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Technical Report
January, 2010 MEMS Accelerometer Accuracy Testing

ABSTRACT: Determine the accuracy of the MEMS accelerometer based level against manufacturer's published specifications.

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Extensive testing of our own SmartTool and all competitive products we can procure has proven that all digital levels are not equal. Internal testing has repeatedly shown that "specsmanship" is widespread in the digital level market as with many technical products. End users are at the disadvantage of not knowing whether their digital level is within specification or not. Products tested often read within specification at 0 degrees or 90 degrees but do not meet specification at other angles. Some products do not meet stated specification at even 0 or 90 degrees. Without the proper test equipment, the end user cannot know that their level is reading falsely.

The MEMS accelerometer based product in this test report is a four foot level with digital display. The published specification for the level is between +1 degree and -1 degree/89 degrees to 90 degrees accuracy is + or - .05 degrees. All other angles are + or - .1 degree.

The temperature specification is between 0 degrees and 50 degrees C (32 and 122 degrees F).

Initial Calibration

Two AA batteries were installed into the MEMS accelerometer level and the unit was calibrated. The calibration instructions are intended to be two steps but there is some confusion on how to follow them. For example, after performing the first calibration step the calibration procedure states to "rotate the level end to end". It is confusing as to whether this means to keep the base of the level on the flat surface and swap the ends around -or- whether it means to rotate the level end for end until the top is now resting on the flat surface. As it turns out, it means to swap the unit end for end while keeping it flat on a surface, not rotating the unit end for end as the procedure states.

At either event, only one way can be the proper way to calibrate the MEMS accelerometer level and this level allows the user to calibrate in either method. As a matter of fact, the MEMS accelerometer level will even allow calibration if the user positions the MEMS accelerometer level in a plumb position for the second calibration step. This will make the plumb position display 45° instead of 90° but the point being, the MEMS accelerometer level should not allow improper calibration methods and it does allow them. This is an obvious flaw in the product.

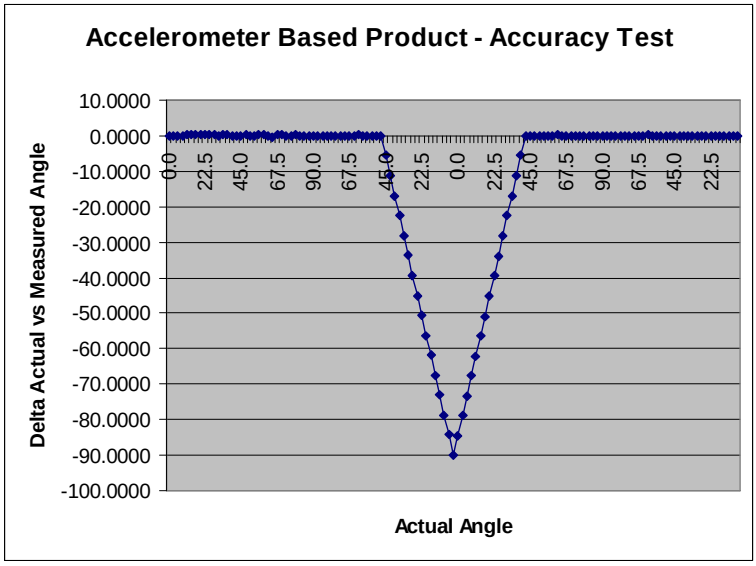
When the level was placed upside down, rather than reading 0º as it should, it read 90º.

Believing this to be an isolated case of a bad level, another product was purchased at a different store, calibrated and set up beside the SmartTool Builder's Angle Finder. The second level, right out of the box, displays the same erroneous reading with the device lying on its top measuring a 180° angle. This is an obvious flaw in this MEMS accelerometer based level.

Accuracy Testing at Ambient Temperature

The unit was placed onto the rotary table of the Environmental Chamber and rotated from a level or flat position through 360° in 2.8125° increments. The measured values were recorded into a spreadsheet and compared to the actual angles. The difference between the two angles were plotted and graphed in the same chart.

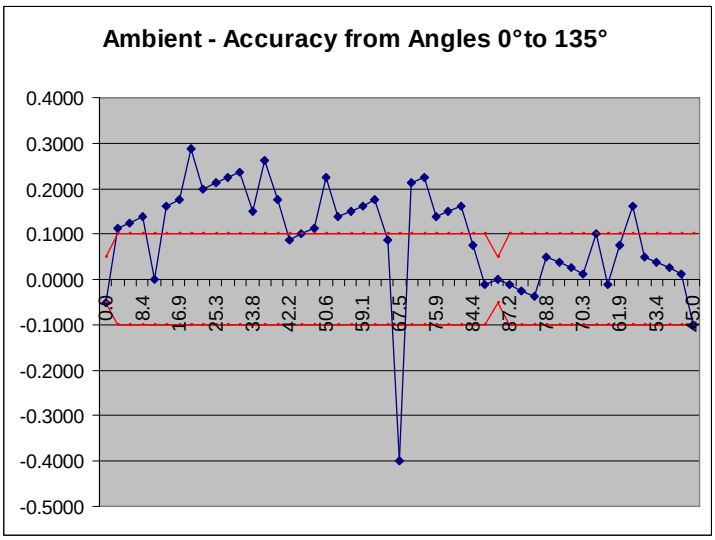
Figure 3: Delta of the Measured Angle vs the Actual Angle for the MEMS accelerometer Level



It is apparent the MEMS accelerometer level fails the accuracy test at ambient temperature. On both levels, from 135° to 225° which equate to 45° angles, the modules roughly tracks the actual angle. However, as one continues approaching 180° the displayed reading instead of approaching 0°, as should be the case, continues towards 90°. With the unit, upside down or positioned in a 180° position the display should show 0.00°. The unit instead displays 90°. This is the third major flaw within the MEMS accelerometer level.

If the area which failed so badly were disregarded and only at the rest of the measurements were graphed, then would the unit meet spec? It is possible to zoom in on the graph and look at the angles 0.00° to 135° where it seemed to track properly and determine just how well the unit performed in that area.

Figure 4: Zooming in on area between Angles 0° and 135°

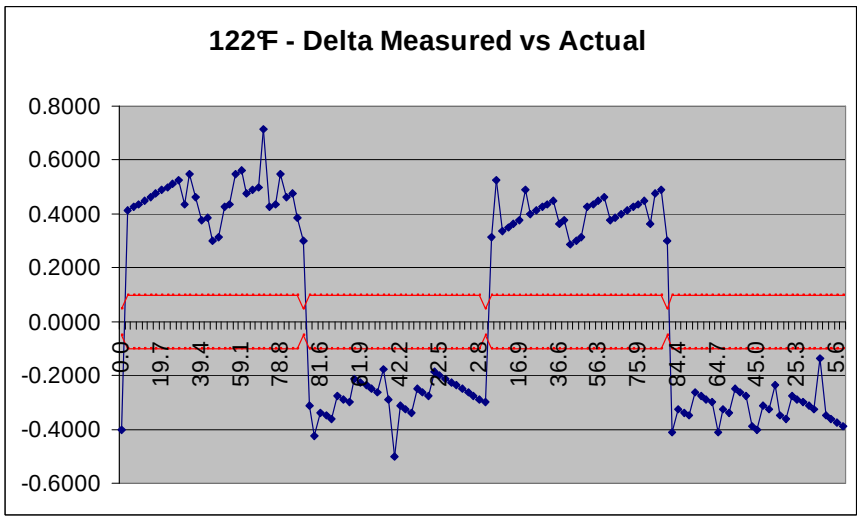


The red-lines indicate the published upper and lower accuracy specifications.

Accuracy Testing at Elevated Temperature

The test was repeated in the environmental chamber at an elevated temperature of 120°F. The published working specification for the MEMS accelerometer level is 122°F/50°C. The unit was rotated through 360° with 128 readings taken. The differences between measured readings compared to the actual readings were plotted. The published accuracy specifications are shown in red.

Figure 5: 120° F – Delta between Measured Angles vs Actual Angles



An interesting observation; during elevated temperature testing the MEMS accelerometer level tracked the angle properly. Though the MEMS accelerometer level was dramatically out of specification it tracked properly from 135° to 225° angles. Refer to Figure 3 for how the MEMS accelerometer level tracked at ambient.

As the MEMS accelerometer level cooled down to ambient it again displayed incorrectly at 180° as shown previously in Figure 2. To confirm this, the second MEMS accelerometer level was placed in an oven in an upside down position. The oven temperature was 140°F. The display on the MEMS accelerometer level should have read 0.00° in the inverted position and instead read 89.95°. After only a few minutes the display corrected itself and displayed 0.10°. The MEMS accelerometer level was immediately removed and placed on a level surface. A fan was placed to blow on the MEMS accelerometer level to cool it down. As the temperature approached ambient temperature of 74°F the display began to flash between 0.05° and 89.95°. As the MEMS accelerometer level cooled more it displayed 89.95° constantly. This is an unacceptable and significant error.

The same error is seen in cooler temperatures. The anomaly of not tracking between 135° to 225° would seem to be prevalent within the temperature range of approximately 64°F and 84°F. At temperatures below 64°F and above 84°F the MEMS accelerometer level tracks roughly as it should though not accurately.

Accuracy Testing at Reduced temperature

The test was repeated again in the environmental chamber at a reduced temperature of 32°F. The published working specification for the MEMS accelerometer level is 32°F/0°C. The unit was rotated through 360° with 128 readings taken. The difference between the measured readings were compared to the actual readings and plotted. The published accuracy specifications are shown in red on the graph.

Figure 10: 32° F – Delta between Measured Angles vs Actual Angles

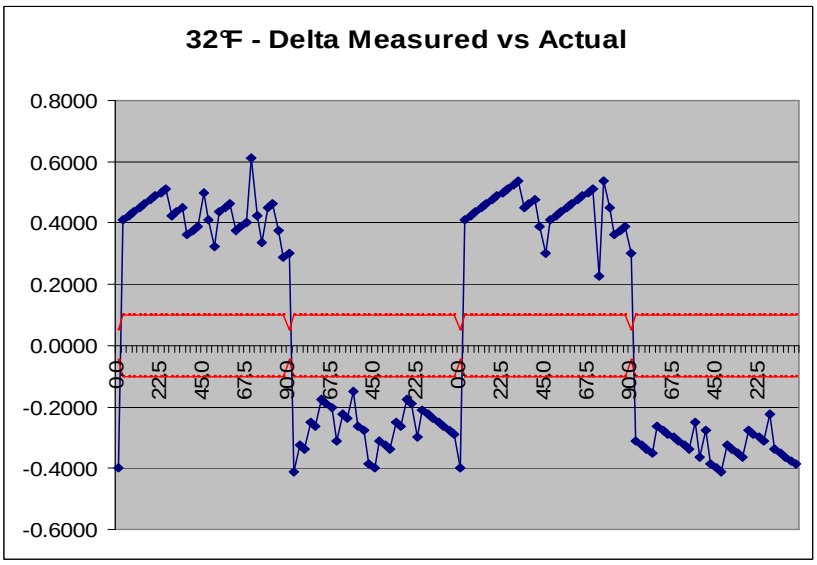
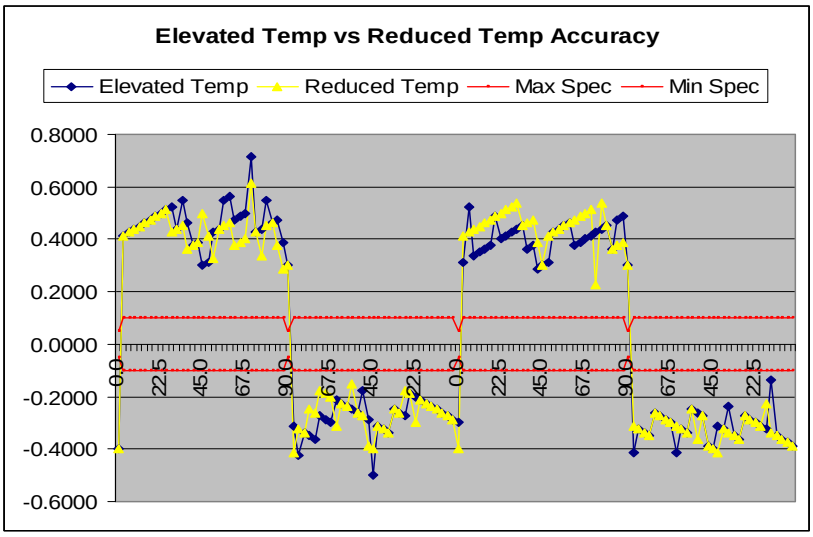


Figure 11: Comparison of Elevated Temperature to Reduced Temperature



Conclusions

The MEMS accelerometer level has some major flaws.

1. The calibration for the MEMS accelerometer level is confusing.
2. The MEMS accelerometer level does not prevent the user from improper calibration. I.e. does not help the user if the procedure is not being followed properly. Instead the unit allows the user to calibrate improperly which results in erroneous angle readings.
3. A calibrated MEMS accelerometer level displays erroneous readings between 135° and 225°, with the greatest error displayed at 180°. These erroneous readings manifest themselves within a temperature range of approximately 64°F to 84°F.
4. The unit is significantly out of specification at most all angles at ambient temperatures.
5. The accuracy of the product worsens with elevated temperature and reduced temperature.
6. Two separate units being purchased from two separate stores may be an indication of a poor quality control system.