Module
1

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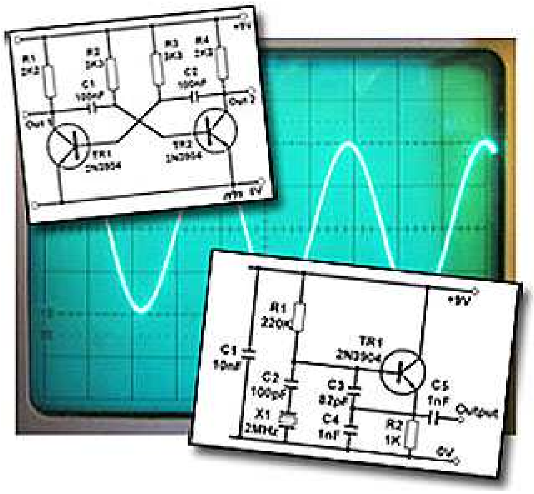
Oscillators

1.0 Oscillator Basics

What you'll learn in Module 1



Introduction

These oscillator modules in Learnabout Electronics describe how many commonly used oscillators work, using discrete components and in integrated circuit form. Also learn how to build and test oscillators circuits yourself.

What is an Oscillator

An oscillator provides a source of repetitive A.C. signal across its output terminals without needing any input (except a D.C. supply). The signal generated by the oscillator is usually of constant amplitude.

The wave shape and amplitude are determined by the design of the oscillator circuit and choice of component values.

The frequency of the output wave may be fixed or variable, depending on the oscillator design.

Types of Oscillator

Oscillators may be classified by the type of signal they produce.

- **SINE WAVE OSCILLATORS** produce a sine wave output.
- **RELAXATION OSCILLATORS** and **ASTABLE MULTIVIBRATORS** produce Square waves and rectangular pulses.
- **SWEEP OSCILLATORS** produce sawtooth waves.

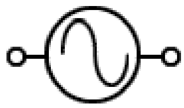


Fig. 1.0.1 Oscillator (AC Source) Circuit Symbol

Sine wave oscillators can also be classified by frequency, or the type of frequency control they use. RF (radio frequency) oscillators working at frequencies above about 30 to 50kHz use LC (inductors and capacitors) or Crystals to control their frequency. These may also be classified as HF, VHF, and UHF oscillators, depending on their frequency.

LF (low frequency) oscillators are generally used for generating frequencies below about 30kHz and are usually RC oscillators, as they use resistors and capacitors to control their frequency.

Square wave oscillators such as relaxation and astable oscillators may be used at any frequency from less than 1Hz up to several GHz and are very often implemented in integrated circuit form.

Sine Wave Oscillators

These circuits ideally produce a pure sine wave output having a constant amplitude and stable frequency. The type of circuit used depends on a number of factors, including the frequency required. Designs based on LC resonant circuits or on crystal resonators are used for ultrasonic and radio frequency applications, but at audio and very low frequencies the physical size of the resonating components, L and C would be too big to be practical.

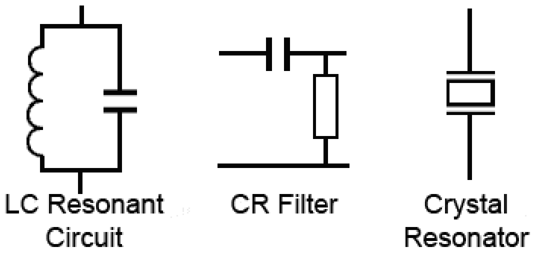


Fig. 1.0.2 Frequency Control Networks

For this reason a combination of R and C is used to a control frequency. The circuit symbols used for these frequency control networks are shown in Fig. 1.0.2

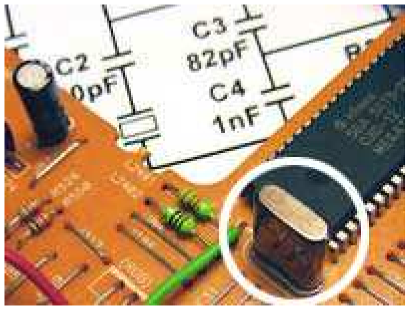
LC oscillators

Inductors and capacitors are combined in a resonating circuit that produces a very good shape of sine wave and has quite good frequency stability. That is, the frequency does not alter very much for changes in the D.C. supply voltage or in ambient temperature, but it is relatively simple, by using variable inductors or capacitors, to make a variable frequency (tuneable) oscillator. LC oscillators are extensively used in generating and receiving RF signals where a variable frequency is required.

RC (or CR) oscillators

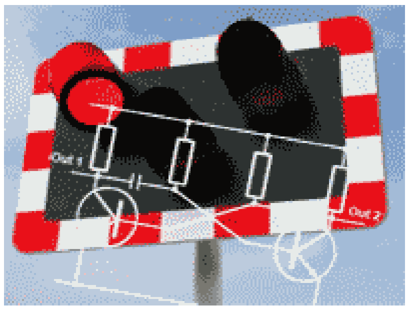
At low frequencies such as audio the values of L and C needed to produce a resonating circuit would be too large and bulky to be practical. Therefore resistors and capacitors are used in RC filter type combinations to generate sine waves at these frequencies, however it is more difficult to produce a pure sine wave shape using R and C. These low frequency sine wave oscillators are used in many audio applications and different designs are used having either a fixed or variable frequency.

Crystal oscillators



At radio frequencies and higher, whenever a fixed frequency with very high degree of frequency stability is needed, the component that determines the frequency of oscillation is usually a quartz crystal, which when subjected to an alternating voltage, vibrates at a very precise frequency. The frequency depends on the physical dimensions of the crystal, therefore once the crystal has been manufactured to specific dimensions, the frequency of oscillation is extremely accurate. Crystal oscillator designs can produce either sine wave or square wave signals, and as well as being used to generate very accurate frequency carrier waves in radio transmitters, they also form the basis of the very accurate timing elements in clocks, watches, and computer systems.

Relaxation oscillators



These oscillators work on a different principle to sine wave oscillators. They produce a square wave or pulsed output and generally use two amplifiers, and a frequency control network that simply produces a timing delay between two actions. The two amplifiers operate in switch mode, switching fully on or fully off alternately, and as the time, during which the transistors are actually switching, only lasts for a very small fraction of each cycle of the wave, the rest of the cycle they "relax" while the timing network produces the remainder of the wave. An alternative name for this type of oscillator is an "astable multivibrator", this name comes from the fact that they contain more than one oscillating element. There are basically two oscillators, i.e. "vibrators", each feeding part of its signal back to the other, and the output changes from a high to a low state and back again continually, i.e. it has no stable state, hence it is astable. Relaxation oscillators can be built using several different designs and can work at many different frequencies. Astables may typically be chosen for such tasks as producing high frequency digital signals. They are also used to produce the relatively low frequency on-off signals for flashing lights.

Sweep oscillators

A sweep waveform is another name for a saw-tooth wave. This has a linearly changing (e.g increasing) voltage for almost the whole of one cycle followed by a fast return to the wave's original value. This wave shape is useful for changing (sweeping) the frequency of a voltage-controlled oscillator, which is an oscillator that can have its frequency varied over a set range by having a variable 'sweep' voltage applied to its control input. Sweep oscillators often consist of a ramp generator that is basically a capacitor charged by a constant value of current. Keeping the charging current constant whilst the charging voltage increases, causes the capacitor to charge in a linear fashion rather than its normal exponential curve. At a given point the capacitor is rapidly discharged to return the signal voltage to its original value. These two sections of a saw-tooth wave cycle are called the sweep and the fly-back.

Module 1.1
Oscillator Operation

What you'll learn in Module 1.1

After Studying this section, you should be able to:

- Recognise that oscillators consist of 3 essential parts.
- Describe the essential parts of an oscillator.
- State the reasons for using positive feedback.
- State methods of frequency control in oscillators
- State reasons for amplitude control oscillators

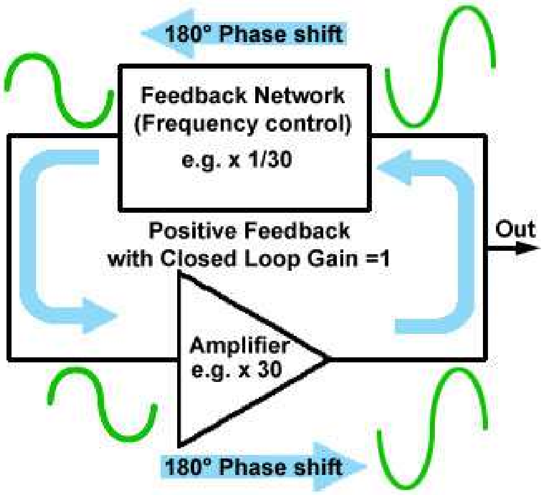


Fig. 1.1.1 The Essential Elements of an Oscillator

Parts of an Oscillator

Most oscillators consist of three basic parts:

1. An amplifier. This will usually be a voltage amplifier and may be biased in class A, B or C.

2. A wave shaping network. This consists of passive components such as filter circuits that are responsible for the shape and frequency of the wave produced.

3. A POSITIVE feedback path. Part of the output signal is fed back to the amplifier input in such a way that the feed back signal is regenerated, re-amplified and fed back again to maintain a constant output signal.

Commonly an oscillator is constructed from an amplifier that has part of its output signal fed back to its input. This is done in such a way as to keep the amplifier producing a signal without the need for any external signal input as shown in Fig. 1.1.1. It can also be thought of as a way of converting a DC supply into an AC signal.

Positive feedback.

The feedback in the amplifier section of an oscillator must be POSITIVE FEEDBACK. This is the condition where a fraction of the amplifier's output signal is fed back to be in phase with the input, and by adding together the feedback and input signals, the amplitude of the input signal is increased. For example, a common emitter amplifier creates a phase change of 180° between its input and output, the positive feedback loop must therefore also produce a 180° phase change in the signal fed back from output to input for positive feedback to occur.

The result of a small amount of positive feedback in amplifiers is higher gain, though at the cost of increased noise and distortion. If the amount of positive feedback is large enough however, the result is oscillation, where the amplifier circuit produces its own signal.

Using Positive Feedback.

When an amplifier is operated without feedback it is operating in "open loop" mode. With feedback (either positive or negative) it is in "closed loop" mode. In ordinary amplifiers negative feedback is used to provide advantages in bandwidth, distortion and noise generation, and in these circuits the closed loop gain of the amplifier is much less than the open loop gain. However when positive feedback is used in an amplifier system the closed loop gain (with feedback) will be greater than the open loop gain, the amplifier gain is now increased by the feedback. Additional effects of positive feedback are reduced bandwidth, (but this does not matter in an oscillator producing a sine wave having a single frequency), and increased distortion. However even quite severe distortion in the amplifier is allowed in **some** sine wave oscillator designs, where it does not affect the shape of the output wave.

In oscillators using positive feedback it is important that amplitude of the oscillator output remains stable. Therefore the closed loop gain must be 1 (unity). In other words, the gain within the loop (provided by the amplifier) should exactly match the losses (caused by the feedback circuit) within the loop. In this way there will be no increase or decrease in the amplitude of the output signal, as illustrated in Fig. 1.1.2.

The conditions for oscillation.

Positive feedback must occur at a frequency where the voltage gain of the amplifier is equal to the losses (attenuation) occurring in the feedback path. For example if 1/30th of the output signal is fed back to be in phase with the input at a particular frequency, and the gain of the amplifier (without feedback) is 30 times or more, oscillation will take place.

The oscillations should take place at one particular frequency.

The amplitude of the oscillations should be constant.

There are many different oscillator designs in use, each design achieving the above criteria in different ways. Some designs are particularly suited to producing certain wave shapes, or work best within a certain band of frequencies. Whatever design is used however, the way of achieving a signal of constant frequency and constant amplitude is by using one or more of three basic methods

Method 1

Make sure that positive feedback occurs only at one frequency, the required frequency of oscillation. This may be achieved by ensuring that only signals of the required frequency are fed back, or by ensuring the feedback signal is in the correct phase at only one frequency.

Method 2

Make sure that sufficient amplification for oscillation can take place only at the required frequency, by using an amplifier that has an extremely narrow bandwidth, extending to the frequency of oscillation only.

Method 3

Use amplifiers in "switch mode" to switch the output between two set voltage levels, together with some form of time delay to control the time at which the amplifiers switch on or off, thus controlling the periodic time of the signal produced.

Methods 1 and 2 are used extensively in sine wave oscillators, while method 3 is useful in square wave generators, sometimes called aperiodic (untuned) oscillators. Oscillators using method 3 often use more than one amplifier and timing circuit, and so are called multivibrators (more than one oscillator).

Constant Amplitude

As shown in Fig. 1.1.1 oscillators must have an amplifier, a positive feedback loop and some method of controlling the frequency of oscillation. In RF sine wave oscillators the frequency may be controlled by an LC tuned circuit, but as well as controlling the frequency of oscillation, there must also be some means, such as negative feedback, of stabilising the amplitude of the signal produced.

Without this stabilisation the oscillations would either die away and stop (damped oscillation) or rapidly increase in amplitude until the amplifier produces severe distortion due to the transistors within the amplifier becoming "saturated" as shown in Fig. 1.1.2. To produce a constant amplitude output the gain of the amplifier is automatically controlled during oscillation.

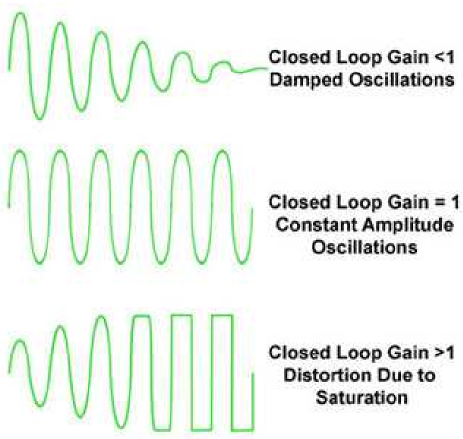


Fig. 1.1.2 The Need For Amplitude Stability

Oscillators – Module 1

1.2 Oscillator Basics Quiz

Try our quiz, based on the information you can find in Oscillators Module 1.

You can check your answers by using the online version at:

http://www.learnabout-electronics.org/Oscillators/osc12.php

1. Which of the following statements most accurately describes an oscillator?

a) An oscillator produces an AC signal without requiring any input.

b) An oscillator is a device for converting DC energy into AC energy.

c) An oscillator is an essential part of a power supply circuit.

d) An oscillator is a radio frequency device.

2. LC resonant circuits are used in:

a) RF and ultrasonic oscillators.

b) AF and ultrasonic oscillators.

c) LF sweep oscillators.

d) Variable frequency crystal oscillators.

3. The tuning stages of an AM radio receiver typically use:

a) LC oscillators.

b) RC oscillators.

c) Crystal oscillators.

d) Switch mode transistors.

4. Which of the following circuit types may typically be used in a relaxation oscillator?

a) Linear audio amplifier.

b) Tuneable LC circuit.

c) Class C amplifier.

d) Amplifiers operating in switch mode.

5. Three essential elements of an oscillator circuit are:

a) An amplifier, a wave shaping network and negative feedback.

b) An AC input, a wave shaping network and an amplifier.

c) An amplifier, a positive feedback path and a wave shaping network.

d) A switch mode amplifier a negative feedback path and an AC output.

6. In oscillators using a common emitter amplifier, what phase shift should be produced by the feedback system?

a) 0°

b) 90°

c) 180°

d) 360°

7. The closed loop gain of a working oscillator circuit is:

a) Less than 1

b) More than 1

c) Exactly 1

d) Infinity

8. For what reason would negative feedback be used in an oscillator?

a) To increase the bandwidth of the oscillator.

b) To enable the frequency to be varied over a wide range.

c) To improve frequency stability.

d) To control the amplitude of oscillations.

9. At the required frequency of oscillation, which of the following conditions must be present?

a) Positive feedback must be occurring.

b) Open loop gain must be less than 1.

c) Amplifier bandwidth must be wide.

d) Closed loop gain must be less than 1.

10. Which of the following oscillator types would be used to generate a variable frequency sine wave of 3MHz to 30MHz?

a) A variable frequency RC oscillator.

b) A radio frequency crystal oscillator.

c) A variable frequency relaxation oscillator.

d) A radio frequency LC oscillator.

