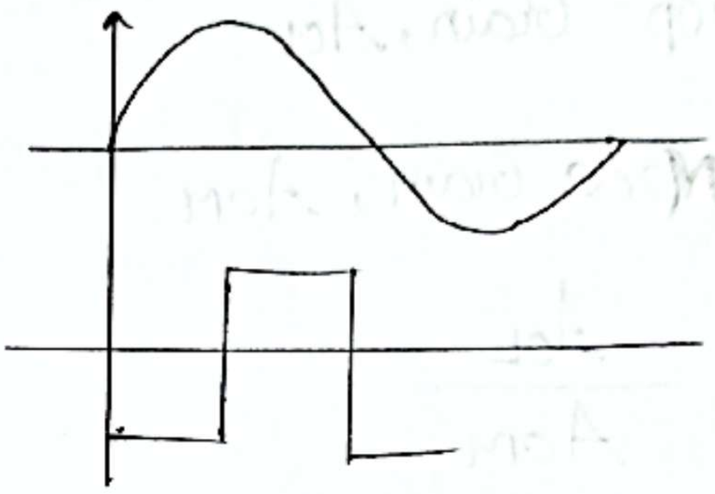
$$= 2\log_{10}\left(\frac{A_{OL}}{A_{CM}}\right) B$$

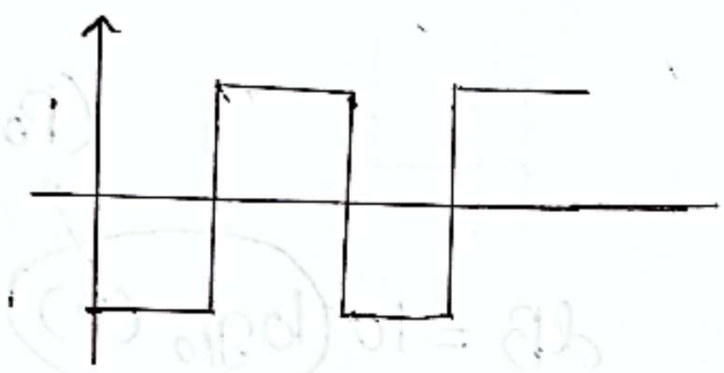
$$\bullet\ CMRR|_{log\ scale} = 20\log_{10}\left(\frac{A_{OL}}{A_{CM}}\right) dB$$

Slew Rate:

Slower, slew rate ↓







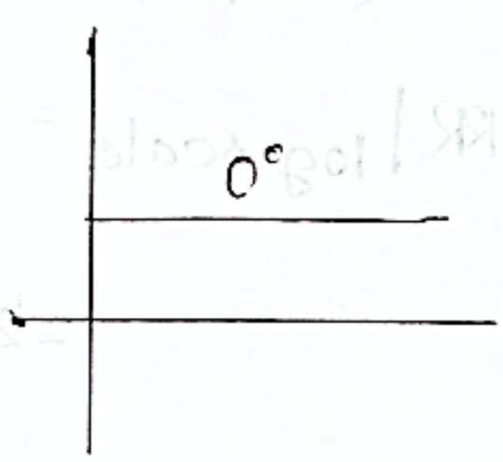
→ ⇒ faster reponse, slew rate ↑

⇒ যত ভালো rectangle wave তত ভালো slew rate

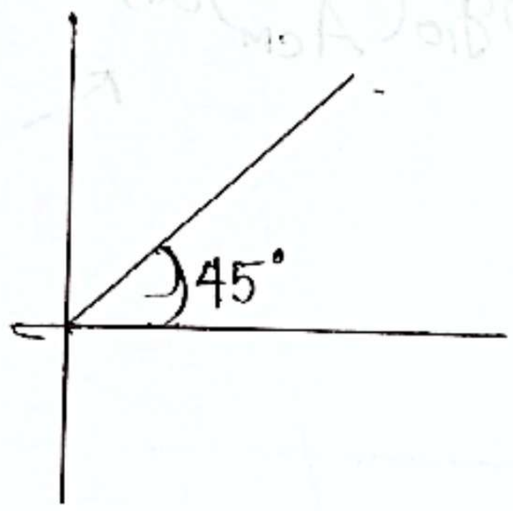
$$\therefore \text{Slew Rate} = \frac{V_{max} - (-V_{max})}{\Delta t}$$

when 7,4 pin voltage same, $= \frac{2V_{max}}{\Delta t}$

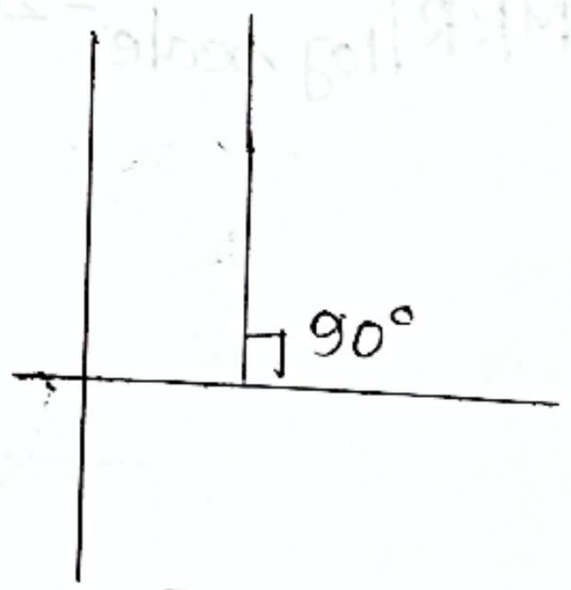
slew rate: Per unit time-এ কোনো কিছুর change (time এর সাপেক্ষে output এর change)



$\tan 0° = 0$



$\tan 45° = 1$



$\tan 90° = \infty$

⇒ Angle যত বেশি হবে, slew rate তত বেশি হবে।

Ex-12.1:

Open loop gain = 1,00,000

Common mode gain = 0.2

CMRR = ?

In log scale = ?

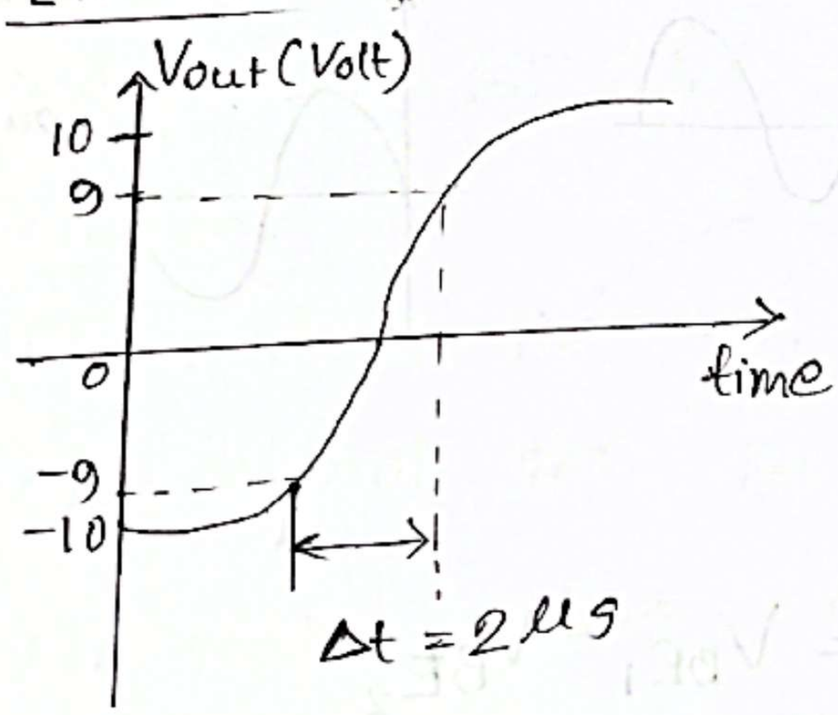
$$\therefore \text{CMRR} = \frac{100000}{0.2}$$

$$= 500,000$$

$$\therefore \text{CMRR}\,|_{\log\text{ scale}} = 20\log_{10}(500,000)\ \text{dB}$$

$$= 113.98\ \text{dB}$$

Ex-12.2:



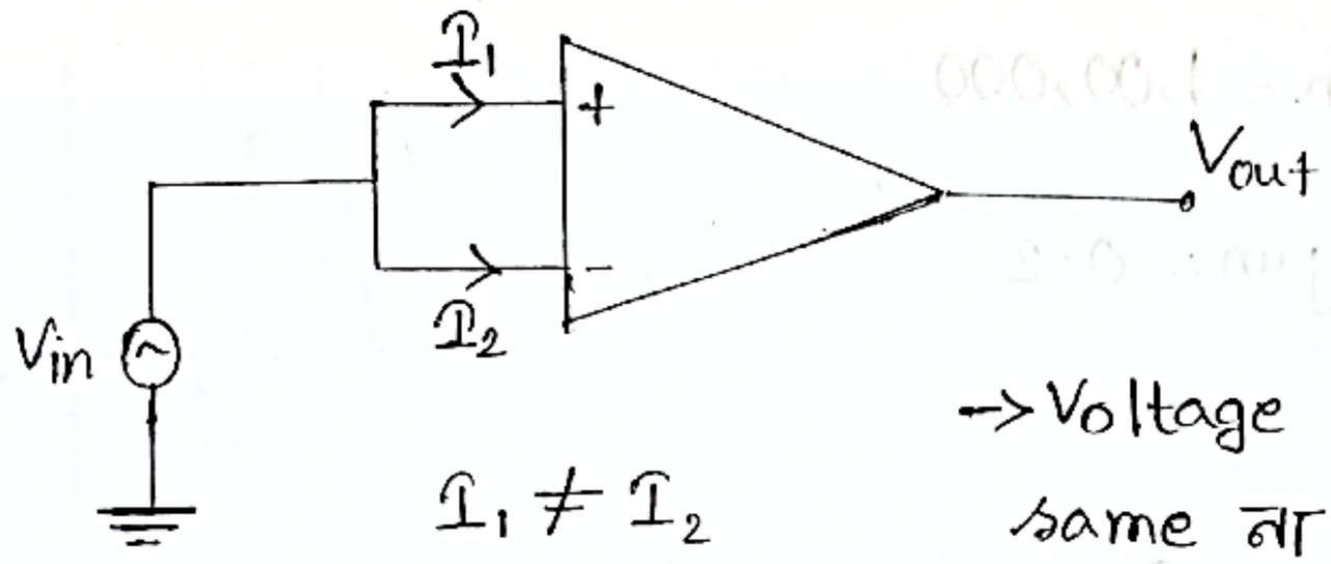
⇒ Slew rate ↑, square wave তত বেশি stiffer হবে এবং দেখতে pure square wave এর মতো মনে হবে।

Determine Slew Rate.

$$SR = \frac{9-(-9)}{2}\ V/\mu s$$

$$= \frac{18}{2}\ V/\mu s = 9\ V/\mu s = 9\times10^{6}\ V$$

Input Bias Current:



$I_1 \neq I_2$

→ Voltage same, কিন্তু current same না হয়ে তাদের মধ্যে কিছু difference থেকে যায়, ঐ difference I.O.Current.

- $I_{bias} = \dfrac{I_1 + I_2}{2} \longrightarrow$ (i)

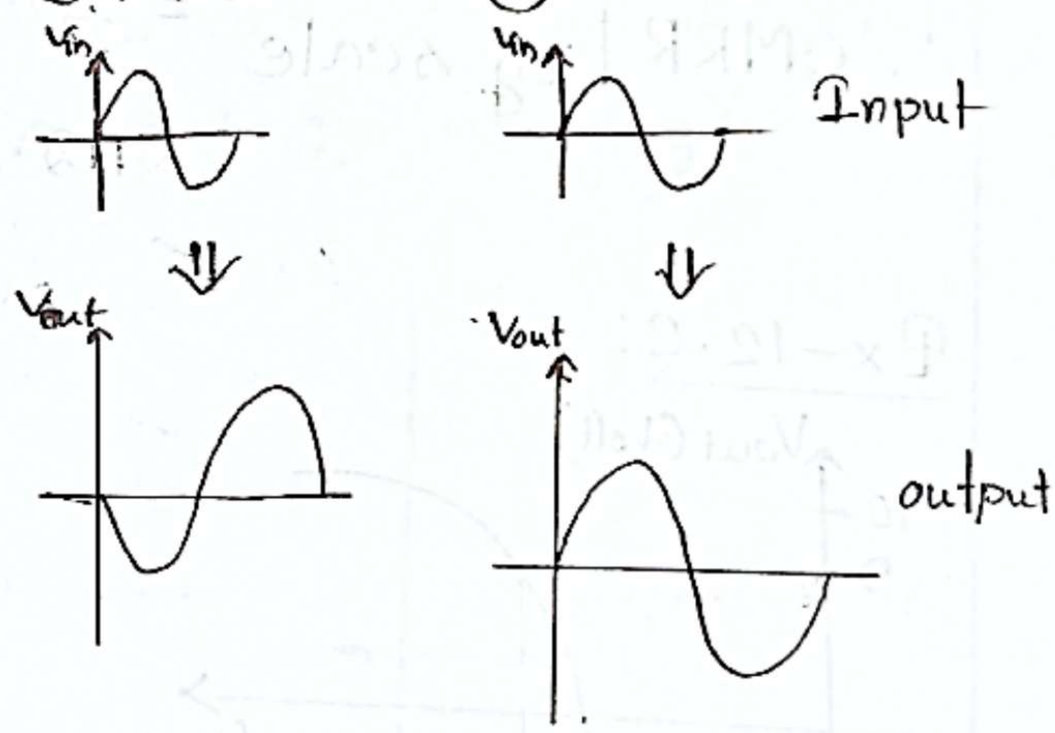
- Input offset current, $I_{offset} = I_1 - I_2 \longrightarrow$ (ii)

⇒ Current different হবার কারন হলো op-amp 2,3 no pin-এ BJT use করা হয়

	BJT_1	BJT_2
BJT Property	$\beta_{DC} = 100$	$\beta_{DC} = 100 \approx 98$
	α_{DC}	α_{DC}
	$I_1 \neq$	I_2
	$V_{BE} \neq$	V_{BE}

কয়েকবার use করার পর, So,

(2) ⇒ CE (3) ⇒ CB



(i) & (ii) ⇒ $I_1 = ?$

$I_2 = ?$

Input Offset Voltage, $V_{offset} = V_{BE_1} - V_{BE_2}$

$\dfrac{5+6}{2} = 5.5$ $\quad \dfrac{5+5.5}{2} = 5.25$ $\quad \dfrac{5+5}{2} = 5$ → I_{Bias} এর average current এর যত কাছাকাছি হবে তত ভালো, I_{Bias} theoritically 0 হবার কথা।

⇒ Input offset current/Voltage যত কম, Op-amp তত ভালো হবে,

⇒ অর্থাৎ value 0 এর যত কাছে, তত ভালো op-amp.

23/11/2025

Lecture-03

Negative Feedback

- What is negative feedback
- Why negative feedback
- Effect of negative feedback

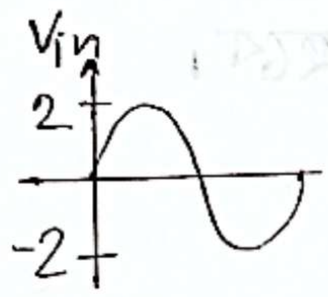
Ideally

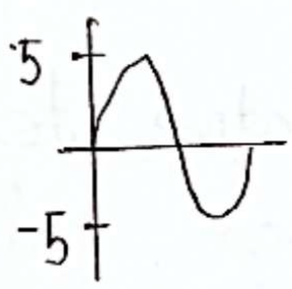
$Z_{in} = \infty$

$Z_{out} = 0$

$G = \infty$

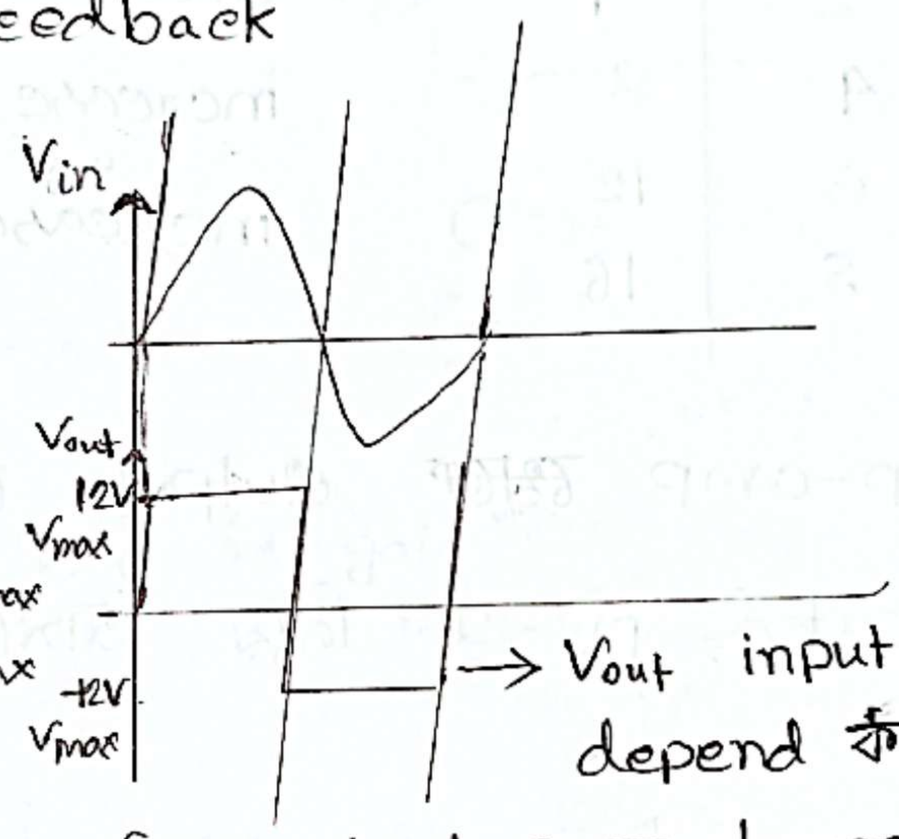
$BW = \infty$





7pin → +Vmax

4pin → Vmax



→ Vout input এর উপর depend করে না।

Problem: → input-এ sine wave, কিন্তু output-এ তা change হয়ে square হয়

→ Amplitude যেটা দিই না কেন, Output-এ always 12V হবে

Solution:

Open loop gain = ∞ → externally connection but doing in op-amp

Closed loop gain = finite

① To reduce the gain → effect

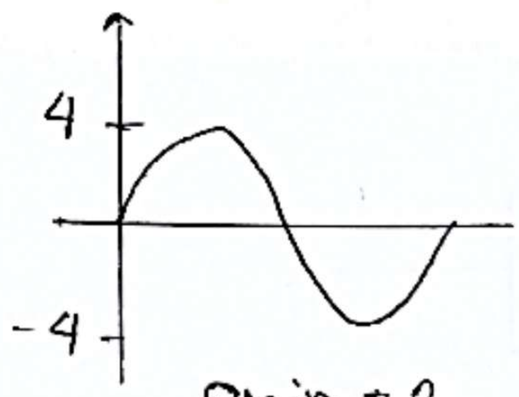
② To control the gain

③ To make a linear amplifier

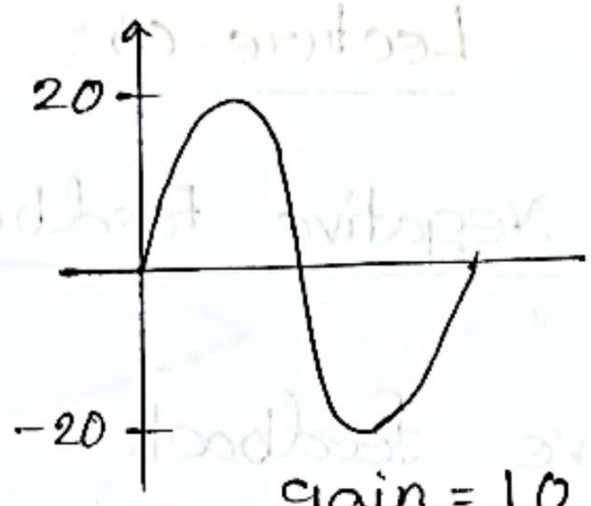
④ To make changes in the input & output impedence

⑤ To reduce the bandwidth → Effect

*Why use negative feedback



gain = 2

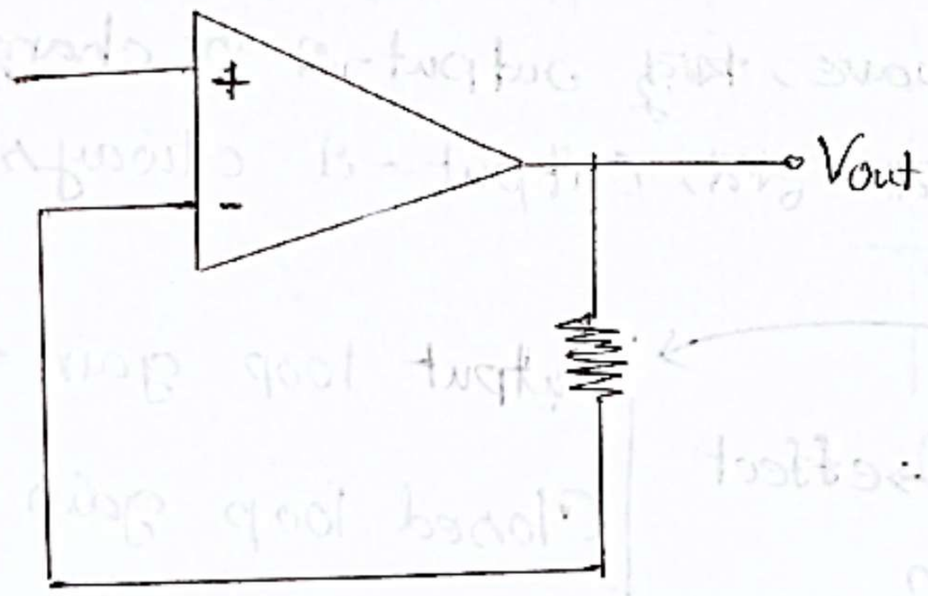


gain = 10

Vin	Vout
2	4
4	8
6	12
8	16

→ linear amplifier = Vin এর value যতগুন increase করবে, Vout এর value ও ততগুন increase হবে।

→ Op-amp এর output থেকে একটা connection feedback হিসেবে - inverted pin-এ নিয়ে আসলে negative feedback.



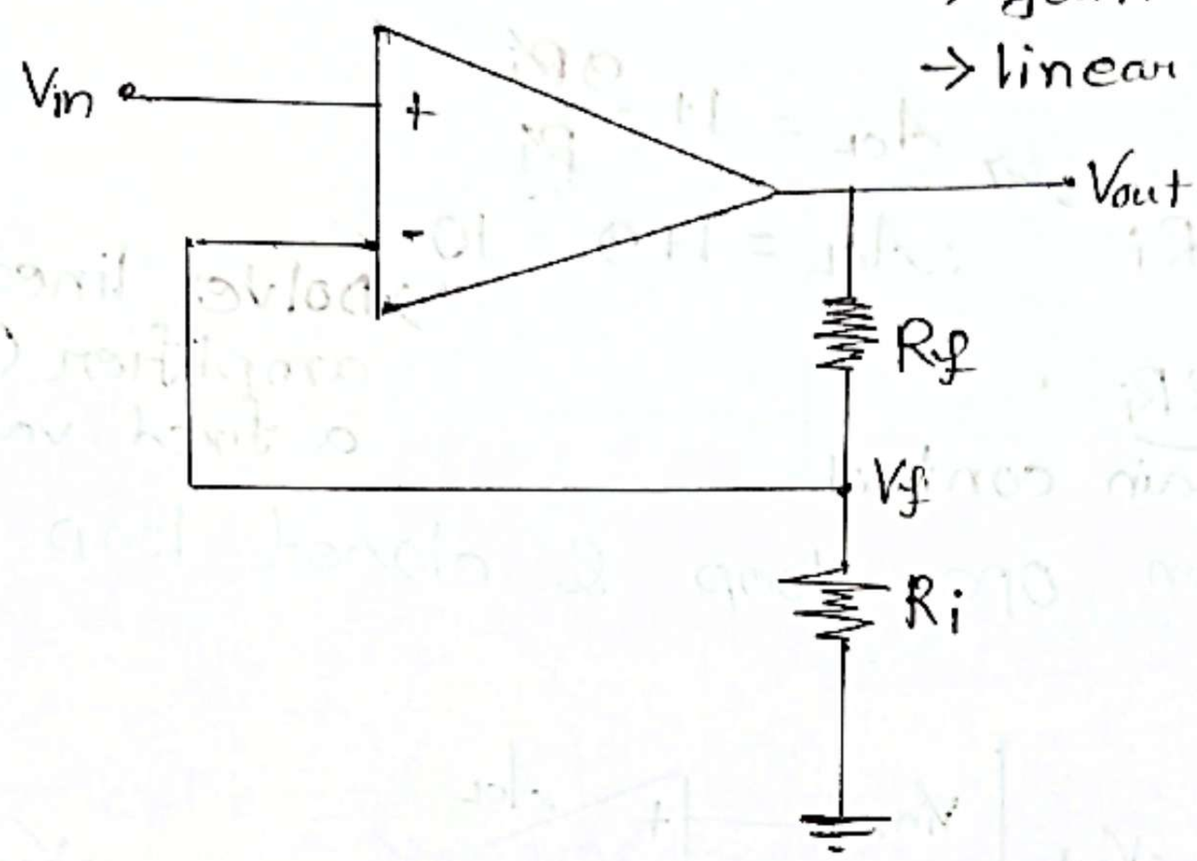
Op-amp with negative feedback

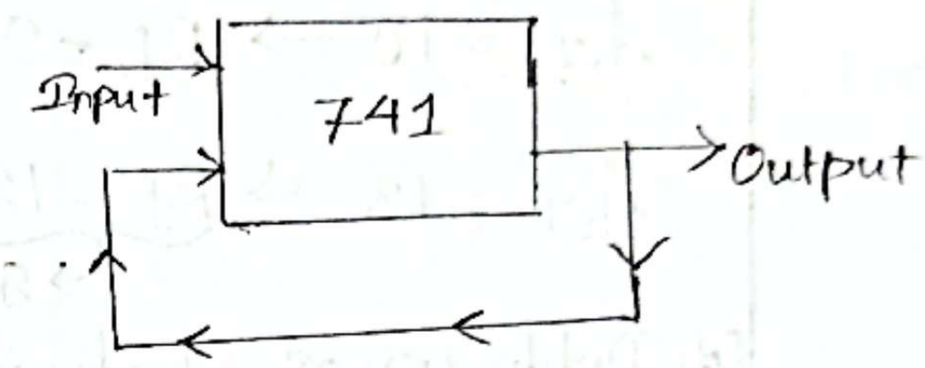
→ Non-inverting Amplifier (Non-inverting pin-এ input এবং inverting pin-এ feedback)

→ Inverting Amplifier (inverting pin-এ input এবং inverting pin-এ feedback)

① Non-inverting Amplifier: check 1st 3 condition:

→ gain reduce ✓
→ gain control ✓
→ linear amplifier ✓





Close looping
(input → output → feedback
→ input → output → fb)

$$A_{CL} = \frac{V_{out}}{V_{in}}$$

A_{CL} = Close to gain
→ signal কতটুকু increase করবে (output/input)

$$= \boxed{?}$$

gain = ∞

$$V_{out} = A_{OL}(\overbrace{V_{in}}^{\text{input}} - V_f)$$

$$\Rightarrow V_{out} = A_{OL}(V_{in} - BV_{out})$$

$$\Rightarrow V_{out} = A_{OL}V_{in} - A_{OL}BV_{out}$$

$$\Rightarrow V_{out}(1 + A_{OL}B) = A_{OL}V_{in}$$

$$\Rightarrow \frac{V_{out}}{V_{in}} = \frac{A_{OL}}{1 + BA_{OL}}$$

$$\Rightarrow A_{CL} = \frac{A_{OL}}{BA_{OL}}$$

$$\therefore A_{CL} = \frac{1}{B}$$

$$V_f = IR_i$$

Circuit-এ কোনো point এর voltage ground এর respect এ বের করি, so, V_f এর জন্য R_i এর across-এ voltage

$$= \frac{V_{out}}{R_i + R_f} R_i$$

$$V_f = \frac{R_i}{R_i + R_f} V_{out}$$

$$= BV_{out}$$

$$A_{CL} = \frac{1}{\frac{R_i}{R_i + R_f}}$$

$$= \frac{R_i + R_f}{R_i}$$

$$\therefore A_{CL}(\text{Non-In}) = 1 + \frac{R_f}{R_i}$$ } reduce gain

$$A_{CL(NI)} = \frac{V_{out}}{V_{in}}$$

$$= 1 + \frac{R_f}{R_i}$$

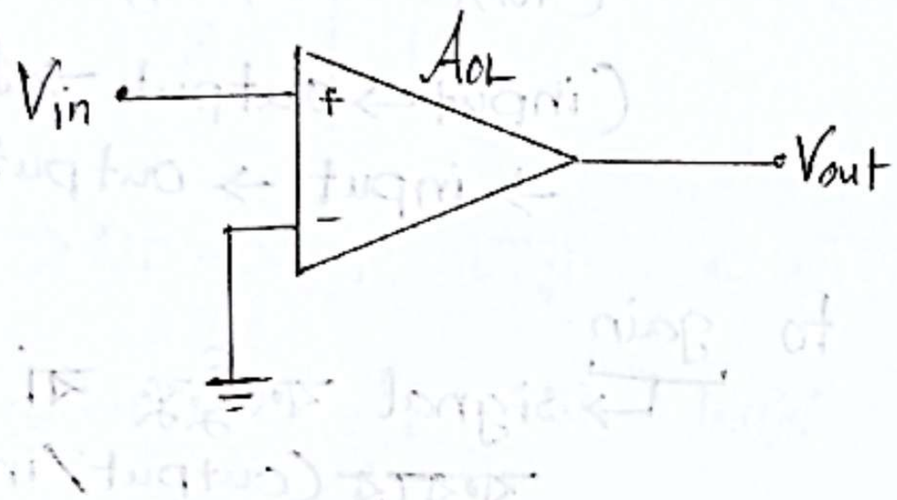
$A_{CL} = 10 \rightarrow R_f = 9R_i$ $\quad \rightarrow A_{CL} = 1 + \frac{9\cancel{R_i}}{\cancel{R_i}}$

$\therefore A_{CL} = 1 + 9 = 10$

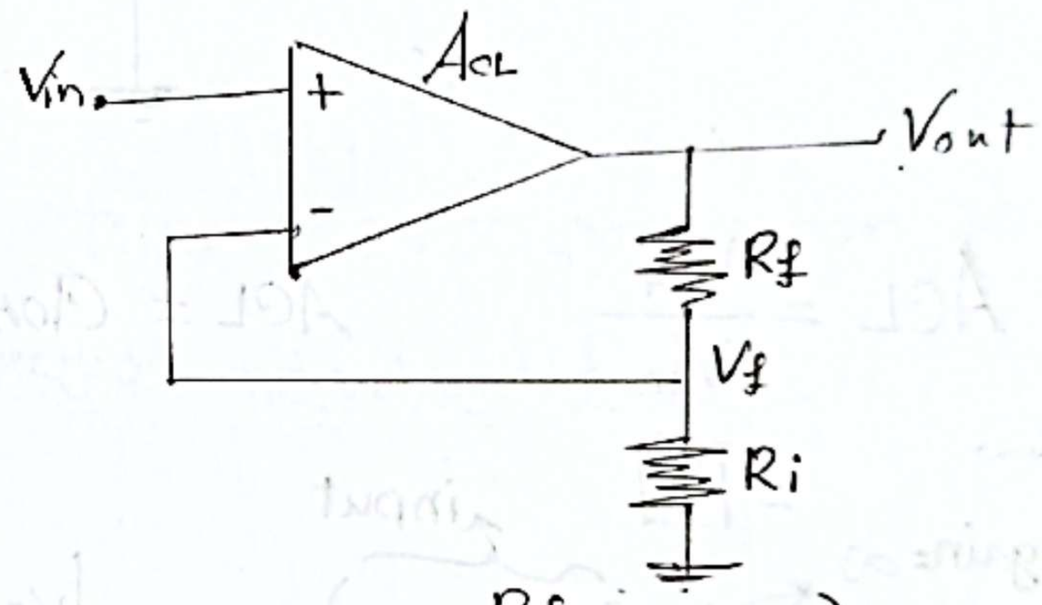
→ make linear amplifier (cz set a fixed value)

$A_{CL} = 13 \rightarrow \underbrace{R_f = 12R_i}_{\text{gain control}}$

Difference between open-loop & closed loop gain.

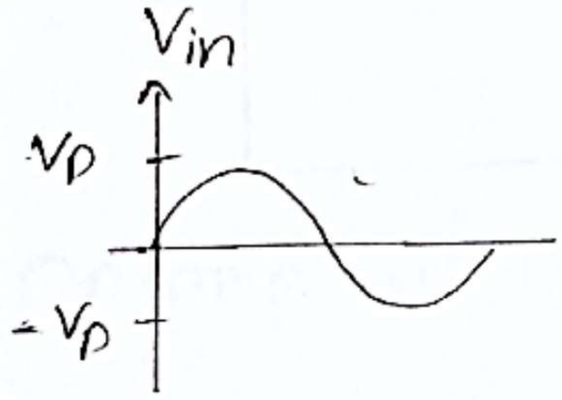


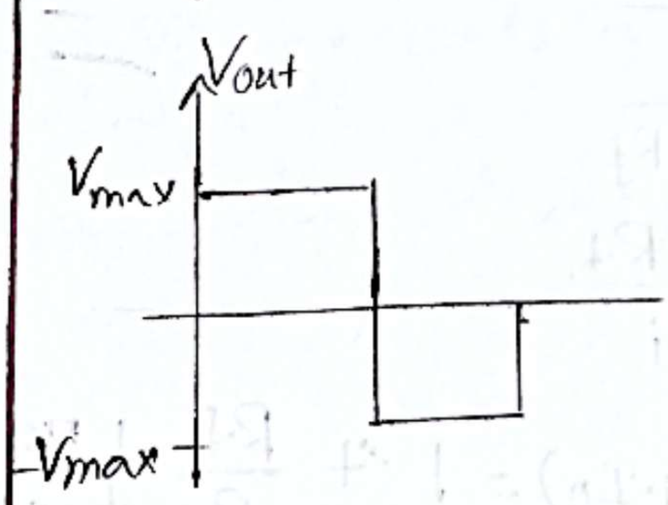
$A_{OL} = \infty$



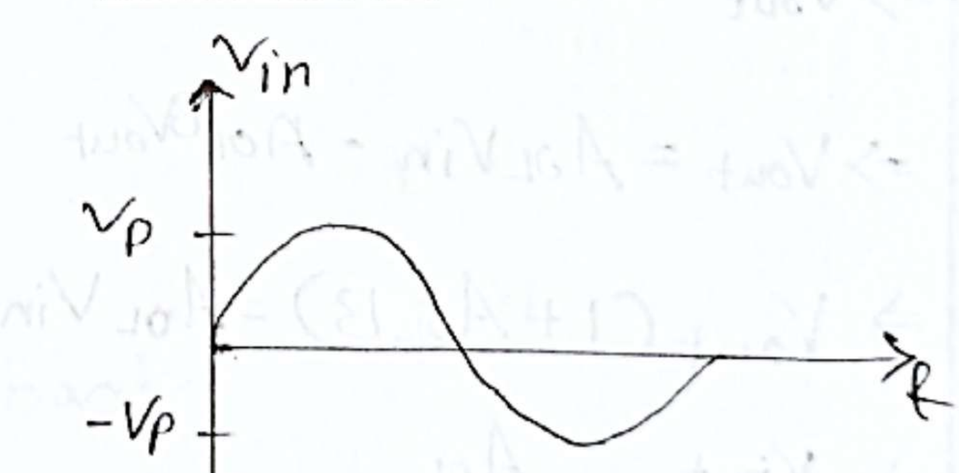
$A_{CL} = 1 + \frac{R_f}{R_i}$ (finite)

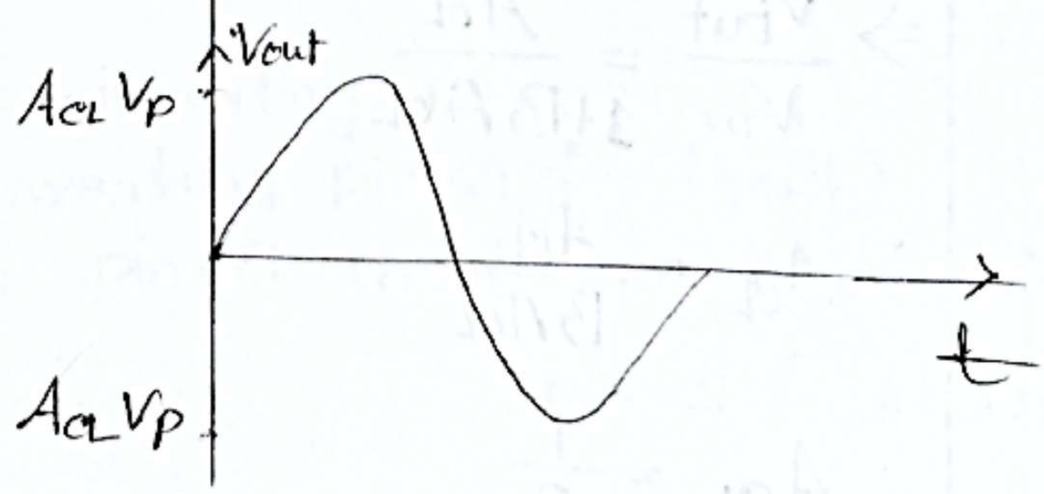
Waveform:





Waveform:

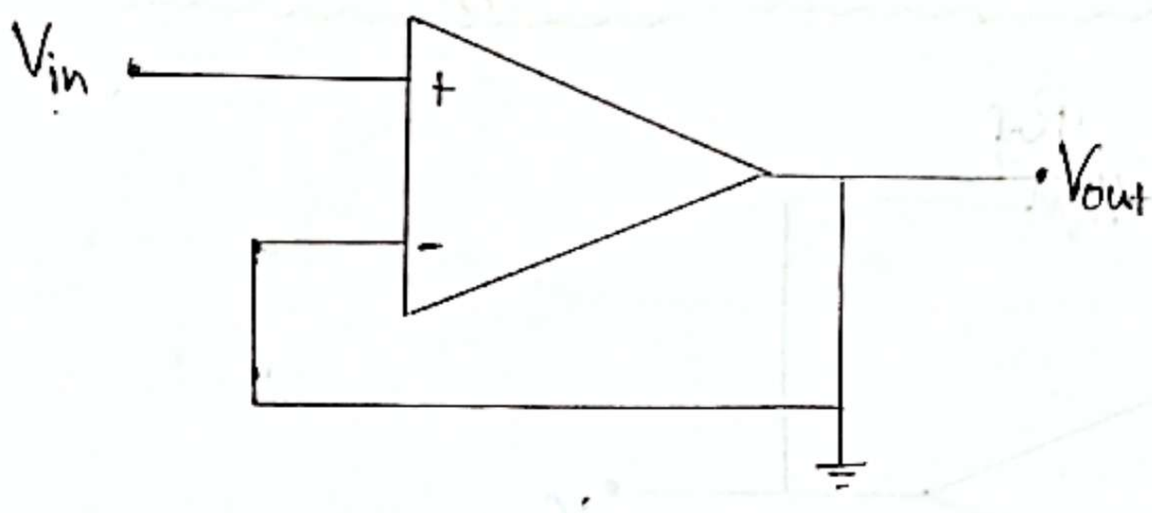




$$Gain = \frac{V_{out}}{V_{in}}$$

Voltage Follower / Buffer Amplifier:

→ Gain 1 হলে তাই B.A.



→ Output voltage, input voltage কে follow করে, input v. যা output v. ও তাই হবে, So, known as voltage follower.

$$A_{CL} = 1 + \frac{R_f}{R_i}$$

$$= 1 + \frac{0}{\infty}$$ → ground এর সাথে connection. So, বসিয়া ∞

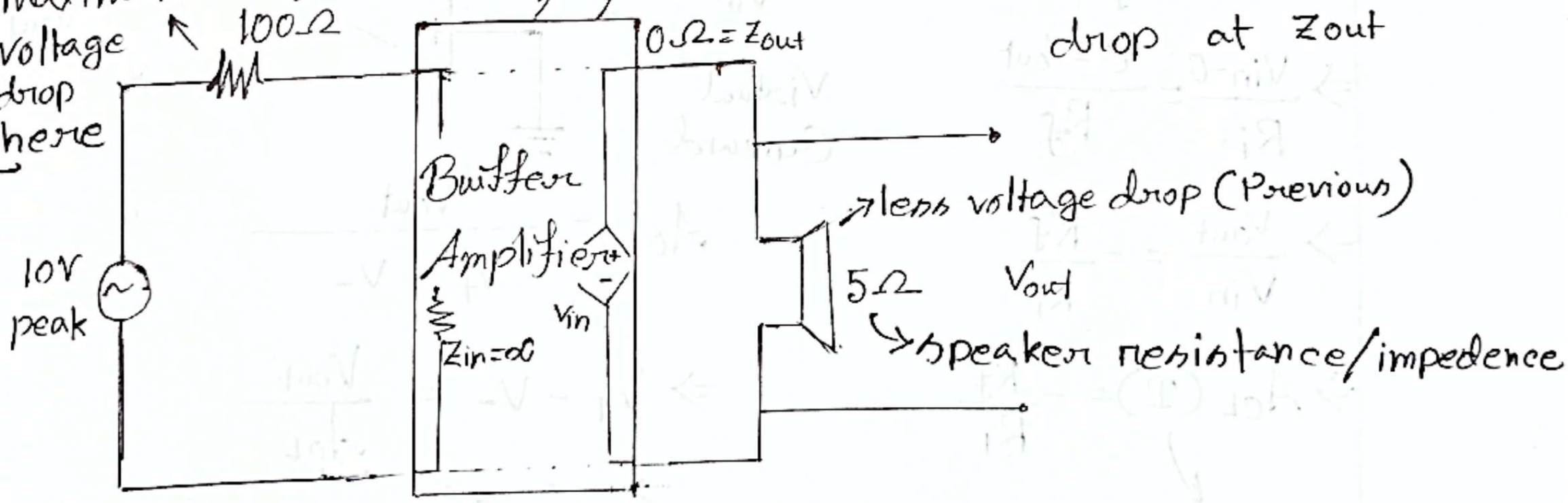
Application: Acts as an impedence matching circuit.

$$\frac{V_{out}}{V_{in}} = 1$$

$\Rightarrow V_{out} = V_{in}$

(∞ > 100Ω, so signal ∞ দিয়ে pass হবে $V_{out} = V_{in}$ করে দিয়ে, then $Z_{out} = 0 < 5\Omega$ So ↓ after using BA all voltage drop at 5Ω, only 0.000... something drop at Zout

কিন্তু আমরা চাই speaker থেকে sound loud আসুক



then we have to use B.A.

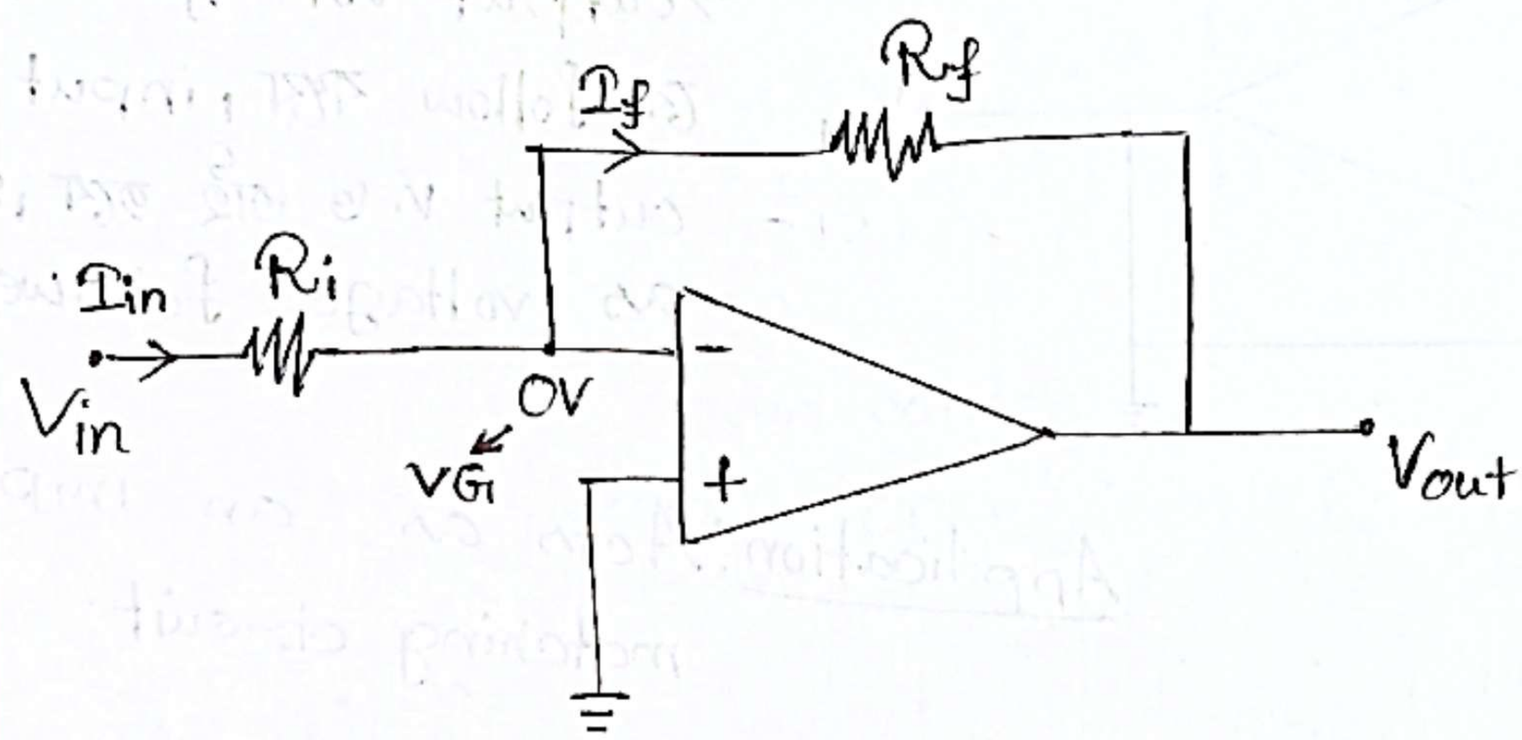
< Impedence mismatch ($Z_{in} \neq Z_{out}$) ⇒ (100Ω ≠ 5Ω)

High Input Impedence ($Z_{in} > Z_{out}$) ⇒ (100Ω > 5Ω)

29/11/2025

Lecture-04

Negative feedback - Inverting Amplifier



$A_{CL}(I) = ?$

$= \frac{V_{out}}{V_{in}} = ?$

$I_{in} = I_f$

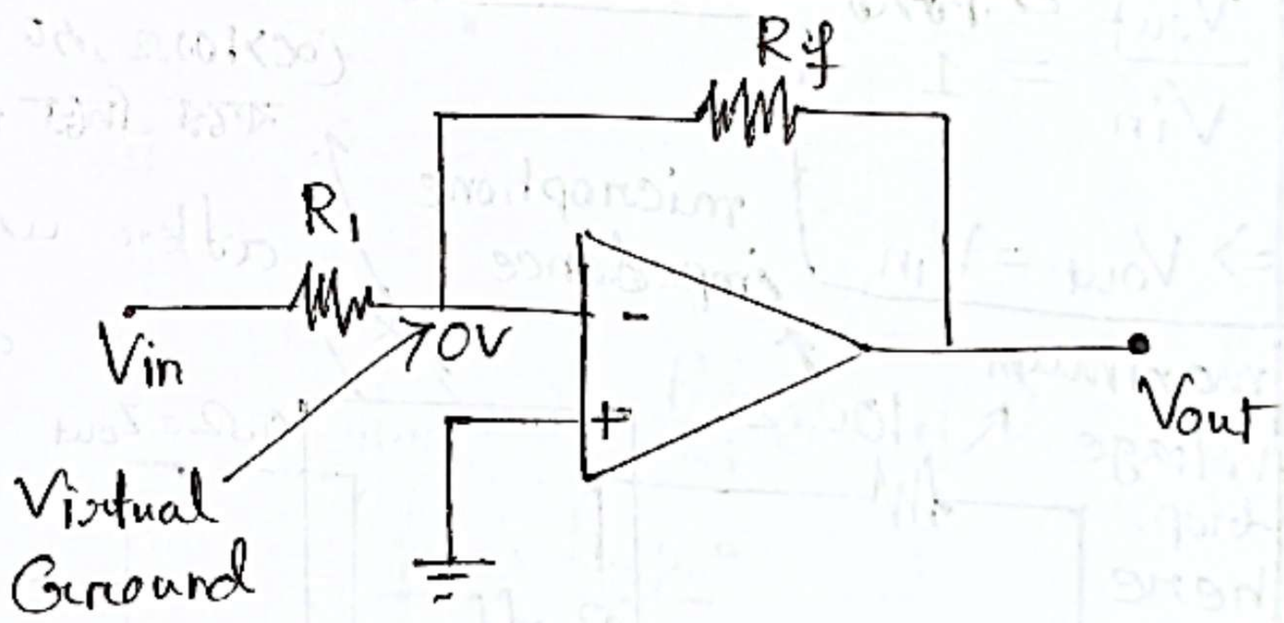
$\Rightarrow \frac{V_{in} - 0}{R_i} = \frac{0 - V_{out}}{R_f}$

$\Rightarrow \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_i}$

$\Rightarrow A_{CL}(I) = -\frac{R_f}{R_1}$

Inverting

Virtual Ground:



$A_{OL} = \frac{V_{out}}{V_+ - V_-}$

$\Rightarrow V_+ - V_- = \frac{V_{out}}{A_{OL}}$

$= \frac{V_{out}}{\infty} = 0$

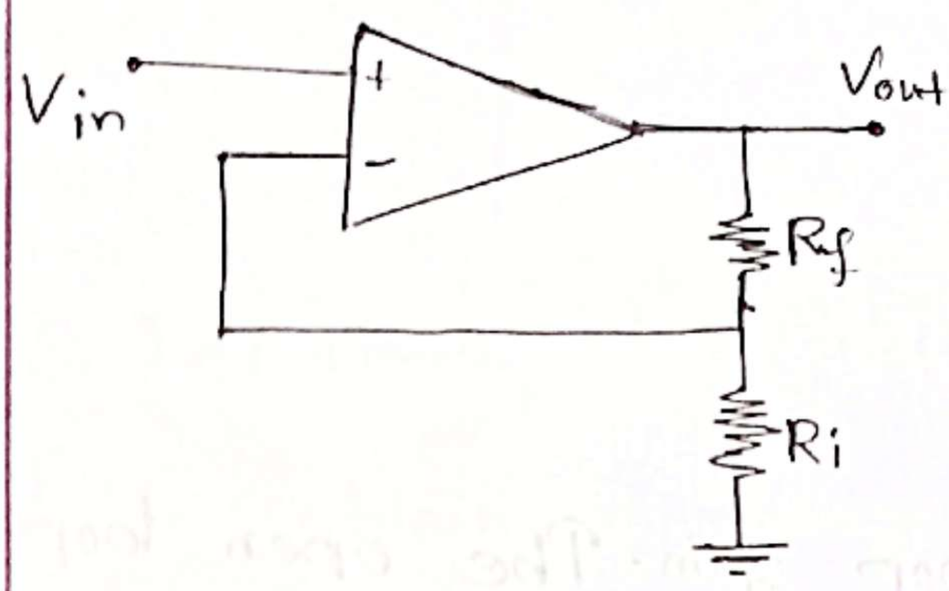
$\therefore V_+ = V_-$

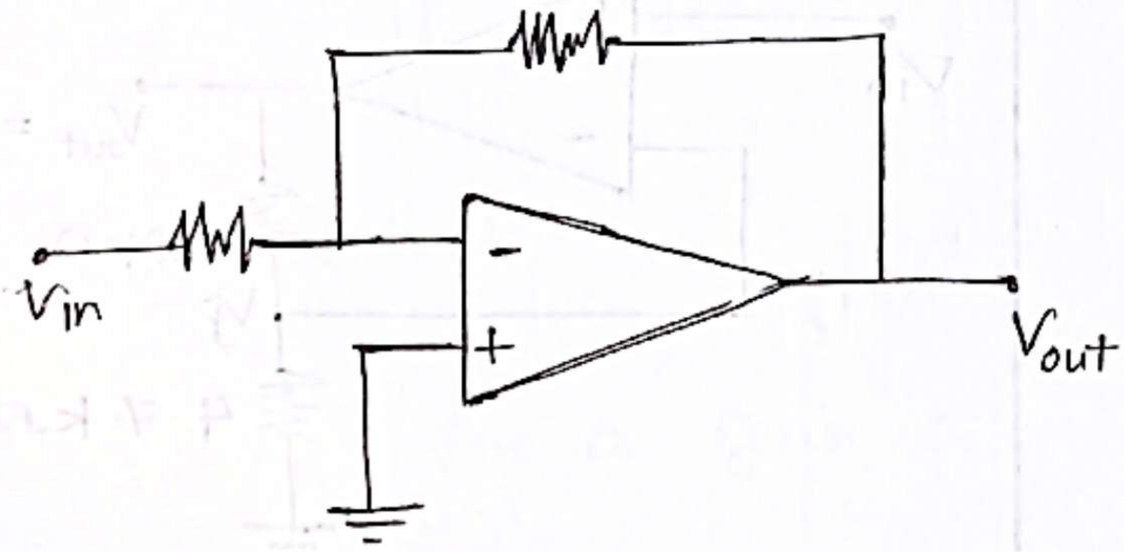
Ground

V_- ground না থাকার স্বত্ত্বেও 0V এর মতো আচরণ করবে

Summary:

Non-Inverting Amplifier:





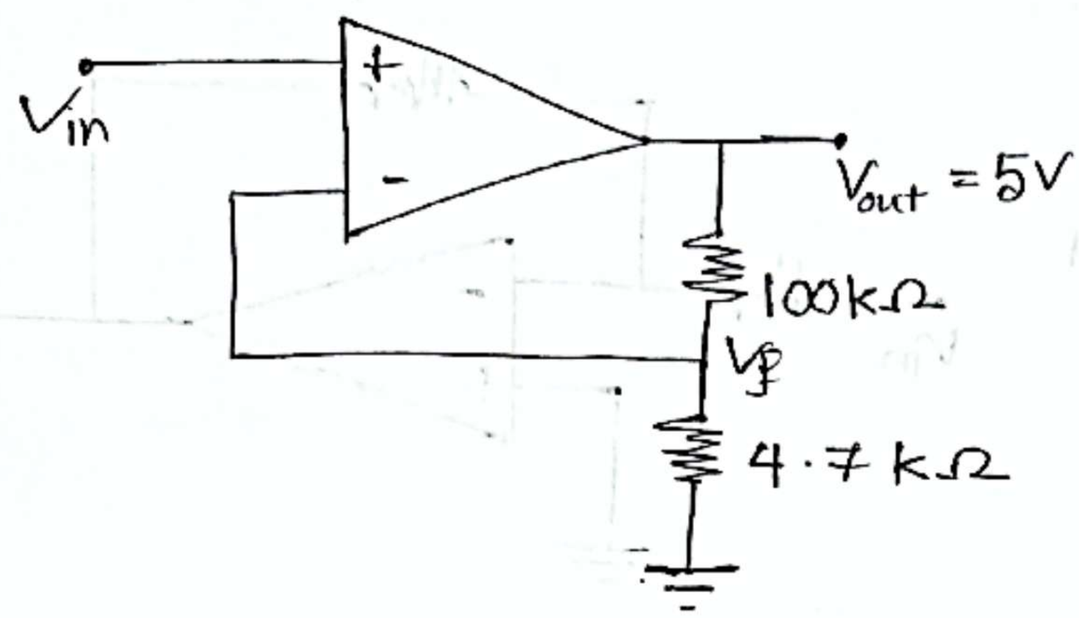
$$A_{CL}(NI) = 1 + \frac{R_f}{R_i}$$

$$A_{CL}(I) = -\frac{R_f}{R_i}$$

$$B = \frac{R_i}{R_i + R_f}$$

$$V_f = B V_{out}$$

Examples: 12·3



ⓐ. Determine the closed loop gain. The open loop gain in 1,00,000

ⓑ. Determine B, V_f

Answer:

ⓐ. Closed loop gain $= 1 + \frac{R_f}{R_1}$

$= 1 + \frac{100\,k\Omega}{4.7\,k\Omega}$

$= 22.27$

ⓑ $B = \frac{R_i}{R_i + R_f}$

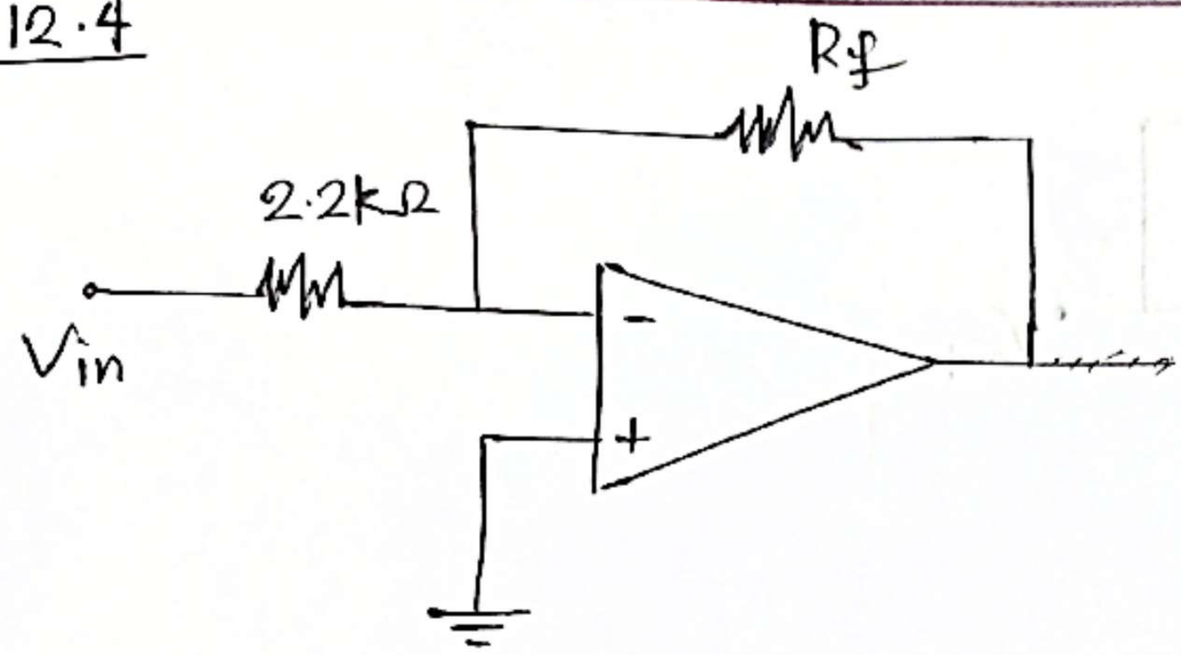
$= 0.044$

$V_f = B\,V_{out}$

$= (0.044 \times 22.27)\,V$

$= 0.224\ V$

12.4



ⓐ. Determine the value of R_f for a gain of -100.

ⓑ. To obtain a range of gain $|A_{CL}|$ as 25 to 100. What is the required range of R_f?

Answer:

ⓐ. $A_{CL} = -\frac{R_f}{R_1}$

$\Rightarrow -100 = -\frac{R_f}{2.2}$

$\Rightarrow R_f = 220\,k\Omega$

ⓑ. $|A_{CL}| = \left|-\frac{R_f}{R_i}\right|$

$\Rightarrow |25| = \left|-\frac{R_f}{2.2k\Omega}\right|$

$\Rightarrow R_f = 55\,k\Omega$

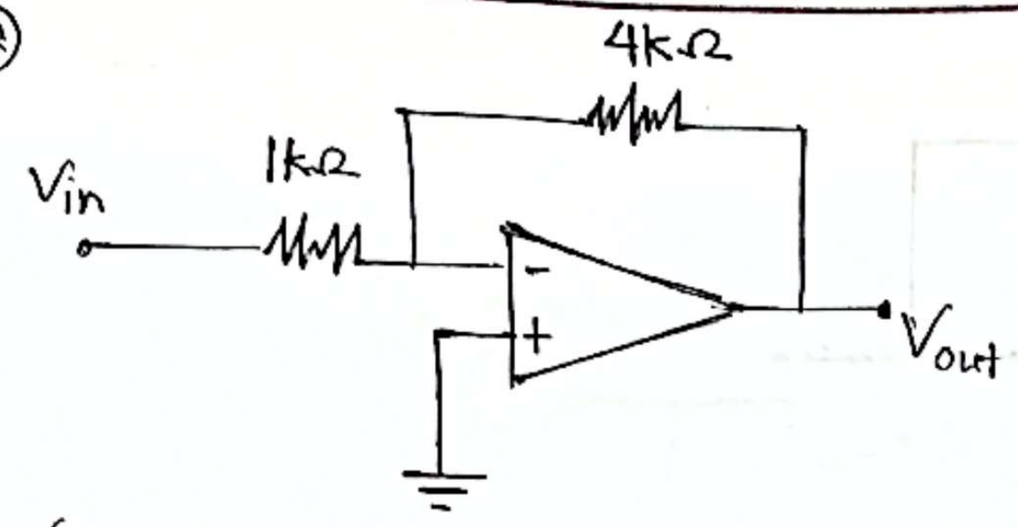
$|A_{CL}| = \left|-\frac{R_f}{R_i}\right|$

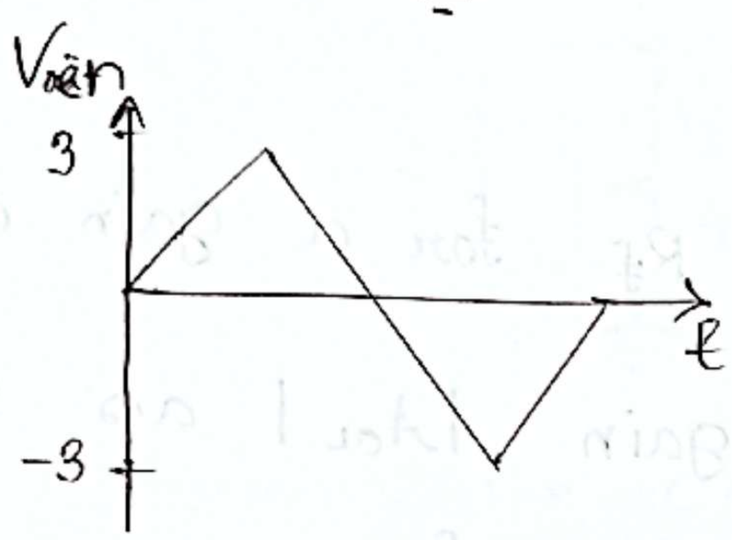
$\Rightarrow |100| = \left|-\frac{R_f}{2.2k\Omega}\right|$

$\Rightarrow R_f = 220\,k\Omega$

$\therefore R_f$ range $= 55\,k\Omega \rightarrow 220\,k\Omega$

(*)



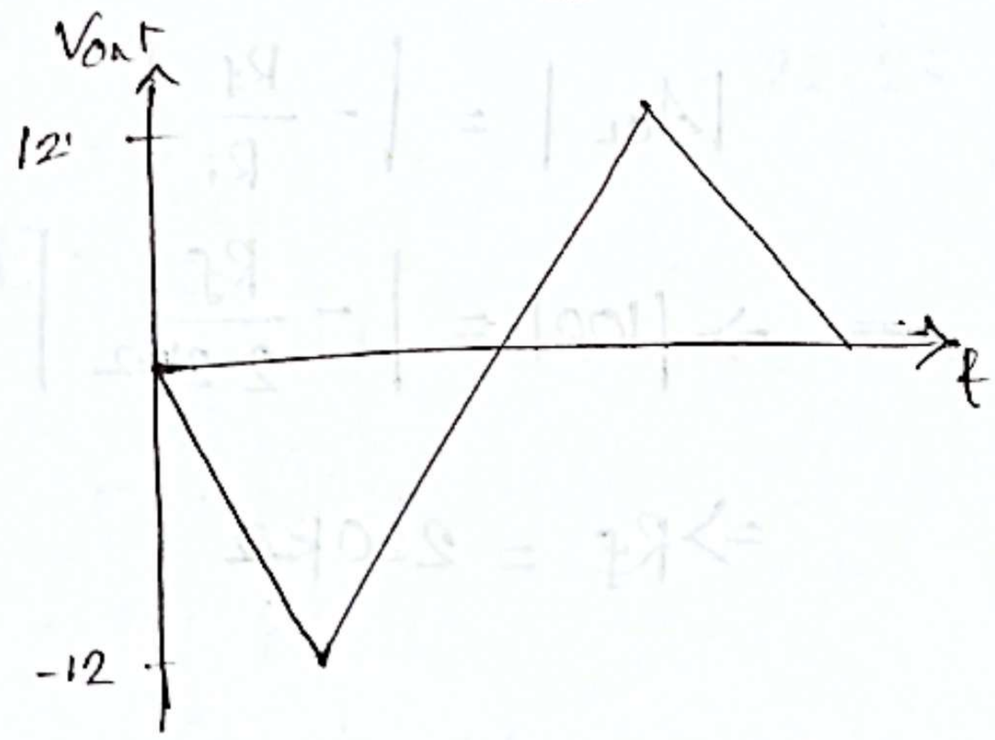


Determine Vout for the following circuit & input waveform.

Answer:

$$A_{CL}(\pm) = -\frac{R_f}{R_i}$$

$$= -\frac{4}{1} = -4$$



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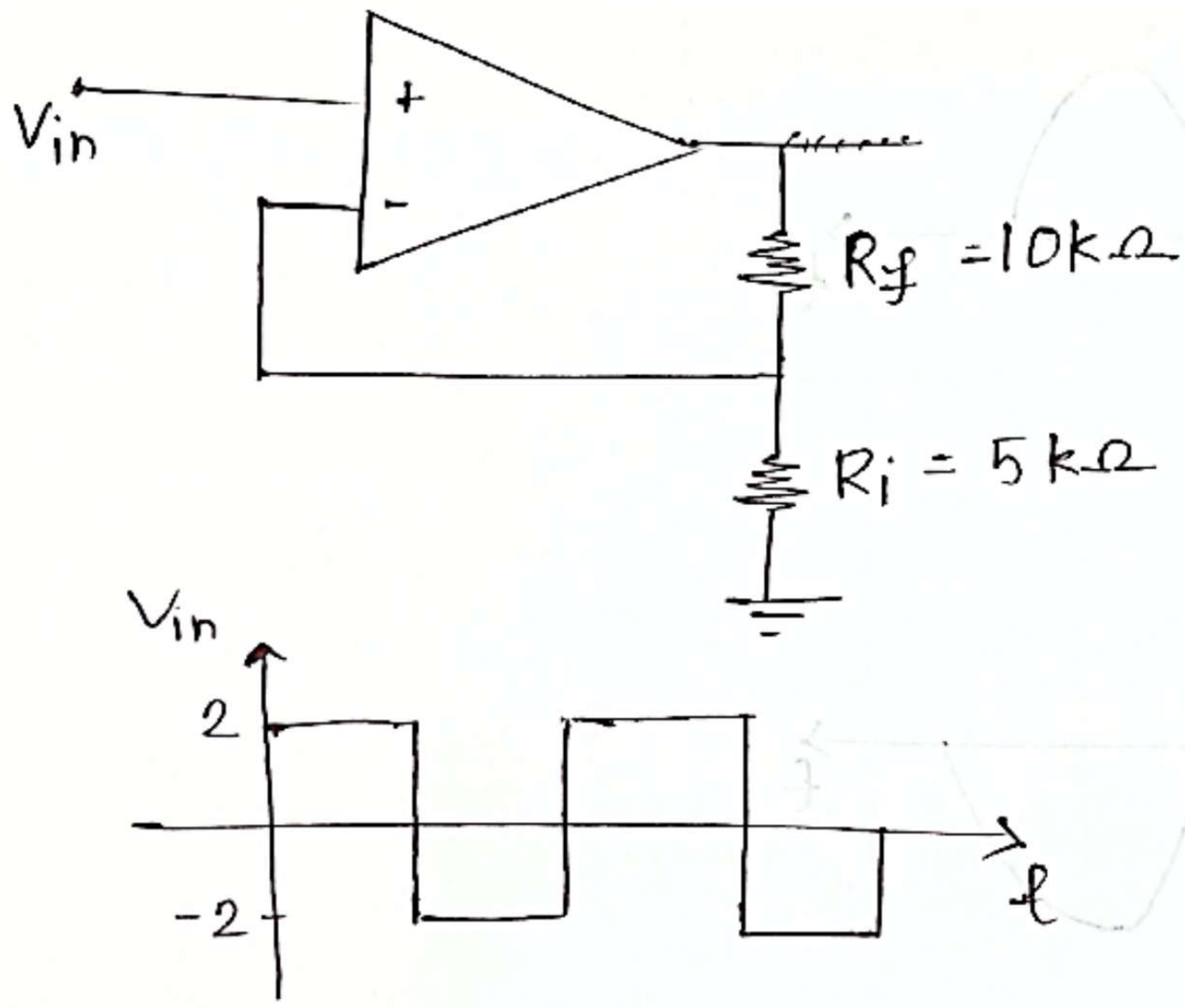


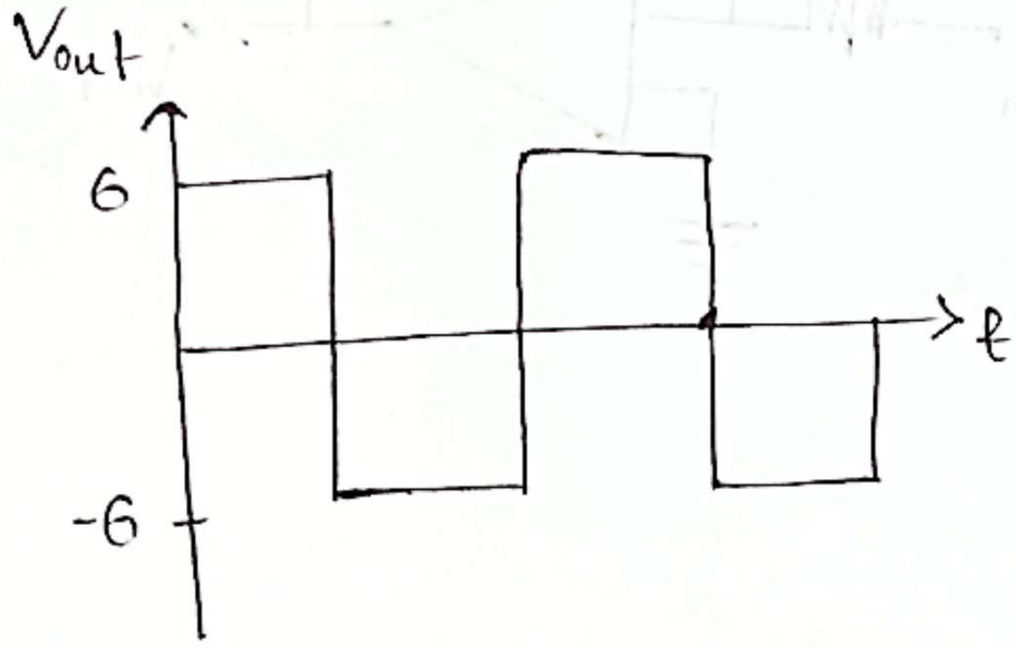
Draw the Vout wave form for the following circuit & input waveform.

<u>Answer:</u>

$$A_{CL} = 1 + \frac{R_f}{R_1}$$

$$= 1 + \frac{10}{5}$$

$$= 3$$



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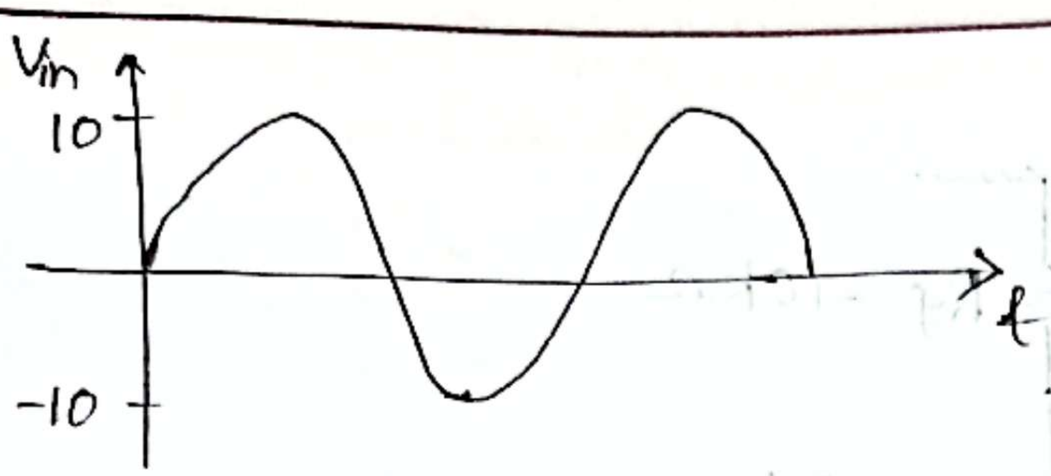
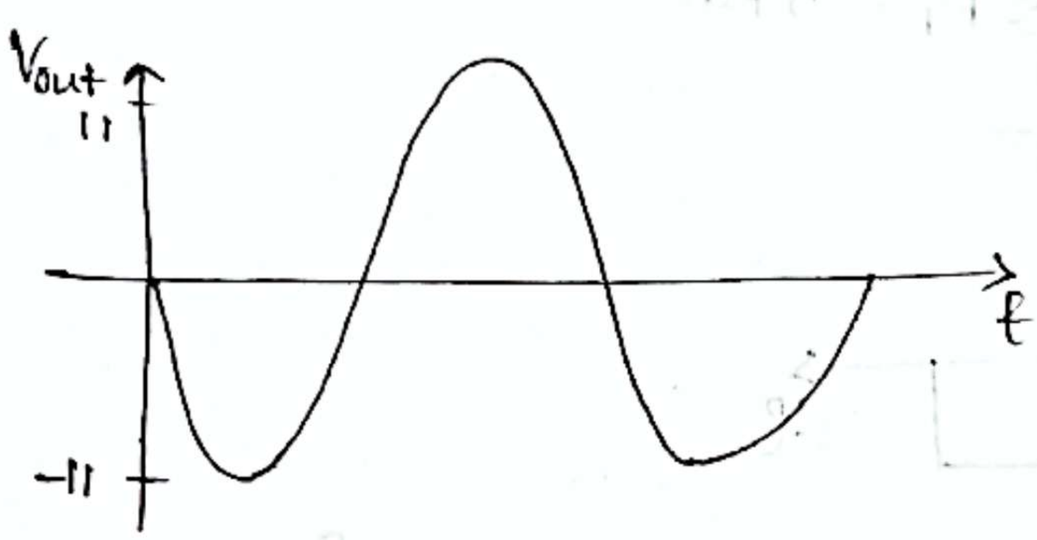




Design an amplifier circuit using op-amp to obtain the following input/output waveform.

Answer:

$$A_{CL}(I) = \frac{-11}{10}$$

$$= -1.1$$

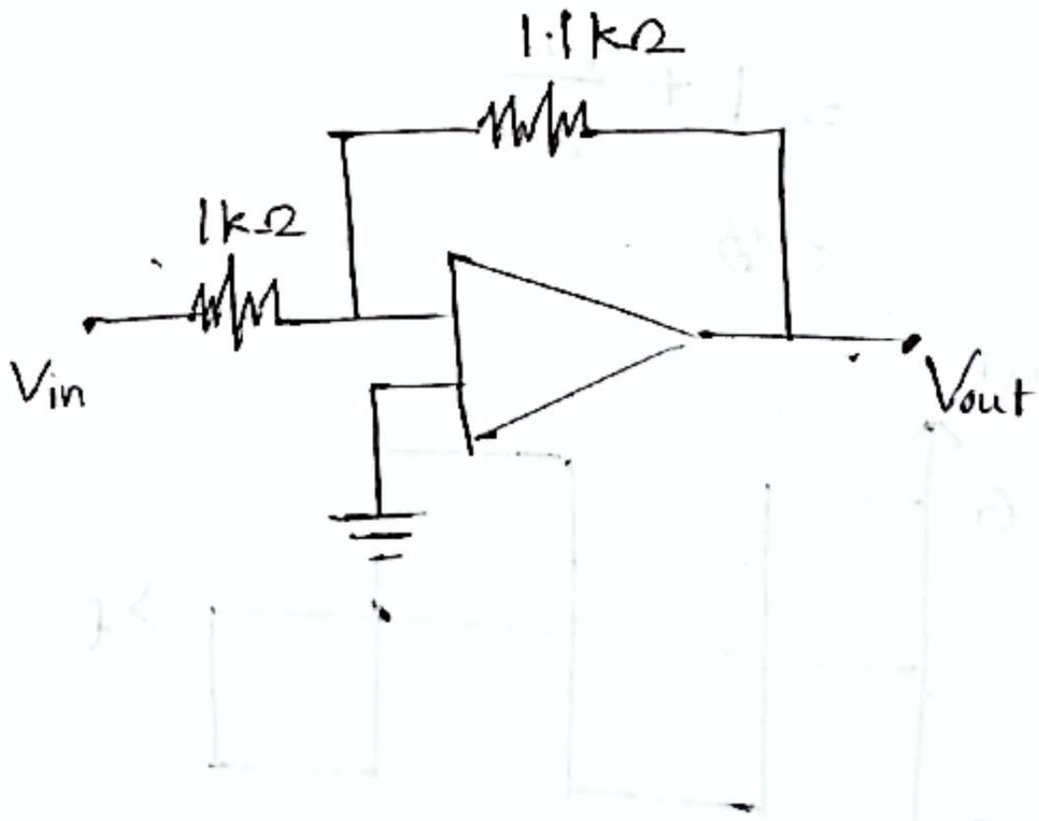
Let, $R_i = 1\,k\Omega$

$$-\frac{R_f}{R_i} = -1.1$$

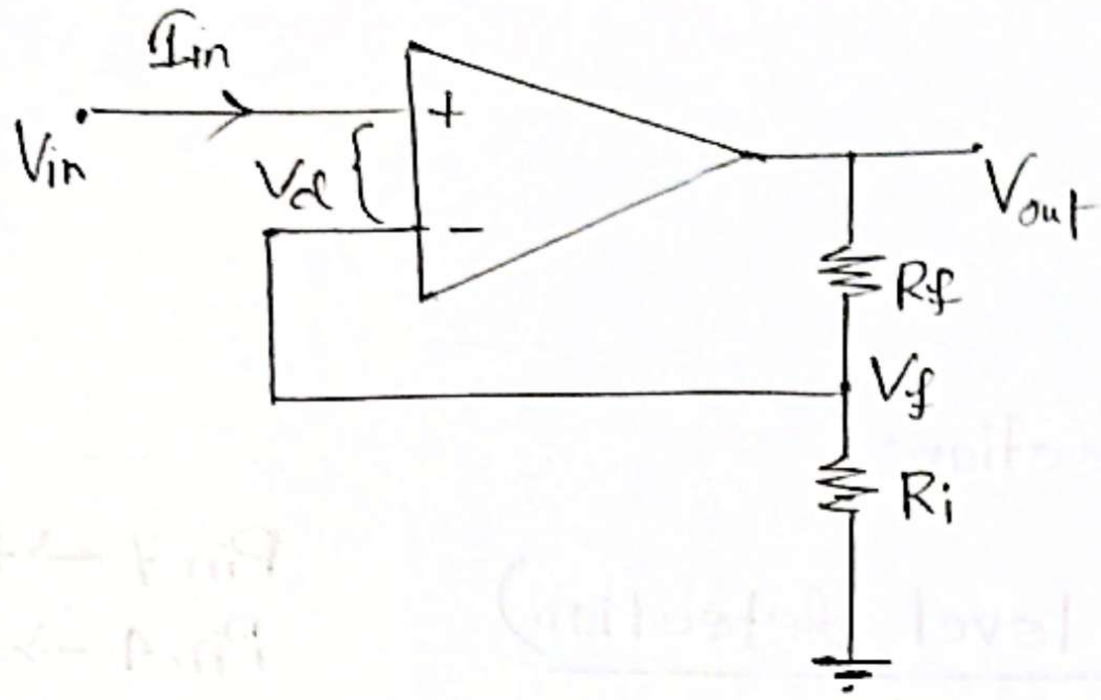
$$\Rightarrow R_f = 1.1 R_i$$

$$\Rightarrow R_f = (1.1 \times 1)\,k\Omega$$

$$\therefore R_f = 1.1\,k\Omega$$



Effect on input impedence: (Non-inverting Amplifier)



Equations:

$$B = \frac{R_i}{R_i + R_f}$$

$$V_f = B\,V_{out}$$

$$A_{OL} = \frac{V_{out}}{V_d}$$

Op-amp ← $$Z_{in} = \frac{V_d}{I_{in}}$$

$$Z_{in}(NI) = \frac{V_{in}}{I_{in}}$$

$$V_d = V_{in} - V_F$$

$$\Rightarrow V_{in} = V_d + V_f$$

$$= V_d + B\,V_{out}$$

$$= V_d + B\cdot(A_{OL}\cdot V_d)$$

$$= V_d\,(1 + BA_{OL})$$

$$\Rightarrow \frac{V_{in}}{I_{in}} = \frac{V_d(1+BA_{OL})}{I_{in}}$$

$$\Rightarrow Z_{in}(NI) = Z_{in}\,(1 + B\cdot A_{OL})$$

30/11/2025

Lecture-05

Comparator

Book → Floyd
Chapter → 13

Application:

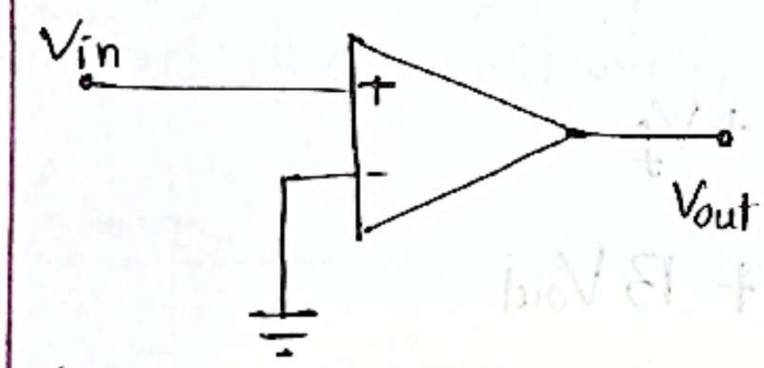
① Zero level detection

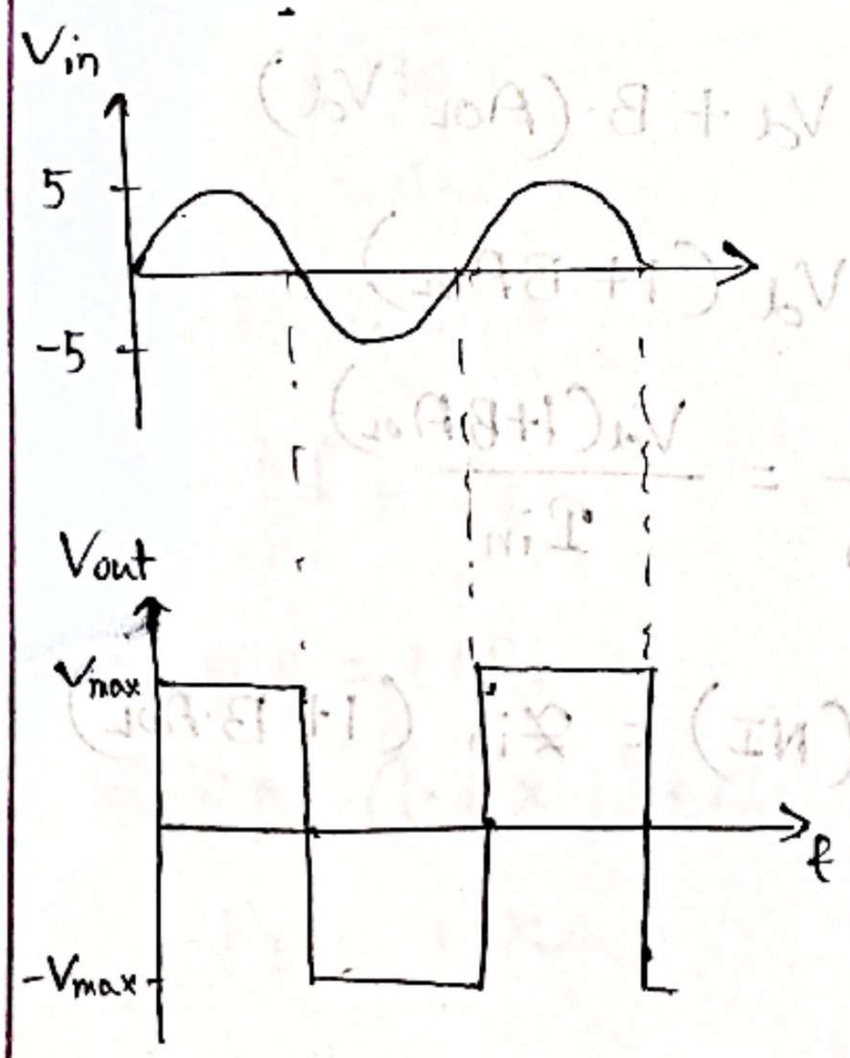
② Non-zero level detection

Comparator: (Zero level detection)

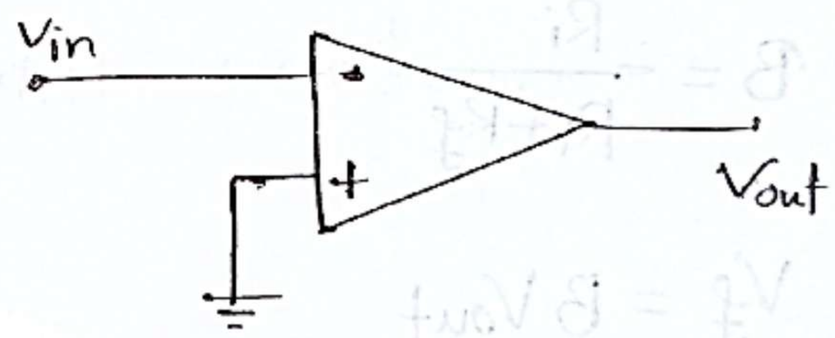
Pin 7 → +Vmax
Pin 4 → −Vmax

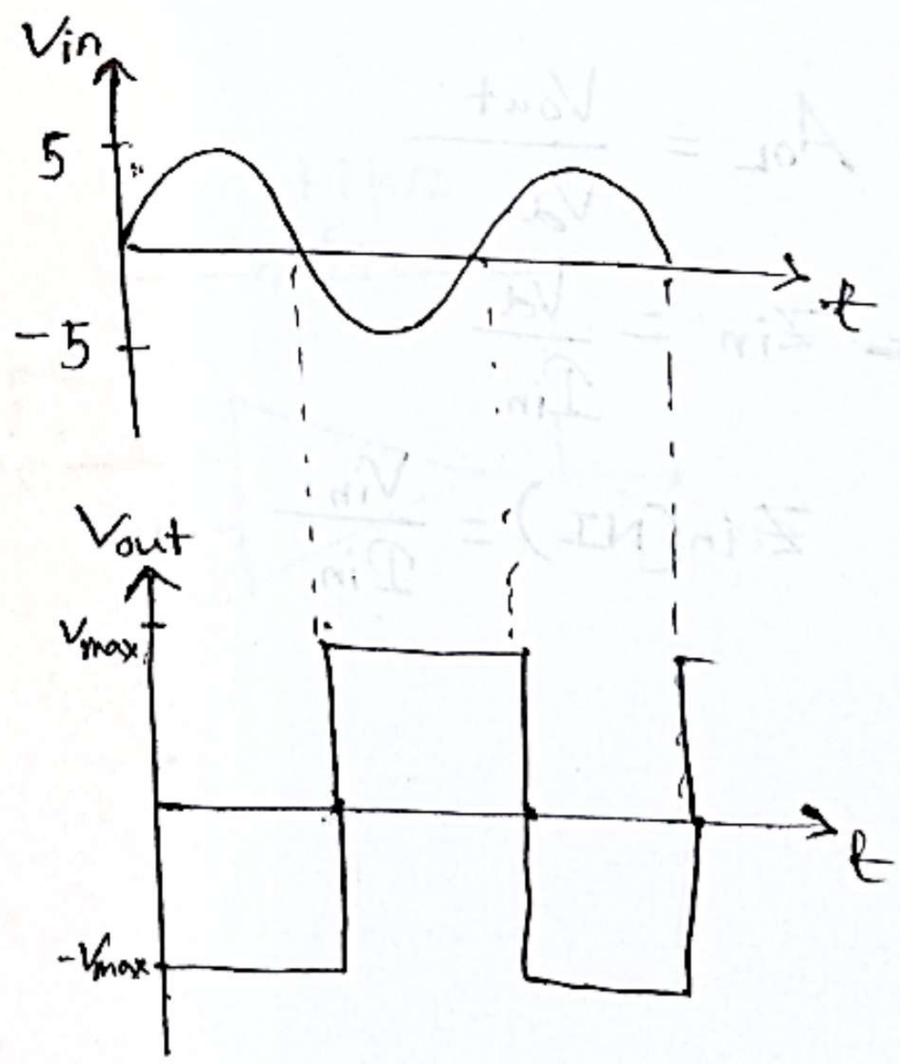
Non-inverting input





Inverting Input

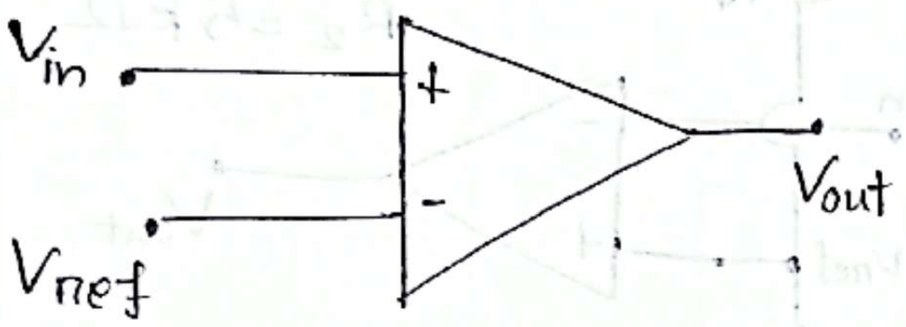


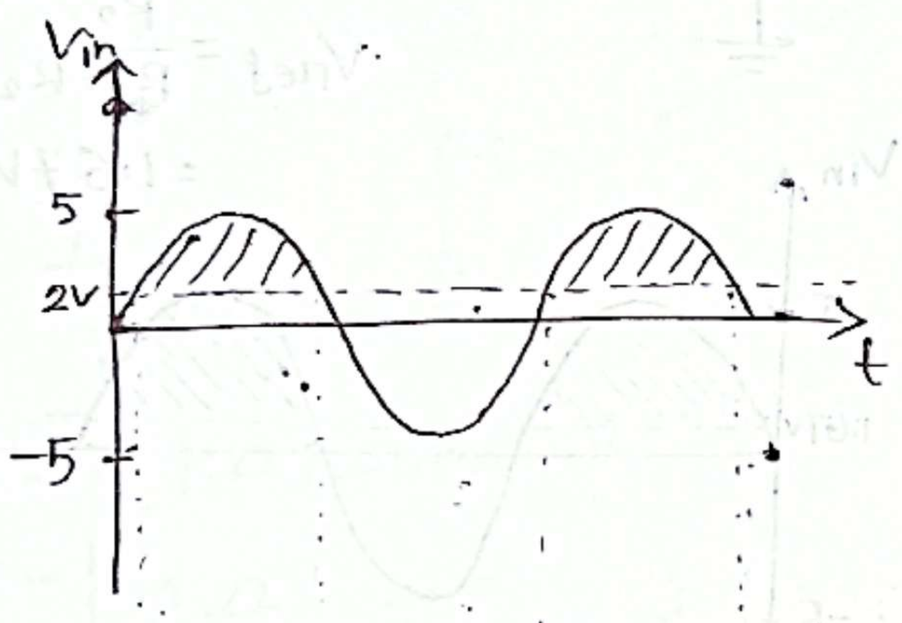


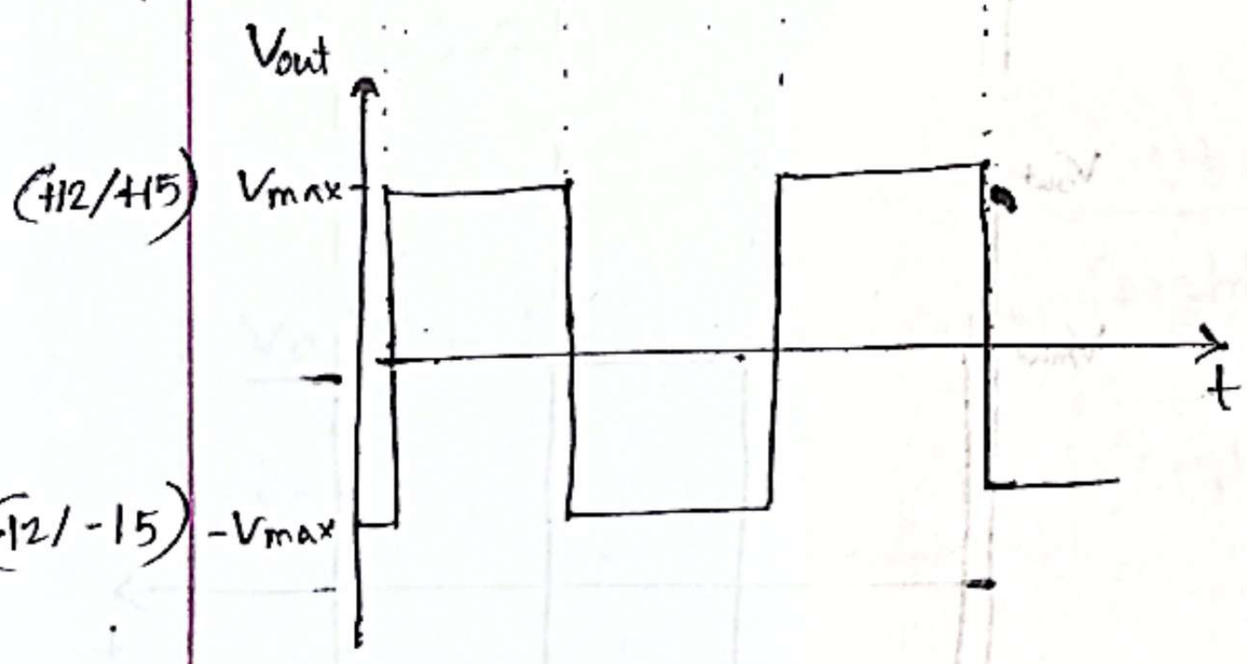
Comparator (Non-zero level detection)

Pin 7 → +Vmax
Pin 4 → -Vmax
Vref → 2V

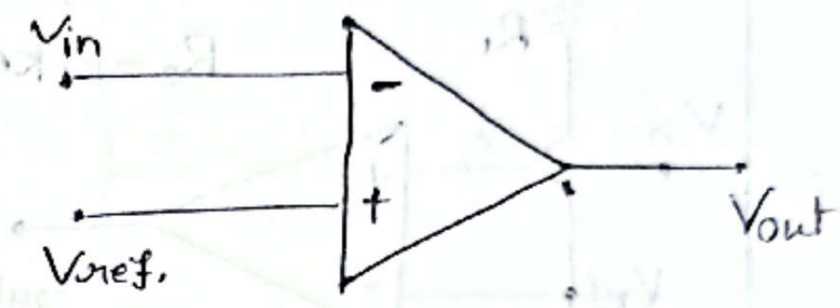
Non-inverting input:

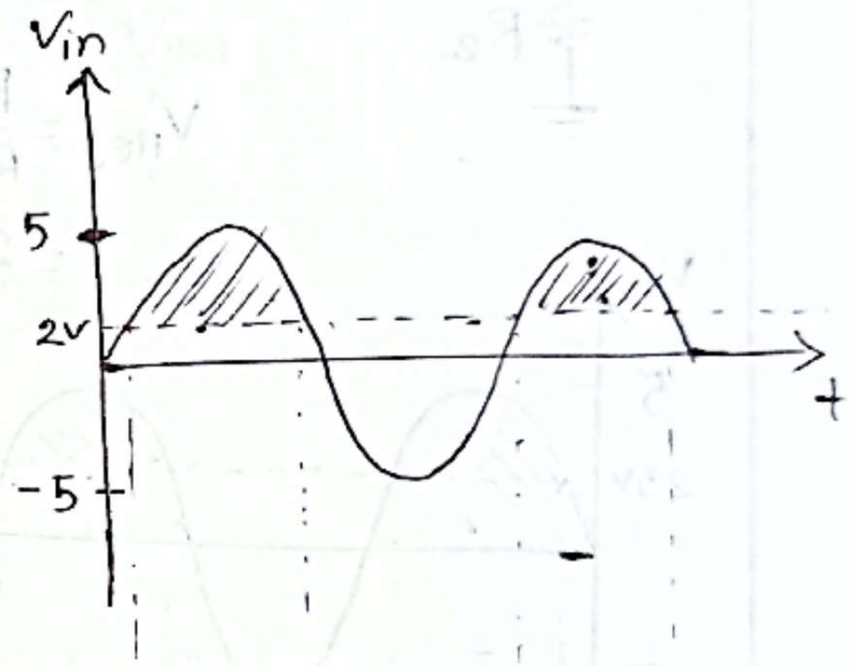


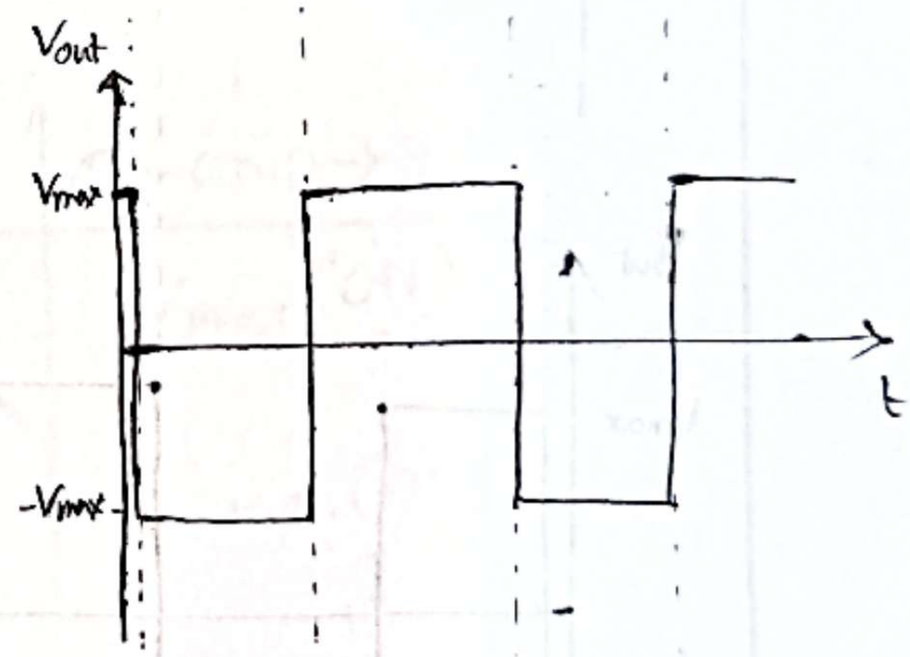




Inverting input

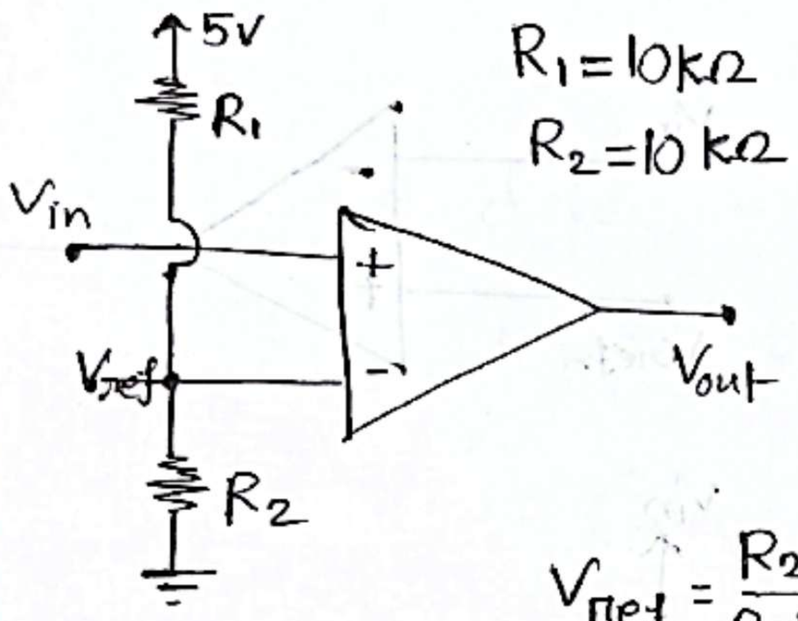






Comparator : Non-zero level detection (Voltage Divider)

Non-inverting input

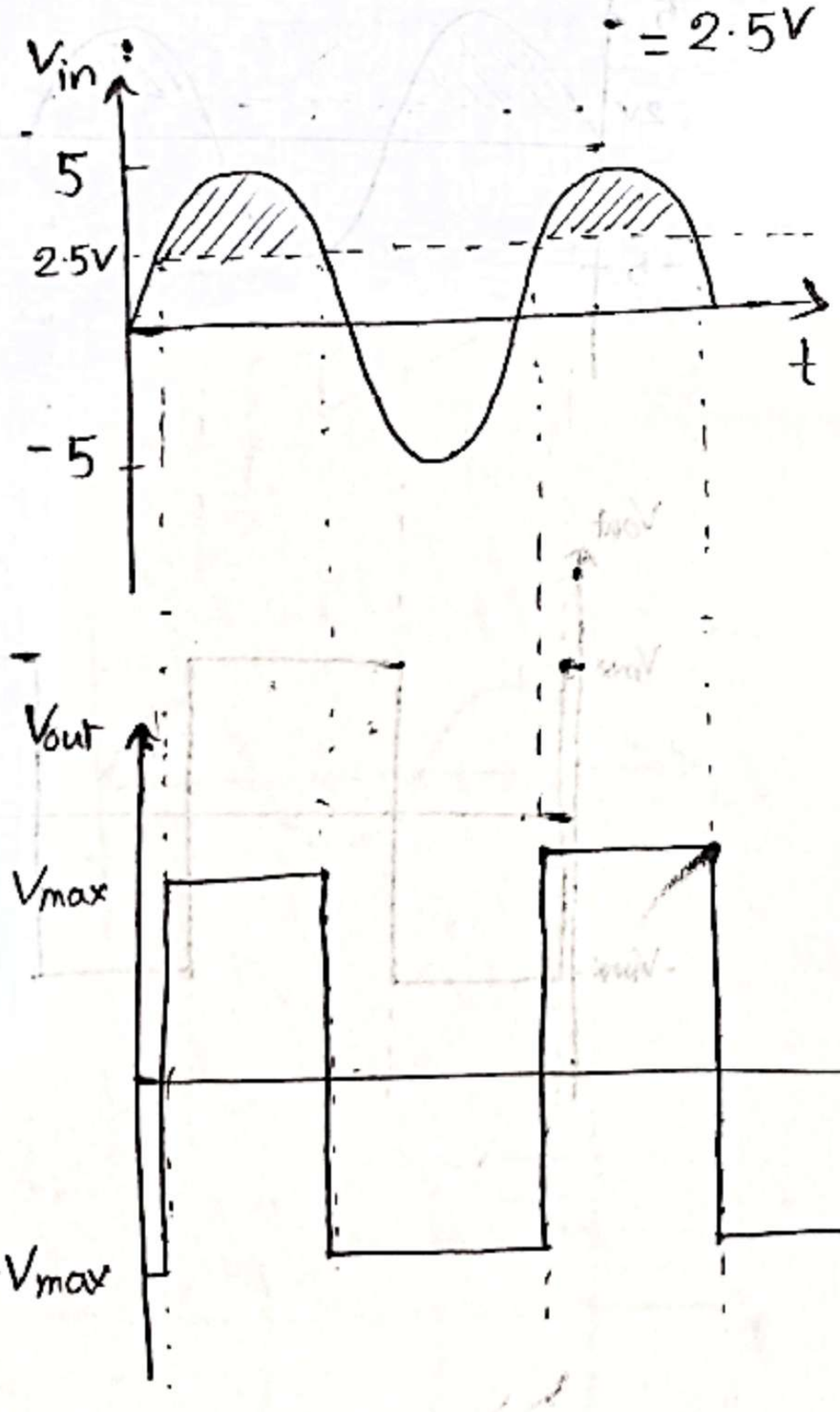


$R_1 = 10k\Omega$

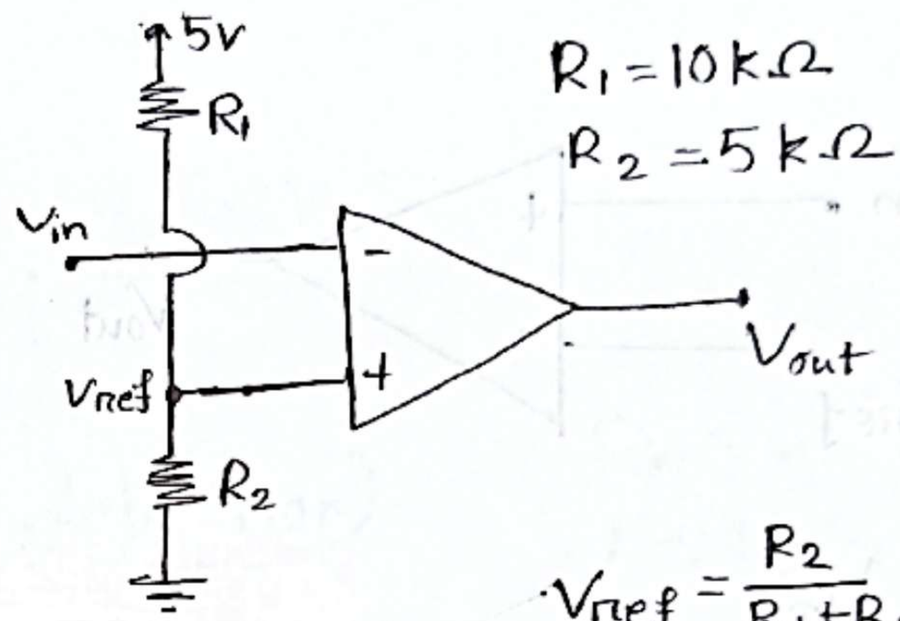
$R_2 = 10\,k\Omega$

$$V_{ref} = \frac{R_2}{R_1+R_2} \times 5V$$

$$= 2.5V$$



Inverting input

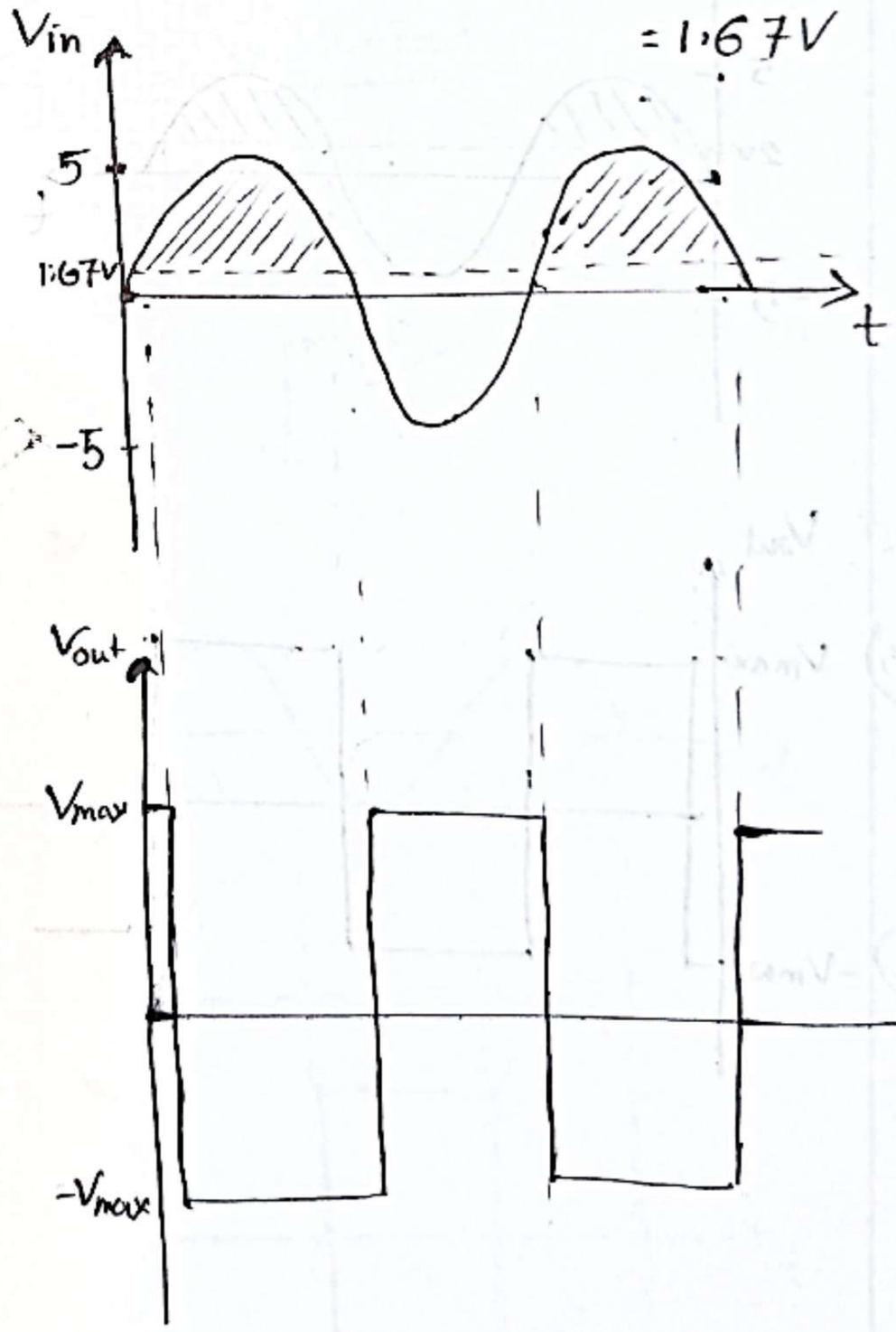


$R_1 = 10\,k\Omega$

$R_2 = 5\,k\Omega$

$$V_{ref} = \frac{R_2}{R_1+R_2} \times 5V$$

$$= 1.67V$$



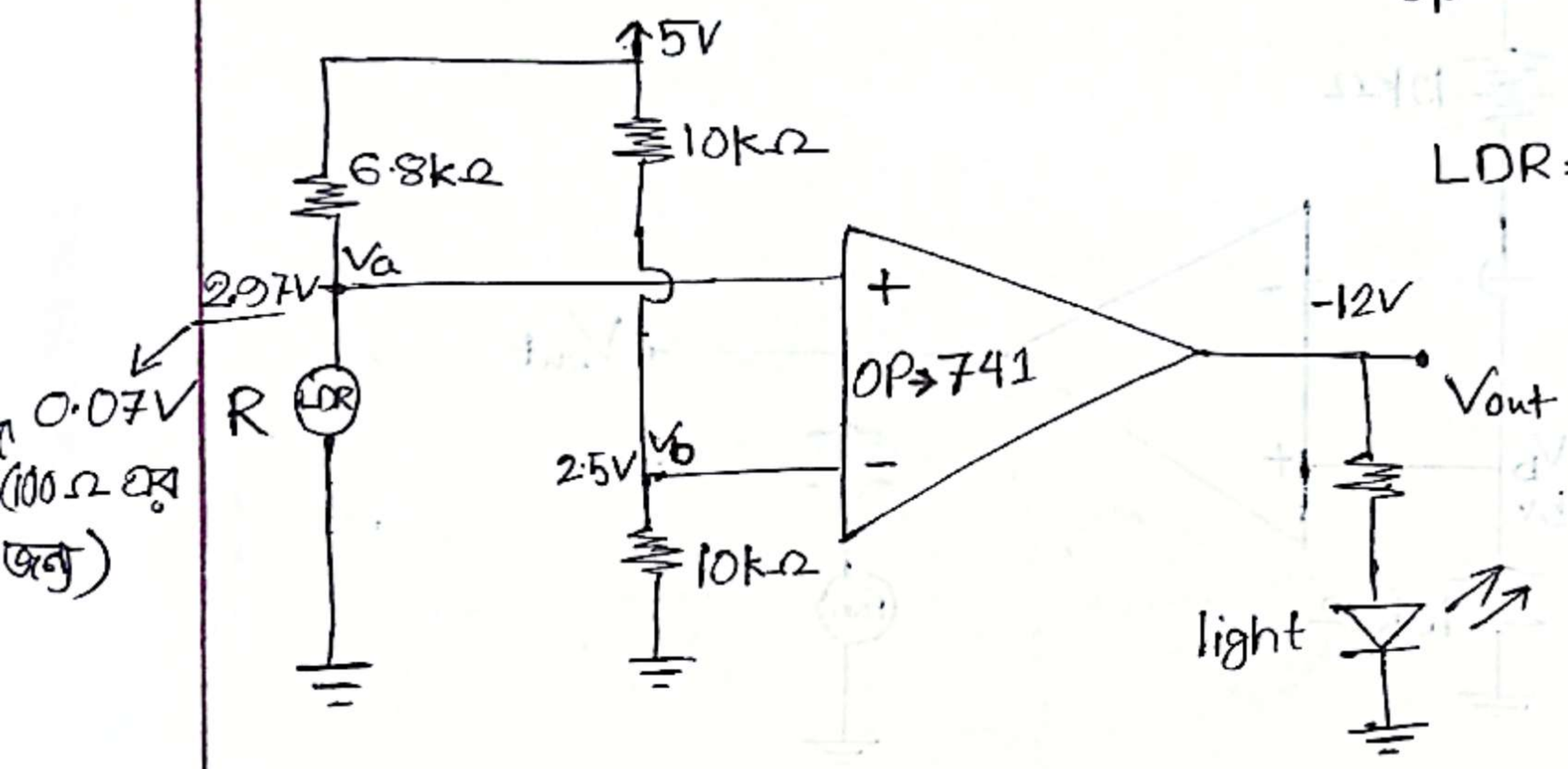
Darkness → Output : Positive

Automatic Street Light:

Op-amp → 741 | 7pin → +Vmax
4pin → -Vmax

Single power supply
↳ Op-amp → 358 | 8pin → Positive
4pin → Ground

LDR = Light dependent Resistance



$V_a = \frac{10}{10+6.8} \times 5$
$= 2.97V$

$V_b = \frac{10}{10+10} \times 5$
$= 2.5V$

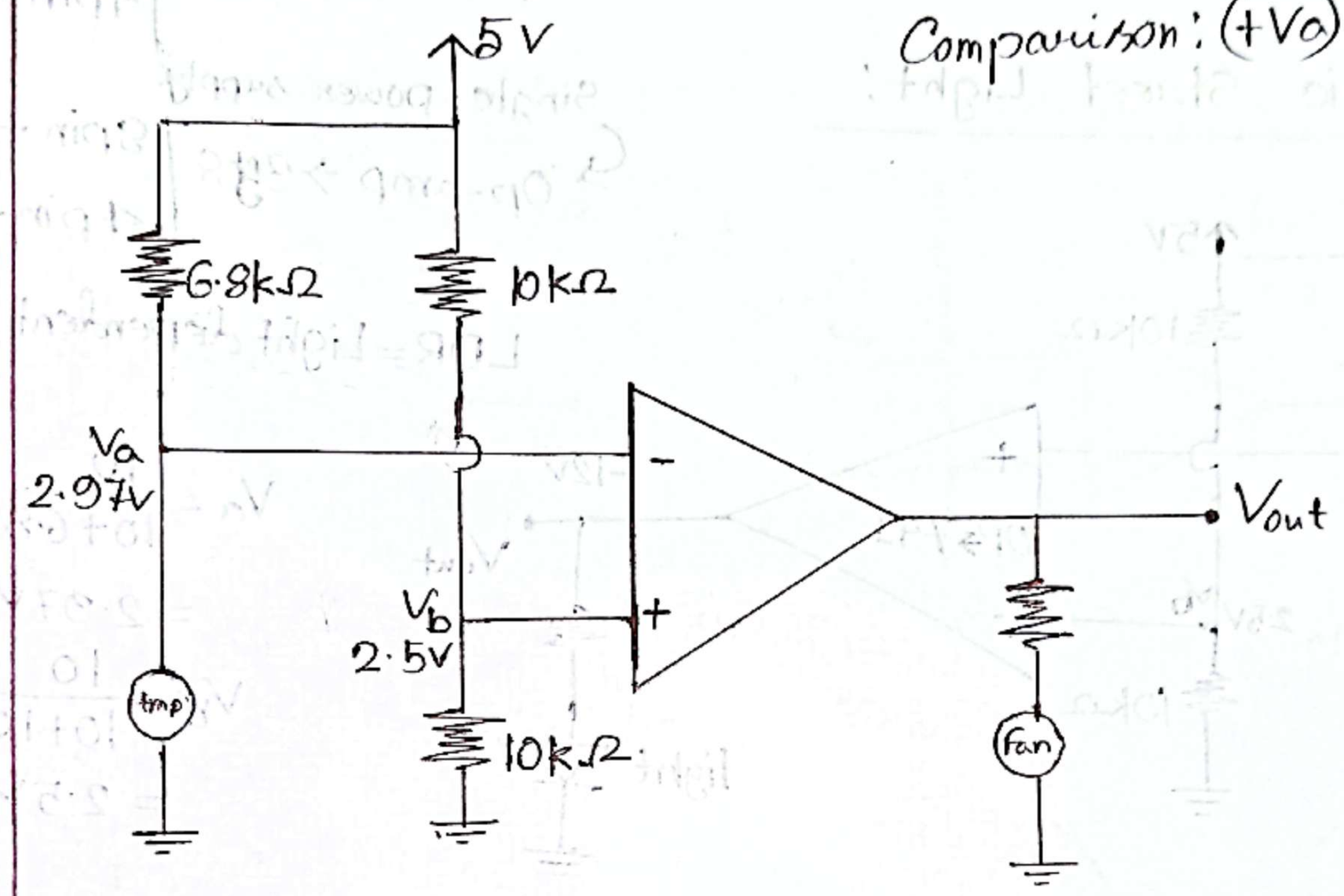
R = 10 kΩ, when dark

R = 100 Ω, when light

≈ 300 Ω, " "

	Op-amp → 358	Op-amp → 741
$V_a > V_b$ হলে,	Vpositive (Light ON)	Vmax (ON)
$V_a < V_b$ হলে,	Ground (Light OFF)	-Vmax (OFF)

Automatic Fan



Comparison: $(+V_a) - (-V_a)$

R = 10 kΩ, when normal temp

R = 100 Ω, when temp. high

≈ 300 Ω, " " "

	Op-amp → 358	Op-amp → 741
$V_a > V_b$ হলে,	Ground Fan OFF	$-V_{max}$ Fan OFF
$V_a < V_b$ হলে,	Vpositive Fan ON	V_{max} Fan ON

6/12/2025

Lecture-06

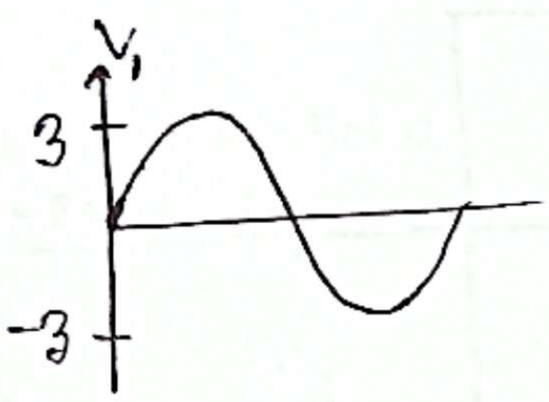
Summing Amplifier

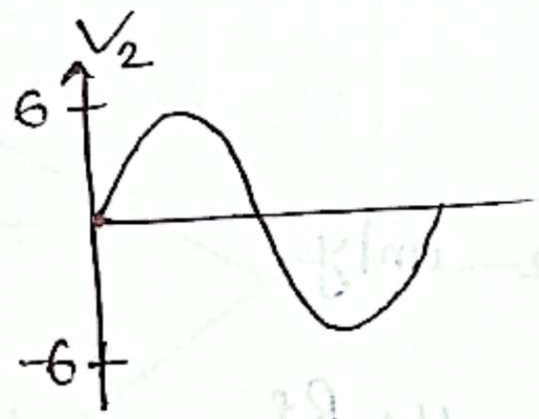
Book: Floyd
Chapter: 13

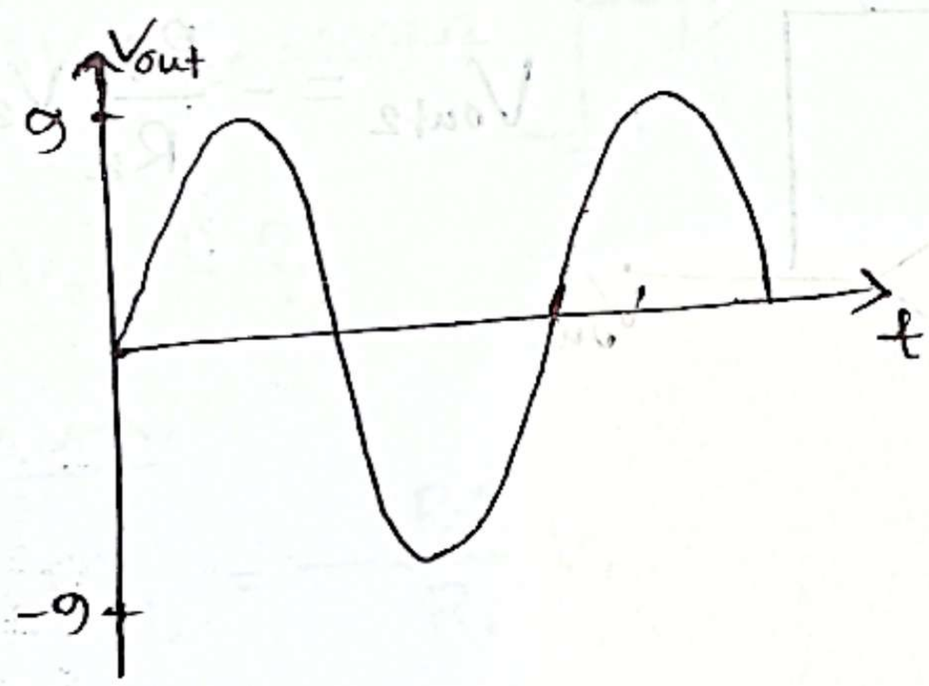
$V_{out} = aV_1 + bV_2 \Rightarrow -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2}\right)$

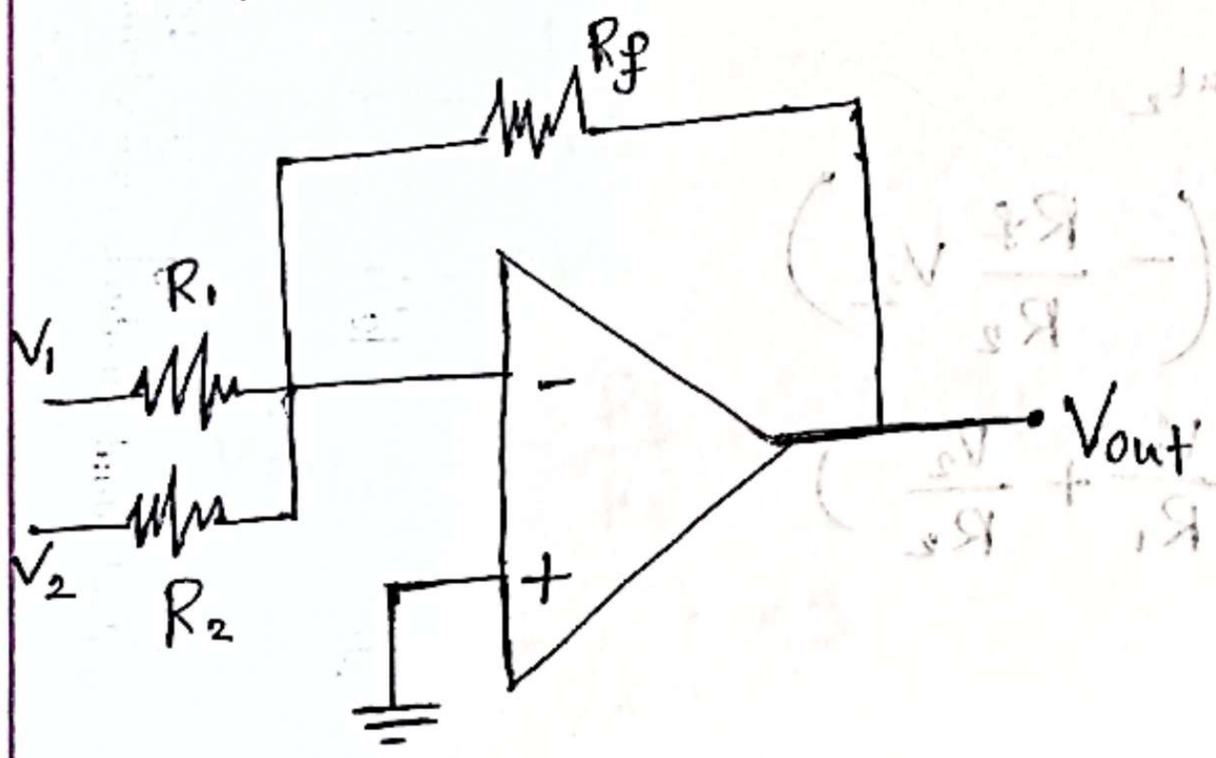
$V_{out} = V_1 + V_2 \Rightarrow R_1 = R_2 = R_f$

$V_{out} = P(V_1 + V_2) \Rightarrow R_1 = R_2$



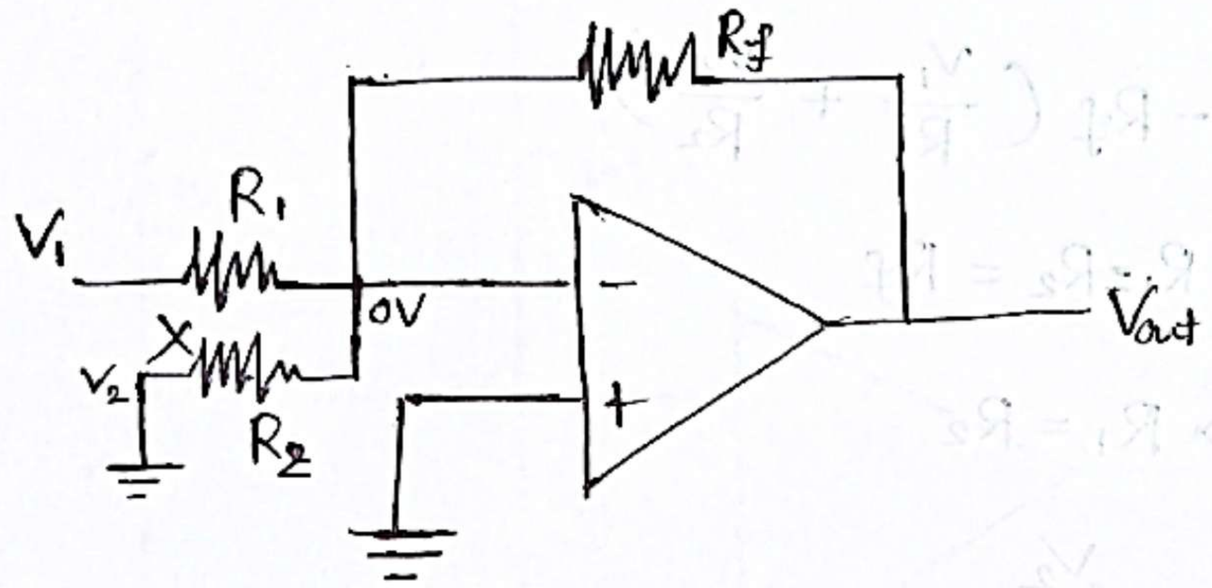






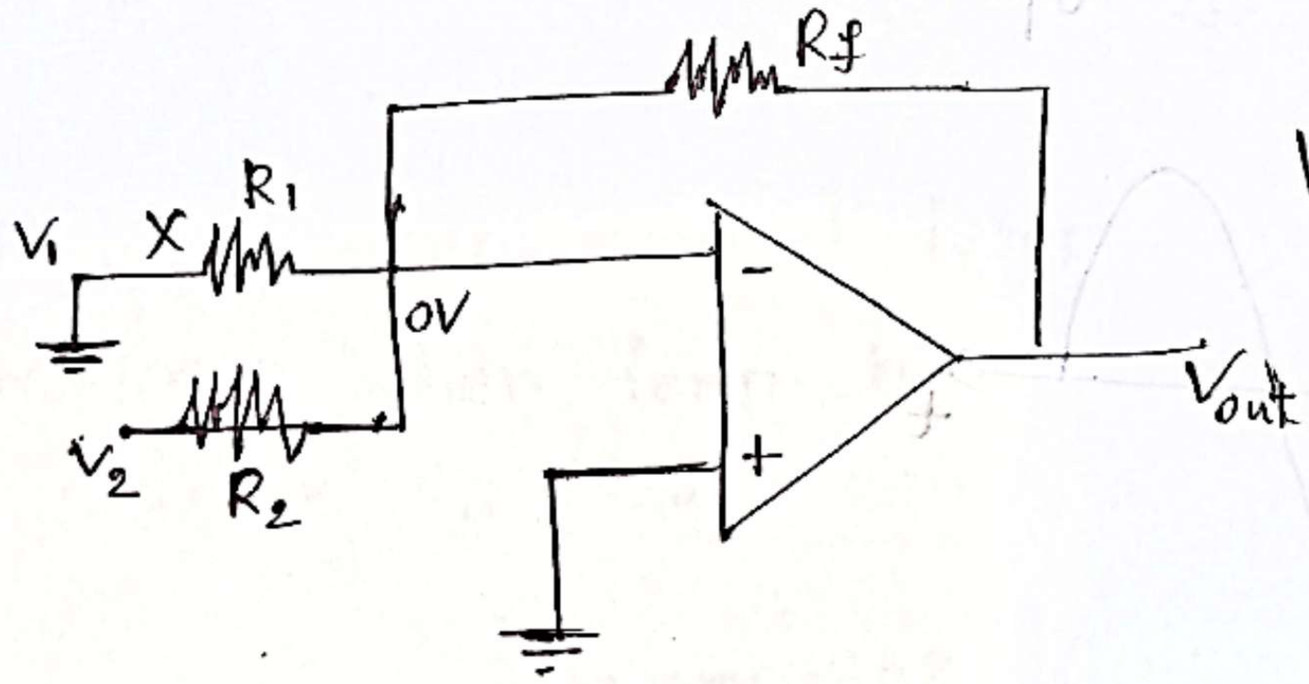
Using Superposition Principle:

① Considering V_1 only:



$$V_{out_1} = -\frac{R_f}{R_1} V_1$$

② Considering V_2 only



$$V_{out_2} = -\frac{R_f}{R_2} V_2$$

$$V_{out} = V_{out_1} + V_{out_2}$$

$$= -\frac{R_f}{R_1} V_1 + \left(-\frac{R_f}{R_2} V_2\right)$$

$$= -R_f \left(\frac{V_1}{R_1} + \frac{V_2}{R_2}\right)$$

Design the following function:

- $V_{out} = -\left(\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2\right)$

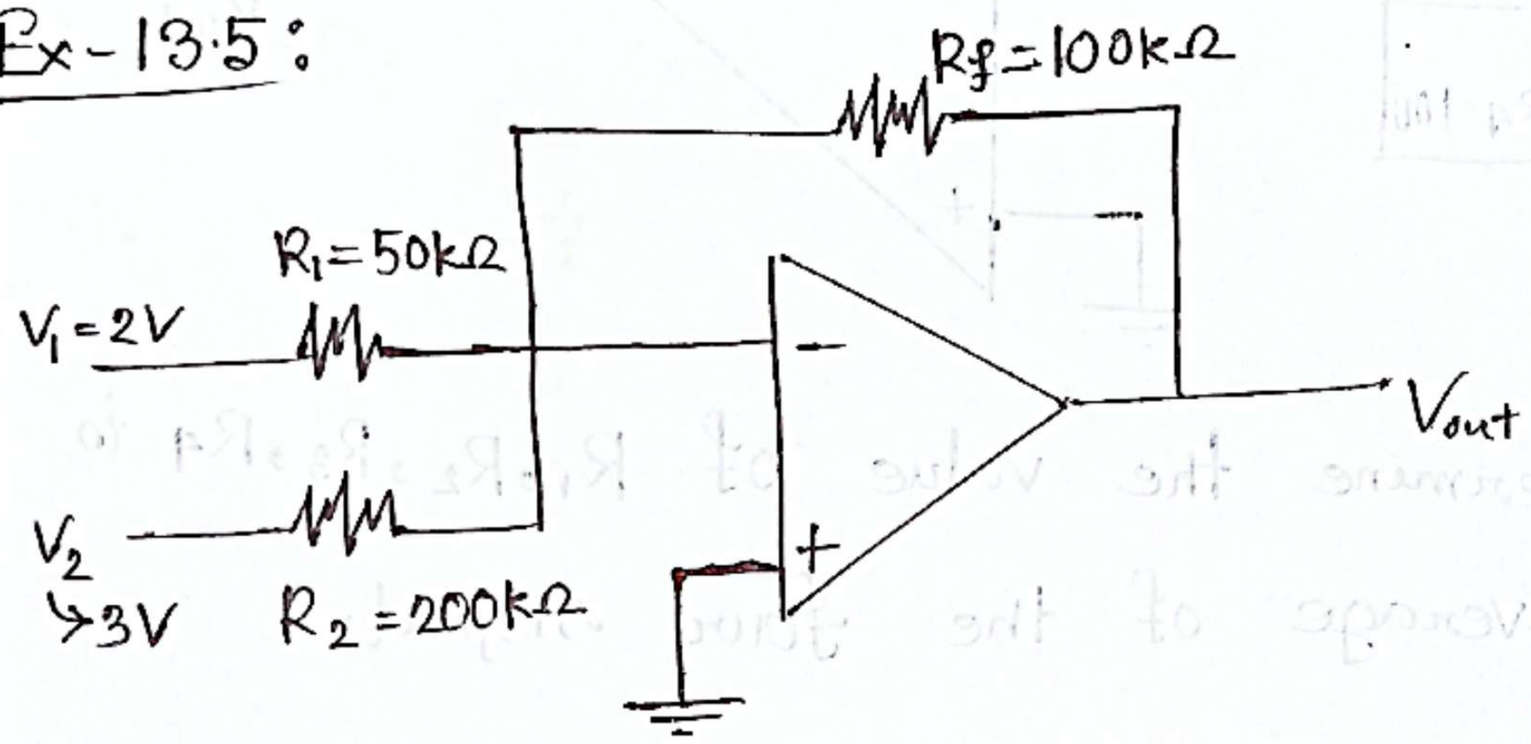
$= -(aV_1 + bV_2)$

① $-(5V_1 + 2.5V_2)$

② $-(V_1 + V_2)$ $\Rightarrow R_1 = R_2 = 1k\Omega$

③ $-3(V_1 + V_2)$ $\Rightarrow R_f = 3k\Omega$

Ex-13.5:



$V_{out} = ?$

Answer:

$$V_{out_1} = -\frac{R_f}{R_1}V_1$$

$$= -\frac{100}{50} \times 2$$

$$= -4V$$

$$V_{out_2} = -\frac{R_f}{R_2}V_2$$

$$= -\frac{100}{200} \times 3$$

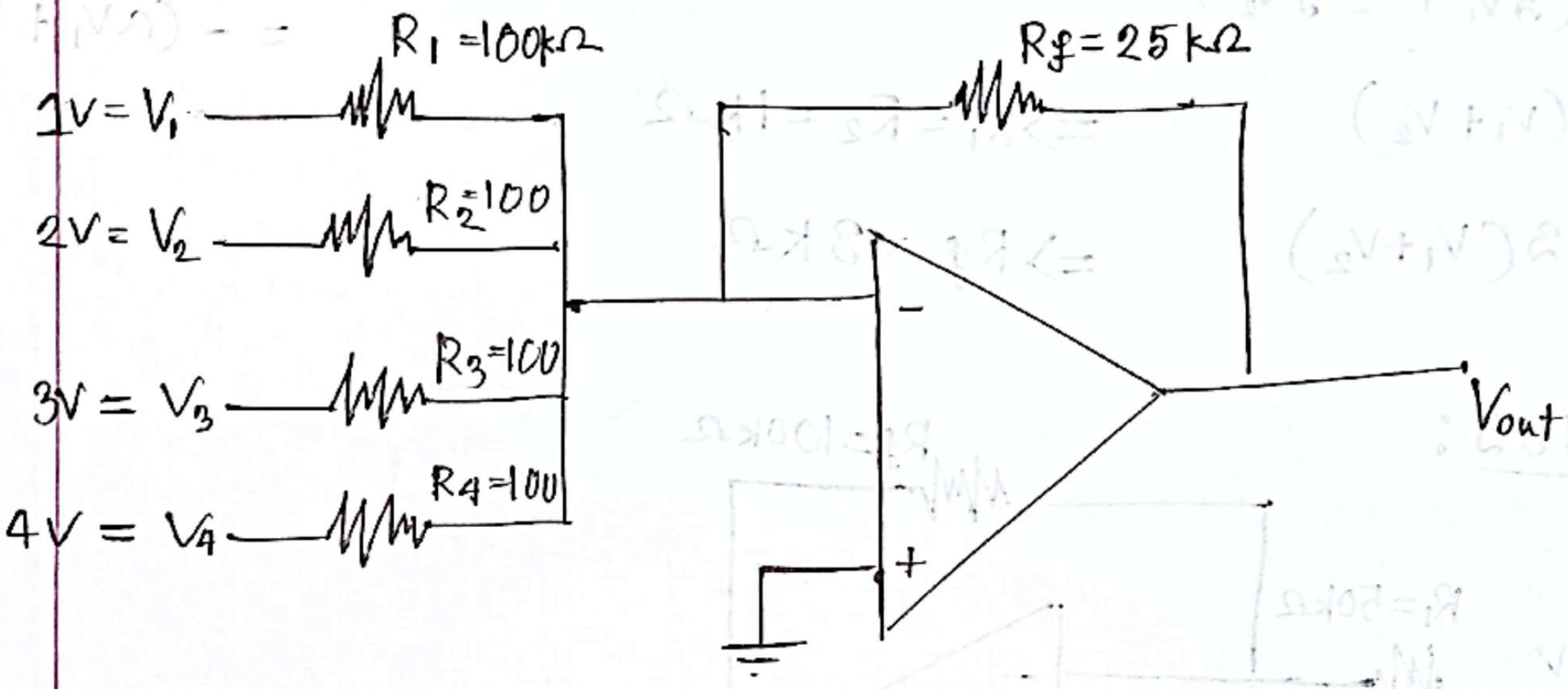
$$= -1.5V$$

$\therefore V_{out} = V_{out_1} + V_{out_2}$

$= -4V + (-1.5V)$

$= -5.5V$

Ex-13.6



Question: Determine the value of R_1, R_2, R_3, R_4 to get the average of the four signal.

Answer:

$$V_{out} = \frac{V_1 + V_2 + V_3 + V_4}{4}$$

$$= \frac{1+2+3+4}{4}$$

$$= 2.5V$$

$$V_{out} = -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} + \frac{V_4}{R_4}\right)$$

$$\Rightarrow -\left(\frac{V_1+V_2+V_3+V_4}{4}\right) = -R_f\left(\frac{V_1}{R} + \frac{V_2}{R} + \frac{V_3}{R} + \frac{V_4}{R}\right)$$

$$\Rightarrow -\left(\frac{V_1}{4} + \frac{V_2}{4} + \frac{V_3}{4} + \frac{V_4}{4}\right) = -\frac{R_f}{R}(V_1+V_2+V_3+V_4)$$

$$\Rightarrow \frac{R_f}{R} = \frac{1}{4}$$

$\therefore R_1 = R_2 = R_3 = R_4 = R$

$R = 4R_f$

$R_f = 25\,k\Omega$

$\therefore R = (4 \times 25)\,k\Omega$

$= 100\,k\Omega$

Averaging Amplifier:

① $R_1 = R_2 = R_3 = \dots R_n = R$

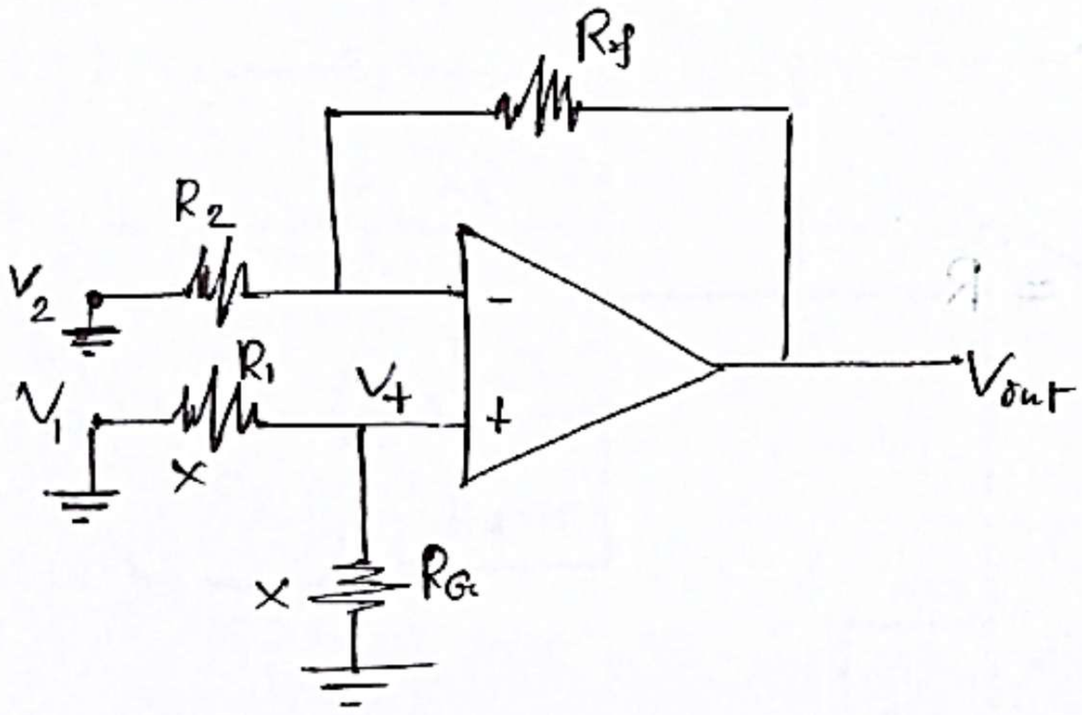
② $R = nR_f$

H.W. $\Rightarrow$ Ex - 13.7

7/12/2025

Lecture-07

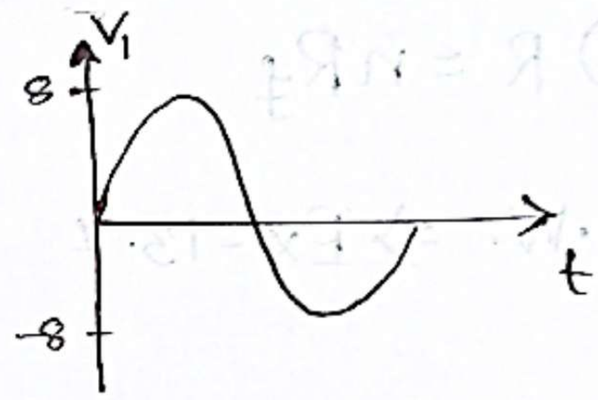
Differential Amplifier

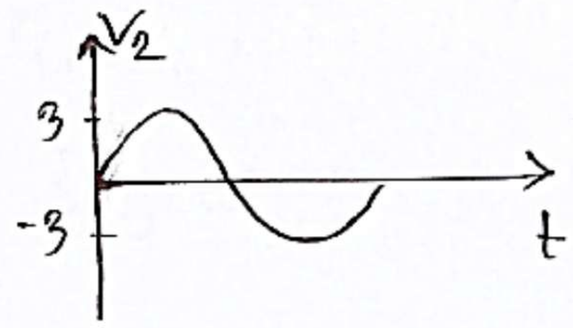


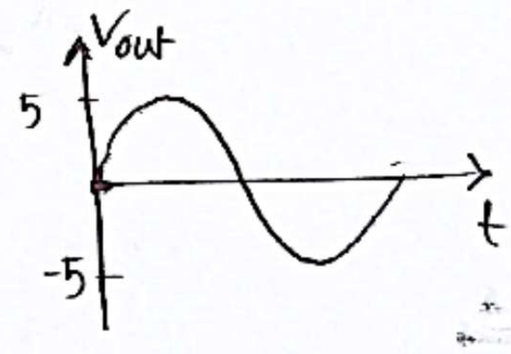
$V_{out} = V_1 - V_2$ [a=b=1]

$V_{out} = aV_1 - bV_2$

$V_{out} = a(V_1 - V_2)$







Using Superposition Principle:

Considering V_2 only;

$$V_{out_2} = -\frac{R_f}{R_2} V_2$$

Considering V_1 only;

$$V_{out_1} = \left(1 + \frac{R_f}{R_2}\right) V_+$$

$$= \left(1 + \frac{R_f}{R_2}\right)\left(\frac{R_G}{R_1 + R_G}\right) V_1$$

$$V_{out} = V_{out_1} + V_{out_2}$$

$$= \left(1 + \frac{R_f}{R_2}\right)\left(\frac{R_G}{R_1 + R_G}\right) V_1 + \left(-\frac{R_f}{R_2}\right) V_2$$

$$= \left(1 + \frac{R_f}{R_2}\right)\left(\frac{R_G}{R_1 + R_G}\right) V_1 - \frac{R_f}{R_2} V_2$$ } → final equation of differential Amplifier.

$$V_{out} = aV_1 - bV_2$$

Design the following function:

① $V_{out} = V_1 - V_2$

② $V_{out} = 2V_1 - 3V_2$

2 types question:

① Circuit given, Vout find

② function given, circuit draw

Answer:

① $V_{out} = \left(1+\frac{R_f}{R_2}\right)\left(\frac{R_G}{R_1+R_G}\right)V_1 - \frac{R_f}{R_2}V_2$

Here, $\frac{R_f}{R_2} = 1$

$\Rightarrow R_f = R_2$

Let, $R_2 = 1k\Omega$

So, $R_f = 1k\Omega$

And, $\left(1+\frac{R_f}{R_2}\right)\left(\frac{R_G}{R_1+R_G}\right) = 1$

$\Rightarrow (1+1)\left(\frac{R_G}{R_1+R_G}\right) = 1$

$\Rightarrow \frac{R_G}{R_1+R_G} = \frac{1}{2}$

$\Rightarrow R_1 + R_G = 2R_G$

$\Rightarrow R_1 = R_G$

Let, $R_1 = 10k\Omega$

$\therefore R_G = 10k\Omega$

→ Circuit draw must

② $V_{out} = \left(1+\frac{R_f}{R_2}\right)\left(\frac{R_G}{R_1+R_G}\right)V_1 - \frac{R_f}{R_2}V_2$

Here, $\frac{R_f}{R_2} = 3$ $[\because V_2 = 3V_2]$

If, $R_2 = 1\ k\Omega$

$\Rightarrow R_f = 3R_2$

then, $R_f = 3\ k\Omega$

And, $\left(1+\frac{R_f}{R_2}\right)\left(\frac{R_G}{R_1+R_G}\right) = 2$ $[\because V_1 = 2V_1]$

$\Rightarrow (1+3)\left(\frac{R_G}{R_1+R_G}\right) = 2$

$\Rightarrow 4\left(\frac{R_G}{R_1+R_G}\right) = 2$

$\Rightarrow \frac{R_G}{R_1+R_G} = \frac{1}{2}$

$\Rightarrow R_1 + R_G = 2R_G$

$\Rightarrow R_1 = R_G$

Let, $R_1 = 10k\Omega$

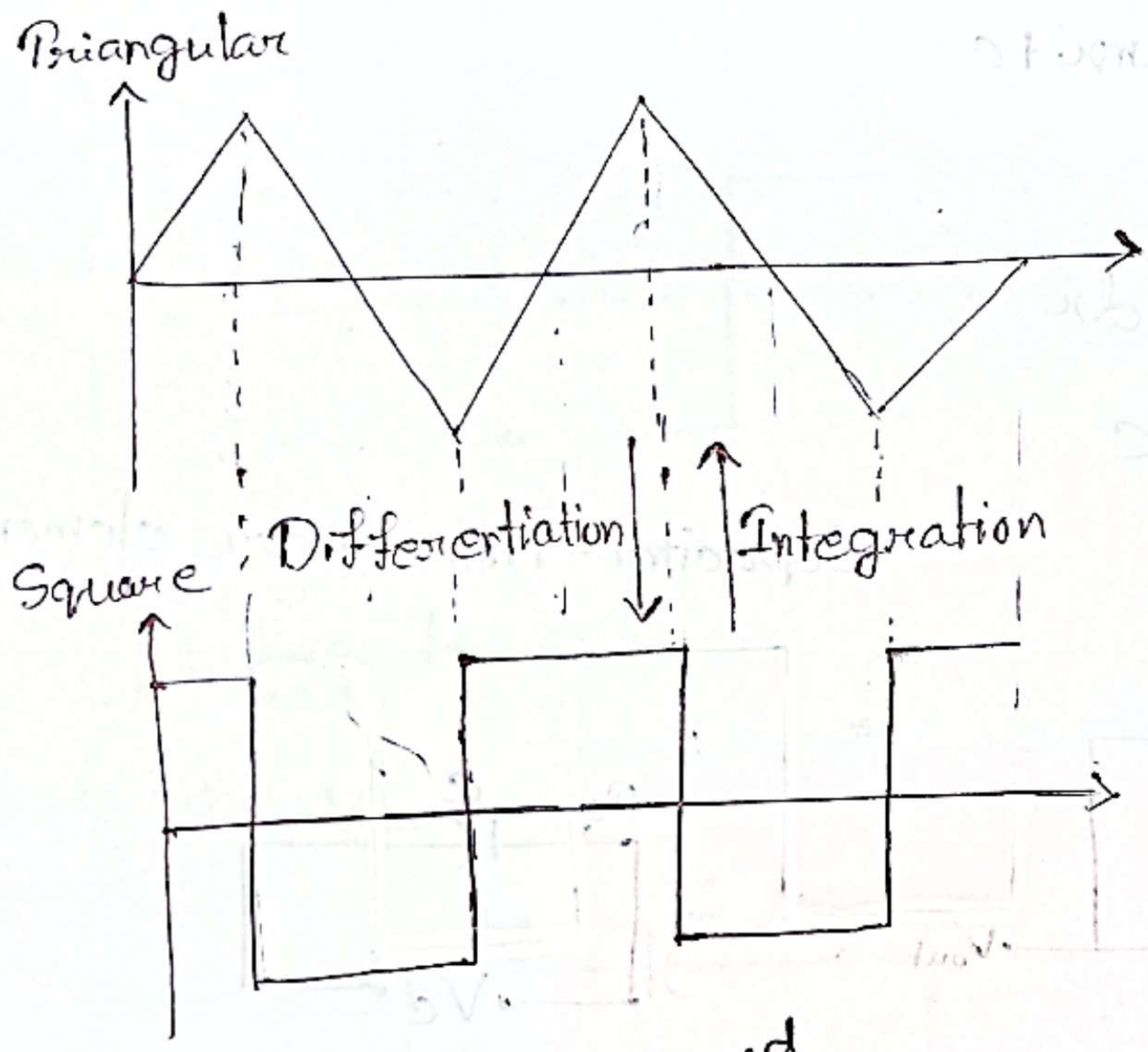
& $R_G = 10\ k\Omega$

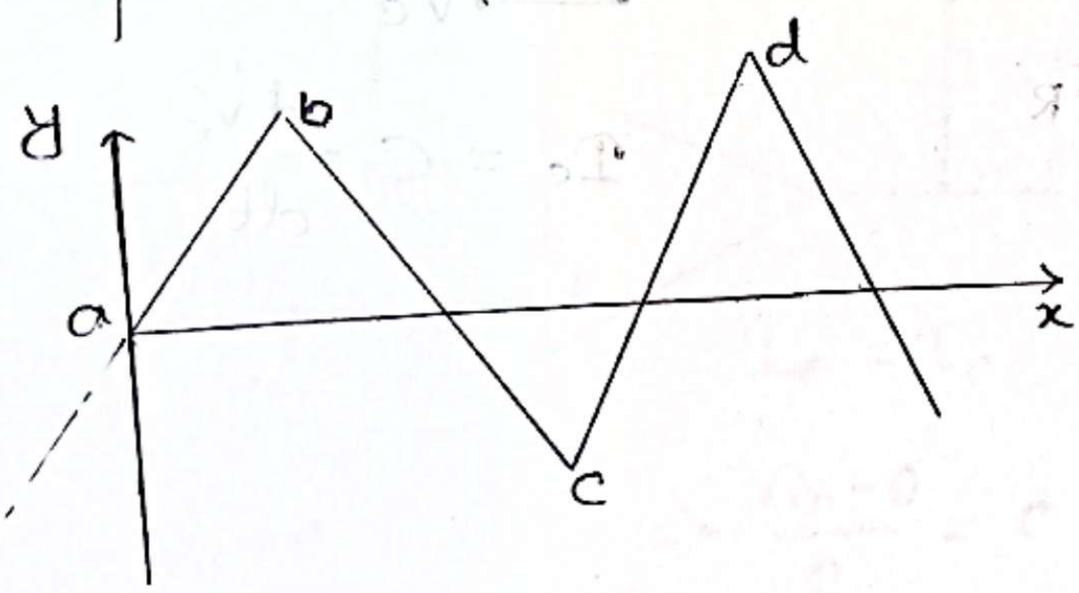
13/12/2025

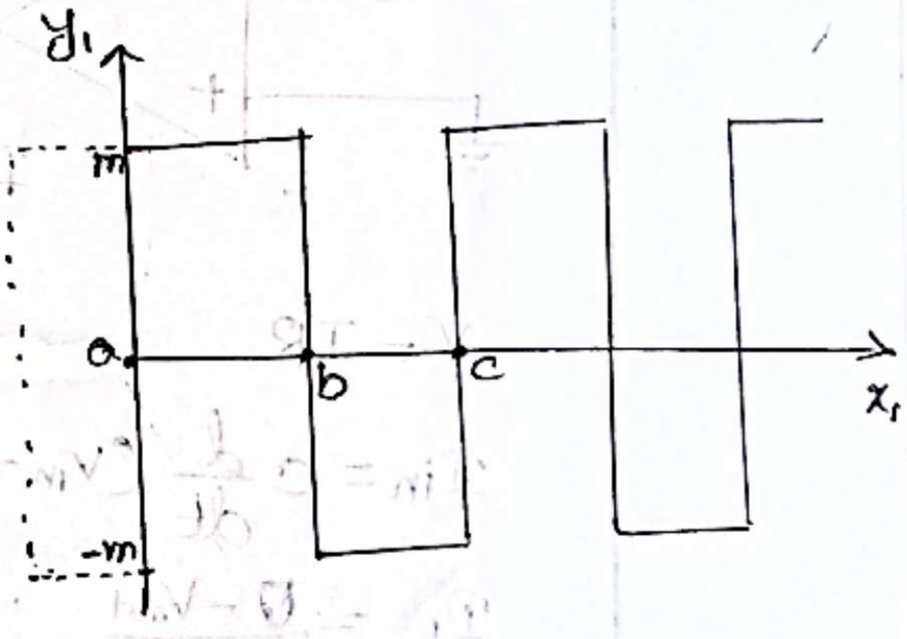
Lecture-08

Differentiator

Show that a triangular signal can be converted into square signal & vice versa. (Using op-amp)







a-b segment: $y = mx$

$$y_1 = \frac{dy}{dx} = m$$

b-c segment: $y = -mx + c$

$$y_1 = \frac{dy}{dx} = -m$$

c-d segment: $y = mx + c$

$$y_1 = \frac{dy}{dx} = m$$

a-b: $y_1 = m$

$$\Rightarrow y_2 = \int y_1 dx = m\int dx$$

$$= mx + c$$

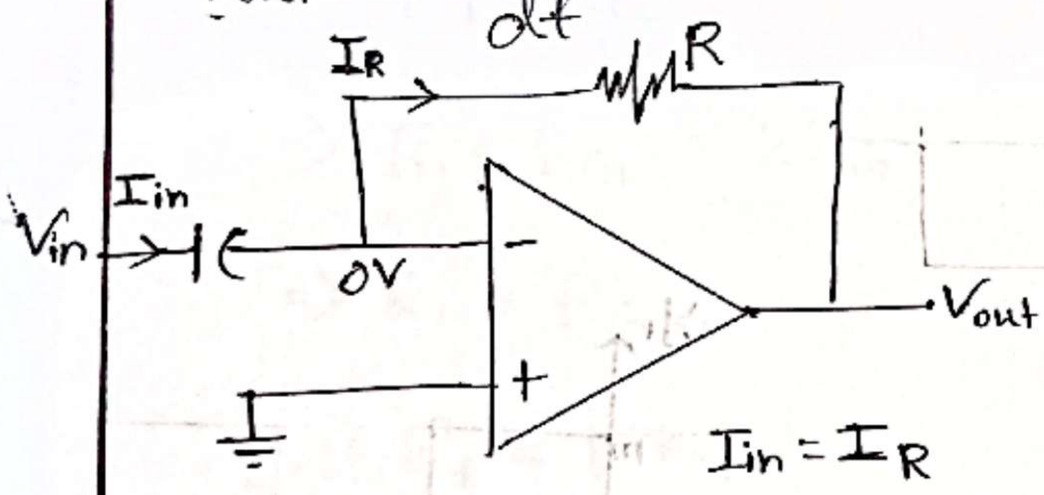
b-c: $y_1 = -m$

$$\Rightarrow \int y_1 dx = -m\int dx$$

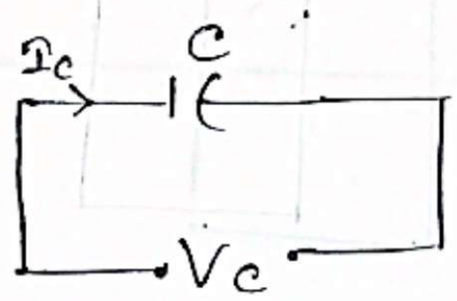
$$\Rightarrow y_2 = -mx + C$$

Capacitor - Non-linear element

$$V_{out} = \frac{dV_{in}}{dt}$$



$I_{in} = I_R$



$$I_c = C\frac{dV_c}{dt}$$

$$V = IR$$

$$I_{in} = C\frac{d}{dt}(V_{in} - 0)$$

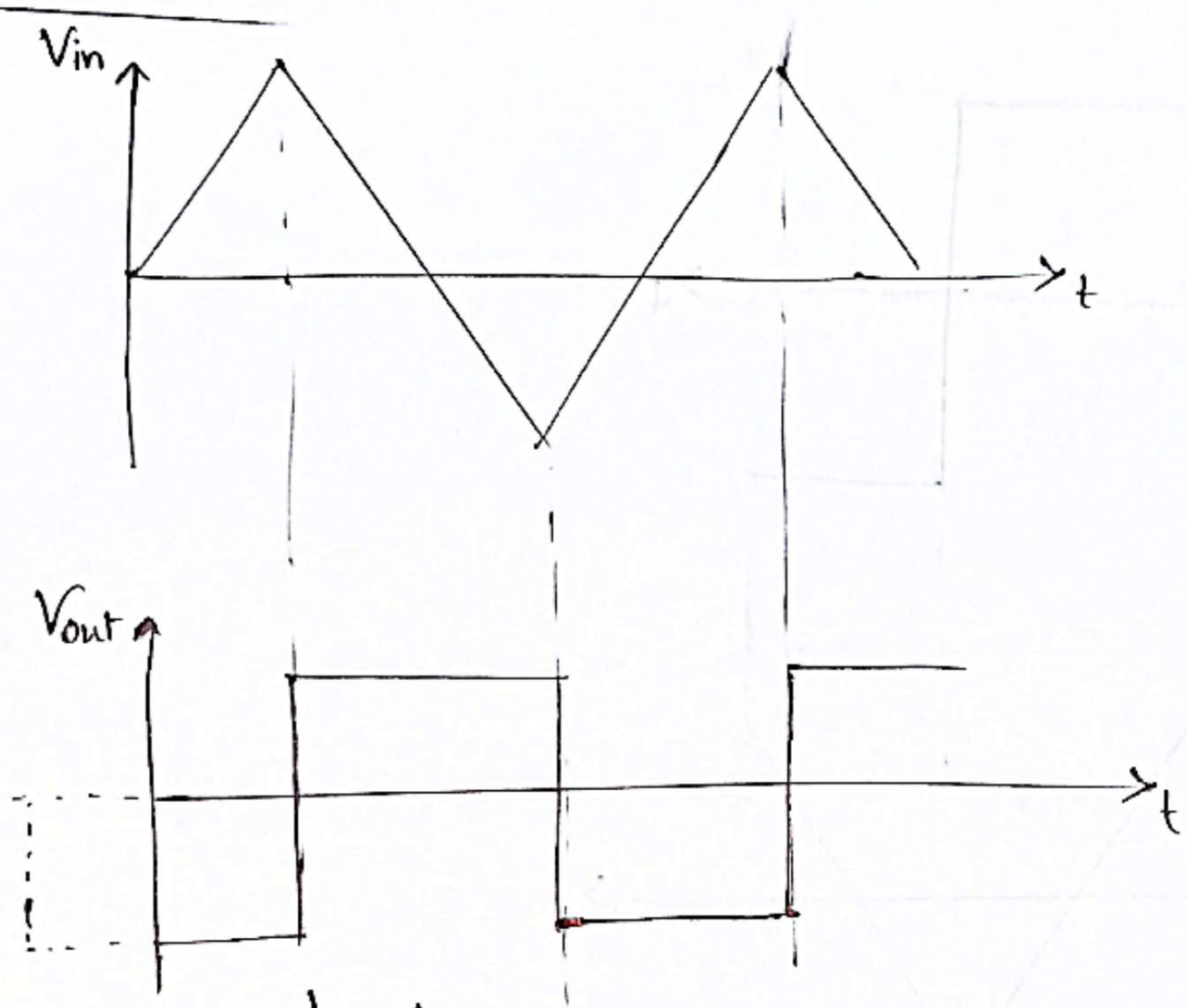
$$I_R = \frac{0 - V_{out}}{R}$$

Now, $I_{in} = I_R$

$$\Rightarrow C\frac{d}{dt}(V_{in} - 0) = \frac{0 - V_{out}}{R}$$

$$\Rightarrow V_{out} = -R_C\frac{dV_{in}}{dt}$$

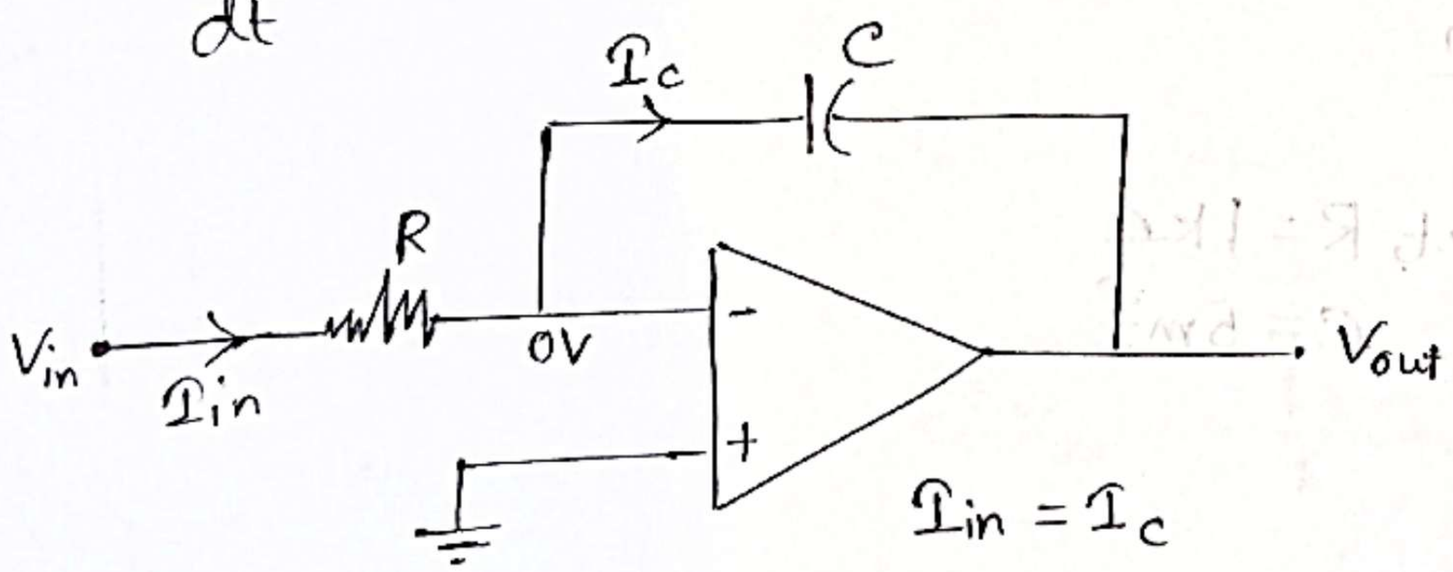
Waveform:



Integrator:

$$V_{out} = \int V_{in}\, dt$$

$$\Rightarrow \frac{dV_{out}}{dt} = V_{in}$$



$$I_{in} = I_c$$

$$I_{in} = \frac{V_{in} - 0}{R}$$

$$I_c = C\frac{d(0 - V_{out})}{dt}$$

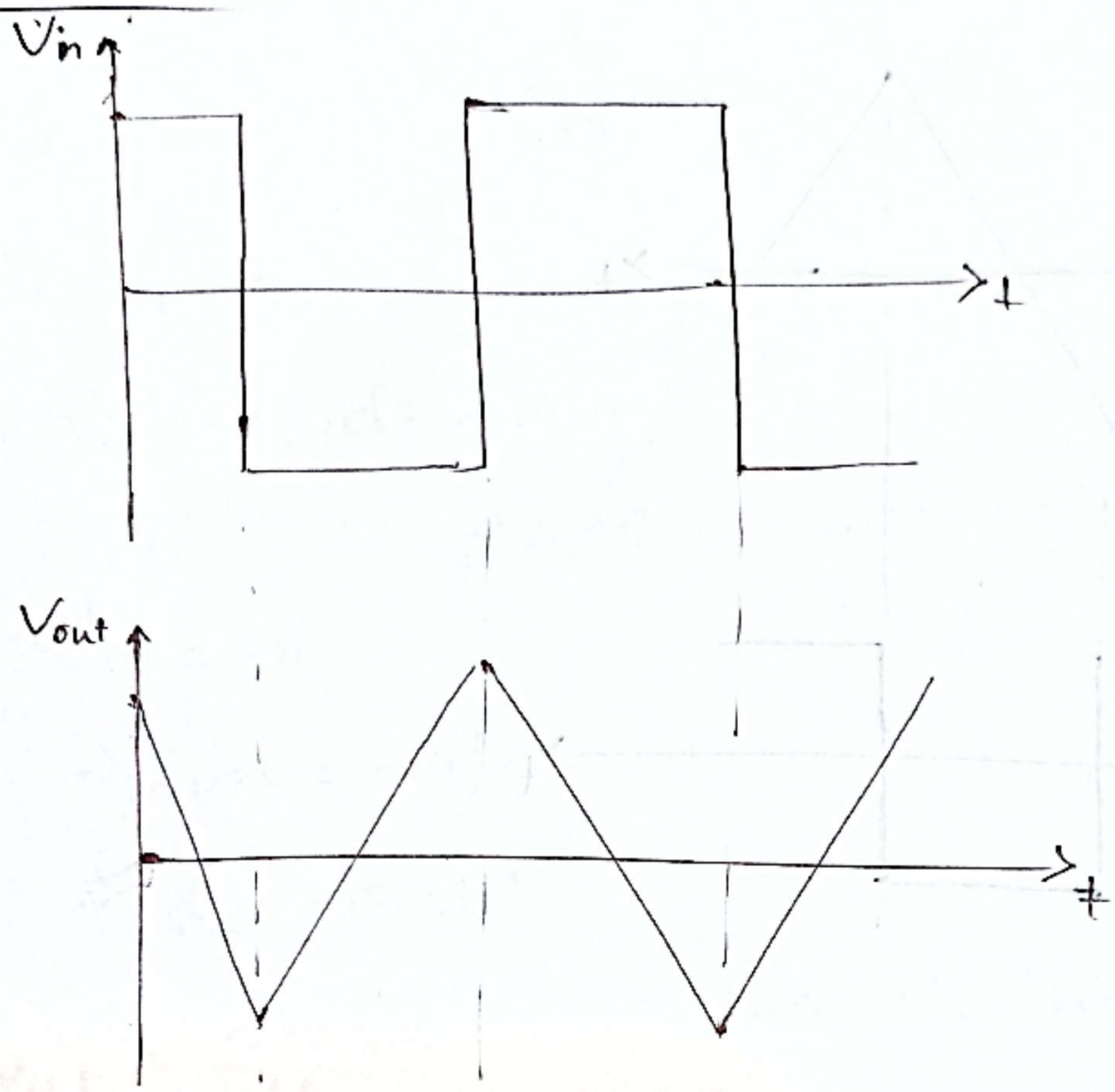
$$\Rightarrow \frac{V_{in} - 0}{R} = C\frac{d(0 - V_{out})}{dt}$$

$$\Rightarrow V_{in} = -RC\frac{dV_{out}}{dt}$$

$$\Rightarrow \int V_{in}\, dt = -RC\, V_{out}$$

$$\Rightarrow V_{out} = -\frac{1}{RC}\int V_{in}\, dt$$

Waveform:



Design the following function:

$$V_{out} = \overset{R_c}{5}\,\frac{dV_{in}}{dt}$$

$R_c = 5$ | let $R = 1k\Omega$, $C = 5mf$

$R_c = 5$

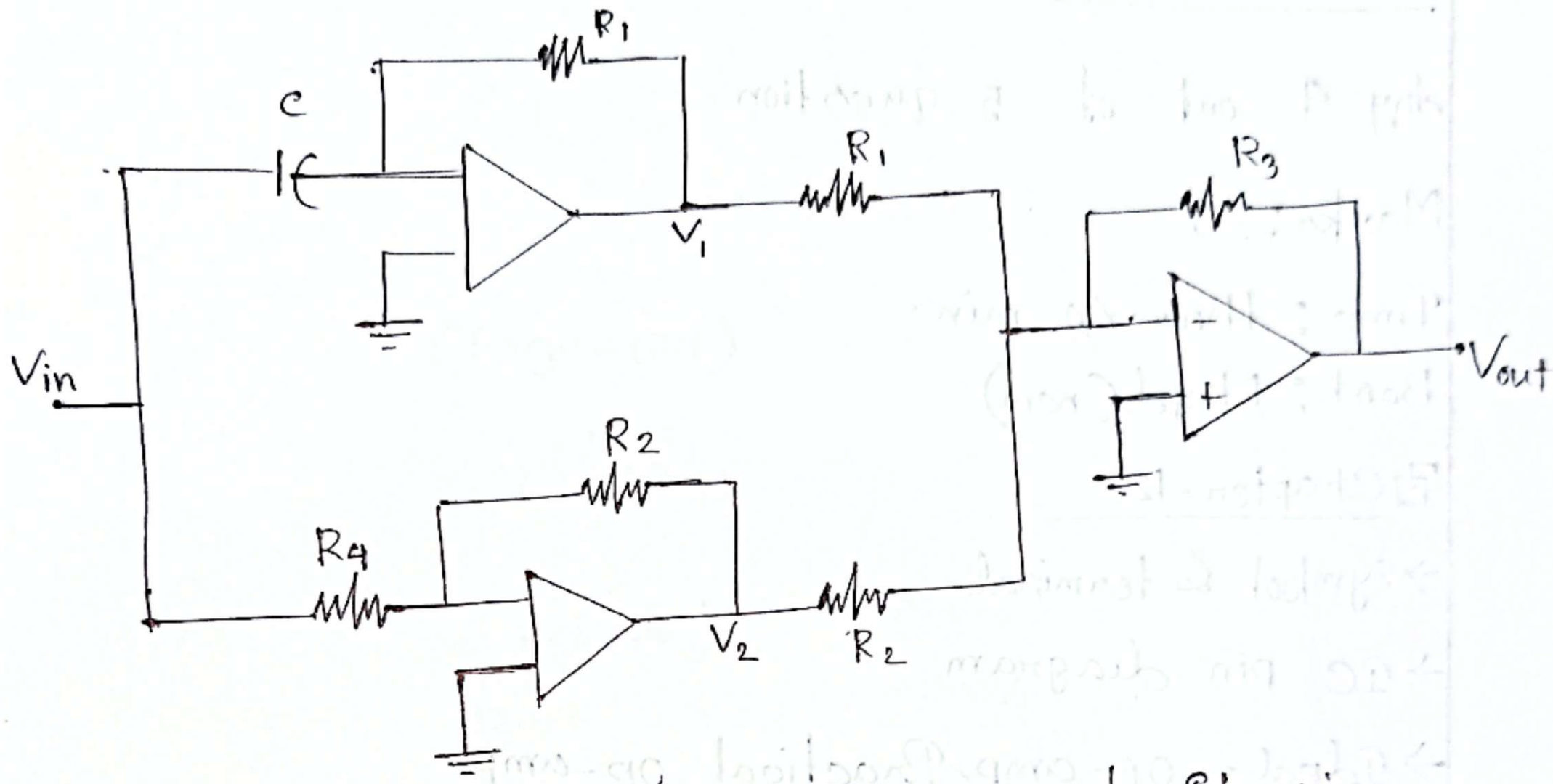
$\Rightarrow 1\times10^{3} \times C = 5$

$\Rightarrow C = 5/1\times10^{-3}$

$\Rightarrow C = 5\times10^{-3}F$

$= 5mF$

Function implementation:



Determine V_{out} w.r.t. V_{in}

$C = 5\mu F$
$R_3 = 100k\Omega$
$R_4 = 50k\Omega$

Steps:

(I) $V_1 = ?$ Differentiator

(II) $V_2 = ?$ Inverting i/p with neg. feedback.

(III) $V_{out} = ?$ Summing Amplifier.

Answer:

(I) $I_{in} = I_R$

$\cancel{\frac{(V_{in}-0)}{R}}$

$$\Rightarrow C\frac{d}{dt}(V_{in}-0) = \frac{0-V_1}{R_C}$$

$$\Rightarrow V_1 = -R_C\frac{dV_{in}}{dt}$$

(II) $$V_2 = -\frac{R_2}{R_4}V_{in}$$

(III) $$V_{out} = -\frac{R_3}{R_1}V_1 - \frac{R_3}{R_2}V_2$$

$$\Rightarrow V_{out} = -\frac{R_3}{R_1}\left(-R_1C\frac{dV_{in}}{dt}\right) - \left(\frac{R_3}{R_2}\right)\left(-\frac{R_2}{R_4}\right)V_{in}$$

$$\Rightarrow V_{out} = R_3C\frac{dV_{in}}{dt} + \frac{R_3}{R_4}V_{in}$$

$$\Rightarrow V_{out} = 100\times10^3 \times 5\times10^{-6}\frac{dV_{in}}{dt} + \frac{100\times10^3\,\Omega}{50\times10^3\,\Omega}V_{in}$$

$$\Rightarrow V_{out} = \frac{1}{2}\frac{dV_{in}}{dt} + 2V_{in}$$

Question Pattern:

Any 4 out of 5 question

Marks: 30

Time: 1hour 40 min.

Book: Floyd (new)

Chapter-12

→ Symbol & terminal

→ IC pin diagram

→ Ideal - op-amp, Practical op-amp

→ Character & Internal structure

→ Internal block diagram. (Fig. 12.3)

→ Input modes explain. (Single Differential Common)

- Circuit
- equation
- inp./outp. waveform

→ Parameter (Basic definition)

- Definition + full form (only for CMRR)
- equation
- CMRR high/low which better? & Reason
- Ex-12.1
- Math

→ Also for Slew rate and figure draw

→ Ex-12.4

→ Math

→ Input bias current, offset voltage, current

→ Only definition & equation

Closed loop

→ Negative feedback

- Definition
- Why use
- effect
- Table 12.2 (Page-614)

→ Non-inverting Amplifier

- Circuit
- equation (final equation)
- waveform - Math: 12.3
- Voltage follower & application

→ Inverting Amplifier

- Circuit
- final equation
- Maths

→ Input impedence final equation no derivation required

→ Math in class lecture, no derivation required in exam

Chapter -13:

→ Comparator

- zero level
- Non-zero level (2 types VR & VD)
- Math → 13.1

→ Summing Amplifier / Differential amp / Differentiator / Integrator

- Circuit
- equation
- math (Summing to Averaging Amp., Diff. amp. math)

→ Differentiator & Integrator input to output waveform & math (Show that ....) in class lecture

→ Design a summing Amp.

→ Design a averaging Amp.

(i) $R_1 = R_2 = R_3 = \cdots R_n = R$

(ii) $R = nR_f$

→ Design the following function:

(1) $V_{out} = -2V_1 - 3V_2$

$V_{out} = -5(V_1 + V_2)$

(2) $V_{out} = V_2 - V_1$ ⟶ (− = inverting pin so, V_1 inverting)

$V_{out} = V_1 - 2V_2$

(3) $V_{out} = -5 \dfrac{dv_{in}}{dt}$

(4) $V_{out} = -100 \int V_{in}\, dt$

$\dfrac{1}{RC} = 100$

(5) Circuit given then V_{out} find

$\Rightarrow RC = \dfrac{1}{10} = 10^{-2}$

$R = 1\,k\Omega = 1 \times 10^3\,\Omega$

$\Rightarrow 1 \times 10^3 \times C = 10^{-2}$

$\Rightarrow C = 10^{-5}$

$= 10 \times 10^{-6}\,F$

$= 10\,\mu F$