

UNIT IV

OSCILLATOR

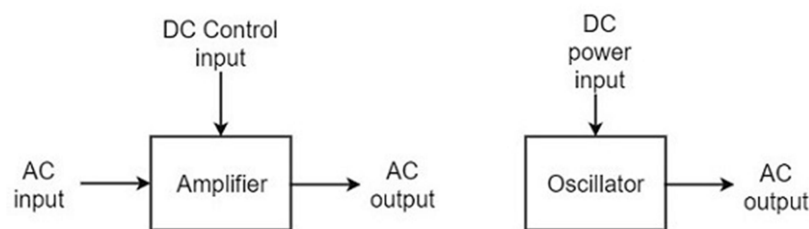
Definition:

An **oscillator** generates output without any ac input signal. An electronic oscillator is a circuit which converts dc energy into ac at a very high frequency. An amplifier with a positive feedback can be understood as an oscillator.

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.

Take a look at the following illustration. It clearly shows how an amplifier takes energy from d.c. power source and converts it into a.c. energy at signal frequency. An oscillator produces an oscillating a.c. signal on its own.



The frequency, waveform, and magnitude of a.c. power generated by an amplifier, is controlled by the a.c. 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.

Classification of Oscillators :

Electronic oscillators are classified mainly into the following two categories

- **Sinusoidal Oscillators** – The oscillators that produce an output having a sine waveform are called **sinusoidal** or **harmonic oscillators**. Such oscillators can provide output at frequencies ranging from 20 Hz to 1 GHz.
- **Non-sinusoidal Oscillators** – The oscillators that produce an output having a square, rectangular or saw-tooth waveform are called **non-sinusoidal** or **relaxation oscillators**. Such oscillators can provide output at frequencies ranging from 0 Hz to 20 MHz.

Sinusoidal Oscillators :

Sinusoidal oscillators can be classified in the following categories

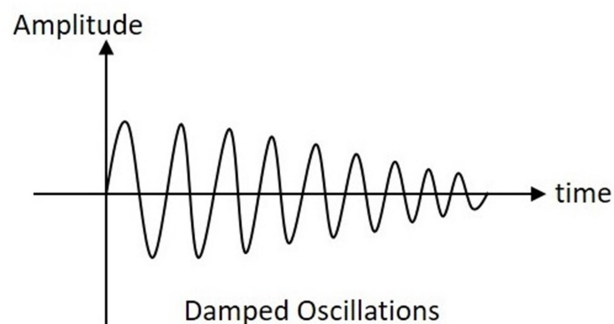
- **Tuned Circuit Oscillators** – These oscillators use a tuned-circuit consisting of inductors (L) and capacitors (C) and are used to generate high-frequency signals. Thus they are also known as radio frequency R.F. oscillators. Such oscillators are Hartley, Colpitts, Clapp-oscillators etc.
- **RC Oscillators** – These 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.

Nature of Sinusoidal Oscillations :

The nature of oscillations in a sinusoidal wave are generally of two types. They are **damped** and **undamped oscillations**.

Damped Oscillations :

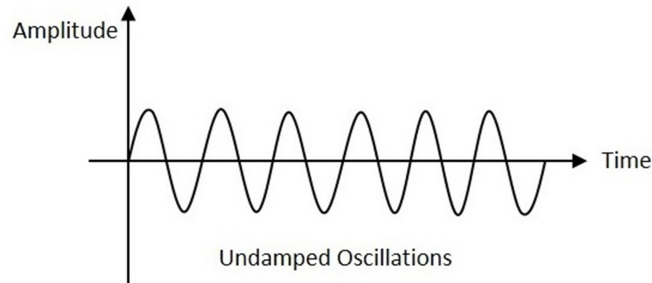
The electrical oscillations whose amplitude goes on decreasing with time are called as **Damped Oscillations**. The frequency of the damped oscillations may remain constant depending upon the circuit parameters.



Damped oscillations are generally produced by the oscillatory circuits that produce power losses and doesn't compensate if required.

Undamped Oscillations :

The electrical oscillations whose amplitude remains constant with time are called as **Undamped Oscillations**. The frequency of the Undamped oscillations remains constant.



Undamped oscillations are generally produced by the oscillatory circuits that produce no power losses and follow compensation techniques if any power losses occur.

Hartley Oscillator

A very popular local oscillator circuit that is mostly used in radio receivers is the Hartley Oscillator circuit. The constructional details and operation of a Hartley oscillator are as discussed below.

Construction :

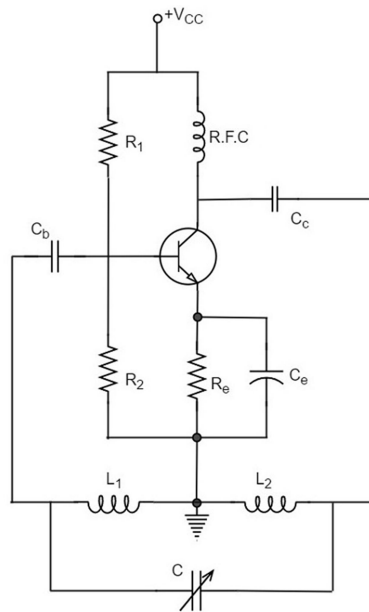
In the circuit diagram of a Hartley oscillator shown below, the resistors R_1 , R_2 and R_e provide necessary bias condition for the circuit. The capacitor C_e provides a.c. ground thereby providing any signal degeneration. This also provides temperature stabilization.

The capacitors C_c and C_b are employed to block d.c. and to provide an a.c. path. The radio frequency choke (R.F.C) offers very high impedance to high frequency currents which means it shorts for d.c. and opens for a.c. Hence it provides d.c. load for collector and keeps a.c. currents out of d.c. supply source

Tank Circuit :

The frequency determining network is a parallel resonant circuit which consists of the inductors L_1 and L_2 along with a variable capacitor C . The junction of L_1 and L_2 are earthed. The coil L_1 has its one end connected to base via C_c and the other to emitter via C_e . So, L_2 is in the output circuit. Both the coils L_1 and L_2 are inductively coupled and together form an Auto-transformer.

The following circuit diagram shows the arrangement of a Hartley oscillator. The tank circuit is shunt fed in this circuit. It can also be a series-fed.



Operation :

When the collector supply is given, a transient current is produced in the oscillatory or tank circuit. The oscillatory current in the tank circuit produces a.c. voltage across L_1 .

The auto-transformer made by the inductive coupling of L_1 and L_2 helps in determining the phase shift is provided by the transformer, which makes 360° phase shift between the input and output voltages frequency and establishes the feedback. As the CE configured transistor provides 180° phase shift, another 180° .

This makes the feedback positive which is essential for the condition of oscillations. When the loop gain $|\beta A|$ of the amplifier is greater than one, oscillations are sustained in the circuit.

Frequency

The equation for **frequency of Hartley oscillator** is given as

$$f = \frac{1}{2\pi\sqrt{L_T C}}$$

$$L_T = L_1 + L_2 + 2M$$

Here, L_T is the total cumulatively coupled inductance; L_1 and L_2 represent inductances of 1st and 2nd coils; and M represents mutual inductance.

Mutual inductance is calculated when two windings are considered.

Advantages :

- Instead of using a large transformer, a single coil can be used as an auto-transformer.
- Frequency can be varied by employing either a variable capacitor or a variable inductor.
- Less number of components are sufficient.
- The amplitude of the output remains constant over a fixed frequency range.

Disadvantages :

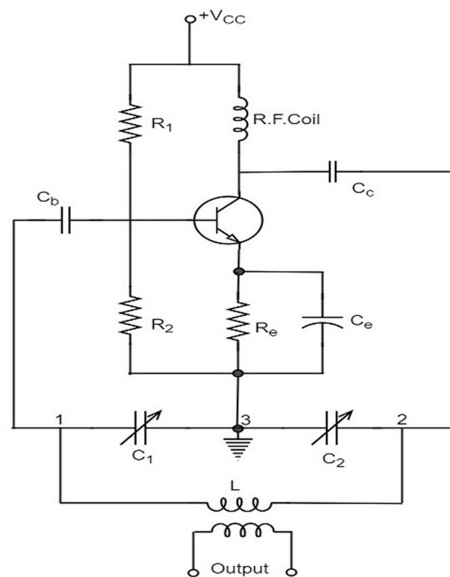
- It cannot be a low frequency oscillator.
- Harmonic distortions are present.

Applications :

- It is used to produce a sinewave of desired frequency.
- Mostly used as a local oscillator in radio receivers.
- It is also used as R.F. Oscillator.

Colpitts Oscillator :

A Colpitts oscillator looks just like the Hartley oscillator but the inductors and capacitors are replaced with each other in the tank circuit.

Construction :

The resistors R_1 , R_2 and R_e provide necessary bias condition for the circuit. The capacitor C_e provides a.c. ground thereby providing any signal degeneration. This also provides temperature stabilization.

The capacitors C_c and C_b are employed to block d.c. and to provide an a.c. path. The radio frequency choke (R.F.C) offers very high impedance to high frequency currents which means it shorts for d.c. and opens for a.c. Hence it provides d.c. load for collector and keeps a.c. currents out of d.c. supply source.

Tank Circuit :

The frequency determining network is a parallel resonant circuit which consists of variable capacitors C_1 and C_2 along with an inductor L . The junction of C_1 and C_2 are earthed. The capacitor C_1 has its one end connected to base via C_c and the other to emitter via C_e . the voltage developed across C_1 provides the regenerative feedback required for the sustained oscillations.

Operation :

When the collector supply is given, a transient current is produced in the oscillatory or tank circuit. The oscillatory current in the tank circuit produces a.c. voltage across C_1 which are applied to the base emitter junction and appear in the amplified form in the collector circuit and supply losses to the tank circuit.

If terminal 1 is at positive potential with respect to terminal 3 at any instant, then terminal 2 will be at negative potential with respect to 3 at that instant because terminal 3 is grounded. Therefore, points 1 and 2 are out of phase by 180° .

As the CE configured transistor provides 180° phase shift, it makes 360° phase shift between the input and output voltages. Hence, feedback is properly phased to produce continuous Undamped oscillations. When the loop gain $|\beta A|$ of the amplifier is greater than one, oscillations are sustained in the circuit.

Frequency

The equation for frequency of Colpitts oscillator is given as

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

C_T is the total capacitance of C_1 and C_2 connected in series.

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$C_T = \frac{C_1 \times C_2}{C_1 + C_2}$$

Advantages :

- Colpitts oscillator can generate sinusoidal signals of very high frequencies.
- It can withstand high and low temperatures.

- The frequency stability is high.
- Frequency can be varied by using both the variable capacitors.
- Less number of components are sufficient.
- The amplitude of the output remains constant over a fixed frequency range.

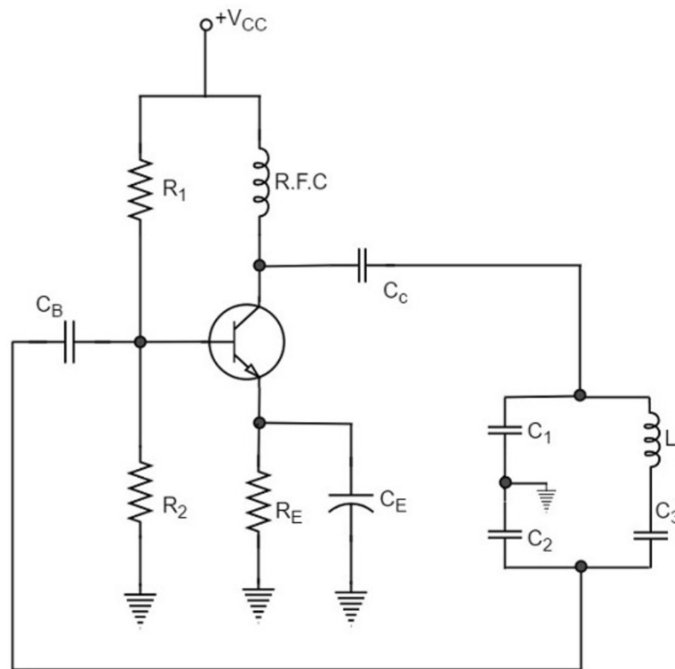
Applications :

- Colpitts oscillator can be used as High frequency sinewave generator.
- This can be used as a temperature sensor with some associated circuitry.
- Mostly used as a local oscillator in radio receivers.
- It is also used as R.F. Oscillator.
- It is also used in Mobile applications.
- It has got many other commercial applications.

Clapp Oscillator :

Another oscillator which is an advanced version of Colpitts oscillator is the **Clapp Oscillator**. This circuit is designed by making a few changes to the Colpitts oscillator.

The circuit differs from the Colpitts oscillator only in one respect; it contains one additional capacitor (C_3) connected in series with the inductor. The addition of capacitor (C_3) improves the frequency stability and eliminates the effect of transistor parameters and stray capacitances.



The operation of Clapp oscillator circuit is in the same way as that of Colpitts oscillator. The frequency of oscillator is given by the relation,

$$f_o = \frac{1}{2\pi\sqrt{L.C}}$$

Where

$$C = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$$

Usually, the value of C_3 is much smaller than C_1 and C_2 . As a result of this, C is approximately equal to C_3 . Therefore, the frequency of oscillation,

$$f_o = \frac{1}{2\pi\sqrt{L.C_3}}$$

It is understood that the Clapp oscillator is similar to the Colpitts oscillator, however they differ in the way the inductances and capacitances are arranged. The frequency stability though is good, can be variable in a Clapp oscillator.

A Clapp oscillator is sometimes preferred over a Colpitts oscillator for constructing a variable frequency oscillator. The Clapp oscillators are used in receiver tuning circuits as a frequency oscillator.

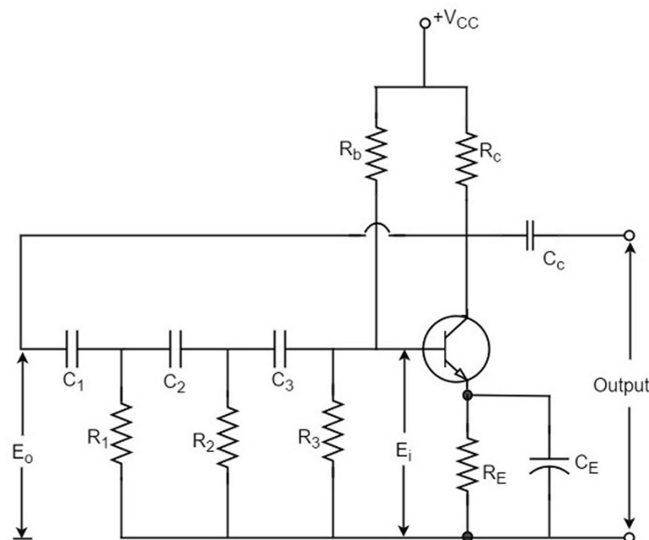
Phase-shift Oscillator Circuit :

The oscillator circuit that produces a sine wave using a phase-shift network is called as a Phase-shift oscillator circuit. The constructional details and operation of a phase-shift oscillator circuit are as given below.

Construction :

The phase-shift oscillator circuit consists of a single transistor amplifier section and a RC phase-shift network. The phase shift network in this circuit, consists of three RC sections. At the resonant frequency f_o , the phase shift in each RC section is 60° so that the total phase shift produced by RC network is 180° .

The following circuit diagram shows the arrangement of an RC phase-shift oscillator.



The frequency of oscillations is given by

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

Where

$$R_1 = R_2 = R_3 = R$$

$$C_1 = C_2 = C_3 = C$$

Operation :

The circuit when switched ON oscillates at the resonant frequency f_o . The output E_o of the amplifier is fed back to RC feedback network. This network produces a phase shift of 180° and a voltage E_i appears at its output. This voltage is applied to the transistor amplifier.

The feedback applied will be

$$m = E_i/E_o$$

The feedback is in correct phase, whereas the transistor amplifier, which is in CE configuration, produces a 180° phase shift. The phase shift produced by network and the transistor add to form a phase shift around the entire loop which is 360° .

Advantages :

- It does not require transformers or inductors.
- It can be used to produce very low frequencies.
- The circuit provides good frequency stability.

Disadvantages :

- Starting the oscillations is difficult as the feedback is small.
- The output produced is small.

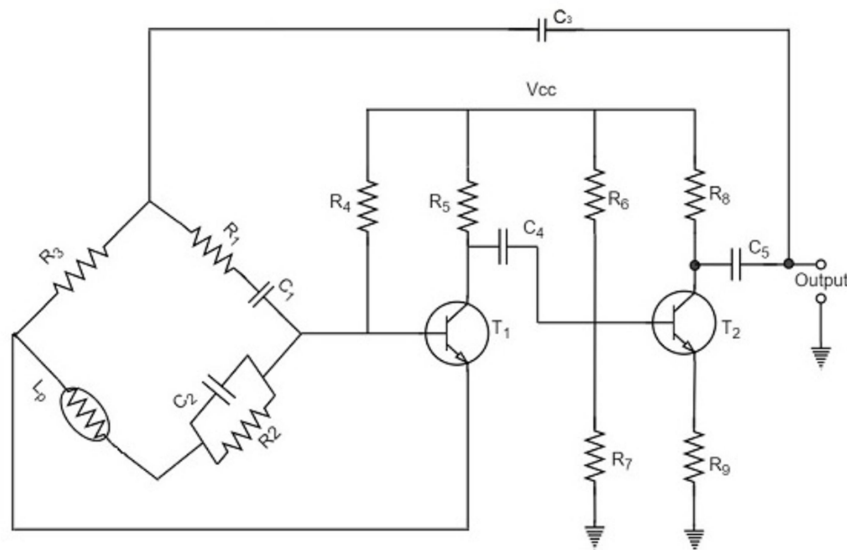
Wien Bridge Oscillator

Another type of popular audio frequency oscillator is the Wien bridge oscillator circuit. This is mostly used because of its important features. This circuit is free from the circuit fluctuations and the ambient temperature.

The main advantage of this oscillator is that the frequency can be varied in the range of 10Hz to about 1MHz whereas in RC oscillators, the frequency is not varied.

Construction

The circuit construction of Wien bridge oscillator can be explained as below. It is a two-stage amplifier with RC bridge circuit. The bridge circuit has the arms R_1C_1 , R_3 , R_2C_2 and the tungsten lamp L_p . Resistance R_3 and the lamp L_p are used to stabilize the amplitude of the output.



The transistor T_1 serves as an oscillator and an amplifier while the other transistor T_2 serves as an inverter. The inverter operation provides a phase shift of 180° . This circuit provides positive feedback through R_1C_1 , C_2R_2 to the transistor T_1 and negative feedback through the voltage divider to the input of transistor T_2 .

The frequency of oscillations is determined by the series element R_1C_1 and parallel element R_2C_2 of the bridge.

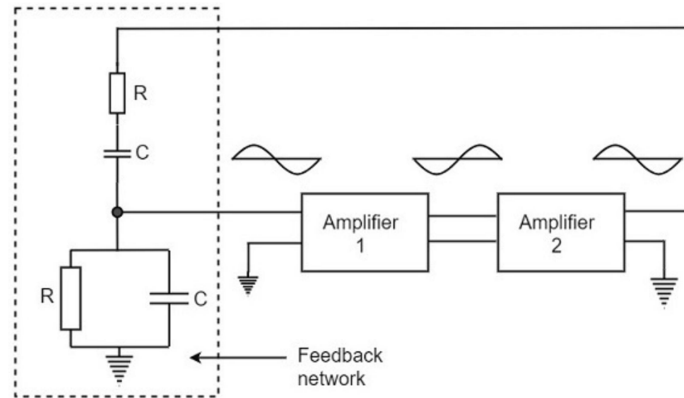
$$f = \frac{1}{2\pi\sqrt{R_1C_1R_2C_2}}$$

If $R_1 = R_2$ and $C_1 = C_2 = C$

Then,

$$f = \frac{1}{2\pi RC}$$

Now, we can simplify the above circuit as follows



The oscillator consists of two stages of RC coupled amplifier and a feedback network. The voltage across the parallel combination of R and C is fed to the input of amplifier 1. The net phase shift through the two amplifiers is zero.

The usual idea of connecting the output of amplifier 2 to amplifier 1 to provide signal regeneration for oscillator is not applicable here as the amplifier 1 will amplify signals over a wide range of frequencies and hence direct coupling would result in poor frequency stability. By adding Wien bridge feedback network, the oscillator becomes sensitive to a particular frequency and hence frequency stability is achieved.

Operation

When the circuit is switched ON, the bridge circuit produces oscillations of the frequency stated above. The two transistors produce a total phase shift of 360° so that proper positive feedback is ensured. The negative feedback in the circuit ensures constant output. This is achieved by temperature sensitive tungsten lamp L_p . Its resistance increases with current.

If the amplitude of the output increases, more current is produced and more negative feedback is achieved. Due to this, the output would return to the original value. Whereas, if the output tends to decrease, reverse action would take place.

Advantages

- The circuit provides good frequency stability.
- It provides constant output.
- The operation of circuit is quite easy.
- The overall gain is high because of two transistors.
- The frequency of oscillations can be changed easily.
- The amplitude stability of the output voltage can be maintained more accurately, by replacing R_2 with a thermistor.

Disadvantages

- The circuit cannot generate very high frequencies.
- Two transistors and number of components are required for the circuit construction.