GMR sensors in automotive application

Performance of GMR-elements in sensors for automotive application

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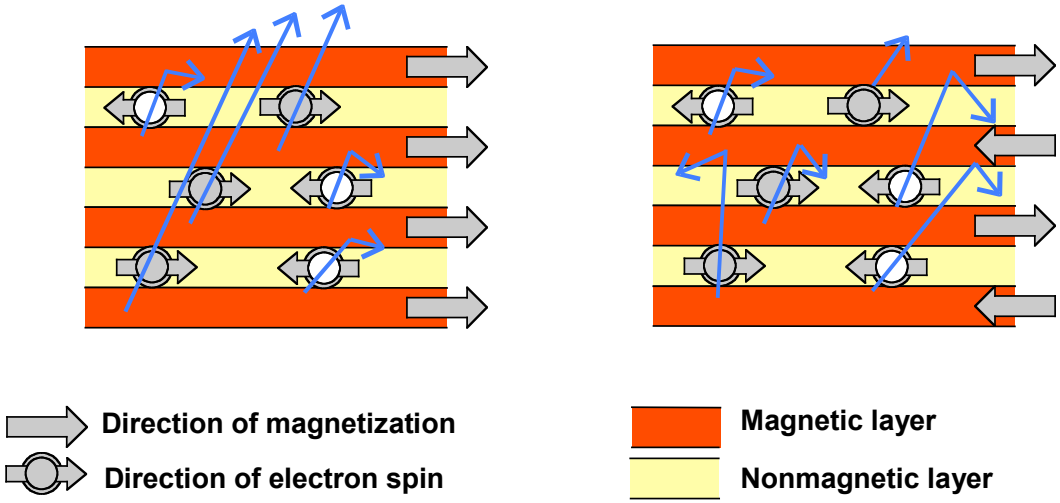
- Introduction to GMR
- Multilayer / Spin-Valve structures
- GMR-ASIC
- Magnetic simulations
- Automotive application requirements
- GMR performance in automotive application
- Comparison of GMR / AMR / HALL technologies

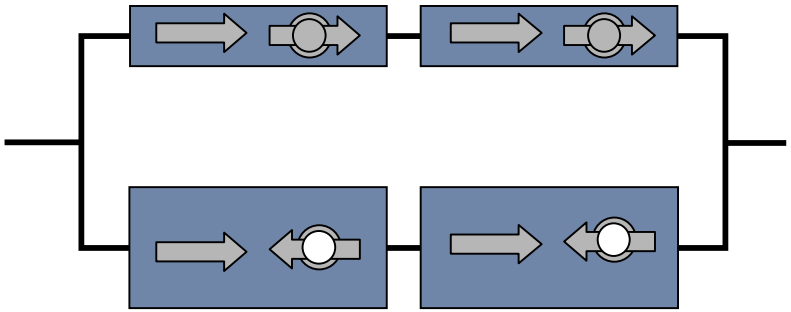
GMR effect



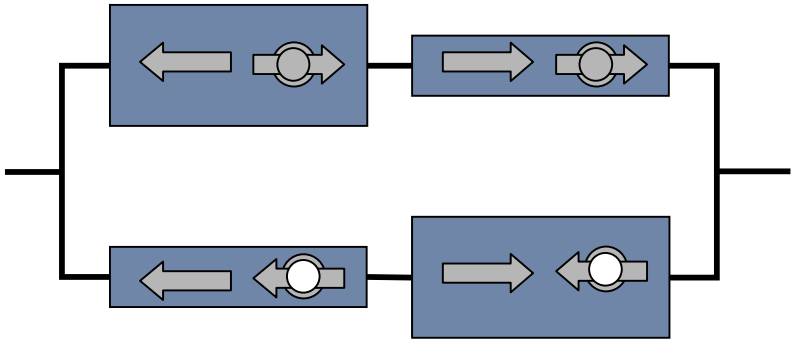
- Stack of ferromagnetic and nonmagnetic layers
- Scattering of electrons at interfaces with unmatched band structures
- Parallel alignment of ferromagnetic layers leads to scattering of electrons of only one spin direction
- Anti parallel aligned stacks lead to scattering of all electrons

Mott's model

Minimal resistance

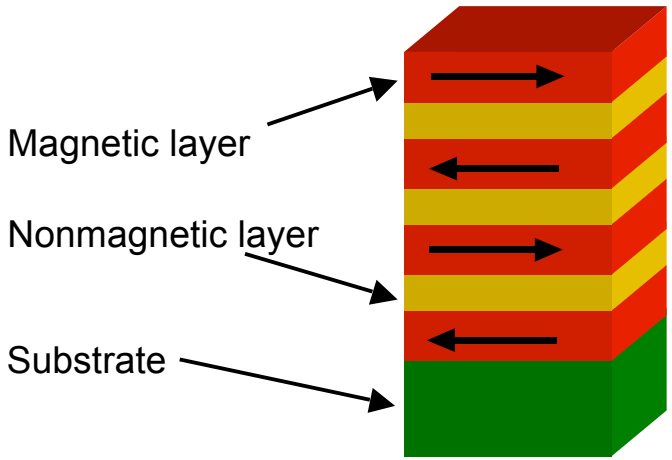


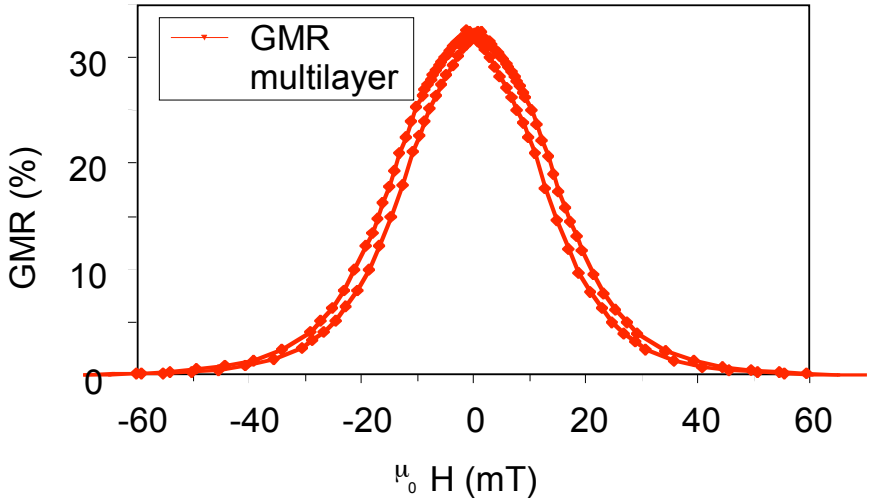
Maximum resistance



- Two path equivalent model is applicable
- Parallel magnetization results in minimal resistance (left)
- Anti parallel magnetization results in maximum resistance (right)

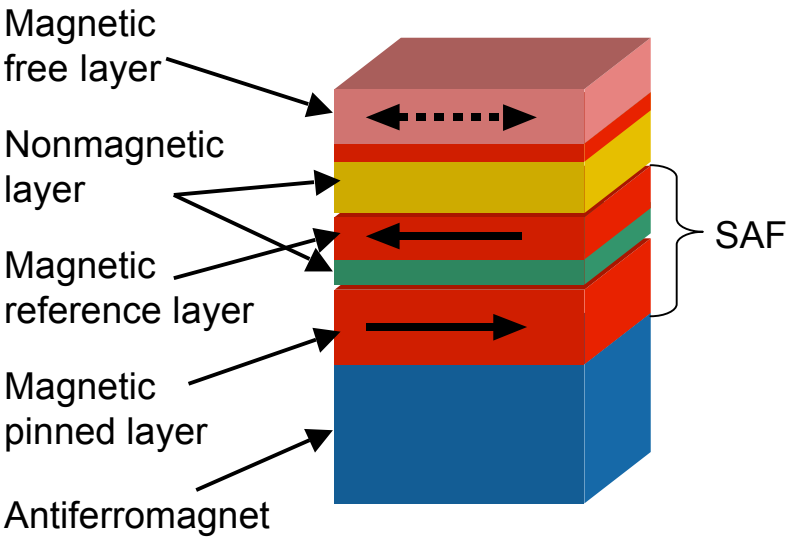
Multilayer structure

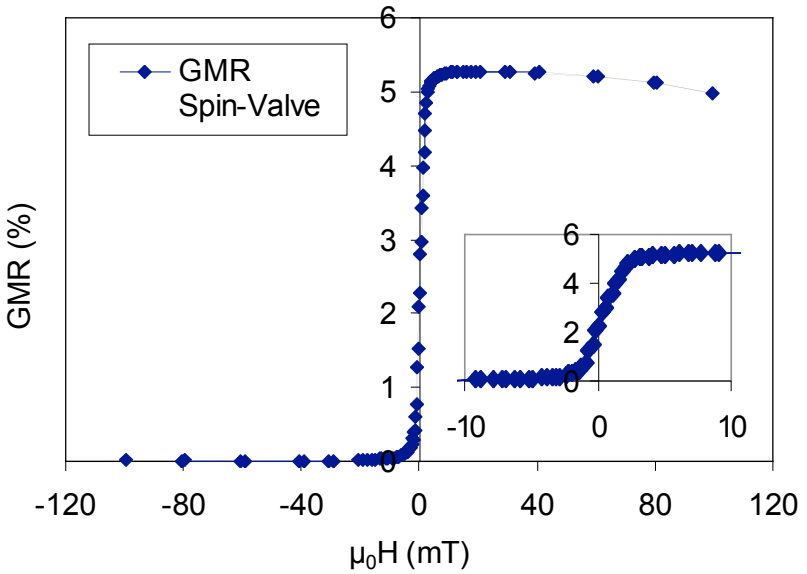




- Simple layer structure: alternating magnetic and nonmagnetic layers
- High magneto resistive effect / high sensitivity at operation point
- High stability against perturbing magnetic fields
- Application: speed sensors, position sensors, current measurement

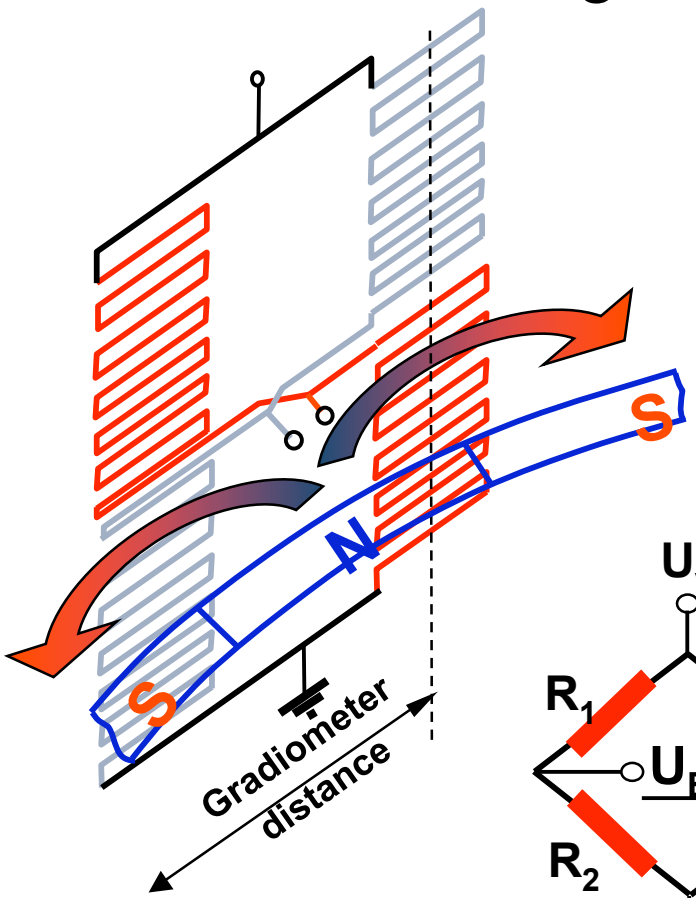
Spin-Valve structure

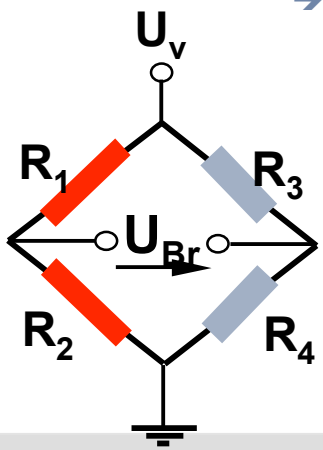


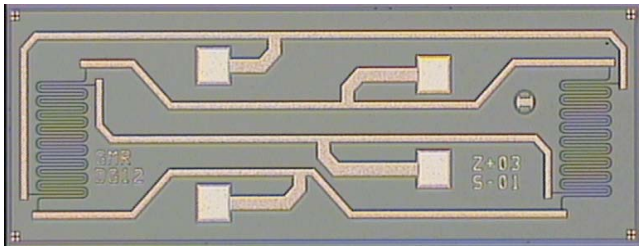


- Two ferromagnetic layers separated by a nonmagnetic metal
- High sensitivity
- High structure stability up to 100 mT
- Negligible hysteresis
- Application: speed sensors, current measurement, field angel sensors

GMR sensor bridge for incremental speed sensors

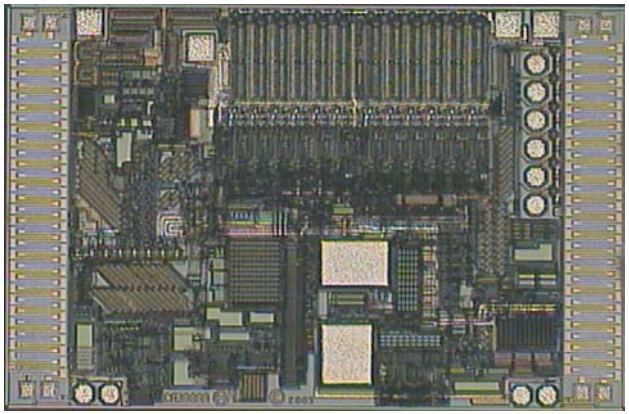




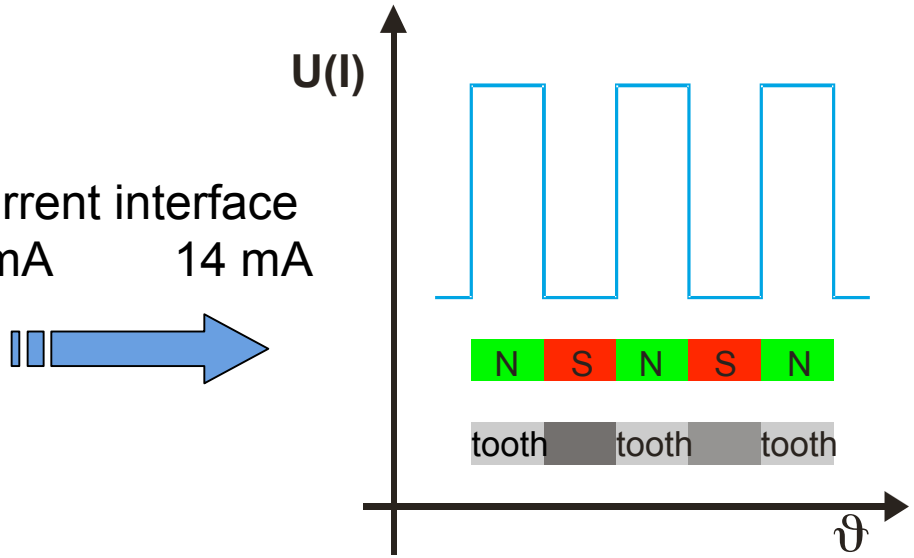


- GMR multilayer sensor bridge for a discrete sensor
- Four resistors of a Wheatstone bridge arranged in a gradiometer geometry:
  - Linear characteristic curve
  - Temperature compensation
  - Suppression of homogenous perturbing fields

Integrated GMR sensor

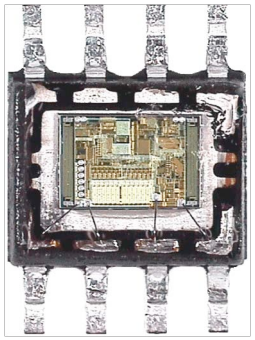


Current interface
7 mA 14 mA



- Depositing of GMR layers on processed ASIC
- Robust handling and smaller outline
- GMR-ASIC with tunable offset, hysteresis, slew rate and current level

Integrated GMR sensor



- Samples of integrated GMR speed sensors packaged in

SOIC8 **PSSO4** **Premold**

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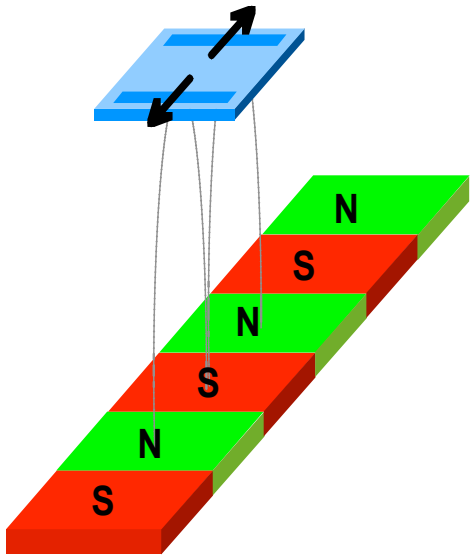
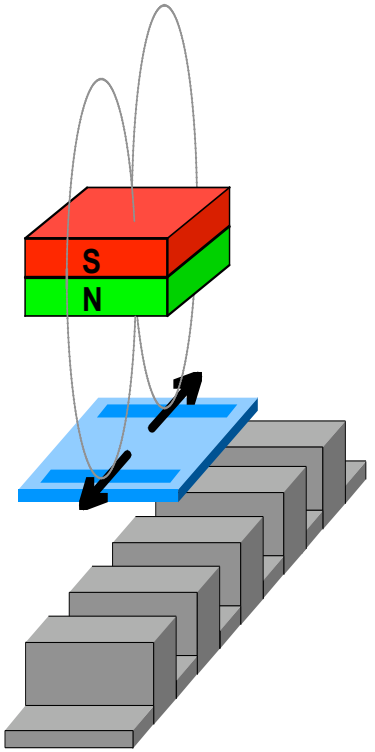
Magnetic stimulation

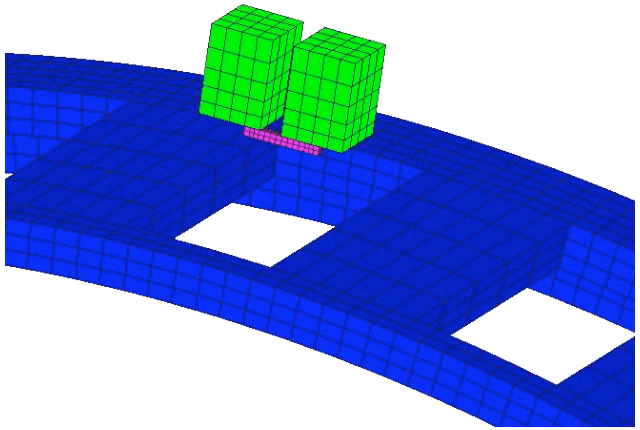


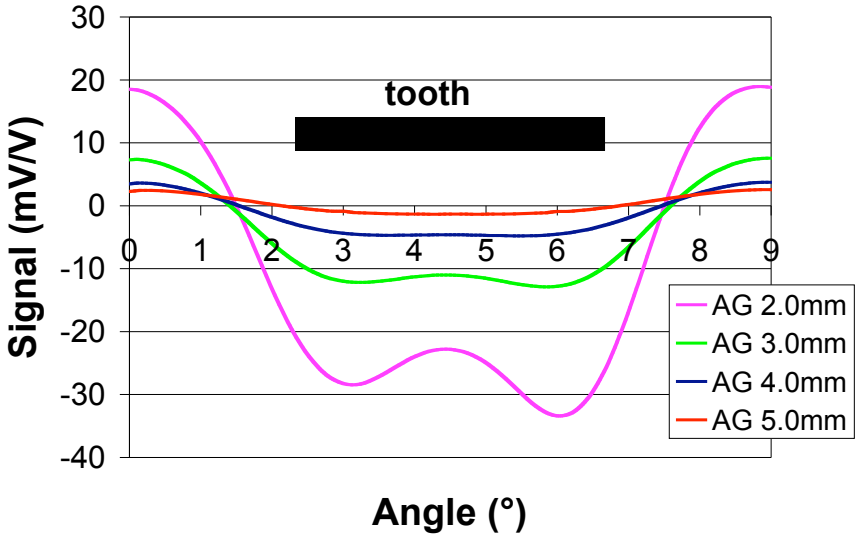
- Magnetic tone wheel
- Alternating magnetization



- Steel tone wheel
- Toothed or perforated

Magnetic simulations





- BEM-FEM simulations for steel wheel application with back bias magnet
- Modeling of magnet in order to optimize sensor signal for application

Automotive application requirements for speed sensors

Application	*Air gap [mm]*	*Frequency [kHz]*	*Temperature [°C]*
Wheel speed	0 ... 3.5	0 ... 4.5	-40 ... 150
Crankshaft	0 ... 3.5	0 ... 10	-40 ... 150
Transmission	0 ... 5.5	0 ... 12	-40 ... 150

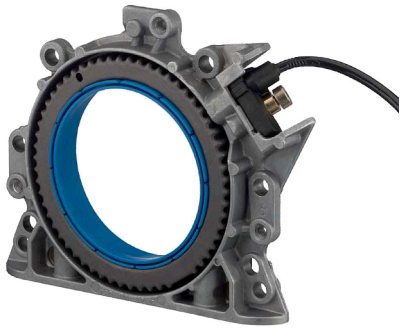
Automotive application requirements

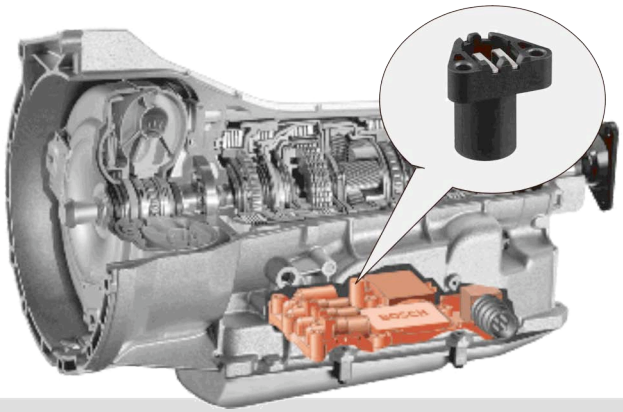
Wheel speed sensors

- Air gap
- Duty cycle
- Jitter
- Magnetic and steel tone wheels

Speed sensors in motor application (crankshaft)

- Magnetic and steel tone wheels
- 360° repeatability
- Low phase drift
- Air gap





Rotational speed sensors in transmission

- Air gap
- Jitter
- Duty cycle
- Mostly steel tone wheels

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Performance of GMR-elements

Air gap	*GMR-SV*	*GMR-ML*	*HALL*	*AMR*
Wheel speed sensor (-40°C, 25°C, 170°C)*	8 mm	7 mm	4.5 mm	/
Speed sensor: Crankshaft (-40°C, 25°C, 170°C)*	7 mm	5.5 mm	3.5 mm	2.8 mm
Rotational speed sensor: Transmission (25°C)*	9 mm	8 mm	5.1 mm	/

*Acceptable duty cycles and jitter were considered for each application and air gap measurement

Summary of competitive sensor technologies

Air gap	*GMR*	*AMR*	*HALL*	*VR* *(variable reluctance)*
Sensitivity	++	+	O	Speed dependent
Jitter	++	+	-	/
Temperature stability	++	+	-	-
Linear working range	O	-	++	++
Module size	+	O	++	-
Power consumption	++	O	++	Speed dependent
Costs	+	O	++	O
Large scale production	No automotive	Yes	Yes	Yes

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Performance of GMR-elements in sensors
for automotive application

Thank you for your attention



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