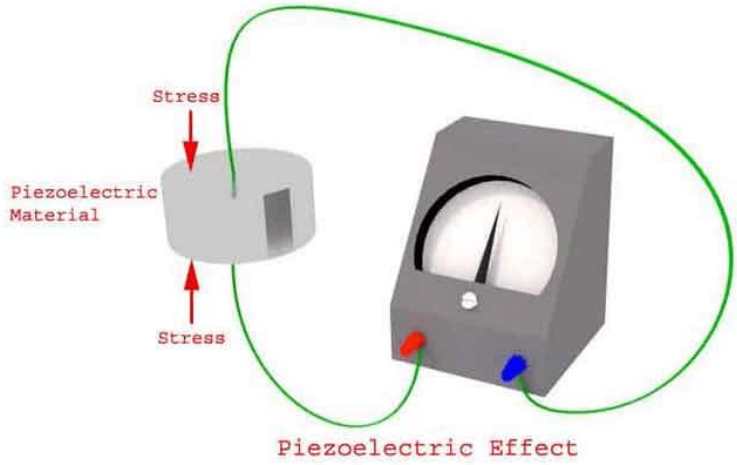
UNIT-2

Piezoelectric Transducer

A **piezoelectric transducer** (also known as a piezoelectric sensor) is a device that uses the piezoelectric effect to measure changes in acceleration, pressure, strain, temperature or force by converting this energy into an electrical charge.

A transducer can be anything which converts one form of energy to another. **Piezoelectric material** is one kind of transducers. When we squeeze this piezoelectric material or apply any force or pressure, the transducer converts this energy into voltage. This voltage is a function of the force or pressure applied to it.

The electric voltage produced by a piezoelectric transducer can be easily measured by voltage measuring instruments. Since this voltage will be a function of the force or pressure applied to it, we can infer what the force/pressure was by the voltage reading. In this way, physical quantities like mechanical stress or force can be measured directly by using a piezoelectric transducer.



Piezoelectric Effect

A piezoelectric transducer consists of quartz crystal which is made from silicon and oxygen arranged in crystalline structure (SiO_2). Generally, unit cell (basic repeating unit) of all crystal is symmetrical but in piezoelectric quartz crystal it is not. Piezoelectric crystals are electrically neutral.

The atoms inside them may not be symmetrically arranged but their electrical charges are balanced means positive charges cancel out negative charge. The quartz crystal has the unique property of generating electrical polarity when mechanical stress applied on it along a certain plane. Basically, There are two types of stress. One is compressive stress and other is tensile stress.

In our day to day life, we come across various situations where we have to measure physical quantities like mechanical stress applied on metal, temperature levels, Pressure levels etc…For all these applications we need a device which could measure these unknown quantities in units and calibrations familiar to us. One such device which is most useful to us is the **TRANSDUCER**. The transducer is an electrical device that can convert any type of physical quantity in the form of proportional electrical quantity either as voltage or **electrical current**. From the large pool of various type of transducer, this article aims to explain about **piezoelectric transducers**.

The **definition of a Piezoelectric transducer** is an **electrical transducer** which can convert any form of **physical quantity into an electrical signal**, which can be used for measurement. An electrical transducer which uses properties of piezoelectric materials for conversion of physical quantities into electrical signals is known as a **piezoelectric.**

Types of Piezoelectric Materials

Some of the types of piezoelectric materials are:

Naturally Available Ones: Quartz, Rochelle salt, Topaz, Tourmaline-group minerals, and some organic substances as silk, wood, enamel, bone, hair, rubber, dentin. Artificially manufactures **piezoelectric materials** are Polyvinylidene difluoride, PVDF or PVF2, Barium titanate, Lead titanate, Lead zirconate titanate (PZT), Potassium niobate, Lithium niobate, Lithium tantalate, and other lead-free piezoelectric ceramics.

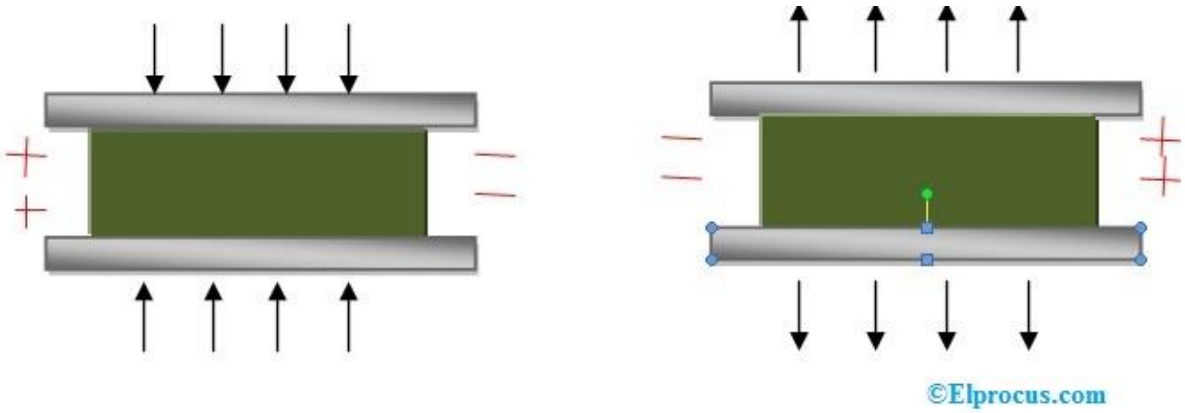
Not all piezoelectric materials can be used in **piezoelectric transducers**. There are certain requirements to be met by the piezoelectric materials to be used as transducers. The materials used for measurement purpose should have frequency stability, high output values, insensitive to the extreme temperature and humidity conditions and which can be available in various shapes or should be flexible to be manufactured into various shapes without disturbing their properties.

Unfortunately, there is no piezoelectric material which has all these properties. **Quartz** is a highly stable crystal which is naturally available but it has small output levels. Slowly varying parameters can be measured with quartz. Rochelle salt gives the highest output values but it is sensitive to environmental conditions and cannot be operated above 1150F.

Piezoelectric Transducer Working

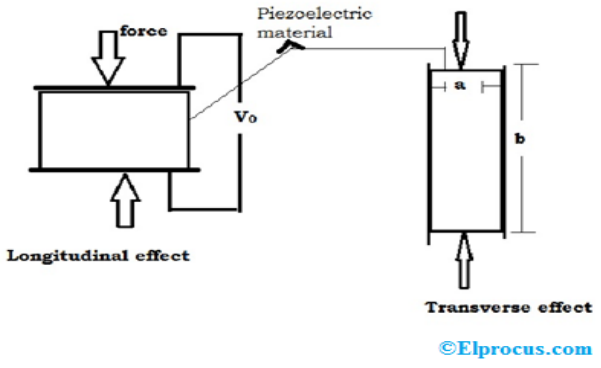
Piezoelectric Transducer works with the principle of piezoelectricity. The faces of piezoelectric material, usual quartz, is coated with a thin layer of conducting material such as silver. When stress has applied the ions in the material move towards one of the

conducting surface while moving away from the other. This results in the generation of charge. This charge is used for calibration of stress. The polarity of the produced charge depends upon the direction of the applied stress. Stress can be applied in two forms as C**ompressive stress** and **Tensile stress** as shown below.



Piezoelectric Transducer Formula

The orientation of the crystal also effects the amount of voltage generated. Crystal in a transducer can be arranged in **longitudinal position** or **transverse position**.



Piezoelectric Transducer Formula

Longitudinal and Transverse Effect

In the longitudinal effect, the charge generated is given by

Q = F * d

Where F is the applied force,d is the piezoelectric coefficient of the crystal.

Piezoelectric coefficient d of quartz crystal is around $2.3 * 10^{-12}$ C/N.

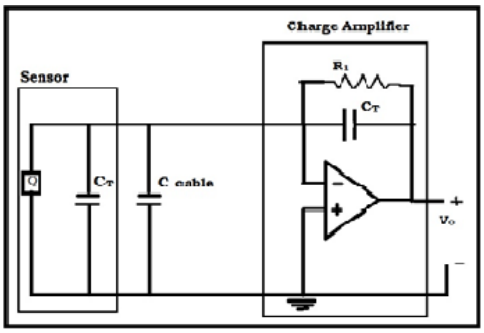
In the transverse effect, the charge generated is given by

Q = F * d * (b/a)

When the ratio b/a is greater than 1 the charge produced by transverse arrangement will be greater than the amount generated by longitudinal arrangement.

Piezoelectric Transducer Circuit

The working of a basic piezoelectric transducer can be explained by the below figure.



Piezoelectric Transducer Circuit

Here quartz crystal coated with silver is used as a sensor to generate a voltage when stress is applied on it. A charge amplifier is used to measure the produced charge without dissipation. To draw very low current the resistance R1 is very high. The capacitance of the lead wire that connects the transducer and **piezoelectric sensor** also affects the calibration. So the charge amplifier is usually placed very near to the sensor.

So in a piezoelectric transducer when mechanical stress is applied a proportional electric voltage is generated which is amplified using charge amplifier and used for calibration of applied stress.

Piezoelectric Transducer Applications

- As piezoelectric materials cannot measure static values these are primarily used for measuring surface roughness, in accelerometers and as a vibration pickup.
- They are used in **seismographs** to measure vibrations in rockets.
- In strain gauges to measure force, stress, vibrations etc…
- Used by automotive industries to measure detonations in engines.
- These are used in **ultrasonic imaging** in medical applications.

Advantages and Limitations of Piezoelectric Transducers

The advantages and limitations of piezoelectric transducers include the following.

Advantages

- These are active transducer i.e. they don't require external power for working and are therefore self-generating.
- The high-frequency response of these transducers makes a good choice for various applications.

Limitations

- Temperature and environmental conditions can affect the behavior of the transducer.
- They can only measure changing pressure hence they are useless while measuring static parameters.

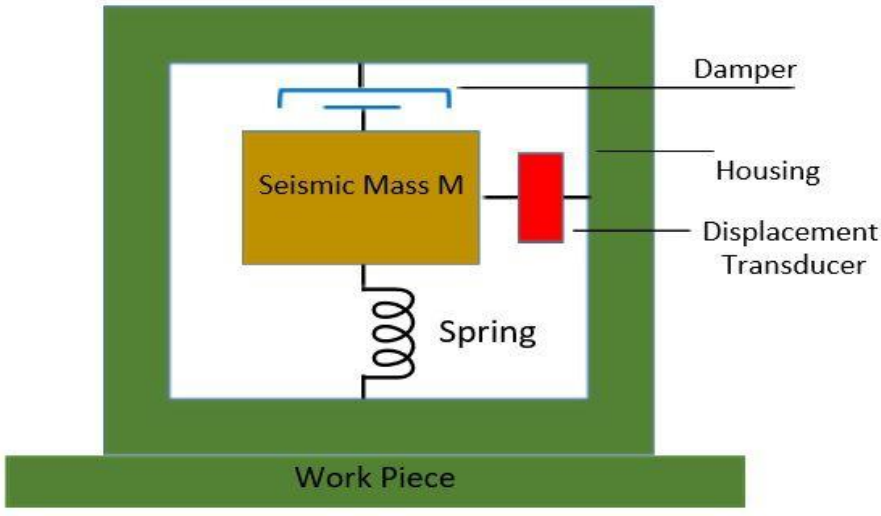
Seismic Transducer

Definition: The seismic transducer is used for measuring the vibration of the ground. The spring, mass damper element and the displacement transducer are the main component of the seismic transducer.

The mass that connected to the damper element and spring without any other support is known as spring mass damper element. And the displacement transducer converts the displacement into the electrical quantity. The seismic transducer is used for measuring the earth vibration, volcanic eruption and other vibrations etc.

Construction of Seismic Transducer

The systematic diagram of the seismic transducer is shown in the figure below. The mass is connected by the help of the damper and spring to the housing. The housing frame is connected to the source whose vibrations need to be measured.



The arrangement is kept in such a way so that the position of the mass remains same in the space. Such type of arrangement is kept for causing the relative motion between the housing frame and the mass. The term relative motion means one of the objects remains stationary, and the other is in motion concerning the first one. The displacement that occurs between the two is sensed and represented by the transducer.

Mode of Transducer

The seismic transducer works in two different modes.

Displacement Mode

Acceleration Mode

The selection of the mode depends on the combinations of the mass, spring and damper combinations. The large mass and soft spring are used for the displacement mode measurement while the combination of the small mass and stiff spring is used for the acceleration mode.

Types of Seismic Transducer

Vibrometer and the accelerometer are the two type of the seismic transducer.

1. Vibrometer – The vibrometer or low-frequency meter is used for measuring the displacement of the body. It also measures the high frequency of the vibrating body. Their frequency range depends on the natural frequency and the damping system.

2. Accelerometer – The accelerometer measures the acceleration of the measuring body. The acceleration shows the total force acting on the object.

Ultrasonic Transducer Working and Its Applications

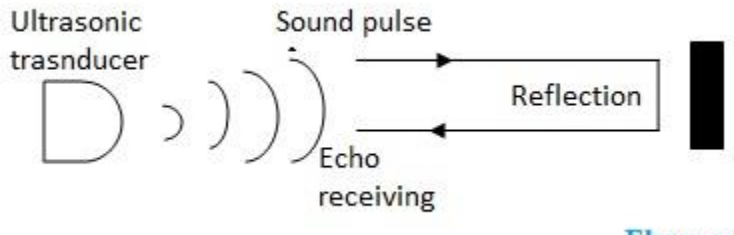
The ultrasonic transducer is one type of sound-related sensor. These transducers send the electrical signals to the object and once the signal strikes the object then it reverts to the transducer. In this process, this transducer measures the distance of the object not by the intensity of the sound. These transducers use ultrasonic waves for the measurement of a few parameters. It has a wide range of applications in various fields. The frequency range of ultrasonic waves is above 20 kHz. These are mainly used in measuring distance applications. The following image indicates the ultrasonic transducer.

ultrasonic-transducer

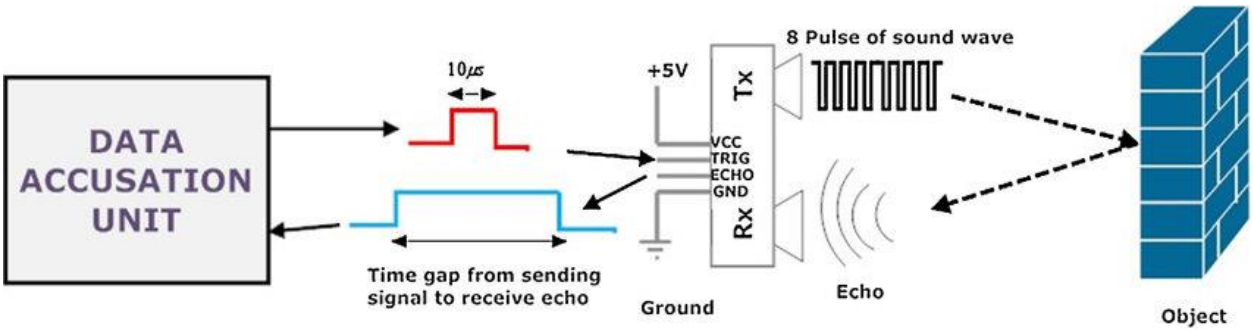
These transducers can be defined as a transducer which is used to convert one type of energy to ultrasonic vibration. By these ultrasonic vibrations, this transducer measures the distance of the object. These are available in two types like active and passive

Ultrasonic Transducer Working Principle

When an electrical signal is applied to this transducer, it vibrates around the specific frequency range and generates a sound wave. These sound waves travel and whenever any obstacle comes, these sound waves will reflect the transducer inform of echo. And at the end of the transducer, this echo converts into an electrical signal. Here, the transducer calculates the time interval between the sending of the sound wave to the receiving the echo signal. The ultrasonic sensor sends the ultrasonic pulse at 40 kHz which travels through the air. These transducers are better than the infrared sensors because these ultrasonic transducer/sensors are not affected by the smoke, black materials, etc. Ultrasonic sensors exhibit excellence in suppressing background interference.



ultrasonic-transducer



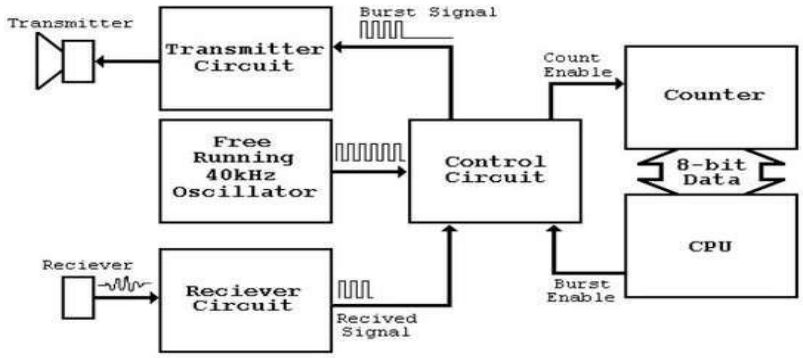
Ultrasonic transducers are mainly used for finding the distance by using ultrasonic waves. The distance can be measured by the following formula.

D = ½ * T * C

Here, D indicates the distance

T indicates the time difference between sending and reception of ultrasonic waves

C is indicating the sonic speed.



Ultrasonic Transducer Types

There are various types of ultrasonic transducers available based on factors like piezoelectric crystal arrangement, footprint, and frequency. They are

Linear Ultrasonic Transducers – In this type of transducers, piezoelectric crystal arrangement is linear.

Standard Ultrasonic Transducers – This type is also called as convex transducers. In this type, the piezoelectric crystal is in a curvy form. For in-depth examinations these are preferable.

Phased Array Ultrasonic Transducers – Phased array transducers have a small footprint and low frequency. (its center frequency is 2 MHz – 7 MHz)

For non-destructive testing, the ultrasonic transducers are again having different types. They contact transducers, angle beam transducers, Delay line transducers, immersion transducers, and dual element transducers.

Ultrasonic Transducer Applications

These transducers have many applications in different fields like industrial, medical, etc. These are having more application because of ultrasonic waves. This helps finds the targets, measure the distance of the objects to the target, to find the position of the object, to calculate the level also the ultrasonic transducers are helpful.

In the medical field, the ultrasonic transducer is having the applications in diagnostic testing, surgical devices while treating cancer, internal organ testing, heart checkups, eyes and uterus checkups ultrasonic transducers are useful.

In the industrial field, ultrasonic transducers have few important applications. By these transducers, they can measure the distance of certain objects to avoid a collision, in production line management, liquid level control, wire break detection, people detection for counting, vehicle detection and many more.

Ultrasonic Transducers Advantages and Disadvantages

- Any system has advantages and a few disadvantages. Here will discuss the advantages of the ultrasonic transducer.
- These ultrasonic transducers can able to measure in any type of material. They can sense all types of materials.
- The ultrasonic transducers are not affected by temperature, water, dust or any.
- In any type of environment, the ultrasonic transducers will work in a good manner.
- It can measure in high sensing distances also.

Disadvantage:

- Ultrasonic transducers are sensitive to temperature variation. This temperature variation may change the ultrasonic reaction.
- It will face problems while reading the reflections from small objects, thin and soft objects.