Optimization of MEMS Based Capacitive Accelerometer for Fully Implantable Hearing Aid Application

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Abstract

INTRODUCTION: According to the 2015 estimates of WHO, 278 million people have disabling hearing impairment. In India, 63 million people suffer from significant auditory loss. The majority of all hearing loss is sensorineural loss which refers to hair cells damage in cochlea, a snail like structure inside the inner ear which connects to the auditory nerve in the brain. The use of conventional hearing aids with external microphones and electronics presents reliability, practicality and social stigma concerns and does not address cochlear hair cells damage. Therefore the development of fully implantable high performance prosthetic system is essential. MEMS based accelerometer is already proposed as an implantable microphone for fully implantable cochlear prosthesis [1]. The accelerometer can be attached to the middle ear bone structure, umbo to convert the bone vibration to an electrical signal representing the original acoustic information.

Comb drive accelerometer consists of fixed fingers attached to the accelerometer frame and movable fingers fixed to the proof mass and suspended by springs [2]. Any external acceleration causes the proof mass and movable fingers to move along the direction of body force, the fixed comb remains stationary. This movement changes the capacitance between the fixed and the movable finger. The capacitance is measured using electronic circuitry. The fixed finger has two movable fingers on either side. Let's say, x1 is the distances of fixed finger from left movable finger and x2 from the right movable finger.

In this paper, different prototypes of accelerometer (using different spring topologies) are presented in (Figure 1). For each prototype, x1 has been kept 2 µm and x2 has been varied from 2 µm to 20 µm. Their sensitivity and nominal capacitance (when no acceleration is applied) have been plotted against x2. The geometry of proof mass and spring for each parameter is designed for resonant frequency of 10000 Hz.

USE OF COMSOL MULTIPHYSICS®: This model is simulated using COMSOL Multiphysics in 2D as a plate structure. The physics used includes electrostatics, solid mechanics, and moving mesh. The geometry parameters of the model are given in (Figure 2). Corresponding to the input voice signal, the acceleration values from 0g to 1g are applied to the designed structures [1]. The structures have been analyzed using Silicon as material and dielectric as air. The proof mass along with movable fingers is connected to 1 V supply and the fixed fingers with ground.

RESULTS: The variation of nominal capacitance and capacitive sensitivity with gap spacing (x2) are plotted in (Figure 3) and (Figure 4). The number of fingers and hence the capacitance

decreases with increasing gap spacing. But the sensitivity varies randomly. So we have optimized the gap spacing which gives higher sensitivity and higher capacitance as well.
CONCLUSION: The optimized results will be used in selecting the prototype structure for designing high performance MEMS accelerometer for fully implantable hearing aid applications.

Reference

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Figures used in the abstract

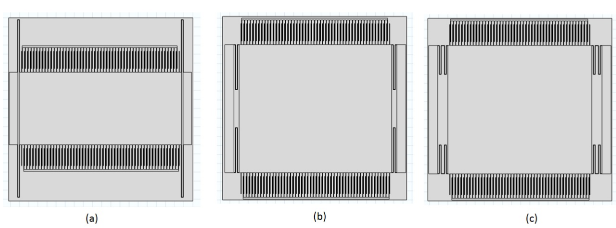

Figure 1. Accelerometer prototypes with different spring topologies

Figure 1: Accelerometer Prototypes (a), (b) and (c) With Different Spring Topologies.

Geometry Parameters	Values (μm)
Thickness of the plate	25
Width of finger	2
Finger overlap length	96
Width of spring beam	2
Length of finger	116

Figure 2. Geometry Parameters

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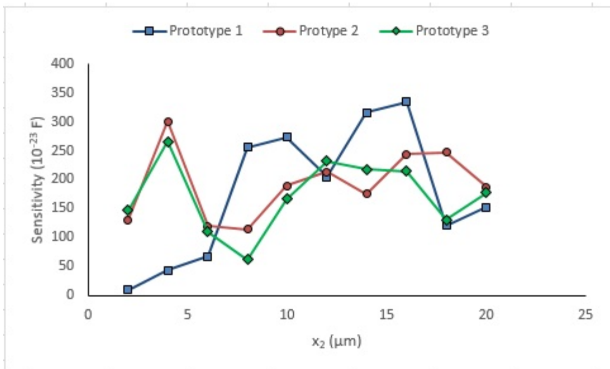

Figure 3: Capacitive Sensitivity vs Finger Gap.

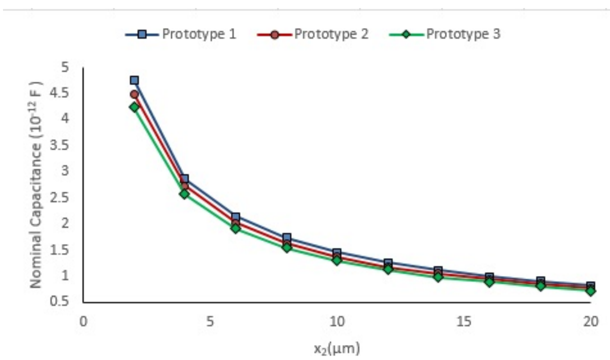

Figure 4: Nominal Capacitance vs Finger Gap.