Güralp 40T

Operator's Guide

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1 Preliminary Notes

1.1 Proprietary Notice

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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 40T is a lightweight seismometer consisting of three sensors in a sealed, stainless steel case, which can measure the north/south, east/west and vertical components of ground motion simultaneously.

The 40T has a rugged, waterproof stainless steel design for ease of installation. The lightweight sensor elements are designed so that no mechanical clamping is required. Because of this, the 40T is ready to record ground movements as soon as you provide it with power. In addition, the sensor does not have to be levelled or centred as long as the base is within 3° of horizontal. For the best results, however, you should install where possible on a hard, near-horizontal surface well coupled to the bedrock.

Each seismometer is delivered with a detailed calibration sheet showing its serial number, measured frequency response in both the long-period and the short-period sections of the seismic spectrum, sensor DC calibration levels, and the transfer function in poles/zeros notation.

2.1 Response options

The standard frequency response for a 40T is flat to velocity from 60 seconds (0.017 Hz) to 100 Hertz.

Standard alternative frequency response options are:

- flat to velocity from 30 seconds (0.03 Hz) to 100 Hertz
- flat to velocity from 1 second (1 Hz) to 100 Hertz

Other frequency response options have been manufactured in the past. Please contact us if you require a difference frequency response.

If you do not require high-frequency data, a low-pass filter may be installed at a frequency (below 50 Hz) that you specify.

Standard 40T instruments output signals representing ground velocity on three pairs of balanced differential lines. An option is available which provides a second, parallel set of outputs at higher gain. The high-gain outputs have a sensitivity nominally ten times higher than the standard (low-gain) outputs.

2.2 Remote nulling option

A small number of 40T instruments were produced with motor-driven potentiometers in the nulling circuitry. This meant that the instrument could be nulled remotely by applying voltages to the motors via pins in the main connector.

2.3 Digital nulling option

A small number of 40T instruments were produced with an automatic nulling process, known as "digital nulling". The nulling potentiometers in these instruments were solid-state units under microprocessor control. See section 3.4.4 on page 17 for more information about this function.

3 First encounters

3.1 Handling notes

Although the 40T has a rugged design, it is still a sensitive instrument, and can be damaged if mishandled. If you are at all unsure about the handling or installation of the device, you should contact Güralp Systems for assistance.

- Avoid bumping or jolting 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.
- Do not ground any of the signal lines from the sensor.

All parts of the 40T are waterproof.

3.2 Connections

The instrument has a single 26-pin military-specification bayonet connector which carries both power, control signals and output signals. This is suitable for connecting directly to a Güralp digitiser.

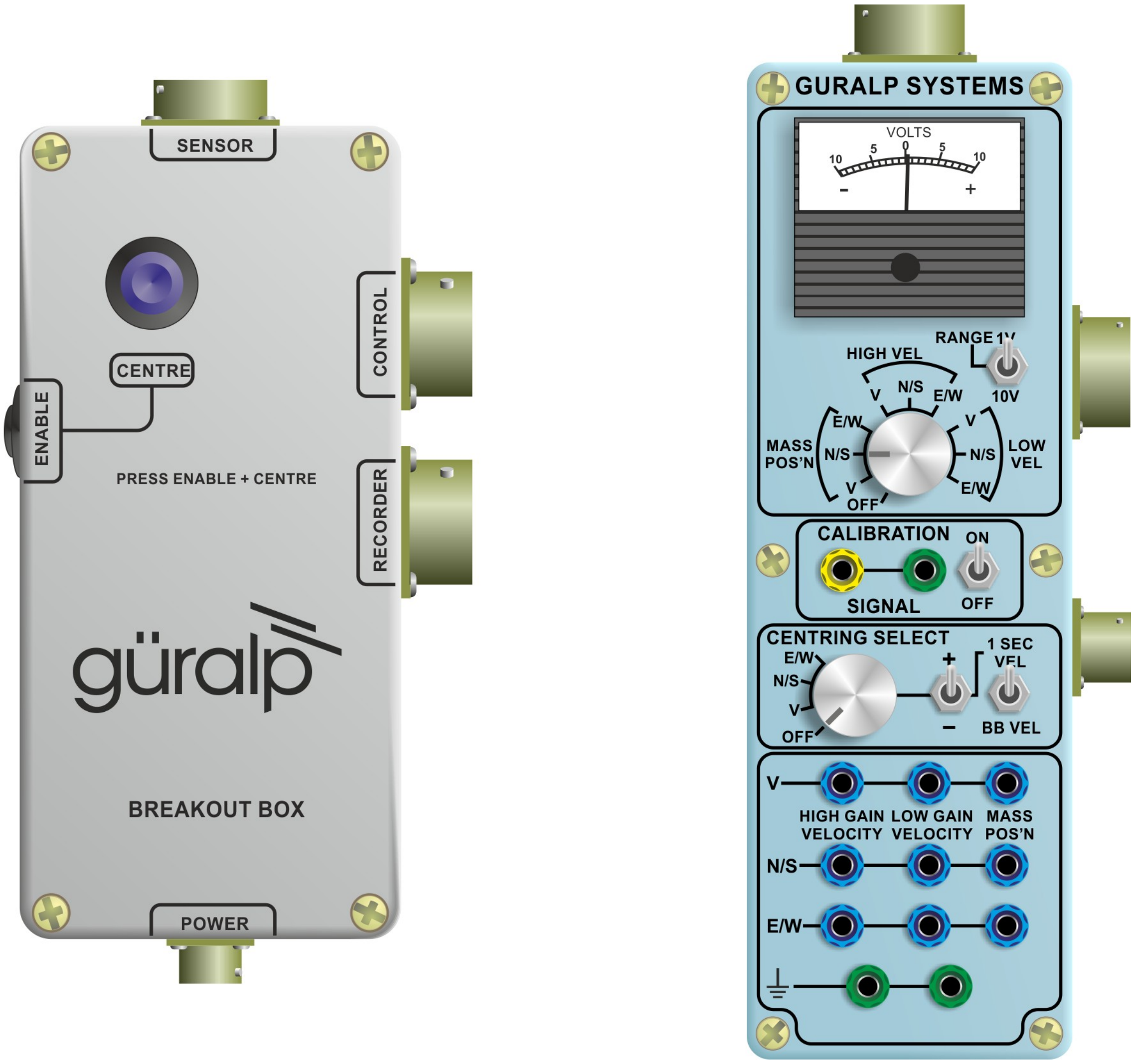
A breakout box is available which provides separate connectors for signal and power. An optional hand-held control unit provides individual connectors for every output signal. These are described in the following sections.

3.2.1 The breakout box

If you are using a Güralp breakout box, it should be attached to the sensor through its *SENSOR* connector. Connectors are also provided at the *CONTROL* and *RECORDER* outputs, for attaching to a hand-held control unit or a Güralp digitiser.

The breakout box also provides a standard Güralp power connector on a ten-pin bayonet connector. The 40T draws a nominal current of 65 mA from a 12 V supply (780 mW) when in use; so, for example, using a 12 V, 25 Ah sealed heavy-duty lead-acid battery, you should expect the instrument to operate for around a week without recharging.

Holding down both the ENABLE and CENTRE buttons switches the instrument into one-second mode for as long as they are pressed. This mode allows you to monitor the mass positions whilst you adjust the offsets manually. If you prefer, you can use the equivalent switch on a Hand-held Control Unit (see below.)



In the illustration above, the break-out box is on the left and the hand-held control unit is on the right.

3.2.2 The hand-held control unit

This portable control unit provides easy access to the seismometer's control commands, as well as displaying the output velocity and mass position (*i.e.* acceleration) on an analogue meter.

3.2.2.1 Signal meter

The upper section of the HCU contains a simple voltmeter for monitoring various signals from the instrument.

- To monitor the low-gain outputs, switch the dial to *V, N/S* or *E/W LOW VEL* according to the component you want to monitor.
- To monitor the high-gain outputs (on a 40T with that option), switch the dial to *V, N/S* or *E/W HIGH VEL.*

- To monitor the mass position outputs, switch the dial to *V*, *N/S* or *E/W MASS POS*. Whilst you are adjusting mass position offsets, you should also switch the instrument out of broadband mode by switching the rightmost *CENTRING SELECT* switch to *1 SEC VEL*, or by holding down the *CENTRE* button on a breakout box.
- You can set the range of the meter with the *RANGE* switch. When switched to 10 V, the meter ranges from –10 to + 10 V (as marked.) When switched to 1 V, the range is –1 to +1 V.

3.2.2.2 Calibration

You can calibrate a 40T sensor through the HCU by connecting a signal generator across the yellow and green *CALIBRATION SIGNAL* inputs and setting the adjacent switch to *ON*. The sensor's response can now be monitored or recorded, and calibration calculations carried out. See Chapter 5 on page 26 for full details.

3.2.2.3 Control commands

If you have ordered a 40T with the remote null facility, you can null its mass position offsets from the HCU.

1. Select the component you want to centre from the *CENTRING SELECT* dial.
2. Switch the signal meter dial to one of the *MASS POS* settings.
3. Switch the rightmost switch to *1 SEC VEL* to enable the centring lines.
4. Press the *+/–* switch towards – to centre a mass from a positive value, or towards + to centre it from a negative value.

3.2.2.4 Banana plugs

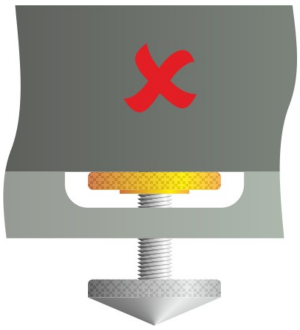
The remainder of the HCU provides useful connections for each of the signal lines from the instrument, for attaching to your own equipment as necessary.

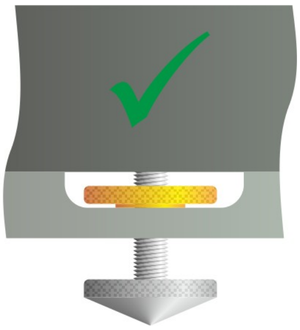
3.3 Levelling the instrument

The instrument must be physically level in order to operate correctly.

To level the instrument, first check the bubble level on the lid: the bubble should be in the centre of the printed circle. If it is not, loosen the lock-nuts on the instrument's feet and then adjust the feet until the bubble is central.

Once levelled, secure the feet by screwing the lock-nuts downwards – *not* upwards – as shown:





3.4 Nulling the instrument

Before installing the 40T, you should check that the mass positions are not significantly offset from zero. The 40T must be perfectly level for this to be effective. The mass position offsets can be affected by any tilt to the instrument as well as rough handling during transportation. The normal range of the mass positions is ±10 V; you should null the offsets of the instrument if any mass reads more than around ±3.5 V (>35% of full scale) when the sensor is level and stationary.

The velocity outputs of the 40T are set at the factory to a nominal value below ±3 mV. Once the instrument is installed and has reached thermal equilibrium with its environment, these outputs should be similar to the factory-set values.

The Güralp 40T can be ordered with a option for automated “digital nulling”. See section 3.4.4 on page 17 for more information and instructions for using this function.

3.4.1 Adjusting the mass position offsets manually

The 40T has three potentiometers (“pots”) accessible within its casing, which should be used to remove any DC offsets electronically:

1. Bring the instrument into one-second response mode by connecting together the *Acc/Vel* and *Signal Ground* pins of the input connector (pins U and Y). If you are using a Hand-held Control Unit, you should select *1 SEC VEL* from the *Velocity Select* switch. Keep the connection or switch in place until you have finished adjusting the instrument.

   If you are using a DM24, you can put the instrument into one-second mode by sending a `CENTRE` command. The effect only lasts for a few seconds in this case so the technique is to make an adjustment, issue the `CENTRE` command, wait five seconds, check the results and then repeat as necessary.

2. Measure the vertical mass position output with a 10 V voltmeter (see Chapter 6 on page 35 for pin-out details) or by selecting *MASS POS, V* from a Hand-held Control Unit's *Display Select* knob. If using a HCU, also check that the *Centring Select* knob is set to *OFF*.

3. If the vertical component needs adjusting, remove the cap on the lid which protects the Vertical pot with a flat-bladed screwdriver.

4. Insert the screwdriver through the opening, and engage the pot. An LED flash-light may be useful for locating the head.

5. Turn the pot either way until the offset readout is as close to 0 V as possible.

6. Repeat steps 2 – 5 for the North/South and East/West components.

If the instrument has motor-driven nulling potentiometers, you can adjust them by providing ±5 V voltage to the relevant pin (pin X for vertical, pin V for N/S and pin W for E/W) relative to pin Y (Digital ground/Motor return).

3.4.2 Adjusting the mass position offsets with an HCU

Some 40T units are equipped with a remote mass centring option, which allows you to adjust the internal potentiometers by applying voltages across control lines to the sensor:

1. Bring the instrument into one-second response mode by selecting *1 SEC VEL* from the *Velocity Select* switch.

2. Measure the vertical mass position output by selecting *MASS POS, V* from the Hand-held Control Unit's *Display Select* knob.

3. Set the *Centring Select* knob to *V*.

4. Press the spring-loaded switch towards + or – to bring the mass position offset from negative or positive values towards zero.

5. Repeat steps 3 and 4 for the *N/S* and *E/W* components.
6. Return the instrument to broadband mode by selecting *BB VEL* from the *Velocity Select* switch.

3.4.3 Nulling a 40TD digital instrument

The offset potentiometers in a 40TD are in the same place as on the 40T. To access them, you will need to remove the digitiser module, which lies on top of the sensor itself. You can monitor the mass position outputs of the sensor using a Hand-held Control Unit and an adapter cable, available from Güralp Systems.

To change the offsets of a 40TD without digital centring:

1. Check the bubble level on the lid of the instrument, to ensure it is not tilted. If necessary, re-level the instrument by adjusting its feet. Take care not to disturb the instrument during the subsequent operations.

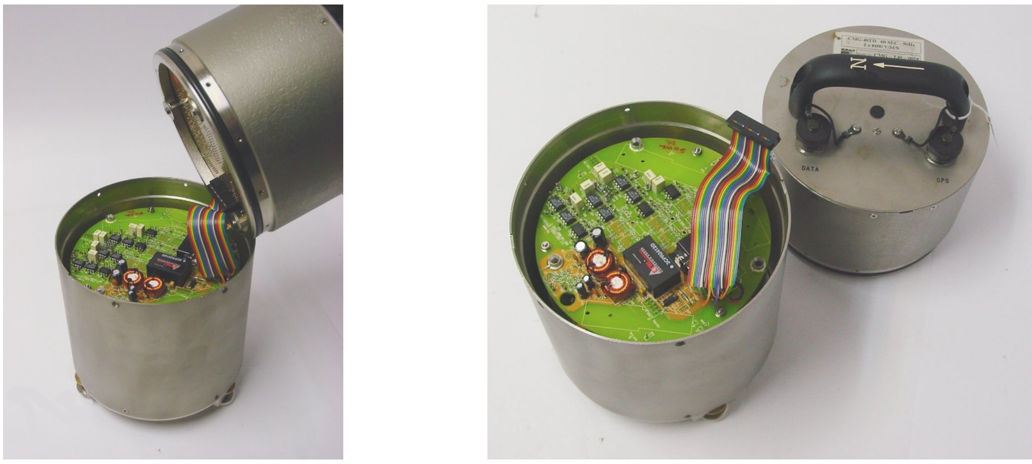
2. Unscrew the vent cap on the lid to allow the air pressure to equalise.

Warning: Güralp instruments are assembled at sea level. If working at altitude, there may be a considerable pressure differential. Take care that the vent cap does not "fly off" when released, causing injury.

3. Using a hexagonal wrench, remove the screws holding the digitiser module onto the sensor.

4. Place a flat-head screwdriver in the notches provided and, holding the bottom part of the instrument steady, twist the screwdriver to lever off the upper digitiser module.

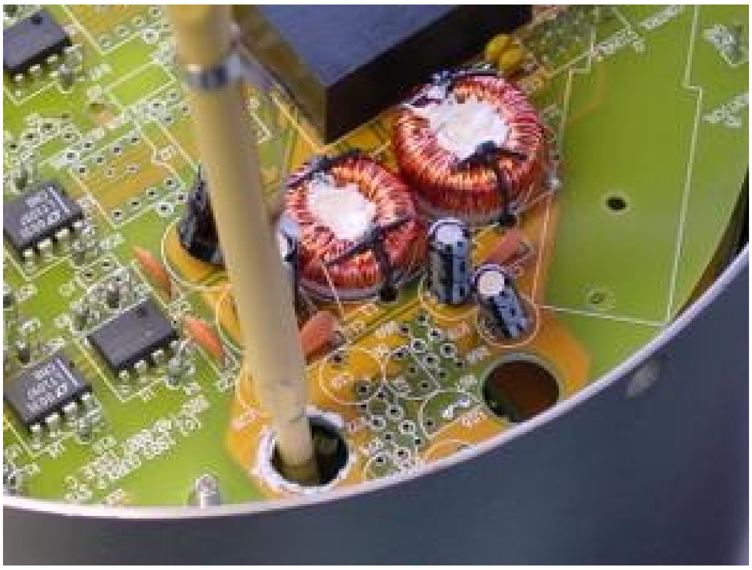
5. Carefully lift off the digitiser module, and unplug the ribbon cable from the sensor electronics.



6. Attach a Hand-held Control Unit and adapter cable to the ribbon connector, and power up the sensor through the control unit.

7. Set the *CENTRING SELECT* switch on the Hand-held Control Unit to *1 SEC VEL*, and the monitoring dial to *V MASS POS.*

8. There are three holes in the topmost electronics board, which provide access to the offset potentiometers. Insert a screwdriver through the appropriate hole, and engage the potentiometer for the vertical component.



9. Adjust the potentiometer until the mass position output reads close to zero.

10. Repeat steps 4 – 6 for the north/south and east/west components.

Alternatively, you can adjust the mass positions and monitor the output digitally.

1. Remove the vent cap, and use a hexagon wrench to remove the screws holding the digitiser module onto the sensor as above.

2. Carefully lift off the digitiser module, and support it nearby, leaving the ribbon cable connected. Extension cables can be obtained from Güralp Systems; otherwise, you can use the casing of the sensor itself as a support.

3. Whilst monitoring the mass position outputs (channels `M8`, `M9` and `MA`), adjust the potentiometers as above.

3.4.4 Digital nulling operation

The Güralp 40T sensor can be ordered with an option for automated "Digital nulling". This removes the need to manually adjust the internal potentiometers to achieve a near zero mass position output for each component. It comprises a micro-controller and three digital potentiometers that replace the standard electromechanical pots.

When installing the instrument, ensure that it is levelled accurately by checking that the bubble in the level lies within the central circle.

On power-up, the micro-controller will automatically null the mass positions of all three axes simultaneously. Nulling can be further triggered via the "centre" control line on pin U. (On instruments without the digital nulling option, grounding pin U (to pin Y) puts the instrument into "one-second mode".)

Automatic nulling takes approximately forty-five seconds to complete, after which the sensor reverts to long period operation and the nulling module enters a low power "sleep" mode. During nulling, the sensor's outputs will fluctuate as the pots are adjusted in a binary search before settling with a mass position of ±0.5V. If the sensor is poorly levelled, the micro-controller will make three attempts to null the mass before giving up and using the closest match.

A test mode is available to check the operation of the digital centring pots. This mode is entered by holding the centre line low during power up. The unit will then set the pots to maximum for thirty seconds; then minimum for thirty seconds; then to the centre position for six minutes. The centre line must be held low continuously, otherwise the unit will abort the test mode and null the sensors as normal.

4 Installing the 40T

4.1 Installation notes

For the best possible results, a seismometer should be installed on a seismic pier in a specially-built vault, where conditions are near perfect. Here, wave-trains arriving at the instrument reflect very well the internal motion of subsurface rock formations. However, this is not always feasible. For example,

- instruments may need to be deployed rapidly, perhaps to monitor the activity of a volcano showing signs of rejuvenation, or to study the aftershocks of a major earthquake;
- installations may be required in remote locations, or otherwise in circumstances where it is infeasible to build a vault.

In these situations, the seismometer and its emplacement need to be considered as a mechanical system, which will have its own vibrational modes and resonances. These frequencies should be raised as high as possible so that they do not interfere with true ground motion: ideally, beyond the range of the instrument.

This is done by

- standing the sensor on bedrock where possible, or at least deep in well-compacted subsoil;
- clearing the floor of the hole of all loose material; and
- using as little extra mass as possible in preparing the chamber.

In temporary installations, environmental factors are also important. The sensor needs to be well protected against:

- fluctuations in temperature;
- turbulent air flow around walls or trees, or around sharp corners or edges in the immediate vicinity of the sensor; and
- vibration caused by heavy machinery (even at a distance), or by overhead power lines.

This can be done by selecting a suitable site, and placing the instrument in a protective enclosure. An open-sided box of 5 cm expanded polystyrene slabs, placed over the instrument and taped down to exclude draughts, makes an excellent thermal shield.

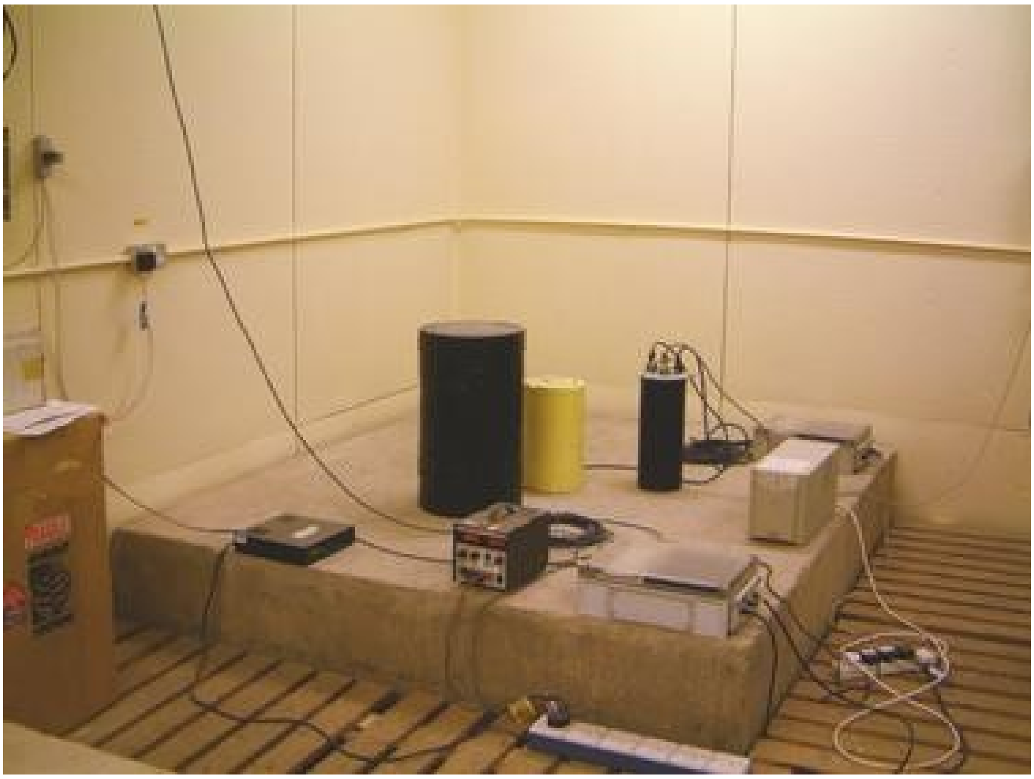
After installation, the instrument case and mounting surface will slowly return to the local temperature, and settle in their positions. This will take around four hours from the time installation is completed.

4.2 Installing in vaults

The 40T is a sensitive instrument designed to measure extremely small movements of the ground. These movements are the sum of all the vibrations arriving at the instrument: as well as distant earthquakes and nearby tremors, the ground responds to surf on nearby beaches, quarry blasts, heavy machinery, traffic, and even people moving around the building. Temperature changes and air currents in the same room as the sensor can also affect its output.

4.2.1 Choosing a location

When studying natural earth movements, any other effects introduce unwanted noise into the system. It is therefore important to choose an appropriate site for the instrument, ideally in an underground vault with the sensor installed on a concrete pier that is in direct contact with the bedrock.



This set-up has a number of advantages:

- It is installed below ground. Most man-made noise tends to travel along the surface, and natural microseisms (tiny natural flexings of the Earth's crust) also occur near the surface.
- Good contact with bedrock means that the signals accurately reflect earth motions; seismic waves do not have to travel through layers of soft soil and sediment.

- If the vault is inside a larger structure, its foundations are separated from the pier, so that nearby vibrations are not transmitted to the sensor.

A high-quality seismic vault can be incorporated into the construction plans of a new building at relatively low cost. However, if you are not in a position to build a dedicated vault, you can still reduce noise to a satisfactory level by

- installing below ground, in the basement or sub-basement of an existing building;
- placing the sensor directly on a cement floor to improve contact; and
- locating the sensor in a quiet corner away from people and machinery (*e.g.* air conditioning and heating systems, elevators, *etc.*)

Installation on higher floors is not recommended, especially for horizontal sensors, since any "give" in the floor near the sensor will cause it to tilt slightly and register a signal.

4.2.2 Temperature stability

The 40T can operate over a wide temperature range (–10 °C to +75 °C). However, the sensor mass is sensitive to fluctuations in local temperature. This affects the response of the instrument at long periods. Sunlight and other bright lights can also cause small mechanical stresses that will be detected by the sensor. You can minimise these effects by

- installing in a basement, where the temperature is normally more stable than above ground;
- locating the sensor in a dark, protected corner, and
- enclosing it in an insulated box (expanded polystyrene works very well). This also helps protect the sensor from air currents.

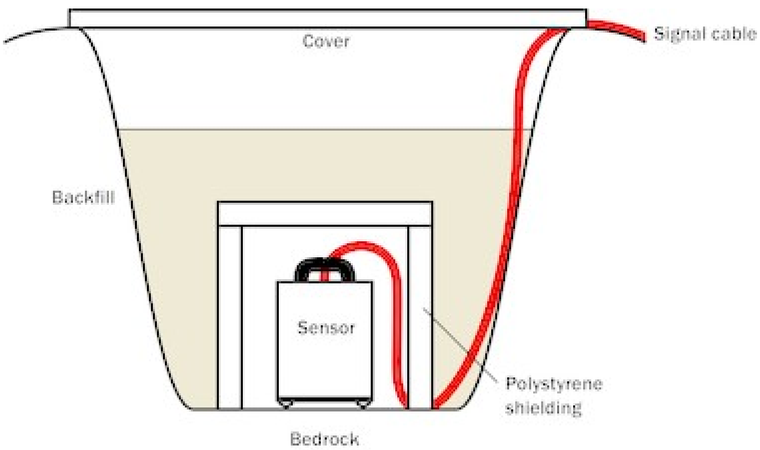
4.2.3 Other considerations

- The sensor and cables should be situated well away from other electrical cables and appliances. Stray radiation from these sources may interfere with the sensor's electronics.
- The sensor should be placed on a smooth, level surface free from cracks. Small cracks tend to open and close slightly with changes in humidity and temperature, causing the surface to move slightly.
- All three of the sensor's metal feet must make good contact with the floor.
- The signal cable from the sensor should rest loosely on the ground nearby, so that vibrations are not transmitted along it.
- If your recording or digitising equipment has front-panel indicators or connectors, make sure it can be reached without disturbing the sensor.
- The GPS unit needs to be in a location where it can see as many satellites as possible. A location with a good view of the sky, preferably down to the horizon, is recommended. If you are in the Northern Hemisphere, make sure as much of the southern sky as possible is visible. Conversely, in the Southern Hemisphere, make sure the GPS can see a large area of sky to the north.

  The GPS unit is supplied with a 15m cable to the digitiser.

4.3 Installing in pits

For outdoor installations, high-quality results can be obtained by constructing a seismic pit.



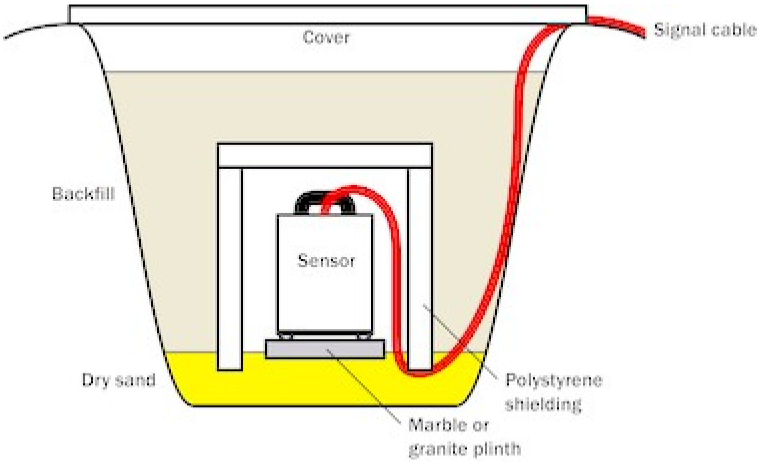
Depending on the time and resources available, this type of installation can suit all kinds of deployment, from rapid temporary installations to medium-term telemetered stations.

Ideally, the sensor should rest directly on the bedrock for maximum coupling to surface movements. However, if bedrock cannot be reached, good results can be obtained by placing the sensor on a granite pier on a bed of dry sand.

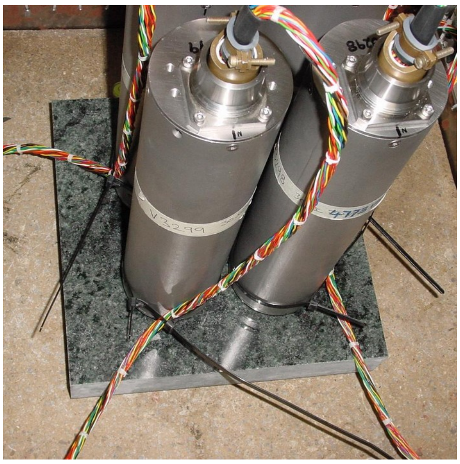
1. Prepare a hole of 60 – 90 cm depth to compacted subsoil, or down to the bedrock if possible.

2. *On granite or other hard bedrock*, use an angle grinder to plane off the bedrock at the pit bottom so that it is flat and level. Stand the instrument directly on the bedrock, and go to step 7.

3. *On soft bedrock or subsoil*, you should install a pier as depicted below.



4. Pour a layer of loose, fine sand into the pit to cover the base. The type of sand used for children's sand-pits is ideal, since the grains are clean, dry and within a small size range. On top of the sand, place a smooth, flat granite plinth around 20 cm across, and shift it to compact the sand and provide a near-level surface.



Placing a granite plinth on a sand layer increases the contact between the ground and the plinth, and improves the performance of the instrument. There is also no need to mix concrete or to wait for it to set, as in step 4.

5. *Alternatively,* if time allows and granite is not available, prepare a concrete mix with sand and fine grit, and pour it into the hole. Agitate ("puddle") it whilst still liquid, to allow it to flow out and form a level surface, then leave to set. Follow on from step 7.

   Puddled concrete produces a fine-textured, level floor for siting the seismometer. However, once set hard, the concrete does not have the best possible coupling to the subsoil or bedrock, which has some leeway to shift or settle beneath it.

6. *Alternatively,* for the most rapid installation, place loose soil over the bottom of the pit, and compact it with a flat stone. Place the seismometer on top of this stone. This method emulates that in step 3, but can be performed on-site with no additional equipment.

7. Set up the instrument as described in Section 3.1, "Installing in vaults" (steps 4 to 9).

8. The instrument must now be shielded from air currents and temperature fluctuations. This is best done by covering it with a thermal shield.

   An open-sided box of 5 cm expanded polystyrene slabs is recommended. If using a seismic plinth on sand (from steps 3–4 or 5), ensure that the box is firmly placed in the sand, without touching the plinth at any point. In other installations, tape the box down to the surface to exclude draughts.

9. *Alternatively,* if a box is not available, cover the instrument with fine sand up to the top.

   The sand insulates the instrument and protects it from thermal fluctuations, as well as minimizing unwanted vibration.

10. Ensure that the sensor cable is loose and that it exits the seismometer enclosure at the base of the instrument. This will prevent vibrations from being inadvertently transmitted along the cable.

11. Cover the pit with a wooden lid, and back-fill with fresh turf.

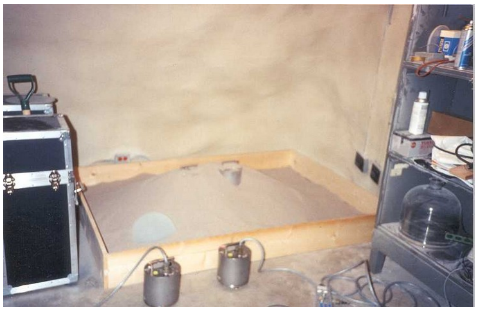
4.4 Other installation methods

The recommended installation methods have been extensively tested in a wide range of situations. However, past practice in seismometer installation has varied widely.

Some installations introduce a layer of ceramic tiles between a rock or concrete plinth and the seismometer (left):


However, noise tests show that this method of installation is significantly inferior to the same concrete plinth with the tiles removed (right). Horizontal sensors show shifting due to moisture trapped between the concrete and tiling, whilst the vertical sensors show pings as the tile settles.

Other installations have been attempted with the instrument encased in plaster of Paris, or some other hard-setting compound (left):

Again, this method produces inferior bonding to the instrument, and moisture becomes trapped between the hard surfaces. We recommend the use of fine dry sand (right) contained in a box if necessary, which can also insulate the instrument against convection currents and temperature changes. Sand has the further advantage of being very easy to install, requiring no preparation.

Finally, many pit installations have a large space around the seismometer, covered with a wooden roof. Large air-filled cavities are susceptible to currents which produce lower-frequency vibrations, and sharp edges and corners can give rise to turbulence. We recommend that a wooden box is placed around the sensor to protect it from these currents. Once in the box, the emplacement may be backfilled with fresh turf to insulate it from vibrations at the surface, or simply roofed as before.

By following these guidelines, you will ensure that your seismic installation is ready to produce the highest quality data.

5 Calibrating the 40T

5.1 The calibration pack

All Güralp sensors are fully calibrated before they leave the factory. Both absolute and relative calibration calculations are carried out. The results are given in the calibration pack supplied with each instrument:

Works Order : The Güralp factory order number including the instrument, used internally to file details of the sensor's manufacture.

Serial Number : The serial number of the instrument

Date : The date the instrument was tested at the factory.

Tested By : The name of the testing engineer.

There follows a table showing important calibration information for each component of the instrument, *VERTICAL, NORTH/SOUTH,* and *EAST/WEST. E*ach row details:

Velocity Output (Differential) : The sensitivity of each component to velocity at 1 Hz, in volts per m/s. Because the 40T uses balanced differential outputs, the signal strength as measured between the +ve and –ve lines will be twice the true sensitivity of the instrument. To remind you of this, the sensitivities are given as 2 × (single-ended sensitivity) in each case.

Mass Position Output : The sensitivity of the mass position outputs to acceleration, in Volts per ms^{-2}. These outputs are single-ended and referenced to signal ground.

Feedback Coil Constant : A constant describing the characteristics of the feedback system. You will need this constant, given in Amperes per ms^{-2}, if you want to perform your own calibration calculations (see below.)

Power Consumption : The average power consumption of the sensor during testing, given in amperes and assuming a 12 Volt supply.

Calibration Resistor : The value of the resistor in the calibration circuit. You will need this value if you want to perform your own calibration calculations (see below.)

5.1.1 Poles and zeroes

Most users of seismometers find it convenient to consider the sensor as a "black box", which produces an output signal V from a measured input x. So long as the relationship between V and x is known, the details of the internal mechanics and electronics can be disregarded.

This relationship, given in terms of the Laplace variable *s*, takes the form

$$\left(\frac{V}{x}\right)(s)=G\times A\times H(s)$$

In this equation

- G is the acceleration output sensitivity (gain constant) of the instrument. This relates the actual output to the desired input over the flat portion of the frequency response.
- A is a constant which is evaluated so that $A \times H(s)$ is dimensionless and has a value of 1 over the flat portion of the frequency response. In practice, it is possible to design a system transfer function with a very wide-range flat frequency response.

  The normalising constant A is calculated at a normalising frequency value f_m = 1 Hz, with $s = j f_m$, where $j = \sqrt{-1}$.
- $H(s)$ is the transfer function of the sensor, which can be expressed in factored form:

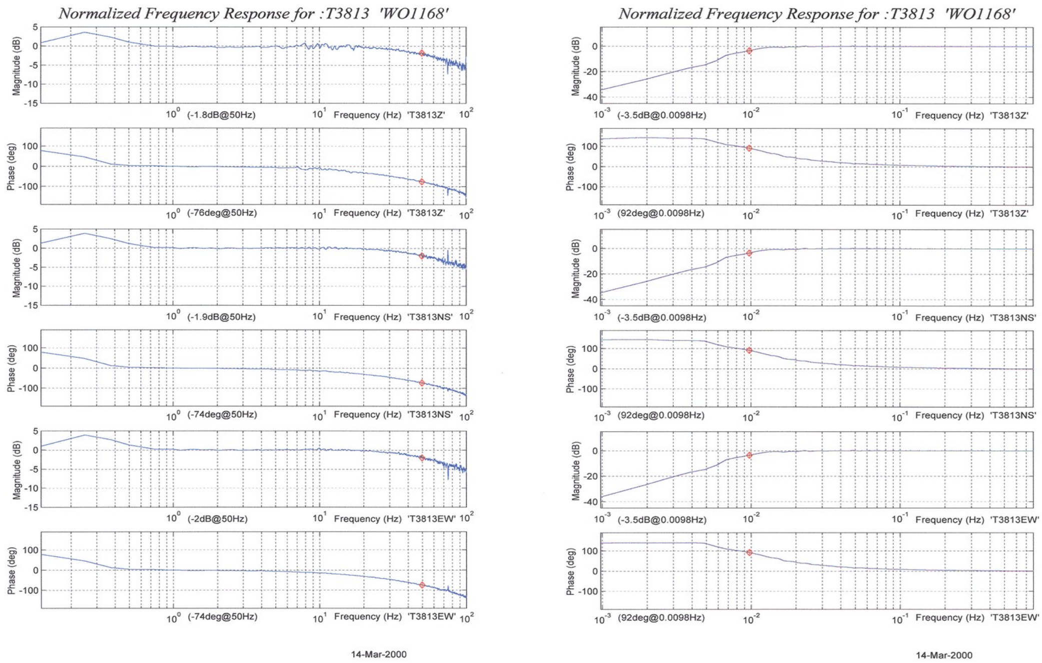
  $$H(s)=N\frac{\prod_{i=1,n} s-Z_i}{\prod_{j=1,n} s-P_j}$$

  In this equation Z_i are the roots of the numerator polynomial, giving the zeros of the transfer function, and P_j are the roots of the denominator polynomial giving the poles of the transfer function.

In the calibration pack, G is the sensitivity given for each component on the first page, whilst the roots Z_i and P_j, together with the normalising factor A, are given in the *Poles and Zeros* table. The poles and zeros given are measured directly at Güralp Systems' factory using a spectrum analyser. Transfer functions for the vertical and horizontal sensors may be provided separately.

5.1.2 Frequency response curves

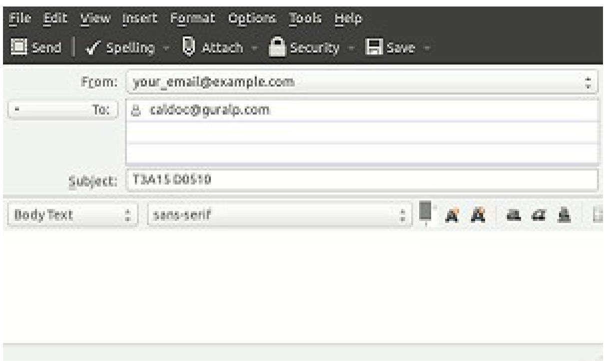
The frequency response of each component of the 40T is described in the normalised amplitude and phase plots provided. The response is measured at low and high frequencies in two separate experiments. Each plot marks the low-frequency and high-frequency cut-off values (also known as –3 dB or half-power points).



If you want to repeat the calibration to obtain more precise values at a frequency of interest, or to check that a sensor is still functioning correctly, you can inject calibration signals into the system using a Güralp digitiser or your own signal generator, and record the instrument's response.

5.1.3 Obtaining copies of the calibration pack

Our servers keep copies of all calibration data that we send out. In the event that the calibration information becomes separated from the instrument, you can obtain all the information using our free e-mail service. Simply e-mail caldoc@guralp.com with the serial number of the instrument in the subject line, *e.g.*



The server will reply with the calibration documentation in Word format. The body of your e-mail will be ignored.

Note: If you have a digital instrument, separate the serial numbers of the analogue part and the digital part with a space, as shown.

5.2 Calibration methods

Velocity sensors such as the 40T are not sensitive to constant DC levels, either as a result of their design or because of an interposed high-pass filter. Instead, three common calibration techniques are used.

- Injecting a step current allows the system response to be determined in the time domain. The amplitude and phase response can then be calculated using a Fourier transform. Because the input signal has predominantly low-frequency components, this method generally gives poor results. However, it is simple enough to be performed daily.
- Injecting a sinusoidal current of known amplitude and frequency allows the system response to be determined at a spot frequency. However, before the calibration measurement can be made the system must be allowed to reach a steady state; for low frequencies, this may take a long time. In addition, several measurements must be made to determine the response over the full frequency spectrum.
- Injecting white noise into the calibration coil gives the response of the whole system, which can be measured using a spectrum analyser.

You can perform calibration either using a Güralp DM24 digitiser, which can generate step and sinusoidal calibration signals, or by feeding your own signals into the instrument through a hand-held control unit.

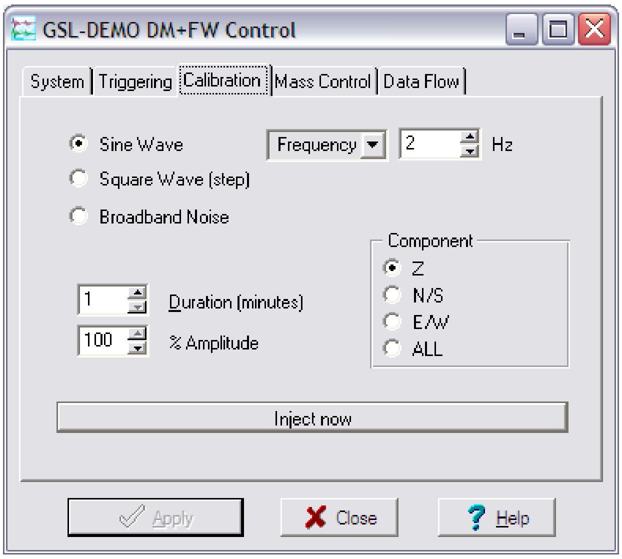
Before you can calibrate the instrument, its calibration relays need to be activated by pulling low the *CAL ENABLE* line on the instrument's connector for the component you wish to calibrate. Once enabled, a calibration signal provided across the *CAL SIGNAL* and *SIGNAL GROUND* lines will be routed through the feedback system. You can then measure the signal's equivalent velocity on the sensor's output lines. Güralp Hand-held Control Units provide a switch for activating the *CAL ENABLE* line.

5.3 Calibration with Scream!

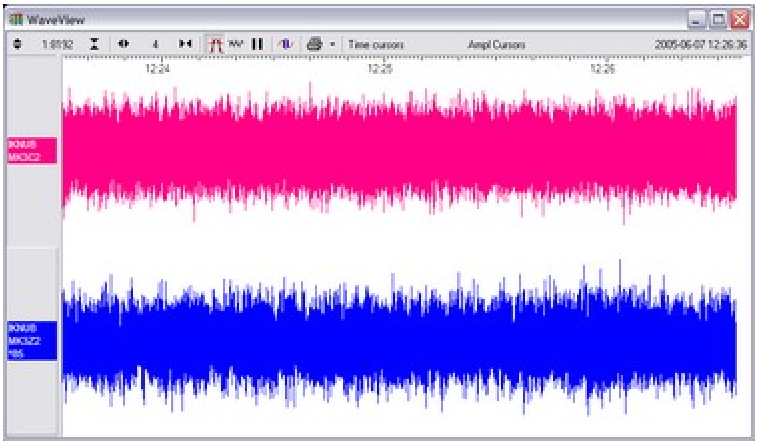
Güralp digitisers provide calibration signal generators to help you set up your sensors. Calibration is most easily done through a PC running Güralp's Scream! software.

Depending on the digitiser type, sine-wave, step and broadband noise signal generators may be available. In this section, broadband noise calibration will be used to determine the complete sensor response in one action. Please refer to the digitiser's manual for information on other calibration methods.

1. In Scream!'s main window, right-click on the digitiser's icon and select **Control...**. Open the *Calibration* pane.



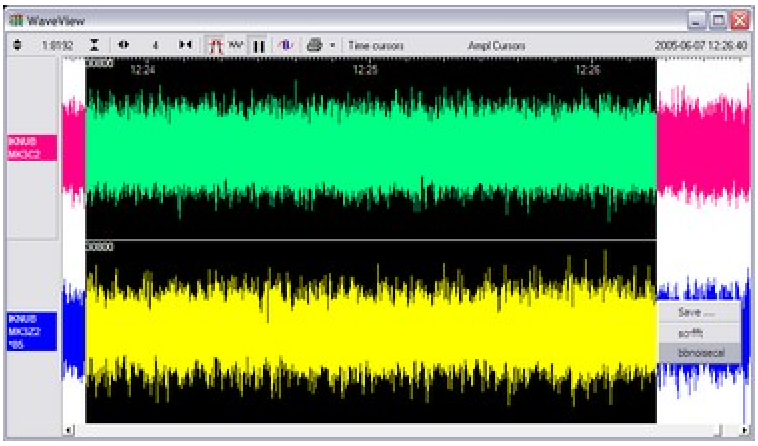
2. Select the calibration channel corresponding to the instrument, and choose **Broadband Noise.** Select the component you wish to calibrate, together with a suitable duration and amplitude, and click the Inject now button. A new data stream, ending C*n* (*n* = 0 – 7) or MB, should appear in Scream!'s main window containing the returned calibration signal.



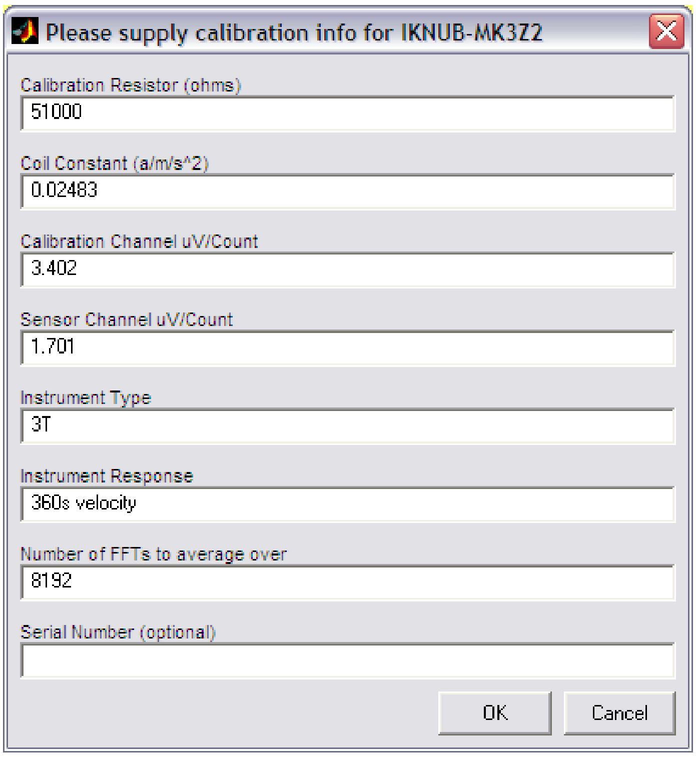
3. Open a WaveView window on the calibration signal and the returned streams by selecting them and double-clicking. The streams should display the calibration signal combined with the sensors' own measurements. If you cannot see the calibration signal, zoom into the WaveView using the scaling icons at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

   Drag the calibration stream C*n* across the WaveView window, so that it is at the top.

4. If the returning signal is saturated, retry using a calibration signal with lower amplitude, until the entire curve is visible in the WaveView window.
5. 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.
6. Pause the WaveView window by clicking on the ❚❚ button.
7. Hold down ⇧ and drag across the window to select the calibration signal and the returning component(s). Release the mouse button, keeping ⇧ held down. A menu will pop up. Choose **Broadband Noise Calibration.**



8. 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. Under *Instrument response*, you should fill in the sensor response code for your sensor, according to the table below. *Instrument Type* should be set to the model number of the sensor.

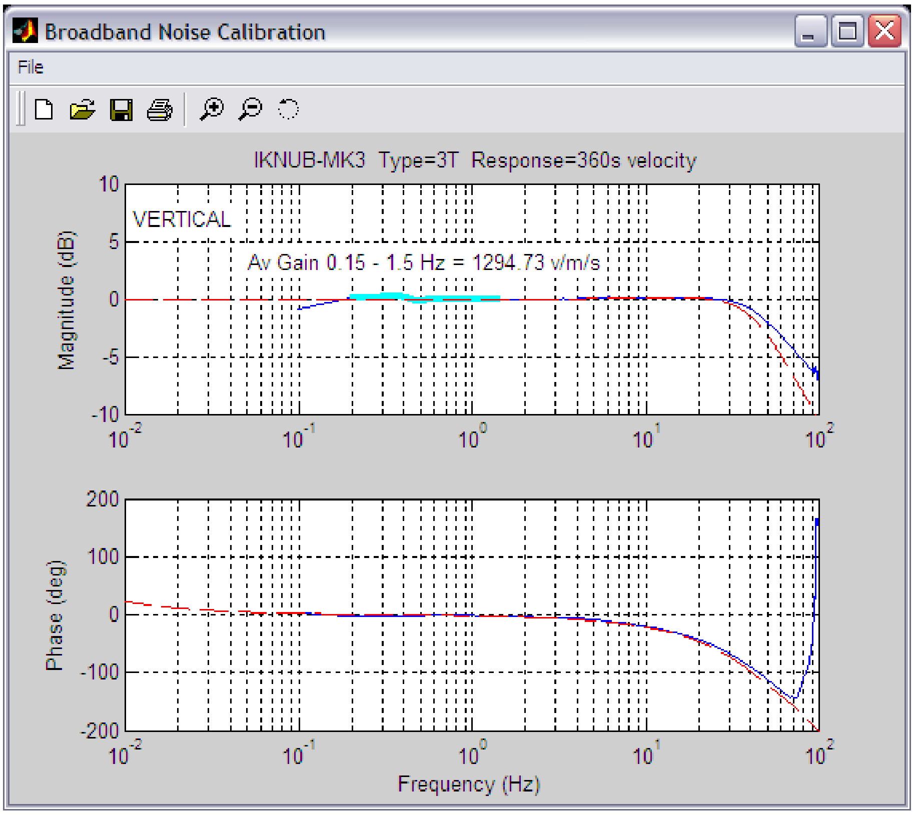
If the file `calvals.txt` exists in the same directory as Scream!'s executable (`scream.exe`), Scream! will look there for suitable calibration values. A sample `calvals.txt` is supplied with Scream!, which you can edit to your requirements. Each stream has its own section in the file, headed by the line `[instrument-id]`. The ***instrument-id*** is the string which identifies the digitiser in the left-hand pane, *e.g.* `GURALP-DEMO`. It is always 6 characters (the system identifier) followed by a dash, then 4 characters (the serial number.)

For example:

```
[instrument-id]
Serial-Nos=T3X99
VPC=3.153,3.147,3.159
G=1010,1007,1002
COILCONST=0.02575,0.01778,0.01774
CALVPC=3.161
CALRES=51000
TYPE=sensor-type
RESPONSE=response-code
```

9. Click OK. The script will return with a graph showing the response of the sensor in terms of amplitude and phase plots for each component (if appropriate.)

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

5.3.1 Sensor response codes

Sensor	Sensor type code	Units (V/A)
40T-1 or 6T-1, 1 s – 50 Hz response	CMG-40_1HZ_50HZ	V
40T-1 or 6T-1, 1 s – 100 Hz response	CMG-40_1S_100HZ	V
40T-1 or 6T-1, 2 s – 100 Hz response	CMG-40_2S_100HZ	V
40T-1 or 6T-1, 10 s – 100 Hz response	CMG-40_10S_100HZ	V
40, 20 s – 50 Hz response	CMG-40_20S_50HZ	V
40, 30 s – 50 Hz response	CMG-40_30S_50HZ	V
40, 60 s – 50 Hz response	CMG-40_60S_50HZ	V

5.4 Calibration with a hand-held control unit

If you prefer, you can inject your own calibration signals into the system through a hand-held control unit. The unit includes a switch which activates the calibration relay in the seismometer, and 4 mm banana sockets for an external signal source. As above, the equivalent input velocity for a sinusoidal calibration signal is given by

$$v = \frac{V}{2\pi f\, R K}$$

where V is the peak-to-peak voltage of the calibration signal, f is the signal frequency, R is the magnitude of the calibration resistor and K is the feedback coil constant. R and K are both given on the calibration sheet supplied with the 40T.

The calibration resistor is placed in series with the transducer. Depending on the calibration signal source, and the sensitivity of your recording equipment, you may need to increase R by adding further resistors to the circuit.

6 Connector pin-outs

6.1 Output port and breakout box RECORDER connector

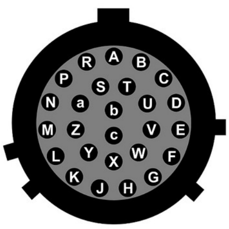
This is a standard 26-pin military specification bayonet plug, conforming to MIL-DTL-26482 (formerly MIL-C-26482). A typical part-number is 02E-16-26P although the initial "02E" varies with manufacturer.

Suitable mating connectors have part-numbers like ***-16-26S and are available from Amphenol, ITT Cannon and other manufacturers.

Pin assignments used when the High Gain option is ***not*** fitted:

Pin	Function	Pin	Function
A	Velocity +ve, vertical ch.	**P**	Calibration signal (all channels)
B	Velocity –ve, vertical ch.	**R**	Calibration enable (all channels)
C	Velocity +ve, N/S ch.	S	*Not connected*
D	Velocity –ve, N/S ch.	T	*Not connected*
E	Velocity +ve, E/W ch.	**U**	One-second mode *
F	Velocity –ve, E/W ch.	**V**	N/S centring motor *
G	Mass position, vertical ch.	**W**	E/W centring motor *
H	*Not connected*	**X**	Vertical centring motor *
J	Mass position, N/S ch.	**Y**	Digital ground / Motor return *
K	*Not connected*	Z	*Not connected*
L	Mass position, E/W ch.	a	*Not connected*
M	-12V DC (3-way power opt)	**b**	Power ground
N	Signal ground	**c**	+12V DC supply

** see notes on following page*



Wiring details for the compatible socket, ***-16-26S, as seen from the cable end.

Note: In the standard instrument, pin U selects one-second mode when grounded to pin Y, which is digital ground.

In instruments with the remote nulling option fitted, pins V, W and X provide access to the motors diving the nulling potentiometers. Pin Y serves as the return for the motor currents.

In instruments with the digital nulling option fitted, grounding pin U for seven seconds initiates the automatic centring process.

These connectors are plug-compatible with the Güralp 3ESP, so you can use Güralp 3ESP hand-held control units and breakout boxes to monitor the low-gain velocity outputs and run calibrations. Pressing *ENABLE* and *CENTRE* on a Güralp 3ESP hand-held control unit activates pin U and switches the 40T into one-second mode for as long as the buttons are held down. You must do this before you can monitor mass position outputs, *e.g.* for offset nulling.

Note: 40T units with the optional additional high-gain outputs cannot be used with a Güralp 3ESP breakout box. The pin-outs for these sensors are given in the next section.

Pin R, *Calibration enable*, is equivalent to the vertical calibration enable line on a Güralp 3ESP, so you can calibrate all channels by setting up Scream! or a hand-held control unit to calibrate the vertical channel.

6.2 Output port and breakout box RECORDER connector (high-gain option)

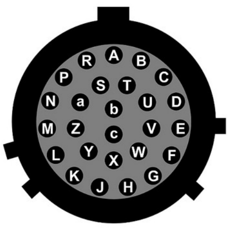
These units use the same plug with the following pin assignments. High gain velocity outputs are denoted HGV.

This is a standard 26-pin military specification bayonet plug, conforming to MIL-DTL-26482 (formerly MIL-C-26482). A typical part-number is 02E-16-26P although the initial "02E" varies with manufacturer.

Suitable mating connectors have part-numbers like ***-16-26S and are available from Amphenol, ITT Cannon and other manufacturers.

Pin	Function	Pin	Function
A	Velocity +ve, vertical ch.	P	Calibration signal (all ch)
B	Velocity −ve, vertical ch.	R	Calibration enable (all ch)
C	Velocity +ve, N/S ch.	S	**HGV -ve, vertical channel**
D	Velocity −ve, N/S ch.	T	**HGV +ve, vertical channel**
E	Velocity +ve, E/W ch.	U	Acc/Vel (or Centre - see P17)
F	Velocity −ve, E/W ch.	V	N/S centring motor*
G	Mass position, vertical ch.	W	E/W centring motor*
H	**HGV −ve, E/W channel**	X	Vertical centring motor*
J	Mass position, N/S ch.	Y	Motor return*
K	**HGV +ve, E/W channel**	Z	**HGV -ve, N/S channel**
L	Mass position, E/W ch.	a	**HGV +ve, N/S channel**
M	-12V DC (3-way power opt)	b	Power ground
N	Signal ground	c	+12V DC supply

** see notes in section 6.1 on page 35.*



Wiring details for the compatible socket, ***-16-26S, as seen from the cable end.

6.3 Breakout box power connector

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 0 V
B	+12 V DC supply
C	*Not connected*
D	*Not connected*
E	*Not connected*
F	*Not connected*
G	*Not connected*
H	–12 V DC supply (3-way power option)
J	*Not connected*
K	*Not connected*

Wiring details for the compatible socket, ***-12-10S, as seen from the cable end.

7 Specifications

In the interests of continual improvement with respect to design, reliability, function or otherwise, all product specifications and data are subject to change without prior notice.

SYSTEM	**Technology**	Force feedback velocity sensor
	Configuration / Topology	Triaxial orthogonal (ZNE)
PERFORMANCE	**Velocity output band** (flat response within -3 dB crossing points)	60 s (0.017 Hz) to 100 Hz standard 30 s or 1 s to 100 Hz options available Contact Güralp for other options
	Output sensitivity	2000 V/ms^{-1} (2 × 1000 V/ms^{-1}) differential standard output (full-scale clip level of 8.8 mm/s) Contact Güralp to discuss alternative high sensitivity (high gain) options
	Peak full-scale output voltage	Differential: ±20 V (40 V peak-to-peak) Single-ended (e.g. mass positions): ±10 V (20 V peak-to-peak)
	Self noise below NLNM (New Low Noise Model; Peterson, 1993, USGS)	7 s (0.15 Hz) to 4 Hz *Independently tested value - see Tasic & Runovc (2012), Journal of Seismology*
	Sensor dynamic range (standard sensitivity)	148 dB @ 1 Hz 151 dB @ 5 Hz
	Cross axis rejection	65 dB
	Linearity	>90 dB
	Lowest spurious resonance	450 Hz
	Damping	70.7% of critical
	Operating tilt range	±2.5°
MASS MONITORING / CONTROL	**Sensor Mass positions**	Three independent sensor mass position outputs (single-ended)
	Mass locking	No mass locking required
	Mass centring / offset nulling	Manually adjustable via pots located under lid. Remote options available.

CALIBRATION	**Calibration input**	Independent signal and enable lines exposed on sensor connector
CONNECTOR	**Single connector: Analogue outputs, power input and control inputs**	26-pin military-specification bayonet connector. Post-hole option: 100 bar/10 MPa waterproof connector
POWER	**Power supply voltage**	10–36 V DC *
	Power consumption (at 12 V DC)	0.78 W * ** Power figures for operation of this unit only. Connection to additional instrumentation or use of longer cables may require a higher input voltage .*
PHYSICAL / ENVIRONMENTAL	**Operating temperature range**	-20 to +75 °C
	Operating humidity range	0-100% relative humidity
	Enclosure ingress protection	IP68 - protection against effects of prolonged immersion at 3 m depth for 72 hours. Posthole option:For deeper, long term immersion, the optional 100 bar/10 MPa waterproof connector is recommended
	Enclosure material	Stainless steel case O-ring seals throughout
	Diameter	168 mm
	Height	With handle: 203 mm Without handle: 177 mm
	Weight	7.1 kg
	Alignment	Bubble level on lid; north arrow on handle and base; adjustable feet
SUPPORTING DOCUMENTATION	**Calibration values**	Measured sensor sensitivity, frequency response, instrument poles and zeros enclosed
	User's guide available online at https://www.guralp.com/documents/MAN-040-0001.pdf	

8 EU Declaration of Conformity

We

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Declare under our sole responsibility that the following product

Equipment name: 40T
Model Number: 40T-JSV101300202L and appropriate variants

Is in conformity with the

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 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
EN 61000-4-11:2004 – Voltage Dips and Short Interruptions Immunity
EN 55011:2009 +A1:2010 – Radiated Emissions
EN 55011:2009 +A1:2010 – Conducted Emissions
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

9 Revision history

9 September, 2021	H	Added EU Declaration of Conformity
21 September, 2020	G	Clarified difference between "remote nulling" and "digital nulling". Clarified related pin-outs. Removed spurious reference to "applying a voltage" to pin U.
27 June, 2019	F	Removed coil constant section. Updated specifications. Updated some graphics.
14 November, 2016	E	Added "Levelling" section.
29 June 2016	D	Added safety warning about pressure-relief screw. Enhanced specifications. Minor edits elsewhere.
3 May 2016	C	Face-lift with no significant content changes
22 Jul 2009	B	Added digital nulling option, improved connector documentation, added revision history
12 Jan 2006	A	New document