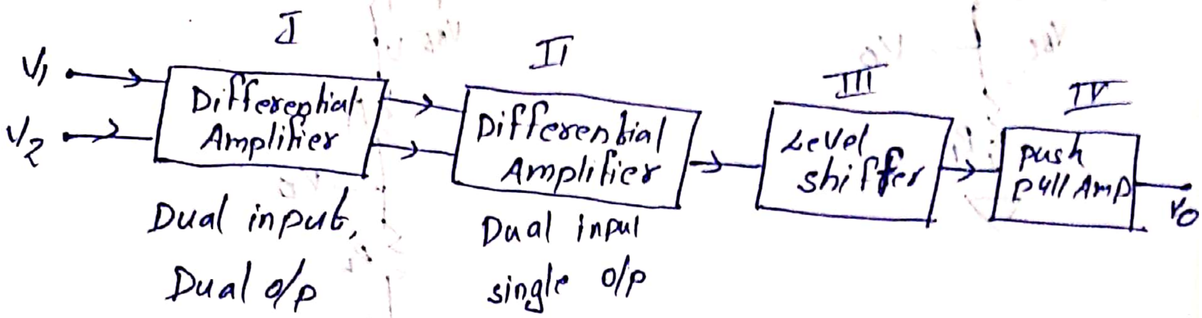
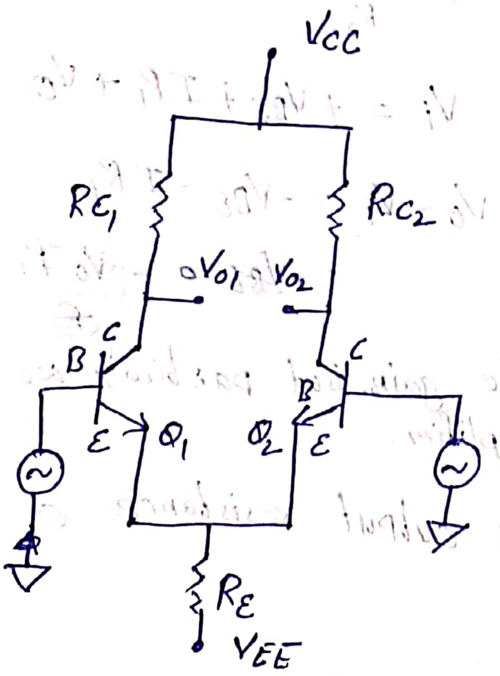
operation Amplifier :

op-Amps is a high voltage gain amplifier.
op-Amps basically have 4 blocks



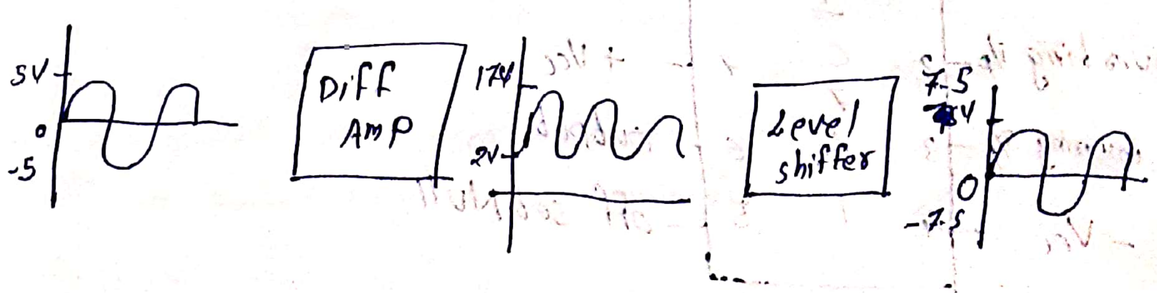
Differential Amplifier :



* $V_{o_1} - V_{o_2} = A_d(V_1 - V_2)$

current gain $\beta = \frac{I_C}{I_B}$

→ Maximum gain in an opamp achive in diff. Amp.
→ Both have same current gain.
→ In II stage we take outputs as V_{o1}, Gound.
→ Rc couple Amplifiec ⇒ Rc allows only mid range frequncies



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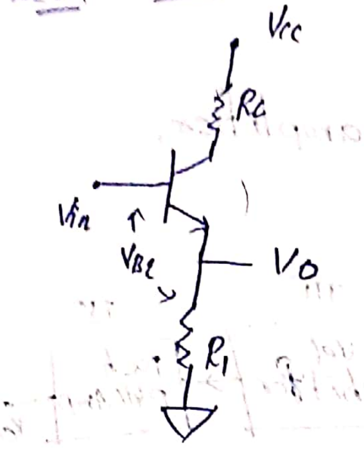
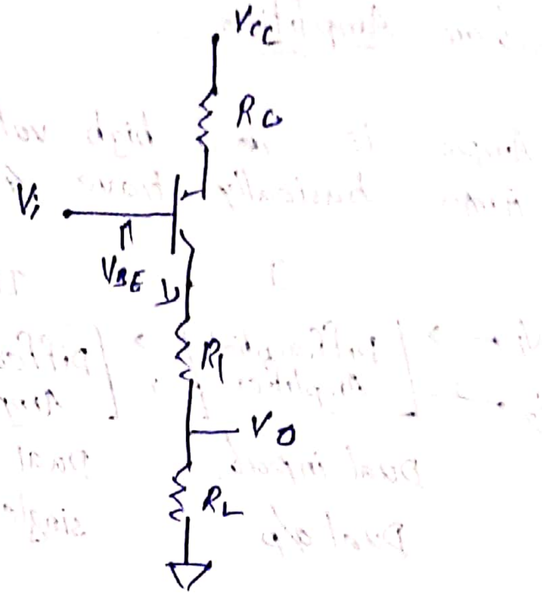
level shifter :-





V_{cc} ~~α~~ $I_C R_C$

$V_{cc} - V_i = I_C R_C$

$\underline{V_o - V_i = -V_{BE}}$

$I_E = \dfrac{V_O}{R_2}$

$V_i = +V_{BE} + IR_1 + V_O$

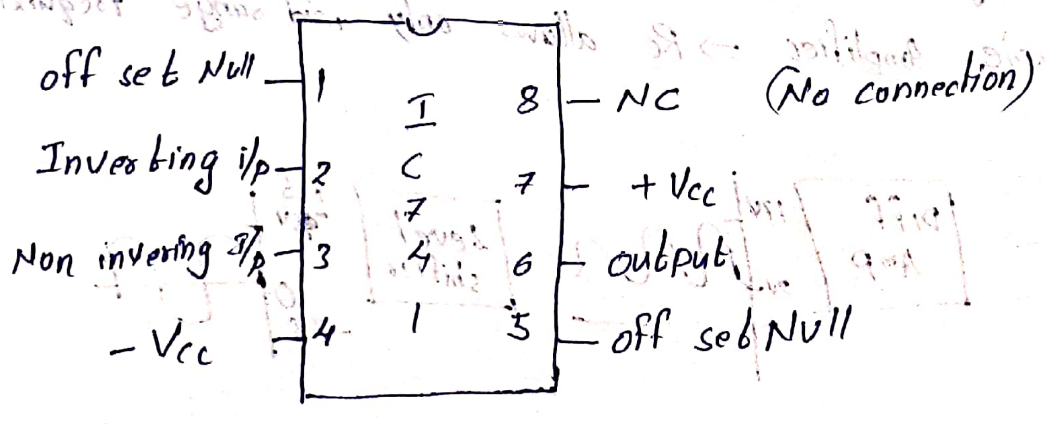
$\underline{V_O - V_i = -V_{BE} - IR_1}$

~~$= -V_{BE} = \frac{V_O}{R} R_1$~~

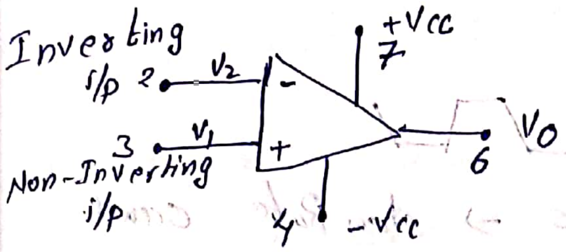
→ ideal op-Amp have infinite gain. But parbicaly we achive it by ~~a~~ ~~Res~~ useing two Amplifier.

→ push-pull amplifier makes output resistance 0, and ~~to~~ to drive the circuit.

IC 741 – op Amp



symbol :-



	Ideal	Practical
Gain (A_0)	∞	10^6
i/p Resistance	∞	10MΩ to 100MΩ
O/p Resistance	0	5 to 10 Ω
CMRR	∞	10^6 or 120dB
Band width	∞	120dB (a) 90dB
slew Rate	∞	0.0.1 V/μs 0.5 to 1 V/μs.

→ To make the current zero, input resistance is made infinity so that Transistors won't brake and the Power consumed by Amplifier is minimum.

→ O/p Resistance is low. Because the output voltage should not drop across resistance so we can provide maximum Voltage (output)

→ CMRR - Common Mode Rejection Ratio = $\frac{A_d}{A_c}$ → differential mode, → common mode. Noise →

→ Band width is maximum to allow more channels (more frequencies) in the Amplifier.

→ Rate of change of ~~the~~ o/p Voltage w.r.t time.

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slew Rate = $\frac{dV_o}{dt}$

i/p

→ due to unavoidable pracidic capacitance → slew Rate Occurs.

→ ideally Their should not be any time delay.

→ so, slew Rate is infinity.

$$V_o = A_d(V_1 - V_2)$$

If $V_1 = 0$

$V_o = A_d \cdot -V_2$

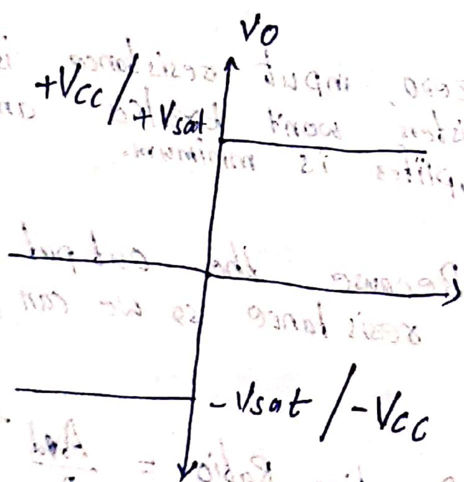
If $V_2 = 0$

$V_o = A_d V_1$

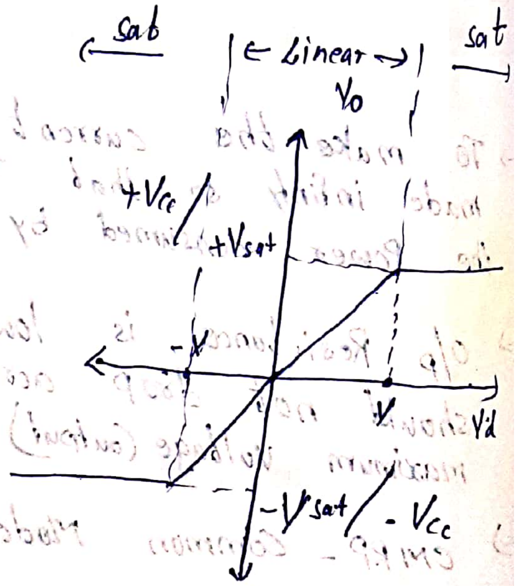
V_2, V_o are out of phase Due to Diff. Amp

Ideal characters:

Voltage Transfer characterists:



ideal.



pratical.

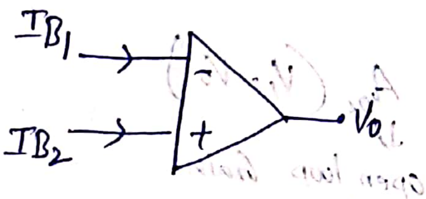
$V_d = V_1 - V_2$ $\qquad V = \frac{V_{sat}}{A} = \frac{V_{cc}}{A}$

$\frac{V_o}{V_d} = A$

$V_o = A\, V_d = A\,(V_1 - V_2)$

Two Regions: Linear Region → Amplifier
Saturation Region → comperators / switch

Input Bias Current (I_B) nA



the average current entering into the inverting + non invering terminal.

$$\boxed{I_B = \frac{I_{B_1} + I_{B_2}}{2}}$$

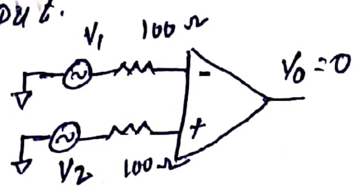
The input offset current (I_{io}) : nA

The difference of invering and non inverting bias current.

$$I_{io} = |I_{B_1} - I_{B_2}|$$

input offset voltage (V_{io}) : mV or µV

It is the difference of input voltage applied to the op-amp in order to nullify the output.



$$V_{io} = V_1 - V_2$$

output offset voltage (V_{oo}) : mV

It is a non-zero output voltage when both the input voltages are zero.

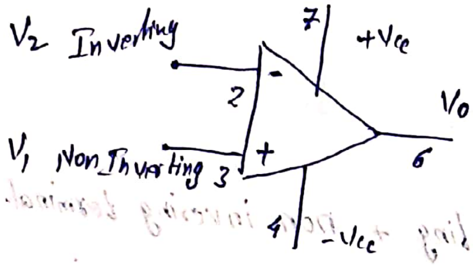
Thermal Drift:

The rate of change of voltage with respect to change in temperature is called Thermal Drift.

$$\frac{\Delta V_0}{\Delta T} \quad \mu V/^{\circ}C$$

V_{io}, I_B, I_{io} - changes due to Temperature.

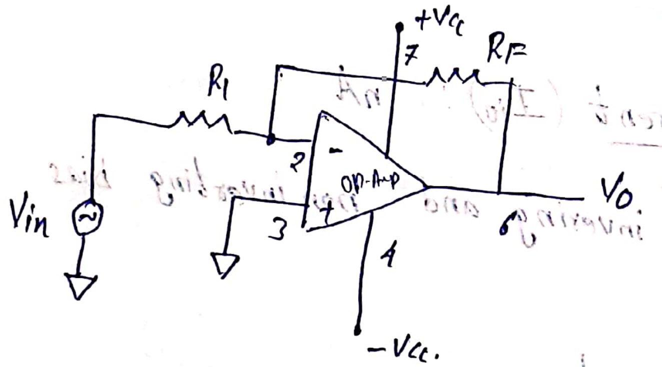
$\mu V/C \quad \mu A/C \quad nA/C$



$V_0 = A_{OL}(V_1 - V_2)$

open loop Gain.

Inverting Amplifier:



Negative Feedback

$$\text{Gain } (A) = \frac{V_0}{V_d} = \infty$$

$$V_d = V_1 - V_2 = 0$$

$$\therefore \boxed{V_1 = V_2}$$

Virtual Ground.

$R_i \to \infty \Rightarrow I_{B_1} = I_{B_2} = 0$

V_0 KCL .. V_2

$$\frac{V_2 - V_{in}}{R_1} + \frac{V_2 - V_0}{R_F} = 0$$

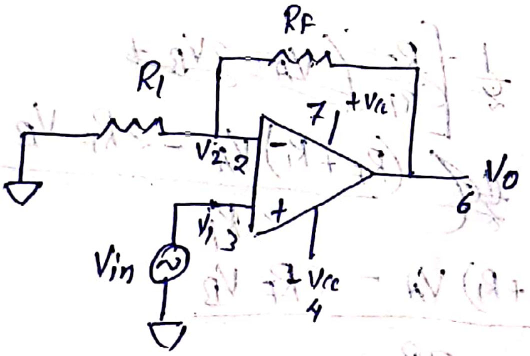
$V_1 = V_2 = 0$

$$\frac{V_{in}}{R_1} + \frac{V_0}{R_F} = 0$$

$$\boxed{V_0 = \left(-\frac{R_F}{R_1}\right) V_{in}} \Rightarrow \frac{V_0}{-V_{in}} = \frac{R_F}{R_1}$$

$$\text{Gain} = \frac{V_0}{V_{in}} = -\frac{R_F}{R_1}$$

Non-Inverting Amplifier:



Negetive-
Feed-back.

$$A = \frac{V_0}{V_d} = \infty \qquad V_d = 0$$

$$\boxed{V_1 = V_2}$$

$$V_{in} = V_2.$$

$$\frac{V_2}{R_1} + \frac{V_2 - V_0}{R_F} = 0$$

$$\frac{R_F V_{in}}{R_1} = V_0 - V_{in}$$

$$V_0 = V_{in}\left(\frac{R_F}{R_1} + 1\right)$$

$$\text{Gain} = \frac{V_0}{V_{in}} = \frac{R_F}{R_1} + 1$$

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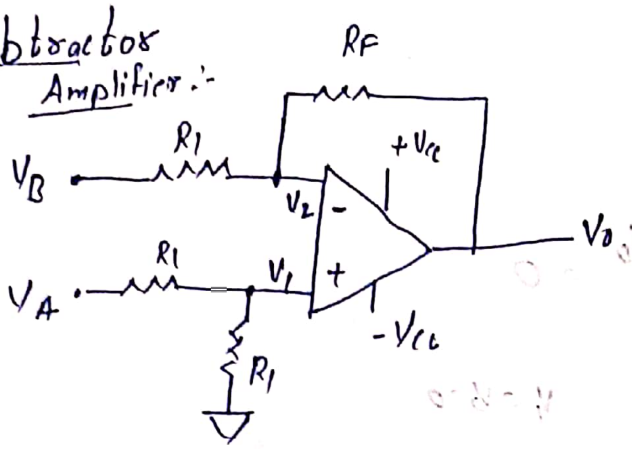
subtractor Amplifier :-



$$\frac{V_1}{\cancel{R_1}} + \frac{V_1 - V_A}{\cancel{R_1}} = 0 \qquad \frac{V_2 - V_B}{R_1} + \frac{V_2 - V_0}{R_F} = 0$$

$$\frac{V_A}{2} = V_1 \qquad \frac{V_2 - V_B}{R_1} = \frac{V_0 - V_2}{R_F}$$

$$R_F \frac{(V_A - 2V_B)}{2R_1} + \frac{V_A}{2} = V_0$$

$$V_0 = \cancel{\frac{1}{2}\left[\frac{R_F}{R_1}\left(V_A - 2V_B\right)\right]}$$

$$= \frac{(R_F + R_1) V_A - 2R_F V_B}{2 \cdot R_1}$$

$$V_0 = \frac{(R_F + R_1) V_A - 2R_F V_B}{2R_1}$$

$$= \frac{1}{2}\left(\frac{R_F}{R_1} + 1\right) V_A - \frac{R_F}{R_1} V_B$$

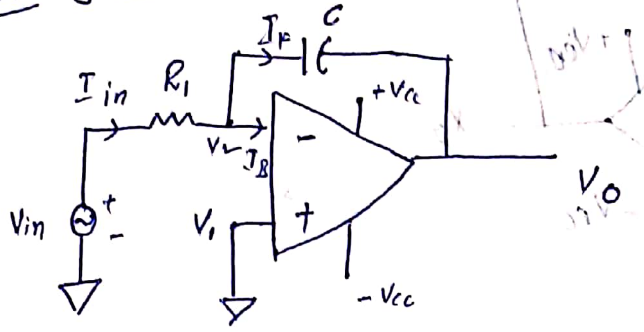
$$= N \cdot I \cdot \cancel{A} + I \cdot \cancel{A}$$

$R_1 = R_F \longrightarrow$ subtractor Amplifier

$$V_0 = V_A - V_B$$

open loop → Comparation.
closed loop → Negetive feed back → decease Gain
↓
Amplifier.

Integration :-



$V_1 = 0 \Rightarrow V_2 = 0$ By virtual ground.

$I_B = 0$ for an op-amp

$$\Rightarrow \frac{-V_2 + V_{in}}{R_1} = I_F \qquad I_F = C \cdot \frac{dV}{dt}$$

$$I_F = \frac{+V_{in}}{R_1}$$

$$C \cdot \frac{dV}{dt} = + \frac{V_{in}}{R_1}$$

$$dV = + \frac{V_{in}}{R_1 C} dt$$

$$V = \frac{1}{CR_1} \int_0^t V_{in} \, dt$$ Apply integration w.r.t time.

$$V_2 - V_o = \frac{1}{CR_1} \int_0^t V_{in} \, dt$$

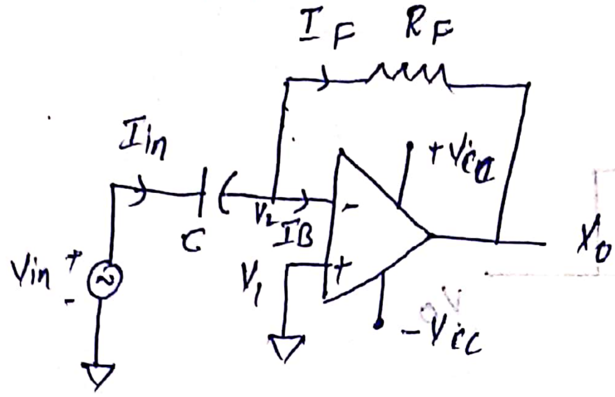
$$\boxed{V_o = -\frac{1}{CR_1} \int_0^t V_{in} \, dt}$$

$$\boxed{V_o = \frac{-1}{R_1 C} \int_0^t V_{in} \, dt}$$

scaling factors → R_1, C $\qquad T = R_1 C$

$$V_o \propto \frac{1}{T}$$

Differentiation.



By virtual ground $V_1 = 0 \Rightarrow V_2 = 0$

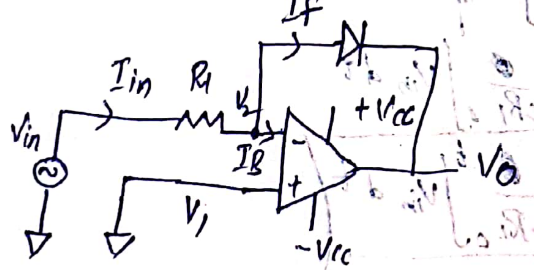
$I_{in} = I_F$

$$I_{in} = \frac{-V_0}{R_F}$$

$$C\frac{dV_{in}}{dt} = \frac{-V_0}{R_F}$$

$$\boxed{V_0 = -R_F C \frac{dV_{in}}{dt}}$$

Logarithemic :- *



diode current :-

$$I_d = I_{do}\left(e^{\frac{-V}{V_T}} - 1\right)$$

I_{do} : Reverse saturation current

V - diode voltage.

V_T - Thermal voltage = 26 mV

$$I_{do}\left(e^{\frac{-V}{V_T}} - 1\right) = \frac{V_{in}}{R_1}$$

$\log_{10} = 0.4343 \ln_e$

$= \frac{1}{2.3} \ln_e$

$$e^{\frac{+V_o}{V_T}} - 1 = \left(\frac{V_{in}}{I_{do} R_1}\right)$$

$$\cancel{\frac{V_o}{V_T} = \log_e\left(\frac{V_{in}}{I_{do} R_1} + 1\right)}$$

$e^{\frac{-V}{V_T}} >> 1$

s.T one is negelted.

$$\cancel{V_o = V_T \log_e\left(\frac{V_{in}}{I_{do} R_1} + 1\right)}$$

$$\cancel{V_T \ln\left(\frac{V_{in}}{I_{do} R_1} + 1\right)}$$

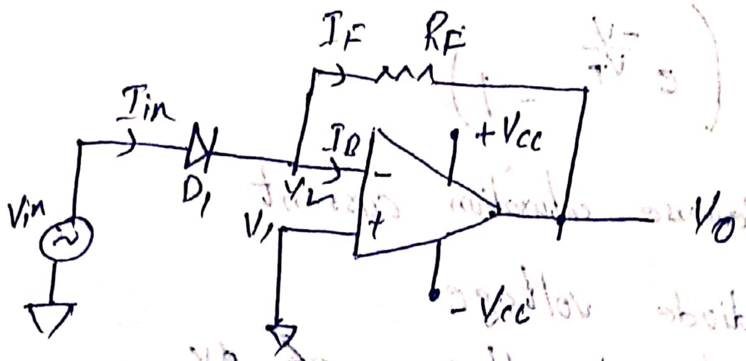
$$\frac{V_{in}}{R_1} = I_{do}\, e^{\frac{V_o}{V_T}}$$

$$\frac{V_o}{V_T} = \log V_{in} - \log R_1 - \log I_{do}$$

$$V_o = V_T \ln V_{in} - V_T \ln R_1 - V_T \ln I_{do}$$

$$\boxed{V_o = K \ln V_{in}}$$

anti-logarithemic (exponetion)



$$I_{in} = \frac{-V_O}{R_F}$$

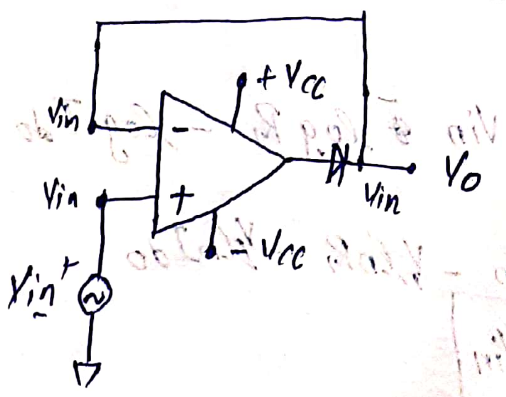
$$I_{do}\left(e^{-\frac{V_{in}}{V_T}} - 1\right) = -\frac{V_O}{R_F}$$

$$e^{-\frac{V_{in}}{V_T}} >> 1$$

$$\Rightarrow \quad I_{do} R_F e^{-V_{in}/V_T} = -V_O$$

$$\boxed{V_O = +K e^{-V_{in}}}$$

Precision Rectifier :- super diode idle diode



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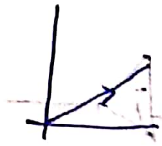
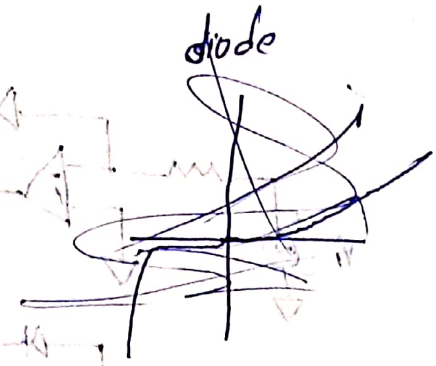
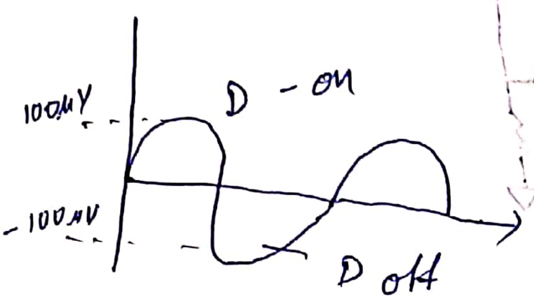
V_0 =

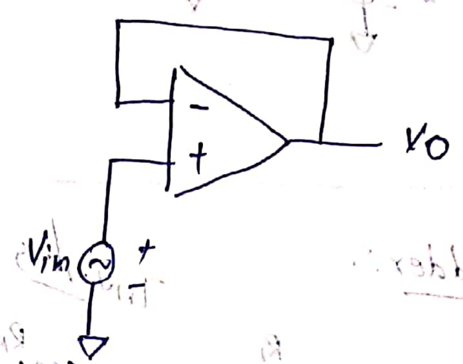
ideal diode

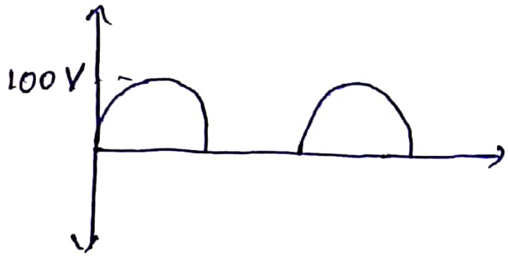


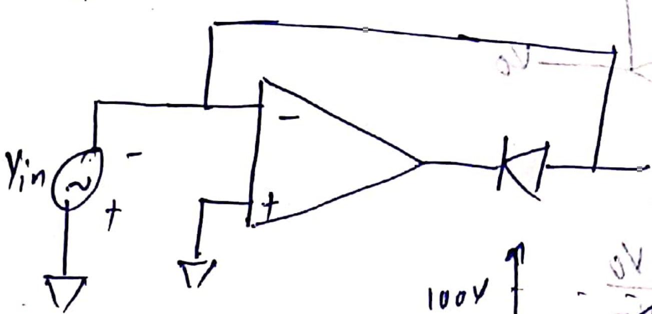


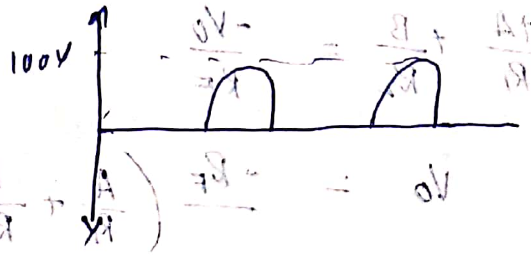


unity gain Amplifier





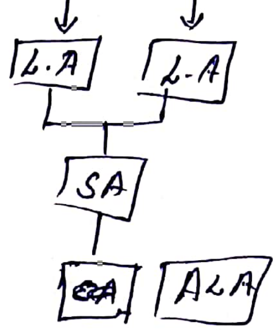


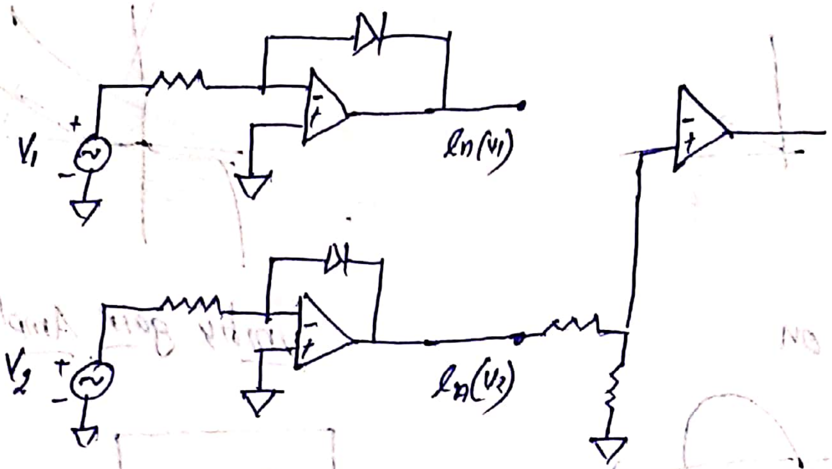


Multipication :-

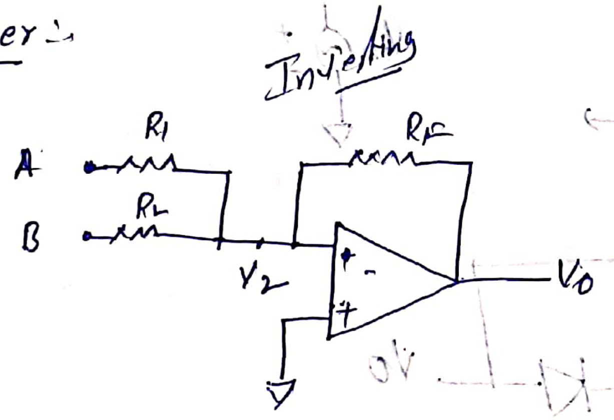
$m \times n$ ✓

~~log~~ $\ln(m \times n) = \ln m + \ln n$





Adder :-



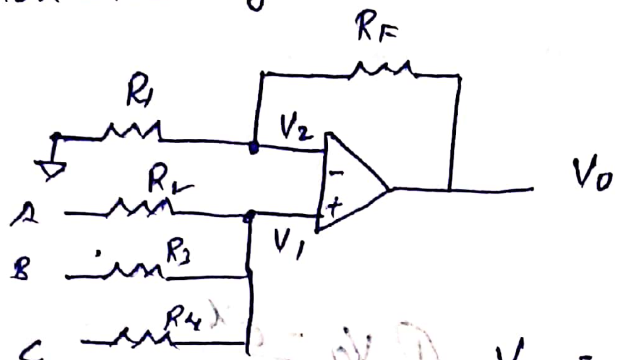
$$\frac{+A}{R_1} + \frac{B}{R_2} = \frac{-V_0}{R_F}$$

$$V_0 = \frac{-R_F}{}\left(\frac{A}{R_1} + \frac{B}{R_2}\right)$$

$$R_F = R_1 = R_2$$

$$\Rightarrow \quad V_0 = -(A+B)$$

Non Inverting



$$V_1 = V_2$$

$$\frac{V_2 - V_0}{R_F} + \frac{V_2}{R_1} = 0$$

$$R_F\left(\frac{V_2}{R_F} + \frac{V_2}{R_1}\right) = V_0$$

$$V_2 = \frac{V_0\ \cancel{R_F}\ R_1}{(R_1 + R_F)\ \cancel{R_F}}$$

$$\frac{V_1 - V_A}{R_2} + \frac{V_1 - V_B}{R_3} + \frac{V_1 - V_C}{R_4} = 0$$

$$V_1\left(\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right) = \frac{V_A}{R_2} + \frac{V_B}{R_3} + \frac{V_C}{R_4}$$

$$\frac{V_0 R_1}{R_1 + R_F}\left(\cancel{R_2}\ \Sigma R_2 R_3\right) = \Sigma V_A R_3 R_4$$

$$V_0 = \frac{(\Sigma V_A R_3 R_4)(R_1 + R_F)}{(\Sigma R_2 R_3) R_1}$$

$\cancel{R_2} = \cancel{R_3} = R_4$

$R_2 = R_3 = R_4$

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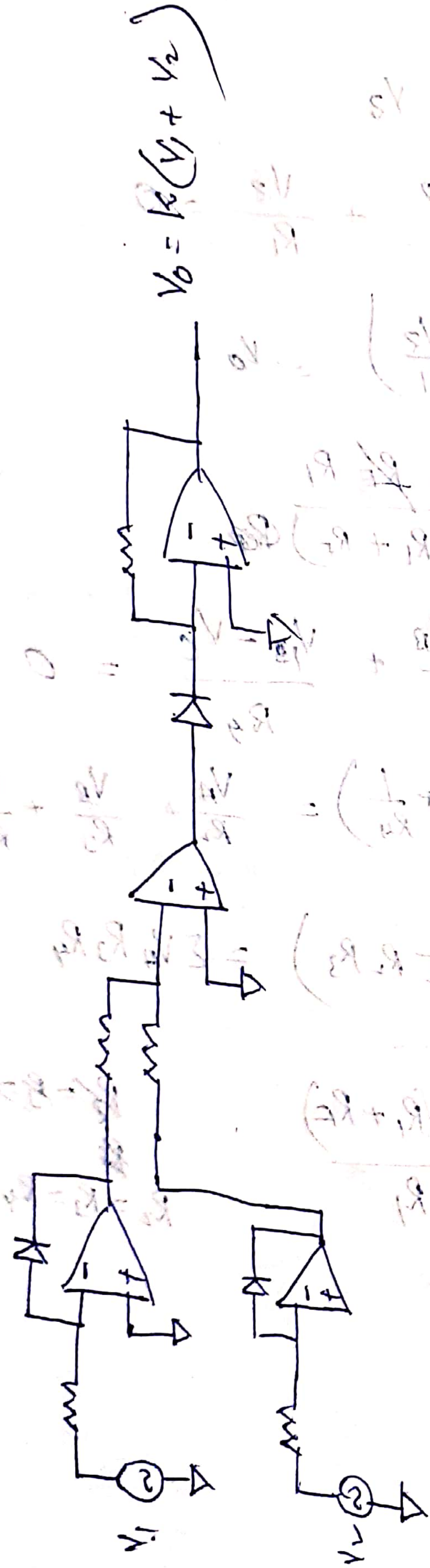
Multiplier



① $V_0 = \dfrac{e^x}{e^x + 1}$

② $V_0 = \dfrac{e^{-x}}{e^x + e^{-x}}$

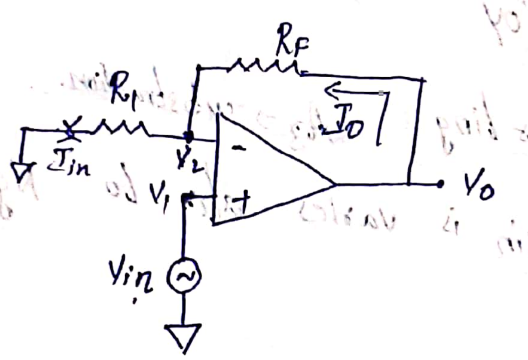
Divider :-

$$\log(a/b) = \log a - \log b$$

$=$

Converters :-

Voltage to current convertor :-



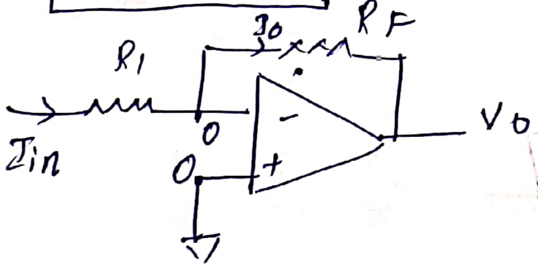
at node V_2

$$I_{in} = I_o \quad \text{where } I_B = 0$$

$$I_{in} = \frac{V_2 - 0}{R_1} = \frac{V_{in}}{R_1} \qquad V_1 = V_2 = V_{in} \text{ from VG}$$

$$I_{in} = \frac{V_{in}}{R_1}$$

output $\rightarrow$ $\boxed{I_o = \frac{V_{in}}{R_1}}$ $\rightarrow$ input



$$\frac{V_o - 0}{R_F} = I_{in}$$

$$\boxed{V_o = I_{in} R_F}$$

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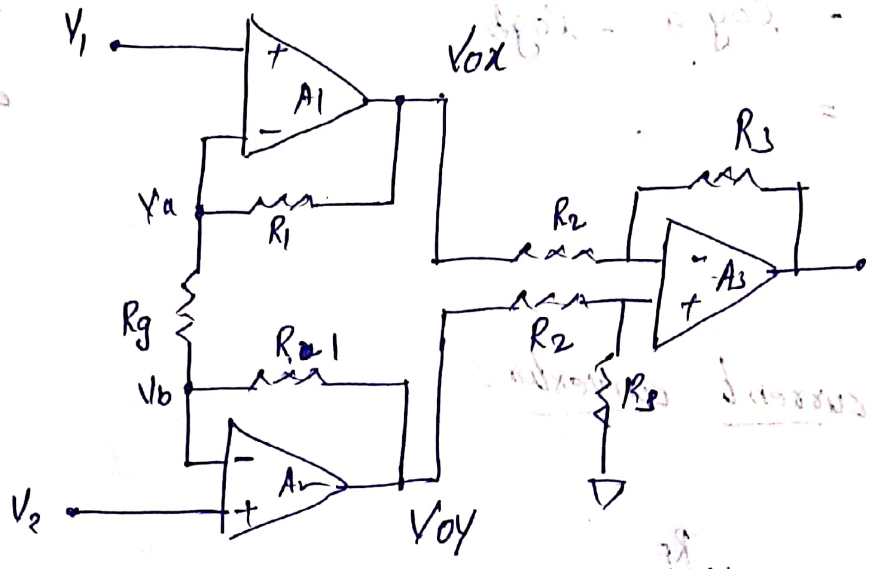
Instrumentation Amplifier :.

=)



A_1, A_2 => ~~Non-Inverting~~ ~~A_3 => subtraction.~~

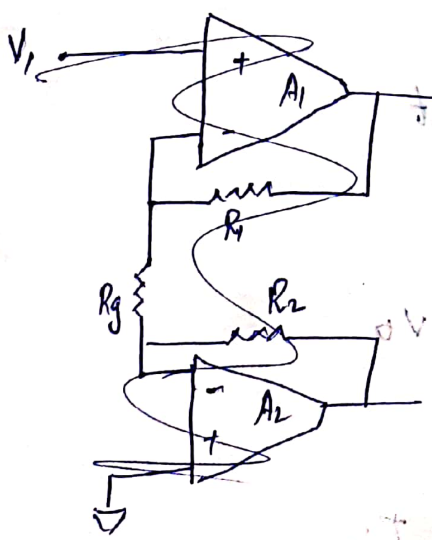
→ very-high gain, gain is varies a/c to R_g.

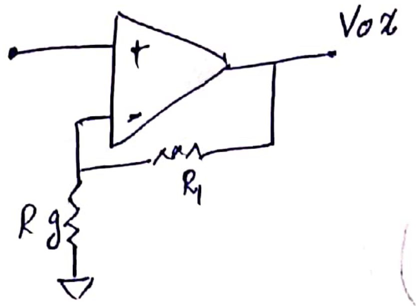
case.i,

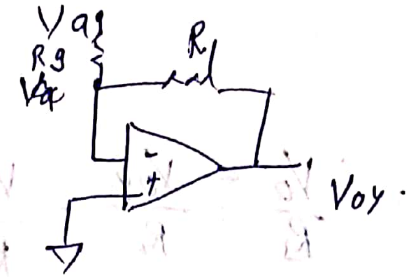
$V_2 = 0$, $V_1 \longrightarrow V$

~~V_{ox} =~~ Then A_1 → Inverting

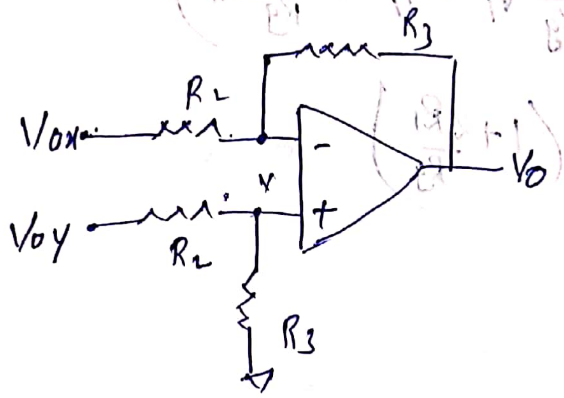
A_2 → Non Inverting







$$V_{ox} = \left(1+\frac{R_1}{R_g}\right) V_1 \qquad V_{oy} = \frac{-R_1}{R_g}$$



$$\cancel{V_0 =}$$

$$\frac{V - V_{ox}}{R_2} + \frac{V - V_0}{R_3} = 0$$

$$V\left(\frac{R_2+R_3}{R_2 R_3}\right) = \frac{V_{ox}}{R_2} + \frac{V_0}{R_3}$$

$$V = \frac{V_{ox}R_3 + V_0 R_2}{R_3 + R_2}$$

$$\frac{V - V_{oy}(R_3+R_2)}{R_2} + \frac{V}{R_3} = 0$$

$$\cancel{\frac{V_{ox}}{R} + \frac{V_{ox}}{R_3+R_2} + \frac{R_2 V_0}{R_3(R_3+R_2)}}$$

$$\frac{V_{ox}R_3 + V_0 R_2 - V_{oy}R_3 - V_{oy}R_2}{R_2} + \frac{V_{ox}R_3 + V_0 R_2}{R_3} = 0$$

$$V_0\left(1+\frac{R_2}{R_3}\right) = V_{oy}\left(\frac{R_3+R_2}{R_2}\right) - V_{ox}\left(1+\frac{R_3}{R_2}\right)$$

$$\frac{V_o}{R_3} = \frac{V_{oy}}{R_2} - \frac{V_{ox}}{R_2}$$

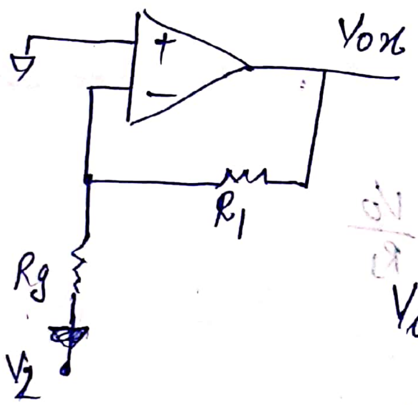
$$\boxed{V_{o_1} = \frac{R_3}{R_2}\left(V_{oy} - V_{ox}\right)}$$

$$V_{o_1} = \frac{R_3}{R_2}\left(\frac{-R_1}{R_g}V_1 - V_1 - \frac{R_1}{R_g}V_1\right)$$

$$= -\frac{R_3}{R_2}V_1\left(1 + \frac{2R_1}{R_g}\right)$$

Case (ii) :-

$V_2 = \cdot$, $V_1 = 0$.



$$V_{ox} = \frac{-R_1}{R_g}V_2$$

$$V_{oy} = \left(1 + \frac{R_1}{R_g}\right)V_2$$

$$V_{o_2} = +\frac{R_3}{R_2}V_2\left(1 + \frac{2R_1}{R_g}\right)$$

Scanned by CamScanner

$$V_o = \cancel{V_{o4}} + V_{o2} + V_{o1}$$

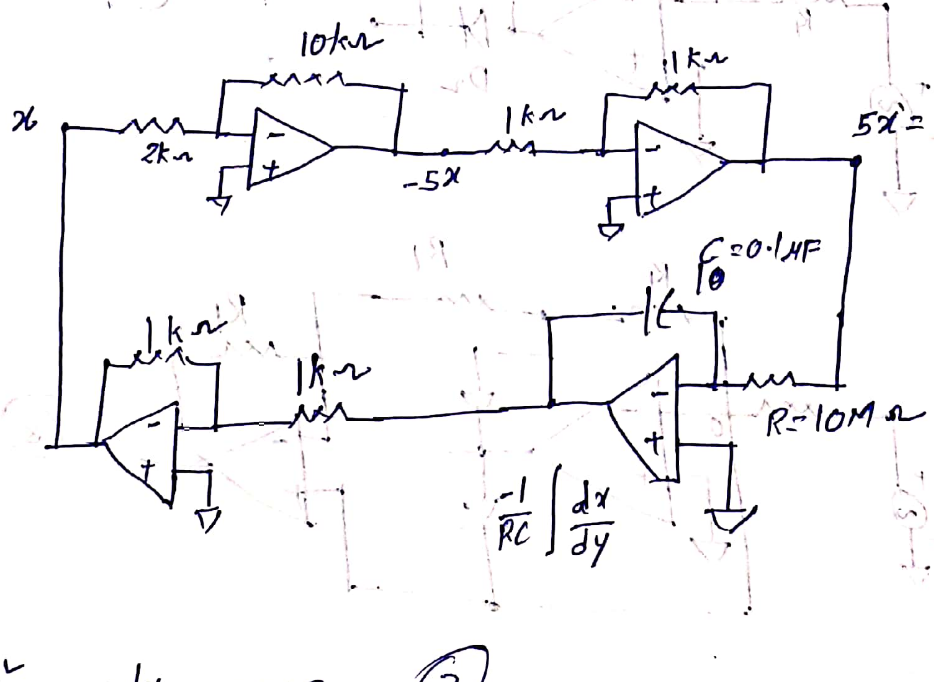
$$\boxed{V_o = \frac{R_3}{R_2}\left(1+\frac{2R_1}{R_g}\right)(V_2 - V_1)}$$

$$\text{Gain} = \frac{V_o}{V_2 - V_1} = \frac{R_3}{R_2}\left(1+\frac{2R_1}{R_g}\right)$$

2) $\frac{dx}{dy} - 5x = 0$

$$\frac{dx}{dy} = 5x$$

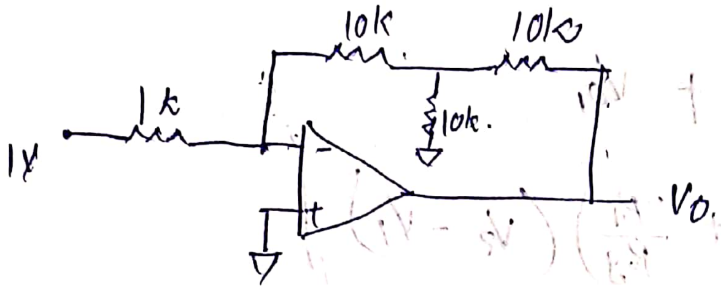
$$dx = 5x\,dy$$



ii) $\frac{d^2x}{dy^2} - \frac{10dx}{dy} + 5x = 0$ 3

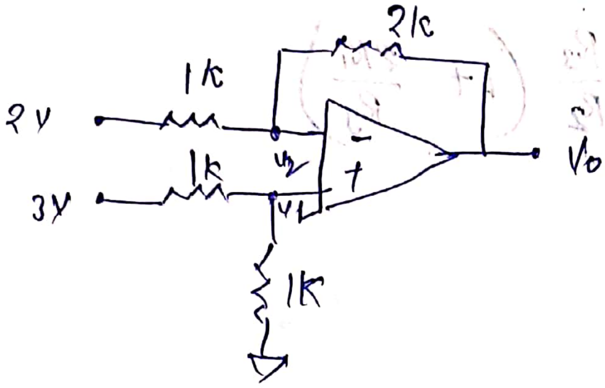
iii) $\frac{d^2x}{dy^2} + 15\frac{dx}{dy} - 10x = 0$ 4

iii),



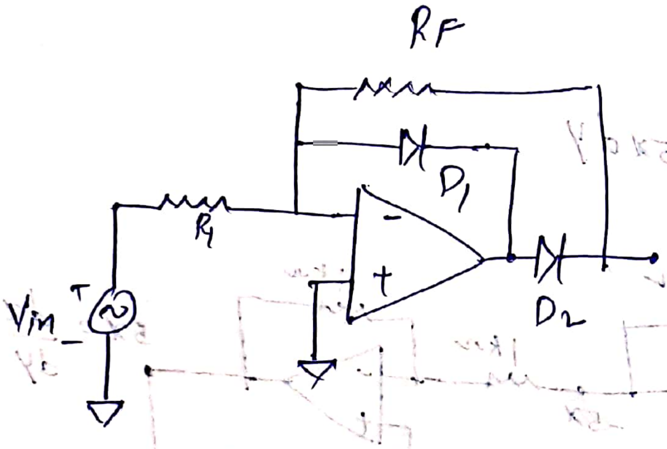
10k
10k
1k
10k.
1V
Vo.

5



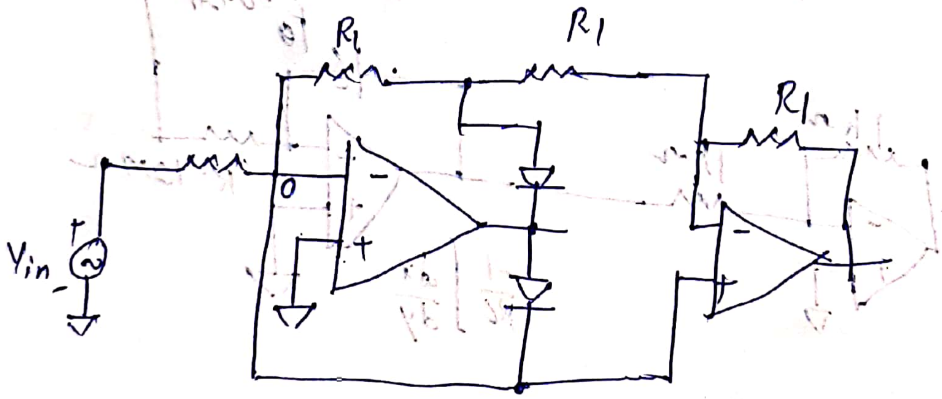
2k
1k
2V
1k
3V
V2
V1
Vo
1K

6



RF
D1
R1
Vin
D2

7



R1
R1
R1
0
Vin

8

$$\frac{dx^2}{dy^2} - 10\frac{dx}{dy} + 5x = 0$$

$$V_1 - 3 + V_1 = 0$$

$$V_1 = 3/2 = V_2$$

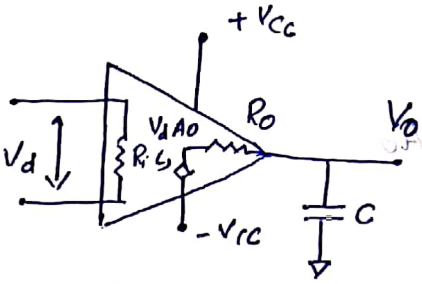
$$\frac{\frac{3}{2} - 2}{1} + \frac{\frac{3}{2} - V_0}{2} = 0$$

$$\frac{3}{2} - V_0 = 1$$

$$V_0 = \frac{3}{2} - 1$$

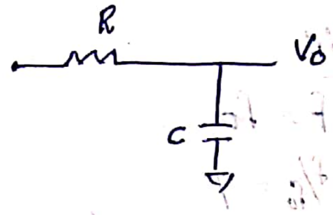
$$= 1/2$$

Frequency response of OP- Amp :-



Equivalent circuit of op- Amp

R_i - input Resistance
R_o - ouput Resistence
C - load capacience.



$$V_0 = \left(\frac{1/sC}{R_0 + 1/sC}\right) V_d A_0$$

$$V_0 = \left(\frac{1/sC}{R + 1/sC}\right) V_1$$

$s = j\omega$

$$V_0 = \left(\frac{1}{1 + sCR}\right) V_d A_0$$

$$= \left(\frac{1}{1 + 2\pi f C R j}\right) V_d A_0$$

Gain $\Rightarrow = \frac{V_0}{V_d} = \frac{A_0}{1 + 2\pi f C R j}$

Let

$$f_0 = \frac{1}{2\pi CR}$$ $\Rightarrow$ Depended on the components.

$$\frac{V_o}{V_d} = \left(\frac{A_o}{1 + j\, f/f_0}\right) \quad 1 - j$$

$$\left|\frac{V_o}{V_d}\right| = \frac{A_o}{1 + (f/f_0)^2}\left(\sqrt{1 + (f/f_0)^2}\right)$$

$$= \frac{A_o}{\sqrt{1 + (f/f_0)^2}} \qquad \theta = Tan^{-1}\left(-f/f_0\right)$$

$$= -Tan^{-1}\left(f/f_0\right)$$

Case.i.:

$f << f_0$

$f/f_0 << 1$

negelt f/f_0

$$\left|\frac{V_o}{V_d}\right| = \frac{A_o}{\sqrt{1}} = A_o$$

Case.ii:

$f = f_0$

$f/f_0 = 1$

$$\left|\frac{V_o}{V_d}\right| = A_o/\sqrt{2}$$

Case.iii:

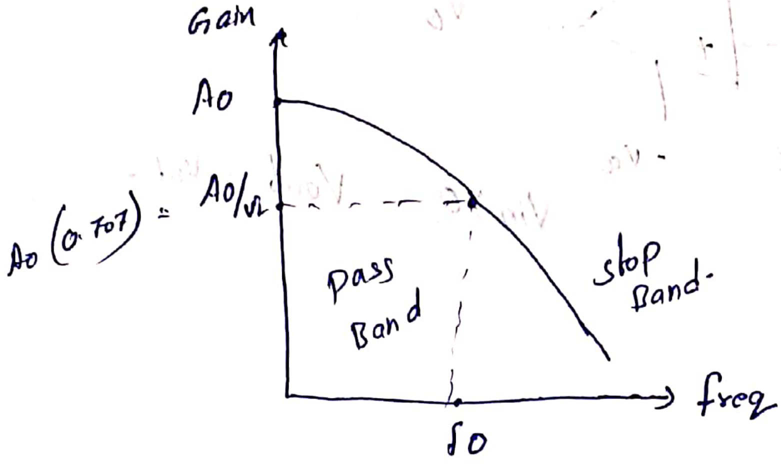
$f >> f_0$

$f/f_0 >> 1$

$$\left|\frac{V_o}{V_d}\right| = A_o \sqrt{\left(\frac{f_0}{f}\right)^2}$$

$$= A_o \frac{f_0}{f}$$

frequcy Vs Gain :-



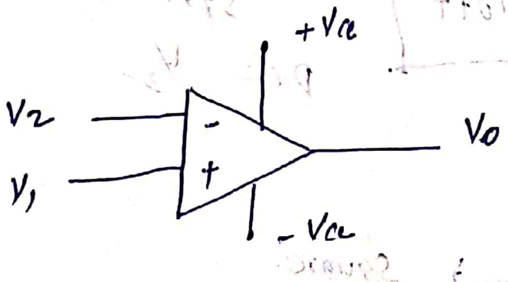
→ Allowing low freqcus.

→ Power calculaed ~~by~~ at $Ao/\sqrt{2}$

→ Op-Amp acts as low-pass filter.

→ At pass-Band it allows freqies.
stop-Band it stops "

Comparators :-
open loop



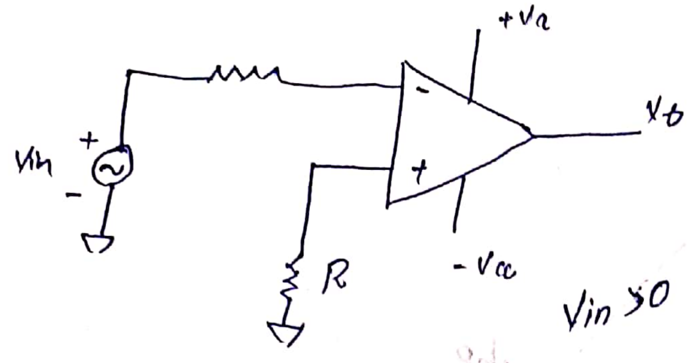
$V_1 > V_2 \rightarrow V_o = +V_{cc} / +V_{sat}$

$V_1 < V_2 \rightarrow V_o = -V_{cc} / -V_{sat}$

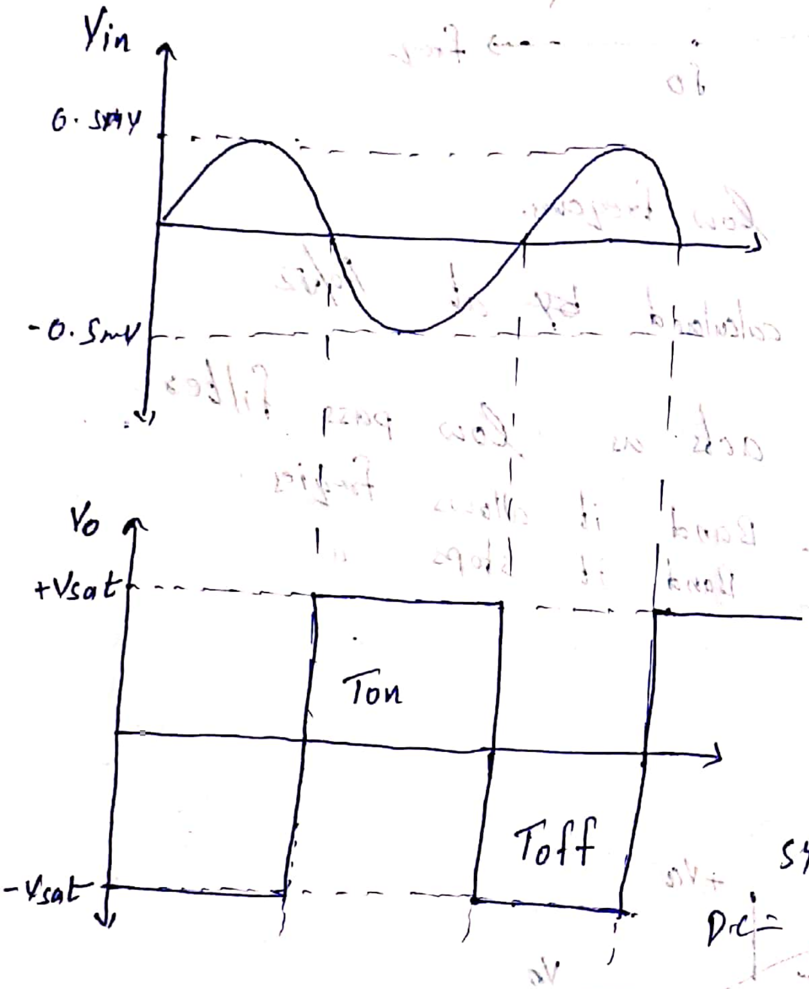
→ converter Analog to digital.

inverting

zero crossing detector.



Vin > 0 - Vout = Vsat.



symmetric

DC = 1/2

sinusoidal ⟶ square.

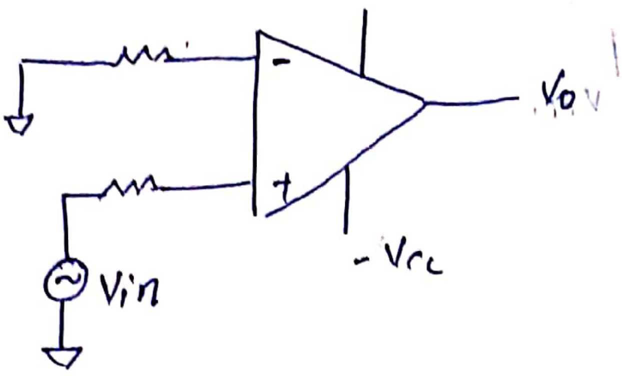
characteristics:

i) High speed

ii) accuracy.

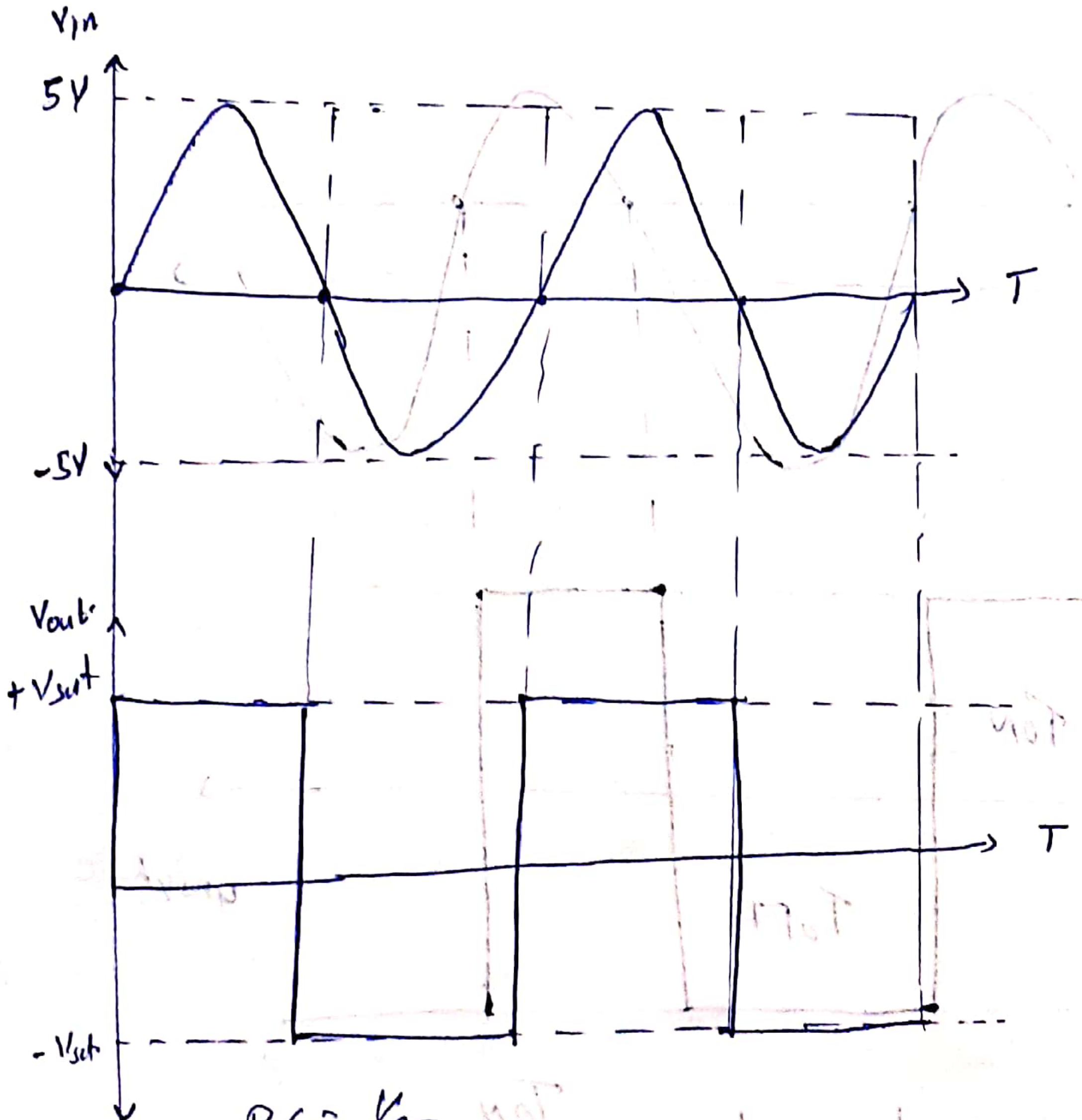
iii) Output is comparable.

Non-inverting



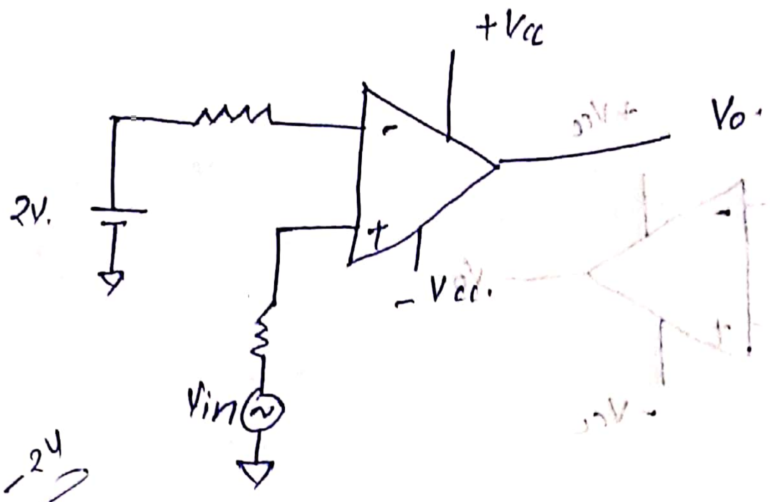
$V_{in} > 0 \rightarrow V_o = +V_{cc}$

$V_{in} < 0 \rightarrow V_o = -V_{cc}$



$DC = 1/2$

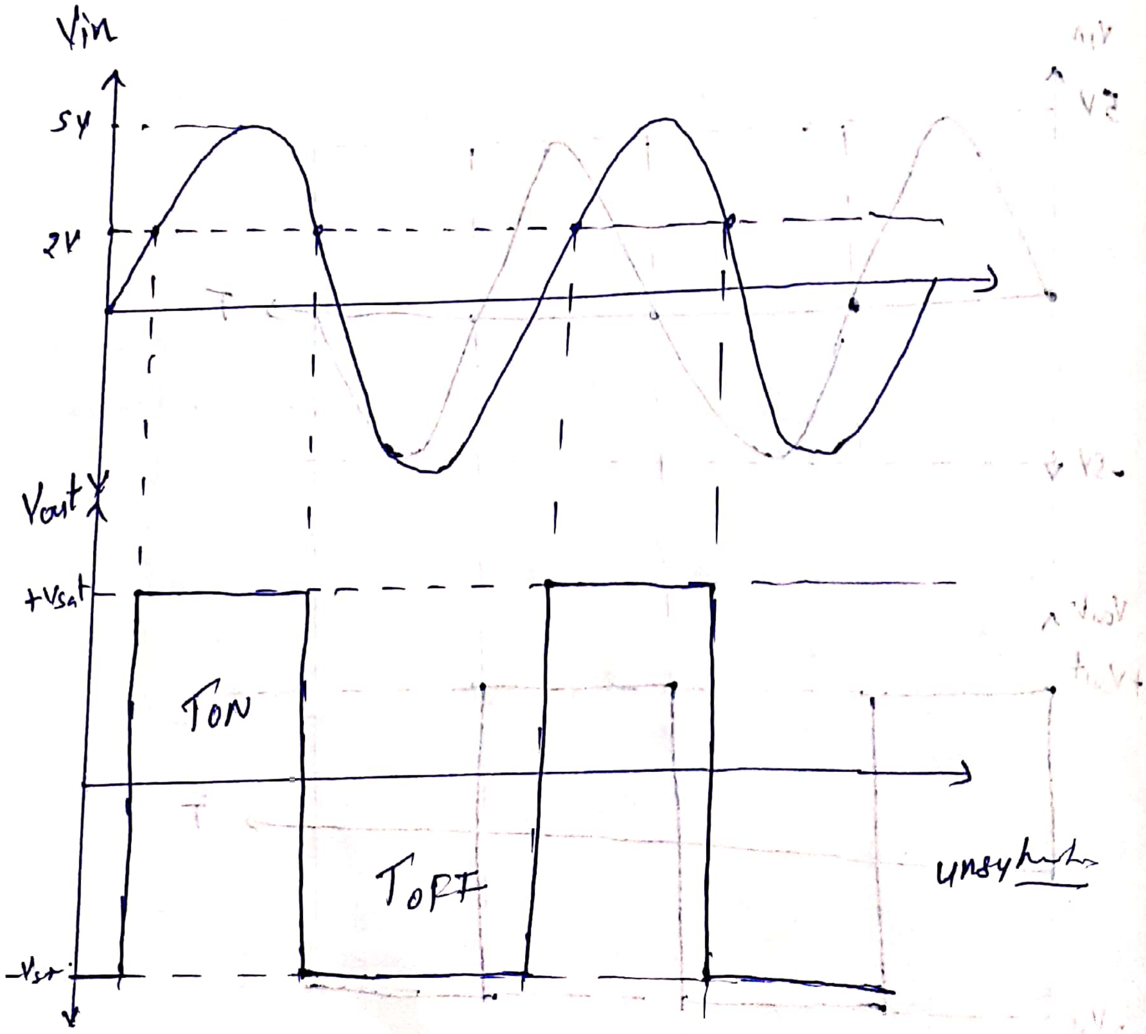
3



-2V

$V_{in} > 2V \quad V_o = +V_{sat}$

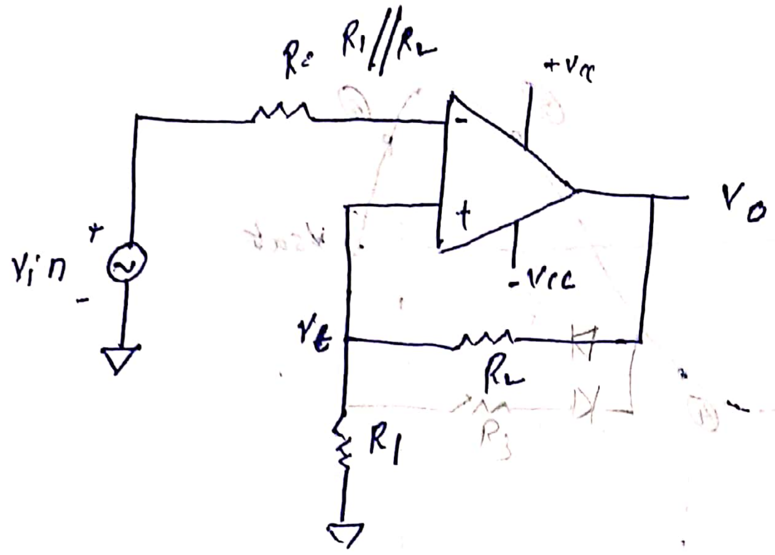
$V_{in} < 2V \quad V_o = -V_{sat}$



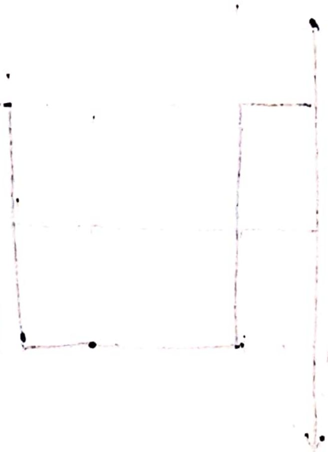
Duty cycle $= \dfrac{T_{ON}}{T_{ON} + T_{OFF}}$

=

schmitt Trigger :-



+Ve feedback



$$\frac{V_t}{R_1} + \frac{V_t - V_o}{R_2} = 0.$$

$$V_t = \frac{V_o}{R_2}\left(\frac{R_1 R_2}{R_1 + R_2}\right)$$

$$= \frac{V_o \cdot R_1}{R_1 + R_2}$$

$V_o = +V_{cc} \rightarrow V_t$ - upper thershhold $= V_{ut}$

$V_o = -V_{cc} \rightarrow V_t$ - lower " $= V_{Lt}$

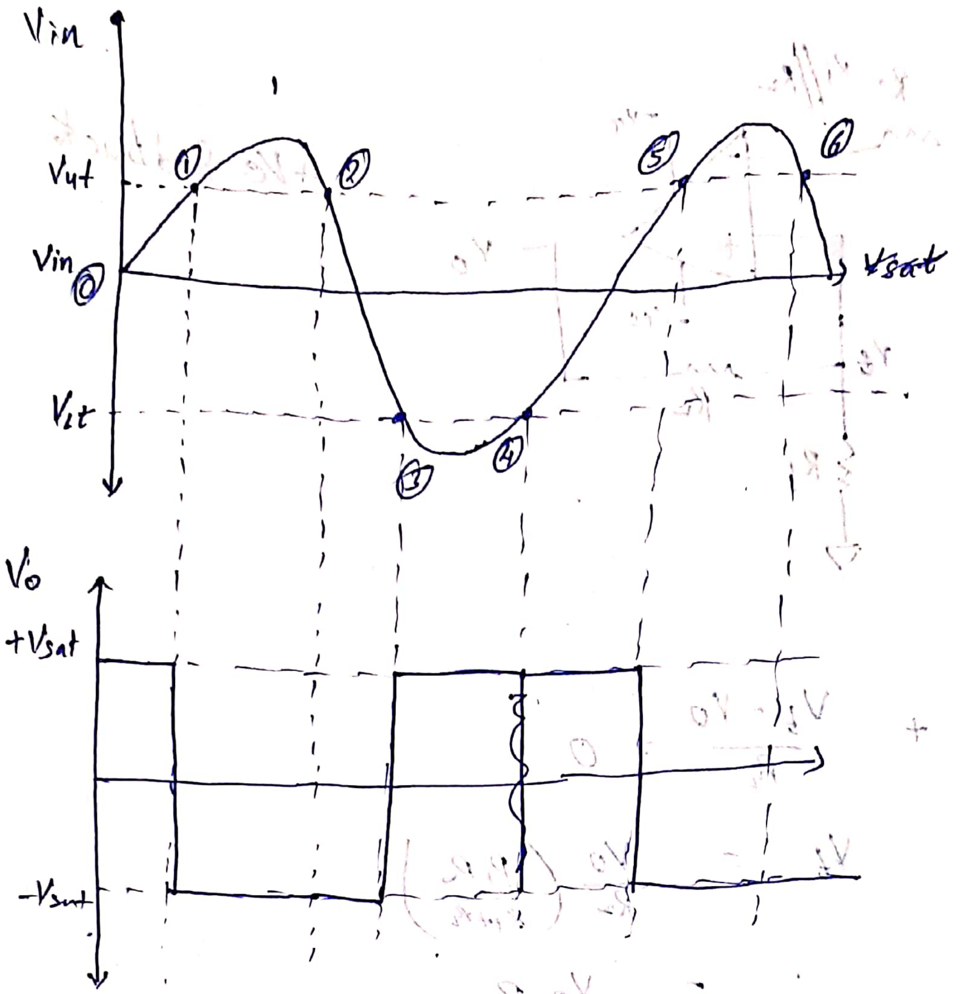
Case i,

$V_{in} > V_t \;=\; V_o = -V_{sat}$

Case ii

$V_{in} < V_t \;=\; V_o = +V_{sat}$

$$V_{ut} = \left(\frac{R_1}{R_1 + R_2}\right)(V_{sat}) \qquad V_{Lt} = \left(\frac{R_1}{R_1 + R_2}\right)(-V_{sat})$$



symmetry

∴ Duty cycle = 50%

Dcam

0 to 1

$V_{in} < V_{ut} \Rightarrow V_0 = +V_{sat}$

$\Downarrow$

$V_t = V_{ut}$

1 to 2 $V_t = V_{ut}$

$V_{in} > V_{ut} \Rightarrow V_0 = -V_{sat}$

$\Downarrow$

$V_t = V_{lt}$

2 to 3 $V_t = V_{lt}$

$V_{in} > V_{lt} \Rightarrow V_0 = -V_{sat}$

$\Downarrow$

$V_t = V_{lt}$

3 to 4 $V_t = V_{lt}$

$V_{in} < V_{lt} \Rightarrow V_0 = +V_{sat}$

$\Downarrow$

$V_t = V_{ut}$

4 to 5 $V_t = V_{ut}$

$V_{in} < V_{ut} \Rightarrow V_0 = +V_{sat}$

$\Downarrow$

$V_t = V_{ut}$

5 to 6 $V_t = V_{ut}$

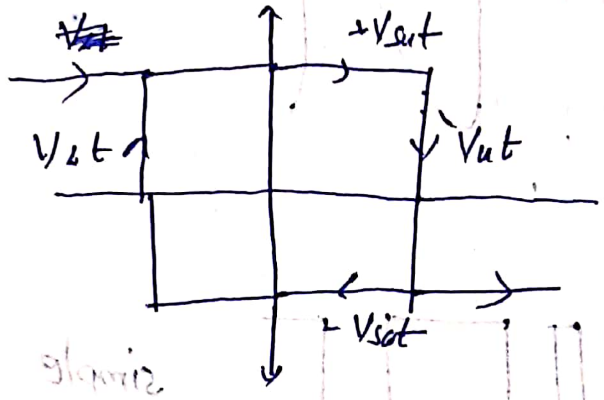
$V_{in} > V_{ut} \Rightarrow V_0 = -V_{sat}$

$\Downarrow$

$V_t = V_{lt}$

Hysteresis curve :-

$V_{HY} = V_{ut} - V_{Lt}$ Dead zone

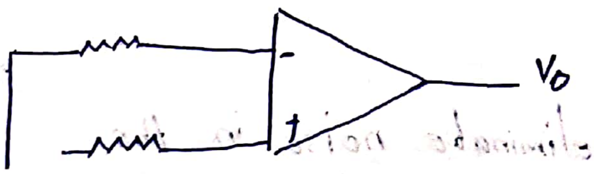


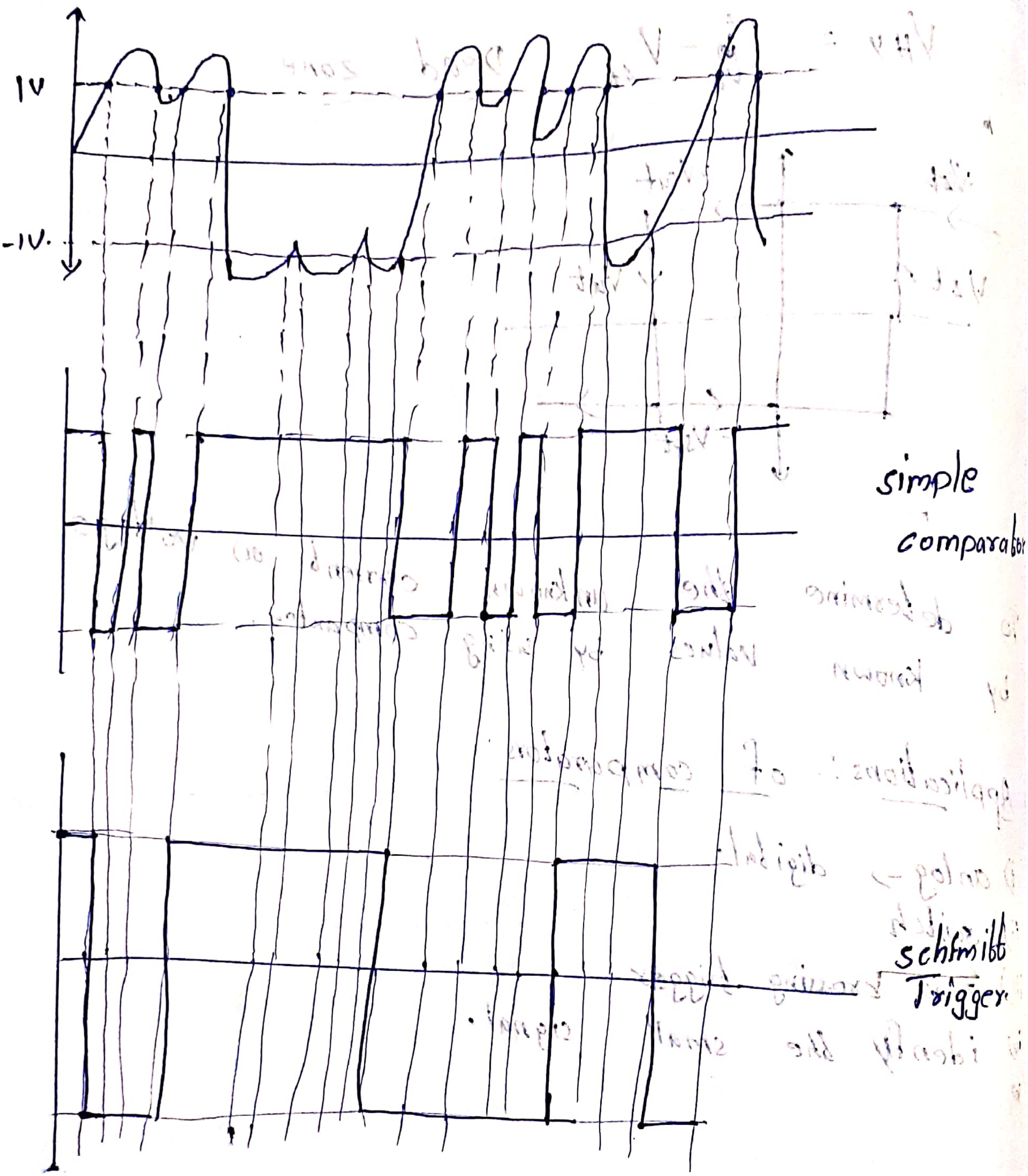
→ To determine the unknown current (or) voltage by known values by using comparators.

→ Applications :- of comparators :-

i) anlog → digital.
ii) switch
iii) zero crossing trigger
iv) idenfy the small signal.
v)

⇒



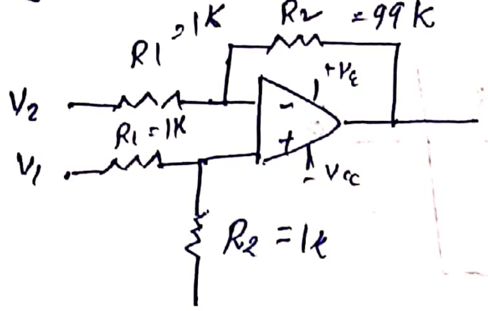


⇒ This used to eliminate noise in the output wave.

(9) i) ⇒ Design a comparator with two threshold lines which are not equal.

(10) i) ⇒ Design a non-Inverting schimtt Trigger

ii)



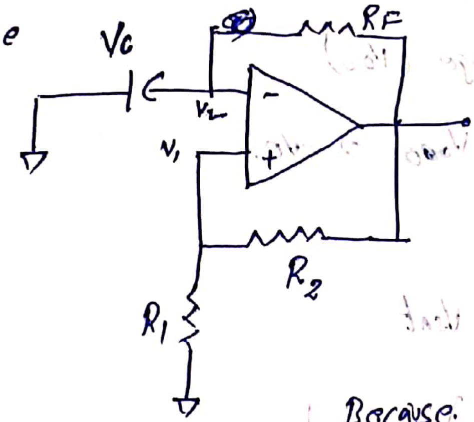
Find CMRR = ?

$$= \frac{A_d}{A_c}$$

iii)

Multivibrator: i) Astable ✓ 3) Bi-stable. ×
2) Monostable ✓

Astable



Free running Oscillator

i) Considering Negative Feedback

Because +ve fb adds the output But there is a saturated value.

$V_1 > V_2 \rightarrow$

i) $V_1 > V_2 \longrightarrow V_0 = +V_{sat}$

ii) $V_1 < V_2 \longrightarrow V_0 = -V_{sat}$

offset ouput Voltage.

at $t=0$, $V_c = 0$

$$V_C = V_2 = 0 < V_1 = \left(\frac{R_1}{R_1+R}\right) V_{00}$$

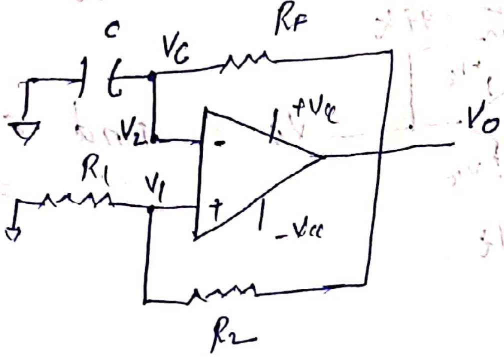
$V_1 > V_2 \Rightarrow V_0 = +V_{sat}$

⇒ Capasitance chargeing ⇒

if This chargeing more than V_1

⇒ $V_C = V_2 > V_1 \Rightarrow V_0 = -V_{sat}$

⇒ Capasitiance discharges. ⇒ Then continues



at $t=0$ $\quad V_C = 0$

$$V_2 = V_C = 0$$

Due to output voltage (V_{oo})

$$V_1 \rightarrow \left(\frac{R_1}{R_1+R_2}\right) V_{oo} \Rightarrow +ve.$$

Case i :-

$$V_1 > V_C \Rightarrow V_0 = +V_{sat}$$

$$V_1 \rightarrow +V_t = \left(\frac{R_1}{R_1+R_2}\right)(+V_{sat})$$

when, $V_0 = +V_{sat}$

$V_C \rightarrow$ charge through R_F

Case ii :- when

$$V_C > V_1 \Rightarrow V_0 = -V_{sat}$$

$$V_1 \rightarrow -V_t = \left(\frac{R_1}{R_1+R_2}\right) - V_{sat}$$

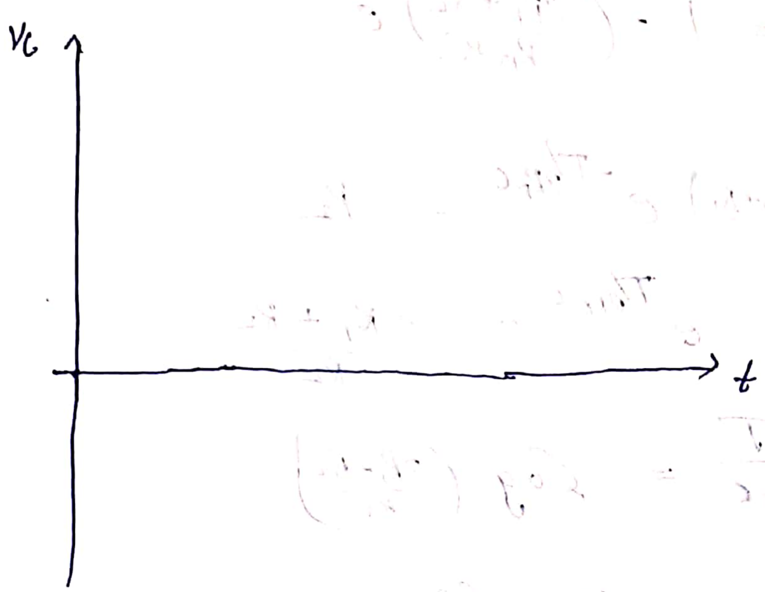
$$V_C \ni V_0 \Rightarrow$$

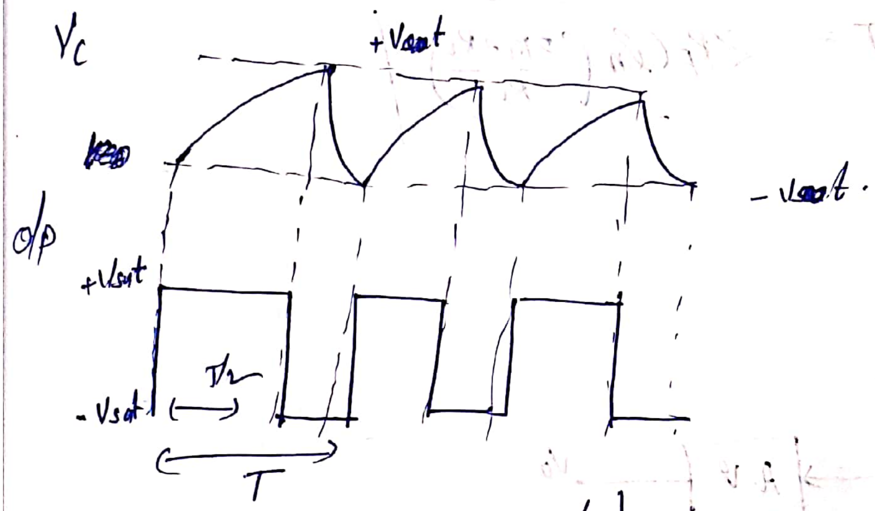
$V_C \Rightarrow$ discharge through R_F

Case iii :- when.

$$V_C < V_1 \Rightarrow V_0 = +V_{sat}$$

$$V_1 = +V_t = \left(\frac{R_1}{R_1+R_2}\right)(+V_{sat})$$





$V_C = V_0 \left(1 - e^{-t/\tau}\right)$ charging

$V_C = V_0 e^{-t/\tau}$ discharging.

$$V_C(t) = V_C(\infty) + \left[V_C(0) - V_C(\infty)\right] e^{-t/\tau}$$

$$= +V_{sat} + \left[\left(\frac{-R_1}{R_1+R_2}\right) V_{sat} - V_{sat}\right] e^{-t/\tau}$$

$t = T/2$

$\tau = RC = R_F C$

$e^{-t/\tau} = e^{-T/2RC}$

$$\left(\frac{R_1}{R_1+R_2}\right) \cancel{V_{sat}} = \cancel{V_{sat}} - \left(\left(\frac{R_1}{R_1+R_2}\right) \cancel{V_{sat}} + \cancel{V_{sat}}\right) e^{-t/\tau}$$

$$\frac{R_1}{R_1+R_2} = 1 - \left(\frac{2R_1+R_2}{R_1+R_2}\right) e^{-T/2R_FC}$$

$$\cancel{2F} \; (2R_1+R_2)\, e^{-T/2R_FC} = R_2$$

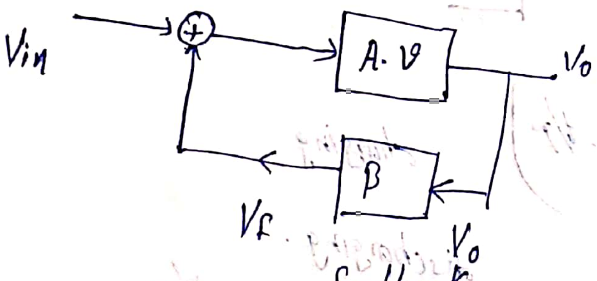
$$e^{T/2R_FC} = \frac{2R_1+R_2}{R_2}$$

$$\frac{T}{2R_FC} = \log\left(\frac{2R_1+R_2}{R_2}\right)$$

$$T = \cancel{2R_FC\log}$$

$$\boxed{T = 2R_FC\ln\left(\frac{2R_1+R_2}{R_2}\right)}$$

Oscillator



$$V_o = A_v V_d$$
$$V_d = V_{in} + V_f$$
$$V_f = \beta V_o$$

$$V_o = A_v\,(V_{in} + \beta V_o)$$

$$V_o = \left(\frac{A_v}{1-\beta A_v}\right) V_{in}$$

$$\boxed{\frac{V_o}{V_{in}} = \frac{A_v}{1-\beta A_v}}$$

$V_{in} = 0 \Rightarrow V_o \neq 0$

$1 - A_v\beta = 0$

$\boxed{A_v\beta = 1}$ Total loop gain = 1

polar form

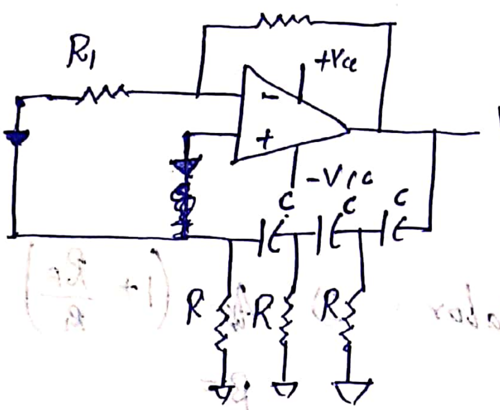
$A_v\beta = 1\angle 0^\circ$ $\angle A_v\beta = 0^\circ$ (or) 360°

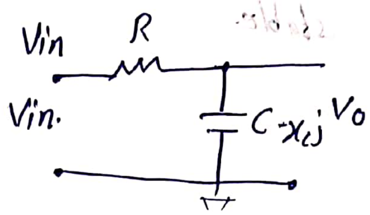
Barkhausan stability critian :

i) $A_v\beta = 1$

ii) phase angle = 0° (or) 360°

RC phase shift oscillator





$\theta = 60^\circ$ for 1RC combination

For -ve feedback 180° phase

+ve → 3×RC ⇒ 3×60 = 180° phase

Total 360°

$A_v\beta = 1$

$A_v = \frac{-R_F}{R_1}$

β

$\boxed{\frac{R_F}{R_1} = 29}$

$R - x_c j$

$\frac{V_{in}}{R - x_c j} = I = \frac{V_o}{-x_c j}$

$\frac{V_{in}}{V_o} = \frac{R - x_c j}{-x_c j}$

$= \frac{\tan^{-1}\frac{-x_c}{R}}{\tan^{-1} - x_c}$

$= \tan^{-1}\frac{-x_c}{R} - \tan^{-1} x_c$

$\tan\left(\frac{1 + \frac{x_c^2}{R}}{\frac{x_c}{R} - x_c}\right)$

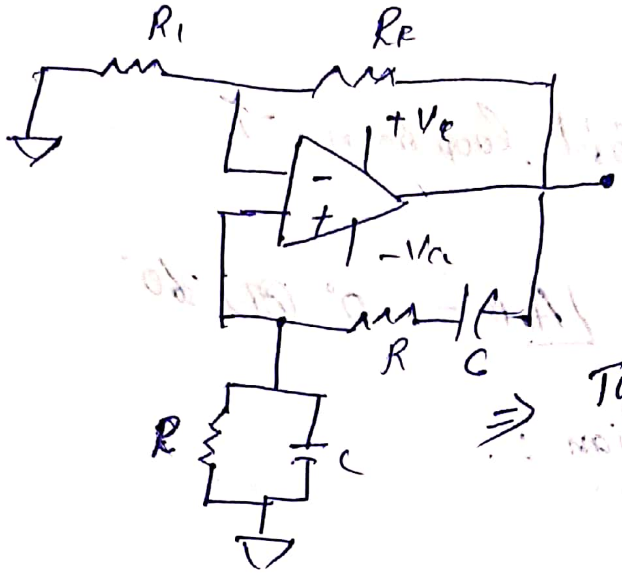
$\frac{R + x_c^2}{x_c - R}$

Pg 527

$f = \frac{1}{2\pi\sqrt{6}RC}$

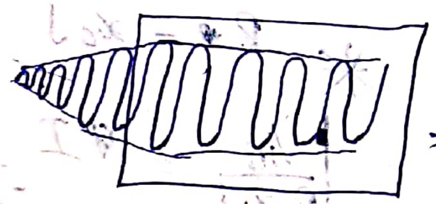
$\sqrt{2N}$

Wien Bridge oscillator :-



⇒ Total feed back is zero phase

→ The input is given by noice of RC.
→ This noice is keep on adding. Then it becomes stable.



→ oscillator

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

$\beta =$

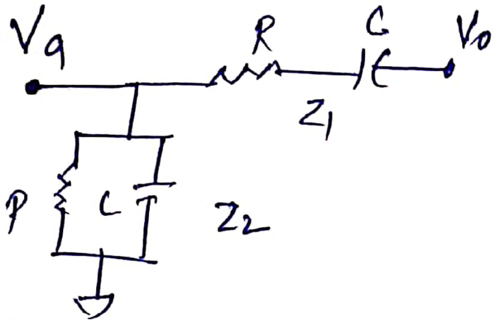
$$\boxed{f = \frac{1}{2\pi RC}}$$

RC phase shift

i) Negetive feedback
ii) less frequncy
iii) limited frequncies.
iv) complex circircut
v) phase differc 360°

Wein Bridge.

i) +Ve. feedback.
ii) more frequncy
iii) Variable frequncy.
iv) simple circple.
v) phase difference 0°



$$\beta = \frac{V_a}{V_o}$$

$$Z_1 = R - X_c j$$
$$= R + 1/sC = \frac{RSC+1}{SC}$$
$$Z_2 = \frac{R\,1/sC}{R + 1/sC} = \frac{R}{RSC+1}$$

$$\frac{V_a - 0}{Z_2} + \frac{V_a - V_o}{R + 1/sC} = 0$$

$$\frac{V_a}{Z_2} = -\frac{V_a - V_o}{Z_1}$$

$$-\frac{Z_1}{Z_2} V_a = V_a - V_o$$
$$V_o = V_a\left(1 + \frac{Z_1}{Z_2}\right)$$

$$\frac{V_o}{V_a} = \frac{Z_2 + Z_1}{Z_2}$$

$$\beta = \frac{Z_2}{Z_2 + Z_1}$$

$$= \frac{\frac{R}{\cancel{RSC+1}}}{\frac{RSC + (RSC+1)^2}{SC}}$$

$$= \cancel{\frac{RSC}{(RSC)^2 - 1 - RSC}}$$

$$= \frac{RSC}{RSC + (RSC+1)^2}$$

Scanned by CamScanner

$$A_v \beta = 1 \qquad A_v = 1 + \frac{R_f}{R_1}$$

$$\left(1+\frac{R_f}{R_1}\right)\left(\frac{RCs}{(RCs+1)^2 + RCs}\right) = 1$$

$$\left(1+\frac{R_f}{R_1}\right) jRC\omega = -R^2C^2\omega^2 + j3RC\omega + 1$$

$$3\cancel{RC\omega} = \cancel{RC\omega}\left(1+\frac{R_f}{R_1}\right)$$

$$\boxed{A_v = 1+\frac{R_f}{R_1} = 3}$$

$$\boxed{R_f = 2R_1}$$

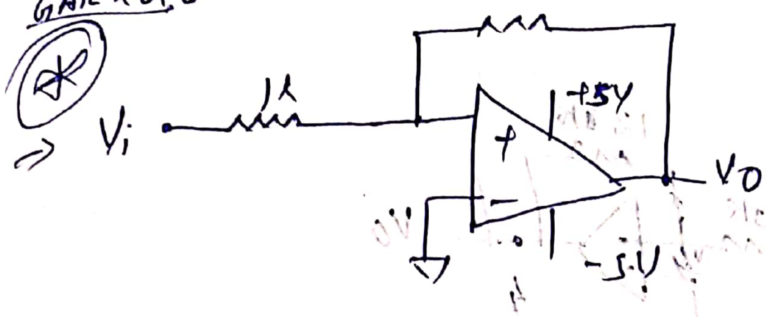
$$1 = R^2C^2\omega^2$$

$$\omega^2 = \frac{1}{R^2C^2}$$

$$f = \frac{1}{2\pi\sqrt{R^2C^2}}$$

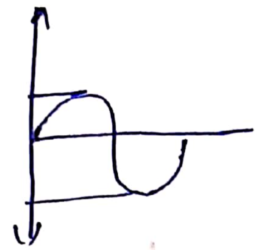
$$\boxed{f_0 = \frac{1}{2\pi RC}}$$

GATE 2020



Non-inverting schmitt Trigger.

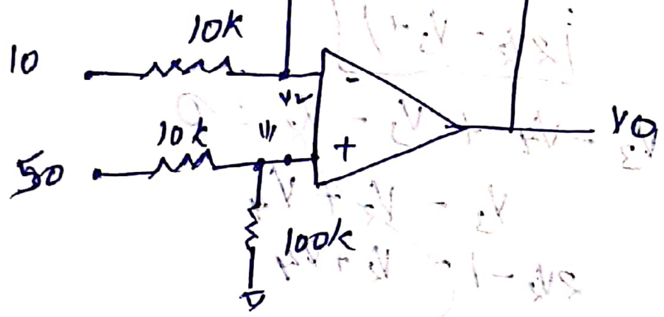
V_i



$\cancel{\frac{V_O}{V_I} = 1 + \frac{R_f}{R_1}}$

$\cancel{V_O =}$

→ straight line.



$\cancel{\frac{V-30}{10} + \frac{V}{100} = 0}$

$11V = 300$

$\cancel{\left(\frac{300}{11}\right) 10}$

$\frac{V-50}{1\cancel{0}} + \frac{V}{10\cancel{0}} = 0$

$11V = 500$

$\cancel{-\frac{100}{10} 10}$

$\cancel{-100 +}$

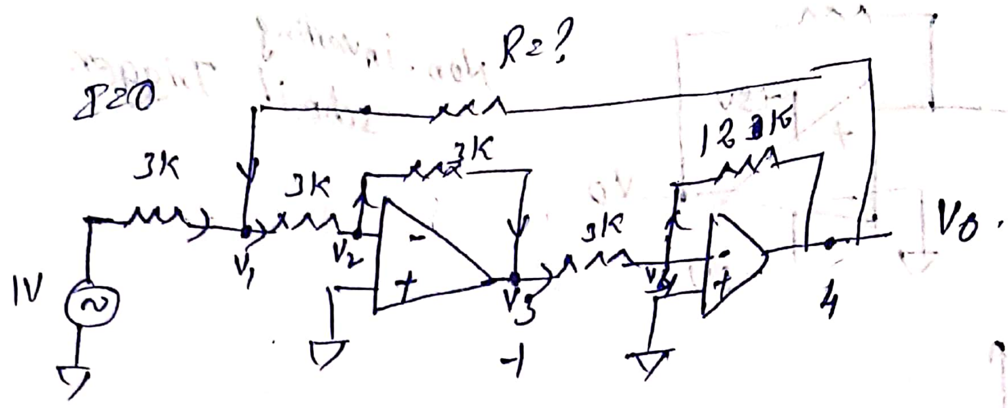
$\frac{V_2 - 10}{1\cancel{0}} + \frac{V_2 - V_0}{10\cancel{0}} = 0$

$11V_2 = V_0 + 100$

$500 = V_0 + 10$

$\boxed{\cancel{V_0 = 290 \text{ mV}}}$

$V_0 = 400$



$\frac{V_1 - 1}{3} = 0$

$\underline{V_1 = 1}$ $\cancel{\frac{V_1 - V_0}{R}}$

$\frac{1 - V_0}{R} + \frac{1 - V_2}{3} = 0$

$\frac{V_2 - V_3}{3} + \frac{V_2 - 1}{3} = 0$

$\boxed{2V_2 = V_3 + 1}$

$\cancel{\frac{V_0 - V_4}{12} + \frac{V_0 - V_1}{R} = 0}$ $V_3 - V_4 + V_3 - V_2 = 0$

$V_3 = V_2 + V_4$

$2V_2 - 1 = V_2 + V_4$

$\underline{V_2 = V_4 + 1}$

$3 - 3V_0 + R - RV_2 = 0$ $\frac{V_4 - V_3}{3} + \frac{V_4 - V_0}{12} = 0$

$\cancel{3 + 9V_2 + 3 + R - RV_2 = 0}$ $5V_4 = 4V_3 + V_0$

$5V_2 - 5 = 8V_2 - 4 + V_0$

$\boxed{3(1 - V_0) + R\left(\frac{1 + V_0}{3}\right) + R = 0}$ $\boxed{3V_2 + 1 + V_0 = 0}$

$3V_2 = -1 - V_0$

$-V_0 = 3V_2 + 1$

$$\frac{V_0 - V_4}{12} + \frac{V_0 - 1}{R} = 0$$

$$(V_0 - V_2 - 1)R + 12(V_0 - 1) = 0$$

$$3(12+R)(V_0 - 1) = V_2$$

$$= -1 - V_0$$

$\boxed{V_2 = 0}$ $\boxed{V_4 = 0}$

$$V_3 = -1$$

$$\frac{1 - V_0}{R} + \frac{1}{3} = 0$$

$$\underline{V_0 = 4}$$

$$\boxed{3 - 3V_0 + R = 0}$$

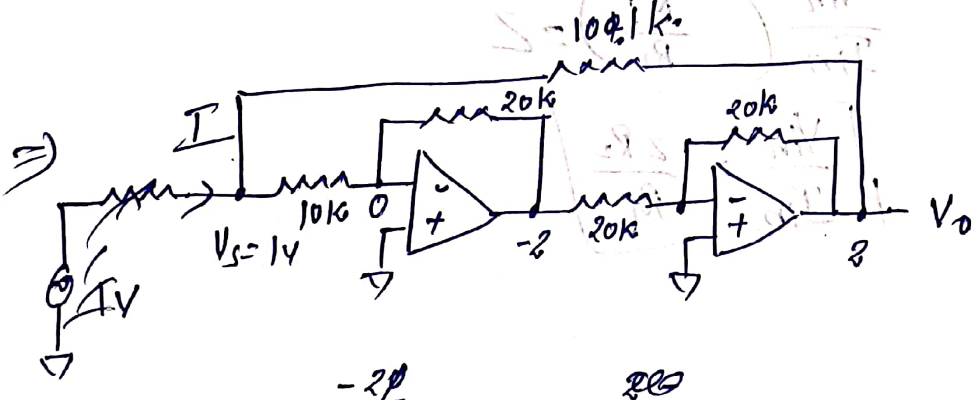
$$\frac{V_0 - V_1}{R} + \frac{V_0 - V_4}{12} = 0$$

$$\frac{4-1}{R} + \frac{4-0}{12} = 0$$

$$\frac{3}{R} + \frac{1}{3} = 0$$

$$\underline{R = +9}$$

$\Rightarrow$



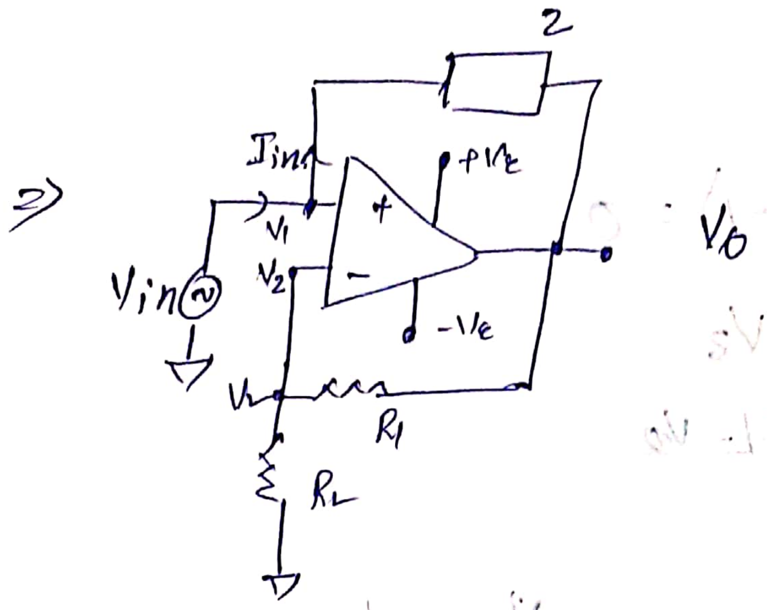
$$-\frac{20}{10}$$

$$I = \frac{1-0}{10} + \frac{1-2}{10.1}$$

$$= \frac{1}{10} - \frac{1}{10.1}$$

$$\frac{10.1 - 10}{101} = \frac{0.1}{101} = \frac{1}{1010}\text{ A.} = 0.99\text{ mA}$$

=>



$V_1 = V_{in}$, $\quad \frac{V_2 - V_0}{R_1} + \frac{V_2}{R_2} = 0$

$V_2\left(\frac{R_1 + R_2}{R_2}\right) = V_0$

$\frac{V_{in} - V_0}{Z} = I_{in}$

$\frac{V_{in}}{I_{in}} - \frac{V_2}{I_{in}}\left(\frac{R_1 + R_2}{R_2}\right) = Z$

$\frac{V_{in}}{I_{in}}\left(\frac{R_1}{R_2}\right) = Z$

$$\boxed{\frac{V_{in}}{I_{in}} = \frac{Z R_2}{R_1}}$$