Welcome to the Webinar
Basics of Precision Measurement by Strain Gauge based Precision Measurement Chains up to highest Forces, Torques and Pressures
André Schäfer

- Business Development Manager High Precision Measurement Chains at HBM
- PhD in measuring technique & precision instruments
- Holds 3 patents, > 100 white papers published
- More than 30 years experience in sensor technology
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Dr. André Schäfer
Business Development Manager
High Precision Measurement Chains
This webinar gives a general introduction to high-precision strain gages based on strain gauges

**Precision transducers:**
- Force, torque and pressure transducer with highest accuracy
- Tracing back these quantities

**Precision Bridge Amplifier:**
- DMP41, the world's most accurate amplifier for strain gage measurements
- QuantumX MX238B, a 2-channel module with accuracy class 25 ppm

**Important influencing factors for the overall measurement uncertainty of precision measuring chains based on strain gage measurement technology**
- Our present activities in the calibration field
High precision electronic weighing
The Hottinger Baldwin (HBM) electronic weighing instrumentation has been certified to maintain ±1 digit in 6000 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.

Quality assurance at HBM (around 1970)
Force competence - at a glance

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

HBM participates in various EMRP Force Metrology projects
Torque competence – at a glance

HBM participates in various EMRP Torque Metrology project
Pressure competence – at a glance
Calibration pyramid: Used in all calibration levels in Germany

- Intercomparison in between national institutes
- PTB (German National Metrology Institute)
- Accredited laboratories (DAkkS) e.g. HBM
- Working standard calibration laboratory, e.g. HBM
- Industrial applications

Increasing accuracy

Traceability
<table>
<thead>
<tr>
<th>Measurand Force</th>
<th>Measurand Torque</th>
<th>Measurand Pressure</th>
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<tbody>
<tr>
<td>Magnitude</td>
<td>Magnitude</td>
<td>Magnitude</td>
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<tr>
<td>Capability</td>
<td>Feasibility</td>
<td>Capability</td>
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</table>

**Available:**

- **Force**
  - **Magnitude**: 16.5 MN
  - **Implemented at PTB**
  - **Measurement uncertainty**: $2 \cdot 10^{-4}$

- **Torque**
  - **Magnitude**: 1.1 MN·m
  - **Implemented at PTB**
  - **Measurement uncertainty**: $1 \cdot 10^{-3}$

- **Pressure**
  - **Magnitude**: 1.2 (1.4) Gpa
  - **Implemented at PTB**
  - **Measurement uncertainty**: $4 \cdot 10^{-4}$

**Medium-term objective:**

- **Force**
  - **30 MN... 50 MN**
  - **Intention of expanding PTB capability**

- **Torque**
  - **5 MN·m / 20 MN·m**
  - **Project started at PTB**

- **Pressure**
  - **1.6 GPa**
  - **Project started at PTB**

**Objective for measurement uncertainty:**

- **Force**
  - **TBD**

- **Torque**
  - **Objective for measurement uncertainty**: $5 \cdot 10^{-3}$
  - **If possible $1 \cdot 10^{-3}$**

- **Pressure**
  - **Objective for measurement uncertainty**: $8 \cdot 10^{-5}$
Quelle: Christian Schlegel, Holger Kahmann, Paula Weidinger, Rolf Kumme
New Perspectives for MN·m Torque Measurement at PTB
IMEKO TC3, Helsinki, 2017
HBM fields of competence

- Force laboratories
- Torque laboratories
- Pressure laboratories
- Manufacturing of transducers
Measuring Large Forces, Torques, and Pressures: Avoided for a Long Time

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<th>Measurand Force</th>
<th>Measurand Torque</th>
<th>Measurand Pressure</th>
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<tbody>
<tr>
<td>Application</td>
<td>Motivation</td>
<td>Application</td>
</tr>
<tr>
<td>MN</td>
<td>kN·m</td>
<td>MPa</td>
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<tr>
<td>Civil engineering</td>
<td>Safety of buildings</td>
<td>Ship building applications</td>
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<tr>
<td>MN</td>
<td>MN·m</td>
<td>GPa</td>
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<tr>
<td>Railroad/Aerospace</td>
<td>Safety of infrastructure</td>
<td>Wind power applications</td>
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Recommendations to make the right choice in relevant calibration levels

- **Initial accuracy 5 ppm (0.0005%)**
  - DMP41
    - Highest Precision Instrument

- **Initial accuracy 25 ppm (0.0025%)**
  - MGCplus
    - with ML38B Precision Module
  - QuantumX
    - with MX238B High Precision Module

- **Initial accuracy 100 ppm (0.01%)**
  - QuantumX
    - with MX430B Precision Module

- **Initial accuracy 300 ppm (0.03%)**
  - MGCplus
    - with ML30B Module
Most important milestone in the history of HBM Precision instruments

Introduction to major precision series

The origin of the DMP series – HBM’s flagship

Digital compensator DK 38S6

...thanks to increasing demands and good cooperation

Manfred Kreuzer, former head of R&D at HBM

Manfred Peters, former vice president of PTB
History of HBM Precision instruments: time line until 1990

Time line

- **DK37**: 1973
- **DK37A**: 1978
- **DMP39**: 1980
- **DK38**: 1982
- **DK38S6**: 1983
- **HBM first German Calibration Service (DKD), now DAkkS**:

1990
History of HBM Precision instruments (II): time line until today
The world's most precise amplifiers for strain gauge based sensors **accuracy class 0.0005** (respectively 5 ppm)
The most important improvements on the instrument at a glance (I)

1) **All versions allow parallel (simultaneous) measurements**

   - DMP41-T2 version: **Two** channel high-precision amplifier
   - DMP41-T6 version: **Six** channel high-precision amplifier

2) **excellent accuracy** does not allow further improvement due to physical limitation

   **However** accuracy class 0.0005 is even maintained at 10 V/m electric field strength EMC

   (previously under these conditions DMP 40 was accuracy class 0.005 only)

3) **Totally new graphical user interface** (GUI) with touch screen
Multiple possibilities for operation
4) „Background Calibration“-

- No freezing but continuous proceeding of the live measurement

5) **Up-to-date interfacing for current laboratory environment**

- Ethernet
- USB Device
- USB Master

Use direct link to product page on HBM.com for more details: http://www.hbm.com/dmp41
QuantumX Precision Module—MX238B

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

Accuracy Class: 0.0025
QuantumX High Precision – MX238B

- TEDS: The transducer is detected in seconds without additional wiring, individual features are taken into account
- 6-wire technology compensates for cable length
- AutoCal routines in the background provide long-term stability and compensate for ambient temperature changes
Wide choice of accuracy – bandwidth combinations

• With the introduction of this module QuantumX offers the ability to process and display multiple signals of very different accuracy-bandwidth combinations at the same time.

• Now the user can choose from now for a number of modules, namely Quantum MX238B, Quantum MX430B, Quantum MX840B, and Quantum MX410B in fine steps of very different accuracy-bandwidth combinations.

• You may choose them depending on the specific needs of the specific measuring task.

• Real-time integration: EtherCAT (CX27B), CAN(MX471B)
Used in all calibration levels and with many different quantities

Application in the calibration world…

But much more in Industry
Mix signals with different bandwidths-accuracy combinations:

Force
Torque
Pressure

Sensor manufacturing

Test stands

Wind tunnel applications

And much more…
Important Influencing Factors of SG-Based Measuring Equipment (I)

Transducer:

Measurement uncertainty specified in the DAkkS calibration certificate:
• Linearity
• Hysteresis
• Relative standard deviation of repeatability ($\sigma_{rel}$)

Application-specific:
• Temperature effect (related to 10 K) on the zero signal ($T_0$)
• Temperature effect (related to 10 K) on the sensitivity ($T_{span}$)

Amplifier:
• Will be considered separately (see on of the next slides)
Of special importance to forces:
- Angle of force application ➤ Lateral force, bending moment

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 large 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
Requirements for Amplifiers

Very large forces, torques, and pressures 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
- Reproducibility and drift should be 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.
The metrology activities of HBM

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<td>Meeting with representatives of the NMIs at the HBM booth; For example: at the &quot;testXpo&quot; in Ulm</td>
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<td>Workshops with PTB &amp; Helmholtz Fonds e. V.: lectures, booth, active participation</td>
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<td>Participation in round tables of metrology</td>
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19th GMA/ITG-Conference „Sensoren & Systems“ gives insights into the latest trends in sensors and sensor systems for industrial use

• is the most important German-speaking scientific event in the field of sensor technology

• HBM is involved in the program committee of the event

• HBM contributed significantly to the sessions "Mechanical Sensors" 1 + 2, both will take place on Tuesday, 26.06.2018

Im NCC Mitte, Messe Nürnberg

Further details see: https://www.sensor-test.de/sensor-test-2018-fuer-kongressteilnehmer/
Submissions of HBM for the XXII IMEKO World Congress

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<th>Technical Committee</th>
<th>Topic of session</th>
<th>Topic of the paper</th>
<th>Applying for</th>
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<tr>
<td>TC3</td>
<td>measurement of force, mass and torque</td>
<td>Improving the characteristics of a high-precision measuring amplifier by a powerful digital signal processing</td>
<td>Oral presentation</td>
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<tr>
<td></td>
<td>measurement of force, mass and torque</td>
<td>A new radially symmetric force transducer for compression forces</td>
<td>Oral presentation</td>
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<tr>
<td></td>
<td>measurement of force, mass and torque</td>
<td>Torque transfer standard TN with improved usability for inter-laboratory comparisons</td>
<td>Oral presentation</td>
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Contents of the latest HBM seminar on “The practical way to determine measurement uncertainty (MU)”

- Based on the GUM guideline
- Measurement uncertainty – Definition and significance
- Calculating steps for determining measurement uncertainty and representing it graphically
- Which parameters contribute to measurement uncertainty
- How to estimate parameters that cannot be read from a specification
- What to do to compute measurement uncertainty

Quote: “Don’t be afraid, determining a measurement uncertainty does not require any complex mathematics. All you need is what you already know about the measurement task.”

Check out dates at: www.hbm.com/seminars
Additional informationen

More information can be found on our website:
More detailed information on calibration services


Calibration Service from HBM

Benefit from the competence and experience of our DAkkS-accredited calibration laboratory in conformance with DIN EN ISO/IEC 17025!

- [Your route to a calibration certificate](#)
- [What you can expect from HBM calibration](#)

Our range of calibration services

- [Force calibration service](#)
- [Pressure calibration service](#)
- [Voltage ratio mV/V calibration service](#)
- [MGCoS / PMX / Spider8 system calibration](#)
- [QuantumX system calibration](#)
- [Torque calibration service](#)

Why calibrate at HBM?

Many years of experience in the field of calibration

In 1977, the first accredited German Laboratory was based at HBM.

Calibration service and measurement technology from a single source

HBM has the know-how in manufacturing. Our staff is highly competent where measurement technology is concerned – you can count on that.
Any questions?

- If you have any questions, please do not hesitate to contact us: webinar@hbm.com
- Or email the presenter directly: andre.schaefer@hbm.com
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