Vibration Transducers and Signal Conditioning

- Types of Vibration Transducers
- The Piezoelectric Accelerometer
- Choosing an Accelerometer
- Using an Accelerometer
- Calibration
- Conditioning Amplifiers

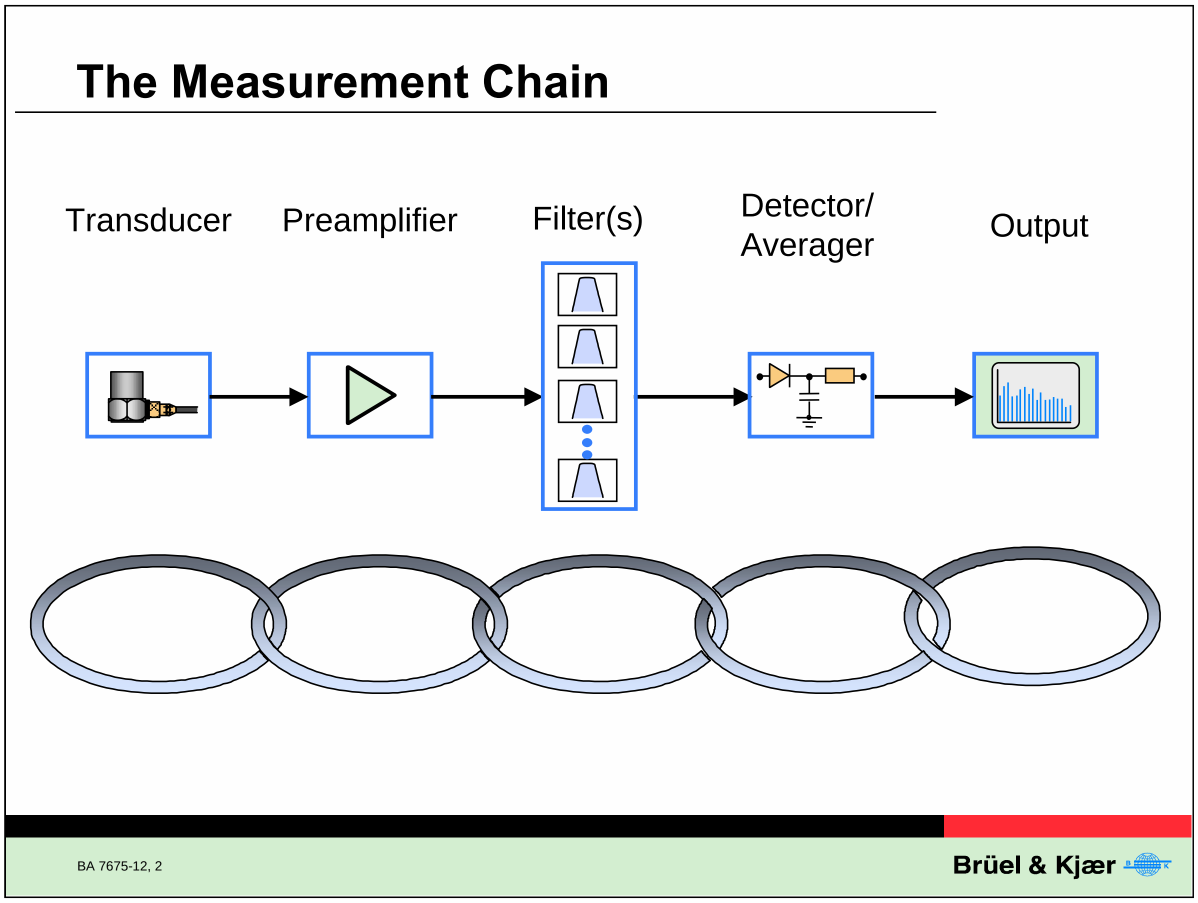
Abstract

A brief explanation of the most commonly used vibration measuring transducers is given at the beginning of the lecture. This is followed by a description of various types of piezoelectric accelerometers and their principle of operation. The basic specifications of accelerometers are explained and the effect of different mountings and their practical application is described in detail. The influence of different environments is discussed and a description of calibration is given. The lecture ends with a description of preamplifiers and signal conditioning.

LECTURE NOTE

English BA 7675-12

Brüel & Kjær



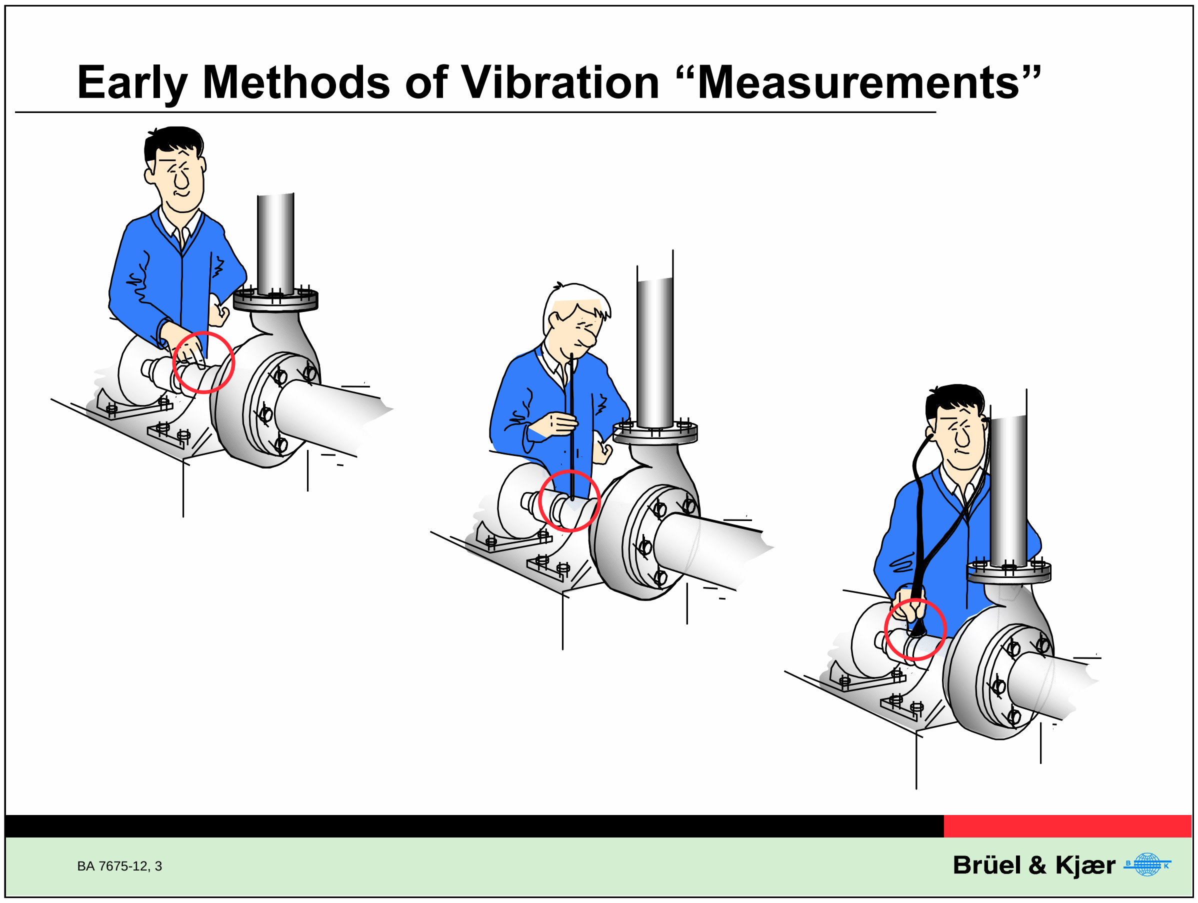
The Measurement Chain

Remember: The system is never stronger than the weakest link in the chain.

Whenever measurements of physical parameters takes place, the method used comprises a transducer to convert the parameter into a more practical parameter, mostly an electromagnetic magnitude because of the vast amount of available methods and components to treat such signals.

Furthermore a certain adaptation between a transducer and normal instrumentation is often necessary in the form of preamplifiers and conditioning of the signal.

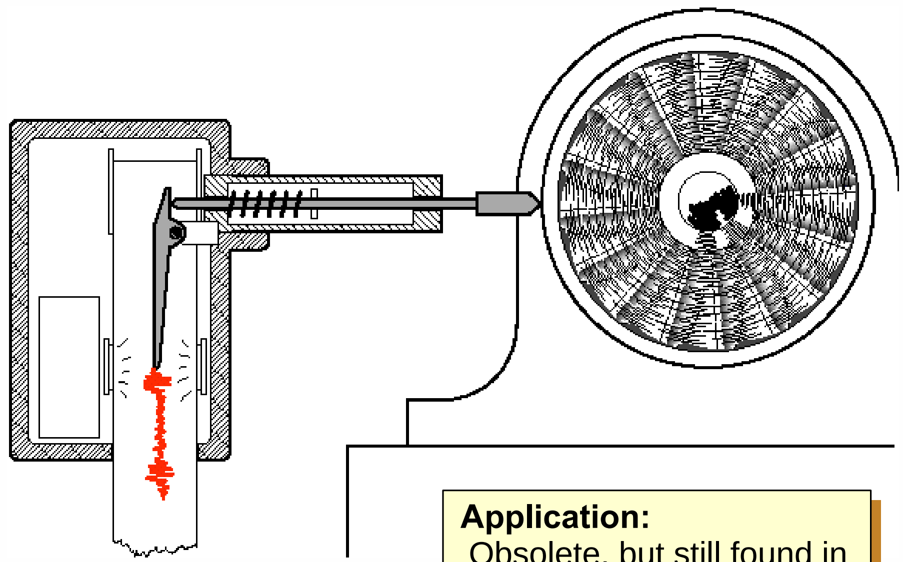
After analysis which today can have many different forms, the result will be presented as an output to screen, paper or storage medium.



Early Methods of Vibration “Measurement"

In the absence of instruments, vibration has been “evaluated” by means of touching the machine; transfer of the vibration signal from the source to the head with the aid of a rod, or by using a doctor's stethoscope. In each of these cases, the signal is evaluated by experience without the aid of numerical values to aid comparison.

Mechanical Lever



Application:
Obsolete, but still found in a few old power stations

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VIBRATION TRANSDUCERS

Mechanical Levers

Measures Displacement.

Advantages:

Self generating

Trace available

Inexpensive

Limitations:

No electrical output

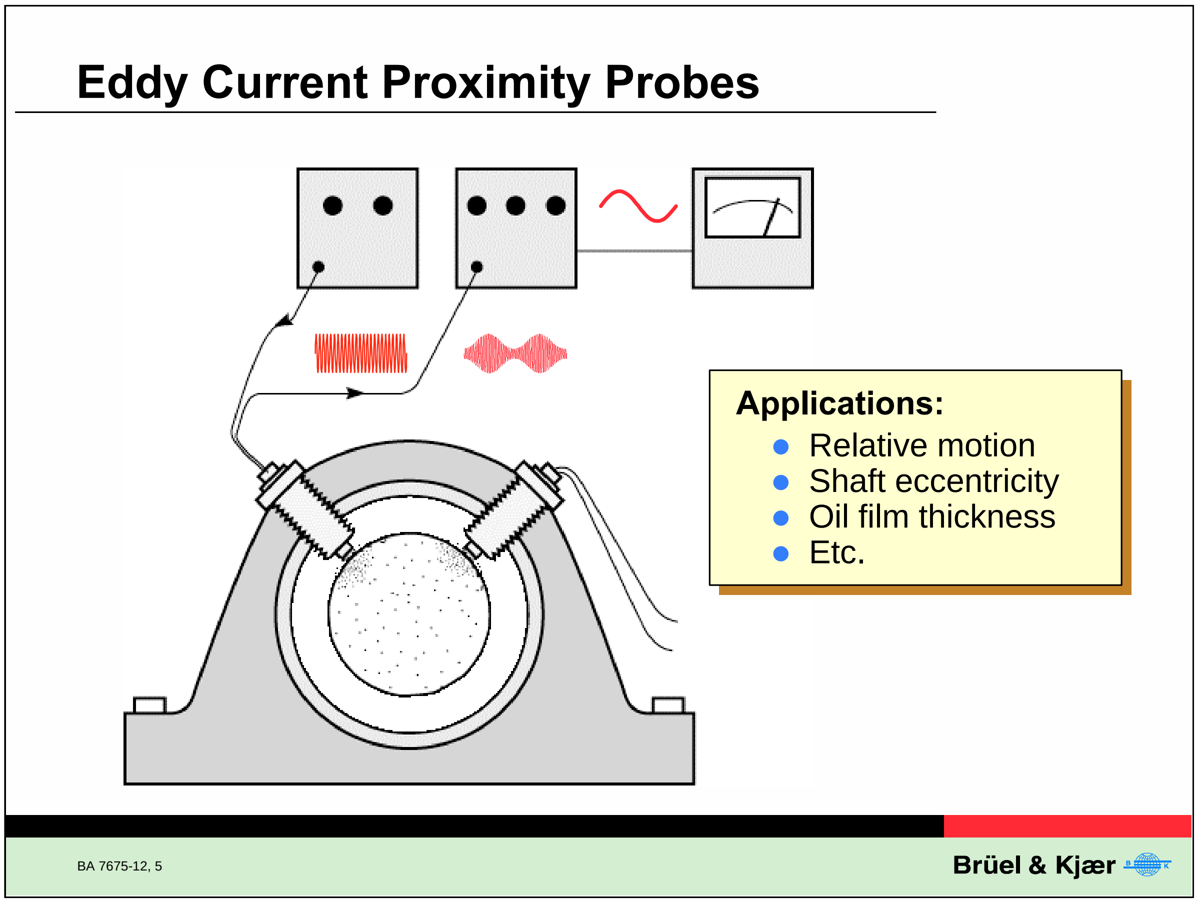
Low frequency only

High amplitudes required

Prone to wear

Loads the vibrating structure

Sensitive to orientation



Eddy Current Proximity Probe

Measures Displacement (mostly according to API 670)

Dynamic range: 500:1

Frequency range: DC -10kHz (Theoretical)

DC -2000Hz (Practical)

Advantages:

Non contacting

No moving parts, no wear

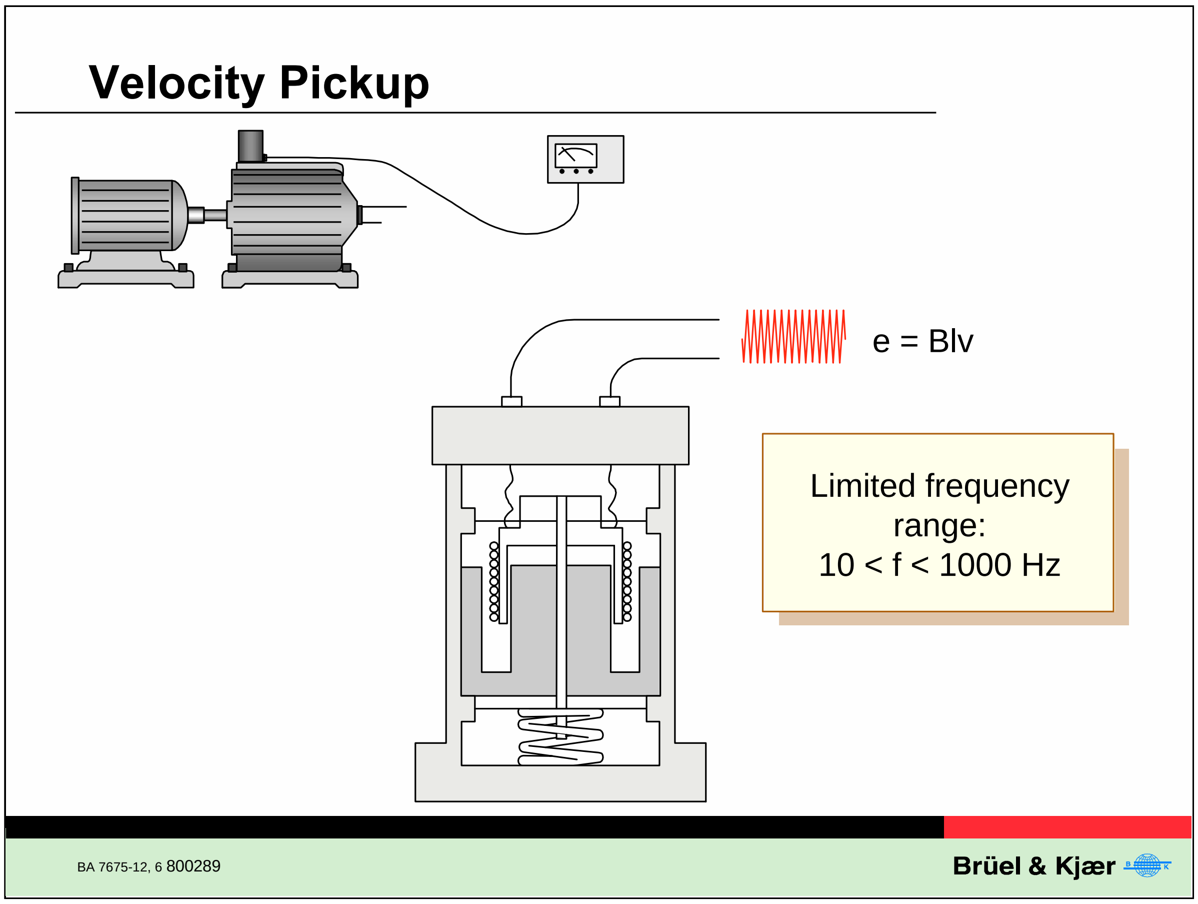
Works to DC

Limitations:

Variations in magnetic properties of shaft and geometric irregularities of shaft give erroneous signal components.

Local calibration necessary

A low dynamic range limits practical frequency range as displacement is relatively small at high frequencies.



Velocity Pickup

Measures velocity

Induced voltage e proportional to:

Magnetic field B, length of windings l and relative velocity v

Dynamic range: 1000:1

Advantages:

Self generating

Low impedance

Limitations:

Moving parts prone to wear

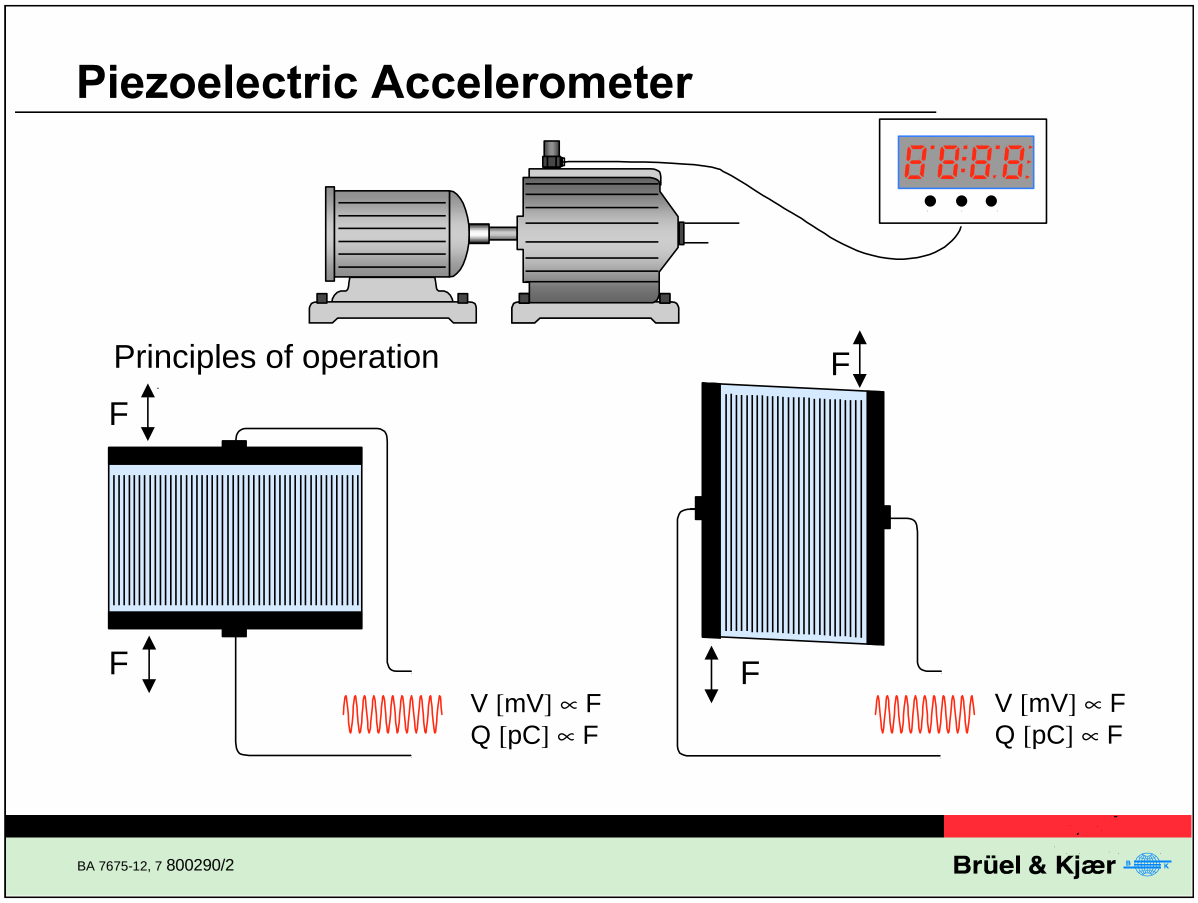
Large size

Sensitive to orientation

Sensitive to magnetic fields

High lower limiting frequency (>app. 10 Hz) as it operates above resonance

Friction against the motion of the Moving Element will cause reduced output signal.



Accelerometer

Measures acceleration

Dynamic range: $10^8 : 1$ (160 dB)

Advantages:

Self generating

No moving parts, no wear

Rugged

Very large dynamic range

Wide frequency range

Compact, often low weight

High stability

Can be mounted with any orientation

Limitations:

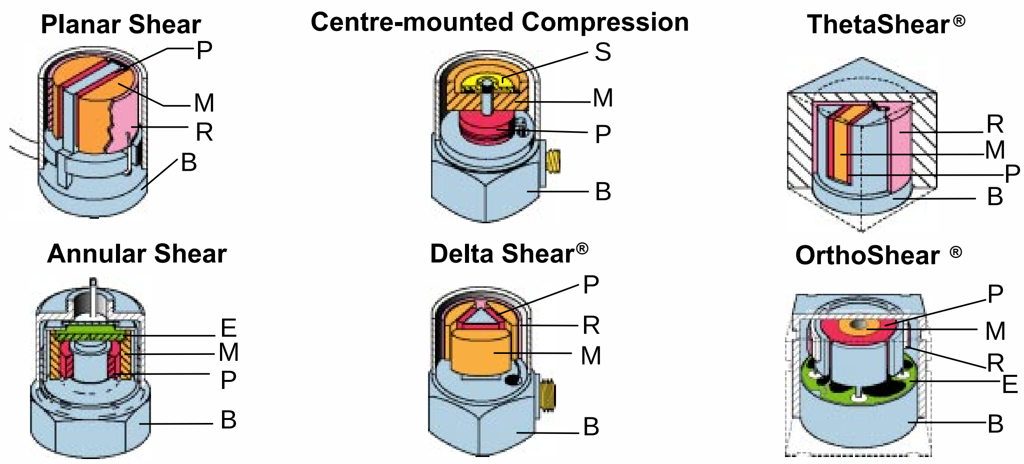
High impedance output

No true DC response

Piezoelectric Materials

When a force is applied to a piezoelectric material in the direction of its polarization an electric charge is developed between its surfaces, giving rise to a potential difference on the output terminals. The charge (and voltage) is proportional to the force applied. The same phenomenon will occur if the force is applied to the material in the shear mode. Both modes are used in practical accelerometer design.

Types of Accelerometers



P: Piezoelectric Elements	**E: Built-in Electronics**	**S: Spring**
R: Clamping Ring	**B: Base**	**M: Seismic Mass**

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Compression Type Design

This traditional, simple construction gives a moderately high sensitivity-to-mass ratio. In the Centre-mounted configuration shown, the piezoelectric element-spring-mass system is mounted by means of a cylindrical centre post attached to the base of the accelerometer.

The design is very stable, but even with careful design the influence from environmental parameters is higher than for the other construction types.

Therefore this design is especially used for accelerometers which are intended for measurement of very high shock levels and special purpose accelerometers.

Shear Type Design

Shear type accelerometers have the advantage that they intrinsically are rather insensitive to environmental parameters like temperature transients and base strain. A high sensitivity-to-mass ratio can be obtained, and this helps to create miniature accelerometers as well as high performance general purpose accelerometers. The piezoelectric elements are arranged in such a way that they are subjected to shear forces from the seismic mass when accelerated.

DeltaShear® Design

Three piezoelectric elements and three masses are arranged in a triangular configuration around a centre post. They are held in place using a high-tensile strength clamping-ring.

The DeltaShear® accelerometers can be used for virtually any application. The advantage of the Delta Shear accelerometer is its excellent overall specifications and very low sensitivity to environmental influences.

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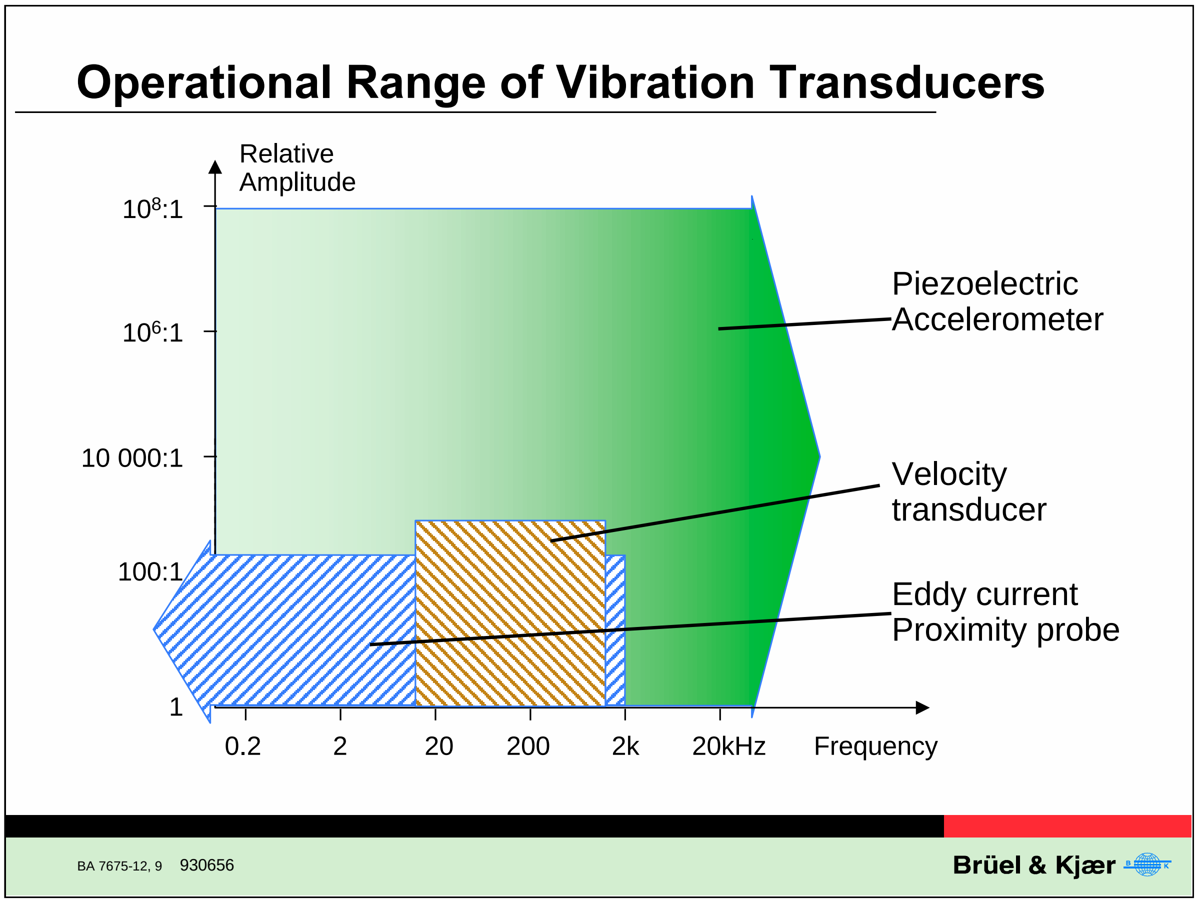


Ranges of Operation

The range of frequencies and levels within which the different transducers typically can operate differs significantly as stated earlier. A graphical representation underlines this.

Continued from previous side:

Planar Shear-Design

This design is a simplified DeltaShear® Design with only two piezoelectric elements and seismic masses. This gives excellent performance even when used in very small accelerometers.

Annular-Shear-Design

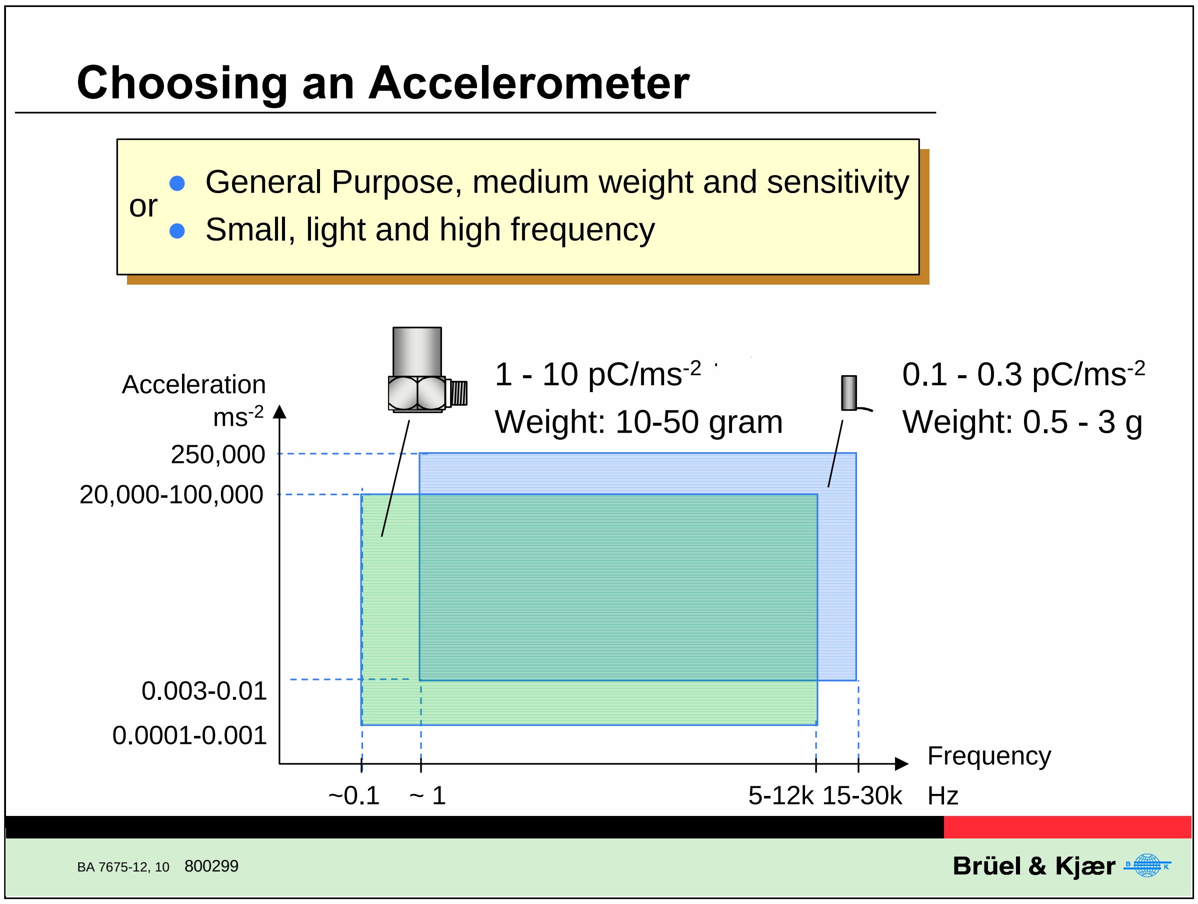
In this design the piezoelectric element and seismic mass are formed into rings and mounted around a centre post. The figure shows an accelerometer with built-in electronics and double shielding.

ThetaShear® Design

This patented design combines the advantages of the shear design, electrical insulation from the mounting surface, simplicity, and low mass-loading to provide low-cost flexible well performing transducers.

OrthoShear® Design (Triaxial)

This design (patent pending), developed for triaxial measurements, has a common seismic mass as reference point (centre of gravity) for all directions. This results in a compact design ensuring accurate and consistent measurements even when exposed to complex patterns of vibration. The seismic mass is surrounded by a piezoelectric ring and four terminals all held in position by a high tensile-strength clamping ring. The X, Y and Z outputs are obtained by appropriate connection to the terminals and summation of signals. Combines the advantages of the shear design, electrical insulation from the mounting surface, simplicity, and low mass-loading to provide low-cost flexible well performing transducers.

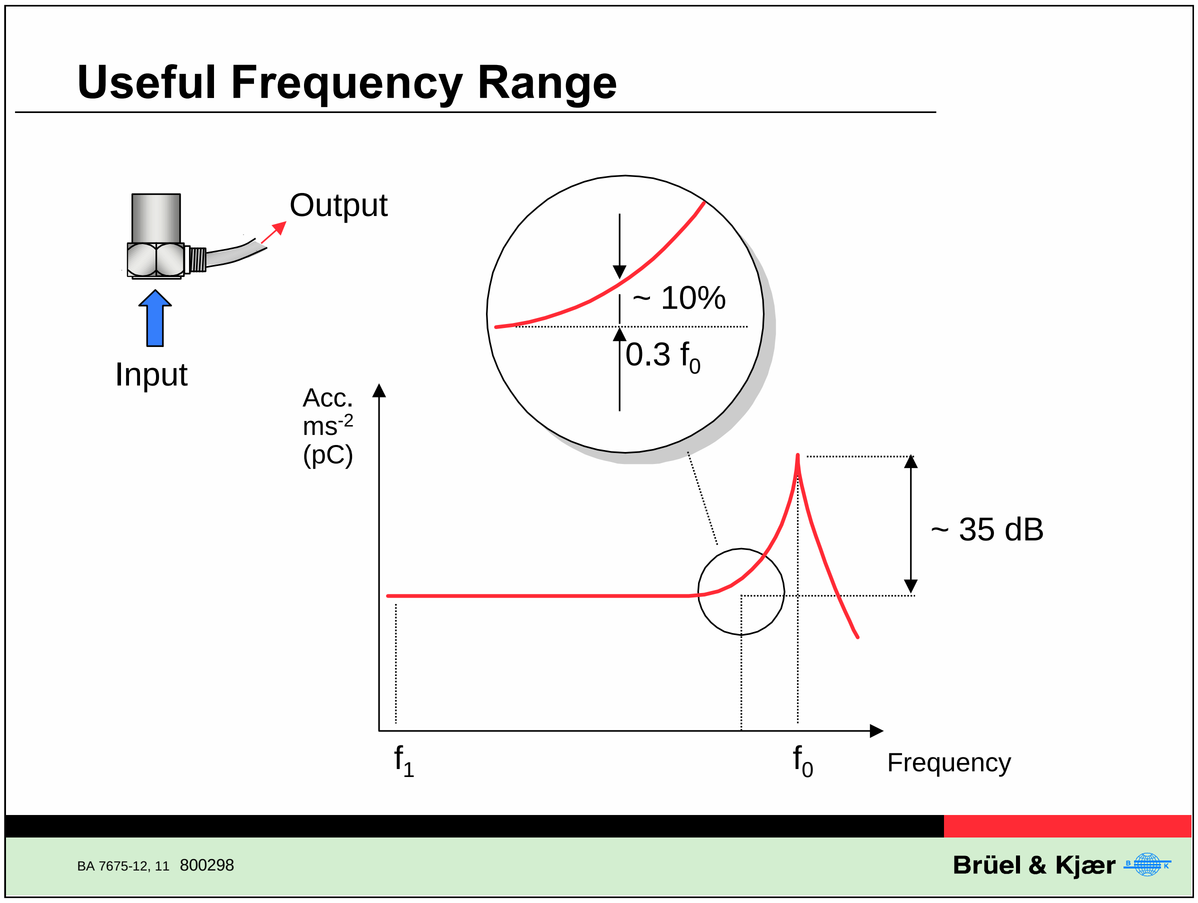


Selection of an Accelerometer

The range of operation is the first to be considered when selecting an accelerometer.

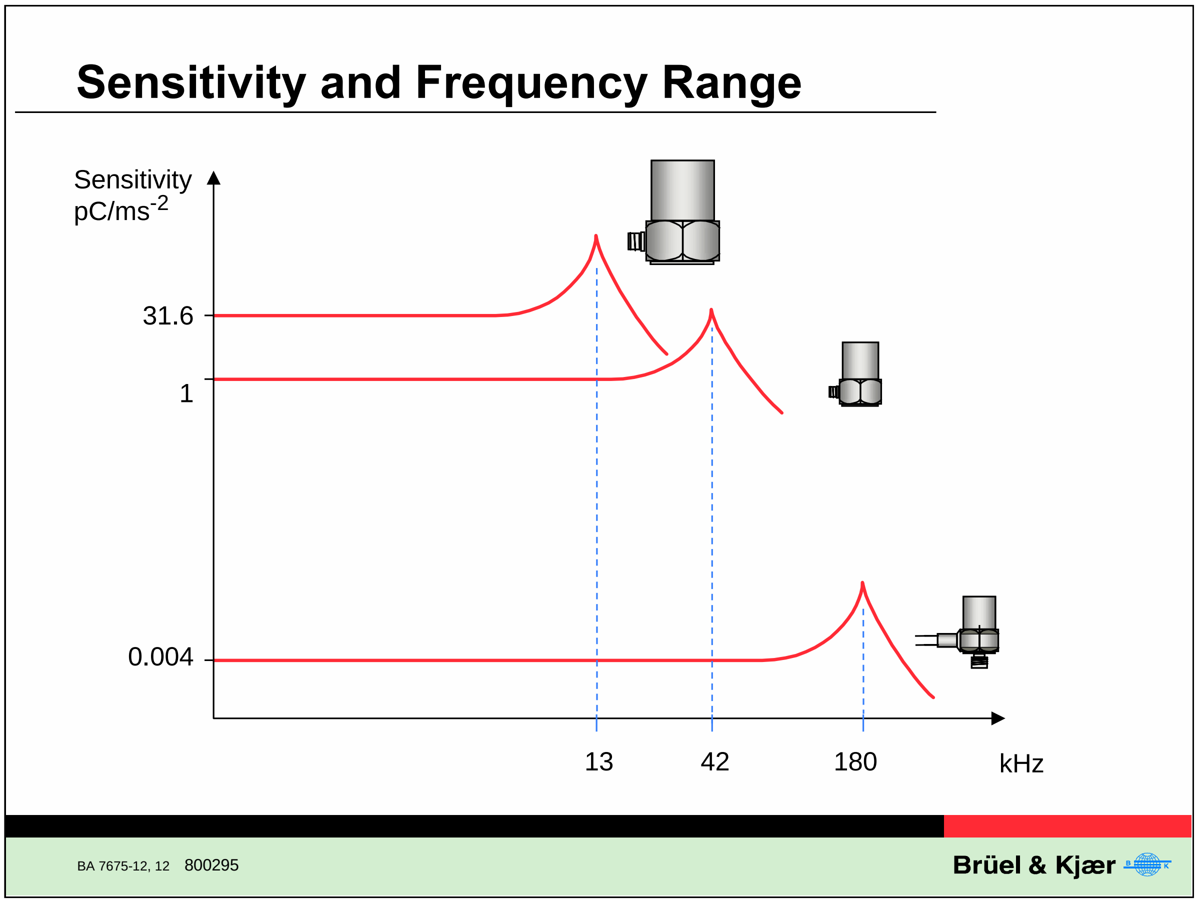
The graph shows two typical groups of accelerometers with typical specifications:

- General Purpose Type Accelerometers
- Small (miniature) Accelerometers



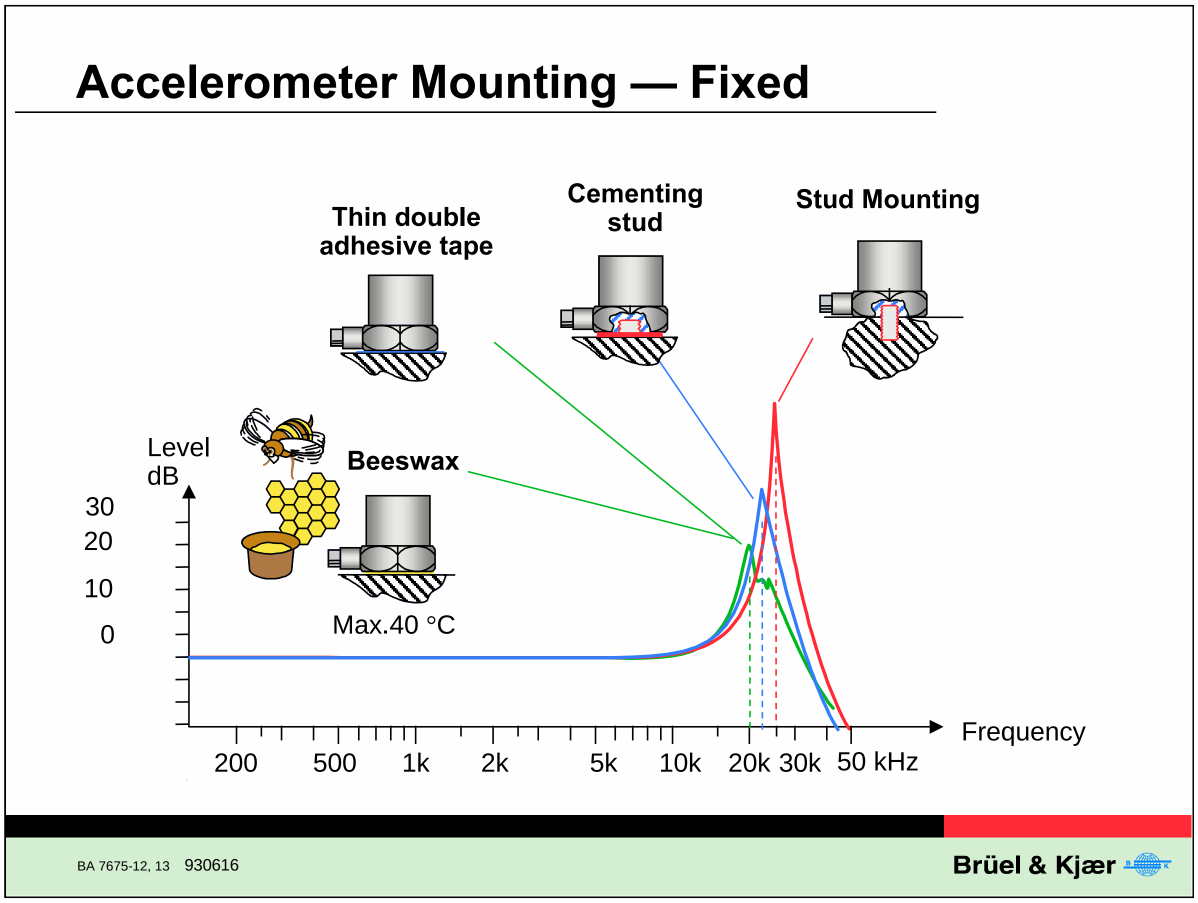
Useful Frequency Range

All accelerometers will give a constant output signal for a constant acceleration from very low frequencies up to a limit set by the increase in output due to resonance of the accelerometer. In general, however, the accelerometer is not used close to its resonance as this could result in a big error in the measured signal. As a rule of thumb, the accelerometer can be used up to one third of its resonance frequency. This will then ensure that the error at that frequency does not exceed approximately 12% or 1 dB. 0.3 times the mounted resonance frequency gives 10 % as shown. Filters can be used to limit the response to well below the accelerometer resonance frequency, but the input stages will still have to handle any signals at the resonance. To avoid this, mechanical filters can be used. This will be discussed later.



Sensitivity and Frequency Range

When the accelerometer is exposed to a constant level of acceleration it will give a constant output signal over a very wide frequency range up to frequencies near its resonance frequency. The sensitivity and frequency range of an accelerometer are related: in general the bigger the accelerometer the higher its sensitivity, and the smaller is its useful frequency range, and vice versa.



The Importance of Correct Mounting

Bad mounting of the accelerometer can spoil vibration measurements by severely reducing the usable frequency range. The main requirement is for close mechanical contact between the accelerometer base and the surface to which it is to be attached.

Stud Mounting

Mounting the accelerometer with the aid of a steel stud is the best mounting method and should be used in all applications wherever possible. The unavoidable resonance of the accelerometer at high frequencies can cause erroneous signals and therefore the accelerometer output should be attenuated at these high frequencies.

Cementing Studs

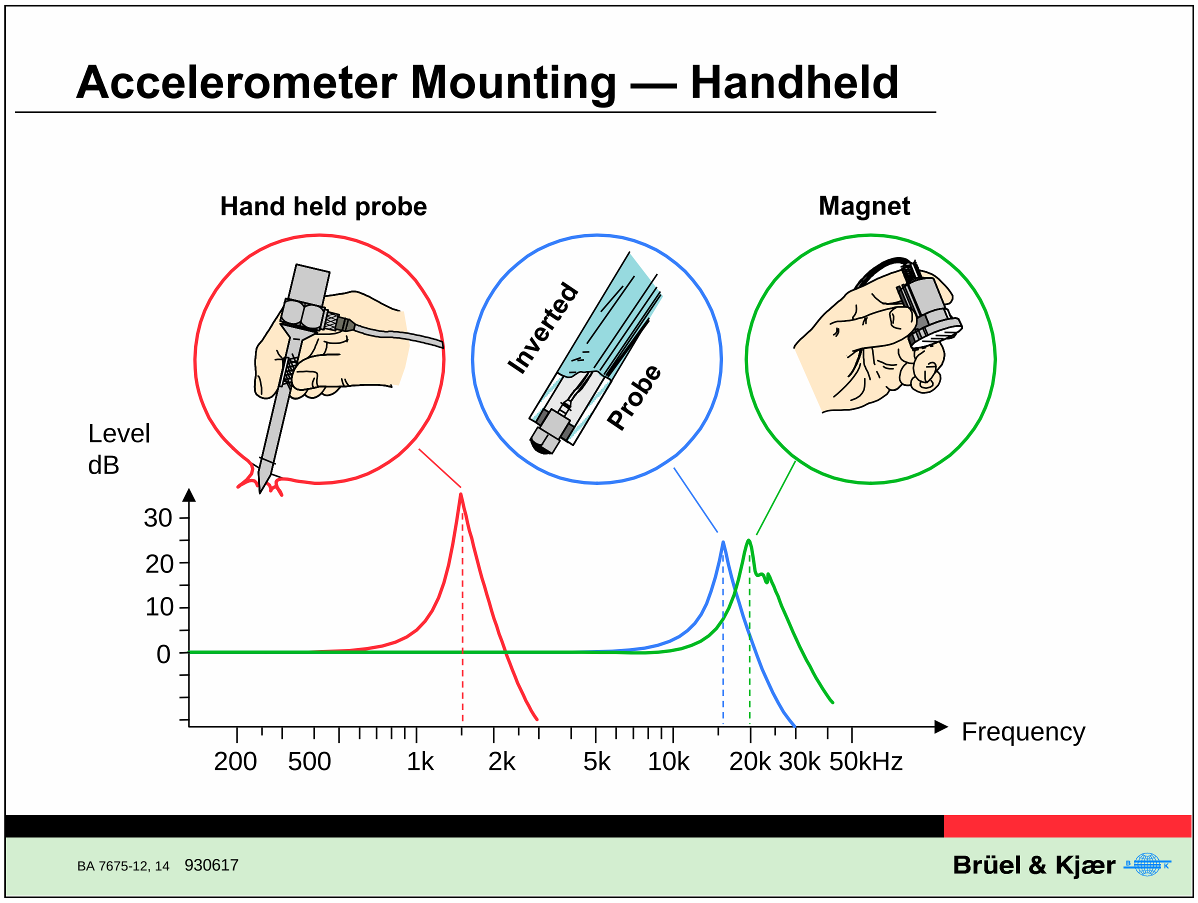
In places where it is not wished to drill and tap fixing holes, a cementing stud can be fixed onto the machine with the aid of an epoxy or cyanoacrylate cement. The frequency response will be nearly as good as that obtained using a plain stud. Soft glues must be avoided.

Mounting with the Aid of Beeswax

For quick mounting of the accelerometers e.g. for surveying vibration in various locations beeswax can be used for mounting the accelerometer. Because beeswax becomes soft at high temperatures, the method is restricted to about 40°C.

Isolated Mounting

In places where it is desirable to isolate the accelerometer from the test object an isolated stud and a mica washer should be used. This could be either because the potential of the test object is different from the ground potential of the test instrumentation or because direct stud mounting will create a ground loop which could affect the measurement. The latter is the most common reason for use of an isolated mounting. This point will be discussed later.



Mounting with the aid of a Permanent Magnet

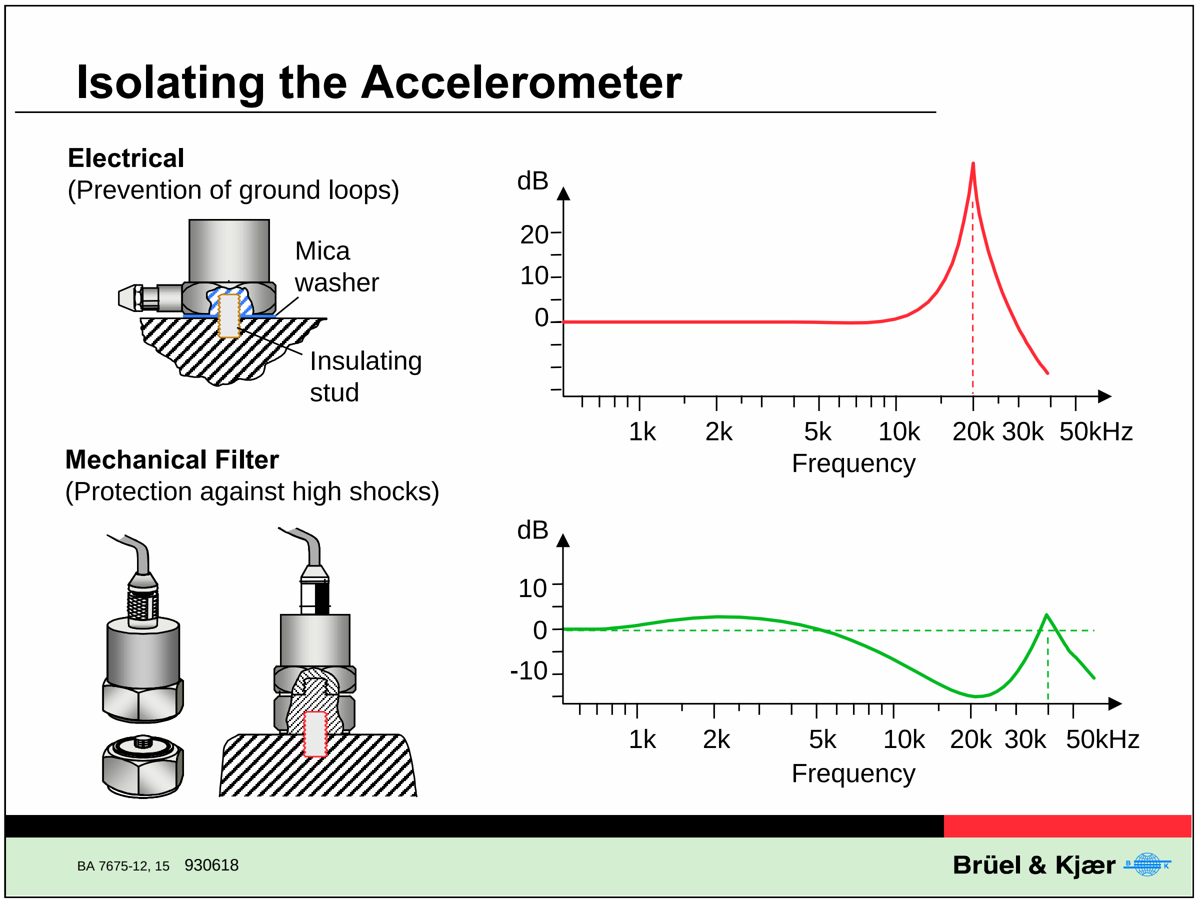
An easy and fast method of mounting the accelerometer is by using a permanent magnet which very easily can be shifted from one position to another. This is especially useful for surveying. The method is restricted to use on ferro-magnetic surfaces and the dynamic range is limited due to the limited force of the magnet. To obtain the maximum frequency range and dynamic range, the ferro-magnetic surface must be clean and flat. By fitting a self adhesive disc on the magnet it will provide electrical isolation between the accelerometer and the surface to which it is attached.

Use of a Hand Held Probe

A hand held probe with the accelerometer mounted on top is very convenient for quick-look survey work, but can give gross measuring errors because of the low overall stiffness.

Mounting the Accelerometer on a Long Rod

Where there is a need for measuring vibration at difficult-to-reach locations the accelerometer can be mounted at the end of a steel pipe or rod in a rubber ring. A slightly rounded tip is mounted onto the mounting surface of the accelerometer. Note that the response is far superior to the “hand held” probe.



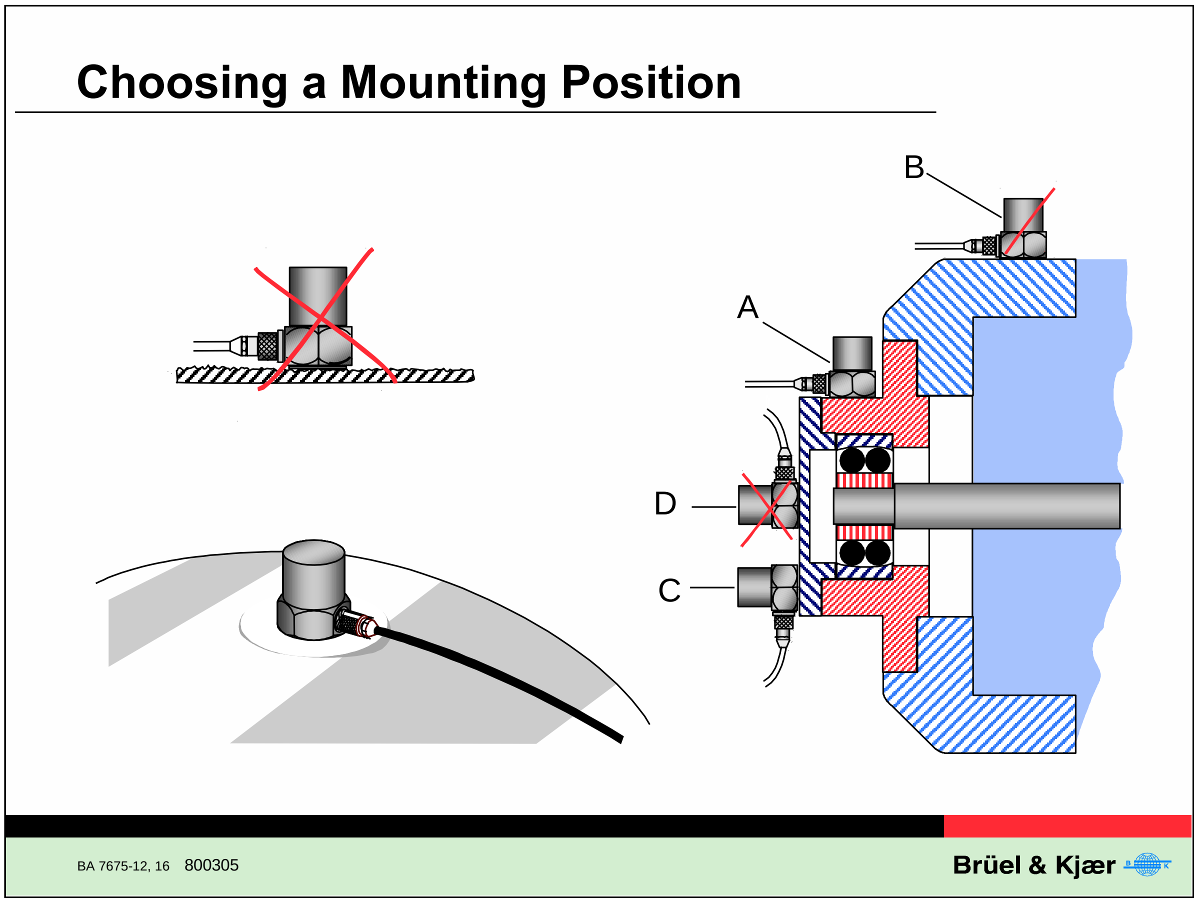
Electrical Isolation

Mica washer plus insulating stud is an easy and efficient method.

Special isolated mounting pads (not shown) made from ceramic and metal brazed together are available for use at high temperatures.

Mechanical Filter

The resonance peak on the accelerometer response curve can be cut-off or reduced in amplitude with the aid of electronic filters in the measuring equipment. As most electronic filtering is made after the input stage in the preamplifier this does not prevent overloading of the input stage or the accelerometer. With the aid of a mechanical filter, which is mounted between the accelerometer and the test object, a filtering of the mechanical signal is obtained, protecting the whole measuring chain. The mechanical filter also provides electrical isolation between the accelerometer base and the mounting point.



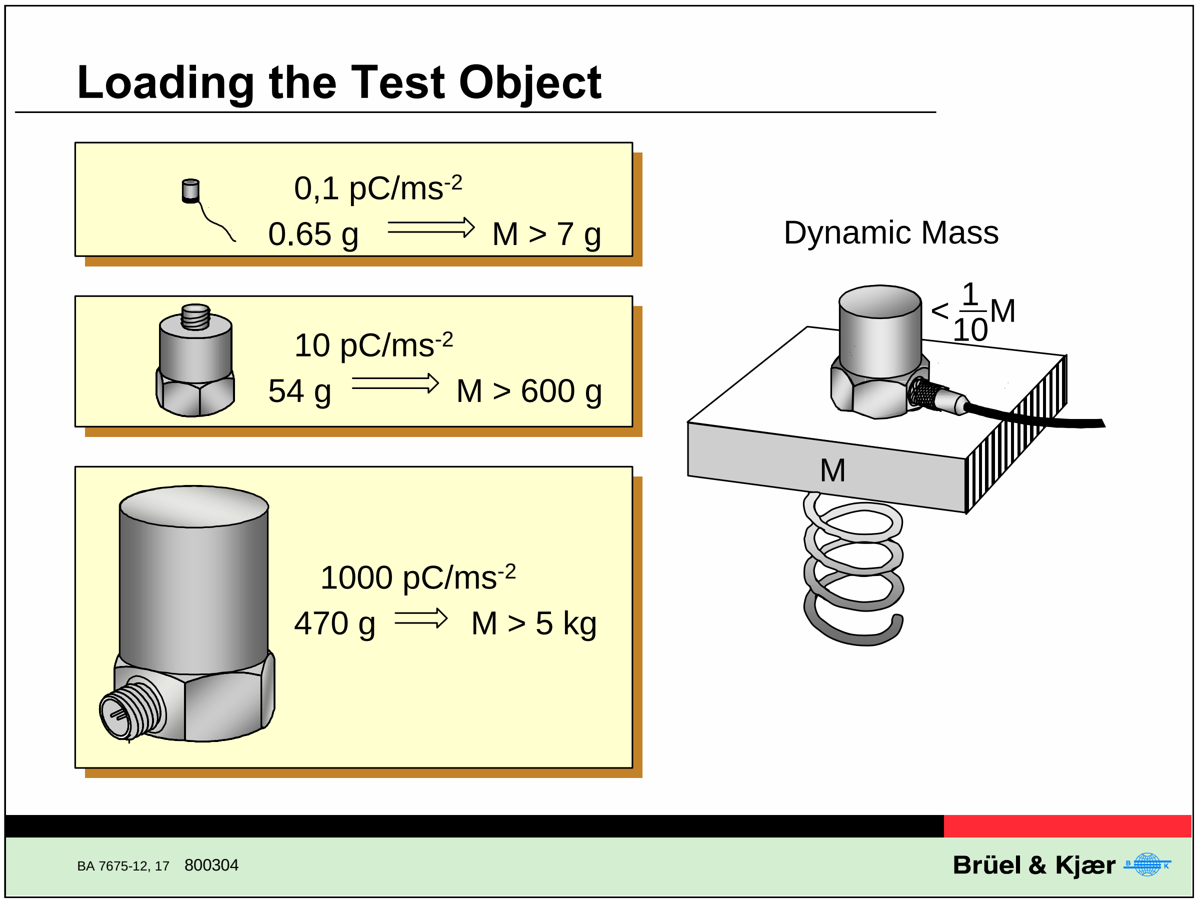
Choosing a Mounting Position for the Accelerometer

The accelerometer should be mounted so that the desired measuring direction coincides with the main sensitivity axis. Accelerometers are slightly sensitive to vibrations in the transverse direction, but this can normally be ignored as the maximum transverse sensitivity is typically only a few percent of the main axis sensitivity.

The reason for measuring vibration will normally dictate the position of the accelerometer. In the figure the reason is to monitor the condition of the shaft and bearing. The accelerometer should be positioned to maintain a direct path for the vibration from the bearing.

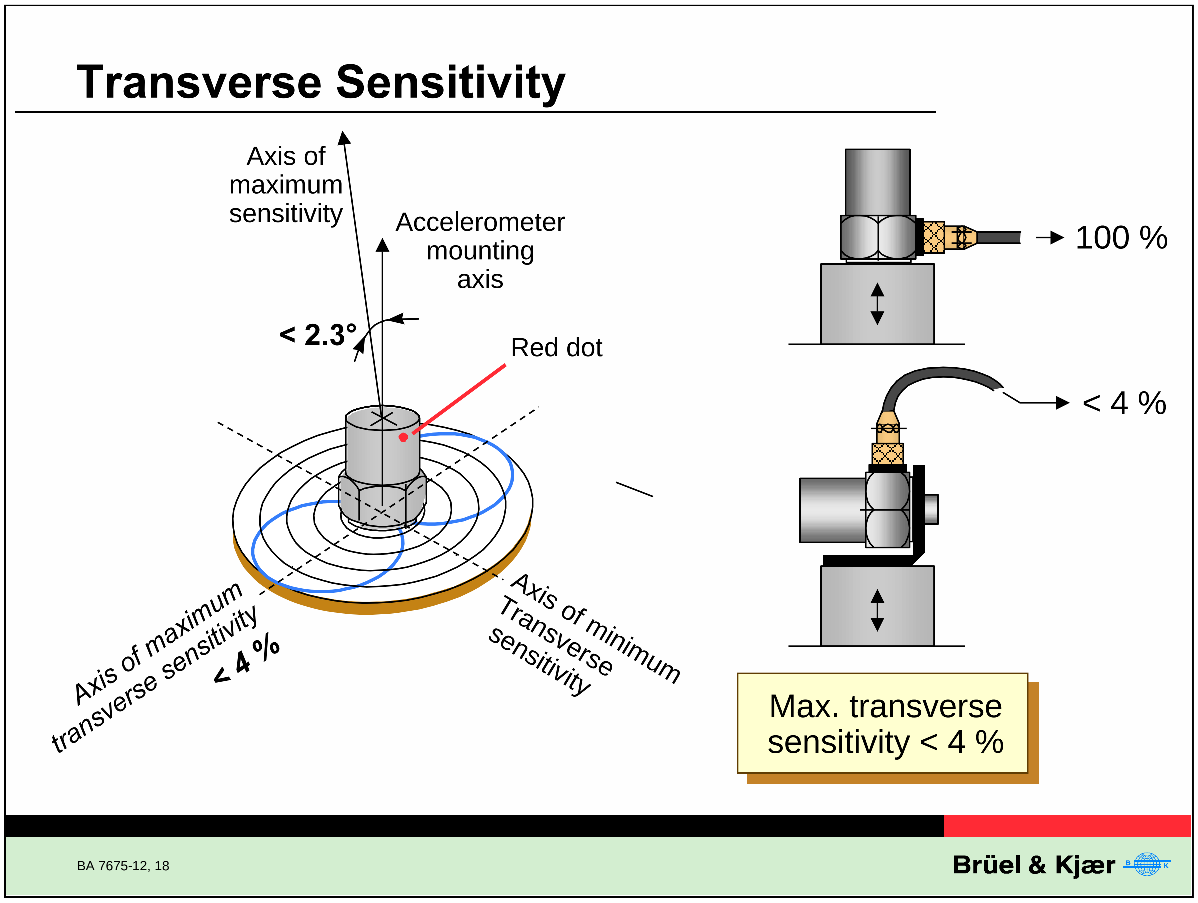
Accelerometer “A” thus detects the vibration signal from the bearing predominant over vibrations from other parts of the machine, but accelerometer “B” receives the bearing vibration modified by transmission through a joint, mixed with signals from other parts of the machine. Likewise, accelerometer “C” is positioned in a more direct path than accelerometer “D”.

It is very difficult to give general rules about placement of accelerometers, as the response of mechanical objects to forced vibrations is a complex phenomenon, so that one can expect, especially at high frequencies, to measure significantly different vibration levels and frequency spectra, even on adjacent measuring points on the same machine element.



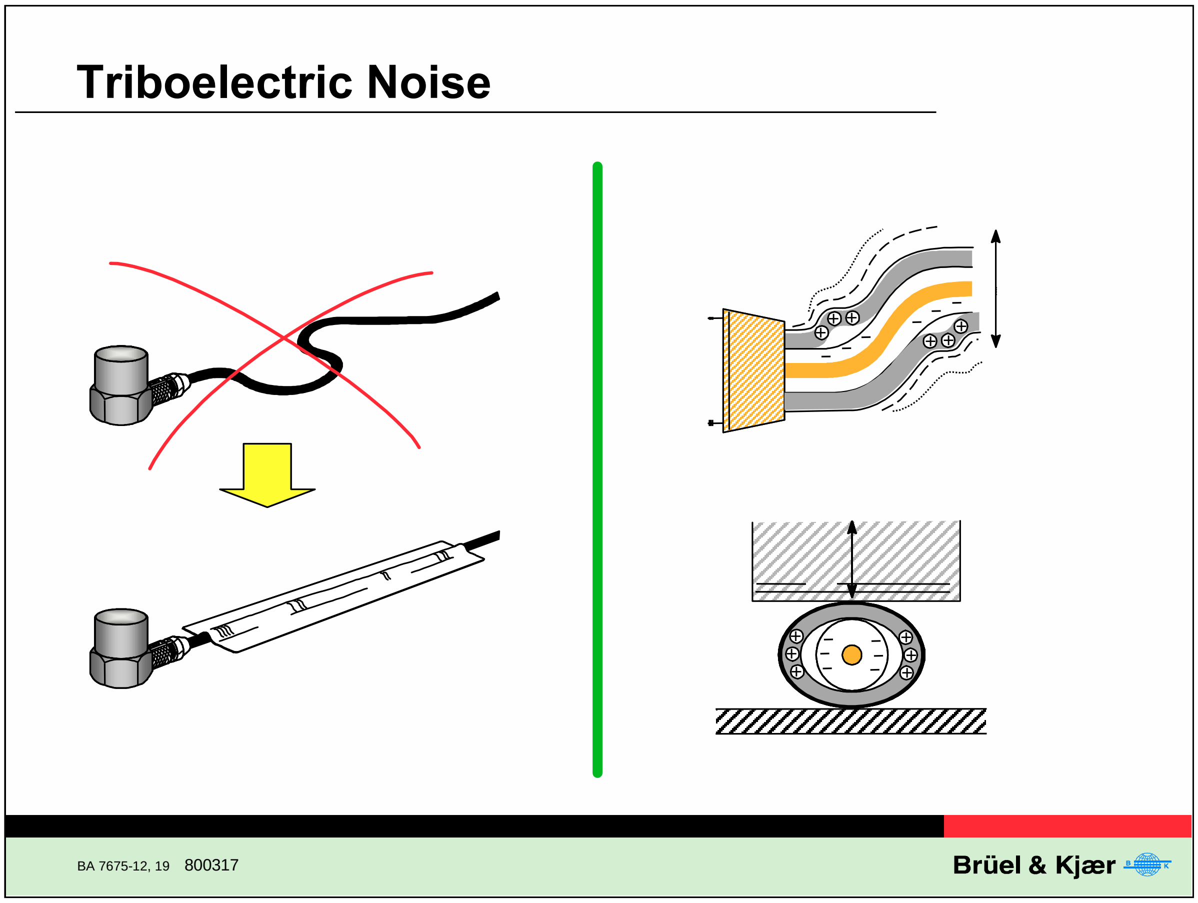
Loading the Test Object

When the accelerometer is mounted on the test object it will increase the mass of the vibrating system, and thereby influence the mechanical properties of the test object. As a general rule the accelerometer mass should be no more than one-tenth of the “local” dynamic mass of the vibrating part onto which it is mounted.



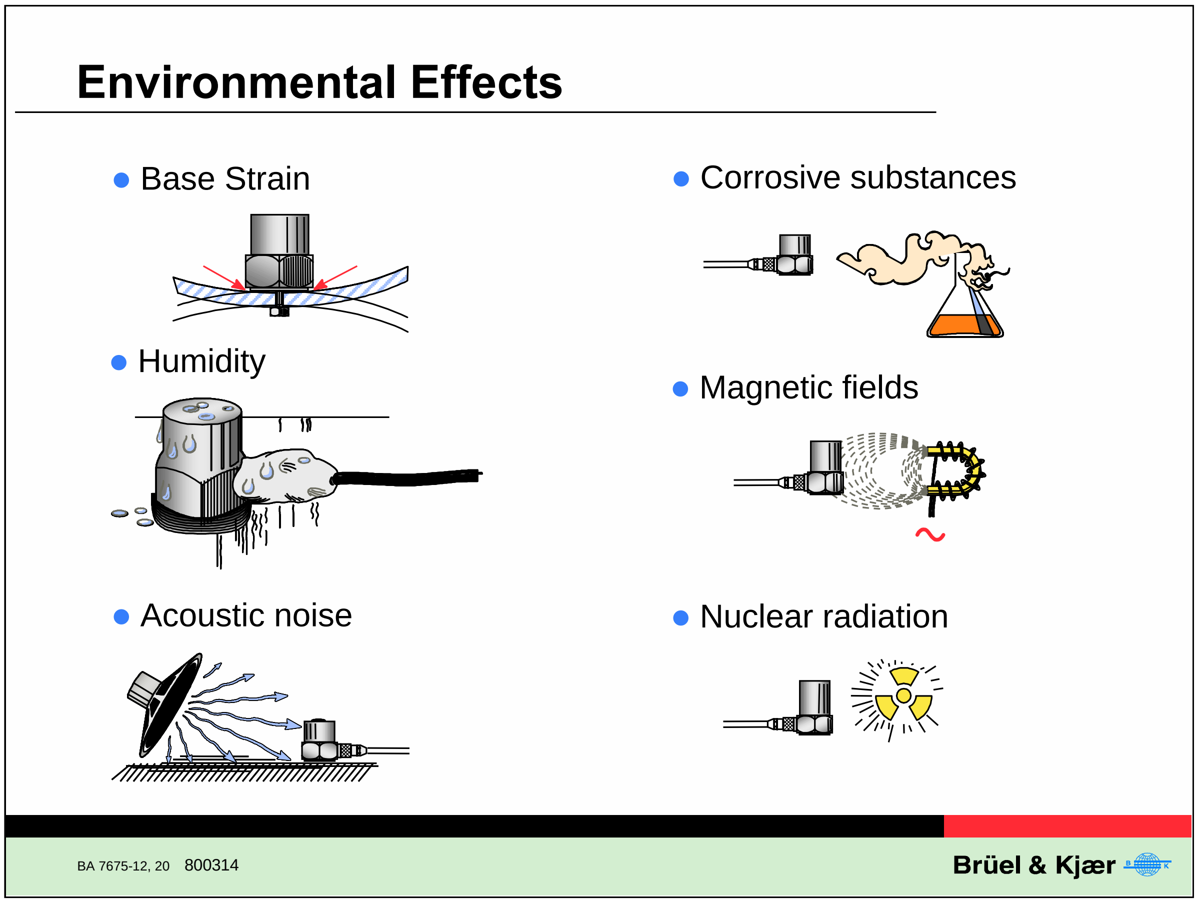
Transverse Sensitivity

The accelerometer has its main sensitivity perpendicular to the base of the accelerometer. However, it is also slightly sensitive to vibrations occurring in a direction transverse to this. In the worst case this will typically be less than 4% of the main-axis sensitivity. The direction of minimum transverse sensitivity is indicated on the accelerometer with a dot of red paint or an angle indication on the calibration chart.



Triboelectric Noise

Movement (vibration) of the accelerometer cable during use can cause the screen of the cable to be separated from the insulation around the inner core of the cable. A varying electrical field is thereby created between the conducting screen and the non-conducting insulation, causing a minute current to flow in the screen which will be superimposed on the accelerometer signal as a noise signal. This phenomenon can be prevented by using low noise (or super low noise, which has similar precautions around the center conductor) accelerometer cables and fixing them to the test object e.g. with the aid of adhesive tape near the accelerometer, and let them leave the structure at a point with minimum motion.



The Influence of Environments

Base Strain: Base strain sensitivity has been reduced by the use of a very thick base in the accelerometers. Delta Shear accelerometers are best in this respect as the elements are not in direct connection with the base.

Humidity: The accelerometer itself is sealed, so moisture can only enter the connector. In wet conditions this effect can be prevented by the use of a silicon rubber sealant.

Acoustic Noise: Has normally negligible influence on the vibration signal from the accelerometer.

Corrosive Substances: Special materials which are resistant to most corrosive substances are used in the construction of the accelerometer.

Magnetic Fields: The magnetic sensitivity is typically in the range

0.5 to 30 ms^{-2}/Tesla and thus normally not causing any problems.

Nuclear Radiation: Most accelerometers can be used under gamma radiation of 100 kRad/h up to accumulated doses of 100 MRad without significant change in characteristics. High temperature (400°C) accelerometers can be used up to 1000 MRad.

Influence of Temperature Transients: Temperature transients (rapid fluctuations) can cause an electrical output from the accelerometer, but this effect has been considerably reduced in the Delta Shear accelerometer. The charges developed on the piezoelectric material due to temperature transients are mainly developed on surfaces normal to the polarisation of the piezoelectric material and are thus not measured.

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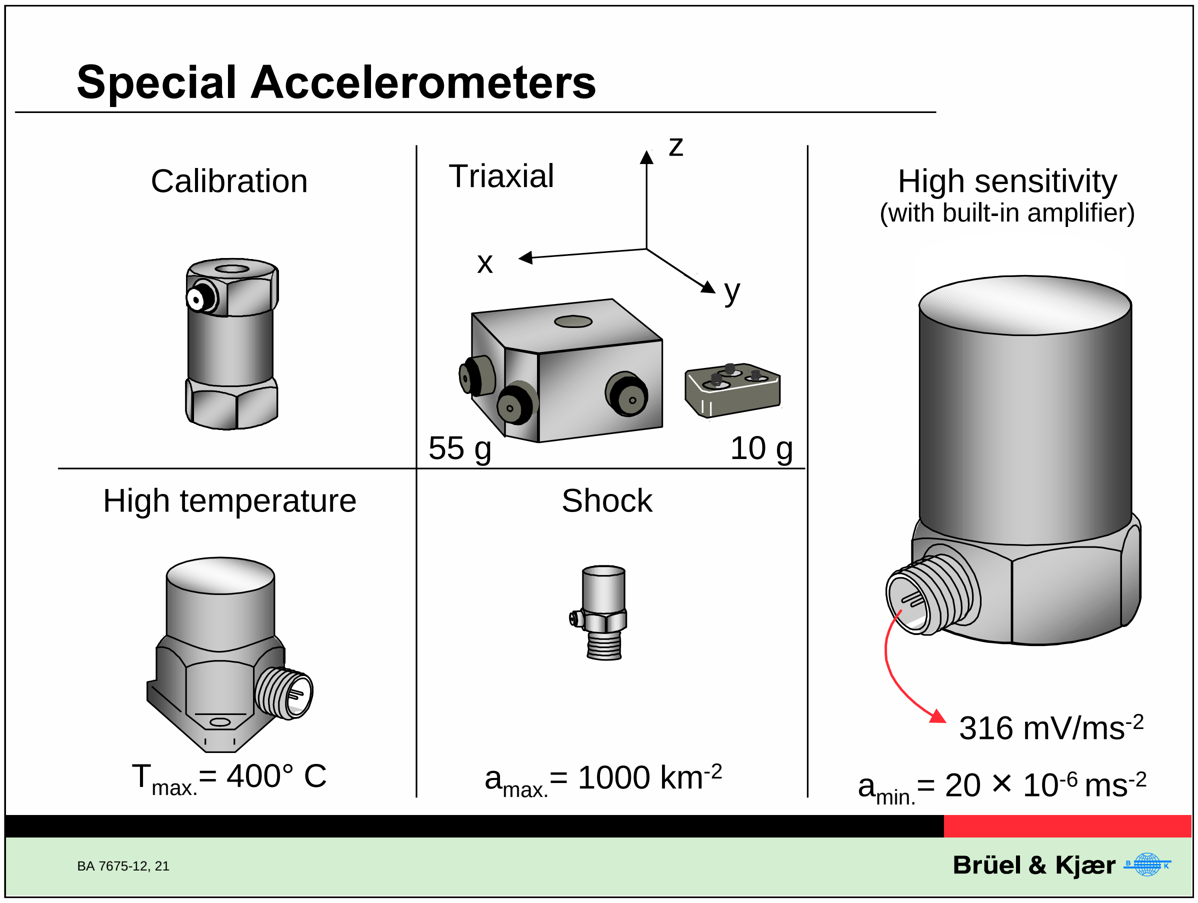

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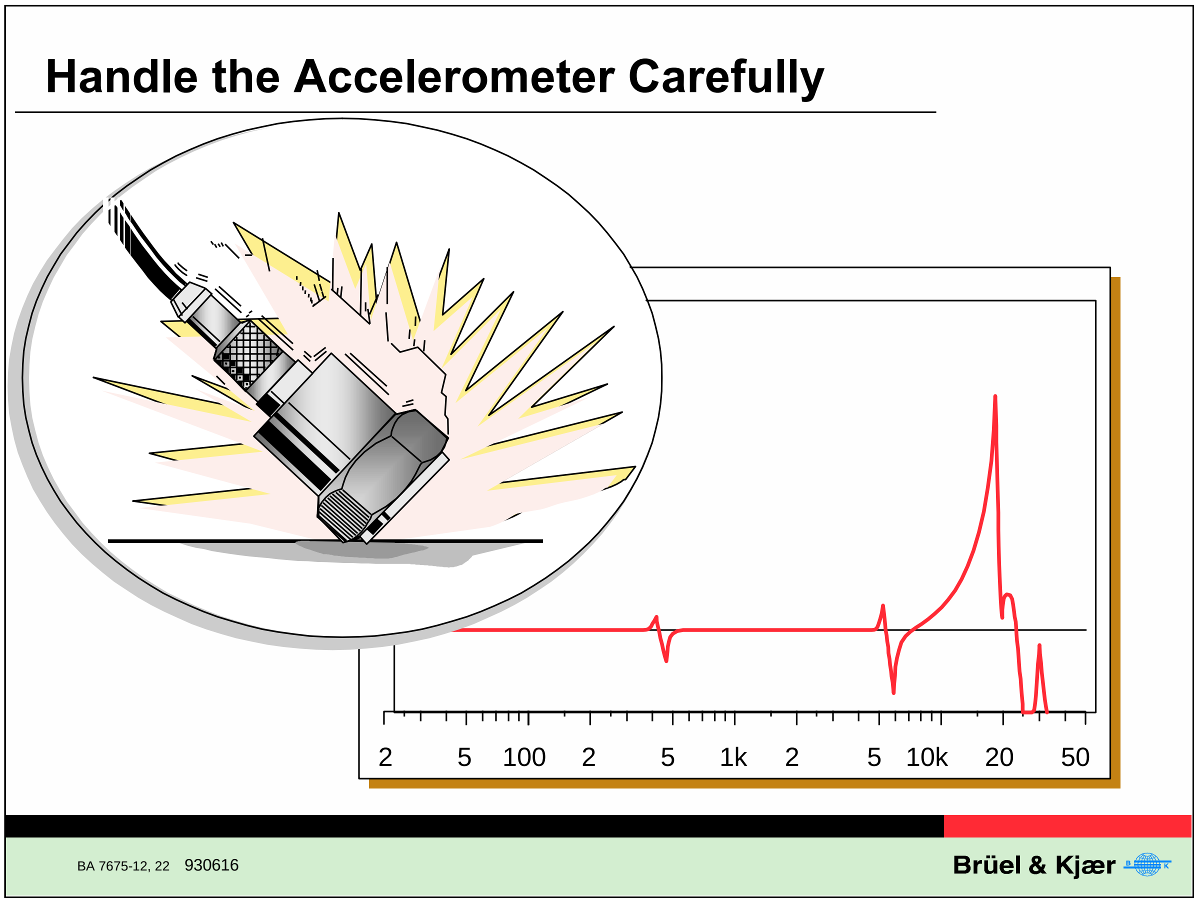
Sensitivity Change due to Temperature:

A shift in temperature will cause a small reversible change in the sensitivity of the accelerometer. For use at high temperatures it is recommended to use one of the accelerometers designed specifically for use in such conditions. The accelerometer base temperature may be kept down if a heat sink and mica washer are included in the mounting. If forced air cooling is employed check that the cooling system (fan) does not induce significant vibration.

Special Type Accelerometers

A number of accelerometers have been specially designed for specific purposes. For example, calibration references, high temperature, triaxial, high shock and very low levels as shown in the above figure.

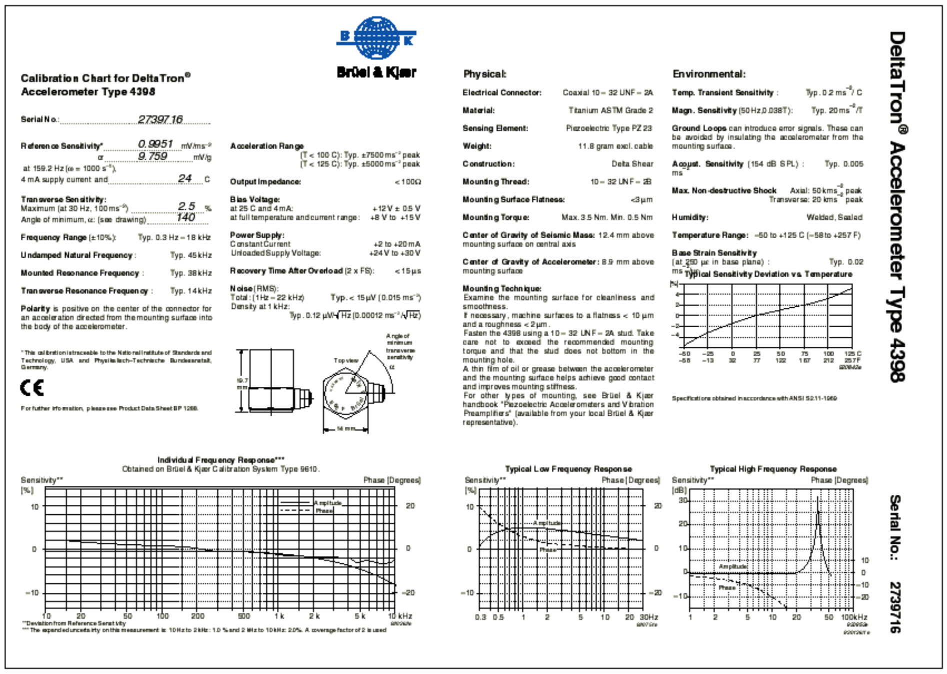


Accelerometer handling

Although most accelerometers are specified to withstand several thousand g's it is quite possible to attain such levels if the accelerometer is handled carelessly. A drop on a hard floor or a hit against a machine part might create shocks of several thousands of g. This could mean change in sensitivity or even severe damage to the accelerometer.

If it is known that the accelerometer has been subjected to such treatment it is advisable to recalibrate the accelerometer, preferably with a check of the frequency response curve.

The Calibration Chart

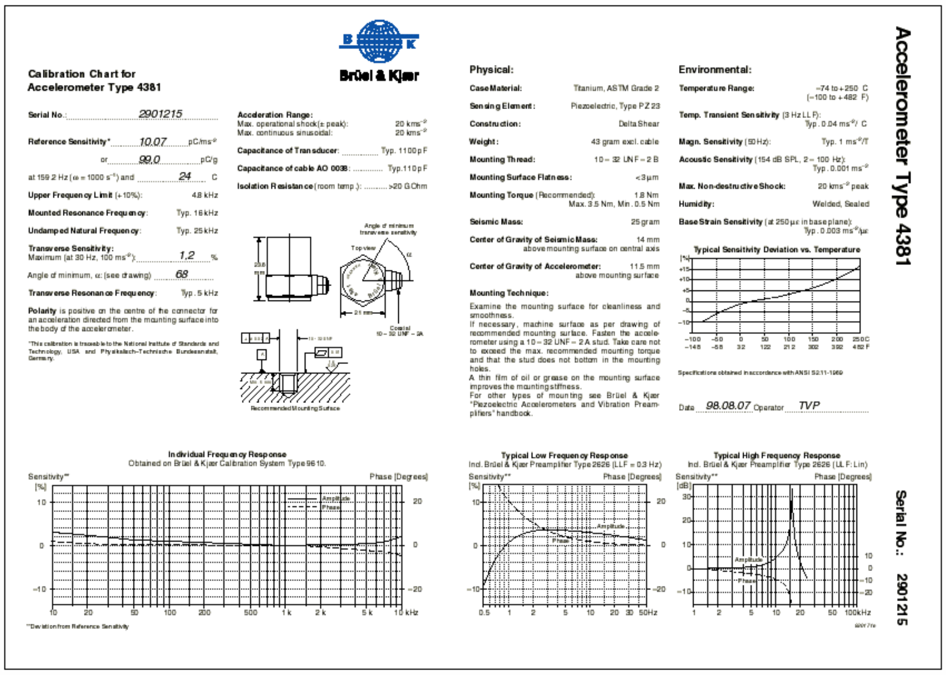


Calibration Chart

Each Brüel & Kjær accelerometer is supplied individually calibrated by the factory and is accompanied by a comprehensive Calibration Chart.

Two examples are shown here, one classical piezoelectric accelerometer, and one with built-in electronics.

The Calibration Chart



Calibration Chart for
Accelerometer Type 4381

Brüel & Kjær

Serial No.: 2901215

Reference Sensitivity*: 10.07 pC/ms⁻²
or 99.0 pC/g
at 159.2 Hz (ω = 1000 s⁻¹) and 24 °C

Upper Frequency Limit (+10%): 4.8 kHz

Mounted Resonance Frequency: Typ. 16 kHz

Undamped Natural Frequency: Typ. 25 kHz

Transverse Sensitivity:
Maximum (at 30 Hz, 100 ms⁻²): 1,2 %

Angle of minimum, α: (see drawing) 68

Transverse Resonance Frequency: Typ. 5 kHz

Polarity is positive on the centre of the connector for an acceleration directed from the mounting surface into the body of the accelerometer.

*This calibration is traceable to the National Institute of Standards and Technology, USA and Physikalisch-Technische Bundesanstalt, Germany.

Acceleration Range:
Max. operational shock (± peak): 20 kms⁻²
Max. continuous sinusoidal: 20 kms⁻²

Capacitance of Transducer: Typ. 1100 pF

Capacitance of cable AO 0038: Typ. 110 pF

Isolation Resistance (room temp.): >20 GOhm

Angle of minimum transverse sensitivity
Top view
21 mm
Coaxial 10 – 32 UNF – 2A
Recommended Mounting Surface

Physical:

Case Material: Titanium, ASTM Grade 2

Sensing Element: Piezoelectric, Type PZ 23

Construction: Delta Shear

Weight: 43 gram excl. cable

Mounting Thread: 10 – 32 UNF – 2 B

Mounting Surface Flatness: <3 µm

Mounting Torque (Recommended): 1.8 Nm
Max. 3.5 Nm, Min. 0.5 Nm

Seismic Mass: 25 gram

Center of Gravity of Seismic Mass: 14 mm
above mounting surface on central axis

Center of Gravity of Accelerometer: 11.5 mm
above mounting surface

Mounting Technique:

Examine the mounting surface for cleanliness and smoothness.
If necessary, machine surface as per drawing of recommended mounting surface. Fasten the accelerometer using a 10 – 32 UNF – 2 A stud. Take care not to exceed the max. recommended mounting torque and that the stud does not bottom in the mounting holes.
A thin film of oil or grease on the mounting surface improves the mounting stiffness.
For other types of mounting see Brüel & Kjær "Piezoelectric Accelerometers and Vibration Preamplifiers" handbook.

Environmental:

Temperature Range: –74 to +250 °C (–100 to +482 °F)

Temp. Transient Sensitivity (3 Hz LLF): Typ. 0.04 ms⁻²/ °C

Magn. Sensitivity (50 Hz): Typ. 1 ms⁻²/T

Acoustic Sensitivity (154 dB SPL, 2 – 100 Hz): Typ. 0.001 ms⁻²

Max. Non-destructive Shock: 20 kms⁻² peak

Humidity: Welded, Sealed

Base Strain Sensitivity (at 250 µε in base plane): Typ. 0.003 ms⁻²/µε

Typical Sensitivity Deviation vs. Temperature

Specifications obtained in accordance with ANSI S2.11-1969

Date 98.08.07 Operator TVP

Accelerometer Type 4381

Individual Frequency Response
Obtained on Brüel & Kjær Calibration System Type 9610.

Typical Low Frequency Response
Incl. Brüel & Kjær Preamplifier Type 2626 (LLF = 0.3 Hz)

Typical High Frequency Response
Incl. Brüel & Kjær Preamplifier Type 2626 (ULF: Lin)

**Deviation from Reference Sensitivity

Serial No.: 2901215

BA 7675-12, 24

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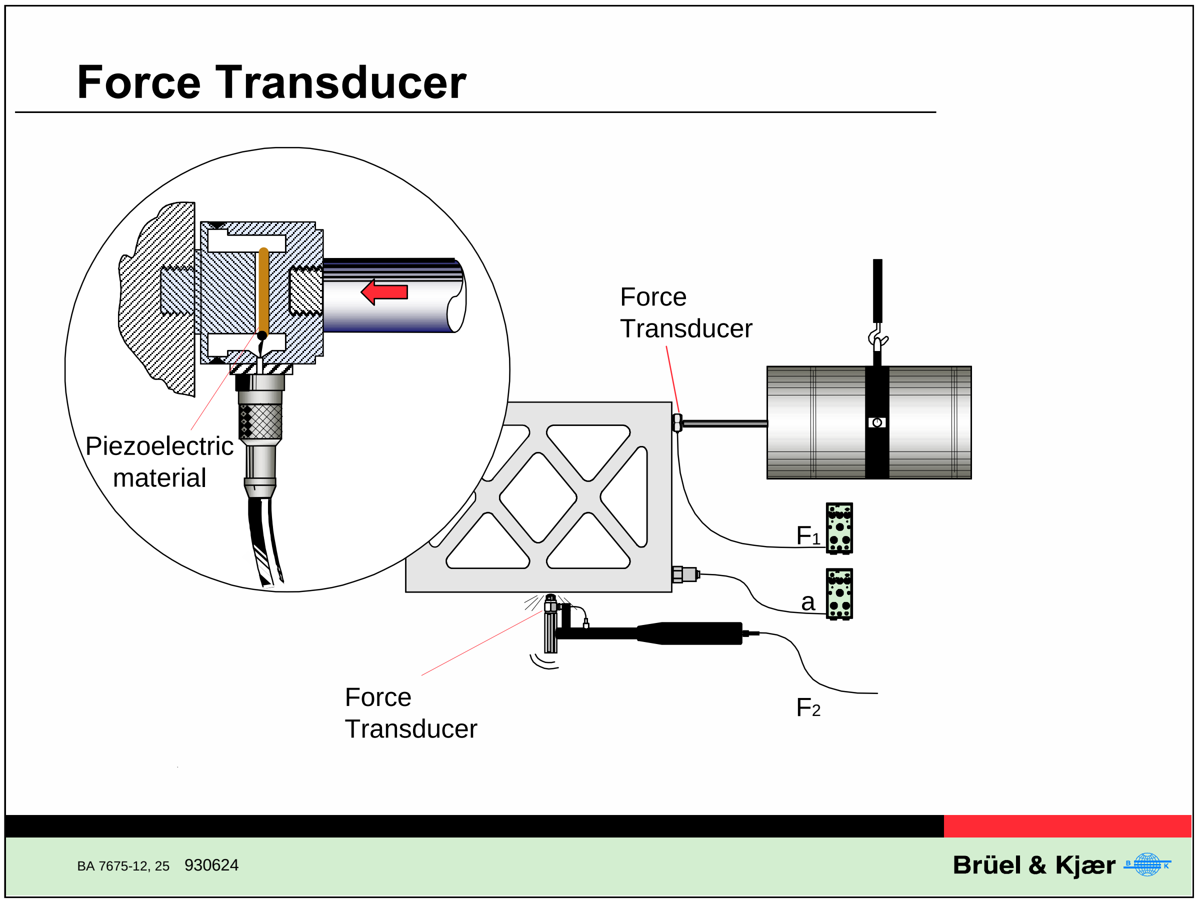
Calibration Chart

Each Brüel & Kjær accelerometer is supplied individually calibrated by the factory and is accompanied by a comprehensive Calibration Chart.

The example shown here is with built-in electronics.



Force Transducers

Force transducers are used in mechanical-dynamics measurements together with accelerometers to determine the dynamic forces in a structure and the resulting vibratory motions. The parameters together describe the mechanical impedance of a structure.

By impacting or exciting a structure at different positions with an instrumented hammer and measuring the structural response, so called modal analysis can be made describing the total behavior of of the structure as a system.

The force transducer also uses piezoelectric elements, but in this case the forces are directed directly to these elements. The instrumentation used with these transducers is identical to the instrumentation used with accelerometers.

Sometimes combined force transducers and accelerometers are used to measure the mechanical impedance of light structures.

Calibration

Why calibrate

- To find the sensitivity

Why recalibrate

- Legal obligation - QA requirement
- Good instrument practice
- Test for damage

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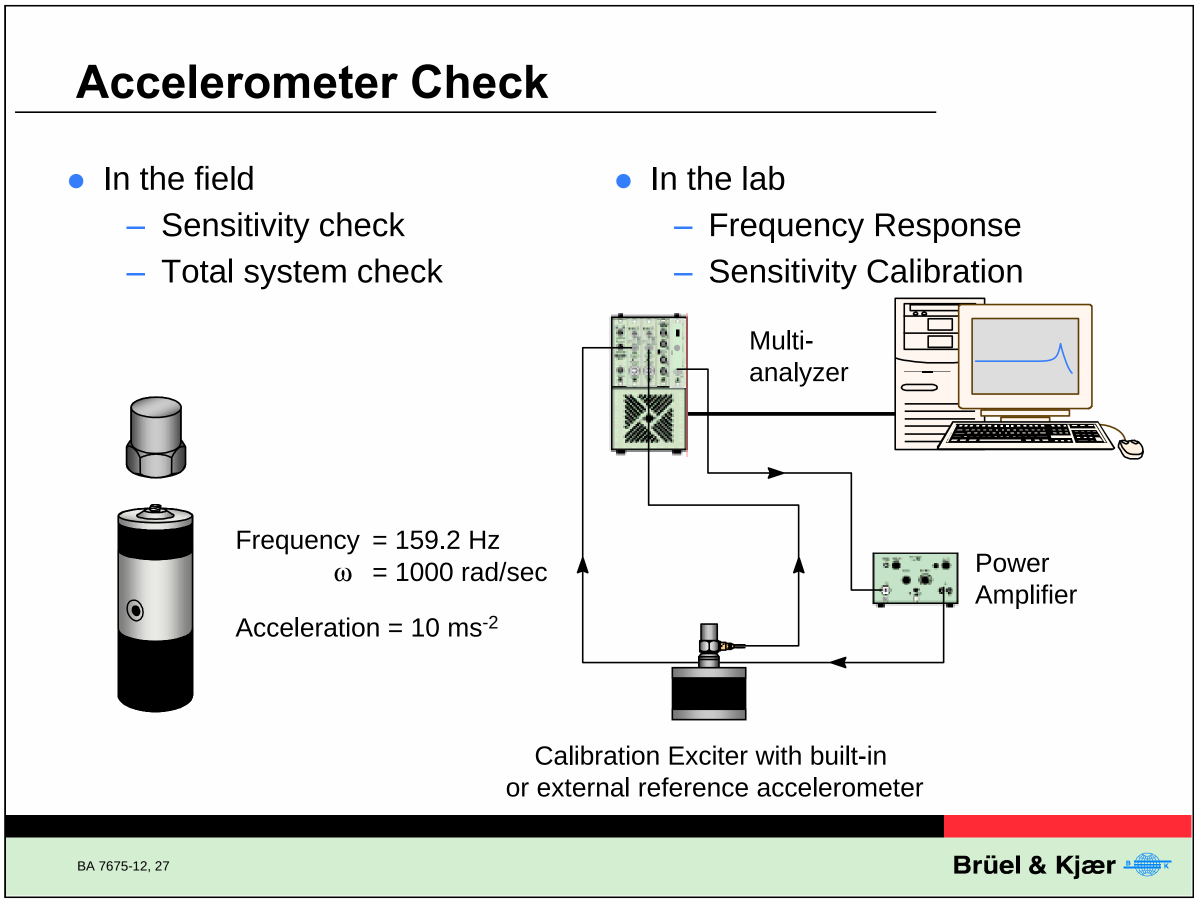
Sensitivity Calibration

Calibration of the accelerometer is normally not necessary if it is handled carefully. It is however reassuring for the user, and often a requirement from QA systems (like ISO 9000) to check his accelerometer and measuring instrumentation against a reference vibration signal before commencement of measurements. The reference signal can be obtained from a simple portable calibrator as shown in a following slide.

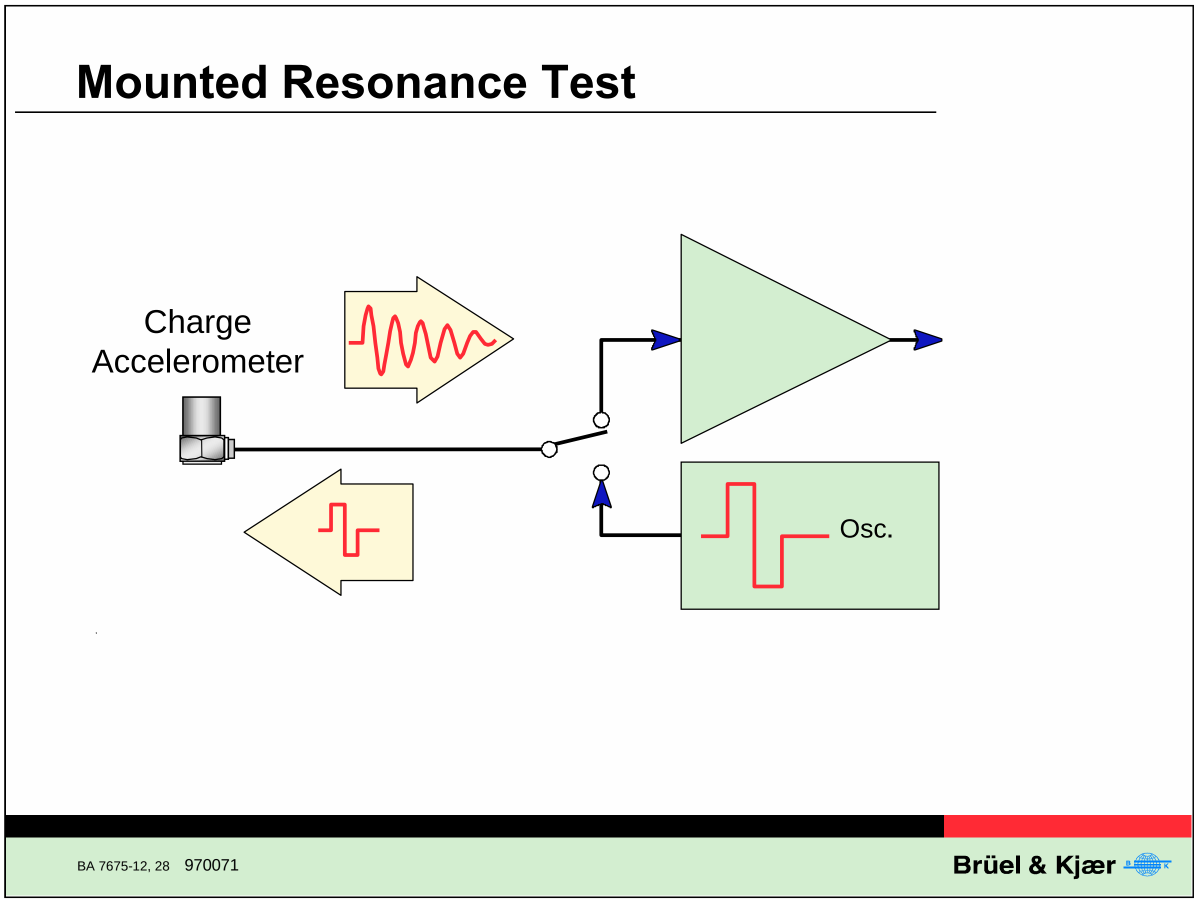


Check of accelerometer sensitivity and system setup

A small portable calibrator providing e.g. 10 ms^{-2} at ω = 1000 rad/sec is ideal for checking accelerometer sensitivity and the whole setup of a measuring chain.

Test of frequency response and Mounting Methods

The frequency response of an accelerometer can easily be tested by the use of a Calibration Exciter, where electronic equipment maintains a constant acceleration of the exciter table up to 50 kHz and measures the ratio of the accelerometer output to the built-in reference.



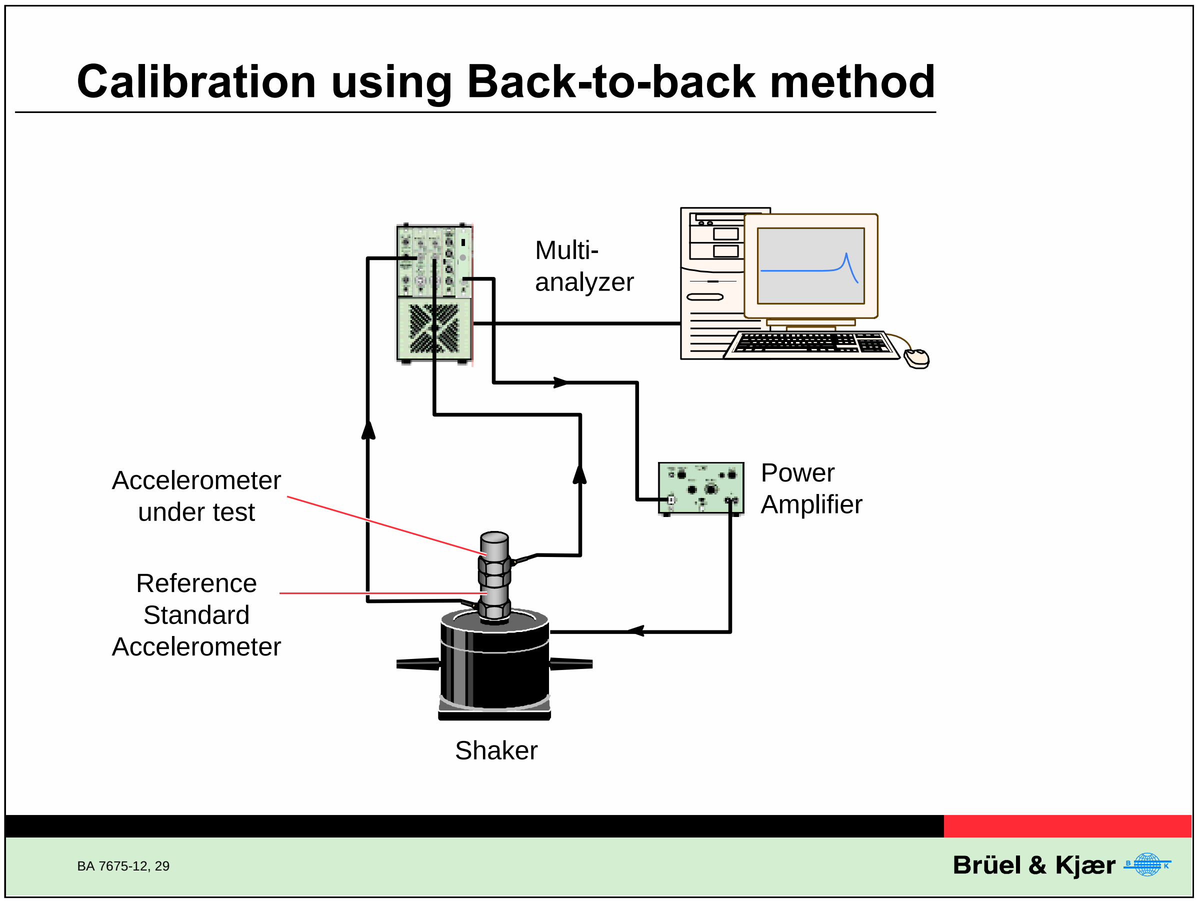
Accelerometer check using mounted resonance techniques

The Mounted Resonance technique is used to check:
1. That a cable is connected to an accelerometer
2. Whether the accelerometer is mounted or hanging loose
3. That the mounting is good, and that the structure does not have a very low mechanical impedance at the mounting location

DeltaTron® accelerometers have built-in electronics and therefore the Mounted Resonance technique does not apply to this type of accelerometer.

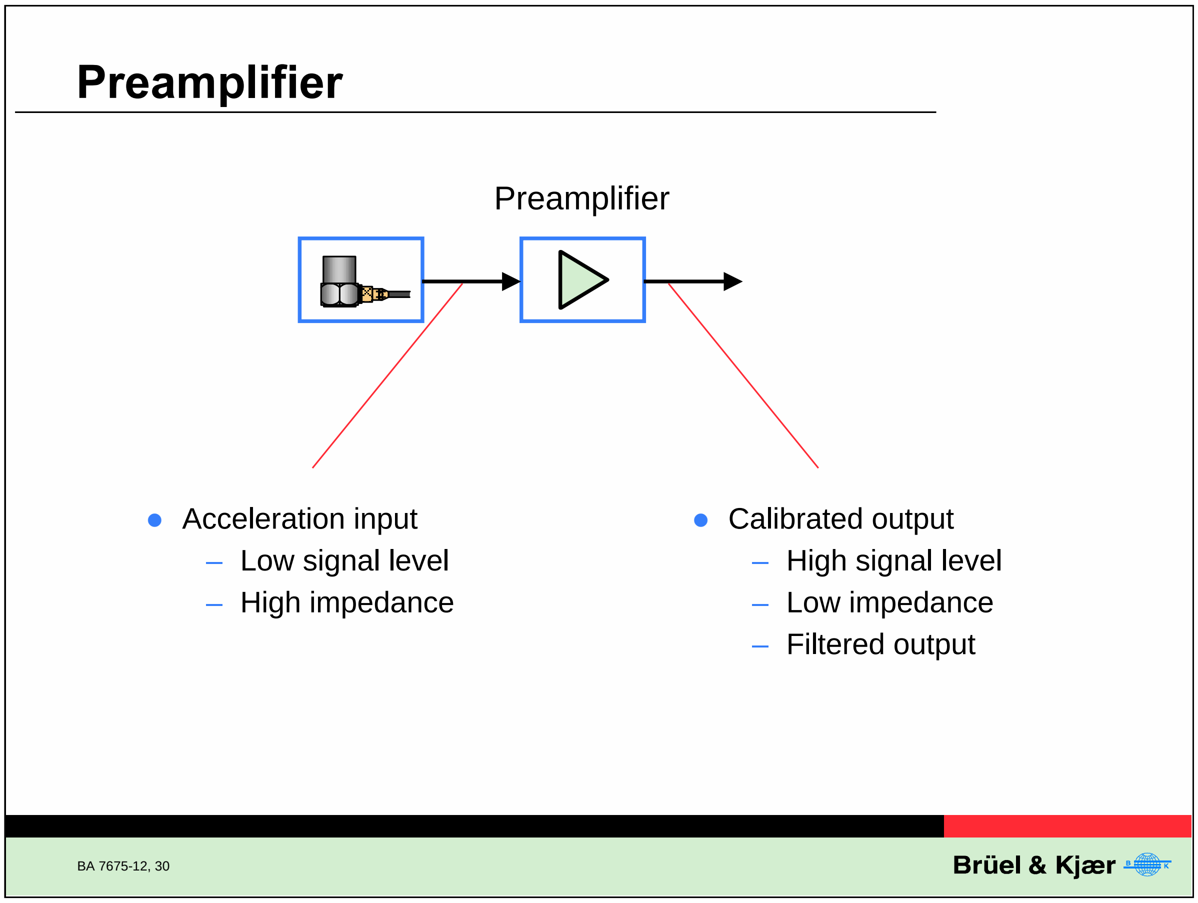
In simple terms, the Mounted Resonance technique works as follows:
1. The accelerometer is excited by a suitable square pulse
2. The response obtained is filtered
3. The frequency is counted
or alternatively to 2 and 3:
An analyzer is used to measure the frequency content of the signal

The frequency found is the mounted resonance frequency which can then be compared to the value on the Calibration Chart.
See *Technical Review No.1 1996* for a full description of the technique.



Calibration of accelerometers

Setups similar to the setup shown above are used to calibrate accelerometers with very high accuracy (1%) at a reference frequency (normally 160 or 80 Hz) and also over wider frequency ranges with slightly less accuracy. This method, using a Reference Standard Accelerometer in a so called Back-to-back configuration or in a fixture, is widely used and also described in great detail in the standard ISO 5347-3.



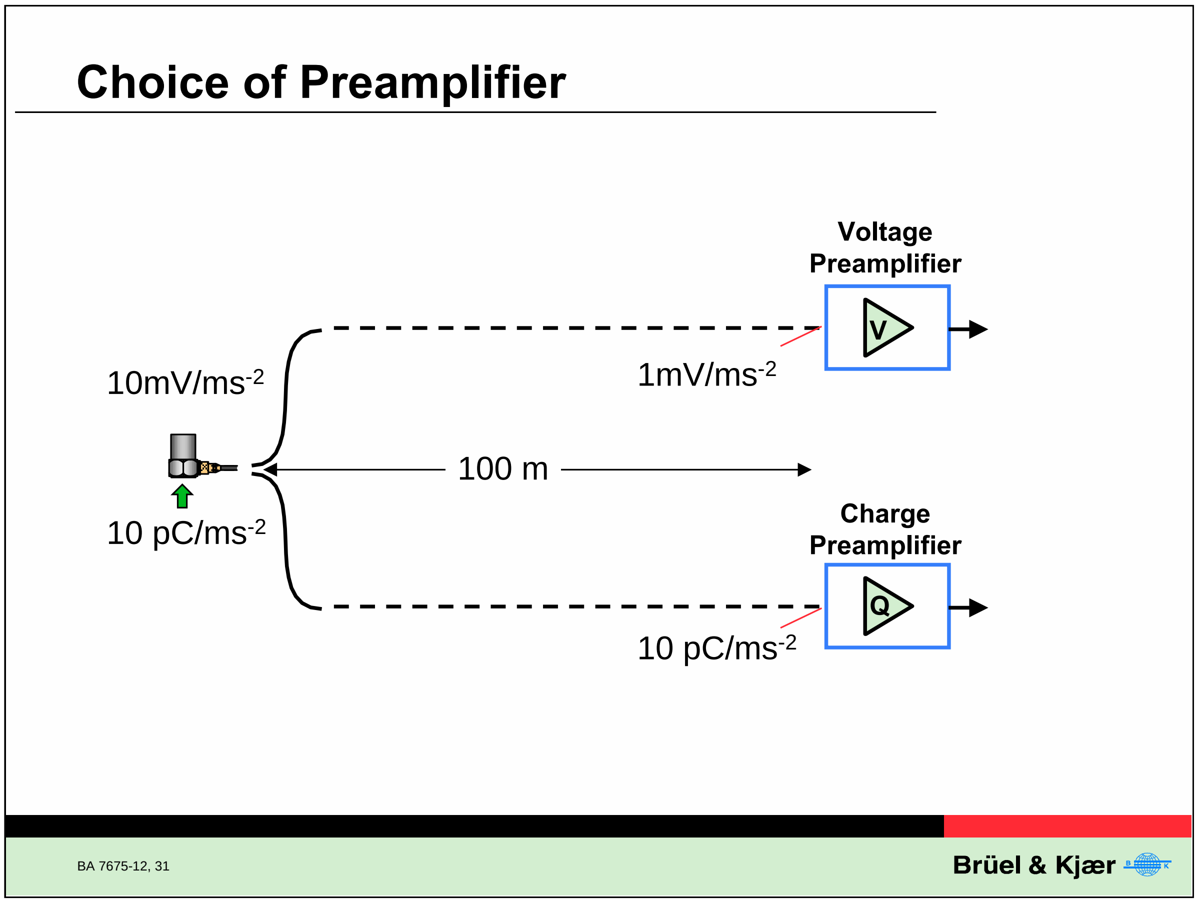
Preamplifiers for piezoelectric accelerometers

Due to the high impedance and low signal levels at the output of a piezoelectric accelerometer it is nearly always necessary to use preamplifiers before entering into common instrumentation.

The functions performed by the preamplifier are:

- Impedance Conversion
- Amplification
- Matching output signal to measuring instrumentation input sensitivity (Conditioning)
- Filtering
- Integration to obtain velocity or displacement output signals
- Warning of overloads anywhere before the following instrumentation

Normally at least the first two points are found in a preamplifier.



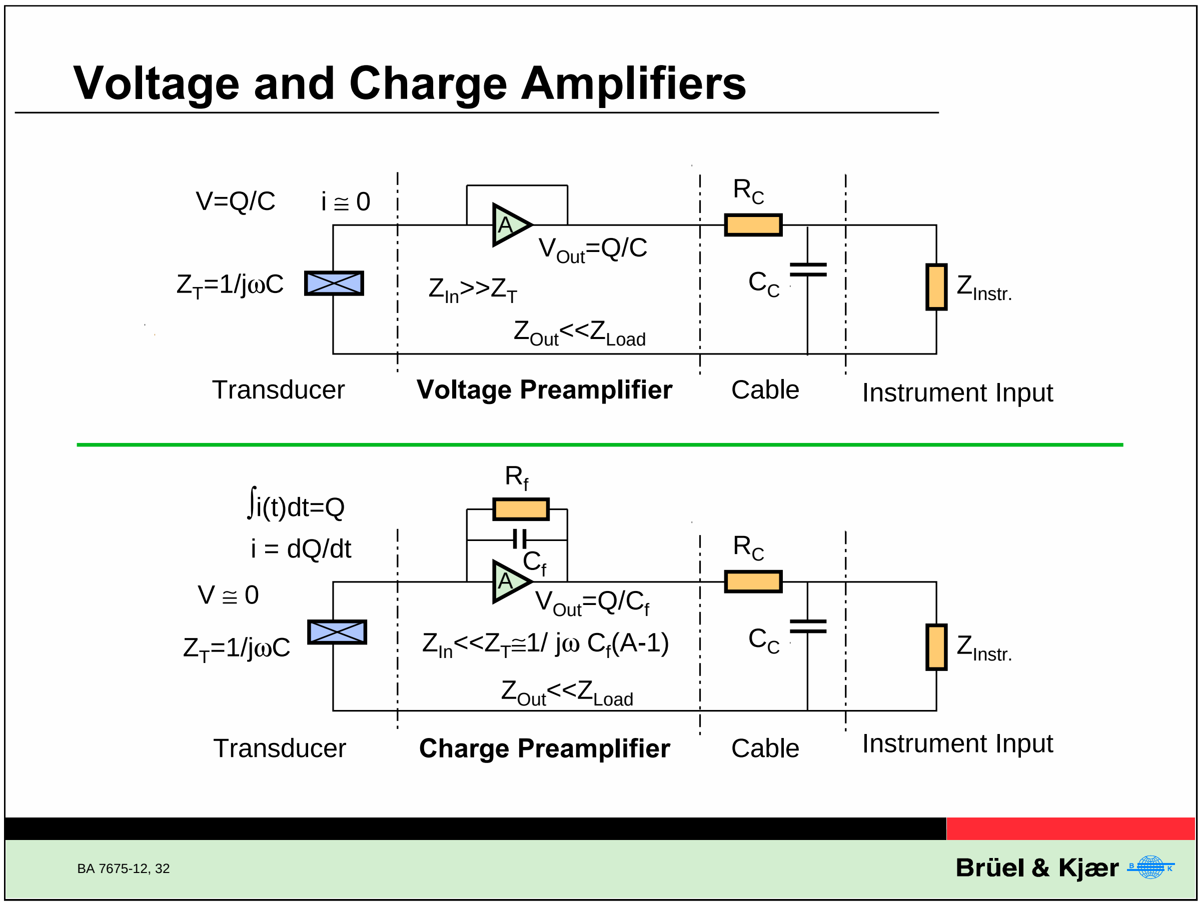
Choice of preamplifier type

In principle both voltage and charge preamplifiers can be used to make the necessary impedance conversion etc.

However, as indicated on the figure, the sensitivity seen by the amplifier varies dramatically with cable length when voltage amplifiers are used. This means that a new calibration (or calculation) has to be made if the cable used is changed. Furthermore the lower limiting frequency can be affected by cable length and resistance.

Therefore the majority of preamplifiers used today are charge amplifiers as they are not affected by cable length or resistance changes within reasonable limits.

For input stages in built-in preamplifiers this is not quite as clear a choice, but for the best performance charge amplifiers are still to prefer.



Amplifier Theory

For the electronically interested, the different parameters concerning the function of charge and voltage amplifiers are given in this figure.

A good way to understand the charge amplifier is to see that it is practically a short-circuit in which the current flowing is integrated. This makes it very insensitive to any impedance changes at the input.

It is also good to repeat the fundamental relationships:

Charge = Current × Time

or

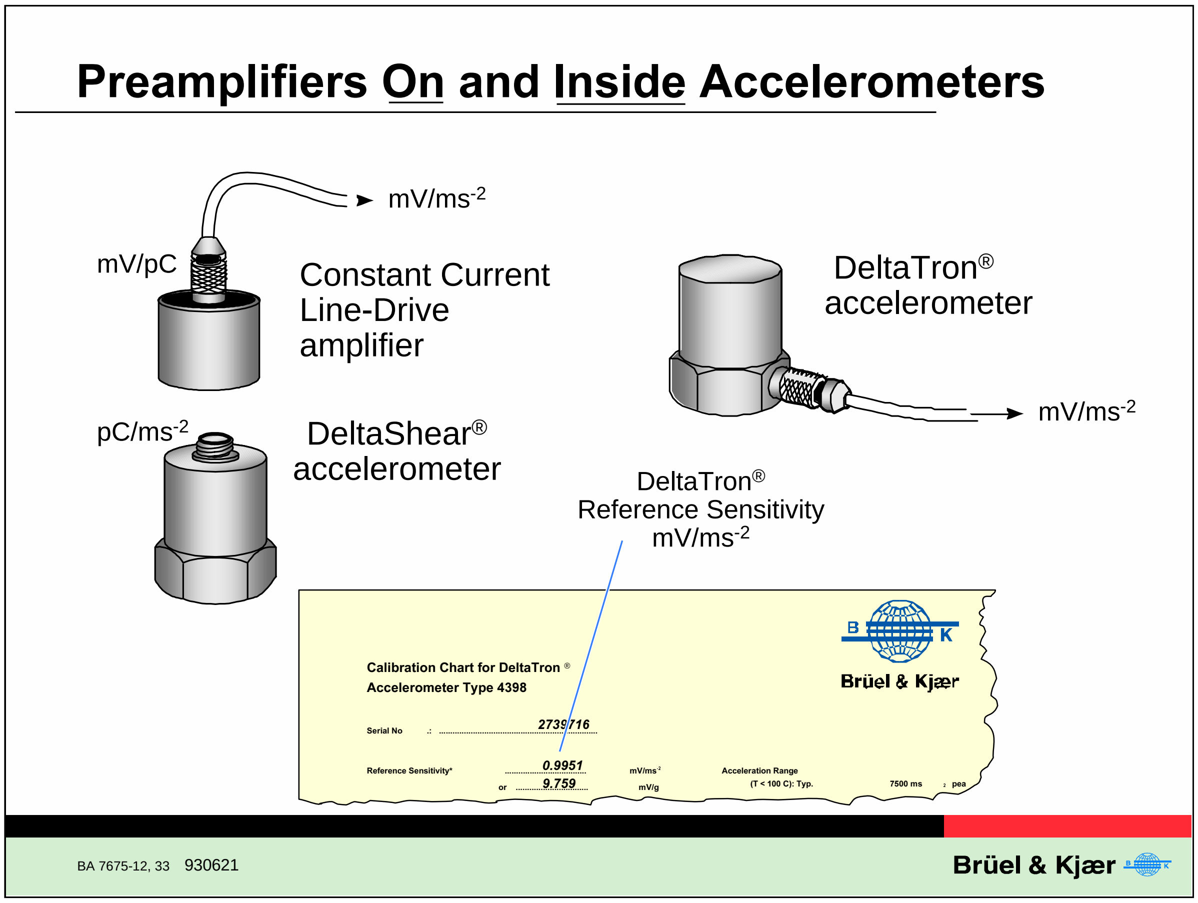
Coulomb = Ampere × Second

and for a capacitor:

Charge = Voltage × Capacitance

or with practical units:

pC = mV × nF

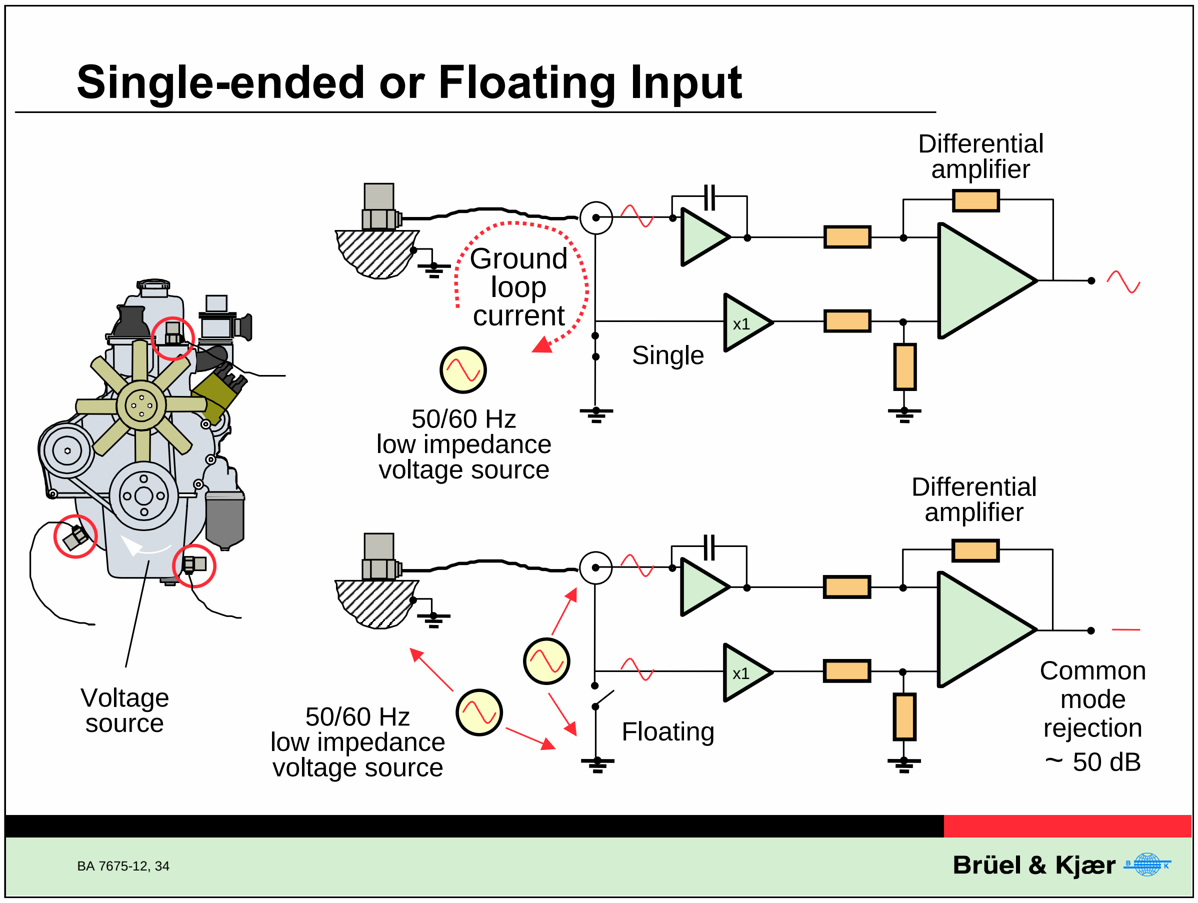


Built-in preamplifiers and screw-on types

To reduce problems due to cable noise and to reduce system price, small built-in preamplifiers and also screw-on type preamplifiers have become very popular.

The de-facto standard today is amplifiers using a supply giving a constant DC current somewhere in the range 2 to 20 mA. Many different trade names like DeltaTron® are used for these transducers.

The output is a voltage swing around a bias voltage defined by the built-in amplifier.



Ground Loops

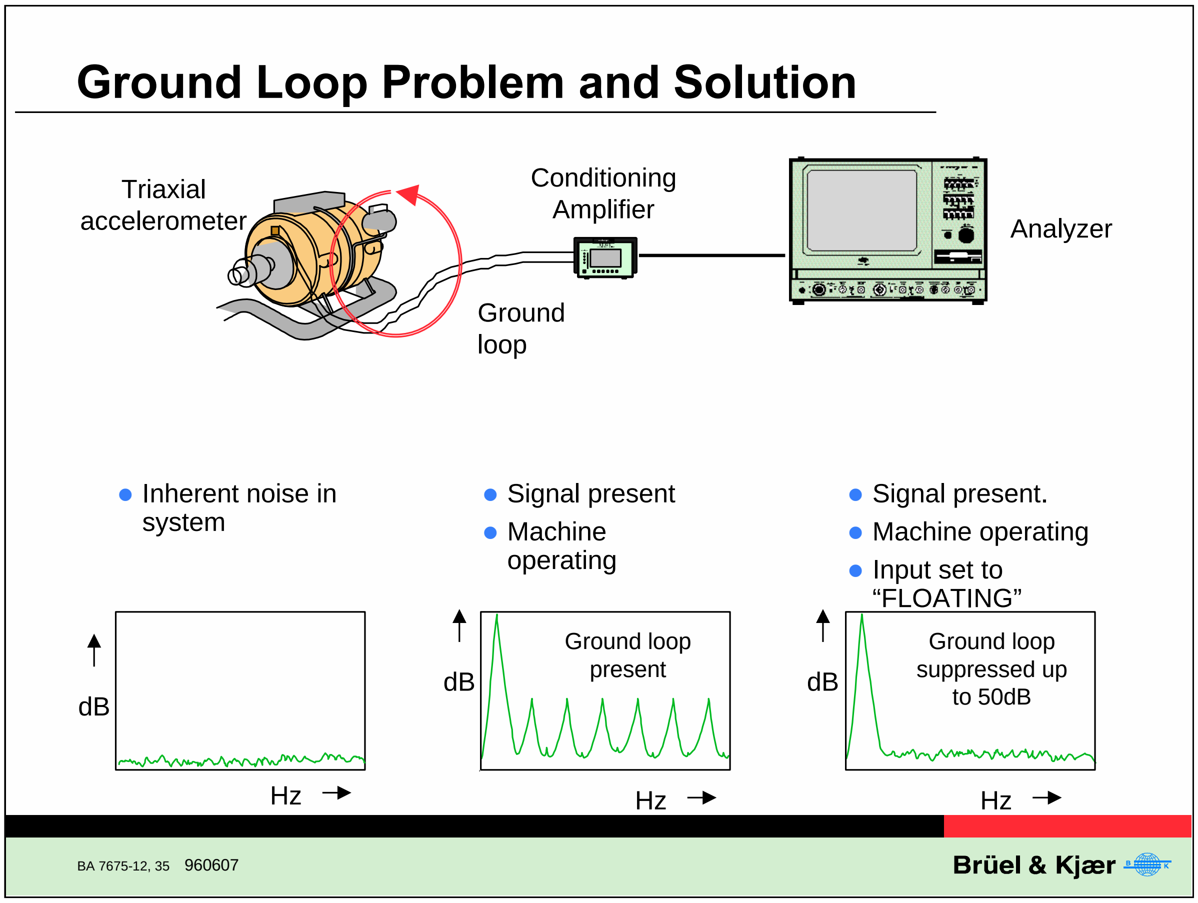
If the accelerometer is fixed to a test object which is connected to the instrument ground, e.g. through another accelerometer channel, then a ground loop is formed. This can cause noise to be superimposed upon the vibration signal from the accelerometer if any ground potential differences or electromagnetic fields are present.

This situation can be avoided by:

Mounting the accelerometer by the aid of an isolating mounting method as discussed earlier. This is normally the most efficient method.

Use of an accelerometer which has its piezoelectric material isolated from the housing e.g. in the form of a differential output (requires differential preamplifier) or a double housing.

Using a preamplifier having a floating input as illutrated in the slide.



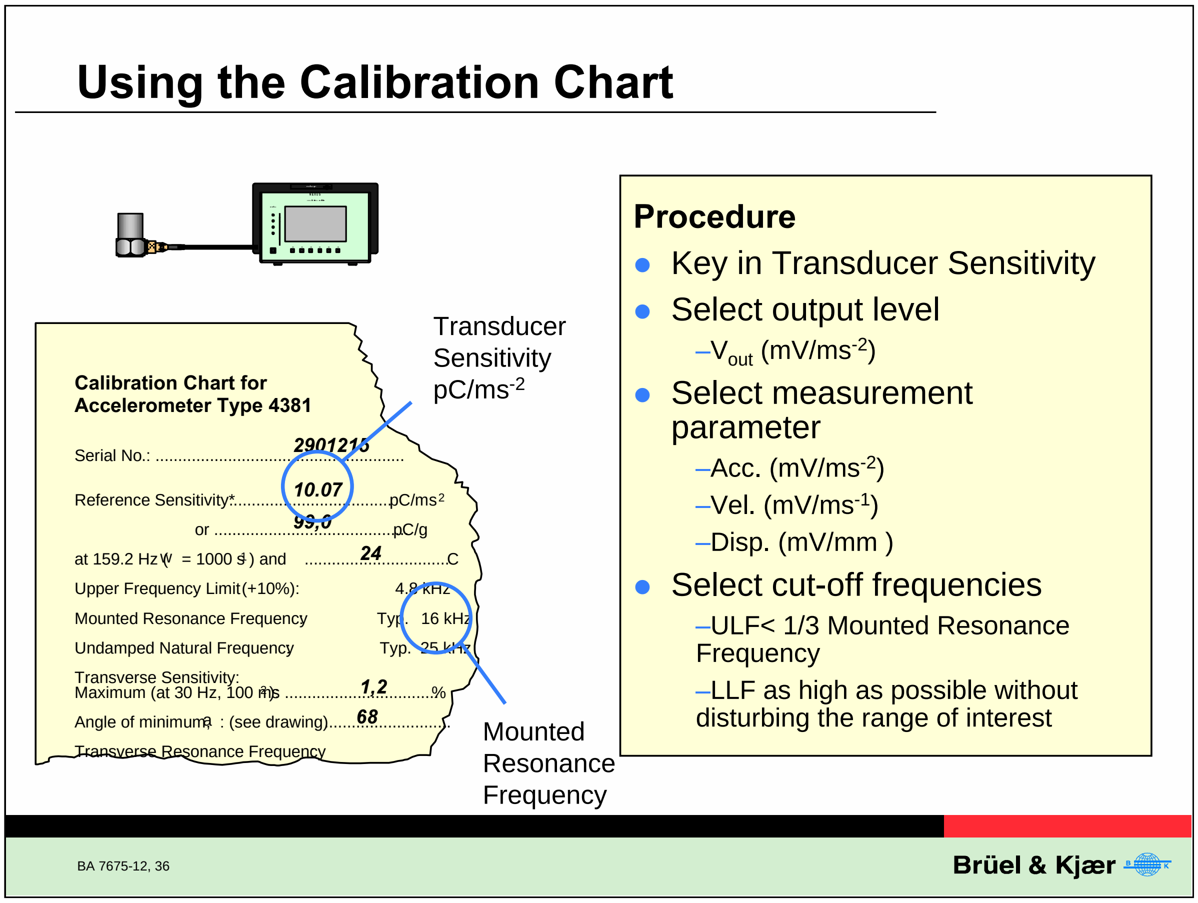
Solving the ground loop problem

The figure shows a typical floating input solution to the ground loop problem.

Floating input involves a ground loop current that is converted into a common mode voltage signal on the input.

In multi-accelerometer systems, floating input gives up to 50 dB better rejection of ground loop signals relative to single-ended input.

Modern preamplifiers can typically cope with earth potential differences of up to +/- 5 V. If these levels are exceeded then a "common mode overload" occurs, (and might be indicated by the preamplifier).



Using the Calibration Chart

The Calibration Charts contains normally a vast amount of information which can prove extremely important in many different situations.

The most important use is to set up the preamplifier correctly.

To do this it is normally practical to read off the sensitivity (using the correct units) and enter this into the preamplifier. This permits the preamplifier to be set up to give a practical number (e.g. 1 V/ ms^{-2}) at the output.

Furthermore filtering and integration has to be set up at the preamplifier.

It is often practical to choose an Upper Limiting Frequency (ULF) at about 1/3 of the mounted resonance frequency.

The Lower Limiting Frequency (LLF) can be chosen as high as possible without disturbing the desired measurement range and thereby reducing noise from preamplifier and Temperature Transients.

Conclusion

This lecture should provide you with sufficient information to:

- Select and use the right transducers for your measurements
- Select and use preamplifiers for your transducers
- Set-up a working measurement chain
- Avoid general problems like ground loops

Brüel & Kjær

Literature for Further Reading

- Piezoelectric Accelerometers and Vibration Preamplifiers
  (Brüel & Kjær Theory and Application Handbook BB 0694-12)
- Shock and Vibration Handbook (Harris and Crede, McGraw-Hill 1976)
- ISO 5347 - Methods for Calibration and Characterization of Vibration and Shock Transducers
- Brüel & Kjær Technical Review
  - No.1 - 1996 (BV 0048-11)