KEITHLEY

Application Note Series

Number 2202

Production Testing of GMR Heads with the Model 2400 SourceMeter® and the Model 7001 Switch Mainframe

Introduction

GMR (Giant Magneto-Resistive) heads provide the ability to read and write information to and from some form of magnetic media. Production testing of GMR heads presents unique challenges for test engineers and technicians. For example, GMR heads are physically small and electrically delicate. They also require a high level of test data accuracy.

Figure 1 represents a simple GMR head with test contacts. Each GMR head contains two sections: the GMR read element and the inductive write coil. The GMR read element is used to read information from the magnetic medium (tape or disk), while the inductive write coil writes the information to the medium. GMR heads are small, typically about 0.05 inches long by 0.04 inches wide and 0.02 inches thick. Their small size and composite structure make them extremely sensitive to electrostatic discharge (ESD). Test levels as low as 20mV or 1mA can cause device damage. Therefore, the test equipment used must be able to provide a limit to the voltage and current applied to the GMR head, making the test application more challenging.

This application note describes how the Keithley Model 2400 SourceMeter and the Model 7001 Switching System can be used in a production environment to get accurate measurements of DC electrical characteristics of GMR heads.

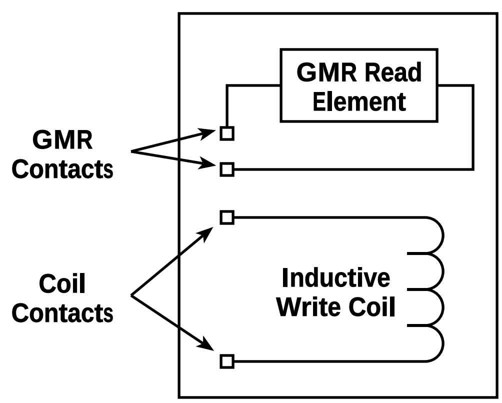

Figure 1. GMR Head Layout

Test Description

Electrical characterization of a GMR head typically involves three DC measurements:

- Resistance of GMR read element.
- Isolation resistance between GMR read element and the inductive write coil.
- Resistance of inductive write coil.

To ensure product quality, these tests are performed at the wafer, slider, and final Head Gimble Assembly (HGA) levels.

DC resistance measurement of the GMR read element

This test provides data that correlates to the quality of the manufacturing process, as well as to the performance characteristics of a GMR head. During this test, a typical GMR read element will yield a resistance value in the 10–100Ω range. This test is performed by first sourcing a 100µA current through the test device, then measuring the resulting voltage drop. The resistance is calculated using the formula for Ohm's law: R = V/I. To pass this test, the GMR read element resistance must fall within the minimum and maximum resistance values specified by the test requirements. If devices fail this test at a rate higher than acceptable limits, it may indicate a deviation within the manufacturing process.

DC isolation resistance measurement between GMR read element and inductive write coil

This test verifies the isolation between the GMR read element and the inductive write coil. Often, the isolation resistance between each section and the substrate is also measured. A decrease in this isolation resistance implies that a static discharge or a production deviation has damaged the GMR read element, inductive write coil, or both.

This is the only resistance measurement greater than 1000Ω that is performed on any part of the GMR head. Performing this test starts with sourcing 1V across the isolation area, then measuring the resulting current flow. Again, the formula for Ohm's law is used to calculate the resistance. A minimum resistance value of 10MΩ is used for the threshold of device failure. Again, if devices fail this test at a rate higher than acceptable limits, it may indicate a deviation within the manufacturing process.

DC resistance measurement of the inductive write coil

This test verifies the DC characteristics of the inductive write coil. A typical inductive write coil should have a DC resistance no greater than 20Ω. First, a current (typically 100µA) is sourced through the device, then the resulting voltage drop is measured. The resistance is calculated using the formula for Ohm's law. To pass this test, the inductive write coil resistance must fall within the minimum and maximum resistance values specified in the test requirements. Higher than acceptable level of device failures may indicate a deviation within the manufacturing process.

Test System Configuration

The production test system illustrated in ***Figure 2*** is designed to perform all the DC tests required to characterize a GMR head electrically.

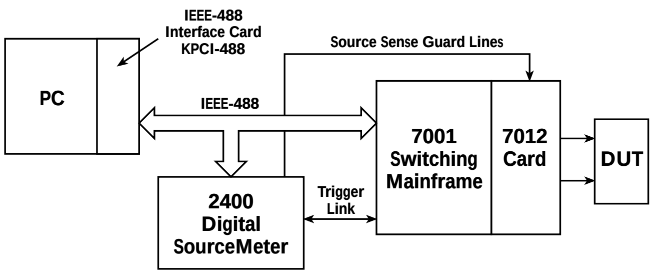

Figure 2. GMR Test System Configuration

The test instrumentation used in this configuration includes the Keithley Instruments Model 2400 SourceMeter and a Model 7001 Switch System with a Model 7012 switch matrix card.

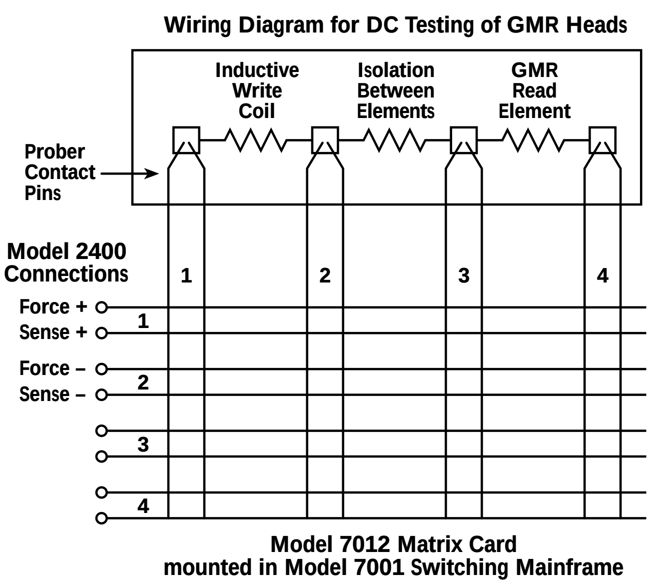

Figure 3. DC Wiring Diagram

There are significant benefits associated with using a matrix card rather than a multiplexer in this application. For example, using a matrix card allows the GMR head test points not presently being tested to be held at the Force low or ground potential, reducing the chances of ESD damage and the number of ESD-related failures significantly.

Figure 3 shows a typical multiplexed wiring configuration.

Methods and Techniques

GMR heads are extremely sensitive to ESD and the applied test voltage. Test voltages greater than 20mV can often destroy a GMR head; therefore, the open circuit voltage applied to the GMR head must be limited. Common DMMs source a current through a device (using the current level determined by the DMM's manufacturer), then measure the corresponding voltage drop across the device. The DMM then calculates the resistance using Ohm's Law. DMMs generally have a different current source level for each of the resistance ranges the instrument provides. This approach to measuring resistance is unacceptable in GMR testing because the sourced current and maximum open circuit voltage are often beyond the tolerable limits of either the GMR read element or the inductive write coil. The Keithley Model 2400 SourceMeter avoids this problem because it allows the user to limit both the voltage and current applied to the device under test during resistance measurements. By ensuring that the applied voltage and current are at a low level, the test will be less damaging to the device, so there will typically be fewer device failures.

Within this application note, a Keithley Model 2400 SourceMeter and 7001/7012 Switch configuration are used to perform these tests. This equipment configuration is used for several reasons:

- The Model 2400 SourceMeter has the ability to make low level resistance measurements and also has programmable source voltage and current compliance levels. The test configuration information can be stored within the memory of the test instrument. This aids the user by reducing the amount of IEEE-488 bus traffic per test. In this way, the total device test time is reduced, increasing the testing throughput.
- The Model 2400 has the four-wire Kelvin mode resistance measurement capability for low resistance measurements. This mode greatly enhances the accuracy and resolution of the test data under these low resistance conditions.
- The Model 2400 offers 0.08% + 0.03Ω accuracy in the 200Ω range, which is significantly better than that required in most applications. The instrument also allows the user to change the integration rate for each of the different tests, which helps reduce the amount of noise within the reading itself.
- The Model 2400 has a rapid test execution capability when used in conjunction with the Model 7001 Switch Mainframe. This capability is called Trigger Link. The availability of this function on both instruments allows for low total device testing and switching times. The Model 7012 has 20 four-pole channels per card.

Test System Safety

Many electrical test systems or instruments, including the Model 2400, are capable of measuring or sourcing hazardous voltage and power levels. It is also possible, under single fault conditions (e.g., a programming error or an instrument failure), to output hazardous levels even when the system indicates no hazard is present.

These high voltage and power levels make it essential to protect operators from any of these hazards at all times. Protection methods include:

- Design test fixtures to prevent operator contact with any hazardous circuit.
- Make sure the device under test is fully enclosed to protect the operator from any flying debris.
- Double insulate all electrical connections that an operator could touch. Double insulation ensures the operator is still protected, even if one insulation layer fails.
- Use high-reliability, fail-safe interlock switches to disconnect power sources when a test fixture cover is opened.
- Where possible, use automated handlers so operators do not require access to the inside of the test fixture or have a need to open guards.
- Provide proper training to all users of the system so they understand all potential hazards and know how to protect themselves from injury.

It is the responsibility of the test system designers, integrators, and installers to make sure operator and maintenance personnel protection is in place and effective.

Typical Sources of Error

Lead Resistance

The amount of series resistance present in the test leads connected to the device under test (DUT) is a common source of error for low impedance measurements. The test lead series resistance is part of the total resistance measurement, so significant errors can be present.

To eliminate the effects of test lead series resistance, a 4-wire technique must be used to connect the DUT. ***Figure 4*** shows how this four-wire connection is made to both the measuring instrument and the device under test.

Noise

When measuring the high resistance value present between the inductive write coil and the GMR read element, different types of interference may affect the measurements. Due to the sensitive nature of the GMR head, the test signals are low, so all measurements become susceptible to extraneous noise interference.

Electrostatic interference can occur when an electrically charged object is brought near an uncharged object, such as a meter that approaches a GMR head. To solve this problem, make sure the SourceMeter instrument's ground and the GMR head are at the same potential prior to testing.

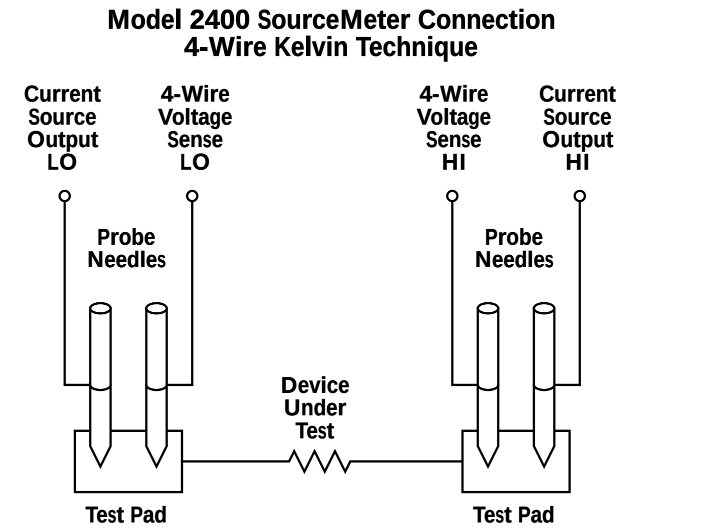

Figure 4

Radio frequency interference (RFI) is caused by high levels of energy from radio transmitters in the local area. These transmitters are often used in emergency vehicles, cellular phones, and by short-wave radio operators. Electric motors and other magnetized devices operating in the surrounding area can cause electrical interference. To reduce RFI and electrical interference, a grounded metal shield must be built to enclose the circuit being measured. The Force LO terminal of the Model 2400 must be connected to the metal shield (ground) to avoid noise from common mode and other interferences as well.

Leakage Currents

Keithley recommends using the Model 2400's cable guard feature for high resistance measurements when it's necessary to eliminate unwanted leakage currents. Unwanted leakage currents can affect measurements when a portion of the test current flows through anything other than the DUT. Moisture or dirt on or around the fixture or cabling can produce this unwanted current flow. Other causes can include inadequate device to fixture isolation or inadequate cabling dielectric.

The instrument's cable guard function reduces unwanted leakage currents by placing the DUT, the test fixture, and outer shielding of cabling at the same potential as the Force HI terminal. By doing this, the test device and fixture are at the same potential, so there are no leakage paths and no unwanted leakage current will flow. In this way, the Model 2400 only measures the current through the DUT itself.

Example Program

Keithley has developed an example program using the TestPoint™ application development package to demonstrate the techniques described in this note. This program tests GMR read element resistance, inductive write coil resistance, and the isolation resistance between elements using the equipment configuration described in ***Figure 2***. A copy of this program (gmrtest1.tst) can be downloaded from Keithley's World Wide Web site at: **http://www.keithley.com**

Note: The test program provided is intended to illustrate the concepts presented within this note. This program may be altered to accommodate other desired test parameters and timing.

The following SCPI commands are used to program the system illustrated in ***Figure 2***.

Setup commands for Model 2400

*This section establishes the triggering scheme and global measuring mode commands.

*rst	Reset 2400 to default state
:arm:tcon:dir acc	Disable bypass trigger
:arm:sour imm	Immediate trigger control source
:arm:coun 1	Specify arm count of 1
:trig:coun 3	Specify trigger count of 3
:trig:outp sens	Output Tlink trigger after sense function
:trig:tcon:asyn:ilin 2;olin 1	Set to asynchronous trigger, trigger input line #2, output line #1
:trig:sour tlin	Set triggering source to Tlink
:syst:rsen on	Enable 4-wire resistance measurement mode
:syst:azer off	Turn off Autozero
:sour:cle:auto on	Automatically disable output after measurement

* This section establishes the measurement setup for the GMR read element.

:sens:func 'res'	Measure resistance from I-source
:sens:res:mode man	Select manual resistance mode for higher speed
:form:elem res	Specify resistance data element type
:sens:volt:nplc .1	Set A/D converter integration rate for higher speed
:sour:func curr	Configure I-source
:sour:curr .0001	Output .0001 amps
:sour:curr:rang:auto off	Disable automatic current ranging
:sour:curr:rang .0001	Set current range to .0001 amps
:sens:volt:prot .02	Set voltage compliance to .02 volts
:sour:mem:save 1	Save test setup in memory location #1

* This section establishes the measurement setup of isolation between elements.

:sour:func volt	Configure V-source
:sens:curr:nplc 1	Set A/D converter integration rate
:sens:curr:prot .001	Set current compliance to 1_mA amps
:sour:volt:rang:auto off	Disable automatic voltage ranging
:sour:volt:rang 2	Set voltage range to 2 volts
:sour:volt 1	Output 1 volt
:sour:mem:save 2	Save test setup in memory location #2

* This section establishes the measurement setup for the inductive write coil.

:sour:func curr	Configure I-source
:sens:volt:nplc .1	Set A/D converter integration rate for higher speed
:sour:curr .0001	Output .0001 amps
:sour:curr:rang:auto off	Disable automatic current ranging
:sour:curr:rang .0001	Set current range to .0001 amps
:sens:volt:prot .02	Set voltage compliance to .02 volts
:sour:mem:save 3	Save test setup in memory location #3

* This section configures a source memory sweep

:sour:func mem	Select memory source mode
:sour:mem:poin 3	Specify number of sweep points

Set-up commands for Keithley 7001

*rst	Reset 7001 to default state
:trig:sour tlin	Set triggering source to Tlink
:trig:tcon:asyn:ilin 1;olin 2	Set to asynchronous trigger, trigger input line #1, output line #2
arm:tcon:dir sour	Enable bypass trigger
:trig:tcon:dir sour	Set as source of trigger pulses
:arm:coun 1	Define arm count
:trig:coun 3	Define trigger count
:arm:sour imm	Immediate trigger control source
:open all	Open all relays
:rout:close(@1!1!1,1!2!2)	Close relays at locations for GMR read element
:rout:mem:sav m1	Save test setup in source memory location #1
:open all	Open all relays
:rout:close (@1!1!2,1!2!3)	Close relays at locations for isolation measurement
:rout:mem:sav m2	Save test setup in source memory location #2
:open all	Open all relays
:rout:close (@1!1!3,1!2!4)	Close relays at locations for inductive write coil
:rout:mem:sav m3	Save test setup in source memory location #3
:open all	Open all relays
:rout:scan (@m1,m2,m3)	Setup scanning order

Setup commands to begin and run test

Output to 2400 :trig:cle	Clear trigger buffer
Output to 7001 :init	Remove from idle state
Output to 2400 :read?	Execute and return data
Output to 7001 :open all	Open all relays

Equipment List

The following equipment is required to assemble the GMR Head test system shown in ***Figure 2*** and to run the example program provided:

- Model 2400 SourceMeter
- Model 7001 Switching mainframe
- Model 7012 Matrix Switching card
- MODEL 7007 IEEE-488 interface cable (quantity 2)
- PC with KPC-488.2 Interface card
- Model 8501-1 Trigger Link Cable
- Interconnecting cables with banana plugs from the 7012 switching card to SourceMeter
- Connection wiring from the 7012 switching card to the component fixture
- Test fixture to hold GMR head

Alternate Solutions

The Keithley Instruments Model 2010 Low Noise Multimeter could be used as an alternative solution for this application. This meter has a voltage limiting “dry circuit” mode for resistance measurements. This mode clamps the open circuit output voltage to the test device to just 20mV. When making low resistance measurements in the dry circuit mode, the four-wire Kelvin technique must be used with this meter.

If the required resolution for the measurement of isolation resistance between the GMR read element and the inductive write coil is lower than 10pA, Keithley recommends using a production test system based on the Model 6517A Electrometer/High-Resistance System or Model 6430 Sub-femtoamp Remote SourceMeter® instrument.

It is also possible to complete the required tests by configuring separate voltage and current sources, as well as the associated measurement instruments. For example, the Model 2001 or 2002 DMMs both have extensive measurement capabilities and digital I/O ports for interfacing to a component handler. In this case, it would be necessary to use an external clamping diode (such as a 1N4148) on the meter’s output to limit the open circuit voltage. This diode would be placed in a forward biased position across the multimeter output. This diode’s leakage current is considered insignificant in low resistance measurements relative to the total source current to the GMR head. However, when measuring the high isolation resistance between the GMR read element and the inductive write coil portions of a GMR head, this diode leakage current represents a much larger portion of the total source current and must be accounted for in the test data.

Specifications are subject to change without notice.

KEITHLEY

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