V1.0 September 2017

MEMS Digital Vertical In-Place Inclinometer

INSTRUCTION MANUAL

CE

GEOSENSE

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1.0 INTRODUCTION

This manual is intended for all users of In-Place Inclinometers manufactured by **Geosense®** and provides information on their principle, installation, operation and maintenance**.**

It is VITAL that personnel responsible for the installation and use of the In-Place Inclinometers READ and UNDERSTAND the manual, prior to working with the equipment.

1.1 General Description

The **Geosense® In-Place Inclinometer (IPI)** equipment is an environmentally sealed assembly that is used to register changes of inclination within specialist inclinometer casing. The assemblies are commonly interlinked and intended to remain static within the inclinometer casing.

In-Place Inclinometers can be installed or included in many types of monitoring regime and can be linked to various types of readout and recording equipment.

The primary uses of IPI's are :-

Measurement of Rotation within a vertical installation.
Measurement of Rotation within an inclined or horizontal installation.

With applications such as, but not limited to, the following :-

Embankment stability and safety monitoring
Stability of retaining walls
Dam monitoring
Horizontal pile testing
Slope stability monitoring

Particular features of **Geosense®** IPI's are:-

Reliable long term performance.
Ruggedness; suitable for demanding environments.
Simple, cable free interconnection.
High accuracy.
Digital output, therefore insensitive to long cable lengths and joints

The **Geosense®** IPI is based upon Micro Electro Mechanical Systems technology (MEMS). The MEMS sensors employed in the IPI is an accelerometer that is configured to measure changes in rotation (tilt or inclination). IPI sensor modules an be configured to include a Uni-axial sensor or a Bi-axial sensor, where the two sensors detect inclination in perpendicular directions (A axis and B axis). Electronic circuitry within each IPI module interrogates its sensor and the corresponding output is converted from an Analogue to a Digital signal, making it

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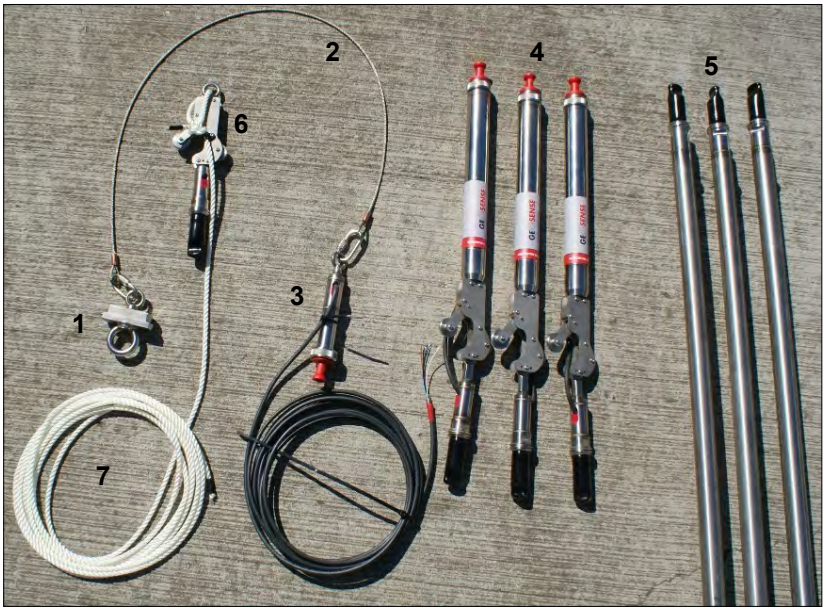
particularly suitable for the demanding environments of geotechnical and civil engineering applications. Digital signals are capable of long transmission distances without degradation.

Each **Geosense**® IPI has a unique identification number, thereby simplifying the interconnection using 4 wire digital protocols.

Geosense® IPI's are supplied in various configurations to suit a range of installations. In most applications they are installed in 'strings' where each IPI is connected to its neighbour by a 'Universal joint'.

Each IPI comprises the following elements:



1.) Top hanger - used to suspend the complete IPI string

2.) Wire hanger extension - used to position the first IPI

3.) Top fly lead assembly - top suspension adaptor and cable connector

4.) In-Place Inclinometer probe - measures tilt in uniaxial or biaxial axes

5.) Extension rod - used to connect each IPI together

6.) Bottom wheel/termination assembly - base reference wheel & RS-485 end termination

7.) Support rope - used to support the IPI string from the base

1.2 Theory of Operation

inclinometer casing is a specially machined plastic tube that is installed in, or fixed to, a structure. The tube has 4 equally spaced, parallel 'keyways' in its inner surface, into which wheeled probes can be inserted, thereby maintaining their orientation. The inclinometer casing is designed to move with the structure into which, or onto which, it is fixed, if the structure changes shape.

In order to detect any changes in the horizontal direction (vertical or inclined access tubes) or vertical direction (horizontal access tubes), an inclinometer systems is inserted into the inclinometer casing.

An inclinometer system comprises a wheeled probe that runs in the inclinometer casing keyways and includes very sensitive electronic tiltmeter(s), a connecting cable and a readout.

Portable inclinometer systems are commonly used where monitoring is to be in -frequent or manual monitoring is in-expensive. These systems are used to determine the inclination of an inclinometer casing at 0.5m intervals along it length. This information is processed to generate a profile of the inclinometer casing, with respect to vertical and sequential profiles being compared with each other to detect changes.

Geosense® In-Place Inclinometers (IPI's) are intended to remain 'in-place' within the inclinometer casing and are employed where continuous or frequent monitoring is required. The completed installation is, in effect, a string of interconnected, inclinometer probes, separated by rods or wires and suspended in the inclinometer casing.

Each **Geosense® IPI** sensor module includes a very sensitive Micro Electro-Mechanical System (MEMS) tiltmeter. The device is extremely sensitive and is detects changes in the angle of the module, if the surrounding inclinometer casing moves. Installations close to vertical can measure movements in 2 directions, whereas

Since they are digital, the cable from the IPI modules can be connected together in a 'string', thereby minimising the cables from each installation.

In most cases, **Geosense® IPI's** are mechanically inter-connected using 'Universal joints' so as to maintain a physically connected profile of measurement. This is critical if a 'truly accurate' profile of the inclinometer casing is to be measured. (Where steel rope is used to interconnect the IPI modules, a true profile cannot be measured).

In addition, it is vital that the IPI modules are suspended between the walls of the inclinometer casing and do not touch them at any time during the monitoring period.

Once installed and suspended in the inclinometer casing, the IPI sensors can be interrogated by various means. The readings from each module will be the angle of the sensors, with respect to vertical, in either degrees or 'sine of the angle' units and the temperature of the module.

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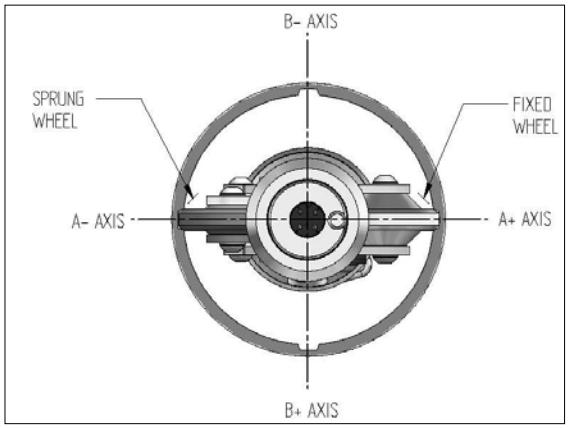
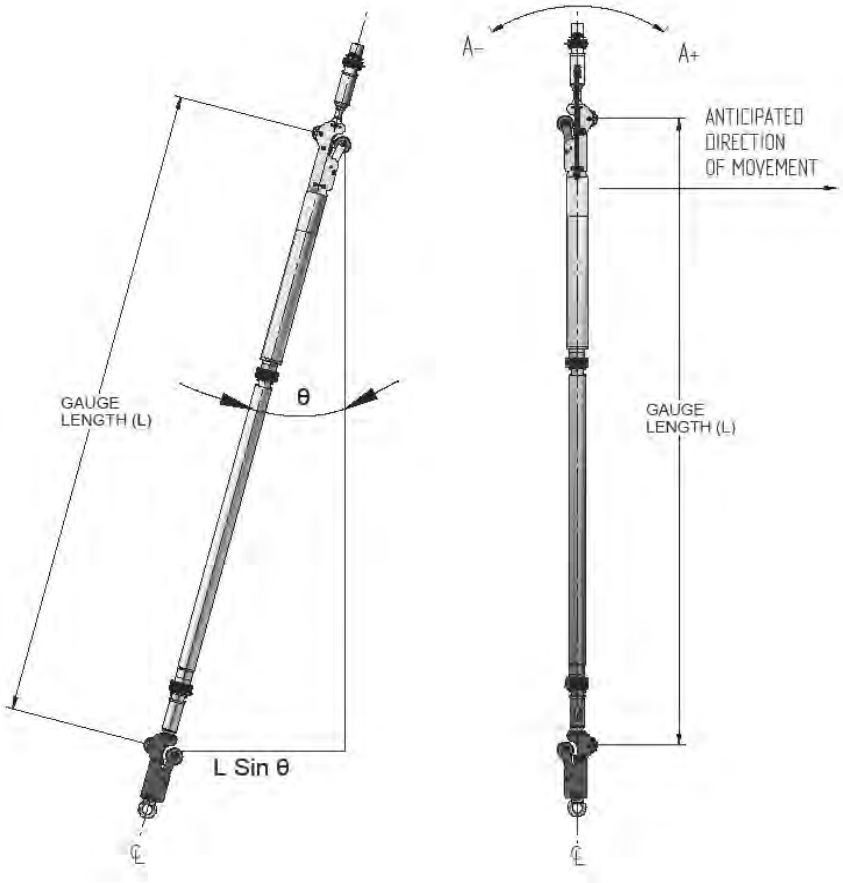
1.3 The measurement of tilt



The A axis is the primary axis and the B axis is the secondary axis. Uni-axial IPI sensors only detect changes in the A axis.

After their installation, the vertical profile of the inclinometer casing is established from the readings of individual IPI sensors. Changes to the verticality of a vertical or inclined inclinometer casing (changes in the horizontal plane) are detected by the sensor and the magnitude of the change is simply computed from the equation 'current reading - initial reading'. Horizontal IPI's detect vertical movement of the inclinometer casing.



2.0 CONFORMITY

Geosense Ltd
Nova House
Rougham Industrial Estate
Rougham, Bury St Edmunds
IP30 9ND
Email: info@geosense.co.uk
Web: www.geosense.co.uk.

Declaration of Conformity

We **Geosense**® Ltd at above address declare under our sole responsibility that the **Geosense**® products detailed below to which this declaration relates complies with protection requirements of the following harmonized EU Directives:-

The Electromagnetic Compatibility Directive 2014/30/EU
Restriction on the use of certain Hazardous Substances RoHS2 2011/65/EU

Equipment description	MEMS Digital IPI
Make/Brand	**Geosense**
Model Numbers	IPI-V-1, IPI-V-2, IPI-I-1, IPI-I-2, IPI-H-1, IPI-H-2

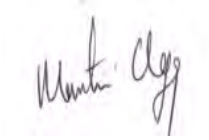
Compliance has been assessed with reference to the following harmonised standard:

EN 61326-1:2013Electrical equipment for measurement, control and laboratory use.
EMC requirements. General requirements.

EN 61010 (2010) Safety requirements for electrical equipment for measurement, control, and laboratory use. General requirements.

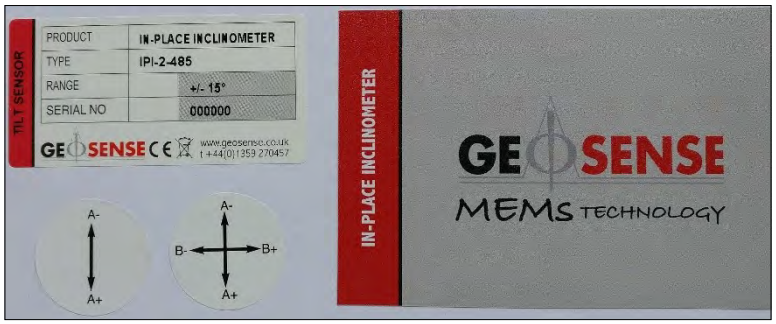
A technical file for this equipment is retained at the above address.

Martin Clegg
Director



September 2017

3.0 MARKINGS



A **Geosense® Digital MEMS In-place Inclinometer systems** are labelled with the following information:-

Manufacturers telephone number & website address

Product group: MEMS Inclinometer system

Product type: MEMS In-place inclinometer system

Model: IPI-V-1, IPI-V-2, IPI-I-1, IPI-I-2, IPI-H-1, IPI-H-2

Range: +/- 15º

Orientation: Uni-axial or biaxial

Input supply: 8-15 Volts DC

Output signal: RS-485

Serial number: XXXXXX

CE mark

WEEE mark

4.0 DELIVERY

This section should be read by all users of IPI's manufactured by **Geosense®** .

4.1 Packaging

Geosense® IPI's are packed for transportation to site. Packaging is suitably robust to allow normal handling by transportation companies. Inappropriate handling techniques may cause damage to the packaging and the enclosed equipment. The packaging should be carefully inspected upon delivery and any damage MUST be reported to both the transportation company and **Geosense®**.

4.2 Handling

Whilst they are a robust devices, **Geosense®** IPI's are precision measuring instruments. They, and their associated equipment, should always be handled with care during transportation, storage and installation.

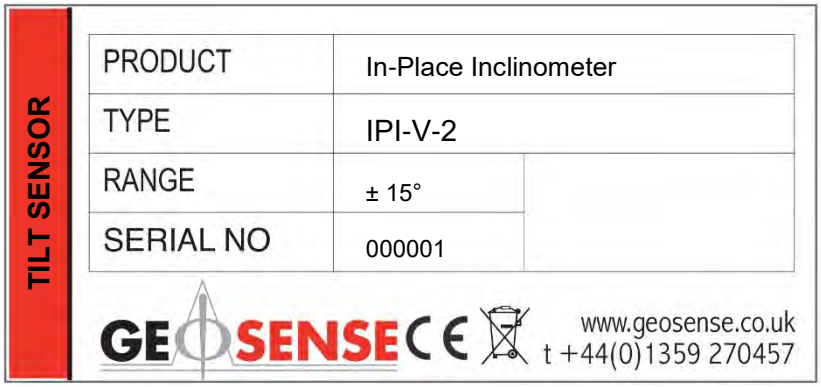
Once the shipment has been inspected (see below), it is recommended that IPI's remain in their original packaging for storage or onward transportation.

Cable should also be handled with care. Do not allow it to be damaged by sharp edges, rocks for example, and do not exert force on the cable as this may damage the internal conductors and could render an installation useless.

4.3 Inspection / functionality check readings

It is important to check all the equipment in the shipment as soon as possible after taking delivery and well before installation is to be carried out. Check that all the components detailed on the documents are included in the shipment. Check that the equipment has not been physically damaged.

ALL **Geosense®** IPI's carry a **unique** identification serial number which is included on the labels on the IPI body (see right). All IPI's are supplied with individual calibration sheets that include their serial numbers and these are shipped with the equipment.



Wherever possible, it is suggested that the IPI's should be functionally checked soon after arrival to ensure they have not been damaged during transportation. This is a basic 'out of the box' functional check. Ensure that the IPI's have been stored in a reasonably stable temperature for at least 60 minutes prior to carrying out a functional check. To carry out the check, follow the steps detailed in Section 6 of this manual.

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4.4 Storage

All equipment should be stored in an environment that is protected from direct sunlight. It is recommended that cables be stored in a dry environment to prevent moisture migrating along inside them in the event of prolonged submersion of exposed conductors.

Storage areas should be free from rodents as they have been known to damage connecting cables.

No other special requirements are needed for medium or long-term storage although temperature limits should be considered when storing or transporting associated components, such as readout equipment.

Calibration Sheets contain VITAL information about the IPI's
We suggest that only COPIES of calibration certificates should be taken to site
The original certificates should be stored safely

5.0 INSTALLATION

This section of the manual is intended for all installers of **Geosense®** IPI's and is intended to provide guidance with respect to their installation.

It must be remembered that no two installations will be the same and it is inevitable that some 'fine tuning' of the following procedures will be required to suit specific site conditions.

It is VITAL that personnel responsible for the installation and use of the piezometers READ and UNDERSTAND the manual, prior to working with the equipment.

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As stated before, it is vital to check all the equipment in the shipment soon after taking delivery and well before installation is to be carried out. Check that all components that are detailed on the shipping documents are included.

5.1 Preparation for Installation

IPI's are designed to be installed within specialist inclinometer casing. The casing must be either installed in a borehole of fixed firmly to a structure. Prior to installation of an IPI, it is essential to establish and confirm details of the installation to be carried out. Some of the main considerations are listed below :-

1. **Intended elevation and length of each IPI element**
   An IPI comprises a series of interconnected elements. The uppermost wheel set must be located a minimum of 250mm from the top of the inclinometer casing so as to accommodate the support and cable connection components. This distance can be varied by adjusting the length of the wire hanger extension (stainless steel rope).

   The IPI probes are the measuring elements and the separation between the IPI probes (referred to as the 'Gauge Length) is maintained by extension rods. Standard extension rods are available to provide 1, 2 and 3 metre gauge lengths and the gauge lengths can vary within a single installation.

   For example; an IPI installed in an inclinometer casing in a landslip might use 3m gauge lengths in its upper zone (within the slip body) and 1m gauge lengths in the slip zone.

2. **Directional Orientation**
   The primary measuring axis of the IPI is A+ / A- which is the same orientation as the wheels. The A+ direction corresponds to the direction of the **FIXED WHEEL** and, consequently, A - is in the direction of the **SPRUNG WHEEL**.

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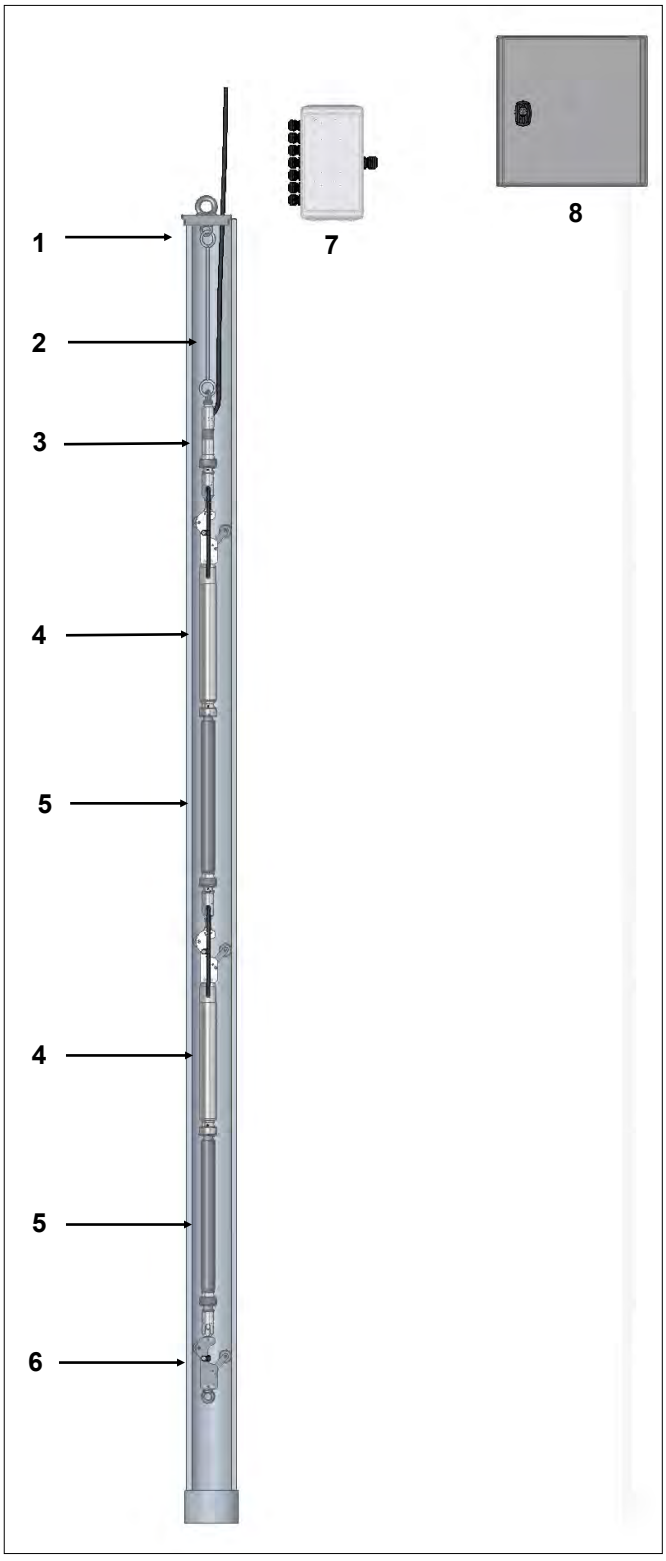
3. **Cable**
Cables should be marked with a unique identification system. Where multiple cables are to be grouped together along one route, markings should be repeated at regular intervals along the cable, so that in the event of cable damage, there may be a chance that the identification could be exposed and the cables re-joined. Multiple cable marks are particularly important close to the ends of the cables. The spacing of markings can vary according to specific site requirements. As a guide, 5m to 10m is commonly applied, but closer spacing nearer the ends.

4. **Tools**
Obtain any tools necessary to carry out the installation. The following is a brief list of tools typically used during the installation of In-Place Inclinometers. Some variation and addition may be necessary for different types of application.

- Fibre measuring tape with a weight added to the end for borehole depth measurement
- Installation fork
- Support rope
- Suitable readout
- Lifting equipment (for deep installations) which must meet all local safety requirements

5.2 System components - extension rod version

Illustrated below are the typical components of a typical IPI installation



1 - TOP HANGER
Used to suspend the complete IPI string. Placed on the top of the 70mm inclinometer casing

INSTALLATION FORK - (not shown)
Used to support the IPI string during installation. It fits into two slots on top of the IPI sensor and is placed on top of the inclinometer casing

2 - TOP STEEL WIRE BOND
A 3mm wire suspension rope used to position the first sensor at the required depth and is connected to the top collar hanger and the IPI top fly lead assembly (G86-502). Available either as pre-assembled lengths (1, 2, 3, 4m) or supplied as site adjustable

3 - IPI TOP FLY LEAD ASSEMBLY
A universal component which acts as top suspension and cable connector. Fitted as standard with 4.5m of digital BUS cable for connection to a readout or data logger. Other cable lengths available on request.

4 - IN-PLACE INCLINOMETER PROBE (IPI)
Instrument fitted with one (Uniaxial) or two (Biaxial) MEMS sensors. It is mounted within a watertight stainless steel tube fitted with two wheel sets that run in the internal grooves of inclinometer casing. One set has a fixed wheel and the other is sprung loaded. The output from the sensors is digital RS-485 BUS so that several IPIs can be connected together on one single cable

5 - EXTENSION RODS
Used to connect each IPI sensor together to create a tilt profile. Specially designed quick connecting fittings on each end, together with an integral internal signal cable. Available in 0.5, 1, 1.5, 2, 3m lengths. (Special lengths are available on request)

6 - BOTTOM WHEEL/TERMINATION ASSEMBLY
Fitted with a rigid joint, the bottom wheel assembly acts as the base reference from which all other readings are taken. It is fitted with an integral end termination resistor which is required at the end of the RS-485 string

7 - WI-SOS 480 WIRELESS DIGITAL NODE
Up to 30 IPI sensors can be attached to each node

8 - GEOLOGGER G8 PLUS
Automatic data acquisition system

5.3 Installation with extension rods

STEP 1 - Assemble the component parts required for a the installation.

STEP 2 - Remove the **BLACK** end cap from the end of one of the rods.

Note the locating socket on this 'male' connector.

STEP 3 - Remove the **RED** plug from the end of an IPI sensor.

(Continued on page 15)

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5.3.Installation with extension rods contd….

Note the corresponding locating pin in the 'Female' end of the interconnection on the IPI sensor

STEP 4 - Offer the two sides of the connector together, aligning the positions of the locating pin and socket

STEP 5 - Push the two halves of the joint together until the threads meet

STEP 6 - Rotate the threaded locking ring until the locking spring clip 'snaps' into place.

It is not necessary to tighten further

If the connections needs to be undone the safety clip should be undone using a screwdriver or similar tool

(Continued from page 15)

Geosense IPI's always have the IPI module at the top of any extension rod

5.3 Installation with extension rods contd….

The bottom wheel assembly should always be installed first

To reduce the installation time it all the rods and sensors can be pre-assembled.

STEP 7 - Connect a length of rope to the bottom wheel assembly using the loop provided.

Shown here is the rope passing through the plastic cable clip, for neatness, but this is not essential.

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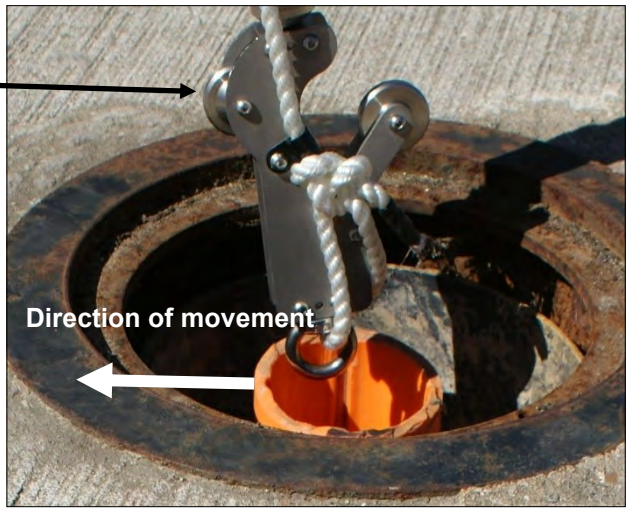
(Continued from page 16)

5.3 Installation with extension rods contd….

8. Remove the red end cap from the end of the extension rod that is going to be connected to the lowest sensor.

STEP 8 - Connect the first extension rod to the bottom wheel assembly making sure to check the ‘pin - socket’ alignment and tighten the connector until the locking clip ’snaps’ into place.



The ‘fixed’ wheel should be located in the keyway in the direction of the expected of movement

Carefully lift the assembly up to vertical and position it over the inclinometer casing, ready for installation.

Ensure that the installation fork is available to be used when the first length is installed.

(Continued on page 18)

(Continued from page 17)

Consequently, the 'sprung' wheel should be located in the keyway in the inclinometer casing **opposite** to the direction of expected movement.

5.3 Installation with extension rods contd….

STEP 9 - Lower the wheel assembly into the inclinometer casing, taking care to orientate the wheels correctly.

STEP 10 - As the assembly is lowered, insert the installation fork into the slots located at the uppermost end of the extension rod (under the IPI module) and continue to lower the assembly.

For added security, fasten the safety rope to a secure object.

STEP 11 - Continue lowering the assembly until the installation fork rests on the top of the borehole

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5.3 Installation with extension rods contd….

STEP 12 - Remove the **RED** dust cap from the lower connector of the next extension rod and sensor assembly to be installed

STEP 13 - Remove the top **BLACK** dust cap from the previously installed IPI sensor and carefully align the

Check to ensure that all connections are free from dust and debris

next extension rod with the sensor

STEP 14 - Tighten the connector and engage the ‘snap clip’.

STEP 15 - Raise the assembly a little and remove the installation fork

STEP 16 - Loosen the safety rope and

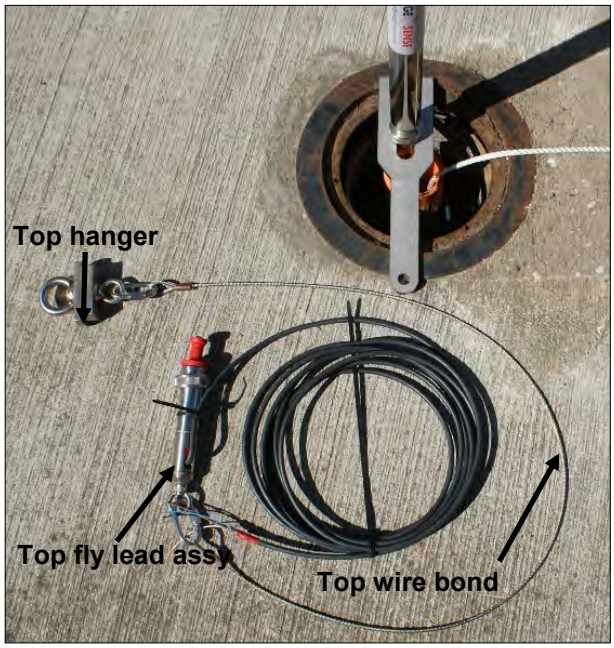
(Continued on page 20)

(Continued from page 19)

lower the assemblies into the inclinometer casing ensuring the wheels are in the same keyways as the bottom wheel assembly

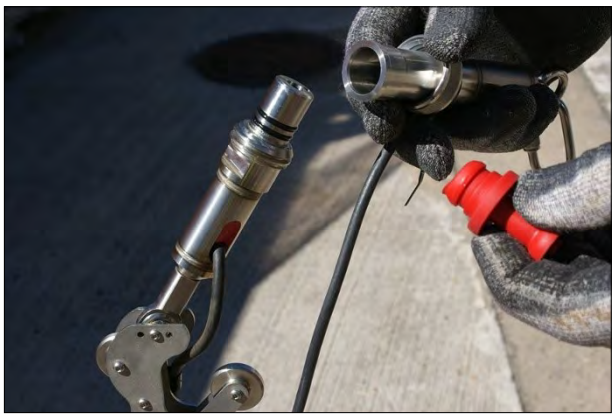
Repeat steps 15 to 20 until all the IPI modules are connected.

5.3 Installation with extension rods contd….



STEP 17 - Connect one end of the top wire bond to the top hanger

The top wire bond is available in pre-assembled lengths (1,2,3,4 etc) or can be provided so it can be adjusted on site



STEP 18 - Connect the other end of the top wire bond to the top fly lead assembly.

STEP 19 - Remove the dust caps and align the connections of the top IPI sensor and the top fly lead assembly

STEP 20– Connect both together.

Note the two red spots on each provide a visual guide for alignment

(Continued on page 21)

(Continued from page 20)

5.3 Installation with extension rods contd….

STEP 21 - with the assembly

The top fly lead assembly is a universal component which acts as the top suspension adaptor and cable connector

suitably and safely supported remove the spport tool

STEP 22 - Loosen the safety rope and lower the assemblies into the inclinometer casing ensuring that the wheels are aligned in the correct grooves

(Continued on page 22)

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5.3 Installation with extension rods contd….

STEP 21 - Continue lowering the a assembly until the top hanger unit rests on the top the inclinometer casing

IPI ASSEMBLIES SHOULD ALWAYS BE SUSPENDED

NEVER REST THEM ON THE BOTTOM WHEEL ASSEMBLY

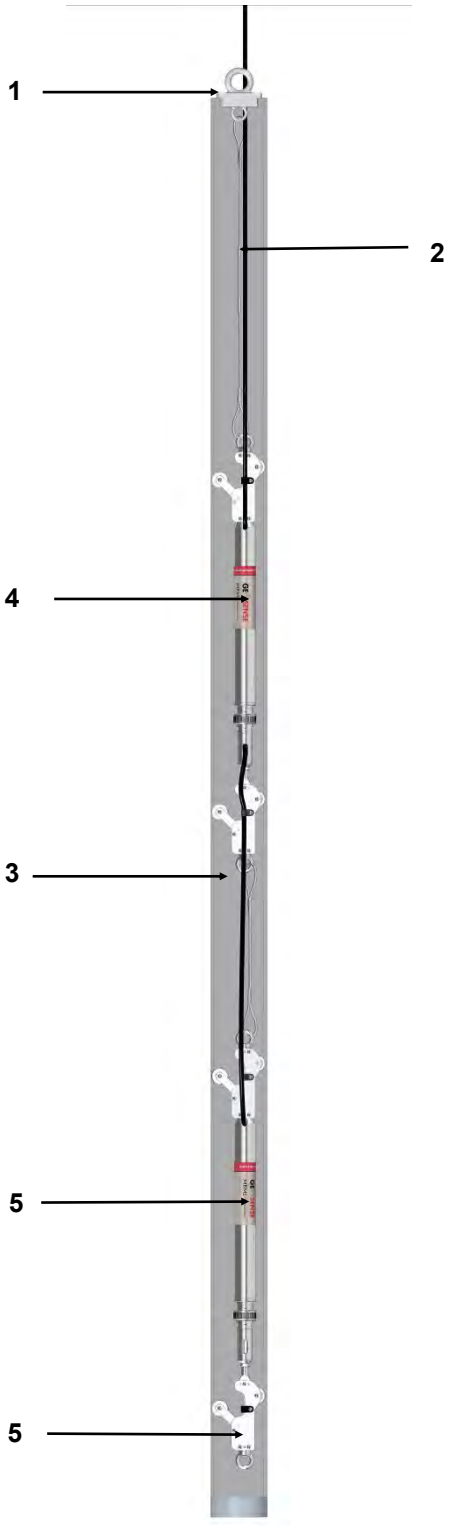
(It is good practice to mark the position of the top hanger on the inclinometer casing,

A PROTECTIVE COVER SHOULD BE USED TO PREVENT UNAUTHORISED ACCESS

so it can re-located if removal is

5.4 System components - wire rope

Illustrated below are the typical components of a typical wire rope IPI installation



1 - TOP HANGER
Used to suspend the complete IPI string. Placed on the top of the 70mm inclinometer casing

INSTALLATION FORK - (not shown)
Used to support the IPI string during installation. It fits into two slots on top of the IPI sensor and is placed on top of the inclinometer casing

2 - TOP STEEL WIRE BOND
A 3mm wire suspension rope used to suspend the top sensor and the total string from the top collar hanger. Available either as pre-assembled lengths (1, 2, 3, 4m) or supplied as site adjustable

3 - INTERMMEDIATE WIRE BOND
A 3mm wire suspension rope used to suspend and connect each IPI-WR sensor. Available either as pre-assembled lengths (0.5, 1.0, 1.5, 2.0, 2.5m) or supplied as site adjustable. These are used to connect each IPI sensor together

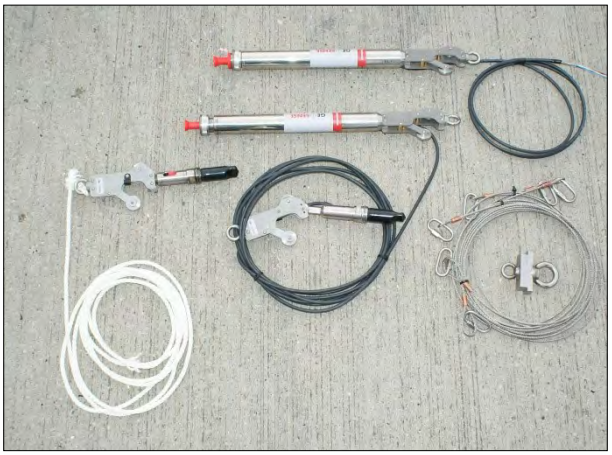
4 - IPI-WR TOP PROBE
Instrument fitted with one (Uniaxial) or two (Biaxial) MEMS sensors. It is mounted within a watertight stainless steel tube fitted with two wheel sets that run in the internal grooves of inclinometer casing. One set has a fixed wheel and the other is sprung loaded. The output from the sensors is digital RS-485 BUS and it is located at the top of the IPI string.

5 - IPI-WR PROBE
Instrument fitted with one (Uniaxial) or two (Biaxial) MEMS sensors. It is mounted within a watertight stainless steel tube fitted with two wheel sets that run in the internal grooves of inclinometer casing. One set has a fixed wheel and the other is sprung loaded. The output from the sensors is digital RS-485 BUS so that several IPIs can be connected together on one single cable

6 - BOTTOM WHEEL/TERMINATION ASSEMBLY
Fitted with a rigid joint, the bottom wheel assembly acts as the base reference from which all other readings are taken. It is fitted with an integral end termination resistor which is required at the end of the RS-485 string

5.5 Installation with wire rope

STEP 1 - Assemble the component parts required for a the installation.



STEP 2 - Identify which sensor is to be located at the **base** of the installation and remove the **RED** plug .

.

STEP 3 - Remove the **BLACK cap** from the end of the bottom wheel/termination assembly

Note the locating socket on this 'male' connector.

5.5 Installation with wire rope contd...

Note the corresponding locating pin in the 'Female' end of the interconnection on the IPI sensor

STEP 4 - Offer the male connection on the bottom wheel assembly to the female connection on the bottom sensor aligning the positions of the locating pin and socket.

STEP 5 - Push the two halves of the joint together until the threads meet.

The red dots provide a visual help for the alignment

STEP 6 - Once the connections are pushed together rotate the threaded locking ring until the locking spring clip 'snaps' into place.

It is not necessary to tighten further.

5.5 Installation with wire rope contd...

STEP 7 - Connect a length of safety rope to the bottom wheel assembly using the loop provided.

Shown here is the rope passing through the plastic cable clip, for neatness, but this is not essential.

STEP 8 - Carefully lower the bottom wheel assembly and the IPI sensor into the inclinometer casing.

Ensure that the installation fork is available to be used.

The 'fixed' wheel should be located in the keyway in the direction of the expected of movement

Consequently, the 'sprung' wheel should be located in the keyway in the inclinometer casing **opposite** to the direction of expected movement.

STEP 9 - Continue to lower the assembly into the casing

5.5 Installation with wire rope contd...

STEP 10 - once the top of the assembly nears the top of the casing place the installation fork into the slots on the top of the connector to support the assembly ready for the next part of the installation

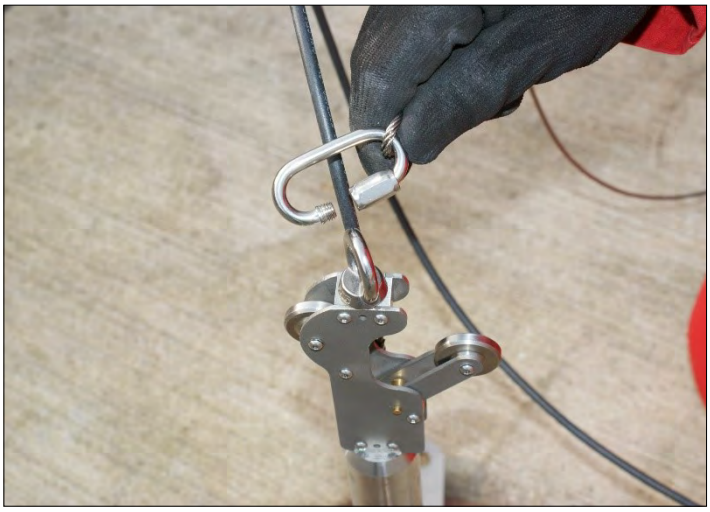
STEP 11 - identify the next IPI sensor to be installed and remove the **RED** plug from the connector

STEP 12 - align the two connections

5.5 Installation wire rope contd...

STEP 13 - tighten the two connectors together as in **STEP 6**

STEP 14 - connect the Rapid Link on one end of an intermediate wire rope support onto the top of the IPI sensor



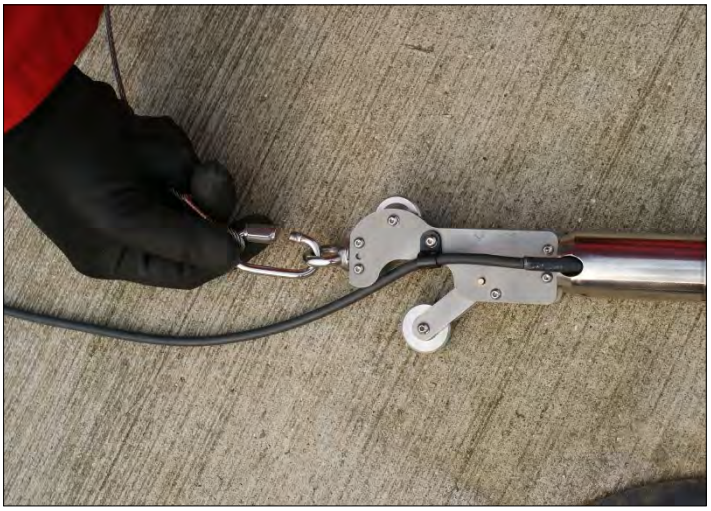
STEP 15 - lift to remove the installation fork and lower the assembly into the casing

5.5 Installation with wire rope contd...

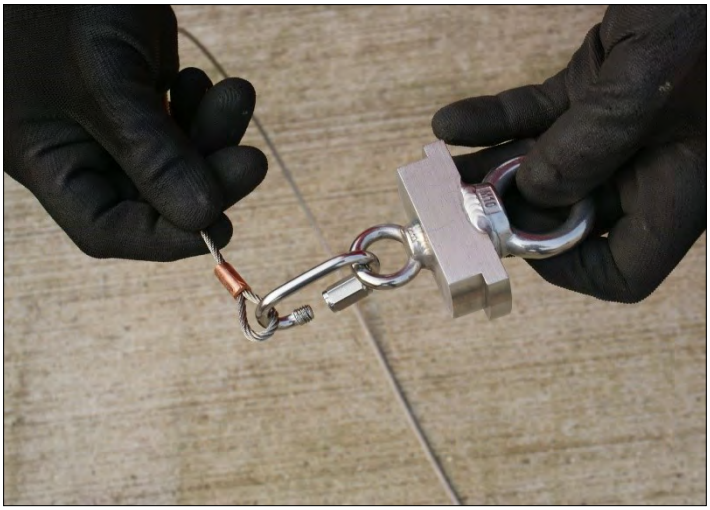
STEP 16 - continue to lower the assembly into the casing

REPEAT FOR ALL SENSORS

STEP 17 - identify the **top IPI sensor** and connect one end of the top support wire rope using the Rapid Link



STEP 18 - attach the other end of the top support wire to the top collar hanger



5.5 Installation with wire rope contd...

STEP 19 - lower the assembly gently into the casing

STEP 20 - once the top collar hanger rests on the top of the casing secure the support rope to its final location.

IPI ASSEMBLIES SHOULD ALWAYS BE SUSPENDED

NEVER REST THEM ON THE BOTTOM WHEEL ASSEMBLY

A PROTECTIVE COVER SHOULD BE USED TO PREVENT UNAUTHORISED ACCESS

5.6 Wiring

5.6.1 Colour coding

The colour coding of the cable from the IPI is as in accordance with follows:-

Brown **V+**

White **Ground**

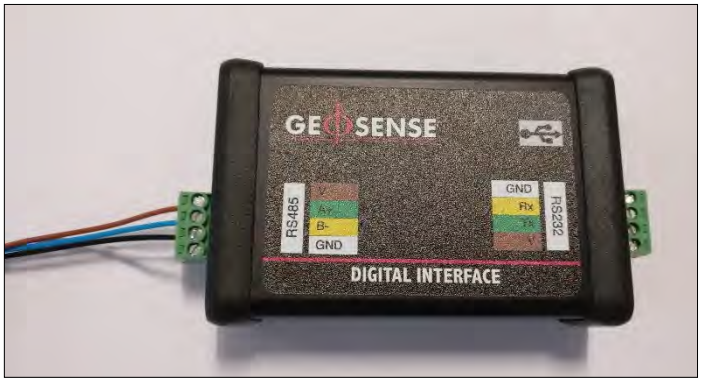
Blue **A+**

Black **B-**

5.6.2 RS-485 to RS-232 Interface

Depending on what type of readout (Windows tablet) or datalogger (e.g. Campbell Scientific) being used with the Geosense IPI an RS-485 to RS-232 Interface module may be required (see below).

Various types of screened cables are available and the Interface has been designed to be used with DIN 47100 colour coding.



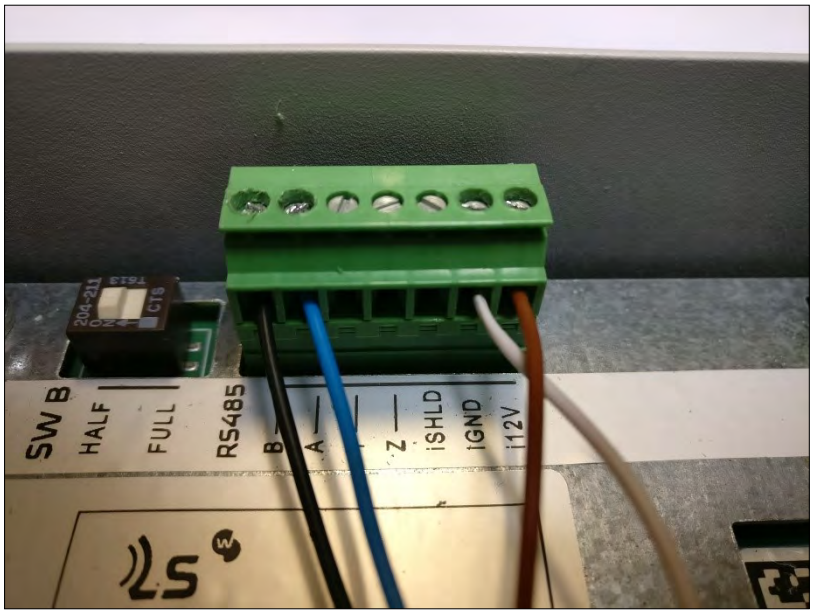
IPI conductor colour	RS-485 colour IN	RS-232 colour OUT
V+ (Volt)	V	V
A +	A+	Tx
B-	B-	Rx
Ground	GND	GND

Please note that the interface is designed to be used with cables having a DIN 47100 colour coding

5.6 Wiring contd...

5.6.3 WI-SOS 480 Digital Node

The **Geosense® In-Place Inclinometer (IPI)** is fully compatible with the WI-SOS 480 Digital Node and is wired as shown below. (Please refer to the WI-SOS 480 manual for further details on configuration)



IPI conductor colour	Digital Node colour IN
V+ (Volt)	12V
A +	A+
B-	B-
Ground	GND

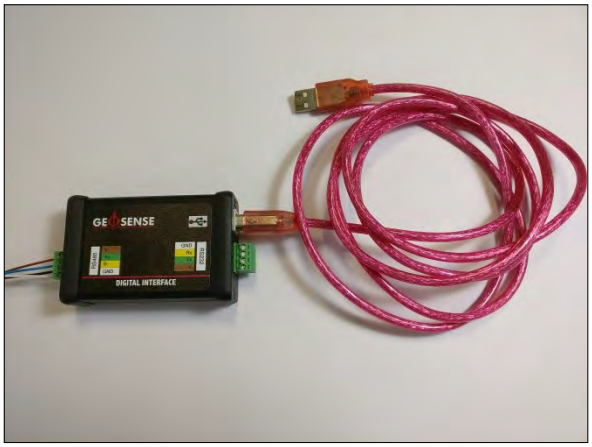
5.6 Wiring contd...

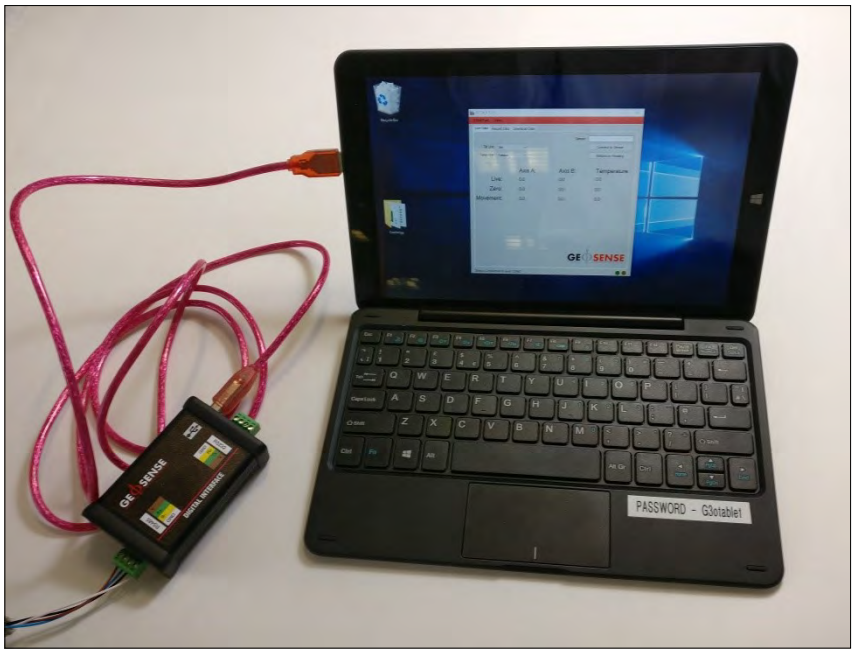
5.6.4 Windows Tablet

The **Geosense® In-Place Inclinometer (IPI)** can be read directly with a Windows Tablet such as the Linx shown below. The accessories that will be needed in addition are:-

- RS-485 to RS-232 Interface
- USB A to B (also known as a “printer cable”

To carry out readings see section 6.0 Taking Readings on next page





6.0 DATA HANDLING

The function of an instrument is to provide useful and reliable data. Accurate recording and handling of the data is essential if it is to be of any value

6.1 Taking readings

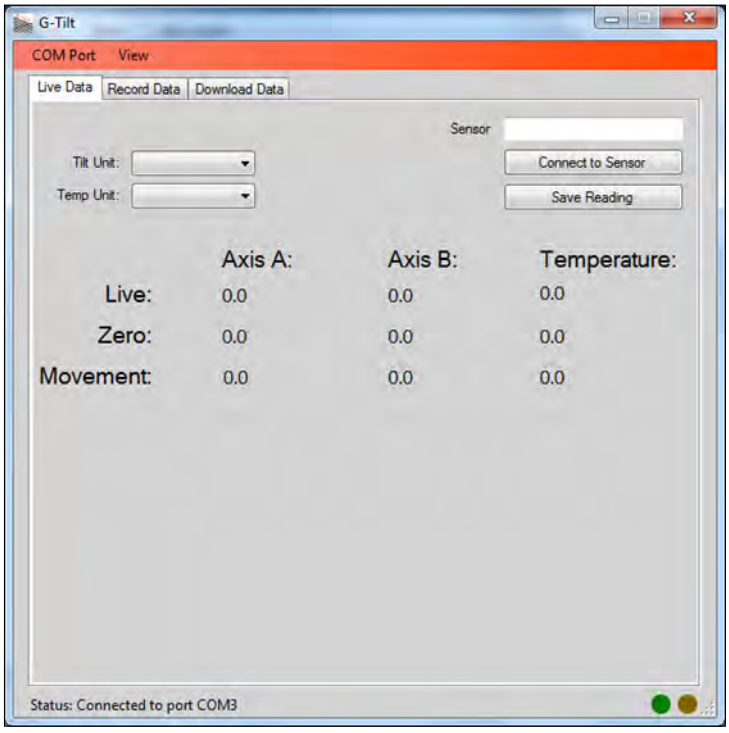
Geosense® IPI's are excited and interrogated using RS-485 digital protocols. A digital interface unit is required to connect from a standard RS-232C connection (as used by dataloggers, tablets, PCs, Notebooks or similar). **Geosense**® supply a dedicated RS232 to RS485 interface to be used with a Windows based device.

Once the installation has been carried out and all the thermal gradients have been removed, it is important to establish the initial reading for each of the IPI's. Depending upon the reading method adopted, the initial readings may in either degrees or 'sine of degrees'.

G-Tilt - IPI Software - Quick Start

The G-Tilt IPI software is only suitable for use on a **Microsoft Windows** based PC, Notebook, Tablet or Smart Phone.

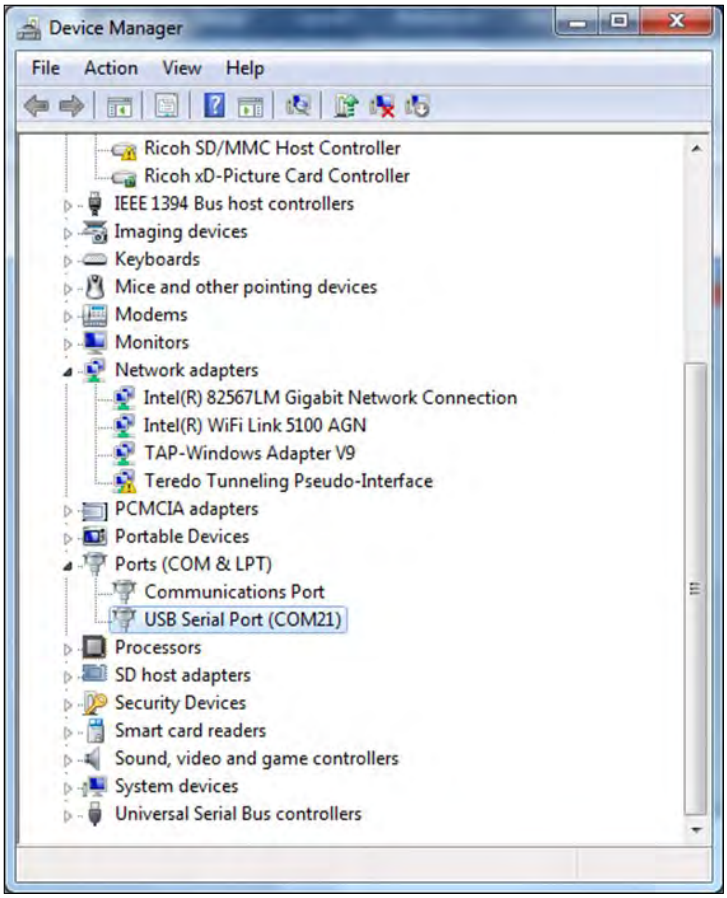
Do not connect the Digital Interface before installing the software



A Locate the G-Tilt software supplied or visit *https://www.geosense.co.uk/technical/downloads*

B Install and Start the software

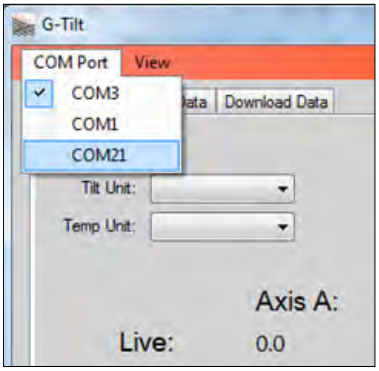
C. Connect the USB cable from the Digital Interface to the machine running the software



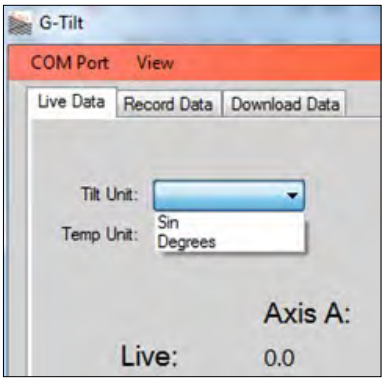
D. **If Windows does not automatically install the device drivers for the Digital Interface, it may be necessary to perform a Windows Update to locate the drivers from the internet**

E. To identify the number of the 'port' to which the Interface is connected, use Device Manager (or similar). See Right.

F. Click on the 'COM Port' tab and select the correct communication port



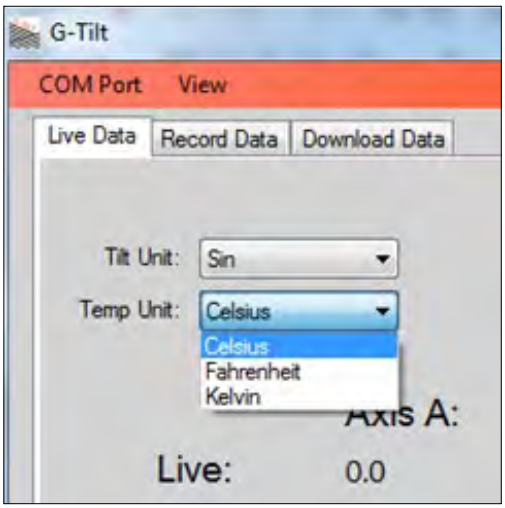
G. Select the preferred units of Tilt (Rotation) from the drop down list - ***Sine of the Angle*** *or* ***Degrees***



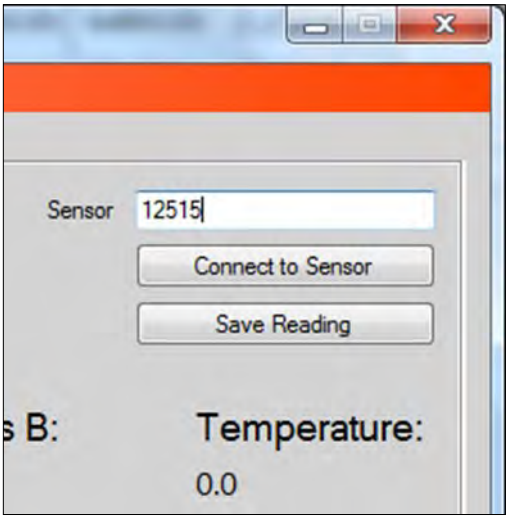
(Continued on page 36)

(Continued from page 35)

H. Select the preferred Temperature Units from the drop down list - ***Celsius, Fahrenheit*** *or* ***Kelvin***

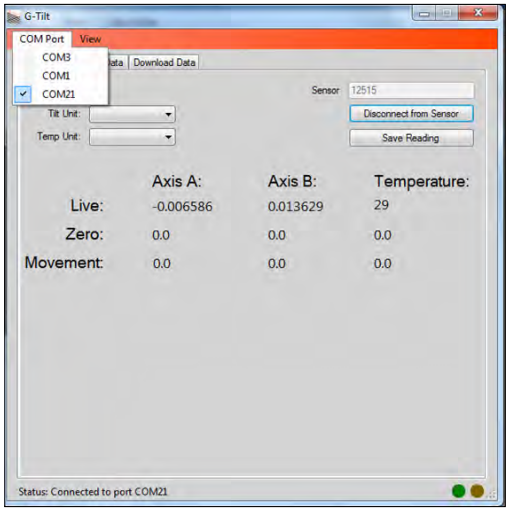


J. Enter the Serial number of the sensor to be interrogated and press the '**Connect to Sensor**' button



K. Once connected, the '**LIVE**' data will be displayed in the window, in the units selected

These are 'absolute vales' and must be referred to initial readings to assess any changes in rotation



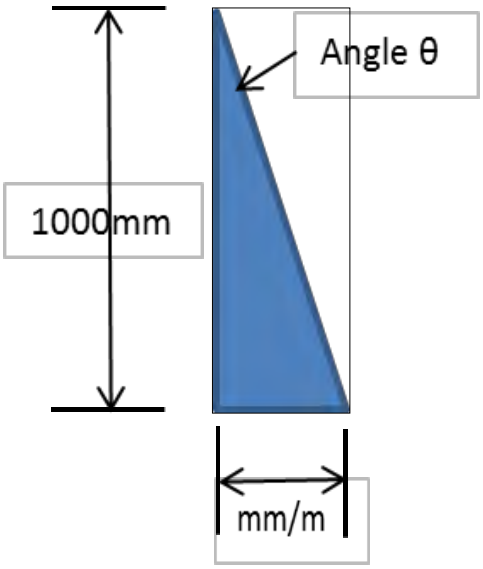
6.2 Data reduction

The output from the sensor must be compared with its calibration sheet to calculate the amount of tilt. Each IPI sensor has a unique calibration sheet and the simple calculation converts the sensor output to engineering units, commonly *degrees* or *mm/metre*.

The readings generated by Digital IPIs are in 'Sine of the Angle'.

-0.2588 sin-1 to +0.2588 sin-1(for ±15°)

The IPI is supplied with 8 - 15 volts to power the internal processor and sensors via the RS485 'bus' cable. Each sensor has a unique identification or 'address'. The interrogating logger or readout 'requests' a reading from a particular 'address'. The value returned from the processor is a value in $\sin^{-1}$ (the sine of the angle with respect to vertical) which can then be easily converted into a reading in degrees or other engineering units.



The calibration sheet for a bi-axial IPI will include the calibration details for both of the sensors (A & B).

Some examples of conversion from Tilt Meter output to other engineering units are shown on the next page.

YOU SHOULD ENSURE THAT YOU ALWAYS HAVE A BASE READING AS EVERYTHING IS MEASURED RELATIVE TO THIS. IT IS THE CHANGE IN READING THAT IS IMPORTANT

6.2 Data reduction contd...

Readings from the IPI will be in sine of the angle

Sine of angle to degrees

$$\Delta Y = (\text{Base reading Sin}^{-1}) - (\text{Current reading Sin}^{-1})$$

Example $\Delta Y = (0.08716 \text{ Sin}^{-1}) - (0.17365 \text{ Sin}^{-1})$

$\Delta Y = (5.000) - (10.000) = - 5.000^{o}$

Sine of angle to mm/m

$$Y = (\text{Base reading Sin}^{-1}) - (\text{Current reading Sin}^{-1})$$

Example $\Delta Y = (0.08716 \text{ Sin}^{-1}) - (0.17365 \text{ Sin}^{-1})$

$\Delta Y = (5.000) - (10.000) = - 5.000^{o}$

$\text{Sin } 5.000 = 0.08715$

$\therefore$ 0.08715×1000

$= 87.15\text{mm/M}$

6.3 Calibration certificate

Nova House, Rougham Industrial Estate, Rougham, Bury St Edmunds
Tel: +44(0)1359 270457 • Fax: +44(0)1359 272860 •
Website: www.geosense.co.uk

GEOSENSE QUALITY FORM	
FORM No	G/QF/148
ISS.	4
DATE :	MAY 17
SIG.	GC

Calibration Record

Vertical In Pace Inclinometer Digital Bus 485 Output

Serial No:	12528	Range (±°):	15
Calibration Date:	18-Apr-17	Cable Length:	N/A
Model:	IPI-M-1V-485B	Orientation:	Vertical

References:	
OMT Rotary Table SN#	AT50/7/71

Calibrated By: JK

A-Axis

Applied Angle (Deg)	Applied Angle (Sin(x))	Tilt meter Output (Sin(x))	Relative Error (Sin(x))
15.00	0.25882	0.25884	-0.00005
11.25	0.19509	0.19509	-0.00004
7.50	0.13053	0.13052	-0.00003
3.75	0.06540	0.06539	-0.00002
0.00	0.00000	-0.00003	0.00000
-3.75	-0.06540	-0.06545	0.00001
-7.50	-0.13053	-0.13058	0.00002
-11.25	-0.19509	-0.19515	0.00003
-15.00	-0.25882	-0.25889	0.00004
		Max Error (Sin)	**0.00005**

B-Axis

Applied Angle (Deg)	Applied Angle (Sin(x))	Tilt meter Output (Sin(x))	Relative Error (Sin(x))
15.00	0.25882	0.25879	-0.00004
11.25	0.19509	0.19506	-0.00004
7.50	0.13053	0.13049	-0.00003
3.75	0.06540	0.06535	-0.00001
0.00	0.00000	-0.00007	0.00000
-3.75	-0.06540	-0.06547	-0.00001
-7.50	-0.13053	-0.13061	0.00001
-11.25	-0.19509	-0.19519	0.00003
-15.00	-0.25882	-0.25891	0.00002
		Max Error (Sin)	**0.00004**

Calibration of OMT Rotary Table model AT50 serial No 07/71, Calibrated 12th January 2016 by Rotary Precision Instruments Ltd using equipment which provides traceability to National Standards (Certificate No CC13111)

THIS CERTIFICATE IS VALID ONLY WHEN CARRYING THE OFFICIAL ORIGINAL STAMP OF GEOSENSE BELOW

6.4 Temperature Considerations

Geosense® has carried out significant research into temperature effects on the IPI and has found that the thermal effects are very small.

Where the IPI is installed in an inclinometer access tube in a borehole or other subsurface structure, there is usually little variation in temperature, so thermal effects will be small and corrections will not be necessary.

However, if an IPI is suspended in a inclinometer an access tube in a location where there is significant groundwater movement, for example, the sensors may be affected by seasonal changes in the temperature of the water. In this instance, temperature corrections may become necessary, depending upon the range of the change.

Thermal influences on an IPI readings can be complex. The effect of temperature changes on the MEMS are insignificant, but this relates purely to the 'sensor' inside the module. Effects on the body of the sensor module and the structure into (onto) which it is installed will be very complicated and difficult to quantify.

Therefore, in order to correct for in-situ temperature changes, it is first necessary to establish the effects of temperature changes on a particular sensor in-situ at a particular location and the effects on the structure in which it is installed. Ideally this would be over a full annual cycle, but this is often un-achievable. Efforts should be made to quantify both the seasonal and daily thermal affects by observational methods.

It may then be possible to carry out mathematical corrections at the time of data processing.

7.0 MAINTENANCE

The **Geosense**® IPI is a maintenance free device for most applications. This is because it is intended for sub-surface installation and would normally be suspended in access tubes within boreholes or attached to structures.

8.0 TROUBLESHOOTING

In almost all cases, a fluctuating reading is a sign of a faulty signal from the sensor. The fault could be in either the sensor, the connecting cable, any switch boxes, the digital interface, or the readout. The best way to fault find an individual sensor is to isolate it from all others in a string and any connections. Where possible begin fault finding from the sensor or end of a string of sensors.

An additional resistance diagnostic check routines are also included to help identify problems with cables.

Fault finding assistance from the Digital Interface manual:-

Typically any failure or error in communication is due to the RS485 sensor being read and not the RS485—RS232/USB interface. However the interface can be checked by sending the command “menu” when it is first powered up. See the interface manual for assistance with this procedure.

Fault	Possible cause	Remedy
No Connection to the Interface	Incorrect wiring	Check wiring diagram for the RS232 or USB side.
No Connection to the Interface	Incorrect Settings - see the Interface manual	Settings on readout / logger Baud rate: 115200 Data Bits: 8 Stop Bits: 1 Parity: None
No Connection to a Sensor	Incorrect wiring	Check wiring diagram for the RS485 side.
No Connection to a Sensor	Incorrect Sensor Settings	Interface only supports baud rates of 9600 (RS485 side)
No Connection to a number of Sensors	Maximum Current Limited Exceeded	Supply RS485 sensor(s) externally
No Connection to a Sensor	Incorrect Command	Check RS485 Sensor manual for correct command structure

8.0 TROUBLESHOOTING contd….

Fault finding assistance for the cabling :-

Using a Resistance meter or Electrical Multi-meter set to measure resistance, check the resistance between each conductor and between each conductor and the drain wire or screen.

There should be a VERY high, or infinite electrical resistance between the conductors and the drain or screen (a value in MΩ's is acceptable).

None of the individual conductors should be shorted to the screen or drain wire (showing Zero resistance) and none should be shorted together (showing Zero resistance).

As a terminal resistor is fitted to a string of IPI sensors, the resistance between the Yellow and the Green conductors and the should be in the order of 100 - 140Ω.

The electrical resistance between the Brown and White, the power conductors will vary significantly depending on the number of sensors in the string. The resistance should never be Zero and should not exceed 2000Ω.

9.0 SPECIFICATION

MODELS			
Orientation	**Range**[1]	**Uniaxial**	**Biaxial**
Vertical	±15° from vertical	IPI-V-1	IPI-V-2
Inclined	±15° from 45°	IPI-I-1	IPI-I-2
Horizontal	±15° from horizontal	IPI-H-1	IPI-H-2

PERFORMANCE	
Accuracy[2]	±0.004°, ±13.5 arc sec, ±0.065 mm/m, ±0.0125% FS
Resolution	0.0005°, 2 arc sec, 0.01 mm/m, 0.0017% FS
Repeatability	±0.002°, ±7.2 arc sec, ± 0.034 mm/m, ±0.006% FS
Temperature sensor range	-40 to +85°C
Temperature sensor accuracy	±1°C
Operating temperature	-40 to +85°C
Thermal stability	±0.005% FS/°C
ELECTRICAL	
Supply input	8-15VDC
Output signal	RS-485 Digital BUS
Output unit	Sine of angle
Sensor type	MEMS
PHYSICAL	
Probe diameter	32mmØ
Probe gauge length	500mm
Probe weight	1.3kg
Compatible casing sizes	70 to 85mm
Extension rods	0.5, 1.0, 1.5, 2.0, 2.5m x 25mm Ø
Enclosure rating	IP68 (20 bar)
MATERIALS	
Probe	Stainless steel
Extension rods	Stainless steel, carbon fibre
EXTENSION CABLE	(If required, to extend from IPI top fly lead assembly to data logger)
Construction	Construction 2 x twisted pair, braided, PUR sheath
Type	Type 800 - multi-core with braid
Diameter	8.0mm

1 Other ranges available on request; 2 Using 3rd order polynomial

10.0 SPARE PARTS

Under normal use spare parts are not generally required for In-Place Inclinometers but replacement components are available as follows:-

Part number	**Description**
B15-001	IPI wheel set assembly

11.0 RETURN OF GOODS

11.1 Returns procedure

If goods are to be returned for either service/repair or warranty, the customer should contact **Geosense®** for a **Returns Authorisation Number,** request a **Returned Equipment Report Form QF034** and, where applicable, a **Returned Goods Health and Safety Clearance Form QF038** prior to shipment. Numbers must be clearly marked on the outside of the shipment.

Complete the **Returned Equipment Report Form QF034**, including as much detail as possible, and enclose it with the returned goods.

All returned goods are also to be accompanied by a completed **Returned Goods Health and Safety Clearance Form QF038** attached to the outside of the package (to be accessible without opening the package) and a copy of both forms should be faxed or emailed in advance to the factory.

11.1.1 Chargeable Service or Repairs

Inspection & estimate
It is the policy of **Geosense®** that an estimate is provided to the customer prior to any repair being carried out. A set charge for inspecting the equipment and providing an estimate is also chargeable.

11.1.2 Warranty Claim

(See Limited Warranty Conditions)
This covers defects which arise as a result of a failure in design or manufacturing. It is a condition of the warranty that the **MEMS Digital In-Place Inclinometer** must be installed and used in accordance with the manufacturer's instructions and has not been subject to misuse.

In order to make a warranty claim, contact **Geosense®** and request a **Returned Equipment Report Form QF034.** Tick the warranty claim box and return the form with the goods as above. You will then be contacted and informed whether your warranty claim is valid.

11.2 Packaging and Carriage

All used goods shipped to the factory **must** be sealed inside a clean plastic bag and packed in a suitable carton. If the original packaging is not available, **Geosense®** should be contacted for advice. **Geosense®** will not be responsible for damage resulting from inadequate returns packaging or contamination under any circumstances.

11.3 Transport & Storage

All goods should be adequately packaged to prevent damage in transit or intermediate storage.

12.0 LIMITED WARRANTY

The manufacturer, (**Geosense Ltd)**, warrants the **MEMS Digital In-Place Inclinometer** manufactured by it, under normal use and service, to be free from defects in material and workmanship under the following terms and conditions:-

Sufficient site data has been provided to **Geosense®** by the purchaser as regards the nature of the installation to allow **Geosense®** to select the correct type and range of **MEMS Digital In-Place Inclinometer** and other component parts.

The **MEMS Digital In-Place Inclinometer** equipment shall be installed in accordance with the manufacturer's recommendations.

The equipment is warranted for 1 year from the date of shipment from the manufacturer to the purchaser.

The warranty is limited to replacement of part or parts which, are determined to be defective upon inspection at the factory. Shipment of defective part or parts to the factory shall be at the expense of the Purchaser. Return shipment of repaired/replaced part or parts covered by this warranty shall be at the expense of the Manufacturer.

Unauthorised alteration and/or repair by anyone which, causes failure of the unit or associated components will void this **LIMITED WARRANTY** in its entirety.

The Purchaser warrants through the purchase of the MEMS Digital In-Place Inclinometer equipment that he is familiar with the equipment and its proper use. In no event shall the manufacturer be liable for any injury, loss or damage, direct or consequential, special, incidental, indirect or punitive, arising out of the use of or inability to use the equipment sold to the Purchaser by the Manufacturer.

The Purchaser assumes all risks and liability whatsoever in connection with the **MEMS Digital In-Place Inclinometer** equipment from the time of delivery to Purchaser.

Nova House . Rougham Industrial Estate . Rougham . Bury St Edmunds . Suffolk . IP30 9ND . England .

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