Deep-Water EL Tiltmeter

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Introduction

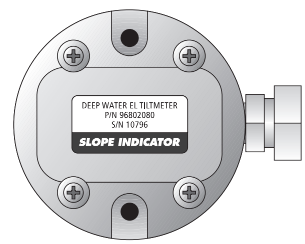
Applications

The Deep-Water EL Tiltmeter is a narrow angle, high resolution device for monitoring changes in the inclination of a structure. The device is designed for long-term submersion in applications such as:

- Monitoring the rotation of retaining walls, piers, and piles in an underwater location.
- Monitoring the behavior of the concrete face slabs of dams and other structures.

Operation

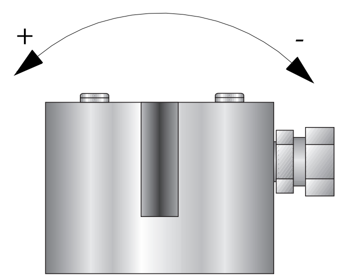
The deep-water tiltmeter consists of an electrolytic tilt sensor housed in a compact, waterproof enclosure.



Top view, looking down at the tiltmeter. Surface with label must be horizontal.

The tiltmeter mounting surface should be horizontal and flat. If the tiltmeter is to be mounted on an inclined surface, a horizontal mounting shelf should be constructed

Two anchors are installed in the structure and the tiltmeter is fastened to the anchors. To ensure that the system is water-tight at high pressure, the tiltmeter has a compression fitting for copper tubing, which must be used as conduit for the signal cable.



Side view. Tiltmeter monitors tilt in the plane of the arrows.

Tilt readings are obtained with a data logger or a portable readout. Readings are in volts and are converted to angles by applying conversion factors. Changes in tilt are found by comparing the current reading to the initial reading.

Installation

Overview

1. Check that required materials are available.
2. Prepare location for tiltmeter.
3. Run cable to tiltmeter location.
4. Install tiltmeter using readout for leveling.
5. Splice cable and seal. Test with readout.

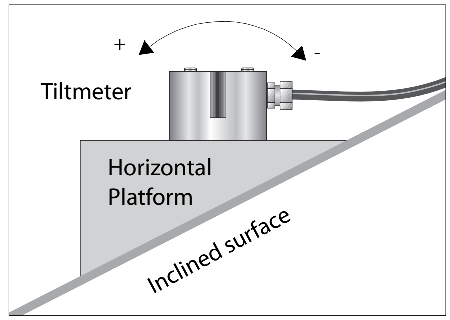
Required Materials

1. Deep-water tiltmeter: The tiltmeter is sealed at the factory and must not be opened. Handle with care
2. Mounting bolts: Two brass mounting bolts are supplied with the tiltmeter. The bolts are 2.5" long with a ¼-20 thread. These are screwed into anchors set into the structure.

   The diameter of the mounting holes is 0.25" or 6.35 mm. If necessary, steel or stainless steel bolts may also be used. Holes are spaced on 3-inch centers.
3. Brass shim stock: Brass shim stock is supplied so that the tiltmeter can be adjusted to perfectly level at installation time.
4. Anchors: These are supplied by the user. Anchors can be brass, steel, or stainless steel.
5. Signal cable: Signal cable is factory-connected to the tiltmeter. A protective, braided hose encases the first 2 meters of cable. The braided hose is terminated in a bulkhead seal and a 1-inch NPT fitting to connect to user-supplied conduit. The bulkhead seal is tested to 2MPa.

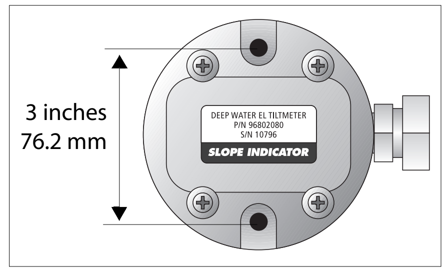
   Slope Indicator specifies shielded cable with seven 22 gauge, tinned copper conductors and a polyurethane jacket. User-supplied cable should meet these specifications.
6. Splice materials: If the full length of signal cable is not ordered with the tiltmeter, the user must splice on the required length of cable. The splice must be waterproof and housed inside protective pipe. The one-inch NPT threads provide a way for the user to connect a housing.
7. Conduit: Signal cable should be protected by water-tight conduit that runs from the tiltmeter to the surface.
8. Readout: A readout is required at installation time to make the tiltmeter perfectly level.

Prepare Surface



1. The tiltmeter must be mounted on a horizontal surface that is level to 1 degree or better.
2. If the structure is inclined, construct a platform that provides a horizontal surface, as shown in the drawing.

Install Anchors



1. Determine the proper orientation for the tiltmeter. See drawing above or introduction.
2. Mark anchor locations. The mounting holes in the tiltmeter body have 3-inch centers (76.2 mm). Check that the spacing of your anchors matches the holes in the tiltmeter.

Run Cable to Tiltmeter

1. Cable must be protected by a waterproof conduit, such as copper tubing. Push cable through the conduit (or slide pipe sections onto the cable). All joints should be water tight.
2. Run the conduit and cable to the location of the tiltmeter.

Install Tiltmeter

1. Bolt the tiltmeter to the anchors, but do not fully tighten. You must use a readout and shim stock to make the tiltmeter perfectly level.
2. Connect a readout or voltmeter to the tiltmeter. See the next chapter, "Manual Readings." for details. When the tiltmeter is perfectly level, the readout will display 0 (zero) volts.
3. Tighten the bolts carefully, adding shim stock as necessary to make the readout show 0 volts.

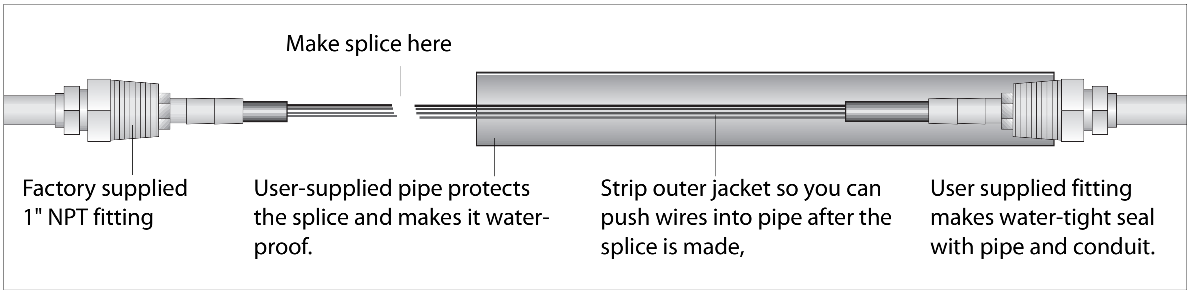
Splice Cable

Signal cable is factory-connected to the tiltmeter. A protective, braided hose encases the first 2 meters of cable. The braided hose is terminated in a bulkhead seal and a 1-inch NPT fitting.

The drawing below shows one way to make a waterproof splice. The idea is to use a pipe to protect and waterproof the splice. Site engineers may specify a different way to accomplish this.

Splice all conductors and the shield wire too. After you make the splice, test it by connecting a readout to the far end of the cable.

If the splice is good, seal both ends of the pipe. You may also fill the pipe with resin for extra waterproofing.



Manual Readings

Reading with the EL Data Recorder

1. Connect tiltmeter to readout as shown below.

Data Recorder Terminals		Factory Supplied Cable	User-Spliced Cable
1	Tilt A	Brown	
2			
3	Temp	Pink	
4	Sig Com	Yellow	
5	Sense	White	
6	+ Power	Green	
7	– Power	Gray	
8	Shield	Drain Wire	

2. Switch on the readout. Choose uniaxial. Tilt is displayed in volts. Temperature is displayed in degrees C.

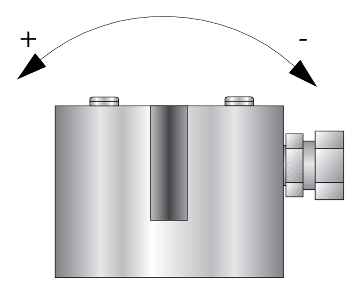
Reading with a Voltmeter

This requires a power source, such as a 9-volt battery, to supply between 5.5 and 15 Vdc to the tiltmeter.

1. Connect green wire to the + terminal of the power source. Connect the white and gray wires to the - terminal of the power source.
2. To read the A-axis sensor, connect the voltmeter to the brown wire and yellow wire.
3. To read the thermistor, connect the voltmeter to the pink and yellow wires.

Test Readings

1. When the sensor body is vertical, you should see a reading of about 0.0 Vdc for either axis of the tiltmeter. The themistor should provide a reading of about 1 Vdc at 25 degrees C.
2. .The tiltmeter monitors tilt in the plane shown in the drawing. The readings should increase to approximately 2 (or -2) volts as the tilt increases to 3 (or -3) degrees.



DataLogging

Requirements

The MonoPod tiltmeter has a built-in 2.5 volt signal conditioning board with inputs and outputs as shown below:

Wire Color	Function	Notes
Green	+ Power	5.5 to 15 Vdc, 6mA max per axis at 12 Vdc
Gray	- Power (Ground)	Power and Analog Ground are tied together at Logger
White	Sense (Analog Ground)	
Yellow	Signal Common (Reference)	Yellow wire is jumpered to logger terminals to provide the - output for differential readings of A tilt and Thermistor
Brown	A Tilt	±2.5Vdc (differential).
Pink	Thermistor	160 to 1820 mV (differential)
Shield		

Wiring Diagrams

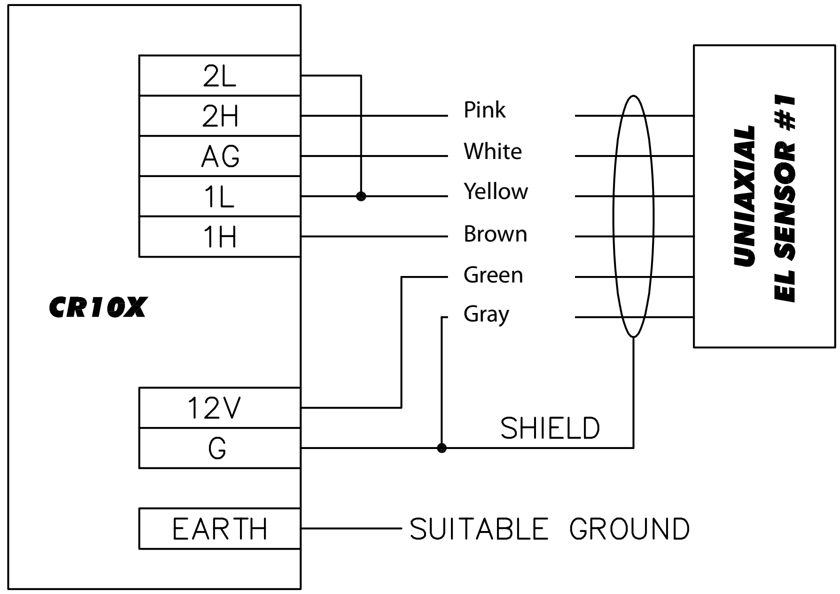
Wiring diagrams on the following pages show how to connect uniaxial and biaxial sensors to the Campbell Scientific CR10X data logger system. The diagrams show how to:

1. Connect a uniaxial sensor directly to CR10.
2. Connect a uniaxial sensor using AM416 multiplexer.

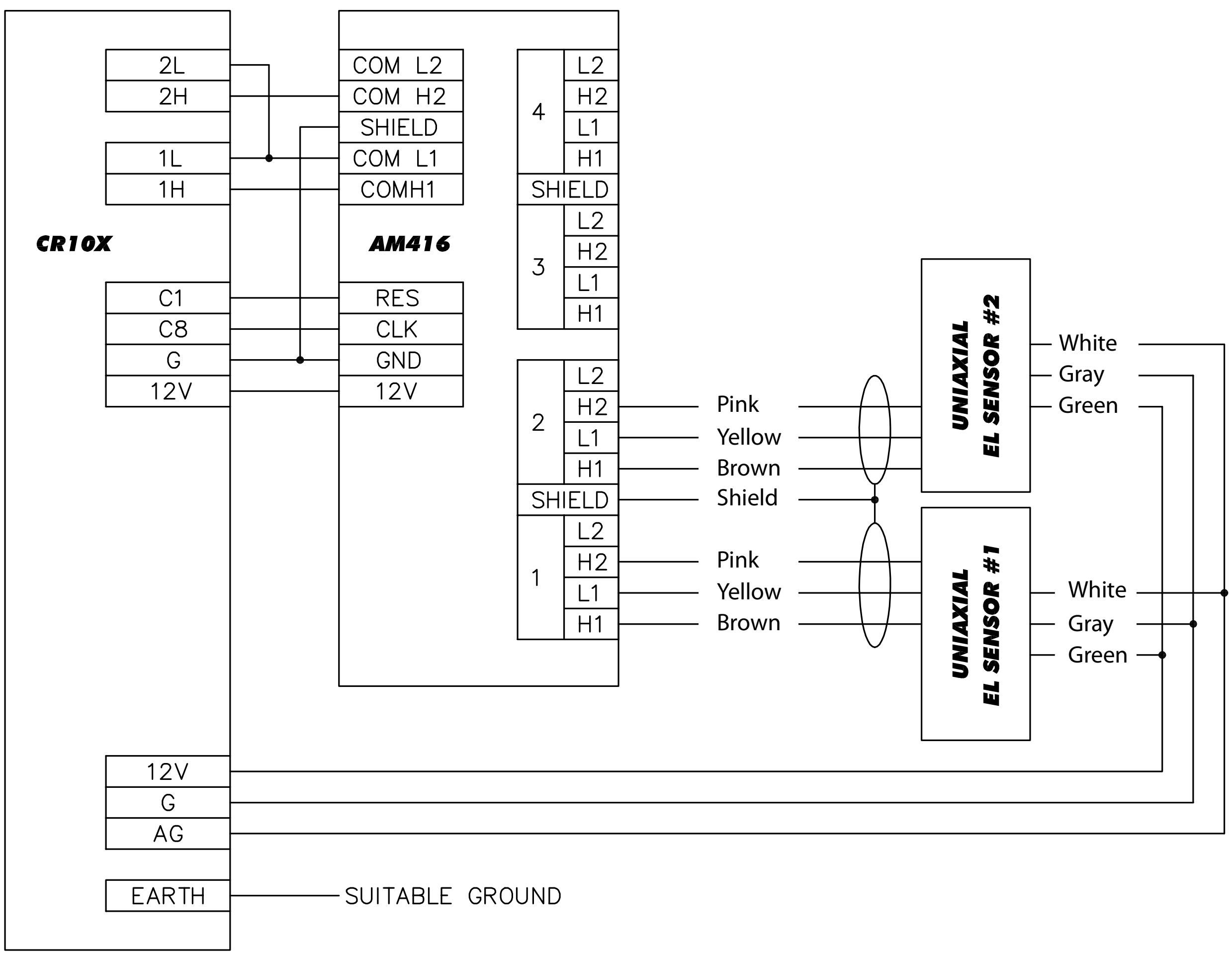
Sample Program

A sample program is available at Slope Indicator's web site. Go to www.slopeindicator.com - support - tech notes. Look at the data logger technotes. You'll see a link for sample programs.

Wiring Diagram 1 Connecting a uniaxial sensor directly to the CR10X:



Wiring Diagram 2 Connecting uniaxial sensors to an AM416 multiplexer:



Data Reduction

Introduction

Data reduction is usually automated because it involves a large number of readings and a large number of calculations.

Here, we explain how to use the sensor calibration record and provide an example of converting a single reading from voltage to minutes of arc.

Calibration Record

A calibration record is provided with each sensor. Note that calibrations are unique for each sensor, so use sensor serial numbers to match sensors with their calibrations.

The sensor calibration record a number of factors. These are explained below. The table at right shows example factors, taken from the calibration record of sensor with serial number 12364. Your sensors will have different factors.

C0	0.78367
C1	80.7737
C2	0.0731179
C3	1.712229
C4	-0.0171356
C5	0.0486938
S0	0.9998561
S1	0.0001133
S2	0.0000016
F0	-0.0036374
F1	0.0026318
F2	0.0001380
Toffset	0.63
Tnom	12

C0 to C5: Use these factors to convert a reading in volts to minutes of arc.

S0 to S2: Use these factors to adjust the mm/m value above for temperature-related changes in sensor sensitivity.

F0 to F2: Use these factors to adjust the mm/meter value for temperature-related changes in the offset of the sensor.

Toffset: Use this factor in the equation to convert a thermistor reading in volts to degrees C.

Tnom: Tnom is normally 12 degrees C.

Applying Calibration Factors

Suppose you obtain a reading of 0.6694 volts from sensor number 12364. How do you convert the voltage reading to tilt in minutes of arc?

Converting sensor reading to mm per meter

Apply the C factors to the voltage reading as shown below. C0 through C5 are factors listed on the calibration sheet for sensor 12364. EL Reading is the reading in volts raised to a particular power. For example, C2 factor is multiplied by the EL reading raised to the power of 2 and the result appears in the Value column.

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

	C Factor	EL Reading	Value
C0	0.78367		0.78367
C1	80.7737	0.6694	54.06991
C2	0.0731179	0.6694^2	0.03276
C3	1.712229	0.6694^3	0.51359
C4	-0.0171356	0.6694^4	-0.00344
C5	0.0486938	0.6694^5	0.00654
		minutes of arc =	55.40303

Temperature Readings

The CR10 delivers thermistor readings in volts. The equation below shows how to convert the volt reading to degrees C.

ET is the volt reading. Toffset appears on the sensor calibration sheet.

$$DegC = (9.3219 \times ET^5) + (-54.3038 \times ET^4) + (131.165 \times ET^3) + (-161.2568 \times ET^2) + (137.7711 \times ET) + (-37.7705) - Toffset$$

Correcting for Temperature

Changes in temperature affect both the sensitivity and the offset of the sensor. In the instructions below, the sensitivity temperature correction is called SENSTC. The offset temperature correction is called OFFSTC.

1. Find the change in temperature from Tnom, which is a value on the sensor calibration sheet.

   DeltaT = DegC - Tnom

   Suppose DegC is 15 °C. Tnom on the calibration sheet is 12 °C, so DeltaT, the change in temperature, is 3 °C.

2. Calculate the sensitivity correction:

   SENSTC = S2•DeltaT^2 + S1•DeltaT + S0

	S Factor	DeltaT	Value
S0	0.9998561		0.9998561
S1	0.0001133	3	0.0003399
S2	-0.0000016	3^2	-0.0000144
		SENSTC =	1.0001816

3. Calculate the offset correction:

   OFFSTC = F2•DeltaT^2 + F1•DeltaT + F0

	F Factor	DeltaT	Value
F0	-0.0036374		-0.0036374
F1	0.0026318	3	0.078954
F2	0.0001380	3^2	0.001242
		OFFSTC =	0.0765586

4. Apply the corrections:

   corrected value = (minutes of arc • SENSTC) + OFFSTC
   = (55.40303 • 1.0001816) + 0.0765586
   = 55.4896497902