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A MEMS Capacitive Accelerometer Design as Middle Ear Microphone Based on Ossicular Chain Micromechanic Characterization at Umbo for Fully Implantable Cochlear Prosthesis

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An accelerometer attached to an umbo is proposed as a middle ear microphone for future fully implantable cochlear prostheses. The micromechanic characterization of cadaveric temporal bones indicates that a miniature accelerometer with a sensing resolution of 35 μg/$\sqrt{\text{Hz}}$, a bandwidth of 8 kHz, and a packaged weight less than 20 mg is required for detecting normal conversation, and that the accelerometer's performance is insensitive to potential position misalignment during the implant procedure. A commercial accelerometer is attached to an umbo as proof of the concept to demonstrate the capability of detecting and converting a temporal bone vibration to an electrical signal in response to an external acoustic stimulus. The commercial device, however, exhibits a high noise floor of 250 μg/$\sqrt{\text{Hz}}$, and thus can only achieve minimum detectable sound pressure levels (SPL) of 82 dB and 55 dB at 500 Hz and 2.4 kHz, respectively, at a measurement bandwidth of 200 Hz, which is inadequate for the detection of normal conversation. A micro-electromechanical systems (MEMS) capacitive accelerometer is then designed with a sensing resolution of 30 μg/$\sqrt{\text{Hz}}$ in ambient limited by the Brownian noise and is fabricated using an SOI-MEMS process. The accelerometer occupies a sensing area of 1 mm^2 and achieves a nominal capacitance of 2.4 pF, a sensitivity of 4 fF/g, and a bandwidth of 6.44 kHz. The diced sensor chip has dimensions of approximately 2 mm×2.4 mm×0.4 mm, and hence, weighs 4.5 mg, which is suitable for the proposed fully implantable cochlear prosthesis.

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