UNIT 4 ULTRASONIC

Unit – 4	Ultrasonic
Learning Outcomes	Students will be able to - Know about Ultrasound and its generation by mechanical and electrical methods. - Enumerate various methods for detection of ultrasonic sound. - Enumerate simple application of ultrasound: detection, ranging, mechanical devices, medical fields, and ultrasonic testing methods (NDT) and its outcomes.
Topics and Sub-topics	**Ultrasonic** - Production: Magnetostriction and piezoelectric methods - Applications : SONAR, NDT through ultrasonic, Medical Applications

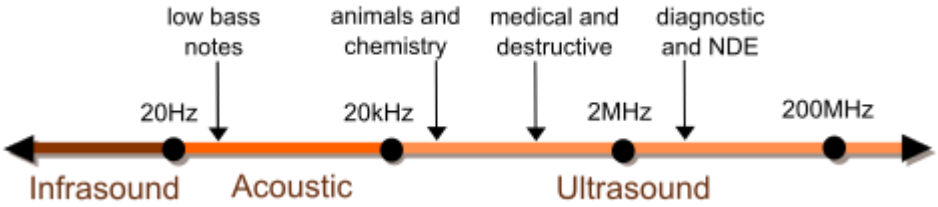
Unit	Unit Title	Teaching Hours
IV	Acoustics and Ultrasonics	6

Unit	Unit Title	Distribution of Theory Marks						
		Cognitive level (Bloom's taxonomy)						
		R	U	An	Ap	E	Sy	Total Marks
IV	Acoustics and Ultrasonics	2	2	2	3	2	-	11

* **Legends:** R = Remember; U = Understand; Ap = Apply; An = Analysis; E = Evaluation, Sy = Synthesis, as per (Bloom's revised taxonomy)

INTRODUCTION

- Ultrasonic means ULTRA (High) + SONIC (Sound)
- "*If the frequency of sound waves is grater than 20 KHz, is known as Ultrasonic Sound Waves. Also t*he term "ultrasonic" applied to sound refers to anything above the frequencies of audible sound, (which includes anything over 20,000 Hz)
  Ultrasonic sound used for SONAR, NDT (Not Destructive Testing),medical diagnostic, industries, measurement and cleaning also.



- *Bats use ultrasonic sound for navigation and their food.* All dogs can hear ultrasound. A dog whistle use to call a dog, dolphins, can hear ultrasound and use such sounds in their navigational system

PROPERTIES OF ULTRASONIC WAVES

- The frequency of ultrasonic waves is greater than 20 KHz
- Their wavelength is small, so penetrating power is high.
- They can travel longer distance as a highly directional beam
- They are highly energetic.
- They travel through longer distances.
- They are reflected, refracted and absorbed similar to ordinary sound waves.
- When ultrasonics are passed through the liquid, it produces stationary wave pattern and makes the liquid to behave as acoustical grating element.
- When an object is exposed to ultrasonics for a longer time it produces heating effect.

DETECTION OF ULTRASONIC WAVES

- *1. KUNDT'S TUBE METHOD*
  Kundt tube used to detect u.s.w. of longer wavelength, Stationary ultrasonic waves are produced in air contained in long glass tube horizontally, Lycodium powder sprinkled in the tube and sound waves are transfer so they produced node and antinodes points. By measuring the distance one can find the wavelength of it.

- *2. Piezoelectric Detector*
  Ultrasonic waves are applied to one pair of faces of a quartz crystal. Which produce an Emf to another two apposite faces, by measuring it one can have a value of wavelength of ultrasonic waves

- *3. Thermal Detection Method*
  A fine platinum wire probe is used in this method, because of alternate compression in the medium, these occurs a change in temperature at nodes and antinodes points and resistance also. This probe is able to measure change of resistance using Bridge CKT.

QU: Production of Ultrasonic Sound Waves.

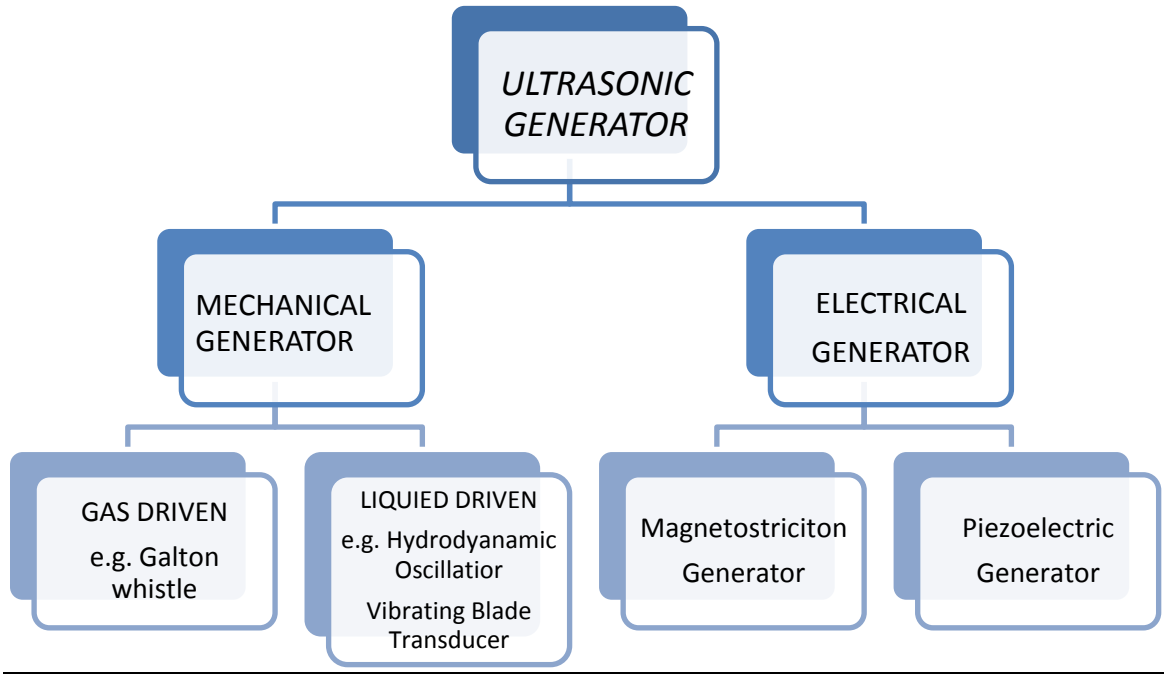
Ultrasonic waves can be generated by mechanical way or electrical way, Mechanical Generator are classified in two categories

(1) Gas Driven
e.g. Galton whistle
*A **dog whistle** (also known as **silent whistle** or **Galton's whistle**) is a type of whistle that emits sound in the ultrasonic range, which people cannot hear but other animals can, including dogs and domestic cats, and is used in their training. It was invented in 1876 by Francis Galton*

(2) Liquid Driven
e.g. Vibrating Blade Transducer
Hydrodynamic Oscillator

Where as Electrical Generators are classified in two categories

(1) Magnetostriction Generator
(2) Piezoelectic Generator



Magnetostriction Generator / Magnetostriction Oscillator

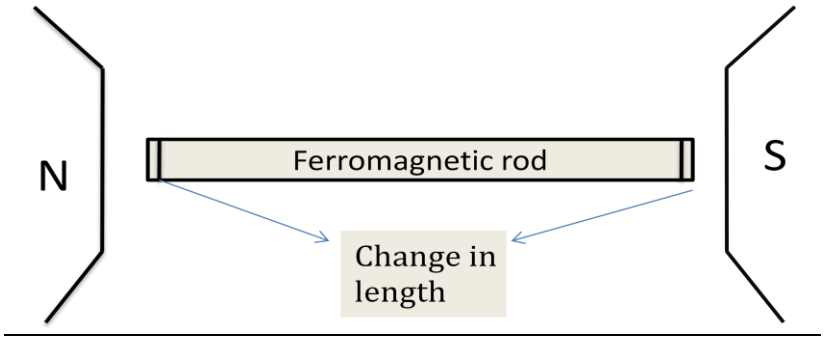
-Principle
-Circuit
-Construction
-Working Method
-Advantages and Disadvantages

Principle

"When a Ferromagnetic Rod is inserted to an alternating magnetic field, which is parallel to its length, rod undergoes alternate expansions and contractions with the frequency of applied magnetic field." This effect is known as Magnetostriction effect.

Magnetostriction *property of ferromagnetic materials that causes them to change their shape or dimensions during the process of magnetization.*

- *Magnetostriction Materials :Ferromagntic materials which are used for the production of ultrasonic waves are called Magnetostriction Materials.*
  e.g. Nickel, Cobalt, Iron etc.

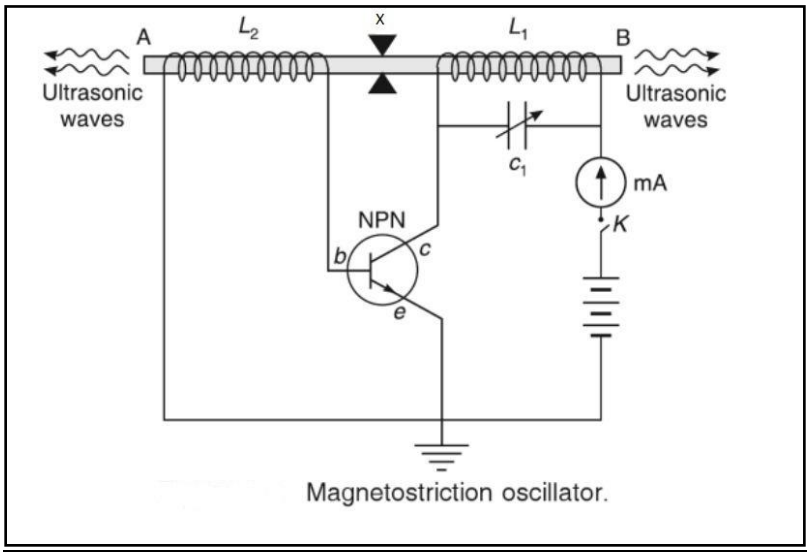


Construction and Circuit

- *As shown in the figure The ferromagnetic rod is clamped at X. Inductors L_1 and L_2 are wound at the end of the rod.*

- *Inductor L_1 is connected to Variable capacitor C1 in parallel form, which is known as a Tank or Resonant Circuit, and they are connected between the emitter(e) and collector(c) of transistor.*

- *Inductor L2 is connected between the base and the emitter and is useful as a feedback loop.*



Working Method:

- *When the power is on, the resonant ckt will setup an alternating current of frequency,*

$$f = \frac{1}{2\pi\sqrt{L1 \cdot C1}}$$

- *So rod get magnetised by the collector current, any change in the collector current brings a change in the magnetisation, and consequently a change in the length of the rod.*
- *This change in the flux in inductor L2, inducing an emf in the coil L2 in the base ckt. which emf applied to the base of the transistor and is fed back to the coil L1,and maintain the oscillations.*
- *By changing the capacitance C1,the frequency of current can be changed, when the frequency of current matches the natural frequency of the material, Resonance occurs, rod vibrates with maximum amplitude and generate the ultrasonic waves at the ends of the rod.*
- *Equation of the natural frequency of material is as under*

$$f_n = \frac{1}{2l} \cdot \sqrt{\frac{E}{\varrho}}$$

where l is a length of rod, ϱ is density of material and E is a Elastic constant or Young Modules of a material

- *At the resonance condition $f = f_n$*

So that i.e. $\frac{1}{2l} \cdot \sqrt{\frac{E}{\varrho}} = \frac{1}{2\pi\sqrt{L1 \cdot C1}}$

Advantages and Disadvantages :

Advanges or Merits:

1.The design of oscillator is simple and made of law cost.

2.one can produce frequencies from 100Hz to 3MHz.

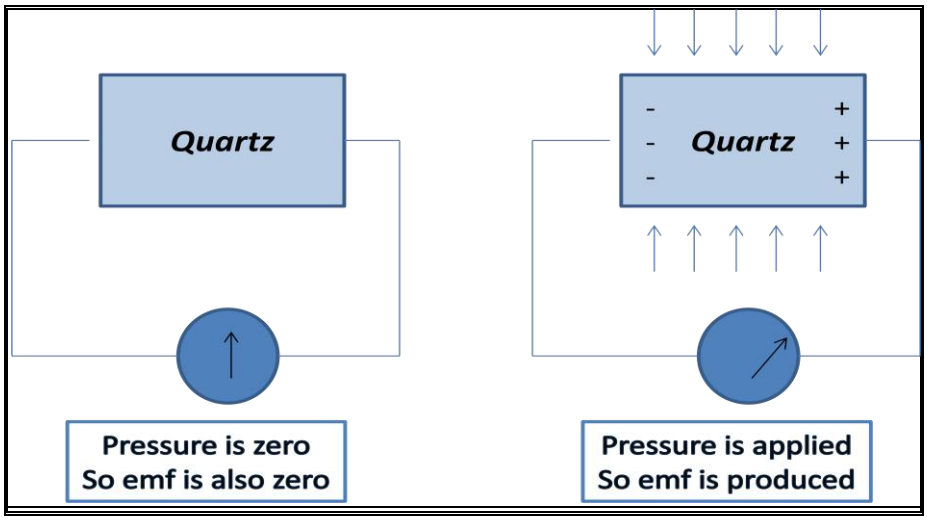
Disadvantages or Demerits

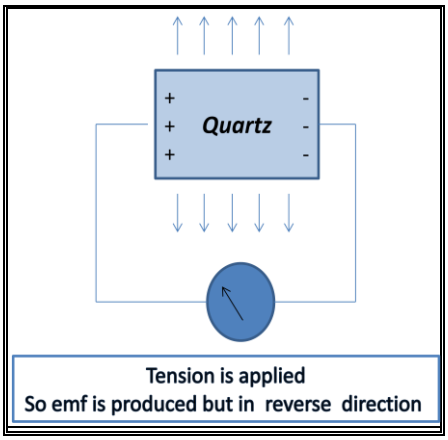
1.It can't generate ultrasonic waves more than 3MHz.
2.The frequency of oscillation depends upon temperature(raised due to Tank Ckt.)
3.There will be losses of energy due to Hysteresis and Eddy Current.

Piezoelectric Generator / Piezoelectric Oscillator

-Principle
-Circuit
-Construction
-Working Method
-Advantages and Disadvantages

- *Greek word 'Piezo' means pressure so literal translation of Piezoelectric would be "Pressure Electricity".*
- *Certain substances like Quartz, Tourmaline, Rochelle Salt have property of generating a voltage when pressure is applied to them*
- *Depending upon applied pressure, size, and nature of Piezo electric material, Electric Potential can be generated*
- *It is one of the phenomenons of nature that makes possible, that one form of energy to another form.*

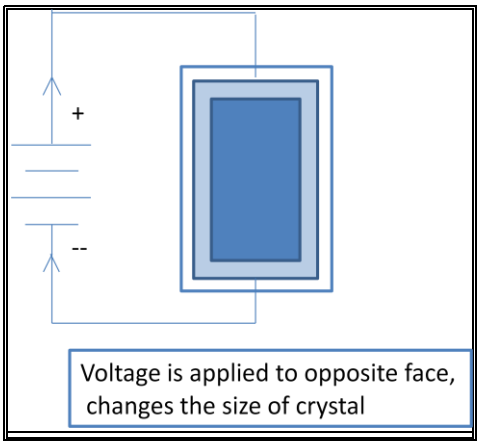




When pressure is applied to one pair of opposite faces of crystal like quartz, tourmaline, Rochelle alt etc, equal and opposite charges appear across its other faces as shown in the figure, This is known as piezoelectric effect, and if tension is applied, it generates the equal and opposite charges but in reverse direction.

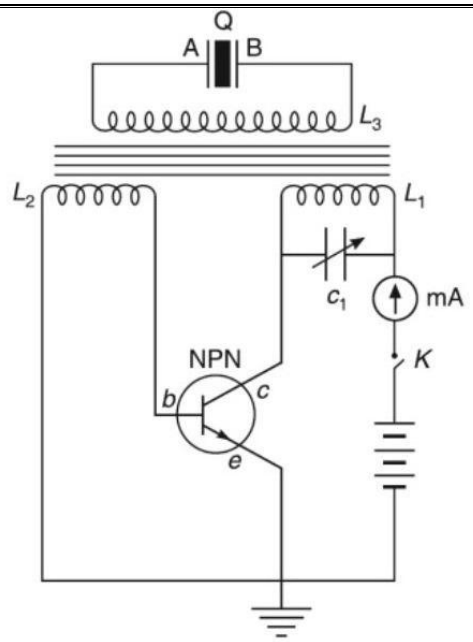
Priciple : Inverse Piezoelectric Method

If an alternating voltage is applied to one pair of opposite faces of the crystal, it produces and alternating expansion and contraction in crystal, so its start to vibrate, This phenomenon is known as inverse piezoelectric effect or elctrostriction effect.



Circuit and Construction

- *There are mainly 4 parts, three coils/Inductors, one Transistor, one Quartz crystal, and one Capacitor*
- *Quartz is placed between metal plates A and B and connected to coil L_3 .*
- *Coil L_1 ,L_2 and L_3 are inductively coupled to the oscillatory circuit of a transistor.*
- *Coil L_2 is connected to Collector and Emitter through battery , whereas L_1 connected in parallel with Capacitor C_1 and forms a Tank CKT.*



Piezoelectric oscillator.

Working Method

When battery is switched on, it produce alternating current of given frequency

$$f = \frac{1}{2\pi\sqrt{L1 \cdot C1}}$$

The frequency of oscillation can be controlled by a variable capacitor C_1

Due to transformer action an emf is induced in the secondary coil L_3, which applied to plates and excite the crystal to vibrates.
By changing the frequency of variable capacitor one can produce the resonance condition in crystal and its start vibrating with maximum amplitude

Thus the vibrating crystal produces longitudinal waves, The frequency of vibration of crystal is

$$f_n = \frac{1}{2l} \cdot \sqrt{\frac{E}{\varrho}}$$

where l is a length of rod, ϱ is density of material and E is a Elastic constant or Young Modules of a material

At the resonance condition $f = f_n$

So that i.e. $$\frac{1}{2l} \cdot \sqrt{\frac{E}{\varrho}} = \frac{1}{2\pi\sqrt{L1 \cdot C1}}$$

Advantages

- *More effective than magnetostriction generator.*
- *It can produce ultrasonic frequency more than 3 MHz.*
- *Its not affected by temperature and humidity.*

Dis-advantages

- *The cost of piezoelectric quartz is very high due to the cutting and shaping of crystal is very complex work. It requires a accuracy.*

Application of ultrasonic sound waves :

(1) SONAR
(2) Ultrasonic waves in NDT
(3) Medical Field.

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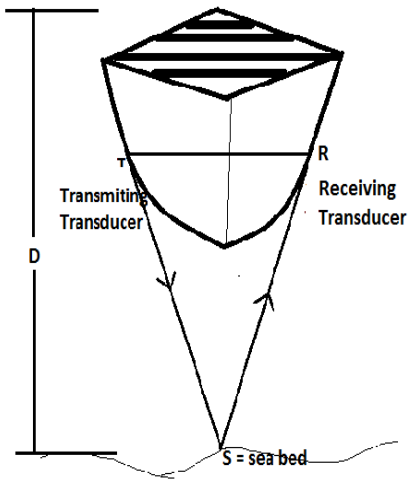
(1) SONAR

*SONAR stands for **SO**UND **NA**VIGATION AND **R**ANGING*

- *Principle : Echo Sounding*
- *Sonar is useful to find out the distance and direction of submarines, depth of sea or seabed, fishes etc.*
- *In sonar high frequency of ultrasonic waves are used ,which transmitted through water, they get reflected by bottom surface of sea or any object come in its way, and received by a Receiver.*

- *The change in frequency of ultrasonic waves helps to find the velocity, direction and distance from it.*
- *By knowing the velocity of ultrasound and time for reflection of it, distance of the object can be determined.*



- *Equation for the depth of a seabed equation can be derived from the above figure,sound waves have travel distance of TS+SR*

$$\text{Velocity of ultrasonic waves } v = \frac{\text{Distance travelled}}{\text{Time taker}}$$

$$v = \frac{TS + SR}{T}$$

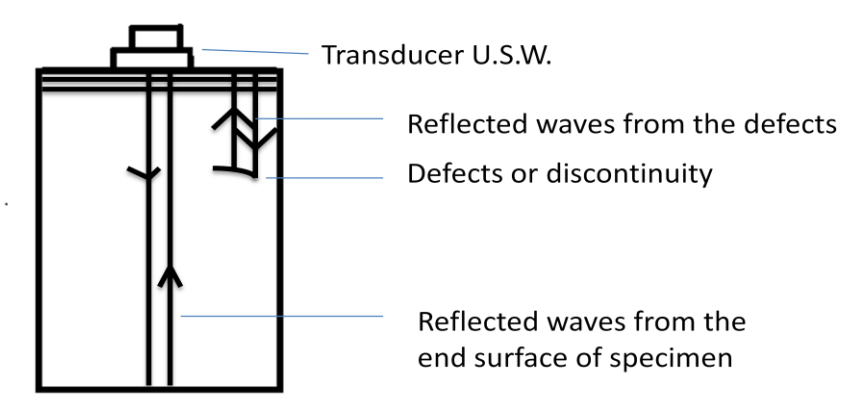
$$V = \frac{2 \bullet d}{T}$$

$$So, \quad d = \frac{v \bullet T}{2}$$

Where v is velocity of sound waves, T is time taken by a sound waves to reflect back, and d is a distance of seabed from the surface.

Ultrasonic waves in NDT

- *Ultrasonic Waves are used to detect defects in the material like blow holes, porosity, cracks, etc.*
- *Ultrasonic Testing is one of the very useful NDT method*
- *In NDT, Piezo electric generator are used as a source of U.S.W. in which frequency from 100 KHz to 25 MHz are used.*
- *If even a small discontinuity exist inside the specimen, the USW are reflected back to the transducer, which can be seen on a screen of CRT. By studying the pulse on it, one can study the type of defects.*



Ultrasonic waves in NDT

Medical Applications

The Ultrasonic sound waves is one of the important tool in medical field. Depending upon the power, frequency and area of interest its classified in two major categories.

(1) Diagnostic Applications
(2) Therapeutic Applcations.

Diagnostic Applications

- *High frequency with low power of sound waves are used, which depends upon the type of diagnostic applications.*
- *It is divided in Continuous mode and Pulse mode*

- *Continuous mode is useful to detect fetus heart pulses and to measure blood flow rate.*
- *Pulse mode is used to detect the defect and location of the problem in the organs in the body without making any cut on the body.*

Therapeutic Apllications

- *Ultrasounds of low several watts and frequency in the order of kHz are used. When ultrasound of low frequency and high power are passed into tissue they hitup the tissue to desire level like thermal heating. Its very much useful in a number of Muscular Alignment Problems and also as a pain reliever.*

THANK YOU