ULTRASONICS

INTRODUCTION

- The word *ultrasonic* combines the Latin roots ultra, meaning *'beyond'* and sonic, or *sound*.
- The sound waves having frequencies above the audible range i.e. above 20000Hz are called

  Ultrasonic waves.
- Generally these waves are called as *high frequency waves*.
- The broad sectors of society that regularly apply ultrasonic technology are the medical community, industry and the military.

PROPERTIES

- They have high energy content.
- Just like ordinary sound waves, ultrasonic waves get reflected, refracted and absorbed.
- They can be transmitted over large distances with no appreciable loss of energy.
- If an arrangement is made to form stationary waves of ultrasonic's in a liquid, it serves as a diffraction grating. It is called an *acoustic grating.*
- They produce intense heating effect when passed through a substance.

PRODUCTION OF ULTRASONIC WAVE

Ultrasonic waves are produced by the following methods.

(1) Magneto-striction generator or oscillator

(2) Piezo-electric generator or oscillator

(1) MAGNETO-STRICTION GENERATOR

Principle:

Magnetostriction effect: When a ferromagnetic rod like iron or nickel is placed in a magnetic field parallel to its length, the rod experiences a small change in its length. This is called magnetostriction effect.

The change in length (increase or decrease) produced in the rod depends upon the strength of the magnetic field, the nature of the materials and is independent of the direction of the magnetic field applied.

$$\frac{dl}{dx} = kB^2$$

Where, k is the material constant

$\frac{dl}{dx}$= change in length per unit of rod

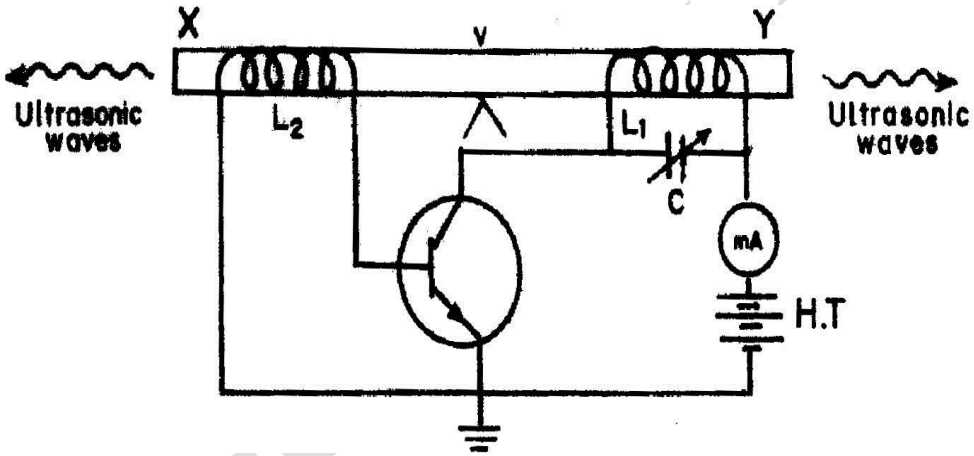
B= magnetic flux

K= +ve (expand)

K= -ve (contract)

Construction:

- The experimental arrangement is shown in Figure.



- XY is a rod of ferromagnetic materials like iron or nickel. The rod is clamped in the middle
- The alternating magnetic field is generated by electronic oscillator.
- The coil L_1 wound on the right hand portion of the rod along with a variable capacitor C.
- This forms the *resonant circuit* of the collector tuned oscillator. The frequency of oscillator is controlled by the variable capacitor.
- The coil L_2 wound on the left hand portion of the rod is connected to the base circuit. The coil L_2 acts as *feed –back loop*.

Working:

- When High Tension (H.T) battery is switched on, the collector circuit oscillates with a frequency.

$$\mathbf{f= \frac{1}{2\pi\sqrt{L1C}}}$$

- This alternating current flowing through the coil L1 produces an alternating magnetic field along the length of the rod. The result is that the rod starts vibrating due to magnetostriction effect.
- The frequency of vibration of the rod is given by

$$\mathbf{f= \frac{1}{2l}\sqrt{\frac{Y}{\rho}}}$$

where l = length of the rod

Y = Young's modulus of the rod material and

ρ = density of rod material

- The capacitor C is adjusted so that the frequency of the oscillatory circuit is equal to natural frequency of the rod and thus resonance takes place.
- Now the rod vibrates longitudinally with maximum amplitude and generates ultrasonic waves of high frequency from its ends.

Advantages:

- The design of this oscillator is very simple and its production cost is low
- At low ultrasonic frequencies, the large power output can be produced without the risk of damage of the oscillatory circuit.

Disadvantages:

- It has low upper frequency limit and cannot generate ultrasonic frequency above 3000 kHz (ie. 3MHz).
- The frequency of oscillations depends on temperature.
- There will be losses of energy due to hysteresis and eddy current.

(2) PIEZO ELECTRIC GENERATOR

Principle:

Inverse piezo-electric effect:

- If mechanical pressure is applied to one pair of opposite faces of certain crystals

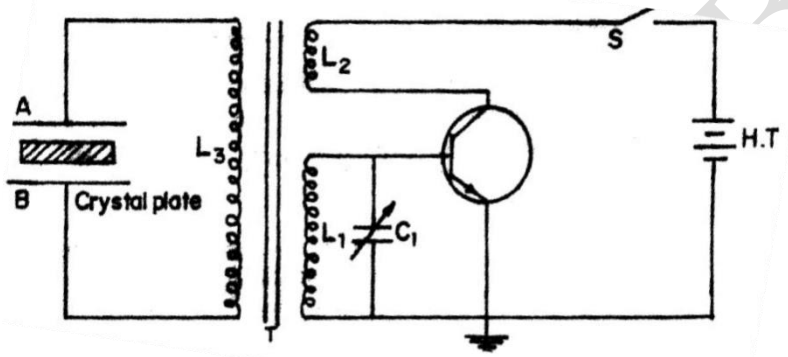
like quartz, equal and opposite electrical charges appear across its other faces. This effect is called as piezo-electric effect.

- The converse of piezo electric effect is also true.

- If an electric field is applied to one pair of faces, the corresponding changes in the dimensions of the other pair of faces of the crystal are produced. This effect is known as inverse piezo-electric effect.

Construction:

The circuit diagram is shown in Figure:



- The quartz crystal is placed between two metal plates A and B.
- The plates are connected to the primary (L_3) of a transformer which is inductively coupled to the electronics oscillator.
- The electronic oscillator circuit is a base tuned oscillator circuit.
- The coils L_1 and L_2 of oscillator circuit are taken from the secondary of a transformer T.
- The collector coil L_2 is inductively coupled to base coil L_1.
- The coil L_1 and variable capacitor C_1 form the *tuned circuit* of the oscillator.

Working:

- When H.T battery is switched on, the oscillator produces high frequency alternating voltages with a frequency.

$$\mathbf{f= \frac{1}{2\pi\sqrt{L1C1}}}$$

- Due to the transformer action, an oscillatory e.m.f. is induced in the coil L_3. This

high frequency alternating voltages are fed on the plates A and B.

- Inverse Piezo-electric effect takes place and the crystal contracts and expands alternatively. The crystal is set into mechanical vibrations.
- The frequency of the vibration is given by

$$\mathbf{f= \frac{K}{2l}\sqrt{\frac{Y}{\rho}}}$$

Where, K = 1,2,3,4 … etc. for fundamental harmonic, first over tone, second over tone etc.

Y = Young's modulus of the crystal.

ρ = density of the crystal.

- The variable condenser C_1 is adjusted such that the frequency of the applied AC voltage is equal to the natural frequency of the quartz crystal, and thus resonance takes place.
- The vibrating crystal produces longitudinal ultrasonic waves of large amplitude.

Advantages:

- Ultrasonic frequencies as high as 5×108Hz or 500 MHz can be obtained with this arrangement.
- The output of this oscillator is very high.
- It is not affected by temperature and humidity.

Disadvantages:

- The cost of piezo-electric quartz is very high
- The cutting and shaping of quartz crystal are very complex.