Instituto Geofísico del Perú

JROMAG-103 MAGNETOMETER USER MANUAL VER 3.1

2024

SUMMARY

This document provides technical information about the JROMAG-MAG103 series variation magnetometers with the intention of providing end users with a clear idea of the operation of each electronic module of the analog part that make up this magnetic variometer.

The parts to be detailed include: The sensor unit, where the magnetic detector and the associated electronics for the conduction of supply voltages and analog signals are installed. The control unit, where the electronics associated with the conditioning and digitization of the signals received from the magnetic sensor are located.

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1. INTRODUCTION

The JROMAG-103 three-axis high-sensitivity digital magnetometer system is developed to carry out studies of the behavior of the Earth's magnetic field as well as the causes that affect this behavior such as solar activity and internal changes in the Earth's core and crust. The complete system consists of a detector unit and a control and acquisition unit.

The detector is based on a Fluxgate XYZ sensor, a three-component Bartington ring core assembled in a double cylinder heavy PVC module with a precise leveling system to be buried.

The control and acquisition units are based on 4-layer printed boards manufactured in the USA and components and analog integrated circuits of the highest stability and precision available in the market to obtain high performance.

The control unit includes a high-resolution 16-bit data logger board with a GPS receiver and USB output to be connected to the SBC (Embedded Computer Card) module, which is included for data acquisition and management. With the consequent advantage of operating with a 12V battery for extended time periods which is very convenient for field work.

2. GENERAL DESCRIPTION

2.1 SYSTEM COMPONENTS

The complete system consists of one detector unit and one control and acquisition unit. The control and acquisition unit are based on 4-layer printed boards manufactured in the USA. Components and analog integrated circuits of the highest stability and precision available on the market have been used to obtain high performance. The system incorporates a GPS and a high-resolution 16-bit +/- 10V, 8 Channel data logger.

At the same time, acquisition and monitoring software has been developed for both Windows and Linux (SO Ubuntu) platforms, as well as data management and plotting software.

2.2 CONTROL UNIT

Figure 1 shows the control unit front panel distribution and description of control components and functions as well.

1. AC/DC Power Switch.
2. Scale selector for display of ranges on the LCD display. x1: up to 199 nT, x10: up to 1999 nT (*).
3. 1PPS GPS Signals Indicator and ADC Sampling.
4. LCD display for XYZ signal display, temperatures (according to SELECT).
5. Power supply +12 VDC,-12 VDC voltage indicators.
6. Precision dial knob, for fine cancellation of the X component.
7. Precision dial knob, for fine cancellation of the Z component.

8. Channels selector display output XYZ, temperatures and reference voltage.
9. Operating dynamic range switch selector, 1000 nT, 2500 nT (**).
10. Analog output connector for external DVM connection depending on the channel selector position.

* Display scale selector toggle switch has three positions, UP=x1, Center=Null, DOWN=x10.
** Dynamic range selector switch has three positions, UP=1 uT, Center=null, Down=2.5 uT.

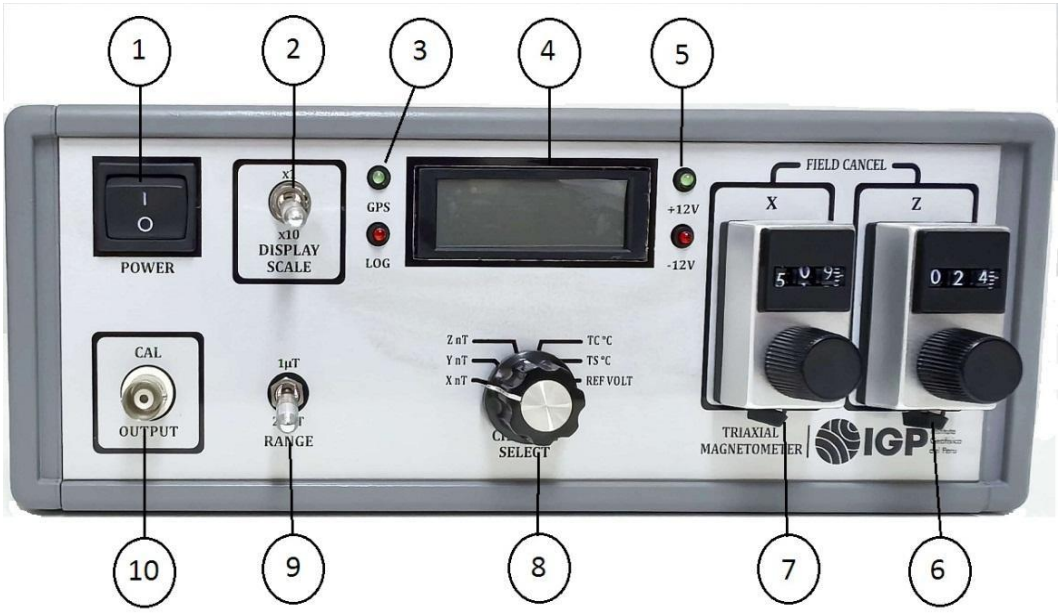


Figure 1. *Distribution of controls and connectors on the front panel of the control unit.*

Figure 2 shows the control unit rear panel distribution and description of control components and function as well.

1. Sensor signal input/output connector.
2. DB25 female connector, signals XYZ analog output and temperature analog output/input.
3. USB connector for data.
4. 12 VDC battery input connector.
5. 12 Fan.
6. AC fuse.
7. DC fuse.
8. 12 VDC power input connector, center pin positive.
9. GPS antenna connector.
10. USB port (memories, USB OUTPUT) integrated SBC module (Raspberry Pi4).
11. USB port (memories), integrated SBC module (Raspberry Pi4).
12. Ethernet port (RJ45) integrated module (Raspberry Pi4).

Note: HDMI Connector not outside available in this version.

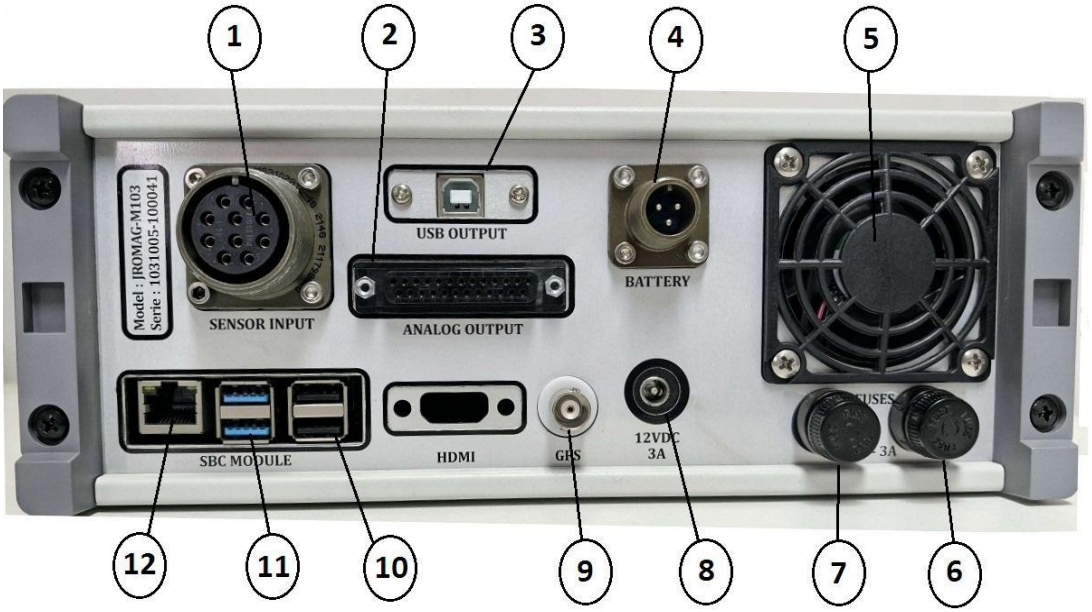


Figure 2. *Distribution of connectors on the rear panel of the control unit.*

2.3 SENSOR UNIT

The sensor unit is based on a tri-axial magnetic detector (XYZ) of the MAG-03 series from Bartington company. This is encapsulated inside a double PVC cylinder to obtain good thermal and mechanical insulation. It is recommended that the sensor be buried 80cm deep in a concrete base if permanent as shown in the figure 3.

The sensor enclosure is composed of three parts, the top cover, the central base and lower cover. The central base is the sensor leveling reference for the internal sensor cylinder so this part contains the fixing and leveling screws (view figure 4) adjusted and calibrated at a calibration facility.

Figure 3. *Orientation of the sensor unit for field installation.*

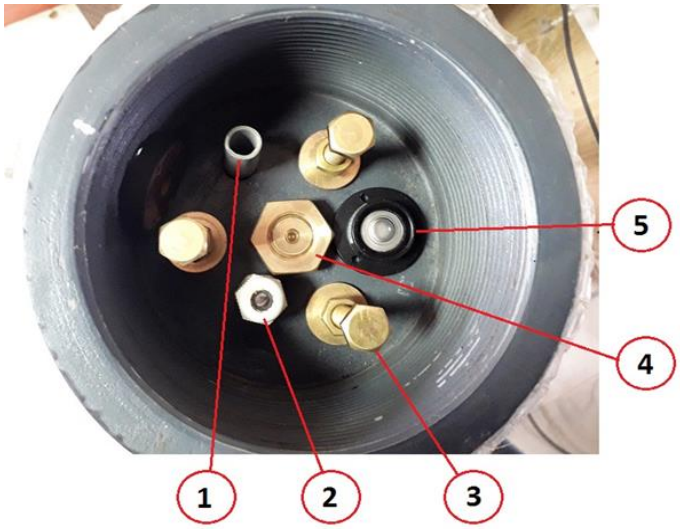


Figure 4. *Main sensor base mechanical components.*

Main sensor base mechanical components and function description:

1. Internal sensor cylinder thermal vent.
2. Internal sensor cable connection gland.
3. Bronze internal sensor cylinder tilt fixing screw.
4. Main bronze internal sensor cylinder fixing screw.
5. Main base bubble level for sensor leveling procedure.

Note: Internal fixing and leveling screws of the main base have been adjusted at a calibration facility, so it is not intended to be adjusted by the user.

2.4 SENSOR UNIT INTERFACE

The sensor unit is based on the Bartington MAG-03 magnetic detector. In addition to the magnetic detector, an electronic board (view figure 5) has also been set up for the connection of sensor cables and an electronic circuit has been added for protection in case of electric shocks.

CONTROL (1) Sensor Conn.	SENSOR (2) Cable Color	SIGNAL	Pin (in board)
F	RED	+12V	1
A	BLUE	X	2
B	YELLOW	Y	3
		NC	4
D	GREEN	GND	5
G	SHIELD	SHIELD	6
		NC	7
C	WHITE	Z	8
E	GREY	TEMP.	9
H	BLAK	-12V	10

Table 1. Interconnection inside sensor interface board.

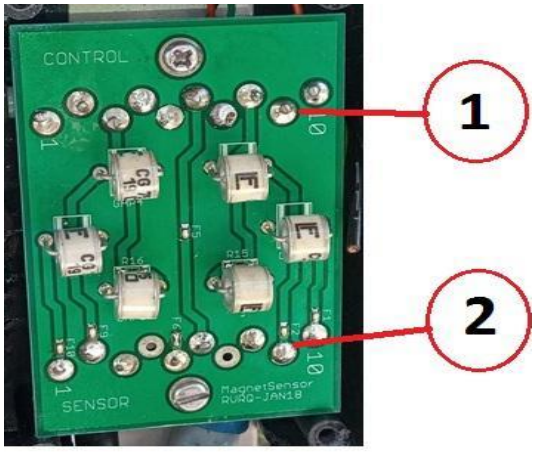


Figure 5. *Sensor Interface board, (1) connection from CU cable, (2) connection from the internal Mag-03 sensor module.*

2.5 CABLES AND ACCESSORIES

1. 80 m multi-wire sensor cable, Flexi-Control-JZ-CY, 12GO, 75mm, 02
2. USB A/B cable 0.8m
3. Garmin GA 25 CMX GPS antenna.

2.6 FIELD CANCELLATION SYSTEM DESCRIPTION

The zero-field cancellation of the X and Z components is performed manually, using an internal DIP switch for coarse adjustments and a front-panel dial potentiometer for fine-tuning.

Local field cancellation of the X and Z components is achieved via an electronic circuit (view figure 6) that generates a precise DC bias voltage based on a highly stable reference voltage IC. Coarse cancellation ranges are set using 8-position DIP switch selectors, with two precision potentiometers on the front panel for fine adjustments of the X and Z components.

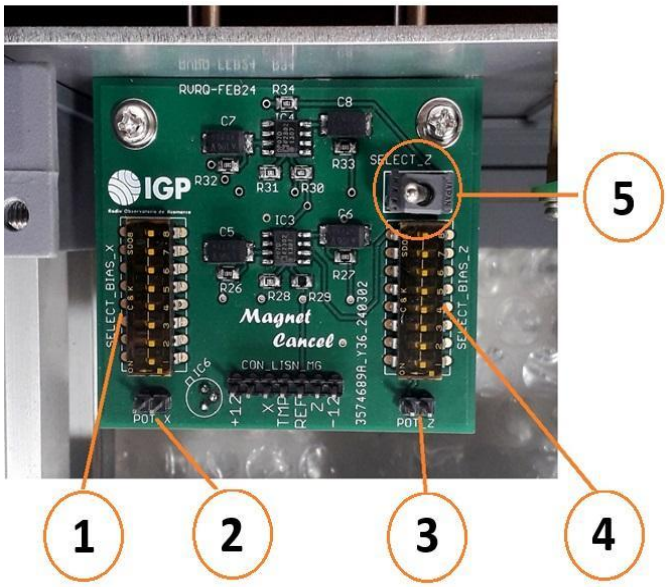


Figure 6. *Local field cancellation board showing the location of the adjustment controls.*

1. DIP switch Bias coarse cancellation select for X component.
2. X connection to front panel potentiometer for fine cancellation adjustment.
3. Z connection to front panel potentiometer for fine cancellation adjustment.
4. DIP switch Bias coarse cancellation select for Z component.
5. Z Polarity select toggle switch, positive to northern hemisphere negative for southern hemisphere.

X and Z DIP switches cover a total cancellation range of +/- 70000 nT in steps of +/-14000 nT per position while panel potentiometers cover a range of +/- 14750 nT.

2.7 LOW PASS FILTER

The LPF control attenuates high frequencies above the -3dB/15 Hz setting, intended to be used for removal of unwanted frequencies present in the magnetic field variation being measured.

There are three toggle switches X, Y, Z in the conditioning board for filter active (ON) or filter disable (Off) the LPF as shown in figure 7.

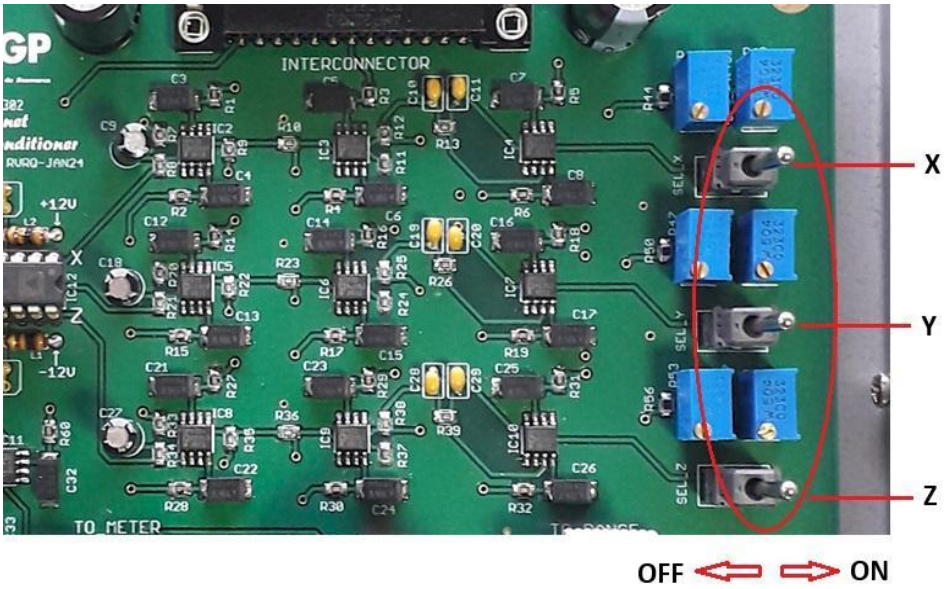


Figure 7. *Toggle LPF switches location for X, Y, Z control.*

2.8 TECHNICAL SPECIFICATIONS

Mechanical specifications

Operating temperature	0 °C to +65 °C
Sensor enclosure	PVC Double Shield (buried)
Sensor protection	Weatherproof sealed
Sensor dimensions	L=104 cm, D=14cm
Sensor cable length	PVC jacket, shielded, 80m
Sensor connector 10 contacts	Amphenol mil. Type
Control unit protection	Splash proof
Total weight	34 Kg

Technical specifications

Total measurement range	+/- 70000 nT
Dynamic range, two selectable	+/- 1000, 2500 nT
Sensitivity	10.0 mV/nT
Resolution	0.1 nT
Accuracy	0.25%
Orthogonality	<0.5°
Offset at T=25 °C	<1 nT
Zero drift	<0.1 nT/C
Supply voltages	+12 VDC (10.5 ~ 28.0 V
Current consumption	650 mA
Analog output voltage	+/- 10 V full scale
Digital output	USB
Bandwidth	DC to 3kHz
Sensor noise	10 pTrms/Hz1/2 at 1Hz
Power supply rejection	>100 dB
DC output impedance	<10 ohm

Data acquisition specifications

ADC type	SAR
Resolution	16 bits
Sampling rate	5 Sps (each channel)
Analog input range	+/- 10 VDC
Digital output	115200 baud (ASCII)
Clock control	Garmin 15xL GPS, NEMA, 1PPS
Embedded single board computer	Raspberry Pi4
SBC operating system	Raspbian- Linux Raspberry PI 5.10.103-v7l+

3. REQUIREMENTS

3.1 SYSTEM REQUIREMENTS

The complete magnetometer system includes the following components:

1. Sensor unit.
2. 80 m of cable.
3. Control and acquisition unit.
4. Power supply 12VDC/5 Amp.
5. 12VDC battery, 7~10 Amp/h and its charging power supply (*).
6. Power, battery, USB cables.

(*) Provided by the user.

Some recommended accessories

- Spirit level.
- Portable Digital Multimeter.
- Dedicated Internet connection for data transmission.
- Switch 10/100 Mbps or faster.
- Spare fuses and line spike protectors.
- UPS Uninterruptible Power Supply, 220V/1Kva.

3.2 SITE REQUIREMENTS

1. The sensor unit should be installed in an area with minimal artificial magnetic disturbances, avoiding locations near metal pipe installations, areas with human traffic, and at least 100 meters away from vehicle traffic.

2. The distance between the sensor and the control unit is limited by the cable length (80 meters); a minimum separation of 50 meters is recommended.

3. The location should have access to 110/220 VAC at 60Hz power, ideally with internet access or a local Ethernet network.

4. The environment where the control unit will be installed should have a temperature range between 10°C and 50°C, with humidity between 10% and 80% RH. The control unit should also be protected from direct sunlight.

5. The magnetic gradient at the chosen site should be low, ideally less than 10 nT per meter. To assess the gradient, a preliminary survey using an inclinometer or proton magnetometer is required.

For the sensor installation process, the following items are also recommended.

3.3 SENSOR CONCRETE BASE (IF PERMANENT)

- The base should be situated at least 50 meters from the location designated for the control unit, in an area with minimal magnetic disturbances.

- A square concrete base, 60 cm x 60 cm and 60 cm deep, is recommended, with a central hole 35 cm in diameter and 80 cm deep (to place the sensor unit).

- The base should be level and have a polished surface.

- Sand and fill material must be free of magnetic contaminants.

3.4 PROTECTIVE COVER FOR SENSOR BASE

- It is recommended to construct a wooden cover frame measuring 60 cm x 60 cm and 40 cm in height, with a 10 cm overhang and its four support columns should be buried to a depth of 40 cm.

- The roof should be made of lightweight, non-magnetic material, such as fiberglass. The top cover must be removable and secured with non-magnetic screws (e.g. copper or bronze).

3.5 SENSOR CABLE ROUTE TRENCH

- A trench 30 cm wide and 40 cm deep is advised, extending from the sensor base to the control unit's location.
- For permanent installations, install a 2-inch diameter PVC pipe in the trench to house the sensor cable.

4. SYSTEM SETUP

4.1 CONTROL UNIT SETUP

1. Connect the sensor cable to the input connector SENSOR INPUT.
2. Attach the GPS antenna and install it with a clear view of the sky, using an L-bracket and pole.
3. Connect the USB output (DIGITAL OUTPUT) to any USB port in the SBC module. If using a PC, connect the USB to any USB port in the PC.
4. Connect the battery cable (White is Positive).
5. Connect the AC power adapter to an appropriate line voltage. (220VAC or 110VAC).
6. Turn on the unit using the front panel power switch.

4.2 SENSOR SETUP

1. Insert the sensor vertically into the base to a depth of 80 cm, with the cable outlet facing magnetic north (view figure 8).
2. The base and cable outlet should be 3 cm over ground level.
3. Fill the tube halfway with non-magnetic material (sand) and unscrew the top of the sensor.
4. Adjust the sensor vertically until the internal bubble level shows it is level.
5. Fill the tube to ground level.
6. Connect the sensor output to the cable (80 m) connector.
7. Insulate cable connectors with waterproof electrical tape or self-bonding electrical tape.
8. Keep the multimeter plugged into the BNC connector on the sensor unit's black box. This is used to measure the voltage of the Y component when it points in the direction of magnetic north (0 V, near the geographic north).

Before turning on the control unit, check:

1. Ensure the sensor cable is securely connected to the SENSOR INPUT.
2. Turn the SELECT knob to the Y component position.
3. Connect the 12 VDC power input connector.
4. Turn on the control unit with the POWER switch. To view voltages in the correct range, use the DISPLAY SCALE switch to select the voltage range, depending on whether it is: up to 2 VDC (x1) or up to 20 VDC (x10).

Figure 8. *Location of the BNC connector, red cap.*

5. OPERATION SETUP

5.1 FIELD CANCELLATION SETUP PROCEDURE

1. Visit a magnetic field calculator or IGRF Web page for getting the current magnetic component values at the installation site.

   https://www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml#igrfwmm

2. Enter the Latitude, Longitude, and Geographic Elevation of the station where the magnetometer is to be installed and get the current epoch value of components H, Z, and Y to be used as a reference for the cancellation settings of the H and Z components and settings of the baseline values to be used in the data acquisition software.
3. Remove the four screws at the back of the control unit as shown in Figure 9.
4. Remove the two gray vertical bars and slide the top metallic cover to access the inner electronics board and connections.
5. The cancel circuit board is located behind the front panel, figure 10 shows the cancel board components and functions.

6. According to the reference values obtained, the appropriate DIP switches positions must be selected and fine-tune using the potentiometers of the front panel.

7. For the Z component, the appropriate polarity must be selected according to the location of the station, positive for the magnetic northern hemisphere and negative for the magnetic southern hemisphere as shown in figure 10.

Figure 9. *Location of upper and bottom cover screws.*

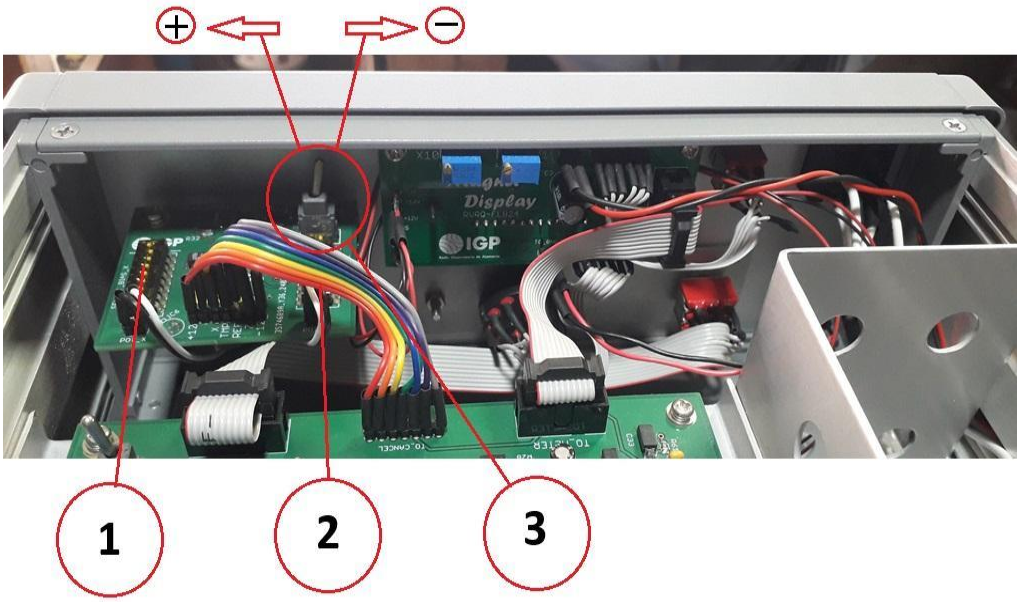


Figure 10. *Local field cancel PCB board location in CU back of the front panel.*

Components and Functions description about figure 10:

1. X component DIP switch for coarse cancel field range.
2. Z component DIP switch for coarse cancel field range.
3. Toggle switch for Z comp. polarity selection.

5.2 SENSOR ORIENTATION AND FIELD CANCELLATION FOR D COMPONENT

1. Set the SELECT to the Y component and DISPLAY SCALE to "x10".
2. Adjust the RANGE about latitude-specific (where the sensor was installed) for cancellation of the Y-component.
   a) For variations of dynamic range of +/-2500 nT. set RANGE to "2.5 uT".
   b) For variations of dynamic range of +/-1000 nT. set RANGE to "1 uT".
3. Rotate the sensor until the display voltage is near zero (view figure 11). Then refill the sensor to ground level, place the top cover, and seal it.

Figure 11. *Orientation of the Y component with magnetic north.*

Note: *To perform the work of orienting the sensor in an easier way, we can connect an external precision voltmeter to the BNC connector that is located on the side of the black box above the sensor module, in this case select the Y channel on the control unit panel.*

5.3 FIELD CANCELLATION FOR X COMPONENT

1. Set the SELECT to X and DISPLAY SCALE to "x10".
2. Adjust the FIELD CANCEL-X dial until the display reading approaches zero.
3. Switch DISPLAY SCALE to "x1" and make finer adjustments.
4. Continue slowly reset the cancel control until it approaches zero. The reading should be between +/- 0.010V approximately.

Note: *The cancellation of the X component is carried out with the RANGE placed in the position chosen for the data acquisition.*

5.4 FIELD CANCEL FOR Z COMPONENT

1. Set the SELECT to Z and DISPLAY SCALE to "x10."
2. Adjust the FIELD CANCEL-Z dial until the display reading is near zero.
3. Switch DISPLAY SCALE to "x1" and fine-tune.
4. Continue slowly reset the cancel control until it approaches zero. The reading should be between +/- 0.010V approximately. If the Z component cannot be fully canceled, check the polarity toggle on the cancel board (view figure 10).

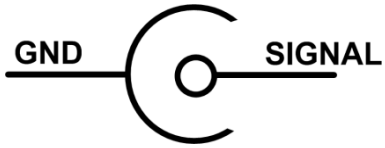
Note: *The cancellation of the Z component is carried out with the RANGE set in the position chosen for the data acquisition.*

5.5 FINAL VERIFICATIONS

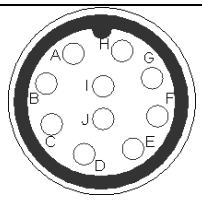
1. Set SELECT to T1 and T2 to check the temperatures of the control and sensor units respectively.
2. Set the SELECT to "REF VOLT" and verify the reading is between 9.98 and 10.0V (previously DISPLAY SCALE to "x10").
3. To verify display readings, connect a voltmeter to CAL OUTPUT and check each channel using the SELECT.
4. Finally, the system will be ready for data recording. Turn off the equipment before proceeding with data acquisition setup (refer to the software user manual).

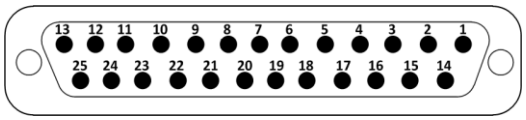
6. CONNECTORS

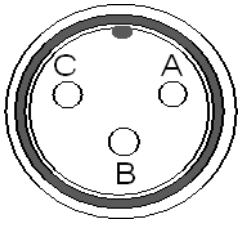
6.1 FRONT PANEL CONNECTORS

CAL OUTPUT		
Symbol	Real View	
		
Pin	Signal	Cable color
SIGNAL	Depending on SELECT	Red
GND	Ground	Black
Note: *Signal voltage output depending on channel selector SELECT position.*		

6.2 REAR PANEL CONNECTORS

SENSOR INPUT		
Symbol	Real View	
		
Pin	Signal	Color Cable (*)
A	Comp. X	Blue
B	Comp. Y	Yellow
C	Comp. Z	White
D	Ground	Green
E	SU Temp.	Grey
F	+12V Power Output	Red
G	Shield	Cable Shield
H	-12V Power Output	Black
I	CAL+	Brown
J	CAL-	Orange
Note: (*) *Internal connection from input connector to interface board.* *SU Temp. is the temperature signal in the sensor unit.*		

ANALOG OUTPUT		
Symbol	Real View	
		
Pin	Signal	Function
1	Comp. X	Analog output
2	Comp. Y	Analog Output
3	Comp. Z	Analog Output
4	CU. Temp.	Analog Output
9	Ground	Analog Ground
14	Aux. 2	Analog Input
15	Aux. 1	Analog Input
16	Aux. 0	Analog Input
17	SU. Temp.	Analog output
23	+12V	Positive Power Output
24	Ground	Power GND Output
25	-12V	Negative Power output
Note: *SU. Temp. is the temperature signal in the sensor unit.* *CU. Temp. is the temperature signal in the control unit.*		

BATTERY		
Symbol	Real View	
		
Pin	Signal	Color Cable
A	+12V Battery Power Input	Red
B	NC	
C	-12V Battery Power Input	Black/White

6.3 SENSOR CABLE CONNECTORS

Figure 12. *Sensor Amphenol connectors male and female.*

Shielded sensor cable connections table			
Pin. Conn	Signal	Color (*)	Cable Number
A	X Comp.	Blue	1
B	Y Comp.	Yellow	2
C	Z Comp.	White	3
D	GND sensor	Green	4
E	Temperature sensor	Grey	5
F	+12V	Red	6
G	SHIELD		
H	-12V	Black	8
I	CAL+	Brown	9
J	CAL-	Orange	10
Note: (*) Internal sensor module connections to Mag-03			