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A Single Chip Packaged MEMS G Sensor for Industrial Applications

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Abstract: Development of a single chip packaged MEMS G sensor for industrial applications is discussed. The developed G sensor is composed of a MEMS sensing element and a signal processing ASIC. The MEMS sensing element is fabricated by using the unique sacrificial/bulk micromachining (SBM) process for better mechanical properties. And the signal processing ASIC is fabricated in 0.5um CMOS process technology and operated with +5Vdc single power supply. The ASIC also has features of over/reverse voltage protection, ESD protection, self-test, and temperature sensor. To ensure high reliability in industrial environment, Low Temperature Co-fired Ceramic (LTCC) packaging is performed. The packaged chip is Land Grid Array (LGA) type which has 18 I/O pads, and the outline dimensions are 9.7mm x 8mm x 1.9mm. The developed G sensor offers analog voltage output with ±2g dynamic range, 0.962mG bias instability, and 76dB SNR.

1. INTRODUCTION

In industrial and automotive applications there has been a huge growth in using motion sensors. A recent trend is to combine the sensors with the electronic control units (ECU) into complete modules that are easy to incorporate into larger control systems. Microelectromechanical systems (MEMS) based G sensors are suitable for embedded sensor modules because they have the advantages of small size, low power and low cost.

In industrial control systems, high performance G sensors are needed to provide information about accelerations and decelerations accurately. In general, G sensors with a range of operation equal to ±2g, a resolution of less than 10mg, and low bias instability are desired. In this paper, development of a MEMS G sensor suitable for high performance industrial applications, including power-line tilt sensing clusters, and vehicle dynamic control systems is discussed.

2. DESIGN AND FABRICATION

The developed MEMS G sensor is composed of MEMS sensing element and signal processing ASIC. Both the sensing element and the ASIC are integrated into a single Low Temperature Co-fired Ceramic (LTCC) package.

2.1 MEMS sensing element

The capacitive type MEMS sensing element is designed and fabricated. When an external force is applied to the sensing element, a proof mass moves closer to one of fixed conductive electrodes thus changing the capacitance between the proof mass and a fixed electrode. Silicon capacitive accelerometers have several advantages such as high sensitivity, good DC response and noise performance, low drift and a simple structure.

The fabrication process used is the sacrificial/bulk micromachining (SBM) process. In SBM process, the microstructure is released by aqueous alkaline anisotropic etching so the bottom surface of the proof mass is notchless and flat, which provides better mechanical properties. Fig. 1 shows SEM photo of the fabricated MEMS G sensing element

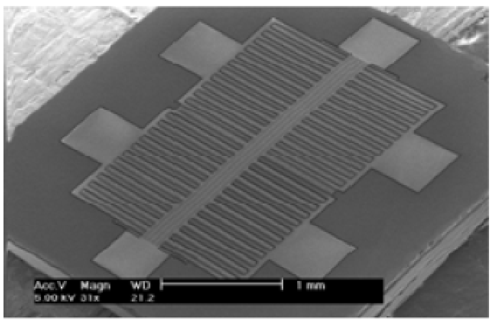

Fig. 1. Fabricated MEMS G sensing element

2.2 Signal Processing ASIC

The signal processing ASIC is fabricated in 0.5um CMOS process technology and operated with +5Vdc single power supply. The operation principle of the designed ASIC is as follows. First, the charge amplifier converts the capacitance change to the voltage signal modulated with the oscillator frequency, then the high pass filter (HPF) blocks DC and low frequency noise on the modulated signal. Following mixer demodulates the modulated signal. Finally, the low pass filter (LPF) and the output amplifier generates analog voltage signal proportional to external accelerations. To ensure high reliability, The ASIC also has features of over/reverse voltage protection, ESD protection, self-test, and temperature sensor. Figure 2 shows system block diagram of the designed ASIC.

Fig. 2. Block diagram of the signal processing ASIC

2.3 Chip Packaging

For chip packaging, LTCC packaging is performed. LTCC package has the advantages of high reliability due to inert nature of substrate, excellent electrical isolation, and higher density due to multiple conductor layers. The packaged chip is 18-pin LGA type and the outline dimension is 9.7mm x 8mm x 1.9mm. Figure 3 shows fabricated LTCC packaged MEMS G sensor.

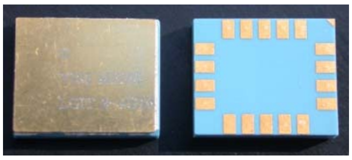

Fig. 3. LTCC packaged MEMS G sensor

3. PERFORMANCE CHARACTERISTICS

The measurement results of the developed G sensors are shown figure 4 and figure 5. The 1000-sec bias instability of 10 experiments is shown in figure 4. The averaged bias instability is calculated to be 0.962mG(1σ). The frequency response of 10 experiments is shown in figure 5. The averaged signal to noise ratio (SNR) is measured to be 76dB. And the averaged noise equivalent resolution (NER) is calculated to be 0.158mG.

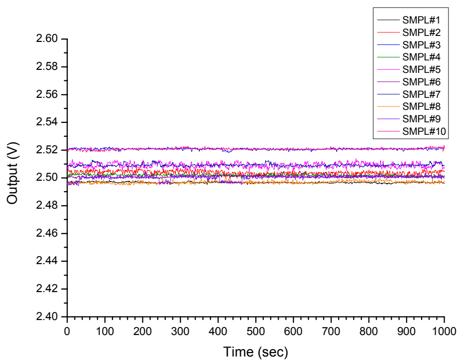

Fig. 4. 1000-sec Bias Instability of 10 experiments

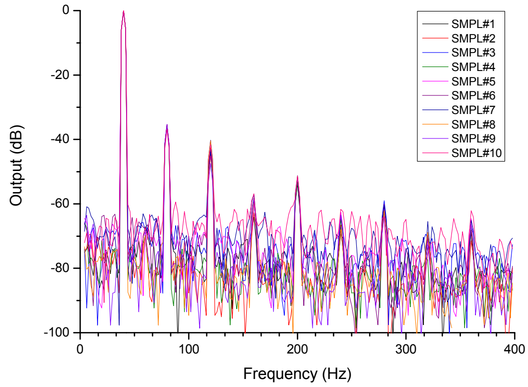

Fig. 5. Frequency response of 10 experiments

4. CONCLUSIONS AND FUTURE WORK

A single chip packaged MEMS G sensor is successfully designed and fabricated. The developed sensors yield good performances such as low bias instability and high resolution which are suitable for high performance industrial and vehicle dynamic control systems. Conventional MEMS G sensors usually provide several tens of mG bias instability. But the measured bias instability is much lower than that of conventional MEMS sensors. And the developed sensor has sufficient resolution to distinguish small vibration in noisy environment. These characteristics of the developed sensor can contribute to the system stability and performance. Our future work is focussed on reliability tests, applying the sensor in embedded control systems, and field tests of the control systems.

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