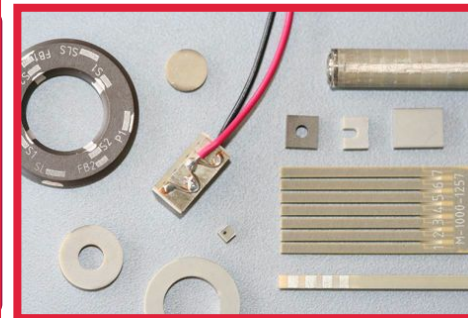


Piezoelectric multilayer triaxial accelerometer



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¹Noliac Motion, ²Noliac Systems

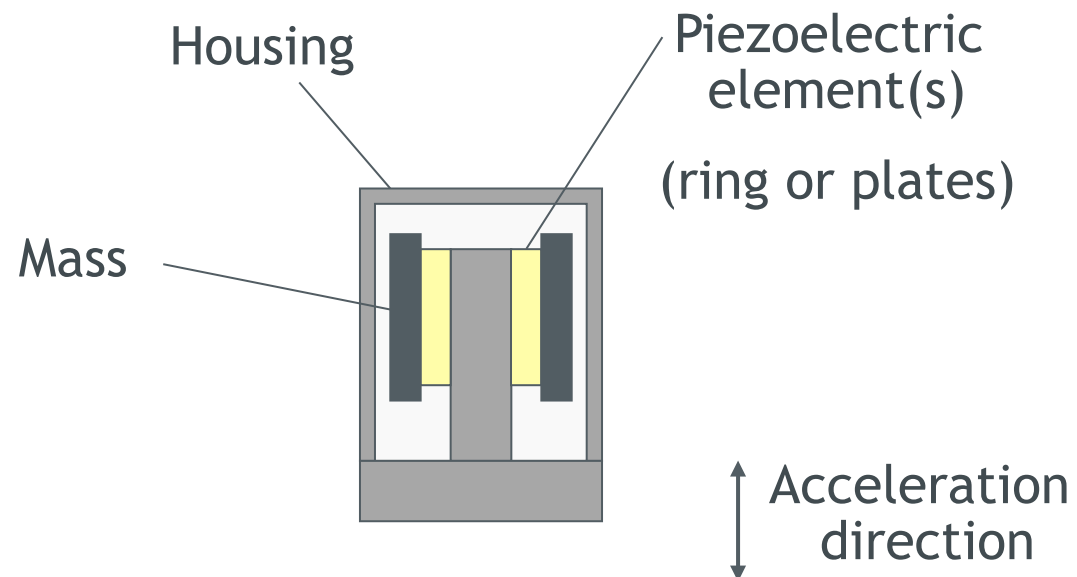
Hejreskovvej 18, Kvistgaard, 3470, Denmark

The accelerometer market

- Conventional systems
 - *Mostly piezoelectric*
 - *Specific applications for piezoresistive*
 - *Very mature market*
 - *Families of sensors for each environment and performance range*
- MEMS
 - *More recent developments*
 - *Increasing number of applications*

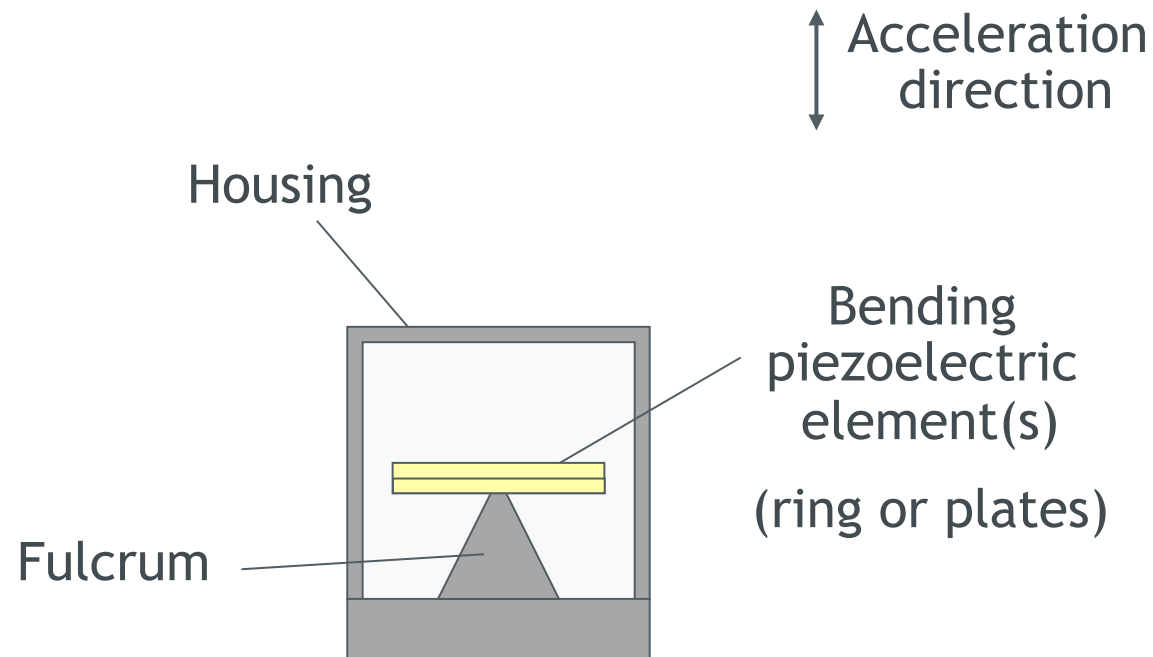
Conventional accelerometers

- Market dominated by shear mode sensors



Conventional accelerometers

- A few bending type accelerometers

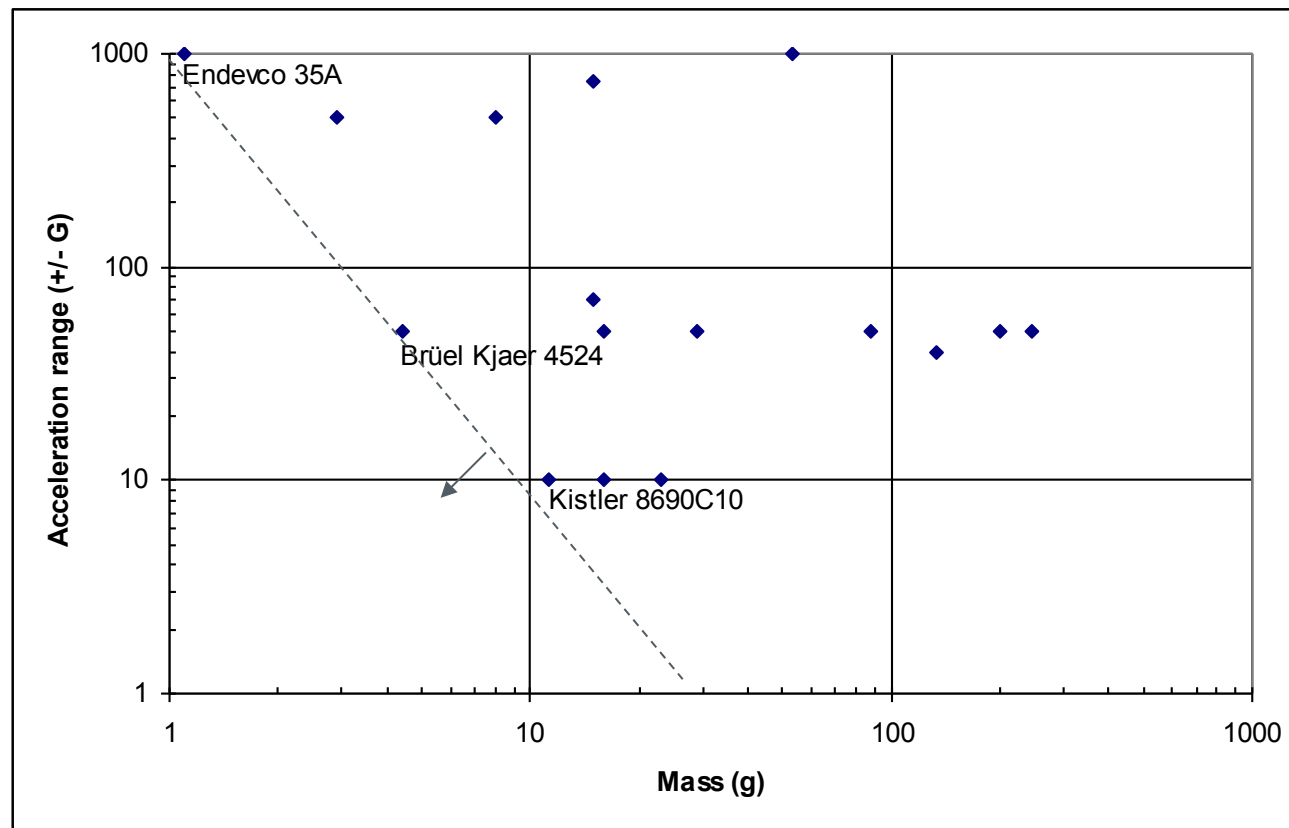


Conventional accelerometers

- + High performance (sensitivity, bandwidth, linearity)
- + Tolerant to environment
- + Large available range
- Complex
- Difficult to miniaturize, heavy
- Costly

Conventional accelerometers

- Market status



MEMS accelerometers

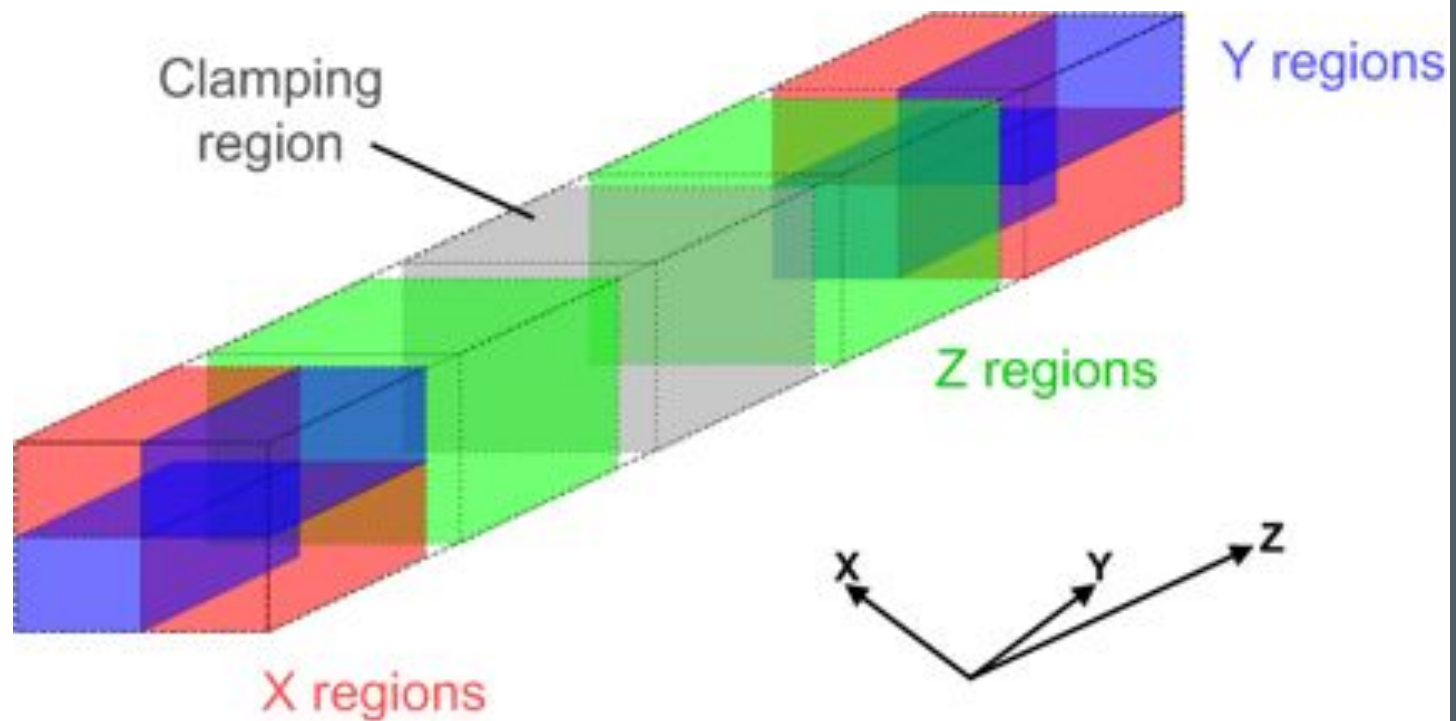
- + Various principles
- + High volume, low cost
- + Light weight
- + Variable performance
- Limited in terms of environment
- Difficult to qualify for aerospace or military applications
- Difficult to customize

Accelerometer development in the Noliac Group

- Cooperation within the group
- Noliac Motion (Denmark)
 - *Expertise in multilayer piezoelectric elements*
- Noliac Ceramics (Czech Republic)
 - *Expertise in ceramic materials*
- Noliac systems (Czech Republic)
 - *Expertise in piezo transducer development*

Ceramic monolithic multilayer triaxial accelerometer (CMMTA)

- 6 regions electrically defined in the same piezoelectric body
- Patent pending

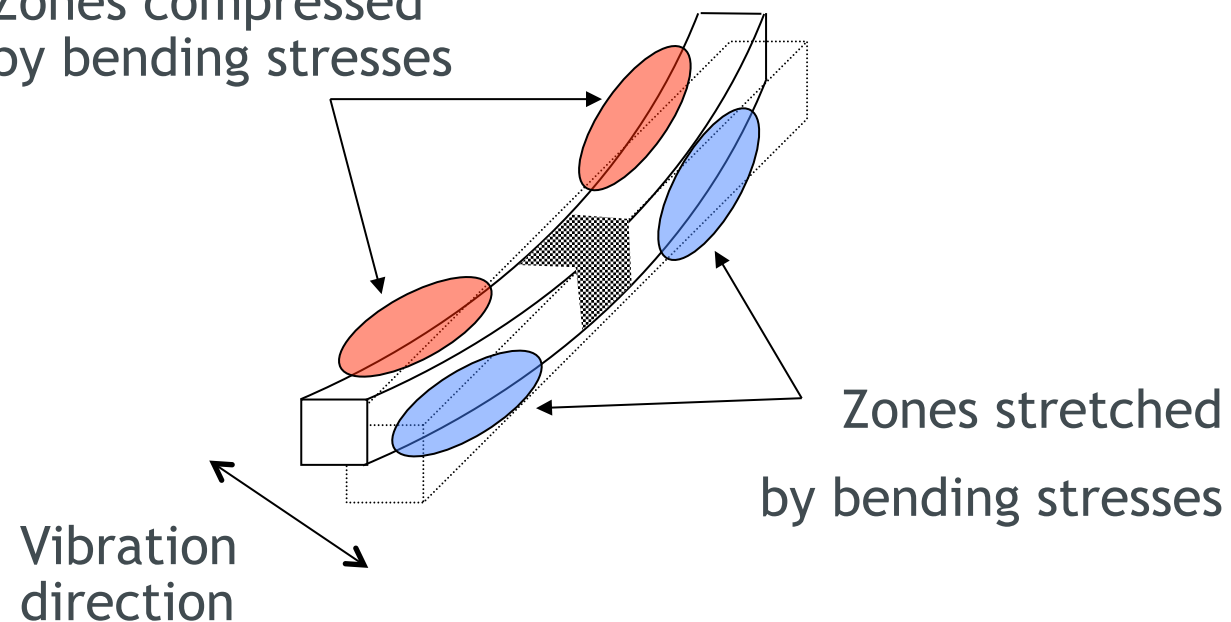


Patent pending

Measurement principle

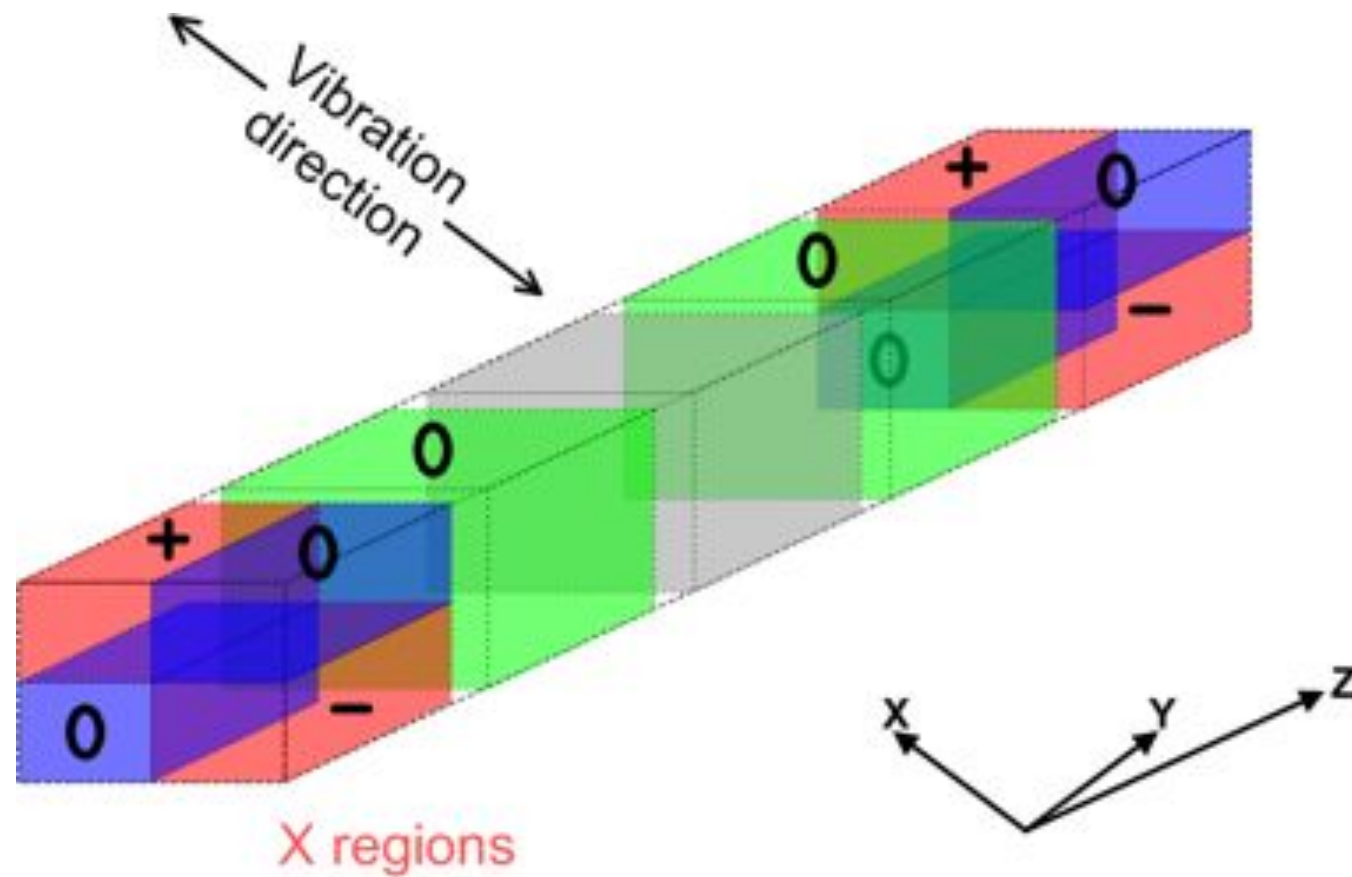
- X-Y axis

Zones compressed
by bending stresses



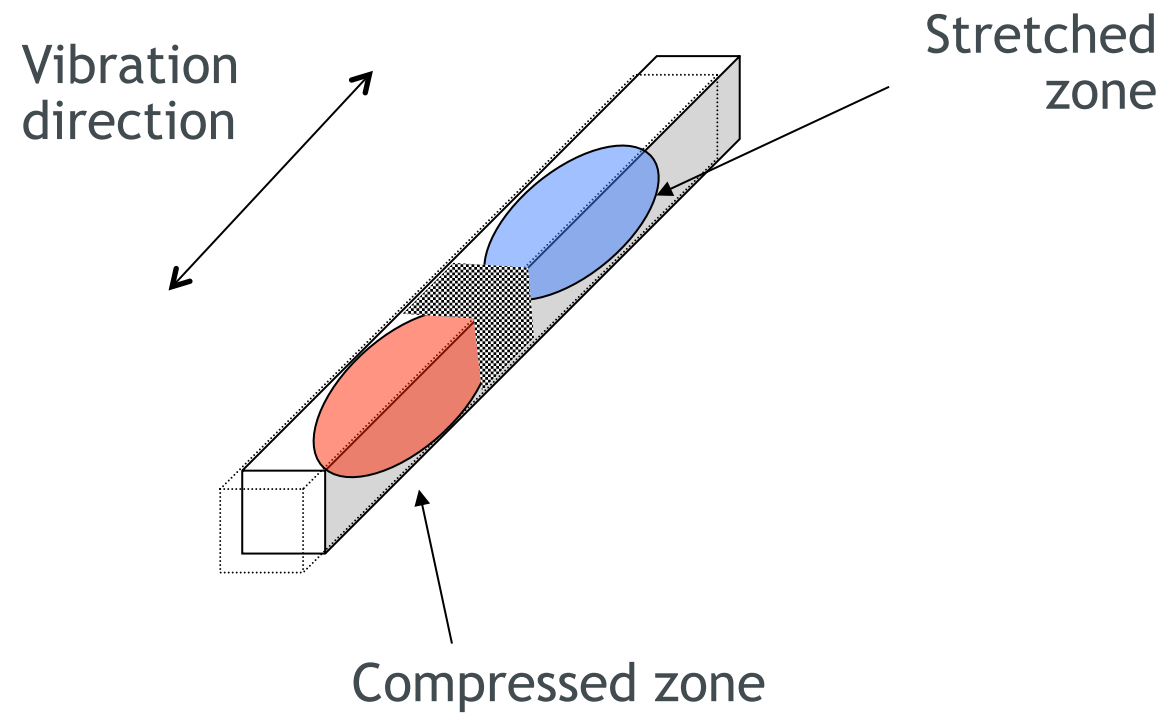
Measurement principle

- X-Y axis: charge movements



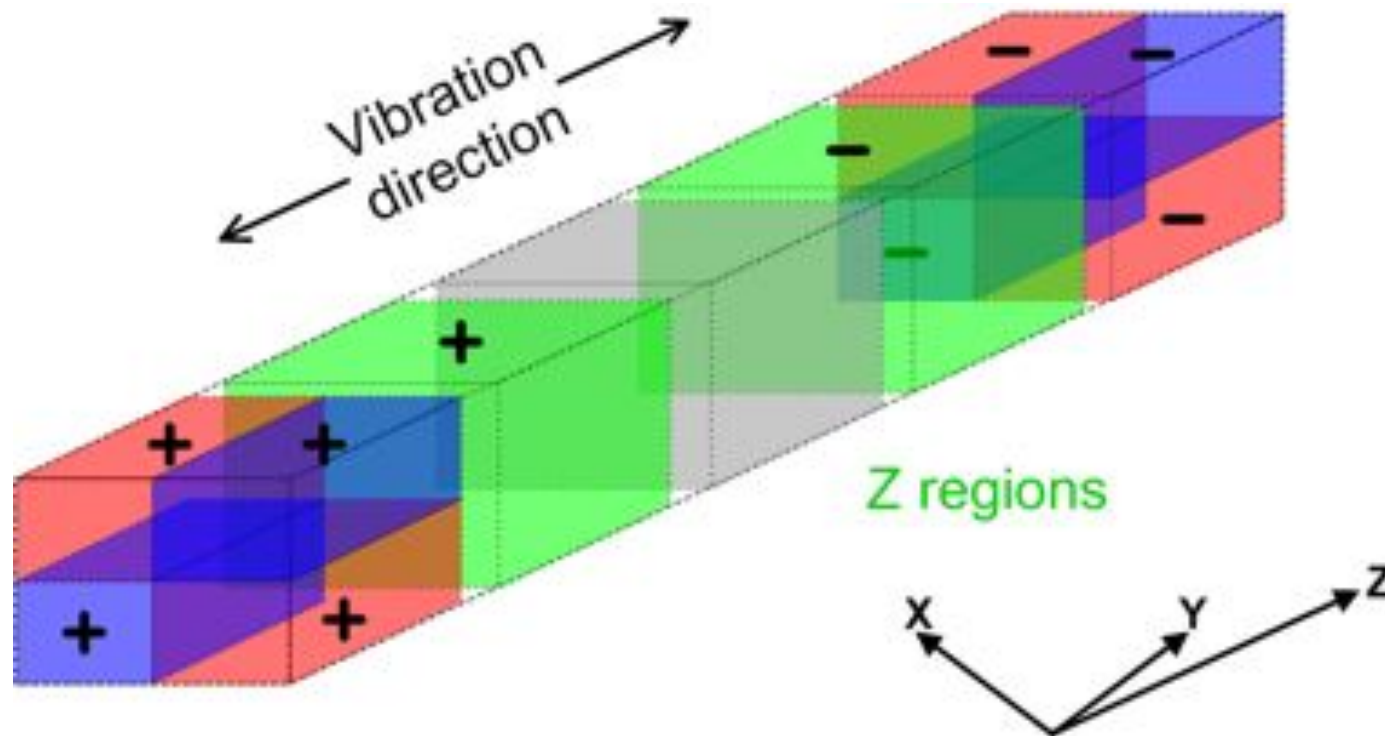
Measurement principle

- Z axis



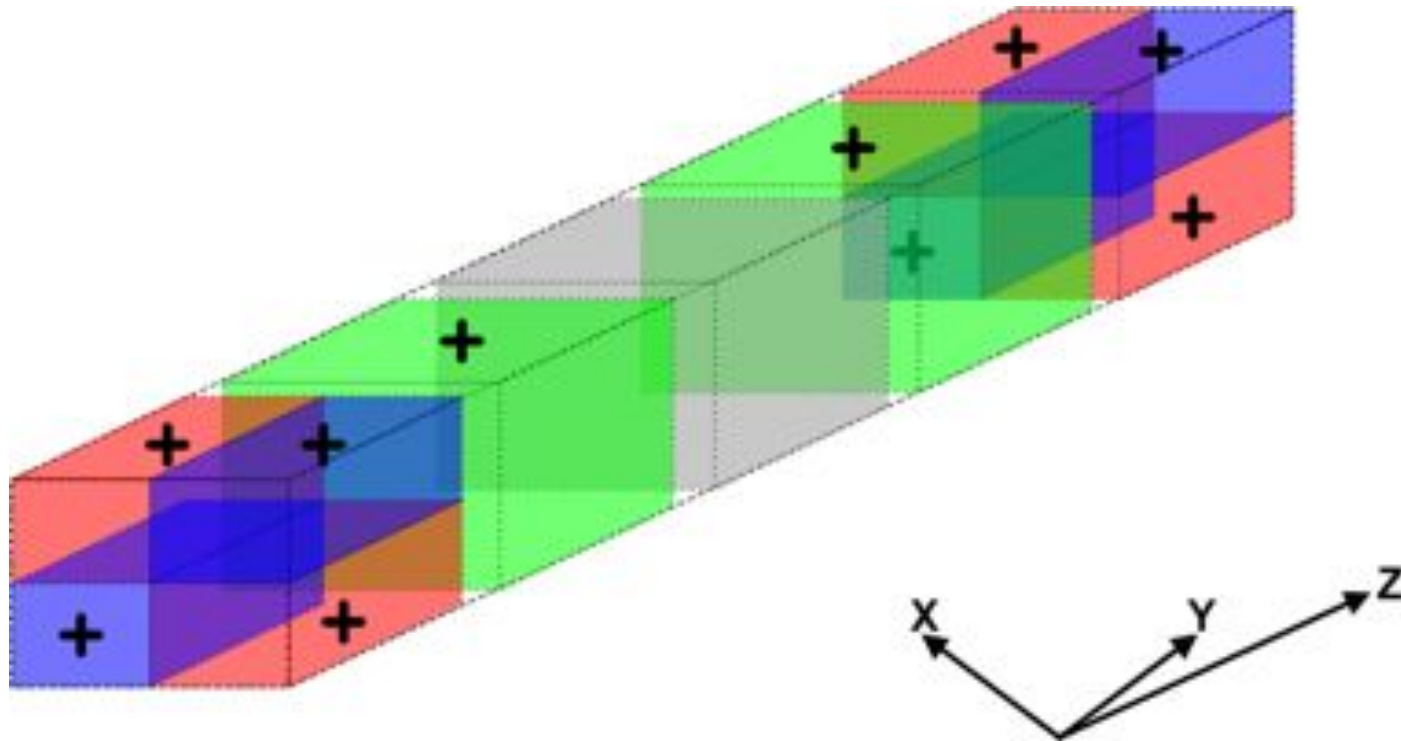
Measurement principle

- Z axis: charge movements



Temperature compensation

- Temperature change: charge movements



SWOT

- Expected advantages
 - *Low cost (simplicity)*
 - *Compact, lightweight solution*
 - *Temperature compensated*
 - *High sensitivity*
 - *Orthogonality of the axes*
 - *Potential for high temperature application*
- Potential disadvantages
 - *Heterogeneity X-Y vs. Z*
 - *Low stiffness*

Prototype design

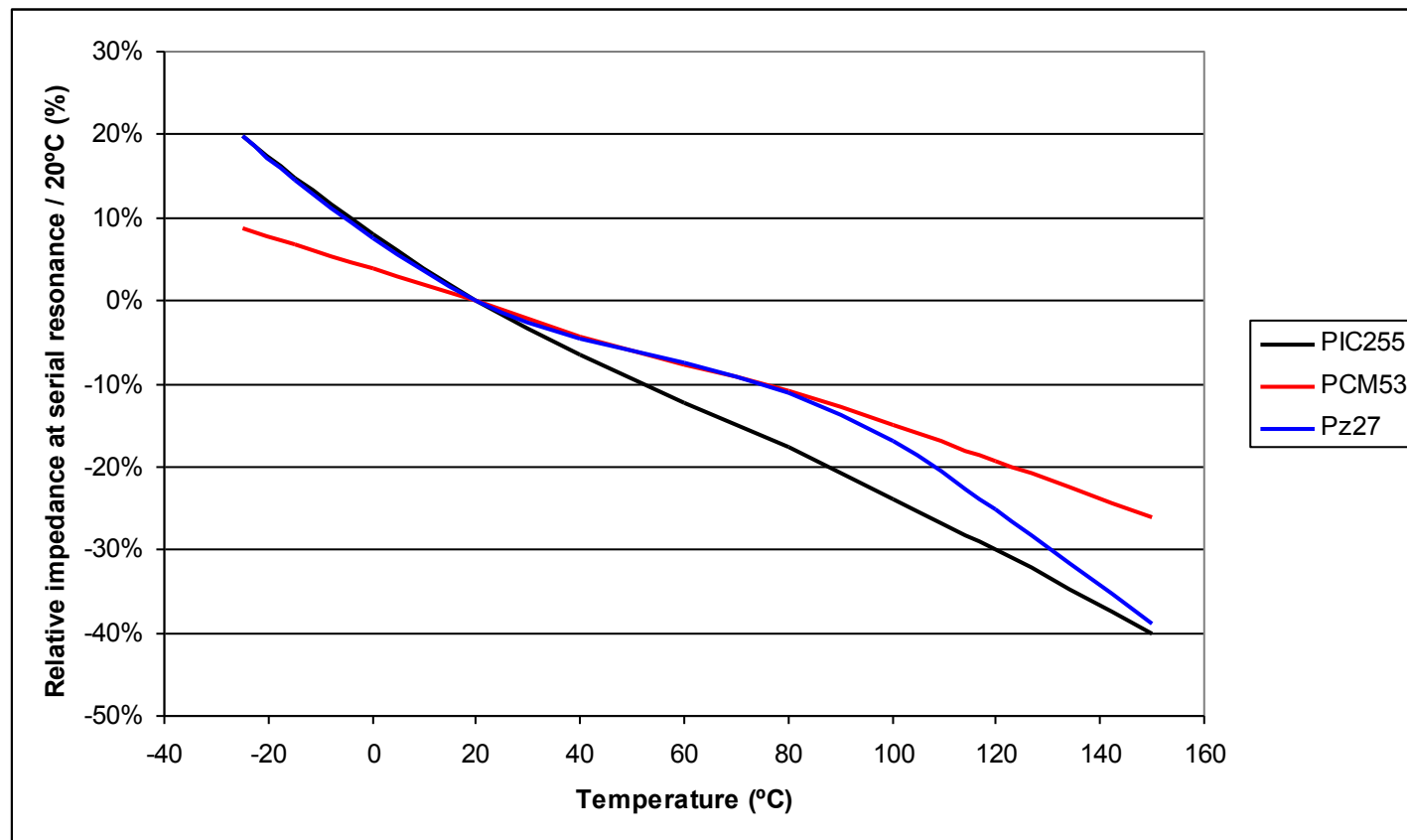
- **Dimensions**
 - *Cross section 2 x 2 mm*
 - *Free length 7 mm*
 - *No seismic mass*
 - *Symmetrical design*
- **Performance**
 - *Calculated first resonance 15 kHz*
 - *Mass 0,68 grams*

Prototype design

- Material
 - *Noliac Ceramics PCM53*
 - *Soft-doped PZT ceramic*
 - $g_{31} = -8,4 \cdot 10^3 \text{ Vm/N}$
 - $T_c = 350^\circ\text{C}$
- Selected for its temperature stability
- Adaptable design
 - *High temperature versions possible*
 - *High g versions possible*

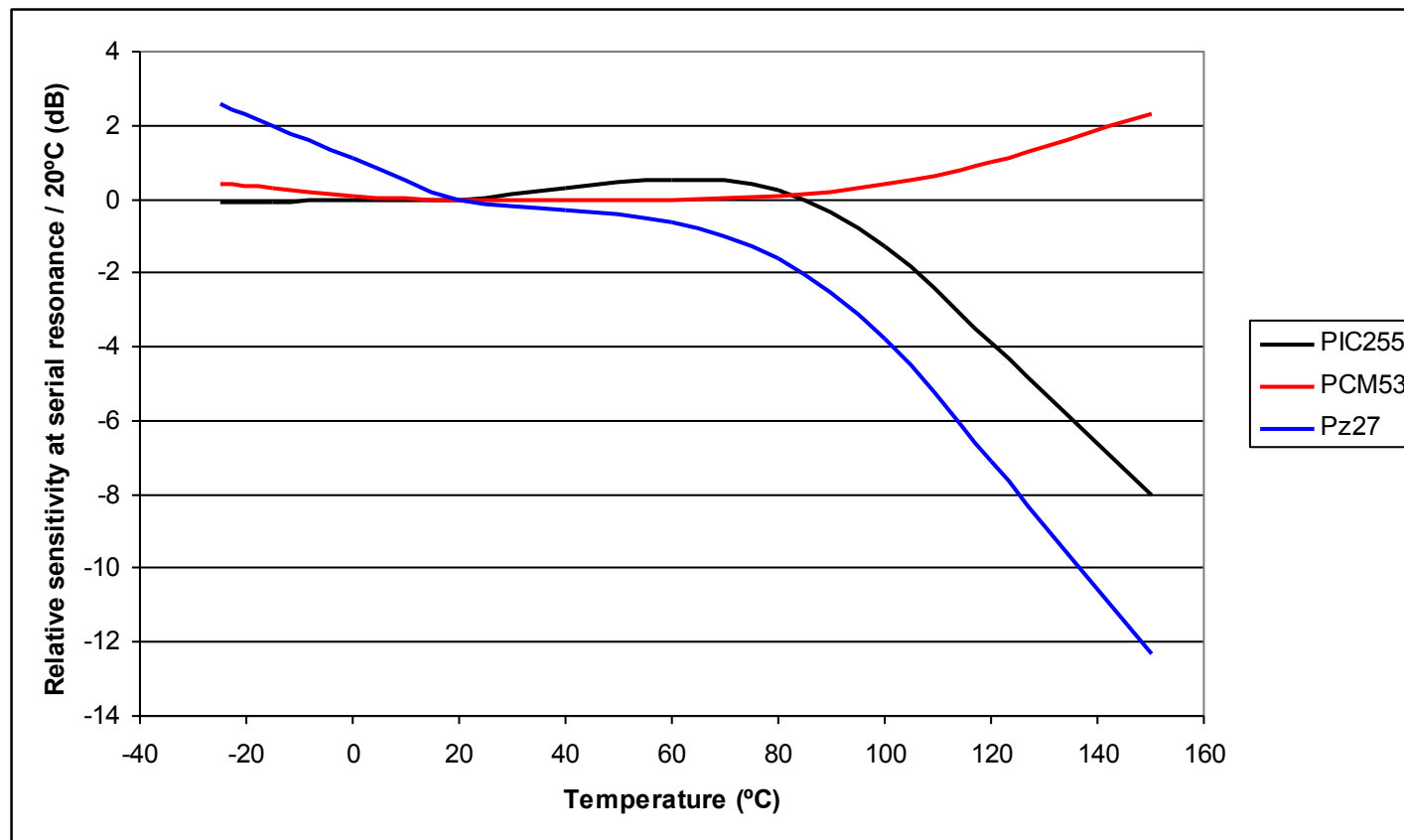
Prototype design

- Temperature stability
 - *Impedance at serial resonance*



Prototype design

- Temperature stability
 - *Sensitivity at serial resonance*



Prototypes

- Ceramic multilayer sensor



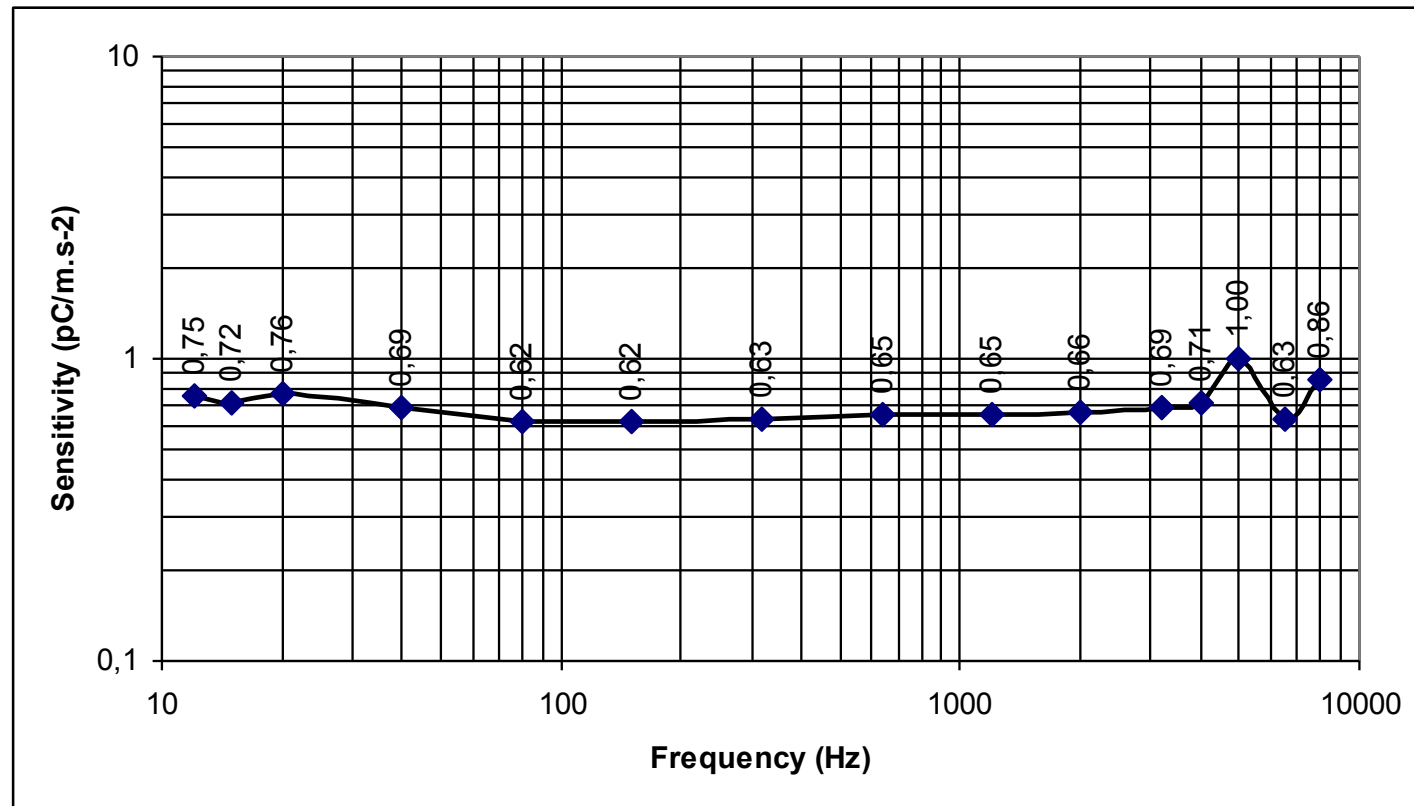
Prototypes

- Prototype on mount and demonstrator



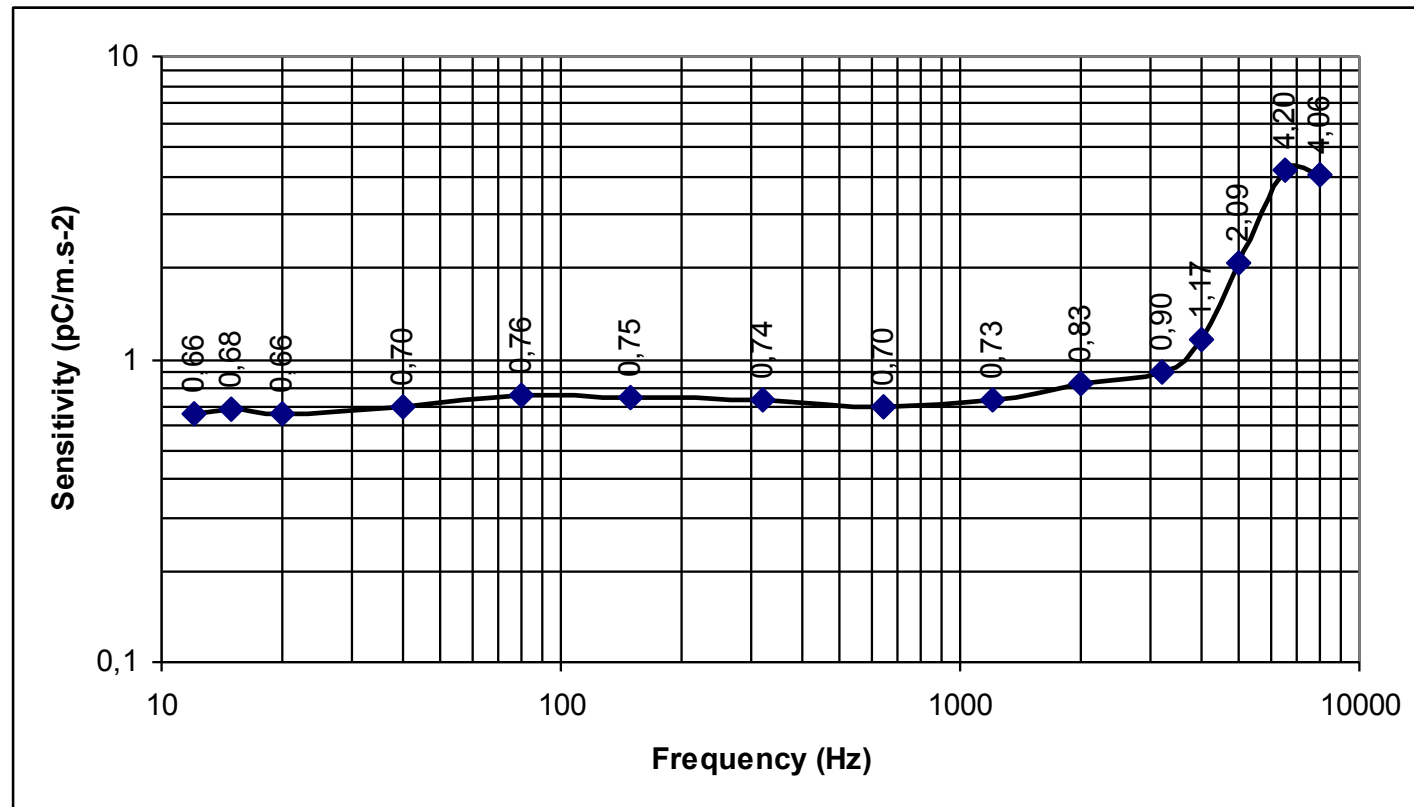
Performance tests

- X axis



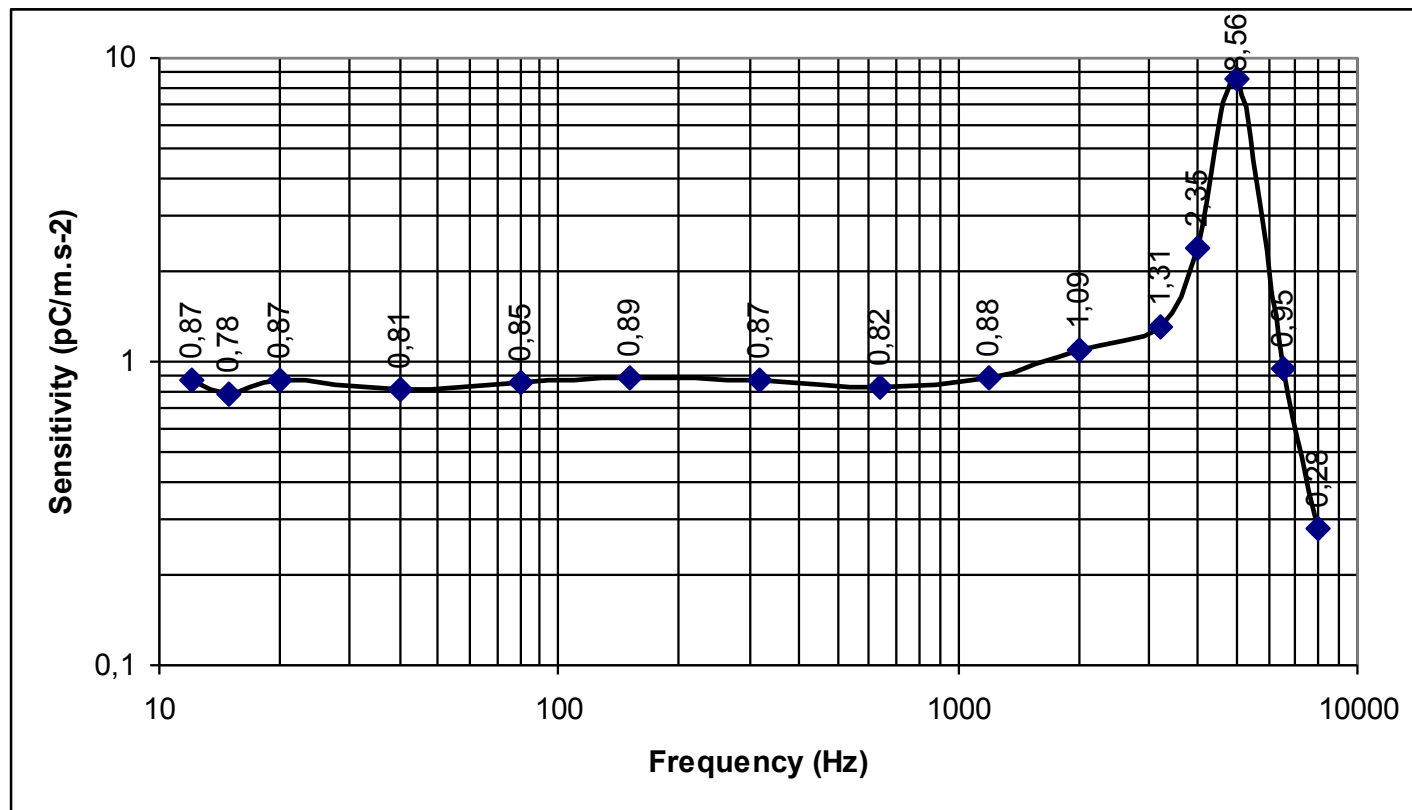
Performance tests

- Y axis



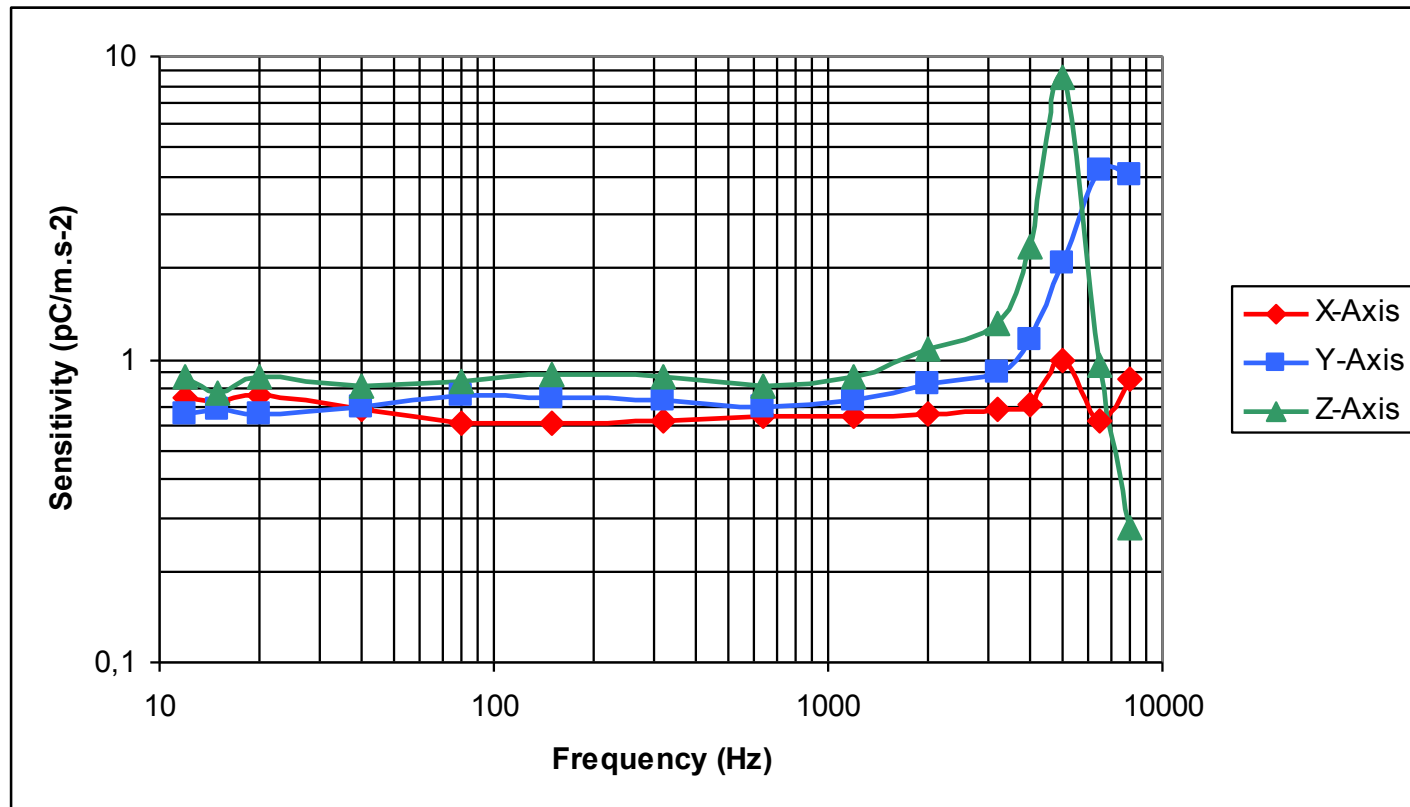
Performance tests

- Z axis



Performance tests

- Homogeneity



Performance

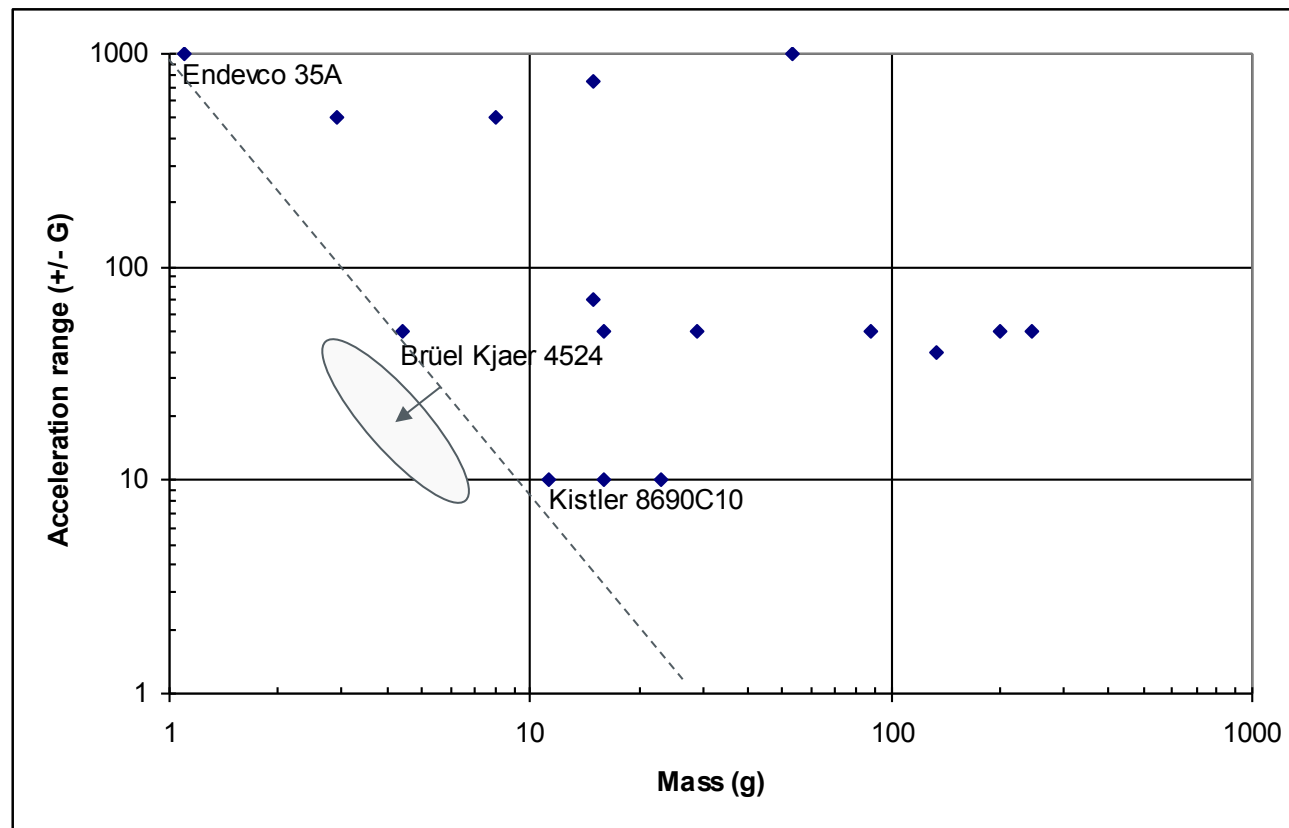
- Homogeneous results for all 3 axes
 - *Sensitivity 0,6-0,8 pC/m.s-2 for X-Y*
 - *Sensitivity 0,8-1,0 pC/m.s-2 for Z*
- Stable response over frequency range
 - *10 Hz to 2 kHz*
 - *Low resonance (5 kHz) due to the fixture*

Summary

- + High sensitivity
- + Flat and homogeneous response
- + Light weight (0,68g ceramic)
- + Simple construction (low cost)
- Bandwidth limited to 2 kHz for this first prototype

Performance range

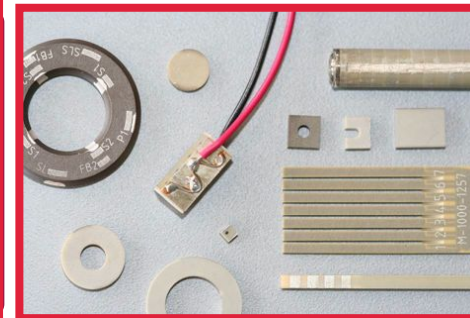
- Position on market



Conclusions

- Unique advantages
- Further development
 - *Packaging*
 - *Integrated electronics*
 - *Range adapted to each measurement*
- Develop market potential
 - *High sensitivity, light weight, temperature stability, compatible with harsh environments*
 - *Aerospace applications*
 - *Instrumentation (f.ex. automotive)*

Thank you for your attention



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