Organisational information

- To enable **audio,** activate your PC **speakers** or connect **headphones** to your PC.
- All participants' **microphones** are **muted** during the webinar.
- If you have any questions, please use the '**Questions and answers**' window.

- Questions will be answered **at the end** of the presentation.
- The webinar is being **recorded** and will soon be made available on our website together with the **presentation materials** – you will then receive an e-mail notification.

Welcome to the webinar:
"Measurement Uncertainty of Force Measurements"

Thomas Kleckers

- **Product Manager Industrial Measurement (IMS) at HBM**
- Degree in Engineering
- 16 years of experience in development (strain gauges)
- Product manager for force sensors
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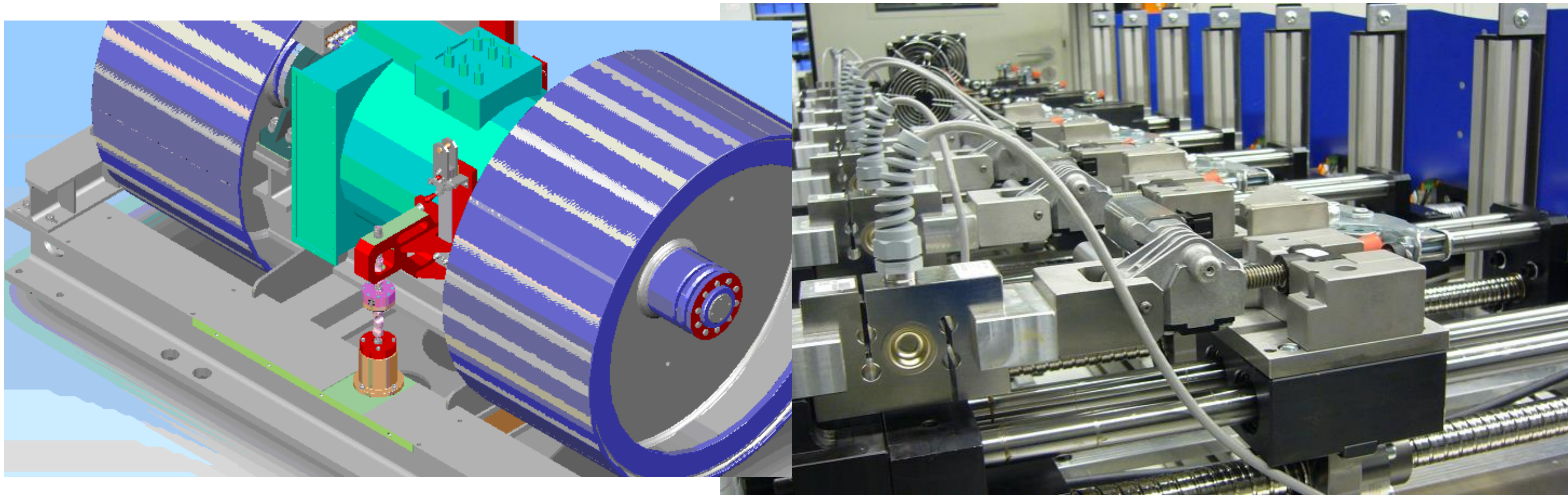
Thomas Kleckers

Agenda

- General remarks / definitions
- Accuracy classes
- Systematic errors
- How to estimate a measurement uncertainty
- Example
- Not precise enough?

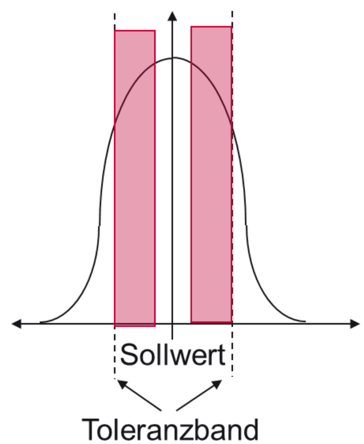
Acccuracy – why?

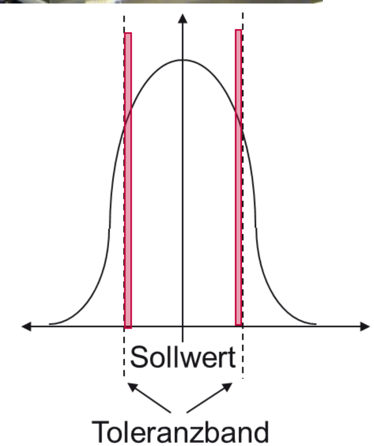


- New more strict regulations and standards require lower measurement uncertainty

- End-of-the-line-Tests: lower tolerance optimize the yield of your production

=> Lower measurement uncertainty helps to reach goals and ensure that the measurement equipment can be used for years





Prof. Werner Richter:

„A measurement result without an uncertainty calculation is so much disputable that it should not be mentioned

Kleckers

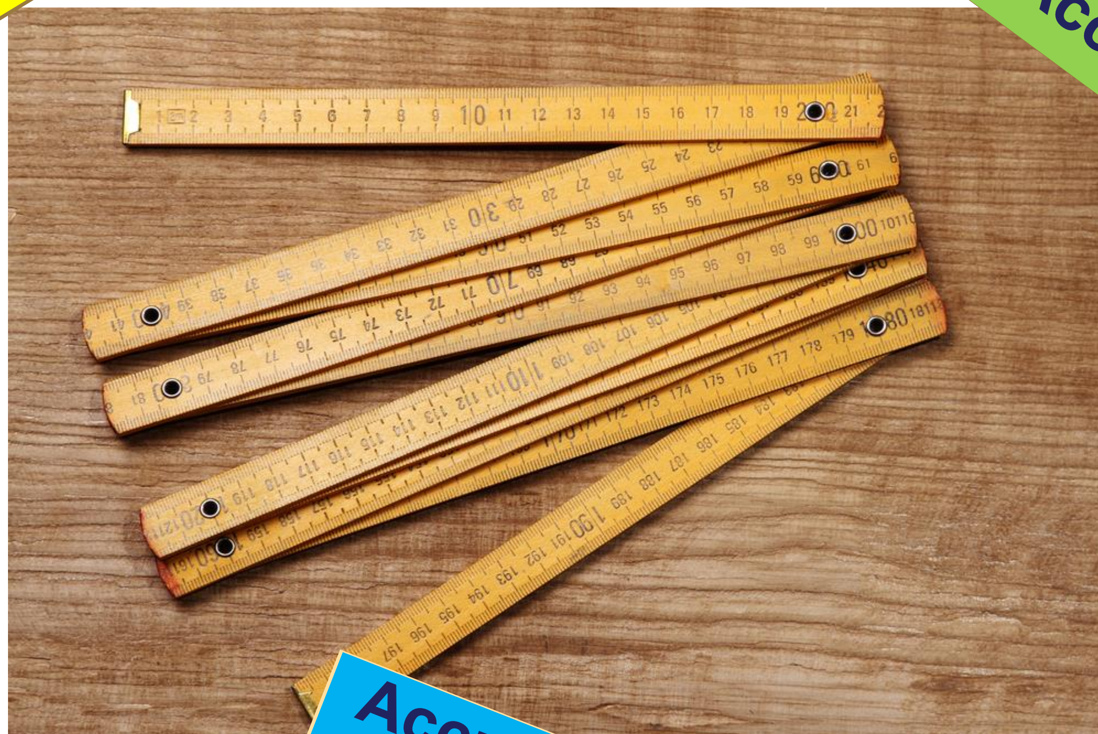
It is important to know

- what the value of my measurement uncertainty is
- how I can improve my accuracy

Terms and definitions

Resolution

Accuracy



Accuracy class

Terms and definitions

Resolution

This measurement device has a resolution of 1 mm

A DMP41 has 2 Mio digits in a measurement range of +/- 2.5 mV/V
Resolution: 2,5mV/V/1Mio=0,0025 µV/V

HBM: public

Accuracy class

Accuracy class?

Strain gauge full bridge, 5 or 10 mV/V measuring range, bridge excitation AC / carrier frequency		
Accuracy class		0.05
Carrier frequency (sine)	Hz	4800 ± 1.5
Bridge excitation voltage (effective)	V	1 and 2.5 (± 5 %)
Transducers that can be connected		strain gauge full bridges
Permissible cable length between MX840B and transducer	m	< 100

?

Type			S2M						
Nominal (rated) force	F_{nom}	N	10	20	50	100	200	500	1000
Accuracy									
Accuracy class			0.02						
Relative reproducibility and repeatability errors without rotation	b_{rg}	%	0.02						
Relative reversibility error	v	%	0.02						
Non-linearity	d_{lin}	%	0.02						
Relative creep over 30 min	[illegible]	%	0.02						

Accuracy class

Accuracy class ?

Amplifier:

- Linearity
- Repeatability
- TCZero
- TC of amplification

Transducer:

· Linearity error
· Hysteresis
· Creep
· Zero point return
· Repeatability in unchanged mounting position
· TCZero
· TCSpan

Accuracy class ?

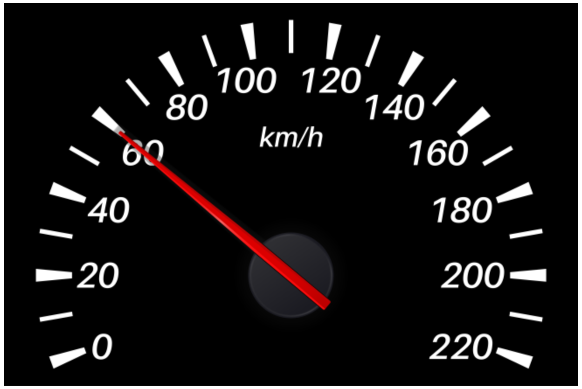
Everybody can do whatever he/she wants!

- No standard existing
- % of full scale
- Do not mix up with
  - Measurement uncertainty
  - Accuracy class according ISO376

- **You can not compare sensors from different suppliers**
- **You can not calculate any errors or uncertainties with the accuracy class**
- **BUT: Choosing a DAQ-System that fits to the sensor- this works!**

It is known if the difference is positive or negative as well as the value of the deviation

➔ **have to be corrected**



Example

The influence of the weight of load introduction parts are used:

=> Tare your measurement chain

What is the accuracy of my measurement chain?

Sorry, depends on ….

Measurement chain

Hysteresis
Linearity
TCZero
TCSpan
Bending moment
sensitivity…

Process

Temperatures
Side load existing?
Hmidity?
…

Post process or real time calculation

Used filter
Rounding error
…

Measurement uncertainty

Adjustment of the measurement chain

According datasheet?
According test certificate?
According individual calibration?
…

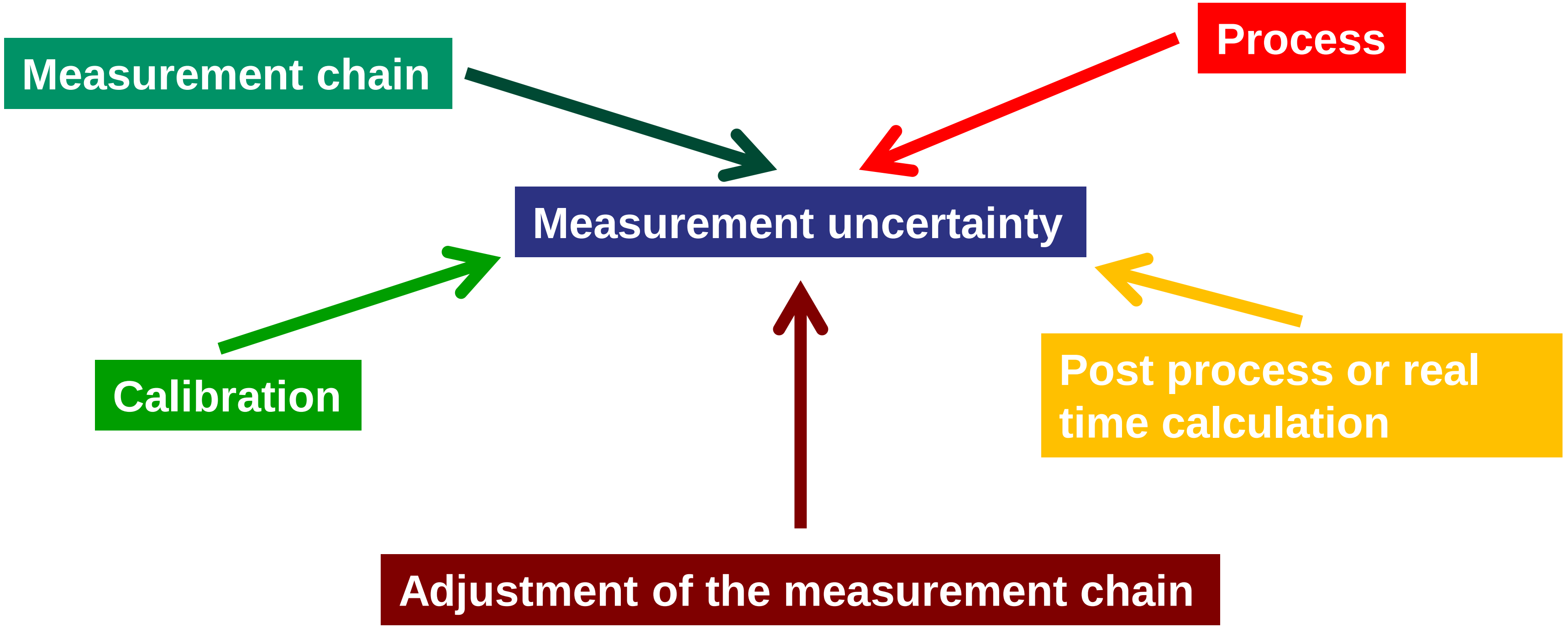
Calibration

Daks-Calibration?
Calibration in mounting position?

Other measurement errors (not systematic)

It is **not** known if the error is positive or negative as well as the value

➔ Measurement uncertainty



A way to estimate the measurement uncertainty realistically

(Accuracy class) X measurement value

Use of the GUM standard

A down to earth way of calculating the individual measurement uncertainty

A way to estimate the measurement uncertainty realistically

GUM =„***G**uide to the Expression of **U**ncertainty in **M**easurement*“

- For highest scientific demands
- complex
- High effort

„The determination of the measurement uncertainty is not a routine job or a math's problem- a detail knowledge about the measurement task is required“

Methods according GUM-standard

Method A

- Get a suitable number of individual measurements
- Calculate the mean value
- The measurement uncertainty can be calculated by calculating the standard deviation of the results

Method B

- Use of existing information on influences that have an impact on the measurement uncertainty
- Calculating the resulting measurement uncertainty by using the single results above

Method B is the better choice for force measurements in most case

A way to estimate the measurement uncertainty

Strategy with measurement uncertainty:

- Calculation of the individual errors
- Statistical characteristic of the individual properties
- Geometrical addition
- Taking care for the range of uncertainty

We need to state: No single error is dependent on another one!

This is a more or less rough estimation

HINT: HBM Seminar “Uncertainty of measurement chains”

Tension measurement for a component test

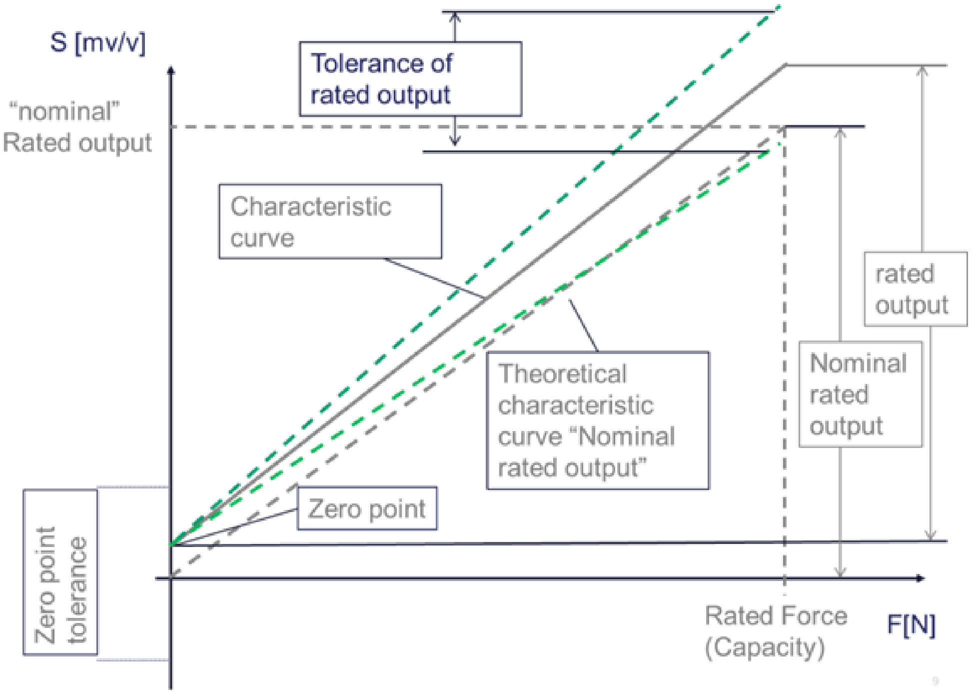
- Load cell U2B/5KN — Capacity 5 kN
- Range of force (Sinus) — between 0 and 1 kN
- Temperature range — 23°C up to 45°C
- Frequency — 15 Hz
- Testing duration — 30 min
- Zero point setting — before every test
- Adjustment according datasheet — 5 kN = 2 mV/V

Data sheet of the U2B:

- Tolerance of rated output: ± 0.2% (related to MV)
- Linearity deviation.: ± 0,1% (related to FS)
- Hysteresis 0,15 % (related to FS)
- TCSpan: ± 0,1% (realted to MV)
- TCZero: ± 0,05% (related to FS)
- Creep (30 min): ± 0,06% (related to MV)

MV = Measurement Value FS = Full scale

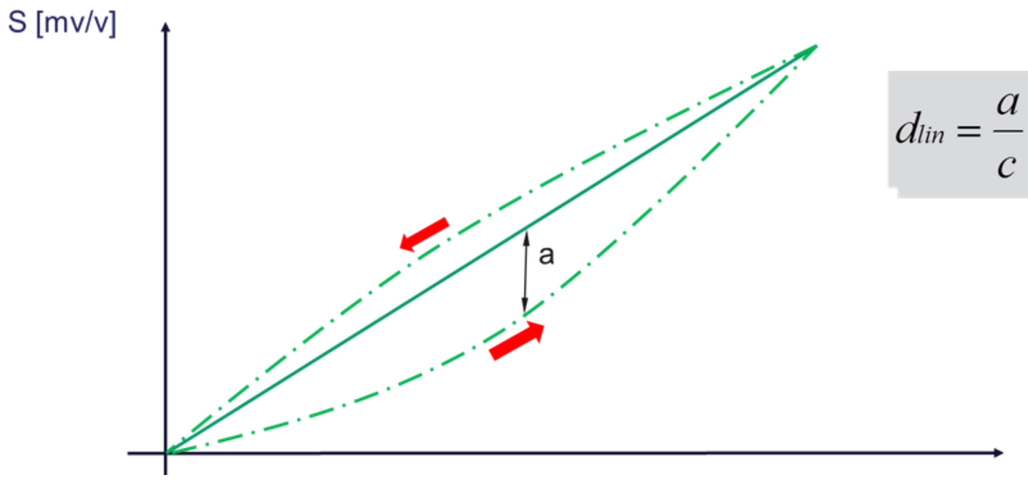
Tolerance of the rated output (related to actual value)



$$\Delta_{d\,C} = 0.2\ \%\ \text{of}\ 1\ \text{kN} = \underline{\mathbf{2\ N}}$$

- **Linearity deviation**

(Related to full scale)



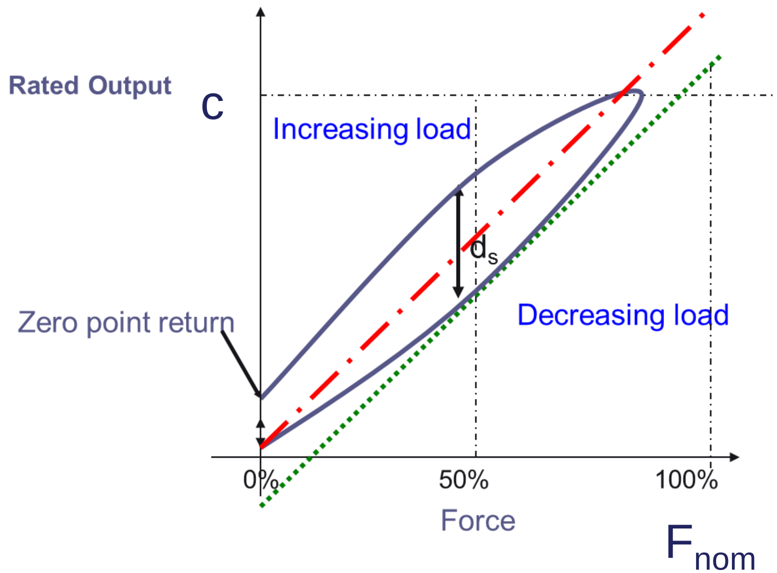
$$d_{lin} = \frac{a}{c}$$

$\Delta_{\text{d lin}}$ = 0,1 % of 5 kN = **5 N**

Example

- **Hysteresis**

(Related to full scale)



$$\upsilon = \frac{d_s}{C}$$

Typical values:

S2M: 0,02%
U10M: 0,02...0.05%
C9c: 0,2%

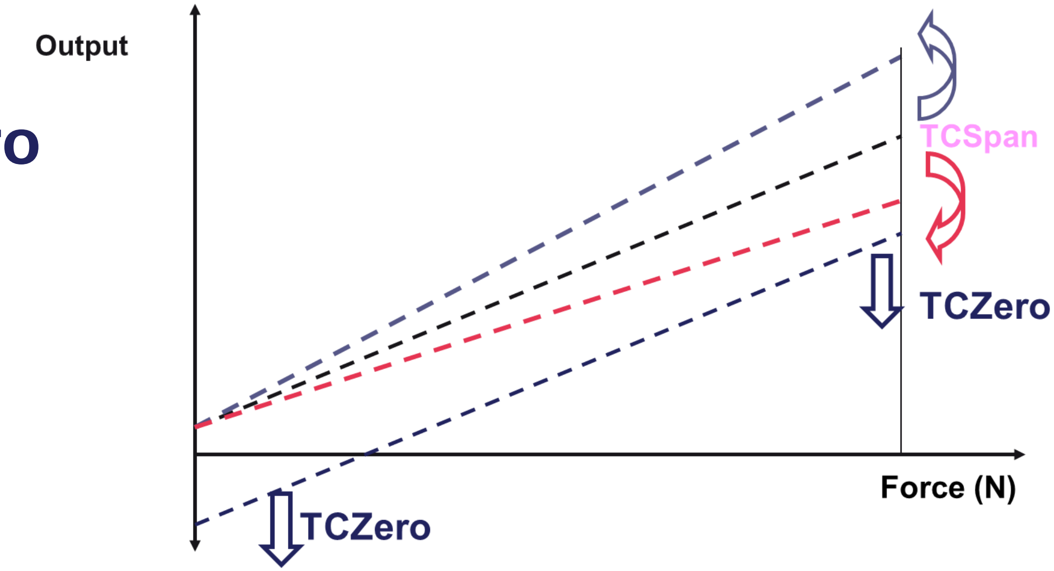
Δ_{hys} = 0.15 % of 5 kN = **7,5 N**

Example

- **Influence of changes in temperature on the zero point: TCZero**

(Related to full scale)

TCZero and TCSpan



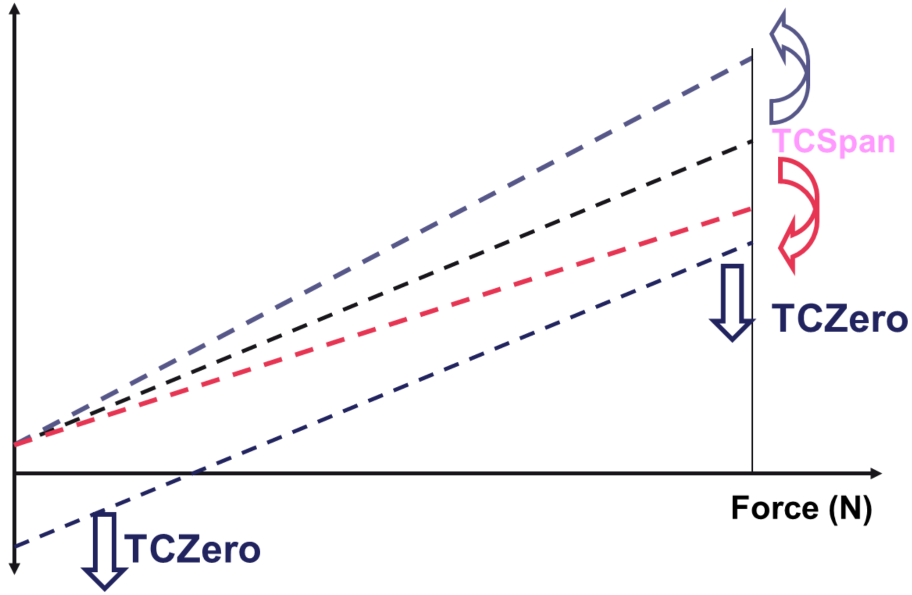
Δ_{TK0} = 0,05 % of 5 kN ·(45°C-23°C)/10K = **5,5 N**

Example

TCZero and TCSpan

• **Influence of changes in Temperature on the Sensitivity: TCSpan**

(related to actual value)

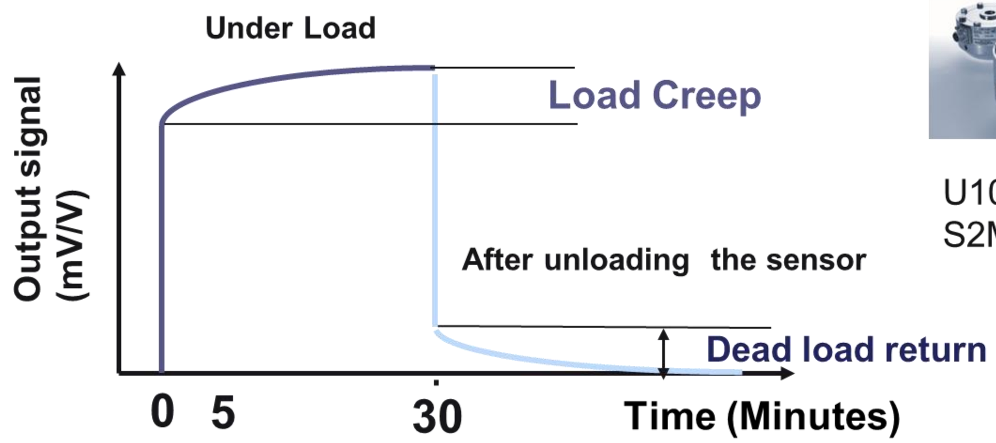


$$\Delta_{TKC} = 0{,}1\ \%\ \text{of}\ 1\ \text{kN} \cdot (45°C-23°C)/10K = \underline{\mathbf{2.2\ N}}$$

Example

- **Creep**

(related to actual value)



U10M: 0,02 %
S2M: 0.02 %

Δ_{cr} = 0,06 % of 1 kN = **0.6N**

Example

- **Tolerance of the rated output** (related to actual value)

  $\Delta_{d\ C}$ = 0.2 % von 1 kN = **2 N**

- **Linearity deviation** (Related to full scale)

  $\Delta_{d\ lin}$ = 0,1 % von 5 kN = **5 N**

- **Hysteresis** (Related to full scale)

  Δ_{hys} = 0.15 % von 5 kN = **7,5 N**

- **TCSpan** (Related to actual value)

  Δ_{TKC} = 0,1 % von 1 kN ·(45°C-23°C)/10K = **2.2 N**

- **TCZero** (related to full scale)

  Δ_{TK0} = 0,05 % von 5 kN ·(45°C-23°C)/10K = **5,5 N**

- **Creep** (related to actual value)

  Δ_{cr} = 0,06 % von 3 kN = **0.6N**

Example

$$U_{ges} \approx \sqrt{\Delta^2_{dC} + \Delta^2_{d\,lin} + \Delta^2_{hys} + \Delta^2_{TKC} + \Delta^2_{TK0} + \Delta^2_{cr}}$$

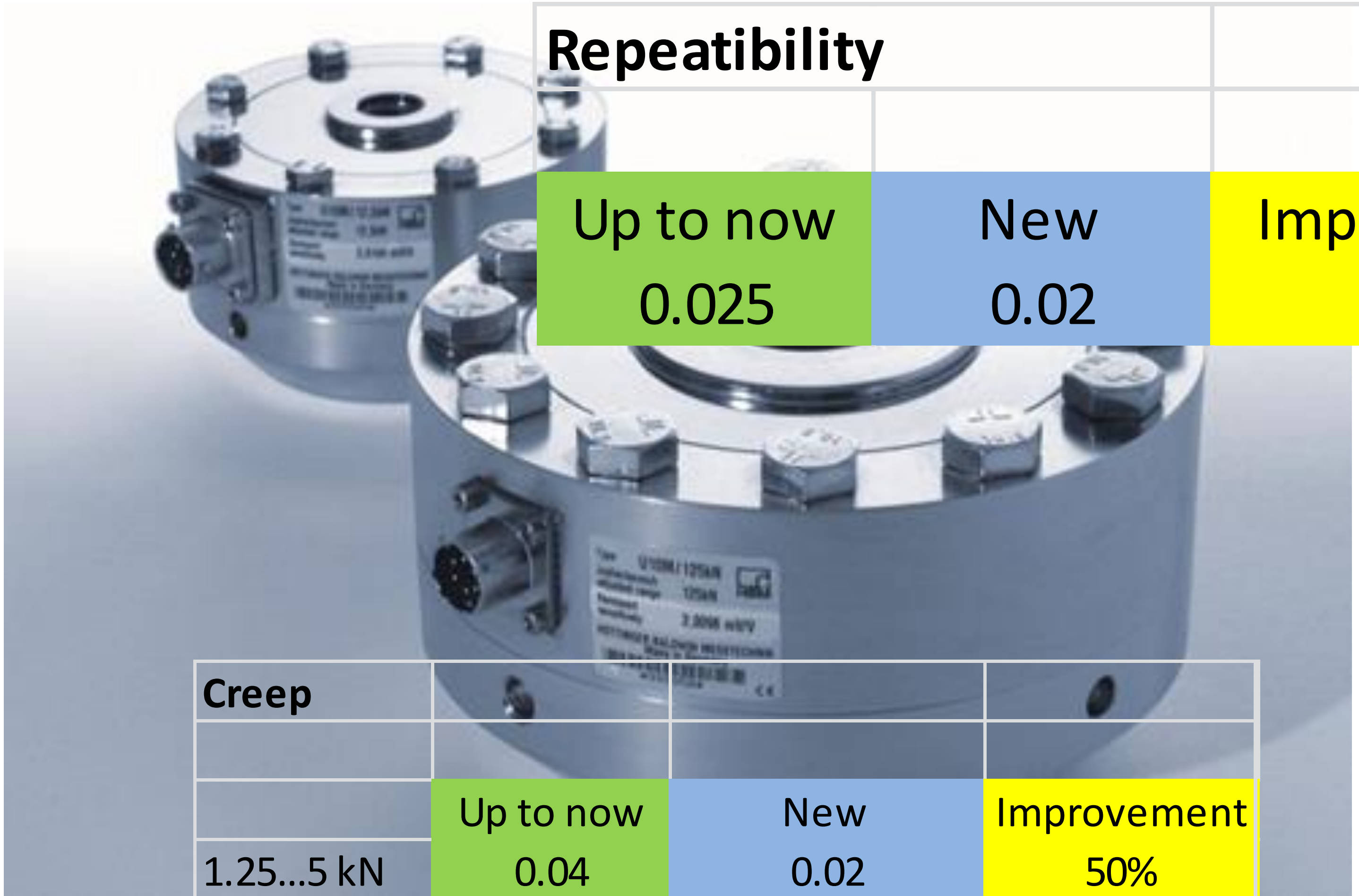
$$= \sqrt{(2\,\mathrm{N})^2 + (5\,\mathrm{N})^2 + (7.5\,\mathrm{N})^2 + (2.2\,\mathrm{N})^2 + (5.5\,\mathrm{N})^2 + (0.6\,\mathrm{N}$$

$$\approx \underline{\underline{10{,}98\,\mathrm{N}}}$$

Uncertainty: 1,1%....too big??

- **Lower capacity**
  (lower influence of all parameters that related to full scale)
- **More stable temperature conditions**
  (lower influence of TCZero/TCSpan)
- **Calibration at HBM**
  (Lower linearity deviation, lower tolerance of sensitivity)

Influence of the Load cell



Repeatability		
Up to now	New	Improvement
0.025	0.02	25%

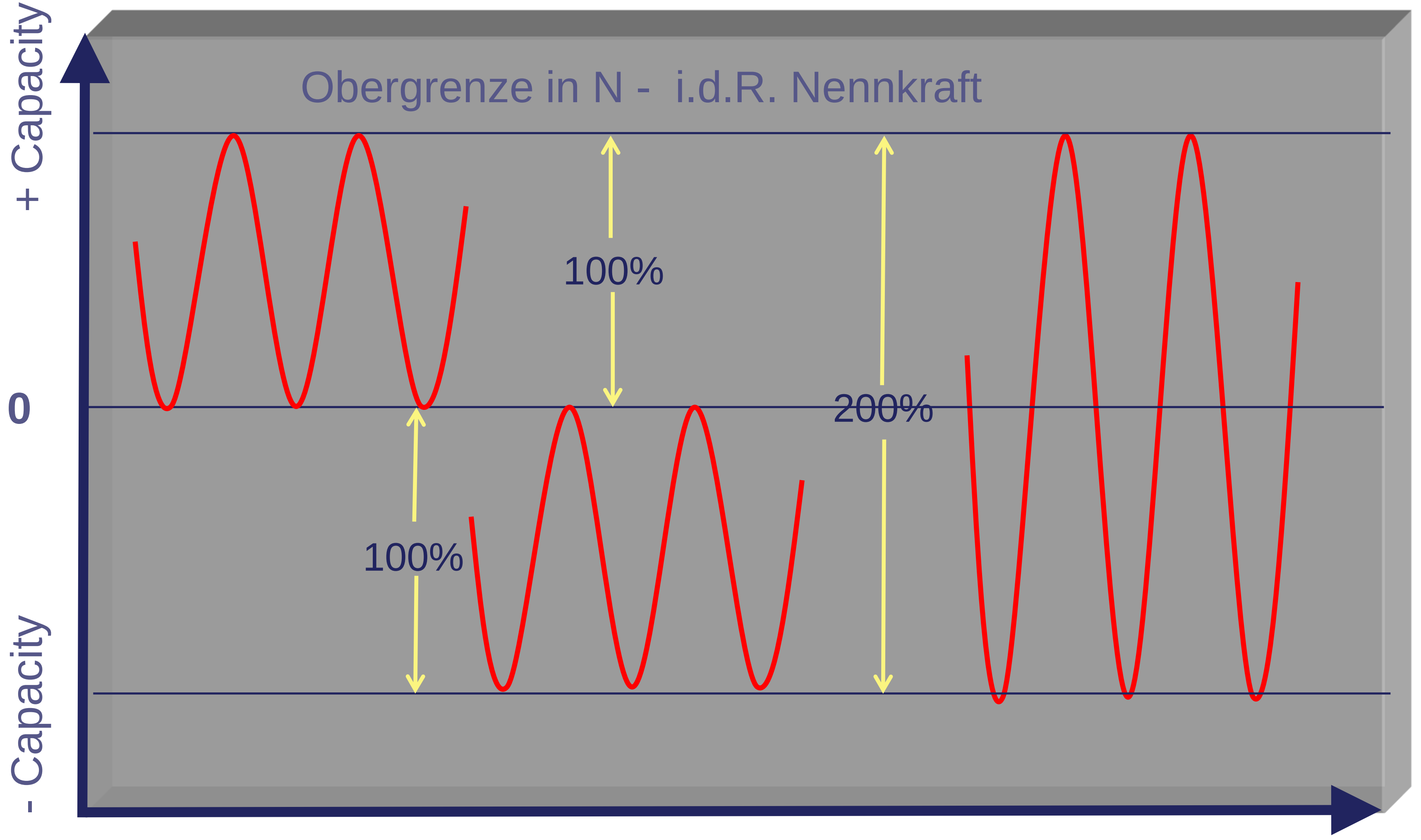
Creep			
	Up to now	New	Improvement
1.25...5 kN	0.04	0.02	50%
12.5...500kN	0.025	0.02	20%

Influence of the load cell

Linearity error			
Capacity	Up to now	New	Improvement
1.25 kN	0.03	0.02	33%
2.5 kN	0.03	0.02	33%
5 kN	0.03	0.02	33%
12.5 kN	0.04	0.03	25%
25 kN	0.04	0.03	25%
50 kN	0.04	0.035	13%
125 kN	0.04	0.035	13%
250 kN	0.04	0.035	13%
500 kN	0.06	0.05	17%

Hysteresis			
Capacity	Up to now	New	Improvement
1.25 kN	0.03	0.02	33%
2.5 kN	0.03	0.02	33%
5 kN	0.03	0.02	33%
12.5 kN	0.04	0.035	13%
25 kN	0.04	0.035	13%
50 kN	0.05	0.035	30%
125 kN	0.05	0.04	20%
250 kN	0.05	0.04	20%
500 kN	0.05	0.05	0%

Use the robustness of HBM´s U10M series: 200 % calibration



- **Tolerance of the rated output** (related to actual value)

  $\Delta_{d\,C}$ = 0.02 % von 1 kN = **0,2 N**

- **Linearity deviation** (related to full scale)

  $\Delta_{d\,lin}$ = 0.02 % von 2.5 kN = **0,5 N**

- **Hysteresis** (related to full scale)

  Δ_{hys} = 0.02 % von 2.5 kN = **0.5 N**

- **TCSpan** (related to actual value)

  Δ_{TKC} = 0,015 % von 1 kN ·(45°C-23°C)/10K = **0.33 N**

- **TCZero** (related to full scale)

  Δ_{TK0} = 0,015 % von 5 kN ·(45°C-23°C)/10K = **0.4125 N**

- **Creep** (related to actual value)

  Δ_{cr} = 0,02 % von 3 kN = **0.2N**

Error: 1,03 N (=0,13%)
(2,06 N (=0,26%) in case of k = 2)

Additional informationen

More information can be found on our website:

www.hbm.com/force

Force Sensors & Load Cells [N]

Force Sensor Product Finder:

Selected: no filter

Capacity | Calibration | Tension / Compression | Load Cell Design | Strain Gauge / Piezo

Your selection returned 26 products.

C10

Force sensor with high lateral force stability for dynamic and static measurement tasks.

U10

Sensor with high bending moment for dynamic and static measurement tasks.

U9C

Dynamic and immediately ready for use: U9C is HBM's cost-effective miniature force load cell for compressive and tensile forces.

C9C

Dynamic and immediately ready for use: C9C is HBM's cost-effective miniature force sensor for compressive force.

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Any questions?

- If you have any questions, please do not hesitate to contact us: webinar@hbm.com
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