

Most Efficient Design Methodology of DC-Contact MEMS Shunt Switch

Neeraj Devarari, Shivika

Low Power VLSI Researcher, Electronics and Communication Department,
Faculty of Technology, Uttarakhand Technical University, Dehradun, Uttarakhand, INDIA.

Abstract: Design of electronics circuit is an indispensable requirement for any high speed, high throughput, digital system, and DSP or Control System. The primary issues in design are area, delay, at the same time low power consumption. Optimization of several devices for their speed, high density & power is deal with low-voltage & low power application, which is overcome by incorporating MEMS. This paper is mainly presents the designing methodology of DC-Contact MEMS Shunt Switch with efficient graph of isolation and reduces the return loss.

Index Terms : MEMS, DC-Contact, Low Power, Digital Signal Processing (DSP), Delay.

I. Introduction

MEMS - Micro Electro Mechanical Systems also known as micro-system or micro-fabrication technology. That is the part of 'miniaturization engineering', which is a multi-disciplinary approach to enable fabrication of 3-dimensional mechanical structures, devices and systems. At least with one of the dimensions in microns or less. The emerging concept is based on the available micro-manufacturing options, material properties and the scaling laws referred to the application under investigation [2]. As the name implies the *micro* establishes the dimensional scale, *electro* suggests either electricity or electronics or both and *mechanical* implies 'moving' device components with degrees of freedom in translation, rotation, tilt or a combination of the either [3].

II. DC-Contact Switch at a glance

A. Basic Concept-

DC-contact shunt switches are similar to MEMS capacitive shunt switches except that a separate electrode is used to pull the membrane to the down-state position. Therefore, it is possible to result in a metal-to-metal contact between the t-line and the ground plane without the electrostatic forces on the switch. The design of RF MEMS switches has reached a mature level with many dc-contact series and capacitive shunt switches available today. The dc-contact series which provides high isolation at 0.1–26 GHz, while the capacitive contact shunt switch with silicon nitride or silicon dioxide provides excellent isolation at 10–120 GHz. In certain cases, a high-dielectric constant material such as Strip is used in the capacitive switch resulting in high isolation at 1–10 GHz. An alternative switch is the dc - contact shunt switch.

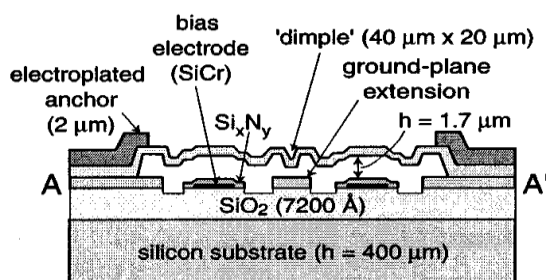


Fig.1 basic DC Shunt switch

III. Physical description of mems shunt switch

A. Basic Structure-

A MEMS shunt capacitive switch is shown in figure follows. The switch geometry follows the same definitions. The switch is suspended on a height g above the dielectric layer on the transmission line and the dielectric thickness with a dielectric constant [8]. The switch is L μm long, w μm wide, with a thickness of t μm . the width of the transmission line is W μm . the substrate can be silicon, GaAs Alumina, LTCC, or a quartz dielectric.

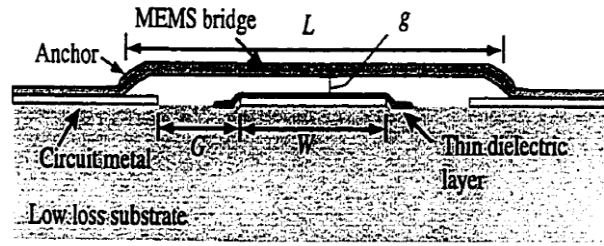


Fig.2 Basic MEMS structure[8]

The applications of the MEMS technology in the radio frequency regime, mostly referred to as RF MEMS, are more recent as compared to the application areas mentioned above. The first MEM switch designed specially for microwave applications was reported in 1990 [2]. At present, RF MEMS devices such as switches or relays, tuneable capacitors or varactors, high Q inductors, resonators and filters, which constitute the 'fundamental building blocks' of radio frequency applications, are the most vigorously pursued MEMS devices by academic and industrial research communities.

TABLE II: Comparison among different technologies[5]

Parameter	RF MEMS	PIN	FET
Voltage(V)	10 – 80	±3 – 5	3 – 5
Current(mA)	0	3-20	0
Power consumption	0.05 – 0.1	5-100	0.05-0.1
Switching Time	1 - 300μS	1 - 100nS	1 - 100nS
C _{up} (Series)(fF)	1 – 6	40-80	70-140
R _s (Series)(Ω)	0.5 – 2	2-4	4-6
Capacitance Ratio	50 – 500	10	NA
Cut off Frequency	20 – 80	1 – 4	0.5 – 2
Isolation(1- 10 GHz)	Very High	High	Medium
Isolation(10-40GHz)	Very High	Medium	Low
Loss(1-100 GHz)dB	0.05 - 0.2	0.3 - 1.2	0.4 - 2.5

B. S-parameter for shunt switch-

The S-parameters are first measured in the up-state position and the measured data (S_{11}) is fitted to get the up-state capacitance of the switch.[4]

$$S_{11} = \frac{-j\omega C_u Z_0}{2 + j\omega C_u Z_0}$$

The S-parameters are measured with the switch in the down-state position, and a CLR model is fitted to the measured data (S_{21})-[4]

$$S_{21} = \frac{1}{1 + j\omega C_d Z_0/2}$$

IV. Modeling of a dc-contact shunt switch

A. Steps in HFSS Tools to perform the tasks in HFSS:

1. Draw a geometric model.
2. Modify a model's design parameters.
3. Assign variables to a model's design parameters.
4. Specify solution settings for a design.
5. Validate a design's setup.
6. Run an HFSS simulation.
7. Create a 2D x-y plot of S-parameter results.
8. Create a field overlay plot of results.
9. Create a phase animation of results.

V. Designing of dc contact shunt switch with HFSS tool

1- Flow chart of bottom wafer formation:

3D modeler--> unit--> μm

- Insert HFSS design:

To Select BOX Draw--> box_1--> assign position (x,y,z), assign value [length(dx), width (dy), height (dz)].

Position: (0, 0, 0), Value: (1000,800,400) μm 3D modeler window--> Attribute Material select--> GaAs

- For Height: For wafer quartz substrate: 400 μm .
- To use the Tab key to assign position and value of box dimension.[1]

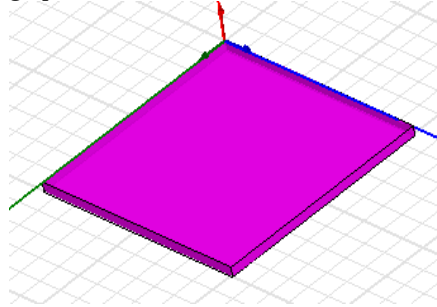


Fig. 3 3D bottom wafer

2. Silicon di oxide layer formation:

- Select BOX Draw_2 --> assign position (x,y,z), assign value [length (dx),width (dy), height (dz)]. Position: (0,0,400), Value: (1000,800,3.6) μm
- Select BOX Draw _2 --> assign position (x,y,z), assign value [length (dx), width (dy), height (dz)]. Position: (0,0,400), Value: (1000,800,3.6) μm
- Select BOX _2--> 3D modeler window--> Attribute Material select-->Silicon di oxide (3.6 μm).

3. Ground plane of Cpw formation:

- Select BOX Draw_5 --> assign position (x,y,z), assign value [length (dx), width (dy), height (dz)]. Position: (0,0,403.6), Value: (1000,290,2.5) μm .
- Same ground plane can be duplicated at either side of the top wafer:
Select BOX_6 --> assign position (x,y,z), assign value [length (dx), width (dy), height (dz)]. Position:(0,510,403.6), Value: (1000,290,2.5) μm .
Select BOX_5,6 -->3D modeler window--> Attribute Material select--> perfect conductor.

4- Transmission line formation-

Select BOX Draw_7--> assign position (x,y,z), assign value [length (dx), width (dy), height (dz)]. Position: (0,350,403.6)mm, Value: (1000,100,2.5) μm .

3D modeler window--> Attribute Material select--> perfect conductor.

5- coaxial pair formation-

- Select cylinder Draw_1--> Radius (R) =50 μm , Height (H) =-70 μm , position (0,400,403.6) μm
- Inner coaxial cable-
3D modelar window--> Grid Plane --> YZ plane, axis = x
3D modelar window--> Attribute Material select--> perfect conductor
- outer coaxial cable-
Centre position (1000,400,403.6) μm
Select cylinder and similarly Draw_12 as cylinder 11--> Radius (R) =80 μm , Height(H) =70 μm
3D modelar window--> Attribute Material select--> Teflon Based
- Take YZ plane.
- To draw the cylinder put the curser at the side wall of the cpw's center point.
- There are two inner coaxial cables,one for input port and other for output port.

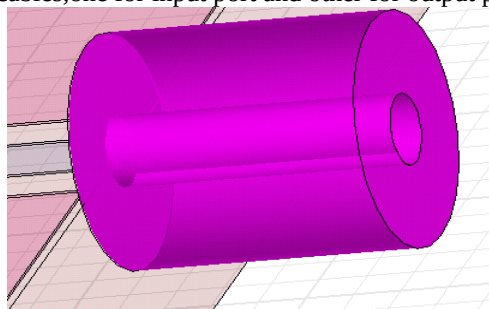


Fig.4 Coaxial cable [6]

- Subtract inner coaxial from outer coaxial pair:
Select BOX_11, 12 --> 3D modeler--> Boolean --> subtract (11 from 12) with clone.
This will be like as-

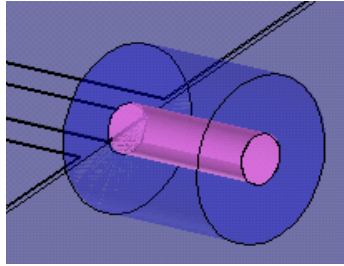


Fig. 5[6]

6- Formation of BRIDGE-

Select BOX Draw_7--> assign position (x,y,z), assign value [length (dx), width (dy), height (dz)]. Position: (450,150,426.11) μm , Value: (100,500,10) μm .

3D modeler window--> Attribute Material select--> perfect conductor.

- Save Modal.
- 7- HFSS main window after design-

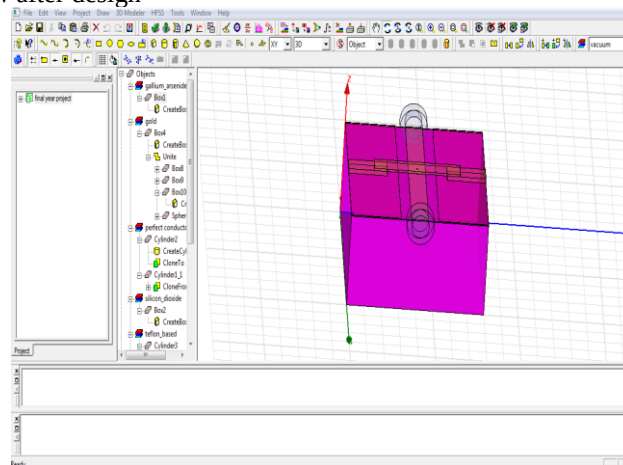


Fig. 6 Full structure view of DC MEMS SWITCH

8- Assign wave port-

- For wave port 1-
HFSS --> Excitations--> Assign--> Wave port 1--> Next--> Integration line--> New line--> draw new line--> Next --> Renormalize--> Finish.
Right click --> select face--> select the sides face of outer coaxial pair
- For wave port 2-
HFSS --> Excitations--> Assign--> Wave port 2--> Next--> Integration line--> New line--> draw new line--> Next --> Renormalize--> Finish
Right click --> select face--> select the sides face of outer coaxial pair of another port.

9- Simulation of device:

CHECK MOD-HFSS --> Validation check--> 3D modal is correct

- Define solution type-
HFSS --> Solution type--> Driven modal--> ok
- Analysis step-
(A) HFSS --> Analysis setup --> Add Solution setup --> General--> Solution frequency
1. Use general solution setup for only for general solution setting not for any other option.
2. HFSS uses solution frequency as the center frequency if it is within the frequency range.
3. Maximum no. of passes is 6 to get good convergence.
(A) HFSS --> Analysis setup --> Add sweep--> select window-ok--> Edit sweep window-->Type - Linear type--> Fill the min. and max. Range of frequency --> fill step size.
Enter the number of modes must be greater than 0 and less than 20.w

10- STEP TO PLOT THE GRAPH:

- HFSS--> Result --> Create report--> Report type-Model simulation data--> ok--> Traces window Category- S parameter--> Quantity- S_{11} , S_{21} --> Add trace--> Done
- Display type – Choose Rectangular plot to get rectangular graph or Data table to get the table.

VI. Output from the HFSS tool

The losses can be view in the graph-

FOR S_{21} - Isolation-

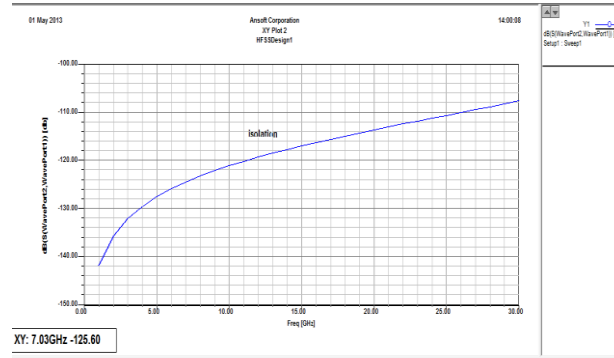


Fig. 7 Isolation graph

FOR S_{11} - Returnloss-

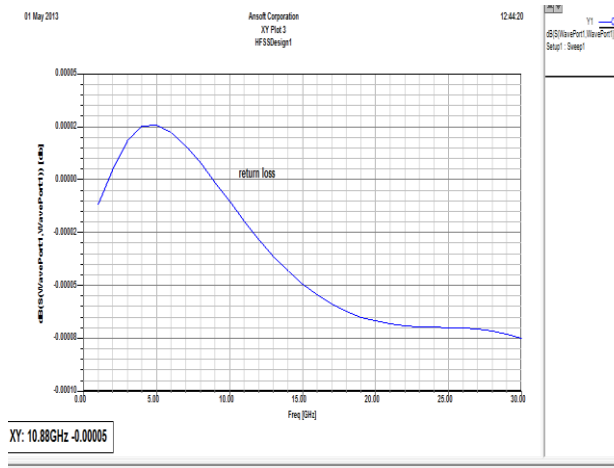


Fig. 8 Returnloss graph

VII. Conclusion and Future Work

HFSS is a high performance full wave electromagnetic (EM) field simulator for arbitrary 3D volumetric passive device modeling that takes advantage of the familiar Microsoft Windows graphical user interface. It integrates simulation, visualization, solid modeling, and automation in an easy to learn environment where solutions to your 3D EM problems are quickly and accurately obtained. Ansoft HFSS employs the Finite Element Method (FEM), adaptive meshing, and brilliant graphics to give you unparalleled performance and insight to all of your 3D EM problems.

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