Verification
of
Microphones and Accelerometers

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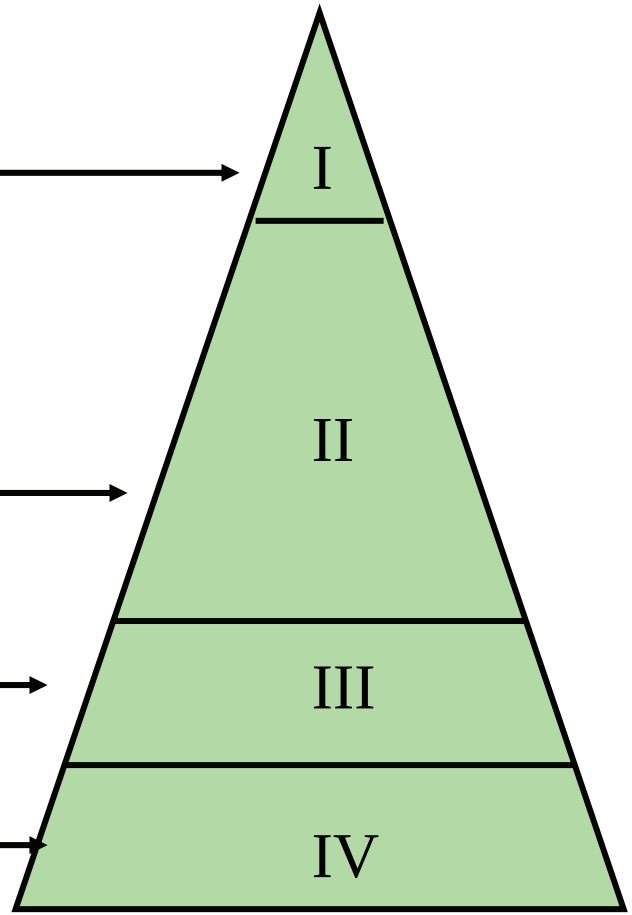
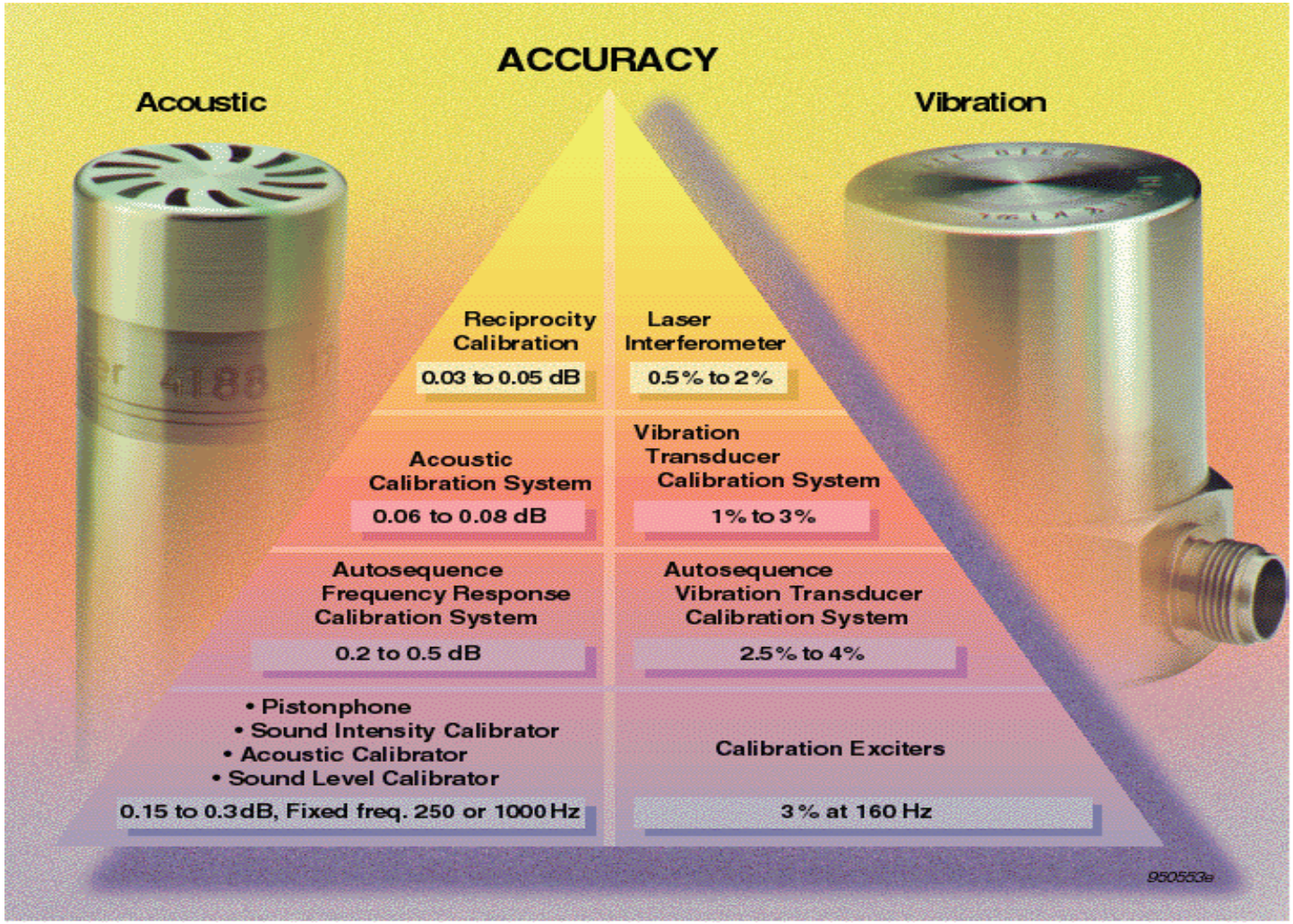
Calibration Levels

- **Primary calibration**
  - Often performed as absolute calibration; that means as close as possible to the fundamental physical units (MKSA in the SI system)
- **Secondary calibration**
  - Performed in the cal. Lab or on site
- **Field calibration**
  - Single point calibration or verification
- **Field measurements**



Uncertainty vs. Level



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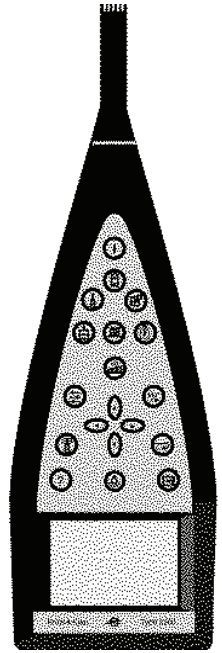
What is Calibration ?

Definition

To determine the deviation between the indicated value and the so called "true value" by tracing a measuring device back to international standards via an unbroken chain of measurements with known uncertainties.

- Traceability
- Uncertainty budget, written procedures
- Controlled environmental conditions
- Regular cal. intervals

Don't mix up calibration with adjustment



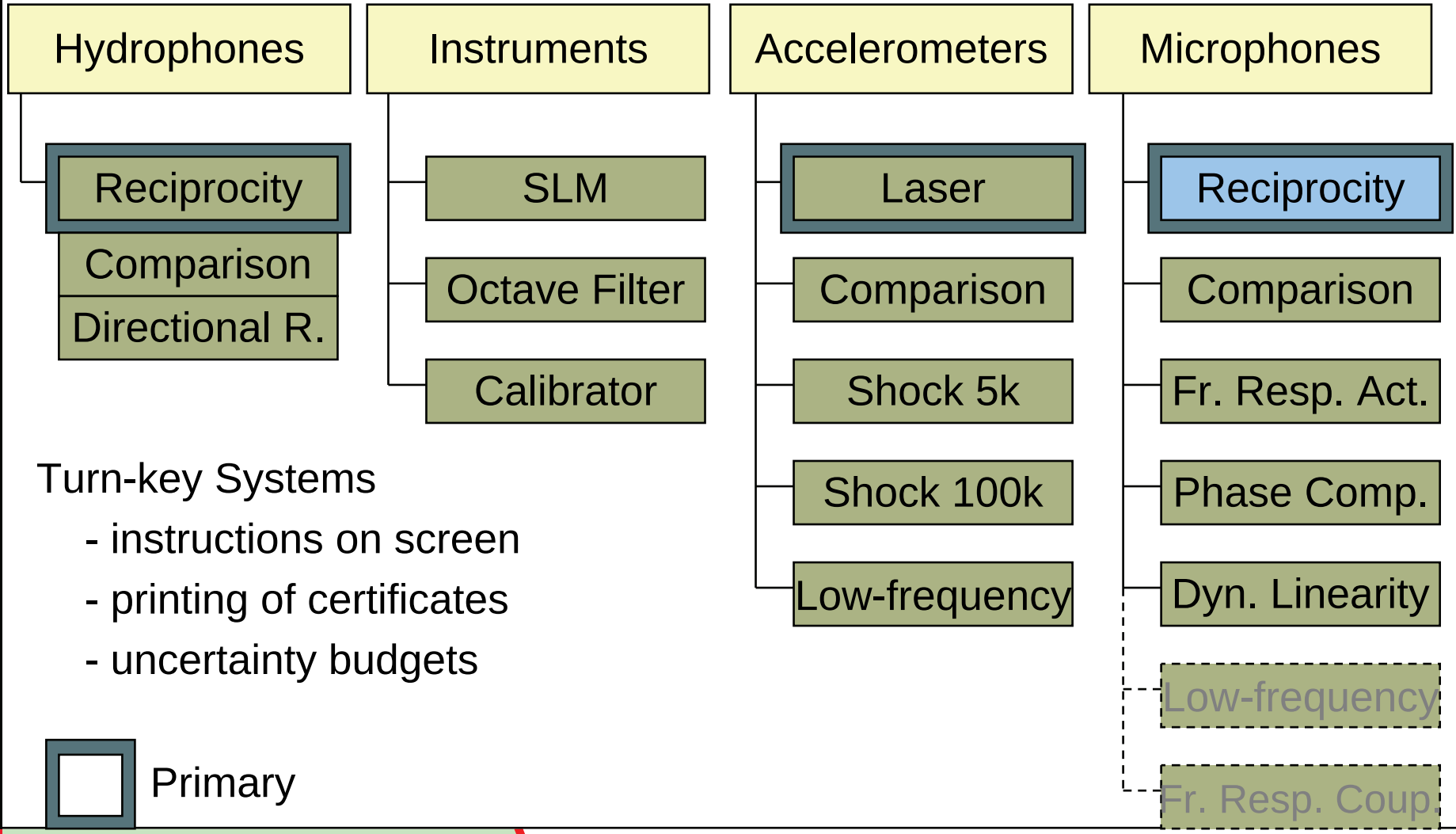
Why Calibration ?

- Uncertainty of the measurement must be known
- Measurements must be traceable to national or international standards

  Without this the measurement is of no real value

- Calibration is the process which fulfils these requirements

Modular Calibration Platform



Turn-key Systems

- instructions on screen
- printing of certificates
- uncertainty budgets

Primary

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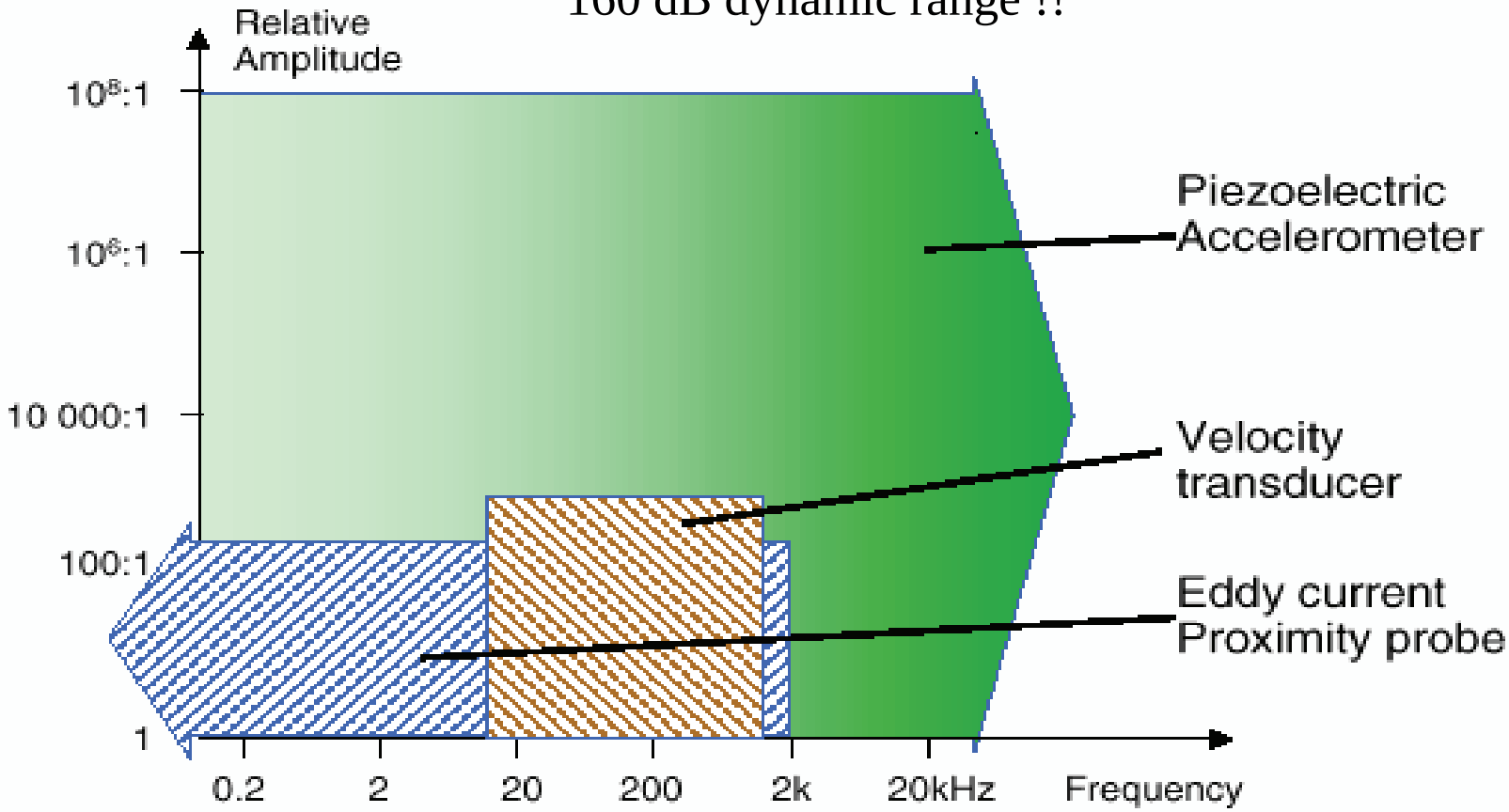
Operating Range of Vib. Transducers

160 dB dynamic range !!



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Calibration of Vibration Transducers

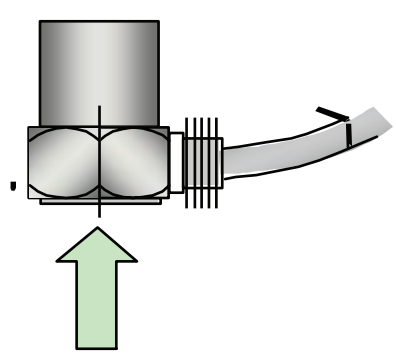
We are basically looking for:

- Sensitivity in pC/g or mV/g,
- Useable frequency range (frequency response)
- Mounted resonance frequency

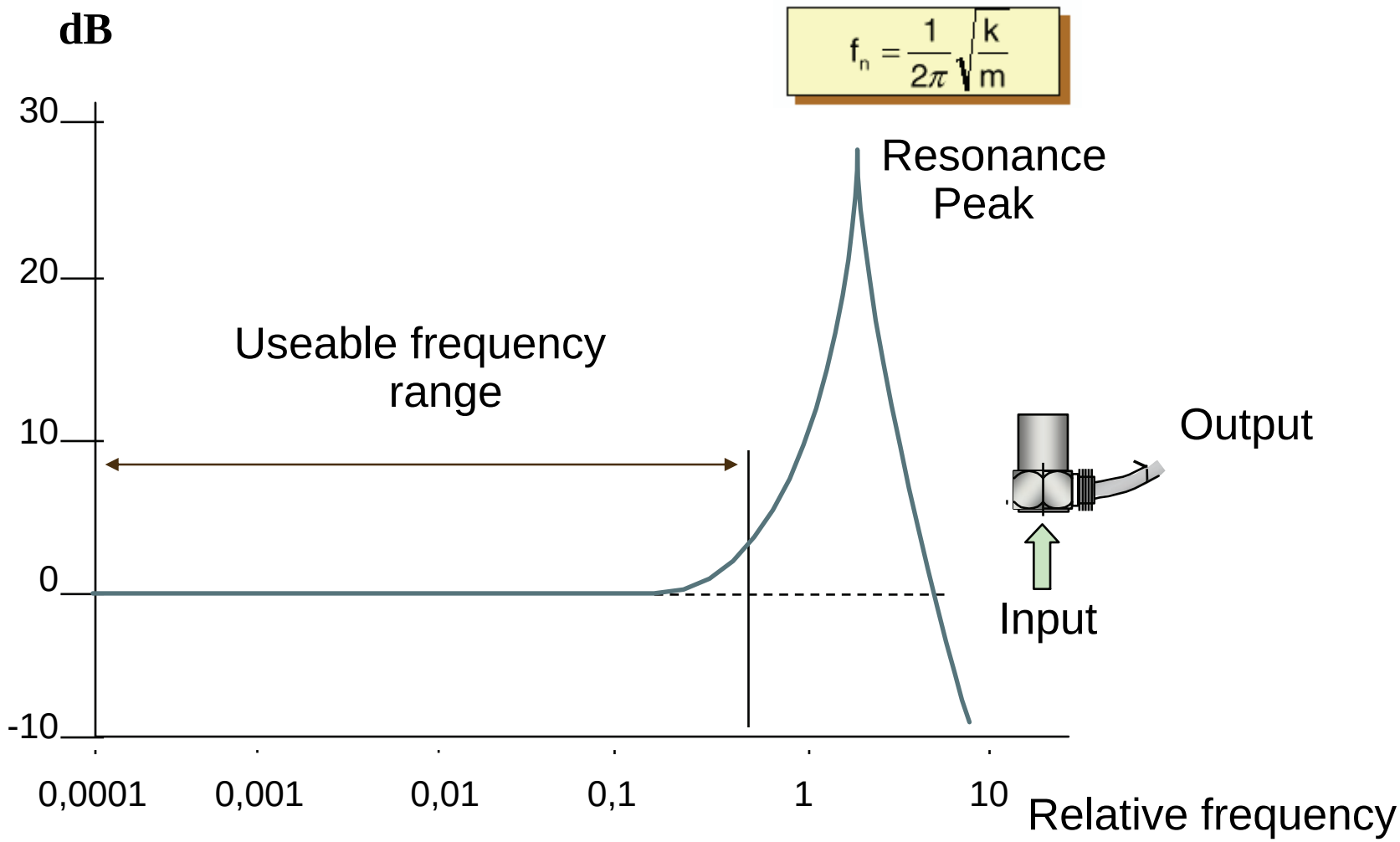
and maybe

- Other parameters like
  - traverse sensitivity
  - temperature dependence
  - etc

- Special types
  - shock calibration
  - extremely low frequency



Spring Mass System



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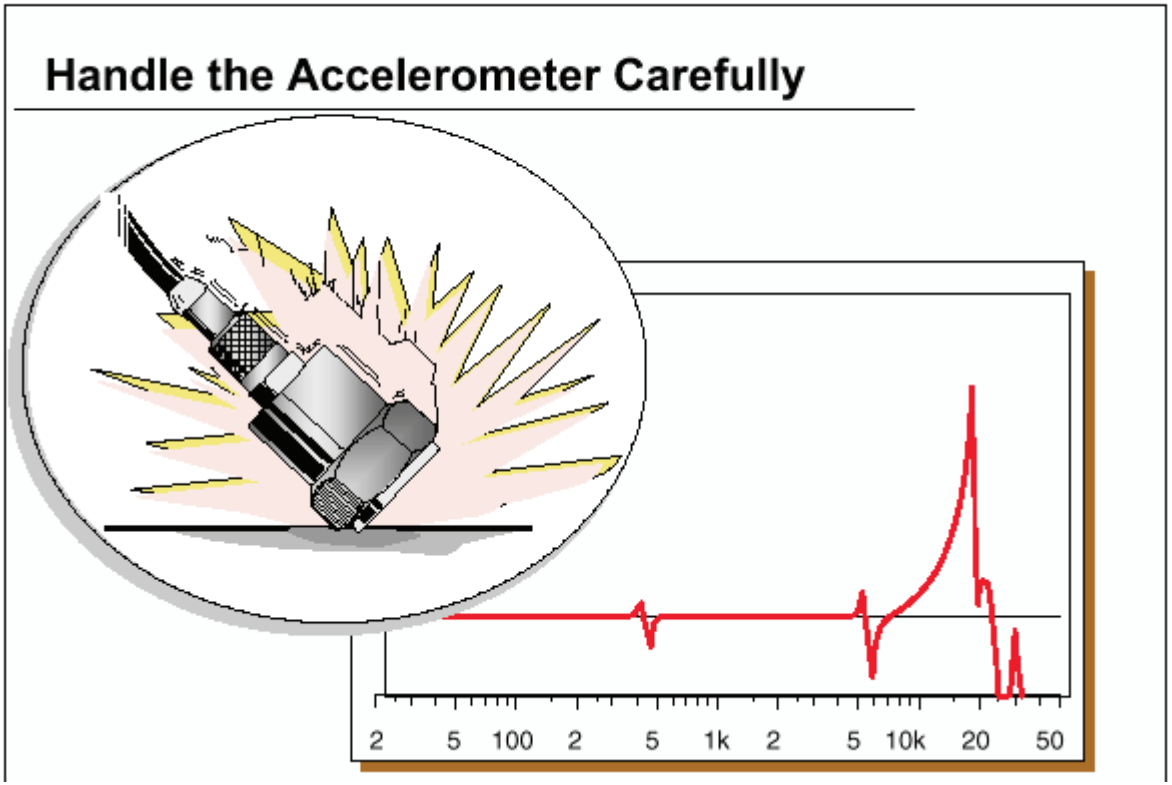
Don’t do this



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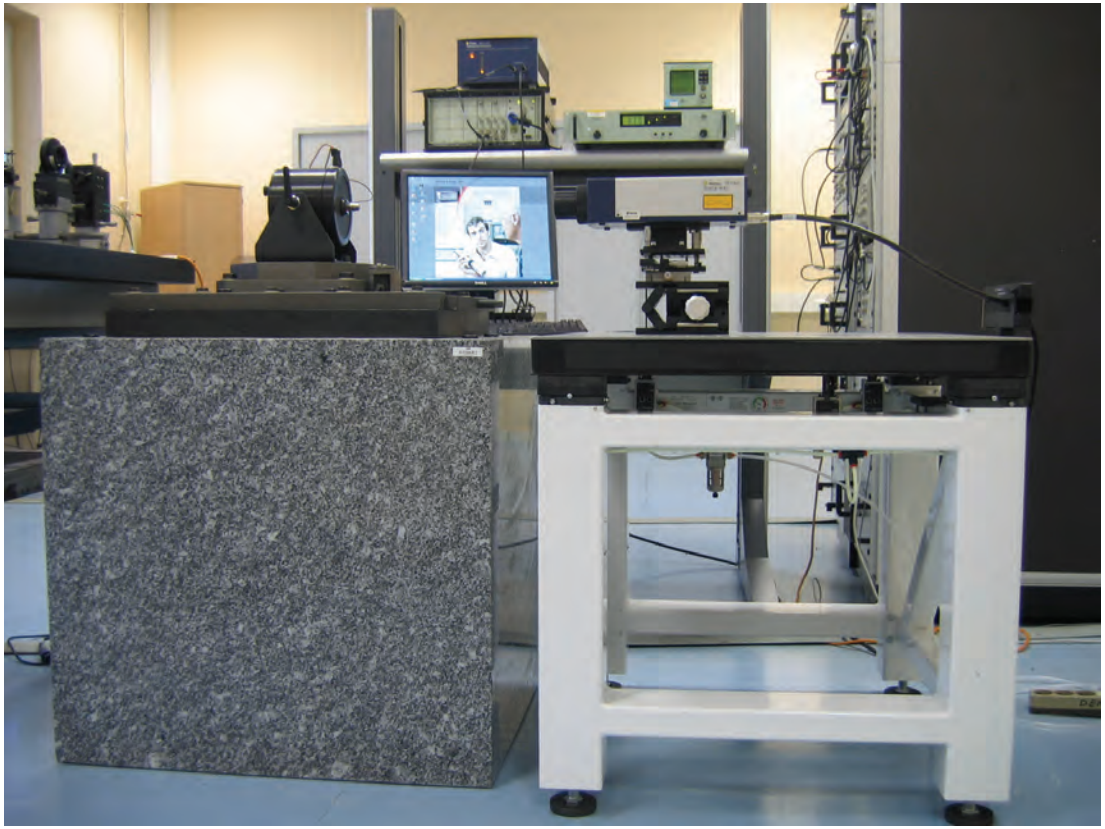
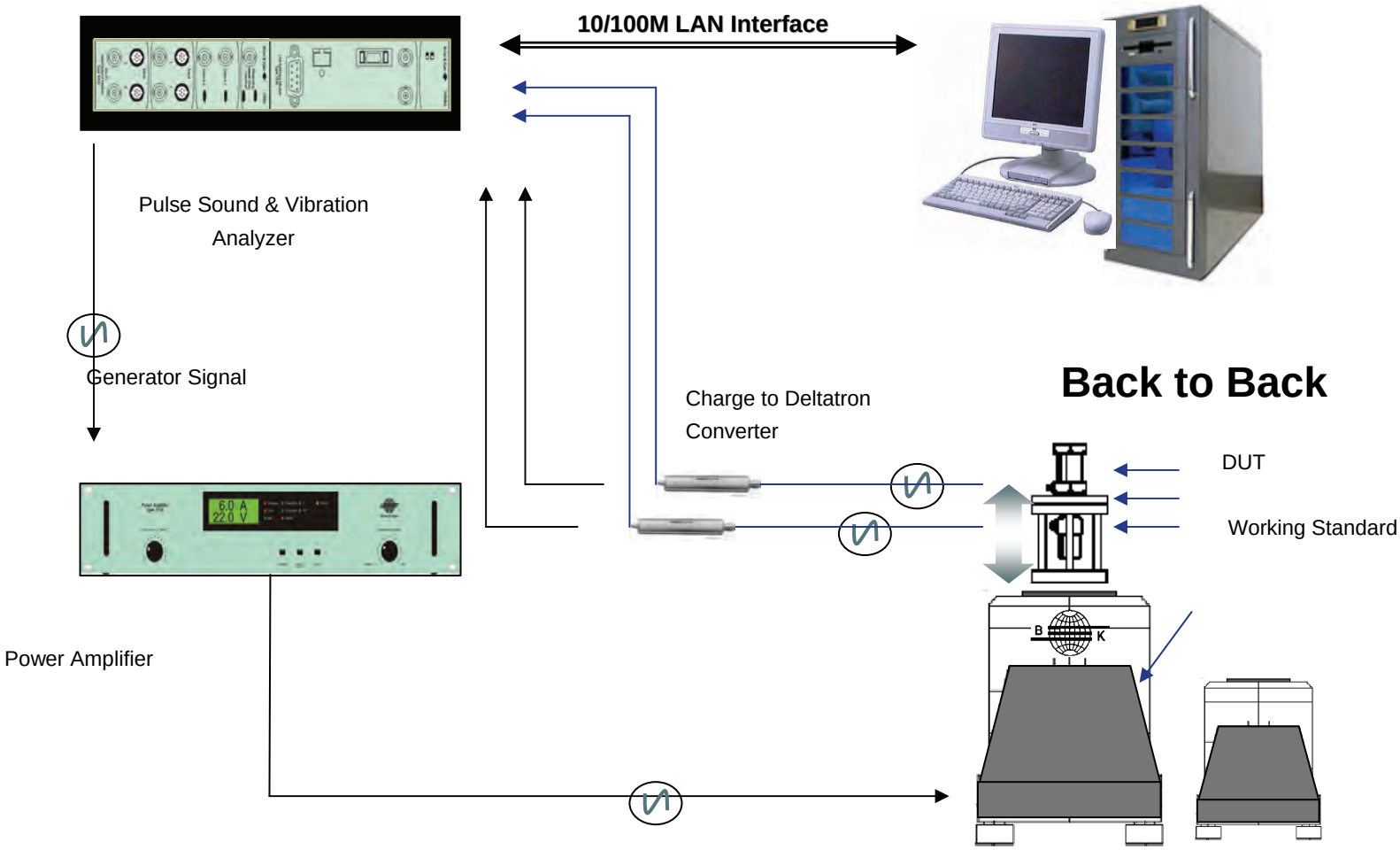
Primary Accelerometer Calibration

- Laser Interference Calibration System
  - Sub Hertz to > 20 kHz



Secondary Calibration



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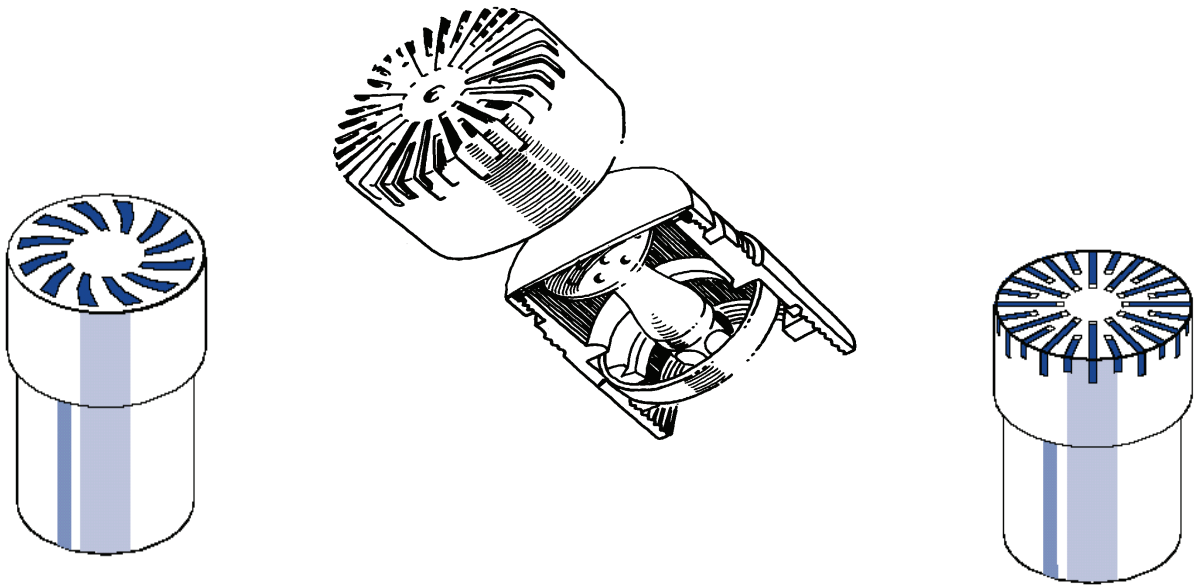
System Features

- Comparison calibration according to ISO 16063 – 21 (former ISO 5347 – 3)
- Calibration uncertainty 0.75% (*k*=2, at reference frequency)
- Calibration of charge and DeltaTron types
- Choice of random or sine excitation
- User defined test frequencies and levels
- User defined reference frequency
- Frequency range 5 Hz to 10 kHz (shaker dependant)

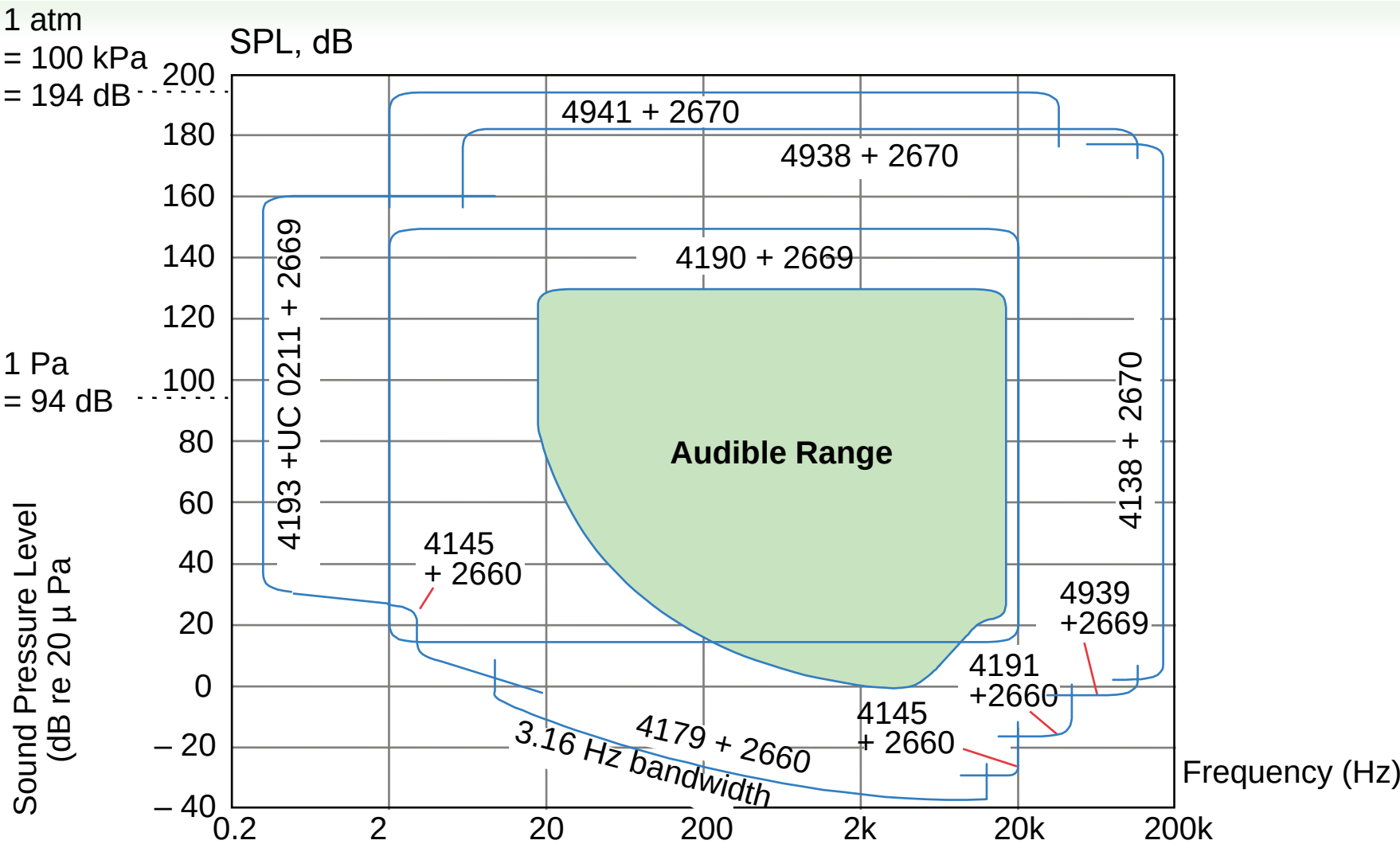
Optional packages

- Shock calibration, sub Hertz calibration, calibration of conditioning amplifiers

Microphone Calibration



Measuring Range of Microphones



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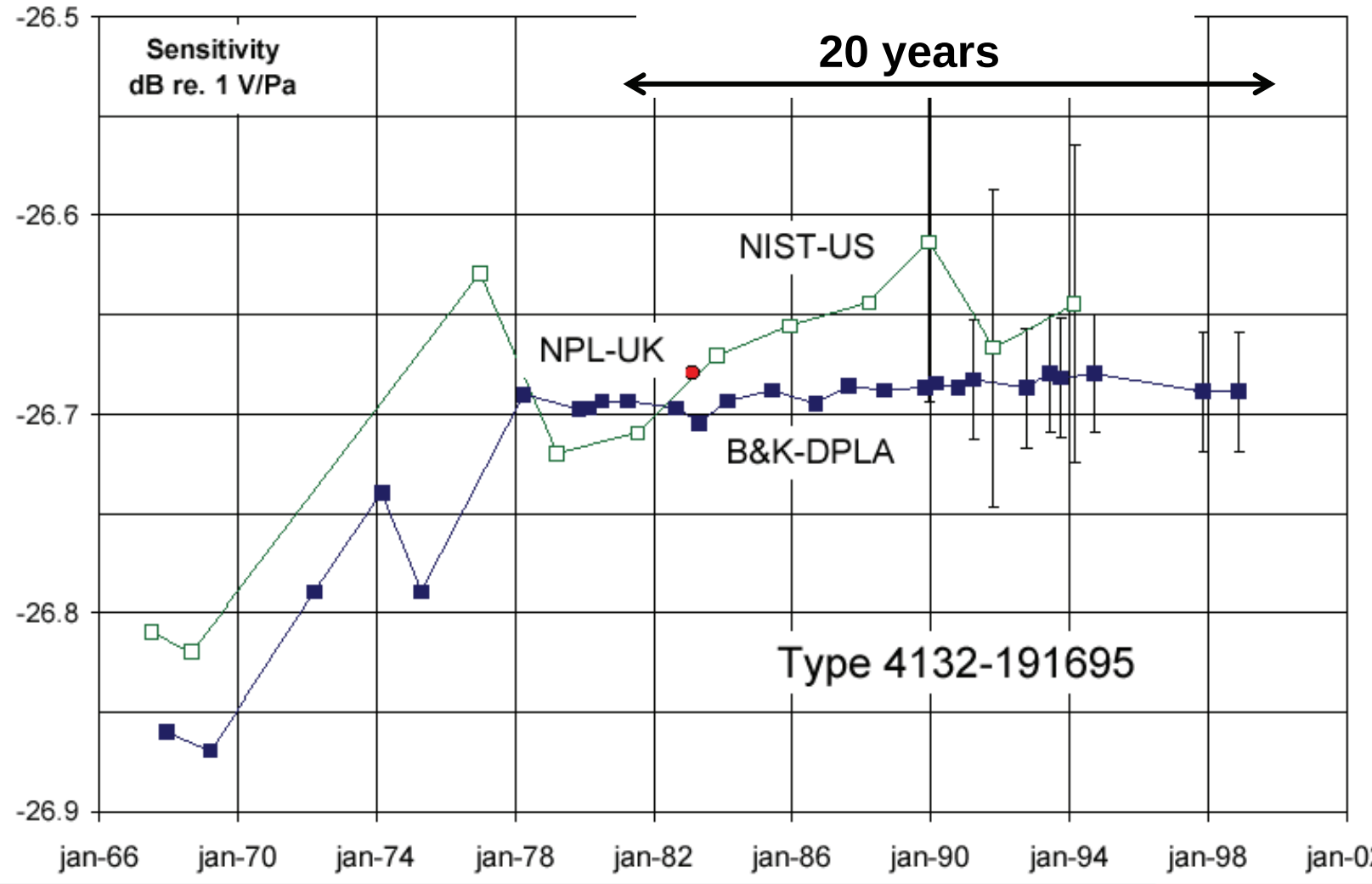
Reciprocity System

Microphone Reciprocity Calibration System

- **Highly Accurate**
- **Slow Method – Fast System**
- **Frequency Range up to 25 kHz**

Calibration History of B&K Reference Standard



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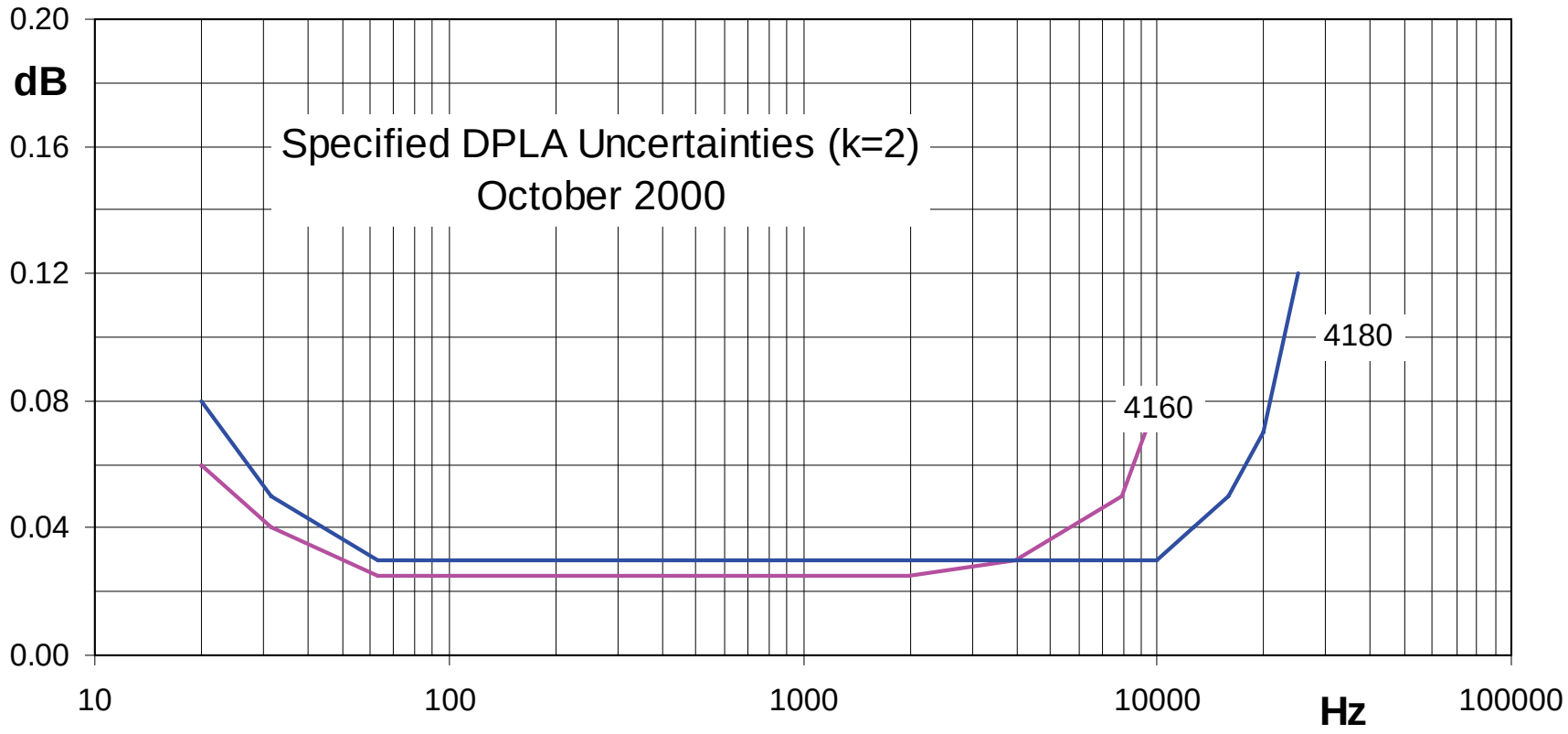
DPLA Calibration Uncertainty,Type 4160 and 4180



Different Microphone – Different calibration

Pressure-field Sensitivity

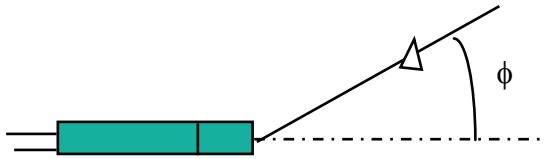
Refers to:

Uniform pressure on microphone diaphragm

Free-field Sensitivity

Refers to:

Pressure of undisturbed free-field



The Sensitivity is a Function
of the Angle of Sound Incidence

Diffuse-field Sensitivity

Refers to:

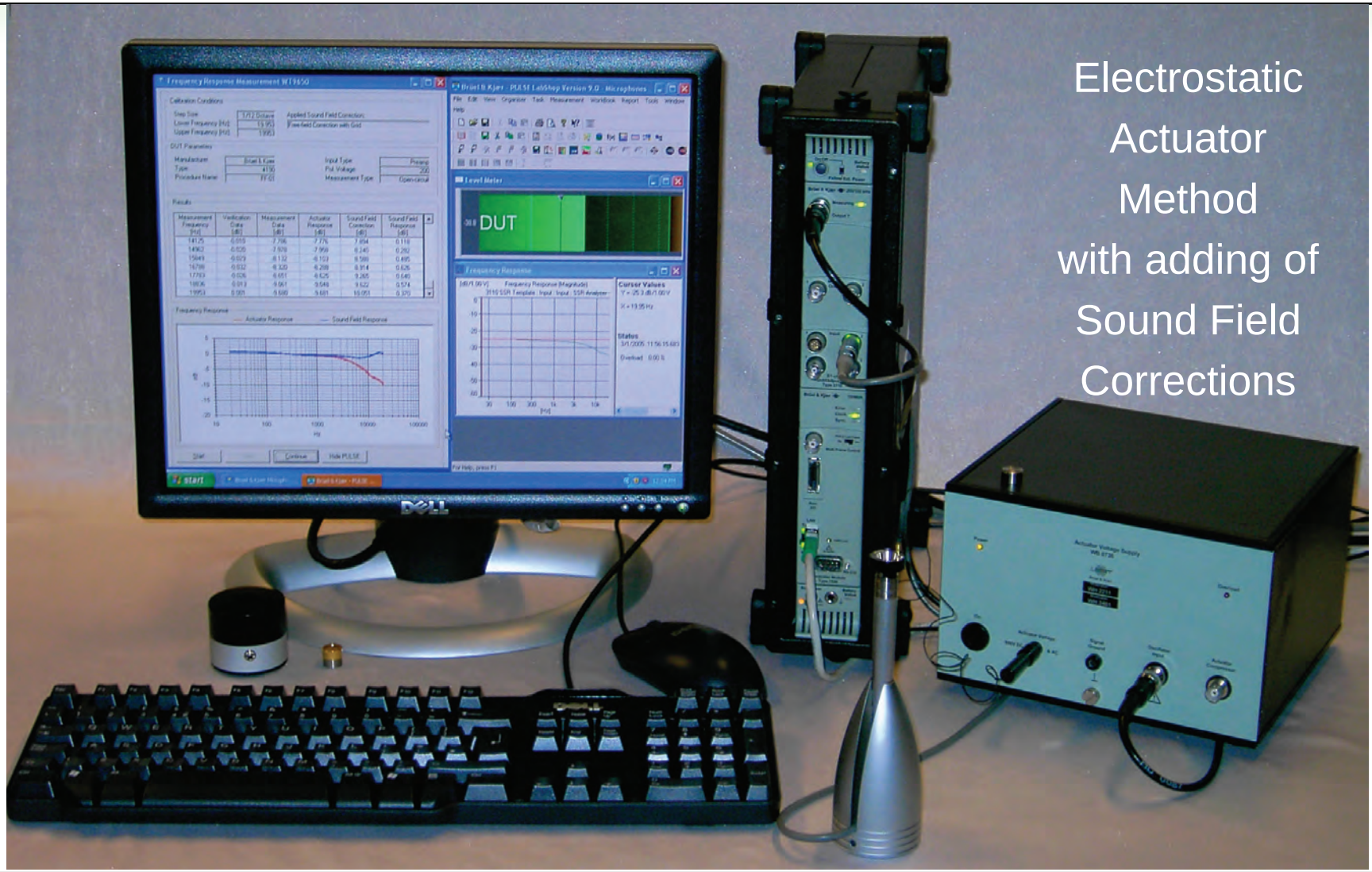
Pressure of undisturbed diffuse-field

The sensitivities mentioned above are different at higher frequencies but are essentially equal at low frequencies (250 Hz, Reference Frequency).

3 Different Calibrations

- For free field response calibration the ff corrections must be ADDED the measured electrostatic actuator (EA) response
  - EA response can be measured relatively easily
- For random field calibration the random corrections must be added to the measured EA response
- For pressure field response we can measure directly in the coupler and no corrections need to be added

Frequency Response Calibration



Electrostatic Actuator Method with adding of Sound Field Corrections

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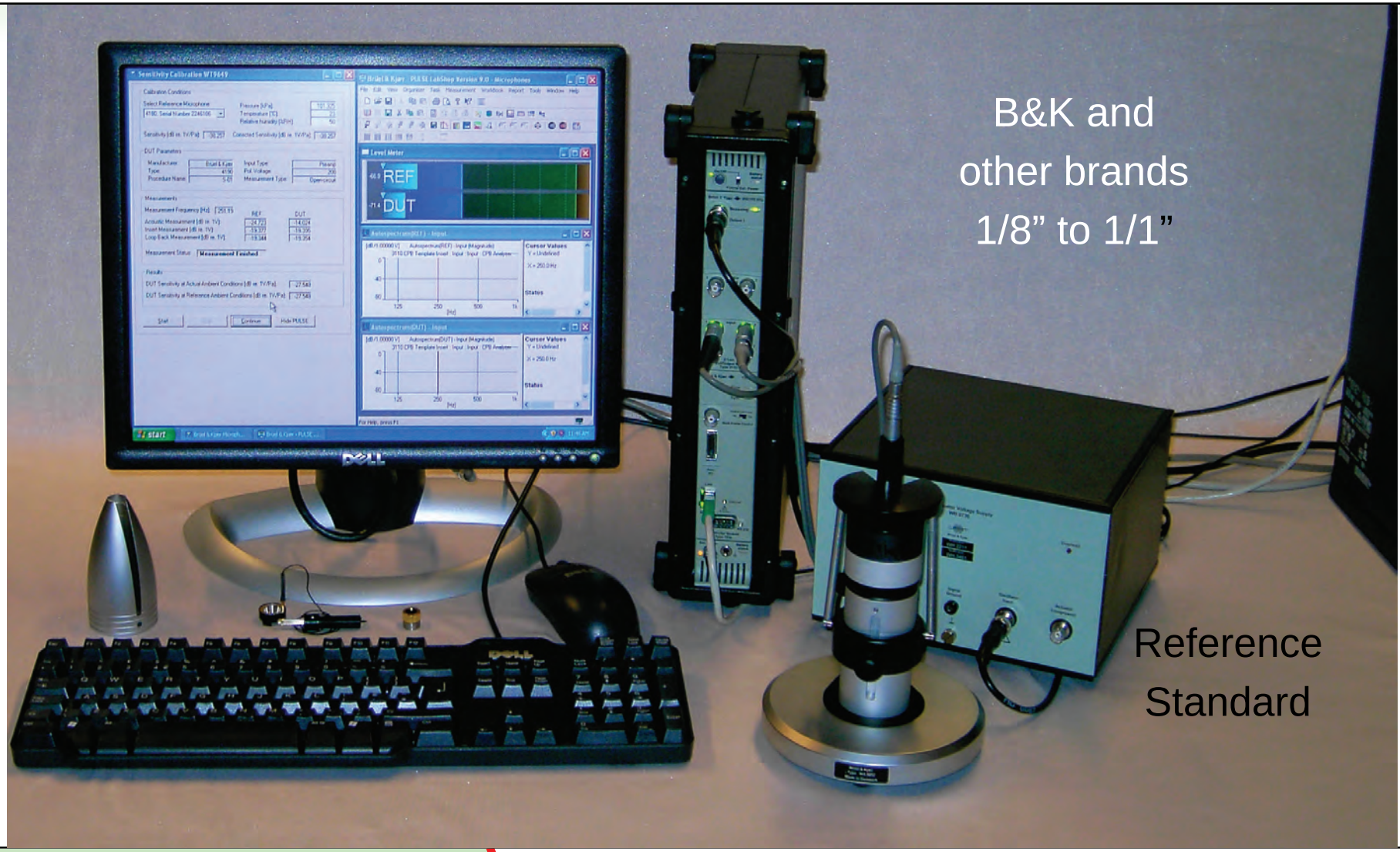
Comparison Calibration



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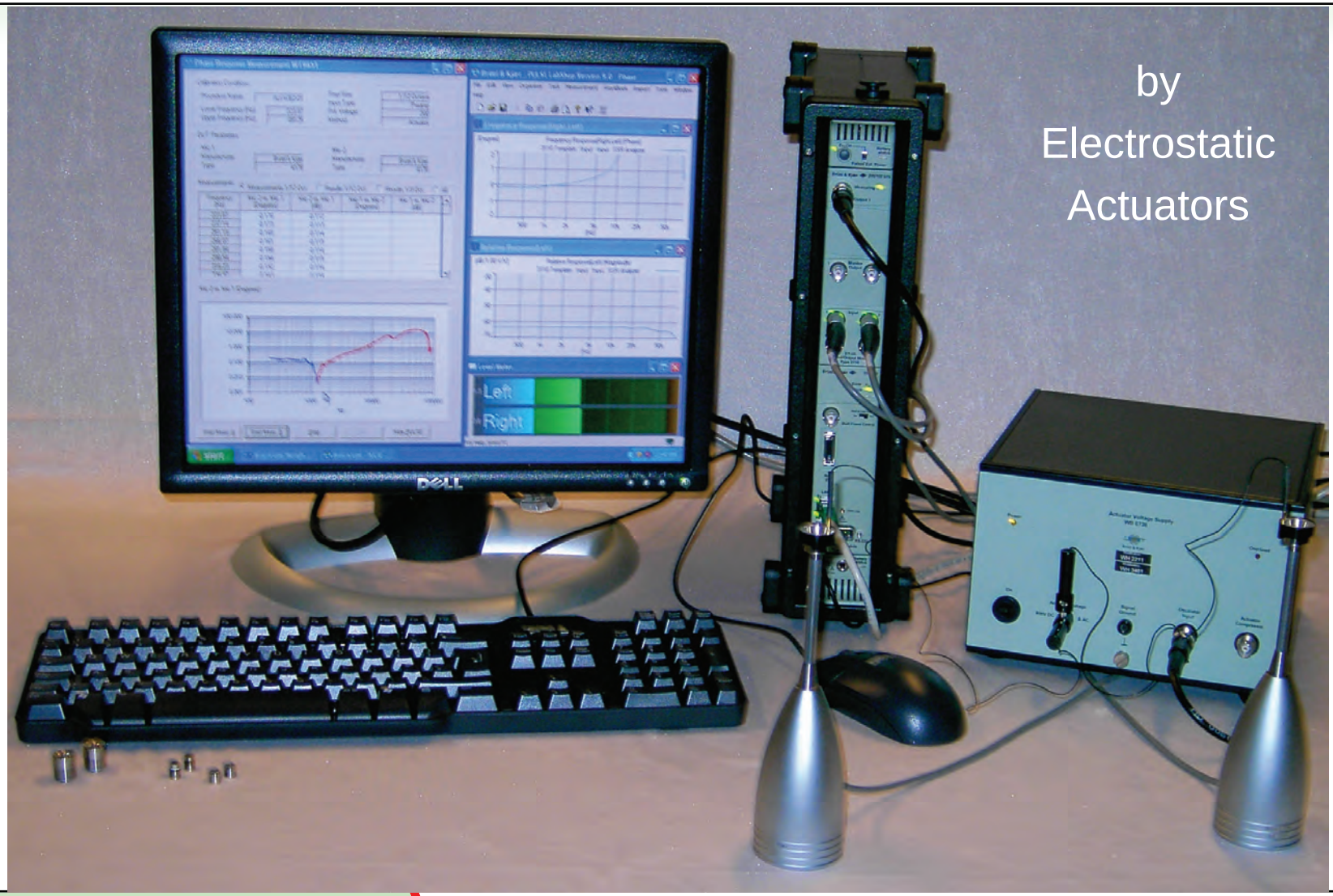
Phase Response Comparison



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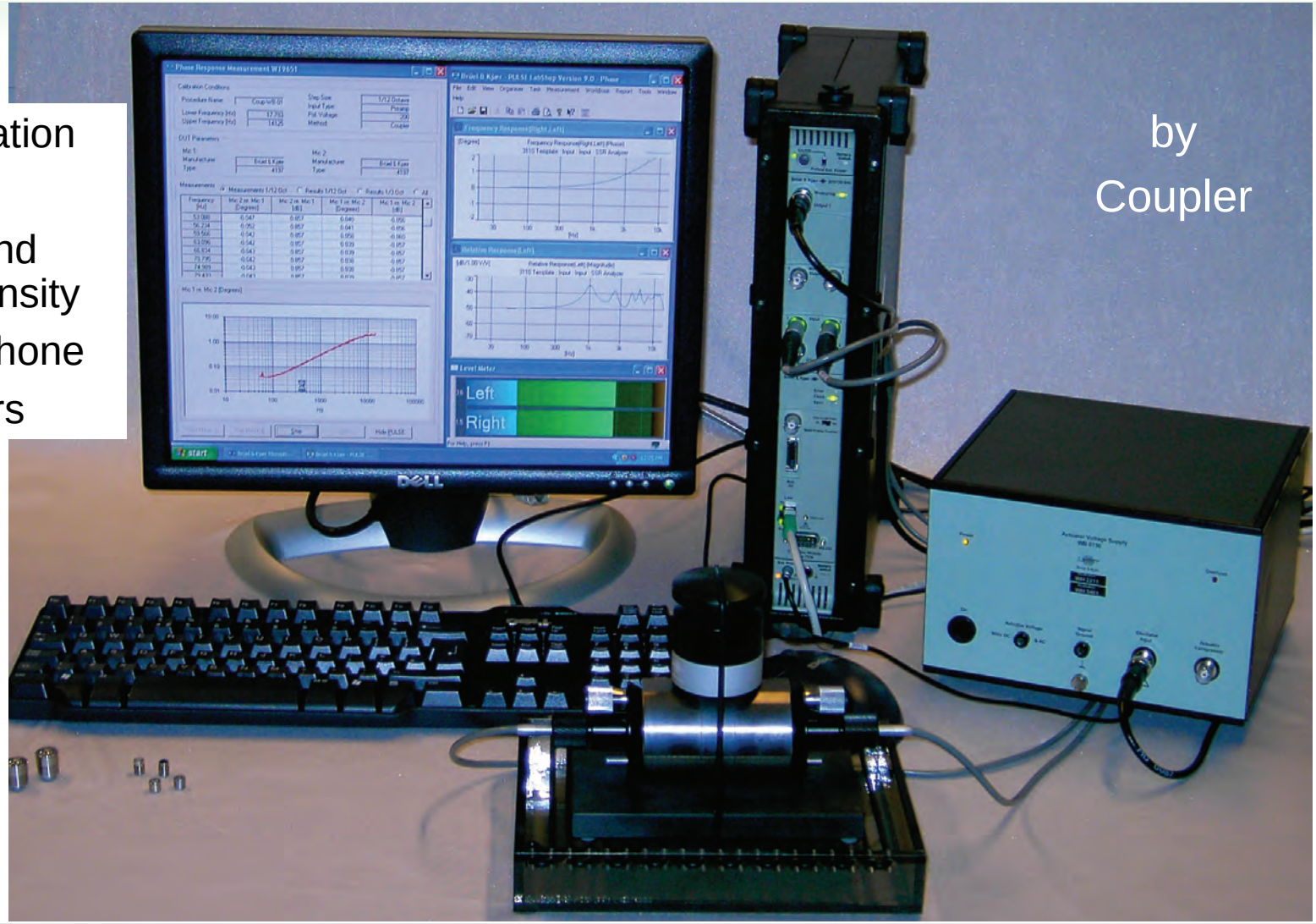
Phase Response Comparison

Calibration of Sound Intensity Microphone Pairs by Coupler

NOW up to 20 kHz



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High Pressure Calibration

Dynamic Linearity
Measurement
94 dB – 174 dB

System
Linearity deviation: < 0.5%
Distortion: < 0.5%
at highest level

Calibration System

Feature	Advantage	Customer Benefit
Windows Interface	Ease of use	Reduced training cost, flexibility
Modularity	Buy (and pay) only what you need	Cost effective, flexibility
Integration in MS Office	Easy reporting	Cost savings, data format compatibility
Tailored at s&v	Accurate measurements	Reduces error cost, Competitive edge
Automated cal.	Fast calibration	Cost savings, no operator errors
Conforms with standards	Avoid discussions	Cost saving, confidence
PULSE based	Standard product, lots of functionality	Protection of investment, flexibility

Field Calibrators

Sound Calibrator

94/114 dB @1 kHz (no pitfalls)

Calibration Exciter

Acceleration 10 m/sec^2
159. 6 Hz

CIC

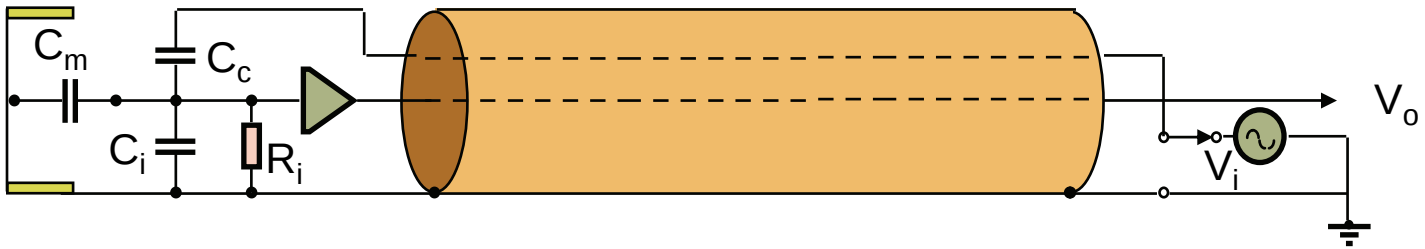
- CIC or Charge Injection Calibration
- NOT intended to replace real calibration, it is more a verification which can be used in order to extend the calibration interval.
  - CIC can be performed remotely.
- Basic philosophy
- Perform a REAL calibration
  - Install the microphone, preamplifier and cable and perform CIC
  - Note the CIC gain (typically around – 40 dB)
  - As long as the CIC gain is unchanged, nothing has changed **and the initial calibration is still valid**

Field Calibration

- Methods
  - pistonphone, calibrator
- When to calibrate
  - “before and after each important measurement” or
  - remote verification
- Where to use remote verification
  - where the microphone is not easy accessible
  - multi channel systems

CIC Principle

Charge Injection Mode **an AC signal is injected via C_c**

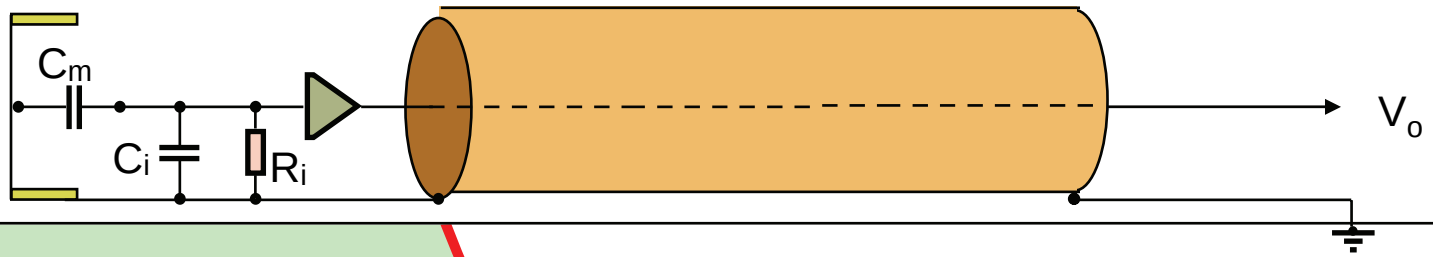


$$\frac{V_o}{V_i} = \frac{C_c}{C_m + C_i + C_c} \sim \frac{C_c}{C_m}$$

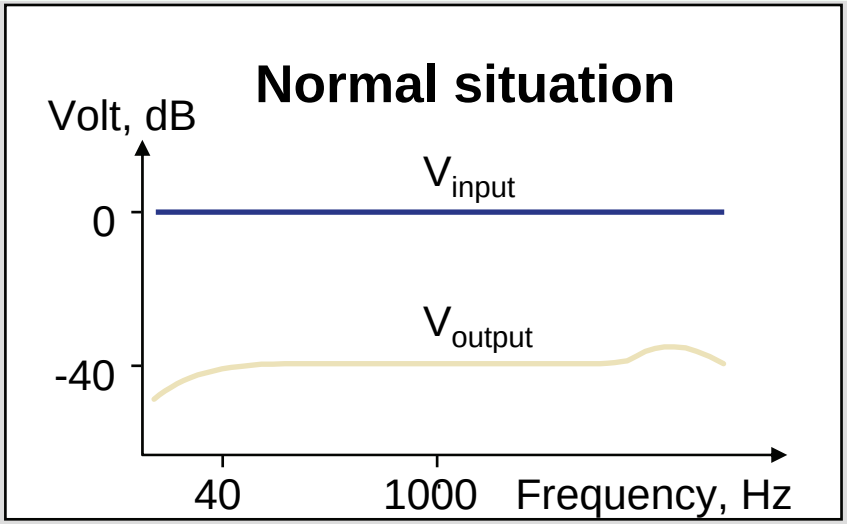
Typical values:
C_m = 20 pF C_i = 0.3 pF
C_c = 0.2 pF R_i = 40 GΩ

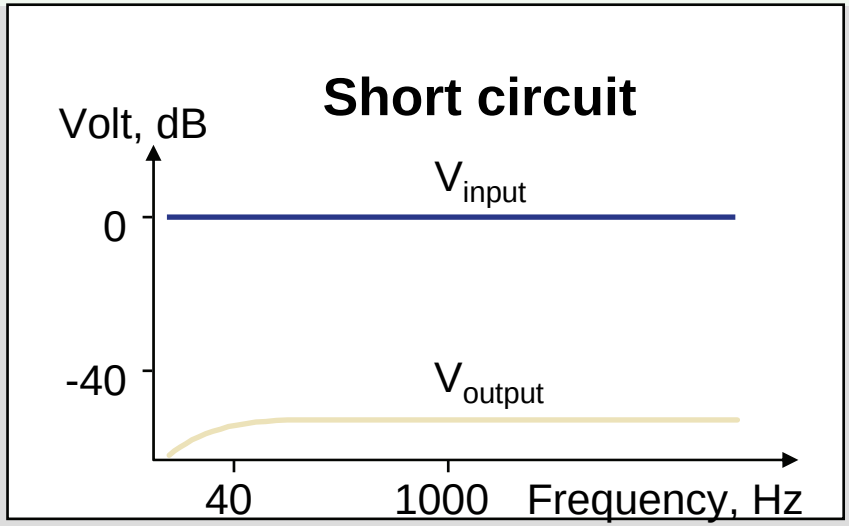
CIC gain typ 0.01 or – 40 dB

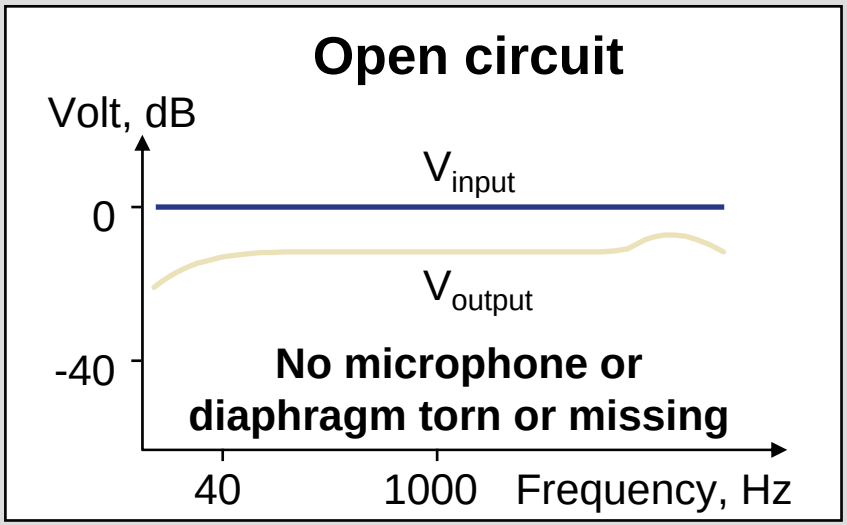
Normal Mode

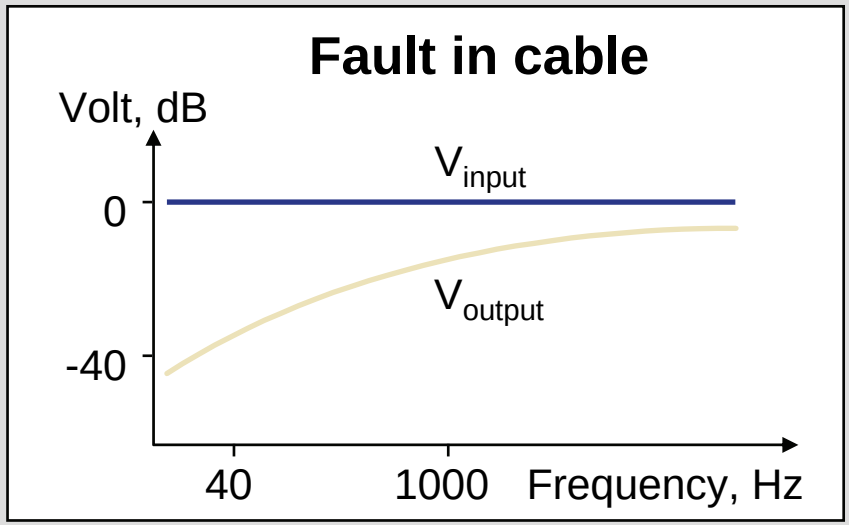


CIC Fault Detection









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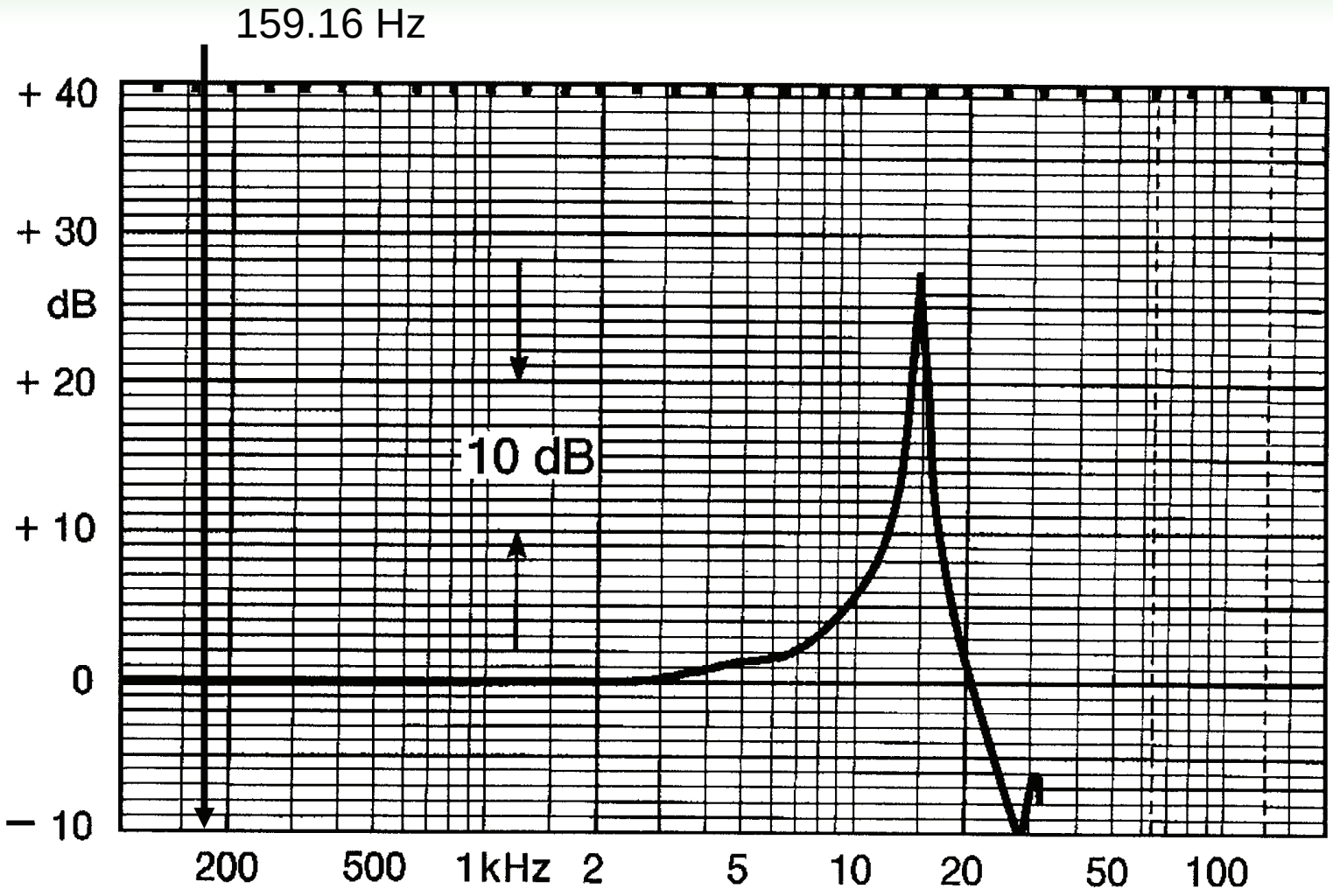
Calibration Method Comparison

	METHOD		
Microphone and Preamplifier Testing	**Insert Voltage**	**CIC**	**Actuator**
Electrical leakage due to humidity	No	Yes	Yes
Mechanical damage of microphone	No	Yes	Yes
Interchange of microphones	No	Yes	Yes
Change in polarisation voltage	No	(Yes)	Yes
Probability of detection of faults	> 50%	> 95%	> 95%
Probability of false alarms	Very low	Very low	Very high
Installation costs	Low	Low	High
Test system maintenance costs	Low	Low	High

Frequency Response of an OK Accelerometer



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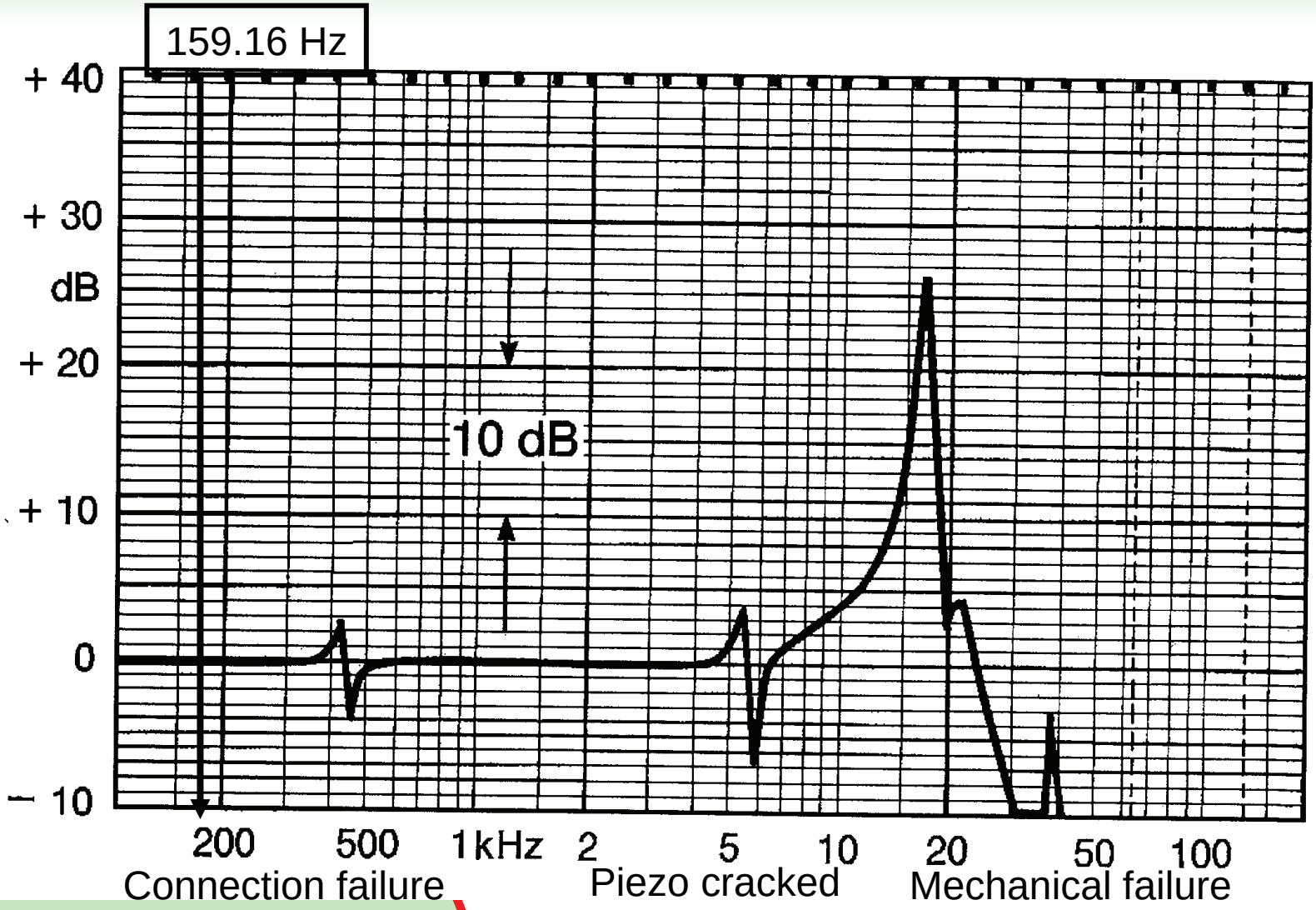
Frequency Response of Damaged Accelerometer



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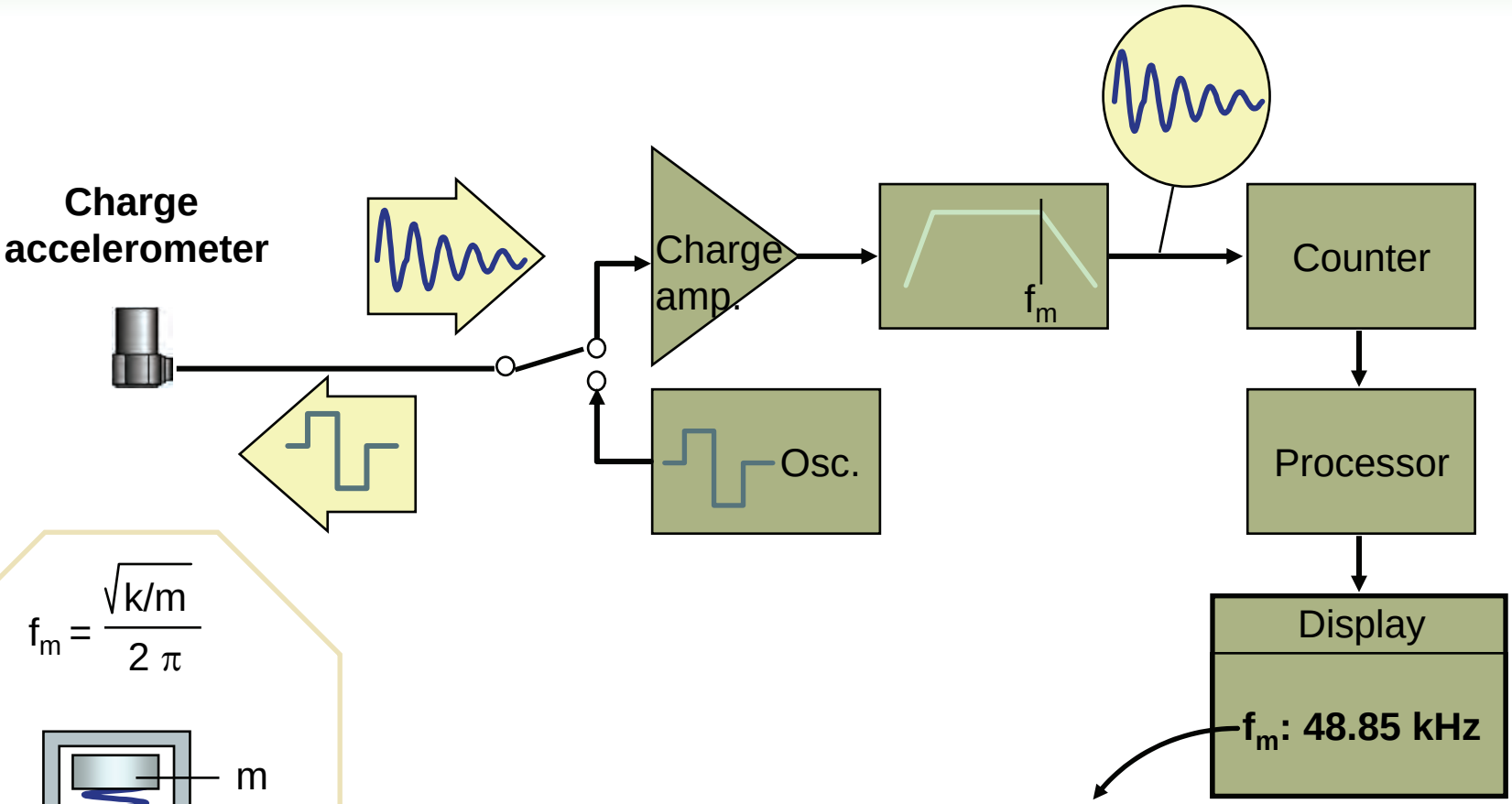
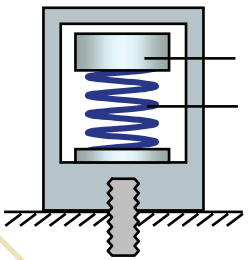
Mounted Resonance technique



$$f_m = \frac{\sqrt{k/m}}{2\pi}$$



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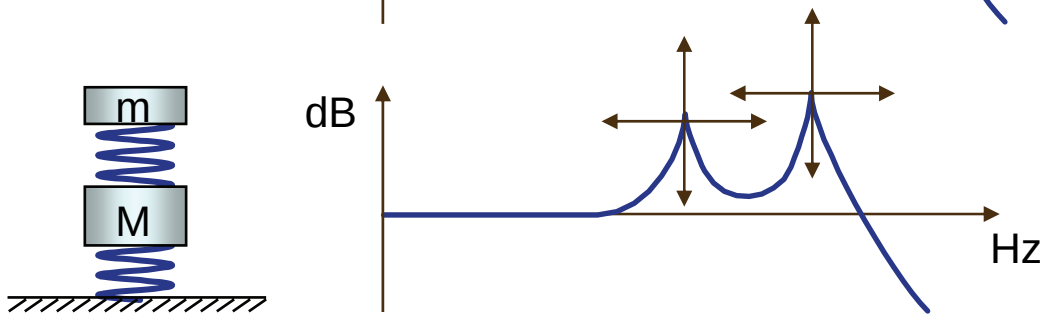
Mounted resonances of accelerometers

- Ideal mounting

- Freely suspended

- Loosely mounted



- Mounted on thin plate
  “Mass loading” effect

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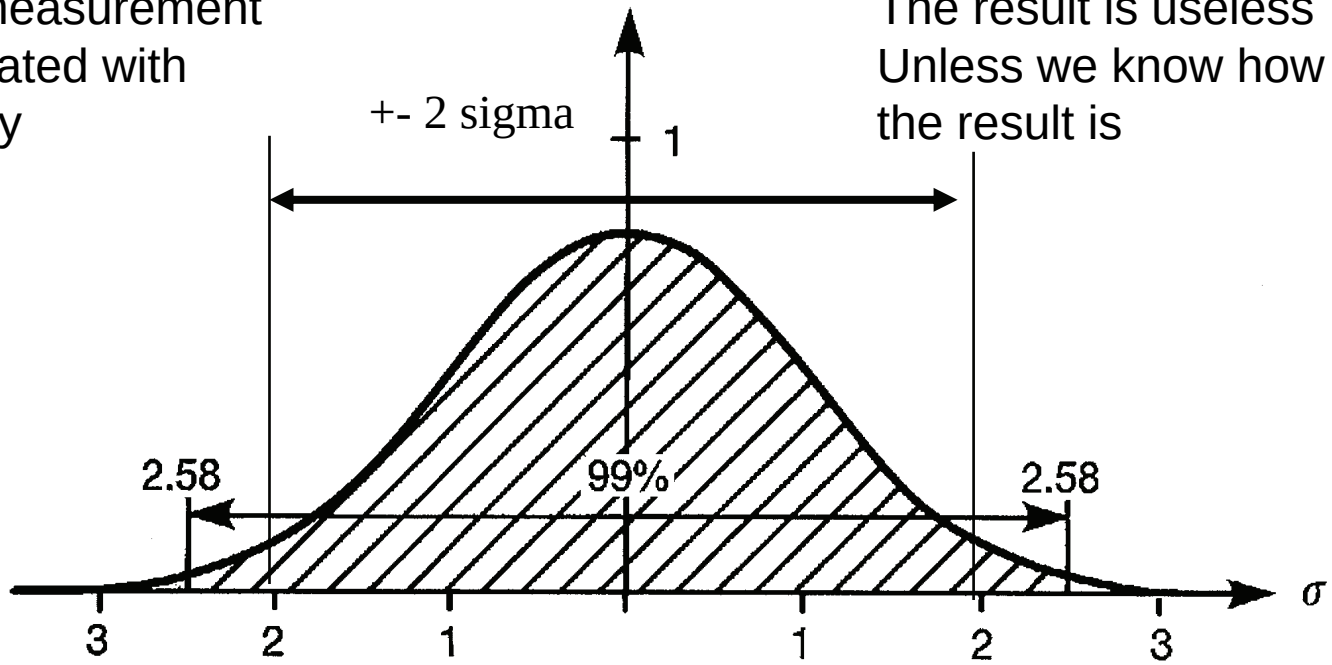
Calibration Uncertainty

The result of a measurement
Is always associated with
Some uncertainty



The result is useless
Unless we know how “true”
the result is

Dispersion of the result around the true value caused by calibration uncertainty
The combined expanded uncertainty (CEU) + - 2 sigma corresponds to 95 % confidence level, and must always be used under accreditation

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Thank you for your attention !!