Novel Analytical Model for Optimizing the Pull-in Voltage in a Flexured MEMS Switch Incorporating Beam Perforation Effect

K. Guha, N.M. Laskar, H.J. Gogoi, A.K. Borah, K.L. Baishnab, S. Baishya

PII: S0038-1101(17)30022-9
DOI: http://dx.doi.org/10.1016/j.sse.2017.08.007
Reference: SSE 7295

To appear in: *Solid-State Electronics*

Received Date: 11 January 2017
Revised Date: 15 June 2017
Accepted Date: 27 August 2017

Novel Analytical Model for Optimizing the Pull-in Voltage in a Flexured MEMS Switch Incorporating Beam Perforation Effect

K. Guha[1], N. M. Laskar[2], H. J. Gogoi[3], A. K. Borah[4], K. L. Baishnab[5], S. Baishya[6]
[1,2,3,4,5,6] *Department of Electronics and Communication Engineering,National Institute of Technology,* Silchar,
Assam - 788010, INDIA

Abstract

This paper presents a new method for the design, modelling and optimization of a uniform serpentine meander based MEMS shunt capacitive switch with perforation on upper beam. The new approach is proposed to improve the Pull-in Voltage performance in a MEMS switch. First a new analytical model of the Pull-in Voltage is proposed using the modified Mejis-Fokkema capacitance model taking care of the nonlinear electrostatic force, the fringing field effect due to beam thickness and etched holes on the beam simultaneously followed by the validation of same with the simulated results of benchmark full 3D FEM solver CoventorWare in a wide range of structural parameter variations. It shows a good agreement with the simulated results. Secondly, an optimization method is presented to determine the optimum configuration of switch for achieving minimum Pull-in voltage considering the proposed analytical mode as objective function. Some high performance Evolutionary Optimization Algorithms have been utilized to obtain the optimum dimensions with less computational cost and complexity. Upon comparing the applied algorithms between each other, the Dragonfly Algorithm is found to be most suitable in terms of minimum Pull-in voltage and higher convergence speed. Optimized values are validated against the simulated results of CoventorWare which shows a very satisfactory results with a small deviation of 0.223V. In addition to these, the paper proposes, for the first time, a novel algorithmic approach for uniform arrangement of square holes in a given beam area of RF MEMS switch for perforation. The algorithm dynamically accommodates all the square holes within a given beam area such that the maximum space is utilized. This automated arrangement of perforation holes will further improve the computational complexity and design accuracy of the complex design of perforated MEMS switch.

Keywords: Pull-in Voltage, non-uniform meander, ligament efficiency, perforated switch , RF MEMS, Optimization, Evolutionary Algorithms, Dragonfly Algorithm.

1. Introduction

In recent times, MEMS switches are becoming more popular in various fields ranging from telecommunication devices, military appliances, biomedical instruments, and many other micro structures [1]-[3]. Gradually, it has been replacing its traditional counterparts such as PIN diode, FET switches, and other mechanical switches owing to its advantages of low power consumption, high reliability, and less manufacturing costs [4][5]. Though the electrostatic actuators are most commonly used as they are easy to fabricate and represent but they are limited by the requirements of high actuation voltage and slow switching time as compared to PIN diodes, FET etc. [6]. Of course, they possess several non-linearities and instabilities due to their inverse relation with the square of the distance between two electrodes [7]. When the switch is actuated from ON state to OFF state at a certain distance, known as critical distance, the moving electrode suddenly snaps down to the other and the corresponding actuation voltage is called Critical Voltage or Pull-in Voltage. A small value of pull-in voltage is desired as it reduces the complexity of voltage down conversion during IC integration of MEMS switch.

Corresponding author at: Koushik Guha, NIT Silchar, Assam, INDIA
E-*mail* address: koushikguha2009@gmail.com
Tel.:+91 9435072274.

Here it is achieved by incorporating designs with small microbeam rigidity i.e. beams with small spring stiffness using serpentine configuration of suspension beam [7]-[8].