Connection of load cells

Welcome to the webinar:
“Connection of load cells”

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- **Product Manager Force Transducers**
- Diploma Physical Engineering
- 16 years of experience in development (strain gauges), 10 years responsibility for force sensors at HBM
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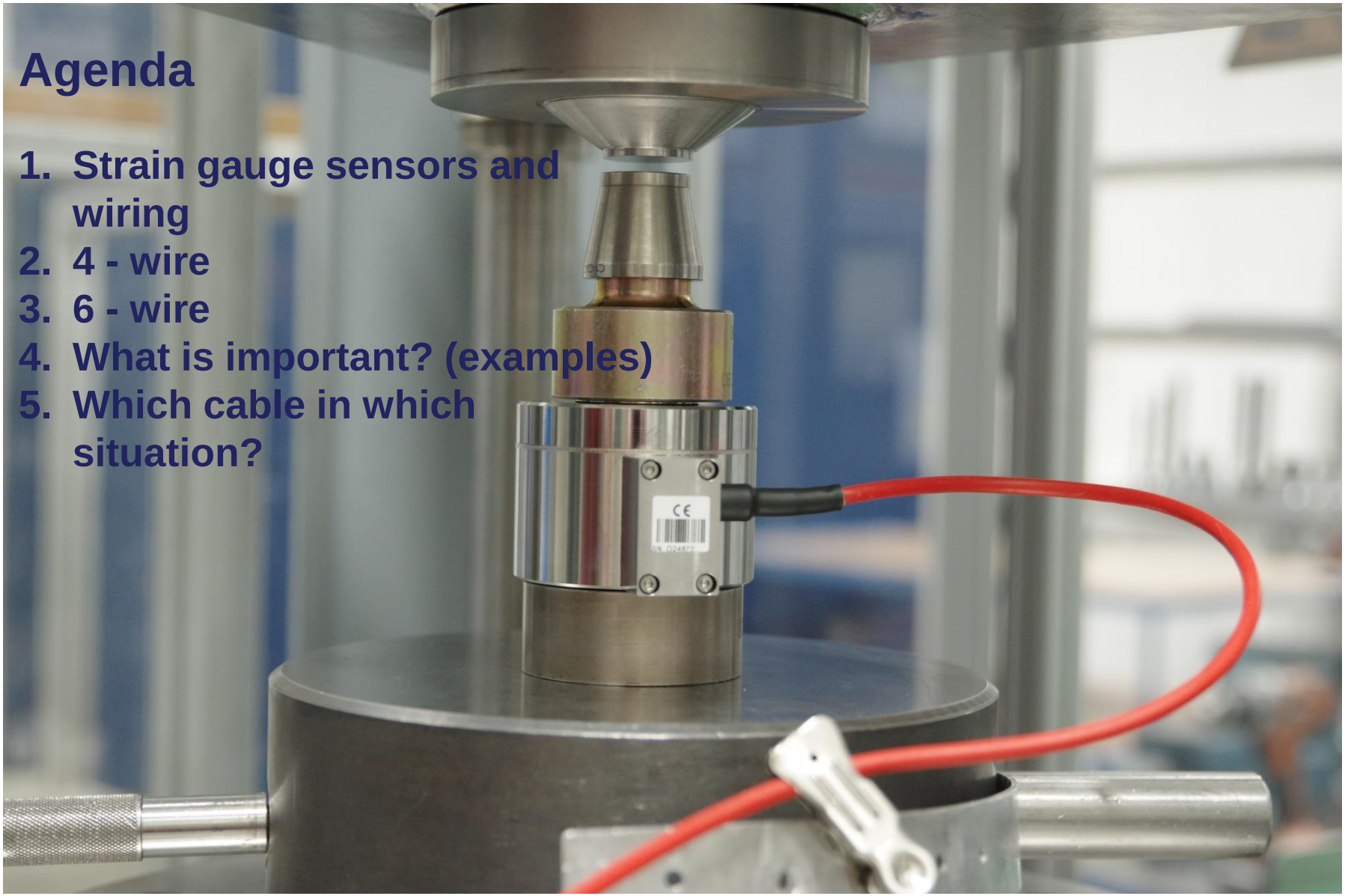
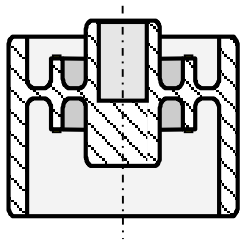
Thomas Kleckers



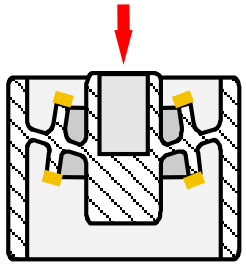
Agenda

1. Strain gauge sensors and wiring
2. 4 - wire
3. 6 - wire
4. What is important? (examples)
5. Which cable in which situation?

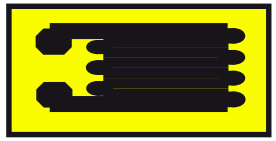
Strain gauge sensors: The principle

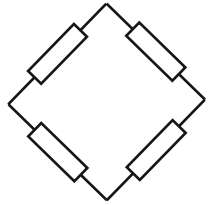


Spring body



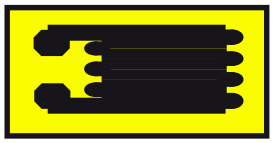
If a load is introduced, strain appears. Strain gauges convert the strain into a change of resistance





The Wheatstone bridge converts the changes in resistance into a measurable voltage

Typical:		
Mech. Stress:	2	200 Mpa
Material:		Steel (200 Gpa)
Strain $\varepsilon = \sigma/E$ =>		0,001 (= 0,1 %)
Usual “Unit”:		µm/m = 10^{-6}



How much is the change in resistance?

$\Delta R/R_0 = k \cdot \varepsilon$ $\quad$ $k \sim 2$ $\quad$ $R_{(typ.)} = 350\Omega$

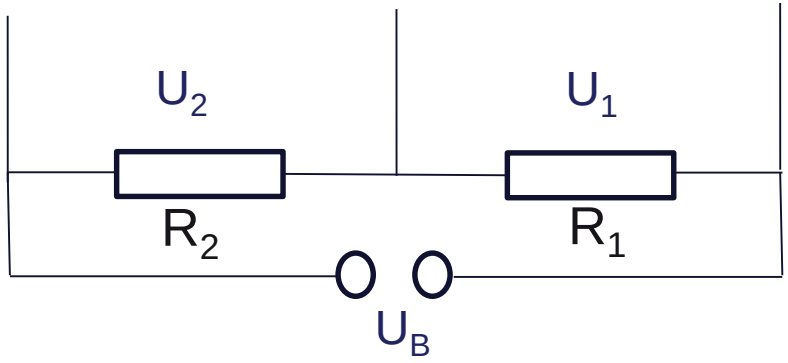
$\varepsilon = 1000\ \mu m/m\ (0{,}1\ \%)$

Strain gauge resistance 350 Ohm Strain 1000 µm/m:
0,7 Ω change of resistance

Ohmmeter: Resolution by far not good enough!

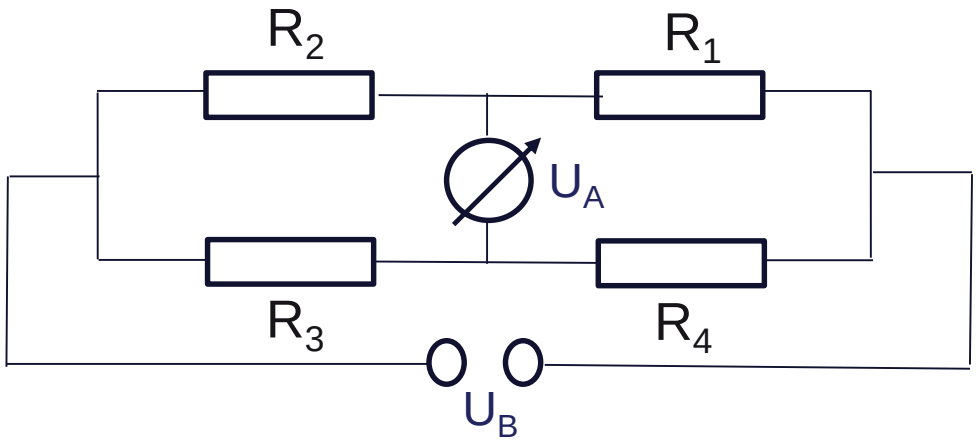
=> **Wheatstone Bridge**

Strain gauge sensors and wiring



$$U_1 = \frac{R_1}{R_1+R_2} * UB$$

$$\frac{U_1}{U_B} = \frac{R_1}{R_1+R_2}$$



$$\frac{U_A}{U_B} = \frac{R_1}{R_1+R_2} - \frac{R_4}{R_3+R_4}$$

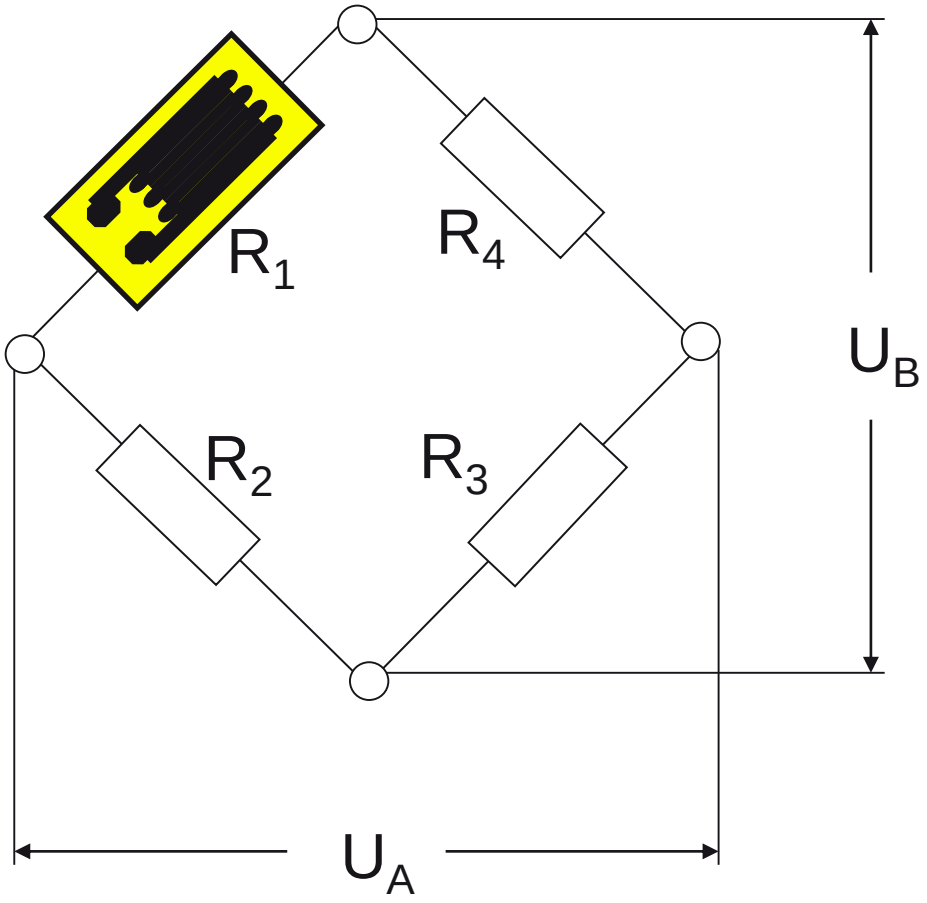
Simplification: $R_1 = R_2$ and $R_3 = R_4$

$$\frac{U_A}{U_B} = \frac{1}{4} \cdot \left(\frac{\Delta R_1}{R_1} - \frac{\Delta R_2}{R_2} + \frac{\Delta R_3}{R_3} - \frac{\Delta R_4}{R_4} \right)$$

R_1 , R_3 : **Increase** of resistance lead to a positve output voltage
R_1 , R_2 : **Decrease** of resistance lead to a positve output voltage

Example:

1000 µm/m, change in resistance 0.7 Ohm



$$\frac{U_A}{U_B} = \frac{R_1}{R_1 + R_2} - \frac{R_4}{R_3 + R_4}$$

$$\frac{U_A}{U_B} = \frac{1}{4} \cdot \left(\frac{\Delta R_1}{R_1} - \frac{\Delta R_2}{R_2} + \frac{\Delta R_3}{R_3} - \frac{\Delta R_4}{R_4} \right)$$

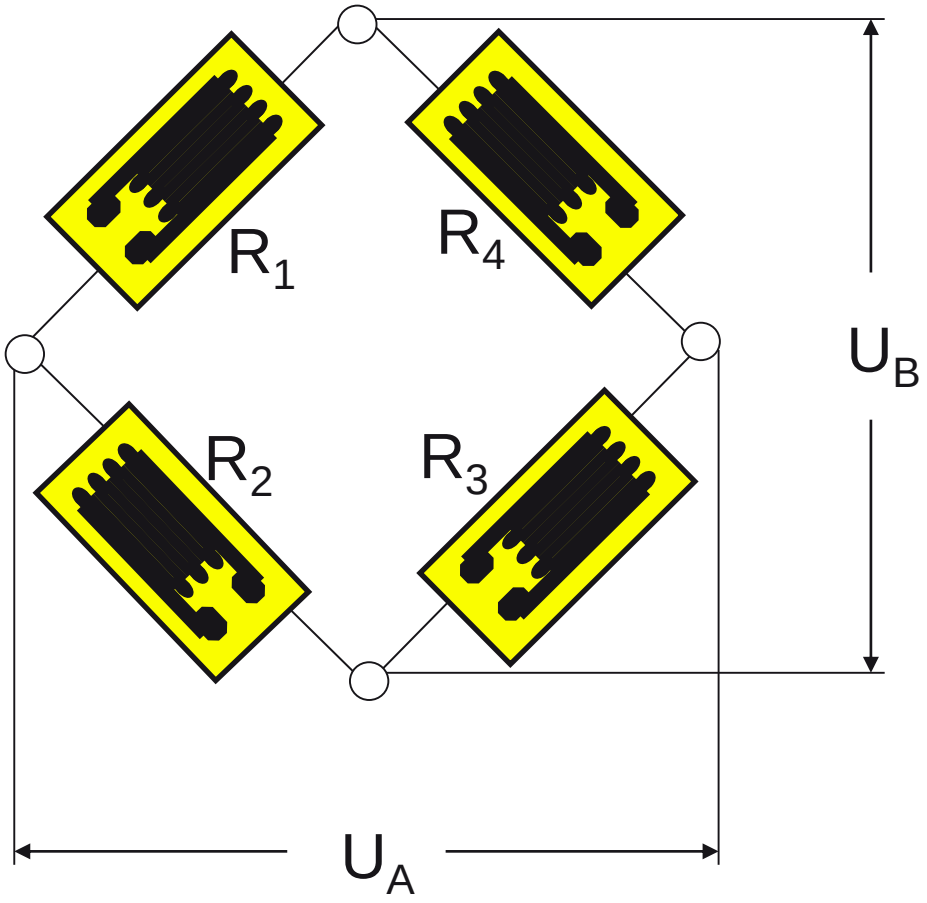
$$\frac{U_A}{U_B} = \frac{1}{4} \cdot \left(\frac{0.7\ \Omega}{350\ \Omega} - \frac{0\ \Omega}{350\Omega} + \frac{0\ \Omega}{350\ \Omega} - \frac{0\ \Omega}{350\ \Omega} \right)$$

$$\frac{U_A}{U_B} = 0{,}0005$$

$$\frac{U_A}{U_B} = 0{,}5\ mV/V$$

Example:

1000 µm/m, change in resistance 0.7 Ohm



$$\frac{U_A}{U_B} = \frac{R_1}{R_1 + R_2} - \frac{R_4}{R_3 + R_4}$$

$$\frac{U_A}{U_B} = \frac{1}{4} \cdot \left(\frac{\Delta R_1}{R_1} - \frac{\Delta R_2}{R_2} + \frac{\Delta R_3}{R_3} - \frac{\Delta R_4}{R_4} \right)$$

$$\frac{U_A}{U_B} = \frac{1}{4} \cdot \left(\frac{0{,}7\ \Omega}{350\ \Omega} - \frac{-0{,}7\ \Omega}{350\Omega} + \frac{0{,}7\ \Omega}{350\ \Omega} - \frac{-0{,}70\ \Omega}{350\ \Omega} \right)$$

$$\frac{U_A}{U_B} = 0{,}002$$

$$\frac{U_A}{U_B} = 2\ mV/V$$

$$\frac{U_A}{U_B} = 2\ mV/V$$

Common supply voltages (U_B):

Between 1 V and 10 V
Very common: **5 V**

Output voltage with full scale:

$$U_{A\,(fs)} = 2\frac{mV}{V} * 5\ V$$

$$U_{A(fs)} = 10\ mV$$

Resolution: 10000 digits:

1 µV

Strain gauge sensors and wiring

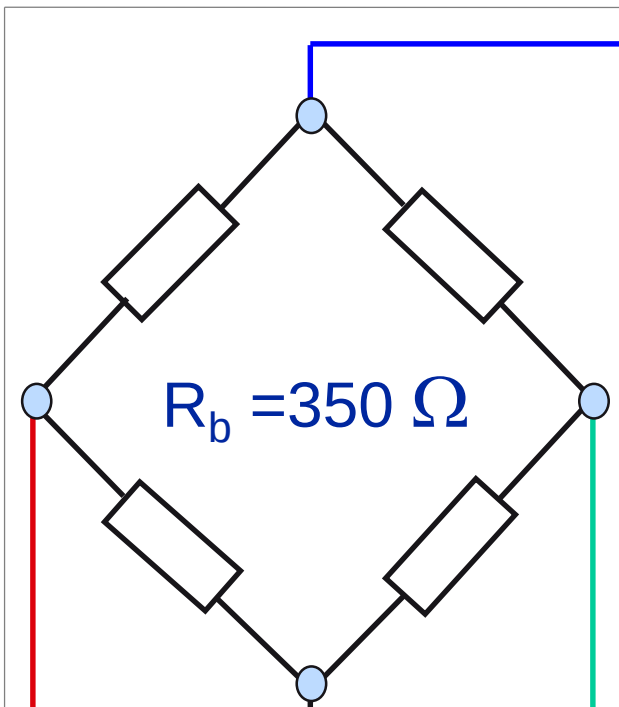
- Rated output of the load cell: 2mV/V
- Supply voltage: 5V
- Max. output voltage: 10mV
- Resolution 100000d: 0,1µV

- Comparisson:
- 321 m
- 3,21 mm Thickness of a CD jewel case

Influences

- *Electrical fields (50 Hz, inverter)*
- *Magnetic fields changing with the time*

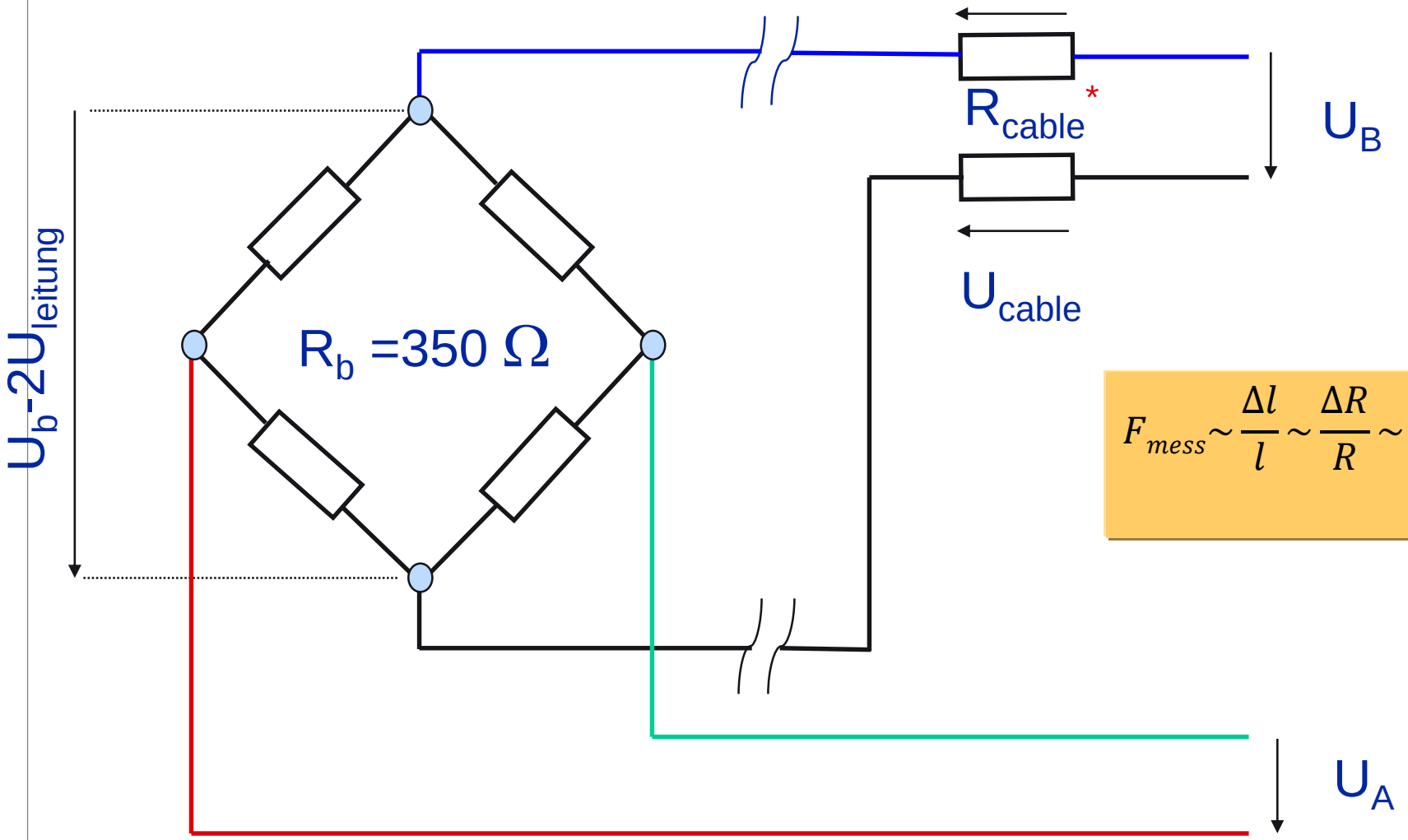
4 – wire circuit



Green is white

$$\frac{U_A}{U_B} = \frac{k}{4}\left(\varepsilon_1 - \varepsilon_2 + \varepsilon_3 - \varepsilon_4\right)$$

4 – wire circuit



$$F_{mess} \sim \frac{\Delta l}{l} \sim \frac{\Delta R}{R} \sim \frac{U_A}{U_B}$$

No influence of the resistance of the output wires on the results due to high input resistance of amplifier

Example

- Bridge Resistance: 350 Ω
- Copper wire, 0,14 mm²
- spec. Resistance ρ=17,8 Ω·mm²/m

$$R_{wire} = \frac{\rho l}{A}$$

Case 1: 5 m Cable length:

- $2 \cdot R_{wire} = 1{,}272\ \Omega$
- Sensitivity change: 0,36 %

Fall 1: 50 m Cable length :

- $2 \cdot R_{wire} = 1{,}272\ \Omega$
- Sensitivity change: 3,6 %

Conclusion

- Perform calibration with the cable used in the measurement **<u>=> HBM is doing so</u>**
- Cable extension may be critical: Shunt calibration?
- *Best thing is to do cable extension by using the 6 wire technology*

4 – wire circuit

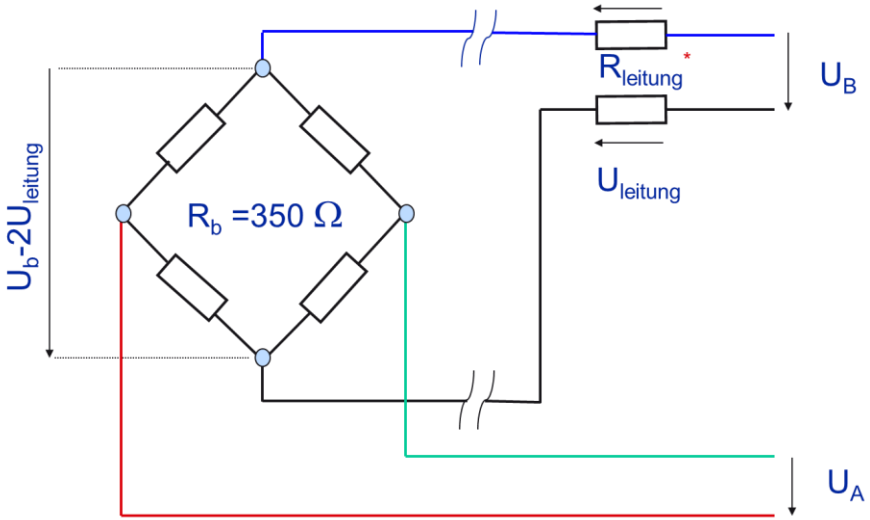
Cable resistance is depending on temperature

Higher temperature

Higher cable resistance

Lower voltage at the Wheatstone bridge

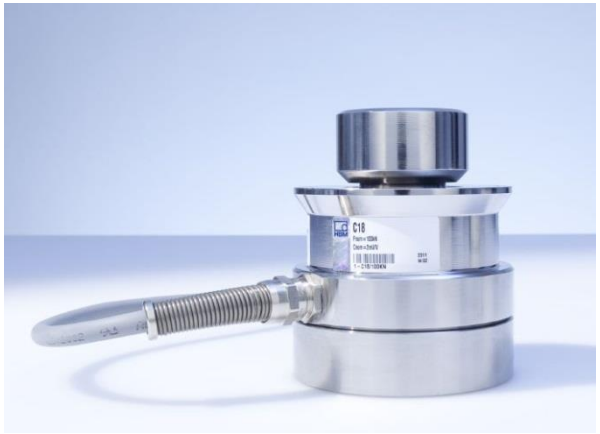
Lower sensitivity



Sensitivity is depending on cable length and temperature (only for 4 – wire!)

With HBM: All characteristics include the cable delivered with the sensor.

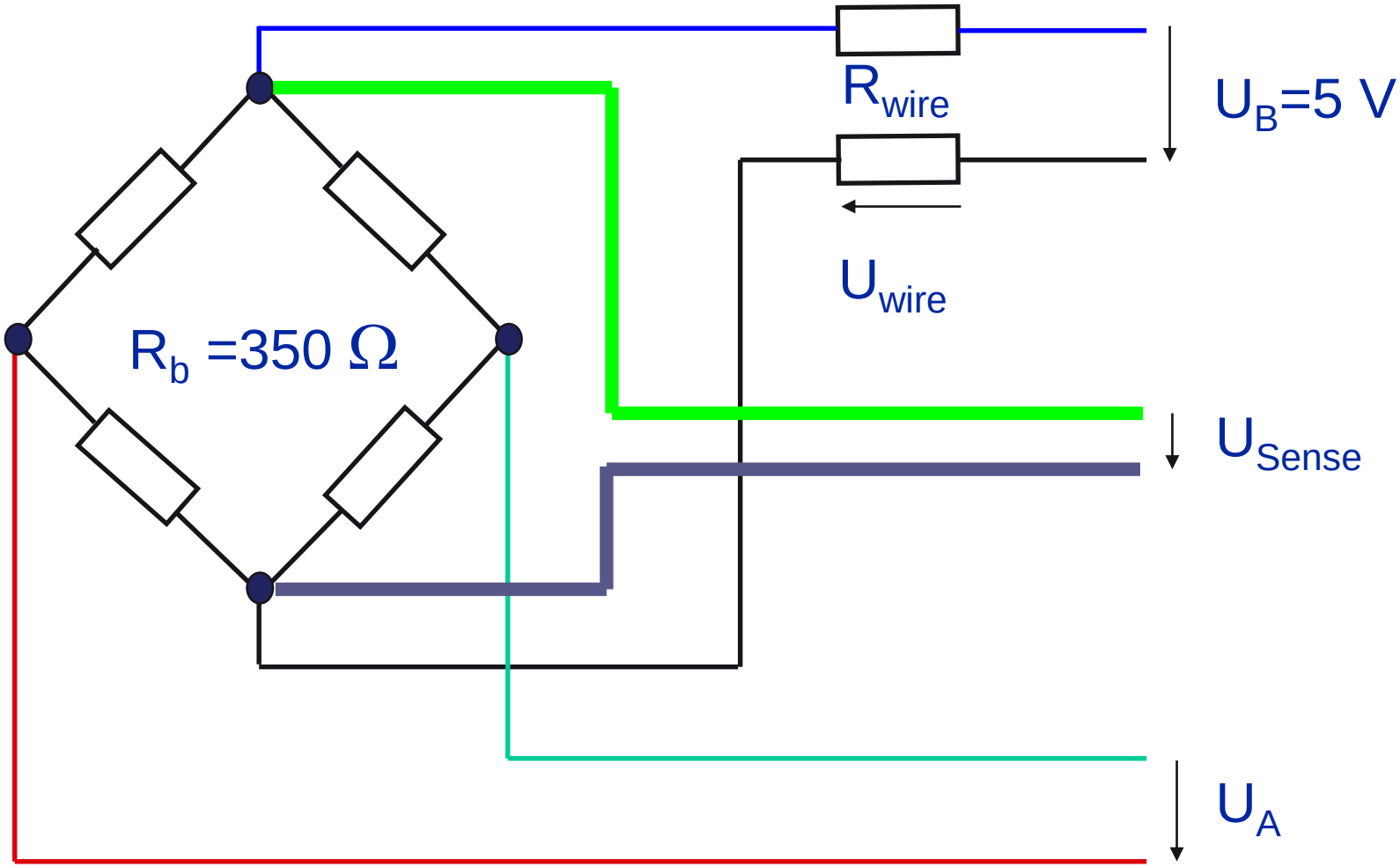
4 – wire circuit



Load cells with 4 –wire connection

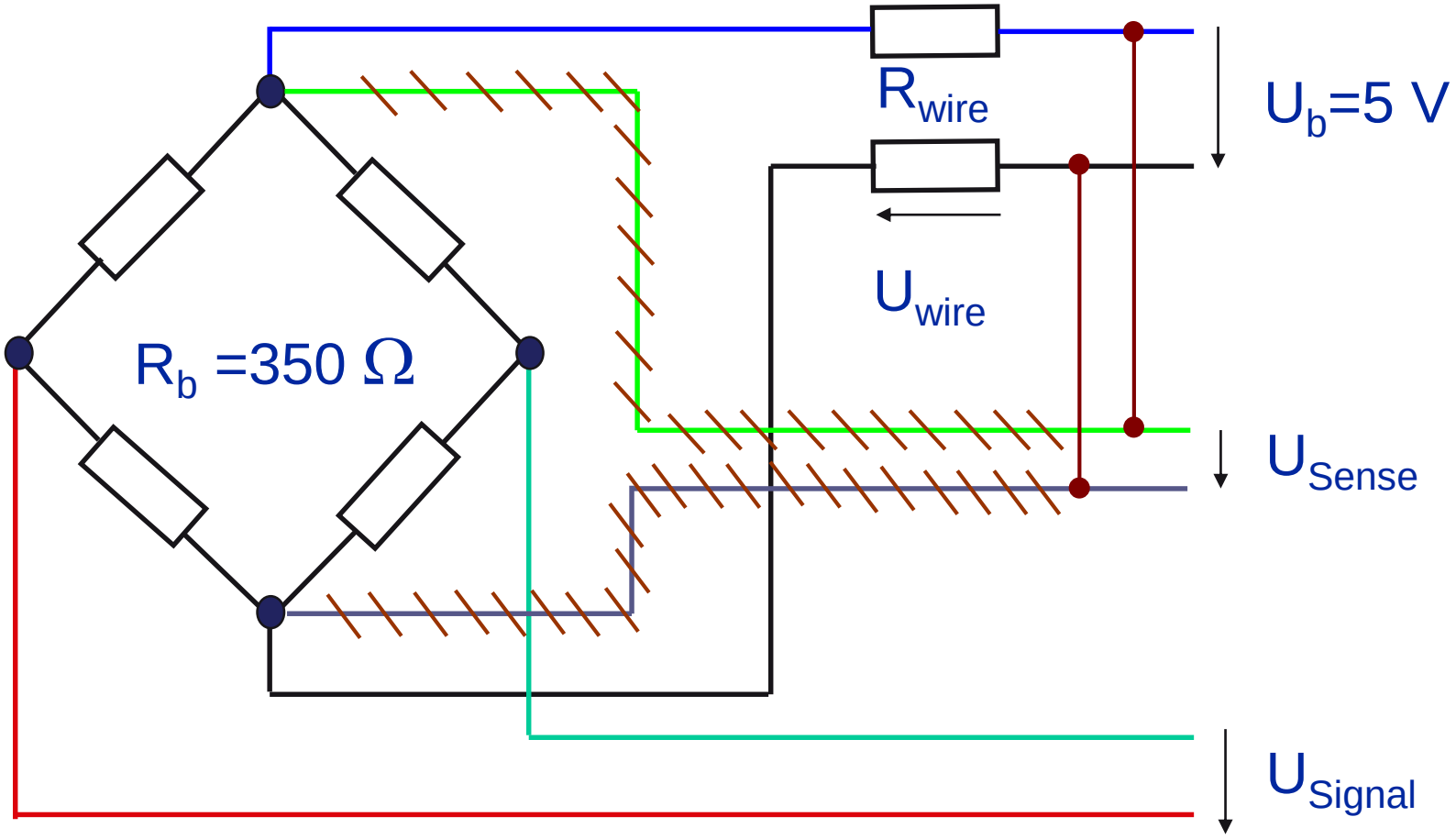
Sensors have to be calibrated in mounting position in 4 – wire connection

6 – wire circuit

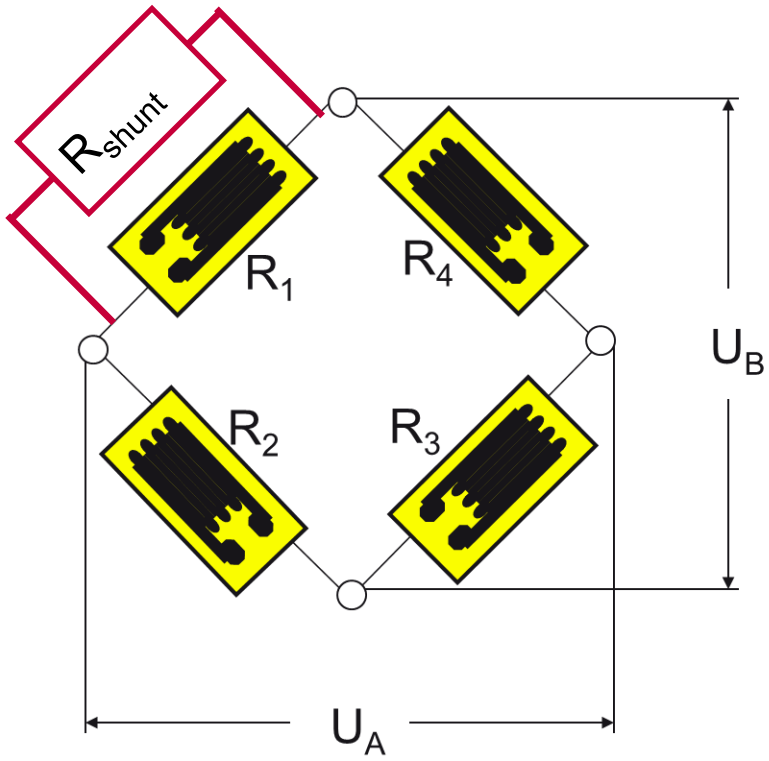


6 – wire circuit: Measurement of the voltage at the Wheatstone bridge, readjustment if required, ffor example in case of changes in temperaure

=> No connection between sense wires and bridge supply, e.g. in the connector



What is important? (examples)



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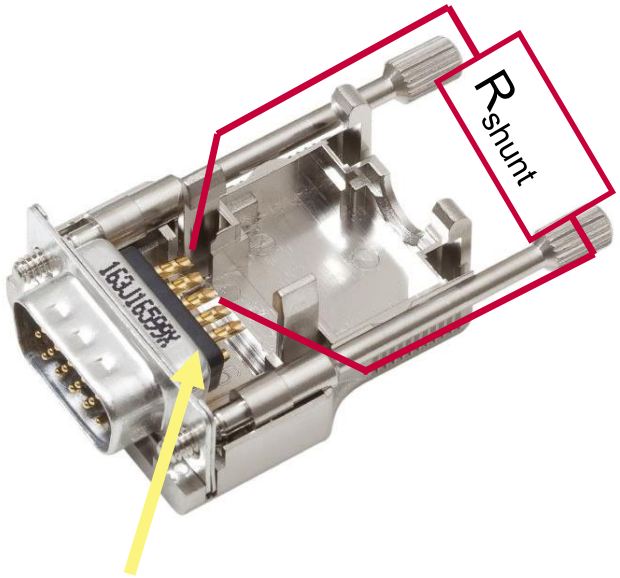


Remove flux!

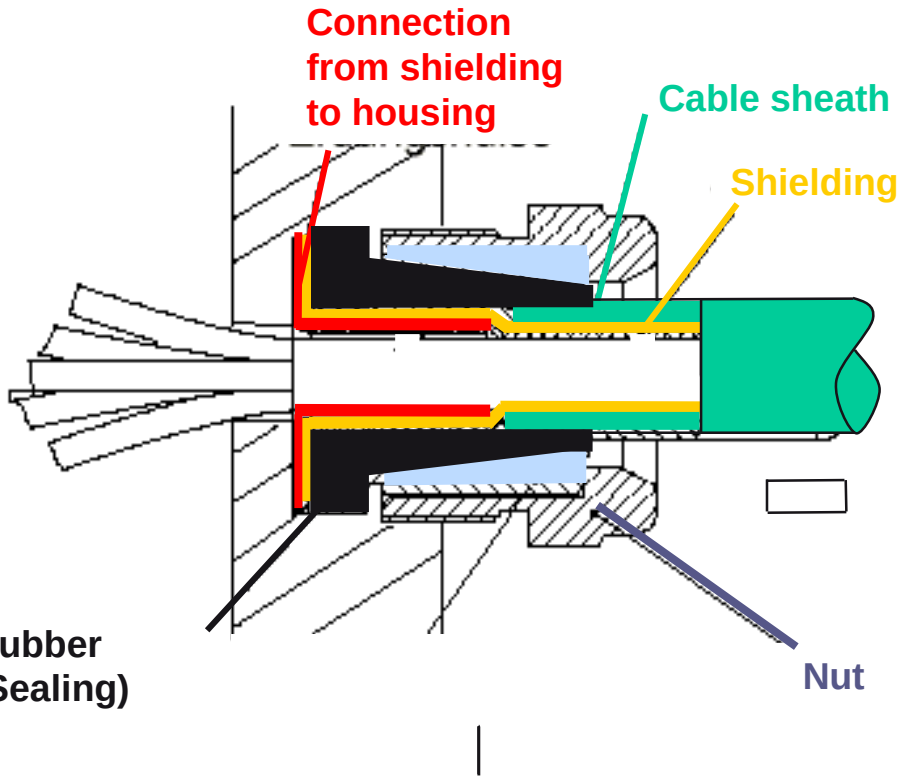
$$\frac{\Delta R}{R} = \frac{R_1 - \frac{R_1 + R_{Shunt}}{R_1 \times R_{Shunt}}}{R_1}$$

Flux changes ist resistance if humidity appears.

=> String influence on zero point

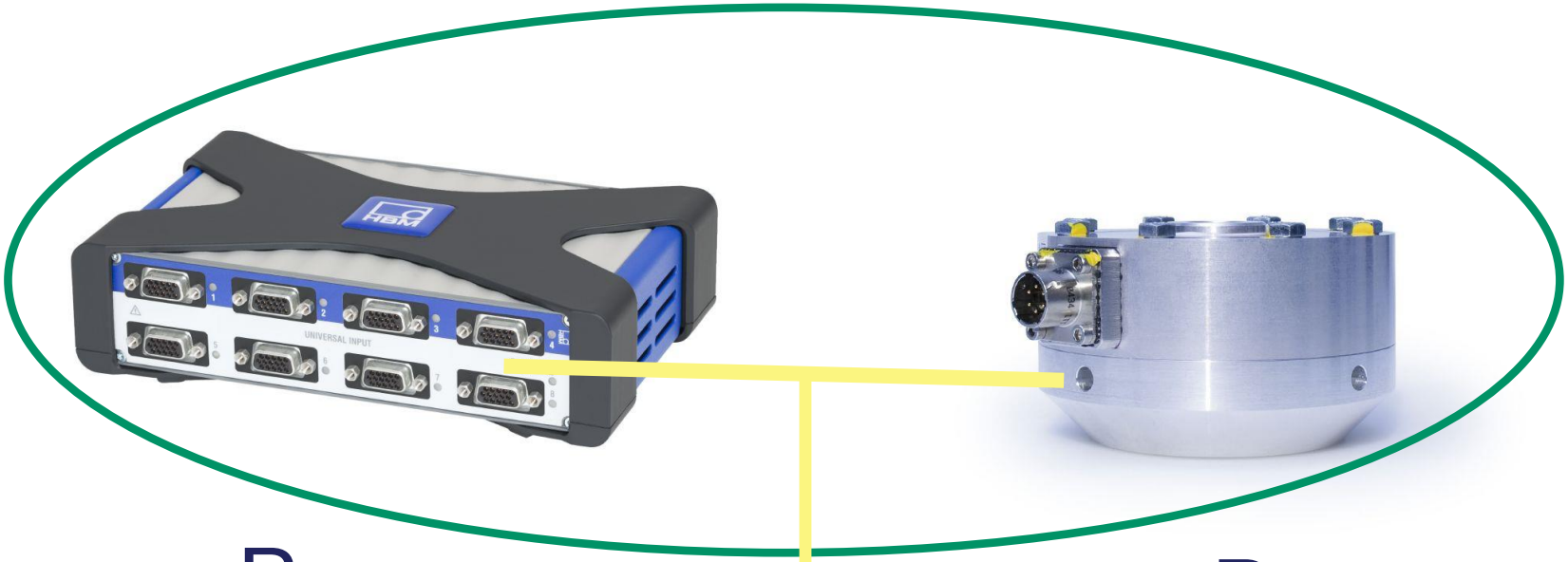
What is important? (examples)

- **Cable shielding is connected to sensor housing**



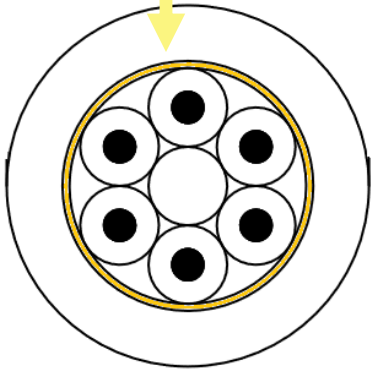
⇒ Faraday´s cage ⇒ good EMC protection => test condition at HBM

What is important? (examples)



P_1

P_2



$P_1 \neq P_2 \Rightarrow$ I

What is important? (examples)

Problem of the concept using the Farrady´s cage:

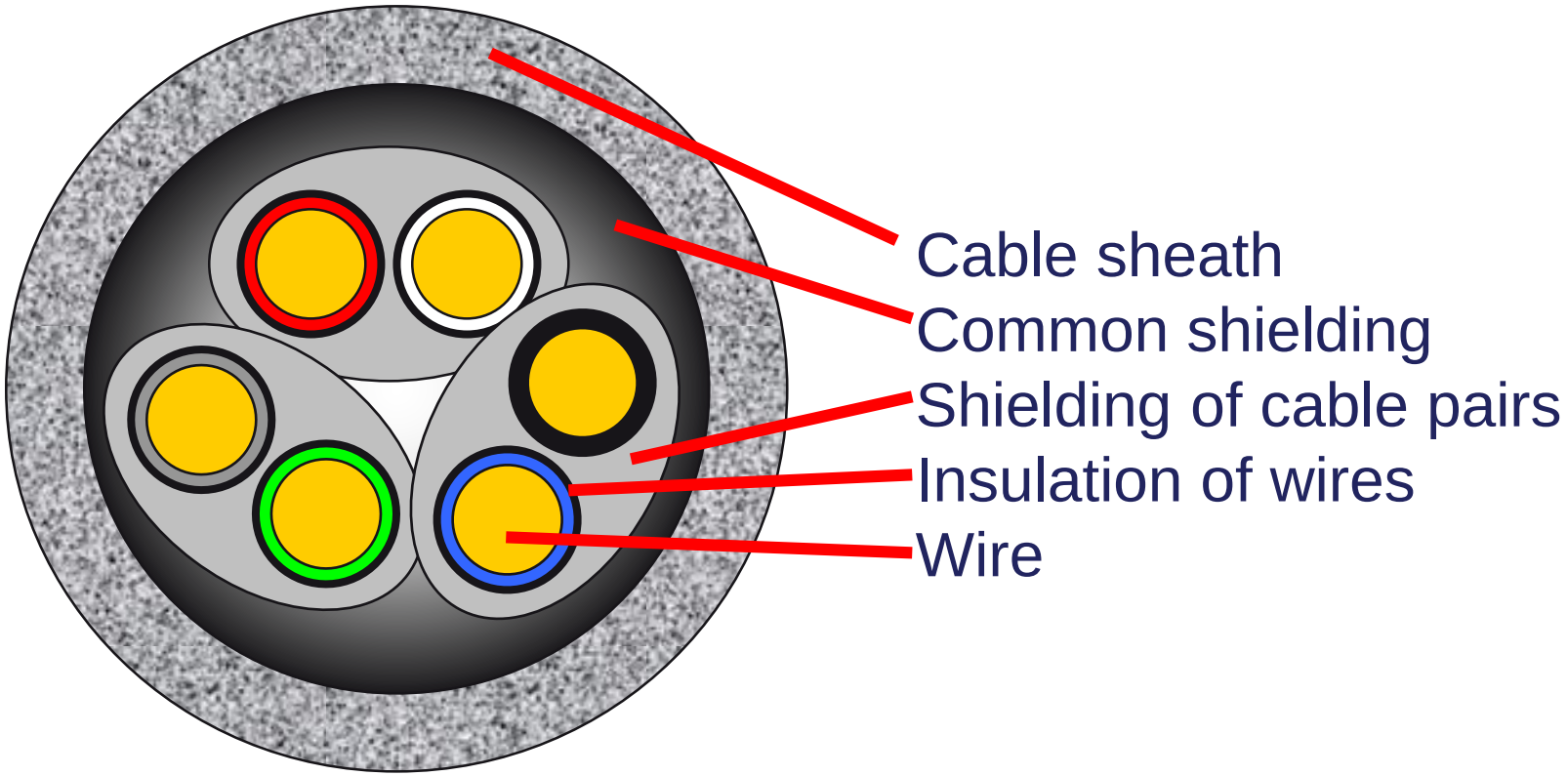
- If the sensor and the amplifier are not on the same electrical potential => Current flows over the shielding
- 50 Hz – interferences may occur

Solution:

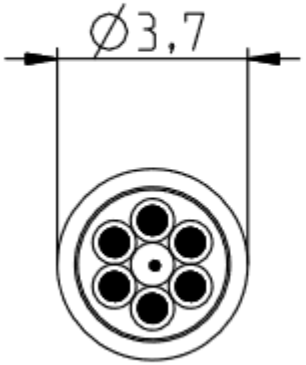
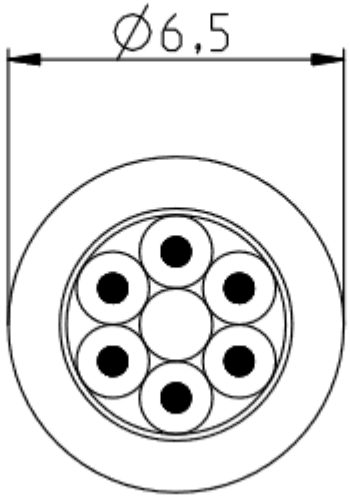
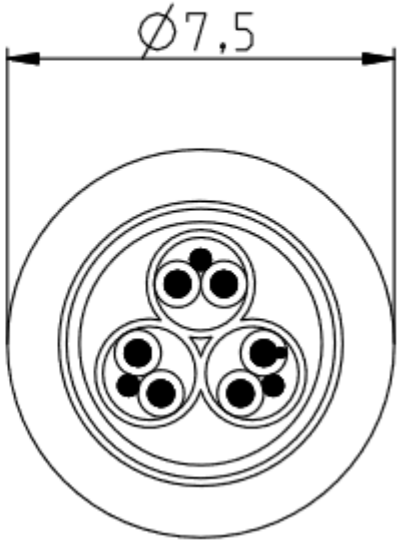
- Use a low resistance connection between sensor and amplifier housing
- Recommendation: very flexible wire, 16 mm^2 Cu

Which cable?

- **Number of wires** **(4 L or 6 L?)**
- **Cross section** **(Cable length)**
- **Temperature**
- **Widhstanding against chemicals**
- **Mechanical requirements** **(drag chain?)**



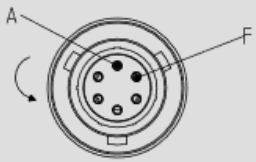
Which cable?

KAB131	KAB157	KAB139B
		
• Very flexible • Low force shunt • Widthstands many operating materials • Higher electrical resistance • Higher capacity	• Widthstands many operating materials • High symmstry • For outdoor use	• Double shielding conceot,low capacity works with long distances, high CF and under harsh EMC - enviroment • Stiff

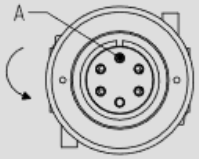
Which cable?

Male connector on sensor-side

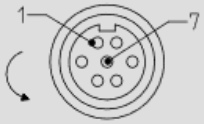
B, L = bayonet



G = thread

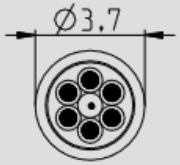


Z = 7-pin binder

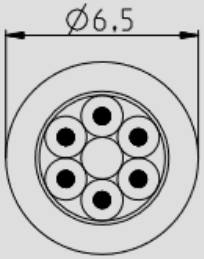


Cable types

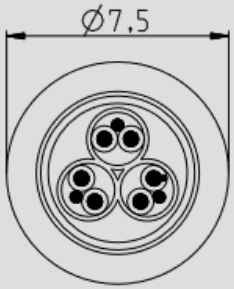
KAB-131



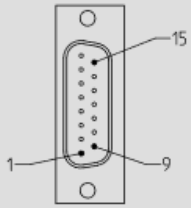
KAB-157



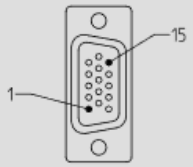
KAB-139B



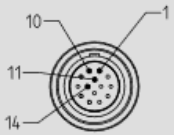
Connection variants for the amplifier



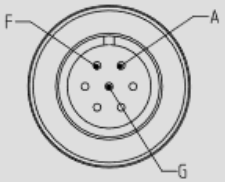
F = Sub-D



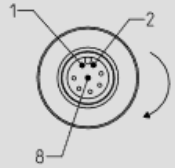
Q = Sub-HD



QP = 14-pin ODU



N = Greenline



M = 8-pin,
M12 female connector

K-CAB-F