



# ENCARDIO RITE

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USERS' MANUAL

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## ELECTROLYTIC LEVEL UNIAXIAL TILT METER/BEAM TILT SENSOR

MODEL EAN-31EL/EAN-31EL-B



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## 1 INTRODUCTION

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Encardio-rite Model EAN-31EL tiltmeters are designed for measuring very small tilts, of the order of half a degree, with a high resolution. It uses a ceramic encapsulated electrolytic bubble level sensor as its sensing element.

The EAN-31EL Tiltmeter is housed in an aluminium die cast enclosure and is generally used as a stand-alone unit for measuring tilt. It is either attached directly to the structure whose tilt is to be monitored using suitable mounting brackets or fixed to horizontal or vertical beams.

EAN-31EL can be mounted on 38 mm x 38 mm hollow square aluminium structural sections (beam). The length of the beam is known as the gauge length and is supplied with suitable mounting hardware for fixing onto concrete or brickwork structures. The beam mounted tilt sensor measures the tilt angle between the end points of the beam. From the measured tilt angle and the beam length the vertical or horizontal displacement (depending on the orientation of the beam) of the endpoints of the beam can be precisely calculated.

The EAN-31EL-B beam sensor is basically an EAN-31EL tilt meter mounted on a beam of specified gauge length and suitable mounting hardware for fixing the beams to the structure. The beams are available in different standard lengths, generally between 1 to 3 meters. The beam sensors are often used as a linear array of linked beams, fixed to anchors at specified lengths. An array of linked beam sensors allows the vertical settlement profile along the array line to be determined.

EAN-31EL tilt meter is available with either voltage output (output option V) or raw half bridge output (output option R).

The voltage output sensors can be read with any digital voltage-measuring device like digital indicators or multimeters but do require an additional low current dc power source. A 12 Vdc battery is sufficient to power the tilt sensor. Most commercially available dataloggers generally have some provision for supplying the required power to the sensor. Although voltage output sensors are costlier their output can be read by any low cost digital voltmeters.

The voltage output option should be preferred for most applications especially if the sensors are spread over a fairly wide area.

The raw half bridge output sensors are lower cost sensors but require a suitable datalogger that can accept half bridge sensor output and provide ac excitation. Encardio-rite suggests the model CR1000 datalogger from Campbell Scientific, U.S.A., for this application. The raw half bridge output option is more popularly used with beam sensors that are used in arrays as a number of sensors are in close proximity requiring a minimum length of wiring to the datalogger while reducing the cost per sensor.

### 1.1 Applications

The EAN-31EL Tiltmeters and EAN-31EL-B Beam Sensors are widely used in following applications:

- Monitoring vertical rotation of retaining walls.
- Monitoring inclination and rotation of dams, piers, piles and other structures.
- Monitoring settlement or heave in ground.
- Monitoring stability of structures in landslide areas.
- Monitoring tunnels for convergence and other movements.
- 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 user's manual is intended to provide you with sufficient information for making optimum use of EI 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 electrolytic tilt / beam sensors: See § 2.1 'Principle of Operation'.*

*For installation of electrolytic tilt / beam sensors: See § 3 'Installation of Tilt and Beam Sensors'.*

*For essential tools and accessories: See § 3.2 'Tools and accessories required for installation'.*

## 2 THE ELECTROLYTIC TILT / BEAM SENSOR

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### 2.1 Principle of Operation

The Tilt / Beam sensor uses a bubble level sensor just like those used in spirit levels except that in this case the spirit is replaced with an electrically conductive fluid known as electrolyte. In EAN-31EL the glass vial of the spirit level is replaced with a more thermally stable and dimensionally accurate ceramic housing.

The ceramic electrolytic bubble level sensor has three terminals and behaves as a resistive half bridge circuit. The electrolytic bubble sensor has two end terminals and a middle terminal. Electrically it appears as a potentiometer with a fixed resistance between its end terminals and the middle terminal behaves as wiper in a potentiometer. When the bubble level tilts, the resistance between the middle and one of the end terminals goes up and between the middle and the other end terminal goes down. The effect reverses if the direction of tilt is reversed.

The change in the ratio of resistance between the middle terminal and the two end terminals can be measured using an electrical half bridge circuit. In a half bridge circuit the indicator / datalogger applies a voltage across the end terminals and measures the output voltage between the middle terminal and one of the end terminals.

Unfortunately, as the electrolyte used in the sensor deteriorates irreversibly if a dc voltage is applied across its terminals, a pure ac excitation voltage source is a must.

In EL tilt sensors with raw output option the bubble level sensor terminals are directly available across the output terminals.

In tilt / beam sensors with voltage output option a signal conditioning card converts the half bridge bubble level sensor output to a proportional dc voltage with a nominal full scale value of  $\pm 1$  V dc.

Tilt / beam sensors with a measurement range lower than  $1^\circ$  are very sensitive sensors and are easily influenced by even small vibrations that appear as noise on the output. These sensors should, as far as possible, be mounted at locations where expected vibration levels are quite low. To exploit the full sensitivity limit of these sensors some kind of averaging facility should be available in the readout unit or datalogger used for monitoring.

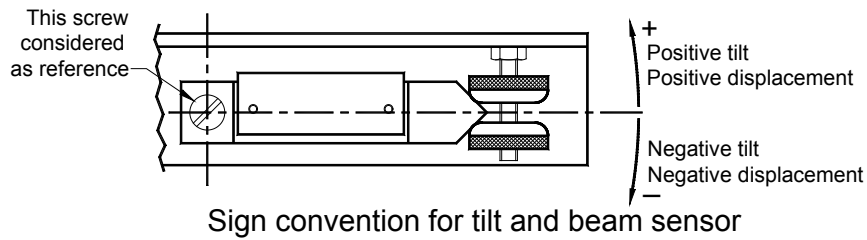
#### 2.1.1 *Temperature sensitivity of electrolytic bubble level sensors*

Electrolytic bubble level sensors have a relatively higher drift in output with ambient temperature. The EAN-31EL / EAN-31EL-B tilt sensors should therefore be located in areas where the change in temperature is expected to be minimum. For example, the sensors should never be mounted at a place where they would be exposed to direct sunlight.

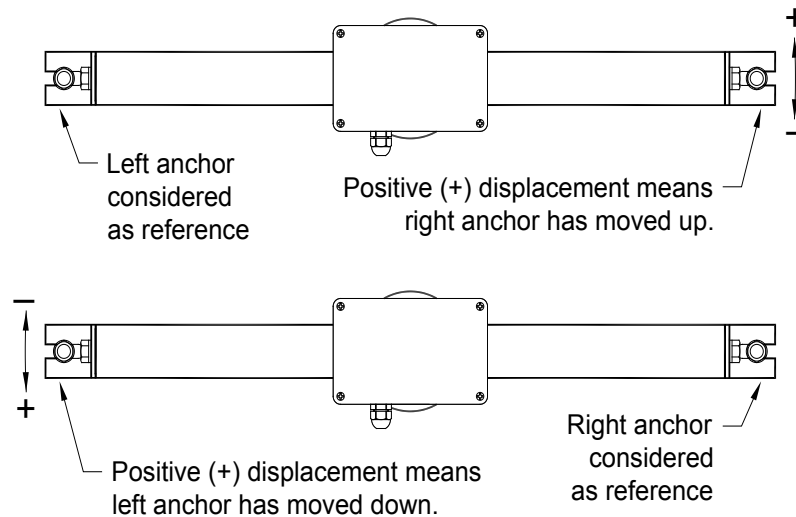
The EAN-31EL tilt meter is supplied with a thermistor temperature sensor, which can be used to measure the sensor temperature. This temperature reading can be used to correlate the change in tilt with sensor temperature to detect change in tilt that can be attributed to change in sensor temperature.

### 2.2 Sign convention for Tilt and Beam Sensors

The tilt and beam sensors basically measure rotation of the electrolytic level sensors. The electrolyte level sensor capsule is mounted on an aluminium block that can rotate about a screw at one end and has a taper at the other end lying between a pair of thumb nuts which are used to set the initial sensor zero. Considering the pivot screw as the fixed reference, if the tapered end of the block rotates counter clockwise the rotation is considered positive. Similarly clockwise rotation is considered negative.



The voltage in case of voltage output sensors are also 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  $\alpha$  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

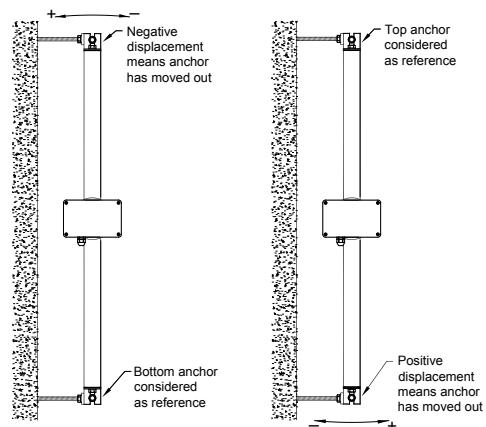
$$d = L \tan(\alpha)$$

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

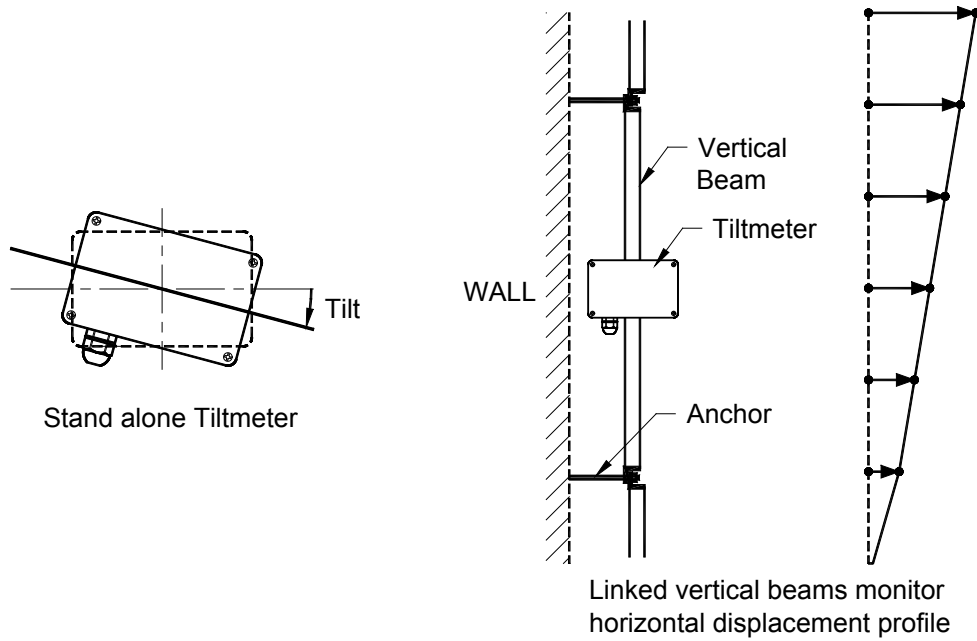
Vertical beam sensors consist of an EAN-31EL Tiltmeter mounted on a beam of suitable gauge length. The figure below shows the sign convention for vertical beam sensors.

**2.3 Usage of Tilt and Beam Sensors**

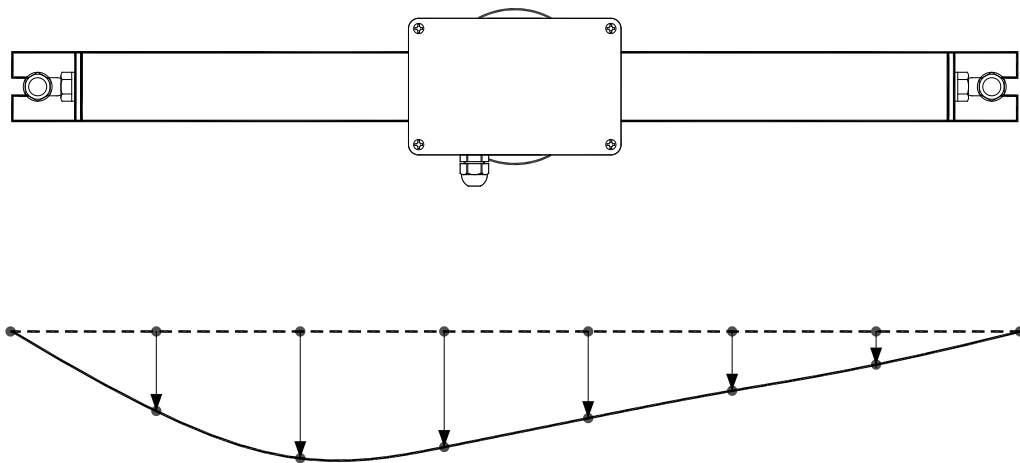
The EAN-31EL Tilt sensor is mostly used for stand-alone applications where only the change in tilt or rotation of the structure is to be measured. The tilt sensor enclosure can be directly mounted on the structure by using two mounting screws or, more often, using a suitable wall mounting bracket that allows some degree of rotational adjustment to orient the tilt sensor true horizontal position. The use of a wall-mounting bracket allows easier drilling of mounting holes as very precise hole locations are not required.



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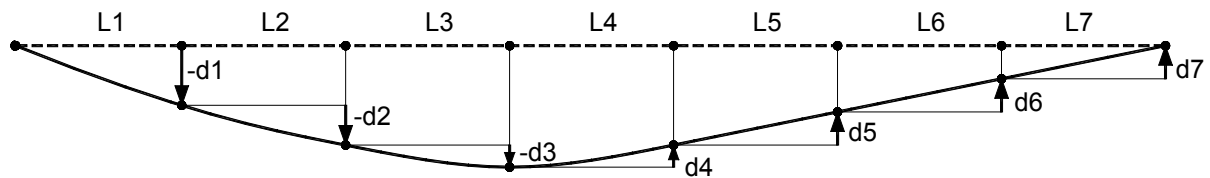
The EAN-31EL Tilt sensor is also used with vertical beams of known lengths to determine the horizontal displacement of walls etc. In most cases a series of linked beams are fixed to the wall vertically using a series of anchors. The distance between the anchors is known as the gauge length. Two adjacent beams in the link share the same anchor.



**Linked horizontal beams monitor vertical settlement or heave**

The EAN-31EL-B Horizontal beam sensor is primarily used for obtaining the vertical displacement (i.e. settlement or heave) profile. A series of beam sensors are fixed to an array of anchors in a straight line in the desired direction along which vertical displacement profile is required. A stand-alone horizontal beam sensor (i.e. when used singly) is equivalent to a simple tiltmeter and offers no additional advantage unless vertical displacement between two anchors at certain distance is required to be measured.





Summation of displacements vs. gauge lengths to obtain displacement profile of a series of linked beam sensors (in above figure all beams have equal gauge length)

When beam sensors are used in an array, plotting the individual displacements against the gauge length of each beam yields the displacement profile as shown in accompanying figure. Gauge lengths in an array can be mixed, using shorter gauge lengths where higher resolution is required and longer gauge lengths where lower resolution is required or expected displacement values are very low. However, use of a uniform gauge length will give satisfactory results for most applications.

The sensor beam lengths in the figure is shown as L1, L2,... L7 and the corresponding displacements measured by each sensor are shown above as d1, d2, ... d7. All beam lengths shown in the figure are equal. The sign of the displacement follows Encardio-rite convention for the EAN-31EL sensors. Displacement of sensors rotating anti-clockwise are shown with a positive sign and displacement of sensors rotating in the clockwise direction are shown with a negative sign.

On plotting the cumulative length vs. the cumulative displacement curve one gets the vertical displacement profile along the line of sensor string.

## 2.4 Sensor measurement range

The EAN-31EL tilt meter is invariably supplied with a full scale tilt measuring range of a  $\pm 0.5^\circ$ . However, in structural and civil engineering applications such small tilt and inclination angles are generally measured and/or specified in terms of gradient such as mm per metre.

For a  $\pm 0.5^\circ$  sensor the corresponding gradient is  $\pm 8.727$  mm per metre. So the full scale range for the EAN-31EL is specified as  $\pm 8$  mm per metre. The calibration certificate supplied with each individual sensor gives the calibration table in terms of mm per metre. The calibration factors supplied with the sensors is valid for the full scale range of  $\pm 8.73$  mm per metre.

## 2.5 Calibration and gauge factors of tilt and beam sensors

The EAN-31EL / EAN-31EL-B tilt and beam sensors are supplied with individual test certificates. The test certificate provides a linear gauge factor and polynomial constants for polynomial calculations. The tilt measurement units are in terms of gradient as mm per metre

The tilt or gradient using linear gauge factors is given by

$$Y = mX + b$$

Where Y is the gradient in "mm per metre" and X is the sensor output is in CR-1000 data units for raw half bridge output option and volts for voltage output option. The factors 'm' and 'b' are provided in the test certificate.

The tilt sensor output curve is quite non-linear. If better accuracy is required then polynomial calculation can be used to get better accuracy. However, this is a fairly complex calculation and is best performed either by a datalogger that has polynomial calculation facility such as Encardio-rite EDAS-10 or Campbell Scientific CR1000 datalogger or a PC with a spread sheet program like Microsoft Excel.

For conversion of measured half bridge or voltage output from the tilt sensor to corresponding tilt in terms of gradient (i.e. mm per metre) the constants of a fifth order polynomial is provided in the test certificate.

The tilt or gradient using polynomial coefficients is given by:

$$Y = C_0 + C_1X + C_2X^2 + C_3X^3 + C_4X^4 + C_5X^5$$

Where, Y is the tilt or gradient in "mm per metre", C<sub>0</sub> through C<sub>5</sub> are the polynomial constants as given in the test certificate, and X is the sensor output measured in terms of CR1000 data units for raw half bridge output sensors and volts for voltage output sensors.

Samples of Raw Output and Voltage Output sensor Test Certificates are attached at the end of this manual. The calibration data shown in the test certificates is obtained by mounting the tilt or beam sensors on a precision 0.500 m long beam.

## 2.6 Specifications

### Specifications for 0.5° sensor (standard)

Measurement range	:	± 0.5° ( ±8.73 mm per metre)
Non-conformance error (polynomial fit)	:	± 0.3 mm per metre (standard)
Repeatability	:	± 3 arc second

### For Voltage output option only

Output voltage between OP+ and OP-	:	± 1V dc nominal (differential) (The output voltage is referenced to the O/P – terminal)
Output Common Mode Voltage	:	2.5 V dc
Power supply voltage	:	12 V dc

### General Specifications

Sensor type	:	Electrolytic level type, uniaxial
Operating Temperature Range	:	-20°C to 55°C
Mechanical zero adjustment range	:	approximately ± 4°
Dimensions	:	See § 6, 'Dimensions'
Output cable	:	4-conductor shielded cable recommended. (6 conductor shielded cable is required for thermistor output if temperature measurement is desired)
Cable gland size for output cable	:	Accommodates cable OD sizes from 2.5 to 6.5 mm.
Temperature sensor	:	R-T curve matched thermistor, 3 kohms at 25°C, provided between screw terminals marked T1 and T2. Dale type 1C3001-B3 or equivalent. (Themistor resistance vs. temperature table is provided at the end of this manual.)

### 3 INSTALLATION OF TILT AND BEAM SENSORS

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The EAN-31EL Tilt meter is housed in a weather proof die cast aluminium box and can be fixed to any structure either directly using 4 mounting screws or fasteners or using a mounting kit that allows more flexibility in mounting the tilt meter.

The beam sensor model EAN-31EL-B consists of an EAN-31EL tilt meter together with a 38mm x 38mm square hollow aluminium structural section (beam) of specified length. The tilt meter may be factory fitted on a beam or the two can be supplied separately for assembly at site. Standard beam lengths are 1m, 2m and 3m but customer specified beam lengths between 0.5 m to 3m are also supplied.

The beam length in the specification refers to the gauge length of the beam in the mounted position. The actual length of the beam is about 36 mm longer than the specified size due to the mounting brackets provided at the end of the beams.

The beams can be fixed either horizontally or vertically as desired depending on the kind of tilt to be measured. The sensor mounting bracket on the beam allows the tilt meter to be rotated by 90° so that irrespective of the orientation of the beam the tilt meter can be mounted in a horizontal position.

#### 3.1 Use of mounting kit

The tiltmeter and the beam sensors can be mounted directly to the anchors on wall or floor using the mounting angles or brackets supplied with the tiltmeter or beam sensors. However, if the structure is likely to deform in directions other than the rotational plane of the beams the use of components supplied in the optionally available mounting kit will give better result.

Mounting kits are available for mounting the tiltmeter and beam sensors on wall or floor but have to be ordered separately. Two mounting kits are required for mounting an individual beam sensor, but as invariably the beam sensors are mounted linked in series for profiling settlement, the number of mounting kits required is one more than the number of beams in a string. The mounting kit is common for wall, floor or series mounting.

Each mounting kit consists a set of groutable 148 mm long all threaded stud anchor, with an angle bracket and a set of nuts, spring washers, and plain washers. Another set of an all thread stud anchor of around 72 mm length and a set of nuts, plain washers, spring washers, disc spring washers, two single shouldered and one double shouldered nylon washer is also included. The nuts and washers are supplied assembled on the respective studs from which the correct position of these components during assembly can be noted.

#### 3.2 Tools and accessories required for installation

The following tools and accessories are required for installation of beam sensors model EAN-31EL-B:

1. EI-beam sensor mounting kits, one more than the number of beams to be mounted in series.
2. Two open-ended spanners of 17mm size and one open ended spanner of 13mm size, or two adjustable wrenches.
3. One flat head screw driver with 4mm blade width.
4. Quick set epoxy grout for grouting the anchors in concrete.
5. Loctite 290 thread sealant or any other 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.

10. One of the following indicators for initial zero adjustment and/or monitoring:

- i) Encardio-rite digital indicator model EDI-53ELV (for voltage output tilt sensors, can be used for both initial zero adjustment and for local monitoring also).
- ii) Encardio-rite EI-beam indicator model EDI-53EL (for raw output sensors zero adjustment only, not suitable for local monitoring);
- iii) 3 ½ digit, 2 V range, indicator or multimeter (for voltage output sensors only, a separate 12 V excitation voltage source is also required);
- iv) CR-1000 datalogger (for both raw output or voltage output sensors but is suitable for remote monitoring only).

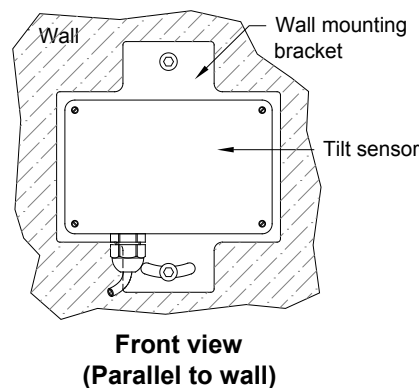
### 3.3 Installation of Tiltmeter

The EAN-31EL Tiltmeter 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 back side (surface) of the tiltmeter.

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

#### 3.3.1 *Rotation expected in the plane of the wall*

If the structural rotation is expected to be in the plane of the surface of the wall, the tiltmeter is mounted directly on the wall using the wall-mounting bracket. The use of wall mounting bracket allows coarse levelling of the tiltmeter 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.

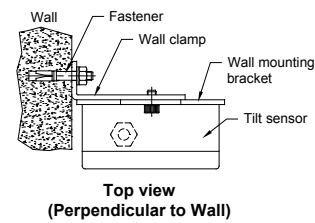


1. Using the wall mounting bracket as a template, mark position of two mounting holes. Visually ensure that the two hole positions are aligned vertically as much as possible.
2. Drill two holes of diameter and depth suitable for the type of anchor to be used.
3. Fix the mounting anchors in holes following the manufacturer's recommendation.
4. Mount the tiltmeter on the wall-mounting bracket.
5. Fix the wall-mounting bracket with the tiltmeter to the anchors on the wall.

#### 3.3.2 *Rotation expected in a vertical plane perpendicular to the wall*

If the surface of the wall is expected to rotate in a vertical plane perpendicular to the wall the tiltmeter should be mounted in an orientation as shown in the accompanying figure. The use of a mounting kit is recommended as this allows easy adjustment of the tiltmeter orientation.

1. Remove tiltmeter cover. Fix the tiltmeter housing to mounting bracket using the two mounting screws. Replace tiltmeter cover.



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2. Drill 12mm diameter anchor holes to a depth of about 100 mm at the marked position.
3. Clear the hole of debris by blowing air or brushing.
4. Fix the longer (148 mm) anchors of the mounting kits with suitable epoxy grout in these holes such that around 50mm length of anchors project out of the surface after fixing. Follow epoxy manufacturer's recommendation for fixing the anchors.
5. Allow the grout to set for the recommended time before handling.
6. Fasten angle brackets to the already grouted 148 mm anchors. Check the relative position of the nuts, washers and angle brackets from the accompanying figure.
7. Fix the 72 mm stud anchors on the angle brackets fixed to the grouted anchors.
8. Fix the tiltmeter mounting bracket on the 72 mm stud anchors as shown in accompanying figure.
9. Lightly tighten the nuts so that the spring washers are slightly compressed.
10. Ensure that the tiltmeter cover surface is both, perpendicular to the wall as well as vertical.
11. 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.

### 3.4 Installation of Horizontal Beam Sensor

#### 3.4.1 Mounting the sensor assembly on the beam

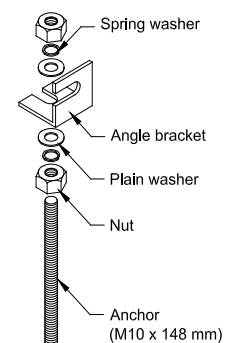
The EAN-31EL-B, EI-beam sensor is generally supplied as EAN-31EL tiltmeter mounted on a beam of customer specified length. However, on specific customer request the tiltmeter and the beams may be supplied separately. In such cases the sensor has to be mounted on the beam before the beams are fixed.

#### 3.4.2 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.

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.
3. 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.



4. Clear the hole of debris by blowing air or brushing.
5. Fix the longer (150 mm) anchors of the mounting kits with suitable epoxy grout in these holes such that around 50mm 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 distances between each anchor in the string.  
Hint: As the anchor centres may be difficult to locate, measure the distance between the left side of each anchor.

### 3.4.3 Fixing the beams

The EI-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 strings of beams are subject to any torsional movement the separately available beam mounting kits provide more flexibility and are strongly recommended.

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

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.
7. 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.

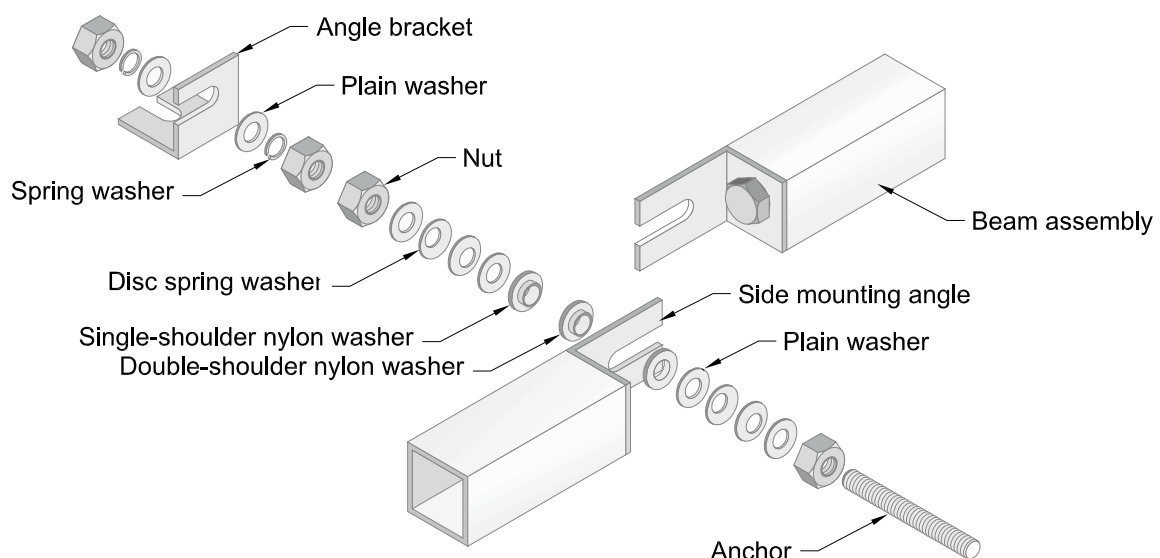
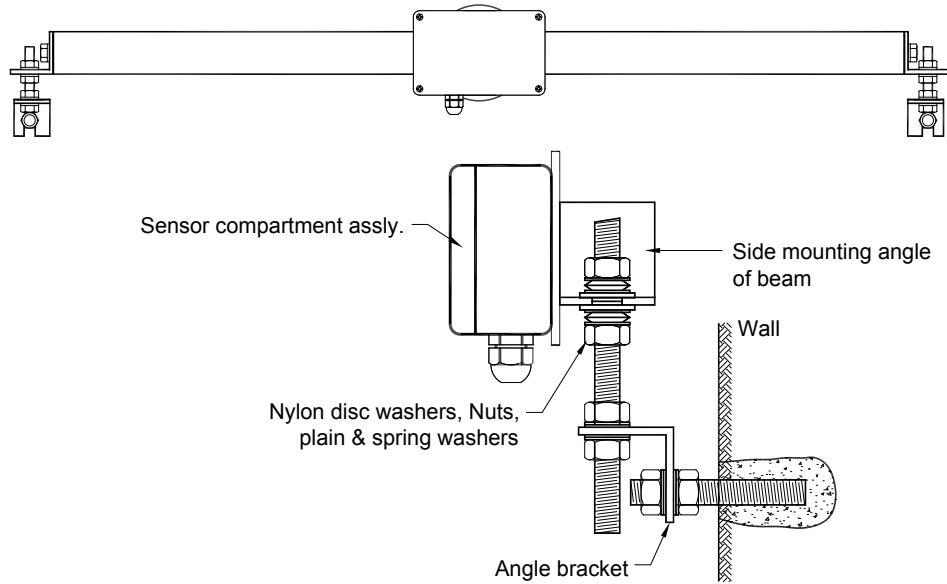
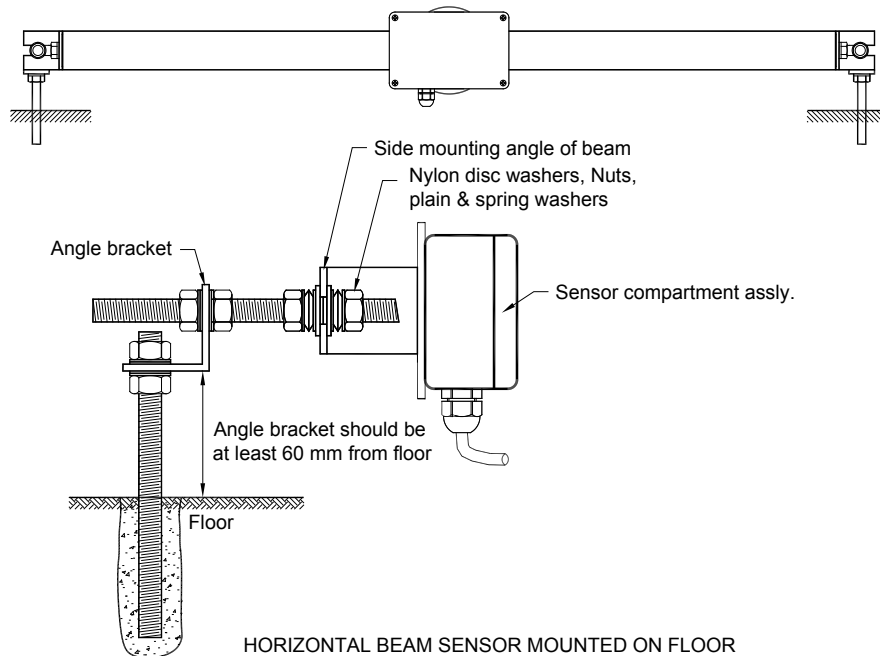


Figure below shows how to mount the EAN-31EL-B horizontal beam sensor on wall using the standard mounting kit.



HORIZONTAL BEAM SENSOR MOUNTED ON WALL

Figure below shows how to mount the EAN-31EL-B horizontal beam sensor on floor using the standard mounting kit.



HORIZONTAL BEAM SENSOR MOUNTED ON FLOOR

### 3.5 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.

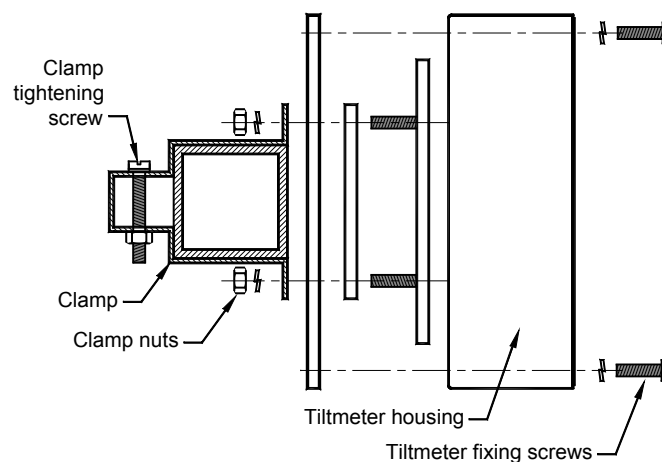
Vertical beam sensors consist of a standard EAN-31EL tiltmeter, an aluminium beam, 38mm x 38 mm square and of specified gauge length and mounting hardware for mounting the tiltmeter on the beam, generally packed separately for shipment.

### 3.5.1 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 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.
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 50mm 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 distances between each anchor in the string. Hint: As the anchor centres may be difficult to locate, measure the distance between the left side of each anchor.

### 3.5.2 Mounting the tiltmeter on the beam

Mount the tiltmeter on the beam as described below. The accompanying figure shows the details.



View from above

1. Slide the beam through the clamp opening of the mounting hardware. Lightly tighten the clamp around the middle of the beam. The mounting angles of the beam should lie towards the clamping screw side of the clamp opening.
2. Remove the tiltmeter cover.

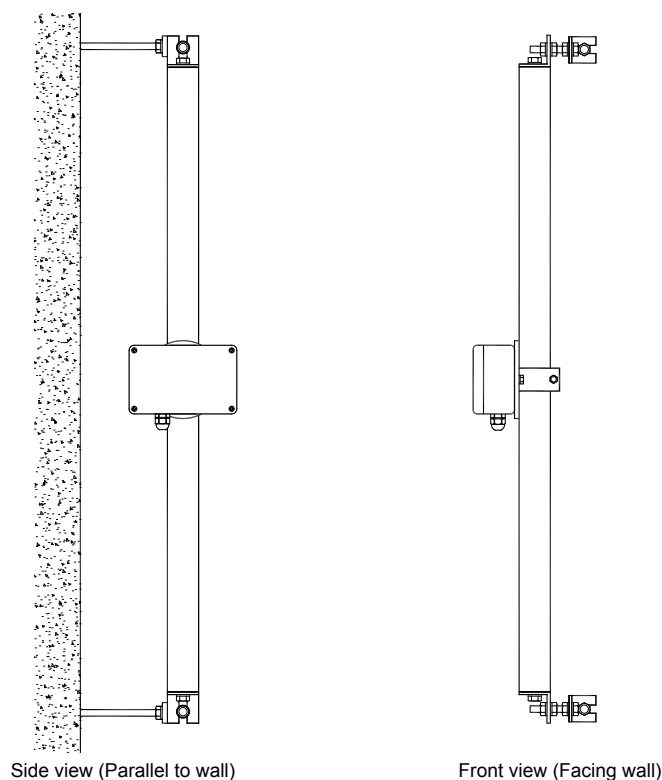


3. Fix the tiltmeter to the mounting plate using the two fixing screws.
4. Clamp tiltmeter to the beam by tightening the two clamp nuts.

### 3.5.3 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 (post assembly thread locking compound) at the accessible junction of each nut on the stud anchors to lock them in place.



## 4 WORKING WITH HALF BRIDGE OUTPUT SENSORS (OPTION R)

The instructions in this section applies to sensors with raw half bridge output (output option R) only. See the next section for initial adjustment of sensors provided with a voltage output.

The EAN-31EL and EAN-31EL-B are identical sensors except that EAN-31EL-B consists of a standard EAN-31EL tiltmeter, mounted on an aluminium beam of 38mm x 38 mm square section.

### 4.1 Making connections

As the sensor is sensitive to very minute changes in tilt (of the order of 1 arc seconds) it is recommended that the signal cable be connected to the sensor output terminals before zero adjustment is carried out. After connecting the signal cable, it should be secured to the wall or any other stationary structural member so that the cable cannot move and affect the sensor position.

Use a good quality 3 or 4 conductor shielded cable for making connections between the sensor and the read out or datalogger unit. Encardio-rite type EC-0107 or Belden type 8723 cables are recommended for this application.

A suggested wiring colour code for connecting above cables is shown below:

CR1000 Terminal	Sensor terminal	Wire colour	Signal name
EX1 (or any of the 2 excitation channels)	E+	Red	AC Excitation
	REF	None	Not used (reference half bridge mid point)
H or L (i.e. any SE channel)	O/P	Green	Sensor output (AC)
G	GND	Black	Analog ground
Earth		Drain wire	Not connected to sensor. Should be connected to ground at datalogger end only if required, to reduce noise pickup.
	T1	Brown	<b>Thermistor</b>
	T2	Blue	

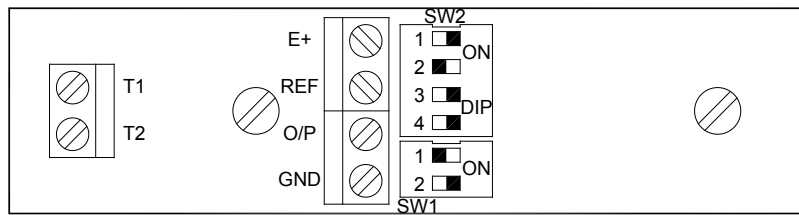
However, the user can use any other suitable cable or colour scheme without affecting performance.

The thermistor terminals are available on screw terminals marked T1 and T2. If temperature measurement is required a 5 or 6 conductor cable (3 conductors for tilt sensor, 2 conductors for thermistor) would be required.

### 4.2 Setting the DIP switches

The sensor printed circuit board (PCB) contains two banks of slide switches, SW1 comprising of two switches and SW2 comprising of four switches. The individual switches are in ON position when the raised

actuators of the individual switches are towards the position marked ON on the switch. In the other position, the switches are OFF.



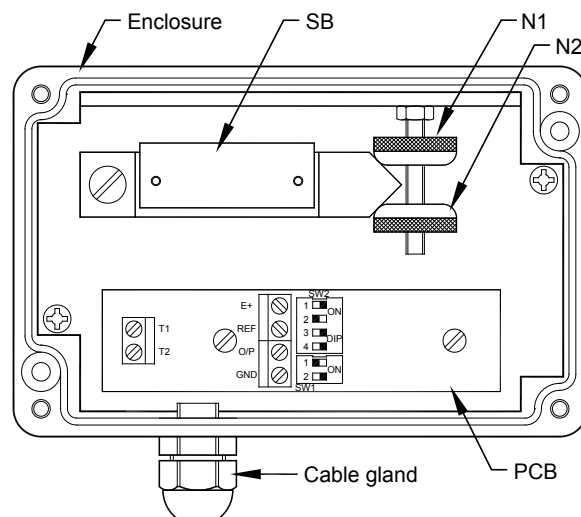
Whenever the signal cable connected to the output terminals need to be tested for continuity or proper wiring etc. using equipment like multimeter all switches should be set to the OFF position. Failure to do this may cause serious damage to the electrolytic sensing element, as it is very sensitive to dc current or voltage.

**4.3 Initial or Mechanical Zero Adjustment**

The tilt measurement range of EAN-31EL/ EAN-31EL-B Electrolytic beam sensors is very small, i.e. of the order of  $\pm 1^\circ$ . While mounting the sensor it is not practically possible to very precisely level the sensor. In most cases the initial sensor tilt would be much greater than its specified tilt measurement range. It is very important that the sensor element, SB in figure below, is initially set to its true horizontal (i.e. zero) position after mounting so that its full tilt measurement range can be utilized.

The EAN-31EL/ EAN-31EL-B sensor is provided with a double thumb wheel arrangement, N1 and N2 that allows the sensor to be precisely leveled after mounting. A level correction range of approximately  $\pm 4^\circ$  from true horizontal is provided.

In principle, to level (i.e. zero adjust) the sensor a suitable read out unit is connected to the sensor output terminals and the twin adjusting thumb wheels rotated to level the sensor holding beam while monitoring the sensor output.



**4.4 Setting sensor zero**

A readout unit has to be connected to the sensor before zero adjustment so that the required amount of adjustment can be displayed.

A CR1000 datalogger can be used as readout during zero adjustment if it is located adjacent to the sensor. Otherwise Encardio-rite model EDI-53EL digital indicator can be used for zero adjustment. However, the EDI-53EL is not recommended for regular tilt measurement for which a CR1000 or equivalent datalogger is essential.

Follow the steps given below if an EDI-53EL indicator is used for zero adjustment:

1. The EDI-53EL indicator first needs to be set up to read the EAN-31EL tilt meter (half bridge output version) output. The setup process is described in detail in the Addendum section of the EDI-53EL Digital Indicator User's Manual.
2. Connect the EDI-53EL indicator to the tilt meter using the signal cable as shown in the EDI-53EL user's manual and turn on the indicator. For more details on how to connect the EDI-53EL to the tilt meter please see the EDI-53EL user's manual.
3. When the EAN-31EL tilt meter is truly horizontal the EDI-53EL indicator will show 5.000. However, as the EAN-31EL is a very sensitive tilt meter achieving a true zero reading is extremely difficult and is also not required as we are more interested in monitoring change in tilt from a reference date. The tilt meter should be considered to be set to horizontal if the display on the EDI-53EL shows a value between 4.900 to 5.100.
4. If the EL-35 sensor shows a reading outside 4.900 to 5.100 rotate the two thumb nuts so that the display shows a reading as near to 5.000 as possible. The display reading will become more positive if the pointed end of sensor beam moves up and more negative when it moves down. DO NOT loosen the sensor beam retaining screw, as it is a friction clutch that introduces a controlled amount of friction to the beam movement. Finger tight the two thumbnuts to the sensor beam.
5. Wait for some time to ensure that the zero reading is stable otherwise a readjustment is required.
6. Put a drop of post assembly thread locking compound, such as Loctite 290, at the junction of the thumb nut and threaded stud to prevent the thumb nuts from loosening.
7. The EDI-53EL readout unit can now be turned off and disconnected from the sensor board.
8. The EAN-31EL/ EAN-31EL-B beam sensor is now ready for use.

#### 4.5 Reading the raw output sensors

EAN-31EL/31EL-B sensors with raw half bridge output behave as a resistive half bridge between the output terminals. The electrolyte fluid used in the sensors gets irreversibly damaged in the presence of even very small dc voltages across the sensor terminals. It is very important that these sensors are always measured using pure ac excitation voltage sources.

The EAN-31EL/31EL-B sensors can be read with any indicator or datalogger that has ac half bridge measurement function. However, Encardio-rite recommends using Campbell Scientific (USA) CR1000 datalogger for acquiring data from a number of sensors for reasons mentioned below.

Although the EAN-31EL/31EL-B is a very sensitive, high resolution and high repeatability tilt sensor, it is a very non-linear sensor. The sensor parameters also vary a lot between units. For these reasons each sensor has to be supplied with an individual calibration sheet. The calibration data is usually supplied in the form of fifth order polynomial coefficients. The polynomial coefficients can be used only if the measurement at the user end is also carried out in the same way as it was done at the factory.

Encardio-rite uses a calibrated Campbell Scientific CR1000 datalogger for computing the polynomial coefficients during calibration of these sensors. Users are advised to use the following CR1000 instruction and parameters while writing their program.

1. Use BrHalf(Dest, Reps, Range, SEChan, ExChan, MeasPEX, ExmV, RevEx, SettlingTime, INtegr, Mult, Offset).
2. Use the following parameter values Reps = 1, Range = mV2500, SEChan = (any SE Channel), ExChan = VX1, MeasPEX = 1, ExmV = 2500, RevEx = 1, SettlingTime = 1000, Integ = 250, Mult = 10, Offset = 0.

#### 4.6 Connecting sensor to CR1000

The wiring between EAN-31EL/31EL-B sensor and the CR1000 depends on how many multiplexers are being used in the system and the control program. However, a typical direct interconnection between a single sensor and a CR1000 can be made as follows. The suggested colour codes are for Encardio-rite type EC-0107 or Belden type 8723 cable.

CR1000 Terminal	Sensor terminal	Wire colour	Signal name
EX1 (or any of the 2 excitation channels)	E+	Red	AC Excitation
	REF		Not used
H or L (i.e. any SE channel)	O/P	Green	Sensor output (AC)
G	GND	Black	Analog ground
Earth		Drain wire	Not connected to sensor. Should be connected to ground at datalogger end only to reduce noise pickup.
	T1	Brown	Thermister (optional)
	T2	Blue	

The switches on the EAN-31EL/31EL-B sensor board should be set to the following position:

Bank	Switch	Switch position	
SW2	1		ON
SW2	2	OFF	
SW2	3		ON
SW2	4		ON
SW1	1	OFF	
SW1	2	OFF	

Use CR1000 function and parameters as given in section 4.5 above to measure the tilt meter output.

## 5 WORKING WITH VOLTAGE OUTPUT SENSORS (OPTION V)

The instructions in this section apply to sensors with voltage output (output option V) only. See the previous section for initial adjustment of sensors with raw half bridge output.

The EAN-31EL and EAN-31EL-B are identical sensors except that EAN-31EL-B consists of a standard EAN-31EL tiltmeter, mounted on an aluminium beam, 38mm x 38 mm square section.

### 5.1 Making connections

As the sensor is sensitive to very minute changes in tilt (of the order of 1 arc seconds) it is recommended that the signal cable be connected to the sensor output terminals before zero adjustment is carried out. After connecting the signal cable, it should be secured to the wall or any other stationary structural member so that the cable cannot move and affect the sensor position.

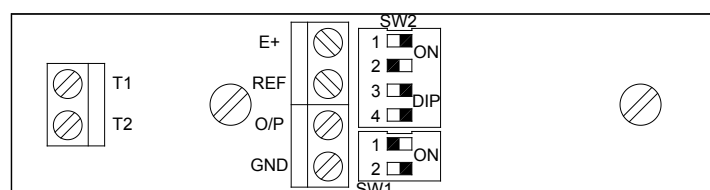
Use a good quality 3 or 4 conductor shielded cable for making connections between the sensor and the read out or datalogger unit. Encardio-rite type EC-0107 or Belden type 8723 cables are recommended for this application.

A suggested wiring colour code for connecting above cables is shown below:

However, the user can use any other suitable cable or colour scheme without affecting performance.

CR-1000 terminal	Sensor terminal	Wire colour	Signal name
+12 Vdc	E+	Red	+12V dc to Sensor
L (of any channel)	REF	White	Sensor output (Lo)
H (of same channel)	O/P	Green	Sensor output (Hi)
G	GND	Black	0V/GND
Earth		Drain wire	Not connected to sensor. Should be connected to ground at datalogger end only to reduce noise pickup.
	T1	Brown	Thermister (optional)
	T2	Blue	

If the optional thermistor for monitoring sensor temperature is also provided the thermistor terminals are available at screw terminals marked T1 and T2.



The electrolytic tiltmeter & beam sensors of voltage output type have basic tilt sensors integrated on a pcb that contains the signal conditioning circuitry on it. This is connected with another pcb shown above. 6 screw terminals shown on it are for making external connections.

There are two pair of terminals on the four position terminal block. The terminals marked E+ and GND have to be connected to a 12V dc power source. The sensor draws around 2 mA current from the power supply.

The sensor output is available as a dc voltage between terminals marked O/P and REF. The output voltage is bipolar, i.e. the O/P terminal can be either positive or negative with respect to the REF terminal. Signal conditioner is internally adjusted to give nearly  $\pm 1$  V dc at full-scale tilt value of  $\pm 0.5^\circ$ .

Any suitable dc voltage source that can supply up to 2 mA current can be used as sensor supply. Any ordinary  $3\frac{1}{2}$  digit multimeter with  $\pm 2$  V measurement range can be used to measure the sensor output.

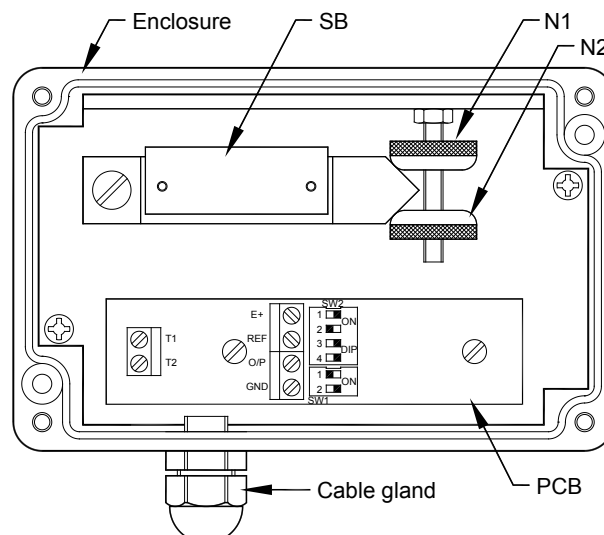
Most of the commercially available dataloggers have provision for providing the power supply required by the sensor. The model CR1000 datalogger from Campbell Scientific, USA is one of the popular dataloggers that is widely used by geotechnical instrumentation engineers worldwide for this application.

## 5.2 Initial or Mechanical Zero Adjustment

The tilt measurement range of EAN-31EL/31EL-B Electrolytic beam sensors is very small, i.e. of the order of  $\pm 0.5^\circ$ . While mounting the sensor it is not practically possible to very precisely level the sensor. In most cases the initial sensor tilt would be much greater than its specified tilt measurement range. It is very important that the sensor element, SB in figure below, is initially set to its true horizontal (i.e. zero) position after mounting so that its full tilt measurement range can be utilized.

The EAN-31EL/31EL-B sensor is provided with a double thumb wheel arrangement, N1 and N2 that allows the sensor to be precisely leveled after mounting. A level correction range of approximately  $\pm 4^\circ$  from true horizontal is provided.

In principle, to level (i.e. zero adjust) the sensor a suitable read out unit is connected to the sensor output terminals and the twin adjusting thumb wheels rotated to level the sensor holding beam while monitoring the sensor output.



## 5.3 Setting sensor zero

A readout unit has to be connected to the sensor before zero adjustment so that the required amount of adjustment can be displayed.

A CR1000 datalogger can be used as readout during zero adjustment if it is located adjacent to the sensor. Otherwise a suitable  $3\frac{1}{2}$  digit multimeter with 2 V measurement range (not supplied by Encardio-rite) together with a DC power supply (or a suitable battery) can be used with the sensor. Encardio-rite Digital Indicator model EDI-53ELV can also be used for this adjustment.

Follow the steps given below for zero adjustment:

1. Connect the indicator / power supply or the CR1000 to the tilt sensor and turn on power to the sensor.
2. If the indicator sensor shows a reading other than zero rotate the two thumb nuts so that the display shows a reading as near to zero as possible. The display reading will become more positive if the pointed end of sensor beam moves up and more negative when it moves down. DO NOT loosen the sensor beam retaining screw, as it is a friction clutch that introduces a controlled amount of friction to the beam movement. Finger tight the two thumbnuts, N1 and N2, to the sensor beam.
3. Wait for some time to ensure that the zero reading is stable otherwise a readjustment is required.
4. Put a drop of post assembly thread locking compound, such as Loctite 290, at the junction of the thumb nut and threaded stud to prevent the thumb nuts from loosening.
5. The indicator / power supply or the CR1000 can now be turned off and disconnected from the sensor board.

#### 5.4 Reading the voltage output sensors

The EAN-31EL/31EL-B sensors can be read with any indicator or datalogger that has  $\pm 2$  V measurement function. Most dataloggers will have some provision for supplying power to the tilt sensor. An additional 12 Vdc power supply would be required if a multimeter or an indicator is used as readout.

Although the EAN-31EL/31EL-B is a very sensitive, high resolution and high repeatability tilt sensor, it is a very non-linear sensor. The sensor parameters also vary a lot between units. For these reasons each sensor is supplied with an individual calibration sheet. The calibration data is usually supplied in the form of fifth order polynomial coefficients. As a lot of processing is required to get accurate tilt data, a datalogger with polynomial calculation function is strongly suggested for use with these tilt sensors.

#### 5.5 Connecting Tiltmeter to CR1000

The wiring between EAN-31EL/31EL-B sensor and the CR1000 depends on how many multiplexers are being used in the system and the control program. However, a typical direct interconnection between a single sensor and a CR1000 can be made as follows. The suggested colour codes are for Encardio-rite

CR-1000 terminal	Sensor terminal	Wire colour	Signal name
+12 Vdc	E+	Red	+12V dc to Sensor
L (of any channel)	REF	White	Sensor output (Lo)
H (of same channel)	O/P	Green	Sensor output (Hi)
G	GND	Black	0V/GND
Earth		Drain wire	Not connected to sensor. Should be connected to ground at datalogger end only to reduce noise pickup.

type EC-0107 or Belden type 8723 cable.

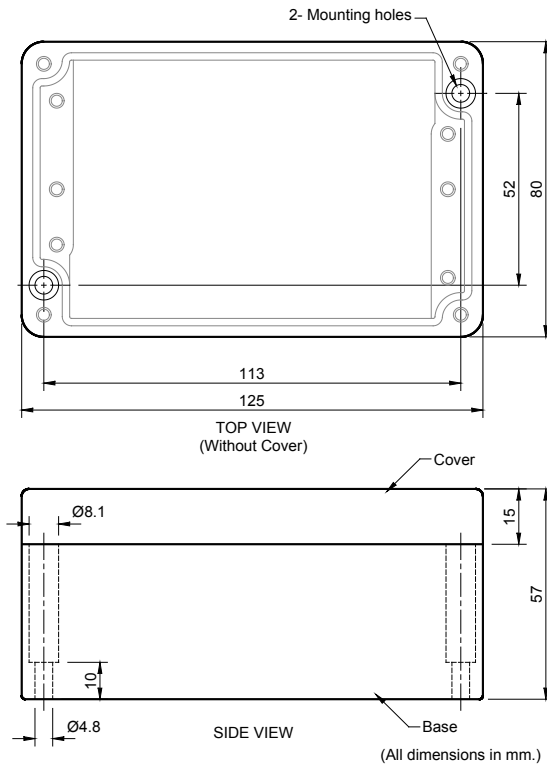
If using the CR1000 use the following instruction to acquire data in your program.

1. Use function VoltDiff(Dest, Repts, Range, DiffChan, RevDiff, SettlingTime, Integ, Mult, Offset) where use Repts = 1, Range = mV2500, DiffChan = (any differential channel), RevDiff = 0, SettlingTime = 0, Integ = 250, Mult = 0.001, Offset = 0.



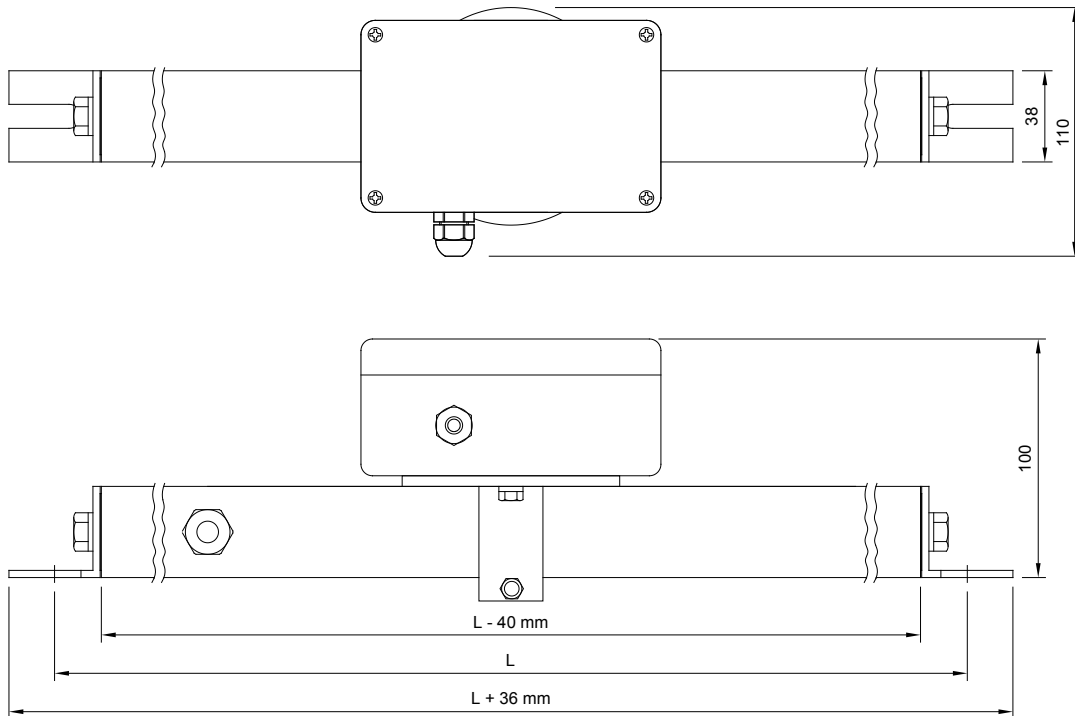
## 6 DIMENSIONS

### 6.1 EAN-31EL Tiltmeter



EAN-30EL, EL Tiltmeter  
Enclosure Dimensions

### 6.2 EAN-31EL-B Beam Sensor (EAN-31EL Tilt meter + beam assembly)



All Dimensions in mm.

'L' is beam gauge length  
Dimensions shown are approximate.

## 7 THERMISTOR RESISTANCE VS. TEMPERAURE TABLE

### 7.1 Thermistor type: Dale 1C3001-B3

### 7.2 Temperature resistance equation

$$T = 1/[A + B(\ln R) + C(\ln R)^3] - 273.2 \text{ } ^\circ\text{C}$$

$$T = \text{temperature in } ^\circ\text{C}$$

$$\ln R = \text{Natural log of thermistor resistance}$$

$$A = 1.4051 \times 10^{-3}$$

$$B = 2.369 \times 10^{-4}$$

$$C = 1.019 \times 10^{-7}$$

Ohm	Temp. °C	Ohm	Temp. °C	Ohm	Temp. °C
201.1k	-50	16.60k	-10	2417	+30
187.3k	-49	15.72k	-9	2317	31
174.5k	-48	14.90k	-8	2221	32
162.7k	-47	14.12k	-7	2130	33
151.7k	-46	13.39k	-6	2042	34
141.6k	-45	12.70k	-5	1959	35
132.2k	-44	12.05k	-4	1880	36
123.5k	-43	11.44k	-3	1805	37
115.4k	-42	10.86k	-2	1733	38
107.9k	-41	10.31k	-1	1664	39
101.0k	-40	9796	0	1598	40
94.48k	-39	9310	+1	1535	41
88.46k	-38	8851	2	1475	42
82.87k	-37	8417	3	1418	43
77.66k	-36	8006	4	1363	44
72.81k	-35	7618	5	1310	45
68.30k	-34	7252	6	1260	46
64.09k	-33	6905	7	1212	47
60.17k	-32	6576	8	1167	48
56.51k	-31	6265	9	1123	49
53.10k	-30	5971	10	1081	50
49.91k	-29	5692	11	1040	51
46.94k	-28	5427	12	1002	52
44.16k	-27	5177	13	965.0	53
41.56k	-26	4939	14	929.6	54
39.13k	-25	4714	15	895.8	55
36.86k	-24	4500	16	863.3	56
34.73k	-23	4297	17	832.2	57
32.74k	-22	4105	18	802.3	58
30.87k	-21	3922	19	773.7	59
29.13k	-20	3748	20	746.3	60
27.49k	-19	3583	21	719.9	61
25.95k	-18	3426	22	694.7	62
24.51k	-17	3277	23	670.4	63
23.16k	-16	3135	24	647.1	64
21.89k	-15	<b>3000</b>	<b>25</b>	624.7	65
20.70k	-14	2872	26	603.3	66
19.58k	-13	2750	27	582.6	67
18.52k	-12	2633	28	562.8	68
17.53k	-11	2523	29	525.4	70