Welcome to the webinar
‘Force measurement using strain transducers’
Speakers

• **Thomas Kleckers**  
  - Joined HBM in 1992 (Strain Gauge Development)  
  - 2008 Product Manager Force Sensors  
  - Education: Study of Phyiscis at University of Applied Sciences Duisburg

• **Michael Guckes**  
  - International Product Management IMS  
  - HBM Test and Measurement  
  - Product manager for industrial amplifiers and software  
  - Graduate engineer  
  - 20 years experience in factory automation
Methods of measuring forces

Inline Force Measurement:

The sensor is calibrated, mounted in the flux of force
All force shunts lead to a measurement error
Methods of measuring forces

Base of „inline“ load cells, based on strain gauges

Spring body

The force applied on the spring body leads to strain. Strain gauges convert the strain into a change of resistance.

The Wheatston bridge changes the change in resistance into a measurable voltage.

Output Signal

\[
\frac{U}{U_0} = \frac{k}{4} \cdot (\varepsilon_1 - \varepsilon_2 + \varepsilon_3 - \varepsilon_4)
\]

\[
\frac{U}{U_0} = \frac{2}{4} \cdot (1000 \cdot 10^{-6} - (1000 \cdot 10^{-6}) + 1000 \cdot 10^{-6} - (-1000 \cdot 10^{-6}))
\]

\[
\frac{U}{U_0} = 2mV / V
\]

Thomas Kleckers
Methods of force measurement

Principle of inline force measurement using piezoelectric sensors

The force to be measured leads to very little deformation inside a crystal.

This little deformation moves the center of charge of each unit of elementary cell. A charge on the surface of the crystal occurs and can be measured.
Inline force measurement - advantages

- Use of calibrated sensors – no need for calibration in mounting position
- Very low measurement uncertainty
- Load cells for forces from 10N to 5MN available
Inline force measurement

- Stiffness of the object is influenced by the stiffness of an inline load cell
- High forces => high capacity load cells => heavy and large dimensions
- Sensor integration sometimes difficult
Measuring forces by using strain sensors

If a force is applied to any kind of object, a strain can be obtained:

- The strain level is depending on the stiffness of the object
- In many cases: linear relation between force and strain
- By calibrating the output signal of the strain sensor the force can be measured

Bridges, civil engineering, molding machines, all kind of presses, wind mills, silo weighing....
Press application

ACCEPTABLE MOUNTING AREA (COMPRESSION)

NUETRAL ZONE

PREFERRED MOUNTING AREA (TENSION)

SHADED AREAS ARE BEST MOUNTING LOCATIONS
Solution 1: Strain Gauges

- Need to be glued on the objects
- Need to be protected
- Need to be wired (which is not that easy)
- Low signal
Strain Links

- To be screwed
- Already wired, with integrated cable (suitable for press applications)
- Strain gauges are well protected
SLB700 VA

- Strain link with integrated electronic
- Output: 4…20mA oder 0…10V
- Teach in Electronic
- Two digital inputs for span and zero point
- Bandwidth 1 kHz (-1dB)
- Mechanical compatible to the old version

SLB700A/06VA strain links with integrated electronic:
1-SLB700A/06VA1-1 Output 0…10V
1-SLB700A/06VA2-1 Output 4…20mA
For low strain levels

CST/300

- piezoelectric strain link
- High sensitivity of app. 50pC/µm/m
- Mounted with just one screw
- Parallel connection is possible
- Insensitive against acceleration or movement of the cable
- Very compact design, just 45 mm long
### The right sensor for every measurement task – From HBM

<table>
<thead>
<tr>
<th>Low force shunt, higher strain level, Extremely flat, for retrofitting and if a strain link cannot be screwed</th>
<th>Standard product for low strain level, compensation of bending, higher requirements to the intelligence of an industrial amplifier system (PMX)</th>
<th>Standard product for lower strain levels, integrated electronic, very economic solution</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Strain Gauges" /></td>
<td><img src="image2.png" alt="SLB 700 and amplifier system" /></td>
<td><img src="image3.png" alt="SLB 700 VA with integrated electronic" /></td>
</tr>
<tr>
<td>Extremely low strain level, very stiff designs, advantages of the piezoelectric principle no space available</td>
<td></td>
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</tr>
</tbody>
</table>
Signal of the strain sensors in mV/V in pC
Use cases and range of applications

**Three key factors count in industry: quality, time and cost**

- Manufacturing Monitoring, Test Rigs, Functional Test Stands, Condition Monitoring
- **Absolute cost control** through integrated systems and functionality according to Industry 4.0
Design concept – Flexibility for the application

Hardware

- Housing with Ethernet, USB host, Synchronization, CAN master/slave (opt.)
- 10-30 VDC power supply
- Flexible slots for sensor, analog output, digital I/O and interface modules
- Slot for communication & bus interfaces
- The slots are equipped as specified by the customer
- Cards can be removed for service
- Cards are calibrated, no recalibration in the field necessary
Use case Process control

- Greater accuracy makes it possible to record manufacturing tolerances more precisely.
- Components are precisely tested and manufactured with the necessary tolerance.
- Reduces rejects and conserves resources while maximizing output.

Process monitoring with conventional measuring amplifiers, high rejection rate due to measuring inaccuracies.

Increased efficiency with PMX, optimum yield with precise measurement results.
TEDS – Immediate usage of (calibrated) sensor data

- TEDS = Transducer added Data Sheet (acc. IEEE1451.4)
- No manual adjustments of the sensor data and amplifier data necessary !!!
- Readout of TEDS-data via existing sensor cables (no additional cables necessary) (0-Wire / 1-Wire)
  ➔ Cable and plugs can be used as usual
Application

- Industrial production, presses, test-stands,..
- Rough conditions with dust, humidity and vibrations
Practical example Process Monitoring

Industry compliant measurement technology

- SLB700 Strain sensors measuring bending on each column
- 2 sensors per column:
  - mounted in opposite position, allow bending compensation of column
  - force measurement on 2 or 4 columns allow load-distribution

\[
x = \frac{F_1 \cdot x_1 + F_2 \cdot x_2 + F_3 \cdot x_3}{F}
\]

\[
y = \frac{F_1 \cdot y_1 + F_2 \cdot y_2 + F_3 \cdot y_3}{F}
\]
Process evaluation

- Faulty stroke
- Warning max.
- Working range
- Warning min.
- Working max.
- Working min.
- Peak detection
- Peak clearing
- Window evaluation

- Machine stop
- Alarm history

- Time [ms]
- Angle [deg]
Modern automation systems provide accurate & robust measurement technology, control and monitoring functions in real-time and easy operation without special programming skills.

| Measurement                                                                 | Evaluation                                                                 | Automation                                                                 |
|                                                                           |                                                                           |                                                                           |
| PMX detects your transducers automatically via TEDS for the most important measurement variables. This saves time and prevents errors. The high resolution of 24 bits allows for accurate partial load measurements and high measuring bandwidths. A sampling rate of 19.2 kHz or 38.6 kHz for frequency measurements for every channel ensures high measuring bandwidths. | PMX analyzes and processes your data in real time (< 1 millisecond). The measuring amplifier system has integrated algorithms to support the actual measurement and pre-process data. 32 computing channels are available. That replaces small and mid-size machine control units and saves a tidy sum of money. | PMX transfers data to your automation system. Ethernet-based fieldbuses and Soft-PLC as well as digital inputs/outputs and monitoring outputs ensure fast machine control and automation. |
| SG full bridges                                                           |                                                                           |                                                                           |
| SG half bridges                                                           |                                                                           |                                                                           |
| Inductive full bridges                                                   |                                                                           |                                                                           |
| Inductive half bridges                                                   |                                                                           |                                                                           |
| Active sensors for current and voltage                                    |                                                                           |                                                                           |
| LVDs                                                                      |                                                                           |                                                                           |
| Potentiometric sensors                                                    |                                                                           |                                                                           |
| Piezoresistive sensors                                                    |                                                                           |                                                                           |
| Current-fed piezoelectric sensors (IEPE)                                  |                                                                           |                                                                           |
| Frequency signals                                                        |                                                                           |                                                                           |
| Angular/incremental encoders                                              |                                                                           |                                                                           |
| SSI sensors                                                               |                                                                           |                                                                           |
| PWM sensors                                                               |                                                                           |                                                                           |
| Magnetic transducers                                                     |                                                                           |                                                                           |
| Pulse counters                                                           |                                                                           |                                                                           |

**Scaling**
- Two-point scaling
- Characteristic curve table
- Polynomials
- Taring
- 3x3 matrix
- Cartesian to polar coordinates
- SG stress analysis
- Dead time

**Technology functions**
- Two-point controllers
- PID controllers
- Signal generators (square, triangle and sine wave)
- Logic blocks (AND, OR, etc.)
- Edge detectors
- Timers
- CODESYS channel

**Mathematical functions**
- Adder
- Multiplier
- Divider
- Multiplier 2:1
- Pulse width measurement
- Counter
- Integrator
- Differentiator
- Modulo function
- Constant signal

**Evaluation functions**
- Angle-synchronous filter
- Peak values
- Hold function (triggerable)
- Mean values (arithmetic RMS)
- Trigger function (range, pulse)
PMX – Real-time controls

- Analog out (+/- 10V): Monitoring
- Calculated channels: Peak-detection, Tolerance windows, Counter alatm, Counter strokes...
- Limit switches & digital I/O: Alarm, Machine Stop...
- Force measuring channel: Direct or bypass
- Optional signals: Displacement, Rotational speed angle

- Optional signals: Displacement, Rotational speed angle
PMX - Innovative Web Technology

Flexible and cost-saving

Whether you are a machine operator or installer, configurable, three-level user administration (operator, service, administrator) always gives you access to all relevant device and diagnostic data. This cuts down on the number of software tools you need and reduces complexity and system faults.

Easy integration with the control system

HBM measurement technology can be easily integrated with the control system and test bench environment using various software drivers, the PMX command set, LabVIEW and the .NET/API programming interface. That makes it easy to implement individual solutions and safeguard application know-how.
Direct and indirect measurement methods

Indirect measurement e.g. strain sensor (uncalibrated)

Direct measurement e.g. force sensor (calibrated)

The future work-area (range) of the system should ideally differ max. +/- 10% of the used calibration signal.
For calibration with the PMX two procedures are available:

- It can be used a reference channel of PMX
- or a reference value to be entered manually.

As a result arises in any case, a **linear two-point scaling**.
PMX – Adjustment assistant

Sensors calibration in 2 steps

1. Step

Now the adjustment process starts. In the first step it is measured in unloaded state, in the second step the sensor is loaded. Click “Adjustment” for every step.
PMX – Adjustment assistant

Finish the calibration process and adjust PMX

Tip:
Afterwards there is the possibility to repeat the process as many times at will. The arithmetic average and the standard deviation of the measurement values are generated. This increases the accuracy if necessary.
More detailed information

→ www.hbm.com/pmx
More detailed information


<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>DO1</td>
<td>Compact strain transducer with high accuracy</td>
</tr>
<tr>
<td>SLB700A</td>
<td>Strain transducer for measuring high forces</td>
</tr>
<tr>
<td>SLB700A/06VA</td>
<td>Strain transducer with voltage or current output</td>
</tr>
<tr>
<td>PACEline CST/300</td>
<td>Highly sensitive piezoelectric strain transducer</td>
</tr>
<tr>
<td>Strain Gauges</td>
<td>HBM strain gauges (strain gages) for all strain measurement applications: Experimental stress analysis, durability testing, transducer manufacturing.</td>
</tr>
<tr>
<td>Optical Strain Sensors</td>
<td>High-Performance Optical Strain Sensor</td>
</tr>
</tbody>
</table>
More detailed information


Measurement technology in production

In production, using test and measurement equipment correctly is key to guaranteeing optimal quality. Modern test and measurement equipment in production helps users produce more efficiently and detect errors at an early stage. You will find the major topics and trends in our collection of articles.

White papers on Industrial Process Control

**Extended application possibilities for modern torque measurement in test benches – with PMX**

The PMX amplifier system also enables you to acquire torque and to automate your test bench. This technical article describes how this works and what benefits there are.

**FailSafe press monitoring - measurement technology as an efficiency driver**

The more precisely force is applied in presses, the higher is the quality of the molded parts. Increasing their presses' accuracy is one of the most important challenges for manufacturers of presses and pressing machines.

**Spoilt for choice: piezoelectric or strain gauge based force transducers?**

Two principles have become dominant in force measurement: Piezoelectric sensors and strain gauge (SG) based force transducers. When is which principle appropriate?

**New HMI Software Solutions for Process Monitoring: A Modular System**

Operability and functional control - it is just these requirements that HBM addresses with the new HMI software solutions of FASTpress Suite.

**Plug and play in production monitoring: Intelligent sensors ensure rapid setup times and drastic cost savings**

The "Transducer Electronic Datashow" (TEDS), which has proved itself consistently in test bench technology, offers interesting options for minimizing setup times, particularly in the manufacturing environment.
More detailed information

→ www.hbm.com/webinars

HBM Webinars
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Force measurement using strain transducers
October 12, 2015, 10 a.m., CET
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- Applications
- Strain Gages
- Torque
- Force
- HBM Data Acquisition (QuantumX, catman, PMX)
- Somat eDAQ, eDAQ Lite, SomatXR and SomatCR
- Genesis HighSpeed (GEN series and Perception)
- Weighing
- Other
Any questions?

• Please contact us for further questions. We look forward to your email: emarketing@hbm.com

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  michael.guckes@hbm.com