OSCILLATORS:

An oscillator is a circuit which produces a continuous, repeated, alternating waveform without any input. Oscillators basically convert unidirectional current flow from a DC source into an alternating waveform which is of the desired frequency, as decided by its circuit components.

Principle of Oscillators:

An oscillator consists of an amplifier and a feedback network. Now, let us see which basic components are required to obtain oscillations.

- 'Active device' either Transistor or Op Amp is used as an amplifier.
- 'Feedback circuit' with passive components such as R-C or L-C combinations .

To start the oscillation with the constant amplitude, positive feedback is not the only sufficient condition. Oscillator circuit must satisfy the following two conditions known as Barkhausen conditions:

1. The first condition is that the magnitude of the loop gain ($A\beta$) must be unity. This means the product of gain of amplifier 'A' and the gain of feedback network 'β' has to be unity.

2. The second condition is that the phase shift around the loop must be 360° or 0°. This means, the phase shift through the amplifier and feedback network has to be 360° or 0°.

Applications of oscillators:

Some common applications of oscillators include:

- Quartz watches (which uses a crystal oscillator).
- Used in various audio systems and video systems.
- Used in various radio, TV, and other communication devices.
- Used in computers, metal detectors, stun guns, inverters, ultrasonic and radio frequency applications.
- Used to generate clock pulses for microprocessors and micro-controllers.
- Used in alarms and buzzes.
- Used in metal detectors, stun guns, inverters, and ultrasonic.
- Used to operate decorative lights (e.g. dancing lights)

Crystal oscillators:

Crystal oscillators operate on the principle of inverse piezoelectric effect in which an alternating voltage applied across the crystal surfaces causes it to vibrate at its natural frequency. It is these vibrations which eventually get converted into oscillations.

These oscillators are usually made of Quartz crystal, eventhough other substances like Rochelle salt and Tourmaline exhibit the piezoelectric effect because, quartz is inexpensive, naturally-available and mechanically-strong when compared to others.

In crystal oscillators, the crystal is suitably cut and mounted between two metallic plates as shown by Figure 1a whose electrical equivalent is shown by Figure 1b. In reality, the crystal behaves like a series RLC circuit, formed by the components

1. A low-valued resistor R_S
2. A large-valued inductor L_S
3. A small-valued capacitor C_S

which will be in parallel with the capacitance of its electrodes C_p.

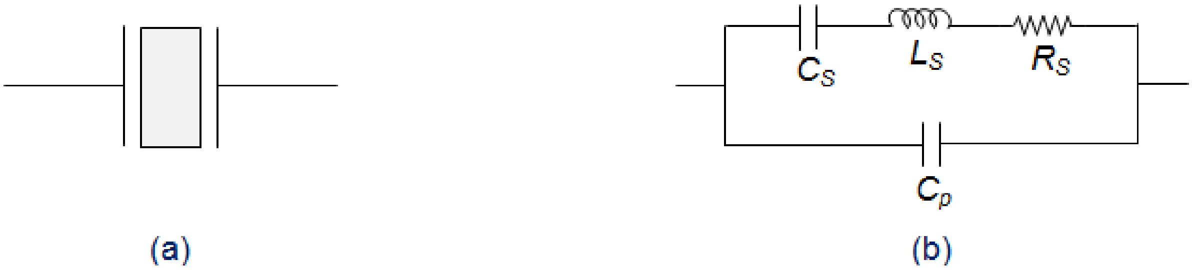

Figure 1 (a) Quartz Crystal (b) Equivalent Electric Circuit

Due to the presence of C_p, the crystal will resonate at two different frequencies viz.,

1. Series Resonant Frequency, f_s which occurs when the series capacitance C_S resonates with the series inductance L_S. At this stage, the crystal impedance will be the least and hence the amount of feedback will be the largest. Mathematical expression for the same is given as

$$f_s = \frac{1}{2\pi\sqrt{L_s C_s}}$$

2. Parallel Resonant frequency, f_p which is exhibited when the reactance of the $L_S C_S$ leg equals the reactance of the parallel capacitor C_p i.e. L_S and C_S resonate with C_p. At this instant, the crystal impedance will be the highest and thus the feedback will be the least. Mathematically it can be given as

$$f_p = \frac{1}{2\pi\sqrt{L_S \frac{C_P C_S}{C_P + C_S}}}$$

The behaviour of the capacitor will be capacitive both below f_S and above f_p. However for the frequencies which lie in-between f_S and above f_p, the crystal's behavior will be inductive. Further when the frequency becomes equal to parallel resonant frequency f_p, then the interaction between L_S and C_p would form a parallel tuned LC tank circuit. Hence, a crystal can be viewed as a combination of series and parallel tuned resonance circuits due to which one needs to tune the circuit for any one among these two. Moreover it is to be noted that f_p will be higher than f_s and the closeness between the two will be decided by the cut and the dimensions of the crystal in-use.

Crystal oscillators can be designed by connecting the crystal into the circuit such that it offers low impedance when operated in series-resonant mode (Figure 2a) and high impedance when operated in anti-resonant or parallel resonant mode (Figure 2b).

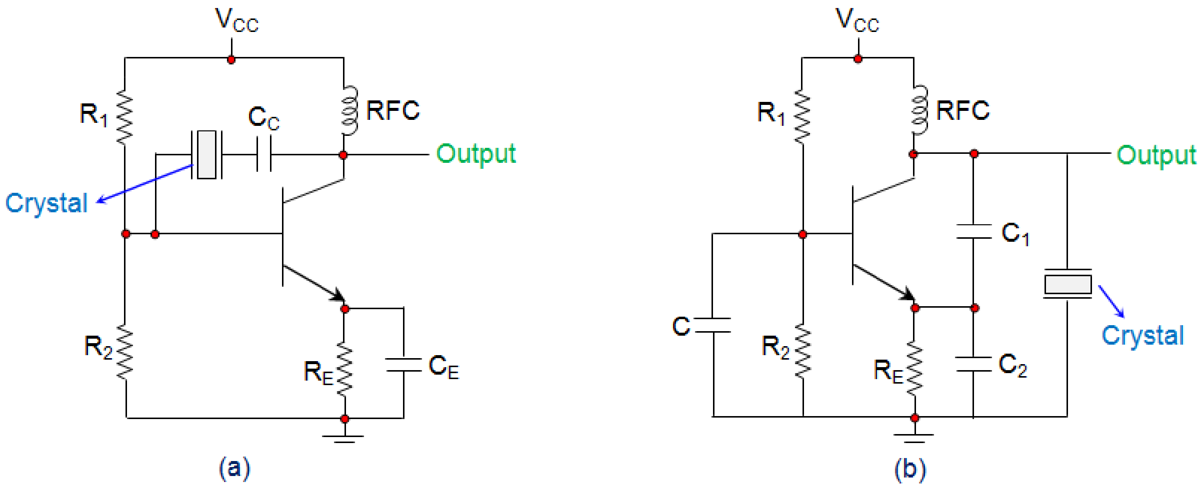

Figure 2 Crystal Oscillator Operating in (a) Series Resonance (b) Parallel Resonance

In the circuits shown, the resistors R_1 and R_2 form the voltage divider network while the emitter resistor R_E stabilizes the circuit. Further, C_E (Figure 2a) acts as an AC bypass capacitor while the coupling capacitor C_C (Figure 2a) is used to block DC signal propagation between the collector and the base terminals. Next, the capacitors C_1 and C_2 form the capacitive voltage divider network in the case of Figure 2b. In addition, there is also a Radio Frequency Coil (RFC) in the circuits (both in Figure 2a and 2b) which offers dual advantage as it provides even the DC bias as well as frees the circuit-output from being affected by the AC signal on the power lines.
On supplying the power to the oscillator, the amplitude of the oscillations in the circuit increases until a point is reached wherein the nonlinearities in the amplifier reduce the loop gain to unity. Next, on reaching the steady-state, the crystal in the feedback loop highly influences the frequency of the operating circuit. Further, here, the frequency will self-adjust so as to facilitate the crystal to present a reactance to the circuit such that the Barkhausen phase requirement is fulfilled.

The typical operating range of the crystal oscillators is from 40 KHz to 100 MHz Crystal oscillators are compact in size and are of low cost due to which they are extensively used in electronic warfare systems, communication systems, guidance systems, microprocessors, microcontrollers, space tracking systems, measuring instruments, medical devices, computers, digital systems, instrumentation, phase locked loop systems, modems, sensors, disk drives, marine systems, telecommunications, engine controlling systems, clocks, Global Positioning Systems (GPS), cable television systems, video cameras, toys, video games, radio systems, cellular phones, timers, etc.

Advantages of Crystal Oscillator:

- The crystal oscillator has very low frequency drift due to change in temperature and other parameters.
- The crystal oscillator Q is very high.
- It has Automatic amplitude control.
- It has very high frequency **stability**.
- The crystal oscillator is possible to obtain very high precise and **stable** frequency of oscillators.

Disadvantages of crystal oscillator:

- Crystals of low fundamental frequencies are not easily available.
- These are suitable for high frequency application.
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Applications of crystal oscillator:
- The crystal oscillators are used in radio and TV transmitters.
- It is used as a crystal clock in microprocessors.
- It is used in the frequency synthesizers.
- It is used in special types of receivers.