# Güralp 5U

## Operator's Guide

Document Number: MAN-050-0002

Issue E – March, 2021

Designed and manufactured by
Güralp Systems Limited
3 Midas House, Calleva Park
Aldermaston RG7 8EA
England

# Table of Contents

# 1 Preliminary Notes

## 1.1 Proprietary Notice

The information in this document is proprietary to Güralp Systems Limited and may be copied or distributed for educational and academic purposes but may not be used commercially without permission.

Whilst every effort is made to ensure the accuracy, completeness and usefulness of the information in the document, neither Güralp Systems Limited nor any employee assumes responsibility or is liable for for any incidental or consequential damages resulting from the use of this document.

## 1.2 Warnings, Cautions and Notes

Warnings, cautions and notes are displayed and defined as follows:

**Warning:** A black cross indicates a chance of injury or death if the warning is not heeded.

**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.

# 2 Introduction

The Güralp 5U sensor is a single-axis strong-motion force-feedback accelerometer in a sealed case, which can be used in either vertical or horizontal orientations. The sensor system is self-contained except for its 12 V DC power supply, which can be provided through the same cable as the analogue data. An internal DC–DC converter ensures that the sensor is completely isolated.


The 5U system combines low-noise components with high feedback loop gain to provide a linear, precision transducer with a very large dynamic range. In order to exploit the whole dynamic range two separate outputs are provided, with high and low gain. Nominally the high gain outputs are set to output a signal 10 times stronger than the low gain outputs.

The 5U sensor outputs are all differential with an output impedance of 47 Ω. A single signal ground line is provided as a return line for all the sensor outputs.

Full-scale low-gain sensitivity is available from 2.0 g down to 0.1 g. The standard frequency pass band is flat to acceleration from DC to 100 Hz. DC to 50 Hz and DC to 200 Hz variants are available.

Each seismometer is delivered with a calibration sheet showing its serial number and measured frequency response in both the long period and the short period sections of the seismic spectrum.

# 3 Installing Güralp 5U sensors

## 3.1 Unpacking and packing

The 5U accelerometer is delivered in a single cardboard box with foam rubber lining. The packaging is specifically designed for the 5U and should be reused 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 accelerometer
- a signal connection cable (if ordered)
- a suitable connector.

The sensor serial number label can be found on the lid of the sensor. If you need to request the sensor production history, you will need to quote either the serial number of the sensor or the works order number, which is also provided on the calibration sheet.

## 3.2 Initial testing

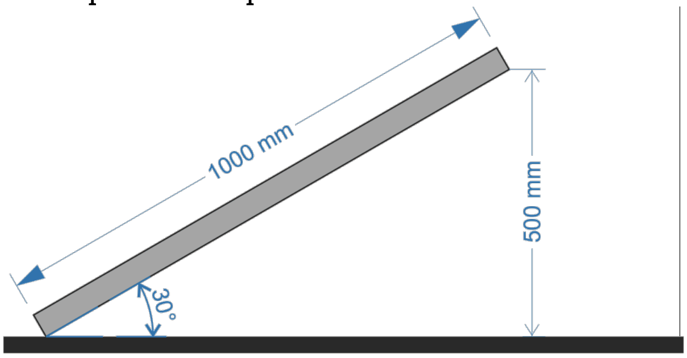
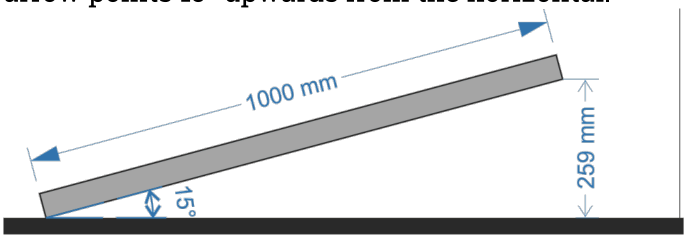
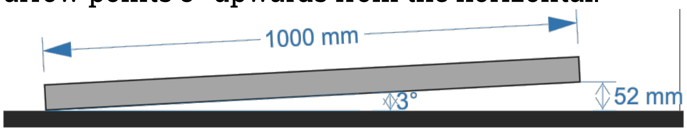
To test the 5U before installation, you will need a DC power source which can deliver 100 mA at 10 to 12 V and a digital voltmeter (DVM) with 1 and 10 V ranges. Connect the supplied cable, ensuring that it is connected with the correct polarity (see the instrument's pin-out in section 5.1 on page 23).

**Caution:** You should never supply more than 12.5 V to the 5U.

To make it easier to measure the output from the sensor, you can use the 5U hand-held control unit or a improvised interface box, which can be manufactured from a screw clamp connector block. This will simplify the connections to the appropriate connector pin outputs.

1. Place the 5U sensor on a flat surface with the POSITIVE ACCELERATION arrow horizontal.
2. Switch on the power supply.
3. Connect the voltmeter to pins J and K of the output connector (corresponding to the low gain vertical component.) Measure the output of the low gain vertical component. The steady output voltage should be about zero (± 10 mV). If it is not, centre the instrument as described in section 3.4 on page 14.

4. Now follow the instructions appropriate to the sensitivity of your 5U as shown in the table below. The correct tilt angles can be achieved by placing the instrument on a board that can be lifted at one end, as shown. The reading on the voltmeter should be close to that shown in the final column:

| **Full-scale** | **Procedure** | **Reading** |
|---|---|---|
| ±2 g | Turn the sensor on its side, so that the POSITIVE ACCELERATION arrow points upwards. | -5.00 V |
| ±1 g | Tilt the sensor so that the POSITIVE ACCELERATION arrow points 30° upwards from the horizontal.   | -5.00 V |
| ±0.5 g | Tilt the sensor so that the POSITIVE ACCELERATION arrow points 15° upwards from the horizontal.   | -5.18 V |
| ±0.1 g | Tilt the sensor so that the POSITIVE ACCELERATION arrow points 3° upwards from the horizontal.   | -5.23 V |

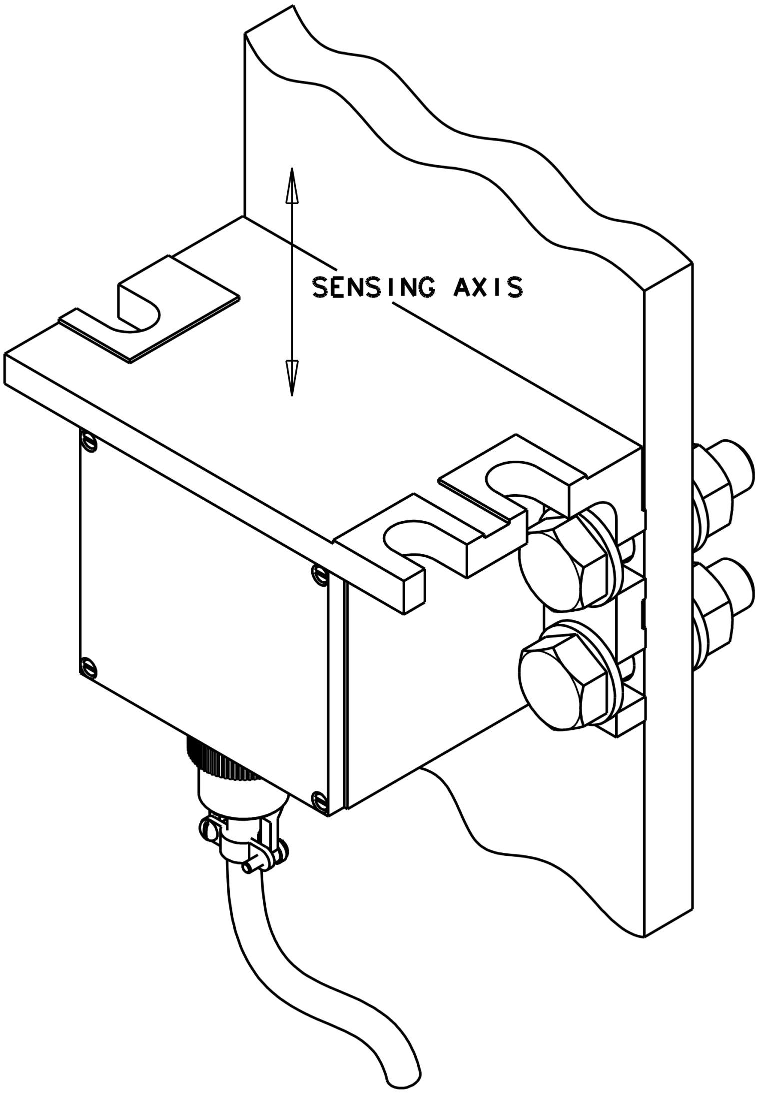
If the performance so far has been as expected, the instrument may be assumed to be in working order and you may proceed to install for trial recording tests.

## 3.3 Installing the sensor

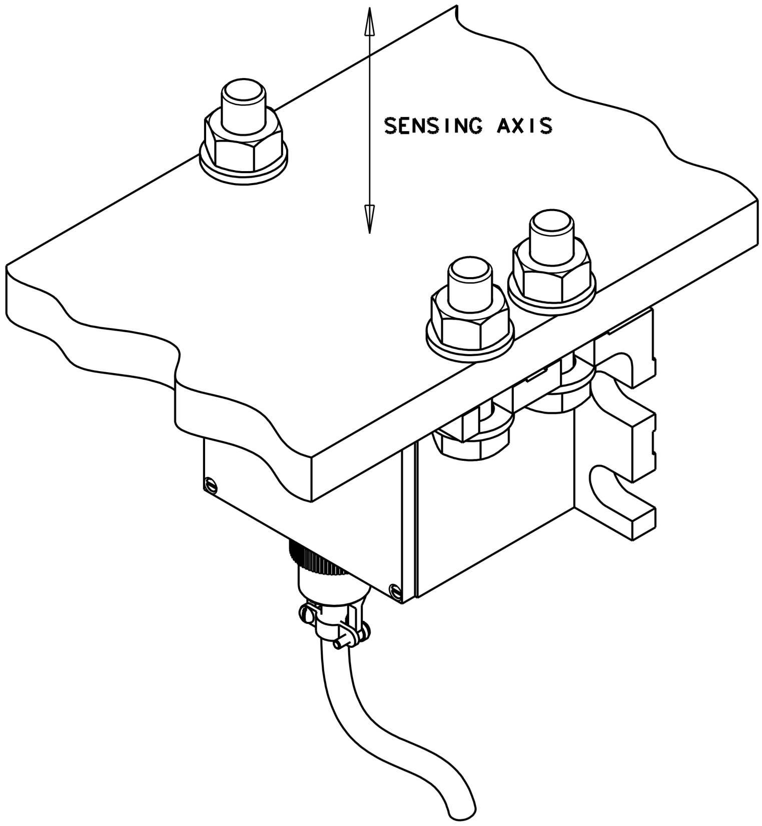
**Caution:** If you are in any doubt about how to install the sensor, you should contact Güralp Systems.

The Güralp 5U can be installed for vertical or horizontal sensitivity. In either case, it can be mounted to a vertical or to a horizontal surface. An optional clamp-block is available which allows mounting to poles or cables. Consult the following diagrams to determine the correct mounting method for your application:

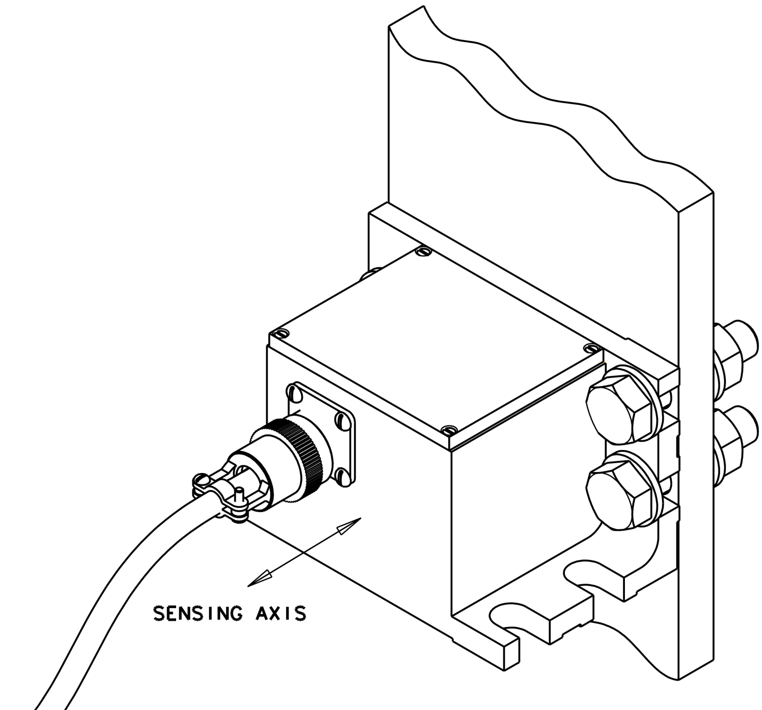
1. Vertical sensitivity, vertical mounting surface



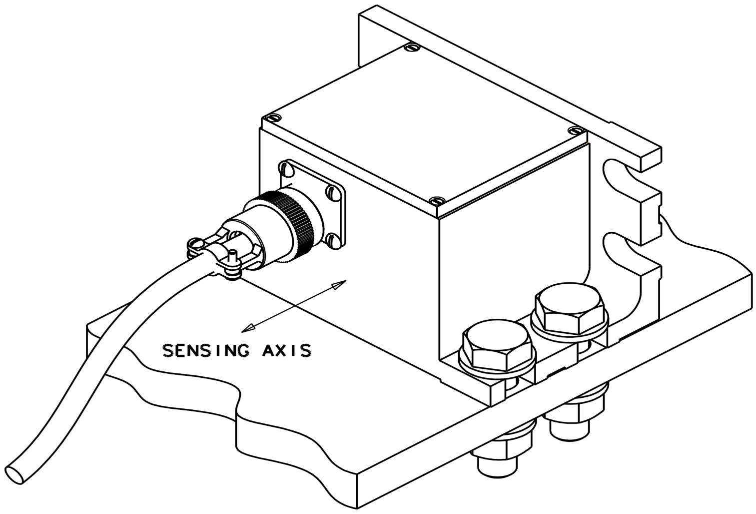
2. Vertical sensitivity, horizontal mounting surface



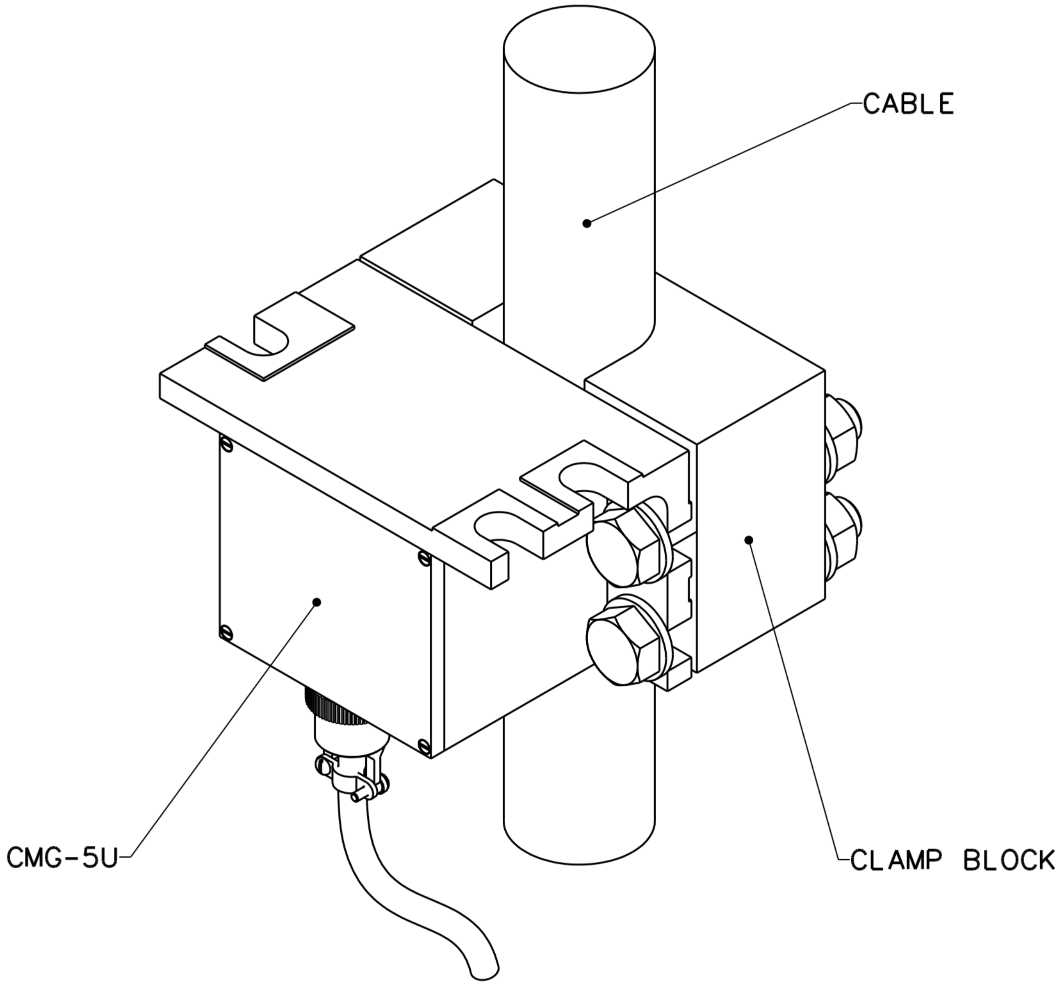

3. Horizontal sensitivity, vertical mounting surface



4. Horizontal sensitivity, horizontal mounting surface

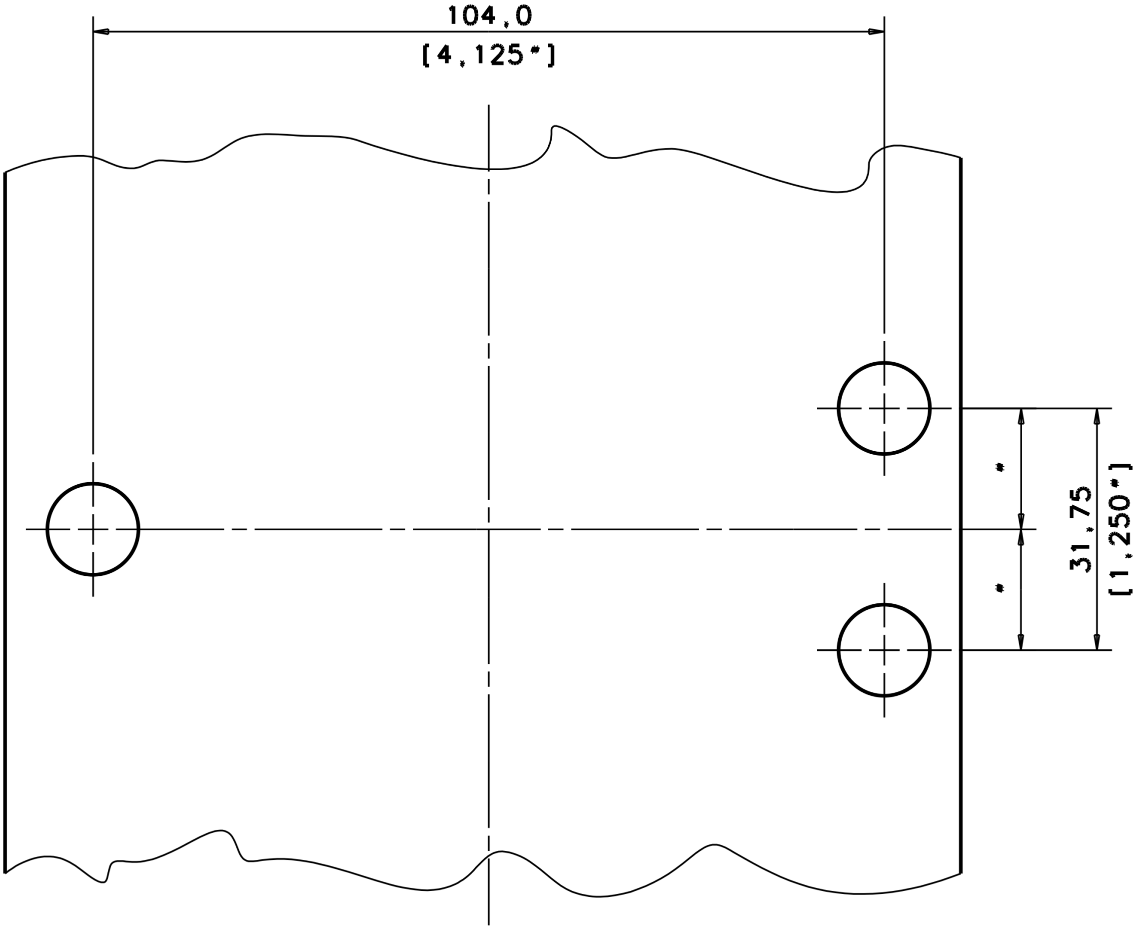



5. Cable or pole mounting, using optional clamp-block




Mounting holes in the mounting surface should be drilled as shown below. M12 or ½ inch hexagonal mounting bolts are preferred but it is also possible to use M10 or

⅜ inch bolts. You may find it useful to copy the footprint of the sensor base onto a metal sheet to use as a template when drilling fixing holes into the surface where you want to mount the sensor.




Regardless of the mounting arrangement, proceed to install the instrument as follows:

1. Fasten the instrument to the mounting surface using three bolts or an appropriate clamp as previously described.
2. Fix the sensor to the mounting surface, with the POSITIVE ACCELERATION arrow pointing in the required direction. The accelerometer has no levelling feet, but can use internal simulated level adjustment to compensate as long as it is fixed to a hard, clean surface within 1 degree of the horizontal.

   The direction of sensitivity the instrument is marked on the outside of the unit, with the arrow pointing towards the positive sensor output orientation. If this arrow is horizontal, the sensor will be responsive to horizontal signals; likewise, if the arrow points upwards, the sensor will respond to vertical ground acceleration (with positive output corresponding to an upwards ground movement.)


Although converting a sensor from horizontal to vertical response involves compensating for the acceleration due to gravity, you do not have to zero the sensor manually. The sensor output offset adjustment is carried out electronically by emulating the shift in mass position. You can then calibrate the offset using a potentiometer within the unit, without any loss of dynamic range.

3. If required, make a screening box for the sensor, to shield it from draughts and sharp changes of temperature. A suitable box can be constructed from expanded polystyrene slabs (e.g. 5 cm building insulation slabs) with sealed joints between them and a hole drilled for the connector. You can then use high-grade glass fibre sealing tape to fix the leads in position, and fasten the box to the mounting surface. Commercial duct sealing tape is ideal.

4. Connect the sensor to the analogue input of the Güralp digitiser using the cable provided, or to another recording device using a cable made up as described in section 3.5 on page 14.

### 3.3.1 Installation in Hazardous environments

The fully enclosed aluminium case design of the 5U instrument 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 ('earthing') to the structure on which it is mounted, forming a path to safely discharge static charge.

Where electrical bonding ('earthing') is required during the installation of a 5U instrument, 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 a 8 mm ring tag or by the mounting bolt itself.

# 3.4 Centring the 5U

Once installed, you should centre the instrument ready for use.

**Note:** The range of the offset adjustment is greater than 1 g equivalent, so that instruments can be used horizontally or vertically. This means that, for more sensitive instruments, such as 0.1 g versions, there will be large parts of the adjustment range where the signal is at positive or negative full scale.

1. Begin monitoring the output signal of the sensor using a digitiser or digital voltmeter, as described in section 3.2 on page 6.
2. Remove the pressure release cap and insert a thin screwdriver or pot-adjuster into the hole.
3. Locate the small potentiometer screw head just inside, and turn it in one direction or another until the output voltage is reading zero.
4. Replace the pressure cap to keep the instrument's electronics protected from water and dust.

After the cover is installed, the accelerometer outputs may drift until the system establishes temperature equilibrium with its environment and the sensor settles down in its position. If required, the offset adjustment can be repeated to achieve a better output offset. With experience, it should be possible to reduce the output level to less than ±1 mV.

# 3.5 Electrical connections

## 3.5.1 Power supply

The Güralp 5U is normally powered directly from the digitiser through the 10-way connector, although you can use a separate 12 V DC power supply if you wish (again, a custom cable will be required). In this case, the positive output from the power supply should be connected to pin B with the power supply ground connected to pin A.

The current consumption from a 12 V supply is about 53 mA. An isolated DC–DC converter installed inside the sensor housing forms the main part of the 5U's power supply; its filtered outputs provide the ±12 V required to operate the sensor electronics. The DC–DC converter is protected against polarity reversal.

**Caution:** You should never supply more than 12.5 V to the 5U.

### 3.5.2 Signal outputs - Standard (low-gain) and High-gain

The Güralp 5U sensor has two separate outputs, one with low gain and one with high gain. The straight-through cable provided will connect the low gain outputs to the digitiser input (see section 5.1 on page 23). To make use of the high-gain signal, you will need to make up a cable connecting the high-gain pins (C and G) of the sensor to the digitiser input pins (J and K). The sensor outputs have an output impedance of 47 Ω, which is low compared to the input impedance of the digitiser., which is typically between 47 kΩ and 1 MΩ.

The low and high gain output lines are differential outputs balanced about signal ground so that either differential drive or single-ended drive is available. For a single-ended drive, the signal ground must be used as the signal return path and the non-inverting (positive) acceleration output must be interfaced to the recorder.

**Caution:** You must not ground any of the active output lines, as this would allow damaging currents to flow through the output circuits.

If you have two analogue inputs available on a connected digitiser, you could make up a three-way cable which connects both high and low gain outputs to the digitiser.

**Caution:** You should not attempt to connect both outputs of the 5U to the same digitiser input port.

### 3.5.3 Calibration signal input

The calibration signal input is referenced to the signal ground. It can be connected directly to the digitiser's calibration output line or to a signal source of your own. A typical amplitude for a calibration signal is ±10 Volts.

### 3.5.4 Calibration enable

The Güralp 5U is available with either an “active low” or an “active high” calibration enable input. This should be specified when ordering. If the instrument is to be used with Güralp Systems' digitisers, “active low” should be chosen.

#### 3.5.4.1 Active low versions

The calibration enable input is TTL-level and is tied high by an internal pull-up resistor. To activate calibration, this input should be connected to signal ground. During normal operation (i.e. when not calibrating) it should either be left floating (disconnected) or connected to a high impedance output.

#### 3.5.4.2 Active high version

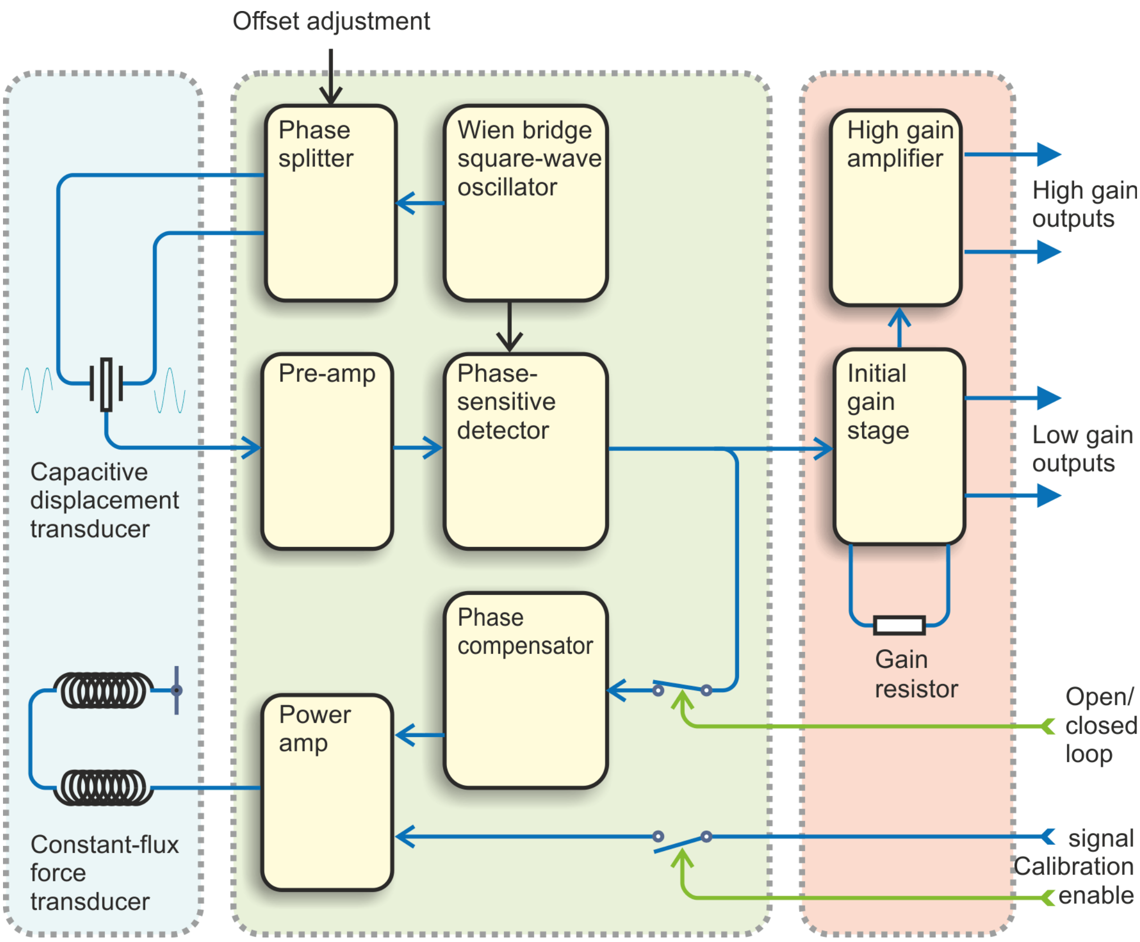
The calibration enable input is TTL-level and is tied low by an internal pull-down resistor. To activate calibration, this input should be connected to a voltage source of +5 to +10 V DC with respect to signal ground. The input presents an impedance of around 10 kΩ . During normal operation (i.e. when not calibrating) it should either be left floating (disconnected) or connected to a high impedance output.

# 4 Calibrating Güralp 5U sensors

The 5U accelerometer is supplied with a comprehensive calibration document, and it should not normally be necessary to calibrate it yourself. However, you may need to check that the response and output signal levels of the sensor are consistent with the values given in the calibration document.

## 4.1 Principle of operation

The 5U is a force-feedback instrument. An inertial mass with a pendulum suspension forms the centre pole of a centre-tapped, variable capacitor, energised with anti-phase sine-waves. The signal from the mass is fed into a feedback loop which drives an electromagnetic coil attached to the mass, such that the mass is maintained centrally in the gap. The current required to do so it proportional to the acceleration experienced by the instrument. The basic arrangement is shown below.



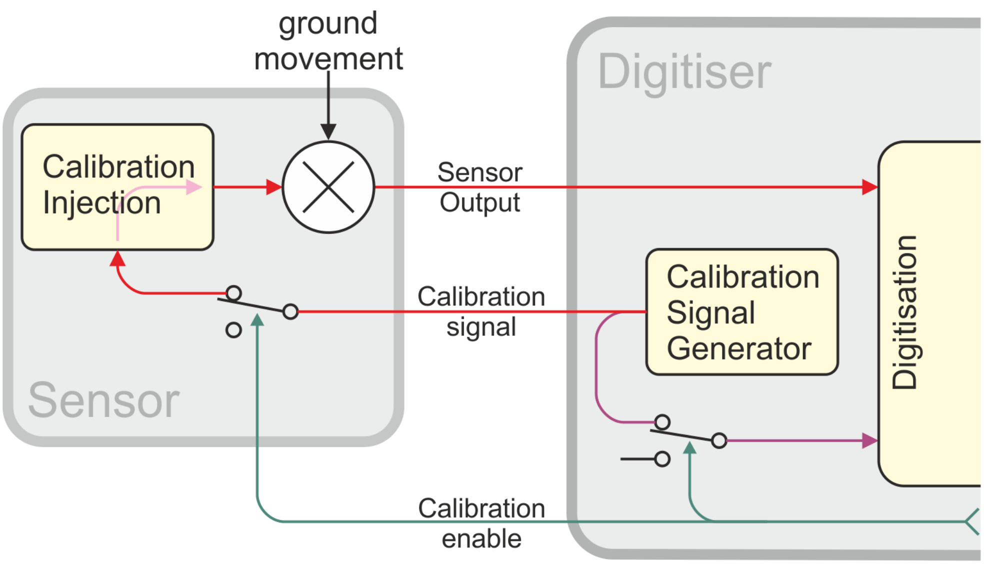
## 4.2 Absolute calibration

The sensor's response (in $V/ms^{-2}$) is measured at the production stage by tilting the sensor through 90 ° and measuring the acceleration due to gravity. The local value of g at the Güralp Systems production facility is known to an accuracy of five digits.

## 4.3 Relative calibration

In addition to the response of the sensor, several other variables are calibrated at the production stage. Using these values, you can convert directly from counts (as measured in Scream!) to acceleration values and back. You can check any of these values by performing calibration experiments.

Güralp sensors and digitisers are calibrated as follows:




In this diagram a Güralp digitiser is being used to activate the calibration enable line and to inject a calibration signal into the sensor. The signal can be a sine wave, a step function or broadband noise, depending on your requirements. As well as going into the sensor, the calibration signal is returned to the digitiser on the dedicated calibration input channel. The calibration signals and sensor output all travel down the same cable from the sensor to an analogue input port on the digitiser.

The signal injected into the sensor gives rise to an equivalent acceleration (marked “EA” on the above diagram) which is added to the measured acceleration to provide the sensor output. Because the injection circuitry, when disconnected) can be a source of noise, a “Calibration enable” line from the digitiser is provided which can disconnect the calibration circuit when it is not required. Depending on the factory settings, the Calibration enable line must be either provided with a DC voltage source (+5 to +10 V) or held low during calibration: this is given on the sensor's calibration sheet.

The equivalent acceleration corresponding to 1 V of signal at the calibration input is measured at the factory, and can be found on the 5U calibration sheet. The calibration sheet for the digitiser documents the number of counts corresponding to 1 V of signal at each input. The sensor transmits the signal differentially, over two separate lines, and the digitiser subtracts one from the other to improve the signal-to-noise ratio by increasing common mode rejection. As a result of this, the sensor output should be halved to give the true acceleration.

All sensors are tuned at the factory to produce 1 V of output for 1 V input on the calibration channel. For example, a sensor with an acceleration response of 0.25 $V/ms^{-2}$ should produce 1 V output given a 1 V calibration signal, corresponding to 1/0.25 = 4 $V/ms^{-2}$ = 0.408 g of equivalent acceleration.

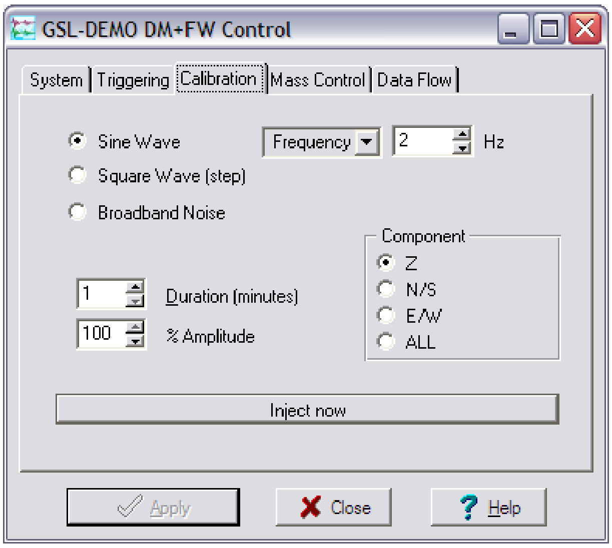
The following section explains how to calibrate Güralp 5U sensors using a DM24 series digitiser and a computer running Güralp Systems Scream! Software.

# 4.4 Using a DM24 series digitiser for calibration

This section describes how to perform a broadband noise calibration. For other calibration techniques, please see our web site, http://www.guralp.com/.

## 4.4.1 The calibration process

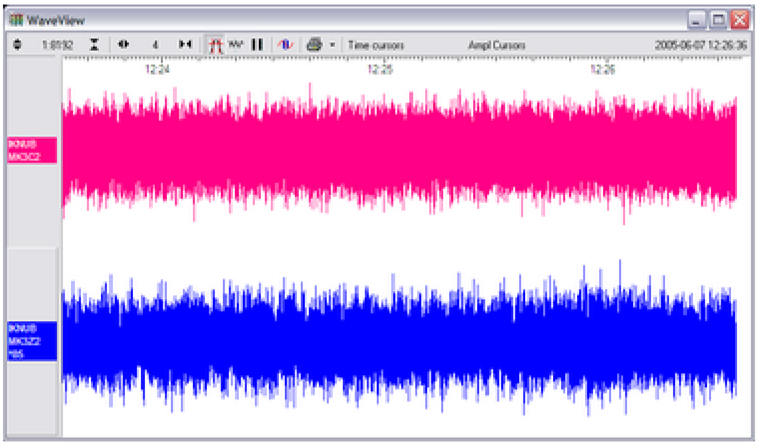
1. In Scream!'s main window, right-click on the digitiser's icon and select Control.... In the resulting dialogue, open the Calibration tab.




2. Choose “Broadband Noise” as the calibration type. In the “Component” frame, select the channel corresponding to the instrument (typically Z for single-instrument set-ups). Set the amplitude to 100% and select a suitable duration (at least ten times the longest period in which you are interested), then click Inject now. A new stream ending C*n* (where *n* represents the tap

identification number) should appear in Scream!'s main window containing the returned calibration signal.

3. Open a WaveView window on the calibration signal and the returned streams by selecting them and double-clicking. The streams should display the calibration signal combined with the sensors' own measurements. If you cannot see the calibration signal, zoom into the WaveView using the scaling icons at the top left of the window or the cursor keys.

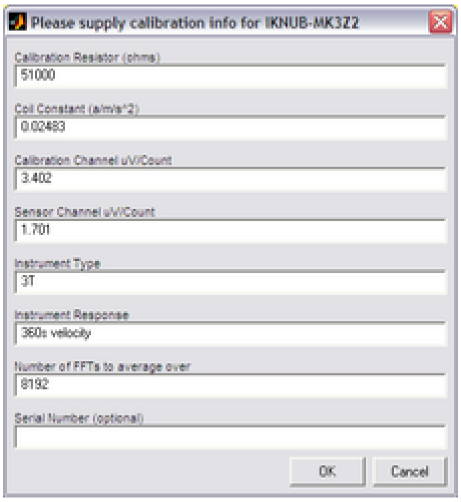



4. If you need to scale one, but not another, of the traces, right-click on the trace and select Scale.... You can then type in a suitable scale factor for that trace.

5. Pause the Waveview window by clicking on the  icon.

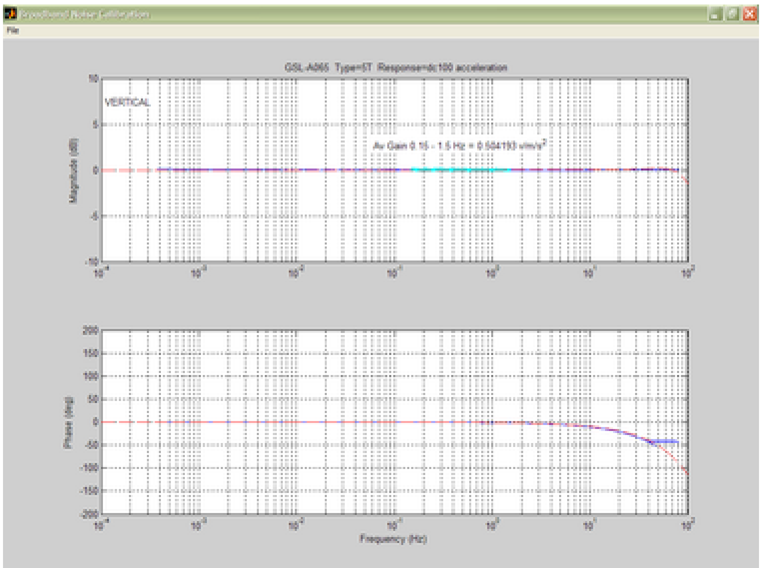
6. Hold down the shift key () and drag across the window to select the calibration signal and the returning component(s). Release the mouse button, keeping  held down. A context menu will pop up: choose “Broadband Noise Calibration”.

7. The script will ask you to fill in sensor calibration parameters for each component you have selected.



Most data can be found on the calibration sheet for your sensor. The fields in this form are described in detail in section 4.4.2 on page 21.

8. Click OK. The script will return with a graph showing the response of the sensor in terms of amplitude and phase, plotted against frequency. The accuracy of the results depends on the amount of data you have selected and its sample rate. To obtain good-quality results at low frequency, it will save computation time to use data collected at a lower sample rate; although the same information is present in higher-rate streams, they also include a large amount of high-frequency data which may not be relevant to your purposes.




The noise calibration script automatically performs appropriate averaging to reduce the effects of aliasing and cultural noise.

## 4.4.2 Calibration values

The calibration parameters required by the script are as follows:

- **Calibration Resistor (ohms)** : The value of the calibration resistor, in Ω, as given on the sensor calibration sheet. This is normally 1 Ω for Güralp 5U instruments.
- **Coil Constant (A/m s⁻²)** : The coil constant for the component being calibrated, in Amps per $ms^{-2}$, as given on the sensor calibration sheet.
- **Calibration Channel µV/Count** : The sensitivity of the digitiser's calibration channel, in µV per count, as given on the digitiser calibration sheet.
- **Sensor Channel µV/Count** : The sensitivity of the digitiser's input channel, in µV per count, as given on the digitiser calibration sheet.
- **Instrument Type** : The model number of the instrument or any other desired text to be displayed in the title of the output graph.

- **Instrument Response** : The theoretical response of the instrument, as defined by its poles and zeroes. This information is used to generate a theoretical response curve.

  The response is entered as a code, as shown in the following table:

| Instrument response | Response code |
|---|---|
| DC to 200 Hz | `CMG-5_200Hz` |
| DC to 100 Hz | `CMG-5_100Hz` |
| DC to 50 Hz | `DC-50` |

- **FFT window size** : This value specifies the FFT length used in the calculation and, hence, the frequencies at which calibration is performed. The default value is automatically chosen to give optimal results, and you should not normally need to change it.
- **Serial Number (optional)** : A serial number to be displayed in the title of the graph.

### 4.4.3 Calibration using non-Güralp equipment

If you prefer, you can inject your own signals into the system at any point (together with a Calibration enable signal, if required) to provide independent measurements, and to check that the voltages around the calibration loop are consistent. For reference, a DM24-series digitiser will generate a calibration signal of around 16000 counts / 4 V when set to 100% (sine-wave or step), and around 10000 counts / 2.5 V when set to 50%.

# 5 Appendices

## 5.1 Connector pin-out

The 5U sensor has a single 10-pin bayonet connector for both power input and acceleration outputs.

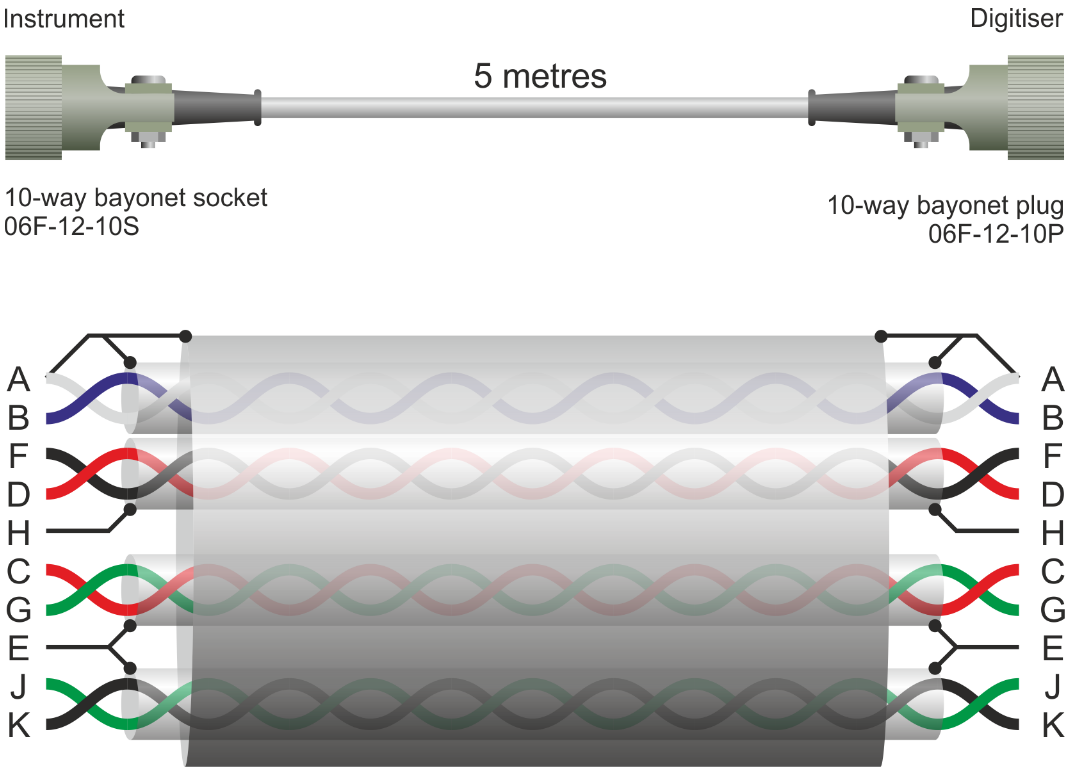
This is a standard 10-pin military-specification bayonet plug, conforming to MIL-DTL-26482 (formerly MIL-C-26482). A typical part-number is 02E-12-10P although the initial "02E" varies with manufacturer.

Suitable mating connectors have part-numbers like ***-12-10S and are available from Amphenol, ITT Cannon and other manufacturers.

| Pin | Function |
|---|---|
| **A** | Power ground |
| **B** | Power +12 V DC |
| **C** | High-gain acceleration non-inverting output (+) |
| **D** | Calibration signal input |
| **E** | Signal ground |
| **F** | Calibration enable |
| **G** | High-gain acceleration inverting output (-) |
| **H** | *not connected* |
| **J** | Low-gain acceleration non-inverting output (+) |
| **K** | Low-gain acceleration inverting output (-) |


Wiring details for the compatible socket, ***-12-10S, as seen from the cable end (*i.e.* when assembling).

## 5.2 Cable from Güralp 5U to DM24S12 (Channels 1-12)



## 5.3 Specifications

| | | |
|---|---|---|
| **Output** | Low gain output options | 2*g*, 1*g*, 0.5*g*, 0.1*g* |
| | Corresponding high gain outputs | 0.2*g*, 0.1*g*, 0.05*g*, 0.01*g* |
| | Dynamic range at 2 g | standard |
| | Dynamic range, 0.005 – 0.05 Hz | > 140 dB |
| | Dynamic range, 3 – 30 Hz | > 127 dB |
| | Standard frequency band | DC – 100 Hz (–3dB point) |
| | Optional low-pass corner | 50, 100 or 200 Hz |
| | Linearity | 0.1 % of full scale |
| | Cross-axis rejection | 0.001*g* / *g* |
| **Physical** | Lowest spurious resonance | 450 Hz |
| | Operating temperature range | –20 to +70 °C |
| | Pressure jacket material | hard anodised aluminium |
| | Power / signal connector | Military-specification connector on sensor housing (02E-14-19P) |
| | Dimensions | 75 × 75 × 125 mm |
| | Weight | 908 g |
| **Power** | Supply voltage | 12 V DC Nominal (11 to 12.5 V DC) |
| | Current at 12 V DC | 8 mA |
| | Power at 12 V DC | 96 mW |

# 6 Revision History

| | | |
|---|---|---|
| E | 2021-03-03 | Improved initial testing instructions and added power-supply voltage to specifications. |
| | 2016-09-29 | Applied new branding. No significant content changes. |
| D | 2013-05-20 | Reformatted, updated calibration section and corrected centring information |
| C | 2007-11-20 | Added section “Installation in hazardous environments” |
| B | 2006-08-30 | Added revision history |
| A | 2004-10-29 | Initial release |