

## A Simple Tiltmeter

Differential capacitance measurement on a bubble level measures angular orientation.

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A simple tiltmeter indicates angular orientation to within 0.05 second of arc. Its sensor is a modified spirit level (or bubble level) such as those used on surveyor's transits.

As shown in Figure 1, the vial of the level is covered by aluminum-foil electrodes. One electrode is a reference electrode, covering all of the outside of the vial except the surface over the path of the bubble. The other two electrodes, located symmetrically on either side of the center position for the bubble, are as long and wide as the bubble.

An electrical indication of the bubble position is obtained by a differential measurement of the capacitances between each sensing electrode and the reference electrode. The liquid in the vial has a dielectric constant of about 80, while the bubble volume has a dielectric constant of 1; the difference in dielectric constant in between the sensing electrodes and the reference produces the changes in differential capacitance.

The measuring circuit for the tiltmeter (see Figure 2) uses a 300-kHz oscillator to excite a diode bridge, which produces a voltage output that depends on the difference in capacitances appearing at either side of the bridge. The circuit has a full-scale output of  $\pm 0.7$  volt, with stable resolution of 1 millivolt. Measurement resolution is determined by the vial geometry; a level vial with 2 mm deflection for a tilt of 5 arc-seconds easily resolves 0.05 arc-second.

The tiltmeter was developed for an experiment on forecasting seismic events by changes in Earth's magnetic field. A shift in the orientation of the magnetic sensors — caused by settling of the ground, for instance — could produce erroneous signals on the order of those expected from impending seismic activity. In this application a tilt resolution of 0.4 arc-second is adequate, so the higher precision of commercial tiltmeters is not required.

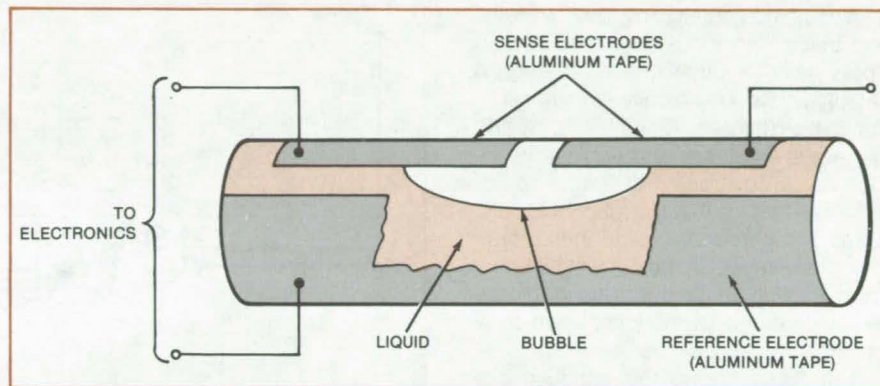


Figure 1. A **Bubble Vial** with external aluminum-foil electrodes is the sensing element for a simple indicating tiltmeter. To measure bubble displacement, a bridge circuit detects the difference in capacitance between the two sensing electrodes and the reference electrode.

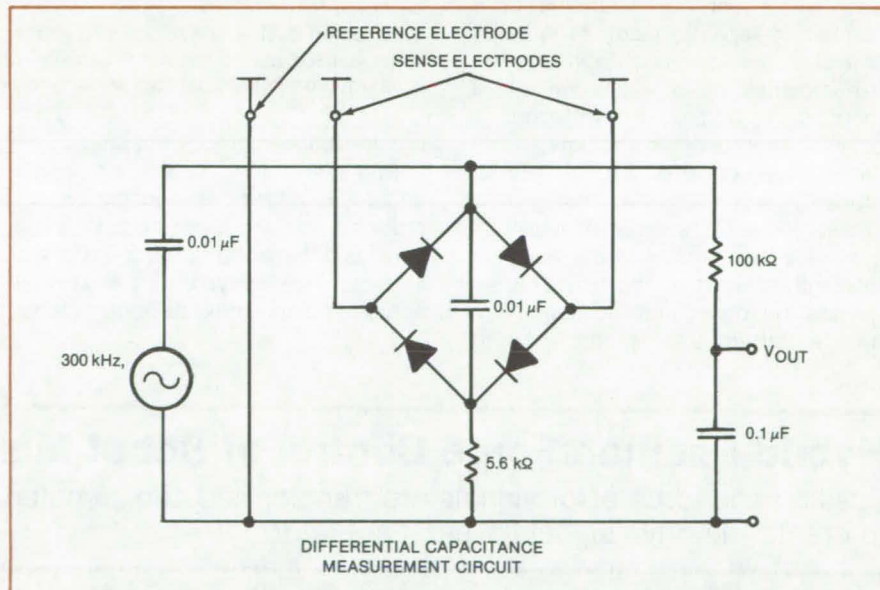


Figure 2. Using this **Differential Capacitance Measurement Circuit**, a tiltmeter level vial with 2 mm deflection for 5 arc-seconds of tilt easily resolves 0.05 arc-second. The four diodes are CA3039, or equivalent.

This work was done by Michael G. Dix, Dean R. Harrison, and Thomas M. Edwards of **Ames Research Center**. For further information, Circle 47 on the TSP Request Card.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page A5]. Refer to ARC-11344.