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RELIABILITY MEASUREMENT OF SINGLE AXIS CAPACITIVE ACCELEROMETERS EMPLOYING MECHANICAL, THERMAL AND ACOUSTIC STRESSES

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MEMS accelerometers are extensively employed in various consumer applications due to their rapidly decreasing costs. In order to meet the low-cost requirements, manufacturers are forced to sacrifice some design parameters that may degrade their accelerometers' reliabilities. Interestingly, there is not much published works on the reliability aspects of MEMS accelerometers. Two reports detailed the reliability qualitative assessment on commercial devices [1-2]. Both works concluded that MEMS accelerometers are high reliable devices with low failure rates. In a recent study [3], a procedure to perform the quantitative accelerated life testing (QALT) on tri-axis accelerometer from STM was proposed, with a crude setup to vary the accelerations and temperatures. The purpose of this paper is to employ the QALT procedure on single axis accelerometers from Analog Device and Freescale. Laser-precision apparatus was designed, built, and employed to provide three types of excitations with great accuracy; mechanical (gravitational) test, thermal test and acoustical test. These tests are designed to mimic the operating conditions of the system, where the devices are employed.

The apparatus is shown in Figure 1. The tilting apparatus being designed for gravitational test consists of two main parts: copper enclosure and holder. The PCB-mounted DUTs are placed inside the copper enclosure parallel with their axis of sensitivity while the holder firmly grips the copper enclosure. The apparatus could accurately generate 0g, +1g and -1g output level. The steel heater plate is positioned at the bottom of the copper enclosure to provide thermal stress up to 120 ^{o}C through conduction to the DUTs. The piezoelectric disc provides acoustical sine signal from 20Hz to 20kHz with $5V_{peak}$ maximum amplitudes, supplied by the external function generator.

Sensitivity (S_o) and zero-g level (V_{off}) are the selected parameters to be analyzed and compared with manufacturers' datasheet. Sensitivity (S_o) is the output voltage change per g unit of acceleration applied, and Zero-g level (V_{off}) is described as the actual output signal in steady state when there is no acceleration and also the factory-calibrated parameter. Table 1 shows the measured S_o and V_{off} for both accelerometers. First, the mechanical test is performed by tilting the DUTs to 0, +1 and –1g. It is observed that both DUTs outputs show excellent linearity and agree well with the specifications. Then, the thermal test is performed, and it is shown that Vout of MMA1220D has better linearity compared to ADXL105 (Fig 2). Finally, the acoustic test is conducted by pumping sine wave to the DUTs with maximum amplitude of 5Vp and frequency of 10kHz. Amazingly, Vout of both DUTs show excellent linearity (Fig 3). We also performed additional tests to check for correlation between the three stresses imposed. The V_{off} and S_o are plotted against temperature and frequency of piezo disc, respectively. The former is performed at 0g, while the latter at $\pm$1g. Two interesting observations were noted. First, the V_{off} of both devices are unstable when subjected to different temperatures, which is due to the increasing thermal electrical and mechanical noise in the DUTs (Fig 4). Second, the S_o is unstable when subjected to different acoustic frequencies, which is most probably due to the vibration of the silicon micro-sensors, and thus giving difference outputs. The results obtained from this work show that when the DUTs are subjected to the combined tests of mechanical, thermal and acoustic stresses, the sensitivity and zero-g level show deviations from the datasheet, making them less reliable as claimed. This is an important finding, as the working environment where these devices are being employed normally consists of these combined stresses.

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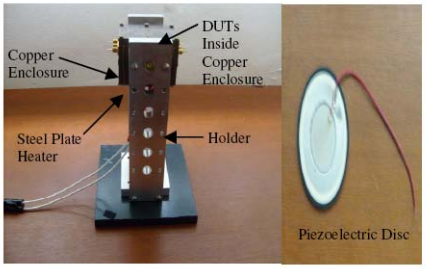

Figure 1: Experiment apparatus

Table 1

Parameter	Tested Accelerometer	
	ADXL105	**MMA1220D**
Sensitivity (S_o)	(80 ~ 275)mV/g	(237.5 ~ 262.5)mV/g
Zero-g Level (V_{off})	Vs/2 +/- 10%	0.45Vs ~ 0.55Vs

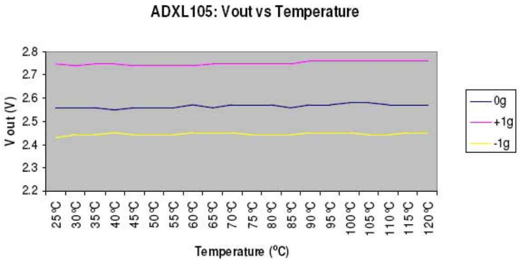

Figure 2: ADXL105 Thermal Test

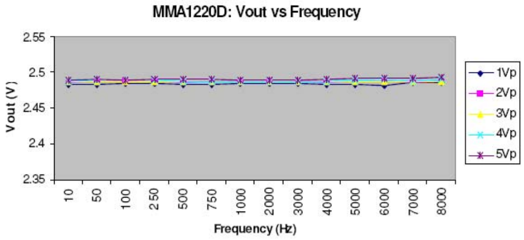

Figure 3: MMA1220D Acoustic Test

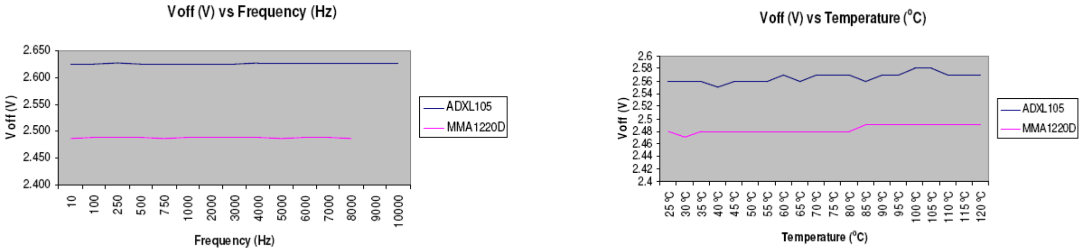

Figure 4: V_{off} vs Frequency and Temperature (when the device is at 0g)

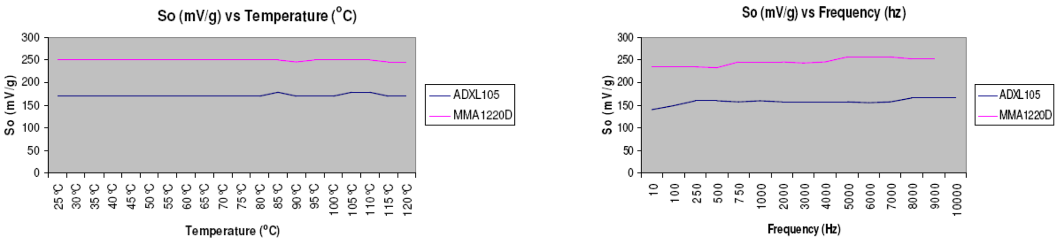

Figure 5: S_o vs Frequency and Temperature (when the device is at $\pm$ 1g)