Typical questions for an oral examination in IN5490 RF MEMS, 2011

(for PhD candidates, taking INF9490, see additional questions at the end of the list!)

1 : Modeling of RF MEMS

- Which are the basic modeling methods that can be used in RF MEMS design?
  - What are the characteristic features of the methods?
- Describe the analytic modeling of a parallel plate capacitor and the 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 the pull-in effect is an advantage or a disadvantage? Why?

2: Serial contact switch in an RF signal transmission line

- Make a sketch on how you can implement a serial contact switch by a cantilever beam?
- Describe the operation of the switch.
- Describe and discuss the following design parameters:
  - Using common or separate actuation and signal electrodes
  - The relation between pull-in voltage, actuation voltage, stiffness of beam and damping with respect to operation and switching speed
  - How to reduce damping
  - Effect of the contact resistance and the contact capacitance
  - Influence of material selection for the different parts
  - Influence of aging, - realiability issues

- RF switch used in an RF transmission line:
  - 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 with the signal in case of an open or shorted transmission 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).

3: Shunt capacitive switch and phase shifters

- MEMS shunt capacitive switch:

    - Make a sketch on how you can implement a shunt capacitive switch of type c-c beam.
    - Describe the operation of the switch.
- Discuss and comment some of the important, critical design parameters for the switch:
    - Using common or separate actuation and signal electrodes
    - Thickness and type of dielectric material used for the capacitive switch
    - Gap dimension
    - Area of overlapping electrodes
    - The relation between pull-in voltage, actuation voltage, stiffness of beam and damping with respect to operation and switching speed
    - How to reduce damping
    - Influence of material selection for the different parts
    - Influence of aging and realiability issues
    - Suspension arrangements

- MEMS phase shifters:
    - In which applications 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?

4: Beam resonators

- c-c beam as a 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?

- free-free beam as a 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?

5: Comb resonator and spring-mass-damper modeling

- Lateral comb resonator:
    - Describe the structure and operation of a lateral comb resonator.
    - Why do you put on a DC voltage on the shuttle? What is the effect?
    - Which parameters are critical for obtaining a maximum resonance frequency?

- 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 of the mechanical system?

6: MEMS filters

- H-filter structure:
  - 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?

- Mixer-filter structure:
  - Describe a combined mixer-filter structure.
  - Which are the main design parameters for this system, and how do they influence the operation?
  - How can the mixer-filter block be used in a general RF transceiver?

7: Tunable MEMS capacitors

- What are the main methods for tuning an RF MEMS capacitor?
- Describe how a 2 plate 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.

- Tunable comb capacitors:
  - 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?

8: RF MEMS inductors

- How can MEMS inductors be implemented?
  - Give examples of in- plane (2-dimensional inductor) and 3D implementations.
- Draw an equivalent circuit diagram of an RF MEMS inductor and discuss the various parasitic contributions.
  - How can the stray components (parasitics) be reduced?

- Which are the basic performance parameters of the RF MEMS inductors?
  - Describe important means for increasing the performance.

9: 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 the main procedures.

- Describe how MEMS can be made out of ordinary CMOS processes (CMOS-MEMS).
    - What are the typical features for the CMOS-MEMS procedure used at Carnegie Mellon University (ASIMPS)?
    - Which advantages and disadvantages do you see?

10: RF receiver

- Describe the typical parts of an RF receiver.
    - 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?

- 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 in a receiver?
    - Which possibilities do you see for realization?

Additional questions for an oral examination in INF9490 RF MEMS, 2011

Give examples of various ways of implementing vibrating disk resonators and some of the benefits and problems with the structures.

What is the problem with the motional impedance level for vibrating resonators, and how can a designer overcome this?

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