STRECKEISEN
SEISMIC INSTRUMENTATION

VELOCITY-BROADBAND SEISMOMETER

STS-2.5

INSTRUCTION MANUAL

Revision 1.1 – Dec 10, 2013

1.1. Revision history

Revision	date	changes
1.0	June 24, 2013	creation
1.1	Dec 10, 2013	Section 8.8, UVW←→XYZ formula corrected

1.2. Important notices – please read, before working with the equipment

- Do not connect the host box type 3-320.02 or the cable type 3-384.xx that comes with this sensor package to an STS-2.
- Do not connect an STS-2 cable or its host box to an STS-2.5 sensor. There will be no damage to the equipment but it will not work.
- Applying voltages beyond the specified limits can permanently damage the equipment.
- This manual has been revised carefully and is believed to be reliable. However we assume no responsibility for errors or omissions in this manual or other publications which are referenced or linked to it. All rights reserved. Any changes to this manual are made without notice.

1.3. Differences between STS-2.5 and STS-2

Item	STS-2.5	STS-2
Sensitivity to atmospheric pressure	reduced by a factor of 10	
case color	grey	green
Case shape	same for both	
host box	type 3-320.xx	green,
cable type	Orange PUR ø8mm, 3-384.xx with grey plastic connector at host box side. Not compatible to STS-2 type	Orange PUR ø10mm with green metal connector at host box side. Not compatible to STS-2.5 type
host box	type 3-xxx Not compatible to STS-2 type	green metal case, 3 connectors Not compatible to STS-2.5 type
locking mechanism	electrically activated by host box command.	manually with screw driver at sensor base ring.
moving in unlocked state	"casual" moving (e.g. building to building) is possible. Lock for transport.	Do not move an unlocked STS-2
user interface (host box)	Lock/unlock and center button, various LEDs	center button
centering mode	fully automatic	semi-automatic
management	remotely readout of sensor humidity, temperature, supply voltages, serial number, user def. string	nothing

Contents

loose attachments: Calibration sheet
Field fact sheet (all important information on one water proof sheet)

2. Introduction

The STS-2.5 is a high performance VBB seismometer designed for quick and simple installation, wide temperature range operation, and secure transport, while resolving minimum earth noise levels over most of the seismometer's pass band.

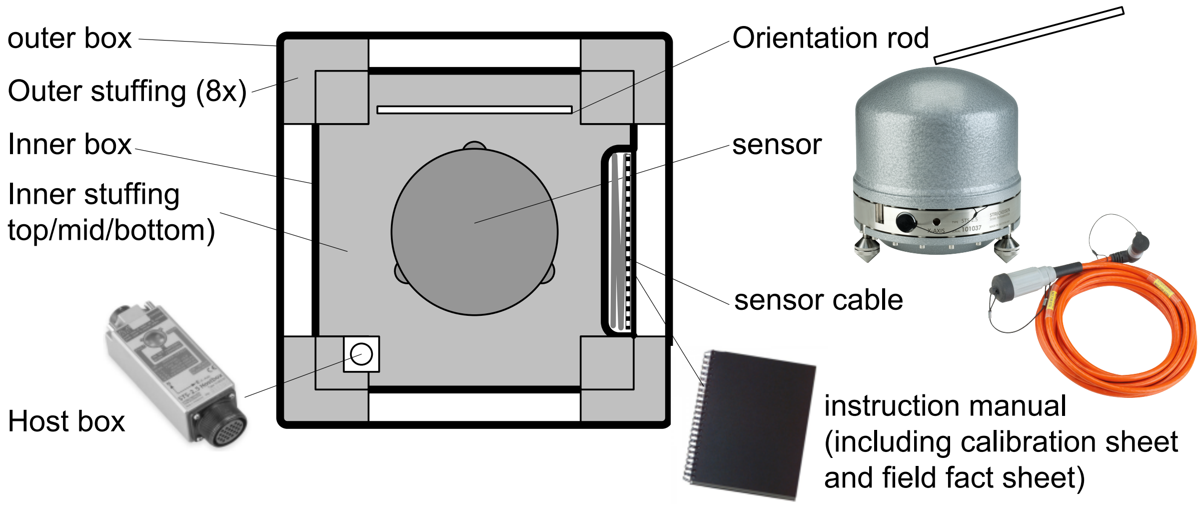
Like the predecessors STS-1 and STS-2, the STS-2.5 is an electronic force-feedback sensor that provides an output signal proportional to ground velocity over a broad range. Similarly, the STS-2.5 also employs the astatic leaf-spring suspension (Wielandt and Streckeisen, BSSA, 1982).

The STS-2.5 uses 3 identical obliquely-oriented mechanical sensor components ("cube-corner" geometry of the sensitivity axes). The tri-axial design guarantees that horizontal and vertical components are matched as closely as possible. Standard vertical and horizontal outputs are derived electrically rather than mechanically.

This manual is organized in a manner that describes install and operate procedures prior to the technical background.

3. Unpacking the sensor and contents of the package

Originally the sensor is shipped in a carton box containing an inner box with the sensor and its accessories:



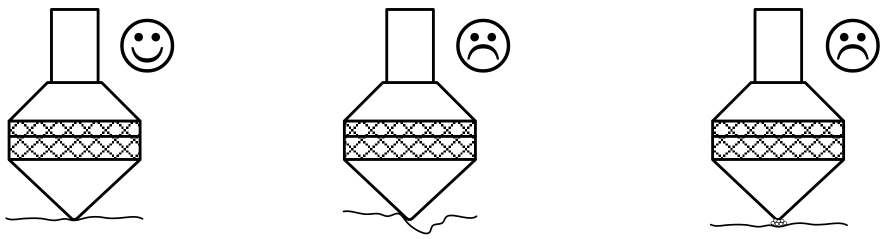
Use this or an equivalent package and stuffing for further transportation or return for repair.

4. Installation

Prior to installation, prepare sensor and location as described in this section. The sensor performance and reliability depend very much on both.

4.1. Sensor installation considerations

Provide a dust- and sand-free surface on a stable and inert substructure either made of slow hardening concrete or bedrock.



good: flat clean surface — bad: uneven surface — bad: dust or dirt under foot tip

Avoid areas where corrosive inclusions such as iron are near or directly under the feet tips. Corrosive processes are most prominent on the horizontal components. Cementing small glass plates (50x50x5mm) with slow hardening cement (free of sand) as foot rest have been proven very effective Avoid trapped air bubbles during cementing process.

Avoid wet location. Although the equipment is watertight regular and/or longer immersion in probably aggressive water will cause corrosion over the years. If possible attach the host box to a wall or put it on an elevated place.

Sensor insulation against temperature variations and air convection

Thermal processes will degrade the seismometer data quality by four different mechanisms:

1. The platform, where the seismometer is placed, may tilt as a function of ambient temperature.
2. Air convection – driven by air temperature differences – applies stress onto the seismometer surface.
3. Heat conduction advances heat into the seismometer and prompts heat-sensitive mechanical and electronic elements to change their system-relevant parameters.
4. Air pressure variations cause adiabatic temperature changes on the seismometer surface or, if present, on the surface of an additional pressure jacket, resulting in the same consequences as stated for process 3.

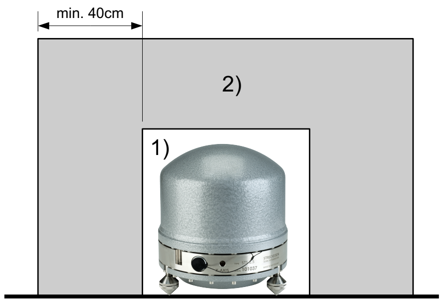
Processes 1 and 2 initiate spurious horizontal signals; spurious horizontal as well as vertical signals are produced by the two other processes. While process 1 may origin from a vast number of different sources, distortions coming from the remaining processes are to be treated by shielding the seismometer thermally, in order to defer heat penetration into its case.

Insulation against heat entering via thermal conduction and air convection

Thermal conduction can be slowed down by placing the seismometer amidst an insulating coat. Air is a very good insulator. A disadvantage is its ability to convect. Even the convection that establishes due to its own power dissipation may suffice for the STS-2.5 to produce a horizontal noise that is five times higher than the quiet-conditions vertical one. Experience has shown that the convection-driven horizontal noise increases with the freely circulating air volume under the shielding.

The best insulating material known consists of foam plastic composed of tiny, thin-walled cells filled with air. The main task of the cell walls is to prevent the air from circulating. The insulating coat shall fit the seismometer case as close as possible, but it shall not be allowed to apply a time-varying tilt force. So, any insulator material contacting the seismometer case has to be chemically inert and physically settled. A newly deployed seismometer may produce spurious horizontal signals for many days or even weeks due to settling of the insulator material that contacts the case.

The joints between insulator and case, between insulator and ambient, as well as any material joints that connect two rough surfaces act by themselves as effective heat barriers. It may be advantageous, therefore, to intercalate two or more insulating coats separated by stable walls. This configuration has been realized successfully using a tube-in-tube concept: (1) an inner enclosure containing the sensor and filled with Styrofoam globules. (2) An outer enclosure consisting of a thick layer of sand.



Insulation against adiabatic temperature changes

Pressure changes cause a thermal response in form of adiabatic temperature changes. These pressure fluctuations advance through all interstices and pores of the thermal shielding material until they are eventually stopped by either the seismometer case or an air-tightened external shielding construction. The thermal response of the solid matter the pressure signal percolates through is negligible compared to the one of the air. Therefore, the higher the volume fraction of air in the insulating coat, the higher is the thermal response. This means that there exists a trade-off with respect to the effectivity of the insulator material: High air volume fraction is required for tackling heat conduction, while a high solid matter fraction acts against the thermal influence of pressure variations. The only remedy resolving this trade-off is to enclose the seismometer together with the insulating coat into a pressure jacket.

At usual weather conditions adiabatic temperature changes will get visible on the STS-2.5 Z signal only at periods exceeding about 180s.

Deployment structure: Shelter, vault, or a simple hole?

The STS-2.5 is far less susceptible to pressure variation than the STS-2. A pressure-tight chamber is therefore only needed at very quiet sites for acquiring very long period signals (> ca. 180s).

Any structure, where the sensor is running, shall combine high temperature stability with non-corrosive atmosphere (non-condensing, no humidity-activated aggressive solutions). Additionally, it shall not protrude from the ground so as to be tilted by the wind. For the same reason avoid trees and high shrubs above the ceiling or in the immediate area of the structure (i.e fund with obsolete military structures)

The STS-2.5 sensor can be deployed in a hole, provided that the feet screws are accessible in order to level the seismometer. In a hole, apart from the elevated temperature stability, a small-area superficial tilt signal stemming from human activity or atmospheric processes is damped down as a quadratic function of burial depth. Yet, it is crucial not to introduce mechanical coupling along the hole via a wall material of high stiffness like concrete or steel. Water drainage may be another challenge to face: Water seeping through the rock material enclosing the hole and variations of the water saturation fraction therein may cause all sorts of noise.

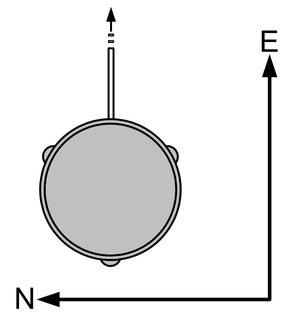
4.2. Prepare the sensor

Before installing the sensor have cable, host box and orientation rod ready. The orientation rod is to be inserted into the respective hole in the base ring besides the main connector. Try it before installing. It will fit tightly and needs maybe cleaning in case the hole is filled with dirt. Remove the rod after testing.

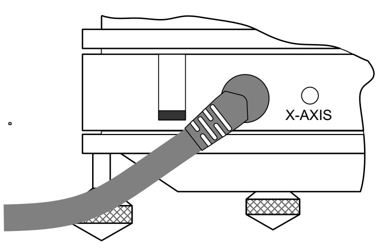
Loosen all three feet by opening their counter nuts by turning them counter clockwise a quarter (the maximum possible is half a turn). Screw all feet to near their short end. The shorter the feet are after installation the better it is with respect to the horizontal nodes of resonance and, in general, coupling to the ground.

4.3. Setting up the sensor

Place the sensor gently on its predefined (and cleaned) place.
Insert the orientation rod and orientate the sensor. Do not apply excessive force to the inserted rod. The rod points towards east.
Remove the rod.

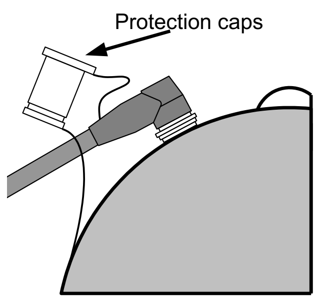


Remove the protection caps from both the cable and sensor connector. Apply the connector to its mate on the sensor with the shown angle. It will fit on this angle only. Plug in the connector with gentle but firm pressure. An audible click indicates a complete connection.



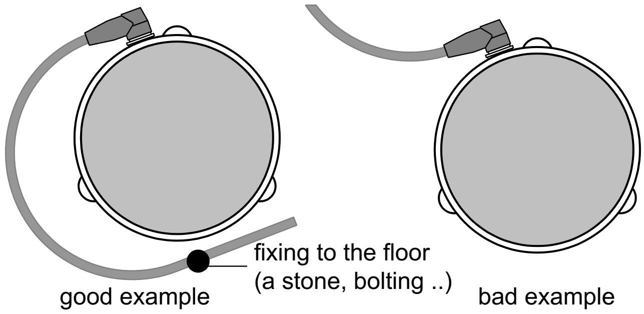
!

- Do not turn a connector when mated.
- A connector that is not fully inserted will not be watertight.

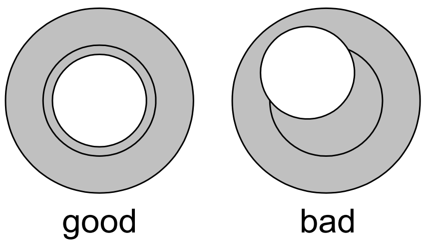


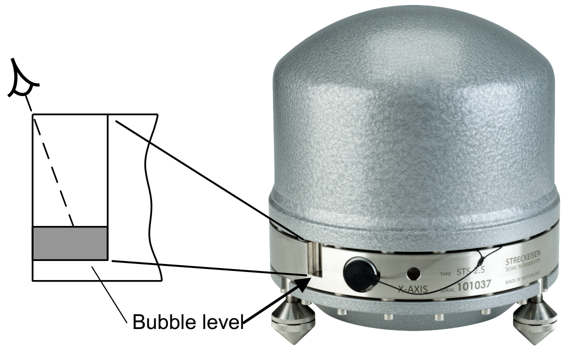
Mate both protection caps (cable and sensor) together.
This prevents them from collecting dirt.

Pay attention to the cable layout around the sensor.
An inadequately lying cable can pick up mechanical motion and guide it into the sensor case.
As a rule of thumb the cable position should remain in its position when the sensor is removed.



Now level the sensor by turning the feet while watching the bubble level. Since the bubble is inside the base ring the view is angled. This fact has been considered in the construction.
The bubble has to be in the center of the inner ring when viewed just below the rim of the cover.





! Finally tighten all three feet by turning their counter nuts clockwise until they lock firmly.
Check it. A loose foot will strongly compromise the signal quality.

5. Operation - Getting started

The operation steps are simple, and mostly the same as for an STS-2, except that locking and unlocking is done electrically, not with a screwdriver. This section describes a straight forward process to get the system work. If any unusual and not described behavior occurs look up section 5.1 *Host box Users Interface*.

The host box has two buttons, one for centering, and one for lock/unlock, because the 2.5 has remote locking instead of manual locking. Locking is not necessary for "casual" transport, such as picking the sensor up and moving it around, or carrying from building to building.
Locking at this time is recommended for shipping and transporting to the installation site.

This section implies a completely assembled and wired system. The sensor is connected to the host box and the host box to the digitizer with appropriate cables.
Press a button for ~1 second or more when demanded in the description below.

Step 1: connecting the host box (HB) to power

After the HB has been connected to power, or following a time after any externally-initiated activity, the HB is asleep. When it is asleep, the LED's entirely are extinguished.

Step 2: waking up the HB

Pressing either button on the HB will wake up the HB and display status.
The sensor was shipping in the locked state; therefore the HB will display the locked status (continuous RED) when being installed for the first time after shipping.

Step 3: unlock the sensor
Press the LOCK/UNLOCK button and the sensor will be unlocked. This takes about 1s. The status LED (RED) will go off and some or all of the three LED's indicating the sensor components states (BLUE) go on.

Step 4: centering the sensor
Press the CENTER button. An autocenter will initiate. If successful, the status LED should be on (GREEN) and it's ready to go. Unlike an STS-2, which may require several autocenter initiations, the STS-2.5 will typically accomplish centering after one initiation.
Be patient, the centering process can take up to several minutes!

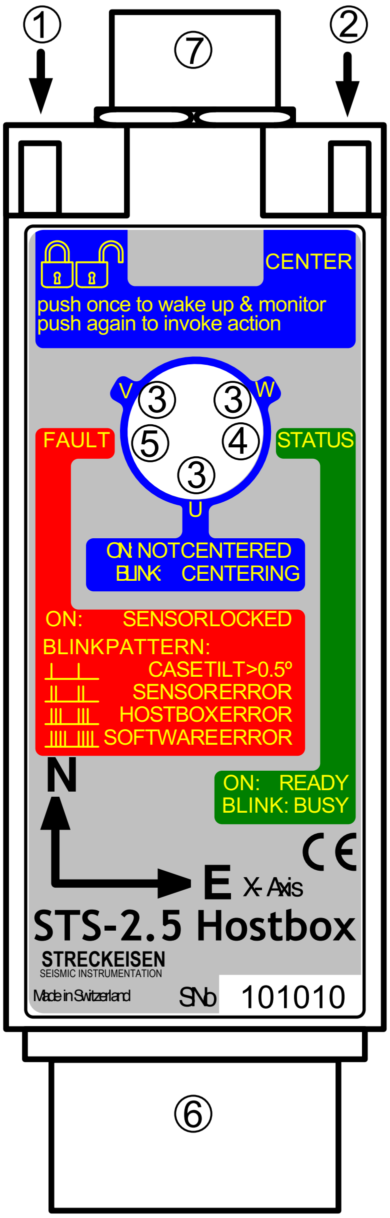
Step 5: It's operating
After ~60s the HB goes asleep again, all LED's extinguish.

Step 6: prepare for shipping
To prepare for shipping, wake up the HB (if asleep), then press the lock/unlock button until the RED status LED is steadily on. Power down and pack. Do not forget to cover the sensor connector with its protection cap.

Remote control from a Q330 is performed the same way as for an STS-2, except that a wake-up command by activating either control input (Pin E, K, L) must precede the operational command whenever the HB is asleep (typically after a period of inactivity). Please wait for about 10s after the wake-up command and then activate the desired control input (centering, calibration etc..) in order to initiate the desired action. If the HB is already awake, it's not necessary to send two commands.

5.1. Host box Users Interface

The system is running regularly when all lights are dark. Pressing any button once only wakes up the system and displays its state. For any desired action a button has to be pressed a second time after some seconds. After ~60s idle time the system goes back to sleep mode.



① **LOCK/UNLOCK button**
Pressing the button while the sensor is locked will unlock it and vice versa. If the HB is asleep, the first press wakes up HB and sensor and displays the system's current state. The second press invokes the desired action.

② **CENTER button**
Pressing the button invokes the centering process. If the HB is asleep, the first press will wake it up and display the system's current state. With a second press the desired action is carried out.

③ **UVW LEDs** (blue)
A steady light indicates the corresponding sensor component being beyond its boom position centering-limits of ±1.5V.
A blinking light indicates that the sensor component is actually being centered.

④ **STATUS LED** (green)

A steady light	indicates a properly running sensor.
A steady blinking	indicates a process is running on sensor or HB (centering, firmware download..).

⑤ **FAULT LED** (red)
Various blink patterns indicate different error conditions:

A steady light	indicates a locked system ⇨ unlock it with the LOCK/UNLOCK button
One short blink	indicates a sensor with a tilt exceeding 0.5º making automatic centering impossible ⇨ level the sensor manually with the help of the bubble level.
Two short blinks	indicate one of various possible sensor errors (Power supply failure, mechanical malfunctions..). ⇨ Most probably this sensor is to be returned to the lab for inspection. This error is also raised with no sensor connected.
Three short blinks	indicate a HB hardware error.
Four short blinks	indicate a software error either of the HB or of the sensor due to version conflicts between HB and sensor. Different software versions are normally corrected automatically and cause no error condition.

⑥ **Connector digitizer side**
24pol neg. Mating connector: CA3106PG24-28P-A176
mating cable: KMI 110959

⑦ **Connector sensor side**
Mating cable: the provided sensor cable type 3-348.xx

5.2. Hostbox electrical interface (connection to the digitizer)

This section describes the signals in the 24pol connector that connects the hostbox to the digitizer. Pin designators displayed as K indicate the same pin and signal as STS-2. See next table for pins that are different.

Signal	Pin	Description
Analog outputs		
+X	D	differential seismic output, X-axis
-X	J	max. level ±20V, impedance 200Ω per line
+Y	C	differential seismic output, Y-axis
-Y	H	max. level ±20V, impedance 200Ω per line
+Z	B	differential seismic output, Z-axis
-Z	G	max. level ±20V, impedance 200Ω per line
UPOS/URAW	T	single-ended auxiliary outputs, boom position (POS, default) or UVW-component (RAW), selectable with SIGSW
VPOS/VRAW	V	
WPOS/WRAW	U	max. level ±10V, impedance 1kΩ
CAL	N	calibration input, max. level ±10V
GNDS	F	analog reference ground
GDNS	M	analog reference ground
Digital control signals (high = 3..30V, 0,5mA to RET, low = <0.5mA or open or short, low = default)		
SIGSW	L	auxiliary output selector, low=POS (default), high=RAW
AUTZ	E	high for 1second = Centering (Autozero)
CALSW	K	high = connects the CAL input to the appropriate sensor component, selected by CSEL1 and CSEL2
CSEL1	Y	calibration selector CSEL1 = low, CSEL2 = low: UVW (default)
CSEL2	Z	CSEL1 = low, CSEL2 = high: U CSEL1 = high, CSEL2 = low: V CSEL1 = high, CSEL2 = high: W
RET	S	Control signal return ground
RXD	P	serial interface input (PC to host box)
TXD	Q	serial interface output (host box to PC)
XAL	R	Alarm output (reserved for future use)
various signals		
+VIN	W	Power supply input (9..30VDC)
-VIN	X	Power supply and serial interface return
CASE	A	Sensor case and sensor cable shield

5.3. Interface differences of STS-2 and STS-2.5

The table below shows the pins with different functions and what happened when an STS-2.5 is directly replaced with an STS-2 by attaching it to the existing 24-pin digitizer cable.

Pin	STS-2.5	STS-2	Comments
M	GDNS	CCOM	connects the ground CCOM and GNDS, If that causes problems, disconnect the wire from this pin.
P	RXD	WCAL	no problem
Q	TXD	UCAL	This pin outputs a digital signal that can influence the CAL signal when the STS-2 signal UCAL/VCAL/WCAL are connected together. If that is so, disconnect the wire from this pin.
R	XAL	PERSW	no problem
Y	CSEL1	–	no problem
Z	CSEL2	–	no problem

6. Calibration

Absolute calibrations (generator constant and axis purity) are performed after assembly in the lab of Streckeisen GmbH. Their values and tolerance limits are given in section 13 *Specifications*. For STS-2 the parameter stability has proven excellent (long-term drift <±0.3 % in ten years), and the one of STS-2.5 will not be worse, because it uses the same components and materials for the crucial parts. Therefore, absolute calibration has not to be repeated for the whole lifetime, provided that the instrument is handled carefully according to the advices given in this manual.

An on-site calibration – or, more precisely, a calibration check – can be done by using the CAL input. Unlike the STS-2, the STS-2.5 lacks separate calibration coils. Instead, the pendulum deflection force is generated by introducing the calibration current into the feedback coils themselves. A voltage-to-current converter protects them from excess input signals at the CAL pin. Therefore the calibration transducer constant is now expressed in V/g instead of A/g (see section 13, *Specifications*).

6.1. Accuracy Limitations of the on-site calibration

The "calibration" input, contrary to what the name expresses, is not calibrated, i.e. the transducer constant (see section 13, *Specifications*) is not internally adjusted to a specified value. The tolerance limits given in the specifications are those the calibration constants can naturally scatter at the maximum.

! Therefore, the calibration constants cannot be used in order to verify the absolute calibration of the instrument!

Yet, the transducer constants remain stable through time on the same level as the absolute calibrations. So, executing excitation through the calibration coils at regular intervals (e.g. once a week) and comparing the outputs with reference output data collected after deployment can help assess the health status of the seismometer. Provided that the temperature is about the same as at the time of reference data acquisition, any deviation exceeding these approved drift values indicates a severe fault within the feedback loop. Value and tolerance limits for the calibration constant are given in section 13, *Specifications*.

Unfortunately, the feedback transducer system (coil and magnet) lies outside the component checking scope of regular on-site calibration, because it is actor (acceleration generator) and re-actor (acceleration meter) at the same time. Any fault-induced parameter shift is canceled out, therefore.

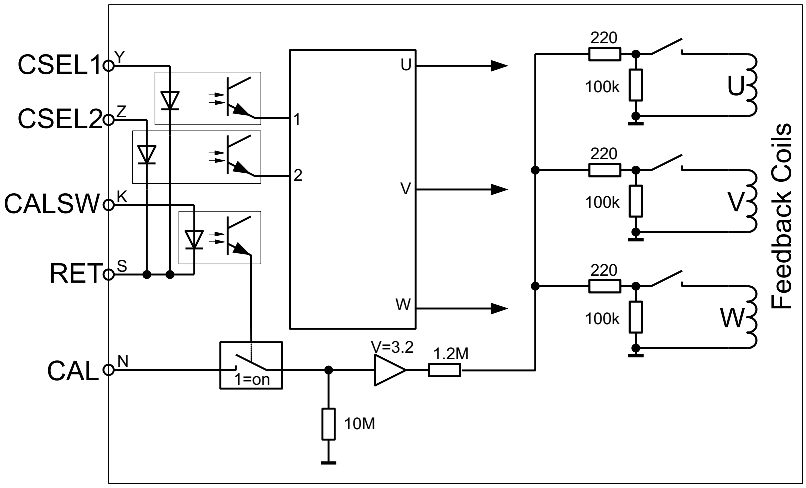
When applying an input source function containing the adequate frequency range, it is possible to evaluate the low-frequency corner period and damping constant with high accuracy.

Period	CAL voltage[1)]	Remarks
34s	3.0V	CSEL1 = CSEL2 = 0 or open (CAL UVW)
120s	1.2V	
360s	2.6V	
1000s	1.8V	

1) Nominal peak Calibration voltage for ½ full scale referring to the RAW or POS signal, whichever is higher.
The peak Z is 87% full scale, while X and Y are virtually zero.

6.2. Electrical calibration interface

The output of the calibration circuit can be connected either to all three components simultaneously or to one selected component using the selector pins (CSEL1, CSEL2) in conjunction with the enable pin CALSW.



CALSW	CSEL1	CSEL2	function
0	X	X	normal operation
1	0	0	CAL UVW
1	0	1	CAL U only
1	1	0	CAL V only
1	1	1	CAL W only

logic 1=3..30VDC, 0=0V or open

1V @ CAL ~ 1µA coil current

6.3. Calibration procedure

Connect a controlled voltage source to the CAL input, set its voltage to 0 V, apply the appropriate code to CSEL1 and CSEL2, and enable CALSW. When setting CALSW, the µCs of the host box and the sensor wake up. First, an offset-driven signal excursion appears on the seismometer outputs. Wait about 2 min. for the outputs to settle. Apply the scheduled calibration signal sequence. To prevent input stage clipping hold the voltage at CAL within ±3.15V. Switch off the CAL voltage and the control signals as soon as the relevant output signal frequencies have been acquired. A similar, but inverse, signal deflection as when switching on appears now. When resetting CALSW, the µCs go asleep after the normal idle time.

7. Output Signal polarity as a function of motion

Provided that the STS-2.5 is properly oriented, the signal output polarities + to - (differential) and POS/RAW/CAL to signal ground (GNDS, single-ended) are as follows.

Seismic signal outputs

Ground motion to east:	X [positive voltage]	Y [0V]	Z [0V]
Ground motion to north:	X [0V]	Y [positive voltage]	Z [0V]
Ground motion upward:	X [0V]	Y [0V]	Z [positive voltage]

Auxiliary outputs

Boom acceleration upward:	positive voltage on UPOS, VPOS, WPOS (SIGSW=0 or open)
Frame motion upward:	negative voltage on URAW, VRAW, WRAW (SIGSW=1)

Calibration input

Positive voltage at CAL:	downward directed force on the boom (U, V, W according to calibration selector CSEL1, CSEL2)

8. Technical Background

This section describes technical details that help the user to a better understanding of the function and behavior of the STS-2.5.

8.1. General description

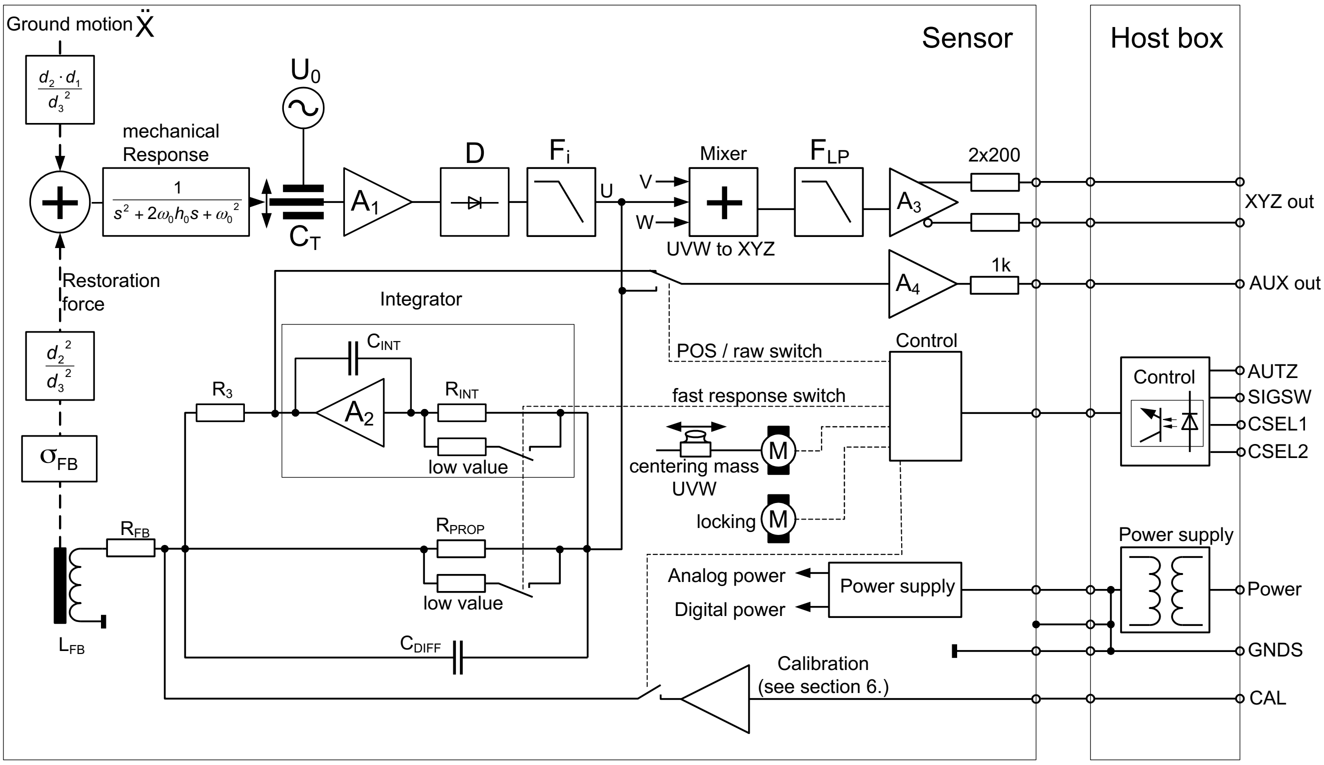
Apart from the control functions, the principle of operation of STS-2.5 is identical to the one of STS-2. Users will find the terms they used when dealing with STS-2 still valid for STS-2.5. Additionally, the feedback elements of STS-2.5 guarantee virtually the same response to ground motion as for the STS-2. Only at frequencies exceeding 10Hz the responses of the two seismometer types progressively differ (see 8.7, Poles and Zeroes).

Within the pass-band the STS-2.5 feedback system delivers a velocity proportional output signal directly from the feedback loop. The low-frequency -3dB corner of the pass-band is set at 120s.

The output stage of the feedback electronics for each component provides a single-ended ±10V output signal which can be observed at three auxiliary outputs for the purpose of failure recognition ("RAW" mode outputs).

The STS-2.5 is air-tight (IP-67 equivalent). The construction is further designed to minimize the distortion of the package by barometric pressure changes by isolating the top and bottom covers from the massive base plate, in a way similar to the isolation of a seismograph pier from its surrounding building. The top and bottom covers are secured to the base plate with compliant O-rings, allowing the covers to compress without stressing the entire package, while avoiding bending forces exerted on the base plate. The sealed construction and massive metal base plate provide thermal insulation and inertia.

8.2. Block diagram



The block diagram shows only the component U. V and W are identical and omitted for simplicity.

Ground motion excites the sensor's frame, whereas, due to its inertia, the pendulum would resist the motion, if not the feedback force acted. The feedback loop starts with the capacitive displacement transducer C_T. It converts the motion signal into an electrical counterpart. Amplifier A_1, demodulator D and the inverse filter F_i eventually shape the raw output signal U which is connected to the feedback components, the POS/raw switch, and the mixer. The feedback components mainly consist of conventional PID control path elements and a force transducer (σ_{FB}), where the feedback loop ends. The control path is switchable to a short-period ("fast response") mode for centering and test purposes.

By analog computing the mixer circuit transforms the oblique signals U, V, W to the conventional X(East), Y(North), and Z(Vertical) signals and adjusts the gains. Amplifier A_3 buffers the output and forms differential signals. One mixer and one amplifier exist for every signal X, Y, and Z.

U, also called U_{RAW}, can be observed at AUX out, if the POS/raw switch is positioned accordingly. The other position of the switch lets the integrator signal U_{POS} be connected to AUX out. The name "POS" stands for "pendulum position". It does not express a real pendulum deflection; rather it is a reminiscence of the true static pendulum deflection the former electro-dynamic broadband seismometers had. Any static pendulum deflection is immediately adjusted to zero (zero voltage on average at output U_{RAW}) by the integrator feedback. Apart from a constant factor and non-ideal responses of the electronic components, every POS signal is the exact integral of the corresponding RAW signal (i.e. U_{POS} is the integral of U_{RAW} etc.).

U_{POS} always has a static signal portion proportional to the static pendulum imbalance. This imbalance is of pure mechanical origin and depends on the sensor placement tilt angle, gravitational acceleration at the deployment site, and the sensor temperature. It is compensated for by moving the centering mass in the course of a centering cycle.

d_1: Distance pendulum rotation axis – center of mass
d_2: Distance pendulum rotation axis – transducer line of action

d_3: Radius of inertia [$\sqrt{\frac{J_0}{m}}$ where J_o = inertia relative to the pendulum rotation axis]

m: Pendulum mass
ω_o, h_o: Pendulum cycle frequency and damping constant of the mechanical free oscillation

8.3. Short-period or fast-response mode

The period of the integrator is switchable. Short-period (or fast-response) is automatically asserted for about 2s after power up and for the whole time centering is active. This short-period mode also reduces the settling time after switching back from centering mode to the normal operation mode. The corresponding measure consists in delaying the back-switching until all three feedback systems have equilibrated. Settling is accomplished after about 2s instead of 200s for normal operation. Yet, after having switched back, the offset voltage at the displacement transducer output, though lower than ±2mV, produces a weak settling excursion on the signal that can reach into the mV region. The output offset is caused by an operational amplifier input offset voltage. It depends on temperature and changes from item to item in a random fashion. Thus, the height of the excursion is not predictable.

8.4. Mass (re-)centering

Suspension of the pendulum

The pendulum suspension is realized with two pairs of crossed hinges representing the rotation axis and two parallel half-circle leaf-springs. The arrangement of the leaf-springs guarantees balance at the oblique angle that is required by the so-called cube corner configuration. Moreover, the suspension used for the STS-2.5 pendulums is one of the many possible realizations of a so-called astatic suspension allowing a very high free mechanical oscillation period up to virtual infinity. The higher the period the lower is its contribution to the long-period noise. In the course of factory calibration the value is adjusted to >3s. The two leaf-springs mentioned have different temperature coefficients of the elastic properties so as to reduce the temperature dependency of pendulum imbalance. In order to account for the remaining temperature dependency and the variability of the gravitational acceleration with location on the Earth, a mass (re-)centering capability is introduced. The drift caused by aging is negligible by experience, once the post-deployment settling phase has finished.

Centering procedure

The centering algorithm initiated with the center button on the host box or via the digitizer ends with the POS output voltages lying between ±1V. Unlike the STS-2, the STS-2.5 needs only one centering call. Apart from exceptional situations (fault, state of extreme deterioration, inadequate operating stand), initiating centering once suffices to arrive at the fully centered state – several minutes later at the most, depending on the degree of deterioration. The built-in tilt sensor will allow centering for a tilt angle of the case up to 0.5°. Otherwise an alarm condition is raised.

Re-centering due to ambient temperature change

The STS-2.5 has a wide temperature range where a re-centering is not necessary, i.e. the POS output voltage stays within the operating range. The temperature range is referenced to the ambient temperature at the time when the last re-centering had been initiated. But, because the relation temperature-to-POS-output is not linear, in reality, the upper and lower temperature limits may not lie symmetric to the re-centering temperature. Moreover, the relation is usually characterized by a considerable hysteresis, i.e. when performing a temperature cycle – the same temperatures at start and end of the cycle – the final POS output will differ significantly from the start output. Therefore, in a strict sense, the no-centering temperature range as defined in the specifications is only valid, if the seismometer has already suffered a temperature variation from the lower to the upper limit, or vice versa, with subsequent re-centering at the symmetry point temperature.

As long as the temperature is fluctuating only around this symmetry point temperature and within the range specified, no further centering is required. But if the temperature leaves this range in either direction, a substantially higher drift may be observed. Say, your vault temperature is -10°C in winter time at the minimum and +10°C in summer time at the maximum. Further assume you deploy the instrument in summer time. Depending on the storage temperature before deployment, occasional re-centering until the next winter time may be required. Afterwards, you do not have to re-center again. On the other hand, if you move the seismometer to a new vault with an annual temperature range of 15 to 35°C, you may have to re-center several times until it has reached 35°C for the first time.

8.5. Ambient temperature limits

Two types of temperature ranges have been introduced in the section 13, *Specifications*.
The operating temperature range presents the absolute limits for proper operation. Going beyond them means that one or more specifications may no longer be met (version “guaranteed”) or internal functions may fail (version “functional”), but it does not mean that an irreversible behavior change or even damages have to be expected.

We do not give the guarantee that the STS-2.5 won’t work when run beyond its functional temperature range. Nevertheless, be cautious with exceeding the limits.

Footnote 1) of operating temperature range “guaranteed” (see section 13, *Specifications*) only holds for long-term, cyclic temperature variations. Short term variations with rates higher than some tenths of °C per day produce noise and offset, because of thermal disequilibrium inside the seismometer housing.

8.6. Transfer function

a) Frequencies below 1Hz

At low frequencies the STS-2.5 seismometer may simply be considered as a long-period, electro-dynamic, three-component seismometer with a free period of 120s and damping 0.707 of critical. These parameters are factory-adjusted to within 1%. The response of the seismometer to ground velocity is described by the transfer function (Laplace notation)

$$TF_{LP}(s) = \frac{G \cdot s^2}{s^2 + 2 \cdot h \cdot \frac{2 \cdot \pi}{T_c} \cdot s + \left(\frac{2 \cdot \pi}{T_c}\right)^2}$$

G = generator constant, $1500 \frac{Vs}{m}$
T_c = corner period, 120s
h = fraction of critical damping, 0.707
s = Laplace complex frequency

b) Frequencies between 1 and 50Hz

The transfer function for the upper frequency range is made up of an experimental part (TF_{CAL}) and a model part (TF_{COR}). The experimental part is extracted from the transfer function test results that are individually evaluated for every sensor component. Considerable (up to >5%) sensor component parameter scattering eventually manifests in a similarly sized filter parameter scattering. The filter parameters that are produced in the “Table of parameters” below are approximate mean values evaluated using a set size of about 300 STS-2.5 test results. The model part is introduced, in order to account for the slightly different response that exists between excitation by ground motion and excitation by forced feedback coil current. It relies on a feedback circuit simulation without any experimental approval.

$$TF_{cal}(s) = \frac{-G \cdot p_1 \cdot p_2 \cdot \left(p_{re3}^2 + p_{im3}^2\right)}{z_1 \cdot z_2} \cdot \frac{(s+z_1) \cdot (s+z_2) \cdot (s+z_5)}{(s+p_1) \cdot (s+p_2) \cdot (s+p_{re3}+i \cdot p_{im3}) \cdot (s+p_{re3}-i \cdot p_{im3}) \cdot (s+p_4)}$$

$$TF_{corr}(s) = \frac{(s+z_{re4}+i \cdot z_{im4}) \cdot (s+z_{re4}-i \cdot z_{im4}) \cdot (s+z_3)}{\left(z_{re4}^2 + z_{im4}^2\right) \cdot z_3}$$

$$TF_{HF}(s) = TF_{cal}(s) \cdot TF_{corr}(s)$$

8.7. Poles and Zeroes

This table of parameters (poles and zeroes) is deduced from a set size of 100 STS-2.5 assembled at the factory. For exact values of the individual sensor please see its individual calibration sheet.

z_1	z_2	z_3	z_{re4}	z_{im4}	z_5	p_1	p_2	p_{re3}	p_{im3}	p_4	common factor
2.5	2.5	96.3	83	153	-153	2.554	2.554	54.0	18.4	153	2π

8.8. Theoretical Transformation Equations UVW⇔XYZ

In order to convert the differential output signals X, Y, Z into the approximate raw sensor output signals U, V, W and vice versa, use the following equations:

$2 \cdot U = 0 \cdot X - \sqrt{\frac{2}{3}} \cdot Y + \sqrt{\frac{1}{3}} \cdot Z$	$\frac{X}{2} = 0 \cdot U - \sqrt{\frac{1}{2}} \cdot V + \sqrt{\frac{1}{2}} \cdot W$
$2 \cdot V = -\sqrt{\frac{1}{2}} \cdot X + \sqrt{\frac{1}{6}} \cdot Y + \sqrt{\frac{1}{3}} \cdot Z$	$\frac{Y}{2} = -\sqrt{\frac{2}{3}} \cdot U + \sqrt{\frac{1}{6}} \cdot V + \sqrt{\frac{1}{6}} \cdot W$
$2 \cdot W = \sqrt{\frac{1}{2}} \cdot X + \sqrt{\frac{1}{6}} \cdot Y + \sqrt{\frac{1}{3}} \cdot Z$	$\frac{Z}{2} = \sqrt{\frac{1}{3}} \cdot U + \sqrt{\frac{1}{3}} \cdot V + \sqrt{\frac{1}{3}} \cdot W$

Please note that these transformation formulas do not match exactly. The UVW gain and axis alignment deviations with respect to gains and alignments inherent to the left formula above are:

±7%	Δgain	X, Y, Z gains
±0.3°	Δφ	φ = angle in the X-Y plane
±2°	Δθ	θ = tilt angle

These deviations arise due to mechanical and electrical parameter scattering. Because the axis triple X,Y,Z has been calibrated during manufacturing, its deviation from the theoretical configuration does not depend on instrument parameters, but on the combination of systematic and random calibration errors alone. The cumulated calibration errors do not exceed:

±0.5%	Δgain	X, Y, Z gains
±0.3°	Δφ	angle error relative to X axis hole within the X-Y plane
±0.3°	Δθ	tilt angle error.

The “exact” UVW gains and axis parameters that have been evaluated in the course of shake-table calibration can be found on the individual calibration sheet. Yet, the discrimination accuracy inherent to the “exact” parameters is not needed for sensor component-related glitch and defect localization, i.e. the formulas given above suffice for these purposes.

9. Noise Performance

This section is currently being reevaluated.

9.1. Long-Period vertical vs. long-Period horizontal Noise

Surface deployments of broad-band seismometers (precisely expressed: Those seismometer types that compensate for gravitation) exhibit a special vertical-horizontal phenomenon at long periods: The horizontal (X, Y) noise is always higher than the vertical (Z) noise. The reason lies in the high sensitivity to tilt fluctuations of a horizontal seismometer. The sensitivity of a vertical seismometer to tilt fluctuations, however, is negligible, because, for small tilt fluctuations, it is proportional to the static tilt angle, i.e. vanishes, if this static angle is zero. This statement is also valid for a 3-component seismometer, like the STS-2.5, which builds horizontal and vertical components by axis transformation.

!

In order to get excellent horizontal component data, it is crucial to avoid tilt fluctuations, mostly caused by deployment errors and air convection due to temperature variations.

9.2. Improving noise performance

The noise performance of the seismometer strongly depends on an adequate deployment strategy. Please consult sections 4 and 11 for corresponding advices and hints.

10. Maintenance

Sensor and host box do not contain any maintainable parts inside. Opening of either sensor or host box can cause malfunction and void warranty.

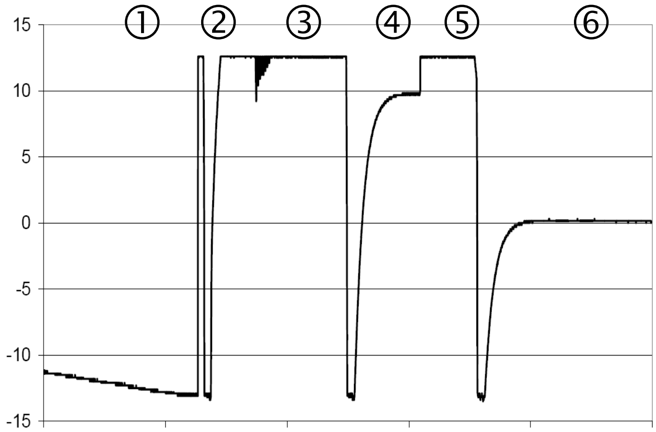
After returning from field installation the STS-2.5 should be treated with a mild agent rather than with aggressive chemicals. Be sure the protection cap sticks firmly in the sensor connector.

10.1. Functional testing in the lab

Place the sensor on a stable ground preferably a pier or floor of concrete or stone and level it.

! A desk or a work bench is NOT a stable ground!

Assert a centering command either with the button on the host box or a command at the control pin. Observe the POS signal of the desired sensor component U, V, or W and. It should look more or less like the following picture (Scope settings: 5V/DIV, 5s/DIV). You will hear a click inside the sensor when it switches to fast response.



① Out of center section, somewhere in the range of ±12V.
② Start of the centering process: POS signal toggles between +12V and -12V
③ Mass moving section: POS signal saturated, the polarity depends on the moving direction.
④ Mass release and measuring section: POS smoothly approaches a value usually smaller than with section 3. Check if the level is below ±1V. Here: NO ➔ continue with centering
⑤ Mass moving section: POS saturated, the polarity is the same as in section ④
⑥ Mass release and measuring section: the signal smoothly approaches a value usually smaller than with section 4. Check if the level is below ±1V. Here: YES ➔ pendulum is centered, process ends; sensor is switched to normal response (audible click).

10.2. Troubleshooting hints

This section summarizes common troubles and their debugging methods. The list is developed by field experiences and is far from being complete.

Types of re-centering failures

1. No failure, just impatience. Please hold on waiting for the green status LED to light up!
2. Case tilt > 0.5° (FAULT LED on the host box shows one short blink). Turn the feet screws in order to align the bubble of the bubble level and try re-centering again.
   Tighten the feet screws after aligning!
3. The bubble is perfectly aligned; “case tilt >0.5°” is still indicated:
   Most probably the bubble level is damaged. Please return the instrument for repair.
4. The seismometer has just been deployed and is now enduring the heaviest phase of temperature equilibration. Temperature gradients within the seismometer provoke large pendulum position drifts. So, in case of a long re-centering time, it is possible that a once properly centered pendulum has drifted to a non-centered state before the re-centering of the other pendulums has finished, and, eventually, the centering process will run into a time-out. Please wait until the temperature has equilibrated enough.
5. You are entrance-testing or demonstrating the seismometer functions, while it is placed on an unstable shelf. The same as has been described in point 4 will happen, though not because of a temperature gradient, but because of the steady, high-amplitude motion of the shelf. Please place the seismometer on a stable ground.

Offset on the signal outputs

After deployment the instrument adapts slowly to the ambient temperature. Moreover, mechanical settling effects may follow a long storage time, especially when having been stored in the locked state. The drift period lasts for a few hours at the minimum, but may extend to more than one day, especially when the whole site has to equilibrate, too. The characteristic of a high drift is a high "offset" on the output signals, preferentially on the Z output signal. "Offset" in this context means a non-zero voltage remaining constant during many step-response settling periods (one settling period is about 180s). Of course, an "offset" also arises, when the vault temperature is continually changing. If this "offset" exceeds some Millivolts at the differential outputs and has not remarkably diminished after some hours, the temperature drift is very critical. A persistently elevated noise level will be the consequence (see also section 8.5 *Ambient temperature limits*).

Note: A broad-band signal looks rather different from a short-period one. For the STS-2.5, any long-period (>120s) change of the internal or external force on the boom deflects the signal proportional to the derivative of this force. Therefore, a constant increase of the force, as it is approximately expressed by a constant temperature drift, converts to a constant “offset” on the output. Normally, short period instruments do not show this behavior or it is concealed by noise.

Deployment related spurious signal phenomena

During some time after deployment, spurious signals can occur, because of mechanical settling effects within the seismometer case. Internal mechanical settling can produce a pendulum force variation that eventually express as a voltage equivalent at the outputs. In most cases the pattern of it is distinguishable from the one of a genuine signal, but sometimes not. Provided that the ambient temperature is stable, these distortions disappear after a few days at the latest.

Prevent the instrument from any temperature drift higher than a few tenths of a degree Celsius per day! Otherwise, a once distortion-free instrument can resume distortion activity.

Distortions of assured internal origin that have remained constant over weeks and months indicate a defective instrument. But keep in mind that, in most cases, distortions are of external origin: Electromagnetic interferences, high temperature drift, pier settling, grains of some non-inert material below the feet, etc. Please contact Streckeisen GmbH in case of uncertainty.

10.3. Return to repair

If an STS-2.5 needs to be repaired, please contact Streckeisen in advance in any case. We can provide helpful information. Please send, if possible, instrument, cable and hostbox to the address at the end of this manual. It is strongly recommended to use the original or at least some equivalent transportation package.

10.4. Decommissioning and Recycling

Although the STS-2.5 equipment does not contain hazardous material it should not be thrown in the urban waste stream. The instrument's high amount of aluminum and stainless steel is easy recyclable. The following table describes dangerous materials and hazards.

Material or hazard	Location	Comments
lead	Electronics (PCB),STS-2.5 and host box	total PCB area 330cm^2
cadmium	green host box connectors	
PVC	internal STS-2.5 cabling	
strong rare earth magnets	sensor components	total <100g

11. Frequently asked Questions (FAQs), see also previous section.

Q: After deployment, leveling, and autozero one or more position signals remain out of range, indicated by the blue LED's "NOT CENTERED" on the host box.

A: Repeat autozero, until all these LED's are extinguished.

Q: After several autozero cycles one sensor constantly remains out of range.

A: Consult 10.2 *Types of re-centering failures*. In case of no success: Assert FAST RESPONSE (via serial interface[1]) and SIGSW (via serial interface or connector pin, see section 5.2 for the latter) and consult the UVW_{POS}/UVW_{RAW} output (UVW for the appropriate sensor component). If the voltage is still out of range (±10V), the most probable cause is pendulum sticking or defective centering function. Please contact Streckeisen GmbH.

Q: The unfiltered vertical output signal (Z) exhibits several millivolts offset which does not vanish neither on autozero nor after several hours of operation.

A: Autozero has no effect on the X, Y, and Z signal offsets. As soon as all position signals lie in the operation range (±10V), all offsets should vanish after two or three step-response settling intervals (about 120s). A residual offset signifies that the temperature within the seismometer is drifting.

Q: How can I distinguish between interferences (pings, excursions, "time-marks") of internal (produced by the instrument itself) or external origin?

A: Import the suspicious data range into an adequate time-amplitude representation program capable of displaying multiple channels synchronously, filtering and maths, manual zooming, manual gain setting, scrolling through time, locked cursor or locked grid lines. The data range should comprise at least several hours, in order to be able to get an impression of the signal background, where the suspicious interferences are embedded. Then proceed as follows:

1. Apply an appropriate band-pass filter to the output signals and, if possible, reduce the sample rate.
   Proposal: High-pass corner at 1mHz, low-pass corner at 33mHz, sampling rate set at 100mHz.
2. Transform the output signals into the approximate raw U, V, and W signals by using the formula from section 8.8.
3. On the display screen present the Z output together with the calculated raw U, V, W outputs. Setting the temporal zoom factor so as to display about 20'000s on one screen (2000 samples per signal at 100mHz sampling rate) has proven most effective. Set the gain so as the noise background to be visible. Glitches now are easily recognized.
4. Place the cursor to the location of a glitch on Z. Examine U, V, and W amplitudes at the cursor position. If the same glitch is found only on one of the raw signals, the glitch is most probably of internal origin. The raw signal, where the glitch has been found, indicates the affected pendulum or rather its feedback system. Inversely, if the same glitch is found on two or three of the raw signals (Do not care about amplitudes and amplitude ratios!), the glitch is most probably of external origin.

High horizontal seismic noise can obstruct the glitch assessment. Small glitches will then be concealed on the raw signal curves, even if they are most prominent on the Z curve. The only recipe against this undesirable situation consists in deploying a second instrument on the same pier, aligning both "X" axes at a tolerance of 0.6°, and subtracting X[target] – X[reference] as well as Y[target] – Y[reference]. A noise-reduced UVW triple can now be calculated by using the target Z together with the calculated X and Y differences. As a further benefit, the reference Z can be used as an independent discrimination agent: A glitch that is found on both Z curves, independent of the amplitude ratio, must be of external origin.

A special case are glitches that can be observed on X and/or Y, but are not present on the Z component. These “horizontal” glitches are frequent, and the vast majority of them come from platform or case tilt processes (see also section 4.1 *Sensor installation considerations*). In rare situations the tilt process may run within the seismometer case. But, here, the side-to-side deployment does not help discriminate: If a horizontal glitch is observed on both seismometers, its origin is undoubtedly external. Yet the reverse statement does not work.

A grain of sand under one of the seismometer's feet may collapse, the platform surface under a foot tip may yield because of corrosion …, always affecting only one seismometer at a time. Nevertheless, the origin of such a glitch is purely external.

When testing a target seismometer against a reference one, be aware to use an inert platform at a dry and dust-poor environment, in order to avoid horizontal glitches of platform surface or foot tip origin.

Q: How can I identify signal excursions caused by electro-magnetic interferences? How can I prevent or, at least, mitigate the effects?

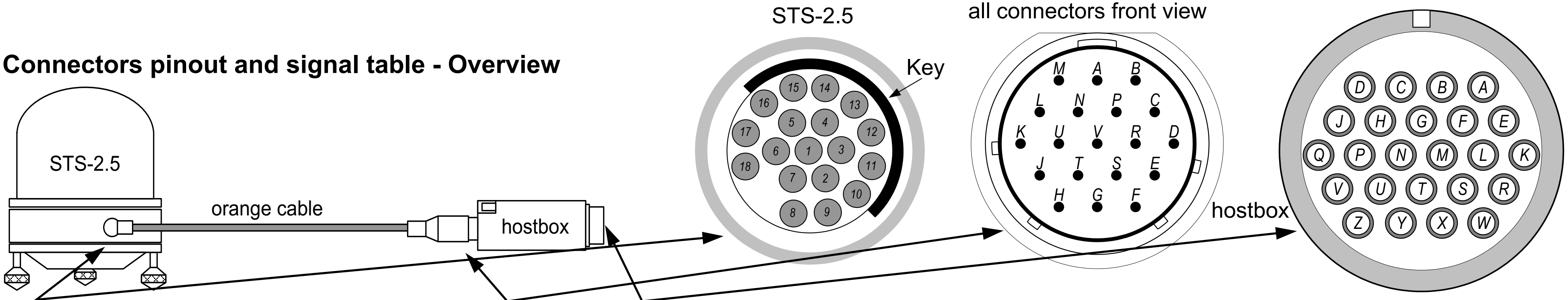
A: Most electro-magnetic interferences can be attributed to currents that are switched on and off in the vicinity of the seismometer (e.g. current through power lines of on-off-controlled battery charger and/or heating device) giving rise to stepwise changes of the magnetic field. Any magnetic field (no matter if DC or AC) exerts a force on the boom. A characteristic property consists in the fact that, in most cases, pulses of the same origin have identical height, and every positive pulse is compensated by a negative one. If it is not possible to deactivate the responsible source or to move it so as to enhance the distance between seismometer and current conducting line(s), the seismometer must be coated with an appropriate magnetic shielding.

Q: In case of a damaged bubble level: Is it still possible to level the seismometer?

A: Yes, it is possible when accessing the seismometer µC via serial interface[1)]. Doing so, the internal tilt sensor can be read out, enabling to level by observing the X and Y tilt values instead of the bubble level.

[1)] Please contact Streckeisen GmbH for advices concerning the access to the serial interface.

12. Connectors pinout and signal table - Overview



Pin	signal name	↔	description	Pin		Pin	signal name	↔	Level	description
Sensor case & cable shield (connected at sensor side)				F	═══	A	CASE	–	0V	hostbox and sensor case
3	Z +	→		N	═══	B	Z+	→	-10V..+10V	differential seismic signal, Z-axis (positive)
7	Y+	→		T	═══	C	Y+	→	-10V..+10V	differential seismic signal, Y-axis (positive)
4	X+	→		P	═══	D	X+	→	-10V..+10V	differential seismic signal, X-axis (positive)
						E	AUTZ	←	+3V..+30V, 0.5mA	Centering control (high=invoke centering)
1	GNDS	–		V	═══	F	GNDS	–	0V	signal GND
2	Z-	→		U	═══	G	Z-	→	-10V..+10V	differential seismic signal, Z-axis (negative)
6	Y-	→		S	═══	H	Y-	→	-10V..+10V	differential seismic signal, Y-axis (negative)
5	X-	→		R	═══	J	X-	→	-10V..+10V	differential seismic signal, X-axis (negative)
						K	CALSW	←	+3V..+30V, 0.5mA	Calibration control (high=calibration)
						L	SIGSW	←	+3V..+30V, 0.5mA	auxiliary signal control, 0=UVW_{POS}, 1=UVW_{RAW}
						M	GNDS	–	0V	signal GND
13	CAL/TCK	←		M	═══	N	CAL	←	-10V..+10V	Calibration signal, see also pin K, Y, Z
						P	RXD	←	-8V..+8V	serial control interface (RS232), PC to host box
						Q	TXD	→	-8V..+8V	serial control interface (RS232), host box to PC
						R	XAL	→	0V or open	Alarm output (low=alarm)
						S	RET	–	0V	control signal GND
15	UPOS/URAW	→		B	═══	T	UPOS/URAW	→	-10V..+10V	auxiliary signal U-axis, see also pin L
16	WPOS/WRAW	→		C	═══	U	WPOS/WRAW	→	-10V..+10V	auxiliary signal W-axis, see also pin L
17	VPOS/VRAW	→		D	═══	V	VPOS/VRAW	→	-10V..+10V	auxiliary signal V-axis, see also pin L
8	CMP_XRES	←	µC control signal	G		W	+VIN	←	+9V..+30V	Power supply (plus)
9	+VAR	←	power supply (+14.2VDC)	H		X	-VIN	-	0V	Power supply and RS232 return
10	-VAR	←	power supply (-14.2VDC)	J		Y	CSEL1	←	+3V..+30V, 0.5mA	calibration select:
11	TXD	→	µC control signal	K		Z	CSEL2	←	+3V..+30V, 0.5mA	YZ=00 or open: UVW, YZ=01:U, 10=V, 11=W
12	+VD	←	power supply, 5VDC	L						
14	RXD	←	µC control signal	A						
18	GNDP	–	Digital GND	E						

STS-2.5 **Hostbox**

Cable ↑

═══ = through connection

13. Specifications

13.1. Electrical

Power supply voltage:	$10..30V_{DC}$, galvanically isolated
Power consumption:	Average: 0.45W, deteriorated state (saturated outputs): max. 2,0W
Seismic signals output:	max. ±20V differential, 220Ω serial resistance per line
Auxiliary signals output:	max. ±10V single-ended, 1kΩ serial resistance per line
Calibration input:	max. ±10V (typical useful range: ±3.125V = $\pm 3.9\cdot 10^{-4}$g)
Calibration Constant	all U/V/W excited, output Z: $7.25\cdot 10^{-5}$g/V ±2 % U selected – U measured (raw mode): $1.25\cdot 10^{-4}$g/V ±10 % V selected – V measured (raw mode): $1.25\cdot 10^{-4}$g/V ±10 % W selected – W measured (raw mode): $1.25\cdot 10^{-4}$g/V ±10 %
Control inputs:	$3..30V_{DC}$, 0.5mA, galvanically isolated
Communication	RS232, galvanically isolated, 8bit, 1Stop, no flow control, 2400Bd operation, 9600Bd firmware download.
Protection:	Reverse polarity, overcurrent, overvoltage (K.21)

13.2. Electro-mechanical

Generator constant:	$2\cdot 750\ \frac{Vs}{m}$ ±1% at a period of ~2s
Response:	flat to ground velocity from 8.33mHz (120s) to 50Hz
Orthogonal accuracy:	≤0.6° at a period of ~2s
Damping factor	0.707±1%
Clip level	≤20Hz: $\pm 13\frac{mm}{s}$ ground velocity >20Hz: linearly derating from $\pm 13\frac{mm}{s}$ to $\pm 5.3\frac{mm}{s}$ ground velocity normalized to frequency: 20..50Hz 0.34g 10Hz 0.17g 1Hz 0.017g 0.1Hz 0.0017g 0.03Hz 0.00055g ($g=9.81\frac{m}{s^2}$)
Parasitic resonances:	>140Hz vertical, >80Hz horizontal
Typical no-centering range:	case tilt: ±0.03deg, Temperature: ±25ºK (range around the last centering, where no re-centering is required)
Case tilt range limit:	0 ±0.48deg in any direction for a centering is successful

13.3. Environmental

Operating temperature:	-20°C to 70°C (guaranteed)[1)], -40°C to 70°C (functional)[2)]
	Humidity: 0-100% RH non condensing

1) Temperature range within the instrument meets the specified limits.
2) Temperature range within the instrument won't fail its function.

13.4. Physical

Enclosure Rating:	IP67 Equivalent
Various:	RoHS and CE Compliant Unit
Size:	Cylindrical package, ø235mm, height 260mm (ø9.3", h=10.2")
Weight:	12kg (26.5 lbs)

14. Spare parts and numbers

Sensor	STS-2.5	
Host box	3-320	
Cable: sensor – host box 3m	3-384.03	
Cable: sensor – host box 5m	3-384.05	(standard)
Cable: sensor – host box 10m	3-384.10	
Cable: sensor – host box 15m	3-384.15	
Cable: sensor – host box 30m	3-384.30	(maximum available length) any non standard cable length up to 30m is available upon request.
Orientation rod (for STS-2 and STS-2.5)	no dedicated number	
Cable Connector mating the 24pin female Host box connector	CA3106PG24-28P-A176	
Cable: host box – Q330 8m	KMI 110959	(other lengths or pigtail upon request)
This Manual	STS-2.5 instruction manual	
Field fact sheet	STS-2.5 field fact sheet	

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