



ENCARDIO RITE

ONE STOP MONITORING SOLUTIONS | HYDROLOGY | GEOTECHNICAL | STRUCTURAL | GEODETIC
Over 50 years of excellence through ingenuity

USERS' MANUAL

TILT BEAM SENSOR

MODEL EAN-41M



Doc # WI-6002.82 R00 | May 2012

ENCARDIO-RITE ELECTRONICS PVT. LTD.

A-7, Industrial Estate, Talkatora Road Lucknow, UP - 226011, India | P: +91 522 2661039-42 | Email: geotech@encardio.com | www.encardio.com

International: UAE | Qatar | Bahrain | Bhutan | Europe | USA

India: Lucknow | Delhi | Kolkata | Mumbai | Chennai | Bangalore | Hyderabad | J&K

Contents

1	INTRODUCTION	1
1.1	Applications	1
1.2	Conventions used in this manual	1
1.3	How to use this manual	1
2	THE TILTMETER	2
2.1	Operation	2
2.2	Installation of Tiltmeter	2
2.3	Installation of Horizontal Beam Sensor	2
2.3.1	Installing the anchors	2
2.3.2	Fixing the beams	3
2.4	Installation of Vertical Beam Sensors	5
2.4.1	Installing the anchors	5
2.4.2	Fixing the beams	5
2.5	Tools and accessories required for installation	6
3	MEASUREMENT OF TILT	7
3.1	Wiring details	7
3.2	Sign convention	7
3.3	Connecting sensor to Encardio-rite Digital readout unit	7
3.4	Connecting sensor to EDAS-10 data acquisition system	8
3.5	Sample Test Certificate	9

1 INTRODUCTION

Encardio-rite model EAN-41M tilt meter is suitable for monitoring inclination and vertical rotation of structures. It is a high resolution tilt meter, is rugged in construction.

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-41M tiltmeter 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 could possibly cause personal injury.

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

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

This users' manual is intended to provide you with sufficient information for making optimum use of tiltmeters and beam sensors in your applications.

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

1.3 How to use this manual

The manual is divided into a number of sections. Each section contains a specific type of information. The list given below tells you where to look for in this manual if you need some specific information.

For understanding principle of tiltmeters: See § 2.1 'Principle of Operation'.

For installation of tiltmeters: See §2.3 'Installation of Tiltmeters'.

For measurement with readout: See § 3 'Measurements'.

For essential tools and accessories: See § 5 'Tools and accessories required for installation'.

2 THE TILTMETER

2.1 Operation

Model EAN-41M tilt meter is built around a Micro-electro mechanical system (MEMS) having range of $\pm 15^\circ$, with high sensitivity and accuracy mounted inside an aluminium enclosure (beam). The tilt sensor provides a bipolar DC voltage output proportional to the sine of tilt angle measured by the tilt meter. The output is zero volts for a truly vertical position.



The sensor provides a relatively low cost tilt measurement solution but still offers excellent resolution and long term stability.

The tilt meter can be fixed to any vertical surface, horizontal floor or ceiling by means of suitable mounting accessories consisting of brackets and anchors. These are available separately when ordered.

The EAN-41M is not intended for absolute determination of tilt of structures. It measures change in tilt of a structure to which the sensor is attached. The initial tilt reading for each tilt sensor is recorded after it has been mounted on the structure to be monitored. Subtracting initial tilt reading from subsequent tilt reading gives change in tilt of structure over a period of time.

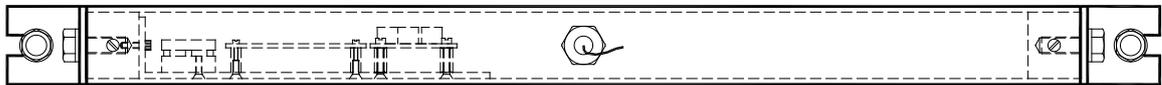


Figure 1

2.2 Installation of Tiltmeter

Model EAN-41M tilt meter (figure 1) can be fixed to a vertical surface and horizontal surface.

2.3 Installation of Horizontal Beam Sensor

2.3.1 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.

- 1 Using a chalk-line and suitable coloured chalk, mark a straight line along which the beam sensors would be fixed. For wall mounting use a spirit 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.
- 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.

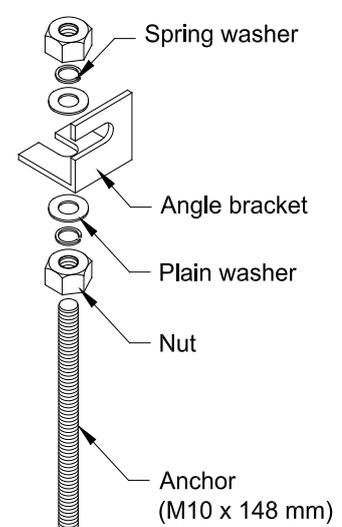


Figure 2

- 3 Drill 12 mm diameter anchor holes to a depth of about 100 mm at the marked positions. Ensure that the holes are as perpendicular to the wall or floor surface as possible.
- 4 Clear the holes of debris by blowing air or brushing.
- 5 Fix the longer (148 mm) anchors (figure 2) 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 all the anchors.
- 6 Allow the grout to set for the recommended time before handling.
- 7 Measure & record the exact centre to centre distances between each anchor in the string.

Note: As the anchor centre may be difficult to locate, measure the distance between the left sides of each anchor.

2.3.2 Fixing the beams

The sensors are provided with two mounting angles on each side (figure 1). 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 separately available beam mounting kits provide more flexibility and are strongly recommended.

The figure 3 also shows the correct position of each component of the kit while mounting the beams.

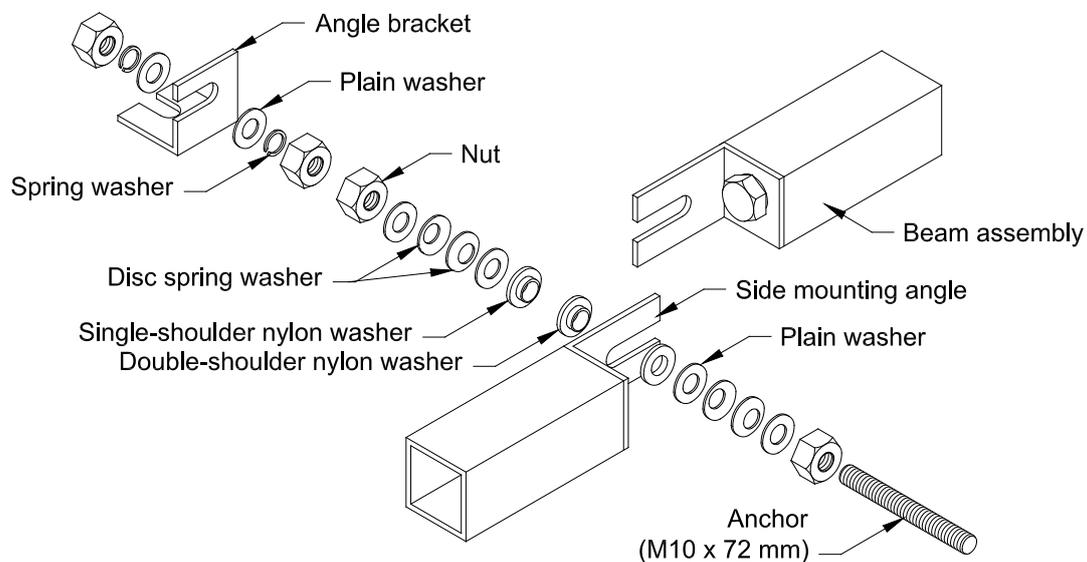
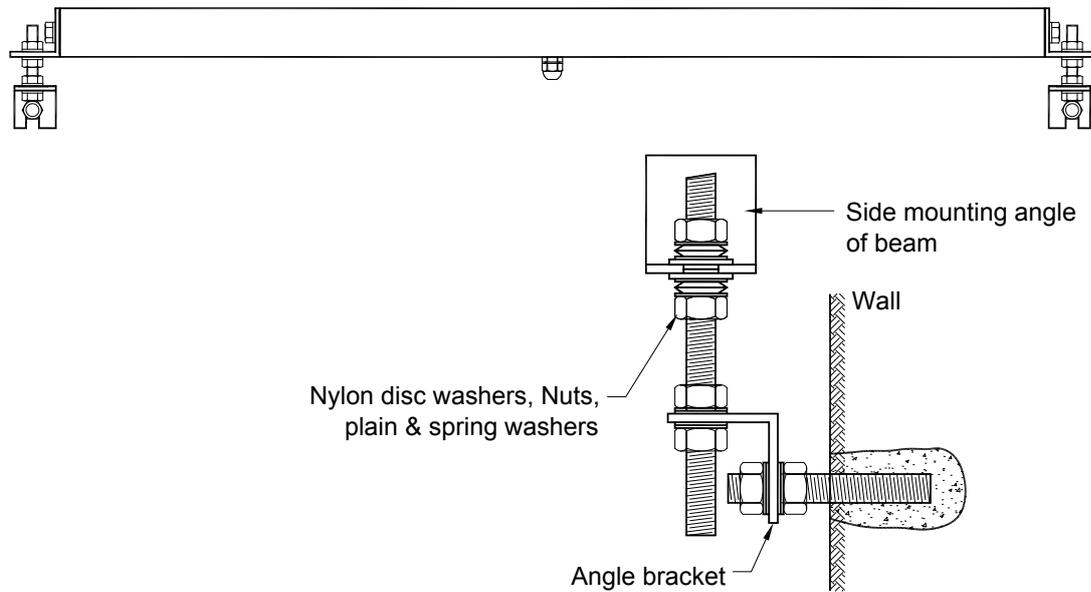


Figure 3

- 1 Fasten angle brackets to the already grouted 148 mm anchors. Check the relative position of the nuts, washers and angle brackets from the drawing.
- 2 Fix the 72 mm stud anchors on the angle brackets fixed to the grouted anchors.
- 3 Slightly loosen the mounting angle at both sides of each beam by loosening the hex nut holding it to the beam.
- 4 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.
- 5 Lightly tighten the nuts so that the spring washers are slightly compressed.
- 6 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.

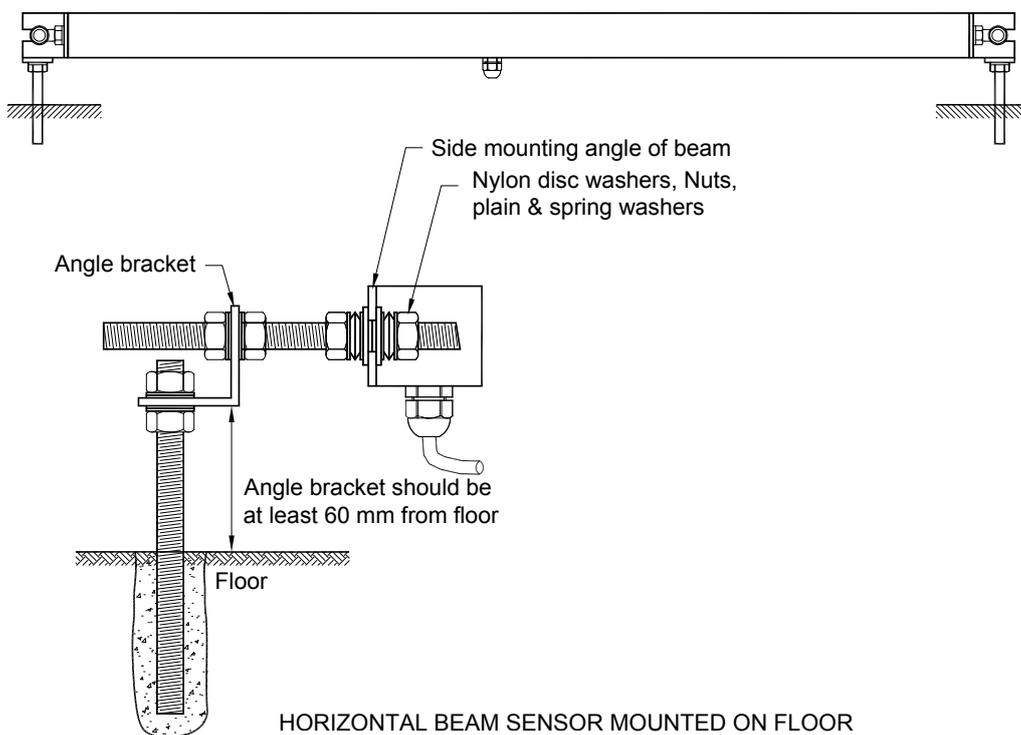
Figure 4 shows how to mount the EAN-41M horizontal beam sensor on wall using the standard mounting kit.



HORIZONTAL BEAM SENSOR MOUNTED ON WALL

Figure 4

Figure 5 shows how to mount the EAN-41M horizontal beam sensor on floor using the standard mounting kit.



HORIZONTAL BEAM SENSOR MOUNTED ON FLOOR

Figure 5

2.4 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-41M 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, generally packed separately for shipment.

2.4.1 Installing the anchors

- 1 Using a plumb line and suitable coloured 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 centre to centre distances between each anchor in the string.

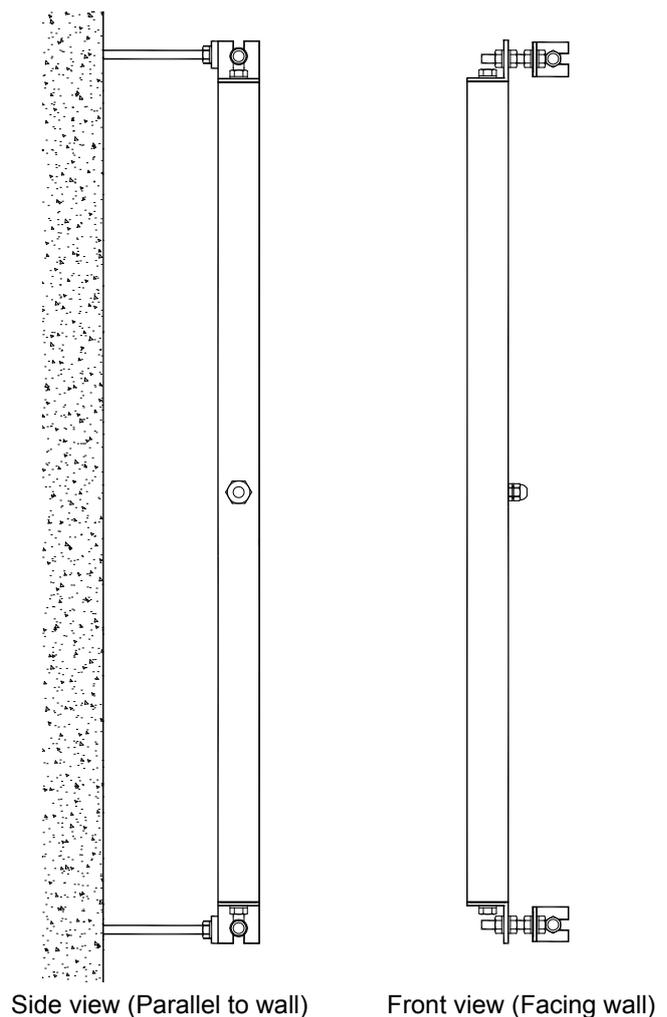


Figure 6

Note: As the anchor centre may be difficult to locate, measure the distance between the left sides of each anchor.

2.4.2 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.

- 1 Fasten angle brackets to the already grouted 148 mm anchors. Check the relative position of the nuts, washers and angle brackets from the drawing.
- 2 Fix the 72 mm stud anchors on the angle brackets fixed to the grouted anchors.
- 3 Slightly loosen the mounting angle at both sides of each beam by loosening the hex nut holding it to the beam.
- 4 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.
- 5 Lightly tighten the nuts so that the spring washers are slightly compressed.
- 6 Tighten the bolt head holding the mounting angles to the beam ends.
- 7 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.
- 8 Put a drop of Loctite 290 or equivalent (post assembly thread locking compound) at the accessible junction of each nut on the stud anchors to lock them in place.

2.5 Tools and accessories required for installation

The following tools and accessories are required for installation of beam sensor model EAN-41M.

- 1 Sensor mounting kits, one more than the number of beams to be mounted in series.
- 2 Two open-ended spanners of 17 mm size and one open ended spanner of 13 mm size, or two adjustable wrenches.
- 3 One flat head screw driver with 4 mm blade width.
- 4 Quick set epoxy grout for grouting the anchors in concrete.
- 5 Loctite 290 threads sealant or any other equivalent post assembly thread sealant.
- 6 Percussion or hammer drill with 12 mm drill bit.
- 7 Chalk line and coloured chalk.
- 8 Tape measure, longer than the maximum beam gauge length to be used.
- 9 Spirit level.

3 MEASUREMENT OF TILT

The output of model EAN-41M tilt meter can be read by Encardio-rite model EDI-53UTM portable digital read-out unit/datalogger. The EAN-41M can also be read or logged from a remote location by an automatic data acquisition system like Encardio-rite model EDAS-10.

The tiltmeter is supplied with 2 m built-in six core cable. The cable can be terminated or extended to the nearest measurement station through a suitable junction box.

When using with Encardio-rite model EDI-53UTM portable digital read-out unit/datalogger, a special junction box having suitable circular connector is available from Encardio-rite.

3.1 Wiring details

Cable colour	Description
Red	+ 12 V DC
Black	- 12 V DC
Green	0 V (Power supply common)
Blue	Output Channel A
Brown	Output Channel B (only for biaxial tilt sensors)
White	Output Common

3.2 Sign convention

The output voltage of the sensors are correspondingly positive for rotation in positive direction and negative for negative direction.

For beam sensors the rotation is converted to a gradient reading using the distance between the anchors at the two ends of the beam, also known as the gauge length. If L is the beam gauge length, and the angle of rotation is α the gradient would be ' $\tan(\alpha)$ '. The perpendicular displacement ' d ' of one end of the beam considering the other end as fixed is given by

$$d = L \tan(\alpha)$$

For counter clockwise rotation of the beam the displacement is considered positive and for clockwise rotation the displacement is considered negative.

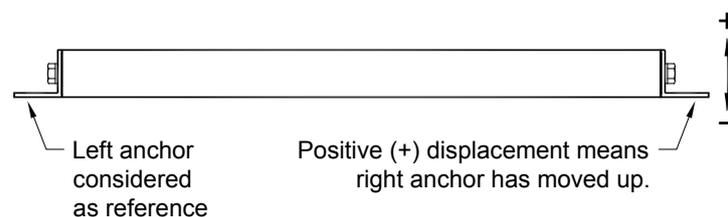


Figure 7

3.3 Connecting sensor to Encardio-rite Digital readout unit

Tiltmeter 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 tiltmeter 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/tiltmeter 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).

For bi-axial tilt measurement setup two beam sensors one for A-axis and one for B-axis in a similar manner.

3.4 Connecting sensor to EDAS-10 data acquisition system

Model EAN-41M tiltmeter requires external power source of ± 12 V DC (regulated) when connected to EDAS-10 data acquisition system. For more than one tiltmeter to be connected, a set of two multiplexers is required. 16 tiltmeters can be connected to each set. One multiplexer of each set will be used to provide power supply to tiltmeter while other will be connected to EDAS-10 input.

Tilt measurement with EAN-41M and EDAS-10 datalogger

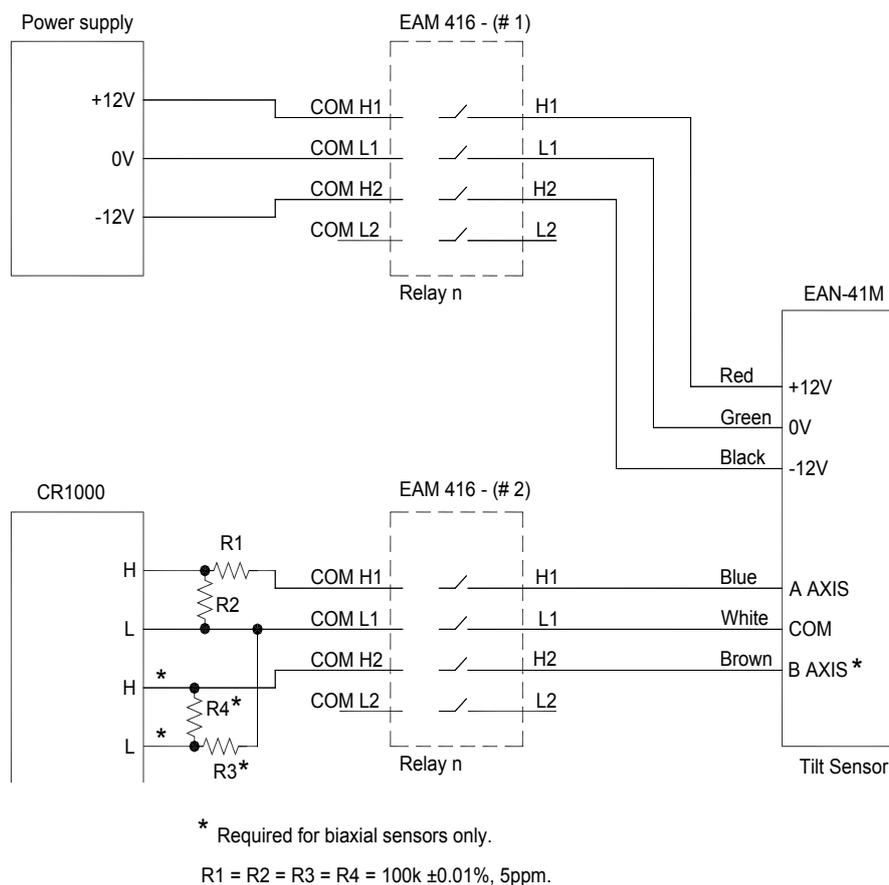


Figure 8

Maximum input of EDAS-10 is ± 2.5 V; whereas output of tiltmeter is ± 4V. A high precision attenuator is therefore required as shown in figure 8 below:

Use EDAS-10 function P2 to read output of tilt sensor in terms of 0.5 volts. The multiplier and offset should be kept as 1 and 0 respectively. 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 § 3.5.

3.5 Sample Test Certificate



Encardio-rite Electronics Pvt. Ltd.

A-7 Industrial Estate, Talkatora Road, Lucknow, UP-226011 India

E-mail: sales@encardio.com, encardio@sanchamet.in; Website: www.encardio.com

Tel. +91 (522) 2661039/40/41/42 Fax +91 (522) 2661043



TEST CERTIFICATE

Customer :
 P.O. :
 Item : Tilt meter Date :12.04.2007
 Model : EAN-41M Temperature :32 °C
 Range : ±15°
 Serial no. : 704007

Test data

Test Position	SinA	output			Offset corrected output (V ₅)	Error 'A' axis (V ₅ - V ₂)	Non-Conformance % fs
		*Calculated (V ₁)	**Ideal (V ₂)	Observed (V ₃)			
Arc degrees (A)		Volts	Volts	Volts	Volts	Volts	
15	0.2588	4.1408	4.106	4.117	4.106	0	0
12	0.2079	3.3264	3.2984	3.308	3.297	0.0014	0.035
9	0.1565	2.5032	2.4822	2.492	2.481	0.0012	0.028
6	0.1046	1.6728	1.6587	1.668	1.657	0.0017	0.042
3	0.0524	0.8376	0.8306	0.84	0.829	0.0016	0.038
0	0	0	0	0.011	0	0	0
-3	-0.0524	-0.8376	-0.8306	-0.819	-0.83	0.0006	0.014
-6	-0.1046	-1.6728	-1.6587	-1.645	-1.656	0.0027	0.067
-9	-0.1565	-2.5032	-2.4822	-2.469	-2.48	0.0022	0.053
-12	-0.2079	-3.3264	-3.2984	-3.285	-3.296	0.0024	0.06
-15	-0.2588	-4.1408	-4.106	-4.095	-4.106	0	0

Sensor gauge factor : 15.866 Volts/Sin (90°) Max non-conformance (% fs) : 0.067
 Calculation of tilt value (arc degree) :

$$\text{SinA} = \text{Observed output} / \text{gauge factor}$$

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

Wiring colour code :

Wire colour	Signal
Red	+12 V (supply)
Black	- 12 V (supply)
Green	0 V (supply)
Blue	Output 'A' axis
Brown	Output 'B' axis
White	Output common

Note :

- *Calculated output Voltage (V₁) worked out based on nominal gauge factor of 16.000 V/ g (i.e. 16 V X Sin A).
- **Ideal output Voltage (V₂) calculated from sine curve passing through sensitivity calibration points (@ ±15°).

Checked by

Tested by