UNIT 2

- **FEEDBACK AND SIGNAL GENERATORS:** Feedback Concepts, Advantages of Voltage series Negative feedback, Oscillator Operation, Barkhausen Criterion, RC Phase Shift Oscillator, Wein Bridge Oscillator, Crystal Oscillator (Only Concepts, Working, Waveforms, No mathematical derivations).

- **OPERATIONAL AMPLIFIERS:** Op-Amp basics, Practical Op-amp circuits- Inverting Amplifier, Non Inverting Amplifier, Voltage Follower, Summer, Integrator, Differentiator(Only Concepts, Working, Waveforms, No mathematical derivations)

Feedback

A part of the output signal is fed back to the input of the circuit through a suitable network, called feedback.

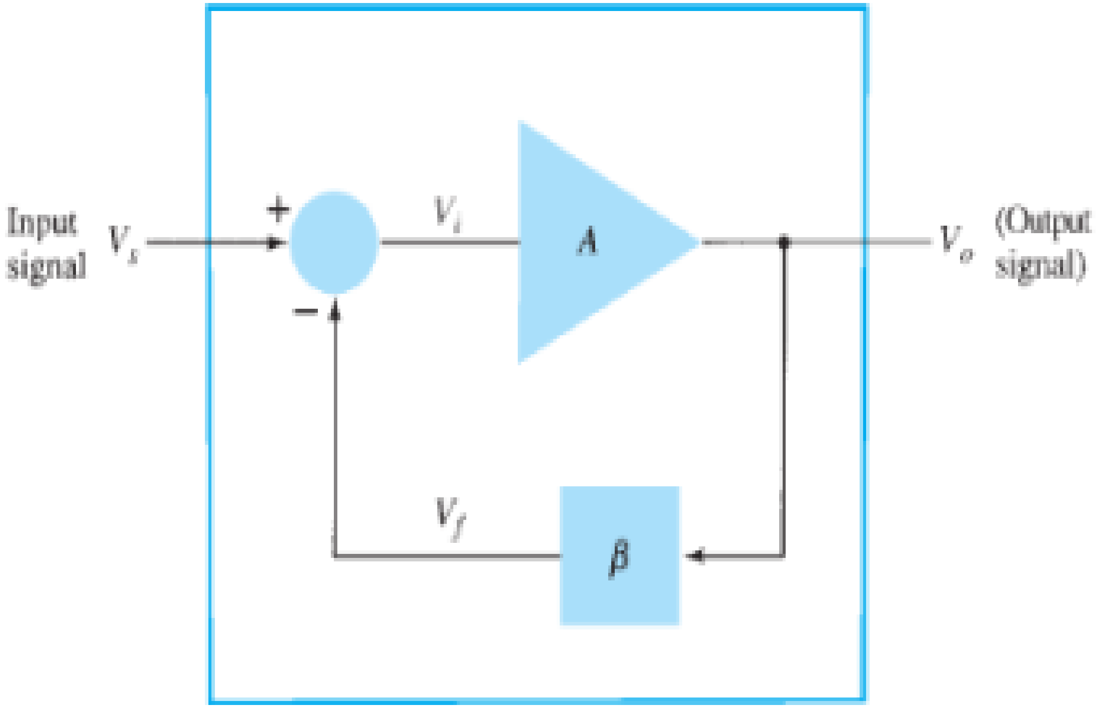
Types:

i. Positive Feedback: The feedback signal ($A_V \times B \times V_{out}$) has the same phase as the V_{IN} signal. Also known as regenerative, or direct feedback

ii. Negative Feedback: The feedback signal has the opposite phase to the V_{IN} signal. Also called **degenerative or inverse feedback**.

Negative Feedback:

Gain with and without Feedback:



Feedback amplifier

$$A = \frac{V_o}{V_i} - - - Open\ Loop\ Gain$$

$$Af = \frac{V_o}{V_S} - - - Closed\ Loop\ Gain$$

$$V_s - V_f = V_{in}$$

$$V_s = V_{in} + V_f$$

$$A_f = \frac{V_O}{V_S} = \frac{V_O}{V_{in}+V_f} = \frac{V_O}{V_{in}+\beta V_O} = \frac{\frac{V_O}{V_{in}}}{\frac{V_{in}}{V_{in}}+\beta\frac{V_O}{V_{in}}} = \frac{A}{1+\beta A}$$

Prove that the stability of the gain A_f of an amplifier with negative feedback improves by a factor (1+βA) compared to that of an amplifier without feedback, where A is open loop gain and β is the feedback factor.

$$\frac{dy}{dx} = \frac{v\frac{du}{dx} - u\frac{dv}{dx}}{v^2}$$

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

Differentiate bs wrt 'A'

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

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

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

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

Divide BS by A_f

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

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

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

$\frac{dA_f}{A_f} = \frac{dA}{A} * \frac{1}{(1+\beta A)}$

$(1+\beta A)$>>1 Thus $(1+\beta A) \approx \beta A$

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

Where, $\frac{dA_f}{A_f}$----Fractional change in amplification with FB

$\frac{dA}{A}$ ----Fractional change in amplification without FB

Advantages of negative feedback amplifiers:

- Input impedance increases by a factor of $1+A\beta$
- Output impedance decreases by a factor of $1+A\beta$
- Bandwidth increases by a factor of $1+A\beta$
- Distortion decreases by a factor of $1+A\beta$
- Noise decreases by a factor of $1+A\beta$
- Stability of the gain improves by a factor of $1+A\beta$

Numericals

A Voltage amplifier needs 10mV input to give a certain output ,when negative feedback is provided to this amplifier, it needs 4V to deliver the same output. If the closed loop gain of the amplifier is 40dB, determine the open loop gain of amplifier and the feedback factor.

Sol. $V_{in}(without\ feedack) = 10mV$

$$V_{in}(with\ feedack) = 4V$$

$$A_f = 40dB = 20\log A_f = 100$$

$$100 = A_f = \frac{V_o}{V_{in}} = \frac{V_o}{4}$$

$$V_o = 400V$$

To find Open Loop Gain

$$A_{oL} = \frac{V_o}{V_{in(without\ feedback)}} = \frac{400}{10m} = 40000$$

To find β

$$A_f = \frac{A}{1+\beta A} = 100 = \frac{40000}{1+\beta 40000}$$

$$\beta = \frac{399}{40000} * 100 = 0.9875$$

Numericals Cont.,

A Voltage amplifier needs 2mV input to give a 10V output ,when negative feedback is provided to this amplifier, it needs 200mV to deliver the same output. Determine closed loop gain, the open loop gain, amount of feedback in dB and the feedback factor.

Sol. $V_{in}(without\ feedack) = 2mV$

$$V_o = 10V$$

$$V_{in}(with\ feedack) = 200mV$$

$$A_{OL} = \frac{V_o}{V_{in(without\ feedback)}} = \frac{10}{2m} = 5000 = 20\log(5000) = 73.97dB$$

$$A_f = \frac{V_o}{V_{in(with\ feedback)}} = \frac{10}{200m} = 50 = 20\log(50) = 33.97dB$$

To find β

$$A_f = \frac{A}{1+\beta A} = 50 = \frac{5000}{1+\beta 5000}$$

$$\beta = \frac{99}{5000} * 100 = 1.98\%$$

Numericals Cont.,

An amplifier has a gain of 40dB, BW of 300KHz, Distortion of 15%, input impedance of 10KΩ, Output impedance of 10KΩ, If Voltage series negative feedback of 3.9% is given to this amplifier, Calculate the gain, $Z_{in}, Z_o, BW\ and$ distortion of the amplifier with negative feedback.

Sol. A_{OL} =40dB=$20\log(A_{OL}) = 100$, BW=300KHz, D=0.15, $Z_{in} = 10K\Omega$, $Z_o = 10K\Omega$, β=0.039

To calculate Gain,

$A_f = \frac{A}{1+\beta A} = \frac{100}{1+0.039(100)}$=20.408=$20\log(20.408) = 26.19dB$

To Find Z_{in}, Z_o,

Z_{in} =($1 + \beta A_{OL}$) Z_{inOL}=(1+0.039*100)*10K=4.9*10K=49KΩ

$Z_o = \frac{Z_{O(OL)}}{(1+\beta A_{OL})}$=10K/4.9=2.04KΩ

To find BW,

BW=($1 + \beta A_{OL}$)BW=(1+0.039(100))*300K=1470KHz

To find D

D= $\frac{D_{(OL)}}{(1+\beta A_{OL})}$=0.15/4.9=3.06%

RC Phase shift Oscillator

An RC phase shift oscillator consists of a common emitter single-stage amplifier with a phase shift feedback network consisting of three identical RC sections

The single-stage amplifier can be built with either a transistor or an operational amplifier (Op-amp) as an active element.

More suitable for low-frequency applications.

Basic principle of Working:

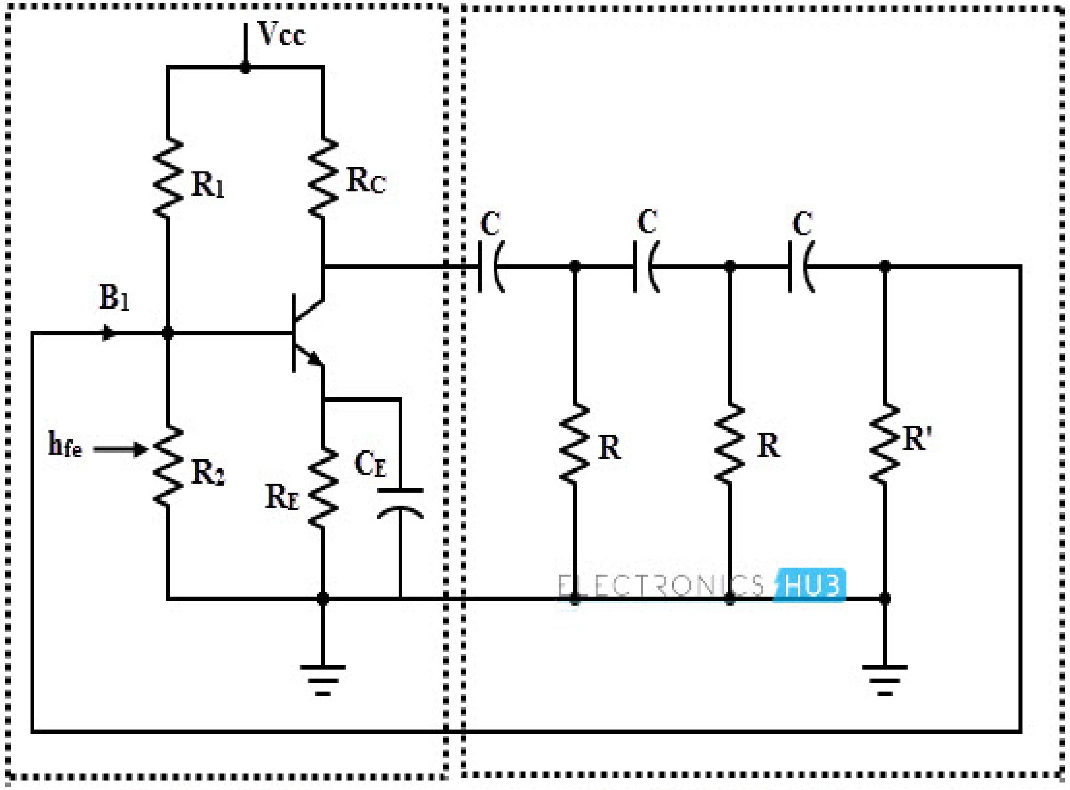
- The necessary condition for producing the oscillation is that the total phase shift around the loop must be 360 degrees.
- In addition to the 180-degree phase shift introduced by the amplifier, this RC phase shift network gives a 180-degree phase shift and hence the total phase shift is 360 degrees which is also equal to zero degrees.

Barkhausen Conditions for Oscillation:

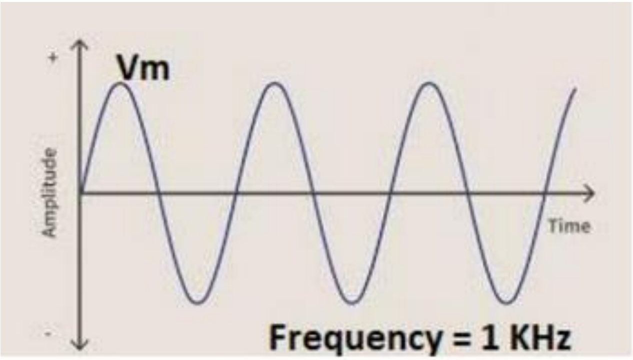
i. The loop gain is equal to one in absolute magnitude, which means that $|\beta A|=1$

ii. The phase shift through the loop is either zero or an integer multiple $\angle\beta A=2\pi n$, $n=0,1,2,...$

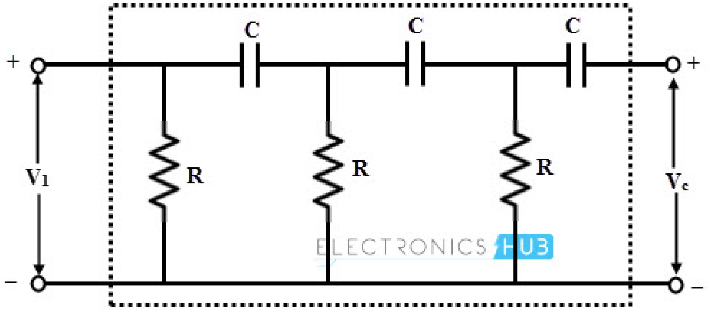
RC Phase Shift Oscillator



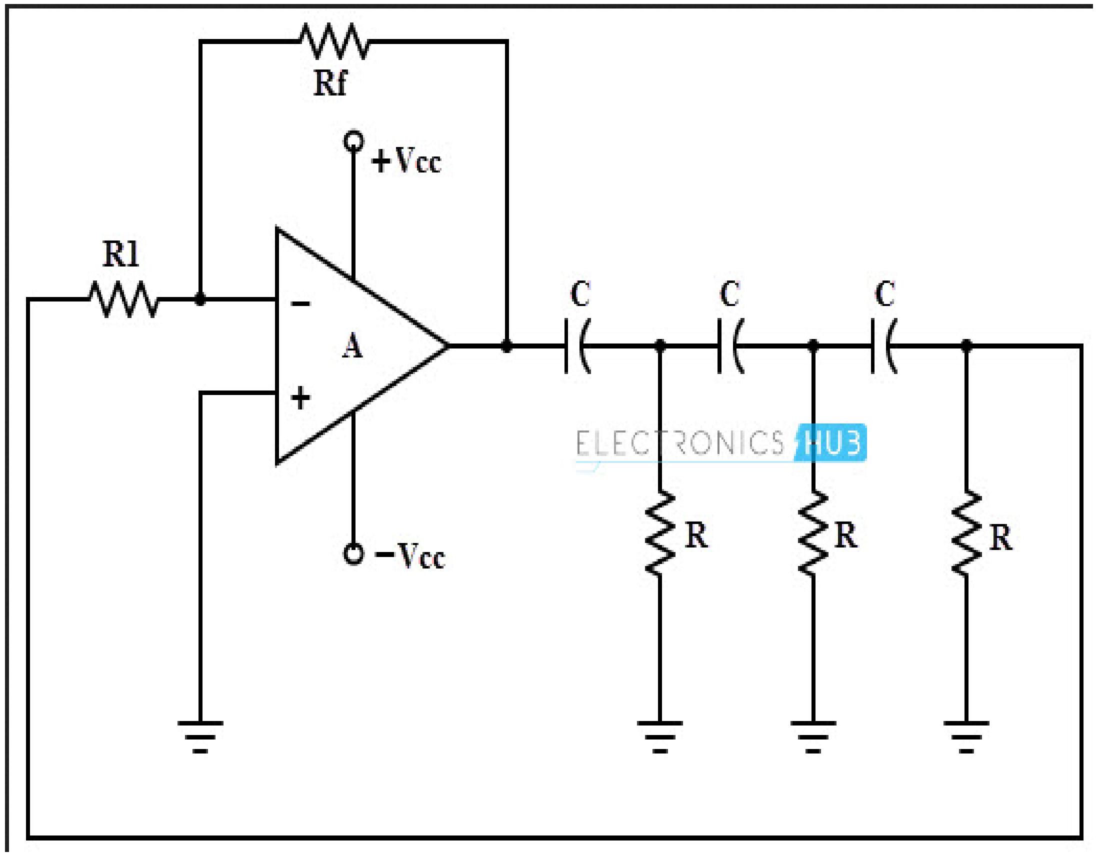
$$f_0 = \frac{1}{2\pi RC\sqrt{6 + 4K}}$$



- An RC oscillator consists of an amplifier and feedback network.
- Feedback network is a phase shift network made with a number of capacitors and resistors arranged in a ladder fashion. Also called as ladder type RC phase shift network.
- A single RC section network provides a maximum of 90 degrees phase shift. Therefore, a minimum of two RC networks are enough to produce required 180 degrees phase shift.
- In a practical RC phase shift oscillator, three RC phase shift networks are cascaded with each section providing 60 degrees of phase displacement.
- So the total phase shift obtained by these three sections in feedback network is 180 degrees (3 × 60).



RC Phase Shift Oscillator Using Op-amp



The frequency of oscillations,

$f=1/(2\pi R C \sqrt{6})$

- Op-amp is operated in inverting mode and hence the output signal of the op-amp is shifted by 180 degrees to the input signal appearing at the inverting terminal.
- An additional 180-degree phase shift is provided by the RC feedback network.
- The gain of the amplifier is adjusted with the help of Rf and R1 resistances.
- To get the required oscillations, the gain is adjusted in such a way that the product of op-amp gain and gain of feedback network is slightly greater than 1.
- The condition of oscillations is given by $A \geq 29$