Introduction

We propose the use of GMR sensors in direct power measurement applications at the integrated circuit level by taking advantage of their multiplicative properties. A simple circuit is simulated in depth showing promising results regarding the application range.

An analytical compact model for Giant MagnetoResistance (GMR) based current sensors implemented in Verilog-A was used for the first time. Different spin-valve based full Wheatstone bridge sensors with the current straps (serial, parallel, wide and narrow) integrated in the chip have been considered.

A remarkable matching between measured and simulated results is observed. A power range from 100 µW to 1 W can be covered. Within this range the device response is close to linearity. The driven currents are maintained at levels where self-heating effects are unappreciable.

GMR sensor internal structure

Three types of MR sensors are available [1]:

- 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

<table>
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<tr>
<th>Spin Valve (SV)</th>
<th>Magnetic Tunnel Junction (MTJ)</th>
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<tr>
<td>Size (&gt;600 µm)</td>
<td>Size (&gt;50 µm)</td>
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<tr>
<td>MR level (~10%)</td>
<td>MR level (~150%)</td>
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</table>

Magnetoresistance Bi-port Circuit Model [2]

\[
R(I) = R_s + f(B) \rightarrow R = R_s + f(I)
\]

\[
R(I) = R_s + MR + I + MR^2 + MR^3 + I^2
\]

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. SERIAL (i) and PARALLEL (ii) current straps have been fabricated and modeled.

Simulations with Wheatstone Bridge Power Meter [3]

- 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 a 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

\[
V_o = MR \frac{R_L}{R_s} + r_L + \left( V_L - I_L \right) R_s R_L + R_C \frac{R_L}{R_s}
\]

References


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