CHAPTER

20 Sinusoidal Oscillators

20.1. INTRODUCTION

An oscillator is the basic element of all ac signal sources and generates sinusoidal signals of known frequency and amplitude. It is one of the basic and useful instruments used in electrical and electronic measurements. For example, an oscillator finds wide applications in electronic communication equipment. In AM (amplitude modulation) and FM (frequency modulation) superheterodyne receivers, "local" oscillators are used to assist in the reduction of the incoming radio frequency (RF) to a lower intermediate frequency (IF). Oscillator circuits are also employed in the "exciter" section of a transmitter to generate the RF carrier. Other applications include their use as "clocks" in digital systems such as microcomputers, in the sweep circuits found in TV sets and oscilloscopes.

Since sinusoidal waveforms are encountered so frequently in electronic measurement work, the oscillator (sinewave generator) represents the largest single category of signal generators. This device covers the frequency range from a few Hz to many GHz.

Although we speak of an oscillator as "generating" a sinusoidal signal, it is to be noted that it does not create energy, but merely acts as an *energy converter*. It simply converts unidirectional current drawn from a dc source of supply into alternating current of desired frequency. The function of an oscillator is reverse of that of a rectifier and, therefore, sometimes called *inverter*. However, we generally think of oscillator circuits as providing an ac *voltage signal*.

It is worthmentioning here that although an alternator (ac generator) generates sinusoidal ac power of 50 Hz, it cannot be called an oscillator. An alternator is a mechanical device that has rotating parts, converts mechanical energy into ac energy but cannot produce ac energy of high frequency* whereas an oscillator is a non-rotating electronic device that converts dc energy into ac energy of frequency ranging from a few Hz to many GHz.

Though alternator generates large amount of ac power but for several applications such as radio transmitters and receivers, radars etc., an oscillator is preferred owing to its numerous advantages over alternators for such applications. These advantages are :

(*i*) Portable and cheap in cost.

(*ii*) An oscillator is a non-rotating device. Consequently, there is no wear and tear and hence longer life.

(*iii*) Frequency of oscillation may be conveniently varied.

(*iv*) Voltage or currents of any frequency (20 Hz to 100 MHz) adjustable over a wide range can be generated.

(*v*) Frequency once set remains constant for a considerable period of time.

(*vi*) Voltages free from harmonics as well as rich with harmonics can be generated by sinusoidal oscillators and relaxation oscillators respectively.

(*vii*) Operation of an oscillator is silent, as there is no moving part in it.

(*viii*) High operation efficiency—due to absence of moving part, there is no wastage of energy owing to friction.

For having a sinusoidal oscillator, we require an amplifier with positive feedback.** The idea is to use the feedback signal in place of an input signal. If the loop gain and phase are correct, there will be an output signal even though there is no external input signal. In other words, an oscillator is an amplifier that is modified by positive feedback to supply its own input signal.

The difference between an amplifier and an oscillator can be explained with the help of Fig. 20.1.

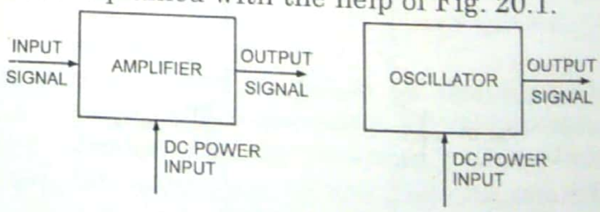


Fig. 20.1

* An alternator cannot be employed for generating frequencies exceeding 1,000 Hz because for generating higher frequencies, either the speed of rotation of the armature has to be made extremely high or the number of poles has to be made large and both options are impracticable.

** If the amplifier output signal increases in magnitude after applying the feedback, then it is called the positive feedback. The positive feedback is cumulative. The amplified signal when fedback and passed through the amplifier becomes even stronger. Theoretically signal approaches infinity but in practice a condition is reached when the amplifier gives an output signal without any need of input signal.

... and on the other hand if the output voltage rises quickly to one voltage level and later drops quickly to another voltage level, the circuit is usually referred to as a pulse or *square-wave generator*.

To understand how an oscillator produces an output signal without an external input signal, let us consider the feedback circuit shown in Fig. 20.2 (*a*), where V_{in} is the voltage of ac input driving the input terminals *bc* of an amplifier having voltage gain A. The amplified output voltage is

$$V_{out} = AV_{in} \qquad ...(20.1)$$

This voltage drives a feedback circuit that is usually a *resonant circuit*, as we get maximum feedback at one frequency. The feedback voltage returning to point *a*

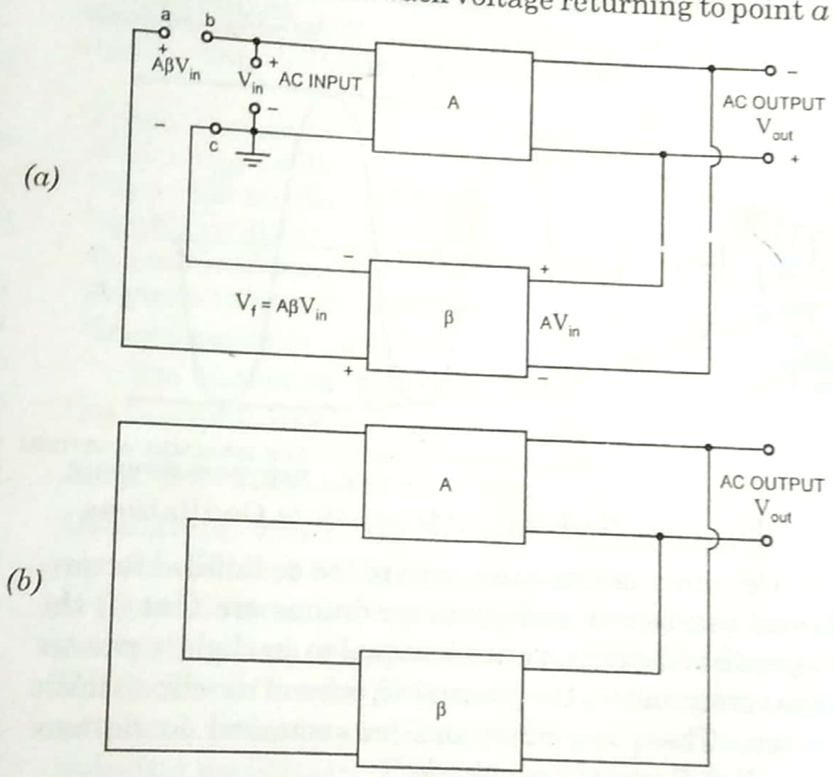


Fig. 20.2

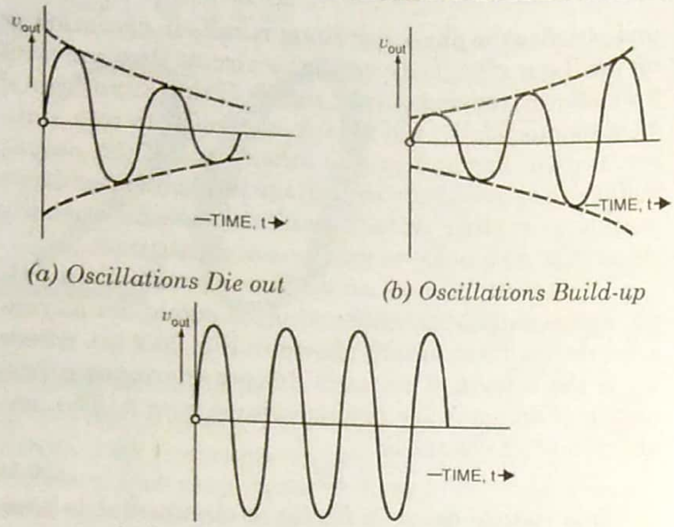
is given by equation

$$V_f = A\beta V_{in} \qquad ...(20.2)$$

where β is the gain of feedback network.

If the phase shift through the amplifier and feedback circuit is zero, then $A\beta V_{in}$ is in phase with the input signal V_{in} that drives the input terminals of the amplifier.

Now we connect point '*a*' to point '*b*' and simultaneously remove voltage source V_{in}, then feedback voltage $A\beta V_{in}$ drives the input terminals *bc* of the amplifier, as shown in Fig. 20.2 (*b*). In case $A\beta$ is less than unity, $A\beta V_{in}$ is less than V_{in} and the output signal will die out, as illustrated in Fig. 20.3 (*a*). On the other hand if $A\beta$ is greater than unity, the output signal will build up, as illustrated in Fig. 20.3 (*b*). If $A\beta$ is equal to unity, $A\beta V_{in}$ equals V_{in} and the output signal is a steady sinewave, as illustrated in Fig. 20.3 (*c*). In this case the circuit supplies its own input signal and produces a sinusoidal output.



(a) *Oscillations Die out* (b) *Oscillations Build-up*

(c) *Oscillations of Constant Amplitude*

Fig. 20.3

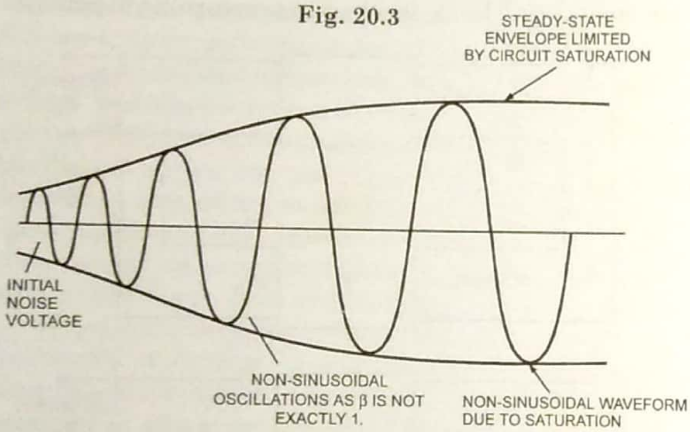


Fig. 20.4. ***Buildup of Steady-state Oscillations***

Certain conditions are required to be fulfilled for sustained oscillations and these conditions are that (*i*) the loop gain of the circuit must be equal to (or slightly greater than) unity and (*ii*) the phase shift around the circuit must be zero. These two conditions for sustained oscillations are called *Barkhausen criteria.*

For initiation of oscillations, supply of an input signal is not essential. Only the condition $\beta A = 1$ must be satisfied for self-sustained oscillations to result. In practice βA is made slightly greater than unity, the system starts oscillating by amplifying noise voltage* which is always present. Saturation factors in the practical circuits *provide* an average value of βA of 1. The resulting waveforms are never exactly sinusoidal. However, the closer the value of βA is to exactly 1, the more nearly sinusoidal is the waveform. Figure 20.4 shows how the noise voltage results in a build up of a steady state oscillation condition.

Another way of seeing how the feedback circuit provides operation as an oscillator is obtained by noting the denominator in the basic feedback equation, $A_f = \frac{A}{1+\beta A}$. When $\beta A = -1$ or magnitude 1 at a phase angle of 180°, the denominator becomes zero and the gain with feedback, A_f, becomes infinite. Thus, an infinitesimal signal (noise voltage) can provide a measurable output voltage, and the circuit acts as an oscillator even without an input signal.

By deliberate design the phase shift around the loop is made 0° at the resonant frequency. Above and below the resonant frequency, the phase shift is different from 0°. Thus oscillations are obtained at only one frequency, the resonant frequency of the feedback circuit.

20.3. ESSENTIALS OF TRANSISTOR OSCILLATOR

From the above discussion it can be inferred that an oscillator must have the following three elements :

1. Oscillatory circuit or element.
2. Amplifier.
3. Feedback network.

The *oscillatory circuit* or *element,* also called the *tank circuit,* consists of an inductive coil of inductance L connected in parallel with a capacitor of capacitance C. The frequency of oscillation in the circuit depends upon the values of L and C. The actual frequency of oscillation is the resonant or natural frequency and is given by the equation

$$f = \frac{1}{2\pi\sqrt{LC}} \text{ Hz}$$

where L is inductance of coil in henrys, and C is the capacitance of capacitor in farads.

The electronic amplifier receives dc power from the battery or dc power supply and converts it into ac power for supply to the tank circuit. The oscillations occurring in the tank circuit are applied to the input of the electronic amplifier. Because of the amplifying properties of the amplifier, we get increased output of these oscillations. This amplified output of oscillations is because of dc power supplied from the external source (a battery or power supply). The output of the amplifier can be supplied to the tank circuit to meet the losses.

The *feedback network* supplies a part of output power to the tank or oscillatory circuit in correct phase to aid the oscillations. In other words the feedback circuit provides *positive feedback*. The block diagram of an oscillator is illustrated in Fig. 20.5.

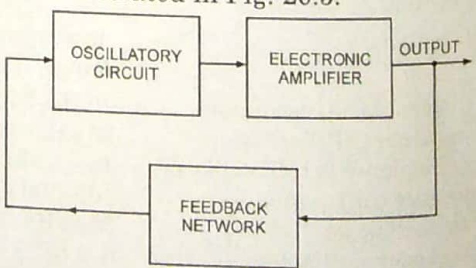


Fig. 20.5. ***Block Diagram of An Oscillator***

20.4. FREQUENCY STABILITY OF OSCILLATOR

An oscillator having initially been set at a particular frequency does not maintain its initial frequency, but

* Because of the ambient temperature, the free electrons contained by resistors move randomly in different directions and generate a *noise voltage* across the resistor. The motion is so random that it contains frequencies to over 1,000 GHz. Each resistor may, thus be thought of as a small ac voltage source producing all frequencies.