

EK2360 Lecture: Basics of MEMS Actuator Design

YOUR NAME

Section 1 - Short introduction to MEMS

Tag the correct answers (multiple correct answers possible)

- ☐ bulk micromachining is building up and structuring layers ontop of a substrate
- ☐ surface micromachining etches structures into the substrate
- ☐ SOI means silicon-on-insulator

Section 2 - Introduction to MEMS actuators

Tag the correct answers (multiple correct answers possible)

- ☐ an actuator typically consists of an actuation mechanism and a restoring mechanism
- ☐ a feedback mechanism is necessary for an actuator to work
- ☐ the most common actuation principle in MEMS actuators is Lorentz-force actuation
- ☐ electrothermal actuation achieves large displacement in comparison to electrostatic actuation

Section 3 - Electrostatic actuators, general

Tag the correct answers (multiple correct answers possible)

- ☐ electrostatic actuators are based on the Lorentz force principle
- ☐ parallel-plate actuators are typically bulk micromachined
- ☐ parallel-plate actuators are only suitable for small displacements ($<4\mu\text{m}$)
- ☐ comb-drive actuators are only suitable for small displacements ($<4\mu\text{m}$)
- ☐ comb-drive actuators have a very high force/area ratio

Section 3a - Parallel plate actuators

Tag the correct answers (multiple correct answers possible)

- ☐ the force over displacement relationship of parallel-plate actuators is very linear
- ☐ the whole operation range of parallel-plate actuators is linear
- ☐ pull-in occurs at a position of the moveable plate of 2/3 of the initial displacement
- ☐ the pull-in point of parallel plate actuators depends on the size of the electrodes
- ☐ the hysteresis in digital-mode operation (on/off) increases the robustness of the actuator to actuation voltage fluctuations

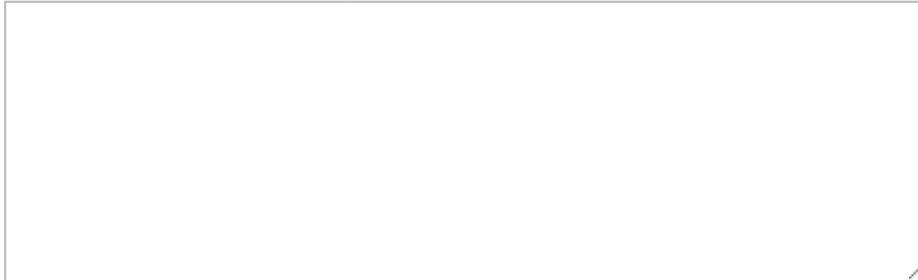
Section 3b - Comb-drive actuators

Tag the correct answers (multiple correct answers possible)

- ☐ A comb-drive actuator creates a constant force over all possible displacements
- ☐ the force in a comb-drive actuator is inversely proportional to the square of the distance between the fingers
- ☐ doubling the height of the comb fingers results in double force
- ☐ a 2.5D simulation model is based on a 2D geometry with information of the thickness of the geometry
- ☐ a 2.5D simulation model is the best compromise between describing the proper behaviour of a comb-drive and acceptable simulation time

Section 3b - Comb-drive actuators

Describe how lateral stability is created in a comb-drive actuator and how it is best avoided by design!



4. Mechanical-spring restoring mechanisms

Tag the correct answers (multiple correct answers possible)

- ☐ four equal springs in parallel result in a total spring constant of 1/4 of the individual spring
- ☐ four equal springs in series result in a total spring constant of 1/4 of the individual spring
- ☐ Hook's law is only applicable in the elastic region of a material/spring
- ☐ a single MEMS cantilever, as a part of a restoring spring mechanism, should not be deflected to more than a few % to avoid leaving the elastic region
- ☐ a clamped-free cantilever is softer than a clamped-guided cantilever
- ☐ for folded beam cantilevers: with every additional folded beam added to the structure, the spring constant will be halved
- ☐ for keeping designs small, it is wise to use folded cantilevers
- ☐ having too many folded cantilevers reduces the stiffness in unwanted directions of movement

Section 5. Actuators and restoring mechanisms working together

Describe the force balance for different operating points for a parallel-plate actuator!



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