PPMG4A

Proton Precession Magnetometer

Model 4A
Firmware 1.23

User Guide

DISCLAIMER: The products described in this user guide are supplied in good faith on the basis that appropriate testing will be carried out by the user to establish their suitability. In the event the described products do not perform as expected, cause loss or damage, RHDC Services Ltd may not be held liable.

WARNING: Never short circuit the sensor connector or disconnect the sensor from the controller whilst the magnetometer is operating as this could damage the electronics. Always shut the magnetometer down properly using the white button or serial port.

ACCURACY: Absolute accuracy and other specifications of this instrument cannot be guaranteed because they have not been measured but derived from theoretical calculation, published constants, and electrical simulation, so users should be aware that there is a possibility of an error.

ENVIRONMENTAL: The PPMG4A system is not waterproof. If it is to be installed outdoors where it might be exposed to rain or damp, separate environmental protection will be required such as a waterproof cover or plastic bag.

1 Scope

This document describes how to use the PPMG4A Proton Precession Magnetometer. For convenience, this system will henceforth be referred to as 'the magnetometer.

Figure 1. PPMG4A Proton Precession Magnetometer

Image shows sensor model PPMG_SENSOR_7A which provides the best performance.

2 Important Notes

Please read the following important notes before using the magnetometer.

1. The magnetometer is not waterproof and must be kept dry. Do not expose the sensor or electronics to the damp or rain. If the magnetometer is to be left outdoors, a waterproof housing should be constructed around it to keep it dry.
2. Observe ESD precautions when making connections to the PPMG4A Control Unit.
3. Controlling Device means PC, laptop or tablet computer.
4. Audio output is calibrated for use with Sennheiser HD 25 headphones.

3 PPMG4A Box Contents

The following items are supplied in the PPMG4A Magnetometer box.

1. 1 x PPMG_CONTROLLER_4A Control Unit
2. 1 x PPMG_SENSOR_7A Sensor Unit.
3. 1 x PPMG_CABLE_4A Magnetometer Sensor Cable (5 to 7 metres long).
4. 1 x VEC65US19 19V 3.42A Mains Power Supply (Farnell order code 2524411).
5. 1 x IEC Mains Power Lead (Farnell order code 220010).
6. 1 x TTL-232R-3V3-AJ FTDI USB to RS232 serial cable (Farnell order code 1740363).

Note. Visit http://www.ftdichip.com/ for Virtual COM Port (VCP) driver download and installation instructions.

Figure 2. PPMG4A Box Contents

4 Additional Hardware and Software Required

In addition to the supplied sensor, controller, PSU, and cables, the following optional items may be required.

1. Controlling Device such as a laptop.
2. Terminal emulation software such as HyperTerminal or CoolTerm.
3. Sennheiser HD-25 Professional Monitoring Headphones or equivalent.
4. Distilled Water (not de-Ionised water) if sensor is supplied empty.
5. Food or pharmaceutical grade Propylene Glycol if sensor is supplied empty.

5 Sensor Preparation

The magnetometer sensor should be prepared as follows.

5.1 Sensor Fluid

The sensor may sometimes be supplied empty to save weight. In this case it must be filled, leaving a small air pocket to allow for expansion, with a mixture of distilled water and propylene glycol in the ratio 4:1 by volume. The 25% propylene glycol protects the sensor from freezing and also increases sensitivity because it produces a stronger proton signal. However, adding more than 30% will start to degrade performance, so 25% is optimal.

Figure 3. Sensor Fluid Components (propylene glycol and distilled water)

5.2 Sensor Installation

Sensor model PPMG_SENSOR_7A is designed to be installed on a 32mm OD plastic pipe, ideally located around 1m above ground and at least 3m away from buildings or strong magnetic gradients. The image below was taken facing just West of magnetic North and shows how to align the sensor for best sensitivity.

Figure 4. Sensor installed on 32mm OD PVC pipe approx. 1m above ground

6 Control Unit

The image below shows the control unit supplied with the PPMG4A magnetometer system. This unit houses all the magnetometer electronics apart from the external power supply and serial port adapter.

Figure 5. PPMG4A Control Unit model PPMG_CONTROLLER_4A.

6.1 Front Panel

The image below shows the front panel connectors and push switch.

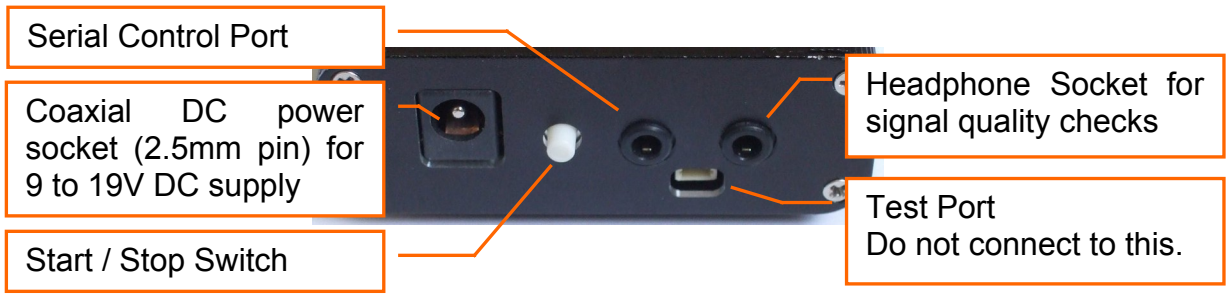

Figure 6. PPMG4A Control Unit (model PPMG_CONTROLLER_4A) - Front Panel

6.2 Rear Panel

The image below shows the rear panel connector and LED indicator.

Figure 7. PPMG4A Control Unit (model PPMG_CONTROLLER_4A) - Rear Panel

6.3 Display

The display shows the magnetic field reading in nT and other information, updated once per second.

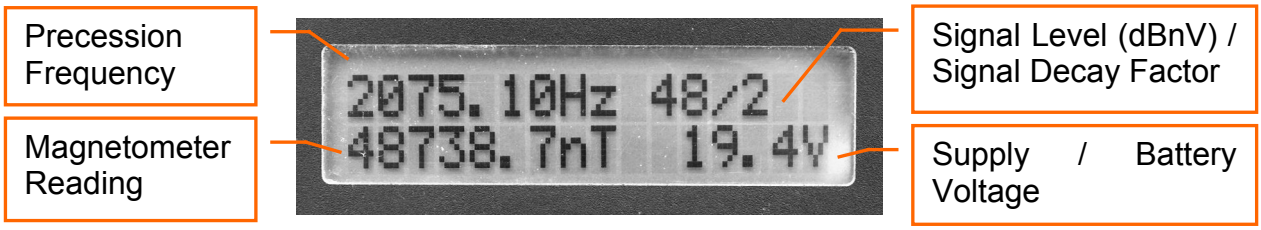

Figure 8. Magnetometer Display

7 Magnetometer Operation

This procedure describes how to make magnetic field readings.

1. Check the sensor is filled with the correct fluid.
2. Check the sensor is installed and aligned as described in a previous section.
3. Connect the sensor to the control unit using the supplied cable.
4. Optionally connect a pair of headphones to the controller's audio output jack for signal checking.
5. Connect the supplied 19V DC supply to a properly earthed mains supply.
6. Press the white button to start the magnetometer.
7. Observe the display and check the signal level is at least 45dB and that the readings are stable.
8. Observe the display and check the signal decay factor is less then 5dB.

If the magnetometer is operating normally, and assuming the sensor is in open ground, the reading in nT should correspond roughly to published values available via free online calculators such as the one below.

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

The Precession Frequency, Signal Level and Signal Decay Factor are not needed for normal operation and can be ignored.

8 Troubleshooting

The section below describes what to do if the reading is unstable, not in the expected range or the magnetometer display reports a problem.

8.1 Display indicates an error

If the control unit is unable to detect a proton signal at all, it may report a message such as "Bad interference" or "Reposition Sensor". The most likely causes are:

1. The sensor is affected by magnetic interference such as fluorescent lighting or mains transformers.
2. The power supply is not properly earthed or is noisy.
3. A wired connection to the control unit's serial port or audio port is introducing interference.

8.2 Readings do not correspond to the expected value

If the magnetometer is operational but the readings are vastly different to the expected value, especially if the displayed frequency is related to mains frequency (harmonics of 50 or 60 Hz depending on your region), this may be because a strong interfering signal is being mistaken for the proton resonance signal.

In the case of mains interference, this can normally be confirmed by connecting a pair of headphones to the control unit's headphone socket which allows the signal coming from the sensor to be monitored during the measurement cycle.

If mains hum is very audible, try to isolate the source of interference. Eg. by moving the sensor further away from buildings or temporarily powering the magnetometer from a car battery etc.

Once the interference has been isolated and eliminated, you should just be able to hear the brief and feint ping of the exponentially decaying proton signal, typically at around 2kHz, once per measurement cycle.

8.3 Readings are not stable

If the magnetometer is operational but the readings are not stable (i.e. the magnetometer is not delivering the expected 0.5nT /Sqrt(Hz) sensitivity or standard deviation) please check the Signal Level and Signal Decay Factor. For normal operation:

1. The Signal Level should ideally be more than 45dB and typically 48dB.
2. The Signal Decay Factor should ideally be less then 5dB and typically 2dB.

If the Signal Level or Signal Decay Factor are not ideal, the most likely cause is the sensor is too near to a strong magnetic gradient. In this case, try moving the sensor to open ground.

A second cause might be that the sensor fluid has not been mixed correctly, is above 30 degrees C, or is contaminated. In this case, try making a new batch, ensuring good quality distilled water is used and is mixed in clean containers.

A third cause might be that the ambient field being measured is fluctuating. In this case, there is nothing wrong with the magnetometer.

9 Remote Operation / Data Logging

The PPMG4A magnetometer includes an RS232 serial port for data logging and remote operation.

In addition, the serial port on the control unit outputs a regulated DC 3.3V supply at up to 100mA which can be used to power a wireless RS232 transceiver such as an HC-06 Bluetooth module (not supplied) for wireless operation.

Note. Using a wireless connection has the advantage of not introducing earth loops or mains interference and ensuring magnetic materials in the controlling device do not affect readings.

9.1 Serial Port Hardware

In order to use the remote operation and data logging facility of the PPMG4A, you must first set up the serial port hardware as follows.

1. If using a wireless connection, connect an HC-06 transceiver to the controller before applying power.
2. If using a wired connection, connect the FTDI USB to RS232 cable to a PC, install the drivers then connect it to the controller.
3. On the PC, open a serial connection to the relevant COM port (via Bluetooth if using the HC-06 module) with the following parameters: 9600 BAUD, no handshaking, 8 data bits, no parity, 1 stop bit.

Note. If a Bluetooth HC-06 transceiver module is plugged into the control unit after applying power, this will short out the 3.3V DC supply which will then be disabled. Therefore, if using the magnetometer with an HC-06 Bluetooth transceiver module, it must be connected before applying power.

9.2 HC-06 Wiring

If using a Bluetooth HC-06 serial module, connect it as follows.

HC-06		3.5mm Jack Plug	
1	TXD	4	Tip
2	RXD	3	Ring 1 (nearest Tip)
12	3.3V In	2	Ring 2 (3.3V out disabled if shorted)
13	GND	1	Ring 3 (nearest cable)

Table 1. HC-06 Module to 3.5mm Jack Wiring

Alternatively, a 4-Way 3.5mm jack to jack lead may be used with the module wired as shown below.

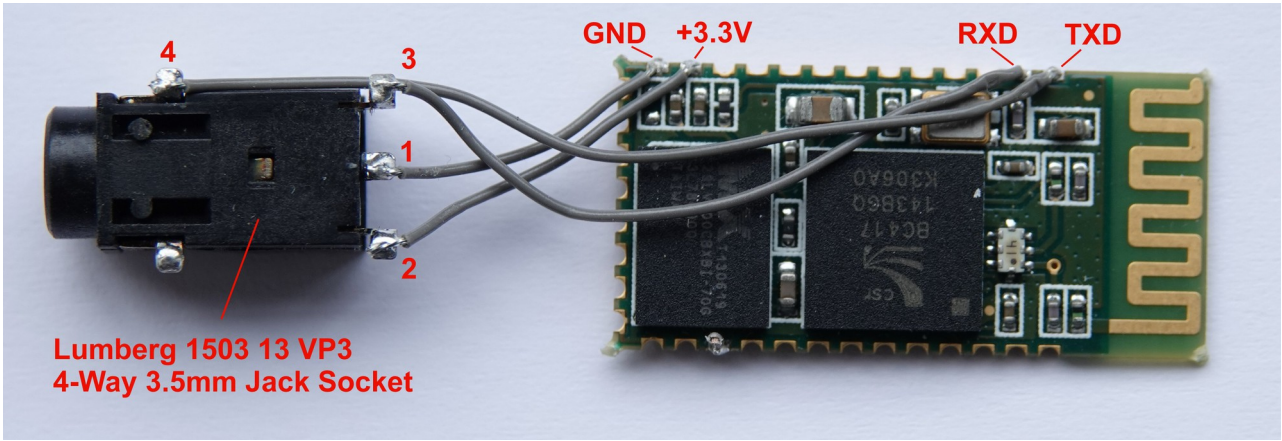

Figure 9. HC-06 Module to Lumberg 1503 13 VP3 jack wiring

9.3 Power Supply Mains-Hum

Proton Magnetometers work by inducing and measuring the Free Induction Decay (FID) Nuclear Magnetic Resonance (NMR) signal of Hydrogen nuclei precessing under the influence of the magnetic field being measured. The FID signal is extremely weak, in the order of 300nV, and is picked up by an induction coil around the proton sample. Unfortunately, the induction coil cannot be shielded against low frequency external AC magnetic fields without making the sensor very large, which unavoidably leaves the magnetometer vulnerable to interference.

Whilst this is not normally a problem, the TTL-232R-3V3-AJ USB to RS-232 adapter cable supplied with the demo system is not galvanically isolated. So depending on the mains filtering arrangement inside the power supply of the device to which it is connected, strong mains-hum with respect to Earth can be present on the USB ports.

Older power supplies or cheap ones bought via the internet are often the worst offenders. In many cases, residual voltages can be high enough to light a neon screwdriver or to give a 'tingling' electric shock. If such power supplies are used with the PPMG4A, strong mains-hum will be induced onto the sensor which will in turn severely affect performance and potentially stop the magnetometer working altogether.

Therefore, in order to achieve the published specifications, please ensure any power supply used with the magnetometer or controlling device is a properly earthed type (i.e. has a 3-pin input connector) and is connected to a properly earthed supply. This will ensure there are only minimal 50Hz voltages on USB ports and thus avoid any mains-hum related problems.

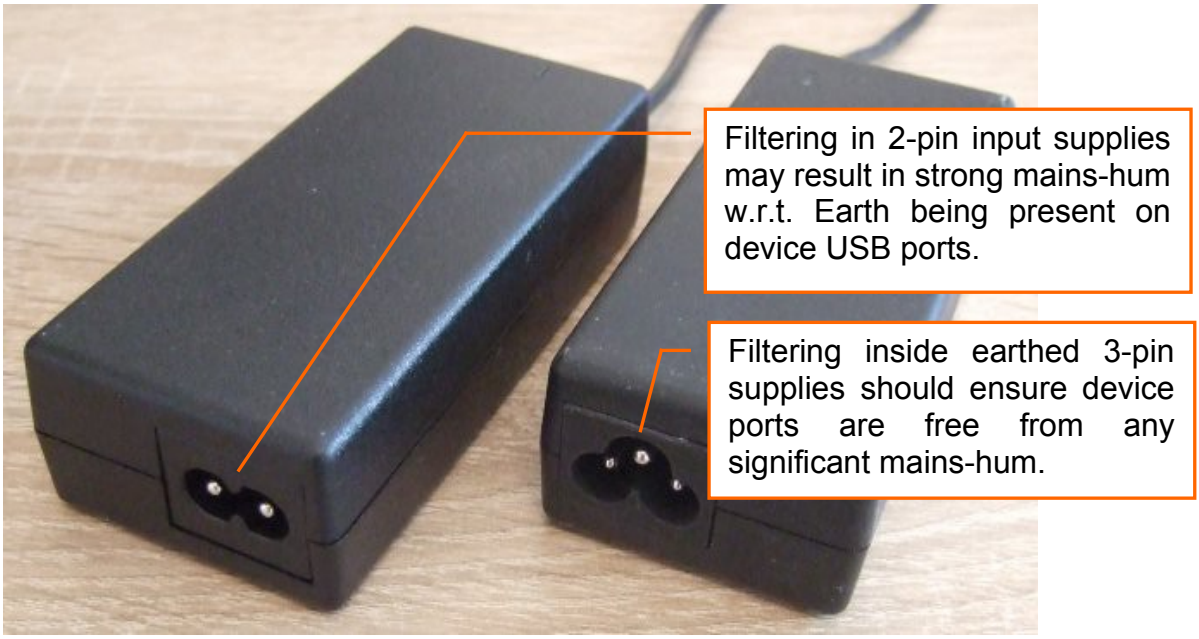

Figure 10. 2-Pin vs 3-Pin Laptop Power Supplies

9.4 Serial Terminal ASCII Setup

You may need to modify the default ASCII setup of your terminal emulation software so that line feeds are appended to each incoming line end. If you are using HyperTerminal, navigate to File -> Properties then select the Settings Tab, check the option as shown below then click OK. Other software should offer a similar option.

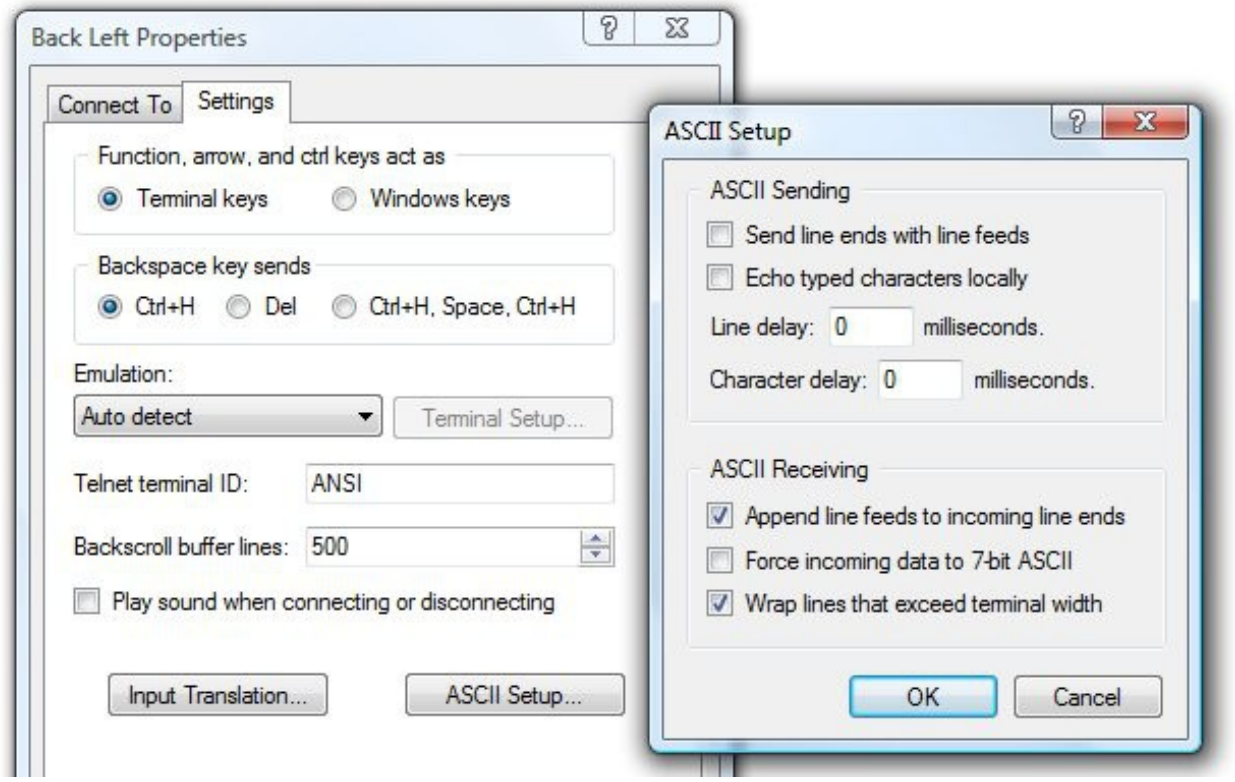

Figure 11. ASCII Setup when using HyperTerminal

9.5 Serial Port Test

Send the magnetometer an ASCII carriage return character by pressing Return or Enter in the active HyperTerminal window. The unit should output a response such as PPMG4A-123.

9.6 Commands

Typing '?' into the terminal window should produce a menu showing all available commands. These are as follows.

1. Power On / Off. The PPMG4A can be switched on or off using these commands. Note. If being used, power will continue to be supplied to the HC06 Bluetooth module, allowing the link to remain open.
2. Reading Output On / Off. Users can control whether readings are output over the serial port or not.
3. Other Controls. A number of other commands such as Sample Rate may be shown by the menu system. However, these are not for use by users and should be left alone.

10 Specifications

Unless Otherwise Stated: Supply = 19V, test field = uniform 50,000nT, Reading Rate = 1Hz, equipment temperature = 20ºC.

Parameter	Min	Typ	Max	Units
Range	25		100	µT
Standard Deviation (sensor fluid at 20ºC)		0.3	0.5	nT/sqrt(Hz)
Absolute Accuracy		3		+/- nT
Temperature Range a) Control Unit b) Sensor Ambient c) Sensor Fluid	 -10 -10 -10		 40 30 40	ºC
Measurement Rate			1	Hz
Average Sensor Power		15		Watts
7A Sensor Weight (full)		2.3		kg
Control Unit		180		grams
Supply Voltage	9	19	20	V

Specifications are subject to change without notice.

Note. If the system is left running continuously, the sensor fluid will heat up due to the 15W average power input. Depending on the ambient temperature, the sensor fluid may eventually exceed 30ºC, after which the precession signal and magnetometer accuracy will be noticeably degraded. For best results therefore, the magnetometer should be used for short periods and the sensor fluid temperature should be checked and ideally maintained at or below 25ºC. Also. If the sensor fluid freezes it will stop the magnetometer working and may damage the sensor housing, so care should be taken to avoid this, especially if the sensor is to be stored outdoors and left unpowered.

11 Limitations

It is acknowledged that the configuration and use of this instrument requires a degree of technical knowledge including experience with serial ports and a basic understanding of how proton magnetometers work.

In the event you are having problems setting the instrument up or obtaining stable readings, please contact RHDC Services Ltd for assistance.