güralp

Certis

Technical Manual

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Table of Contents

1   Preliminary Notes

1.1   Proprietary Notice

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1.2   Cautions and Notes

Cautions and notes are displayed and defined as follows:

> **Caution:** A yellow triangle indicates a chance of damage to or failure of the equipment if the caution is not heeded.

> **Note:** A blue circle indicates indicates a procedural or advisory note.

1.3   Manuals and Software

All manuals and software referred to in this document are available from the Güralp Systems website: https://www.guralp.com/ unless otherwise stated.

1.4   Conventions

Throughout this manual, examples are given of command-line interactions. In these examples, a fixed-width typeface will be used:

        Example of the fixed-width typeface used.

Commands that you are required to type will be shown in bold:

        Example of the fixed-width, bold typeface.

Where data that you type may vary depending on your individual configuration, such as parameters to commands, these data are additionally shown in italics:

        Example of the fixed-width, bold, italic typeface.

Putting these together into a single example:

        System prompt: **user input with *variable parameters***

2   Overview

The Güralp Certis is a compact, low-power, medium-motion seismometer suitable for surface and post-hole applications. No locking or centring is required and the instrument is capable of operation over a wide range of angles, up to 90° from the vertical. An innovative digital feedback system permits both analogue and digital[*] outputs. The output is flat to velocity at frequencies up to 100 Hertz with a long-period corner which can be adjusted[*] between 1 second and 120 seconds. State-of-health information, response parameters and calibration figures are all available digitally[*]. The compact, stainless-steel body provides environmental protection to IP68 and includes a convenient lifting-hook on the top, alongside the single connector, an engraved arrow to indicate the direction which should face North and a bubble-level.

The Certis stands 112 mm high and is 80 mm wide. The illustration below is actual size:

The industry-standard, analogue, 40 V peak-to-peak, differential output is suitable for use with a wide variety of digitisers. For best results, however, we recommend the Güralp Minimus series. Using a Minimus, Minimus+ or Minimus2 digitiser with the Certis unlocks the features marked with asterisks above.

3   Principles of Operation

The Certis is a broadband force-feedback seismometer. Each of the three components consists of an inertial mass suspended on a friction-free pivot in such a way that it can only move in one direction – a single degree of freedom.

The mass is located between two capacitor plates, energised with anti-phase sinusoidal signals. The mass thus acts as the centre-plate of a three-terminal, variable capacitor so, if the mass is not central, a signal appears on it. The phase of this signal indicates the direction of displacement and the amplitude is proportional to the deviation from the central position.

The signal from the mass passes through a hybrid analogue/digital P.I.D. controller. The differential (D) component of the controller is implemented in the analogue domain while the proportional (P) and integral (I) components are realised digitally. The two resulting correction signals are summed via R_f and C_f and fed to a coil mounted on the mass. This surrounds a permanent magnet fixed to the instrument so that the combination forms an electromagnet which acts to drive the mass back to its centre position. A simplified block-diagram is shown below.
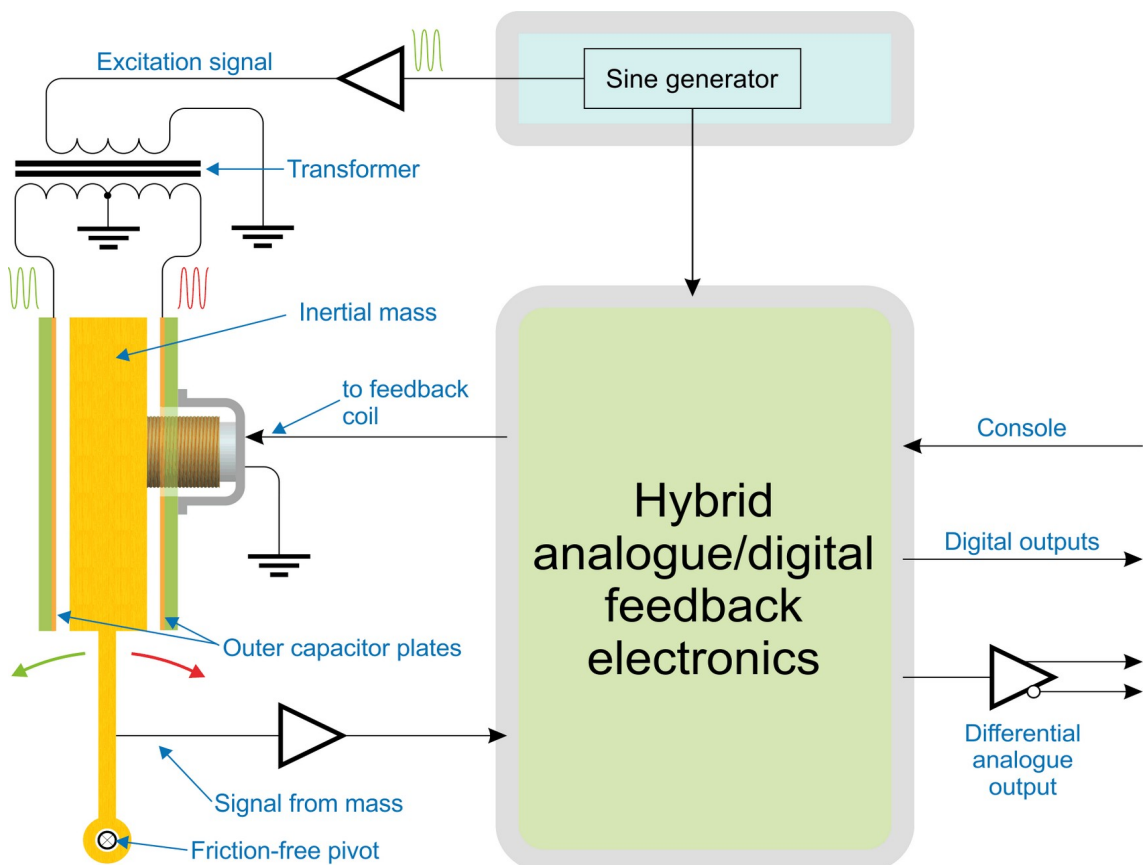
A chain of linear, proportional relationships connect the acceleration experienced by the instrument with the current flowing through the coil:

- The capacitor plates and pivot are connected to the instrument so, to keep the mass central, the feedback system must impart an acceleration to the mass which is equal to that experienced by the instrument.

- The mass is constant so, by F=ma, this acceleration is proportional to the force applied.

- The coil geometry and the magnetic field in which it moves are both constant, so the force on the mass is proportional to the current through the coil.

In this way, the system produces a signal which is proportional to the acceleration experienced by the instrument. A signal proportional to velocity is present at the output of the forward-path compensation circuity and this is made available as the analogue output. Since it is also fed to an ADC, a digital output is also available.

3.1   Velocity and mass-position outputs

The Certis produces six main output signals: one each proportional to velocity in the three directions vertical (Z), North/South (N) and East/West (E) and, when connected to a Minimus in digital mode (see section 3.2 on page 7), an additional three known as the "mass position" outputs: one corresponding to each of those directions.

Although referred to almost universally as "mass position outputs", this second set of outputs do not actually correspond to the physical position of the masses. Instead, they are proportional to the force being applied to keep the mass central, averaged over the time period corresponding to the low-frequency cut-off point of the velocity outputs. Ideally, this should be as close to zero as possible, in order to maximise the output before clipping and minimise the power consumption.

Traditional force-feedback seismometers required the operator to monitor the mass position outputs at regular intervals and to take corrective action, known as nulling or centring, if any of them deviated too far from zero. This is not necessary with the Certis: the built-in microprocessor monitors the mass positions at all time and applies automatic correction when required. This technique enables the instrument to be operated at any angle up to 90° from the vertical.

3.2   Analogue and/or digital outputs

The Certis' analogue outputs allow it to be used with a wide range of seismic digitisers. Once connected to a suitable DC power source, it will start operating and producing six analogue outputs: three proportional to velocity in the three directions and three corresponding mass position outputs.

The analogue velocity outputs are transmitted differentially. This means that a second, inverted copy of the signal is transmitted alongside the original. A differential input subtracts the inverted copy from the original, yielding a signal twice as strong and, in the process, cancelling out any noise picked up by the cable.

The analogue mass position outputs are not transmitted in this way because they only contain low-frequencies so any line noise can be filtered out after reception.

Each output carries a signal which varies between ±10 V, measured relative to ground – *i.e.* 20 V peak-to-peak. Each differential output consists of two such signals of opposite polarity, transmitted on different wires, so the difference between them varies between ±20 V. This is sometimes referred to as 40 V peak-to-peak.

When paired with a Güralp Minimus, Minimus+ or Minimus2 digitiser, however, a digital output can be enabled – either in addition to the analogue output or as an alternative. The digital output allows error-free transmission of the velocity data and additional environmental channels as well as identification, calibration and state-of-health information from the instrument. This greatly simplifies the administrative burden of setting up a station or network.

3.3   Additional outputs

The Certis' digital outputs include, in addition to the main velocity outputs,

- Three mass-position outputs

- The calibration signal return (see section 8.3 on page 28)

- Three MEMS accelerometer outputs

- A magnetometer with a heading output

- A thermometer

- A barometer

- A relative hygrometer

- PLL parameters: phase, control and quality

For details of output channel names, see section 8.2 on page 27.

3.4   Polarity of output signals

The front of the instrument is identified by an arrow on the lid. (The engraved words Güralp Certis are on the back, or South face of the instrument.) Wherever possible, the instrument should be placed on a level surface with the front pointing to geographical or magnetic North, as desired. Once so positioned:

- If the instrument is moving upwards, the Z (vertical) output will produce a positive signal.

- If the instrument is moving to the North, the N (North/South) output will produce a positive signal.

- If the instrument is moving to the East, the E (East/West) output will produce a positive signal.

The internal MEMS accelerometer produces outputs with the same polarity with respect to acceleration (regardless of the direction of velocity), so

- If the instrument experiences positive acceleration upwards, the Z (vertical) MEMS output will produce a positive signal.

- If the instrument experiences positive acceleration to the North, the N (North/South) MEMS output will produce a positive signal.

- If the instrument experiences positive acceleration to the East, the E (East/West) MEMS output will produce a positive signal.

> **Note:** The internal MEMS accelerometer output is not compensated for the expected acceleration due to gravity when normally orientated. This means that, when the instrument is stood upright, the Z-component output of the MEMS accelerometer will indicate +1 g.

4   Getting Started

4.1   Configuration Overview

> **!** **Note:** The Certis can be used with any of the Minimus digitiser family –
> Minimus, Minimus+ or Minimus2 – using the same techniques.
> Throughout this manual, however, only the term "Minimus" is used, even
> though the instructions apply equally to any of the Minimus family.

The Certis can be configured in three ways:

- When connected digitally to a Minimus, it can be configured using Güralp's free Discovery software. This method is described in section 4.2 on page 10.

- When a Minimus is not available, the Minimus can be configured using its serial console via a terminal emulator. This method is described in section 4.3 on page 4.

- Some configuration options can be affected by hardware control lines exposed on the instrument's connector. This method is described in section 4.4 on page 17.

Configuration changes are stored within the Certis so, if the instrument is pre-configured using a Minimus and Discovery, it can then be used with a 3rd-party digitiser and the pre-set configuration will be retained.

4.2   Configuration using a Minimus and Discovery

4.2.1 Enabling digital connections

To connect digitally to a Minimus, the digitiser must first be configured for digital connections. To do this:

1. Open the Discovery application and locate the digitiser in the main list.

2. Right-click on the digitiser in the main list and select Control Centre from the context menu:
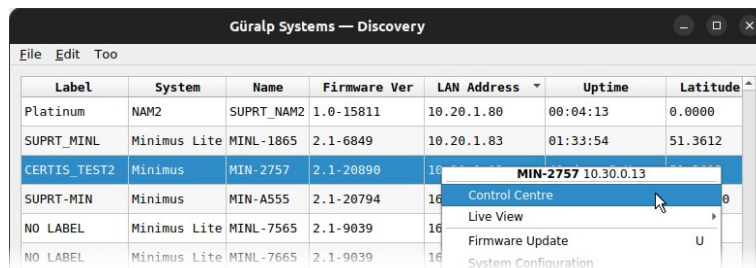
3. When the Control Centre window opens, click the Console icon in the left-hand tool bar.

4. When the Console window opens, place the cursor in the command box at the bottom and type the following:

   resource add uartp6 96

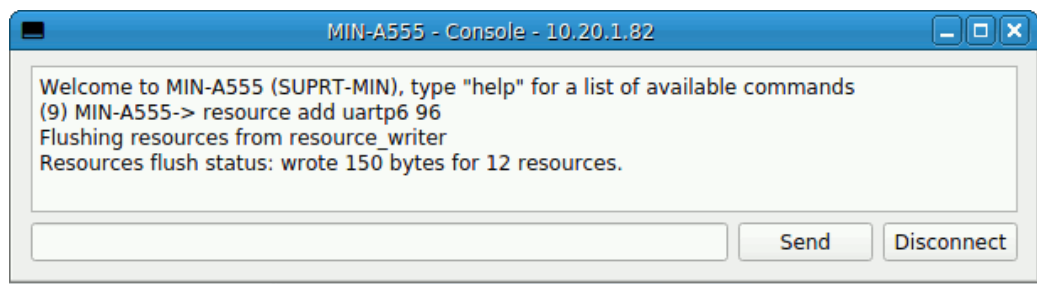   Your screen should look like this:

5. Click [Send] and the Minimus will respond with a short message:

6. With the Certis connected to the Minimus, type

   reboot

   and click [Send] again. This will power-cycle the digitiser. Click [Disconnect] to end the console session and close the Control Centre window.

When it has finished rebooting, the Minimus will communicate digitally with the Certis.

Note: Some values in the web interface, such as the Certis' component sensitivities, are communicated from the instrument to the digitiser at power-up and might not appear immediately.

To configure the instrument, open the web interface of the Minimus and navigate to the Setup tab. Scroll down past the Digitiser Controls and Digitiser Config sections.

The information and controls related to the Certis are grouped together in a section entitled Serial Sensor.

To configure the Certis using this screen, refer to the instructions in the following sections.

4.2.2 Selecting analogue or digital outputs

If your Certis is to be used with a digitiser from the Minimus family, you have the choice of analogue outputs, digital outputs or both.

If your Certis is to be used with a different digitiser – i.e. not a Minimus, Minimus+ or Minimus2 – only the analogue outputs are useful.

The Certis is shipped from the factory pre-configured in "auto" mode. This enables the digital output if a Minimus is detected and an analogue output otherwise.

> **Note:** Güralp recommend the use of only digital outputs when the Certis is connected to a Minimus. This reduces the overall power consumption. The exception is Earthquake Early Warning systems where power is not an issue and the low-latency digitisation channels of the Minimus can be used to improve the response-time of the warning system.

4.2.2.1 Using only digital outputs

Digital outputs can only be used with digitisers from the Minimus family.

To enable the digital outputs, connect the Certis digitally to a Minimus as described in section 4.2.1 on page 10. The digital outputs are always enabled when the Certis is connected like this but the analogue outputs can be disabled in order to save power.

To do this, open the web interface of the Minimus and navigate to the Setup tab. Scroll down to the Serial Sensor section. At the bottom right-hand-side of this section, in the Calibrate sub-section, set the Analogue out drop-down menu to Off or Auto.

> **Note:** This field is not persistent and may not reflect the current configuration, so it must be changed at least once before setting it to the required value.

4.2.2.2 Using both digital and analogue outputs

Digital outputs can only be used with digitisers from the Minimus family.

To use both analogue and digital outputs simultaneously, connect the Certis digitally to a Minimus as described in section 4.2.1 on page 10. Open the web interface of the Minimus and navigate to the Setup tab. Scroll down to the Serial Sensor section. At the bottom right-hand-side of this section, in the Calibrate sub-section, set the Analogue out drop-down menu to On.

> **Note:** This field is not persistent and may not reflect the current configuration, so it must be changed at least once before setting it to the required value.

4.2.2.3 Using analogue outputs

Only analogue outputs are available when the Certis is used with a standard digitiser. The Certis is shipped from the factory in analogue mode so it can be connected immediately and used without configuration.

If the Certis has previously been used with a Minimus and has had its analogue outputs disabled, it is necessary to re-enable the analogue outputs. To do this, reconnect the Certis to a Minimus and set the Analogue out drop-down menu to On, as described in the previous section.

> **Note:** This field is not persistent and may not reflect the current configuration, so it must be changed at least once before setting it to the required value.7

4.2.3 Adjusting the frequency response

The Certis has a frequency response which is flat to velocity between a configurable long-period corner and 100 Hz.

> **(!)** **Note:** The frequency response can only be adjusted when the Certis is connected digitally to a digitiser from the Minimus family but, once set, the setting is retained if the instrument is reconnected to a different digitiser.

To adjust the long-period corner, connect the Certis in digital mode to a Minimus, as described in section 4.2.1 on page 10, open the web interface of the Minimus and navigate to the Setup tab. Scroll down to the Serial Sensor section.

The current response is shown in the Response sub-section as Current TC.

The adjacent drop-down menu can be set to any of 10, 20, 30, 45, 60, 90, 100 and 120 seconds. Select the desired long-period corner and wait for a few seconds for the instrument to adjust. The Current TC value will change to show the new response once the process is complete.

> **(!)** **Note:** The RESP files available from the Data Stream and Data Record tabs of the web interface will not change until the Minimus has been re-booted.

4.2.4 Setting the sample rate

The sample rates for streaming outputs and for recorded data are set independently: those for streaming outputs are configured via the Data Stream tab and those for recorded data are configured via the Data Record tab of the Minimus' web interface. Each channel on these two tabs has an associated drop-down menu which presents a wide choice of sample rates along with an option to disable the channel.

> **(!)** **Note:** Each of these tabs has a drop-down menu called Display Streams, located just above the Channels configuration section. It offers the choice of Enabled only, Disabled only and All. If the channels that you wish to configure do not appear in the table below, set this control to All or Disabled only, configure the desired sample rates for the missing channels and then set this control back to Enabled Only.

Since it is normal for all three components from a triaxial instrument to be sampled at the same rate(s), the configuration tabs include a check-box labelled Apply configuration for tap groups, located just above the Channels configuration section. When ticked, changing the sample rate for one component will automatically change the sample rates for the other two components to match. When the check-box is clear, all sample-rates can be set independently of each other.

> **Note:** Changing the sample-rate of a channel requires the Minimus to be rebooted before the change takes effect, although several such changes may be made consecutively without intervening reboots. The words *Reboot Required* appear in red italics at the top right of the web interface when such changes have been made but not enacted.

4.2.4.1 Digital outputs

When connected digitally, the digital outputs of a Certis can be streamed and/or saved to the Minimus' SD card:

- On the Data Stream tab of the Minimus' web interface, the Certis' digital channels appear as:

	Vertical	North/South	East/West
Velocity channels	CertisZ0_	CertisN0_	CertisE0_
Mass position channels	CertisMassZ_	CertisMassN_	CertisMassE_

- On the Data Record tab of the Minimus' web interface, the Certis' digital channels appear as:

	Vertical	North/South	East/West
Velocity channels	CertisZ0_sd	CertisN0_sd	CertisE0_sd
Mass position channels	CertisMassZ_sd	CertisMassN_sd	CertisMassE_sd

4.2.4.2 Analogue outputs

- On the Data Stream tab of the Minimus' web interface, the Certis' analogue channels, if enabled, appear as:

	Vertical	North/South	East/West
Higher-rate velocity channels	0ACCZ0	0ACCZ0	0ACCZ0
Lower-rate velocity channels	0ACCZ2	0ACCZ2	0ACCZ2
Mass position channels	0ACCM8	0ACCM9	0ACCMA

- On the Data Record tab of the Minimus' web interface, the Certis' analogue channels, if enabled, appear as:

	Vertical	North/South	East/West
Higher-rate velocity channels	S0SeisZA	S0SeisNA	S0SeisEA
Lower-rate velocity channels	S0SeisZB	S0SeisNB	S0SeisEB
Mass position channels	S0IntZ	S0IntN	S0IntE

4.2.4.3 Setting the gain

The sensitivity of the digital output of the Certis is factory set to 2.38 (nm s^{-1})/count (i.e. 4.2×10^8 counts/ms^{-1}) and cannot be changed. When the Certis' analogue output is used with a Minimus digitiser, however, the input gain of the Minimus' ADC can be

set to one of Unity, ×2, ×4, ×8, ×12 or ×64. Combined with the Certis' analogue sensitivity of 1000 V/ms^{-1}, these give the system the following sensitivities:

Minimus ADC gain	Overall Sensitivity
Unity (×1)	1000 counts / ms^{-1}
×2	2000 counts / ms^{-1}
×4	4000 counts / ms^{-1}
×8	8000 counts / ms^{-1}
×12	12000 counts / ms^{-1}
×64	64000 counts / ms^{-1}

4.3   Configuration via the serial console

The Certis can be configured via a serial console, accessible using the serial console cable. This can be connected to a PC running terminal emulation software.

> **Note:** Güralp recommend the use of Picocom terminal emulation software on Linux PCs and PuTTY terminal emulation software on Windows PCs.

Configure your terminal emulation software to operate at 115200 Baud, 8-N-1 (one start bit, eight (8) data bits, no (N) parity bit, and one (1) stop bit) and disable all hardware and software flow control (*i.e.* no X-ON/X-OFF, RTS/CTS or DSR/DTR).

The available commands are described in the following sections.

4.3.1 Setting the frequency response

The long-period corner of the Certis' frequency response can be set to any value between 10 seconds and 240 seconds. To set the corner period, enter the command

```
fbk save nnn
```

replacing *nnn* with the desired period in seconds. For example, the command

```
fbk save 30
```

will result in a frequency response which is flat to velocity between 30 seconds and 100 Hertz.

4.3.2 Controlling automatic-centring

The Certis can be configured for automatic centring with the command

        `mot auto`

and automatic centring can be disabled with the command

        `mot stop`

The `mot` command takes other arguments, as shown in the table below:

Command	Action
`mot auto`	enable automatic centring
`mot stop`	stop all centring operations and disable automatic centring
`mot status`	show the current centring status
`mot recent 1`	initiate re-centring of the Z mass
`mot recent 2`	initiate re-centring of the N/S mass
`mot recent 4`	initiate re-centring of the E/W mass
`mot recent 7`	initiate re-centring of all masses
`mot idle 0`	force the Z channel into long period mode *
`mot idle 1`	force the E/W channel into long period mode *
`mot idle 2`	force the N/S channel into long period mode *
`mot test`	run mechanical centring diagnostic program

* Components undergoing centring are put into short-period mode in order to get rapid feedback about the response to centring motor movements. The idle commands place the specified components back into long-period mode.

4.3.3 Calibration commands

The cal command and its arguments are described in section 8.3 on page 28.

4.4   Configuration using hardware control lines

The Certis has a number of hardware control lines exposed on its connector. See section 8.1 on page 8.1 for the relevant pin numbers. The possible operations are described in the following sections.

4.4.1 Changing the frequency response

The Certis can be toggled between normal, long-period mode, where the long-period corner of the frequency response is as configured, and short-period mode, where the long-period corner of the frequency response is set to 20 seconds.

To change the mode between these two options, connect the Short Period mode pin to Logic / RS232 ground for eight seconds.

4.4.2 Controlling automatic centring

The Certis can be forced to recentre its masses at any time by connecting the Initiate Centring pin to Logic / RS232 ground for eight seconds.

Automatic centring can be disabled (and any current centring operation cancelled) by connecting both the Initiate Centring pin and the Short Period mode pin to Logic / RS232 ground for eight seconds.

4.4.3 Calibration

Calibration operations are described in section 8.3 on page 28.

4.4.4 Busy status

The status of the centring subsystem can be displayed with an LED connected between the Busy pin and Logic / RS232 ground. The Busy pin provides a 3.3 V DC supply connected via a 200 Ω resistor so no additional components are required other than the LED.

> **Note:** A standard 6.3 mm red LED has a V_f of around 1.7 V so the current will be (3.3-1.7)/200 = 8 mA and the power dissipated by the LED will be around 14 mW. A lower V_f will give a brighter light and vice-versa.

The LED will blink whenever the instrument is carrying out a centring operation.

When the LED is extinguished, the instrument is fully centred.

5   Physical installation

The goal of any seismic installation is to ensure that wave-trains arriving at the instrument accurately reflect the internal motion of sub-surface rock formations. To achieve this, the seismometer and its emplacement need to be considered as a mechanical system, which will have its own vibrational modes and resonances. These frequencies should be raised as high as possible so that they do not interfere with true ground motion: ideally, beyond the range of the instrument.

In particular, the sensor needs to be protected against environmental factors such as:

- fluctuations in temperature,

- turbulent air flow around walls or trees, or around sharp corners or edges in the immediate vicinity of the sensor;

- vibration caused by equipment in or near the installation, particularly computer equipment; and

- vibration caused by heavy machinery (even at a distance), or by overhead power lines.

In seismic vaults, instruments are often installed on piers. It is important to ensure that the interface between the pier and the floor does not introduce noise, and that the pier itself does not have resonant frequencies within the passband. Ideally, a seismic pier will be significantly wider than it is high (to minimize flexing) and will form a single piece with the floor, e.g. by moulding a poured concrete floor within a wooden frame.

Many situations do not allow for the construction of a seismic vault. For example, you may need to deploy quickly to monitor the activity of a volcano showing signs of rejuvenation, or to study the aftershocks of a major earthquake. In other cases the site itself may be too remote to ship in construction equipment.

Temporary installations can be protected against spurious vibrations by:

- selecting a suitable site,

- placing the instrument in a protective enclosure (an open-sided box of 5 cm expanded polystyrene slabs, placed over the instrument and taped down to exclude draughts, makes an excellent thermal shield),

- standing the sensor on bedrock where possible, or at least deep in well-compacted subsoil;

- clearing the floor of the hole of all loose material; and

- using as little extra mass as possible in preparing the chamber.

After installation, the instrument case and mounting surface will slowly return to the local temperature and settle in their positions. This will take around four hours from the time installation is completed. Note that the Certis will need to re-centre its

masses during this period – possibly more than once. The process is automatic but may show up in the recorded data.

5.1   Vault deployments

You can install a Certis into an existing seismic vault using the following procedure:

1. Unpack the Certis from its packaging, which should be saved for later use.

2. Prepare the mounting surface, which should be smooth and free of cracks. Remove any loose particles or dust, and any pieces of loose surfacing. This ensures good contact between the instrument's feet and the surface.

3. Inscribe an accurate North-South line on the mounting surface, if it is not already present.

4. Place the sensor over the scribed line, so that the North pointer on the lid is aligned with the marked directions. This can be done by rotating the base of the sensor whilst observing it from above.

5. Check that the Certis is level using the bubble indicator built into the top of the instrument. The bubble should be entirely within the black circle printed on the viewing window:

If the instrument is not perfectly level, try moving it to a slightly different position, either along the scribed line or from side to side until a position is found where it is naturally level. Re-check the North/South alignment after moving the instrument.

6. If the instrument cannot be levelled in this way, either

   ◦ the pier surface can be re-shaped with an angle-grinder to create a level area; or

   ◦ the resulting data can be rotated mathematically using an appropriate digitiser, such as the Güralp Minimus family

7. Connect the sensor to the digitiser.

⚠️ **Caution:** The locking ring on the connector should by tightened by hand only. Do not use tools.

8. Cover the instrument with thermal insulation – for example, a 5 cm expanded polystyrene box. This will shield it from thermal fluctuations and convection currents in the vault. It also helps to stratify the air within the seismometer

package. Position the thermal insulation carefully so that it does not touch the instrument casing. The cable entry should be at the base in order to reduce transmission of vibrations to the instrument along the cable.

5.2   Post-hole deployments

In areas with non-trivial cultural noise, a post-hole deployment can provide significant benefits over a surface deployment. Post-holes can be used both for rapid, temporary deployments and for long-term stations.

5.2.1 Rapid deployment

The Certis is an ideal instrument for use in emergency rapid deployments for purposes such as aftershock monitoring or volcanology. It can be deployed with the minimum of preparation and tools.

A suitable hole can be drilled using a hand-portable, petrol-powered auger. A diameter of 150 mm is suggested although smaller diameter holes are usable. The depth must be less than ten meters. If possible, pour a little loose sand into the bottom of the hole and tamp it down to form a firm base.

Connect a suitable steel wire to the instrument's lifting shackle. The wire should be long enough to reach the bottom of the hole plus an additional 5 m to allow for the use of a winch to remove the instrument at the end of the deployment, if necessary.

If possible, provide a long, wooden pole with a J-hook on the end for manipulating the instrument when it is at the bottom of the hole. An endoscopic camera with built-in LED illumination, of the type that connects to a mobile phone, can be taped to the pole near the bottom end.

Connect the sensor cable to the instrument, hook the pole to the instrument's lifting shackle and lower it into the hole, maintaining tension on the suspension cable in case the hook slips. Using the pole and camera, rotate the instrument until the arrow on the top surface is facing North. A small laser fitted with a diffraction grating, as sold in D.I.Y. stores, can be used to project a line to the bottom of the hole, which can help with alignment.

Once aligned, manipulate the instrument until it is level, as indicated by the bubble on the top of the instrument. The bubble should be entirely within the printed black circle:

Without disturbing the instrument, unhook the pole. Check with the camera that the instrument is still level and correctly aligned before fully withdrawing the pole.

Gently pour a small quantity of sand into the hole: enough to just cover the instrument. This protects the Certis from convection currents and improves its coupling to the underlying bedrock.

Close the top of the hole with a rock or other suitable cover. Lead the sensor cable and the excess wire rope a short distance from the hole to where the power supply and digitiser can be located, using a shallow trench if desired. 12 V or 24 V vehicle batteries can be wrapped in plastic and buried to provide power for short- and medium-term deployments.

When the instrument is to be removed, do so by pulling on the wire rope only: never pull on the sensor cable. As the inside of the post-hole may have partially collapsed, considerable force may be required. A portable tripod winch is recommended for this purpose.

5.2.2 Permanent post-hole deployments

Post-holes make suitable vaults for permanent deployments. Many techniques are possible but the following description makes a good starting point.

Auger a 200 mm (8″) hole to the desired depth; up to 10 m maximum. Prepare an appropriate length of 150 mm (6″) PVC pipe, joining multiple sections with solvent-weld if necessary. Lower the pipe into the post-hole and insert a suitable grout into the space between the pipe and the surrounding earth. If the pipe floats, weigh it down until the grout has set.

Pour some bentonite or Fuller's earth into the bottom of the pipe to provide a waterproof seal and tamp it down well. Add a layer of sand on top of the bentonite and tamp it down to provide a suitable surface for the instrument.

Remove the earth around the top of the pipe and provide a suitable well-head enclosure, either using brickwork, concrete form-work or a pre-fabricated steel box. In all cases, provision should be made to add a lockable lid. Fit a water-proof tee-piece near the top of the pipe, inside the well-head enclosure, to allow the sensor and suspension cables to exit through a 50 mm (2″) PVC pipe or metal conduit. This can be just below the level of the surrounding ground to allow burial of the cables to the power supply and digitiser enclosure.

Provide a wooden or aluminium pole with a J-hook on the end for manipulating the instrument when it is at the bottom of the hole. An endoscopic camera with built-in LED illumination, of the type that connects to a mobile phone, can be taped to the pole near the bottom end.

Provide a steel suspension wire with eyelets on both ends. Its length should be the depth of the borehole plus at least an additional 5 m.

Thread the sensor cable and the steel wire though the tee-piece, from the outside into the pipe, and attach both to the Certis, hand-tightening the cable connector and using a shackle to attach the suspension cable to the lifting hook. Hook the pole to the instrument's lifting shackle and lower the Certis into the pipe, maintaining

tension on the suspension cable in case the hook slips. Using the pole and camera, rotate the instrument until the arrow on the top surface is facing North. A small laser fitted with a diffraction grating, as sold in D.I.Y. stores, can be used to project a line to the bottom of the pipe, which can help with alignment.

Once aligned, manipulate the instrument until it is level, as indicated by the bubble on the top of the instrument. The bubble should be entirely within the printed black circle:

Without disturbing the instrument, unhook the pole. Check with the camera that the instrument is still level and correctly aligned before fully withdrawing the pole.

Gently pour a small quantity of sand into the pipe: enough to just cover the instrument. This protects the Certis from convection currents and improves its coupling to the underlying bedrock.

Seal the top of the PVC pipe with a suitable locking plug – this prevents moisture ingress – and lock the well-head cover to provide security.
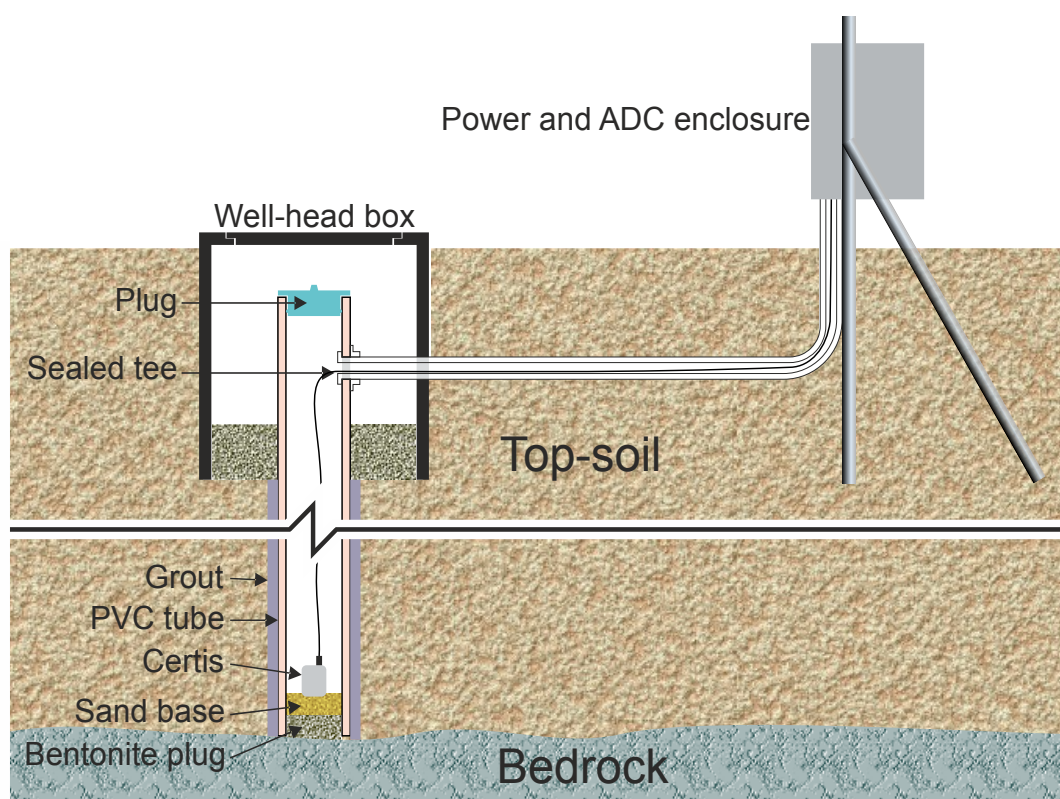
If the power supply and digitiser enclosure are to be above-ground, take care that they do not function as an inverted pendulum. A simple steel box mounted on a single stake will have a strong natural resonance which will couple directly to the earth near the instrument. Depending on the location of the enclosure (and, in particular, the GNSS receiver if used) consider providing lightning protection for the installation.

6   Metadata

No deployment is complete without an installation record. As well as the precise location and orientation of the instrument, together with the model and serial numbers of the equipment, this should include the metadata that describes the instrument's sensitivity and frequency response together with the digitisers' bit-weight and filter configuration. This gives analysts freedom to interpret and process the data at any time in the future.

6.1   Calibration and response parameters

The digital integration between the Certis and the Minimus family of digitisers makes obtaining the metadata simple. A more laborious process needs to be followed if a different digitiser is used.

6.1.1 Using a Minimus

When a Certis is connected digitally to a Minimus, it will upload its metadata to the Minimus each time it powers up. You can access these metadata in RESP format and in StationXML format.

To obtain metadata in RESP format, open the web interface of the Minimus and navigate to either the Data Stream tab or the Data Record tab as appropriate. Locate the channels of interest and to the right of each, click the RESP hyperlink to download a customised RESP file for that channel.

6.1.2 Using a different digitiser

Each Certis is shipped with a calibration document which shows the sensitivity, measured in Volts per metre per second (V/ms^{-1}) of each of the three orthogonal components, together with the poles and zeros which characterise the frequency response. These data can be used to assemble a file which describes the instrument's meta-data in the desired format. Consult the documentation for the required format for further information.

7   Specifications

| Broadband Seismometer System	
Technology	Force-feedback digital sensor with digital and analogue outputs
Configuration / Topology	Triaxial orthogonal (ZNE)
Performance	
Frequency response	120 s (0.0083 Hz) to 100 Hz
	User selectable long-period corner of 1, 10, 20, 30, 45, 60, 90, 100 or 120 seconds.
Full-scale analogue output	Differential: ±20 V (40 V peak-to-peak)
	Single-ended: ±10 V (20 V peak-to-peak)
Output sensitivity (analogue)	1000 V/ms^{-1}
	(other options available)
Output sensitivity (digital)	4.2×10^8 counts/ms^{-1}
Clip level	26×10^{-3} ms^{-1}
Sensor dynamic range	155 dB
Self-noise	-173 dB at 10 seconds
Operational tilt range	±90°
Cross axis rejection	> 65 dB
Linearity	> 95 dB
Lowest spurious resonance	> 450 Hz
Transfer function	Measured sensitivity, frequency response and instrument poles and zeros are stored within the instrument and accessible via web interface of Minimus digitiser
State-of-health	
Mass positions	Three independent mass-position outputs
Centring	Automatic, but can be disabled
Orientation sensor	MEMS-based accelerometer (three component)
Other sensors	Temperature, pressure and relative humidity
Operation and power	
Operating temperature	-20 to +60 °C
Relative humidity range	Zero to 100 %
Power supply	10 − 36 Volts DC
Power consumption @ 12 V	250 mW (As a result of semiconductor availability problems, this figure is subject to change without notice)
Physical	
Casing material	Stainless steel
Weight	1.9 kg (without cable)
Dimensions	80 mm × 80 mm × 112 mm high to top of connector
Connector type	MIL-DTL-38999 Series III, 22-pin male
Installation depth	≤ 10 m
Environmental protection	IP68

8   Appendices

8.1   Connector pin-out

This is a standard 22-pin military-specification "tri-start" bayonet connector, conforming to MIL-DTL-38999 series Ⅲ (formerly MIL-C-38999), with Amphenol part number TVS07RF-13-35PN-W63.

Suitable mating connectors have part-numbers like ***-13-35S and are available from Amphenol, ITT Cannon and other manufacturers.

Pin	Function	Pin	Function
1	RS232 data input (Rx)	12	Busy
2	RS232 data output (Tx)	13	Serial console RS232 data input
3	+12 V DC power input	14	Serial console RS232 data output
4	Power Ground	15	Calibration signal
5	E/W Velocity inverting (-)	16	Calibration signal return
6	E/W Velocity non-inverting (+)	17	E/W signal ground
7	N/S Velocity non-inverting (+)	18	N/S signal ground
8	N/S Velocity inverting (-)	19	Z signal ground
9	Z Velocity inverting (-)	20	Short Period mode
10	Z Velocity non-inverting (+)	21	Initiate Centring
11	Calibration enable	22	Logic / RS232 ground
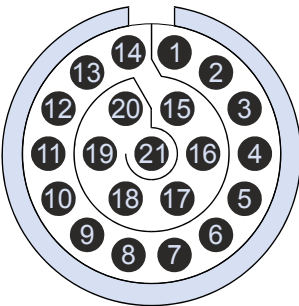
Wiring details for the compatible socket, ***-13-35S, as seen from the cable end (*i.e.* when assembling).

8.2   Channel names

When connected to a Minimus, the names of the various output channels of the Certis change according to context, as shown in the tables below.

8.2.1 Analogue channels

Source	Data Stream	Data Record	GCF *	GDI †
Z velocity, higher rate	0VELZ0	S0SeisZA	VELZ0	0VELZ0
N velocity, higher rate	0VELN0	S0SeisNA	VELN0	0VELN0
E velocity, higher rate	0VELE0	S0SeisEA	VELE0	0VELE0
Z velocity, lower rate	0VELZ2	S0SeisZB	VELZ2	0VELZ2
N velocity, lower rate	0VELN2	S0SeisNB	VELN2	0VELN2
E velocity, lower rate	0VELE2	S0SeisEB	VELE2	0VELE2
Z mass position	0VELM8	S0IntZ	VELM8	0VELM8
N mass position	0VELM9	S0IntN	VELM9	0VELM9
E mass position	0VELMA	S0IntE	VELMA	0VELMA
Calibration return	0AUXX0	S0SeisXA	AUXX0	0AUXX0

Note: * Analogue GCF stream IDs appear in Scream's source tree under the heading Ainstrument. † GDI stream IDs are prefixed with the serial number of the digitiser.

8.2.2 Digital channels

Source	Data Stream	Data Record	GCF *	GDI †
Z velocity	CertisZ0_	CertisZ0_sd	CERSZ0	CertisZ0_
N velocity	CertisN0_	CertisN0_sd	CERSN0	CertisN0_
E velocity	CertisE0_	CertisE0_sd	CERSS0	CertisE0_
Z mass position	CertisMassZ_	CertisMassZ_sd	CERSSZ	CertisMassZ_
N mass position	CertisMassN_	CertisMassN_sd	CERSSN	CertisMassN_
E mass position	CertisMassE_	CertisMassE_sd	CERSSE	CertisMassE_
Calibration return	Calibrate_	Calibrate_sd	CALATE	Calibrate_
Z MEMS	AccelerometerZ_	AccelerometerZ_sd	ACCERZ	AccelerometerZ_
N MEMS	AccelerometerN_	AccelerometerN_sd	ACCERN	AccelerometerN_
E MEMS	AccelerometerE_	AccelerometerE_sd	ACCERE	AccelerometerE_
Heading	Heading_	Heading_sd	HEAING	Heading_
PLL phase	PLLPhase_	PLLPhase_sd	PLLASE	PLLPhase_
PLL quality	PLLQuality_	PLLQuality_sd	PLLITY	PLLQuality_
PLL control	PLLControl_	PLLControl_sd	PLLROL	PLLControl_
Pressure	Pressure_	Pressure_sd	PREURE	Pressure_
Relative humidity	RelHumidity_	RelHumidity_sd	RELITY	RelHumidity_
Temperature	Temperature_	Temperature_sd	TEMURE	Temperature_

Note: * Digital GCF stream IDs appear in Scream's source tree under the heading Dinstrument. † GDI stream IDs are prefixed with the serial number of the Certis.

8.3   Calibration

Güralp force-feedback instruments, like the Certis, do not generally display any significant drift of calibration values. There may be times, however, when you might need to verify the calibration of the instrument for regulatory reasons. A calibration procedure can also be useful if damage to the instrument is suspected.

Calibration of Güralp force-feedback instruments involves injecting a known signal into the circuitry at the point where the feedback system drives the feedback coil. Because the inertial mass and coil geometry are constant, the known signal is equivalent to a known acceleration, to which the response of the instrument can be evaluated.

The Certis can be calibrated using an external signal sources or by using its own, internal signal generator.

8.3.1 Initiating calibration

A calibration can be initiated in three ways. If used with a Minimus, the entire calibration can be performed using the Minimus and Discovery. If a Minimus is not being used, a calibration can be initiated using the serial console or by using the hardware control line.

8.3.1.1 Using a Minimus

To initiate a calibration using a Minimus, open the Discovery software, right-click on the Minimus in the main device list and choose View Web Page (in system browser) from the context menu.

> ![!] **Note:** If you are on the same LAN as the Minimus, right-click in the LAN Address column of Discovery's main window to connect using the LAN address. If you can only connect via a WAN. right-click in the WAN Address column to connect using the WAN address.

When the web interface opens, log in as normal and navigate to the Setup tab. The calibration controls are at the bottom of the Serial Sensor section:

Select the desired calibration type from the Cal Source drop-down menu and the desired amplitude from the Cal Level drop-down menu. Leave the Analogue Out drop-down menu set to Off. For general calibration, we recommend setting the Cal Source to Random and the Cal Level to 100%.

To terminate the calibration, set the Cal Source to Off.

8.3.1.2 Using serial console commands

Open a serial console as described in section 4.3 on page 16. The following serial console commands are available for controlling calibration:

Command	Action
`cal extern` *nnn*	Initiate a calibration using an external signal. Parameter *nnn* controls an attenuator that can be used to reduce the amplitude of the signal in units of percent. Specifying 100 for *nnn* passes the signal through unattenuated while specifying 50 will attenuate the external signal by 3 dB.
`cal reset`	Cancels a calibration using an external signal.
`cal sin` *nnn mmm*	Initiate a calibration using an internally-generated sine-wave signal. Parameter *nnn* controls the amplitude in units of percent. Parameter *mmm* controls the frequency in units of micro-Hertz (μHz). 1×10^6 μHz = 1 Hz. For example, the command `cal sin 50 1000000` initiates a sine-wave calibration at 50% amplitude and 1 Hz.
`cal tri` *nnn mmm*	Initiate a calibration using an internally-generated triangle-wave signal. Parameter *nnn* controls the amplitude in units of percent. Parameter *mmm* controls the frequency in units of micro-Hertz (μHz).
`cal step` *nnn mmm*	Initiate a calibration using an internally-generated square-wave signal. Parameter *nnn* controls the amplitude in units of percent. Parameter *mmm* controls the frequency in units of micro-Hertz (μHz).

8.3.1.3 Using hardware control lines

Calibration can also be initiated using that hardware control lines exposed on its connector. See section 8.1 on page 8.1 for the relevant pin numbers. Calibrations initiated in this way must use an external signal source.

Before initiating a calibration, connect the external signal source to the Calibration signal pin, relative to the Calibration signal return pin. To initiate the calibration, connect the Calibration enable pin to the Logic / RS232 ground pin and leave the connection in place during the calibration.

To terminate the calibration, break the connection between the Calibration enable pin and the Logic / RS232 ground pin. The external signal source can then be disconnected.

8.3.2 Analysing results

Once a calibration is initiated, open the Discovery software, locate the Minimus in the main device list, right-click on it and select Live View → GDI from the context menu. The Live View window opens.

> **Note:** For clarity, you may wish to turn off the display of any unnecessary streams. This can most easily be done by clicking the top-most check-box (labelled with the serial number of the Minimus) twice. This turns off display of all streams. You can then re-enable the desired streams as described below.

Ensure that the calibration signal and the desired return signals are displayed by expanding the DInstrument section of the stream selection tree and ticking the check-boxes to display the stream ending Calibrate_ as well as one or more of the streams ending CertisZ0_, CertisN0_ and CertisE0_, as desired.
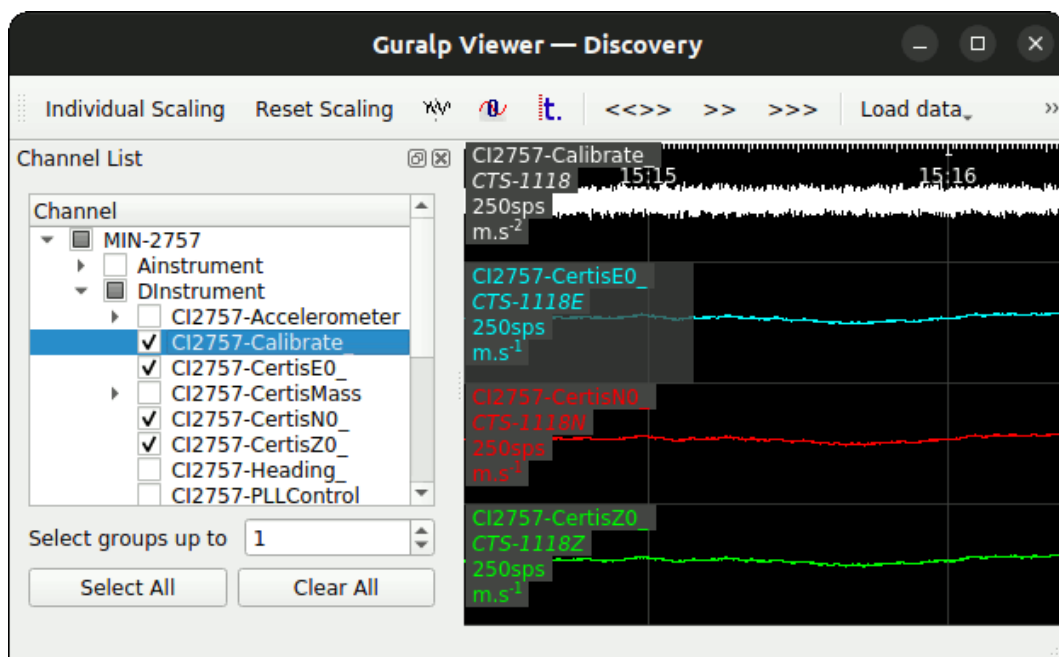

Zoom in or out as necessary in order to display a reasonable period of the calibration data. The longer the period of data captured, the better the results, especially at longer periods.

Hold the left mouse button down while dragging horizontally across the Calibrate_ stream: the area over which you have dragged will be highlighted. Right-click on one or more of the streams ending CertisZ0_, CertisN0_ and CertisE0_, as desired: the highlighted section will be extended.

Right-click in the highlighted section and select Transfer Function from the context menu.
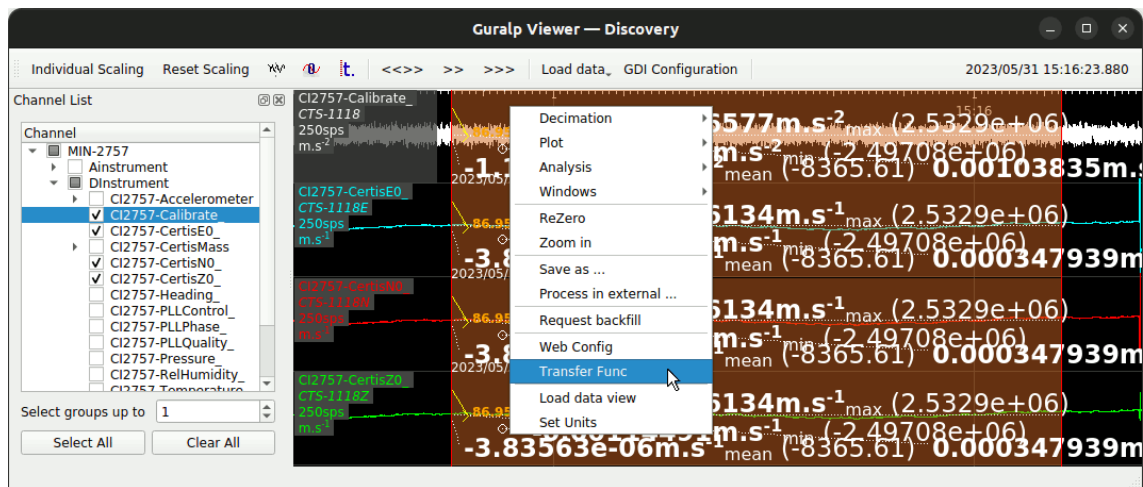

Click OK on the Choose Mode dialogue:
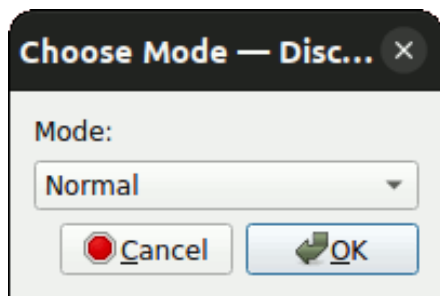
Click Yes or No on the Plot Phase Wrapped dialogue as desired:

until a window is displayed containing two graphs: one of amplitude against frequency and one of phase against frequency. If you are calibrating more than one component, the above sequence of dialogues will be repeated for each component that you selected.

On each graph, the theoretical response is shown in blue and the measured response is shown in red. A set of poles and zeros is computed which matches the measured amplitude and phase response and the average sensor gain over the pass-band is computed and displayed.

In the example graph below, taken part-way through the production process, it can be seen that the phase response is more flat than the theoretical response and the bandwidth is wider than the theoretical response. This instrument will need further attention.
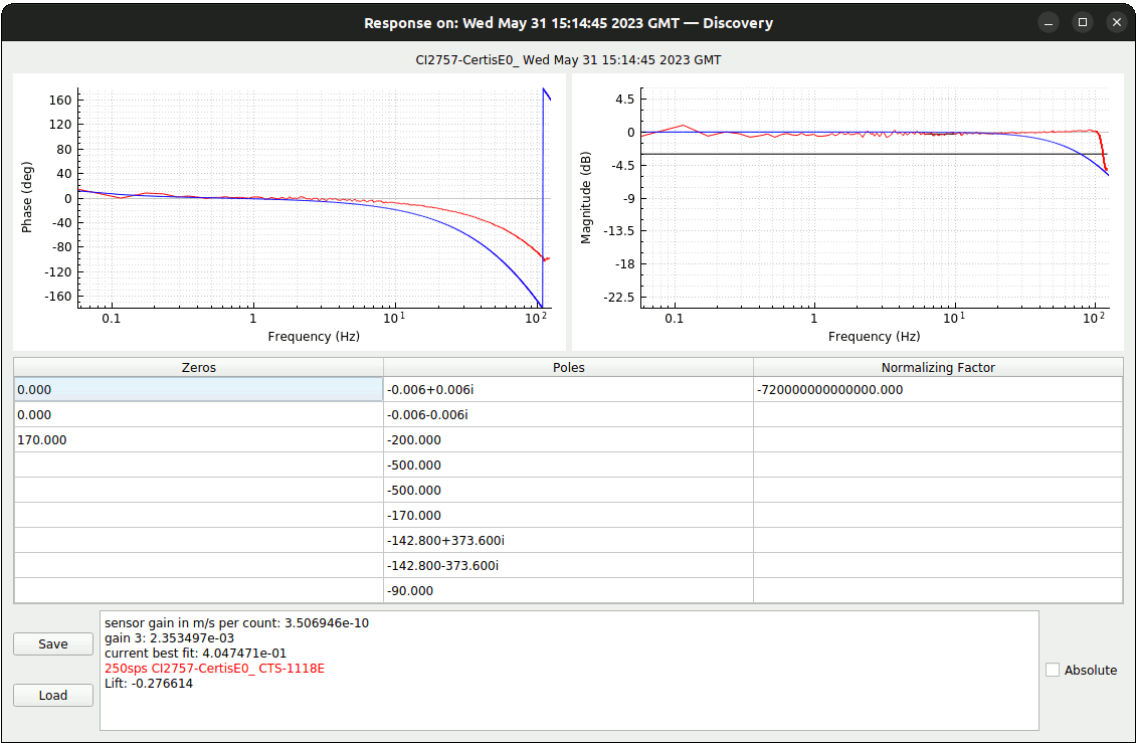
9   Revision History

A   2023-06-13   Initial release