Application of MEMS Tunable Capacitor for RF VCOs

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Abstract

In this work, a voltage control oscillator is used to characterize a MEMS tunable capacitor. The upper plate of the capacitor rises above the surface of the substrate and as a result, the gap between the two plates of the parallel-plate capacitor gets bigger or smaller. Therefore the capacitance changes. A brief description of fabrication process for the variable capacitor is also presented. HSIPCE is used to measure Q, and the result shows that the capacitor presented in this paper is not suitable for VCO design.

Introduction

Variable RF capacitors are major control components of high frequency receivers and transmitters. Also, variable capacitors are largely used for designing voltage control oscillators, which themselves are main components of phase lock loops (PLLs). If the output frequency of an oscillator varies by a voltage, then the circuit is called "VCO" [5]. Almost all VCOs use off-chip tank capacitances to control the frequency. The schematic of a tank capacitance is shown in figure 1. Having a tank capacitance means that some off-chip circuitry is required. Therefore more fabrication is required and the overall cost of the design increases. Also, having off-chip circuitry adds to the complexity of the design and there are reliability issues that need to be addressed. In addition, many of the today's passive RF components have big sizes [4]. Therefore a monolithic design for passive devices can help to

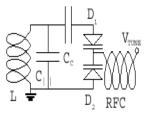


Figure 1: Tank Capacitance

reduce the negative effects mentioned above.

Theory and Design

Capacitance can be varied by either changing the dielectric thickness or by changing the overlapping area between the two parallel plates. This is in accordance with the equation (E1) assuming a constant dielectric.

The design used in this work is based on the Micro-Elevator for Self-Assembly (MESA) [4]. In this method, the dielectric (air for this design) thickness is changed in order to make a variable capacitor. Three surface micro-machined plates are connected to each other using hinges as shown in figure 2 (the other two sides of the middle plate are also connected to two plates for better support but they are not shown in figure 2 for simplicity). Two electrostatic actuators (comb-drives) are biased such a way that they move towards each other with the same speed. As a result, the top plate of the capacitor rises above the surface (max height is 250µm from surface) of the silicon and consequently the gap between the two plates widens. The bottom plate of the capacitor is stationary. The entire process is shown in figure 2.

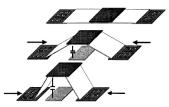


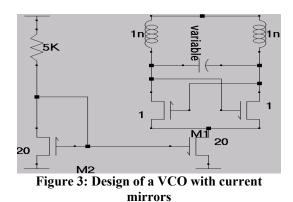
Figure 2: The variable capacitance process

Fabrication Process

The standard MUMPS process will be used to fabricate the variable capacitor. MUMPS is a three-layer polysilicon surface micro-machining process.

Results and Conclusion

The designed capacitor is used in the circuit shown in figure 3. HSPICE simulation shows that the Q value of 15 at 950MHZ is achieved. The obtained for value of Q is very low compare to other designs [1], [7].



Lateral actuation of the comb-drives, which is transferred to the upper plate's vertical movement, causes the Q to drop. Also, contact resistance between the hinges reduces the Q [4]. The main problem with this design is the variation of the capacitance. Because the inverse relationship between the capacitance and the dielectric thickness, the capacitance variation is huge (500fF-25fF) [4]. Consequently the variable capacitance is not suitable for finetuning. Fine-tuning is required for the voltage control oscillator. Some changes to the design will improve the value of Q. For example, using thermal actuator instead of comb-drive theoretically improves the Q. Since thermal actuator can be used to move the upper plate up without any lateral

movement, the hinges can be eliminated from the design. As a result, the hinge resistance is eliminated from the design. Also, by using a 2-D actuator, instead of changing the dielectric thickness, the overlapping area between the two parallel plates can be changed. Referring to (E1), area is linearly proportional to the capacitance; therefore huge variation of capacitance can also be eliminated. Other designs have been demonstrated for the variable capacitor [1], [2], [3], [7].

Acknowledgement

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Reference

- A. Mohamed, H.Elsimary, M.Ismail, "Design of MEMS Tunable Capacitor all Metal Microstructure for RF Wireless Application," Analog VLSI Lab, Ohio State University
- K.F.Harsh, W.Zhang, V.M.Bright, Y.C.Lee, "Flip-Chip Assembly for Si-Based RF MEMS," Department of Mechanical Engineering,

University of Colorado, Boulde.

- C.L.Goldsmith, A.Malczewski, Z.J.Yao, S.Chen, J.Ehmke, D.H.Hinzel, "RF MEMS Variable Capacitor for Tunable Filters," Raytheon Systems Corporation, Dallas, Texas
- 4. L.Fan, R.T.Chen, A.Nespola, M.C.Wu, "Universal MEMS Platforms for Passive RF Components: Suspended Inductor and Variable Capacitors," Department of Electrical Engineering, University of California, Los Angeles
- B.Razavi, "RF MICROELECTRONICS," Prentice Hall Communication Engineering and Engineering Technologies Series, 1998
- D.J.Young, B.E.Boser, "A Micromachined Variable Capacitor for Monolithic Low-Noise VCOs," Solid-State Sensor and Actuator Workshop, Hilton Head Island, SC, June 3-6, 1996