Typical questions for an oral examination in IN5490 RF MEMS, 2010

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?

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