Operation Manual for

Mag-01 & Mag-01H Single Axis Fluxgate Magnetometers with Mag Probes B-G

Bartington® Instruments

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1. About this Manual

This manual describes the installation, operation and maintenance of the Mag-01 and Mag-01H Magnetometer. It should be read in conjunction with the product brochure DS0003, which can be found on the Mag-01 and Mag-01H product page on the Bartington Instruments website at: www.bartington.com. Probe outline drawings are also available on this page.

See Application Note AN0045: 'Magnetic Units and Measurements', available from Bartington Instruments, for important information about magnetic field measurement units.

1.1. Symbols Glossary

The following symbols used within this manual call your attention to specific types of information:

WARNING: Indicates a situation in which serious bodily injury or death could result if the warning is ignored.

Caution: Indicates a situation in which bodily injury or damage to your instrument, or both, could result if the caution is ignored.

Identifies items that must be disposed of safely to prevent unnecessary damage to the environment.

Note: Provides useful supporting information on how to make better use of your purchase.

2. Safe Use

WARNING: The Mag-01 and Mag-01H can be powered by mains electricity, either in operation or during their battery charging cycle, and contain uninsulated parts. Ensure that the unit is properly earthed at all times. Only properly trained personnel should carry out procedures described in this manual which require the casing to be opened.

WARNING: These products are not qualified for use in explosive atmospheres or life support systems. Consult Bartington Instruments for advice.

3. Introduction

The Mag-01 and Mag-01H magnetometer systems are intended for the measurement of relatively weak (nT), slowly varying (10Hz max) magnetic fields in one axis.

The system comprises one of a range of compact fluxgate probes connected by a cable to a compact electronics unit (the magnetometer).

4. The Magnetometers

4.1. Introduction to the Magnetometers

4.1.1. Mag-01 Front Panel

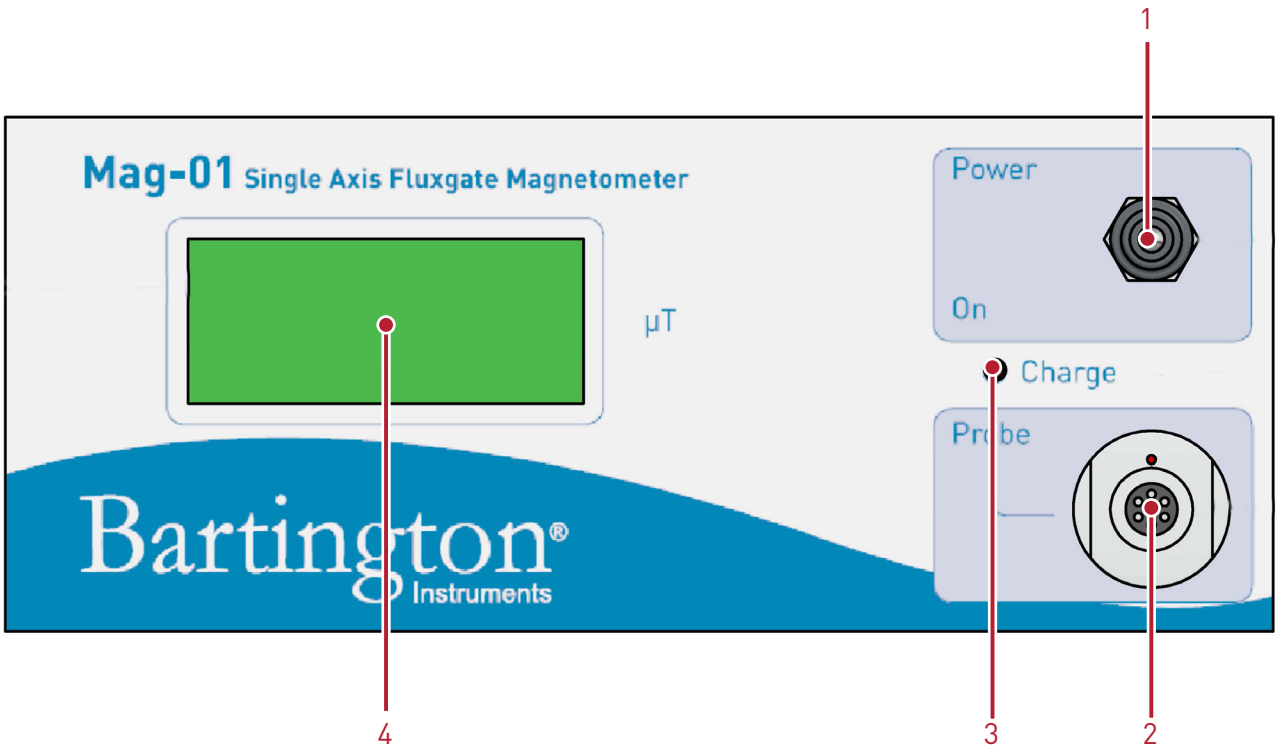

Figure 1. Mag-01 front panel functions.

Key to Figure 1

1. Power switch.
1. Waterproof connection to probe.
1. Charge light, illuminated when internal batteries are on charge.
1. 4½ digit LCD display. Displays directly in microtesla. Autoranging: decimal point shifts to LEFT when display value decreases below 10.00; RIGHT when display value increases above 19.999. Battery voltage automatically displayed at switch-on: 5V minimum.

4.1.2. Mag-01H Front Panel

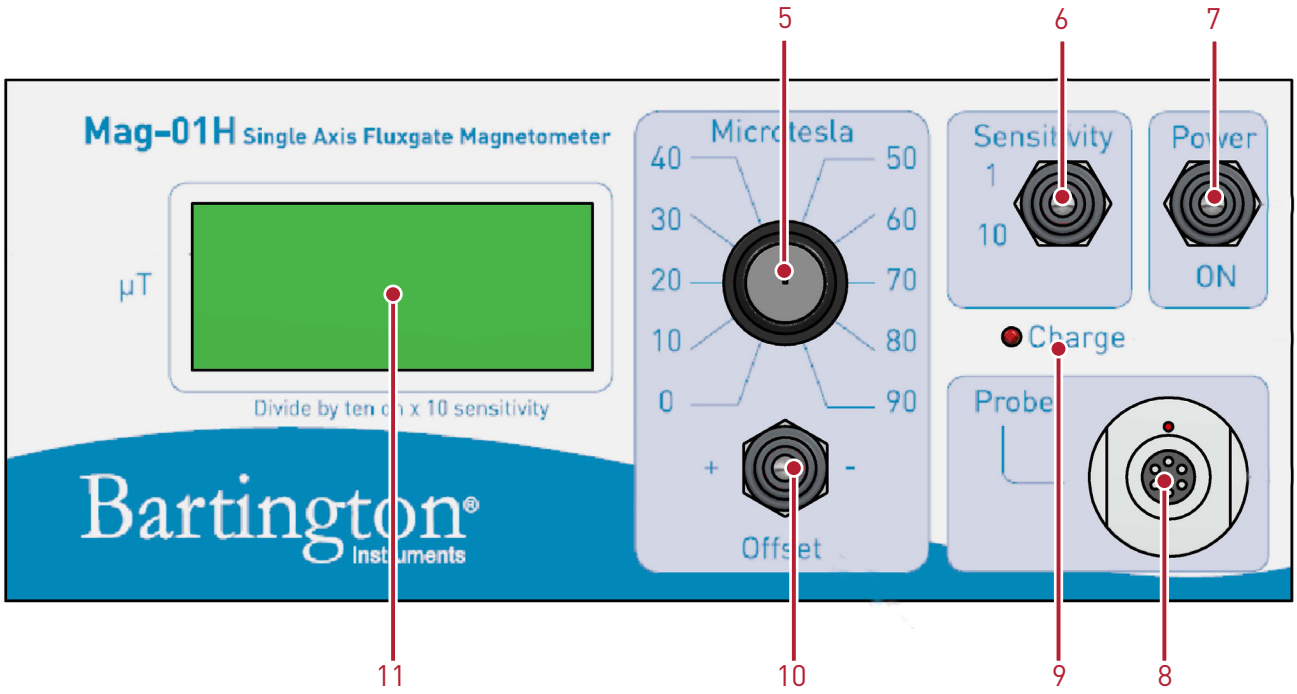

Figure 2. Mag-01H front panel functions.

Key to Figure 2

5. Offset control switch. This and the offset toggle switch [10] are used to apply an offset signal to the probe from 0 to ±90μT in 10μT steps. See Using the Offset Control.
6. Sensitivity selector. Select x10 to achieve 0.1nT sensitivity. Does not modify offset.
7. Power switch.
8. Waterproof connection to probe.
9. Charge light, illuminated when internal batteries on charge.
10. Offset toggle switch. See [5].
11. 4½ digit LCD display. Displays directly in microtesla at x1 sensitivity. See Using the Sensitivity x10 Control. On x10 sensitivity the displayed value is a factor of 10 larger than the true value, e.g. if the displayed value shows 0.1 (100nT); then the true measurement equals 0.01 (10nT). Autoranging: decimal point shifts to LEFT when display value decreases below 10.00; RIGHT when display value increases above 19.999. Battery voltage automatically displayed at switch-on: 5V minimum.

4.1.3. Mag-01 and Mag-01H Rear Panel

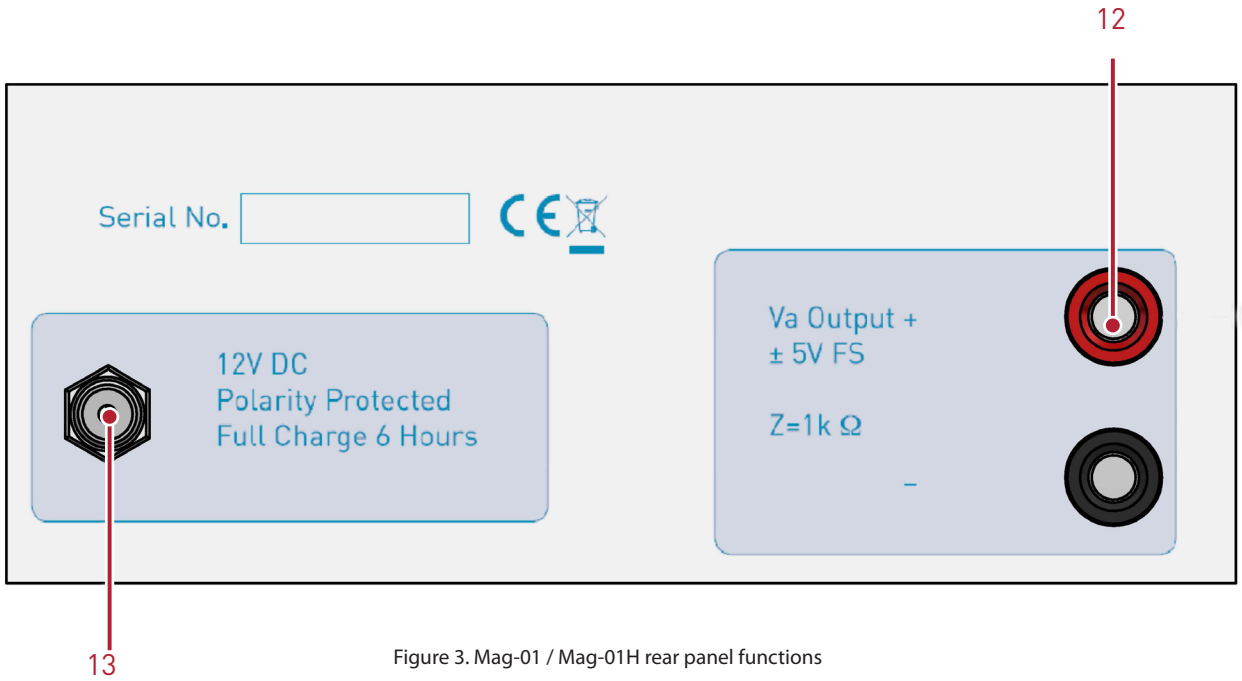

Figure 3. Mag-01 / Mag-01H rear panel functions

Key to Figure 3

12. Analogue output. ±5V maximum = ±500µT. Offsets and range change apply. (For high field probe D ±4.5V = ±4.5mT.)
13. 2.1mm DC inlet. Charge from mains adaptor or vehicle dashboard cable. Voltage may be between 9-18V. The input is polarity protected against accidental incorrect connection.

4.1.4. Operation

The magnetometers contain circuitry to convert the signals produced by the probe into a measurement of flux density. This is displayed on the front panel LCD, or in the form of an analogue output voltage for connection to a DVM or acquisition unit. A rechargeable battery is included, making the unit suitable for portable use.

The use of low signature components, including a non-magnetic battery, allows the magnetometers and probes to be used as close together as 0.5 metres without errors becoming significant.

A precision voltage-to-current converter maintains precise calibration over the full range of operating temperatures.

The additional features of the Mag-01H include a x10 sensitivity control to increase resolution, and a precision offset control to expand the measuring range.

Both instruments display the battery voltage for 2 to 4 seconds after switch-on. An audible alarm signals when the battery should be recharged.

4.2. Circuitry

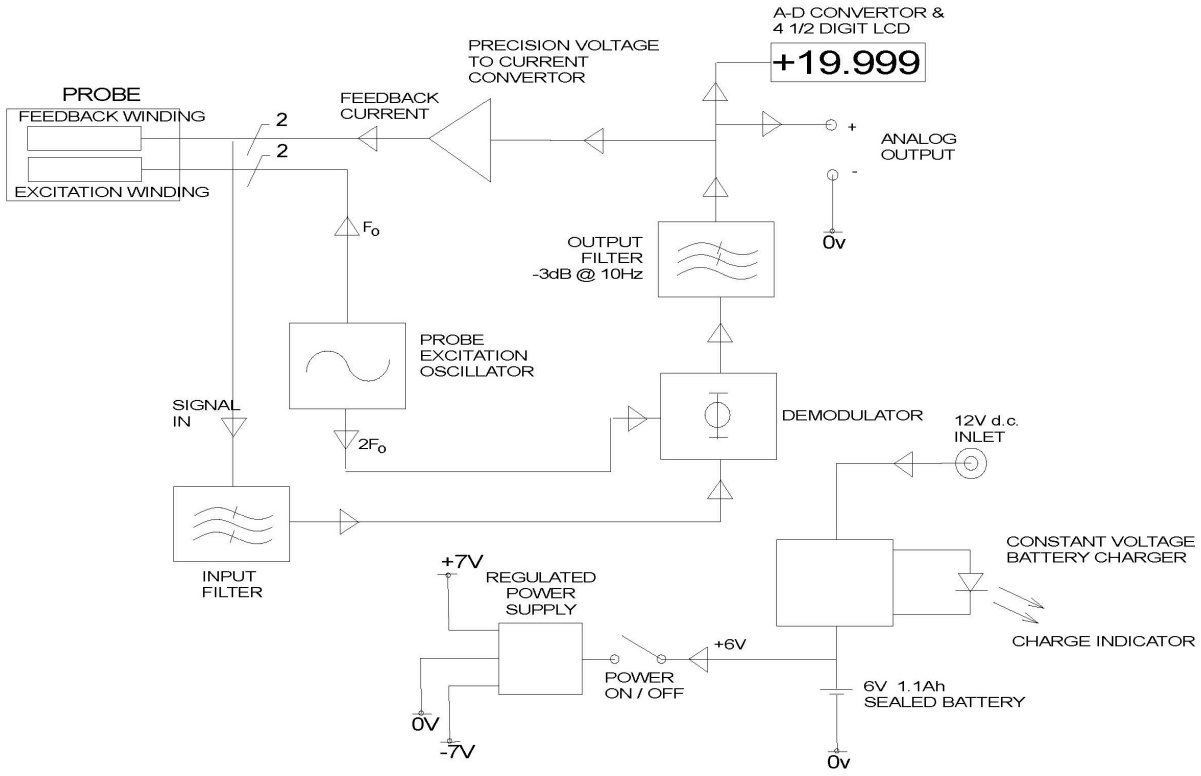

Figure 4. Mag-01 system schematic

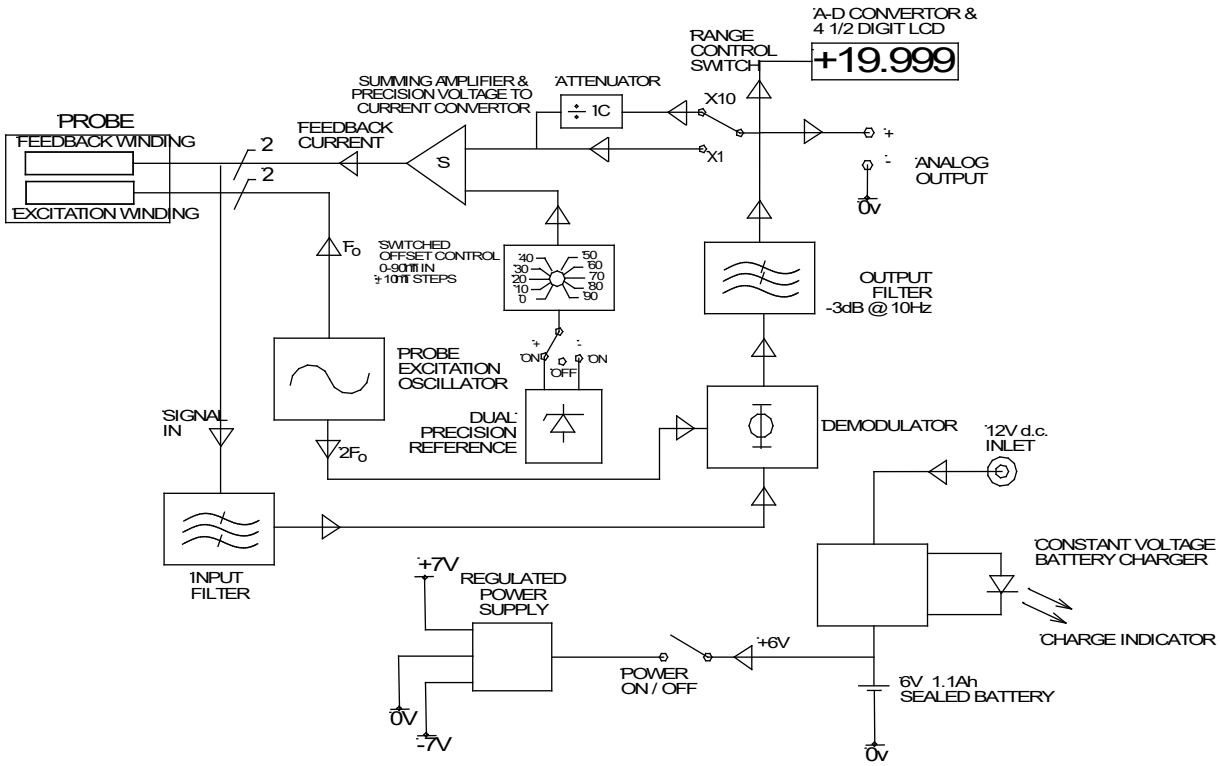

Figure 5. Mag-01H system schematic.

See Figures 4 and 5 for circuitry diagrams. See Introduction to the Probes for the principles of fluxgate operation.

The alternating field used in the operation of the probes is driven by a high purity alternating signal (the excitation signal) from the probe excitation oscillator to the excitation winding.

The axial component (i.e. the component aligned with the axis) of any magnetic field intercepted by the probe produces a signal which is filtered to eliminate unwanted noise from the excitation signal. Following detection, any error arising from the processing is fed back to the probe via a current converter and the feedback winding, where nulling of the magnetic field occurs.

In this way, with the error removed, a precise measurement of field strength is obtained in the form of a voltage which is fed to the auto-ranging 4½ digit display and analogue output socket.

The battery charger, rechargeable battery and voltage regulators power the electronics unit.

4.2.1. Additional Circuitry for Mag-01H

The Mag-01H contains an attenuator which, when selected by the x10 range control switch, reduces the current feedback to the probe and thereby increases the sensitivity by a factor of 10.

The Mag-01H also contains a switched precision offset current control which can be used to back-off field strength values and thereby display or record measurements to the highest resolution.

4.3. Power Supplies and Battery Charging

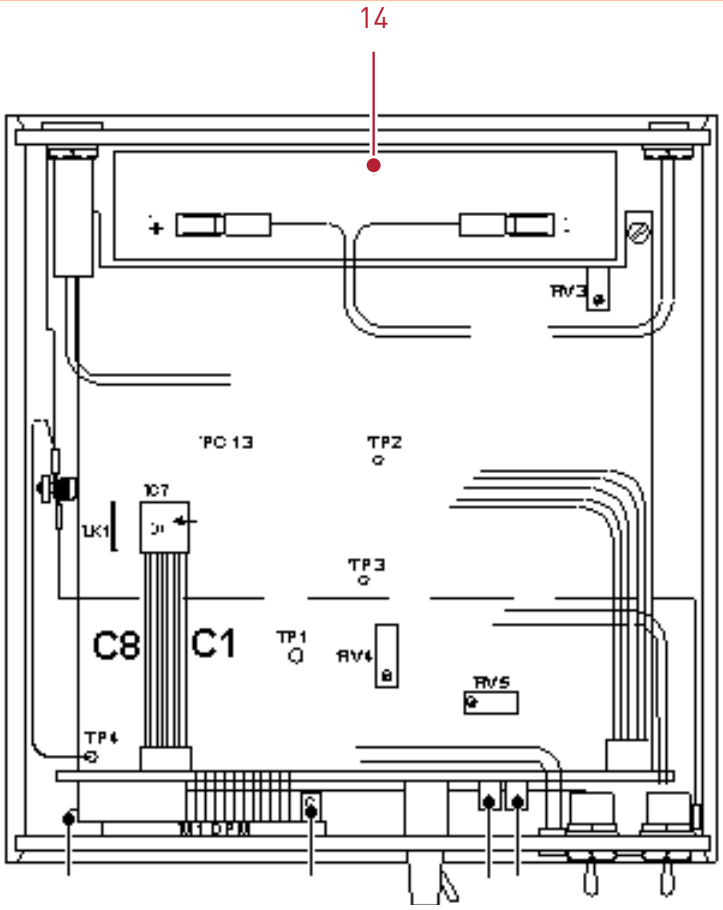

Figure 6. Mag-01H: internal view

Key to Figure 6

14. Battery 6V 1.2Ah lead acid gel type

The instruments are powered either continuously from the mains, via a power supply, or from the internal 6V rechargeable battery. The battery provides more than 12 hours continuous use. It can be recharged at 12V, either from the mains or from a vehicle battery. Recharging is completed in 5 hours and overcharging is virtually impossible. The 12V (6-18V DC) external power supply inlet is protected against incorrect polarity supplies.

A charge indicator on the front panel is illuminated when the external supply is connected.

> **Note:** If the instrument is to be powered continuously from the mains supply, for example where it is to be built into a larger system, the internal battery will not be required. The battery can be taken out of service by disconnecting it.

Caution: Care must be taken when disconnecting the battery, if unsure please ask a qualified service person or seek advice from Bartington Instruments.

Disconnect the battery in the following way:

i. Ensure that the battery is fully charged. In this way it will not degrade for periods of non-use up to 1 year.

ii. Open the instrument case by removing the two retaining screws located at the edges of the instrument base. Remove the cover of the instrument, leaving the front and rear panels located in the base. The battery will be seen supported on the rear panel of the instrument. (See Figure 6.)

iii. Remove one of the push-on battery connectors and tape it to the side of the battery.

WARNING: The battery can deliver a current of several tens of amperes. Do not, under any circumstances, allow any conductive material to form an electrical pathway between the positive and negative terminals of the battery.

iv. Replace the instrument top cover.

Note: To maintain the life span of the internal rechargeable battery it should be recharged at least once a year.

4.4. The Autoranging Display

The front panel LCD reads directly in μT when the instrument is used with the low field (0.2mT) Mag probes type B, C and F. Display values should be multiplied by 10 to obtain true readings when using the high field Mag probes (2.0mT) type D, E and G.

The display is autoranging. It provides three places of decimal resolution at low values (<10.000) and two places of decimal resolution if values exceed 20.000.

Built-in hysteresis prevents undesirable range hopping.

Should the full-scale range of ±199.99 be exceeded, the LCD will over-range and the display will show ±1_____.

4.5. Analogue Output

Analogue output frequency response for the Mag-01 and Mag-01H is shown in figure 7 below.

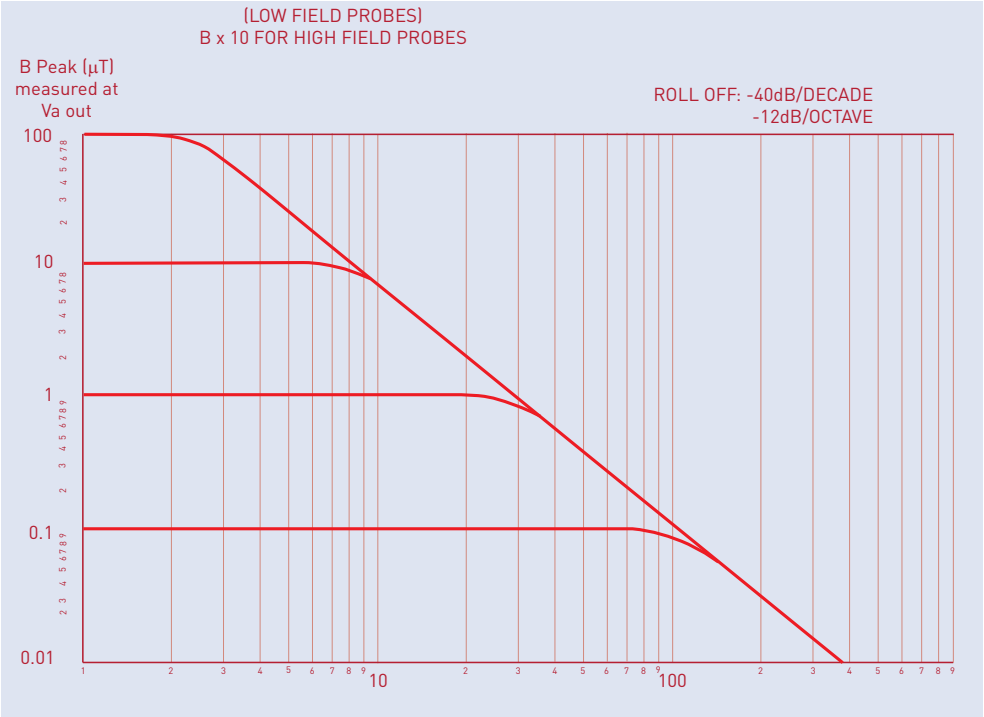

Figure 7. Mag-01H Analogue Output Frequency Response

The Mag-01 is primarily intended for the long term precise investigation of static or slowly varying, low intensity magnetic fields. The frequency response of the instrument is tailored to remove noise from high frequency sources. The output frequency response is slew rate limited and a screened connecting cable is recommended with the screen grounded at one end only.

When using the analogue output, the full scale range will, for the low field probes, exceed the ±2V range monitored by the LCD and will be ±5V full scale. Due to the internal resistance of the high field probes the analogue output voltage can only be considered linear with respect to the magnetic field up to ±4.5V.

For the cryogenic probe type F the measuring range on the analogue output is ±0.2mT.

5. The Probes

5.1. Introduction to the Probes

The range of probes for low field and high field are described in the product brochure.

The probes B-G are of dual core fluxgate design. A pair of high permeability cores are driven in and out of saturation by an AC signal applied to the two excitation coils. A third pick-up coil is

wound around the two cores to detect any imbalance of saturation between them, this generates a voltage proportional to the external field.

A feedback arrangement designed to null the field injects a feedback current through the pick-up coil to oppose the background field.

5.2. Probe Cables

The probe connecting cable is a four-conductor overall screened type, as indicated in the product brochure. The cable length with which the probes are normally supplied and the length to which this can be extended are also described in the brochure.

> **Note:** If extending the cable beyond the length indicated in the product brochure, use a cable of a lower conductor resistance. This will avoid measurement errors.

5.3. Types of Probe

Probes are available in sensitivity ranges and constructions as indicated in the product brochure. Each is identified by a code letter on the label affixed close to the plug on the probe cable.

For axial construction, the sensing direction is in the direction of the connecting cable entry. For transverse probes, the element is in the T section which is perpendicular to the direction of cable entry.

The measuring range stated for each probe is that which is obtained on the LCD with no offset applied (Mag-01H only).

The following table shows the standard probes available:

Type	Low field probes (0 to 0.2mT)*	High field probes (0 to 2mT)
Axial	Mag B Probe	Mag D
Transverse	Mag C Probe	Mag E Probe
Cryogenic	Mag F Probe	Mag G Probe

> **Note:** * The LCD of the magnetometer is limited to ±0.2mT maximum.

A magnetometer probe switch unit is available for the sequential selection of two or three Mag probes, types B - G, for operation with a single Mag-01 or Mag-01H instrument. The Mag probes can be operated at a distance of up to 25 metres from the switch unit.

5.3.1. Standard Packaging Probes (Types B, C, D, E)

Note: When clamping these probes in fixed installations, the clamp pressure should not be applied in the region of the sensing element. These probes are engraved with an arrow indicating the sensing direction and a spot indicating the centre of the sensitive region.

The sensing axis of the B and D probes is in line with the axis of the cylindrical enclosure. The sensing axis of the C and E probes is along the axis of the short cylinder at the end of the probe. The magnetic detection axis and centre of sensitive volume are marked on each probe.

5.3.2. High Field Probes (Types D, E, G)

Note: When using the high field probes, the displayed values and offset (Mag-01H) should be multiplied by 10 to obtain the true reading. For these probes the maximum analogue output range is ±4.5V, with the maximum range of the LCD limited to 2mT.

5.3.3. Cryogenic Probes (Types F, G)

Note: The cryogenic probes are suitable for operation at temperatures down to that of liquid helium and have 1m of 4 x 0.2mm enamelled copper wires connected to the element, for use in a cryostat. This length can be extended to a maximum of 5m if required.

Note: The cryogenic probe can be mounted by bonding, using a minimal mount epoxy adhesive, or by loosely supporting the probe within a tube.

Note: The potted section on the solder terminal contains variable resistors that may be affected by low temperatures. It is therefore recommended these are kept at room temperature, outside any cryogenic chamber.

Note: The four enamel-coated 1m x 0.2mm diameter copper connecting wires should be subjected to the minimum amount of flexure to avoid fractures. The probes are unprotected and should be handled with great care.

Note: When mounting the cryogenic probe, the copper sensor wires should be either fed through an access hole in the chamber or disconnected from the electronics and soldered directly onto a feedthrough connector. The outside of the feedthrough should then be connected to the board.

Note: For wiring information, please refer to drawings DR2908 (Mag F Probe) and DR2909 (Mag G Probe) on the product page of the Bartington Instruments website.

5.3.4. Proximity Effects

Note: Mag cryogenic probes can only operate in close proximity to each other if they are mutally orthogonal. Otherwise, to avoid interaction, no two Mag cryogenic probes should be operated within 10mm of each other.

6. Operating Instructions

Refer to figures 1, 4 and 5.

6.1. Switching On

Connect the probe selected to the probe socket and switch on the magnetometer.

> **Note:** The plug locking mechanism requires that the outer shell of the plug is retracted (towards cable) during insertion and removal.

For the first 2-5 seconds following switch-on, the battery voltage will be displayed on the LCD.

> **Note:** If the battery voltage is below 5V then the instrument must be put on charge immediately. An audible alarm will also signal when the battery requires recharging. The instrument should never be left in a discharged state as the capacity of the battery will be adversely affected.

Some increase in noise can be expected during the first few minutes of charging. The charging circuit is temperature compensated and the instrument may be left on charge indefinitely without harm to the battery.

The optimum stability of the magnetometer will be achieved in approximately 10 seconds following switch-on. Check that the instrument is working by subjecting the probe to a slowly varying magnetic field. This is best done for a free probe by rotating it in the earth's magnetic field and observing the change in values. The geomagnetic field will be between 30μT and 90μT.

6.2. Magnetic Hygiene

Any object that is magnetic, or has a high magnetic susceptibility, may cause a change in the surrounding magnetic field and therefore to the field measured by the Mag-01H. Ensure that the operator and the surrounding environment are magnetically clean when perfoming measurements.

Caution: Avoid any exposure of the probes to very high fields. (Fields up to 1T have been shown to cause no permanent damage or impaired performance.) The instrument will fully recover from severe overload in around 5 seconds.

6.3. Using the Offset Control (Mag-01H only)

To obtain the maximum resolution on the autoranging LCD, the bipolar offset control can be used to add a positive or negative offset to the field strength experienced by the probe.

Example: if F=90.00μT and offset is set to -80, then the display will then show +10.00.

Note: If possible, select a setting which produces three places of decimal resolution on the display.

6.4. Using the Sensitivity x10 Control (Mag-01H only)

With this set to x10, all displayed values must be divided by 10.

Example: In a field with strength 11.185μT, on the x10 setting the display will show 111.85. Divide this value by 10 to get the correct measured result of 11.185μT.

6.5. Battery Replacement

Should the internal battery fail to provide at least 10 hours continuous use after two years service, it will need replacing. The instrument can be returned to the company's agents if they provide service, or to Bartington Instruments in the UK. Alternatively customers can carry out battery replacement themselves as follows.

6.4.1. Instructions for Battery Replacement

Open the case in the manner described in Power Supplies and Battery Charging.

Remove the two case retaining screws in the base of the instrument and remove the top cover. Disconnect the battery leads (Mag-01) or the battery connector (Mag-01H) and fit a replacement battery. Re-connect.

6.6. Electromagnetic Compatibility

The Mag-01 and Mag-01H instruments contain no high frequency electronics likely to cause emissions which could affect other apparatus. The design, including the use of a rechargeable battery that is charged from a mains adaptor, and decoupling of internal power supplies, is intended to produce minimal emissions. Other equipment operating in the area is therefore unlikely to be affected.

The unit is also unlikely to be affected by interference from other equipment in the normal operating environment. However the sensors, being designed to measure magnetic fields, are susceptible to electromagnetic interference, and operation close to high frequency sources of radiation should be avoided. Interference is indicated by instability in the reading when the probe is maintained in a fixed position.

7. Troubleshooting, Care and Maintenance

7.1. Troubleshooting

Special equipment is required for the diagnosis of faults within the unit. Much of this equipment is beyond the scope of normal service facilities. Therefore, in the event of any apparent malfunction, please email service@bartington.com or telephone the Bartington Instruments service team on +44 (0)1993 706565. Attempted repair or opening of the casing by users in a manner or for reasons other than given in the manual may invalidate the warranty.

A re-calibration service is available which is traceable to international standards.

7.2. Checking the System

7.2.1. Battery Check

Connect the battery charger to a live supply. The charge indicator on the magnetometer should illuminate.

After 10 to 20 minutes, switch on the magnetometer. The battery voltage is shown for a few seconds at switch-on and should be between 6.5V and 7V.

Disconnect the battery charger. Switch the magnetometer off and on again. The battery voltage should not be less than 6V.

7.2.2. Functional Check

Set the sensitivity switch to x1. Vary the orientation of the probe with respect to the direction of the Earth's magnetic field. The LCD should respond with changes in sign and magnitude.

Orientate the probe so that the LCD indicates some low value, e.g. approximately 5nT (+0.005µT).

Momentarily select x10 sensitivity. The LCD should respond by displaying +0.050. Alternatively select ±30µT using the offset control. The LCD should respond by ±30 µT.

7.2.3. Over-range

If the magnetic field reading is above the maximum range of the display a 1 will be displayed. It may be possible to use the negative offset option to bring the value back into a range that can be displayed on the LCD.

Should the cable fail due to fatigue or damage, the LCD will always read as if over-ranged.

7.3. Care and Maintenance

Note: Surface or dirt contamination should be removed using a mild detergent solution only. If the connector pins become contaminated then they should be lightly cleaned with a swab of isopropyl alcohol.

8. Storage and Transport

Your magnetometer is a precision electronic instrument and should be treated as such.

Note: Avoid exposing this instrument to shocks or continuous vibration.

Note: Store only within the temperature range as indicated in the product brochure.

Note: Do not expose this instrument to strong magnetic fields while being stored.

8.1. Shipping your Instrument with a Battery

Batteries, and equipment containing batteries, should only be shipped in accordance with local regulations. Refer to the IATA website (www.iata.org) for regulations regarding air transport.

Caution: If there is any doubt at all as to the integrity of a battery (for example, cracked or dented casing) then it **must not** be shipped. Remove it from the equipment and dispose of it according to local regulations.

When changing batteries in this equipment, ensure that the replacement battery is of the same type as described in the product brochure.

9. End of Life Disposal

This product should not be disposed of in domestic or municipal waste. For information about disposing of your sensor safely, check local regulations for disposal of electrical / electronic products.

9.1. Waste Electrical and Electronic Equipment (WEEE) Regulations

This sensor complies fully with Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) and WEEE Regulations current at the time of printing.

Notes

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