GEOKON

The World Leader in Vibrating Wire Technology

48 Spencer Street
Lebanon, NH 03766, USA
Tel: 603•448•1562
Fax: 603•448•3216
E-mail: geokon@geokon.com
http://www.geokon.com

Instruction Manual

Model 6201

Portable Tiltmeter

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1. Specifications

Range	±30°
Displayed Output at 30 degrees tilt	±10,000 digits, (20,000 sinθ).
Resolution	±10 sec arc
Accuracy	±0.02% F.S.
Scale Factor Thermal Sensitivity	±0.002% F.S./°C
Temperature Range, Operating	0 to 50°C
Temperature Range, Storage	–25 to +70°C
Shock Survival	1000g 0.011 sec 1/2 sine
Dimensions	*Sensor*: 6.5 x 3.5 x 5.75 in. (140 x 60 x 230mm) *Case:* 13 x 13.9 x 5.75 in. (330 x 350 x 146)
Weight	*Sensor:* 6.1lbs. (2.7KG) *Case:* 4.3lbs. (2.0KG)

2. Introduction

The Geokon Model 6201 Tiltmeter is a precise, portable instrument designed to make rapid determinations of tilt in the monitoring of structures and soil and rock masses.

It has applications in landslide monitoring, subsidence adjacent to excavations, tilting in buildings, retaining walls, bridge abutments, dams, etc.

2.1 Description

The tiltmeter system usually consists of three main components. They are the tiltmeter, the readout system and the tilt plate.

Tilt plates are designed to be permanently attached to the structure, either by epoxy bonding (ceramic plates) or bolting (brass plates).

The sensing element of the tiltmeter is a high accuracy servo-accelerometer sealed in a waterproof housing.

The sensor is aligned on the tiltplate for measurements with alignment bars so that the same position and orientation is guaranteed for every reading.

The output of the Geokon Model 6201 tiltmeter is equal to 5 volts at 30°. When used with a GK-603, GK-651 or GK-652 readout box, the display will be 20,000 sin θ such that at 30° the readout box will display ±10,000 (the exception to this is when the GK-652 readout box is set to a resolution of 1 second when the displayed output is 200,000 sin θ). (If a GK-603 readout box is being used, make sure that in the “Configure Probe” screen the units are set to 2.0 sin θ and not 2.5 sin θ). (2.5 sinθ is reserved for Sinco type sensors with an output of 25,000sinθ).

The polarity of the tiltmeter is set such that if tilted downward in the positive (+) direction the output will increase positively. See Figure 1and Figure 2.

3. Installation

Portable tiltmeters must be manually read so the location of the tiltmeter plate must be both protected and accessible. Covers are available for installations in areas where heavy construction is ongoing or where vandalism may be a problem.

The tiltplates should be installed on firm, clean surfaces as close to flat as is possible. Most installations utilize epoxy as the body-bonding medium. A resin such as Devcon VW 11800 can be used. The epoxy should be allowed to fully cure before readings commence.

For vertical installations such as building walls, bridge abutments, etc., the tilt plate pegs must be aligned as close to vertical as possible with Peg #1 at the top.

For Horizontal installations point the Peg #1 in the same direction as the expected tilt

4. Taking Readings

Connect the sensor to the readout and check to see that the system is operating. Clean all dirt from both the sensor and the tiltplate. It is a good idea to let the sensor warm up for 2-3 minutes before taking readings.

The tiltplate that is being observed should have an I.D. number written on it

Some tiltplates are numbered 1 to 4 counter-clockwise and others **clockwise**. In the following the number in **bold** pertains to the **clockwise** numbering

When taking readings in the **vertical plane** first hold the + end of the tiltmeter so that the long bar lies to the left of pegs 1 and 3 and the short bar lies on top of peg 4,(**2**). Now take the first reading. Turn the tiltmeter end for end and position the long bar to the right of pins 1 and 3 with the short bar resting on top of peg 2(**4**). Now take the second reading. The second reading is the reverse (180°) of the first reading. This procedure eliminates any zero offset in the sensor. See Figure 2 for the positioning of the bars relative to the pegs.

When taking readings in the **horizontal plane** the tilt can be measured in two orthogonal directions. First hold the + end of the tiltmeter over peg 1, so that the long bar on the underside of the tiltmeter lies to the left of pegs 1 and 3 and the short bar lies against peg 4(**2**), as shown in figure 1 Now take the first reading. Turn the tiltmeter end for end so that the + end of the tiltmeter is over peg 3 and position the long bar to the right of pins 1 and 3 with the short bar resting against peg 2(**4**), as shown in figure 1. Now take the second reading. The second reading is the reverse (180°) of the first reading. This procedure eliminates any zero offset in the sensor.

Repeat the procedure for pegs 2 and 4 referring to figure 1 for the positioning of the long and short bars on the underside of the tiltmeter. Begin with the plus end of the tiltmeter over peg 4.

Note: Care should be taken to avoid nicking or cracking the ceramic surface of the tiltplate pegs. The ceramic material is very brittle.

5. Data Recording and Reduction

The data should be recorded on field sheets that have columns for the readings as in Figure 3. Position the tiltmeter such that the + is over peg 1. Record this number in the column labeled Peg 1. Rotate the unit 180° placing the plus (+) end over Peg 3. Record this data in the column headed Peg 3.

Repeat the above for column pegs 2 and 4, always locating the plus (+) end of the sensor over the respective peg.

Note: *It is advisable to take the pairs of readings, one immediately after the other, to avoid the effects of temperature drift, etc.*

When recording the Readout Box output it is not necessary to record the actual numbers; ignore the decimal point, only the significant digits need to be recorded; i.e., + .0123 would be + 123.

The difference column is the algebraic difference between the readings, i.e., (Peg 1) – (Peg 3).

Example: of readings from a vertical tiltplate

Peg 1 reading = 82 and Peg 3 reading = –99

DIFF = (82) – (–99) = +181

The conversion of this difference to degrees of angle is done as follows:

Reading with either the Geokon GK601 or GK 603 readouts

$$\theta \text{ degrees} = \sin^{-1} \frac{DIFF}{4} \times 10^{-4}$$

The tilt can be expressed also as a tilt in mm/meter or inches per foot as follows.

Tilt = 0.0003 x DIFF inches per foot, or

Tilt = 0.025 x DIFF mm/meter

The change column is determined by subtracting the initial DIFF from the current DIFF algebraically.

Example of readings taken from a horizontal tiltplate

Four readings are taken; two each for Pin 1 and 3 and two each from Pins 2 and 4, following the instructions of Section 4.

Reading Peg 1 to 3	+0.0025
Reading Peg 3 to 1	–0.0078
Reading Peg 2 to 4	–0.0063
Reading Pin 4 to 2	+0.0011

Peg 1 and 3. Tilt in this direction is given by the difference +25 – (–78) = +103

Peg 2 and 4. Tilt in this direction is given by the difference –63 – (+11) = –74

Note that the tilt is towards Peg 1 and towards Peg 4. (A positive figure for both the differences means that the tilt is towards Pin 1 and Pin 2.)

The magnitude of the tilt can be calculated in degrees from the formula:

$$\theta \text{ degrees} = \sin^{-1} \frac{DIFF}{4} \times 10^{-4}$$ for all Geokon tiltmeters and Sinco English tiltmeters

or, in mm/m, or thousands of inches/inch **tilt = DIFF/40**

[or θ degrees $= \sin^{-1} \frac{DIFF}{5} \times 10^{-4}$ for Sinco **metric** tiltmeters only.]

[or, in mm/m, or thousands of inches/inch tilt= DIFF/50]

Assuming that the present example is from a Geokon metric tiltmeter:

The tilt in the Peg 1 direction is $\sin^{-1} \frac{103}{4} \times 10^{-4} = 0.148° = 2.58$mm/m

The tilt in the Peg 4 direction is $\sin^{-1} \frac{74}{4} \times 10^{-4} = 0.106° = 1.85$mm/m

These two tilts can be combined, to give the maximum resultant tilt and its direction. This is done by first calculating the angle of the combined or resultant tilt from the formula

$$\text{Tan } \theta_R = \sqrt{(\text{Tan } \theta_1)^2 + (\text{Tan } \theta_2)^2}$$

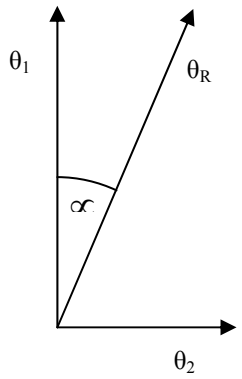
Where θ_1 = The tilt angle across Pegs 1 and 3, and θ_2 = the tilt angle across pegs 2 and 4.

In the present example $\text{Tan } \theta_R = \sqrt{0.002583^2 + 0.00185^2} = 0.003177$

And the tilt $\theta_R = 0.182°$

Or 3.177 mm/m

And the direction to θ_R is given by:



$\propto = \cos^{-1} (\text{Tan } \theta_1 / \text{Tan} \theta_R) = \cos^{-1} (0.002583/0.003177)$

In the present example = 35.6° clockwise from the Peg 1 direction

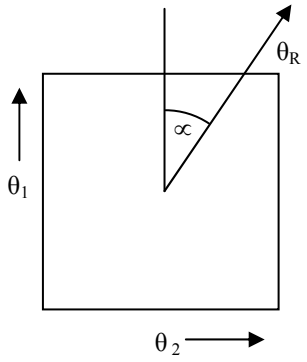
Vertical Tiltplates

If the readings are taken on vertically mounted tiltplates, then in order to get the magnitude and direction of the maximum tilt, it is necessary to have two vertically mounted tiltplates oriented at 90° to each other, e.g., mounted on adjacent faces of a square column.

θ_1 is the tilt measured on one face

θ_2 is the tilt measured on the other face

Again $\text{Tan } \theta_R = \sqrt{(\text{Tan } \theta_1)^2 + (\text{Tan } \theta_2)^2}$



And $\propto = \cos^{-1} (\text{Tan } \theta_1 / \text{Tan} \theta_R)$

(***Note:*** the offset of the tiltmeter is given by the *summation* of the two readings on Pegs 1 and 3 and again by the two readings on Pegs 2 and 4.

Thus… from Pegs 1 and 3 offset is +25 + (–78) = –53/2 = –26.5

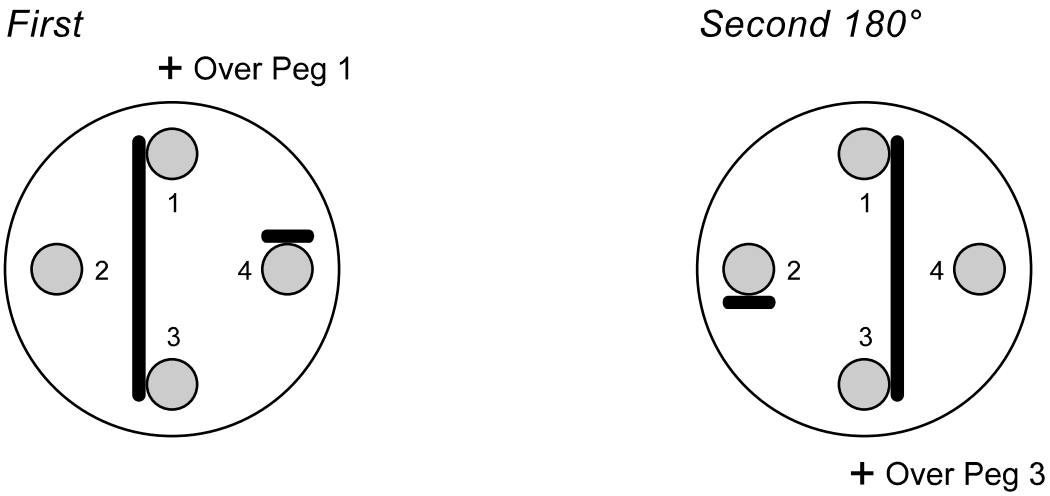
from Pegs 2 and 4 offset is –63 + (+11) = –52/2 = –26.0

The difference of 1 digit is due to the normal lack of precision inherent in the measurement. This tiltmeter offset should remain constant.)

6. Troubleshooting

The main concerns of tiltmeter surveys are the measurement of change in magnitude and direction of rotational movement. The zero offset of the sensor is not critical because the algebraic difference of the two readings eliminates the effect. A tiltplate tilted at an angle and located on a stable surface can be read periodically to check the calibration of the instrument. The sensor itself should not be opened in the field and if the unit fails to work it should be returned to Geokon for repair.

Tiltmeter Orientation When Measuring in 1 - 3 Direction



Tiltmeter Orientation When Measuring in 2 - 4 Direction

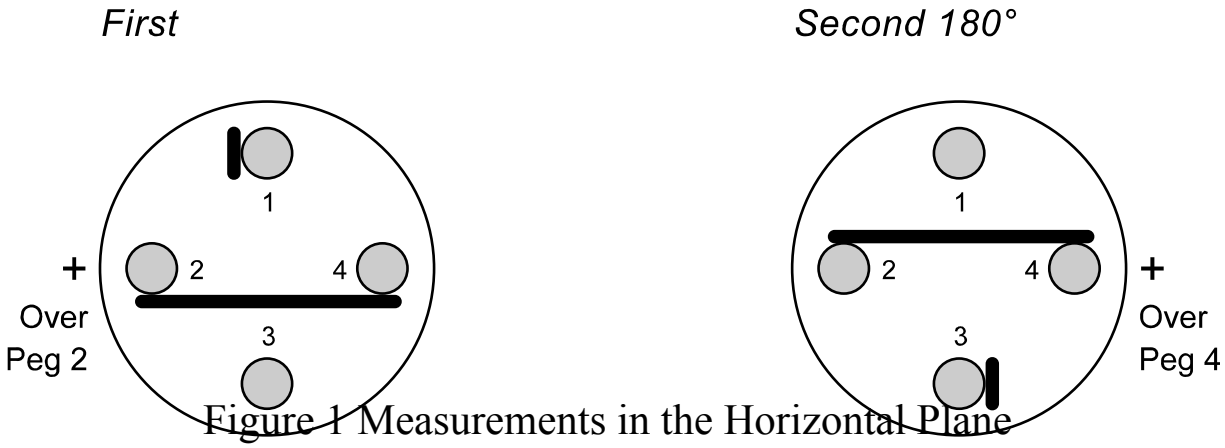
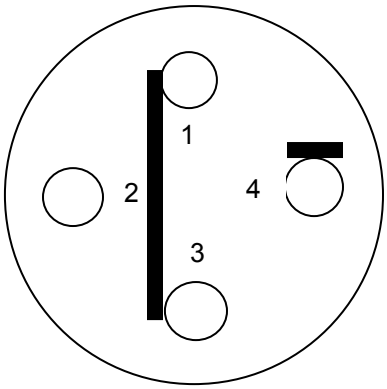
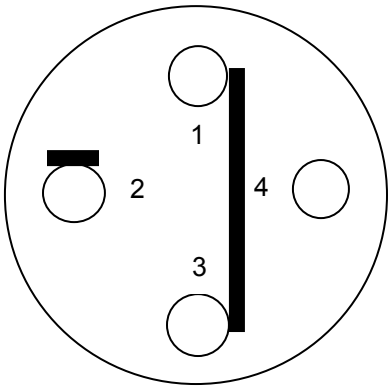


Figure 1 Measurements in the Horizontal Plane



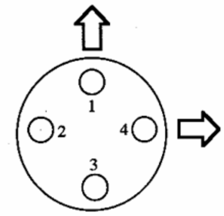


+ Plus End **– Minus End**

Figure 2 Measurements in the Vertical Plane

(Note some tilt plates have their numbers running clockwise instead of counter-clockwise. In these cases Pegs 1 and 3 remain the same but pegs 2 and 4 are reversed.)

Tiltmeter Data Sheet



Instrument S/N ____________________ Readout Type ___________ S/N ____________

Tilt Plate Number ______________________

Location ____

Date	Time	Temp	Direction ______________				Direction ______________			
			Peg 1	Peg 3	Diff	Change	Peg 4	Peg 2	Diff	Change

Note: + Sign in the **Diff** and **Change** columns indicates tilt in the direction shown by arrows at top of page.

Figure 3 Tiltmeter Data Sheet