

Piezoelectric Principle

The active element of an accelerometer is a piezoelectric material. Figure 1 illustrates the piezoelectric effect with the help of a compression disk. A compression disk looks like a capacitor with the piezoceramic material sandwiched between two electrodes. A force applied perpendicular to the disk causes a charge production and a voltage at the electrodes.

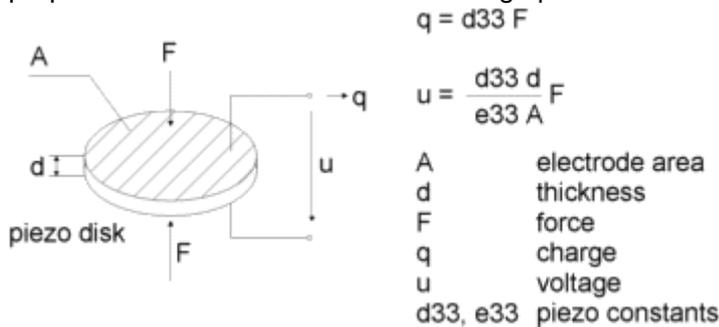


Figure 1: Piezoelectric effect, basic calculations

The sensing element of a piezoelectric accelerometer consists of two major parts:

- Piezoceramic material
- Seismic mass

One side of the piezoelectric material is connected to a rigid post at the sensor base. The so-called seismic mass is attached to the other side. When the accelerometer is subjected to vibration, a force is generated which acts on the piezoelectric element (compare Figure 2). According to Newton's Law this force is equal to the product of the acceleration and the seismic mass. By the piezoelectric effect a charge output proportional to the applied force is generated. Since the seismic mass is constant the charge output signal is proportional to the acceleration of the mass.

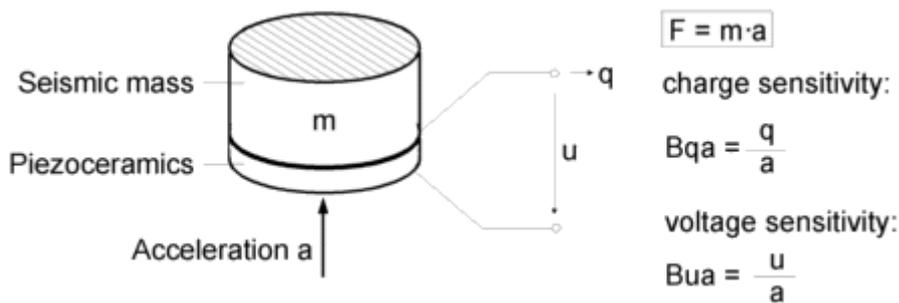


Figure 2: Principle of a piezoelectric accelerometer

Over a wide frequency range both sensor base and seismic mass have the same acceleration magnitude. Hence, the sensor measures the acceleration of the test object.

The piezoelectric element is connected to the sensor socket via a pair of electrodes. Some accelerometers feature an integrated electronic circuit which converts the high impedance charge output into a low impedance voltage signal.

Within the useful operating frequency range the sensitivity is independent of frequency, apart from the later mentioned limitations.

A piezoelectric accelerometer can be regarded as a mechanical low-pass with resonance peak. The seismic mass and the piezoceramics (plus other "flexible" components) form a spring mass system. It shows the typical resonance behavior and defines the upper frequency limit of an accelerometer. In order to achieve a wider operating frequency range the resonance frequency should be increased. This is usually done by reducing the seismic mass. However, the lower the seismic mass, the lower the sensitivity. Therefore, an accelerometer with high resonance frequency, for example a shock accelerometer, will be less sensitive whereas a seismic accelerometer with high sensitivity has a low resonance frequency.

Figure 3 shows a typical frequency response curve of an accelerometer when it is excited by a constant acceleration.

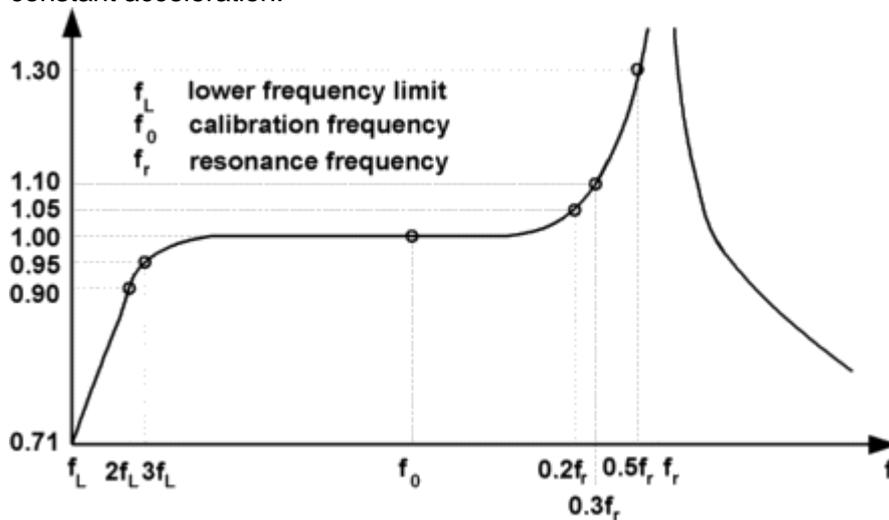


Figure 3: Frequency response curve

Several useful frequency ranges can be derived from this curve:

- At approximately 1/5 the resonance frequency the response of the sensor is 1.05. This means that the measured error compared to lower frequencies is 5 %.
- At approximately 1/3 the resonance frequency the error is 10 %. For this reason the "linear" frequency range should be considered limited to 1/3 the resonance frequency.
- The 3 dB limit with approximately 30 % error is obtained at approximately one half times the resonance frequency.

The lower frequency limit mainly depends on the chosen preamplifier. Often it can be adjusted. With voltage amplifiers, the low frequency limit is a function of the RC time constant formed by accelerometer, cable, and amplifier input capacitance together with the amplifier input resistance.