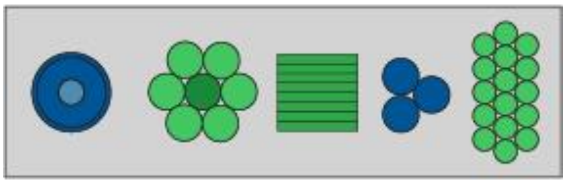
Piezoceramic Elements

The main component of an ultrasonic transducer is the piezoceramic element

Piezoceramic elements convert electrical pulses into sound waves, and when the echoes return, the piezoceramic elements convert the sound waves back into electrical energy.

What does a piezoceramic element look like?

Piezoceramic elements are most often in a disk form, but they may also be in the shape of a bar or a ring. A transducer may contain one element or a series of elements linked together called an array.



How are piezoceramic elements made?

When made of Barium Titanate (BT) or Lead Zirconate Titanate (PZT), the elements go through several processes:

- **Pressing**—Both BT and PZT begin in powdered form. The powder is pressed into the desired shape.
- **Firing**—The pressed shapes are baked in a kiln. The temperature of the kiln depends upon the element's maximum heat tolerance. It is important to fire the piezoceramic at precisely the right temperature. Like a piece of porcelain that has been fired in a kiln, the piezoceramic element is very strong, yet brittle and easily cracked or broken. Any piezoceramic element that has been cracked or chipped, even slightly, will not function properly in a transducer.
- **Coating**—After pressing, the piezoceramic element is coated on two sides with a layer of silver and baked a second time so the silver actually bakes onto the element. This silver functions as the electrode - the material that will conduct electric current through the element.
- **Polarizing**—Next, the piezoceramic element is polarized. Piezoceramic elements are made up of individual crystals that have a positive (+) and negative (–) electric charge on respective ends. These crystals normally rest in a haphazard way within the piezoceramic element. But if a high voltage electric field is applied to the element, the crystals will adjust their alignment until nearly all are positioned in straight columns with their positive (+) and negative (–) poles lying in the same direction.

Note: Since this process is done in an oil bath, it is very important that the piezoceramic element has all of the oil carefully removed or material will not bond to it. A weak bond will result in poor transducer performance and poor reliability.

How do piezoceramic elements work?

Transducers work by taking electrical pulses from the power amplifier and changing them into sound waves. This process is reversed when the transducer is acted upon by the pressure of the returning echoes which is called transduction.

The internal arrangement of the piezoceramic element's crystals with their positive (+) and negative (–) poles lying in the same direction is the key factor. Pulses of alternating current (AC) from the power amplifier activate the piezoceramic element. The AC changes its direction of flow back and forth [which is why it is said to alternate, and this change in the direction of the flow is noted as (+) and (–)]. Because the piezoceramic elements are polarized, they will expand when a positive voltage is applied and contract when a negative voltage is applied. The piezoceramic's expansion and contraction changes the electrical pulse into sound waves that will travel until they bounce off an object or weaken and finally dissipate.

When an echo returns to the transducer, the pressure of the sound waves acts on the piezoceramic element causing it first to contract and then to expand as each cycle in the echo hits it. This alternating pressure on the element creates a small voltage which is then sent back to the transceiver and microprocessor.

The element expands and contracts at the frequency of the electrical pulse. This occurs very rapidly, faster than can be seen by the eye. The frequency of the expansion and contraction is controlled by the frequency of the pulse generator in the power amplifier.

How do engineers know which piezoceramic element to use?

When an electrical voltage is applied to a piezoceramic element, it will vibrate best at a certain frequency. Piezoceramic materials can be thought of as bells. When a bell rings, it produces a tone. Each bell has its own natural resonant frequency. Those who cast bells know the size and shape necessary to create a bell that produces a certain tone.

Like bells, every piezoceramic material has its own natural resonant frequencies. The size, shape, and thickness of the piezoceramic element determine the frequency at which it will vibrate best. Engineers very carefully control these factors to produce transducers that resonate at the correct frequency to meet the customers' needs.

A transducer can be designed with one piezoceramic that operates at two frequencies. Transducers can house a piezoceramic element that can vibrate efficiently at two separate frequencies. The element resonates at one frequency in the thickness mode and at another frequency across its diameter which is called the radial mode. A transducer that can operate at two frequencies will have characteristics of both frequencies, such as both shallow and deep water with good bottom definition.

What is capacitance?

Capacitance comes from the word capacity. It is the ability of a material to store an electrical charge. Piezoceramic elements are first class capacitors, able to hold a large electrical charge. In fact, the larger the piezoceramic the larger the charge that can be stored.

Piezoceramic elements can store a charge. Since even slight cooling and heating will build up an electrical charge, all piezoceramics must be handled with great care. Production workers must always short a piezoceramic before handling it. If this is not done, the piezoceramic may discharge, damaging other components in a multi-sensor transducer or even giving the handler a very nasty, albeit harmless, shock.

Despite the precautions that need to be taken with piezoceramics, their ability to store an electrical charge can be used to an advantage. With a simple capacitance meter, the piezoceramic can be tested after wires have been soldered in place and a cable has been attached. If a wire connection is faulty, only a small capacitance will show on the capacitance meter. A much larger capacitance will indicate that the piezoceramic is wired properly. This is an easy check of the manufacturing process.

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