

Design and Development of Hybrid Integrated MEMS Capacitive Gyroscope-ROIC Module

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Abstract— In this paper, we are reporting the development of a MEMS capacitive gyroscope-ROIC module for possible use in micro aerial vehicle (being developed by CSIR-NAL). The gyroscope is fabricated using an SU-8 based UV-LIGA process. The associated ROIC is designed in-house and is fabricated through Euro-practice in AMS 0.35 μm CMOS technology. The sensor and the ROIC chips are hybrid integrated and vacuum packaged in a 24-pin dual-in-line package to make the module. The module is tested for its spectral and rate responses.

Keywords: Gyroscope, Hybrid integration, MEMS, ROIC, Vacuum packaging

1 Introduction

A gyroscope is an inertial sensor that is used to measure an angular-rate of rotation. Compared to the traditional gyroscopes (sperry gyroscope, ball electrostatic gyroscope, ring laser gyroscope etc.), MEMS gyroscopes have many advantages such as low cost, small size, and light weight. As a result, they have attracted a lot of attention in past few years for many applications e.g. automobile, consumer electronics, inertial navigation system etc. In this paper, we are reporting the development of a hybrid integrated and vacuum packaged MEMS capacitive gyroscope-ROIC module for possible use in micro aerial vehicle (being developed by CSIR-NAL).

2 Design and Fabrication

The conceptual schematic of the gyroscope structure is shown in Fig. 1a. The drive gimbal is vibrated torsionally about the x -axis by applying a DC polarization voltage to the gyroscope structure and AC excitations to the electrodes underneath the drive gimbal. When the gyroscope is subjected to an angular rotation around the z -axis, a sinusoidal Coriolis torque at the frequency of the drive mode vibrations is generated about the y -axis and hence, the sense gimbal starts vibrating torsionally about the y -

axis. By measuring the capacitance change between the sense gimbal and the electrodes underneath it, during the sense mode vibrations, the applied angular-rate can be derived. We have optimized this design to have resonance frequency of 8 kHz for both drive and sense modes. The sensor is then fabricated using an SU-8 based UV-LIGA process having 8 μm thick Ni-Fe as the key structural layer [1]. The SEM image of the fabricated gyroscope is shown in Fig. 1b.

The sense capacitance change produces a proportional change in the current. A transimpedance amplifier (TIA) acts as the front-end interface circuit for the gyroscope that converts this current to voltage. TIA is implemented using a folded cascode op-amp architecture with tunable T-bridge resistive feedback circuit. Further amplification to the voltage output of the TIA is provided using second gain stage. Pre-amplified differential sense signals are converted to a single-ended signal using a differential-to-single ended converter. A demodulator circuit with low pass filter (LPF) is used to obtain the DC voltage proportional to the rate change. This configuration is shown schematically in Fig. 2a. This read-out integrated circuit (ROIC) chip is fabricated through Euro-practice in AMS 0.35 μm CMOS technology (Fig. 2b). Experimental results show that the TIA has a sensitivity of 93 mV/nA.

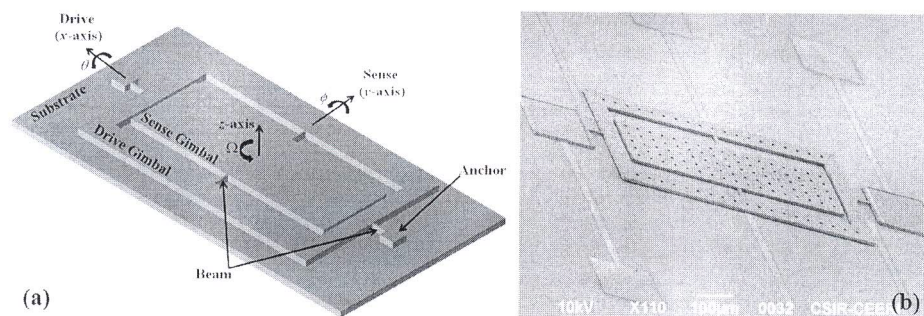


Fig. 1: (a) Conceptual schematic of the gyroscope, (b) SEM image of the gyroscope.

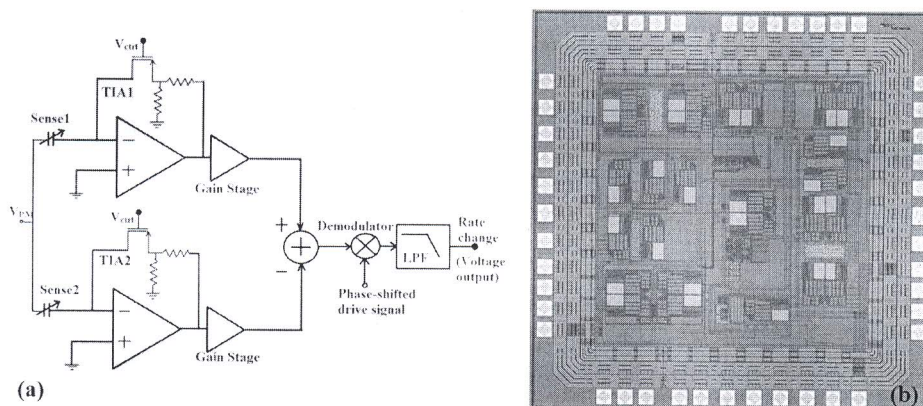


Fig. 2: (a) Schematic of the ROIC, (b) Optical image of the ROIC.

3 Packaging and Testing

The fabricated gyroscope and ROIC chips are mounted on a 24-pin dual-in-line package and hybrid integrated to reduce the effect of parasitic capacitance. Also, the package is sealed in vacuum to minimize the effect of air-damping and get the operating voltage below 5 V. Thus developed module is shown in Fig. 3.

The module is tested for its frequency response using laser Doppler vibrometer. The drive resonance frequency is found to be 7.55 kHz (Fig. 4a). The module is also characterized for preliminary rate response. The FFT spectrum after applying the angular rate is shown in Fig. 4b. This response is taken before performing demodulation.

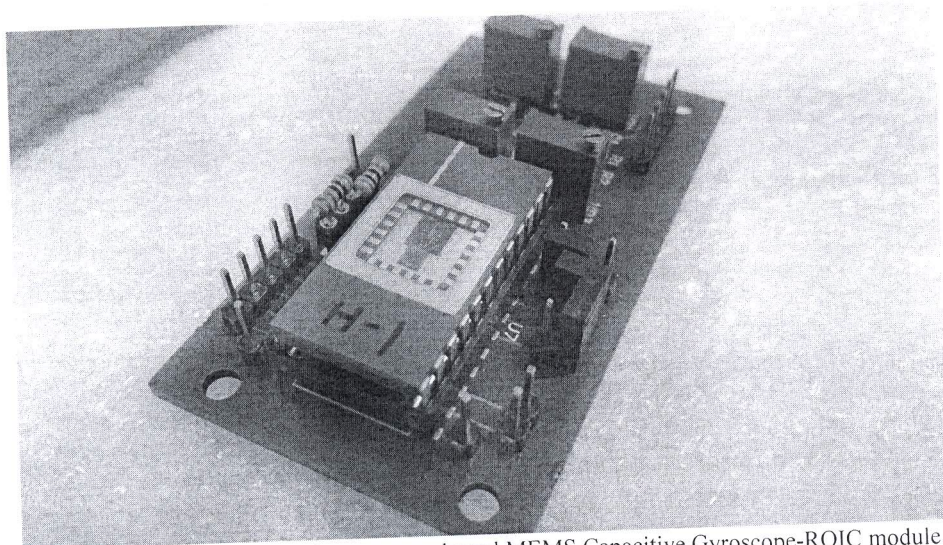


Fig. 3: Hybrid integrated and vacuum packaged MEMS Capacitive Gyroscope-ROIC module

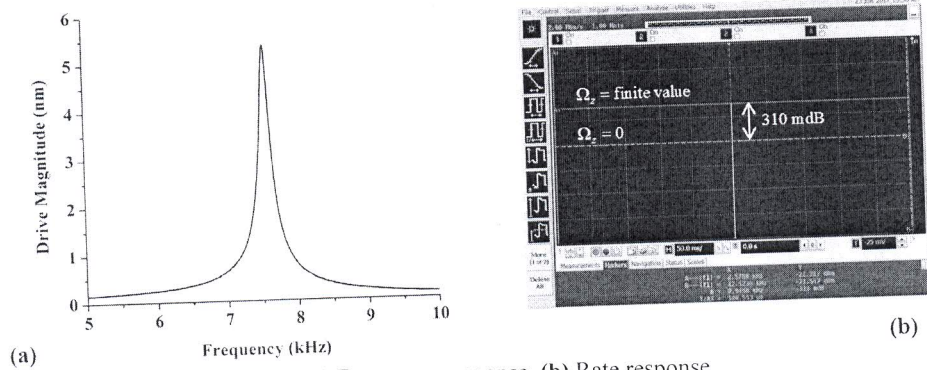


Fig. 4: (a) Frequency response, (b) Rate response.

4 Conclusion

The development of a MEMS capacitive gyroscope-ROIC module for possible use in micro aerial vehicle (being developed by CSIR-NAL) is reported. The gyroscope is implemented using an SU-8 based UV-LIGA process. The associated ROIC is designed in-house and is fabricated through Euro-practice in AMS 0.35 μm CMOS technology. The sensor and the ROIC chips are hybrid integrated and vacuum packaged in a 24-pin dual-in-line package to make the module. The module is characterized for its spectral and rate responses.

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References

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