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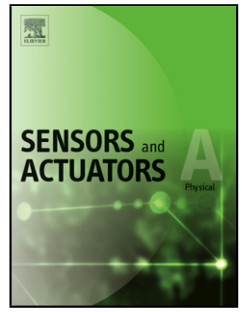

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A Novel Comprehensive Approach to Feedback Control of Membrane Displacement in Radio Frequency Micro-electromechanical Switches

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***Abstract*— In this work, a novel feedback control technique for MEMS switch membrane is presented. Due to difficulties associated with measurement of membrane displacement, the capacitor current is used as the controller feedback signal. System identification is utilized to construct a transfer function relating Membrane displacement to capacitor current. Accelerating electrostatic pulse is utilized to accelerate the membrane at the start of the closing stage while a two degree-of-freedom, proportional-integral-derivative control is implemented and tuned to attain soft landing of the membrane on the electrode. The proposed technique eliminates membrane impact bouncing, reduces switch closing time, and improves the durability and reliability of the switch. The technique also improves the membrane transient response during pull-in and release stages. Simulation of the structural model dynamics shows good agreement with experimental results. The proposed technique achieved 200% increase in switch closing speed, 100% reduction in impact bouncing, 75% reduction in release overshoot, and an average of 55% reduction in membrane settling time at zero electrostatic voltage. The proposed model is benchmarked against experimental data, while the control technique is validated via simulation.**

***Index Terms*— RF-MEMS Membrane Displacement, Squeeze Film Damping, Feedback Control, 2DoF PID**

I. Introduction

Modeling of radio frequency (RF) micro-electromechanical systems (MEMS) switches is critical for the understanding of their behavior during operation. In general, adequate modeling of RF MEMS switches involves two sub-models: An electrical model of its circuit and a mechanical model of its structural dynamics. Several electrical models for different types of RF MEMS switches are available in the literature [1]. Mechanical models, however, have not achieved the same level of maturity as their electrical counterparts, mainly due to the complexity of such micro scale switches. Those switches usually include submicron gaps as well as fluid-structure interaction between gas and membrane. In most related research work, mechanical models are often simplified, and as a result, it is less representative of the actual behavior of RF MEMS switches [2]-[4]. Extended life and reliable operation of RF MEMS switches can be achieved through proper control of its dynamics, knowing that dynamic loading and related stresses are the root cause of its failure. Excessive vibration of the membrane can lead to undesirable impact forces, high stresses, and sluggish operation. The potential to enhance the reliability of those switches through the elimination of electrode bouncing, or the reduction of bouncing speed, is desirable [5]. The main problems associated with real-time active control of RF MEMS switches are the switch size, and the difficulties associated with obtaining feedback measurement of switch membrane position.

Currently, a practical and economically viable transducer that can provide the necessary displacement measurements needed for the effective control of membrane's position is not available. Several approaches have been reported on the control of RF MEMS switches dynamics [6]-[7]. These switches are desirable because they consume significantly less power than their solid state counterparts. They also have better linearity and power handling capabilities [8]. Therefore, the ability to control such switches will not only increase their lifetime, but will also allow for their use in equipment with stringent reliability requirements such as satellites, avionics systems, navigation and guidance systems, etc. However, to control these switches efficiently, control systems require, in addition to reliable feedback measurements, an accurate model of the MEMS device. This is crucial for durability and proper operation of the switch.

Extensive research is being carried out to construct reliable and accurate models of RF-MEMS switches. This is due to model's importance in determining the switching time, transient characteristics [1], and built-in energy dissipation mechanisms [2]. Furthermore, significant research effort has focused on modeling the effect of squeeze film (SF) on the switch dynamics, and the