Oscillator

INTRODUCTION:

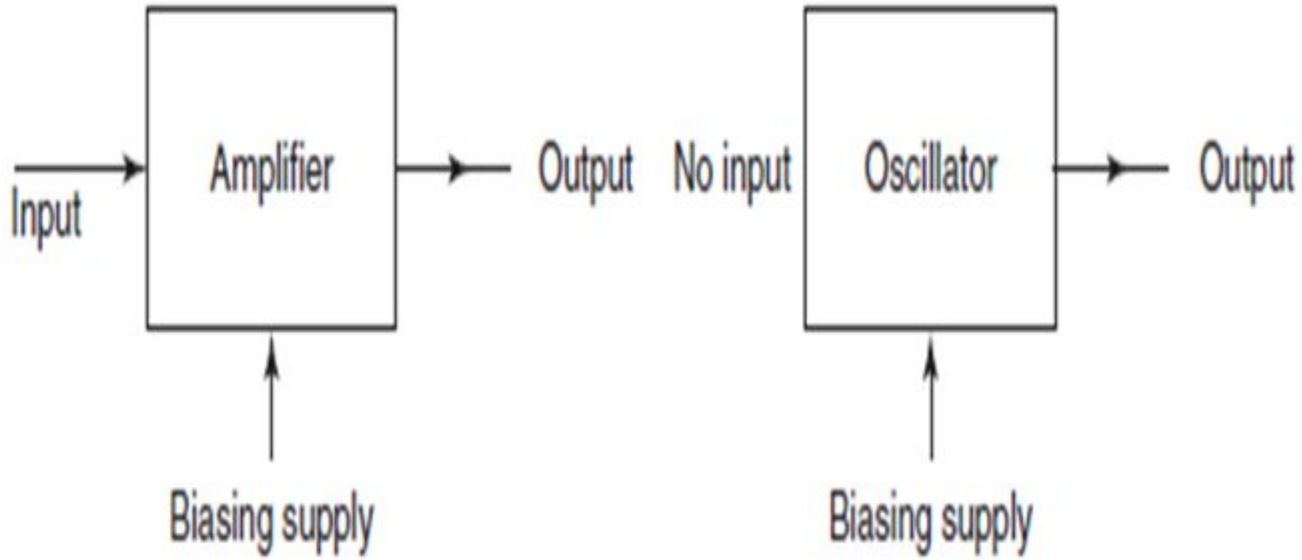
- An oscillator is an electronic circuit that gives an output without any input signal.

- It comprises active and passive circuit elements and sinusoidal produces repetitive waveforms at the output without the application of a *direct external input signal to the circuit.*

- *It* converts the dc power from the source to ac power in the load. A rectifier circuit converts ac to dc power, but an oscillator converts dc noise signal/power to its ac equivalent.

- The general form of a harmonic oscillator is an electronic amplifier with the output attached to a narrow-band electronic filter and the output of the filter attached to the input of the amplifier.

Difference between an amplifier and an oscillator:



Schematic block diagrams showing the difference between an amplifier and an oscillator

CLASSIFICATIONS OF OSCILLATORS:

- Oscillators are classified based on the type of the output waveform.
- If the generated waveform is *sinusoidal or close to sinusoidal* (with a certain frequency) then the oscillator is said to be a *Sinusoidal Oscillator*.

  If the output waveform is *non-sinusoidal,* which refers to square/saw-tooth waveforms, the oscillator is said to be a

  Relaxation Oscillator.
- An oscillator has a positive feedback with the loop gain infinite.

CONDITIONS FOR OSCILLATION: BARKHAUSEN CRITERIA

Earlier we established that the overall gain of a feedback amplifier is $A_f = A/(1 + A\beta)$, where A is the gain of the internal amplifier, β is the feedback ratio, and $-A\beta$ is the loop gain. For positive feedback, the feedback gain is expressed as:

$$A_f = \frac{A}{1 - A\beta}$$

For $A\beta = 1$, Eq. yields $A_f = \infty$. The amplifier then produces an output voltage without any externally applied input voltage. Thus, the amplifier becomes an oscillator. When the signal equals $V_o' \Rightarrow A\beta V_o = V_o$ or $A\beta = 1$, the output voltage regenerates itself and the amplifier oscillates. This condition is called the Barkhausen criterion. This condition means that $|A\beta| = 1$ and the phase angle of $A\beta$ is zero or an integral multiple of 360. The basic conditions for oscillation in a feedback amplifier are: (1) the feedback must be regenerative, (2) the loop-gain must be unity, and (3) the phase difference must be zero or an integral multiple of 360.

CLASSIFICATIONS OF OSCILLATORS:

- The classification of various oscillators is shown in the table

Different types of oscillators and their frequency ranges

Type of Oscillator	*Frequency Range Used*
1. Audio-frequency oscillator	20 Hz – 20 kHz
2. Radio-frequency oscillator	20 kHz – 30 MHz
3. Very-high-frequency oscillator	30 MHz –300 MHz
4. Ultra-high-frequency oscillator	300 MHz – 3 GHz
5. Microwave oscillator	3 GHz – 30 GHz
6. Millimeter wave oscillator	30 GHz – 300 GHz

CHARACTERISTICS OF OSCILLATORS:

- Oscillators are a common element of almost all electronic circuits. They are used in various applications, and their use makes it possible for circuits and subsystems to perform numerous useful functions.
- In oscillator circuits, oscillation usually builds up from zero when power is first applied under linear circuit operation.
- The oscillator's amplitude is kept from building up by limiting the amplifier saturation and various non-linear effects.
- Oscillator design and simulation is a complicated process. It is also extremely important and crucial to design a good and stable oscillator.
- Oscillators are commonly used in communication circuits. All the communication circuits for different modulation techniques—AM, FM, PM—the use of an oscillator is must.
- Oscillators are used as stable frequency sources in a variety of electronic applications. (Quartz watches)
- Oscillator circuits are used in computer peripherals, counters, timers, calculators, phase-locked loops, digital multi-metres, oscilloscopes, and numerous other applications.

CRYSTAL OSCILLATOR:

- Crystal oscillator is most commonly used oscillator with high-frequency stability. They are used for laboratory experiments, communication circuits and biomedical instruments. They are usually fixed frequency oscillators where stability and accuracy are the primary considerations.
- In order to design a stable and accurate LC oscillator for the upper HF and higher frequencies it is absolutely necessary to have a crystal control; hence, the reason for crystal oscillators.
- Crystal oscillators are oscillators where the primary frequency determining element is a quartz crystal. Because of the inherent characteristics of the quartz crystal the crystal oscillator may be held to extreme accuracy of frequency stability. Temperature
- compensation may be applied to crystal oscillators to improve thermal stability of the crystal oscillator.

- The crystal size and cut determine the values of *L, C, R and C'. The resistance R is the friction of* the vibrating crystal, capacitance *C is the compliance, and inductance L is the equivalent mass. The capacitance C' is the electrostatic capacitance between the mounted pair of electrodes with the crystal as the dielectric.*

Equivalent Circuit Diagram of Piezoelectric Crystal :

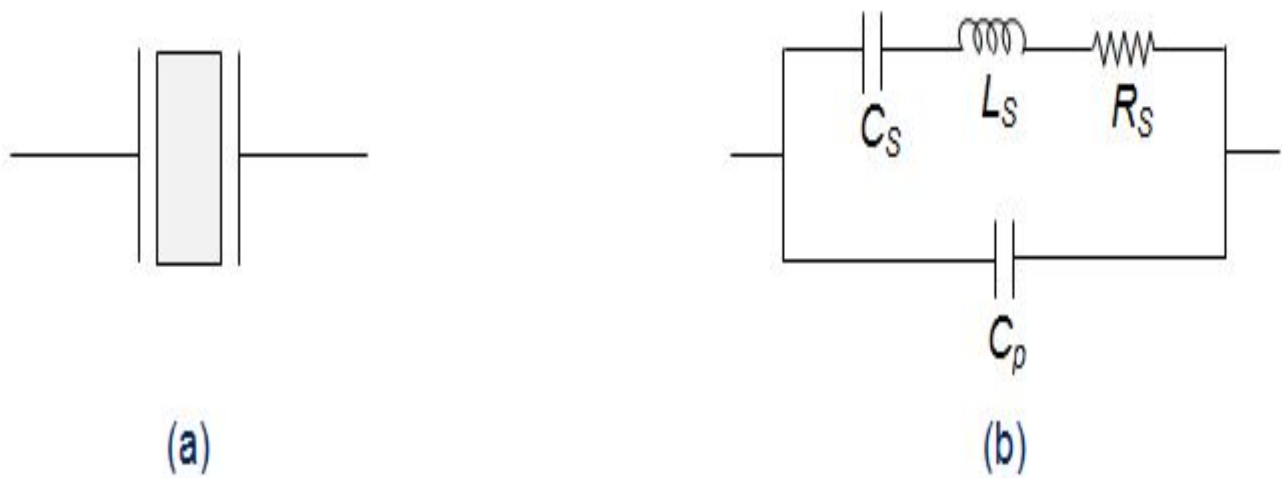


Figure (a) Quartz Crystal (b) Equivalent Electric Circuit

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

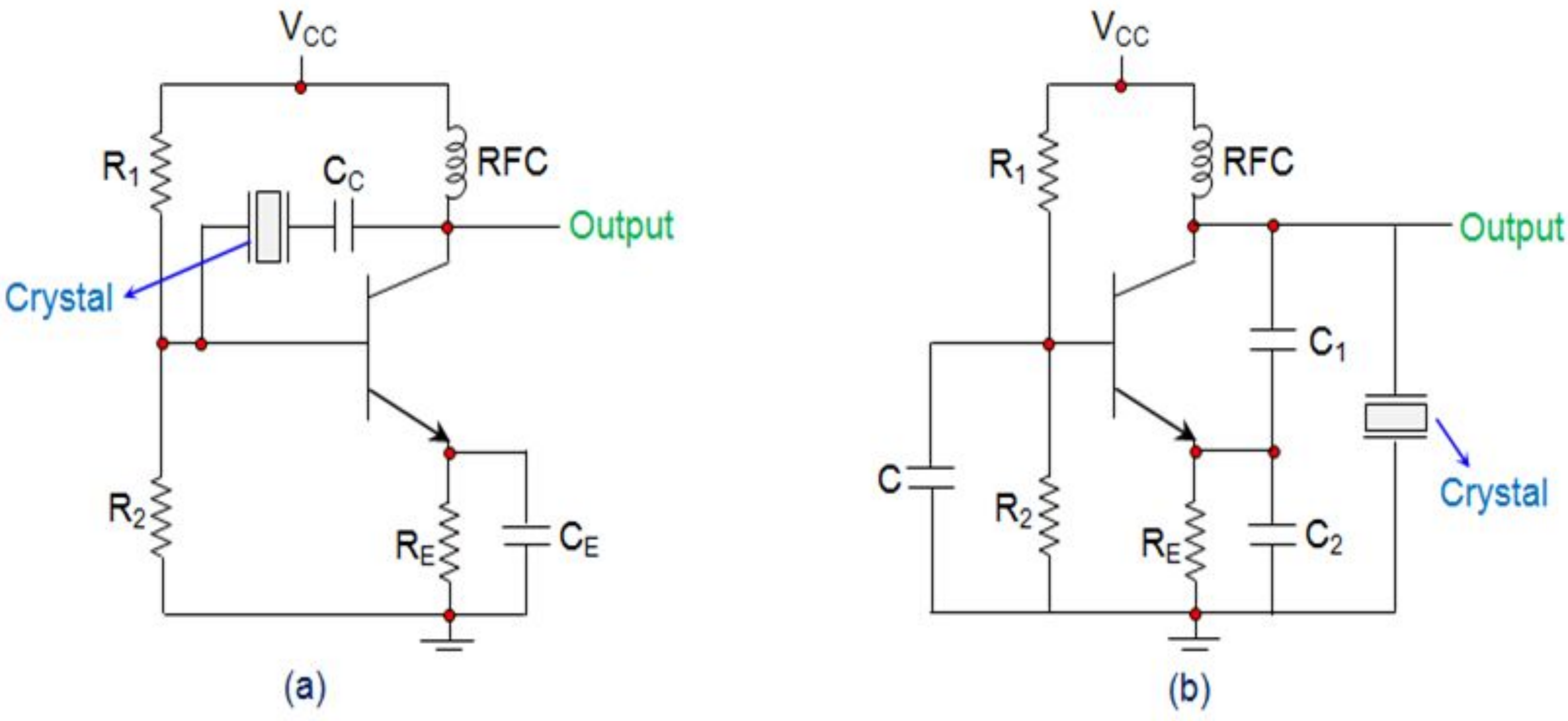
1. Series Resonant Frequency, f_s which occurs when the series capacitance C_S resonates with the series inductance L_S. At this stage, the crystal impedance will be the least and hence the amount of feedback will be the largest. Mathematical expression for the same is given as

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

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

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

Circuit Diagram of crystal oscillator:



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

Operation of Crystal Oscillator:

- 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 acts as an AC bypass capacitor while the coupling capacitor C_C 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 addition, there is also a Radio Frequency Coil (RFC) in the circuits 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 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

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.

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.