SLIMLINE MONOLITHIC MANUFACTURE

Last month, Swiss watchmaker Frederique Constant launched a technological breakthrough in the field of precision timekeeping. Redefining the principles of mechanical watch regulation, its Slimline Monolithic Manufacture delivers industry-leading precision by ticking ten times faster than most mechanical movements. Etched from silicon, its monolithic oscillator, designed as a compliant mechanism by Dutch company Flexous Mechanisms, replaces an assembly of several parts and eliminates many of the major weaknesses of mechanical watches. The high-frequency oscillator fits inside a traditional movement configuration, housed inside a 40-mm case.

The way mechanical watches are regulated has not changed during the last three centuries. The invention of the sprung balance in the 17th century has exerted a lasting influence on mechanical watchmaking. Since then, mechanical watches have relied almost exclusively on the sprung balance. Consisting of a thin, coiled spring attached to the balance wheel, it allows the balance to oscillate back and forth at a constant frequency. In doing so, it controls the speed at which the gears of the watch rotate and influences the rate. Although it has been improved over time, the principle of the sprung balance has remained unchanged and virtually unchallenged for over three centuries.

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Presented in a 40-mm round case, the Frederique Constant Slimline Monolithic Manufacture features an elegant dial with a guilloché/stamped hobnail pattern, printed Roman numerals paired with Breguet-style hands. The pulsating high-tech oscillator is visible in an aperture at 6 o'clock, while the pointer date at 12 o'clock was designed to create a classic counterpoint [V1].

Watch principles

The basic principle behind a mechanical watch is as follows:

Energy ⟶ Transmission ⟶ Escapement ⟶ Oscillator

The energy (stored by a coiled spring in a watch) is released in discrete bursts by the regulating organ, which is comprised of an escapement and an oscillator. The escapement transmits impulses to the oscillator (the balance wheel for the vast majority of mechanical wristwatches). The escapement, in turn, is regulated by the oscillator. Each oscillation, therefore, allows the gear train to advance or 'escape' a determined amount. For a bit more background on watch principles, see the Slimline Monolithic Manufacture video [V1].

Compliant mechanisms

In watchmaking, compliant or flexible mechanisms are the next big thing, opening a new realm of possibilities. Given the elastic properties of certain materials like silicon, it is possible to create compact, precise monolithic components to replace some of the assembled mechanical parts. Frederique Constant now has used these flexible, jointless structures in the design of its revolutionary oscillator. They have replaced the 26 components of their standard assortment (i.e., assembly of watch components) with a single component fitted with two regulation weights. Made of monocrystalline silicon, the monolithic oscillator also integrates the escapement anchor in its flexible structure.

EDITORIAL NOTE

This article was based on the presentation during the press event for the launch of the Slimline Monolithic Manufacture, a press release by Frederique Constant, and input from Nima Tolou, CEO of Flexous Mechanisms.

Three innovations distinguish the oscillator:

1. A small-size one-piece oscillator.
   Thanks to the geometry of flexures and masses, it is possible to produce for the first time a flexible pivot oscillator in the footprint of a traditional balance wheel.
2. An ultrathin oscillator with a new anchor system.
   The escapement anchor is incorporated into the oscillator and, for the first time, its function is integrated into the flexures allowing a substantial reduction in size while keeping all the functions in one thin silicon layer.
3. Adjustment weights to regulate the flexure oscillator.
   These weights are just like those used on a traditional free-sprung balance. Watchmakers can easily fine-tune the frequency and precision by simply turning two weights.

Monolithic oscillator

Frederique Constant integrated the concept of a monolithic oscillator in its new Slimline Monolithic Manufacture watch design (Figure 1) and developed it in collaboration with Flexous Mechanisms (see the text box on the right). The distinctive technical objectives for an innovative flexure oscillator were straightforward:

1. A size comparable to that of a traditional balance to fit inside a standard movement with minor adjustments.
2. The highest possible frequency.
3. An 80-hour power reserve.
4. A cost-effective formula that would allow the manufacture of significant quantities at a reasonable price.

The engineering of the oscillator's flexures and geometry enabled reduction of its dimensions to the size of a conventional regulator and increased its frequency for enhanced accuracy. The new topology of the flexures and masses constitutes an unprecedented compact size for a flexure pivot oscillator (9.8 mm in diameter and 0.3 mm in thickness). For the very first time, the anchor has been integrated within the flexure. The design combines high frequency with low amplitude (6° versus ~300° for a regular balance wheel), which prevents excessive speeds in the mechanism and increases accuracy. For confidentiality reasons, no more details of the oscillator design can be disclosed.

While many traditional mechanical movements operate at a frequency of 28,800 vibrations per hour, the Slimline Monolithic Manufacture represents the first Swiss-made mechanical watch oscillating ten times faster, at 288,000

Watch partners

Frederique Constant is a watchmaking manufacture located in Geneva, Switzerland. The maison was founded in 1988, "to offer quality Swiss watches at competitive prices, with the aim of democratising luxury Swiss Made watches".

Flexous Mechanisms is an independent horology technology company specialised in the design and development of flexible watch parts with the focus on mechanical watches. Flexous was founded in 2012 in Delft (NL), as a spin-off of the research in the field of flexible mechanisms at Delft University of Technology. Flexous develops and produces custom-made innovative watch parts from concept to product, "to bridge the fields of traditional watch making and 21st century flexible mechanism design".

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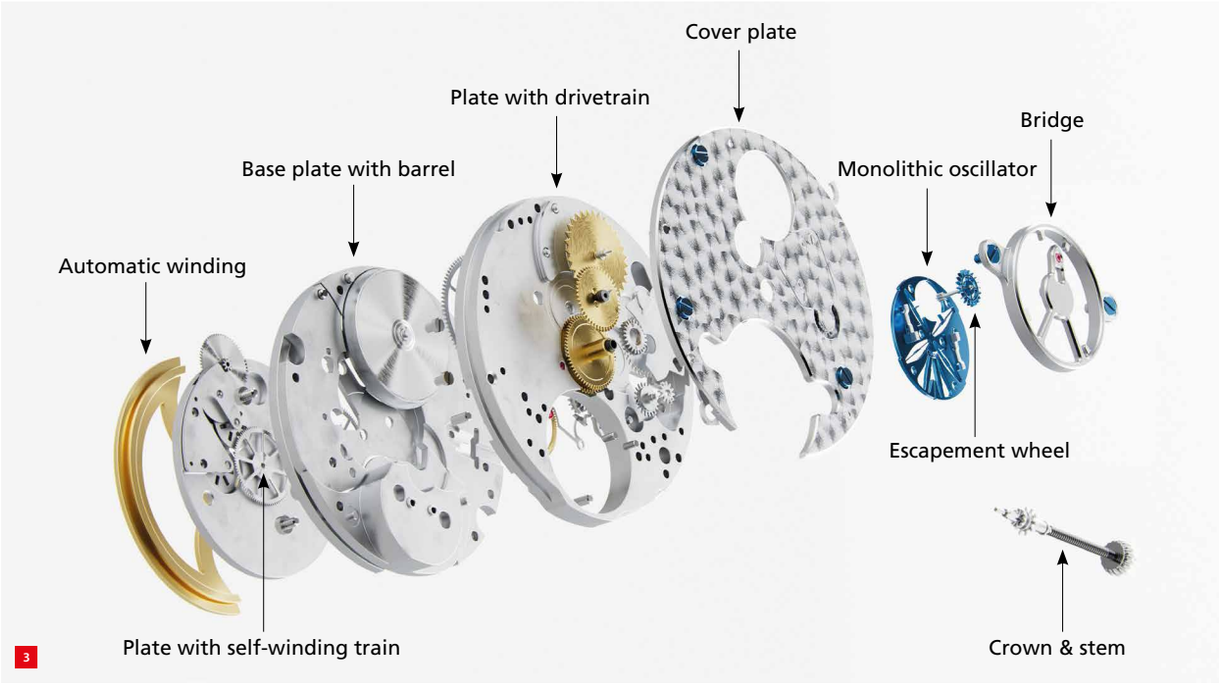
The new flexure oscillator.
(a) Close-up of the monolithic mechanism, containing a total of six flexures. The escapement wheel is shown in purple.
(b) Mounting of the adjustment weights.



Exploded view of the Slimline Monolithic Manufacture, showing the various components.

vibrations per hour, i.e. 40 Hz. Despite this high frequency, the efficiency of the mechanism delivers more than twice the run time of a regular watch.

The choice of material for the oscillator eliminates key weaknesses of traditional sprung balances. Monocrystalline silicon is 100% anti-magnetic, resilient to fluctuations in temperature (due to a specific treatment), less sensitive to gravity and four times lighter than a regular assortment. The absence of mechanical coupling means a lower generation of friction and wear on the parts. Consequently, less power is needed to drive the escapement wheel and the oscillating system. This results in reduced force between the components: 2.5 times less torque/couple is generated. In particular, the energy waste related to the stop & go motion of the Swiss lever escapement is eliminated. Finally, yet importantly, silicon does not require lubrication. This enhances the long-term reliability of the escapement and avoids the oiling demands generated by high frequency.

The rate regulation is performed using adjustment weights, just like the system used in a traditional free-sprung balance. The setting system is extremely precise, dividing time intervals in hundredths of a second versus tenths of a second for regular mechanical movements running at 4 Hz.

Given the innovative design of the escapement, the traditional devices to measure the rate of the movement (which rely on the ticking sound of the movement) are inoperative. To determine the average rate in seconds per day, laser cameras taking 250,000 images per second were used.

Smooth motion

It soon became apparent that a traditional gear train could not cope with the high speed of a 40-Hz regulator. This led to the design of a completely new base movement, automatic calibre FC-810, capable of performing with the speed of the new silicon oscillator. The entire kinetic chain had to be re-engineered, and the gear train was fitted with four wheels between the barrel and the escape pinion, instead of the three wheels found in a conventional movement. However, the efficiency of the regulator still manages to deliver the 80-hour power reserve. Figure 3 shows an exploded view of the complete watch design [V1].

In a regular mechanical movement beating at 28,800 vibrations per hour, the seconds hand makes eight moves to complete one second. With the FC-810 Monolithic Manufacture calibre, the seconds hand performs 80 moves per second, delivering very smooth motion. A nice analogy can be made to a bird flapping its wings: the 'coarse', slow flapping of a pigeon vs. the smooth, high-speed flapping by a hummingbird. Enabled by its low weight and efficient musculature, a hummingbird can hover in mid-air in front of a flower to gather its meal for the day; nectar.

VIDEO

[V1] *www.youtube.com/watch?v=PBjtEoHnV70*