

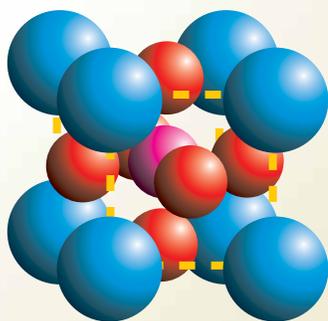
CIRCUIT DESIGNER'S NOTEBOOK

Piezoelectric Effect in Ceramic Capacitors

The Greek root of the word piezo means "to press". In 1880, Jacques and Pierre Curie discovered that pressure applied to a quartz crystal creates an electrical potential on the crystal. Likewise, they also discovered that an electrical potential impressed on the crystal creates a deformation of the crystal. They referred to this phenomenon as the piezoelectric effect.

The piezoelectric effect can be readily defined as the generation of an electrical potential as a result of applying pressure or by mechanically deforming a piezo crystal lattice structure. This deformation causes the molecules in the material to become electrical generating dipoles resulting in a potential difference across the crystal.

The piezoelectric effect occurs in crystals that have no center of symmetry. This lends itself to a net polarization of the crystal. The



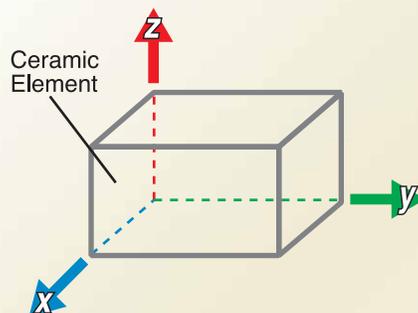
Example of a Perovskite Ceramic - Barium Titanate (BaTiO₃)

most widely known piezoelectric material is quartz. Others include various polycrystalline ceramics that are frequently used in capacitor dielectric formulations. One such group of materials is known as perovskites. Perovskites are one of the most abundant minerals on earth and are used in a large family of crystalline ceramic formulations such as barium titanate, calcium titanite and lead zirconate titanate. These crystals have some inherent piezoelectric properties that require careful processing to minimize the piezoelectric effect when used in capacitor fabrication.

Piezoelectric Ceramics:

Because of the anisotropic nature of many ceramics materials, piezoelectric effects are dependent on direction of mechanical excitation. This concept is illustrated by the ceramic element shown in the following figure. The axes labeled x, y, and z follow the classical right hand orthogonal axial set. The orthogonal coordinate system shown here is commonly used to describe piezoelectric properties. The reference direction is conventionally chosen as the z axis. A mechanical or electrical response in any of the three directions will produce a response in its corresponding orthogonal axis. For example, an electric field in the z direction causes a mechanical deformation in the x direction, and conversely a mechanical deformation in the x direction will result in an electric field in the z direction. The piezoelectric effect along any axis is dependent on a mechanical excitation of an orthogonal axis.

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Circuit Application Considerations:

Stability: Issues regarding the generation of microphonics due to the piezoelectric effect can lead to a myriad of performance issues in many circuit applications.

Some examples are:

- Production of extraneous (unwanted) signal voltages due to structure borne vibration that can de-tune high Q circuits.
- Oscillator instability, especially where tuning is accomplished with passive components.
- Ringing in pulsed circuit applications.
- Generation of erroneous data in digital circuits.

Mechanical Stress:

Mechanical stress on the capacitor due to vibration can disrupt the termination-ceramic interface. The shear forces that exist in piezoelectric ceramics can lead to unreliable ceramic-termination interface. This condition may gradually reduce performance by progressively degrading the loss tangent (DF).

When RF voltage is applied to the capacitor, the microstructure will grow and shrink at the same frequency as that of the applied voltage. This can lead to shear forces that can cause deformations leading to reduced reliability or catastrophic failure.

Phase Sensitive Applications:

Capacitors exhibiting piezoelectric effects should not be used in filter network designs. Phase shifters, filters, oscillators, or any design where phase stability is essential, should avoid the application of piezoelectric dielectric materials, because phase variations in accordance with the mechanical excitation may occur.

Coupling Applications:

Interstage coupling applications are frequently sensitive to capacitors exhibiting piezoelectric effect. The designer should avoid using these capacitors in sensitive applications as they can pass along non-linear distortions to succeeding stages.

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