Introduction to Ultrasonics

- 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 field of ultrasonics have applications for imaging, detection and navigation.
- The broad sectors of society that regularly apply ultrasonic technology are the medical community, industry, the military and private citizens.

Properties of ultrasonic waves

(1) They have a high energy content.

(2) Just like ordinary sound waves, ultrasonic waves get reflected, refracted and absorbed.

(3) They can be transmitted over large distances with no appreciable loss of energy.

(4) They can be polarised.

(5)They produce intense heating effect when passed through substance.

Ultrasonics Production

Ultrasonic waves are produced by the following methods.

(1) Magneto-striction generator or oscillator

(2) Piezo-electric generator or oscillator

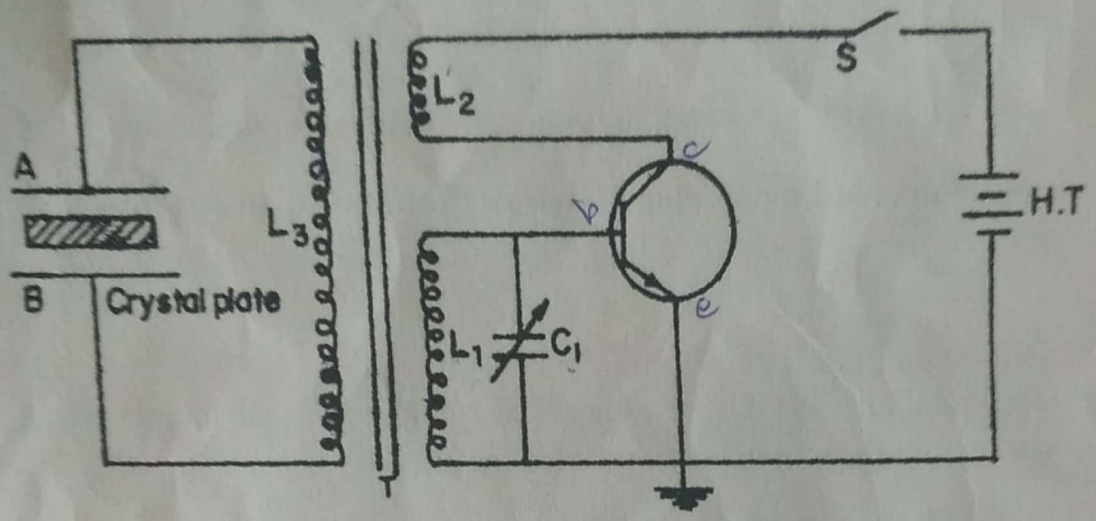
Principle: The general principle involved in generating ultrasonic waves is to cause some dense material to vibrate very rapidly. The vibrations produced by this material. Then cause air surrounding the material to begin vibrating with the same frequency. These vibrations then spread out in the forms of ultrasonic waves.

Piezo Electric Generator or Oscillator

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 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 is known as *inverse piezo electric* effect or *electrostriction*.

Construction



- 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 *tank circuit* of the oscillator.

Working

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

$$f = \frac{1}{2\pi\sqrt{L_1 C_1}}$$

- 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

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

where, Y = Young's modulus of the crystal and ρ = density of the crystal.

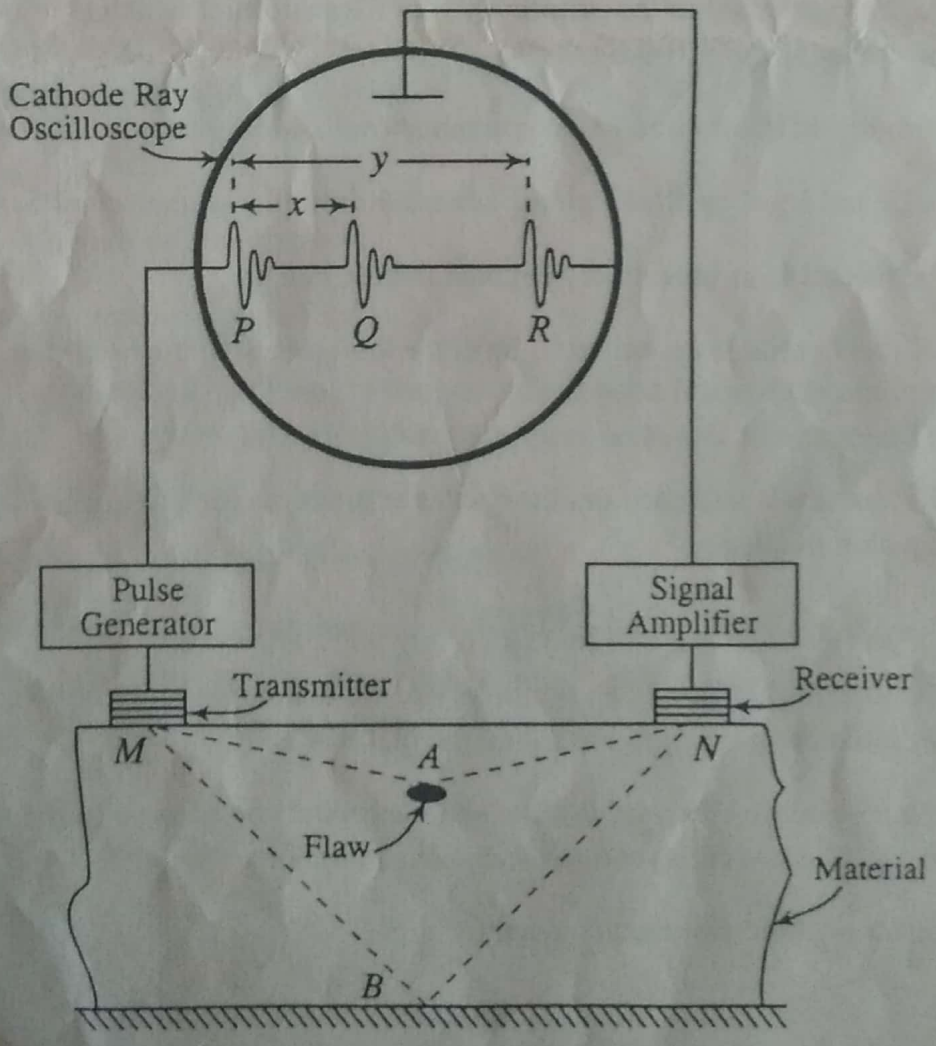
- The variable condenser C_1 is adjusted such that the frequency of the applied AC voltage is equal to the natural frequency of the quartz crystal, and thus resonance takes place.
- The vibrating crystal produces longitudinal ultrasonic waves of large amplitude.

Applications of Ultrasonic Waves in Engineering Materials (Non Destructive Testing – NDT)

Principle

- Ultrasonic waves are used to detect the presence of flaws or defects in the form of cracks, blowholes porosity etc., in the internal structure of a material
- By sending out ultrasonic beam and by measuring the time interval of the reflected beam, flaws in the metal block can be determined.

Experimental setup



The arrangement consists of a pulse generator, a transmitter, a receiver, a signal amplifier and a cathode ray oscilloscope (C.R.O), as shown in Fig. 2. The time base of the CRO is connected to the pulse generator. The pulse generator produces pulses each comprising of electric oscillations of ultrasonic frequency. The a.c. field so produced is applied to a piezoelectric crystal. The crystal executes mechanical vibrations of the same frequency as that of the pulse waves. The piezoelectric crystal is kept in perfect body contact with the specimen since, the pulse energy suffers great amount of dissipation by any air gap present within the contact region. A thin film of oil spread between the two, ensures elimination of air gaps. Thus the vibrations of the crystal are transmitted efficiently into the body of the specimen, and the **crystal performs the function of transmitter** of ultrasonic pulsed beam. Also, at the same instant the pip '*P*' appears as the source signal on the screen. The beam suffers reflection at places wherever there is change in density. The change in density occurs wherever there is discontinuity in the material of the specimen. The discontinuity occurs at *A* the site of the flaw, and also at the boundaries like the side face '*B*'.

A part of the injected beam is reflected at *A*. It reaches the receiver at *N*. The **receiver is also a piezoelectric crystal** kept in tight contact with specimen, and is set into mechanical vibrations by the reflected beam reaching it. Due to piezoelectric effect, a feeble alternating electric voltage is induced across the crystal. This voltage acts as an echo signal and fed into the signal amplifier whose output is fed into CRO.

Let '*x*' and '*y*' be the distances of the echoes *Q* and *R* respectively from the source pulse *P*. With the help of the time base calculation of CRO, the lengths '*x*' and '*y*' can be evaluated. The values of '*x*' and '*y*' are proportionate measures of the path distances *MAN* and *MBN*. The specimen is studied by placing the

Transmitter and receiver at various places on it, which provides a set of values for x and a corresponding set of values for y. The size of the flaw and its location in the specimen are determined on the basis of the values of x and y so obtained.