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RELIABILITY OF MEMS COMPONENTS IN HARSH ENVIRONMENTS: CONCURRENT TEMPERATURE CYCLING AND VIBRATION TESTING

Abstract

Reliability assessment of robust MEMS components for harsh environments, such as space, requires extensive testing for acquiring enough information to construct relevant statistics. Reliability testing, as being done today, aims at providing realistic conditions that represent stresses a component will undergo in operation. Such testing is traditionally performed with a single parameter being varied, while accumulative testing, on the other hand, is a method that even if existing since the beginning of the space age, remains so far limited to thermal vacuum. However, unexpected component failures still occur in-orbit regardless of the reliability assessment performed upfront. The present work reports a concurrent, bi-parameter reliability procedure – being referred as an A+B simultaneous testing method – applied to MEMS for space applications. It is completed by a Finite Element Analysis (FEA) backing up the investigations of the degradation phenomena taking place down to the sub-component level.

High reliability, commercial off-the-shelf automotive inertial measurement units are subjected to severe accumulated stress conditions: thermal cycles over the range -40^{o}C/180^{o}C and vibrations up to 30g over sweeps of 20-2000 Hz, applied simultaneously. The devices are tested until failure criteria are attained or a complete loss of functionality occurs. As found in a preliminary work, the maximum loads, applied individually and following the standards MIL-STD-883 and -750, did not cause failure on the selected components. Such procedures are therefore insufficient for elaborating robust reliability assessments. On the other hand, the combination of loads of different natures in an accumulative fashion (A-then-B sequence) resulted in failures, which drives the interest of combining stresses (A+B, thermal and mechanical) simultaneously. Contrary to other works, the samples are tested in a standalone fashion, removing from the equation the surrounding electronics and soldering. A dedicated socket and sample

holder are designed for characterization and testing. The failure root-cause and effect analysis (FMEA) shows package as well as die attach failures as being at the origin of the loss of functionality of the devices. The failure statistics is compared to previous results of reliability testing under accumulative sequential "thermal-then-vibration" testing, which permits to assess the lifetime difference between an A+B method with respect to A-then-B sequence. The FEA is elaborated in order to assess the thermal and mechanical loads at the sub-system level (especially the die attach) and is compared to the real-life experiment.