Design and Characterization of MEMS Based Accelerometers for Various Applications

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Abstract

Today, MEMS based accelerometers are used in a variety of applications. To name a few, they are used in safety systems in automobiles, it has added a new dimension to miniaturization of devices, it has replaced traditional piezoelectric accelerometers, which were big and difficult to use. For its various applications, differing bandwidth (operating frequency range) and amplitude of vibration are required. For example, the bandwidth for portable electronics is around 100-1000Hz; while for air bag application in automobile is around 1000-10000Hz. Thus, it becomes necessary for us to study the design, principle and characteristic parameters involved in them. No doubt, experimental data are always useful and accurate. However, there always exists a need to consult theoretical phenomena and mathematics, and FEA provides the best platform for this.
In the present work, we have proposed three different designs for accelerometers. The designs (as shown in the Figure 1) have a rectangular proof masses suspended with crab-leg shaped cantilever supports. They are characterized using COMSOL Multiphysics® software. We did the following two analyses to characterize our devices: (a.) Eigen Frequency Analysis (b.) Frequency Domain Analysis. The resonance frequency for the designs turns out to be 37 KHz, 85 KHz and 135 KHz respectively in vacuum conditions (Figure 2). The corresponding bandwidths for the designs are found to be 10 KHz, 30 KHz and 40 KHz respectively. The results matched the experimental data, which was done on Laser Doppler Vibrometer.
The characterization of the devices revealed that the devices can cater to varied applications ranging from automobile to electronics. As we know, the characteristic parameters for the devices are strong functions of the packaging conditions (pressure). Depending on the packaging conditions, the phenomenon called squeeze film damping influences characteristic parameters such as amplitude of oscillation, resonant frequency and band-width. This allows us to use them in different applications just by changing the packaging conditions. However, the changes observed are very irregular and cannot be predicted. Thus, we simulated the designs for different working pressures. The resonant frequency versus pressure graphs for the designs are plotted (Figure 3) and results are experimentally verified. Finally, different packaging conditions are determined for different applications while taking care of other design parameters. Also, all the important characteristic parameters such as sensitivity, cross axis sensitivity, range, bandwidth, and resonance frequency are found for the devices. It is seen that the implementation of squeeze film damping in FEA software results in a lot of computation. Thus, to cross check the values, we even proposed a novel way of modeling squeeze film damping in electrical domain using the circuit comprising of parallel inductors and resistors. Finally, the values of simulation are used to

verify our new approach of modeling squeeze film. They matched in a very encouraging way.

Reference

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Figures used in the abstract

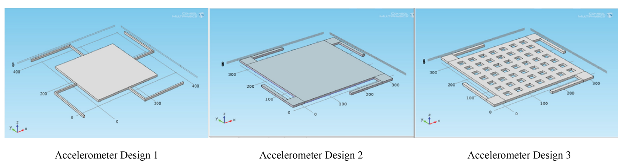

Figure 1: The proposed and optimised designs of the accelerometers.

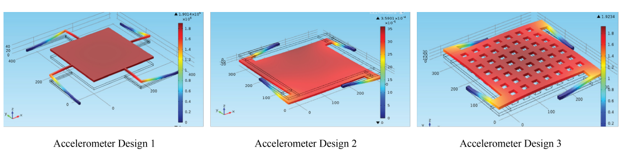

Figure 2: Eigen Frequency Analysis- Mode of vibration for the accelerometer designs.

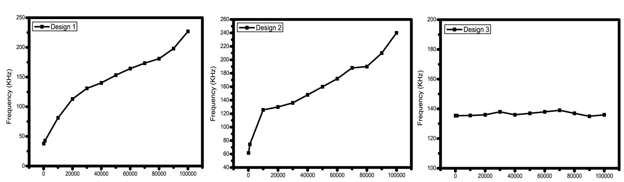

Figure 3: Pressure versus Resonance Frequency Plot for the different designs.