




User Manual & Installation Guide

AC-73-DH Force Balance Accelerometer



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Warnings and Safety



*The sensor housing provides no protection against explosive atmosphere. It must not be directly operated in an area where explosive gases are present.
In case of any doubt about the installation, please contact GeoSIG for advice.*

1. Introduction

This document describes the steps needed for the installation of GeoSIG AC-7x-DH series down-hole accelerometers, including some guidelines for the borehole drilling.

Such installation procedures / instructions always require to be reviewed according to the local situation and must be used as guidelines only.

The AC-73-DH is an accelerometer sensor that covers the full range for strong-motion measurement over the required amplitude and frequency ranges. For a detailed description of the sensor and its interface, please refer to section 4.

The reasons to have a borehole sensor instead of a sensor at surface can be:

- To measure the acceleration at the rock level without the influence of sediments or soft soil.
- To define site condition to know amplification factor. The acceleration level at surface can be measured with a simple sensor such as AC-73 and with borehole measurement where the amplification factor can be defined. This factor is highly dependent on local conditions and can vary to a great extent from one location to another.
- To avoid human induced noise present at surface.

2. Pre-installation

A good understanding of the installation requirements is the basis for a successful and reliable sensor installation and good quality measurement. As a first requirement, the parameters of the borehole should be well defined. For the requirement related to the sensor itself, the requirements can be simply summarised as below:

- Free borehole diameter of 100 mm as a minimum (larger when casing is installed).
- Water level above the sensor in the borehole should never be more than 100 meters. At installation, water level should be less than 50m to allow for rising water level during rain.
- In cases where there is water in the hole, combination of the chemical compositions and temperature should be evaluated for compatibility with the sensor housing material. This usually concerns installations located in areas with hot springs or near volcanoes.
- A casing *may* be installed in the borehole. The decision depends mainly on the kind of rock to be bored. The point of the casing is only to provide integrity to the borehole during installation, which typically lasts several weeks. The casing has no effect on the sensor or signal during operation.
- The selection of the casing type has an influence on how the orientation of the sensor after insertion in the borehole can be defined. The sensor has an internal compass (toward magnetic North) to define the orientation of its X/Y axes relative to magnetic North. Its measurement will be only valid if no casing or non-magnetic material is used (plastic, aluminium, fibre glass casing). In case of steel casing, the orientation of the sensor should be calculated using some recorded earthquakes (or explosion data at a known azimuth) and a reference surface sensor at borehole top.

In the following page, an overview of the layout of a typical installation is provided.

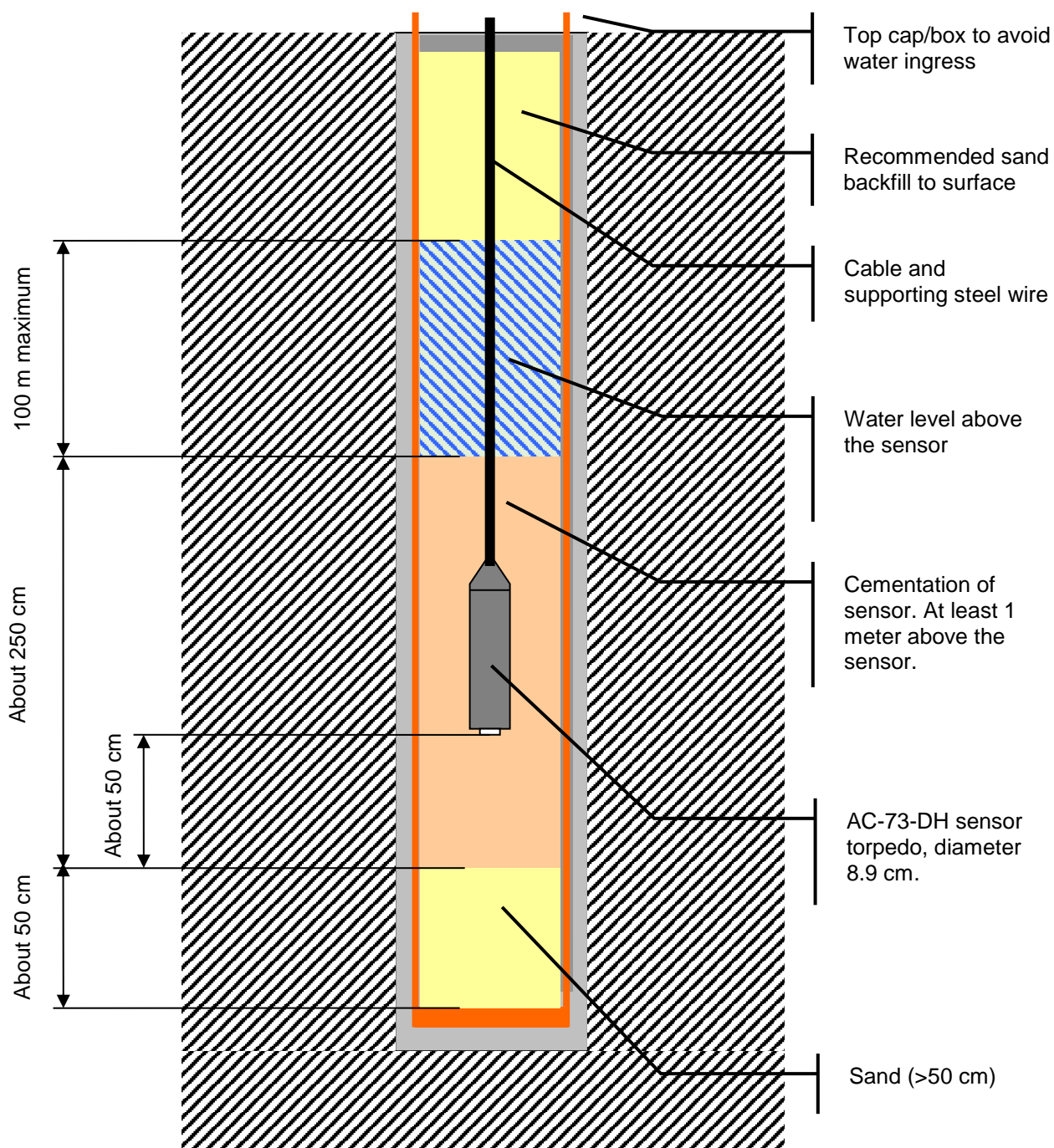


Figure 1. Typical Installation Layout (not to scale)

2.1. Preparation check list

The following should be prepared before installation:

- Drawing of site implementation, including cable length.
- Installation of sensor recorder.
- Drilling of the borehole.
- Installation and cementation of the borehole casing, if applicable.
- Verification of the borehole, depth of the water level and the path in the hole is free for the sensor. See Section 2.2.
- Preparation of wire lowering device and top cap/box, if applicable
- Trench/conduit for routing of signal cable from top of borehole to recorder. Under-ground routing is preferred.

2.2. Borehole and Casing

The borehole must either have a casing (e.g. steel or PVC) or adequate steps must be taken to protect the integrity of the borehole walls and avoid ground material falling in the hole before the sensor can be installed and grouted.



If the hole is lined with a casing, cement must be injected in the annular region between the casing and borehole wall, generally over the full height of the casing. Generally, one week delay should be allowed for curing of the cement.

For drilling depths of more than 20 meters, the drill diameter (or internal casing diameter) must be at least 12 cm to ensure the sensor reaches the full depth. For holes of less than 20 meters, a drill diameter (or internal casing diameter) of 10 cm is sufficient. Where injection tubes are used for grout, this diameter must be selected allowing for space to run the injection tube and/or reasonable grout flow around the sensor to avoid a cavity below the torpedo.

The deviation of the hole must remain within the following specifications to ensure clear installation of the sensor torpedo, as well as preserve the alignment of signal axes:

- The deviation drift must remain below $\pm 1^\circ$ / 3 meters
- The deviation at sensor location should be within $\pm 3^\circ$, the maximum recommended deviation is $\pm 9^\circ$ from vertical.

For plastic casing (e.g. PVC), some water may need to be added to the inside to avoid buoyancy and pressure difference at the bottom of the borehole. Otherwise, there is the risk that the casing can break.



It is highly important that the cementation at the bottom of hole is as solid as possible to ensure a good coupling near the level of the sensor. So injection should be performed first from the bottom. An injection plastic tube should be routed along the casing when it is inserted in the hole. If the injection cannot be fully performed from the bottom, the rest of injection should be done from the top.

If possible, the cementation should be verified within the next 24 hours using ultrasonic measuring equipment or measuring the temperature profile in the hole. For both methods, water must be present in the hole.

Downhole sensors that are encased in concrete are not retrievable in case of failure. In the unlikely scenario that a failed downhole sensor must be replaced, it is not recommended to install the spare sensor in the same borehole, on top of the original sensor. For some installations, it can be useful to install and cap 1 or 2 additional boreholes during the initial boring, such that a spare sensor can be installed immediately, if required.

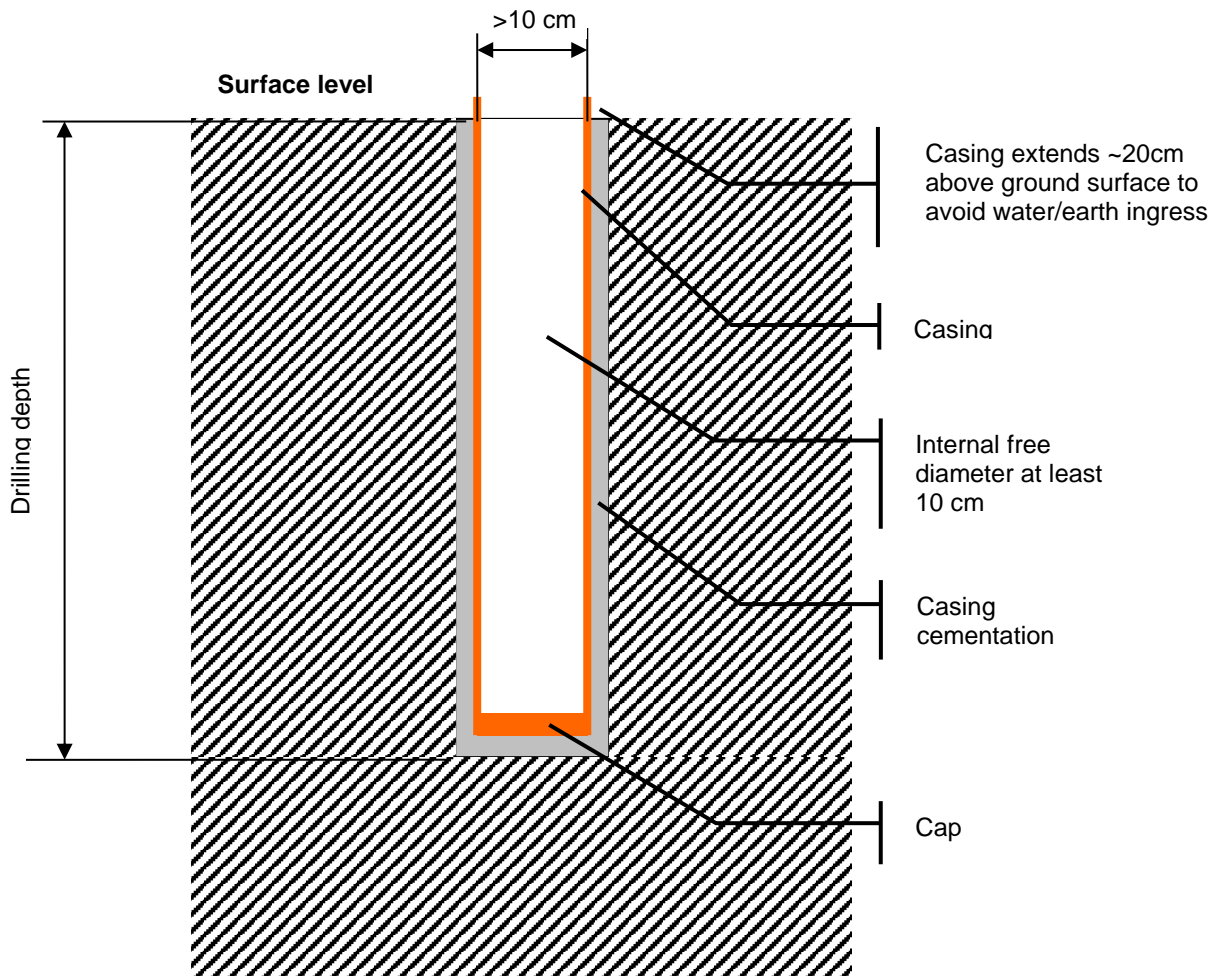


Figure 2. Typical Installation of Casing (not to scale)

2.3. Materials and tools for installation

In addition to a common set of basic tools, the following tools and materials are required. Items to be provided by GeoSIG as part of the BOM include:

- Sensor torpedo with integral cable and suspension wire loop;
- Junction Box at the top of the borehole, if applicable;
- Associated recorder for the sensor (e.g. GMSplus or SMS Recorder).

Tools provided by GeoSIG for installation (see Section 4.6):

- Laptop (Windows based) to run GeoSIG utility for iSensor interface (iSensorUI.zip);
- A serial adapter for RS-485 like MOXA TCC-801 to interface the laptop serial port (or through a USB adapter) with the RS-485 interface of the sensor.

Items to be provided by customer or subcontractor include:

- Depth probe with water level indicator to know the real depth of the hole;
- Steel wire for sensor suspension with the appropriate lock nut for the depth of the hole plus an additional length of at least 10 meters. Typically stainless steel wire 3 mm diameter with a capacity of up to 100 kg;
- Grout injection tube to be fixed along the steel wire and on the side of sensor (provided there is enough space);
- A fixation point at the surface close to the borehole for the steel wire;
- Construction materials as listed in Section 2.3.1.

2.3.1. Construction Materials

Sand and concrete are necessary for the installation of the sensor and/or casing. This includes:

- Annular cementation between the casing and borehole (if applicable; Section 2.2)
- Sand cushion for the sensor (0.5-1.0m)
- Cementation of the sensor (see Section 3.1)
- Sand backfill

External hole or casing diameter [cm]	Volume between hole and tube [dm ³ / meter]	Volume of sensor [dm ³]
10	8	3.2
12	11.3	3.2
15	17.7	3.2

Table 1. Estimation of Construction Material Quantity

$$Volume = \pi \times \frac{Diameter^2}{40} \quad \text{With: Volume [dm3], Diameter [cm]}$$

Cement mix is required to have sand, bentonite and cement. The quantities should be evaluated according to the diameter of the hole, the depth and the mixture requirement outlined in Section 3.1.

If the installation does not utilize a casing, there must be an extra reserve for cementation of the sensor inside the borehole as there could be cavities in the earth that require additional volume of cement.

2.4. Unpacking and handling of the sensor

The accelerometer is precision measurement equipment and should be handled with care. Although the sensor is designed and manufactured to be strong for its class, drop shock with hard surfaces should be avoided.

Due to its long cylinder shape, when the sensor is placed on its base, there is a risk that it may fall. It is recommended that it is stored on its side, however care should be taken that it doesn't start rolling and fall from the surface it is placed on.

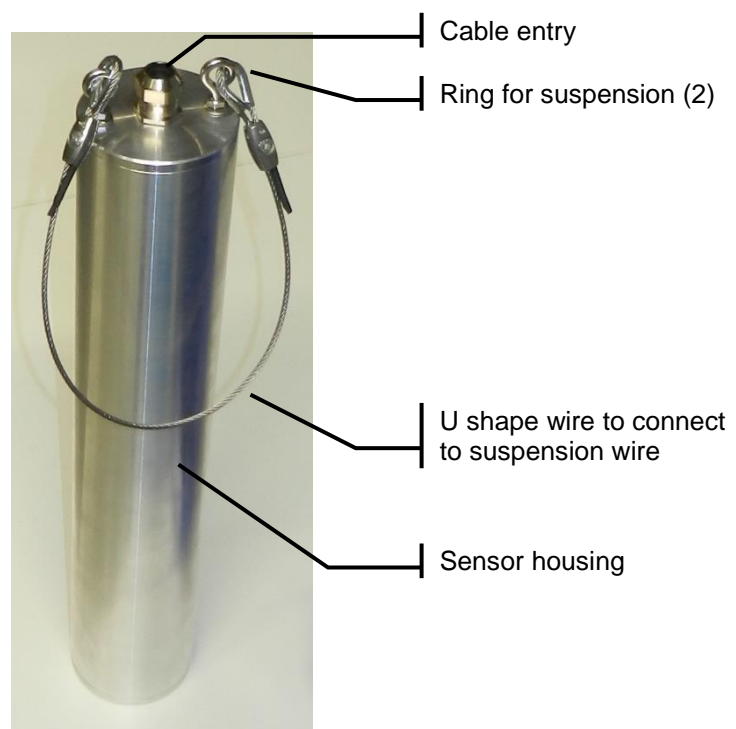


Figure 3. Sensor view

3. Installation

1. iSENSOR

- a. Make sure the communication with the iSensor is working as described in chapter 4.6.
- b. Perform a compass calibration as described in chapter 4.6.4.

2. SENSOR TORPEDO

- a. Verify water level in borehole, if applicable
- b. Deposit the equivalent of at least 50 cm of sand (see section 2.3.1 for the volume) in the borehole/casing.
- c. Gently bind the sensor cable about every 3 meters to the suspension wire, ensuring that the cable will not kink or strain. The sensor cable is not made to support the weight of the sensor and cable.
- d. If applicable, fasten the grout injection tube to the side of the sensor torpedo.
- e. Lower the sensor in the casing/borehole until it reaches the sand at the bottom, when the suspension wire becomes slack. The movement should be controlled using the steel wire. The sensor cable and cement injection tube should be free of tension.
- f. Lift the sensor up by 50 cm so it is suspended by the wire (to ensure it is in a *vertical* orientation). See Figure 1.
- g. Connect the cable to the junction box at top of borehole (if applicable).

3. INSTRUMENTATION

- a. Route the cables from the borehole (junction box or integral cable) to the recorder.
- b. Perform a sensor test from GeoDAS or from the recorder console.
- c. Test the whole system.
- d. A continuous monitoring of the system pre-grout should be performed for a few days. This ensures the operation/reliability of the sensor (e.g. no water ingress).
- e. A longer period of pre-grout monitoring can also be used to ensure that the location of the sensor suits the customer requirements with regards to noise level or seismic transfer function to a reference sensor. In this case, it is recommended to *temporarily* fix the sensor in place with sand or glass beads.

4. GROUTING

- a. Final cementation/grouting of the sensor in the borehole/casing (see Section 3.1).
- b. When the cementation is complete (e.g. after curing), sand should be deposited in the borehole – preferably to the surface – to avoid that the cable and steel wire can sway in case of earthquake and create triboelectric (parasitic) signals.
- c. Release of steel wire.



It is not recommended to perform the cementation of the sensor in the borehole/casing right after its insertion. The whole installation should be finished and the system should run for several weeks and show correct operation before the final cementation of the sensor inside the hole is performed.



Care must be taken with the cable to avoid kinking, cutting or abrasion of the cable jacket, which can lead to water ingress and sensor failure. Always maintain the minimum bending radius of >180mm.

3.1. Grouting

After the sensor has been successfully tested in its place, the cavity between borehole/casing and the sensor can be grouted. Inject a grouting mixture consisting of 100 liters of water, 50 kg of cement, and 10 kg of bentonite. The bentonite percentage may be increased or reduced according to the consistency of the examined soil and water content). It must be liquid enough that it will not form a cavity under the torpedo. Use low pressure and low flow for the expected required amount of the mixture. The grout should be cured within one week. Backfill the rest of the internal cavity with sand, if applicable, and add a top cap, if applicable. Note sensor cable minimum bending radius at casing exit. Perform additional noise measurements after completion.

4. Reference

The AC-73-DH sensor package is a true electro-mechanical triaxial down-hole accelerometer designed for earthquake monitoring and applications requiring highly sensitive and ruggedized sensors with minimum maintenance and a simple method for periodic testing. The core of this accelerometer is based on the same electronics used in AC-73 or AC-73i with the same performance. The housing for the AC-73-DH is made for insertion into a borehole with a diameter of 100 mm or higher. The orientation of the sensor in the hole can be defined either by the integrated compass (accessible over the iSensor interface) or by calculation using the azimuth of recorded known earthquakes and the borehole location.

4.1. Specifications

The key specifications of the sensor are in the table below. For more detailed specifications, please refer to the AC-73-DH leaflet.

Sensor P/N	AC-7x-DH
Input range	Acceleration, ± 0.5 , ± 1.0 , ± 2.0 , ± 3.0 or ± 4.0 g
Output range	0 ± 10 Volt differential output (20 Vpp)
Frequency range	DC to 200 Hz
iSensor	Digital monitoring of sensor condition accessible through RS-485 interface, it provides the following information: <ul style="list-style-type: none">• Temperature inside sensor• Humidity inside sensor• Tilt along X and Y axis• Orientation to magnetic North
Protections	All connector pins are over-voltage protected by double stage circuit
Power supply	9.5 – 18 VDC
Current drain	Typical 80 mA @ 12 VDC
Dimensions	Diameter 89 mm x 502 mm (excluding screws and cable entry)
Housing Material	Stainless Steel (Austenitic) - EN 1.4401/14404 (AISI 316/316L)
Volume	3.2 dm ³
Weight	4.2 kg
Density	1.3 kg/dm ³ (No additional weight needed for insertion in borehole with water)

Table 2. AC-7x-DH Basic Specifications

4.2. Description

The rugged mass suspension moving coil system improves the signal to noise ratio. The magnetic system and capacitive position sensors offer symmetrical controls for the accurate electronic centring of the mass. At rest the accelerometer mechanism is in balance and no electrical output is generated. Acceleration applied to the AC-73-DH will result in an electrical output proportional to the current used to keep the mass centred. This accelerometer output signal is calibrated to "g" gravity so that the current scale factor of the AC-73-DH is in units of milliamps per g. Because of the symmetrical positioning system incorporated with the force balance servo accelerometer principle, the accelerometer cannot arbitrarily change its scaling or drift out of calibration.

The sensor interface to the recording system is based on a differential voltage for each axis over 2 twisted wires (twisted pair) to avoid disturbance over long distance.

The AC-73-DH is equipped with electronic offset adjustment features that keep the offset low and make its installation very user friendly. This powerful feature allows the users to install the AC-73-DH without mechanical offset adjustment. Additionally, no fine levelling is necessary and the sensor can easily adapt to typical deviations from vertical found in drilled borehole installations.

The DC response allows the sensor to be easily repaired, tilt tested or recalibrated in the field. With the help of the test line the AC-73-DH accelerometer can be tested, assuring proper operation and accurate acceleration measurement. This test line is internally connected to the external world only when a given command is sent to the sensor to avoid any noise pick-up through the test input.

The sensor can be powered from 9.5 to 18 VDC source with the advantage that its power input is insulated from the sensor's electronic ground. This avoids ground loops and reduces noise induced through the power supply.

The sensor "State Of Health" can be digitally monitored through the proprietary "iSensor" interface provided over 2 wires and a RS-485 interface.

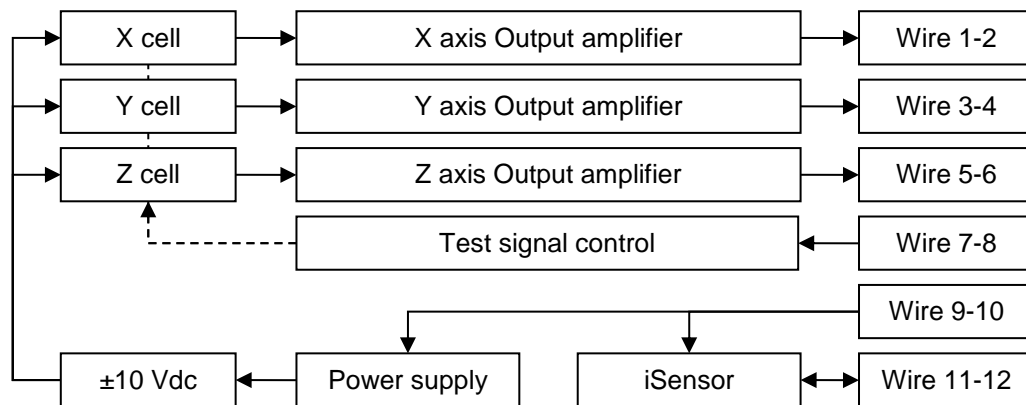


Figure 4. Block diagram

Technical drawing of a vertical cylinder with the following specifications:

- Dimensions:**
 - Top flange diameter: 89 mm
 - Top flange inner diameter: 64 mm
 - Main cylinder height: 502 mm
 - Main cylinder diameter: 502 mm
- Labels and Features:**
 - 2 x M6 thread for support Aligned with X axis
 - Cable gland 32 mm diameter reserved
 - Diameter of main cylinder
 - There is a sealing nut at bottom with 8 mm height and the cable gland with cable at top
 - 2 x M6 thread x 64 mm as on top Aligned with X axis
 - 32 mm diameter x 8 mm reserved as on top for sealing nut
- Coordinate System:**
 - +X = East
 - +Y = North
 - +Z = Up

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4.4. Sensor interface

The sensor interface is the same as other GeoSIG sensors with a differential voltage output for each axis having a ± 10 volts range (20 Vpp).

A digital sensor test input is available to create the equivalent of 0.125 g step at output (whatever is the sensor's full scale).

Power supply input is insulated from the rest of the electronics in the sensor to avoid any ground loop.

Finally a digital interface (RS-485) using MODBUS protocol is provided to retrieve sensor "state of health" (SOH) during installation and maintenance. This digital sensor is named "iSensor". The required software is provided for running on a computer (Running Windows OS). More details can be found in section 4.6.

4.5. Connection

The AC-7x-DH accelerometer is supplied with a cable mounted at factory. It uses 12 wires for the full signal interface. The connector pin assignment and cable colour code is as per DIN47100:

Pin	SIGNAL	Comment	Colour	
1	OUTPUT X (+)	0 V \pm 5 V voltage output, 100 Ω output impedance	White	
2	OUTPUT X (-)	0 V \pm 5 V voltage output inverted, 100 Ω output impedance	Brown	
3	OUTPUT Y (+)	0 V \pm 5 V voltage output, 100 Ω output impedance	Green	
4	OUTPUT Y (-)	0 V \pm 5 V voltage output inverted, 100 Ω output impedance	Yellow	
5	OUTPUT Z (+)	0 V \pm 5 V voltage output, 100 Ω output impedance	Grey	
6	OUTPUT Z (-)	0 V \pm 5 V voltage output inverted, 100 Ω output impedance	Pink	
7	TEST INPUT	Test input, each axis output will have the equivalent of a 0.125 g step when activated high (+8 to +18 V toward GND)	Blue	
8	GND	Electrical ground reference, connected to recorder's ground signal	Red	
9	+12 VDC power	Power input, +9.5 to +18 VDC range, 80 mA @ +12 VDC	Black	
10	0 VDC power	Power return	Violet	
11	RS-485 D-	iSensor interface, RS-485, "DATA-" wire	-	
12	RS-485 D+	iSensor interface, RS-485, "DATA+" wire	-	

Table 3. AC-7x-DH Cable Wire Assignment and Colour Code

When a GeoSIG connector is mounted at the cable end, the pin number is show in the first column. In case of a custom connector, please refer to the separate document which will be included with the sensor.

4.6. iSensor interface

The AC-73-DH sensor is an intelligent sensor (iSensor) containing the following additional sensors to simplify the installation.

- Temperature sensor
- Humidity sensor
- Tilt sensors
- Magnetic compass

The humidity sensor can be used for verification of the water tightness of the sensor after its installation. The tilt sensors give a feedback if the sensor is aligned vertically in the down-hole and the magnetic compass helps to align the sensor axes.



The communication with the iSensor should be checked before the sensor is installed in the down-hole.

4.6.1. Preparation

For communication with the iSensor AC-73-DH, the following are required:

- AC-73-DH sensor
- Computer with serial port and *iSensorUI* software
- RS-485 to RS-232 converter (not required in case the computer provides an RS-485 port)
- 15 VDC power supply

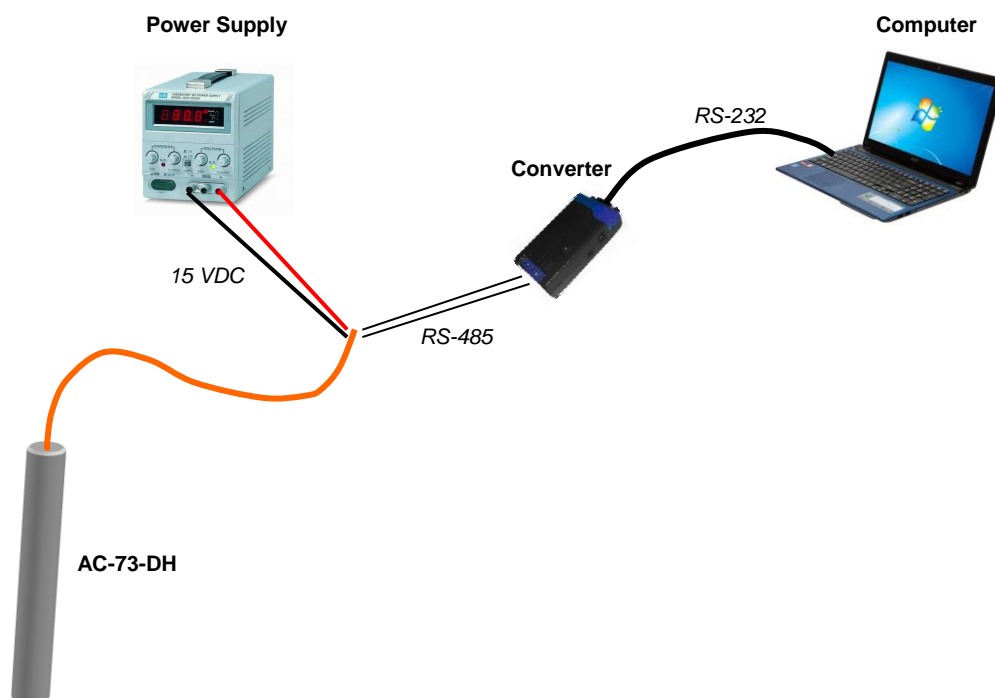


Figure 6. Overview of cabling

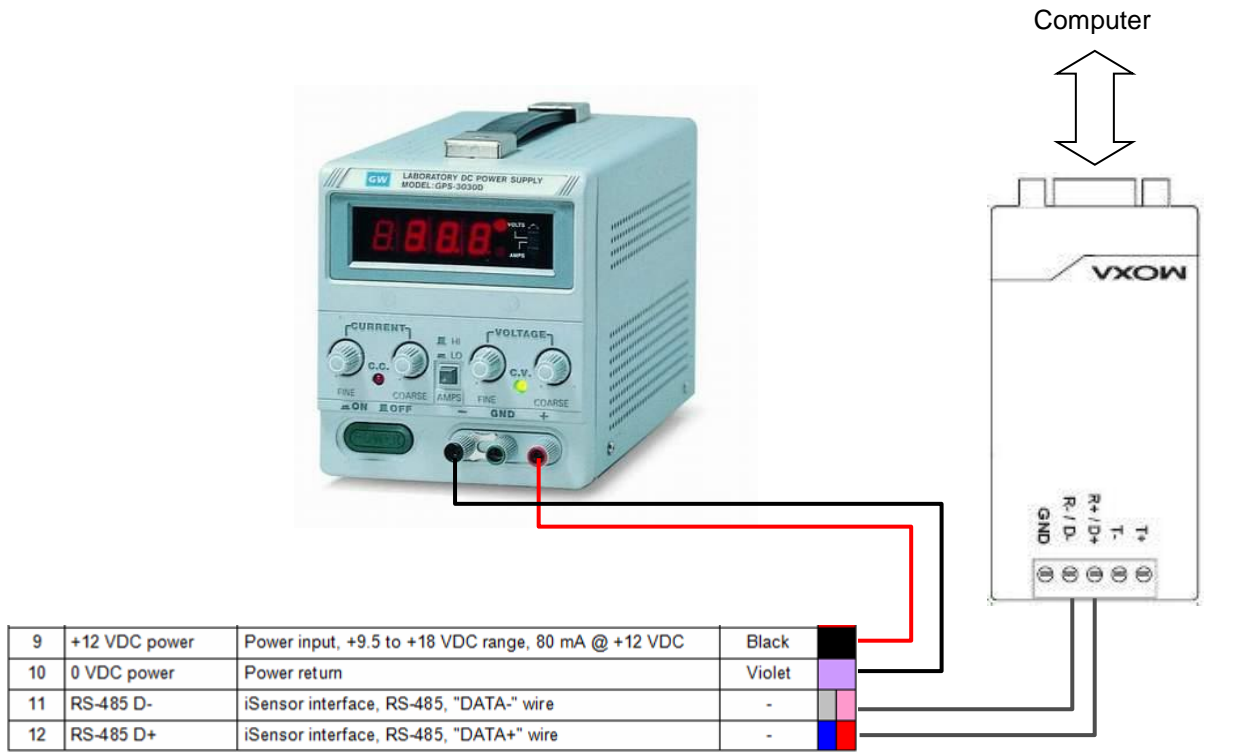


Figure 7. Detailed cabling



Make sure no shortcuts are made between all the other wires of the cable.

4.6.2. Installation of the Software

To install the user interface, extract the content of the file **iSensorUI.zip** to any folder on your computer (e.g. C:\iSensorUI\). The following files should be present in the folder after extraction:

- iSensorUI.exe
- libmodbus-5.dll
- iSensor_Expert.bat
- iSensor_Start.bat

4.6.3. Simple User Interface

Make sure that the sensor is powered and the setup is wired according to the Figure 6 and Figure 7. Then double-click on **iSensor_Start.bat**.

The following command prompt appears

Enter COM Port Number:

Enter the number of the serial port that the sensor is connected to. In case of COM1, just type '1', in case of COM2, type '2', etc... If you are unsure about the serial port, please check in Windows under Start → Control Panel → System → Device Manager.



Only serial port numbers COM1 to COM9 are supported.

The following screen should appear, plotting the readings from the internal sensors every second.

Enter COM Port Number: 1						
Time	T(deg C)	RH (%)	TiltX(deg)	TiltY(deg)	MH, (deg)	
2013/11/07 18:23:33	26.5	38.4	0.5	-0.5	203.0	
2013/11/07 18:23:34	26.5	38.4	0.5	-0.5	203.0	
2013/11/07 18:23:35	26.5	38.4	0.5	-0.5	202.4	
2013/11/07 18:23:36	26.5	38.4	0.5	-0.5	203.0	
2013/11/07 18:23:37	26.5	38.4	0.5	-0.5	203.2	
2013/11/07 18:23:38	26.5	38.4	0.5	-0.5	203.5	
2013/11/07 18:23:39	26.5	38.4	0.5	-1.0	202.9	
2013/11/07 18:23:41	26.5	38.4	0.5	-1.0	202.8	
2013/11/07 18:23:42	26.5	38.4	0.5	-1.0	202.5	
2013/11/07 18:23:43	26.5	38.4	0.5	-1.0	202.9	

- Time: Time of the reading
- T: Temperature inside the AC-73-DH down-hole sensor in °C
- RH: Relative humidity inside the AC-73-DH down-hole sensor in %
- TiltX: Tilt of the AC-73-DH sensor tube in direction of the X axis in °
- TiltY: Tilt of the AC-73-DH sensor tube in direction of the Y axis in °
- MH: Magnetic heading of the Y axis. When the MH is showing 0°, then the Y-axis points to the direction north. In case of 90°, the Y-axis points east, 180° for south and 270° for west.

At the same time, the values are logged into the file **iSensor_Output_YYYYMMDD_HHMMSS.csv**, whereas YYYYMMDD_ HHMMSS stands for the year (YYYY), month (MM), day (DD), hour (HH), minute (MM) and second (SS) when the measurement has started. For example the file name could be: **iSensor_Output_20131107_182333.csv**

The program measurement can be stopped by closing the command prompt window or pressing **<CTR> + 'C'**.

The CSV file can be opened by any text editor or the Microsoft Excel for further analysis.

	A	B	C	D	E	F	G
1	Time	T(C deg)	RH(%)	TiltX(deg)	TiltY(deg)	MH(deg)	
2	07.11.2013 18:23	26.5	38.4	0.5	-0.5	203	
3	07.11.2013 18:23	26.5	38.4	0.5	-0.5	203	
4	07.11.2013 18:23	26.5	38.4	0.5	-0.5	202.4	
5	07.11.2013 18:23	26.5	38.4	0.5	-0.5	203	
6	07.11.2013 18:23	26.5	38.4	0.5	-0.5	203.2	
7	07.11.2013 18:23	26.5	38.4	0.5	-0.5	203.5	
8	07.11.2013 18:23	26.5	38.4	0.5	-1	202.9	
9	07.11.2013 18:23	26.5	38.4	0.5	-1	202.8	
10	07.11.2013 18:23	26.5	38.4	0.5	-1	202.5	
11	07.11.2013 18:23	26.5	38.4	0.5	-1	202.9	
12							
13							

Figure 8. CSV file opened in the Microsoft Excel

4.6.4. Compass Calibration



Compass calibration shall be done before the installation of the AC-73-DH sensor.

Make sure that the sensor is powered and the setup is wired according to the Figure 6 and Figure 7. Then double-click on **iSensor_Compass_Calibration.bat**.

The following command prompt appears:

```
Enter COM Port Number:
```

Enter the number of the serial port to which the sensor is connected. In case of COM1, just type '1', in case of COM2, type '2', etc... If you are unsure about the serial port, please check in Windows under Start → Control Panel → System → Device Manager.



Only serial port numbers COM1 to COM9 are supported.

Then follow the instructions on the screen. After the calibration is finished, the correction factors are stored into the iSensor.

4.6.5. Expert Mode

A double-click on **iSensor_Expert.bat** starts the expert mode of the iSensorUI software. The help content will be shown immediately.

The iSensorUI software can be started with several parameters.

```
isensorui -parameter value
```

Parameter	Value	Description
-h	-	Shows the help text
-a	show-sensors	Shows the measurements of the iSensor
	Show-fw-ver	Shows the firmware version of the iSensorUI
	calibrate-compass	Starts the calibration of the compass
-p	COM1, COM2, COM3, ...	Serial port for the communication with the sensor
-b	1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200	Baud rate of the serial port (default is 9600)
-s	1, 2, 3, ...	Slave address of the AC-73-DH iSensor (default is 1)
-t	1 ... 3600	Delay in seconds between the measurements (default is 1)
-l	1, 2, 3, ...	Limit the read values by the specified value. Program stops when the specified measurements have been done
-o	filename.csv	Print the sensor values to the selected CSV file
-V	-	Show the version of the software

4.6.5.1. Example 1

The sensor is connected to **COM1** and **iSensor values shall be plotted**.

```
isensorui -p COM1 -a show-sensors
```

Then the sensor sends the measurements as shown below to the screen.

Time		T(deg C)	RH (%)	TiltX(deg)	TiltY(deg)	MH, (deg)
2013/11/07	16:39:35	26.5	38.1	0.5	-0.5	203.0
2013/11/07	16:39:36	26.5	38.1	0.5	-1.0	203.0
2013/11/07	16:39:37	26.5	38.1	0.5	-1.0	202.4
2013/11/07	16:39:38	26.5	38.1	0.5	-1.0	203.0
2013/11/07	16:39:39	26.5	38.1	0.5	-1.0	203.2

4.6.5.2. Example 2

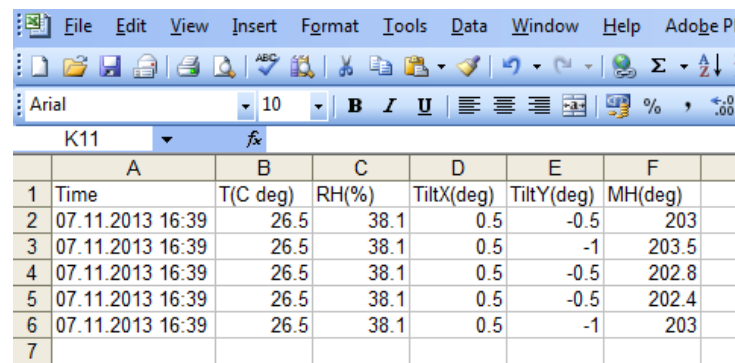
The sensor is connected to **COM4** and **iSensor** values shall be plotted and saved to the file **installation.csv** every 5 seconds.

```
isensorui -p COM4 -a show-sensors -o installation.csv -t 5
```

Then the sensor sends the measurements as shown below to the screen.

Time		T(deg C)	RH (%)	TiltX(deg)	TiltY(deg)	MH, (deg)
2013/11/07	16:39:35	26.5	38.1	0.5	-0.5	203.0
2013/11/07	16:39:40	26.5	38.1	0.5	-1.0	203.5
2013/11/07	16:39:45	26.5	38.1	0.5	-0.5	202.8
2013/11/07	16:39:50	26.5	38.1	0.5	-0.5	202.4
2013/11/07	16:39:55	26.5	38.1	0.5	-1.0	203.0

Additionally the data are stored in the CSV file *installation.csv*



	A	B	C	D	E	F	
1	Time	T(C deg)	RH(%)	TiltX(deg)	TiltY(deg)	MH(deg)	
2	07.11.2013 16:39	26.5	38.1	0.5	-0.5	203	
3	07.11.2013 16:39	26.5	38.1	0.5	-1	203.5	
4	07.11.2013 16:39	26.5	38.1	0.5	-0.5	202.8	
5	07.11.2013 16:39	26.5	38.1	0.5	-0.5	202.4	
6	07.11.2013 16:39	26.5	38.1	0.5	-1	203	
7							

4.6.5.3. Example 3

The sensor is connected to **COM2** and only **3 measurements** with an interval of **20 seconds** shall be read out from the **iSensor**.

```
isensorui -p COM2 -a show-sensors -l 3 -t 20
```

The reading stops after 3 measurements.

Time		T(deg C)	RH (%)	TiltX(deg)	TiltY(deg)	MH, (deg)
2013/11/07	16:40:00	26.5	38.1	0.5	-0.5	203.0
2013/11/07	16:40:20	26.5	38.1	0.5	-0.5	202.4
2013/11/07	16:40:40	26.5	38.1	0.5	-0.5	202.8

5. Maintenance

Maintenance should be periodically performed to ensure that the recorded data is valid and can be correctly interpreted. The issue with any strong-motion borehole sensor is that it cannot usually be retrieved after installation and that maintenance capability is therefore limited. Consequently, reliability of the sensor is vitally important for its long term maintenance-free operation.

The sensor should be opened for maintenance only by a qualified technician who has been trained by GeoSIG and has the required special tools. During the normal life of the sensor, there will be no need to open the sensor casing.

5.1. Testing

The tests outlined in this section can be performed remotely over the sensor cable without having physical access to the sensor itself. Such tests should be performed at intervals of one month to one year.

5.1.1. Test input

Basic testing is mainly done using the test input provided by applying a voltage in the range of 7 to 18 V_{DC} on wire 7 toward ground wire 8 (GND).

It should be verified that the acceleration step created at sensor output is the equivalent of 0.125 g \pm 10%.

5.1.2. Power

The second test is related to the power consumption and should establish that a current of \sim 80 mA_{DC} (could change according to sensor model) is drawn from a 12.0 V_{DC} power supply when sensor is in normal position. The sensor uses a DC/DC device to convert the input power voltage and this result is typically constant electrical power consumption and the input current will be dependent on the input voltage.

5.1.3. Offset

When used with GeoSIG recorders, offset can be compensated without losing signal range for up to \pm 10% of the output range. This corresponds to an offset of \pm 100 mV for the \pm 10 V output range. Therefore it should be checked that the voltage offset at output remains within \pm 100 mV.

5.1.4. Gain

Gain can only indirectly be verified through the test input (section 5.1.1). Absolute gain verification would require taking the sensor out of the borehole, which is usually not practical and requires a tilt or shaker calibration.

5.1.5. Noise

Specific noise measurement is not usually required during a maintenance period. It is normally the recorded data which is used to evaluate the noise performance. This naturally requires knowing clearly, what is the real seismic or human induced noise which is present at the installation location.

5.2. Calibration

Calibration can be performed before installation by doing tilt (rotation of sensor toward earth acceleration) to apply on the sensor up to \pm 1g on horizontal axes and 0 to -2 g on the vertical axes.