

Frequently asked questions

Question:

What is a resonance in a piezoceramic part?

What are overtones?

Answer:

A resonance in a piezoceramic part can be considered as an acoustic phenomenon. If a sound wave is transmitted onto a piezoelectric part, this will create a vibration with the same frequency in the material.

At some frequencies the wavelength of the transmitted sound is exactly at such a length, that a standing half-wave through a determining dimension can be formed. At this stage, the impedance will reach a minimum, and the system is said to be resonating.

Electrically this is characterised by a situation, where the capacitive and inductive contributions to the complex impedance cancel each other out. Resonances are therefore characterised by purely ohmic impedances.

At a slightly higher frequency the capacitive and inductive parts will reach a maximum, and a maximum in impedance is therefore also observed. The frequency where this occurs is called anti-resonance.

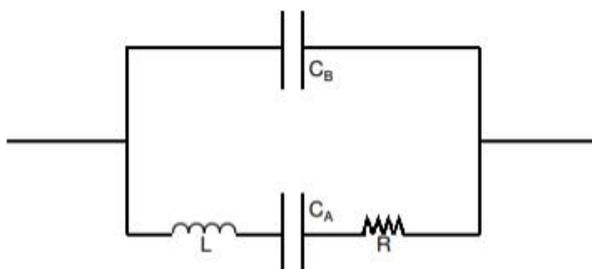


Fig 1. Equivalent circuit for piezoceramic part at frequencies close to a fundamental resonance.

In a normal piezoceramic material an equivalent circuit, as shown in Fig 1, can approximate a resonance and anti-resonance. As for any such circuit, which is driven by an AC signal, it can be shown, that the impedance reaches a minimum, when the following condition is fulfilled:

$$\omega = \frac{1}{\sqrt{LC_A}} \quad \text{where} \quad f = \frac{\omega}{2\pi}$$

At this frequency the impedance the impedance can be calculated to be purely ohmic:

$$Z = \sqrt{R^2 + \left(L \cdot \omega - \frac{1}{C_A \cdot \omega}\right)^2} = \sqrt{R^2} = R$$

The resonance frequency is therefore located at this point.

Similarly the impedance can be found to have a maximum, when the following condition is fulfilled:

$$\omega = \sqrt{\frac{C_A + C_B}{L \cdot C_A \cdot C_B}}$$

This frequency therefore indicates the anti-resonance.

Following these general observations, it can be seen, that different resonances can exist in different parts, but also that different types of resonances can exist in the same part. Piezoceramic discs for example have both a fundamental planar resonance mode, and a fundamental thickness resonance mode.

The planar resonance mode corresponds to a situation, where the frequency matches a standing half-wave, having a length equal to the diameter. The primary vibration mode at this frequency is thus taking place in the planar direction, with an oscillating change of the diameter.

At another frequency with a wavelength corresponding to a standing half-wave in the thickness direction, a thickness resonance will be formed. The primary vibration at this frequency is taking place in the thickness direction, and the part is therefore oscillating with a change primarily of the thickness.

Depending on other geometrical issues, there are also possibilities to have so-called overtones in the part. In the above case with a circular disc, it is simple to see, that you can have 3, 5, 7,... standing half-waves over one determining dimension.

At even numbers of half-waves (2, 4, 6,...) the expansion of the part created by the positive regime of the wave is cancelled by the contraction caused by the negative part, so these types cannot be observed.

In the below figure, an impedance plot for a PZT disc is shown, and Table 1 gives an overview of the general types of resonances in various common geometries.

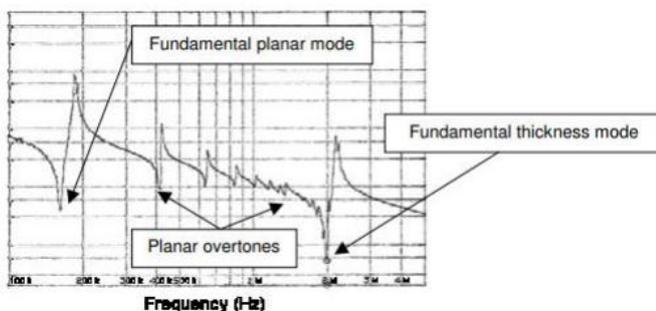


Fig 2. Impedance spectrum for a circular PZT disc

Table 1. Fundamental resonances in various geometries.

| Geometry | Determining dimension & Type of resonance |
|-----------------|--|
| Disc | <ul style="list-style-type: none">• Diameter / Planar mode• Thickness |
| Ring | <ul style="list-style-type: none">• Medium diameter• Wall thickness• Thickness |
| Plate | <ul style="list-style-type: none">• Length• Width• Thickness |
| Tube | <ul style="list-style-type: none">• Medium diameter• Wall thickness• Thickness |
| Shear plate | <ul style="list-style-type: none">• Thickness |
| Shear tube | <ul style="list-style-type: none">• Wall thickness |