Analysis of Offset Fluctuation Generated by Temperature Dependency of 3-Axis Accelerometer MMA7260QT

Petar Mostarac, Hrvoje Hegeduš, Roman Malarić

Faculty of Electrical Engineering and Computing, University of Zagreb
Unska 3, 10000 Zagreb, Croatia, Email:{petar.mostarac[1],hrvoje.hegedus[2],roman.malaric[3]}@fer.hr

Abstract- This paper describes the comparison of a two inertial sensing boards based on Freescale™ accelerometer MMA7260QT. Measurement results have shown that they are dependable on voltage supply. It is known that acceleration measurements depend on interferences and numerous noise sources. We have examined the offset fluctuation/moving bias of two inertial sensing boards generated by temperature and time dependency.

I. Introduction

Measurements of time and temperature offset dependency have been performed in real conditions with no motion on two inertial sensing boards. First board is stand alone *ZSTAR Wireless Sensing Triple Axis demo board* from Freescale™ based on accelerometer MMA7260QT and second is *AKC 2.0 acceleration sensor board* also based on accelerometer MMA7260QT and voltage reference REF3233 developed in our lab. It is essential to learn how environment affects the sensor behavior so they could be used properly. Measurement graphs show impact of temperature on variability of accelerometer characteristics. One part of characteristic variability is not temperature dependent, but working time dependent. Error is of cumulative nature and it significantly affects the amount of measured acceleration in these systems. These parameters are needed to model the sensors and to compensate measurement results.

II. Measurements and results

The simple accelerometer model [1] relates the accelerometer output (a_o) to the true acceleration (a_t), constant offset bias (c_b), a moving bias (m_b) and a white noise of sensor (w_n).

$$a_o = a_t + c_b + m_b + w_n \qquad (1)$$

We measured all three axes of *ZSTAR* and *AKC 2.0* boards, along with measurement of temperature, supply voltage and reference voltage. Measurements were focused on defining a part of m_b which is dependent on time for the compensation while using the accelerometer. From the temperature graph the part which is dependent on m_b can be defined.

A. ZSTAR Wireless Sensing Triple Axis demo board

The ZSTAR Wireless Sensing Triple Axis demo board [2] consists of the two boards (Figure 1.):
- Sensor Board (or remote board) containing the MMA7260QT 3-axis accelerometer, MC9S08QG8 8-bit microcontroller and the MC13191 2.4GHz RF chip for wireless communication.
- USB sticks with the MC13191 RF front-end and the MCHC908JW32 for the USB communication.

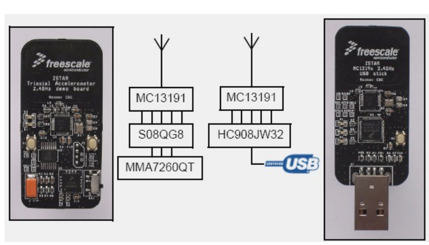

Figure 1. ZSTAR board

The MMA7260QT is low cost capacitive micromachined accelerometer with a low pass filter, temperature compensation and g-Select which allows for the selection among 4 sensitivities. The device consists of two surface micromachined capacitive sensing cells (g-cell) and a signal conditioning ASIC contained in a single integrated circuit package. The Sensing elements are sealed hermetically at the wafer level using a bulk micromachined cap wafer.

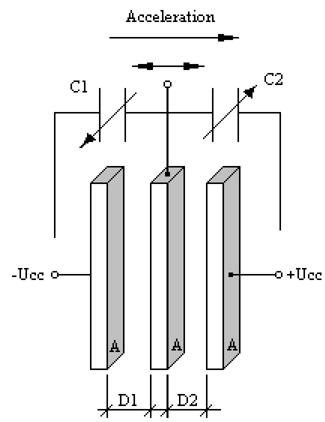

Figure 2. Simplified Transducer Physical Model

The g-cell beams form two back-to-back capacitors (Figure 2). As the center beam moves with acceleration, the distance between the beams changes and each capacitor's value will change, ($C = A\varepsilon/D$). Where A is the area of the beam, ε is the dielectric constant, and D is the distance between the beams.
The ASIC uses switched capacitor techniques to measure the g-cell capacitors and extract the acceleration data from the difference between the two capacitors. The ASIC is also performing signal conditioning and filtering (switched capacitor) of the signal, providing a high level output voltage that is ratiometric and proportional to acceleration.

B. AKC 2.0 acceleration sensor board

AKC 2.0 acceleration sensor board is developed in Primary electromagetic laboratory of Croatia (PEL) (Figure 3. and 4.) on printed circuit board of small dimensions (30x17 mm). It contains Freescale™ accelerometer MMA7260QT and the Texas Instruments™ voltage reference REF3233 used as stabilized voltage source (high voltage accuracy 0.01%, 7ppm/°C max at 0°C to +125°C).

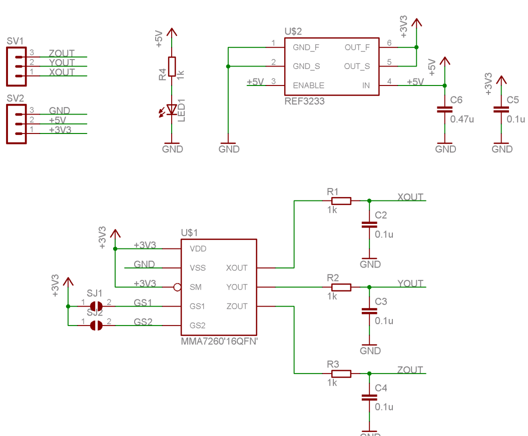

Figure 3. AKC 2.0 sensor board schematics

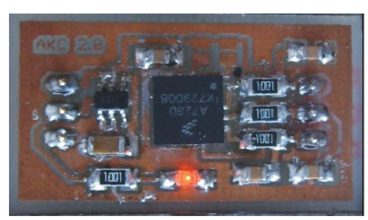

Figure 4. AKC 2.0 sensor board

C. Measurement setup

For data aquisition of acceleration and temperature from AKC 2.0 National Instruments™ PCI 6014 16-bit DAQ sensor board is used [3] [4] while ZSTAR sensor board has its own 10-bit data aquisition system which measures acceleration, temeperature and supply voltage (Figure 5.). All measured data are processed with Labview™ and Matlab™ software tools.

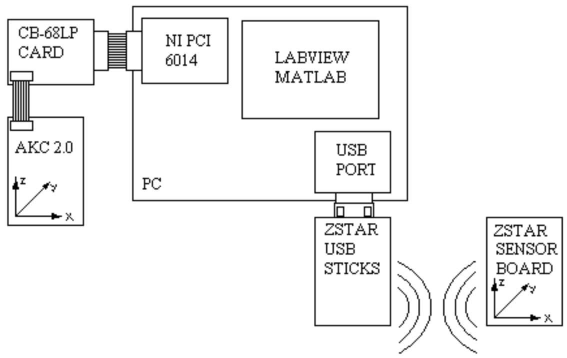

Figure 5. Measurement system

All tree axis of accelerometer with no motion, reference voltage, supply voltage and temperature are measured for 24 hours. X, Y and Z axis outputs of MMA7260QT [2] are ratiometric which means that the output offset voltage and sensitivity will scale linearly with applied supply voltage. This is a key feature when interfacing to the microcontroller with A/D converter reference levels tied to a power supply, because it provides system level cancellation of supply induced errors in the analog to digital conversion process. Thus, the influence of ZSTAR's supply voltage change is not considered.

D. Results of measurements

Offset drift can be assigned to temperature conditions. X and Y axes of ZSTAR have significant offset drift. Using coefficients for temperature sensitivity of MMA7260QT accelerometer given in Table 1 and measurement graph, compensation for X and Y axes at zero-g measurements is measured.

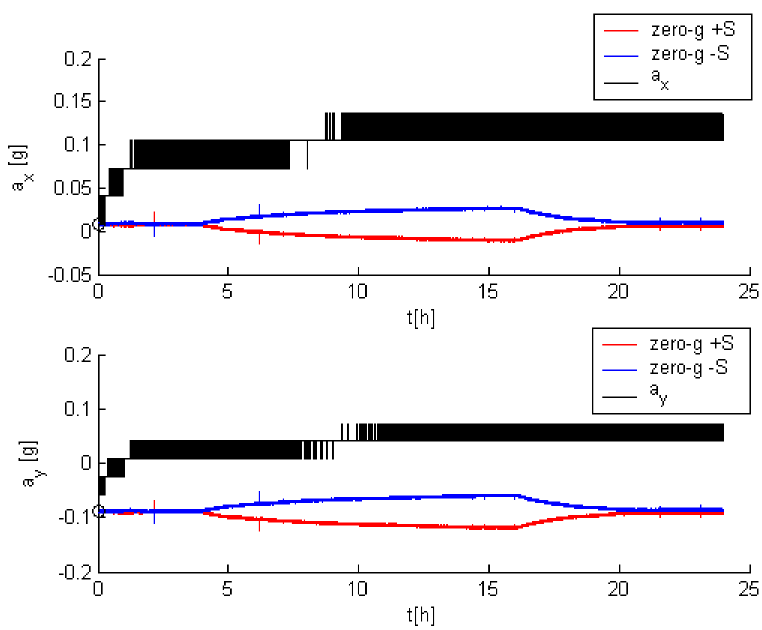

Figure 6. Temperature compensation of zero-g measures for ZSTAR

The area of maximum predicted acceleration drift with temperature is shown on Figure 6 and is located between the blue and red graph. By watching the shape and time of manifestation of offset drift it is clear

that the greatest drift occurs when the temperature is the most stable. Results show that the temperature is not the most significant influence factor on acceleration offset drift.
Only 8 most significant bits out of 10 measured by ZSTAR are considered. The two less significant bits are not taken in consideration because they are too noised. The noise influence on third less significant bit results with oscillations of 32.2 mg, calculated by Equation 2:

$$\frac{Ucc}{(2^{NobAD}-1)\times S}\times 2^{3}=0.032[g] \tag{2}$$

*U*cc – supply voltage
S – Sensitivity shown in table 1
NobAD – Number of bits in the A/D converter

For comparison, AKC 2.0 sensor board that contains the same sort of accelerometer MMA7260QT is also monitored. Its X and Y axes are much more stable and can be defined by temperature change, as shown in Figure 7.

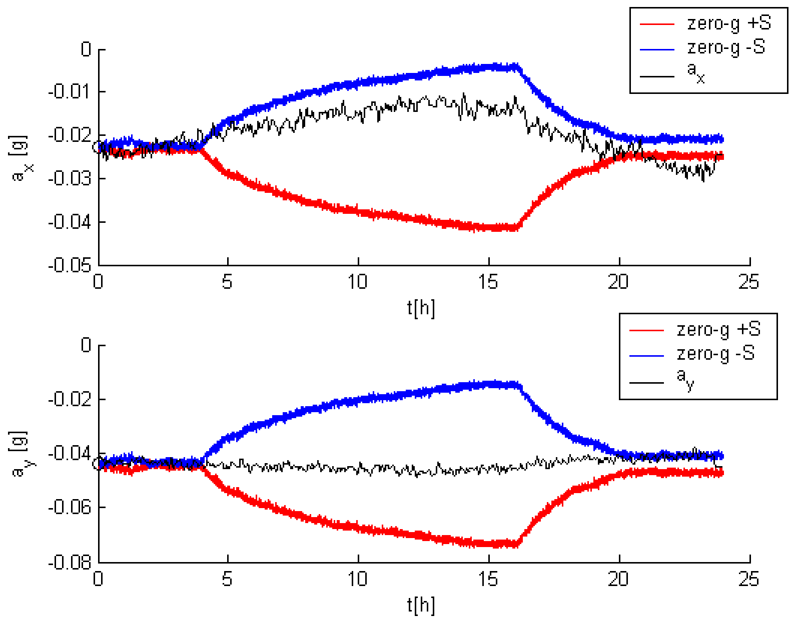

Figure 7. Temperature compensation of zero-g measures for AKC 2.0

III. Conclusions

Time offset drift of ZSTAR sensor board is not negliglible, nor listed in technical manual [2], but has significant influence on measurement values and has to be compensated. MMA7260QT accelerometer is not a problem, because, it is shown that with stable supply voltage, as in case of AKC 2.0 sensor board and NI DAQ card, there is temporally independent offset drift and that it can be compensated. Low-cost solutions are implemented in various applications, but it is necessary to define influences that could induce errors to the measurements so they can be compensated to improve the measurement accuracy.

References

[1] Flenniken, W., Wall, J., Bevly, D.M., "Characterization of Various IMU Error Sources and the Effect on Navigation Performance," *Proceedings of the 2005 ION GNSS*, Long Beach, CA, September 13-16, 2005.
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