Project: MEMS-Based Performance Enhancement

Issued Tuesday, March 31, 2020
Due Week of May 4, 2020 (at Project Presentation)

Executive Summary: A state-of-the art MEMS technology project in which groups of three students investigate a new application or concept for which scaling provides substantial improvement in one or more performance specifications. In this project, groups will quantify the pros and cons (i.e., what parameters might go bad?) of the approach, then add value to the current understanding of the literature and disseminate findings via an annotated PowerPoint presentation.

Overview: In this project, groups of three students will investigate applications or concepts where MEMS-based scaling technologies can be used to either greatly improve the performance of an existing application or render possible an entirely new application space. The project will describe the scaling approach with references to existing previous work (if any), provide engineering design data and models to quantify the degree of improvement possible, critique the potential down side of the approach, and add value to the present state of understanding by providing a sample design that meets some practical target specifications. The use of CAD tools is highly encouraged in this investigation. A short (15 min) PowerPoint presentation with annotated notes pages comprises the main deliverable.

SPECIFICATIONS

Important Basic Literature: (Slide Set #1 draft due 5 p.m., Friday April 10, by email) Subject and 3 key references together with a few notes on their content, key data, and main points.

Hypothesis: (Slide Set #2 draft due 5 p.m., Friday April 17, by email) Critique of the literature and hypothesis that you will investigate. This should include a proposal of some sample (numerical) specifications that you intend to meet and that represent significant advances over the state-of-the-art. It would be good to have a chart comparing parameters (with numerical values) of the state-of-the-art macro realization to those you think are achievable after scaling.

Investigation: (Slide Set #3 draft with investigation plan due 5 p.m., Friday, April 24, by email) In-depth investigation of the literature or your own analysis/simulation resulting in systematic evidence or a quantitative design graph to support or disprove the hypothesis. This investigation is the heart of the project and about half of the level of effort should be spent on trying to add original value to the understanding of the subject.

Conclusion: (Slide due at presentation) Clear statement that summarizes the findings of your investigation and that suggests interesting avenues for possible further investigation.

Presentation: (Final set of slides that should number about 10) Short 15 min talk to be done via Zoom at a time to be determined. Prof. Nguyen will send around an electronic sign-up sheet on which you can sign up to give your presentation. More details on the exact logistics will be forthcoming. Given the importance of conference presentations for advancing actual research in MEMS, the presentation will be a very significant part of the project grade. You will need to be able to give a very good presentation at the end of all of this. It is in fact largely your presentation skills (both PowerPoint and oral) that this project aims to develop.

SUGGESTED TOPICS

The following are examples of topics that could be interesting. Note that this is just a suggested list, and you are not limited to this set of topics; rather, you can choose your own topic provided it gets approved (via the April 10^{th} slide).

- A micro-oven-control system that maintain a constant temperature environment for a given application (e.g., gyroscope, resonator, etc.), thereby providing better drift stability and improved performance. In a project like this, you would be expected to choose some reasonably aggressive temperature stability specifications, e.g., 0.1^{o}/hr bias drift for a gyroscope, and perhaps show that a miniaturized oven-control system can achieve much better temperature stability at much lower power consumption.
- Methods for cryogenically cooling a tiny sample using a micro-scale cooling system. What are the pros and cons of a micro-scale cryogenic cooler? How does efficiency at the micro-scale compare with that at the macro-scale? Are there new physics that can be harnessed at the micro-scale that cannot be harnessed at the macro-scale. (The answer is yes, but you'll need to contemplate how.)
- The use of radioisotopes to generate power for extremely long periods. Emitted radioactive particles are used today to power such applications as exit signs, implantable biodevices (e.g., pacemakers), and NASA spacecraft. If scaled to micro-sizes, is it possible to improve the efficiency of such devices? Here, you would need to select a power output target and design an example system that meets the specification.
- Separation analyzers that separate desired analytes from interferents in mixtures, thereby greatly improving the false alarm rate of the sensor (e.g., gas or bio) they feed. Here, one angle you could take is to show that miniaturization of the separator (e.g., chromatograph, centrifuge, etc.) can lead to great benefits (e.g., faster separation speed, lower power consumption required for separation, ability to use smaller samples).
- Applications that harness faster speed via scaling, such as micromechanical resonators for communications, micromechanical switches for antenna switching or logic applications, direct-write optical lithography systems that utilize fast moving micromirrors, etc. Here, you should be sure to emphasize both the pros and cons.
- Energy scavengers based on resonance or some other method that benefit greatly from small size, perhaps to allow more efficient collection of energy at higher frequencies.
- Micro-scale power generation concepts, such as micro-engines, micro-fuel cells, and micro-batteries. Here, you could perhaps focus on scaling methods for maximizing energy density, or maximizing power density. Again, you would need to give some specific performance specs that trump the state-of-the-art.
- Explore the effect of MEMS-enabled scaling on the cost of systems that utilize them. Is there always a cost reduction? (Answer is no.)
- The use of phenomena like surface-enhanced Raman scattering (SERS) to perhaps make micro-scale spectroscopy systems practical, with resolutions and capabilities equaling or bettering that of macro-scale versions, and at much lower power consumption.