SINUSOIDAL OSCILLATORS

* Sinusoidal oscillator

An electronic device that generates sinusoidal oscillations of desired frequency is known as a sinusoidal oscillators.

An oscillator generates frequency, it should be noted that it does not create energy, but acts as energy converter. It receives d.c. energy and changes it into a.c. energy of desired frequency. The frequency of oscillations depends upon the constants of the device.

Although an alternator produces sinusoidal oscillations of 50 Hz, it can not be called an oscillator, because,

(i) an alternator is a mechanical device having rotating parts whereas an oscillator is a non-rotating electronic device.

(ii) an alternator converts mechanical energy into a.c energy while an oscillator converts d.c energy into a.c energy.

(iii) an alternator can not produce high frequency oscillations whereas an oscillator can produce oscillations ranging from a few Hz to several MHz.

Although oscillations can be produced by mechanical devices, but electronic oscillators have the following advantages:

(i) An oscillator is a non-rotating device

(ii) It has longer life

(iii) The operation of the oscillator is silent.

(iv) An oscillator can produce waves from small (20 Hz) to extremely high frequency (> 100 MHz).

(v) The frequency of oscillator can be easily changed

(vi) It has good frequency stability.

(vii) It has very high efficiency.

* Types of Sinusoidal Oscillations

Sinusoidal electrical oscillations can be of two types:

⟨I⟩ damped oscillations, and

⟨II⟩ undamped oscillations

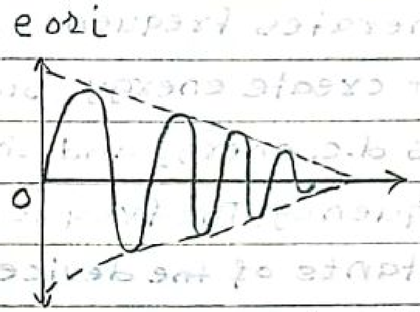


Fig 1 Damped oscillations

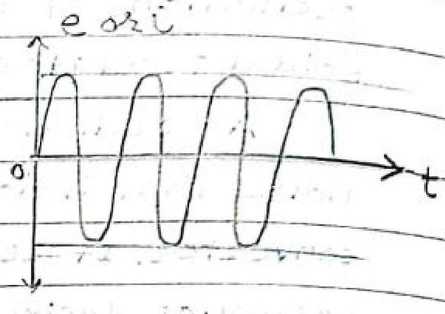


Fig 2 Undamped oscill^n

⟨I⟩ Damped oscillations -

The electrical oscillations whose amplitude goes on decreasing with time are called damped oscillations. Fig 1 shows waveform of damped electrical oscillations. The electrical system in which these oscillation are generated has losses and some energy is lost during each oscillation. No energy is provided to compensate for the losses, so the amplitudes of the generated wave decreases gradually. The frequency of oscillations remain unchanged since it depends upon the constants of the electrical system.

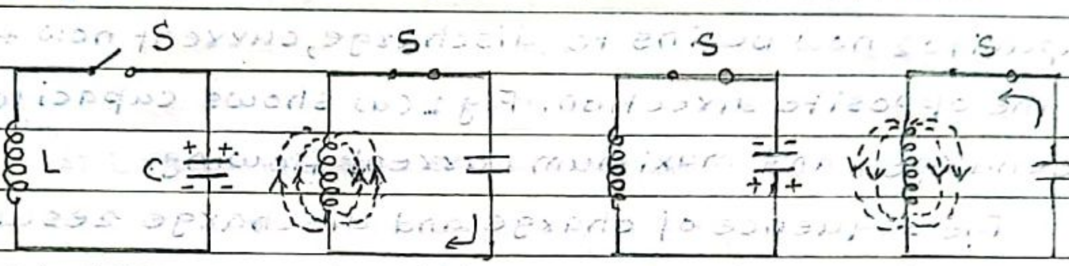
⟨II⟩ Undamped oscillations.

The electrical oscillations whose amplitude remains constant with time are called undamped oscillations. Fig. 2 shows waveform of undamped electrical oscillations. Although the electrical system in which these oscillations are being generated has also losses but some amount of energy is being supplied to overcome the losses, consequently, the amplitude of the generated wave remains constant. An oscillator is required to produce undamped electrical oscillations for utilising in various electronics equipment.

* Oscillatory Circuit

A circuit which produces electrical oscillations of any desired frequency is known as an oscillatory circuit or tank circuit.

A simple oscillatory circuit consists of a capacitor (C) and inductance coil (L) in parallel as shown in below Fig. 1. This electrical system can produce electrical oscillations of frequency determined by the values of L and C. Suppose the capacitor is charged from a d.c source with a polarity as shown in Fig. 1a:



(a) (b) (c) (d)

Fig 1. Oscillatory circuit

(i) In the position shown in Fig. 1 (a), the upper plate of capacitor has deficit of electrons and the lower plate has excess of electrons. Therefore, there is a voltage across the capacitor and the capacitor has electrostatic energy.

(ii) When switch S is closed as shown in Fig. 1 (b), the capacitor will discharge through inductance and the electron flow will be in the direction indicated by the arrow. This current flow sets up magnetic field around the coil. Due to the inductive effect, the current builds up slowly towards a maximum value. The circuit current will be maximum when the capacitor is fully discharged. At this instant, electrostatic energy is zero but because electron motion is greatest the magnetic field energy around the coil is maximum. This is shown in Fig 1 (b). The electrostatic energy across the capacitor is completely converted into magnetic field energy around the coil.

(iii) Once the capacitor is discharged, the magnetic field will begin to collapse and produce a counter emf. According to Lenz's law, the counter e.m.f. will keep the current flowing in the same direction. The result is that the capacitor is now charged with opposite polarity, making upper plate of capacitor negative and lower plate positive as shown in Fig 1. (c).

(iv) After the collapsing field has recharged the capacitor now begins to discharge, current now flowing in the opposite direction. Fig 1 (d) shows capacitor fully discharged and maximum current flowing.

The sequence of charge and discharge results in alternating motion of electrons or an oscillating current. The energy is alternately stored in the electric field of the capacitor (C) and the magnetic field of the inductance coil (L). This interchange of energy between L and C is repeated over and again resulting in the production of oscillations.

The frequency of oscillations in the tank circuit is determined by the constants of the circuit i.e. L and C. The actual frequency of oscillations is the resonant frequency of the tank circuit given by:

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

It is clear that frequency of oscillations in the tank circuit is inversly proportional to L and C.

* Positive Feedback Amplifier - Oscillator

A transistor amplifier with proper positive feedback can act as an oscillator i.e. it can generate oscillations without any external signal source. Fig. 1. shows a transistor amplifier with positive feedback.

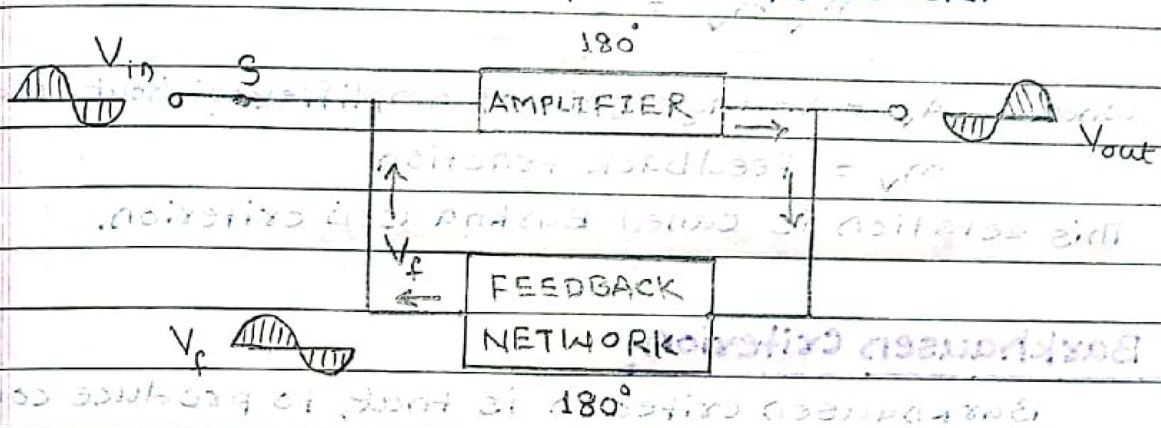


Fig 1

The positive feedback amplifier is one that produces a feedback voltage (V_f) that is in phase with original input signal. A phase shift of 180° is produced by the amplifier and the further phase shift of 180° is introduced by feedback network. Hence, the signal is shifted by 360° and fed to the input i.e. feedback voltage is in phase with the input signal.

When the switch S is open i.e the input signal (V_{in}) is removed. However, V_f is still applied to the input signal. V_f will be amplified and send to the output. The feedback network sends a portion of the output back to the input. Therefore, the amplifier receives another input cycle and another output cycle is produced. This process will continue so long as the amplifier is turned on so, the amplifier will produce sinusoidal output with no external signal. The following points may be noted:

(a) A transistor amplifier with proper positive feedback will work as an oscillator.

(b) The circuit needs only a quick trigger signal to start the oscillations. once the oscillations have started, no external signal source is needed.

(c) To get continuous undamped output from the circuit, the following condition must be satisfied.

$$m_v A_v = 1$$

where A_v = Voltage gain of amplifier without feedback

m_v = feedback fraction

This relation is called Barkhausen criterion.

* Barkhausen Criterion

Barkhausen criterion is that, to produce continuous undamped oscillations at the output of an amplifier, the positive feedback should be such that

$$m_v A_v = 1$$

Once this condition is set in the positive feedback amplifier, continuous undamped oscillations can be obtained at the output.

The voltage gain of positive feedback amplifier is given by

$$A_{vf} = \frac{A_v}{1 - m_v A_v}$$

If $m_v A_v \rightarrow 1$, then $A_{vf} \rightarrow \infty$

* Colpitt's oscillator

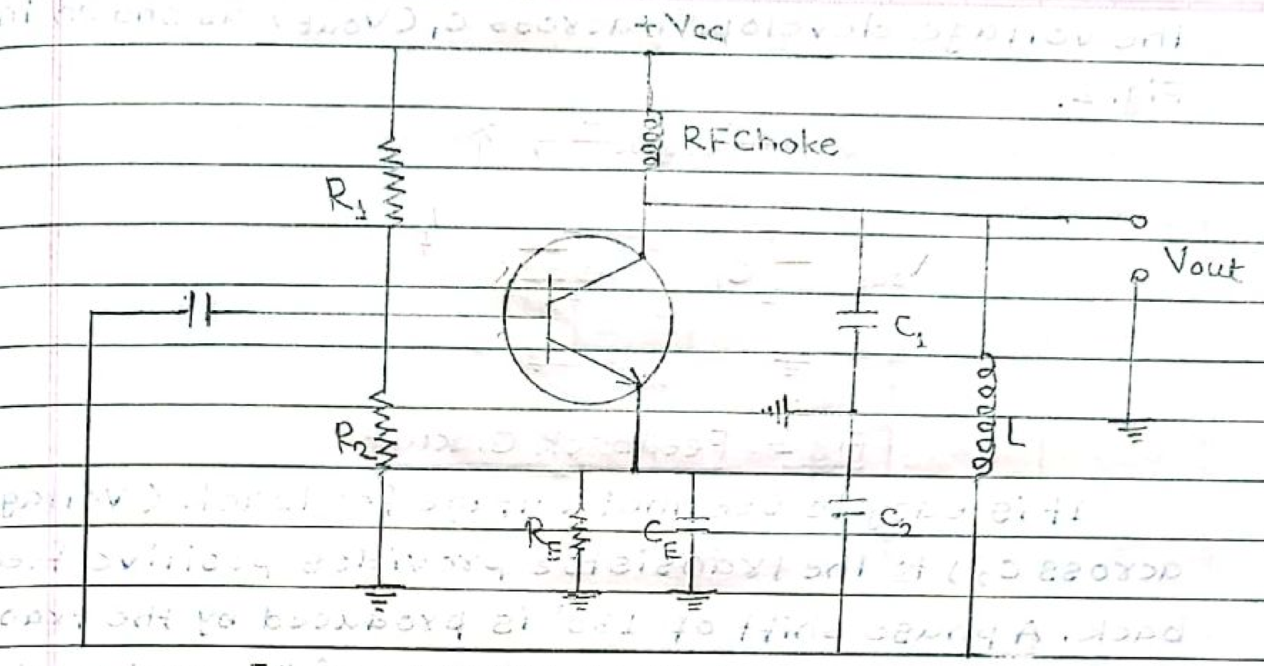


Fig.1 :- Colpitts Oscillator

The above Fig. 1 shows a Colpitts oscillator. It uses two capacitors and placed across a common inductor L and the centre of the two capacitors is tapped. The tank circuit is made up of C_1, C_2 and L. The frequency of oscillations is determined by the values of C_1, C_2 and L and is given by:

$$f = \frac{1}{2\pi\sqrt{LC_T}} \quad \text{--- (1)}$$

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

Note that $C_1 - C_2 - L$ is also the feedback circuit that produces a phase shift of 180°.

Circuit operation

When the circuit is turned on, the capacitors C_1 and C_2 are charged. The capacitors discharge through L, setting up oscillations of frequency determined by eqn (1). The output voltage of the amplifier appears across C_1 and feedback voltage is developed across C_2. The voltage across it is 180° out of phase with the voltage developed across C_1 (V_{out}) as shown in Fig. 2.

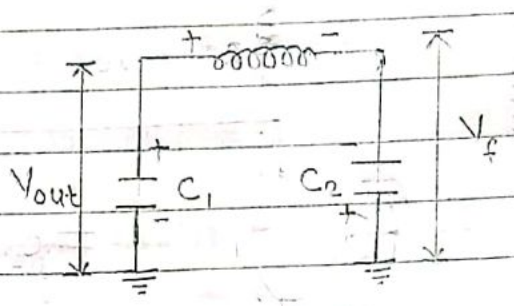


Fig 2 Feedback Circuit

It is easy to see that voltage feedback (voltage across C_2) to the transistor provides positive feedback. A phase shift of 180° is produced by the transistor and further phase shift of 180° is produced by the transistor and a further phase shift of 180° is produced by $C_1 - C_2$ voltage divider. In this way, feedback is properly phased to produce continuous undamped oscillation.

Feedback Fraction (m_v)

The amount of feedback voltage in colpitts oscillator depends upon feedback fraction m_v of the circuit. For this circuit,

$$\text{Feedback fraction } m_v = \frac{V_f}{V_{out}}$$

$$= \frac{X_{C2}}{X_{C1}} = \frac{C_1}{C_2}$$

$$\therefore m_v = \frac{C_1}{C_2}$$

* Hartley Oscillator

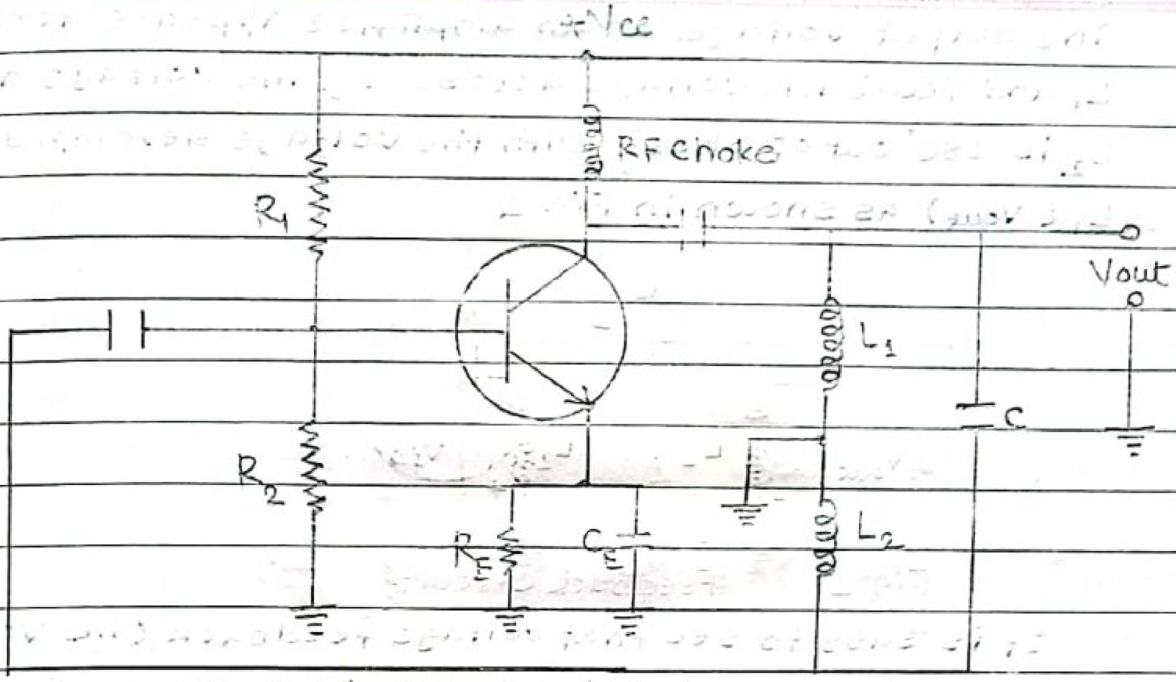


Fig. 1 Hartely Oscillator

The Hartley oscillator is similar to Colpitt's oscillator with minor modifications. Instead of using tapped capacitors, two inductors L_1 and L_2 are placed across a common capacitor C and the centre of the inductors is tapped as shown in above Fig. 1. The tank circuit is made up of L_1, L_2 and C. The frequency of oscillations is determined by the values of L_1, L_2 and C and given by:

$$f = \frac{1}{2\pi\sqrt{CL_T}} \quad \text{------} (1)$$

where $L_T = L_1 + L_2 + 2M$

Here M = mutual inductance between L_1 and L_2

Note that $L_1 - L_2 - C$ is also the feedback network that ~~provides~~ produces a phase shift of 180°.

Circuit Operation

When the circuit is turned on, the capacitor is charged. When this capacitor is fully charged, it discharges through coils L_1 and L_2 setting up oscillations of frequency determined by eq. (1).

The output voltage of an amplifier appears across L_1 and feedback voltage across L_2. The voltage across L_2 is 180° out of phase with the voltage developed across L_1 (Vout) as shown in Fig 2

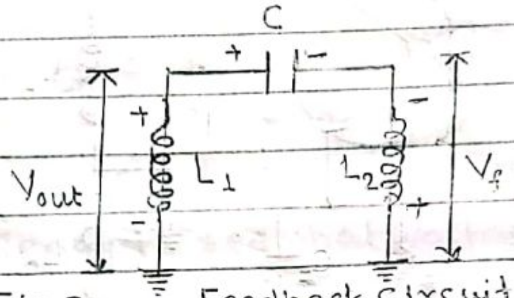


Fig 2 Feedback circuit

It is easy to see that voltage feedback (i.e. voltage across L_2) to the transistor provides positive feedback. A phase shift of 180° is produced by the transistor and a further phase shift of 180° is produced by L_1-L_2 voltage divider. In this way, feedback is properly phased to produce continuous undamped oscillations.

Feedback fraction (m_v)

In Hartley oscillator, the feedback voltage is across L_2 and output voltage is across L_1.

∴ Feedback fraction,

$$m_v = \frac{V_f}{V_{out}} = \frac{X_{L_2}}{X_{L_1}}$$

$$= \frac{\omega L_2}{\omega L_1}$$

$$\therefore m_v = \frac{L_2}{L_1}$$

* R-C Network

A phase shift circuit consists of an R-C network. Fig. 1 shows a single section of RC network.

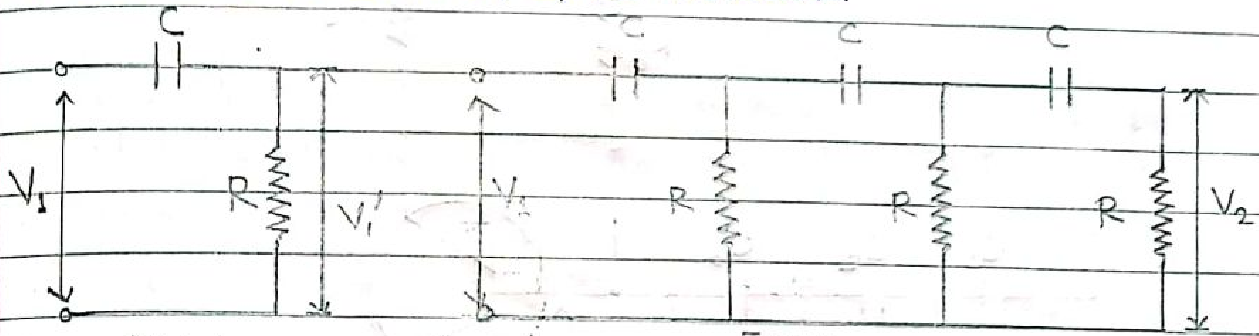


Fig 1 Fig.2

From the elementary theory of electrical engineering, it can be shown that alternating voltage V_1' across R leads the applied voltage V_1 by $\phi°$. The value of ϕ depends upon the values of R and C. If resistance R is varied, the value of ϕ also changes. If R were reduced to zero V_1' will be lead V_1 by 90° i.e. $\phi = 90°$. 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°.

Fig.2 shows the three sections of RC network. Each section produces a phase shift of 60°. consequently, a total phaseshift of 180° is produced i.e. Voltage V_2 leads the voltage V_1 by 180°.

Good frequency stability and waveform can be obtained from oscillators employing resistive and capacitive elements. such amplifiers are called R-C or phase shift oscillators. They have the additional advantage that they can be used for very low frequencies.

* Phase Shift Oscillator

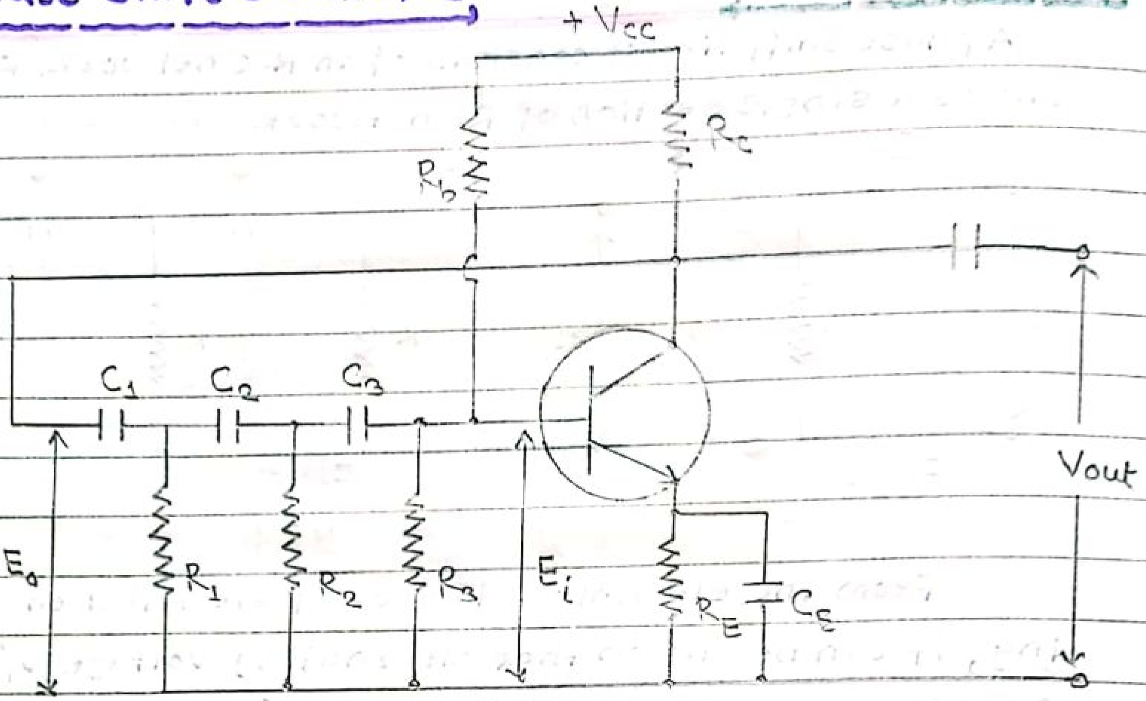


Fig. 1 Phase shift oscillator

The above Fig. 1 shows the circuit of a phase shift oscillator. It consists of a single transistor amplifier and a RC phase shift network. The phase shift network consists of three sections R_1C_1, R_2C_2 and R_3C_3. At some particular frequency f_o, the phase shift in each RC section is $60°$ so that the total phase shift produced by the RC network is $180°$. The frequency of oscillations is given by

$$f_o = \frac{1}{2\pi RC\sqrt{6}} \quad \text{------} (1)$$

where $R_1 = R_2 = R_3 = R$

$C_1 = C_2 = C_3 = C$

Circuit operation

When the circuit is switched on, it produces oscillations of frequency determined by exp. (1). The output E_o of the amplifier is feedback to RC feedback network. This network produces a phase shift of $180°$ and a voltage E_i appears at its output which is applied to the transistor amplifier.

The feedback fraction m is given by

$$m = \frac{E_i}{E_o}$$

The feedback phase is correct. A phase shift of 180° is produced by the transistor amplifier. A further phase shift of 180° is produced by the RC network. As a result, the phase shift around the entire loop is 360°.

Advantages

(i) It does not require transformers or inductors.

(ii) It can be used to produce very low frequencies.

(iii) The circuit provides good frequency stability.

Disadvantages

(i) It is difficult for the circuit to start oscillations as the feedback is generally small.

(ii) The circuit gives small output.