Magnetoresistive Sensors for Angle, Position, Magnetic Field and Electrical Current Measurement in Spacecraft

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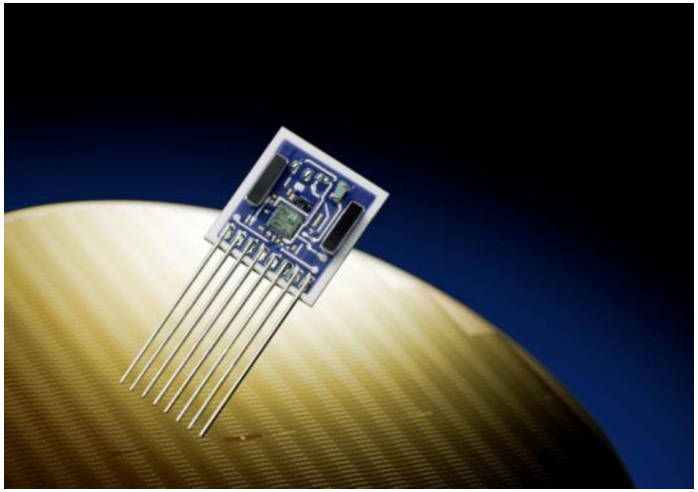
9th ESA Round Table on Micro- and Nano-Technologies

10th – 13th June, Lausanne, Switzerland

Agenda

- Introduction
- MR Technology Basics
- Advantages of MR Sensors
- Applications of MR Sensors
- Application examples in Space
- Outlook and Summary



The Space Industry needs new sensor technologies

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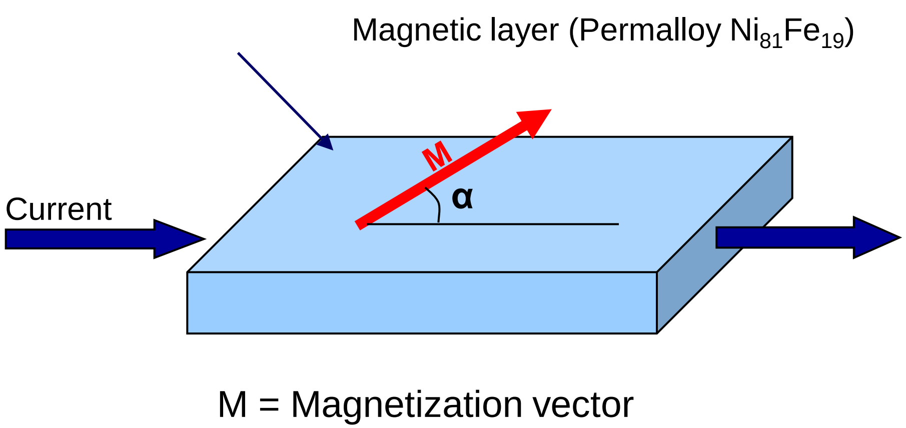
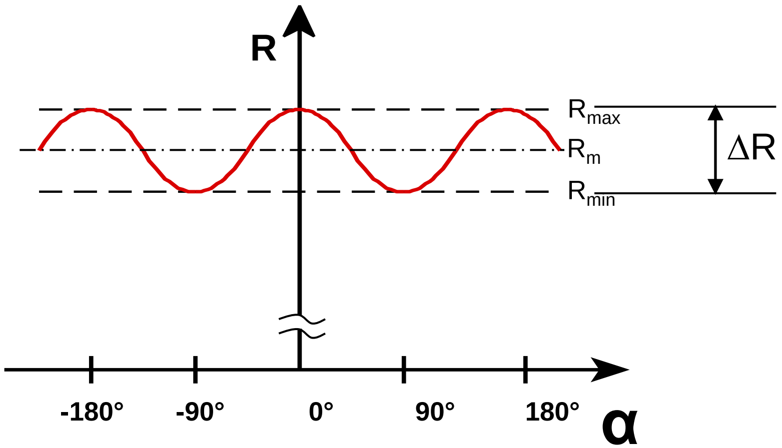
- Angle, position, magnetic field and current measurement continue to be „tough nuts to crack" in space applications
- Resistive shunts and hall effect-based sensors are conventional solutions for current measurement; Optical encoders and resolvers are „traditional" solutions for angle and position measurement
- The power losses induced by shunts are proving a problem in new applications (due to reduced battery life, heat dissipation etc.)
- The limited radiation hardness of hall-effect based sensors is a major obstacle to space applications
- The high cost and limited robustness of optical encoders limits their applications
- The high weight and large volume of resolvers is a major disadvantage
- The space industry needs „multi-purpose" and „rad-hard" sensor technologies
- Sensors based on the **magnetoresistive (MR)** effect offer the potential for a miniaturized, rad-hard, highly accurate and highly dynamic solution

What is the MR effect?

Magnetoresistance (MR) refers to the change in resistance of a material when a magnetic field is applied.





MR Sensor Technology in brief:

- MR effect first discovered in 1857 (Lord Kelvin)
- Applications in data storage technology (read-heads for hard discs) from ca. 1980
- First sensor applications from ca. 1990
- Sensitec manufactures three types of MR sensors: AMR (anisotropic), GMR (giant) und TMR (tunnel)
- MR sensors can be used for angle, length, electrical current and magnetic field measurement

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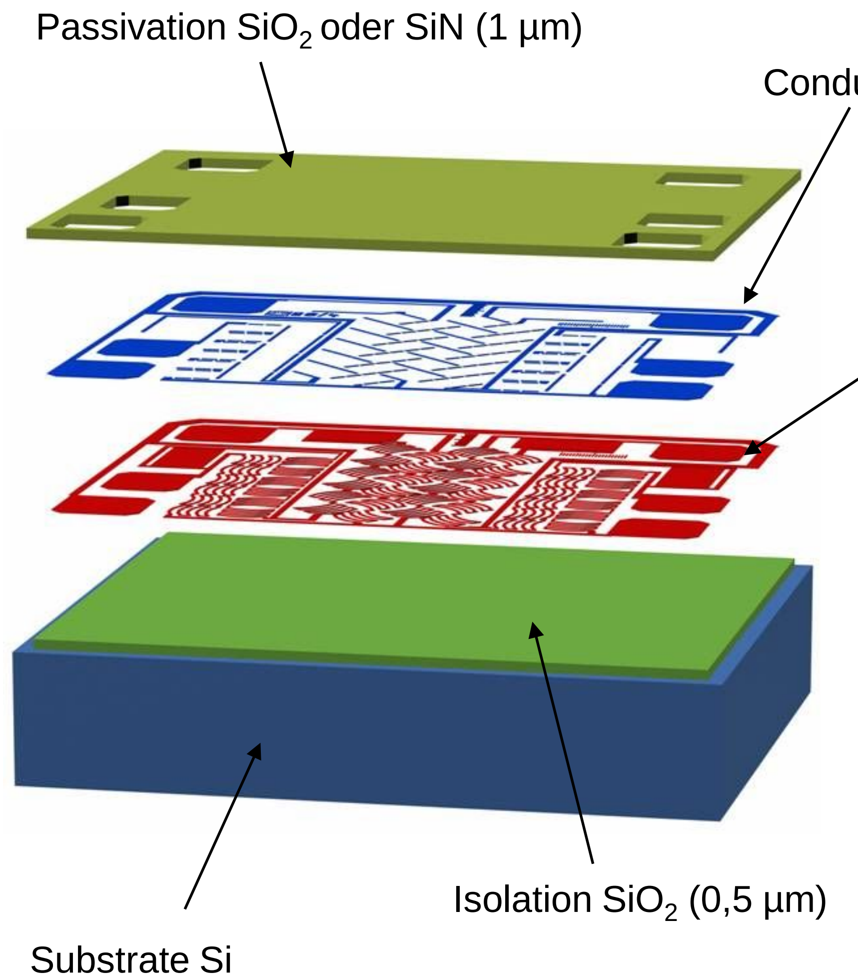
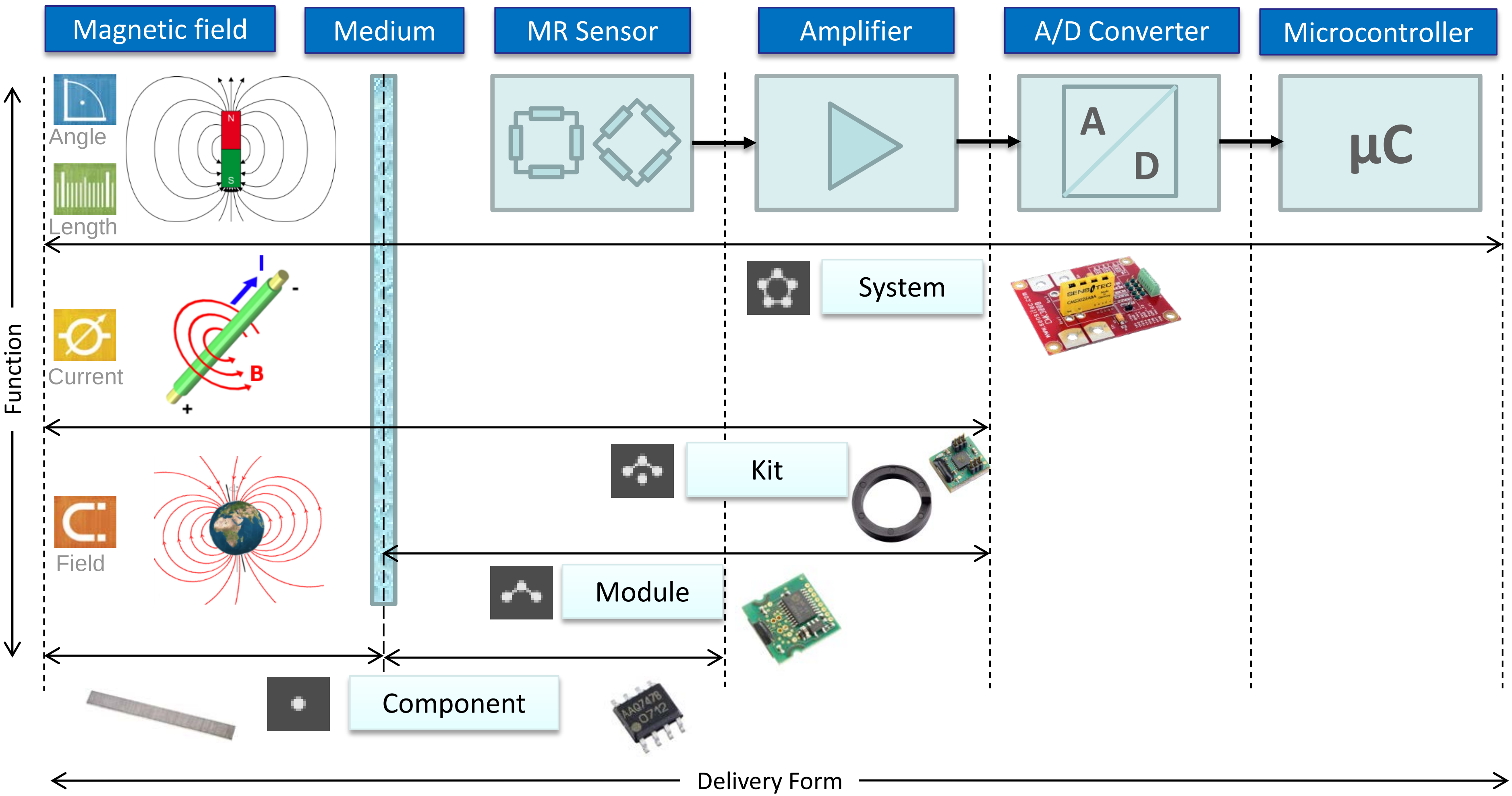
Basic construction of MR sensor chip (Angle sensor)



Sensitec Clean Room in Mainz

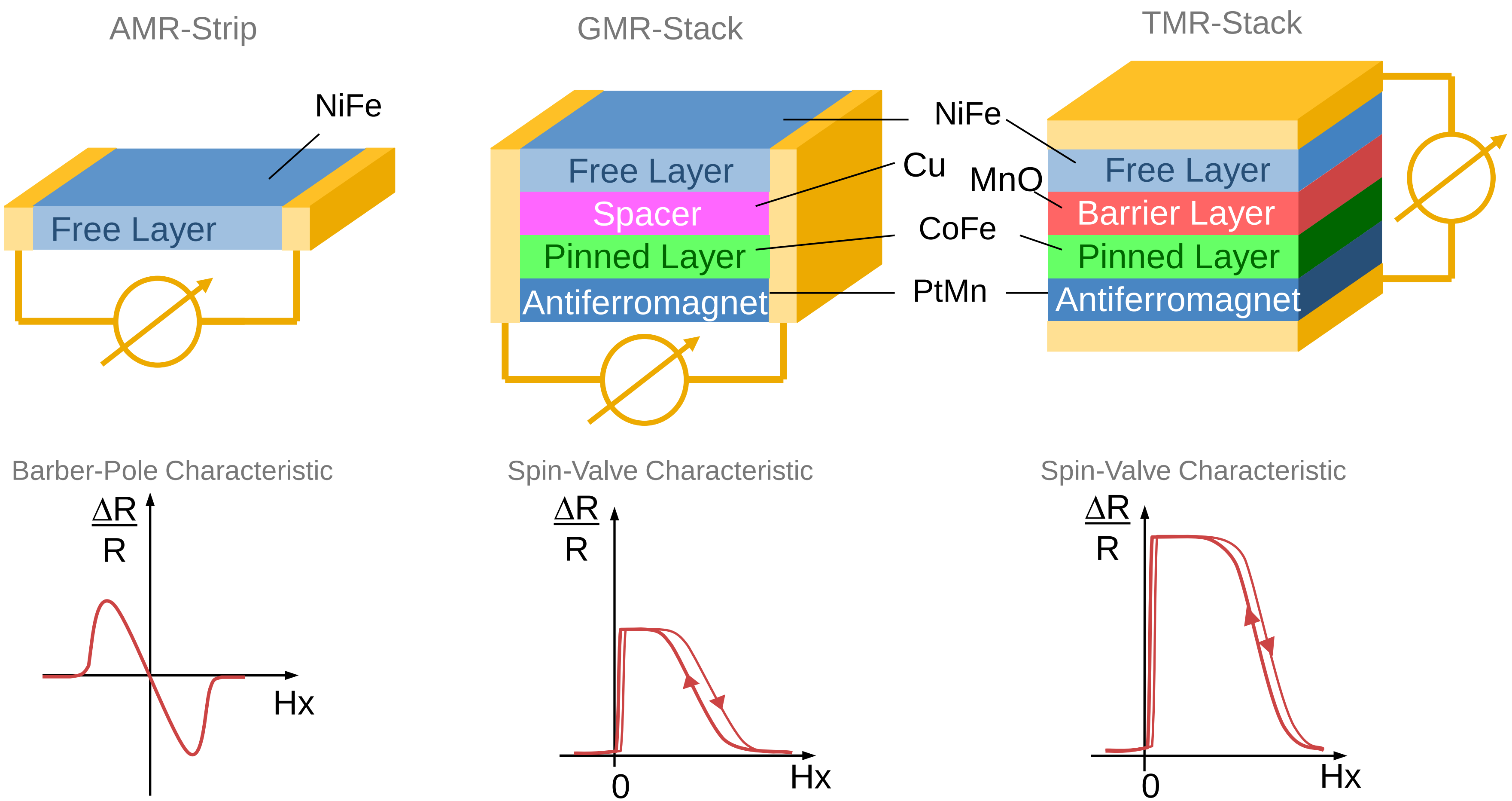
MR Technology Basics (5)

Measurement Functions and Signal Chain for MR Sensors



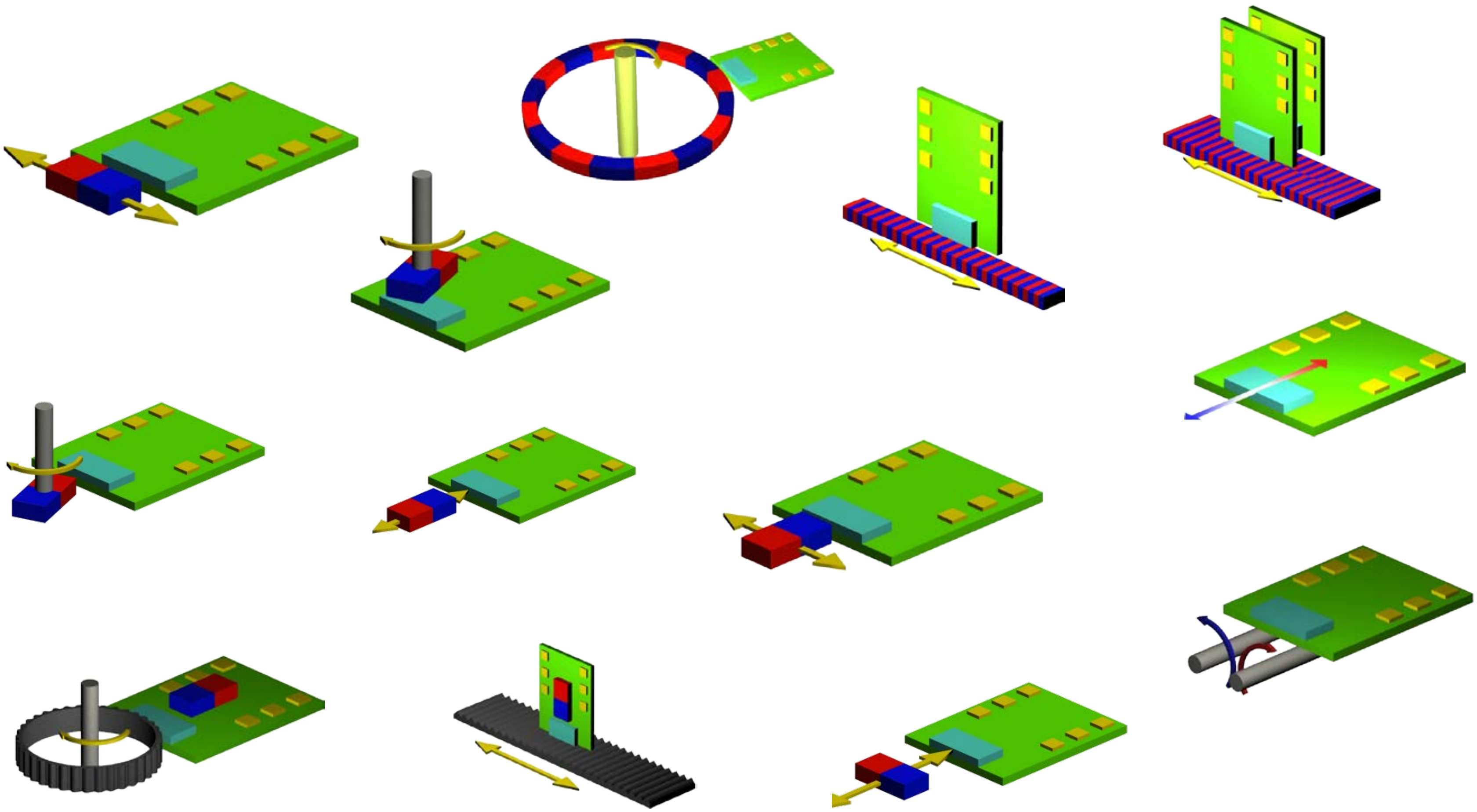
MR Technology Basics (6)

XMR-Technology Comparison (simplified topologies)



MR Sensor Configurations

The small dimensions and high sensitivity of MR sensors make them easy and flexible to use for angle, path, magnetic field and electrical current measurement



Why use MR sensors from Sensitec? (1)

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Advantages of MR sensors (in general)

- High accuracy and high resolution
  - In range of µm (nm resolution) or arcmin (arcsec resolution)
- High dynamic performance
  - Bandwidth from 0 to 10 MHz
- Very robust
  - Almost impervious to high/low temperatures, radiation, oil, dirt etc.
- High reliability
  - < 0,2 ppm in automotive applications (for ca. 110 million wheel speed sensors) to date
- High sensitivity
  - High output signal from physically very small sensors (typical size of bare die 750 x 750 µm)
- Low power consumption
  - High resistivity for battery-powered applications
- Long operating life
  - Contactless, wear-free measurement principle

Why use MR sensors from Sensitec? (2)

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Sensitec-specific advantages

- Space heritage (MR sensors on Mars since 2004)
- COTS* or „near-COTS“ sensors can be used in space applications
- High level of traceability (Automotive-qualified supplier according to ISO/TS 16949)
- Stable technology platform (low risk of rapid component obsolesence)
- Design and process changes are given with good warning
- Extensive reliability data (ca. 100 million automotive AMR sensors in the field)
- Numerous system-level simulation tools available

* COTS = **C**ommercial **O**ff **T**he **S**helf

Applications of MR Sensors

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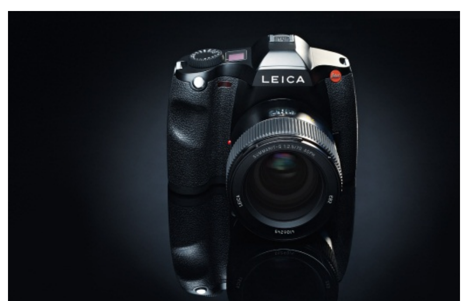
Measuring drill-bit wear and bore direction in deep-bore drilling

Torque sensor for active steering

Current sensors for motors in wind turbines

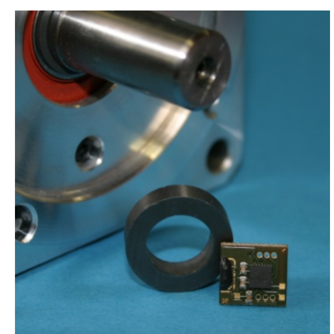
Motor encoder for Mars Rover



Focus measurement in cameras

Linear encoder for biometric measurements

Length measurement in a workshop calliper



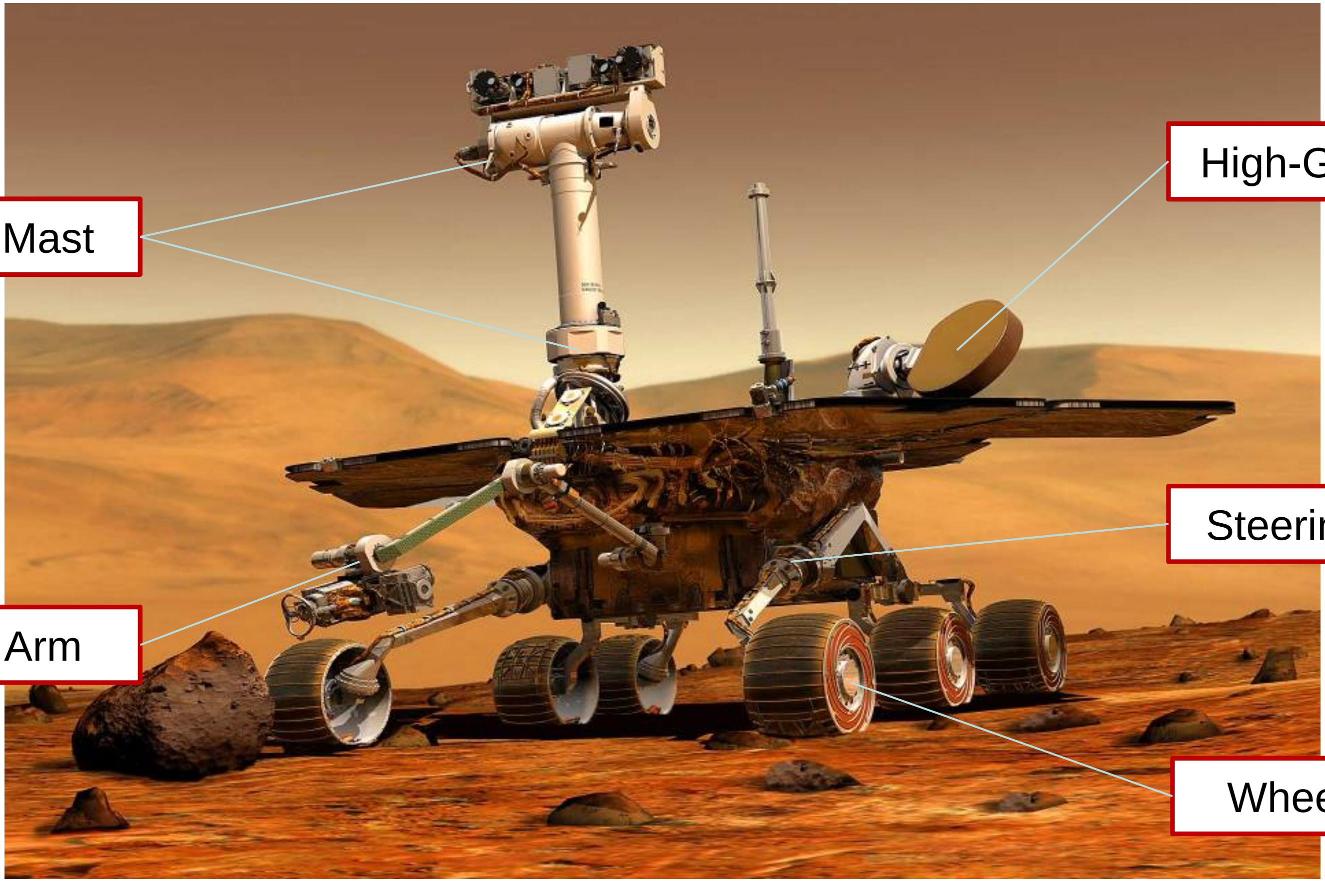
Motor feedback system for BLDC motor

Applications for MR-sensors in Space

- **Magnetic encoders for control of electric motors** (rovers, robots…)
- Magnetic encoders for antenna pointing mechanisms
- Magnetic encoders for reaction wheels
- Angle sensors for hinges and latch mechanisms
- Angle sensors for magnetic torquers
- Proximity sensors for optical shutters
- Magnetic field sensors for compact magnetometers
- **Current sensors for power distribution modules**
- Current sensors for condition monitoring of power electronics
- and many more…..

Angle Sensors on Spirit and Opportunity

39 actuators use MR-Encoders for motor position feedback



Source: NASA/JPL-Caltech

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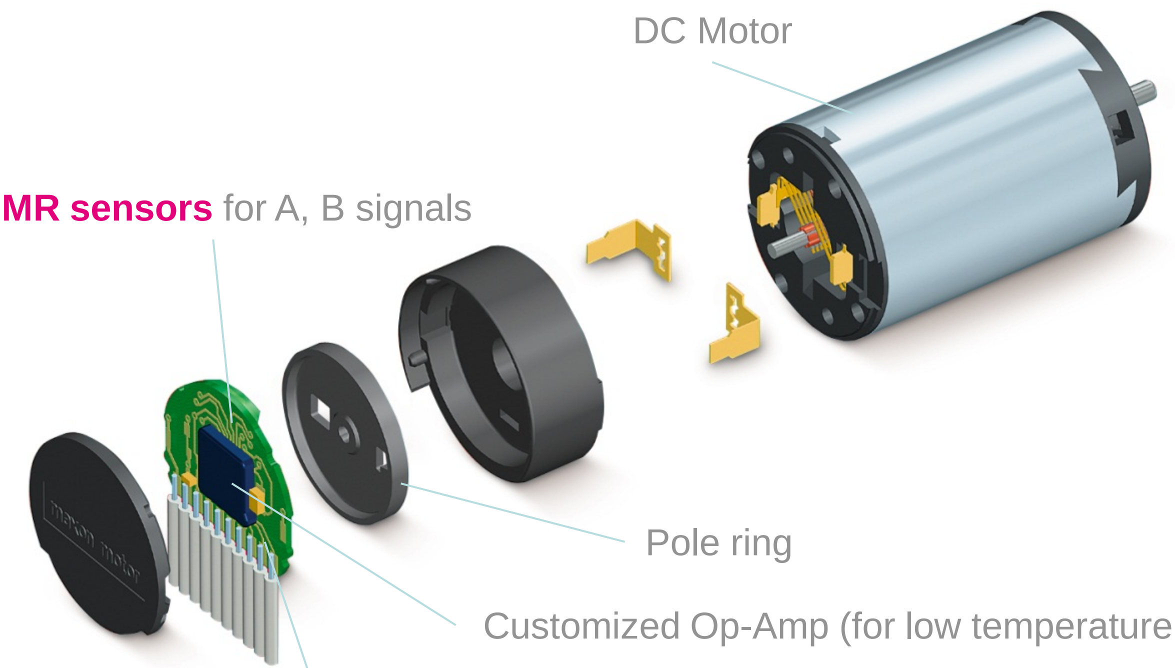
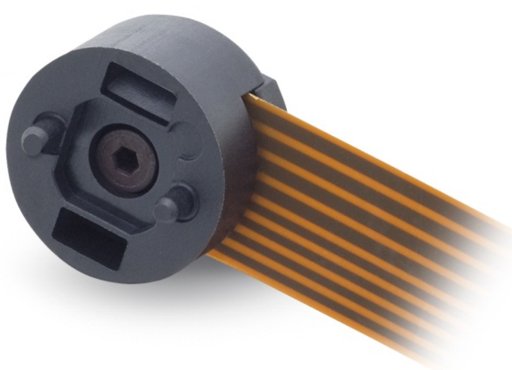
MR-Encoder as part of DC Motor from Maxon Motors (CH)

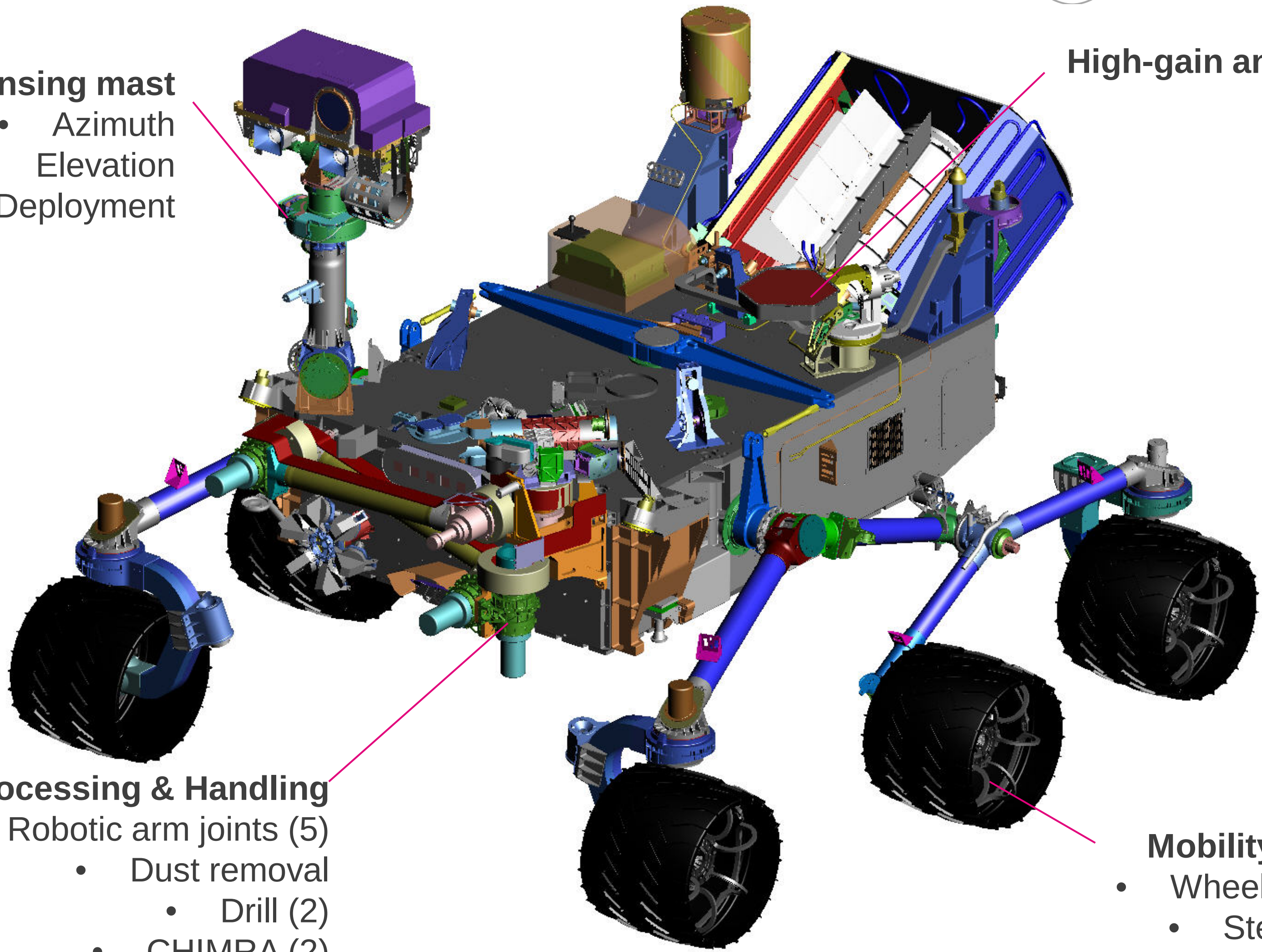




Angle Sensors on Curiosity

Remote sensing mast
- Azimuth
- Elevation
- Deployment

High-gain antenna system
- Azimuth
- Elevation



Sample Processing & Handling
- Robotic arm joints (5)
- Dust removal
- Drill (2)
- CHIMRA (2)
- Inlet covers

Mobility system
- Wheel drive (6)
- Steering (4)

Source: NASA/JPL-Caltech

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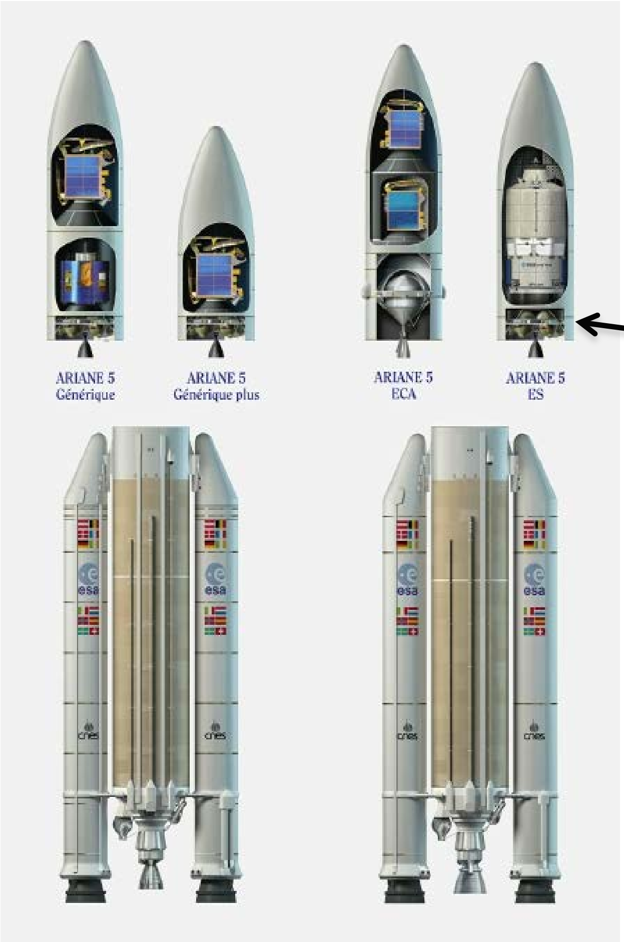
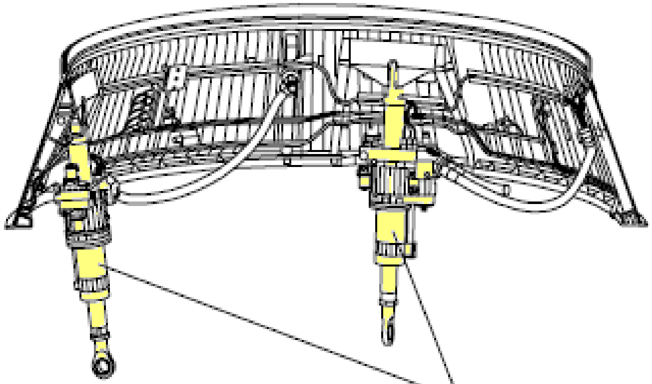
West of „Dingo Gap“ on Mars (March 2014)

Source: NASA/JPL-Caltech

Power electronics for electro-mechanical Thrust Vector Actuator

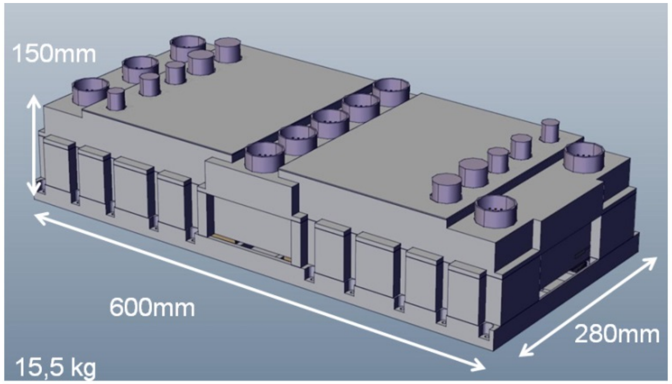


3rd stage engine
« TVC ELECTRIQUE 5kW »
for Ariane 5 ME



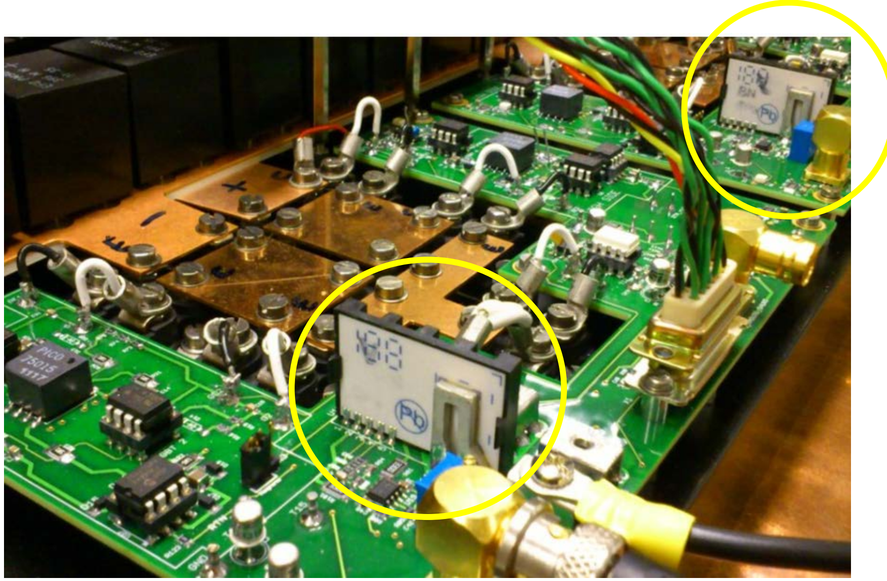
Thrust Vector Actuator (TVA)

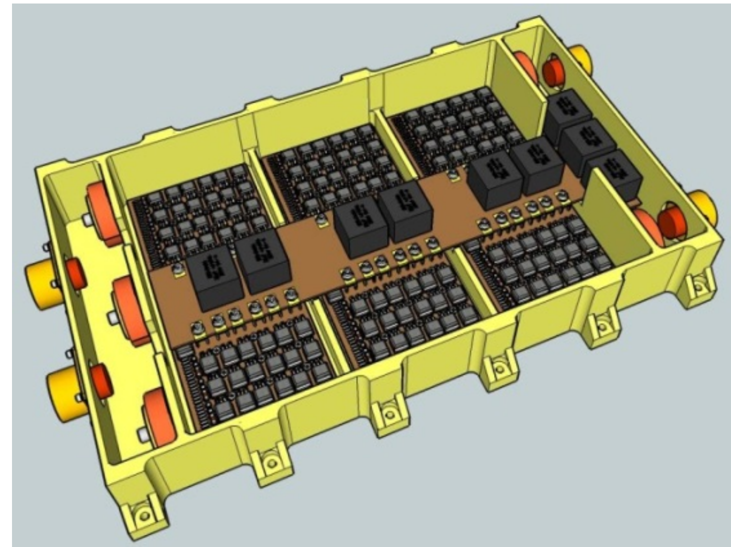
Driver for Thrust Vector Actuator (4-phase motor)



Initial Breadboard Tests

Initial Tests with COTS AMR Current Sensor





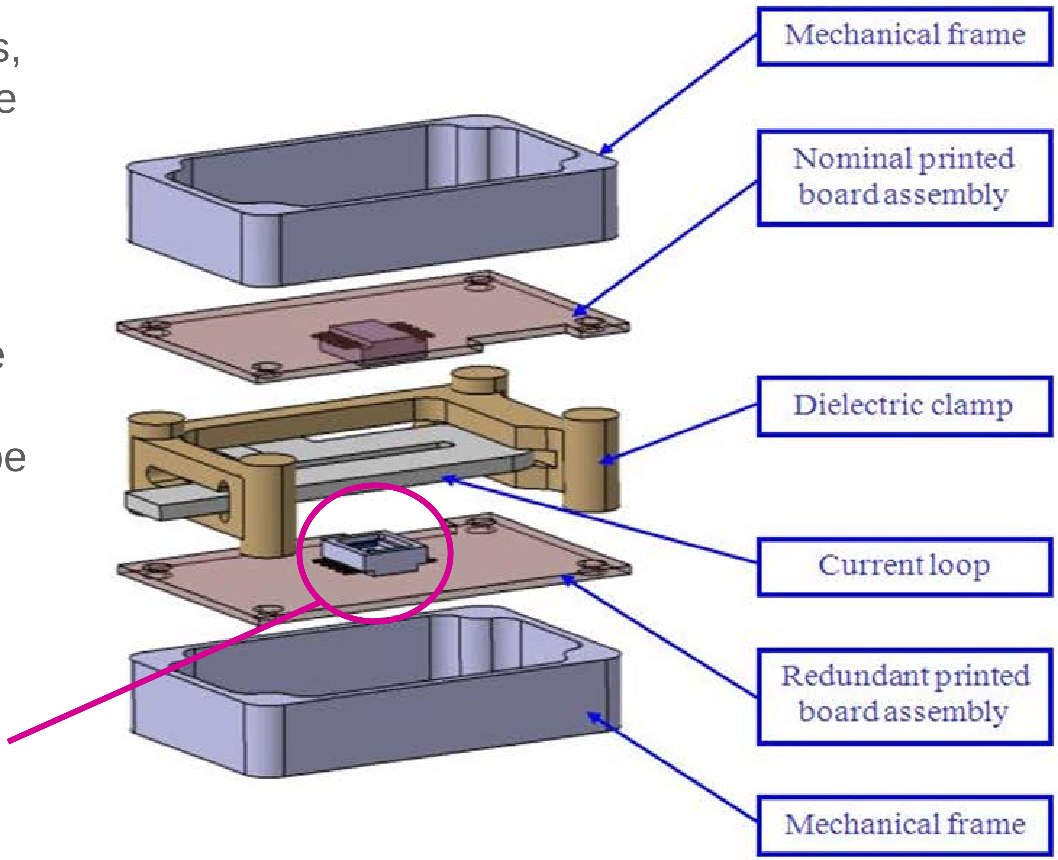
The breadboard of the ECPU was initially tested with conventional shunts to monitor the phase current but not satisfactorily. The power losses incurred by the shunts were unacceptable and also the signal-to-noise ratio did not fulfil the requirements. The losses would have necessitated additional power supplies at system level.

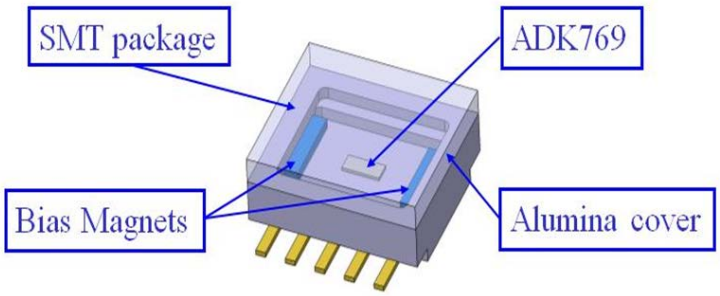
From that stop point, the same breadboard has been successfully tested after implementing a **CMS3050-SP3** AMR current sensor from Sensitec. The industrial current sensor, however, cannot be used directly for space applications due to the unsuitability of the packaging and the non-space-qualified COTS signal conditioning components.

Current Measurement Cell

Design Proposal

- Hermetically seal the AMR current sensor bridge and the 2 bias magnets, in a standard non-conductive package (HTCC ceramic package).
- Design a conditioning circuit using discrete components from QPL.
- Directly use the copper bus bar of the equipment (ECPU), in a U-shape, to properly present the primary field to be measured close to the AMR bridge.





Summary and Outlook

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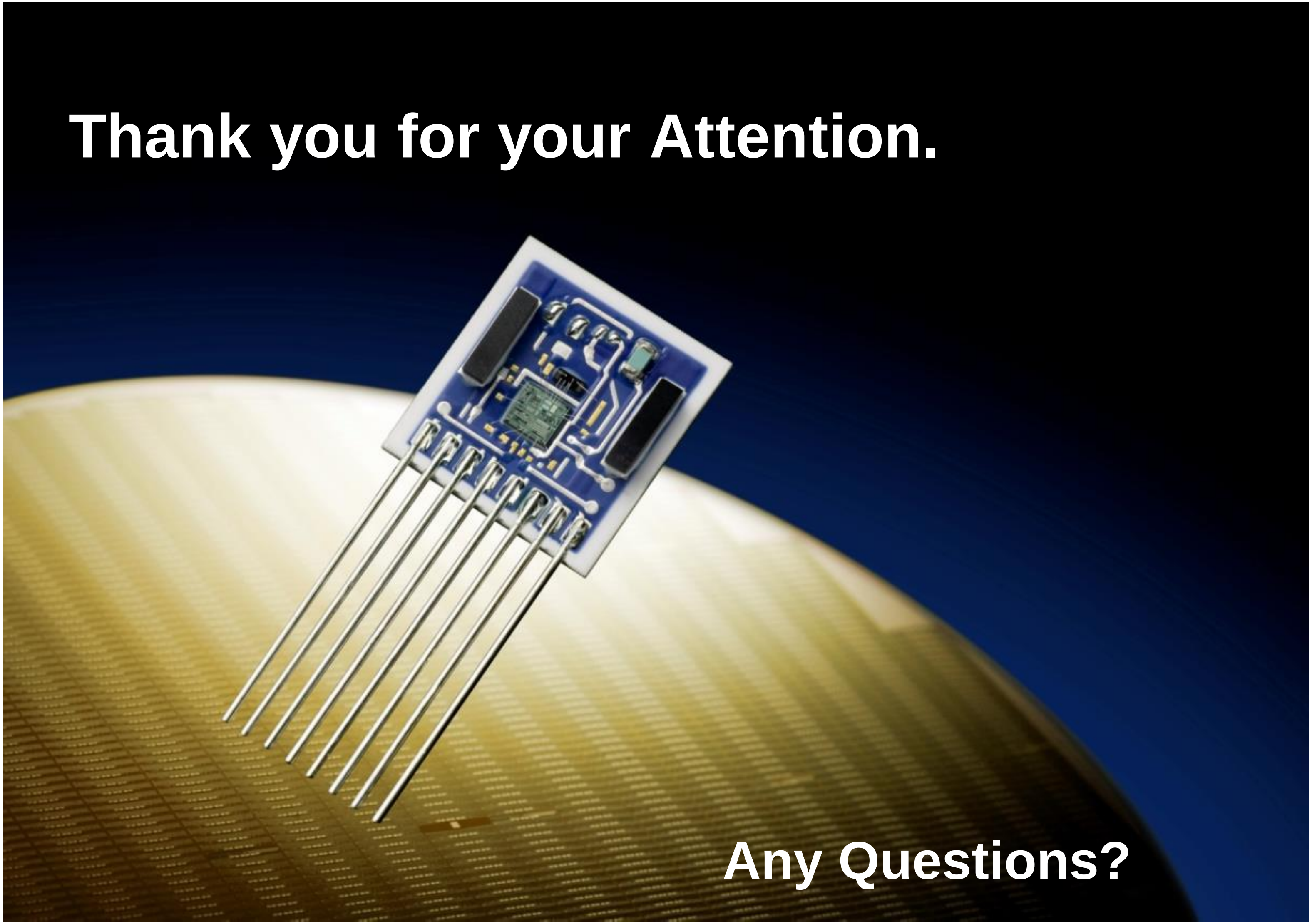
- MR sensors are robust, reliable, dynamic, precise, miniaturized and rad-hard
- The application field of MR sensors is growing continuously
- MR sensors present developers with completely new possibilities to measure angle, linear travel, electrical current or magnetic fields
- Sensitec and HTS have recently completed an ESA-funded feasibility study for contactless angle measurement using MR sensors
- Space-qualifiable current sensors are being developed in co-operation with Thales Alenia Space Belgium
- MR sensors are an important enabler for innovative space applications
- So get thinking !


Thank you for your Attention.
Any Questions?