Journal of Advances in Science and Technology

Vol. V, Issue No. X, August-2013, ISSN 2230-9659

MECHANICAL ANALYSIS AND DESIGN OF VIBRATORY MICROMACHINED GYROSCOPES

AN INTERNATIONALLY INDEXED PEER REVIEWED & REFEREED JOURNAL

www.ignited.in

Journal of Advances in Science and Technology
Vol. V, Issue No. X, August-2013, ISSN 2230-9659

Mechanical Analysis and Design of Vibratory Micro machined Gyroscopes

Ranjeet Kumar

Assistant Professor, Sityog institute of Technology Aurangabad Bihar

Abstract – Various Micro machined Vibratory Gyroscopes employ a wide range of the mechanical structures as well as actuation and sensing mechanisms. It is followed by a methodical design implementation of vibratory micro gyroscope. This completion includes both mechanical and electrical components of the micro gyroscopes.

Keywords: Gyroscopes, Mechanical, Analysis, Actuation Mechanisms

---------------------------♦-----------------------------

INTRODUCTION

During the development of micro machined gyroscopes, a variety of actuation mechanisms have been explored to oscillate the vibrating structure in the primary drive-mode. The most common ones comprise electrostatic, piezoelectric and electromagnetic means [6-9]. Electrostatic actuation using a comb drive design is the currently prevailing advance [6, 7] as they can stimulate high frequency resonant modes. The background theory including the operating Vibratory micro machined gyroscopes typically exhibit certain undesirable behaviors that impede the angular rate measurement, such as nonlinearity, cross-axis sensitivity, scale factor offset, and quadrature error. These errors have sources in both the mechanical and electrical components of a gyroscope.

Linear, lumped-parameter models are derived for two classes of vibratory rate gyroscopes, one based on translations of a proof mass and one based on rotations. The models include terms that are often omitted in the published literature. These terms are shown to produce cross-axis sensitivity. Scaling laws for evaluating the implication of the terms producing these errors are discussed. Contributions of the suspension becomes to spurious mechanical behavior is examined widely. A nonlinear rod theory, which models flexure (including shearing deformations), torsion, and axial extension/compression, is applied to the suspension of a micro machined gyroscope based on proof mass rotations. A linearized version of the speculation is used to derive a continuum model of the suspension beams. Approximations to the nonlinear theory provide formulas for the coefficients of cubic stiffening, which enable forecasts of spring-hardening behavior, as demonstrated by a comparison with experimental data. Suspension designs which minimize nonlinearity and design rules for the maximum achievable linear displacement for common micro system suspension designs are discussed. A model for nonlinear elastic coupling between the drive and sense modes of a gyroscope is derived, and is used to show how the suspension can generate scale factor offset and quadrature error even in the absence of manufacturing defects. However, such defects also contribute to spurious dynamics, and so a linear model for a gyroscope with non-identical suspension beams is obtainable.

REVIEW OF LITERATURE:

A. Sharma,etc al [2] This paper presents the design and implementation of an in-plane solid-mass single-crystal silicon tuning fork gyro that has the potential of attaining sub-deg/hr rate resolutions. A design is devised to achieve high Q in the drive and sense resonant modes (Qdrive=81,000 and Qsense=64,000) with effective mode decoupling. The gyroscope was fabricated on 40μm thick Silicon-on-Insulator (SOI) using a simple two-mask process. The drive and sense resonant modes were balanced electrostatically to within 0.07% of each other and the measured rate results show a sensitivity of 1.25mV/º/s in a bandwidth of 12Hz. X. Xiong, etc al [1] In this paper, a novel DRIE (Deep Reactive Ion Etching) bulk micro machined single-crystal silicon comb vibratory micro gyroscope is introduced. The device uses glasses substrate so that parasitic capacitance can be alleviated. Due to DRIE technique the device thickness can be increased to be more than 100μm. The working principle of the micro gyroscope is introduced. The dynamics analysis of the gyroscope is also performed. Based upon the analysis, an optimized micro gyroscope design is proposed. The designed gyroscope is expected to have a sensitivity of V/(°/sec).μ4 Xuesong Jiang, etc al [3] A monolithic surface micro machined Z-axis vibratory rate gyroscope with an on-chip A/D m-thick mechanicalμ CMOS and 2.25μπconverter is fabricated in a monolithic MEMS/circuits technology with 2 polysilicon. The on-chip position sense circuit uses correlated double sampling to reject l/f and kT/C noise and resolves V/°sec/.\IHz at atmospheric pressure andμ0.02Angstrom displacements. The gyroscope achieves a sensitivity of 3 operates from a single 5V supply. Z.Y. Guo, Z, etc al [4] A decoupled lateral-axis TFG (tuning fork gyroscope) with novel driving and sensing combs is presented. The EFBD (electrostatic force balanced comb driver) adopted in the TFG can efficiently suppress the mechanical coupling in a simple manner. The structure of the gyroscope is also optimized to suppress the coupling further. Moreover, torsional sensing combs are adopted to detect the out-of-plane movement, so it can work at atmospheric pressure. The TFG was fabricated and tested at atmosphere. The measured CFDTS (coupling from driving mode to sensing mode) and CFSTD (coupling from sensing mode to driving mode) are -45dB and -51dB respectively. The sensitivity is 2.9mV/°/s while the nonlinearity is 0.9% with the full scale of 800°/s. The noise floor is 0.035°/s/Hz1/2.

Actuation Mechanisms: Actuation Mechanisms Mainly six actuation mechanisms are available for the design and development of MEMS based devices and sensors. Depending upon the applications, these distinct actuation mechanisms are widely used in the development of various RF and Optical MEMS, best suited for commercial, industrial, military and space sensors applications [10-16].

1. Electrostatic actuation
2. Piezoelectric actuation
3. Electromagnetic actuation
4. Electro thermal actuation
5. Electrodynamics actuation

CONCLUSION:

A comprehensive description of vibratory micro machined gyroscopes is a part of this paper. We further discussed different actuation mechanism used to drive micro gyroscopes with a special emphasis on electrostatic and electro thermal actuations.

REFERENCES:

[1] X. Xiong, D. Lu and W. Wang, "A Bulk-micromachined Comb Vibrating Microgyroscope Design", the 48th IEEE International Midwest Symposium on Circuits & Systems, Vol.1, pp. 151-154, Aug 7-10, 2005.

[2] A. Sharma, F. Zaman, B. Amini and F. Ayazi, "A High-Q In-Plane SOI Tuning Fork Gyroscope", Proceedings of IEEE Volume , Sensors, Vol.1 Oct. 24-27, PP. 467-470, 2004.

[3] W. Clark, R. Howe, and R. Horowitz, "Surface Micromachined Z-axis Vibratory Rate Gyroscope", IEEE Proceedings on Solid-state Sensors and Actuators, Hilton Head Island, SC, USA, pp. 283-287, Jun. 2-6, 1996.

[4] Z. Y. Guo, Z. C Yang, L. T. Lin, Q. C. Zhao, J. Cui, X. Z. Chi, and G. Z. Yan, “A lateral-axis micromachined tuning fork gyroscope with novel driving and sensing combs,” in Proc. Transducers Conf., Denver, pp. 288– 91, Jun. 21–29, 2009.

[5] http://sunzi.lib.hku.hk/ER/detail/hkul/2688518

[6] S.E Alper, T. Akin, “A Single Crystal Silicon Symmetrical and Decoupled MEMS Gyroscope on an Insulating Substrate” Journal of Microelectromechanical Systems, 2005, 14(4), pp 707-717.

[7] C. Acar and A. Shkel, “Non-resonant Micromachined Gyroscopes with Structural Mode-Decoupling” IEEE Sensor Journal, 2003, 3(4), pp 497-506.

[8] T. K. Tang, R.C. Gutierrez, et al. “A Packaged Silicon MEMS Vibratory Gyroscope for Micro-spacecraft” Proc. IEEE Microelectromechanical Systems Workshop (MEMS‟97), 1997, Japan, pp. 500-505.

[9] R. Voss, K. Bauer, W. Ficker, et al. “Silicon Angular Rate Sensor for Automotive Applications with Piezoelectric Drive and Piezoresistive Read-Out” Tech. Dig. 9th Int. Conf. Solid-State Sensors and Actuators (Transducers‟97), Chicago, IL, 1997, pp. 879-882.

[10] M. Baltzer, T. Kraus, E. Obermeier, “A Linear Stepping Actuator in Surface Micromachining Technology for Low Voltages and Large Displacements” in Transducers 97: 9th Int. Conf. Solid-State Sens. Actuators, 1997, pp. 781–784.

[11] D. Damjanovic and R. Newnham, “Electrostrictive and Piezoelectric Materials for Actuator Applications” Journal of Intelligent Material Systems and Structures, Vol. 3, no. 2, pp. 190–208, 1992.

[12] H. Tilmans, E. Fullin, H. Ziad, M. van de Peer, J. Kesters, E. van Geen, J. Bergqvist, M. Pantus, E. Beyne, K. Kaert, and F. Naso, “A Fully-Packaged Electromagnetic Microrelay” in Proc. IEEE Micro Electro

Mechanical Systems, Orlando, FL, 1999, pp. 25–30.

[13] J. Butler, V. Bright, and W. Cowan, “Average Power Control and Positioning of Polysilicon Thermal Actuators” Sensors and Actuators, A, Physical, vol. 72, pp. 88–97, 1999.

[14] E. Enikov and K. Lazarov, “PCB Integrated Metallic Thermal Micro-Actuators” Sensors and Actuators A, Physical, vol. 105, no. 1, pp. 76–82, 2003.

[15] C. Neagu, J. E. Gardeniers, M. Elwenspoek, and J. Kelly, “An Electrochemical Active Valve” Electrochimica Acta, vol. 42, no. 20–22, pp. 3367–3373, 1997.

[16] E. Quandt and A. Ludwig, “Magnetostrictive Actuation in Microsystems” Sensors and Actuators A, Physical, vol. 81, no. 1–3, pp. 275–280, 2000.

[17] http://prr.hec.gov.pk/Chapters/395S-2.pdf