TECH NOTE :: Mechanical Testing of Electronics using QuantumX

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Abstract

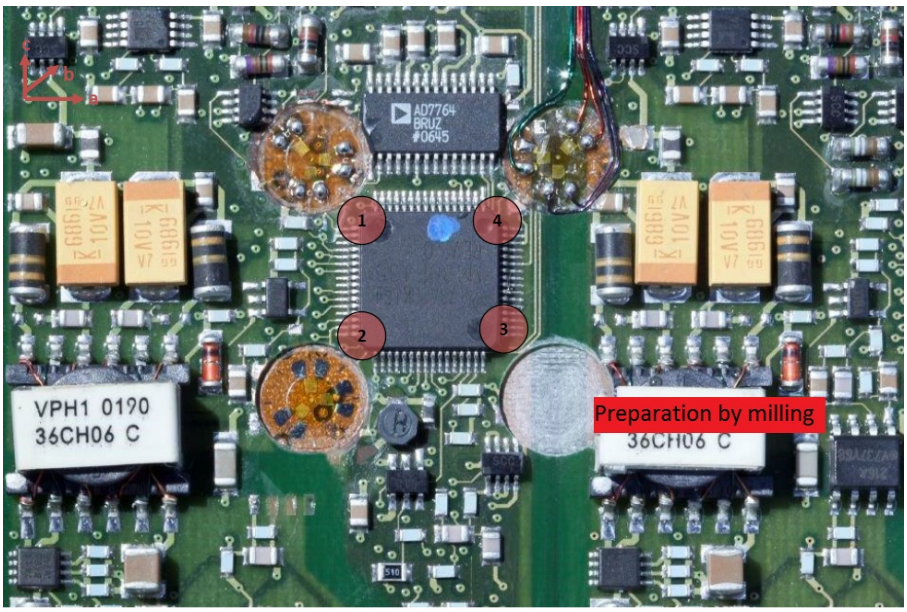
This TECH NOTE gives you some background information concerning **mechanical testing of printed electronics or circuit board assemblies** and describes a possible data acquisition solution introducing the seamless measurement chain based on electrical strain gages, QuantumX instruments and catman as data acquisition software from HBM.

Printed circuit boards or in general electronics used in mobile applications like vehicles or smart phones must withstand enormous mechanical load and impact as they are often used in harsh environments experiencing static load (bending), vibration, shock, temperature and humidity just to name a few. Even slight cracks can cause electronics or the entire system to fail with all the consequences to first of all function, safety and environment. Therefore manufacturers delivering high quality products **think about the complete life cycle of your product and all the overall environmental influence to it** – which starts in production by integrating a socket, delivery of the product in using common logistics to the world up to daily use from different users in again all kind of ambient environment over an estimated time till life cycle end.

Especially mechanical influence and its risk to harm the overall functionality needs to be tested intensively which often led to a final optimization of the printed circuit board and its integration into a housing or other components.

HBM can provide a seamless solution, beginning with a field proven complete measurement chain based on our own strain gages and transducers, high quality instruments with maximum noise suppression to easy-to-use software with test reporting capability.

Over **60 years of history** with its nucleus in strain gage technology, products around it and engineering service we are market leader when it comes to mechanical test and analysis. We are 100% service oriented delivering best in class so to our customers so that their products can be further improved in functionality, efficiency, performance and durability.



Background

Cars drive over cobblestone pavement; commercial vehicles make their way through bumpy construction sites. In summer they are exposed to heat and in winter freezing temperatures. All of this sets high requirements to all individual components and products and thus also to electronics or more technical PCA (printed circuit assemblies = board and parts including plugs). Vibration and thermal deformation can cause small cracks between the board and the component located on it, which can lead to failure affecting the entire electronics system of the product. Because of this designers measure the effect of mechanical loading very precisely during the development and production of prototypes. In this way they can ensure that the electronics will function properly up to a certain loading limit and also not undergo any damage in the production process.

Cars and commercial vehicles are just one application where measuring mechanical load is obvious. In general all moving transport systems need to be considered. Trains and ships are also continuously exposed to vibrations, as are smart phones, laptops and tablet PCs. Basically there is a risk of breaks and cracks at every connection between the PCA and a component placed on it or in its interfaces to the outer world – during production or in field and over life-time. It is expensive in many ways if electronics in a transport system no longer work and original equipment manufacturer (OEM) or supplier has to recall a complete mass production series which still happens very often. Secure operation is a must target for all manufacturers of products in no way risking life or health of the end user. A potential loss of image in your own market is not easy to calculate. And because more and more electronic modules are being used in automobiles, all electronic suppliers need to prove mechanical stability of electronic control units (ECU) within parameters assigned by them and send a test report. Visual tests such as X-ray or CT are not enough for this purpose. A strain based test and analysis are by far the best and most established way getting reliable results and is base for any predictive estimation in terms of mechanical stress. Strain gauges from HBM are dominantly used in this type of application. They can be easily and quickly placed directly on the PCA, are cost effective and small.

Lead-free but more sensitive

But the requirements for these tests have become more stringent in recent years. One factor driving this is the conversion to lead-free soldering. A directive of the European Union (RoHS) prohibits the use of certain hazardous substances in electrical and electronic devices. This includes lead, which was previously used frequently for solder connections between the board and the component. The lead-free solution is more sensitive for mechanical influences and therefore breaks more easily. Another factor that makes tests more stringent is the increasing use of more compact modules such as Ball Grid Arrays (BGA). They allow for more connections than a conventional Surface-Mounted Device (SMD). However, compared to the solder connections joining SMDs and the board, the contacts of BGAs are more rigid. These mechanical stresses act on the PCA and are therefore transferred more forcefully.

Why Testing?

Modern printed circuit board assemblies fail due to different reasons.

In field electronics are used in all kind of environmental areas – installed in vehicles on the ground or in aerospace or consumer goods following us everywhere we go

- direct sun / high temperature or in snow / lowest temperature or operating the unit through the dew point
- with heavy mechanical load, shock and vibration
- in small space / extreme height and thin air with limited heat dissipation
- in water or in high humidity
- in dust, dirt, salt or other influences

Environmental influences and life-time performance can be simulated in labs with prototypes during engineering process. Some tests are also obligatory during production for quality assurance.

In production - mechanical tests are also necessary when it comes to production of PCAs:

- analysing maximum mechanical or thermal load
- around ceramic SMD capacitors or BGTs

    - for this purpose they are removed and mechanical strain is analysed during PCA equipping and final assembly
- static or dynamic load measurement during assembly or placed on a shaker
- load measurement during plug insertion (PCB thickness dramatically decreased in the last 20 years)
- during In-circuit-test (ICT) for load monitoring

This affects electronic or in general contract manufacturers, PCB assemblers and component suppliers.

New production process due to environmental initiatives and legal issues
The Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment 2002/95/EC (commonly referred to as the Restriction of Hazardous Substances Directive or RoHS) was adopted in February 2003 by the European Union. The RoHS directive took effect on 1 July 2006, and is required to be enforced and become law in each member state. This directive restricts the use of six hazardous materials in the manufacture of various types of electronic and electrical equipment. It is closely linked with the Waste Electrical and Electronic Equipment Directive (WEEE) 2002/96/EC which sets collection, recycling and recovery targets for electrical goods and is part of a legislative initiative to solve the problem of huge amounts of toxic e-waste. RoHS is often referred to as the lead-free directive, but it overall restricts the use of six substances. Meanwhile all global manufacturers of electronic equipment are following that rule to produce lead-free.

Soldering lead-free in assembly process has a life-cycle impact due to different performance instead of traditional tin-lead solder. The higher brittleness of lead-free assemblies is prone to cause cracks on mechanical stress like static load or vibration and thus faults in contact and functionality which reduces product quality and reliability and extends cost.

Increasing density of electronic components, its size and mechanical constraints
Because of the increasing functional density in single electronic components, their size extends and the amount of pins is getting higher. In many cases compact Ball Grid Arrays (BGA) are used – see picture.

BGAs have many advantages compared to surface-mounted electronic components:

- high density - with many hundreds of pins and less difficulties for the soldering process
- better heat conduction - with a lower thermal resistance between the package and the PCA
- low inductance leads - with a very short distance between the package and the PCA improving electrical performance

BGAs have also disadvantages compared to surface-mounted electronic components:

- Connection surface between PCA and BGA is relatively stiff or in other words not that flexible like longer leads, so in case of mechanical load or vibration this can lead to fractures and faults
- But also bending because of thermal stress due to a difference in coefficient of thermal expansion between PCA substrate and BGA can also cause the solder joints to fracture
- Difficulty of inspection once the package is soldered down.

Several inspection methods are available like X-ray and industrial CT scanning machines and special microscopes. Mechanical testing equipment is required to

In-Circuit or Burn-In tests are already established production tests of electronic components.

Best Practise versus Standardized Testing

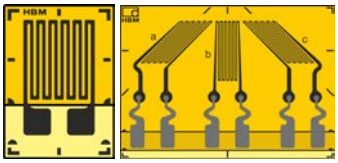
Different standards have been developed for this type of measurement and testing based on strain gauges placed on PCA (for example **IPC/JEDEG-9702**) including a detailed description of where, how and with what measurements are conducted. Many companies have also developed specific test procedures based on their own experience.

Bernd Wolf, Structural Testing Project Engineer responsible since 20 years for this type of application at HBM:
"*Mechanical load in later use and some factors during production process must be considered in modern electronics*

design. Especially for production of a new product, the entire process need to be accompanied by measurements – roughly from when the PCA's are fitted until the electronics is mounted in the housing. Strain is measured around certain critical components where there is a risk that they will be destroyed or loses connection during life-time. As a rule of thumb we can say that 400 µm/m is the maximum strain allowed on a PCB during production but the overall maximum strain on PCA's are a matter of experience and best-practise we built up over decades working with almost all automotive electronics manufacturers in central Europe".

Strain gages from HBM

Typical HBM strain gages in this field are RY8 series, RV91-3/120 and LE11 (waterproof). There are more strain gages available which differ in size, type and environmental characteristic (temperature, protection class, thermal conductivity). Custom made strain gages can be designed on a significant number.



Data Acquisition System and Software

Quantum^{X} is a modular, freely scalable and distributable data acquisition system from HBM for measurement and testing purposes allowing quicker innovation. All modules offer Ethernet and FireWire interface and can be freely combined with each other – all channels are fully time synchronized.

Find more info about QuantumX on our web page!

Picture: MX1615B – 16 channels strain gage bridge amplifier

MX1615B offers 16 channels, every input supports:

- Strain gage bridge in
  - full bridge configuration, supporting 6 wire technology (cable and temperature compensation)
  - ½ bridge configuration, supporting 5 wire technology
  - ¼ bridge configuration, supporting 3 and even 4 wire technology
  - configurable excitation voltage: 0,5 / 1 / 2.5 / 5 V, Carrier Frequency (CF) with maximum noise oppression and highest accuracy or DC excitation bridge voltage for maximum dynamics
  - Auto Cal / Adjust routines improving measurement quality during all ambient conditions and start-up
  - Internal 100 kΩ shunt resistor, simply activated by software
- RTD or PT100 temperature measurement for temperature compensation of your measurement spot
- Standardized ± 10 V input
- Configurable data rates up to 20 kHz per channel and signal bandwidth up to 3.2 kHz (DC excitation, AC only 400 Hz)
- Automatic sensor recognition and channel parameterization: TEDS (IEEE 1451.4 standard)
- All channels Galvanically isolated to each other, to communication bus and to power supply (no ground loops)
- Full channel to channel and module to module time synchronization
- Easy to prepare push-in terminals for quick integration of pure wires within seconds

QuantumX can be integrated in real-time over analog outputs (MX878B or MX879B), CAN (MX471B) or EtherCAT bus (CX27B).

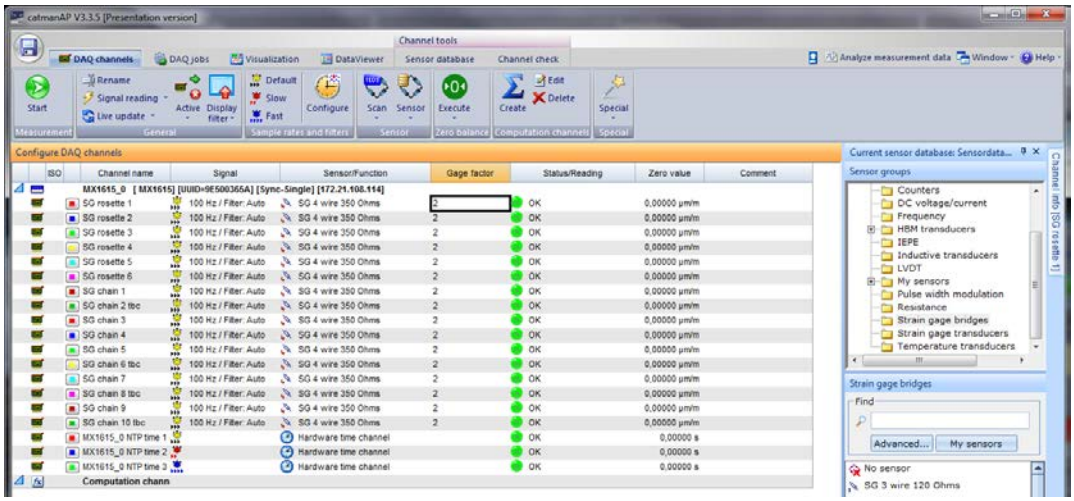
Quantum^{X} has been established world-wide with far over 10.000 modules operating in over thousand different company sites in the market automotive, aerospace, machinery, railway, marine, energy, civil engineering, agriculture, forestry, consumer industry and many research departments of universities. QuantumX has been the first Ethernet based compact distributable DAQ system in the world and can be seen as reference in terms of quality and flexibility.

catman from HBM is a powerful software package for

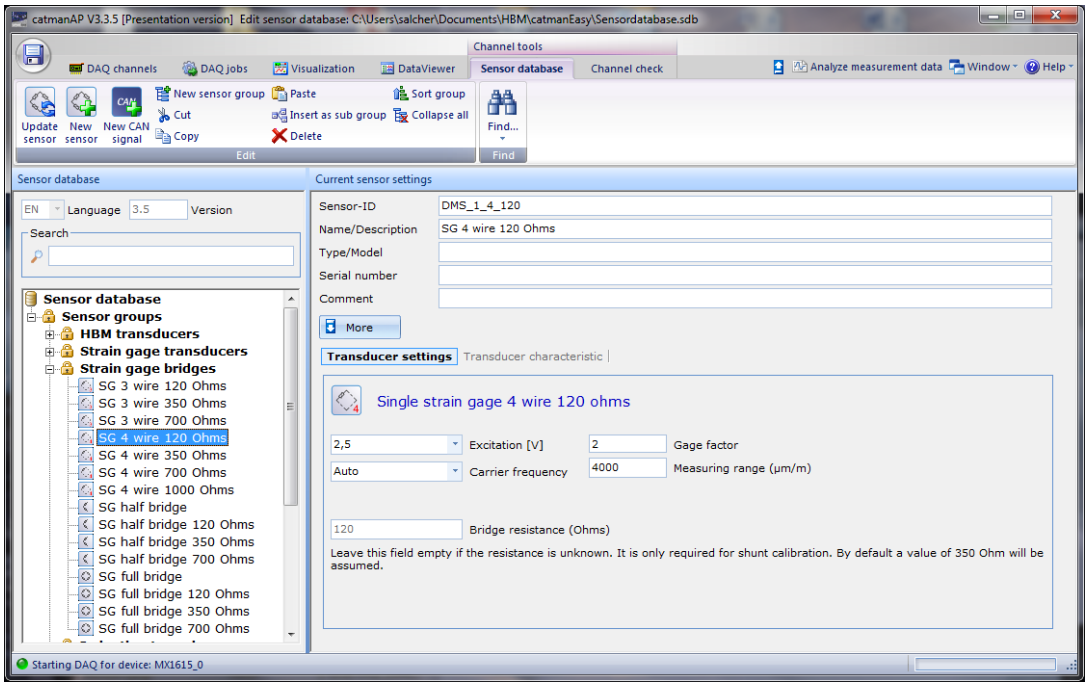
- system configuration: module scan and naming, synchronization type and check
- channel parameterization: inputs (analog, digital, video), outputs, virtual channels
- measurement job description: meta data, timing, trigger, data formats
- visualization: different panels showing live data in different objects and color
- automation: auto sequencer, scripting
- analysing: graphical in time or frequency domain, position or video based
- reporting, exporting

Thanks to an **intuitive user interface** only a few mouse clicks are needed to start measurement and get results. Simply configure the channel by drag and drop using the integrated channel or sensor database, press the start button and the test can start. Many options for graphical data view and analysis and its versatile export options make catman a reliable and indispensable tool for every measurement job. Without programming to result.

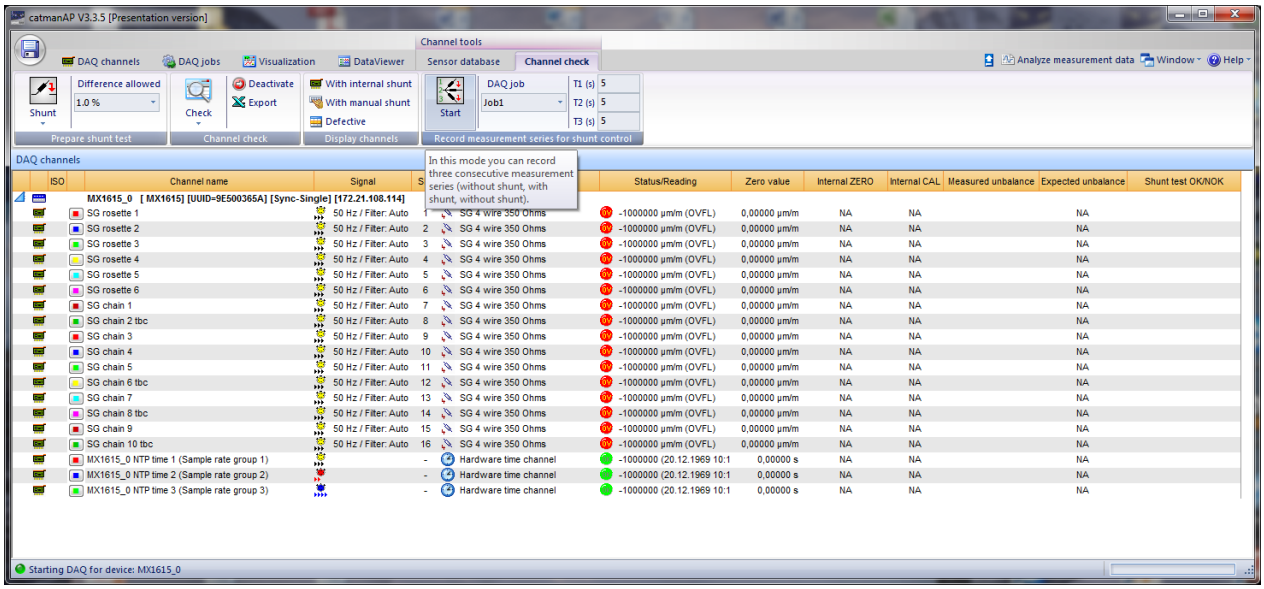
Online channel configuration



Integrated Sensor Database

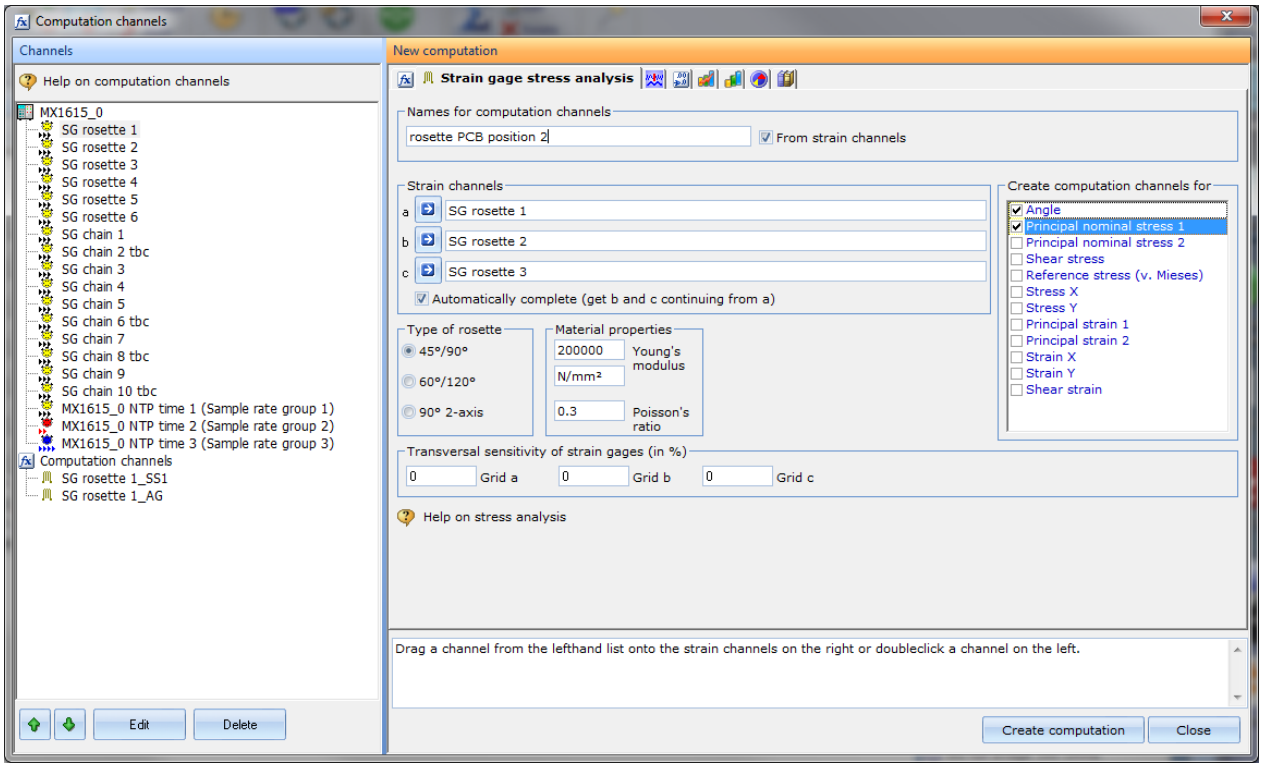


Shunt calibration or quick channel health check using the internal shunt resistor

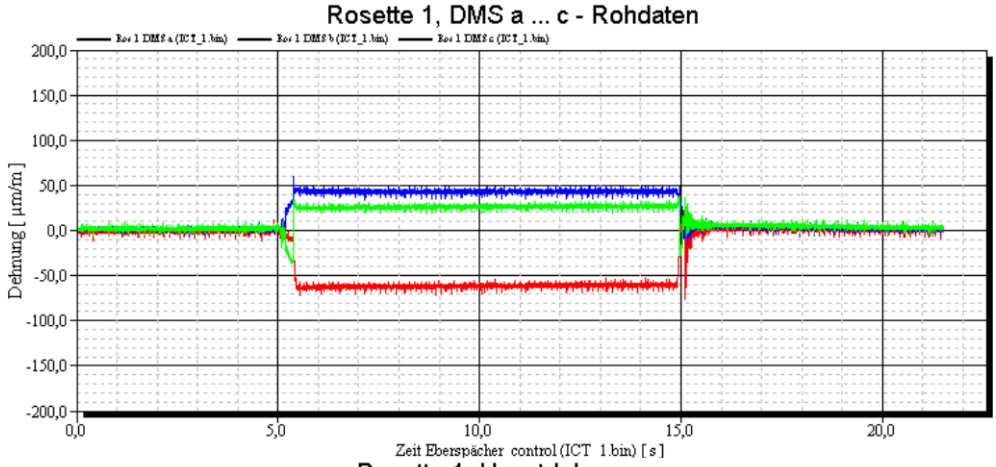


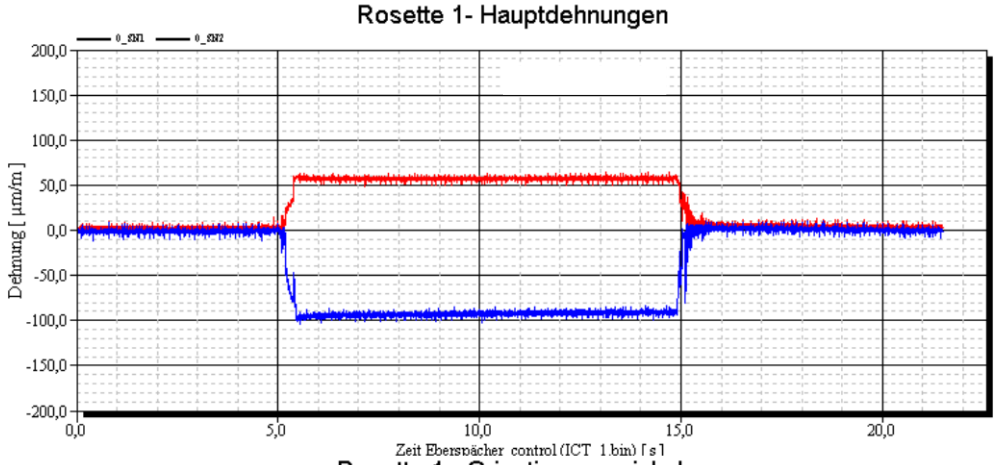
Create online math computation signals based on any input

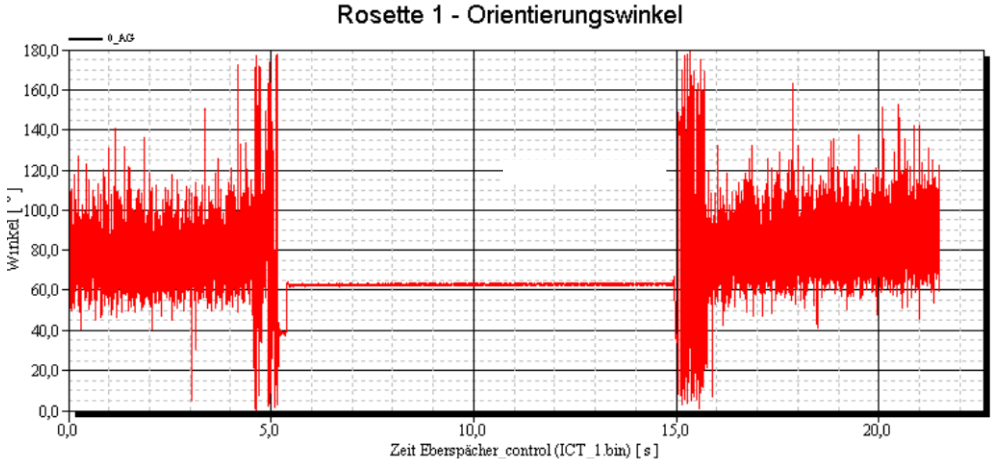
When using strain gage rosettes all calculations like *angle* or *principal nominal stress* are done with just a mouse click.



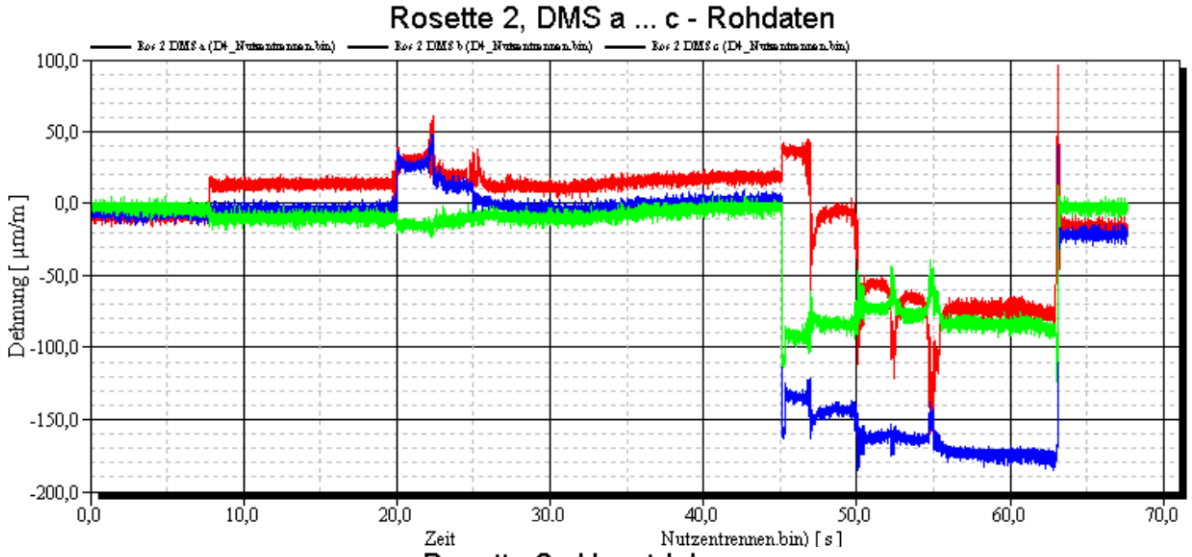
Measurement data: ICT – testing, measurement 1

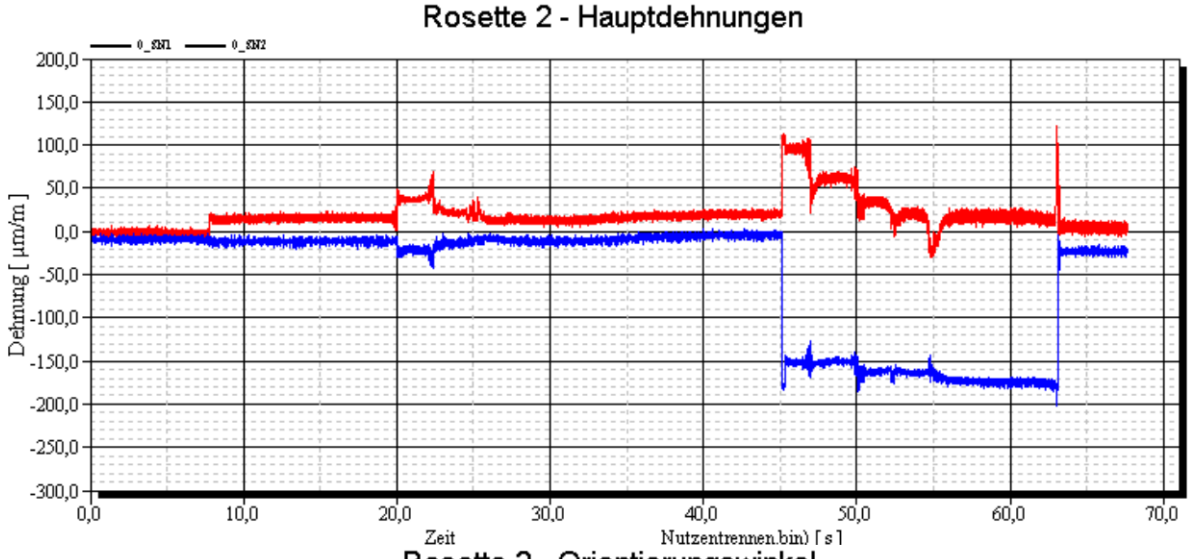


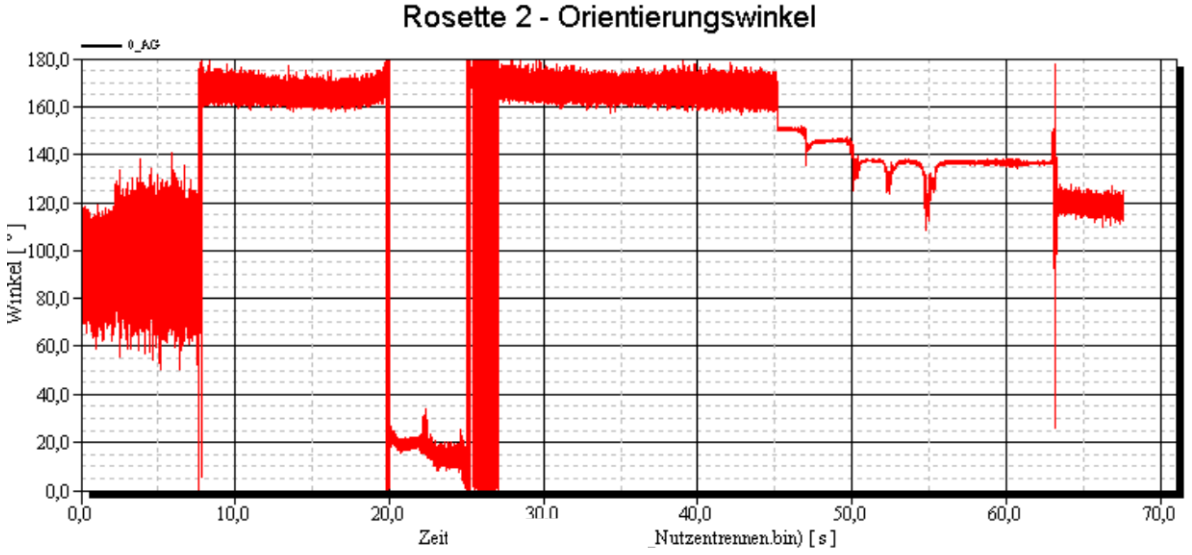




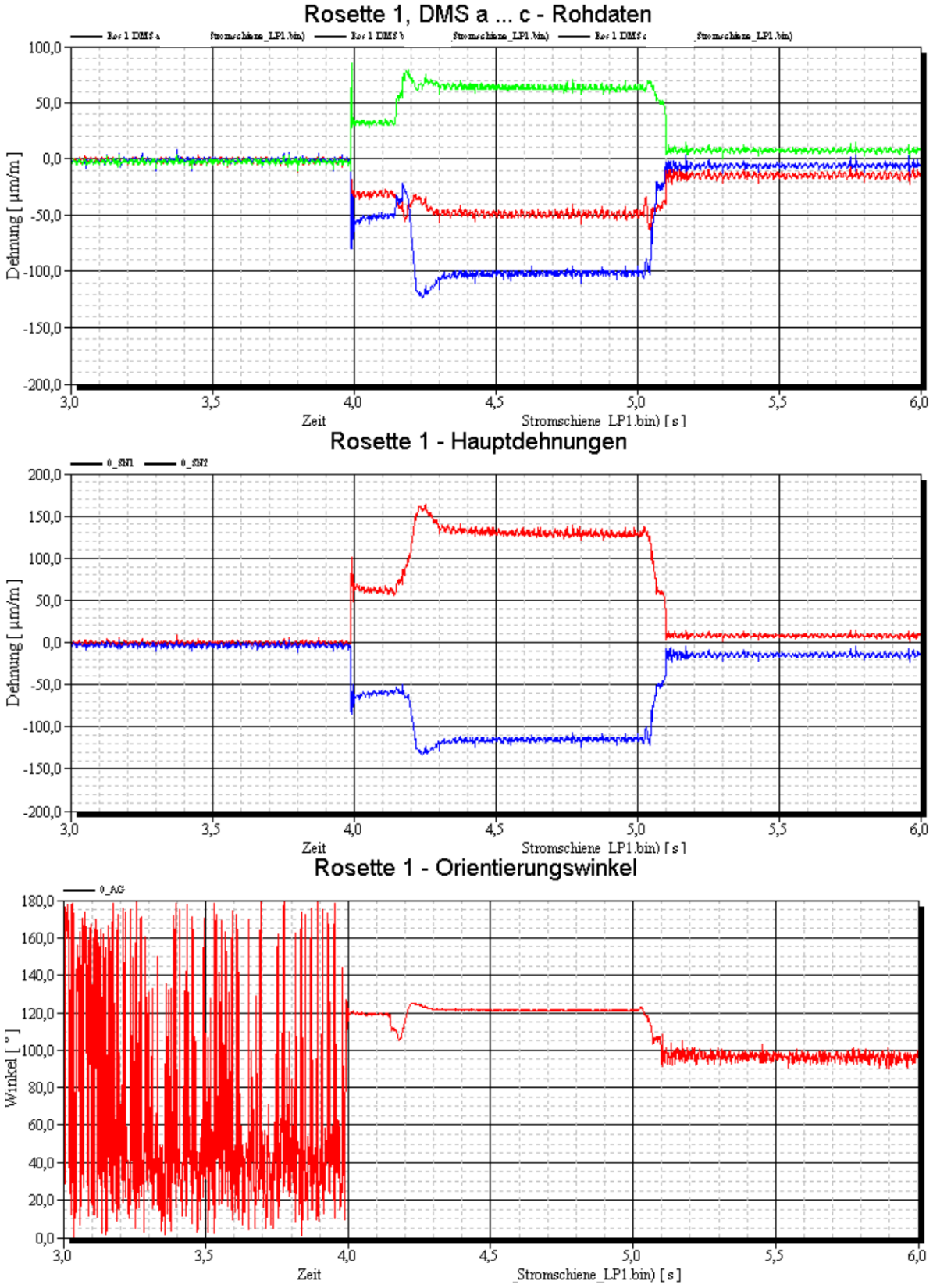
Measurement data:



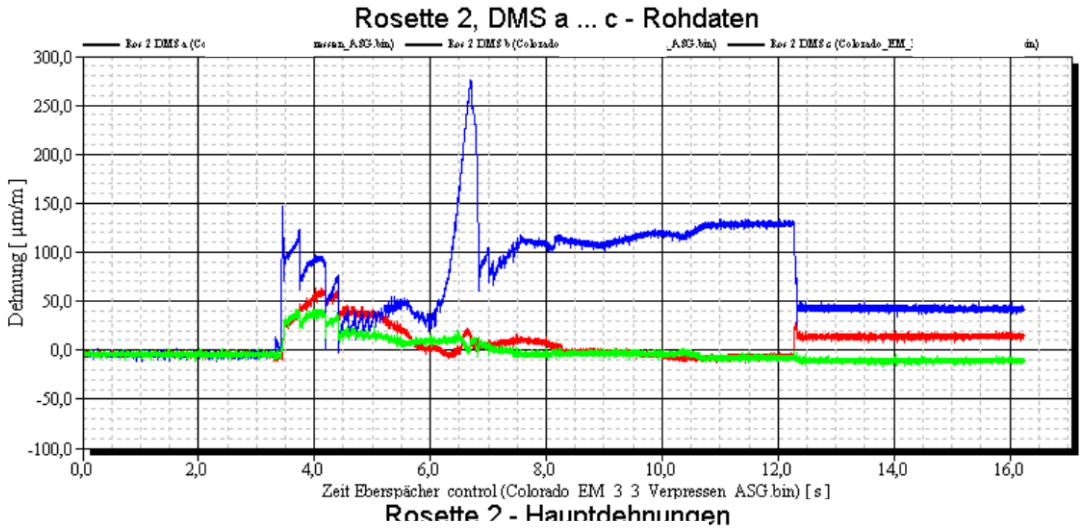


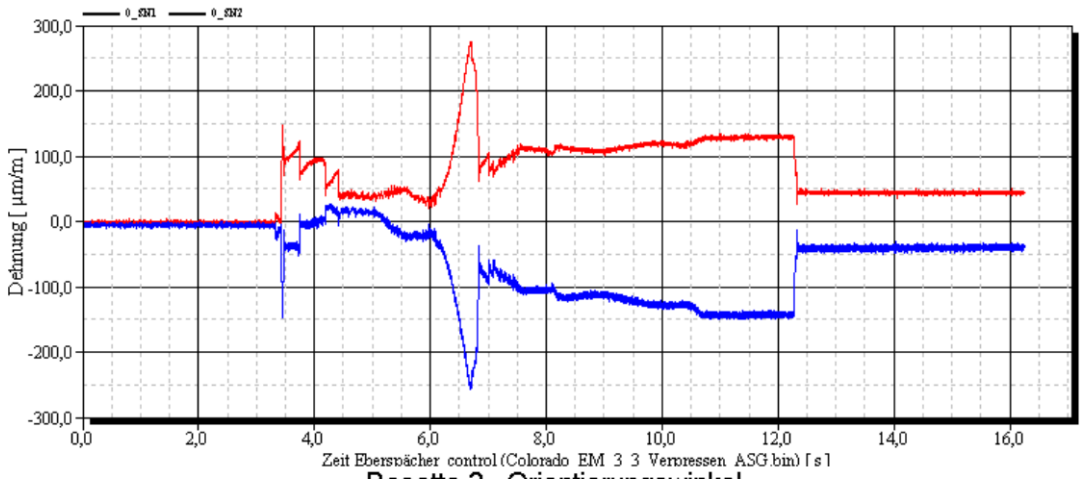


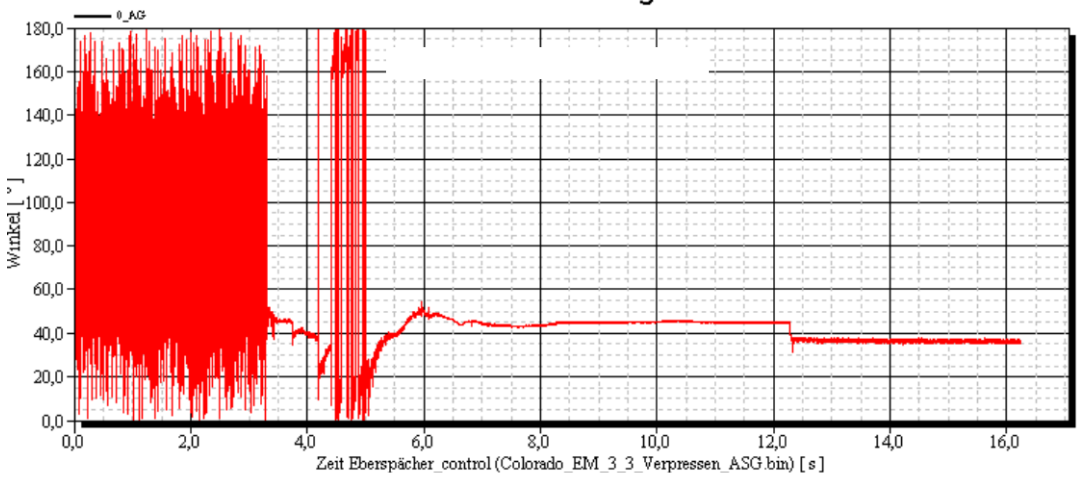
Measurement data: fitting of current bar



Measurement data: fitting into housing


Rosette 2, DMS a ... c - Rohdaten
Dehnung [µm/m]
300,0
250,0
200,0
150,0
100,0
50,0
0,0
-50,0
-100,0
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0
Zeit Eberspächer control (Colorado EM 3 3 Verpressen ASG.bin) [s]


Rosette 2 - Hauptdehnungen
0_HN1
0_HN2
Dehnung [µm/m]
300,0
200,0
100,0
0,0
-100,0
-200,0
-300,0
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0
Zeit Eberspächer control (Colorado EM 3 3 Verpressen ASG.bin) [s]


Rosette 2 - Orientierungswinkel
0_AG
Winkel [°]
180,0
160,0
140,0
120,0
100,0
80,0
60,0
40,0
20,0
0,0
0,0
2,0
4,0
6,0
8,0
10,0
12,0
14,0
16,0
Zeit Eberspächer control (Colorado EM 3 3 Verpressen ASG.bin) [s]

Analysis and Report

Once you have acquired the raw strain data, you can begin the last step of the PCA strain gage test – analysing this data to calculate resultant stresses (maximum and minimum) induced on the board during the test. You can complete this analysis online during the test or offline after the test has finished and you have collected all of the data.

Analysis details vary with the particular strain limit criteria you are using. Many strain limit criteria may require obtaining strain rates or principal strain calculations using Mohr's circle equations. According to the IPC-9704 guideline, at a minimum, you should provide the peak values of the principal or axial strain (maximum and minimum) for each step monitored.

A common way to report data is with a strain versus strain-rate chart, where the y-axis represents maximum allowable principal strain (µm/m) and the x-axis represents strain rate (µm/m per second). Strain-rate is the change in the absolute value of strain between consecutive readings.

When you do not need to analyse the data online, you can export the data in a suitable other file format for post-process analysis in a different tool too.

Training & Service

HBM Academy offers valuable practice-oriented know-how in training and workshops. Competent lecturers cover all aspects of data acquisition, strain-gauge measurement and the professional analysis of measurement data and give you practical guidance.

The specialists of the *HBM Service Group* can take on full responsibility for your measurement and testing task - from requirements analysis over sensor application to data acquisition and reporting. If you are lacking in resources, know-how or if you want to bring in a neutral reference, our experts take over and engineer.

Best Practise and Service Support from the Specialists

HBM is a product oriented company and offers strain gages, data acquisition electronics and software; but also offers support and service to get the most out of measurement and testing. The measurement method varies depending on the application. "The customer tells us where on the component the strain on the surface of the PCB should be measured," explains HBM measurement engineer Wolf. This is a job requiring intuitive flair, as many PCBs are only a few centimetres in size. The strain transducers, which must be precisely positioned on the PCBs, are accordingly delicately detailed. The different measurement tasks and their constraints require the use of different strain gauges. HBM offers a wide selection for this purpose. For example, HBM's type RY rosettes have three measuring grids that can be adapted to different geometries, dimensions and nominal (rated) resistances. Their temperature responses are adjusted for steel, aluminium or to customer specification.

HBM has done engineering services for over 150 companies in PCA testing. HBM has given some significant consultancy value to improve production tools and process to produce assembled robust PCAs. Most of them have internal best practice guides which are interesting to talk about.

HBM

HBM offers products and services from virtual to physical testing. For over 60 years, the name HBM stands for reliability, precision and innovation all over the world. The company is the technology and market leader and offers products and services for an extensive range of measurement applications in many industries. Users worldwide rely on the perfectly matched components of the complete measurement chain that guarantees maximum accuracy of measurement results and enables optimization of the complete product life cycle: from the development through the testing stages, as well as in manufacturing and production.

HBM's product range covers strain gages and data acquisition systems as well as software for structural durability investigations, tests and analysis. The potential fields of application can be found in every branch of engineering and industry in both virtual and physical test and measurement.

HBM has 27 subsidiaries and sales offices in Europe, America and Asia. HBM also has representatives in another 40 countries around the world. In addition to headquarters in Darmstadt (Germany), other HBM production facilities are located in Marlboro (USA) and Suzhou (China).

HBM has been the first company in Germany to be certified per ISO9001. In 1996, HBM's environmental management system was certified per ISO14001.

In 1977, HBM was the first company in Germany to be accredited as an official "DKD" (German Calibration Service) calibration laboratory. HBM calibrates measuring instruments to customer order, guaranteeing reproducibility to DIN EN ISO 9001 standards.

HBM offers a wide range of service which covers applying strain gages on-site, calibration of instruments on-site, software development, system infrastructure for collaborative work, data analysis and on-site training.

I instantly hope that this article brings value to you and we find a way together improving the things in the world.

-- END

Literature

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- Keil, Stefan Beanspruchungsermittlung mit Dehnmessstreifen, Verlag Cuneus, 1995, ISBN-Nr.: 3-9804188-0-4

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