Certis

Technical Manual

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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 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.

Three components measure movement in the x,y,z planes. These typically maps to the East/West, North/South and Vertical directions.

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 **Error! Bookmark not defined.**), 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 and to adapt to changes in orientation due to land slip, glacial movement etc.

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 three analogue outputs proportional to velocity in the three directions.

The worst case mass deviation is available on a separate analogue output.

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.

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 and noise-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.

For more information, please see section 4.2.2 on page **Error! Bookmark not defined.**.

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 **Error! Bookmark not defined.**)

- Internal Three MEMS accelerometer outputs

- Internal temperature

- Internal Humidity (for early warning of potential leakage of the instrument)

- PLL parameters: phase, control and quality – indication of sample clock accuracy

For details of output channel names, see section 8.2 on page **Error! Bookmark not defined.**.

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. This permits the instruments orientation with respect to gravity to be calculated.

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 **Error! Bookmark not defined.**.

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

- 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 **Error! Bookmark not defined.**.

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. Typically the factory defaults are adequate for most applications.

4.2   Configuration using a Minimus and Discovery

> ⓘ **Note: A manual entirely dedicated to Discovery is now available!** After
> downloading Discovery (<u>Güralp Support: Discovery Download Page
> (guralp.com)</u>) click on Help → Help → Discovery Manual. The user is referred to
> Discovery's manual for detailed instructions on how to use the software.

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. If you are using Discovery v1, right-click on the digitiser in the main list and select Control Centre from the context menu:
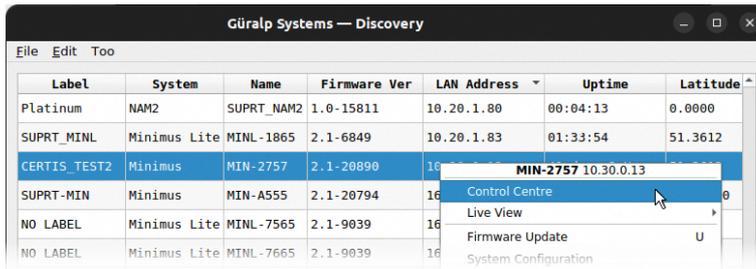
3. When the Control Centre window opens, click the **Console** icon in the left-hand tool bar. If you are using Discovery v2, right-click on the digitiser and select **Console**.

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:
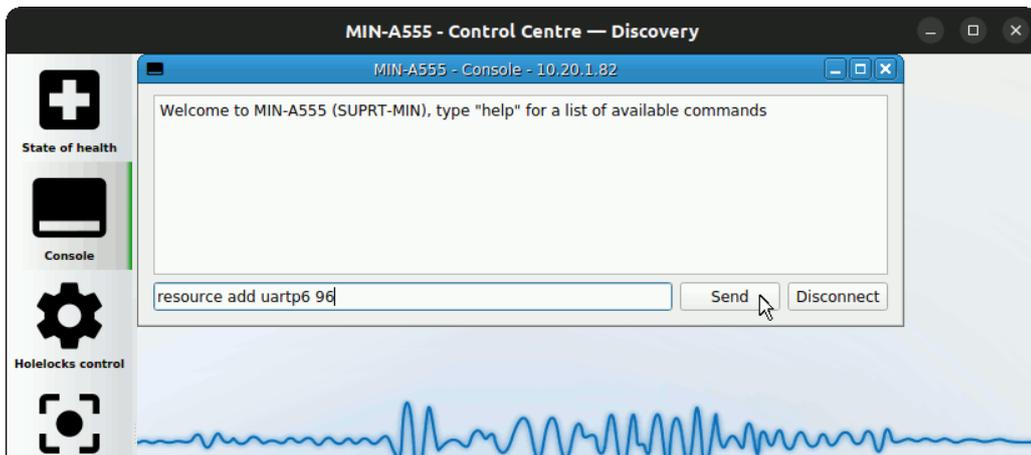
5. Click [Send] and the Minimus will respond with a short message:
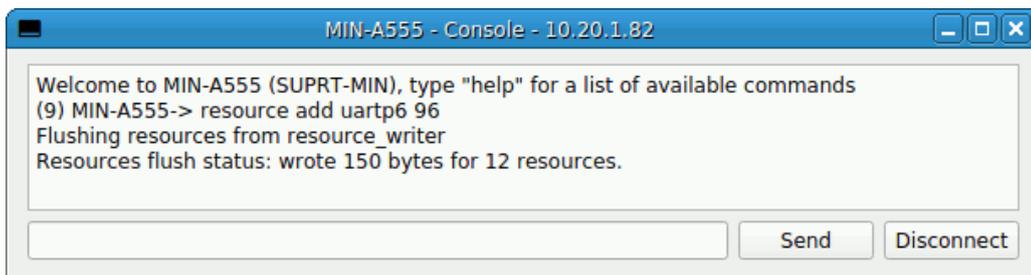
6. With the Certis connected to the Minimus, type

   `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 Dual Analog/Digital Sensor.

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

4.2.2 Basic Certis Operation
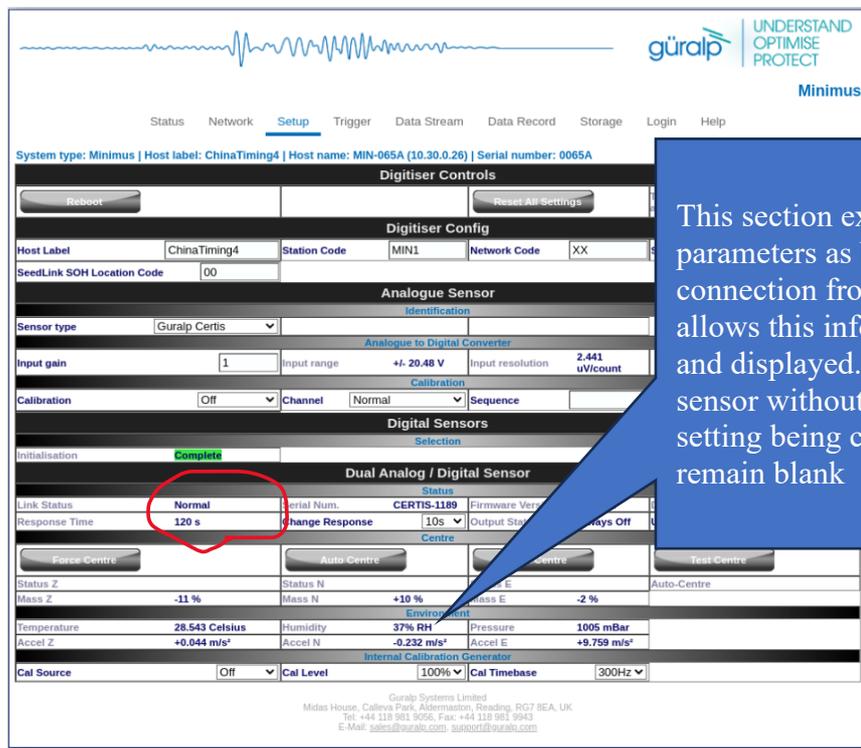
Figure 1 Certis setup once enabled

Once enabled as described the Setup tab should show the status of the connection to the Certis. Setting the Sensor Type to 'Certis' now displays further options for the calibration generator of the digitiser.

The Link Status must show 'Normal'. Failure to do so indicates a loss of connectivity to the Certis.

Once a good link it detected the digitiser loads calibration and response information from the sensor. These values (poles and zeros etc) are available in the respective response file that can be downloaded with the link as shown below: Any analytical

functions performed within Discovery (Power Spectral Density etc) use this parameters to reflect true ground movement.

Figure 2 Response file offers response information

4.2.3 Verifying Instrument Response of the Certis

The Minimus digiser has a calibration signal generator that can be programmed to send a calibration signal to the attached instrument. This is the preferred method to operate with a Certis as with any other 'Analog' instrument.
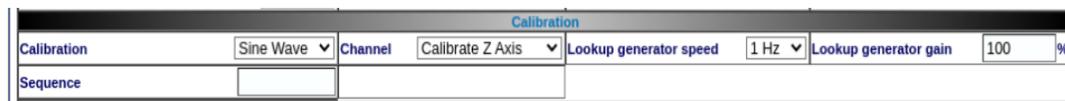
Figure 3 Running the digitiser calibration signal generator

The generator's output is automatically sent to the instrument attached to the 26 Way sensor cable. The same signal is also available as a stream to enable downstream processing of the instrument's response to the signal alongside the excitation signal.

Discovery can be used to perform this operation.

Figure 4 The calibration generator's output stream

In more advanced applications it is possible for the Certis to be used along side another Analog instrument on the single port of the Minimus digiser. The Certis uses serial RS232 connectivity so requiring just 3 wires. An analog instrument would connect to the traditional analog signals and control lines.

In this very specific case, the internal calibration signal generator of the Certis can be used allowing the digitiser's calibration signal generator to be used for the Analog instrument.

4.2.4 Setting the sample rates

The Data Streams page allows sample rates of the various streams to be configured. First choose the Certis page as shown below:

Figure 5 Choose Certis category of streams

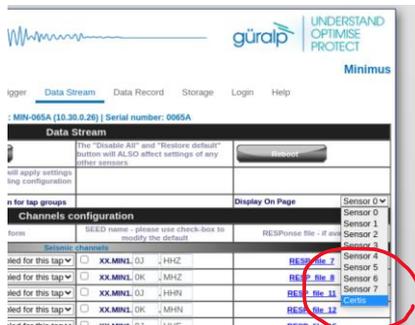The sample rates for streaming outputs and for recorded data are set independently: those for streaming outputs are configured via the Data Stream tab and those for recorded data are configured via the Data Record tab of the Minimus' web interface. Each channel on these two tabs has an associated drop-down 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.
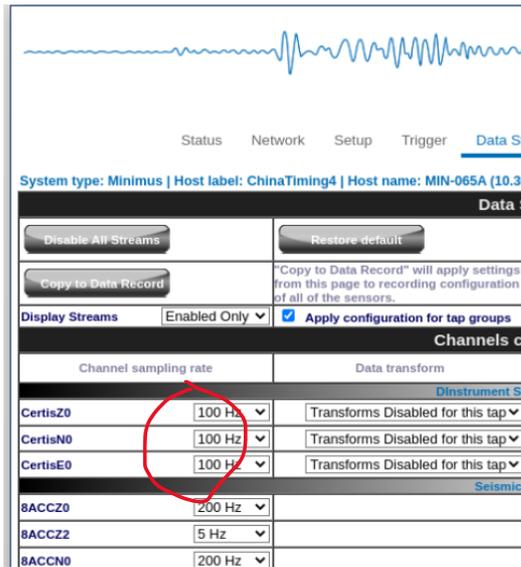
Figure 6 Setting sample rate of Certis Seismic channels

4.2.5 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.
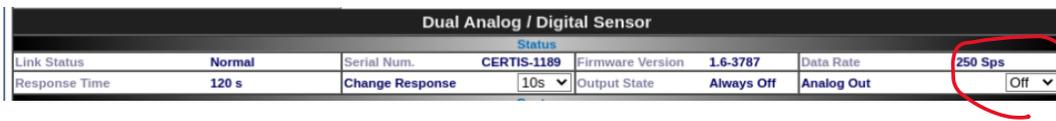
Figure 7 Analog output configuration

4.2.5.1   *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 **Error! Bookmark not defined.**. 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.

4.2.5.2   *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 **Error! Bookmark not defined.**. 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.

4.2.5.3   *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

4.2.6 Adjusting the frequency response

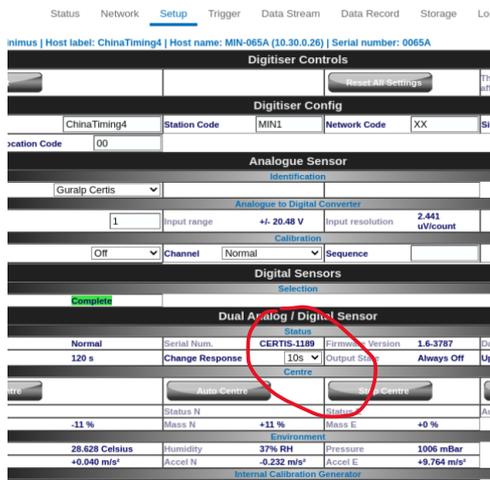The Certis has a frequency response which is flat to velocity between a configurable long-period corner and 100 Hz.

Figure 8 Changing Certis long period corner

> **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.
>
> **Direct connection to the Certis's serial port allows this to be changed and the setting saved if used with third party digitisers.**

To adjust the long-period corner, connect the Certis in digital mode to a Minimus, as described in section 4.2.1 on page **Error! Bookmark not defined.**, 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.

4.2.6.1   *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

4.2.6.2   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	0VELZ0	0VELZ0	0VELZ0
Lower-rate velocity channels	0VELZ2	0VELZ2	0VELZ2
Mass position channels	0VELM8	0VELM9	0VELMA

- 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

4.2.6.3   Setting the gain

The sensitivity of the digital output of the Certis is factory set to 2.38 (nm s^{-1})/count (i.e. $4.2{\times}10^8$ 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 (Non Guralp Digitiser)

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. This is only necessary if a Guralp digitiser is not being used and you wish to change the default behaviour of the instrument.

> **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 20 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 **Error! Bookmark not defined.**.

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 **Error! Bookmark not defined.**.

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.
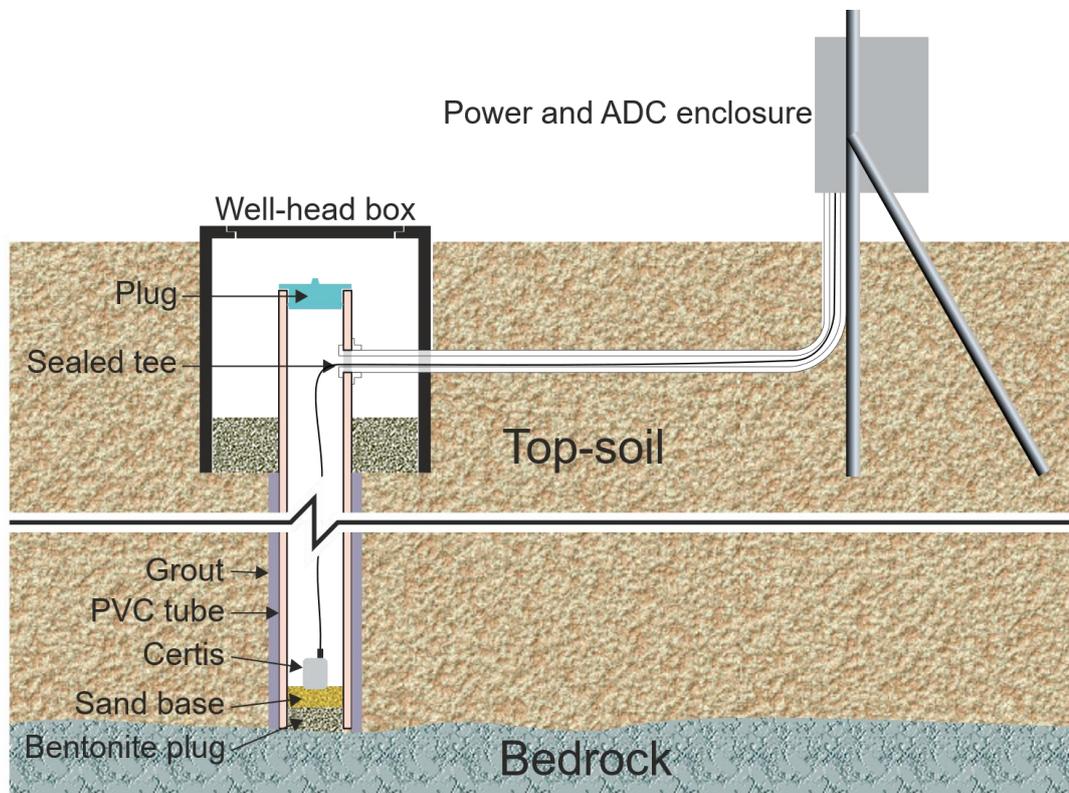
If the power supply and digitiser enclosure are to be above-ground, take care that they do not function as an inverted pendulum. A simple steel box mounted on a single stake will have a strong natural resonance which will couple directly to the earth near the instrument. Depending on the location of 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.
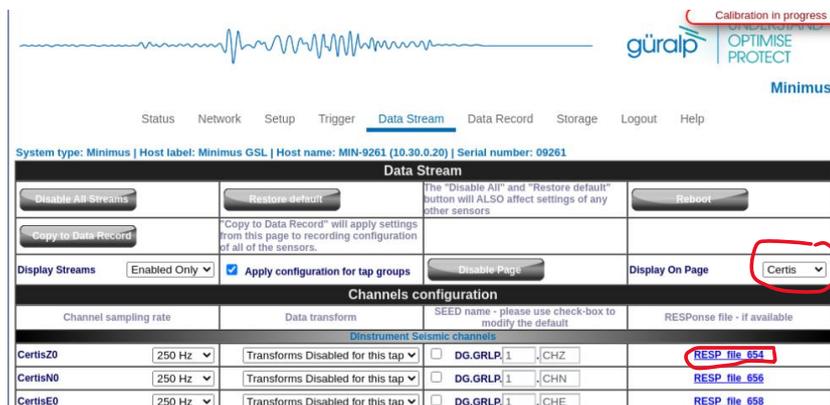

Figure 9 Choose the Certis tab to show the associated streams

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
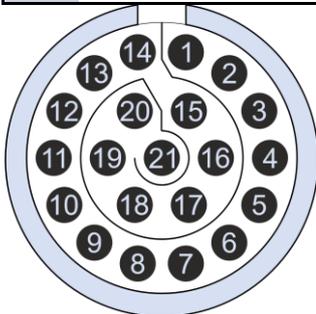
Wiring details for the compatible socket, ***-13-35S, as seen from the cable end (*i.e.* when assembling).

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 mass. 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.

When used with a Guralp Minimus or Minimus2 digitiser it is recommended that the Minimus Calibration Signal generator is used (Not Certis internal). The Certis internal generator can be used in the specific case when another Analog instrument shares the same digitiser port as the Digital Certis. Eg When a Strong motion analog instrument (Fortis) and a Certis are deployed on the same single digitiser port.

8.3.1 Initiating calibration

A calibration can be initiated in a number of ways. If used with a Minimus/Minimus2, 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 lines .

8.3.1.1   *Using a Minimus (or Minimus2) Manually*

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.

When the web interface opens, log in as normal and navigate to the Setup tab. The calibration controls are at the bottom of the Analogue Sensor section:
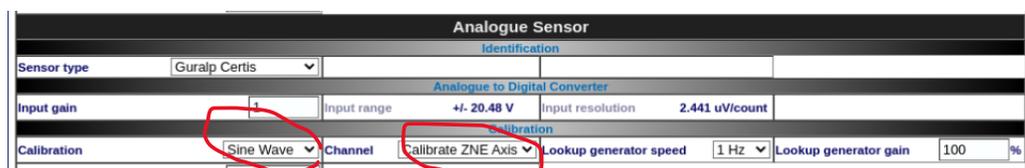
Select the desired calibration type from the Calibration drop-down menu and the Channels to apply this to (All 3 in a Certis) and the desired amplitude from the Generator Gain drop-down menu.

In order to analyse the data both the instrument output and the Calibration Signal streams need to be enabled in the Data Stream tab.
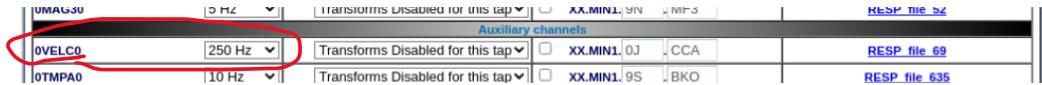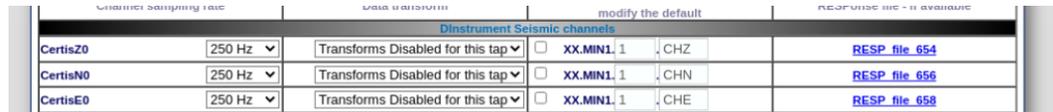

Figure 10 Calibration Generator Stream

Figure 11 Certis Instrument Seismic streams

The same sample rate for excitation and instrument output is required. To terminate the calibration, set the Cal Source to Off. A digitiser restart also disables calibration.

8.3.1.2   *Using Minimus for Scheduled Calibration*

The minimus can run scripts at specific time and dates. These can be used to enable calibration of a sensor automatically.

8.3.1.3   *Using serial console commands*

This procedure uses the calibration generator **internal** to the Certis. This is not normally required when any Seismic digitiser is used.

Open a serial console as described in section 4.3 on page **Error! Bookmark not defined.**. 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.

Command	Action
`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).

8.3.2 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.

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.

Note: Sample rates of the excitation atream and the Instruments must be the same for analysis to work.
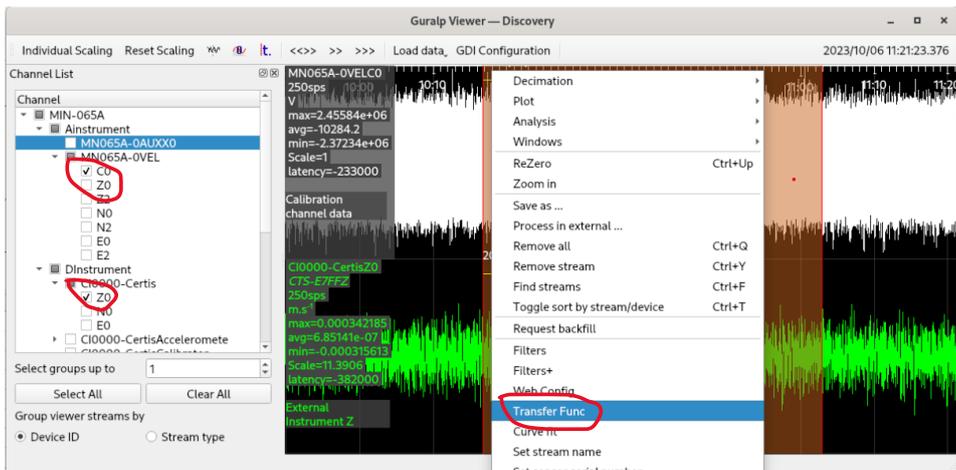.

Figure 12 Setting up to analyse instrument response

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.

Figure 13 Verification of instrument response

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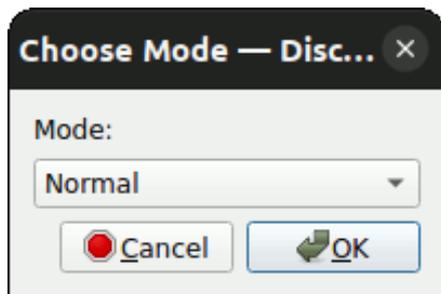
Click Yes or No on the Plot Phase Wrapped dialogue as desired:

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.
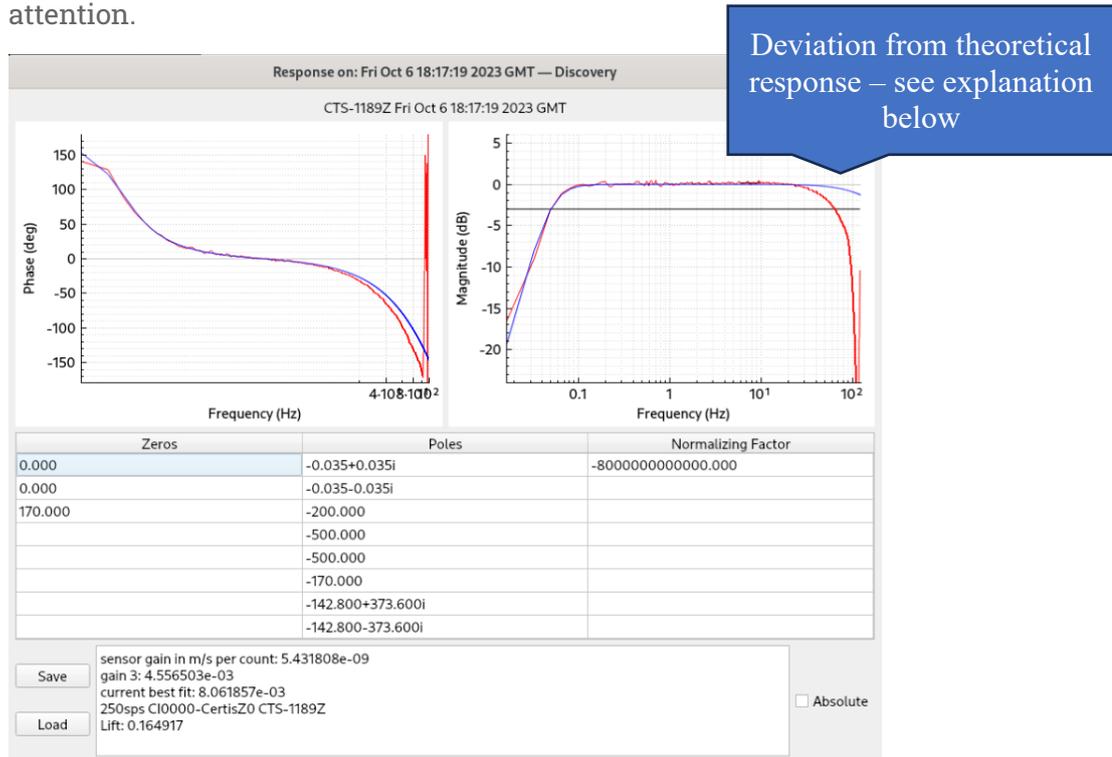

Figure 14 Measured instrument response

The example shown above fits reasonably well with the theoretical response over all parts of the spectrum except from the higher frequencies. This instrument has a high frequency corner of -3dB at 200Hz. The sample rate chosen is 250 Samples per second. The Nyquist point of this sample rate is 125Hz thus the instruments output is limited by the displayed sample rate.

The same operation can be performed on the Certis Analog outputs rather than using the digital outputs as in the above example. The Poles and Zeros must be manually entered on te Calibration Editor page in Discovery for the Digitiser channel being used – Sensor 0 or 1 typically – for the blue line to be plotted correctly.

8.4   Updating firmware

The firmware within the Certis can be updated by transferring a new firmware file to the system using the File Transfer applet.
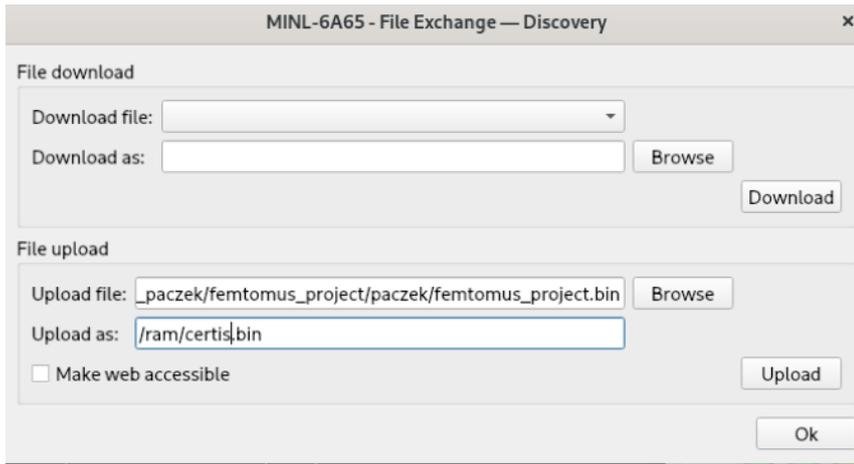
Figure 15 Updating Certis software by file transfers

The Upload as must be set as shown. The Upload file is as supplied. The operation takes about 3 minutes.

The new software version should be shown on the Minimus setup WEB tab.

9   Revision History

A   2023-06-13   Initial release