Typical questions for an oral examination in IN5490 RF MEMS, 2008

Q1: Micromachining
What are the main differences between bulk and surface micromaching? Describe the main steps for implementing a polySi c-c beam with an underlying electrode of polySi.

Which problems do you see when removing the sacrificial layers, and how can the problems be avoided?

Describe the typical features of a RIE etch compared to an isotropic or anisotropic wet etch.

Q2: Modeling a parallel plate capacitor
Which forces are involved when you have a spring-suspended plate capacitor and put on a voltage between the plates? What happens when you increase the voltage?

Q3: Modeling of spring-mass-damper
Set up the transfer function of a spring-mass-damper system. Which physical parameters determine the resonance frequency and Q-factor? What is a corresponding electrical equivalent?

Describe some central features of analyzing MEMS devices by using Finite Element Methods compared to other methods. What are the advantages and drawbacks?

Q4: Pull-in effect
What is the pull-in effect? For which RF MEMS components can this effect be an advantage or disadvantage?

How does the pull-in effect influence the operation of MEMS switches (contact, capacitive)? Explain why hysteresis arises.

Q5: Energy domains
Which corresponding effort and flow parameters do you have for different energy domains? How can you benefit from using such equivalents?

How do you transfer mechanical components to electrical equivalents?

In which cases can you replace a general electromechanical transducer with a simple transformer? What determines the turn ratio of the transformer in the case where the transducer is a two-plate capacitor?

Q6: RF transmission
Describe typical features of the propagation at RF signals compared to low frequency transmission?

How do you define the characteristic impedance of a transmission line and what does that parameter tell you? 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).

Q7: Serial contact switch
How can you implement a cantilever beam serial contact switch?

Discuss important and critical design parameters for the switch. Which influences have material choice, separate activation electrodes, contact resistance and capacitance, damping, activation voltage, aging?

Compute the signal insertion loss if the switch is ON (conducting) when the characteristic impedance for the transmission line is Z0 both before and after the switch.

Q8: Shunt capacitive switch
Describe the structure and operation of a shunt capacitive switch of type c-c beam.

Discuss some of the important and critical design parameters for the switch, e.g. separate control electrodes, overlapping electrode area, activation voltage, damping, gap, pull-in voltage, dielectric material, suspension, material selection?

Which factors would influence the switching speed?

Compute the reflection (return loss) when the shunt capacitive switch is OFF (not conducting RF) if it is placed in a transmission line having the characteristic impedance of Z0 both in front of and after the switch.

Q9: MEMS phase shifter
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?

Q10: 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?

What is the relation between the displacing force on the beam and the applied voltage? Why do you usually want to linearize this expression? How can that be done?

Describe essential factors which influence the damping of a c-c beam.

How can you increase the Q-factor of the c-c beam resonator? How can you increase the resonating frequency?

Q11: 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?

How can the comb resonator be used as an oscillator?

Q12: Modeling a comb resonator
Describe the principal features of how you can transfer a comb resonator from a mechanical description to an electrical domain by using the electromechanical coupling coefficient.

Q13: free-free beam and disk as resonators
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?

Describe how a disk resonator can operate. What are the critical design parameters? What are the advantages compared to using a beam resonator?

Q14: H-filter
Describe the structure and operation of a micromechanical filter implemented as an H-structure. How can you model the system?

Which factors determine the frequency and bandwidth of the H-filter? Describe a typical procedure for designing such a filter.

How can the bandwidth of the filter be changed in an easy way?

Which factors determine the operational performance of the filter?

Q15: Mixer-filter structure
Describe how the H-filter can be used to implement a combined mixer-filter structure. Which signal processing can be done? Which design parameters are central?

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

Q16: MEMS filter bank
Describe the structure and operation of an RF MEMS filter bank. What are the advantages and disadvantages of such a filter bank?

Q17: Q-factor
How is the Q-factor defined?

How can you define the Q-factor for an RF MEMS filter, capacitor and inductor?

How does the Q-factor influence the stability of a resonating tank? What is the difference between a high and low Q-factor for a tank used in the feedback loop of an oscillator?

Describe some of the factors influencing the Q-factor if a resonator is implemented as a c-c beam, an f-f- beam or as a Radial Contour Mode Disk?

Q18: Gap-tuning of MEMS capacitors
What are the main methods for tuning a RF MEMS capacitor?

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.

Q19: 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?

How can you use temperature as a tuning mechanism for capacitors?

Q20: Planar RF MEMS 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?

How can MEMS inductors be implemented in the plane (2-dimensional inductor)?

Q21: Increasing RF MEMS inductor performance
Which mechanisms do you have for increasing the L-value (inductance) of a MEMS inductor? Then, how are the Q-factor and self-resonance frequency influenced?

Why would you want to elevate inductors above the ground plane? Describe an example.

Q22: Skin-depth
Describe what happens with the AC current distribution in electrical conductors when the frequency is increased. What is skin-depth, and how does this effect come into effect when implementing RF MEMS inductors?

How can the effect of skin-depth be minimized for inductors?

Q23: RF MEMS packaging
Which factors make packaging of RF MEMS more challenging than packaging of IC circuits? What do you need to take into account?

What are “Microcaps”? Why and how can they be used?

Q24: Integration of MEMS and IC
How can you combine MEMS and integrated circuits on a single chip (monolithic integration)? Describe typical features (+/-) of the main procedures.

Describe an example of a post-CMOS procedure.

Q25: RF transceiver
Describe the typical parts of an RF transceiver. What are the current bottlenecks for miniaturization and where can RF MEMS replace current components?

Which advantages can be obtained? What are the restrictions?

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