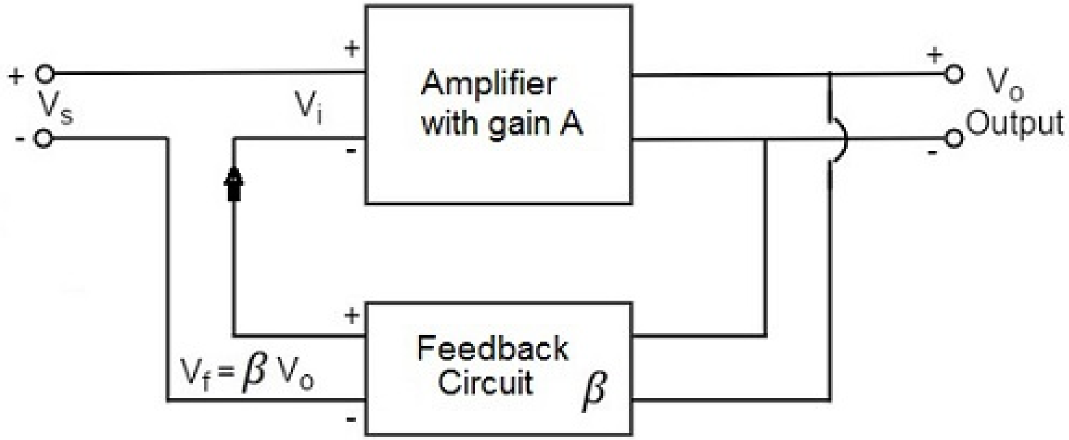
Oscillators

Feedback Amplifier

A feedback amplifier generally consists of two parts. They are the amplifier and the feedback circuit.

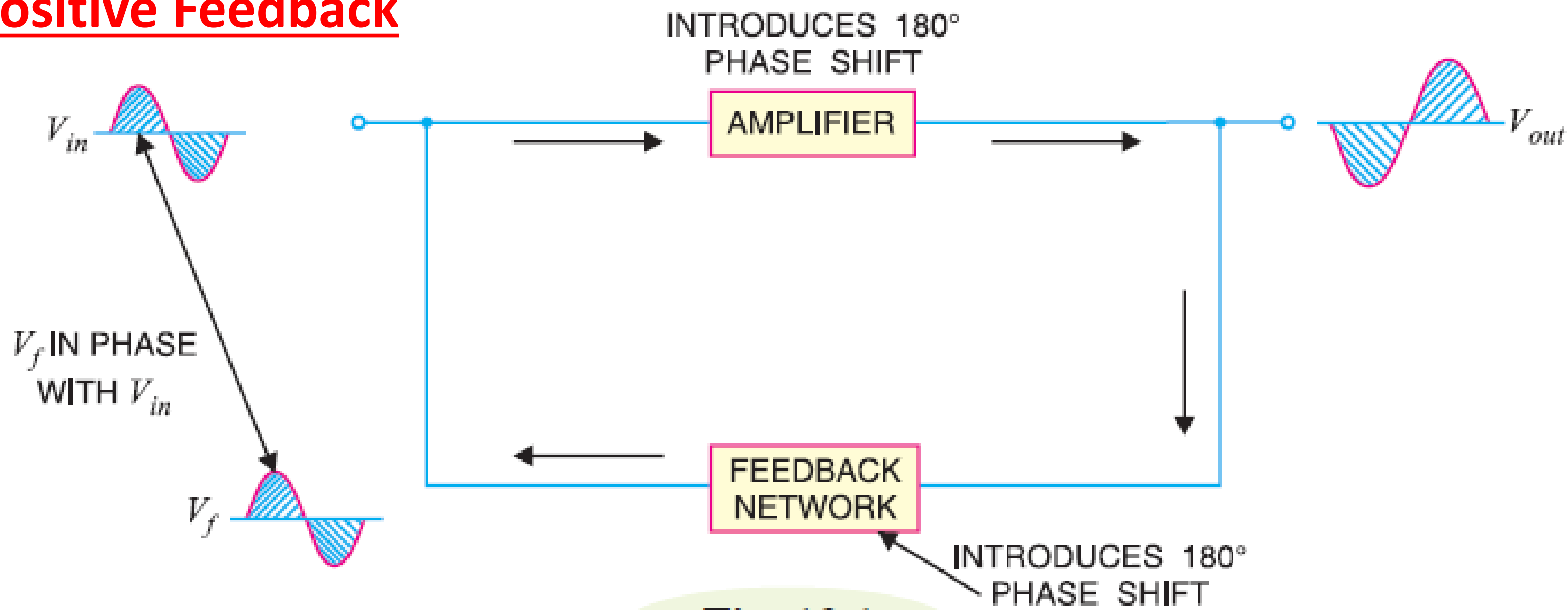


The feedback may be positive or negative. The feedback network extracts a voltage $V_f = \beta V_o$ from the output V_o of the amplifier. This voltage is added for positive feedback and subtracted for negative feedback, from the signal voltage V_s.

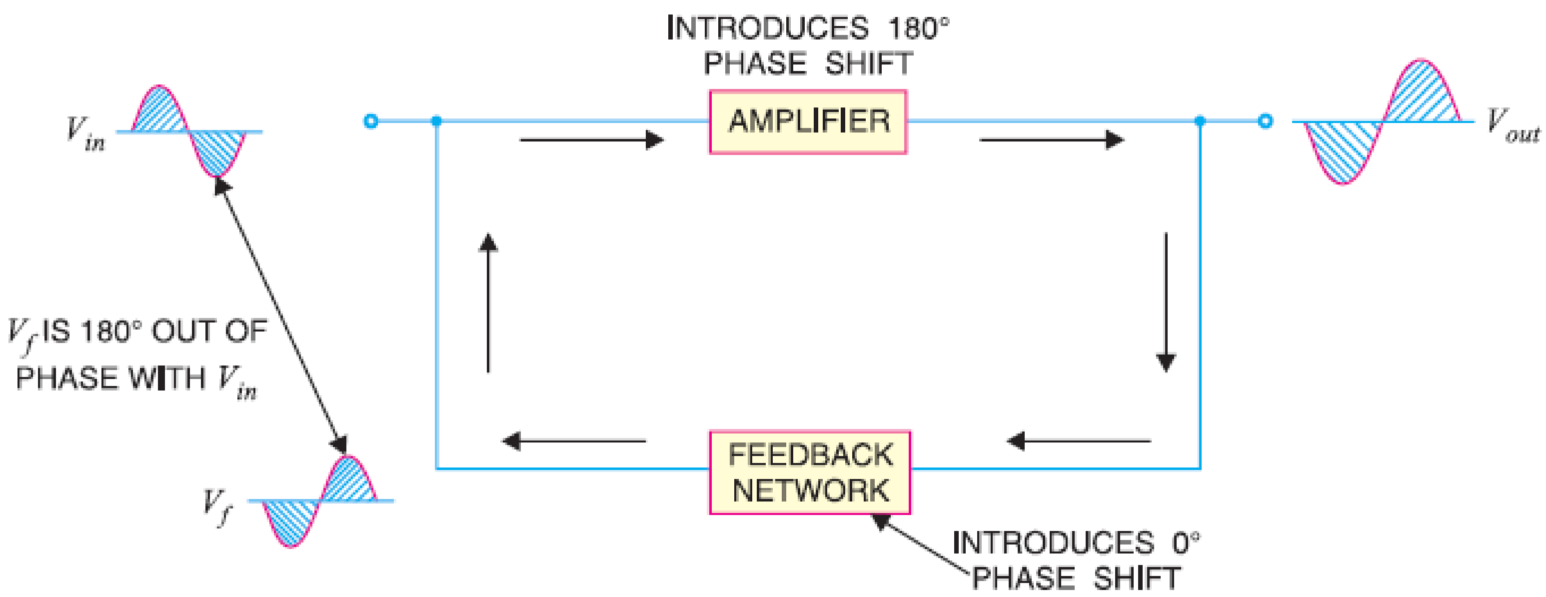
For positive feedback, $V_i = V_s + V_f = V_s + \beta V_o$

For negative feedback, $V_i = V_s - V_f = V_s - \beta V_o$

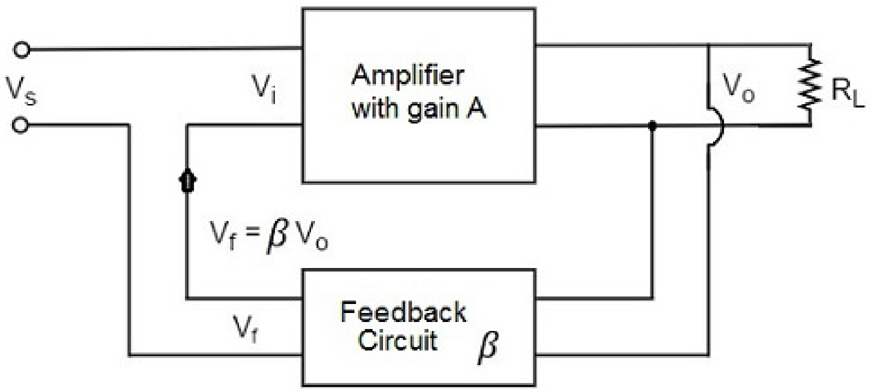
Positive Feedback



Negative Feedback

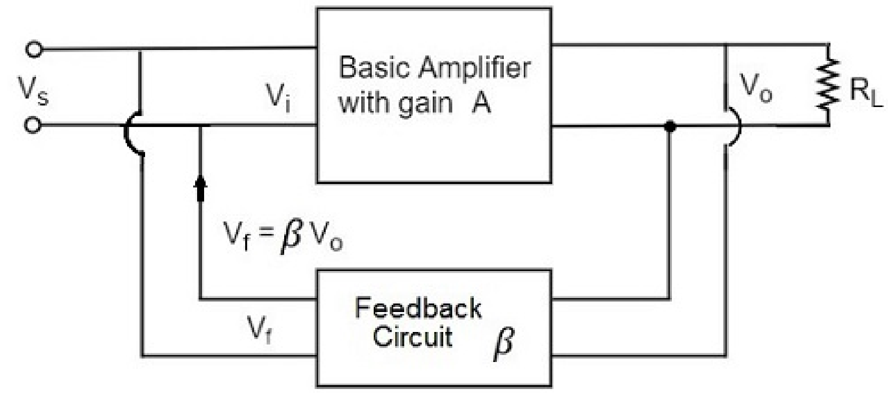


Voltage-Series Feedback



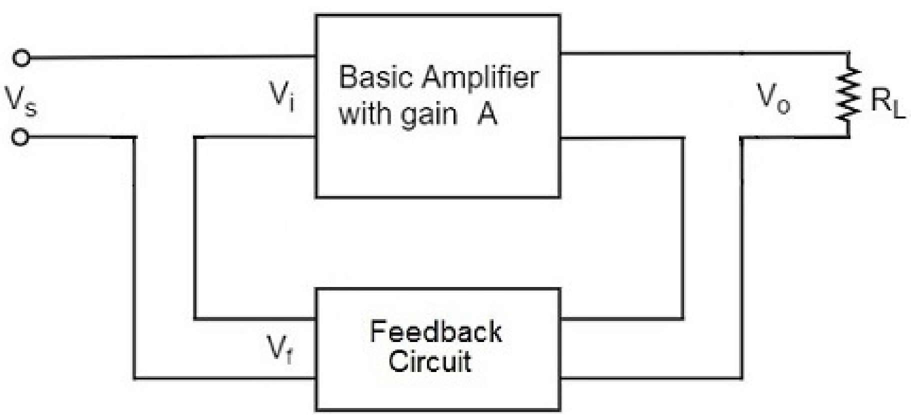
a fraction of the output voltage is applied in series with the input voltage

Voltage-Shunt Feedback

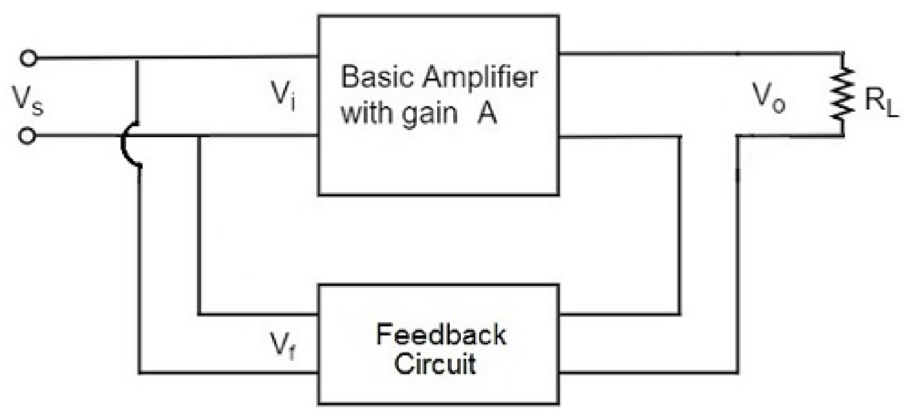


a fraction of the output voltage is applied in parallel with the input voltage

Current-Series Feedback



Current-Shunt Feedback



An oscillator is a circuit which produces a continuous, repeated, alternating waveform without any input signal. Oscillators basically convert DC power to AC power. The initial signal to trigger the oscillations is obtained from noise voltage (comes from switching the system on) with a wide frequency spectrum.

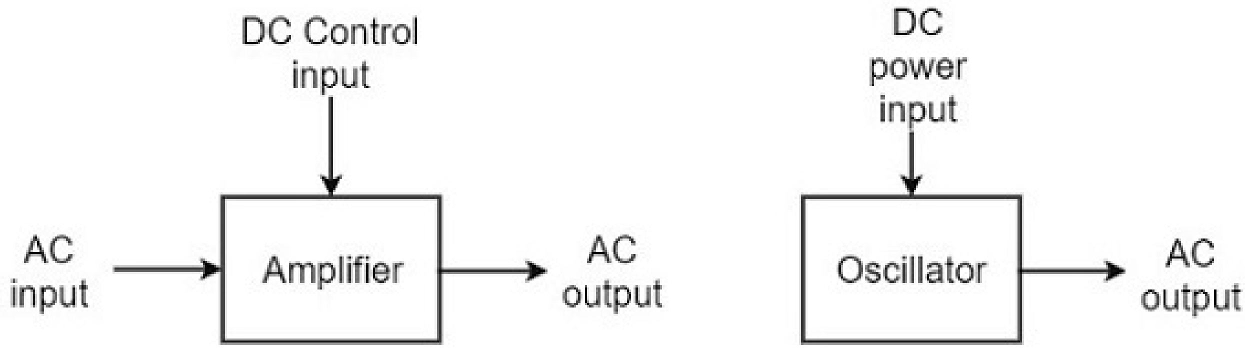
There are basically types of Oscillators

1. Sinusoidal Oscillators – these are known as Harmonic Oscillators and are generally a "LC Tuned-feedback" or "RC tuned-feedback" type Oscillator that generates a purely sinusoidal waveform which is of constant amplitude and frequency.

2. Non-Sinusoidal Oscillators – these are known as Relaxation Oscillators and generate complex non-sinusoidal waveforms that changes very quickly from one condition of stability to another such as "Square-wave", "Triangular-wave" or "Sawtoothed-wave" type waveforms.

Amplifier vs. Oscillator

An **amplifier** increases the signal strength of the input signal applied, whereas an **oscillator** generates a signal without that input signal, but it requires DC for its operation. This is the main difference between an amplifier and an oscillator.



The frequency, waveform, and magnitude of AC power generated by an amplifier, is controlled by the AC signal voltage applied at the input, whereas those for an oscillator are controlled by the components in the circuit itself, which means no external controlling voltage is required.

Sinusoidal Oscillators

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.

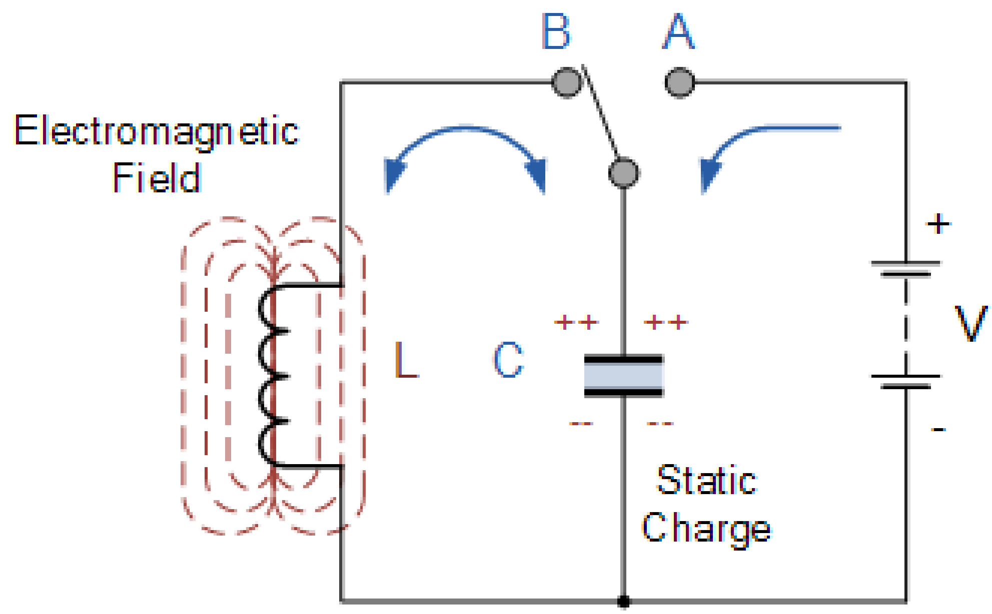
RC Oscillators – There oscillators use resistors and capacitors and are used to generate low or audio-frequency signals. Thus they are also known as audio-frequency (A.F.) oscillators. Such oscillators are Phase –shift and Wein-bridge oscillators.

Crystal Oscillators – These oscillators use quartz crystals and are used to generate highly stabilized output signal with frequencies up to 10 MHz. The Piezo oscillator is an example of a crystal oscillator.

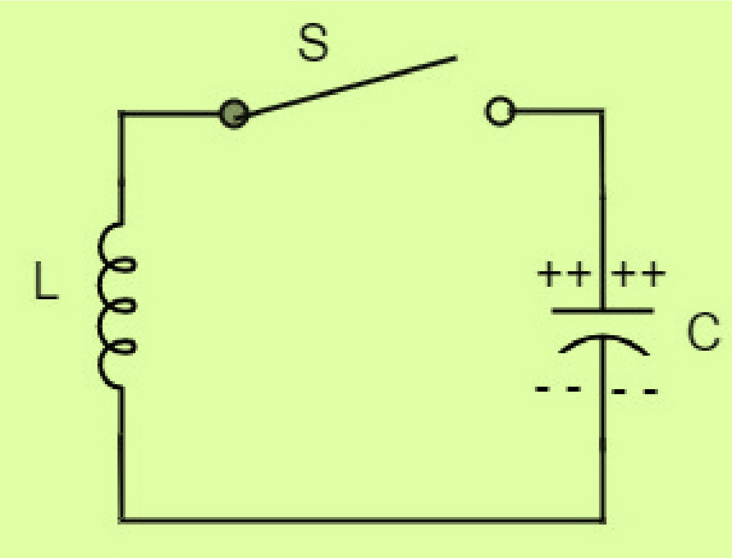
Negative-resistance Oscillator – These oscillators use negative-resistance characteristic of the devices such as tunnel devices. A tuned diode oscillator is an example of a negative-resistance oscillator.

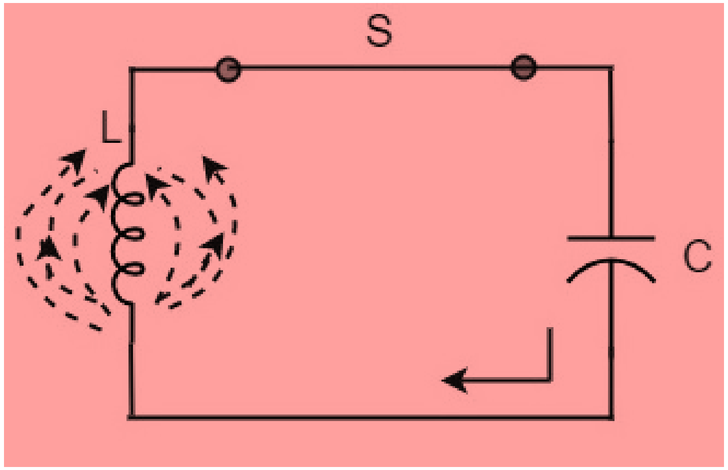
Basic Oscillatory Circuit

An oscillatory circuit produces electrical oscillations of a desired frequency. They are also known as tank circuits. A simple tank circuit comprises of an inductor L and a capacitor C both of which together determine the oscillatory frequency of the circuit.



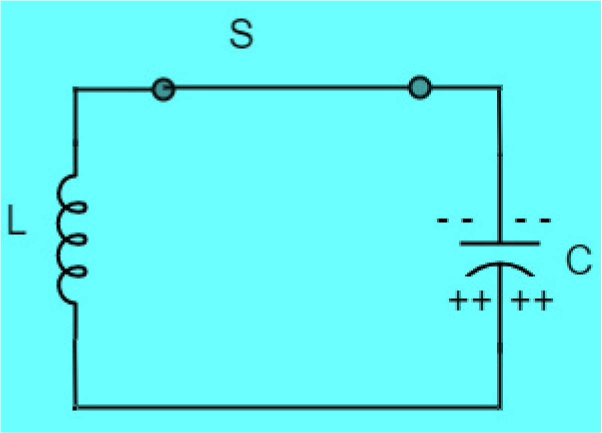
The capacitor stores energy in the form of an electrostatic field and which produces a potential (*static voltage*) across its plates, while the inductive coil stores its energy in the form of an electromagnetic field. The capacitor is charged up to the DC supply voltage, V by putting the switch in position A. When the capacitor is fully charged the switch changes to position B.



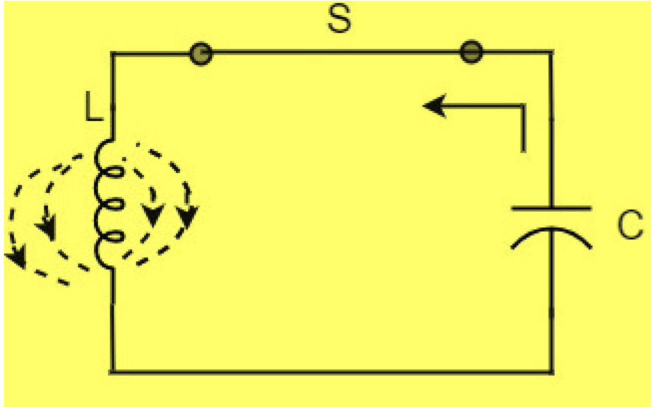


The capacitor in this circuit is already charged using a dc source. The capacitor holds some electrostatic energy and there is a voltage across the capacitor.

When the switch S is closed, the capacitor discharges and the current flows through the inductor. Due to the inductive effect, the current builds up slowly towards a maximum value. Once the capacitor discharges completely, the magnetic field around the coil is maximum.



Once the capacitor is discharged completely, the magnetic field begins to collapse and produces a counter EMF according to Lenz's law. This will again charge the capacitor.

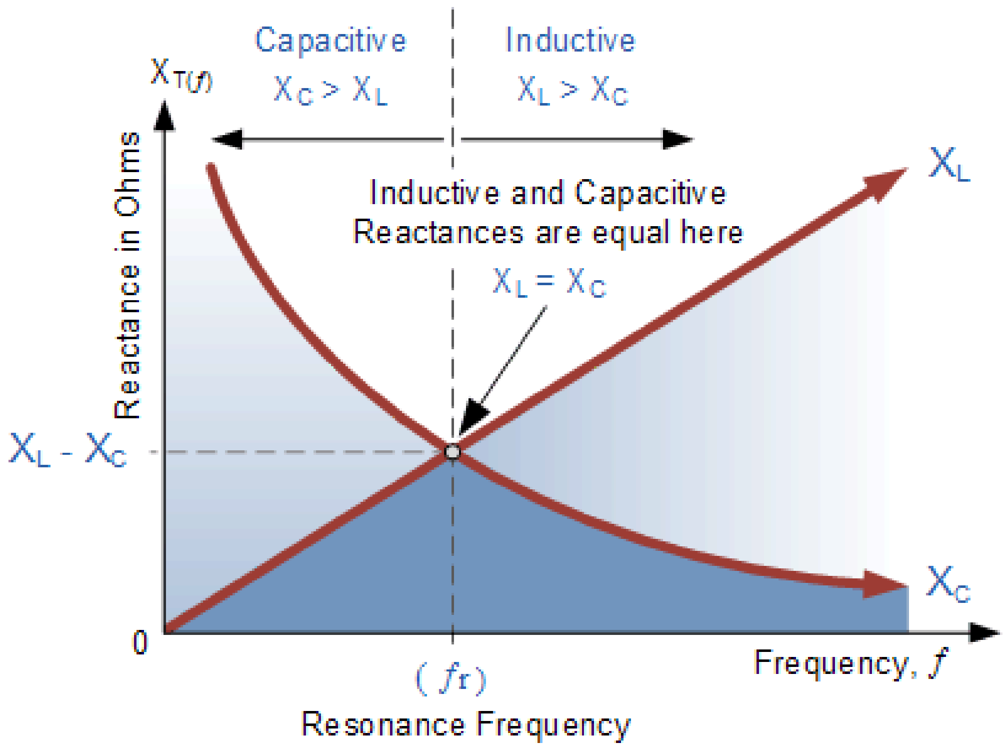


Once the capacitor is fully charged, it starts to discharge to build up a magnetic field around the coil.

This continuation of charging and discharging results in alternating motion of electrons or an oscillatory current. The interchange of energy between L and C produce continuous oscillations. In an ideal circuit, where there are no losses, the oscillations would continue indefinitely. In a practical tank circuit, there occur losses such as resistive and radiation losses in the coil and dielectric losses in the capacitor. These losses result in damped oscillations.

Resonance Frequency (Frequency of Oscillations)

The frequency of the oscillatory voltage depends upon the value of the inductance and capacitance in the LC tank circuit. We now know that for *resonance* to occur in the tank circuit, there must be a frequency point were the value of X_C, the capacitive reactance is the same as the value of X_L, the inductive reactance ($X_L = X_C$).



$$X_L = 2\pi f L \quad \text{and} \quad X_C = \frac{1}{2\pi f C}$$

$$\text{at resonance:} \quad X_L = X_C$$

$$\therefore \; 2\pi f L = \frac{1}{2\pi f C}$$

$$2\pi f^{2} L = \frac{1}{2\pi C}$$

$$\therefore \; f^{2} = \frac{1}{(2\pi)^{2} LC}$$

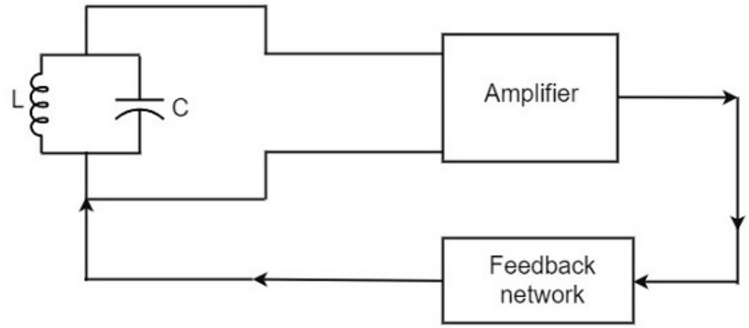
$$f = \frac{\sqrt{1}}{\sqrt{(2\pi)^{2} LC}}$$

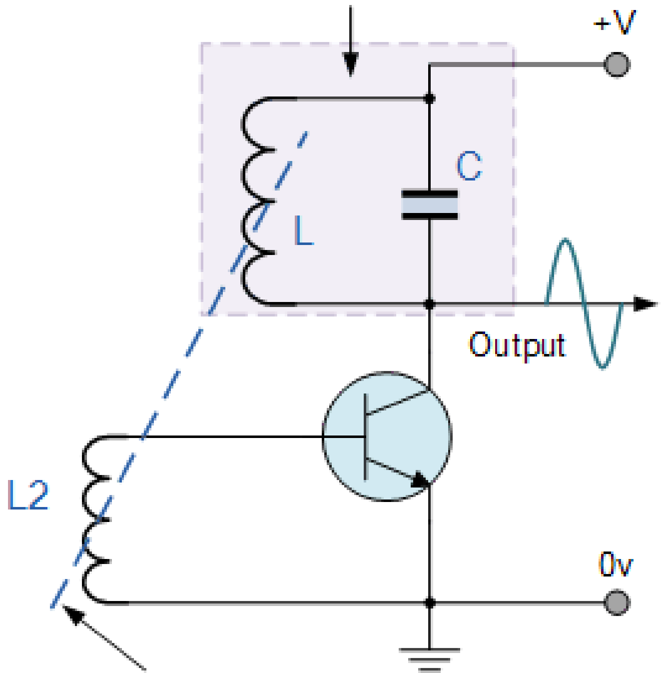
Resonance Frequency calculation

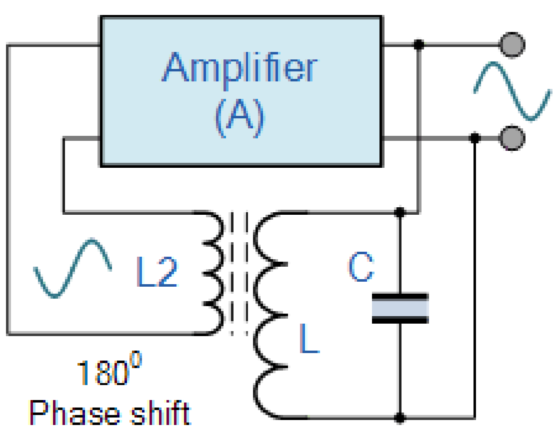
$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

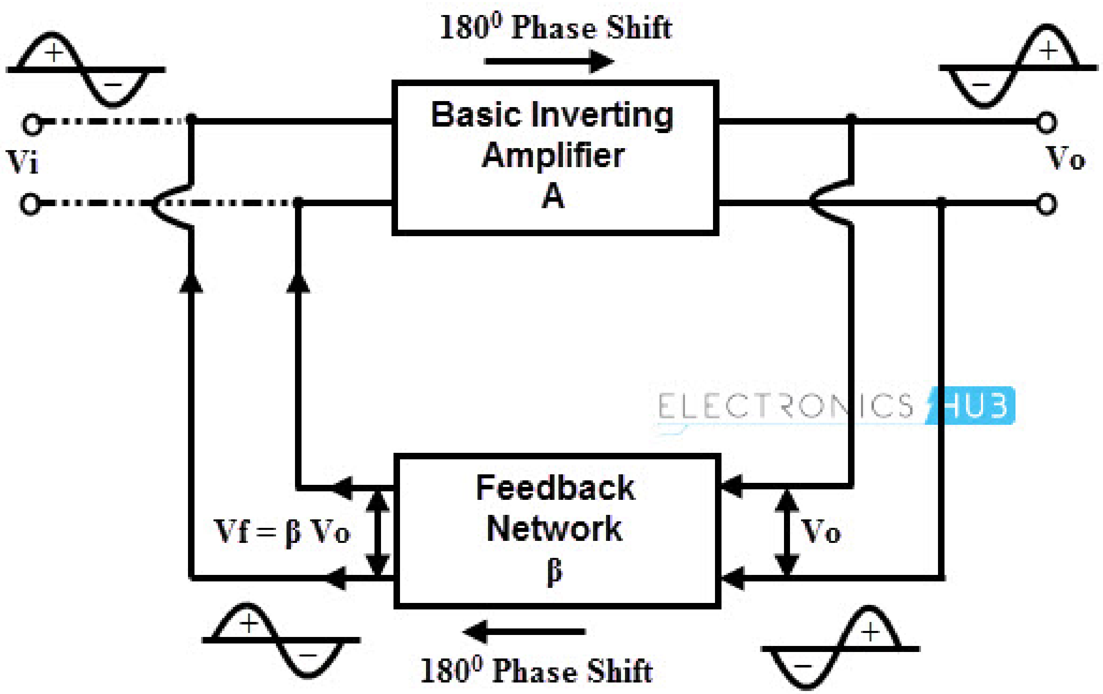
To keep the oscillations going in an LC tank circuit, we have to replace all the energy lost in each oscillation and also maintain the amplitude of these oscillations at a constant level. The amount of energy replaced must therefore be equal to the energy lost during each cycle. The simplest way of replacing this lost energy is to take part of the output from the LC tank circuit, amplify it and then feed it back into the LC circuit again. This process can be achieved using a voltage amplifier using an op-amp, FET or bipolar transistor as its active device. However, if the loop gain of the feedback amplifier is too small, the desired oscillation decays to zero and if it is too large, the waveform becomes distorted.

Practical Oscillator Circuit

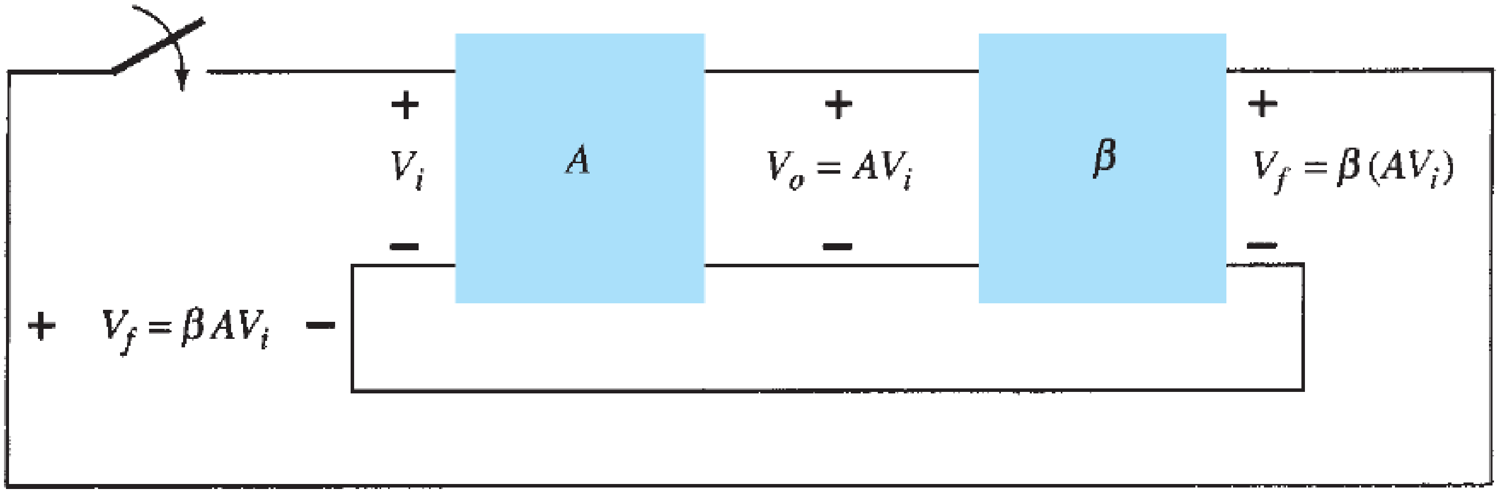








Oscillators are nothing but the amplifier circuits which are provided with a positive or regenerative feedback wherein a part of the output signal is fed back to the input. Here the amplifier consists of an amplifying active element which can be a transistor or an Op-Amp and the back-fed in-phase signal is held responsible to keep-up (sustain) the oscillations by making-up for the losses in the circuit.

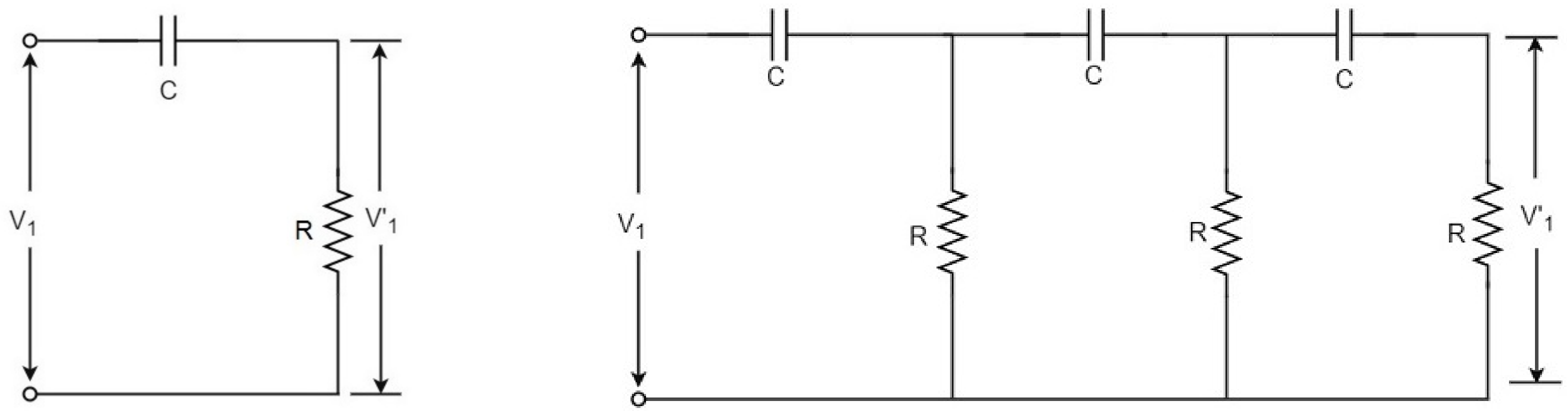


When the switch at the amplifier input is open, no oscillation occurs. Consider that we have a *fictitious* voltage at the amplifier input V_i . This results in an output voltage $V_o = AV_i$ after the amplifier stage and in a voltage $V_f = \beta(AV_i)$ after the feedback stage. Thus, we have a feedback voltage $V_f = \beta AV_i$, where βA is referred to as the *loop gain.*

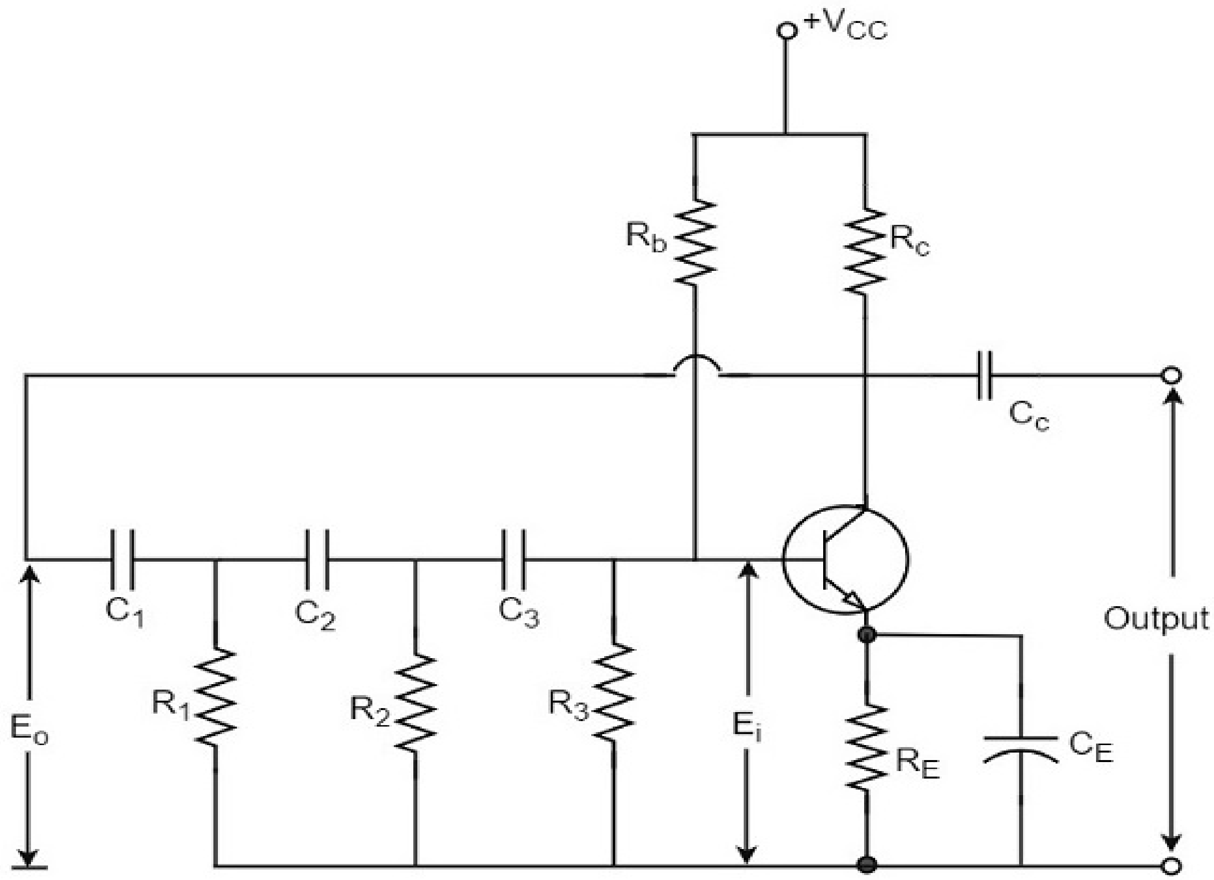
The output waveform will still exist after the switch is closed if the condition $\beta A = 1$ is met. This is known as the B*arkhausen criterion* for oscillation.

R-C or Phase shift Oscillator

We know that the output voltage of an RC circuit for a sinewave input leads the input voltage. The phase angle by which it leads is determined by the value of RC components used in the circuit.



The output voltage V_1' across the resistor R leads the input voltage applied input V_1 by some phase angle ϕ^o. If R were reduced to zero, V_1' will lead the V_1 by 90^o i.e., $\phi^o = 90^o$. However, adjusting R to zero would be impracticable, because it would lead to no voltage across R. Therefore, in practice, R is varied to such a value that makes V_1' to lead V_1 by 60^o. So the right side figure will produce total phase shift of 180^0.

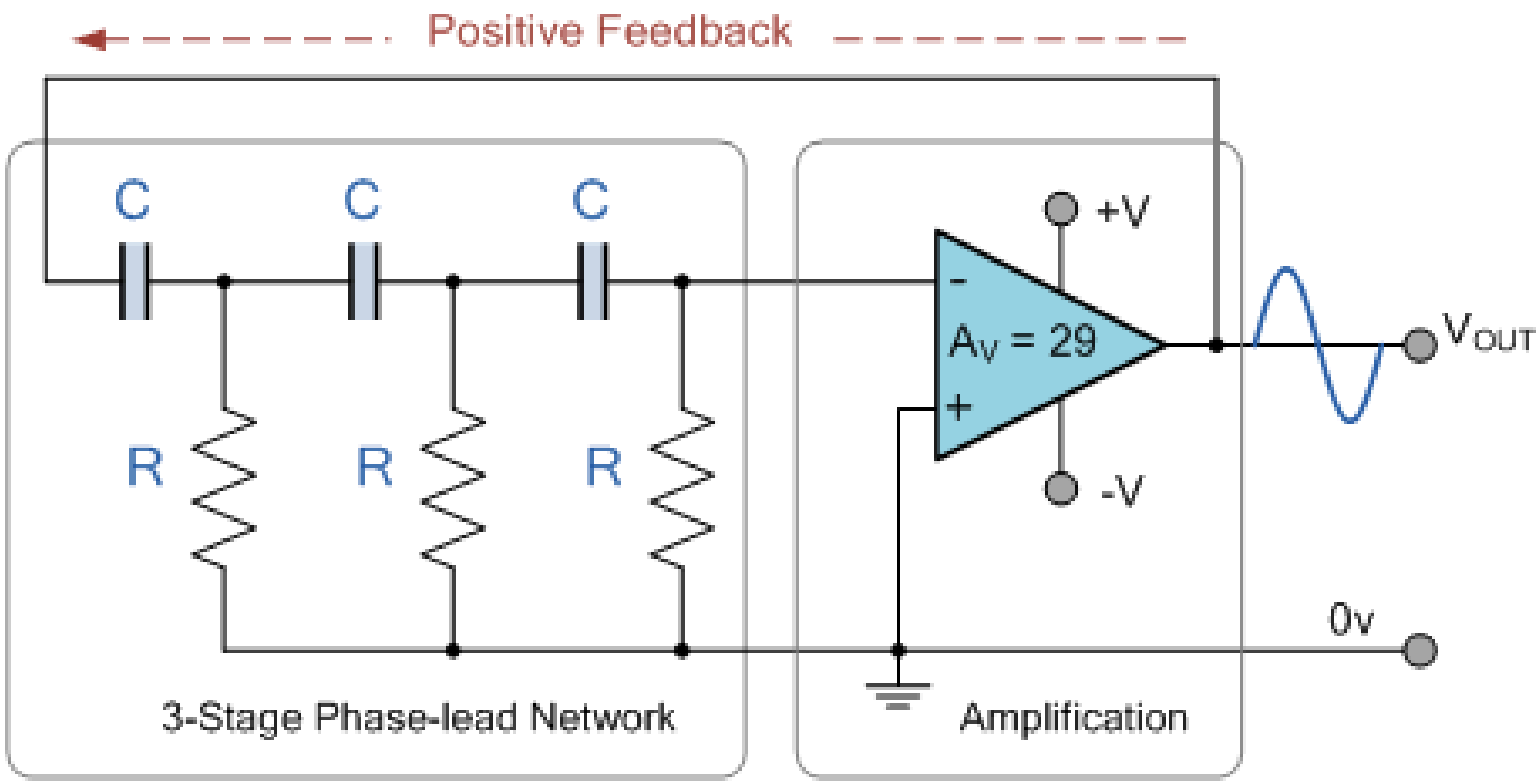


If the three resistors, R are equal in value, that is $R_1 = R_2 = R_3$, and the capacitors, C in the phase shift network are also equal in value, $C_1 = C_2 = C_3$, then the frequency of oscillations produced by the RC oscillator is simply given as:

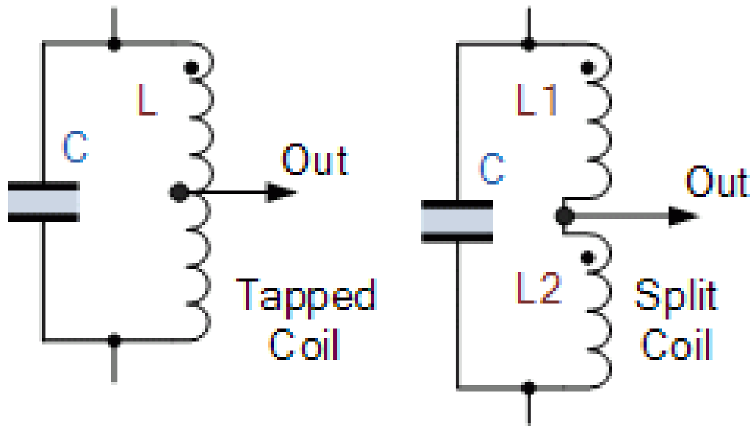
$$f_r = \frac{1}{2\pi RC\sqrt{2N}}$$

Where N is the number of RC feedback stages.

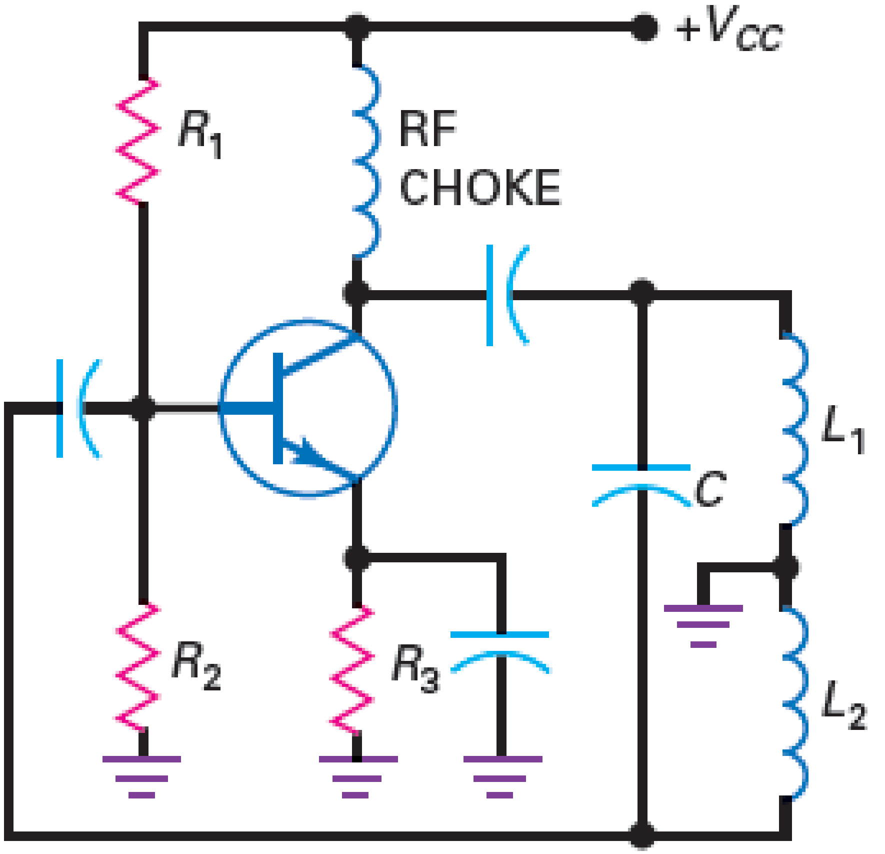
Op-amp Phase-lead RC Oscillator Circuit



Hartley Oscillator

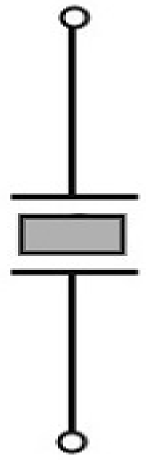


The Hartley Oscillator design uses two inductive coils in series with a parallel capacitor to form its resonance tank circuit producing sinusoidal oscillations and typically tuned to produce RF waves. The tuned LC circuit is connected between the collector and the base of a transistor amplifier. As far as the oscillatory voltage is concerned, the emitter is connected to a tapping point on the tuned circuit coil. The feedback part of the tuned LC tank circuit is taken from the center tap of the inductor coil or even two separate coils in series which are in parallel with a variable capacitor.

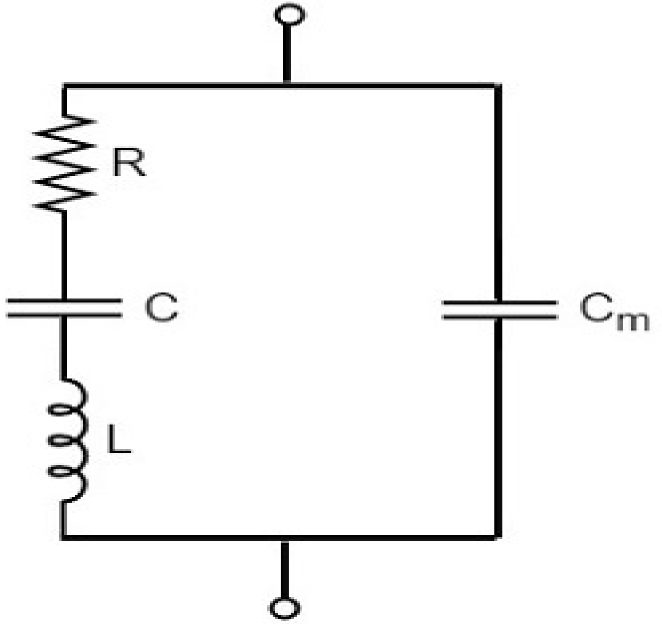

+V_{CC}
R_1
RF
CHOKE
L_1
C
R_2
R_3
L_2

Crystal Oscillators

In RC and LC oscillators the values of resistance, capacitance and inductance vary with temperature and hence the frequency gets affected. In order to avoid this problem, the piezo electric crystals are being used in oscillators. When a piezo electric crystal is subjected to a proper alternating potential, it vibrates mechanically. The amplitude of mechanical vibrations becomes maximum when the frequency of alternating voltage is equal to the natural frequency of the crystal. Crystal Oscillators are used to improve the accuracy and stability of the oscillation frequency.

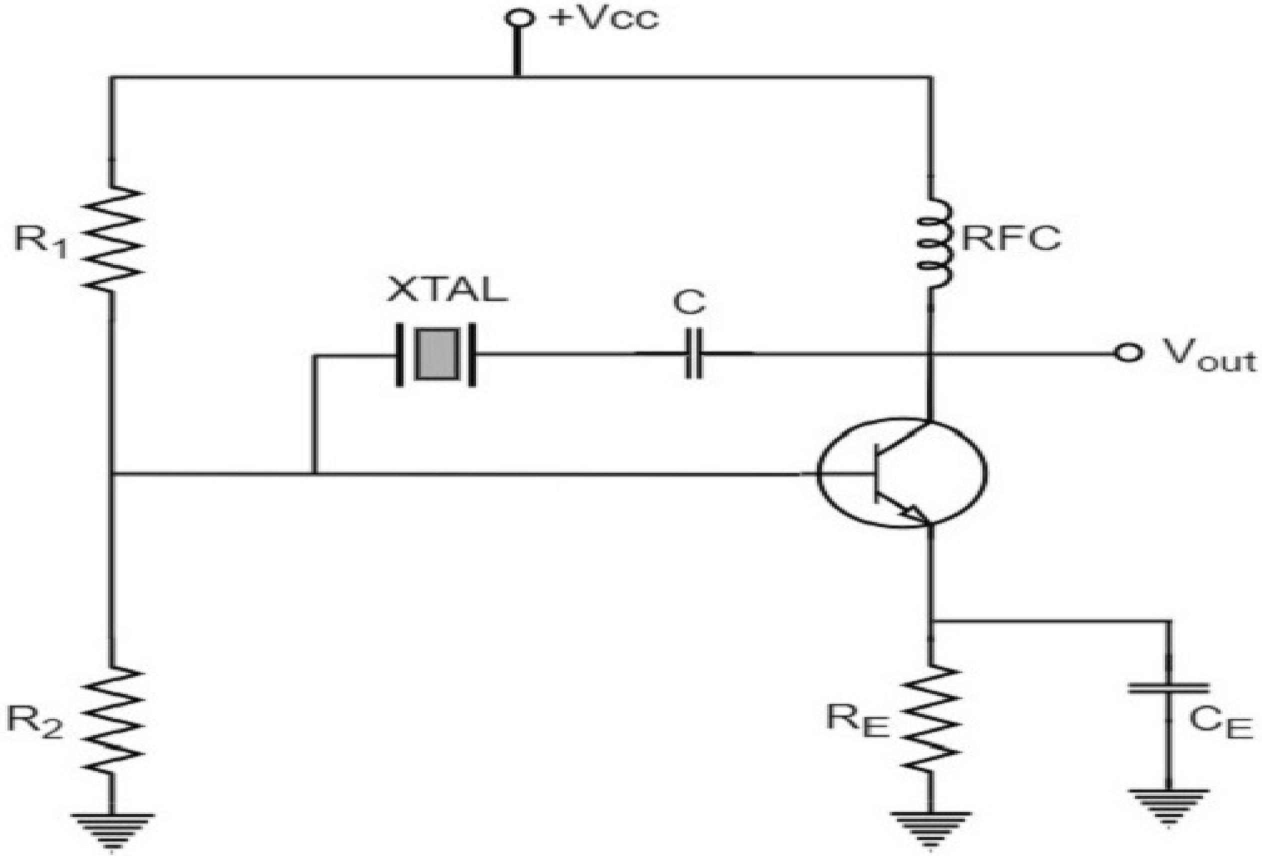


Symbol of a Crystal



Equivalent circuit of a crystal

The above equivalent circuit consists of a series R-L-C circuit in parallel with a capacitance C_m. When the crystal mounted across the AC source is not vibrating, it is equivalent to the capacitance C_m. When the crystal vibrates, it acts like a tuned R-L-C circuit.



The crystal (XTAL) is connected as a series element in the feedback path from collector to the base. The crystal acts like a large inductor in series with a small capacitor. The circuit frequency of oscillation is set by the series resonant frequency of the crystal and its value is given by the relation,

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