



Güralp 6T

User'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: <https://www.guralp.com/> unless otherwise stated.

2 Introduction

The CMG-6T is an ultra-lightweight seismometer consisting of three sensors in a sealed case, which can measure simultaneously the North/South, East/West and vertical components of ground motion over a wide frequency range. This frequency response is made possible by advanced force-balance feedback electronics.. It is ideally suited for rapid, temporary installations in locations with medium noise.



The 6T has a rugged, waterproof, lightweight aluminium design for ease of installation. The robust sensor elements are designed so that no mechanical clamping is required. Because of this, the 6T 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 the 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 6T can be supplied with a response which is flat to velocity from 100 Hz to any of 0.1 Hz (10 s), 0.033 Hz (30 s) or 0.01 Hz (100 s). The 6T is also available as the high-frequency CMG-6T-1 variant, which has a 100Hz to 1s response.

Two variants, the CMG-6V (vertical) and CMG-6H (horizontal), are available for single-component applications.

3 First Encounters

3.1 Handling notes

Although the 6T 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 sensor, you should contact Güralp Systems for assistance.

- Avoid bumping or jolting the seismometer 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 6T are waterproof.

3.2 Unpacking

The 6T seismometer is delivered in a single transportation case. The packaging is specifically designed for the 6T 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 safe, clean surface. For each instrument in the packaging, you should have received:

- the seismometer;
- the breakout box (which provides separate connections for the signal, control and power lines);
- a data cable, for connecting the instrument to a Güralp digitiser, such as the CMG_DM24;
- a calibration and installation sheet.

Assuming all the parts are present, stand the seismometer in the centre of a bench and identify its external features:

- a handle with North indication,
- a 26-way bayonet plug for data and power;
- a pressure-release cap;
- a cover-plate for the output offset adjustment potentiometers;
- a spirit level,
- three feet (two adjustable, and one fixed), and
- two accurate orientation pins (one brass and one steel).

3.2.1 Serial number

The sensor's serial number can be found on the label affixed to the side of the instrument. You should quote this serial number if you ever need assistance from Güralp Systems.

3.3 Connection

The instrument is supplied with a 26-way cable with mil-spec bayonet connectors on each end; this carries both power and output signals and is suitable for connecting directly to a Güralp digitizer.

An optional breakout box, if ordered, provides individual signal and power connectors, or you can make up your own cable if you prefer.

3.3.1 The breakout box

If you are using the optional Güralp breakout box, the data cable from the instrument should be attached to its *SENSOR* connector. Connectors are also provided at the *CONTROL* and *RECORDER* outputs, for attaching to an optional hand-held control unit or a Güralp digitizer.

The breakout box also provides a standard Güralp power connector on a 10-pin mil-spec plug. The 6T draws a nominal current of 38 mA from a 12 V supply when in use; thus, using a 12V, 25 Ah sealed heavy-duty lead-acid battery, you should expect the instrument to operate for around a week without recharging.

The *CENTRE* button switches the instrument into one-second mode whilst it is 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.)



3.3.2 The hand-held control unit (HCU)

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.

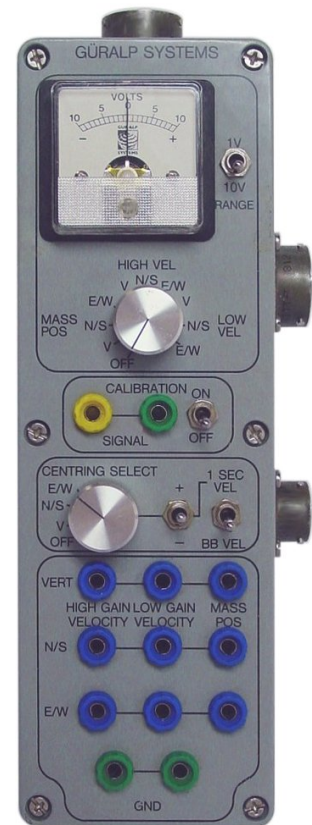
The upper section of the HCU contains a simple voltmeter for monitoring various signals from the instrument.

- To monitor the velocity outputs, switch the dial to *V*, *N/S* or *E/W LOW VEL* according to the component you want to monitor.
- 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.

You can calibrate a 6T sensor using an 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 section 4 on page 20 for full details.

You can zero the mass position offsets using the HCU. The normal range of the mass positions is ± 10 V; you should zero the instrument if any mass reads more than around ± 3.5 V when the sensor is stationary. See section 3.4 on page 9 for full details.

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.



3.4 Centring (zeroing) the instrument

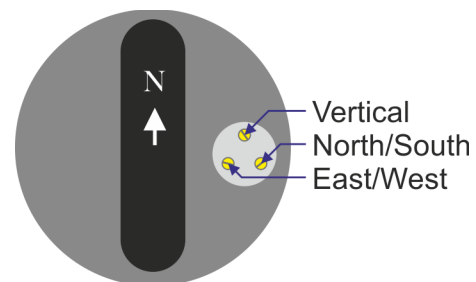


For each axis, the instrument's feedback electronics drives an electromagnet which acts to keep the inertial mass central. For optimal operation, the magnetic force should be zero in the absence of a seismic signal. For historical reasons, the magnitude of this force is universally known as the *mass position*, even though that term is misleading. The dynamic range of the instrument is reduced if the mass positions are too high.

The mass positions are affected by the angle at which the instrument is installed as well as by the ambient temperature. The instrument should be physically levelled and then allowed to acclimatise itself before final centring is carried out.

The mass positions are directly output by the instrument as analogue voltages in the range ± 10 Volts. They are available at the bayonet connector where they can be monitored by a Güralp Systems digitiser (they appear as streams M8 (vertical), M9 (N/S) and MA (E/W)) or by using the meter on the hand-held control unit. The offsets can be nulled using three potentiometers, located under a protective cover on the instrument's lid and adjustable using a trim-pot tool or a very small flat-bladed screwdriver.

The cover can be removed without tools: three potentiometers are then exposed. The one nearest the "North" of the instrument controls the vertical mass offset and the other two, proceeding clockwise, control the North/South and East West offsets.



1. Select the component you want to centre using 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. Switch the *RANGE* selector to *10V* (coarse adjustment);
5. Adjust the relevant potentiometer until the signal meter reads zero:
 - a) If the vertical mass position is too low, turn the adjustor anti-clockwise;
 - b) If the North/South mass position is too low, turn the adjustor anti-clockwise;
 - c) If the East/West mass position is too low, turn the adjustor clockwise.

The adjustors have a sensitivity of around 0.6 Volts per turn.

6. Switch the *RANGE* selector to *1V* (fine adjustment);
7. Adjust the relevant potentiometer until the signal meter reads as close to zero as possible.
8. Change the rightmost switch back to the *BB VEL* position to re-enable broadband mode.

If there is a fault or if the instrument is too far from level, it may be impossible to null a mass position. In this case, the adjustor will continue to turn without making any further difference to the output. If you cannot resolve this by physically levelling the instrument, please contact GSL Support for advice.

3.4.1 Remote centring option

For instruments fitted with the remote centring option, the mass position offsets are adjusted using a micro-controller and three digital potentiometers that replace the standard electromechanical potentiometers.

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 zero the mass positions of all three axes simultaneously. Zeroing can be further triggered via the “centre” control line on pin U. (On instruments without the digital nulling option, pin U is the 'Acc/Vel' line).

Automatic zeroing 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 $\pm 0.5V$. If the sensor is poorly levelled, the micro-controller will make three attempts to zero 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.

3.5 Test installation

This section gives an overview of how to set up a CMG-6T and begin recording data. We recommend that you set up a test instrument in your office or laboratory as a “dry run” to gain a basic understanding of the system and to check that it is functioning as expected.

This test installation will use the instrument's default settings. Data will be digitised using a CMG-DM24 and received using Güralp Systems' Scream! software, available from our website

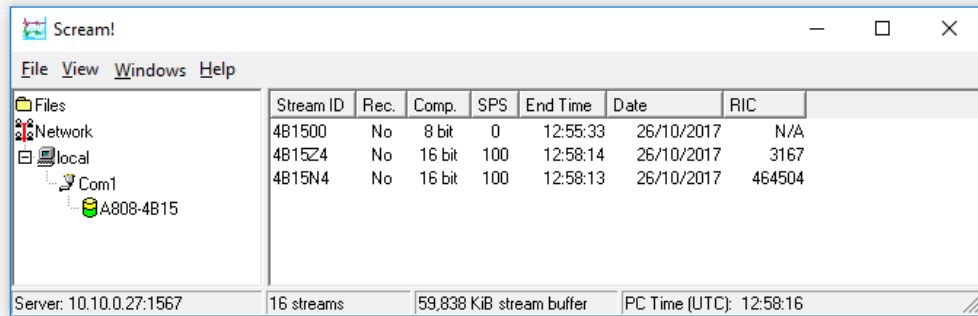
<http://www.guralp.com/>

You will need access to a PC with a 9-pin RS232 port, and a 12 V power source.

1. Install Scream! on your PC and run it.
2. Connect the GPS receiver to the CMG-DM24 using the brown cable supplied with the digitiser. Position the GPS receiver so that it has a good view of the sky. If you do not have a view of the sky, you can operate the sensor without a GPS unit, but timing information may be inaccurate.
3. Connect the grey data cable between the CMG-6T and the *SENSOR A* connector on the digitiser.
4. Using the blue/grey combined data/power cable that is included with the CMG-DM24, connect the digitiser to the PC's serial port and then to a 12V power supply.

The instrument is now fully operational, and will already be producing data.

- After a few seconds you should see the digitizer appear under **Network - Local - Com1** in the left-hand panel of Scream!'s main window. (If your PC has multiple serial ports, it may appear under some other *Com_port* name.) Soon after, data streams will begin appearing in the right-hand panel. Streams with higher sample rates will appear sooner than those with lower sample rates.




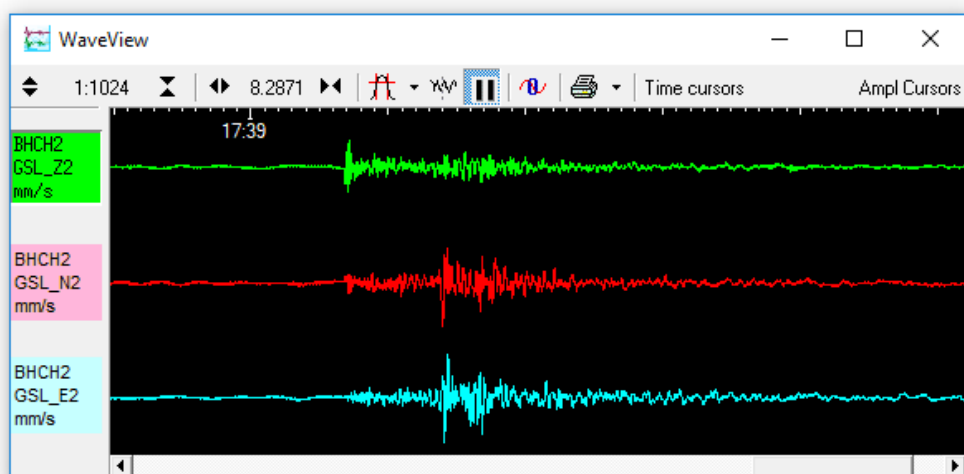
If this does not happen, check all connections, and ensure the power supply is providing the correct voltage and current.

- Each data stream has a *Stream ID*, a six-character string unique to it. Stream IDs normally identify the instrument, component and sample rate of each stream. Thus the stream 1026Z2 refers to a Z-component stream from instrument 1026, at tap 2.

Data streams ending in 00 and 01 are *status* streams containing any extra information sent from the digitizer. Streams with IDs ending in IB are InfoBlocks and can be configured to contain calibration information for the attached sensor. Please see the relevant digitiser manual for more information.

- To view data, select a stream and then double-click to open a *Waveview* window.

You can view several streams at once by holding down  as you select, and then double-clicking the selection.



8. To start recording new data to a file, right-click on a stream or a selection of streams and choose **Start recording** from the pop-up menu. Recording settings, directories, etc., can be altered by selecting **File → Setup...** from the main menu and switching to the *Recording* tab.

3.6 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;
- vibration caused by heavy machinery (even at a distance), or by overhead power lines.

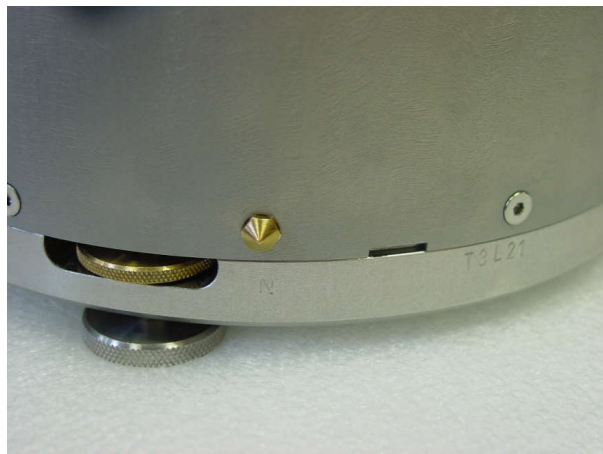
This can be done by selecting a suitable site, and placing the instrument in a protective enclosure. An open-sided box of 5 cm expanded polystyrene slabs, placed over the instrument and taped down to exclude draughts, makes an excellent thermal shield.

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.

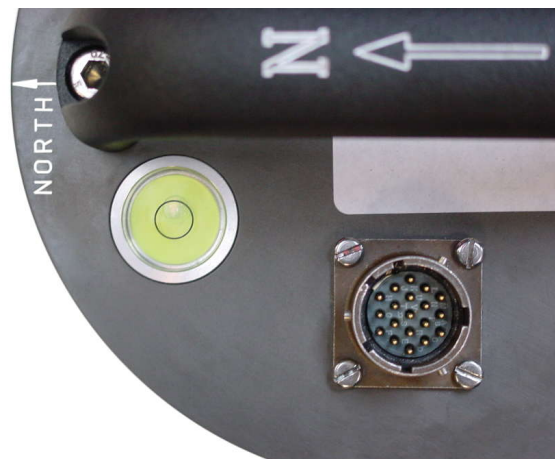
3.7 Installing in vaults

You can install a CMG-6T in an existing seismic vault with the following procedure:

1. Unpack the sensor from its container, saving the shipping boxes for later transportation.
2. Prepare the mounting surface, which should be smooth and free of cracks. Remove any loose particles or dust, and any pieces of loose surfacing. This ensures good contact between the instrument's feet and the surface.
3. If it is not already present, inscribe an accurate North-South line on the mounting surface.
4. Place the sensor over the scribed line, so that the brass and steel pointers are aligned with the marked directions, with the brass pointer facing North. This can be done by rotating the base of the sensor whilst observing it from above. The brass pointer can be found next to one of the feet.



5. If you cannot easily see the pointers, you should align the sensor using the north arrow on the handle. However, the alignment of the handle with the sensors inside is less accurate than the metal pointers, so they should be used wherever possible.
6. The top panel of the CMG-6T includes a spirit level.
Level the sensor using each of the adjustable feet of the instrument in turn, until the bubble in the spirit level lies entirely within the inner circle. (The instrument can operate with up to 2 ° of tilt, but with reduced performance.)



7. The feet are mounted on screw threads. To adjust the height of a foot, turn the brass locking nut anticlockwise to loosen it, and rotate the foot so that it screws either in or out. When you are happy with the height, tighten the brass locking nut clockwise to secure the foot.

When locked, the nut should be at the *bottom* of its travel for optimal noise performance.



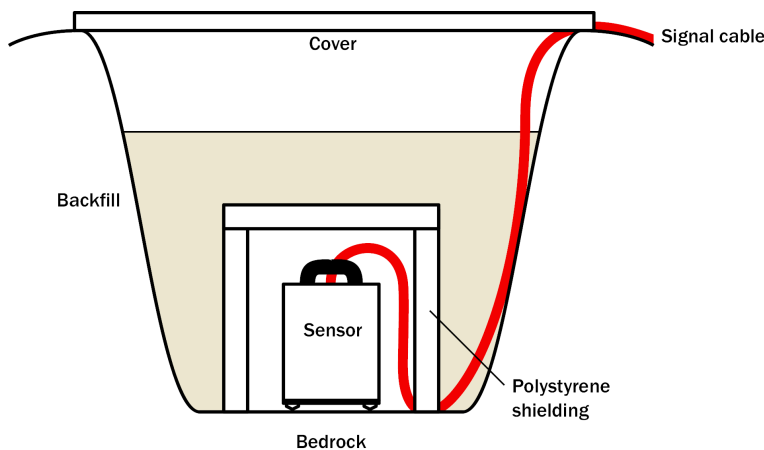
8. Connect the grey sensor cable to the digitiser.
9. Connect a GPS receiver, a PC and a 12 V fused power supply to the digitiser.
10. Run Scream! on the PC and check that data are being produced.
Optionally, also check the mass position outputs (streams ending `M8`, `M9` and `MA`.) These streams are digitized at a slower rate, and may take up to 15 minutes to appear.
11. Cover the instrument with thermal insulation, for example, a 5 cm expanded polystyrene box. This will shield it from thermal fluctuations and convection currents in the vault. It also helps to stratify the air in the seismometer package. Position the thermal insulation carefully so that it does not touch the sensor package.



12. 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.

3.8 Installing in pits

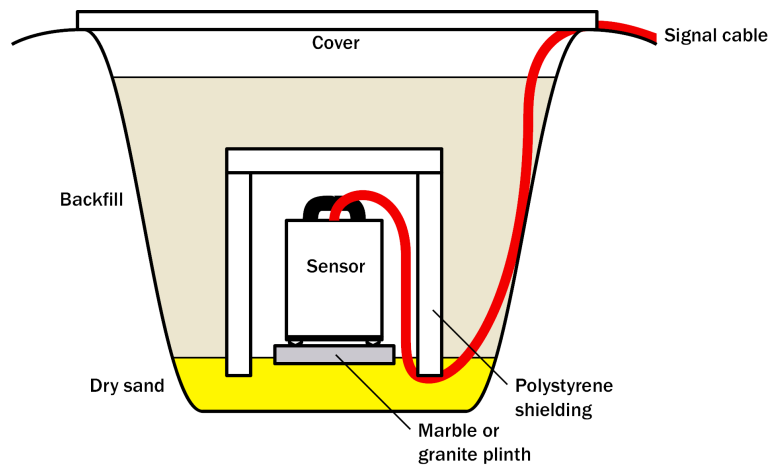
For outdoor installations, high-quality results can be obtained by constructing a seismic pit.



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.

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 situating 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 3.7, page 14 (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.

3.9 Other installation methods

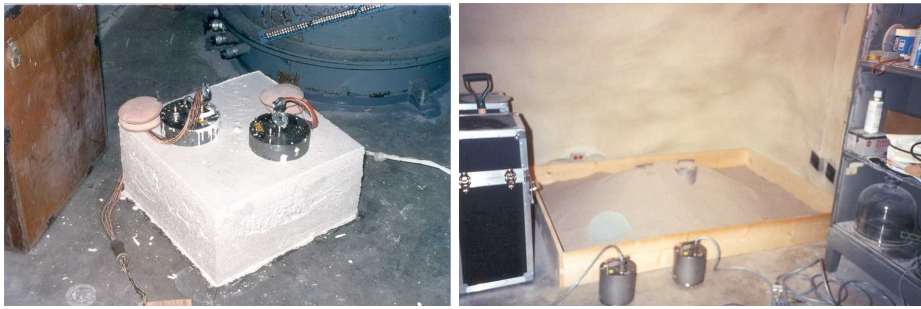
The recommended installation methods have been extensively tested in a wide range of situations. However, past practice in seismometer installation has varied widely.

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.



4 Calibrating the CMG-6T

4.1 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*. Each row details:

Velocity Output (Differential) : The sensitivity of each component to velocity at 1 Hz, in Volts/ms⁻¹. Because the 6T 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/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/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 terms of the current (in amperes) drawn from a 12 V 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.)

4.2 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

$$[V/x](s) = G A H(s)$$

In this equation

- G is the 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 $A H(s)$ 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:

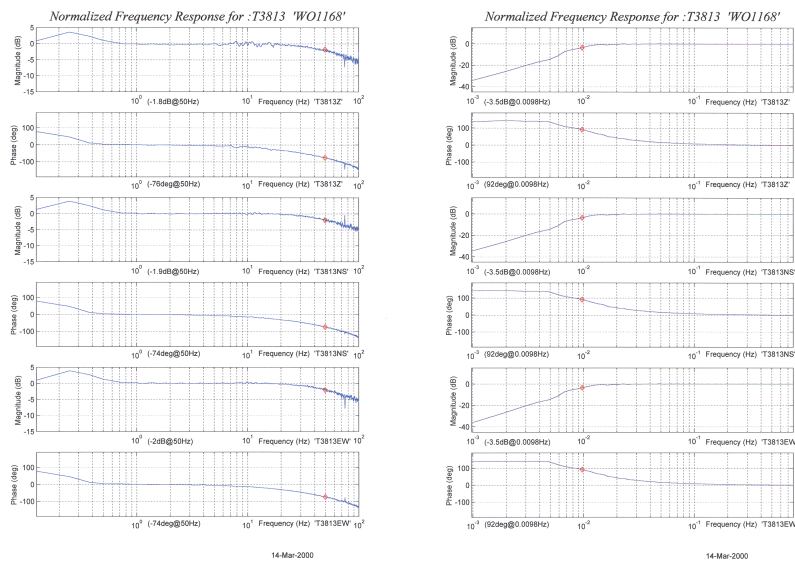
$$H(s) = N \frac{\prod_{i=1,n} s - Z_i}{\prod_{j=1,m} s - P_j}$$

In this equation z_n are the roots of the numerator polynomial, giving the zeros of the transfer function, and p_m 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_n and p_m , 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.

4.3 Frequency response curves

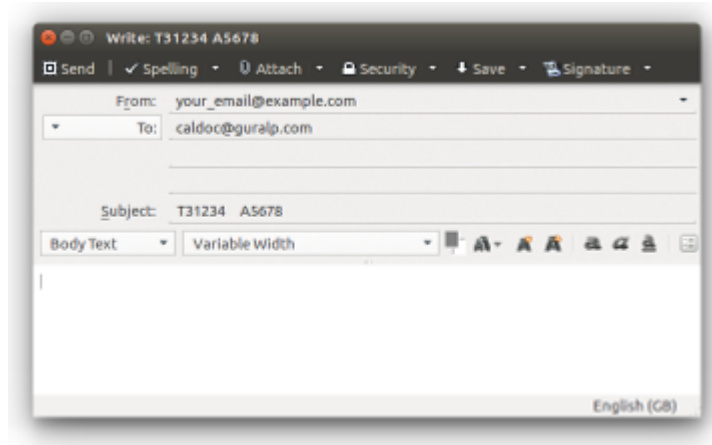
The frequency response of each component of the 6T is described in the normalised amplitude and phase plots provided. The response is measured at low and high frequencies in two separate experiments. Each plot marks the low-frequency and high-frequency cutoff values (also known as -3 dB or half-power 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 digitizer or your own signal generator, and record the instrument's response.

4.4 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(s) in the subject line, e.g.



The server will reply with the calibration documentation in Microsoft Word format (note that, since these documents contain active content, they cannot be viewed in, for example, openoffice.org's *writer* software.) The body of your e-mail will be ignored.

4.5 Calibration methods

Velocity sensors such as the 6T 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.

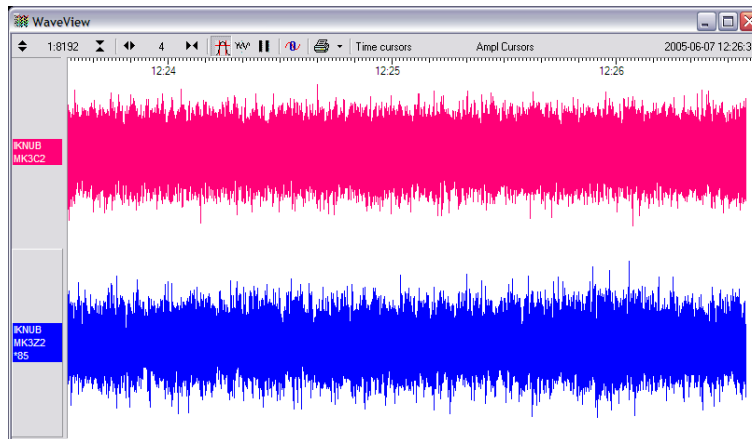
You can calibrate a 6T sensor using any of these methods, using the signal generator built in to all Güralp Systems' digitisers.

4.6 Noise calibration with Scream!

The most convenient way to calibrate a 6TD instrument is to use a CMG-DM24's pseudo-random broadband noise generator along with Scream!'s noise calibration extension. The extension is part of the standard distribution of Scream!, and contains all the algorithms needed to determine the complete sensor response in a single experiment.




Information on other calibration methods is available on the Güralp Systems Web site.

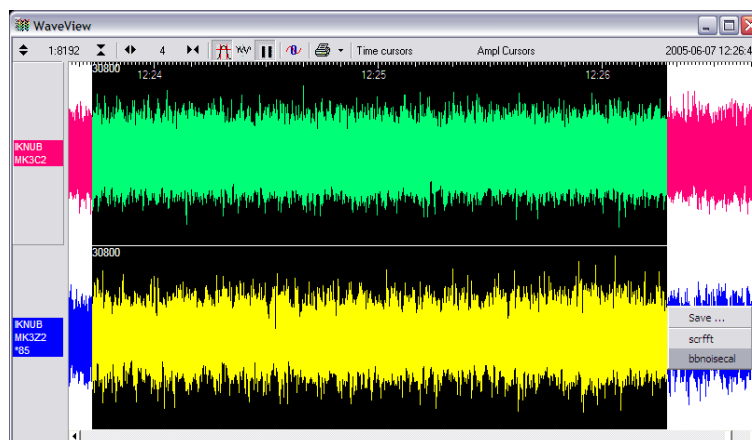
1. In Scream!'s main window, right-click on the digitizer's icon and select **Control....** Open the *Calibration* pane.
2. Select the calibration channel corresponding to the instrument, and choose **Broadband Noise**. Select the component you wish to calibrate, together with a suitable duration and amplitude, and click **Inject now**. A new data stream ending c_n ($n = 0 - 7$) should appear in Scream!'s main window containing the returned calibration signal.



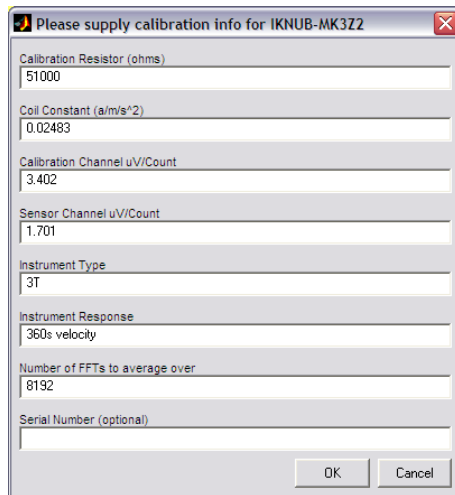
3. Open a Waveview window on the calibration signal and the returned streams by selecting them and double-clicking. The streams should display the calibration signal combined with the sensors' own measurements. If you cannot see the calibration signal, zoom into the Waveview using the scaling icons at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



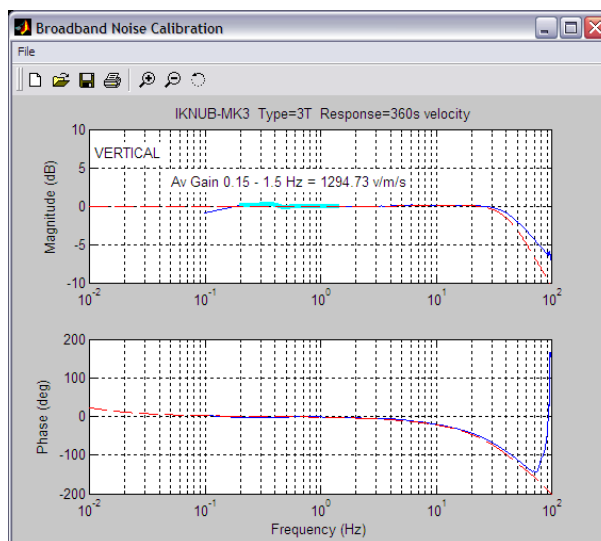
Most data can be found on the calibration sheet for your sensor. Under *Instrument response*, you should fill in the sensor response code for your sensor, according to the table below. *Instrument Type* should be set to the model number of the sensor.

If the file `calvals.txt` exists in the same directory as `Scream!`'s executable (`scream.exe`), `Scream!` will look there for suitable calibration values.

See the `Scream!` manual for full details of this file. Alternatively, you can edit the sample `calvals.txt` file supplied with `Scream!`.

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

4.6.1 Sensor response codes

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

4.7 The coil constant

The feedback coil constant K is measured at the time of manufacture, and printed on the calibration sheet. Using this value will give good results at the time of installation. However, it may change over time.

The coil constant can be determined by tilting the instrument and measuring its response to gravity. To do this, you will need apparatus for measuring tilt angles accurately.

1. Measure the acceleration due to gravity, g , at your location.
2. Tilt the instrument slightly, and measure its attitude and the value of the *mass position* output for the component you wish to calibrate.

To make it easier to measure mass positions, you should use the `RESP` command to place the instrument in 1 second response mode beforehand. To do this, open a *Terminal* window in *Scream!* and issue the commands

```
OK-1
1 RESP
MASSES?
0 RESP
```

3. Repeat this measurement for several tilt angles.

4. For the vertical sensor, the input acceleration is given by $a = g \sin \varphi$, whilst for the horizontal sensor, it is $a = g (1 - \cos \varphi)$.

Calculate the input acceleration for each of the tilt angles used, and plot a graph of mass position output against input acceleration.

5. The gradient of the line obtained gives the sensitivity of the coil (in V/ms^{-2} , if g was measured in ms^{-2} and the mass position in V.)
6. The coil constant K is equal to this sensitivity divided by the value of the displacement feedback resistor, given on the calibration sheet.

5 Connector pin-outs

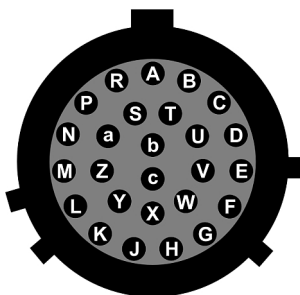
5.1 Instrument, HCU RECORDER and SENSOR connectors

This is a standard 26-pin “mil-spec” 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 channel	P	Calibration signal (all channels)
B	Velocity -ve, vertical channel	R	Calibration enable (all channels)
C	Velocity +ve, N/S channel	S	<i>not connected</i>
D	Velocity -ve, N/S channel	T	<i>not connected</i>
E	Velocity +ve, E/W channel	U	One-second response mode
F	Velocity -ve, E/W channel	V	<i>not connected</i>
G	Mass position, vertical channel	W	<i>not connected</i>
H	<i>not connected</i>	X	<i>not connected</i>
J	Mass position, N/S channel	Y	Logic ground
K	<i>not connected</i>	Z	<i>not connected</i>
L	Mass position, E/W channel	a	<i>not connected</i>
M	<i>not connected</i>	b	Power ground
N	Signal ground	c	Power +ve



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

5.2 Breakout box and HCU power connector

This is a standard 10-pin “mil-spec” 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	<i>not connected</i>
D	<i>not connected</i>
E	<i>not connected</i>
F	<i>not connected</i>
G	<i>not connected</i>
H	<i>not connected</i>
J	<i>not connected</i>
K	<i>not connected</i>



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

6 Specifications

Velocity output bandwidth	10s - 100 Hz (standard), 30s - 100 Hz (optional) <i>or</i> 1s - 100 Hz (model CMG-6T-1)
Velocity output sensitivity	2 x 1,200 V/ms ⁻¹ (Other responses available - please refer to your sales contact.)
Peak output	±10V (20V peak-to-peak)
Lowest spurious resonance	450 Hz
Linearity	> 90 dB
Cross-axis rejection	> 65 dB
Electronics self-noise	-172 dB (relative to 1 m ² s ⁻⁴ Hz ⁻¹)
Operating temperature	-40 to +75°C
Temperature sensitivity	< 0.6 V per 10 °C
Mass recentring range	±3° from horizontal
Construction	Hard anodised aluminium case with 'O'-ring seals throughout
Case diameter	154 mm
Case height (with handle)	207 mm
Weight	2.49 kg
Power supply	10 - 36 VDC
Optional low-power version	5 VDC supply, ±4.5 V output
Calibration controls	common signal and enable lines exposed on sensor connector
Offset nulling	potentiometers, adjustable through case
Optional remote nulling	microprocessor controlled motor drives
Optional accessories	Break-out box Hand-held control unit

7 Revision history

2010-09-23	A	New document
2011-07-19	B	Corrected diagram showing offset trim-pot locations
2015-05-06	C	Added direction and sensitivity information for offset trims.
2018-03-15	D	Rebranded and corrected sensitivity specifications