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C3Or3B-03: A methodology for evaluating MEMS switch reliability at cryogenic temperatures

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Our goal is to develop testing methodologies to evaluate the performance and reliability of commercial off-the-shelf fully packaged MEMS switches for cryogenic applications. RF Micro Electro Mechanical Systems (MEMS) switches possess a number of advantages over conventional switches, such as lower insertion loss, high isolation and linearity, faster switching speed, smaller size, and very low power consumption. However commercially available MEMS switches are designed for room temperature operation and may exhibit several potential issues at cryogenic temperatures and with thermal cycling. When operated at cryogenic temperatures MEMS switches can have operational or reliability issues including material property changes, and temperature-induced thermal stresses, which can gradually affect the device's performance over time. Since commercial MEMS are enclosed in sealed packages, we developed experimental methods to evaluate and monitor the gradual changes in the MEMS structural behavior . We purchased a single-pole, four-throw, electrostatically actuated commercial MEMS switch. The switch is sealed in a ceramic package on a printed circuit board. Next, we mounted the board on a custom thermal adapter on a cryostatic chamber's cold stage. We cycled the cryostat from room temperature to around fifty degrees Kelvin in fifty-degree increments. Switch one had previously been tested at cryogenic temperatures and extensively tested at room temperature, as we had reported at CEC 2023. For this new set of tests, only switches one, two and three were operated at cryogenic temperatures. The fourth switch was also cycled through the temperature profile but was not operated below room temperature to serve as a control. Our team developed a set of four tests for the switches. The first test measured the resistance across a closed switch for one hour. Next, two types of hysteresis tests were performed, ramping power voltage to the switch from fifty to ninety volts and then back to fifty volts in one-volt increments. MEMS switches exhibit hysteresis, the voltage to turn on the switch (pull-down) is higher than the return voltage that opens the switch (pull-up). Two different measurements were made for the hysteresis tests. First, we measured resistance across the switch. Next, we measured a three-volt carrier voltage across the switch. For the final test, we cycled power to the switches at low frequency (0.5 Hertz) and measured residual voltage across the switch each time power was turned off. Our tests show that a single cooling cycle down to 55K was enough to induce subtle but permanent changes in a commercial MEMS switch's characteristics. Therefore, these tests may be used to help monitor fully packaged commercial MEMS switches for potential drift or damage accumulation. It is envisioned that these test methods and data may help to predict and thus avoid MEMS switch failures in applications involving cryogenic temperatures. Future work involves testing the MEMS to lower temperatures and performing high-cycle tests.

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