TRIAXIAL ACCELEROMETER FOR PLACEMENT INSIDE THE EAR CANAL

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Outline of the Problem

Brain trauma from race car and motorcycle crashes has been extensively studied during the past decade by the FIA (Formula One), the Indy Racing League, the Air Force Research Lab, and others. For a quantitative measurement of the shocks incurred during these crashes, the racing industry has relied on a shock measurement system which includes three accelerometers mounted in the outer portions of the driver's ear in a custom-molded ear plug (first-generation in-ear shock measurement system). Recent industry research has determined the need for a triaxial accelerometer that is small enough to fit into the ear canal to measure more accurately by having better coupling to the skull. Another area where such a device could be employed to study brain trauma is in contact sports, such as football. A Congressional hearing in late 2009 involving professional football players, the NFL and medical doctors has brought much attention to a possible link between brain diseases –such as dementia and Alzheimer's– and sustaining repetitive concussive hits to the head on the football field.

Innovation of Solution

The second generation in-ear shock measurement system presented here consists of the world's smallest triaxial accelerometer die, a shielded flex circuit for signal transmission, a 3-axis analog signal conditioning module, and an instrumentation data recorder using flash memory which supplies excitation voltage, adjustable anti-aliasing filtering and amplification. It is the world's first and only triaxial accelerometer to fit deep inside the ear canal.

The sensor has a range of 500 g and is approximately a 0.08 inch cube. For electrically noisy environments such as race cars it is necessary to amplify the signal out of the accelerometer as close as possible to the sensor to reduce noise pickup. The signal conditioning module amplifies the MEMS sensor output to about 3.6 mV/g for each of the three axes. The 0.4 x 0.4 x 0.15 inch electronic signal conditioning module provides bridge completion, ESD protection, along with adjustable signal amplification and low-pass filtering for each axis based on the customer's needs. The module is located less than one inch from the sensor and is molded into the outer portions of the ear plug.

To complete the system, a flexible cable mates with the flex circuit and carries the analog acceleration signals out to the instrumentation data recorder which is housed remotely from the molded ear plug. To reduce noise pickup, the accelerometer, flex circuit, and electronic module are completely shielded with a spray-on EMI/RFI flexible shielding.

The Figures on the following page show a close-up of the accelerometer die, a picture of the complete in-ear shock measurement system, and a typical frequency response plot for one of the axes of the shock measurement system.

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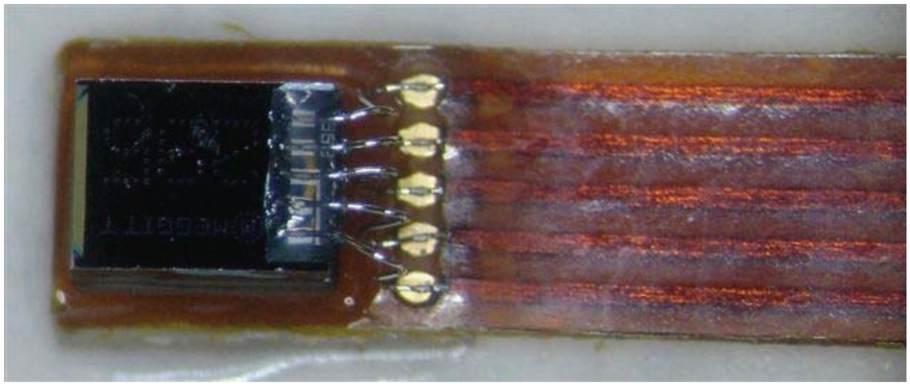

Figure 1. Close-up of the triaxial accelerometer die mounted on a flex; before potting.

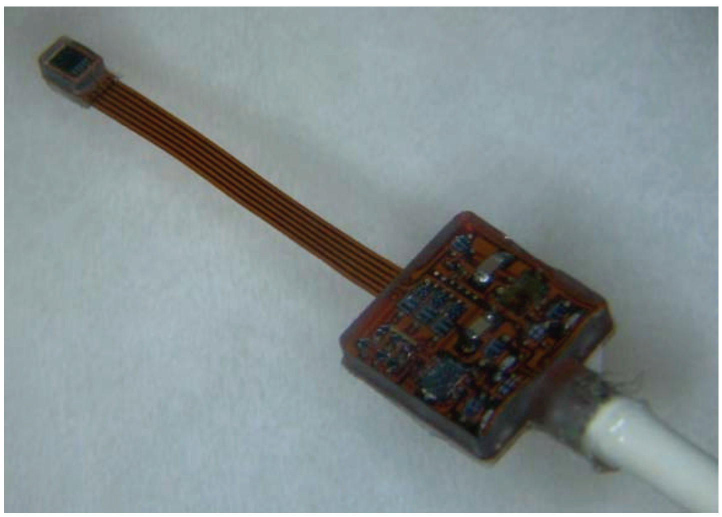

Figure 2. Complete in-ear triaxial shock measurement system.

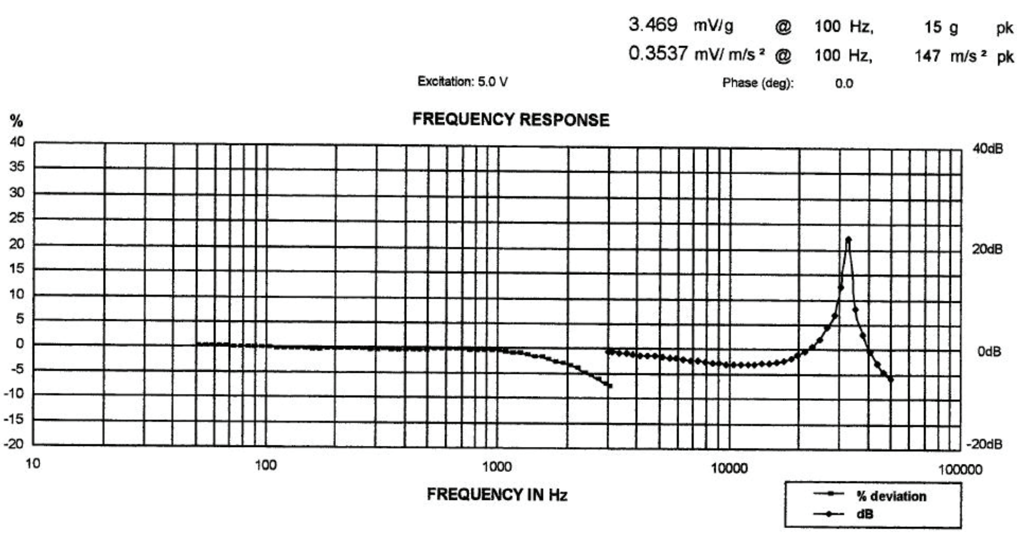

Figure 3. Frequency response of one of the axes of the triaxial shock system (plots for the two remaining axes look similar).