Clock source technologies

PI: Tommaso Bocchietti, Department of Mechanical & Mechatronics Engineering, University of Waterloo
Contact: Tommaso Bocchietti, tbocchie@uwaterloo.ca
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Abstract Project proposal for the course *ME738 - Special Topics in Materials* at the University of Waterloo. The project aims to investigate the state of the art of clock source technologies, with a focus on the most recent advancements in the field and their potential applications. Topics may change or get refined during the first research phase.

Keywords Crystal oscillators, MEMS resonators, MEMS Atomic Clocks, State-of-the-art, Applications

1 Introduction

Every electronic device requires the use of a timing system (usually referred as clock) that sets the reference for the operation of the device. This timing system is implemented through the use of various electronic components such as clock source, phase comparator, frequency dividers....

The aim of this project is to investigate the state of the art of clock sources technologies, with a focus on the most recent advancements in the field and their potential applications. In particular, the project will focus on the following topics:

- ***Crystal oscillators*** (optional) : electric oscillator type circuit that uses a piezoelectric resonator, a crystal, as its frequency-determining element (Wikipedia definition).
- ***MEMS resonators*** (main focus) : small electromechanical structures that vibrate at high frequencies (Wikipedia definition).
- ***MEMS Atomic Clocks*** (time permitting): the combination of a MEMS system fabrication with atomic clocks for small, cheap, low-power devices [2].

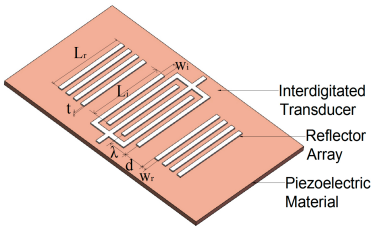

Figure 1: Schematic diagram of SAW resonator [1]

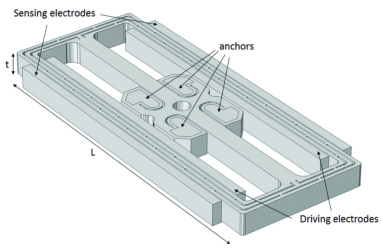

Figure 2: MEMS oscillator [2]

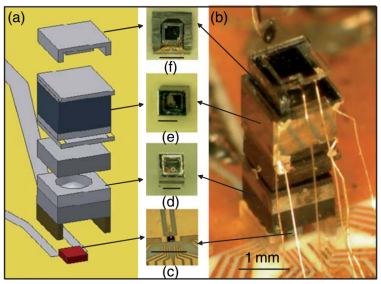

Figure 3: Chip-scale atomic clock (CSAC) [3]

Topics are mostly indicative and will be refined during the project development also based on professor's feedback, affinity with the course subjects, and personal interests.

2 Methods

For each of the clock sources mentioned in the introduction, the project will follow the same structure:

1. Working principle: a detailed explanation of the working principle of the clock source, including the physical phenomena involved and the main equations that govern its operation.
2. Simulations (when applicable): basic self-made simulations of the clock source, using `Matlab` or `COMSOL Multiphysics` (if available through a university license).
3. State of the art: a review of the most recent advancements in the field (scientific papers driven section).
4. Applications: a review of the most recent applications of the clock source, including the main challenges and the potential future developments (patents driven section).

Given the time constraints of the course, the project will focus on the first two points for each clock source, with the third point being addressed only if time permits.

In general, given a time constraint of 4/5 weeks, the project will be divided as follows (tentative):

- Week 1: Crystal oscillators
- Week 2: MEMS resonators
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- Week 4: MEMS Atomic Clocks (time permitting)
- Week 5: Final report writing

3 Expected Results

Being a literature review, the expected results of the project are mainly related to the knowledge acquired during the research process. In particular, the project aims to provide a comprehensive overview of the state of the art of clock sources technologies, with a focus on the most recent advancements in the field and their potential applications.

Eventually, when summing up the results of the project, we will try to add some insights on the potential future developments of the clock sources technologies, based on the most recent advancements and the main challenges that are still open and need to be addressed.

A References

[1] Baofa Hu, Shaoda Zhang, Hong Zhang, Wenlong Lv, Chunquan Zhang, Xueqin Lv, and Haisheng San. Fabrications of l-band linbo3-based saw resonators for aerospace applications. *Micromachines*, 10(6), 2019. URL: `https://www.mdpi.com/2072-666X/10/6/349`, `doi:10.3390/mi10060349`.

[2] Svenja Knappe. 3.18 - mems atomic clocks. In Yogesh B. Gianchandani, Osamu Tabata, and Hans Zappe, editors, *Comprehensive Microsystems*, pages 571–612. Elsevier, Oxford, 2008. URL: `https://www.sciencedirect.com/science/article/pii/B9780444521903000483`, `doi:10.1016/B978-044452190-3.00048-3`.

[3] Valentina Zega, Attilio Frangi, and Gabriele Gattere. Nonlinear dynamics of mems resonators: numerical modelling and experiments. In *2019 IEEE SENSORS*, pages 1–4, Oct 2019. `doi:10.1109/SENSORS43011.2019.8956703`.