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Research paper

Classification of electronic oscilla-tors

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Abstract

This paper introduces main types of electronic oscillators as devices that in general convert energy from a direct-current source to a periodically varying electric output. Oscillators take two general forms: First, stand-alone benchtop units designed for electronic testing and measurement and Second, circuits integrated to other devices and many electronic circuits, such as radio receivers, transmitters, sciences, music, broadcasting, medical diagnosis, computing and other devices.

Keywords: *Amplifier; Oscillators; Resonators.*

1. Introduction

An oscillator is an electronic device for generating an AC signal voltage for radio and electronic equipment. Oscillators generate sinusoidal or non-sinusoidal waveform from very Low Frequencies (LF) up to very High Frequencies (HF). The local oscillator in most present-day broadcasts band of Amplitude Modulation (AM) that super heterodynes cover a range of frequencies approximately from 1000 to 2100 KHz. Namely, an oscillator is a circuit to generate alternating voltage of desired frequency and amplitude. It converts DC energy to an AC voltage. It has wide applications, such as to test a stereo amplifier, an audio signal generator producing 20 to 15 kHz at the transmitter and 47 to 230 MHz frequency at receiver end, in radio the carrier frequency varies from 550 KHz to 20 MHz and for TV broadcasting high frequency oscillators are required.

Therefore, an oscillator is one of the major devices in many electrical, electronics and communication equipment that must provide amplification and a portion of the output is feedback to sustain the input. In fact, oscillator is electronic device that produces the alternating signal output without giving an alternating input. Here in an oscillator the energy for producing the AC voltage is supplied from the DC source provided. If the output voltage is sinusoidal means that it is sinusoidal or harmonic oscillator. However, if the output voltage is non-sinusoidal means that it is relaxation oscillator, such as square, triangular and saw tooth.

According to frequency generated components there are Audio Frequency Oscillator (AFO), which frequency range is up to 20 KHz, Radio Frequency Oscillator (RFO), which frequency range is between 20 KHz to 30 MHz, Very High Frequency Oscillator (VFO), which frequency range is between 30 KHz to 300 MHz, then Ultra High Frequency Oscillator (UFO), which frequency range is between 300 MHz to 3GHz, and finally Microwave Frequency Oscillator (MFO), which RF range is above 3 GHz. According to type of the electronic circuit used the sine or square wave oscillators may be classified as LC tuned and RC phase shift oscillators [1].

2. Basic of electronic oscillators

An oscillator is an electronic circuit that creates a waveform output from a direct current input and produces a repetitive electronic signal, often a sine wave or a square wave. A basic oscillator is a capacitor and inductor connected together. As the capacitor discharges, the current creates a magnetic field in the inductor. When the capacitor is fully discharged, the field collapses and induces an opposite current that charges the capacitor again. This cycle continues until all the energy is lost through resistance. The frequency of the oscillations depends on the size of the capacitor and inductor.

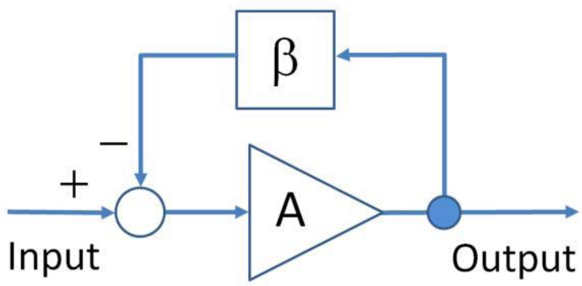

Fig. 1: Amplifier with Positive Feedback [2].

As stated above, an oscillator must provide amplification and a portion of the output is feedback to sustain the input, as shown in Figure 1. Enough power must be feedback to the input circuit for the oscillator to drive itself as in case of signal generator. The oscillator is self-driven, because the feedback signal is regenerative i.e. positive feedback.

Therefore, how oscillators do work? Oscillators are electronic amplifiers with positive feedback.

When some portion of output signal is feedback to the input of amplifier but with same phase as the input signal, it is called as positive feedback. In such a way can be achieved first condition to start oscillation, and second one is value of feedback.

In the other words, therefore, the use of positive feedback is useful for designing and producing oscillators. The expression for positive feedback is that a portion of the output of the open-loop gain (A) is combined in phase with the input of the feedback factor (β), which loop gain (Aβ) amount of feedback is expressed by the following condition:

$$A\beta = 1 \quad (1)$$

Where A = is amplification of amplifier (times); β = is value of signal feedback to amplifier input.
Thus, oscillators are special electronic circuits that generate a continuous voltage output waveform at a required frequency with the values of the inductors, capacitors or resistors forming a frequency selective LC resonant tank circuit and feedback network. The feedback network is an attenuation network which has a gain of less than one β<1 and starts oscillations when Aβ>1 which returns to unity Aβ =1 once oscillations commence.
The large open loop gain of an operational amplifies makes it inevitable that the condition will be reached and the gain of the feedback amplifier or closed-loop gain (A_f) is expressed with the following relation:

$$A_f = V_o/V_i = A/1 - A\beta$$

And

$$V_o = A(V_i + \beta V_o) = 1 - A\beta = A\ V_i \quad (2)$$

Where V_o = Vout and Vi = Vin.
In practice, the gain that applies at low signal amplitudes will be reduced until the signal output amplitude reaches some constant value, which limits will be independent of input, allowing the circuit to produce a designed output [1], [2].

Fig. 2: AF Oscillator [3].

3. Audio frequency oscillator (AF oscillator)

The first division of oscillators will bi operation frequency region, such as Low (LFO) and High Frequency Oscillators (HFO). In the case when is discussion about the LFO usually means that it is Audio Frequency (AF) oscillator.

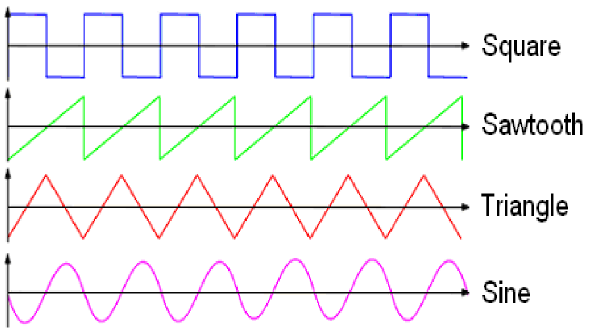

Fig. 3: AF Waveforms [4].

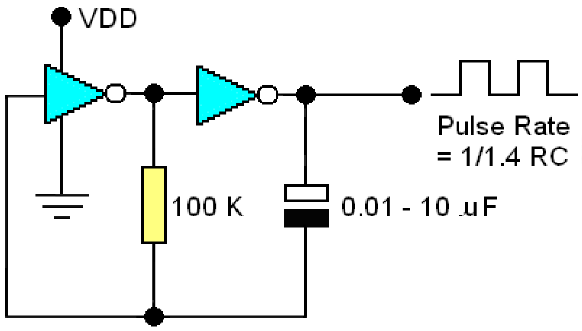

Fig. 4: Diagram of TTL Oscillator [5].

Thus, the same term is present in radio frequency as well to, so in such a way it will be used term audio frequency up to 30 kHz, although the frequency limit is not strictly ordered. Now let's start with review of AF oscillators. An AF oscillator is a useful test instrument, which is illustrated in Figure 2.
This oscillator is capable of generating square, sawtooth, triangle and sine waveforms at any required frequency and in switched decade sub-ranges, which are depicted in Figure 3
The next AF oscillator is Transistor-Transistor Logic (TTL) oscillator with rectangle output signal of 1/1.4 RC pulse rate, which diagram is illustrated in Figure 4.
The term LFO is an audio signal usually below 20 Hz that creates a pulsating rhythm rather than an audible tone referred to an audio technique specifically used in the production of electronic music. On most synthesizers and sound modules, LFO feature few controllable values with different waveforms, a rate control, routing options, a tempo sync feature and an option to control how much the LFO will modulate the audio signal. Electronic musicians use LFO for many applications, such as to add simple vibrato or tremolo to a melody or for more solutions, such as triggering gate envelopes, etc.
The AF oscillator has output banana sockets and a maximum wave output of 20 volts peak-to-peak approx, which may be adjusted by an amplitude control potentiometer. Accordingly, the frequency of the signal source is set on a dial (1 to 11), along with a multiplier range switch (x1, x10, x100, x1K, x10K, x100K). It is widely used in industry and education institutions. Furthermore, sometimes it is very important to consider signal purity and frequency stability or both. At this point, various techniques are implemented to get wanted results and in cost of complex schematic.

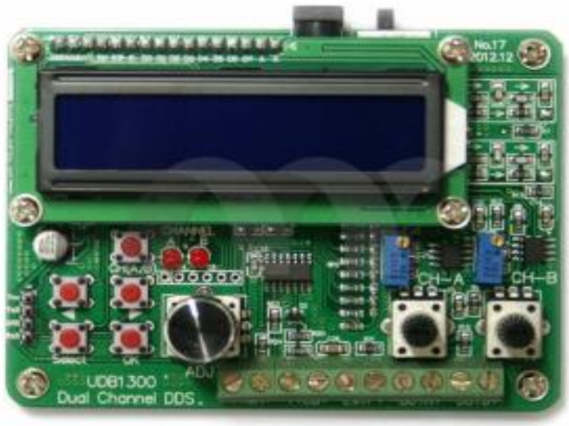

Fig. 5: Sample of Source Signal Generator [6].

In Figure 5 is shown 8MHz Dual TTL DDS Source Signal Generator 60MHz Sweep Frequency Counter based on Direct Digital Synthesis (DDS) technology applicable to laboratories and used by engineering technicians. It has high stability and low distortion, two channel TTL output, DC bias, external frequency measurement, counter and so on [3 - 6].

4. Crystal and ceramic resonator oscillators

Crystal oscillators are used in early days of BC radio and radio communication as reference to calibrate frequency scale of received frequencies. Difference between crystal and synthetic ceramic resonator is in their long-term frequency stability. Compare them to then room temperature Quartz has drift of $\Delta f/f \approx 1.2$-6 to 5-6 and ceramic resonator has 50-120 ppm change of nominal frequency. Schematics of oscillators for both of them are the same. Here will be introduced just more common crystal oscillators:

1) Colpitts Oscillator – This oscillator is invented in 1918 by American engineer Edwin H. Colpitts. It is one of a number of designs for LC oscillators, electronic oscillators that use a combination of inductors (L) and capacitors (C) to produce an oscillation at a certain frequency. The distinguishing feature of the Colpitts oscillator is that the feedback for the active device is taken from a voltage divider made of two capacitors in series across the inductor. Colpitts oscillator is illustrated in Figure 6 designed around the common emitter amplifier stage. The input signal to the transistor base is inverted at the transistors output. Thus, the output signal at the collector is than taken through an 180º phase shifting network, which includes the crystal operating in a series resonant mode.

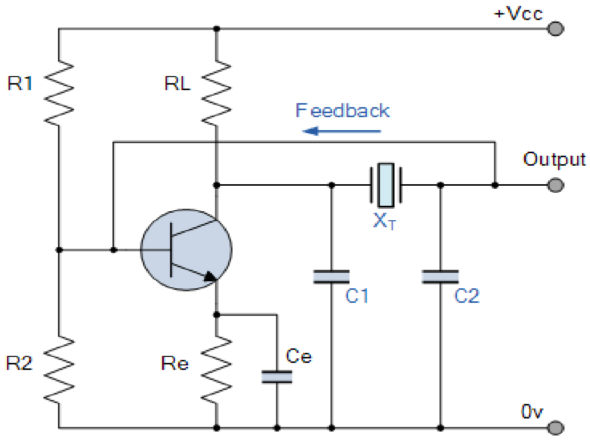

Fig. 6: Colpitts Oscillator [5].

2) Pierce Oscillator – This oscillator is shown in Figure 7 as another common design of the quartz crystal oscillator.

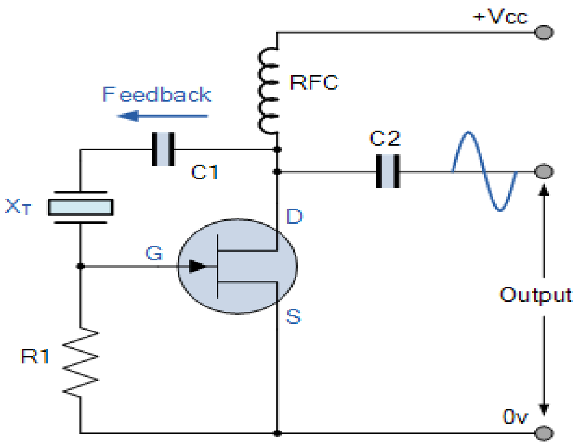

Fig. 7: Pierce Oscillator [5].

It is uses the crystal as part of its feedback path and therefore has no resonant tank circuit. It also uses a JFET as its amplifying device as it provides very high input impedance with the crystal connected between the output Drain terminal and the input Gate terminal. Pierce electronic oscillator is particularly well suited for use in piezoelectric crystal oscillator circuits, named for its inventor George W. Pierce (1872-1956) and is a derivative of the Colpitts oscillator.

Virtually all digital IC clock oscillators are of Pierce type, as the circuit can be implemented using a minimum of components: a single digital inverter, two resistors, two capacitors, and the quartz crystal, which acts as a highly selective filter element. The low manufacturing cost of this circuit and the outstanding frequency stability of the quartz crystal, give it an advantage over other designs in many applications [1], [5].

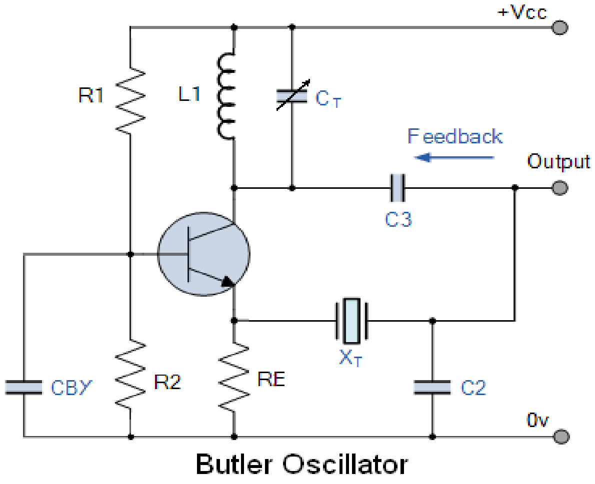

Fig. 8: Butler Oscillator [5].

3) Butler Oscillator – This is one very interesting type of oscillator shown in Figure 8, which is able to oscillate on fix frequency either fundamental or one of higher harmonics, which is excellent replacement for frequency multiplier. Alignments is easy, just replace crystal and L1 with 50 Ω resistor and adjust L1 and 11 pF capacitor to resonate on wonted frequency, after that put on place crystal and if needed L1 and that is all. Inductor L1 isn't always necessary it depends on used crystal. Environment temperature variation is the main reason for frequency drift of quartz crystal.

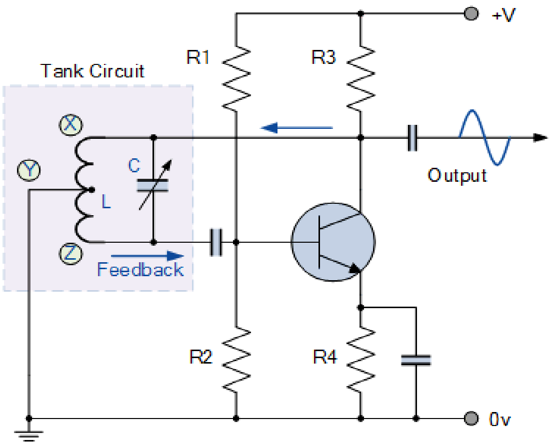

Fig. 9: Hartley Oscillator [7].

4) Hartley Oscillator – The electronic oscillator circuit, shown in Figure 9 is special oscillator, known as a Hartley, in which the oscillation frequency is determined by a tuned circuit consisting of capacitors and inductors, that is, an LC oscillator.

The circuit was invented in 1915 by American electronic engineer Ralph Hartley. Thus, the distinguishing characteristics of the Hartley oscillator is that the tuned circuit consists of a single capacitor in parallel with two inductors in series (or a single tapped inductor), and the feedback signal needed for oscillation is taken from the center connection of the two inductors [1], [5].

5) Microprocessor Crystal Quartz Clocks Oscillator – This specific oscillator is known as Microprocessor crystal clocks, illustrated in Figure 10. Virtually this crystal oscillator is all

microprocessors, micro-controllers, Programmable Intelligent Computer (PIC) and CPU generally operate using a Quartz Crystal Oscillator as its frequency determining device to generate their clock waveform because as we already know, crystal oscillators provide the highest accuracy and frequency stability compared to resistor-capacitor (RC) or inductor-capacitor (LC) oscillators.

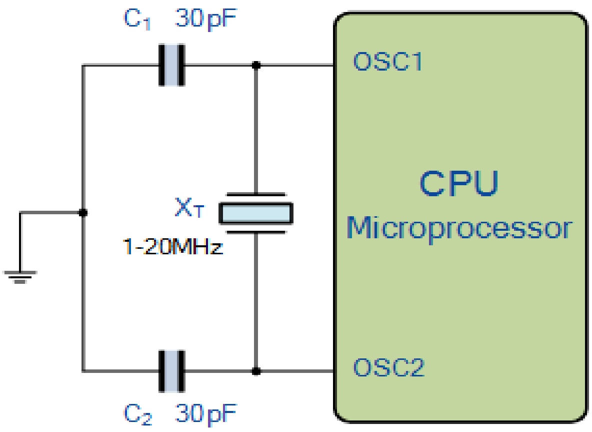

Fig. 10: Microprocessor Oscillator [7].

In fact, most microprocessors, micro-controllers and PIC have two oscillator pins labeled OSC1 and OSC2 to connect to an external quartz crystal circuit, standard RC oscillator network or even a ceramic resonator. In this type of microprocessor oscillator solution the Quartz Crystal Oscillator produces a train of continuous square wave pulses whose fundamental frequency is controlled by the crystal itself. Among the rest, this fundamental frequency regulates the flow of instructions that controls the processor device and for example the master clock and system timing [1], [7].

6) Clapp Oscillator – This is one of several types of electronic oscillator constructed from a transistor or vacuum tube and a positive feedback network, which is illustrated in Figure 11. The Clapp Oscillator is using the combination of an inductance (L) with a capacitor (C) for frequency determination, thus also called LC oscillator, published by researcher James Kilton Clapp in 1948. According to Vackar oscillators of this kind were independently developed by several inventors and one developed by Gouriet had been in operation at the BBC since 1938 [1], [8].

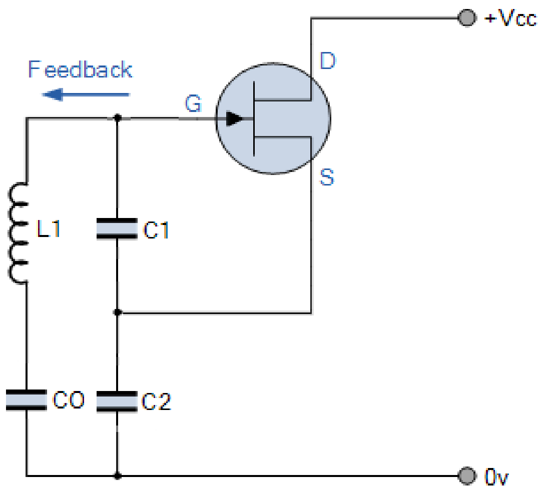

Fig. 11: Clapp Crystal Oscillators [8].

In practice, there are many other solutions of harmonic and relaxation oscillators, then Variable Frequency Oscillators (VFO), UHF oscillators, magnetrons, etc.

Therefore, in Figure 12 (A) are shown different examples of ceramic resonators, in Figure 12 (B) is illustrated quartz crystal resonator ready for encapsulating and Figure 12 (C) shows fix frequency quartz 1.0 MHz TTL Crystal Oscillator Full Size Dual In-line Package (DIP) ready to be soldered on PCB.

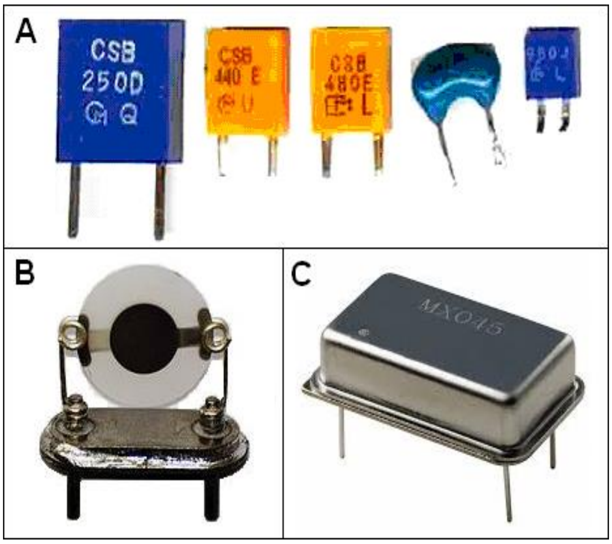

Fig. 12: Different Types of Resonators and Oscillators [9].

A ceramic resonator is an electronic component consisting of a piece of a piezoelectric ceramic material with two or more metal electrodes attached. When connected in an electronic oscillator circuit, resonant mechanical vibrations in the device generate an oscillator signal of a specific frequency. Like the similar quartz crystal, they are used in oscillators for purposes such as generating the clock signal used to control timing in computers and other digital logic devices [1], [9], [10].

5. Conclusion

In this paper is shortly introduced implementation of several types of electronic oscillators for major practical applications. Electronic oscillator contains circuit that generates an output signal without necessity of an input signal. Thus, it is a circuit that produces a repetitive waveform on its output with only DC supply as input. In general, oscillators can be sinusoidal or non-sinusoidal type. As stated, electronic oscillators can be used in many applications such as communication, radio and digital systems, which also include many practical solutions for testing, measurements and integrated electronic circuits.

The most important parameter is the gain margin of the oscillator in practical solutions, which determines if the oscillator will start up or not. In such a way, this parameter has to be calculated at the beginning of the design phase to choose the suitable crystal for the application. The second parameter is the value of the external load capacitors that have to be selected in accordance with the CL specification of the crystal, provided by the crystal manufacturer. This determines the frequency accuracy of the crystal. The third parameter is the value of the external resistor that is used to limit the drive level. However, in the 32 kHz electronic oscillator part, it is not recommended to use an external resistor.

Because of the number of variables involved, in the experimentation phase designer should use components that have exactly the same properties as those that will be used in production. Likewise, designers should work with the same oscillator layout and in the same environment to avoid unexpected behavior and therefore save time.

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