

*Operation Manual for  
Mag-03 Three-Axis Magnetic Field Sensors*



## Table of Contents

1. About this Manual	4
1.1. Symbols Glossary	4
2. Safe Use	4
3. Introduction	4
4. General Description	5
5. Enclosures	5
6. Compatible Power Supply and Data Acquisition Units	6
7. Cables and Connectors	6
7.1. Cables	6
7.2. Mating Connectors	6
7.3. Mag-03MSS Connection	7
7.4. Mag-03MSS-TC	7
8. Accessories	8
8.1. Mag-03 Calibration Unit	8
8.2. Mounting Accessories	8
9. Mounting	8
10. Operation	9
10.1. Connector Pin Allocation	9
10.2. Interface	9
10.3. Power Supplies	9
10.4. Signal/Power Ground	10
10.5. Independent Elements, Flying Leads and Two-Part Construction Sensors	11
10.6. Connecting Power	11
10.7. Electromagnetic Compatibility	11
11. Performance	12
11.1. Frequency Response	12
11.2. Noise	12

11.3. Excitation Frequency	13
11.4. Over Range	13
12. Signal Processing	13
13. Troubleshooting, Care and Maintenance	14
13.1. Troubleshooting	14
13.2. Care and Maintenance	14
14. Storage & Transport	14
15. Disposal	15
15.1. Waste Electrical and Electronic Equipment (WEEE) Regulations	15
Notes	15

## 1. About this Manual

This manual describes the installation, operation and maintenance of the Mag-03 range of three axis magnetic field sensors. It should be read in conjunction with the product brochure [DS0013](#), which can be found on the product page of the Bartington Instruments at: [www.bartington.com](http://www.bartington.com).

Details of the enclosures, mounting, connector dimensions, connector pin allocation and the position of the sensing elements relative to the enclosure are given in [outline drawings](#) on the product 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:** These products are not qualified for use in explosive atmospheres or life support systems. Consult Bartington Instruments for advice.

## 3. Introduction

These compact, high performance sensors with integral electronics provide measurements of static and alternating magnetic fields in three axes. The sensors, also described as magnetometers, convert magnetic flux density, measured in three axes, into a bipolar analogue voltage. Analogue output voltages  $V_x$ ,  $V_y$  and  $V_z$  vary linearly with magnetic flux density.

The analogue output is positive for conventional flux direction, South to North, in the direction of the arrow shown on the label for each axis; i.e. the maximum positive output will be obtained from any axis when the arrow points towards magnetic north along the total field vector. The measurement axes are designated X, Y and Z in the Cartesian co-ordinate system, when viewed from the top or non-connector end of the sensor.

In designing the Mag-03 series, the policy has been to provide a high performance sensor having a flat amplitude response and a small, predictable phase lag over a wide bandwidth. The analogue outputs may require external filters if not used with a Bartington Instruments data acquisition unit to achieve the noise specification of the sensor. See [Signal Processing](#).

## 4. General Description

This section describes the features common to the Mag-03 range of sensors. Exceptions are described in the product brochure.

Three fluxgate sensing elements are mounted orthogonally at one end of an enclosure, which also contains the electronic circuitry. The connector is mounted at the opposite end of the enclosure. The position and direction of each sensing element is shown on the outside of the sensor, together with the product code, measuring range and serial number. The sensor elements are precisely aligned along the centre lines of the package, directly beneath the diagram on the label.

Details of the enclosures, mounting, connector dimensions, connector pin allocation and the position of the sensing elements relative to the enclosure are given in outline drawings on the Mag-03 product page.

The sensors provide three high precision analogue outputs, proportional to the magnetic field along each axis. The relationship between the magnetic field and the analogue output is extremely linear.

The low output impedance of the sensor ensures it can be operated over long cables and permits it to be interfaced to high impedance data acquisition systems. The zero field offset error, scale factor, orthogonality and frequency response are individually calibrated.

## 5. Enclosures

A variety of enclosures and measuring ranges are available. A full list of sensors with specifications is provided in the product brochure.

**Note:** Several Mag-03 enclosures are awarded IP (Ingress Protection) ratings as determined by the IEC 60529 standard. These ratings are shown in the product brochure. Users are advised to consult this standard, available from the IEC website at [www.iec.ch](http://www.iec.ch), for the precise definitions and limitations of each IP rating.



**Caution:** Using your sensor in an environment that exceeds its rating may result in the need for repair at the customer's expense.

## 6. Compatible Power Supply and Data Acquisition Units

A number of Bartington Instruments products will work with the Mag-03 as power supply and/or data acquisition units. These are listed in the product brochure, and can be found at [www.bartington.com/data-acquisition-and-conditioning-units.html](http://www.bartington.com/data-acquisition-and-conditioning-units.html).

For further information on power supplies see [Power Supplies](#).

For information on using your own power supply or data acquisition unit see AN0042: 'Connecting your own Power Supply to a Bartington Magnetic Field Sensor', available from Bartington Instruments.

## 7. Cables and Connectors

### 7.1. Cables

Cables are available to connect the range of Mag-03 sensors to the range of suitable Bartington Instruments power supply and data acquisition units. Specifications for each of the cables are given in the product brochure.

**Note:** Cables must be ordered separately.

**Note:** Customers manufacturing their own cables must ensure the cables are shielded to prevent them picking up EM (electromagnetic) interference.

**Note:** The connecting cable to the sensor should be an eight-core screened cable. Two cores will be used for positive and negative power supply lines, three cores for output signals, one core for signal common and one for power supply ground. The screen should be connected to supply ground at the supply end only. The capacitance between cores should be less than 200pF per metre. A cable with individually shielded cores should be considered for long cable applications.

**Note:** The length of the cable is limited by the voltage drop in the power supply lines and the capacitance between the cores. For this reason it is recommended that the cable is limited to a maximum length of 600 metres.

### 7.2. Mating Connectors

All sensors, except for the Mag-03MSS, are supplied with a non-magnetic mating connector if no cable for connection to a power supply or data acquisition module is purchased.

**Note:** The Mag-03MSS mating connector must be purchased separately.

### 7.3. Mag-03MSS Connection

The Mag-03MSS needs to be connected correctly to the cable to avoid damage to the connector.

The small groove on the Mag-03MSS should be lined up with the slightly raised ridge in the cable connector.

**Note:** This ridge may be difficult to see as it is covered up by the screw on sheath. Shining a light into the connector may help.

Place the two connectors against one another and slightly adjust the mating connector to ensure that the groove is lined up with the ridge. The mating connector should then be inserted into the sensor connector.

**Note:** The 'O' ring may cause a little resistance, but only limited force should be required to overcome it.

Once correctly connected, tighten the screw-on sheath. Turn it through just under three rotations so that it is finger tight.



**Caution:** Do not over-tighten the sheath.

When the sensor is connected to the sensor, correct handling is described below.



**Caution:** Do not handle the cable/Mag-03MSS assembly by the sensor as this will lead to strain on the connector. Instead the assembly should be held either directly at the connector, or by the cable, allowing the sensor to hang downwards. Avoid lateral strain on the connector as this may damage the connector.

### 7.4. Mag-03MSS-TC

-TC versions of Mag-03 MSS feature a test coil which applies a magnetic field to all axes when activated. The corresponding changes in X, Y and Z output voltages confirm that all axes of the sensor are operational.

Variations from the standard Mag-03 MSS are as follows.

1. Connector is a 9-way type IE-XSJ-9-BCR with pin 8 used as the TEST ENABLE pin. See drawing DR3000, available via the product page.
2. Cable features a 9-way IE-XSJ-9-CCP connector at sensor end: see drawing DR2982. A version can be supplied with a Hirose RM15TPD10S connector at the user end: see drawing DR2980.

- TEST ENABLE is activated by connecting pin 8 of IE-XSJ-9-BCR connector to PG (pin 4).

## 8. Accessories

### 8.1. Mag-03 Calibration Unit

A variety of battery powered calibration units are available, described in further detail in the product brochure. These produce a sinusoidal alternating magnetic field of defined frequency and magnitude. The units provide a reference magnetic field for checking the calibration of the sensors but cannot be used to perform a calibration directly. If the calibration unit shows that calibration is required then the sensor should be returned to Bartington Instruments.

### 8.2. Mounting Accessories

The compatible mounting accessories are shown in the product brochure. See also [Mounting](#) below.

## 9. Mounting

The method of mounting will depend on the application and the enclosure. For details of the mounting arrangements for each sensor, refer to the product brochure and to the relevant outline drawings on the product page.

**Note:** Avoid the use of magnetic materials in the mounting arrangement. All mounting components should be checked before installation by placing the component within the immediate vicinity of the sensing elements of a working magnetometer and observing any variation in the background field.

**Note:** For sensors where the label area of the sensor is recessed, the label area should not be used for clamping.



**Caution:** The absolute maximum screw penetration depth within the body, as shown in the relevant outline drawing, must not be exceeded.



**Caution:** Do not place the sensor head of unpackaged or IE sensors in the immediate vicinity of electrically conductive materials.



## 10. Operation

### 10.1. Connector Pin Allocation

The connector pin or cable colour allocation for the connection to each package type is shown on the appropriate outline drawing available on the product page.

### 10.2. Interface

A simplified interface schematic for the Mag-03 series is shown in the product brochure. The analogue outputs for the X, Y and Z axes are buffered to give a low output impedance, enabling the unit to be operated over long cables and interfaced to high impedance data acquisition systems.

### 10.3. Power Supplies

The normal power supply of the sensors is shown in the product brochure. The ideal power supply units are those manufactured by Bartington Instruments and listed at [www.bartington.com](http://www.bartington.com). Alternatively, users may wish to provide their own supply. This would normally provide the minimum shown in the product brochure. For the lowest noise applications, ripple in the power supply should not exceed a few mV.

**Note:** Adequate performance of the sensor cannot be guaranteed if used with non-Bartington Instruments products.

The nominal current requirements are shown in the product brochure together with an additional current of 1.4mA per 100 $\mu$ T per axis that will be drawn in proportion to the measured field from the positive or negative supply, depending on the direction of the field.

In the temperature range -40°C to +70°C, and with an external load of 10k $\Omega$ , the maximum output voltage will be less than the supply voltage by the value shown in the product brochure. All parameters, other than the output voltage range, remain unaffected for supply voltage ( $V_s$ ) changes in the range from  $\pm 8$  to  $\pm 15$ V.

The current drain is independent of the power supply voltage and the unit will operate with supply voltages down to  $\pm 8$ V. For a unit with a full scale range of  $\pm 100\mu$ T the output voltage for each axis is 0.1V/ $\mu$ T of the field in the direction of that axis. As the output voltage swing is limited to slightly less than the supply voltage, for a supply of  $\pm 8$ V the output will operate normally with any output between +7.3V and -7.3V representing a field of 0.73 of the full scale value in each direction. The scaling factor and linearity will remain at the normal value up to this saturation point. The output will remain at the saturation level if the field is increased beyond this point.

Asymmetric supplies may be used provided that the minimum and maximum voltages are not exceeded for either polarity.

#### 10.4. Signal/Power Ground

**Note:** The two signal/power ground conductors are connected to a common point within the sensor, and the power supply common (power 0 V) should be connected to only one of them. The other signal/power ground conductor should be used as the signal output common (0V). Each signal is then measured between the signal output conductor and the signal output common. In this way, the signal output common carries no power supply currents.

**Note:** On long cables, the minimum current in the power ground conductor will give rise to an appreciable potential difference between the power supply end and the sensor end of the power ground conductor. The use of separate power and signal ground conductors will ensure that this voltage is not included in the voltage measured between the signal output and the signal common.

The product brochure shows the voltages between sensor and power supply. To ensure that the power supply return current does not affect the analogue measurements in any way, observe the following precautions:

- A. A signal common line, separate from the power common line, should be connected between the Mag-03 magnetic field sensor and any measurement or data acquisition system.
- B. If the signal ground line is to constitute a system ground point then a fully floating power supply must be employed, e.g. a pair of batteries or a fully isolated power supply. A number of commercially available dc to dc converters fulfil the voltage isolation requirement adequately. For this arrangement, only single ended analogue inputs to the data acquisition system are required for the three axes.
- C. If the power supply is to constitute a system ground point then the data acquisition analogue inputs must be of the differential type. Each differential input can then be connected between the remote end of the signal common line and the individual analogue outputs.
- D. The above considerations also apply if more than one Mag-03 sensor is used.
- E. Any data acquisition system analogue inputs should ideally have a very high input impedance, but satisfactory performance can be obtained with impedances down to 50k $\Omega$ . Impedances below this should be avoided, particularly where very long cables are used.
- F. When using the low noise unit, to obtain optimum performance, additional care should be exercised to avoid ground currents in the signal leads.

**Note:** When using a compatible power supply unit from Bartington Instruments, the above requirements will be met without further consideration by the user.

### 10.5. Independent Elements, Flying Leads and Two-Part Construction Sensors

**Note:** On flying lead versions, leads are susceptible to EM interference and should be screened wherever possible. This may also apply to the leads between the electronics and sensor head for the Mag-03MCTP, Mag-03MCUP, Mag-03IE, Mag-03IEv1, Mag-03IEv2 and Mag-03IEHV sensors.

### 10.6. Connecting Power



**Caution:** Check that the polarity of the supply is correct. Using the power supply provided by Bartington Instruments will guarantee that the polarity is correct, as it is impossible to connect the wrong way round.



**Caution:** The power supply should be connected to the sensor before the supply is energised, as this prevents high surge currents which could cause damage. Apply the positive and negative supplies simultaneously and avoid leaving the sensor connected to one polarity only.

### 10.7. Electromagnetic Compatibility

Except for the Mag-03MCT, the Mag-03 range of sensors are not shielded for immunity from, or emission of, electromagnetic fields. Any shield placed around the sensor will limit the bandwidth of the sensor response. Emissions are at the frequency of the energising field of the sensor. The sensor is required to respond to magnetic fields within the specified frequency band.



**Caution:** Do not operate the sensor in very strong electromagnetic fields as it may develop a permanent offset, or damage could occur to the sensing coils.

**Note:** Do not place the sensor near to any equipment which may be affected by the very small local field produced by the sensor excitation.

## 11. Performance

### 11.1. Frequency Response

Typical amplitude, phase response and bandwidth are shown in the product brochure.

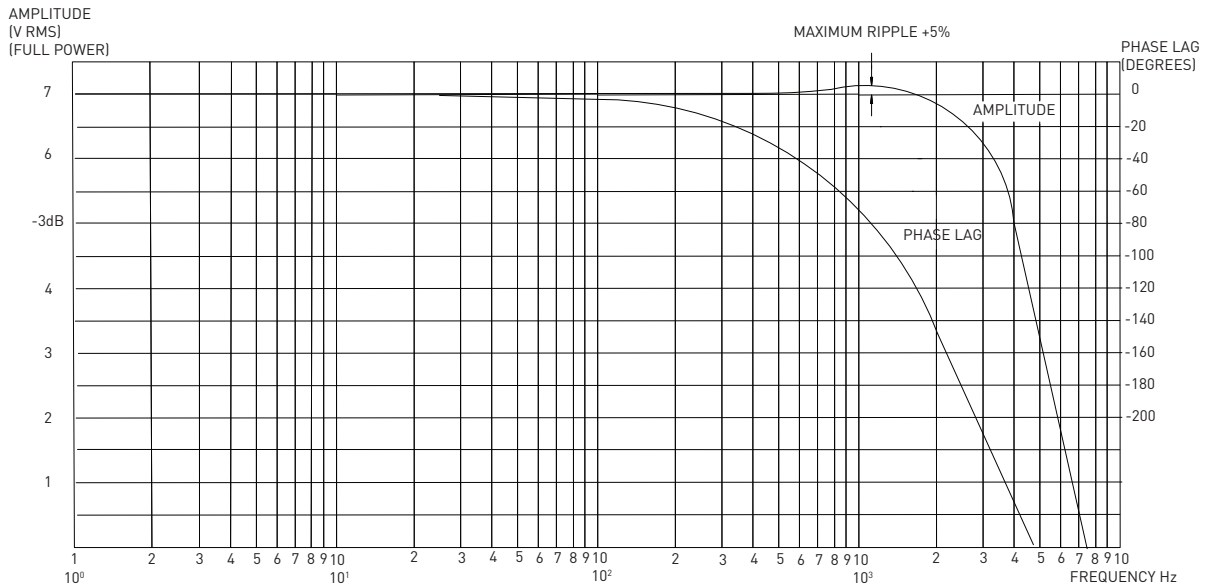


Figure 1: Typical frequency dependent amplitude and phase response

### 11.2. Noise

The Mag-03 range includes different noise versions that are specified in the product brochure. These versions correspond to the internal noise of the sensor, which can only be achieved in a shielded environment where no external fields are present.

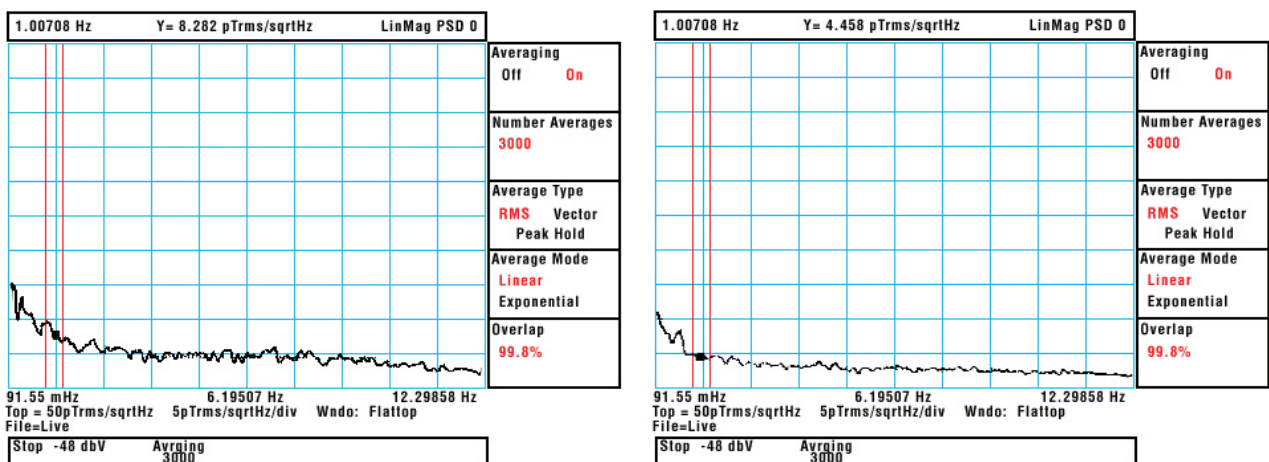


Figure 2: Typical Noise plot between 0.1 and 10Hz for a) Standard Version Mag-03, and b) Low Noise Version Mag-03.

### 11.3. Excitation Frequency

The output signal for each axis will also contain breakthrough, which is a residual signal associated with the excitation frequency. (See the product brochure for frequency and level of breakthrough.) All Bartington Instruments power supply and signal conditioning units have a filter to remove the breakthrough.

**Note:** When using a non-Bartington Instruments power supply, it will be necessary to provide a filter to remove the breakthrough. Not doing so will lead to a higher noise level than that specified. See application note 'AN0042: Connecting your own Power Supply to a Bartington Magnetic Field Sensor' from Bartington Instruments for further information.

### 11.4. Over Range

As the field in any axis approaches the full scale value, the output will rise in proportion until it reaches a value of approximately 1V less than the relevant supply line. The output will then saturate and remain at this level regardless of any further rise in the field.

**Note:** Very high fields, in the hundreds of mT or higher, should be avoided as they may give rise to a permanent shift in offset in the region of a few nT, measured at zero field.

## 12. Signal Processing

All Bartington Instruments power supply and data acquisition products feature a degree of signal processing. The most comprehensive processing is provided by the SCU1 signal conditioning unit, which provides filters with independent control of the low and high pass filter sections, together with offset and gain control for the output of each axis. The PSU1, Magmeter, Spectramag-6 and Mag-03DAM all contain a single low pass and high pass filter.

The range of available units and further details on each can be found at [www.bartington.com](http://www.bartington.com).

The output from all fluxgate sensors includes a low level of the excitation frequency. For the Mag-03 range this noise is well above the bandwidth of the sensors.

**Note:** It is particularly important to attenuate the breakthrough before digitising the signal to prevent aliasing. Aliasing can generate spurious signals or noise in the wanted frequency band by intermodulation between excitation and data sampling frequencies. See application note 'AN0042: Connecting your own Power Supply to a Bartington Magnetic Field Sensor' from Bartington Instruments for further information.

## 13. Troubleshooting, Care and Maintenance

### 13.1. 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. In the event of any apparent malfunction, email [service@bartington.com](mailto:service@bartington.com) or telephone the Bartington Instruments service team on +44 (0)1993 706565.

**Note:** Attempted repair or opening of the casing by users may invalidate the warranty.

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

### 13.2. 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.

When further service or maintenance is required, contact Bartington Instruments or your local agent company.

## 14. Storage & Transport

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



**Caution:** Avoid exposing this instrument to shocks or continuous vibration.



**Caution:** Store only within the temperature range specified in the product brochure.



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

## 15. 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.

### 15.1. Waste Electrical and Electronic Equipment (WEEE) Regulations



Bartington Instruments Mag-03 sensors comply 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



# Bartington® Instruments

**T:** +44 (0)1993 706565  
**F:** +44 (0)1993 774813  
**E:** sales@bartington.com

Bartington Instruments Limited  
5 Thorney Leys Business Park,  
Witney, Oxford, OX28 4GE, England.

[www.bartington.com](http://www.bartington.com)

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