Güralp Fortimus

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 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: 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 System Overview

Thank-you for purchasing a Güralp Fortimus digital accelerometer.

This section describes the key components of a Fortimus system. The Fortimus unit is the main, standard product in the system; other components and accessories are optional and can be purchased separately. Please check your order confirmation to see which components were purchased with your system.

2.1 Key features

- Digital, three-axis, strong-motion, force-feedback accelerometer.
- Flat response to ground acceleration from DC to 315 Hz.
- Selectable gains for full-scale readings of ±4 g, ±2 g, ±1 g and ±0.5 g.
- 24-bit digitiser with a nominal sensitivity of 2.44 µV per count.
- Selectable sample rates from 1 sample per hour to 5000 sps.
- Data streaming in real-time using GCF (Scream!), GDI-link and SEEDlink.
- Compact form, measuring just 165 × 165 × 84 mm.
- Internal ±2 g MEMS accelerometer for orientation.
- Identification of I.P. address via Güralp Discovery software and, optionally, a cloud-based or organisational registry server.
- Remote instrument and data management via Discovery software.
- Android app for installation integrity checking via Bluetooth.
- Low-latency mode for Earthquake Early Warning (< 40 ms).
- Hot-swappable data storage with dual redundant 64 GB microSD cards.
- GNSS time-synchronisation, compatible with Navstar (GPS), GLONASS, BeiDou and Galileo constellations, with PTP available as an alternative time-source.
- Touch-sensitive, 2.4 inch colour LCD for monitoring and control operations.

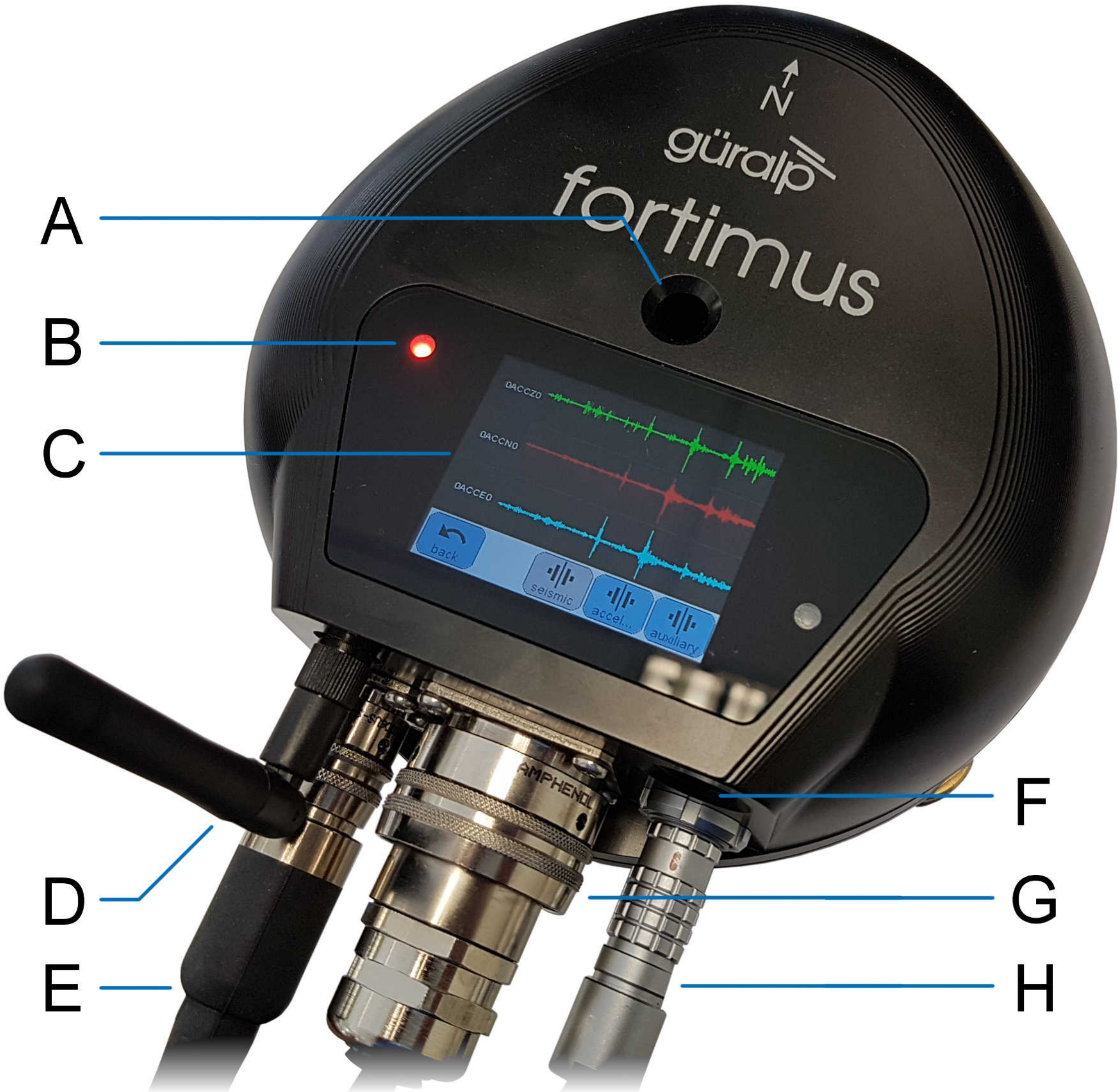
2.2 Typical applications

- Earthquake Early Warning systems.
- Multi-scale seismic networks and arrays.
- Structural health monitoring (e.g. dams, industry, buildings).
- Surface and vault installation.
- Posthole deployment.

3 System description

3.1 Güralp Fortimus digital accelerometer

The Güralp Fortimus is a Fortis triaxial accelerometer combined with a Minimus digitiser. The Minimus acquires data from – and allows direct control of – the Fortis analogue instrument.



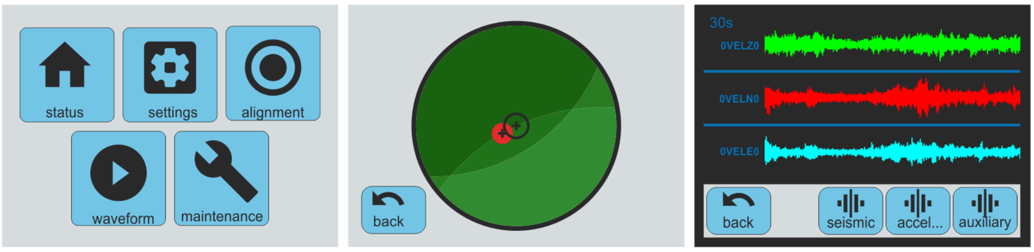
The labelled parts are:

A	Hole for mounting bolt	**E**	Power connection
B	Status LED	**F**	Cover for SD card
C	Touch-screen display	**G**	Ethernet connection
D	WiFi antenna	**H**	GNSS connection

The hard-anodised aluminium casing protects the instrument from water, allowing it to be deployed in a range of environments. Installation is simple, using a single fixing bolt to attach the sensor to a hard surface. If required, you can also level the sensor using its adjustable levelling feet. An integrated digital bubble-level – available in the display menu – provides quick visual feedback during levelling.

3.1.1 Liquid Crystal Display

The Fortimus is equipped with a multi-touch sensitive, 2.4 inch, full colour LCD touch-screen which shows waveforms and a virtual instrument level. Its menu system allows control of instrument state of health, gain settings and network configurations.



The LCD features are described in detail in chapter 5 on page 33.

3.1.2 LED indicator

The Fortimus has an LED indicator on the upper surface, which provides status and configuration information.

This information is encoded in sequences of coloured flashes. In general, red flashes indicate that initialisation is in progress or that the instrument has encountered a problem, green flashes indicate normal operation and blue flashes show trigger activity. The various codes are:

- 
  One quick red flash followed by a one second pause: the removable microSD card is present in the Fortimus' external slot, but no fixed microSD card is present inside the Fortimus.

- 
  Two quick red flashes followed by a one second pause: the fixed microSD card is present inside the Fortimus but no removable microSD card is present in the Fortimus' externally-accessible slot.

- 
  Three quick red flashes following by a one second pause: both microSD cards are present but either the GNSS receiver is disconnected or the GNSS lock is not sufficiently accurate.

- 
  A green flash every four seconds: this is the standard operating heartbeat. GNSS and both internal and external microSD cards are present, which indicates that the Fortimus can be successfully deployed and left to record data.

  Note: Depending on the digitiser's recent history, it can take up to ten minutes to reach this state after power-up.

- 
  1 blue flash: a trigger event has been detected.

3.1.3 Bluetooth connectivity

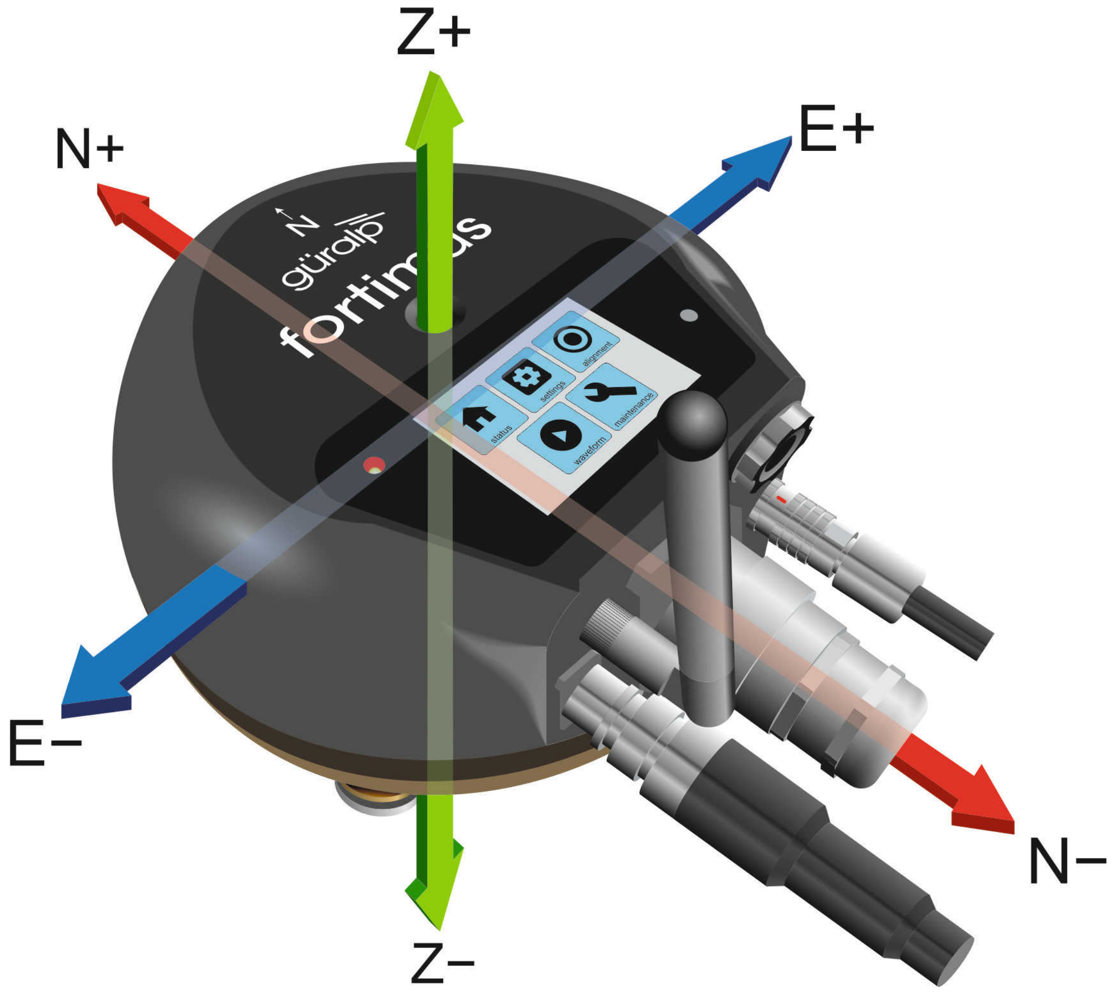
The Fortimus features Bluetooth connectivity, allowing sensor and state-of-health data to be monitored using the Güralp GüVü app (see Section 3.4 on page 20) running on an Android mobile phone or tablet.

Bluetooth can be disabled via software to save processor usage but the hardware module cannot be switched off. BLE (Bluetooth Low Energy) technology is used to minimise the power requirement. The Bluetooth transmitter/receiver is in permanent standby mode and always ready to receive a connection from a phone or tablet.

See Chapter 8 on page 125 for further details on connecting to the Fortimus using a phone or tablet.

3.1.4 MEMS accelerometer

The Fortimus digital accelerometer is equipped with a triaxial **M**icro **E**lectro-**M**echanical **S**ystem (MEMS) accelerometer with a measurement range of ±2 g. The three axes of sensitivity, Z, N and E, align with those of the main accelerometer outputs and are orientated as illustrated below:



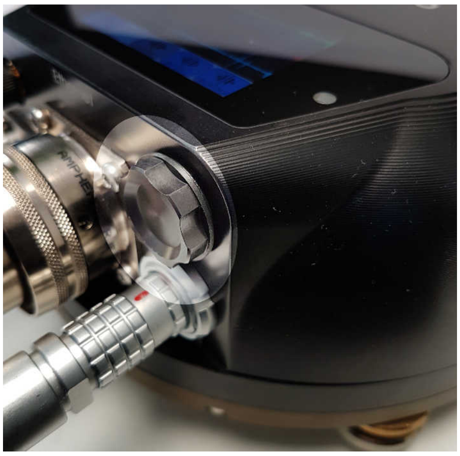
3.1.5 Data storage

The Fortimus uses microSD (non-volatile) memory technology to store seismic data within the instrument. The Fortimus features two such microSD cards in order to provide redundancy; this helps to protect the recorded data in the unlikely event of any corruption or problem with the memory cards. One card is internal and cannot be removed by the customer; the other is hot-swappable and easily accessible without any technical knowledge.

The Fortimus is supplied with two microSD cards that are of equal storage capacity (e.g. two 64 GB cards).

3.1.5.1 Primary (removable / hot-swappable) microSD card slot

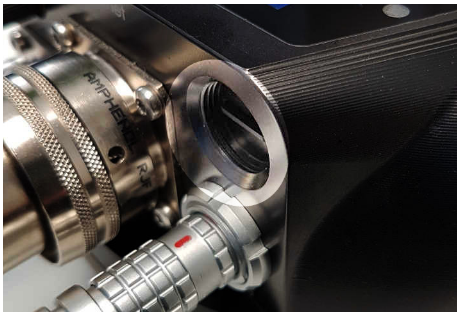
To remove a card, follow the sequence below:



The microSD card is protected by a screw-in cap, located next to the Ethernet connector and above the GNSS connector

Remove the cap by unscrewing it anticlockwise, as shown.

Caution: Finger pressure is sufficient. Do not use tools.



The horizontal edge of the microSD card is now visible

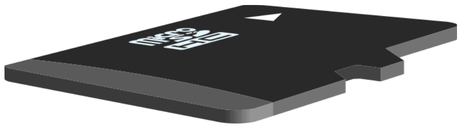
The card slot has a spring lock: pushing the card firmly inwards locks it into place; a second push releases the card so that it can be withdrawn.

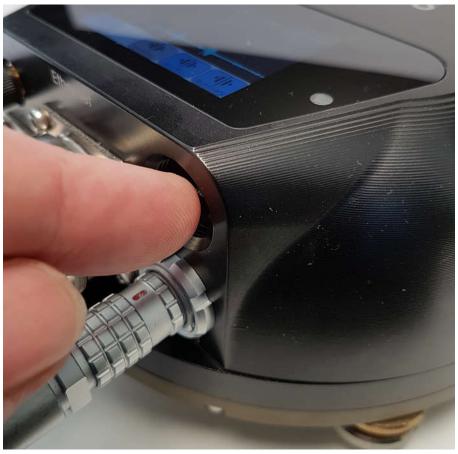
Lightly push the edge of the microSD card with a fingertip or soft implement. Once the initial spring resistance has been overcome, the card will partially eject itself.

The card should now protrude enough that it can be grasped and withdrawn.

To replace the card, remove any existing card, as shown previously, and then:

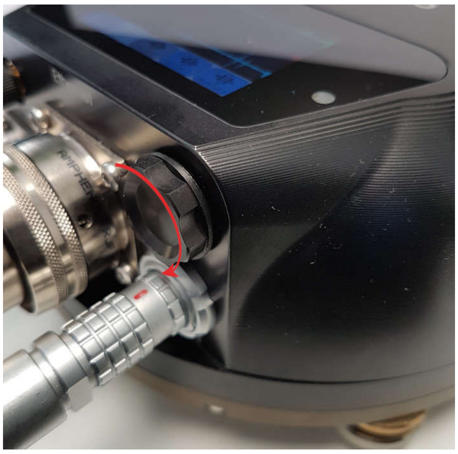
Gently insert the replacement card into the slot with the logo facing upwards and the straight edge of the card on the left, as shown. The card must be perfectly horizontal in order to align properly.





Push the card gently into place until the pressure of the spring lock is felt. If it does not glide into place, remove and start again. Do not force the card.

Check that the card is fully engaged by pressing lightly to unlock it and then pressing to lock it again. The card should be engaged firmly when locked and slide freely otherwise. Ensure the card is locked before proceeding.



Offer the cap to the opening, taking great care to align the screw-thread correctly. Replace the cap by screwing it in clockwise, as shown.

Caution: Finger pressure is sufficient. Do not use tools.

Note: In order to ensure data integrity and security, Güralp only recommend using the supplied industrial-grade microSD cards.

Caution: When the external microSD card is removed, the internal card keeps recording data, unless recording is stopped using Unmount Cards. button (see Section 7.10.3 on page 57). However, when the external card is re-connected, any data written to the internal card while the removable card was absent will overwritten.

3.1.5.2 Internal (back-up) microSD card

The second microSD card is factory-installed in a slot inside the Fortimus.

Caution: The internal microSD card is not accessible by the user. Attempts to remove or replace it will void the Fortimus' warranty.

3.1.6 WiFi connectivity

The Fortimus is provided with a Siretta Delta 7A omnidirectional antenna, suitable for both 2.4 GHz and 5.8 GHz networks.

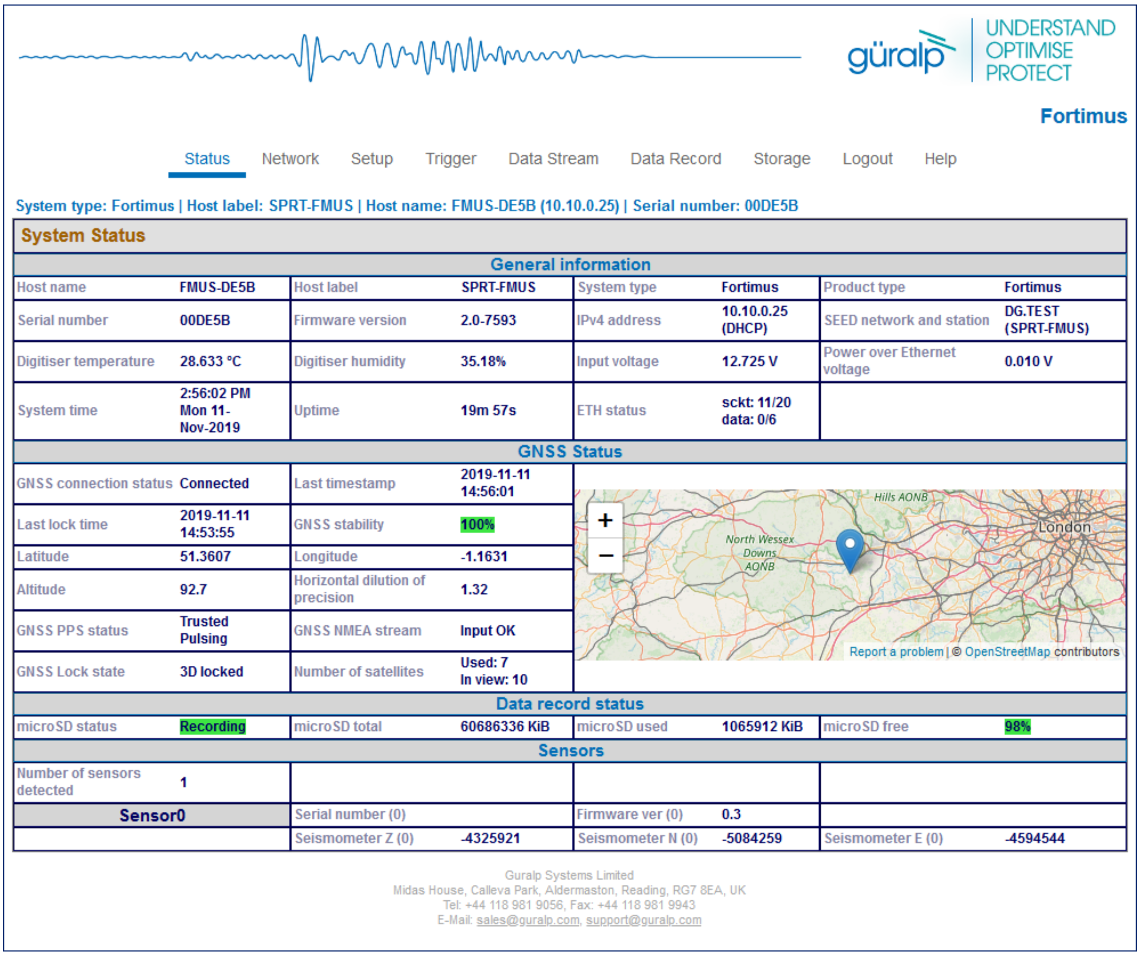
The antenna connects directly to the Fortimus using an SMA connector. It can be removed and replaced with a high-gain, directional antenna if required. To remove, grasp the knurled locking sleeve and turn anti-clockwise, as shown.

See Section 7.5 on page 49 for further details on how to configure the Fortimus to connect to a wireless network.

Note: It is not necessary to have the antenna fitted if wireless operation is not required.

3.1.7 Web interface

The Fortimus contains on-board firmware that presents monitoring and configuration interfaces. These are accessible through Güralp's Discovery software (see Section 3.3 on page 19) or, with the built-in web server, via Discovery's browser interface or any standards-conformant web browser.



The web interface allows a number of instrument monitoring, control and configuration options:

- Sensor readings and instrument State-of-Health
- Network configuration and authentication
- Sensor, timing, and station configuration/information
- Remote data-streaming configuration
- Local data-storage configuration

Please refer to Chapter 7 on page 44 for full usage instructions.

3.2 Accessory package

3.2.1 Ethernet cable

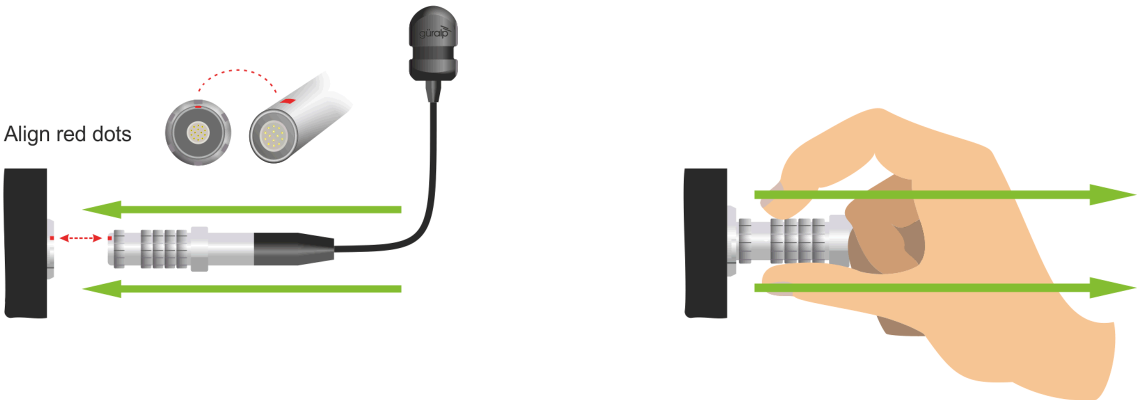
The Ethernet connector allows use of 10BASE-T, 100BASE-T or 1000BASE-T networks. The metal gland shell-type connector that connects to the Fortimus is IP68-rated and ensures consistent connection in harsh installation environments. At the other end of the blue Ethernet cable, there is a standard 8P8C modular jack (often incorrectly called an RJ45) for attachment to all common networking devices (e.g. PC, laptop, router, switch, modem etc.).

Please see Section 12.1 on page 141 for the pin-out and further details.

3.2.2 Compact GNSS receiver and cable

The Fortimus is supplied with a new-generation compact GNSS receiver with an in-built antenna that supports the GPS (Navstar), GLONASS, BeiDou and Galileo satellite constellations.

The receiver comes with a black RS-422 cable that has an over-moulded 14-way LEMO connector. LEMO connectors use an innovative latching mechanism which is different to the bayonet connectors used elsewhere. To mate, simply line up the red marks – one on the chassis and one on the free connector – and gently push the connector into place until they latch together with a click. To disconnect (un-mate), grasp the outer sleeve of the connector and pull gently.



Caution: Do not twist the connector or use any tools.

Please see Section 12.3 on page 143 for pin-out details.

3.2.3 Power cable

The Fortimus comes with a dedicated power cable with a standard military-specification bayonet connector on one end and bare ends at the other.

> **Note:** The Fortimus does not use a grey/blue combined power/data cable, as used with many other Güralp products.

Please see Section 12.2 on page 142 for the pin-out details.

3.2.4 Diagnostic GNSS to Serial cable adapter

The Fortimus comes with an adapter to connect the GNSS LEMO connector to a female nine-pin D-subminiature connector (DE9f), which can be used with a standard serial port to allow diagnosis and debugging of the Fortimus using a serial terminal emulator. (See Section 9 on page 131).

> **Note:** This facility should rarely be required. It is primarily intended for use by the Güralp Support Team to help diagnose any problems with the Fortimus that may be experienced by the user.

A serial-to-USB converter (not supplied) may need to be used to connect to PCs or laptops that don't have a nine-pin serial connector. Please see Section 12.3 on page 143 for full pin-out details.

3.3 Güralp Discovery software

Güralp Discovery is a software application for seismometer configuration and control, state-of-health monitoring, and waveform viewing and acquisition.

	Status	Label	System	Name	Serial#	Firmware Ver	WAN Address	LAN Address	Uptime	Latitude	Longitude
1		NO LABEL	Minimus	MIN-2757	10071	1.2-257	89.213.16.113	10.30.0.132	15:25:49	0.0000	0.0000
2		NO LABEL	Minimus	MIN-C457	50263	1.2-230	89.213.16.113	10.30.0.68	00:29:13	0.0000	0.0000
3		NO LABEL	Minimus Plus	FMUS-9655	38485	1.2-194	89.213.16.113	10.30.0.61	1 days 19 Hrs	0.0000	0.0000
4		NO LABEL	Minimus	MIN-1456	5206	1.2-181	89.213.16.113	10.30.0.43	2 days 21 Hrs	0.0000	0.0000
5		NO LABEL	Minimus	MIN-D457	54359	1.2-146	89.213.16.113	10.30.0.58	15:17:39	0.0000	0.0000
6		NO LABEL	Minimus	MIN-D357	54103	1.2-146	89.213.16.113	10.30.0.31	00:03:11	0.0000	0.0000
7		NO LABEL	Minimus	MIN-C355	50005	1.1-8	89.213.16.113	10.30.0.75	16:56:08	0.0000	0.0000
8		RAD Comp Soak	Minimus	MIN-E256	57942	1.1-1022	89.213.16.113	10.20.0.232	17:53:49	51.3604	-1.1634
9		NO LABEL	Minimus	MIN-E656	58966	1.1-1022	89.213.16.113	10.30.0.21	7 days 18 Hrs	51.3612	-1.1641
10		Support	Minimus	MIN-C555	50517	1.1-1022	89.213.16.113	10.10.0.13	00:02:18	0.0000	0.0000
11		DEMO 83	Minimus	MIN-C456	50262	1.1-1022	89.213.16.113	10.10.0.36	6 days 17 Hrs	0.0000	0.0000
12		NO LABEL	Minimus	MIN-CF57	53079	1.1-1022	89.213.16.113	10.20.0.37	00:09:48	51.3607	-1.1635
13		NO LABEL	Minimus	MIN-D157	53591	1.1-1022	89.213.16.113	10.20.0.102	00:09:48	51.3607	-1.1634
14		NO LABEL	Minimus	MIN-2B57	11095	1.1-1022	89.213.16.113	10.30.0.87	7 days 18 Hrs	51.3612	-1.1640
15		TR1191-4A7	Minimus	MIN-AA57	43607	1.1-1022	89.213.16.113	10.30.0.152	2 days 17 Hrs	51.3612	-1.1640

An important benefit of Discovery is that it allows the user to identify the instruments' I.P. addresses on a LAN or via a cloud-based or organisational registry server without the need for static I.P. addresses at the stations.

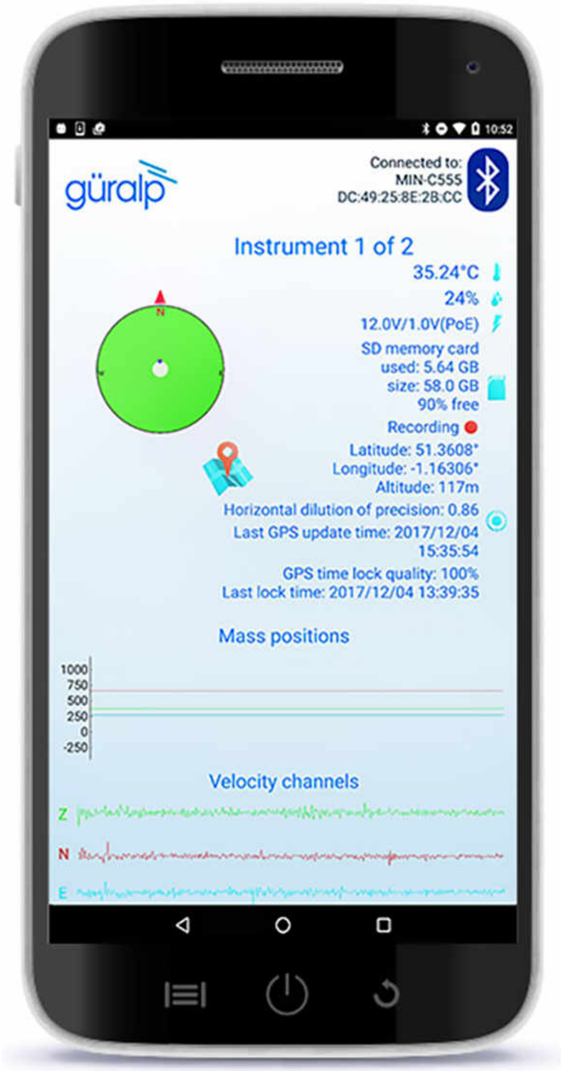
Discovery also provides simple, convenient instrument and data management with access to hardware State-of-Health (SoH), data streaming; GNSS location; response and calibration data.

Discovery can download Fortimus firmware from the Internet and remotely install it onto any connected Fortimus.

3.4 Güralp GüVü Android and iOS app

For added confidence during deployments in the field, Güralp GüVü, a Bluetooth App, displays waveforms, orientation, temperature and humidity data for instant checking of installation integrity.

Please refer to Chapter 8 on page 125 for installation and usage instructions.



4 Getting started

4.1 Unpacking and packing

The Fortimus is delivered in environmentally-friendly, flat-packable, suspension packaging. The packaging is specifically designed for the Fortimus and should be re-used whenever you need to transport the sensor. Please note any damage to the packaging when you receive the equipment and unpack on a clean surface. The package should contain the digital accelerometer, the pigtail power cable, the GNSS receiver and cable, the Ethernet cable and the fixing bolt.

Caution: Although the Fortimus is a strong motion instrument, it contains sensitive mechanical components which can be damaged by mishandling. If you are at all unsure about the handling or installation of the device, you should contact Güralp Systems for assistance.

- Do not bump or jolt any part of the sensor when handling or unpacking.
- Do not kink or walk on the data cable (especially on rough surfaces such as gravel), nor allow it to bear the weight of the sensor.
- Do not connect the instrument to power sources except where instructed.
- Never ground any of the output signal lines from the sensor.

4.2 System set-up

Güralp highly recommends exploring and gaining familiarity with the Fortimus inside your lab before installation in an outdoors environment.

A typical set-up for the Fortimus is shown in the figure below:

To get started, connect the cables as shown in the figure above and as described in Section 3.2 on page 17.

Power up the Fortimus using a power supply with a DC output of between 10 and 36 Volts.

Caution: Observe the correct polarity when connecting the power supply. The red lead (from pin B) must be connected to the positive terminal, typically labelled "+", and the **black** lead (from pin A) must be connected to the **negative terminal**, typically labelled "**-**". An incorrect connection risks destroying the instrument, the power supply and any connected accessories.

If the Fortimus is directly connected to a laptop or PC using the blue Ethernet cable, make sure that the laptop or PC is configured to obtain an I.P. address automatically. More details on how to correctly configure the connection using APIPA (Automatic Private I.P. Addressing) are in Section 14 on page 158.

4.3 Güralp Discovery software installation

To view live waveforms, and to control and configure the Fortimus, you will need to use Güralp Discovery software.

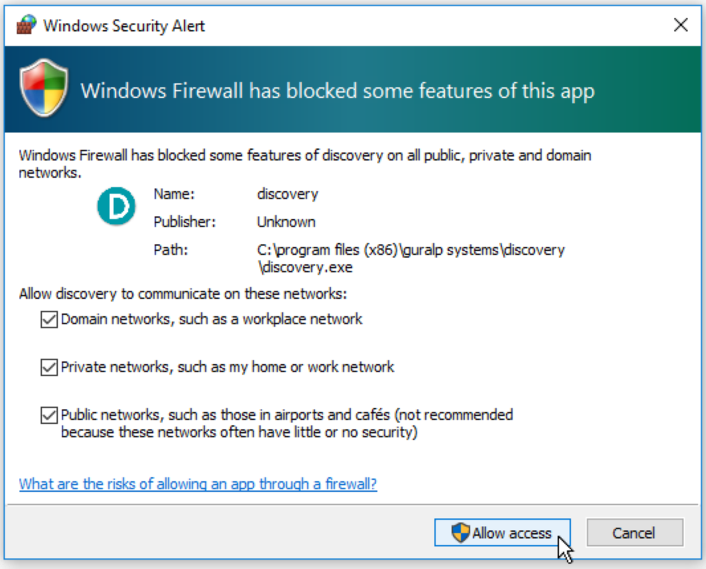
Visit www.guralp.com/sw/download-discovery.shtml for links for all available platforms (currently Windows 32-bit and 64-bit, macOS 64-bit and Linux 64-bit).

Download the installer appropriate for your architecture and operating system, run the installer and follow the instructions on screen. (Full details of installation and upgrading are in Section 13 on page 144.)

Note: Windows users may have to reconfigure the Windows FireWall in order to allow Discovery to communicate properly. Please see Section 13.4 on page 151 for full details. Brief instructions are below.

Under Windows, the first time that you start Discovery, Windows may ask you to specify how you wish Discovery to interact with the Windows Firewall. Because Discovery requires network communication in order to function, it is important that you understand the options available.

The following screen is displayed:



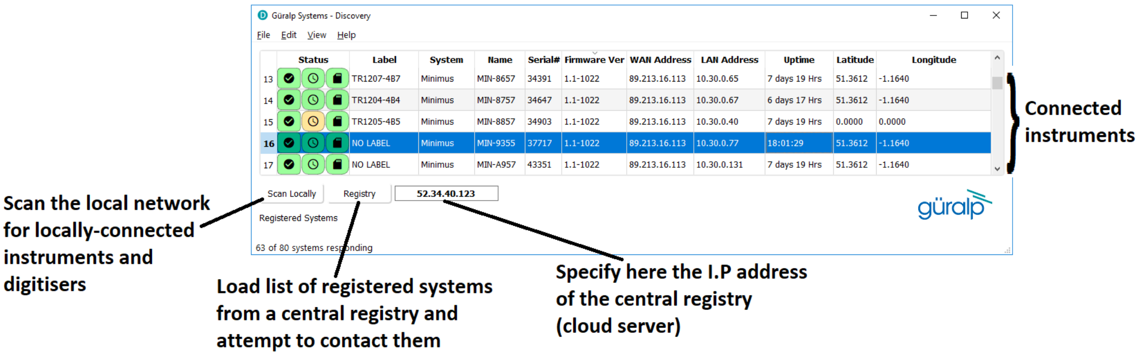
The screen provides three check-boxes which indicate whether Discovery can communicate with networked devices in the "Domain" profile, the "Private" profile or the "Public" profile. (Profiles are also known as "network locations".)

The "Domain" profile applies to networks where the host system can authenticate to a domain controller. The "Private" profile is a user-assigned profile and is used to designate private or home networks. The default profile is the "Public" profile, which is used to designate public networks such as WiFi hotspots at coffee shops, airports, and other locations.

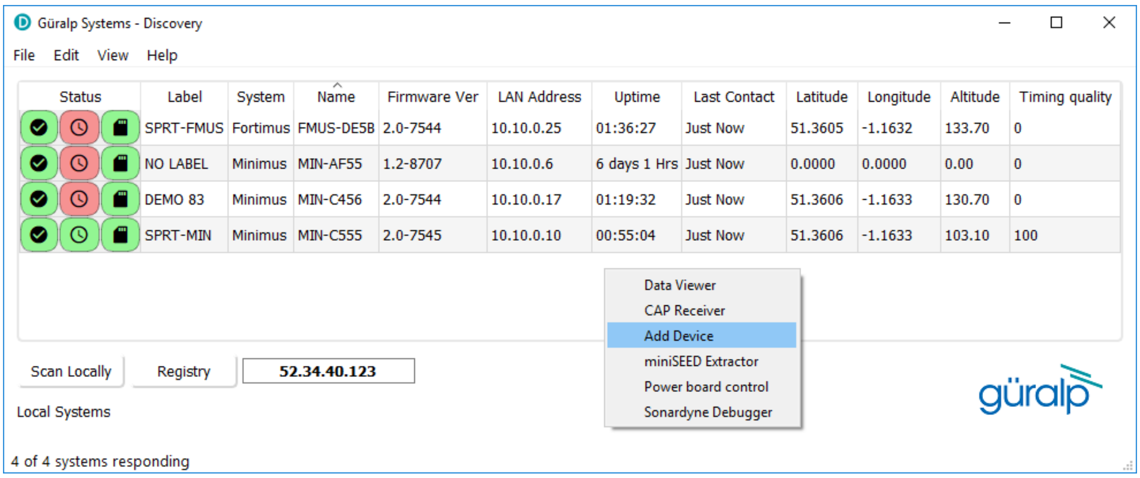
For a more complete discussion of this topic, please see www.tenforums.com/tutorials/6815-network-location-set-private-public-windows-10-a.html or your Windows documentation.

Once you have specified your firewall preferences, Discovery displays a main window which normally shows a list of both locally and remotely connected instruments. If you close this main window, Discovery will quit.

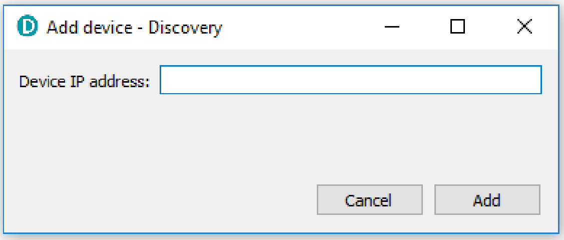
Discovery will initially "listen" for connected instruments on your local network. This mode can be refreshed by clicking the Scan Locally button or by pressing the short-cut keys Ctrl + L. These features are identified below:



You can add instruments to the list by right-clicking in the blank area and selecting "Add device" or choosing this option from the Edit menu:



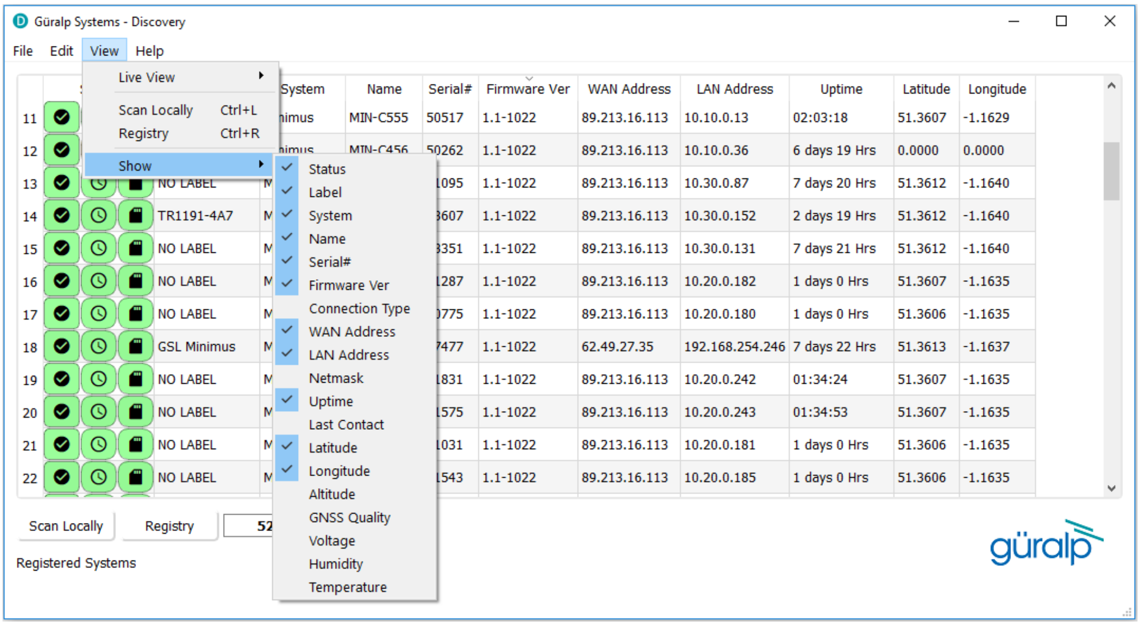
The following dialogue is displayed:



Enter the IP address of the Fortimus (or other device, such as Güralp Minimus) to be added and click the Add button. The newly added device will appear in the device list.

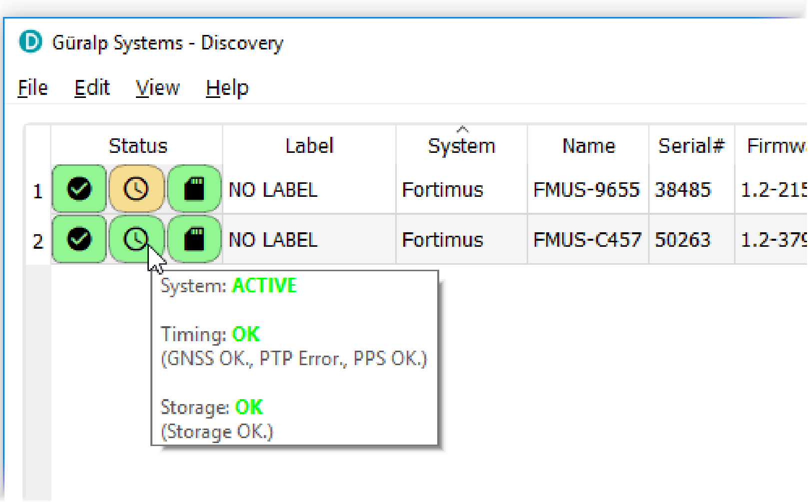
Note: The newly added device will be removed from the list and not automatically re-added if a local network scan is performed.

You can choose which information is shown for each device in the main window. You can select which columns to display – and hide unwanted ones – by clicking on "Show" from the "View" menu.



The "Status" column is composed of three icons that represent the digitiser connectivity status (whether Fortimus is reachable/active or not), timing status (GNSS/PTP/PPS) and storage status (primary/secondary) respectively.

Hovering the mouse over any of these three icons will display tool-tips giving a brief description of the status including, for the timing indicator, details of which timing subsystems are operating:



4.4 Viewing waveforms and system state-of-health

Waveform data recorded by the Fortimus' internal sensors and other connected sensors can be viewed using several methods, which are described in the following sections.

4.4.1 Using Discovery's "Live View" window

4.4.1.1 Main features

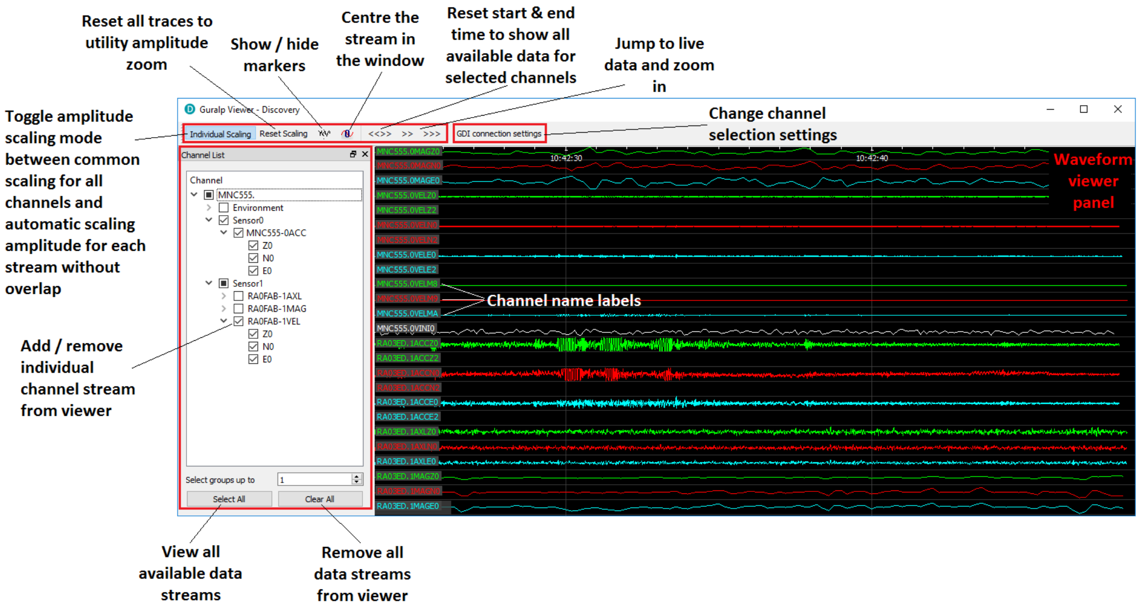
Discovery offers a versatile live waveform/data viewer. To open the Viewer, in Discovery's main window, select an instrument and, from the View tab in the toolbar, select "Live View". The menu will then present three options for data streaming:

- GDI and GCF channels
- GDI only
- GCF only

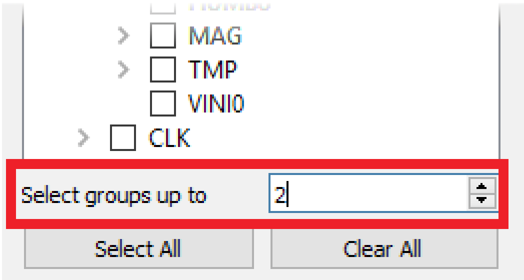
The GCF option uses the Scream! Protocol to stream data in GCF packets of, typically, 250, 500 or 1,000 samples. The GDI protocol streams data sample-by-sample and also allows the sending of each instrument's calibration parameters so that data can be expressed in terms of physical units rather than digitiser counts.

Güralp recommends using the "GDI only" option for waveform viewing.

The main features of – and the key buttons within – the Live View window are shown in the following screen-shot. Basic amplitude and time zoom functions are given in the Window zoom controls panel and streams can be easily added to or removed from the window by using the check-boxes in the left panel.



The channels are divided in groups with different hierarchical importance. The most important are the velocity/acceleration channels with higher sample rates: these belong to group 1. The least important belong to group 6, which includes humidity, temperature, clock diagnostics *etc*. When the live view is launched, only the channels in group 1 are selected. It is possible to change this setting by selecting a different group number from the “Select group up to” box at the bottom of the channel list.



When only few channels are selected for viewing, the channel name labels also show data statistics, including the maximum, minimum and average amplitudes in physical units.

If too many channels are in view for this information to be visible, you can left-click on a label and the label and trace will then expand to half the height of the screen, revealing these statistics. The other channels will be compressed into the remaining space. Another left-click on the same channel will return the window to normal. Alternatively, a left-click on a different channel will shrink the original one and expand the newly-selected one.

By selecting and dragging the mouse over a window of waveform data, the viewer will display similar statistics for the data within the selected window. When a window of data is selected, use the ⇧ key to subtract the ADC offset from the maximum, minimum and average values. Use the Alt key to calculate the integral of the selected data. By right-clicking on the window, you can perform advanced analysis on the data, including plotting power spectral density graphs (PSDs), spectrograms and discrete Fourier transforms (DFTs), as shown below:

4.4.1.2 Window control short-cuts

You can change the display of the waveforms with based on a combination of keystrokes and mouse-wheel scrolling (or track- / touch-pad scrolling on a laptop).

These commands are shown in the table below:

Command	Window control
Amplitude control	
	Increase/decrease amplitude of all traces2
+ hover cursor over channel label	Increase/decrease amplitude of individual trace
Ctrl + + hover cursor over channel label	Shift individual trace offset up/down
Time control	
Ctrl +	Pan time-scale right/left
⇧ +	Zoom time-scale in/out
Trace focus	
on trace label	Focus on individual trace
Trace selection	
Del + hover cursor over on individual trace / trace label	Remove / de-select trace from Viewer window
Details control	
⇧ + hover cursor over on individual trace / trace label	Reset the maximum and minimum values to the average value of the selected data

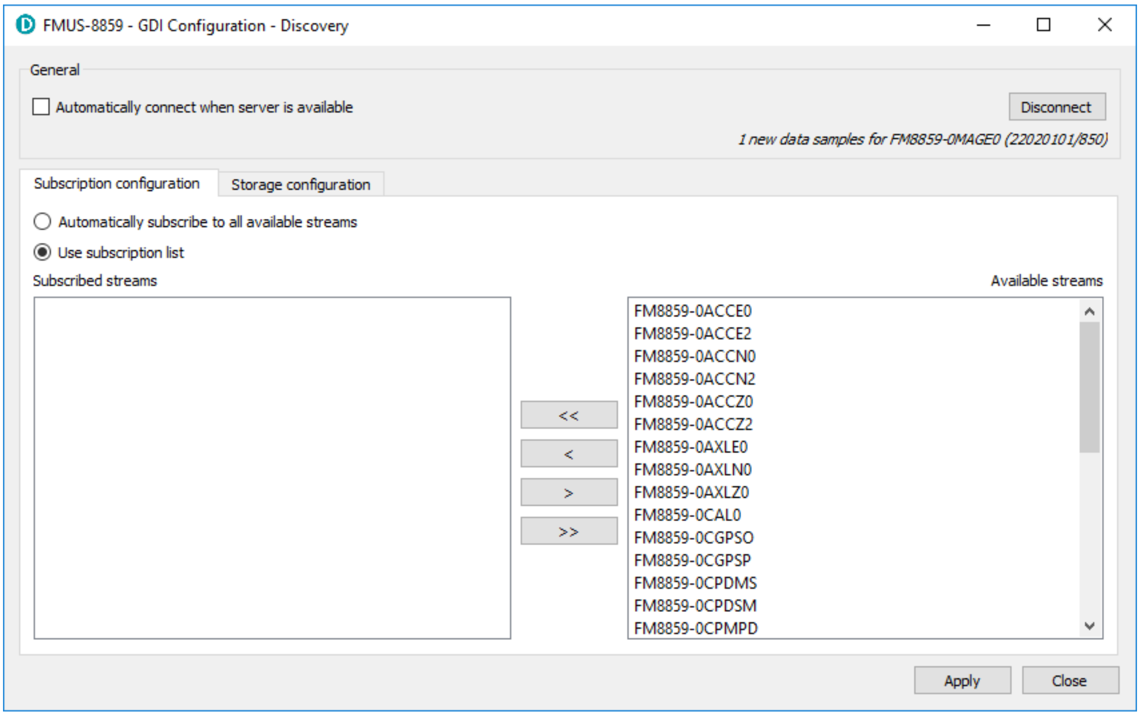
4.4.1.3 GDI connection settings

The GDI protocol allows a receiver, such as Discovery, to select which channels to receive by use of a “channel subscription list”. This feature can be useful in cases where the connection between Fortimus and Discovery has limited bandwidth. To subscribe to specific channels, right-click on a digitiser in Discovery’s main window and select “GDI Configuration” from the context menu.

The resulting window has two very similar tabs. The “Subscription configuration” tab refers to channels selected for transmission and the “Storage configuration” tab affects which channels are selected for recording.

Click on the Connect button to connect to the Fortimus GDI server.

By default, Discovery subscribes to all channels. To alter this behaviour, change the radio-button from “Automatically subscribe to all available channels” to “Use subscription list”. In subscription list mode, the channels in the list on the left-hand side are those to which Discovery subscribes. All available channels are listed on the right-hand side.



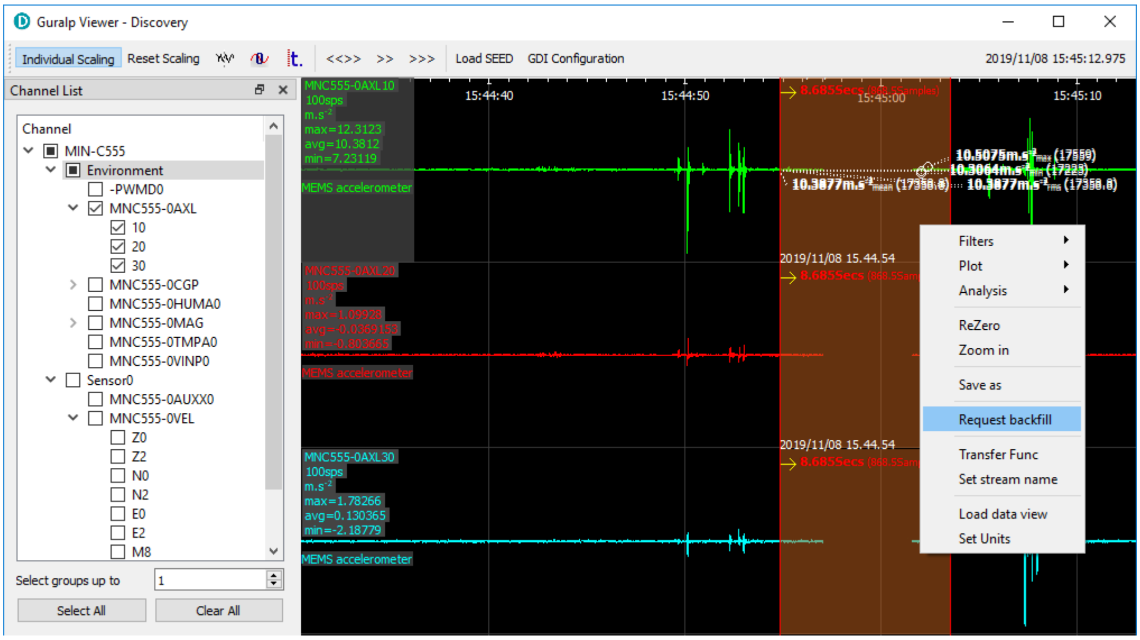
Channels can be moved between lists – *i.e.* switched between being subscribed and being unsubscribed – by using the arrow buttons on the middle:

<<	Subscribe to all channels shown in the **Available channels** list
<	Subscribe to all selected channels in the **Available channels** list
>	Unsubscribe from all selected channels in the **Subscribed channels** list
>>	Unsubscribe from all channels in the **Subscribed channels** list

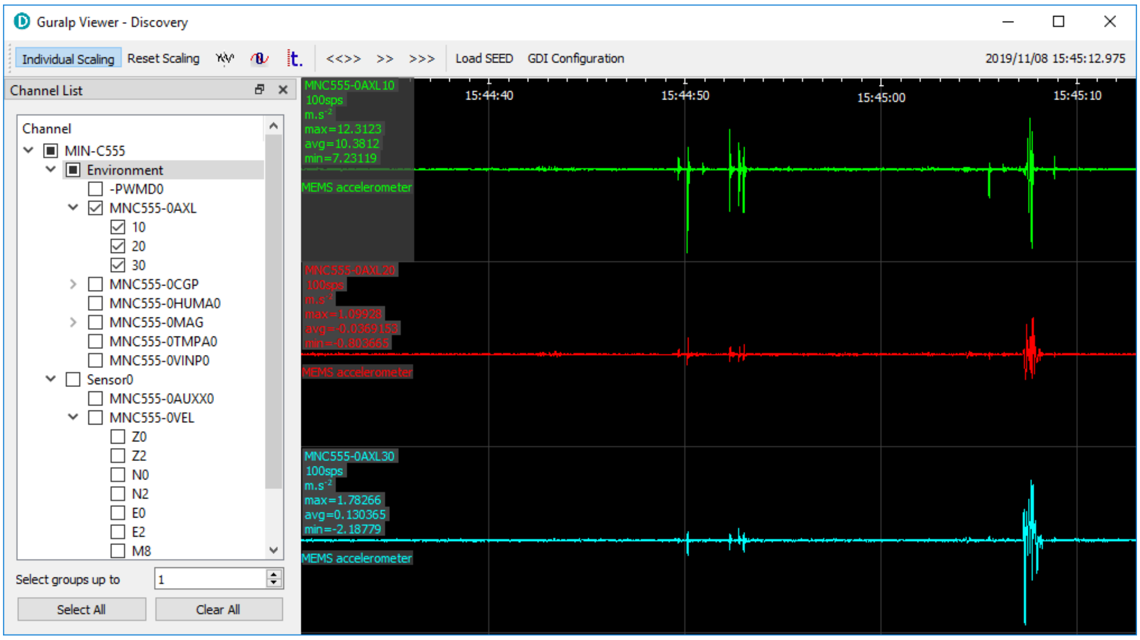
4.4.1.4 Backfill from microSD card

Gaps in the waveforms due to network disconnections can be backfilled by requesting missing data to the local storage.

In the Discovery GDI “Live View”, highlight the portion of data including the gap, right-click and select “Request backfill”.



The gaps are backfilled automatically for all the streams selected, if the requested data is available in the microSD card.

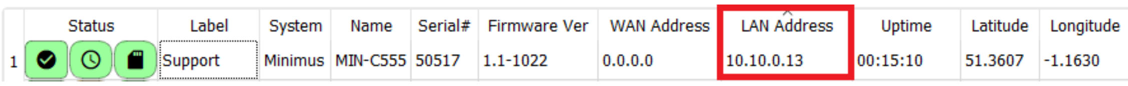


4.4.2 Using Scream!

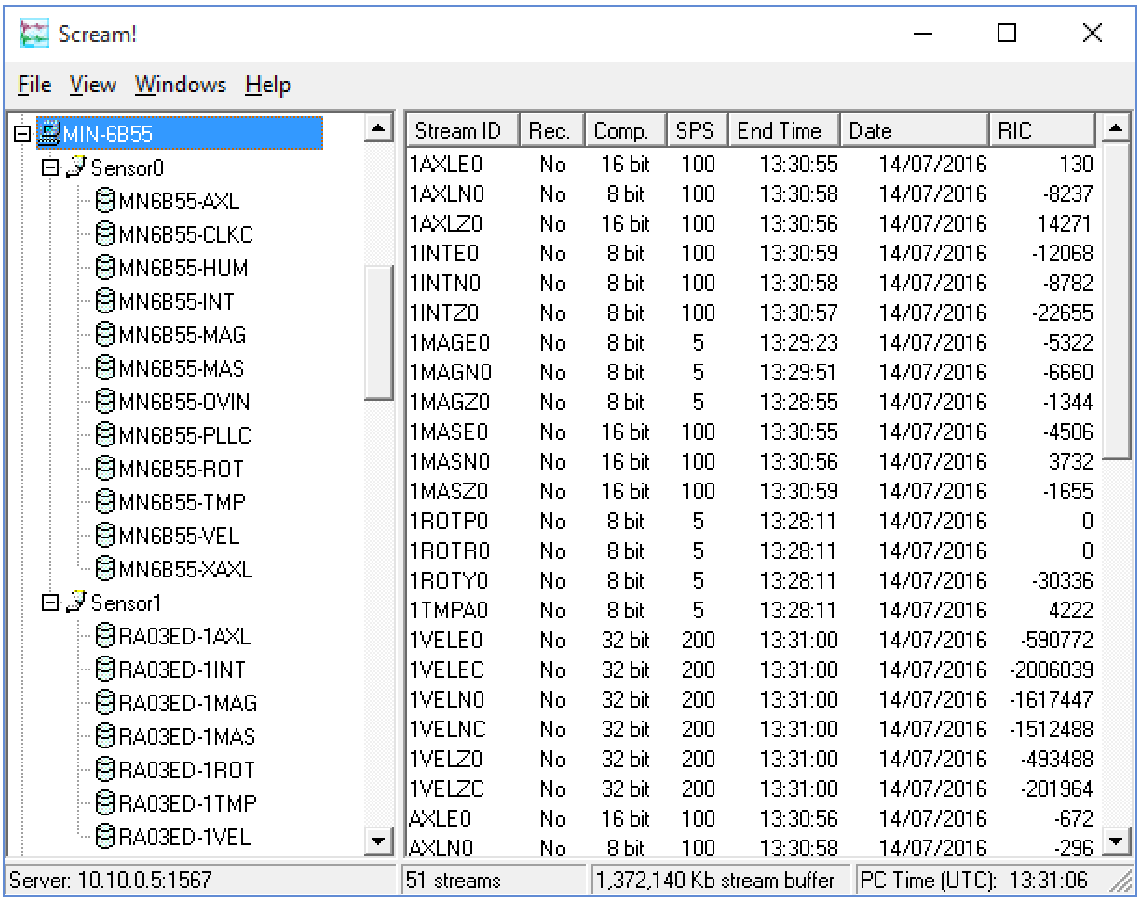
Data from the Fortimus can also be viewed and analysed using Güralp's Scream! Software.

For full usage information on Scream!, please refer to the on-line Güralp manual **MAN-SWA-0001**.

In Scream!'s Network Control window, add a UDP or TCP Server using the address reported under "LAN Address" in Discovery's main window (as described in Section 4.3 on page 23).



Right-click on the newly-added server and select `GCFSEND:B` (or `Connect`) from the context menu. This sends a command to the Fortimus to start data transmission. Once the `GCFSEND:B` (or `Connect`) command has been issued, the instruments and their associated streams should begin to appear in Scream!'s main window.



To configure the Fortimus, double-click on its entry to open its web page.

Note: If stream recording is enabled, make sure that the file-name format in Scream! (on the Files tab of the File→Setup dialogue) is set to `YYYY\YYYYMM\YYYYMMDD\I_A_YYYYMMDD_HHNN` in order to prevent file names conflicting. More information can be found in Scream! manual **MAN-SWA-0001** available on the Güralp website.

5 LCD Display menu

The Fortimus is equipped with a multi-touch, 2.4 inch (61 mm), full colour LCD display that shows the instrument's state of health, inclination and real-time output waveforms. It also allows configuration of the instrument as well as some control operations.

While the Fortimus is booting up, it displays a white screen with the Güralp logo in the middle and a progress-bar at the bottom.

Once the Fortimus has booted up completely, the LCD automatically displays the “status” page.

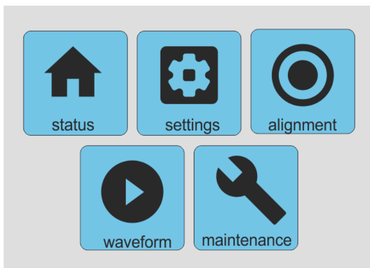
To move back to the main menu, touch anywhere in the screen and the main menu will be displayed.

> **Note:** When using the touch screen, keep your finger in place on each button for approximately half a second to ensure that your touch is registered. This delay helps prevent accidental triggering of menu functions. The LCD's touch features can be disabled completely if desired: see Section 5.6.3 on page 40 for details.

The LCD behaviour can be configured in the Fortimus web interface, see Section 7.8 on page 52 for more details.

The complete LCD menu map is illustrated in Section 15 on page 161.

5.1 Main menu



The main menu offers the following options:

- status
- settings
- alignment
- waveform
- maintenance

These are discussed in the following sections.

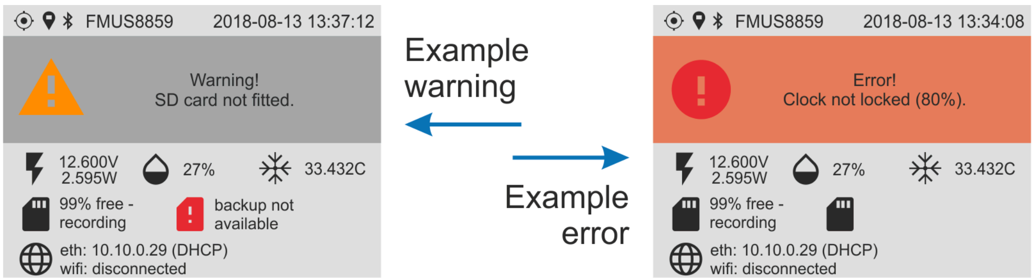
5.2 Status

The "status" page shows information about serial number, Bluetooth status, time and date, GNSS/PTP status, input voltage and power, humidity, temperature, microSD cards recording status, I.P. address.

The top of the status display shows a series of icons:

These, from left to right, correspond to synchronisation (), GNSS location (), WiFi reception () and Bluetooth status (). The icon does not appear if the relevant service is disabled. If the service is enabled but in a fault condition (i.e. not connected or no GPS fix found), the icon is shown with a line through it.

Warning and errors are shown here when necessary. Warnings are shown with an amber triangle on a grey background (), as shown on the left below. Errors are show with a red circle on an amber background (), as shown on the right.



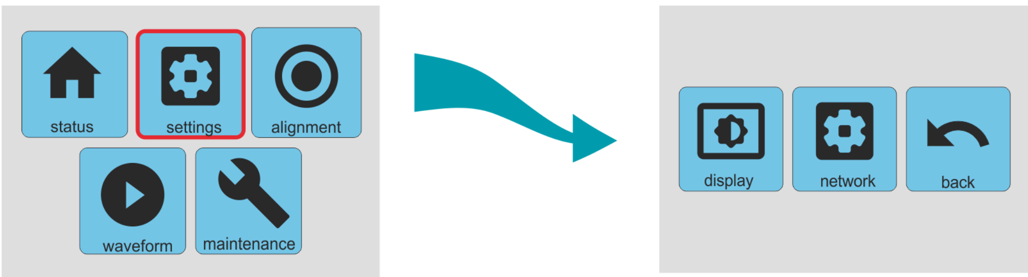
The messages that can be displayed are:

- Normal operation:
  - **System OK** : GNSS or PTP are locked, microSD cards are recording.
- Warnings:

- **Warning! SD card not fitted** : At least one of the microSD cards is not recording.
- **Warning! Waiting for PPS lock** : PPS signal is unstable.

- Errors:
  - **Error! Clock not locked (0%)** : GNSS quality is less than 95% and PTP is not available.
  - **Error! Clock not locked (PTP 0%)** : PTP quality is less than 80% and GNSS is not available.
  - **Error! Clock not locked (NTP only)** : GNSS quality is less than 95% and PTP quality is less than 80%.

5.3 Settings

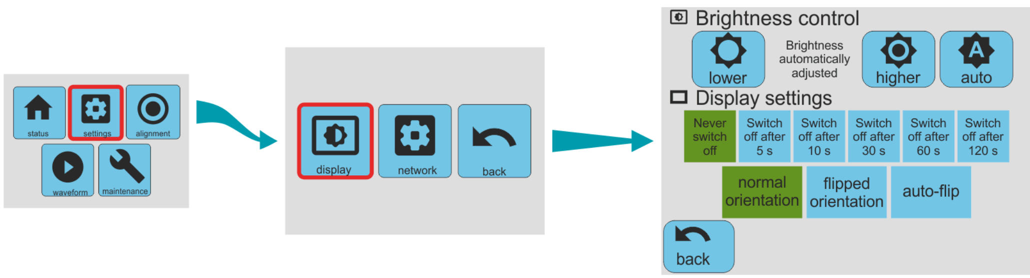


The "settings" menu offers the following options:

- display; and
- network.

These are discussed in the following sections.

5.3.1 Settings → display



The "display" page allow control of brightness, the inactivity time-out and the orientation of the display.

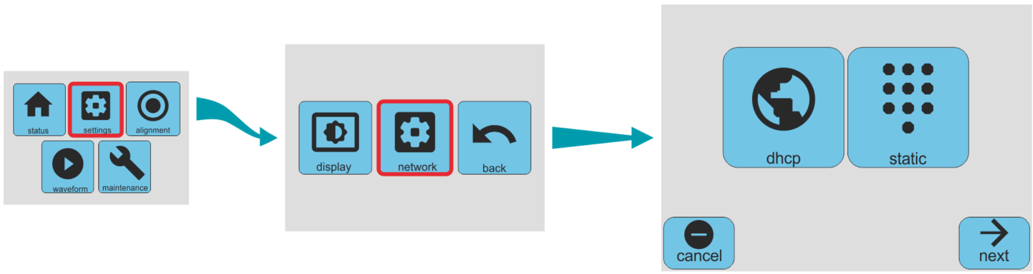
- The brightness can be set to be adjusted automatically, based on the ambient light level, or manually adjusted with the "lower" and "higher" buttons.

- The display can be set to stay on permanently (with a consequent increase in power consumption) or to automatically switch off after 5 s, 10 s, 30 s, 60 s or 120 s of inactivity. The currently-selected mode is indicated by the green background.

  When the display has been switched off, it can be switched on again by touching and holding for a second.

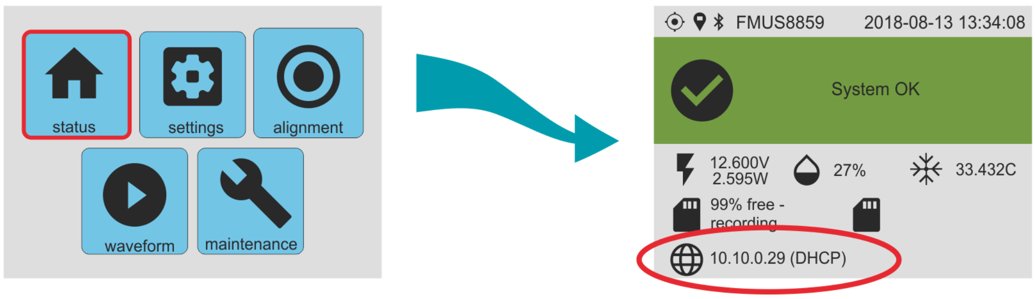
- The orientation can be set to be normal or flipped. Selecting "auto-flip" will instruct the instrument to flip the display automatically based on attitude as determined by the internal MEMS accelerometer. The currently-selected mode is indicated by the green background.

5.3.2 Settings → network

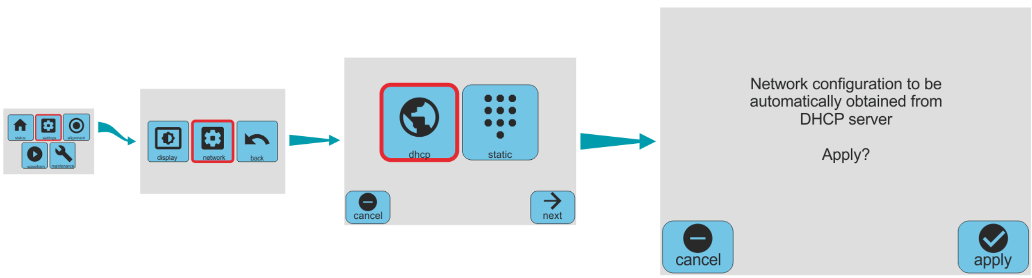


The network page allows you to choose between DHCP mode, where the networking parameters are set by an external DHCP server, or static mode, where the network parameters must be typed in manually.

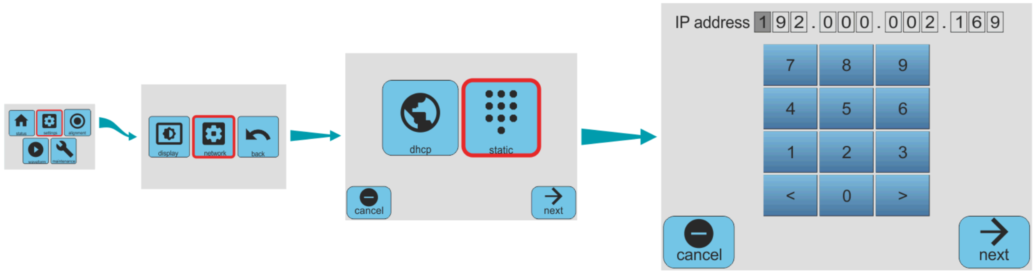
The current network mode is shown on the main status display:



If you select DHCP mode from the network page, you are asked for confirmation but no other configuration is required:

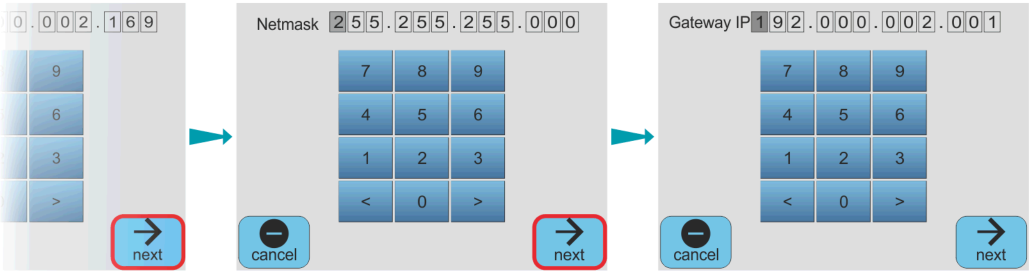


If you select static mode from the network page, you are prompted first for the IP address:

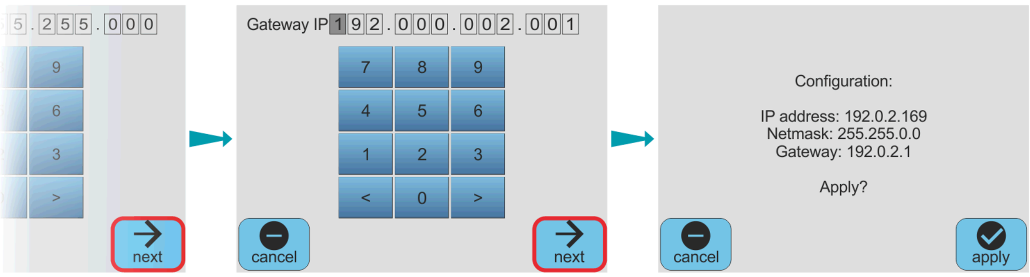


Enter the desired IP address using the on-screen virtual numeric keypad and then press "next", which takes you to the netmask screen.

Enter the desired netmask in the same way. Pressing "next" again takes you to the "Gateway IP" screen:



After entering the IP address of your gateway (default router), press "next" again to reach the confirmation screen:



Pressing "apply" here configures the Fortimus with the parameters that you have just entered. Pressing "cancel" discards all of the changes and the Fortimus' networking configuration is not affected.

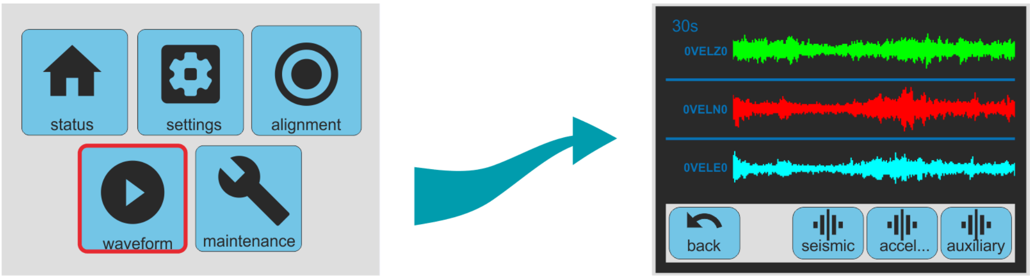
5.4 Alignment

The “alignment” page shows a virtual bubble level based on the output of the MEMS accelerometer built-in the Fortimus. The red circle moves around the screen as the position of the Fortimus is altered, mimicking the bubble in a real bubble level; i.e. the red circle moves towards the highest part of the top of the instrument.

> **Note:** The virtual bubble level works if and only if the MEMS accelerometer channels are enabled for streaming and/or recording.

See Section 6.1 on page 41 for more details about using the alignment tool.

5.5 Waveform



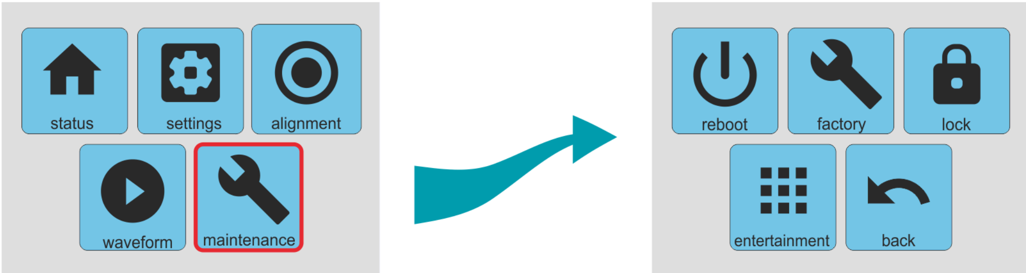
The “waveform” page shows real-time data in graphical format. The horizontal axis represents time and the display constantly scrolls to the left as the latest data are plotted on the right-hand side of the graph. Three modes are available:

In "seismic" mode, the signals from the main acceleration outputs of the Fortimus are displayed.

In "accel..." mode, the outputs from the internal MEMS accelerometer are displayed.

In "auxiliary" mode, the display graphs the output from the internal temperature sensor, the internal supply voltage and the power consumption.

5.6 Maintenance

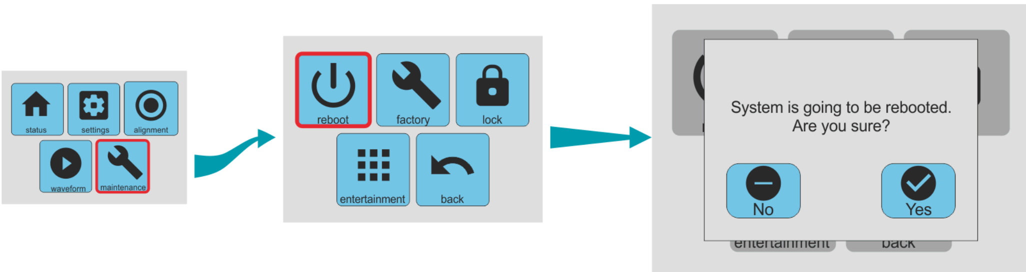


The “maintenance” page allows the user :to

- reboot the system;
- reset the configuration to factory values; and
- lock the “settings” and “maintenance” pages to prevent undesired alteration.

These are discussed in the following sections.

5.6.1 Reboot



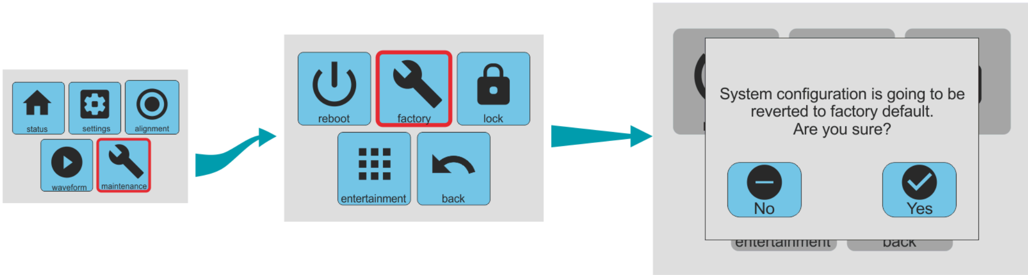
This option reboots the processor in the Minimus digitiser without interrupting power. Because this will interrupt digitisation and potentially affect the configuration (some changes only take effect after a reboot), it is protected by a confirmation screen.

Click 

if you wish to continue and 

if you have arrived at this screen unintentionally and wish to return to the main menu.

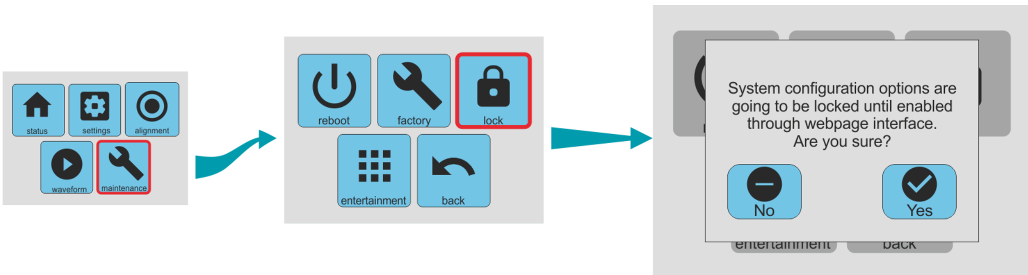
5.6.2 Restore factory settings



This option restores the configuration to the state in which the instrument was delivered. Because this will interrupt digitisation and affect the configuration, it is protected by a confirmation screen.

Click Yes if you wish to continue and No if you have arrived at this screen unintentionally and wish to return to the main menu.

5.6.3 Lock the configuration



This option locks the LCD interface so that the instrument can only be reconfigured via its web interface. This can be useful when physical access to the instrument cannot be fully controlled. Because this can be disruptive, this option is protected by a confirmation screen.

Click Yes if you wish to continue and No if you have arrived at this screen unintentionally and wish to return to the main menu.

Note: Once “settings” and “maintenance” are locked, they can only be re-enabled from the Fortimus web page. See Section 7.8 on page 52 for more details.

6 Installation

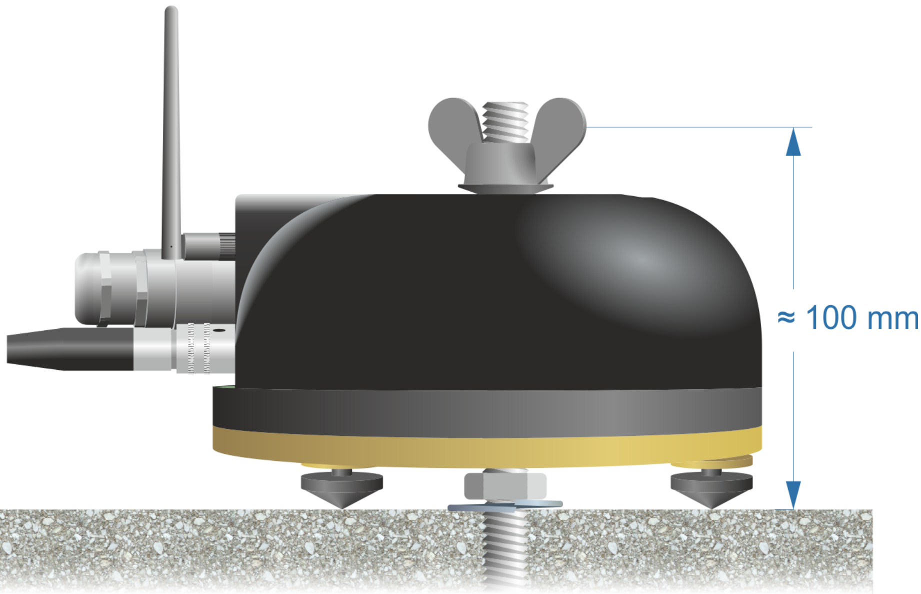
6.1 Permanent installation

You will need a hard, clean surface such as a concrete floor, to install the Fortimus.

If you are in any doubt about how to install the sensor, you should contact Güralp Systems' Technical Support, via support@guralp.com.

1. Prepare the surface by scribing an accurate N/S orientation line and installing a grouted-in fixing bolt on the line, near the middle. An anchor terminating in a 6 mm or 8 mm (¼ or 5⁄16 inch) threaded stud is suitable.

   The exposed thread should project approximately 100 mm (4 inches) above the surface. Significant excess length should be removed.



2. Place the accelerometer over the fixing bolt and rotate to bring the orientation line and pointers accurately into registration with the scribed base-line.

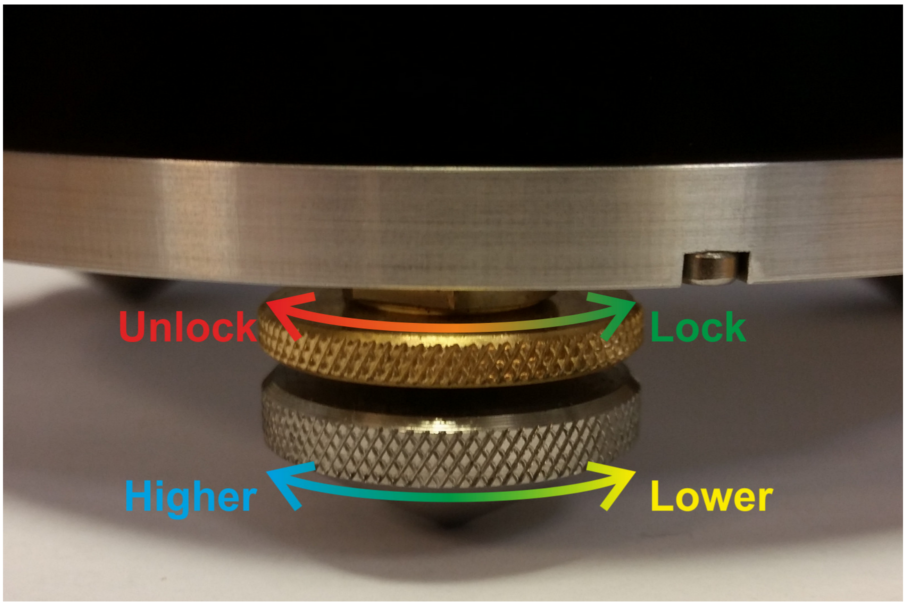
   For more accurate alignment, a long, thin rod or a length of stiff wire can be aligned with a slot machined into the base of the instrument. It can be held in place by hand or, if preferred, by inserting two 3mm screws into the threaded holes provided.

3. Connect all the cables as described in Section 4.2 on page 22 and power on the Fortimus.

4. Touch the alignment button at the top right of the LCD screen: This will display the digital levelling tool

The red circle behaves like the bubble in a traditional bubble-level, moving towards the highest edge of the instrument. The further from the centre it is, the more adjustment is needed.

5. Level the sensor, using its adjustable feet, until the red circle lies entirely within the inner circle of the indicator.



The feet are mounted on screw threads. To adjust the height of a foot, turn the brass locking nut clockwise (when viewed from above) to loosen it and rotate the entire foot so that it screws either in or out. When you are happy with the height, tighten the brass locking nut anti-clockwise to secure the foot.

6. Secure the instrument to the mounting stud using the conical washer provided and a wing-nut.

> **Caution:** Hand-tighten only: do not use tools.

The instrument is now installed and transducing ground motion.

6.2 Temporary installations

The Fortimus is ideal for monitoring vibrations at field sites, owing to its ruggedness, high sensitivity and ease of deployment. Temporary installations will usually be in hand-dug pits or machine-augered holes. Once a level base is made, the accelerometer can be sited there and covered with a box or bucket. One way to produce a level base is to use a hard-setting liquid:

1. Prepare a quick-setting cement/sand mixture and pour it into the hole.
2. "Puddle" the cement by vibrating it until it is fully liquefied, allowing its surface to level out.
3. Follow the cement manufacturer's instructions carefully. Depending on the temperature and type of cement used, the mixture will set over the next 2 to 12 hours.
4. Install the sensor as above, then cover and back-fill the emplacement with soil, sand, or polystyrene beads.
5. Cover the hole with a turf-capped board to exclude wind noise and to provide a stable thermal environment.

If you prefer, you can use quicker-setting plaster or polyester mixtures to provide a mounting surface. However, you must take care to prevent the liquid leaking away by "proofing" the hole beforehand. Dental plaster, or similar mixtures, may need reinforcing with sacking or muslin.

6.3 Installation in Hazardous environments

The fully enclosed, aluminium case design of the Fortimus makes it suitable for use in hazardous environments where electrical discharges due to the build up of static charge could lead to the ignition of flammable gasses. To ensure safe operation in these conditions, the metal case of the instrument must be electrically bonded ('earthed') to the structure on which it is mounted, forming a path to safely discharge any static charge.

Where electrical bonding ('earthing') is required during the installation of a Fortimus, the central mounting hole that extends through the instrument should be used as the connection point. This is electrically connected to all other parts of the sensor case. Connection can be made by either a cable from a local earthing point terminated in an 8 mm ring tag or via the mounting bolt itself.

7 System configuration

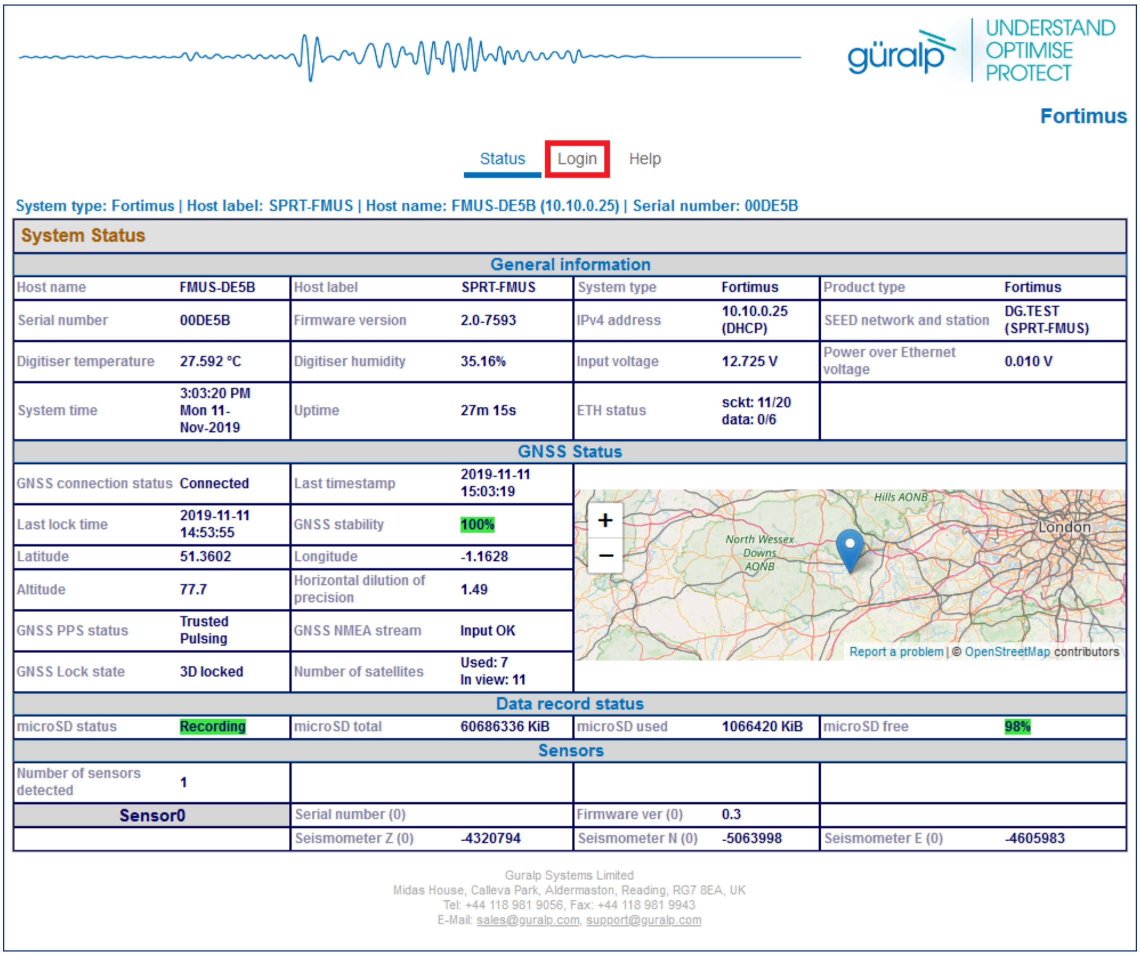
Advanced system configuration control and configuration tools are available by selecting an instrument in Discovery, right-clicking its entry and selecting "View Web Page". Alternatively, the web interface can be viewed by navigating to the LAN address of the instrument from any common web browser.

> **Note:** Some changes in the settings require a system reboot to be applied. This is notified on the top right of the Fortimus web page with the message *Reboot Required* . It is suggested to perform all the modifications and reboot the Fortimus when the configuration is completed clicking on any of the Reboot buttons.

7.1 Web Page login

The web interface can be protected by username and password. There are two levels of access to the web page: normal user and administrator.

If the login is required, the web interface will initially show a status display only.

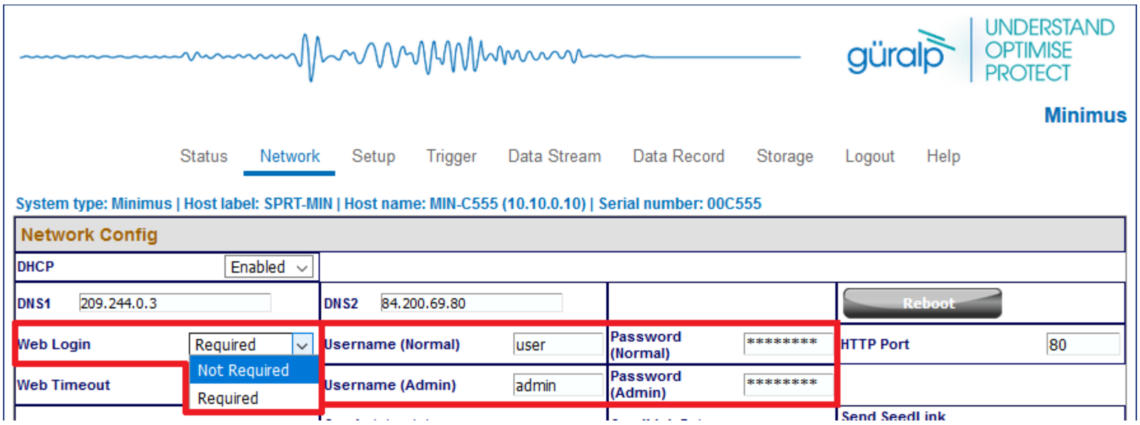


Clicking on “Login” opens allows to type in the user-name and password to access the content of the web page.

Logging in with normal user account unlocks only basics configuration and control features in order to prevent any advanced settings to be modified. The default user-name for normal user login is `user` and password of `user`.

Logging in with the administrator account unlocks all the configuration and control features available in the Fortimus web page. The default user-name for administrator user login is `admin` and password of `admin`.

Once logged in, the “Web Login” drop-down menu in the Network tab allows to disable the request of login every time the web page is accessed. The user-name and password for both normal user and administrator login are configurable in the “Network” tab.



7.2 System status

The “Status” tab of the web browser interface provides state-of-health information about the Fortimus. These parameters are described as follows:

- **Host name**: the serial number of the Fortimus;
- **Host label**: the customisable name of the Fortimus system;
- **System type**: the name of the connected instrument, e.g. “Fortimus”;
- **Product type**: the type of the connected instrument, e.g. “Fortimus”;

- **Serial number**: the serial number of the Fortimus;
- **Firmware version**: the DIG firmware version running on the Fortimus;
- **IPv4 address:** the static or Dynamic LAN I.P. address of the Fortimus;
- **SEED network and station**: Network and Station SEED codes of the Fortimus;
- **Temperature**, **humidity**, **Input voltage** and **PoE voltage**: the internal temperature and humidity of the Fortimus; input voltage supplied and optional PoE voltage supplied to the Fortimus;
- **System time**: the current internal system date and time;
- **Uptime**: the time the Fortimus has been running since the last reboot;
- **ETH status**: the number of total active TCP connection in use and connection used for data transmission;
- **GNSS status**, **last GNSS timestamp**, **last GNSS lock time** since significant timing drift or re-boot, **GNSS stability** of the lock, **horizontal dilution of precision** (based on satellite coverage), **GNSS PPS status**, **GNSS NMEA stream**, **GNSS lock state** (2-D or 3-D), **number of satellites** used and in view;
- **Latitude**, **longitude** and **altitude** of the system, as provided by the GNSS receiver;
- **PTP state**, **last PTP timestamp**, **last PTP lock time** since significant timing drift or re-boot, **PTP stability** in time accuracy, **master IPv4 address** (I.P. address of the PTP master), **master clock class** and **accuracy**, **master time source**, **network path delay**, **network jitter estimate** (quality indicator in ns), **network outliers**;
- MicroSD card **recording status**, **total storage capacity**, **used storage space** and **available storage space**;
- **Real-time sensor values** from the accelerometer.

7.3 Station meta-data

Discovery provides a number of flexible station meta-data inputs. These are accessible from the "Setup" tab of the instrument's web page.

"**Label**" and "**Site Name**" are used in Discovery only and appears in the list of instruments in the main window.

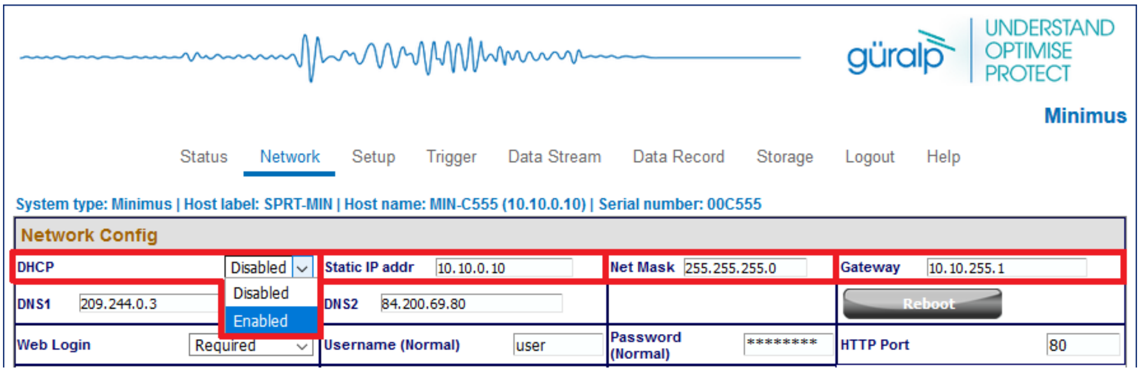
"**Station Name**", "**Network Code**" are all standard meta-data header values used by the miniSEED file format, which will be included in locally-stored miniSEED files (see Section 7.9 on page 54).

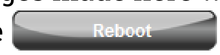
7.4 Network configuration

7.4.1 I.P. address and gateway

By default, the Fortimus uses DHCP (Dynamic Host Configuration Protocol) to acquire its network configuration but static addressing can be used if required.

To configure static addressing, visit the "Network" tab of the instrument's web page and, under "DHCP", change the mode from "Enabled" to "Disabled" in the drop-down menu. In this mode, it is possible to specify the I.P. address, the Net Mask and the address of the Gateway (default router), as shown:



Before any changes made here will take effect, the Fortimus must be re-booted. To do this, click the 

button on the "Data Record" tab.

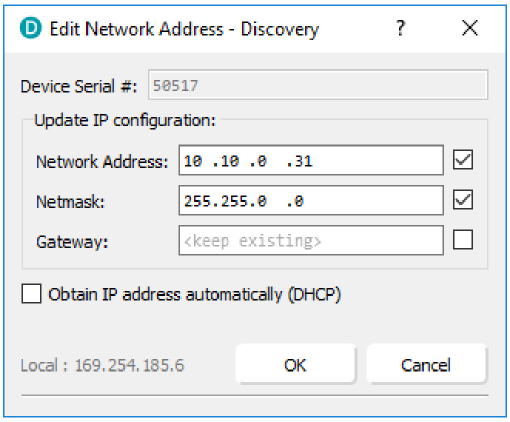
Note: By default, the static I.P. address assigned to each Fortimus is unique and derived from the specific serial number of the device. These addresses are in the default network for link-local (APIPA) addresses: `169.254.0.0/16` (in CIDR notation).

The first two bytes of the address, therefore, are always *`169.254`*. The third byte is the equal to the last two characters of the serial number interpreted as a hexadecimal number and then converted into base 10. The forth byte is the equal to the next-to-last two digits of the serial number, also converted from hexadecimal into base 10.

For example, if the serial number of the Fortimus is FMUS-C555, the preassigned Static I.P. address will be *`169.254.85.197`*, where

- FMUS-C5**55** ⇒ "55" ⇒ $(55)_{16}$. = $(85)_{10}$ ⇒ `85` and
- FMUS-**C5**55 ⇒ "C5" ⇒ $(C5)_{16}$ = $(197)_{10}$ ⇒ `197`

Network settings are also available in Discovery by right-clicking on the Fortimus' entry in Discovery's main window and selecting "Edit Network Address".



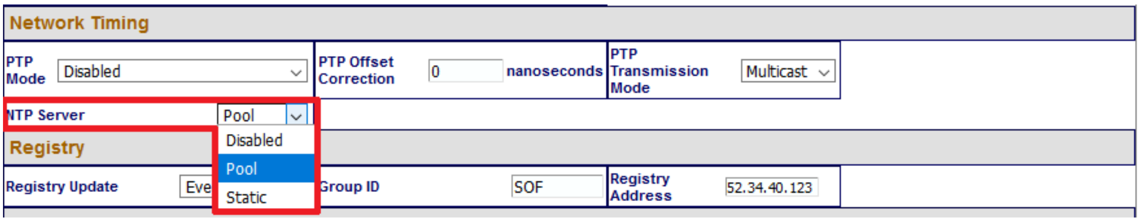
7.4.2 NTP (Network Timing Protocol) configuration

Note: Network Timing Protocol (NTP) is only used for setting the system's internal clock at boot-up, it is ***not used for sample timing***. See Section 7.12 on page 72 for details about synchronising the sample clock.

However: if neither GNSS nor PTP are available but NTP is locked and the sample clock's time is more than five seconds different from NTP's time, the sample clock will be adjusted (in a step-change) to NTP time.

By default, the NTP server option under the "Setup" tab of the instrument's web page is set to "Pool" which uses the virtual server pool `pool.ntp.org`. This accesses a dynamic collection of networked computers that voluntarily provide moderately accurate time via the NTP to clients worldwide.

Alternatively, it is possible to specify the I.P. address of your preferred NTP server. To do this, select the "Static" option from the "NTP server" drop-down menu, which activates the "NTP IP Addr" setting, and enter the I.P. address of your NTP server here.

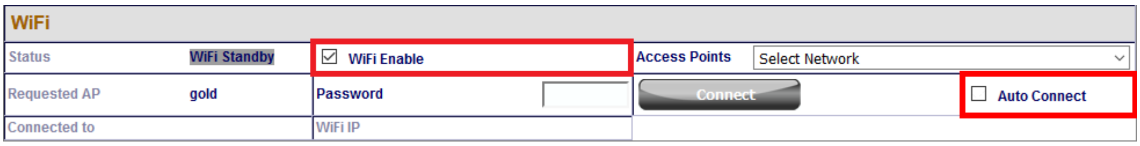


7.5 WiFi

The Fortimus can act as a WiFi client, connecting to an existing WiFi network. Both open and secure (WEP, WPA and WPA2) networks are supported.

> **Note:** The Fortimus does not function as WiFi access point (AP) so it is not possible to connect a WiFi-enabled laptop, for example, directly to the unit. A separate WiFi AP is required in this case so that both laptop and Fortimus can connect to the same network.

The WiFi connection is configured and monitored from the "Network" tab of the Fortimus web page:



7.5.1 Connecting to a WiFi network

Visit the "Network" tab of the Fortimus web page and ensure that:

- the "WiFi Enable" check-box is ticked; and
- the "Auto Connect" check-box is clear as high-lighted above.

Use the "Access Points" drop-down menu to select the desired network and enter the password or passphrase in the "Password" text field, if required.

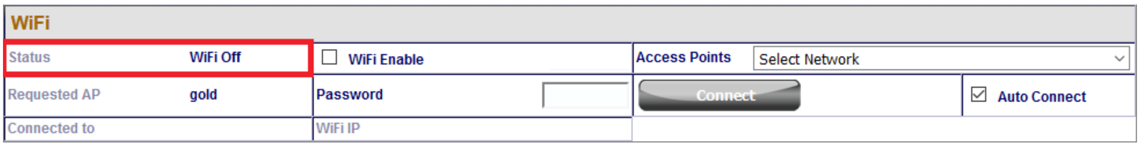
Click the 

button to connect to the network.

Note: A Fortimus connect to a WiFi network automatically appears in Discovery's "Scan Locally" section only when (a) the computer running Discovery is connected to the same WiFi network ***and*** (b) the Fortimus' Ethernet is disconnected or disabled.

7.5.2 WiFi connection status

The status of the WiFi connection is displayed at the top left of the WiFi section of the Network tab of the web page:

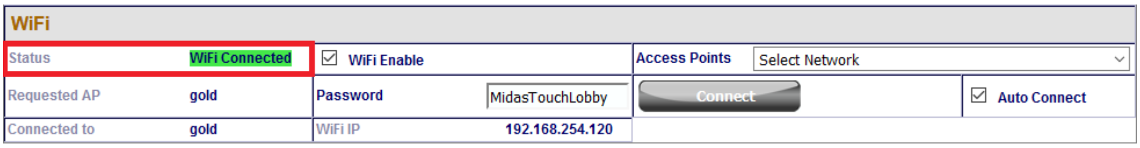


The possible values for the status are:

- WiFi off - the WiFi interface is disabled. Tick the "WiFi Enable" check-box to enable the interface, if required.
- WiFi Standby - the WiFi interface is enabled but not currently connected to any network. If no connection is required, clear the "WiFi Enable" check-box to disable the interface.
- WiFi Connecting - the WiFi interface is in the process of connecting to the selected network.
- WiFi Connected - the WiFi interface is connected to the network shown in the box below and the DHCP server has allocated the IP address displayed in the adjacent box. (Static IP addressing is not supported).

Once a successful connection is established, tick the "Auto Connect" check-box so that the Fortimus will attempt to reconnect to the same network whenever possible. The name of the selected network appears in the "Requested AP" box.

7.5.3 Changing WiFi networks



A different network can be selected from the "Access Points" drop-down menu – and the new password entered – while the Fortimus is still connected to a network. The instrument will not connect to the new network until the  button is clicked.

7.6 GDI push (auto-connection)

A Fortimus normally acts as a GDI server, where a client initiates a connection in order to pull data from it. This is the mechanism used when the GDI viewer in Discovery is launched.

The "GDI auto-connection" feature enables the Fortimus to establish *outgoing* network connections in order to *push* data to one or more remote clients, such as Platinum systems or an Earthworm system running the `gdi2ew` plug-in.

To configure an auto-connection, type either the I.P. address or the host-name of the target client, a colon (':') and the port number (*e.g.* *`192.0.2.91:1566`* or *`affinity10.example.com:1566`*), into any of the connection fields in the "Network" tab of the web page.

GDI auto-connection settings							
Connection		Connection		Connection		Connection	

When auto-connection from a Fortimus to a host is configured, the Fortimus will attempt to open a connection to the host. If it fails, it will re-try every 60 seconds. A suitably configured host will accept the connection and the Fortimus will then negotiate a link and start streaming data.

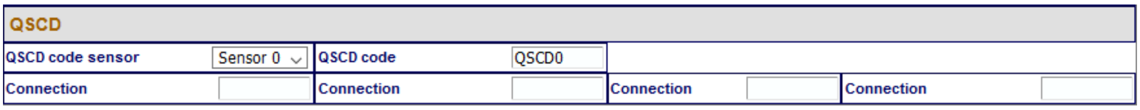
If the connection drops, the Fortimus will attempt every 60 seconds to reconnect.

Note: The default port number for a GDI-link receiver is 1566. Push servers will normally connect to this port. The default port number for a GDI-link transmitter is 1565. Receivers wishing to pull data will normally connect to this port. See Chapter 11 on page 140 for a list of the network ports used by the Fortimus.

7.7 QSCD

The Fortimus can push data in QSCD format (**Q**uick Seismic **C**haracteristic **D**ata) to one or more clients, using outgoing network connections.

To configure a connection, locate the QSCD section of the Network tab of the web page, as shown below. Type either the I.P. address or the host-name of the target client into any of the “Server” fields. This will push data using UDP port 9908, which is the default. If you wish to use a different port number, add a colon (':') and the port number to the end of the specification. For example, ***192.0.2.91:9876*** or ***qscd.server.com:9876***.

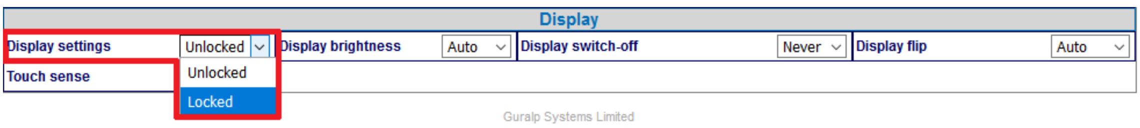


The Fortimus does not automatically send all data when using the QSCD protocol. Channels to be transmitted must be selected (in Z/N/E triplets) and each channel passed through a QSCD transform. See Section 7.16.12 on page 99 for details on how to configure this transform.

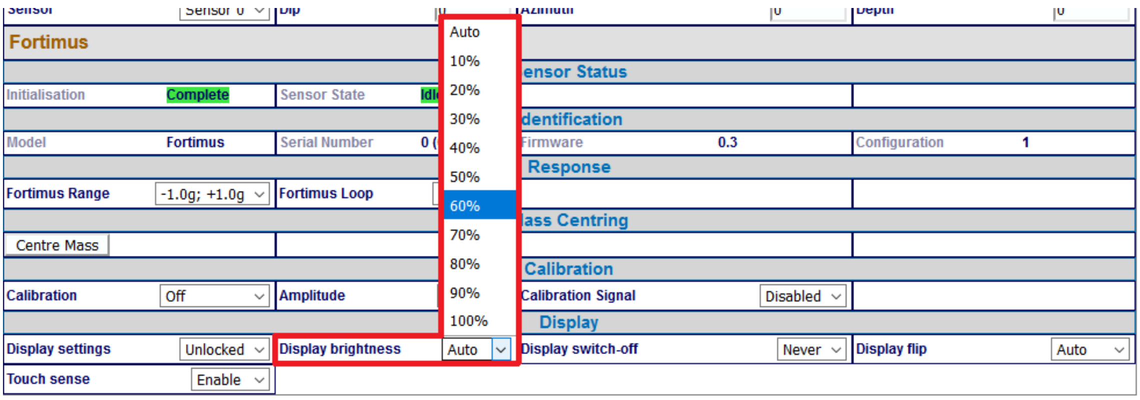
7.8 Controlling the LCD from the web interface

In the “Setup” tab of the Fortimus web page, the user can remotely control the LCD display settings.

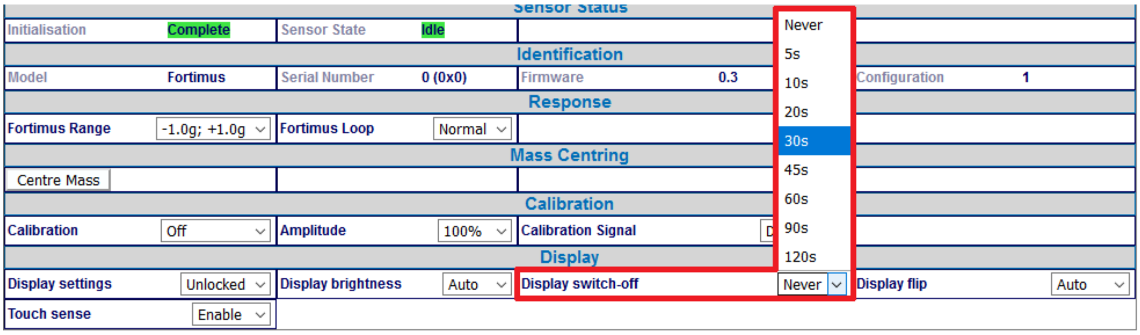
Locking and unlocking of the “settings” and “maintenance” features can be selected using the drop-down menu named “Display settings”:



The display brightness is adjustable using the drop-down menu named “Display brightness”:



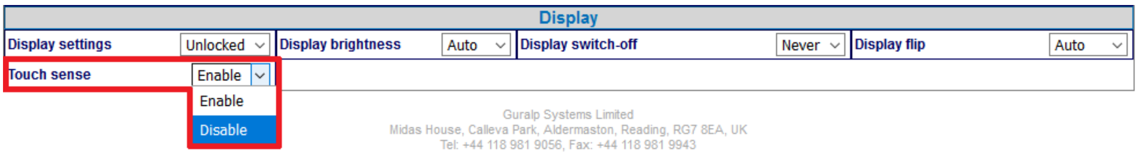
The display can be set to switch off after a selectable period of time while it is untouched. When the display is off, it can be switched back on by touching it for a couple of seconds.



The LCD is, by default, oriented with the top of the screen pointing North (relative to the instrument). The orientation can be flipped by 180 degrees if required or it can be set to "automatic". When the auto-flip is enabled the orientation changes according to the MEMS output.

For security reasons, the LCD's touch sensor can be disabled using the option “Touch sense”. Once disabled, touching the screen has no effect and no commands can be issued via the LCD.

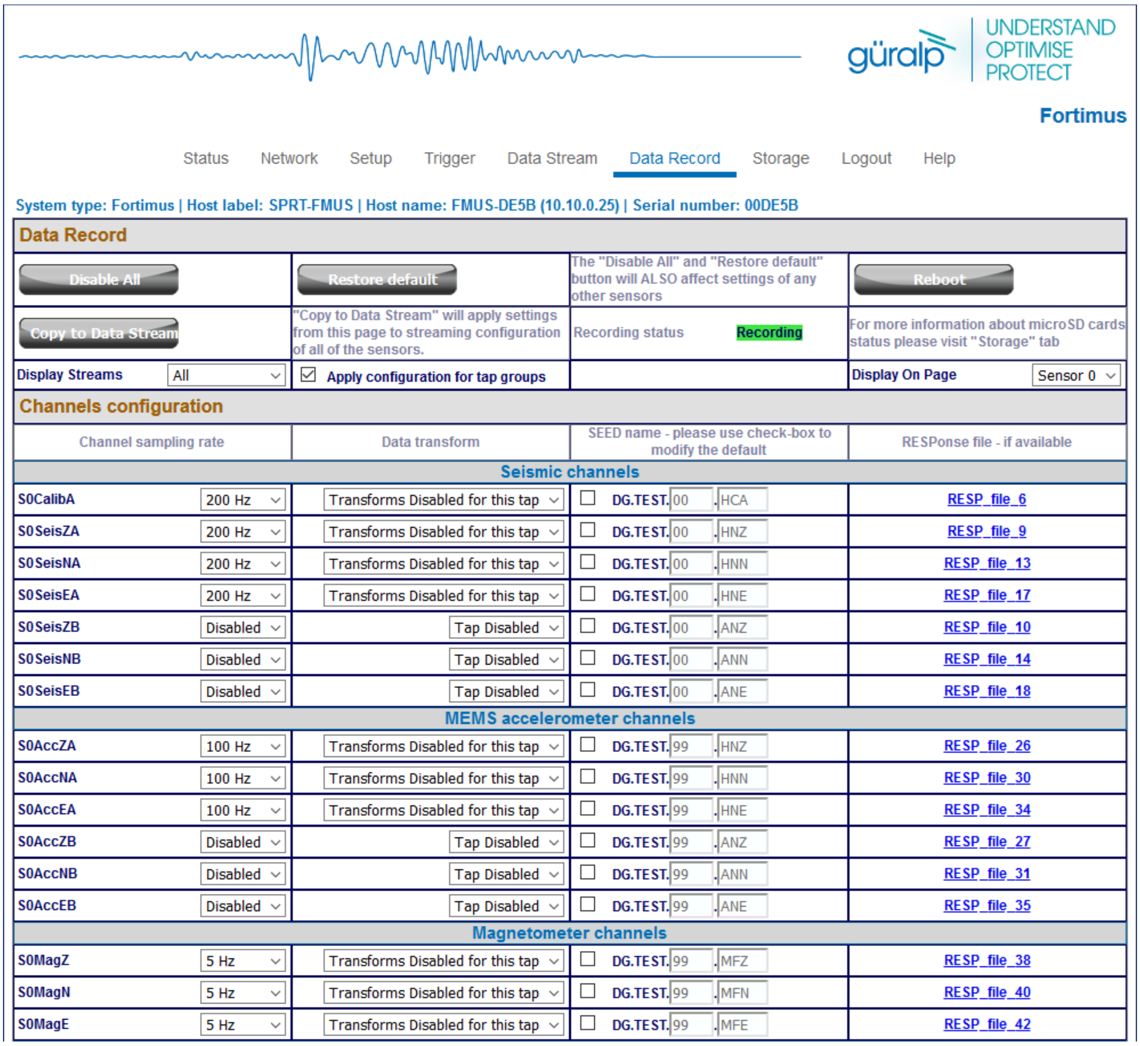
To restore normal operation, set "Touch sense" to "Enable" from the Fortimus web page.



Note: "Touch sense" can be re-enabled *only* from the web interface. It is not possible to re-enable it using the LCD screen.

7.9 Data storage

The main panel of the "Data Record" tab in the web interface is shown here:



This page allows to configure the recording channels available in the Fortimus.

The names and contents of each file are described in Section 10 on page 137.

Note: When changing a setting in the Fortimus web page, ensure that you wait until the page refreshes before changing another setting. This allows time for the previous change to take effect.

The drop-down box at the top-left of the page named “Display Streams” filters out visible channels among All, Enabled and Disabled. The option “Apply configuration for tap groups” automatically apply the same configuration to three streams that belong to the same tap, e.g. S0SeisZA, S0SeisNA, S0SeisEA.

The page is divided in four columns:

- in most-left column, drop-down boxes are available for each channel to either select a sample rate or to exclude the channel from streaming (by selecting the "Disabled" option). All streaming can be stopped by clicking the Disable All button. Same configuration can be applied to real-time transmission channels by clicking the Copy to Data Stream button. Default channel configuration can be applied by clicking the Restore default button.
- in second column from the left, drop-down boxes are available for each channel to enable/disable transforms and, once transform is enabled, to select the transform to apply (see Section 7.16 on page 87);
- in third column from left, Location and Channel SEED codes can be configured. Cells are greyed out by default (default values applied) and they can be edited by clicking on the check-box;
- in most-right column contains links to the RESP files associated to each of the seismic channels (see Section 7.14.4 on page 81).

Upon changing the sample rate, enabling a transform or changing Location and Channels codes, the Fortimus will need to be restarted for the changes to come into effect; this can be done by pressing the Reboot button.

During the reboot, the LEDs will flash, displaying the starting-up sequence (see Section 3.1.2 on page 10) and the instrument web page will display the following screen.

FMUS-C456 is rebooting ...

Once the Fortimus has successfully restarted, the full web browser display and controls will be available for use again.

7.10 Storage

7.10.1 Recording status

MicroSD cards need to be specifically formatted to operate with the Fortimus. The cards shipped with the Fortimus and with Radian systems are supplied pre-formatted.

Data are stored on the microSD cards in miniSEED format. Each channel is saved as a series of 128 MiB files. Instrument and station meta-data (e.g. instrument response, coordinates, compression type etc.) are stored in "Dataless SEED" format.

The MicroSD card and data recording status can be monitored in the upper panel of the "Storage" tab.

The left-hand column provides details of the external (primary, removable) microSD card and the right-hand column shows the status of the internal (backup, fixed) card.

SD Cards status			
External microSD card present	PRESENT	Number of 128-MiB miniSEED files	452
External microSD card usable	USABLE	Internal microSD card usable	USABLE
External microSD card init count	1	Internal microSD card init count	1
External microSD card is primary microSD card	PRIMARY	Internal microSD card is primary microSD card	BACKUP
Primary microSD card is recording samples	RECORDING	Backup microSD card is recording samples	RECORDING

Sections of this panel indicate the status of the following:

- Whether a card is inserted;
- Whether an inserted card is usable (i.e. correctly formatted); and
- Whether the card is recording data.

Note: If the recording status of the cards is marked NOT RECORDING, clicking on Quickformat Cards or Fullformat Cards may solve the issue. Note that the quick format simply moves the write-pointer to the beginning of the recording space, hence overwriting any existing data. The full format, in contrast, erases all the existing data (and can take several hours).

7.10.2 MicroSD card re-formatting

The card re-formatting process fills the card with 128 MiB files containing zeroes. Each file is given a temporary, place-holder name. When data are written, these files are renamed and then over-written with data.

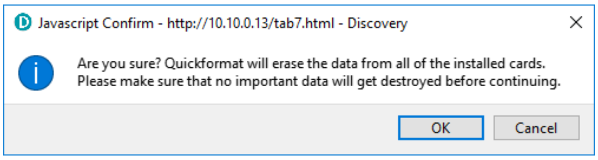
There are two methods for card reformatting: "Quick format" and "Full format". The quick format mode should be used for pre-deployment tests (e.g. stomp/huddle tests) to ensure that the instruments are operating properly. This mode simply marks the existing files as empty without deleting their contents. Full formatting should be used prior to a long-term deployment to ensure that all headers are included and files are fully clean before writing.

The formatting process formats both fixed and removable cards, sequentially.

Note: A series of tests separated only by quick formats can leave some files with residual data in them. This is not normally a problem because a deployment will typically create data-sets longer than any test, over-writing any data remaining from the tests. The miniSEED extractor utility described in Section 7.11.3.1 on page 71 can be used to remove the residual data if they cause any problems.

7.10.2.1 Quick format

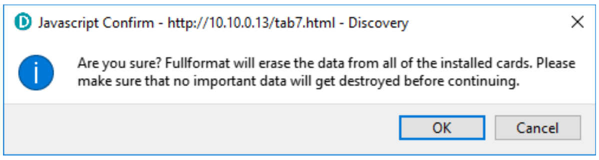
Ensure that the external microSD card is correctly inserted. Click the Quickformat Cards button in the "Storage" tab: a dialogue box will appear to confirm the formatting operation – click on OK button to continue.



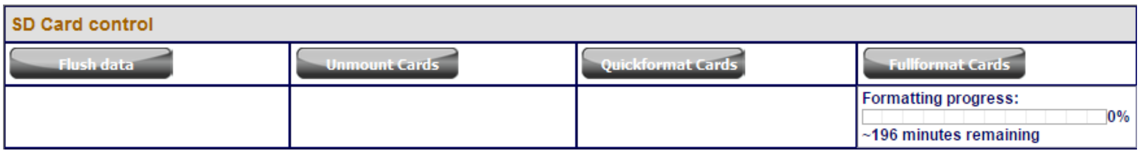
The instrument web page will refresh and return to the "Status" tab. The reformatting operation is now complete.

7.10.2.2 Full format

Ensure the external microSD card is correctly inserted. Click the Fullformat Cards button in the "Storage" tab and a dialogue box will appear to confirm the formatting operation – click on OK button to continue.



The process takes several hours: check the status countdown indicators on the top-right of "Storage" tab.



Caution: Do not remove or insert the external microSD card while formatting is taking place.

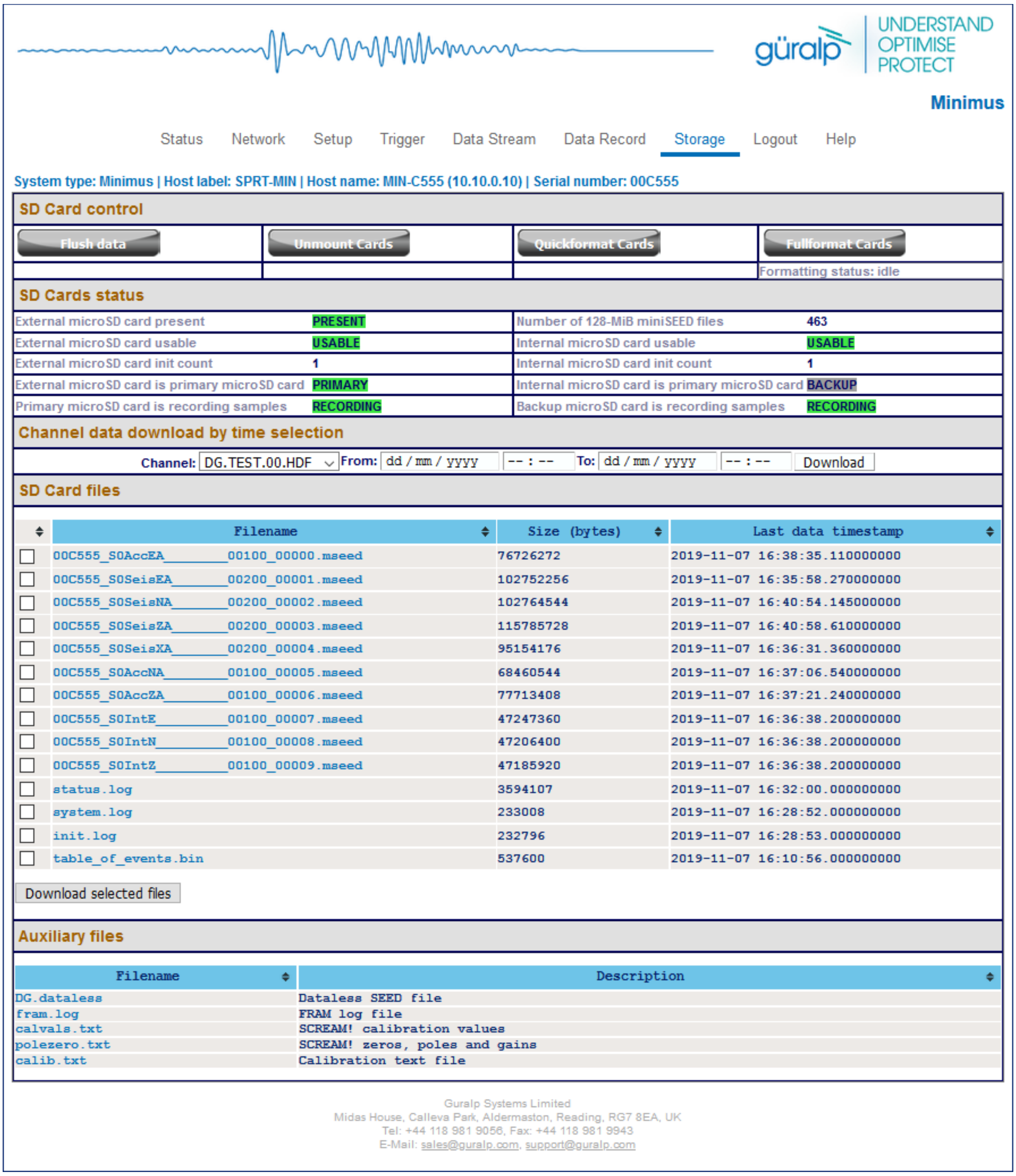
7.10.3 MicroSD card data flushing and unmounting

The Flush data button flushes data still in the buffer into the microSD card storage. Perform a flushing before downloading data from the Storage tab (see Section 7.10.4 on page 58) or event table (see Section 7.17.5 on page 110).

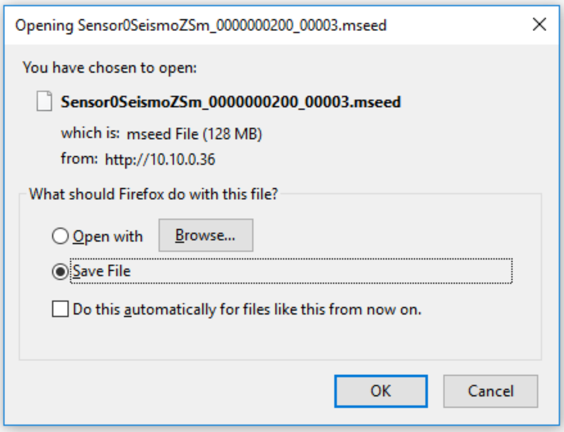
The Unmount Cards button flushes the data from the buffers into the microSD cards and interrupts the recording. The recording restarts if a new card is inserted in the slot or if a quick-format (or full-format) is performed.

7.10.4 Download recorded data

The “Storage” tab of the web browser interface displays the miniSEED files stored on the microSD card:



Clicking on the file from the list automatically starts a download using your browser's standard mechanism:

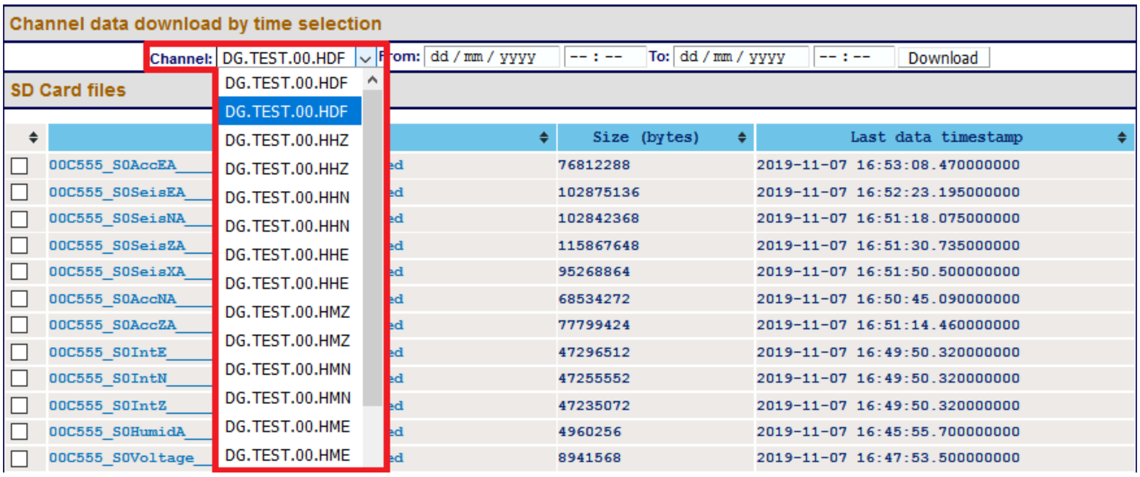


Multiple files can be downloaded simultaneously by ticking the boxes on the left of each link and clicking on Download selected files button.

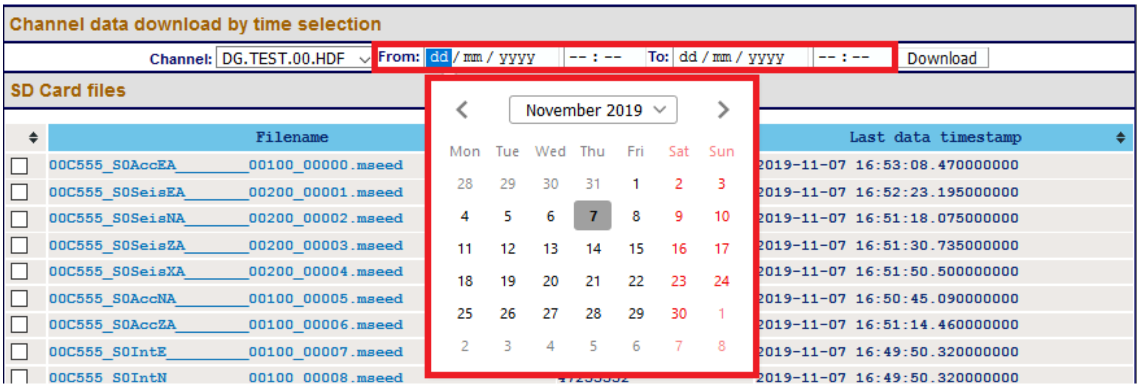
The microSD cards are formatted with empty files which are filled with data as they become available. The file-names are also changed when the files are written to. Until they are written to, they are marked as "hidden" files, so that it is easier to see how many files contain data when looking at the contents of the card.

7.10.5 Downloading data for specific time-intervals

Data for a single stream spanning a specific time-interval can be downloaded from the Storage page of the web interface. To do this, start by selecting the desired stream from the drop-down menu:



... then select the start and end dates and times using the pop-up calendars:



Lastly, click the Download download button to initiate a file transfer using your browser's standard mechanism.

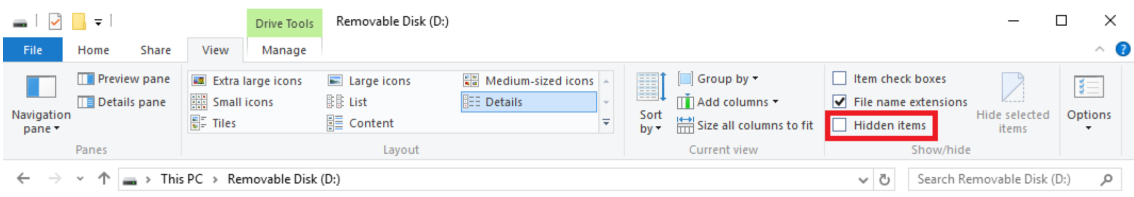
Note: The pop-up calendars are not supported by Discovery's built-in browser. The required dates can simply be typed in or the entire operation can be performed in an external web browser.

7.10.6 Bulk data extraction

To view files saved on the external microSD card, remove the card, as described in Section 3.1.5 on page 12. Insert the card into a microSD card reader (external or in-built) on your PC/laptop. Within a few seconds, the card should appear as a removable disk/drive.

A microSD card formatted for the Fortimus contains many "hidden" files. They are created at format time with no contents and then renamed, unhidden and filled with data as required.

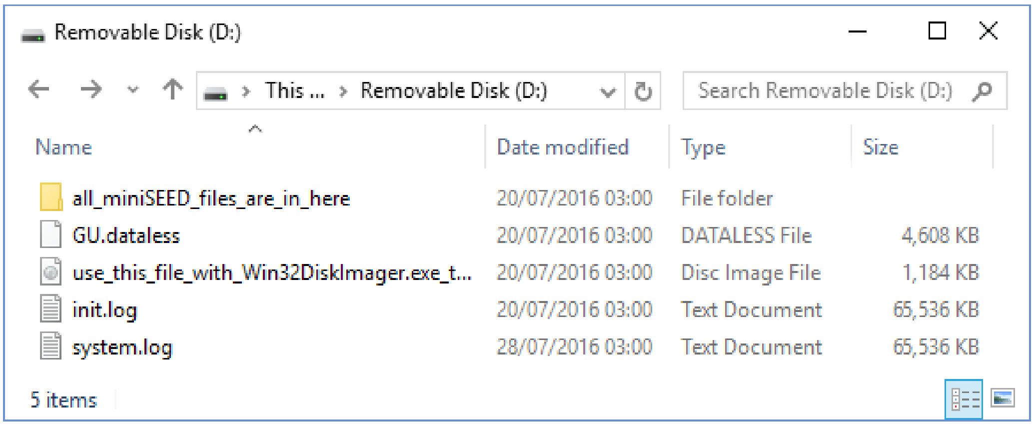
When viewing files in Windows Explorer, it may be helpful to configure your system so that "hidden" files are not shown. In Windows 10, this can be done by clearing the “Hidden items” check-box within the ribbon of Windows Explorer.



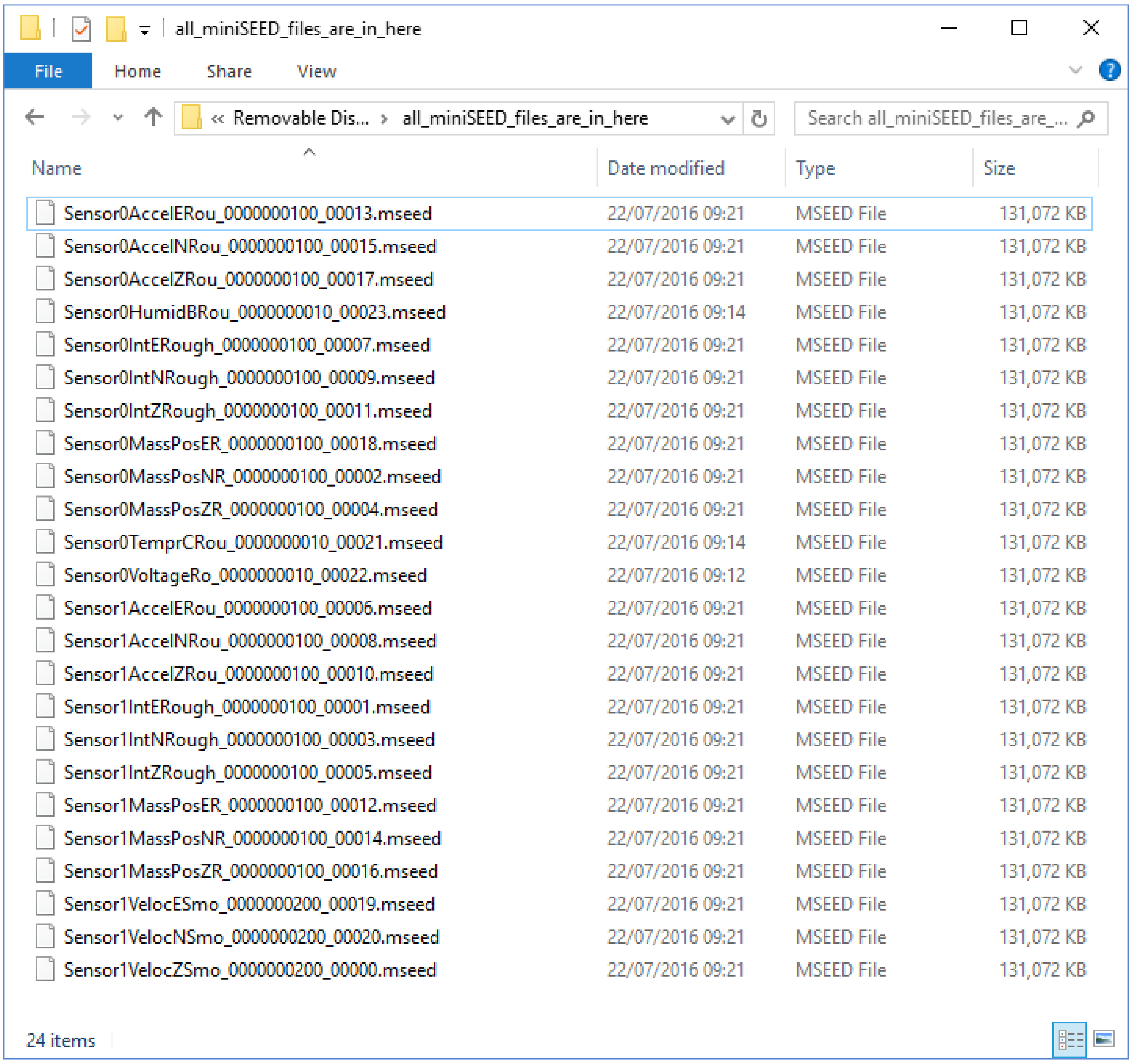
7.10.7 The contents of the microSD card

The root directory of the disk contains seven items:

- a file named `init.log`. This “write-once” file contains the first 32 MiB of system log information since the card was last formatted;
- a file named `system.log`. This “re-use” file contains the last 64 MiB of the system log;
- a file named `status.log`. This “re-use” file contains the last 32 MiB of damps of system state of health information. A new dump is generated every 20 minutes.
- a disk image file which Güralp technical support may ask you to use if you have problems with the card;
- a file named `table_of_events.bin`. This is not human readable: it is used by the Seismic Events Table in the “Trigger” tab
- a directory named `all_miniSEED_files_are_in_here`. Within this directory, there will be a miniSEED file for each recording channel. The file-name prefix is the same as the channel name description given in the “Data Record” tab. Each file is 128 MiB in size.



The typical contents of the `all_miniSEED_files_are_in_here` directory looks like this:



Name	Date modified	Type	Size
Sensor0AccelERou_0000000100_00013.mseed	22/07/2016 09:21	MSEED File	131,072 KB
Sensor0AccelNRou_0000000100_00015.mseed	22/07/2016 09:21	MSEED File	131,072 KB
Sensor0AccelZRou_0000000100_00017.mseed	22/07/2016 09:21	MSEED File	131,072 KB
Sensor0HumidBRou_0000000010_00023.mseed	22/07/2016 09:14	MSEED File	131,072 KB
Sensor0IntERough_0000000100_00007.mseed	22/07/2016 09:21	MSEED File	131,072 KB
Sensor0IntNRough_0000000100_00009.mseed	22/07/2016 09:21	MSEED File	131,072 KB
Sensor0IntZRough_0000000100_00011.mseed	22/07/2016 09:21	MSEED File	131,072 KB
Sensor0MassPosER_0000000100_00018.mseed	22/07/2016 09:21	MSEED File	131,072 KB
Sensor0MassPosNR_0000000100_00002.mseed	22/07/2016 09:21	MSEED File	131,072 KB
Sensor0MassPosZR_0000000100_00004.mseed	22/07/2016 09:21	MSEED File	131,072 KB
Sensor0TemprCRou_0000000010_00021.mseed	22/07/2016 09:14	MSEED File	131,072 KB
Sensor0VoltageRo_0000000010_00022.mseed	22/07/2016 09:12	MSEED File	131,072 KB
Sensor1AccelERou_0000000100_00006.mseed	22/07/2016 09:21	MSEED File	131,072 KB
Sensor1AccelNRou_0000000100_00008.mseed	22/07/2016 09:21	MSEED File	131,072 KB
Sensor1AccelZRou_0000000100_00010.mseed	22/07/2016 09:21	MSEED File	131,072 KB
Sensor1IntERough_0000000100_00001.mseed	22/07/2016 09:21	MSEED File	131,072 KB
Sensor1IntNRough_0000000100_00003.mseed	22/07/2016 09:21	MSEED File	131,072 KB
Sensor1IntZRough_0000000100_00005.mseed	22/07/2016 09:21	MSEED File	131,072 KB
Sensor1MassPosER_0000000100_00012.mseed	22/07/2016 09:21	MSEED File	131,072 KB
Sensor1MassPosNR_0000000100_00014.mseed	22/07/2016 09:21	MSEED File	131,072 KB
Sensor1MassPosZR_0000000100_00016.mseed	22/07/2016 09:21	MSEED File	131,072 KB
Sensor1VelocESmo_0000000200_00019.mseed	22/07/2016 09:21	MSEED File	131,072 KB
Sensor1VelocNSmo_0000000200_00020.mseed	22/07/2016 09:21	MSEED File	131,072 KB
Sensor1VelocZSmo_0000000200_00000.mseed	22/07/2016 09:21	MSEED File	131,072 KB

The file-name consists of four components:

- The stream name, truncated to 16 characters – see Section 10 on page 137 for a full list of these;
- The sample rate, (in samples per second), as a ten-digit decimal number, left-padded with zeroes;
- A number which functions as a counter to ensure unique name for all files. Each time a file is created, this number is incremented so that the next file to be created will use the next value; and
- The `.mseed` extension which identifies this as a miniSEED file.

The “Storage” tab also shows links to five auxiliary files, which are either saved in the Fortimus' flash RAM or are dynamically generated:

Auxiliary files

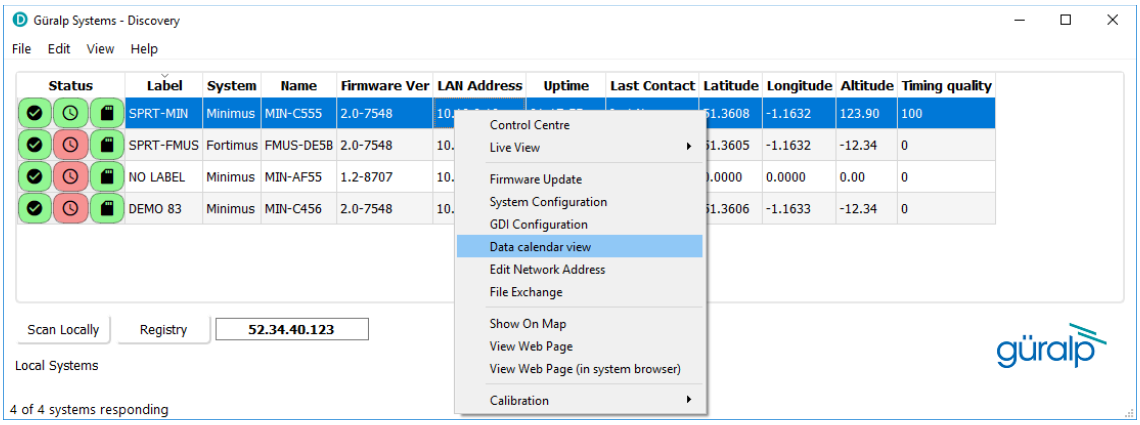
Filename	Description
DG.dataless	Dataless SEED file
fram.log	FRAM log file
calvals.txt	SCREAM! calibration values
polezero.txt	SCREAM! zeros, poles and gains
calib.txt	Calibration text file

- `network.DATALESS`: where *network* is the two-character Network code defined in the “Setup” tab (e.g. GU.DATALESS). This file is a Dataless SEED volume that contains meta-data including instrument responses, coordinates, compression type etc. The Dataless SEED volume is generated from the .RESP files for each channel;
- `fram.log`: FRAM log file (stored in FRAM);
- `calvals.txt`: calibration values in the format compatible with the Scream! Software package (dynamically generated);
- `polezero.txt`: poles, zeros and normalising factors in the format compatible with the Scream! software (dynamically generated);
- `calib.txt`: calibration text file with poles, zeros and gains expressed in hexadecimal (stored in FRAM);

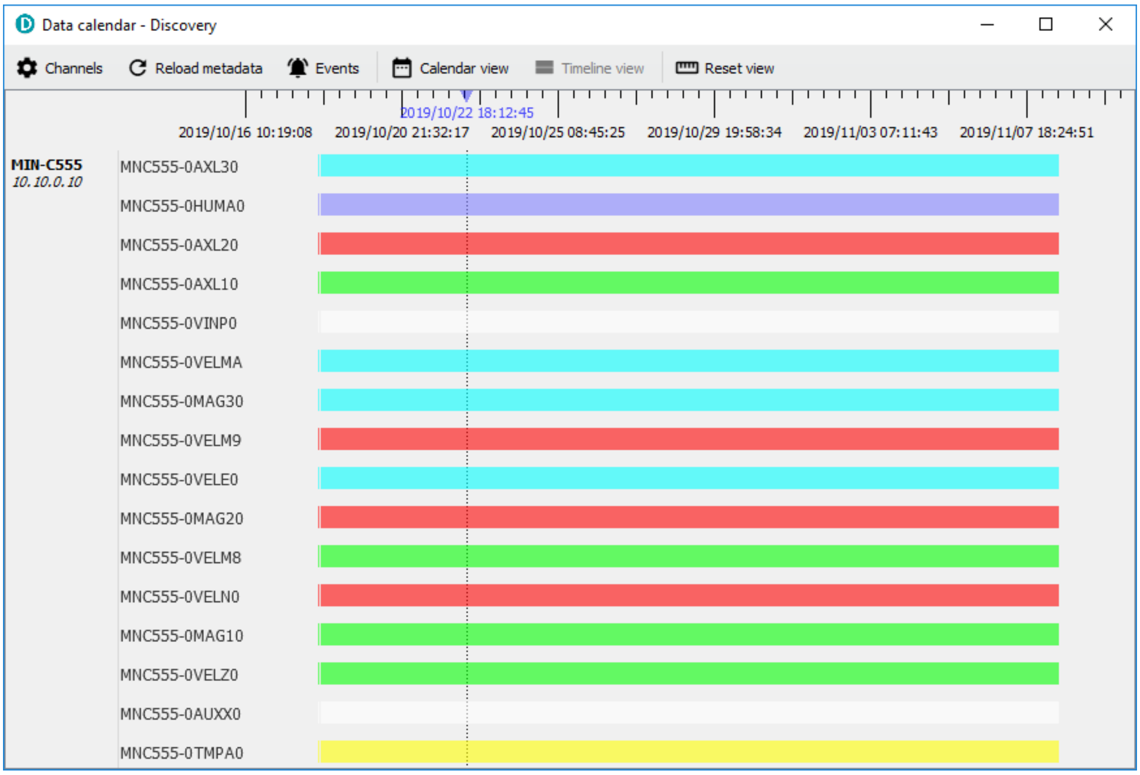
7.10.8 Request data from microSD card

Discovery can be used as viewer of seismic data locally recorded in the microSD card of a Fortimus.

Select the Fortimus of interested, right-click and choose “Data calendar view” to open the complete list of streams.



The calendar shows two weeks of data preceding the time when the request is sent and it includes all the available channels recorded in the microSD card, distinct by stream name and predefined colour.

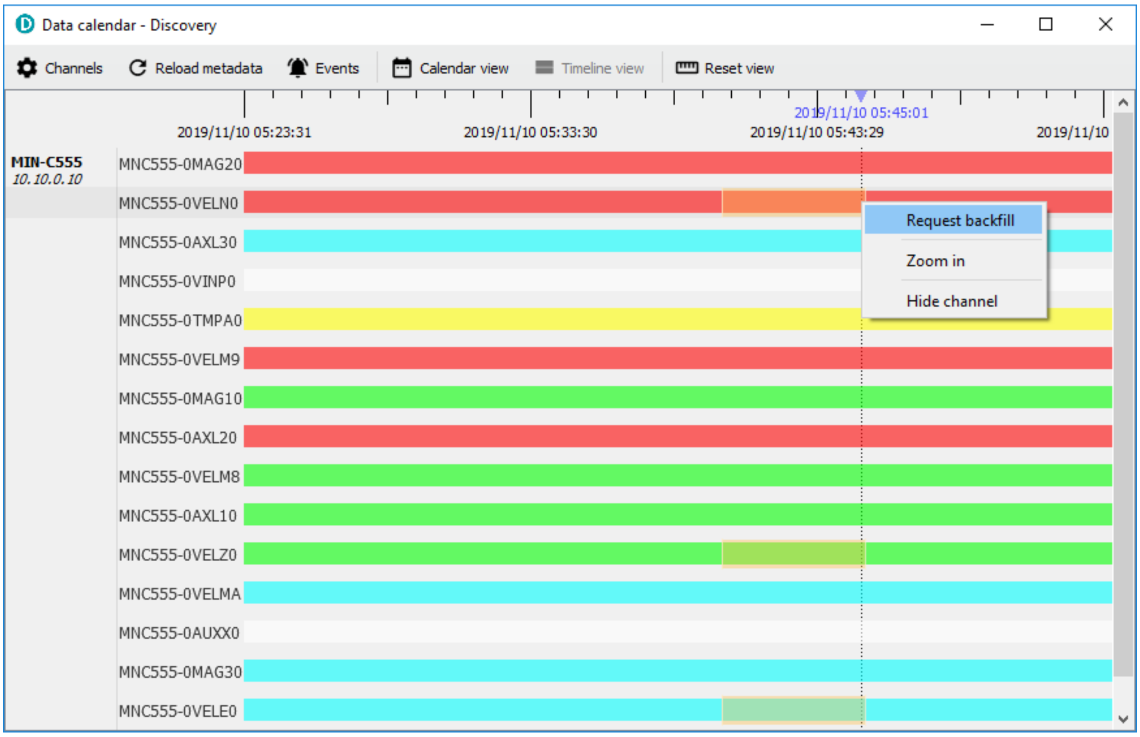


Note: Any gap in the calendar view is symptom of a gap in the recorded data.

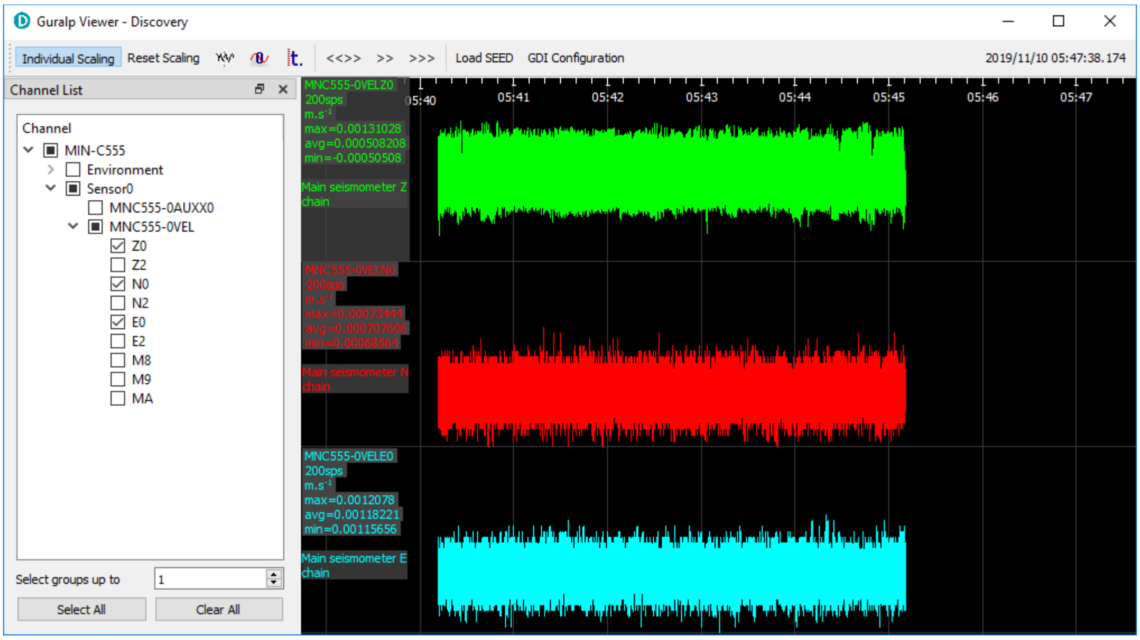
Use the mouse-wheel scrolling (or track- / touch-pad scrolling on a laptop) or highlight a portion of data, right-click and select “Zoom in” to zoom into the data. Multiple channel are selectable using key Ctrl.

In Discovery, right-click on the Fortimus of interest and select “Live View” → “GDI” to open a data viewer window. Select the streams that are going to be backfilled with recorded data.

In the calendar window select the portion of data to backfill into the viewer. Right-click and select “Request backfill”.



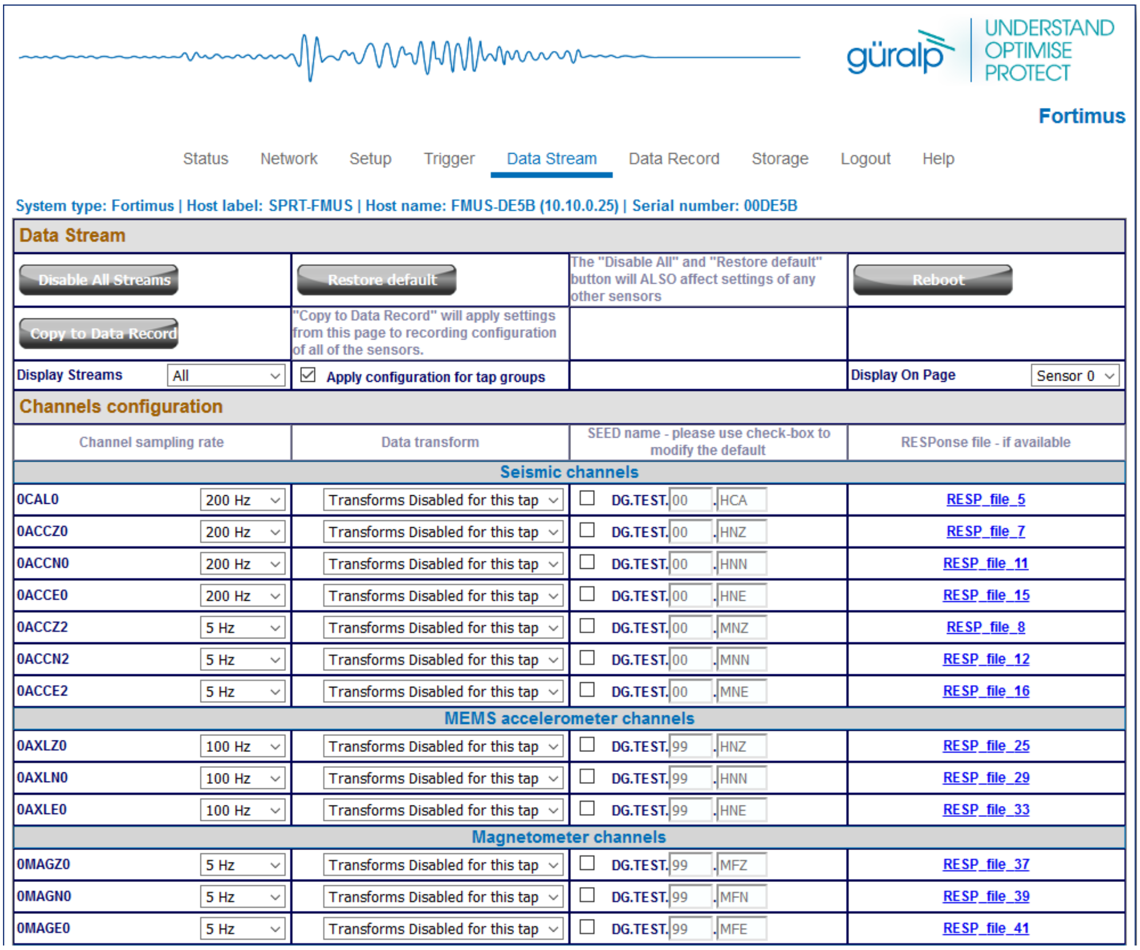
The requested data is automatically imported in the GDI data viewer in Discovery.



Note: The time required to upload the data depends on the window duration and the sample rate. Subsequent requests are queued and a new one is served once the previous one is completed.

7.11 Data transmission

The monitoring and configuration of transmitted data is handled using the “Data Stream” tab of the instrument’s web page.



This page allows to configure the transmitted channels available in the Fortimus.

The names and contents of each channel are described in Section 10 on page 137.

> **Note:** When changing a setting in the Fortimus web page, ensure that you wait until the page refreshes before changing another setting. This allows time for the previous change to take effect.

The drop-down box at the top-left of the page named “Display Streams” filters out visible channels among Enabled and Disabled. The option “Apply configuration for tap groups” automatically apply the same configuration to three streams that belong to the same tap, e.g. 0ACCZ0, 0ACCN0, 0ACCE0.

The page is divided in four columns:

- in most-left column, drop-down boxes are available for each channel to either select a sample rate or to exclude the channel from streaming (by selecting the "Disabled" option). All streaming can be stopped by clicking the **Disable All** button. Same configuration can be applied to recorded channels by clicking the **Copy to Data Record** button. Default channel configuration can be applied by clicking the **Restore default** button.
- in second column from the left, drop-down boxes are available for each channel to enable/disable transforms and, once transform is enabled, to select the transform to apply (see Section 7.16 on page 87);
- in third column from left, Location and Channel SEED codes can be configured. Cells are greyed out by default (default values applied) and they can be edited by clicking on the check-box;
- in most-right column contains links to the RESP files associated to each of the seismic channels (see Section 7.14.4 on page 81).

Upon changing the sample rate, enabling a transform or changing Location and Channels codes, the Fortimus will need to be restarted for the changes to come into effect; this can be done by pressing the **Reboot** button.

During the reboot, the LEDs will flash, displaying the starting-up sequence (see Section 3.1.2 on page 10) and the instrument web page will display the following screen.

FMUS-C456 is rebooting ...

Once the Fortimus has successfully restarted, the full web browser display and controls will be available for use again.

7.11.1 Scream! (GCF format + Scream protocol)

The Fortimus can act as a Scream! Server and streams data by sending GCF (Güralp Compressed Format) packets over a network connection using the scream data transmission protocol.

This is primarily intended to support Güralp's Scream! Software (see Section 4.4.2 on page 31) or any software that can communicate using the Scream! Protocol, including SeisComP3.

These include:

- Güralp instruments with embedded acquisition modules (e.g. 40TDE)
- Güralp DM24 and CD24 digitisers with embedded acquisition modules (e.g. Güralp DM24S*x*EAM[U])

- Affinity digitiser
- Network Acquisition Module (Güralp NAM)

Data can also be received by software that can communicate using the Scream! Protocol, including SeisComp3 and Earthworm.

> **Note:** Güralp devices running the Platinum software *can* receive GCF data over the Scream protocol, but the GDI-link protocol is preferred in these cases.

7.11.2 GDI-link protocol

The Fortimus can also transmit data using the GDI-link protocol. GDI-link can currently be used with:

- Güralp instruments with embedded acquisition modules (e.g. 40TDE)
- Güralp DM24 and CD24 digitisers with embedded acquisition modules (e.g. Güralp DM24S*x*EAM[U])
- Güralp Affinity digitisers
- Güralp NAM (Network Acquisition Module)
- Earthworm software (www.isti.com/products/earthworm/)

GDI-link supports both data push and pull from/to the Fortimus. See Section 7.6 on page 51 to configure data push to one or more remote clients, e.g. NAM.

GDI-link provides a highly efficient, low latency method of exchanging data via TCP between seismic stations and data centres. The protocol allows state-of-health information to be attached to samples during transmission. A receiver can accept data from multiple transmitters, and a single transmitter can send data to multiple receivers, allowing maximum flexibility for configuring seismic networks. GDI-link streams data sample-by-sample (instead of assembling them into packets) to minimise transmission latency.

A significant advantage of GDI-link is that it has the ability to stream data pre-converted into real physical units instead of just as raw digitiser counts, obviating a requirement for receivers to be aware of calibration values.

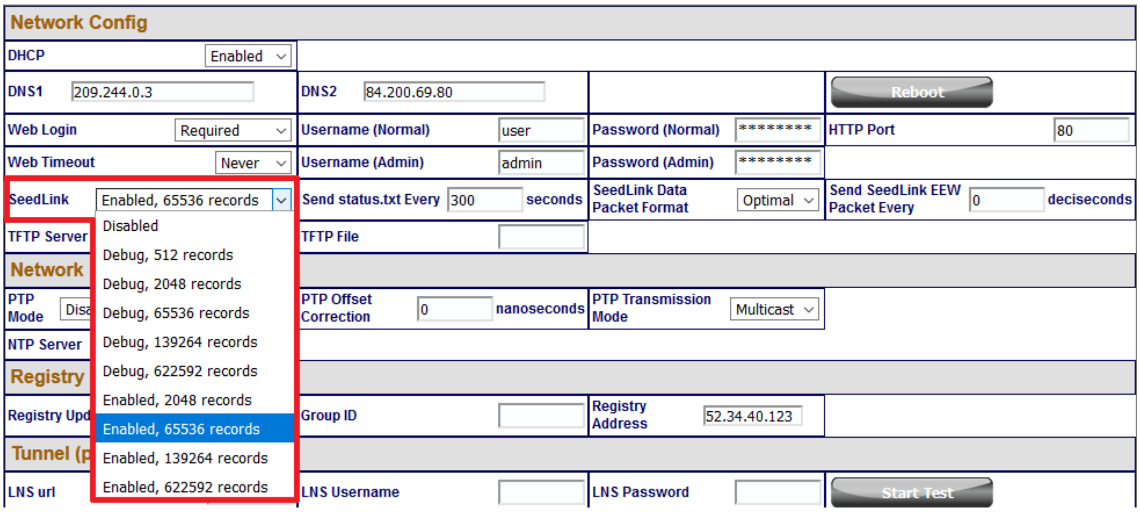
For more information on GDI-link, please refer to Güralp manual **SWA-RFC-GDIL**.

7.11.3 SEEDlink protocol

The Fortimus can act as a SEEDlink server to send miniSEED data packets over a network connection. The SEEDlink server is enabled by default but it can be disabled and re-enabled if desired. The server has a configurable back-fill buffer.

Note: The Fortimus SEEDlink back-fill implementation is packet-based.

FortimusIn the “Network” tab of the Fortimus web page, select the desired SEEDlink mode.



The choices are:

- “Enabled” - This is the normal operating mode. Choose between backfill buffer sizes of 2,048 records, 65,536 records, 139,264 records or 622,592 records;
- “Disabled” - turns off the SEEDlink server; and
- “Debug” - this mode produces additional messages in the *seedlink.log*. which may be helpful if trying to diagnose a problem. It is available with backfill buffer sizes as before and, additionally, 512 records.

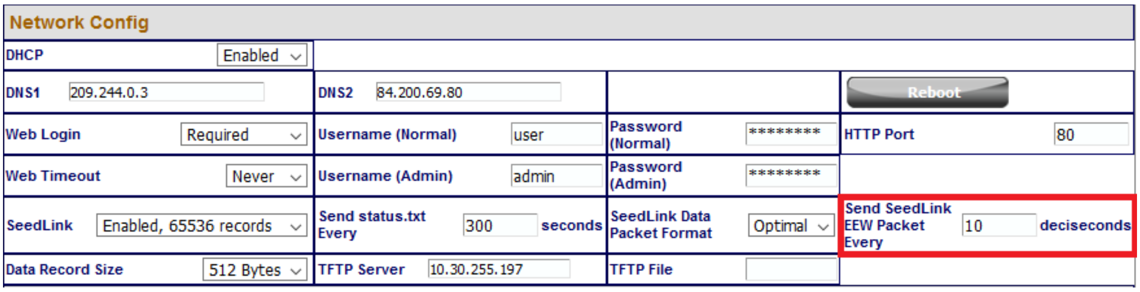
Note: As a general guide, we find that 139,264 records is normally sufficient to store around one day of triaxial, 100 sps data.

Standard SEEDlink has a fixed packet size of 512 Bytes and each miniSEED packet is completely populated with data before it is transmitted. The Fortimus supports a modified version of SEEDlink that allows the transmission of incomplete packets. This improves latency.

Note: The modified SEEDlink is only available for EEW channels - i.e. the main seismic channels (generated with causal low latency filters) and the STA, LTA, STA/LTA ratio channels.

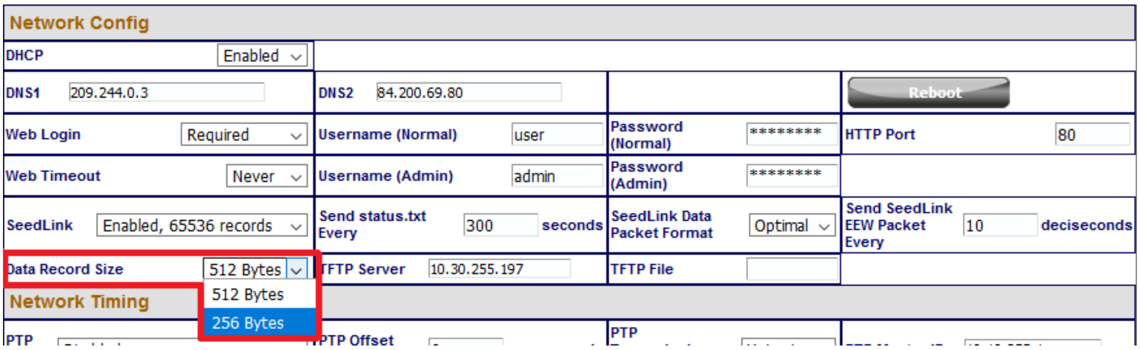
The user can specify the rate at which miniSEED packets must be transmitted. If populating complete packets would result in this rate not being achieved, incomplete packets are transmitted instead. The number of samples in each packet, therefore, depends both upon this setting and on the sample rate.

In the “Network” tab of the Fortimus web page select the interval in deciseconds (1 decisecond = 100 ms or 0.1 seconds) between miniSEED packets.



The modified SEEDlink protocol also allows the use of 256-byte records as an alternative to the standard 512-byte format. The “Data Record Size” drop-down menu on the “Network” tab of the Fortimus web page controls this behaviour.

Note: Not all SEEDlink clients can accept 256-byte records. Consult your client's documentation if in doubt.



To test the SEEDlink server, Güralp recommends using the *slinktool* software for Linux, which is distributed by IRIS. For more information and to download a copy, see http://ds.iris.edu/ds/nodes/dmc/software/downloads/slinktool/.

To show a list of available miniSEED streams, issue the command:

slinktool -Q *IP-Address*

which produces output like the following:

```
DG TEST  00 CHZ D 2016-09-13 10:42:18  -  2016-09-13 10:46:56
DG TEST  01 HHZ D 2016-09-13 10:42:18  -  2016-09-13 10:46:56
DG TEST  00 CHN D 2016-09-13 10:42:18  -  2016-09-13 10:46:56
DG TEST  01 HHN D 2016-09-13 10:42:18  -  2016-09-13 10:46:56
DG TEST  00 CHE D 2016-09-13 10:42:18  -  2016-09-13 10:46:56
DG TEST  01 HHE D 2016-09-13 10:42:18  -  2016-09-13 10:46:56
DG TEST  00 MHZ D 2016-09-13 10:42:18  -  2016-09-13 10:46:56
DG TEST  00 MHN D 2016-09-13 10:42:18  -  2016-09-13 10:46:56
DG TEST  00 MHE D 2016-09-13 10:42:18  -  2016-09-13 10:46:56
⋮
```

To print miniSEED data records of a single channel, you will need the following command:

slinktool -p -S *DG_TEST:00HNZ.D IP-Address*

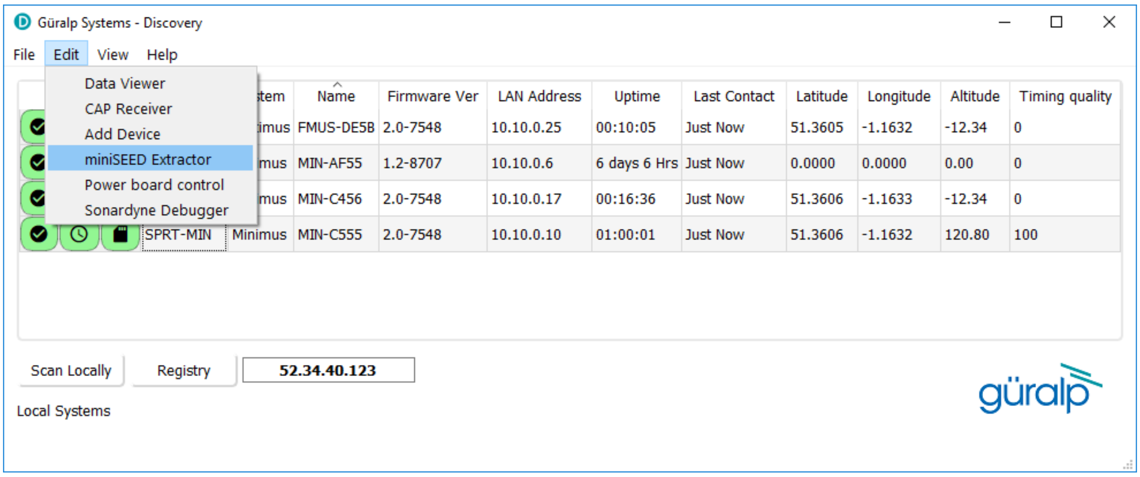
which produces the following output:

```
DG_TEST_00_HNZ, 412 samples, 100 Hz, 2016,257,10:43:42.000000
(latency ~2.9 sec)
DG_TEST_00_HNZ, 415 samples, 100 Hz, 2016,257,10:43:46.120000
(latency ~2.6 sec)
DG_TEST_00_HNZ, 416 samples, 100 Hz, 2016,257,10:43:50.270000
(latency ~3.0 sec)
DG_TEST_00_HNZ, 413 samples, 100 Hz, 2016,257,10:43:54.430000
(latency ~2.6 sec)
DG_TEST_00_HNZ, 419 samples, 100 Hz, 2016,257,10:43:58.560000
(latency ~3.0 sec)
DG_TEST_00_HNZ, 418 samples, 100 Hz, 2016,257,10:44:02.750000
(latency ~2.6 sec)
DG_TEST_00_HNZ, 415 samples, 100 Hz, 2016,257,10:44:06.930000
(latency ~3.0 sec)
⋮
```

The SEEDlink server on the Fortimus also supports the use of the "?" character as a wild-card within network, station and channel codes. This allows you to request multiple streams using a single command.

Note: Because the '**?**' character has special meaning to the shell, it is safest to quote this character with a preceding backslash ('\') when used in command arguments.

7.11.3.1 MiniSEED extractor

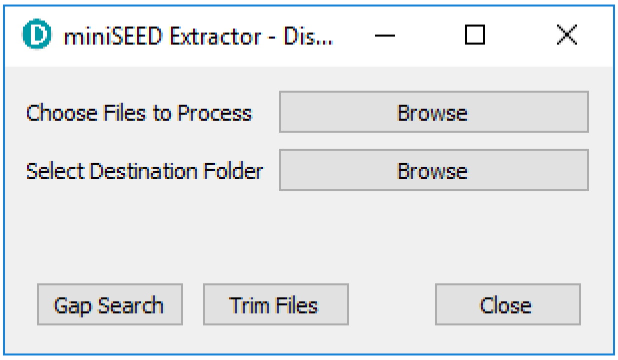


The miniSEED extractor serves two purposes:

- When an SD card is quick-formatted, each file is marked as unused but previously recorded data can still remain in them. Subsequent recordings overwrite these files from the beginning but, if the previous recording had a longer duration, old data will remain in the files. When the files are copied from the SD card to a PC, these older data can cause problems.

- The format used on the SD cards consists of fixed-length, 128 MiB files. Some recordings might not use all of this space. When the files are copied from the SD card to a PC, this can cause wasted disk space.

The miniSEED extractor reads miniSEED files on the PC and copies them to a selected Destination folder, keeping track of the latest block time-stamp as it goes. If it encounters either an unused block or a time-stamp which is earlier than the previous one, it stops copying, truncating the output file at that point. This guarantees that each output file contains only blocks in time order and contains no wasted space.



To use the tool, select "miniSEED Extractor" from the Edit menu. Click the first Browse button to select which files you wish to process and then the second Browse button to select the folder into which you wish the output files to be written. Finally, click the Trim Files button to extract the valid data from the selected files into new files in the selected destination folder.

The same tool can also generate a report of any gaps in the data from the input files. To use, select the input files as before and then click Gap Search to view the report.

7.12 Synchronisation of the sample-clock

The Fortimus system synchronises its sample clock using an attached GNSS receiver or, if that is not available, Precision Time Protocol (PTP).

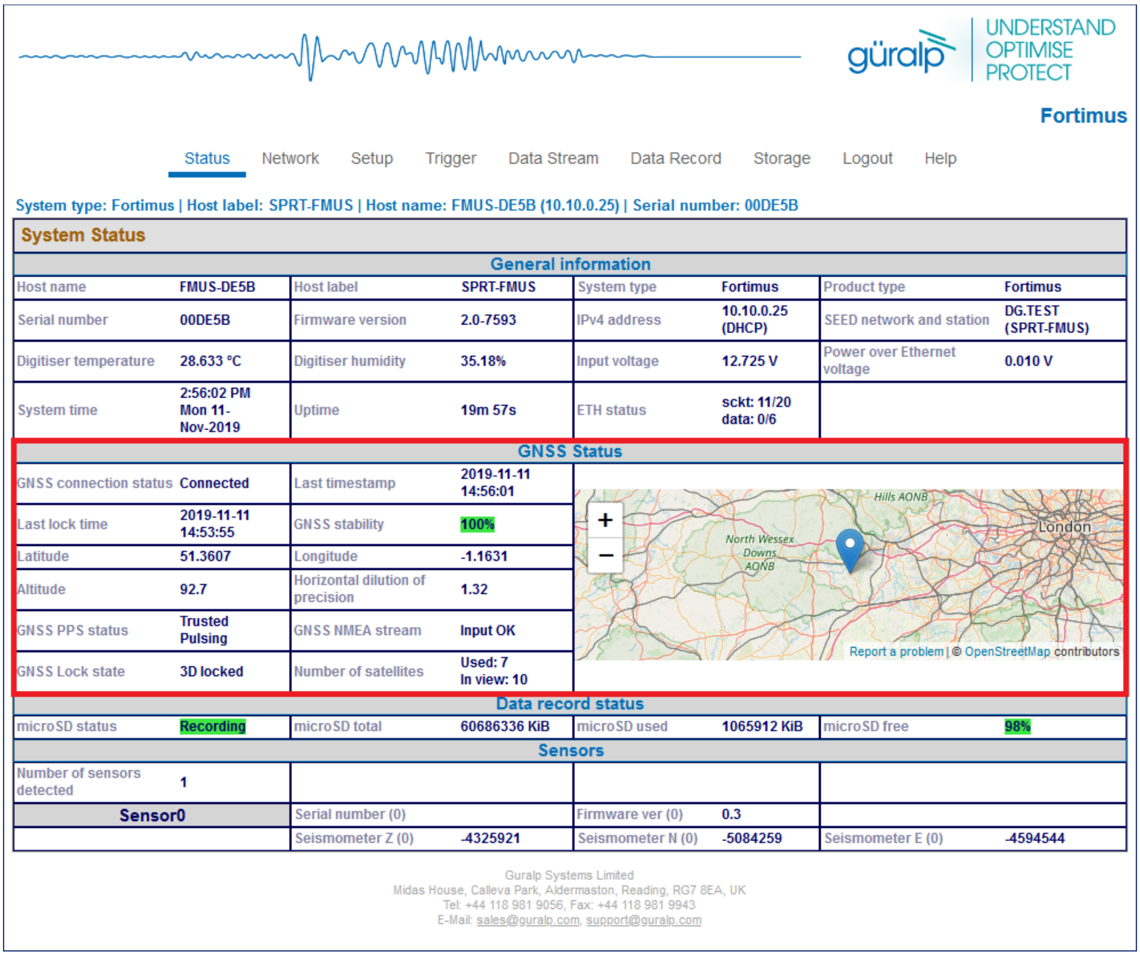
The currently supported GNSS systems are Navstar (GPS), GLONASS, BeiDou and Galileo.

Note: The GNSS can use only three different types of satellites simultaneously and GPS is always used, if available. The other two spots available can be either GLONASS, BeiDou or Galileo.

If visibility of the satellite constellation is available, this is the most accurate way to synchronise your digitiser. The Fortimus accessory pack includes a combined GNSS antenna and receiver for this purpose: see Section 3.2.2 on page 17 for details.

7.12.1 GNSS lock status

This is available in the “Status” tab of the instrument’s web page.



UNDERSTAND OPTIMISE PROTECT

Fortimus

Status Network Setup Trigger Data Stream Data Record Storage Logout Help

System type: Fortimus | Host label: SPRT-FMUS | Host name: FMUS-DE5B (10.10.0.25) | Serial number: 00DE5B

System Status							
General information							
Host name	FMUS-DE5B	Host label	SPRT-FMUS	System type	Fortimus	Product type	Fortimus
Serial number	00DE5B	Firmware version	2.0-7593	IPv4 address	10.10.0.25 (DHCP)	SEED network and station	DG.TEST (SPRT-FMUS)
Digitiser temperature	28.633 °C	Digitiser humidity	35.18%	Input voltage	12.725 V	Power over Ethernet voltage	0.010 V
System time	2:56:02 PM Mon 11-Nov-2019	Uptime	19m 57s	ETH status	sckt: 11/20 data: 0/6		
GNSS Status							
GNSS connection status	Connected	Last timestamp	2019-11-11 14:56:01				
Last lock time	2019-11-11 14:53:55	GNSS stability	100%				
Latitude	51.3607	Longitude	-1.1631				
Altitude	92.7	Horizontal dilution of precision	1.32				
GNSS PPS status	Trusted Pulsing	GNSS NMEA stream	Input OK				
GNSS Lock state	3D locked	Number of satellites	Used: 7 In view: 10				
Data record status							
microSD status	Recording	microSD total	60686336 KiB	microSD used	1065912 KiB	microSD free	98%
Sensors							
Number of sensors detected	1						
Sensor0		Serial number (0)		Firmware ver (0)	0.3		
		Seismometer Z (0)	-4325921	Seismometer N (0)	-5084259	Seismometer E (0)	-4594544

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E-Mail: sales@guralp.com, support@guralp.com

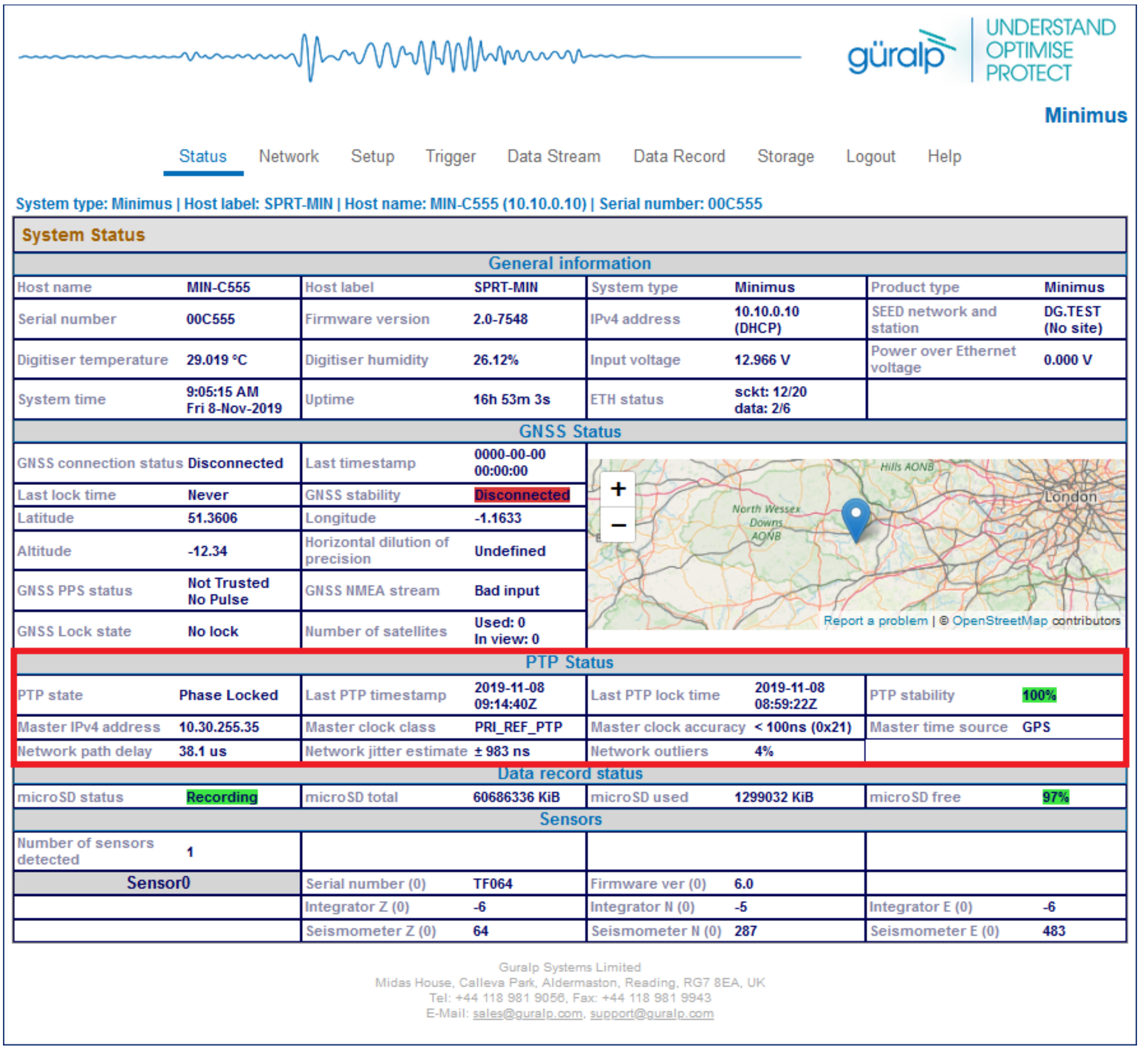
A number of GNSS reporting parameters are given, including:

- Connection status
- Last GNSS update (sync) & last GNSS lock date/time
- GNSS Stability:
  - 0% = no receiver connected;
  - 1% = receiver connected, but waking up (this can occur if the GNSS receiver has been moved a long distance since last power-up).
  - 2-99% = view of sky obstructed.
  - 100% = normal operation with clear view of sky
- Latitude, longitude, altitude
- Horizontal dilution of precision (quality of satellite fix due to position of satellites relative to receiver)

- GNSS PPS status
- GNSS NMEA streaming
- GNSS lock state (2D/3D)
- Number of available satellites (in use / in view)

7.12.2 Precision Time Protocol (PTP)

The Fortimus system supports timing provided through PTP.



General information							
Host name	MIN-C555	Host label	SPRT-MIN	System type	Minimus	Product type	Minimus
Serial number	00C555	Firmware version	2.0-7548	IPv4 address	10.10.0.10 (DHCP)	SEED network and station	DG.TEST (No site)
Digitiser temperature	29.019 °C	Digitiser humidity	26.12%	Input voltage	12.966 V	Power over Ethernet voltage	0.000 V
System time	9:05:15 AM Fri 8-Nov-2019	Uptime	16h 53m 3s	ETH status	sckt: 12/20 data: 2/6		
GNSS Status							
GNSS connection status	Disconnected	Last timestamp	0000-00-00 00:00:00				
Last lock time	Never	GNSS stability	Disconnected				
Latitude	51.3606	Longitude	-1.1633				
Altitude	-12.34	Horizontal dilution of precision	Undefined				
GNSS PPS status	Not Trusted No Pulse	GNSS NMEA stream	Bad input				
GNSS Lock state	No lock	Number of satellites	Used: 0 In view: 0				
PTP Status							
PTP state	Phase Locked	Last PTP timestamp	2019-11-08 09:14:40Z	Last PTP lock time	2019-11-08 08:59:22Z	PTP stability	100%
Master IPv4 address	10.30.255.35	Master clock class	PRI_REF_PTP	Master clock accuracy	< 100ns (0x21)	Master time source	GPS
Network path delay	38.1 us	Network jitter estimate	± 983 ns	Network outliers	4%		
Data record status							
microSD status	Recording	microSD total	60686336 KiB	microSD used	1299032 KiB	microSD free	97%
Sensors							
Number of sensors detected	1						
Sensor0		Serial number (0)	TF064	Firmware ver (0)	6.0		
		Integrator Z (0)	-6	Integrator N (0)	-5	Integrator E (0)	-6
		Seismometer Z (0)	64	Seismometer N (0)	287	Seismometer E (0)	483

The IEEE 1588 Precision Time Protocol (PTP) is a network protocol which uses modified network hardware to accurately time-stamp each PTP packet on the network at the time of transmission, rather than at the time that the packet was assembled. If you do not have an existing PTP infrastructure, the simplest way to use PTP is to add a "grand-master clock" to the same network segment as the digitisers. A typical such clock is the Omicron OTMC 100, which has an integrated GNSS antenna and receiver which it uses as its own synchronisation source. PTP timing can be extended over up to 100 metres of Ethernet cable or longer distances when fibre-optic cable is used. PTP is significantly more accurate than NTP but generally requires specialised hardware support.

In the “Status” tab of the Fortimus web page, a number of reporting parameters are given, including:

- PTP state
- Last PTP time-stamp and last PTP lock date/time
- PTP Stability:
  - Standby ⇒ PTP is running but timing is provided by GNSS;
  - No Master ⇒ PTP not available;
  - 1-100% ⇒ PTP locking process indicator. 100% indicates a time accuracy of better than 200 ns.
- Master IPv4 address
- Master clock class and accuracy
- Master time source
- Network path delay
- Network jitter estimate: quality indicator
- Network outliers

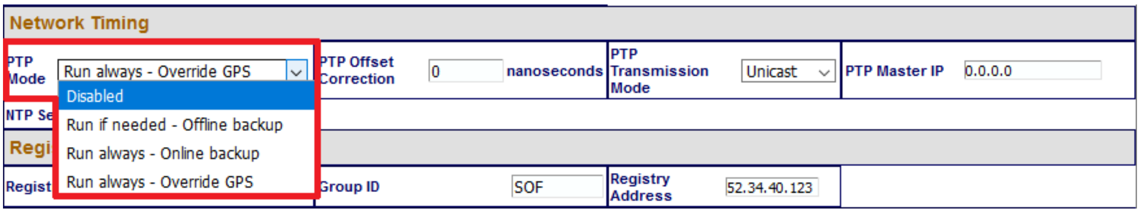
Under the heading “Network config” are four options:

- **Disabled** ⇒ PTP is never used (default settings).

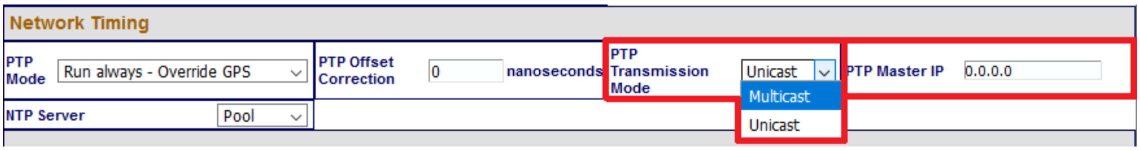
- **Run if needed – Offline backup** ⇒ PTP is automatically enabled whenever the GNSS signal is lost. It is disabled while GNSS is available. This mode is used to minimise network traffic when GNSS is the primary timing source.

- **Run always – Online backup** ⇒ PTP is always running but GNSS is used as the primary timing source. This mode is useful for faster fall-back from GNSS to PTP timing and for validation that PTP is available.

- **Run always – Override GPS** = PTP is always running and takes priority over GNSS. This mode is useful in a system where PTP is the primary timing source, but GNSS may occasionally be connected for validation purposes.



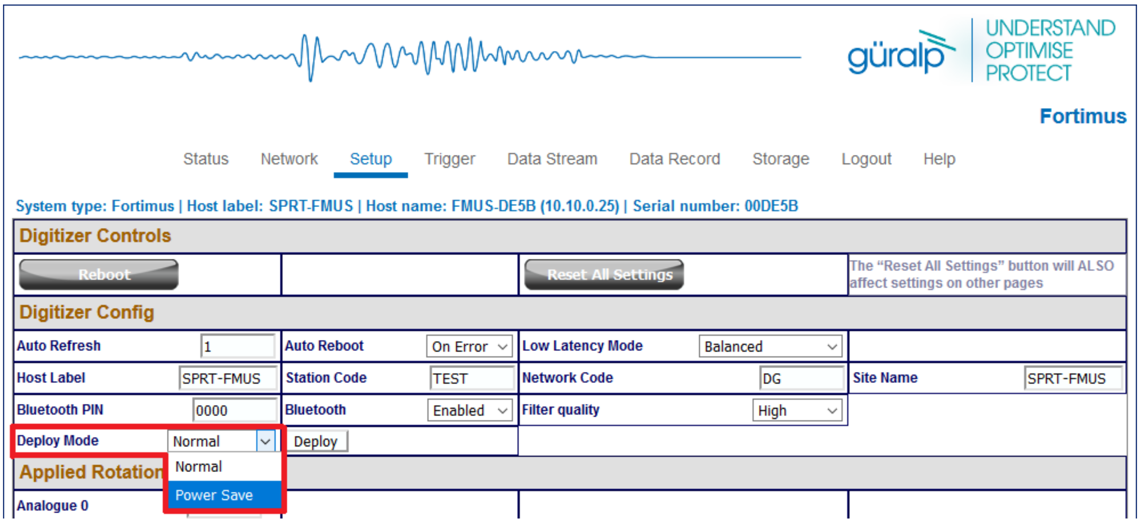
PTP can be configured for multicast or unicast mode. In unicast mode, the server I.P. address must be specified. This is available in the “Network” tab of the digitiser’s web page.



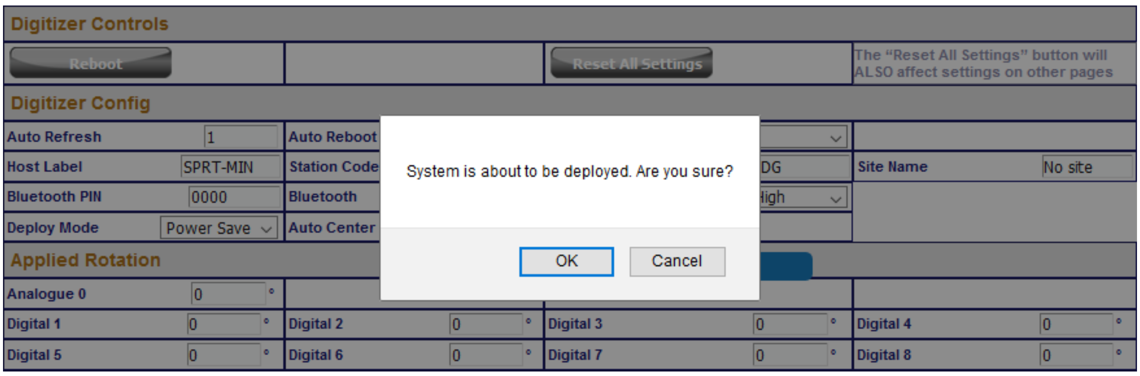
7.13 Deploy mode: Full power-save

The Fortimus digitiser offers two deployment modes: "Normal" and "Power Save". "Full power-save" mode makes a number of configuration changes in order to reduce the unit's power consumption. This mode is particularly useful when using Maris digital ocean-bottom sensors.

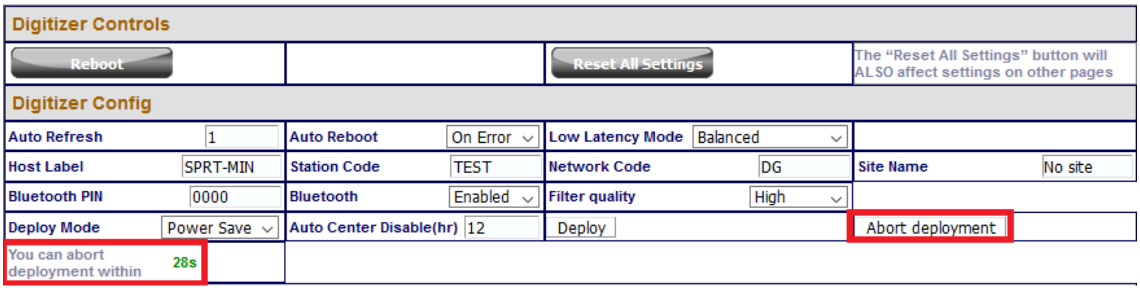
The desired mode can be specified using the “Deploy mode” drop-down menu in the “Setup” tab of Fortimus web page. Changes are not applied immediately.



The final step is to click on the Deploy button and confirm or cancel the operation from the pop-up window that appears.



A thirty-second count-down will start before the system enters power-save mode. The screen changes and a new button is added:



You can cancel the operation before the countdown is complete by clicking the 

button.

Caution: The power-save mode will disable the Ethernet and GNSS modules. You will not be able to continue to use the web interface.

Once in deploy mode, the only way to re-enable the Ethernet module is to connect to the Fortimus via a serial connection (see Section 9 on page 131) or to use the GüVü Bluetooth app (see Section 8.3 on page 128).

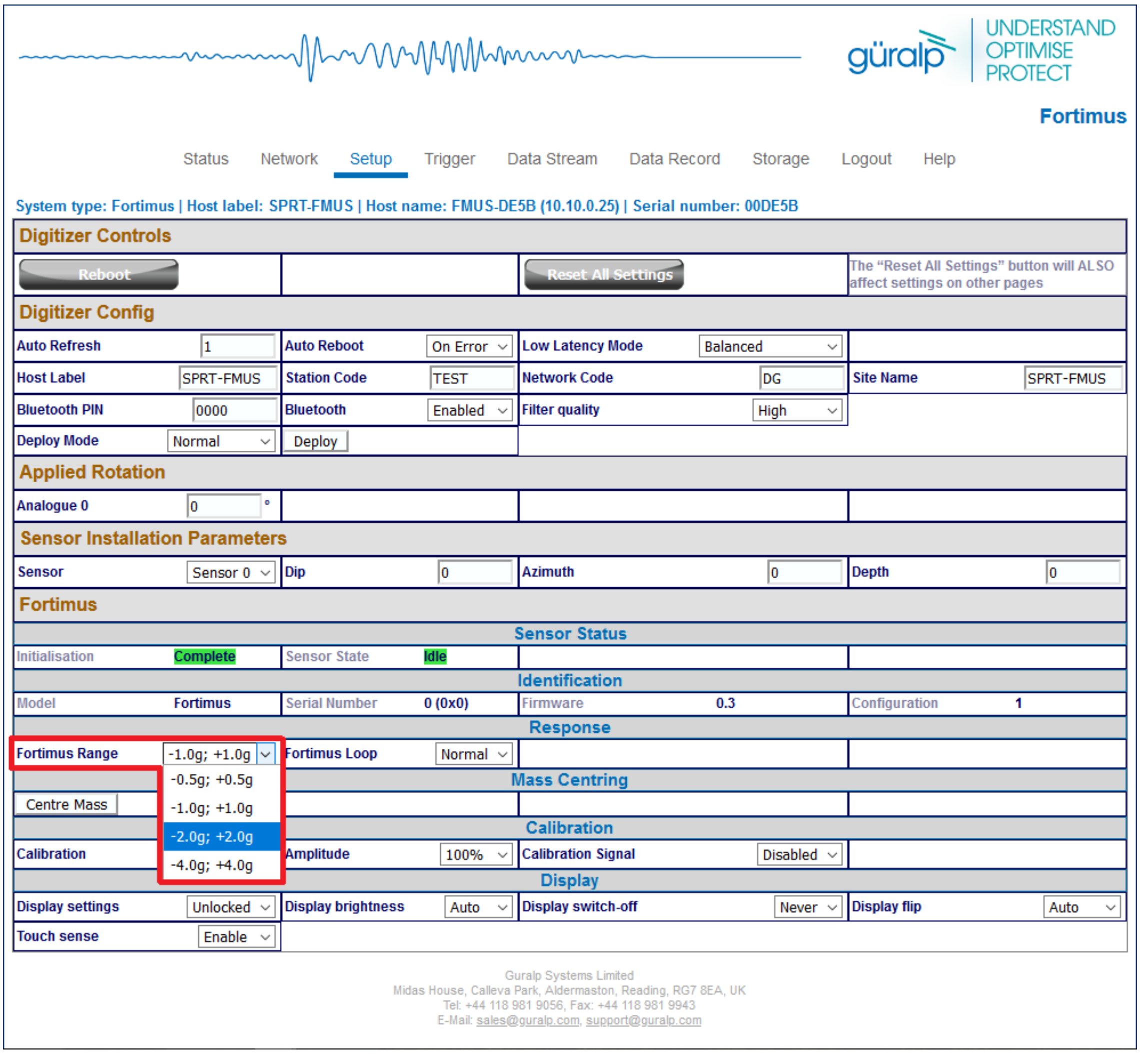
When a serial or Bluetooth connection is established, type the command `powersave off` in the console to disable the "Full power-save" mode and re-enable Ethernet communication.

7.14 Configuration and control of the accelerometer

7.14.1 Setting instrument (sensor) gain

The Güralp Fortimus strong-motion digital accelerometer features a remotely-switchable gain option that can be controlled from inside Discovery.

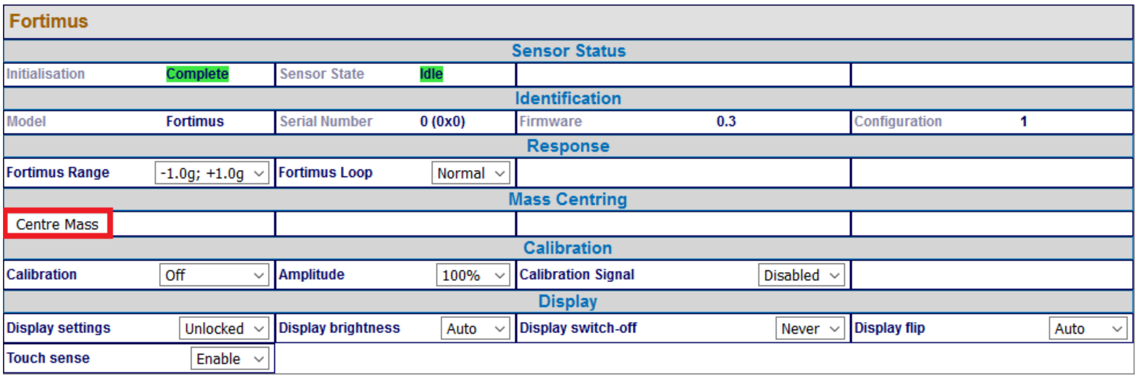
The gain is settable in the "Fortimus" section in the "Setup" tab of the Fortimus web page. Under the "Instrument Gain", select a gain setting (options: ±0.5 g; ±1 g; ±2 g; ±4 g).



Note: A reboot is required after this change.

7.14.2 Sensor centring

The Fortimus accelerometer automatically centres when it is powered up. To manually re-centre click on Centre Mass button under the "Fortimus" section in the Setup tab.



7.14.3 Output polarity

The polarity of output from each component of the instrument is as follows:

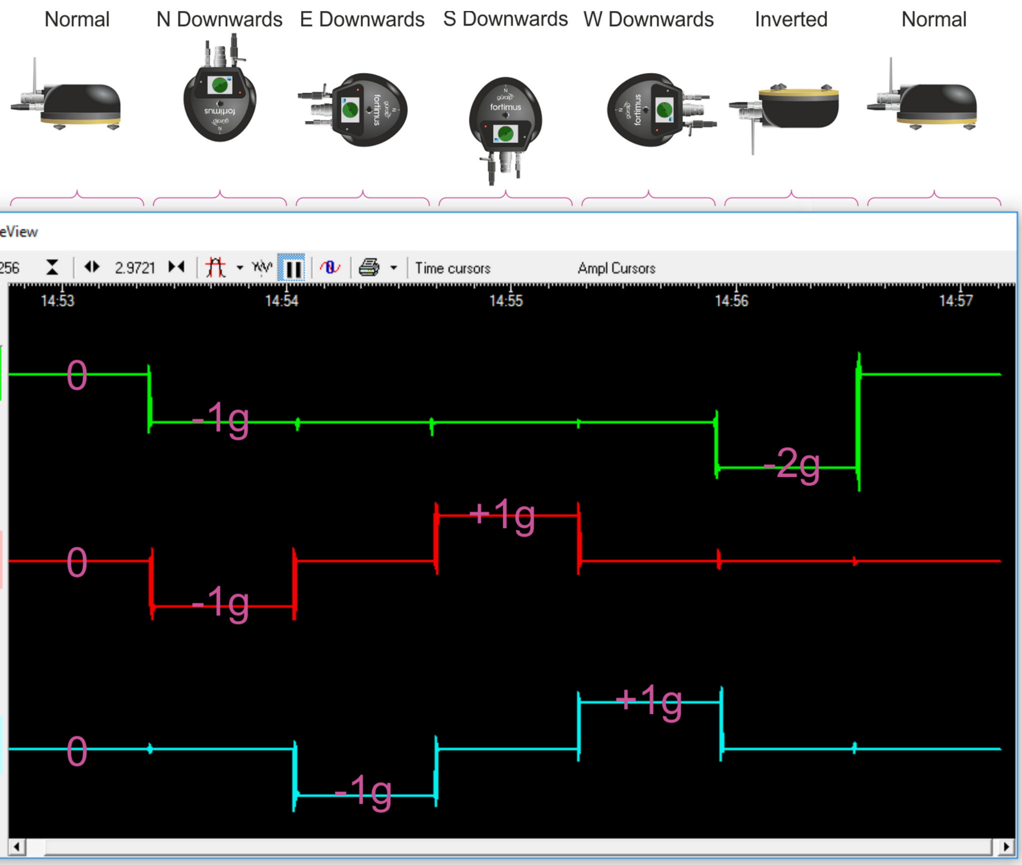
Direction of ground acceleration	Polarity of Z output	Polarity of N/S output	Polarity of E/W output
Upwards	**positive**	zero	zero
Downwards	**negative**	zero	zero
Northwards	zero	**positive**	zero
Southwards	zero	**negative**	zero
Eastwards	zero	zero	**positive**
Westwards	zero	zero	**negative**

If the ground accelerates northwards, this moves the casing of the instrument northwards and the N-axis inertial mass is left behind. From the instrument's frame of reference, the mass appears to have been deflected southwards. The feedback system then needs to provide a balancing force to accelerate it northwards and this, by design, will result in a positive output signal from the N/S component.

If the instrument is mounted with the 'N' arrow pointing downwards, gravity will try and pull the inertial mass in the direction of the instrument's N-axis. The feedback system then needs to provide a balancing force to accelerate it upwards which, from the instrument's frame of reference, is now southwards. This is the opposite of the situation described above, so the output from the N/S component will now be negative.

The converses are also true: if the ground accelerates southwards, the instrument will produce a negative output signal from the N/S component and if the instrument is orientated with it's 'N' arrow pointing upwards, it will produce a positive output signal from the N/S component

The polarity of the output signals with respect to acceleration can be demonstrated by selecting a sensitivity of 1 g, 2 g or 4 g and orientating the instrument as shown in the following diagram:



7.14.4 Instrument response parameters

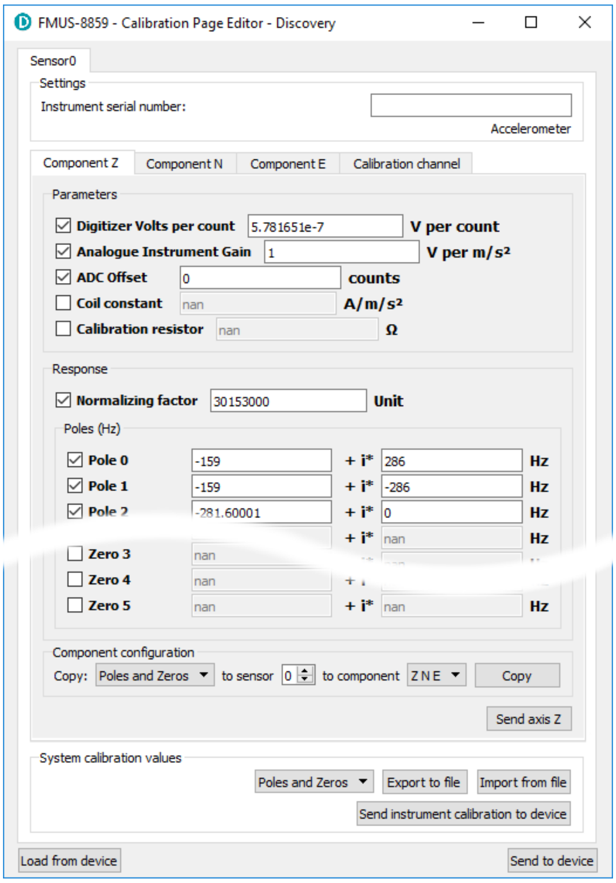
Calibration is a procedure used to verify or measure the frequency response and sensitivity of a sensor. It establishes the relationship between actual ground motion and the corresponding output voltage. Calibration values, or response parameters, are the results of such procedures.

Response parameters typically consist of a sensitivity or "gain", measured at some specified frequency, and a set of poles and zeroes for the transfer function that expresses the frequency response of the sensor. A full discussion of poles and zeroes is beyond the scope of this manual.

The gain for a seismometer is traditionally expressed in volts per ms^{-1} and, for an accelerometer, in volts per ms^{-2}. Other instruments may use different units: an electronic thermometer might characterise its output in mV per °C.

A calibration procedure is also used to establish the relationship between the input voltage that a digitiser sees and the output, in counts, that it produces. The results are traditionally expressed in volts per count. Each Fortimus is programmed at the factory so that it knows its own calibration values.

To explore the calibration values of the Fortimus' sensor and digitiser, right-click the Fortimus in Discovery's main window and select "Calibration" → "Calibration Editor". The resulting screen is shown here shortened:

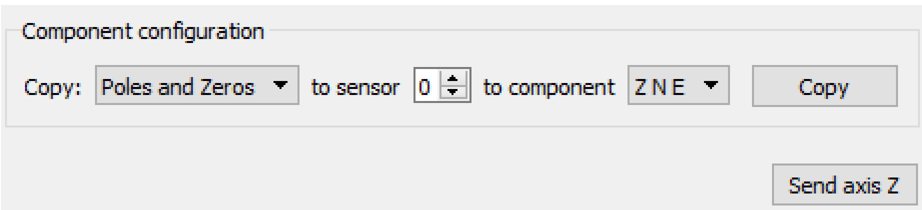


This form has one tab for each seismic component. The instrument's response values are:

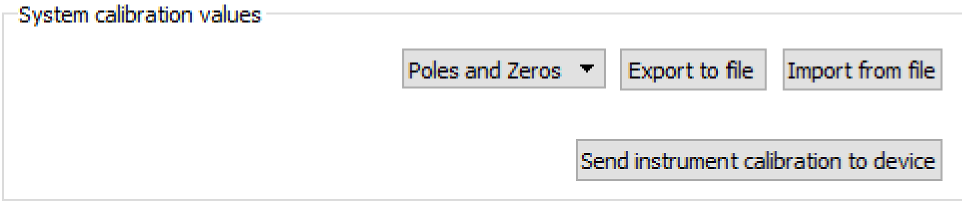
- The **Digitiser Volts per Count (VPC)** - the ratio between the input voltage and the digitised output value ("counts"). This field will be populated automatically with the correct value for this input channel of the Fortimus.
- **Analogue instrument gain –** this specifies the output voltage of the accelerometer per unit of ground motion in ms^{-2}, as measured at 1 Hertz.
- The **ADC offset** is the quiescent output seen when digitiser input is zero. This field will be populated automatically with the correct value for this input channel of the Fortimus.
- The **Coil constant** is the coil constant for the component being calibrated, in $A/m/s^2$, as given on the analogue sensor calibration sheet.
- The **Calibration resistor is t**he value of the calibration resistor, in Ω, as given on the sensor calibration sheet. This is common to all sensor components.
- The **Normalising factor** specifies the value that the transfer function (as specified by the poles and zeroes) must be multiplied by in order to provide unity gain at 1 Hz.
- The **Poles** and **Zeros** describe the frequency and phase response of the component. They must be specified in Hertz.

The calibration parameters for one component can be copied to any other component of the same instrument, or other instruments. This is especially useful for poles and zeros, because they are typically identical for all three components of all instruments in a class.

The drop-down menu in the "Component configuration" section allows selection of what to copy: poles and zeros, gains or everything. The destination sensor and component(s) can be selected in the subsequent drop-down menus. Click on the Copy button to copy and paste the selected values. Finally click on Send axis Z button to send the calibration values to the digitiser and save them permanently. Repeat this last step for the other axis. Note that Send axis Z only sends the calibration of the selected axis.

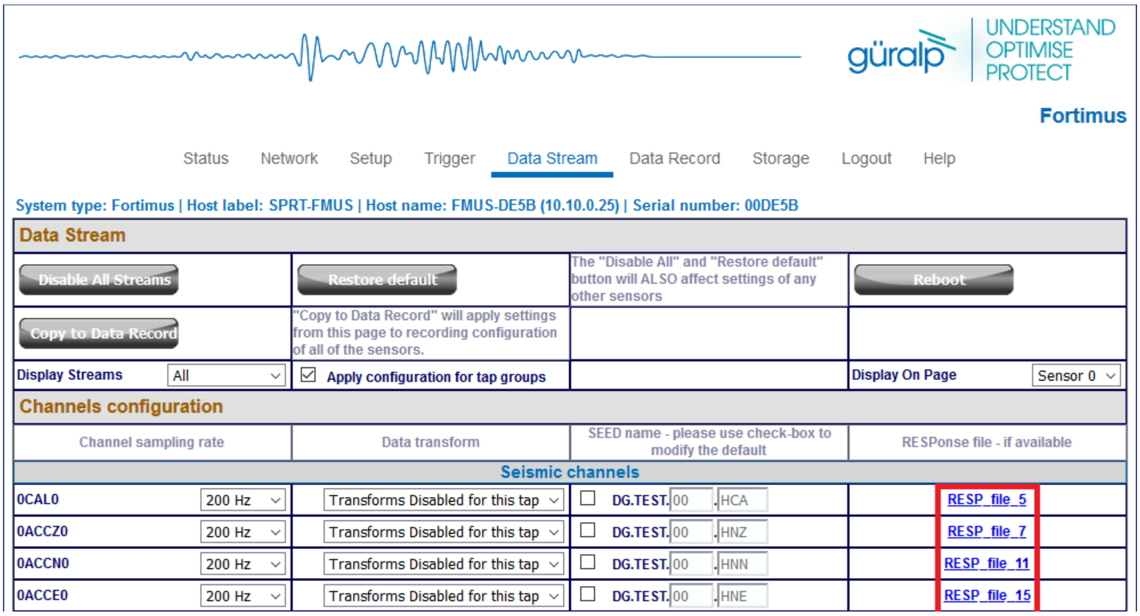


The overall system calibration parameters can be exported and saved in a file for future use by clicking on the Export to file button under "System calibration values".



The resulting file-name will have the extension `.conf`. Values from an existing calibration file can be imported using the Import from file button. The associated drop-down menu allows specification of what to import: poles and zeros, gains or everything. Click on Send instrument calibration to device to send the calibration values to the digitiser and save them permanently. Note that this action will only send the calibration of the selected sensor. Click on Send to device button to send the complete calibration to the digitiser.

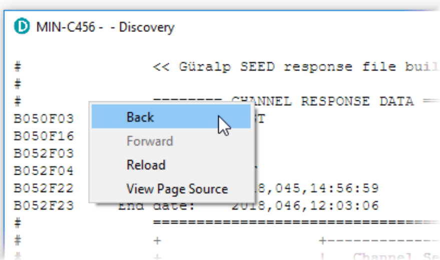
When transmitting MiniSEED data, the responses of the instruments and digitisers are encoded in a message called a "Dataless SEED" volume. The contents of these volumes can be displayed in human-readable form, known as RESP, by clicking on the "RESP file" link of each channel in the "Data flow" and "Data record" tab of the Fortimus web page.



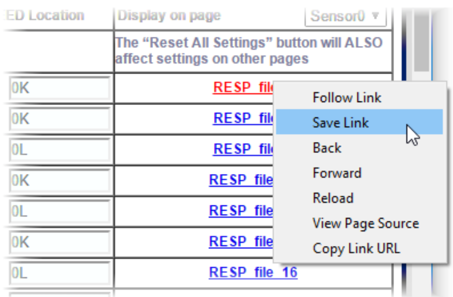
Clicking on a RESP file link produces a page like this:

```
#             << Guralp SEED response file builder v1.2-8615 >>
#
#             ======== CHANNEL RESPONSE DATA ========
B050F03     Station:     TEST
B050F16     Network:     DG
B052F03     Location:    0K
B052F04     Channel:     HNZ
B052F22     Start date:  2018,214,11:26:48
B052F23     End date:    No Ending Time
#             =======================================
#               +                  +----------------------------------------+                  +
#               +                  |   Channel Sensitivity,  TEST ch HNZ    |                  +
#               +                  +----------------------------------------+                  +
#
B058F03     Stage sequence number:                 0
B058F04     Sensitivity:                           2.131148E+05
B058F05     Frequency of sensitivity:              1.000000E+00 HZ
B058F06     Number of calibrations:                0
#
#               +               +----------------------------------------------+               +
#               +               |   Response (Poles & Zeros),  TEST ch HNZ     |               +
#               +               +----------------------------------------------+               +
#
B053F03     Transfer function type:                A [Laplace Transform (Rad/sec)]
B053F04     Stage sequence number:                 1
B053F05     Response in units lookup:              M/S**2 - Acceleration in Metres Per Second Squared
B053F06     Response out units lookup:             V - Volts
B053F07     A0 normalization factor:               3.022955E+12
B053F08     Normalization frequency:               1.000000E+00
```

Right-click anywhere and select “Back” to return to the Fortimus web page.



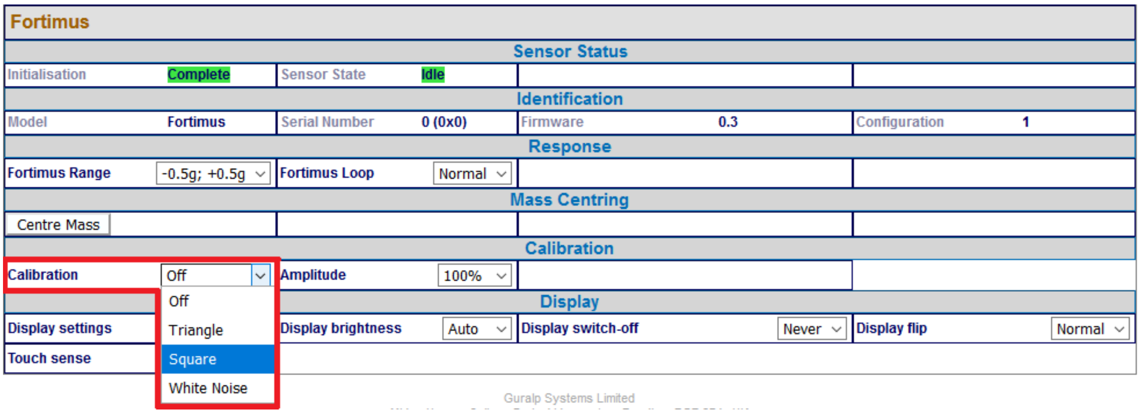
To save a RESP file, right click on it in the main list and select "Save Link":



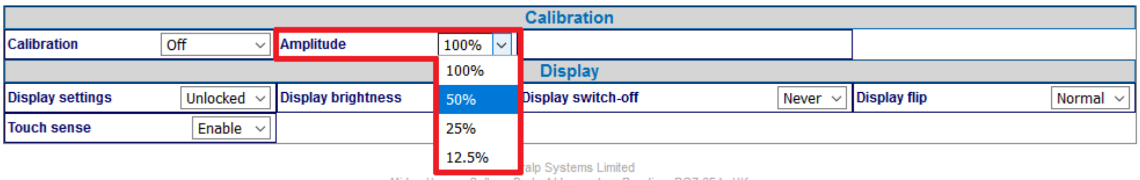
Note: RESP files are not available for channels that have a transform enabled. For details about transforms, see Section 7.16 on page 87.

7.14.5 Inject a calibration signal

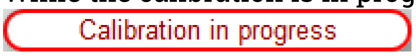
To check whether the Fortimus is correctly calibrated, go to the Setup tab of the web page and use the drop-down menu to choose between Triangle, Square and White Noise signal to be injected into the sensor's feedback loop.



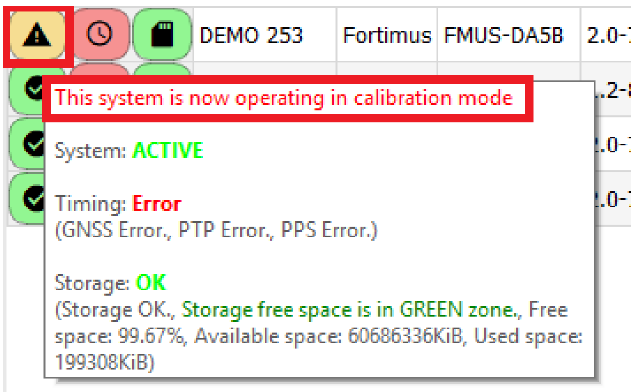
Adjust the calibration signal amplitude at 100%, 50%, 25% or 12.5% of the DAC full range.



Note: The calibration channel, named *0ACCC0*, produces an output if and only if the calibration is in progress.

While the calibration is in progress, the webpage shows the warning message 

and Discovery flags the status icon in yellow.

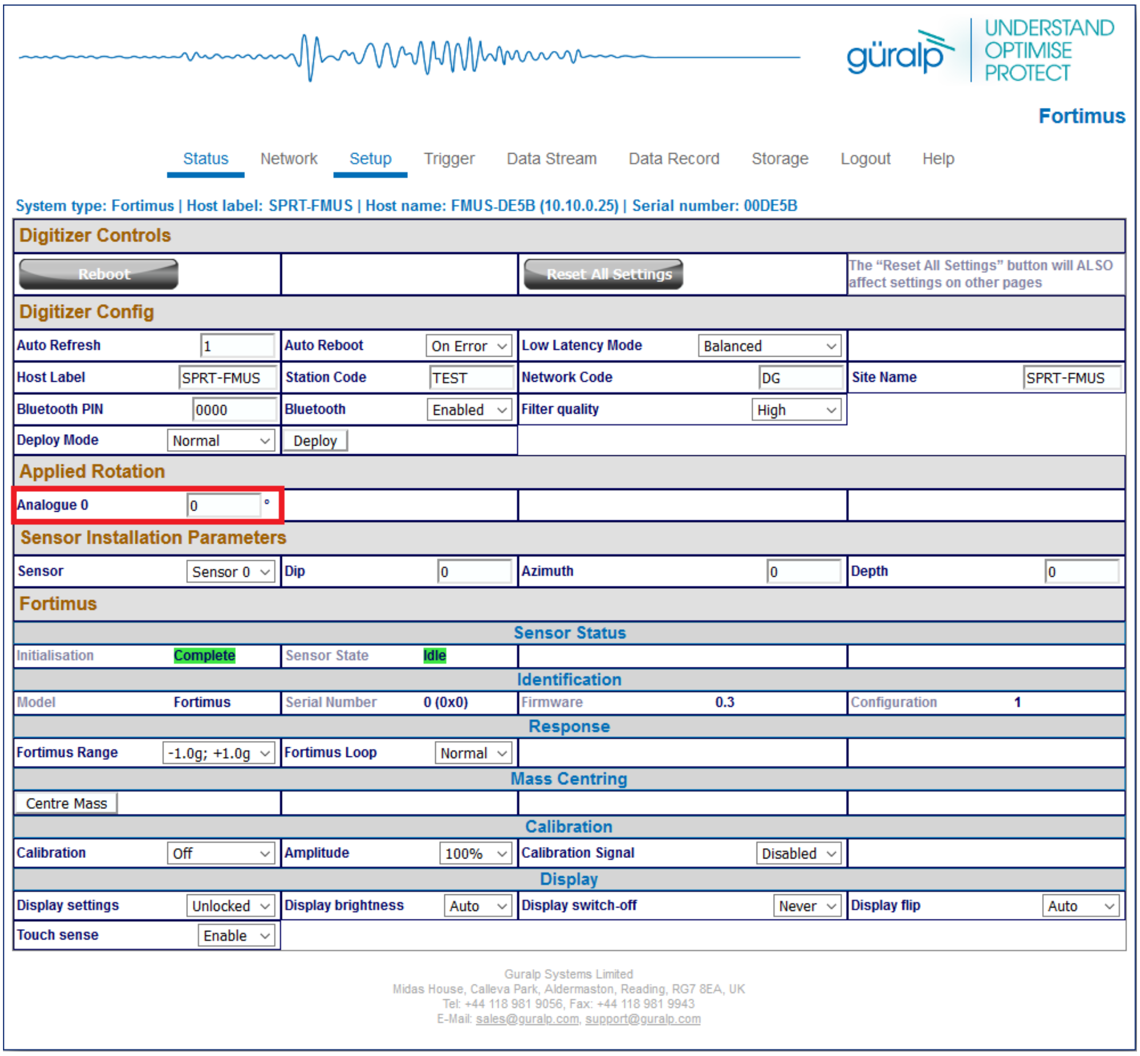


7.15 Setting sensor orientation and depth parameters

7.15.1 Applied rotation

A Matlab extension for Scream! allows easy determination of the exact orientation of a sensor relative to a surface reference sensor (which can be accurately aligned magnetically or geographically. The procedure is explained at https://www.guralp.com/howtos/determining-sensor-orientation.

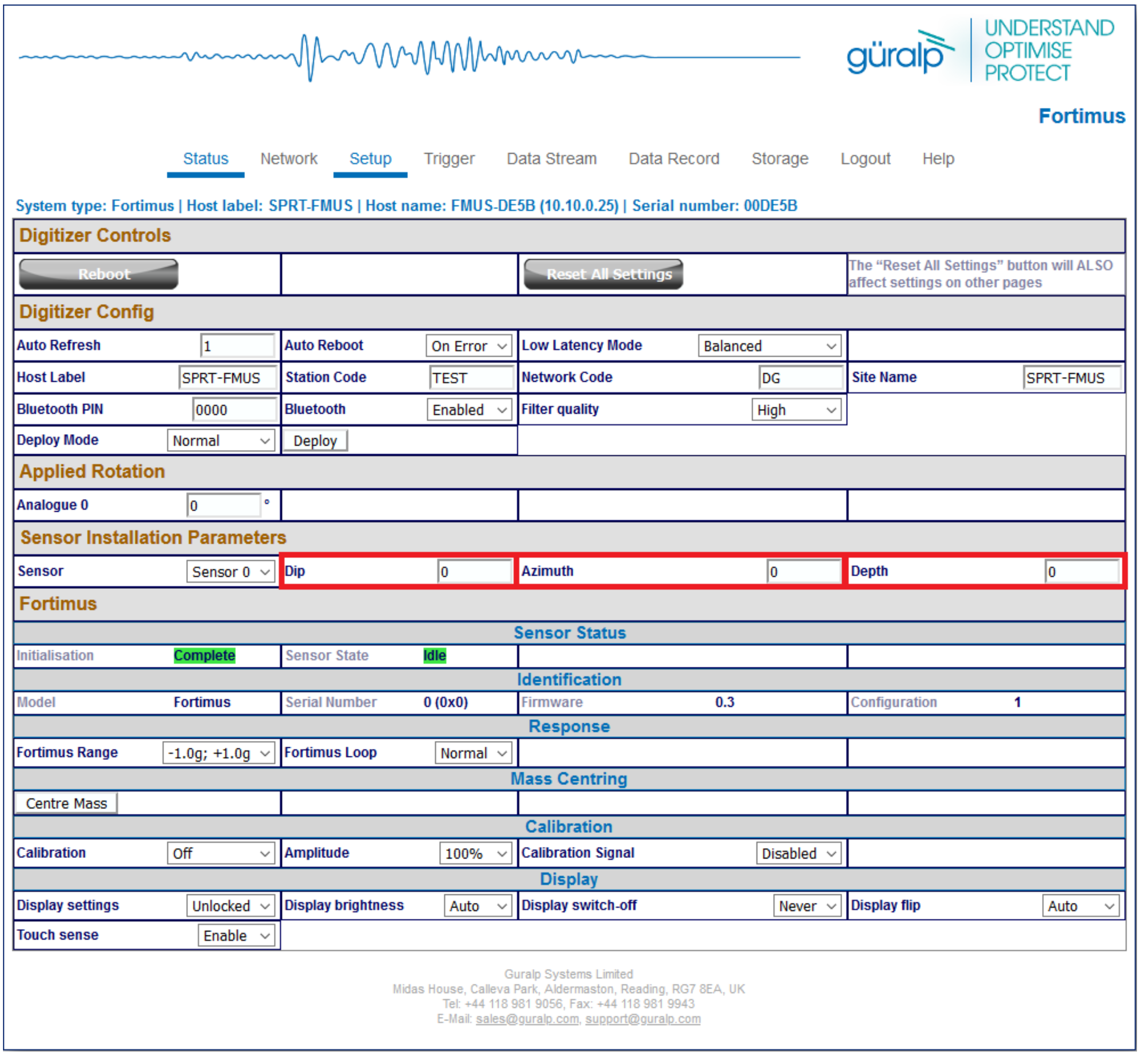
The Relative Orientation extension of Scream! provides a correction angle that can be entered into the Sensor Orientation section of the Fortimus web page.



Note: The input rotation is automatically applied to both transmitted and recorded data.

7.15.2 Instrument installation parameters

The Dip (tilt angle from vertical), Azimuth (tilt direction from North) and Depth of Fortimus can be set in the “Setup” tab of the web interface in the section “Instrument Installation Parameters”. The instrument to which the displayed parameters apply is selected using the drop-down menu.



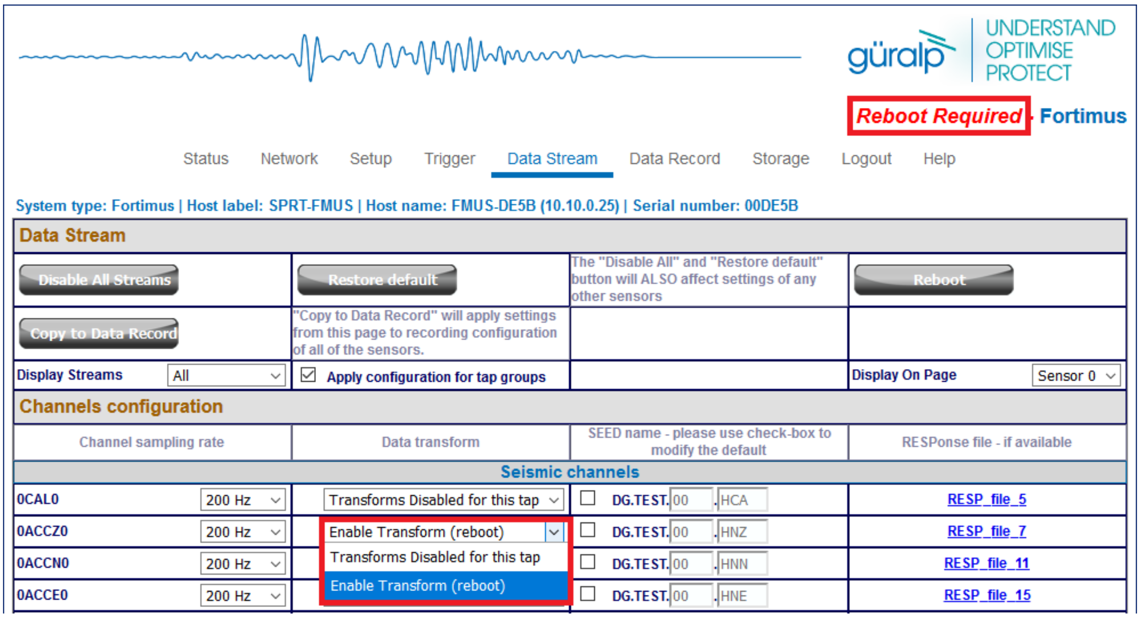
Note: The orientation and depth are not applied to the data, the parameters are only saved in the Dataless SEED.

7.16 Transforms

The Fortimus is capable of applying mathematical transforms to the streamed and recorded data. These include low-pass and high-pass filters, integration, differentiation, rotation, STA/LTA trigger etc.

When a specific transform is activated on a particular channel, the resulting streamed (or recorded, accordingly to the chosen configuration) data output is automatically transmitted and/or recorded with the transform applied. The units-of-measure are re-calculated accordingly.

Transform functions are enabled or disabled from the “Data Stream” and “Data Record” tabs for each channel.



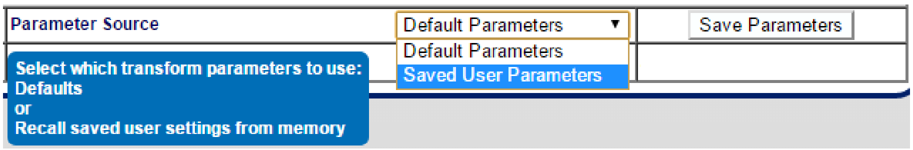
Note: To enable or disable a transform on any channel, it is necessary to reboot the Fortimus. Transforms can be applied only on enabled channels.

The available transforms are:

- Pass-through – see Section 7.16.1 on page 89.
- 2nd order bi-quadratic filter – see Section 7.16.6 on page 92.
- 1st order low-pass filter – see Section 7.16.3 on page 90.
- 1st order high-pass filter – see Section 7.16.4 on page 91.
- 1st order band/Notch filter – see Section 7.16.5 on page 91.
- STA/LTA ratio – see Section 7.16.10 on page 96.
- Integration – see Section 7.16.7 on page 93.
- Double integration – see Section 7.16.8 on page 94.
- Three-dimensional rotation – see Section 7.16.11 on page 98.
- EEW parameters – Observer – see Section 7.16.9 on page 95.
- Differentiation – see Section 7.16.2 on page 90.
- QSCDx sender – see Section 7.16.12 on page 99.
- MMA logger – see Section 7.16.13 on page 100.

Some transforms require parameters such as frequencies or coefficients. For these, the user can either use a fixed, default set, or create their own custom set.

To use customised parameters, visit the “Transform” tab and select the “Saved User Parameters” option in the “Parameter Source” drop-down menu. Type in the required parameters and then click Save Parameters to store them. It is possible to switch between Default and Saved User Parameters without altering the stored custom parameters but clicking Save Parameters while “Default parameters” is selected will overwrite the customised parameters with the default values.

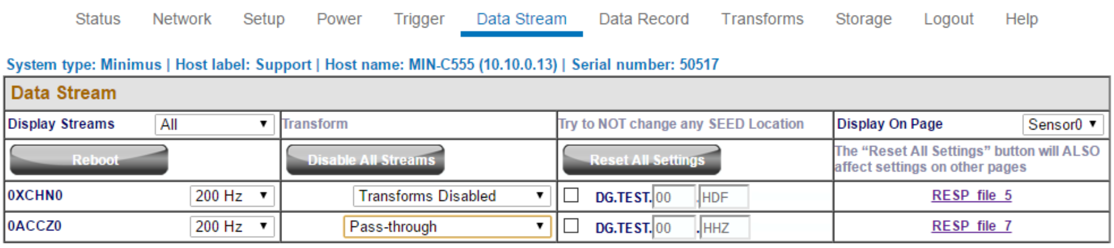


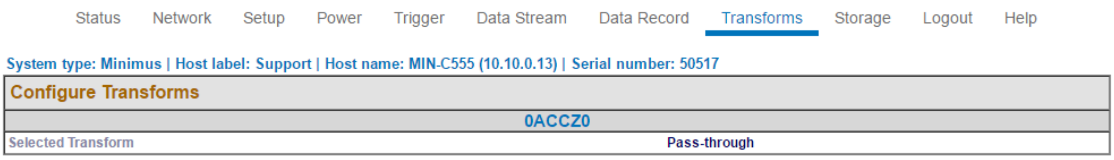
The various transforms are each described in the following sections.

Caution: The Disable All Streams button at the top of the "Transform" column does not disable *transforms* for all streams. It stops *transmission* of all streams, which may not be what you intend.

7.16.1 Pass-through

This null transform simply outputs a copy of the input data, without applying any transform. It has no configuration parameters.

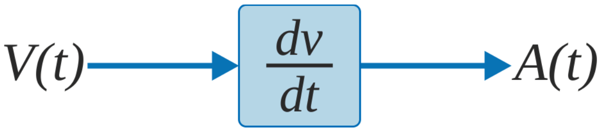


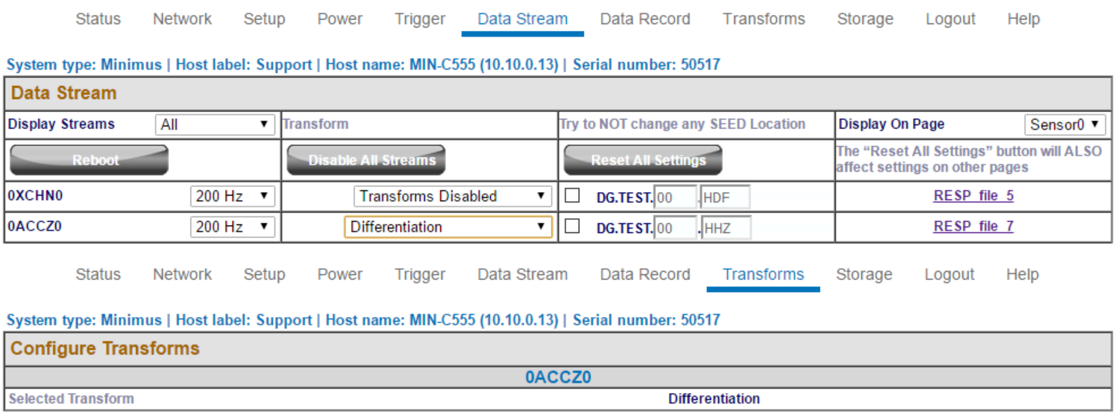


Note: This transform is selected by default when transforms are first enabled or when an invalid transform is selected. Do not use pass-through as a method of disabling transforms: instead, select "Disable transforms" from the drop-down menu next to each stream on the "Data Streams" tab,

7.16.2 Differentiation

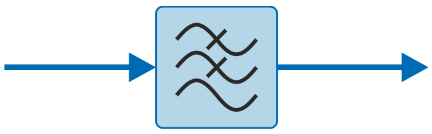
This transform differentiates the input data, e.g. if the input is a velocity (ms^{-1}) channel, the output will be acceleration (ms^{-2}). It has no configuration parameters.



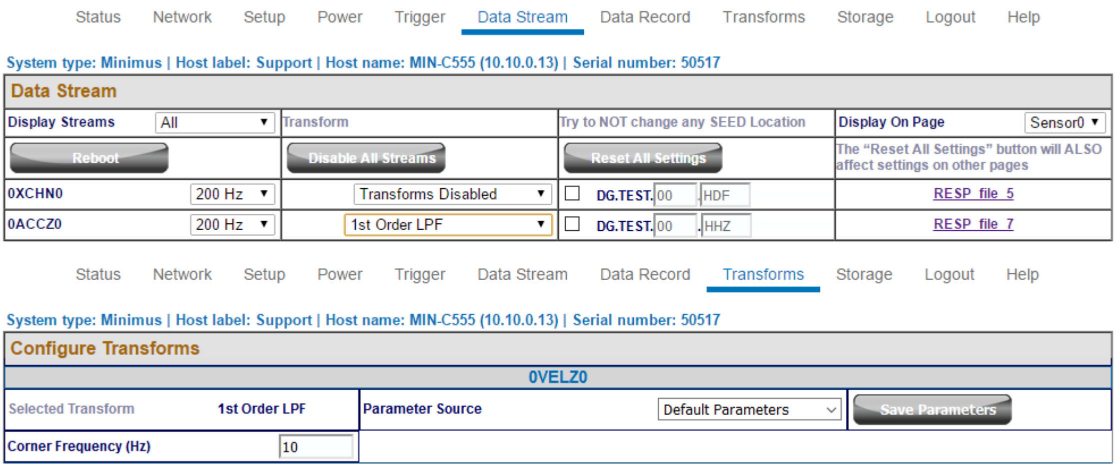


7.16.3 1st order LPF

This transform applies a first-order low-pass filter to the input data.

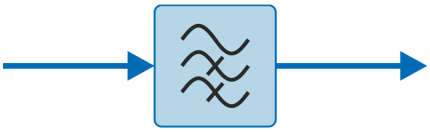


The single configurable parameter is "Corner Frequency": this specifies, in Hz, the frequency at which the output power is attenuated by -3 dB. Above this frequency, output power is attenuated by a further 6 dB per octave or 20 dB per decade.



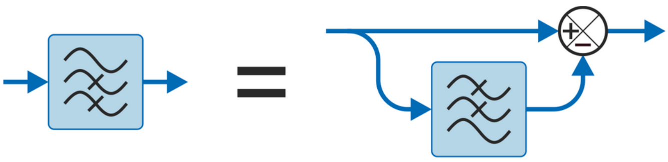
7.16.4 1st Order HPF

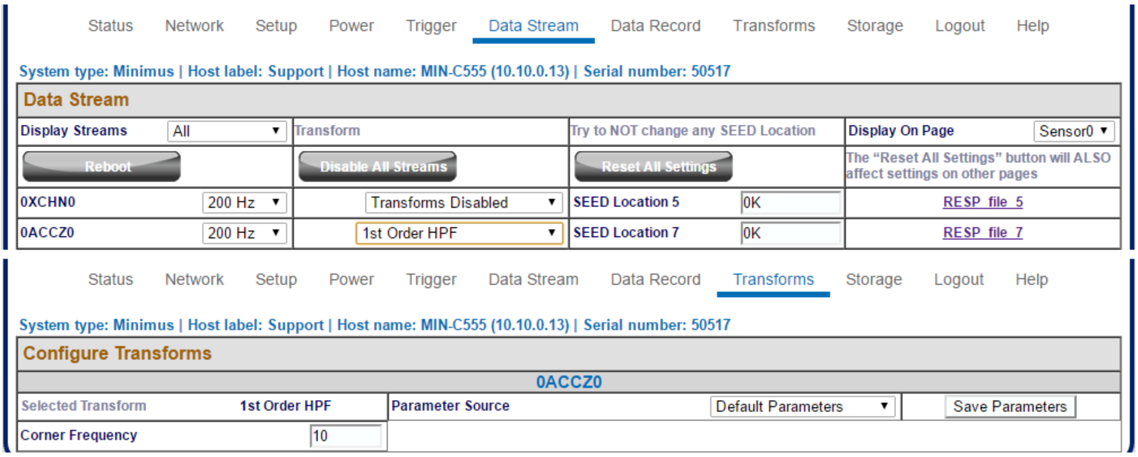
This transform applies a first-order high pass filter to the input data.



The output is the difference between a low-pass filtered copy of the signal and the unfiltered signal.

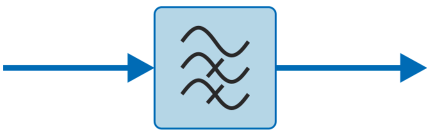
The single configurable parameter is "Corner Frequency": this specifies, in Hz, the frequency at which the output power is attenuated by -3 dB. Below this frequency, output power is attenuated by a further 6 dB per octave or 20 dB per decade.

> **Note:** The high-pass filter is implemented by subtracting the output of a low-pass filter from the unfiltered data:
>
> 



7.16.5 1st Order Band/Notch filter

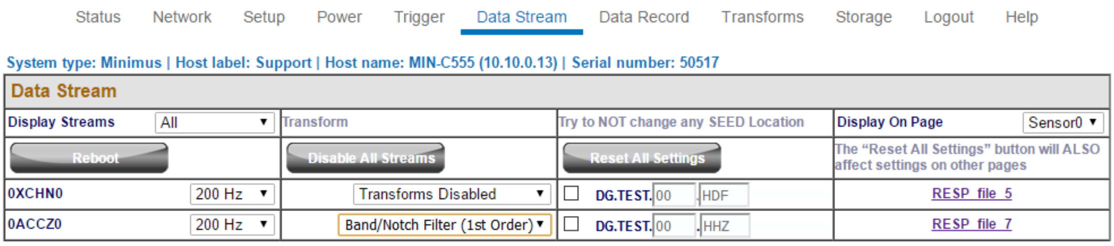
This transform applies first-order band stop or Notch filter to the input data.

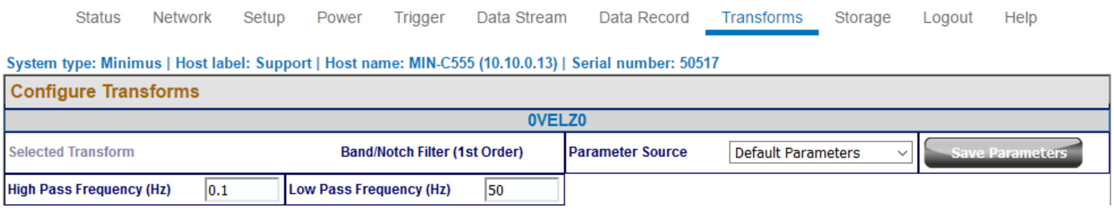


The band-stop filter is implemented as a configurable chain of two components:

- A 1st order high pass filter (implemented using an LPF and a subtractor, as described in Section 7.16.4 on page 91), to gradually attenuate low-frequency integrator drift.
- A 1st order low pass filter (implemented as described in Section 7.16.3 on page 90).

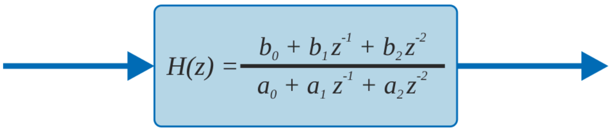
The configurable parameters are the "High Pass Frequency" (HPF corner frequency as defined in Section 7.16.4 on page 91) and the “Low Pass Frequency” (LPF corner frequency as defined in Section 7.16.3 on page 90).





7.16.6 2nd Order biquad

This transform applies a second-order bi-quadratic filter to the input data.

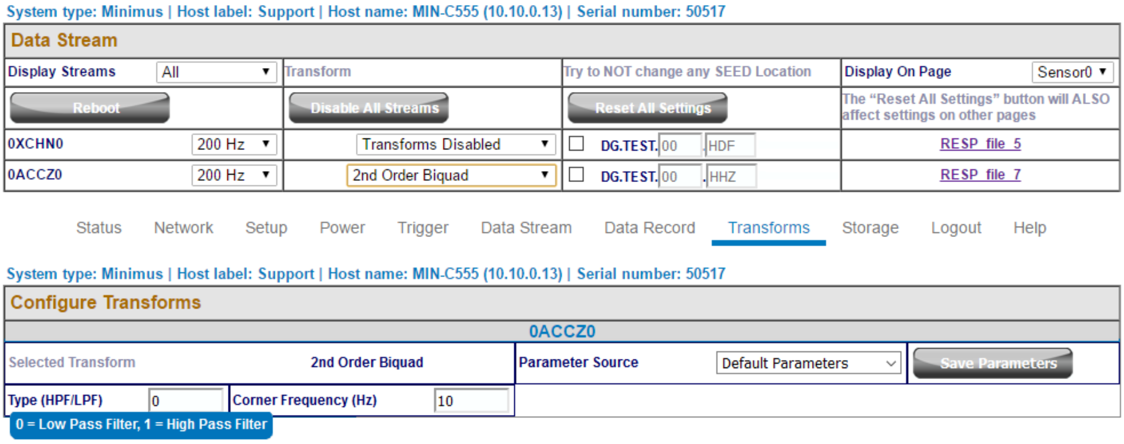


$$H(z) = \frac{b_0 + b_1 z^{-1} + b_2 z^{-2}}{a_0 + a_1 z^{-1} + a_2 z^{-2}}$$

The biquad filter is a second-order recursive linear filter, containing two poles and two zeros. In the Z-plane, the transfer function is the ratio of two quadratics in z, as shown.

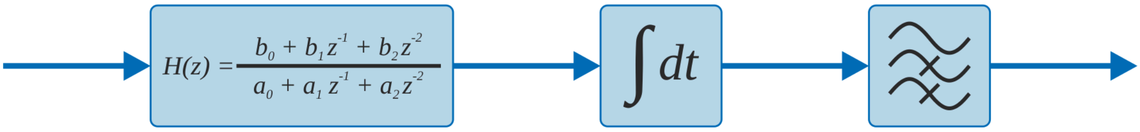
The two configurable parameters are:

- "Corner Frequency": this specifies, in Hertz, the frequency at which the output power is attenuated by -3 dB; and
- "Type":
  - 0: low-pass mode; and
  - 1: high-pass mode.



7.16.7 Integration

This transform integrates the input data, e.g. if the selected channel unit is velocity (ms^{-1}), the output produced is displacement (m).

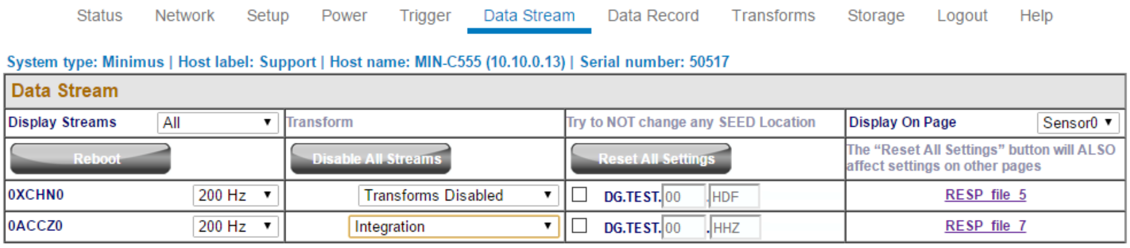


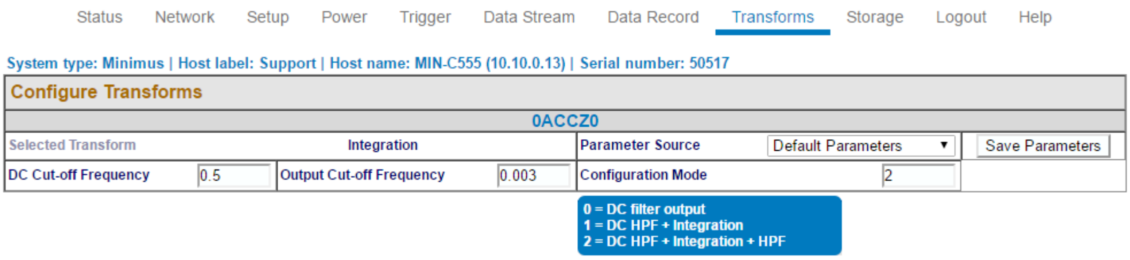
The integration transform is implemented as a configurable chain of three components:

- A DC filter (2nd order high-pass bi-quadratic) removes any DC component, which would cause the output to grow without limit;
- The integrator itself; and
- A 1st order high pass filter (implemented using an LPF and a subtractor, as described in Section 7.16.4 on page 91), to gradually attenuate low-frequency integrator drift.

The configurable parameters are:

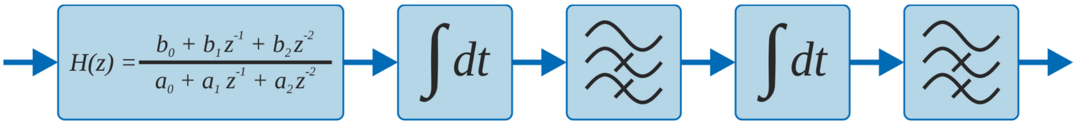
- "DC Cut-off Frequency": this specifies the -3 dB point (in Hertz) for the initial high-pass filter;
- "Output Cut-off Frequency": this specifies the -3 dB point (in Hertz) for the output high-pass filter;
- “Configuration Mode”, which configures how many elements of the chain are used. The options are:
    - Apply only the initial DC filter;
    - Apply the DC filter and the integrator; and
    - Apply the DC filter, the integrator and the output HPF.





7.16.8 Double Integration

This transform integrates the input data twice so, for example, if the selected channel is acceleration (ms^{-2}), the output produced is displacement (m).

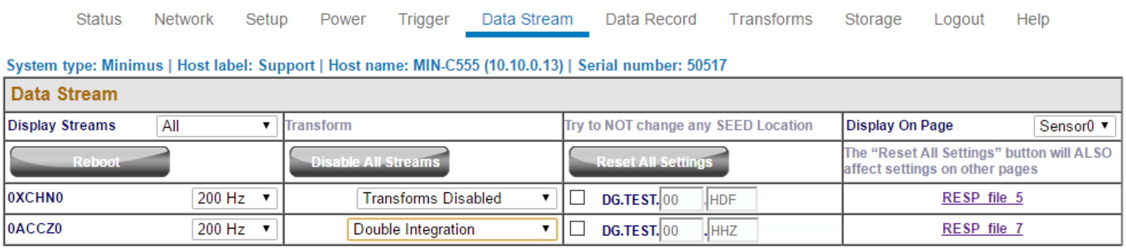


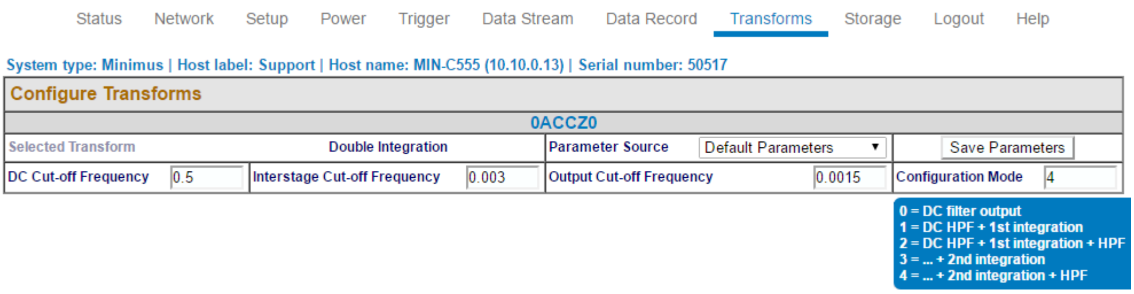
Analogously to the single integrator, the double integrator applies an initial DC high-pass filter and then two further high-pass filters, one at the output of each integrator. The high-pass filters are implemented using an LPF and a subtractor, as described in Section 7.16.4 on page 91.

The configurable parameters are:

- "DC Cut-off Frequency": this specifies the -3 dB point (in Hertz) for the initial high-pass filter;
- "Interstage Cut-off Frequency": this specifies the -3 dB point (in Hertz) for the first integrator output high-pass filter;
- "Output Cut-off Frequency": this specifies the -3 dB (in Hertz) point for the second integrator output high-pass filter;
- “Configuration Mode”, which configures how many elements of the chain are used. The options are:
  - Apply only the initial DC filter;
  - Apply DC filter and first integrator;
  - Apply DC filter, first integrator and interstage HPF;
  - Apply DC filter, first integrator, interstage HPF and second integrator; and

- Apply DC filter, first integrator, interstage HPF, second integrator and second output HPF.

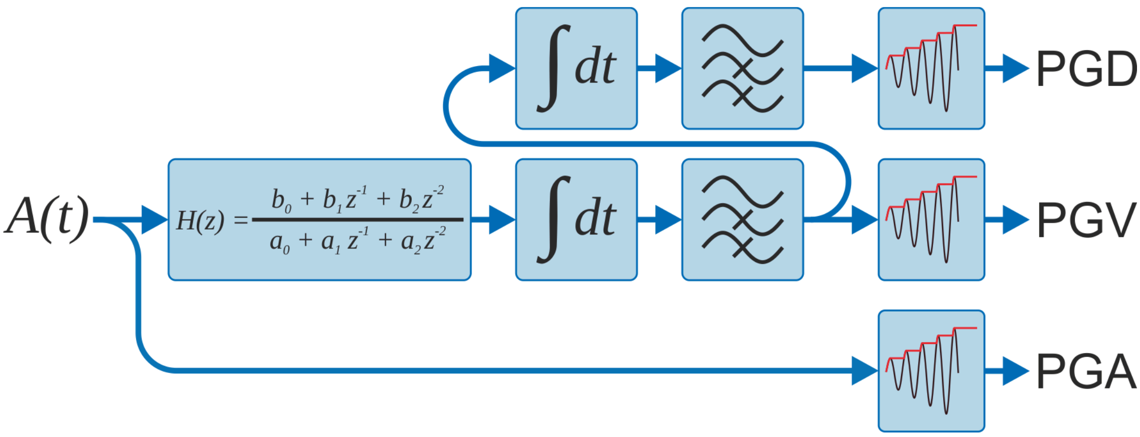




7.16.9 EEW Parameter Observer

When an EEW trigger occurs (or is simulated – see below), the peak ground motion values (Peak Ground Acceleration (PGA), Peak Ground Velocity (PGV) and Peak Ground Displacement (PGD)) are calculated and automatically recorded over the selected time-window and subsequently transmitted as a CAP message (see Section 7.17 on page 101 for more details). This transform allows the operator to directly observe the acceleration, velocity and displacement output on the real-time streams. It is available for use with both velocity and acceleration input signals.

Note: The EEW parameter transform can work as an observer: doesn't necessarily modify the data streams on which it is applied.

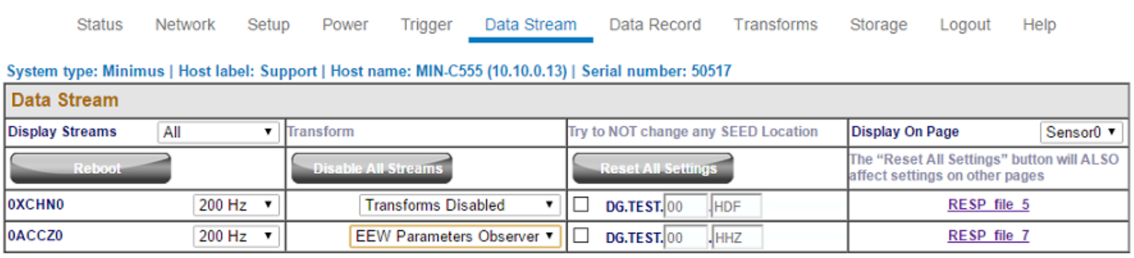


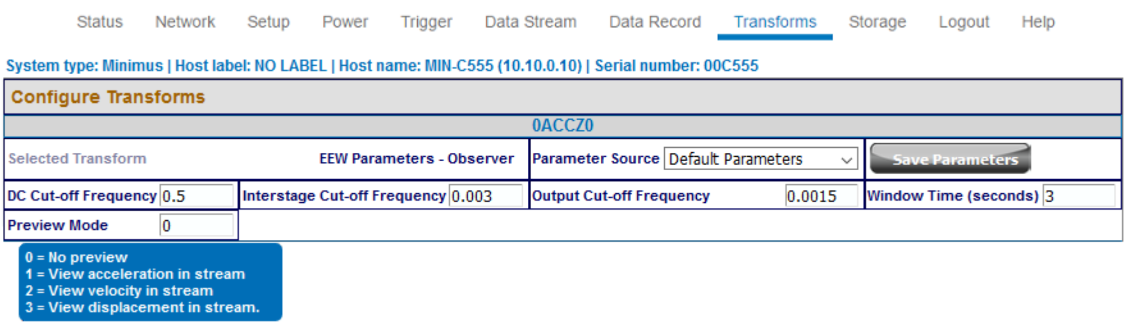
The high-pass filters are implemented using an LPF and a subtracter, as described in Section 7.16.4 on page 91.

The configurable parameters are:

- "DC Cut-off Frequency": this specifies the -3 dB point (in Hertz) for the initial high-pass filter;
- "Interstage Cut-off Frequency": this specifies the -3 dB point (in Hertz) for the first integrator output high-pass filter. This is only used when the input signal is acceleration;
- "Output Cut-off Frequency": this specifies the -3 dB (in Hertz) point for the sole (velocity input) or final (acceleration input) integrator output high-pass filter;
- "Window time": this specifies the duration, in seconds, of the time-window over which the peak values are reported; and
- The values to be shown in the output stream:
    - Peak Ground Acceleration (PGA);
    - Peak Ground Velocity (PGV); or
    - Peak Ground Displacement (PGD).

Note: Güralp recommend using the integration (Section 7.16.7 on page 93) and double integration (Section 7.16.8 on page 94) transforms to test the filter parameters, because the effect of the parameters will then be clearly visible in the transformed streams. Once suitable parameters have been determined, they can be copied to the EEW Parameter Observer transform.

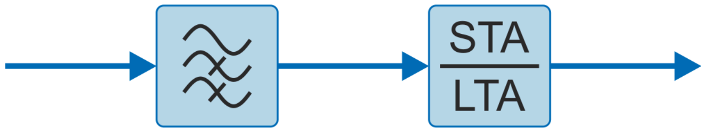




7.16.10 STA/LTA Ratio

The Earthquake Early Warning system (EEW) compares the ratio of a short-term average (STA) to a long-term average (LTA) in order to detect "trigger" conditions. For more information see Section 7.17 on page 101.

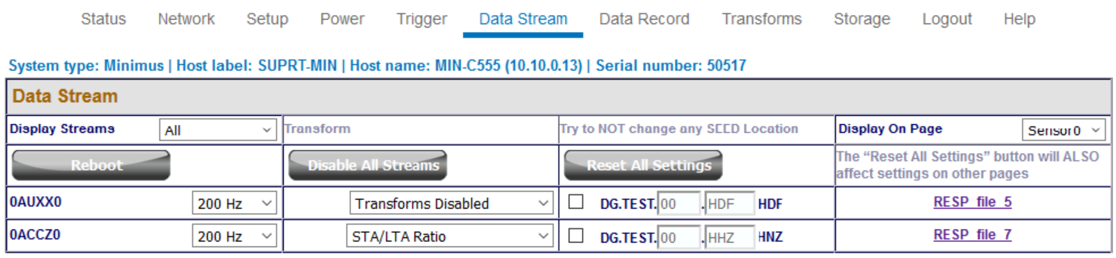
This transform is included to help determine parameters for configuring the EEW system. It does not affect the operation of the EEW system in any way. The transform calculates the ratio between the result of the Short Term Average filter and the Long Term Average filter. The input signal is passed through a high-pass filter which removes any DC offset.

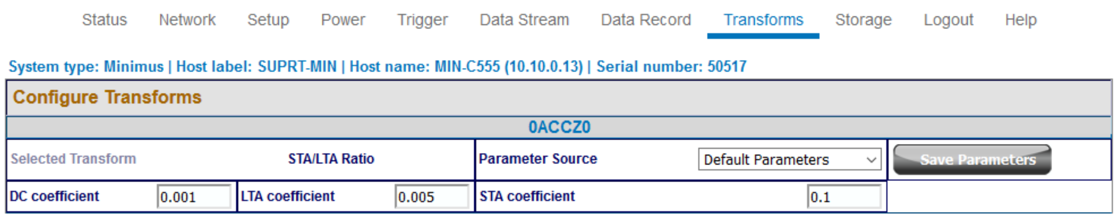


The configurable parameters are:

- "DC Frequency (Hz)": this specifies the corner frequency (-3 dB point) in Hertz for the initial high-pass filter;
- "LTA Period (seconds)": this is the Short Term Average filter time period (the reciprocal of the corner frequency);
- "STA Period (seconds)": this is the Long Term Average filter time period (the reciprocal of the corner frequency);
- “Trigger Threshold”: this is the STA/LTA ratio threshold value above which a trigger will occur;
- “Event Window (Seconds)”: this is the duration of the event after the STA/LTA trigger occurs; any subsequent threshold crossing within this period is treated as belonging to the same event. This can be used to avoid spurious false triggers.
- “Initial Timeout (Seconds)”: this specifies an initial period of insensitivity after the trigger function is initialised or changed. This can be used to avoid spurious false triggers.

The high-pass filter is implemented using an LPF and a subtracter, as described in Section 7.16.4 on page 91.

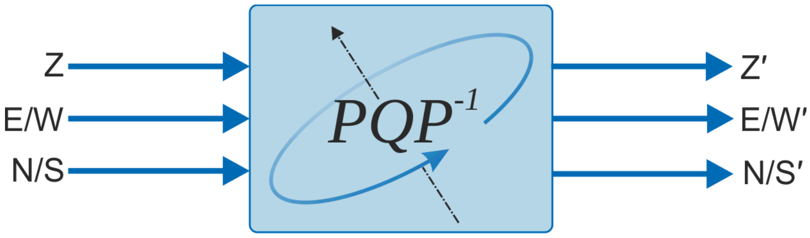




7.16.11 Three-dimensional rotation

This transform rotates three velocity/acceleration seismic components in space. Rotations are represented by unit quaternions (in preference to the more usual Euler angles: yaw, pitch and roll) because they are unambiguous and avoid the problem of gimbal lock.

Note: The rotation transform can only be applied if it is enabled in all three velocity/acceleration components of a single instrument at the same sample rate.



Any rotation in three dimensional space can be represented as a combination of a unit three-dimensional vector, $\vec{u}$, which specifies the axis (and sense) of the rotation, and a scalar angle, θ, which specifies the amount of rotation

Güralp follows a North, East, Up convention when describing sensor orientation. Using this convention, we can represent $\vec{u}$ as [u,v,w] and use Pauli's extension to Euler's formula:

$$\mathbf{q} = \cos\left(\frac{\theta}{2}\right) + (\, u\,\mathbb{i} + v\,\mathbb{j} + w\,\mathbb{k}\,)\sin\left(\frac{\theta}{2}\right)$$

to form a quaternion: $\mathbf{q} \equiv [a, b, c, d]$ where:

$$a = \cos\left(\frac{\theta}{2}\right),\quad b = \sin\left(\frac{\theta}{2}\right) u,\quad c = \sin\left(\frac{\theta}{2}\right) v \quad \text{and} \quad d = \sin\left(\frac{\theta}{2}\right) w$$

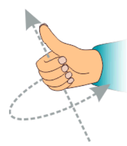
For example, a perfectly- oriented sensor has a (null) rotation of $[1,0,0,0,]$, where the sensor's Z, N and E axes align with the North, East and Up global axes.

A rotation of

$$\left[\frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}, 0, 0\right]$$

represents a sensor that has been rotated 90° about its x axis to align the sensor's Z, N and E axes with global North, Down and East respectively.

Note: Clockwise rotations, when looking along an axis, are denoted as positive. This is generally known as the "right-hand rule" because, if you point your right thumb along the (directed) axis, your fingers will curl in a clockwise direction about it.



In the degenerate case of a simple rotation about a vertical axis (commonly used to correct data from a misaligned borehole instrument), the axis of rotation is vertical, so our unit vector is [0,0,1] (following the "North, East, Up" convention). To rotate by θ (where positive θ is clockwise when looking upwards), our quaternion should be:

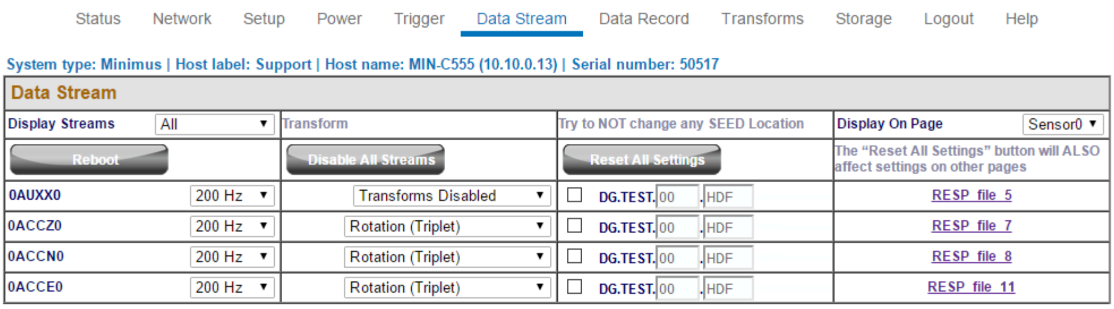
$$\mathbf{q} = \cos\left(\frac{\theta}{2}\right) + (\,0\,\mathbb{i} + 0\,\mathbb{j} + 1\,\mathbb{k}\,)\sin\left(\frac{\theta}{2}\right) \equiv \left[\cos\left(\frac{\theta}{2}\right),\, 0\,,\, 0\,,\, \sin\left(\frac{\theta}{2}\right)\right]$$

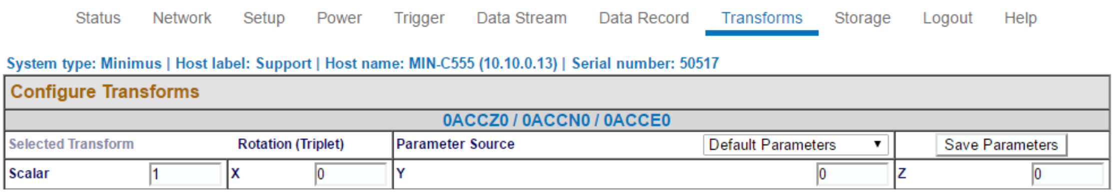
As a final check, note that

$$a^2+b^2+c^2+d^2 = \cos^2\left(\frac{\theta}{2}\right) + 0^2 + 0^2 + \sin^2\left(\frac{\theta}{2}\right) = 1$$

which satisfies our requirement for a unit quaternion. The parameters to enter in the Configure Transforms fields are, therefore:

$$\textbf{Scalar} \Rightarrow \cos\left(\frac{\theta}{2}\right)\ ,\quad \mathbf{X} \Rightarrow 0\,,\quad \mathbf{Y} \Rightarrow 0 \quad \text{and } \mathbf{Z} \Rightarrow \sin\left(\frac{\theta}{2}\right)$$

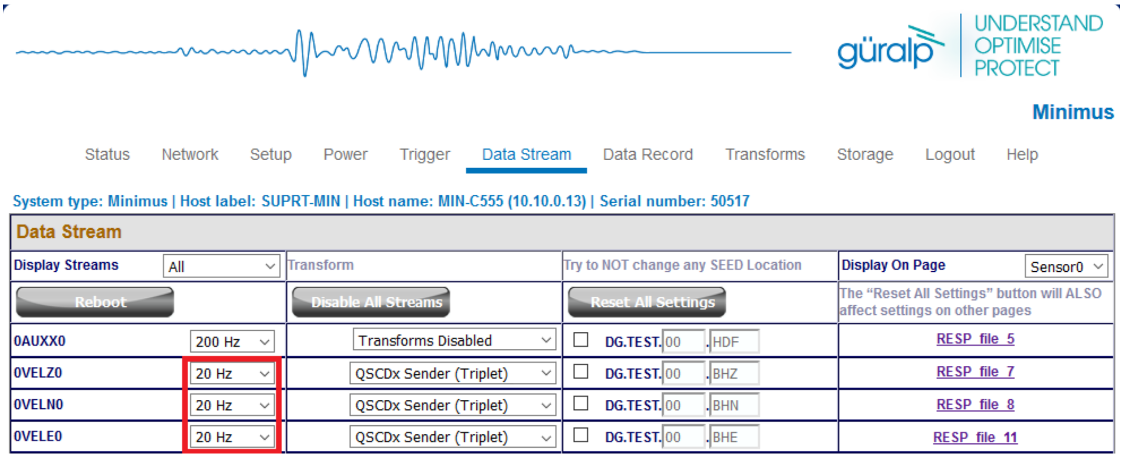




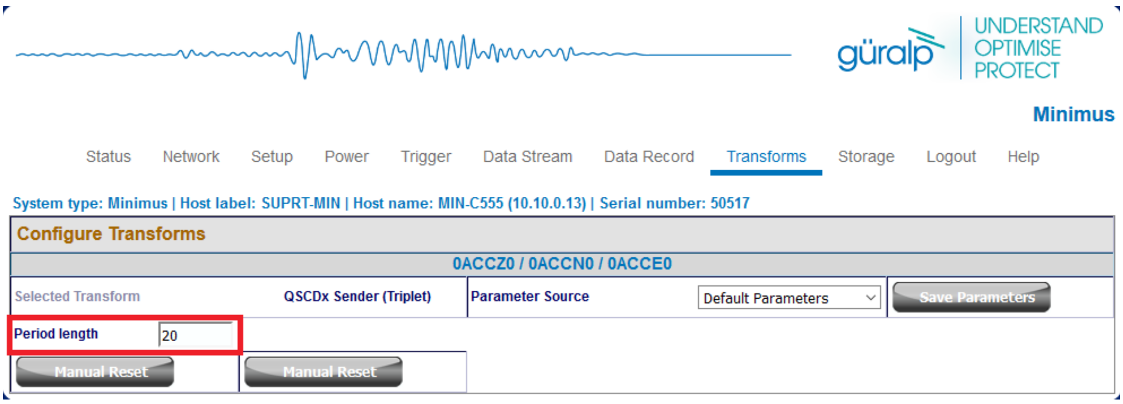
7.16.12 QSCD Sender (triplet)

The QSCD protocol (Quick Seismic Characteristic Data) transmits values computed from the three triaxial streams of an instrument. One packet is transmitted every second so the number of samples in each packet is equal to the sample rate of the three input streams.

QSCD calculations are implemented using transforms and configured via the Data Stream tab of the Fortimus web page. The three input channels must all be configured with the QSCD (triplet) transform. (The transform is disabled if the sample rates of the input streams do not match.)



In the Transform tab, the parameter "Period length" configures the number of samples to include in a QSCD packet. For example, QSCD20 requires the sample rate of the streams to be 20 sps so the "Period length" must be set to 20 (samples), in order to send a packet every second.



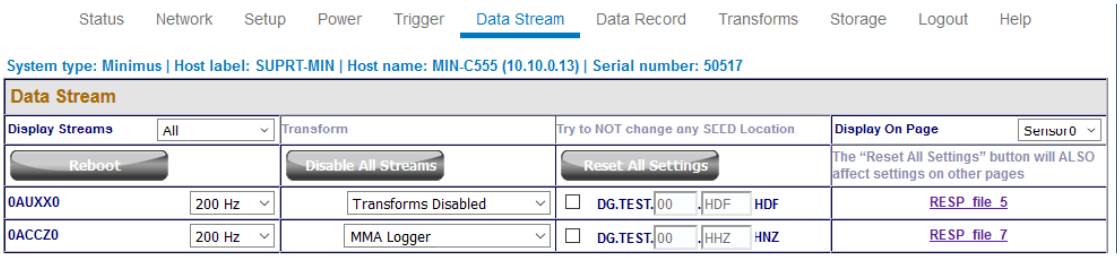
7.16.13 MMA Logger

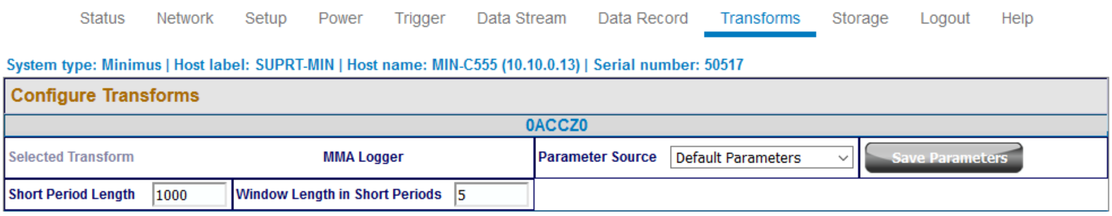
The MMA logger transform [is a function that periodically calculates and logs Maximum Minimum and mean (Average) values over a selected window of data.

Note: The EEW parameter transform is an observer: doesn't modify the data streams on which it is applied.

The two configurable parameters are:

- "Short Period Length": this is the length of time between logging events expressed in samples, e.g. 200 samples when applied to a tap configured at 100sps produces an MMA calculation and logging every 2 seconds.
- "Window Length in Short Periods": is the length of window over which the Max, Min and Average values are calculated, in terms of number of short periods.





7.17 Earthquake Early Warning

The “Trigger” tab is dedicated to Earthquake Early Warning settings. These are disabled by default because of the amount of processing resource – and hence, power – consumed by triggering calculations.

The Triggers section of the web page enables the user to configure the triggering system. The trigger Sources should be configured firstly because different configuration options are displayed for different source types. Once the source-specific settings are configured, the scores and destinations should be specified. Destinations can be shared between sources, allowing the creation of networks (directed graphs) of systems for distributed event detection.

The heart of the Earthquake Early Warning subsystem are the triggering algorithms: an STA/LTA (Short-Time-Average divided by Long-Time-Average) and level (threshold) algorithms.

The STA/LTA algorithm continuously calculates the average values of the absolute amplitude of a seismic signal in two simultaneous moving-time windows. The short time average (STA) is sensitive to seismic events while the long time average (LTA) provides information about the current amplitude of seismic background noise at the site. When the ratio of STA to LTA exceeds a pre-set threshold value an event is “declared”.

The threshold algorithm, instead, declares the presence of an event when the raw data in input passes above or below a pre-set threshold value.

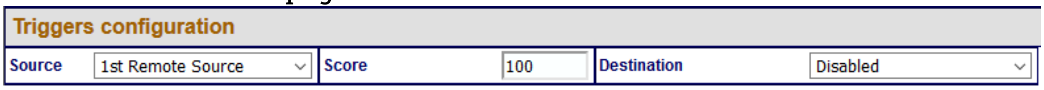
7.17.1 Trigger sources

The available sources for the trigger are listed below, along with the configurable fields available in each case.

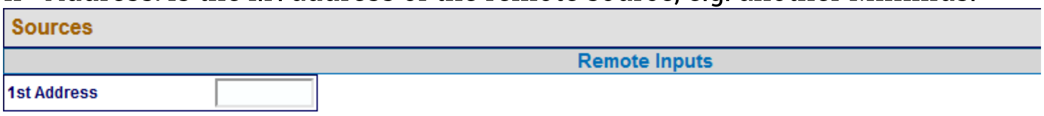
- **1st/2nd/3rd/4th Remote Source**: This setting is used for multiple-source triggering networks. The sources specified here are other Fortimus or Minimus based instruments, specified by the I.P. addresses configured in the "Remote Inputs" section:

  The configurable fields in these cases are:

  - Score: this assigns a number of points to this trigger. The points value is used when assessing multiple-source triggers. This value is ignored when a trigger is not configured to use multiple sources.
  - Destination: this drop-down menu specifies the destination for the trigger. See Section 7.17.2 on page 105 for more information.



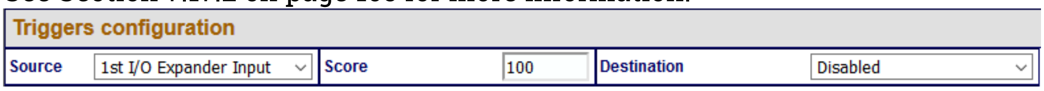
  - n^{th} Address: is the I.P. address of the remote source, e.g. another Minimus.



- **1st/2nd/3rd/4th I/O Expander Input**: Select this value to use inputs from a connected Fortimus 8 channel I/O Expander Module.

  The configurable fields in these cases are:

  - Score: this assigns a number of points to this trigger. The points value is used when assessing multiple-source triggers. This value is ignored when a trigger is not configured to use multiple sources.
  - Destination: this drop-down menu specifies the destination for the trigger. See Section 7.17.2 on page 105 for more information.



- **Tap Trigger *N***: seismic or environmental Fortimus channels selectable among any of the active taps in the "Data Stream" and "Data Record" tabs.

  The configurable fields in these cases are:

  - Score: this assigns a number of points to this trigger. The points value is used when assessing multiple-source triggers. This value is ignored when a trigger is not configured to use multiple sources.

- Destination: this drop-down menu specifies the destination for the trigger. See Section 7.17.2 on page 105 for more information.

Triggers configuration					
Source	Tap Trigger A [0ACCZ0]	Score	100	Destination	Disabled

- Sensor number: this drop-down menu is required to enables the trigger on one of Sensor0, the Fortimus.
- Tap: this drop-down menu select the stream to use as input of the trigger algorithm. The choice is between single taps, e.g. *0ACCZ0*, or triplets, e.g. *First Seismo Triplet*.
- Trigger type: this drop-down menu chooses to use either STA/LTA or threshold algorithm.

  The STA/LTA trigger algorithms includes the configuration of the following parameters:

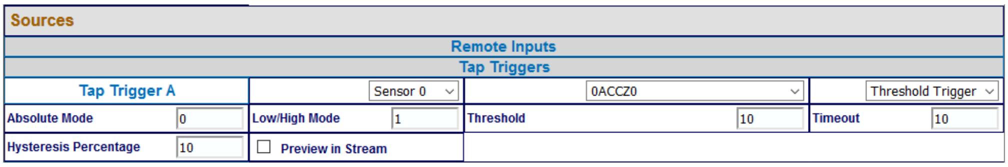
  - "DC Frequency": initial AC coupling HPF corner frequency;
  - "LTA Period": Long Term Average filter time period (1/corner frequency);
  - "STA Period": Short Term Average filter time period (1/corner frequency);
  - "Trigger Threshold": STA/LTA ratio level at which trigger occurs;
  - "Event Window": After and even has been detected, subsequent crossing of the STA/LTA ratio threshold within the defined event window are treated as part of the same event and, therefore, not considered as new trigger event;
  - "Initial Timeout": period of inactivity after the trigger function is initialised in order to avoid false triggers.

Sources							
Remote Inputs							
Tap Triggers							
Tap Trigger A		Sensor 0		0ACCZ0		STA/LTA Trigger	
DC Frequency (Hz)	0.04	LTA Period (Seconds)	12	STA Period (Seconds)	0.5	Trigger Threshold	12
Event Window (Seconds)	5	Initial Timeout (Seconds)	10	☐ Preview in Stream			

  The threshold trigger algorithms includes the configuration of the following parameters:

  - "Absolute Mode": specifies if the threshold has to act on magnitude with sign (0) or absolute value of the signal (1).
  - "Low/High Mode": defines whether the threshold is exceeded when the signal passes below it (0) or above it (1);
  - "Threshold": value of the threshold expressed in native signal unit, e.g. m/s^2;

- "Timeout": specifies the time to wait (in seconds), after the threshold crossing, before accepting a new event;
- "Hysteresis Percentage": defines the hysteresis point in terms of percentage of threshold value below or above threshold. The hysteresis point is below the threshold for High Mode, above the threshold for Low Mode.



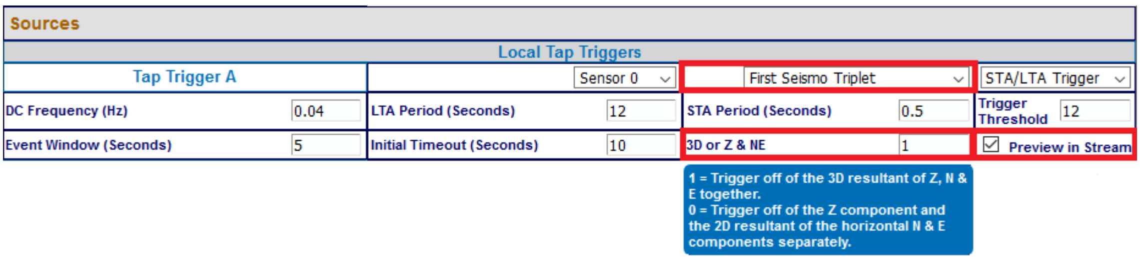
The "Preview in Stream" box temporally shows the in the live streams the output calculated by the trigger algorithm, e.g. the STA/LTA ratio. In the STA/LTA ratio trigger, when a single stream is selected as source, the calculated STA/LTA ratio is shown in place of the original data.

> **Note:** Only STA/LTA ratio has preview on single streams, both Threshold and STA/LTA ratio have preview of triplets.

When a triplet is selected as source, "3D or Z & NE" parameters is used to choose what type of preview to visualise.

For STA/LTA ratio trigger algorithm:

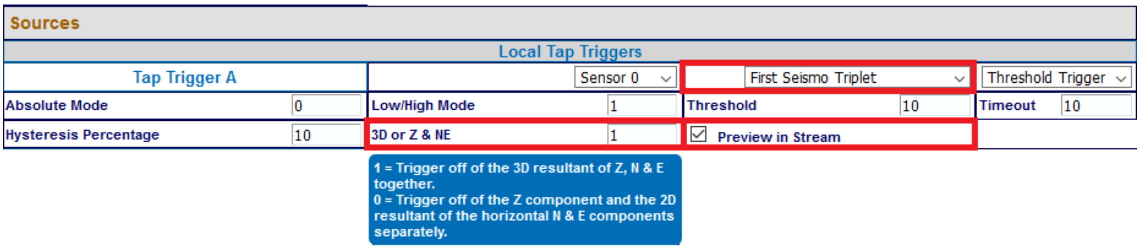
- 0: shows STA/LTA ratio calculated on 2D resultant vector of N and E components. The 2D STA/LTA ratio is shown in place of original E/W component. Also, shows the STA/LTA ratio calculated on Z component and it is shown in place of original Z component. N/S component shows normal seismic output.
- 1: shows STA/LTA ratio calculated on 3D resultant vector of Z, N and E components. The STA/LTA ratio is shown on E/W component. Z and N/S components show normal seismic output.



For Threshold trigger algorithm:

- 0: shows the 2D resultant vector of N and E components. The 2D resultant is shown in place of E/W component. Z and N/S components show normal seismic output.

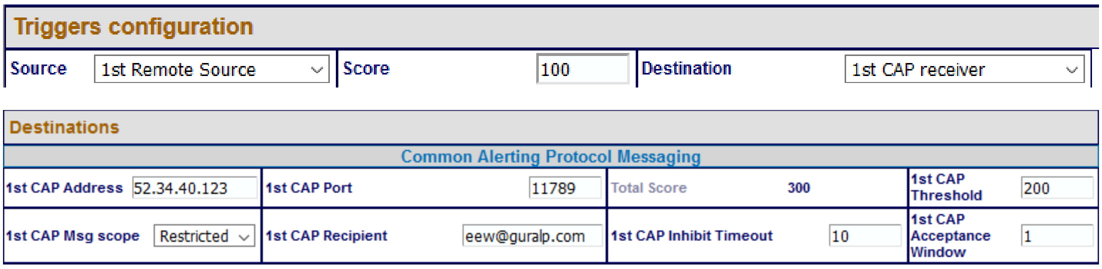
- 1: shows the 3D resultant vector of Z, N and E components. 3D resultant is shown in place of E/W component. Z and N/S components show normal seismic output.



7.17.2 Trigger destinations

The options available form the various Destination fields are:

- **1st/2nd/3rd/4th CAP receiver**: When a trigger is declared, the system will issue messages using the Common Alerting Protocol (for the full specification of this protocol, please refer to http://docs.oasis-open.org/emergency/cap/v1.2/CAP-v1.2-os.html). This field selects to which of the four available CAP receivers the trigger information should be sent to.



Various parameters control how the CAP message is created:

- n^{th} CAP Address: the I.P. address or DNS name of the CAP receiver;
- n^{th} CAP Port: the UDP port on which the CAP receiver is listening;
- Total Score: this is an information field, it displays an automatically-calculated total of the scores from all of the input sources that specify this destination;
- n^{th} CAP Threshold: this threshold is used when multiple input sources contribute to this trigger. Otherwise trigger threshold from source configuration is used.
- n^{th} CAP Msg scope: this value is copied to the "scope" field of the CAP message;
- n^{th} CAP Recipient: this value is copied to the "addresses" field of the CAP message;

- *n*th CAP Inhibit Timeout: is the time the Fortimus waits before sending new CAP message if a new event is detected after a previous CAP message was sent;
- *n*th CAP Acceptance Window: subsequent source triggers for a given destination are counted towards the cumulative score if they arrive within this window;

Common Alerting Protocol								
CAP Msg Expiry	300	seconds	CAP Msg Web URL	https://cap-validator.appspot.com	CAP Msg HMAC Key	secret		

- CAP Msg Expiry: this parameter determines the value used to populate the optional “expires” field in the CAP message. If required, it should be specified in seconds.
- CAP Msg Web URL: this parameter determines the value used to populate the optional “web” field in the CAP message. It should be a full, absolute URI for an HTML page or other text resource with additional or reference information regarding this alert.
- CAP Msg HMAC Key: a shared key used for signing the CAP message. All CAP messages generated by Fortimus are signed. The user should set this key to a private value. The HMAC digest can then be used to both authenticate the sender and validate the contents of CAP messages by anyone who is privy to the shared key. This prevents the generation of false, malicious CAP messages by a third party.

EEW parameters (PGA, PGV and PGD values) are sent in the CAP messages body if and only if the “EEW parameter – Observer” transform is enabled on the source taps (see Section 7.16.9 on page 95).

- **1st-8th I/O Expander Output**: Select this value to use outputs from a connected Fortimus 8 channel I/O Expander Module. See MAN-MIN-1001 for more details.

Triggers configuration					
Source	Tap Trigger A [0VELZ0]	Score	100	Destination	1st I/O Expander Output

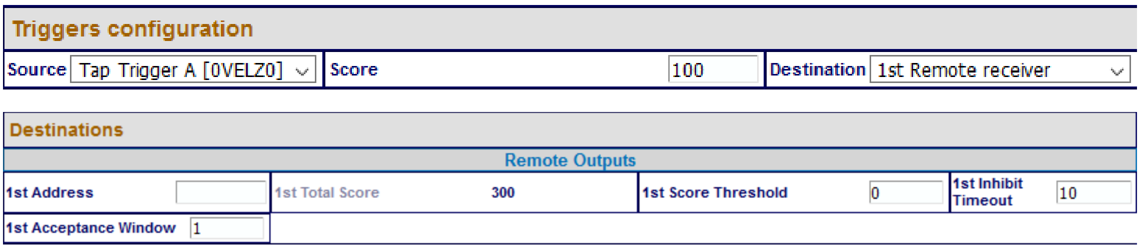
Destinations							
Relay Outputs							
1st Hold Time	1			1st Total Score	300	1st Score Threshold	200
1st Inhibit Timeout	10	1st Acceptance Window	1				

Various parameters control how the I/O Expander behaves:

- *n*th Hold Time: is the relay switch timeout in seconds. If configured to *0*: no timeout is used, otherwise relay will be released after specified number of seconds;

- ◦ n^{th} Total Score: this is an information field, it displays an automatically-calculated total of the scores from all of the input sources that specify this destination;
- ◦ n^{th} Score Threshold: this threshold is used when multiple input sources contribute to this trigger. Otherwise trigger threshold from source configuration is used;
- ◦ n^{th} Inhibit Timeout: is the time the Fortimus waits before sending new command to the I/O Expander if a new event is detected after a previous command was sent;
- ◦ n^{th} Acceptance Window: subsequent source triggers for a given destination are counted towards the cumulative score if they arrive within this window.

- **$1^{st}/2^{nd}/3^{rd}/4^{th}$ Remote Source**: This setting is used for multiple-destination triggering networks. The destinations specified here are other Fortimus or Minimus based instruments, specified by the I.P. addresses configured in the "Remote Outputs" section:

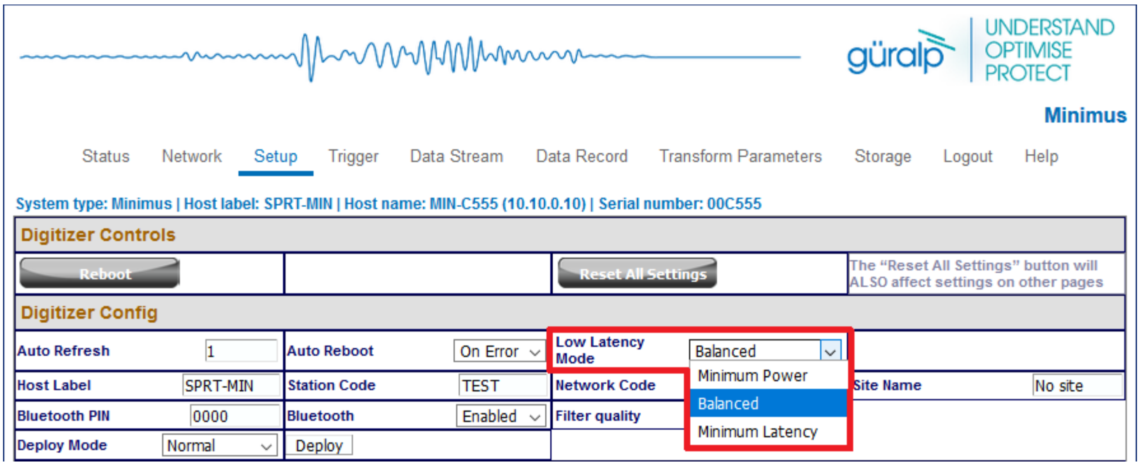


- ◦ n^{th} Address: the I.P. address of the remote Fortimus;
- ◦ n^{th} Total Score: this is an information field, it displays an automatically-calculated total of the scores from all of the input sources that specify this destination;
- ◦ n^{th} Score Threshold: this threshold is used when multiple input sources contribute to this trigger. Otherwise trigger threshold from source configuration is used.
- ◦ n^{th} CAP Inhibit Timeout: is the time the Fortimus waits before sending new message if a new event is detected after a previous message was sent;
- ◦ n^{th} Acceptance Window: subsequent source triggers for a given destination are counted towards the cumulative score if they arrive within this window.

7.17.3 Low Latency Mode

In the "Setup" tab, the "Low Latency Mode" drop-down menu controls the processor workload that affects the power-consumption of the Fortimus. This control can be used to prioritise power-consumption at the expense of latency, to balance the two or to optimise latency regardless of the power consumption. Three settings are available:

- Minimum Power ⇒ slow processing / higher latency;
- Balanced ⇒ optimal;
- Minimum latency ⇒ fast processing / lower latency.

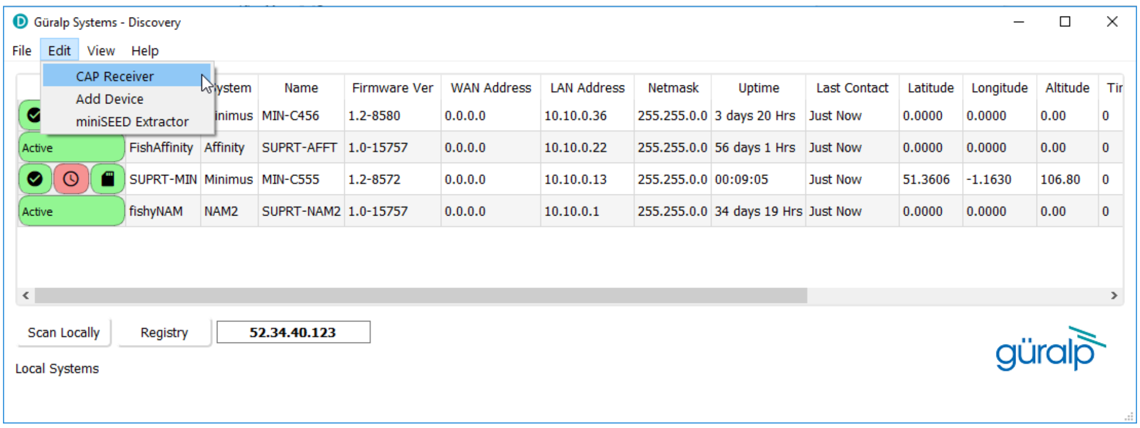


7.17.4 CAP receiver

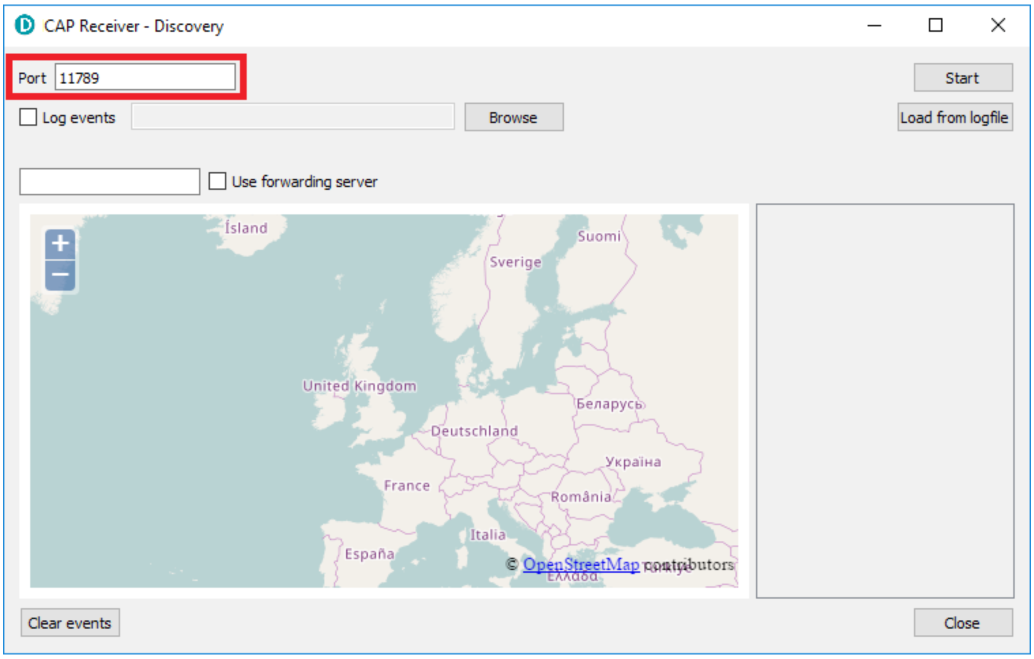
Güralp Discovery includes a CAP (Common Alerting Protocol) receiver. It listens on a specified UDP port for incoming CAP messages. When one arrives, it is displayed and plotted on a map. In addition, the receiver can open a TCP connection to the cloud-based registry server and display CAP messages that have been sent to the registry server. See Section 7.18 on page 112 for information about configuring a registry server.

All CAP messages can be stored in a log-file. The full message is recorded so that it can be re-loaded later, if required.

The CAP receiver functionality is accessed using the context (right-click) menu in Discovery or clicking on "Edit" in the menu bar:

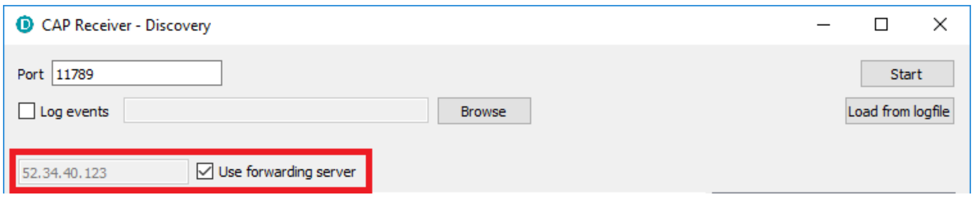


The CAP receiver window allows specification of the listening port. Each Fortimus from which messages should be received must have this value specified as the "CAP Port" in its triggering settings (see Section 7.17.2 on page 105). The value should be between 1025 and 65535. You should avoid numbers in the list at https://en.wikipedia.org/wiki/List_of_TCP_and_UDP_port_numbers.

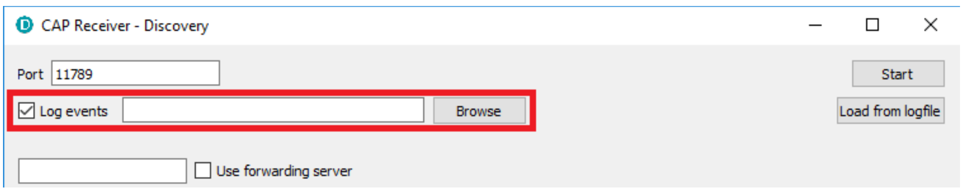


The reception of CAP messages can be enabled or disabled clicking on the Start button at the top, right-hand side of the window.

If you wish to forward the CAP messages to a server, type its IP address into the field and tick the check-box named "Use forwarding server". An error message is displayed if the entered IP address is not valid.

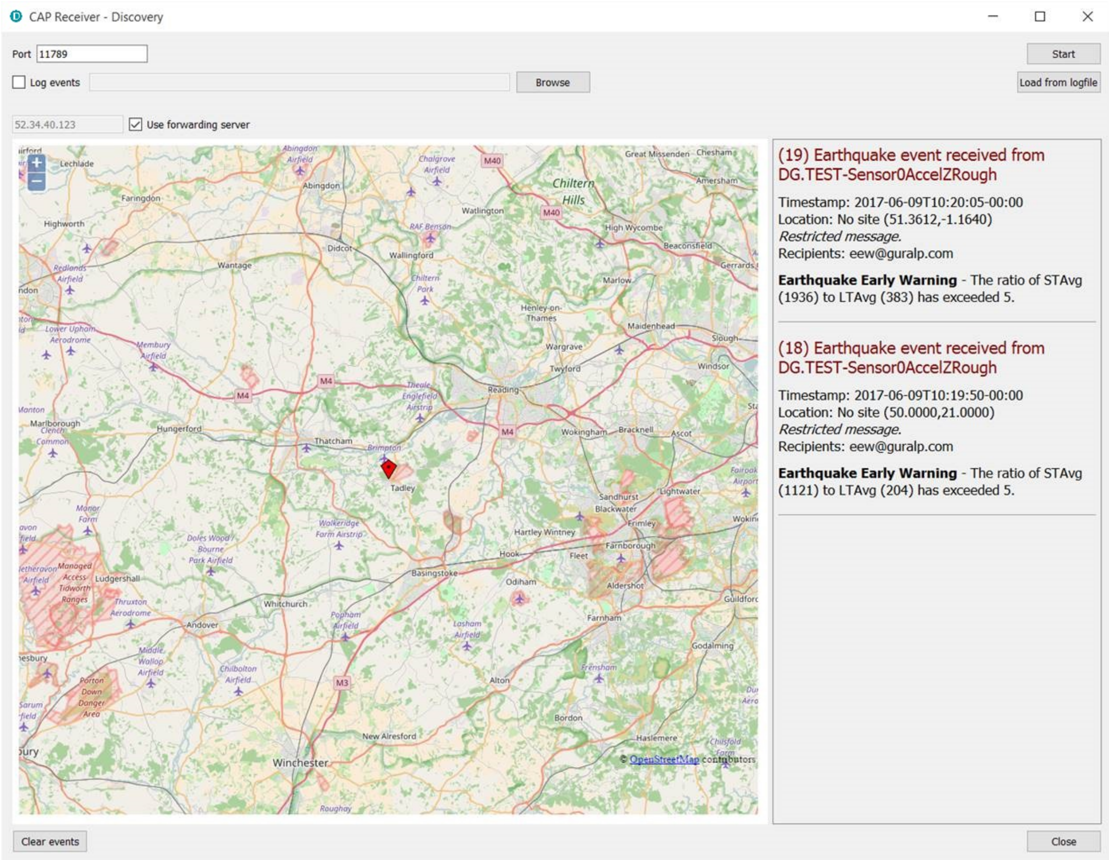


To log CAP messages to a file, tick the "Log events" check-box and use the Browse button to select an appropriate location for the database file.



To import an existing database of events, first enable logging, then browse to the file using the Browse button and, finally, click the Load from logfile button to load the file.

If no file is specified, the logging is automatically switched off and a pop-up message is displayed.



When an event is detected and a CAP message is received, the location of the Fortimus that generated the trigger is identified by a pointer displayed on the map. The events and the information contained in the CAP message are displayed at the right-hand side of the window. This includes the SEED identifiers, network, station, channel and location, along with the time, the recipients and the threshold value which was exceeded.

If the EEW parameters are enabled in a particular source, after the first CAP message containing the event information, three other messages with the PGA/PGV/PGD details are sent, one for each component.

Click on the Clear events button to clear markers from the map and descriptions from the right-hand-side list. This action does not affect the contents of the log-file.

7.17.5 Seismic Event Table

The Fortimus can generate a “Seismic Event Table”. This is list of events detected by the STA/LTA or threshold trigger enabled on taps. It contains information about the time when the event occurred, its duration, the channel that generated the trigger and the peak magnitude of the event. The seismic data before, during and after the event are saved in miniSEED format and can be downloaded using links in the table.

The table is located at the bottom of the “Trigger” tab in the Fortimus web page.

Seismic Events Table			
Download Settings:	Seconds Pre 10	Seconds Post 10	☑ Download Z,N,E Triplet
Time of Event Duration	Trigger Function (Tap) Peak Magnitude (Time)	Download Source Tap	Download
Thu Aug 2 12:21:17 2018 < 1 second	STA/LTA Trigger (0AXL10) 0.50187 m.s	S0AccZA	Request Event Data
Thu Aug 2 12:21:17 2018 < 1 second	STA/LTA Trigger (0AXL10) 0.58626 m.s	S0AccZA	Request Event Data
Thu Aug 2 12:21:17 2018 < 1 second	STA/LTA Trigger (0AXL10) 0.27047 m.s	S0AccZA	Request Event Data
Thu Aug 2 12:20:46 2018 < 1 second	STA/LTA Trigger (0AXL20) 0.08352 m.s	S0AccNA	Request Event Data
Thu Aug 2 12:20:46 2018 < 1 second	STA/LTA Trigger (0AXL10) 0.74786 m.s	S0AccZA	Request Event Data
Thu Aug 2 12:20:46 2018 < 1 second	STA/LTA Trigger (0AXL20) 0.14463 m.s	S0AccNA	Request Event Data
Wed Aug 1 09:27:20 2018 < 1 second	STA/LTA Trigger (0AXL20) 0.2666 m.s	S0AccNA	Request Event Data

The Fortimus allows the download of event data in miniSEED format in a time range that is user selectable. The user can select how many seconds before and after the event detection to include in the miniSEED file.

Download Settings:	Seconds Pre 10	Seconds Post 10	☑ Download Z,N,E Triplet

Note: Use the Flush data button in the Storage tab to copy most recent data into the microSD cards (see Section 7.10.3 on page 57).

The event table shows which of the components has caused the trigger and the user can chose to either download data related to that single component by deselecting the option “Download Z, N, E Triplet” or download data for all three components by leaving the option enabled.

Download Settings:	Seconds Pre 10	Seconds Post 10	☑ Download Z,N,E Triplet

The last column of the table contains links to downloaded and saved miniSEED files related to each event.

Time of Event Duration	Trigger Function (Tap) Peak Magnitude (Time)	Download Source Tap	Download
Thu Aug 2 12:21:17 2018 < 1 second	STA/LTA Trigger (0AXL10) 0.50187 m.s	S0AccZA	Request Event Data
Thu Aug 2 12:21:17 2018 < 1 second	STA/LTA Trigger (0AXL10) 0.58626 m.s	S0AccZA	Request Event Data
Thu Aug 2 12:21:17 2018 < 1 second	STA/LTA Trigger (0AXL10) 0.27047 m.s	S0AccZA	Request Event Data
Thu Aug 2 12:20:46 2018 < 1 second	STA/LTA Trigger (0AXL20) 0.08352 m.s	S0AccNA	Request Event Data
Thu Aug 2 12:20:46 2018 < 1 second	STA/LTA Trigger (0AXL10) 0.74786 m.s	S0AccZA	Request Event Data
Thu Aug 2 12:20:46 2018 < 1 second	STA/LTA Trigger (0AXL20) 0.14463 m.s	S0AccNA	Request Event Data
Wed Aug 1 09:27:20 2018 < 1 second	STA/LTA Trigger (0AXL20) 0.2666 m.s	S0AccNA	Request Event Data

Note: The links produce downloadable miniSEED files if and only if the requested data is available in the microSD card. This depends on last flushing time and selected post event time.

7.18 Using a registry

Discovery can maintain a list of all Minimus and Fortimus units in a local or cloud-based registry, simplifying management of medium to large networks and removing the need for static IP addresses at telemetered stations. Registered digitisers appear in the selection list in the main screen, regardless of whether they are on the local network or not.

Administrators can create their own registry servers by installing a simple program on a server. The server itself must have a static IP address and be accessible to all connected Minimus/Fortimus units, as well as the PCs running discovery. Registry servers programs are currently available for Linux and Windows. Please contact Güralp technical support for details.

For administrators not wishing to install their own registry, Güralp provide a shared registry server in the cloud at `52.34.40.123` which customers are welcome to use.

Registered digitisers must be assigned to groups, each of which has a **Group Identifier**. Instances of Discovery must also be configured with a Group ID and can only display registered digitisers from the matching group. This allows partitioning of large networks into smaller administrative domains. It also makes possible the simultaneous use of the Güralp shared registry server by multiple organisations.

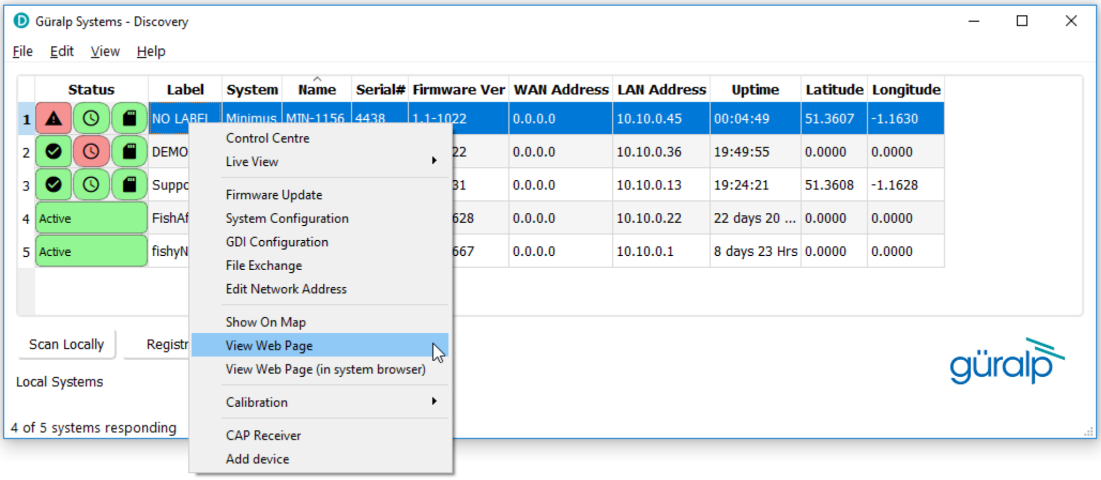
To use a registry:

1. Choose whether to use the Güralp shared registry or to deploy your own. If deploying your own, install the software on your chosen server and note its public IP address.
2. Choose one or more Group IDs for your digitisers
3. Set the Registry server address and Group ID in each Minimus/Fortimus
4. Set the Registry server address and Group ID in each instance of Discovery.

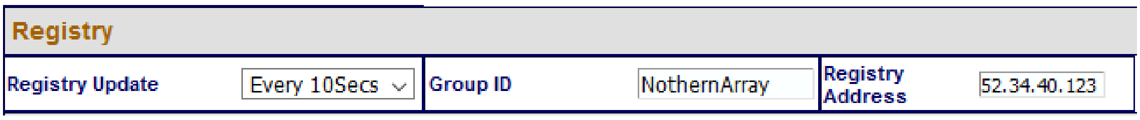
7.18.1 Configuring a Fortimus for use with a registry

The address of the registry server and the chosen Group ID must be set individually for each participating Fortimus.

To do this, first connect the Fortimus to the same network as a PC running Discovery and click the Scan Locally button, so that the Fortimus appears in the main Discovery list. Right-click ( ) on the digitiser's entry and select "View Web Page" from the context menu:



In the resulting web page, select the "Network" tab. The Registry parameters can be found near the bottom of the resulting screen:



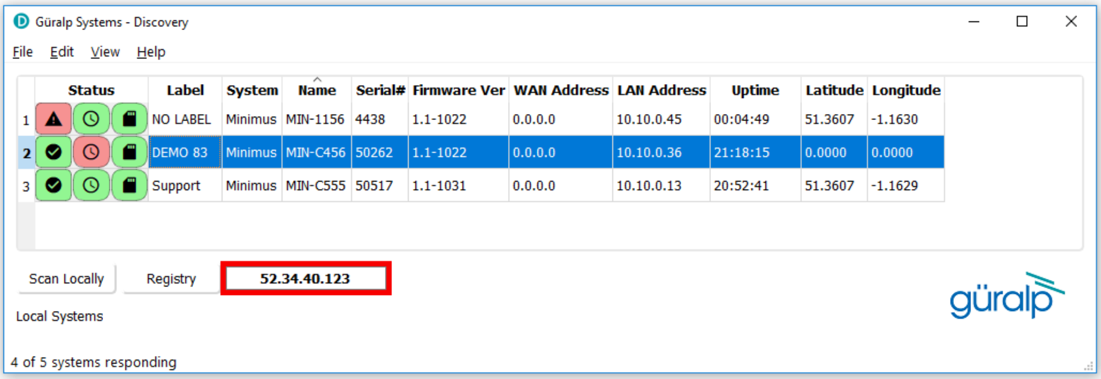
These are:

- **Registry Update**: the frequency at which the registry is updated with details of this digitiser can be specified here, using the drop-down menu;
- **Group ID**: the chosen Group Identifier should be entered here;
- **Registry Address**: the I.P. address of the registry should be entered here. To use the Güralp shared cloud server, enter `52.34.40.123`.

Once you have set the correct values, the digitiser must be rebooted before they will take effect. To do this, click the Reboot button.

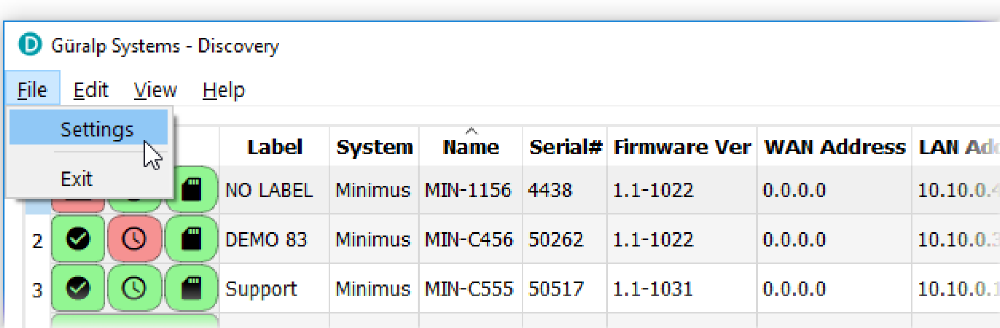
7.18.2 Configuring Discovery for use with a registry

To specify a registry server for an instance of discovery, type its address into the field at the bottom left of the main screen:

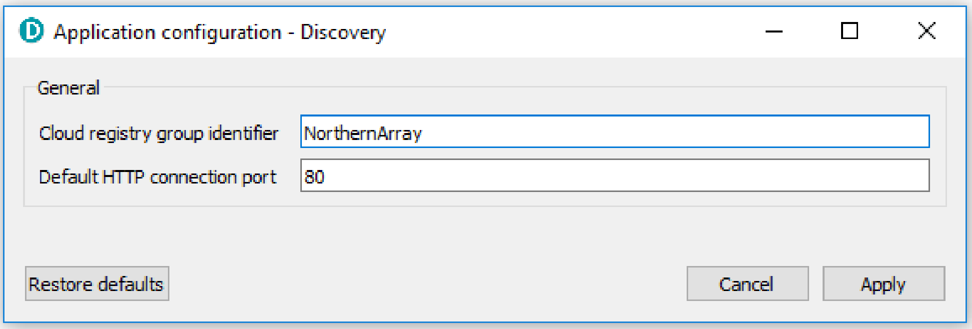


To set the Group ID in Discovery:

1. Select "Settings " from the “File” menu:



2. Type the chosen Group ID in the “Cloud registry group identifier” field and click Apply.

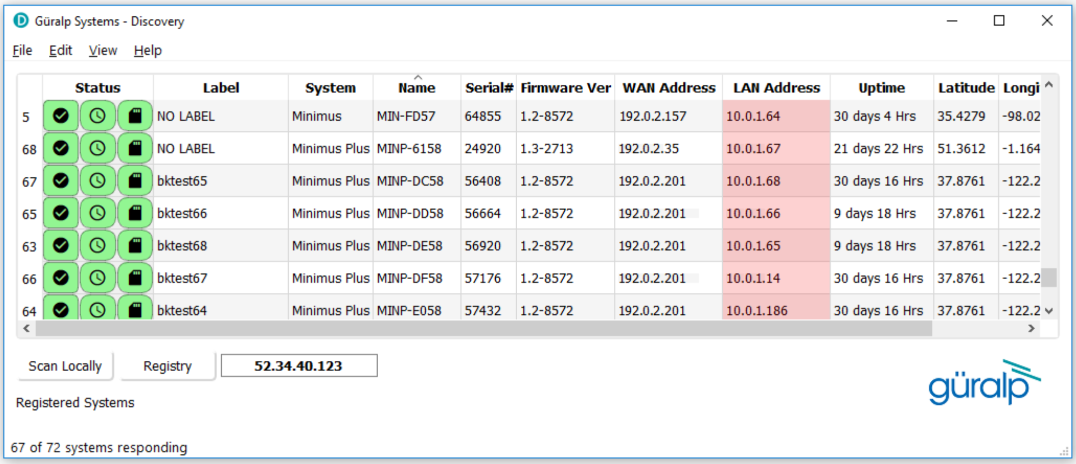


Return to the main windows and test the configuration by clicking the Registry button. All Fortimus using the same Registry server and Group ID should appear in the main list.

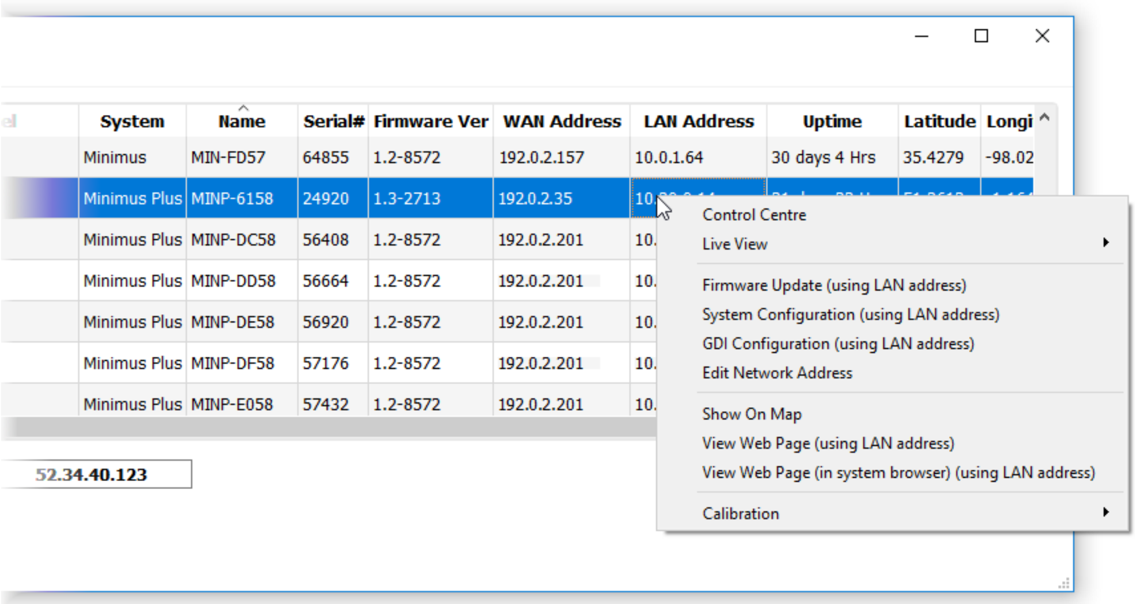
7.18.3 Registry mode: using WAN or LAN addresses

When Discovery displays a list of devices found from a local scan, all access to those systems is initiated via the LAN address. When displaying a list of registered devices, you have the option of using either the LAN address or the WAN address. This can be useful when the WAN address has been configured but is not yet available or when a registered device is installed remotely and not available on the LAN. The feature is controlled by exactly where you right-click in the list of devices.

If you right-click anywhere other than in the LAN address column, the WAN address is used and the behaviour is otherwise exactly as previously documented. To access the digitiser via its LAN address, right-click in the LAN address column, as shown below:

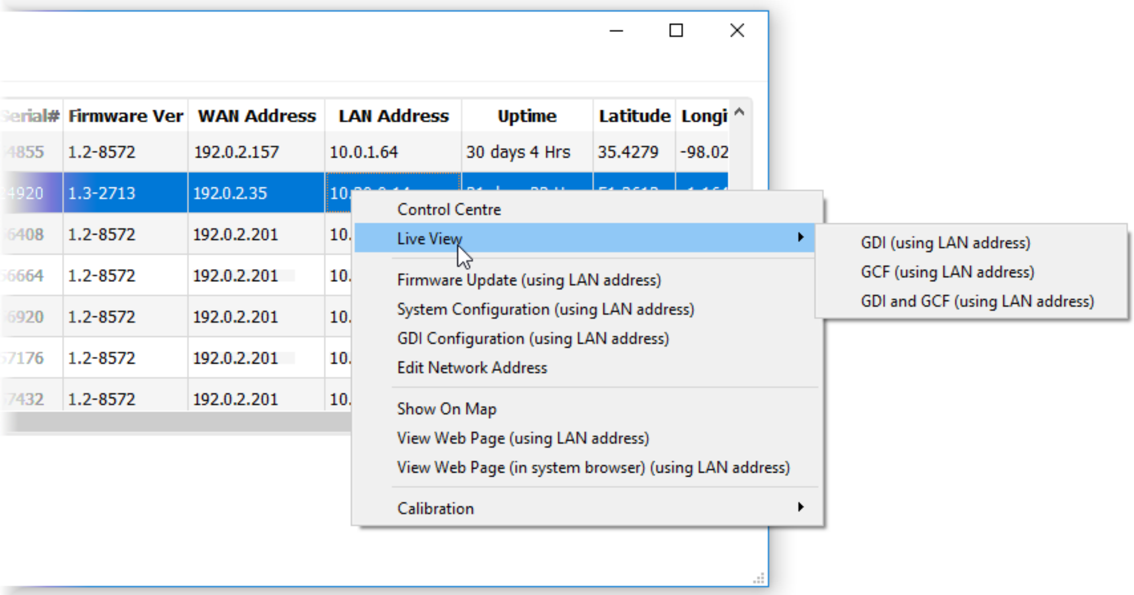


When you click on the LAN address of an entry, the context menu changes:

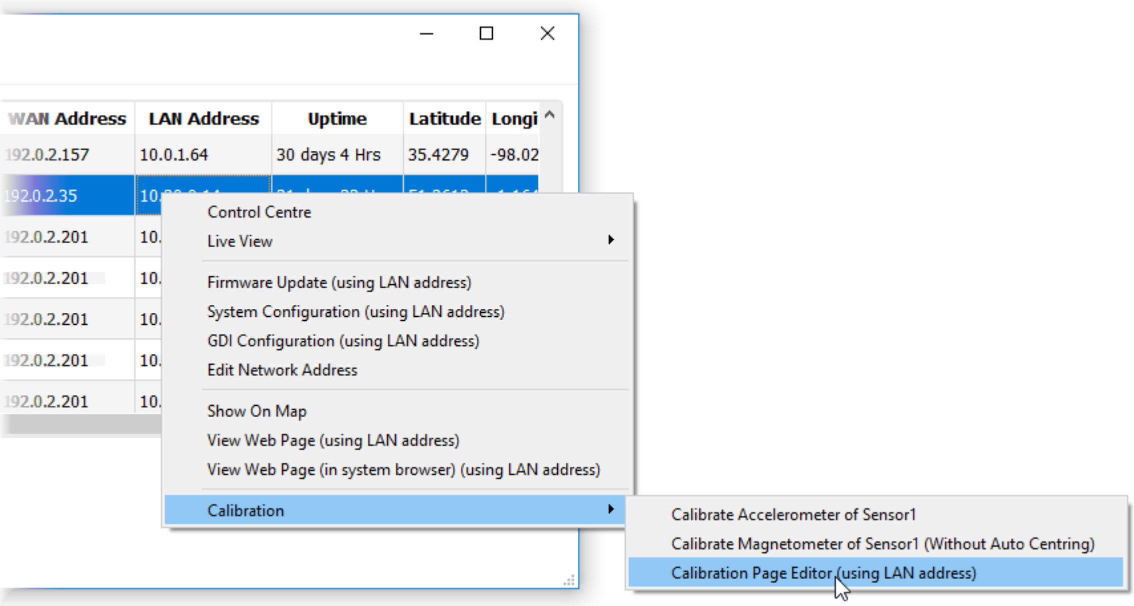


Entries for firmware updates, system and GDI configuration and web page access all now use the LAN address rather than the WAN address.

In addition, all options on the Live View sub-menu use the LAN address:



and the calibration page editor is also invoked using the LAN address:



Note: For these techniques to work, the digitiser and PC must be connected to the same LAN.

7.19 Updating Fortimus firmware

The firmware of the Fortimus is upgradeable. New releases appear regularly – mostly to add new features but, occasionally, to fix problems. Güralp recommends that the Fortimus is regularly checked for availability of firmware updates and, when convenient, these updates should be installed.

The procedure below guarantees a straightforward upgrade and prevents any data loss or misconfiguration.

Note: The latest version of Discovery software must be used to perform the firmware update of any Fortimus digitiser. See Section 13.5 on page 154 for more details.

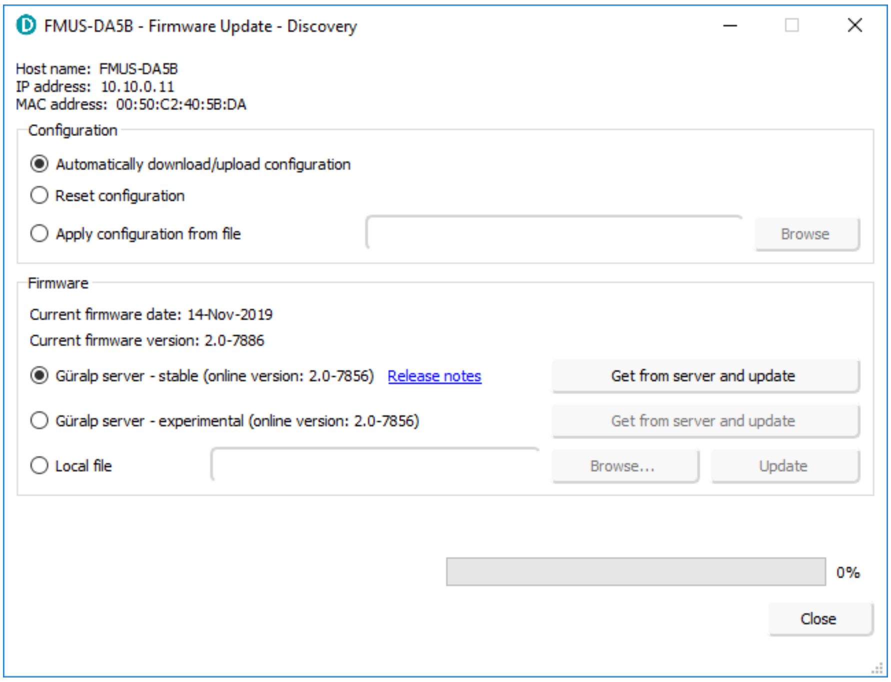
If you have any recorded data that you value, backup all files from the Fortimus microSD card:

1. Unplug the external microSD card from your Fortimus.
2. Plug the external microSD card into your PC.
3. Copy all files from the external microSD card into your PC.
4. Unplug the external microSD card from your PC.
5. Plug the external microSD card back into your Fortimus.

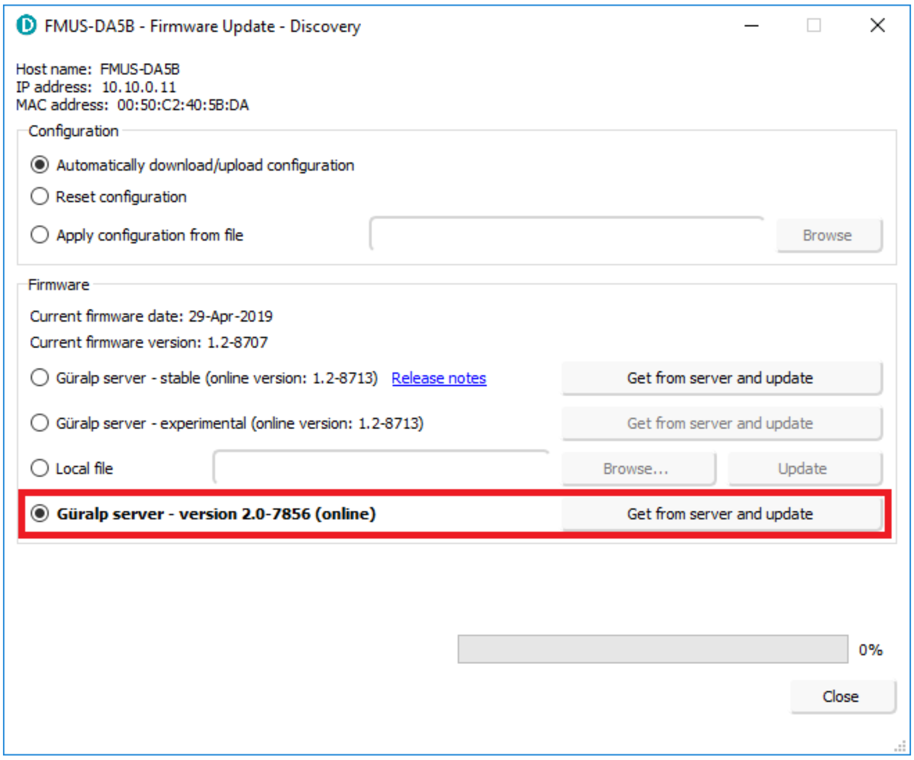
Once this is complete, to upgrade the Fortimus:

1. Run Discovery.
2. Right-click on the Fortimus in Discovery main window and select “Firmware Update”.

3. In the “Firmware Update” tab, select “Güralp server – stable (online version: 2.0-****)” to obtain the new firmware from the Internet via a local Ethernet connection. Click Get from server and update.

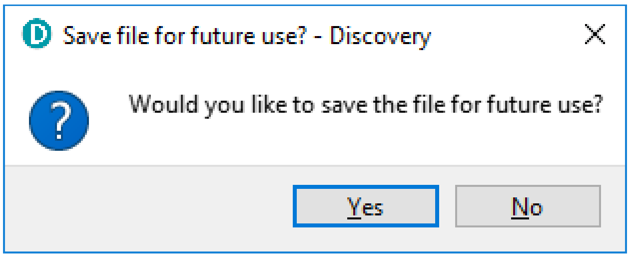


Caution: If updating from any release of v1.2 to v2.0, select the option "Güralp server – version 2.0-**** (online)" only. Do not use "Local file" option unless agreed case-by-case with support@guralp.com.

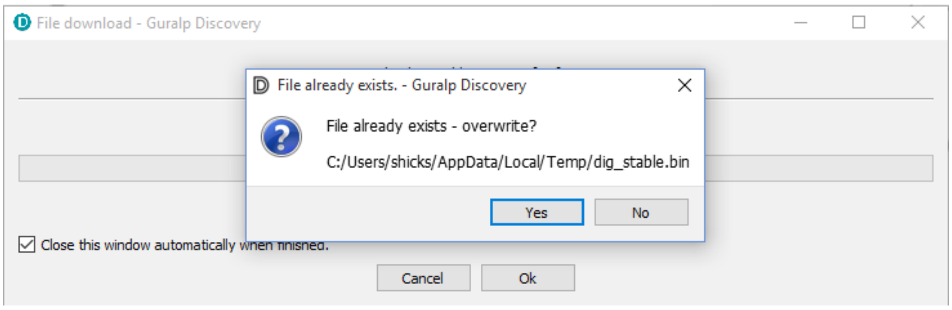


If updating from any release of below v1.2, contact support@guralp.com before proceeding.

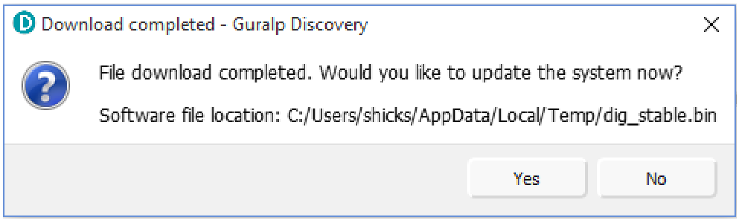
4. Discovery will ask you if you want to save the Firmware binary file for future use – click Yes for future use, e.g. update other systems offline using same firmware file. Otherwise, proceed with No.



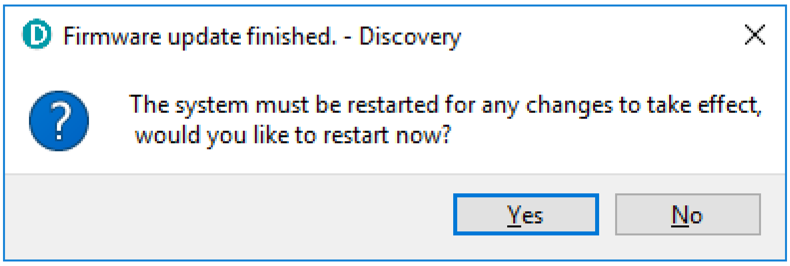
5. Discovery may ask to overwrite a temporary file on your PC – click Yes to allow it to do so.



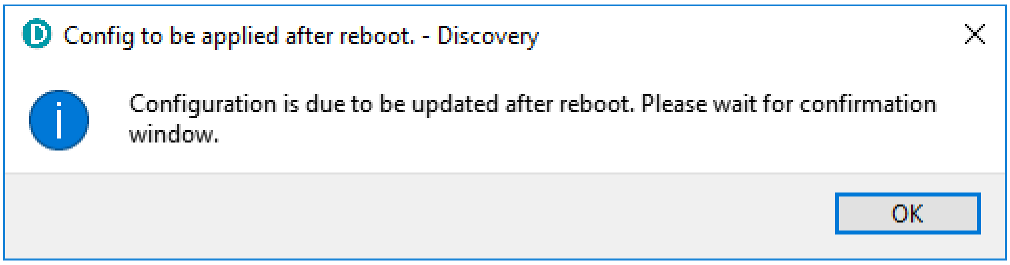
6. Discovery will confirm through another dialogue box that the file download is complete. Click Yes to begin the firmware upload to the Fortimus.



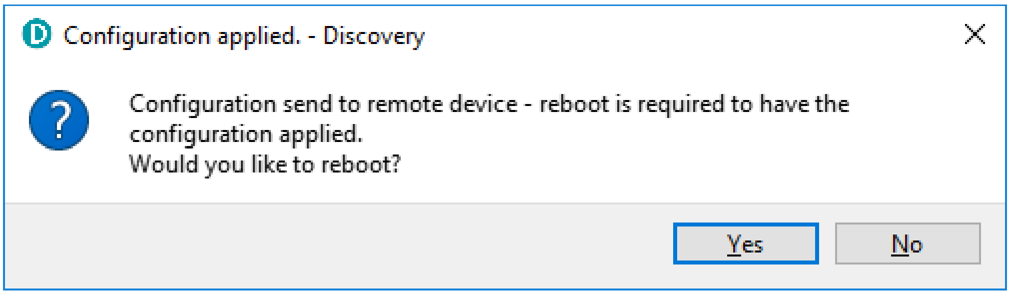
7. At the end of the uploading process, the dialogue box will ask to restart the Fortimus. Click Yes to finalise the process.



8. A dialogue box will ask you if you want to upload the previous configuration. Click Yes to finalise the process.



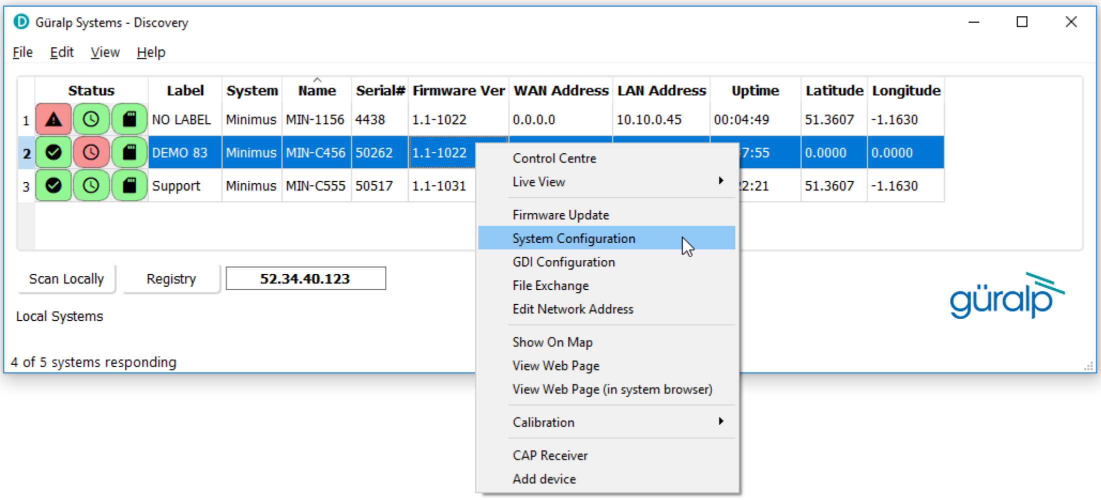
9. When the configuration is uploaded, the Fortimus needs to be restarted again. Confirm with Yes to the dialogue box.



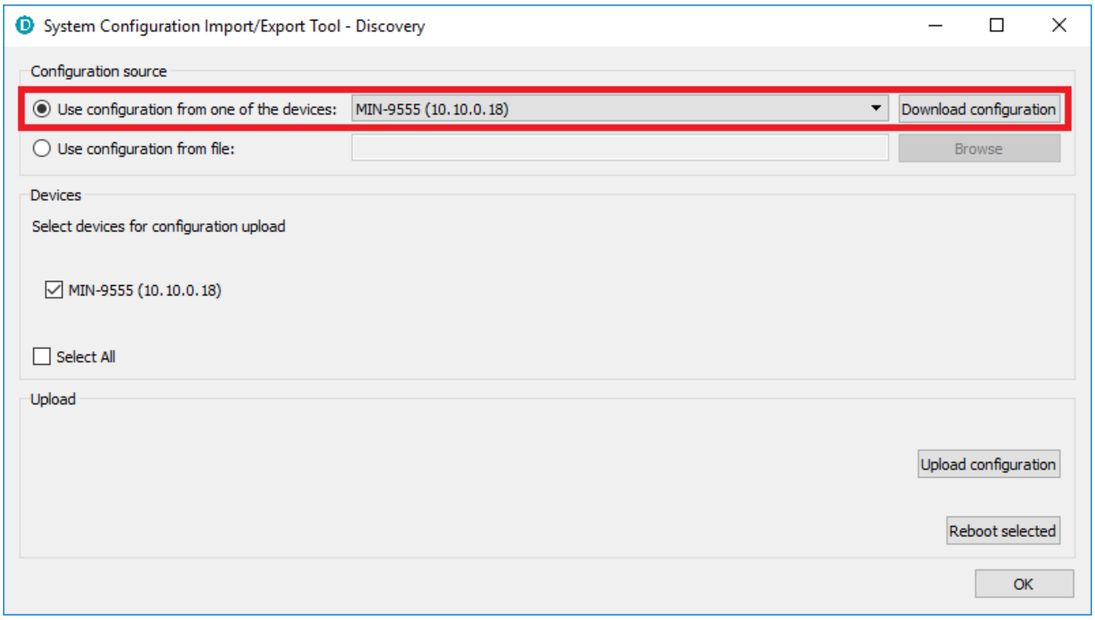
10. The Fortimus will re-boot and, during this process, the displays will show a white screen with the Güralp logo in the middle and a progress-bar at the bottom.
11. Go to the "Storage" of the Fortimus web page and Quick-format the microSD cards of your Fortimus (for details, see Section 7.10.2.1 on page 57).
12. Check that all indicators are green (i.e. nothing in red nor in yellow) in Discovery.
13. Go to the "Status" tab of the Fortimus web page.
14. Check that your Fortimus firmware version is as expected.
15. Check that nothing red or yellow shows up in the "Status" tab of the Fortimus web page.

7.20 Import / Export an existing configuration

Updating the Fortimus' firmware can, occasionally, cause loss of configuration. We recommend that you export and save the current configuration before proceeding with an upgrade. This operation can be done through Discovery by right-clicking on the digitiser in the list and selecting "System Configuration" from the context menu:

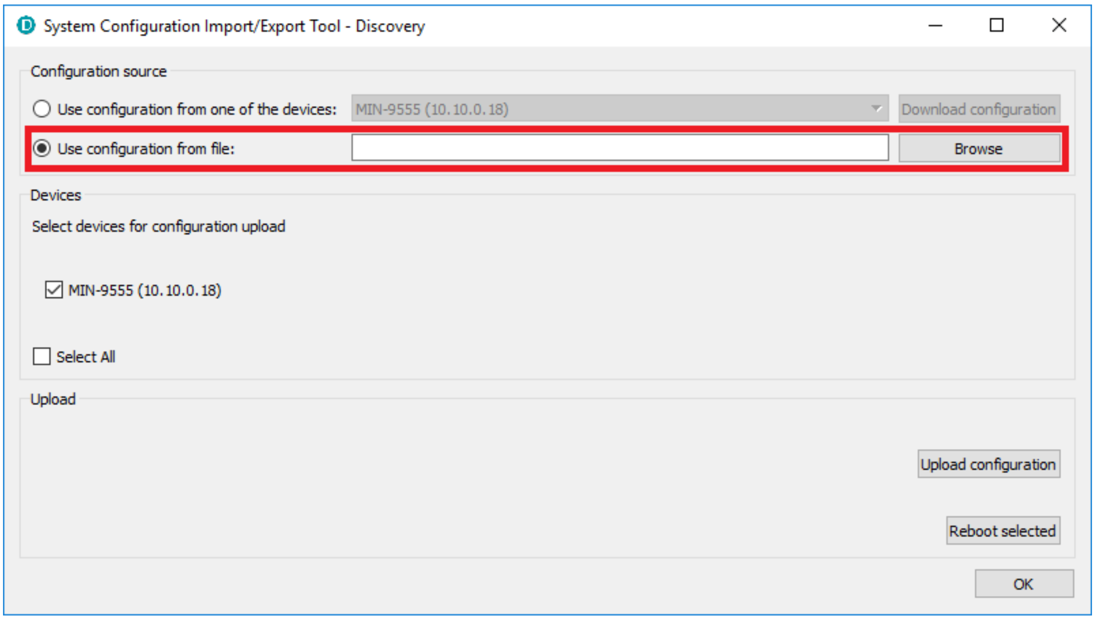


Select "Use configuration from one of the devices". If more than one device is available, select the one from which the configuration should be downloaded. Click the Download configuration button and browse to a suitable location (on your PC) into which to save the configuration file.



After the firmware update is successfully completed, the previous configuration can be imported, if required, by following the instructions below.

Right-click on the digitiser's entry in the Discovery list and select "System Configuration" from the context menu. Select the "Use configuration from file" option.



Select the configuration file from where it was saved in the File Explorer and confirm. Use the check-boxes to select the devices to which the configuration should be uploaded and click on the Upload configuration button.

Wait until the process finishes. To apply the new configuration, the unit has to be rebooted: the Reboot selected button can be used to perform the required system restarts.

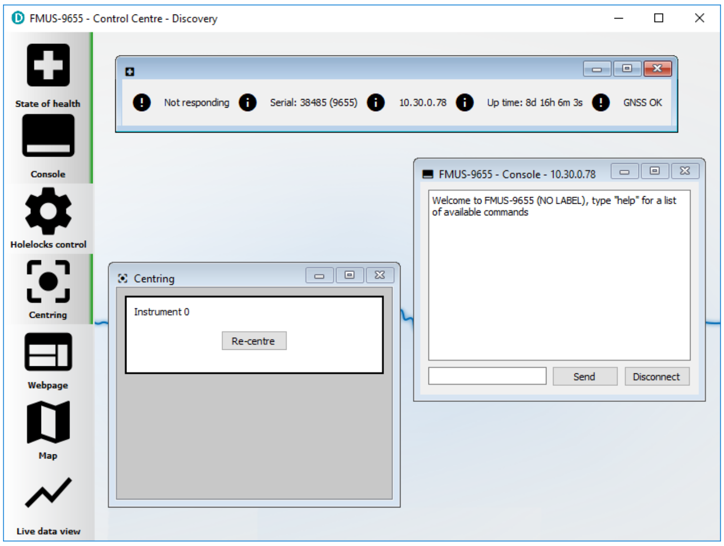
> **Note:** The configuration export and upload doesn't preserve the settings related to the applied transforms.

7.21 Control Centre

Several actions can be taken from within Discovery to control your Fortimus digital accelerometer.

These operations can be performed by right-clicking on the digitiser's entry in the list and select "Control Centre" from the context menu. The meanings of the icons are given in the table below:

Icon	Function
	This tab provides information about the general state of the instrument, its serial number and I.P. address, its up-time (time since last boot) and GNSS status.
	This button launches a console that allows interactions with the command line of the Fortimus. The list of available commands and their respective descriptions can be displayed by entering the command "help". This should generally only be done on the advice of the Güralp technical support team.
	This button is equivalent to the "View Web Page" entry in the context (right-click) menu of the Fortimus in the Discovery main window.
	This button is equivalent to the "Show on Map" entry in the context (right-click) menu of the Fortimus in the Discovery main window.
	This button is equivalent to the "Live View" entry in the context (right-click) menu of the Fortimus in the Discovery main window.
	This tab allows manual centring of the Fortimus accelerometer.


FMUS-9655 - Control Centre - Discovery
State of health
Console
Holelocks control
Centring
Webpage
Map
Live data view
Not responding
Serial: 38485 (9655)
10.30.0.78
Up time: 8d 16h 6m 3s
GNSS OK
FMUS-9655 - Console - 10.30.0.78
Welcome to FMUS-9655 (NO LABEL), type "help" for a list of available commands
Send
Disconnect
Centring
Instrument 0
Re-centre

8 GüVü app

The GüVü app provides monitoring and control of near-by Fortimus digital accelerometer using the Bluetooth protocol. It is available for both Android and Apple devices.

GüVü can be downloaded from the Google Play store at:

https://play.google.com/store/apps/details?id=com.guralp.whisper

or from the Apple store at:

https://itunes.apple.com/us/app/id1208418113

8.1 Getting stated

To launch GüVü, follow the steps shown in the figure below:

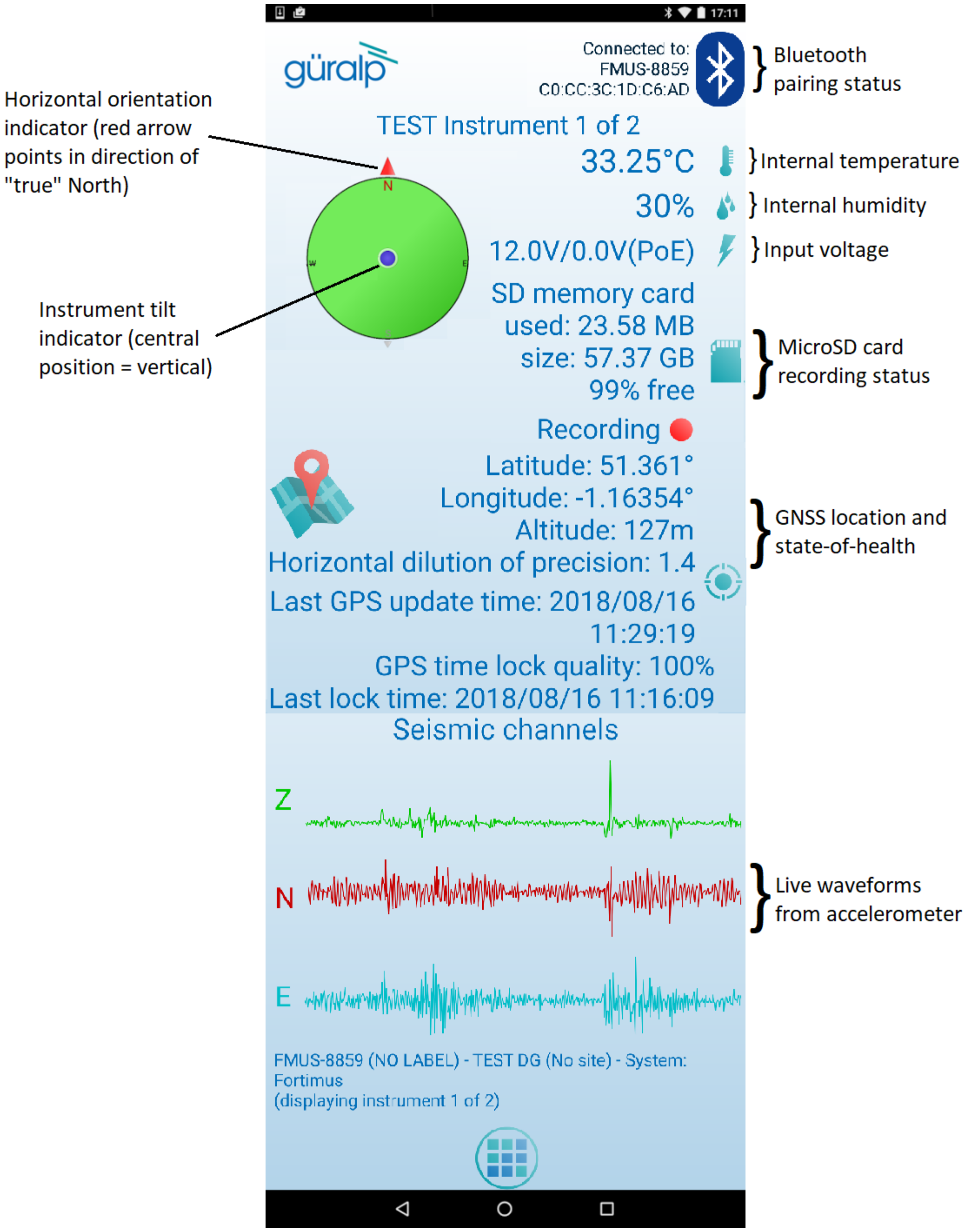
Steps for launching the GüVü App:

1. Launch by clicking on the GüVü icon from either the Apps menu or from the Home Screen.
2. Wait a few seconds for the app splash screen.
3. Press the Bluetooth icon ( ) to enable Bluetooth connectivity (if not already enabled) and to search for available devices with which to pair.
4. Select the appropriate Fortimus device from the list of available devices. Wait a few seconds for the main viewer screen to show.

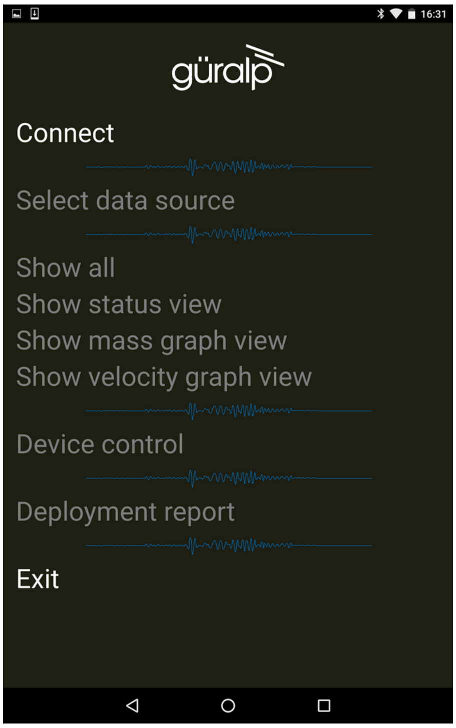
The instrument connection screen can also be accessed by pressing the menu icon ( ) on the main instrument status window, and selecting the "Connect" option.

If you experience problems connecting, try forcing GüVü to quit and then re-launching the app.

Once the device is connected, the main view of the app will be displayed. This screen displays a number of status indicators associated with both the digitiser and accelerometer. These features are summarised in the figure below:



Access the menu by pressing the menu icon ( ) on the main instrument status window:



8.2 View settings

The user can customise the view of the main instrument status window. Four different view options can be cycled through by tapping the menu icon ( ) on the main instrument status window:

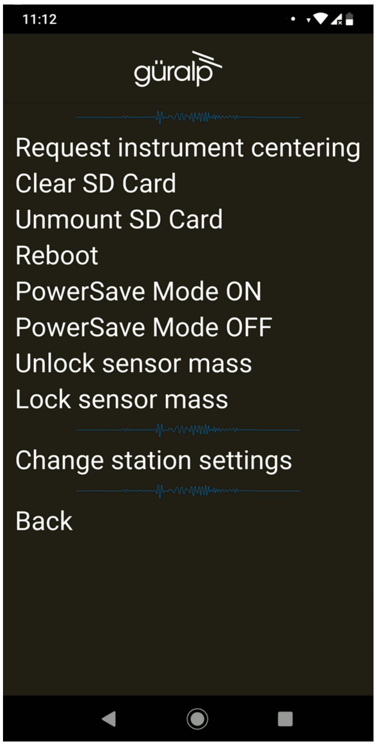
- **Show all** – the default view setting; show state-of-health status, mass positions, and sensor traces on a single screen;
- **Show status view** – show state-of-health on the main screen only;
- **Show mass graph view** – show mass position traces on the main screen only; and
- **Show velocity graph view** – show sensor traces on the main screen only.

8.3 Instrument control

Several features of the Fortimus can be controlled and configured remotely over Bluetooth using GüVü:

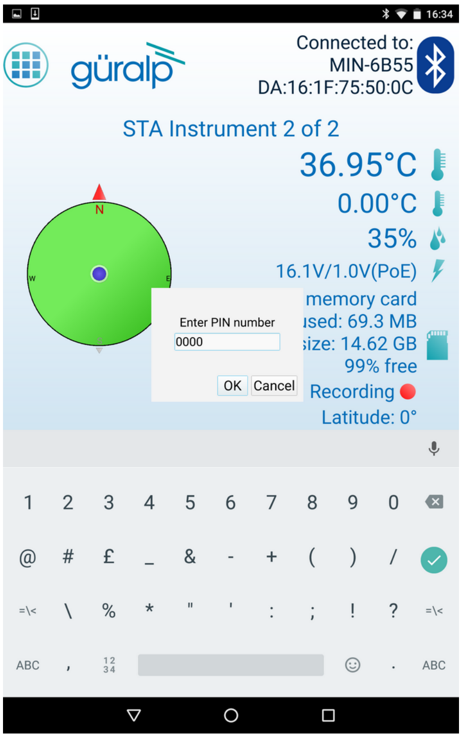
- Accelerometer centring
- Clearing and un-mounting SD card
- Rebooting the Fortimus
- Enable/disable power-saving mode
- Station meta-data (User Label, Station Name, Network Code, Site Name)
- Network setting (I.P., Netmask, Gateway)
- Changing channels' sampling rates

In each case, GüVü will report whether the selected command has been successfully sent to the device.



Note: After any modification to channels' sampling rates, the Fortimus must be rebooted before the changes will take effect.

These options can be accessed by tapping the menu icon ( ) and choosing the "Device control" option. To access the instrument control and configuration sub-menu, a PIN code has to be entered by selecting the text entry box and tapping OK.

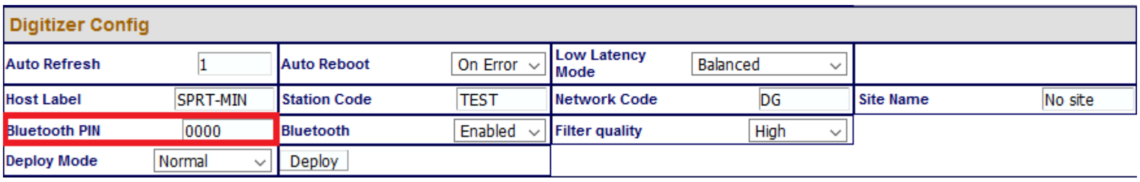


The default PIN code used to access the Instrument Control menu is "0000".

> **Caution:** Güralp recommends changing the PIN code from the default, as described in the following section, in order to maintain station security.

8.3.1 Setting the PIN code

The PIN code for accessing the instrument control menu of GüVü can be changed from the "Setup" menu of Güralp Discovery. The new four-digit PIN code should be entered into the "Bluetooth PIN" field. The new value is applied by keying ENTER( ); or clicking the left mouse button in any other setting box.



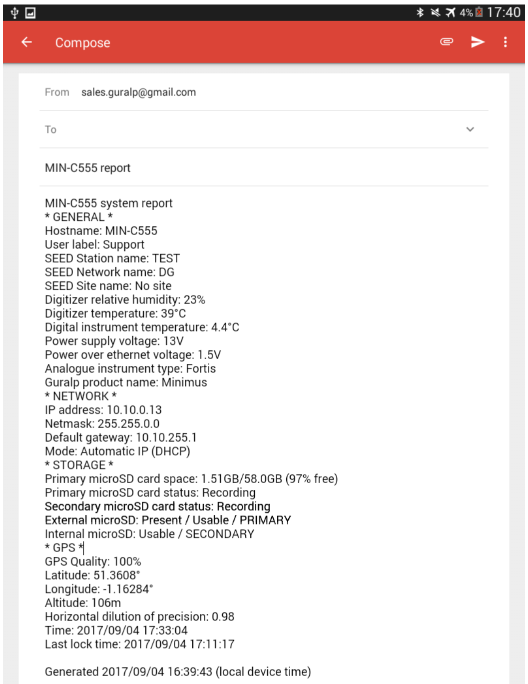
8.4 Emailing a deployment report

The GüVü app has a feature that allows the user to generate an automatic deployment report that can then be filed via email.

The deployment report includes the following details:

- System name
- Station name
- Network code
- Instrument user label
- Memory card storage size and recording status
- Location of site (GNSS latitude, longitude, elevation)
- Time of deployment
- GNSS lock quality
- Power supply status
- Instrument temperature and humidity recordings

To send a deployment report, tap the menu icon ( ) and choose the "Deployment report" option. GüVü will then open the default email application on the device, showing a draft email which will include the parameters described above.

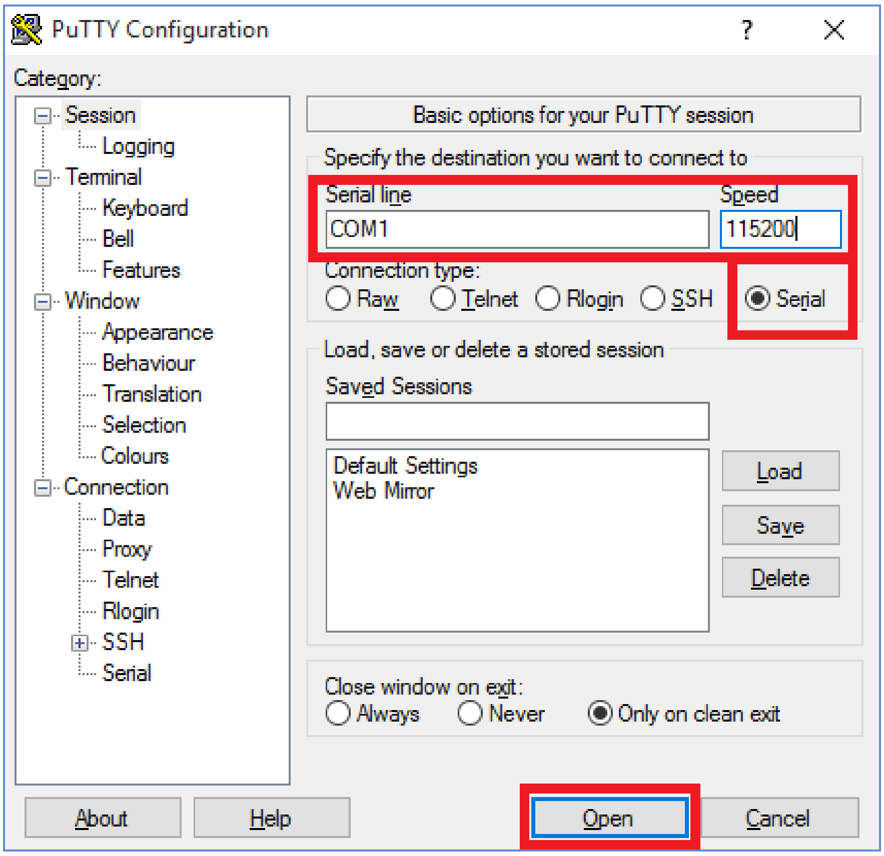


9 Advanced troubleshooting

In the unlikely event of the user experiencing problems with the operation of the Fortimus, a diagnostics tool is available via the GNSS connector, which also acts as a terminal communications device via a Serial connection.

The user should first plug in the serial adapter to the GNSS connector, which is then attached to a 9-pin COM port on your PC/laptop (if a 9-pin COM port is not available, a serial-to-USB converter should be used instead and connected to an available USB port. Güralp recommend converters based on the FTDI chip-set.)

A connection is then made using a terminal emulator, such as minicom under Linux or PuTTY under Windows. The appropriate COM port should be entered in the "Serial line" box and the Speed should be set to 115,200.



Finally click the Open button and a terminal window will open, connected to the console of the Fortimus.

In the event of any operational issues, the Güralp Support Team may request you to interact with the console in order to diagnose and fix problems.

9.1 Reset all settings during boot phase

The Fortimus can be reset to its factory settings during its boot-up stage. This is useful in cases where:

- the user is not able to communicate with the Fortimus via the LCD;
- the user is not able to communicate with the Fortimus via a network connection;
- the unit is not responsive; or
- the unit does not appear in the Discovery software's scan results.

To carry out a full system reset, connect to the terminal port via a serial connection (as described in Section 9 on page 131). During the middle part of the boot phase, when the text `@GURALP SYSTEMS` and the firmware version number is displayed, key Ctrl+R. This causes all settings (except Username, Password and Bluetooth PIN) to revert to their factory default values, and the Fortimus will re-boot. It may be necessary to enter this key combination several times.

A typical boot log is shown below, identifying the stages where Ctrl+R will cause the Fortimus to reset and re-boot.

Do not press any buttons during the first phase of boot-up:

```
RomBOOT

SCKC_CR = 0xA, CKGR_MOR = 0x100FF0A, CKGR_PLLAR = 0x20FDD101,
PMC_MCKR = 0x1122, PIO_PDSR = 0xF2357EB5
SCKC_CR = 0xA, CKGR_MOR = 0x100FF0A, CKGR_PLLAR = 0x20AC3F01,
PMC_MCKR = 0x0202, PIO_PDSR = 0xF2357C25
AT91Bootstrap v3.8.10-1.guralp

NAND: ONFI flash detected
NAND: Manufacturer ID: 0x2C Chip ID: 0xDA
NAND: Page Bytes: 2048, Spare Bytes: 64
NAND: ECC Correctability Bits: 4, ECC Sector Bytes: 512
NAND: Disable On-Die ECC
NAND: Initialize PMECC params, cap: 4, sector: 512
NAND: Image: Copy 0x92000 bytes from 0xE000 to 0x2FA0E000
NAND: Done to load image
SCKC_CR = 0xA, CKGR_MOR = 0x100FF02, CKGR_PLLAR = 0x20AC3F01,
PMC_MCKR = 0x0202, PIO_PDSR = 0xF2357C25


U-Boot v2019.10-1.guralp

CPU:   SAMA5D36
External clock:  12.000 MHz
CPU clock:      528.000 MHz
Master clock:   132.000 MHz
```

```
DRAM:   512 MiB
NAND:   256 MiB
MMC:    Atmel mci: 0, Atmel mci: 1
Loading Environment from NAND... OK
In:     serial
Out:    serial
Err:    serial
Net:    eth0: ethernet@f0028000
Total of 1 word(s) were the same
PHY 0x07: OUI = 0x0885, Model = 0x22, Rev = 0x02,  10baseT, HDX
Hit any key to stop autoboot:  0

NAND read: device 0 offset 0x5C0000, size 0x360000
 3538944 bytes read: OK
Uncompressed size: 5009436 = 0x4C701C
crc32 for 21000000 ... 214c701b ==> b6ae61d4
Total of 2 word(s) were the same
Total of 1 word(s) were the same
## Starting application at 0x00300000 ...

(boot)Crash Info###
 Number of crash left=0
(boot)Last crash time:1970-01-01T00:00:00.000
Board type set to: Fortimus
Recognised external clock: 12000000 Hz
SCKC_CR = 0xA, CKGR_MOR = 0x100FF02, CKGR_PLLAR = 0x20AC3F01,
PMC_MCKR = 0x0202, MCK = 132000000 Hz

@GURALP SYSTEMS
```

Once the "`@GURALP SYSTEMS`" banner has been printed, keying Ctrl + R (at least once) will cause all settings (except Username, Password and Bluetooth PIN) to revert to their default values and cause the Fortimus to reboot.

```
v2.0-7642 by teamcity on 10:41:19 12-Nov-2019
Vecbase: 300000 CPUid: 410fc051 Cache: c5187d
PMT init
Unsafe to change DBGU clock while running
mux start SP 300fb4
FPU start
VFP Id=41023051
    0.00 | -> init_dbgprint
    0.00 | -> init_cmdutils
    0.00 | -> init_pmt_dlg
    0.00 | -> init_memdlg
    0.00 | -> malloc_debug
    0.00 | -> start_timer_interrupts
    0.01 | -> rtc_init
RTC Time: 2019-11-13T10:05:37 UTC
    0.01 | -> uart_start_ints
    0.01 | -> init_arm_parse
    0.01 | -> t_init_task_utils
    0.01 | -> gpio_init
##### NORMAL INITIALISATION MODE #####
    0.01 | -> unit_test_init
    0.01 | -> init_devio
    0.01 | -> init_usart
```

```
    0.01 | -> init_devio_cmds
    0.02 | -> rpc_init
    0.02 | -> ram_init
    0.02 | -> ram_exchange_init
    0.03 | -> system_update_init
```

If your key-strokes have been recognised, `Ctrl+R` will be printed in the boot log, as shown below – once for each time your keystrokes were logged:

```
    0.03 | -> i2c_init
i2c_configure( 0, 100000Hz )
Using pclk 33000000, cdiv 161, shift 0 => 100000
i2c_configure( 1, 100000Hz )
Using pclk 33000000, cdiv 161, shift 0 => 100000
i2c_configure( 2, 100000Hz )
Using pclk 33000000, cdiv 161, shift 0 => 100000
    0.06 | -> i2c_dac_init
Ctrl+R
Ctrl+R
Ctrl+R
Ctrl+R
Ctrl+R
Ctrl+R
Ctrl+R
    0.06 | -> i2c_humid_init
Humidity sensor test SUCCESS
    0.07 | -> fram_init
Installing NVR device. size 12640
    0.10 | -> net_sockets_init
    0.14 | -> newtask_init
USE ADC FORTIMUS
    0.14 | -> display_init
i2c_rd S_FAILED [bus: 2 | slave: 0x38]
i2c_rd S_FAILED [bus: 2 | slave: 0x38]
i2c_rd S_FAILED [bus: 2 | slave: 0x38]

###FAIL OF  i2c write( 2, 38, 1[000000], 1, 0x22a4ff7b )
 after 3 attemptsi2c_configure( 2, 100000Hz )
Using pclk 33000000, cdiv 161, shift 0 => 100000

If you saw the previous i2c operations failing, do not panic, it
was an attempt to detect FT6x36 touchscreen...

GT911 PIN CONFIGURATION...
GT911 SETTING PINS TO 0...
GT911 SETTING PINS TO 0...
GT911 SETTING RESET TO 1...
GT911 SETTING GT911_PIN_IRQ TO INPUT...
GT911 Config checksum: 9a
GT911 Product ID: 00 31 31 39
GT911 Firmware Version: 1060
GT911 Vendor Id: 00
GT911 Config Version: 00
GT911 Written Resolution of X/Y Axis: 0000-0000
GT911 resolution X (0x8146) / resolution Y (0x8146) / Touch
number: 0000 / 0000 / ff
gt911 has been detected    2.69 | -> aux_ioexp_init
    2.70 | -> init_whalesong
```

```
    2.70 | -> analog232_init
    2.73 | -> start_timers
    2.76 | -> spi_datalink_init_semaphores
    2.79 | -> chain_init
Using 251 coefficients.
    2.87 | -> var_user_init
    3.20 | -> calibration_init
    4.86 | -> gcftx_init
    4.89 | -> spi_datalink_chains_init
Sensor0 is accelerometer
    5.15 | -> init_nand
    6.18 | -> adc12_init
    6.20 | -> init_random
    6.24 | -> ltc4151_vc_monitor_init
    6.27 | -> voltage_sniffer_init
    6.31 | -> init_lut
    6.42 | -> i2c_humid_init_ui
    6.45 | -> sd_init
    6.48 | -> sd_file_init
    6.51 | -> sd_log_init
    6.54 | -> streaming_client_init
2019-11-13T10:05:43.000Z Retime Request Waiting (35s/3600s/Boot
delay)
    6.59 | -> xtaltable_init
No XTAL table found.
    6.71 | -> gps_pps_init
Chain 54 already set.
Chain 54 already set.
Chain 54 already set.
Chain 54 already set.
Chain 54 already set.
Chain 54 already set.
Chain 54 already set.
Chain 54 already set.
FMUS-DA5B->     6.82 | -> init_var_debug
    6.85 | -> tcpdump_init
    6.88 | -> var_html_init
    6.91 | -> init_http_server
    6.94 | -> sd_init_var
    6.96 | -> gps_pps_ui_init
    6.99 | -> xtaltable_ui_init
checking for xtaltable.txt
    7.03 | -> init_fpga_datalink
    7.06 | -> init_auto_center
    7.09 | -> init_embedded_fs
    7.12 | -> status_txt_init
    7.18 | -> lan_init_web

#####tx_lock:
majic:f710f7f7
 Call_lock value:-1    7.19 | -> init_responder_ui
1969-12-31T23:59:59.459Z User variable "Group ID" modified (called
from init_responder_ui)
    7.20 | -> init_tunnel_ui
    7.24 | -> quasar_init
Quasar Serial Isolated Input/Output Module support is disabled.
    7.31 | -> quasar_init_ui
    7.31 | -> applied_rot_init_web
```

```
7.31 | -> installation_parameters_init_web
7.35 | -> init_fortimus_web
7.39 | -> analog232_init_web
7.46 | -> init_transforms
7.49 | -> triggers_init_ui
7.66 | -> chain_init_web
7.95 | -> transform_init_web
9.11 | -> storage_init_web
9.16 | -> spi_datalink_ui_init
9.20 | -> gps_init_ui
9.23 | -> gps_init
```

Once the boot-up reaches this stage, pressing Ctrl + R will no longer have any effect.

If Ctrl + R was recognised during the second stage of boot-up, then the Fortimus will reset and re-boot:

```
Ctrl+R NVR load, resetting all vars to their default values and
then rebooting
Forcing all vars to default values (including non-default-able)
PPS clock sources ACTIVE: 0x00000001  [GPS:0 PTP:0 RTC:0 TABLE:1]
PPS clock sources ACTIVE: 0x01000001  [GPS:1 PTP:0 RTC:0 TABLE:1]
PPS clock sources ACTIVE: 0x01010001  [GPS:1 PTP:1 RTC:0 TABLE:1]
PPS clock sources ACTIVE: 0x01010101  [GPS:1 PTP:1 RTC:1 TABLE:1]
Ctrl+R
Ctrl+R
Ctrl+R
sd_manager: probed both microSD card slots
11.58 {calibration.c;1142}  calibration_write_to_fram:
successfully wrote calib to FRAM
11.60 {var_nvr.c;773}  'sd_format_time' $20301021 --> $00000000
11.61 {var_nvr.c;773}  'sd_unmount_time' $22647008 --> $00000000
11.62 {var_nvr.c;773}  'pps_src_table' 168 --> 1
11.63 {var_nvr.c;773}  'pps_src_gps' 0 --> 1
11.63 {var_nvr.c;773}  'pps_src_ptp' 69 --> 1
11.64 {var_nvr.c;773}  'pps_src_rtc' 132 --> 1
11.64 {var_nvr.c;773}  'rtcSavedOffsetSecs_nv' -1737983855 --> 0
11.65 {var_nvr.c;773}  'rtcSavedOffsetNano_nv' 402788896 --> 0
11.66 {var_nvr.c;773}  'rtcSavedFreqErrorPPB_nv' -2129883872 -->
1000000
11.67 {var_nvr.c;773}  'rtcSavedOffsetTime_nv' $52080158 -->
$00000000
11.68 {var_nvr.c;773}  'xtaltable_offset' 610275339 --> 0
⋮
```

10 Appendix 1 – Instrument/channel names

The tables in this section show the names and codes of the streamed channels along with the record names and channel codes for recorded data. The first character “x” in miniSEED channel code represents the sample rate. The possible values are shown in the table below:

F	≥ 1000 Hz to < 5000 Hz
C	≥ 250 Hz to < 1000 Hz
H	≥ 80 Hz to < 250 Hz
B	≥ 10 Hz to < 80 Hz
M	> 1 to < 10
L	≈ 1
V	≈ 0.1 Hz
U	≈ 0.01 Hz
R	≥ 0.0001 Hz to < 0.001

The “Data record names” of the seismic channels and MEMS accelerometer channels are postfixed with “A” or “B”. This notation distinguishes between the two different sample rates that is possible to select for each recorded channel. For example, the recorded streams `S0AccZA` and `S0AccZB` carry digitisations of the same signal, differing only in the sample rate.

10.1 Environmental channels

Sensor	Comp.	Data streaming			Data recording	
		Digital filter mode	Live stream name	Live Stream code	Data record name	Mini SEED channel code
MEMS accelerometer	1	Acausal	S0AccZ	0AXL10	S0AccZA	xN1
					S0AccZB	xN1
		Causal	S0AccelZLowLat	0AXL1C		xN1
	2	Acausal	S0AccN	0AXL20	S0AccNA	xN2
					S0AccNB	xN2
		Causal	S0AccelNLowLat	0AXL2C		xN2
	3	Acausal	S0AccE	0AXL30	S0AccEA	xN3
					S0AccEB	xN3
		Causal	S0AccelELowLat	0AXL3C		xN3
Magnetometer	1	Acausal	S0MagZ	0MAG10	S0MagZ	xF1

Sensor	Comp.	Data streaming			Data recording	
		Digital filter mode	Live stream name	Live Stream code	Data record name	Mini SEED channel code
	2	Acausal	S0MagN	0MAG20	S0MagN	xF2
	3	Acausal	S0MagE	0MAG30	S0MagE	xF3
Input voltage		Acausal	S0Voltage	0VINP0	S0Voltage	xYV
Digitiser power usage		Acausal	S0Power	0PINP0	S0Power	xYP
Humidity	Relative within Minimus	Acausal	S0HumidA	0HUMA0	S0HumidA	xIO
	Within sensor enclosure	Acausal	S0HumidB	0HUMB0	S0HumidB	xIO
Pressure	Within sensor enclosure	Acausal	S*n*Pressure	*n*PRSR0	S*n*Pressure	xDI
	External	Acausal	S*n*ExtPressure	*n*PRSR1	S*n*ExtPressure	xDO
Temperature	Precision temperature	Acausal	S0TemprA	0TMPA0	S0TemprA	xKO
	First derivative of temperature	Acausal	S0TemprD	0TMPD0		xKD
Internal Clock	Internal clock offset from GNSS	Acausal	ClkGpsOffset	0CGPSO	ClkGpsOffset	BEO
	Internal clock period difference from GNSS	Acausal	ClkGpsPeriod	0CGPSP	ClkGpsPeriod	BEF
	Internal clock DAC frequency pulling	Acausal	ClkDacFreqPull	0CVDAC	ClkDacFreqPull	BED
	Test internal clock drift	Acausal	ClkTestPbpS	0CTSTB	ClkTestPpbS	BEB
	Internal clock offset from PTP	Acausal	ClkPtpOffset	0CPTPO	ClkPtpOffset	BEP
	Delay MS	Acausal	ClkPtpDelayMS	0CPDMS	ClkPtpDelayMS	BEA
	Delay SM	Acausal	ClkPtpDelaySM	0CPDSM	ClkPtpDelaySM	BEB
	Mean path delay	Acausal	ClkPtpMeanPathDelay	0CPMPD	ClkPtpMeanPathDelay	BEC
PLL clock offset		Acausal	S*n*PLLOffset	0PLLO0	S*n*PLLOffset	xYO

10.2 Broadband accelerometer channels

Sensor	Comp.	Data streaming			Data recording	
		Digital filter mode	Live stream name	Live Stream code	Data record name	Mini SEED channel code
Analogue accelerometer	Vertical	Acausal	S0SeisZ	0ACCZ0	S0SeisZA	xNZ
			S0SeisZ	0ACCZ2	S0SeisZB	xNZ
		Causal	Se0SeisZLowLat	0ACCZC	Se0SeisZLowLat	xNZ
	North	Acausal	S0SeisN	0ACCN0	S0SeisNA	xNN
			S0SeisN	0ACCN2	S0SeisNB	xNN
		Causal	Se0SeisNLowLat	0ACCNC	Se0SeisNLowLat	xNN
	East	Acausal	S0SeisE	0ACCE0	S0SeisEA	xNE
			S0SeisE	0ACCE2	S0SeisEB	xNE
		Causal	Se0SeisELowLat	0ACCEC	Se0SeisELowLat	xNE
Calibration channel		Acausal	S0Calib	0ACCC0		xCA

11 Appendix 2 – Fortimus network ports

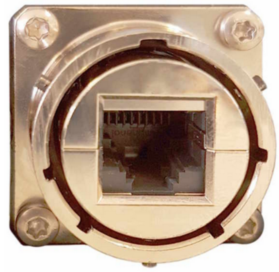
The following network ports are used by the Fortimus:

Port	Layer 4 Protocol	Description
80	TCP	HTTP server
1565	TCP	GDI transmission protocol
1567	TCP/UDP	GCF transmission protocol
4242	TCP	File exchange protocol
4244	TCP	Remote console
11788	UDP	Remote procedure calls
18000	TCP	SEED-link transmission protocol

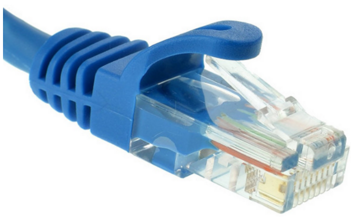
12 Appendix 3 – Connector pin-outs

12.1 Ethernet

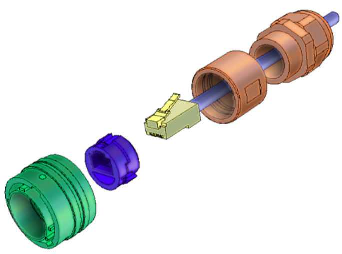
This is an Amphenol RJField-series 8P8C connector. It consists of a standard ISO 8877 8P8C modular socket (often called RJ45) in a bayonet mounting compatible with MIL-DTL-26482 (formerly MIL-C-26482).



Pin	10BASE-T & 100BASE-TX	1000BASE-T
1	Transmit Data +	BI_DA+
2	Transmit Data -	BI_DA-
3	Receive Data +	BI_DB+
4	*not connected*	BI_DC+
5	*not connected*	BI_DC-
6	Receive Data -	BI_DB-
7	*not connected*	BI_DD+
8	*not connected*	BI_DD-



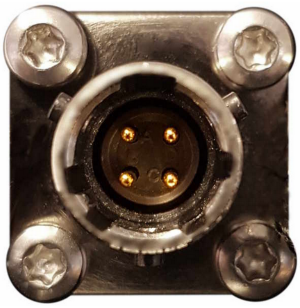
This connector accepts unmodified ISO 8877 8P8C modular connectors (often called RJ45 connectors or Ethernet "Cat 5/6" connectors).



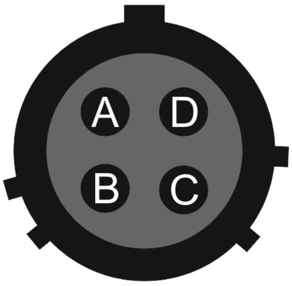
When used in hostile environments, a standard Ethernet cable can have a mating environmental shield (Amphenol part number RJF6MN) fitted.

12.2 Power

This is a standard 4-pin military-specification bayonet plug, conforming to MIL-DTL-26482 (formerly MIL-C-26482).



Pin	Function
A	Ground
B	10-36 V DC input
C	*not connected*
D	*not connected*



Wiring details for the compatible socket as seen from the cable end (i.e. when assembling).

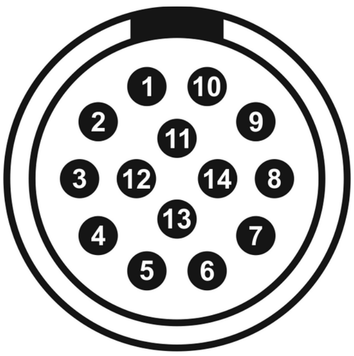
Caution: Observe the correct polarity when connecting the power supply. The red lead (from pin B) must be connected to the positive terminal, typically labelled '+', and the **black** lead (from pin A) must be connected to the **negative terminal**, typically labelled '-'. An incorrect connection risks destroying the digitiser, the power supply and any connected instruments.

12.3 GNSS/serial

This is a 14-pin LEMO EEG.1K socket. Suitable mating connectors can be found in the LEMO FGG.1K.314 range.

- To engage the mating connector, line up the red marks and push firmly home.
- To disengage, hold the mating connector by the gnurled outer sleeve and pull steadily.

Pin	Function
1	Ground
2	*not connected*
3	Ground
4	Debug (serial) receive
5	Debug (serial) transmit
6	*not connected*
7	GNSS power
8	GNSS pulse-per-second signal – RS-422 positive
9	GNSS receive – RS-422 positive
10	GNSS transmit – RS-422 positive
11	GNSS transmit – RS-422 negative
12	*not connected*
13	GNSS pulse-per-second signal – RS-422 negative
14	GNSS receive – RS-422 negative



Wiring details for the compatible plug, FGG.1K.314.*, as seen from the cable end (*i.e.* when assembling).

13 Appendix 4 – Güralp Discovery installation

Güralp Discovery is a software package for Microsoft Windows, MAC and Linux, which facilitates the identification, configuration and management of Güralp digitisers and instruments.

Güralp Discovery has a conventional `.msi` -based installer. Once installed, the software can check whether it is the current version and can update itself using a button on the Help→About menu.

13.1 Installation in Linux

The Linux version of Discovery 64-bit is delivered in a self-contained package.

To install Güralp Discovery:

1. Open the terminal
2. Visit www.guralp.com/sw/download-discovery.shtml to download the appropriate installation script or use the command

   wget http://www.guralp.com/download/discovery/Discovery.run

3. Make the downloaded file executable using the command

   chmod +x Discovery.run

4. Run the script with the `-h` option to see the installer's help message:

```
./Discovery.run -h
Online installer for Guralp Systems Discovery application
Usage: ./Discovery.run [parameters]
Parameters:
-h : this message
-i : perform installation
-o <directory> : output directory (default
/opt/guralp/discovery)
```

5. Execute the script, either accepting the default installation directory

   ./Discovery.run -i

   or providing your own, alternative location

   ./Discovery.run -i -o *usr/lib/discovery*

The script proceeds through the following installation stages:

1. A confirmation prompt:

```
Guralp Discovery will be installed in:
/opt/guralp/discovery. [C]ontinue/[A]bort
```

   Type C to continue installation in listed directory, or A to abort and change directory using the `-o` execution parameter

2. Downloading. The following message is printed:

```
Downloading Discovery from Guralp Systems server
[Downloading]
```

   This step downloads the discovery package from the Güralp server. It is around 50 MiB in size so downloading may take a long time if you have a slow Internet connection.

3. Next, the following message is printed:

```
Creating installation directory: /opt/guralp/discovery
[OK]
```

   This step creates the installation directory. If an error occurs at this stage, please make sure that the user running the installation script has permission to create the specified directory.

4. The downloaded archive is now unpacked into the specified installation directory. The following message is printed:

```
Unpacking Discovery to /opt/guralp/discovery [OK]
```

5. The next step removes the downloaded file from the disk.

```
Removing downloaded Discovery archive [OK]
```

6. A this point, the installation is complete. The message

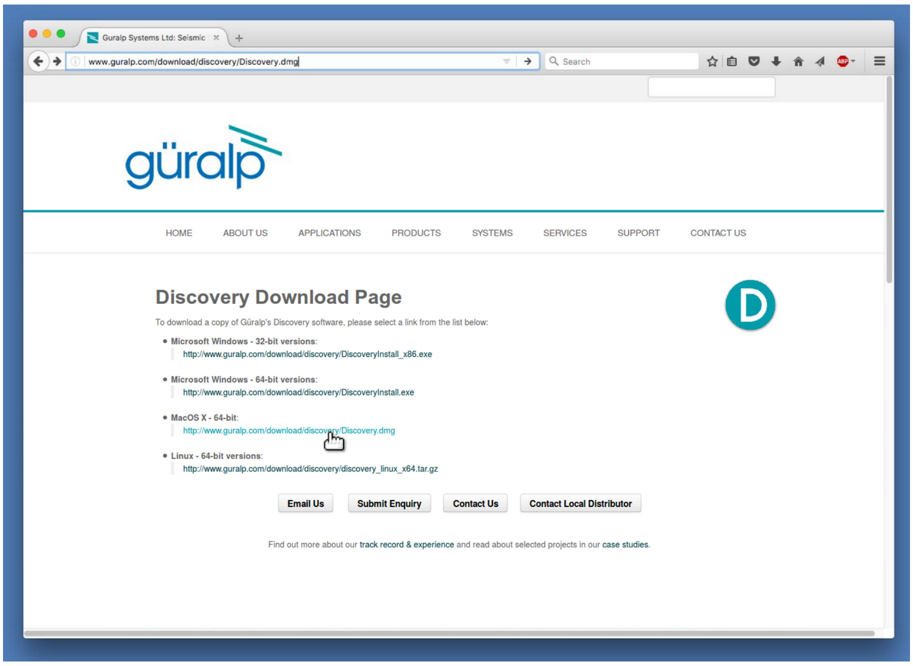
```
Discovery is now installed in:
/opt/guralp/discovery/discovery
```

   is displayed and the application is available in the specified directory.

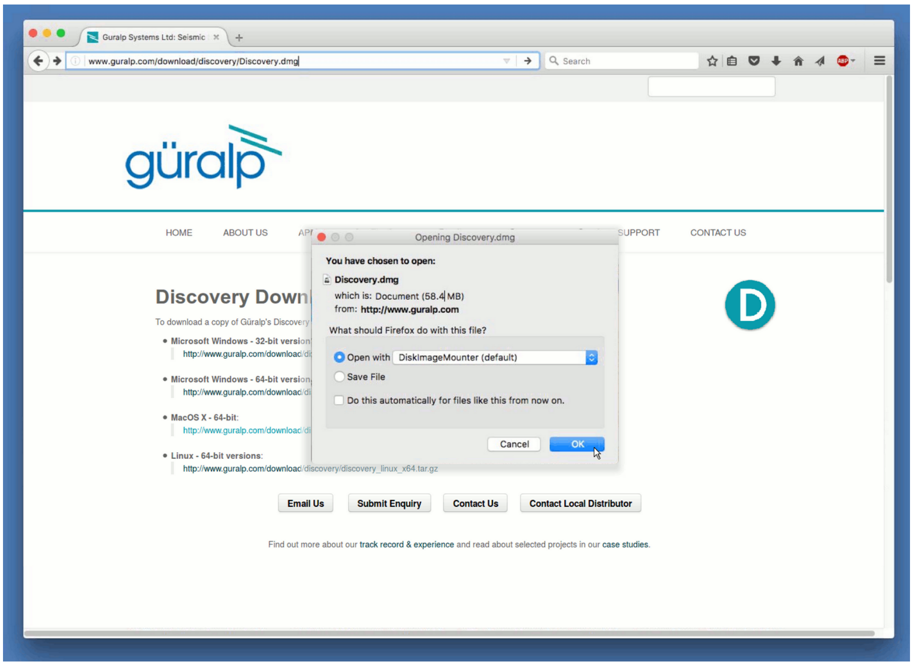
13.2 Installation in Mac

To install Güralp Discovery in a macOS machine:

1. Open Safari, visit www.guralp.com/sw/download-discovery.shtml and download the appropriate disk-image file.

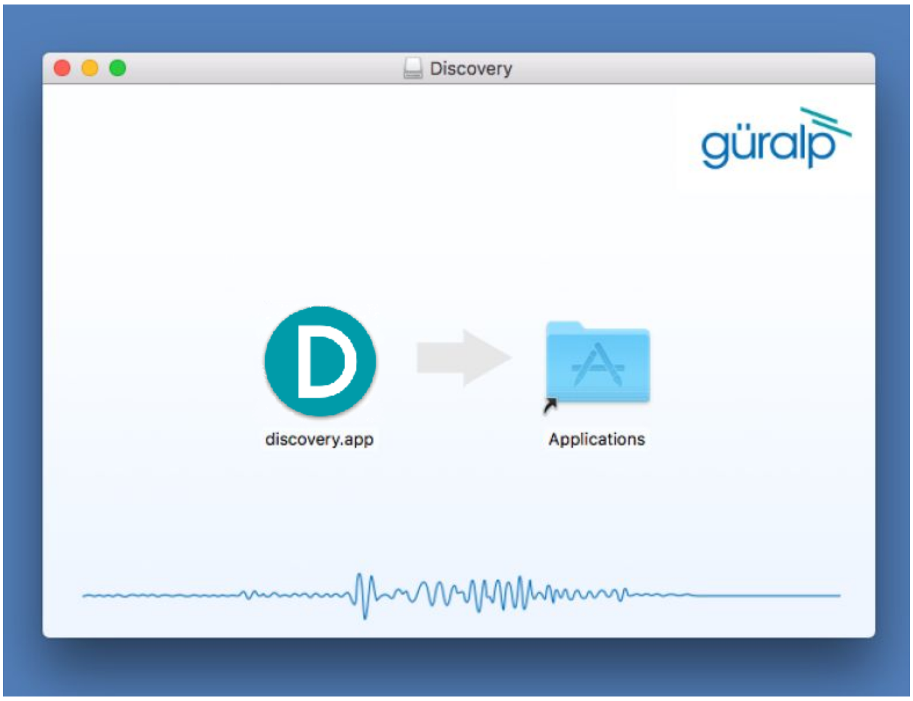


2. Either save the downloaded file on a local drive, or automatically open it with DiskImageMounter.

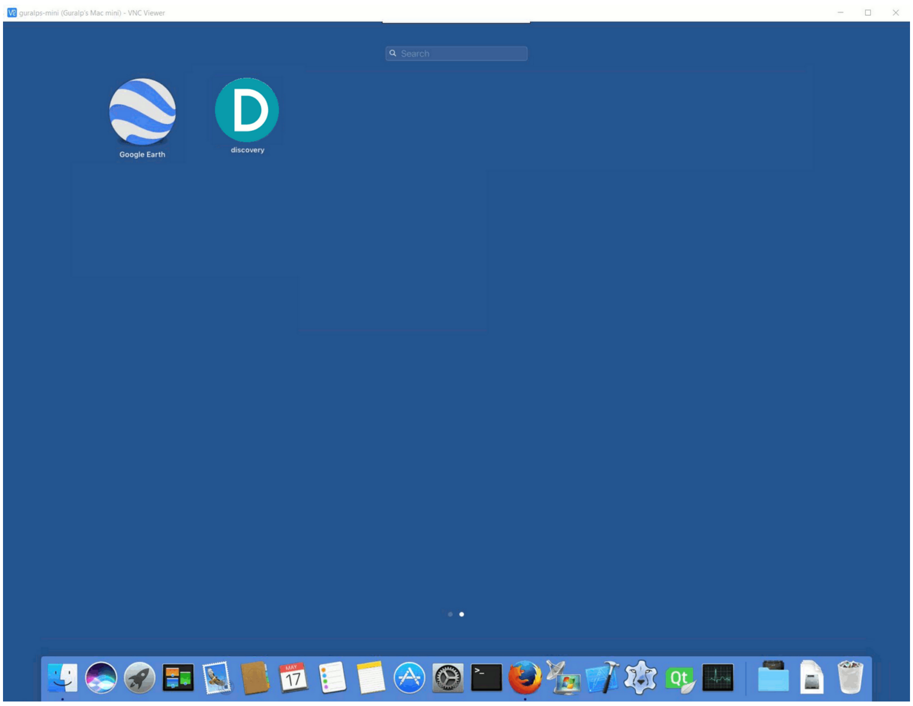


3. If you saved the file to disk, navigate to the download location and open `Discovery.dmg` with DiskImageMounter.

4. Successful mounting should result in the display of the Discovery drag and drop installation window:



5. Drag and drop discovery.app to the Applications folder.
6. When finished, the installation is complete and the Discovery app can be found in Launcher or Applications folder in Finder.



13.3 Installation in Windows

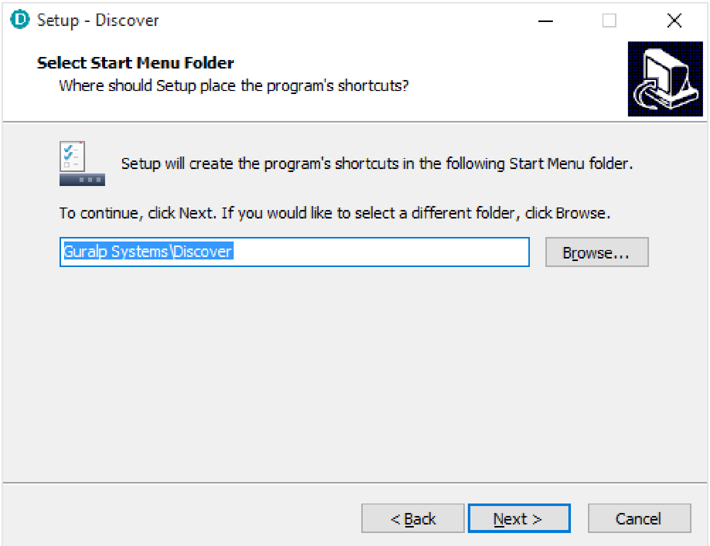
To install Güralp Discovery on a Windows machine:

1. Download the appropriate installer – 32-bit or 64-bit – from

   https://www.guralp.com/sw/download-discovery.shtml

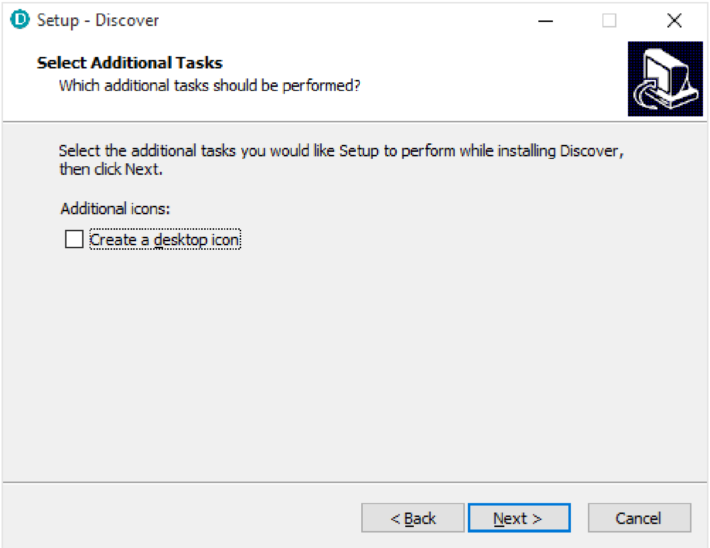
2. Double-click the downloaded file. You may be asked whether you wish to continue: answer yes.

3. The following screen asks where, in the Start Menu, you would like to place the Discovery short-cut. The default location is normally satisfactory but you can change it from here if you wish.



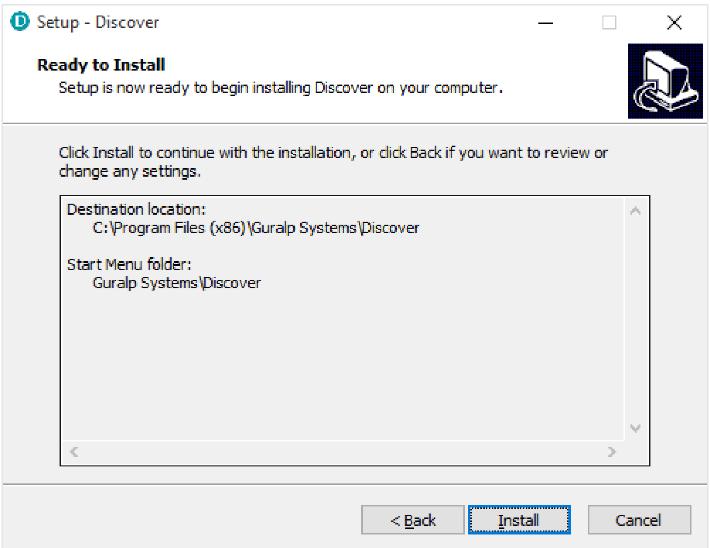
Click Next >, key ↵ or key Alt + N to continue.

4. The next screen asks whether you would like to place an icon for Discovery on the desktop:



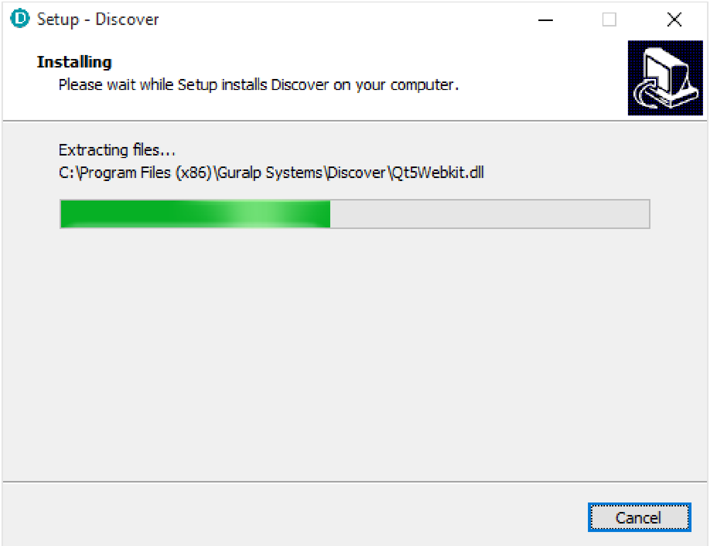
Tick the check-box if you wish and then click Next >, key ↵ or key Alt + N to continue.

5. The installer then offers a last chance to change any of your decisions:



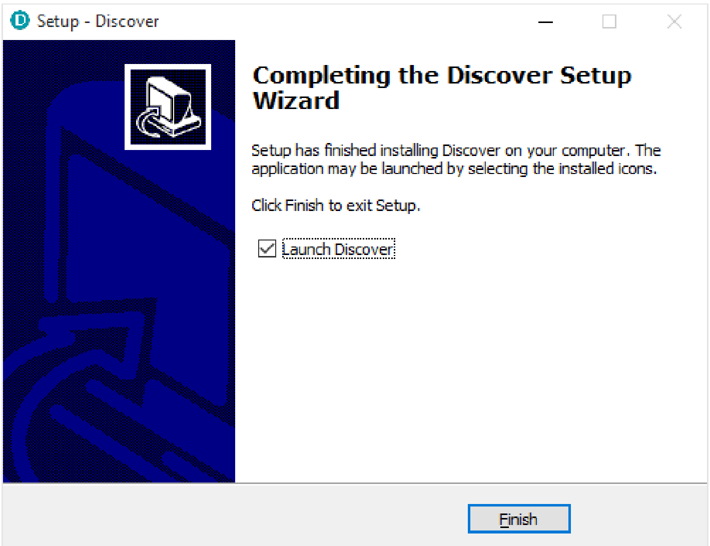
Click Install, key ↵ or key Alt + I if you are happy with your choices or click < Back (or key Alt + B) if you wish to revisit any of them.

6. Once you have clicked Install, the installation begins and a progress screen is displayed:



Pressing Cancel or keying Esc now will remove all of the installed files (except the installer itself) and reverse any changes made so far.

7. Once installation is complete, the following screen is displayed:



Press Finish, key ↵ or key Alt + F to close the installer and launch Discovery.

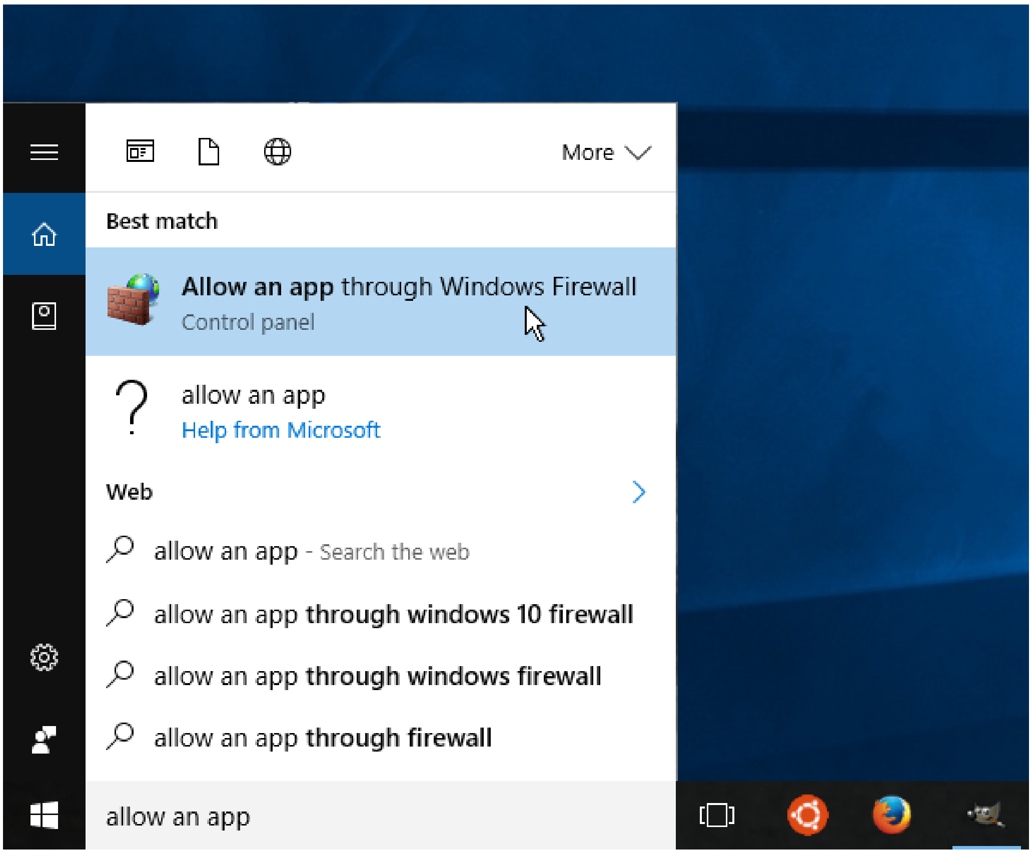
Note: Discovery for Windows 64-bit requires Microsoft Visual C++ 2015. Discovery may ask to install it if it is not installed yet.

13.4 Configuring Windows Firewall

Windows Firewall can interfere with Discovery's ability to send information to instruments and/or receive information from instruments over the network. If you use Windows Firewall, you should make special provision for allowing Discovery to communicate, as described in this section.

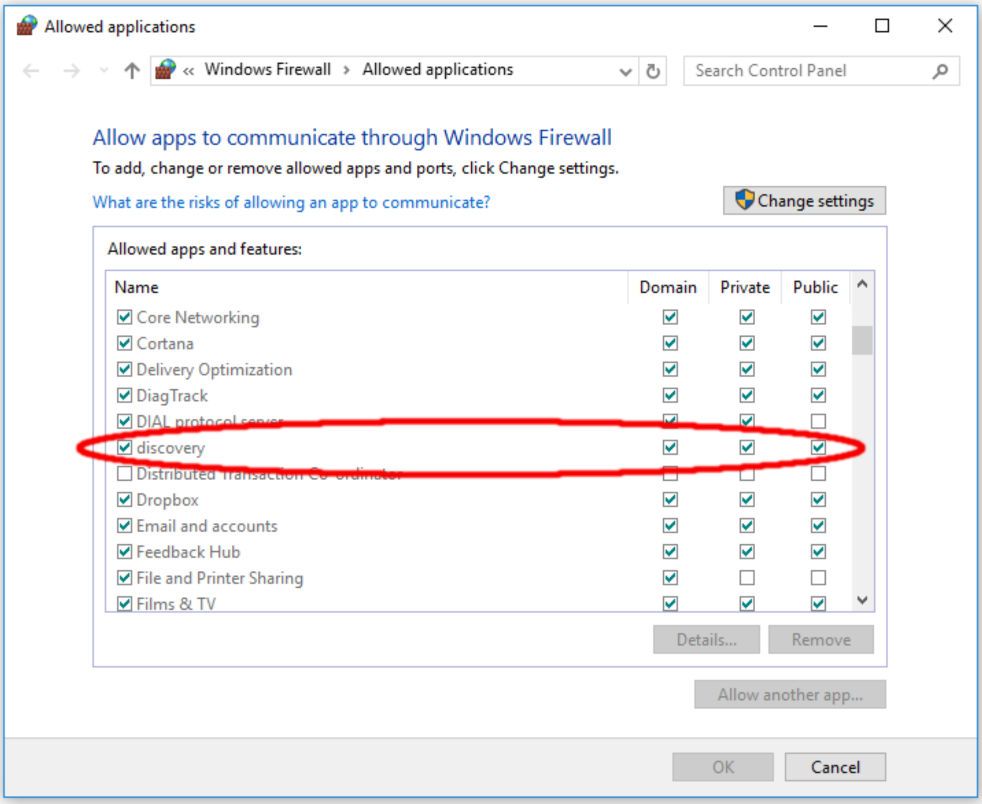
1. Click in the "Ask me anything" search box at the bottom left of your Windows screen:

2. Type "allow an app"



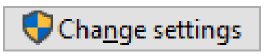
3. Select "Allow an app through Windows Firewall" from the search results.
4. Windows will display the "Windows Firewall Allowed Applications" screen.

   This displays a list of applications in alphabetical order. Each application is provided with three check-boxes which indicate whether the application can communicate with networked devices in the “Domain” profile, the “Private” profile or the “Public” profile. (Profiles are also known as “network locations”.)



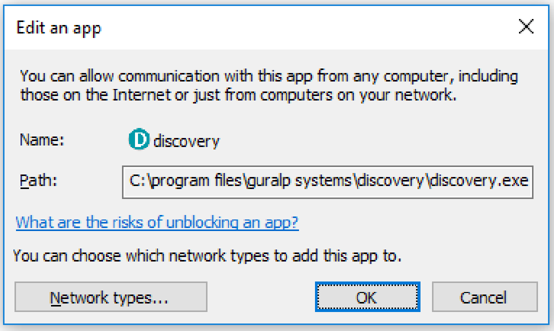
The “Domain” profile applies to networks where the host system can authenticate to a domain controller. The “Private” profile is a user-assigned profile and is used to designate private or home networks. The default profile is the “Public” profile, which is used to designate public networks such as WiFi hotspots at coffee shops, airports, and other locations.

For a more complete discussion of this topic, please see http://www.tenforums.com/tutorials/6815-network-location-set-private-public-windows-10-a.html or your Windows documentation.

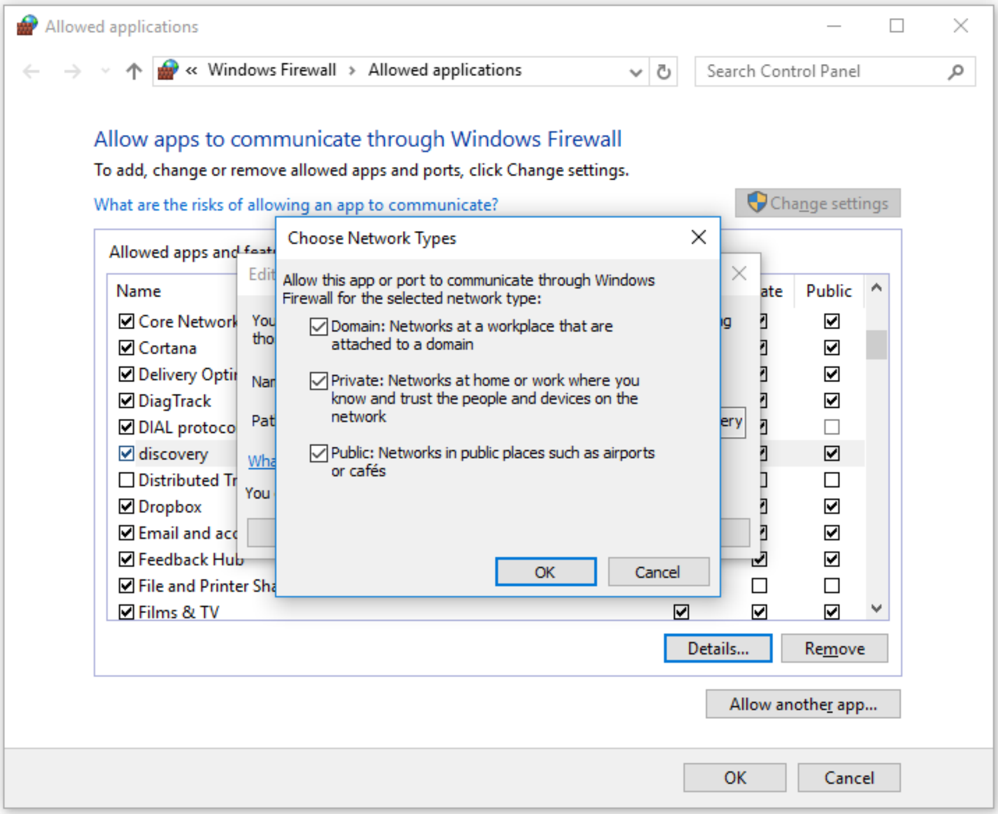
5. First click the 

buttons to activate the interface.

6. Highlight the "discovery" line and then click the Details... button. The "Edit an app" window is shown:



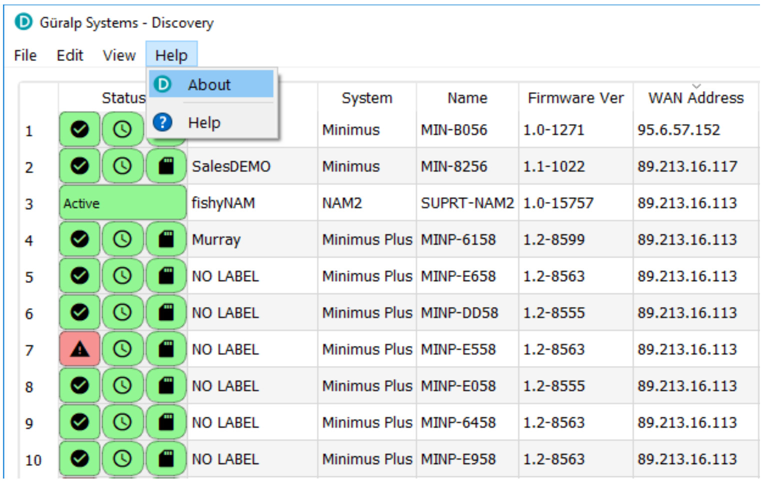
7. Click the Network types... button. The "Choose network types" window is shown:



8. After making appropriate changes, click OK first in the "Choose network types" window, then in the "Edit an app" window, then in the "Windows Firewall Allowed Applications". This closes the Windows Firewall "Allowed Applications" tool and saves the changes that you have made.

13.5 Update

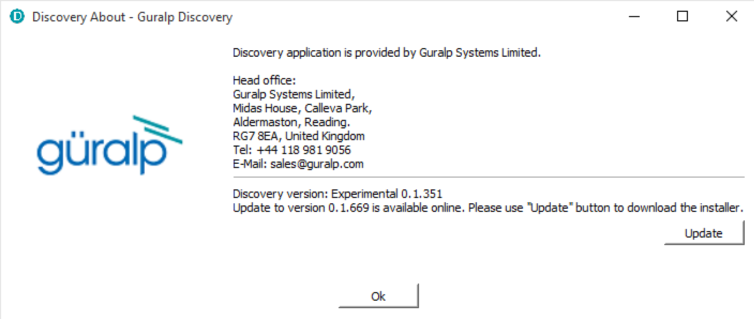
If a PC running Güralp Discovery has an Internet connection, Discovery can check whether an update is available. To initiate this, click About from the Help menu or type Alt + H followed by A:



A screen like the following is displayed:

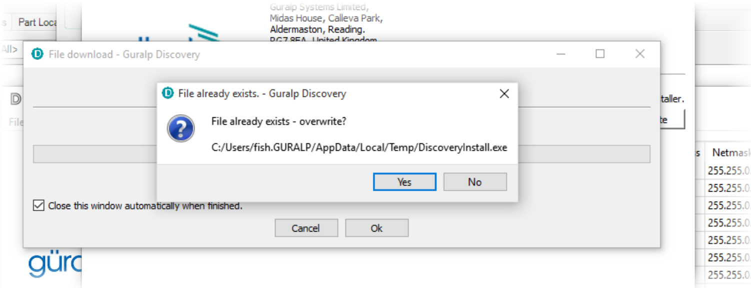
The currently installed version is shown. If this is the most recent version available, the screen will say `Up to date` and the Update button will be disabled, as shown above.

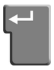
If a newer version is available, the screen will look like this:



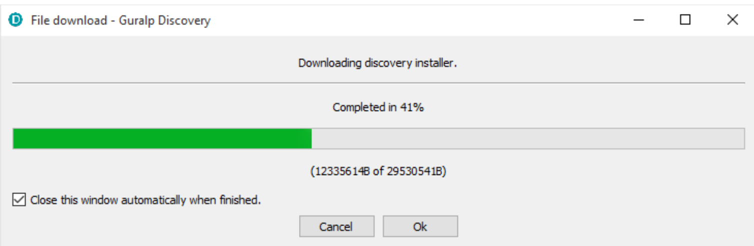
If you with to proceed with downloading the newer version, click the Update button. This does not commit to an immediate upgrade: it just downloads the installer. If you do not wish to download the installer, click Ok to close the "Discovery About" dialogue.

If you clicked Update, you may see the following warning if the previous installer is still in your download folder:

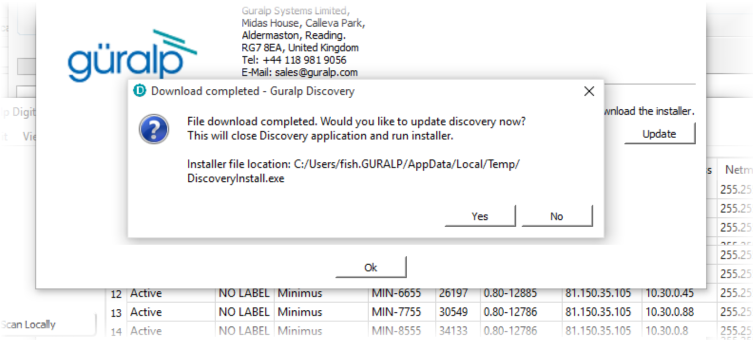


Simply click Yes or key  to continue: the download will start immediately.

While the download is in progress, the following indicator will be displayed:



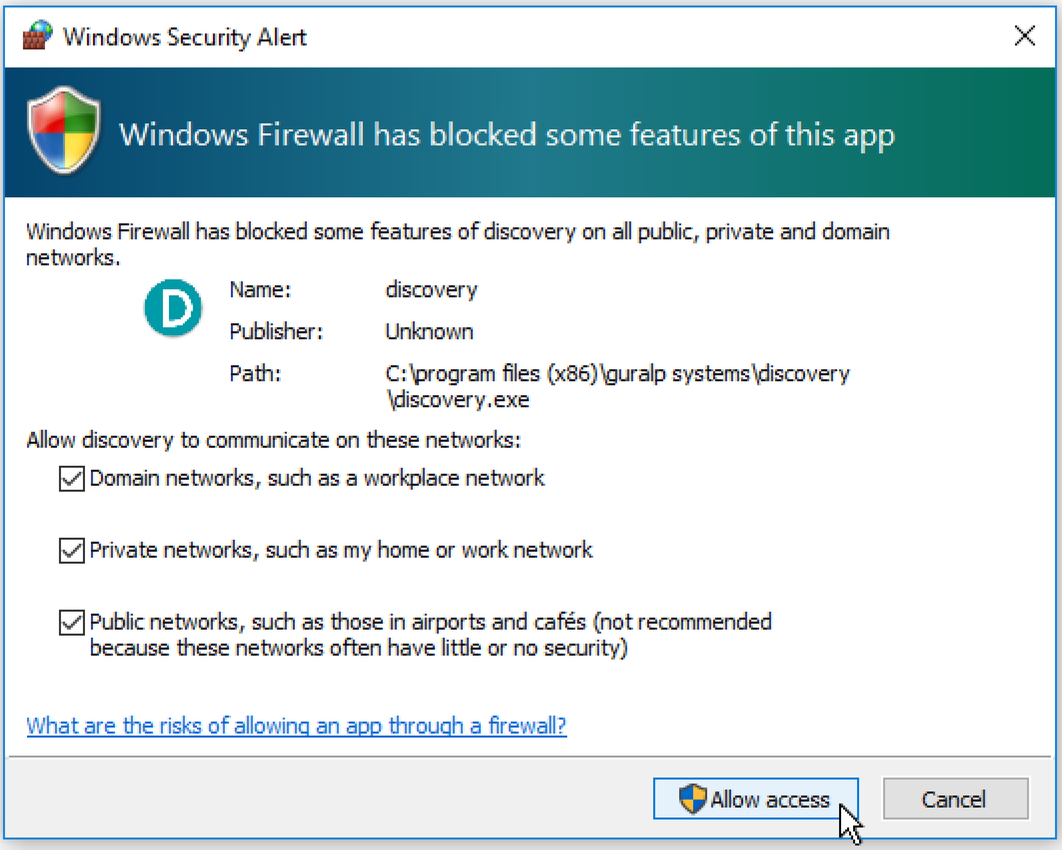
When the download is complete, the following screen is displayed:



If you wish to complete the installation immediately, click Yes. If you would rather defer the installation, click No and run the installer at a more convenient time.

Once the upgrade is complete, start Discovery in the usual way. Windows, recognising that the program has changed, may ask you to specify how you wish Discovery to interact with the Windows Firewall. Because Discovery requires network communication in order to function, it is important that you understand the options available.

The following screen is displayed:



The screen provides three check-boxes which indicate whether Discovery can communicate with networked devices in the “Domain” profile, the “Private” profile or the “Public” profile. (Profiles are also known as “network locations”.)

The “Domain” profile applies to networks where the host system can authenticate to a domain controller. The “Private” profile is a user-assigned profile and is used to designate private or home networks. The default profile is the “Public” profile, which is used to designate public networks such as WiFi hotspots at coffee shops, airports, and other locations.

For a more complete discussion of this topic, please see www.tenforums.com/tutorials/6815-network-location-set-private-public-windows-10-a.html or your Windows documentation.

14 Appendix 5 – I.P. address configuration on PC or Laptop

With APIPA (Automatic Private I.P. Addressing), a laptop or PC can automatically configure itself with an IP address in the range `169.254.0.1` to `169.254.255.254`. The default subnet mask is `255.255.0.0`.

Connect the Fortimus to the laptop or PC using the blue Ethernet cable and power it up.

14.1 On Linux

On your Linux computer, open the terminal and type the command

```
sudo bash
```

Key ↵ and provide the appropriate password. Then, enter the command

```
ifconfig
```

to identify the Ethernet network interface to which the Fortimus is connected. Once you have identified the correct interface, connect the Fortimus, power it up and enter the commands

```
ifconfig wlp2s0 down
ifconfig wlp2s0 up
```

replacing ***wlp2s0*** with the name of the appropriate interface on your PC.

Enter the command **`ifconfig`** again to verify that the IPv4 address of the Ethernet adapter is now included in the network `169.254.0.0/16` - i.e. the address begins `169.154.…`

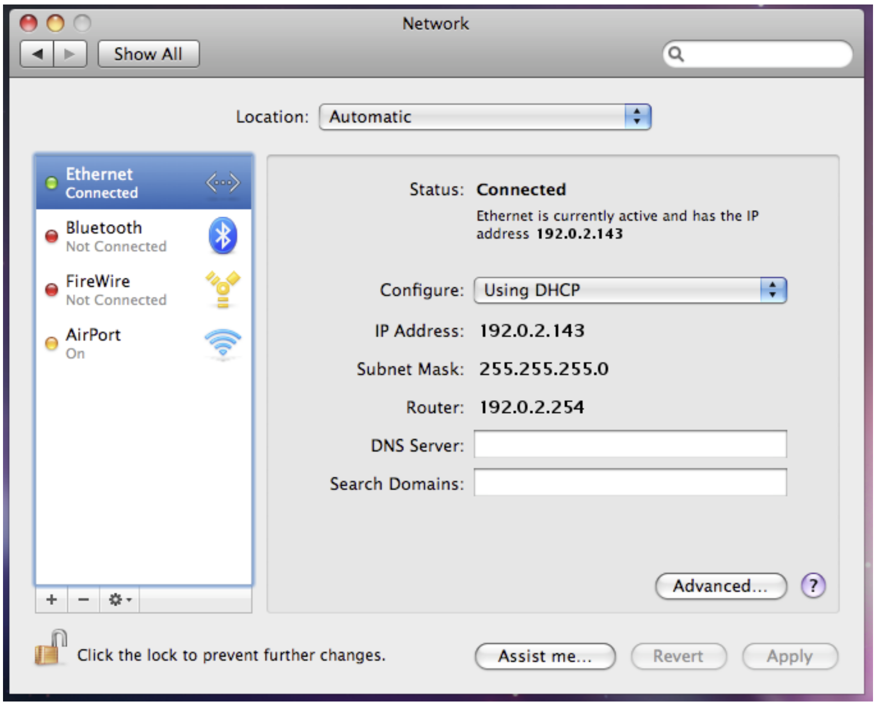
```
wlp2s0  flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 169.254.139.29  netmask 255.255.0.0  broadcast 169.254.255.255
        ether 94:65:9c:ab:3c:9a  txqueuelen 1000  (Ethernet)
        RX packets 556837  bytes 722823565 (689.3 MiB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 320424  bytes 42811910 (40.8 MiB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0
```

In the example above, the interface has been allocated address `169.254.139.29`, which is in the correct network.

14.2 On macOS

Click the Apple icon in the upper-left corner of the screen, and select "System Preferences."

1. Click the "Network" icon to open the Network Preferences pane and select "Ethernet" from the list on the left side of the window.



2. Click the gear button, , in the lower-left corner of the window, then click "Make Service Inactive." Click the "Apply" button to disable the NIC (Network Interface Card).

3. With the Fortimus connected and powered up, click the  button again, click "Make Service Active" and click "Apply" to re-enable the NIC.

4. Check that the interface has been assigned an address in the correct network:

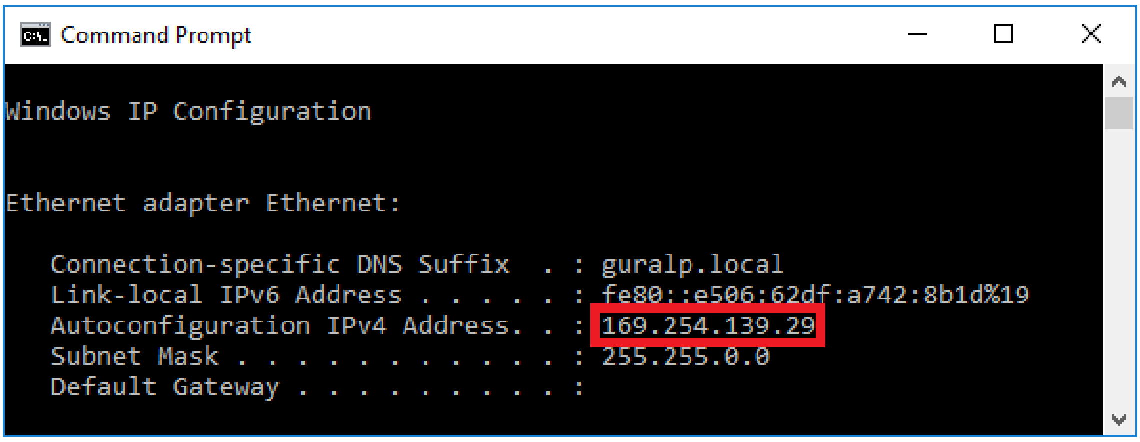
In the example above, the interface has been allocated address `169.254.56.230`, which is in the correct network.

14.3 On Windows

On a Windows computer, key + R to open the "Run" dialogue, enter **`ncpa.cpl`** and key .

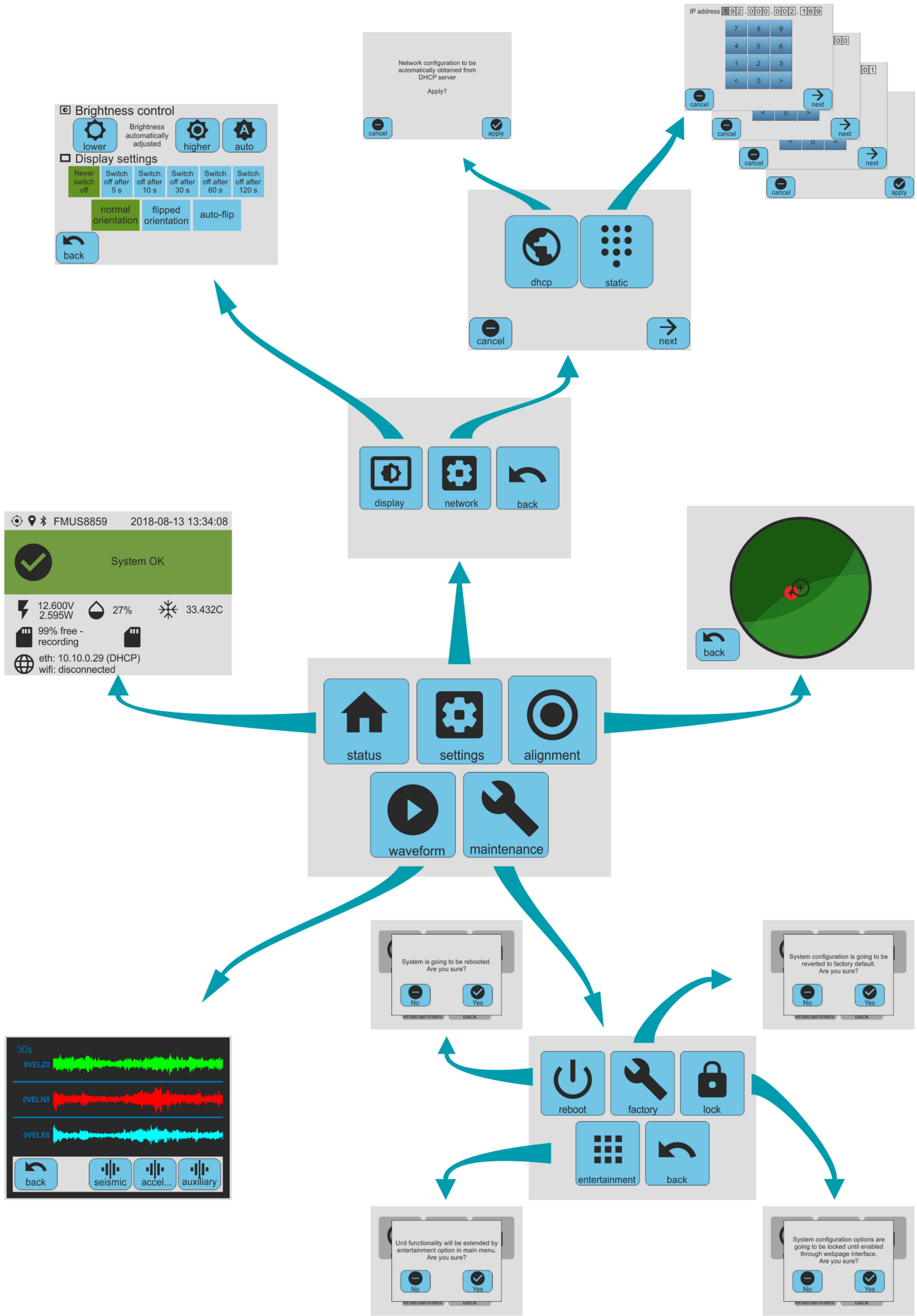
Right-click on the network adapter which is connected to the FortimusFortimus and select “Disable” from the context menu. Right-click on the same adapter again and select “Enable”. Close the network settings window.

Key + R and type **`cmd.`**, then . This opens a command window. Type the command **`ipconfig`** and verify that the IPv4 address of the Ethernet adapter is included in network *`169.254.*.*`*.



In the example above, the interface has been allocated address 169.254.56.230, which is in the correct network.

15 Appendix 6 – LCD menu map



16 EU Declaration of Conformity

We

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READING, RG7 8EA.

Tel: +44 118 981 9056
E-mail: technical@guralp.com

Declare under our sole responsibility that the following product

Equipment name: Fortimus with GPS
Model Number: FMUS-0001 and appropriate variants

Is in conformity with the

Radio Equipment Directive 2014/53/EU
Electromagnetic Compatibility Directive 2014/30/EU
Low Voltage Directive 2014/35/EU
Restriction of Hazardous Substances (RoHS) Directive 2011/65/EU
by applying the following harmonised standards and technical specifications:
EN 55011, EN 55016:2009 +A1:2010 – Conducted Emissions
EN 55011, EN 55032 :2009 +A1:2010 – Radiated Emissions
EN 61000-4-2:2009 – Electrostatic Discharge Immunity
EN 61000-4-3:2006 +A1:2008 +A2:2010 – Radiated RF Immunity
EN 61000-4-4:2012 – Electrical Fast Transients Immunity
EN 61000-4-5:2014 – Voltage Surge Immunity
EN 61000-4-6:2014 – Conducted RF Immunity
EN 61000-4-8:2010 – Power Frequency Magnetic Field Immunity
IEC 61010-1 3rd Edition - Low voltage Safety
2011/65/EU – RoHS

Signed for and on behalf of
Guralp Systems Ltd
on 25 February 2020

Systems Director

17 Revision History

D	2021-09-09	Added EU Declaration of Conformity
C	2020-01-06	Corrected labels for main illustration in system description.
B	2019-12-02	Updated web page screenshots. Updated Data Stream and Data Storage. Updated stream and file names. Updated and added Transforms. Updated EEW and Triggering. Added back-fill from miscoSD card.
A	2018-08-19	Initial release