www.Distinti.com

100GV Hall Effect Probe

The 100GV Hall Effect Probe adapts just about any type of equipment to the task of measuring or recording static or dynamic magnetic fields. Such equipment includes DVMs, oscilloscopes and audio equipment.

Features

100 Gauss per Volt sensitivity
+/- 500 Gauss (50mT) range
+/- 450 Gauss Guaranteed linear range
30 KHz bandwidth
1% Full Scale Accuracy
10 milligauss Sensitivity (see note 2 below)

Figure 1-1

Description

The 100GV Hall Effect probe is a versatile and accurate device for measuring static and dynamic magnetic fields.

The proprietary "popsicle" stick probe is completely sealed for harsh environments. The design of the probe enables it to be accurately mounted and positioned.

Coupling the 100GV to an oscilloscope enables researchers to measure fast moving and dynamic magnetic fields up to 30 KHz in bandwidth.

The 100GV can also be connected to a DVM or other voltage measuring device with input impedance greater then or equal to 100KOhm.

The cost savings of this device are realized by the fact that it is used to adapt pre-existing equipment to the task of measuring and recording magnetic fields. Any device such as a DVM, strip recorder, scope, frequency counter, and even audio systems can be used. Use a tape recorder, the audio track of a video cassette recorder or computer audio input to record magnetic field phenomenon for later playback or analysis.

Notes:

1) The unit comes complete with AC wall adaptor and scope/audio adaptor. DVM jumpers (AC006) for connecting the probe to a DVM can be purchased separately.
2) Because of ambient magnetic noise (approx 2G p-p), the 10 milligauss sensitivity is obtained using a DVM or a scope with an averaging capability. This is explained in more detail inside.
3) For the electrical characteristics of the scope/audio adaptor see our website. The scope adaptor product SKU is AC008 and is found in the accessories section. The scope has a flat frequency response from DC to beyond 1 MHz. This far exceeds the requirements of this product.

100GV Hall Effect Probe

Table of Contents

1 Overview of The 100GV

Unlike other Hall Effect instrumentation, the 100GV was designed to adapt a multitude of equipment to the measurement or “display” of magnetic fields.

Figure 1-1 The 100GV kit (The probe shows a white cable tie use to protect the probe during shipment)

1.1 The Probe

The 100GV features a proprietary “popsicle stick” probe design as shown in Figure 1-2. The Hall Effect sensor along with support components are surface mounted to the probe board which is then dipped in rubber to seal the probe against the elements.

The probe board contains both English (1/10th inch) and metric graduations to help the researcher accurately position the magnetic sensitive point of the probe. The sensitive (Hall Effect) point is located along the centerline at the 0 position relative to the graduations.

For reference purposes, the x-axis of the probe is along the graduation centerline, the y-axis is parallel to the graduation tick marks (positive direction toward the upper left of photo) and the z-axis is perpendicular to the graduation printing (positive direction coming out of the photo). The origin is the Hall Effect point; where the z=0 position is the graduation printing.

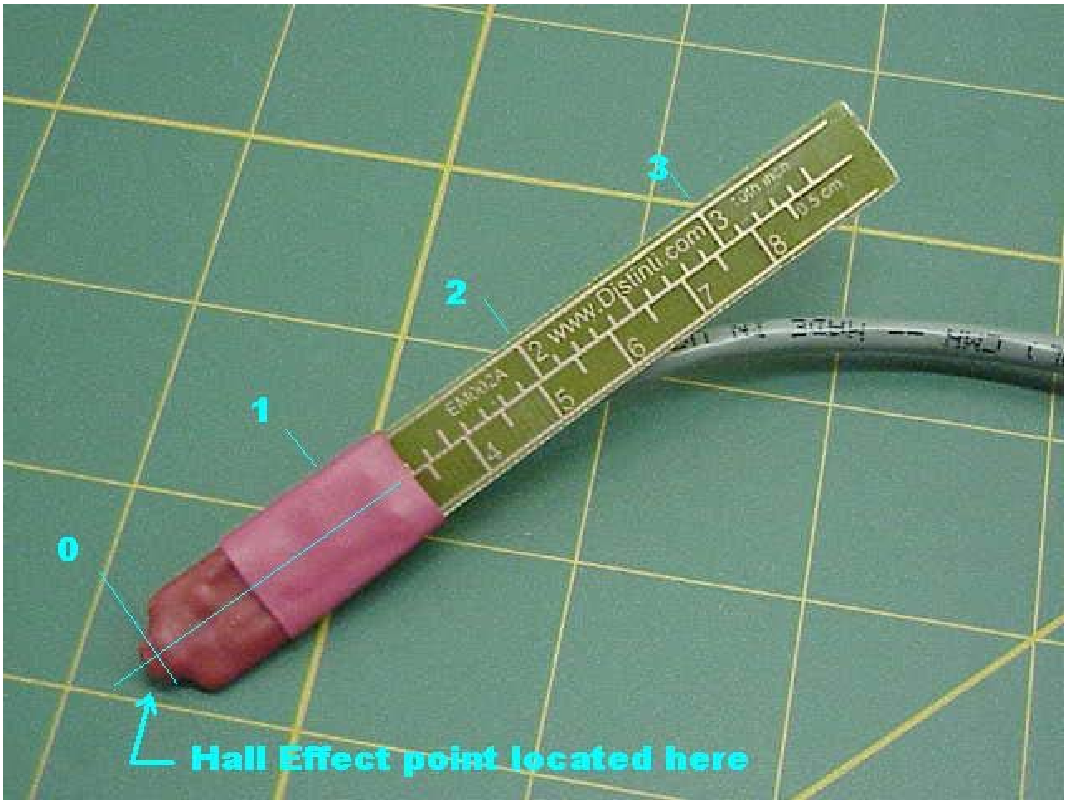

Figure 1-2 The "Popsicle Stick" probe design (white shipping cable tie removed)

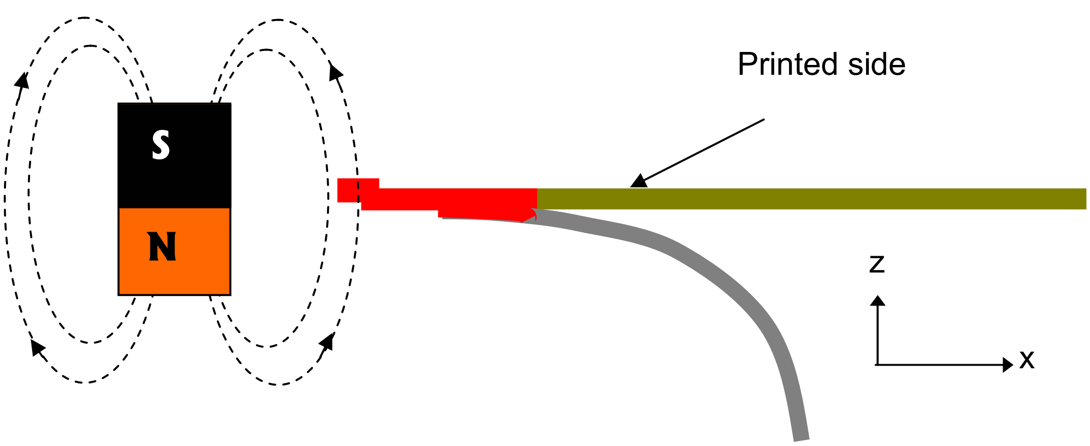

Figure 1-3: Side view of probe board

When viewed from the side (Figure 1-3) the Hall Effect point is in the same plane as the printing (z = 0)

The 100GV will produce a positive reading when magnetic flux lines are passing through the origin parallel to the z-axis as shown in Figure 1-3.

The placement accuracy of the Hall Effect point is 0.01 inches.

1.2 Mounting the Probe

An important advantage of the "Popsicle Stick" probe design is the versatility it provides for mounting. The following photo shows the use of spring clips to hold the probe to a yardstick.

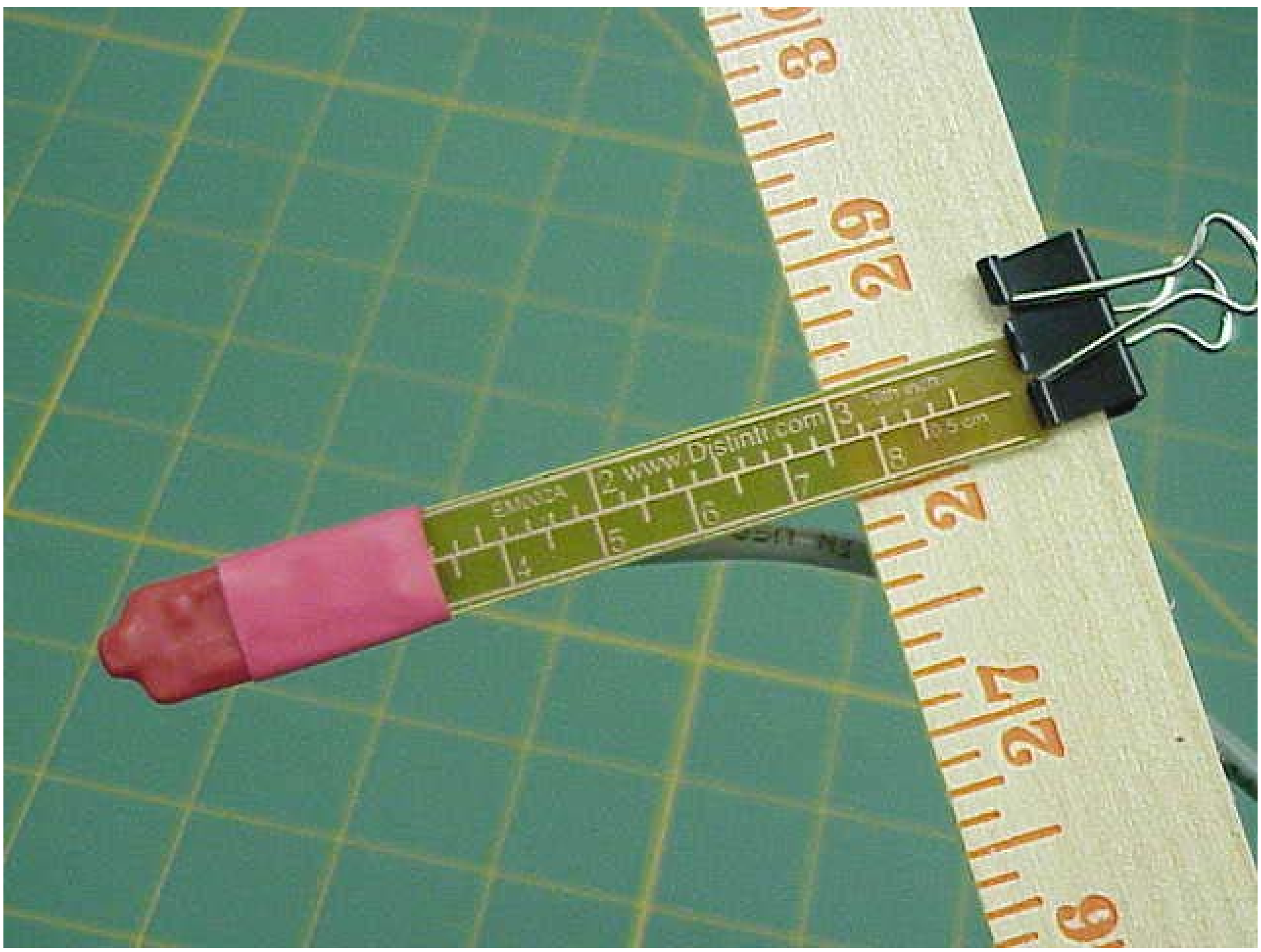

Figure 1-4 Mounting with spring clips

Although the spring clips are made of steel and may tend to interfere with the measurements (we will show how to check for this) they are the easiest clamping method we could find. In most cases they are far enough away from the Hall Effect point such that measurements are not noticeable affected.

There are many other mounting methods that are less intrusive to the measurement; however, this manual will use the spring clip. Because we prefer to use spring clips, we will demonstrate a technique for determining their effect on the measurements.

1.2.1 The Probe Holder

A probe holder is a device for holding the probe for measurements. Depending upon the experiment, there are many different way to make a probe holder. The probe holder shown in the following photos is used for table top measurement.

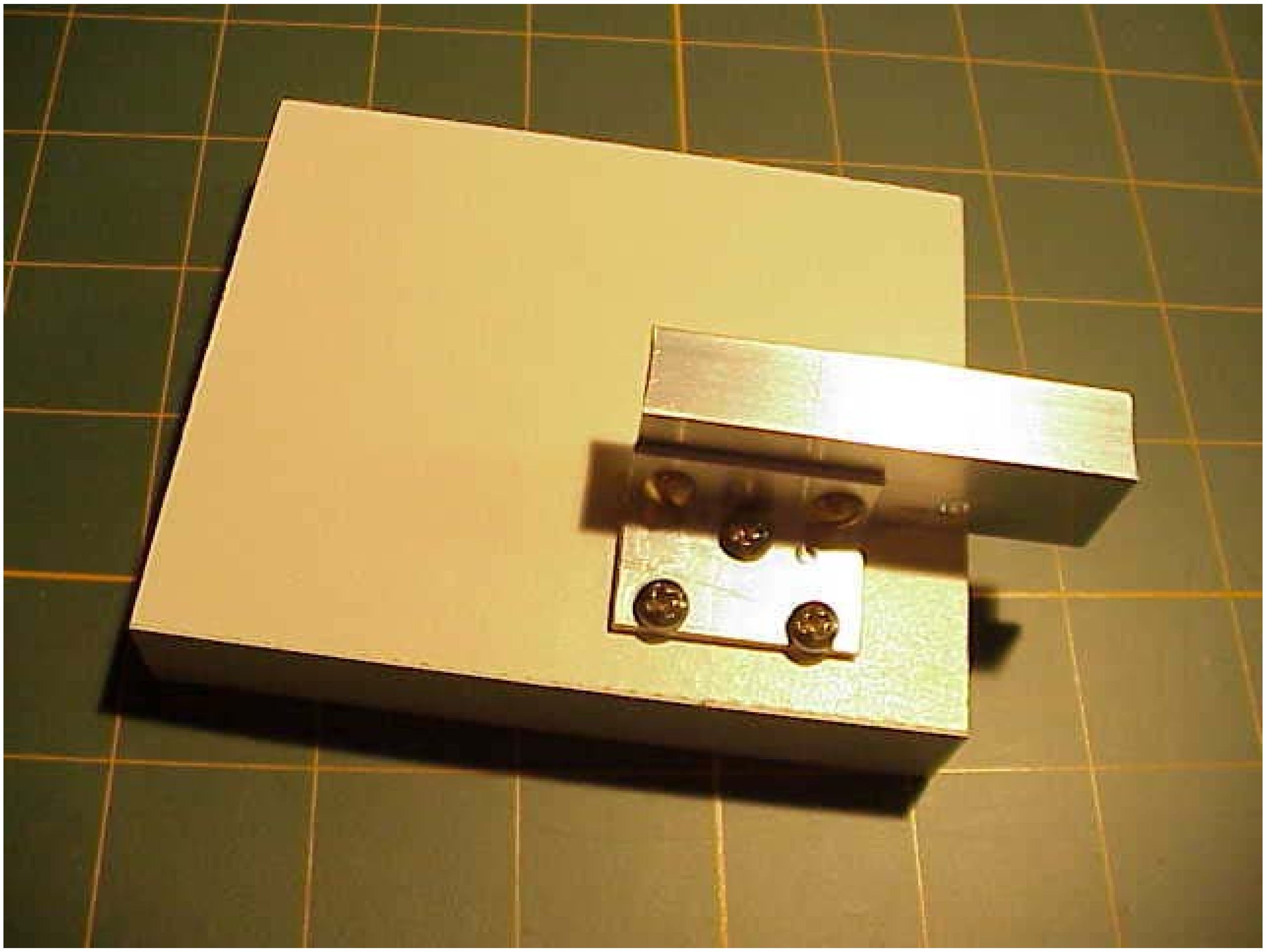

Figure 1-5 A Probe Holder

The probe holder is constructed from melamine board and extruded aluminum "L" channel. The purpose of the probe holder is to hold the probe stationary to a field that is being measured. The "L" channel allows us to clamp the probe horizontal (Figure 1-6) or perpendicular (Figure 1-7) to the test bench (see next section)

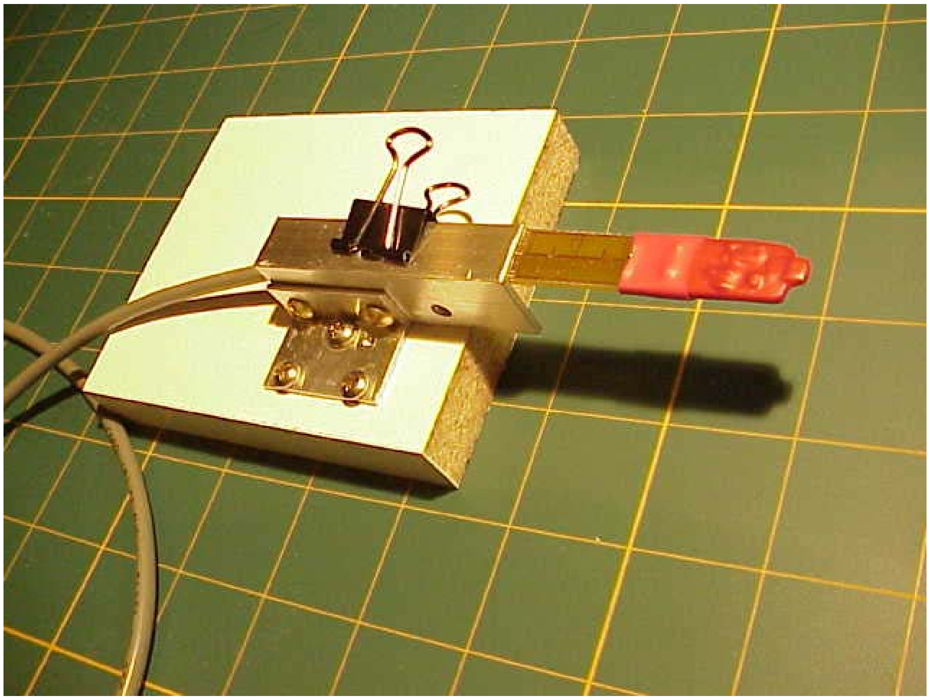

Figure 1-6 Horizontal to the Bench

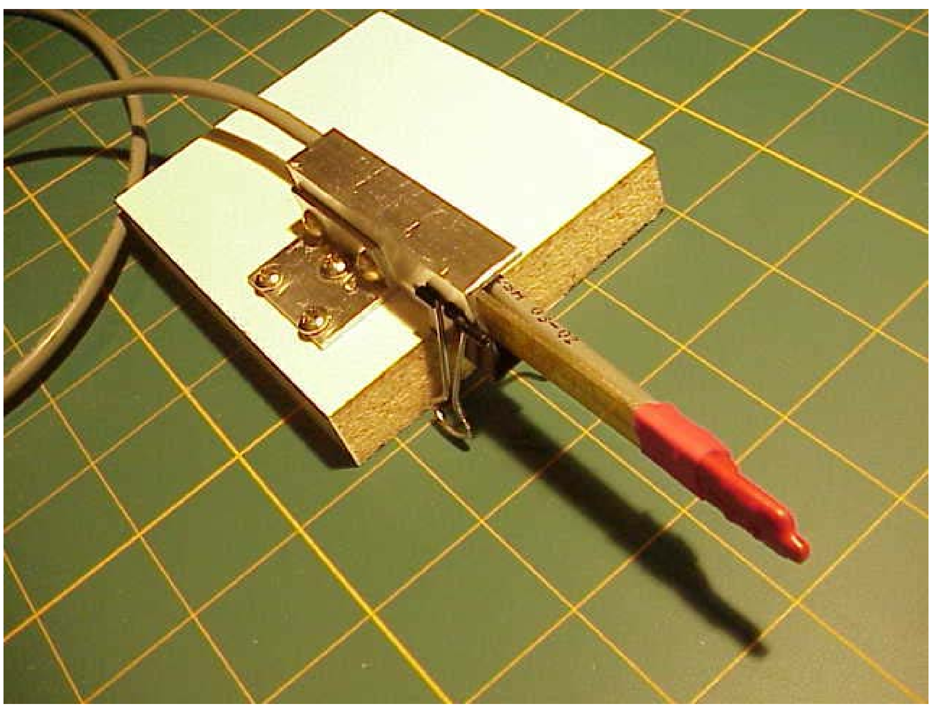

Figure 1-7 Perpendicular

Later chapters will demonstrate the use of the probe holder.

1.3 Making Measurements

This section will demonstrate simple measurements in order to show how to connect the 100GV to a DVM and Oscilloscope.

The Applications/Demonstrations section shows advanced measurement techniques for making very precise measurements to 10 milligauss accuracy.

The 100GV can be attached to any device with a 100K ohm (or greater) input impedance. The next sections show examples of measurements made with a DVM (DMM) and Oscilloscope.

1.3.1 Measurements with a DVM

The following photograph shows the 100GV attached to a DVM using a set of short banana jumpers (available separately from www.Distinti.com).

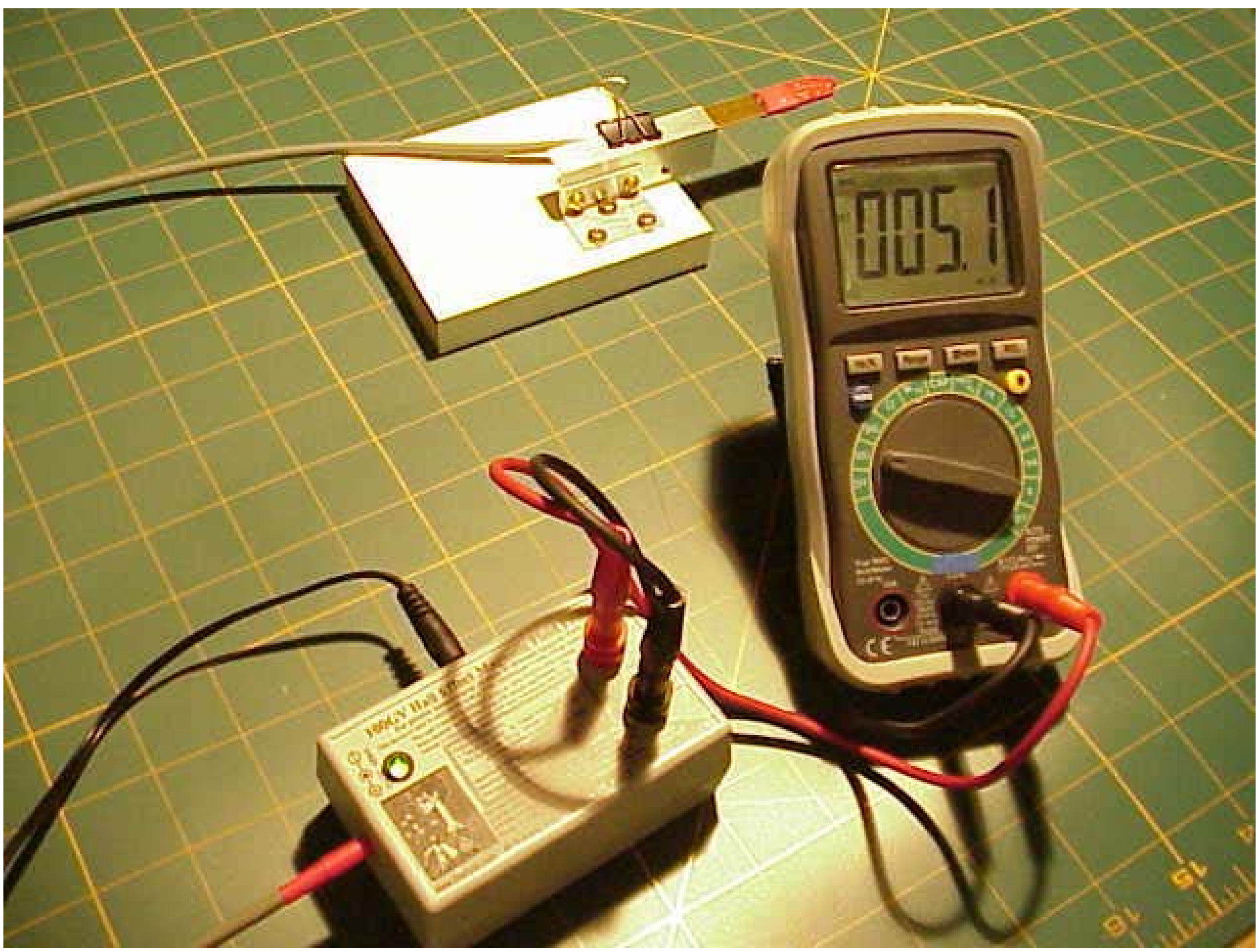

Figure 1-8 Connection of 100GV to DVM

DVM setup:

1) Set meter to measure DC or AC voltage (depending upon experiment)

1.3.1.1 To make a simple DC measurement:

1) Place a magnet near the probe.
2) Set the DVM to DC
3) Read the voltage from the meter.
4) Multiply by 100 to convert the reading to Gauss
5) Divide by 100 to convert the reading to Teslas

1.3.1.2 To make a simple AC measurement:

1) Place the probe near an AC magnetic field (such as the ballast of a fluorescent fixture)
2) Set the DVM to AC
3) Read the voltage from the meter
4) The reading is RMS. If you wish to concert to peak, them multiply by 1.414
5) Multiply by 100 to convert the reading to Gauss
6) Divide by 100 to convert the reading to Teslas

You will notice up to 20mV (2 Gauss) error on the AC or up to 6mV (0.6 Gauss) error on the DC settings when the probe is not near any magnetic source (see Figure 1-8). This error due to many factors to include the magnetic field of the Earth and ambient magnetic noise sources (power lines, radio, etc). For experiments with field strength of 100 Gauss or more, this 2 Gauss error represents 2% of the reading. Adding this to the 1% accuracy tolerance of the 100GV represents a reading that is within 3% of the actual. 3% accuracy is sufficient for most purposes. However, when higher accuracy is required or when measuring smaller magnetic fields, this 2 gauss error may not be acceptable. For higher accuracy readings, section 2 shows how to set up a magnetic test bench and demonstrate the proper techniques to mitigate these errors.

1.3.2 Measurements with an Oscilloscope

The 100GV is connected directly to a scope BNC connector using a Scope/Audio adaptor as shown in the following photo. Most DPO scopes are smart enough to default their inputs to X1 when a standard BNC connector is attached.

The following photo shows how to connect the 100GV to a common scope.

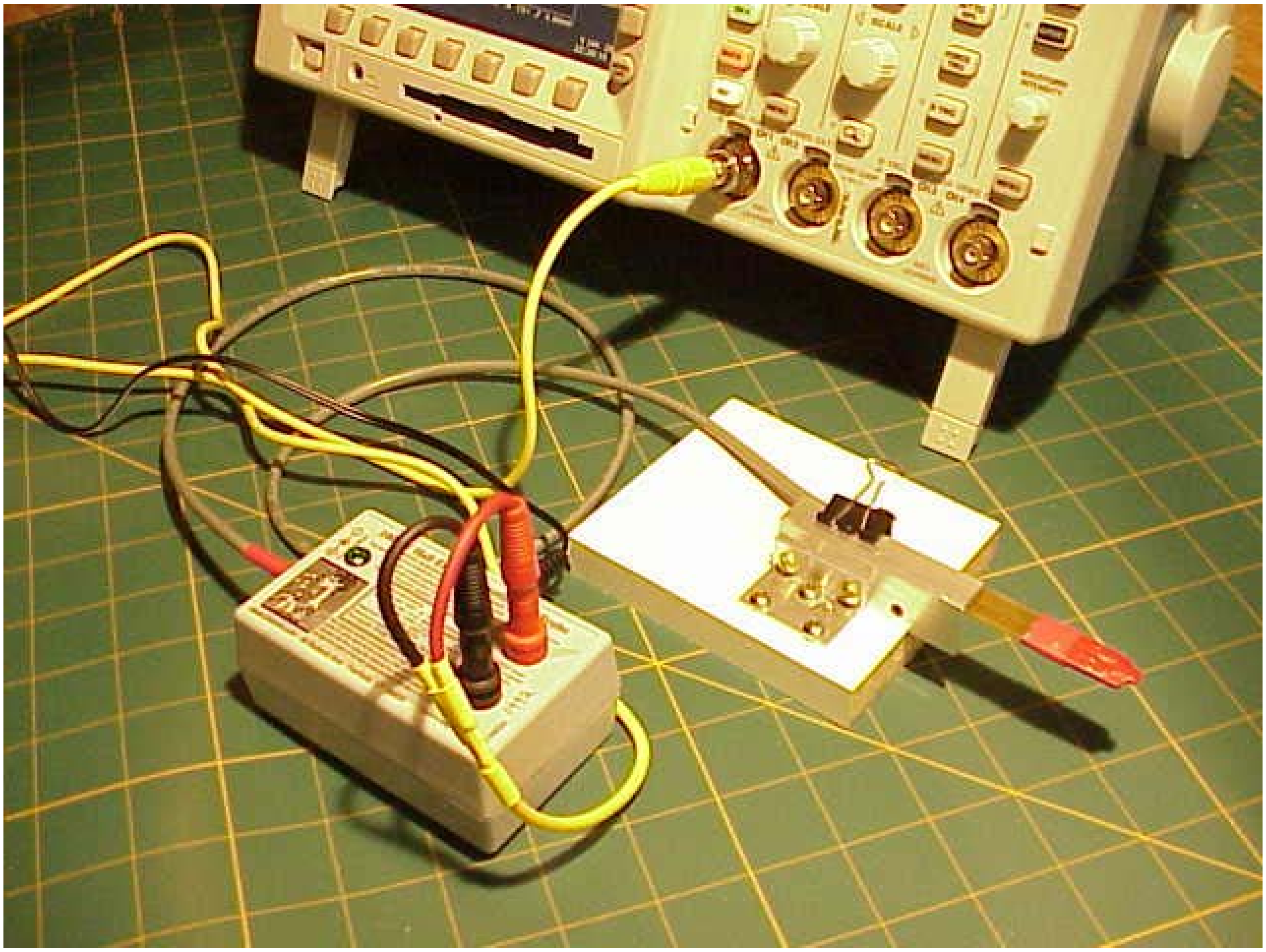

Figure 1-9 Connection of 100GV to scope

Here are the recommended scope settings (some scopes may not have these selections)

1) Input impedance of scope should be set to 1M
2) Probe settings should be voltage, x1 (some scopes default to this automatically)
3) Bandwidth limit set to lowest setting
4) High frequency reject enabled on trigger menu (Your scope may have a “DC low sensitivity” trigger mode that may be more appropriate depending upon the experiment).
5) If you are looking at a repetitive signal, signal averaging (at least 16 waves) will produce excellent results. If you are looking at transient signals, then turn signal averaging off.
6) If you are looking at very low frequency signals you may want to use untriggered roll

You will notice up to 20mV (2 Gauss) noise (see Figure 1-10) and up to 6mV (0.6 Gauss) offset when the probe is not near any magnetic source (see Figure 1-8). This error due to many factors to include the magnetic field of the Earth and ambient magnetic noise sources (power lines, radio, etc). For experiments with field strength of 100 Gauss or more, this 2 Gauss error represents 2% of the reading. Adding this to the 1% accuracy tolerance of the 100GV represents a reading that is within 3% of the actual. 3% accuracy is sufficient for most purposes. However, when higher accuracy is required or when measuring smaller magnetic fields, this 2 gauss error may not be acceptable. For higher accuracy readings, section 2 shows how to set up a magnetic test bench and the proper techniques to mitigate these errors.

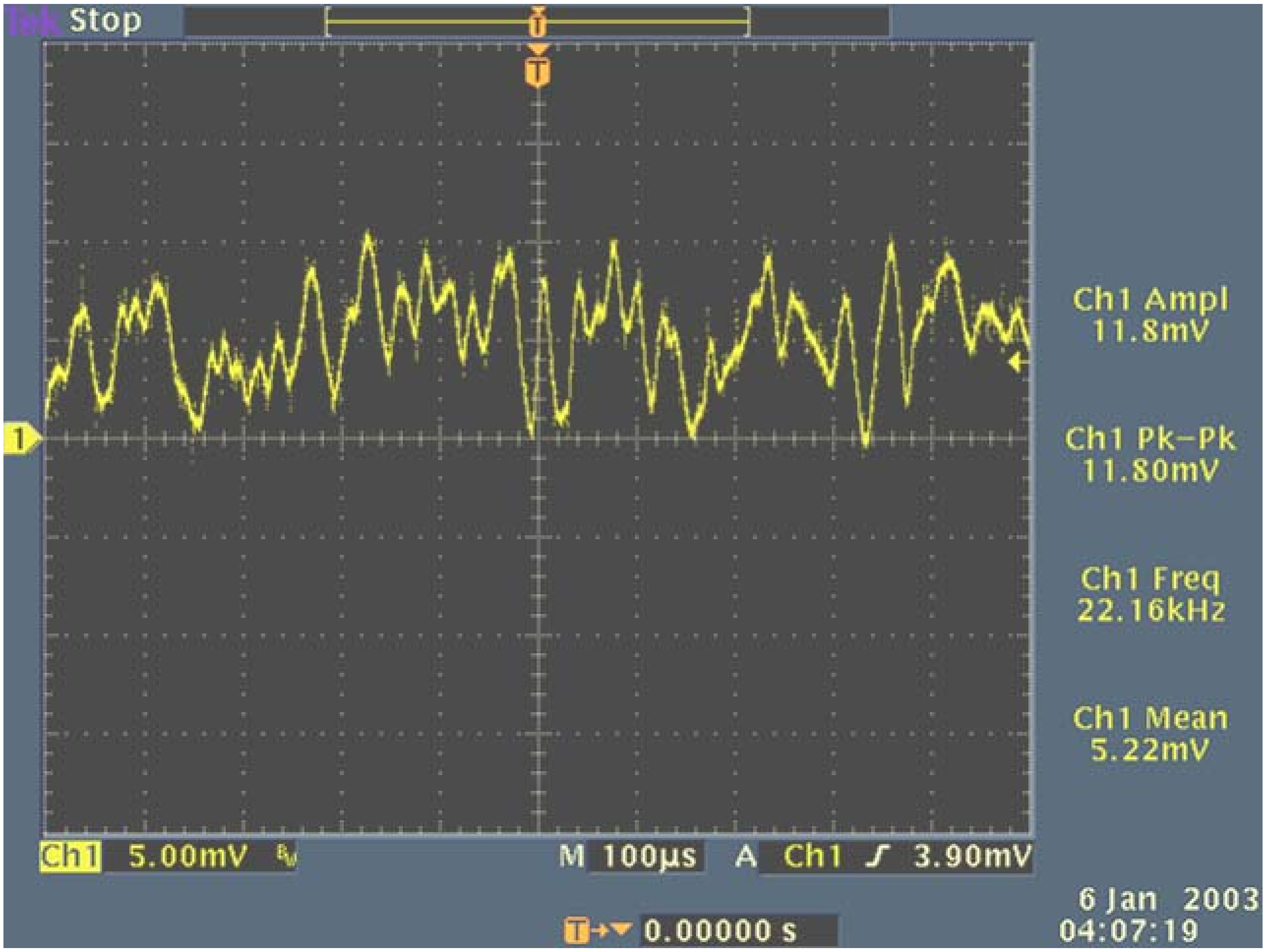

Figure 1-10 A snapshot of ambient magnetic noise

2 Sample Applications/Demonstrations

2.1 Setting up a magnetic test bench and making high accuracy measurements

The sensitivity range of the 100GV includes the magnetic field of the Earth (Earth field) as well as ambient magnetic field noise. This section demonstrates procedures to identify and compensate for the effects of Earth magnetic field and ambient magnetic noise.

Note: This section is only required if accurate measurements of small magnetic fields are required. In most cases the background effects may not be significant.

The strength of the Earth field varies over the surface of the Earth but is usually about 0.5 Gauss (5 millivolts from the 100GV).

The ambient noise results from many sources to include radio, cell phones, power lines, etc. Although the frequencies of most of the noise sources are beyond the bandwidth of the Hall Effect sensor, the sensor incorporates a “chopper stabilization” circuit which can cause some of the high frequency noise to alias into the sensitive range of the device. The ambient noise can peak to as much as 2 Gauss (20mV) depending upon your environment. With good equipment this noise can be bypasse to make precision measurements.

2.1.1 Bench Construction

The most important requirement of a magnetic test bench is a level table that contains no steel or iron supports or fasteners near the table top. We have constructed a wood bench where the top supports of the bench are press fit and the plywood top of the bench is screwed on with brass screws. The only steel is located in the base (3 feet from the table top) which includes carriage bolts and casters. (We will publish the design if there is any interest). You can purchase plastic lawn table from your home improvement store as an alternative.

2.1.2 The Grid Reference

The next most important requirement is a grid reference aligned to the magnetic field present in the lab; which is most presumably the magnetic field of the Earth. Our pictures show a green "Miracle Mat" with a 1 inch grid pattern in yellow. As an alternative, a 50 sheet pad of 18x24 inch paper with 1 inch quadrille rule is available from an office supply store (look where they sell pads for those presentation boards). Note: don't use the entire pad, just one sheet.

The first step in the alignment process is to suspend a thread with a weight over the grid reference as shown in the following photo.

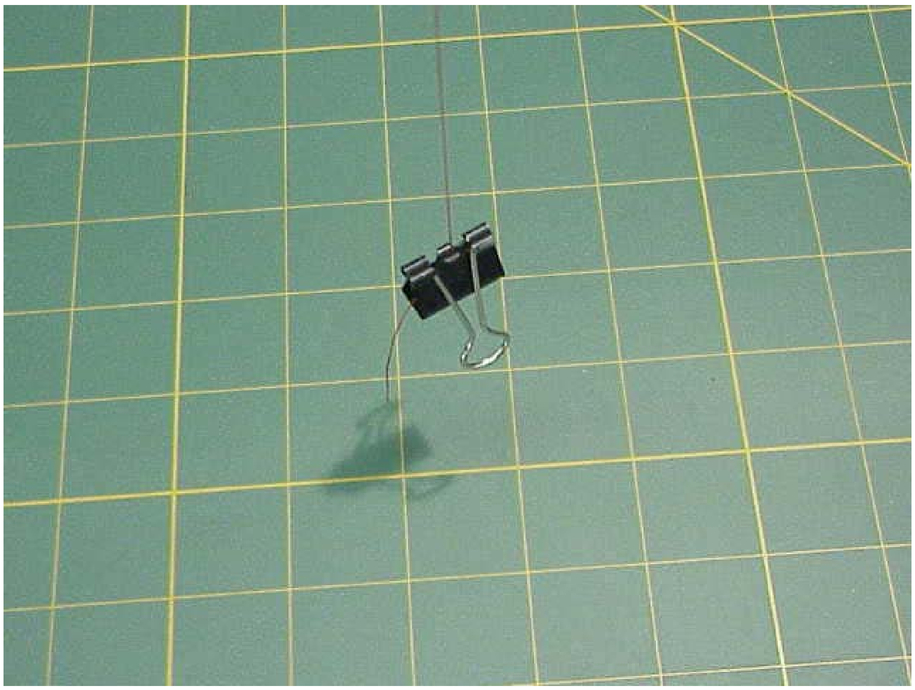

Figure 2-1 Allowing the thread to "unwind"

The objective is to "unwind" the thread. It may take a few minutes for this system to settle down. When all motion is gone, attach two button magnets to the thread as shown in the next photo. Use a single "point" light source (an incandescent bulb will do) suspended high above the magnets to cast an accurate shadow.

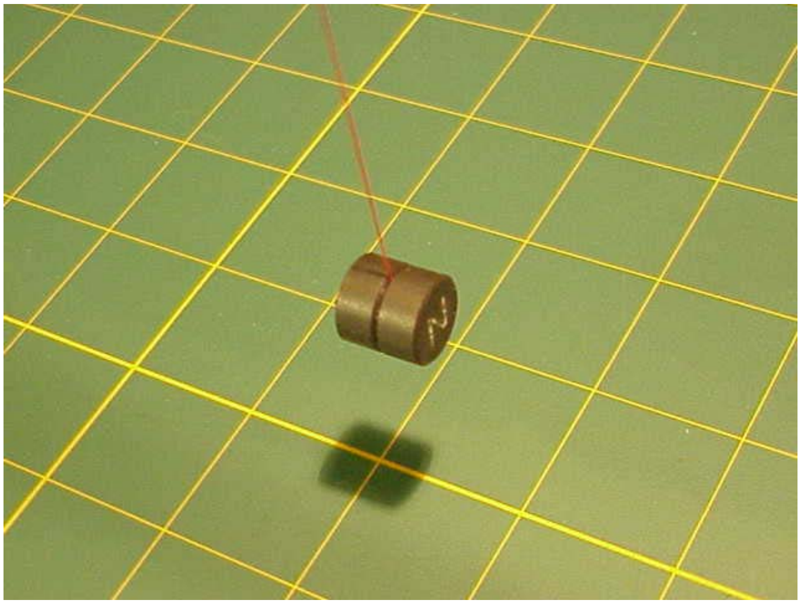

Figure 2-2 Aligning the grid reference to north

Allow generous time for the magnets to come to rest. They will align with the magnetic field of the Earth (or at least the magnetic field present in the Lab).

Using the shadow cast by the light source, or other means, adjust the grid reference such that one axis aligns with the magnets. This completes the task of aligning the axis of the grid reference to the magnetic field of the Earth.

When you are reasonably sure that the grid is aligned with the magnetic field of the Earth, suspend the magnets at different locations over the grid reference to ensure that other points of the grid reference also align to the magnetic field of the Earth. If other locations on the grid do not align, then there are magnetic field anomalies caused by metallic objects, or other magnetic field sources nearby. Eliminate the effects of the anomalies by either removing the source of the anomaly or moving your test bench somewhere else.

Another, perhaps more accurate, method for aligning the grid reference is to use a non-declinated military compass. Again, use the compass to verify that the field is uniform over the grid reference.

2.2 Calibrating the magnetic offset of the 100GV

No device is free of offset; the 100GV is rated not to have more than 0.1 gauss (1 mV) of offset. For most applications this offset can be ignored; however, when making precise measurements, this offset can be factored out to improve the accuracy of the result.

To measure the magnetic offset of the 100GV, attach the 100GV to a DVM and place the probe into a fixture (Such as the probe holder shown in previous sections) that keeps the face of the "Popsicle" stick perpendicular to the table top. As shown in the next photo.

Next, take four measurements, one each in the north, west south and east directions as shown in the following four photos. For best results, the end of the probe (where the Hall Point is located) should preside over the same spot on the grid for each measurement.

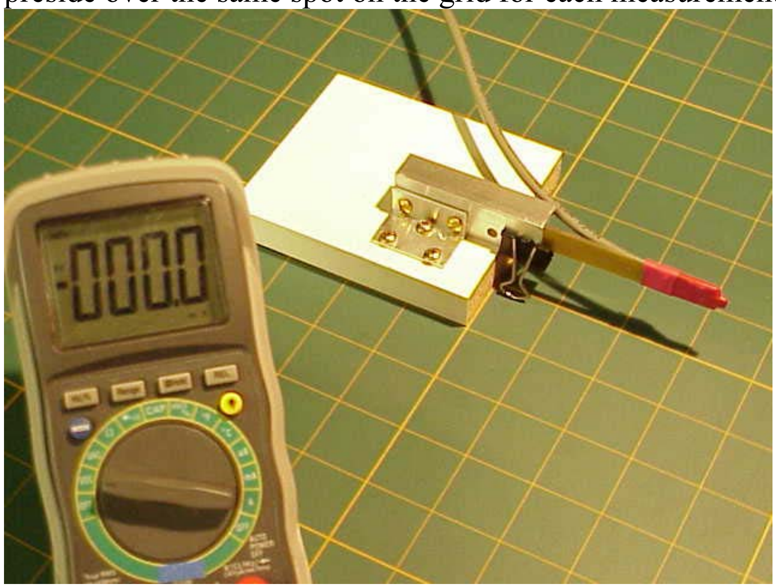

Figure 2-3 The North Reading

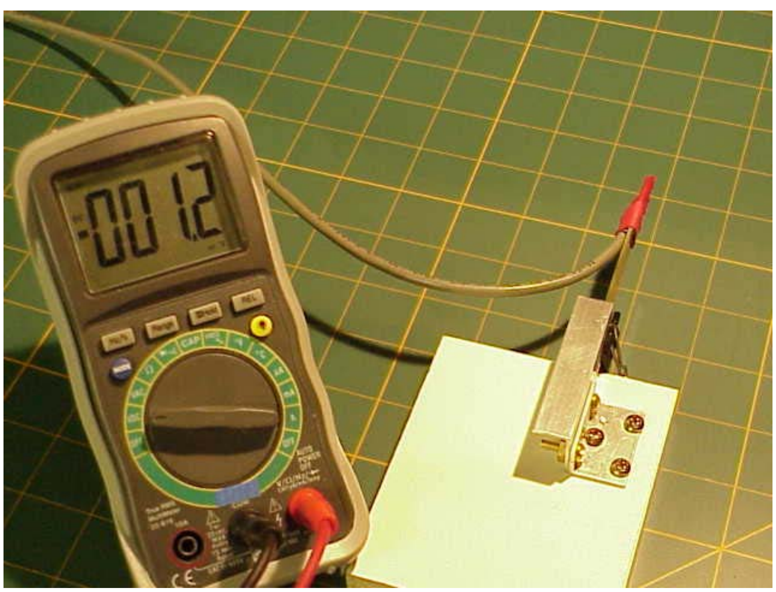

Figure 2-4 The West reading

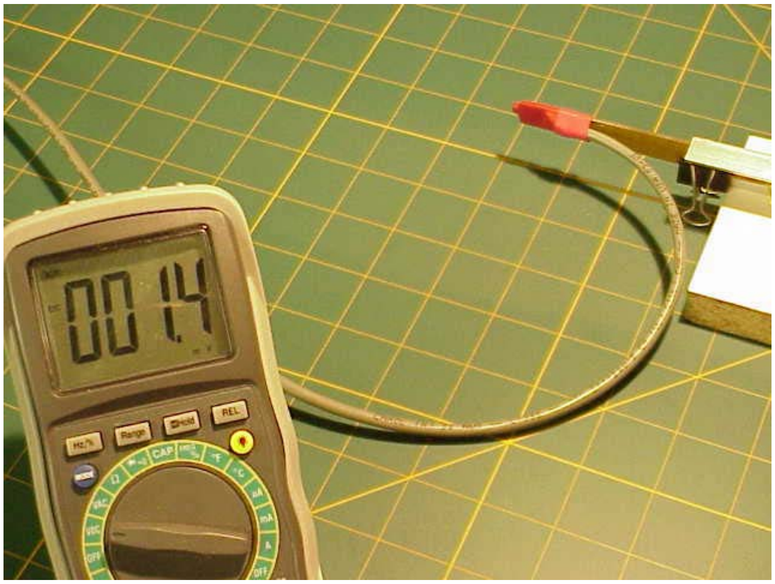

Figure 2-5 The South reading

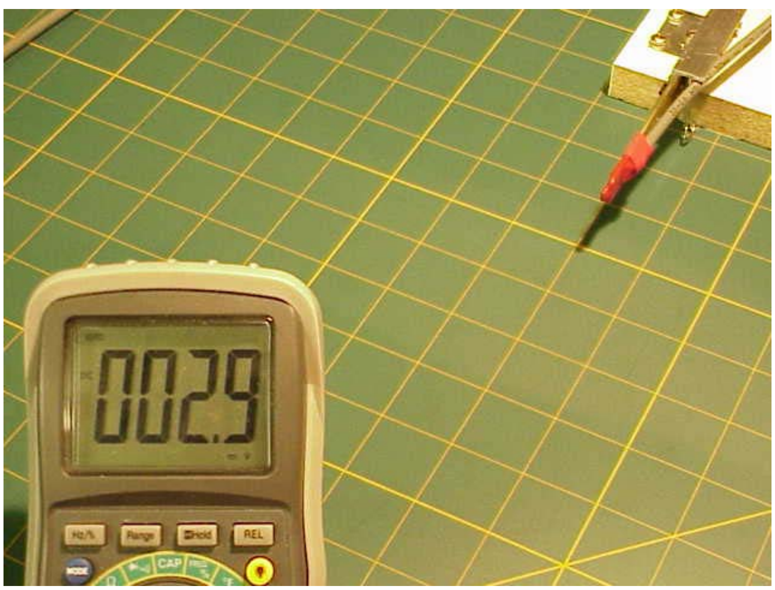

Figure 2-6 The East reading

The readings are

1) North 0
2) West -1.2
3) South +1.4
4) East +2.9

To calculate the probe offset, take the average of the four readings:
Avg = [(0)+(-1.2)+(+1.4)+(+2.9)]/4= 0.8mV

The probe offset is 0.8mV which corresponds to 0.08G which is within the rated 0.1G maximum offset.

To correct this offset, turn the probe holder until the meter reads the offset (in this case 0.8 mV). Then do either of the following:

1) Hit the Rel button on your meter. This tells your meter to remove the 0.8 mV from all further readings.
2) Manually Subtract the 0.8 volts from all future readings
3) Remove the screws from the back of the 100GV and adjust the trim pot that is closest to the power jack until the meter reads 000.0 mV. Be careful, this is a delicate instrument.

Next, realign the grid in the direction where the probe reads zero. You should then be able to get the same reading of 0 (+/-0.1 mV) in both the north and the south directions. Adjust the mat until this is so. You should also get equal and opposite readings in the east and west directions (in our case we get 2.0 and -2.0 respectively). Note: A variation of +/-0.1 mV is very good in all cases above.

The grid is now calibrated perfectly to the static magnetic field in the lab as the probe sees it. In our case, the original field direction from the button magnets and the final direction were different. A check with a compass shows that the final direction of the grid is very close (it is calibrated to the probe so do not change it according to the compass). After an investigation it was determined that the thickness of the thread between the two button magnets caused them not to be parallel.

The probe is designed with the highest quality components available; however, the offset will drift with temperature and age. If you are making small measurements (under 100G), it is recommended that you test the offset at least once at the beginning of the day after about 5 minutes of warm-up or when the temperature changes by more than 5 degrees C.

2.2.1 Test bench field components

After the probe offset has been mitigated, and the grid realigned, you should repeat the North, West, South, East measurements and record the readings for future reference.

2.2.2 The bench vertical field component

The final component of test bench offset is the vertical component.

In the previous sections the probe face was always perpendicular to the bench to which means that we were measuring the field entering the bench from the points of the compass.

Another important direction for magnetic field offset is the vertical direction. The vertical offset of the bench is measured as shown in the following photo and should be noted for future experiments

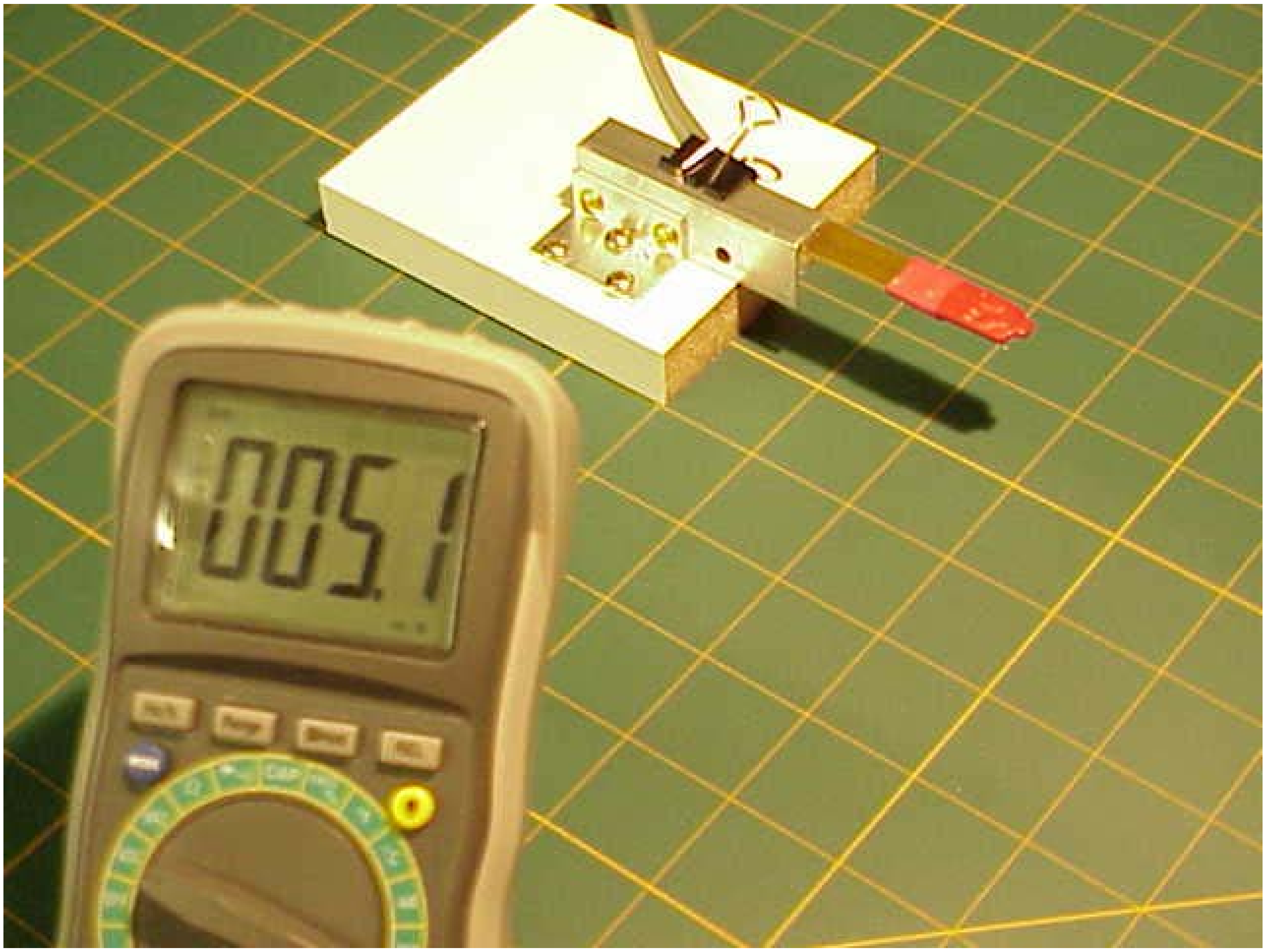

Figure 2-7: the vertical field component of the Bench

When ever we mount the probe face up on this particular test bench, we should expect 5.1mV (0.51 Gauss) of field offset. This offset is shown again later.

2.2.3 Making high accuracy static field (DC) measurements

Making high accuracy DC field measurements is quite easy once you have a calibrated magnetic bench.

The best tool for DC measurements is the DVM. The DVM integrates the input which eliminates the 20mV of AC noise allowing measurements to 0.01 Gauss.

Since magnetism is an inverse square law, the slightest movement of the probe can cause great changes in the reading. By using a probe holder (as shown in previous sections) the probe jitter is greatly reduced (if not eliminated) allowing very precise measurements.

Before introducing the magnetic source to the bench, place the probe into the probe holder. It is preferred the probe be positioned where the readings are zero (as we set up in the previous section). If this is not possible, that's ok; the following procedure works in either case

Here are the steps

1) Before introducing the source to the table, write down the present reading from the DVM. This is the initial offset reading and is the error present at the probe at the beginning of this set of measurements. This error can be due to the magnetic field of the Earth, temperature induced offset in the probe or other field sources present.
2) Place the field source on the table and position it to the point for measurement. It is always better to move the source than the probe when high accuracy is desired. Otherwise it is difficult to account for the offset without making precise position measurements of probe.
3) Continue to move the source and make measurements.
4) After all of the desired measurements have been taken, remove the source from the table and write down the value on the face of the meter. This is your ending offset reading. In most cases it should be the same as your starting offset.
5) Average the two offset readings and subtract the result from the source measurements (steps 2 and 3).
6) If desired, measure the starting room temperature and the ending room temperature and average it. Using the average room temperature enter the table in Figure 3-1 to determine the temperature adjusted conversion.
7) Multiply each voltage reading by the conversion factor (100G/V or 0.01T/V or value from step 6) to convert the readings from volts to Gauss or Teslas.

With good laboratory equipment, procedure and consistency, these reading can be repeated to within +/-0.01G (0.1mV). With average equipment and procedure +/-0.05G (0.5mV) repeatability is easy to obtain.

A crafty individual could set up an Excel spread sheet to take care of this.

2.2.4 Making high accuracy dynamic field (AC) measurements

It is possible to make milligauss accurate dynamic readings with the 100GV in spite of the ambient noise. The following picture shown the probe inserted between the coils of a small Helmholz like coil pair.

The coil set is drive by a 1 KHz sine current with peak amplitude of 100mA. Figure 2-9 shows the raw 100GV output of the field activity at the center of the coils. The first thing you will notice is the very small signal seems to be completely obscured by the ambient noise. The second thing you will notice is that there is a 5.1mV offset in the signal.

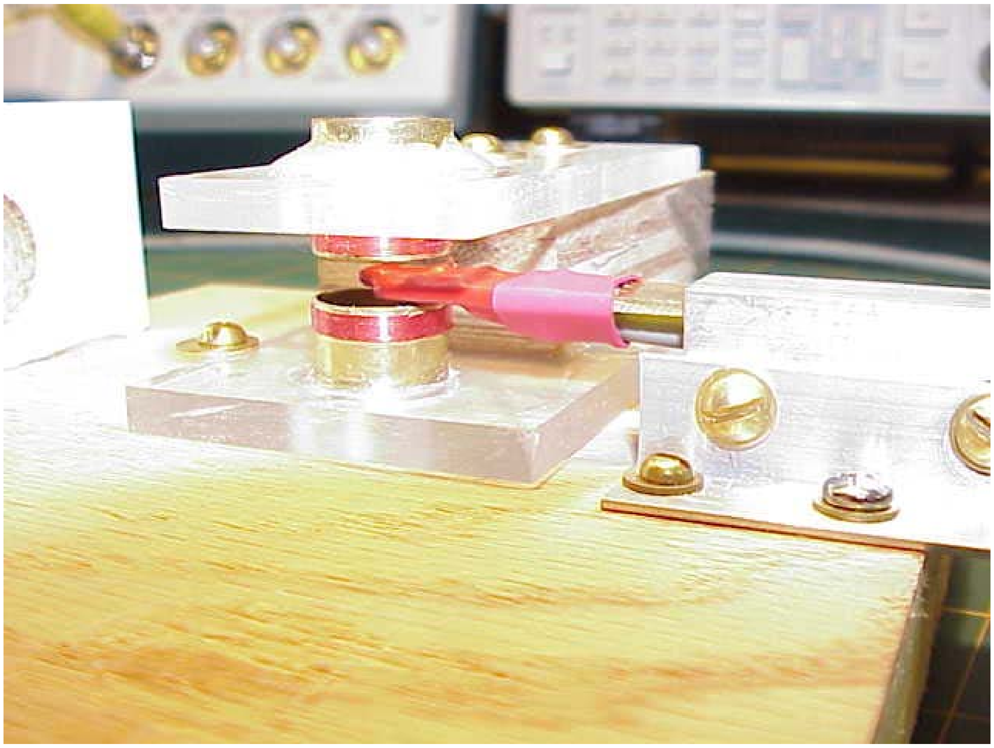

Figure 2-8 Miniature Helmholz coil

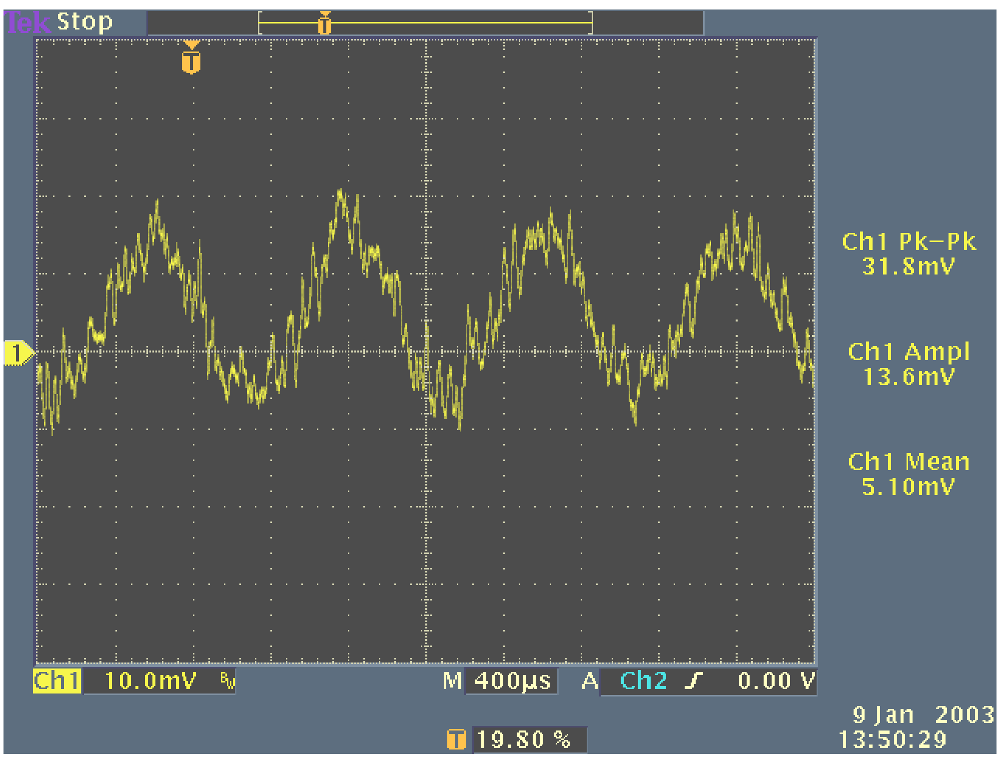

Figure 2-9 The raw 100GV reading of the field at the center of the coil pair.

The 5.1 mV offset is known to us when we measured the vertical field component of test bench (see section 2.2.1). A good scope pilot can use the offset function of the scope to eliminate the known offset of the bench prior to taking measurements.

To remove the ambient noise requires us to use the averaging capability of a scope (analog scopes do not have this feature). The key to accurate averaging is proper triggering on the exact same position of a periodic wave. Since accurate triggering on the signal in Figure 2-9 is nearly impossible due to the ambient noise, we then attach the source signal to the scope (Blue trace) and use it as the triggering source. The next scope screen capture shows the averaging capability enabled. It was necessary to average 128 waves to converge out the noise.

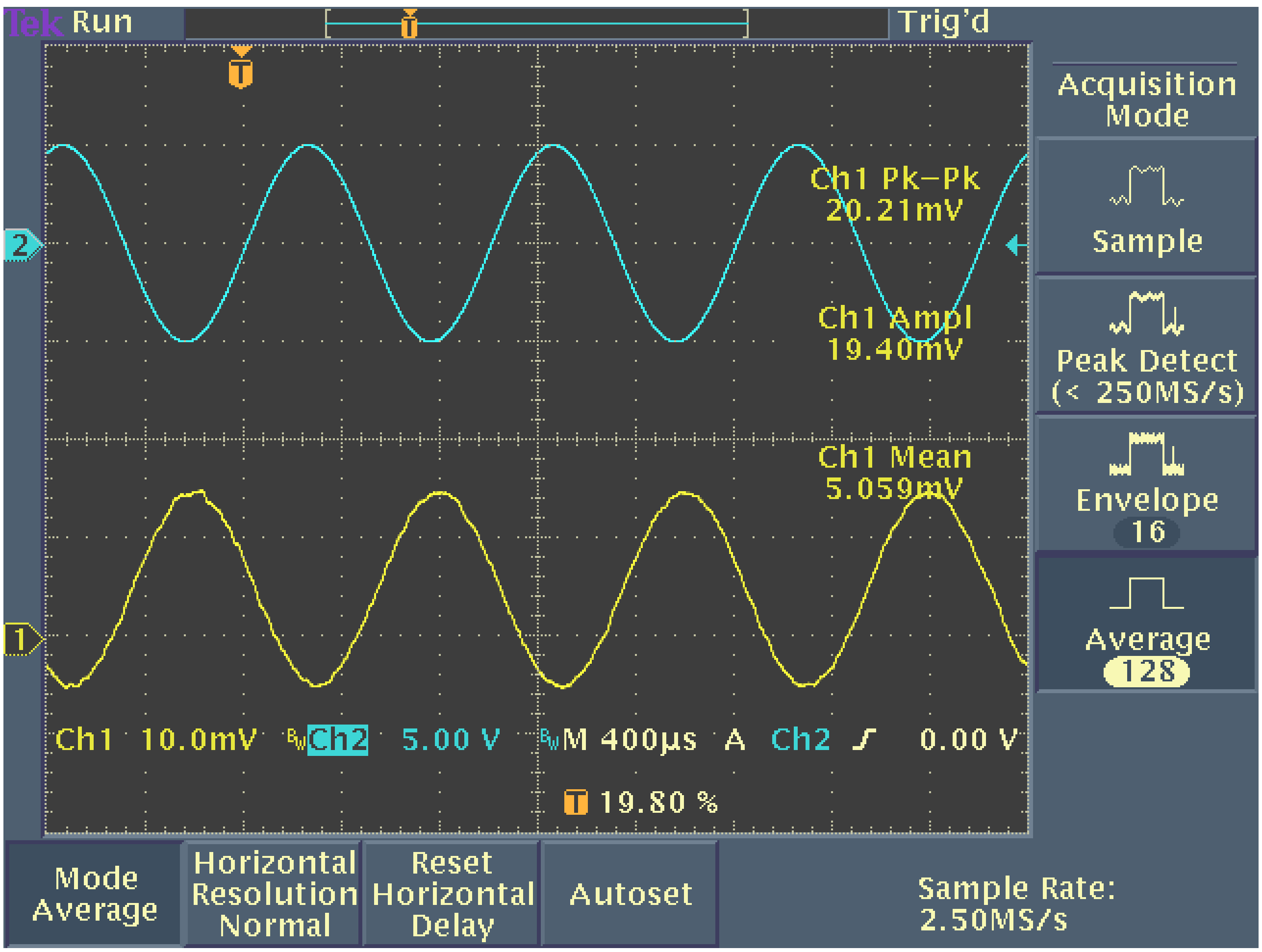

Figure 2-10 Averaging enabled.

The output wave (Yellow) is decently clean and is resolvable to at least a millivolt. Thus the output is 19.4 (+/- 0.5) Millivolts which corresponds to 1.94 (+/- .05 Gauss).

2.3 A simple experiment

The following experiment shows a simple application of a moving magnet. A bar magnet is suspended from a steel slinky over the probe. The magnet is given a very small upward push to make it oscillate up and down ever so slightly. This experiment generates signals greater than 100mV; therefore probe offset is ignored.

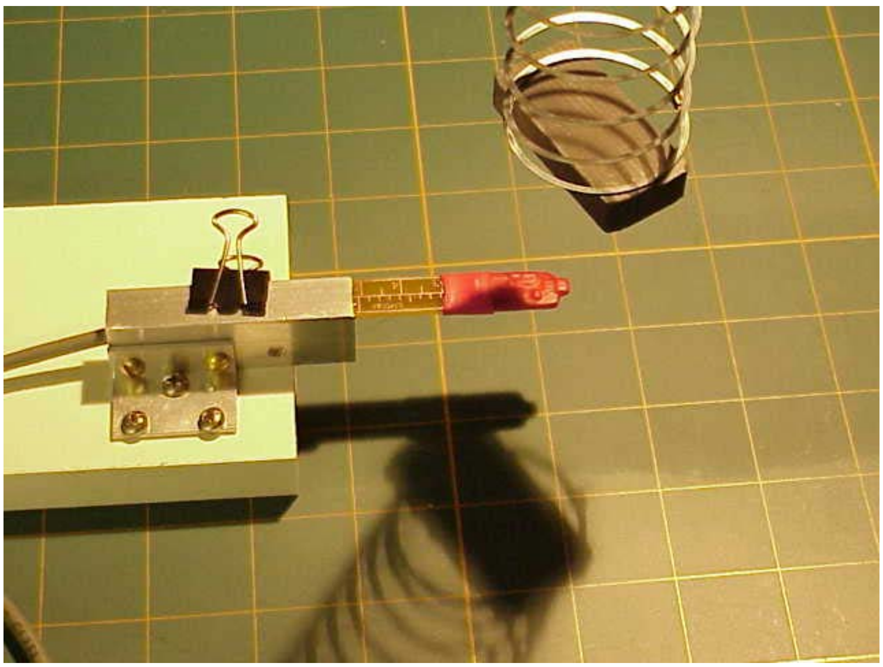

Figure 2-11: Slinky Magnet experiment

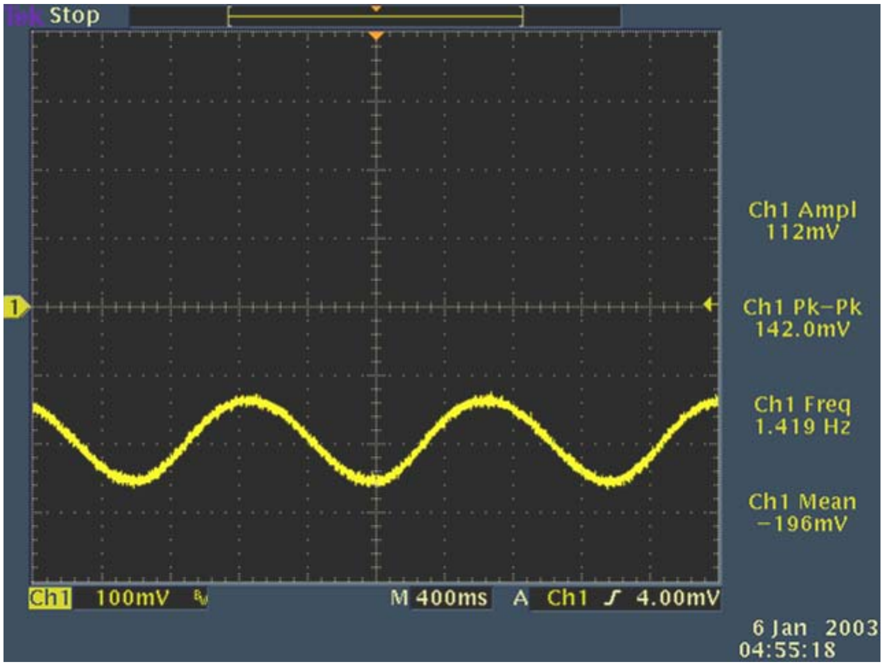

Figure 2-12: The Scope Output

2.4 Mapping the magnetic field of a static magnet

This section to be added at later time

2.5 The kinematics of rotating magnetic fields

This section to be added at later time

2.6 More experiments

This document will be revised whenever new experiments for this device are developed.

3 Electrical Specifications

Table 1: General Specifications

Parameter	Symbol	Conditions	Min	Typ	Max	Units	Notes
Offset	Gos			+/-0.05	+/-0.1	G	
Offset drift				+/-0.0013	+/-0.002	G/°C	
Maximum Field	Gmax			+/-500G			1
Linear Range	GLin			+/-450G			
-3dB Frequency	Flp		28	30	32	KHz	
Sensitivity (see chart)		@25 °C	99	100	101	G/V	
Change in sensitivity vs probe temp (See Chart)				-0.05		G/V/ °C	
Probe Maximum Voltage		Theoretical		300		V	

Note 1: Fields beyond this will not harm the unit

This section to be expanded at a later time

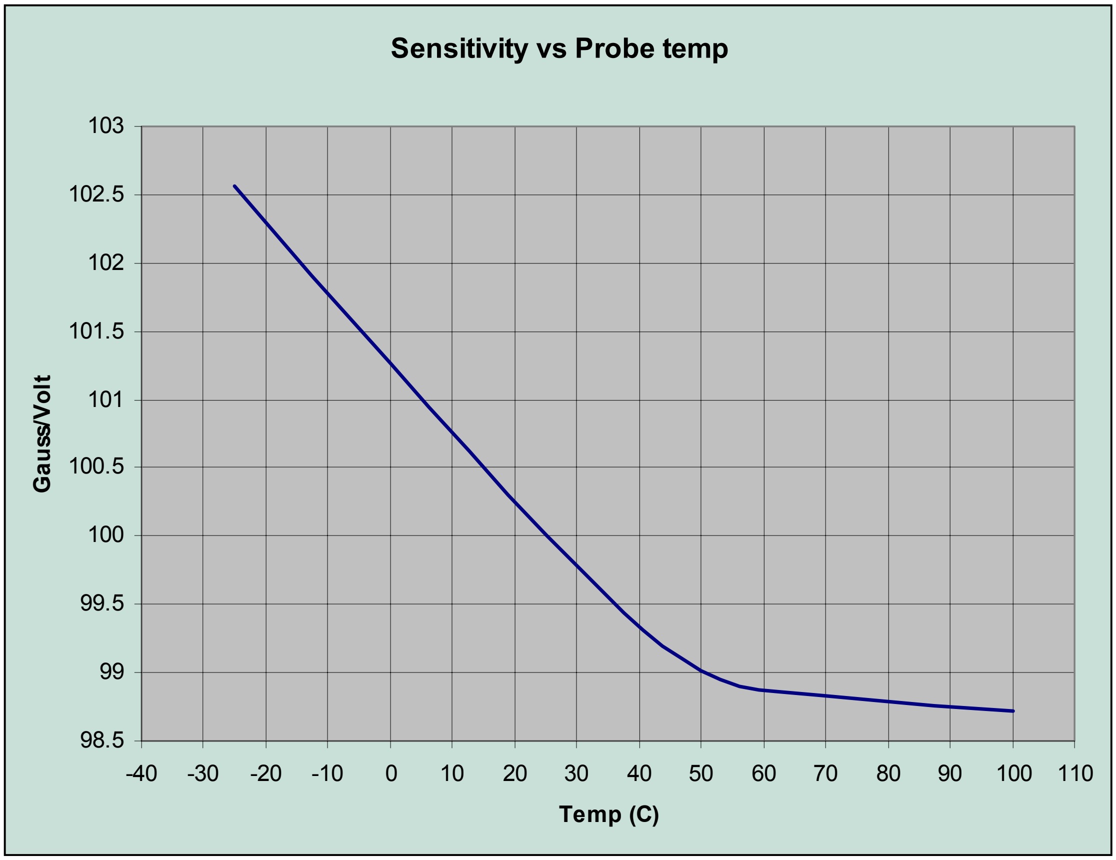

Figure 3-1 Sensitivity Vs Temperature (Exaggerated scale)

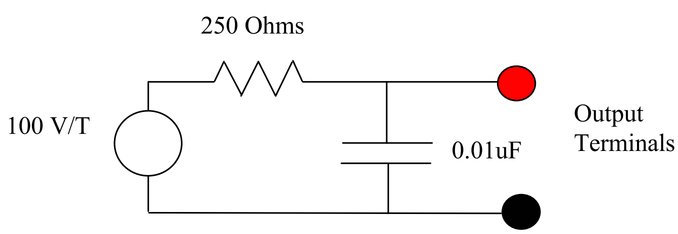

Figure 3-2 Equivalent output circuit

4 Making Short Male-Male Jumpers

These instructions have been made into their own manual located under the accessories section (product AC006). The AC006 manual shows you how to make them yourself, or, you can order them preassembled from www.Distinti.com

Figure 4-1