V1.3 March 2015

MEMS IN-PLACE TILT METER

ANALOGUE

INSTRUCTION MANUAL

CE

GEOSENSE

CONTENTS

1.0 INTRODUCTION

This manual is intended for all users of the **Geosense® MEMS Tilt Meter** and provides a guide for its installation, operation and maintenance.

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

1.1 General Description

The **Geosense® MEMS Tilt Meter** comprises either a single tilt sensor (uni-axial) or a pair of tilt sensors (bi-axial) mounted in an environmentally sealed enclosure. This enclosure would be mounted onto a surface to register changes in the tilt (rotation) of that location. Commonly these Tilt meters are used for monitoring structural elements within civil engineering, but they are suitable for many other applications where the measurement of rotation is required.

A **Geosense® MEMS Tilt Meter** can be installed or included in many types of monitoring regime and can be linked to various types of readout equipment.

The primary use for **Geosense® MEMS Tilt Meters** is for the measurement of tilt of structures and retaining walls.

Examples of other applications are:-

- Monitoring of compensation grouting works.
- Effects of construction e.g. tunnelling or excavations on adjacent structures.
- Analysis of the performance of bridges, beams and dams under loading.
- Structural safety monitoring in areas of mass movement.
- Monitoring of retaining wall rotation.
- Convergence monitoring within tunnels (in association with other sensors).

Particular features of the **Geosense® MEMS Tilt Meter** are:-

- Reliable long term performance.
- Suitably rugged for use in demanding environments.
- High accuracy and repeatability
- Designed to be resistant to EMF
- Suitable for long cable lengths or RF data transmission

Geosense® MEMS Tilt Meter sensors are particularly suitable for the demanding environments of civil engineering projects since the signals are capable of long transmission distances, without degradation. They are also ***water resistant*** and can be shielded from interference from external electrical noise.

1.2 EMC - Electro Magnetic Compatibility

EMC is the electromagnetic interaction of electrical and electronic equipment with other electrical and electronic equipment. All electronic devices have the potential to emit and be affected by electromagnetic fields. With the reduction in size of electrical components and the ever increasing amount of electrical & electronic devices such as mobile phones, two-way radios, safety control systems, signalling, generators, welding equipment, power cables etc in all environments, especially construction sites, there is a huge potential for devices to interfere with each other.

Geosense® MEMS Tilt Meters have been designed and tested for EMC under the relevant CE marking directives to comply with the highest standards including requirements set out in London Underground requirements G-222 & 1-222. This ensures correct operation under the harshest of site conditions.

However to ensure compliance and correct operation it is vital that all cables connected to **Geosense® MEMS Tilt Meters** provide adequate 360 degree screening against EMC and that suitable EMC glands are used for any connection to junction boxes or data logger cabinet. However, as it is likely that **Geosense® MEMS Tilt Meters** will be used in conjunction with data loggers, it is essential that they too are designed and constructed to comply with the relevant CE marking directives (contact Geosense for details).

FAILURE TO PROVIDE SUITABLY SCREENED CABLES & ENCLOSURES TOGETHER WITH EMC GLANDS COULD RESULT IN INCORRECT OPERATION OF THE EQUIPMENT

1.3 The Effects of Temperature Changes

The MEMS sensors used in the **Geosense® MEMS Tilt Meters** offer significant advantages over other types of rotational movement sensors, with respect to thermal stability. The sensors themselves are almost unaffected by environmental temperature changes.

However, whilst efforts have been taken to minimise the effects, the instrument mountings and the enclosure will be affected by significant temperature changes, along with the structure onto which the instrument is fixed. Effects will be highest when the temperature changes are large and over a short period of time.

For this reason, **Geosense® MEMS Tilt Meters** include a Temperature measurement facility (Thermistor) to help identify the in-situ effects of any thermal changes.

1.4 Theory of Operation

Geosense® Tilt Meters employ 'State of the Art' MEMS sensor technology. MEMS (Micro - Electro - Mechanical Systems) are an integration of mechanical elements, sensors, actuators and electronics on a common silicon substrate through micro fabrication technology.

The mechanical structure of a typical MEMS sensor is shown in Figures 1 & 2 below.

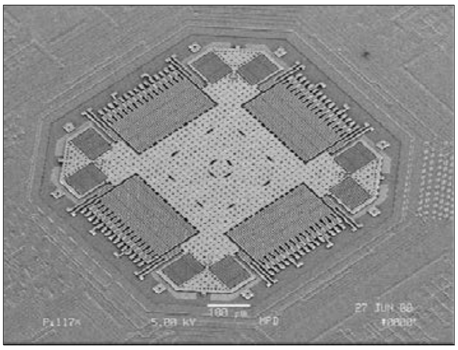

Figure 1

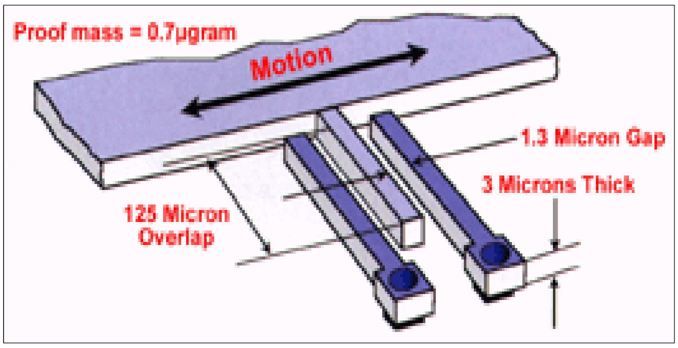

Figure 2

Polysilicon springs suspend the MEMS structure above the substrate such that the body of the sensor (also known as the 'proof mass') can move in the X and Y axes. Acceleration causes deflection of the proof mass from its centre position. Around the four sides of the square proof mass are 32 sets of radial fingers.

These fingers are positioned between plates that are fixed to the substrate. Each finger and pair of fixed plates make up a differential capacitor, and the deflection of the proof mass is determined by measuring the differential capacitance.

This sensing method has the ability of sensing both dynamic acceleration (i.e. shock or vibration) and static acceleration (i.e. inclination or rotation).

Signal conditioning is carried out within the **Geosense® Tilt Meters** so that a simple output signal is obtained. This output can be used in conjunction with a calibration sheet to easily calculate the amount of tilt that has occurred.

The MEMS sensors within **Geosense® Tilt Meters** are configured measure inclination from vertical. As movement occurs, the **Geosense® Tilt Meter** will move with its mounting, thus changing the inclination of the internal sensors.

The MEMS sensors **within Geosense® Tilt Meters** measure tilt over a range of +/- 15º. In the bi-axial model, a second MEMS sensor is mounted at 90º to the other sensor and measures tilt in the orthogonal direction, on the horizontal plane. Once mounted on a structure they are normally adjusted to read close to zero, their mid-point. An **'initial reading'** is then recorded and any changes in the inclination of the structure are identified by comparing the current readings with the initial readings.

(Continued on page 7)

Whilst the major advantage of MEMS based measuring systems, over the older electro-level based systems, is their stability and reduced thermal sensitivity, MEMS sensors are also significantly less likely to suffer from 'long term drift'. The 'solid state' construction and robust nature of the MEMS based systems, makes them very suitable for use in geotechnical instrumentation as the instruments are often located in areas that are highly prone to shocks and varying thermal conditions.

Extensive thermal testing has been carried out to confirm that thermal effects over their operating range are negligible.

The linearity of MEMS accelerometers is very good and provide increases in stability, sensitivity and accuracy. MEMS sensors are suitable for use where long cables are necessary.

2.0 CONFORMITY

Geosense Ltd
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Suffolk , IP30 9ND
United Kingdom

Tel: +44 (0)1359 270457, Fax: +44 (0)1359 272860
www.geosense.co.uk

EC Declaration of Conformity

We Geosense Ltd at above address declare that the equipment detailed below, complies with the requirements of the following EU Directives:-

- Electromagnetic Compatibility Directive 2004/108/EC
- General Product Safety Directive (GPSD)2001/95/EC
- Restriction on the use of certain Hazardous Substances RoHS2 2011/65/EU

Equipment description: **MEMS Tilt Meters**
Make/Brand: **Geosense**
Model Numbers: **In-place & Portable Tilt Meters**

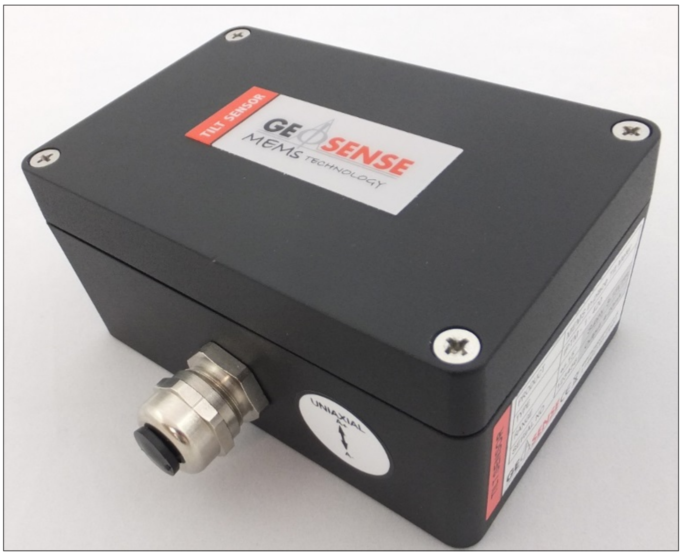
Compliance has been assessed with reference to the following harmonised standard:
EN 61326-1:2006 Electrical equipment for measurement, control and laboratory use. EMC requirements. General requirements.

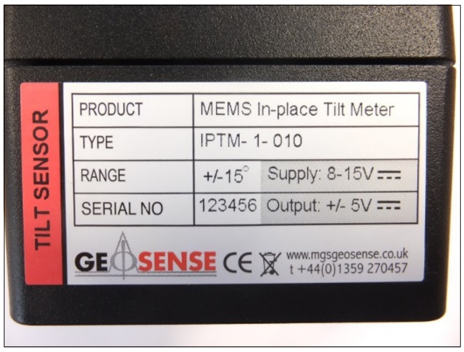
EN 61010 (2010) Safety requirements for electrical equipment for measurement, control, and laboratory use. General requirements

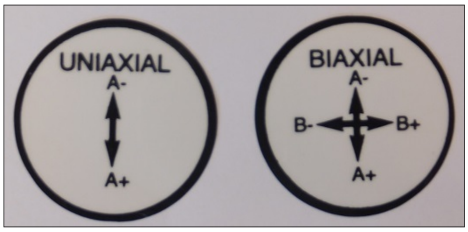
A technical file for this equipment is retained at the above address.

Martin Clegg
Director
Rougham, March 2015

3.0 MARKINGS







A **Geosense® MEMS Tilt Meter** is labelled with the following information:-

Manufacturers telephone number & website address

Product group: Tilt Sensor

Product type: MEMS In-place Tilt Meter

Model: IPTM-1-420, IPTM-2-420, IPTM-1-010, IPTM-2-010

Range: +/- 15º

Orientation: Uni-axial or biaxial

Input supply: 8-15 Volts DC

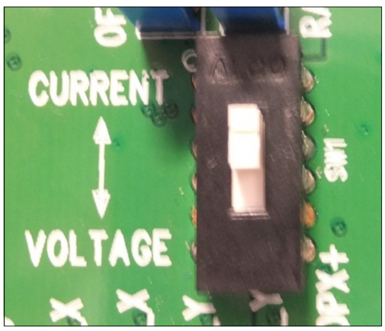
Output signal: 4-20mA, +/- 5 Volts DC

Serial number: 123456

CE mark

WEEE mark

THE SWITCH LABELLED
CURRENT / VOLTAGE IS FACTORY SET
AND MUST NOT BE CHANGED



4.0 DELIVERY

This section should be read by ALL users of **Geosense® MEMS Tilt Meters**

4.1 Packaging

Geosense® MEMS In-place Tilt Meters 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® MEMS In-place Tilt Meters** 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 **Geosense® MEMS In-place Tilt Meters** remain in their original packaging for storage or transportation.

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

DO NOT DROP AS THIS MAY CAUSE DAMAGE TO INTERNAL COMPONENTS

4.3 Inspection

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.

Geosense® MEMS In-place Tilt Meters carry a **unique** identification serial number and are supplied with individual calibration sheets that include their serial numbers, which will shipped with the tilt meters.

Calibration Sheets contain VITAL information about the Tilt Meters. They should be stored in a safe place and only copies should be taken to site.

4.4 Storage

Geosense® MEMS In-place Tilt Meters are precision instruments containing sensitive electronics and whilst they are mounted within a waterproof (IP66) enclosure, the internal circuit board can be affected by excessive moisture.

Geosense® MEMS In-place Tilt Meters are factory fitted with a silica gel moisture adsorbent pouch which should be replaced periodically, especially for any long term storage or operation in environments with a relative humidity above 50%.

DO NOT REMOVE

SILICA GEL ADSORBENT

REPLACE AS REQUIRED

It is also recommended that cables be stored in a dry environment to prevent moisture migrating along inside them in the event of prolonged submersion of exposed ends.

Storage areas should be free from rodents as they commonly damage connecting cables.

5.0 INSTALLATION

This section of the manual is intended for all users of **Geosense® MEMS In-place Tilt Meters** 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.

5.1 Preliminary Considerations

Prior to installation of **Geosense® MEMS In-place Tilt Meters** it is essential to establish and confirm details of the installation to be carried out. Some of the main considerations are listed below :-

a. Structure / Installation location. The location of the installation can have implications with regard to planning, access and environmental considerations. For example, a city structure installation would demand different considerations than a dam face application.

b. Structure / Installation type. The main consideration is access. The installation of tilt meters on a lift shaft, for example, requires special attention, whereas installation on the face of a low retaining wall requires less consideration, perhaps.

c. Intended Position. This will usually be specified by the monitoring system designer and will be defined by the changes to be measured. However, some 'on-site' adjustments may be necessary but any changes should be approved by the system designer. Considerations such as the proximity of moving plant or other vibrations will also need to be addressed.

d. Mounting requirements. Mounting brackets can be configured for almost any type of structure. This is best discussed and agreed with all interested parties, well before the installation is to be carried out.

e. Connections. The selection of the most suitable and appropriate method of linking the sensors to a convenient readout location will depend upon many factors and should be decided upon prior to ordering the equipment (see section 5.2).

f. Location of readout / data logger (as required). This must take into account the connection method selected, in addition to the EMF generated by adjacent and local equipment and cables.

g. Protection of the Tilt Meters & cables from physical damage.

(Continued on page 13)

5.1.1 Tools & Consumables

The following is a brief list of tools and equipment typically used during the installation:-

- Mounting Brackets and Template
- Electric Drill
- Suitable Drill Bits
- Spirit Level
- Bolts & Fixings or Epoxy Resin
- Set of spanners
- Suitable readout
- Wire cutter / stripper
- Small flat screwdriver
- Pozi-drive #2 Screwdriver

5.1.2 Cabled & Wireless Connections

There are 3 main options for connecting a tilt meter to a readout device. Firstly, a readout could be connected directly to the tilt meter locally, using a 'flying lead'; secondly, it could be connected to a remote readout / logger location using cables and lastly, it could be linked to a remote readout location using a wireless communication method.

Local readout connection.

For this type of connection, a cable socket is fitted to the tiltmeter housing and a 'flying lead' is provided with the handheld readout device. No onsite cabling is required.

Cable connections

Sensors with 4-20mA or voltage outputs require a single cable from each sensor housing (Uni-axial or Bi-axial) to a readout location.

Planning of cable routes is critical as they are easily damaged and can cause an inconvenience. Protection of the cables is also essential in any locations where they could be damaged.

For Voltage type sensors, the cable lengths must be kept to a minimum so as to minimise the 'cable resistance' as this will affect the sensor output.

For 4-20mA sensors, cables that do not exceed 500m are not electronically critical, but will have a logistical and economic impact. For some applications, it may be economical to employ multicore, twisted pair, cables where a number of remote sensors would be linked to a local junction box and connected to a single 'multi-conductor' cable for routing to the readout location.

So as to maintain clarity, cables should be marked with unique codes at both ends and at intermediate points. The codes must be noted in a site record for future reference.

Wireless Connections

In congested locations where wired connections would be difficult, the use of Wireless / Radio Frequency systems may be a more appropriate communication solution. These systems can only be employed when using a data logger for interrogation of the tilt sensors.

Here each tilt sensor is locally wired to an RF transmitter module (‘node’). The RF module becomes a ‘transparent’ link to the matched RF receiver (‘gateway’) which is liked to a data logger.

Please refer to the appropriate Wi-SOS documentation.

5.1.3 Functionality testing

Prior to installation of the **Geosense® MEMS IN-place Tilt Meters** it is recommended that they are always checked for correct operation. Each Tilt Meter is supplied with a calibration sheet which shows the relationship between output signal (mA or Volts) and inclination. Digital tilt meters produce an angular output (sine of the angle).

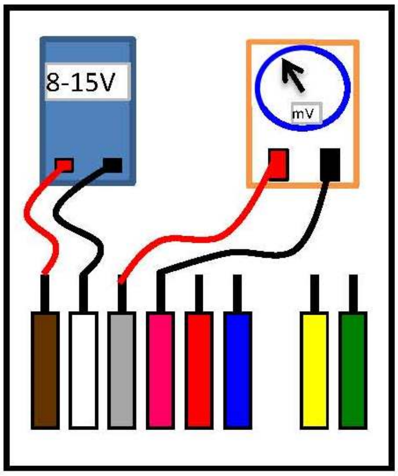
Remove the Tilt Meters from packaging & dispose in a responsible way. Connect the cable as in section 5.2 and place the Tilt Meter on approximately horizontal surface and observe the reading. The readings should be close to the factory vertical reading.

The following will be required for functionality testing:-

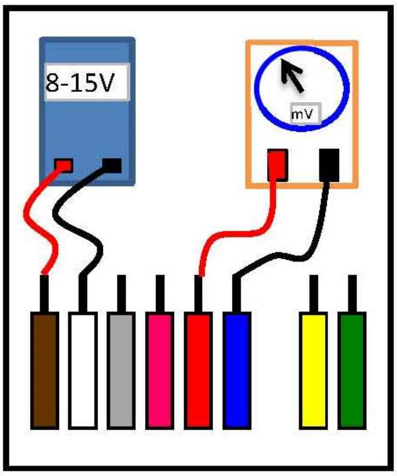
4-20mA Geosense® Readout (see section of this manual) or suitable Multi-meter to read mA and an 8 -15 Volt power supply.

0-10 Volts Geosense® Readout (see section of this manual) or suitable Multi-meter to read +/- 5 Volts using a 8 -15 Volt power supply.

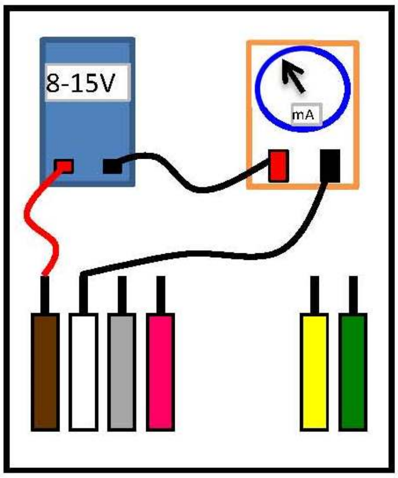
Voltage output - Checking Axis A



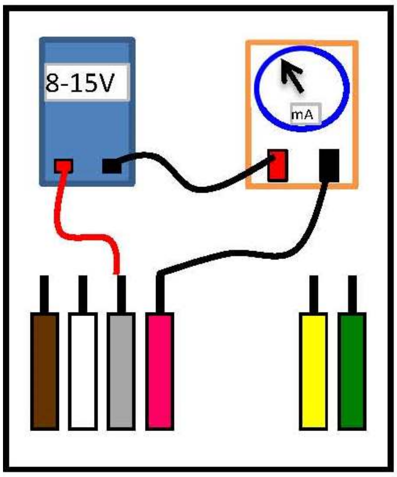
Voltage output - Checking Axis B



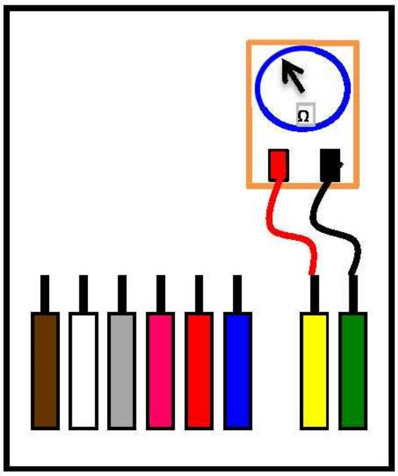
4-20 mA output - Checking Axis A



4-20 mA output - Checking Axis B



Thermistor Temperature Checking Axis A



The above connection and testing arrangement is not used for routine measurements as most multi-meters will not be sensitive enough to provide the required resolution.

5.2 Installation procedures

The intended location of the tilt meters and the material onto which they are to be mounted will define the type of mounting brackets and fixings that should have been ordered. Standard brackets are available for mounting the tilt meters onto vertical and horizontal surfaces using various fixing methods. However, other brackets are produced to suit particular requirements.

Common bracket fixing methods include:

- Drilled type: Through bolts (preferred option)
  Expanding Bolts
  Plugs and Screws
- Adhesives ‘Hard’ type epoxy resins are commonly used
- Welding Spot welds using ARC systems or gas welding / brazing

The following are brief overviews of some ‘typical’ installations that serve to highlight the issues and considerations that may need to be addressed.

As no two installations are the same, the methods described below are intended as guidance only.

Uni-axial tilt meter brackets MUST be orientated correctly so that the tilt meter fixes to the bracket in the required direction. Check this prior to fixing the brackets. It may be necessary to adjust the mounting location or bracket to achieve the desired monitoring orientation.

It is recommended that, where the sensor is required to operate over its full range (+/- 15 degrees), the tilt meter fixing surface of the bracket will need to be installed close to horizontal . A bubble level can be used to check that this can be achieved. Where only a portion of the operating range is required, the levelling of the mounting plate is not so critical (but is still good practice).

5.2.1 Drilled Fixings - Vertical Surface

Whist the holes in the mounting brackets are 10 mm diameter we recommend that a 6mm fixing is used, together with a washer. The mounting plates are generally fabricated from mild steel and then zinc plated. We, therefore, recommend the use of ‘plated’ fixings. Stainless steel fixings should only be used with stainless steel mounting brackets.

1. Ensure the mounting surface at the intended location is clean and free of any obstructions that may affect the ease of installation.

2. Apply the tilt meter bracket to the location intended for installation. Take care to ensure that the bracket is orientated correctly, with respect to the tilt meter box fixings and the direction of tilt.

3. Mark the location of the fixing holes and remove the bracket.

4. Using an appropriately sized bit, drill to a depth that will accommodate the selected fixings.

5. Remove any dust from the holes and insert the fixings.

6. Repeat for the second fixing

7. Position the mounting plate and loosely tighten the fixings.

8. Where necessary, adjust the plate to level it and tighten the fixings.

9. Position the tilt meter box on the bracket and orientate it correctly.

10. Line up the fixing holes on underside of tilt meter box with the holes in the bracket and fit the first screw.

11. Using an 'Allen' key, secure the fixing screw.

12. Locate the other sixing screw and tighten both screws to fix the box to the bracket securely.

13. The box is now ready for wiring. For wiring details see Section 6 of this manual.

14. Once wiring has been completed and the system has been tested the box cover should be replaced and the screws tightened to ensure a waterproof seal.

5.2.2 Bonded - Horizontal Surface

Horizontal mounting plates can be attached a surface using a variety of techniques, such as Bolts, Bonding, Welding, tec. The mounting plates are supplied with 10 mm diameter holes but we recommend that a 6mm fixing is used, together with a washer. The mounting plates are generally fabricated from mild steel and then zinc plated. We, therefore, recommend the use of ‘plated’ fixings. Stainless steel fixings should only be used with stainless steel brackets. Where the plates are to be welded, we suggest that plating be removed locally, prior to welding or ordered in an un-plated condition.

Since tilt meters detect very small movements, any bonding material used to fix the mounting brackets MUST be rigid when it has cured (set). Many, apparently rigid, materials are not actually rigid and can ’creep’ with time. (For example, ARALDITE(TM), a proprietary epoxy resin appears ’hard’ when cured but is, in fact, **NOT** a rigid fixing material.)

1. Position the bracket on the location intended for installation. The tilt meter fixing surface of the bracket will need to be close to horizontal where the sensor is required to operate over its full range (+/- 15 degrees). A bubble level can be used to check that this can be achieved. Where only a small portion of the operating range is required, the levelling of the mounting plate is less critical. Mark the location of the bracket and remove it.

2. Ensure the mounting surface at the intended location is clean and free of any raised areas that may prevent good contact with the underside of the tilt meter bracket. Since this installation uses an adhesive, it is necessary to ensure that the bracket has good contact with the underlying surface. It may be necessary to use a grinder to remove raised areas.

3. Clean the surface under the plate with a wire brush and remove any dust from both surfaces.

4. Any grease or silicon under the plate will prevent the adhesive from making a solid bonded connection so de-greasing the surfacing may be necessary.

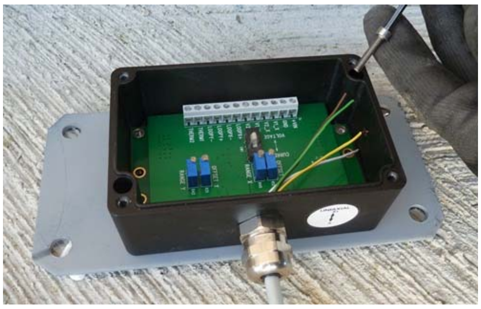
5. The selected adhesive should be applied in accordance with the manufacturers instructions. Ensure enough adhesive is applied to bridge any undulations and provide a good bonding surface.

6. Position the plate in line with the markings.

7. Press down firmly on the plate, and where necessary, hold it, or leave it in place, until the bonding agent has cured (set)

8. After the bond has achieved sufficient strength, the tilt meter should be fitted bracket.

9. Position the tilt meter box on the bracket and orientate it correctly. Line up the fixing holes on underside of tilt meter with the holes in the bracket and fit the screws. Tighten to secure the tilt meter.



10. For wiring details see below and Section 5.3 on page 23.

IN-PLACE MEMS TILT METER WIRING DETAILS ANALOGUE 4-20mA

BI-AXIAL

BOARD LOCATION	WIRE COLOUR	DESCRIPTION
+ VIN	UNUSED	
GND	UNUSED	
V1_X	UNUSED	
V2_X	UNUSED	
V1_Y	UNUSED	
V2_Y	UNUSED	
LOOP X+	BROWN	**A AXIS +**
LOOP X -	WHITE	**A AXIS -**
LOOP Y+	GREY	**B AXIS +**
LOOP Y-	PINK	**B AXIS -**
THERM 1	YELLOW	TEMPERATURE*
THERM 2	GREEN	TEMPERATURE*

*** OPTIONAL**

UNI-AXIAL

BOARD LOCATION	WIRE COLOUR	DESCRIPTION
+ VIN	UNUSED	
GND	UNUSED	
V1_X	UNUSED	
V2_X	UNUSED	
V1_Y	UNUSED	
V2_Y	UNUSED	
LOOP X+	BROWN	**A AXIS +**
LOOP X -	WHITE	**A AXIS -**
LOOP Y+	UNUSED	
LOOP Y-	UNUSED	
THERM 1	YELLOW	TEMPERATURE*
THERM 2	GREEN	TEMPERATURE*

*** OPTIONAL**

GEOSENSE

IN-PLACE MEMS TILT METER WIRING DETAILS
ANALOGUE +/- 5 VOLTS

BI-AXIAL

BOARD LOCATION	WIRE COLOUR	DESCRIPTION
+ VIN	BROWN	SUPPLY VOLTAGE +
GND	WHITE	SUPPLY VOLTAGE -
V1_X	GREY	**A AXIS +**
V2_X	PINK	**A AXIS -**
V1_Y	RED	**B AXIS +**
V2_Y	BLUE	**B AXIS -**
LOOP X+	UNUSED	
LOOP X -	UNUSED	
LOOP Y+	UNUSED	
LOOP Y-	UNUSED	
THERM 1	YELLOW	TEMPERATURE*
THERM 2	GREEN	TEMPERATURE*

*** OPTIONAL**

UNI-AXIAL

BOARD LOCATION	WIRE COLOUR	DESCRIPTION
+ VIN	BROWN	SUPPLY VOLTAGE +
GND	WHITE	SUPPLY VOLTAGE -
V1_X	GREY	**A AXIS +**
V2_X	PINK	**A AXIS -**
V1_Y	UNUSED	
V2_Y	UNUSED	
LOOP X+	UNUSED	
LOOP X -	UNUSED	
LOOP Y+	UNUSED	
LOOP Y-	UNUSED	
THERM 1	YELLOW	TEMPERATURE*
THERM 2	GREEN	TEMPERATURE*

*** OPTIONAL**

5.3 Wiring

Where Geosense Tilt Meters are to be read at a distance from their installed location, a cable can be used to link them to a convenient readout point or to a data logger.

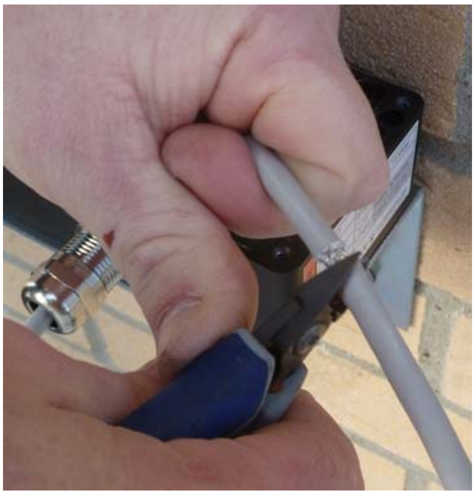
To comply with all the CE and WEE regulations, the type of cable used to link the sensors to a readout location must be selected carefully. Please see the cable specification recommended in section 10.0 on page 39.

1. Cut the end of the cable to produce a clean, square end. Remove the cover of the Tilt Meter.

2. Insert the cable into the EMC cable gland and push it through until it reaches the back of the box. Mark the cable as shown.

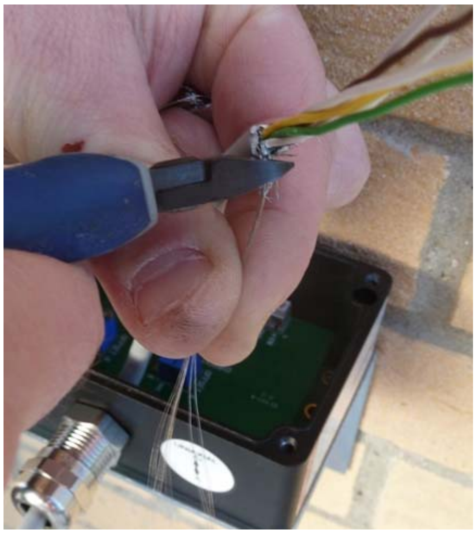
3. Draw the cable through the gland until the mark is clearly visible.

4. Cut the outer sheath at the mark. Take care not to cut into the braided shield.

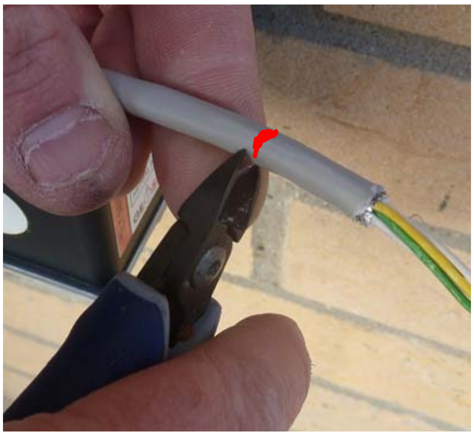


5. Remove the sheath to expose the braided shield.

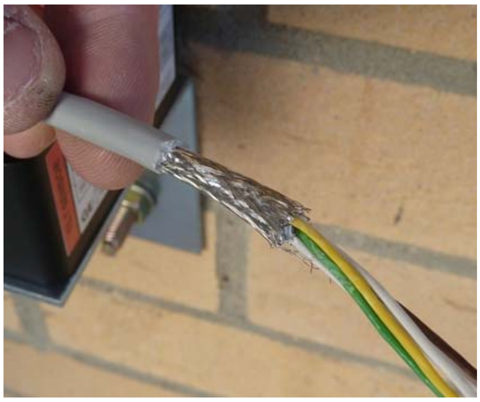
6. Carefully cut and remove the braided sheath. Then cut the inner ‘drain’ conductors (the fine inner conductors that are not sheathed) as shown in the photograph.



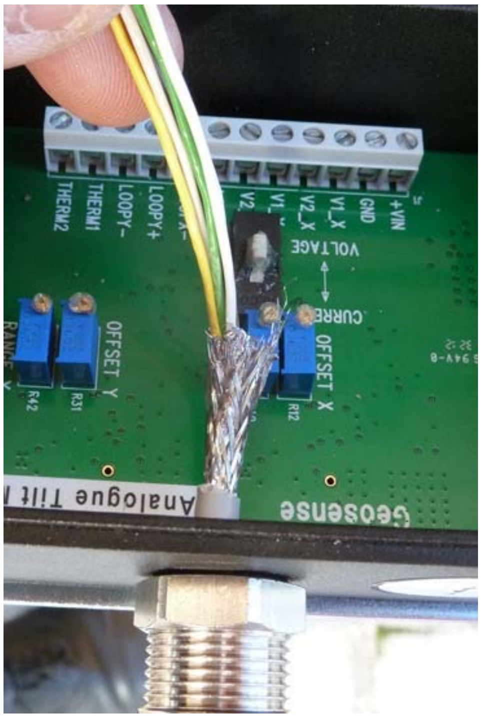
7. Measure 30mm back from the end of the sheath and carefully cut the sheath using either cutters or a sharp knife. Take care not to cut the braided shield.



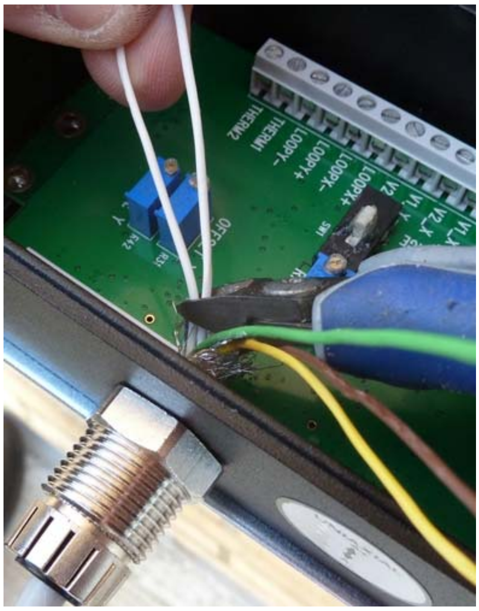
8. Remove the sheath to expose the braided shield.



9. Draw the cable back into the box so that the braided section is just inside the gland.

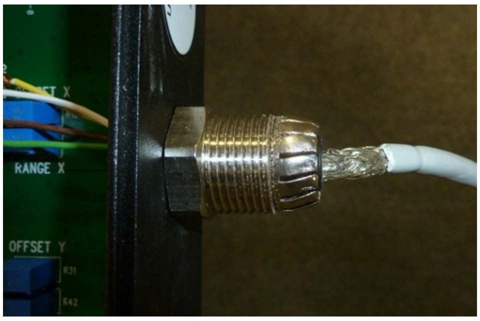


10. Trim out any ‘fillers’. These are solid plastic cores used to fill the voids in the cable. They have no conductors within them and are white in colour.

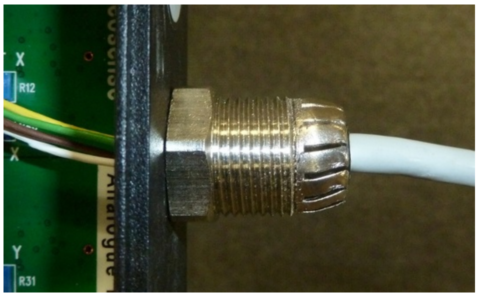


ONLY CUT THE FILLERS, NOT THE WHITE WIRE WITH CONDUCTORS

11. Carefully draw the cable back out of the gland until the braided section is just visible.

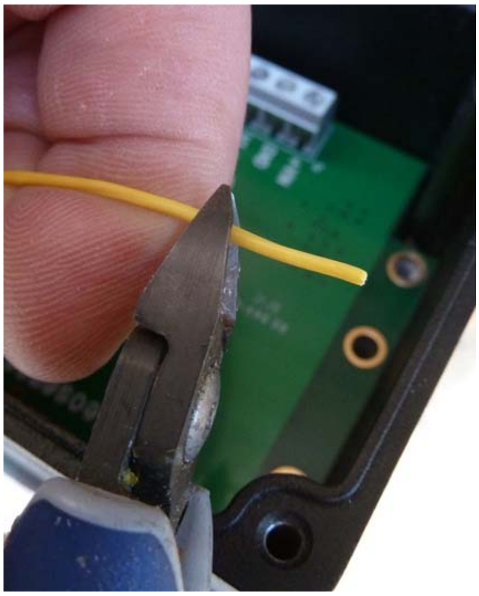


12. Now push the cable back in through the gland so that the braided section is within the gland but the rubber seal in the outer section of the gland is over the outer sheath of the cable.

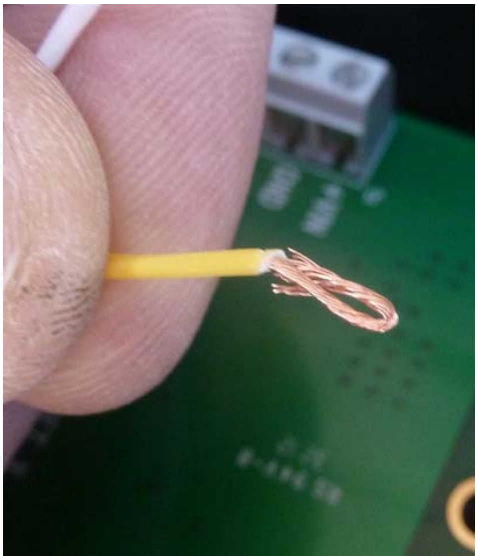


13. Hold the cable in position and carefully tighten the gland nut to complete the seal onto the cable and the ‘sheath to gland’ connection.

14. VERY carefully remove approximately 10mm of the conductor sheaths to expose the copper conductors.

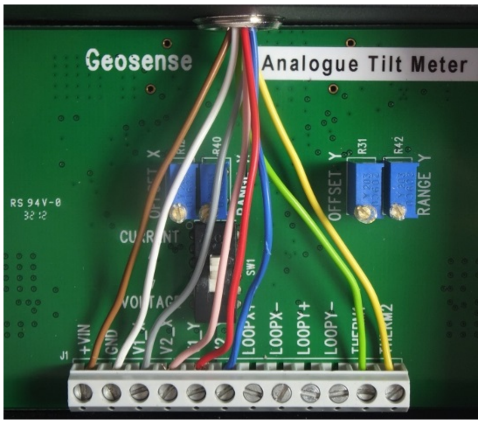


15. Twist the copper conductors together and them fold them back onto themselves to create a good contact surface.

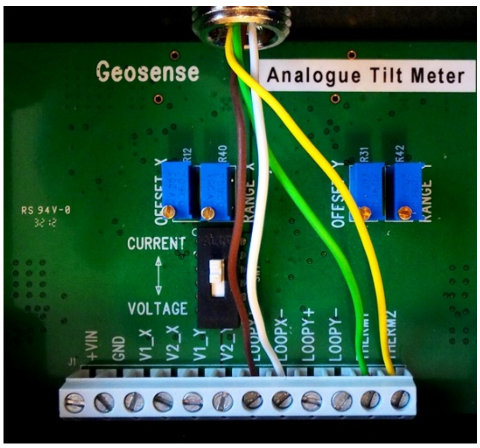


16. Using a small flat screwdriver, connect the conductors into the terminal on the circuit board. The number and colours of the conductors and the connectors used will depend upon the type of output selected.

A) - Uni Axial Voltage Connections
(with Temperature)



B) - Bi Axial Voltage Connections
(with Temperature)



C) - Uni Axial Current (4-20mA) Connections
(with Temperature)

D) - Bi Axial Current (4-20mA) Connections (with Temperature)

ONCE INSTALLED TAKE BASE READINGS

To see how to take readings using a portable readout see next section 6.

GEOSENSE

6.0 READOUTS

Geosense® MEMS In-place Tilt Meters require an 'excitation' voltage to power the internal electronics. Once energised, the output from the sensors can be read using a number of devices. Selection of the most appropriate device will be dependant upon both site conditions and the type of signal output from the sensors.

The voltage required to power the internal electronics is 8 - 15 Volts, DC, which is usually supplied by the readout device.

The **Geosense® MEMS In-place Tilt Meter** sensors with analogue (voltage / 4-20mA) outputs can be read using either a hand held readout or a data logger. In order to obtain the sensitivity, a readout must have a resolution of at least 3 decimal places (XX.XXX).

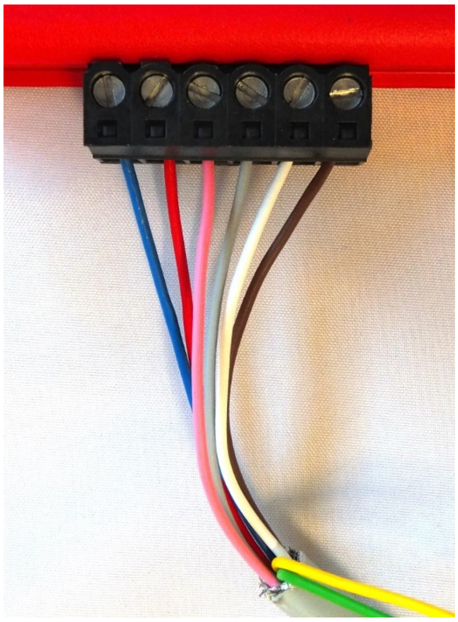
Portable readouts can be used to take readings during and after installation as follows:-

6.1 Analogue Voltage output using the IC6800V

1. Connect a cable to the Tilt Meter as detailed in the wiring instructions (see right for Bi-axial Voltage connections). Since the hand held readout does not accommodate temperature these connection can be ignored.

2. Connect the other end of the cable to the terminal on the readout unit, taking care to maintain the correct connections.

TILTMETER		READOUT
V IN	-	V+
GND	-	GND
V1_X	-	A+
V2_X	-	A-
V1_Y	-	B+
V2_Y	-	B-



The temperature conductors (green and yellow) are ignored when using the handheld readout. A pocket Multi-meter can be used to measure the resistance over the temperature conductors for conversion to temperature using the lookup table at the rear of this manual.

If an alternative cable with different coloured conductors s is used, the connections should match those defined by the table above.

(Wiring for Bi-axial unit shown)

3. Pressing the button marked A will display a voltage output from the A axis sensor (sometimes called the X axis).

4. Pressing the button marked B will display a voltage output from the B axis sensor (sometimes called the Y axis)

5. The output from the sensor is displayed in Volts. Refer to the sensor calibration sheet to calculate the actual angle of the sensor.

6. The centre of the range is 0 Volts and the range is -5 Volts to + 5 Volts.

6.2 Analogue 4-20mA output using the VA700

1. Connect a cable to the Tilt Meter as detailed in the wiring instructions (see right for Uni-axial 4-20 mA connections). The hand held readout does not accommodate temperature these connection can be ignored.

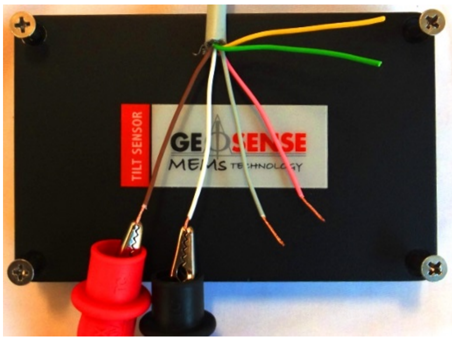
2. Connect the supplied fly-leads to the VA700 as shown. (Red into the **LOOP** connector and the black into the **mA** connector).

3. Pressing and holding the button marked ⏻ will turn the readout on.

4. Press the INPUT/OUTPUT button so that the display reads INPUT in the top left corner.

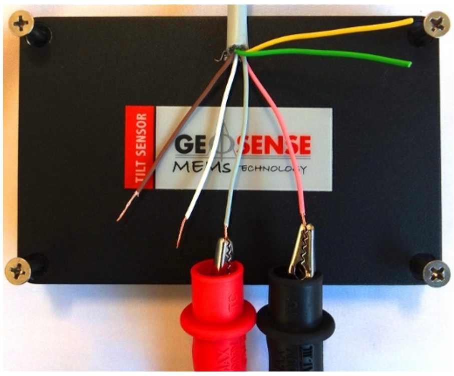
5. Press the mA/mA% button so that mA is indicated in the lower right of the display.

6. To measure the output from the A axis, use the clip connector to attach the RED flylead to the LOOP X+ (Brown) cable & the BLACK flylead to the LOOP X- (White) Pressing the button marked B will display a voltage output from the B axis sensor (sometimes called the Y axis)



(Continued on page 32)

7. To measure the output from the B axis, use the clip connector to attach the RED flylead to the LOOP Y+ (Grey) cable & the BLACK flylead to the LOOP Y- (Pink) Pressing the button marked B will display a voltage output from the B axis sensor (sometimes called the Y axis)



8. The display on the readout will be ‘mA ‘. Refer to the sensor calibration sheet to calculate the actual angle of the sensor.

9. The centre of the range is 12 mA and the range of the output is 4 mA to 20 mA.

6.2 Data loggers

Data loggers have the ability to automatically excite and interrogate a number of sensors together with the ability to store large numbers of readings that might be associated with tilt monitoring.

This is the preferred and most common method of monitoring tilt meter installations and is the recommended method of interrogating multiple installations of **Geosense® MEMS In-place Tilt Meters.**

The following are 'industry standard' data loggers that are typically used for connection to **Geosense® MEMS In-place Tilt Meters:-**

- Campbell Scientific loggers
- DataTaker loggers

Since +5 to –5 Volts and 4 - 20 mA's are common instrument outputs, it is possible to use a wide variety of data logging devices to record their readings. However, only those manufactured by the above companies are currently supported by **Geosense® .**

Connection to Data loggers

Campbell and DataTaker based data loggers and their associated components are configured and programmed to suit a sites' particular requirements, reflecting site conditions, instrument numbers and the required monitoring regime.

Connections to each logger will, therefore, vary. Details of specific connections will be included with each logger supplied.

7.0 DATA HANDLING

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

7.1 Data Conversion

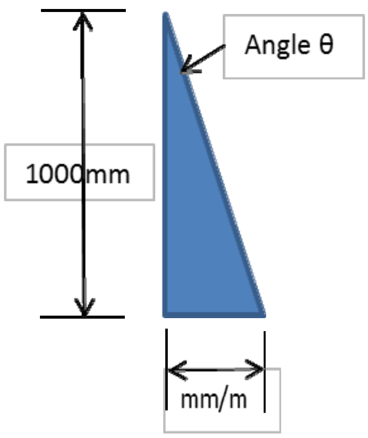
The readings generated by the tilt meters are in one of two formats:

- *Voltage* : +5 volts to -5 Volts for +15 degrees to –15 degrees

  The tilt meter is supplied with 8 - 15 volts and a return **voltage** is read by the readout unit. As the sensor is tilted the output changes from 0 to - 5 Volts at 15 degrees in the negative direction of its axis and from 0 to +5 Volts at 15 degrees in the positive direction. This voltage can then converted into an angle by a simple **linear** calculation using the supplied calibration details.

- *Current* : 4mA to 20mA for -15 degrees to +15 degrees

  The tilt meter is powered with a 8 - 15 volt current loop (two wires) from which it draws the current to power itself. As it is tilted the output changes from 4 mA at 15 degrees in negative direction of its axis, to 20 mA at 15 degrees in the positive direction. The current is then converted into an angle by a simple **linear** calculation using the supplied calibration details.



7.1 Data Conversion contd...

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

Calibration factors - below are typical calibration factors found on an **Analogue** tilt meter calibration sheet.

A AXIS		
Calibration Factors	**0.05217**	mV to Sin θ
	2.99781	mV to Degrees θ
	53.5898	mV to mm/m
B AXIS		
Calibration Factors	**0.03234**	mA to Sin θ
	1.87418	mA to Degrees θ
	33.4937	mA to mm/m

<u>Individual Calibration Sheets are provided for all sensors.</u>

The calibration sheet for a bi-axial tilt meter will include the calibration details for both of the sensors (A & B). Typically, the calibration factors would be presented as above but the units will vary depending upon the sensors output.

Some examples of conversion from tilt meter output to engineering units are shown below.

- **Voltage Reading Into Sine of the Angle**

The conversion of a voltage output into Sin of the Angle, with respect to vertical, is based on the linear **Y** = **(** X **- C)** *__M__ relationship, where ….

Y = Angle (Sin θ) with respect to vertical
M = Calibration Factor (for Sine of the Angle per mV from calibration sheet)
X = Voltage reading (V)
C = Voltage reading (V) at Zero (Vertical)

If for example:

M = 0.05217
X **= +0.3134 Volts**
C = -0.00763 at Vertical
Y = (+0.3134 - (- 0.007630)) *0.05217
Y **= +0.1675 (Sine of the angle)**

- **Voltage Reading Into Degrees**

The conversion of a voltage output into degrees is based on the linear **Y** = **(** X **- C)** *__M__ relationship, where ….

Y = Angle (in degrees), with respect to vertical.
M = Calibration Factor (for degrees, from the calibration sheet)
X = Voltage reading
C = Volt reading at Zero - if applicable (from the calibration sheet)

7.1 Data Conversion contd...

If for example:

M = 2.99781 degrees/volt
X = +0.3134 Volts
C = -0.00763 at Vertical
Y = (+0.3134 - (- 0.007630)) *2.99781
Y = +0.9624 degrees

- **Voltage Reading into mm / m**

The conversion of a voltage output into degrees is based on the linear **Y** = **(** X **-** **C** **)** ***M** relationship, where ….

Y = Angle in mm/m with respect to vertical.
M = Calibration Factor (for mm/m from the calibration sheet)
X = Voltage reading
C = Volt reading at Zero - if applicable (from the calibration sheet)

If for example:

M = 53.5898 mm/m
X = +0.3134 Volts
C = -0.00763 at Vertical
Y = (+0.3134 - (- 0.007630)) *53.5898
Y = +17.20 mm/m

- **Milliamps Reading into Sine of the Angle**

The conversion of a milliamp output into the Sine of the angle is based on the linear **Y** = **(M * X)** +**C** relationship, where ….

Y = Value of the Sine of the angle of tilt
M = Calibration Factor (for Sine of the angle from the calibration sheet)
X = Milliamp reading
C = Zero reading (from the calibration sheet)

If for example:

M = 0.03235 per mA.
X = 14.974 mA
C = 12.000 mA at Zero degrees
Y = (14.974 - 12.000) * 0.03235
Y = +0.09624

7.1 Data Conversion contd...

- **Milliamps Reading into Degrees**

The conversion of a milliamp output into an angle in degrees is based on the linear **Y** = **(M * X)** +**C** relationship, where ….

Y = Value of the angle of tilt from vertical
M = Calibration Factor (for the angle from the calibration sheet)
X = Milliamp reading
C = Zero reading (from the calibration sheet)

If for example:

M = 1.8750 per mA.
X = 14.974 mA
C = 12.000 mA at Zero degrees
Y = (14.974 - 12.000) * 1.8750
Y = + 5.57625 degrees

- **Milliamps Reading into mm/m**

The conversion of a milliamp output into a mm / m value is, again, based on the linear **Y** = **(M * X)** +**C** relationship, where ….

Y = Theoretical offset from vertical over a distance of 1m, with respect to vertical.
M = Calibration Factor (for mm/m, from the calibration sheet)
X = Milliamp reading
C = Zero reading (from the calibration sheet)

If for example:

M = 32.3524 mm per mA.
X = 14.974 mA
C = 12.000 mA at Zero degrees
Y = (14.974 - 12.000) * 32.3524
Y = +96.22 mm/m

NOTE: FOR A BIAXIAL SENSOR REPEAT THE ABOVE CALCULATIONS FOR THE B AXIS

8.0 MAINTENANCE

Geosense® MEMS In-place Tilt Meters are maintenance free devices, for most applications. However should the unit be subjected to an impact, be producing "un-expected" readings or have been moved to another project after an extended period, it is recommended that they be returned to **Geosense®** for re-calibration.

9.0 TROUBLESHOOTING

PROBLEM	**READOUT**	**REMEDY**
No output signal	Hand Held	Check for loose cable connections
No output signal	Hand Held	Check for correct settings on readout
Over range signal	All	Check angle of sensor and adjust.
NAN displayed	Logger	Check for loose cable connections
NAN displayed	Logger	Check correct supply voltage polarity
NAN displayed	Logger	Check cables, glands, logger box for EMC

If after all of the above checks have been carried out and the Tilt Meter still does not operate correctly, please contact **Geosense®** for advice, or return unit for inspection.

IF A "**NAN**" IS DISPLAYED IN A LOGGER DATA STRING, IT MEANS THAT THE DEVICE IS NOT CONNECTED OR IS NOT FUNCTIONING CORRECTLY

IT SHOULD IMMEDIATELY BE INSPECTED TO RECTIFY THE FAULT

10.0 SPECIFICATION

TILT METERS

ITEM	IPTM-1-420	IPTM-2-420	IPTM-1-010	IPTM-2-010
Range	±15°	±15°	±15°	±15°
Axis	Uniaxial	Biaxial	Uniaxial	Biaxial
Output	4-20mA	4-20mA	+/-5 Volts	+/-5 Volts
Resolution	±5 arc sec	±5 arc sec	±5 arc sec	±5 arc sec
Non linearity	±0.05% FS	±0.05% FS	±0.05% FS	±0.05% FS
Repeatability	±0.025% FS	±0.025% FS	±0.025% FS	±0.025% FS
Sensor	MEMS	MEMS	MEMS	MEMS
Excitation	8-15 V DC	8-15 V DC	8-15 V DC	8-15 V DC
Operating Temp	-40 to +85°C	-40 to +85°C	-40 to +85°C	-40 to +85°C
Dimensions	125x80x60mm	125x80x60mm	125x80x60mm	125x80x60mm

CABLES

Standard

TILT METER MODEL	CABLE	PART NUMBER	CABLE + TEMP	PART NUMBER
Uniaxial voltage	2 twisted pair	Q10-151	3 twisted pair	Q10-152
Bi-axial voltage	3 twisted pair	Q10-152	4 twisted pair	Q10-153
Uniaxial current	1 twisted pair	Q10-150	2 twisted pair	Q10-151
Bi-axial current	2 twisted pair	Q10-151	3 twisted pair	Q10-152

Low smoke halogen free (LSHF)

TILT METER MODEL	CABLE	PART NUMBER	CABLE + TEMP	PART NUMBER
Uniaxial voltage	2 twisted pair	Q10-161	3 twisted pair	Q10-162
Bi-axial voltage	3 twisted pair	Q10-162	4 twisted pair	Q10-163
Uniaxial current	1 twisted pair	Q10-160	2 twisted pair	Q10-161
Bi-axial current	2 twisted pair	Q10-161	3 twisted pair	Q10-162

LUL Approved

TILT METER MODEL	CABLE	PART NUMBER	CABLE + TEMP	PART NUMBER
Uniaxial voltage	2 twisted pair	Q10-171	4 twisted pair	Q10-172
Bi-axial voltage	4 twisted pair	Q10-172	4 twisted pair	Q10-172
Uniaxial current	1 twisted pair	Q10-170	2 twisted pair	Q10-171
Bi-axial current	2 twisted pair	Q10-171	4 twisted pair	Q10-172

11.0 SPARE PARTS

There are no spares parts available for **Geosense® MEMS In-place Tilt Meters.**
In the case of damage to the connectors on the readout unit or the tilt meter, Geosense can provide the replacement parts and a service to attach the connectors.

12.0 RETURN OF GOODS

12.1 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, 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 and a copy of the form should be faxed or emailed in advance to the factory.

12.2 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.

12.3 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 **Geosense® MEMS In-place Tilt Meters** 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.

12.4 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.

12.5 Transport & Storage

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

13.0 LIMITED WARRANTY

The manufacturer, Geosense Ltd, warrants the **Geosense® MEMS Tilt Meter** 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 In-place Tilt Meter** and other component parts.

The **Geosense® MEMS In-place Tilt Meter** 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 Geosense® MEMS In-place Tilt Meter 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 **Geosense® MEMS In-place Tilt Meter** equipment from the time of delivery to Purchaser.

Geosense Ltd

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