

Characterizing MEMS Magneto-Impedance Sensors Using Agilent 4294A and E4991A Impedance Analyzers

- Application Note
- ▶ Excellent accuracy and repeatability
 - ▶ Easy evaluation of Magneto-Impedance characteristics
 - ▶ A wide variety of design-automation tools and functions

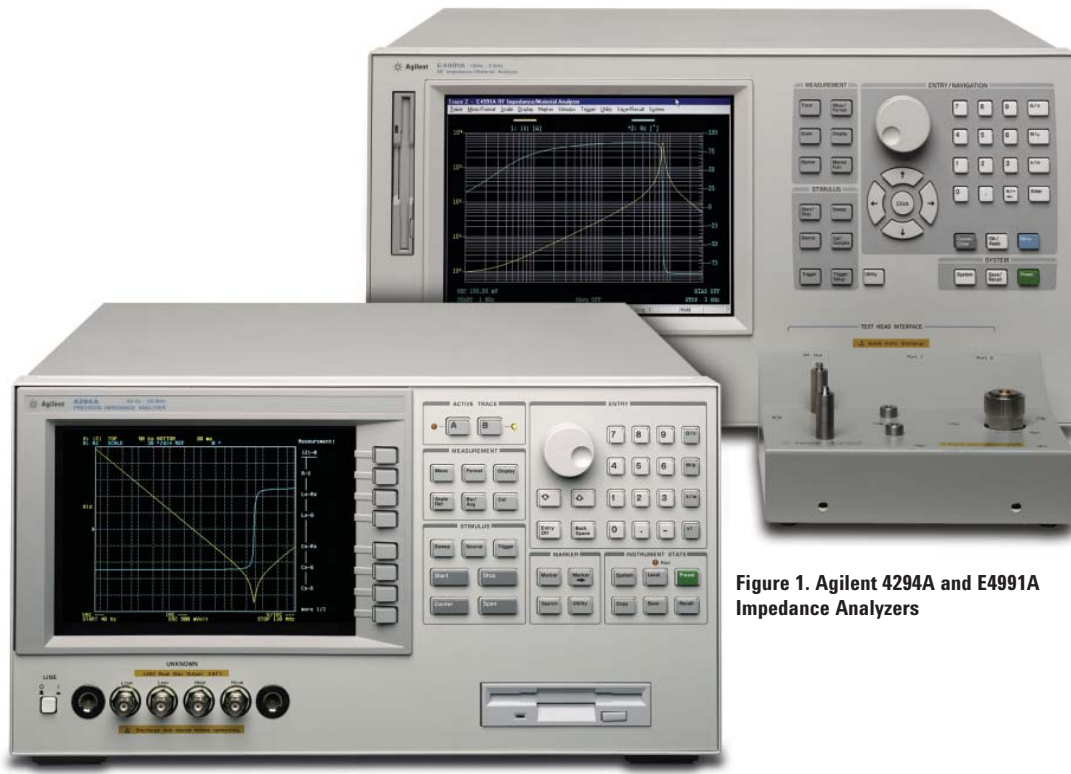


Figure 1. Agilent 4294A and E4991A Impedance Analyzers



Introduction

This application brief describes the benefits of using Agilent impedance analyzers for device characterization of MEMS Magneto-Impedance (MI) sensors and how they improve design and test efficiency while offering a wide variety of design-automation tools and functions.

Agilent Impedance Analyzers

The 4294A covers the range of 40 Hz to 110 MHz and the E4991A, from 1 MHz to 3 GHz. These impedance analyzers (see Figure 1) offer excellent impedance measurement accuracy and are optimum tools for both design and manufacturing test of MEMS MI sensors.

MEMS MI Sensor

The MI sensor applies the principle of the MI effect. The impedance of the amorphous magnetic material changes depending on the external magnetic field when high frequency current is applied. Figure 2 shows the equation of this characteristic. High sensitive MI sensors are easily miniaturized into MEMS devices.

$$Z = \frac{a}{2\sqrt{2\rho}} R_{dc} (1 + j) \sqrt{\omega\mu (H_{ex})}$$

- Z: impedance of amorphous magnetic material
- a: diameter of amorphous magnetic material
- ρ : ratio resistance
- R_{dc} : DC resistance
- ω : angular frequency of current flow
- μ : circumference magnetic permeability
- H_{ex} : external magnetic field

Figure 2. Impedance calculation formula for amorphous magnetic materials

Evaluation of MI Characteristics of the Amorphous Magnetic Material

Evaluating the MI sensor's sensitivity is very important because its sensitivity depends on the impedance change of the amorphous magnetic material when high frequency is applied.

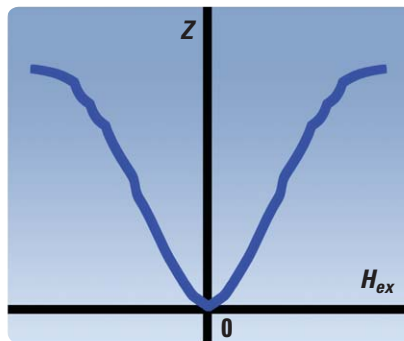


Figure 3. Impedance vs. Magnetic Field

For an MI sensor, the impedance is low at low frequencies and changes rapidly at high frequencies (Figure 4). The instrument's impedance accuracy with sufficient test frequency resolution is required to know the true performance of an MI sensor. Agilent impedance analyzers have frequency resolution up to 1 mHz, enabling them to follow rapid impedance changes. These impedance analyzers have advanced calibration and fixture compensation capabilities and offer excellent accuracy and repeatability by removing the instruments' systematic error and residual impedance of the test fixture used.

In addition, the Agilent impedance analyzers display frequency characteristics on their screens in real time, which helps users analyze the MI characteristics of the amorphous magnetic material quickly. (Figures 5 and 6)

A Wide Variety of Design-Automation Tools and Functions

Agilent impedance analyzers provide various design-automation tools and functions that increase test productivity. The built-in programming function allows users to customize the parameters to be evaluated and/or to build an automated test environment and customize it without an external PC. The data output functions corresponding to Touchstone (4294A) and CITI file (E4991A) formats enable much more advanced analysis using the external simulator, which improves the device design efficiency.

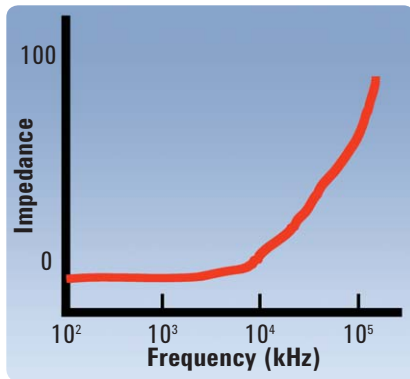


Figure 4. Magneto-Impedance frequency characteristic

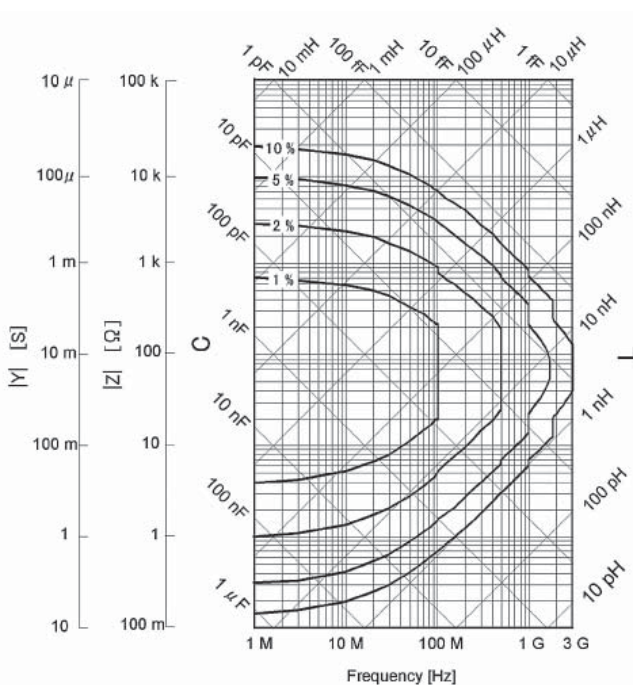


Figure 5. E4991A impedance measurement accuracy chart

Summary

The Agilent 4294A and E4991A Impedance Analyzers are ideal test instruments for characterizing MEMS MI sensors. These analyzers offer excellent accuracy and repeatability because of the advanced calibration function that removes instrument system measurement errors and residual impedance of the test fixture used. In addition, a wide variety of design-automation tools help designers improve the design productivity.

For more information, please refer to the following literature and websites:

- ▶ Agilent 4294A Technical Overview (P/N 5968-3808E)
- ▶ Agilent 4294A Data Sheet (P/N 5968-3809E)
- ▶ Agilent E4991A Technical Overview (P/N 5980-1234E)
- ▶ Agilent E4991A Data Sheet (P/N 5980-1233E)
- ▶ MEMS/NEMS Device Measurement Solution:
www.agilent.com/find/mems
- ▶ Agilent 4294A Precision Impedance Analyzer:
www.agilent.com/find/4294a
- ▶ Agilent E4991A Impedance/Material Analyzer
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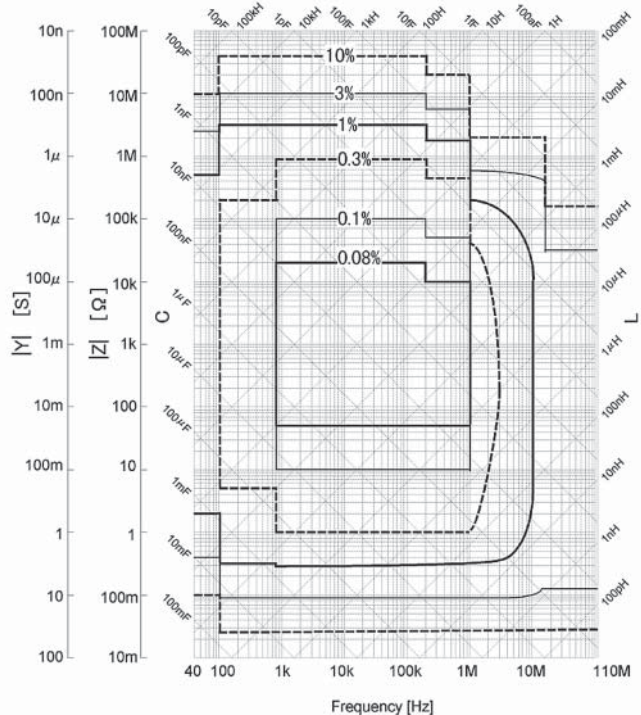


Figure 6. 4294A impedance measurement accuracy chart

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