Lehrstuhl für Sensorik
Universität Erlangen-Nürnberg
Daniel Kiefer, Michael Nierla

**Supervisor**: Daniel Kiefer (daniel.kiefer@fau.de)
**Deadline 1 (present first results)**: February 2nd, 2021
**Deadline 2 (submission)**: February 9th, 2021
**Presentation**: February 11th, 2021 during lecture class.

# Project 1: Electrostatics — Acceleration Sensor

Interdigital sensors are capacitive sensors that can be used for measuring small displacements on or within micro-electro-mechanical devices (MEMS). One example is an airbag sensor where a seismic mass deflects one electrode according to acceleration forces. The given assembly consists of two finger electrodes opposing each other. The desired measurement quantity is the vertical movement (see Figure 1).

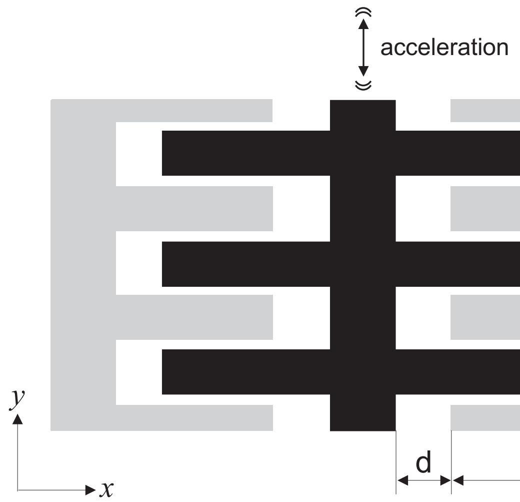


Figure 1: Interdigital sensor

The fingers of both electrodes (inner part and outer parts) have a width $w$ of 5 mm, a length $l$ of 15 mm and a spacing $s$ equal to 7 mm. As long as no forces are acting onto the inner part (idle state), the vertical distance $g$ between inner and outer fingers is 1 mm and the lateral distance $d$ is equal to 5 mm to each side.

The main objectives of this project are:

- Determine the sensitivity of the sensor w.r.t. to lateral and vertical movements of the inner part.
- Optimize the design in such a way, that the vertical sensitivity is optimized and the lateral (cross-)sensitivity is minimized.

## 1 Modeling

1.1. Setup the plane assembly as shown in Fig. 1. Choose an appropriate distance to the outer boundary of the calculation region (the sensor operates in air).

1.2. Keep the length $l$, the height $w$, the distance $d$ and the gap $g$ as independent parameters.

1.3. The spacing $s$ between two fingers and the total width of the sensor shall remain constant. If the inner part shifts in lateral or vertical direction, i.e. the air gaps $d$ or $g$ increase, the air gaps on the opposing side of the inner part have to shrink accordingly.

## 2 Analysis

2.1. Calculate the capacitance of the sensor for different vertical shifts of the inner part, i.e. for varying parameter $g$. Determine the sensitivity

$$S_g = \frac{\partial C}{\partial g} \tag{1}$$

of the sensor w.r.t. $g$.

2.2. Repeat the previous task for different values of $w$ but constant value of $s$. Please keep in mind, that an increase in $w$ will decrease the maximal vertical moving distance $g$. Try to find optimal values for the ratio $w/s$.

2.3. Take the optimized value for $w$ from the previous analysis and center the inner part w.r.t. to its y-position, i.e. set $g$ to $(s - w)/2$. Now vary the lateral air gap size $d$ and determine capacitance and sensitivity

$$S_d = \frac{\partial C}{\partial d} \tag{2}$$

of the sensor w.r.t. $d$. Try to optimize the design by varying the length $l$ of the fingers, such that the cross-sensitivity $S_d$ is much smaller than $S_g$ for comparable values of $d$ and $g$.

## 3 Presentation

Prepare for a **ten minutes** presentation followed by a **five minutes** discussion. Your presentation should consist of the following blocks:

3.1. Introduce yourselves (names, fields of studies).

3.2. Motivate and introduce the topic, i.e., what is this project about, how does the shown sensor/actor/assembly work in practice, what is it used for, what are the main objectives.

3.3. Present the major aspects of your modeling and analysis, i.e., what quantities were analyzed, are there any analytic estimates, what major difficulties had to be solved, how did you overcome these difficulties, etc.

3.4. Show and discuss your results in a descriptive way using graphs, screenshots, videos, etc.

3.5. Give a short conclusion.

## Some remarks

- Brainstorm a concept on how to proceed and think about the desired goals and how you can achieve them. Focus on the relevant aspects of the project.
- Start early with your project and meet regularly to work together and/or exchange ideas. You might be able to distribute some tasks inside your group.
- The task description is rather vague on purpose and has room for your own interpretations. If you face uncertainties, e.g., regarding the choice of some parameter, discuss in the group first and think about reasonable choices. Only if this does not help, contact your supervisor.
- Present your project milestones to your supervisor **twice or thrice** during the course of the project. Discuss your "almost" final slides with your supervisor **before the first** deadline. Keep in mind, that you might need to make substantial changes and/or more simulations after this discussion.

- You can/should use Matlab where you deem it useful.
- When making animations, make sure to fix the color range of surface plots.

## Submitting your project

Hand in your

- `.mph` file (clear all meshes and results beforehand, see the COMSOL Tutorial),
- Presentation in PowerPoint or PDF format

before the final due date (second deadline) by uploading to the project section on StudOn.