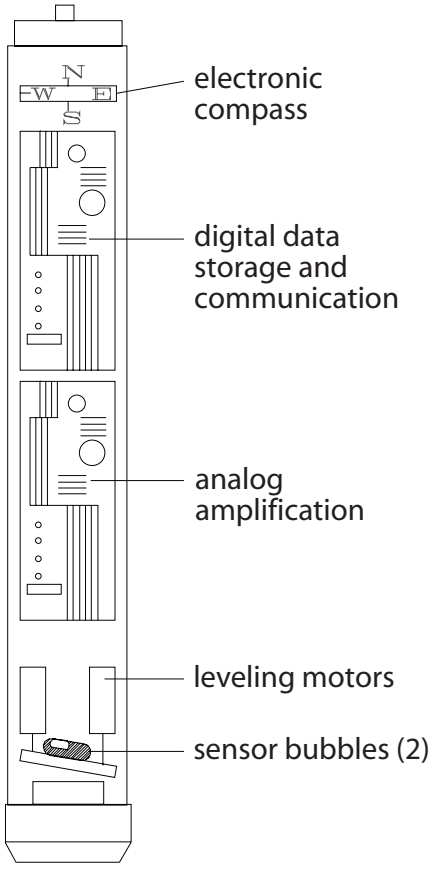
Series 5000 Tiltmeter

GET RESULTS

- Accurate and robust measurements
- R&D 100 Award-winning design
- Simple installation and automatic leveling



Pinnacle Technologies Series 5000 Tiltmeter Schematic

Pinnacle's advanced series 5000 Tiltmeter is designed to provide high precision tilt data from an easy to use device in a rugged, field-ready package.

Pinnacle tiltmeters operate on the same principle as a carpenter's level. At the core of each tiltmeter is a pair of orthogonal bubble levels with a precise curvature. Electrodes detect minute movements of the air bubble within a conductive fluid as the fluid seeks the lowest spot in the sensor. The series 5000 tiltmeter can resolve tilt as little as one billionth of a radian (or 0.00000005 degrees).

Custom designed electronics measure and amplify the tilt from the two sensors. Pinnacle's unique analog electronics are specially designed to achieve very low noise levels and low power consumption. The analog electronics have 4 gain levels which can be changed remotely for mapping tilt signals of a wide range of magnitudes. The operating range of the tiltmeter electronics is from -40°C to 85°C (-40°F to 185°F). Optional electronics are available which extend the upper temperature limit to 125°C (260°F).

Pinnacle designed custom digital tiltmeter electronics in a cooperative project with Lawrence Livermore National Laboratories. Most sensing devices in use today send analog signals up a cable to the recording device, incurring signal losses and adding noise along the way. Pinnacle placed high precision 24 bit A/D converters adjacent to the analog amplifiers. Purely digital communication ensures no noise is added during transmission to the surface.

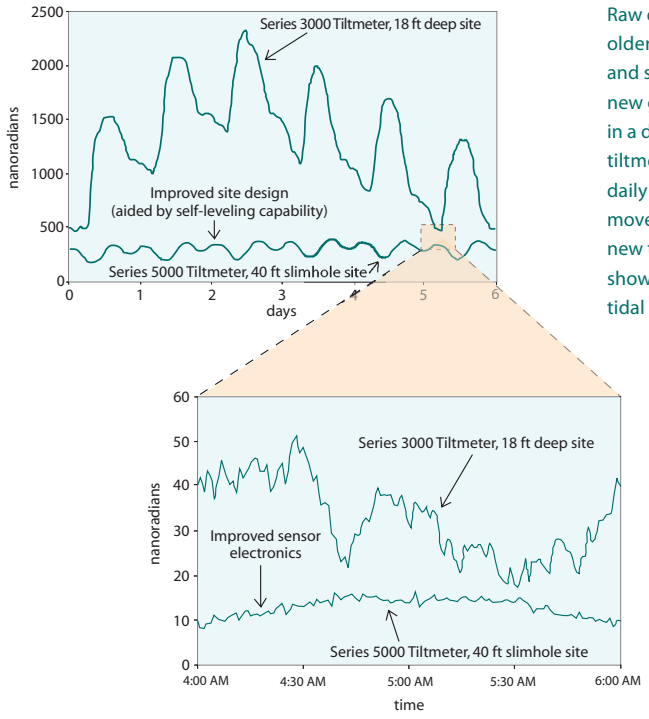
Conventional high gain tiltmeters can be difficult to install. Since any high gain sensor has a limited range, the sensor plate must be very close to perfectly horizontal to map an event. Getting the sensors level is normally accomplished by gently tapping the ground on one side of the tool, which gets awkward and requires a large diameter hole for sites deep below the surface. Since it is desirable to install tiltmeters at least 3 m and up to 12 m (10-40 ft) below the surface to achieve low background noise levels required for detecting small movements, the limited range of conventional tiltmeters paradoxically also limits their sensitivity. Pinnacle's series 5000 tiltmeters are equipped with an on-board digital processor and automatic leveling mechanism to allow simple installation in deep, narrow boreholes. Once in place, motors automatically bring the two sensors very close to level, and will continue to keep the sensors in their operating range even if large disturbances move the instrument.

Besides tilt, the tiltmeter internally records relevant information such as location, orientation, supply voltage, and sensor temperature. A solid state magnetic compass provides the tool orientation so tilt direction can be determined. On-board looped memory provides up to 8 months of data storage which is easily uploaded via a serial port connection at the surface, a direct cable connection to another computer (optional communication protocols are available to support communication through up to 8,000 m (25,000 ft) of cable), radio links, or a cell phone interface. The 5000 tiltmeter can be programmed to cycle

Pinnacle Technologies Series 5000 Tiltmeter Specifications

Specification	Value
Tilt Resolution at sensor	1 nR
Range	±10 degrees from vertical
Gain (Max)	1000 mV/uR
Gain Levels	4
Leveling Ability	Self Leveling
Data Storage	
(30 sec. sample rate)	30 Days*
Data Storage Type	Internal A/D & storage
A/D Resolution	24 bits
Data Collection Rate	38,400 Baud
Orientation	Int. magnetic compass (±2°)
Installation Depth	Unlimited (typically 3–12 m
Borehole Diameter	Min 7 cm
Dimensions	6.4 cm dia x 107 cm
Operating Range	-40 °C to 85 °C**
Mass	4 kg
Avg. Power Consumption	280 mW

* Internal memory stores 88,000 data points. Sampling rate can vary from 1 sec to 4 minutes.
** 125°C version available



Raw data from a typical older generation tiltmeter and site compared to a new generation tiltmeter in a deeper site. The older tiltmeter shows large daily thermal-induced movements where the new tiltmeter clearly shows twice daily earth tidal responses.

power to a radio or cell phone device on a daily schedule to conserve battery power. Memory is retained in the event power to the tool is lost.

The exterior of Pinnacle's series 5000 tiltmeter is an aluminum cylinder roughly 107 cm (42 in.) long and 7 cm (2.5 in.) in diameter. Although not designed for underwater use, o-ring seals protect the internal components from splash and dust intrusion. Other casing materials are available for use in corrosive environments. The tiltmeter is powered by a small battery and solar panel combination at the surface.

The figure on this page shows the improvement in background noise using a series 5000 tiltmeter in a new design site versus an older series 3000 tiltmeter in an old design site. The first plot shows six days of raw background tilt data. The old site shows large (about 1000 nanoradian) daily swings resulting from near-surface thermal strains. Note the steep rise in the data when the sun rises in the morning and the rapid decline with the sunset. This level of background motion is insignificant when mapping a shallow fracture treatment, but becomes very significant when the fracture-induced surface tilts are only a few nanoradians. The raw data from the series 5000 tiltmeter over the same six-day period shows only the very smooth (and predictable) background of earth tides that swing roughly 100 nanoradians twice per 24-hour period.

Finally, cost reductions in both the tool and the site construction allow the use of more tiltmeters in each array, which significantly enhances the resolution of ground movement. As a result of these modifications, Pinnacle was awarded an R & D 100 Award in 1997 for the design of the series 5000 tiltmeter. More importantly, we've gained the ability to peer deeper and more clearly into the earth. Please contact us to learn how Pinnacle's award-winning diagnostics can help you.

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