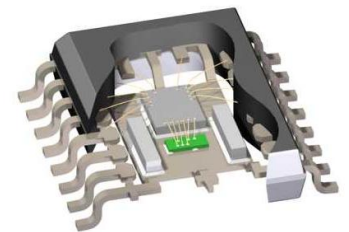


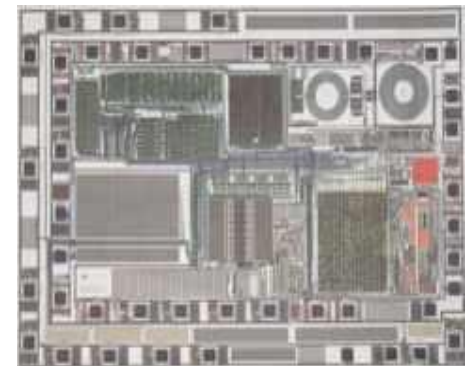
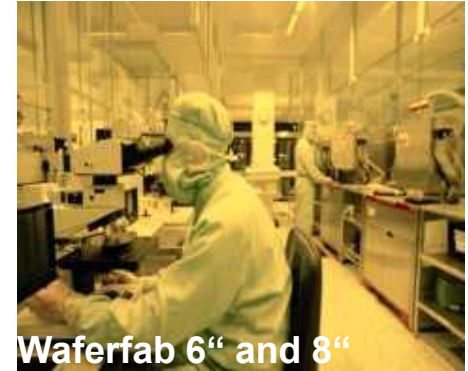


## Architecture of an Integrated Current Sensor System (IACS) for a wide Range of Applications



# Elmos Semiconductor AG

- **Founded 1984 as an independent semiconductor manufacturer for integrated system solutions**
- **1000 Employees, Revenue 2010 €184,7 Mio**
- **2 independent 8" CMOS Fabs**
- **Focused on Automotive Applications (>85%)**
- **Core competence in**
  - analog/mixed-signal solutions based on proprietary HV-CMOS technology driven by automotive needs
  - MEMS development and manufacturing
  - Special packaging technologies
- **To be found in all European as well as many American and Asian cars (>2 Billion ICs in the field)**



# Integrated AMR Current Sensor (IACS)

## Content

- Motivation
- IACS System Concept
- Technical Base
- A Wide Range of Applications
- Target Performance
- Application Example
- Summary

# Integrated AMR Current Sensor (IACS)

## Content

- **Motivation**
- IACS System Concept
- Technical Base
- A Wide Range of Applications
- Target Performance
- Application Example
- Summary

- **More important than ever: Energy Saving**

- **Automotive: “Run more miles with the same battery”**
- **Industry: “Get rid of energy-overcapacity by smart networks”**
- **Consumer: “Wash A grade with less energy”**



⇒ **Reducing current consumption requires precise current measurement**

- **Target applications are**

- **Automotive: Hybrids and e-vehicles**
  - **3-phase motor control (BC / EC / BLDC motors)**
  - **Battery management (driving, charging)**
- **Industry: Inverters / IGBT for i.e. Solar Panels**
- **Consumer: Motor control for i.e. Home Appliance**



# Integrated AMR Current Sensor (IACS)

## Content

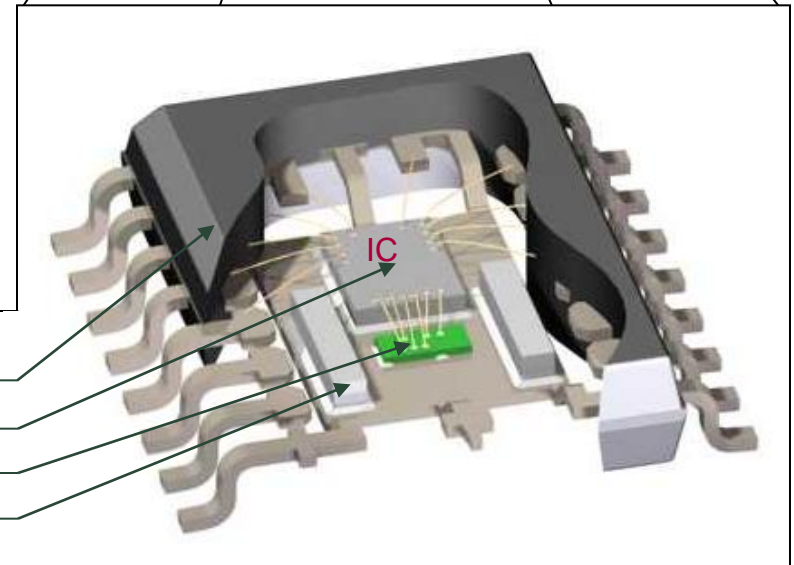
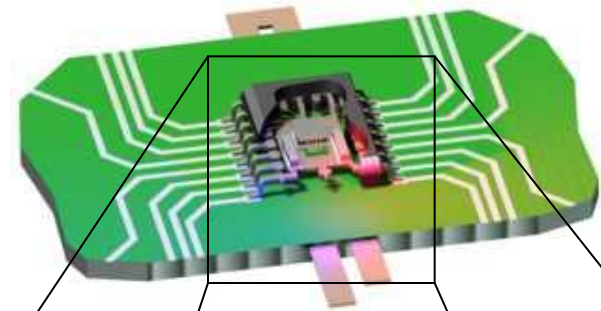
- Motivation
- **IACS System Concept**
- Technical Base
- A Wide Range of Applications
- Target Performance
- Application Example
- Summary

# IACS System Concept

## Integrated AMR Current Sensor (524.50)

- Developed in cooperation with SENSITEC GmbH
- Contactless current measurement based on **Anisotropic Magneto-resistive Effect (AMR)**
- Compared to conventional Hall Sensor or Shunt Resistor solutions the AMR principle has following advantages:

- + Excellent isolation sensor to U-shaped primary current line
- + No hysteresis
- + 0 ... 10A up to 0 ... >400A ("one size fits all")
- + High bandwidth > 500kHz (-1dB) / response <1 $\mu$ s
- + Immunity towards external stray fields
- + High accuracy over temperature -40°C...150°C
- + One product fits to various applications



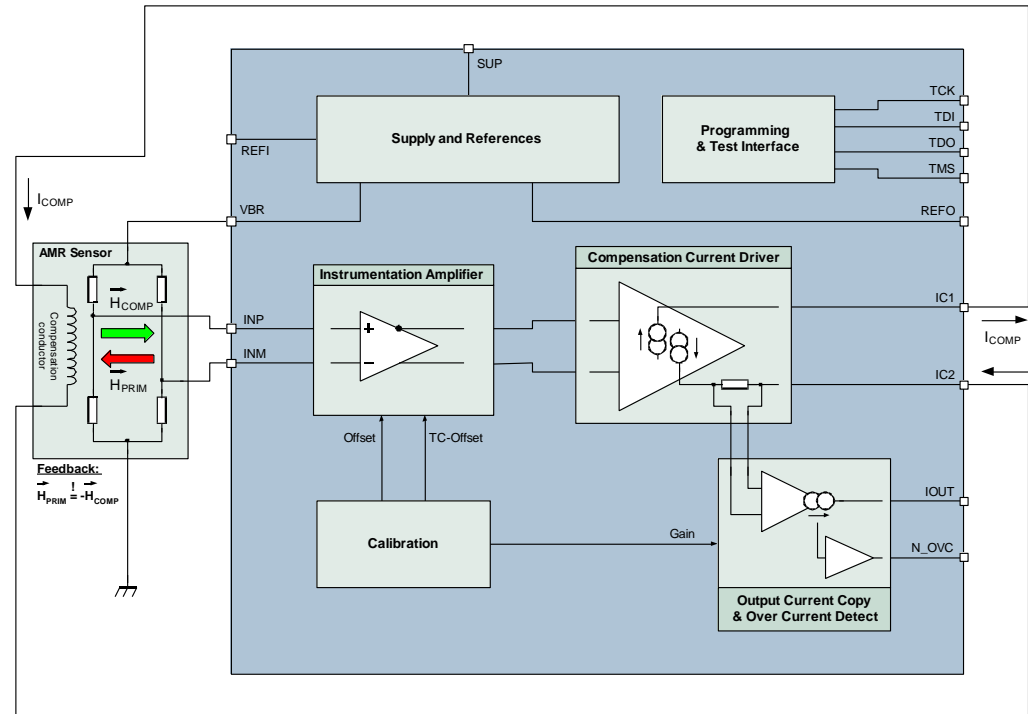
- All sensor elements are integrated in a standard SO16-package (One size fits all.):
  - Measurement and signal conditioner IC
  - AMR-Sensor
  - Permanent magnets (bias field)

# IACS System Concept

## Signal Conditioning

### Features:

- Excellent accuracy: failure < 1.5%
- Good linearity due to compensated closed loop feedback principle
- No hysteresis as no iron core is needed
- Adjustable over-current detection
- System single supply voltage 5V (3.3V)
- Step response time < 1  $\mu$ s for fast current transient measurement
- SNR > 66 dB
- Precise peak signal for up to 3-times nominal current



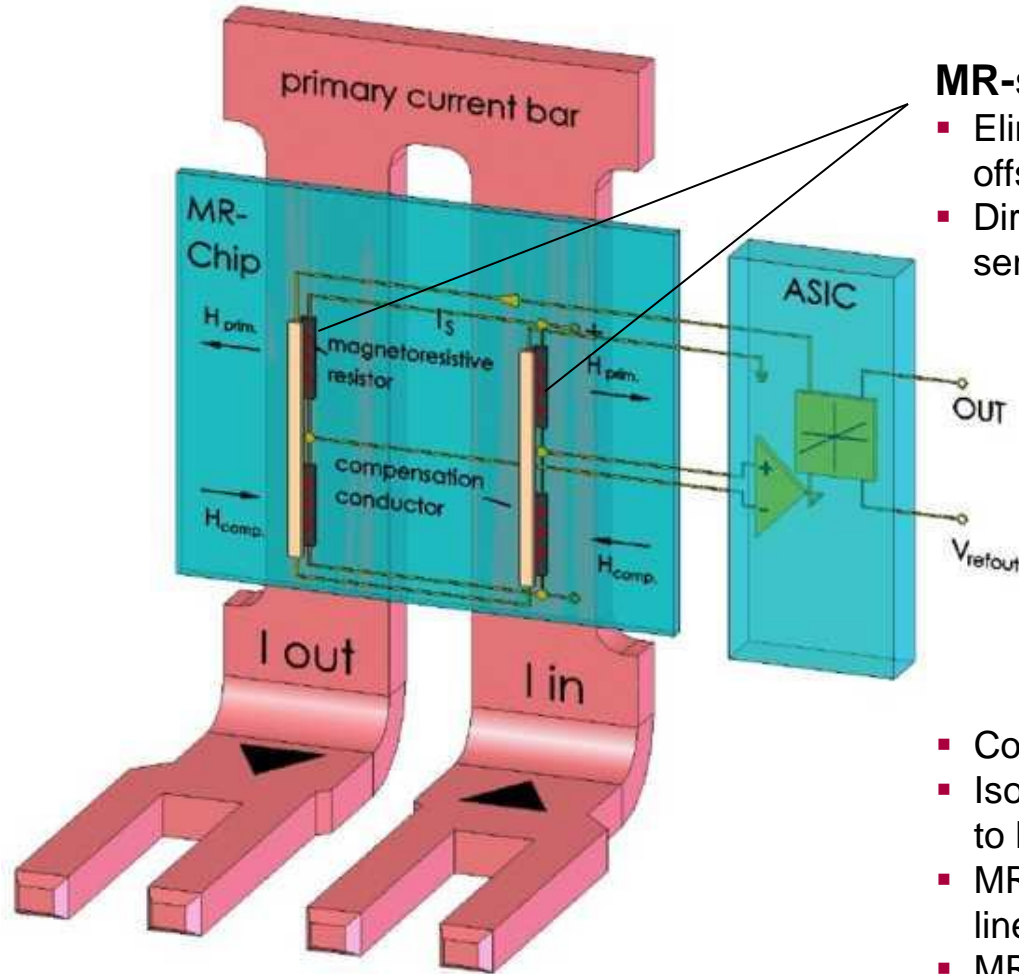
# Integrated AMR Current Sensor (IACS)

## Content

- Motivation
- IACS System Concept
- **Technical Base**
- A Wide Range of Applications
- Target Performance
- Application Example
- Summary

# Technical Base

## Principle of operation (1)



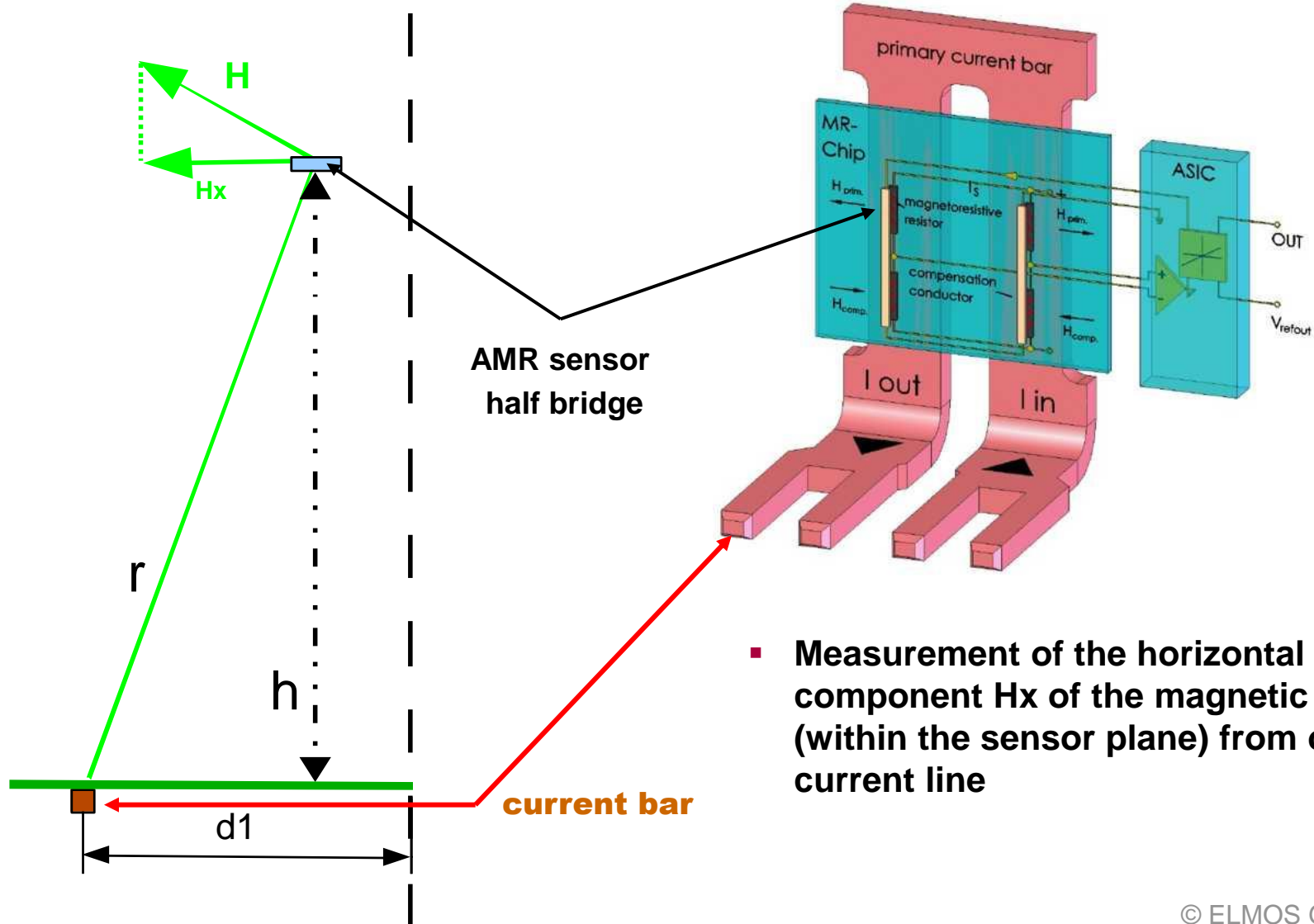
### MR-strips in Wheatstone bridge arrangement:

- Eliminates effects of sensitivity and offset variability over temperature
- Direction of Barber poles effectively doubles sensitivity of sensor

- Compensation technique:
- Isolated aluminum conductors mounted close to MR strips generate compensating field
- MR strips operate close to null-point, improves linearity and avoids temperature effects
- MR strips close together to eliminate effects of temperature gradients over the substrate

# Technical Base

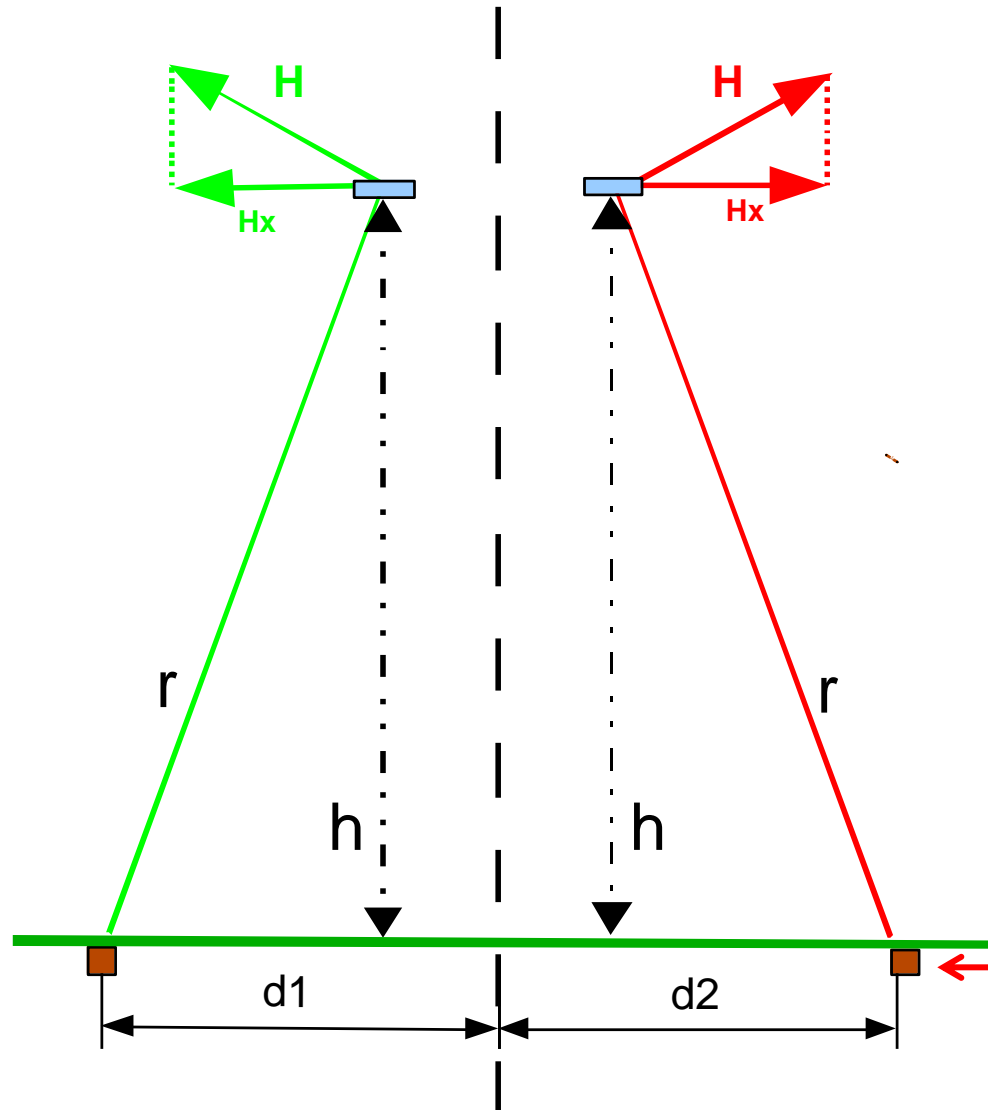
## Principle of operation (2a)



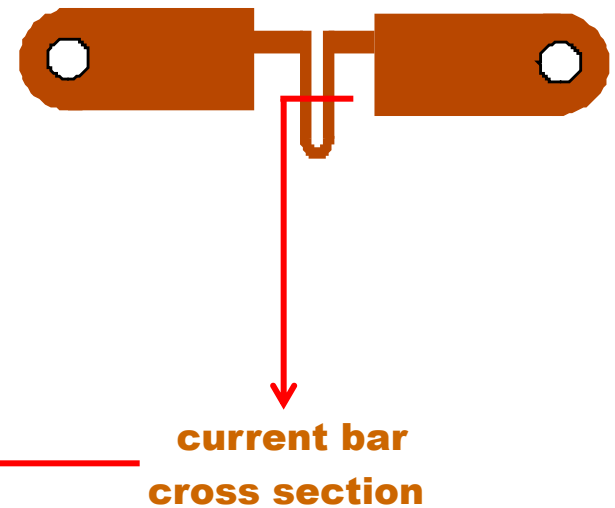
- Measurement of the horizontal component  $H_x$  of the magnetic field (within the sensor plane) from one current line

# Technical Base

## Principle of operation (2b)

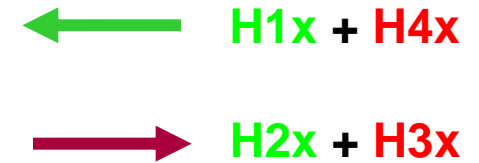
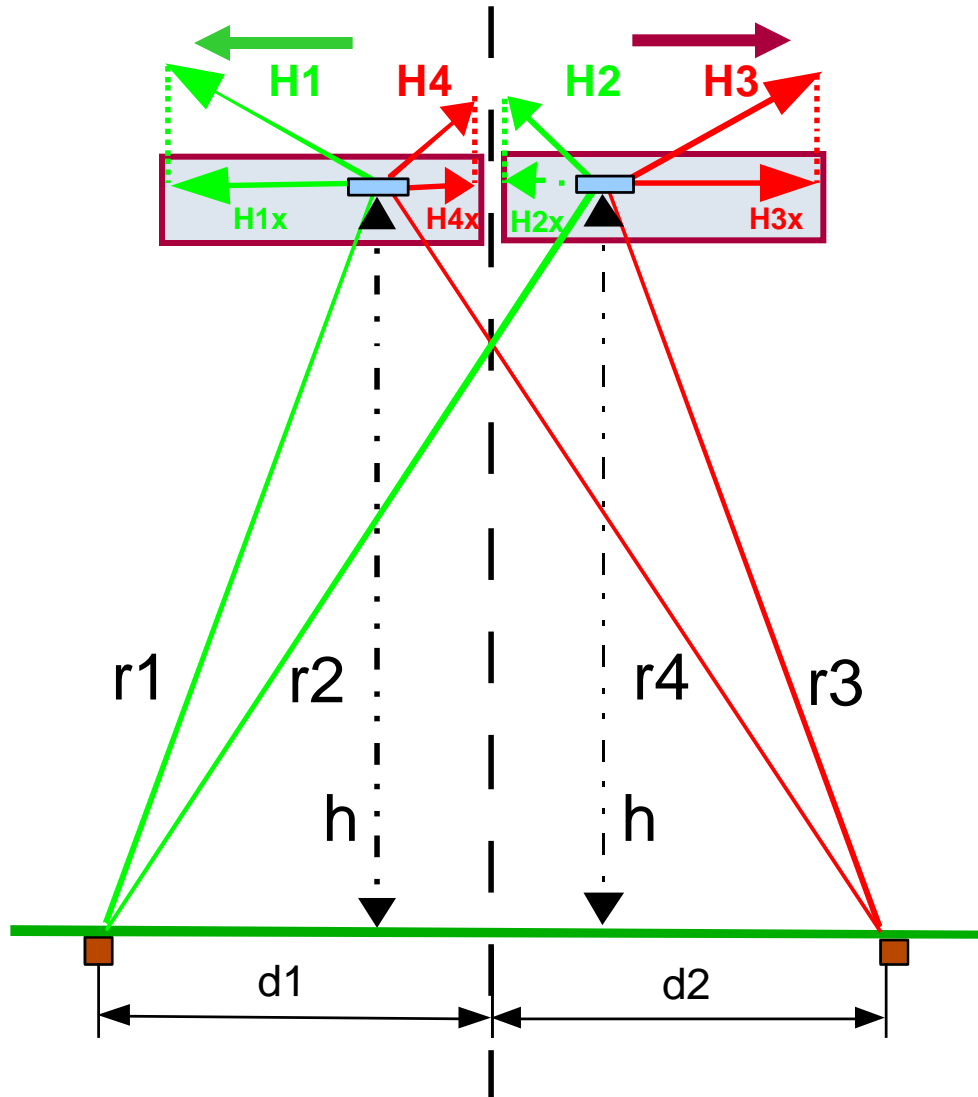


- In case of an U-shaped current line, each half of the Wheatstone Bridge does not only see a magnetic field component from the closest current line...



# Technical Base

## Principle of operation (2c)



- ....but also from the opposite branch

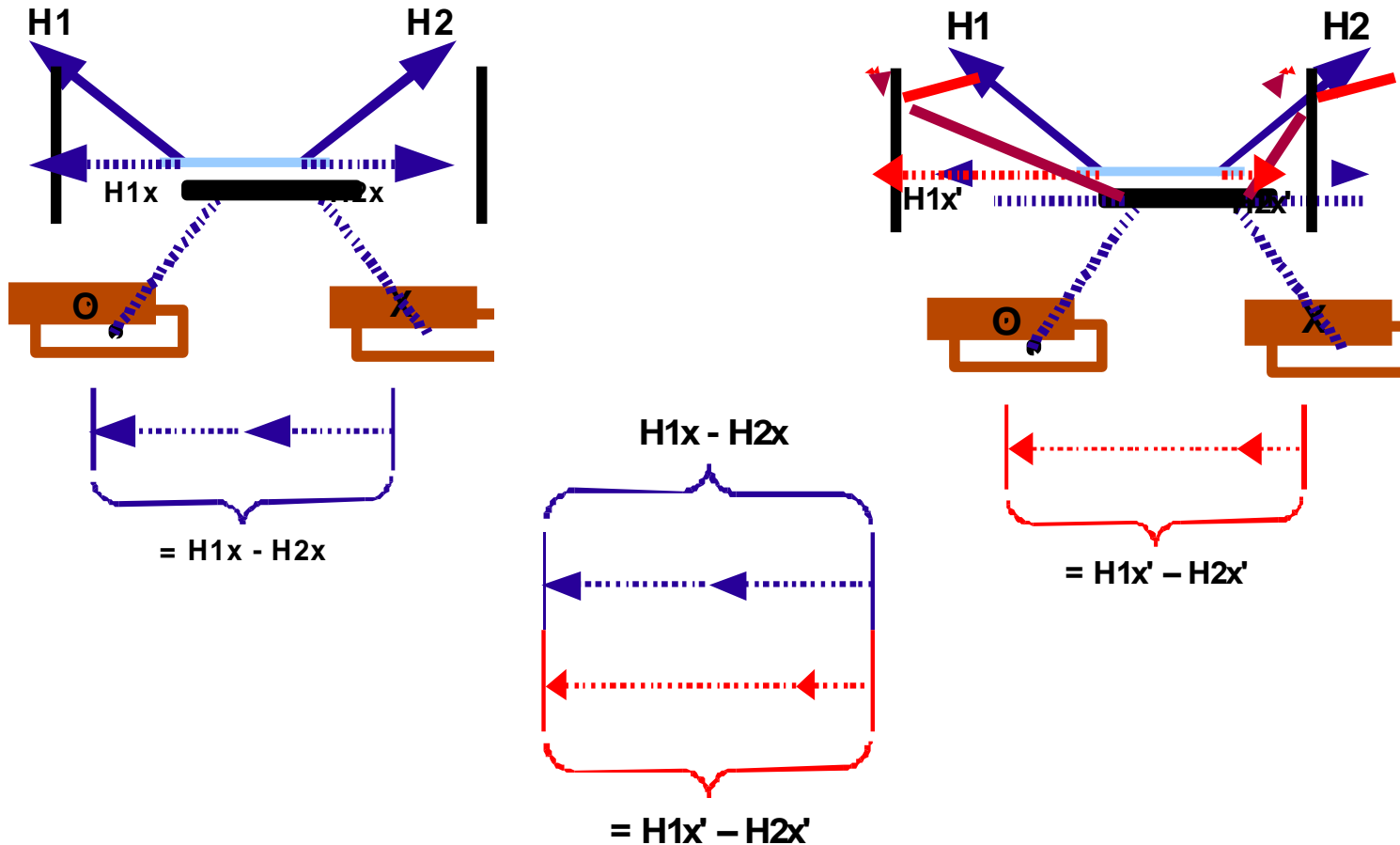
- The difference between the resulting Hx- components generates the bridge signal

- Target:

1400 ... 1600 A/m/mm difference field

# Technical Base

## Stray Field Immunity



- Measurement of the horizontal component of the differential field eliminates the influence of stray fields.

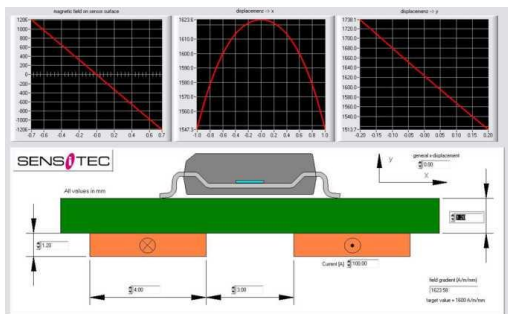
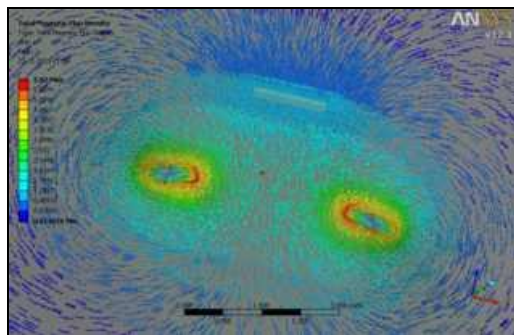
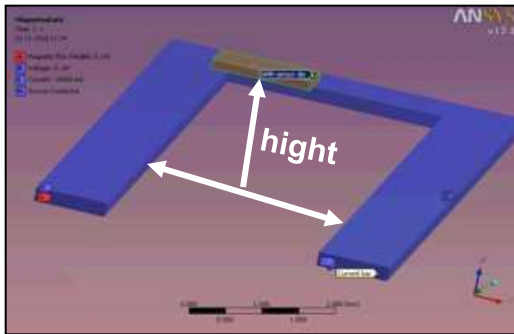
# Integrated AMR Current Sensor (IACS)

## Content

- Motivation
- IACS System Concept
- Technical Base
- **A Wide Range of Applications**
- Target Performance
- Application Example
- Summary

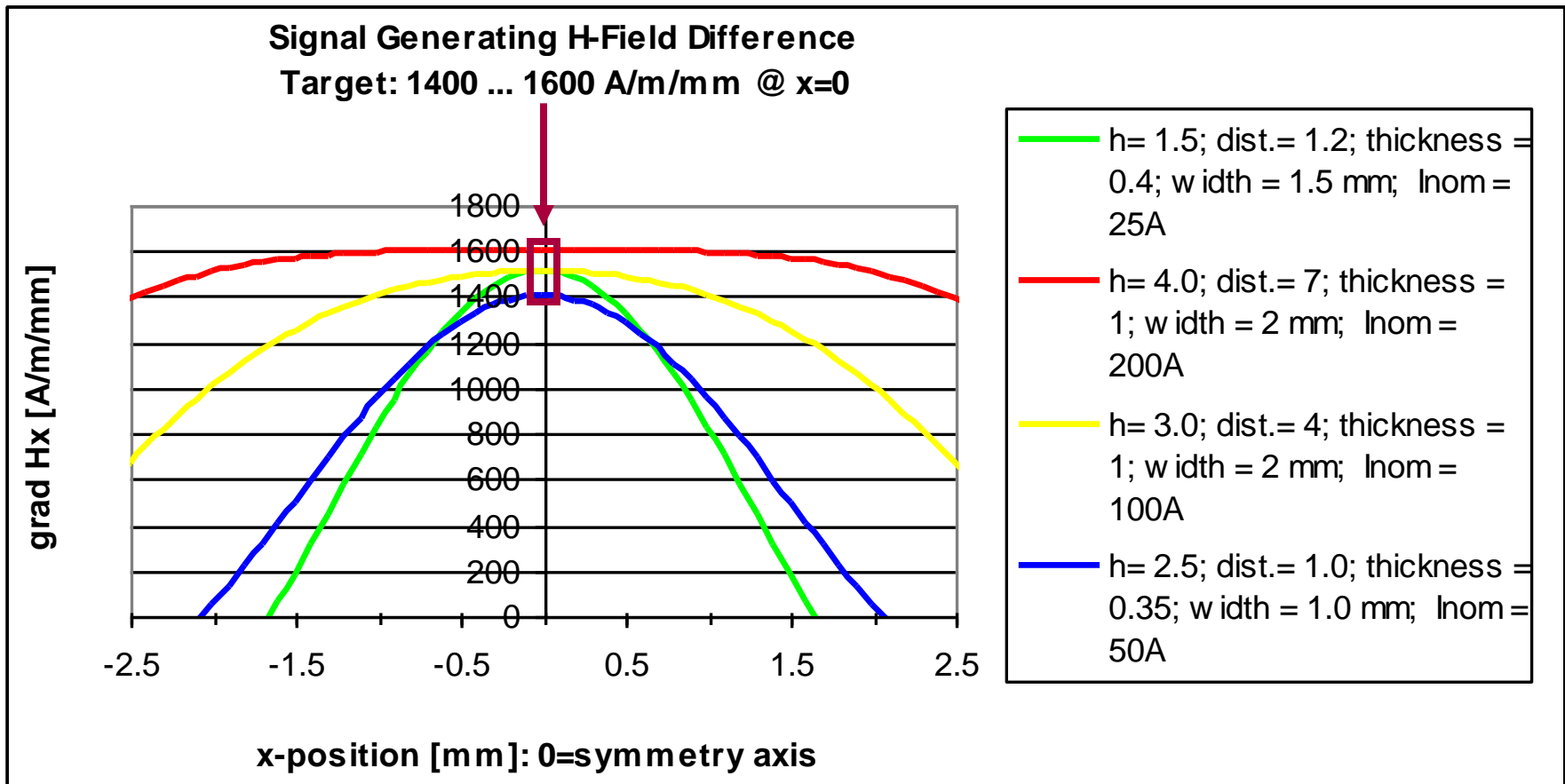
# A Wide Range of Applications

## Prim. Current Bar Design



- Starting point of the current bar geometric design comes from basic calculations:
  - Distance between the current bars
  - Vertical distance (height) of the current bar plane to the AMR sensitive structure within the IACS
  
- 3 - D simulation of the magnetic field of the U-shaped primary current bar delivers
  - static magnetic field strength
  - Time dependent current effects (up to a certain limit)
  - Influence of assembly deviations
  
- Final current bar design for a certain application can be derived from FEA analysis results

# A Wide Range of Applications



green: 25A

blue: 50A

yellow: 100A

red: 200A

**All current ranges can be measured with just one product by changing the geometry of the primary current line!**

# Integrated AMR Current Sensor (IACS)

## Content

- Motivation
- IACS System Concept
- Technical Base
- A Wide Range of Applications
- **Target Performance**
- Application Example
- Summary

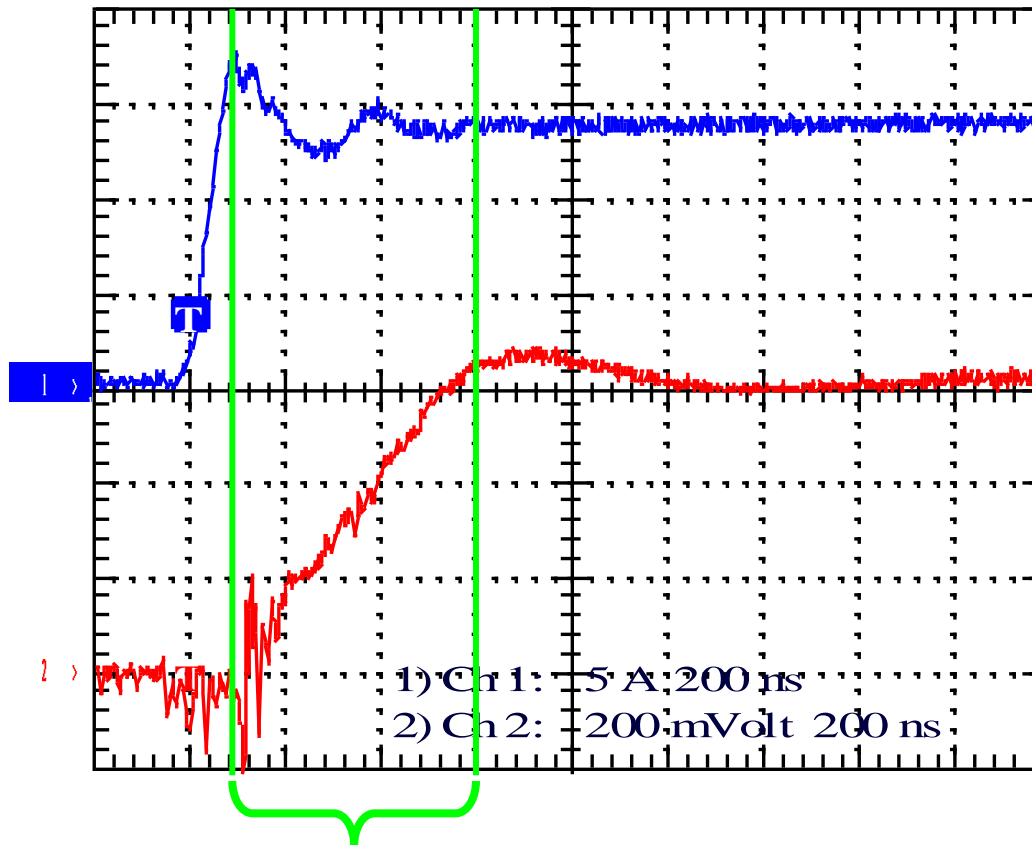
# Performance Comparison Current Sensors (Hall vs. AMR)

Parameter	Competitor 1 Hall-based	Competitor 2 Hall-based	Competitor 3 Hall-based	Competitor 4 Hall-based	Sensitec & ELMOS IACS 524.50 AMR
Nominal input (peak input)	± 200mT	± 25A (± 75A)	± 3.3mT	± 20mT	± 1.25mT (± 3.75mT)
Nom. Output(Peak)	± 2.0V	± 0.7V (± 2.1V)	± 2.0V	± 2.0V	± 2mA (± 6mA)
Sensitivity	10 mV /mT	28 mV/A	600 mV/mT	100 mV/mT	0.9 mA/mT
Stray field immune	no	no	no	no	yes
Bandwidth / response time	50kHz / 7µs	120kHz / 4µs	105kHz / 5µs	100kHz / 8µs	500kHz / <1µs
Output noise (@BW)	1.3 mVrms (50kHz)	typ. 1 mVrms (120kHz)	4.7 mVrms (100kHz)	4.0mVrms (100kHz)	2.0 µArms (200kHz)
Sig,Nom / Nrms	1500	2000	425	500	1000
Offset in Temp (% Nominal)	n.a.	± 2.6%	± 1.25%	± 2.5%	± 0.75%
Sensitivity drift (in Temp)	< ±2.5%	< ± 2.8%	< ± 3.5%	< ± 7%	< ± 1.0%
Linearity error (% Nominal)	< ±3.0%	< ± 0.75%	< ± 1.5%	< ± 1.0%	<± 0.3% @ OUTn <± 1.5% @ OUTpk

Operating Temperature (all devices): -40 ... +125°C

# Performance A-Samples

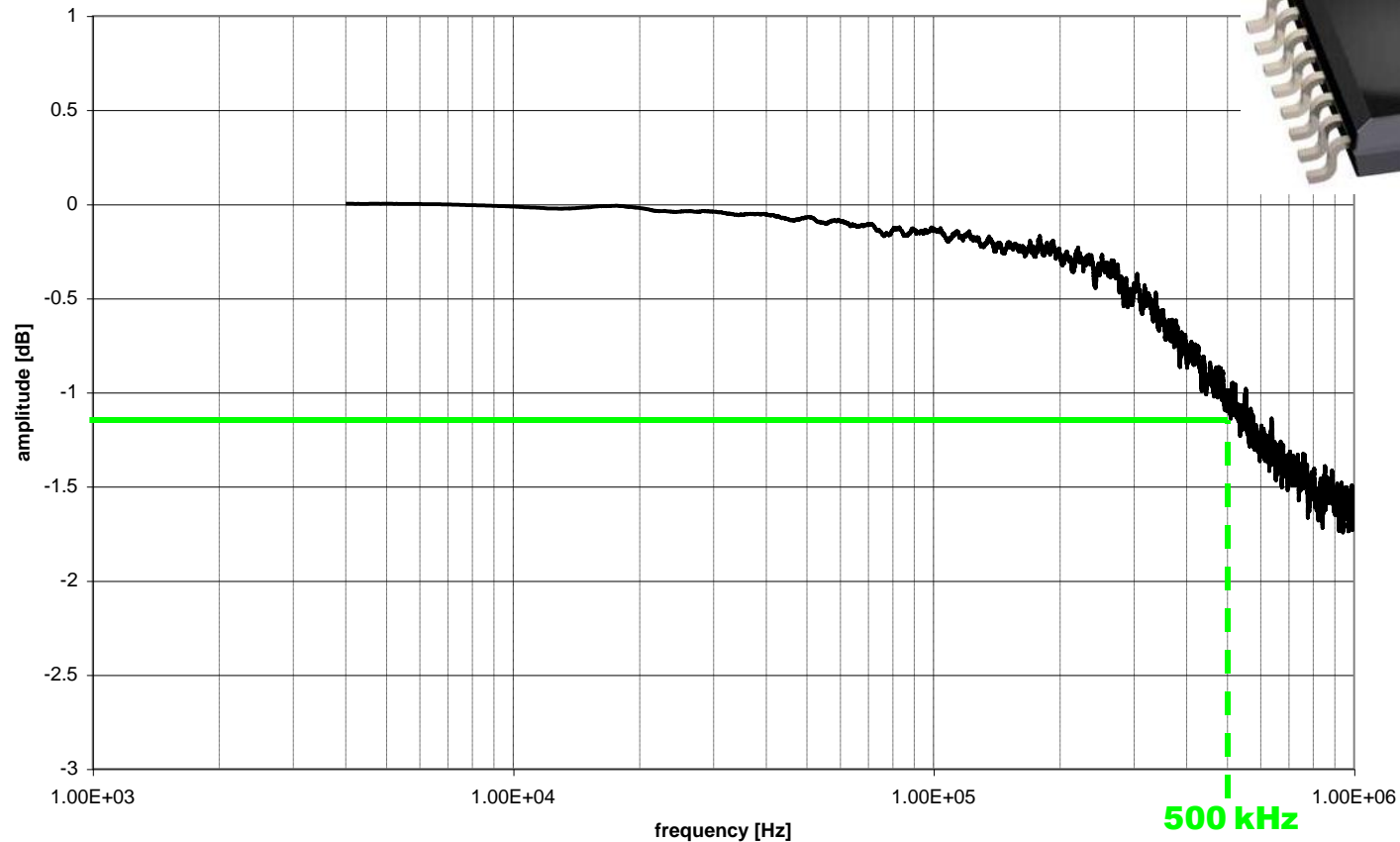
## Current Step Response



Rise Time < 600ns

# Performance A-Samples

## Bandwidth



3dB corner frequency: >500kHz

# Integrated AMR Current Sensor (IACS)

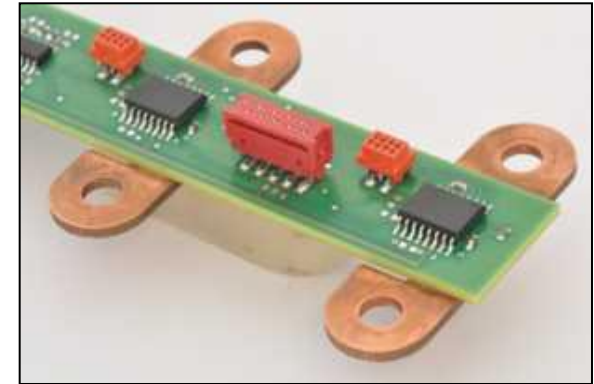
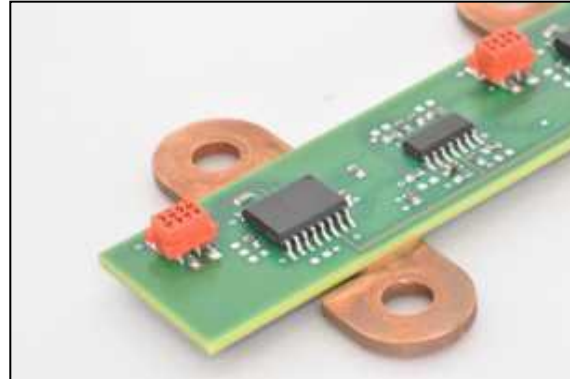
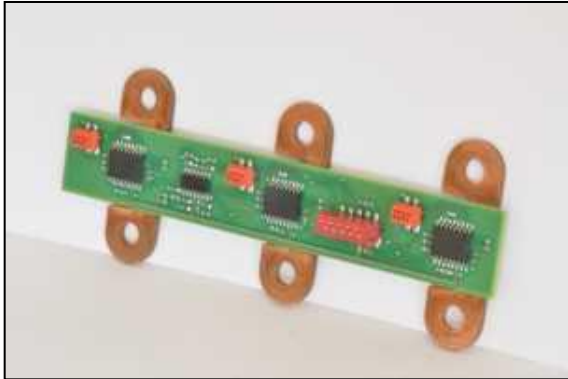
## Content

- Motivation
- IACS System Concept
- Technical Base
- A Wide Range of Applications
- Target Performance
- **Application Example**
- Summary

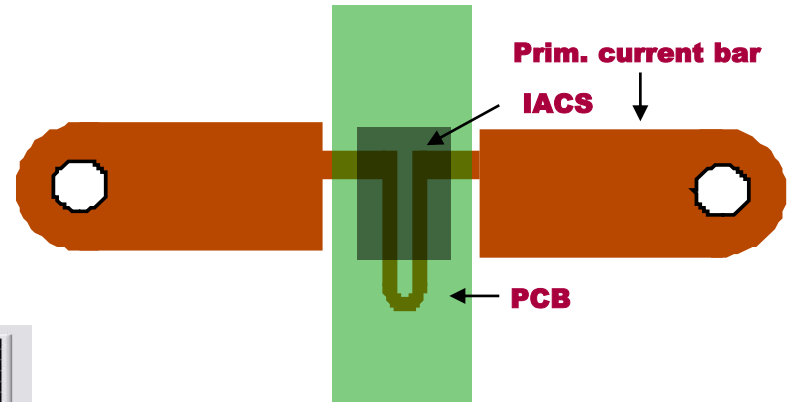
# Application example

## 524.50: Integrated AMR Current Sensor (IACS)

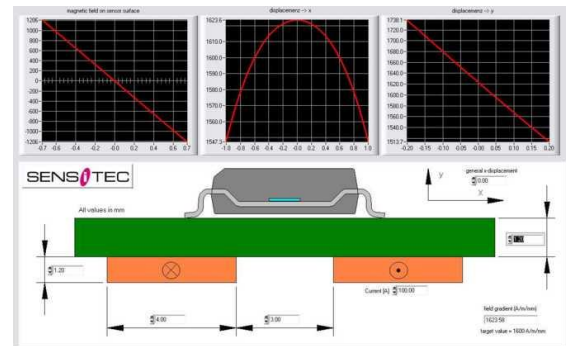
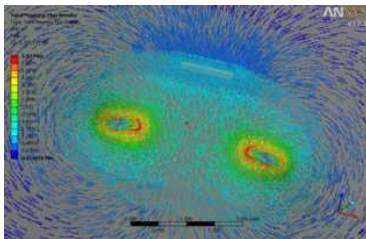
### 3 Phase module for customer evaluation



- 200 A current measurement
- No galvanic coupling
- Standard SMT mounting and reflow soldering on PCB
- Simulation Tool available for customer PCB design



Typical design of a current bar on backside of PCB



# Integrated AMR Current Sensor (IACS)

## Content

- Motivation
- IACS System Concept
- Technical Base
- A Wide Range of Applications
- Target Performance
- Application Example
- **Summary**

## IACS current sensor:

- Measures current via H-field using AMR-effect (contactless)
- Results in excellent figures of accuracy & resolution
- Immune to magnetic stray fields
- Adjustable over current detection integrated
- Very fast current sensing possible due to optimized architecture for high bandwidth
- Full integration in standard SO16 package (SMD)
- One product for all applications
- B-Samples available July/ 2011 / PPAP, SOP Q4/2012



**Thank you very much for your attention!**

## ELMOS Semiconductor AG

Heinrich-Hertz-Str. 1 | 44227 Dortmund | Germany  
Telefon: + 49 231 75 49 0 | Telefax: + 49 231 75 49 0  
info@elmos.de | www.elmos.de

### DISCLAIMER

This presentation contains forward-looking statements based on beliefs of ELMOS' management. Such statements reflect the company's current views with respect to future events and are subject to risks and uncertainties. Many factors could cause the actual results to be materially different, including, among others, changes in general economic and business conditions, changes in currency exchange rates and interest rates, introduction of competing products, lack of acceptance of new products or services and changes in business strategy. Actual results may vary materially from those projected here. ELMOS does not intend or assume any obligation to update these forward-looking statements.