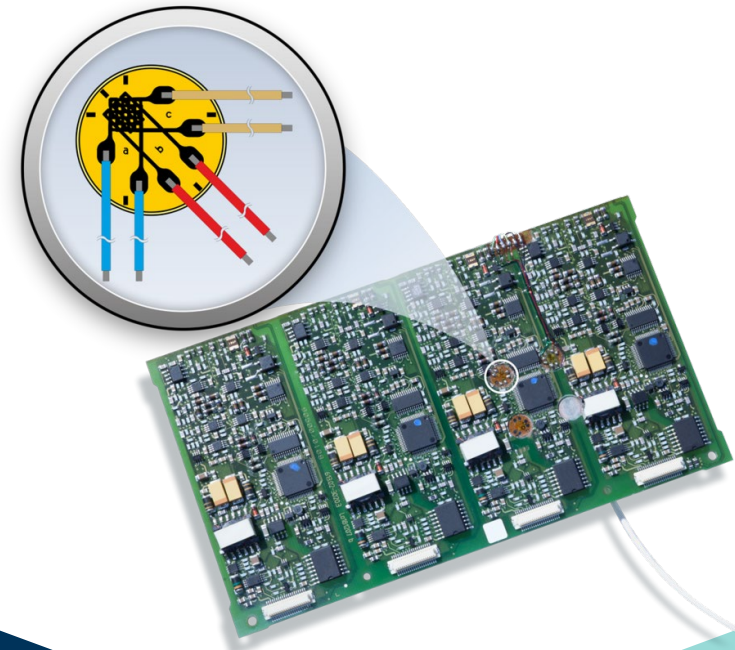


# Strain and Strain Rate Measurement on PCBs

APPLYING THE IPC/JEDEC 9704



Malte Grieme

# Agenda

## WHAT ARE WE GONNA TALK ABOUT

1. Why are strain measurements performed on PCBs?
2. How to measure strain on PCBs?
3. Where to measure strain on PCBs?
4. How to do data analysis?



# Why are strain measurements performed on PCBs?

# During the manufacture of PCBs

- ▲ Bending strain during the installation
- ▲ Breakage during mounting SMD, SMT, THD, THT and PIH fitting
- ▲ Stress cracks and dislodging of solder points with ball grid arrays (BGA)



# During the manufacture of PCBs

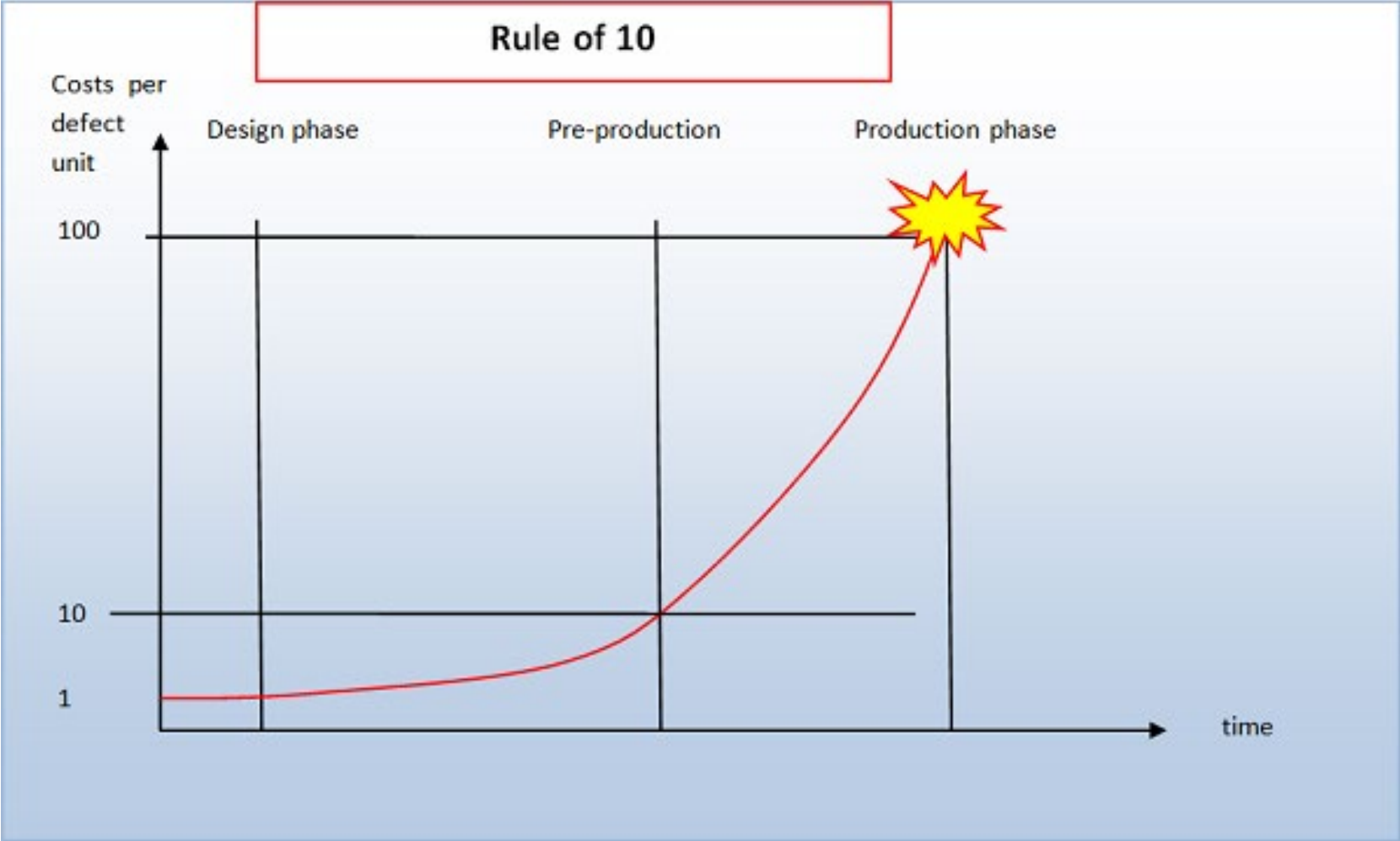
- ▲ Transient strain peaks during separation (determination of critical strains/shear strains during separation)
- ▲ Elevated mechanical stress (strain)
- ▲ Broken SMD capacitors due to high bending stress in other steps of the process
- ▲ Hard touchdown of the test probes during the ICT

# During transport and operation

- ▲ Mechanical load (static)
- ▲ Vibration and splicing (dynamic)
- ▲ Thermal effects resulting in cracks caused by thermal expansion (differing  $\alpha$  values of housing, heat sink, printed circuit board, and electronic components)

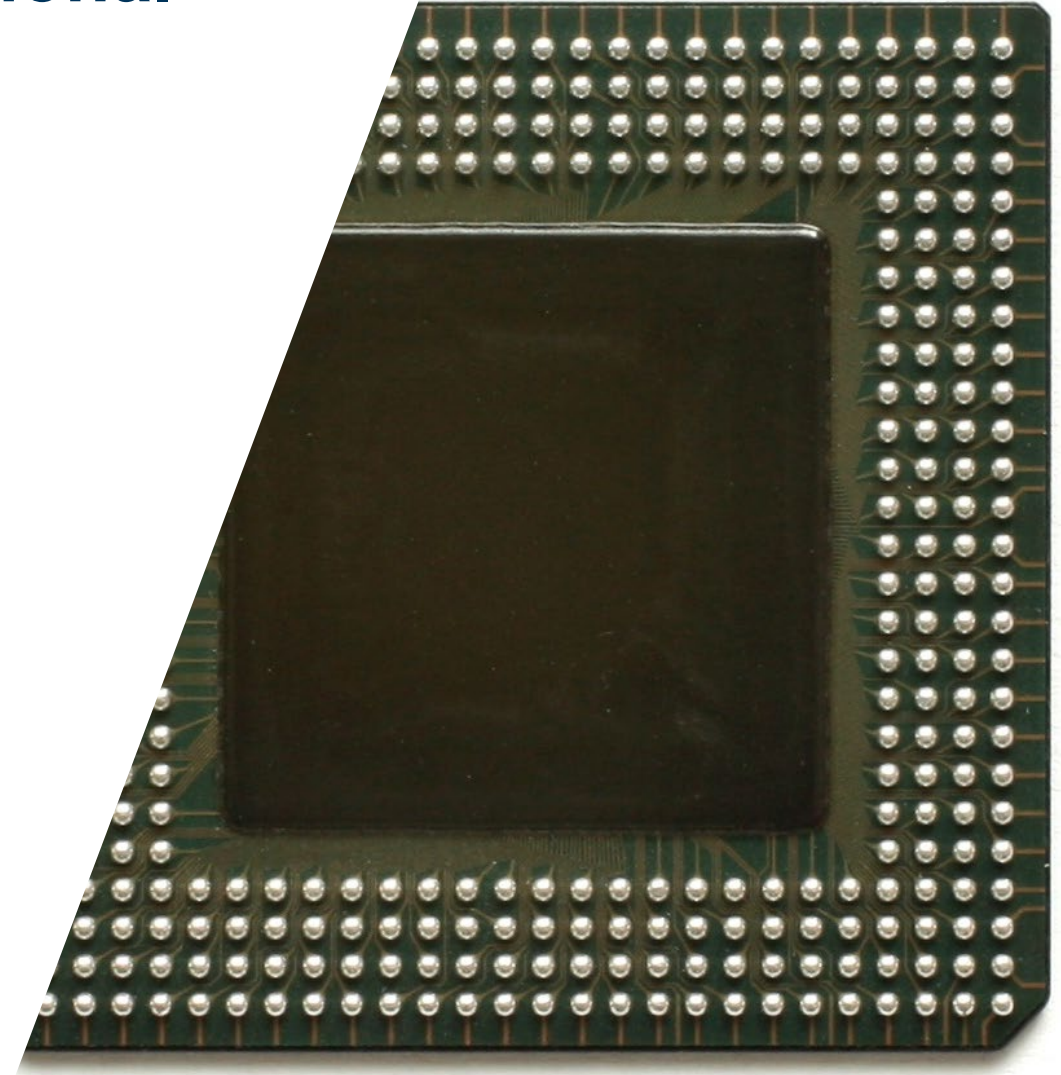


# Rule of 10



# Extended Requirements and International Standards for PCB Testing

- ▲ Use of lead-free solder (RoHS conformity, EU guideline) that is more sensitive in relation to mechanical load and tends to crack earlier (flexure-induced damage)
- ▲ More compact construction elements such as ball grid arrays (BGA) instead of surface-mounted devices (SMD)
- ▲ Stiffer contacts that lead to higher mechanical tension

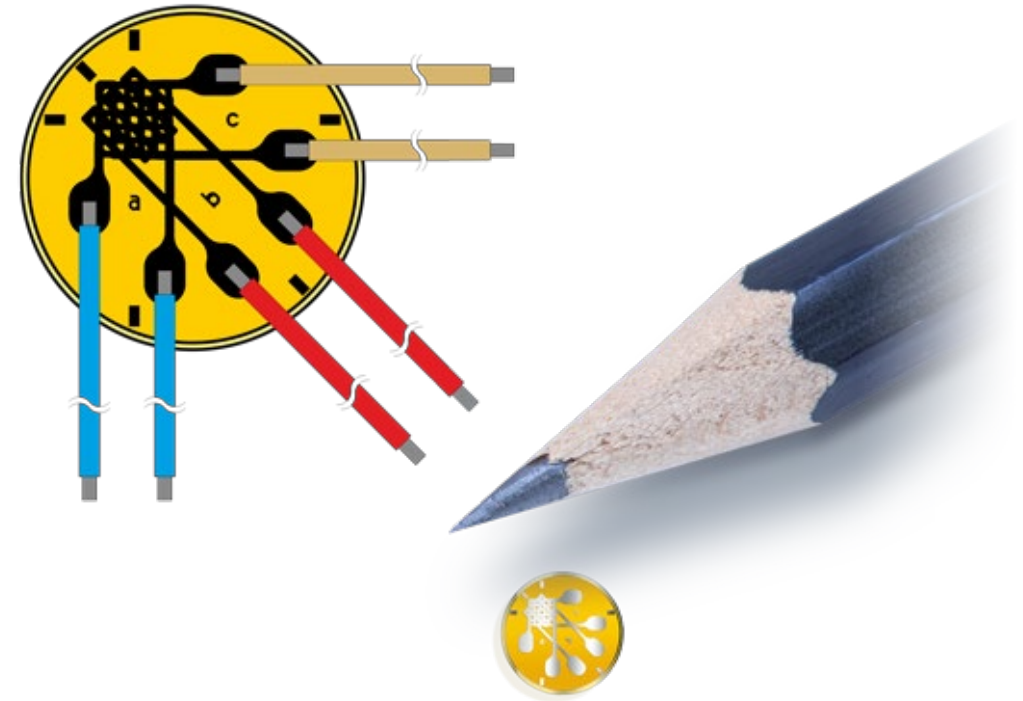




# How to measure strain on PCBs?

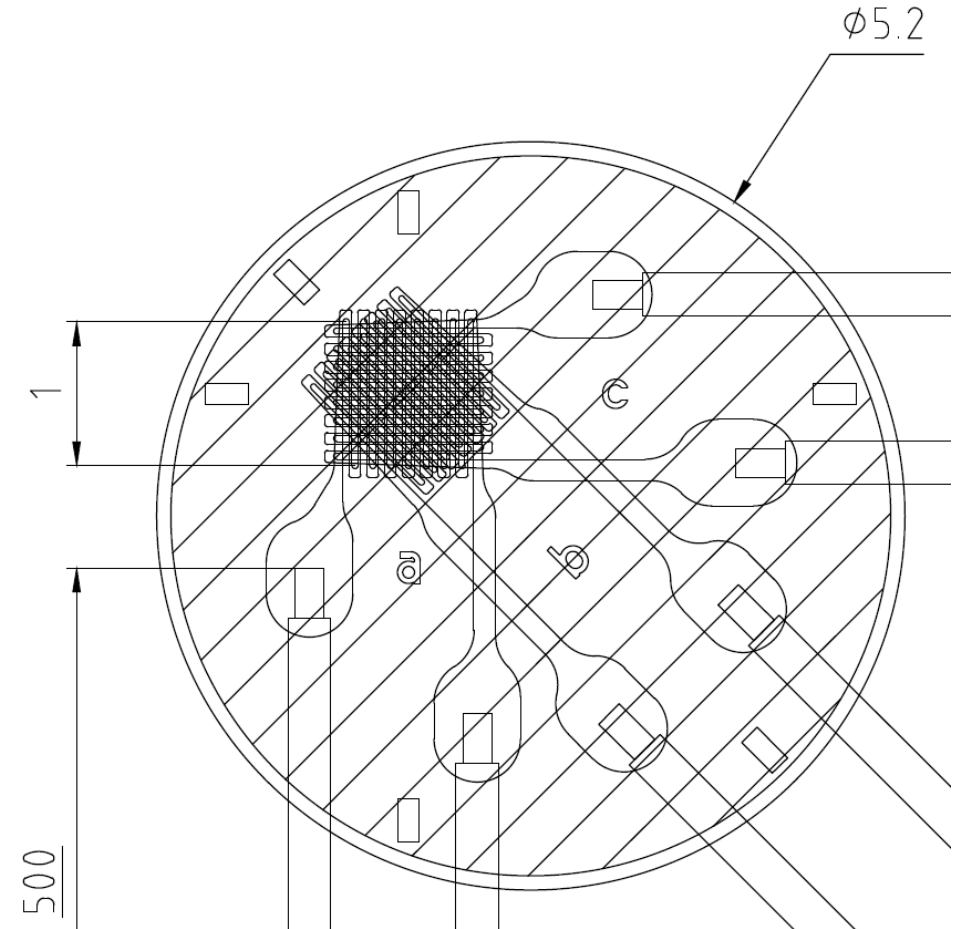
# Why strain gauges?

- ▲ Numerical simulation methods such as FEA are limited in their scope since they are based on mathematical model approaches.
- ▲ CTs and X-rays are not sufficiently adequate to check the influence of the mechanical impact and are, on top of that, expensive methods to employ
- **Therefore, strain gauges are designated to measure the deformation of the PCBs to an extremely accurate degree.**

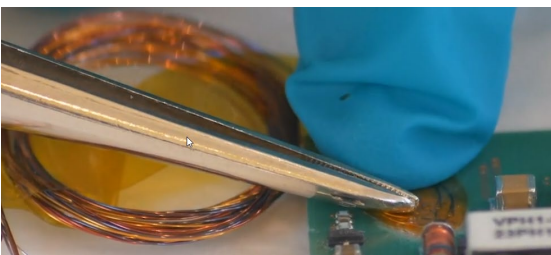
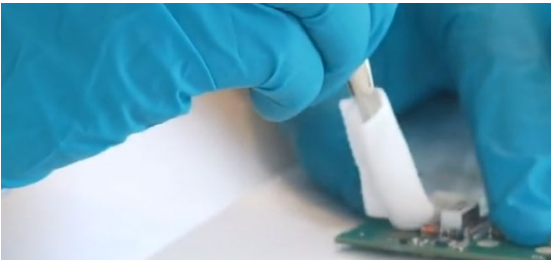
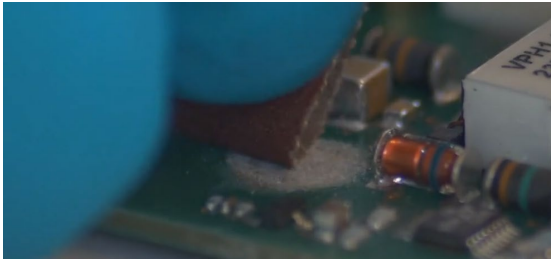
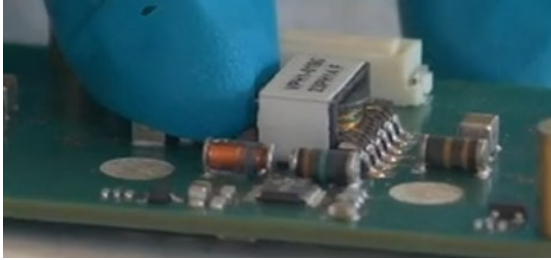


# What are the requirements for the strain gauge?

- ▲ Three element stacked (0/45/90) rosette
- ▲ 1.0 to 2.0 mm<sup>2</sup>, nominal, gage sensor size
- ▲ Lead wires attached
  - 30 AWG lead wire preferred
- ▲ Coefficient of Thermal Expansion (CTE) is not critical as long as the gauge factor is stable in the temperature range.



# How to install the strain gauge onto a PCB?

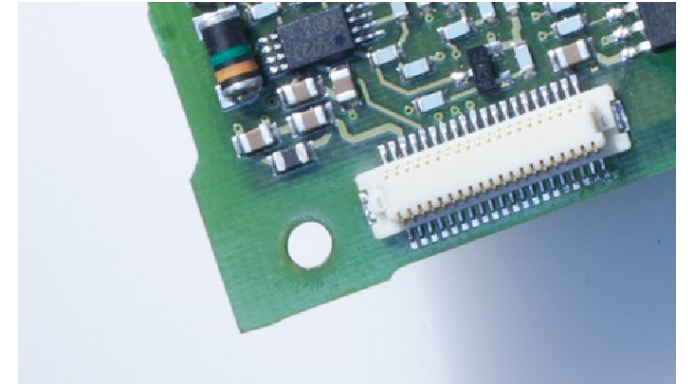


- ▲ The installation point should have a surface that ensures good adhesion between strain gauge and PCB.
  
- 1. Removal of the uppermost lacquer layer by means of face milling cutter
- 2. further roughening of the surface with sandpaper if necessary
- 3. Clean the adhesive surface with a suitable cleaner (chemically pure) -> RMS1
- 4. Bonding of the strain gage by using Z70 fast adhesive
  
- On our website you will find a video tutorial

# Where to measure strain on PCBs?

# How to select the measurement points?

- ▲ Tension status on PCBs is mostly unknown and mechanically complex
- ▲ Measurements on PCBs are set at areas where the risk of failure is estimated to be especially high such as:
  - **Corners:** Corners can be mechanically critical if they are fixed.
  - **Stiff regions of the board** (e.g. the ones close to capacitors): Bigger elements lead to increased stiffness of PCBs.
  - **Regions close to interconnects** (solder-joint failures): Solder points are weak points in terms of yield strength.



# How to select the measurement points?

## ▲ Components and devices:

- In general: User and supplier agree on components and measuring points
- Recommendations:
  - a. Area Array Components:
    - I. Evaluate any package body  $> 27 \times 27 \text{mm}$  and pitch component  $> 10 \text{mm}$
    - II. If a lot of components are present, take the 3 worst ones.
    - III. Let experience values flow in, where weak points are.
    - IV. All four corners should be measured, if possible
    - V. 6-10mm next to BGA solder points (grids should be in parallel with solder rows)
  - b. Non-Area Array Components:
    - I. MLCC are critical and should be considered to measure (not more than 1mm away from the edge)



# How to do data analysis?

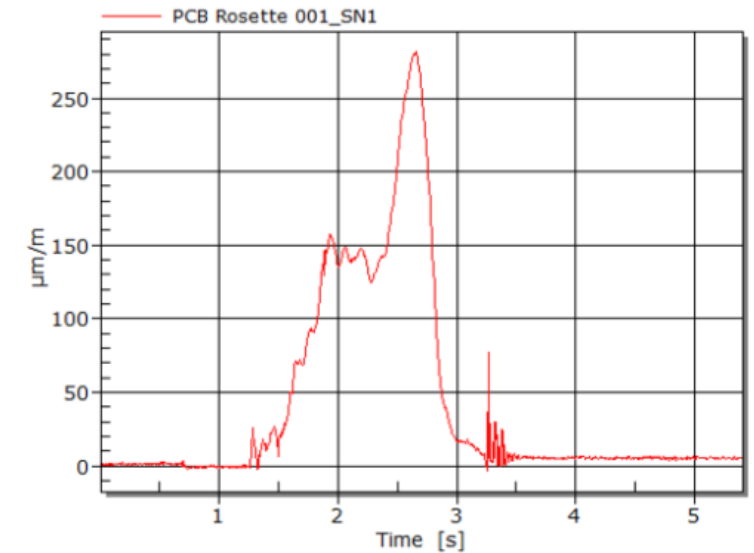


# Maximum allowed strain

- ▲ In general: users and suppliers agree on limit values.
- ▲ Some manufacturers of critical components specify limit values for their parts.

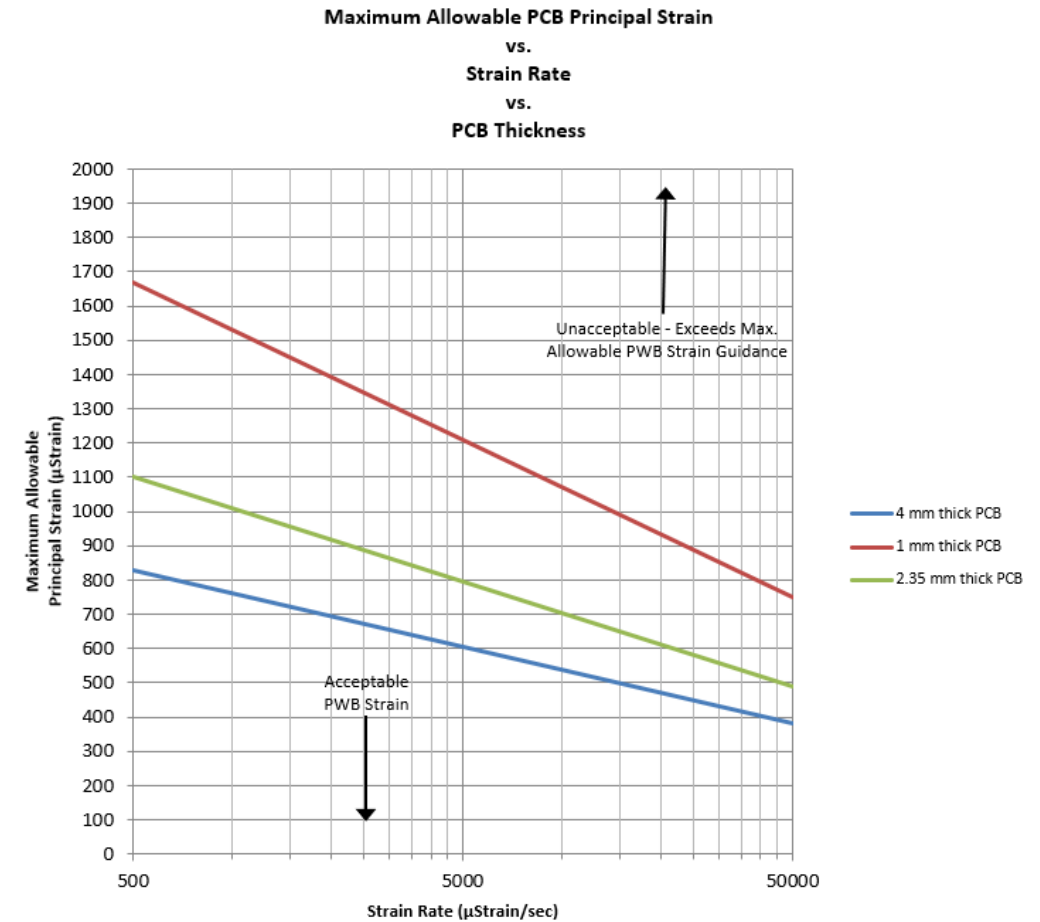
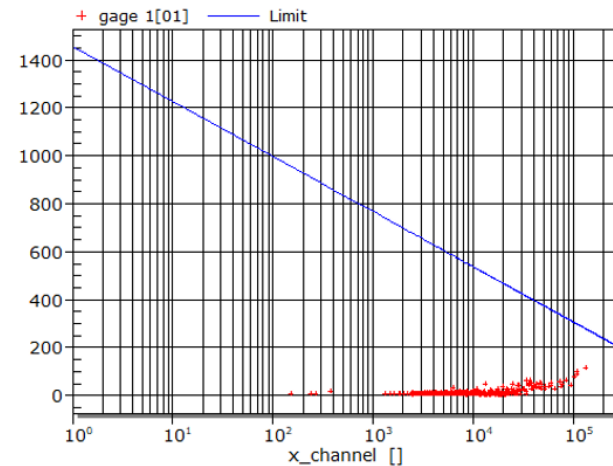
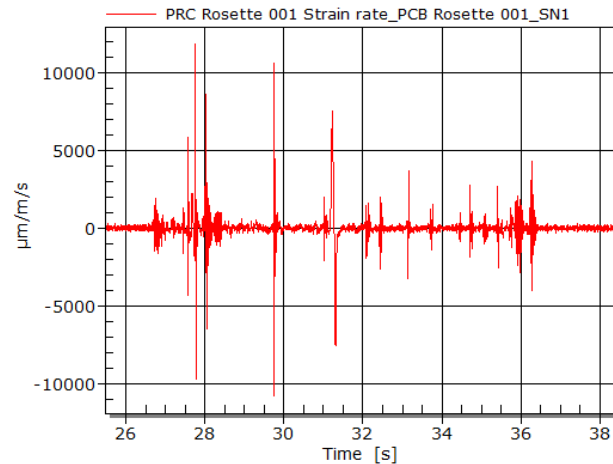
$$\varepsilon_1 = \frac{\varepsilon_A + \varepsilon_C}{2} + \frac{1}{\sqrt{2}} \sqrt{(\varepsilon_A - \varepsilon_B)^2 + (\varepsilon_C - \varepsilon_B)^2}$$

- ▲ Requirements for the Measurement equipment:
  - Minimum allowed measurement frequency 500 Hz.  
Recommended is 2 kHz
  - Sampling resolution of 12 to 16 bits
  - Suitable low pass filters are recommended.



# Strain rate

- ▶ The strain rate means that the lifespan of a PCB is impacted not only by the pure value of the maximum principal strain but also by the speed of changing the strain (impulse).
- ▶ Boundary lines as a function of the strain rate and the board thickness (IPC / JEDEC-9704A)



# Catman AP

Configure DAQ channels Devices: 1 Hardware channels: 16 Computation channels: 8 [Display filter active]

Channel name	Reading	Sample rate/Filter	Slot	Type	Type expected	SensorFunction
1 MX1615B	36,49 $\mu\text{m/m}$	300 Hz / BE 50 Hz (Auto)				
5 PCB Test Rosette grid_A	34,07 $\mu\text{m/m}$	300 Hz / BE 50 Hz (Auto)	1	MX1615B	MX1615B	SG quarter bridge 120 Ohm
6 PCB Test Rosette grid_B	38,01 $\mu\text{m/m}$	300 Hz / BE 50 Hz (Auto)	2	MX1615B	MX1615B	SG quarter bridge 120 Ohm
7 PCB Test Rosette grid_C	20,80 $^{\circ}\text{C}$	300 Hz / BE 50 Hz (Auto)	3	MX1615B	MX1615B	Resistance thermometer F
8 MX1615 CS_9029_CH 4	No signal	300 Hz / BE 50 Hz (Auto)	4	MX1615B	MX1615B	Resistance thermometer F
9 MX1615 CS_9029_CH 5	No signal	300 Hz / BE 50 Hz (Auto)	5	MX1615B	MX1615B	Resistance thermometer F
10 MX1615 CS_9029_CH 6	No signal	300 Hz / BE 50 Hz (Auto)	6	MX1615B	MX1615B	DC Voltage
11 MX1615 CS_9029_CH 7	No signal	300 Hz / BE 50 Hz (Auto)	7	MX1615B	MX1615B	DC Voltage
12 MX1615 CS_9029_CH 8	No signal	300 Hz / BE 50 Hz (Auto)	8	MX1615B	MX1615B	DC Voltage
13 MX1615 CS_9029_CH 9	No signal	300 Hz / BE 50 Hz (Auto)	9	MX1615B	MX1615B	DC Voltage
14 MX1615 CS_9029_CH 10	No signal	300 Hz / BE 50 Hz (Auto)	10	MX1615B	MX1615B	DC Voltage
15 MX1615 CS_9029_CH 11	No signal	300 Hz / BE 50 Hz (Auto)	11	MX1615B	MX1615B	DC Voltage
16 MX1615 CS_9029_CH 12	No signal	300 Hz / BE 50 Hz (Auto)	12	MX1615B	MX1615B	DC Voltage
17 MX1615 CS_9029_CH 13	No signal	300 Hz / BE 50 Hz (Auto)	13	MX1615B	MX1615B	DC Voltage
18 MX1615 CS_9029_CH 14	No signal	300 Hz / BE 50 Hz (Auto)	14	MX1615B	MX1615B	DC Voltage
19 MX1615 CS_9029_CH 15	No signal	300 Hz / BE 50 Hz (Auto)	15	MX1615B	MX1615B	DC Voltage
20 MX1615 CS_9029_CH 16	No signal	300 Hz / BE 50 Hz (Auto)	16	MX1615B	MX1615B	DC Voltage
<b>Computation channels</b>						
22 Peak counter principal stress_MAX	0,00000 $\mu\text{m/m}$					Peak-Valley (PCB Test Rosette)
23 Peak counter principal stress_MIN	0,00000 $\mu\text{m/m}$					Peak-Valley (PCB Test Rosette)
24 Peak counter principal stress_COUNTS	0,00000					Peak-Valley (PCB Test Rosette)
25 PCB Stress SS1	N.A.					Rainbow From-To (PCB Test)
26 PCB Rosette 001_SNA						45°/90° rosette Angle (PCB)
27 PCB Rosette 001_SNB						45°/90° rosette Principal strain
28 PCB Rosette 001_SNC						45°/90° rosette Principal strain
29 PCB Rosette 001_SND						45°/90° rosette Angle (PCB)

Drag and Drop

Strain gage configuration

Channel: PCB Test Rosette grid\_A

Gage factor: 2,5 V Excitation voltage

Bridge factor: Auto Carrier frequency

Measuring range ( $\mu\text{m/m}$ ): 4000

Execute conversion mV/V ->  $\mu\text{m/m}$  in hardware

Optionally you can correct temperature influences on strain gage signals by a compensation measuring point or by the temperature response polynomial to be found on your strain gage package.

More information about compensation of temperature influences

Temperature compensation using compensation S/G

Temperature compensation using temperature response polynomial

Temperature response polynomial (see strain gage data sheet)

$-0,20,59$  a0  $0,0000093$   $\alpha$  S/G

$1,95$  a1  $0,0000093$   $\alpha$  Material

$-0,00516$  a2  $20$  T<sub>Ref</sub> ( $^{\circ}\text{C}$ )

$0,000233$  a3

Temperature data from: MX1615 CS\_9029\_CH 4

Update in sensor database

Create new sensor

OK Cancel

Configure sample rate, groups and filters

Classic (e.g. 1200) Sample Rate and Filters

Sample rate groups

Useful sample rates...

Slow sample rate: 10 Hz

Default sample rate: 300 Hz

Fast sample rate: 4800 Hz

Channel: PCB Test Rosette grid\_A

Use current device settings

Filter is set via TEDS or Setup Assistant.

Use automatic Anti-Alias filters

The frequency will be determined before DAQ start based upon the sample rate. Usually a Bessel characteristic will be selected.

Working without filter

Choose characteristics and frequency

If the frequency selected is not supported by the device the best possible frequency will be selected.

Butterworth 0.01 Hz

Butterworth 0.02 Hz

Butterworth 0.1 Hz

Butterworth 0.2 Hz

Butterworth 0.5 Hz

Butterworth 1 Hz

Butterworth 2 Hz

Butterworth 5 Hz

Butterworth 10 Hz

Butterworth 20 Hz

Help regarding filter settings

OK Cancel

Edit computations

Create computation Close Help on computation channels

S/G

Rosettes Temperature compensation Strain rate

Name: PCB Rosette 001

From strain channels

Strain channels

- a PCB Test Rosette grid\_A
- b PCB Test Rosette grid\_B
- c PCB Test Rosette grid\_C

Automatically complete (get b and c continuing from a)

Type of rosette

- 45°/90°
- 60°/120°
- 90° 2-axis
- Single S/G

Material properties

200000 Young's modulus

N/mm<sup>2</sup>

0.3 Poisson's ratio

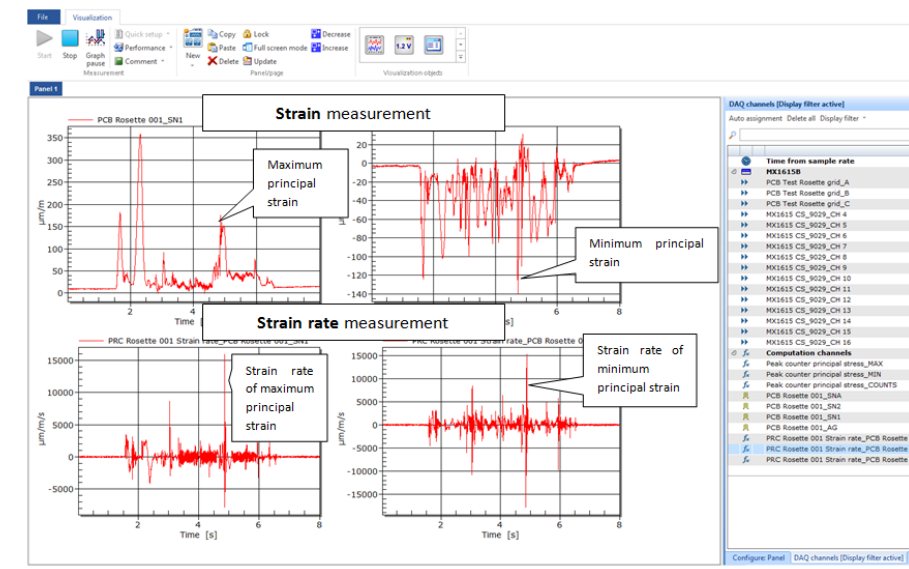
Transversal sensitivity in %

- 0,1 Grid a
- 0,1 Grid b
- 0,1 Grid c

Create computation channels

- Angle
- Principal nominal stress 1
- Principal nominal stress 2
- Shear stress
- Reference stress (v. Mises)
- Stress X
- Stress Y
- Principal strain 1
- Principal strain 2
- Strain X
- Strain Y
- Shear strain

Help on stress analysis



# All in one solution

COMING  
SOON



# Further Information

## HOW WE CAN HELP YOU.

**General strain gauge knowledge database:**

[www.hbm.com/strain-fundamentals](http://www.hbm.com/strain-fundamentals)



**Special application PCB testing:**

<https://www.hbm.com/en/7698/how-to-measure-strain-rate-on-printed-circuit-boards-pcbs/>



**Trainings:**

<https://www.hbm.com/en/7172/seminar-pcb-testing-with-strain-gauges/>



**On-site service:**

[helpme@hbkworl.com](mailto:helpme@hbkworl.com)



# Thank You



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