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Published

2007

Conference Title

2007 INTERNATIONAL SEMICONDUCTOR DEVICE RESEARCH SYMPOSIUM, VOLS 1 AND 2

DOI

10.1109/ISDRS.2007.4422474

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Student Paper

Low Frequency Noise Measurement of Three-Axis Surface Micro-Machined Silicon Capacitive Accelerometer

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A three-axis surfaced micro-machined accelerometer is one of the latest MEMS products on the market. Major applications are for the video game systems, disk drive protections, health care and toys. It's mechanical sensor uses a single proof-mass for sensing the x, y and z axes. The ultimate performance of this device is limited by the intrinsic noise within the device, mainly due to the combined effect of thermally dependent electrical and mechanical noise sources, and the cross-axis distortion. Noise from any source limits the utility of the accelerometer in low g and high accuracy situations. Understanding and controlling the relative importance and interactions of electrical and mechanical noise are intellectually challenging problems.

Over the years, a number of research groups had modeled and characterized the noise of a single axis micro-accelerometers, but none of them investigated the dependence of noise on acceleration. Levinzon [1] presented the fundamental noise limit of piezoelectric accelerometers based on the mechanical-thermal and electrical-thermal noise. Yoshida et al. [2] proposed a linear noise model which does not include the thermal-mechanical characteristics in the circuit noise. They found that the simulated noise spectrum is generally matched to the measured noise from capacitive-servo accelerometer. Rocha at al. [3] attempted to characterize directly the mechanical-thermal noise spectrum by repeatedly bringing the capacitive micro sensor to pull-in, and measuring the pull-in time followed by FFT. Although the mechanical-thermal white noise measured is in agreement with existing theory on damping and mechanical-thermal noise, they recognized the need to carry out more extensive analysis to fully validate the results.In all three groups, the accelerometer was custom-made.

This group performed the Low Frequency Noise Measurement (LFNM) technique (Figure 1) to study noise characteristics of commercial accelerometers with single and dual axis [4]-[5]. In this work, we studied the noise characteristics of a three-axis accelerometer using an improved and sensitive test setup to avoid cross-axis distortion. The noise spectrum was measured as a function of the acceleration of gravity in the range from -1 to +1g. A common spectral behavior of noise was found, with $1/f$ noise dominating at low frequencies and white thermal noise being the limiting factor at higher frequencies. Unexpected resonances were also observed in the commercial devices. Most importantly, an acceleration dependence of the noise was found, in contrast to prevailing theory [6]. The noise characteristics of STM accelerometer x axis(in-plane) and z axis (out-of-plane) are shown in Figure 2 and Figure 3, respectively. The data shows that the noise power spectral density (PSD) of z-axis is approximately 10 dBm higher than the x-axes. Furthermore, the noise PSD of x-axes at 0g is higher than at $\pm$1g, while the reverse is true for the z-axes.

References:
[1] F.A. Levinzon "Fundamental Noise Limit of Piezoelectric Accelerometer", IEEE Sensors Journal, Vol. 4, No. 1, pp 108-111, Feb 2004 (Journal Article).
[2] Y. Yoshida, H. Kakuma, H. Asanuma, H. Niitsuma "A Linear Model Based Noise Evaluation of a Capacitive Servo Accelerometer Fabricated by MEMS", IEICE ELEX, Vol. 2, No. 6, 198-205, 2005 (Journal Article).
[3] L.A. Rocha, E. Cretu, R.F. Wolffenbuttel "Measuring and Interpreting the Mechanical Thermal Noise in MEMS", J. Micromech. Microeng, Vol. 15, S30-38, 2005.
[4] F. Mohd-Yasin, C.E. Korman, D.J. Nagel "Measurement of Noise Characteristics of MEMS Accelerometers", Solid State Electronics Journal, Vol/Issue: 42/2, pp. 357-360, 2003 (Journal Article).

978-1-4244-1892-3/07/$25.00 ©2007 IEEE

[5] F. Mohd-Yasin, D.J. Nagel, D.S. Ong, C.E. Korman, H.T. Chuah "Low Frequency Noise Measurement And Analysis of Capacitive Micro-Accelerometers", Microelectronics Engineering, in press (Journal Article).
[6] T.B. Gabrielson, "Mechanical-Thermal Noise in Micromachined Acoustic and Vibration sensors", IEEE Transactions on Electron Devices, Vol. 40, No. 5. pp. 903-909, May 1993. (Journal Article).

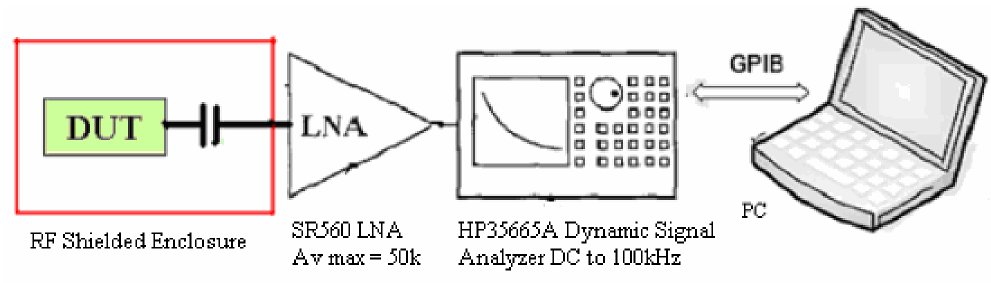

Figure 1: LFNM set up

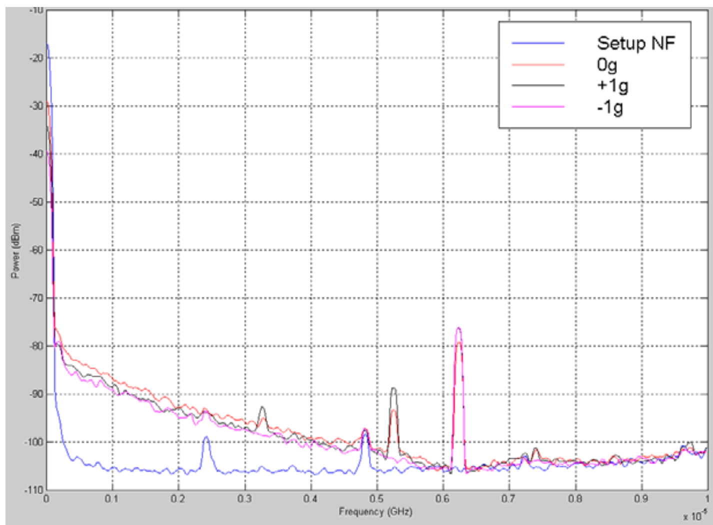

Figure 2: The noise characteristics of STM's x-axes at 0g, +1g and –1g, in comparison to the measurement set up noise floor. Note that Noise PSD @ 0g is higher than noise PSD at +1/-1 g.

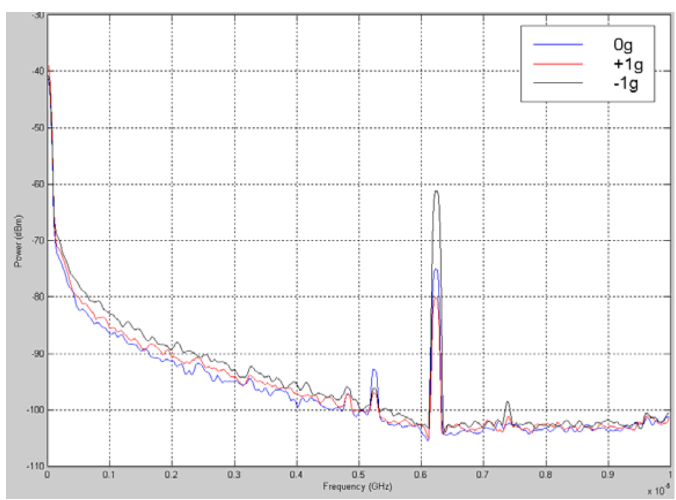

Figure 3: STM z-axes noise characteristics at 0g, +1g and –1g. Note that Noise PSD @ 0g is lower than noise PSD at +1/-g