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C10T (Analog Systems and Apllications)

Topic – Amplifiers (Part – 4)

We have already discussed part 3 of this e-report.

Now let us continue part 4 of it.

Sub Topic – Sinusoidal Oscillators

Introduction:

Many electronic devices require a source of energy at a specific frequency which may vary from a few Hz to several MHz. This is achieved by an electronic device called an *oscillator*. Oscillators are extensively used in electronic equipment. For example, in radio and television receivers, oscillators are used to generate high frequency wave (called *carrier wave*) in the tuning stages. Audio frequency and radiofrequency signals are required for the repair of radio, television and other electronic equipment. Oscillators are also widely used in radar, electronic computers and other electronic devices.

Oscillators can produce sinusoidal or non-sinusoidal (e.g. square wave) waves. In this e-report, we will keep our discussion for sinusoidal oscillators i.e. those which produce sine-wave signals.

Sinusoidal Oscillators:

An electronic device that generates sinusoidal oscillations of desired frequency is known as a sinusoidal oscillator. Although we speak of an oscillator as generating a frequency, it should be noted here that it does not create energy, but merely acts as an energy converter. It receives DC energy and changes it into AC energy of desired frequency. The frequency of oscillations depends upon the constants of the device.

Types of Sinusoidal Oscillations:

Sinusoidal electrical oscillations can be of two types viz. damped oscillations and undamped oscillations.

(i) Damped Oscillations. The electrical oscillations whose amplitude goes on decreasing with time are called damped oscillations. Obviously, the electrical system in which these oscillations are generated has losses and some energy is lost during each oscillation. Further, no means are provided to compensate for the losses and consequently the amplitude of the generated wave decreases gradually. But the frequency of oscillations remains 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. Although the electrical system in which these oscillations are being generated has also losses, but now right amount of energy is being supplied to overcome the losses. Consequently, the amplitude of the generated wave remains constant. It should be emphasized that an oscillator is required to produce undamped electrical oscillations for utilizing in various electronics equipments.

Illustration of an 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. From our earlier discussion, it is recalled that a positive feedback amplifier is one that produces a feedback voltage (V_f) that is in phase with the original input signal. As it can be seen, this condition is met in the circuit shown in Fig. 1. A phase shift of a 180^0 is produced by the amplifier and a further phase shift of 180^0 is introduced by feedback network. Consequently, the signal is shifted by 360^0 and fed to the input i.e., feedback voltage is in phase with the input signal.

We note that the circuit shown in Fig. 1 is producing oscillations in the output. However, this circuit has an input signal. This is inconsistent with our definition of an oscillator i.e., an oscillator is a circuit that produces oscillations *without any external signal source*.

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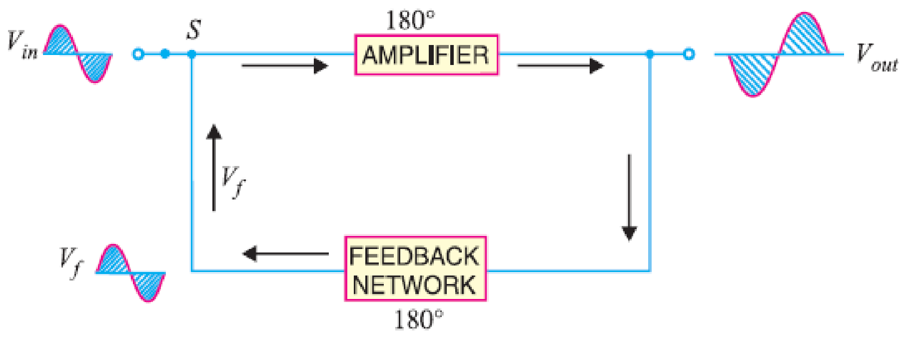

Fig. 1

When we open the switch S of Fig. 1, the input signal (V_{in}) is removed. However, V_f (which is in phase with the original signal) is still applied to the input signal. The amplifier will respond to this signal in the same way that it did to V_{in} i.e. V_f will be amplified and sent 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. Therefore, the amplifier will produce sinusoidal output with no external signal source. The following points may be noted carefully.

(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) In order to get continuous undamped and self-sustained output from the circuit, *Barkhausen Criterion* must be met.

Barkhausen Criterion and Explanation:

Barkhausen Criterion is that in order to produce continuous undamped and self-sustained oscillations at the output of an amplifier, the positive feedback should be such that

$$A_v m_v = 1$$

where A_v = voltage gain of amplifier without feedback and m_v = feedback fraction. Once this condition is set in the positive feedback amplifier, continuous undamped oscillations can be obtained at the output immediately after connecting the necessary power supplies.

We need to look into the explanation of this mathematically. We already know, the voltage gain of a positive feedback amplifier is given by

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

Now if $A_v m_v = 1$, then $A_{vf} \rightarrow \infty$. But achieving infinite gain in an amplifier is not practically possible. So, in physical terms this result means that a vanishing small input voltage would give rise to finite output voltage even when the input signal goes zero. Thus once the circuit receives the input trigger, it would become an oscillator, generating oscillations with no external signal source.

Different Types of Sinusoidal Oscillators:

Here in this e-report, we will discuss about three different types of sinusoidal oscillators, viz. Colpitt's Oscillator, Hartley Oscillator and Phase Shift Oscillator.

Colpitt's Oscillator:

Fig. 2 shows a Colpitt's Oscillator. It uses two capacitors C_1 and C_2 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 $f = \frac{1}{2\pi\sqrt{LC_T}}$ where $C_T = \frac{C_1 C_2}{C_1 + C_2}$. The two capacitors and the inductor make the feedback circuit, which produces a phase shift of 180^0.

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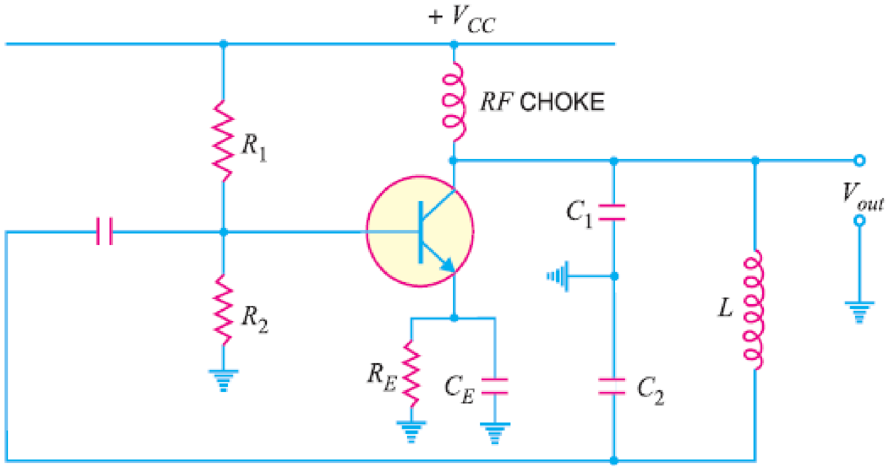

Fig. 2

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 $f = \frac{1}{2\pi\sqrt{LC_T}}$. The output voltage ($V_{out}$) of the amplifier appears across C_1 and feedback voltage (V_f) is developed across C_2. Here V_{out} is 180^0 out of phase with the feedback voltage V_f. It is easy to see that voltage fed back (voltage across C_2) to the transistor provides positive feedback. A phase shift of 180^0 is produced by the transistor and a further phase shift of 180^0 is produced by C_1C_2 voltage divider. In this way, feedback is properly phased to produce continuous undamped oscillation.

Feedback fraction. The amount of feedback voltage in Colpitt's Oscillator depends upon feedback fraction m_v of the circuit. For this circuit $m_v = \frac{V_f}{V_{out}} = \frac{X_{C_2}}{X_{C_1}} = \frac{j\omega C_1}{j\omega C_2} = \frac{C_1}{C_2}$.

Hartley 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 Fig. 3. The tank circuit is made up of L_1, L_2 and C. The frequency of

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oscillations is determined by the values of L_1, L_2 and C and is given by $f = \frac{1}{2\pi\sqrt{CL_T}}$ where $L_T = L_1 + L_2 + 2M$, M being the mutual inductance between the two inductors. The two inductors and the capacitor make the feedback circuit, that produces a phase shift of 180^0.

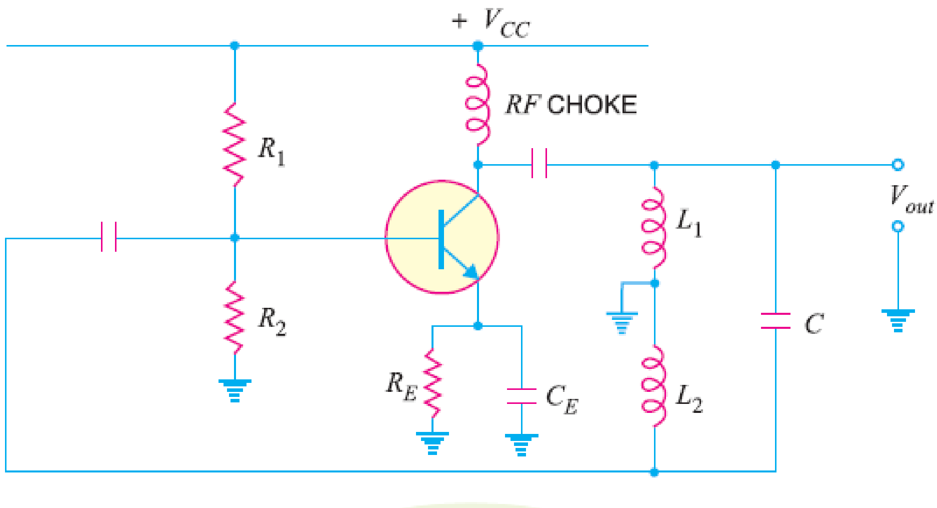

Fig. 3

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 $f = \frac{1}{2\pi\sqrt{CL_T}}$. The output voltage of the amplifier (V_{out}) appears across L_1 and feedback voltage (V_f) across L_2. V_{out} is 180^0 out of phase with the feedback voltage V_f. It is easy to see that voltage fed back to the transistor provides positive feedback. A phase shift of 180^0 is produced by the transistor and a further phase shift of 180^0 is produced by L_1L_2 voltage divider. In this way, feedback is properly phased to produce continuous undamped oscillations.

Feedback fraction. In Hartley Oscillator, the feedback voltage is across L_2 and output voltage is across L_1. Therefore, feedback fraction $m_v = \frac{V_f}{V_{out}} = \frac{X_{L_2}}{X_{L_1}} = \frac{j\omega L_2}{j\omega L_1} = \frac{L_2}{L_1}$.

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Phase Shift Oscillator:

Fig. 4 shows the circuit of a phase shift oscillator. It consists of a conventional 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_0, the phase shift in each RC section is 60^0 (Rs are adjusted such a way to get a phase shift of 60^0), so that the total phase-shift produced by the RC network is 180^0. The frequency of oscillations is given by $f_0 = \frac{1}{2\pi RC\sqrt{6}}$, where $R_1 = R_2 = R_3 = R$ and $C_1 = C_2 = C_3 = C$.

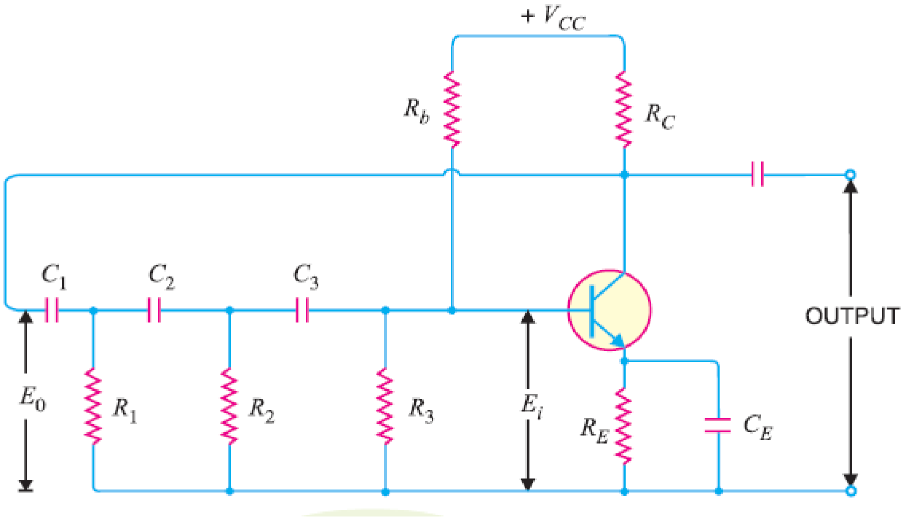

Fig. 4

Circuit operation. When the circuit is switched on, it produces oscillations of frequency determined by $f_0 = \frac{1}{2\pi RC\sqrt{6}}$. The output E_0 of the amplifier is fed back to RC feedback network. This network produces a phase shift of 180^0 and a voltage E_i appears at its output which is applied to the transistor amplifier.

Feedback fraction. Obviously, the feedback fraction $m_v = \frac{E_i}{E_0}$. A phase shift of 180^0 is produced by the transistor amplifier. A further phase shift of 180^0 is produced by the RC network. As a result, the phase shift around the entire loop is 360^0.

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This concludes part 4 of this e-report.

The discussion will be continuing in the part 5 of this e-report.

Reference:

Principles of Electronics, V.K. Mehta & Rohit Mehta, S. Chand & Company

(All the figures have been collected from the above mentioned reference)