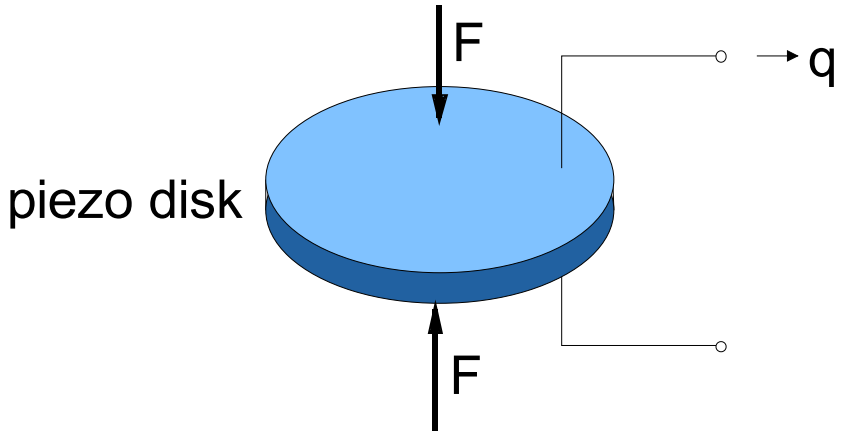
Piezoelectric Accelerometers

Theory and Application

Piezoelectrc Effect

Piezoceramics or Quartz generate a charge output when subjected to force



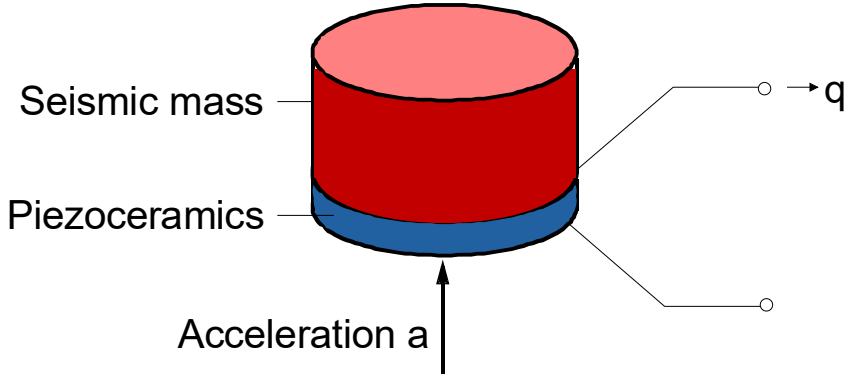
$$q = d \cdot F$$

F	force
q	charge
d	piezo constant

Piezoelectrc Accelerometer

A piezoelectric accelerometer consists of
a piezoelectric material and a seismic mass

The charge output is proportional to acceleration



$F = m \cdot a$

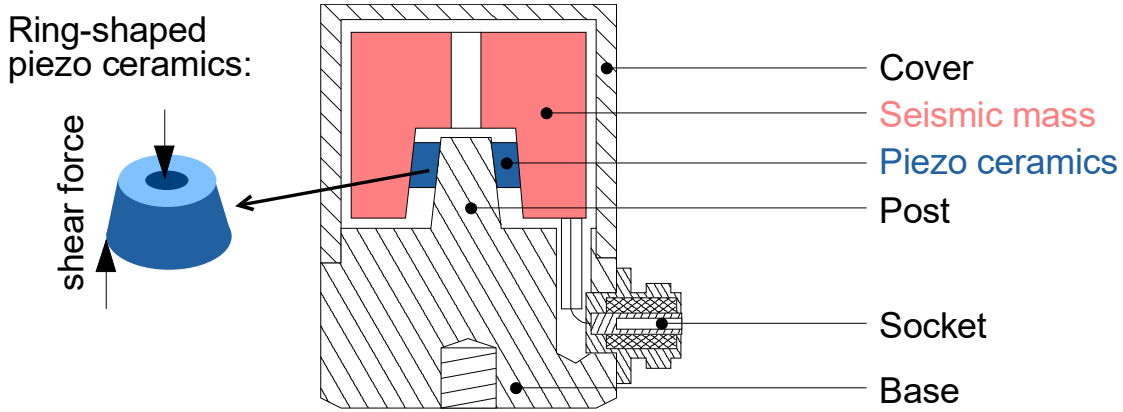
charge sensitivity:

$$B_{qa} = \frac{q}{a}$$

Accelerometer Design

Example: Shear type accelerometer with ring-shaped piezoceramics

The inertial force of a seismic mass generates an electric signal at the electrodes of the piezo material



Other Types of Vibration Sensors

Comparison with piezoelectric accelerometers:

Sensor Type	Advantages	Disadvantages
Piezoresistive (strain gauge)	Measures static acceleration Robust	Limited resolution Only up to some kHz Power supply required
Electrodynamic	Measures static acceleration	Only for low frequencies
Capacitive (MEMS)	Measures static acceleration Cheap semiconductor process	Limited resolution Fragile

Advantages of Piezoelectric Accelerometers

Extremely wide dynamic range, almost free of noise - suitable for shock measurement as well as for almost imperceptible vibration

Excellent linearity over full dynamic range

Wide frequency range, high frequencies can be measured

Compact yet highly sensitive

No moving parts – long service life

Self-generating - no external power required

Charge Mode and IEPE Accelerometers

Charge mode accelerometers provide the direct charge output of the piezo material. Disadvantages: Maximum cable length 10 m, low-noise cables required

IEPE compatible accelerometers have a built-in amplifier.
Advantage: Standard coaxial cables of several hundred meters length possible

Proprietary names for IEPE: ICP®, CCLD, Isotron®, Deltatron®, Piezotron®

Characteristics: Sensitivity

The sensitivity of charge mode sensors is measured in pC per m/s² or pC per g.
Typical range: 0.1 – 100 pC/ms^{-2} or 1 –1000 pC/g

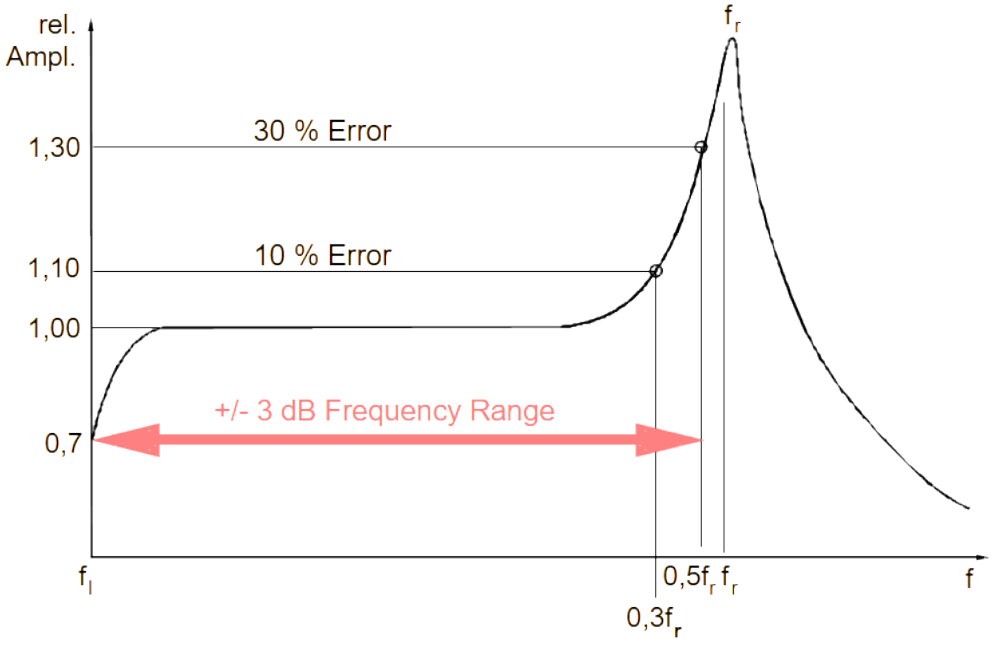
The sensitivity of IEPE sensors is measured in mV per m/s² or mV per g.
Typical range: 1 - 1000 mV/ms^{-2} or 10 – 10 000 mV/g

Sensitivity stated in the data sheet is usually calibrated at 80 or 160 Hz.

Characteristics: Frequency Response

A typical accelerometer has a resonance at 10 – 30 kHz

For 3 dB accuracy it can be used up to approx. 50 % of this resonant frequency



Selecting an Accelerometer Type

Acceleration to be measured:

Low	►High sensitivity accelerometers (...µm/s² to 5 m/s²)
Medium	►Standard Accelerometers (5 to 5000 m/s²)
High	►Low sensitivity Accelerometers (> 5000 m/s²)

Selecting an Accelerometer Type

Weight:

The weight of an accelerometer should not exceed 10 % of the test object

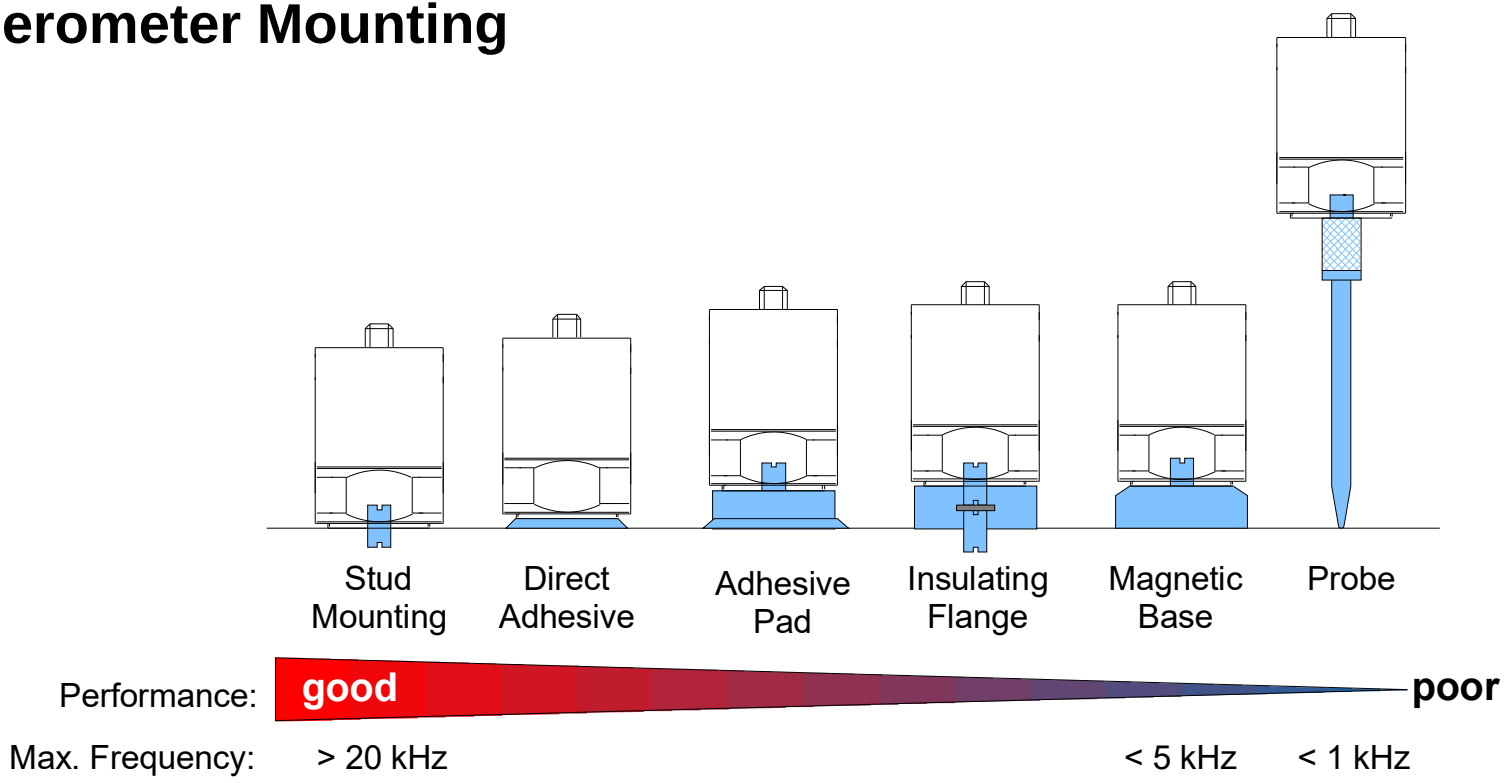
Miniature Accelerometers have a very low weight (<5 grams)

Selecting an Accelerometer Type

Environmental Conditions:

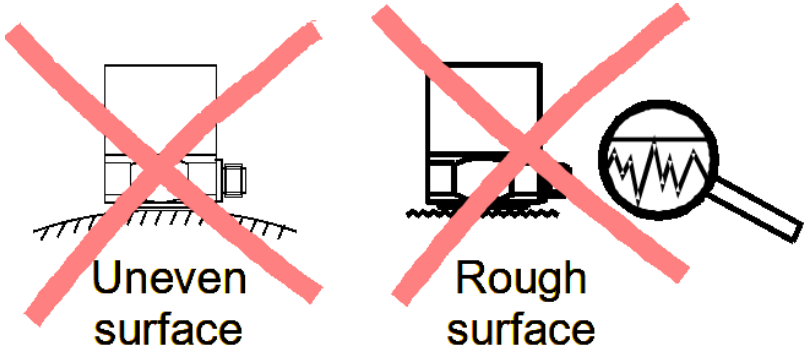
Humidity and dust	► Industrial Accelerometers with protection grade >IP67
Electromagnetic fields	► Industrial Accelerometers with double shielding
Ground loops	► Industrial Accelerometers with insulated case

Accelerometer Mounting



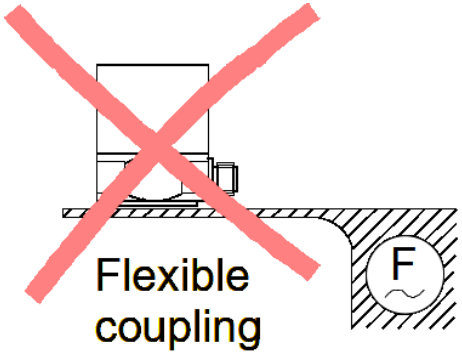
Accelerometer Mounting

For best performance, particularly at high frequencies, the accelerometer base and the test object should have clean, flat, smooth, unscratched and burr-free surfaces



Accelerometer Mounting

A stiff mechanical connection between the sensor and the test object is important. Sheet metal or plastic parts and other thin and flexible components are unsuited for accelerometer mounting



Mounting Accessories

Stud bolts
and adapters

Clamping
magnets

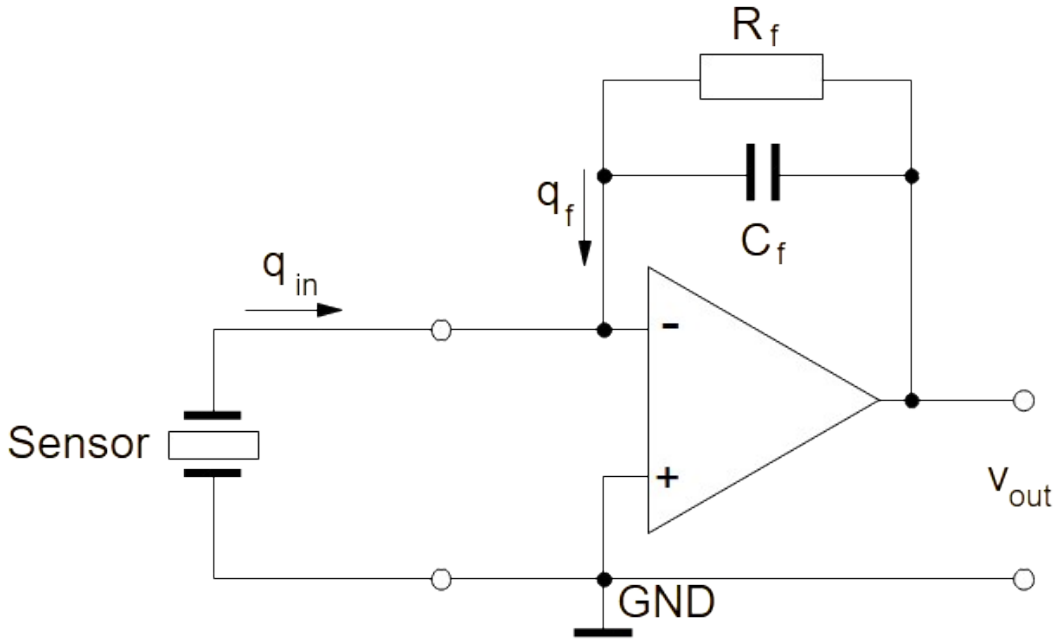
Triaxial
mounting cubes

Adhesive and
insulating flanges

Instrumentation for Charge Mode Sensors

Charge mode accelerometers require a charge amplifier input

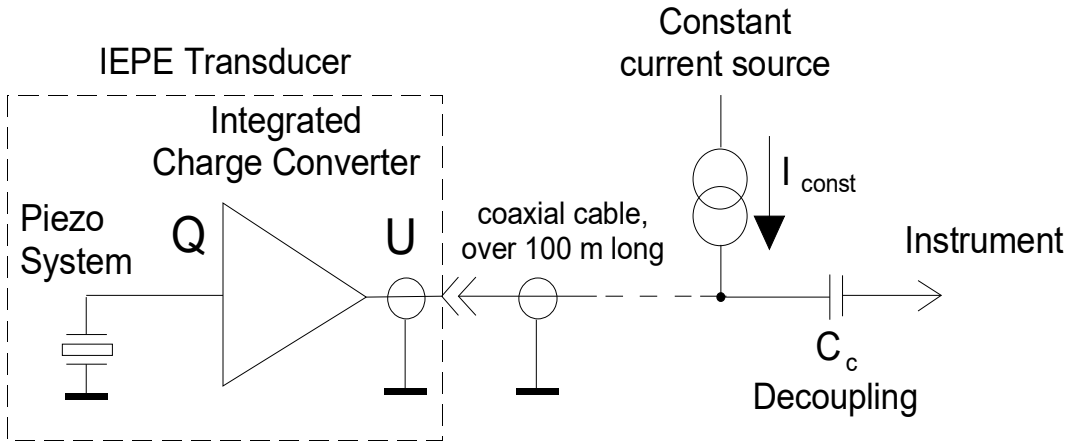
A charge amplifier is a differential amplifier with capacitive feedback



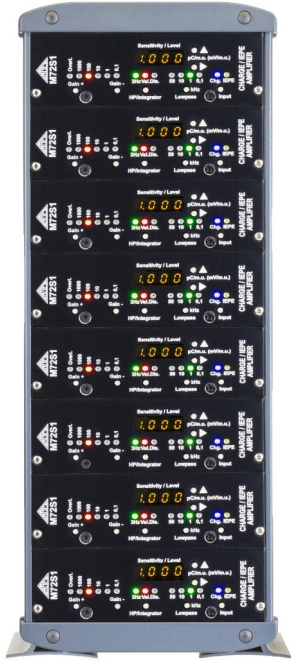
Instrumentation for IEPE Accelerometers

Accelerometers with IEPE output require a constant current supply of 2 to 20 mA via the sensor output

The constant current source can be part of the instrument or a separate unit



Signal Conditioners from Metra



Accelerometers with TEDS (IEEE1451.4)

TEDS = Transducer Electronic Data Sheet
Only for IEPE type accelerometers

The accelerometer contains a memory chip with:

- Model and version number
- Serial number
- Manufacturer
- Measurand
- Sensitivity
- Calibration date
- User data

Advantages of TEDS Transducers

Easier sensor identification, with large channel numbers, no cable tracking and marking

Automatic calibration of the measuring system, no manual input of sensor data

"Plug & play" sensor replacement without setup

Sensor can be used, even if the printed calibration data sheet is just not at hand