Oscillators

Feedback

+ve feedback

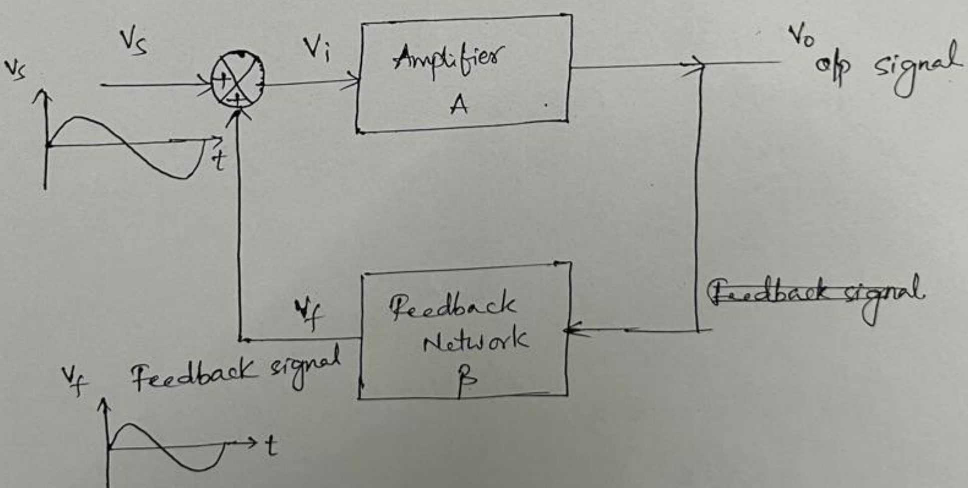
→ If the i/p signal is inphase with the feedback signal then it is called +ve f/b

-ve feedback.

→ If the i/p signal is out of phase with the f/b signal then it is called -ve f/b.

→ Positive f/b results in oscillations. So, it is ~~called~~ used in electronic ckts to generate oscillations. of desired freq. such a ckt is called oscillator.

Theory of oscillator:



→ Consider the above block diagram

V_s – Source signal.

V_i – i/p signal to basic amp.

V_o – o/p of the amp.

A – open loop gain of the amp $(A = \frac{V_o}{V_i})$

V_f – F/b signal.

β – gain of the f/b n/w $(\beta = \frac{V_f}{V_o})$

→ open loop gain (or) (Gain of the amp. without f/b) $\quad A = \frac{V_o}{V_i}$

closed lopp gain (or) Gain of the amp. with f/b $\Big\}$ $\quad A_f = \frac{V_o}{V_s}$

Here we are using +ve f/b

$$\therefore V_i = V_s + V_f$$

$$\beta = \frac{V_f}{V_o} \Rightarrow V_f = \beta V_o$$

$$\therefore V_i = V_s + \beta V_o$$

$$\Rightarrow V_s = V_i - \beta V_o$$

$$A_f = \frac{V_o}{V_s}$$

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

Divide Nr and Dr. with V_i we get

$$A_f = \frac{\left(\frac{V_o}{V_i}\right)}{1 - \beta\left(\frac{V_o}{V_i}\right)}$$

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

Let us consider that A is kept const and β is varied ②

A	β	A_f
20	0.005	22.22
20	0.04	100
20	0.045	200
20	0.05	∞

→ from above values we can say that i.e. the ~~gain~~ ckt will produce o/p without external i/p, just by feeding a part of output as its i/p.

→ Practically the o/p from this ckt is not infinite but it produces oscillations

→ The f/b factor should be always less than 1, In the oscillator ckt to start oscillations $\therefore A\beta > 1$, but the ckt adjusts itself to get $A\beta = 1$, to produce sinusoidal oscillations

Definition of oscillator:

Conditions of oscillations:

Barkhausen Criterion:

(1) → The total phase shift around the closed loop must be 0° or 360°

(2) → The magnitude of the product of openloop gain of the amplifer and magnitude of f/b factor is unity

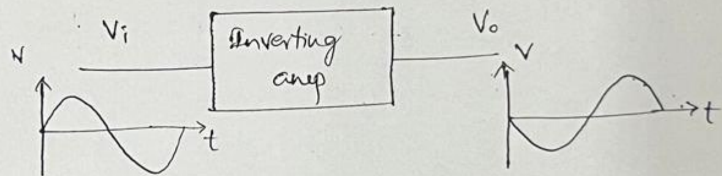
i.e $|A\beta| = 1$

If the ckt satisfies these two conditions then it works as an oscillator with constant freq. and amplitude

Condition (1)

~~[illegible]~~

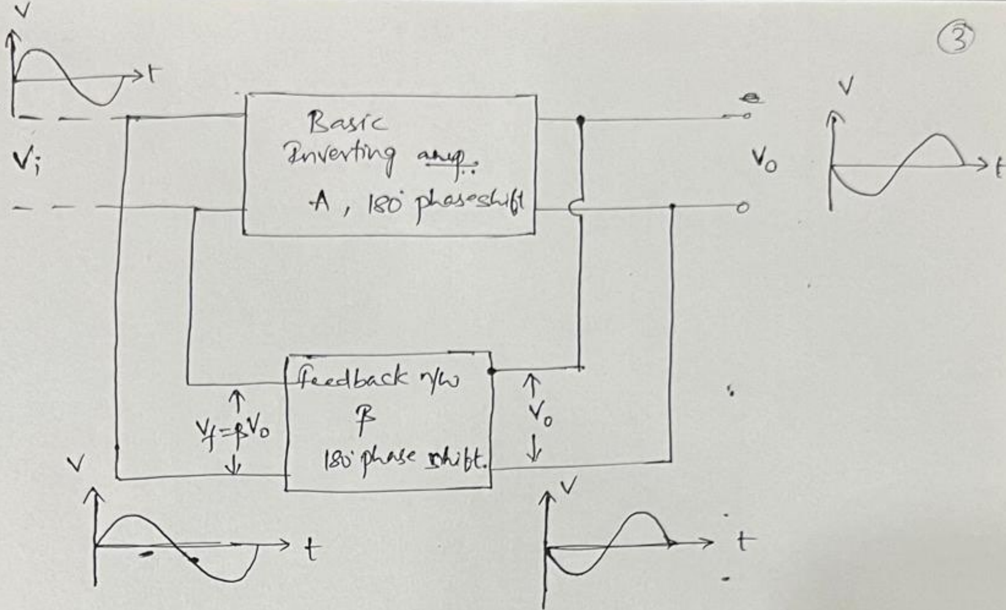
If the basic amp. is an inverting amp.



~~Here to get total phase shaft~~

In the above ckt the basic amp. is providing 180° phase shift. But to get oscillations the closed loop phase shift should be 0° or 360°.

So to get 360° phase shift the f/b n/w will provide 180° phase shift. as shown in fig.



In the above ckt the total phase shift is 360°

Condition(2):

The open loop gain $A = \frac{V_o}{V_i}$

$\Rightarrow V_o = A V_i$

The f/b factor $\beta = \frac{V_f}{V_o}$

$\Rightarrow V_f = \beta V_o$

But $V_o = A V_i$

$\Rightarrow V_f = \beta A V_i$

To get $|A\beta| = 1$ $V_f = V_i$

i.e

For oscillator the f/b signal will drive the amp.

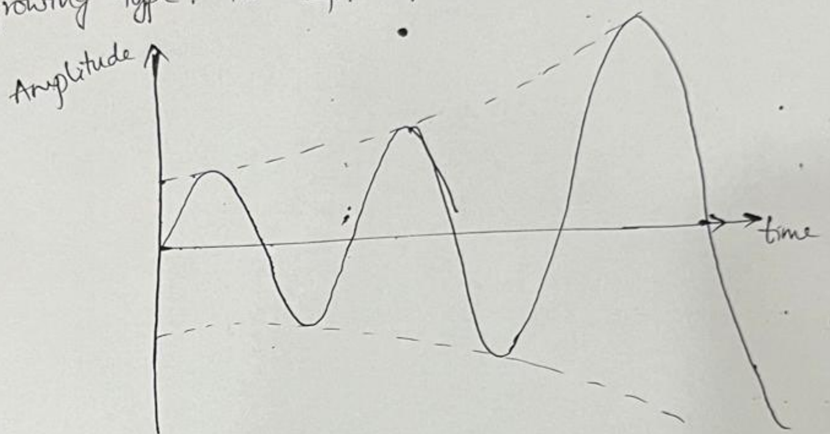
So the f/b signal should acts as i/p signal

The o/p of the oscillator depends on the product of $A\beta$

<u>Case (1).</u>

If $|A\beta| > 1$

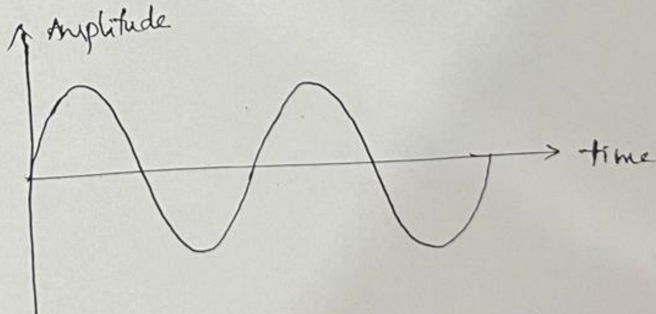
When the total phase shift around the loop is $0°$ or $360°$ and $|A\beta| > 1$, Then the o/p oscillates. The oscillations are "growing type". The amp. of oscillations goes on increasing.



<u>Case (2)</u>

If $|A\beta| = 1$

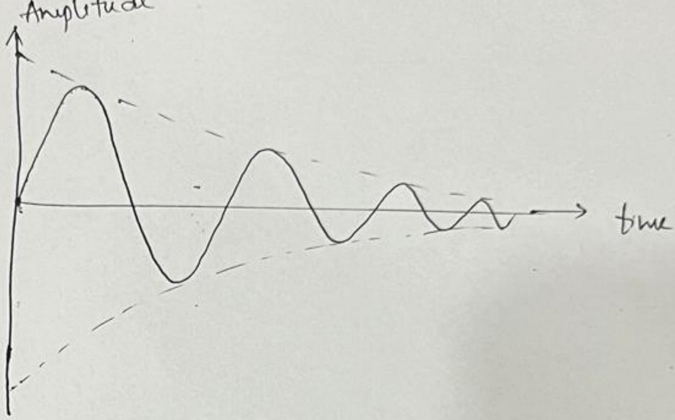
When the total phase shift around the loop is $0°$ or $360°$ and $|A\beta| = 1$ Then the oscillations are constant with constant frequency and amplitude. These oscillations are called "sustained oscillations".



Case (3)

If $|A\beta| < 1$

When the total phase shift around the loop is 0° or 360° and $|A\beta| < 1$ then the oscillations are called as "decaying type". The amplitude of the oscillations decrease exponentially and finally reduces to a small value



→ So, to start oscillations $|A\beta|$ is kept higher than unity and then the ckt must adjust itself to get $A\beta = 1$ to get sustained oscillations.

Classification of oscillators

Oscillators are classified on different parameters.

Oscillators

(1) Based on o/p wave form

→ Sinusoidal oscillator
or
Harmonic oscillator

→ Non-sinusoidal oscillator
or
Relaxation oscillator.

(2) Based on ckt components.

→ RC-oscillator

→ LC-oscillator

→ Crystal oscillator.

(3) Based on the range of operating freq.

→ Audio freq. oscillator – upto 20KHz

→ Radio freq. oscillator – 20KHz to 30 MHz

→ Very High freq. oscillator – 30MHz to 300MHz

→ Ultra High freq. oscillator – 300MHz to 3GHz

→ Microwave freq. oscillator – above 3GHz

(4) Based on whether f/b is used or not

→ Non. f/b oscillators, i.e -ve resistance oscillator

Ex: UJT relaxation oscillator

→ f/b oscillator.

Sinusoidal oscillator:

If the o/p of the oscillator is a pure sinusoidal wave form then that oscillator is called sinusoidal oscillator. These are also called as "Harmonic oscillators"

Non-sinusoidal oscillator:

If the oscillator generates the wave forms other than sinusoidal signal then it is called non sinusoidal oscillators. These are also called as "relaxation oscillators"

output of these oscillators may be triangular, square, sawtooth etc

LC oscillators:

→ The oscillators which uses Inductor (L) and capacitor (C) elements to produce oscillations are called LC oscillators.

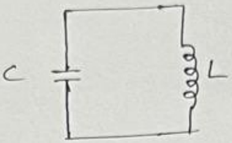
→ The LC oscillators uses

Tank ckt (or)
Oscillatory ckt (or)
Resonant ckt (or)
Tuned ckt

→ These oscillators are used for high freq. range from 200KHz to few GHz.

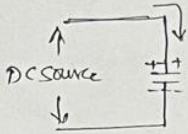
Operation of LC Tank ckt:

→ The LC tank ckt consists of L and C elements in parallel to each other



— LC tank ckt

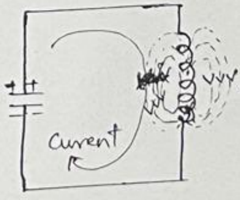
→ The capacitor is initially charged from D.C source with the polarity shown in fig.



→ When the capacitor gets charged, the energy stored is in the form of electrostatic energy.

→ Now if an inductor is connected across the capacitor, the capacitor starts discharging through L, due to the current flow magnetic field is developed around the inductor L

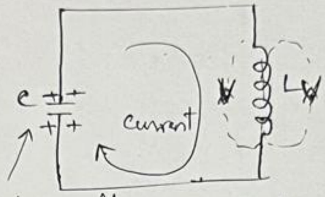
→ Now the inductor stores the energy in magnetic field.



← Magnetic field around L

→ Now all the electrostatic energy is stored in the form of magnetic energy in the inductor.

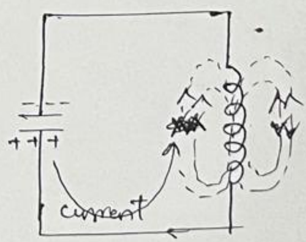
→ The magnetic field around 'L' starts collapsing. Now the capacitor starts charging in the opposite direction of the initial direction



Capacitor getting charged

→ After some time capacitor gets fully charged. Now the entire magnetic energy get converted back to electrostatic energy. which is stored in capacitor.

→ Again capacitor starts discharging through L. Now the direction of current is opposite to the earlier direction. Again electrostatic energy is converted to magnetic energy



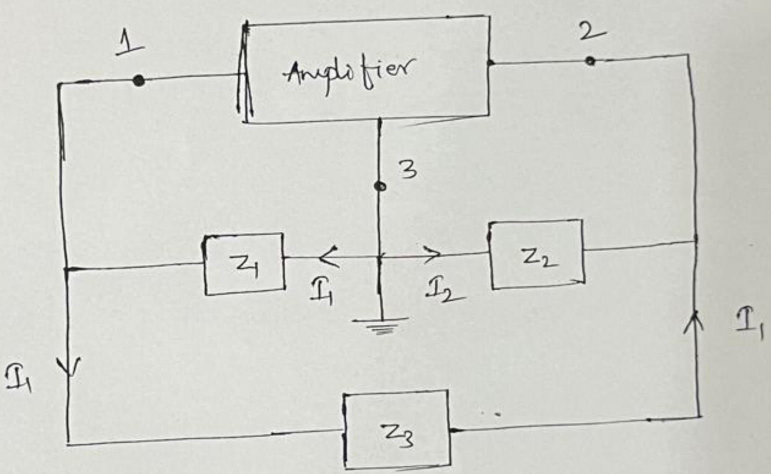
→ This is oscillatory current, but due to the transfer of energy from L to C and C to L. The amplitude of the oscillating current keeps on decreasing every time. Due to the external supply of energy we get sustained or undamped oscillations.

→ The freq. of oscillations generated by LC tank ckt depends on the values of L and C

$$\boxed{f = \frac{1}{2\pi\sqrt{LC}}}$$

f - Hz, L - Henry, C - Farad

General form of LC oscillator:



→ In the above ckt we are having one biasing amp.

→ Z_1, Z_2 and Z_3 are the reactive elements, this ckt which contains Z_1, Z_2 and Z_3 is the f/b tank ckt

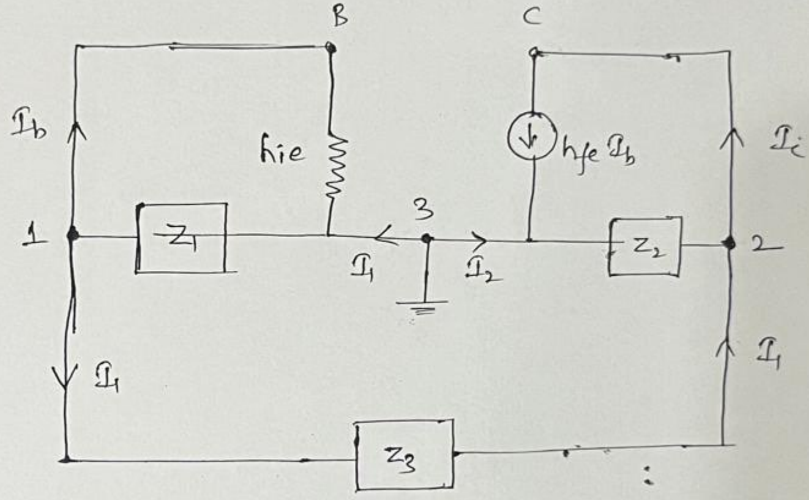
→ Z_1 and Z_2 serves as a.c voltage divider for o/p voltage and f/b signal

→ The voltage drop across Z_1 is the feedback signal

→ z_1, z_2 and z_3 can be capacitors or inductors.

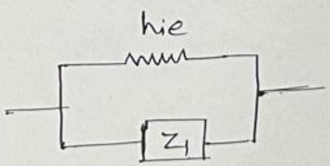
→ Here the o/p terminals are 2 and 3 and i/p terminals are 1 and 3.

→ If the basic amp. is a transistor then we can draw the equivalent ckt as follows.



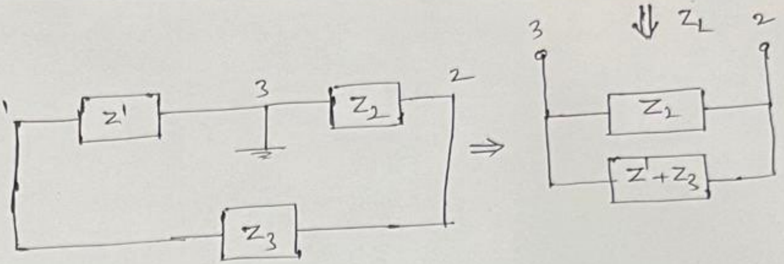
Load impedance:

Here z_1 is in parallel with hie of the transistor.



$$z' = z_1 \| h_{ie}$$

$$\Rightarrow z' = \frac{h_{ie} z_1}{z_1 + h_{ie}}$$



The Load impedance is b/w the terminals 2 and 3.

→ From the above ckt we can say that Z' and Z_3 are in series

→ Now the load impedance is nothing but Z_2 in parallel with the series combination of Z' and Z_3.

$$\Rightarrow \quad \frac{1}{Z_L} = \frac{1}{Z_2} + \frac{1}{Z'+Z_3}$$

$$= \frac{1}{Z_2} + \frac{1}{\frac{h_{ie}Z_1}{h_{ie}+Z_1} + Z_3}$$

$$= \frac{1}{Z_2} + \frac{h_{ie}+Z_1}{Z_1 h_{ie} + Z_3 h_{ie} + Z_1 Z_3}$$

$$= \frac{1}{Z_2} + \frac{h_{ie}+Z_1}{h_{ie}(Z_1+Z_3) + Z_1 Z_3}$$

$$= \frac{h_{ie}(Z_1+Z_3) + Z_1Z_3 + Z_1Z_2 + h_{ie}Z_2}{Z_2\left[h_{ie}(Z_1+Z_3)+Z_1Z_3\right]}$$

$$= \frac{h_{ie}(Z_1+Z_2+Z_3) + Z_1Z_2 + Z_1Z_3}{Z_2\left[h_{ie}(Z_1+Z_3)+Z_1Z_3\right]}$$

$$\boxed{Z_L = \frac{Z_2\left[h_{ie}(Z_1+Z_3)+Z_1Z_3\right]}{h_{ie}(Z_1+Z_2+Z_3)+Z_1Z_2+Z_1Z_3}}$$

Voltage gain without f/b : (A_V)

$$\text{Voltage gain} = \frac{\text{current gain} \times \text{Load impedance}}{\text{Input impedance}}$$

$$\text{Current gain} = \frac{\text{o/p current}}{\text{i/p current}}$$

$$= \frac{-I_c}{I_b}$$

$$= \frac{-h_{fe} I_b}{I_b}$$

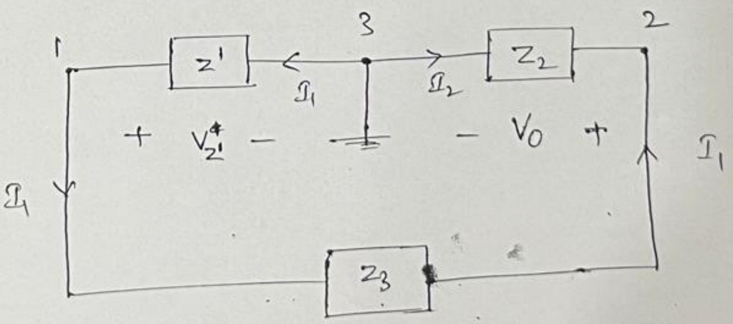
$$= -h_{fe}$$

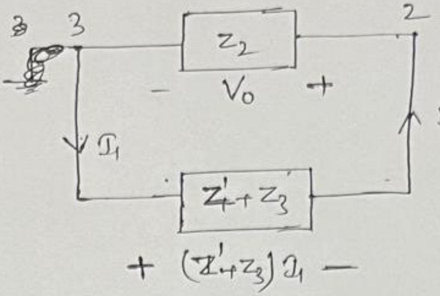
$$\Rightarrow \text{Voltage gain} \quad \boxed{A_V = \frac{-h_{fe} \cdot Z_L}{h_{ie}}}$$

A_V is vol gain of basic amp. i.e for transistor.

Feedback factor: (β)

The o/p vol b/w the terminals 3 and 2 in terms of I_1 is given as





Apply KVL in the loop

$$-I_1(Z'+Z_3) - V_0 = 0$$

$$\Rightarrow \quad V_0 = -I_1(Z'+Z_3)$$

$$= -I_1\left[\frac{h_{ie} Z_1}{h_{ie}+Z_1} + Z_3\right]$$

$$= -I_1\left[\frac{Z_1 h_{ie} + Z_3(h_{ie}+Z_1)}{Z_1+h_{ie}}\right]$$

The f/b voltage is nothing but the vol. across Z'

i.e $\quad V_f = V_{Z'} = -I_1 Z'$

$$= -I_1\left(\frac{h_{ie} Z_1}{h_{ie}+Z_1}\right)$$

The f/b factor $\beta = \dfrac{V_f}{V_0}$.

$$\beta = \frac{-\cancel{I_1}\left(\frac{h_{ie} Z_1}{h_{ie}+Z_1}\right)}{-\cancel{I_1}\left[\frac{h_{ie} Z_1 + Z_3(h_{ie}+Z_1)}{Z_1+h_{ie}}\right]}$$

$$\boxed{\beta = \frac{h_{ie} Z_1}{Z_1 h_{ie} + Z_3(Z_1 + h_{ie})}}$$

Equation for oscillations

For sustained oscillations

$\cancel{|A\beta| = 1}$

$A\beta = 1$

$$\left(\frac{-h_{fe} Z_L}{h_{ie}}\right)\left(\frac{Z_1 h_{ie}}{h_{ie}(Z_1+Z_3)+Z_1Z_3}\right) = 1$$

$$\left\{\frac{h_{fe} \quad Z_2 \left[h_{ie}(Z_1+Z_3)+Z_1Z_3\right]}{h_{ie}(Z_1+Z_2+Z_3)+Z_1Z_2+Z_1Z_3}\right\}\left\{\frac{Z_1}{h_{ie}(Z_1+Z_3)+Z_1Z_3}\right\} = -1$$

$$\frac{h_{fe} Z_1 Z_2}{h_{ie}(Z_1+Z_2+Z_3)+Z_1Z_2+Z_1Z_3} = -1$$

$$\Rightarrow \quad h_{ie}(Z_1+Z_2+Z_3)+Z_1Z_2+Z_1Z_3 = -h_{fe} Z_1 Z_2$$

$$\Rightarrow \quad \boxed{h_{ie}(Z_1+Z_2+Z_3) + Z_1Z_2(1+h_{fe}) + Z_1Z_3 = 0}$$

This is the general equation for the oscillator.

LC oscillator

→ Hartley oscillator

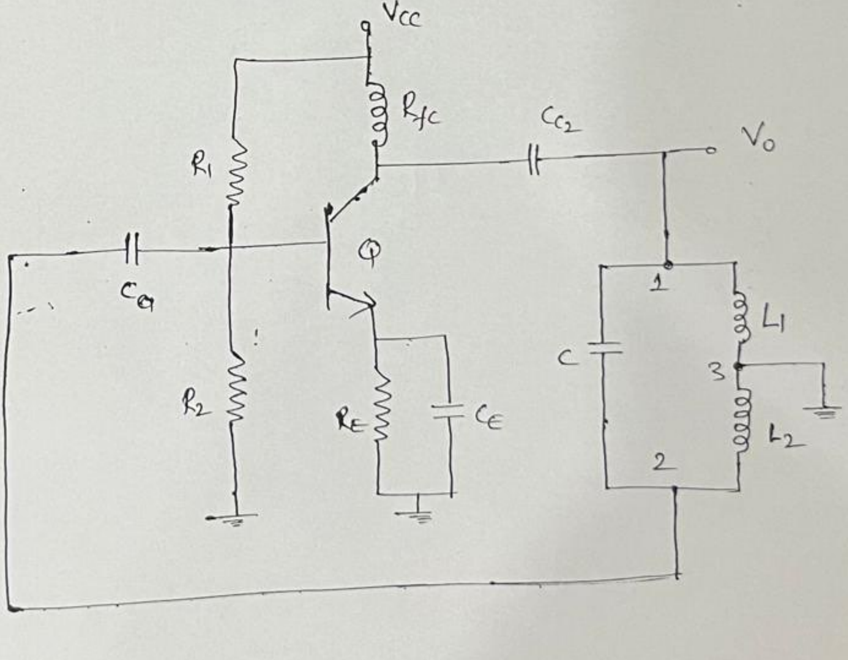
→ Colpitts oscillator.

Oscillator type	Z_1	Z_2	Z_3
→ Hartley oscillator	L	L	C
→ Colpitts oscillator	C	C	L

Hartely Oscillator :

An LC oscillator which uses two inductors and one capacitor in the f/b n/w is called Hartley oscillator

Transistorised Hartley oscillator:



→ In the above fig. the basic amp. is a common emitter amp.

→ R_1, R_2 and R_E are biasing resistors.

→ C_E is emitter bypass capacitor.

→ C_{C1} and C_{C2} are coupling capacitors

→ R_{fc} is the radio freq. choke. This is used for isolation of a.c and d.c

→ The reactance value is high for high frequencies. so it is acts as open ckt ($X_L = L\omega$)

→ For d.c condition the reactance is zero.

→ Here common emitter will produce a phase shift of 180°

→ The f/b tank ckt will produce a phase shift of 180°

$$\Rightarrow \text{Total phase shift} = 180^\circ + 180^\circ$$
$$= 360^\circ$$

Operation

→ when the dc supply V_{CC} is switched ON, a transient current is produced in the tank ckt, so it produces ~~sustained~~ oscillations in the ckt

→ Since terminal 3 is grounded, the terminal 1 is +ve w.r.t 3 and terminal 2 is −ve w.r.t 3.

⇒ Between the terminals 1 and 2 there is a phase shift of 180°

→ The freq. of oscillations is

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

Here $L = L_1 + L_2 + 2M$

M – Mutual inductance b/w L_1 and L_2

→ The condition for sustained oscillations is

$$\boxed{h_{fe} \geqslant \frac{L_1 + M}{L_2 + M}}$$

Analysis

Here Z_1 and Z_2 are inductors and Z_3 is capacitor.

Let M be the mutual inductance between inductors.

$$\therefore \quad Z_1 = j\omega L_1 + j\omega M$$

$$Z_2 = j\omega L_2 + j\omega M$$

$$Z_3 = \frac{1}{j\omega C} = \frac{-j}{\omega C}$$

The general equation of the oscillator is

$$h_{ie}(Z_1 + Z_2 + Z_3) + Z_1 Z_2 (1 + h_{fe}) + Z_1 Z_3 = 0$$

Substituting the values of Z_1, Z_2 and Z_3 in

the above eq.

$$h_{ie}\left(j\omega L_1 + j\omega M + j\omega L_2 + j\omega M - \frac{j}{\omega C}\right) + (j\omega L_1 + j\omega M)(j\omega L_2 + j\omega M)(1+h_{fe})$$
$$+ (j\omega L_1 + j\omega M)\left(\frac{-j}{\omega C}\right) = 0$$

$$\Rightarrow j\omega h_{ie}\left(L_1 + L_2 + 2M - \frac{1}{\omega^2 C}\right) + \left(j^2\omega^2 L_1 L_2 + j^2\omega^2 L_1 M + j^2\omega^2 M L_2 + j^2\omega^2 M^2\right)(1+h_{fe})$$
$$-\frac{j}{\omega C}(j\omega L_1) - \frac{j}{\omega C}(j\omega M) = 0$$

$$\Rightarrow j\omega h_{ie}\left(L_1+L_2+2M - \frac{1}{\omega^2 C}\right) - \left(\omega^2 L_1 L_2 + \omega^2 L_1 M + \omega^2 L_2 M + \omega^2 M^2\right)(1+h_{fe})$$
$$+ \frac{(L_1+M)}{C} = 0$$

$$\Rightarrow j\omega h_{ie}\left(L_1+L_2+2M-\frac{1}{\omega^2 C}\right) - \omega^2(L_1L_2 + L_1M + L_2M + M^2)(1+h_{fe}) + \left(\frac{L_1+M}{C}\right) = 0$$

$$\Rightarrow j\omega h_{ie}\left(L_1+L_2+2M-\frac{1}{\omega^2 C}\right) - \omega^2\left[(L_1+M)(L_2+M)\right](1+h_{fe}) + \left(\frac{L_1+M}{C}\right) = 0$$

$$\Rightarrow j\omega h_{ie}\left(L_1+L_2+2M-\frac{1}{\omega^2 C}\right) - \omega^2(L_1+M)\left[(L_2+M)(1+h_{fe}) - \frac{1}{\omega^2 C}\right] = 0$$

To get the freq. of oscillation equate imaginary part to zero

$$\Rightarrow \quad \omega h_{ie}\left(L_1+L_2+2M-\frac{1}{\omega^2 C}\right) = 0$$

$$\Rightarrow \quad L_1+L_2+2M-\frac{1}{\omega^2 C} = 0$$

$$\frac{1}{\omega^2 C} = L_1+L_2+2M$$

$$\omega = \frac{1}{\sqrt{(L_1+L_2+2M)C}}$$

$$2\pi f = \frac{1}{\sqrt{(L_1+L_2+2M)C}}$$

$$\boxed{f = \frac{1}{2\pi\sqrt{(L_1+L_2+2M)C}}}$$

By varying L_1, L_2 and C we can vary the freq. of oscillations

To get the condition for oscillations. Equate real part to zero.

$$\Rightarrow \quad \omega^2 (L_1+M)\left[(L_2+M)(1+h_{fe}) - \frac{1}{\omega^2 C}\right] = 0$$

$$\Rightarrow \quad (L_2+M)(1+h_{fe}) - \frac{1}{\omega^2 C} = 0$$

$$\Rightarrow \quad (L_2+M)(1+h_{fe}) = \frac{1}{\frac{1}{(L_1+L_2+2M)\cancel{C}}\cdot \cancel{C}} \qquad \left(\because \frac{1}{\omega^2 C} = L_1+L_2+2M\right)$$

$$\Rightarrow \quad (L_2+M)(1+h_{fe}) = (L_1+L_2+2M)$$

$$\cancel{(L_2+M)} + h_{fe}(L_2+M) = (L_1+M) + \cancel{(L_2+M)}$$

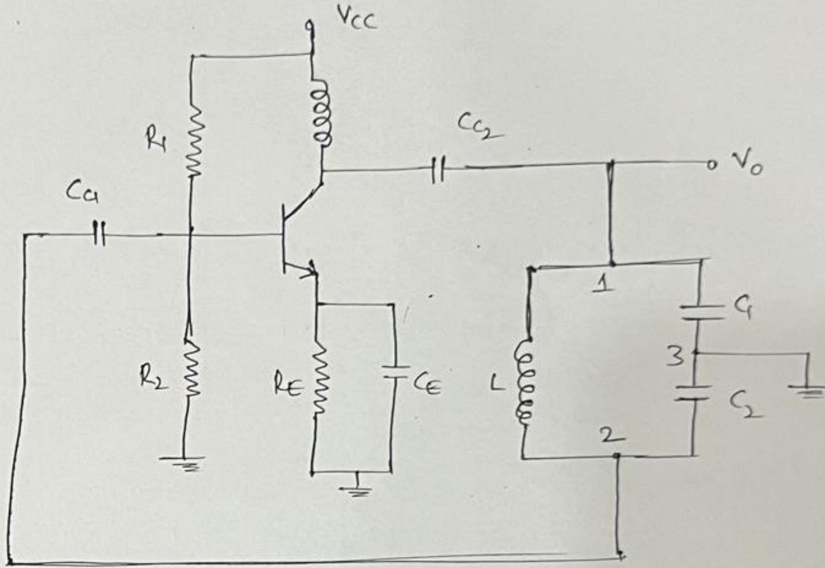
$$h_{fe}(L_2+M) = L_1+M$$

$$\Rightarrow \quad \boxed{h_{fe} = \frac{L_1+M}{L_2+M}}$$

Colpitts oscillator:

An LC oscillator which uses two capacitors and one inductor in the f/b network i.e in the tank ckt is called colpitts oscillator.

Transistorised colpttis oscillator:



→ The amp. stage consists of transistor in common emitter configuration.

→ The common emitter amp. produces a phase shift of 180°, the tank ckt produces the phase shift of 180°.

Total phase shift = 360°

Operation:

→ Here $R_1 R_2$ and R_E are biasing resistors.

→ C_E is bypass capacitor

→ C_{C_1} and C_{C_2} are coupling capacitors

→ When the power supply V_{cc} is switched ON, a transient current is produced in the tank ckt. which produces oscillations in the ckt

→ The point 3 is grounded 1 is +ve w.r.t 3 and 2 is -ve w.r.t 3

B/W 1 and 2 there is a phase shift of $180°$.

→ The freq. of oscillation of the oscillator is

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

where $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$

$$\Rightarrow \quad C = \frac{C_1 C_2}{C_1 + C_2}$$

Analysis:

Here $Z_1 = \frac{1}{j\omega C_1} = \frac{-j}{\omega C_1}$

$$Z_2 = \frac{1}{j\omega C_2} = \frac{-j}{\omega C_2}$$

$$Z_3 = j\omega L$$

The general eq. for oscillator is

$$h_{ie}(Z_1 + Z_2 + Z_3) + Z_1 Z_2 (1 + h_{fe}) + Z_1 Z_3 = 0$$

substituting the values of z_1, z_2 and z_3 in the above eq.

$$h_{ie}\left(\frac{1}{j\omega C_1}+\frac{1}{j\omega C_2}+j\omega L\right)+\frac{1}{j\omega C_1}\frac{1}{j\omega C_2}(1+h_{fe})+\frac{1}{j\omega C_1}j\omega L=0$$

$$j\,h_{ie}\left(\frac{-1}{\omega C_1}-\frac{1}{\omega C_2}+\omega L\right)-\frac{1}{\omega^2 C_1C_2}(1+h_{fe})+\frac{L}{C_1}=0$$

$$j\,h_{ie}\left(\frac{1}{\omega C_1}+\frac{1}{\omega C_2}-\omega L\right)+\frac{1}{\omega^2 C_1C_2}(1+h_{fe})-\frac{L}{C_1}=0$$

$$j\,h_{ie}\left(\frac{1}{\omega C_1}+\frac{1}{\omega C_2}-\omega L\right)+\left(\frac{1+h_{fe}}{\omega^2 C_1C_2}-\frac{L}{C_1}\right)=0$$

To get freq. of oscillations equate imaginary part to zero

$$\Rightarrow\quad h_{ie}\left(\frac{1}{\omega C_1}+\frac{1}{\omega C_2}-\omega L\right)=0$$

$$\Rightarrow\quad \frac{1}{\omega C_1}+\frac{1}{\omega C_2}=\omega L$$

$$\frac{1}{C_1}+\frac{1}{C_2}=\omega^2 L$$

$$\omega^2 L=\left(\frac{C_1+C_2}{C_1C_2}\right)$$

$$\cancel{\omega^2 L = C} \quad \text{where } C=\frac{C_1C_2}{C_1+C_2}$$

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

$$\omega=\frac{1}{\sqrt{LC}}$$

$$\boxed{f=\frac{1}{2\pi\sqrt{LC}}} \quad \text{where } C=\frac{C_1C_2}{C_1+C_2}$$

To get condition for oscillator, equate real part to zero

$$\frac{1+h_{fe}}{\omega^2 C_1 C_2} - \frac{L}{C_1} = 0$$

$$\frac{1+h_{fe}}{\omega^2 \cancel{C_1} C_2} = \frac{L}{\cancel{C_1}}$$

$$1+h_{fe} = \omega^2 L C_2$$

$$1+h_{fe} = \frac{1}{\cancel{L}C} \cdot \cancel{L} C_2 \qquad \left(\because \omega^2 = \frac{1}{LC}\right)$$

$$= \frac{1}{\left(\frac{C_1 C_2}{C_1+C_2}\right)} \cdot C_2$$

$$= \frac{C_1+C_2}{C_1 \cancel{C_2}} \cdot \cancel{C_2}$$

$$\Rightarrow \quad 1+h_{fe} = \frac{C_1+C_2}{C_1}$$

$$C_1(1+h_{fe}) = C_1+C_2$$

$$\cancel{C_1} + C_1 h_{fe} = \cancel{C_1} + C_2$$

$$\Rightarrow \quad \boxed{h_{fe} = \frac{C_2}{C_1}}$$

RC – oscillators :

There are two types of RC-oscillators

→ RC-Phase shift Oscillator

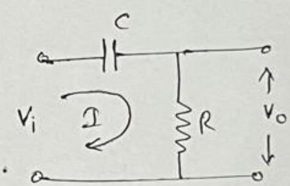
→ Wein-Bridge oscillator

RC Phase shift Osc :

→ It is consisting of basic amp and a feedback n/w

→ The f/b n/w consists of resistors and capacitors which are arranged in the ladder form. so it is also called as "Ladder type RC phase shift osc"

→ The general RC ckt is



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

The total impedance of the ckt $z = R - jX_c$

$$= R - j\frac{1}{WC}$$

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

$$|Z| = \sqrt{R^2 + X_c^2}$$

$$\phi = \tan^{-1}\left(-\frac{X_C}{R}\right) = -\tan^{-1}\frac{X_C}{R}$$

The current $I = \frac{V_i \angle 0^\circ}{Z}$

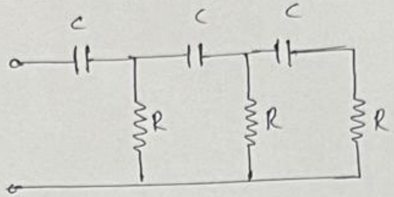
The voltage drop across resistor R is $V_R = V_0 = IR$

The voltage drop across capacitor $V_c = IX_c$

→ By selecting proper values of R and C we can make

ϕ as 60°

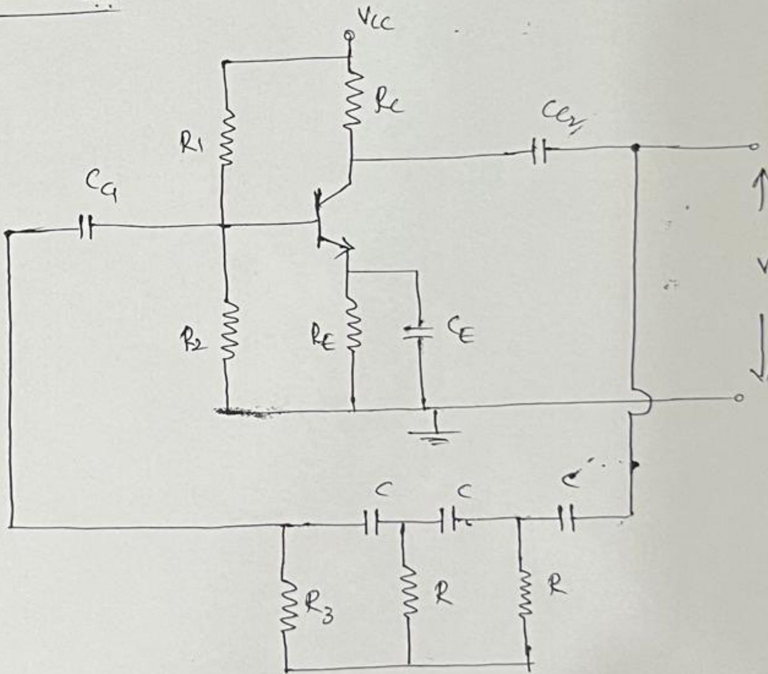
RC f/b ckt:



60° + 60° + 60° = 180°

In the f/b ckt each RC section will provide 60 phase shift. So totally we will get 180 phase shift

Basic ckt:



→ We are using CE amp. as basic amp. So it will produce a phase shift of $180°$. And the f/b ckt will provide $180°$ phase shift so the total phase shift is $360°$.

→ The freq. of 'sustained' oscillations' is given as

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

→ According to Barkhausen criteria, the freq. is given as

$$f = \frac{1}{2\pi RC} \cdot \frac{1}{\sqrt{6+4K}}$$

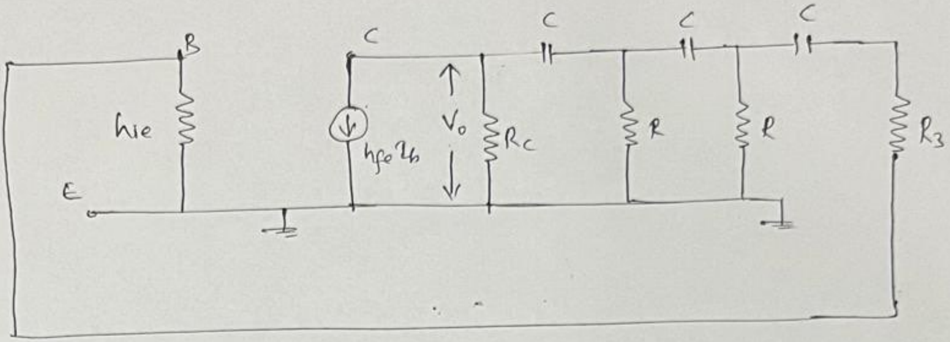
$$K = \frac{R_C}{R}$$

→ The condition for oscillations is given by

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

Derivation for freq. of oscillations:

Replace the transistor with its approximate hybrid model



→ If we neglect R_1 and R_2

$$\text{I/p resistance} = h_{ie}$$

⇒ The value of R should be in such a way that

$$R = h_{ie} + R_3$$

→ If we consider R_1 and R_2

$$\text{I/p resistance } R_i' = R_1 || R_2 || h_{ie}$$

then the value of R is given by

$$R = R_i' + R_3$$

→ In the above ckt replace the current source with voltage source we get