Güralp 5T Compact

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:

HARMFUL

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.

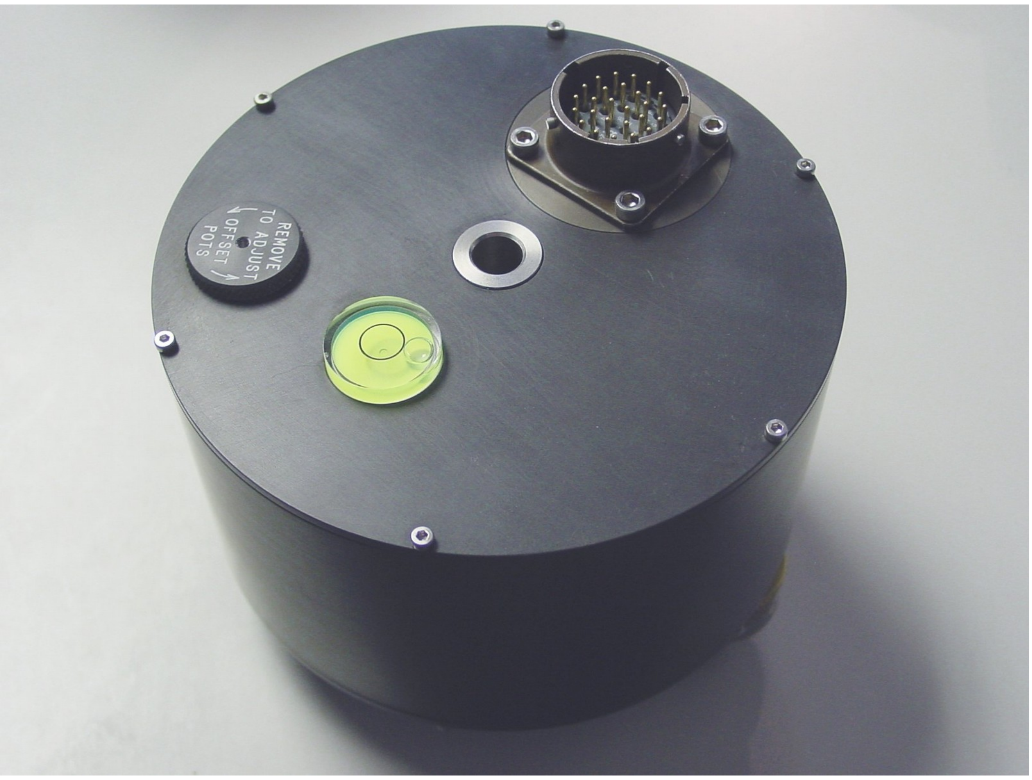
Note: A blue circle indicates indicates a procedural or advisory note.

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

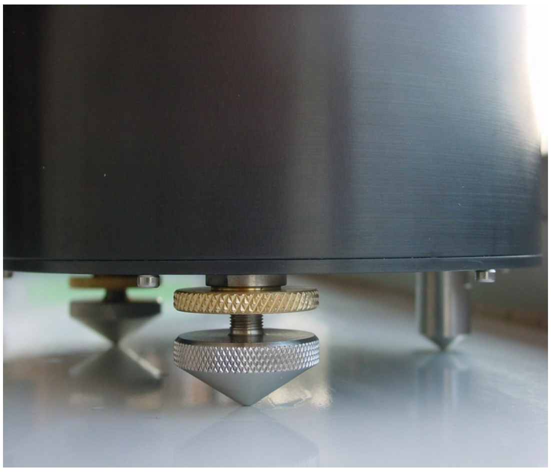
The 5T Compact is a three-axis, strong-motion, force-feedback accelerometer in a sealed case. The accelerometer is self-contained except for its 10 – 36 V power supply, which can be provided through the same cable that carries the analogue data. An internal DC–DC converter ensures that the sensor is completely electrically isolated. Optionally, this converter can be omitted, in which case an external ±12 Volt DC three-way or 'dual rail' power supply is required. Sensors with this option have substantially lower power requirements than those fitted with the DC–DC converter.



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

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

Full-scale low-gain sensitivity is available from 4.0 g down to 0.1 g. The most common configuration is for the 5T Compact unit to output 5 V single-ended output for 1 g (≈ 9.81 ms^{-2}) input acceleration. The standard frequency pass band is flat to acceleration from DC to 100 Hz (although other low pass corners from 50 Hz to 100 Hz can be ordered.) A high frequency option provides flat response from DC to 200 Hz.



Each accelerometer is delivered with a detailed calibration sheet showing its serial number, measured frequency response, sensor DC calibration levels and the transfer function in poles/zeroes notation. Installation is simple, using a single fixing bolt to attach the sensor to a hard surface. If required, you can also level the sensor using its two adjustable levelling feet.

Optionally, you can use a Güralp Hand-held Control Unit (HCU) and breakout box to distribute power and calibration signals to the sensor and to receive the signals it produces. It is available in standard, rack-mounted and water-resistant portable formats.

The accelerometer housing itself is completely waterproof, with a hard anodised aluminium body and "O"-ring seals throughout. 5T Compact instruments have been tested for long periods of total immersion in water.

3 Installation

3.1 Unpacking and packing

The 5T Compact accelerometer is delivered in a single cardboard box with foam rubber lining.

The packaging is specifically designed for the 5T Compact and should be re-used whenever you need to transport the sensor. Please note any damage to the packaging when you receive the equipment and unpack on a clean surface. The package should contain:

- the accelerometer,
- a signal connection cable (if ordered),
- a 26-pin connector (unless fitted to the supplied cable).

Place the accelerometer on a clean surface and identify:

- the signal cable connector on the top of the unit,
- the N/S orientation line, engraved on the lid,
- the bubble level,
- the screw-on cover for the output offset adjuster (see Section 3.4 on page 11),
- the central hole for the main fixing bolt and
- the serial number.

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

3.2 Initial testing

To test the 5T Compact before installation, you will need a power source which can deliver >100 mA at 10 to 36 V to cover initial transients and a digital voltmeter (DVM) with 1 and 10 V ranges. Also ensure that the supplied cable is connected with the correct polarity.

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

1. Place the 5T Compact sensor on a flat, horizontal surface.
2. Connect the power supply, observing the correct polarity for the cable supplied and switch on.
3. Connect the voltmeter to pins A and B of the output connector (corresponding to the low gain vertical component). Measure the output of the low gain vertical component. The steady output voltage should be about zero (±10 mV).
4. Repeat the measurement for the N/S and E/W low-gain component outputs (pins C/D and E/F respectively).
5. Now turn the sensor on its side, propping it carefully to stop it rolling.
6. The low gain vertical component should now read about –5 V, corresponding to –1 g.
7. Roll the instrument until the N/S line is vertical, with N at the top.
8. The low gain N/S component should now read +5 V, corresponding to +1 g.
9. Roll the instrument until the N/S line is horizontal.
10. The low gain E/W component should now read +5 V.

If the performance so far has been as expected, the instrument may be assumed to be in working order and you may proceed to install the unit for trial recording tests. In many cases, there will be a slight offset to the readings. This can be compensated for after installation, by adjusting potentiometers (see Section 3.4 on page 11).

3.3 Installing the sensor

You will need a hard, clean surface such as a concrete floor, to install the 5T Compact.

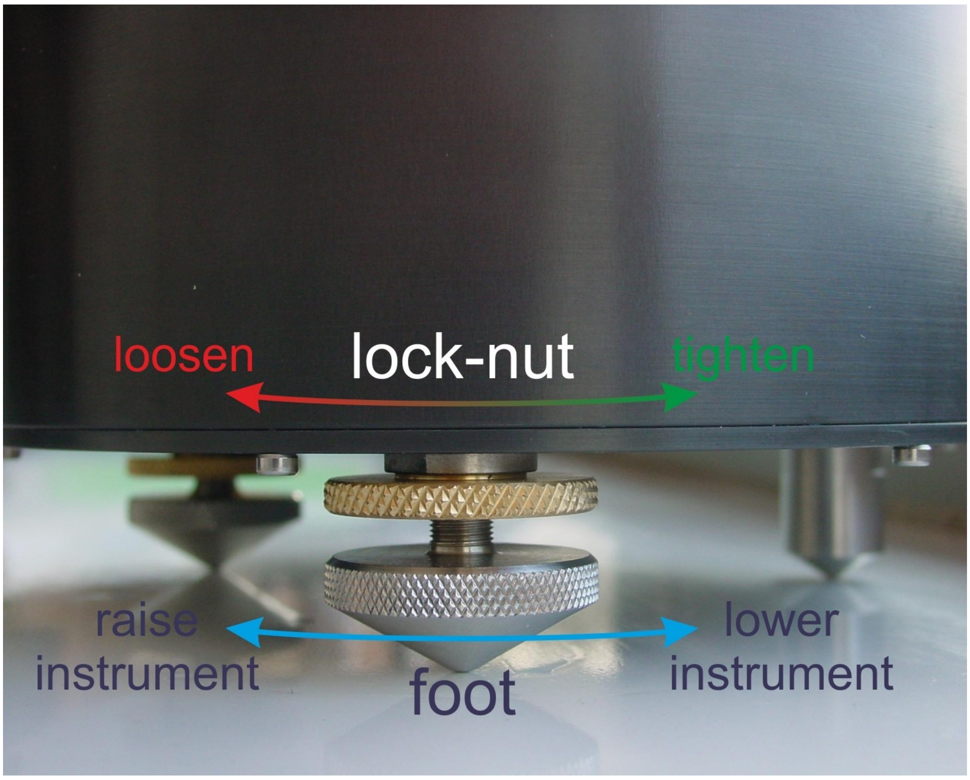
If you are in any doubt about how to install the sensor, you should contact Güralp Systems.

1. Prepare the surface by scribing a N/S orientation line and installing a grouted-in fixing bolt on the line, near the middle. A 6 mm (0.25 inch) threaded stud is suitable, as is an expanding-nut rock bolt or anchor terminating in a threaded stud. The bolt should be about 120 mm (5 inches) long.

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

3. Level the sensor, using its adjustable feet, until the bubble lies entirely within the inner circle of the level indicator.

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

   The instrument can use internal simulated level adjustment to compensate for tilt, as long as it is fixed within 1 ° of the horizontal.

4. Secure the accelerometer in place using a fixing nut with spring washer. Do not screw down the instrument too tightly, as the casing may be deformed.

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

and to fasten the box securely to the mounting surface. Commercially available duct sealing tape is ideal for this purpose.

6. Connect the sensor to your digitizing equipment or Hand-held Control Unit to start receiving signals.

3.3.1 Temporary installations

5T Compact sensors are ideal for monitoring vibrations at field sites, owing to their ruggedness, high sensitivity and ease of deployment. Temporary installations will usually be in hand-dug pits or machine-augered holes. Once a level base is made in the floor, the accelerometer can be sited there and covered with a box or bucket. One way to produce a level base is to use a hard-setting liquid:

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

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

3.3.2 Installation in Hazardous environments

The fully enclosed, aluminium case design of the 5T Compact instrument makes it suitable for use in hazardous environments where electrical discharges due to the build up of static charge could lead to the ignition of flammable gasses. To ensure safe operation in these conditions, the metal case of the instrument must be electrically bonded ('earthed') to the structure on which it is mounted, forming a path to safely discharge static charge.

Where electrical bonding ('earthing') is required during the installation of a 5T Compact instrument, the central mounting hole that extends through the instrument should be used as the connection point. This is electrically connected to all other parts of the sensor case. Connection can be made by either a cable from a local earthing point terminated in a 8mm ring tag or by the mounting bolt itself.

3.4 Removing offsets from the 5T Compact

Once installed the sensor needs to be as level as possible to ensure the output offset is minimised. Levelling is carried out by adjusting the feet until the bubble level on the top of the sensor has the bubble completely within the scribed ring.

When power is applied to the 5T Compact, offset adjustments are carried out automatically.

For more information about the effects of offsets and how to avoid them, visit http://www.guralp.com/minimizing-sensor-offsets/.

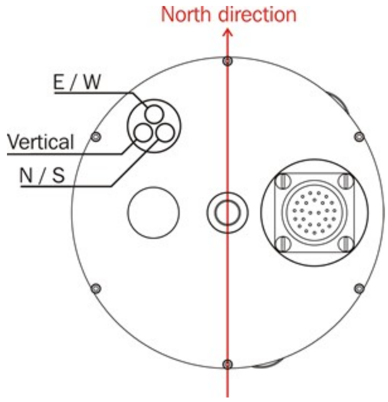
Should there be a need to reset the offsets, the simplest method is to power cycle the sensor. If this is not possible the following methods can be used.

3.4.1 Manual offset removal

Early versions of the 5T Compact had a port in the sensor lid to allow for manual offset adjustment. If the sensor has a knurled screw cover then there is a manual offset adjustment option.

1. Remove the screwed cover protecting the level adjusters. The cavity contains three adjustment screws.

2. Power up the sensor and connect a digital multimeter to its low-gain vertical outputs (pins A and B). Alternatively, use a Hand-held Control Unit (see Section 3.5, page 13) to monitor the outputs more easily.



3. Adjust the vertical screw until the output voltage reads zero.

4. Repeat steps 2 and 3 for the N/S and E/W channels, (with the meter connected across pins C/D and E/F respectively).

5. If necessary, continue to adjust each channel in turn until consistent results are obtained on all three channels.

6. Repeat steps 2 to 5 using the high-gain outputs, if available and refine the settings as far as possible. The high gain outputs for the vertical, N/S and E/W channels appear across pins S/T, Z/a and H/K respectively, as shown in section 6 on page 25.
7. Ensure that the "O"-ring seal on the adjuster screw cap is present and intact and replace the cap firmly, to keep the instrument's electronics protected from water and dust.

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

3.4.2 Removing offsets using a terminal connection

Note: this method will only work for the instrument connected to the sensor A port on a digitiser.

Open a terminal window for the required sensor and enter the command:

```
CENTRE MONITOR
```

or

```
CENTER MONITOR
```

The current offset values will display. Once the process has completed the Scream! status window will display (in green):

```
CENTERING COMPLETE
```

Note: if you enter the command `CENTRE` or `CENTER` the process will still take place but the mass position values will not display.

3.4.3 Removing offsets using a third party digitisers

To remove offsets while using third party digitisers, connect pin U on the sensor connector to pin Y (see section 6 on page 25). Note that the sensor must be powered while performing this operation.

The connection between pins U and Y must be maintained for seven seconds before the centring function is activated. The connection must then be released. Centring will continue for as long as is required after the connection is broken,

3.5 The hand-held control unit

The 5T Compact can be supplied with an optional hand-held control unit (HCU). This is a portable device which provides easy access to the seismometer's controls, as well as displaying the output acceleration on an analogue meter. The 5T Compact uses the same HCU as Güralp 5TB and 40T instruments but there are a few differences. The output from the 5T Compact is acceleration not velocity so, to view the high gain acceleration, select the 'HIGH VEL' switch and to select the low gain acceleration select the 'LOW VEL'. The 5T Compact also doesn't output the mass position and has no electronic centring so these parts of the HCU should be ignored.

3.5.1 Signal meter

The upper section of the HCU contains a simple voltmeter for monitoring the 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, switch the dial to *V, N/S* or *E/W HIGH VEL.*
- The *V, N/S* or *E/W MASS POS* settings are not applicable to 5T instruments.
- 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.

3.5.2 Calibration

You can calibrate a 5T Compact 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 4, page 15, for full details.

When you have finished calibrating, switch the *ON/OFF* switch back to the *OFF* position.

3.5.3 Open-loop response

The next section of the HCU contains a dial marked *CENTRING SELECT* and two switches. The *CENTRING SELECT* dial and the switch next to it have no effect on 5T Compact instruments: the *1 SEC VEL / BB VEL* switch is used to enable open-loop response mode.

To place the instrument in this mode, move the switch to *1 SEC VEL*. The feedback loop will be broken, allowing the masses to move freely. To return to normal operation, move the switch back to *BB VEL*.

3.5.4 Banana sockets

Beneath the *CENTRING SELECT* dial (which is not applicable to 5T Compact instruments) are connections for each of the signal lines from the instrument, for attaching to your own equipment as necessary.

4 Calibration

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

4.1 Absolute calibration

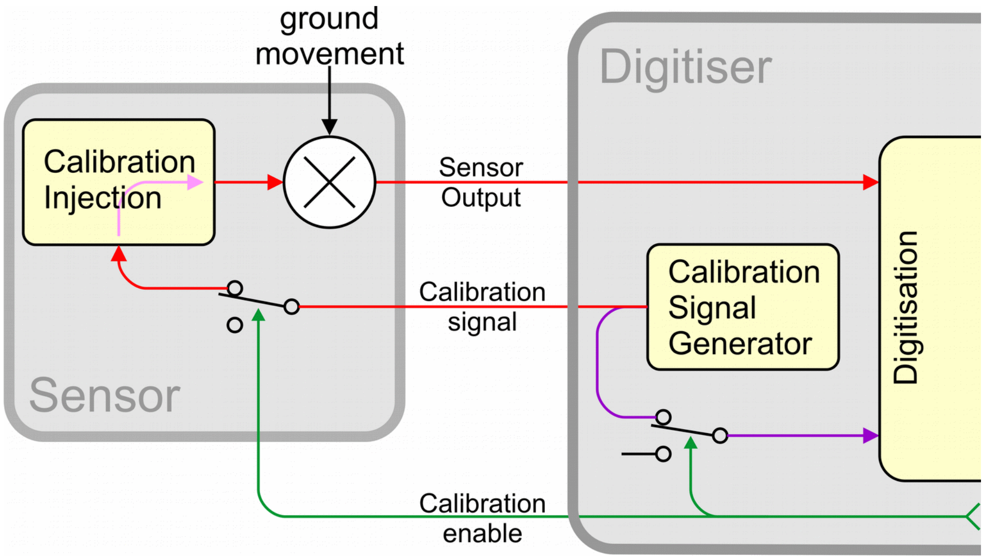
The sensor's response (in V/ms^{-2}) is measured at the production stage by tilting the sensor through 90 ° and measuring the acceleration due to gravity. In addition, sensors are subjected to the "wagon wheel" test, where they are slowly rotated about a vertical axis.

The response of the sensor traces out a sinusoid over time, which is calibrated at the factory to range smoothly from 1 g to –1 g without clipping.

4.2 Relative calibration

The response of the sensor, together with several other variables, is measured at the factory. The values obtained are documented on the sensor's calibration sheet. Using these, you can convert directly from voltage (or counts, as measured in Scream!) to acceleration values and back. You can check any of these values by performing calibration experiments.

Güralp sensors and digitizers are calibrated in the following way:



In this diagram, a Güralp digitizer is being used to inject a calibration signal into the sensor. This can be either a sine wave, a step function or broad-band noise, depending on your requirements. As well as going to the sensor, the calibration signal is returned to the digitizer on a full rate channel (older digitizers used one of the 4 Hz auxiliary (Mux) channels). The calibration signals and sensor output all travel down the same cable from the sensor to an analogue input port on the digitizer.

The signal injected into the sensor gives rise to an equivalent acceleration (EA on the above diagram) which is added to the measured acceleration to provide the sensor output. Because the injection circuitry can be a source of noise, a Calibration enable line from the digitizer is provided which disconnects the calibration circuit when it is not required. Depending on the factory settings, the Calibration enable line must be either allowed to float high (+5 to +10 V) or held low (0V, signal ground) during calibration: this is specified on the sensor's calibration sheet.

The equivalent acceleration corresponding to 1 V of signal at the calibration input is measured at the factory and can be found on the sensor calibration sheet. The calibration sheet for the digitizer documents the number of counts corresponding to 1 V of signal at each input port.

The sensor transmits the signal differentially, over two separate lines. This improves the signal-to-noise ratio by increasing common mode rejection. If you are not using a Güralp Systems digitizer, the voltage across the output pins should be halved before converting to acceleration.

5T Compact instruments are tuned at the factory to produce 1 V of output for 1 V input on the calibration channel. For example, a sensor with an acceleration response of 0.25 V/ms^{-2} should produce 1 V output given a 1 V calibration signal, corresponding to 1/0.25 = 4 ms^{-2} = 0.408 g of equivalent acceleration.

4.3 Calibrating accelerometers

Both the DM24 digitizer and Scream! software allow direct configuration and control of any attached Güralp instruments. For full information on how to use a DM24 series digitizer, please see its own documentation. If you are using a third-party digitizer, you can still calibrate the instrument as long as you activate the *Calibration enable* line correctly and supply the correct voltages.

1. In Scream!'s main window, right-click on the digitizer's icon and select **Control...**. Select the *Calibration* tab.
2. Under *Component*, select *ALL.* The 5T has a single *Calibration Line* for all three components. Other choices will not have a useful effect.
3. Make any other choices you require and click **Inject now**. A new data stream, ending `Cn` (*n* = 0 – 7) or `MB`, should appear in Scream!'s main window containing the returned calibration signal.
4. Open a Waveview window on the calibration signal and the returned streams by selecting them and double-clicking. The streams should

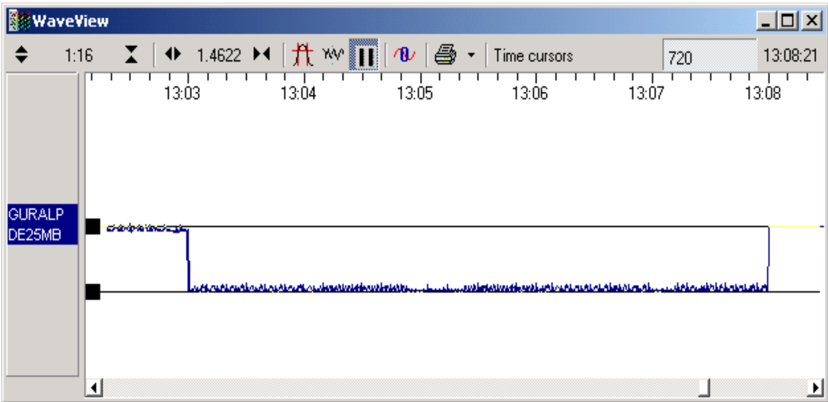
display the calibration signal combined with the sensors' own measurements. If you cannot see the calibration signal, zoom into the Waveview using the scaling icons at the top left of the window or the cursor keys.

5. If you need to scale some of the traces individually, right-click on each desired trace and select **Scale...**. You can then type in a suitable scale factor for that trace.

6. Click on **Ampl Cursors** in the top right hand corner of the window. A white square will appear inside the Waveview at the top left. This is in fact two superimposed cursors.

7. Drag one cursor down to be level with the lowest point of the signal trace.

8. Drag the other down to be level with the highest point. In the following example, a step function of 1 minute duration has been applied to the `Z3` stream. Note that ground movements continue to be observed, superimposed on the returned calibration signal.



The **Ampl Cursors** button will now be displaying a value, which is the strength of the returned signal in counts (doubled, if using a sine wave). Measure the other two signal strengths in the same manner.

Note that if you have used the **Scale...** option described above, you will need to take the scale factor into account to produce the correct number of counts. For example, if the `C2` (calibration input) signal has been scaled by a factor of 40, the signal strength as measured by the **Ampl Cursors** must be *divided* by 40 to yield the correct value.

9. Convert to volts using the *μV/Bit* values given on the digitizer's calibration sheet for the relevant input ports and compare the returned signal with the input calibration signal (`C2`).

10. Suppose we measure the following values:

Input calibration signal strength (`C2`)	697,221 counts
Returning signal strength (`Z3`)	701,512 counts

The calibration sheets provide us with the remaining values needed to calibrate the sensor. For example, we might have:

Sensor acceleration response	0.254 V/ms^{-2}
Equivalent accel. from 1V calibration	1.968 ms^{-2}
Digitizer input port sensitivity	3.507212 µV/Bit
Calibration channel sensitivity	3.491621 µV/Bit

From these, we calculate that the calibration signal is producing 697,221 × 3.491621 = 2,434,431 µV (2.434 V). This corresponds to an equivalent input acceleration of 2.434 × 1.968 = 4.791 ms^{-2}.

The sensor's acceleration response is given as 0.254 V/ms$^{-2,}$ so that an acceleration of 4.791 ms^{-2} will produce an output of 0.254 × 4.791 = 1.217 V (1,216,904 µV), which corresponds to a count number at the digitizer's input port of
1,216,904 / 3. 507212 = 346,972 counts.

Because this calibration is being carried out with a differential-output sensor, the count number observed at the digitizer should be double this: 693,944 counts. All Güralp Systems sensors use balanced differential outputs.

The actual signal at the digitizer of 701,512 counts is within 1.5% of this value, indicating that the sensor is adequately calibrated.

11. If you know the local value of *g*, you can also perform absolute calibration by tilting the sensor by 90° and varying the calibration signal until it precisely compensates for the signal generated due to gravity.

12. Calibrate any other sensors connected to the digitizer in the same way. You must wait for the previous calibration to finish before doing this: clicking **Inject now** has no effect whilst the *Calibration enable* relay is open.

If you prefer, you can inject your own signals into the system at any point (together with a Calibration enable signal, if required) to provide independent measurements and to check that the voltages around the calibration loop are consistent. For reference, a DM24-series digitizer will generate a calibration signal of around 16,000 counts (4V) when set to 100% (sine-wave or step) and around 10,000 counts (2.5 V) when set to 50%.

4.3.1 Open-loop calibration

The 5T Compact exposes a logic level control line on the signal connector which switches the instrument into open-loop mode whilst it is activated. In this mode, force feedback to the masses is disabled, leaving each one free to oscillate at the fundamental resonance frequency of its spring. Voltages representing the acceleration of the masses can be measured on the normal channels.

On the Hand-held Control Unit, the logic line is connected to the 1 SEC VEL/BB VEL switch. Move this switch to "1 SEC VEL" to enable open-loop mode. You can carry out calibration experiments whilst in this mode. Move the switch back to "BB VEL" to restore normal operation.

Opening the feedback loop merely enables the masses to move freely. If the masses are already near their equilibrium positions, switching to open-loop mode will not have a large effect.

4.4 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.

4.4.1 The calibration sheet

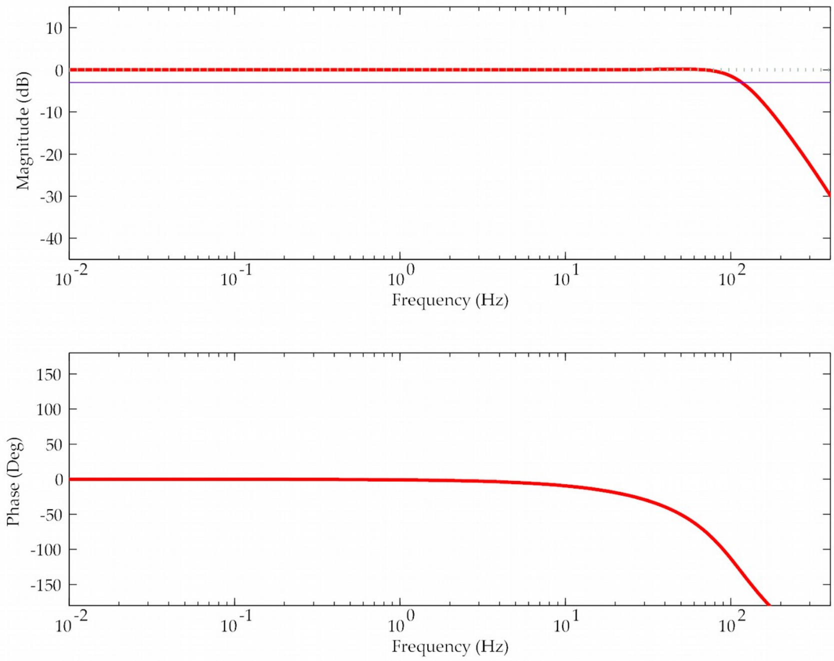
The calibration sheet provides the measured acceleration output over the flat portion of the sensor frequency response in units of volts per metre per second squared (V/ms-2). Because the sensor produces outputs in differential form (also known as push-pull or balanced output), the signal received from the instrument by a recording system with a differential input will be twice the true value. For example, the calibration sheet may give the acceleration response as "2 x 0.50 V/ms-2", indicating that this factor of 2 was not included in the value given.

Caution: Never ground any of the differential outputs. If you are connecting to a single-input recording system, you should use the signal ground line as the return line and ignore the inverting output.

4.4.2 Frequency response

The poles and zeroes table describes the frequency response of the sensor. If required, you can use the poles and zeroes to derive the true ground motion mathematically from the signal received at the sensor. The 5T Compact is designed to provide a flat response (to within 3dB) over its passband.

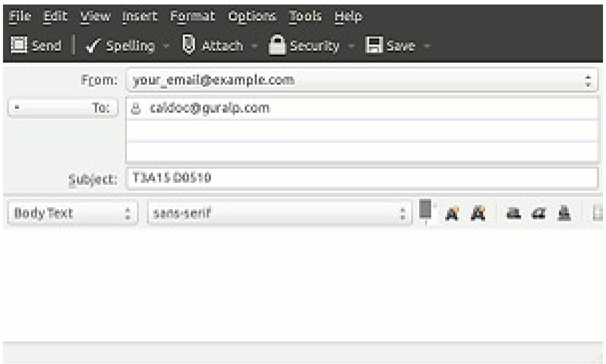
Güralp Systems performs frequency response tests on every sensor at the time of manufacture. All records are archived for future reference. The results of these tests are provided with the sensor.



When testing the instrument to confirm that it meets its design specification, the range of frequencies used are concentrated over about 3 decades (*i.e.* 1000 : 1) of excitation frequencies. Consequently, the frequency plots of each component are provided in normalised form. Each plot marks the frequency cut-off value (often quoted as "-3 dB" or "half-power" point).

4.4.3 Obtaining copies of the calibration pack

We keep a copy 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 email service. Simply email caldoc@guralp.com with the serial number of the instrument in the subject line. For example,



The server will reply with the calibration documentation in Word format. The body of your email will be ignored. If you need multiple documents, enter all the serial numbers in the subject line, separated with spaces and/or commas.

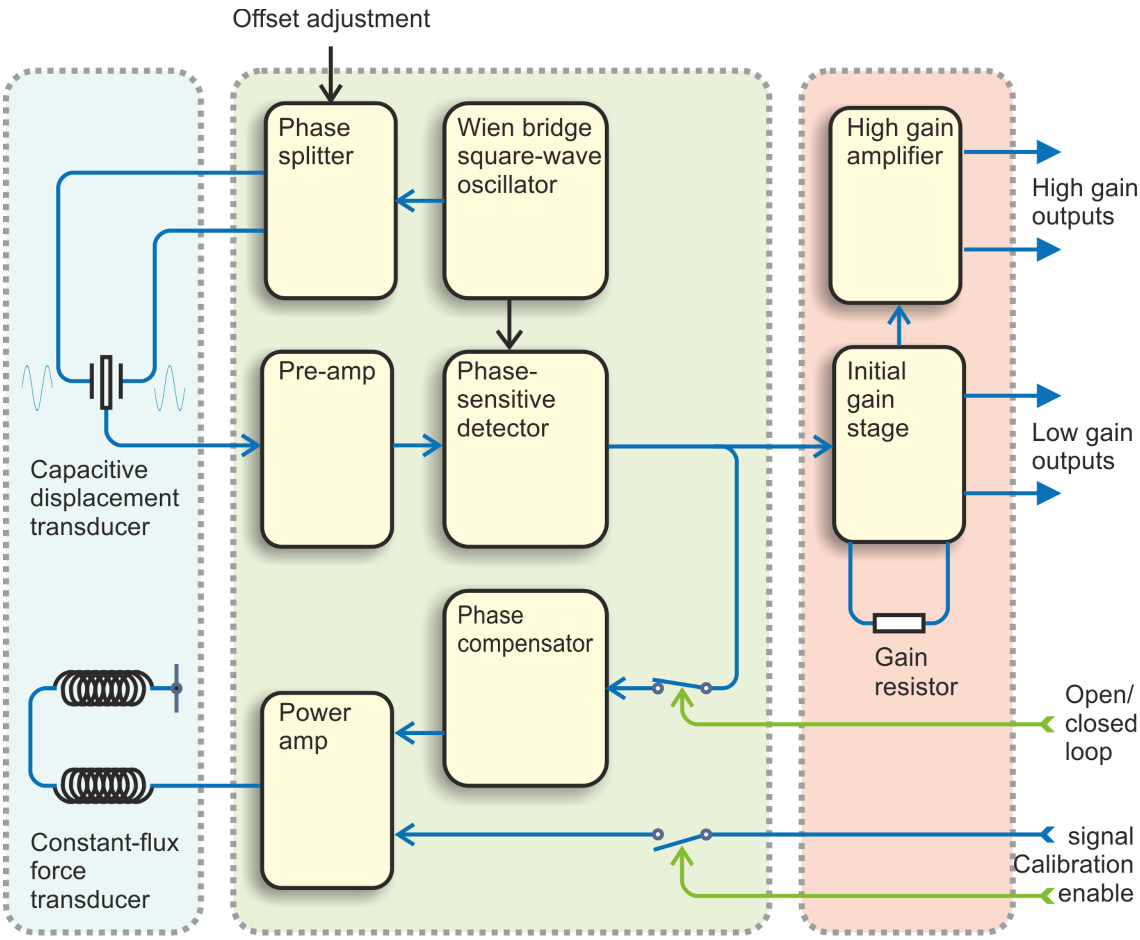
5 Inside the 5T Compact

The 5T Compact unit is constructed of hard-anodised aluminium with "O" rings throughout, ensuring a completely waterproof housing.

Inside, the masses of the vertical and horizontal components are attached to the rigid frame with parallel leaf springs. The geometry of the spring spacing, together with the symmetrical design, ensures large cross-axis rejection. The sensor mass is centred between two capacitor plates and moves in a true straight line, with no swinging motion. Feedback coils are attached to either side of the sensor mass, forming a constant-flux, force-feedback transducer.

The vertical and horizontal sensors are identical in mechanical construction; the vertical sensor's mass spring system is adjusted to compensate for gravity. They are mounted directly onto the base above the feedback control board.

The signal and feedback circuits inside the 5T Compact accelerometer are arranged according to the following diagram:



The mass and the capacitor plates are energised by a two-phase transformer driver, forming a differential capacitor. This acts as a capacitive transducer, whose signal is then demodulated with a phase-sensitive detector. The accelerometer feedback loop is completed with a phase compensator and a feedback force transducer power amp. A switchable input line allows the feedback loop to be broken, providing open-loop response when required.

The differential output amplifier scales the output sensor sensitivity and a second stage amplifier provides a further cascaded gain stage.

5.1 The force transducer

The 5T Compact is a force-feedback strong-motion accelerometer which uses a coil and magnet system to generate the restoring feedback force. Such accelerometers inherently depend on the production of a constant-strength field in the magnet gap. Although the high quality magnets used in the 5T Compact accelerometer are exceedingly stable under normal conditions, if the sensor is sited in an area where the background seismic noise is much higher than that of a vault constructed in a seismically stable location, the flux density may be affected by the external magnetic field generated by the feedback transducer coil.

In order to minimise non-linearities in the feedback force transducer, the 5T Compact uses a symmetrical system of two magnets and two force coils. Any increase in flux in one coil is cancelled by a corresponding decrease in flux in the other, thus eliminating any non-linearity due to lack of symmetry.

5.1.1 The sensor transfer function

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

$$(V/x)(s) = G \times A \times H(s)$$

In this equation

- G is the acceleration output sensitivity (gain constant) of the instrument. This relates the actual output to the measured 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 fm = 1 Hz, with s = j fm, where j = √−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 zeroes 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 zeroes table. The poles and zeroes given are measured directly at Güralp Systems' factory using a spectrum analyser. Transfer functions for the vertical and horizontal sensors may be provided separately.

5.2 Electrical connections

Each channel inside the 5T Compact sensor has four output lines: a pair of differential outputs with low gain and another pair with high (nominally 10 ×) gain.

The two pairs of output lines are balanced about signal ground so that either differential drive or single-ended drives of opposite polarity (phase) are available. For a single-ended drive, the signal ground must be used as the signal return path. You must not ground any of the active output lines, as this would allow damaging currents to flow through the output circuits. Also, if single-ended outputs are used, the positive acceleration outputs must be the ones interfaced to the recorder.

For distances up to 10 metres, you can connect the sensor outputs using balanced screened twin lines terminated with a high-impedance differential input amplifier. The sensor outputs have a nominal impedance of 47 Ω.

The 5T Compact is normally powered directly from a connected Güralp digitizer through its signal connector, although you can use a separate 10 – 36 V DC power supply if you wish. An isolated DC–DC converter installed inside the sensor housing forms the main part of the 5T's power supply; its filtered outputs provide the ±12 V required to operate the sensor electronics. The DC–DC converter is protected against polarity reversal. Optionally, this DC–DC converter can be omitted, in which case you will need to provide a ±12 V three-way power supply yourself.

The calibration signal and calibration enable inputs are referenced to the signal ground. If you are using a Güralp digitizer, these lines can be connected directly to its calibration lines. For “active high” instruments, you will need to provide a 5 V logic level, referenced to the signal ground. For “active low” instruments, you can connect these lines to the signal ground to activate the associated function. See Chapter 4 on page 15, for more details.

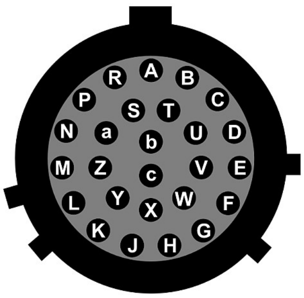
6 Connector pin-out

The connector 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.

The connector is compatible with Güralp Systems' velocity sensors, so you can use the same cables for any type of sensor. It is also compatible with breakout boxes and HCUs for 40T and 5TB instruments.

Pin	Function	Pin	Function
A	Acceleration +ve, Z channel	**P**	Calibration signal (all channels)
B	Acceleration -ve, Z channel	**R**	Calibration enable (all channels)
C	Acceleration +ve, N/S channel	**S**	High Gain -ve, vertical channel
D	Acceleration -ve, N/S channel	**T**	High Gain +ve, vertical channel
E	Acceleration +ve, E/W channel	**U**	Offset control
F	Acceleration -ve, E/W channel	V	*not connected*
G	*not connected*	W	*not connected*
H	High Gain -ve, E/W channel	X	*not connected*
J	*not connected*	**Y**	Digital Ground
K	High Gain +ve, E/W channel	**Z**	High Gain -ve, N/S channel
L	*not connected*	**a**	High Gain +ve, N/S channel
M	-12 V DC supply (three-way power option)	**b**	Power ground
N	Signal ground	**c**	+ 12 V DC supply



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

7 Specifications

Outputs and response	Low gain output options	4 *g*, 2 *g*, 1 *g*, 0.5 *g*, 0.1 *g*
	Corresponding high gain outputs	0.4*g* , 0.2 *g*, 0.1 *g*, 0.05 *g*, 0.01 *g*
	Clip level at 4 *g*	4.2 *g*
	Peak output	±10 V differential
	Nominal output impedance	47 Ω
	Dynamic range, 0.005 – 0.05 Hz	> 145 dB
	Dynamic range, 3 – 30 Hz	> 127 dB
	Standard frequency band	DC > 100 Hz (–3 dB point)
	Optional low-pass corner	50, 100 or 200 Hz
	Linearity	0.1 % of full scale
	Cross-axis rejection	0.001 *g* / *g*
Calibration controls	Open-loop response	Connector pin
	External inputs	Sine-wave, step, or pseudo-random
Physical	Lowest spurious resonance	> 450 Hz
	Operating temperature range	–20 to +70 °C
	Pressure jacket material	Hard anodised aluminium
	Power / signal connector	Mil-spec connector on sensor housing (KPT02A16-26P)
	Weight	1310 g
Power	Current at 12 V DC	51 mA
	Current at 12 V DC (3-way power option)	2 × 12 mA (nominal)

8 Revision history

2016-04-27	H	Removed references to optional high-pass filter
2016-01-22		Face-lift with no significant changes to content
2013-04-29	G	Corrected power consumption
2012-01-11	F	Corrected information about lock-nuts for feet and -12V input. Reformatted revision history.
2011-02-15	E	Revised Offset removal section, updated connector pin out section.
2009-11-24	D	Updated block diagram, connector pin-out and calibration sections.
2007-11-20	C	Installation in Hazardous environments section added.
2007-11-15	B	Corrections for production instrument.
2006-03-15	A	New document.