INSTRUCTION MANUAL

μMAG

Handheld Digital Magnetometer

Manufactured by

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GENERAL

The **μMAG** is a sophisticated and highly accurate instrument, yet it is simple and easy to use. There are no adjustments to make. Just turn the range knob from OFF to the range of interest and the field measurement appears on the 3 ½ digit display. The measurements are accurate to ±0.5% of full scale over the 0° C to 50° C operating temperature range.

A low impedance output is provided which can be used to connect the **μMAG** to strip chart recorders or data acquisition systems. This output maintains the same accuracy and stability as the digital display.

The **μMAG** is powered by a conventional 9 Volt battery. The **μMAG** may also be powered by a battery eliminator which may be purchased from MEDA or many other sources. See the section on BATTERY ELIMINATOR for its specification. The next section describes how to operate the **μMAG**. This is followed by some general information on maintenance. The section on Applications briefly describes how the **μMAG** can be used to solve some typical measurement problems.

OPERATIONS

The **µMAG** is turned on by rotating the range selection switch clockwise from the OFF position to any of the ranges. The switch should be returned to the OFF position after being used in order to preserve battery life.

Range Selection

The range is selected by aligning the vertical bar of the range selection switch with the number which represents the full-scale range in mG. This action also causes the analog output full-scale range to correspondingly change and the decimal point on the meter to adjust so that the meter reads in milliGauss (mG).

Probe Orientation

The displayed measurement represents the vector component of the magnetic field directed along the sensitive axis of the sensor which is indicated by an arrow on the top of the probe. The sensitive axis of the Longitudinal sensor is along the length of the probe. The sensitive axis of the Transverse sensor is across the width of the probe. A positive reading indicates the field vector is in the same direction as the arrow. The fluxgate sensor element, which is located near the probe tip (the end opposite the cable entry point), is approximately 1” square by about 0.5” high.

Analog Output

The **µMAG** analog output provides a low impedance buffered version of the signal going to the LCD panel meter. A dual banana plug is used to connect the **µMAG** to external devices. This output can be short-circuited without damaging the **µMAG** or disturbing the displayed measurements. If the cable connecting the **µMAG** to an external device is greater than six feet long, connect a low value resistor (100 to 1000 ohms) in series with the plus output at the **µMAG** end of the cable.

The output voltage range is ±2 Volts which corresponds to the full scale range selected by the range switch. The output voltage can be as great as ±4 Volts. Accuracy is not guaranteed for outputs beyond ±2 Volts.

Field Nulling Controls

The **µMAG-01N, µMAG-02N** and **µMAG-03N** models include controls for nulling the local ambient field to permit the measurement of small changes in the field. One control (left side of unit) selects the polarity of the nulling field and also turns the nulling field off. A second control (right side of unit) is used to adjust the magnitude of the nulling field from 0 to 750 mG (minimum). The magnitude control is equipped with a locking tab to secure the control from accidental movement once nulling has been achieved.

Use the following procedure to null the ambient field:

1) Secure the sensor so that it cannot move. Small angular motions in a large field can change the reading.

2) Set the polarity control in the OFF position, and turn the **µMAG** Range switch from the OFF position to the most sensitive range where the meter reading remains on scale.

3) Make sure the magnitude control is set to 0. Set the polarity switch to match the polarity of the value shown on the panel meter.

4) Rotate the magnitude control until the meter displays all zeros.

5) Change the range to the next more sensitive range and repeat step 4.

6) Lock the magnitude control.

You are now ready to measure and record changes in the ambient field.

Changing Sensors

The **μMAG-03** and **μMAG-03N** sensors are attached to the electronics unit with a connector which allows the user to switch sensors. For example, a Longitudinal probe can be interchanged with a Transverse probe or a different Longitudinal probe. Although neither the sensor nor electronics unit will be harmed if the **μMAG** is on during the interchange, it is highly recommended that the unit be off while changing the sensor. To switch sensors, turn the **μMAG** off, disconnect the first sensor then connect the replacement sensor. Before inserting the sensor connector into the electronics unit, rotate the sensor connector so that the arrow head on the sensor connector is facing up. Make sure the sensor connector is inserted all the way into the electronics unit connector.

After changing sensors, you may notice a slight difference in the measured value of the magnetic field. The zero offset of the sensor can change as much as 0.05 mG, and the sensitivity can change as much as 0.5%.

Battery Low Indicator

When the battery voltage drops below 5.1 Volts, the left most decimal point turns on indicating that the battery is low and should be replaced. The **μMAG** will continue to operate but the indicated field value may not be reliable.

Battery Eliminator

The **μMAG** may be powered by a 9 Volt battery eliminator which may be purchased from MEDA. The battery eliminator is connected to the **μMAG** through a standard barrel connector on the lower right side of the case. The battery does not need to be removed.

MAINTENANCE

The **μMAG** requires very little maintenance. There are no operator adjustments required. The electronics unit is housed in a shock resistant plastic case. This case is not watertight and should not be immersed in water. The LCD display may be cleaned using a damp cloth. Do not apply pressure while wiping the LCD.

The sensor probe may be immersed in water. It is encapsulated and the sensor cable is watertight.

Battery Replacement

The battery is contained in a compartment located on the lower back side of the electronics unit case. A sliding hatch door provides access. The **μMAG** was designed to be powered by a conventional 9 Volt alkaline battery. Other kinds of 9 Volt batteries may be used. A list of some of these batteries is given below:

Manufacturer	Part Number	Type
Eveready	No. 522	Alkaline
Duracell	MN1604	Alkaline
Eveready	E146X	Mercuric Oxide
Duracell	DA146	Zinc/Air
Ultralife	U9VL	Lithium

The zinc/air battery will last about twice as long as the alkaline battery. A Lithium battery will provide the longest operating time (approximately three to four times longer than an alkaline battery).

Calibration Schedule

The **μMAG** will remain within specifications for at least one year. The **μMAG** should be recalibrated annually to assure that its performance remains within specifications. MEDA can perform the calibration which includes a Certificate of Calibration traceable to the National Institute of Standards and Technology (NIST).

Precautions

Although the **μMAG** is a very rugged and reliable instrument, some precautions are required to prevent its performance from being adversely affected.

- Never place the sensor probe close to a source of a large magnetic field such as a magnet. This can cause the zero field reading to be permanently shifted.

- Do not drop the sensor onto a hard surface or strike it with a hammer or other object. This could cause internal damage to the fluxgate sensor element which will result in erratic behavior and zero instability.

- Protect the electronics unit from moisture when operating outside in inclement weather.

- Do not open the electronics unit. The **μMAG** cannot be repaired by the user without invalidating its calibration. If there appears to be a problem with the instrument, call MEDA for technical support.

APPLICATIONS

The **μMAG** has many applications including measuring Earth's magnetic field, determining the magnetic signature of vehicles, measuring shielding effectiveness, determining the magnetic moment of an object, detecting magnetic anomalies, counting magnetized objects, and screening parts for magnetic contamination. The following subsections illustrate how to use the **μMAG** by describing some examples of applications.

Earth's Magnetic Field

Most of us are aware that Earth has a magnetic field of its own. We are all familiar with compasses. The compass needle is itself a magnet and, when placed in Earth's magnetic field, it points toward the north magnetic pole which coincidentally is very near the geographic pole. The reason the compass needle points north is because the Earth's field interacts with the field of the compass needle, causing a torque on the needle. This torque causes the needle to align with the magnetic field vector in the plane in which the compass needle rotates.

The compass needle only provides us with directional information about the vector pointing to the magnetic north pole. The **μMAG** can be used to measure both the DIRECTION and MAGNITUDE of the Earth's field vector as well as its north-south, east-west, and vertical vector components. Follow the steps described below. Make sure you are outside and at least ten feet away from any magnetic object (anything made from iron or steel).

1) Tape a piece of paper to a level surface made from non-magnetic material. Place the probe on the paper.

2) Set the **μMAG** on the 2000 mG range and rotate the probe for a zero reading. Draw a straight line on the paper along the edge of the probe.

3) Use a protractor or right angle triangle to draw a line at 90 degrees to the first line. Align the probe edge along this line and record the **μMAG** reading. This is the horizontal component (*H*) of the Earth's field.

4) Orient the probe in the vertical direction with the end flat against the surface where the two lines cross. Record the **μMAG** reading. This is the vertical component (*V*) of Earth's field.

5) Compute the total field magnitude $F = \sqrt{H^2 + V^2}$.

6) Compute the inclination of the field $I = \arctan(V/H)$ radians.

The first line drawn on the paper is the east-west direction. The second line is the north-south direction. The Inclination angle is the angle between the Earth's magnetic field vector and the horizontal plane.

A positive reading when measuring H indicates the direction of the north magnetic pole.

Table 1.0 lists the approximate values of I, H, V, F and D (magnetic declination) in several U.S. cities. This data was determined by using a computer model available from the U.S. Department of Commerce. The magnetic declination can be used to determine the Geodetic north. If the sign is positive then the Geodetic north is west of the magnetic north. If it is negative then it is east of the magnetic north.

Table 1 Magnetic Data for Some U.S. Cities

City	H(nT)	V(nT)	F(nT)	I (deg)	D (deg)
Washington, DC	20,535	49,866	53,929	67	-13
New York, NY	19,508	51,553	55,121	69	-13
Miami, FL	25,721	39,768	47,360	57	-3
Chicago, IL	18,643	53,922	57,054	71	-1
Denver, CO	21,509	50,636	55,015	67	11
San Francisco, CA	25,094	36,658	44,424	56	-16
Los Angeles, CA	25,283	42,260	49,246	59	14
San Diego, CA	25,674	41,413	48,726	58	14
Seattle, WA	19,208	52,742	56,131	70	20
New Orleans, LA	24,797	43,902	50,421	61	2
Boston, MA	18,881	52,003	55,324	70	-16

H - Horizontal Component V - Vertical Component

F - Total Field Magnitude I - Inclination

D - Declination

Package Inspection

The U.S. Federal Aviation Administration (FAA) requires that a package which contains magnetic material must be inspected to make sure that its influence on the local field will not affect magnetic navigational equipment. The **μMAG** can be used to perform this inspection. Its 1nT sensitivity and 0.5% accuracy are more than adequate to meet the FAA requirement.

The specification requires that the package produce a change in the magnetic field of less than 525 nT at a distance of 15 feet from its geometric center. When performing this test, it is important that the sensor and package be well away from objects which are made of magnetic material that can interact with ‘the magnetic field of the package. Objects which are made of iron or steel should be at least ten feet away from the closest point of the sensor or package. Reinforcing rods in the cement floors of a building can cause problems. Keep the package at least three feet above the floor.

The person performing the test should remove any objects from his or her body such as belt buckles, watches or keys which can cause an error in the reading. Also, no objects other than the package under test should be moved during the test. The test site should be at least fifty feet away from a roadway or parking lot where automobiles might be driving by.

The test method is described below:

1) Place the **μMAG** probe in a horizontal position on a non-magnetic structure at approximately the same height above the floor as the geometric center of the package. The line joining the probe and package should be approximately east-west.

2) With the package removed, rotate the probe in the horizontal plane until the **μMAG** reads zero within 10 nT. If you have a **μMAG** with nulling controls, use them to null the field instead of rotating the probe. Record the meter reading.

3) Place the package under test at a horizontal distance of fifteen feet from the probe and in line with the arrow on top of the probe. The geometric center of the package should be at the same height as the probe. The line joining the probe and package should be at right angles to one side of the package.

4) Slowly rotate the package one revolution about the X axis while observing the **μMAG** display. Record the maximum reading.

5) Repeat step 4 for the Y and Z axes. If any maximum reading exceeds 525 nT, the package has failed inspection.

6) Remove the package and record the **μMAG** reading. If the difference between this and the step 2 reading is greater than 10 nT, then repeat the test.

Calibrating Solenoids

The solenoid is one of the simplest and easiest ways to generate a uniform magnetic field. It can be constructed using tubing made from non-magnetic material, such as PVC which can be purchased from a plumbing supply store. The field inside the solenoid is uniform over a large volume.

The field at the very center of the solenoid directed along its length is

$$H = \frac{0.4\pi NI}{L\sqrt{1+\left(D/L\right)}} \text{ Gauss}$$

where *I* is the current in the solenoid (Amperes), *N* is the number of turns, *L* is the length of the solenoid (cm) and *D* is the diameter of the winding (cm).

The magnitude of the field depends on the number of turns per cm, the current and the ratio of coil diameter-to-length. The turns per cm are determined by the wire diameter, if closely packed, or by the spacing between turns. Long thin solenoids are very insensitive to changes in coil diameter.

The solenoid can be calibrated using the **μMAG**, a precision voltmeter, a voltage source and a precision resistor. The resistor should have a sufficient power rating and temperature coefficient so that its value will not change more than 0.1% when passing the calibration current. The voltage source must be very stable during the calibration period. A bench top power supply is not usually good enough. The voltage should not change more than one part in 10,000 over the period of calibration.

If these conditions are met, the calibration procedure described below should yield a coil constant (mG per mA) which is accurate to better than 1%.

The solenoid should be at least three feet away from any ferromagnetic object, otherwise its presence may influence the field inside the solenoid.

1) Place the **μMAG** probe at the geometric center of the solenoid with the arrow on the probe being parallel to the long axis of the solenoid.
2) Rotate the solenoid and probe until the **μMAG** reads less than 10 nT. Put the **μMAG** on the 2000 mG range.
3) Adjust the voltage source until the **μMAG** reads 1000 mG. Record the voltmeter reading.
4) Reverse the solenoid leads so that the current is flowing in the opposite direction.
5) Adjust the voltage source until the voltmeter reads the same value recorded in step 3.
6) The **μMAG** should indicate about 1000 mG but with a polarity which is opposite to that observed in step 3. Add the magnitude of the step 3 and step 6 **μMAG** readings and divide by 2.
7) Divide the voltmeter reading by the resistance value to compute the current which produced the field.
8) Compute the solenoid coil constant by dividing the field magnitude computed in step 6 by the current computed in step 7.
9) Disconnect the voltage source and read the **μMAG**. If the reading is greater than 1 mG then repeat the calibration procedure.

MAGNETIC FIELD CONVERSION FACTORS

1 gamma	=	1 nanoTesla (nT)
1 Tesla	=	10^4 Gauss
1 Tesla	=	1 Weber/meter^2
1 Ampere/meter	=	$4\pi \times 10^{-2}$ Oersted
1 Weber	=	1 volt-second
1 Gauss/Oersted	=	$4\pi \times 10^{-7}$ Henry/meter

SPECIFICATIONS

Ranges	: ±2000, ±200.0, ±20.00 mG full scale (FS)
Resolution	: 1 part in 2000 (1nT on 20 mG range)
Accuracy	: ±0.5% of FS ±1 count
Power Consumption (at 9 Volts)	
μMAG-01, μMAG-02	: 150 milliwatts maximum
μMAG-01N, μMAG-02N, μMAG-03	: 225 milliwatts maximum
μMAG-03N	: 315 milliwatts maximum
Power Source	: 9 Volt alkaline battery
Analog Output	: ±2 Volts FS
Frequency Response	: 100 Hz standard, 400 Hz optional
Linearity	: 0.05% of FS
Weight	: 15 oz. (0.425 Kg) including sensor
Temperature Range	: 0 to 50° C
Display	: 3 ½ digit LCD

WARRANTY

This instrument is warranted by Macintyre Electronic Design Associates, Inc. (MEDA) to be free from defects in materials and workmanship. If a defect is discovered within one (1) year from date of purchase, MEDA will service the instrument as long as the original purchaser returns it to our factory. The original purchaser must prepay all transportation charges and demonstrate that the defect is covered by this warranty. Model and serial number must be supplied when returning for service.

If the cause of the instrument failure is found to be misuse or abnormal operating conditions, repairs will be billed at cost upon authorization from the purchaser.

Under no circumstances will MEDA's liability exceed the cost to repair or replace the defective parts. MEDA's liability will cease and terminate at the completion of the one year warranty period.

OTHER MEDA PRODUCTS

- High sensitivity wide bandwidth Induction Coil Magnetic Field Sensors covering the 0.2 Hz to 200 kHz range.
- Single and three channel portable Sensor Signal Conditioners.
- Three-axis Helmholtz Coil Systems.
- Handheld ELF Magnetometers for power line frequency and video display terminal magnetic field measurements.
- Hi-Rel Satellite Magnetometers for measuring the three components of a magnetic field.