



A Verilog-A implementation of a model for spin-valve based current sensors



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Introduction

In this work we propose a DC electrical model for spin-valve based GMR (Giant-MagnetoResistance) current sensors. The model has been developed making use of experimental results. The model has been implemented in Verilog-A and used in simulations of characteristic instrumentation circuits.

With this approach we are able to model non-linear devices even in the high driven current regime up to 10A with commercial magnetic current sensors. In addition, we reproduce the output voltage offset in Wheatstone bridge circuits based on these devices. Consequently, by using these sensors, the power consumption of a circuit can be monitored in the range of 100µW to 1W.

Three types of GMR sensors are available [1, 2]:

- AMR (Anisotropic magnetoresistance) permalloy based sensors.
 - SV (Spin Valves) - High Sensitivity
 - MTJ (Magnetic Tunnel Junctions) - High Level of integration
- Possibility of measurement of in-plane magnetic fields

Advantages

GMR sensor internal structure

Spin Valve (SV)

$$\Delta V = \frac{1}{2} \frac{\Delta R}{R_0} \frac{I_0}{I} (V_0 \cos \theta - R_0)$$

Contras	• Size (>500µm ²) • MR level (~10%)
Pros	• Linear range • Impedance

Magnetic Tunnel Junction (MTJ)

$$\Delta V = (1/2) \frac{\Delta R}{R_0} \frac{I_0}{I} (V_0 \cos \theta - R_0)$$

Contras	• Linear range • Impedance
Pros	• Size (<50µm ²) • MR level (>150%)

Non-linear Magnetoresistance Modeling [3]

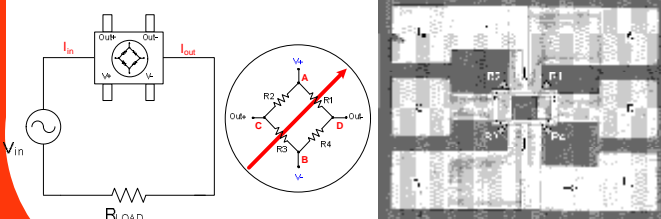
$$R(I) = R_0 + f(B) \rightarrow R = R_0 + f(I)$$

$$R(I) = R_0 + MR_1 \cdot I + MR_2 \cdot I^2 + MR_3 \cdot I^3$$

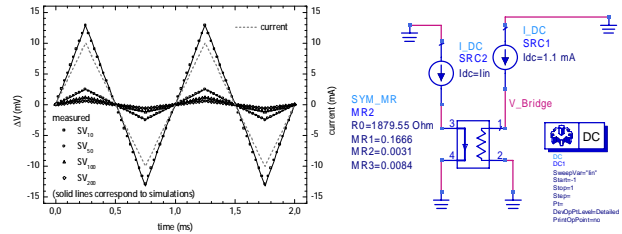
	R_0 (Ω)	MR_1 (Ω/A)	MR_2 (Ω/A ²)	MR_3 (Ω/A ³)
R_1	1870.41	-1.06	0.0055	-0.0088
R_2	1879.55	0.1666	0.0031	0.0084
R_3	1861.31	1.24	0.0065	-0.0088
R_4	1847.32	0.0051	0.00719	0.0083

Wheatstone Bridge Scheme

MR sensors can be arranged in a four elements bridge configuration, due to its inherent linearity and the expected null output in the absence of magnetic field.

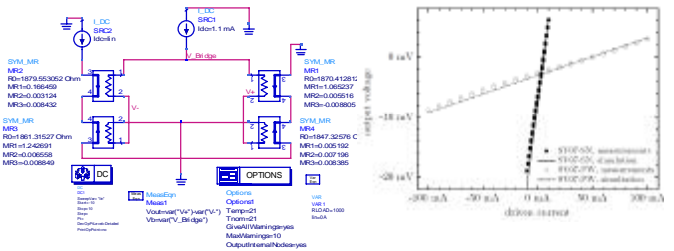


Circuit Simulations with Magnetoresistances

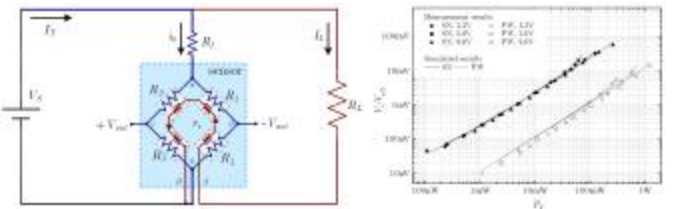


Circuit Simulations with Wheatstone Bridge

- Wheatstone bridges can be used as analog multipliers.
- MR Wheatstone based sensor is biased by a signal whose value is proportional to the voltage of the measured signal.
- A current proportional to the current of the measured signal is led through a current strap, which generates a magnetic field that influences the Wheatstone bridge.



Electrical power measurement circuitual scheme



Conclusions

- Verilog-A has been successfully used as behavioural modeling language for MR based current sensors.
- A DC model has been developed and validated by considering experimental measurements in the useful current range of operation.
- Circuit applications have been studied making use of the model developed for the MR current sensors with success.

References

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