University of California at Berkeley
College of Engineering
Mechanical Engineering Department

ME219, Spring 2012 **Liwei Lin**

Project #1 for ME219 Spring 2012 – 30% Class Grade Weight

Parametric Design of a MEMS Surface-Micromachined Accelerometer
Due Date: 9:00 a.m. Monday 5 March 2012

For this project, please perform a parametric design of a MEMS surface-micromachined, polysilicon accelerometer. Get started EARLY, this project is not as easy as it looks.

Specifically, you must select the fundamental dimensions of the accelerometer using a decision method of your choice. Whatever algorithm or method you use, please formulate a specific plan and then document it in the “Theory” section of the report. The plan you use will be graded as part of the project. Use that plan to choose your dimensions and then check that all the engineering goals and engineering constraints are met. You may need to iterate several versions of your design until you successfully meet all constraints and goals. The manner in which you decide to iterate is part of your plan and I am requiring you to document it. I strongly recommend that you develop a MATLAB® program (or program this up in spreadsheet software such as Excel®) to perform the routine computations so you may spend more time thinking about your choice of parameter instead of computing numbers endlessly. If you use MATLAB®, then submit M-Code in the “MATLAB Source” portion of report. If you use a spreadsheet, then put the spreadsheet equations in the report instead of MATLAB Source. If you derive equations, please put the derivations in the “Theory” portion of the report. Please state the assumptions when you derive any equation. If you simply copy the equation from class notes (perfectly OK if you find one that fits), then there is no need to re-derive it, but please list it in the theory section as one of the equations used in the project. For the next project we will use systematic methods to make these selections.

The attached figure shows the basic design and defines the dimensions of the MEMS, surface-micromachined polysilicon accelerometer. Please do not change the basic design. You need only provide the dimensions for it. I have reduced the scope of the design so that you have a limited number of parameters for which you must choose specific values. (Technically, the design has already been “type synthesized” and now you will perform a “dimensional synthesis” for that design type.) In an unusual circumstance, you may feel the need to define more parameters to describe the problem. Contact me before doing so. This usually means you are proceeding in the wrong direction to the solution of the problem.

The following parameters are fixed and therefore are not adjustable by you:

$g = h_l = h_t = 2.0\ \mu m$
thickness = 6 μm
$X_A = 3.0 h_t$
E = 160 GPa (Note: typical thin-film polysilicon)
$\rho = 2.33\ gm/cm^3$ (Note: typical thin-film polysilicon)
Capacitance Resolution = 10 attoFarad (Note: for comb tooth motion)

The following must be maintained when the deflection of the proof mass is at its maximum:

$x_S \geq 2.0g$
$x_L \geq 3.0g$

The following are the four engineering goals you must meet:
Minimum DC acceleration resolution, $a_R \leq 0.05$ g
Maximum DC acceleration survival, $a_{MAX} \geq 10{,}000$ g
Maximum die area $\leq 160{,}000\ (\mu m)^2$
Maximum stress in suspension, $\sigma_{MAX} \leq 0.16$ GPa

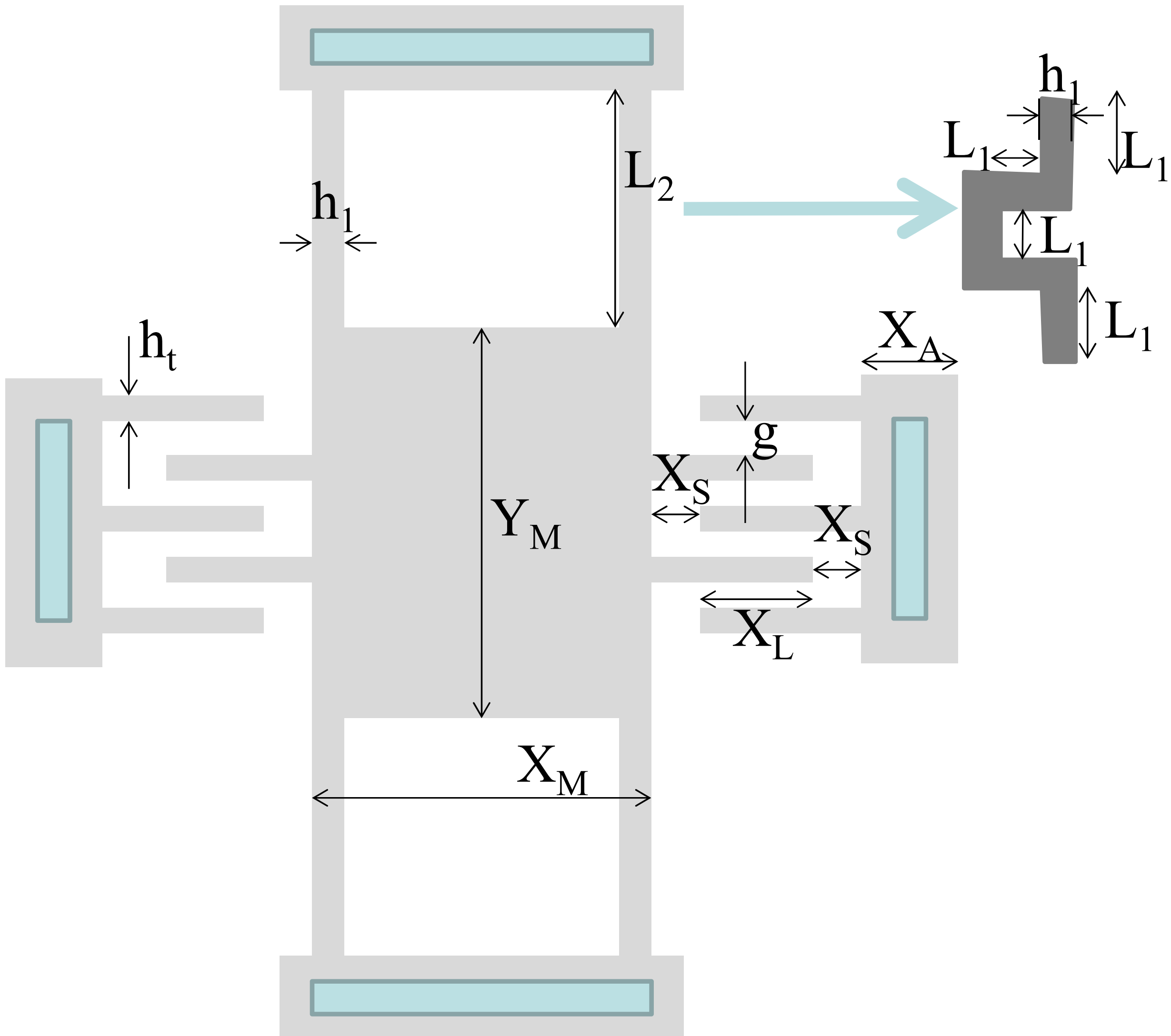
Note that you may change the number of comb teeth in the design. The figure shows two teeth on each side of the proof mass, you may add more. Note well: There is a limit to the number of comb teeth you can add, based on the size of the proof mass! The die area is defined as a rectangle drawn around the entire device as shown on the figure. This die area is one of your engineering goals.

Please complete the design of the accelerometer by selecting numerical values (in micrometers) for all necessary design dimensions so that your design meets all constraints and goals. If you cannot meet all engineering goals, then attempt to meet them as best you can and be sure to explain why you feel your particular choice of parameters is the best possible. Be sure to define what you mean by "best." For your project report, please follow the format given on the class website. In that report, please be sure to state explicitly the values of:

1. All chosen dimensions for your design.
2. Chosen number of comb teeth.
3. Calculated spring constant for your suspension (sense direction).
4. Definition of the die area expressed in terms of the design parameters.
5. Values achieved for all engineering goals.
6. Location of maximum stress in the suspension.
7. If the polysilicon film has a residual stress of 50MPa, please discuss the impact to the device performances in the case of tensile residual stress and compressive residual stress, respectively.

In the "Theory" section of the report, please be sure to state clearly your decision logic in choosing the values of the dimensions you select. "I just made guesses," "I gave up after 2 hours of trying," "I moved values up and down until it worked," or similar characterizations are not acceptable statements of the decision logic.

Note that all requirements for z-axis shock, cross-axis sensitivity, bandwidth, noise and frequency response have been relaxed for this project. (i.e., this is still considered an "easy" design problem!)



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