Application Note

Continuous Real Time Field Control in Magnetic Measurement Systems

Introduction

In the R&D and production of magnetic materials, one of the most important goals is to have strict control over the field-related properties of magnetic materials. Sometimes a change of a few percent in the coercive field of a material will make the material useless. For some materials, the coercivity is measured in mOe.

To get the best measurements on this type of materials, having a system with real-time field control is highly beneficial. This is the reason why most companies and research labs working on materials with critical field requirements rely on MicroSense magnetic measurement systems with Real Time Field Control for both research measurement systems and production quality control systems. MicroSense VSM systems offer field noise that is at least 10 times lower than our most common competitors. The field resolution is 50 times better than some Helmholtz coil based VSM systems and 60 times better than some super conducting magnet based VSMs.

Field Control

What is Real Time Field Control and what makes it so special? Most magnetic measurement systems use an electro- magnet to apply fields. This electromagnet typically consists of a pair of coils, a yoke and a pair of poles. Both the yoke and the poles are made of magnet iron or a magnetic alloy that inherently behaves non-linearly. The current vs. field curve is not a straight line and it shows hysteresis. What may be even worse is that the field at a certain current is not constant; it changes with time as domain walls in the pole tips move and eddy currents die out in the first few seconds and minutes after changing the magnet current. So, to correct for this, a field control system is needed. To explain the advantages of the real-time field control, it helps to first understand how systems traditionally tried to solve this problem.

The traditional, non real-time, part-time field control

Traditionally, measurement systems such as VSMs often used an indirect form of field control. When the user (or the program that runs the magnetic measurement) wants to set a field, the sub-routine that controls the field will first program a current (which may have been obtained from a lookup or calibration table or such) from the magnet power supply. After this, an iterative process starts of taking a field readings from the Gaussmeter and adjusting the magnet current until the field subroutine is satisfied with the achieved field and allows the user or the measurement to continue.

This was typically a slow process because of the lag in the communication between the Gaussmeter and the response of the power supply. What is even worse is that once the field subroutine is satisfied and allows the software to take its measurement reading, the field is still not constant. It may still change by several Oersted, due to slow magnetization or demagnetization processes taking place in the pole tips and magnet yoke. By the time the software takes it reading, the field may be different from what it was intended to be and a signal reading will be taken at a field that differs from the field that is reported to the user. This can lead to significant measurement inaccuracies. This problem is potentially even worse when remanence measurements are done, where it is very important that the remanence reading is taken at exactly zero field. If this type of field control sets the field to zero and then stops controlling the field, the field will slowly overshoot beyond zero and reduce the accuracy of the remanence measurement.

DSP based systems

Nowadays many systems have moved the field control from the PC to a DSP inside the field control unit. This is much faster and full time (it doesn't stop controlling the field after the target field has been reached) but it is still an iterative process with some lag in the response and for example 30 updates per second. Possibly more problematic is that in order to use a DSP, the field readings and current setting at some point must be digitized. If one would want a system that regulates the field with a resolution of 1 mOe with a maximum field of 20 kOe, one would need a true resolution of 24 bits in the AD conversion and in the DA conversion. While 24 bit AD converters exist, these converters are typically not linear enough to accomplish true 24 bit linearity. Furthermore in this type of processing a large amount of noise is introduced. While most of our competitors do not specify the field noise in their systems, based on other information they provide we know that the minimum field noise in their systems is at least 0.5 Oe peak to peak, some 20 times higher than what is offered in MicroSense systems.

Fulltime, real-time field control

The field control that is used in MicroSense measurement systems works completely differently from what is described above. The field control in MicroSense systems is not managed by a subroutine that resides in the PC running the measurements or in the software of a DSP. Instead, a dedicated piece of hardware has been developed that has only one task: controlling the field. This field control is part of an electronic control loop that continuously adjusts the field to maintain the field to the set point. Because this is dedicated analog hardware, the field control is fulltime. This means that if the remanence of the pole tip slowly changes, the field control unit immediately detects it and continuously makes minute changes in the magnet current to correct for the change. As a result, the field is absolutely steady. Because the field values are never digitized, no quantization noise and similar phenomena are introduced in the process, the field noise in the MicroSense system is extremely low. The noise in the MicroSense VSM systems is essentially equal to the noise in the hall probe measuring the magnetic field.

So the magnetic material that is being measured experiences a field that is absolutely steady. If a remanence measurement point needs to be taken at zero field, one can be sure that the field where the point is taken is actually exactly zero and not at a value that has resulted from drifting away from zero (as a result in a change in the magnetization of the pole tips of the magnet).

This is not only of vital importance in the accurate determination of the coercive field, the remanent coercive field and pinning fields etc, but it is also very important in the exact determination of the remanent signal and in the accuracy of time decay measurements.

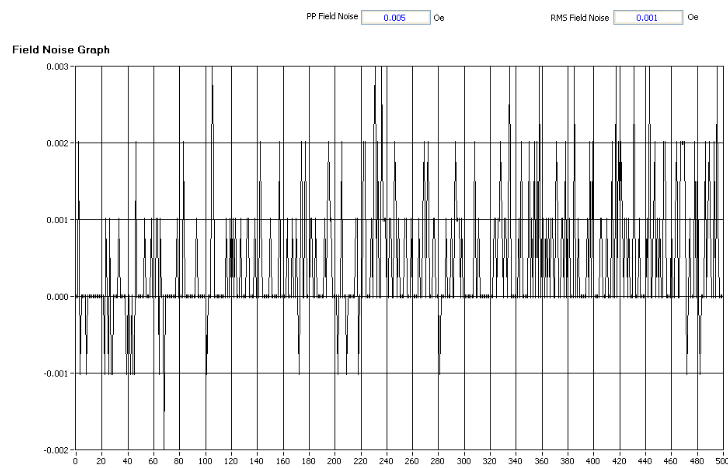

Figure 1. Typical measurement of the field noise in an EV7 VSM. The spec is 4 mOe RMS noise, which is easily met.

One added benefit is that the real-time field control is faster than many other field control systems. This allows a much more aggressive approach in setting a field, leading to much faster measurements. Users who have had a chance of comparing a system with real-time field control to systems using non real-time field control have consistently reported that the real-time systems are approximately 3 times faster.

Results obtained with a MicroSense EV7 VSM using real-time field control

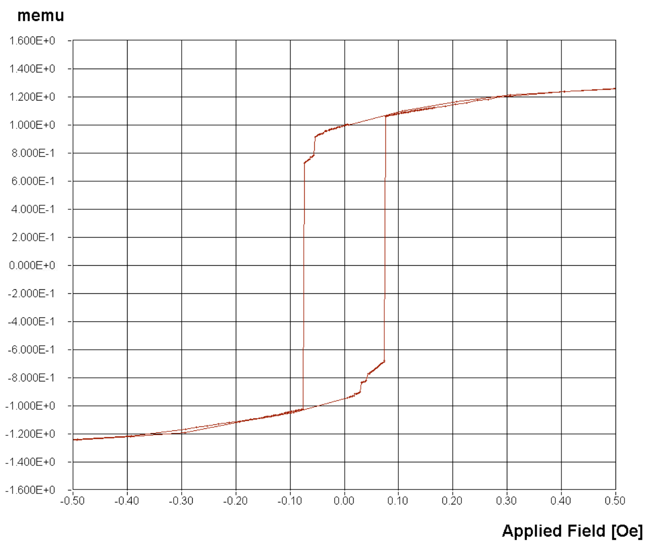

Figure 2. Measurement result on a 10 µm mirco-wire. The discrete steps in the loop are caused by Barkhausen jumps.In this measurement steps of 0.002 Oe (2 mOe) were used in the area around the coercivity..

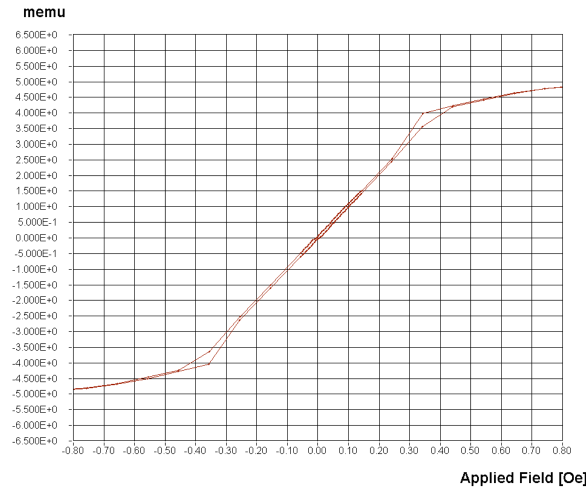

Figure 3. Measurement on a sample with a coercivity of 4 mOe. Thanks to the real-time field control system and the low system noise, the loop stays open, even though the horizontal separation is less than 10 mOe and the vertical separation is only 10 µemu.

In figure 2 we can see that the real-time direct field control system allows users of an MicroSense EV VSM to step through a measurement with steps as small as 1 mOe, thus showing details in measurements that are not seen with any other type of measurement system.

In figure 3 we see a measurement on a material with a coercivity of only 0.004 Oe (0.31 A/m).

Dynamic Gauss-Range Change

Another feature that is incorporated in the MicroSense VSMs is Dynamic Gauss Range Change. This feature allows the system to change to another Gauss range, while the field is applied, in the middle of a measurement. Users can measure a hysteresis loop up to the maximum field that the system can apply and still get the highest resolution field readings while measuring at low fields. This is particularly useful for measurements on spin-valve, MTJ, MRAM and GMR samples, where the materials produce a M(H) curve that shows hysteresis on multiple levels. To accurately determine the coercivity and layer thickness of the so-called “free layer”, it is important to be able to measure very precisely at low fields. It is also very useful for other materials with a low coercivity and a high saturation field. The Dynamic Gauss Range Change feature allows one to measure the entire loop with high accuracy where necessary, while still being able to saturate the sample with a high field.

Compared to Helmholtz Coil Systems and Superconducting Magnet based VSM systems

Some of our competitors offer a VSM based on a Helmholtz coil because they can’t offer the field control needed for low coercivity materials in a system that uses an electromagnet with a yoke. This type of solution requires the user to switch magnets between low field measurements and high field measurements. Because the maximum magnetic field in some of these systems is limited to a maximum field of 100 Oe, these systems are unsuitable for low coercivity materials with higher saturation fields. Even with this low maximum field in the Helmholtz coil based systems, the minimum field step in those systems is only 0.05 Oe, 50 times higher than what is offered in all MicroSense magnetic systems.

Similarly, the field resolution in the MicroSense VSMs is 60 times better than the most popular superconducting magnet based VSMs.

Neither the Helmholtz coil VSMs nor the superconducing Magnet based VSMs could measure the samples measured on a MicroSense VSM shown in figure 2 and 3.

http://www.microsense.net/products-vsm.htm