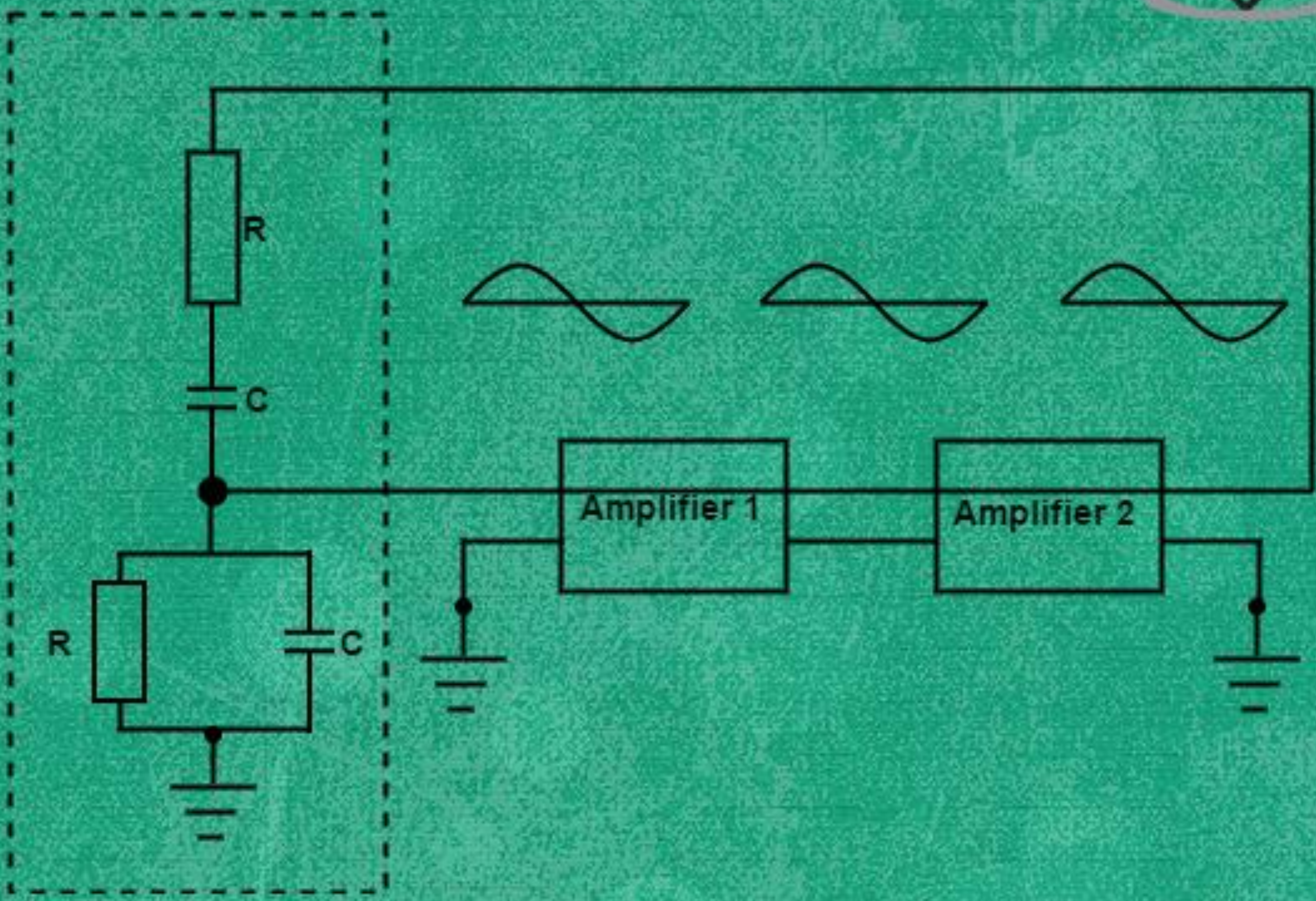

Sinusoidal Oscillators

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About the Tutorial

In this tutorial, we will discuss the important features of different types of sinusoidal oscillators, starting from their basic working principle to their circuit arrangement and behavior. If you are interested in learning the concepts of non-sinusoidal oscillators, then please refer to our tutorial on Pulse Circuits.

Audience

This tutorial will be useful for all those readers who want to learn the basic principles of sinusoidal oscillators and oscillator circuits.

Prerequisites

This tutorial is intended for beginners in the field of Electronics and communications. However, we assume that the readers have prior knowledge on the fundamental concepts of Basic Electronic Circuits and the behavior of different electronic components. For reference, the readers can browse through our Electronic Circuits tutorial.

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Table of Contents

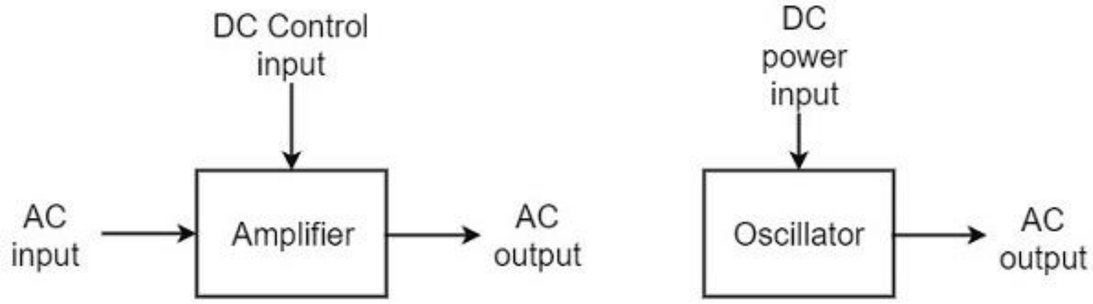
1. Sinusoidal Oscillators – Introduction

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.

Alternator vs. Oscillator

An **alternator** is a mechanical device that produces sinusoidal waves without any input. This a.c. generating machine is used to generate frequencies up to 1000Hz. The output frequency depends on the number of poles and the speed of rotation of the armature.

The following points highlight the differences between an alternator and an oscillator:

- An alternator converts mechanical energy to a.c. energy, whereas the oscillator converts d.c. energy into a.c. energy.
- An oscillator can produce higher frequencies of several MHz whereas an alternator cannot.
- An alternator has rotating parts, whereas an electronic oscillator doesn't.
- It is easy to change the frequency of oscillations in an oscillator than in an alternator.

Oscillators can also be considered as opposite to rectifiers that convert a.c. to d.c. as these convert d.c. to a.c. You can get a detailed description on rectifiers in our Electronic Circuits tutorial.

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.

We will discuss only about Sinusoidal Oscillators in this tutorial. You can learn the functions of non-sinusoidal oscillators from our Pulse Circuits tutorial.

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** — 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.

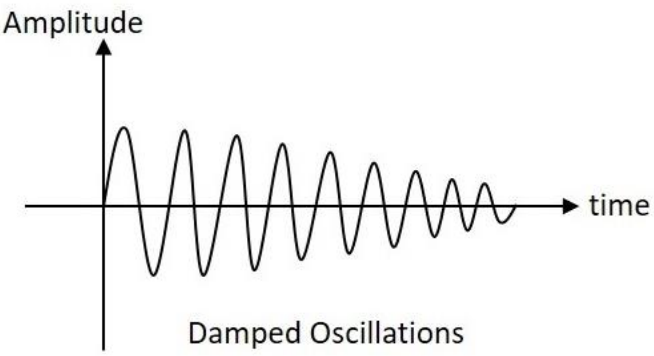
- **Negative-resistance oscillator** — These oscillators use negative-resistance characteristic of the devices such as tunnel devices. A tuned diode oscillator is an example of a negative-resistance oscillator.

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

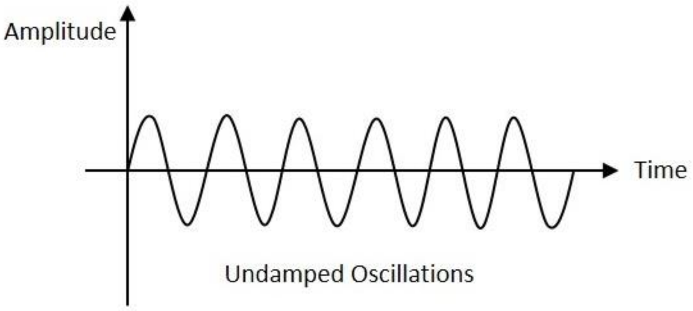
The electrical oscillations whose amplitude goes on decreasing with time are called as **Damped Oscillations**. The frequency of the damped oscillations may remain constant depending upon the circuit parameters.



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.

2. Sinusoidal Oscillators – Basic Concepts

An amplifier with positive feedback produces its output to be in phase with the input and increases the strength of the signal. Positive feedback is also called as **degenerative feedback** or **direct feedback**. This kind of feedback makes a feedback amplifier, an oscillator.

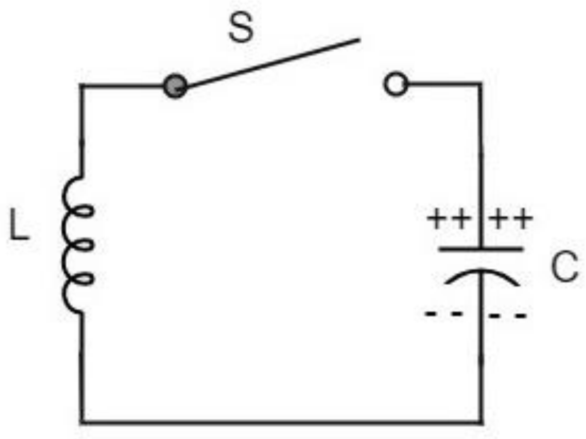
The use of positive feedback results in a feedback amplifier having closed-loop gain greater than the open-loop gain. It results in **instability** and operates as an **oscillatory circuit**. An oscillatory circuit provides a constantly varying amplified output signal of any desired frequency.

The Oscillatory Circuit

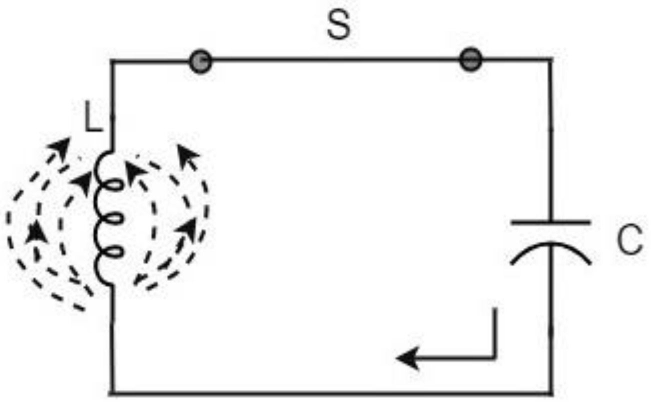
An oscillatory circuit produces electrical oscillations of a desired frequency. They are also known as **tank circuits**.

A simple tank circuit comprises of an inductor L and a capacitor C both of which together determine the oscillatory frequency of the circuit.

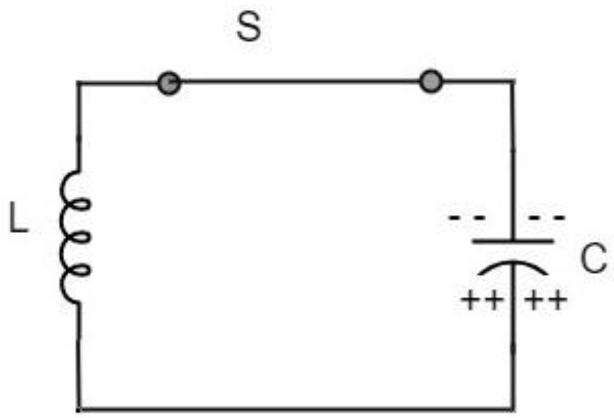
To understand the concept of oscillatory circuit, let us consider the following circuit. The capacitor in this circuit is already charged using a dc source. In this situation, the upper plate of the capacitor has excess of electrons whereas the lower plate has deficit of electrons. The capacitor holds some electrostatic energy and there is a voltage across the capacitor.



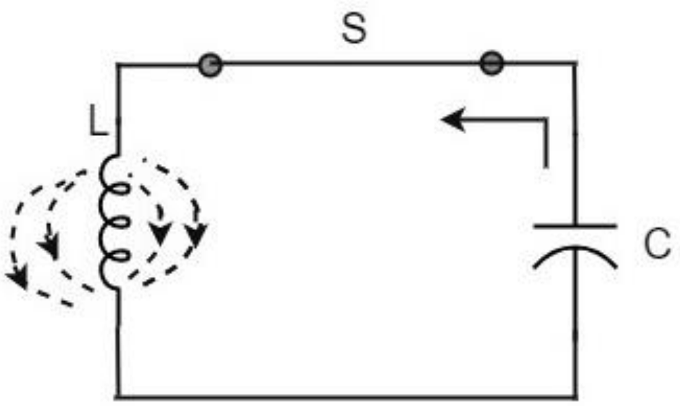
When the switch **S** is closed, the capacitor discharges and the current flows through the inductor. Due to the inductive effect, the current builds up slowly towards a maximum value. Once the capacitor discharges completely, the magnetic field around the coil is maximum.



Now, let us move on to the next stage. Once the capacitor is discharged completely, the magnetic field begins to collapse and produces a counter EMF according to Lenz's law. The capacitor is now charged with positive charge on the upper plate and negative charge on the lower plate.



Once the capacitor is fully charged, it starts to discharge to build up a magnetic field around the coil, as shown in the following circuit diagram.



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.

Frequency of Oscillations

The frequency of the oscillations produced by the tank circuit are determined by the components of the tank circuit, **the L** and **the C**. The actual frequency of oscillations is the **resonant frequency** (or natural frequency) of the tank circuit which is given by

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

Capacitance of the capacitor

The frequency of oscillation f_o is inversely proportional to the square root of the capacitance of a capacitor. So, if the value of the capacitor used is large, the charge and discharge time periods will be large. Hence the frequency will be lower.

Mathematically, the frequency,

$$f_o \propto 1/\sqrt{C}$$

Self-Inductance of the coil

The frequency of the oscillation f_o is proportional to the square root of the self-inductance of the coil. If the value of the inductance is large, the opposition to change of current flow is greater and hence the time required to complete each cycle will be longer, which means time period will be longer and frequency will be lower.

Mathematically, the frequency,

$$f_o \propto 1/\sqrt{L}$$

Combining both the above equations,

$$f_o \propto \frac{1}{\sqrt{LC}}$$

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

The above equation, though indicates the output frequency, matches the **natural frequency** or **resonance frequency** of the tank circuit.

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