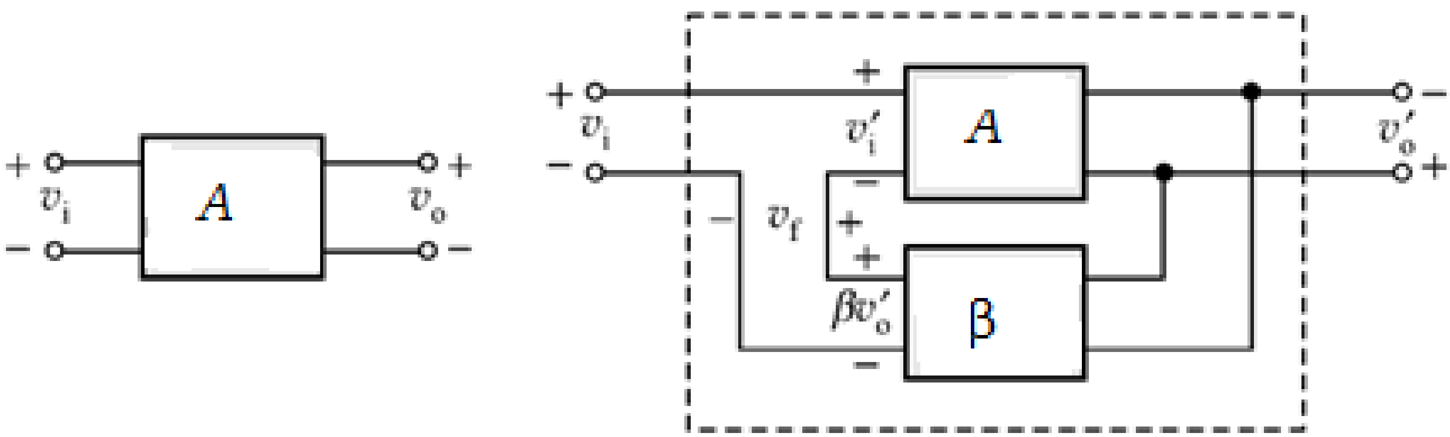
CONCEPTS OF FEEDBACK IN AMPLIFIERS:

The important characteristics of an amplifier are i) **voltage gain**, ii) **input impedance**, iii) **output impedance,** iv) **bandwidth** and are almost constants for an amplifier and cannot be changed. These parameters can be changed in number of ways. If we want to change voltage gain, input impedance or output impedance of an amplifier a resistive network is used either in the input or output. The ***feedback technique*** is also used to change these parameters.

Feedback is the process of taking a part of the output signal and **feeding** it **back** to the input circuit. The voltage gain of an amplifier A is given by

$$A = \frac{v_o}{v_i}$$



(a) Block diagram (b) Feedback introduced

In fig. a output is not connected with the input, so for any reason if output changes net input remains unaffected. Such a system is called ***open – loop*** or ***non – feedback*** system.

In fig. b the output of the amplifier is fed back to the input through a network called feedback network or β network. A fraction of the output voltage βv_o is going back to the input. This changes the net input voltage to the amplifier and thus the output modifies the input signal. Such a system is called ***closed – loop*** or ***feedback*** system.

TYPES OF FEED BACK:

When feedback voltage v_f is out of phase with input voltage v_i, then the net input voltage v_i' of the amplifier is

$$v_i' = v_i - v_f$$

The net input v_i' of the amplifier reduced, the output of the amplifier also decreases from v_o to v_o'. The gain of the amplifier reduces because of the feedback. This type of the feedback is called ***negative feedback, inverse feedback*** or ***degenerative feedback***.

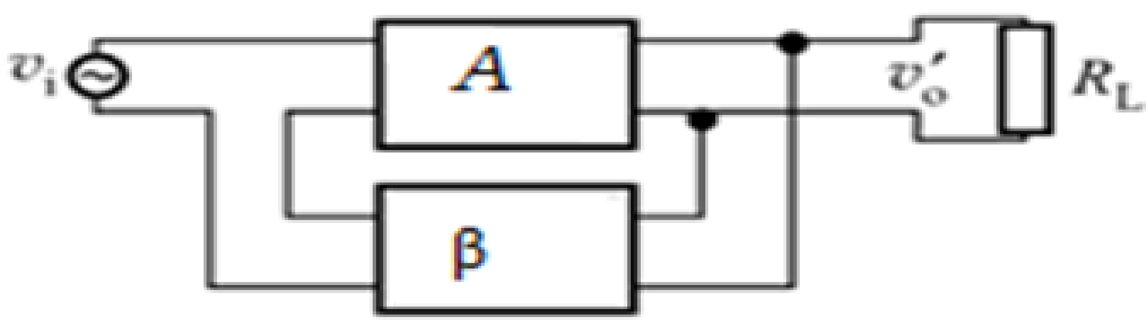
The feedback voltage can be also in phase with the external input voltage. In such a case the net input voltage v_i' to the amplifier is increased. That increases the output voltage to v_o' from v_o. This type of the feedback is called ***positive feedback, direct feedback*** or ***regenerative feedback***.

The positive feedback in amplifier increases distortion and decreases stability of the gain, so in amplifier always negative feedback is used.

The feedback can also classify as ***voltage feedback*** or ***current feedback.*** In voltage feedback, the signal fed back is proportional to the output voltage. In current feedback, the signal fed back is proportional to the output current. A combination of voltage and current feedback may be present in the circuit. Voltage and current can be fed back to the input either in the series or parallel. Thus, there are four basic ways of connecting the feedback signal.

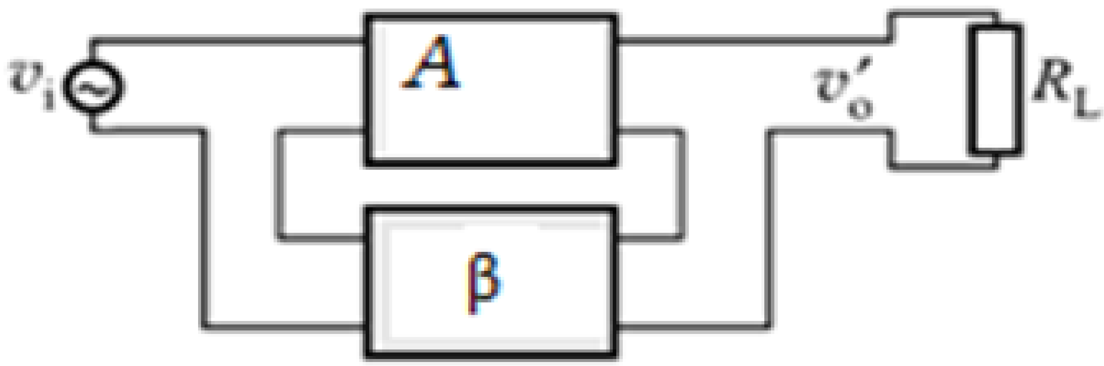
Series – feedback connections increases the input impedance of the amplifier, while shunt – feedback connections tends to decrease the input impedance. Voltage – feedback decreases the output impedance, while current – feedback increases the output impedance.

SERIES – VOLTAGE FEEDBACK:



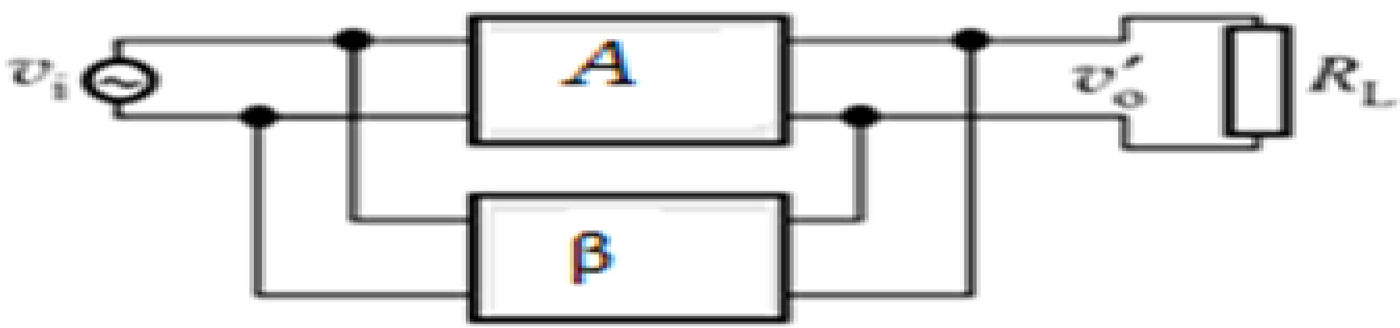
(a) Series-voltage feedback

SERIES – CURRENT FEEDBACK



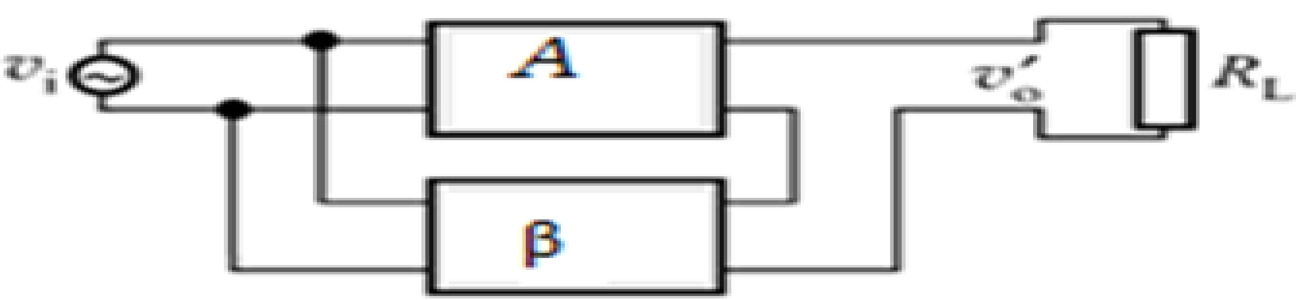
(b) Series-current feedback

SHUNT – VOLTAGE FEEDBACK



(c) Shunt-voltage feedback

SHUNT – CURRENT FEEDBACK:



(d) Shunt-current feedback

VOLTAGE GAIN OF FEEDBAC AMPLIFIER:

The voltage across the R_L (=R_1 + R_2) v_o' is fed to a β – network consisting of voltage divider circuit consists of resistors R_1 and R_2. The feedback voltage v_f is developed across resistor R_1 is fed back to the input side in series with the input voltage v_i. Hence this circuit is example of series – voltage feedback.

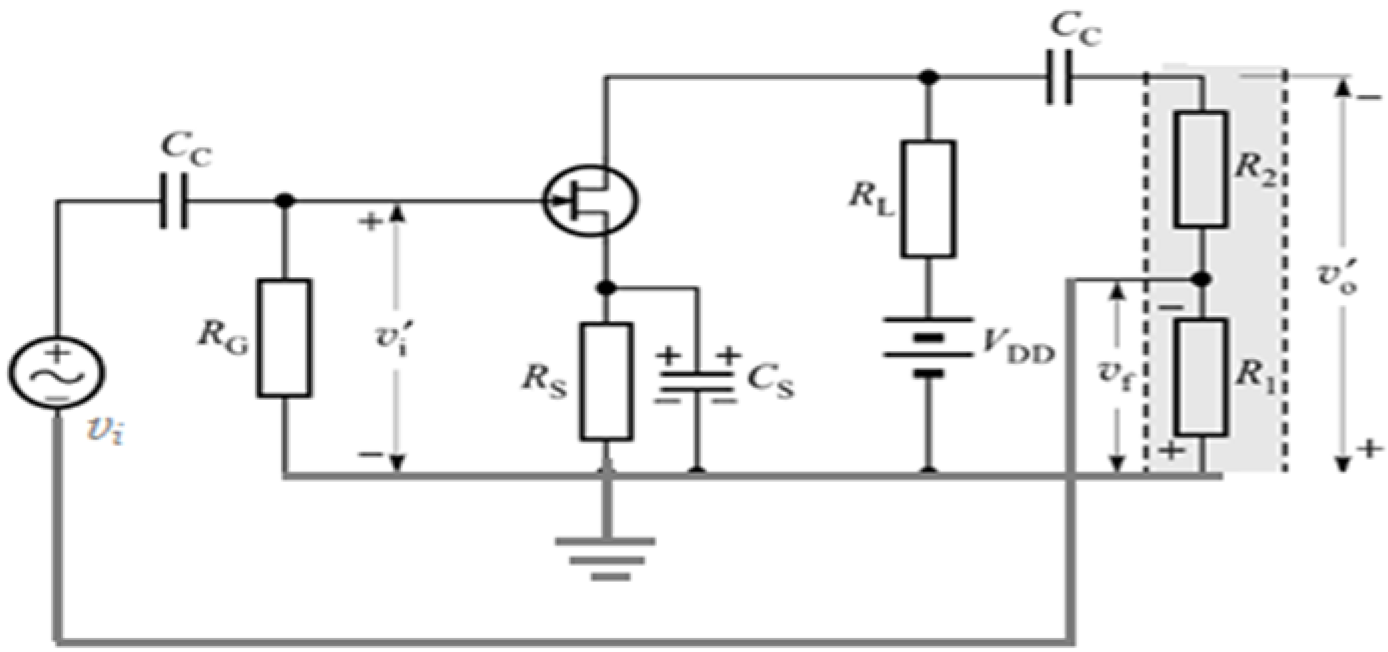


Fig 1 amplifier with series voltage feedback using FET

In single stage common source amplifier the amplified output signal v_o' is 180^0 out of phase with the input signal v_i so feedback signal v_f is also out of phase with the input signal v_i. The effective input signal $v_i' = v_i - v_f$ therefore reduced. The type of the feedback is therefore negative.

Block diagram of series voltage feedback of Fig.1 is shown in Fig. 2. The input of this feedback amplifier is v_i and output is v_o'. The voltage gain with feedback is given by

$$A_f = \frac{v_o'}{v_i} \qquad 1$$

The effective input of the basic amplifier is v_i' and is

$$v_i' = v_i - v_f \qquad 2$$

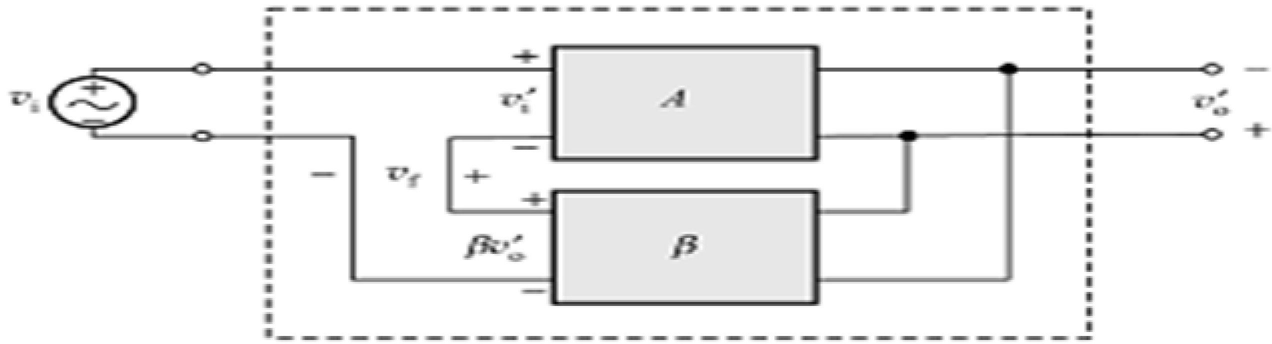


Fig 2. blok diagram of series voltage feedback

The feedback voltage v_f is due to $v_o^{'}$ through the β feedback network. And so

$$v_f = \beta v_o' \qquad 3$$

The constant is known as feedback factor and form Fig. 1the value of β is

$$\beta = \frac{R_1}{R_1 + R_2} \qquad 4$$

The voltage gain of the basic amplifier is A and is the ratio of the input voltage of the basic amplifier $v_i^{'}$ with the output voltage of the basic amplifier $v_o^{'}$. A is called internal gain of the amplifier.

$$A = \frac{v_o'}{v_i'} \quad or \quad v_i' = \frac{v_o'}{A} \qquad 5$$

Substituting equation 3 and 5 into equation 2 we have

$$v_i' = v_i - v_f$$

$$\frac{v_o'}{A} = v_i - \beta v_o'$$

$$v_o' = Av_i - A\beta v_o'$$

$$v_o'(1 + A\beta) = Av_i$$

$$\frac{v_o'}{v_i} = \frac{A}{(1 + A\beta)} \qquad 6$$

Comparing equation 6 with equation 1 we have $\boldsymbol{A_f = \frac{A}{(1+A\beta)}}$ 7

For the positive feedback, the feedback voltage v_f is in phase with the input voltage v_i, and both are added to give net input to the amplifier v_i' and we have

$$v_i' = v_i + v_f$$

$$\frac{v_o'}{A} = v_i + \beta v_o'$$

$$\frac{v_0'}{v_i} = A_f = \frac{A}{(1 - A\beta)} \qquad 8$$

Equation 8 shows that when positive feedback is applied, it increases the voltage gain of the amplifier. For the good performance of the amplifier always negative feedback is used. Positive feedback is used in oscillator.

ADVANTAGES OF NEGATIVE FEED BACK:

The gain of the amplifier is reduced when negative feedback is introduced in the amplifier. But negative feedback improves the performance of the amplifier. The advantages of the negative are

Stabilization of gain.

Reduction in distortion and noise.

Increase in input impedance.

Decrease in output impedance.

Increase in bandwidth.

STABILIZATION OF GAIN

Voltage gain of the negative feedback amplifier with feedback is

$$A_f = \frac{A}{(1+A\beta)} \qquad ; \quad \text{Where} \quad A\beta \gg 1$$

Then we can consider $1 + A\beta = A\beta$ and voltage gain with feedback

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

Thus, the gain of the amplifier A_f of the feedback amplifier becomes independent of the internal gain of the amplifier A. The gain A_f depends only on β, depends on passive component like resistors. The value of the resistors remains constant, and hence the gain is stabilized if $A\beta \gg 1$.

If some change in the internal voltage gain of the amplifier takes place, the corresponding percentage change in the overall voltage gain of the feedback amplifier is given by $\frac{d}{dA}(A_f)$

$$\frac{d}{dA}(A_f) = \frac{d}{dA}\left(\frac{A}{(1+A\beta)}\right)$$

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

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

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

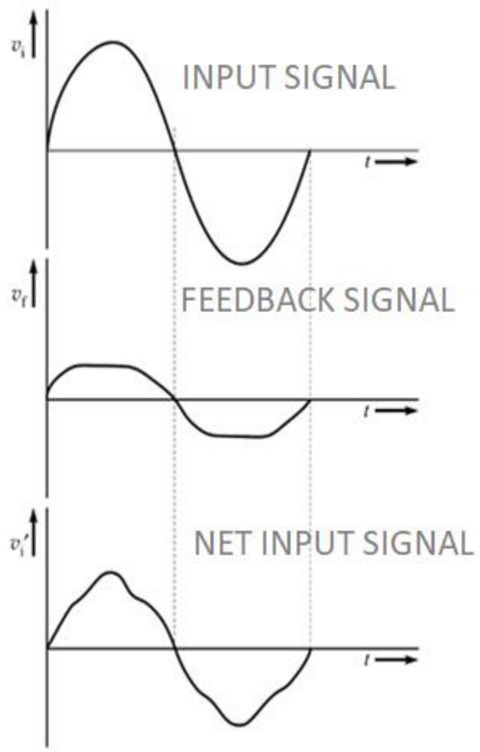
$$\frac{dA_f}{A_f} = \frac{dA}{(1+A\beta)^2} X \frac{(1+A\beta)}{A}$$

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

Since $(1+A\beta) \gg 1$, the percentage change in A_f is much less than the percentage changes in A.

REDUCTION IN DISTORTION AND NOIS:

Negative feedback reduces harmonic distortion. When sinusoidal voltage v_i is given to the input of a basic amplifier gives distorted output by flattening the peaks. The feedback signal v_f has the same waveform as the output voltage. The feedback voltage v_f gets subtracted from input voltage v_i and gives net input voltage to $v_i^{'}$ the amplifier. Since the pick of the voltages v_f are flattened when subtracted from the v_i, the peak of the resulting $v_o^{'}$ will become more picked. Thus net input $v_i^{'}$ is predistorted in such a way so as to partially compensate for the flattening caused by the amplifier. Now when peaked input voltage $v_i^{'}$ gets amplified, the output will tend to be sinusoidal because the amplifier tries to flatten the peaks.

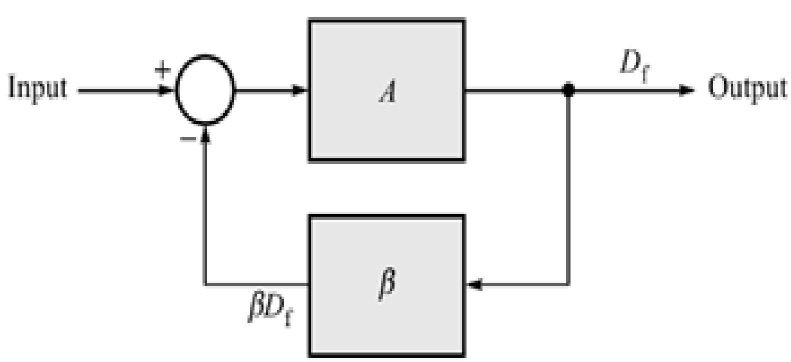


Feedback voltage V_f predistorts the net input V_i to partially compensate the distortion

The amount of the reduction in the distortion caused by negative feedback can be found by following figure. The amplifier with a gain A produces distortion D without feedback. This distortion appears at the output. After feedback is applied, the gain becomes A_f and the distortion in the output becomes D_f. A part βD_f of the distortion D_f is fed back to the input. This gets amplified by basic amplifier by A times and becomes $A\beta D_f$. This gets added in reverse polarity to the original distortion D to make the net distortion D_f, and is

$$D_f = D - A\beta D_f$$

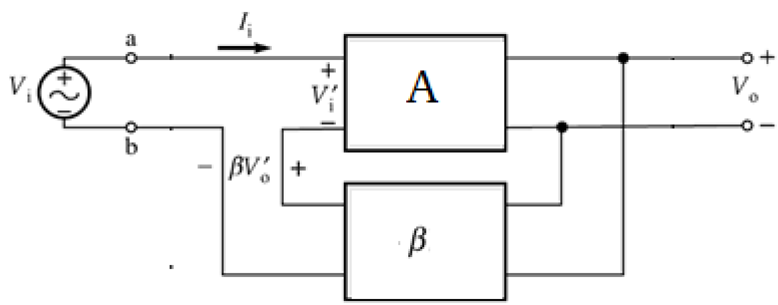
$$D_f = \frac{D}{(1 + A\beta)}$$



A block diagram showing the distortion in the output of a feedback amplifier

The distortion is reduced by the factor $1 + A\beta$. If negative feedback is employed, the net noise in the output reduces, and the performance of the amplifier is much improved.

INCREASE IN INPUT IMPEDANCE:



For an amplifier it is desired to have high input impedance, so that it will not load the preceding stage of the input voltage source. The increase input impedance characteristics can be achieved with the help of negative series – voltage or series – current feedback.

Input impedance with feedback is given by

$$Z_{if} = \frac{v_i}{I_i} \qquad 1$$

$$v_i = v_i' - v_f \quad ; \qquad v_f = \beta v_o'$$

Hence, $$v_i = v_i' - \beta v_o' \ ; \qquad v_o' = A v_i'$$

$$v_i = v_i' - \beta A v_i' \ ; \qquad v_i = v_i'(1 + A\beta) \qquad 2$$

Input impedance without feedback is given by

$$Z_i = \frac{v_i'}{I_i} \quad ; \qquad v_i' = Z_i \, I_i \qquad 3$$

On substituting equation 2 into equation 1 we get

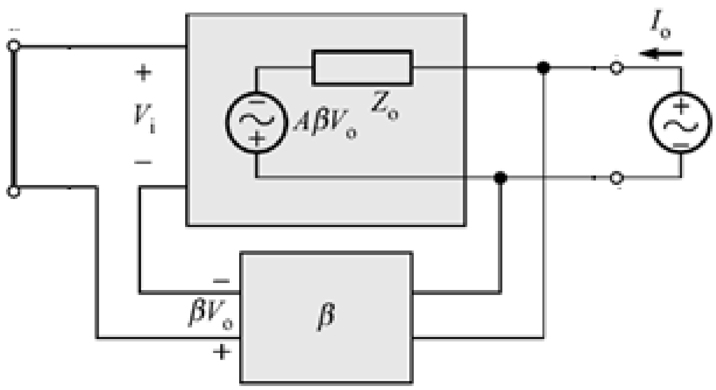
$$Z_{if} = \frac{v_i'(1 + A\beta)}{I_i}$$

Substituting equation 3 in above equation gives

$$\boldsymbol{Z_{if} = Z_i(1 + A\beta\,)} \qquad 4$$

From equation 4 we can say that when negative series – feedback is introduced in an amplifier, the input impedance increases by the factor $1 + A\beta$. The negative shunt – voltage and shunt – current feedback decreases the input impedance by the factor $1/\,(1 + A\beta)$

DECREASE IN OUTPUT IMPEDANCE:



Amplifier with low output impedance is capable of delivering power to the load without much loss. The negative series – voltage feedback or shunt – voltage feedback, when employed in the amplifier it reduces output impedance.

Above figure is the block diagram of a voltage – series feedback, in which output circuit has been replaced by an equivalent voltage source $A\beta v_o$ in series with impedance z_o. The input terminals have been shorted. Apply a voltage source having voltage v_o at the output terminals. If input impedance of the feedback network is assumed to be very high then on applying KVL at the output loop we get

$$V_o = I_o Z_o - A\beta V_o$$

$$V_o + A\beta V_o = I_o Z_o \; ; \qquad V_o(1 + A\beta) = I_o Z_o \qquad 2$$

Output impedance with feedback Z_{of} is written as

$$Z_{of} = \frac{V_o}{I_o}$$

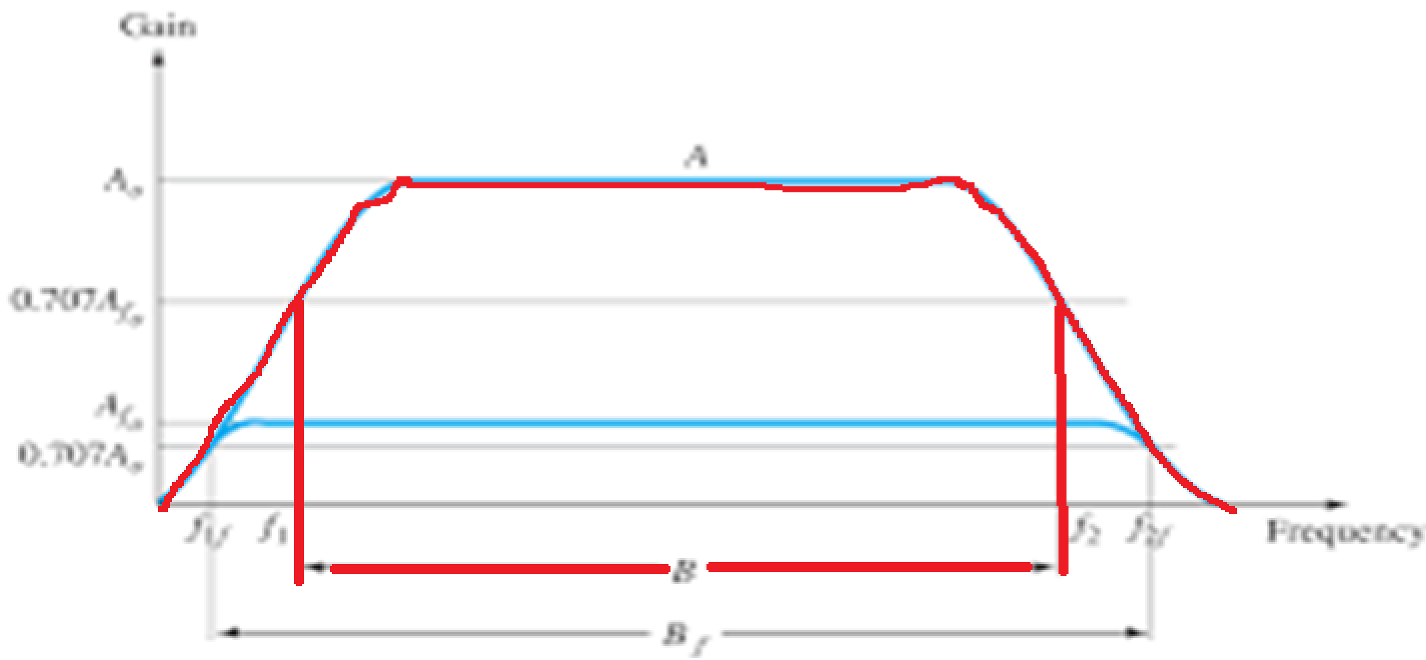
Substituting equation 2 in above equation we have,

$$Z_{of} = \frac{I_o Z_o}{I_o(1 + A\beta)} \qquad ; Z_{of} = \frac{Z_o}{(1 + A\beta)} \qquad 3$$

From above equations we can see that when negative series – voltage or shunt – voltage feedback introduced in the amplifier the output impedance decreases by a factor (1 + Aβ). The inclusion of negative series – current or shunt – current feedback in amplifier increases the output impedance.

INCREASE IN BANDWIDTH:

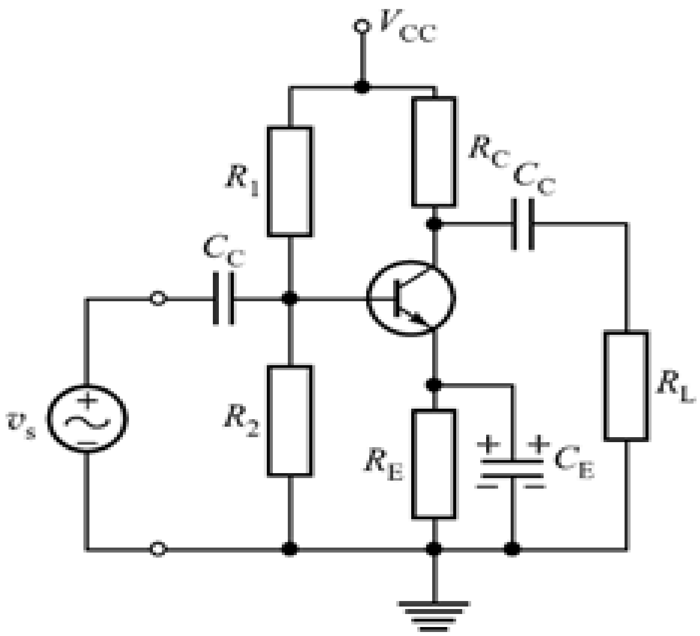
When negative feedback introduced in amplifier, the gain of the amplifier reduces by the factor (1+Aβ). Where A is the internal gain of the amplifier and β is the feedback factor of the feedback network. The negative feedback reduces the lower cutoff frequency f_{1f} by a factor (1+Aβ) and increases upper cutoff frequency f_{2f} by a factor (1+Aβ). The bandwidth of the amplifier is the difference between upper cutoff frequency and lower cutoff frequency. So, when negative feedback employed in an amplifier it increases the bandwidth by a factor (1+Aβ) and decreases the gain of the amplifier by the same factor (1+Aβ). The gain bandwidth product (GBP) of the amplifier is always constant.



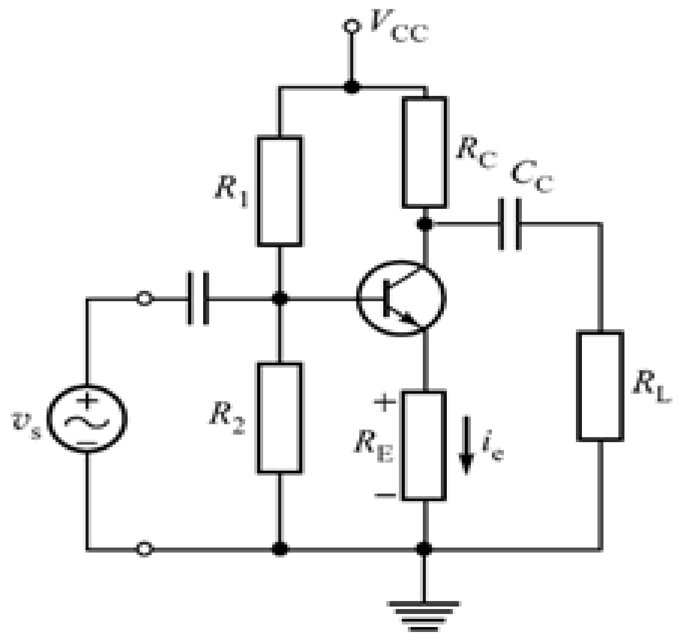
Effect of negative feedback on gain and bandwidth.

AMPLIFIWE CIRCUIT WITH NEGAVTI FEEDBACK:

RC COUPLED AMPLIFIER WITHCOUT BYPASS CAPACITOR:



An ordinary *RC*-coupled amplifier



The same circuit when emitter bypass capacitor is removed

The common emitter RC coupled amplifier circuit is shown in Fig 1. The effective input voltage of this amplifier is the ac signal between the base and emitter same as the voltage v_s supplied from the signal source.

When the bypass capacitor C_E is removed as shown in Fig.2, the effective input voltage is changed. During the increase in positive half cycle of the input source voltage v_s, the emitter – base junction becomes more forward biased. The collector current i_c increases, which increases emitter current i_e in the same direction. This develops ac voltage v_e (i_eR_E)across the resistor R_E. The effective input voltage between base and emitter is given by applying KVL at the input loop we get

$$v_s = v_{be} + v_e$$

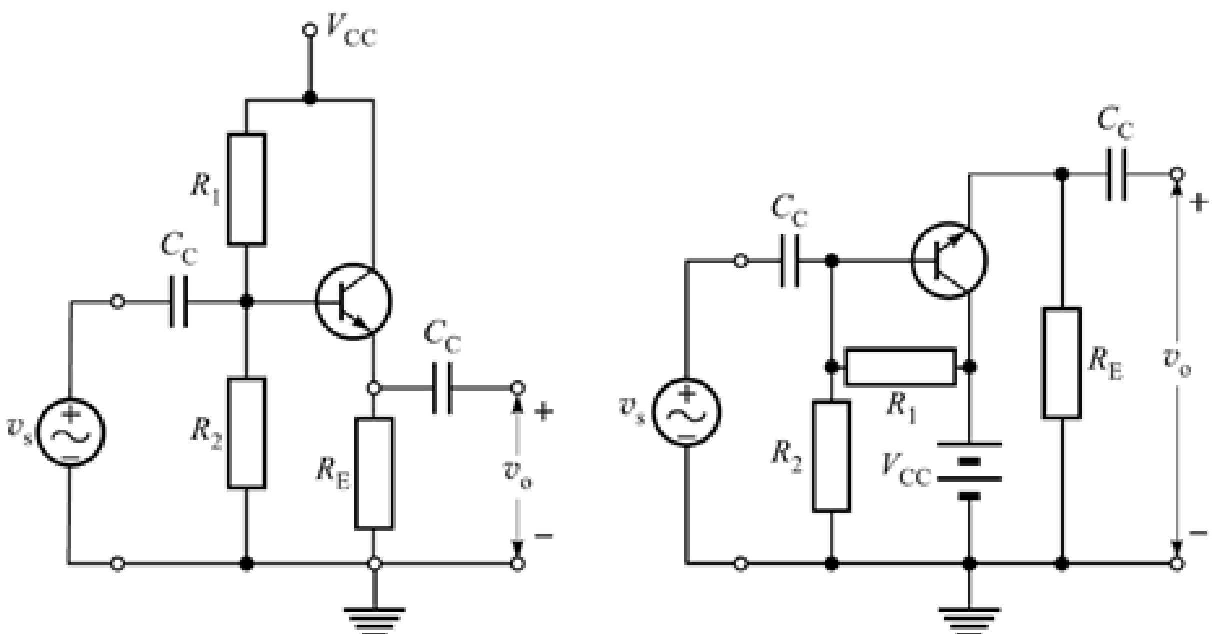
$$v_s - v_e = v_{be}$$

From above equation we can say that the effective input voltage between base and emitter decreases. Hence it is the case of the negative feedback. The feedback voltage i_eR_E is proportional to the output current i_e=i_c, and it appears in series with the source voltage. Hence this is the case of the series – voltage feedback. This circuit is widely used in public address systems, tape recorders etc... Sometimes the emitter resistor is partly bypassed, so that the gain is not reduced excessively with the advantages of the negative feedback.

EMITTER FOLLOWER:

To construct emitter follower circuit the collector biasing resistor R_C is reduced to zero and output voltage is taken from the emitter is called emitter follower circuit or common collector amplifier. The collector is common between input and output. From the ac point of view, the supply voltage V_{CC} is short circuited and hence the collector is grounded. The input is given between the base and collector and the output appears between emitter and collector as shown in Fig.b.

The effective input voltage for this circuit is $v_s - v_o$, because the whole output v_o is fed back to the input side. The gain of the amplifier is drastically reduced. The voltage of this amplifier is less than unity. The output of this amplifier is less than the input. The input impedance of this circuit is very high and output impedance is very low. The emitter amplifier is used for impedance matching in the multistage amplifier, the last stage of the signal generator. Because of high input impedance and low output impedance properties, emitter amplifier is capable of giving power to the load connected to its output without requiring much power at its input. So emitter amplifier is used as a buffer amplifier.



(a) Emitter-follower circuit; (b) The same circuit drawn in a different way to show that it is a common-collector amplifier

When input signal v_s becomes positive, the output voltage is also becomes positive. Thus output and input are in same phase with the output is almost same as the input (v_o is slightly less than v_s). The emitter closely follows the input. Hence it is called emitter follower.

NEED OF AN OSCILLATOR:

An **oscillator** is a circuit which produces a continuous, repeated, alternating waveform without any input. Oscillators basically convert unidirectional current flow from a DC source into an alternating waveform which is of the desired frequency, as decided by its circuit components

CLASSIFICATION OF AN OSCILLATOR:

Mainly there are two types of the oscillator, Sinusoidal & non– sinusoidal. Sinusoidal oscillator produces sine wave, while non – sinusoidal oscillator generates square wave, triangle wave, saw– tooth wave or pulses. The circuit which generate pulses or square wave is called ***multivibrators***.

The sinusoidal oscillators are classified by the type of the feedback network used in an amplifier.

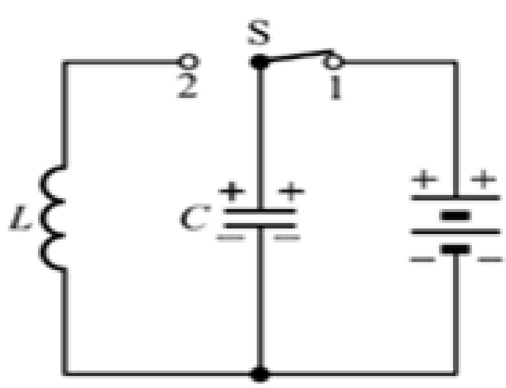
Tuned circuit oscillators: inductor L and capacitor C are used to generate high frequency signals. Hartley and colpitts are the example of the tuned circuit oscillator.

RC oscillators: resistors R and capacitors are used to generate low or audio frequency signal. Phase shift and wein bridge are the example of rc oscillator

Crystal oscillators: quartz crystals are used to generate high frequencies up to 10MHz signals. It generates a highly stabilized output signal.

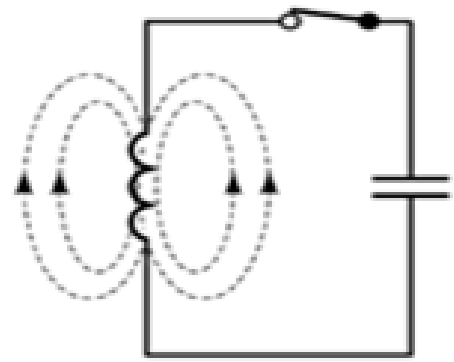
TUNNED CIRCUIT FOR GENERATION OF OSCILLATOR:

An inductor and capacitor connected in parallel form a tank or tuned circuit.

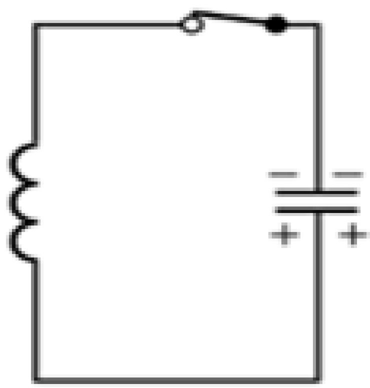


The energy is introduced into tank circuit by connecting the capacitor to a D.C. voltage source as shown in figure. The negative terminal of the battery supplies electrons to the lower plate of the capacitor. Because of the accumulation of electrons, the capacitor gets charged and there is a voltage across it. The energy is stored in the capacitor in the form of electric potential energy.

When the switch is thrown to position 2, current starts flowing in the circuit. The capacitor now starts discharging through the inductor. Since the inductor has the property of opposing any change in current, the current builds up slowly. Maximum currents flows in the circuit when the capacitor is fully discharged at this instant, the potential energy of the system is zero but the electron motion being greatest, the magnetic field energy around the coil is maximum.

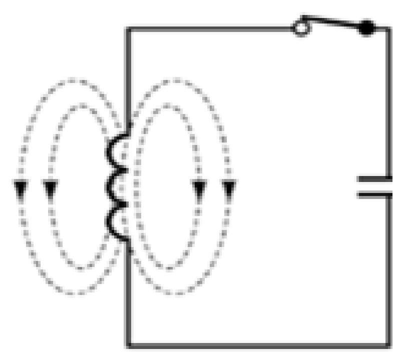


Once the capacitor is fully discharged, the magnetic field begins to collapse. The back emf in the inductor keeps current flowing in the same direction.

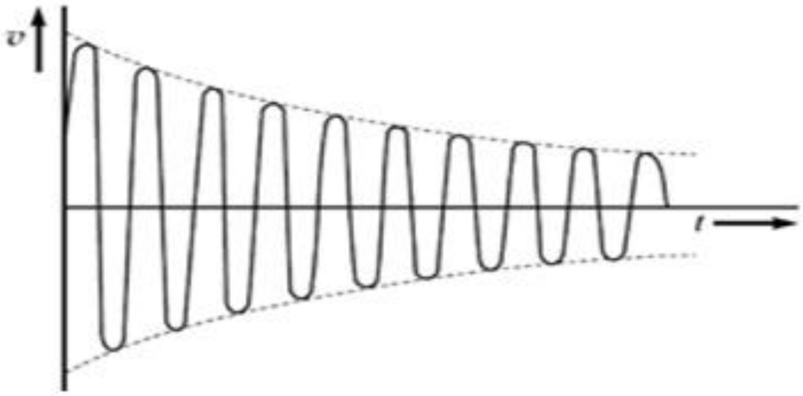


The capacitor starts charging, but with opposite polarity as shown in figure. As the charge builds up across the capacitor, the current decreases and the magnetic field decrease. The magnetic field drops to zero when the capacitor charges to the value it had in previous condition. Again all the energy is in the form of potential energy. The capacitor now begins to discharge again. This time current flows in opposite direction.

As shown in figure the capacitor is fully discharged and shows the maximum current flowing in the circuit. Again, all the energy is in the magnetic field. The interchange or oscillation of energy between L and C is repeated again and again.



The inductor coil will have some resistance and dielectric material of the capacitor will have some leakage. Because of these some energy loss takes place during each cycle of the oscillation. As a result of this loss, the amplitude of oscillation decreases continuously and ultimately oscillations die down. Thus, the tank circuit is capable of producing oscillations but they are damped as shown in below figure.



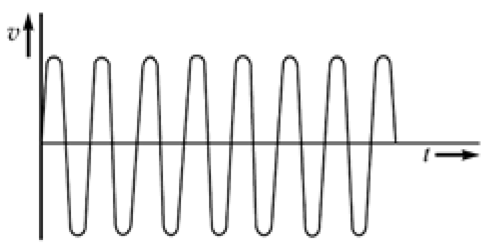
FREQUENCY OF OSCILLATIONS IN LC CIRCUIT:

In the electrical LC circuit, the constants of the systems are the inductance of an inductor L and the capacitance of the capacitor C. The frequency of oscillation for the tank circuit is given by equation

$$f_{osc} = \frac{1}{2\pi\sqrt{LC}}$$

SUSTAINED OSCILLATION:

The oscillations of LC circuit can be maintained at a constant level by supplying a pulse of energy at the right time in each cycle, the resulting undammed oscillations are called sustained oscillations. Such oscillations are generated by the electronic oscillator circuits.

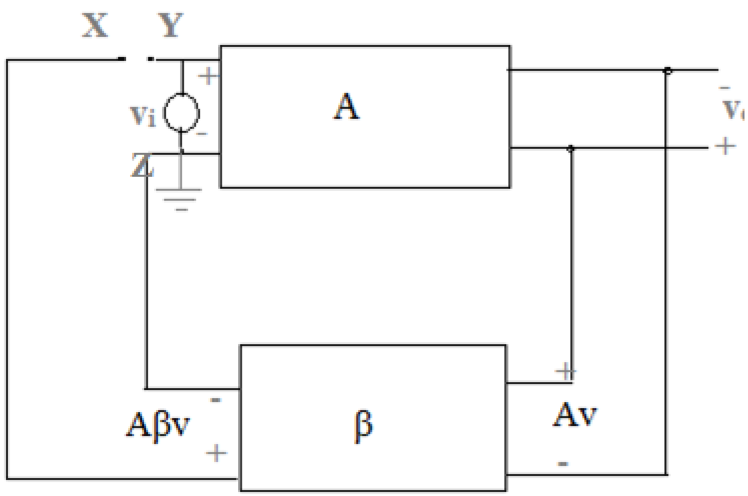


There are many verities of LC – oscillator circuits. All of them have following three features in common

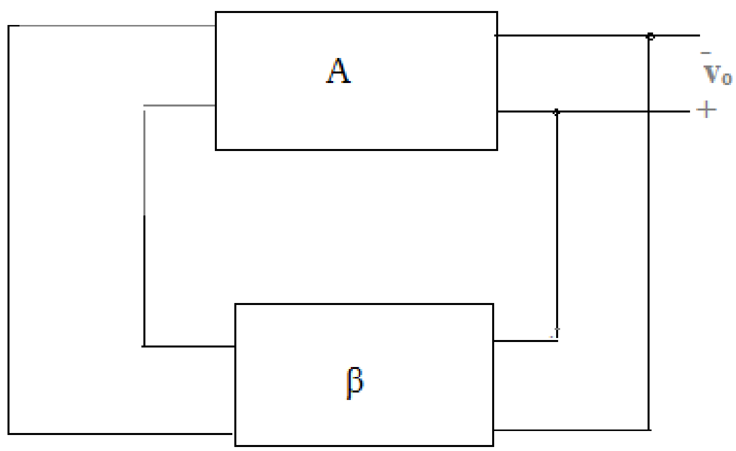
i) They must contain an active device (BJT or FET) that work as an amplifier.
ii) There must be positive feedback in the amplifier.
iii) The amount of feedback must be sufficient to overcome the losses.

POSITIVE FEEDBACK AS AN OSCILLATOR:

Main application of positive feedback is in oscillator. Oscillator generates ac output signal without any ac input signal. A part of the output is fed back to the input; and this feedback signal is the only input to the internal amplifier.

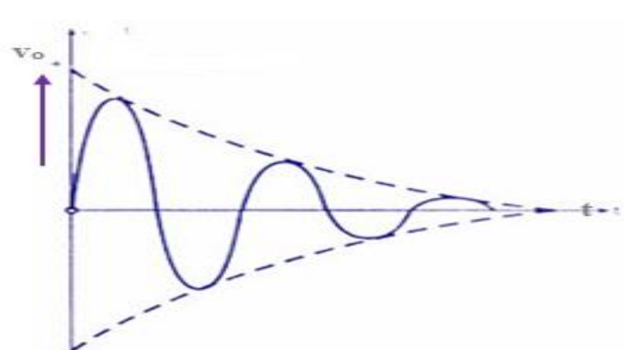


The voltage source v_i drives the input terminals of the internal amplifier. The amplified signal Av_i drives the feedback network to produce feedback voltage $A\beta v_i$. This voltage returns to the input point X. if the phase shift due to the amplifier and feedback network is correct. The signal at point X will exactly in phase with the signal driving the input terminals of internal amplifier.

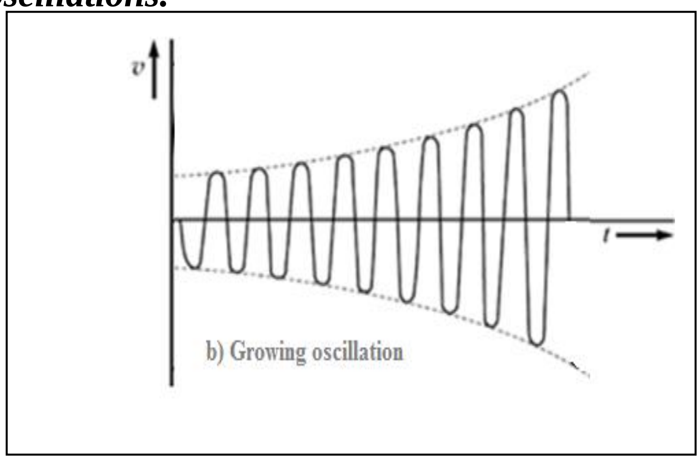


Now we connect the point X and Y and remove voltage source v_i. The feedback signal now drives the input terminals of internal amplifier. If $A\beta$ is less then unity, $A\beta v_i$ is less than v_i and the output signal will die out as shown in fig. a, because enough voltage is not returned to the input of the amplifier.

If $A\beta > 1$, $A\beta v_i$ is greater than v_i and output voltage builds up as shown in fig b. Such oscillations are called ***growing oscillations.***

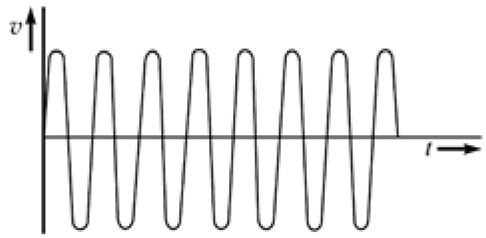


a. Damped oscillations



b) Growing oscillation

If $A\beta = 1$, no change occurs in the output, the amplitude of the output signal remains constant as shown fig. c.



To find the necessary condition for the sustained oscillations, we have to derive the expression for the overall voltage gain of an amplifier with positive feedback and are written as

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

If $A\beta = 1$ then $A_f = \infty$. The gain becomes infinity that means there is output without any input. The amplifier becomes oscillator. The condition $A\beta = 1$ is called ***Barkhausen criterion of oscillation.***

THE STARTING VOLTAGE:

The staring voltage of an oscillator is provided by noise voltage. Noise voltages are produced due to the random motion of electrons in resistors used in the circuit and the active device.

This noise voltage contains almost all the sinusoidal frequencies of very small amplitude. It gets amplified and appears at the output terminals. The amplified noise drives the feedback network, which is either LC network or RC network. Because of this feedback voltage $A\beta$, is maximum at particular frequency f_{osc}, the frequency of oscillation. The phase shift required for positive feedback is produced only for this frequency signal only. Thus, from the noise voltage which contains almost all frequencies, the output of the oscillator will contain only a single sinusoidal frequency.

When the oscillator circuit is switched on, the loop gain $A\beta > 1$, then becomes $A\beta = 1$. The oscillations build up. Once a suitable level is reached, the gain of the amplifier decreases, and the value of the loop gain decreases to unity. So the constant level oscillations are maintained. The requirements of an oscillator circuit are

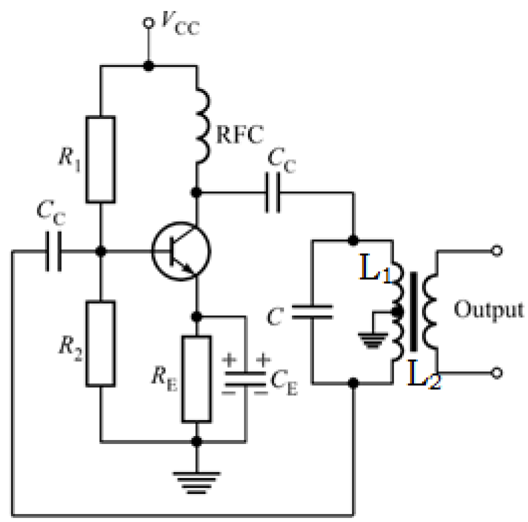
i) There must be a positive feedback.

ii) Initially loop gain $A\beta > 1$.

iii) After, the desired level is reached, the loop gain Aβ must be decreased to unity.

HARTLEY OSCILLATOR:

The RFC radio frequency chock permits an easy flow of DC current and also offers very high impedance for the high frequency currents. RFC is short for DC signal and open for ac signal. Hartley oscillator uses split – tank inductor in the feedback circuit.



The coupling capacitor C_C in the output circuit does not permit the DC currents to go to the tank circuit. The radio – frequency energy developed across the RFC is capacitively coupled to the tan circuit through the coupling capacitor C_C. The circuit oscillates at a frequency

$$f_{osc} = \frac{1}{2\pi\sqrt{L_{eq}C}}$$

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

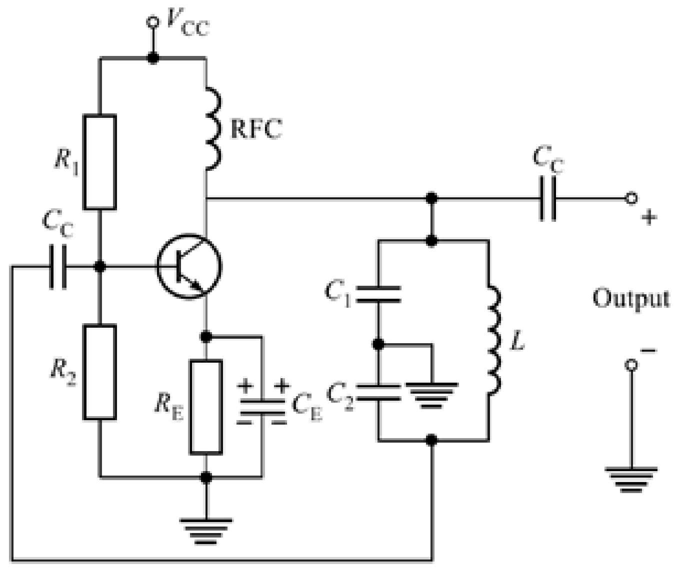
And M is the mutual inductance of an inductor.

COLPITT'S OSCILLATOR:

Colpitts oscillator is widely used in commercial signal generators above 1MHz. The colpitts oscillator uses a split – tank capacitor. The load across the C_2 capacitor provides regenerative feedback required for the sustained oscillations. The frequency of oscillation is given by

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

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



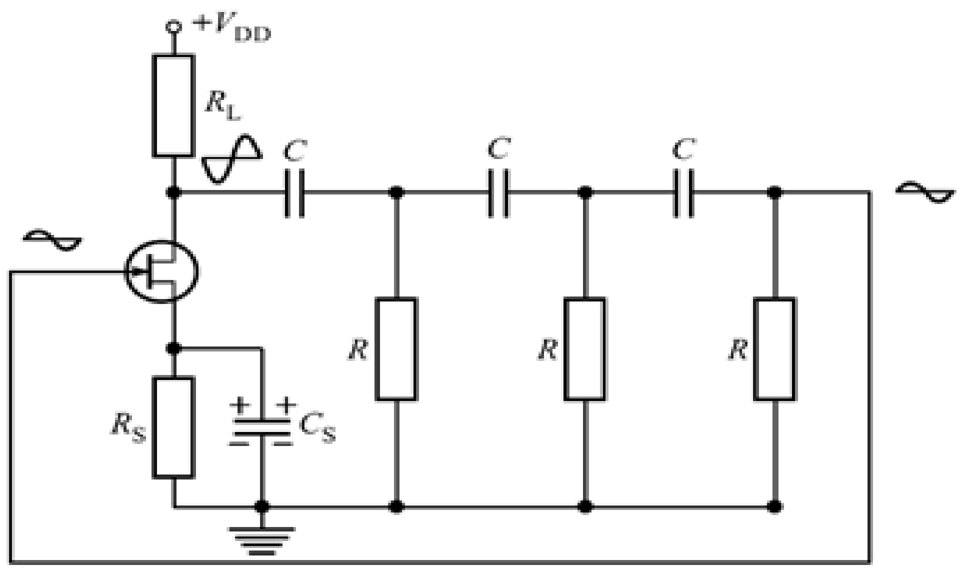
BASIC PRINCIPLES OF RC OSCILLATORS:

The amplifier gives amplification of the input signal and also shifts the phase of the input signal by $180^0$the part of the output is feedback to the input, a negative feedback takes place. The net output decreases. For producing oscillations, positive feedback is required. Positive feedback occurs only when the fed back signal is in phase with the original input signal. This condition can be achieved by two ways. The part of the output of the single stage amplifier when passed through the feedback network, the feedback network provides additional 180^0 phase shift. Thus, a total phase shift of 360^0 occurs. This principle is used in phase – shift network.

Another way of getting 360^0 is to use two stage of an amplifier each giving 180^0. A part of the output is fed back to the input through a feedback network without producing further phase shift. This principle is used in wein bridge oscillator.

PHASE SHIFT OSCILLATOR:

In phase shift oscillator resistor R_S and capacitor C_S in the source circuit provides self – biasing for the amplifier. Output of this amplifier is 180^0 out of phase with input signal. The output of the amplifier is applied to the feedback network. The feedback network is consisting of three RC networks. Each RC network provides a phase shift of 60^0. The total of 180^0 of phase shift is provided by the feedback network. The output of the feedback network is in the same phase as the original input signal of the amplifier.



When the condition $A\beta = 1$ is satisfied the circuit sustain sinusoidal oscillation at the frequency

$$f_{osc} = \frac{1}{2\pi RC\sqrt{6}}$$

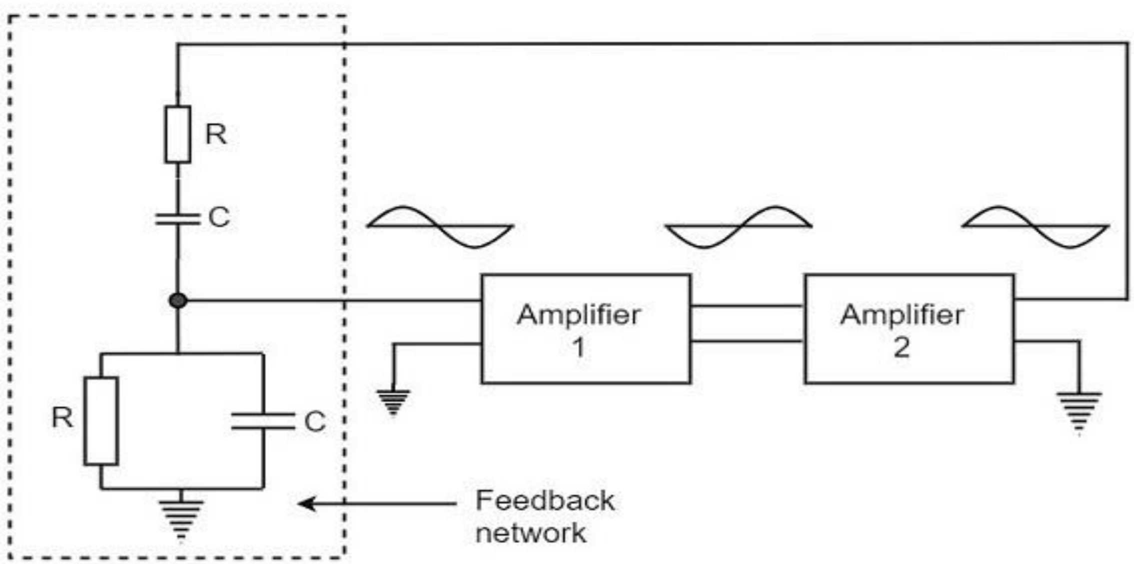
At this frequency, the feedback factor if the feedback network is $\beta = 1/29$. For self starting of oscillations, $A\beta > 1$. Hence the gain of the amplifier must be greater than 29, only then oscillation can start.

WIEN BRIDGE OSCILLATOR:

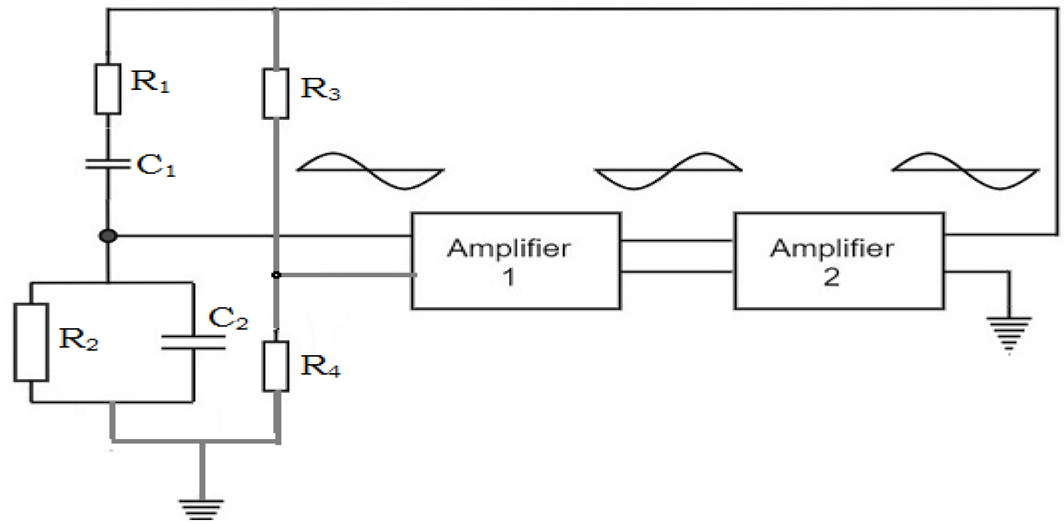
Wien bridge oscillator is used to generate frequencies in the range of 10 Hz to 1MHz. it is used in audio signal generators. It consists of two stage RC coupled amplifier and a feedback network.

A_1 and A_2 represent the two stages of amplifier. The output of the A_2 goes to the feedback network. The voltage across the parallel combination of $R_2C_2$is fed to the input of amplifier A_1. The net phase shift through two amplifiers is zero. Therefore, it is the case of positive feedback. The phase shift through the feedback network must be zero, and this condition occurs at a frequency

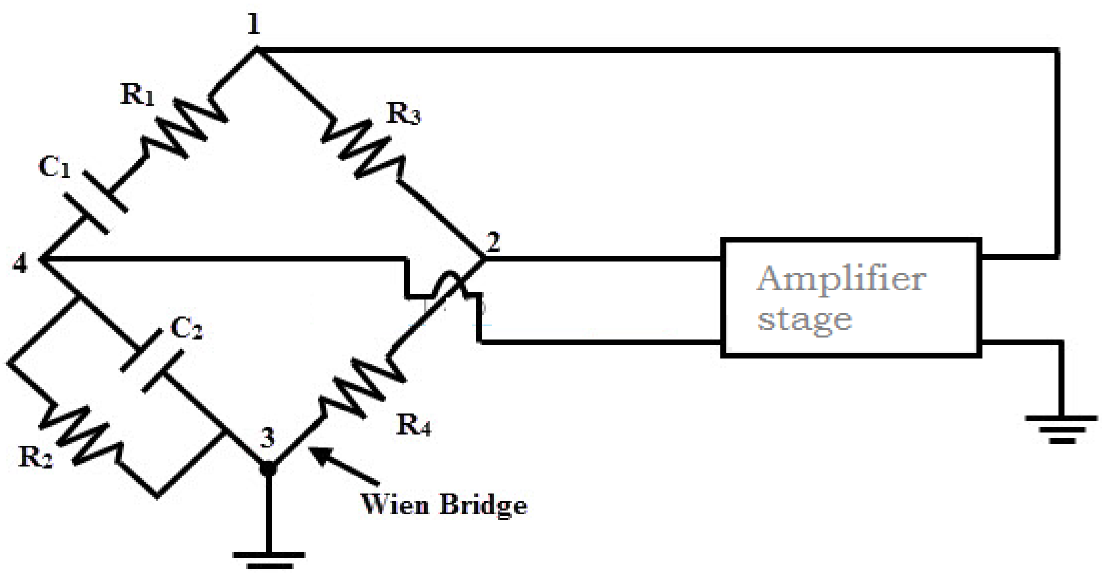
$$f_{osc} = \frac{1}{2\pi\sqrt{R_1R_2C_1C_2}}$$



When this condition is satisfied the feedback factor $\beta = 1/3$. This means that the amplifier must have gain of at least 3 to satisfy the barkhausen criteria $A\beta = 1$. To have a gain of as low as 3 a negative feedback is added by introducing resistor divider network R_3 and R_4 as shown in below figure.



The resistors R_3 and R_4 provide negative feedback and are connected to the lower input terminal. Frequency of the oscillator can be changed by varying two capacitors C_1 and C_2 simultaneously. We can change frequency range by switching various resistors R_1 and R_2.



Reading materials for students

Reference:

Basic Electronics and Linear Circuits
D. C. Kulshreshtha, N. N. Bhargava, and S.C. Gupta