

# Welcome to the Webinar



## The presentation will begin at 10am Central time

All attendees' microphones are muted for the entire webinar session. Be sure your speaker is active and join the audio conference.

If you have a question, please send it to the host using the “Q&A” function. Questions will be answered at the end of the presentation.

# Organizational Information

- ▲ All participants' **microphones** are **muted** during the webinar.
- ▲ Please do not forget to **activate** your PC **speakers** to enable **audio** or connect **headphones** to your PC. You may have to take the step of joining the audio conference to hear sound.
- ▲ Please type any questions you have into the WebEx Q&A dialog
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- ▲ Today's presentation will be E-mailed to all attendees. The webinar will also be posted on our website: <http://www.hbm.com/en/9232/webinars/>
- ▲ If you have additional technical questions, feel free to contact our technical support team at [support.de@hbkworld.com](mailto:support.de@hbkworld.com)

# Questions?

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# Introduction of the speaker



## Dr.- Ing. André Schäfer

- Currently Product & Application Manager Calibration Systems at HBK, 28 years in the company
- Holds a PhD in measuring technique & precision instruments
- holds 3 patents, > 100 white papers published
- more than 32 years experience in sensor technology
- Get more details at „Research Gate“: [www.researchgate.net](http://www.researchgate.net) (see most important papers with close to 4000 reads and 100 citations)
- Contact at E-Mail: [andre.schaefer@hbkworld.com](mailto:andre.schaefer@hbkworld.com)

# Topics

- 1. How to set up a High Precision Measuring Chain?**
  - How to find out your needs regarding its Measurement Uncertainty?
- 2. How to choose the right Reference Sensor ?**
  - For Force, Torque & Pressure
- 3. How to choose the right High Precision Amplifier?**
  - Emphasizing DMP41, the world 's most accurate amplifier for strain-gauge based measurements
- 4. Summary**
- 5. Frequent Problems and possible solutions to them, Questions**

# Mechanical Calibration Systems for Calibration of Mechanical Quantities

New challenging norms and regulations in this field are especially driving market growth.



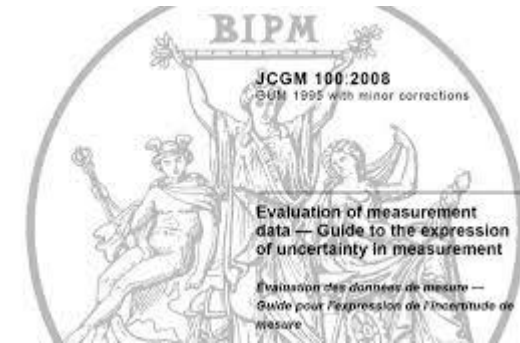
**precision measurement chain**

consisting of

Reference sensor



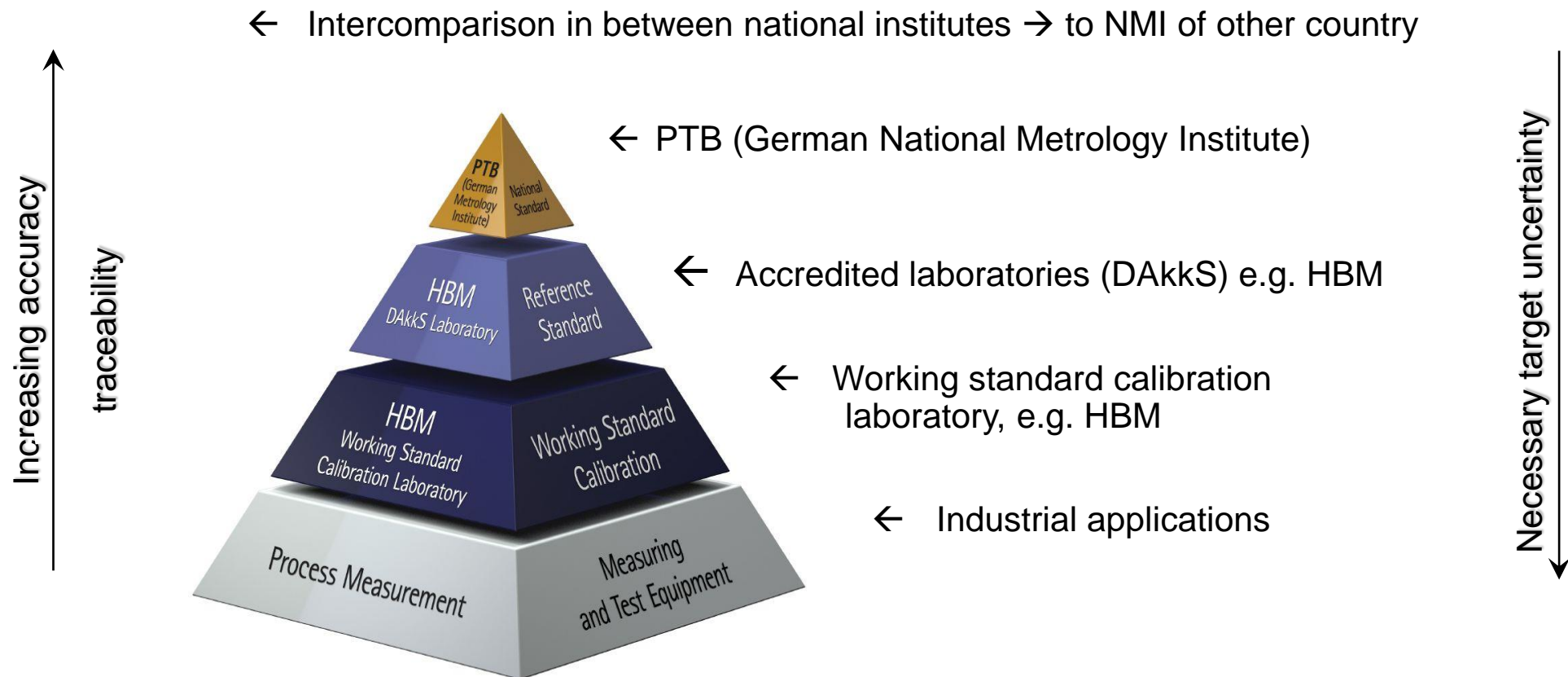
Precision amplifier



▲ Depending on the application: Target Uncertainty for the whole precision measurement chain

# Calibration pyramid: Shows “calibration level”

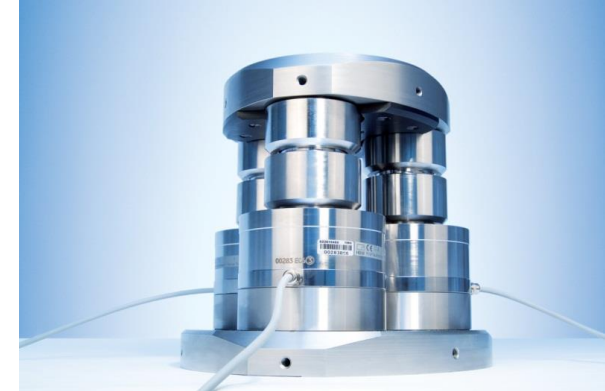
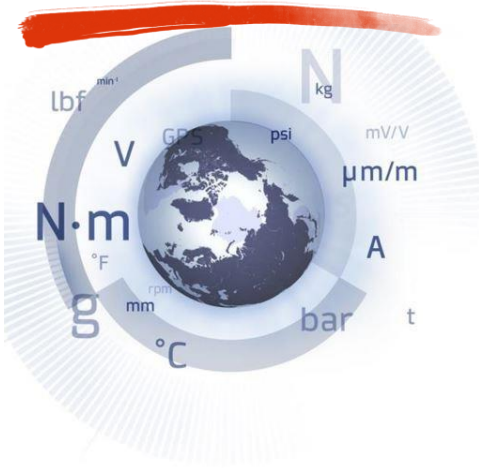
Explained on the example of Germany





# Reference Force transducers

## Force



Build-up system for force calibration  
Class 00 acc. ISO 376

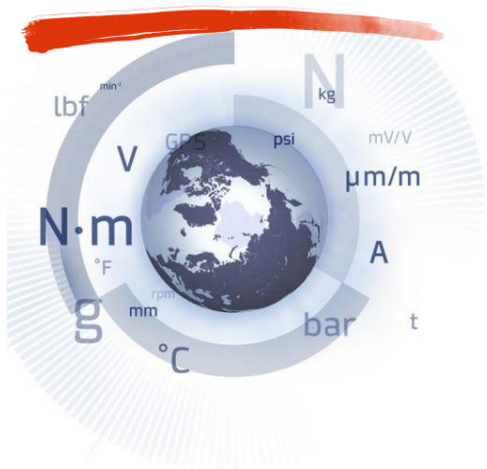


HBM participates in various EMRP Force Metrology projects



# Reference Torque transducers

## Torque



TB2  
Reference transducer



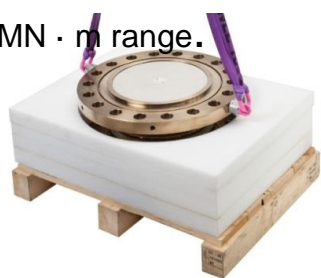
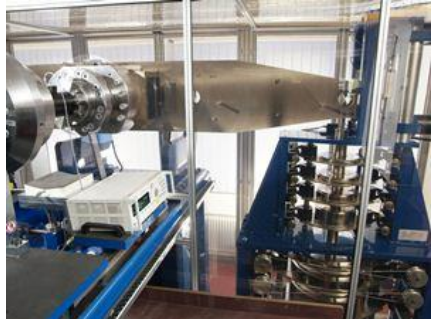
TTS for  
calibration of  
Torque wrenches



Customized transducers for the  
MN · m range.

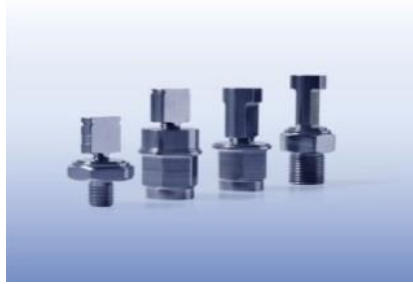


Reference transducer as transfer standard in NMIs

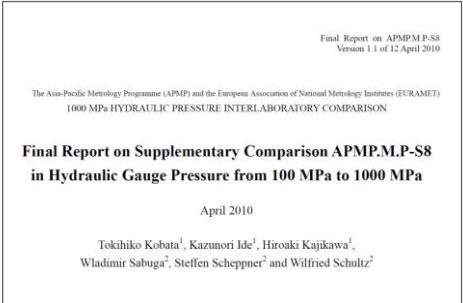


# Reference Pressure transducers

## Pressure



**BlueLine**  
Ultra high pressure transducers



HBM Exhibition booth at IMEKO TC16  
„Pressure & Vacuum“

# Important influencing factors, important for all types of strain gauge-based sensors

- It is best to use Measurement uncertainty specified in the DAkkS calibration certificate:
  - Linearity
  - Hysteresis
  - Relative standard deviation of repeatability ( $\sigma_{rel}$ )
  - Creep
- Application-specific:
  - Temperature effect (related to 10 K) on the zero signal ( $TC_0$ )
  - Temperature effect (related to 10 K) on the sensitivity ( $TC_{span}$ )

Note: In practice, the accuracy class provides an indication of the classification of the respective type series within the HBM range. However, it says nothing about the total measurement uncertainty in practical use, because the various individual influences act here simultaneously.



# Special influencing factors of the individual types of strain gauge-based sensors

Of special importance to forces:

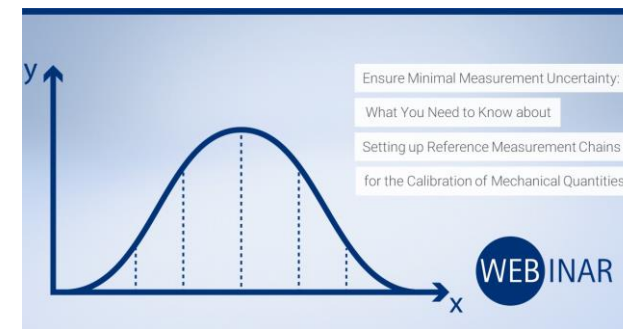
- Angle of force application ► Lateral force, bending moment
- Zero point return

Of special importance to torques:

- Effect of applying the mechanical quantity to the transducer, e.g.
  - Parasitic loads
  - Axial force
  - Lateral force
  - Bending moment
- Mechanical remanence (also “zero-point hysteresis”/”toggle effect”), i.e. the transducer’s zero drift when the loading direction is changed.

Of special importance to pressures:

- depending on measuring body used:  
e.g. changes in the cross section of the measuring element-





# HBK field of competence: Our own HBK Calibration laboratories for mechanical quantities



Force laboratories



Torque laboratories















Pressure laboratories



Vibration laboratories

# What large forces, torques, and pressures are needed for

Measurand Force		Measurand Torque		Measurand Pressure	
Application	Motivation	Application	Motivation	Application	Motivation
	<b>kN</b>		<b>kN·m</b>		<b>MPa</b>
Civil engineering 	Safety of buildings	Ship building applications 	Environment, required reduction of emissions	Water-jet cutting 	Finding a compromise between sensitivity and service life
<b>MN</b>	 Source: PTB, Physik.-techn. Bundesanstalt, Braunschweig, Germany	<b>MN·m</b>	 Source: PTB, Physik.-techn. Bundesanstalt, Braunschweig, Germany	<b>GPa</b>	 Source: PTB, Physik.-techn. Bundesanstalt, Braunschweig, Germany
Railroad/ Aerospace 	Safety of infrastructure	Wind power applications 	Efficiency of wind turbine drive trains and generators	Autofrettage 	Finding a compromise between sensitivity and service life



# Special Influencing Factors of the individual types of strain gauge-based sensors



Of special importance to large forces and torques:

- Special features when it comes to estimating the measurement uncertainty are above all:
- Statistic approach and Standard uncertainty can often only be obtained from very few samples (as they are huge), so this method is often not suitable for large mechanical quantities
- By "upscaling" often the significance of some influences, which were previously negligible, grows, so they suddenly have to be considered (new influences have to be added).

Of special importance to larger pressures:

- The time until the “steady state” is reached, resulting from
- The fluid’s viscosity (which changes depending on the pressure)
- The small diameter of the pipes (necessary for safety reasons)
- The resulting very long compensation time

Note: In these pioneering areas, expert knowledge must very often be consulted in order to assess influences. Therefore, one should admit that the measurement uncertainties for very large forces, torques and pressures will always be quite high.



#### High precision electronic weighing

The Hottinger Baldwin (HBM) electronic weighing instrumentation has been certified to maintain  $\pm 1$  digit in 6 000 digits during a range of loading and thermal cycling tests. The units tested were a DK 37 Digital Compensator and a Load Cell Type C3H.

Load cell production in the late 1960ies-  
Forced the development of DK (38) and DMP (39) series

# History and basic principles of HBM Precision instruments

1977 HBM was the first calibration lab in Germany for force in the framework of the “German Calibration Service” (DKD).

Until 1992/1993 HBM’s 20 kN·m torque dead weight machine played the role of a “national standard” in Germany.

Since 2010 we saw a constantly increasing demand for traceability of higher force, torque and pressure values up to MN·m range: HBM participated in several EU metrology projects (EURAMET)

Today: Market leader in high-precision test & measurement applications

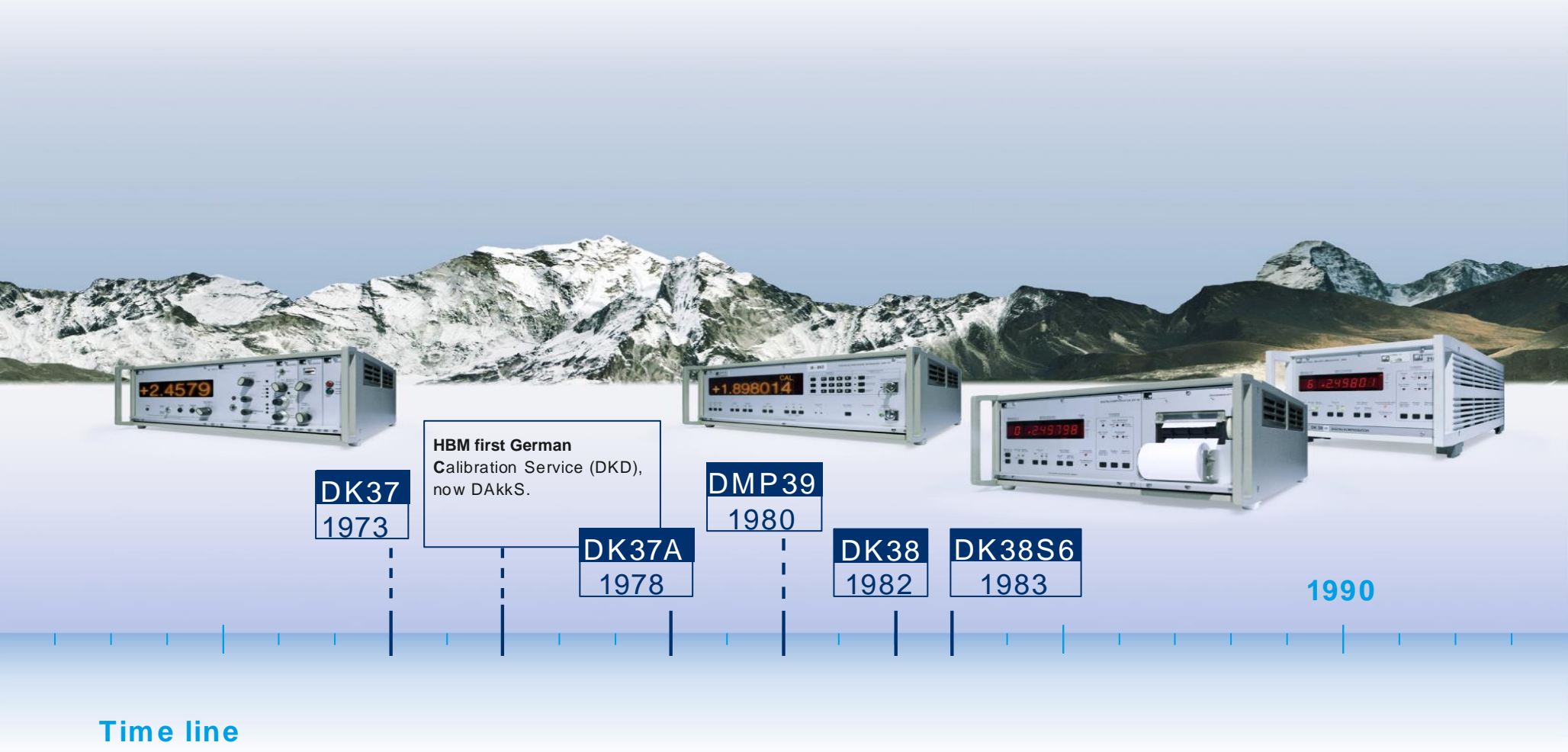


Manfred Kreuzer,  
former head of R&D at HBM



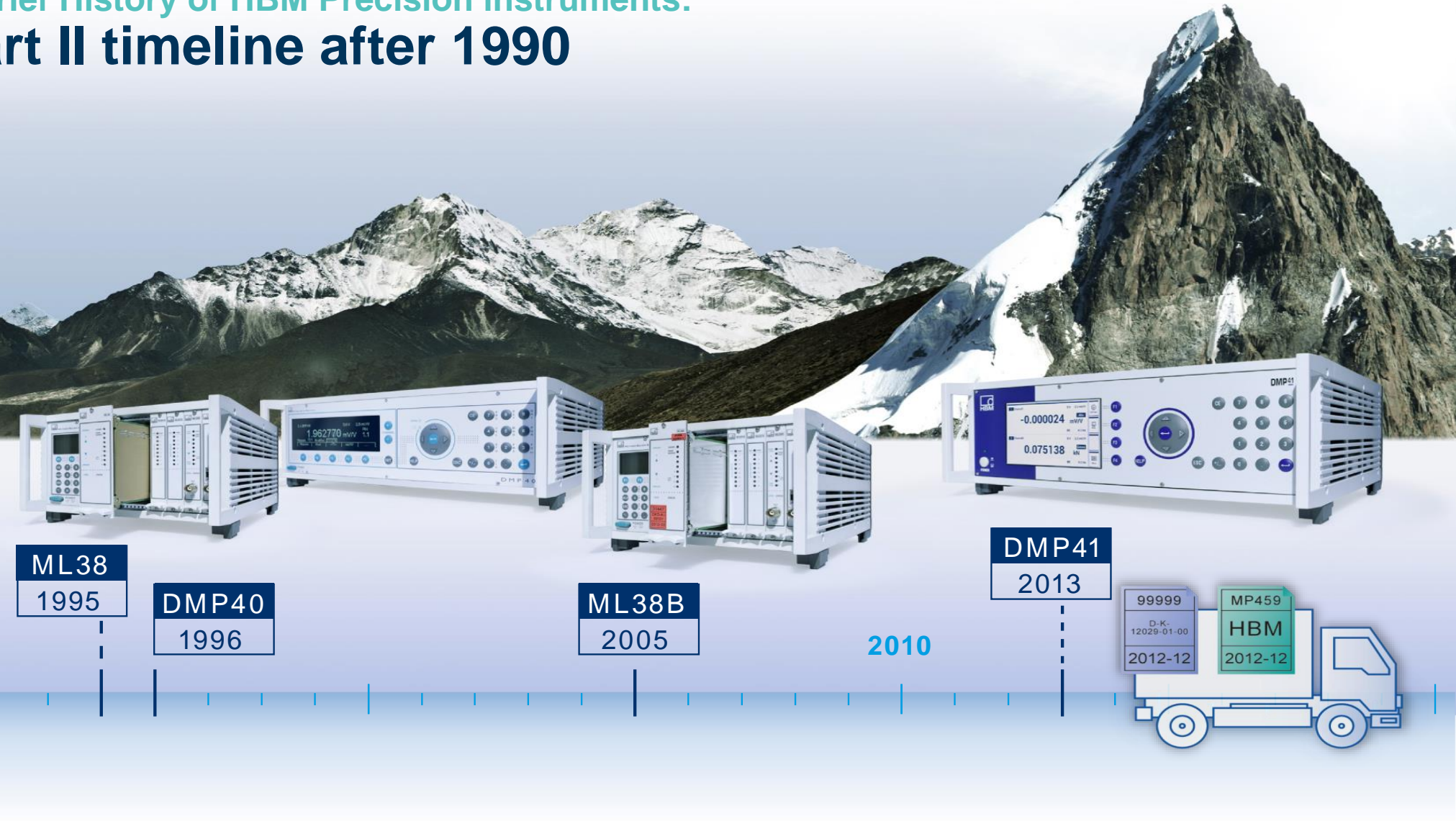
Manfred Peters,  
former vice president of PTB

A Brief History of HBM Precision instruments:  
**Part I timeline before 1990**



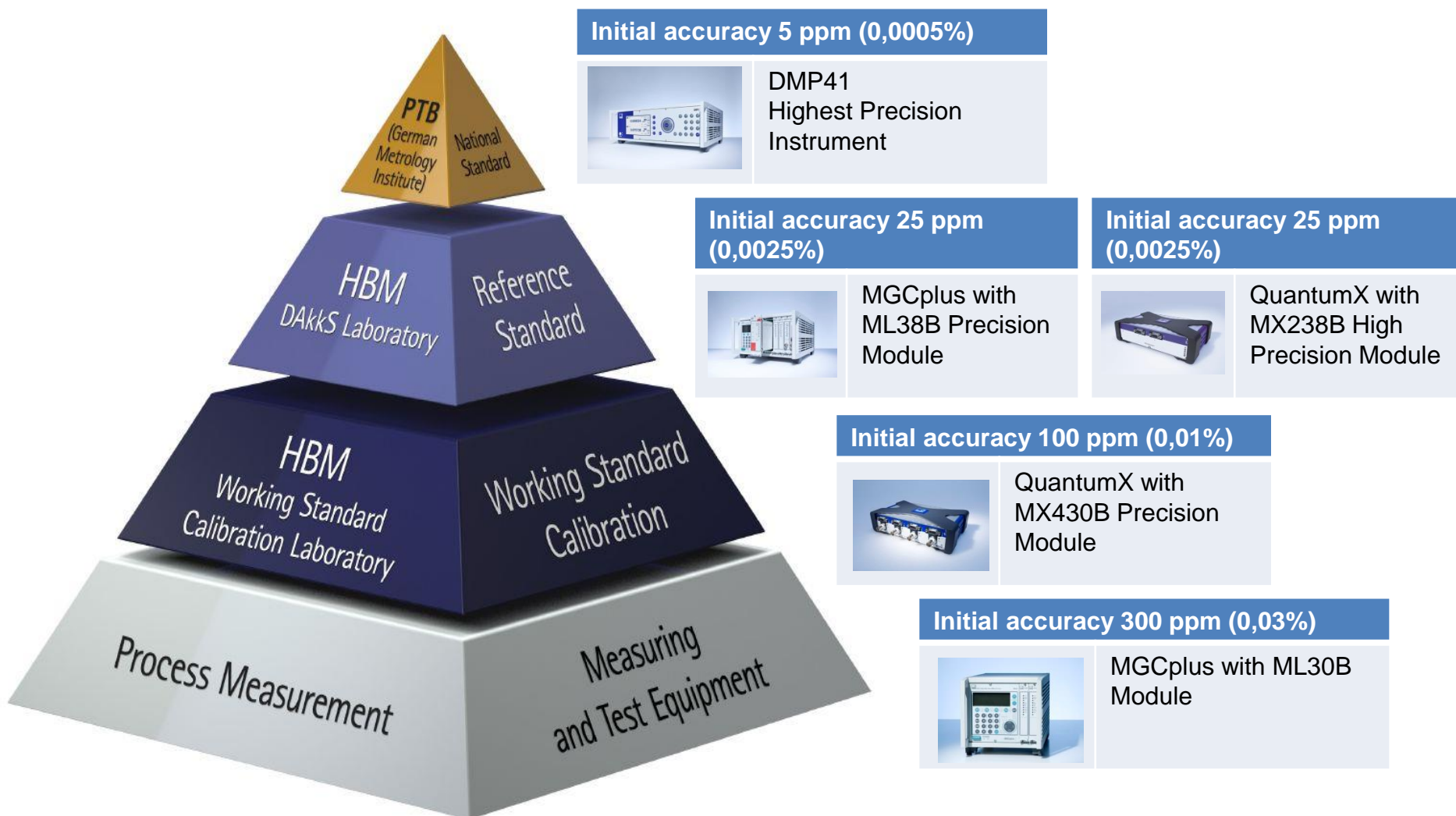


A Brief History of HBM Precision instruments:  
**Part II timeline after 1990**



# Our choice of precision measuring instruments

in relevant calibration levels



# DMP41 – HBMs „Flagship precision amplifier“

## Simultaneous measurement

### By using well proven principles:

- 225 Hz carrier frequency amplifier
- Inductive voltage divider
- 6- wire-technique
- Indicated with 2 Mio. Digits

### „Background Calibration“

- No freezing but continuous proceeding of the live measurement

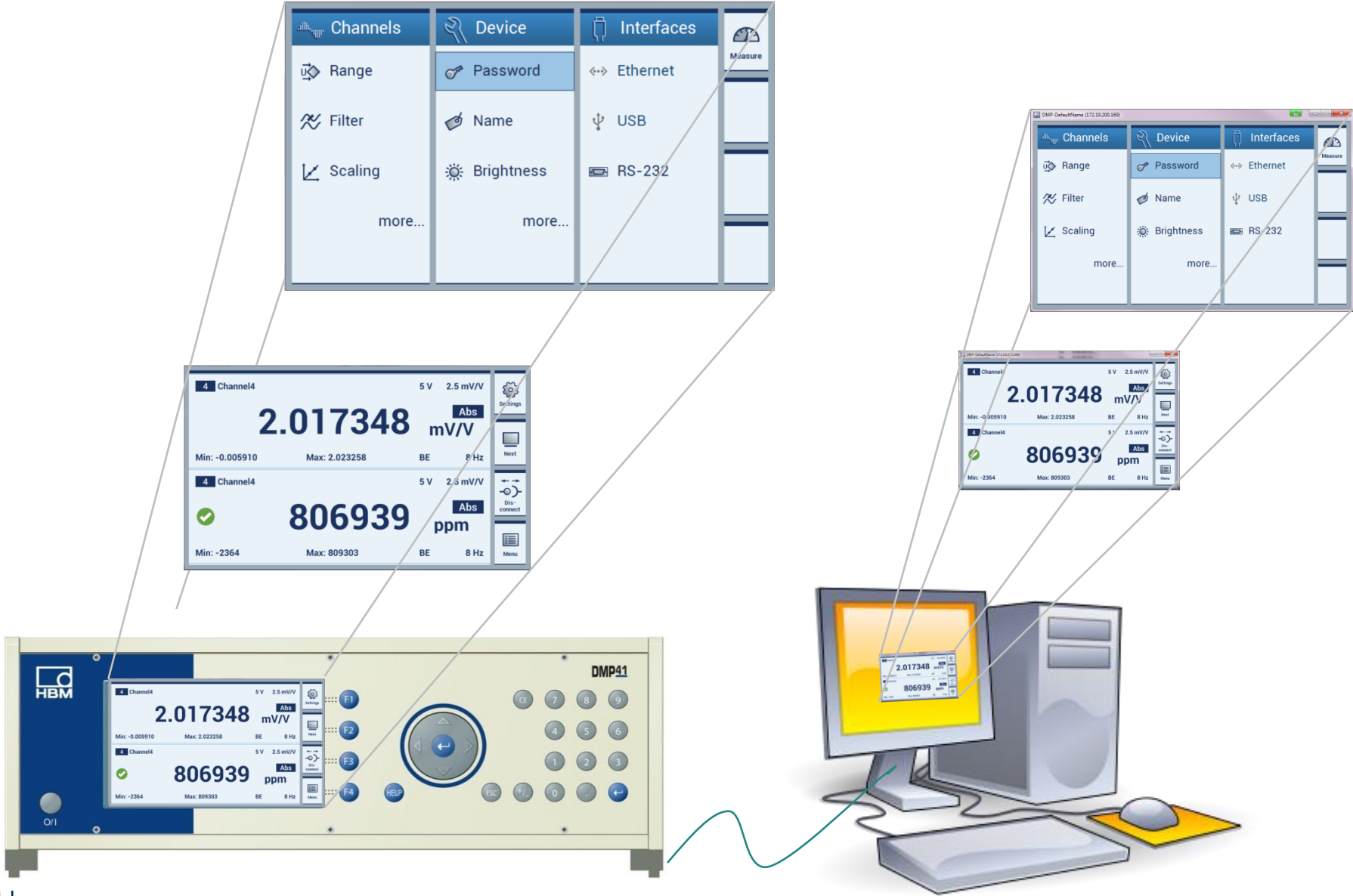


DMP41 in Setup mode





# Versatile Graphical Interface: Multiple possibilities for operation



# QuantumX Precision module – MX238B

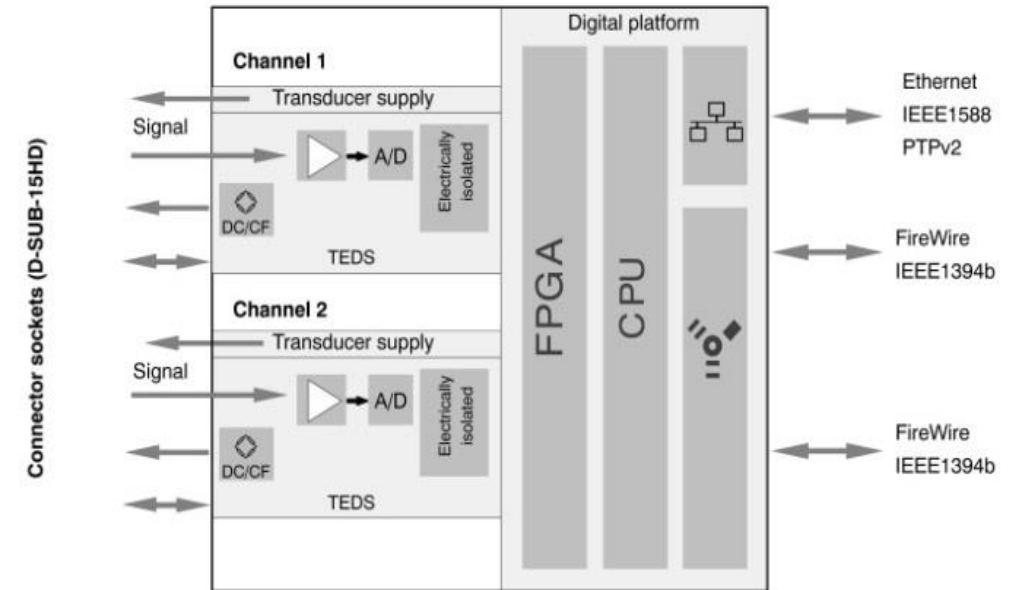
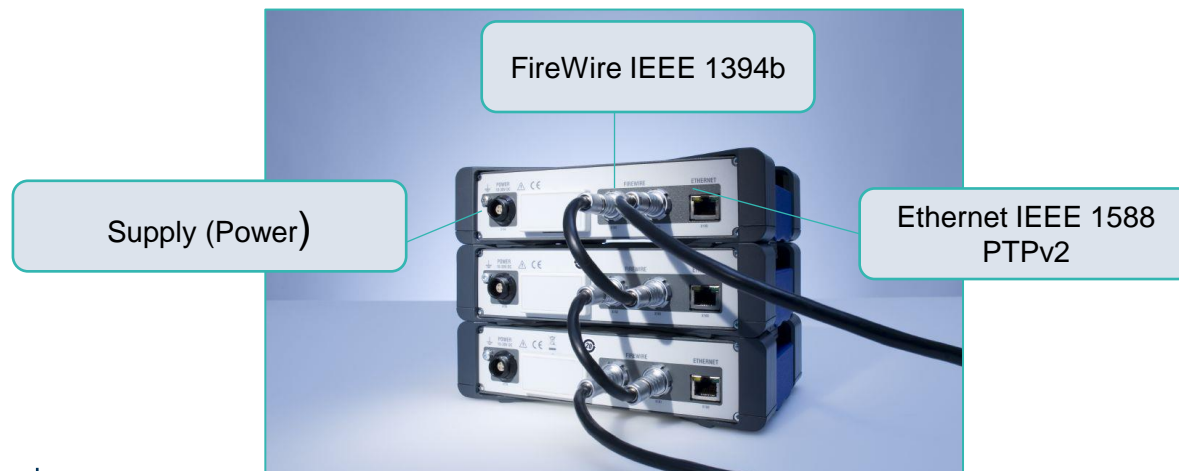
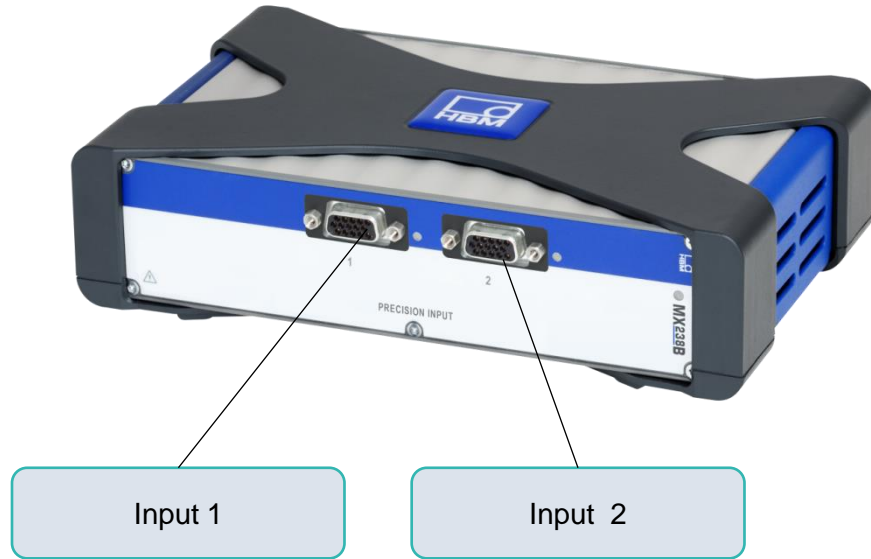
- ▲ New integration with high compactness first time in this class
- ▲ Can be combined with all modules of the extensive family of devices QuantumX
- ▲ TEDS : Transducer is detected without additional wiring in seconds,
- ▲ Thus individual characteristics
- ▲ Can be taken into account

Accuracy  
class  
0.0025



# Details on QuantumX Precision module – MX238B

- Two precision strain gauge bridges measuring channels Per channel 24-bit A / D converter Carrier frequency 225 Hz Patented background calibration



Block Diagram of Quantum MX238B

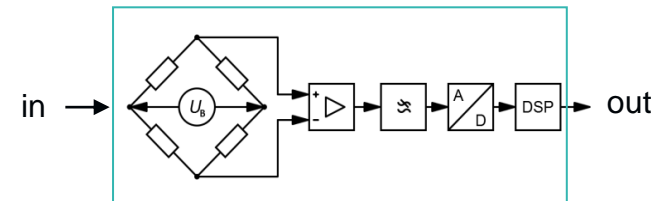
# Requirements to precision amplifiers

Strain gauge based forces, torques, and pressure transducers require high-grade instrumentation to be used.

- The resolution, defined as the smallest detectable change in an input signal's value
  - Depends on the ADC resolution
  - Is limited by the signal-to-noise ratio as the physical limit
- A “7-digit” display is a must-have (preferably 2 million digital steps)
  - In this case, the resolution no longer is a factor that is essential to the calculation of the overall uncertainty
- Linearity, Reproducibility and drift of the amplifier should be small.
- For our amplifier temperature effects on the zero signal ( $TC_0$ ) and on the sensitivity ( $TC_{span}$ ) are both very small.

The amplifier should be selected such that its impact on the overall measurement uncertainty compared with the transducer (for which an arbitrarily small uncertainty cannot be achieved) can be neglected.

► Today, it is realistic to place such high demands on the amplifier.





# Summary

## METROLOGY



- ▲ We can globally assist you in your attempt **to minimize measurement uncertainty**
- ▲ **Offer trusted results:** leading competence in this business field, capture value of our technology **is expressed in a lower measurement uncertainty**
- ▲ **We have the latest updates** by keeping close contact to National Metrology Institutes and even BIPM.
- ▲ Get further Information on **our offered choices**
  - <https://www.hbm.com/en/2315/precision-amplifiers-and-calibration-instruments/>

# Use our guidelines on hbm.com, of how to built a calibration system

## Sensors (Calibration Products)

Reference force transducers



Reference torque transducers



Reference pressure transducers



## Precision Amplifiers (Calibration Products)



Measuring amplifiers and electronics for highest-precision tasks  
When highest precision of test results counts, measuring amplifiers and electronics from HBM are the first choice throughout the world.

Not only are users in the fields of industry, research and universities convinced by the quality of HBM's high-precision data acquisition instruments, but many National Metrological Organizations, too, have employed, for example, the DMP41 precision measuring amplifier as a reliable reference instrument.

Pushing the limits of physical feasibility

The key factor to ensure minimal measurement uncertainty is the choice of measurement principle. The demand for more precise transducers and amplifiers has grown as a consequence of strain gauge technology becoming increasingly widespread over the past decades. Today, whenever low measurement uncertainty is required, transducers based on strain gauges (SG) using the Wheatstone bridge circuit have a clear advantage. HBM has pushed the physical limits of the technical possibilities provided by this technology.

Precision measuring instruments



Highly precise reference measuring chains ensure reliable results

When measurement results of highest precision are required, HBM offers both sensors and amplifiers as well as precision measuring instruments providing very low measurement uncertainty to allow measuring chains with an extremely high overall accuracy to be implemented; these are also called reference measuring chains.

Force transducers, torque transducers and pressure transducers are also available as so-called reference transducers with a particularly small contribution of the measurement uncertainty.

Advantages

- HBM provides strain gauges, amplifiers and data acquisition software and thus covers the entire measuring chain, with measurement uncertainty achieving the lowest possible level.
- HBM takes an active part in many international metrological research projects (BIPM, OIML, GUM) enabling product development to benefit from the latest scientific findings.
- Strain gauge based reference transducers for calibration are mainly implemented in the form of monolithic measuring bodies. This enables sensors to take high loads and show constant properties over the entire measuring range, which means that they offer both extremely high precision and long service life.
- HBM has been in the market for precision measuring instruments for over 40 years. Key product characteristics such as the extremely high long-term stability could thus be monitored and confirmed over a long period of time.
- HBM's precision measuring instruments are being used in over 100 national metrology institutes throughout the world.

Bridge calibration units



## Use of the Calibration systems

Applications for HBM high-precision measurement systems

### Metrology

Measurements are becoming ever more accurate. Instruments increasingly precise. Metrology as a branch of science focuses on measurement reproducibility of measurement results throughout the world is key in this context. Hence it is essential in metrology to guarantee traceability from any calibration level to the primary standard. The primary standard is ensured by the national metrology institute and is the standard with the smallest measurement uncertainty in the respective country.

Metrological traceability needs to be guaranteed

These traceability "chains" for ensuring the reproducibility of measurements in practice are based on reference measurement chains implemented with HBM transducers and highest-precision measuring instruments. Over 100 metrology institutes throughout the world use HBM high-precision test and measurement equipment.

Users benefit from the fact that strain gauge technology enables measurement chains with an extremely small measurement uncertainty to be implemented which, at the same time, have excellent long-term stability.

### Sensor production

When producing transducers and sensors, it is often beneficial to permanently integrate all devices into the production process. HBM's DMP41 high-precision measuring instrument satisfies this requirement. DMP41 has been designed for installation in control cabinets and allows convenient use in environments with demanding EMC conditions such as those encountered in production.

Calibration and recalibration  
Regardless of the product type involved - be it force transducers, torque transducers or pressure transducers (force sensors, torque sensors, pressure sensors) or load cells - HBM relies on DMP41 when it comes to offering sensors with maximum measurement accuracy. Manufacturers can use DMP41 to calibrate their customers' sensors and, if necessary, recalibrate them.

The key advantage is that two or six measurement channels can be made available, thus enabling sensors with a much smaller measurement uncertainty than usual to be tested and, in addition, produced at the same time.

### Comparison measurements

Measurement errors can prove fatal in some branches of industry. For example in aviation: When measuring altitude of an aircraft, the slightest deviation could potentially endanger human life. For this reason, a small measurement uncertainty is indispensable for such critical applications. It is guaranteed by comparison measurements. Here high-precision measuring instruments from HBM are particularly well suited and have been used in comparison measurements, on a national and international level, for decades.

Interlaboratory comparisons with small measurement uncertainty  
Interlaboratory comparisons compare and analyze the results provided by several measurement chains. Here users benefit from the extremely small measurement uncertainty and excellent long-term stability made possible by strain gauge technology.

Recommended for you





# Take advantage of our participation in basic research – We successfully participated in Metrology Research Projects

## Selected Topic complexes

EMPIR 17IND12 MET4FoF „**Metrology for the factory of the future**” in conjunction with joint advisory board in EMPIR “SmartCom”

EMPIR 14IND14 “**Traceability in the MNm-range**”, Followed up by ENG EFCY 019 “**Traceable mechanical and electrical power measurement for efficiency determination of wind turbines**” soon

EMRP IND 09 “**Traceable Dynamic Measurement of Mechanical Quantities**”, Followed up by EMPIR 08 SIP14 Support of impact “**dynPT -Dynamic PRT -Development of measurement and calibration techniques for dynamic measurements**”



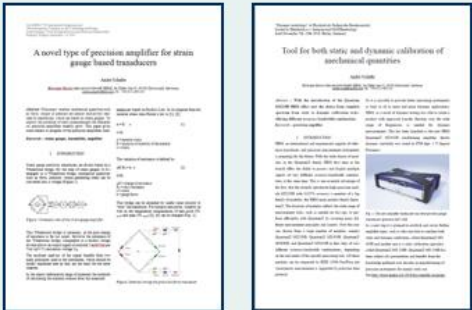
Industrial Dynamic Measurements:  
A Best Practice Guide

## Metrology Publications

### Books with HBM content



### White papers on metrology events



### Deep publications with extensive content



### Publications on special events



# Reference / Calibration Systems and Calibration Services



Reference force transducers



Reference torque transducers



Reference pressure transducers



High precision instruments



Calibrators /Bridge standards



Microphone calibration systems



Vibration transducer calibration systems



Systems for calibration of SLM



force transducer calibration



torque transducer calibration



pressure transducers calibration



mV/V and system calibration



Microphone calibration



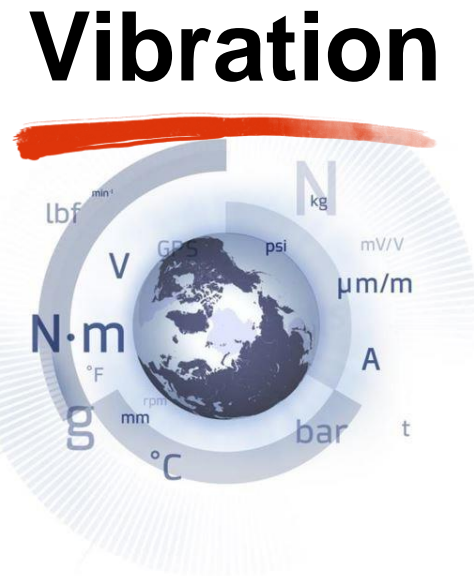
Vibration transducer calibration



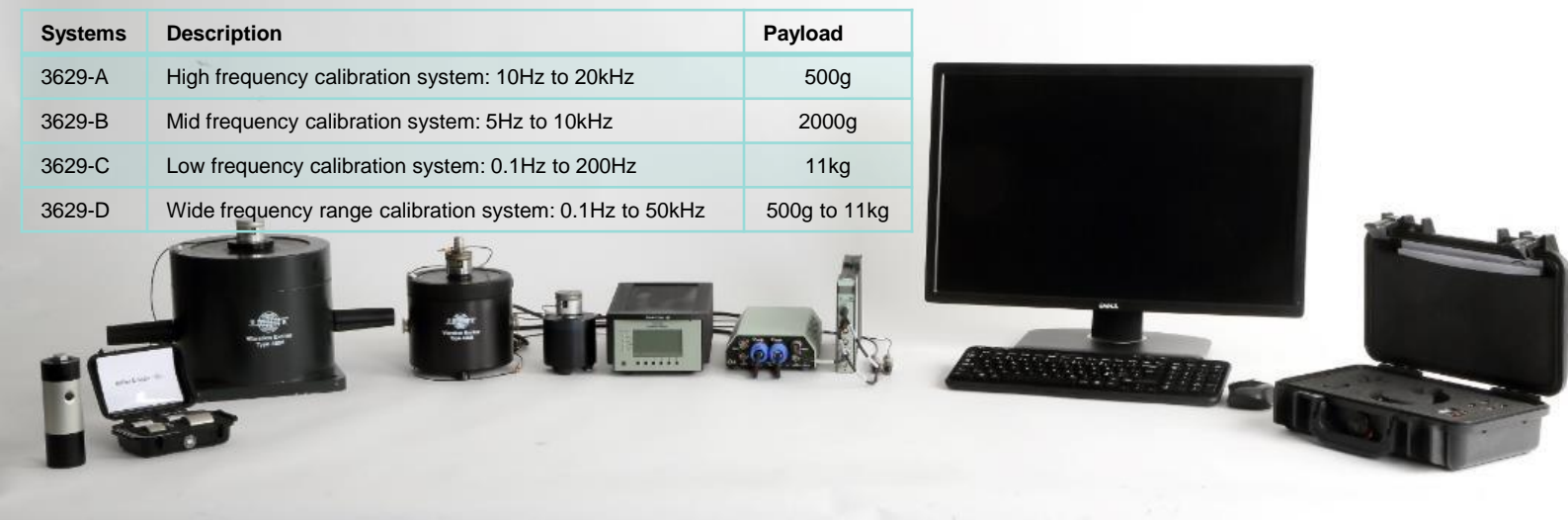
SLM calibration

# Vibration Calibration Systems for accelerometer calibration

## Recently Standardized Secondary Vibration Calibration Systems



Systems	Description	Payload
3629-A	High frequency calibration system: 10Hz to 20kHz	500g
3629-B	Mid frequency calibration system: 5Hz to 10kHz	2000g
3629-C	Low frequency calibration system: 0.1Hz to 200Hz	11kg
3629-D	Wide frequency range calibration system: 0.1Hz to 50kHz	500g to 11kg

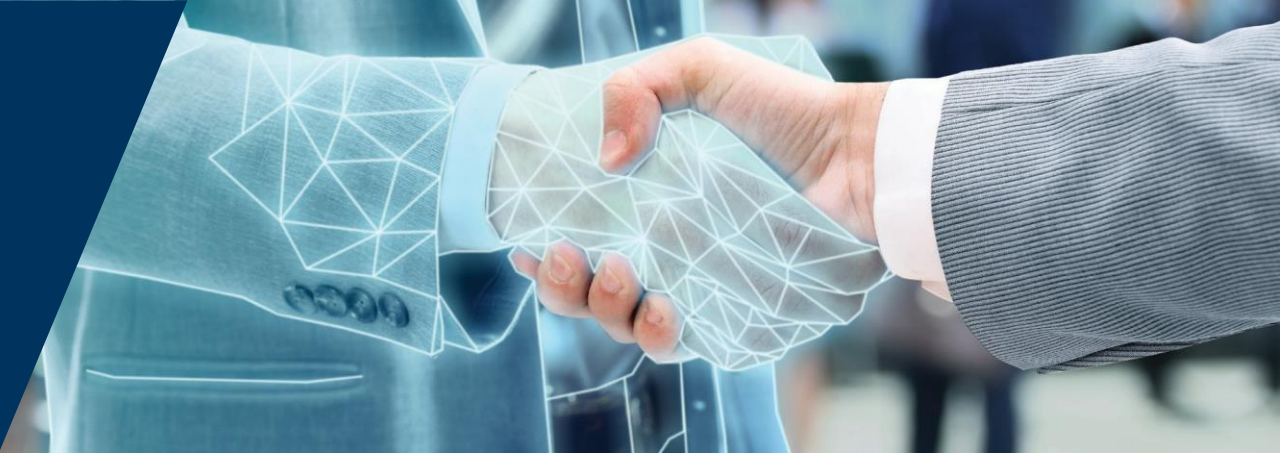




HBK PRODUCT PHYSICS CONFERENCE

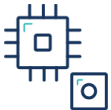
# HBK's Global Virtual Conference experience

October 13th – 14th – 15th



## **Presentations**

Our presenters are the highlight of the conference. They will not only share best practices with you but also share their expert knowledge on a wide range of applications.



## **Technology**

See the latest test and measurement solutions from HBK and its sub-brands, HBM, Brüel & Kjær and Prenscia, including electric power testing, smart sensors and more.



## **Networking**

Seize this opportunity to network with other HBK users in our virtual networking areas. Share experiences and expand your personal network during and after the conference.



## **Interaction**

Participate in our interactive exhibition area and explore real-life challenges with experts in live discussion panels.

**Want to learn more? Register today**

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# Questions?



# Thank You

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andre.schaefer@hbkworld.com



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