SILOSCAPE – a Novel Escapement for FlexMEMS-based Watch Oscillators

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CSEM, with its combined expertise in micro-manufacturing techniques and precision mechanisms, has been a pioneer in the design and production of centimeter scale silicon parts featuring fine mechanical functions comprising flexures (FlexMEMS), opening up new opportunities for both the design and production of novel watch mechanisms. In the frame of SILOSCAPE MIPs, CSEM is focusing on the design and production of novel high-performance watch oscillators and escapements. This year, CSEM is presenting a novel escapement specifically targeted to exploit the potential and specificities of FlexMEMS based oscillators.

With the invention of the thermally compensated Silicon hairsprings, CSEM paved the way to a new trend in the watch industry: the use of silicon as a base material for the design and production of mechanical watch parts [1]. For the past 20 years, CSEM has relentlessly kept on working to push forward the technological boundaries of the micromechanical structuration of silicon at the watch scale [2], proposing new watch mechanisms that can only be addressed with this approach [3]. Leveraging its expertise in the design of precision mechanisms guided by flexure blades in lieu of classical bearings, a frictionless guiding approach requiring no lubrification, CSEM has proposed the so-called "FlexMEMS approach", which combines the advantages provided by the precise micromechanical structuration of silicon to those of flexure bearings, for the design and production of novel high-end oscillators and escapements [4]. In the past years, with the "Siloscape" [5, 6] and the "Double Hammer" [7] escapements, CSEM has addressed two complementary market segments: high power reserve and chronometric performances.

The so called "frog escapement" is the latest escapement designed and produced by CSEM (Figures 1 and 2). This innovative escapement is designed to be paired with FlexMEMS oscillators and is targeting a very precise time keeping (typically +/-2 s/d) together with a regular power reserve and a simple design.

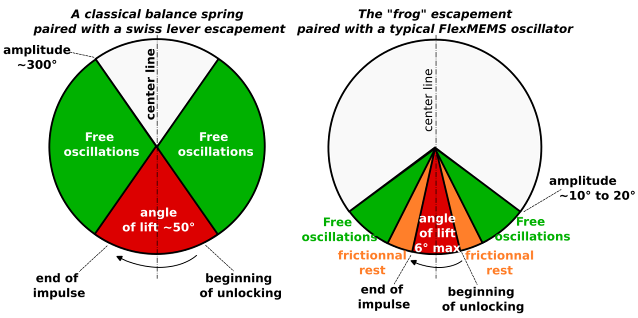

Figure 1: Comparison of the oscillation characteristics of a classical balance spring paired with a Swiss lever escapement and a FlexMEMS oscillator paired with the "frog" escapements.

A classical balance spring has an amplitude of about 300° and is characterized by a large free swing portion followed by a swing portion of about 50°corresponding to the angle of lift, i.e., the angle where the release of the escape wheel and the impulse of the escapement to the inertial element take place. Compared to a balance spring, FlexMEMS oscillators are characterized by a higher rigidity of the return spring, lower oscillation amplitudes (< 20°) and lower angles of lift (< 6°) which make them difficult to be auto-starting with a Swiss lever escapement unless the angle of lift is lowered further. However, it is impossible to resize the fork of a traditional Swiss lever escapement to make it compatible with an angle of lift of 6° or less. Indeed, the clearances and securities between the fork and the impulse pin would be unachievable. Furthermore, due to the higher stiffness of the return spring of a FlexMEMS oscillator compared to a classical balance spring, it would be very difficult to ensure the self-starting of the FlexMEMS oscillators while keeping the typically low driving torque of the escape wheel.

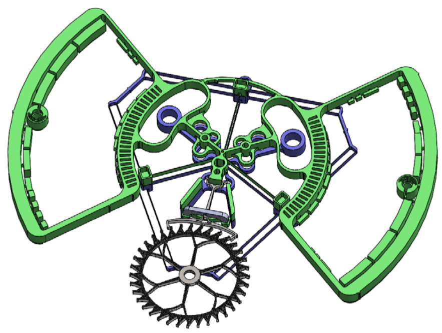

Figure 2: The Frog escapement (paired with a CR3 oscillator).

To design a self-starting lever escapement compatible with the specificities of FlexMEMS oscillators, CSEM has added a frictional resting phase to lower the angle of lift and make it possible to build a fork-and-pin mechanism with a very low angle of lift and reasonable clearances and securities. The unlocking phase is preceded by a first frictional resting phase, which is itself preceded by a first free oscillation phase. The impulse phase is followed by a second frictional resting phase, which is itself followed by a second free oscillation phase. The frog escapement is therefore at rest during a portion of the oscillation but is free outside this portion of oscillation. In that sense, the frog escapement is a semi-detached escapement. A first prototype featuring for the first time a CR3 oscillator [8] in a watch movement, was assembled and first functional tests confirmed the validity and potential of the concept.

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[1] A. Perret, "Le silicium comme matériau dans la fabrication de pièces mécaniques", SSC, 2001.

[2] O. Dubochet, *et al.*, " L'hybridation du silicium", SSC, 2015.

[3] M. Despont, *et al.*, "Tic-Tac" made in Silicon", SSC, 2019.

[4] F. Barrot, *et al.*, "Un nouveau régulateur mécanique pour une réserve de marche exceptionnelle", SSC, 2014.

[5] F. Barrot, *et al.*, "A Novel Silicon-based Flextech Watch Escapement", CSEM Scientific and Technical Report (2019) 20.

[6] G. Musy, *et al.*, "Les technologies de micro-fabrication et de l'aérospatiale au service de l'innovation horlogère", SSC 2021.

[7] F. Barrot, *et al.*, "A novel Constant Force Escapement", CSEM Scientific and Technical Report (2021) 14.

[8] F. Barrot, *et al.*, "Flexure based oscillators for mechanical watches", CSEM Scientific and Technical Report (2018) 19.