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J4Or1A-03: Characterizing MEMS Switch Reliability for Cryogenic Applications such as Quantum Computing

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Micro Electro Mechanical Systems (MEMS) switches possess many advantages over their bigger conventional counterparts, such as much smaller size, weight and power consumption. Being able to operate MEMS switches at cryogenic temperatures is critical for replacing conventional switches in superconducting circuits, which drive a range of applications from high-speed telecommunications to quantum computing. Implementing MEMS in a product or application can be cost-prohibitive, however, because in-house MEMS fabrication requires expensive precision tools, a highly controlled environment or "cleanroom", manpower to carry out the highly skilled labor-intensive fabrication and maintain the fabrication facility, and expertise in MEMS design and process design. These factors make MEMS components out of reach for many academic research programs and small companies. Alternative, commercial MEMS foundry services are also expensive and also require in-house MEMS design expertise. Therefore, commercial off-the-shelf MEMS devices play an important role in commercialization of the above cutting-edge technologies. However, commercial MEMS switches are designed for ambient conditions and as such there is little/no data available regarding their operation and performance at cryogenic temperature near and below 4 K. Research in the academic literature has focused on custom MEMS switches fabricated with exotic materials and more elaborate fabrication process, however, long-term cryogenic operation and repeated thermal cycling are still known to limit the device lifetime. Furthermore, because the commercial MEMS switches come fully packaged inside sealed housings which cannot be easily removed nondestructively, inspection of the switches accumulation of material/structural damage, which can alter the switches'operating characteristics, is not feasible. We are therefore developing the testing methodologies and system to evaluate the structural reliability of commercial off-the-shelf fully packaged MEMS switches for cryogenic applications, with a focus on quantum computing. Our test methods consist of DC and low-frequency tests which are informative of the switches'structural reliability, conducted at room temperature down to ~15 K. In this paper we present ambient performance data and cryogenic data for temperature below 80 K down to about 15 K. We also present information regarding the development of the repurposed GM-type cryostat to perform these characterizations. This data will inform our understanding of the commercial MEMS switch reliability and provide guidance for switch damage-mitigation strategies during implementation in advanced cryogenic application such as quantum computing.

Key words: cryogenic, MEMS - Micro Electro Mechanical System, MEMS switch, structural reliability

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