BARTINGTON

MAG-01 AND MAG-01H

SINGLE AXIS FLUXGATE MAGNETOMETERS WITH PROBES B - G

OPERATION MANUAL

Distributed by:
GMW Associates
955 Industrial Road, San Carlos, CA 94070 USA
Tel: (650) 802-8292 Fax: (650) 802-8298
Email: sales@gmw.com
website: http://www.gmw.com

Manufactured by:
Bartington Instruments Ltd.
10 Thorney Leys Business Park
Witney, Oxford OX8 7GE
England
Tel: 011 44 1993 706565 Fax: 011 44 1993 774813
Email: sales@bartington.com
website: http://www.bartington.com

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OPERATION MANUAL FOR *Mag*-01 AND *Mag*-01H SINGLE AXIS FLUXGATE MAGNETOMETERS WITH MAG PROBES B-G

Bartington Instruments Ltd
10 Thorney Leys Business Park
Witney
Oxford
OX8 7GE
UK

Tel: +44 1993 706565
Fax: +44 1993 774813

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This product is not qualified for use in explosive atmospheres or life support systems. Consult Bartington Instruments for advice.

CE

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Note: All dimensions are in mm

Mag -01/ ***Mag*** -01H brochure

1.0 INTRODUCTION

The ***Mag*** -01(H) magnetometer system is intended for the vectorial analysis of relatively weak (nT) slowly (10 Hz max) varying magnetic fields.

The system comprises one of a range of miniature fluxgate probes connected by a cable to a compact electronics unit. The electronics unit contains circuitry to convert the signals produced by the probe into a measurement of flux density for display on the front panel LCD or in the form of an analog output voltage for chart-recording purposes. A rechargeable battery is included making the unit suitable for portable use.

The use of low signature components including a non-magnetic battery within the magnetometers permit the instruments to be used close to the probe. Errors will not be significant with the probe and magnetometer as close as 0.5 metres.

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

The ***Mag*** -01H differs from the ***Mag*** -01 due to the addition of a x10 sensitivity control to increase resolution and the provision of a precision offset control to expand the measuring range.

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

2.0 THE MAGNETOMETERS - See figures 2, 3, 4, 5 and 6

Circuitry

The probe excitation oscillator supplies a high purity alternating signal to the excitation winding of the ***Mag*** probe. The axial component of any magnetic field intercepted by the probe produces a signal which is filtered in the input filter to eliminate unwanted noise. Following detection an amplified error signal is fed back to the probe via a current converter and precision wound feedback winding where nulling of the magnetic field occurs. In this way 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 analog output socket.

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

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.

2.1 Power supplies and battery charging

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

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

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.

NOTE: Battery disconnection should only be carried out by qualified service personnel or those familiar with electrical storage batteries. 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.

(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.

To conserve the full life of the internal rechargeable battery it should be recharged at least once a year.

2.2 The autoranging display

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

The display is autoranging. Two ranges provide 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 display will show ±1_____. The sign is preserved but only the leading 1 is displayed.

2.3 Analog output - See figure 1

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 is particularly suited for use with a chart recorder. A connecting cable is recommended which is screened and grounded at one end only, preferably to the ground earth of the chart recorder.

When using the analog output the full scale range will, for the low field probes, exceed the ±2 V range monitored by the LCD and will be ±5 V full scale. The internal resistance of the high field probes limits the analog output for these to ±2 V
(or 2 mT), with the exception of special high field probes type D/S where the measuring range at room temperature is ±5 V (or 5 mT).

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

3.0 THE PROBES

Principles of Operation

Probes are of the fluxgate type. A pair of very high magnetic permeability cores in the centre of the probe is driven in and out of magnetic saturation by the alternating field within each of two excitation windings. This causes the permeability of the cores to alter from a high to a low value twice for every cycle of excitation current.

In this way a static magnetic field is converted into an alternating magnetic field within the cores by their gating action. The alternating field is detected by the combined detection/feedback winding within the probe and processed by the magnetometer electronics to produce a measurement of the flux density B. The feedback arrangement maintains the core in a null field to ensure that the precise magnetic properties of the core material do not contribute significantly to the final measurement accuracy.

Probe Cables

The probe connecting cable is a four conductor overall screened type as indicated in the technical specifications.

The probes are normally supplied with a 5m length cable and have been shown to operate successfully using the specified cable type with the length extended to 25 m. If extending the cable beyond 25 m it is suggested that a cable of a lower conductor resistance is used; this will avoid measurement errors.

3.1 Vector sensing

The cores within the probe only respond to the component of a magnetic field which is along the axis of the cores. The probes are therefore vector sensing and produce a cosine directional response.

The measured value $V = B_{max} \cos\theta$
where B_{max} is the total field strength and θ is the angle between the probe axis and the direction of the total field.

The probes may also be used to detect small changes in flux direction. In this mode the probe is positioned perpendicular to the flux under investigation.

The response then becomes:

$\delta\theta = \sin^{-1} \delta V/B$
where $\delta\theta$ is the small change in flux direction, δV is the measured value (axial component) and B is the total flux.

All probes are supplied with the axis of the cores aligned to better than 0.3^{o} to the body of the probe.

3.2 Types of probe

Probes are available in two sensitivity ranges (0.2 mT and 2 mT maximum) and three different constructions (axial, transverse and cryogenic). Each is identified by a code letter on the label affixed close to the plug on the probe cable. The measuring range stated for each probe is that which is obtained on the LCD with no offset applied (MAG-01H only).

Low Field Probes Type B,C and F (0.2 mT)

These employ a 30 mm length fluxgate element and can detect fields as low as 1 nT (***Mag*** -01H). When used in conjunction with the analog output a measuring range of ±500 μT to full specification is available. The LCD is limited to ±200 μT maximum.

High Field Probes Type D, D/S, E and G (2.0 mT)

These employ a shorter 20 mm length fluxgate element which limits their resolution to around 2 nT (***Mag*** -01H x10). These probes are an adaptation of the low field design and, for this reason, no provision has been made within the magnetometer electronics to provide direct reading.

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

Special probe type D/S possesses the shorter (9 mm) sensing element and, when used in conjunction with the ***Mag*** -01(H) specially set up for the purpose, will permit measurements on the analog output of ±5.3 V, equivalent to 5.3 mT, with the probe at a temperature no higher than 25°C. Above this temperature the measuring range of the probe will decrease.

Transverse and Axial Probes

High and low field probes are available in either axial or transverse construction. 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.

Standard Packaging (Probes Type B,C,D,E)

Axial and transverse probes for normal (non-cryogenic) applications are housed in a robust brass outer case which accurately defines the probe outline for mechanical registration purposes and gives a high degree of environmental protection. The sensing element and cable are moulded within the tube using GRP (glass reinforced plastic) to provide hermetic sealing and create a very strong package.

When clamping these probes in fixed installations the clamp pressure should ideally 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.

3.3 Cryogenic probe type F (0.2mT) and type G (2.0mT)

These probes are of axial construction only. They are designed for continuous operation down to liquid helium temperature. The use in their construction of a minimum number of dissimilar materials makes them tolerant to the stresses induced by shrinkage which are incurred during cooling. The power dissipation has been kept to a minimum. The power levels stated in the specifications are the maximum values which occur as full scale measurements.

The four enamel-coated 1 m x 0.2 mm 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.

Mounting the Cryogenic Probe

The probe can be mounted in a number of ways;

(i) By bonding; use a minimal mount epoxy adhesive.

(ii) By loosely supporting the probe within a tube.

Proximity Effects

No two ***Mag*** cryogenic probes should be operated within 10mm of each other if interaction is to be avoided. If the probes are mutually orthogonal they may be placed in contact with no adverse effects.

3.4. Conventions

The sensing direction for the probes is the direction for which conventional flux will produce a positive value to be recorded.

Definition
Conventional flux direction is said to be "out-of-the-page" when produced by a conventional current (+ve to -ve) circulating counter-clockwise in a conducting loop "parallel-to-the-page".

4.0 OPERATING INSTRUCTIONS - See figures 2, 5 and 6

Switching On

Connect the probe selected to the 6 way probe socket and switch on the magnetometer. Note that 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. If battery voltage is below 5 V 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 30 μT and 90 μT. If used within a steel framed building the shunting effect of the steel could reduce the field below the outdoors value.

Using the offset control (*Mag* -01H only)

To obtain the maximum resolution on the autoranging LCD or to bring measurements within the range of a chart recorder a back-off value can be added arithmetically to the field strength experienced by the probe using the bipolar precision offset control.
If possible select a setting which produces three places of decimal resolution on the display.

Using the sensitivity x10 control (*Mag* -01H only)

With this set to x10 all measured values must be multiplied by 10.

Precaution
Accidental exposure of the probes to very high fields should be avoided. No permanent damage or impaired performance has been found following exposure to fields as high as 1 T. The instrument will fully recover from severe overload in around 5 seconds.

4.1 Battery replacement

Should the internal battery fail to provide at least 10 hours continuous use after 2 years' service, it will require replacement. Either the instrument can be returned to the company's agents or the UK factory or battery replacement can be carried out by the customer.

Instructions for battery replacement

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.

4.2 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, 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 the magnetic field, are susceptible to electromagnetic interference and operation close to a 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.

5.0 TECHNICAL SPECIFICATIONS

5.1 *Mag* -01 electronics unit

Mechanical

Dimensions	:	15.5 x 17 x 6.8 cms
Materials	:	high impact ABS
Weight	:	1.5 kgs

Environmental

Operating temperature range	:	-10°C to +50°C
Relative humidity	:	80% maximum

Performance

Measuring range	:	1 nT to 2 mT (dependent on probe)
Noise	:	<0.5 nT pk low field probes 5 nT pk high field probes
Bandwidth (low field probes)	:	dc to -3 dB at 10 Hz, 20 µT p-p -12dB per octave roll off
Calibration accuracy	:	0.1% (for ultimate accuracy see probe specifications)
Temperature coefficient	:	<10 ppm/°C
Liquid crystal display	:	4½ digit auto ranging Displays 0 - ±20 µT with 1 nT resolution and 0 - ±200 µT with 10 nT resolution

For high field probes multiply reading on display by 10 to obtain true value.

Front panel controls/socket

On/off switch	:	switches on the internal battery supply
Probe inlet	:	via 6 pole waterproof Fischer connector
Charge indicator	:	LED illuminated when external supply is connected

Rear panel sockets

Battery charger inlet	:	2.1 mm socket dc 0.5 A max. Polarity protected 6-18 V continuous or intermittent use
Analog output	:	via 2 x 4 mm rear panel insulated sockets
Output impedance	:	1 kohm
Low field probes	:	100 µT/V, ±5 V fs, 1 nT resolution
High Field Probes	:	1 mT/V ±2 V fs, 10 nT resolution (Probe D/S ±5 V fs, 20 nT resolution)

5.2 *Mag* -01H electronics unit

Mechanical

Dimensions	:	15.5 x 17 x 6.8 cms
Materials	:	high impact ABS
Weight	:	1.5 kgs

Environmental

Operating temperature range	:	-10°C to +50°C
Relative humidity	:	80% maximum

Performance

Measuring range	:	0.1 nT to 2 mT (dependent on probe)
Noise	:	<0.5 nT pk low field probes

		5 nT pk high field probes
Bandwidth x1 sensitivity (low field probes)	:	dc to -3 dB at 10 Hz, 20 µT p-p -12dB per octave roll off
Calibration accuracy	:	0.1% (for ultimate accuracy see probe specifications)

***Mag* -01H electronics unit (continued)**

Maximum resolution	:	0.1nT (low field probes)
Zero field offset	:	±5 nT at room temperature
Offset drift	:	0.01 nT/^{o}C
Calibration temperature coefficient	:	<10 ppm/^{o}C
Liquid crystal display	:	4½ digit auto ranging
Low field probes on x1 sensitivity	:	displays 0 - ±20 µT with 1 nT resolution and 0 - ±200 µT with 10 nT resolution
Low field probes on x10 sensitivity	:	Displays 0 - ±2 µT with 0.1 nT resolution and 0 - ±20 µT with 1 nT resolution. When used in conjunction with the offset control will resolve to 0.1 nT for values lying in the range 10 µT (x 1-9) ±2 µT

For high field probes multiply reading on display by 10 to obtain true reading.

Front panel controls/sockets

On/off switch	:	switches on the internal battery supply
Probe inlet	:	via 6 pole waterproof Fischer connector
Charge indicator	:	LED illuminated when external supply is connected
Offset control (low field probes)	:	allows a preselected field strength between ±90 µT in ±10 µT steps to be subtracted from the field experienced by the probe
Sensitivity control	:	increases the sensitivity of the magnetometer by a factor of 10

Rear panel sockets

Battery charger inlet	:	2.1mm socket dc 0.5 A max. Polarity protected 6-18 V continuous or intermittent use
Analog output	:	via 2 x 4 mm rear panel insulated sockets
Output impedance	:	1 kohm
Low field probes	:	100 µT/V, ±5 V fs, 1 nT resolution
x1 sensitivity		
Low field probes	:	100 µT/V, ±5 V fs, 1 nT resolution
High Field Probes	:	1mT/V, ±5 V fs, 10 nT resolution (Probe D/S ±5 V fs, 20 nT resolution)
x10 sensitivity		
Low field probes	:	10 µT/V, ± 5 V fs, 1 nT resolution
High field probes	:	100 µT/V, ±5 V fs, 2 nT resolution

Offset can be used to increase range.

5.3 *Mag* probes

Operating temperature range	:	-30°C to +75°C
Calibration accuracy	:	1%
Linearity	:	0.01%
Connecting cable	:	4 core screened 5 metre with integral 6 pole Fischer connector
Environmental	:	submersible in water to 10 metres
Shock resistance	:	drop tested from 0.5 metres on to PVC floor 3 times
Materials of enclosure	:	glass fibre reinforced plastic with brass jacket
Dimensions	:	see MAG-01/MAG-01H brochure
Measuring range/resolution	:	refer to magnetometer specifications
Probe alignment	:	better than 0.2°

Probes can be aligned to better than 0.1° if required. An additional charge is made for this facility.

Low field *Mag* probes type B, C and F

Temperature coefficient : Of calibration		±10 ppm/°C over full range of operating temperatures
Offset error	:	5 nT
Offset error drift	:	<1 nT over full range of operating temperatures
Sensitive volume	:	0.02 cm^3
Excitation power	:	26 mW

High field *Mag* probes type D, D/S, E & G

Temperature coefficient : of calibration		±30 ppm/°C over full range of operating temperatures
Offset error	:	20 nT (60 nT Probe D/S)
Offset error drift	:	40 nT over full range of operating temperatures
Sensitive volume	:	0.0015 cm^3 (0.0012 cm^3 Probe D/S)
Excitation power	:	16 mW
Cable	:	Standard length 5 metres, screened 4 conductor twisted quad, equivalent to BBCPSF4/IM. Conductors 14/0.12 mm Insulation 0.25 mm min. PVC Jacket 4.7 mm max soft PVC Lay-up central core 12.5 mm lay screen 48/0.15 Capacitance unbalance 80 pF/100 m
Connector type	:	Fischer 6 pole sealed type SE 103A 056-3

5.4 ACCESSORIES

Power supply unit	:	ac mains battery charger 110 V or 240 V
Vehicle dashboard connector	:	12 V dc

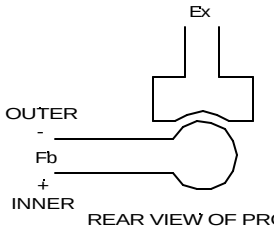
Terylene carrying bag for instrument and probes

DR0637(1)

SECURITY CLASSIFICATION

DO NOT SCALE

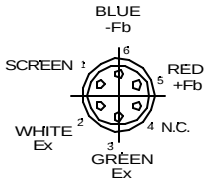
FOR EXPLANATION OF DIMENSIONING ETC. REFER TO BS308



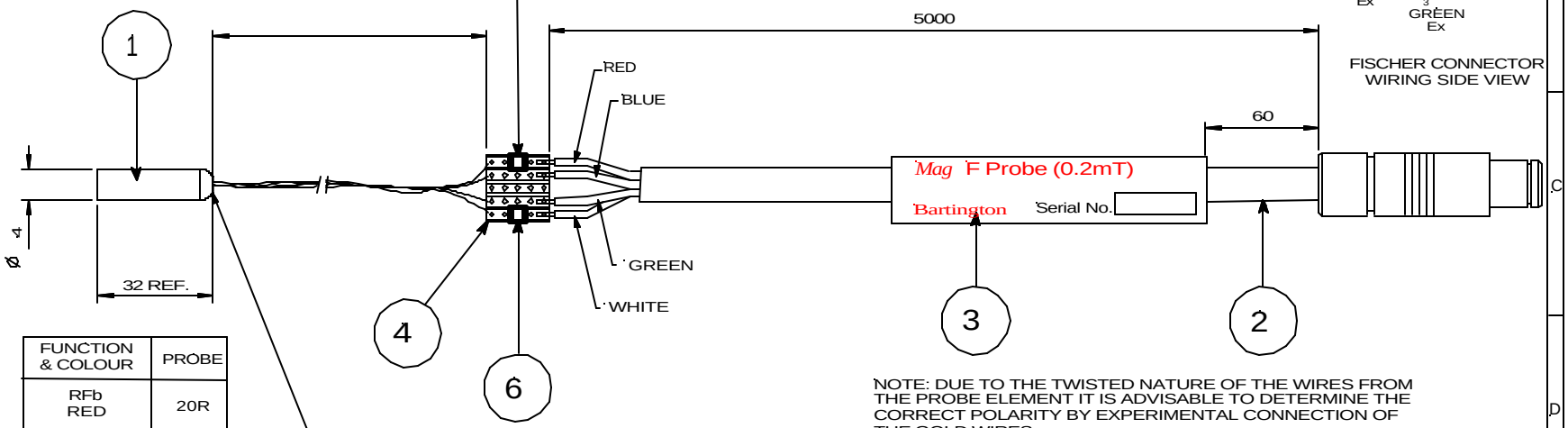
REAR VIEW OF PROBE

Fb	130R
Ex	23R

APPROXIMATE WINDING RESISTANCE (AT ROOM TEMP.)



FISCHER CONNECTOR WIRING SIDE VIEW



FUNCTION & COLOUR	PROBE
RFb RED	20R
REx WHITE	10R

TEMPERATURE COMPENSATION RESISTORS (ITEMS 5 & 6)

NO POWDER OR HIGH VISCOSITY CONTAMINANTS TO ENTER HERE
DO NOT SUBJECT WIRE SPILLS TO REPEATED FLEXURE

NOTE: DUE TO THE TWISTED NATURE OF THE WIRES FROM THE PROBE ELEMENT IT IS ADVISABLE TO DETERMINE THE CORRECT POLARITY BY EXPERIMENTAL CONNECTION OF THE GOLD WIRES.
A +ve READING SHOULD BE OBTAINED WHEN POINTING THE CLOSED END OF THE PROBE TOWARDS MAGNETIC NORTH.

ASSEMBLE IN ACCORDANCE WITH MI0356

Bartington Instruments

THIRD ANGLE PROJECTION

DIMS IN mm

SCALE 1=1

UNTOLERANCED DIMENSIONS ± 0.3
ANGLES ±

SURFACE TEXTURE 1.6 mm

MATERIAL
PL0356

PROTECTIVE FINISH

CHECKED

DRAWN

CUSTOMER

USED ON

PROJECT No.
Mag F PROBE

TITLE
Mag F PROBE ASSEMBLY

ISSUE
6

SEE AMENDMENT RECORD FOR CHANGE HISTORY

DRAWING No.
DR0356

A3

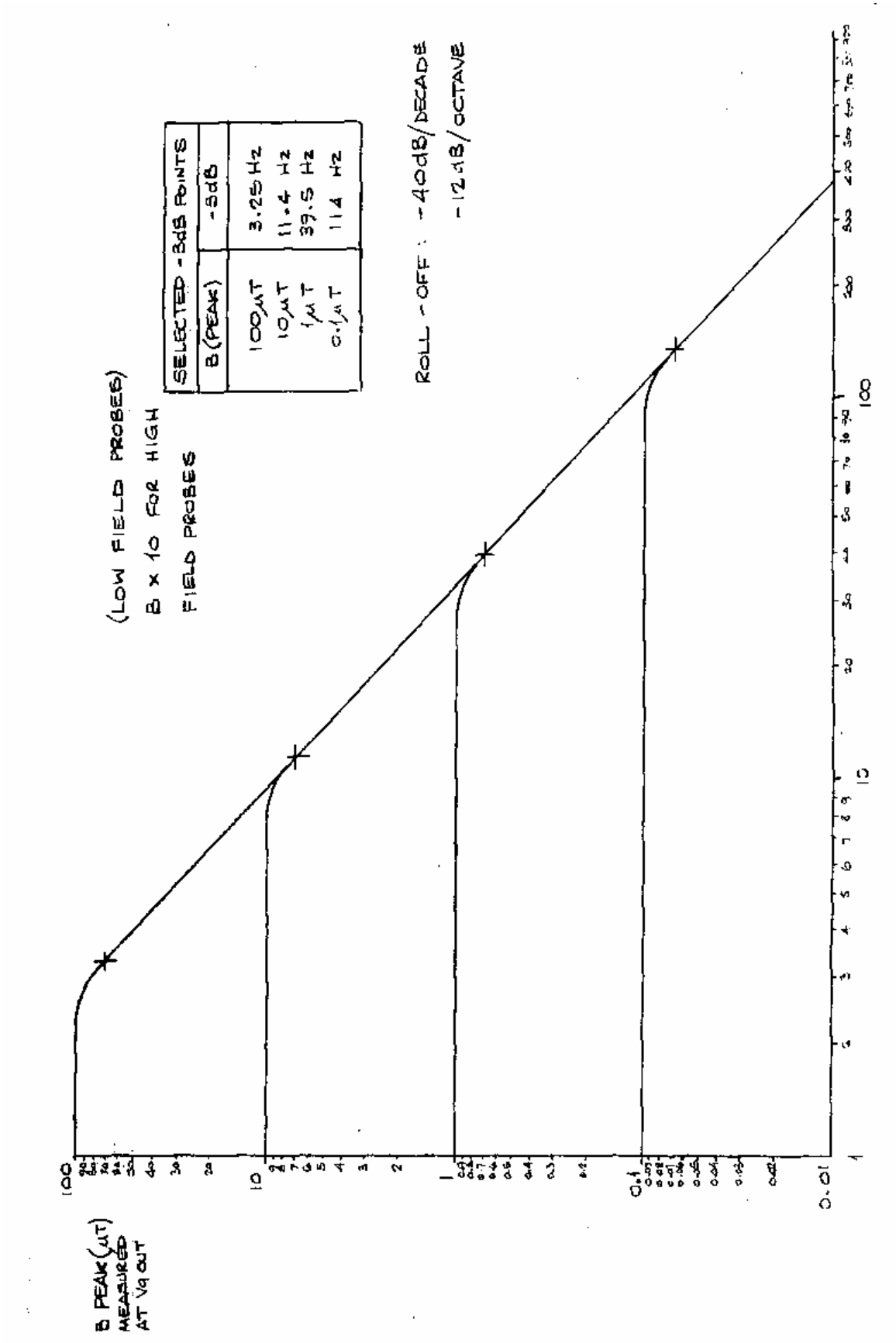


Figure 1 Analog output frequency response for *Mag*-01 & *Mag*-01H

DR0233(4)

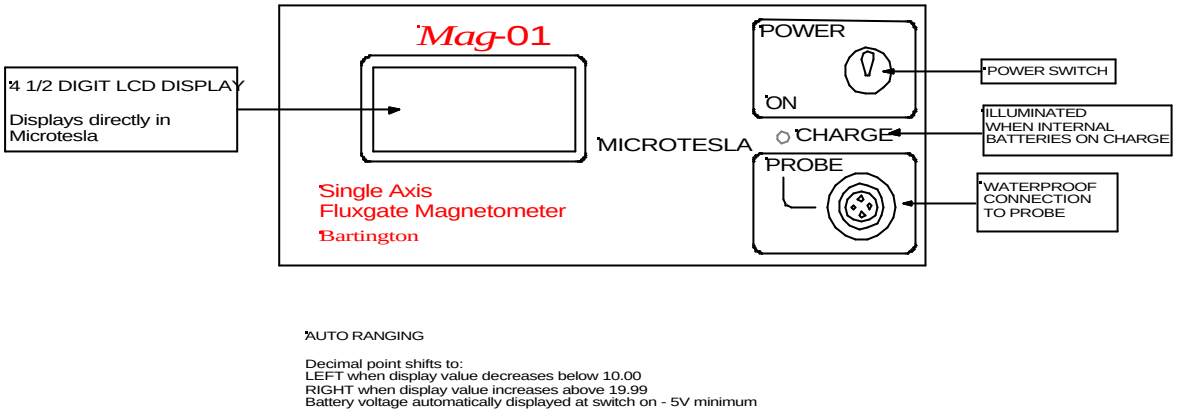


Figure 2 *Mag*-01 FRONT PANEL FUNCTIONS

DR0222(4)

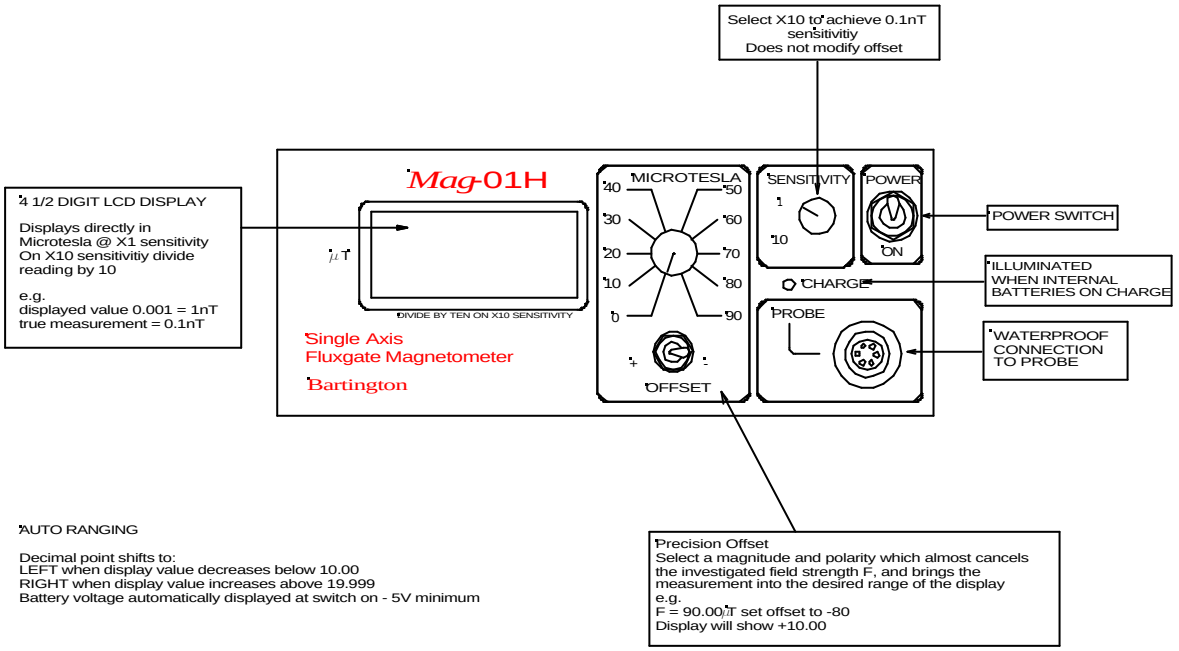


Figure 3 *Mag*-01H FRONT PANEL FUNCTIONS

DR0237(4)

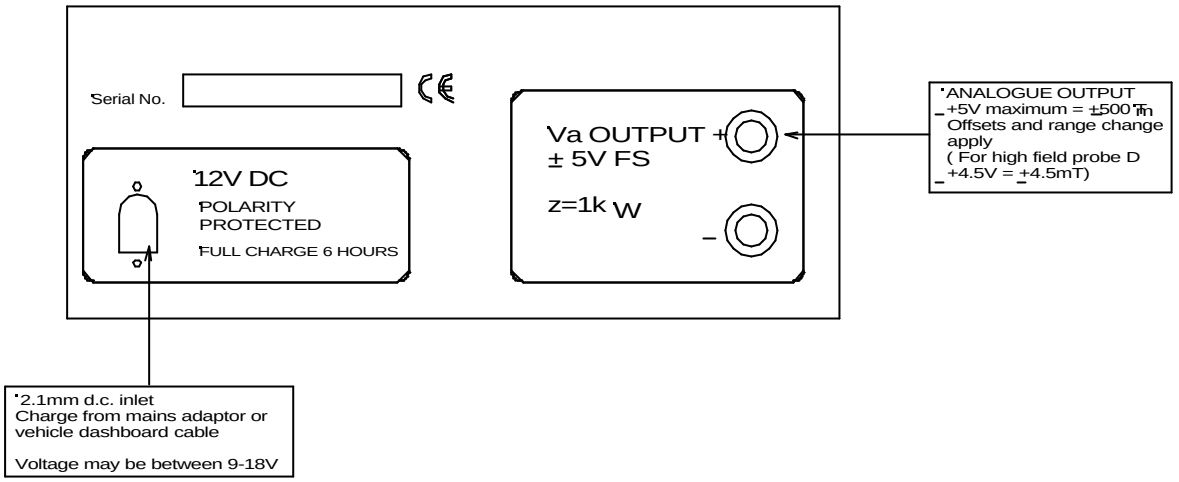
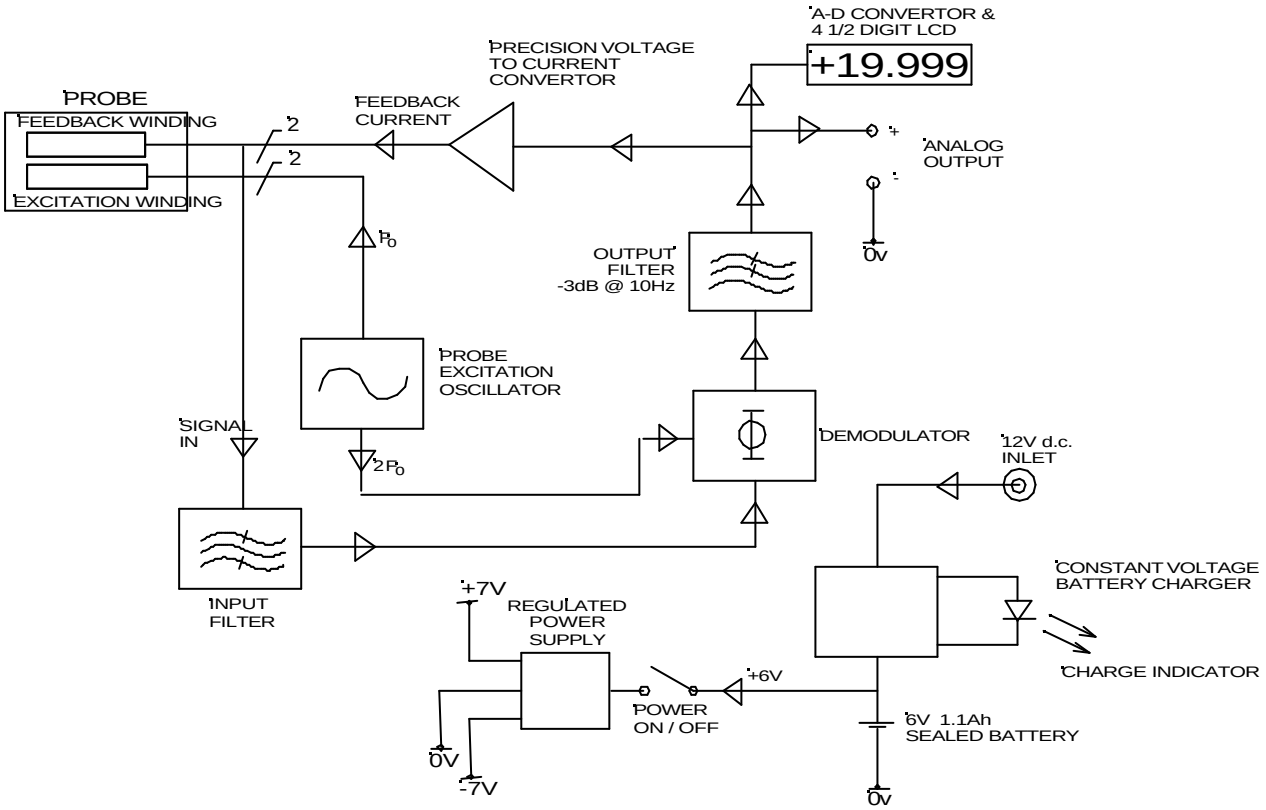


Figure 4 *Mag*-01 / *Mag*-01H REAR PANEL FUNCTIONS



DR0226(3)

Figure 5 *Mag*-01 SYSTEM SCHEMATIC

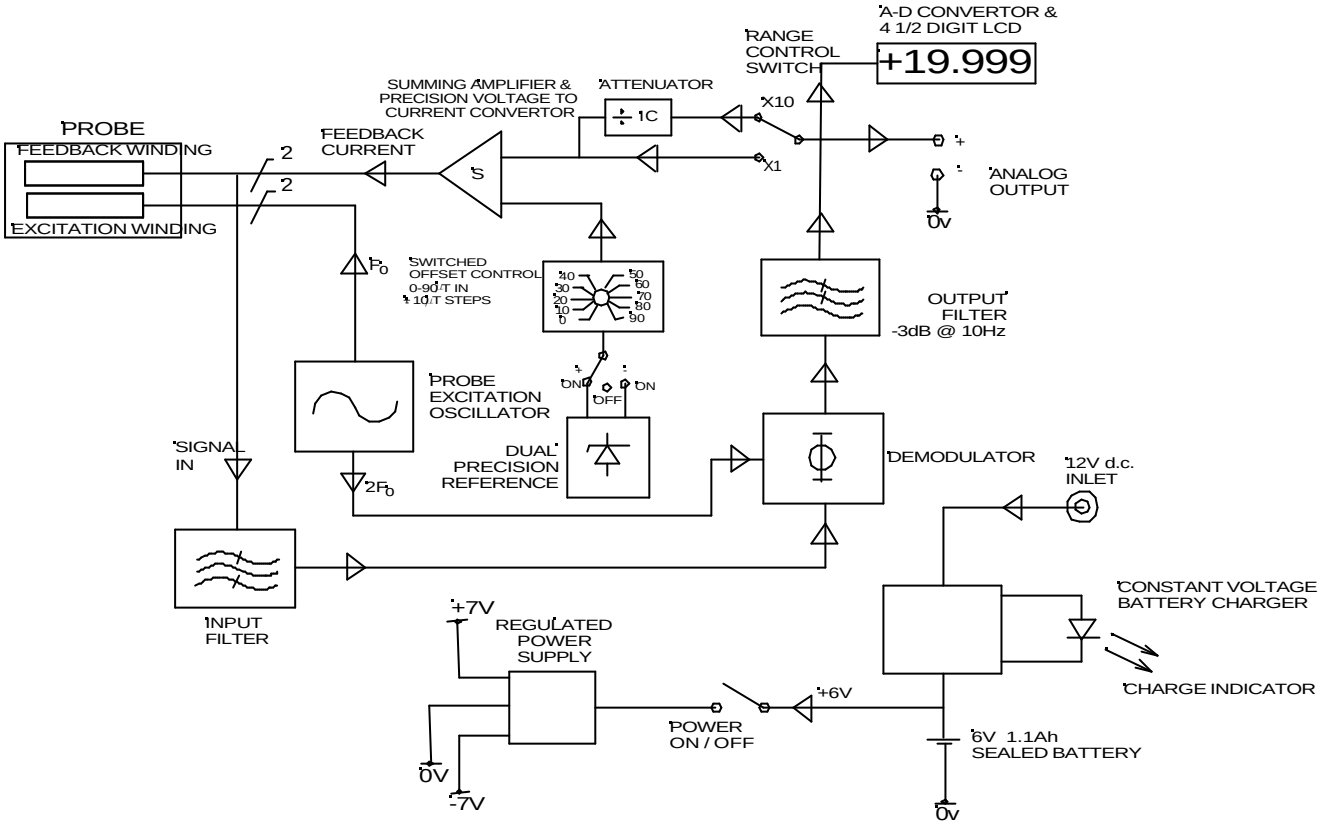


Figure 6 *Mag*-01H SYSTEM SCHEMATIC