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Summary of the Magnetoelectric Response Task

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Introduction

An exciting new area of scientific exploration examines the potential usefulness where magnetic field effects occur simultaneously with ferroelectric effects in materials and structures. Where these two properties, ferromagnetism and ferroelectricity, are coupled in the same material, the material is called *a multiferroic*. The most common material studied today for this characteristic is Bismuth Iron Oxide (BFO). Similar properties can be created in a device by physically bonding magnetic materials to piezoelectric or ferroelectric materials. Such a device will be referred to as a magnetoelectric composite device. Magnetoelectric composites have great potential to create new sensors and energy harvesters. One such device was fabricated at Radiant using an RC-166A Sensor Die (http://www.ferrodevices.com/1/297/sensor_die.asp) and is shown below.

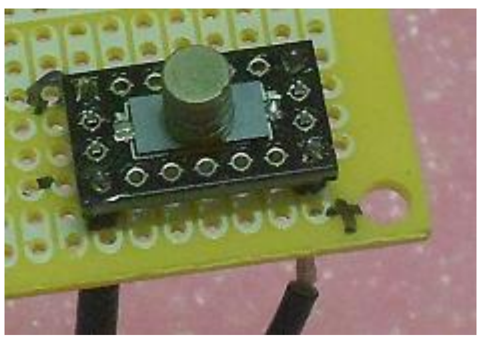

Fig. 1: Hand-built magnetoelectric sensor

The magnetoelectric test is executed in Vision on a Precision ferroelectric tester by the Magnetoelectric Response Task, MR Task for short. For those unfamiliar with the Vision operating system on Radiant testers, please go to http://www.ferrodevices.com/1/297/software.asp and select the *Introduction to Vision*.

There are a variety of tests that may be executed on a multiferroic capacitor or an ME composite. This application note will deal only with the MR Task which cycles a magnetic field around the sample while measuring any charge generated by the sample in response to the magnetic field.

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Anatomy of a Magnetoelectric Response Test

In a normal polarization vs voltage test, the DRIVE output of a Precision tester stimulates the capacitor sample with a voltage waveform while counting electrons coming out of the sample into the RETURN input. The Magnetoelectric Response Task in the Vision Library drives a magnetic coil with the tester DRIVE output while capturing any charge transfer into or out of the sample. It is the symmetrical parallel to the polarization hysteresis test with the exception that the sample is stimulated by a magnetic field waveform instead of an electric field waveform. The simplest test configuration for this test is in Figure 2.

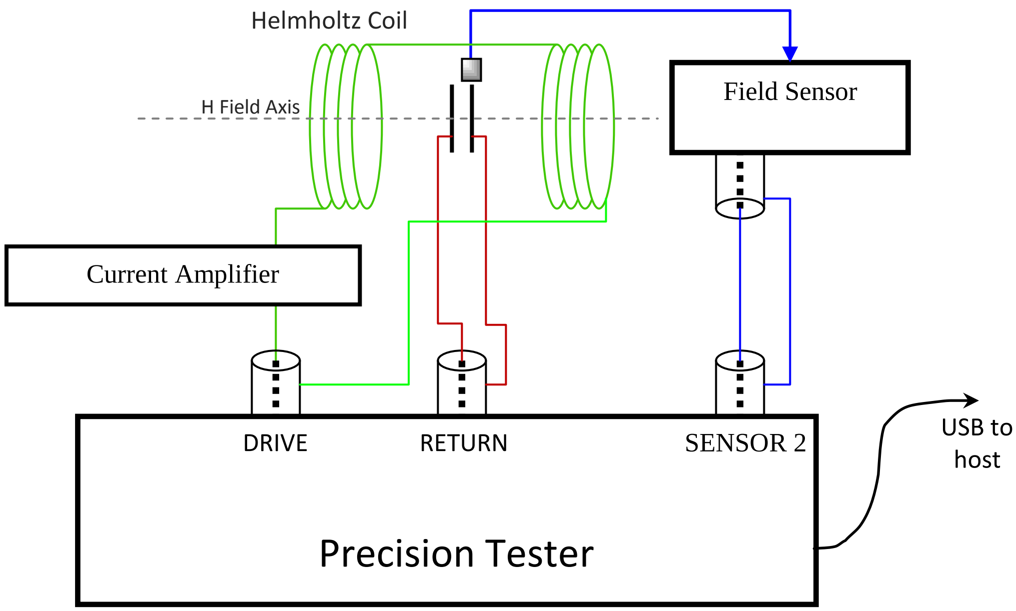

Fig. 2: The standard test configuration for the MR Task

The charge generation measured during the test execution must be plotted against the B-field generated during the test. The B-field applied to the sample is captured by a Gauss meter with a Hall Effect probe next to the sample.

Additional Test Parameters

Radiant has an accessory compatible with its Multiferroic, Premier II, RT66B, and late model LC testers that allows Vision to apply DC voltages during tests. The accessory is called the I2C DAC Controller.

Fig. 5: I^2C DAC.

The I2C DAC Controller connects to the I^2C port of the tester using 6-wire telephone cable that may be acquired from Radiant. The cable provides commands to the unit as well as ±15V power. The I2C DAC Controller allows greater complexity in magnetoelectric testing. The drive coil and sample may be placed inside the active volume of a larger field coil. The magnetic field generated by the field coil can be used to set a background static magnetic field level to bias the sample. The voltage output of the I2C DAC Controller is used to set the value of this background magnetic field.

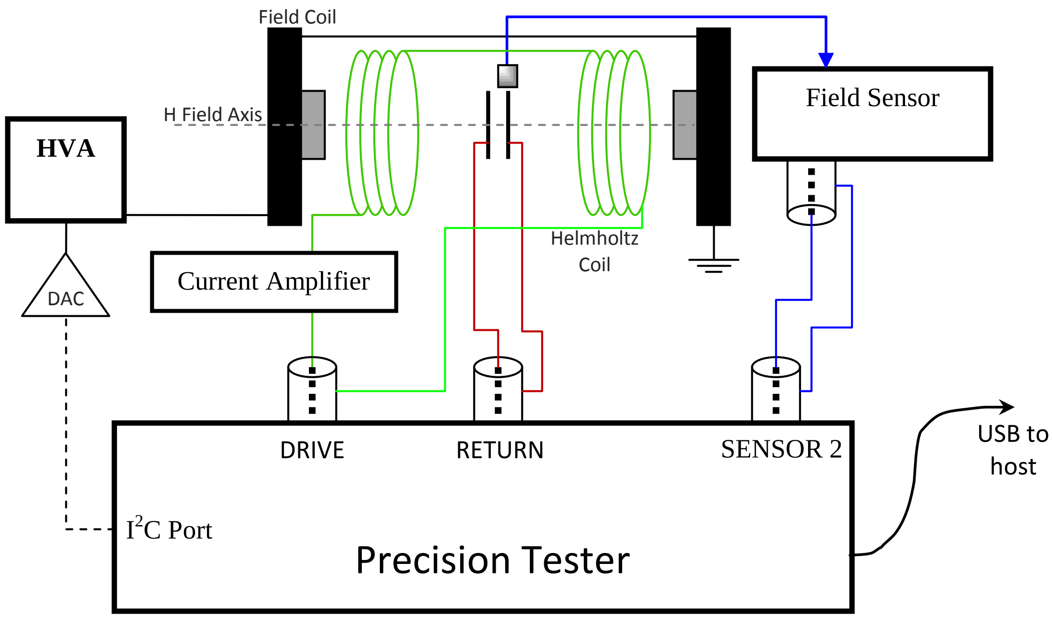

Fig. 3: Sensing magnetic field directly on Sensor 2.

A second application for the I2C DAC Controller is to apply a DC voltage bias to the test capacitor during the test as shown in Figure 4.

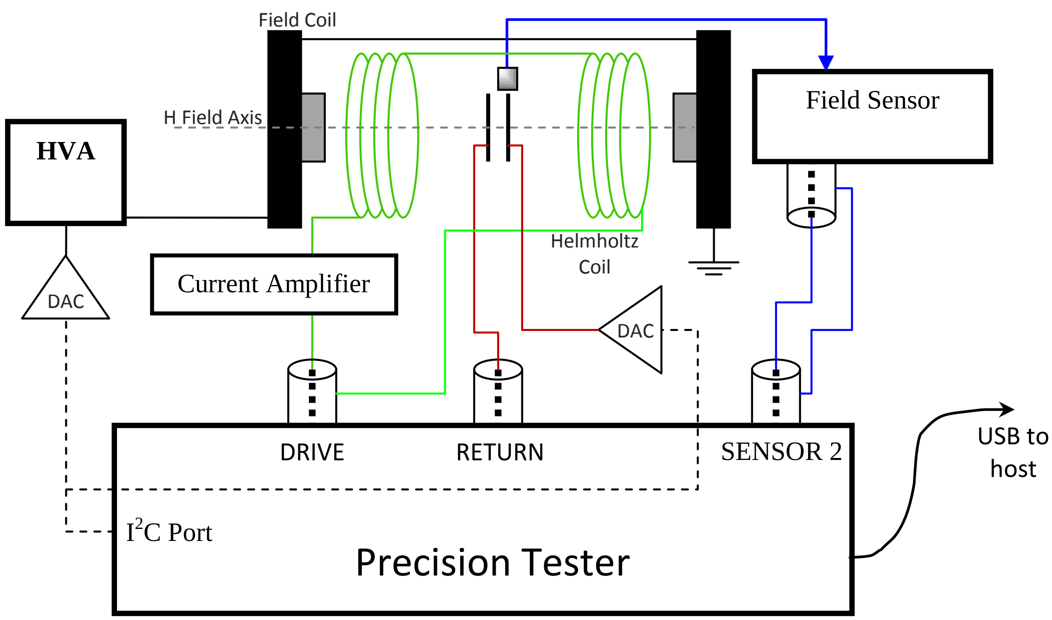

Fig. 4: The MR test configuration with DC field coil and sample voltage bias.

Figure 5 below shows the response of the reference sample in Figure 1 measured with the Magnetoelectric Response Task. The result in Figure 5 was within 15% of the theoretical value given the calculated strength of the magnet and the piezoelectric coefficients of the PNZT capacitor.

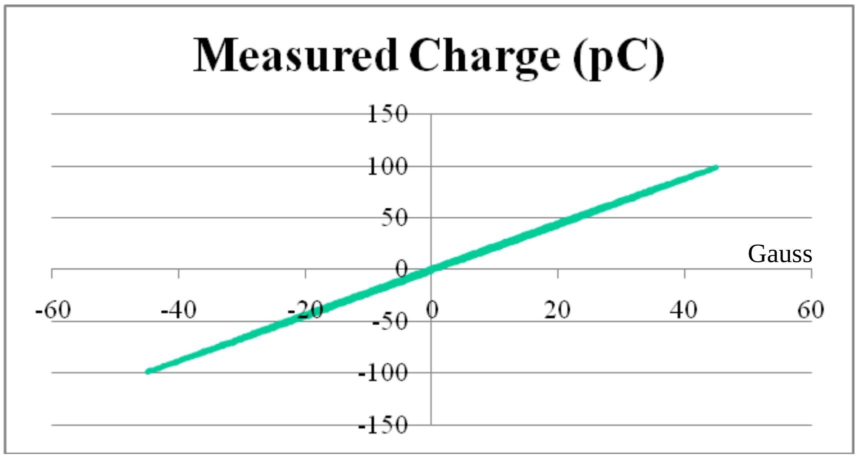

Fig. 5: The MR test configuration with DC field coil and sample voltage bias.

Conclusion

The Magnetoelectric Response Task adds a new dimension to the characterization of capacitors. It measures the charge generated by a multiferroic capacitor or a magnetoelectric composite device while the sample is stimulated with a magnetic field. The MR Task will accommodate a wide variety of coils and magnetic field sensors. For a full description of the task, the theory behind its operation, and detailed explanations of how to attain accurate measurements, see Radiant's full application note on the Magnetoelectric Response Task.