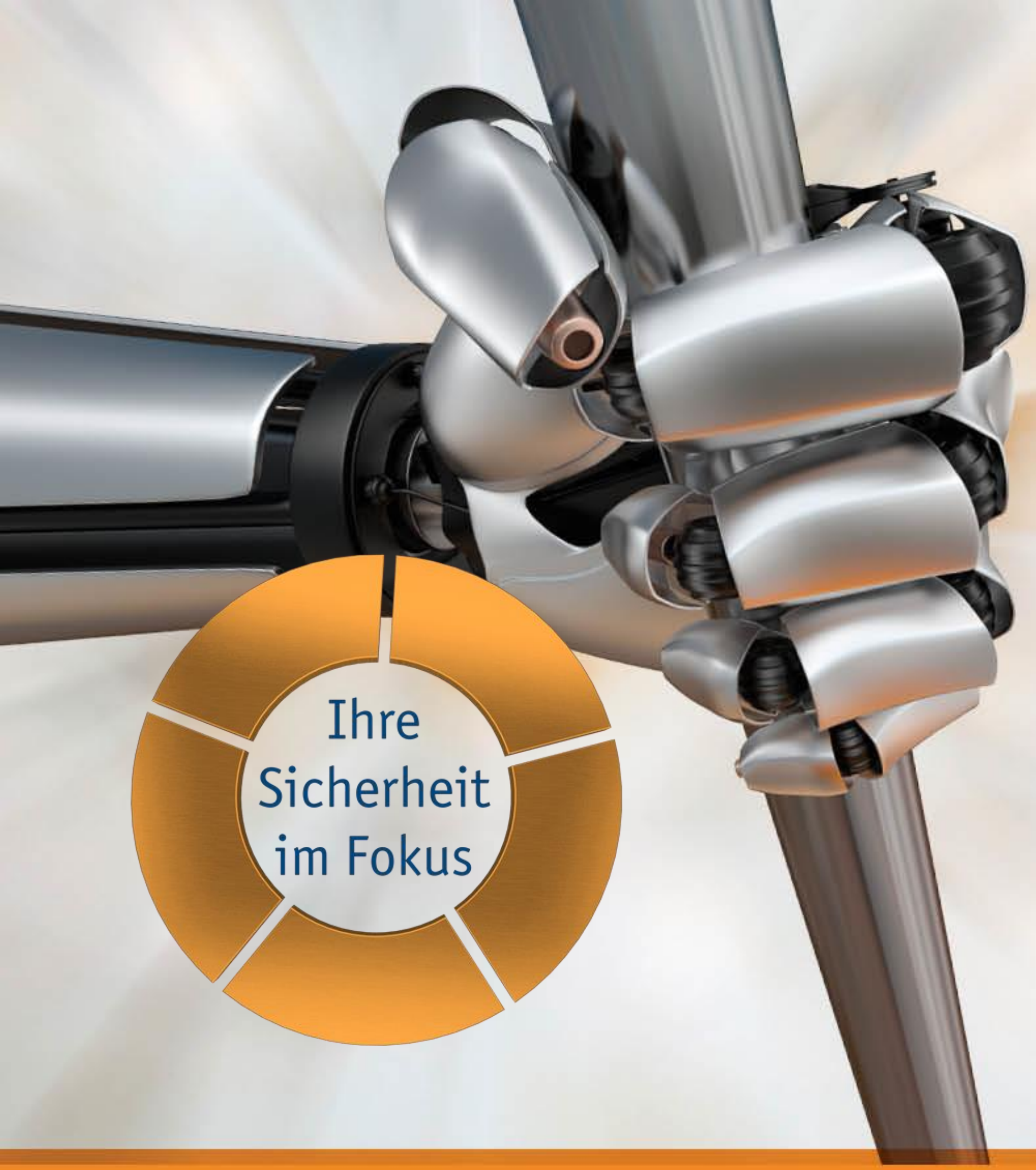

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Ferraris Sensoren

Eine vergessene Technologie?

DGFT Tagung 2024
Dr. Thomas Haase
Dresden, 27.09.2024

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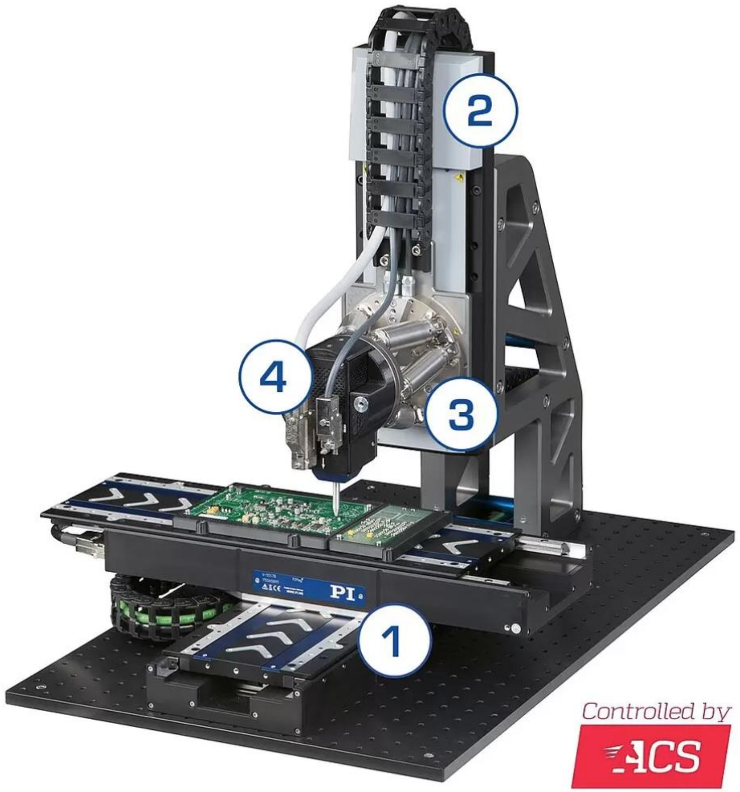
Wie können Abstürze detektiert werden?



Quelle: https://www.physikinstrumente.com/

Auf der Suche nach dem Ferraris Sensor

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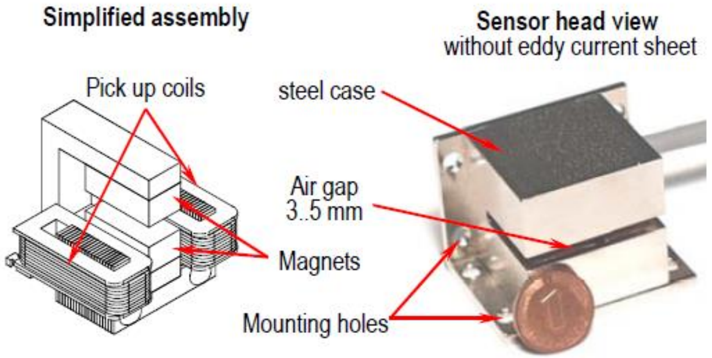
* Bernhard Hiller ist Leiter des Engineering Solutions Center, Berlin

(ID:45543698)

Bernhard Hiller ist Leiter Engineering Solutions Center, Berlin.
(Bild: Kübler)

Quelle: https://www.konstruktionspraxis.vogel.de/smarte-lagerlose-drehgeber-systeme-in-antrieben-a-775301/



Ferraris Acceleration Sensor -
Principle and Field of Application in Servo Drives

Bernhard Hiller
Hübner Elektromaschinen AG, Berlin, Germany
Tel.: +49/30/69003-101, email: hiller@huebner-berlin.de

Abstract: The Ferraris principle for measurement of the relative acceleration has been known for more than 100 years. In academic works the potential of this sensor principle has been demonstrated again and again /1, 2/. But only commercial production which has been started some years ago opened up possibilities for the senso[Kein Titel] principle in industrial applications. The simple and robust design, combined with non-contact object measurement, predetermines the sensor for application in rotary and linear motion axis. Ferraris sensors can be used either for analysis of motion behaviour or for improved control of servo drives of all kind. This lecture describes the principle, the design and the profitable application fields of the relative acceleration sensor.

Motivation

Continuous request for increasing productivity together with higher precision of N/C machines, such as machine tools, printing machines, but also robots and a variety of machines in the field of automation engineering results in increasingly high requirements for the servo or main drives used therein. High dynamics, good synchronism and best possible disturbance reaction of controlled drives are basic conditions for increase in productivity and quality of the entire plant. This in turn requires that the state variables position, velocity and acceleration must be acquired quickly and precisely so that, despite of disturbance and machining forces effecting the drive, the desired motion can be performed exactly, dynamically and in synchronisation with other drives.
Requirements for the quality of state variable acquisition are especially high for direct drives, as the stiffness has to be provided by the control device exclusively. To make full use of the potential of direct drives which origins from omission of deficiencies caused by gears and spindle such as elasticity or backlash, high resolution and dynamics of the state variables have to be demanded.
If moreover at servo drives, especially at direct drives, concepts of acceleration feedback, state control, cascaded acceleration control or active damping for further improvement of control performance shall be applied - which have been known since long, but applied only seldom - direct acquisition of the relative acceleration is required in addition to the position.

Present Acquisition of State Variables

...day cascade control is mainly applied in digital servo drives. Measurement is limited to the current and the position only. Position acquisition is mainly based on incremental or absolute rotary or linear encoders. High resolutions can be achieved by sine encoders as their analogue signals can be multiple partitioned compared to the signal period. Optical systems allow signal periods which are typically 20 µm and permit resolutions of 20 nm and below. In applications with lower requirements concerning positioning accuracy magnetic, inductive and partly capacitive systems are applied. In these systems the signal periods are within the millimeter range and permit resolutions of 1 µm and below. Better robustness in comparison to optical systems, higher assembly tolerances and lower costs, are arguments for these position measuring devices. However, significant cuts have to be made in the achievable control performance due to lower resolution and precision. For all systems it should be taken into consideration that precision within one signal period is considerably worse than the resolutions as the sampled signals and their processing are never optimal /2/.

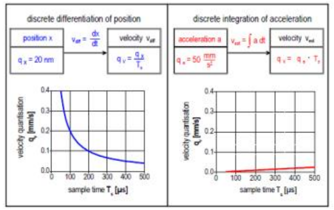


Figure 1: Velocity acquisition and quantization

Velocity is mostly determined by discrete differentiation of the position. Thus quantization and

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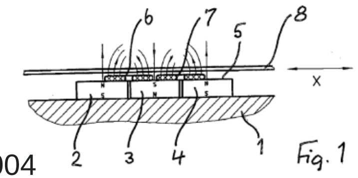
Anhängende Zeichnungen



1.DE 103 18 482 B3 2004

1.Status: Expired - Fee Related

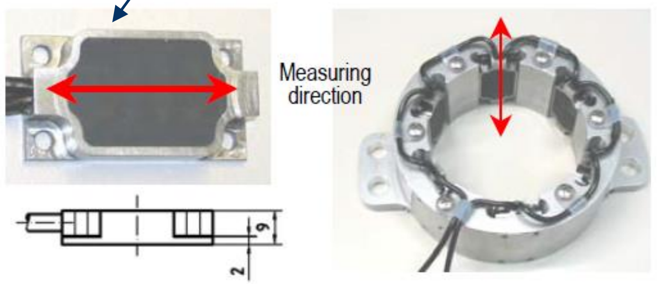


Figure 5: Single-side acceleration sensor ACC 22

The latest development is the ACC 22 type as shown in Figure 5 left side which is scanning the eddy current sheet or just a non-magnetic body on one side only. This requires a considerably smaller space for installation. Due to a new patented magnet and coil arrangement the sensor is only 9 mm in high and provides a bandwidth up to 5 kHz. The transfer ratio, however, is lower than in ACC 93. Moreover it has to be consid-

Hübner Elektromaschinen AG Berlin

www.huebner-berlin.de

Startseite | Elektrik/Elektronik | Hübner HEAG 164-15 Verstärker SN: 1555759 + ACC 93 Sensor > ungebraucht! <

HÜBNER HEAG 164-15 VERSTÄRKER SN: 1555759 + ACC 93 SENSOR > UNGEBRAUCHT! <

Artikelnummer:	**34754**
Kategorie:	**Elektrik/Elektronik**
Hersteller:	**Hübner**

BESCHREIBUNG BEWERTUNGEN

Hübner HEAG 164-15 Verstärker SN: 1555759 + ACC 93 Sensor SN: 1555754 ,

ungebraucht, 100% funktionsfähig, Lieferumfang gem. Fotos

Ve	0,24 kg
Ar	0,20 kg

1,234.99 €

inkl. 19% USt. , zzgl. Versand (Standard - 5kg)

Lieferzeit: 1 - 2 Werktage (DE - Ausland abweichend)

− 1 +

In den Warenkorb

Direkt zu PayPal

Ferraris Sensoren der Fa. Baumer

Quelle: https://www.ebay.de/itm/114239935905

Hübner Elektromaschinen GmbH
Tel: 0049 (0)30 / 69003 -105

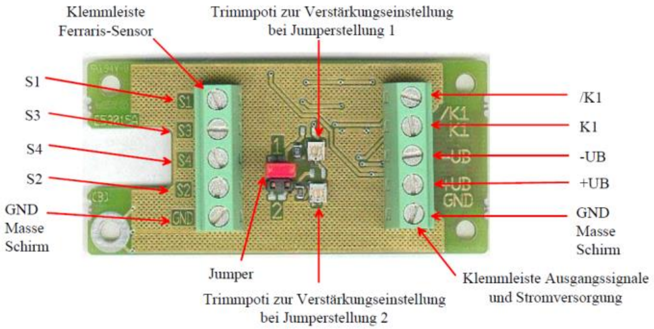
Dipl.-Ing. Bernhard Hiller

30.04.2002

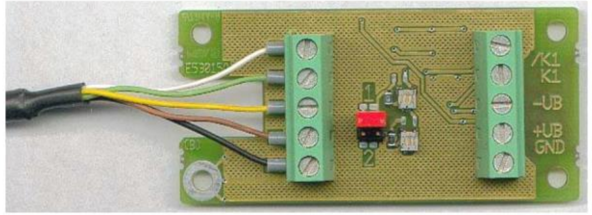
Technische Daten HEAG 164-15

Versorgungsspannung		nominal ±15 V ±20 % zulässig: ±5 V bis ±18 V
Stromaufnahme		max. 70 mA je Zweig
differentieller Ausgangsspannungshub		max. 22 V
Ausgangstreiberstrom		max. 50 mA
Verstärkung V		2..2000 (kundenspezifisch)
Verstärkungseinstellung		Jumper und Trimmpotentiometer
Bandbreite	2 < V < 200	> 30 kHz
	200 < V < 2000	> 10 kHz

Anschlussbilder



Anschlüsse, Jumper und Trimmpotentiometer des HEAG 164-15



Kabel eines Ferraris-Sensors, angeschlossen an den HEAG 164-15

Kurzdokumentation HEAG 164-15 2

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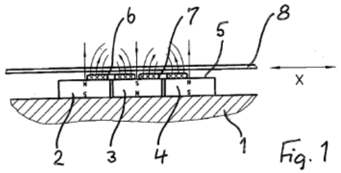
Anhängende Zeichnungen



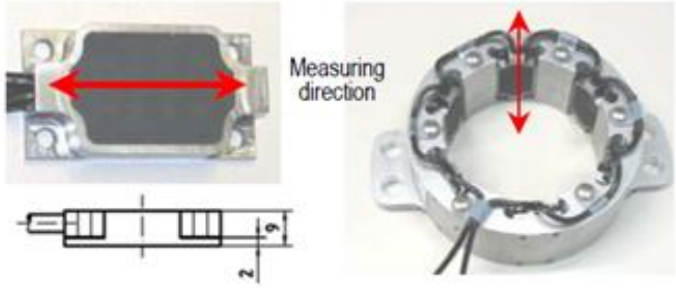
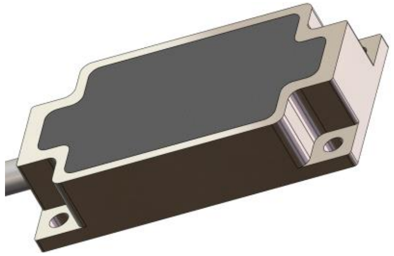
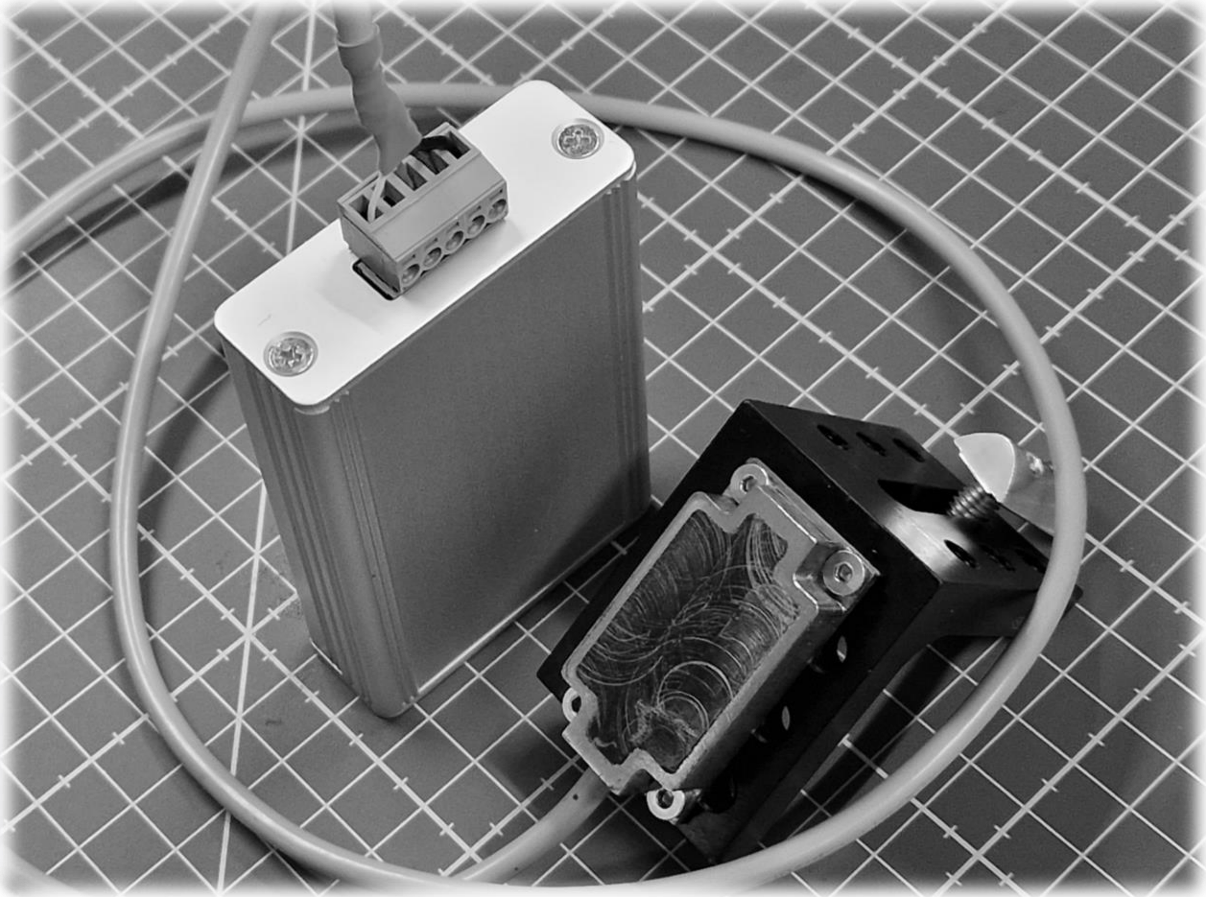


Figure 5: Single-side acceleration sensor ACC 22





Funktionsweise

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$$U_{ind} = -n \cdot \frac{d\theta}{dt} = -\frac{d(B_1 A_M)}{dt} = -B_1 \cdot \frac{dA_M}{dt} = -B_1 \cdot y_M \cdot \frac{dx}{dt} = -B_1 \cdot y_M \cdot v$$

$$R_i = \frac{l}{\kappa \cdot A} = \frac{y_M}{\kappa \cdot z_C \cdot x_M}$$

$$I_{ind} = \frac{U_{ind}}{2.5 \cdot R_i} = \frac{-B_1 \cdot y_M \cdot v}{2.5 \cdot R_i}$$

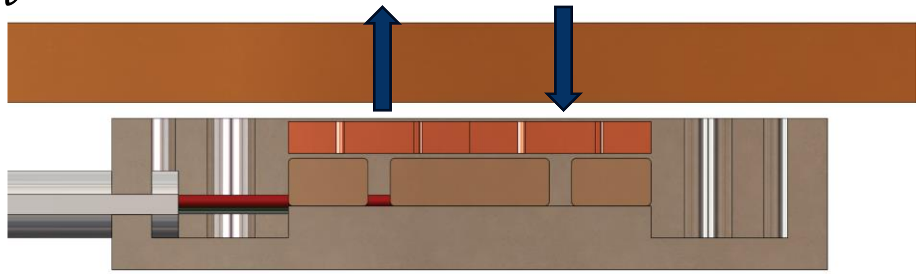
Der Wirbelstrom wirkt wie eine Spule, die ihrerseits ebenfalls ein Magnetfeld aufbaut

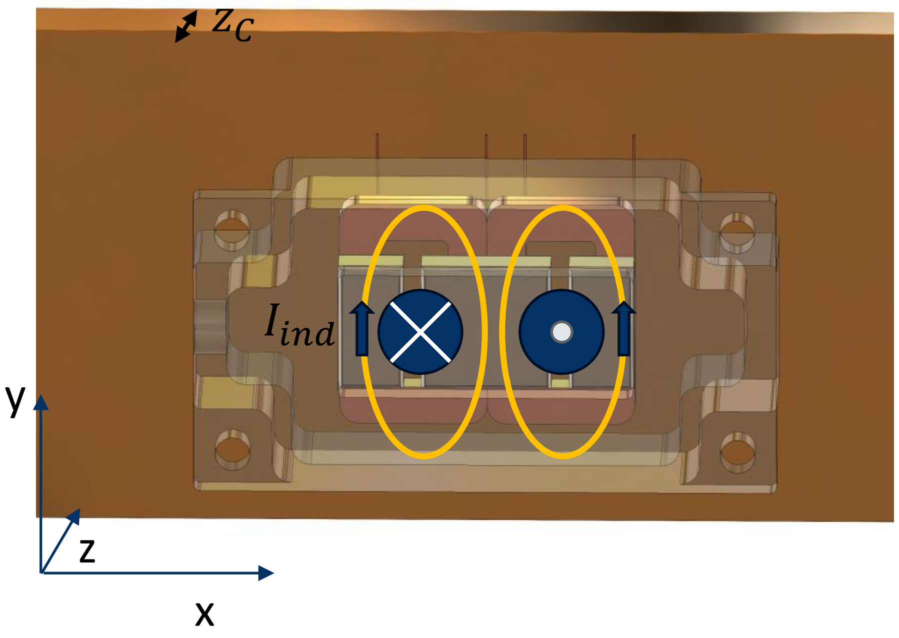
$$B_2 = \mu_0 \cdot \mu_r \cdot \frac{N \cdot I}{l} = \mu_0 \cdot \mu_r \cdot \frac{I_{ind}}{z_C}$$

Dieses Magnetfeld ist „ortsfest“ zu den Pick-Up-Spulen des Ferraris-Sensors:

$$U_{ind,PUS} = -n \cdot \frac{d\theta}{dt} = -n \cdot \frac{d(B_2 A_s)}{dt} = -n \cdot A_s \cdot \frac{dB_2}{dt} \approx \frac{dv}{dt} \approx \ddot{x}$$

Reine Relativbeschleunigung

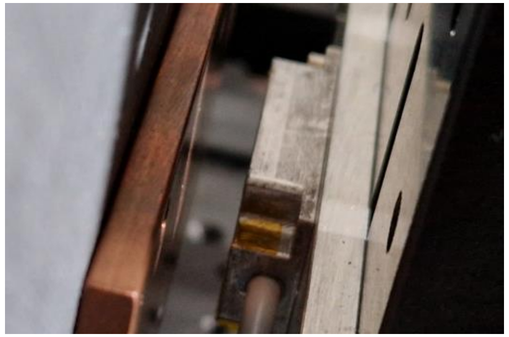


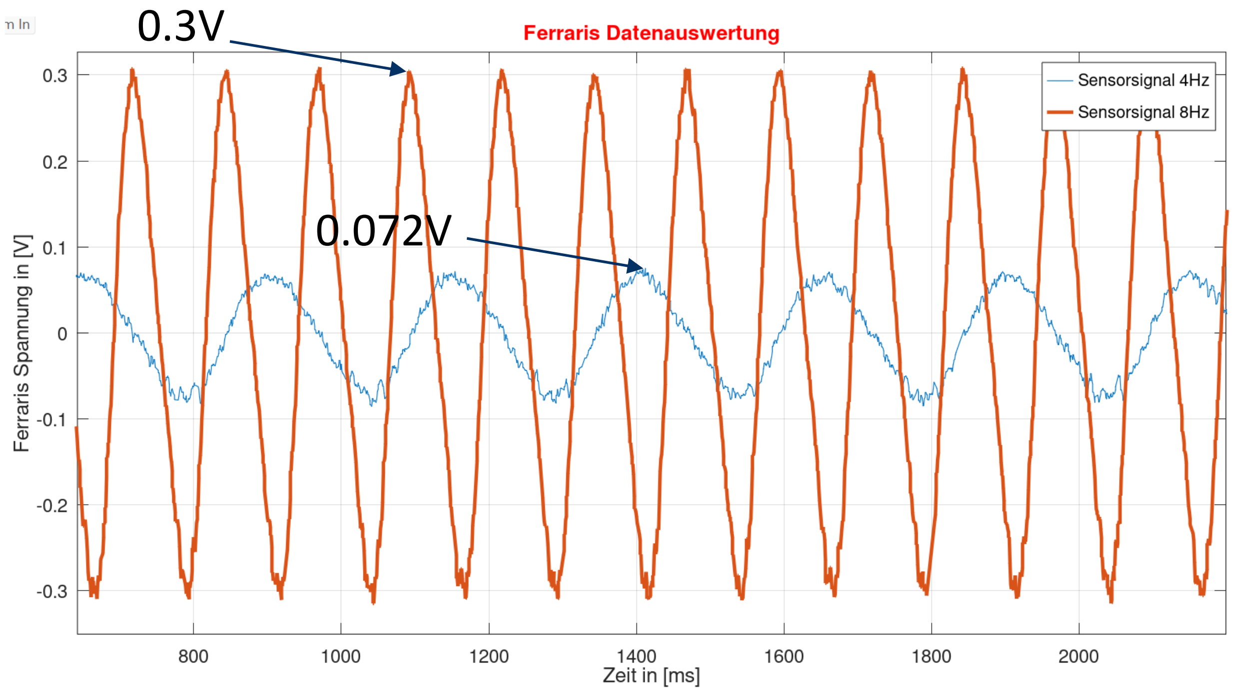


Messergebnisse: Kupfer, 1mm Abstand

- Kupferplatte
  - Messabstand 1mm
  - Sinus-Bewegung mit 4Hz/8Hz, A=5mm
  - Verstärkung: 2000
  - 1kHz Abtastrate, 10bit Auflösung
- $\ddot{x} = A \cdot \omega^2$
  - $\ddot{x} = 5mm \cdot (2\pi \cdot 4Hz)^2 = 3.16 \frac{m}{s^2}$
    - $U_{max} = 72mV$
  - $\ddot{x} = 5mm \cdot (2\pi \cdot 8Hz)^2 = 12.63 \frac{m}{s^2}$
    - $U_{max} = 300mV$
  - 4-fach Beschleunigung zeigt 4-faches Messignal
  - Lineare Interpolation: $U_{9.81} = 233mV$
    - bei Verstärkung von 2000:
    - **Sensorauflösung: $\mathbf{U \approx 0.12\ mV/g}$**

2000x





Messergebnisse: Kupfer, 1mm Abstand

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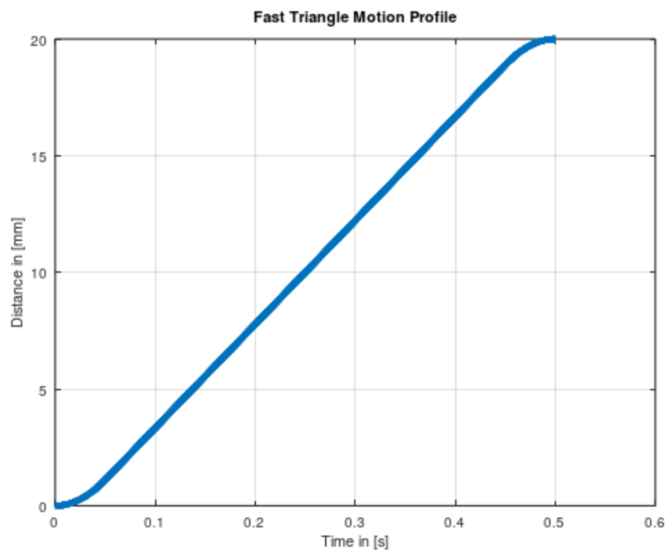
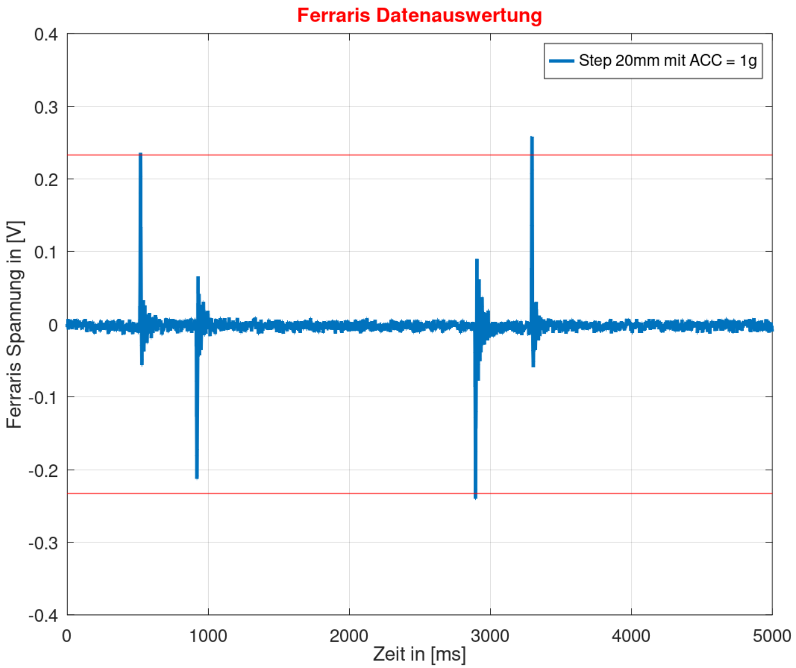
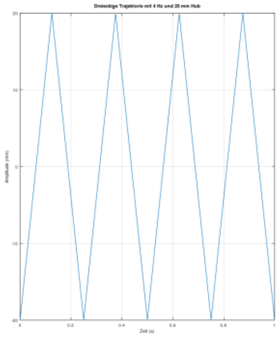
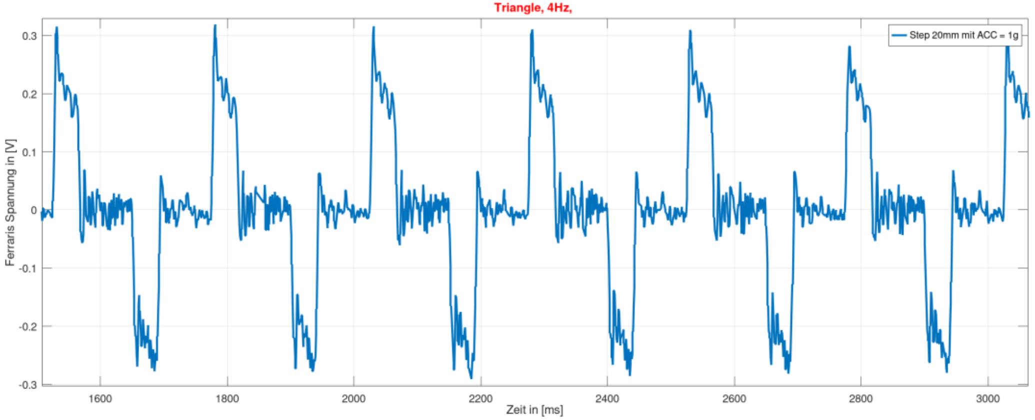
- Kupferplatte
  - Messabstand 1mm
  - Step
    - 20mm
    - $\ddot{x} = 9.81 \frac{m}{s^2}$
    - $\dot{x} = 50 \frac{mm}{s}$
  - Dreieck
    - 20mm
    - $4Hz$
    - $\ddot{x} = 9.81 \frac{m}{s^2}$
- Lineare Interpolation: $U_{9.81} = 233mV$
    - bei Verstärkung von 2000:
    - **Sensorauflösung: $\mathbf{U \approx 0.12\ mV/g}$**









Messergebnisse: Kupfer, Messabstand

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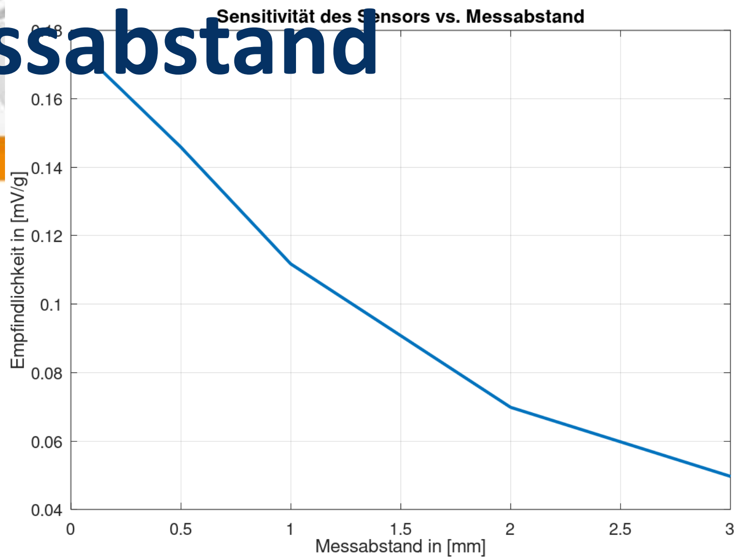
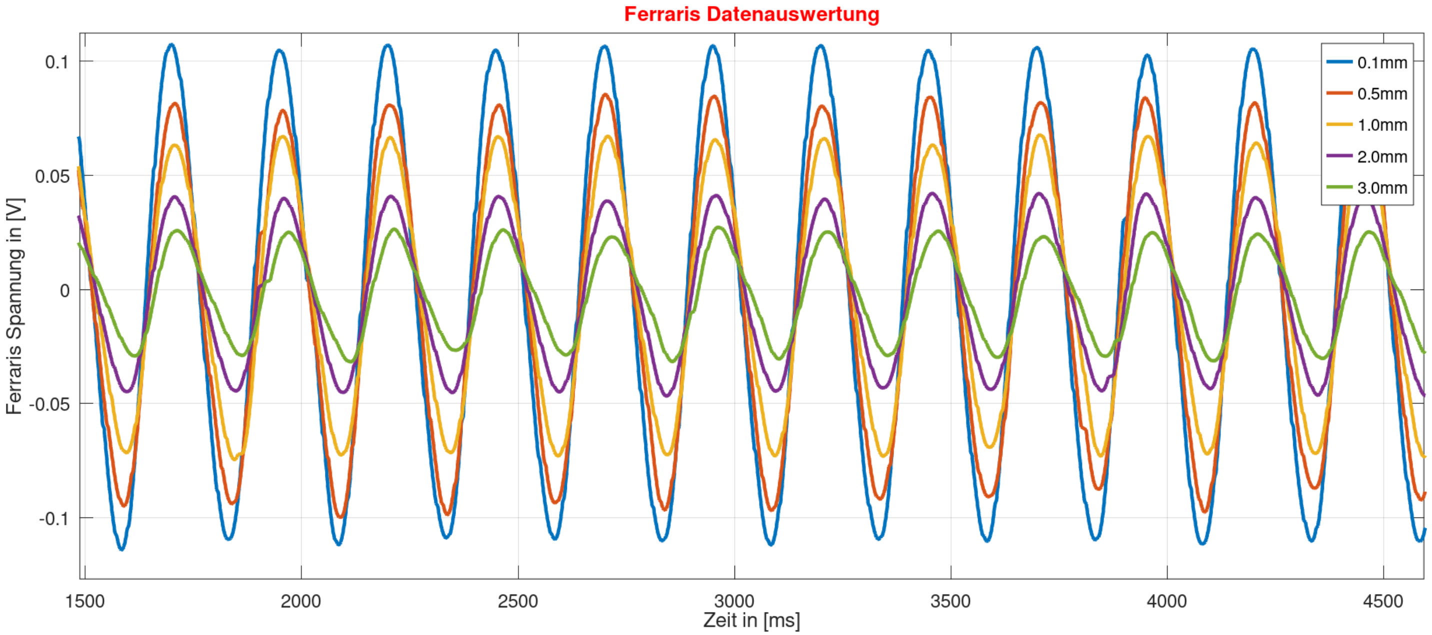


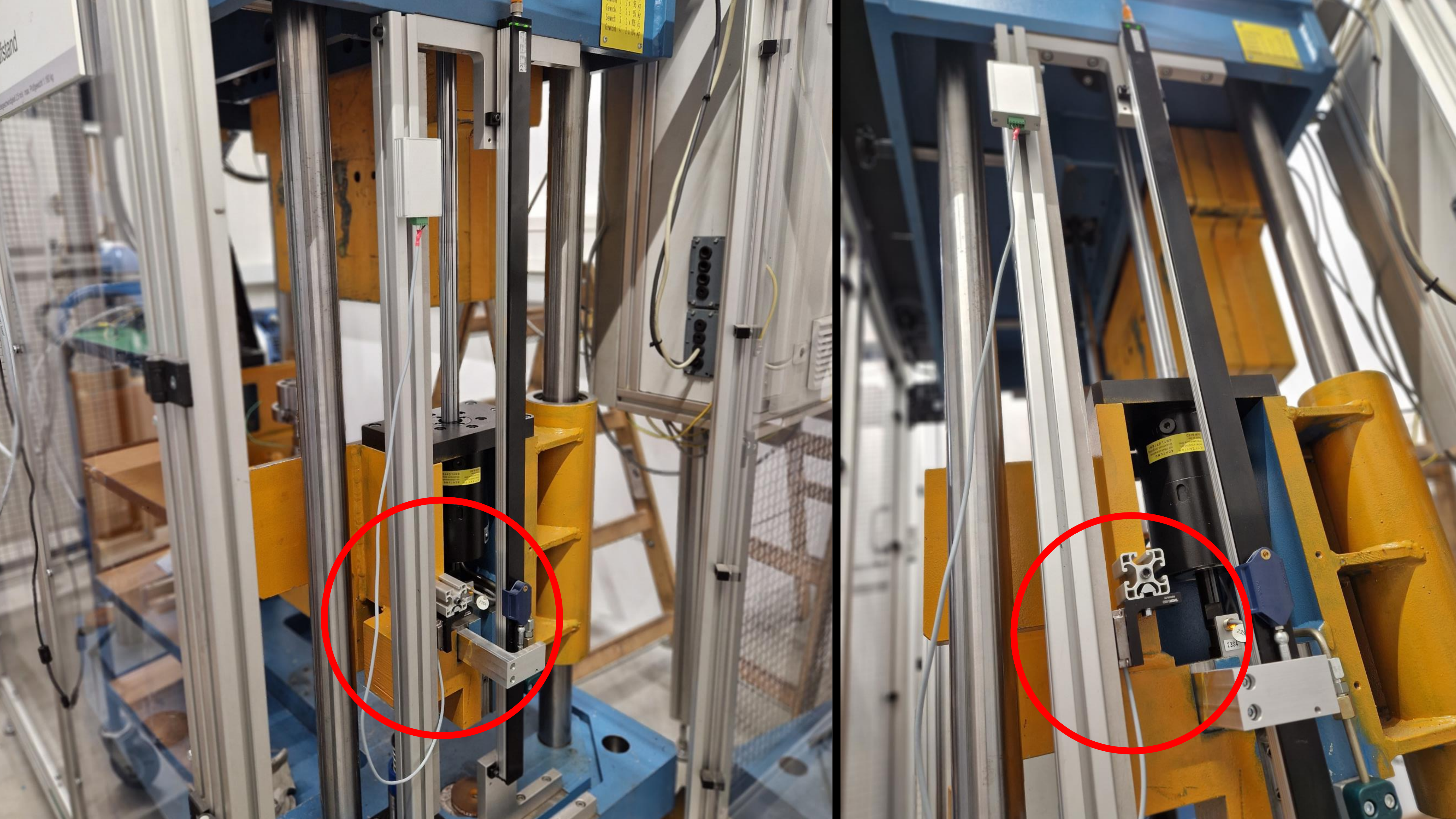
- Kupferplatte
  - Messabstand variabel
  - Sinus-Bewegung mit 4Hz, A=5mm
  - Verstärkung: 2000

- $\ddot{x} = A \cdot \omega^2$
  - $\ddot{x} = 5mm \cdot (2\pi \cdot 4Hz)^2 = 3.16\frac{m}{s^2}$
    - $U_{max,0.1mm} = 110mV \longrightarrow 0.17mV/g$
    - $U_{max,0.5mm} = 94mV \longrightarrow 0.146mV/g$
    - $U_{max,1mm} = 72mV \longrightarrow 0.12mV/g$
    - $U_{max,2mm} = 45mV \longrightarrow 0.0698mV/g$
    - $U_{max,3mm} = 32mV \longrightarrow 0.0496mV/g$

Variation des Messabstandes (Signale hier tiefpassgefiltert)




Fallprüfstand

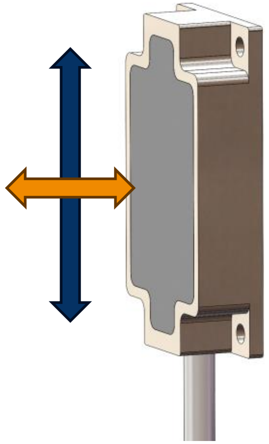


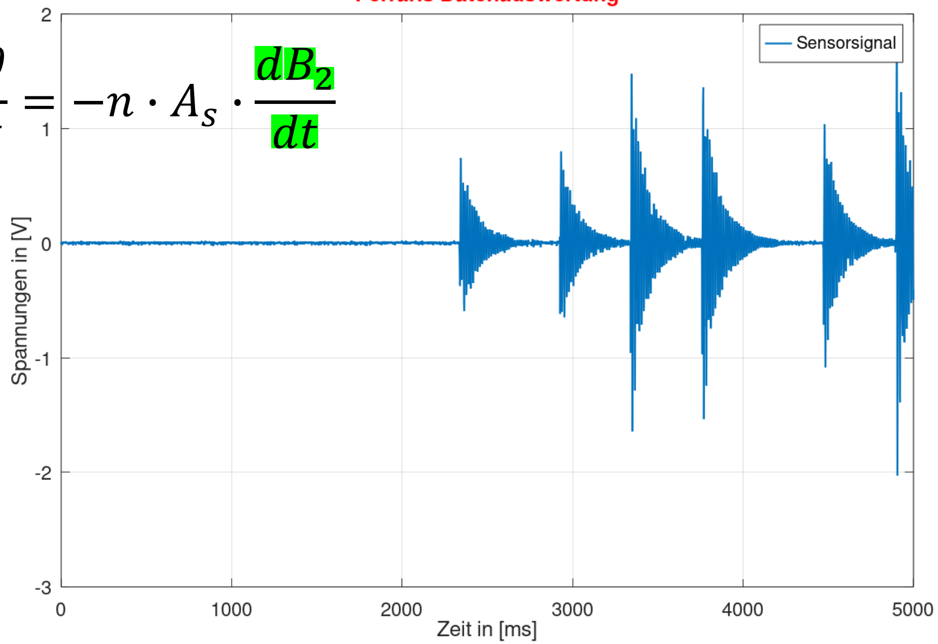
Ferraris-Sensoren im Fallprüfstand

$$U_{ind} = -\frac{d(B_1 A)}{dt} = -B_1 \cdot \frac{dA}{dt} = -B_1 \cdot y_M \cdot \frac{dx}{dt} = -B_1 \cdot y_M \cdot v$$

$$U_{ind} = -\frac{d(B_1 A)}{dt} = -\left(\cdot B_1 \frac{dA}{dt} + A \cdot \frac{dB_1}{dt} \right)$$

$$U_{i,PUS} = -n \cdot \frac{d\theta}{dt} = -n \cdot A_s \cdot \frac{dB_2}{dt}$$





Ein Seismograph!

Schwingungs-Entkopplung

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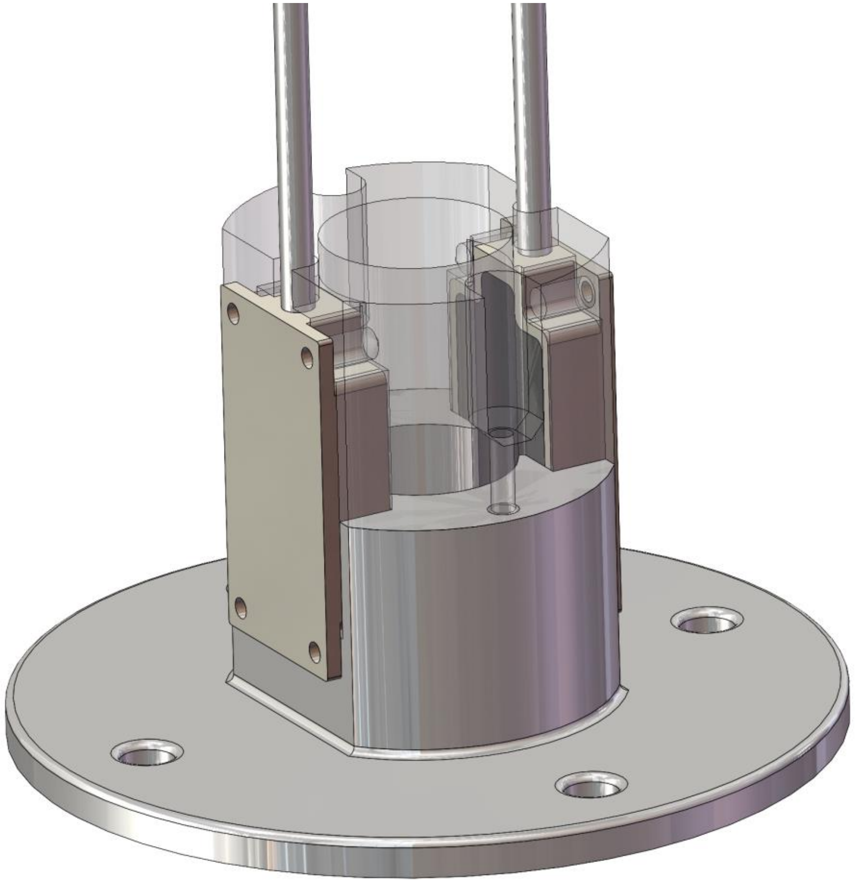
2 Sensoren 180°C versetzt

- In die gleiche Richtung messend
  - Reihenschaltung: 2x Sensitivität in Fallrichtung
- Annahme: lineares Verhalten der Sensitivität
  - Subtraktion der horizontalen Schwingungen
    - V1: digitale Subtraktion
    - V2: analoge Subtraktion
- 2. Maßnahme: Messung an ferritischer Stange
  - Höhere Sensitivität in Messrichtung vs. Anziehungskräfte der Sensoren an die Stange

$$U_{i,PUS} = n \cdot A_s \cdot \frac{\mu_0 \cdot \mu_r \cdot B_1 \cdot y_M}{z_c \cdot 2.5 \cdot R_i} \cdot \ddot{x}$$



Schwingungs-Entkopplung

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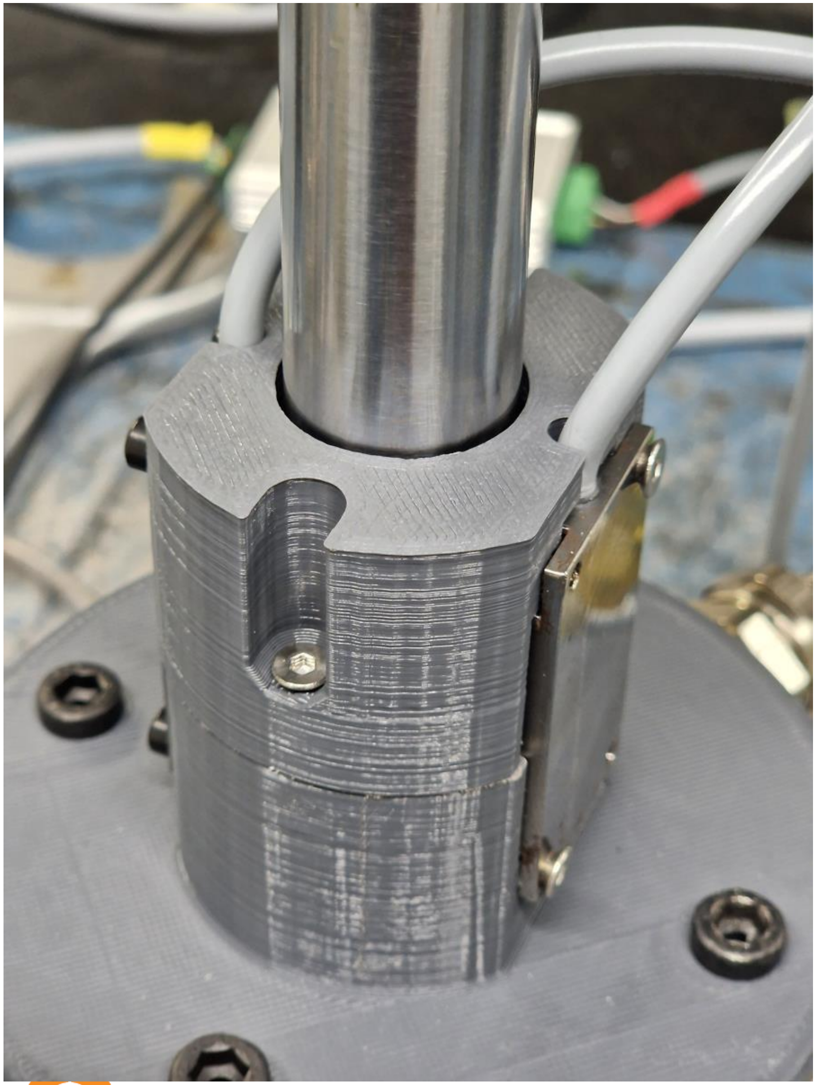

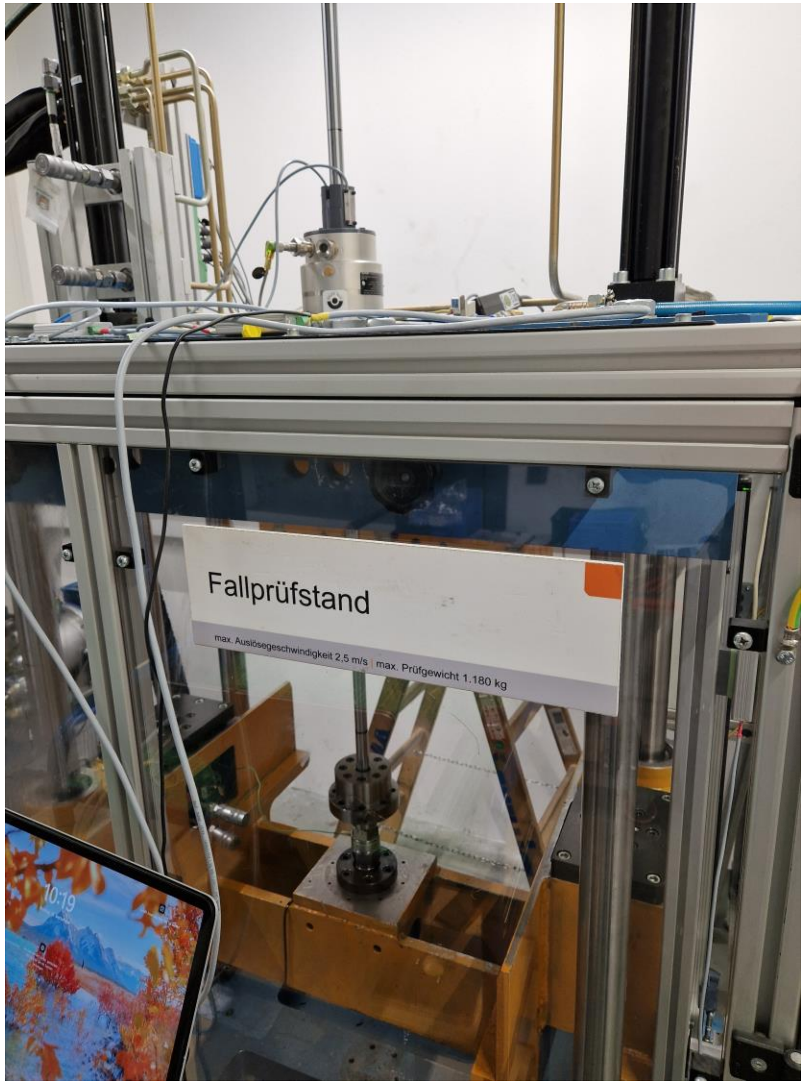

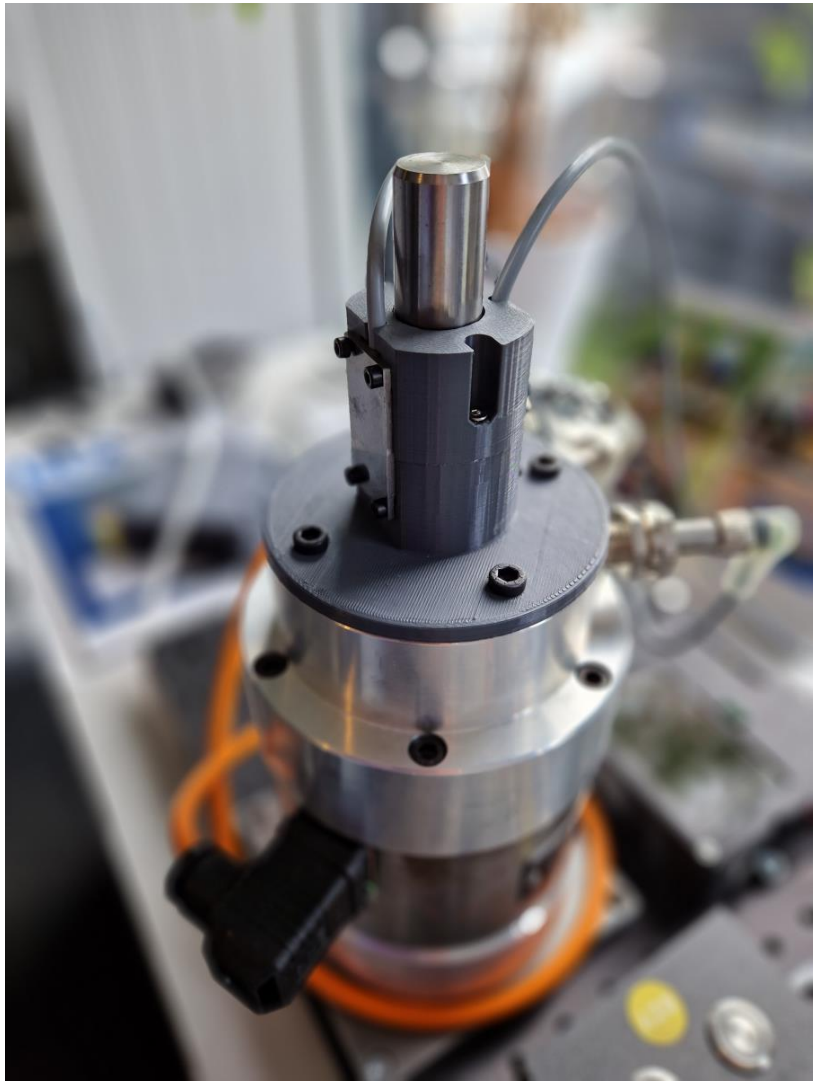

Schwingungs-Entkopplung

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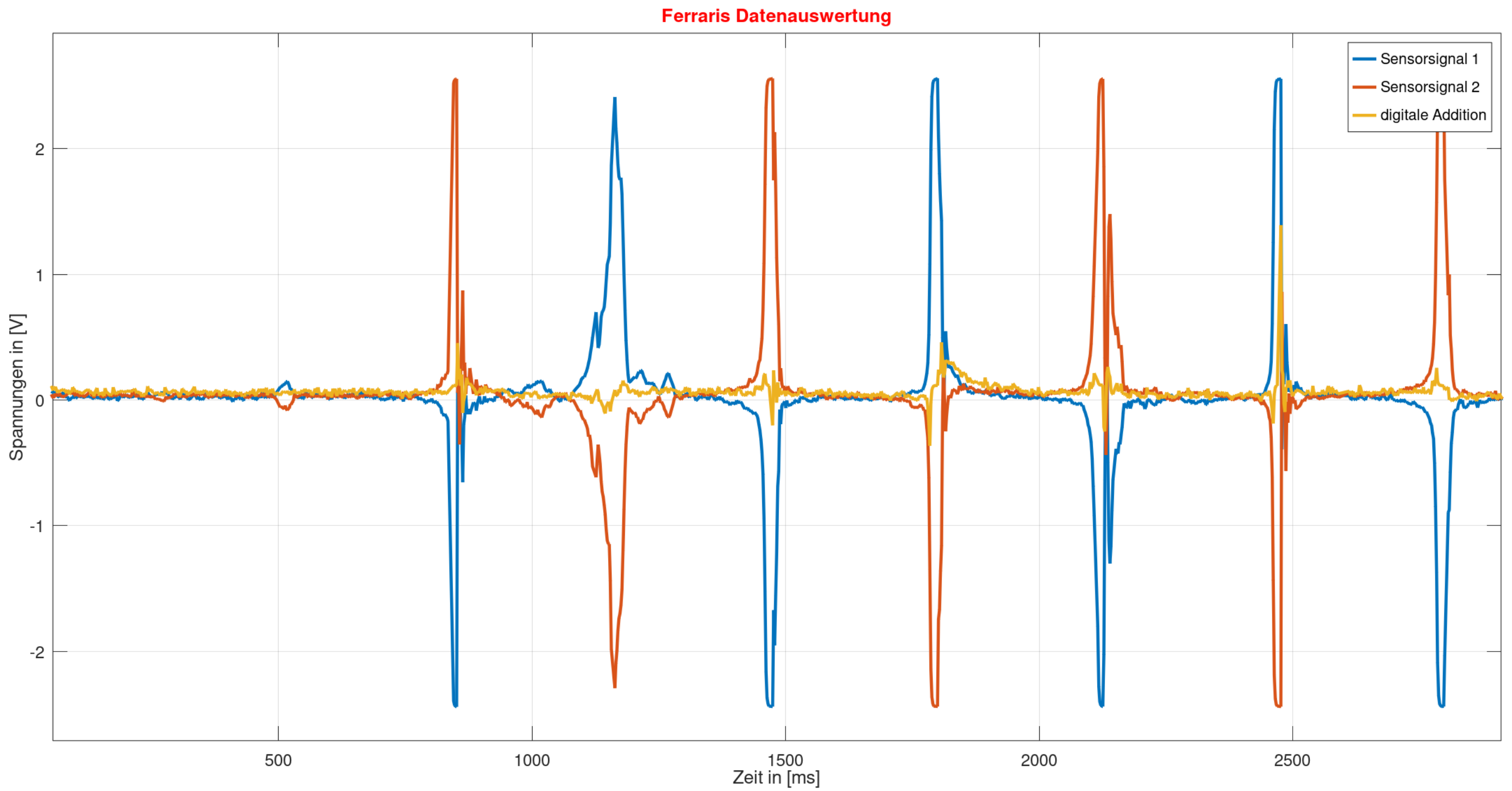
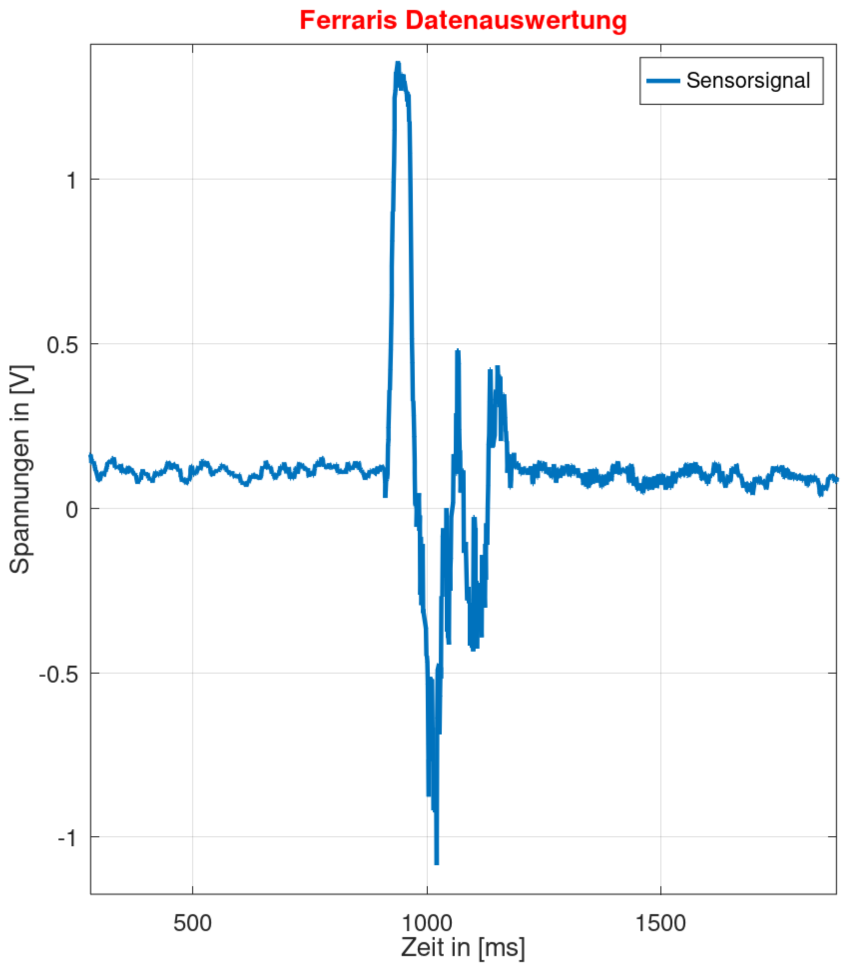
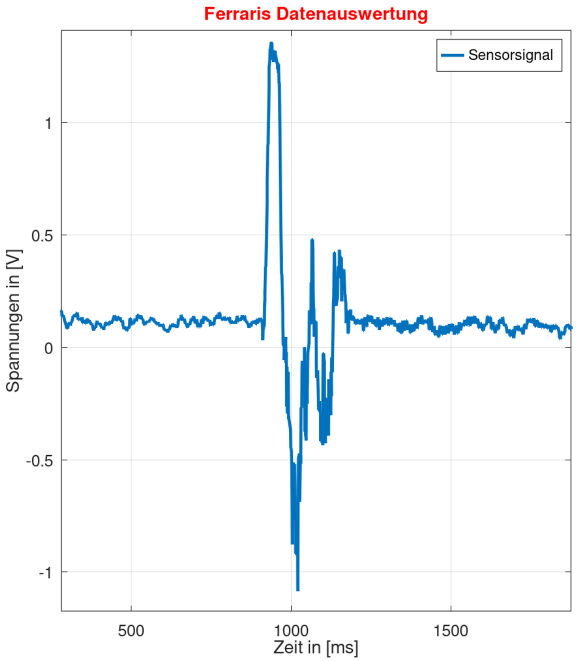
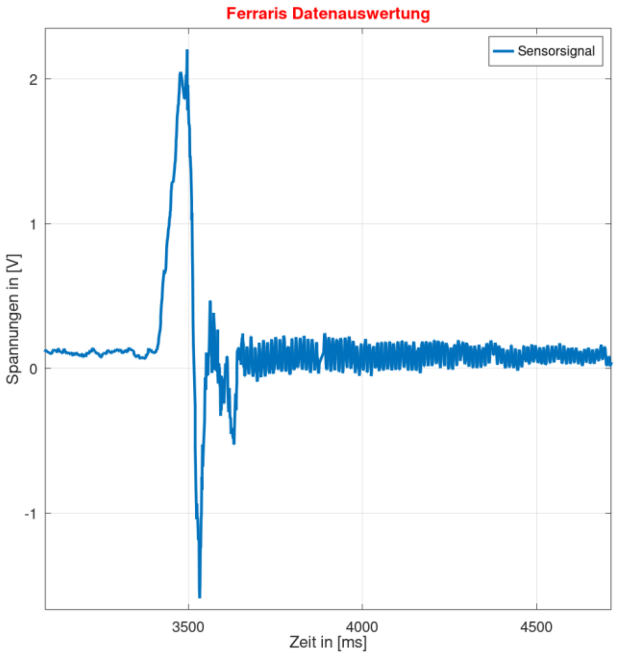
2 Sensoren 180°C versetzt

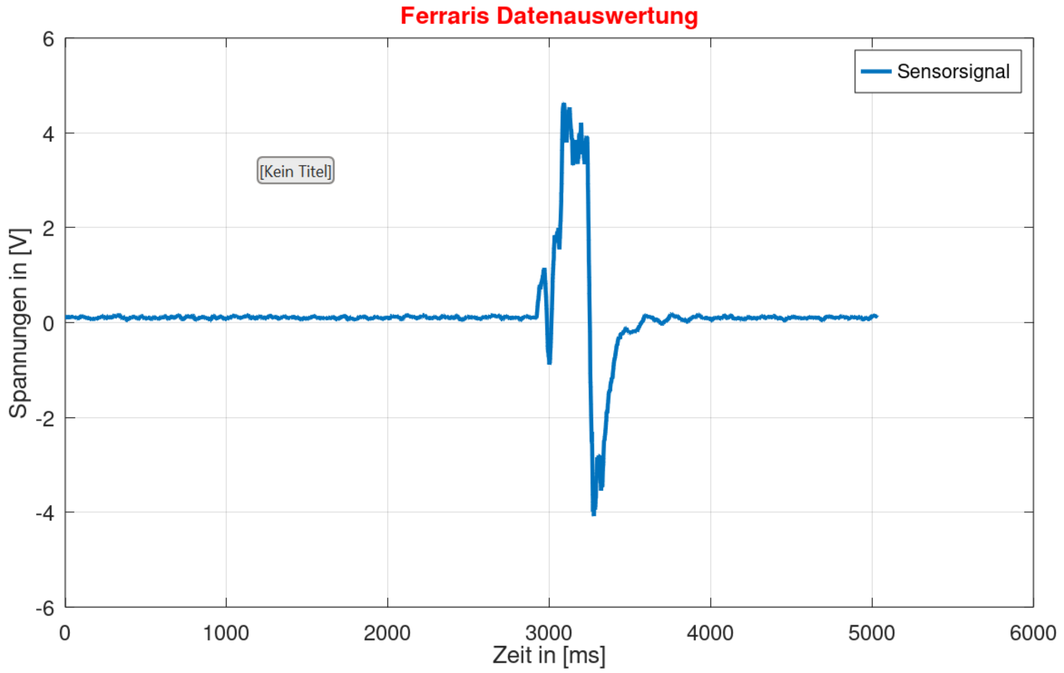




Sensorsignale im Fallprüfstand

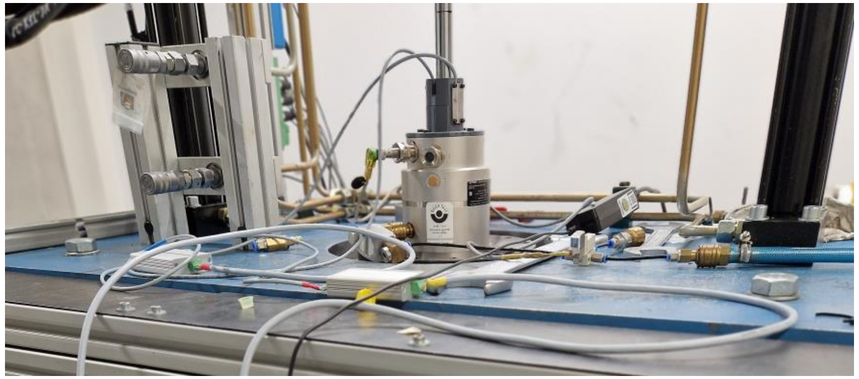




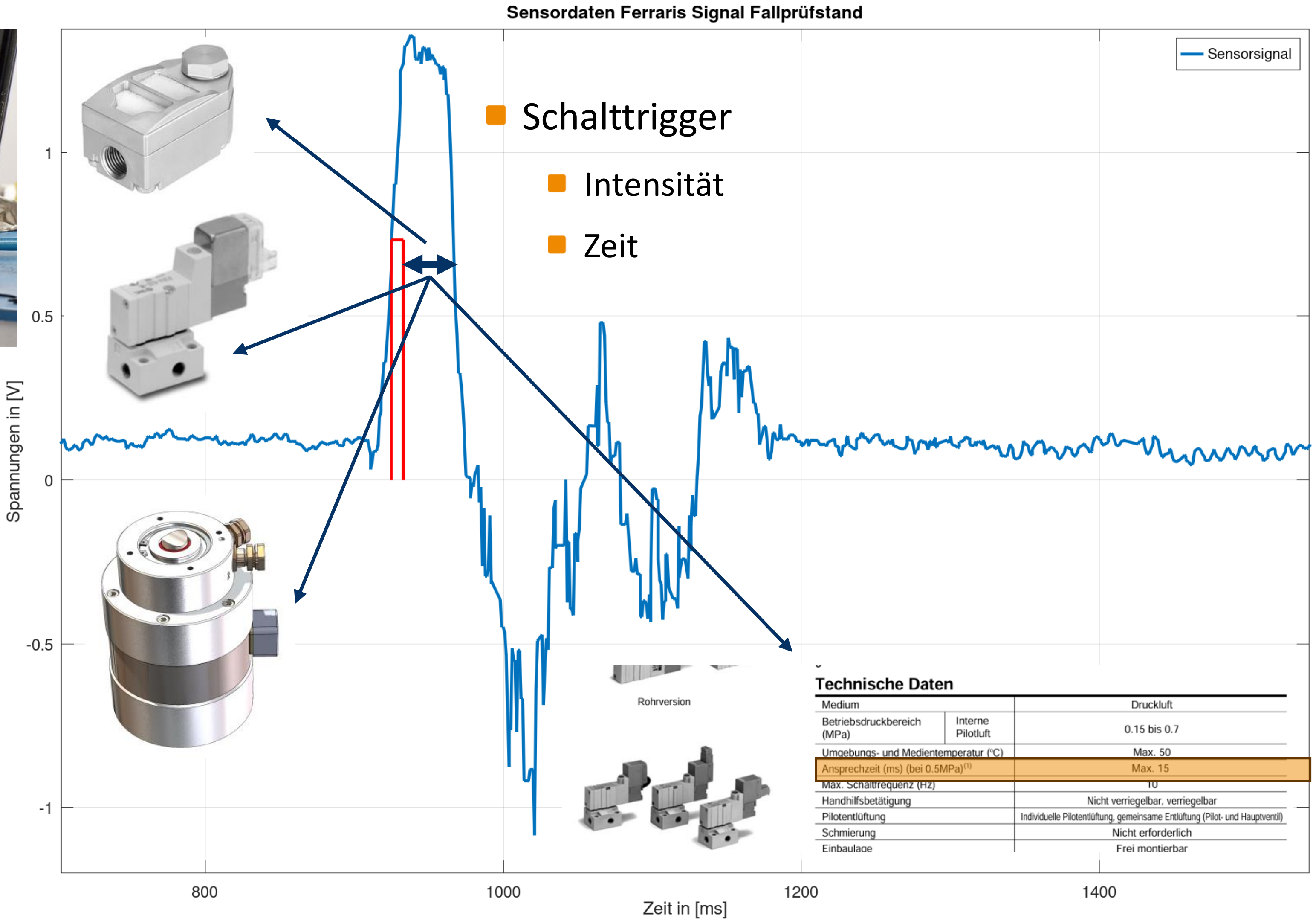


Fallhöhe ansteigend

Sensorsignale im Fallprüfstand



- Fallweg
  - Ca. 6cm
- Zeitanalyse 50ms
  - 10ms Schaltzeit
  - 15ms SYJ314 Schaltventil
  - Schnellentlüftungsventil VBQF
  - Schaltzeit Sicherheitsbremse KSE 022
    - SITEMA: 35-45ms



Medium		Druckluft
Betriebsdruckbereich (MPa)	Interne Pilotluft	0.15 bis 0.7
Umgebungs- und Medientemperatur (°C)		Max. 50
Ansprechzeit (ms) (bei 0.5MPa)[1]		Max. 15
Max. Schaltfrequenz (Hz)		10
Handhilfsbetätigung		Nicht verriegelbar, verriegelbar
Pilotentlüftung		Individuelle Pilotentlüftung, gemeinsame Entlüftung (Pilot- und Hauptventil)
Schmierung		Nicht erforderlich
Einbaulage		Frei montierbar

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