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USERS' MANUAL

TILT METER & BEAM SENSOR

(BOX TYPE)

MODEL EAN-91M (TILT METER) & EAN-91M-B (BEAM SENSOR)

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Content

1 INTRODUCTION

Encardio-rite model EAN-91M/EAN-91M-B (with beam) tilt meter is suitable for long term monitoring inclination and vertical rotation of structures.

Continuous data logging and real-time monitoring helps to provide early warning in case of impending failure allowing time for corrective action to be taken or if necessary for safe evacuation of the area.

Tilt change in a structure may be caused by construction activity like excavation; tunneling or de-watering that may affect the ground supporting the structure. Change in tilt could also result from loading of the structure, such as loading of a dam during impoundment, loading of a diaphragm wall during excavation or loading of a bridge deck due to wind and traffic. Data from the tilt meter provides early warning of threatening deformations, allowing time for corrective action to be taken or if necessary for safe evacuation of the area.

1.1 Applications

EAN-91M tilt meter is widely used in following applications:

- Monitoring vertical rotation of retaining walls.
- Monitoring inclination and rotation of dams, piers, piles and other structures.
- Monitoring stability of structures in landslide areas.
- Monitoring tunnels for convergence and other movement.
- Monitoring safety of structures around zones of excavation or tunneling.
- Monitoring deflection in bridges and struts under different loading conditions.

1.2 Conventions used in this manual

WARNING! Warning messages calls attention to a procedure or practice that if not properly followed, it could possibly cause personal injury.

CAUTION: Caution messages calls attention to a procedure or practice, that if not properly followed, it may result in loss of data or damage to equipment.

NOTE: Note contains important information and is set off from the regular text to draw the users' attention.

1.3 How to use this manual

This users' manual is intended to provide you with sufficient information for making optimum use of tilt meters in your applications.

To make the manual more useful we invite valuable comments and suggestions regarding any additions or enhancements. We also request to please let us know of any errors that are found while going through the manual.

NOTE: Installation personnel must have a background of good installation practices and knowledge of fundamentals of geotechnics. Novices may find it very difficult to carry on installation work. The intricacies involved in installation are such that even if a single essential but apparently minor requirement is ignored or overlooked, the most reliable of instruments will be rendered useless.

A lot of effort has been made in preparing this instruction manual. However best of instruction manuals cannot provide for each and every condition in field that may affect performance of the sensor. Also, blindly following the instruction manual will not guarantee success.

Sometimes, depending upon field conditions, installation personnel will have to consciously depart from written text and use their knowledge and common sense to find solution to a particular problem.

Installation of a tilt meter requires expertise. It is recommended that potential users themselves practice all the operations laid down in this manual by repeated installations.

NOTE: The sensor is normally used to monitor site conditions and will record even a minor change that may affect behaviour of structure being monitored. Some of these factors amongst others, are, seasonal weather changes, temperature, rain, barometric pressure, nearby landslides, earthquakes, traffic, construction activity around site including blasting, tides near sea coasts, fill levels, excavation, sequence of construction and changes in personnel etc. These factors must always be observed and recorded as they help in correlating data later on and may give an early warning of potential danger or problems.

2 GENERAL DESCRIPTION

Model EAN-91M tilt meter (Figure 1) is built around a Micro-Electro Mechanical System (MEMS) technology tilt sensor having range of ±15°, with high sensitivity and accuracy mounted inside a compact weatherproof enclosure. The tilt sensing module provides a bipolar DC voltage output proportional to the sine of tilt angle measured by the beam. The output is zero volts for a truly vertical or horizontal position.

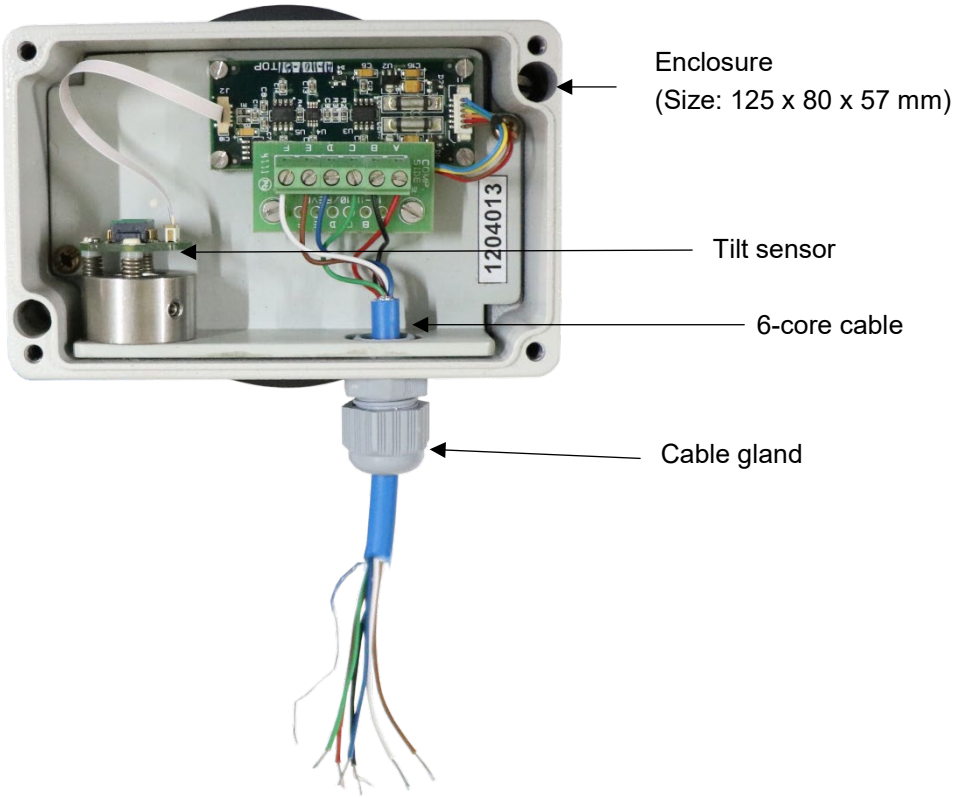


Figure 1: EAN-91M tilt meter

The EAN-91M tilt meter is not intended for absolute determination of tilt of structures. It measures change in tilt of a structure to which it is attached. The initial tilt reading for each tilt sensor is recorded after it has been mounted on the structure to be monitored. Subsequent tilt readings will be displayed w.r.t. initial reading.

2.1 Sample test certificates

TEST CERTIFICATE

Item : Tilt beam sensor (Uniaxial)
Model : EAN-91M-B
Range : ±15º
Serial no. : xxxxxx
Next calibration due on : 08.12.2020

Date : 09.12.2019
Temperature : 20 ºC

Test data

Test position Arc degrees (A)	SinA	*Calculated output (V_1) Volts	**Ideal output (V_2) Volts	Observed output 'A' axis (V_3) Volts	Offset corrected output (V_4) Volts	Error 'A' axis (V_4 - V_2) Volts	Non-conformance % fs
15	0.2588	4.141	4.142	4.144	4.142	0.0002	0.01
12	0.2079	3.326	3.328	3.329	3.327	0.0004	0.01
9	0.1565	2.503	2.504	2.505	2.504	0.0002	0.00
6	0.1046	1.673	1.673	1.674	1.673	0.0004	0.01
3	0.0524	0.838	0.838	0.839	0.838	0.0000	0.00
0	0.0000	0.000	0.000	0.001	0.000	0.0000	0.00
-3	-0.0524	-0.838	-0.838	-0.837	-0.838	0.0002	0.00
-6	-0.1046	-1.673	-1.673	-1.673	-1.674	0.0004	0.01
-9	-0.1565	-2.503	-2.504	-2.503	-2.504	0.0001	0.00
-12	-0.2079	-3.326	-3.328	-3.326	-3.327	0.0008	0.02
-15	-0.2588	-4.141	-4.142	-4.141	-4.143	0.0002	0.01

Max non-conformance (% fs) : 0.02

Sensor gauge factor : 16.006 Volts/Sin(90)

Calculation of tilt value (arc degree) :

SinA = Observed output / gauge factor

A = Sin^{-1}(observed output / gauge factor)

Wiring colour code :

Wire colour	Signal
Red	+12 V (supply)
Black	- 12 V (supply)
Green	0 V (supply)
Blue	Output 'A' axis
White	Output common
Brown	Not to be used

Note :

* Calculated output Voltage (V_1) worked out based on nominal gauge factor of 16.000 V/ g (i.e. 16V X Sin A).

** Ideal output Voltage (V2)' calculated from sine curve passing through sensitivity calibration points (@ ±15º) .

Tested by

3 INSTALLATION PROCEDURE

The EAN-91M tilt meter (uniaxial) is used to measure simple rotation of structures in a single plane known as plane of rotation. The plane of rotation is a plane parallel to the backside (surface) of the tiltmeter.

Depending on monitoring requirement, the tiltmeter can be mounted in two different ways as described below.

3.1 Pre-installation checks

3.1.1. Connect the 6-core cable to the tilt meter through screw terminal as per wiring details shown in Figure 1.

3.1.2. Connect the tilt meter to the digital readout unit or data acquisition system and configure to display the readings (refer to § 4.4/§ 4.5)

3.1.3. Tilt the sensor towards +ve side (counter clockwise) on the swivel bracket provided (Figure 9), output of the sensor will increase in positive direction (+ve sign is marked on the right side of top of enclosure). Similarly, the output will decrease when sensor is tilted in - ve direction (clockwise).

3.2 Installation on a vertical surface

3.2.1 Installation of tilt meter on the swivel bracket

- *Installation parallel to the wall*

If the structural rotation is expected to be in the plane of the surface of the wall, the tilt meter is mounted directly on the wall using the wall-mounting bracket as shown in Figure 2. The use of wall mounting bracket allows coarse levelling of the tilt meter and the alignment of the anchors need not be very precise. The wall-mounting bracket is fixed to the wall using any commercially available 8 mm anchors/fasteners suitable for brick or concrete wall.

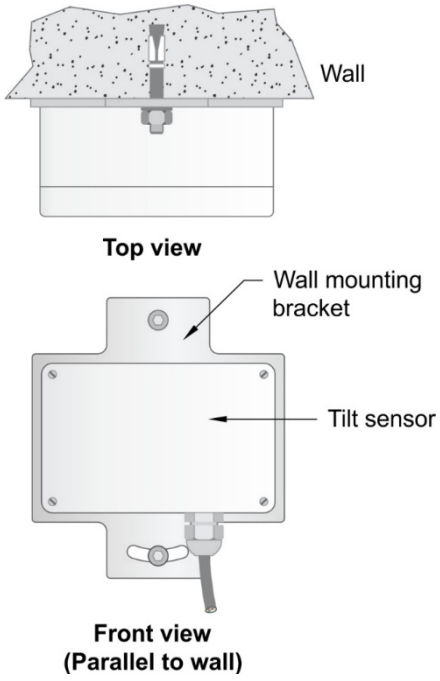


Figure 2: Installation parallel to the wall

- *Installation perpendicular to the wall*

If the surface of the wall is expected to rotate in a vertical plane perpendicular to the wall, the tilt meter should be mounted in an orientation as shown in the Figure 3. The use of a mounting kit is recommended, as this allows easy adjustment of the tilt meter orientation.

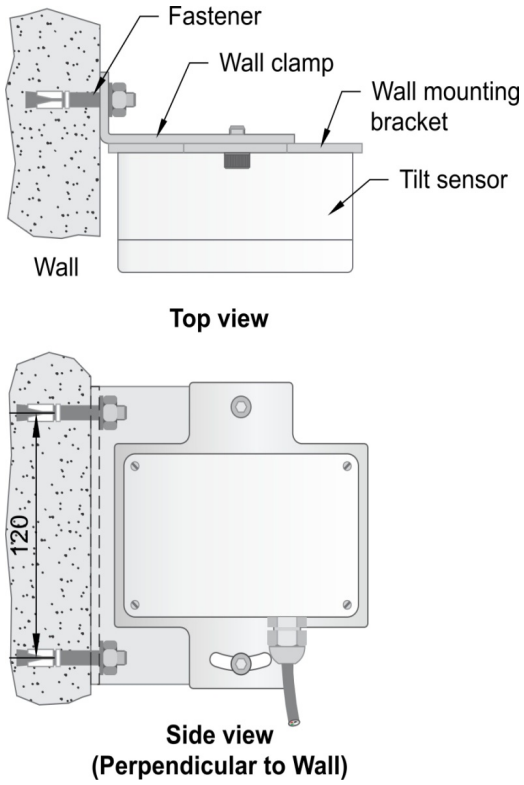


Figure 3: Installation perpendicular to the wall

3.2.2 Procedure

Installation procedure for both type of mounting arrangements is mentioned below:

- For installation parallel to the wall - using the wall mounting swivel bracket as a template, mark locations of two mounting holes. Visually ensure that position of the two holes are aligned vertically using a spirit level.
- For installation perpendicular to the wall - using the wall mounting swivel bracket as a template, mark locations of two mounting holes. Visually ensure that position of the two holes are aligned vertically using a spirit level.
- Drill two holes for 8 mm diameter anchors/fasteners and depth suitable for the type of anchor to be used.
- Fix the mounting anchors in holes following the manufacturer's recommendation.
- Mount the tilt meter on the wall-mounting bracket.
- Fix the wall-mounting bracket with the tilt meter to the anchors on the wall.

3.3 Installation of horizontal beam sensors

3.3.1 Mounting the sensor assembly on the beam

The EAN-91M-B, MEMS beam tilt sensor is generally supplied as EAN-91M tiltmeter mounted on a beam of customer specified length. However, on specific customer request the tiltmeter and the beams may be supplied separately. In such cases the sensor has to be mounted on the beam before the beams are fixed.

3.3.2 Installing the anchors

Horizontal beam sensors are used to find the relative vertical displacement of the two anchors at its ends. The distance between the two anchors is known as the gauge length of the beam sensor. The beam sensors are generally supplied in standard gauge lengths of 1, 2 or 3 m, but other customer specified lengths are also available.

The beam sensors are generally used in a string with two beam sensors sharing a common anchor for fixing.

- Using a chalk-line and suitable colored chalk mark a straight line along which the beam sensors would be fixed. For wall mounting use a sprit level and a beam to ensure that the line is as horizontal as possible. For floor mounting the line should be aligned along the direction in which the vertical settlement profile is desired.
- With a tape measure, on the above line, mark off distances corresponding to the gauge length of the beams to be fixed. It may be noted that the beams are slightly longer than their gauge length. If required, beams of different gauge lengths may be used in the same string. Each mark corresponds to an anchor position.
- Drill 12mm diameter anchor holes to a depth of about 100 mm at the marked position. Ensure that the holes are as perpendicular to the wall or floor surface as possible.
- Clear the hole of debris by blowing air or brushing.
- Fix the longer (148 mm) anchors of the mounting kits with suitable epoxy grout in these holes such that around 50 mm length of anchors project out of the surface after fixing. Follow epoxy manufacturer's recommendation for fixing the anchors.
- Allow the grout to set for the recommended time before handling.
- Measure and record the exact center distances between each anchor in the string. Hint: As the anchor centers may be difficult to locate, measure the distance between the left side of each anchor.

3.3.3 Fixing the beams

The beam tilt sensors are provided with two mounting angles on each side. The beams can be fixed to the anchors directly using these mounting angles. However, if the strings of beams are subject to any torsional movement, the beam mounting kits provide more flexibility and are strongly recommended.

The Figure 4 below shows the correct position of each component of the kit while mounting the beams.

- Fasten angle brackets to the already grouted anchors. Check the relative position of the nuts, washers and angle brackets from the drawing.
- Fix the 72 mm stud anchors on the angle brackets fixed to the grouted anchors.
- Slightly loosen the mounting angle at both sides of each beam by loosening the hex nut holding it to the beam.

- Fix the beams on the 72 mm stud anchors as shown in drawing. Use the double-shouldered nylon washer between the mounting angles of two adjacent beams.
- Lightly tighten the nuts so that the spring washers are slightly compressed.
- Tighten the bolt head holding the mounting angles to the beam-ends.
- Put a drop of Loctite 290 (post assembly thread locking compound) at the accessible junction of each nut on the studs to lock them in place.

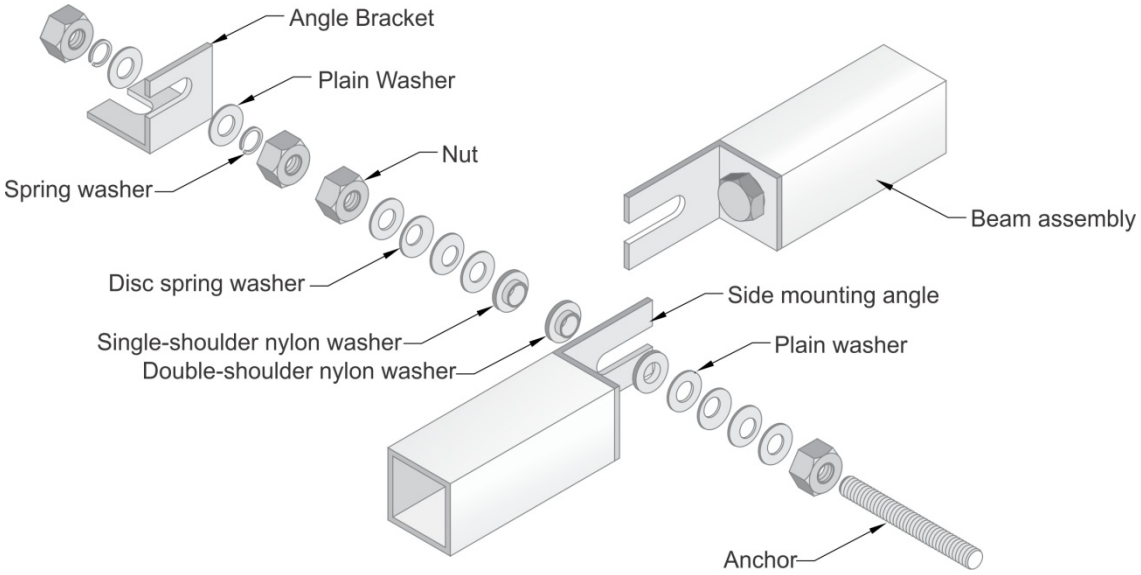


Figure 4: Installation of the anchor and the nuts & washer set

Figure 5 below shows how to mount the EAN-91M-B horizontal beam sensor on wall using the standard mounting kit.

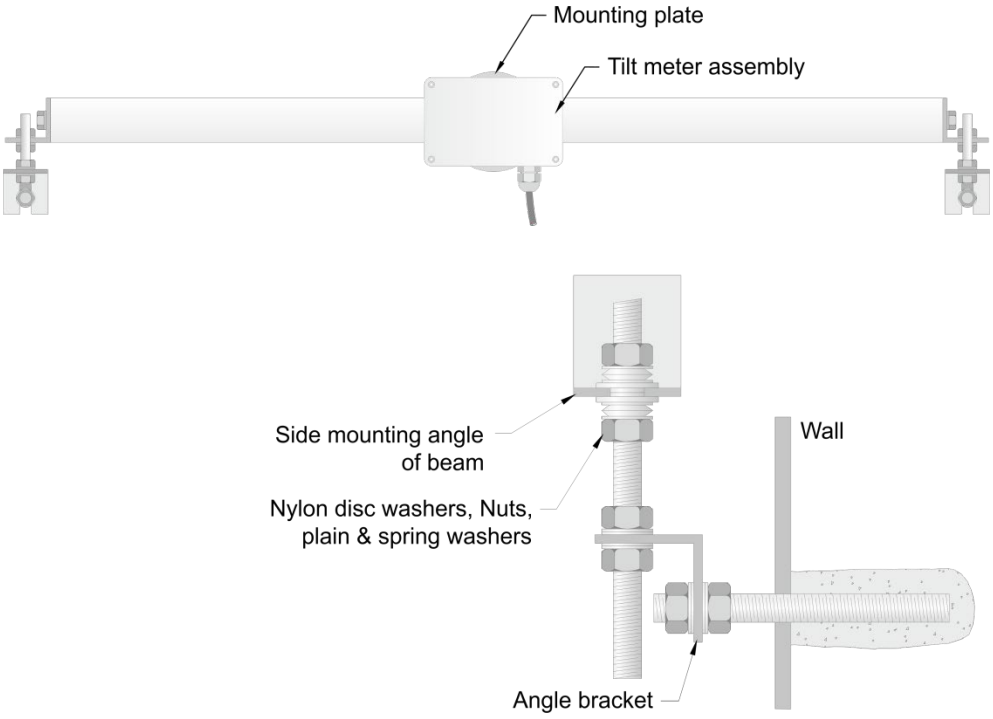


Figure 5: Installation of the EAN-91M-B sensor horizontally on the wall

Error! Reference source not found. below shows how to mount the EAN-91M-B horizontal beam sensor on floor using the standard mounting kit if the installation is in required in strings.

If an individual beam sensor is to be installed, please refer to Figure 7 for installation details of the anchors, nut and washer.

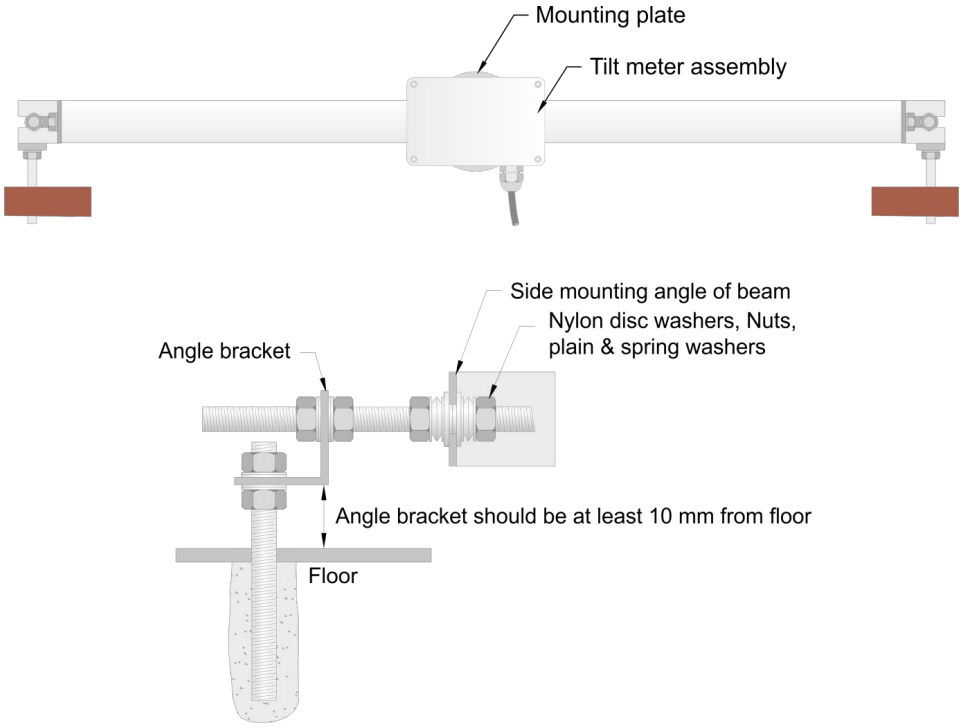


Figure 6: Installation of EAN-91M-B sensor horizontally on the floor

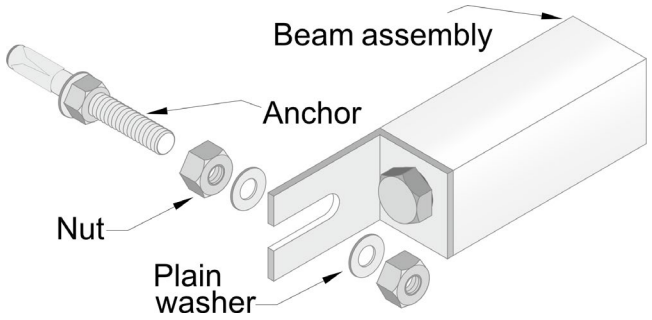


Figure 7: Installation of an individual EAN-91M-B sensor on the wall

3.3.4 Installation of vertical beam sensors

Vertical beam sensors are used to find the relative horizontal displacement of the two anchors at its ends. The distance between the two anchors is known as the gauge length of the beam sensor. Vertical beam sensors are generally supplied in standard gauge lengths of 1, 2 or 3 m, but other customer specified lengths are also available. The beam sensors are generally used in a string with two beam sensors sharing a common anchor for fixing.

Vertical beam sensors consist of a standard EAN-91M tiltmeter, an aluminium beam, 38 mm x 38 mm square and of specified gauge length and mounting hardware for mounting the tiltmeter on the beam.

3.3.5 Installing the anchors

1. Using a plumb line and suitable colored chalk mark a vertical straight line along which the beam sensors would be fixed.
2. With a tape measure, on the above line, mark off distances corresponding to the gauge length of the beams to be fixed. It may be noted that the beams are slightly longer than their gauge length. If required, beams of different gauge lengths may be used in the same string. Each mark corresponds to an anchor position.
3. Drill 12 mm diameter anchor holes to a depth of about 100 mm at the marked position. Ensure that the holes are as perpendicular to the wall or floor surface as possible.
4. Clear the hole of debris by blowing air or brushing.
5. Fix the longer (148 mm) anchors of the mounting kits with suitable epoxy grout in these holes such that around 50 mm length of anchors project out of the surface after fixing. Follow epoxy manufacturer's recommendation for fixing the anchors.
6. Allow the grout to set for the recommended time before handling.
7. Measure and record the exact center distances between each anchor in the string. Hint: As the anchor centers may be difficult to locate, measure the distance between the left side of each anchor.

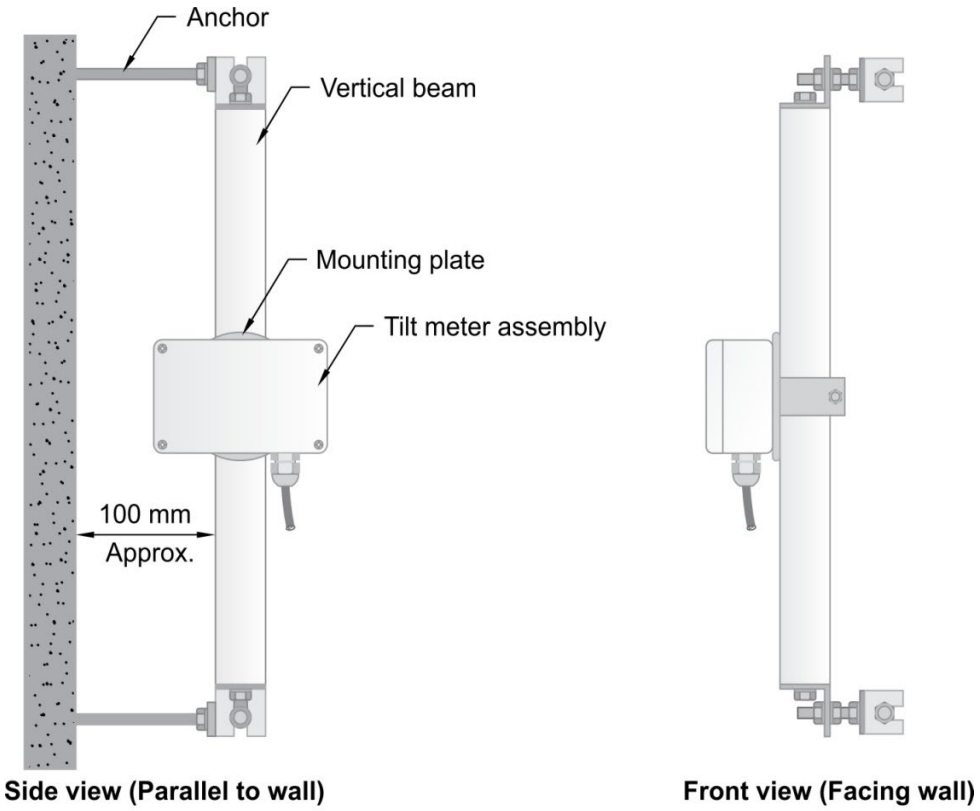


Figure 8: Installation of an individual EAN-91M-B on a vertical beam

3.3.6 Fixing the beams

The sensor beams are provided with two mounting angles on each side. The beams can be fixed to the anchors directly using these mounting angles. However, if the string of beams are subject to any torsional movement the separately available beam mounting kits provide more flexibility and are strongly recommended.

- Fasten angle brackets to the already grouted 148 mm anchors. Check the relative position of the nuts, washers and angle brackets from the drawing.
- Fix the 72 mm stud anchors on the angle brackets fixed to the grouted anchors.
- Slightly loosen the mounting angle at both sides of each beam by loosening the hex nut holding it to the beam.
- Fix the beams on the 72 mm stud anchors as shown in drawing. Use the double shouldered nylon washer between the mounting angles of two adjacent beams. The beams should be roughly parallel to the wall surface.
- Lightly tighten the nuts so that the spring washers are slightly compressed.
- Tighten the bolt head holding the mounting angles to the beam ends.
- Check that the top of the tiltmeter enclosure is level. If not, then remove cover, loosen the two mounting screws and rotate housing. Tighten mounting screws and replace cover when done.
- Put a drop of Loctite 290 (post assembly thread locking compound) at the accessible junction of each nut on the stud anchors to lock them in place.

3.4 Protection of tilt meter

Avoid installation of tilt meter in parts of the structure exposed to direct sunlight. If this is not feasible, a box made from Thermocole or similar heat insulating material should be installed covering the tilt meter and protecting it from direct sunlight.

If certain degree of mechanical protection is also required, wooden or fibreglass protection boxes may be considered. Heat insulating tape can be fixed to the inner surface of such boxes for thermal insulation.

3.5 Other considerations

Install tilt meter on a structural member of a building and not on the façade or boundary wall which may behave in a different manner than the main building. Do not install it at a location having vibrations, for example caused by a heavy rotary machinery. Avoid installing at location where it can be vandalized or get hit by pedestrians.

4 MEASUREMENT OF TILT

The output of model EAN-91M tilt meter can be read by EDI-53 UTM or logged from a remote location by an automatic data acquisition system like Encardio-rite model ESDL-30/EDAS-10.

A 6-core cable can be terminated or extended to the nearest measurement station through a suitable junction box.

4.1 Wiring details

Cable colour (CS-0703)	Description
Red	+12 V DC (supply)
Black	-12 V DC (supply)
Green	0 V (Power supply common)
Blue	Output Channel A
Brown	Not to be used for uniaxial tilt sensors
White	Output Common

4.2 Sign convention

Carefully orient the tilt sensor during installation. A (+) sign is on the top right side of the enclosure. If the enclosure is tilted counter clockwise then readings shows an increase (with positive sign) - Figure 9 (left). If the enclosure tilts clockwise then readings shows a decrease (with a negative sign) -Figure 9 (right).

After the enclosure is fixed to the structure, the sensor is adjusted to the zero reading (initial). Subtracting the initial tilt reading from the subsequent tilt reading gives change in tilt of structure over a period of time.

4.3 Zero adjustment of tilt meter

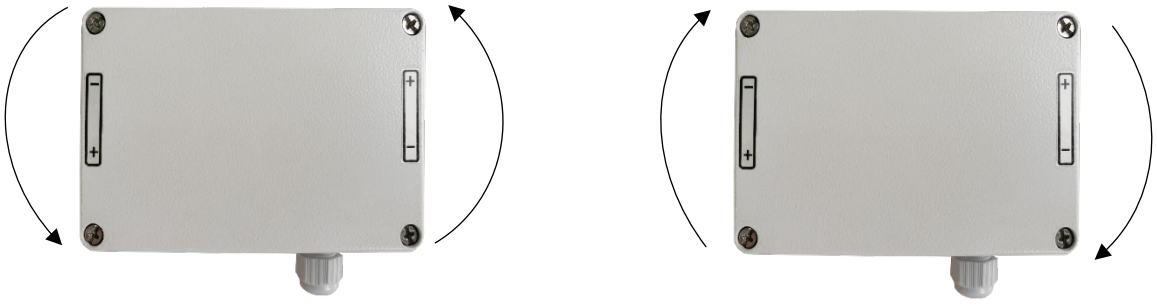


Figure 9 Sign Convention of tilt for EAN-91M tilt meter

Connect the EAN-91M/EAN-91M-B tilt meter with the datalogger and adjust the sensor housing/beam to make it as close to zero and then fix it firmly such that it does not get disturbed.

4.4 Measurement using Encardio-rite Digital readout unit

Tilt meter can be connected to Encardio-rite model EDI-53UTM portable digital read-out unit/datalogger through a break-out box. Break-out box provides the mating circular connector to read-out unit. The cable can also be extended through the break-out box. The breakout box is also equipped with lightning arrestor.

Encardio-rite model EDI-53UTM portable digital read-out unit/datalogger reads sine of tilt angle when parameter of typical tilt meter is fed. To read sine of tilt angle, set-up EDI-53UTM channel as follows:

Unit [UNITS]	No units (key 9)
Initial reading [IR]	Set to zero
Gauge factor [GF]	2/tilt meter gage factor in volts/sin 90°
Coeff of X^2	Set to zero
Decimal point [DP]	as required (recommended value is 4)

Tilt angle can be calculated by $\sin^{-1}$(observed value).

4.5 Measurement using EDAS-10 data acquisition system

Model EAN-91M tilt meter requires external power source of ± 12V DC (regulated) when connected to EDAS-10 data acquisition system. For connecting tilt meter, a multiplexer model EAM-616 is required. 16 tilt meters can be connected to each multiplexer model EAM-616.

Maximum input of EDAS-10 is ± 2.5 V; whereas output of tilt meter is ± 4V at 15° proportional to sine of angle. A high precision attenuator is therefore required as shown in diagram below:

Tilt measurement with Tilt sensor and DAS

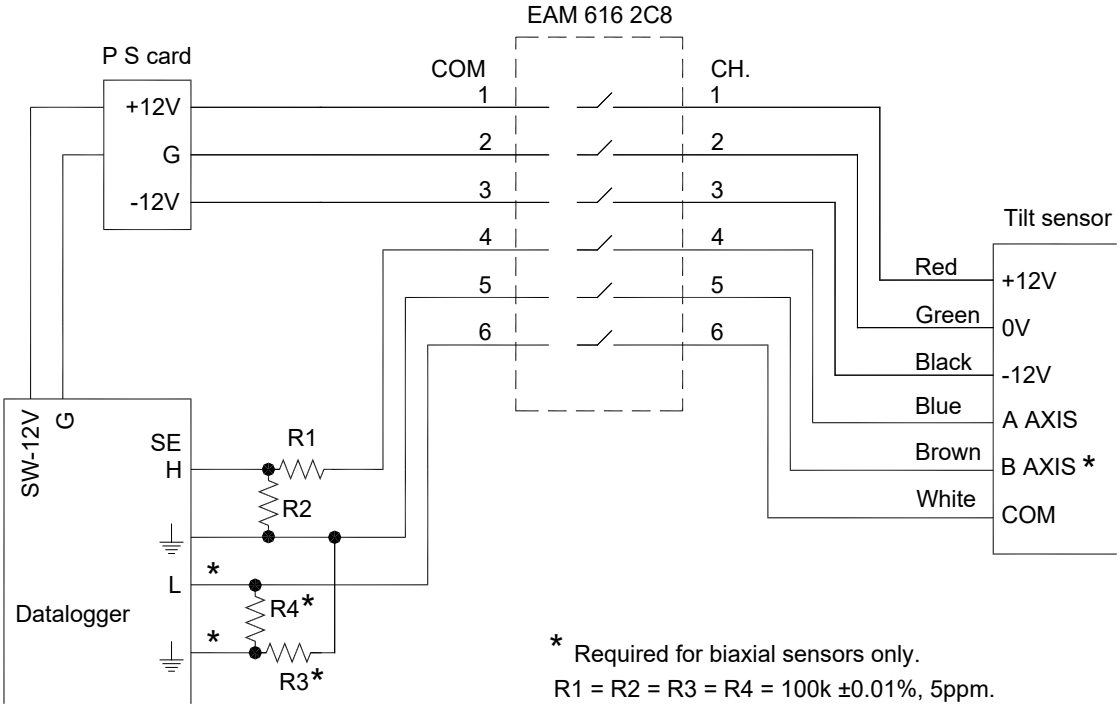
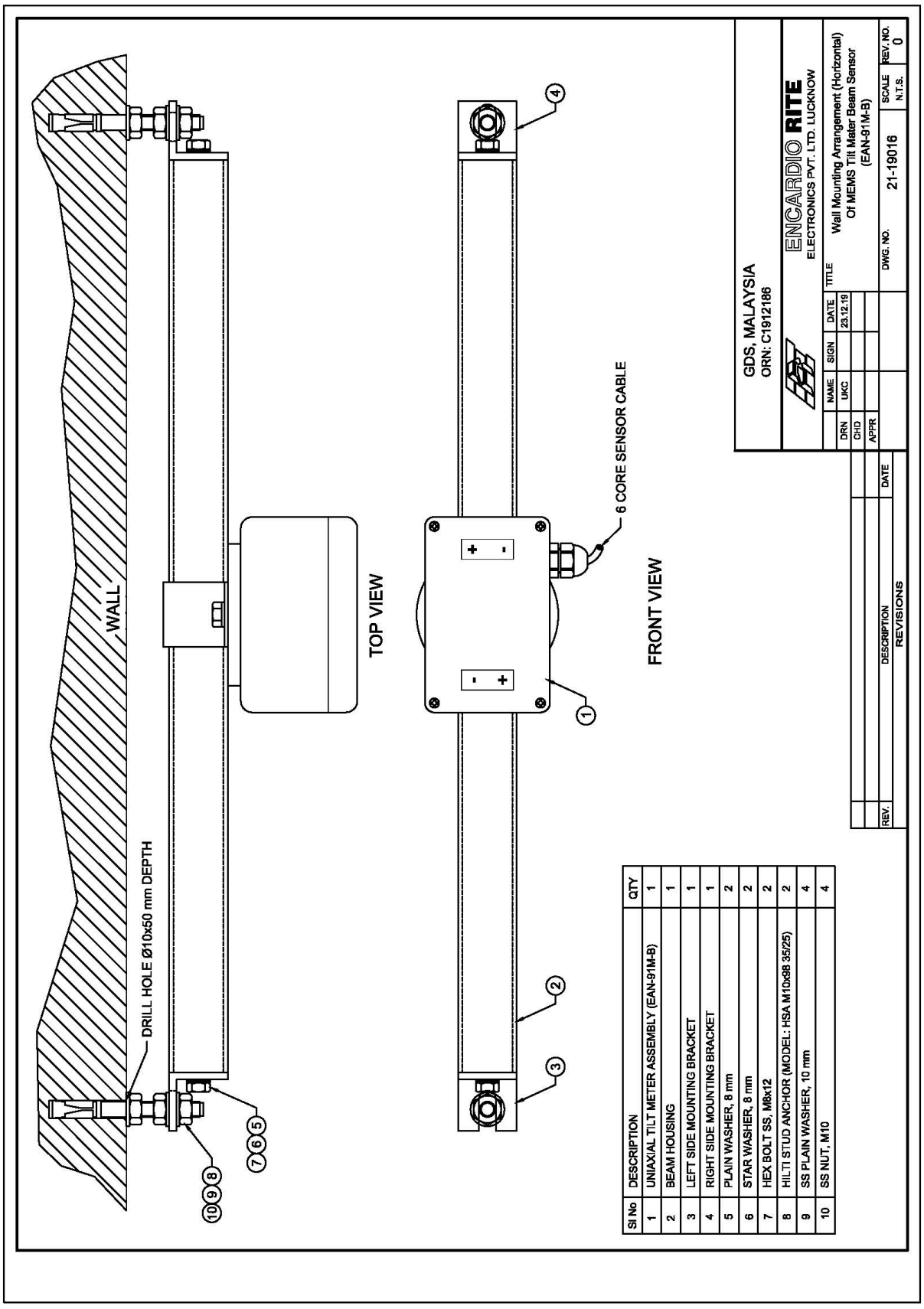


Figure 10: Tilt meter connected to DAS

To get tilt angle refer to typical gage factor and formula given in relevant test certificate. A sample test certificate for uni-axial sensor can be referred to in section 2.1

NOTE: For detailed instructions on configuration of Encardio-rite model EDAS-10 data acquisition systems based on measurement and control modules CR 1000/CR 800/CR 200, refer to Campbell Scientific's relevant Users' Manual.

ANNEXURE 1: WALL MOUNTING ARRANGEMENT FOR FIXING EAN-91M-B BEAM SENSOR



Sl No	DESCRIPTION	QTY
1	UNIAXIAL TILT METER ASSEMBLY (EAN-91M-B)	1
2	BEAM HOUSING	1
3	LEFT SIDE MOUNTING BRACKET	1
4	RIGHT SIDE MOUNTING BRACKET	1
5	PLAIN WASHER, 8 mm	2
6	STAR WASHER, 8 mm	2
7	HEX BOLT SS, M8x12	2
8	HILTI STUD ANCHOR (MODEL: HSA M10x98 35/25)	2
9	SS PLAIN WASHER, 10 mm	4
10	SS NUT, M10	4