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APPLICATION NOTE

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Temperature Compensation Techniques for Low *g* iMEMS® Accelerometers

by Harvey Weinberg

Introduction

Analog Devices' iMEMS accelerometers' ability to sense static acceleration make them uniquely suited for high performance tilt measurement systems. However, the 0 *g* stability over temperature performance of these sensors may, initially, lead one to believe that they would be unusable over wide temperature ranges. This application note describes several techniques to compensate for 0 *g* drift over temperature.

Analyze the Application

Each temperature compensation strategy is suitable for only certain applications. In order to find a practical temperature compensation technique, the first step must be an evaluation of the application. The most effective technique will usually be one where the static acceleration (dc) component can be ignored, and the accelerometer ac-coupled. The simplest manifestation of this is shown in Figure 1.

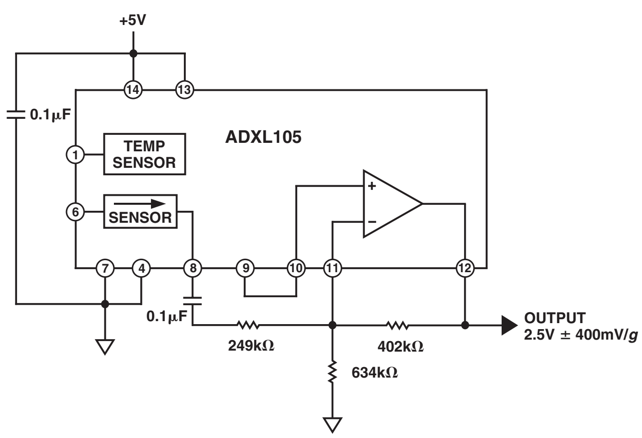

Figure 1. AC-Coupling the ADXL105

Simple ac-coupling is most effective in applications where one is most interested in sensing shock, vibration, or fairly high speed changes in inclination (e.g., checking if something has fallen over or been picked up).

Digital Trickery

Often, simple ac-coupling is not practical. In applications where the input stimulus frequency range is under 0.5 Hz, the coupling capacitor may become rather large. Fortunately, similar results can be achieved by resorting to a clever algorithm.

In applications where small, infrequent changes in inclination must be detected, the following technique is very effective: maintain a long-term average (several minutes) of the accelerometer output in memory and subtract the actual accelerometer measurement from the long-term average. As temperature changes rather slowly in the real world (rarely faster than 1°C per minute), the long-term average will slowly change as temperature causes the accelerometer output to drift. The actual stimulus will have a negligible effect on the long-term average as it rarely occurs, compared to the large number of samples taken to make the average.

Another method of measuring small changes in inclination while rejecting 0 *g* drift due to temperature is to look for a certain acceleration rate of change (Δ angle/Δ time). The apparent acceleration rate of change due to temperature drift will be very slow (less than 80 µ*g* per second for a 1°C per minute rate of change of temperature) because temperature is a slowly changing parameter, whereas actual tilt angle changes are usually much faster. This technique is commonly used in automobile tilt alarms where two-degree inclination changes (35 m*g*) must be detected in an environment where the temperature can change as much as 50°C in an hour. See the Car Alarm Reference Design on the Analog Devices website at: www.analog.com/technology/mems/markets/automotive/ref_design.html for more information.

Brute Force Techniques

If none of the above-mentioned techniques is compatible with the application, some form of hardware temperature compensation may be required.

Each accelerometer is "born" with a given temperature characteristic that does not change over its life. Since both the magnitude and sign of the temperature coefficient are variable from unit to unit, the temperature compensation technique cannot simply consist of a temperature sensor in the feedback loop of an amplifier.

There are two basic techniques that can be used: temperature mapping or ovenization. Temperature mapping is fairly straightforward in concept. A temperature sensor is added to the circuit and the temperature is varied while there is no stimulus (other than gravity) to the accelerometer. The accelerometer output is read and used to construct a compensation table or a formula that is later used for temperature compensation. Since the temperature characteristic of iMEMS accelerometers is fairly linear, usually only two or three temperature points are needed.

Normally the software used to construct the compensation table or formula is resident in the system microcontroller and the temperature sweeps are performed during system level test or burn-in. In some systems, there is even no need to perform a temperature sweep, since the system can be made self-learning. For example, an earthquake monitor can be built and then warehoused in an unheated space for a few days. As the temperature changes, the system learns how the temperature changes affect the acceleration signals. As long as the systems do not experience any movement during the "learn time," the compensation table will be correct.

Ovenization solves the temperature drift problem by fixing the temperature to some value at or higher than the maximum ambient temperature. This technique is most easily and accurately realized with accelerometers that have an on-chip temperature sensor such as the ADXL105. The simplest manifestation is shown in Figure 2.

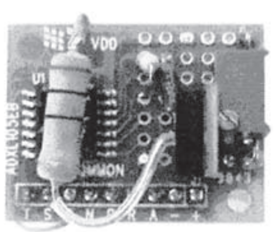

Figure 2. Using a Power Resistor as a Heating Element to Ovenize an ADXL105

Here a power resistor is mounted on top of an ADXL105. The on-chip temperature sensor is connected to the inverting input of the ADXL105's uncommitted op amp while the noninverting input is connected to a fixed voltage chosen to correspond with the on-chip temperature sensor's output voltage at the desired temperature set point. The uncommitted op amp output controls a small MOSFET that switches power to the resistor. The schematic is shown in Figure 3.

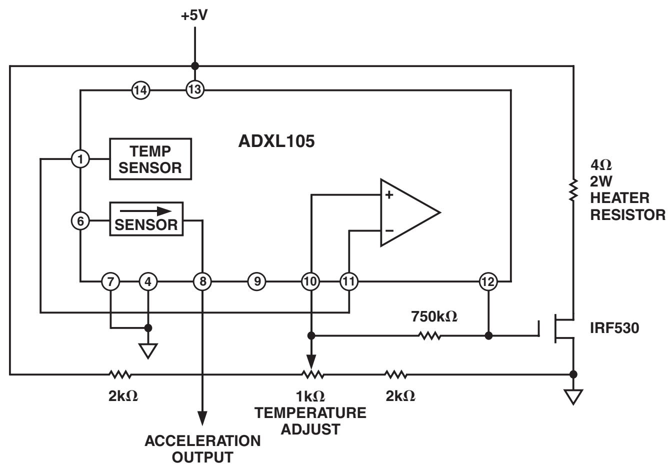

Figure 3. Schematic for ADXL105 Ovenization Circuit

Using the values shown in Figure 3, the 0 *g* drift due to temperature went from 216 m*g* to 44 m*g* over a 0°C to 70°C range (3.1 mg/°C without ovenization to 0.44 mg/°C with ovenization).

The main disadvantage of ovenization is the relatively high power consumption (approximately 6 W) which makes it impractical for battery-powered systems.

Conclusion

There are a variety of methods that can be used for temperature compensation. In order to choose one effectively, one must examine the application carefully and capitalize on its particular requirements and possibilities. The most effective methods of temperature compensation often use no hardware at all, only clever algorithms.

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