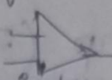
23/9/24.

CO-3.



5V - 12V

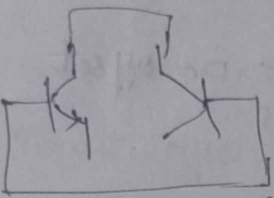
OP - AMP → Analog.

→ voltage controlled voltage source

→ High gain differential amplifier.

→ Ic form ☆

open loop = No feedback.



$V_o = V_1 - V_2$

op

differential amplifier. → voltage amplifiers

— differential amplifier — diff amp — level shift — op stage

voltage follower.

μA 741IC ↔ an omp

- metal can (TO) package.
- Dual in line (DIP)
- Flat package (14 pins)

manufactured by - fairchild - μA741

National semiconductors

Texas industries.

741 → ~~No connection pins~~ op

working

power pins

ip pins

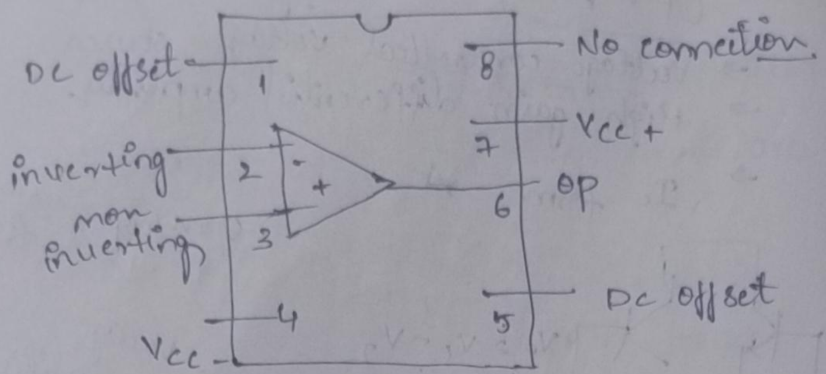
741 → op

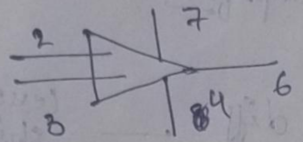
↓

active pins functional pins → capable of taking ip (ip, op, Vcc+/-)

Om-Amp (741).

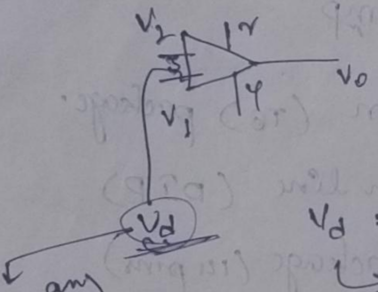
pin diagram.





symbol.

① High gain differential amplifier.



$V_d = V_1 - V_2$ → differential ip

It (amp) should amplify ~~this~~ where

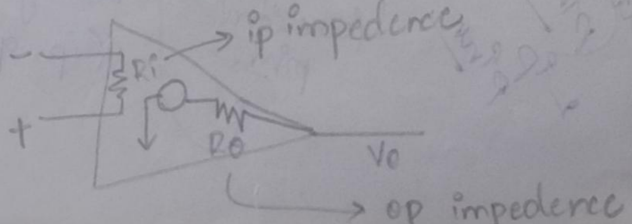
$V_0 \propto V_d$

$V_0 = A_{OL} V_d$

$\frac{V_0}{V_d} = A_{OL}$ open loop.

(Gain . op/ip).

$A_{OL} = \frac{V_0}{V_d} = \frac{V_0}{V_{in}}$



Ideal characteristics.

① Input impedence $R_{in} | Z_{in} = \alpha$ → suitable for low & high source

$\Rightarrow R_{in} = \frac{V_{in}}{I_1} = \alpha$ → $I_1 = 0$

can drive any load

② output impedence = 0

$\frac{V_o}{I_o} = 0$ $R_o | Z_o = 0$ means omp amp is not drawing any current

↳ more op can be connected.

③ Bandwidth $= \alpha$

④ Input offset voltage = 0

⑤ Input offset current = 0

⑥ open loop gain $= \alpha$ — A_{dm} differential mode gain

⑦ CMRR $= \alpha$ — $A_d | A_c$ ↳ common mode gain. common mode gain A_{CM}.

common mode rejection rate ↳ ability to reject V_c.

$$\frac{A_{DM}}{A_{CM}} = \frac{A_{DM}}{0} = \alpha$$

CMRR

⑧ common mode voltage $V_c = \frac{V_1 + V_2}{2}$ when $V_1 = V_2$, $V_d = 0$ what is the rejection rate.

↓ shld be rejected and V_d is to be considered.

↓ idealy = 0

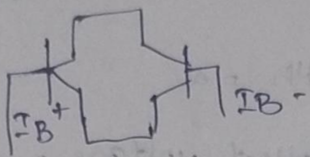
⑨ Slew rate → tym taken to react for given ip

↳ Rate of change of op when step ip is given

$$\frac{dV_o}{dV_i} = \frac{\Delta V_o}{\Delta V_i} = V/\mu s$$

(V_{os}) Input offset voltage
~~Stat~~ (I_{os}) " current
" bias current, } for understanding DC chara.
(I_B)

I_B = differential amplifier.



$$I_B = \frac{I_B^+ + I_B^-}{2}$$

offset ⇒ ip = 0 ⟶ op = 0 not possible bcoz of internal R | temp.

min voltage | current to nulify the op.

input offset voltage
or
input offset current.

$I_{os} = |I_B^+ - I_B^-|$

For BJT V_{os} = 50 pA ⟶ 10^{-12}

For FET V_{os} = 50 pA

For I_B - BJP = 200pA

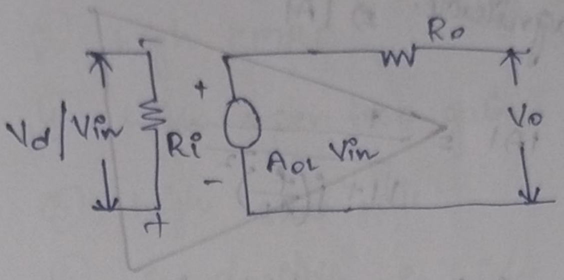
For FET I_B = 200pA

$\frac{\partial V_b}{\partial V_b}$

Equivalent circuit

$V_o = A_{OL} V_{in}$ → ip voltage
↳ open loop gain

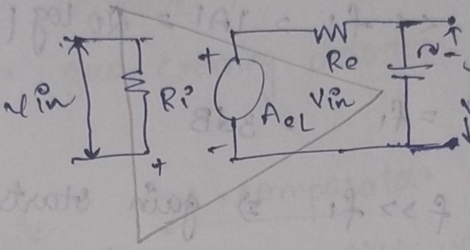
DC



→ DC

gain = const

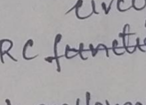
for higher frequency there is a roll off, gain starts to roll off which is compensated by capacitor at op.



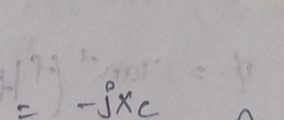
A C characteristics

AC

① Frequency response:



logarithmic freq



circuit RC ~~function~~ so, transform function $= \dfrac{-jX_c \, A_{OL}}{R_o - jX_c}$

$$A = \frac{-jX_c}{R_o - jX_c} A_{OL}$$

$$= \frac{1}{1 + j2\pi f R_o C} A_{OL}$$

dk/ decay ⟷ $f_1 = \dfrac{1}{2\pi R_o C}$ → cutoff frequency / corner frequency

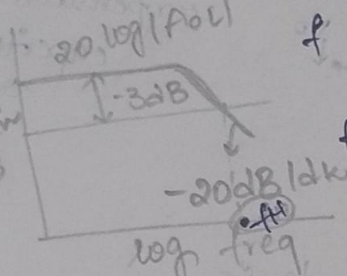
$$\Rightarrow A = \frac{1}{1+j\left(f/f_1\right)} A_{OL}.$$

magnitude $\Rightarrow |A|$

$$|A| = \frac{1}{\sqrt{1+j\left(\frac{f}{f_1}\right)^2}}$$

phase $(\phi) = \tan^{-1}(f/f_1)$.

magnitude plot,



$f << f_1 \Rightarrow |A| = 20 \log |A_{OL}|$

$f = f_1 \quad = 3dB$

$f >> f_1 \Rightarrow$ gain starts to roll off at once only.

there is only 1 corner freq so one roll off.

$f_1 \rightarrow$ is where gain starts to roll off.

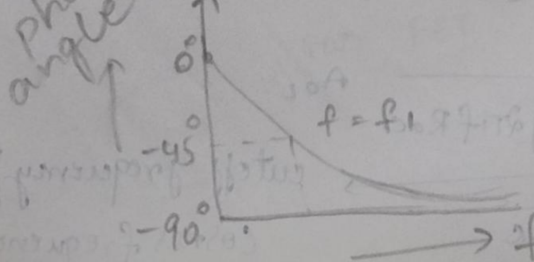
$f_H = \text{upper} = \frac{1}{2\pi R_o C}$

$R_o C = -20$ dB/dk

phase plot,

$\phi = \tan^{-1}(f/f_1)$

① $f << f_1$ ② $f = f_1$ ③ $f >> f_1$



PRATICAL CHARA

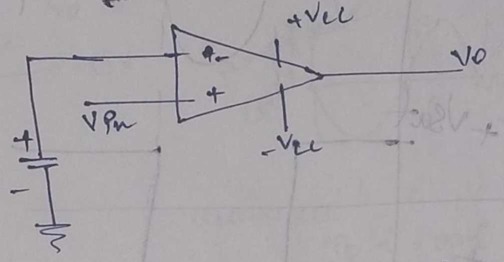
① high input impedence
② low output "
③ high CMRR
④ high open loop gain
⑤ high slew rate
⑥ Bandwidth is high

open loop configuration → +Vsat, -Vsat → No feedback ⇒ high gain amplify.

appl → comparator → vin & Vreference
→ zero crossing detector.

+ve comparator

Limitation
i) when noise is prsnt op voltage is effected.



$V_{in} > V_{ref} \Rightarrow V_o = +V_{sat}$

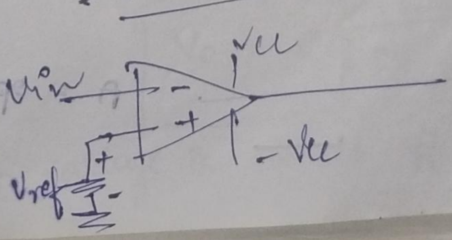
$V_{in} < V_{ref} \Rightarrow V_o = -V_{sat}$

op v is limited by power supply.

$V_o = A_{OL} V_{in}$ $V_{in} = 2$

Vcc < $V_o = A_{OL}\ 2v$

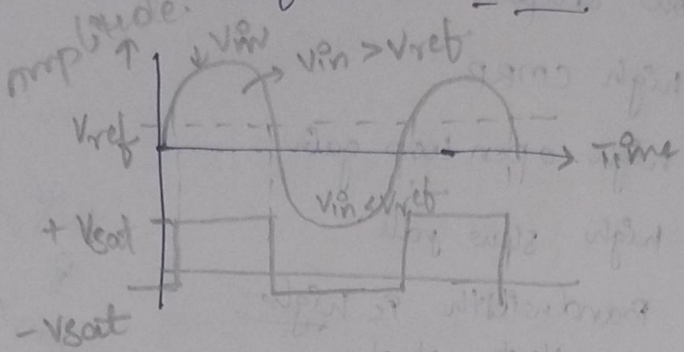
-ve comparator



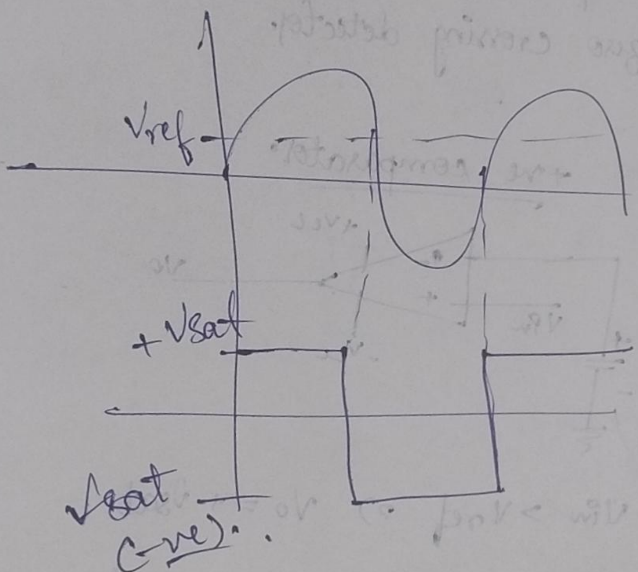
$V_{in} > V_{ref}$, $V_o = +V_{sat}$

$V_{in} < V_{ref}$, $V_o = -V_{sat}$.

Non Inverting



zero crossing detector.

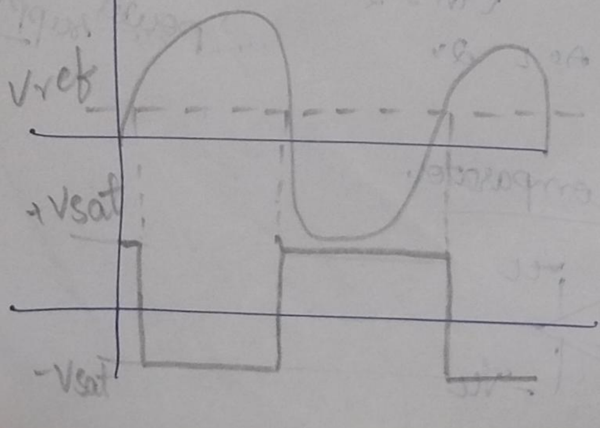


Inverting comparator

linear → gain shld reduce ↓ by providing -ve feedback.

$\boxed{\beta \text{ - feedback factor}}$

A = open loop gain



$A_{CL} = \frac{A}{1+A\beta}$ $\quad A_{CL} = \frac{A}{1-(-A\beta)}$

Buildathon/
1 Hackthon
2 samyak fee
3 SIL
4 meeting

$A_{CL} \gg A \rightarrow$ oscilations are produced.

30/9/24.

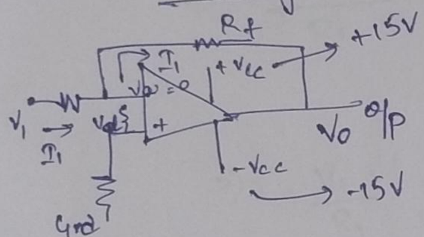
Closed loop Configuration:

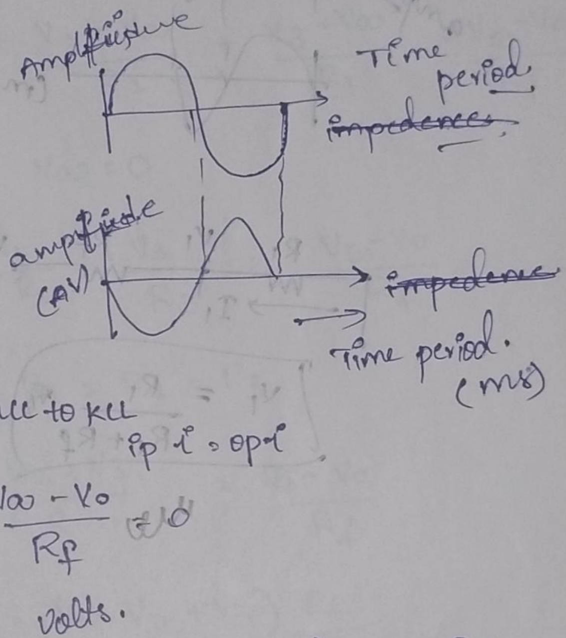
$A_{OL} = \alpha$

$\Rightarrow A_{CL} \rightarrow$ loses

→ Amplifies - negative feedback.

Inverting.





acc to KCL
ip i = op i

$$\frac{V_{\infty} - V_1}{R_1} + \frac{V_{\infty} - V_0}{R_f} = 0$$

$V_{\infty} = 0$ volts.

$$-\frac{V_1}{R_1} - \frac{V_0}{R_f} = 0$$

$$-\frac{V_1}{R_1} = \frac{V_0}{R_f}$$

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

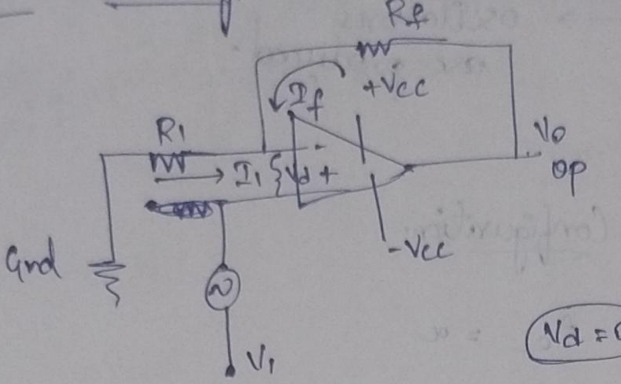
$A_{CL} = \frac{-R_f}{R_1}$
↓
close loop gain.

$V_0 = -V_{in}$ ✗
we need
$V_0 = V_{in}$

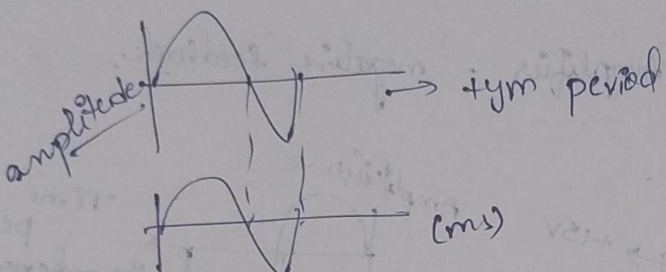
→ op voltage is clipped off at +15V & -15V.

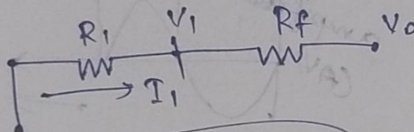
→ more than ±15 V op vastly clipped off.

Non inverting.



$\boxed{V_d = 0}$ bcoz it's draw any current.





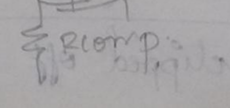
$$\boxed{V_1 = \frac{R_1}{R_1 + R_f}}$$

$$V_o = \frac{R_1 + R_f}{R_1} V_1$$

$$\boxed{V_o = \left(1 + \frac{R_f}{R_1}\right) V_1}$$

$$\Rightarrow \boxed{V_o = A_{CL} V_1}$$

To componsete offset voltage (Rcomp) Resistor componsetor is ~~used for~~ placed at non-inverting terminal.

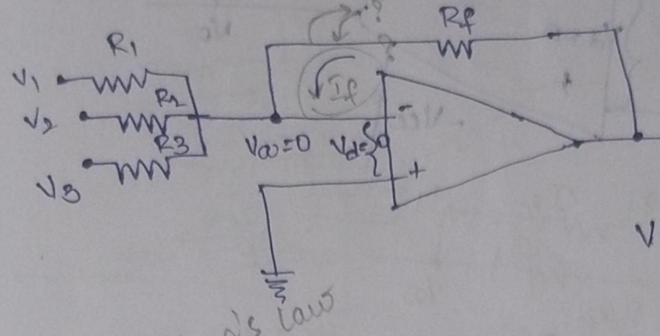


OP-AMP as adder.

→ V_{output} is sum of all V_{ins}.

• Inverting adder. → op is 180° out of phase

1) $V_1\ V_2\ V_3$ & $R_1\ R_2\ R_3$ are given



$V_o = -(V_1 + V_2 + V_3)$ becoz ip for inverting terminal.

ohm's law

$I_1 + I_2 + I_3 = I_f$

$V = IR$

$$\frac{V_1 - V_a}{R_1} + \frac{V_2 - V_a}{R_2} + \frac{V_3 - V_a}{R_3} = \frac{V_a - V_o}{R_f}$$

$V_a = 0$

$$\Rightarrow \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} = \frac{V_a - V_o}{R_f}$$

$R_1 = R_2 = R_3$

$$\frac{V_1 + V_2 + V_3}{R} = \frac{\cancel{V_a} - V_o}{R_f}$$

$$\cancel{V_a} - V_o = (V_1 + V_2 + V_3)\frac{R_f}{R}$$

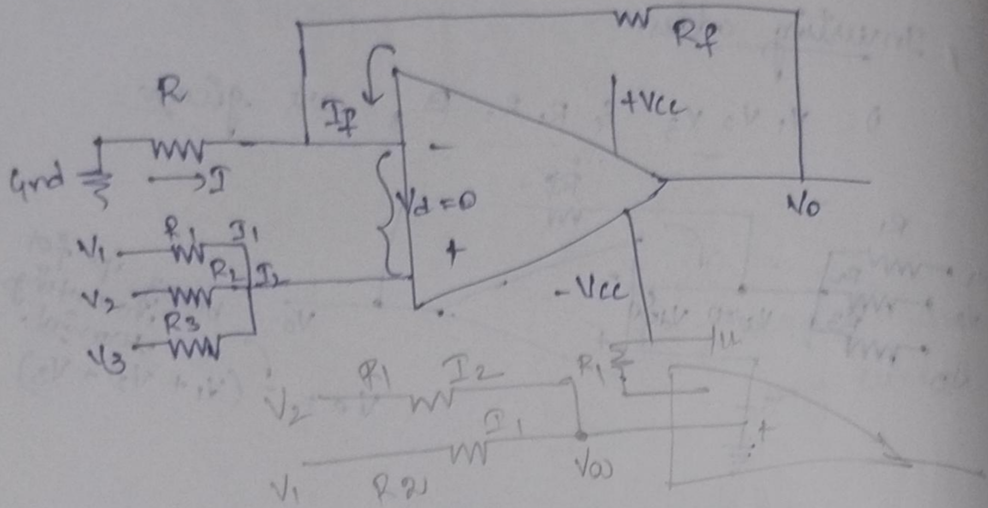
$$+V_o = (V_1 + V_2 + V_3) - \frac{R_f}{R}$$

$R_f = R$

$$\Rightarrow \boxed{V_o = -(V_1 + V_2 + V_3).}$$

$R_f = 10R \Rightarrow V_o = -10(V_1 + V_2 + V_3).$

Non - Inverting Adder.



non-inverting terminal

V_a

$V_o = +(V_1 + V_2)$

$I_f = I_1 + I_2$

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

$$\frac{V_a}{R} + \frac{V_a}{R_f} = \frac{V_o}{R_f}$$

$$V_a\left(\frac{1}{R} + \frac{1}{R_f}\right) = \frac{V_o}{R_f}$$

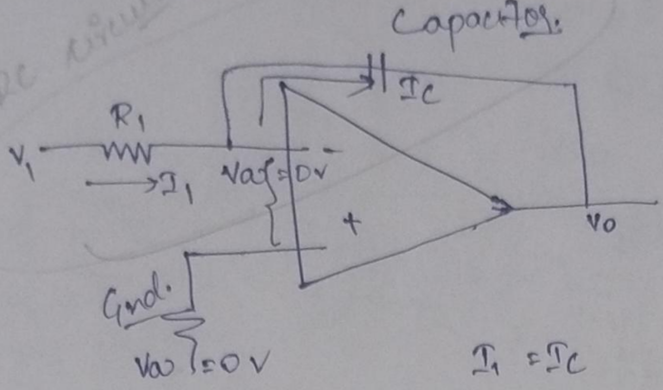
$$V_a\left(\frac{R + R_f}{R R_f}\right) = \frac{V_o}{R_f}$$

$$V_a = \frac{V_o}{R_f}\left(\frac{R R_f}{R + R_f}\right)$$

$$\boxed{V_a = \left(\frac{R}{R + R_f}\right) V_o}$$

$$\boxed{V_o = \frac{V_a (R + R_f)}{R}}$$

OP-Amp as integrator → low pass Filter.



$$I_1 = I_C$$

$$\frac{V_1 - Va}{R_1} = \frac{C\,dV_C}{dt}$$

$$\frac{V_1 - \cancel{Va}}{R_1} = \frac{C\,d(-V_0 + \cancel{Va})}{dt}$$

$$\frac{V_1}{R_1} = -C\frac{dV_0}{dt}$$

integrate

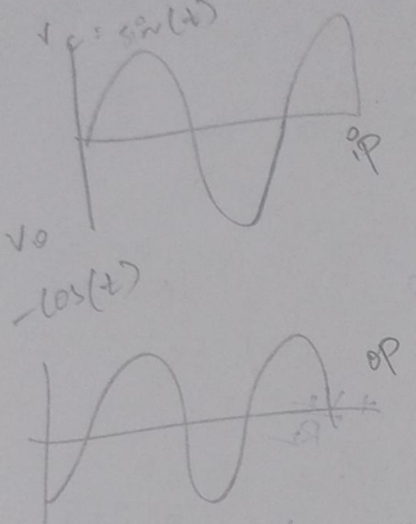
$$\int \frac{V_1}{R_1}\,dt = \int -C\,\frac{dV_0}{dt}\,dt$$

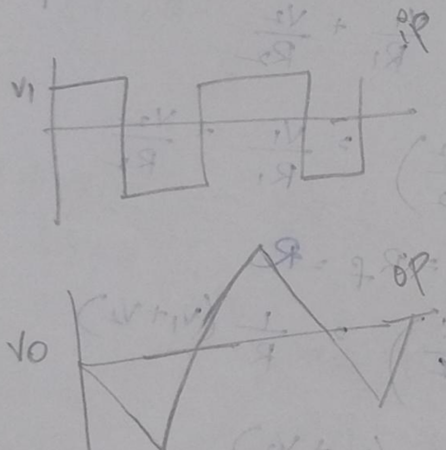
$$V_0 = \frac{-1}{R_1 C}\int V_1\,dt$$

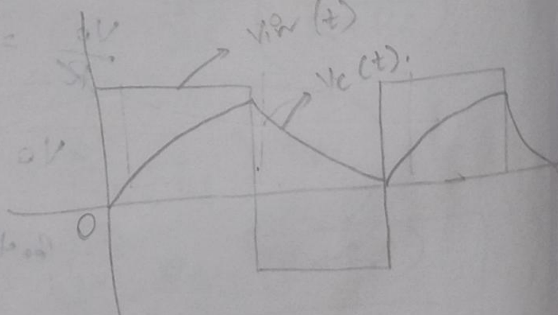
$R_1 = R$

$$\boxed{V_0 = \frac{-1}{RC}\int_0^t V_1(t)\,dt + c}$$

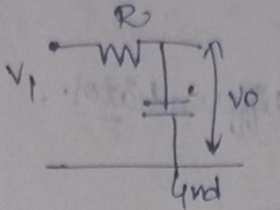
RC = time const.



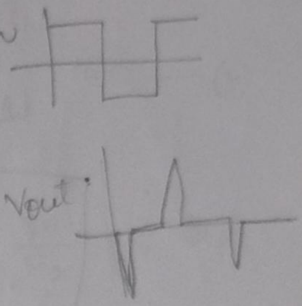




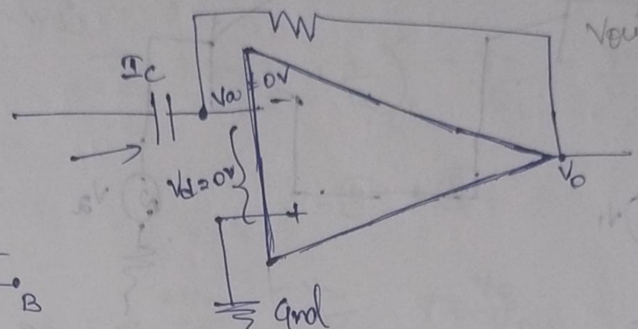
when cap 1 end is grd then it's called low pass filter.

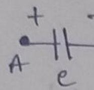


High pass filter



Op-Amp differentiator:





AB (-c)

BA (c)

current in capacitor,

$$\frac{c\,dV_c}{dt} + \frac{V_a - V_o}{R_f} = 0$$

ip - square wave

op - Ramp

ip - sin wave

op - cos wave

$V_a = 0V$

$$\frac{c\,dV_c}{dt} = \frac{V_o}{R_f}$$

$$(V_c = V_a - V_1)$$

$$\Rightarrow \frac{c\,d(V_a - V_1)}{dt} = \frac{V_o}{R_f}$$

$V_a = 0V$

$$c\,d/dt\,(-V_1) = \frac{V_o}{R_f}$$

$$-c\frac{dV_1}{dt} = \frac{V_o}{R_f}$$

$$\boxed{V_o = -RC\frac{dV_1}{dt}} \qquad \boxed{V_o = -R_f\,c\frac{dV_1}{dt}}$$

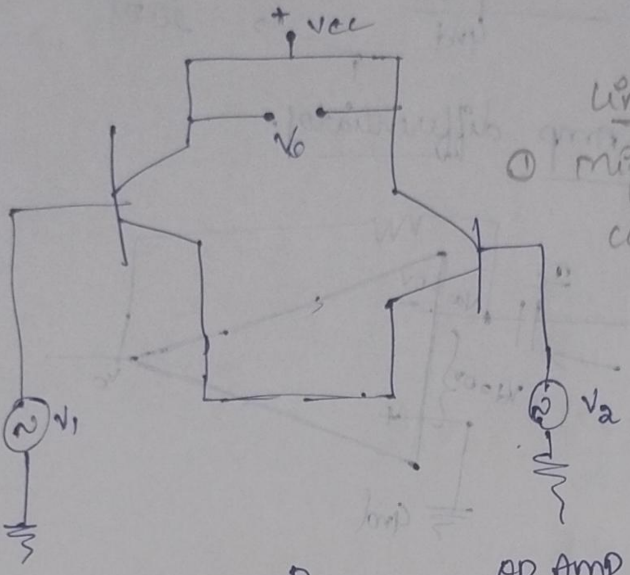
time const when $R_f = R$

7/10/24

A has to amplify the diff in input voltage without common voltage

Differential Amplifiers.

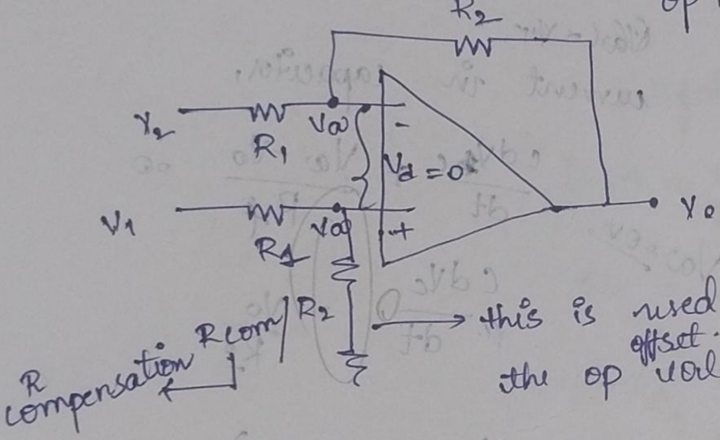
it's different from differentiators.



Limitation

① might amplify common voltage

op Amp Subtractor.



① → this is used to nullify the op offset voltage.

Using super position theorem

→ Grnd V1

→ Grnd V2

$$\frac{V_a - V_2}{R_1} + \frac{V_a - V_0}{R_2} = 0 \quad \text{—— ①}$$

$$\frac{V_a - V_1}{R_1} + \frac{V_a - V_0}{R_2} = 0 \quad \text{—— ②}$$

from ① & ②

$$\frac{V_{a}}{R_1} - \frac{V_2}{R_1} + \frac{V_a}{R_2} - \frac{V_o}{R_2} = 0$$

$$V_{a}\left(\frac{1}{R_1} + \frac{1}{R_2}\right) - \frac{V_2 - V_o}{R_1 \quad R_2} = 0$$

$$\rightarrow \cancel{V_{a}\left(\frac{1}{R_1} + \frac{1}{R_2}\right)} - \frac{V_1}{R_1} = 0 \quad — ④$$

$$\rightarrow \cancel{V_{a}\left(\frac{1}{R_1} + \frac{1}{R_2}\right)} - \frac{V_2}{R_1} = \frac{V_o}{R_2} \quad — ③$$

$-④ + ③$

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

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

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

suppose $R_2 = 100 R_1$

$V_o = \frac{100\cancel{R_1}(V_1 - V_2)}{\cancel{R_1}}$ ★

$V_o = 100$ times of diff in ip voltages

modes
- common mode $(V_1 = V_2)$
- difference mode

the ability of common ~~registy~~ mode transistor to reject the differential signal & giving amplified signal is called common mode rejection.

$$V_o = V_1 A_1 + V_2 A_2$$

$V_{cm} = \frac{V_1 + V_2}{2}$, $V_d = V_1 - V_2$

V_{cm} ↳ common mode voltag

V_d ↳ difference mode.

$$V_1 = V_{cm} + \frac{1}{2} V_d$$

$$V_2 = V_{cm} - \frac{1}{2} V_d$$

$$A_{dm} = \frac{1}{2}(A_1 - A_2)$$

$$A_{cm} = A_1 + A_2$$

$\Rightarrow V_o = V_{dm} A_{dm} + V_{cm} A_{cm}$

$\rightarrow \boxed{V_o = V_d A_d + V_c A_c} \rightarrow V_o = V_d A_d$

$CMRR = \left|\frac{A_{dm}}{A_{cm}}\right|$ we use buffer circuit.

in dB

$CMRR = 20 \log \frac{A_{dm}}{A_{cm}}$.

voltage follower. – acts as buffer circuit.

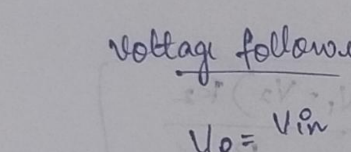
$V_o = V_{in}$

$\Rightarrow V_o = A_{CL} V_{in}$

$A_{CL} = 1$

Non inverting

$$V_o = \underbrace{\left(1 + \frac{R_f}{R_1}\right)}_{A_{CL} \text{ gain}} V_{in}$$



when $R_f = 0 \quad R_1 = \infty$

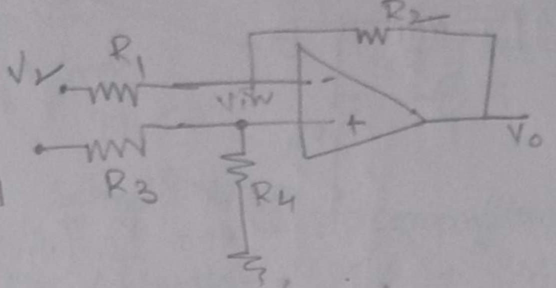
$V_o = V_{in}$, → high ip impedence.

differential amplifier + Buffer circuit at 2 ip's → Instrumental amplifier

Differential amplifier + Buffer circuit or voltage followers at 2 inputs = Instrumental amplifier.

→ to ↑ gain

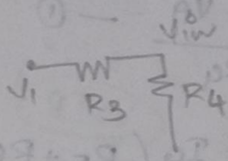
Instrumental Amplifier.



V = IR

No i
same V
same diff

V_2 = Gnd



$$V_{in} = \frac{R_3}{R_3 + R_4} V_1$$

$$V_o = \left(1 + \frac{R_2}{R_1}\right) \frac{R_4}{R_4 + R_3} V_1 - \frac{R_2}{R_1} V_2$$

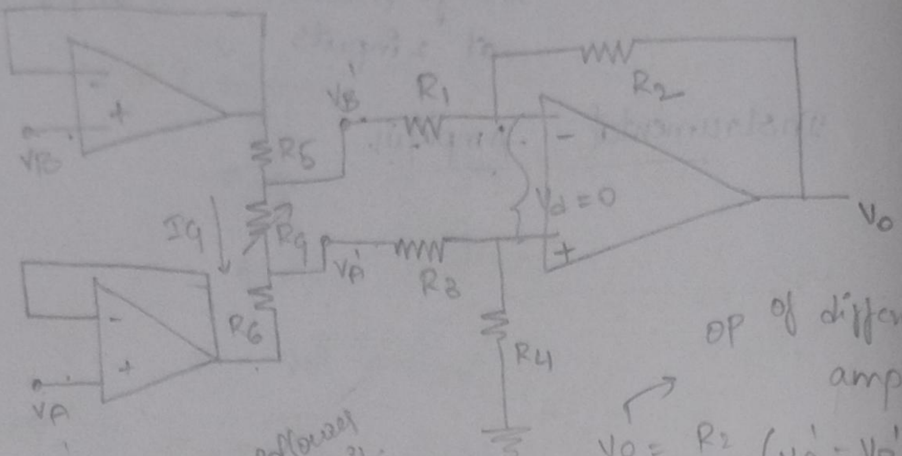
$$\Rightarrow V_o = \frac{R_4}{R_3} \cdot \frac{1 + \frac{R_2}{R_1}}{1 + \frac{R_4}{R_3}} V_1 - \frac{R_2}{R_1} V_2$$

when $\frac{R_4}{R_3} = \frac{R_2}{R_1}$

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

$$\Rightarrow V_o = \frac{R_2}{R_1}(V_A - V_B)$$

Instrumental Amplifier

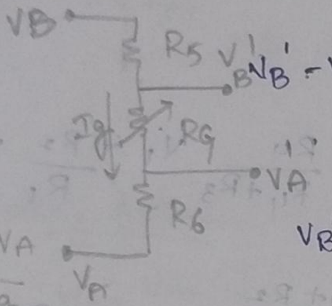


ip = voltage follower circuit.

op of differential amplifier

$$V_o = \frac{R_2}{R_1}(V_A' - V_B')$$

$$I_G = \frac{V_B - V_A}{R_G} \quad — ①$$



$$i_g = \frac{V_B - V_A}{R_g}$$

$V = IR$

$$V_B' - V_A' = I_G(R_5 + R_G + R_6)$$

$R_5 = R_6$

$$V_B' - V_A' = I_G(2R_5 + R_G) \quad — ②$$

① in ②

$$V_B' - V_A' = \frac{V_B - V_A}{R_G}(2R_5 + R_G)$$

$$V_B' - V_A' = V_B - V_A\left(1 + \frac{2R_5}{R_G}\right)$$

$$\Rightarrow \boxed{V_A' - V_B' = V_A - V_B\left(1 + \frac{2R_5}{R_G}\right)}$$

op of instrumentation amplifier.

$$V_o = \frac{R_2}{R_1}\left(V_A - V_B\left(1 + \frac{2R_5}{R_4}\right)\right)$$

$\Rightarrow$ op of instrumentation amplifier.

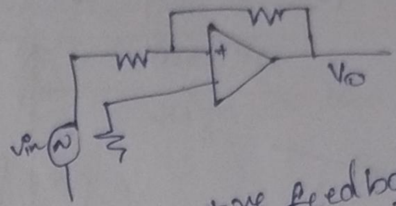
Schmitt Trigger.

1) positive feedback.   2) Regenerative circuit ~~signals~~ comparator.

Inverting

- → Vin
+ → Gnd.

Non inverting



+ve feedback.

Schmitt trigger : comparator → has effect on op (noise)
↓ + Hysteresis → to nufiy this noise effect on output
Vupper thershold
V lower "

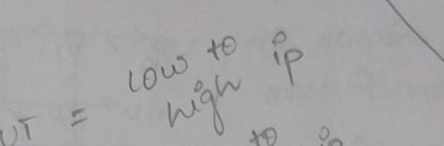
Responds to Vsat & -Vsat

V_{UT} = low to high ip

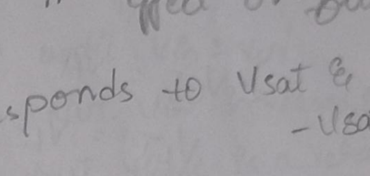
V_{LT} = high to low ip

Hysteresis $V_H = V_{UT} - V_{LT}$

Schmitt trigger.



inverting



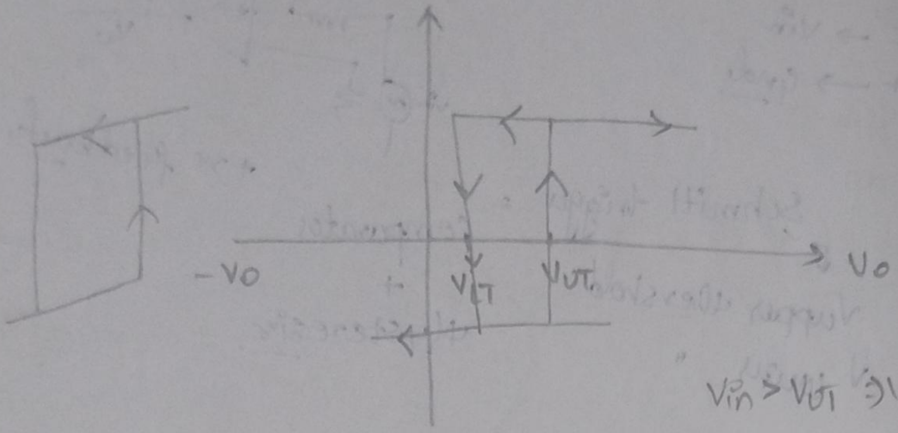
Non inverting.

Hysteresis

→ Hy Steresis.

Transfer characteristics of Hysteresis curve.

Non Inverting



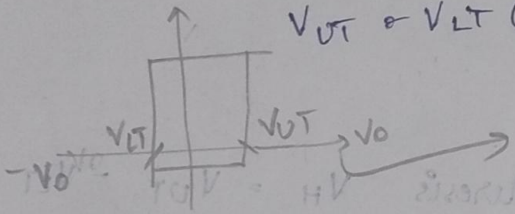
$V_{in} > V_{UT} \Rightarrow V_o = V_H$

$V_{in} < V_{LT} \Rightarrow V_o = V_L$

$V_{UT} = V_H$

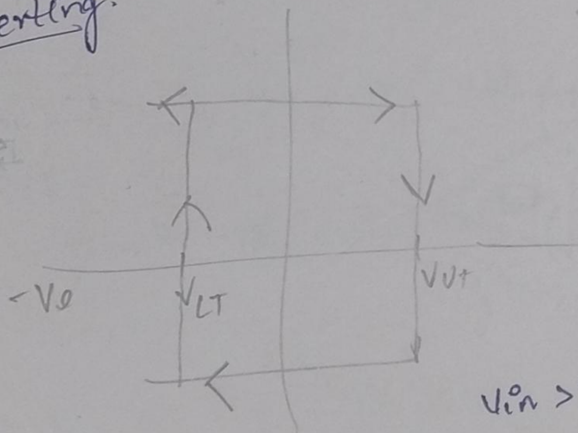
$V_{LT} = V_L$

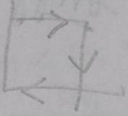
$V_{UT} = V_{LT}$ (symmetric).



non inv
symme

Inverting.





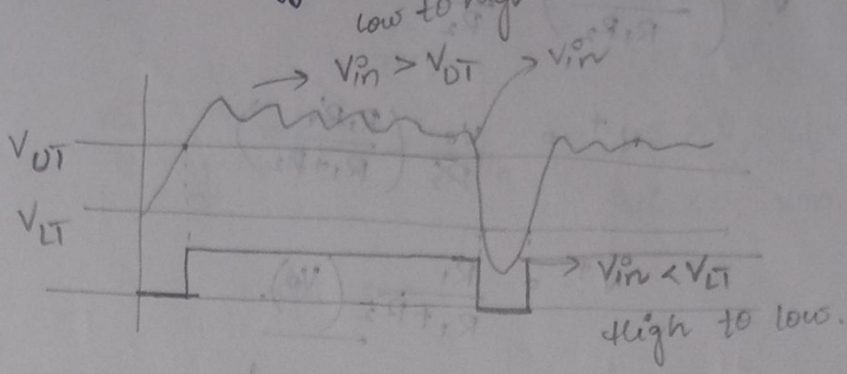
$V_{in} > V_{UT}$

$V_{op} = V_{low}$

$V_{in} < V_{UT}$

$V_{op} = V_{high}$

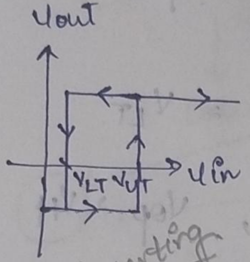
8/10/24 Schmit Trigger.



→ Inverting

→ Non inverting

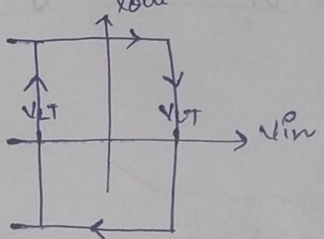
Hysteresis curve is the transfer chara curve drawn b/w Vin & Vout.



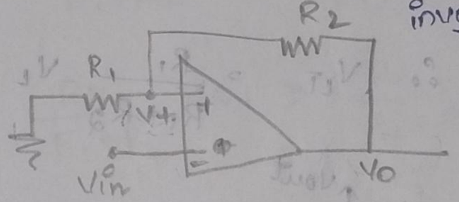
Non inverting

Vin remains low until $V_{in} > V_{UT}$ once it reaches V_{UT} Vin increases & remains const but there is a change in Vout.

Once when it ~~reaches~~ Vin is less than V_{LT} it decreases.



inverting.



$V_{in} > V^+ \Rightarrow V_{op} = V_{low}$

$V_{in} < V^+ \Rightarrow V_{op} = V_{high}$

Nodal analysis

$$\frac{V^+ - 0}{R_1} + \frac{V^+ - V_0}{R_2} = 0$$

$$\frac{V^+}{R_1} + \frac{V'}{R_2} = V_0/R_2$$

$$V^+\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = \frac{V_0}{R_2}$$

$$V^+\left(\frac{R_1+R_2}{R_1R_2}\right)=\frac{V_0}{R_2}$$

$$V^+=\frac{V_0}{\cancel{R_2}}\left(\frac{R_1\cancel{R_2}}{R_1+R_2}\right)$$

$$V^+=\frac{R_1}{R_1+R_2}(V_0).$$

V_0 possible are $V_L \mid V_H$

1) $V_1=\frac{R_1}{R_1+R_2}V_H=V_{UT}$

$V_{in}>V_1$, $V_{op}=V_L$

2) $V_2=\frac{R_1}{R_1+R_2}V_L=V_{LT}$

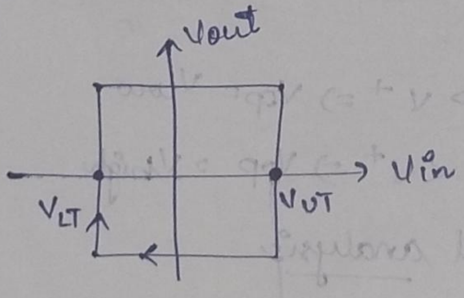
$V_{in}>V_2$, $V_{op}=V_H$

$\therefore\ V_{UT}=\frac{R_1}{R_1+R_2}V_H$

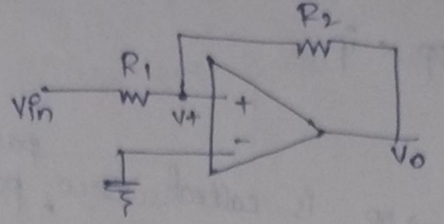
$\rightarrow V_{LT}\rightarrow$ high - low

$\rightarrow V_{UT}\rightarrow$ low - high

$\therefore\ V_{LT}=\frac{R_1}{R_1+R_2}V_L$



Non inverting switchh trigger.



$V_{in} > 0$, $V_{op} = V_{High}$

$V_{in} < 0$, $V_{op} = V_{Low}$

Nodal eqn

$$\frac{V^+ - V_{in}}{R_1} + \frac{V^+ - V_o}{R_2} = 0$$

initial op Low ↓ High: V_{UT}

High ↓ Low: V_{LT}

$$V^+\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = \frac{V_{in}}{R_1} + \frac{V_o}{R_2}$$

$$V^+\left(\frac{R_1+R_2}{R_1R_2}\right) = \frac{V_{in}}{R_1} + \frac{V_o}{R_2}$$

$$V^+ = \frac{V_{in}R_2}{R_1+R_2} + \frac{R_1}{R_1+R_2}V_o$$

★ initial op to be low → $V_{in} > 0$, $V_{op} = V_H$

initial op = L

$$V^+ = \frac{R_2}{R_1+R_2}V_{in} + \frac{R_1}{R_1+R_2}V_L$$

Low

$$\frac{R_2}{R_1+R_2}V_{in} > \frac{-R_1}{R_1+R_2}V_L$$

High → $V_{in} > \frac{-R_1}{R_2}V_L \rightarrow V_o = V_H$

$$\boxed{\therefore V_{UT} = \frac{-R_1}{R_2}V_L}$$

High → $V_{in} < 0$

$$\frac{R_2}{R_1+R_2}V_{in} < \frac{-R_1}{R_1+R_2}V_H$$

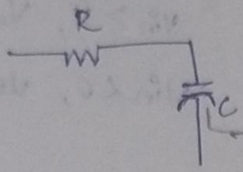
$$\boxed{\therefore V_{LT} = \frac{-R_1}{R_2}V_H}$$ $\frac{R_1}{R_1+R_2}V_L$

$V_{in} < -\frac{R_1}{R_1+R_2}V_H \rightarrow V_{LT}$.

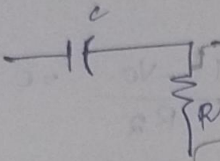
14/10/24

FILTERS.

attenuation → op < ip



→ op is called low pass passive.



→ op is called high pass passive.

→ ALLOW DC
BLOCK AC

using inductors produces some unnecessary EMI
cap connected as feedback, electro magnetic interference.

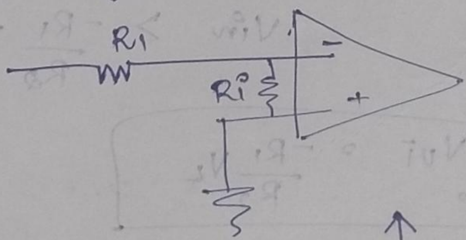
so inductors are not used.

$\boxed{\text{short time const} \quad \tau = \frac{dt}{10}}$ ★

• ip impedence of non inverting is high than inverting.

Between 1, 2 pins there is an Resistor with 1, 2 MΩ
so called input impedence.

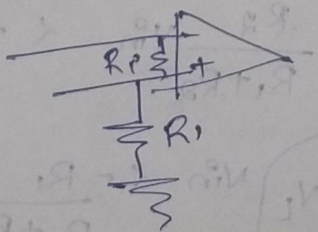
Inverting



ip impedence = $R_1 \| R_i$

↑

Non - Inverting →



ip impedence = R_i series with R_1

(or) $R_i + R_1$.

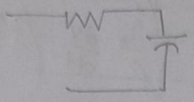
Bardwidth of NI is high than Inverting.
that's filters are with Non inverting only.

Active filter

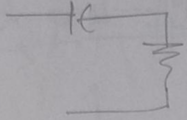
1. Dual power supply
2. Costly for higher frequencies designs

Passive filters

1. No power supply
2. Less cost.



first order low pass

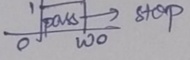


first order high pass.

cascaded
op of 1 is given to another one as ip.
→ Band pass.

cascading in parrel → Band stop (reject)

ideal.



Low pass allows only less frequencies.

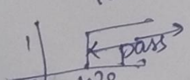
n^{th} Order of system → $20(n)$

1st → $20(1)$

2nd → $20(2) = 40$

3rd → $= 60$

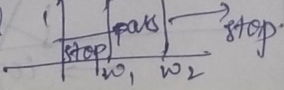
ideal.



High pass → allow high

Band pass → only certain frequencies are allowed.

ideal



Band stop ⟶ stops that particular range of frequencies

TYPERS OF FILTERS

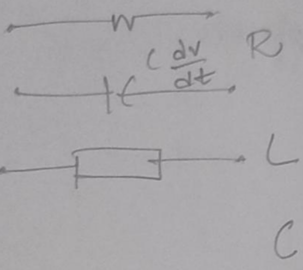
① Butterworth

② Chebyshev.

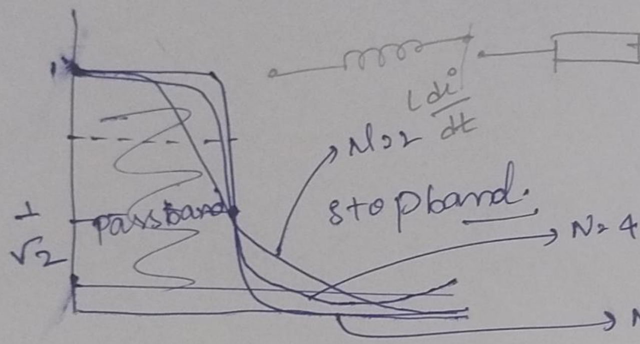
③ Ceuer.

Capacitor → Allow AC
Blocks DC

$R = V/I$



Butterworth



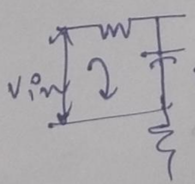
$j\omega L = jX_L = V_L$

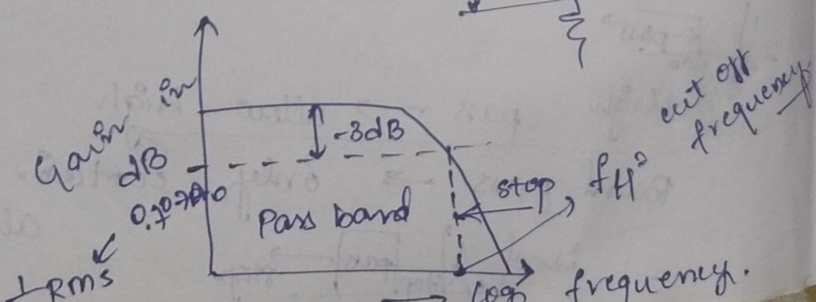
$V_C = \frac{1}{j\omega C_0}$

Active filters
↳ mostly we use op amp
for ↑ voltage gain.

Frequency Response.

low pass filter.

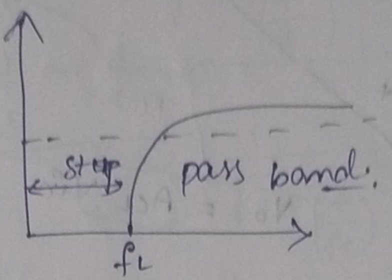


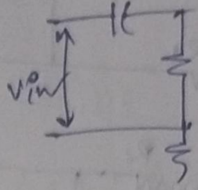


$0 < f_L \rightarrow$ pass band

$> f_L \rightarrow$ stop / attenuate.

High pass ~~frequency~~ filter.

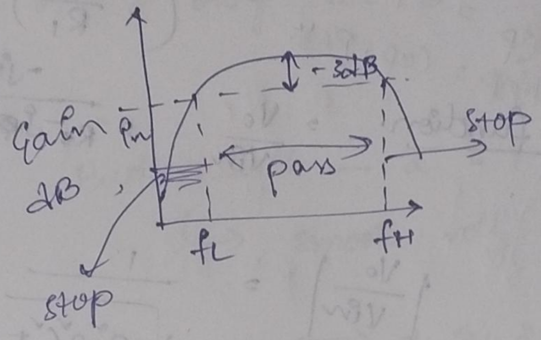




$f_C = f_H = f_c$.

Band pass filter

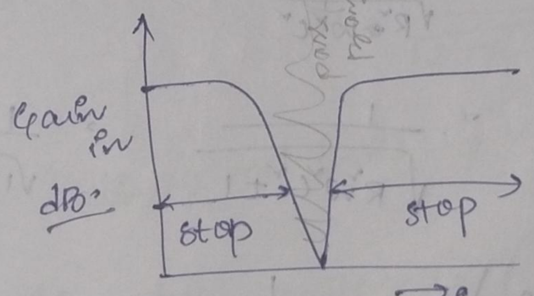
low + High pass



$f_H - f_L$ = pass band.

Band stop / Reject

low || High
el

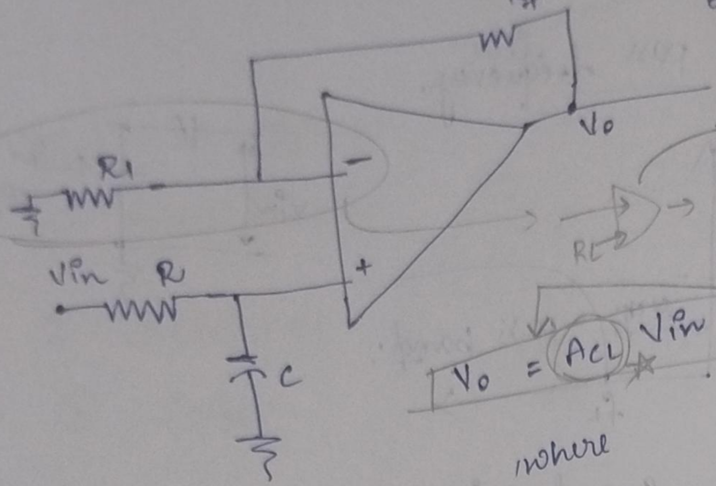


voltage follower $\Rightarrow$ Voutput = Vin.

$V_{Gain} = 1$.

Active low pass filter

→ frequency selective circuit bcoz cut off is selected by R & C



→ $V_o = V_{in}$

→ Gain = 1

so Gain > 1

$$\boxed{V_o = A_{CL} V_{in}}$$

where

$$A_{CL} = \left(1 + \frac{R_f}{R_1}\right)$$

low pass ki op at cap

V_{outp} = cap ⇒ $V_o = \left(1 + \frac{R_f}{R_1}\right) V_{in}$

V_{inp} = cap, Res.

Transfer function $= \frac{V_o}{V_{in}} = \frac{-jX_C}{R - jX_C}$

$$\left|\frac{V_o}{V_{in}}\right| = \frac{1}{\sqrt{R^2\omega^2C^2 + 1}}$$

$X_C = \frac{1}{\omega C}$

$$\left|\frac{V_o}{V_{in}}\right| = \frac{\frac{1}{\omega C}}{\sqrt{R^2 + \frac{1}{\omega^2 C^2}}}$$

$$= \frac{1}{\sqrt{R^2\omega^2C^2 + 1}} = \frac{1}{\sqrt{1 + \left(\frac{\omega}{\omega_C}\right)^2}}$$

$\omega = \nu r$

$$\left|\frac{V_o}{V_{in}}\right| = \frac{1}{\sqrt{1 + \left(\frac{2\pi f}{2\pi f_C}\right)^2}} = \frac{1}{\sqrt{1 + \left(\frac{f}{f_C}\right)^2}}$$

$$\boxed{\frac{1}{RC} = \omega_C}$$

$\rightarrow f_c = \frac{1}{2\pi RC}$.

$V_o = A_{CL} V_{in}$

$\Rightarrow V_o = \frac{1}{\sqrt{1+\left(\frac{f}{f_c}\right)^2}} A_{CL}$

$V_o = \frac{1}{\sqrt{1+\left(\frac{f}{f_c}\right)^2}} \left(1+\frac{R_f}{R_1}\right)$.

$\alpha \rightarrow$ Rate at which gain is rolled off.
$\hookrightarrow$ Damping ratio

Based on α only we choose effective filter

B S C

Butterworth — $\alpha = 1.414$.
$\hookrightarrow$ smooth roll over.

Chbeum $\rightarrow \alpha \approx 2.158$.

2^{nd} order — 2 RC networks.

$f_c = \frac{1}{\sqrt{2\pi R_1 C_1 R_2}}$

Gain is not stable $\rightarrow$ bcoz of impedance mismatch

That's why sallen key we use
$\downarrow$
1^{st} RC is given as feedbak

21/10/24.

CO-4.

- Oscillators - op-amp.
- Multivibrators - IC 555 times.

Negative feedback - op shld not be inphase with ip.

Op amp.

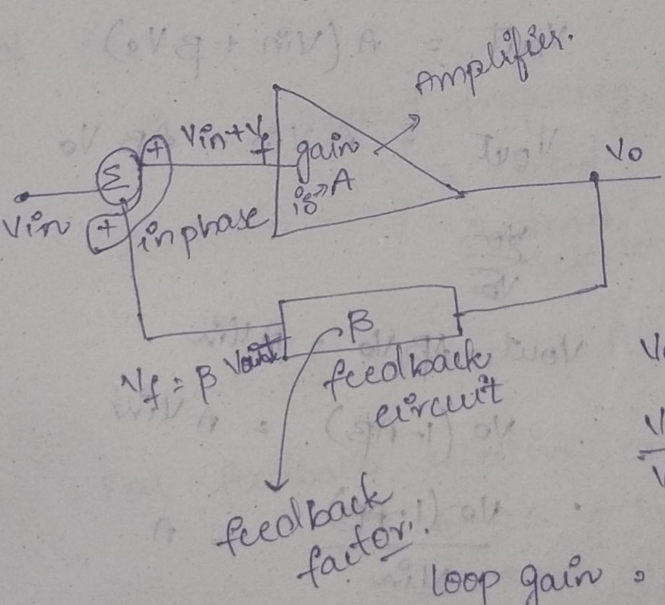
- Good stability
- Poor gain.

Oscillator = amplifier + positive feedback.

① Generator sinewave or non-sinusoidal wave

is called harmoic oscillators — are called as Relaxation oscillators.

where / which uses or produces time contains an oscillator.



$V_o = A V_{in}$

$= A(V_{in} + V_f)$

$= AV_{in} + AV_f$

$V_{out} = AV_{in} + A\beta V_{out}$

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

Loop gain = $A\beta$

• conditions to be an oscillator.

$|A\beta| = 1$

phase $\angle A\beta = 0°$ or $360°$.

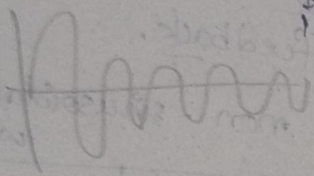
↳ Barkehausan criteria.

what if $A\beta < 1$

assume $\beta = 0.9$, $V_{in} = 2$

$V_0 = 2 \times 0.9$

$= 1.8$ → the thing which is ip for next round.



$V_0 = 1.8 \times 0.9$

↓

oscillations

which means each time the reduces, which doesn't produce sin waves.

---

what if $A\beta > 1$

$V_{out} = A(V_{in} + \beta V_o)$

$V_{out} = A V_{in} + A\beta V_o$

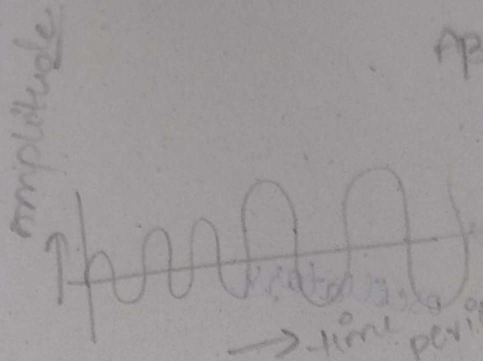
$\frac{\cancel{V_o}}{V_o}$

$V_{out} - A\beta V_o = A V_{in}$

$V_o(1 - A\beta) = A V_{in}$

$\frac{V_o(1 - A\beta)}{V_{in}} = A$

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



$A\beta > 1$ $= 2$

$= 1.2 \times 2$

$= 2.4$

2.4×2

$= 4.8$

Firstly to produce oscillations $A\beta > 1$ then to get sustain oscillation we $A\beta = 1$.

Oscillator ip is DC signal.
op is AC signal.

Feedback circuit is called thermal noise.

So, this means an oscillator doesn't require any ip of AC.

fr = resonant frequency.

feedback → is called feedback selective or resonance frequency

because at one point it's sustained.

For feedback selective circuits we use
1. RC - Harmonic | Low frequ
2. RLC
3. LC

RC → low frequency → used in audio freq range (KHz)

LC

or

Harmonic

- Sin waves.

RLC - IC 555 timer

- Relaxation oscillators.

High frequency. (MHz).

Radio frequency range.

RC < RC phase shift / Wein bridge.

LC < Hartley / Colpitts.

Relaxation < Bistable (self learning). / monostable / Astable.

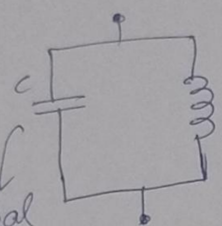
28/10/24.

High Frequency Oscillators.

↳ LC Oscillators.

RC can't be used in high frequency range bcoz R, C decreases when freq increases.

LC oscillators are called as trans circuit.



energy is stored as electrical field

as magnetic field.

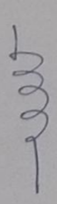
→ Resonant circuit or Tank circuit.

↳ LC | RLC.

Positive feedback - op in phase with ip

Negative feedback - op out of phase.

★ At high frequencies there is a gain roll of so as an amplifier we don't use op-amp we use transistor instead. ★



impedence of an inductor

$$Z = j\omega L$$

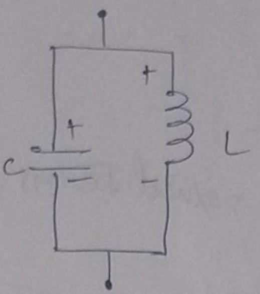
$$v = L\frac{di}{dt}$$

↓ instantaneous voltage

↳ Inductance

~~$X_L = X_C$~~

Tank Circuit → produces oscillations but energy, no enough gain



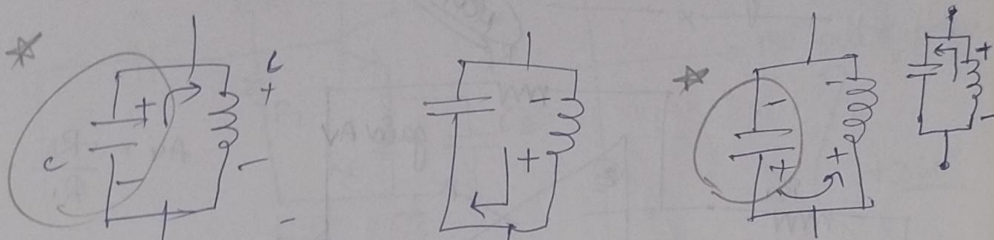
$E = \frac{1}{2} L I^2$

$B = \frac{\mu_0 I}{2\pi r}$

B → magnetic field.

when C is fully charged it starts to discharge. → i increases.

L starts dishcharges means i ~~increases~~ decreases

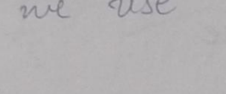


C discharges

L discharges
i decreases

C charges but in opp direction

capacitors charges in one direction & discharges in another direction.



these produces oscillations which are not sustained so we use oscillator with positive feedback

$X_L = X_C$ → frequency at which oscillation is setup.

$$j\omega L = \frac{1}{j\omega C}$$

$$j 2\pi f L = \frac{1}{j 2\pi f C}$$

$$f^2 = \frac{1}{j2\pi C \times j2\pi L}$$

$$f^2 = \frac{1}{2^2\pi^2 j^2 CL}$$ cancel $\sqrt{}$ (-1)

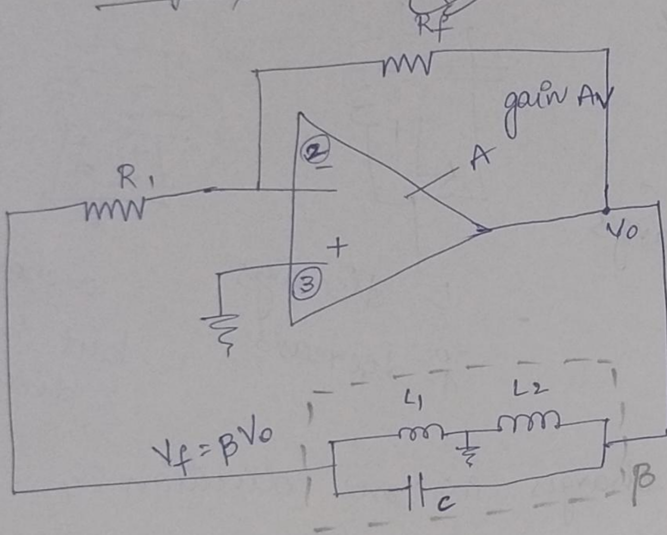
$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

$$X_C = \frac{-1}{2\pi f c}$$

Hartley Oscillator.

Harmonic

op amp



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

attenuation/ feedback factor $\beta = \frac{V_f}{V_o} = \frac{L_1}{L_2}$

frequency of oscillation (or) frequency resonance $= f_r = \frac{1}{2\pi\sqrt{L_{eq} C}}$

$L_{effective} = L_1 + L_2 + 2M$

mutual inductance

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

WKT

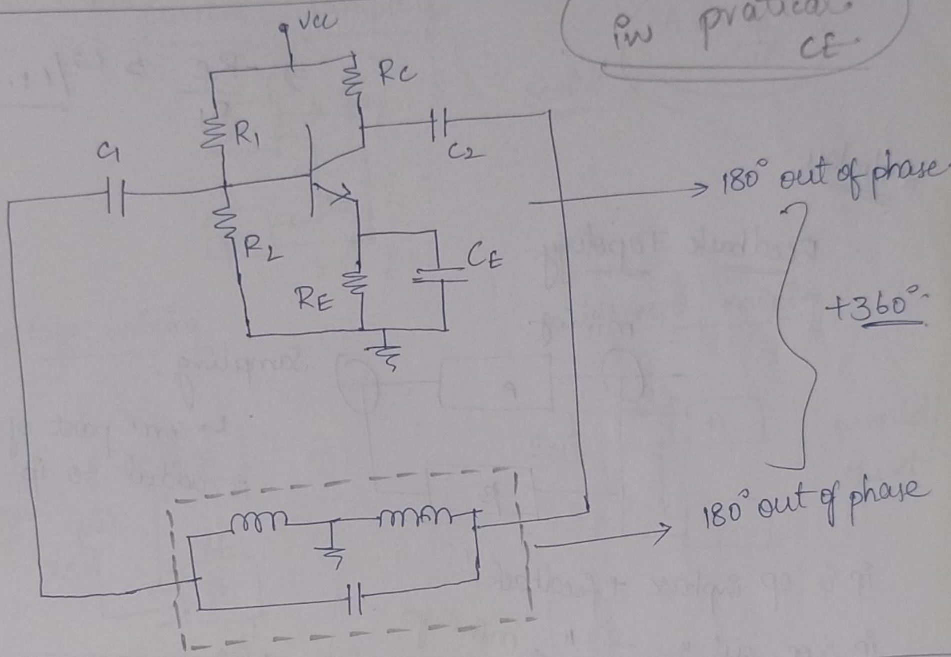
$A\beta = 1$

when $\beta = L_1/L_2$ then $A = \frac{L_2}{L_1}$.

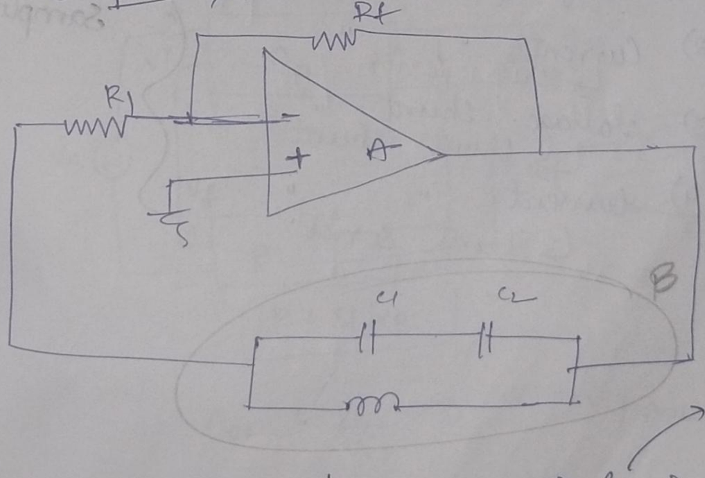
To initiate oscillation, $A_v > \frac{L_2}{L_1}$

$\Rightarrow -\frac{R_f}{R_1} > \frac{L_2}{L_1}$.

in pratical CE



Colpitts Oscillator.



$f_r = \frac{1}{2\pi\sqrt{LC}}$ $\Rightarrow f_r = \frac{1}{2\pi\sqrt{LC_{eff}}}$

resonant freq

$$C_{eff} = \frac{C_1 + C_2}{C_1 C_2}$$

$$\beta = \frac{C_1}{C_2}$$

$$A_v \beta = 1$$

$$\Rightarrow A_v = \frac{C_2}{C_1}$$

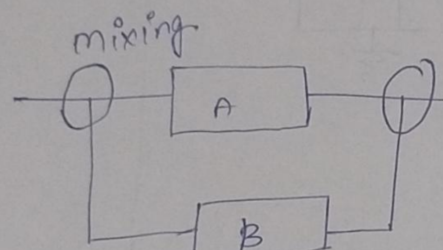
to initiate oscillation

$$A_v > C_2/C_1$$

$$\Rightarrow \frac{-R_f}{R_1} > C_2/C_1.$$

29/10/24.

Feedback Topology.



Sampling.

↳ some part of op is added to ip

ip & op inphase + feedback.

ip & op out " - "

mixing ← series shunt → sampling

1) Voltage series feedback

2) Current " " ↳ series series

3) Voltage " ↳ shunt shunt

4) current " ↳ shunt series

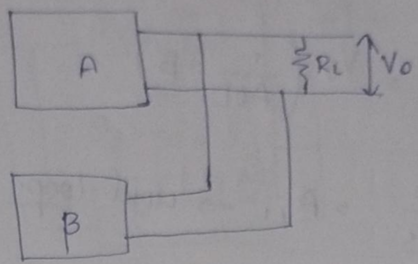
} Sampling + Mixing

Voltage Sampling

samp - V - shunt
i - series

mixi - V - series
i - shunt

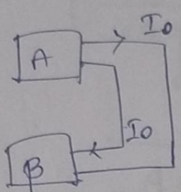
parallel/
shunt



current sampling

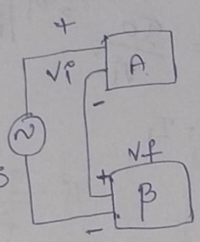
series

$A_v = \frac{V_o}{V_i}$

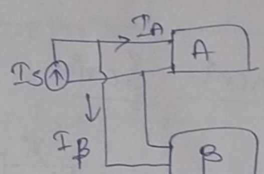


Voltage mixing

series

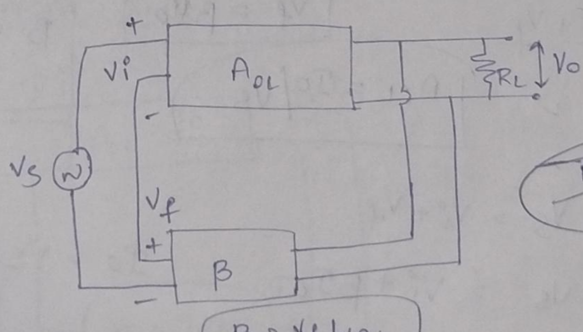


Current mixing.



parallel/
shunt

Voltage Series feedback topology | Shunt series shunt



$\cancel{A_i = \frac{I_o}{I_i}}$

$\beta = V_f / V_o$.

$$A_{OL} = \frac{V_o}{V_i} \Rightarrow V_i = V_o / A_{OL}$$

$$V_s = V_i + V_f$$

$$V_s = V_i + \beta V_o$$

$$V_s = \frac{V_0}{A_{OL}} + \beta V_0$$

$$V_s = V_0\left(\frac{1}{A_{OL}} + \beta\right)$$

$$\boxed{\frac{V_0}{V_s} = A_{CL}} \rightarrow \text{closed loop}$$

$$V_s = V_0\left(\frac{1}{A_{OL}} + \beta\right) \Rightarrow \left(\frac{1+\beta A_{OL}}{A_{OL}}\right) V_0 = V_s$$

$$V_0 = V_s\left(\frac{A_{OL}}{1+\beta A_{OL}}\right)$$

Negative feedback adv.

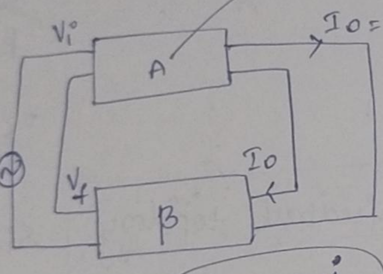
$$\frac{V_0}{V_s} = \frac{A_{OL}}{1+\beta A_{OL}}$$

① less interference

② less noise.

Current Series

$$A_{OL} = \frac{I_0}{V_i} = op/ip$$



$$V_i = \frac{I_0}{A_{OL}}$$

$$\boxed{V_f = \beta I_0}$$

$$\boxed{\beta = \frac{V_f}{I_0}}$$

$$V_s = V_i + V_f$$

$$R_m = \frac{V_0}{I_i}$$

$$\boxed{A_{CL} = I_0 / V_s}$$

$$V_s = V_i + V_f$$

$$V_s = V_i + \beta I_0$$

$$= \frac{I_0}{A_{OL}} + \beta I_0$$

$$V_s = I_0\left(\beta + \frac{1}{A_{OL}}\right)$$

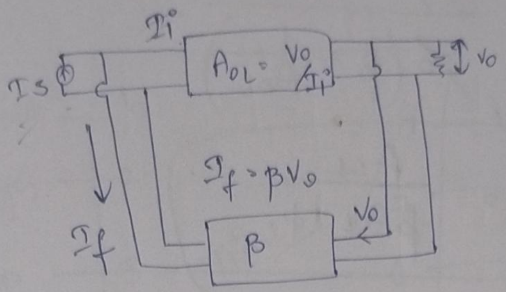
$$(A_{OL}\beta + 1)$$

$$I_0 = V_s\left(\frac{A_{OL}}{A_{OL}\beta + 1}\right)$$

$$A_{CL} = \frac{\cancel{V_s}\left(\frac{A_{OL}}{A_{OL}\beta+1}\right)}{\cancel{V_s}}$$

$$\boxed{A_{CL} = \frac{A_{OL}}{A_{OL}\beta + 1}}$$

Voltage shunt



$\beta = I_f / V_o$

$A_{OL} = \dfrac{V_o}{I_i}$

$A_{CL} = \dfrac{V_o}{I_s}$

$g_m = \dfrac{I_o}{V_i}$

$I_s = I_i + I_f$

$I_s = I_i + \beta \boxed{V_o}$

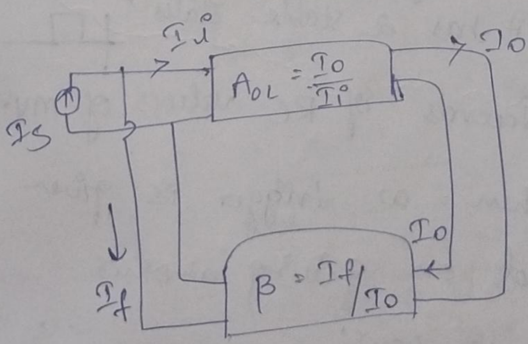
$= I_i + \beta A_{OL} I_i$

$I_s = I_i (1 + \beta A_{OL})$

$\dfrac{I_s}{} = 1 + \beta A_{OL} \left(\dfrac{V_o}{A_{OL}}\right)$

$=$

Current shunt



$I_f = \beta I_o$

$A_{OL} = \dfrac{I_o}{I_i}$

$A_{CL} = \dfrac{I_o}{I_s}$

$I_s = I_f + I_i$

$= \beta I_o + \dfrac{I_o}{A_{OL}}$

$I_s = I_o \left(\beta + \dfrac{1}{A_{OL}}\right)$

$$A_{CL} = \frac{\cancel{I_0}}{\cancel{V_0}\left(\beta + \frac{1}{A_{OL}}\right)}$$

$$\boxed{A_{CL} = \frac{A_{OL}}{\beta A_{OL} + 1}}$$

4/11/24.

IC555 Timers.

555 ⟶ 3, 5KΩ Resistors

→ Manufactured by

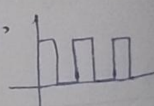
① Signetics → NE 555 timer IC

Tachometers, Waveform Generation,

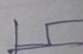
↳ Relaxation oscillators.

(Non sinusoidal waveform).

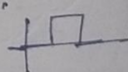
Multivibrators. → NO ip given BLOR No stable state → Ramp generator → Square wave "

→ ~~A~~stable - free running multivibrator. 

one shot MV

→ Monostable → it has only 1 stable state 

→ Trig ip is given

→ Bistable. (SL) → it has 2 stable states. 

ON & OFF depends of RC values of MV.

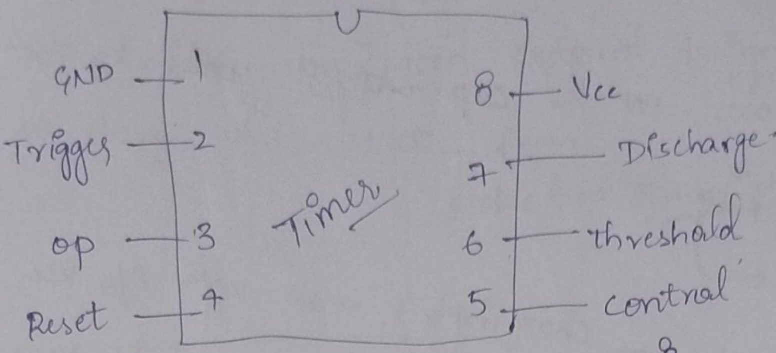
Bistable means when a trigger is given goes to high state and on giving another trigger it goes to low.

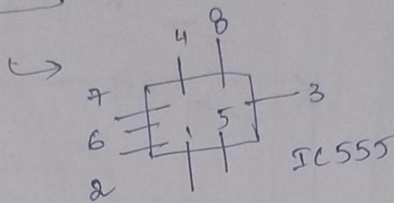
↳ used in flip flop.

frequency divider.

IC 555 Timer

→ definite stable timer

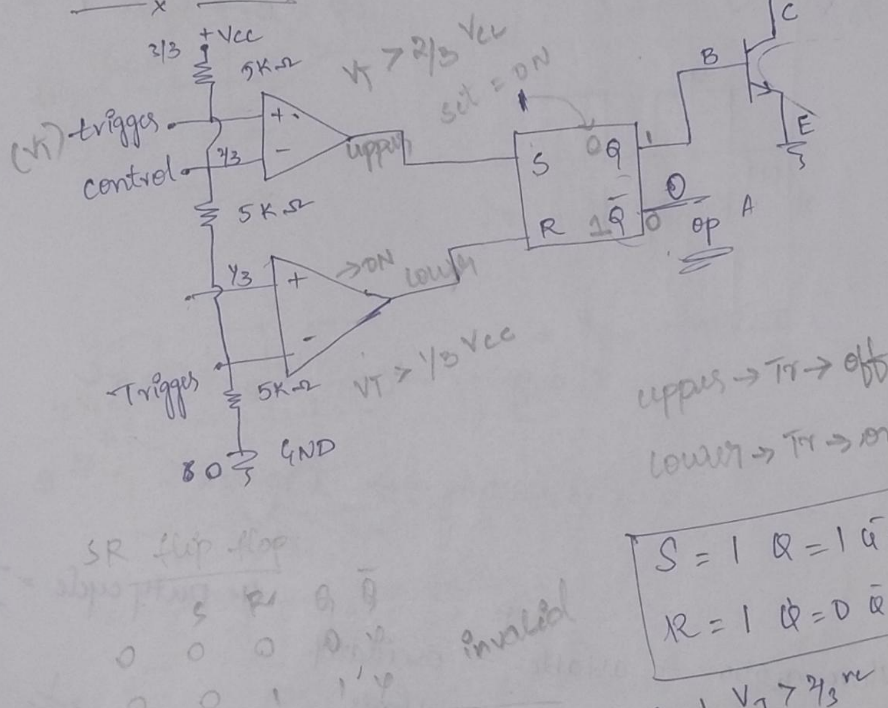




SR

Internal circuit

~~Astab~~



upper → Tr → off

lower → Tr → on

$$\boxed{\begin{array}{l} S = 1 \quad Q = 1 \quad \bar{Q} = 0 \\ R = 1 \quad Q = 0 \quad \bar{Q} = 1 \end{array}}$$

$S = 1 \quad V_T > 2/3 \, V_{cc}$

$< 1/3 \, V_{cc} \quad R = 1$

$S = 1 \quad O/P - 0$

$R = 1 \quad Q = 0$

$\bar{Q} = 1$

SR flip flop

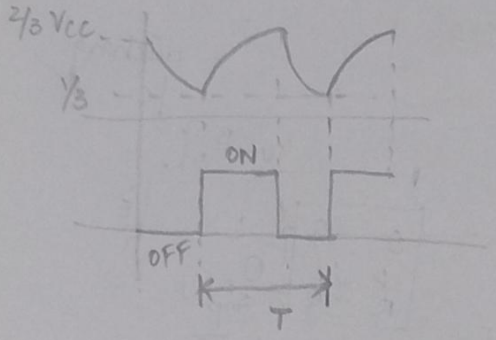
	S	R	Q	$\bar{Q}$	
0	0	0	0	1	invalid
0	0	1	1	1	
0	1	0	0	1	set
0	1	1	1	1	
1	0	0	0	0	
1	0	1	1	0	reset
1	1	0	0	0	no change
1	1	1	1	1	

Astable.

set
↑
Trans - off - Vcc through cap discharge

Trans - ON - cap charges until 2/3 Vcc.
↓
Reset

→ charging is max upto 2/3 Vcc
→ dis " " " " 1/3 Vcc.



op = 1 → set   Q 0 $\bar{Q}$ 1
op = 0 → Reset   Q 1 $\bar{Q}$ 0

charging - c = $R_A + R_B + C$

discharging → Transistor + R_B

% Duty cycle = $\frac{T_{on}}{T}$

Here IC555 - astable - oscillator (no i/p)
- mono - timer.
- bistable - f/f

$= \frac{1}{T}$ clock frequency

→ $T = 0.693(R_A + 2R_B)C$ ⇒ $T = T_1 + T_2$.

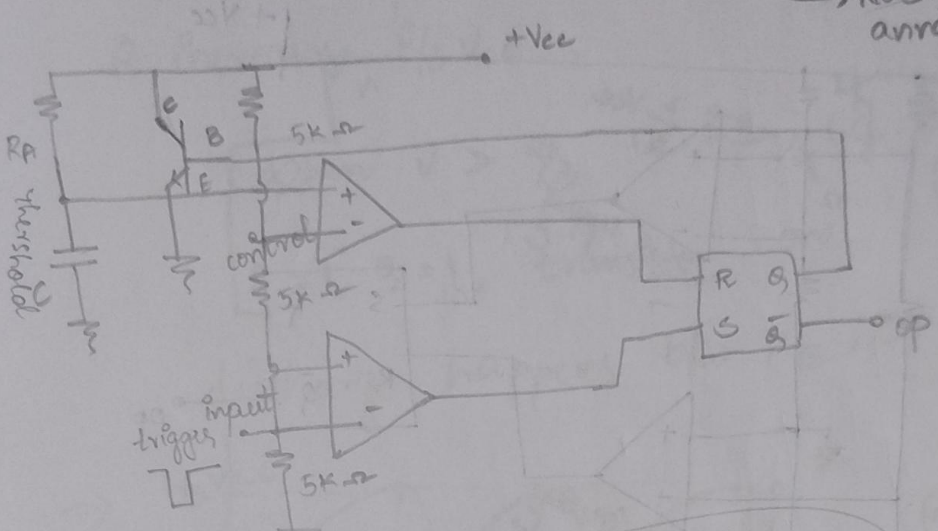
T_{OFF} | T_2 - discharging $= 0.693 R_B C$

T_{ON} | T_1 - charging $= 0.693(R_A + R_B)C$

* Monostable *

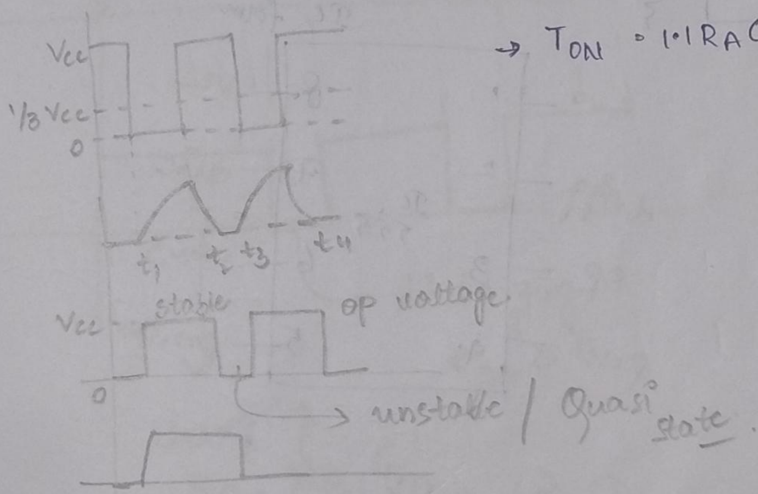
- It's only have one stable state
- To operate you need external trigger ip, this is to change the state from

stable → Quasi stable state → No stable annratu.



$T = \ln 2 R_A C$ *

→ $T_{ON} = 1.1 R_A C$



* A multivibrator circuit, oscillates b/w a high state & a low state producing a continues op.

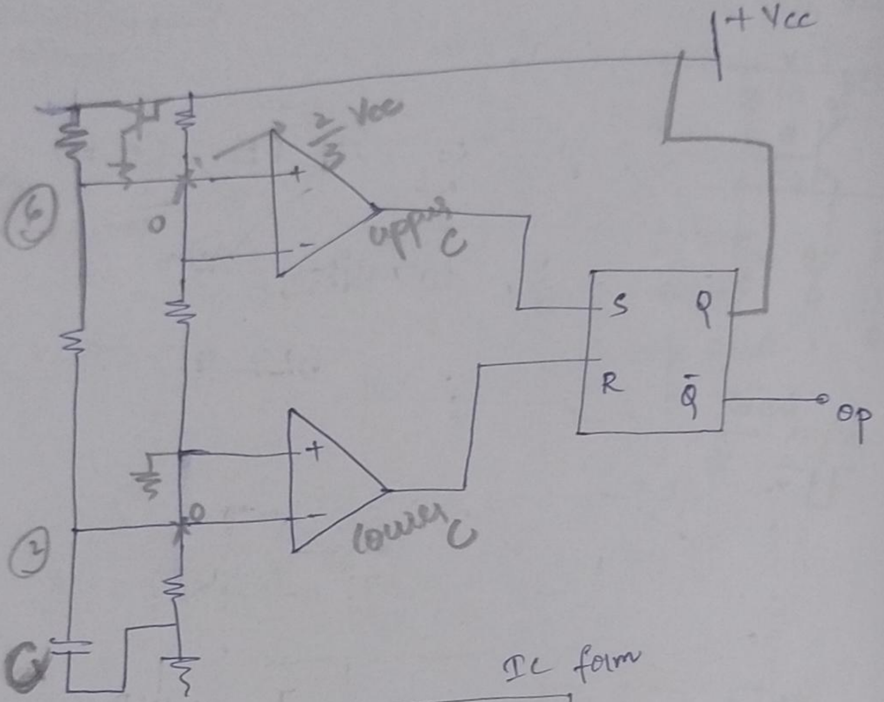
Astable multivibrates has even duty cycle.

* Astable → ON - 50%, OFF - 50%

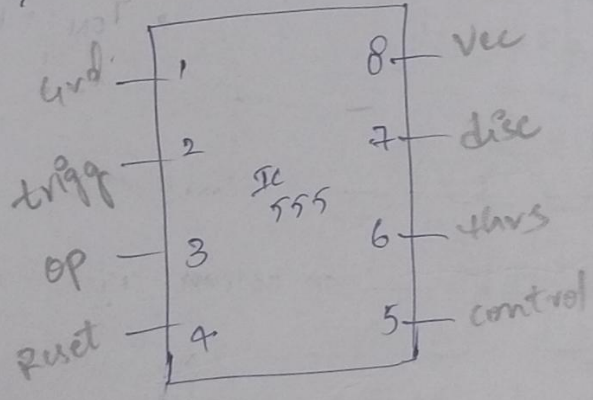
$T = T_{ON} + T_{OFF}$

Monostable is called one shot mv that have one stable state. As external ip is given it returns back to its original state.

Astable



IC form



(6), (2) $= 0V$

$x < \frac{1}{3} Vcc$ $\quad LC = 1 \longrightarrow$ Reset $= 1$

$UC = 0$

Initially $x' = 0 < \frac{2}{3} Vcc \rightarrow$ to turn on $x' > \frac{2}{3} Vcc$

R = 1, Q = 0, transistor = off

No i in Base, C_1 will be charging through Vcc, RA, RB.

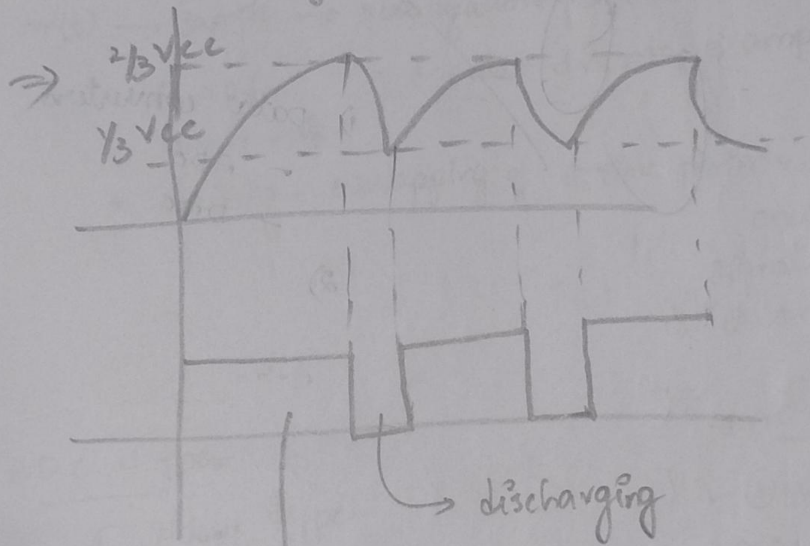
voltage across Vc ↑

it increases upto 2/3 Vcc.

when v > 2/3 UC = 1, LC = 0

S = 1, Q = 1, transistor = on

discharge happens b/w R_B, C



$T_{ON} = 0.693(R_A + R_B)C$ $T_{OFF} = 0.693 R_B C$

$\boxed{\text{Duty cycle} = T_{ON} / T}$ $T = 0.693(R_A + 2R_B)C$

$$\Rightarrow \frac{\cancel{0.693}(R_A + R_B)\cancel{C}}{\cancel{0.693}(R_A + 2R_B)\cancel{C}}$$

$$\text{duty cycle} = \frac{R_A + R_B}{R_A + 2R_B}$$

CO-5

1) Data converters

- ADC
- DAC

11/11/24

Analog to Digital & Converters

Sampling - continuous in amplitude
discrete in time

Analog - cnts in time, amplitude

conditions for sampling

① $f_s > 2f_{msg}$ → sampling theorem
↳ sample

② $T_s \leq \frac{1}{2f_m}$ → Nyques theorem.

Quantization - discrete in time, amplitude

m(t) → sample → quantization → encoder
• cnts - discrete ⇒ amplitude

$f_s > 2f_m$

- Nyqus rate
- alaising - overlapping of 2 time periods.

encodes the signal by assigning 0,1 to amplitude.

ADC types

① Flash type
② Single / Dual slope
③ successive ~~or~~ aproximation
④ Delta sigma.

DAC types.

① Binary weighted resistor
② R-2R ladder type.

Sampling we use sample & hold circuit to get correct time period samples.

ADC

→ 3 bit ADC

→ full scale output voltage.

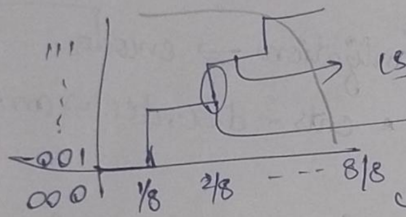
(or) → $V_{ref}/2$

Resolution - given in no of bits.

$\frac{V_{max} - V_{min}}{2^n}$ (or) → $\frac{\text{full scale outputs voltage}}{2^n}$

min voltage for ADC $= 1.25\,V. \rightarrow \frac{10}{2^3}$

$= 125\,mV.$



→ LSB

→ step size

→ full scale voltage.

001 — 010

step size = 1.25 because it's min for ADconver.

at 8 = 111

$$\boxed{\text{Resolution} - \frac{(2^n - 1)\,V_{ref}}{2^n}}$$

→ step size

→ Resolution $= 2^n - 1 \times$ step size

→ Rate at which ADC at which A voltage is converted to digital op

→ is no of bits.

No of bits ↑'s Resolution ↑'s