UNIT-4

FEEDBACK AMPLIFIERS AND OSCILLATORS

FEEDBACK AMPLIFIERS:

INTRODUCTION

Definition: Feedback Amplifier is a device that is based on the principle of feedback. The process by which some part or fraction of output is combined with the input is known as feedback.

In simple words, we can say feedback amplifiers are the type of amplifiers in which a part of the output is given back to the input.

An input signal V_s is applied to the amplifier with gain A, that produces an amplified signal, V_o. The output quantity [either voltage or current] is sampled by a suitable sampler is of two types

(i)Voltage sampler and

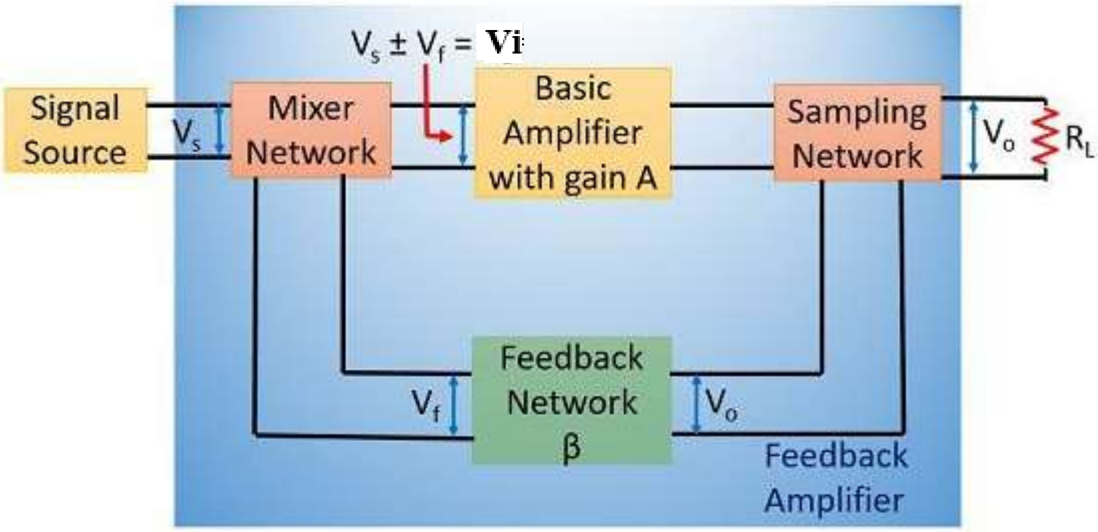
(ii)Current sampler

The output of feedback network which has a fraction of output signal is combined with external signal source through a mixer and fed to the basic amplifier.

The mixer is also two types

(i)Series mixer

(ii)Parllel/Shunt mixer



Block diagram of Feedback Amplifier

1. Gain of basic amplifier $A=Vo/Vi$
2. Gain of feedback amplifier $Af=Vo/Vs$
3. Feed back network or feedback factor $\beta=Vf/Vo$

CONCEPT OF FEEDBACK

An amplifier circuit simply increases the signal strength. But while amplifying, it just increases the strength of its input signal whether it contains information or some noise along with information. This noise or some disturbance is introduced in the amplifiers because of their strong tendency to introduce hum due to sudden temperature changes or stray electric and magnetic fields.

Therefore, every high gain amplifier tends to give noise along with signal in its output, which is very undesirable. The noise level in the amplifier circuits can be considerably reduced by using negative feedback done by injecting a fraction of output in phase opposition to the input signal.

TYPES OF FEEDBACK

The process of injecting a fraction of output energy of some device back to the input is known as Feedback. It has been found that feedback is very useful in reducing noise and making the amplifier operation stable. Depending upon whether the feedback signal aids or opposes the input signal, there are two types of feedbacks used.

(1.)Positive feedback amplifier

If the feedback voltage Vf is inphase with the input signal Vs, then the net effect of feedback will increase the input signal given to the basic amplifier.

$$\mathbf{Vi=Vs+Vf}$$

Hence the input voltage applied to the basic amplifier is increased, their by Vo also increases.This type of feedback is said to be positive feedback.

The gain of amplifier with positive feedback is

$$A_f = \frac{V_o}{V_s} \qquad \left[\begin{array}{l} V_i = V_s + V_f \\ V_s = V_i - V_f \end{array}\right]$$

$$A_f = \frac{V_o}{V_i - V_f}$$

$$A_f = \frac{1}{\frac{V_i}{V_o} - \frac{V_f}{V_o}}$$

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

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

The product of open loop gain(A)and feedback factor(β) is called as loop gain(Aβ).

If $|A\beta|=1$ then $A_f=\infty$

Hence the gain of amplifier with positive feedback is infinite and the amplifier gives an AC output signal without AC input signal.Thus the amplifier act as an oscillator.

Though the positive feedback increases the gain of the amplifier, it has the disadvantages such as

- Increasing distortion
- Instability

It is because of these disadvantages the positive feedback is not recommended for the amplifiers. If the positive feedback is sufficiently large, it leads to oscillations, by which oscillator circuits are formed.

(2.)Negative feedback

If the feedback voltage Vf is out of phase with the input signal Vs,then **Vi=Vs-Vf.** So,the input voltage applied to the basic amplifier is decreased, and the corresponding output is decreased.This type of feedback is said to be negative feedback.

$$A_f = \frac{V_o}{V_s} \qquad \begin{bmatrix} V_i = V_s + V_f \\ V_s = V_i - V_f \end{bmatrix}$$

$$A_f = \frac{V_o}{V_i + V_f}$$

$$A_f = \frac{1}{\frac{V_i}{V_o} + \frac{V_f}{V_o}}$$

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

$$\boxed{A_f = \frac{A}{1 + A\beta}} \qquad A_f << A$$

Though the gain of negative feedback amplifier is reduced, there are many advantages of negative feedback such as

- Stability of gain is improved
- Reduction in distortion
- Reduction in noise
- Increase in input impedance

- Decrease in output impedance
- Increase in the range of uniform application

It is because of these advantages negative feedback is frequently employed in amplifiers.

EFFECT OF FEEDBACK ON AMPLIFIER CHARACTERISTICS

(1.)D-sensitivity of negative amplifier gain:

The gain of the amplifier may change due to the changes in the parameters of the transistor or the supply voltage variation. The gain A of the feedback amplifier is independent of internal gain A and depends only on feedback fraction.

$$A_f = \frac{A}{1+A\beta} \qquad \text{W.K.T } \frac{vu' - uv'}{v^2}$$

Diff. w.r.to 'A'

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

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

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

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

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

$$\Rightarrow \boxed{\frac{dA_f}{A_f} = \frac{1}{1+A\beta} \cdot \left(\frac{dA}{A}\right)}$$

The above equation shows that the percentage change in closed loop gain Af is less than the percentage change in open loop gain A by a factor of (1+Aβ).

1/(1+Aβ) is called sensitivity and (1+Aβ) is called De-sensitivity.

(2.)Distortion:

A power amplifier will have non-linear distortion because of large signal variations. The negative feedback reduces the nonlinear distortion. It can be proved mathematically that:

$$Df = D/(1+A\beta)$$

Where D = distortion in amplifier without feedback
Df = distortion in amplifier with negative feedback

It is clear that by applying negative feedback, the distortion is reduced by a factor (1+Aβ)

(3.)Noise:

There are numbers of sources of noise in an amplifier. The noise N can be reduced by the factor of (1+Aβ), in a similar manner to non-linear distortion, so that the noise with feedback is given by

$$Nf = N/(1+A\beta)$$

However, if it is necessary to increase the gain to its original level by the addition of another stage, it is quite possible that the overall system will be noisier that it was at the start. If the increase in gain can be accomplished by the adjustment of circuit parameters, a definite reduction in noise will result from the use of negative feedback.

(4.)Input impedance/Output impedance:

The input and output impedances will also improve by a factor of (1+Aβ), based on feedback connection type.

(5.)Voltage Gain:

If the voltage gain of open loop amplifier is (Av)then the closed loop amplifier gain is

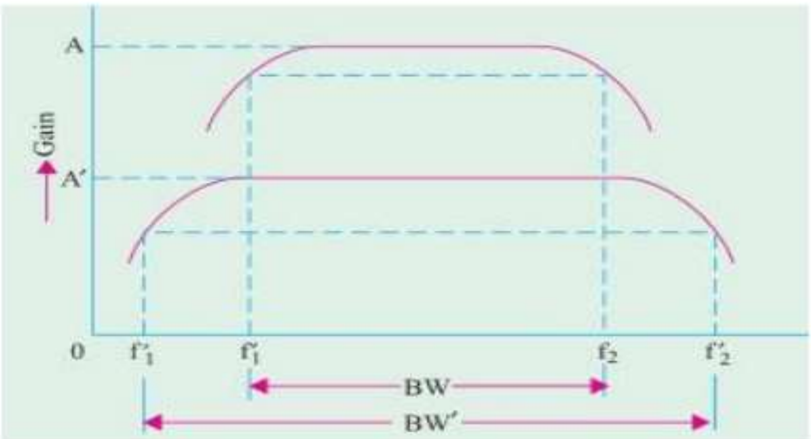
$$Avf=Av/(1+ A\beta)$$

(6.)Bandwidth:

The bandwidth of an amplifier is the difference between the upper cutoff frequency and lower cutoff frequency.

If "A" is gain and "Bw" is bandwidth then gain bandwidth product (A*Bw) is always constant.

With the negative feedback (or)closed loop feedback the voltage decreases at the sametime the bandwidth of that amplifier is increased by (1+ Aβ) times to make (A*Bw)



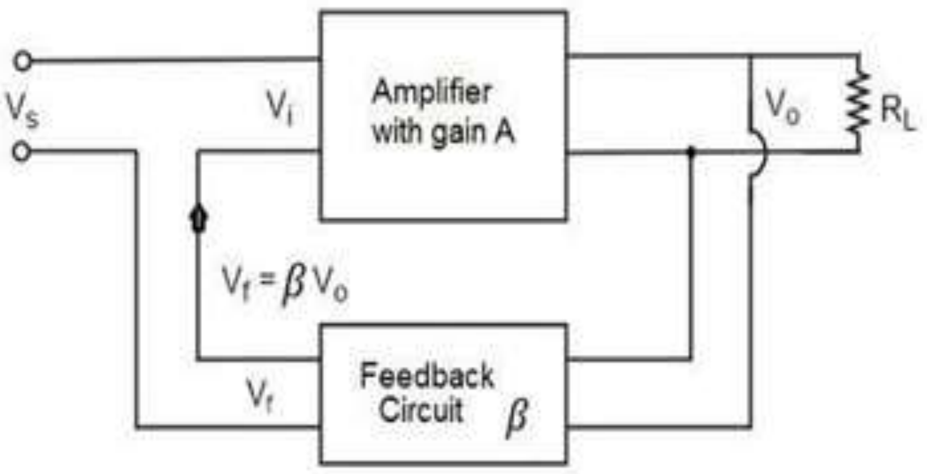
Bandwidth and Gain-bandwidth Product

TYPES OF FEEDBACK TOPOLOGIES

VOLTAGE SERIES FEEDBACK

In the voltage series feedback circuit, a fraction of the output voltage is applied in series with the input voltage through the feedback circuit. This is also known as shunt-driven series-fed feedback, i.e., a parallel-series circuit.

The following figure shows the block diagram of voltage series feedback, by which it is evident that the feedback circuit is placed in shunt with the output but in series with the input.



As the feedback circuit is connected in shunt with the output, the output impedance is decreased and due to the series connection with the input, the input impedance is increased.

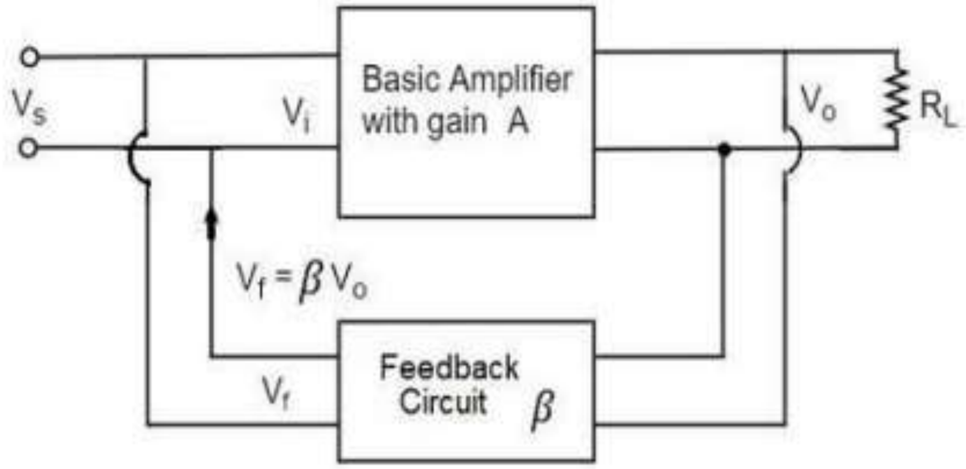
(1.)Voltage gain $A_f = V_o/V_s = A/1 + A\beta$

(2.)Output resistance $R_{of} = V_o/I_o = R_o/(1 + A\beta)$

(3.)Input resistance $R_{if} = R_i(1 + A\beta)$

VOLTAGE SHUNT FEEDBACK

In the voltage shunt feedback circuit, a fraction of the output voltage is applied in parallel with the input voltage through the feedback network. This is also known as shunt-driven shunt-fed feedback i.e., a parallel-parallel proto type. The below figure shows the block diagram of voltage shunt feedback, by which it is evident that the feedback circuit is placed in shunt with the output and also with the input.



As the feedback circuit is connected in shunt with the output and the input as well, both the output impedance and the input impedance are decreased.

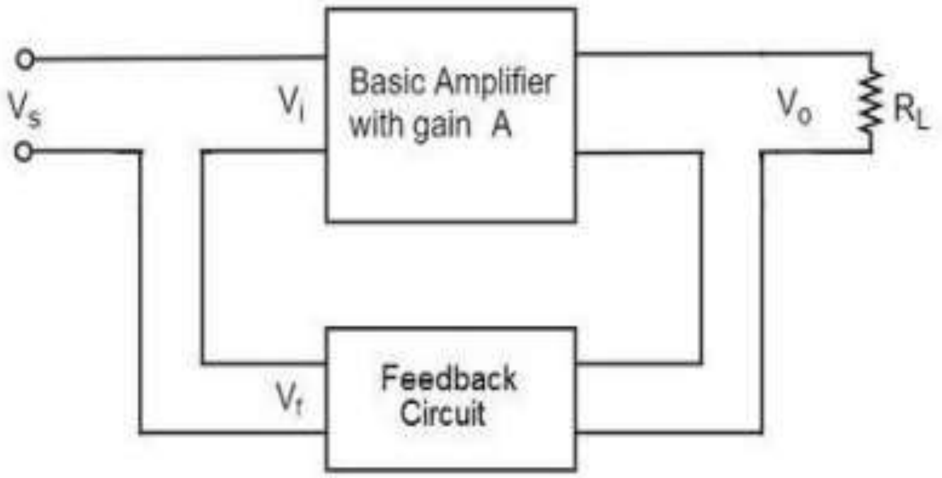
(1.) Voltage gain $Af=Vo/Vs=A/1+A\beta$

(2.)Output resistance $Rof=Vo/Io=Ro/(1+A\beta)$

(3.)Input resistance $Rif=Ri/(1+A\beta)$

CURRENT SERIES FEEDBACK

In the current series feedback circuit, a fraction of the output voltage is applied in series with the input voltage through the feedback circuit. This is also known as series-driven series-fed feedback i.e., a series-series circuit. The following figure shows the block diagram of current series feedback, by which it is evident that the feedback circuit is placed in series with the output and also with the input



As the feedback circuit is connected in series with the output and the input as well, both the output impedance and the input impedance are increased.

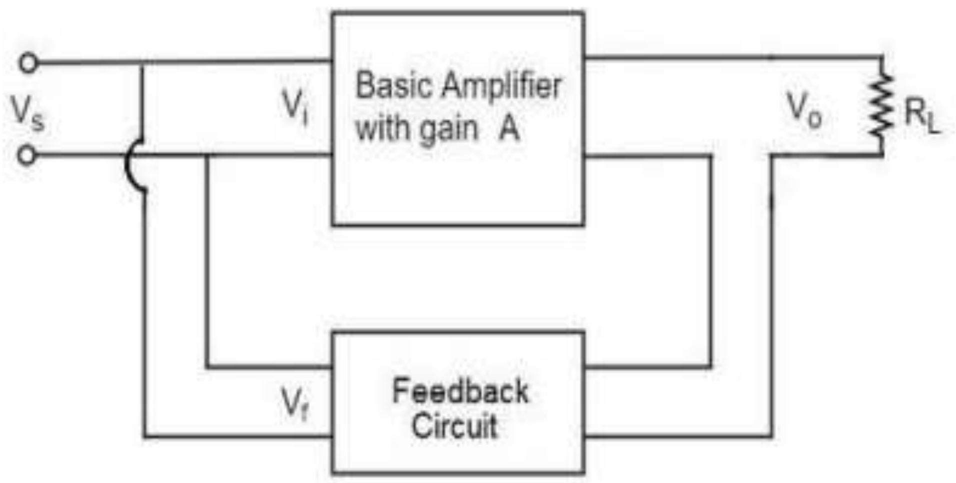
(1.) Voltage gain Af=Vo/Vs=A/1+Aβ

(2.)Output resistance Rof=Vo/Io=Ro(1+Aβ)

(3.)Input resistance Rif=Ri(1+Aβ)

CURRENT SHUNT FEEDBACK

In the current shunt feedback circuit, a fraction of the output voltage is applied in series with the input voltage through the feedback circuit. This is also known as series-driven shunt-fed feedback i.e., a series-parallel circuit. The below figure shows the block diagram of current shunt feedback, by which it is evident that the feedback circuit is placed in series with the output but in parallel with the input.



As the feedback circuit is connected in series with the output, the output impedance is increased and due to the parallel connection with the input, the input impedance is decreased.

(1.) Voltage gain Af=Vo/Vs=A/1+Aβ

(2.)Output resistance Rof=Vo/Io=Ro(1+Aβ)

(3.)Input resistance Rif=Ri/(1+Aβ)

Let us now tabulate the amplifier characteristics that get affected by different types of negative feedbacks.

Characteristics	Types of Feedback			
	Voltage-Series	Voltage-Shunt	Current-Series	Current-Shunt
Voltage Gain	Decreases	Decreases	Decreases	Decreases
Bandwidth	Increases	Increases	Increases	Increases
Input resistance	Increases	Decreases	Increases	Decreases
Output resistance	Decreases	Decreases	Increases	Increases
Harmonic distortion	Decreases	Decreases	Decreases	Decreases
Noise	Decreases	Decreases	Decreases	Decreases

Difference between Positive feedback and Negative feedback

Positive Feedback	Negative Feedback
Positive feedback is also called as regenerative feedback.	Negative Feedback is also called as degenerative feedback
The system gain of the positive feedback is high	The system gain of the negative feedback is low.
The Stability of positive feedback is less	The Stability of negative feedback is Comparatively more
The phase shift of positive feedback is 0degree or 360degree	The phase shift of negative feedback is 180 degree
Feedback is taken from Non-inverting terminal of an op-amp	Feedback is taken from Inverting terminal of an op-amp
Transfer Function of positive feedback is TF = G/1-GH	Transfer Function of negative feedback is TF = G/1+GH
Sensitivity of positive feedback is Low	Sensitivity of negative feedback is High
The positive feedback can be used in oscillators	The negative feedback can be used in Amplifiers

UNIT 4

FEEDBACK AMPLIFIERS AND OSCILLATORS

OSCILLATORS

- Oscillator is an Electronic circuit which generates Periodic signal waveform without having any External input signal.
- During the process of generation of Ac signals, Oscillator draws DC power from supply source and converts it into AC power.
- Oscillators will be used in applications like radio, TV, Communication Equipment, RADAR, bio-medical Instrumentation, Mobile phones,Computers and so on.

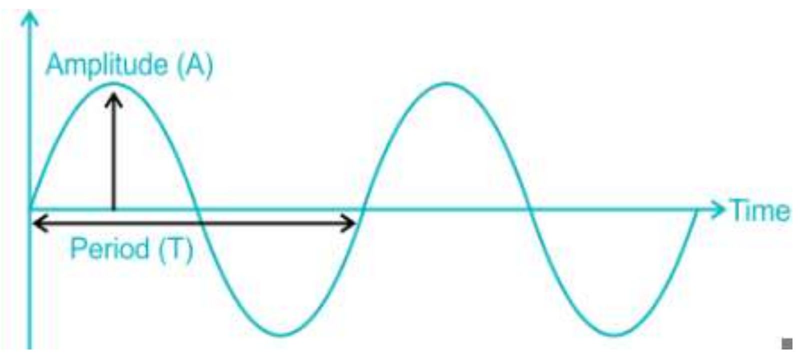
CLASSIFICATION OF OSCILLATORS

Oscillators are classified into the following different ways

1. **Based on output waveform**

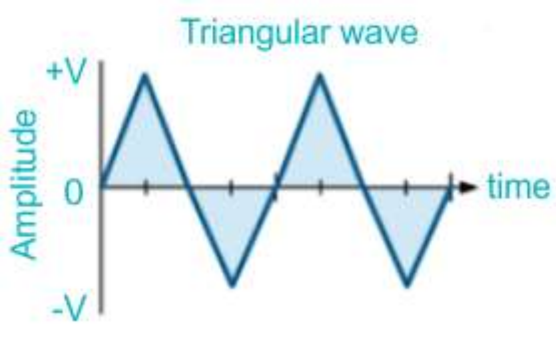
(a)Sinusoidal waveform: The oscillators which generate a sinusoidal (Either sine or cosine) wave as output are called sinusoidal oscillators. Examples:

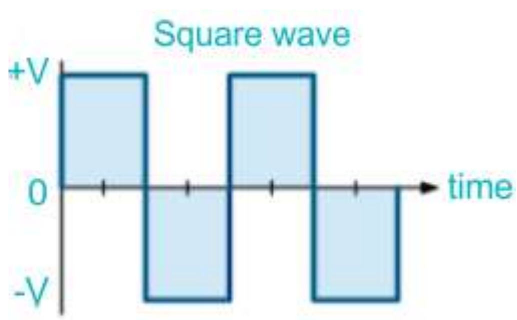
- RC Oscillators (Made with combinations of Resistors and Capacitors)
- LC Oscillator (Made with combinations of Inductors and Capacitors)



(b)Non Sinusoidal waveform: The oscillators which generate a non-sinusoidal wave (like a square wave, or triangular wave) as output are called non-sinusoidal oscillators. Examples include:

- Relaxation Oscillators
- MultiVibrators





(2.) Based on frequency

(a)Audio Frequency Oscillators: Audio oscillations are those whose frequency lies between 20 Hz and 20 kHz. These oscillations are used in audio signal generators and sound systems for producing or testing sound signals.
(b) Radio Frequency (RF) Oscillators: Radio frequency oscillations range from 20kHz to 30MHz. They are widely used in communication systems, including radio and TV transmitters.
(c)Very High Frequency (VHF) Oscillators: VHF oscillations cover frequencies from 30 MHz to 300MHz. Applications include FM radio broadcasting and television transmissions.
(d)Ultra High Frequency (UHF) Oscillators: UHF oscillations have frequencies between 300 MHz and 3 GHz. They are used in mobile communications, Wi-Fi, and radar systems.
(e)Microwave Oscillations: Microwave oscillations lie between 3GHz and 300GHz. These are essential in satellite communication and radar applications.

(3.) Based on Frequency determine circuit components

(a)Tuned Circuit Oscillators : These oscillators use a tuned-circuit consisting of inductors (L) and capacitors (C) and are used to generate high-frequency signals. Thus they are also known as radio frequency R.F. oscillators. Such oscillators are Hartley, Colpitts, Clapp-oscillators etc.
(b)RC Oscillators: There oscillators use resistors and capacitors and are used to generate low or audio-frequency signals. Thus they are also known as audiofrequency (A.F.) oscillators. Such oscillators are Phase –shift and Wein-bridge oscillators.

CONDITIONS FOR OSCILLATIONS

It is also called as Barkhausen Criterion.The Barkhausen Criterion gives the necessary condition for feedback amplifier to produce sustained oscillations.

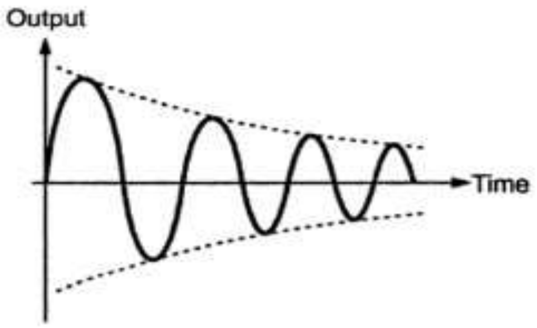
Conditions:

- Loop Gain ($|A\beta|$) = 1: The product of amplifier gain (A) and feedback factor (β) must be exactly 1.
- Phase Shift = 0° or 360°: The total phase shift around the closed loop must be 0° or 360° for sustained oscillations.

Different Cases of $|A\beta|$:

Case 1: $|A\beta| < 1$

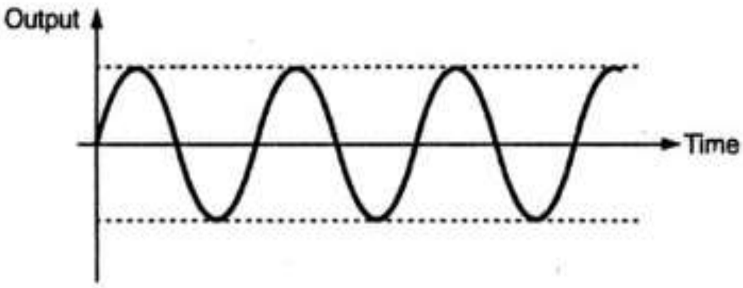
- The loop gain is less than 1.
- Oscillations decay with time, reducing in amplitude called underdamped or decaying type oscillation.
- Feedback is insufficient to maintain amplitude



Exponentially decaying oscillations

Case 2: |Aβ| = 1

- The loop gain is exactly 1.
- Oscillations continue with constant amplitude called sustained or critical oscillation.
- Feedback exactly compensates for energy loss.
- This is the ideal condition for designing practical oscillators.



Sustained oscillations

Case 3: |Aβ| > 1

- The loop gain is greater than 1.
- Oscillations increase with time, growing in amplitude called overdamped or growing type oscillation.
- Feedback is too strong ;output grows until limited by nonlinearities.
- Circuit must include amplitude stabilization to prevent distortion or damage.

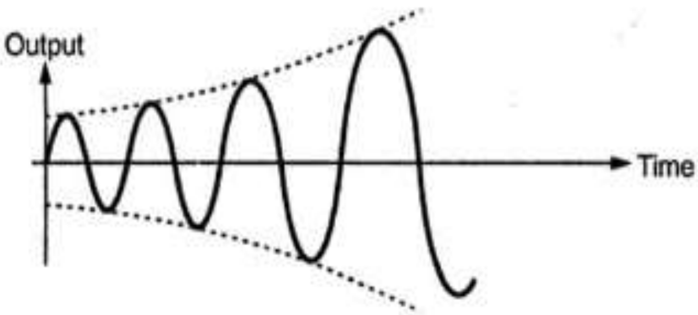
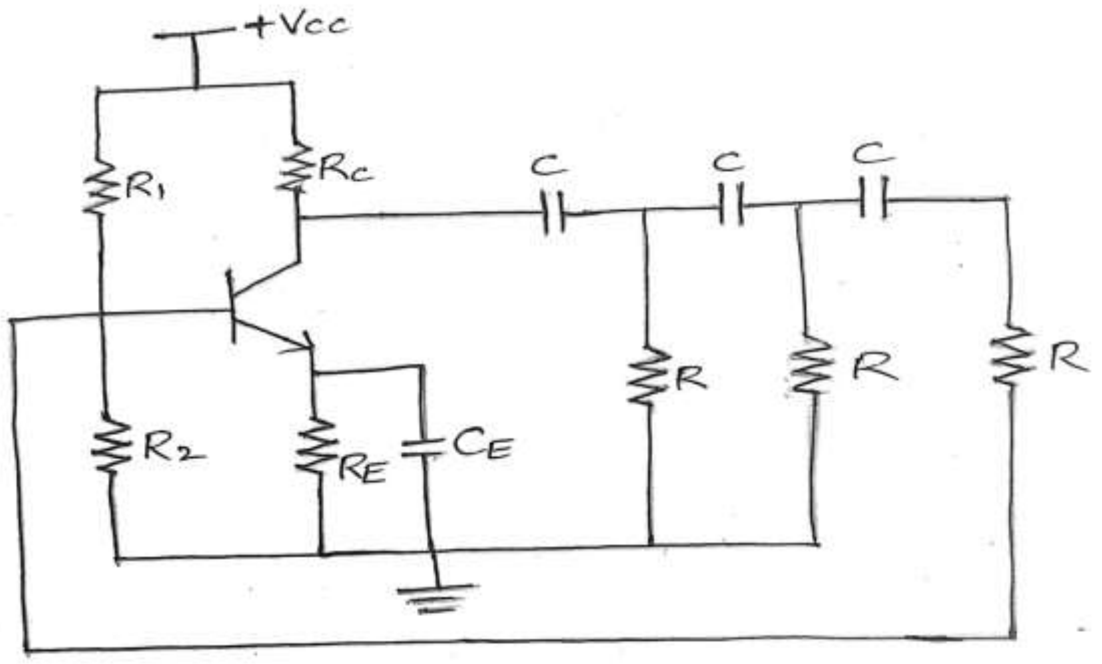
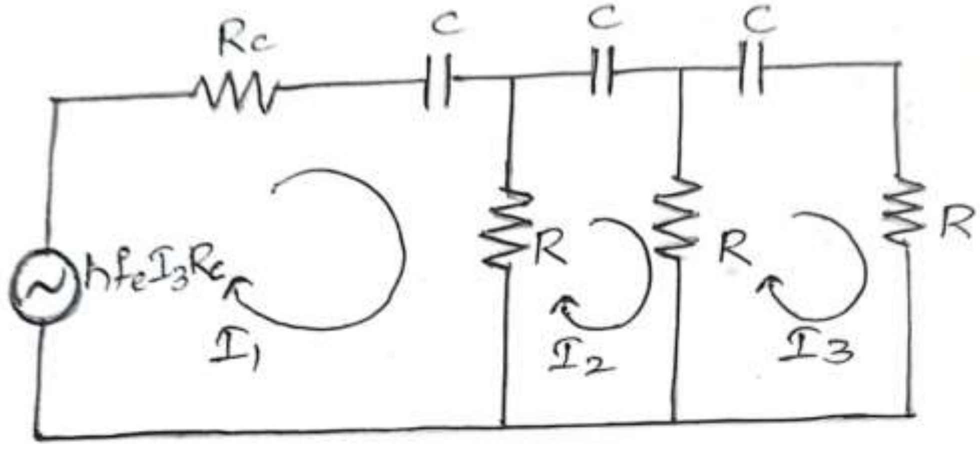


Fig. 4.4 Growing type oscillations

RC PHASE SHIFT OSCILLATOR



- The combination of R1, R2, Rc and Vcc function as basic amplifier to provide voltage amplification. The output voltage of CE transistor amplifier will be 180° out of phase with effective input Voltage Vin.
- Three identical Rc elements are used as feedback network to provide signal path from output port of transistor amplifier to its input port.
- The three Rc elements produce 180° phase shift for the signal Vout moving through it. It also produces an attenuation of magnitude [β].β=1/A
- The overall phaseshift around the loop becomes 360°or 0°.
- Thus the output an input voltages will be inphase at the input port of transistor which increases the effective input signal.
- Then the circuit begins to work as an Oscillator satisfying Barkhausen Condition for Oscillation.
- The output voltage of oscillator circuit will be a sinusoidal signal with desired frequency decided by the feedback network.



Apply KVL to loop 1,

$R_cI_1 - jX_cI_1 + R(I_1 - I_2) + h_{fe} I_3 R_c = 0$

$R_cI_1 - jX_cI_1 + RI_1 - RI_2 + h_{fe} R_c I_3 = 0$

$(R_c - jX_c + R) I_1 - RI_2 + h_{fe} R_c I_3 = 0 \longrightarrow (1)$

$-jX_cI_2 + R(I_2 - I_3) + R(I_2 - I_1) = 0$

$-jX_cI_2 + RI_2 - RI_3 + RI_2 - RI_1 = 0$

$-RI_1 + (2R - jX_c) I_2 - RI_3 = 0 \longrightarrow (2)$

$-jX_c I_3 + RI_3 + R(I_3 - I_2) = 0$

$-jX_c I_3 + RI_3 + RI_3 - RI_2 = 0$

$-RI_2 + (2R - jX_c) I_3 = 0 \longrightarrow (3)$

$$\begin{bmatrix} R_c - jX_c + R & -R & h_{fe}R_c \\ -R & 2R - jX_c & -R \\ 0 & -R & 2R - jX_c \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

Determinant $= 0$

$$\begin{bmatrix} R_c - jX_c + R & -R & h_{fe}R_c \\ -R & 2R - jX_c & -R \\ 0 & -R & 2R - jX_c \end{bmatrix} = 0$$

$$(R_c - jX_c + R)\left[(2R - jX_c)^2 - R^2\right] + R\left[(-R)(2R - jX_c)\right] + h_{fe} R_c \left[R^2\right] = 0$$

$$(R_c - jX_c + R)(4R^2 - X_c^2 - 4RX_c j - R^2) + (-2R^2 + jRX_c)R + h_{fe}R_cR^2 = 0$$

$$4R^2R_c - R_cX_c^2 - 4RR_cX_cj - R_cR^2 - 4R^2jX_c + jX_c^3 - 4RX_c^2 + jX_cR^2 + 4R^3 - RX_c^2 - 4R^2X_cj - R^3 - 2R^3 + jR^2X_c + h_{fe}R_cR^2 = 0$$

$$R^2R_c(4 - 1 + h_{fe}) - R_cX_c^2 - 4RX_c^2 + 4R^3 - RX_c^2 - R^3 - 2R^3 - 4RR_cX_cj - 4R^2jX_c + jX_c^3 + jX_cR^2 - 4R^2jX_c + jR^2X_c = 0$$

$$R^2R_c(3 + h_{fe}) + R^3 - R_cX_c^2 - 4RX_c^2 - RX_c^2 + j(-4RR_cX_c - 6R^2X_c + X_c^3) = 0$$

$$R^2R_c(3 + h_{fe}) + R^3 - R_cX_c^2 - 5RX_c^2 + j(-4RR_cX_c - 6R^2X_c + X_c^3)$$

Equating imaginary part to '0'

$$X_c^3 - 4RR_cX_c - 6R^2X_c = 0$$

$$X_c^2 - 4RR_c - 6R^2 = 0$$

$$X_c^2 = 6R^2 + 4RR_c$$

$$X_c^2 = R^2\left[6 + 4\frac{R_c}{R}\right] \qquad \left\{ X_c = \frac{1}{\omega_c}, \quad k = \frac{R_c}{R} \right\}$$

$$\frac{1}{(\omega_c)^2} = R^2[6 + 4k]$$

$$\frac{1}{\omega_c} = R\sqrt{6 + 4k}$$

$$\omega_c = \frac{1}{R_c\sqrt{6 + 4k}}$$

$$\boxed{f = \frac{1}{2\pi R_c\sqrt{6 + 4k}}}$$

In eqn make real part equal to '0'.

$$R^3 + (3+h_{fe})R^2R_c - 5RX_c^2 - R_cX_c^2 = 0$$

Substitute $X_c^2 = 6R^2 + 4RR_c$

$$R^3 + 3R^2R_c + R^2R_ch_{fe} - (5R+R_c)(6R^2+4RR_c) = 0$$

$$R^3 + 3R^2R_c + R^2R_ch_{fe} - 30R^3 - 20R^2R_c - 6R^2R_c - 4RR_c^2 = 0$$

$$\Rightarrow -29R^3 + R^2R_ch_{fe} - 23R^2R_c - 4RR_c^2 = 0$$

$$R(-29R^2 + RR_ch_{fe} - 23RR_c - 4R_c^2) = 0$$

$$h_{fe}RR_c = 29R^2 + 23R_cR + 4R_c^2$$

$$h_{fe} = 29\frac{R}{R_c} + 23 + 4\frac{R_c}{R} \qquad \left[k = \frac{R_c}{R}\right]$$

$$\boxed{h_{fe} = \frac{29}{k} + 23 + 4k} \longrightarrow (4)$$

Minimum value of h_{fe} :-

Diff. eqn (4) w.r. to 'k'.

$$\frac{d(h_{fe})}{dk} = 0 \qquad y = \frac{1}{x}, \quad \frac{dy}{dx} = -\frac{1}{x^2}$$

$$-\frac{29}{k^2} + 0 + 4 = 0$$

$$4 = \frac{29}{k^2}$$

$$k^2 = \frac{29}{4}$$

$$k^2 = 7.29$$

$$k = 2.69$$

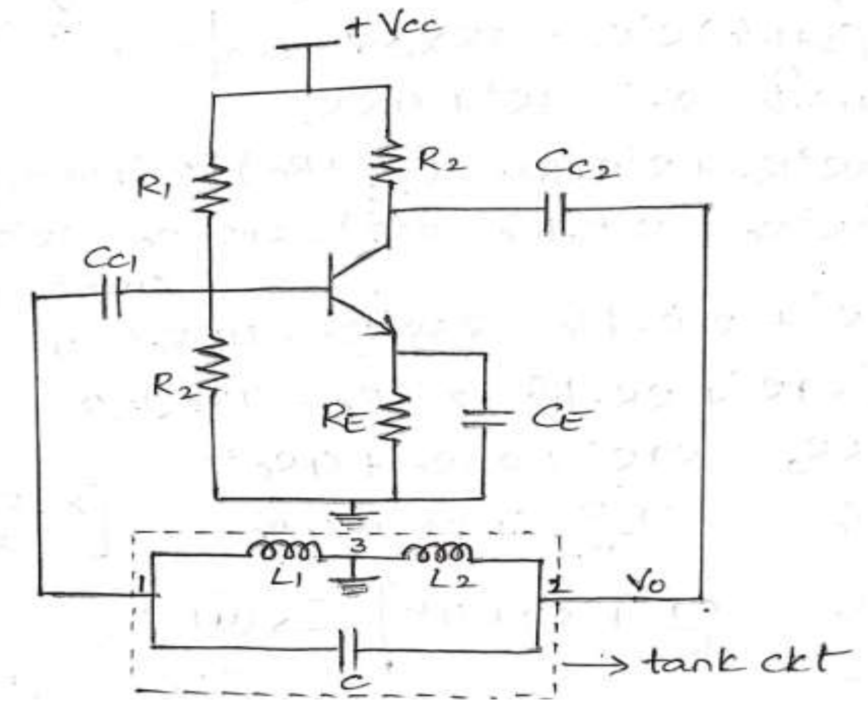
$$\boxed{k = 2.7}$$

$$h_{fe}(min) = \frac{29}{2.7^2} + 23 + 4(2.7)$$

$$\boxed{h_{fe}(min) = 44.54}$$

GENERALIZED ANALYSIS OF LC OSCILLATORS

1.HARTLEY OSCILLATOR



- In hartley Oscillators, the tank circuit contains two Inductors and one Capacitor.
- The Amplifier stage uses an active device as a transistor in CE Configuration.
- R1 and R2 are the biasing resistance which provides Dc Bias to the transistor.
- The feedback network consist of two Inductors & one Capacitor, which is used for determing the frequency Of oscillation.

Oscillation:- When the supply voltage Vcc is switched ON, The capacitor starts charging, & when the capacitor is fully charged then it starts to discharge through L1 & L2. Hence it produce oscillation with certain frequency.In feedback network the portion of output voltage of amplifier appears across L2 and feedback voltage appears across L1

Phase shift due to feedback:- As terminal 3 is grounded, it is a 0° potential. If terminal 1 is positive potential, terminal 2 will be negative and w.r.to terminal 3. Thus the phase difference between the terminal 1 & 2 is always 180°. In CE Configuration, the transistor provides a phase shift of 180° between input & output. The total phase shift is 360°. If the feedback is adjusted so that loop Aβ=1, then the circuit acts as an Oscillator.

$Z_1 = j\omega L_1, \quad Z_2 = j\omega L_2, \quad Z_3 = \frac{1}{j\omega C}$

The generalized equation for LC oscillator is given as.

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

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

Case 1:- frequency of oscillation

The frequency of oscillation can be determined by making imaginary part to '0'.

$$\omega L_1 + \omega L_2 - \frac{1}{\omega c} = 0$$

$$\omega(L_1 + L_2) = \frac{1}{\omega c}$$

$$\omega^2 = \frac{1}{(L_1+L_2)c}$$

$$\omega = \frac{1}{\sqrt{(L_1+L_2)c}}$$

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

Case 2:- Condition for oscillation

Make real part to '0'.

$$-\omega^2 L_1 L_2 (1+h_{fe}) + \frac{L_1}{c} = 0$$

$$\omega^2 L_1 L_2 (1+h_{fe}) = \frac{L_1}{c}$$

$$(1+h_{fe}) = \frac{L_1}{c L_1 L_2 \omega^2}$$

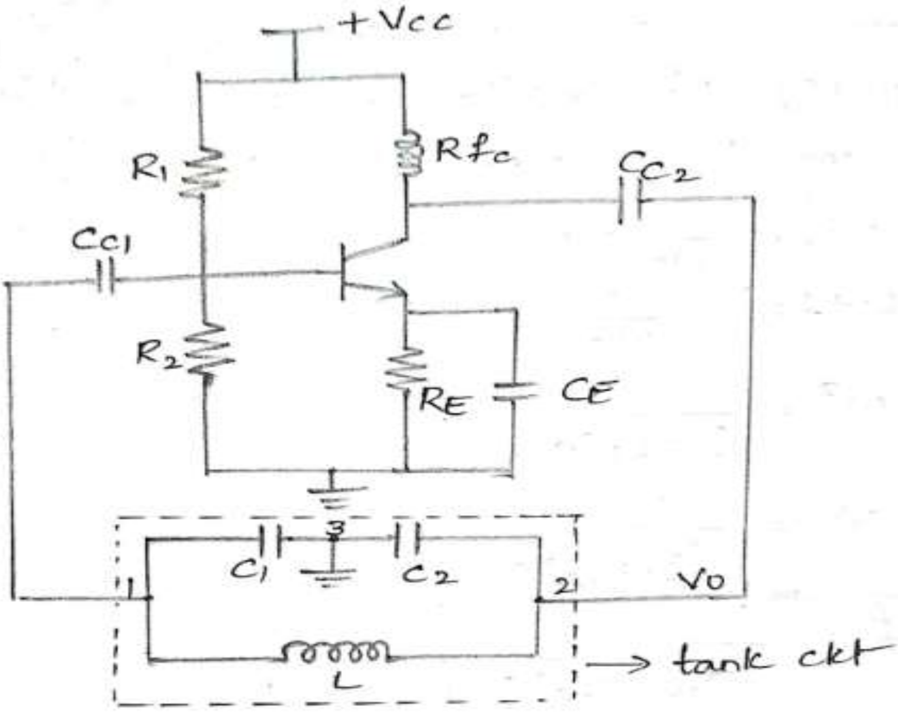
$$(1+h_{fe}) = \frac{1}{\cancel{c} L_2 \cdot \frac{1}{(L_1+L_2)\cancel{c}}}$$

$$1+h_{fe} = \frac{L_1+L_2}{L_2}$$

$$1+h_{fe} = \frac{L_1}{L_2} + \frac{\cancel{L_2}}{\cancel{L_2}}$$

$$\boxed{h_{fe} = \frac{L_1}{L_2}}$$

2.COLPITT'S OSCILLATOR



The Colpitts Oscillator is similar to Hartley Oscillator with a minor modification. Instead of using tapped inductors, C1 & C2 are placed across L and the junction of two capacitors C1 & C2 is grounded.

Operation: When the collector supply voltage is switched ON by closing the switch, collector current starts rising and charging the capacitors C1 and C2. When these capacitors C1 and C2 are fully charged they discharge through coil (L) setting up oscillations in the tank circuit.

The oscillatory current in the tank circuit produces an AC voltage across C1 which is applied to the base-emitter junction of the transistor and appears in the amplified form in the collector circuit.

The output voltage of the amplifier appears across C1. As the terminal 2 is grounded the voltage across is 180° out of phase with the voltage developed across C2.

So, there is a phase shift of 180° between input & output. The Common Emitter amplifier also produces a further phase shift of 180° between input & output. Thus the total phase shift becomes 360°, this makes the feedback positive which is essential condition for oscillation. When the loop gain |Aβ| of the amplifier is great & than one, Oscillation are sustained in the circuit.

$Z_1 = \frac{1}{j\omega C_1}$, $Z_2 = \frac{1}{j\omega C_2}$, $Z_3 = j\omega L$

The generalized expression for LC oscillator is given by,

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

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

$$+\frac{1}{j\omega C_1}\times j\omega L=0$$

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

Case 1:- Frequency of oscillation.

The frequency of oscillation at resonant frequency can be determined by making imaginary part to zero.

$$-\frac{1}{\omega C_1}-\frac{1}{\omega C_2}+\omega L=0$$

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

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

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

$$\left[C_{eq}=\frac{C_1 C_2}{C_1+C_2}\right]$$

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

$$\omega=\frac{1}{\sqrt{L C_{eq}}}$$

$$\boxed{f=\frac{1}{2\pi\sqrt{L C_{eq}}}}$$

Case 2:- Condition for oscillation

Make real part to '0'.

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

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

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

$$1+h_{fe}=\frac{L\,\frac{C_1+C_2}{L(C_1C_2)}\cdot C_1C_2}{C_1}$$

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