Operation Manual for

CU2 Closed Loop Module

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1. About this Manual

This manual provides the information necessary to help customers connect and operate the CU2 Closed-Loop Module for use with Bartington Helmholtz Coil Systems.

Photographs of key components are included, labelled with numbers. A number in the text in square brackets [ ] refers to that label.

The CU2 Closed-Loop Module is one of the components of a Helmholtz Coil System. Manuals for the other components of the system include:

- OM3226 HC1, OM3342 HC2, OM3878 HC9, OM4048 HC16
- OM3225 PA1 Power Amplifier.
- OM3224 CU1 Control Unit.

All are available via the Helmholtz Coil System Operation Manuals webpage. Additionally, the datasheet DS2613, the CU2 outline drawing DR3999, and the CU2 connections drawing Appendix A should be consulted.

Note: 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: A paragraph in this format provides useful supporting information on how to make better use of your purchase.

2. *Safe Use*

WARNING: Ensure all local and national codes on electrical installation and grounding are observed. Safety protection will be impaired if the unit is used in a manner not specified in this manual.

WARNING: There are no customer serviceable components within this unit. The unit should be opened by Bartington Instruments personnel only.

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

3. *Introduction*

The CU2 Closed-Loop Module unit is used to add active compensation of magnetic field variations to our Helmholtz Coil System. By using the CU2 Reference Magnetometer mounted in the homogeneous area in the centre of the coil, it monitors the changes in magnetic field inside the coil which are not attributed to a user-driven change, and alters the current supplied to the Helmholtz Coil to remove them.

> **Note:** The CU2 Closed-Loop Module is specifically calibrated to a particular type of coil. The CU2 cannot therefore be transferred from one type of coil to another (e.g. HC1 to HC16).

The unit can allow for compensation of DC and AC field. Figures of field attenuation at AC can be found in the product datasheet. Cancellation is carried out at the location of the CU2 Reference Magnetometer.

When used, the coil will generate fields referenced to the CU2 Reference Magnetometer, it is important to first align the CU2 Reference Magnetometer axes with that of the Helmholtz coil, and second to align the Device Under Test (DUT, where applicable) to the CU2 Reference Magnetometer.

The module connects between the CU1 Control unit and the PA1 Power Amplifier, and is supplied complete with CU2 Reference Magnetometer, CU2 Module, and all interconnecting cables between the CU2, CU1 and PA1. Power to the CU2 Module and CU2 Reference Magnetometer is provided by the CU1 via the Auxiliary Connection. Some analogue filtering is also applied to the CU2 Reference Magnetometer by the CU2 module.

A full Helmholtz Coil including closed-loop correction will consists of:

- One of Bartington's Helmholtz Coils (HC1, HC2, HC9 or HC16) or Ferronato Coils (BH1300)
- PA1 Power Amplifier: the power amplifier for the system. See OM3225.
- CU1 Control Unit.

A diagram showing the connection of these separate items into one system is given in Appendix A: Connecting the Components of the Helmholtz Coil System.

Bartington can also provide the necessary acquisition card which will allow connection of the system to a PC, together with the necessary control software.

4. General Description

4.1. Front View

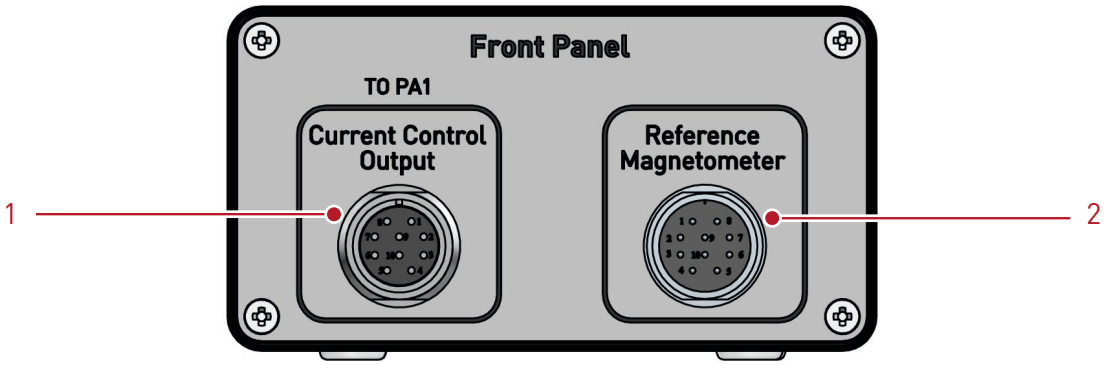


Figure 1. Front view of CU2 Closed Loop Module

Key

1. Current Control Output
2. CU2 Reference Magnetometer Input

Current Control Output [1]: this is a differential output for current control of the Helmholtz Coil. This should be connected to the Current Control Input of the PA1 Power Amplifier.

CU2 Reference Magnetometer Input [2]: this is the input for the three-axis reference magnetic field sensor supplied with the CU2.

> **Note:** The CU2 Reference Magnetometer and the CU2 module are paired. Only the Reference Magnetometer supplied with the CU2 should be used.

4.2. Rear View

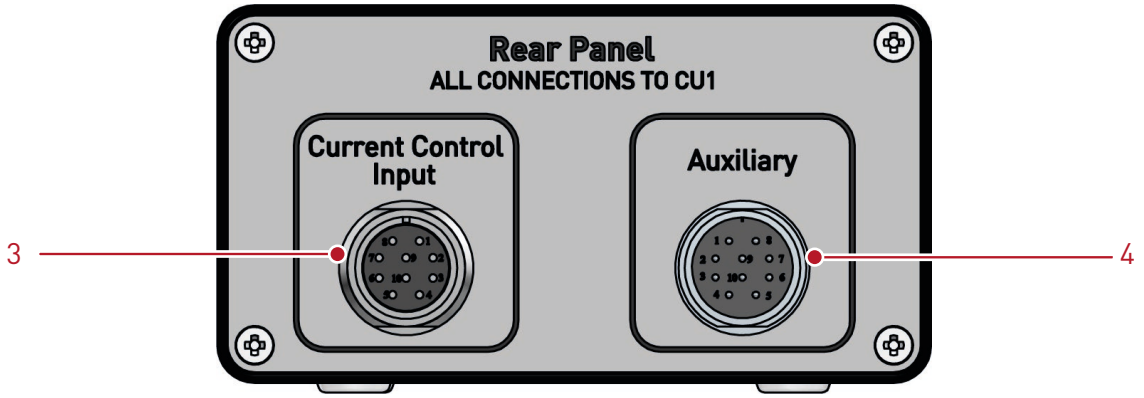


Figure 2. Rear view of CU2 Closed Loop Module

Key

3. Current Control Input
4. Auxiliary Connection

Current Control Input [3]: this provides three differential analogue inputs and should be connected to the CU1 current control output.

Auxiliary Connection [4]: connects to the CU1 Auxiliary Input - power the CU2 Module and CU2 Reference Magnetometer and allows the CU2 Reference Magnetometer output to be made available on the Auxilliary output through the CU1.

4.3. Top View

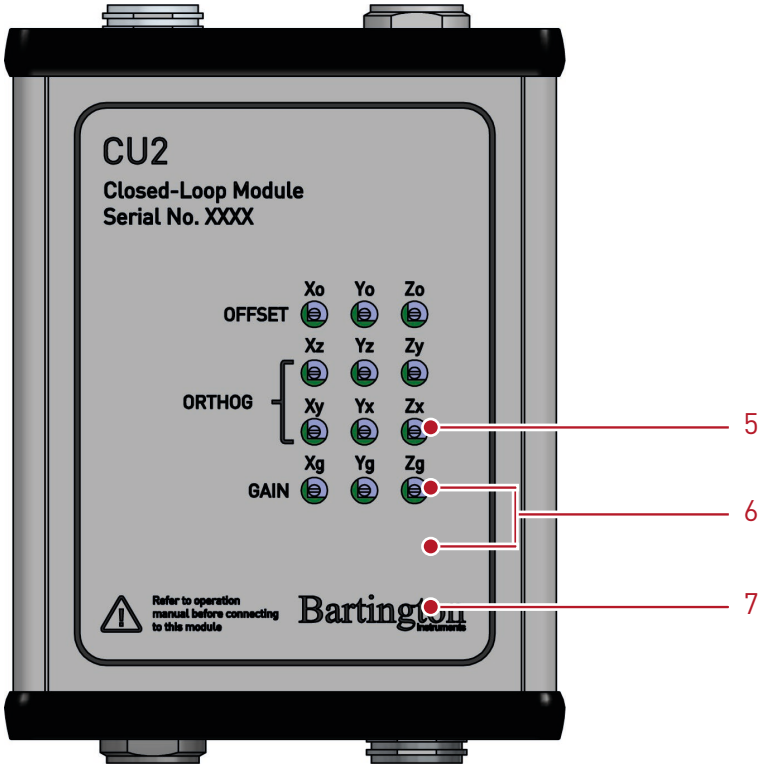


Figure 3. Rear view of CU2 Closed Loop Module

Key

5. Offset Adjust Potentiometers
6. Orthogonality Adjust Potentiometers
7. Gain Adjust Potentiometers

Offset Adjust Potentiometers [5]: this provides adjusment control of the CU2 Reference Magnetometer offset, one potentiometer for each X, Y and Z.

Orthogonality Adjust Potentiometers [6]: this provides adjusment control of the CU2 Reference Magnetometer Orthogonality. Potentiometers are for X errors due to a field generated on Y and Z (Xy and Xz), Y errors due to a field generated on X and Z (Yx and Yz) and Z errors due to field generated in X and Y (Zx and Zy).

Gain Adjust Potentiometers [7]: this provides adjusment control of the CU2 Reference Magnetometer gain, one potentiometer for each X, Y and Z.

5. CU1 Closed-Loop Module Installation

5.1. Equipment Location and Ventilation Requirements

The CU2 has no forced ventilation requirements and can be sited close to the CU1 and PA1.

To achieve best overall system performance, the Helmholtz coil should be located away from the PA1 (using the cable length supplied - at least 3m). The CU2 Reference Magnetometer should be placed within the 0.1% homogeneous volume of the Helmholtz coil.

The CU2 will cancel any external field variations at the point where the CU2 Reference Magnetometer is located. If strong gradients are present within the coils, the CU2 will only be able to cancel in one point rather than the complete volume. It is therefore essential to ensure that the coils are not positioned close to metallic or magnetic structures. It is advisable to keep a clearance of 3-5m. Individual circumstances will lead to changes to this recommendation. A survey prior to setting the coil is recommended. Please contact Bartington Instruments for advice.

Field cancellation will also be more effective for anomalies that only create a weak gradient across the homogeneous volume. The further away from the coil the source of anomaly is, the more stable the field will be across the coil volume.

The CU2 Reference Magnetometer should be located within the area of highest homogeneity within the coil. The CU2 Reference Magnetometer and DUT (if applicable) should be placed as close to each other as possible and be aligned mechanically.

Further information on suitable location of the Helmholtz Coil system can be found in AN0052, which is available from our website.

Please refer to the Helmholtz Coil datasheet for dimensions of the homogeneous volume.

> **Note:** For optimum results, the CU2 should be operating within the temperature range specified in the datasheet DS2613.

5.2. Connecting the CU2 to the Helmholtz Coil System

The CU2 Closed-Loop Module has 2 inputs for connection to the CU1 Control Unit, 1 input for connection of the CU2 Reference Magnetometer, and 1 output for connection to the PA1 Power Amplifier.

> **Note:** The CU2 Closed-Loop Module is specifically calibrated to a particular type of coil. The CU2 cannot therefore be transferred from one type of coil to another (e.g. HC1 to HC16).

The CU2 should be connected to the Helmholtz Coil System while the system is switched off.

If it is necessary to connect the CU2 while the Helmholtz Coil system is powered, use the following connection sequence.

1. Connect the CU2 Reference Magnetometer to the CU2 Module. The CU2 Reference Magnetometer should be located in the homogeneous area of the Helmholtz coil.
2. Connect the Auxiliary Input, for connection of the CU1 via the CU1 to CU2 auxiliary cable. Power to the CU2 is provided through this input.
3. Connect the Current Control Input, for connection to the CU1 via the CU1 to CU2 current control cable.
4. Connect the Current Control Output, for connection to the PA1 via the PA1 to CU2 current control cable.

Use the above procedure in reverse to disconnect the system.

Always use the cables supplied by Bartington Instruments. The use of longer cables may leads to interferences and a reduction in the performance level of the system. Details of the pin-outs are available in drawing DR3999.

See Appendix A: Connecting the Components of the Helmholtz Coil System for the connection diagram.

WARNING: Under no circumstances should a reference magnetometer other than the CU2 Reference Magnetometer supplied with the CU2 Module should be used. The CU2 Module and CU2 Reference Magnetometer are calibrated as a pair. Use of another magnetometer will cause a higher field to be generated by the Helmholtz Coil System.

5.3. Locating the CU2 Reference Magnetometer

Any corrections made by the CU2 will be based on the reading of the CU2 Reference Magnetometer, so correct placement is essential.

For accurate operation, the CU2 Reference Magnetometer must be placed in the homogeneous area of the Helmholtz Coils. Additionally, the CU2 Reference Magnetometer should be mechanically aligned with the Device Under Test.

5.4. Power Supply

The CU2 Closed-Loop Module is powered by the CU1 Control Unit via the Auxiliary Connection.

6. CU2 Closed-Loop Module Functions

In order to trim and calibrate the system parameters, an array of potentiometers is provided on the CU2 module. These are set up at the factory and calibrated with the CU2 Reference Magnetometer provided with the module.

The potentiometer functions are as follows:

- Gain Potentiometers: used to trim the system gain for each X, Y, and Z channels.
- Orthogonality potentiometers: used to trim the system orthogonality for each of the X, Y, and Z channels.
- Offset potentiometers: used to trim the system offset for each of the X, Y, and Z channels.

7. Using the HC2 Closed-Loop Module

7.1. Switching the Equipment On and Off

Use the following sequence for powering-up the various components of a Helmholtz Coil System, once all are connected:

1. If your measurement system includes one, power-up your PC or National Instruments system.
2. Ensure that the CU2 Reference Magnetometer is plugged into the CU2.
3. Power-on the CU1 Control Unit using the ON/OFF switch on the right of the front panel. This will also provide power to the CU2 Closed-Loop Module.
4. Power-on the PA1 Power Amplifier.

Use the above procedure in reverse when powering down the system.

7.2. Bartington Instruments Control Software Settings with CU2

Due to scaling considerations within the CU2, when using the CU2 Closed-Loop System, the "Closed Loop" tick box should be selected. When this is used, it bypasses any scaling factors.

7.3. Calibrating the CU2

An initial calibration of the CU2 Closed-Loop Module is done at Bartington Instruments assuming a central position of the CU2 Reference Magnetometer. However location of the coil at the customer site together with an off-centre position of the CU2 Reference Magnetometer

and additional equipment within the coil (e.g. DUT), may lead to a required fine tuning by the customer.

> **Note:** For optimum system performance, the PA1 and CU1 should have been left to warm up for 12 hours before system calibration is undertaken, and the CU2 connected for at least the warm-up period stated in the datasheet. Where possible, connect the CU2 prior to switching on the system for warm-up.

Calibration should be performed once the CU2 Reference Magnetometer is located in it's final location inside the coil and any additional equipment is placed within the coil.

Before performing the calibration of the CU2, the PA1/Helmholtz coil combination should have it's DC offset potentiometers adjusted to the location where the coil is installed (i.e. ensure that when a zero field is applied, a magnetometer in the centre reads zero). Please refer to the HC/PA1 calibration document available from Bartington Instruments.

As calibration is performed with DC fields, the low-pass filter selectable through the software (measure tab) should be set to 10Hz.

1. Open the Helmholtz Coil Control Software to calibrate the CU2 and CU2 Reference Magnetometer. The CU2 Reference Magnetometer should be corrected for offset, orthogonality and scaling errors within the Helmholtz Coil homogeneous area.

2. To correct for Offset, switch to "Generator" tab, set HC Type to HC1 (regardless of the Helmholtz Coil type). Rest of the parameters should remain as shown in Figure 4. The Output should be set to off.

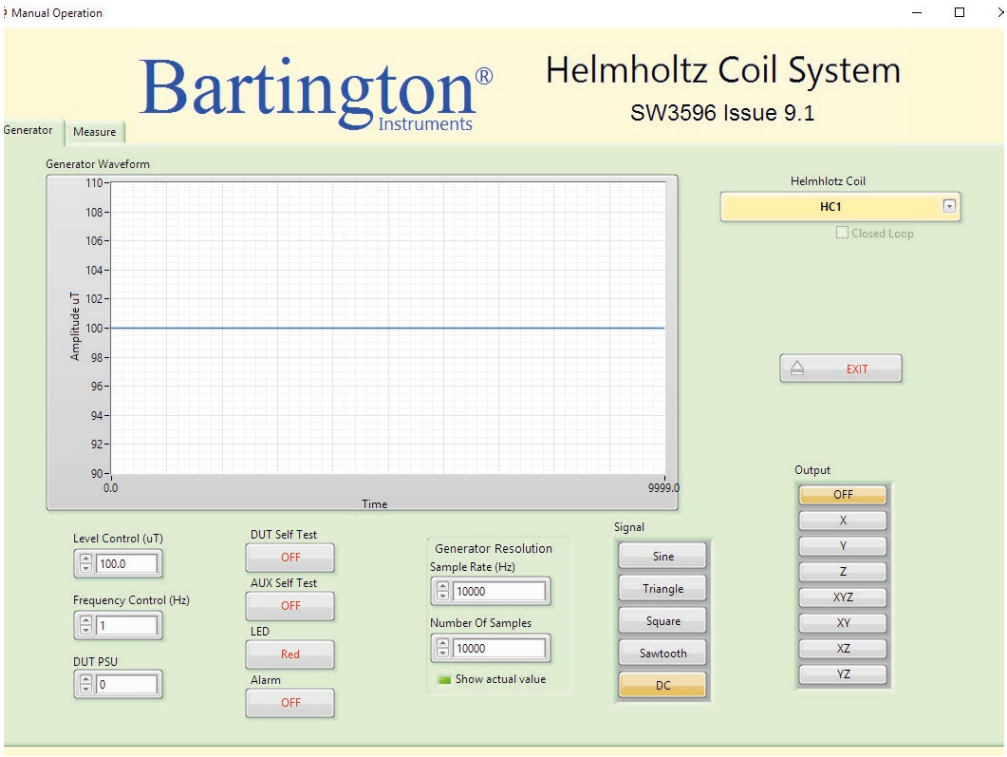


Figure 4. Offset adjustment Generator Tab template

3. Switch to "Measure" tab, press "Start Read" and monitor the values of X, Y and Z offsets. They should be as close to 0nT as possible. Use a screw driver adjusting the Offset potentiometers **[5]** on the top panel of the CU2 Module. Adjust for each one of the axes.

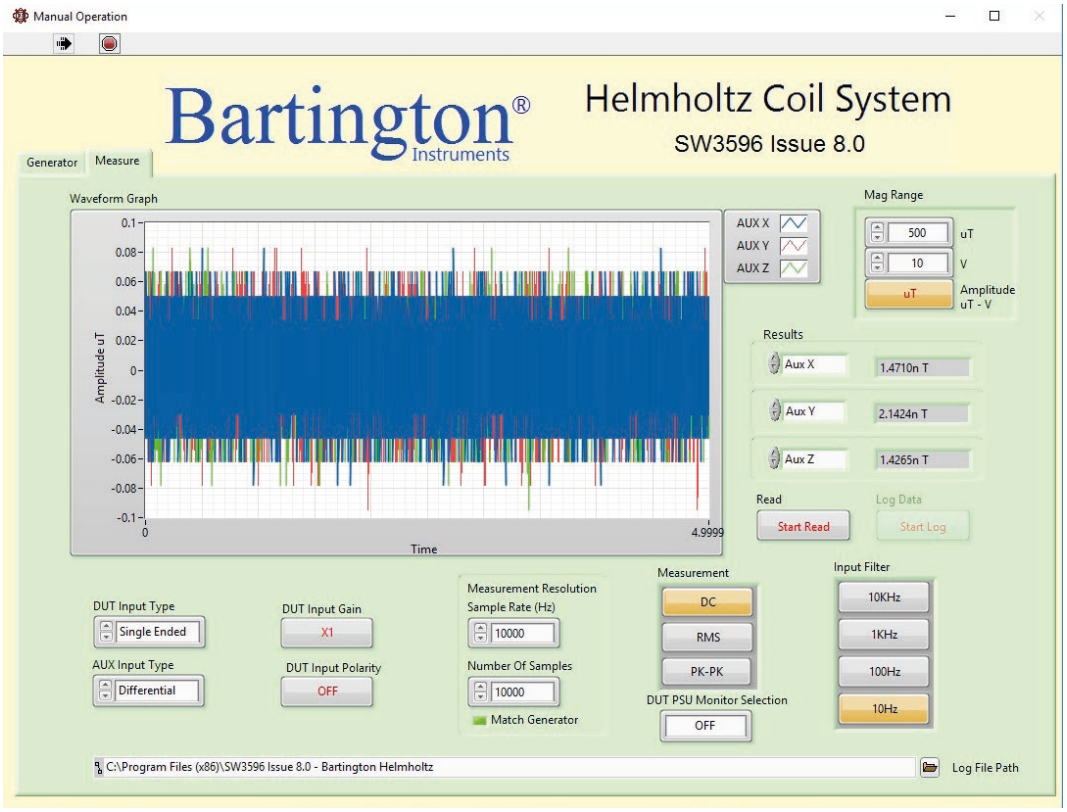


Figure 5. Offset adjustment example measure tab

4. To correct for gain and orthogonality, switch to “Generator” tab and select X as an “Output”. Set the field amplitude to 500uT in DC.(The same workflow should be followed for Y and Z axes).

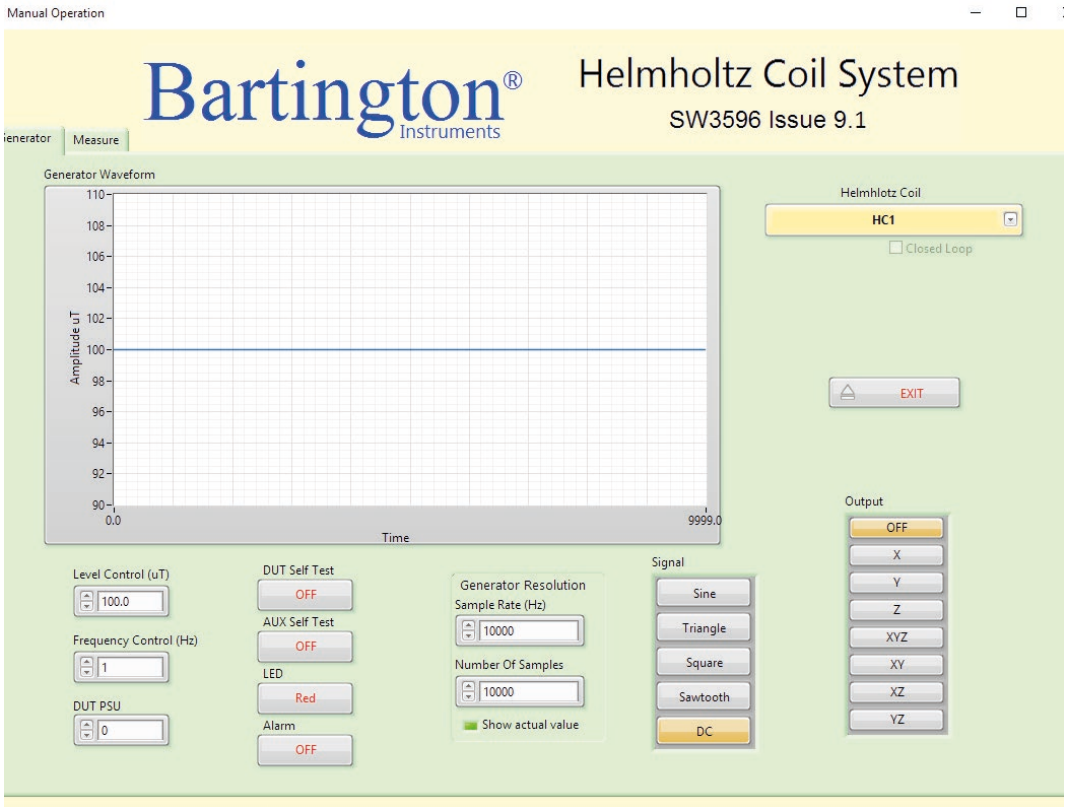


Figure 6. Generator Tab setup for Scaling and Orthogonality adjustments

5. Under the "Measure" tab, set "Input Filter" to 10Hz and select "Start Read". The value of X axis should be set to 500μT. If not, adjust the potentiometer **[7]** on CU2 Gain for X axis.

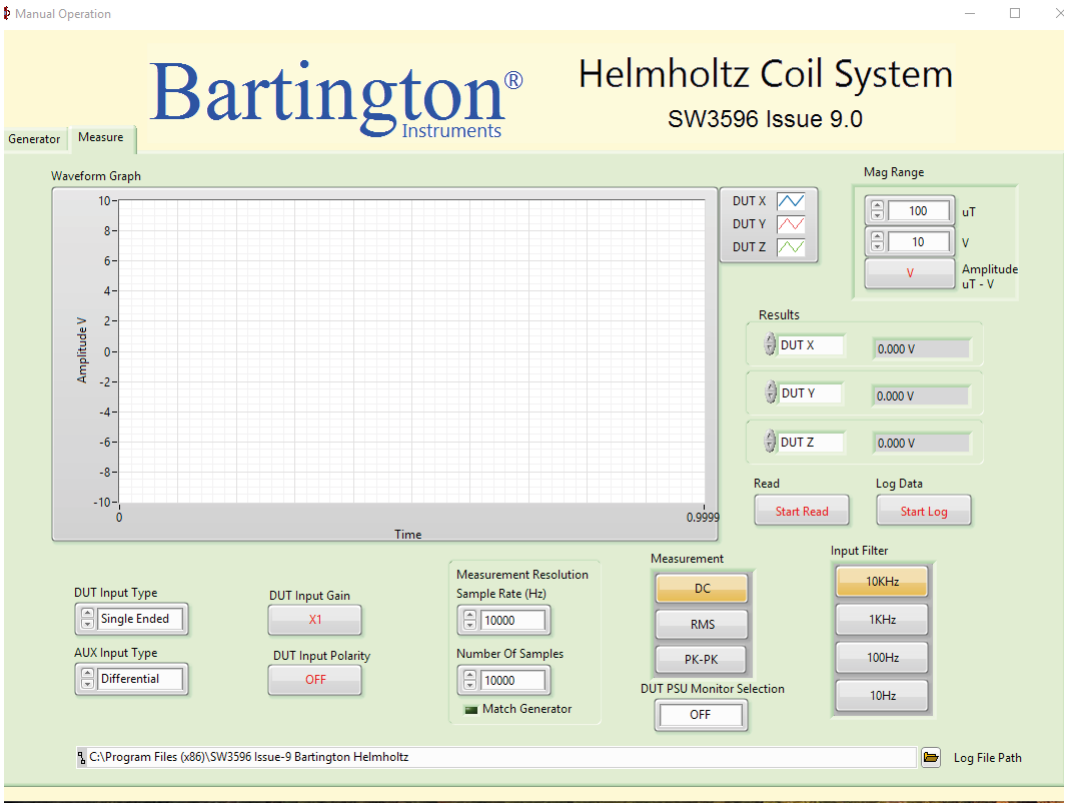


Figure 7. Measure tab for Gain and Orthogonality correction

6. Additionally, you have to correct for the Y and Z component on X axis. These values should be as close to 0nT as possible. In order to adjust the Y component visible when field is generated in X, use the Yx potentiometer **[6]**. In order to adjust the Z component visible when field is generated in X, use the Zx potentiometer **[6]**.

7. Once X axis has been adjusted, adjustment should be carried out on Y and Z following the same protocol, using Xy and Zy when adjusting orthogonality with Y axis generating, and Xz and Yz when adjusting orthogonality with Z axis generating.

8. Once all these steps are completed, the user should check setup again starting with offsets, and then rechecking scaling and orthogonality on X Y and Z to ensure that all readings are optimised. Re-adjust if required.

7.4. Operating the System

Once connected and powered the CU2 Closed-Loop Module will provide compensation automatically based on the values measured by the CU2 Reference Magnetomer.

The required magnetic field should be set using the Helmholtz Coil Control Software. When the CU2 is connected between the CU1 and PA1, the CU2 Module compares the field applied by the software to the field measured by the CU2 Reference Magnetometer. When these are different,

the signal sent to the PA1 is adjusted to compensate for the deviation measured by the CU2 Reference Magnetometer. This automatic adjustment is provided as long as the CU2 Module and CU2 Reference magnetometer are powered, with the CU2 Reference Magnetometer located in the homogeneous area of the Helmholtz Coil.

Any DC and low frequency AC magnetic field changes not caused by a change of field set in the Helmholtz Coil Control Software will be accounted for. A low pass filter in the CU2 Module prevents pick up of higher frequencies that the module is unable to compensate for. See DS2613 for further information.

Additionally, the CU1 has a selectable low pass filter which can be set to 10, 100, 1000 or 10000Hz. Optimum operation will be achieved with a filter set at either 10, 100 or 1000Hz, depending on the requirement. Use the guideline below:

- If using the CU2 purely to cancel DC and near DC variations (less than 1Hz), the CU1 low pass filter can be set to 10Hz.
- If using the CU2 to cancel DC and slightly higher frequency and where optimum attenuation of mains 50Hz or 60Hz is not critical, the low pass filter can be set to 100Hz (some minor attenuation of the mains frequencies will occur).
- If you are using the CU2 to achieve the best attenuation of mains frequencies, the low pass filter should be set at 1kHz.

It should be noted that the filter frequency mentioned is the frequency at which -3dB attenuation is obtained. Therefore there will be some attenuation at lower frequencies as well.

Caution: If the CU2 Reference Magnetometer is not connected to the CU2 when the system is powered on, the Helmholtz Coil will output a higher magnetic field than required by the user. When the CU2 is connected the CU2 Reference Magnetometer should be connected at all times.

8. *Troubleshooting, Care and Maintenance*

In the event of any apparent malfunction, please email service@bartington.com, or telephone the Bartington Instruments service team on +44 (0)1993 706565.

Note: Fault finding by customers may invalidate the warranty.

9. *Storage and Transport*

The CU2 Closed-Loop Module should be handled with care.

Bartington Instruments has supplied this product in appropriate packaging for transporting it safely. This packaging should be used for any future transport.

Refer to datasheet DS2613 for this product's maximum environmental, electrical and mechanical ratings.

Caution: Exceeding the maximum environmental ratings may cause irreparable damage to the equipment.

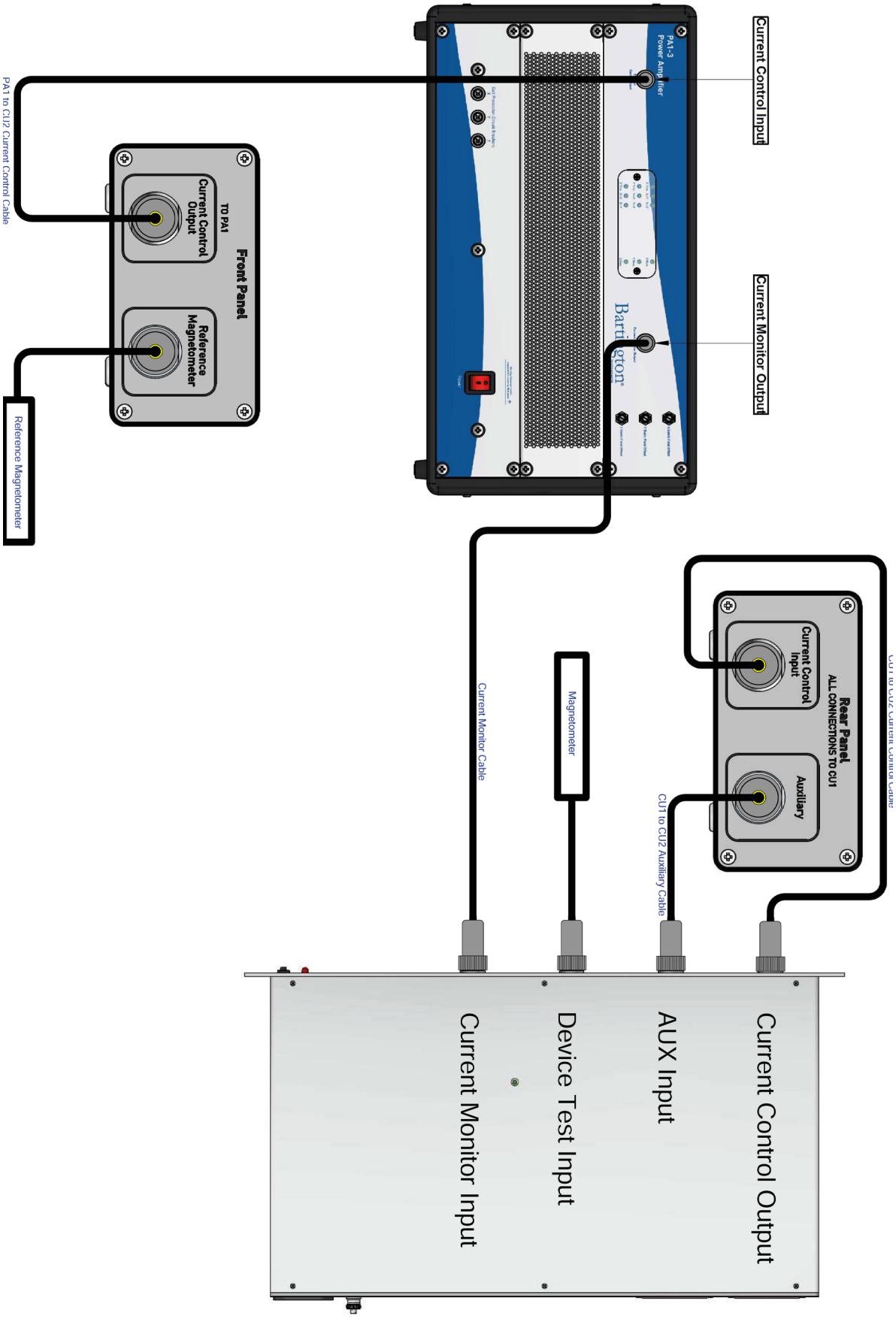
10. Disposal

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.

10.1. 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: Connecting the Components of the Helmholtz Coil System



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