

EL Tilt Sensor

(For Tilt and Beam Sensors)

Standard & SC Versions

56802198

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Introduction to Tilt Sensors

Tiltmeter Applications

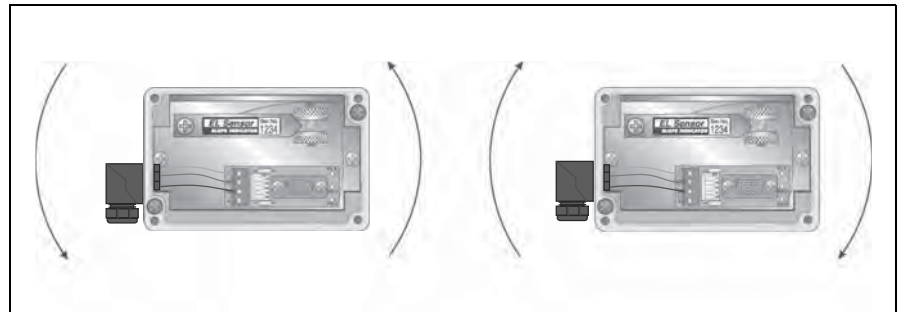
The EL tiltmeter is a narrow angle, high resolution device for monitoring changes in the inclination of a structure. Applications for the tiltmeter include:

- Monitoring the rotation of retaining walls, piers, and piles.
- Monitoring the behavior of structures under load.

Operation

The tiltmeter consists of an electrolytic tilt sensor housed in a compact, weatherproof enclosure. The tilt sensor is a precision level that is sensed electrically as a resistance bridge. The bridge circuit outputs a voltage proportional to the tilt of the sensor.

After the housing is fixed to the structure, the sensor is adjusted to its zero point, and then the initial reading (near zero) is recorded. Changes in inclination are found by comparing the current reading to the initial reading.

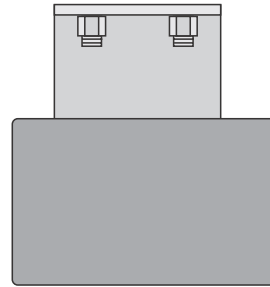


A positive change in tilt indicates counter clockwise rotation.

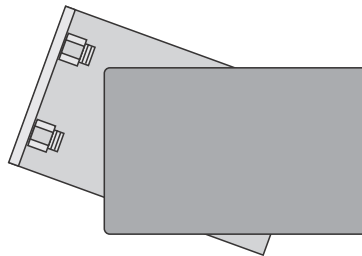
A negative change in tilt indicates clockwise rotation.

Installation of Tilt Sensors

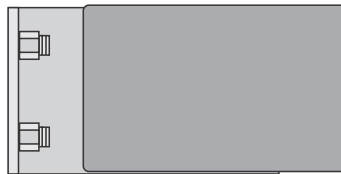
Mounting the Tiltmeter The tiltmeter can be mounted on various surfaces.



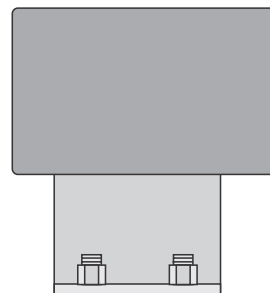
Swivel bracket fixed to a ceiling.



Swivel bracket fixed to a non-vertical surface.



Swivel bracket fixed to a wall or pillar.



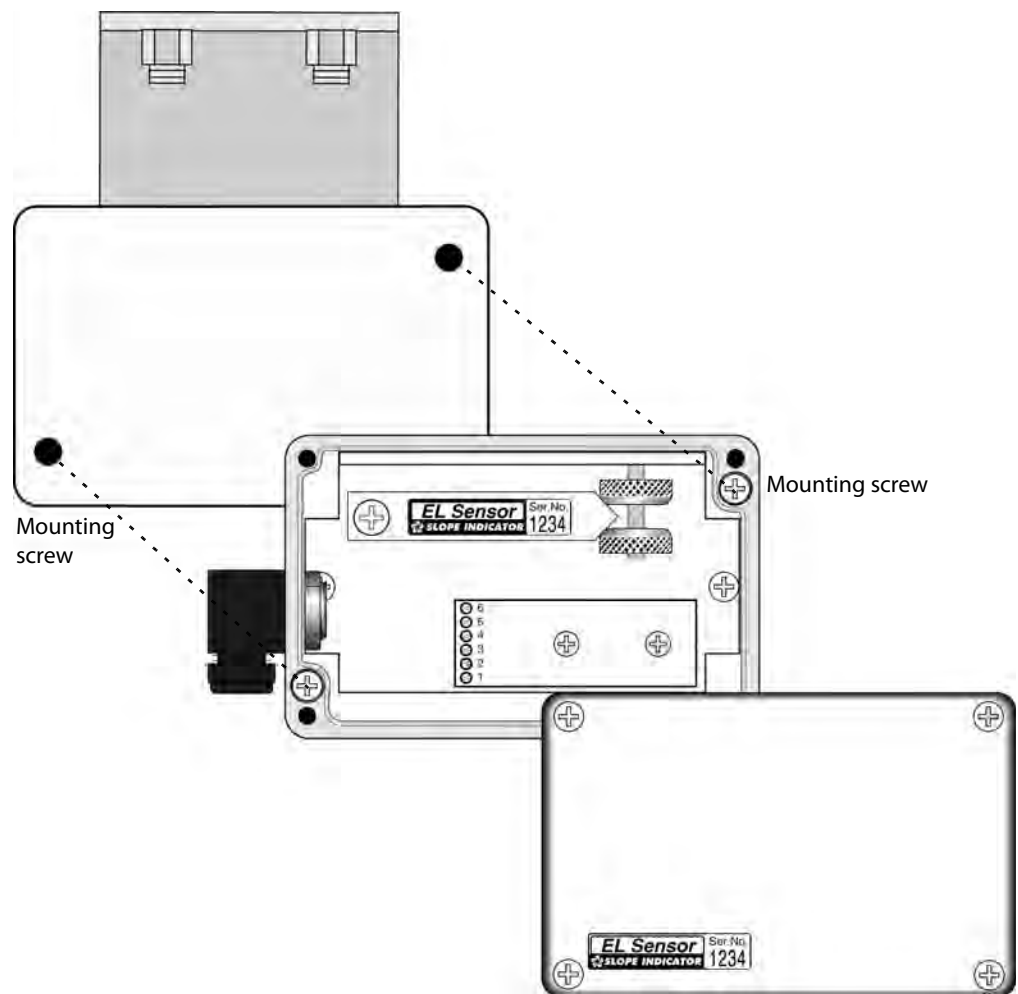
Swivel bracket fixed to a floor.

Installing Anchors

1. Mark locations for anchors. The Rotating L-Bracket requires two anchors.
2. Drill the anchor holes in structure deep enough to embed the anchors. Remove debris.
3. Mix epoxy grout as directed by manufacturer. Fill holes with grout, then insert anchors.

Attaching the Tiltmeter

- Mount the Rotating L-bracket to the anchors.
- Mount the EL Tiltmeter to the Rotating L-bracket with the two mounting screws (see illustration below). Tighten the tiltmeter against the bracket.



Introduction to Beam Sensors

Beam Sensor Applications

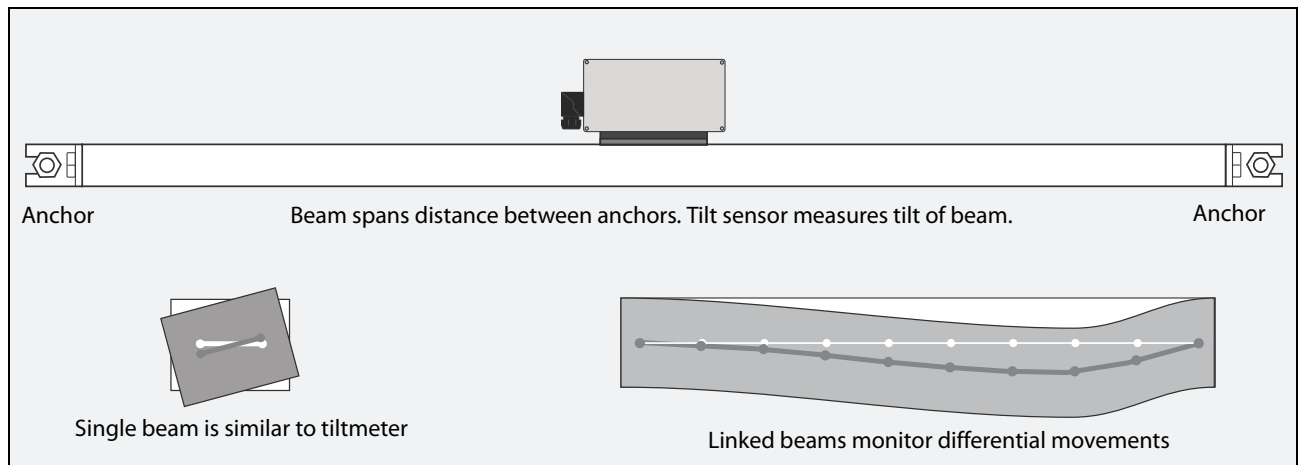
EL beam sensors monitor rotation and differential movement in structures. When mounted horizontally, beam sensors are used to monitor settlement and heave. When mounted vertically, they can be used to monitor lateral displacement. Linked end-to-end, beam sensors can monitor differential movement.

Operation

The beam sensor consists of an electrolytic tilt sensor that is first attached to an Omni bracket, then attached to a rigid metal beam. The tilt sensor is a precise level that is sensed electrically as a resistance bridge. The bridge circuit outputs a voltage proportional to the tilt of the sensor.

The beam, which is typically one to two meters long, is mounted on anchor bolts that are set into the structure. Movement of the structure changes the tilt of the beam and the output of the tilt sensor.

The voltage reading from the tilt sensor is converted to a reading in mm per meter. Displacement is calculated by subtracting the initial reading from the current reading.



Beam Sensor Components

Beam sensor components include a beam with end brackets, an anchor kit, an Omni bracket, and an EL tilt sensor.

Beams

Beams are square section aluminum beams supplied in gauge lengths up to 2 meters. End brackets are included with each beam.

Each beam is supplied with end-brackets that can be secured directly to wall anchors. This method of installation is satisfactory with solitary beams that only rotate. However, if beams are linked, or if the structure is likely to deform, the mounting hardware included in the anchor kit will provide better results.

Anchor Kit

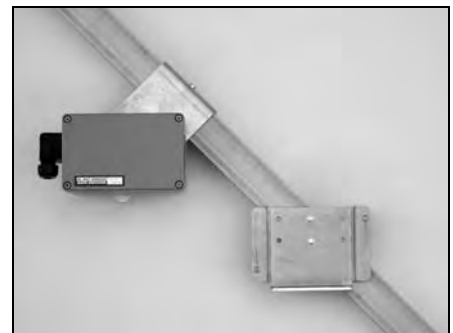
The anchor kit contains one stainless steel M10 x 200 mm all-thread stud, an angle bracket, low-friction bushings, and other hardware. Use two anchor kits for a single beam. Linked beams share anchors, so use one anchor kit for each beam plus one anchor kit for the last beam.

EL Tilt Sensor

The tilt sensor mounts to an Omni bracket that is then mounted to the beam.



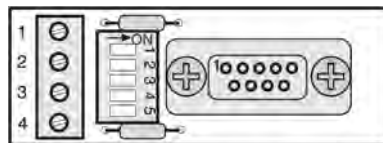
Horizontal tilt sensor



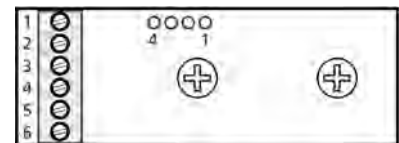
Vertical tilt sensor

Terminal Board

The tilt sensors may be supplied with a standard terminal board or an SC (Signal Conditioning) terminal board. Wiring and reading methods differ according to the type of board supplied.



Standard terminal board has 4 terminals. Other notable features are a DB9 connector and a bank of switches.



SC terminal board has 6 terminals. The only other notable feature is the row of four pins at the top of the board.

Installing Horizontal Beam Sensors

Installation Overview

4. Install anchors.
5. Mount Omni bracket to beam.
6. Install Tilt sensor to Omni bracket.
7. Install beam.

Installation Materials

- Quick-set epoxy grout, 250 ml or larger package. This is used to secure the all-thread anchors in the drill holes.
- Blue Loctite (#242) or equivalent thread-locking compound to keep the sensor in its adjusted position.
- Teflon tape (optional). To be wrapped on anchors to prevent bonding of grout and anchor. Used when anchors must be removed.

Installation Tools

- Spirit level.
- Percussion/hammer drill with 12 to 19 mm masonry drill bit.
- Two adjustable wrenches.
- Two screw drivers, one flat head and one phillips.

Installing Anchors

The beam sensor monitors the relative movement of two anchors. The gauge length of the beam sensor is the distance between the center point of each anchor. You can choose any convenient gauge length. For example, you can have some anchors spaced at 1.5 meters and other anchors at 0.8 meters.

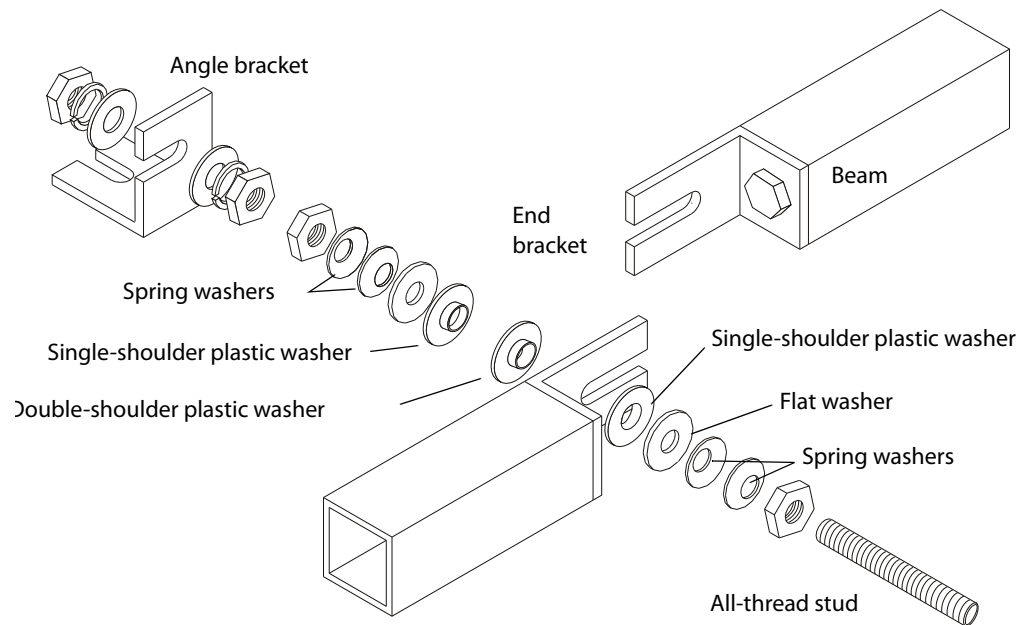
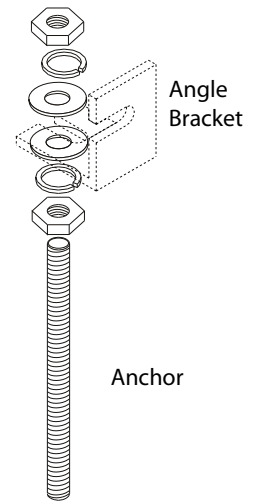
Once anchors are grouted in, you must measure the center to center distance between each anchor carefully, since this value is used in displacement calculations.

1. Mark locations for anchor holes: Draw a horizontal line on the structure, then mark off gauge lengths for each sensor. Linked beams share anchors.
2. Drill anchor holes to depth of about 100 mm. Take care to drill holes at same angle.
3. Remove debris from holes. Mix epoxy grout as directed by manufacturer. Fill hole with grout, then insert anchor.
4. Allow grout to harden before mounting beam.
5. Measure the center to center distance between each pair of anchors.

Installing the Beam

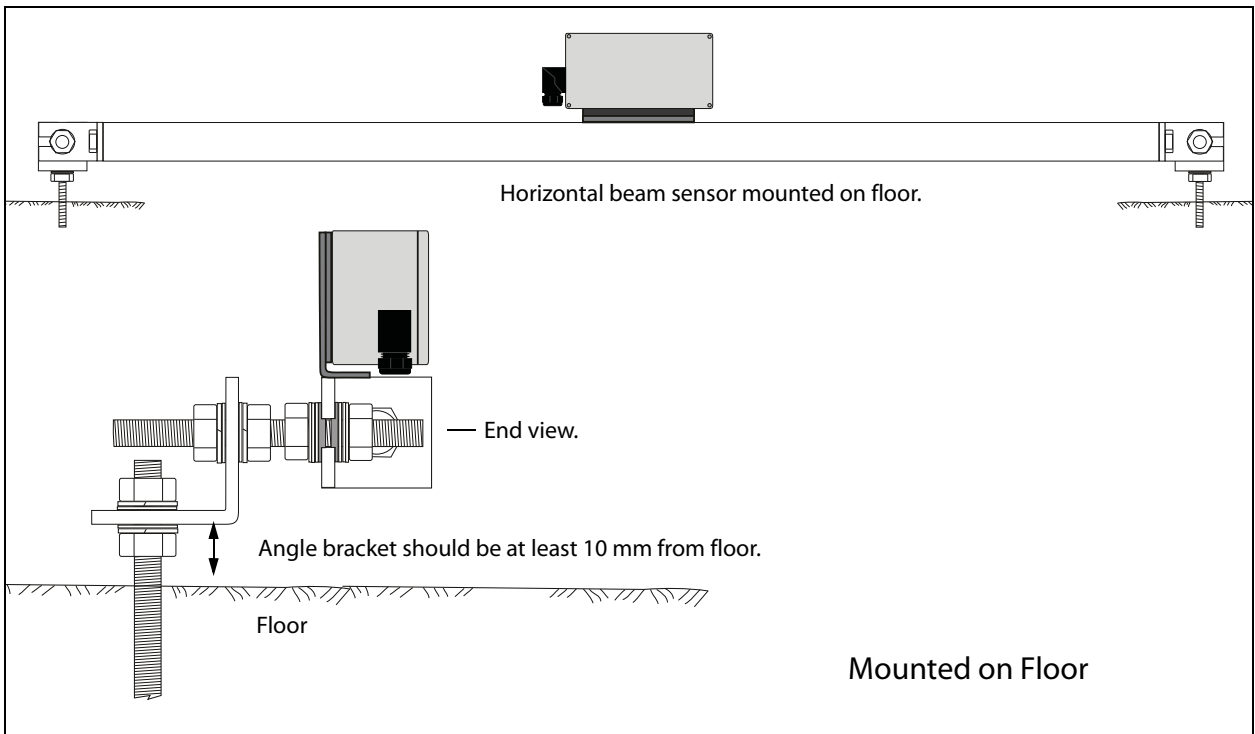
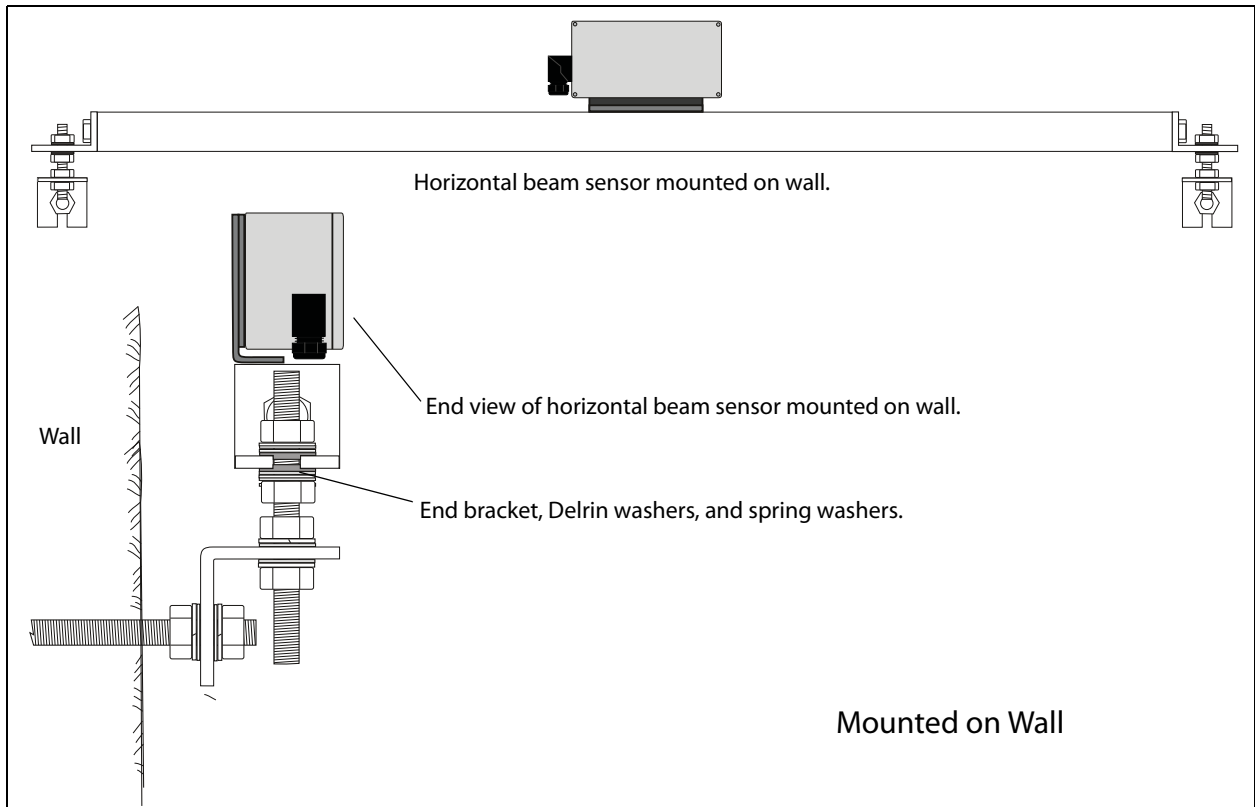
Each beam is supplied with end brackets that can be secured directly to wall anchors. This method of installation is satisfactory with solitary beams that monitor only rotation. However, if beams are linked, or if the structure is likely to deform, the mounting hardware included in the anchor kit will provide better results. See installation drawings below and on the next page.

1. Check that anchors are parallel. Adjust anchors by bending the line, if necessary.
2. Check that end brackets are inserted into beams, but not completely tight.
3. Fasten angle brackets to anchors, as shown in the drawing at right.
4. Fasten end bracket of beam sensor to angle brackets. Hardware is usually supplied with all washers in place. Use drawing below to see where end brackets and angle brackets fit. Tighten nuts so that spring washers are just slightly compressed.



Installing the Beam
continued

5. Check that beam is properly oriented, as shown below.
Apply thread-locking compound to all nuts.



Installing Vertical Beam Sensors

- Installation Overview**
1. Install anchors.
 2. Mount Omni bracket to beam.
 3. Install Tilt sensor to Omni bracket.
 4. Install beam.
- Installation Materials**
- Quick-set epoxy grout, 250 ml or larger package. This is used to secure the all thread anchors in the drill holes.
 - Blue Loctite (#242) or equivalent thread-locking compound to keep the sensor in its adjusted position.
 - Teflon tape (optional). To be wrapped on anchors to prevent bonding of grout and anchor. Used when anchors must be removed.
- Installation Tools**
- Spirit level.
 - Percussion/hammer drill with 12 to 19 mm masonry drill bit.
 - Two adjustable wrenches.
 - Two screw drivers, one flat head and one phillips.
 - 8 mm socket wrench, used to tighten nuts on swivel plate.
- Installing Anchors**
- The beam sensor monitors the relative movement of two anchors. The gauge length of the beam sensor is the distance between the center point of each anchor. You can choose any convenient gauge length. For example, you can have some anchors spaced at 1.5 meters and other anchors at 0.8 meters.
- Once anchors are grouted in, you must measure the center-to-center distance between each anchor carefully, since this value is used in displacement calculations.
1. Mark locations for anchor holes: Draw a vertical line on the structure, then mark off gauge lengths for each sensor. Linked beams share anchors.
 2. Drill anchor holes: Take care to drill holes at same angle. Do not use end-brackets as drill guides, since enlargement of slot may interfere with performance of beam sensor.

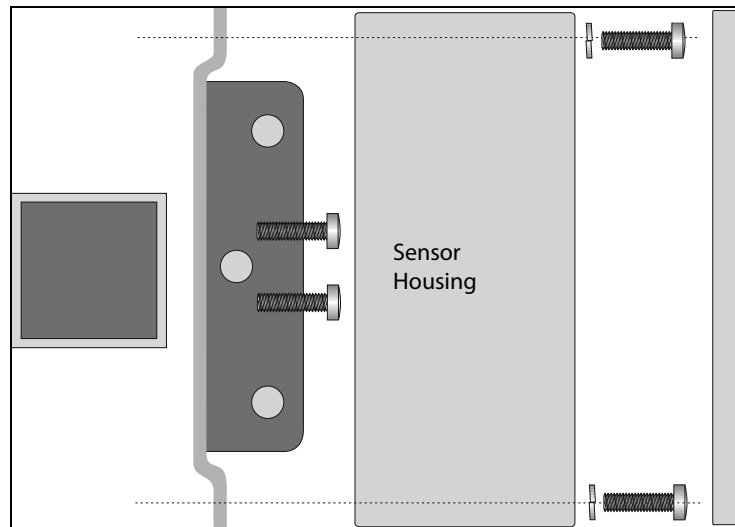
-
3. Remove debris from holes: Mix epoxy grout as directed by manufacturer. Fill holes with grout, then insert anchors. Anchor must extend at least 100 mm from wall to provide clearance for sensor housing.
 4. Allow grout to harden before mounting beam.
 5. Measure the center-to-center distance between each pair of anchors.

Mount Omni Bracket to Beam

1. Using a level, place Omni bracket on beam in the desired position.
2. With 2 self-tapping screws, secure the Omni bracket to the beam.

Attaching the Sensor to the Beam

1. Remove cover.
2. Attach tilt sensor to Omni bracket as shown below.
3. Replace cover.
4. Clamp sensor housing to beam. Tighten nuts on clamp.

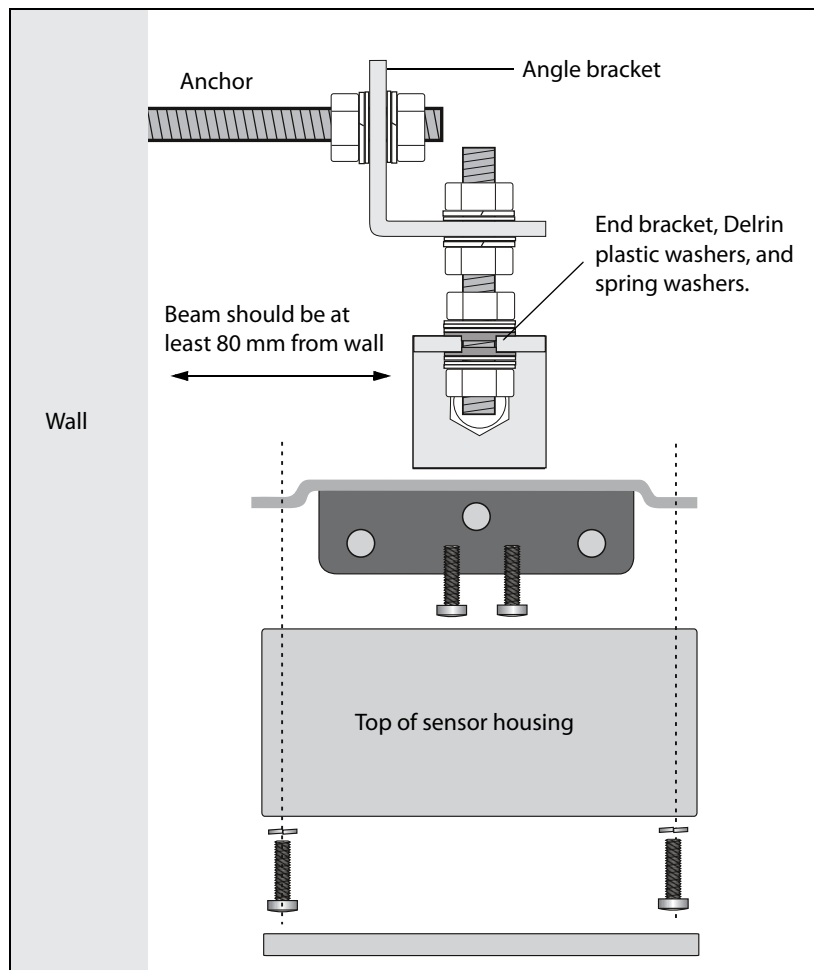


Installing the Beam

Each beam is supplied with end-brackets that can be secured directly to wall anchors. This method of installation is satisfactory with solitary beams that monitor only rotation. However, if beams are linked, or if the structure is likely to deform, the mounting hardware included in the anchor kit will provide better results.

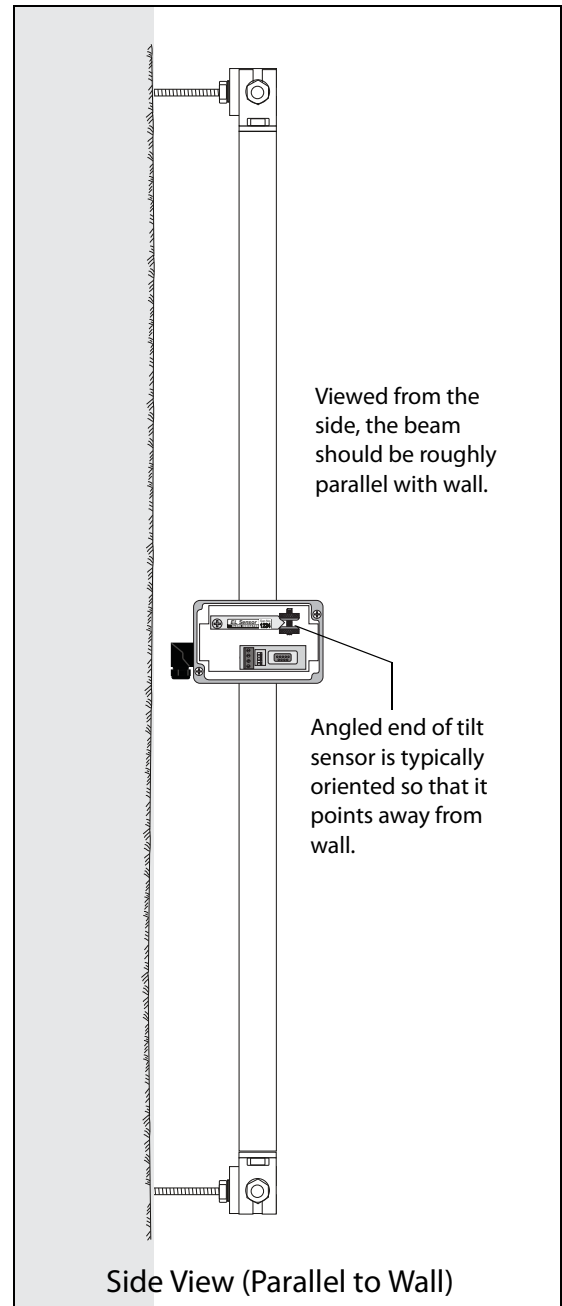
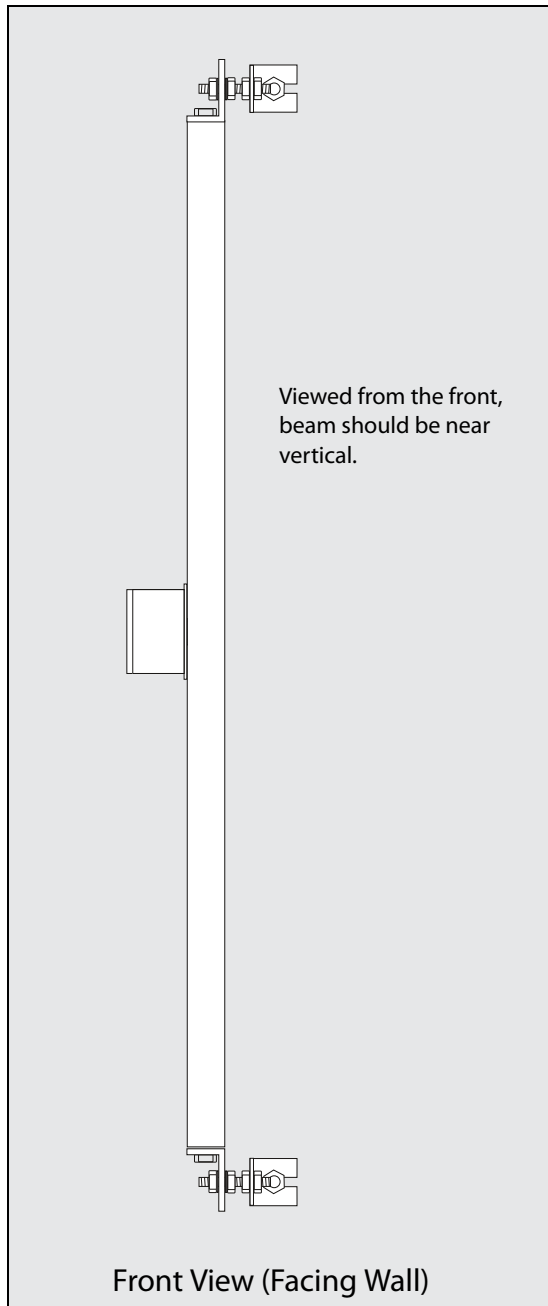
See installation drawings below and on the next page.

1. Check that anchors are parallel. Adjust anchors by bending, if necessary.
2. Fasten angle-brackets onto anchor.
3. Fasten end-brackets of beam to angle brackets. Check that washers are inserted as in the drawing on page 5. Tighten nut so that spring washers are just slightly compressed.



View from Above

4. Viewed from the front, beam should be near vertical. Viewed from the side, the beam should be roughly parallel with the wall.
5. Check that top of sensor housing is level. To adjust, remove cover, loosen the two mounting screws, and rotate housing. Then tighten mounting screws and replace cover.
6. Apply thread-locking compound to all nuts.

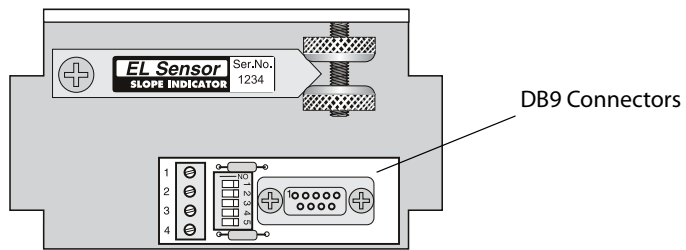


Zero-Adjusting Standard Sensors

Introduction The EL tilt sensor has a very narrow range, so it must be adjusted so that its initial output is as close as possible to null. This makes the full tilt range of the sensor available for monitoring.

The standard terminal board has a DB9 socket for connecting a zeroing device.

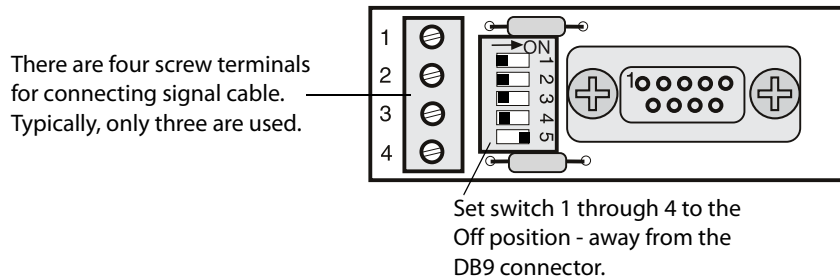
EL tilt sensor with standard terminal board.



- Overview of Zeroing**
1. Connect signal cable to the sensor. The sensor is very sensitive to even small movements, so it is best to connect signal cable to it before you attempt to zero the sensor. Otherwise, you may have to re-zero the sensor when you connect the cable.
 2. Zero the sensor using the EL Nulling Device.

Connecting Signal Cable

1. Remove cover of sensor housing.
2. While you connect signal cable, set switches 1 through 4 to the OFF position.



3. Connect signal cable as shown in the table below:

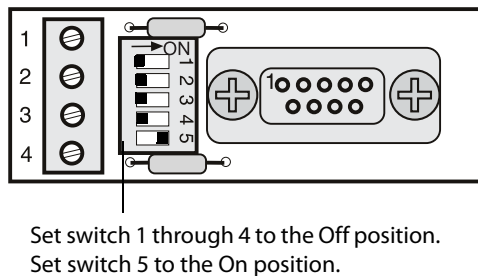
Standard Terminal	Cable 50612804	Function
1	White	AC Excitation
2	not used	
3	Green	AC Output
4	Red	Analog Ground
	Drain	Not connected to sensor

After connecting the signal cable, secure it to the wall or floor so that it will not cause the sensor to move. Note that any testing of the signal cable should be performed with switches 1 through 4 in the “Off” position. This prevents cable-test operations from damaging the sensor.

Zeroing the Sensor

Zero the sensor using the EL Nulling Device. Instructions appear as follows:

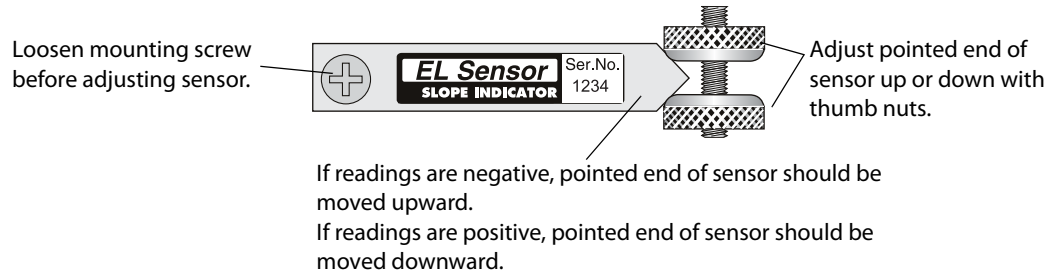
1. Remove cover and set switches on terminal board. Switches 1 through 4 should be OFF. Switch 5 should be ON.



2. Connect the EL Nulling Device to the DB9 socket on sensor board and switch on.

If you do not have the DB9 adapter, you can connect using the bare wire adapter, but you must set the switches differently. See note below.

3. Adjust sensor to zero tilt: Loosen sensor mounting screw and the two thumb nuts to allow adjustment of tilt sensor. Use the thumb nuts to adjust the sensor up or down. The goal is to light the middle LED on the EL Nulling Device.



4. Turn thumb nuts until both are in contact with the sensor, then gently tighten the mounting screw. Finger tight is good enough. Over-tightening can cause the reading to change and stress the sensor.
5. Check that the sensor is still zeroed, then switch off and gently disconnect the zeroing device. Make a note of sensor location and serial number.
6. Apply a temporary thread-locking compound to prevent screw and nuts from turning. You may need to adjust sensor again later, so do not use a permanent compound.
7. Carefully reset the switches so that switches 1, 3, and 4 are ON and switches 2 and 5 are OFF.

Note: Using the Bare-Wire Adapter for Zeroing

1. Set all switches to the ON position.
2. Connect the bare wire adapter as follows:

Bare Wire Adapter	Tilt Sensor Terminal
5	1
2	2
1	3
6	4

Reading Standard Sensors

Data Logging The standard sensor must be read with a CR1000 data logger. These instructions below assume that signal cable is already connected to the sensor, as explained in the previous chapter.

CR1000 Instructions Use the P78 and P5 instructions for single ended channels.

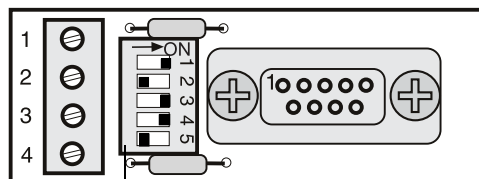
P78 (Resolution) • High Resolution

P5 (AC Half Bridge) • 2500 mV Fast Range
• 2500 mV Excitation
• Multiplier (10)

Wiring for CR1000 The exact wiring for the CR1000 depends on your program and whether you use multiplexers or not. A generic connection is shown in the table below. Download a sample monitoring program from www.slopeindicator.com. Go to Support >> Tech-notes >> Data Loggers. Then find a link for sample programs.

CR1000 Terminals	Wire Color	Sensor Terminal	Function
E	White	1	AC Excitation
		2	Not Used
H or L	Green	3	AC output
AG	Red	4	Analog Ground
G	Drain	Drain wire not connected to sensor	

Setting Switches for CR1000 3. Set the switches as shown below.



Switches 1, 3, and 4 are ON.
Switches 2 and 5 are OFF

Zero Adjusting SC Sensors

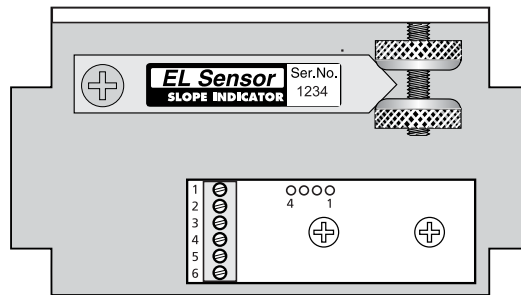
Introduction

Because the EL tilt sensor has a very narrow range, it must be adjusted so that its initial output is as close as possible to null. This makes the full range of the sensor available.

Connecting signal cable to the sensor. The sensor is very sensitive to even small movements, so it is best to connect signal cable to it before you attempt to zero the sensor. Otherwise, you may have to zero the sensor again after connecting signal cable.

Sensors equipped with the SC terminal board, illustrated below, can be zeroed with the MEMS/EL Data Recorder, M-Logger, EL Nulling Device or a voltmeter.

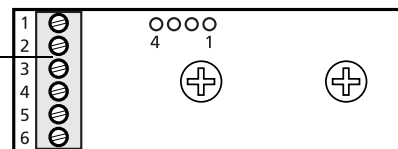
EL tilt sensor with SC terminal board.



Connect Signal Cable

The drawing shows the SC terminal board. Connect signal cables as shown in the table below. After connecting the signal cable, secure it to the wall or floor so that it will not cause the sensor to move

There are six screw terminals for connecting signal cable.



SC Terminal Board	Cable 50613527	Function
1	Green	+ Power
2	Black	- Power
3	Orange	Tilt
4	Yellow	Signal Common
5	Red	Temperature
6	Violet	Sense

Connect a Readout Connect the MEMS/EL Data Recorder, M-Logger or a Voltmeter to the sensor.

MEMS/EL Data Recorder

1. Connect sensor to readout as shown in the table below.
2. Switch on. Choose uniaxial sensor. Tilt is displayed in volts. Temperature is displayed in degrees C.

Data Recorder Terminal	Signal Cable Wire	SC Terminal Board
1 Tilt A	Orange	3
2		
3 Temp	Red	5
4 Sig Common	Yellow	4
5 Sense	Violet	6
6 Power +	Green	1
7 Power -	Black	2
8 Shield	Drain Wire	

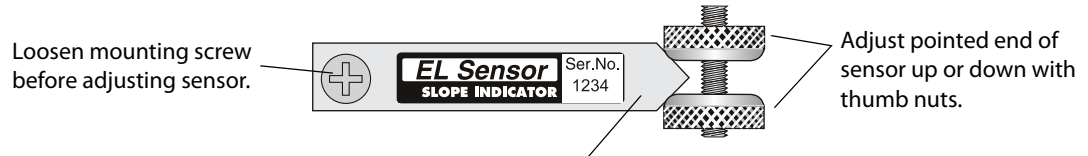
EL Nulling Device See page 13 for detailed instructions on how to zero your sensor with the EL Nulling Device.

Voltsmeter In addition to a voltmeter, you must have a power source, such as a 9-volt battery to supply between 7.5 and 14 Vdc to the sensor.

1. Connect the green wire to the + terminal of the battery.
2. Connect the violet wire and black wire to the - terminal of the power source.
3. To read the tilt, connect the voltmeter to the orange wire and the yellow wire.
4. To read the thermistor, connect the voltmeter to the red wire and the yellow wire.

Adjusting Zero

1. Adjust sensor to zero tilt: Loosen sensor mounting screw and thumbscrews to allow adjustment of tilt sensor. Use thumb nuts to adjust sensor up or down according to the sign (+ or -) of the reading. The object is to get the reading as close to zero as possible.



If readings are negative, pointed end of sensor should be moved upward.

If readings are positive, pointed end of sensor should be moved downward.

2. Turn thumb nuts until both are in contact with the sensor, then gently tighten the mounting screw. Finger tight is good enough. Over-tightening can cause the reading to change and stress the sensor.
3. Check that reading is still zeroed, then disconnect the read-out. Make a note of sensor location and serial number and replace the cover.
4. Apply temporary thread-locking compound to prevent screw and nuts from turning. You may need to adjust sensor again later, so do not use a permanent compound.

Reading SC Sensors

Introduction You can read an EL SC sensor with an EL/MEMS Data Recorder, M-Logger, a precision voltmeter, or a data logger.

Manual Readings MEMS/EL Data Recorder

1. Connect the readout to the sensor as described in the previous chapter.
2. Obtain the reading and write it down or record it.
3. Later, apply calibration factors to convert the reading in volts to engineering units, as described in the chapter on Data Reduction.

Additional information about the EL/MEMS Data Recorder and the M-Logger can be found on Slope Indicator's website. Go to www.slopeindicator.com. Click on Support, then click on Technotes. Find the Readout section and click on the link for the EL/MEMS Data Recorder or M-Logger.

Voltmeter

Reading with a voltmeter requires a power source, such as a 9-volt battery, to supply between 7.5 and 14 Vdc to the sensor. The table below shows possible clip colors.

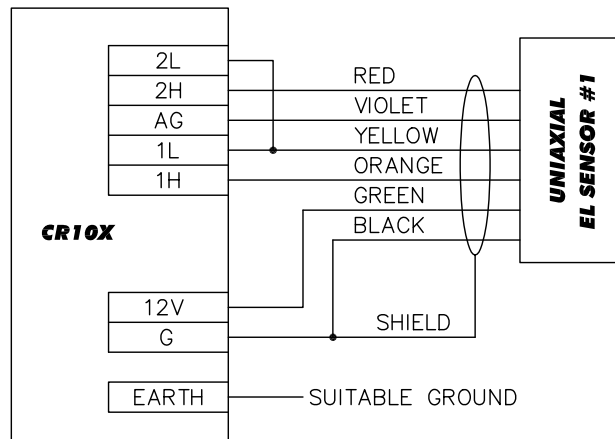
Sensor Board	Cable 50613527	Batt & Voltmeter	Function
1	Green	+ (Batt)	+ Power
2	Black	- (Batt)	- Power
6	Violet		
3	Orange	+ DC (VM)	Tilt
4	Yellow	Common (VM)	Signal Common

- Set the voltmeter to DC to measure at a narrow range, for example, the 1 volt range. The right-most digit might be unstable, but other digits should be stable.

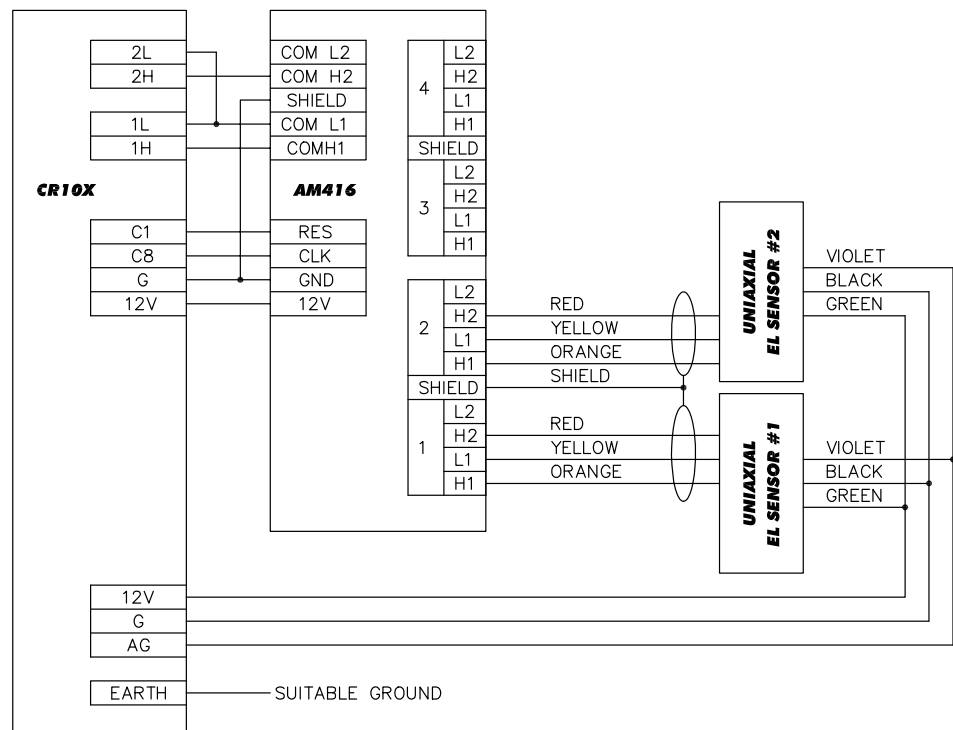
Data Logging

These wiring diagrams show how to connect SC sensors to a Campbell Scientific CR1000 data logger. You can download a sample monitoring program from Slope Indicator's website. Go to www.slopeindicator.com > Support > Tech Notes. Look at the data logger technotes to find a link for sample programs that you can download.

Wiring Diagram 1 Connecting a uniaxial sensor directly to the CR1000:



Wiring Diagram 2 Connecting a uniaxial sensor to an AM416 multiplexer:



Data Reduction, Tilt Sensors

- Overview**
1. The EL tilt sensor produces a voltage value that is recorded by the readout or data logger.
 2. Each EL tilt sensor has a serial number and a calibration sheet with unique factors.
 3. To obtain tilt in degrees, apply these factors to the voltage reading.

Data Reduction Example Suppose you obtain a reading of 1.1061 volts from a sensor.

Calibration Sheets Find the calibration sheet for that sensor. In this case, we show factors for sensor 36204. The factors on your calibration sheets will be different. These factors are coefficients for a 5th order polynomial expression.

C5	1.74849351E-2
C4	-2.91482607E-3
C3	-4.38752771E-2
C2	6.06793437E-3
C1	2.28093126E-1
C0	-2.4647589E-4

Convert voltage reading to tilt in degrees Process the voltage reading with the polynomial equation shown below.

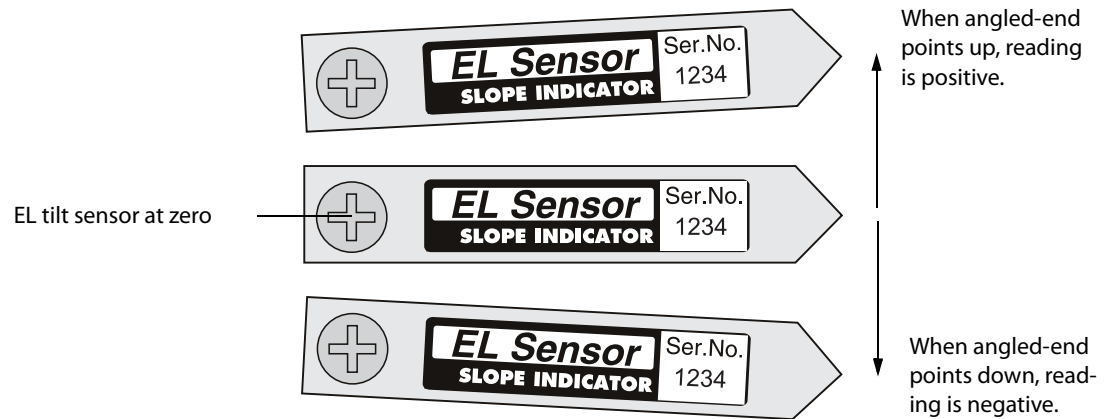
$$\text{tilt in degrees} = C5 \cdot EL^5 + C4 \cdot EL^4 + C3 \cdot EL^3 + C2 \cdot EL^2 + C1 \cdot EL + C0$$

	C Factor	Reading Raised to Appropriate Power	Value
C5	1.74849351E-2	1.1061 ⁵	0.0289491613
C4	-2.91482607E-3	1.1061 ⁴	-0.0043630502
C3	-4.38752771E-2	1.1061 ³	-0.0593749216
C2	6.06793437E-3	1.1061 ²	0.0074238581
C1	2.28093126E-1	1.1061	0.2522938067
C0	-2.4647589E-4	1	-0.0002464759
tilt in degrees =			0.2246823783

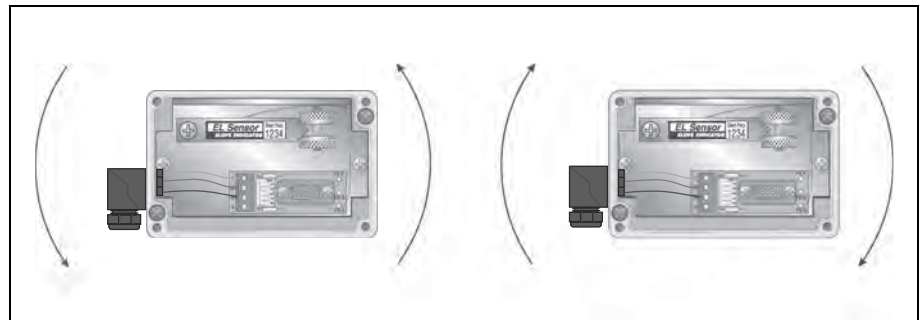
Calculate Change in Tilt To calculate displacement, subtract the initial reading from the current reading.

$$\text{change in tilt} = \text{current tilt} - \text{initial tilt}$$

Direction of Tilt The drawing below shows the orientation of the sensor when reading is positive or negative.



Change in Tilt Change in tilt is found by subtracting the initial tilt value from the current tilt value. The sign (+ or -) of the resulting value indicates rotation as shown in the drawing below.



A positive change in tilt indicates counter clockwise rotation.

A negative change in tilt indicates clockwise rotation.

Converting the thermistor reading to degrees C. SC terminal boards are equipped with a thermistor. If you have obtained a thermistor reading in volts, use the equation below to convert volts to degrees C. ET is the thermistor reading in volts.

$$\text{DegC} = 58.6752 \cdot \text{ET}^5 - 278.839 \cdot \text{ET}^4 + 509.188 \cdot \text{ET}^3 - 449.099 \cdot \text{ET}^2 + 233.754 \cdot \text{ET} - 48.4917$$

Data Reduction, Beam Sensors

Data reduction is usually automated because it involves a large number of readings and a large number of calculations. Here, we explain the manual operations required to convert voltage readings to mm of displacement.

1. The EL tilt sensor produces a voltage value that is recorded by the readout or data logger. To convert the voltage value to a tilt value, you must apply calibration factors listed on the sensor calibration sheet.
2. The factors on the sensor calibration sheet are coefficients for a 5th order polynomial equation. Processing the voltage reading with this equation transforms the voltage reading into tilt in units of mm per meter. (Think of this tilt value as “grade” in tenths of a percent).
3. Multiply the tilt by the gauge length of the beam sensor (the center-to-center distance between anchors). This results in a reading in mm.
4. To find displacement, the distance that one anchor has moved relative to the other, subtract the initial reading in mm from the current reading in mm.

Data Reduction Example

Suppose you obtain a reading of -0.58571 volts from the sensor.

Calibration Sheets

Find the calibration sheet for your sensor. In this case, we show factors for sensor 8889. The factors on your calibration sheets will be different.

These factors are coefficients for a 5th order polynomial expression.

C5	1.6426E-1
C4	-1.5836E-2
C3	-2.6881E-1
C2	-7.9904E-2
C1	3.5098
C0	8.1185E-2

Convert Voltage Reading to Tilt in mm per Meter

Process the voltage reading with the polynomial equation shown below. C5 through C0 are the coefficients that appear on the sensor calibration record. EL is the voltage reading from the sensor, in this case 0.144 V. The result of the calculation is a value in mm per meter.

$$\text{mm/meter} = C5 \cdot EL^5 + C4 \cdot EL^4 + C3 \cdot EL^3 + C2 \cdot EL^2 + C1 \cdot EL + C0$$

	C Factor	EL Reading	Value
C5	1.6426E-1	-0.58571 ⁵	-0113225700
C4	-1.5836E-2	-0.58571 ⁴	-0.0018637002
C3	-2.6881E-1	-0.58571 ³	0.0540123829
C2	-7.9904E-2	-0.58571 ²	-0.0274115629
C1	3.5098	-0.58571 ¹	-2.0557249580
C0	8.1185E-2	1	0.0811850000
mm per meter deviation =			-1.9611254082

Apply Gauge Length

Multiply the mm/meter value by the gauge length of the sensor.

$$\text{reading in mm} = \text{mm/meter value} \cdot \text{gauge length of sensor.}$$

In this example, the gauge length of the beam is 2 meters, so the reading in mm is 2 x -1.961 or about -3.922 mm.

Calculate Displacement

To calculate displacement, subtract the initial reading from the current reading.

$$\text{displacement in mm} = \text{current reading} - \text{initial reading.}$$

If the initial reading were 0.5 mm, then displacement would be about -3.4 mm. See Direction of Movement on the next page for help in understanding this reading.

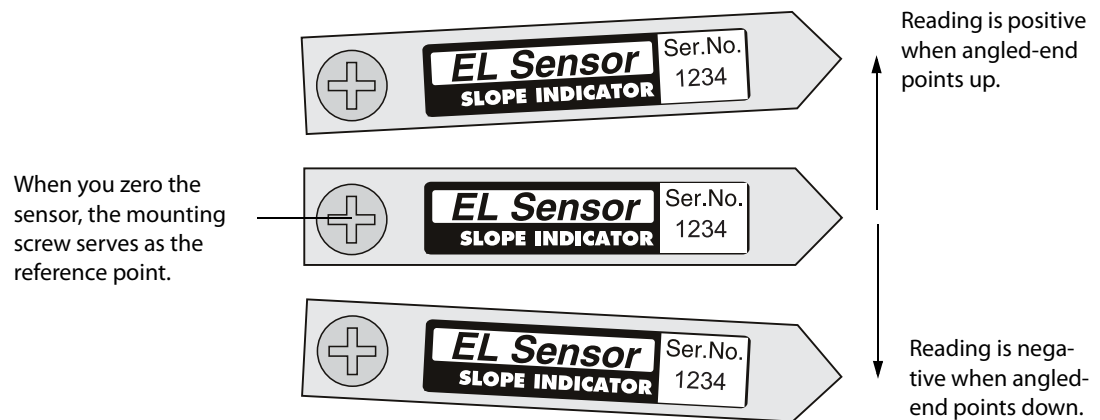
Direction of Movement

The beam sensor spans the distance between two anchors. When the beam sensor reading changes, it means that one anchor has moved relative to the other anchor.

- With horizontal sensors, one anchor has moved up or down relative to the other anchor.
- With vertical sensors, one anchor has moved laterally (right or left) relative to the other anchor.

Tilt of the Sensor

In the process of zeroing the sensor, you move its angled end up or down relative to the mounting screw. Moving the angled end above horizontal results in a positive (+) reading. Moving the angled end below horizontal results in a negative (-) reading.

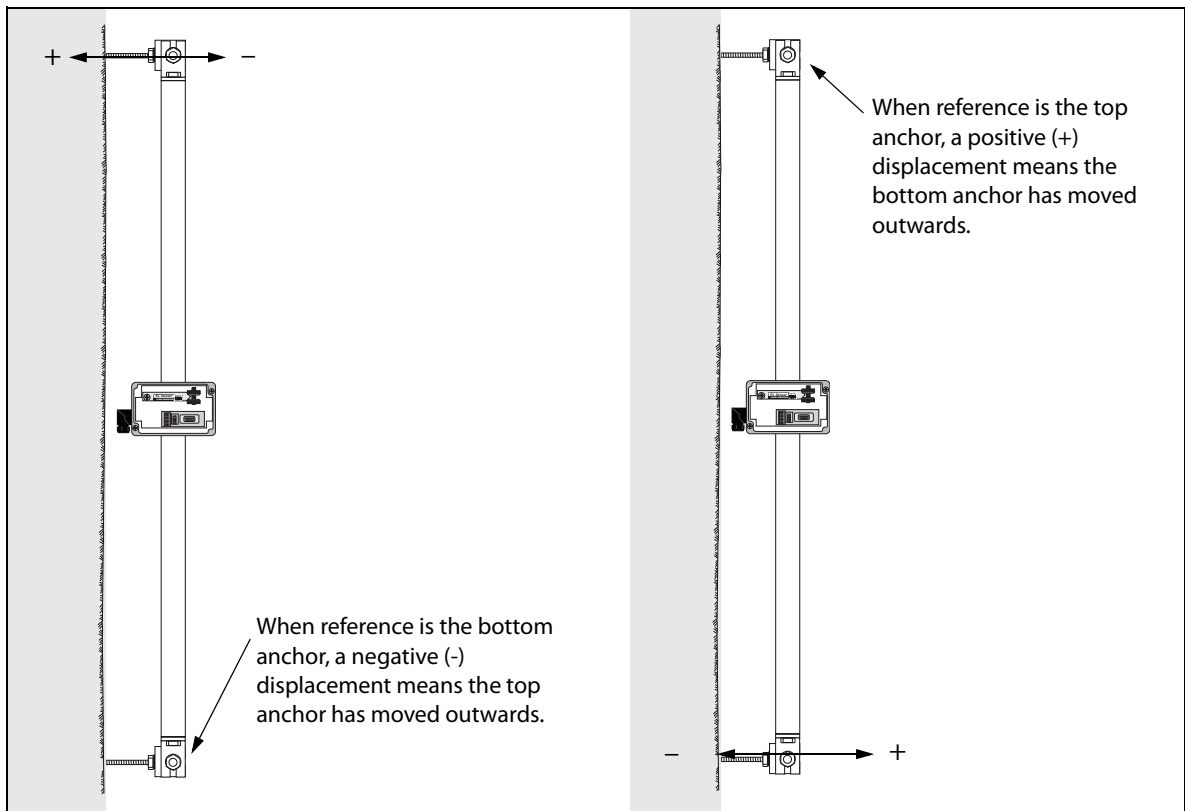
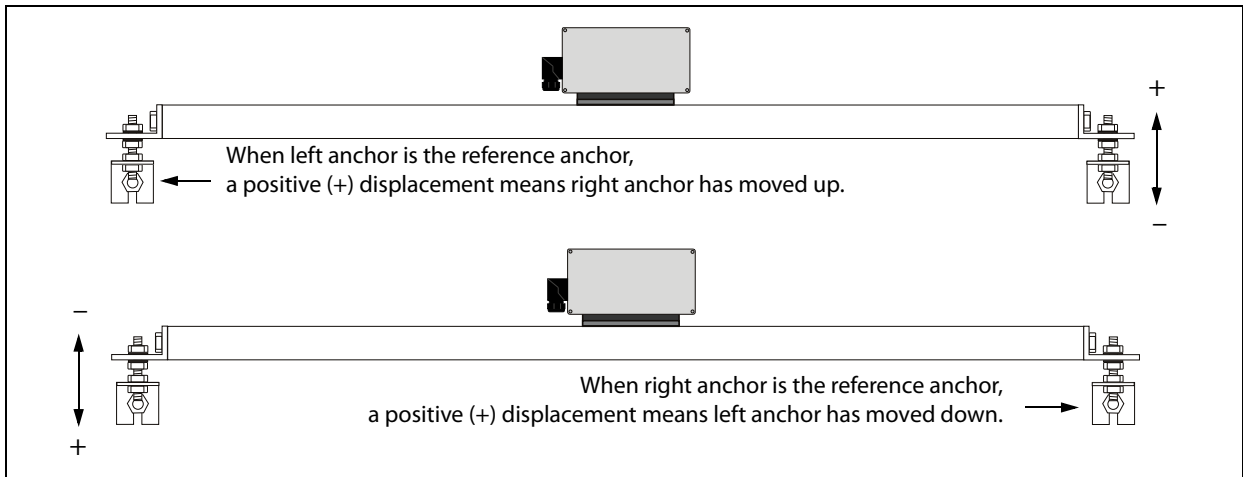


Note that the relation of up-positive and down-negative would be reversed if you held the angled-end of the sensor and moved the screw end up or down.

Thus in determining the direction of movement, you must choose a reference point. In the case of the beam sensor, you must choose an anchor to serve as the reference, as shown on the next page.

Reference Point and Direction of Movement

The drawings below show how the reference point affects the direction of movement.



Converting the thermistor reading to degrees C.

SC terminal boards are equipped with a thermistor. If you have obtained a thermistor reading in volts, use the equation below to convert volts to degrees C. ET is the thermistor reading in volts.

$$\text{DegC} = 58.6752 \cdot \text{ET}^5 - 278.839 \cdot \text{ET}^4 + 509.188 \cdot \text{ET}^3 - 449.099 \cdot \text{ET}^2 + 233.754 \cdot \text{ET} - 48.4917$$