Typical questions for an oral examination in IN5490 RF MEMS, 2009

1 : Modeling a parallel plate capacitor and pull-in effect
Draw a sketch of a spring-suspended two-plate capacitor.
Which forces are involved when you put on a voltage between the plates?
When does pull-in occur and why? Explain why hysteresis arises.
Give examples of RF MEMS components where this effect is an advantage or a disadvantage?

2: Modeling of spring-mass-damper
Draw a sketch of a typical spring-mass-damper system.
Set up the transfer function. Which physical parameters determine the resonance frequency and Q-factor of the system?
Show an electrical equivalent to the mechanical system?

3: RF transmission
Why do you need to use transmission lines for connecting components at RF?
If you have a lossless transmission line with characteristic impedance Z0 and load Z_load, how can you obtain a maximum signal transmission to the load?
What happens in case of an open or shorted line?

Suppose a MEMS contact switch is placed serially in a transmission line having a characteristic impedance of Z0 before and after. Compute the reflection (return loss) of the signal when the switch is open (not conducting).

4: Serial contact switch
Make a sketch on how you can implement a serial contact switch by a cantilever beam? Describe the operation.

Discuss and comment important, critical design parameters for the switch:
contact resistance
contact capacitance
pull-in voltage
stiffness of beam
actuation voltage
damping
material choices
using common or separate actuation electrodes with respect to the signal path
aging

5: Shunt capacitive switch
Describe the structure and operation of a shunt capacitive switch of type c-c beam.

Discuss and comment some of the important, critical design parameters for the switch:

thickness and type of dielectric material
gap
area of overlapping electrodes
pull-in voltage
control electrodes separated from the signal path
damping
material selection and stiffness of beam
aging
suspension arrangements

Which factors would influence the switching speed?

6: MEMS phase shifter
In which cases can a MEMS phase shifter be useful?
How can you implement a 2-bit digital MEMS phase shifter?

How can you implement a phase shifter based on distributed MEMS capacitances?
Which parameters determine the obtainable phase shift?

Describe the operation of a reflection phase shifter. What are the benefits?

7: c-c beam as resonator
Describe the structure and operation of a c-c beam used as a resonator.
Why do you put on a DC voltage on the resonator beam? What is the effect?

Which factors will influence the Q-factor of the c-c beam resonator and how can you increase the Q-factor?
How can you increase the resonating frequency?

8: Lateral comb resonator
Describe the structure and operation of a lateral comb structure used as a resonator.
Why do you put on a DC voltage on the shuttle? What is the effect?

Which parameters are critical for obtaining a high resonance frequency?

9: free-free beam as resonator
Describe the structure and operation of a free-free beam used as a resonator.
What are the advantages of using an f-f- beam compared to a c-c- beam?

Which are the critical parameters for implementing an f-f- beam with optimal performance?

10: H-filter
Describe the structure and operation of a micromechanical filter implemented as an H-structure.

Which factors determine the frequency and bandwidth of the H-filter? Describe a typical procedure for designing such a filter, and how can the bandwidth of the filter be changed in an easy way?

11: Mixer-filter structure
Describe a combined mixer-filter structure.
Which are the main design parameters and how do they influence the operation?

How can the mixer-filter block be used in a general RF transceiver?

12: MEMS filter bank
Describe the structure and operation of an RF MEMS filter bank. What are the advantages and disadvantages of using such a filter bank?

13: Gap-tuning of MEMS capacitors
What are the main methods for tuning a RF MEMS capacitor?

Describe how a 2 plate tunable MEMS capacitor can be used as a tunable capacitor. What are the restrictions, and which tuning ratio can be obtained?

Describe how a 3 plate tunable MEMS capacitor can be implemented? What are the restrictions, and which tuning ratio can be obtained?

How does a tunable double air-gap MEMS capacitor function? How can you get the maximum tuning range out of such a structure? Describe principal features of an implementation.

14: Tunable comb capacitor
Describe the structure and operation of a tunable comb capacitor. What are the benefits of using such a structure compared to gap tuning? Which constraints do you see?

15: Planar RF MEMS inductor
How can MEMS inductors be implemented in the plane (2-dimensional inductor)?
Draw an equivalent circuit diagram of an RF MEMS inductor and discuss the various parasitic contributions. How can the stray components (parasitics) be reduced?

16: Integration of MEMS and IC
How can you combine MEMS and integrated circuits on a single chip (monolithic integration)? Describe typical advantages and disadvantages of main procedures.

17: RF transceiver
Describe the typical parts of an RF transceiver.
What are the current bottlenecks for miniaturization?
Where can RF MEMS replace current components in a receiver block?

Which advantages can be obtained? What are the restrictions?

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