Unit-3

Feedback Amplifiers

$$A_V = -g_m \left(\frac{R_i}{R_i+R_s}\right) R_o = -\frac{I_o}{V_{in}} \frac{R_i}{R_i+R_s} \cdot R_o$$

$$= \frac{-I_o}{V_{in}} \cdot \frac{1}{R_i} \cdot R_o \quad [\text{if } R_s = 0]$$

$$A_V = -A_I \cdot \frac{R_O}{R_i}$$

If $A_I = 100$, $R_i = 1.1k$, $R_O = 2.2k$ $A_V = -200$

if $V_i = 1mV$

$$V_O = |A_V| \cdot V_i = 200 \times 1mV = 200mV$$

If temp ↑, A_i ↑es to 110

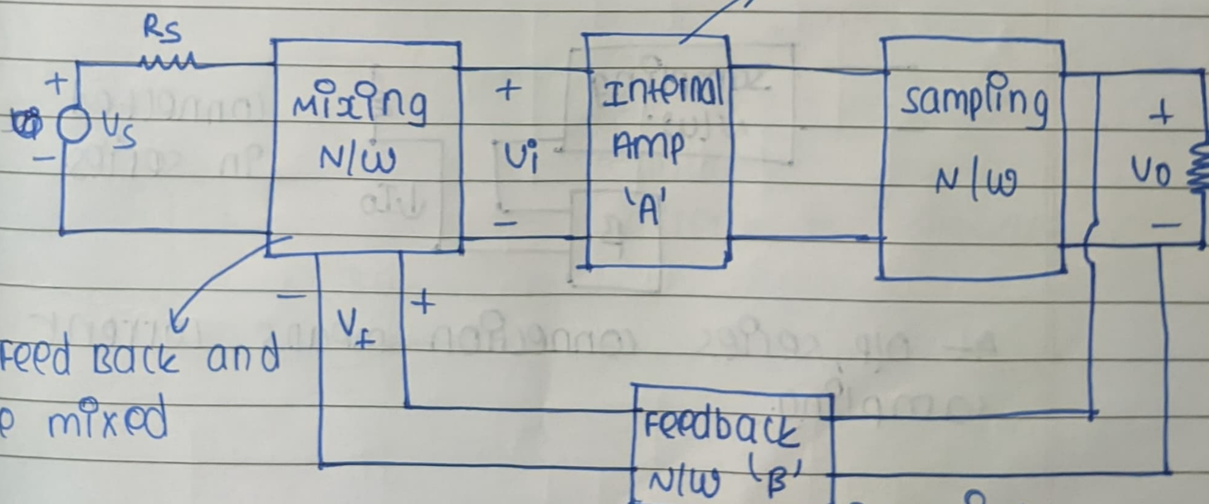
then,

$$A_V = 110 \cdot \frac{2.2k}{1.1k} = 220$$

$$V_O = 220 \cdot 1mV$$
$$= 220mV$$

(um) Feedback amp Block Diagram:

A is open loop gain



(V_f) Feed back and V_s are mixed

passive elements

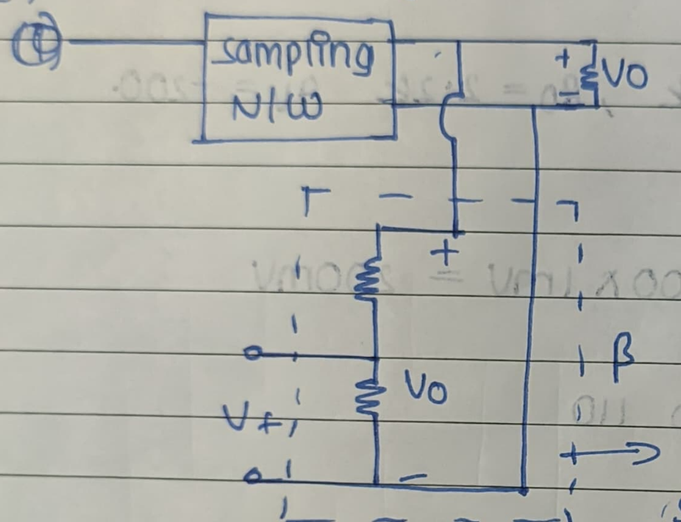
$$\underbrace{V_i = V_s - V_f}_{\text{i/p after mixing}}$$

* If $V_o\uparrow$ due to any fluctuations,
  $V_f\uparrow$ ∴ $V_i\downarrow$ ⇒ Brought down V_o to constant

* If $V_o\downarrow$, $V_f\downarrow$, $V_i\uparrow$ ⇒ Brought down V_o to constant

Sampling:

(i) Voltage sampling:

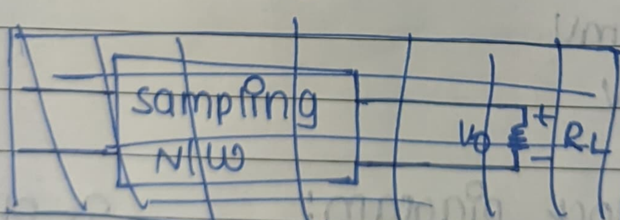


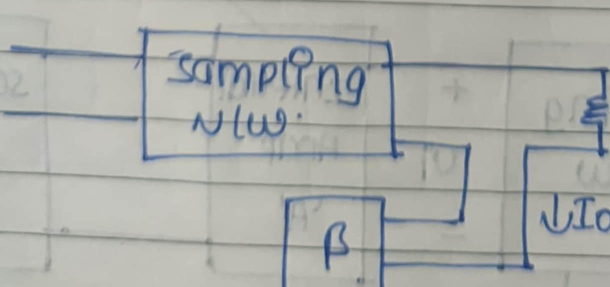
Voltage sampling.

N/W - Network

Voltage sampling [shunt connection]

(ii) Current sampling





connected in series.

At O/P, series connection means current sampling.

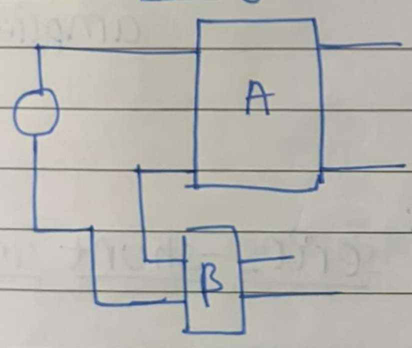
* when temp increase Ai increases ~~on~~ which leads to increase i Vo (o/p voltage)
so, it order to eliminate ~~...~~ this effect and remove this instability a small sample of Vo is feed back into the transistor.

* The sampled N/W can have both current (or) voltage.

* feedback n/w is always made of passive elements. (RC--)

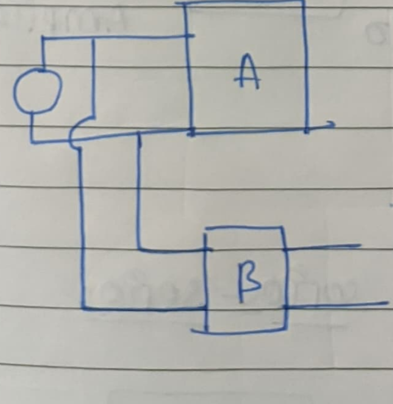
<u>Mixing N/W</u>

i) <u>series mixing.</u>



At the i/p series connection means voltage is feed.

ii)

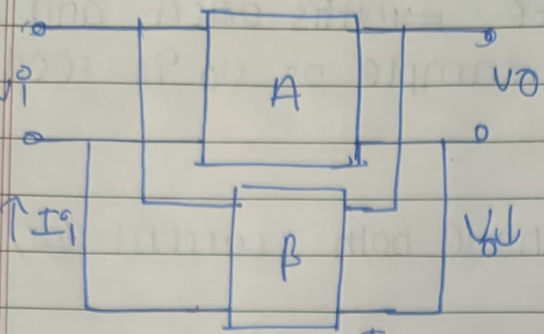


At the i/p shunt connection means current is feedback

4 Different types of sampling amplifiers

Shunt-Shunt-Amp

$\boxed{\beta = \frac{1}{A}}$



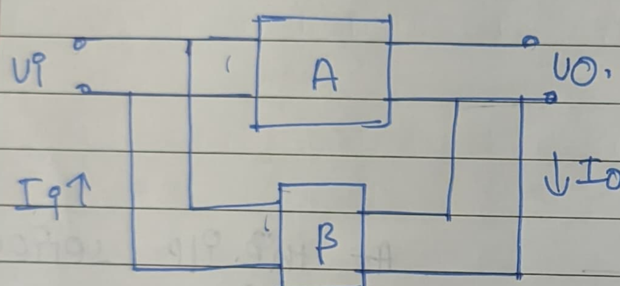
$\beta = \frac{I}{V}$

Voltage shunt feedback Amplifiers

$\boxed{A = \frac{V_o}{I_i}}$ → Trans-Resistance amplifier

Current shunt FB amp:

Shunt-series amp

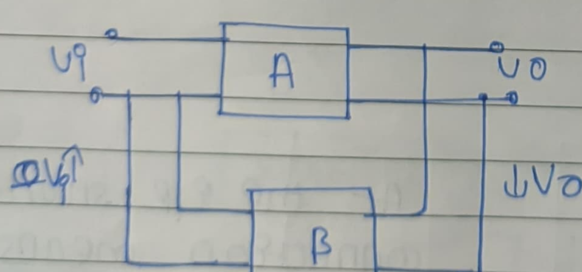


$\beta = \frac{I_i}{I_o}$

$\boxed{A = \frac{I_o}{I_i}}$ → Current amplifier

Voltage-series FB amp:

Series-shunt amp

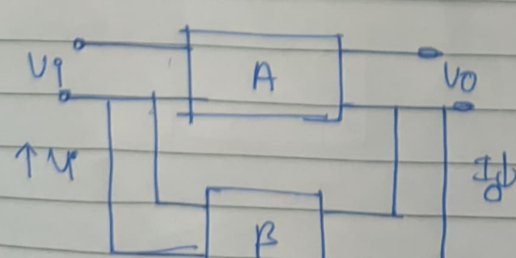


$\beta = \frac{V_i}{V_o}$

$\boxed{A = \frac{V_o}{V_i}}$ → Voltage Amplifier

Current-series FB Amp

Series-series

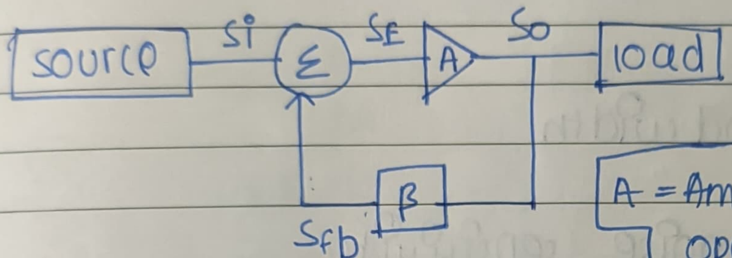


$\beta = \frac{V_{in}}{I_o}$

$\boxed{A = \frac{I_o}{V_{in}}}$ → Transconductance amplifier.

Types of feedback:

* Positive feedback → for oscillators
* Negative feedback. → for amps.



β = feedback transfer ~~factor~~ function. (or) feed back factor

A = Amplification factor (or) open loop gain.

$S_o = A S_E$

$S_{fb} = \beta S_o$

$S_E = S_i - S_{fb}$

$S_o = A(S_i - S_{fb}) = AS_i - A\beta S_o$.

$AS_i = S_o + A\beta S_o$

$A\beta$ = loop gain

$A\beta >> 1 \quad \therefore A_{fb} = \frac{A}{A\beta} = \frac{1}{\beta}$

$A_{fb} = S_o/S_i = \frac{A}{1+A\beta}$ → closed loop gain

↓

Negative feedback

$A_{fb} = \frac{A}{1-A\beta}$ → for positive feedback

Advantages of feedback loop:

1) Reduction in gain sensitivity

sensitivity of V_0 to temp and other factors is reduced.

2) Increased Band width

3) Reduction in noise sensitivity

4) Reduction of non-linear distortions.

5) Good control over the impedance levels at i/p and o/p sides.

Disadvantages

1) Gain will be reduced. / overall gain is reduced.

$$A_{fb} \propto \frac{1}{\beta}.$$

(Q) Calculate feedback transfer function β if $A = 10^5$, $A_f = 50$ find β.

(A)

$$A_f = \frac{A}{1+A\beta}$$

$$A_f + A_f A\beta = A$$

$$\beta = \frac{A - A_f}{A_f A} = 0.01999.$$

* Advantages of negative feed back

(i) Reduction in gain sensitivity:

$$A_f = \frac{A}{1+A\beta}$$

$$\frac{dA_f}{dA} = \frac{1}{1+A\beta} - \frac{A}{(1+A\beta)^2}\cdot\beta$$

$$\frac{dA_f}{dA} = \frac{1}{(1+\beta A)^2} \; ; \; dA_f = \frac{dA}{(1+\beta A)^2}$$

$$\frac{dA_f}{A_f} = \frac{dA/(1+\beta A)^2}{A/(1+A\beta)} = \frac{1}{1+A\beta}\,\frac{dA}{A}.$$

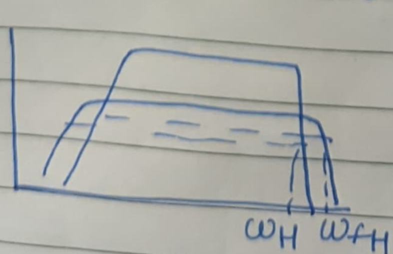
(ii) Band width Extension:

$$A(s) = \frac{A_0}{1+\frac{s}{\omega_H}}$$

$$A_f(s) = \frac{A(s)}{1+\beta(A(s))^2} = \frac{A_0}{(1+s/\omega_H)}\cdot\frac{1}{\left(1+\frac{\beta A_0}{(1+s/\omega_H)}\right)}$$

$$= \left(\frac{A_0}{1+\beta A_0}\right)\left(\frac{1}{1+s/\omega_H(1+\beta A_0)}\right)$$

i.e, ω_H is increased to $\omega_{Hf} - \omega_H(1+\beta A_0)$

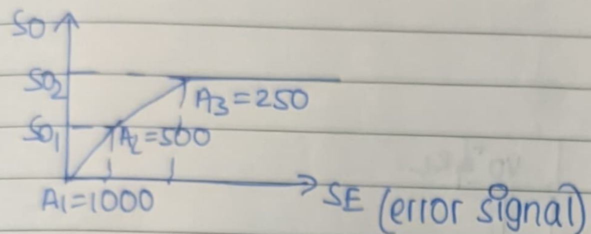


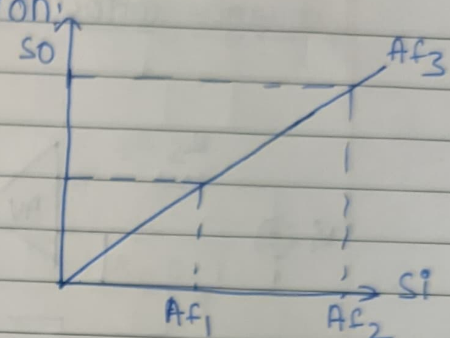
(3) Noise of Distortion Reduction:

$$N_f = \frac{N}{1+\beta A} \qquad D_f = \frac{D}{1+\beta A}$$

Since gain is divided by $\frac{1}{1+\beta A}$ noise & distortion will also be divided.

(4) Reduction in non-linear Distortion:





$$A_{f_1} = \frac{1000}{1+(0.099)(1000)} = 10$$

$$A_{f_2} = \frac{500}{1+(0.099)(500)} = 9.90$$

$$A_{f_3} = \frac{250}{1+(0.099)(250)} = 9.7$$

Noise:

* It is caused due to random movement of charge carriers in the circuit.
  This happens when there is ~~teme~~ temperature change, when there are imperfection on the circuit etc...
* It is internally created.

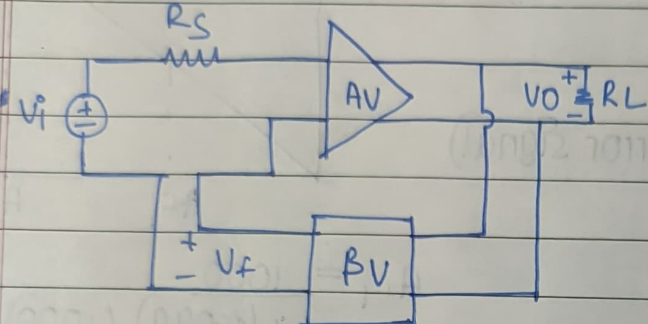
Distortion

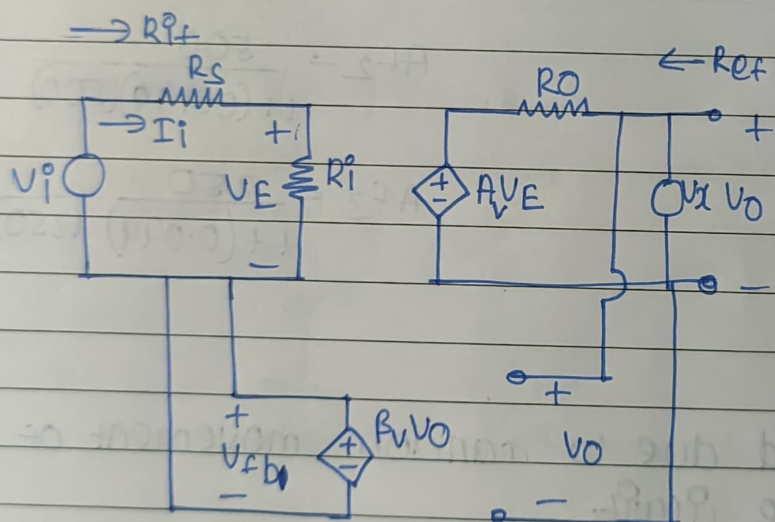
* Due to changes in the design of the transistor there will be an undesirable o/p. This is called Distortion

* The only disadvantage of negative feedback is that the gain is reduced.

series-shunt configuration

voltage-series feedback amp (voltage amp)





$V_o = A_V \cdot V_E$, $V_{fb} = \beta_V V_o$

$\cancel{V_E = \frac{V_i}{V_{fb}}}$ $V_E = V_i - V_{fb}$

$V_o = A_V(V_i - V_{fb}) \Rightarrow \frac{V_o}{V_i} = \frac{A_V}{1+\beta_V A_V}$

$\cancel{V_o = A_V \cdot \frac{V_i}{V_{fb}} \Rightarrow V_o = \frac{A_V V_i}{\beta_V V_o}}$ $= A_{Vf}$

$\cancel{\frac{V_o^2}{V_i} = \frac{A_V}{\beta_V}}$ $\cancel{V_o =}$

$V_i = V_E + V_{fb} = V_E + \beta_V V_O$

$\cancel{V_i = (V_i - V_{fb}) + V_{fb}}$

$V_i = V_E + \beta_V (A_V V_E)$

$V_E =$

$I_i = \frac{V_E}{R_i}$ $R_{if} = \frac{V_i}{I_i} = R_i(1 + \beta_V A_V)$

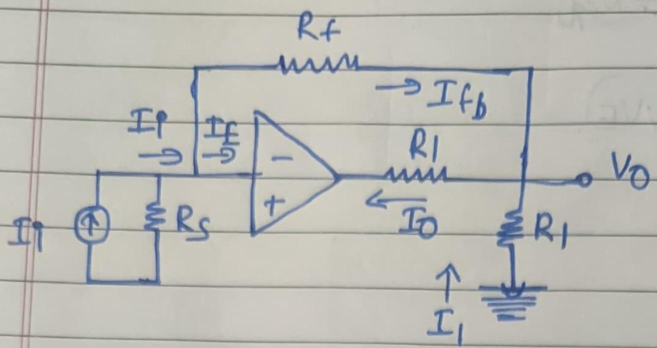
<u>O/P Impedance</u>:-

$V_E + V_{fb} = V_E + \beta_V V_x = 0$

$V_E = -\beta V \cdot V_x$

$I_x = \frac{V_x - A_V V_E}{R_O} = \frac{-(V_x - A_V)\beta V \cdot V_x}{R_O} + V_x$

Current Amp (shunt-series Amp)



$$V_O = -I_{fb} R_f = -I_i R_f$$

$$I_1 = \frac{-V_O}{R_1}$$

$$I_O = I_{fb} + I_1$$

$$= I_i + \left(-\frac{1}{R_1}\right)\left(-I_i R_f\right)$$

$$I_O = I_i\left(1 + \frac{R_f}{R_i}\right)$$

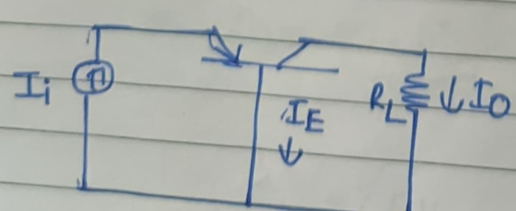
$$\frac{I_O}{I_i} = 1 + \frac{R_f}{R_i}$$

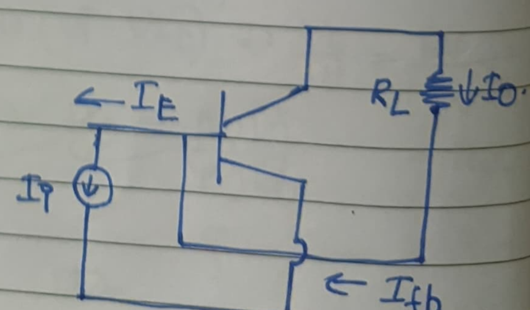
$$A_{if} \simeq \frac{1}{\beta_i} = \frac{I_O}{I_i}$$

$$\therefore \beta_i = \frac{1}{\left(1 + \frac{R_f}{R_i}\right)}$$

Examples:-

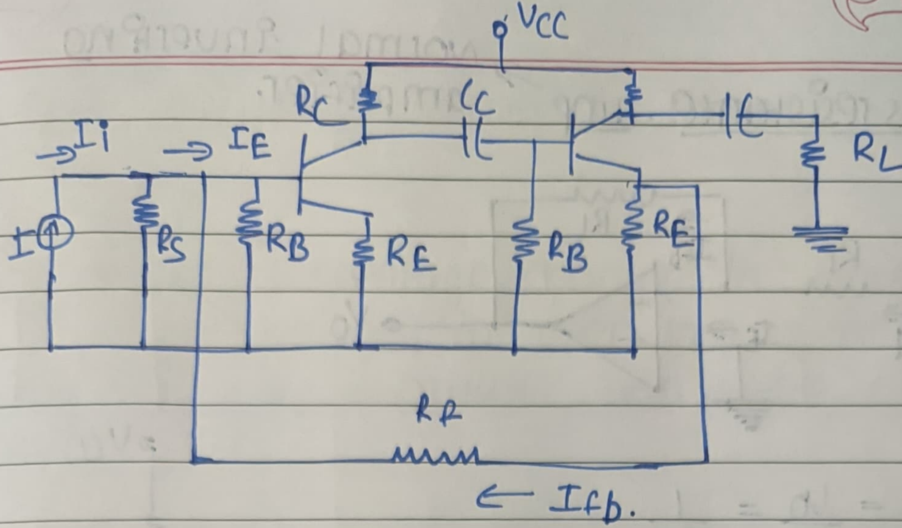
CB circuit:



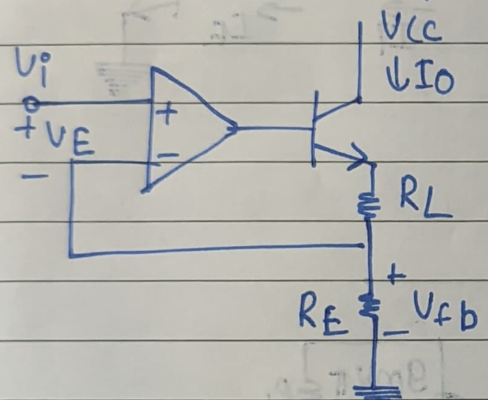


$$A_i = \frac{I_O}{I_E} = h_{fe} \qquad A_{if} = \frac{h_{fe}}{1 + h_{fe}} = \frac{A_i}{1 + A_i}$$

β_i = unity.



Transconductance Amp

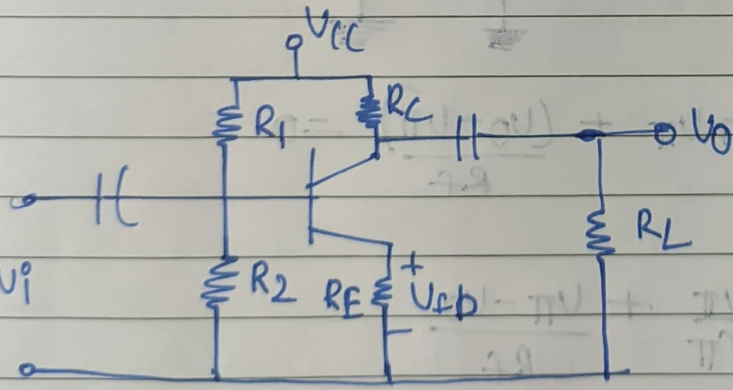


$$A_{gf} = \frac{I_o}{V_i} = \frac{1}{\beta_2}$$

$$V_i = V_{fb} - I_o R_E$$

$$A_{gf} = \frac{I_o}{V_i} = \frac{1}{R_E}$$

$$\beta_2 = R_E.$$



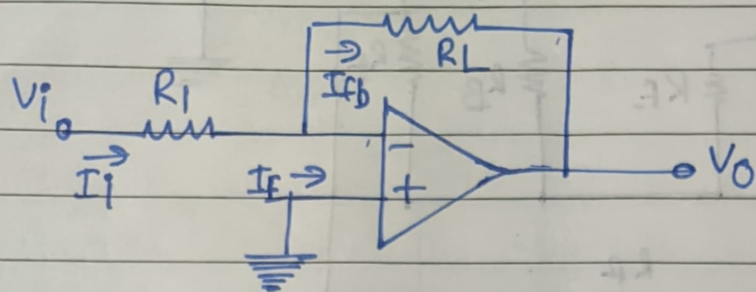
$$I_o = (-g_m v_\pi)\left(\frac{R_L}{R_C + R_L}\right)$$

$$V_{fb} = \left(\frac{v_\pi}{r_\pi} + g_m v_\pi\right) R_E$$

$$V_i = v_\pi + V_{TH} = v_\pi\left(1 + \left(\frac{1}{r_\pi} + g_m\right) R_E\right)$$

$$A_{gf} = \frac{I_o}{V_i} =$$

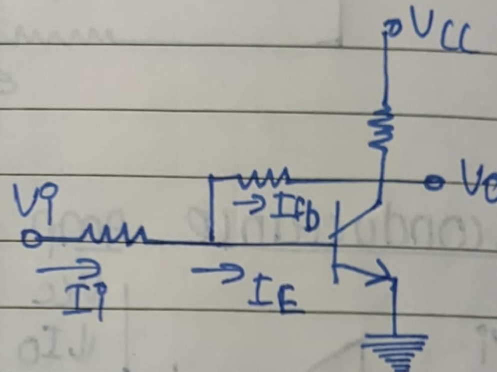
trans resistance amp → normal inverting amplifier.



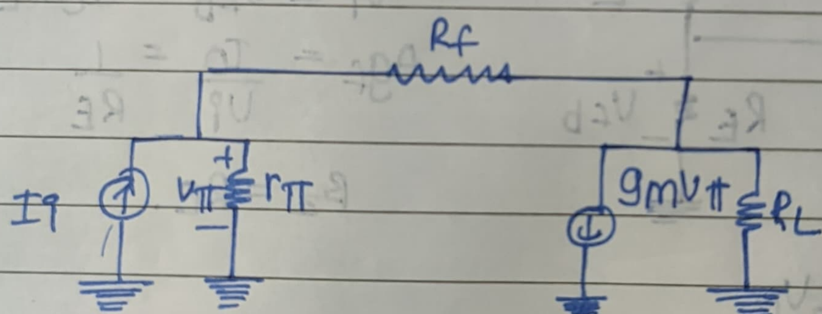
$$A_{zf} = \frac{V_o}{I_i} = \frac{1}{\beta g}$$

$$A_{zf} = -R_L$$

$$V_o = -I_{fb} R_L$$



$$\beta g = -\frac{1}{R_L}$$



$$\frac{V_o}{R_C} + g_m V_\pi + \frac{(V_o - V_\pi)}{R_f} = 0$$

$$I_i = \frac{V_\pi}{r_\pi} + \frac{V_\pi - V_o}{R_f}$$

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

classmate

Date

Page

* Example for current amp is common base amp.

Q) calculate the percentage change in close loop gain of, given a change in open loop gain a.

If $A = 10^5$, $\beta = 0.01999$, ~~...~~ $dA = 10^4$

$A_f = 50$

change closed loop gain: $\frac{dA_f}{A_f} = ?$

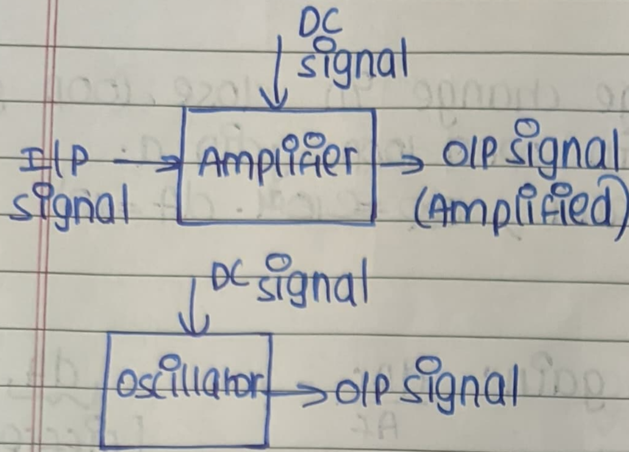
$\underbrace{dA}$ [Differential gain]

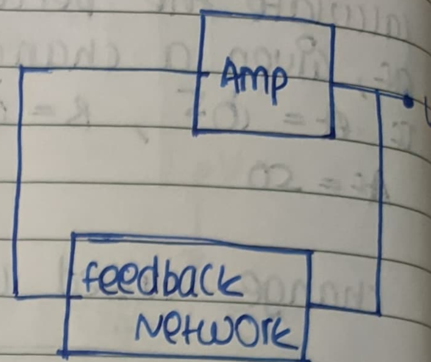
$$\boxed{dA_f = \frac{A_f}{1+\beta A} \cdot \frac{dA}{A}}$$

$dA_f = 2.5 \times 10^{-3}$.

$\frac{dA_f}{A_f} =$ ~~...~~ $5 \times 10^{-5}\%$.

Oscillators





$$\boxed{A_f = \frac{A}{1-\beta A}}$$

* It converts DC to AC.

if $\beta A = 1$ (βA = loop gain).

$A_f = \frac{A}{1-1} = \frac{A}{0} = \infty$.

Condition for oscillator:

$\beta A = 1\angle 0°$

i) $|\beta A| \geq 1$

ii) $\angle \beta A = 0°$ or $360°$

Barkhausen criterion

Types:

i) sinusoidal or harmonic oscillator

ii) Non-sinusoidal or relaxation oscillator. → -ve resistance oscillator.

under sinusoidal oscillators

According to frequency of oscillation

1) Audio frequency oscillator ⇒ (20 Hz to 20 kHz)

2) Radio frequency oscillator.

↳ Generate freq of osc beyond 20kHz.

Frequency stability

It depends on:
* operating point
* circuit components
* supply voltage
* output load
* Int

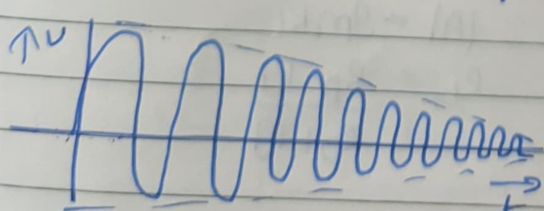
* oscillator converts a DC signal into an AC signal without any input signal.

* Audio freq oscillators
  - RC phase shift
  - wein bridge

* Radio freq oscillator
  - Hartley
  - colpitt
  - clapp.

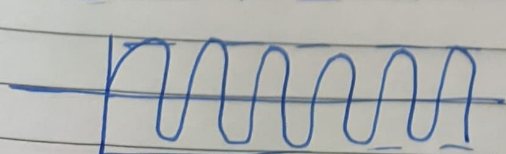
Types of oscillations

1) Damped. (overdamped/underdamped).



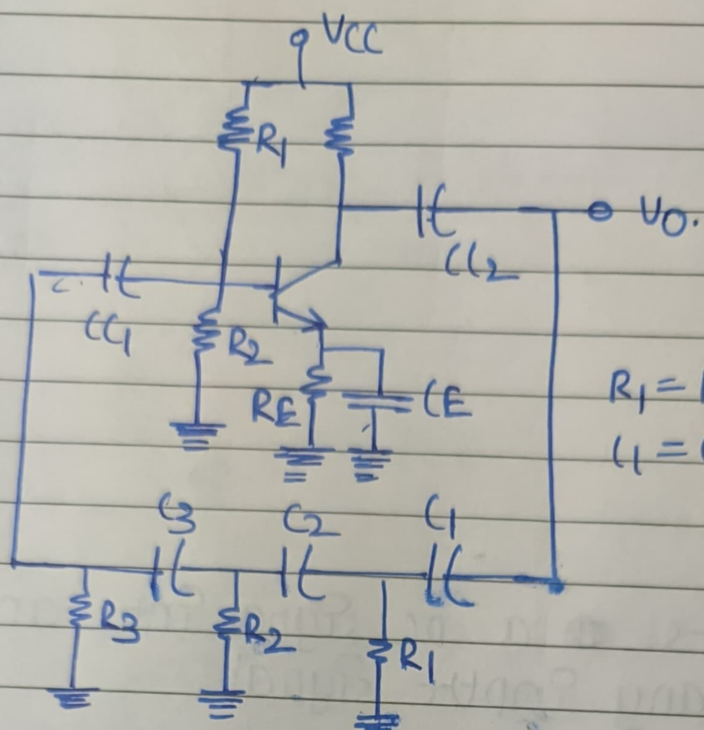
oscillations decrease over time

2) sustained/undamped



* const Ampli
* const frequency.
* Freq should be stable.

RC phase shift oscillator:



$\beta = \frac{1}{29}$

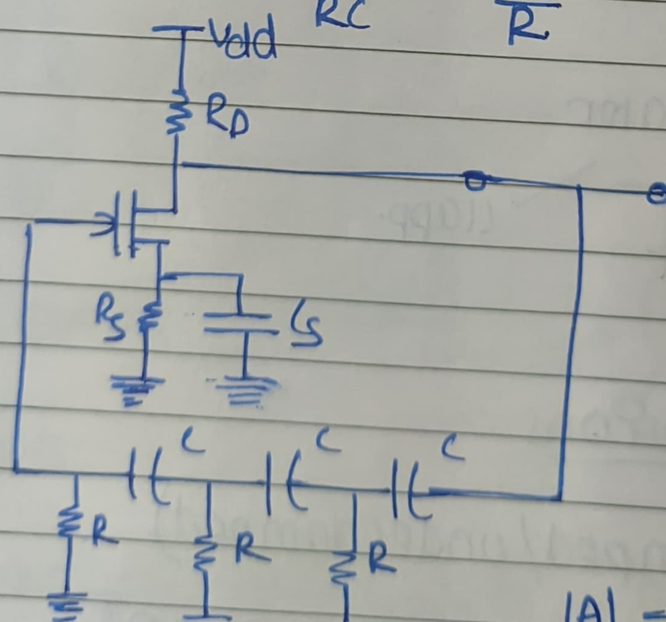
$A > 29$

$R_1 = R_2 = R_3 = R$

$C_1 = C_2 = C_3 = C$

$$f = \frac{1}{2\pi RC} \cdot \frac{1}{\sqrt{6 + 4(R_C/R)}}$$

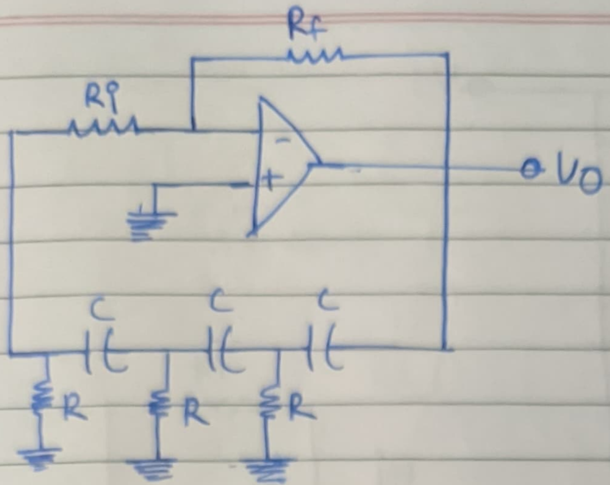
$$h_{fe} > 23 + 29\frac{R}{R_C} + \frac{4R_C}{R}$$



$|A| - g_m R_L$

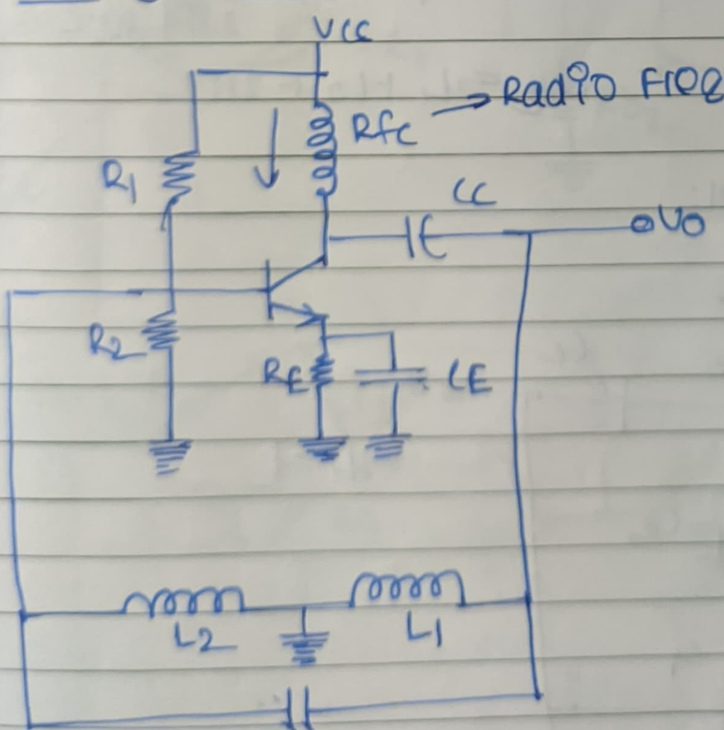
$R_L = \frac{R_D \cdot r_d}{R_D + r_d}$

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

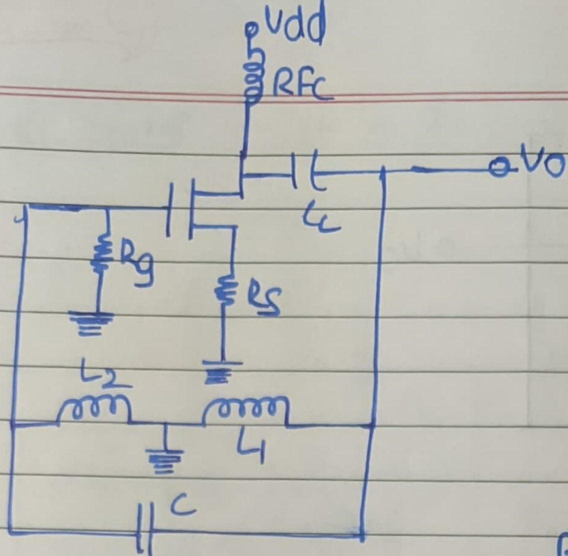


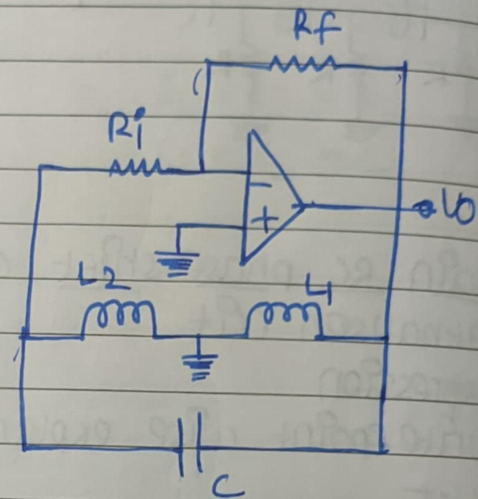
* Explain RC phase shift oscillator:
- Bakhausen crit
- Expression
- write point wise explanation & def by drawing ckt

Hartley oscillator



Radio Frequency coil (inductance).
[Allows DC and Blocks AC]



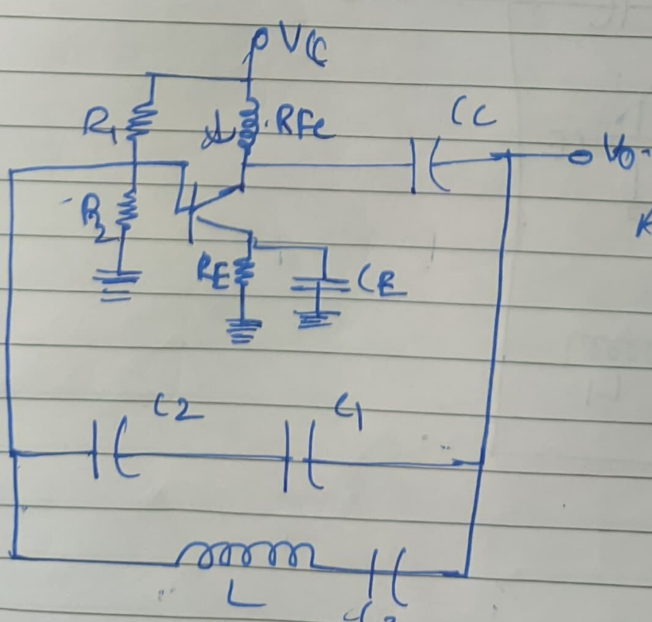


$$\beta = \frac{L_2}{L_1}$$

$A = L_1/L_2$ $\quad f_0 = \dfrac{1}{2\pi\sqrt{L_{eq}\cdot C}}$

$L_{eq} = L_1 + L_2 + 2M.$

colpitt oscillator:



$A\beta = 1$

Clapp oscillator:

$$f_0 = \frac{1}{2\pi\sqrt{LC_{eq}}}$$

$$C_{eq} = \left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right]$$

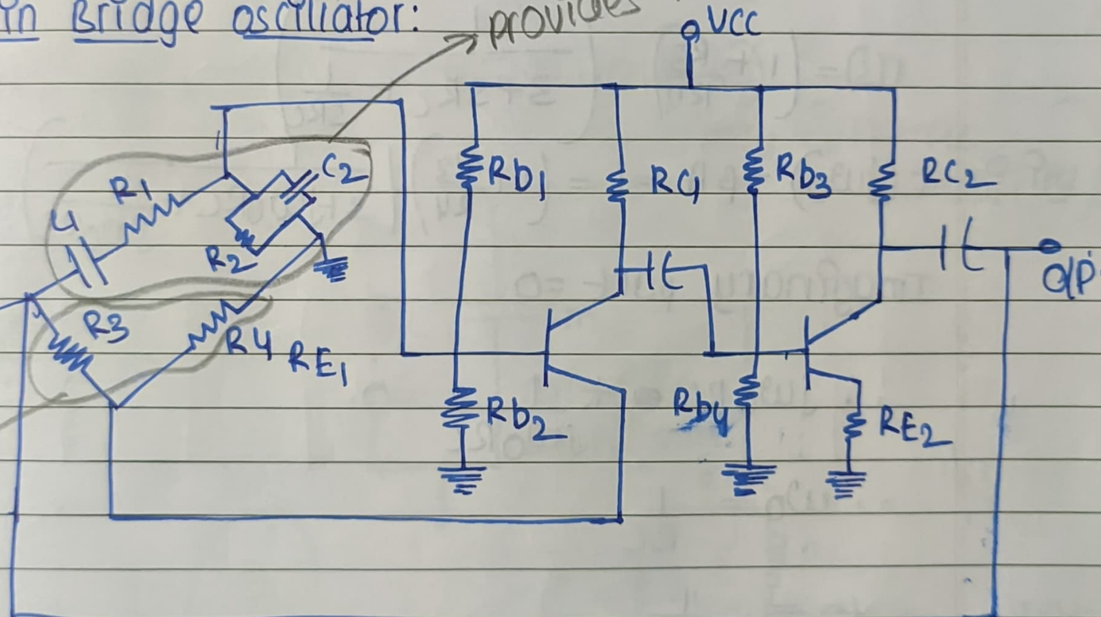
C_3 = small

$$f_0 \cong \frac{1}{2\pi\sqrt{LC_3}}$$

wein Bridge oscillator:

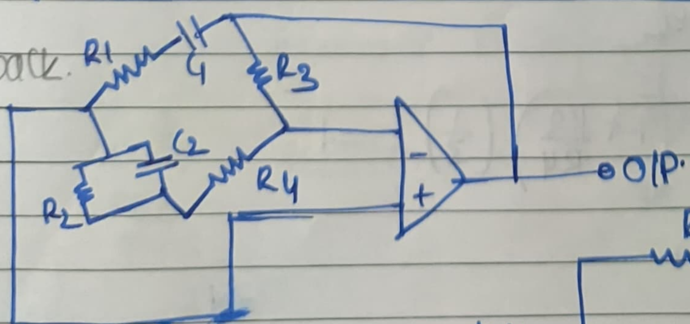
(20Hz - 1MHz)

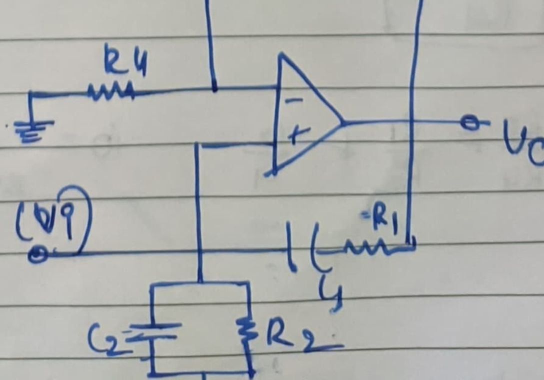
provides +ve feedback



one wein Bridge network.

provides -ve feedback.





$$A = 1 + \frac{R_3}{R_4}$$

$$\beta = \frac{Z_P}{Z_P + Z_S} \qquad Z_P = \frac{R_2 \times \frac{1}{sC_2}}{R_2 + \frac{1}{sC_2}} = \frac{R_2}{sR_2C_2 + 1}$$

$$Z_S = R_1 + \frac{1}{sC_1} = \frac{1 + sR_1C_1}{sC_1}$$

$$T(s) = \beta A = \left(1 + \frac{R_3}{R_4}\right)\left(\frac{Z_P}{Z_P + Z_S}\right)$$

If $R_1 = R_2 = R \qquad C_1 = C_2 = C$

$$T(s) = \left(1 + \frac{R_3}{R_4}\right)\left(\frac{1}{3 + sRC + \frac{1}{sRC}}\right)$$

$$T(j\omega_0) = \beta A = 1 = \left(1 + \frac{R_3}{R_4}\right)\left(\frac{1}{3 + j\omega_0 RC + \frac{1}{j\omega_0 RC}}\right) = 1$$

Imaginary part $= 0$

$$\therefore j\omega_0 RC + \frac{1}{j\omega_0 RC} = 0.$$

$$\therefore \omega_0 = \frac{1}{RC}$$

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

Real part, $\left(1 + \frac{R_3}{R_4}\right)\left(\frac{1}{3}\right) = 1$

$$\boxed{\frac{R_3}{R_4} = 2}$$

$$\frac{R_3}{R_4} = \frac{R_1}{R_2} + \frac{C_2}{C_1} \qquad f_0 = \frac{1}{2\pi\sqrt{R_1R_2C_1C_2}}$$

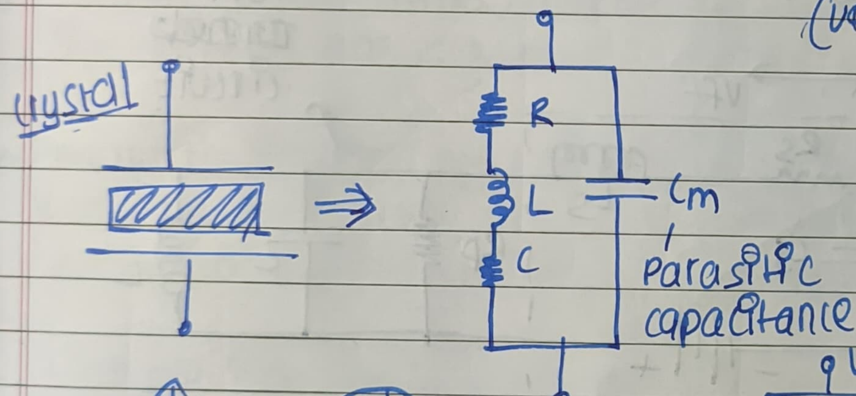
* The wein Bridge network is only for frequency determination.

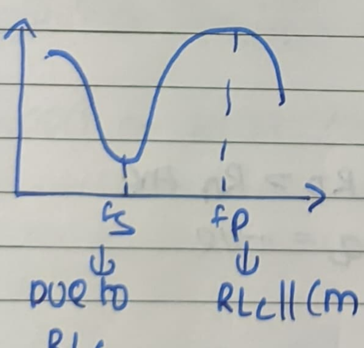
Advantages:
Good temp & freq stability
produces pure sine wave.

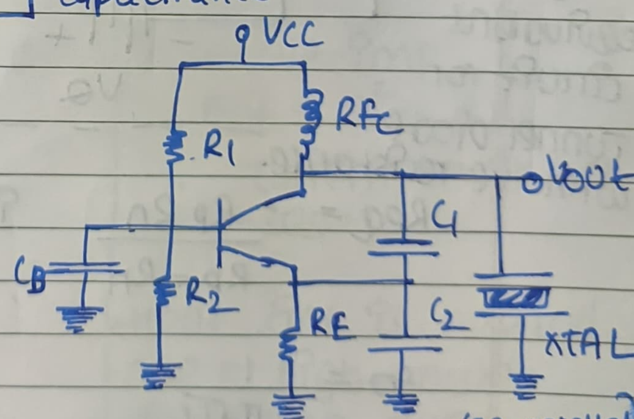
CT-2

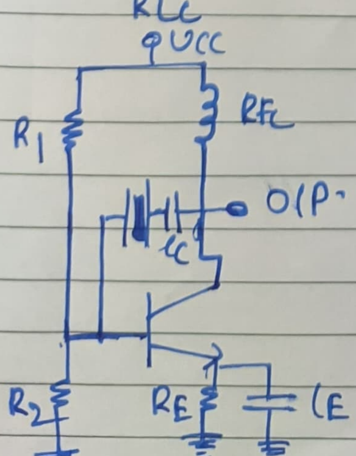
crystal & -ve resistance oscillators are for unit-4 ⇒ CT3

Crystal oscillator (10kHz to 200MHz)
(very high freq stability)



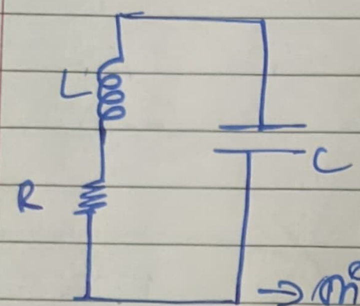




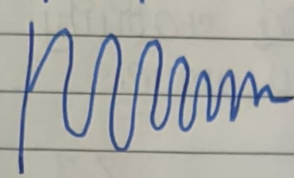


* It is an RF oscillator.

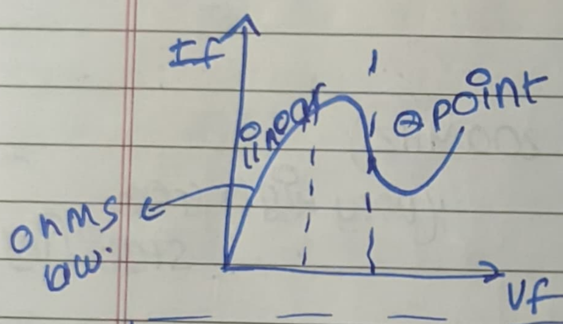
Negative resistance oscillator:

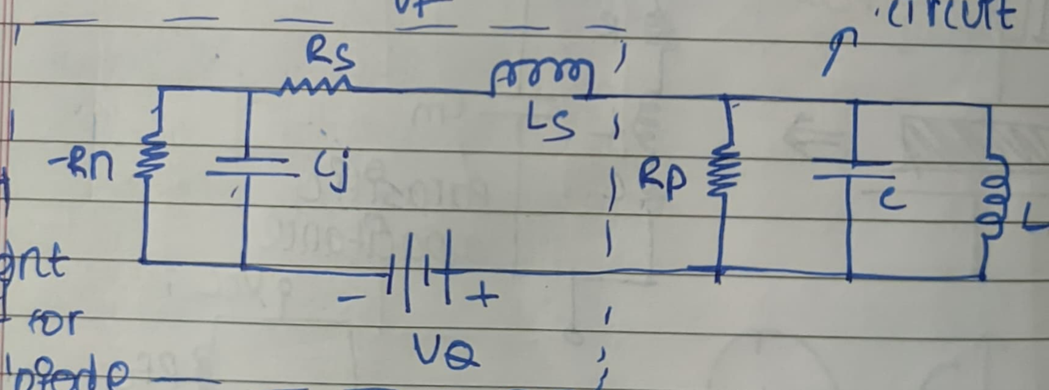


Damped oscillator



→ This RLC network is used in parallel in below circuit.





equivalent circuit for Tunnel diode with -ve resistance.

$$R_{eq} = \frac{-R_p R_n}{R_p - R_n}$$

if $R_p > R_n$ then $R_{eq} = -ve$

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$