Frequently asked questions

Question:

How do geometry and size influence resonances and overtones?

Answer:

Based on basic knowledge on the nature of resonances, it can be seen that the smaller the determining dimension is, the higher the resonance frequency will be. The exact location of a resonance will depend on the speed of sound through the piezoelectric material for one specific mode (since this gives the wave length in the material), combined with the size of the element:

$$f_{resonance} = \frac{\text{Speed of sound}}{2 \cdot \text{Size}} = \frac{\text{Frequency constant}}{\text{Size}}$$

Example: In most PZT materials the thickness frequency constant is around 2000 Hz·m (m/s). This means, that a 2 mm thick part will have a thickness resonances of approximately 1 MHz, while a 0,2 mm part will have a thickness 10 times higher at 10 MHz.

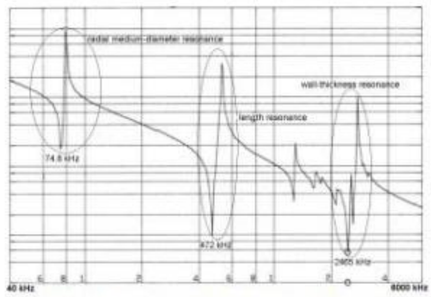
In other words: The dimension of a part therefore directly controls the resonances in the part. The smaller the part is, the higher the resonance frequencies will be.

If a part have fundamental resonances close to each other, there will be some interference between these, which creates so-called spurious modes (e.g. bending vibration modes). Furthermore each fundamental mode have several overtones, which of course also can be located close to a higher fundamental mode. These overtones can also create spurious modes, when they interact with other fundamental modes.

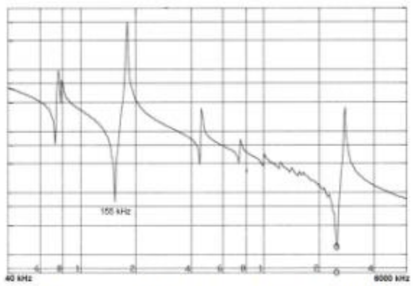
The effect of this is often, that one resonance either "pushes" another resonance away from its natural position, or split it into several smaller sub-resonances. Both situations can have a serious effect, which the drive electronics need to be adjusted for.

In the figure below, an example with a PZT tube with various length is shown. As the length is increased, the resonance decreases and gradually begins to interfere with the lower mediumdiameter resonance.

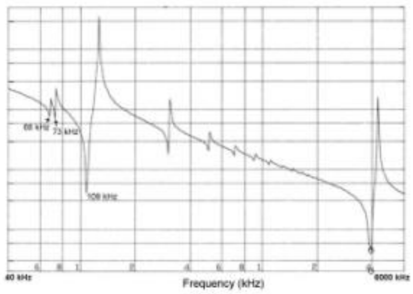
When designing a piezoceramic part it is therefore important to try to keep as high dimensional aspect ratios between the determining dimensions as possible (e.g. diameter versus thickness). In many cases this may be impossible due to other geometrical limitations in the device. More sophisticated electronics may then be necessary in order to fine-tune the device.



Tube Length = 3,2 mm   => Length resonance at 472 kHz and undisturbed medium diameter resonance



Tube Length = 10 mm   => Length resonance at 155 kHz and slightly disturbed medium diameter resonance



Tube Length = 15 mm   => Length resonance at 109 kHz and very disturbed medium diameter resonance

Fig 1: Example of the influence of length/diameter ratio on the impedance spectrum. The samples are three tubes of Pz27 with outer diameter 12.7 mm, inner diameter 11.1 mm