

MAGNETIC SENSOR SYSTEMS

# System Performance and Benefits of SmCo-Polewheels in Combination with Infineon's TMR-Sensors

*Opening New Horizons*

Precision **that holds.**



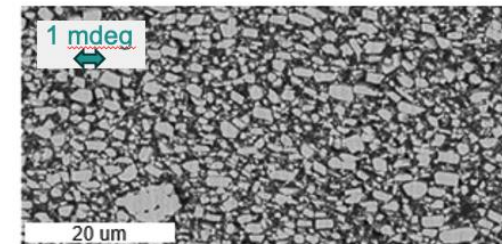
Werner Pessenhofer · Nanomag GmbH

MagSense2026, Imaginata Jena · Session “Applications – Encoders”

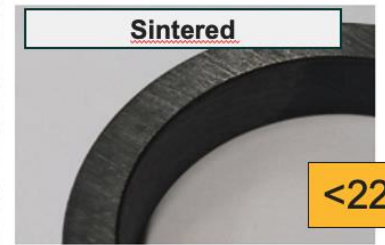
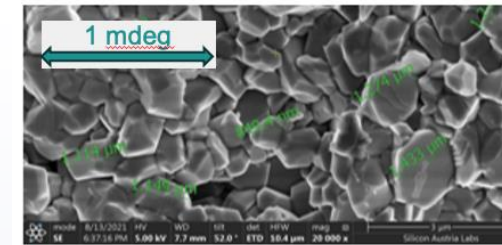
# Fully metallic SmCo-polewheels

## SmCo Polewheels

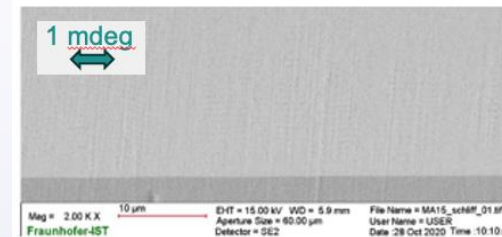
### Material homogeneity – 3 Technologies



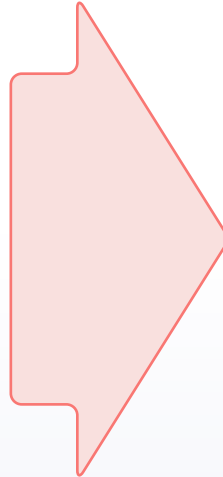
<120°C



<220°C



<350°C



#### Current Systems

Gear Wheel Systems



Polymer wheel based systems



Optical Encoder



Resolver





# Nanomag's Value Proposition

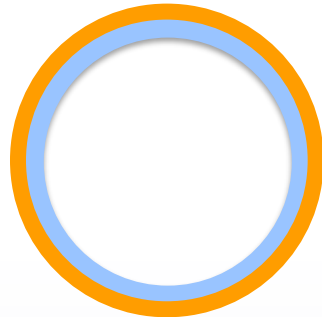
 Core Competence

Substrate



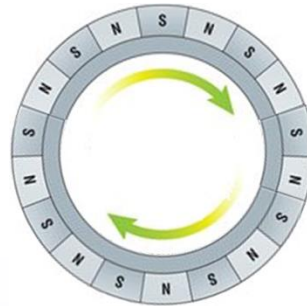
Metallic substrates e.g.  
Stainless steels  
1.4057, 1.4301

SmCo-Coating



Samarium-Cobalt (SmCo)  
coating  
  
Hollow-cathode sputtering  
30 - 100 µm

Magnetisation /  
Encoding



Incremental  
Index  
Nonius  
Pseudo-Random Code  
  
0,5 - 2 mm pole lengths

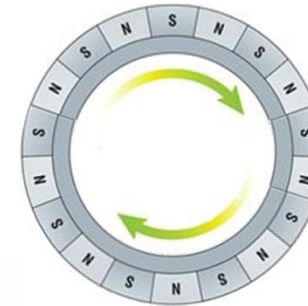
 **NEUROSENSE**  
 **SAL**  
SILICON AUSTRIA LABS

 **SENSITEC**  
MAGNETORESISTIVE SENSORS

 **TDK**

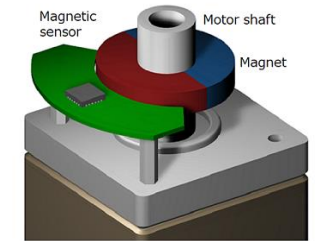
 **Infineon**

Optimisation Sensor -  
wheel



Development Kits  
  
Sensitivity  
Signal processing  
High RPMs  
...

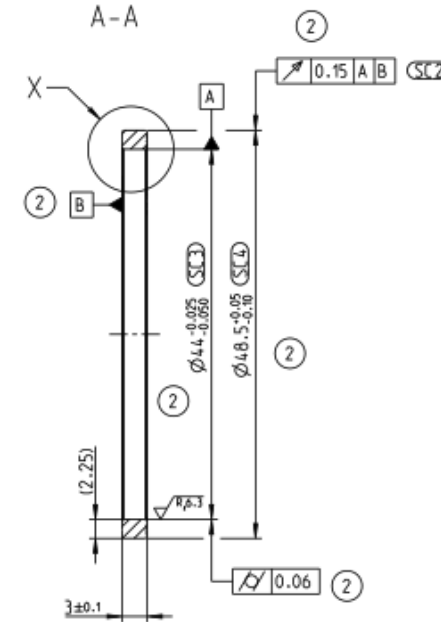
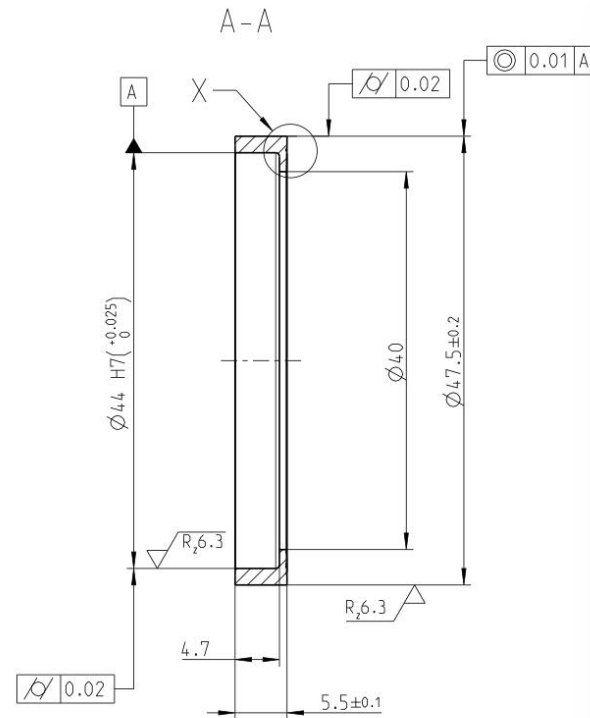
Encoder  
manufacturer / OEM





## USP's of NANOMAG'S pole wheels

- ✓ **Extremely lightweight without losing robustness**
- ✓ **Guaranteed runout**
- ✓ **Inert against chemicals and radioactivity**
- ✓ **High RPMs **together** with high temperatures**
- ✓ **Demagnetisation nearly impossible, even at high temperatures (>300°C)**
- ✓ **Very low SmCo material consumption - domestic sources sufficient**

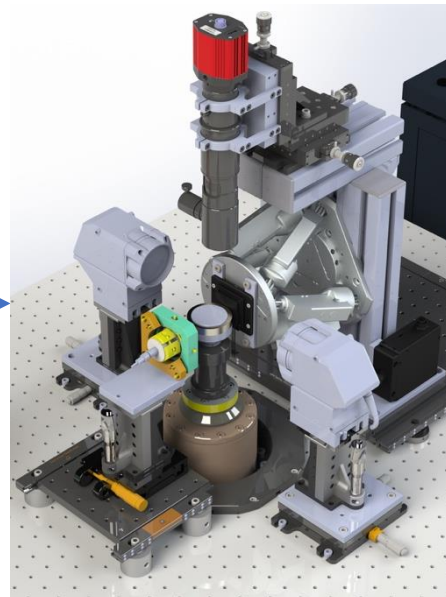
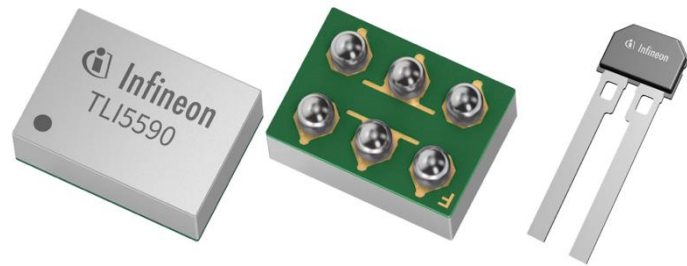




# A Joint Development Project

Nanomag × Silicon Austria Labs × Infineon

***Goal: Combine a differential TMR sensor with SmCo Polewheels and analyse the performance in **airgap**, **accuracy** and **robustness*****





## The Questions We Started With

- ✓ **How exact** must the Sensor be **positioned**? How influence **tilting and rotation** the performance of the output?
- ✓ How large an **airgap** is actually achievable with **TMR instead of Hall**?
- ✓ What sensor operating point and circuit topology are needed – especially for **stray-field robustness**?
- ✓ What are the **results compared to High-End Hall-Sensor** configuration?
- ✓ **Which industries/applications benefit** from such a combination?



How did we measure?

**The setup**



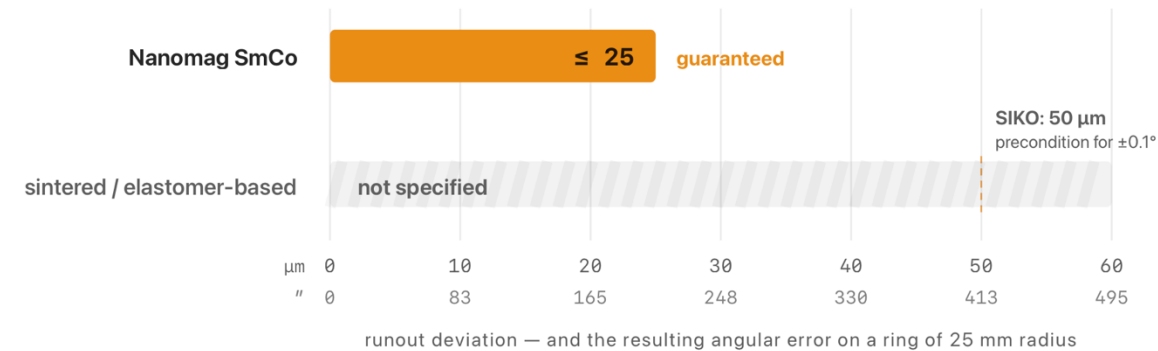
# Test Setup: SmCo - Polewheels

Part 1 of 3 – Active magnetic part



Nanomag SmCo Polewheels – best in class in precision and robustness:

- ✓ Outer diameter (OD) 57 mm
- ✓ Substrate 1.4301 (stainless steel)
- ✓ Appr. 65µm layer thickness (SmCo)
- ✓ Magnetic configurations:
  - ✓ 1 mm incremental
  - ✓ 2 mm incremental
  - ✓ Nonius 44/45 pole pairs (2 mm pole length)



≤ 25 µm

runout deviation —  
guaranteed, not merely  
typical

−273...+300 °C

verified operating range,  
with no speed limit

−0.03 %/K

reversible temperature  
coefficient of remanence

> 94 %

field strength after years  
of media exposure

100 %

fully metallic — no binder,  
no coating

# Test Setup: The Infineon TMR Sensors

## Part 2 of 3 – sensing technology

### iTMR

Highly linear TMR combines the benefits of GMR and Hall technology: technology:

- ✓ Sensitivity comparable with GMR
- ✓ Large linear range
- ✓ **XENSIV TLI5590**: two discrete linearized TMR bridges, analog interface.
- ✓ **XENSIV TLE55493iC**: two linearized TMR bridges + integrated analog and digital signal processing integrated on the same silicon. developed for automotive application (ISO 26262 ASIL-D; AEC-Q100)
- ✓ Both differential & linearized TMR – the basis for weak-field sensing (this section) and stray-field immunity (later).



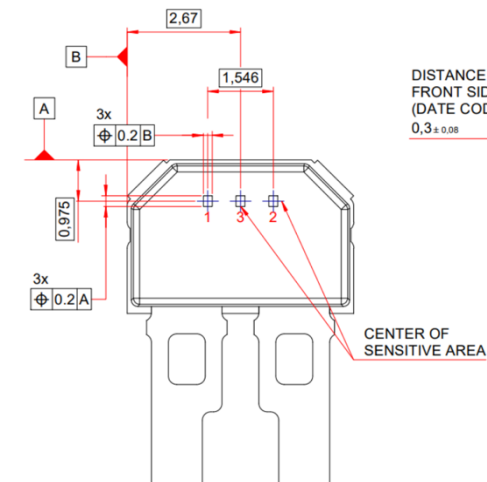
TLI5590



TLE55493iC

### INTERFACE & OPERATING RANGE

- ✓ Interface:  
TLI5590 analog, differential ratiometric output;  
TLE55493iC digital (two-wire AK or SPI).
- ✓ Rated junction temperature:  
TLI5590 –40...+125 °C;  
TLE55493iC –40...+170 °C  
(190°C 500h max.)



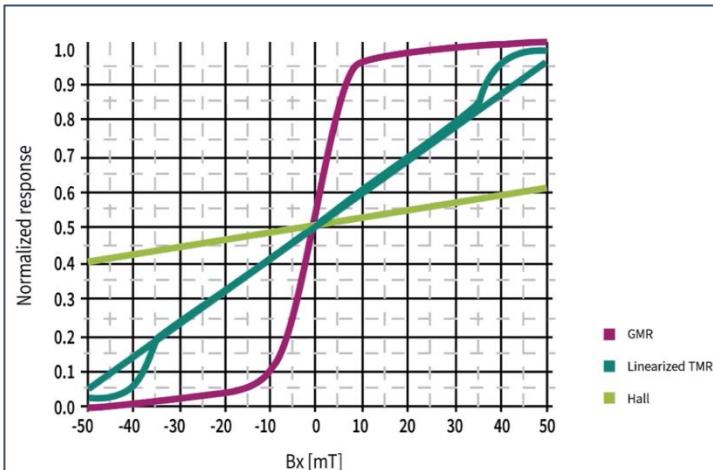
# Robustness Against External Fields

Differential sensor setup

Linearized TMR combines the benefits of GMR and Hall technology:

**Very good sensitivity** for excellent jitter and airgap performance

**Large linear range** to allow for high resolution and fast direction detection algorithms:



TMR

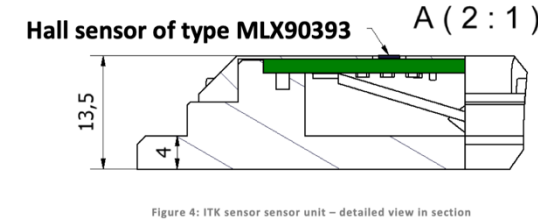
TLE55493  
key features

DSP

Analog and digital signal processing to reach highest SNR (signal-to-noise);  
With digital interface

robust

intrinsic stray field robust with differential magnetic field measurement



# Test Setup: Rings and Pole Wheel Scanner

## Part 3 of 3 – samples and measurement rig

### SAL Pole Wheel Scanner

- ✓ Comprehensive wheel/sensor evaluation (tolerances, axle runout, airgap, orientation, displacement)
- ✓ 6DoF hexapod calibrates sensor position ( $<0.1 \mu\text{m}/0.1 \text{ mdeg}$ )
- ✓ White-light interferometer & telecentric optics for  $\mu\text{m}$ -precision runout & positioning
- ✓ Low-runout spindle:  $<0.55 \text{ mdeg}$  angle precision,  $<1 \mu\text{m}$  runout

### TMR-sensors compared with:

- ✓ Matesy 3D-Hall Sensor with sensor type MLX90393 –  $10 \mu\text{T}/\text{LSB}$

### SAL TEST RIG

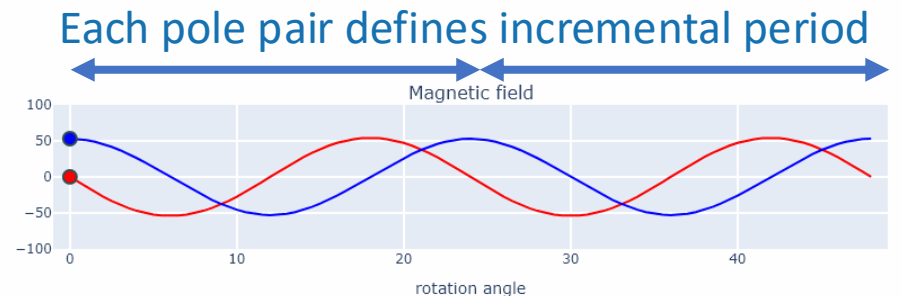
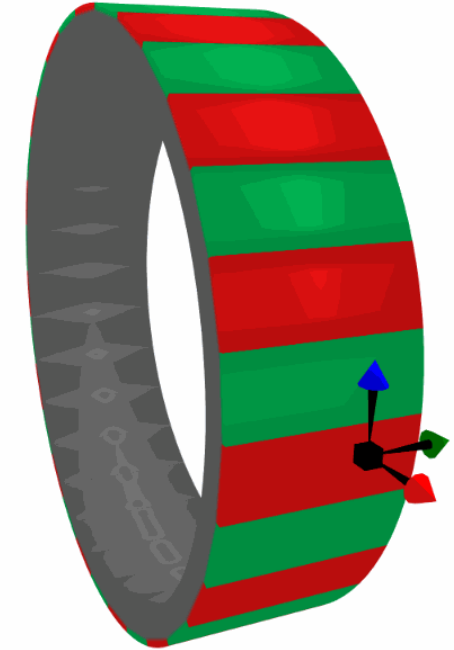
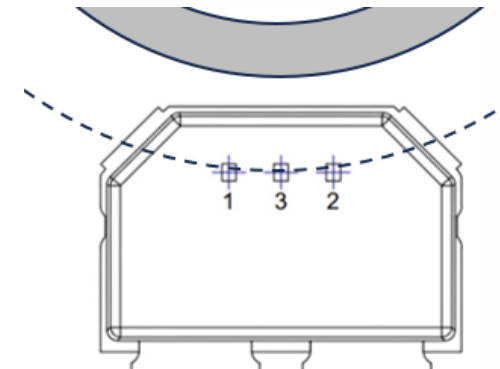


High-End Magnetic Pole Wheel Scanner – automated airgap and rotation sweeps, laser interferometer + wheel marker for alignment.

# Measurement Methodology

Part 3 of 3 – how the numbers on the next slides were obtained

- ✓ Measurement of Sin/Cos curves via pixels
- ✓ Calculation of ArcTan inside Sensor (each pole) **without post-processing** → Angle information
- ✓ Average error over all pole pairs around full rotation
- ✓ Standard deviation over all pole pairs around full rotation
- ✓ Change of geometrical position → repeat procedure
- ✓ Same methodology used consistently across Hall and TMR, and across all three rings.





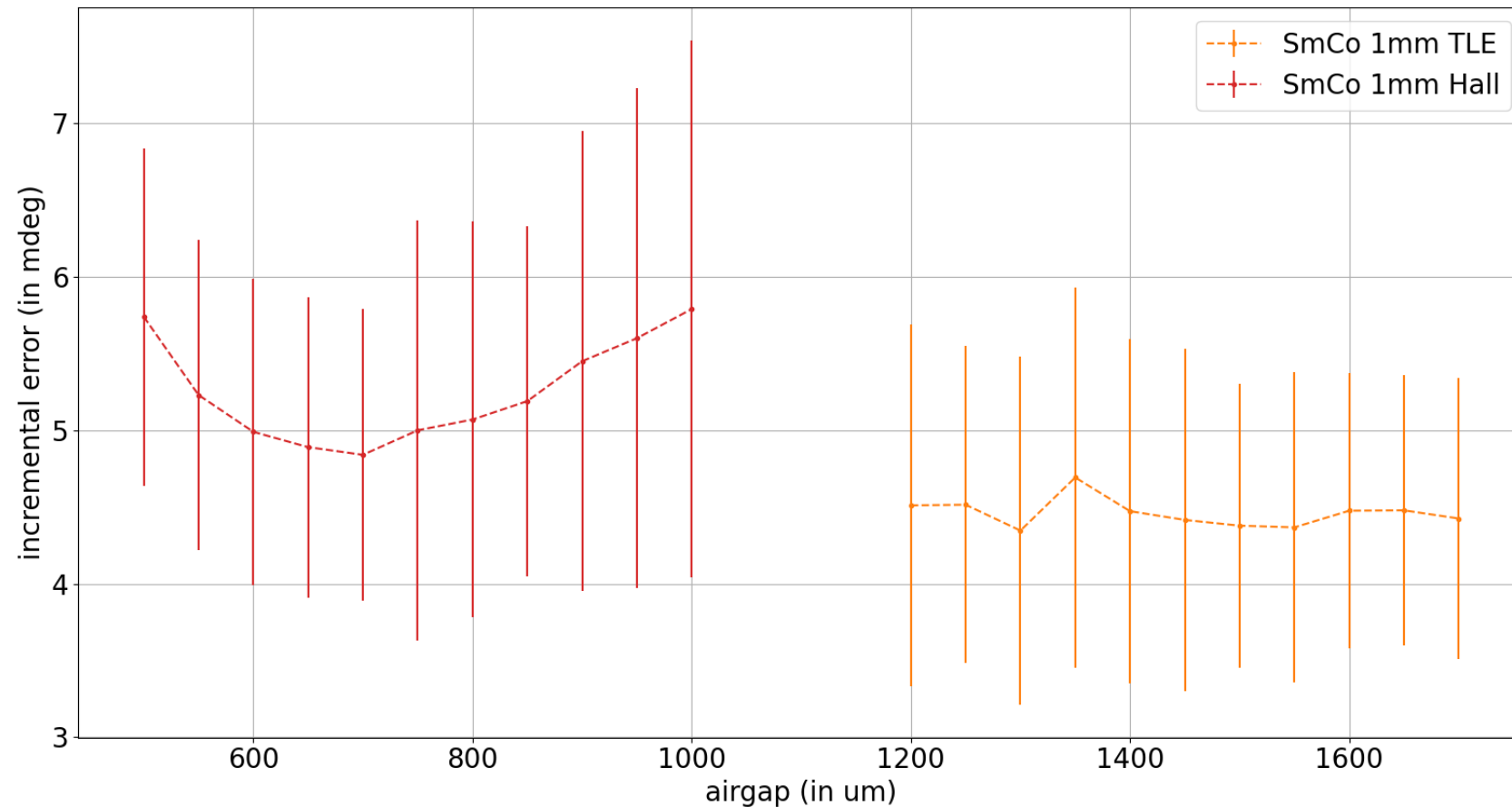
Is inaccuracy of sensor positioning a  
problem?

**Tilting, rotating  
and airgap**

# Airgap Gain (1 mm)

Nanomag SmCo 1 mm ring – TMR TLE55493iC compared to 3D-Hall

■ Nanomag SmCo, 1 mm (Hall)  
■ Nanomag SmCo, 1 mm (TMR)



(dashed = compensated)

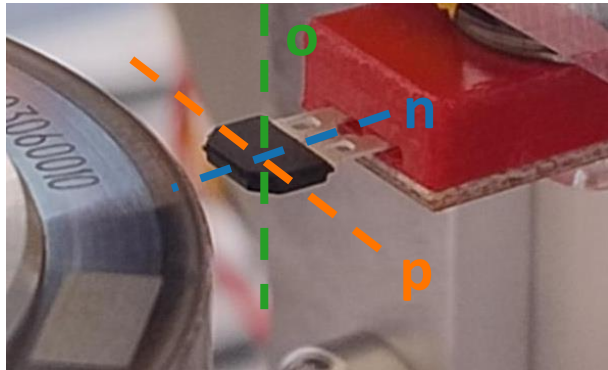
Accuracy  $4.51 \pm 1.05 \text{ m}^\circ$

16,2 bit resolution

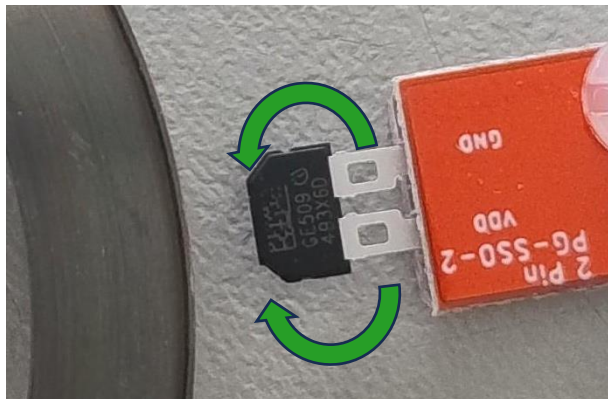
Airgap: 1,4x pole length  
(1mm pole length  $\rightarrow$  1,4 mm airgap)

# Tilting and rotating

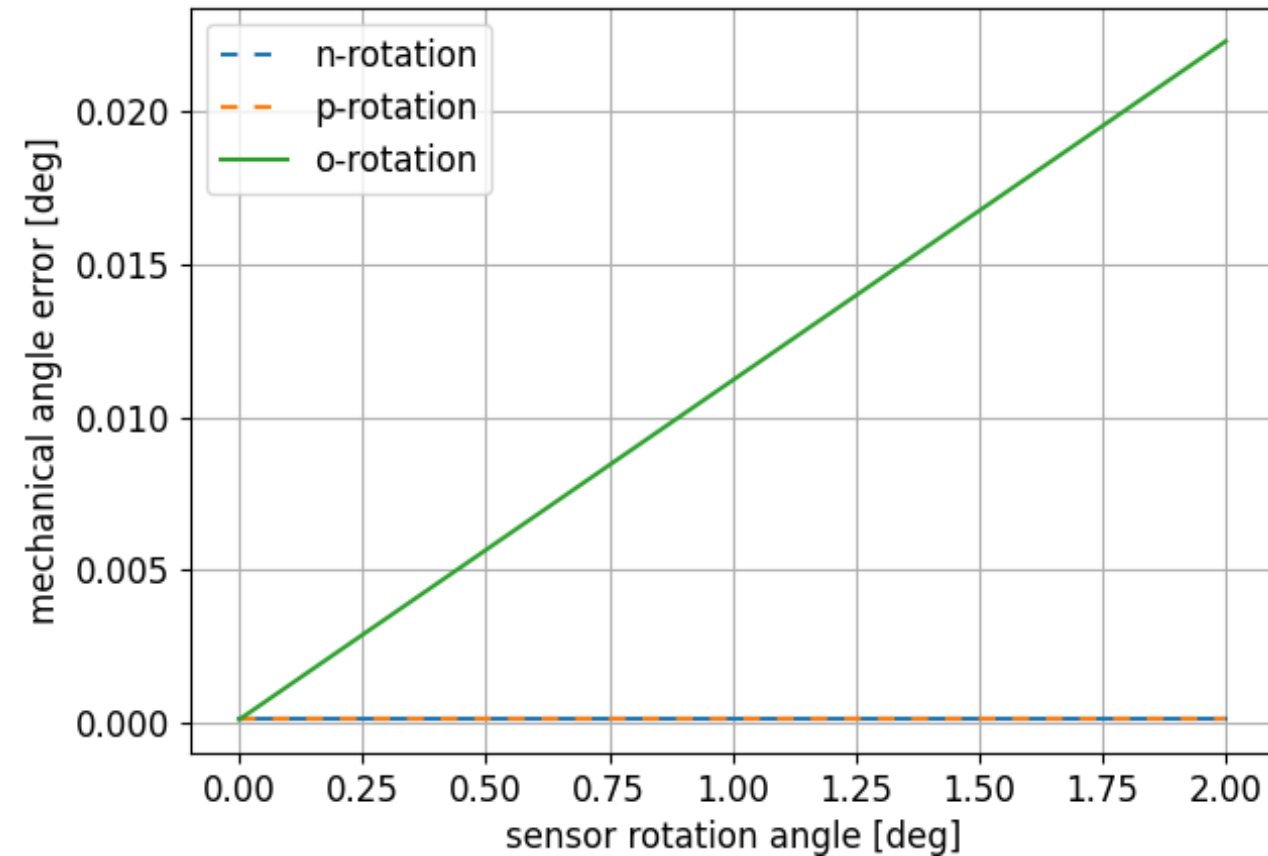
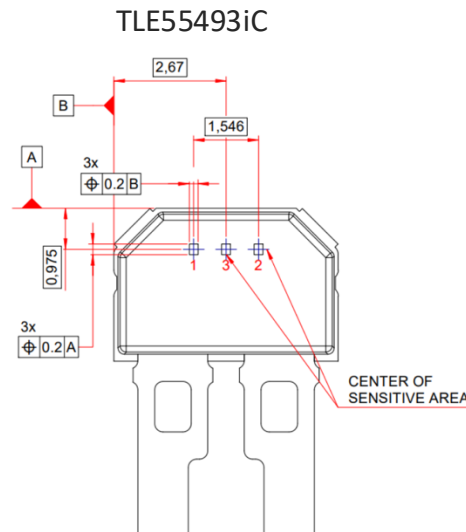
Only one direction is problematic



Three rotation axes



Movement of sensor in rotation around o-axis

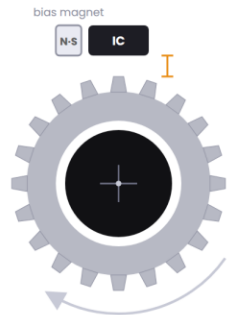


Photos: Infineon Technologies (product pages TLI5590-A6W / TLE55493IC-LR). Source: Infineon TLE55493 / TLI5590-A6W datasheets

# Airgap Gain

TMR doubles the usable airgap of Hall and 7x of passive systems

## SCHEMATIC MEASUREMENT SETUP

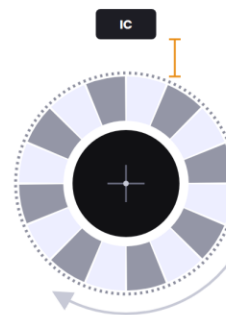


**≈ 0.20 mm**  
BACK-BIAS (STEEL GEAR)

Ferrite bias magnet in the sensor package + unmagnetized steel gear as target



airgap = tooth length ÷ 4 · 0.8 mm tooth, module 0.5 gear (Lenord+Bauer)



**≈ 0.55 mm**  
ELASTOMER-BOUND RING

NdFeB powder bonded in rubber/plastic (HNBR) — typical external competitor ring



rated 25–30 mT airgap spec of an HNBR-bonded reference ring (competitor datasheet)



**≈ 1.40 mm**  
NANOMAG SmCo (METALLIC)

RECOMMENDED PAIRING

Sputtered SmCo on a stainless-steel carrier + differential TMR sensor — no binder, no bias magnet

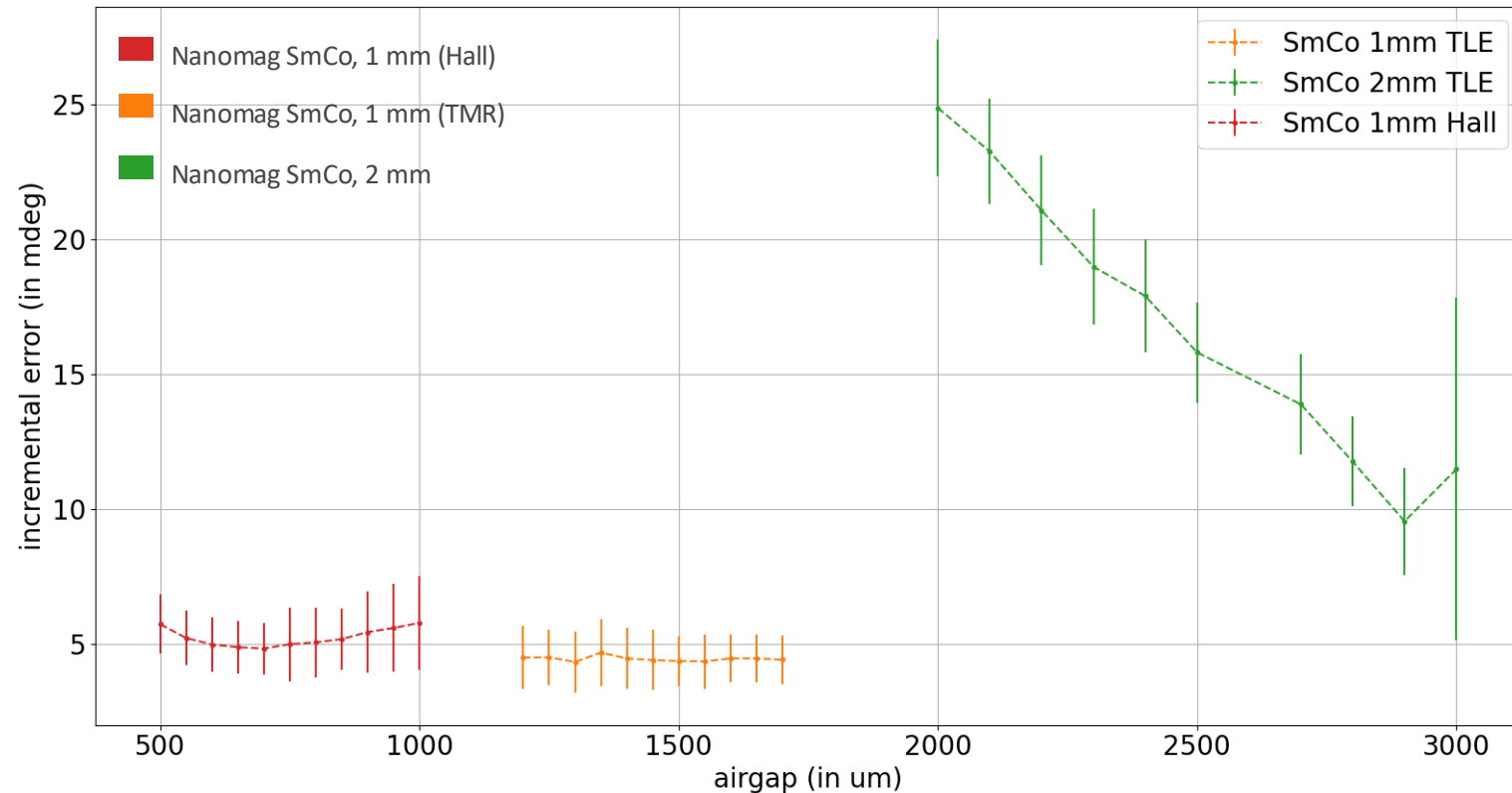


airgap = pole length × 1.4 · N3, 1.0 mm pole — confirmed by SAL/Infineon measurement

# Airgap Gain (2 mm) – **Work in progress**

Shift in incremental error currently under investigation

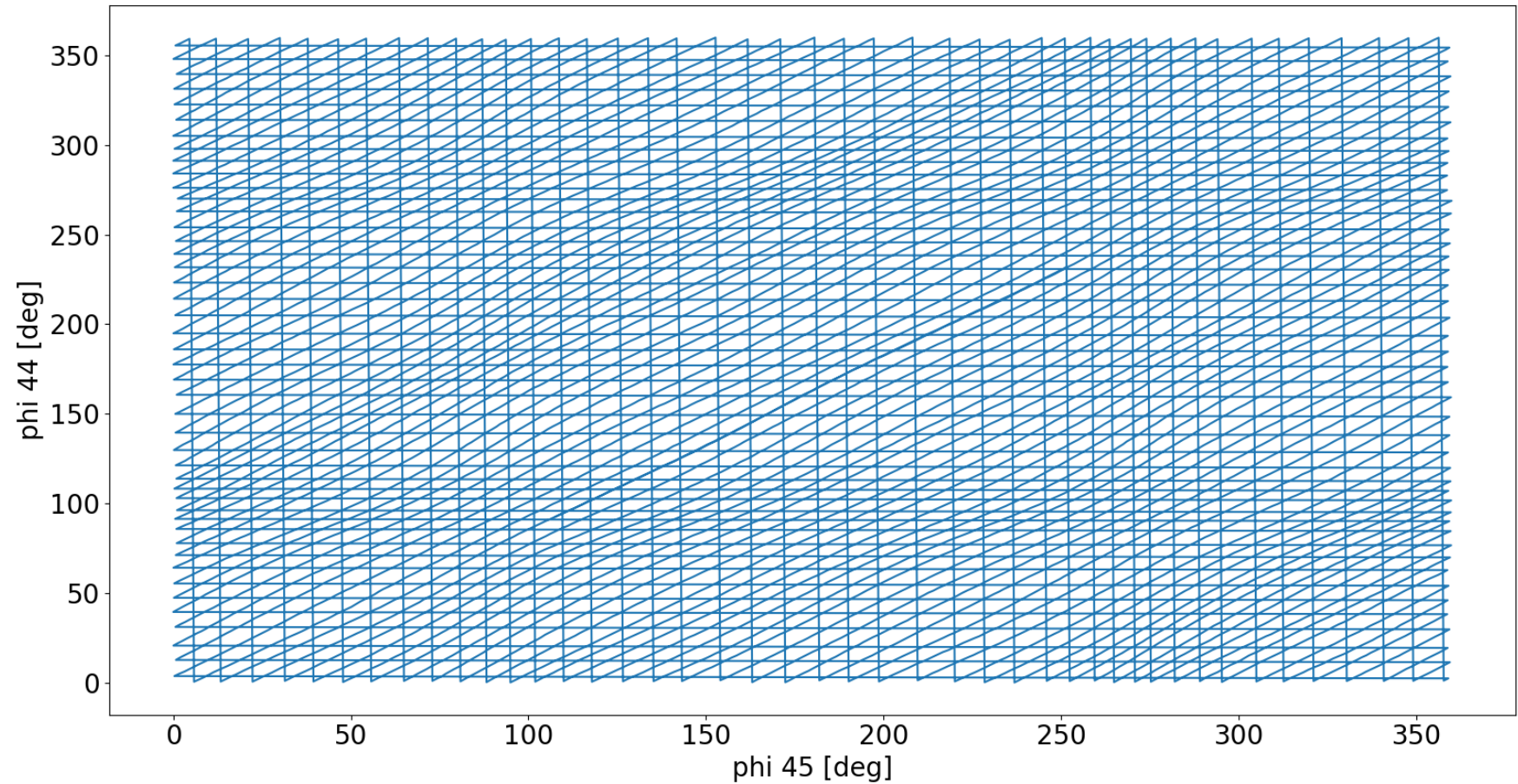
- ✓ With 2 mm pole lengths → **airgaps of 2,5 of 2,5 mm** are usable
- ✓ **Shift** in incremental error currently **under investigation**



(dashed = compensated)

## Nonius – Work in Progress

- ✓ Nonius wheel
- ✓ OD = 57 mm
- ✓ 44/45 pole pairs
- ✓ TLE55493iC
- ✓ Airgap 2,6 mm
- ✓ uncompensated



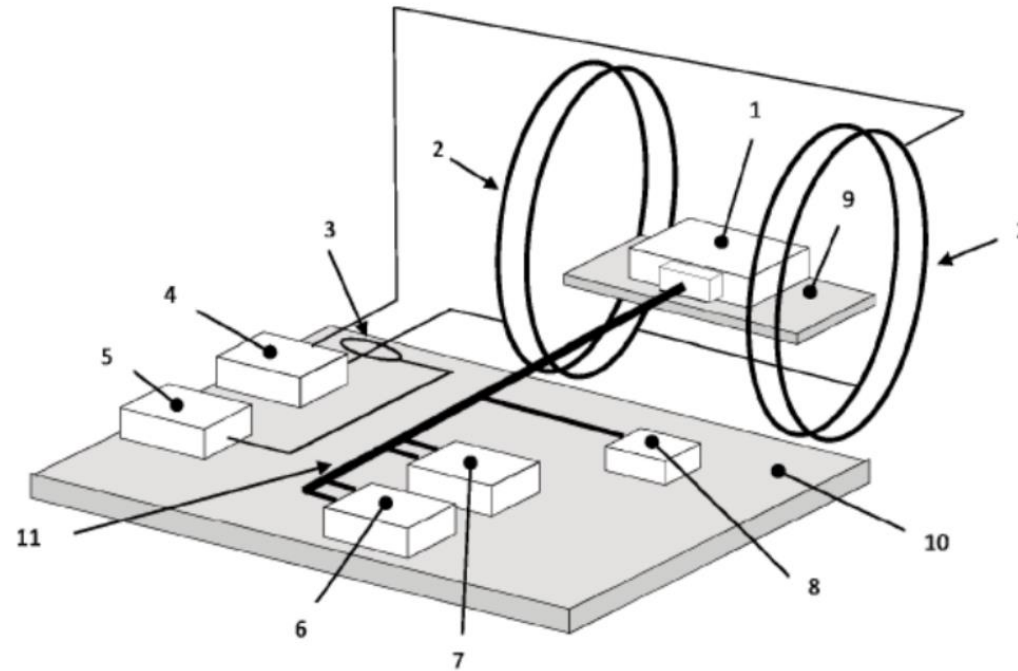


Punish the system

**Strayfield**  
**robustness**

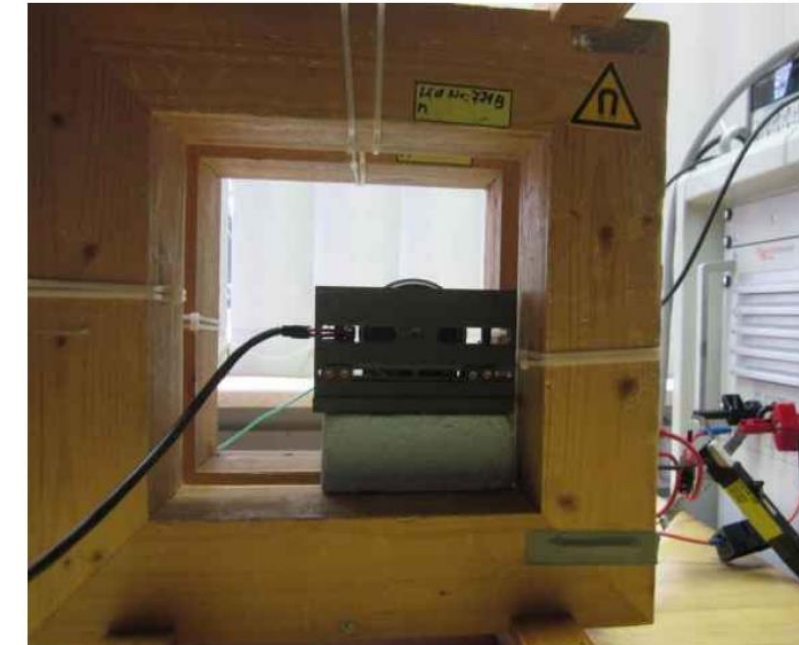
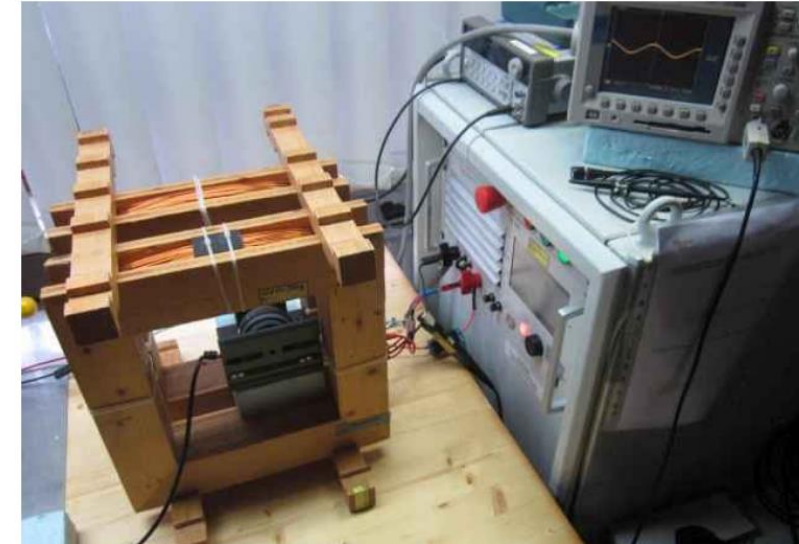
# Strayfield robustness test

TLE55493 test setup  
ISO-11452-8



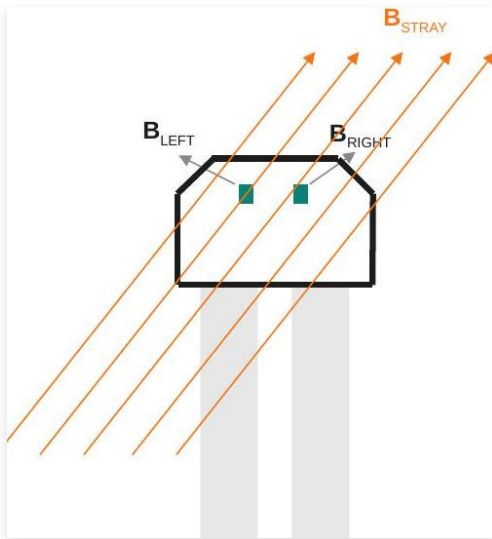
## Key

- |                                             |                                                |
|---------------------------------------------|------------------------------------------------|
| 1 DUT                                       | 7 battery                                      |
| 2 helmholtz coil                            | 8 load simulator                               |
| 3 current probe                             | 9 insulating support                           |
| 4 generator and amplifier/d.c. power supply | 10 ground plane (if required in the test plan) |
| 5 oscilloscope                              | 11 test harness                                |
| 6 power supply                              |                                                |



# Intrinsic Immunity to External Fields

Differential TMR sensor setup – eliminating



- ✓ Two sensing elements on the chip; **differential field**  $\text{dB} = B_{\text{RIGHT}} - B_{\text{LEFT}}$ .
- ✓ A **homogeneous external stray** field  $B_{\text{STRAY}}$  **cancels out of dB** – the same principle behind TLI5590 and TLE55493iC.
- ✓ **TLE55493iC** is **robust against** external fields **up to +/- 5 mT**

up to  $\pm 5 \text{ mT}$

Acc. ISO-11452-8, Level IV

$< 0.05 \%$

TMR jitter at 1.4 mm airgap

$< 0.75 \%$

Hall jitter at 0.5 mm airgap

## WHAT “JITTER” MEANS HERE

Short-term noise on the output signal under an external disturbing field – position appears to wobble even though the target isn’t moving. It shows up immediately as noise, not as a slow drift.

## WHAT IT MEANS FOR THE ENCODER MAKER

A cleaner signal near motor and cable EMI, with no extra shielding or downstream filtering – a steadier velocity/commutation signal and a tighter servo loop.

Sources: SAECE paper (Li, Hainz et al., Infineon), Fig. 21; stray-field schematic:



Industries & Applications

# Benefits for end customers



## Takeaways for end customers

SmCo polewheels together with Infineons differential TMR-Sensors open new horizons

- ✓ **Airgaps up to 2,5 mm** easily achievable – but **with outstanding resolution and accuracy** (no need of 5 mm poles)
- ✓ **Robust against tolerances** without losing accuracy – only tilting in one direction matters
- ✓ SmCo-polewheel **1mm (OD = 57mm)** with **TLE55493iC: 16 bit** resolution, **< 5 mil°** accuracy, **1,4 mm** airgap
- ✓ Robust against **strayfields** (TLE554939): **ISO 11452-8, Level IV qualified**



# Which End Industries Gain

Where Nanomag pole rings prove themselves – [nanomag.at](https://nanomag.at) / Applications



## Machine tools & spindles

Coolant, chips, continuous duty: the fully metallic design survives the environment in which binders fail.

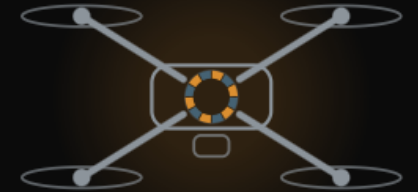
Higher airgaps

Robustness

Higher tolerances

Lightweight

- ✓ Drones & UAV – every gram at the rotor costs flight time; thin-walled SmCo cuts mass without losing robustness.



## Drones & UAV

Every gram at the rotor costs flight time. The thin-walled SmCo ring cuts mass and moment of inertia without yielding to vibration or heat.

Low energy consumption

Robustness

Lightweight

## ✓ Machine Tools & Spindles:

- ✓ Larger airgaps, more lightweight
- ✓ Significant higher tolerances
- ✓ coolant, chips, continuous duty: the fully metallic design survives where binders fail



# Which End Industries Gain

Where Nanomag pole rings prove themselves – [nanomag.at](https://nanomag.at) / Applications



**Off-highway & heavy-duty**

Mud, ice and bearing play force large working distances. Modern TMR sensing still reads the ring there — without coarsening the pole pitch.

- Accuracy
- Robustness
- Lightweight

## ✓ Cobots & Lightweight Robots:

- ✓ Compact and accurate
- ✓ Inert against oils & fats



**Cobots & lightweight robots**

Highly dynamic axes need a clean signal at low inertia. The uniform magnetic layer keeps the pole pitch constant.

- Media exposure
- Compact
- Accuracy

## ✓ Unbeaten accuracy with same airgap:

- ✓ High resolution polewheels possible
- ✓ Same airgap



## Summary and Outlook

- ✓ Understand and **improve 2 mm incremental**
  - ✓ Further **optimization of nonius / absolute angle functionality**
  - ✓ **Transferring technology into real life!**
- 
- ✓ **For follow-up project: We're searching for an end customer partner – interested?**

Interested in an evaluation sample or corporation?

Get in touch – [wpe@nanomag.at](mailto:wpe@nanomag.at)

# Thank You

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