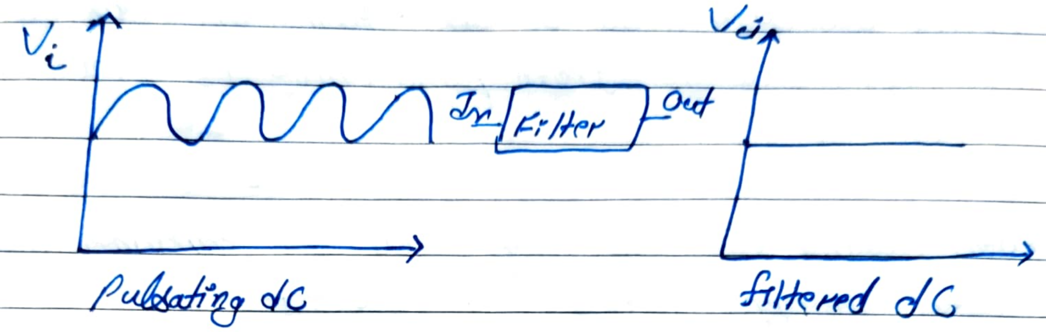
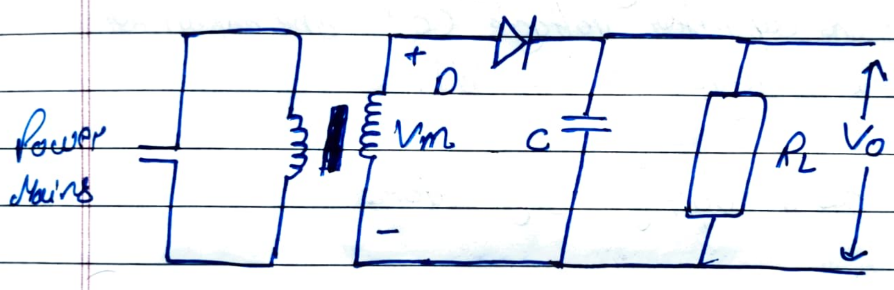
Transformer may be used for isolation even if not required for stepping up or down the input ac.

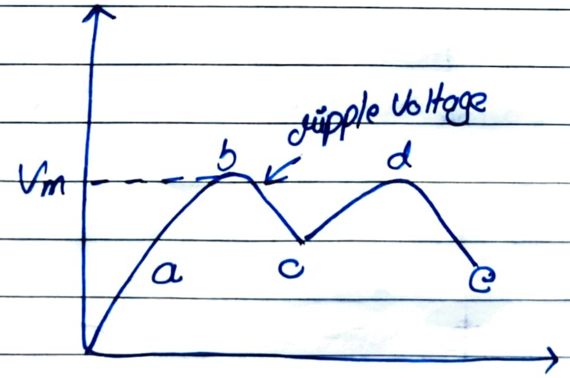
- Filters:

To minimise the ripple content.



- Shunt Capacitor filter →





i) When the +ve half cycle of the AC input is applied the diode is in forward bias and hence it'll conduct. So this allows the capacitor to quickly charge upto Vm, i.e. upto (b).

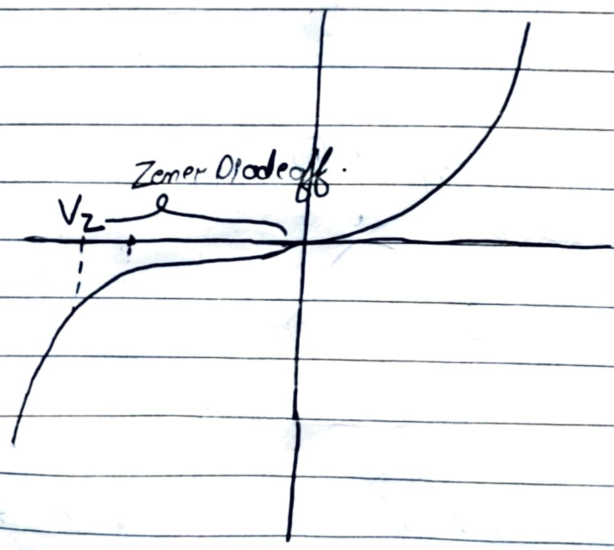
ii. After we fully charge, the capacitor holds the charge till the input ac supply to the rectifier goes negative.

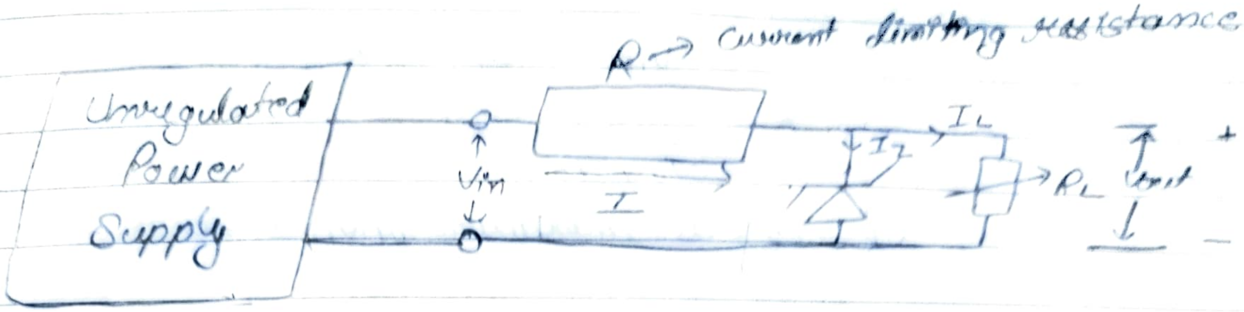
iii. During the -ve half cycle the capacitor attempts to discharge. However, it can't discharge through diode being reverse bias is off. Hence it'll ~~...~~ discharge from load resistor from point (b) to (c) and its voltage decreases somewhat.

iv. Even during the -ve half cycle the capacitor maintains large voltage across load resistor.

v. During the next +ve half cycle when the rectifier voltage exceeds the capacitor voltage (c), the capacitor is again quickly charged to Vm (d).

• Zener diode as a voltage regulator:





$V_{in} \geq V_Z$

$I = I_Z + I_L$

Voltage Regulator is used to keep constancy in the d.c voltage

Case 1 Suppose R_L is kept fixed but supply voltage Vin is slightly increased.

i The increase in current I will be absorbed by zener diode without affecting I_L.

ii The increase in Vin will be dropped across R thereby keeping Vout constant.

iii On the other hand, if the supply voltage decrease the diode takes a smaller current and voltage drop across R is reduced, thus again keeping Vout constant.

iv When Vin changes I and IR drop changes in such a way as to keep $V_{out} = V_Z$ constant

2. Case II: Vin is fixed but I_L is changed.

i When I_L increases, diode current I_Z decreases thereby keeping I and IR drop constant. In this way Vout remains unaffected.

ii When I_L decrease, diode current I_Z increases thereby keeping I and IR drop constant. In this way Vout remains unaffected.

Date
Page

$$V_{out} = V_{in} - IR$$
$$= V_{in} - (I_L + I_Z)R$$
$$R = \frac{V_{in} - V_{out}}{I_L + I_Z}$$

If I_Z is maximum then $I_L = 0$

So $R = \frac{V_{in} - V_{out}}{I_{Z(max)}}$

Half Wave Rectifier:

Ripple factor $= \frac{1}{2\sqrt{3} f R_L C}$

Full wave Rectifier:

Ripple factor $= \frac{1}{4\sqrt{3} f R_L C}$

In a centre tap full wave rectifier the load resistance $R_L = 1k\Omega$. Each diode has forward bias resistance of 10Ω. The voltage across half the secondary winding is $220 \sin 314t$ volt. Find

i) Peak value of current

ii) DC / average value of current

iii) Rms value of current.

iv) ripple factor

v) Rectification efficiency.

classmate

Date

Page

vi) $v = 220 \sin 100\pi t$

$2\pi f = 100\pi$

$f = 50 hz$

$R_L = 1000 \Omega$

$I_m = \frac{22\cancel{0}}{101\cancel{0}} = 0.217 A$

ii) $\frac{2I_m}{\pi} = \frac{2 \times 0.217}{3.14} \simeq 0.138 A$

iii) $\frac{0.217}{\sqrt{2}} = 0.15\cancel{3}$

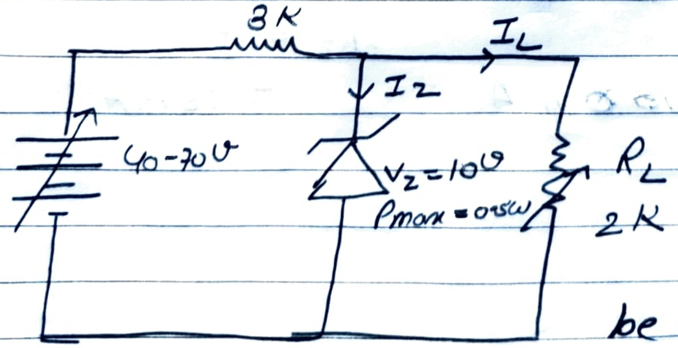
iv) ~~0.482~~ $\gamma = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$

$= 0.478$

v) $\eta = \frac{P_{dc}}{P_{ac}} = \frac{(I_{dc})^2 \times R_L}{I_{rms} \times (R_L + R_d)}$

$\simeq 81.2\%$

Q



Calculate the battery current I, I_Z and I_L in the circuit. How will these values be affected if source voltage increases to 70V.

Neglect zener resistance.

$P_{max} = I_z \cdot V_z$

$0.5 = I_z \times 10$

$0.05\,A = I_z$

$5 \times 10^{-2}\,A = I_z$

So $\cancel{I = \frac{40}{8 \times 10^{3}}}$

$\cancel{I = 8 \times 10^{-3}\,A}$

$V_{RL} = 30\,V$

So $V = IR$

$\frac{30/5}{2 \times 10^{3}} = I_L$

$15 \times 10^{-3} = I_L$

$I_z + I_L = I$

$15 \times 10^{-3} \times 5$

When $V_{in} = 40\,V$

$V_z = 10\,V$

$30\,V = IR$

$30 = I \times 3 \times 10^{+3}$

$10 \times 10^{-3} = I$

$10\,mA = I$

$\cancel{9.5\,mA = I_L}$

$I_z = 5\,mA$

~~V_o~~

$IR = 30\,V$

$\frac{30}{3} \times 10^{-3} = I$

$10\,mA = I$

$i_L = \frac{10}{2000}$

$= 5\,mA$

$i_z = I - i_L$

$= 5\,mA$

So $V_{in} = 70\,V$

$IR = 60$

$= \frac{60}{3} \times 10^{-3}$

$= 20\,mA$

$i_L = \frac{10}{2000} = 5\,mA$

$i_z = I - i_L$

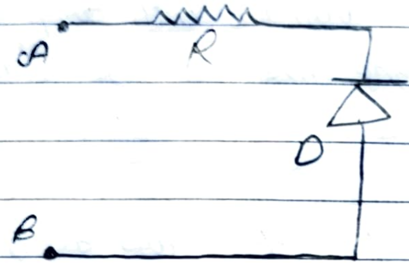
$= 15\,mA$

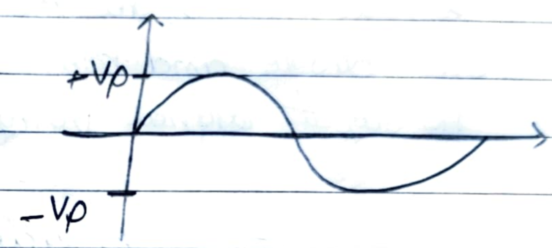
• Clippers and Clampers:

portion of input signal is clipped off

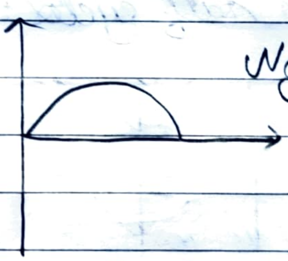
lift up or lift down the input signal to a different dc ~~circuit~~ level.

Clipper circuit:





Input Sine Wave Signal

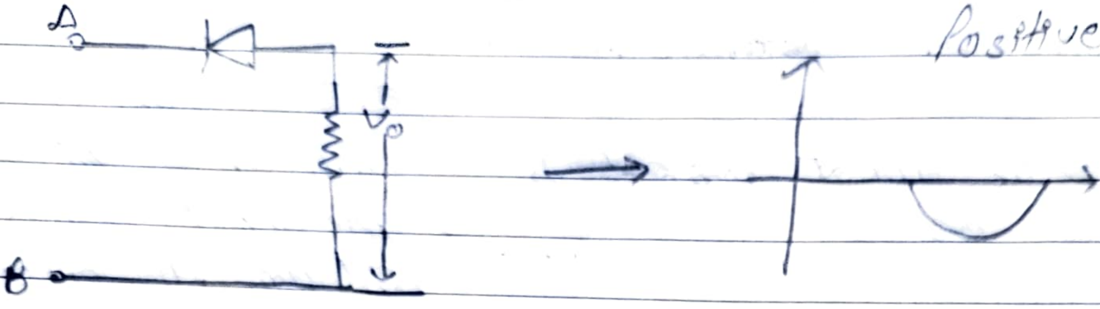


Negative Clipper

When the +ve half cycle of the signal is applied on the clipper A is +ve ~~on~~ wrt B the diode D is reverse biased. Hence it acts as an open circuit.

During the -ve half cycle D is forward biased, hence it acts a closed ~~circuit~~ switch.

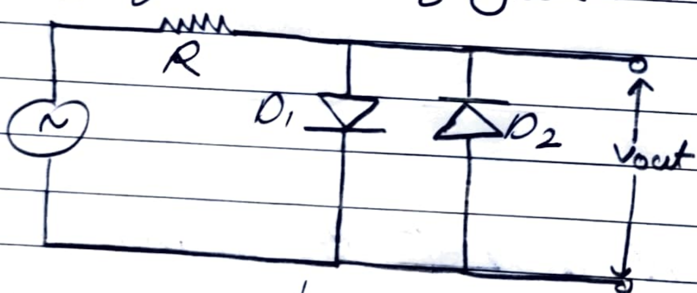
Positive Clipper

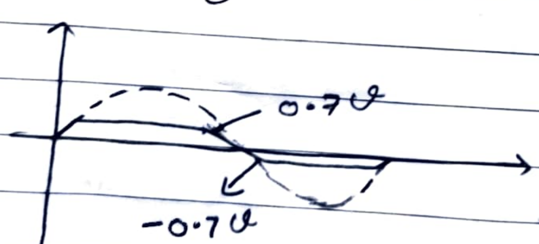


During the +ve half cycle of signal D acts an open switch, hence, all the applied voltage will drop across the diode and none across the resistor. So there's no output signal voltage.

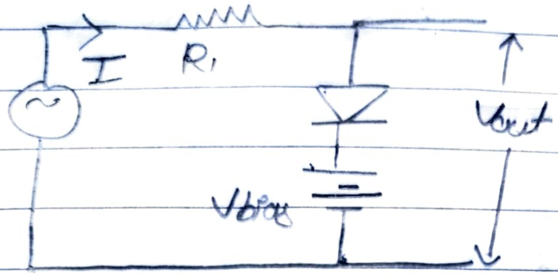
During the -ve half cycle D is in f.B. so all the voltage is across R.

Clipping of both half cycles:

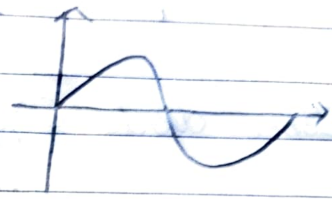




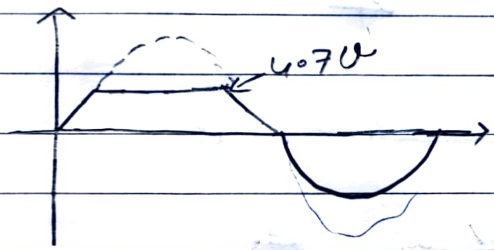
- Bias diode Clipping Circuits :



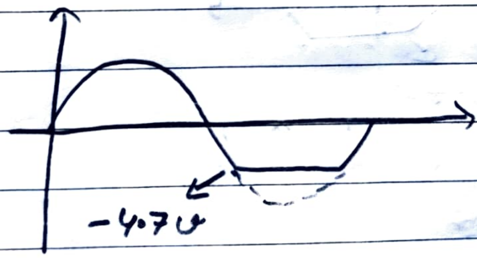
Positive bias diode



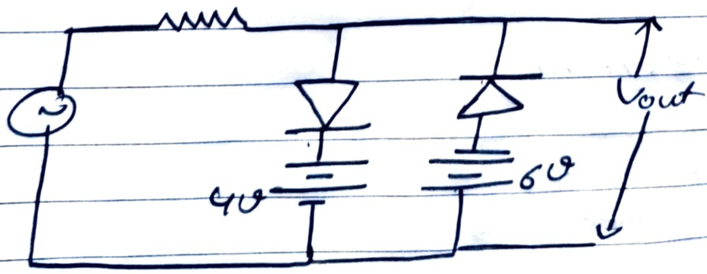
$V_{bias} + V_{diode} \leq V_{AC}$

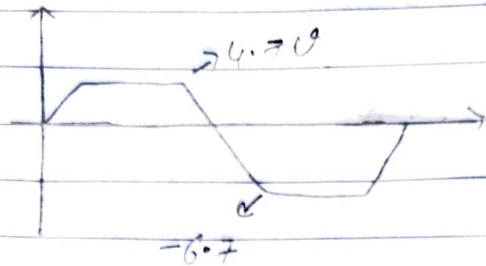


Negative bias

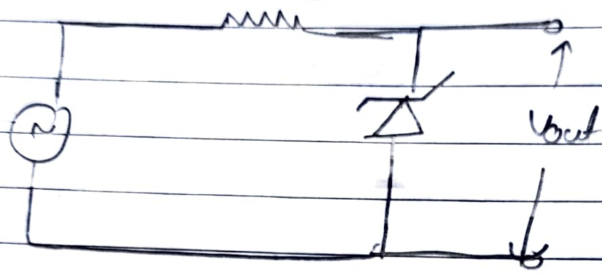


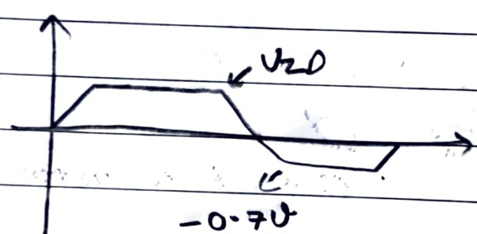
Q find o/p wave form.





- Zener diode clipping:



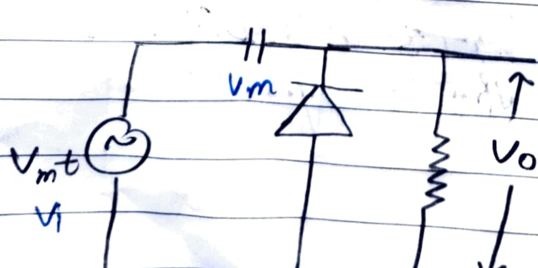


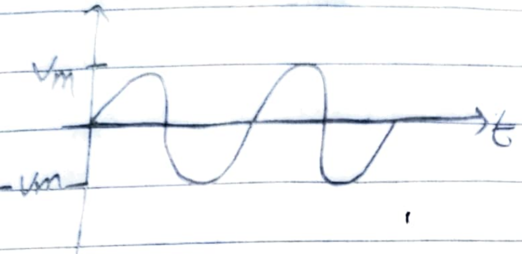
- Clampers:

time constant $\to \lambda = CR$

$\lambda >> \frac{T}{2}$, where T = time period of the signal

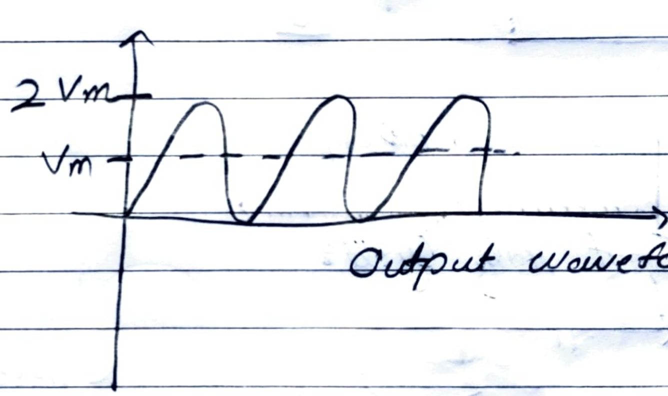
1. Positive Clampers Circuit:



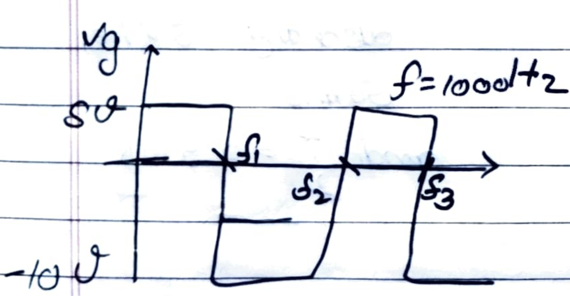


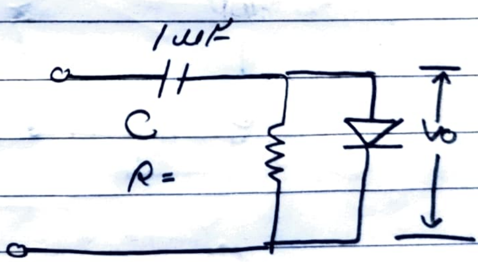
-ve half cycle:
Diode → F.B.
Capacitor → fully charge to +ve Vm.

+ve half cycle:
Diode → R.B.
O/p → $V_i + V_m = 2V_m$



Output waveform





The input signal of fig. (a) is applied to clamper circuit in (b). Draw the o/p waveform of o/p voltage V_o.

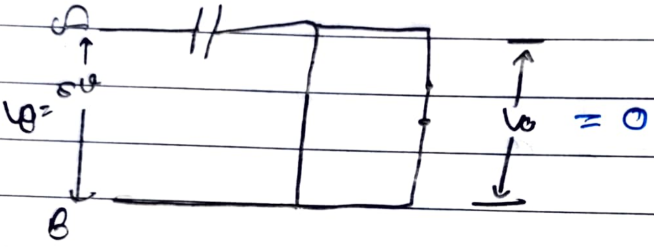
Time period of signal $= \frac{1}{f} = 1ms$

$\frac{T}{2} = 0.5ms$

$\partial = 10ms$

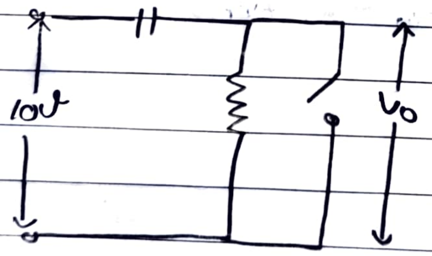
$\partial >> \frac{T}{2}$

Positive Input Half-Cycle:



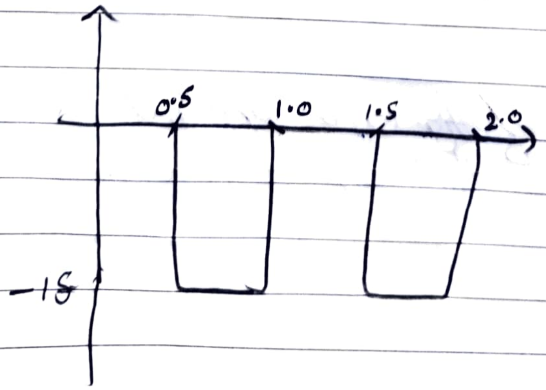
+5V will be applied on A for 0.5ms

Negative Input Half Cycle:

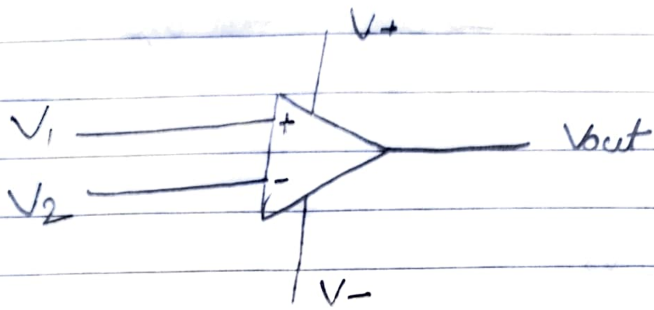


C needs 5∂ to discharge 5V i.e. 50 m/s.

and $\frac{T}{2} = 0.5ms$



• Operational Amplifier (Op Amp):

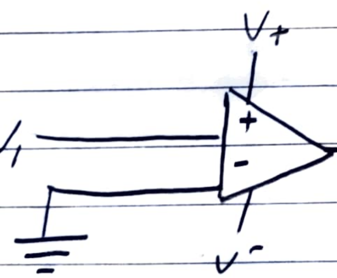


⇒ Two types:

i) Non-Inverting

ii) Inverting

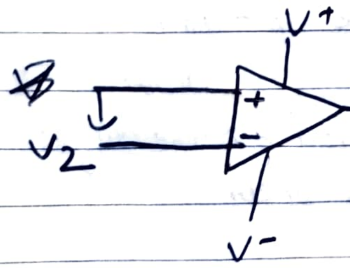
$$V_{out} = \underbrace{A}_{\text{Gain}}(V_1 - V_2)$$



$V_{out} = AV_1$

Non-Inverting Op Amp

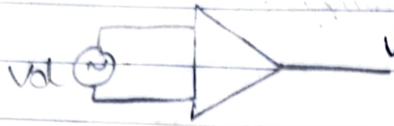
* No change in phase



$V_{out} = -AV_2$

Inverting Op Amp

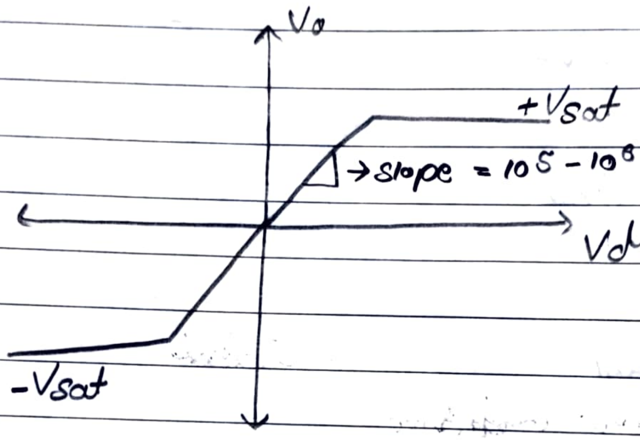
* change in phase = 180°



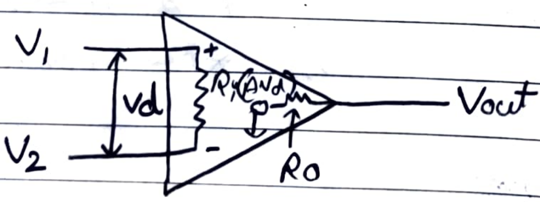
$V_{out} = A\, V_d$

↳ differential i/p V.

$A \approx 10^5 - 10^6$



⇒ Equivalent circuit of Op-Amp:



R_i = input impedance of the op-amp
R_o = output impedance of the op-amp
V_{out} = open loop gain multiplied by the difference b/w the input signals V_1 and V_2.

- Characteristics of an Ideal Op-Amp:

1. $R_i = \infty$, so that the input that is being applied b/w the input terminals will be directly applied to the op-amp.

2. $R_o = 0$,

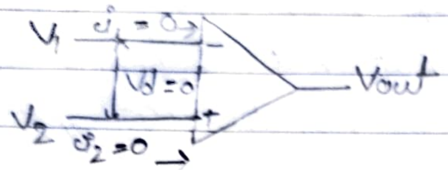
3. Bandwidth $= \infty$.

4. $A = \infty$

⇒

	Ideal	Practical
1. Infinite Input Impedance	$R_i = \infty$	$M\Omega$
2. Zero o/p Impedance	$R_o = 0$	Ω
3. Infinite open loop gain	$A = \infty$	$10^5 - 10^6$
4. $V_{out} = 0$ when $V_{in} = 0$		mV

$i_1 = i_2 = 0$ as R_i is ∞



⇒ Op-Amp draws no current at both the input terminals i.e. $i_1 = i_2 = 0$;

⇒ As the gain is infinite the Voltage b/w the inverting and non-inverting terminals ~~is~~ i.e. differential input voltage i.e. $V_d = (V_1 - V_2)$ is essentially zero, for the finite o/p voltage V_o.

- Feedback in Ideal op-amp:

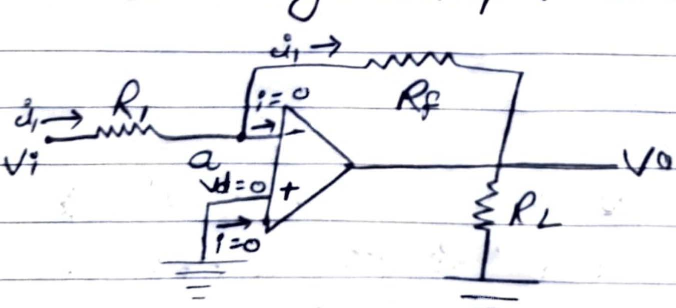
⇒ -ve feedback:

→ 2 basic feedback connection used.

Realistic Assumptions
i. The current drawn by the either of the i/p terminals is negligible.

ii. The differential i/p Voltage b/w non-inverting & inverting input terminal is zero.

⇒ The Inverting Amplifier:



(a) Inverting Amplifier

$$i_1 = \frac{V_i}{R_1}$$

$$V_o = -i_1 R_f = -V_i \frac{R_f}{R_1}$$

Gain of the inverting amplifier (Closed loop gain):

$$A_{CL} = \frac{V_o}{V_i} = -\frac{R_f}{R_1}$$

The nodal eqn. at the node 'a' is

$$\frac{V_a - V_i}{R_1} + \frac{V_a - V_o}{R_f} = 0$$

V_a is the Voltage at node 'a'.

a is grounded, so $V_a = 0$

$$\frac{V_o}{V_i} = -\frac{R_f}{R_1}$$

Q Design an amplifier with the gain of -10 and input resistance 10 kΩ.

Ans

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

$R_1 = 100\,k\Omega$

Q $R_1 = 10\,k\Omega$, $R_f = 100\,k\Omega$ $V_1 = 1V$, A load of 25kΩ is connected to the o/p terminal. Calculate i_1, V_o, i_L and the total current i_o in o/p.

Ans

$$i_1 = \frac{V_i}{R_1} = 10^{-4} A$$

$$\cancel{i_L = \frac{V_o}{R_f} = \frac{10}{100 \times 10^{-4}}}$$

$$V_o = \frac{-R_f}{R_1} \times V_i = -10\,V$$

$i_L = \frac{10}{25\times10^3}$

$= \frac{1\times10^{-2}}{25}$

$= 4\times10^{-4}$

$= 0.4\ mA$

$i_T = (0.4 + 0.1)\ mA$

$= 0.5\ mA$

- **Practical Inverting Amplifier:**

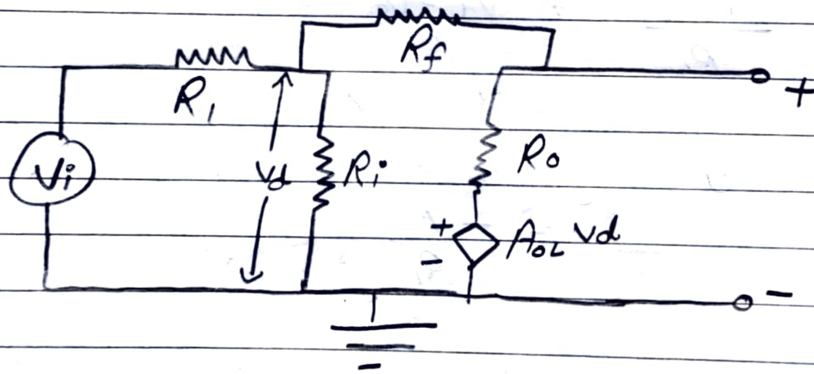


Fig: Equivalent circuit of a practical op-amp inverting amplifier

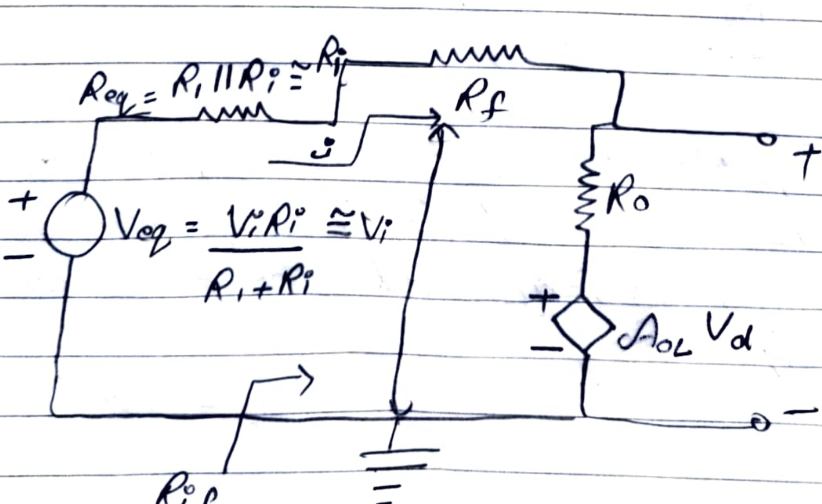


Fig: Simplified circuit by using Thevenin's Equivalent

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Date

Page

from the o/p loop:

$$V_o = iR_o + \underbrace{A_{OL} V_d}_{\text{Open loop gain}} \quad - (i)$$

Also

$$V_d + iR_f + V_o = 0 \quad - (ii)$$

Putting the value of V_d from (1) to (2) and simplifying.

$$\frac{V_o - iR_o - A_{OL} V_d}{A_{OL} V_o + iR_f A_{OL} + A_{OL} V_d}$$

$$V_o(1 + A_{OL}) + i(R_f A_{OL} - R_o) = 0$$

$$V_o = \frac{(R_o - R_f A_{OL})i}{1 + A_{OL}} \quad - (3)$$

$$\frac{V_o - iR_o}{A_{OL}} = V_d$$

$$V_o - iR_o + i$$

Also, the KVL loop eqn.

$$V_i = i(R_1 + R_f) + V_o \quad - (4)$$

Put the value of i from (3) into (4) and solve for closed loop gain,

$$A_{CL} = \frac{V_o}{V_i}$$

$$i = \frac{V_o(1+A_{OL})}{R_o - A_{OL}R_f}$$

$$V_i = V_o\frac{(1+A_{OL})(R_1+R_f)}{R_o - A_{OL}R_f} + V_o$$

$$V_i = V_o\left[\frac{1+A_{OL} + R_o - A_{OL}R_f}{R_o - A_{OL}R_f}\right]$$

$$\frac{V_o}{V_i} = \frac{R_o - A_{OL}R_f}{1+A_{OL}+R_o - A_{OL}R_f}$$

$$\frac{V_o}{V_i} = \frac{R_o - A_{OL}R_f}{1+A_{OL}(1-R_f)+R_o}$$

$$V_i = V_o\left[\frac{R_1+R_f + A_{OL}(R_1+R_f) + R_o - A_{OL}R_f}{R_o - A_{OL}R_f}\right]$$

$$\frac{V_o}{V_i} = \frac{R_o - A_{OL}R_f}{R_1+R_f+R_o+R_1A_{OL}}$$

$$= \frac{R_o - A_{OL}R_f}{R_1(1+A_{OL})+R_o+R_f}$$

If $A_{OL} >> 1$, $A_{OL}R_1 >> R_o+R_f$ and neglecting R_o,

$$A_{CL} = \frac{V_o}{V_i} = -\frac{R_f}{R_1}$$

⇒ Input resistance, R_{if}

$$R_{if} = \frac{V_d}{i}$$

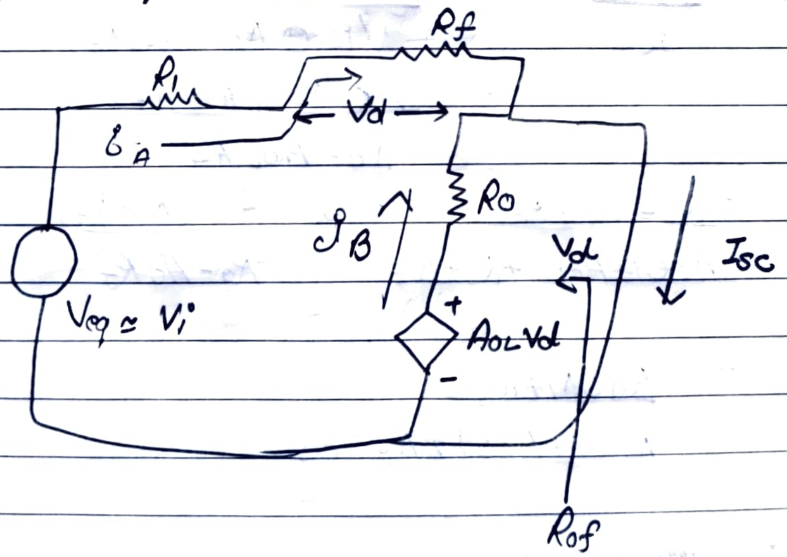
Writing the loop eqn. and solving for R_{if}.

$$V_d + i(R_f + R_o) + A_{OL} V_d = 0$$

$$V_d(1 + A_{OL}) = -i(R_f + R_o)$$

$$R_{if} = \frac{V_d}{i} = \frac{(R_f + R_o)}{1 + A_{OL}}$$

⇒ Output impedance, R_{of}



$$i_A = \frac{V_i}{R_1 + R_f} \quad -(1)$$

$$i_B = \frac{A_{OL} V_d}{R_o} \quad -(2)$$

$$V_d = -i_A R_f$$

$$i_B = -\frac{A_{OL} i_A R_f}{R_o}$$

$$i_{sc} = i_A + i_B$$
$$= i_A - \frac{A_{OL} i_A R_f}{R_o}$$
$$= i_A \left(1 - \frac{A_{OL} R_f}{R_o}\right)$$
$$= \frac{V_i}{(R_i + R_f)} \frac{(R_o - A_{OL} R_f)}{R_o}$$

$$A_{CL} = \frac{V_{oc}}{V_i}$$
$$A_{CL} V_i = V_{oc}$$

$$R_{of} = \frac{V_{oc}}{i_{sc}} = \frac{A_{CL} \cdot V_i R_o (R_i + R_f)}{V_i (R_o - A_{OL} R_f)}$$
$$= \frac{A_{CL} R_o (R_i + R_f)}{R_o - A_{OL} R_f}$$
$$= \frac{(R_o - A_{OL} R_f)}{R_i (1 + A_{OL}) + R_o + R_f} \times \frac{R_o (R_i + R_f)}{R_o - A_o R_f}$$

$$R_{of} = \frac{R_o (R_i + R_f)}{R_i (1 + A_{OL}) + R_o + R_f}$$

It can be written as,

$$R_{of} = \frac{\frac{R_o (R_i + R_f)}{R_o + R_i + R_f}}{1 + \frac{R_i A_{OL}}{R_o + R_i + R_f}}$$

- The Non-Inverting Amplifier:

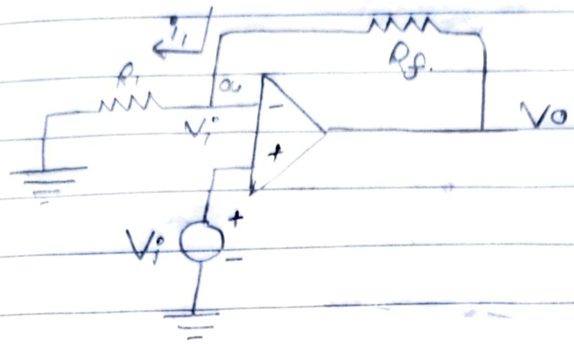


fig. Non-Inverting Amplifier

Two assumptions:

i. Input current = 0
ii. Vd = 0

$$V_i = \frac{V_o}{R_1 + R_f} R_1 \cancel{R_f R}$$

$$\frac{V_o}{V_i} = \frac{R_1 + R_f}{R_1}$$

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

- Practical Non-Inverting Amplifier:

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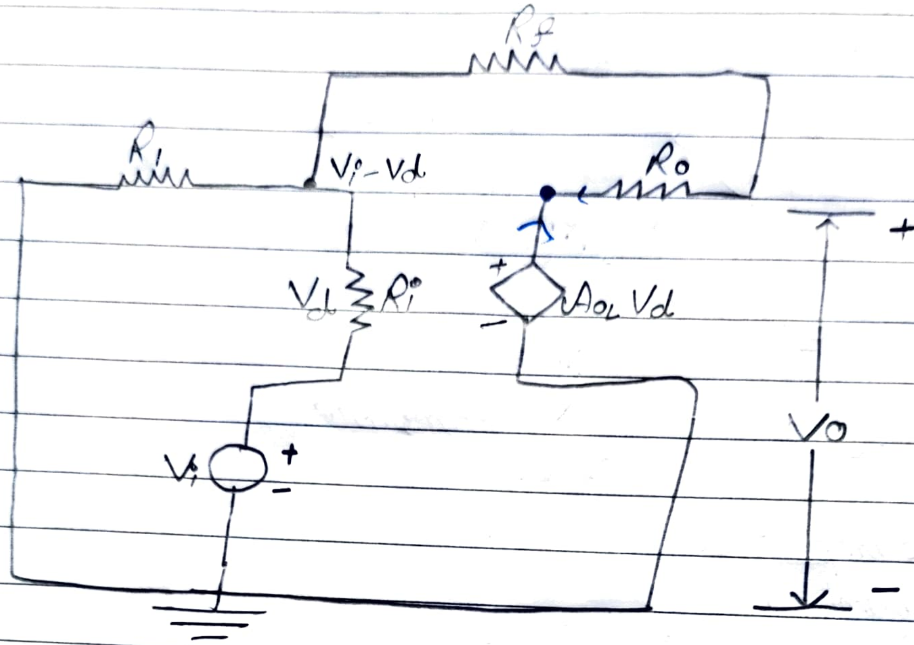

Fig. Equivalent circuit of non-inverting amplifier.

$$\cancel{V_i + V_d = I R_1}$$

$$\frac{V_i - V_d}{R_1} + \frac{V_d}{R_i} + \frac{V_i - V_d - V_o}{R_f} = 0$$

$$(V_i - V_d)Y_1 + V_d Y_i + (V_i - V_d - V_o)Y_f = 0$$

$Y \rightarrow$ Admittance

or

$$-(Y_1 + Y_i + Y_f)V_d + (Y_1 + Y_f)V_i = Y_f V_o \quad -(1)$$

$$(Y_1 + Y_f)V_i - Y_f V_o = V_d(Y_1 + Y_f - Y_i$$

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Date

Page

$\Rightarrow V_i Y_1 - V_d Y_1 + V_d Y_i + V_i Y_f - V_d Y_f - V_o Y_f = 0.$

$\Rightarrow V_d [Y_i - Y_1 - Y_f].$

$\Rightarrow - V_d[- Y_i + Y_1 + Y_f] + V_i[Y_1 + Y_f] - V_o Y_f$

At output node: KCL

$Y_f(V_i - V_d - V_o) + (A_{OL} V_d - V_o) Y_o = 0$

$- V_o(Y_f + Y_o) + Y_f V_i + V_d(-Y_f + A_{OL} Y_o) = 0$ — (2)

$- V_o(Y_f + Y_o) + Y_f V_i = V_d(A_{OL} Y_o + Y_f)$

$(Y_1 + Y_f - Y_i)(- V_o(Y_f + Y_o) + Y_f V_i) = (Y_1 + Y_f) V_i - Y_f V_o$

$(Y_1 + Y_f - Y_i)(- V_o Y_f - Y_o V_o + Y_f V_i) = Y_1 V_i + Y_f V_i - Y_f V_o$

$- V_o Y_f Y_1 - Y_o V_o Y_1 + Y_f V_i Y_1 - V_o Y_f^2 - Y_o V_o Y_f + Y_f^2 V_i + Y_i V_o Y_f + Y_i Y_o V_o - Y_f V_i Y_i - Y_1 V_i - Y_f V_i + Y_f V_o = 0$

$V_o(- Y_f Y_1 - Y_o Y_1 - Y_f^2 - Y_o Y_f + Y_i Y_f + Y_o Y_i + Y_f) + V_i(Y_f Y_1 + Y_f^2 - Y_f Y_i - Y_1 - Y_f) = 0$

$\frac{V_o}{V_i} = Y_f Y_1 + Y_o Y_1$