

Operation Manual for

Grad-13

Digital Three-Axis Magnetic Gradiometer

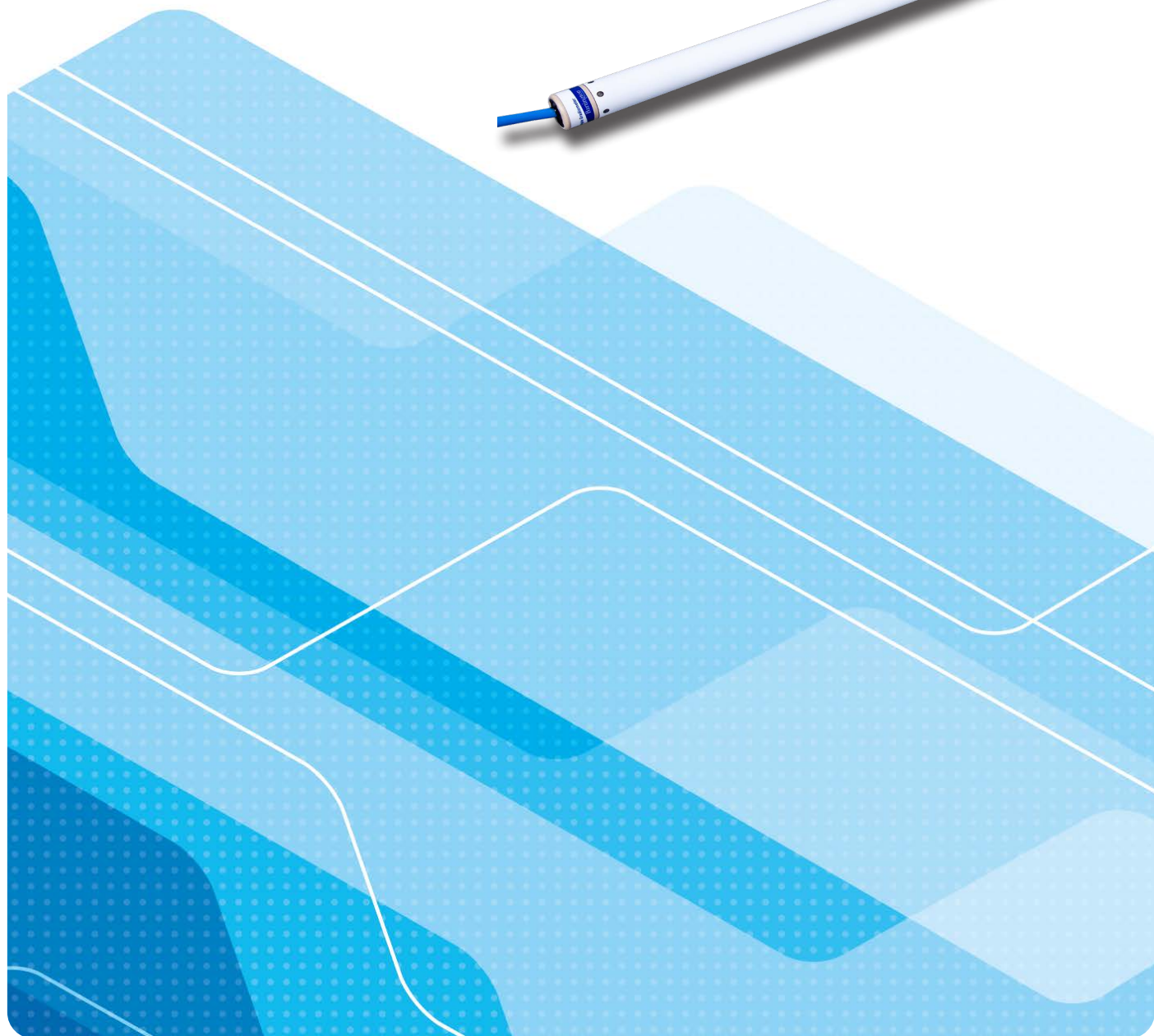


Table of Contents

1. About this Manual	3
1.1. Symbols Glossary	3
2. Safe Use	4
3. Introduction	4
4. Grad-13 Digital Three-Axis Fluxgate Gradiometer	4
4.1. Grad-13 Battery Box & Multiplexing box	5
4.2. Grad-13 Cable Assembly	5
5. Grad-13 Battery Box	6
5.1. Functional Description	6
5.2. The Battery Box Front Panel	7
5.3. Power Supply	8
6. The Grad-13 Port Multiplexing Box	9
7. Installation of the Grad-13	10
7.1. Unpacking	10
7.2. Orientation	10
7.3. Mounting	10
7.4. Connecting	10
7.5. Connecting Custom Systems	10
8. Operating Instructions	11
8.1. Operation	11
8.2. Visual Grad-13 Software Instructions	11
9. Storage	23
10. Servicing & Maintenance	23
11.1. Waste Electrical and Electronic Equipment (WEEE) Regulations	23
Appendix A: Guidance for Connection to Mains Supply	24

1. About this Manual

This document describes the installation, operation and maintenance of the Grad-13 digital three axis fluxgate gradiometer from Bartington Instruments. It should be read in conjunction with the [product brochure](#) DS3100, which can be found on the [product page](#) on the Bartington Instruments website at www.bartington.com. Outline drawings are also available on this page.

Note that failure to follow the instructions in this manual may invalidate your product's warranty. If in doubt, do not hesitate to contact Bartington Instruments.

Bartington Instruments cannot advise on the integration of this equipment with any third party products.

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

The Grad-13 is a three-axis digital fluxgate gradiometer which is available in multiple configurations; two enclosure variants: Grad-13L for environmentally-sealed outdoor operation and Grad-13S for underwater operation down to 200m submersion, three baselines: 500mm, 750mm and 1000mm and two sensor measuring ranges: $\pm 70\mu\text{T}$ and $\pm 100\mu\text{T}$.

The unit is comprised of two, three-axis, fluxgate magnetometers mounted either-end of a mechanical stable chassis. Each cluster of fluxgates is arranged such that the centres of the three magnetic axes coincide at a common point. The baseline is the distance between these two common points. Vector magnetic fields experienced by each of the three sensing axes are converted to digital signals and transmitted via an RS422 interface.

4. Grad-13 Digital Three-Axis Fluxgate Gradiometer

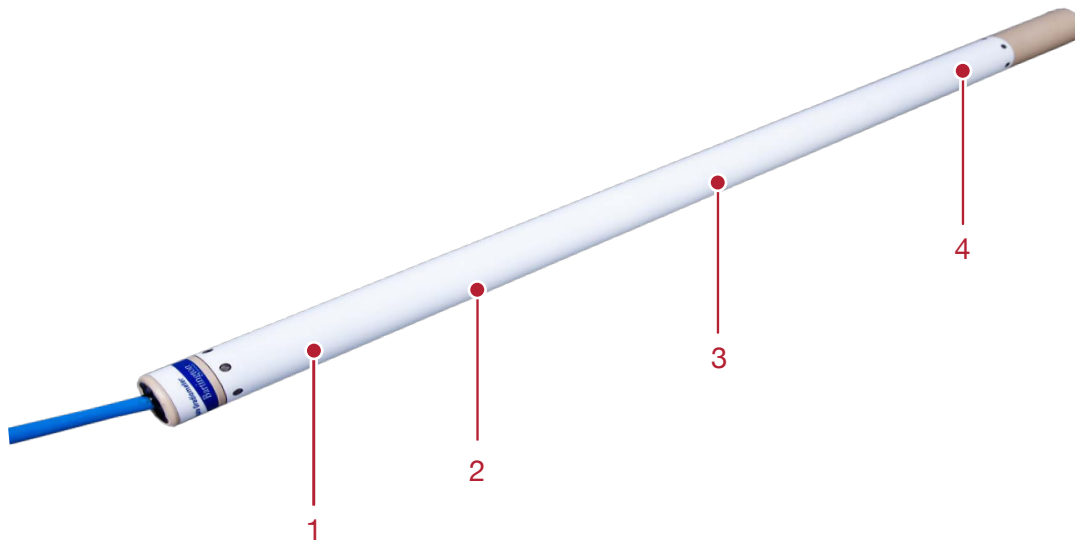


Figure 1: Grad-13S Digital Three-Axis Fluxgate Gradiometer

Key

1. Cable to Grad-13 Battery/Multiplexing Box
2. Three-axis “Reference” magnetometer
3. Three-axis Accelerometer
4. Three-axis “Sense” magnetometer

Note: Refer to the outline drawing DR3344 or DR3286 on the product webpage for further information.

The magnetometer assemblies are supported on shock resistant mounts inside a carbon fibre composite tube having 'O' ring seals at each end. Power is applied to the unit and digital signals are transmitted via an environmentally sealed connector.

The electronics are designed to minimise offset, scaling and orthogonality errors.

Power supply is provided using the Grad-13 Battery or Multiplexing Box and basic software is provided to interpret the RS422 digital data.

4.1. Grad-13 Battery Box & Multiplexing box

Bartington Instruments can provide two options for powering the Grad-13 and converting the signal output to either USB or ethernet output. These options are the Grad-13 Battery Box or the Grad-13 Multiplexing box. Grad-13 can be powered through customer's own hardware if available.

4.1.1. Grad-13 Battery Box

The Grad-13 Battery Box converts the signal from the Grad-13 to USB output. It is designed to be used with up to two gradiometers. See Section 5. Grad-13 Battery Box for further information.

4.1.2. Grad-13 Multiplexing Box

The Grad-13 Multiplexing Box will convert the signal from the Grad-13 to ethernet output. It will be designed to be used with up eight gradiometers. (under development)

4.2. Grad-13 Cable Assembly

Note: See drawing DR3344 (Land version) and DR3286 (Marine version) on the product webpage.

The cable supplied with the Grad-13 for connection to the Grad-13 battery box is appropriate to and dependent upon the version it is supplied for, i.e. Land or Marine. The polarity of the connectors prevents incorrect connection.

To connect the Grad-13S variant to a battery box, an accessory cable, the Grad-13S Underwater to Land Extension Cable, is required.

5. Grad-13 Battery Box

This section describes the installation and operation of the Grad-13 Battery Box.

5.1. Functional Description

The Grad-13 battery box allows connection of one or two Bartington Instruments Grad-13 gradiometers. It powers the gradiometer and converts the RS422 communication to USB. A rechargeable battery is built into the box and a dedicated charger is provided with the unit. A dedicated USB cable is also provided to provide connectivity to a computer.

5.2. The Battery Box Front Panel

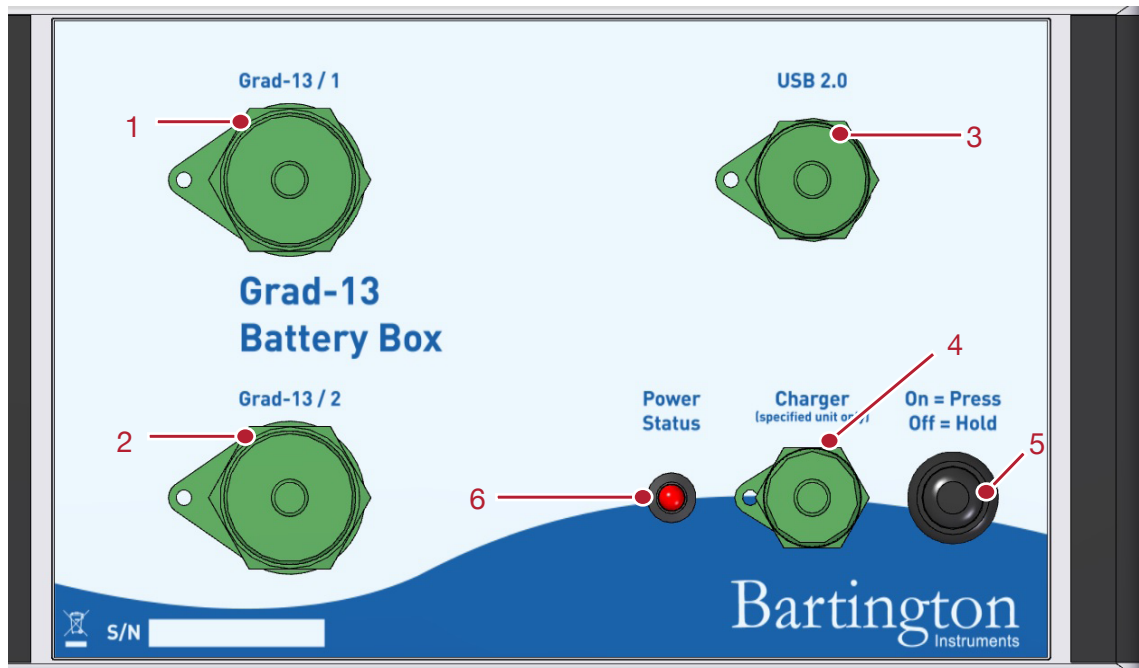


Figure 2: The Grad-13 Battery Box

Key

- 1,2: Connector for connection to Grad-13 gradiometer
- 3: Connector for connection to PC via USB 2.0
- 4: Charger connector for connection to mains power
- 5: ON/OFF power switch
- 6: Power status indicator

Note: See the outline drawing DR3911 on the product webpage for further information.

On-off switch operation:

- a. Push and hold on for half a second to turn on.
- b. Push and hold for over three - four seconds to turn off.

The units are housed in a polycarbonate enclosure. Connectors on the front panel provide connections to two Grad-13's and to a PC for digital output, with a socket for the charger input.

5.3. Power Supply

The battery box contains a lithium ion battery with a nominal voltage of 26V and an energy density of around 7Wh. It is capable of powering a single Grad-13 for up to 16 hours, and two Grad-13s for up to 8 hours, dependent on temperature and cable length.

The On/Off power switch light will flash when the battery is around 80% discharged. The length of time taken to discharge to this level depends upon the number of gradiometers connected, the battery age, and the battery temperature.



WARNING: The mains supply to the charge must be switched off before connecting or disconnecting the charger to the Grad-13 battery box.

5.3.1. Charging

Note: Charging temperatures should be between 0°C and 45°C.

The battery charger supplied with the battery box is shown below. The mains input socket is at the rear. The charge input voltage range is 100-240V, so no voltage selector switch is required.



The front panel of the charger includes a yellow/green LED, which indicates power and charging status.



At switch-on the LED flashes yellow/green and then indicates the following statuses.

LED Indication	Status
Yellow	Standby mode
Yellow/green flashing	Outside of valid temperature (wait)
Green flashing	Charging
Green	At least 80% charged. Wait for one further hour for full charge.
Yellow flashing	Error

Battery charging time from flat is around three hours, but charging for longer (typically overnight) is acceptable as the charger will switch to standby mode when the battery has reached full charge.

All multi-cell Lithium Ion batteries should be kept charged during storage to avoid deep discharging. The battery will gradually discharge when the Grad-13 Battery Box is de-powered due to a small current draw caused by the battery's internal protection circuit. Re-charge after each use up to at least 80% charge (green LED on charger). If the Grad-13 Battery Box is going to be stored for long periods, then charge the device beforehand and charge at least twice a year to avoid irrecoverable deep discharge.

6. The Grad-13 Port Multiplexing Box

Product in development - expected 2022 release.

7. Installation of the Grad-13

7.1. Unpacking

Safe handling precautions must be observed.

7.2. Orientation

See Outline Drawings for axis orientation.

7.3. Mounting

The sensor assembly is mounted in a stress free manner within the outer protective tube.

Note: Ensure that the Grad-13 enclosure is not excessively stressed, as the alignment of the sensors may be affected or the assembly integrity may be compromised allowing the ingress of foreign matter.

Note: See drawings DR3344 and DR3286 on the product webpage.

7.4. Connecting

The Grad-13 is connected to the Grad-13 battery box using the cable supplied. Connect Grad-13 to connections 1 or 2 of the battery box located on the front of the unit using the cable provided.

7.5. Connecting Custom Systems

A data protocol DP2629 can be provided if the Grad-13 is to be powered by and connected to a custom system. The API/software may still be able to be used if an Ethernet or Serial Connection is provided. Please contact Bartington Instruments for further information.

8. Operating Instructions

8.1. Operation

During operation, ensure that the battery box and cables are kept away from the gradiometer sensors.

Bartington Instruments can supply VisualGrad13 software for communication with the Grad-13.

If the user wishes to expand upon this or create their own software, this is simplified by using the API or Data Protocol (DP0105), available on request from Bartington Instruments.

8.2. Visual Grad-13 Software Instructions

8.2.1. Installation

In order to connect the Grad-13 to a PC, an RS422 to USB/Ethernet converter is required. The converter used and tested by Bartington instruments is a 'Brainboxes' RS422 converter, and this will be referred to in this manual. However, there are many other commercially available converters that can also be used.

The installation requires Brainboxes (or other) device drivers as well as the Bartington Grad-13 software. These need to be installed on a PC with a Windows OS.

Firstly install brainboxes USB to Serial software (driver for RS422 converter) before installing the Grad 13 software.

8.2.2. Installing the Brainboxes USB to Serial drivers

To install the Brainboxes USB to Serial drivers, run the Brainboxes Setup.exe, without plugging in the device. Accept all default options during installation.

The Grad 13 should then be plugged in (including the USB lead to Battery box). Plug the Grad-13 into the Battery box and turn it on. The PC will then look for the correct device drivers for the Grad 13. Allow the Brainboxes drivers to be installed for the plugged in device.

8.2.3. Installing the Grad13 Software

Note: Uninstall any existing versions of D660, Grad-13 or the Visual Grad-13 software via the control panel before installing this software.

Run the Visual Grad13Install.exe, and follow the instructions. Once this has been completed it will create three shortcuts on your desktop:

VisualGrad13 - Main Grad 13 Master Interface application.

DataPro - Data processor for data generated from the Grad13 Master application.

Grad13Logs - Shortcut to the Grad13 log file directory.

Note: The Visual Grad 13 Interface and Grad13 Data Processor application interfaces with Microsoft's Excel; if Excel is not installed on the PC then an error may appear when trying to send data to Excel from Visual Grad 13 Interface and the Data Processor application. The software can still be used without Excel installed.

8.2.4. Using the software

Open the Visual Grad-13 application (using the VisualGrad13 shortcut from the desktop), this will display the Visual Grad-13 application as shown in Figure 7:

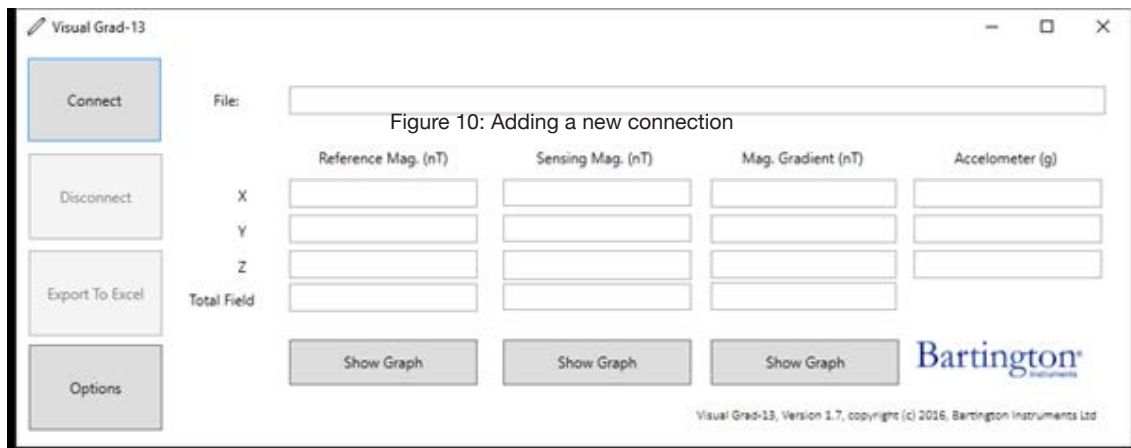


Figure 7: Visual Grad-13 Software Main Window

8.2.4.1. Connecting to a Grad-13

Connect: The '**Connect**' button is used to connect the software to the Grad13, the device connection window shown in Figure 8 will then be displayed.

Note: the Grad 13 needs to be plugged in and powered before trying to connect.

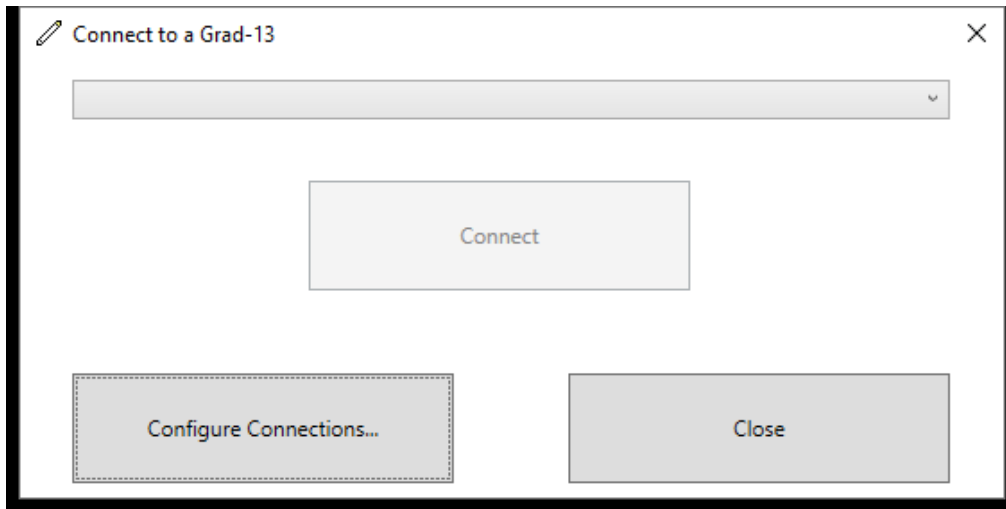


Figure 8: The 'Connect to a Grad-13'

This window allows you to connect to a Grad-13 device, if the connection has already been correctly configured. All connections that are currently available are listed in the drop down list box at the top of the window. If this is blank, then you will need to configure a new connection. Click '**Connect**' to attempt to connect to the Grad-13 device using the selected connection.

Note: the Grad 13 may not be listed in the drop down list if it has not been plugged in before selecting 'Connect' from the main window.

Configure Connections

Before you can connect to a Grad-13 device, or if you wish to edit a connection, you need to use the '**Configure Connections**' option in the 'Connect to a Grad-13' window to set up your connections. Clicking on this will display the window shown in Figure 9:

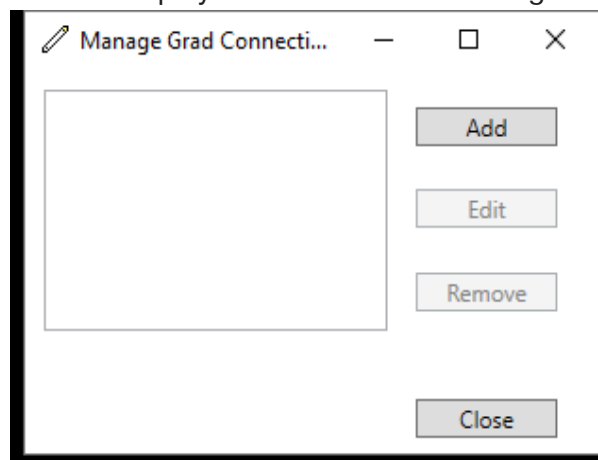


Figure 9: The 'Manage Grad Connections' Window

The '**Edit**' button can be used to edit any existing connections that are listed. The '**Remove**' button allows you to remove a preconfigured connection.

To create a new connection, click '**Add**', this displays the window shown in Figure 10:

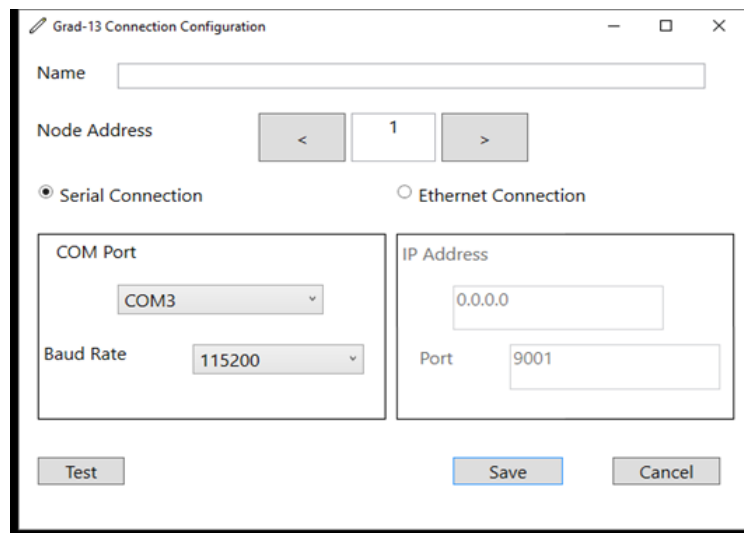


Figure 10: Adding a new connection

This window allows you to specify:

The **'Name'** of the connection, this appears in the drop down list when you attempt to connect to a Grad-13 device.

The **Node Address** of the Grad-13 is set during manufacture and should be kept as 1 by default.

Whether the connection is a **Serial Connection** (i.e. USB to Serial) or an Ethernet connection.

Serial Settings

If connecting via serial connection, the correct COM Port should be selected (this is normally the last one in the list). By default, only the Brainbox ports are listed (to which the Grad-13 is connected), hence you may only see one COM port in the list.

The correct COM port can be identified by looking for the RS422/RS422 Serial Port (COM...) in your PC's Device Manager under Ports (COM & LTP), see Figure 11 for an example.

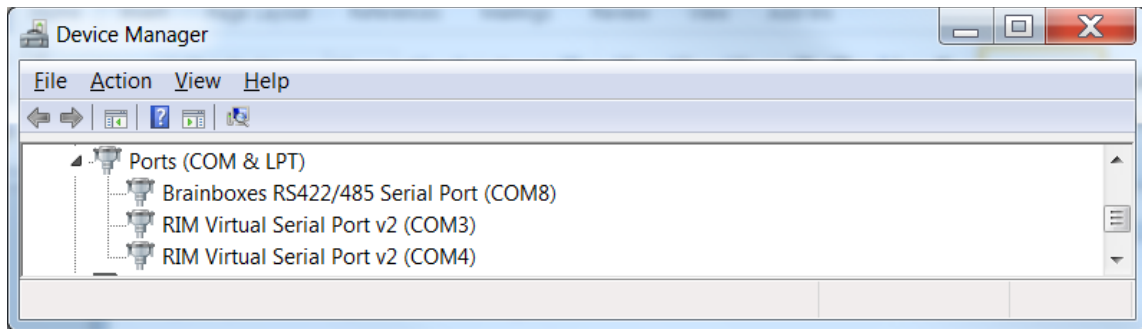


Figure 11: Identifying the correct port using Device Manager

Baud Rate: The default baud rate is 115200.

Note: The Baud Rate has to be programmed in the Grad 13, therefore in most cases the default rate should be used. The exception to this is when the Baud rate has been changed by Bartington Instruments in order to output the full 200Hz bandwidth.

Ethernet Settings

Input the '**IP Address**' and the '**Port Number**' on the IP Address. (This will be printed on the multiplexing box)

After configuring the settings and ensuring the Grad-13 device is powered on and connected, you may test your settings by clicking '**Test**'. This will test the connection but will not leave the connection open, and will disconnect from the Grad-13 upon completion. This test will display either a success or failure message prompting you to check the configuration.

Clicking '**Save**' will save the connection and the new name will then be listed in the Manage Grad Connections window. The connection can then be selected in the drop down list shown in Figure 8.

Successful Connection

When you successfully connect to your Grad-13 device, the Visual Grad-13 application window options will change as shown in Figure 12:

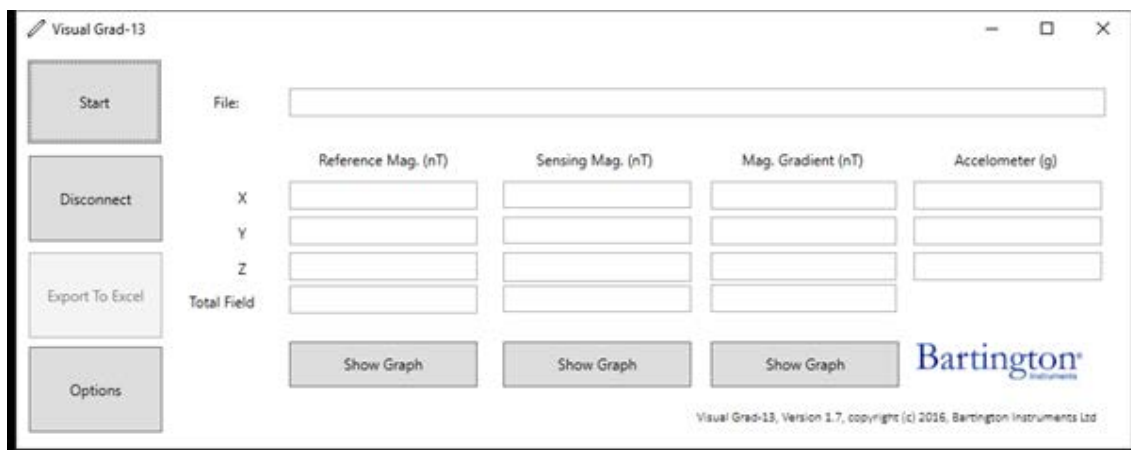


Figure 12: Main window following successful connection to Grad-13

This window now gives the options to start a scan, display graphs or disconnect from the Grad-13.

Note: Connections can fail if the Grad-13 device is not connected, connected to the wrong connection, not powered, or incorrectly configured. This will lead to an error message when attempting to connect.

8.2.4.2. Starting a scan

Once a Grad 13 is connected, a scan can be started. Scans are saved to .pct files in the Grad 13 Log directory (a shortcut to this is placed on the desktop by default during the installation). Scan files are numbered sequentially, and created each time a scan is started.

Click '**Start Scan**' to start a scan, as shown in Figure 13.

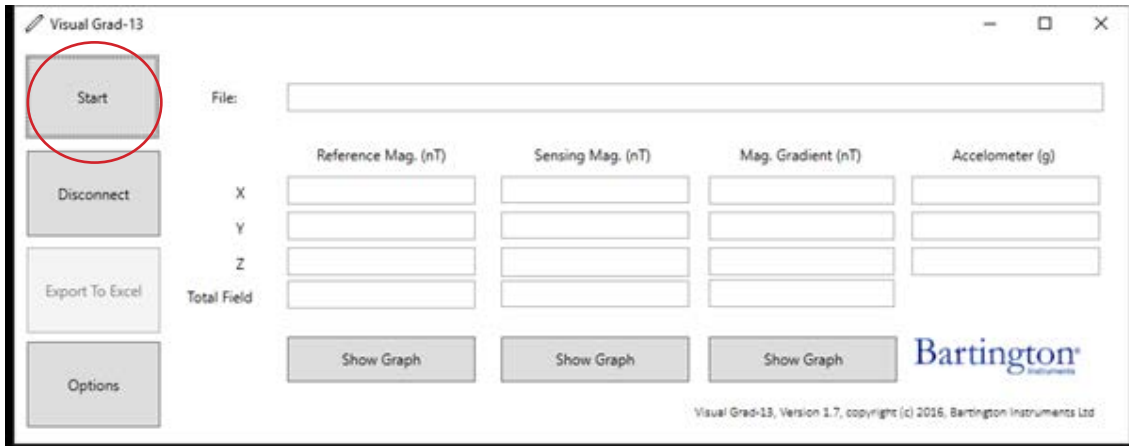


Figure 13: Start Scan

When a scan is started, a window is displayed that allows the location of the .pct file to be specified, as well as allowing notes to be entered for the scan. These notes are stored within the .pct scan file and may be referred to later, this window is shown in Figure 14.

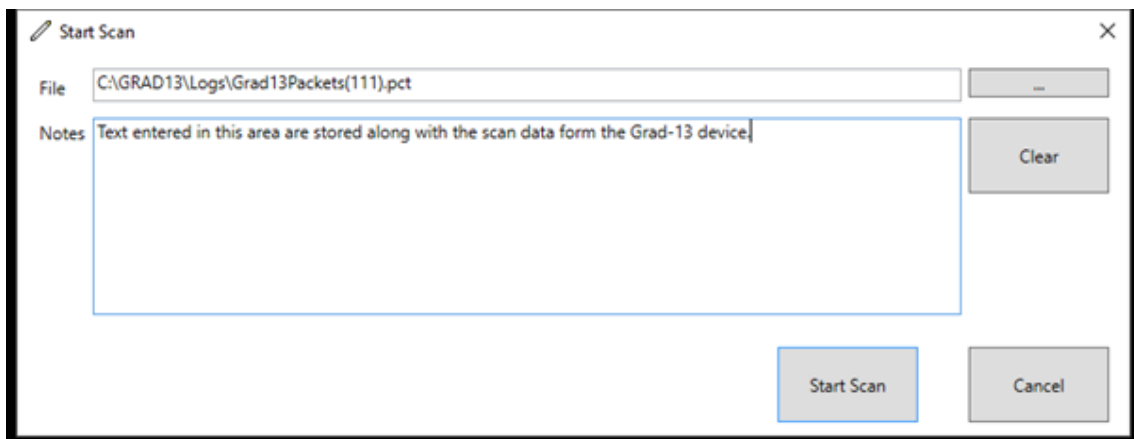


Figure 14: Scan Notes

Click on '**Start Scan**' to begin.

Once '**Start Scan**' is clicked, data from the Grad-13 device is collected and stored within the .pct file specified within the Start Scan window. Graphs may be displayed by clicking on '**Show Graph**', see Figure 15.

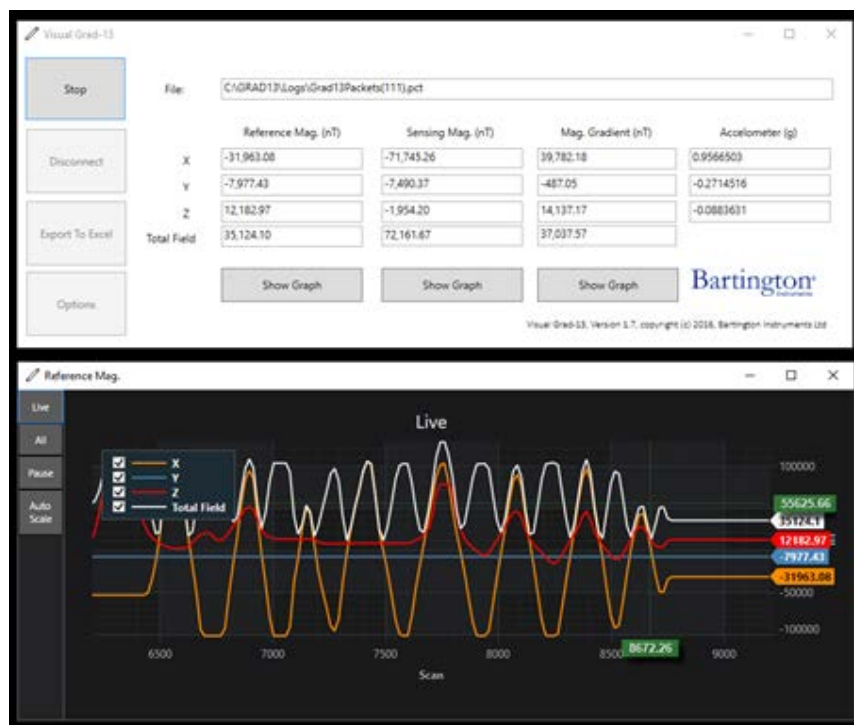


Figure 15: During a scan

Note: The Visual Grad-13 software will sometimes slow down the display of data on the screen when the PC it is running on is unable to handle screen updates at the rate that the data is being collected at (scans are coming in at ~200 scans per sec). This does not slow the data gathering or data storage. The Visual Grad-13 application will attempt to speed up the visual screen updates again as soon as it is possible to do so without affecting the data that is gathered from the Grad-13 device. This is intended functionality of the software and exists to safeguard and favour the data stored to file instead of the screen display.

8.2.4.3. Stopping a scan

Whilst a scan is running, only the **'Stop'** and the **'Show Graph'** buttons are available. To stop a scan, click **'Stop'**:

Once the scan is stopped, the following buttons will become available:

'Start': A new scan can be started.

'Disconnect': Disconnects from the Grad-13 device.

'Export to Excel': Sends the data to Excel, see section 5.2.4.6.

'Options': See section 5.2.4.4.

8.2.4.4. Options

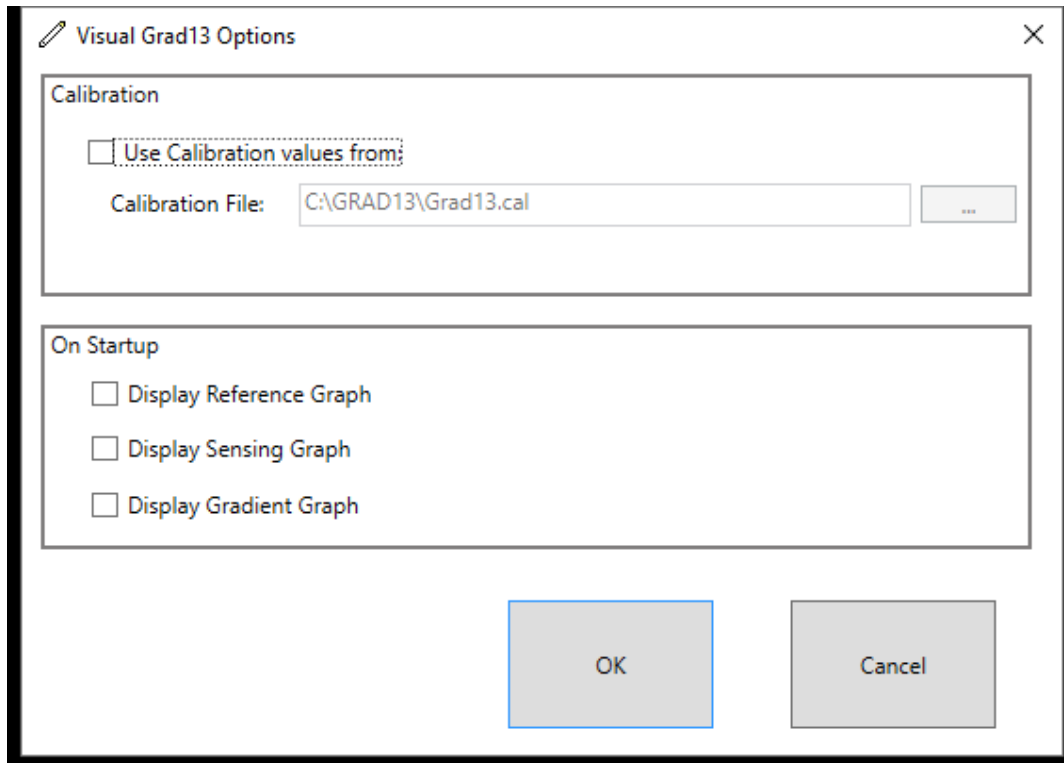


Figure 16: During a scan

Clicking the '**Options**' button in the Visual Grad-13 main window brings up the window shown in Figure 16. This button will be greyed out if a scan is running.

Two different options are available, '**Calibration**' and '**On Startup**'.

The first tickbox, '**Use Calibration Details from:**', allows a user to select an alternate calibration file to apply to the Grad-13 data. This option is primarily for use by the Bartington Instruments technical team to apply additional calibration values should it be required. The file is in.txt format, and can be edited using Notepad.

Note: Applying correction coefficients will affect the display of data but not the recorded values until they are exported to Excel.

The three tickboxes '**Display Reference Graph**', '**Display Sensing Graph**', and '**Display Gradient**' Graph, can be selected so that the graphs will be displayed when the Visual Grad-13 application is first started. By default these are unchecked and the user must click on the display graph buttons.

8.2.4.5. Graphs

Three graphs can be displayed using the Visual Grad-13 software:

- **'Reference Mag. Graph':** Displays the values being recorded by the reference mag (see position 2 in Figure 1).
- **'Sensing Mag. Graph':** Displays the values being recorded by the reference mag (see position 4 in Figure 1).
- **'Mag.Gradient Graph':** Displays the difference between the Reference and Sensing Magnetometers.

Each graph has the same functionality and displays the data for its associated items in nT.

A graph has three modes which are available by clicking on the buttons on the left side of the graph:

- **Live:** displays the last ~15 secs of scans.
- **All:** displays all scans (up to a maximum of 1000000 scans).
- **Pause:** pauses the current "Live" display, Zoom may be used in this mode by mouse click and drag. This button does not halt the acquisition.



Figure 17: The Live and Pause Graph views

The value of any specific point on the graph can be found by moving the mouse pointer to that point and reading the green marker values at the edge of the graph, as shown in Figure 17.

Data displayed on the graph can be turned on and off by the use of the legend check boxes:

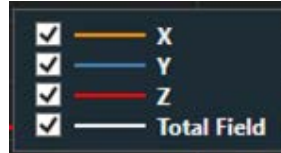


Figure 18: The Graph Legend and Axis Selection box

The '**Auto Scale**' button allows the Y scale to scale automatically based on the selected items in the graph when in Pause mode.

8.2.4.6. Exporting Data

The '**Export to Excel**' button will export the data to Microsoft Excel .csv format and will open it in Excel if it is installed. The file will be stored in the same folder as the .pct file specified in the **File** location, see Figure 19. If calibration data has been selected the correction factor will be applied here.

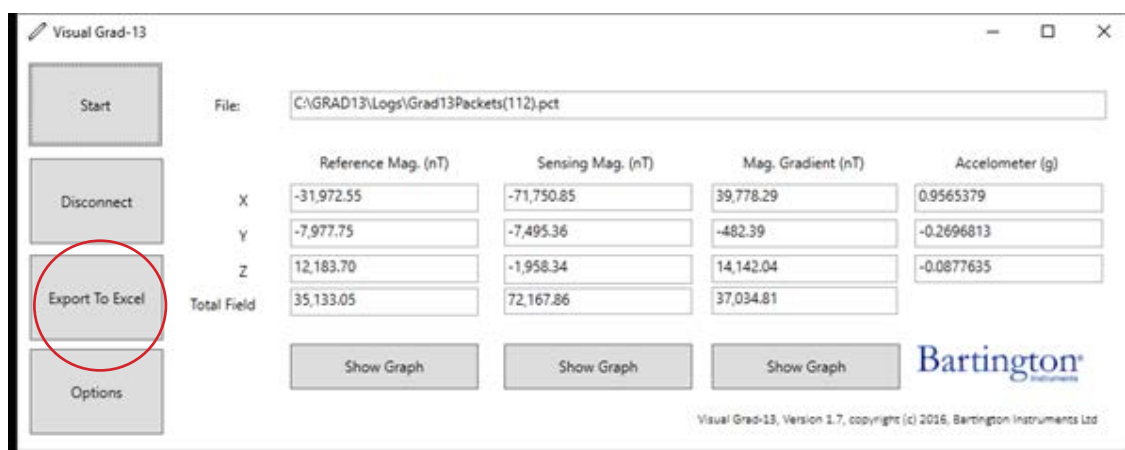


Figure 19: Export to Excel

Figure 20 shows an example of the resulting Excel .csv file. Magnetometer data is displayed in nT.

8.2.4.7. Data Processor

Packet No	Time (ms)	Low Speed	Low Speed-Mag X	Mag Y	Mag Z	Mag XD	Mag YD	Mag ZD	Accel X	Accel Y	Accel Z	Temp A	Temp B	Flags	Auto Gen
0	0	0	15670	-71749.2	-7492.79	-1506.07	39781.73	-488.79	14139.14	0	0	0	0	0	0
1	4.992	1	-4420	-71749.5	-7492.81	-1506.09	39782.03	-488.85	14139.27	0	0	0	0	0	0
2	9.984	2	-1445	-71749.8	-7493.33	-1506.64	39781.7	-487.44	14139.91	0	0	0	0	0	0
3	14.976	3	413	-71750.2	-7494.27	-1507.65	39780.28	-484.71	14141.25	0	0	0	0	0	0
4	19.968	4	401	-71750.2	-7494.55	-1507.9	39779.24	-483.82	14141.57	0	0	0	0	0	0
5	24.96	5	0	-71749.9	-7494.62	-1508.05	39778.2	-483.57	14141.85	0.956421	-0.26978	-0.0882	25.81	25.06	0
6	29.952	0	15660	-71750.6	-7494.75	-1508.11	39778.37	-483.34	14141.91	0	0	0	0	0	0
7	34.944	1	-4418	-71749.9	-7494.72	-1508.16	39777.47	-481.2	14141.83	0	0	0	0	0	0
8	39.936	2	-1439	-71750.2	-7494.7	-1508.11	39777.65	-483.41	14141.82	0	0	0	0	0	0
9	44.928	3	413	-71750.3	-7494.74	-1508.16	39777.43	-483.28	14141.92	0	0	0	0	0	0
10	49.92	4	401	-71750.6	-7494.72	-1508.13	39777.6	-483.28	14141.92	0	0	0	0	0	0
11	54.912	5	0	-71750	-7494.67	-1508.14	39777.01	-483.41	14141.85	0.955811	-0.26965	-0.08783	25.81	25.06	0
12	59.904	0	15669	-71750	-7494.66	-1508.07	39777.18	-483.5	14141.71	0	0	0	0	0	0
13	64.896	1	-4413	-71750.3	-7494.72	-1508.18	39777.19	-483.22	14141.89	0	0	0	0	0	0
14	69.888	2	-1440	-71750.5	-7494.71	-1508.13	39777.57	-483.39	14141.9	0	0	0	0	0	0
15	74.88	3	413	-71749.8	-7494.66	-1508.06	39776.84	-483.46	14141.89	0	0	0	0	0	0
16	79.872	4	401	-71750.7	-7494.7	-1508.12	39777.78	-483.4	14141.95	0	0	0	0	0	0

Figure 20: Example Excel Export

This application processes the data from the Grad13 Master application, it works with the files that the VisualGrad13 Master application creates and is used to send the data to Excel.

GRAD-13 Data Processor Software

File Tools Help

Cal File: ...

Date/Time:

☐ Burst Scan

Serial No: Device Add.:

Acquisition: Firmware:

Protocol: File Version:

File Type: Packet Type:

Baud Rate: Mag FSD:

N.O. Packets: Grad FSD:

Sum Count:

Errors:

Checksum

☐ None

☒ Basic

☐ CRC

Open...

Export as CSV

Send To Excel

Exit

Version 1.128 build 160405:104200

Bartington Instruments 2016

Figure 21: Data Processing Window

- **'Open...'**: this opens a .pct data file (the Grad13 master application uses the .pct file type to store scans). Once opened, a .dat file with the same name will be created (this is a working file that is used during processing). Once a file is opened, information regarding the scan is displayed. It is not uncommon that a small number of errors may exist, you should note that the Data Process application makes allowances for format inconsistencies that can occur due to CRC or state changes within the Grad13. Small numbers of errors can be ignored.
- **'Export as CSV'**: This exports the data as a .csv file which can be opened using database software or notepad. The file generated is placed in the same directory as the .pct file and has the same name except it has a .csv file extension.
- **'Send to Excel'**: this exports a .csv file and opens it in Excel (if Excel is installed on your PC).

9. Storage

Store the Gradiometer and in a container in a dry environment with no risk of condensation. Do not leave the Grad-13 exposed to strong magnetic fields (above it's measuring range) for prolonged periods of time. This can cause performance degradation.

10. Servicing & Maintenance

The Grad-13 contains no user-serviceable components and must be returned to Bartington Instruments for repair or re-calibration.

The Grad-13 Battery Box has no internal serviceable parts. See Section 5.3.1 on charging recommendations.

The equipment can be wiped clean with a damp cloth if required.

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

11.1. Waste Electrical and Electronic Equipment (WEEE) Regulations



This product 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 writing.

Appendix A: Guidance for Connection to Mains Supply

1. Ensure that the mains feed is from a clean AC supply with the following characteristics:-

Voltage Range	100V to 240V AC (Selectable on Charger)
Frequency	50/60Hz

It is highly recommended that this mains feed is via an appropriate Residual Current Circuit Breaker, rated at 30mA trip current. This must comply with local regulations.

2. The mains input connectors are as follows:

Device	Input Connector	Mating Cable Connector
8-Way Multiplexing Box	IEC C14	IEC C13
Battery Box	IEC C8	IEC C7

These cables are available in specific versions for most countries.

3. If an un-terminated IEC connector lead is supplied with the equipment, the wires must be wired accordingly:-

BROWN	LIVE
BLUE	NEUTRAL
GREEN/YELLOW	EARTH

4. It is recommended that the mains to each unit is supplied via an 13A mains fuse:

This is appropriate for the use over the whole supply voltage range.

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The specifications of the products described in this brochure are subject to change without prior notice.

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