SYNTHESIS REPORT

Year 2024-25 Mentor: Javier Martínez

24-hour format Quarter Repeater - *Marteau avec Fer à Cheval*

Bi-directional Retrograde Indicator - A Screwless Innovative Complication

Joan Castro Pizarro

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A New Dimension in Striking Time

Joan Castro Pizarro

The acoustic indication of time has long constituted one of the most poetic and technically sophisticated dimensions of horology.

Traditional chiming mechanisms-ranging from simple hour strike movements to complex minute repeaters-serve not only as functional tools but also as expressions of mechanical art, encoding temporal data into sequences of sound. While the prevailing paradigm in acoustic timekeeping assumes a direct proportionality between informational granularity and the number of auditory signals, the possibility of compressing greater semantic content into a constrained chime pattern presents a compelling theoretical challenge.

This project investigates whether it is mechanically and perceptually feasible to enhance the temporal resolution of a quarter repeater without increasing the number of discrete acoustic events. Specifically, it explores the integration of an additional semantic layer-namely, the differentiation between ante meridiem (AM) and post meridiem (PM) hours-into the chime sequence of a conventional quarter repeater. The goal is to achieve this entirely through sound, without resorting to visual indicators or auxiliary complications.

Figure 2.

Figure 1.

The conceptual framework for this study is grounded in both mechanical minimalism and acoustic perceptibility. Rather than adding new strike types or gongs, the project seeks to exploit variations in strike sequence, tonal articulation, and dynamic contour to encode additional temporal information. Such an approach raises fundamental questions at the intersection of mechanical design, psychoacoustics, and user cognition: How much information can be conveyed by subtle modulations in sound alone? And to what extent can traditional mechanisms be reinterpreted to serve new communicative functions without departing from established horological principles?

As a mechanical foundation for experimentation

and implementation, the project utilizes a "Goliath" quarter repeater pocket watch. Chosen for its generous internal volume and robust architecture, this platform allows for significant reengineering of the striking train and associated components. The movement serves not merely as a host, but as a constraint system within which all new functions must operate-without aesthetic compromise, and with full reversibility in mind.

The broader objective of this work is to push the conceptual boundaries of the quarter repeater as a genre, challenging the assumption that each increase in informational clarity necessitates a corresponding growth in mechanical or acoustic complexity. Through a series of mechanical innovations and acoustic refinements, the study proposes a novel method for temporally contextualized chime sequences that distinguish between day and night using only the language of

Preservation of the Integrity of the Original Components

One of the fundamental design constraints of this project was to introduce a mechanism capable of differentiating the striking sequences for ante meridiem (AM) and post meridiem (PM) hours, all while preserving the integrity and original structure of the quarter repeater. This challenge, which lies at the intersection of mechanical preservation and functional innovation, required a careful and highly precise approach to ensure that the core functionality of the repeater remained unchanged. The goal was to achieve a refined distinction between AM and PM through acoustic signals alone, providing users with an intuitive and efficient means of distinguishing between daytime and nighttime hours without altering the appearance or operation of the original mechanism.

The technical complexity of this task was considerable, as it necessitated an in-depth understanding of the traditional striking system, its acoustics, and the integration of new components in such a way that the modified system would retain both its aesthetic appeal and functional coherence. The design had to adhere to the principles of mechanical horology, with full reversibility, ensuring that all modifications could be undone if necessary without detracting from the original construction or diminishing the watch's intrinsic value.

To address this challenge, the project was developed with a clear and firm commitment to maintaining the integrity of the repeater. The mechanical solution was approached through a multi-faceted framework, incorporating the integration of new systems that could operate within the existing architecture. Specifically, three core systems were devised and implemented to fulfill this mission: the Snail-Cam System, the Dual Strike-Rack System for AM/PM Differentiation, and the *Marteau avec Fer à Cheval*.

Each of these systems was designed to fulfill a distinct function, with a focus on minimizing interference with the existing mechanism, while still allowing for the essential differentiation of the AM and PM periods. The Snail-Cam System served as the foundation for the new interaction of components, ensuring a precise and controllable mechanism for striking during both periods. The Dual Strike-Rack System was instrumental in introducing a second, independent chime sequence that would activate exclusively during the PM cycle, providing the necessary differentiation between the two time periods. Finally, the Marteau avec Fer à Cheval mechanism, inspired by the trébuchet hammer, was integrated to achieve compactness and efficiency within the limited space, while ensuring that all modifications were mechanically stable and acoustically distinct.

Snail-Cam System

A completely redesigned snail-cam system was developed for the implementation of a 24-hour time format in this quarter repeater. Central to this innovation was the introduction of a 24-step star wheel, meticulously engineered to interface with the hour-snail driver. In contrast to traditional 12-hour mechanisms, where the star wheel completes a cycle in 12 steps, this system was required to handle double the number of steps to account for the full 24-hour period. This increased step count posed a significant challenge, particularly regarding the stability of the star wheel and the preservation of the finer, more delicate teeth of its mechanism. To address this, a newly introduced wheel-jumper was incorporated into the design. This component stabilizes the star wheel, minimizing the risk of misalignment and providing protection against wear and breakage of the teeth, which are more vulnerable due to the increased operational demands of a 24-step cycle.

To ensure the precise synchronization of the system over the full 24-hour period, the hour-snail mounted on the star wheel was redesigned to feature a 12 + 12 step configuration. This allows for seamless engagement throughout the entire cycle, ensuring that both the AM and PM hours are precisely delineated by the striking system. The design of the hour-snail was carefully calibrated to maintain engagement accuracy for the entire span of the day, accounting for both the mechanical constraints and the need for consistent operation.

An additional auxiliary snail-cam was positioned above the primary star wheel assembly to further refine the system's operation. This auxiliary cam is a dual-function component: the first half mirrors the geometry of the original hour-snail, providing continuity and reinforcing the system's precision; the second half, however, is elevated by half a step relative to the one o'clock position. This elevation serves a critical function: it prevents the 24-hour strike-rack from engaging at inappropriate times, thereby ensuring that the system only strikes when it is intended to do so. This feature is essential for preserving the accuracy of the striking mechanism and preventing any potential mechanical errors caused by premature or erroneous activations of the chime.

This reconfigured 24-hour snail-cam system not only guarantees precise synchronization across the entire day but also significantly enhances the overall durability and reliability of the repeater mechanism.

Figure 3. The Snail-Cam assembling.

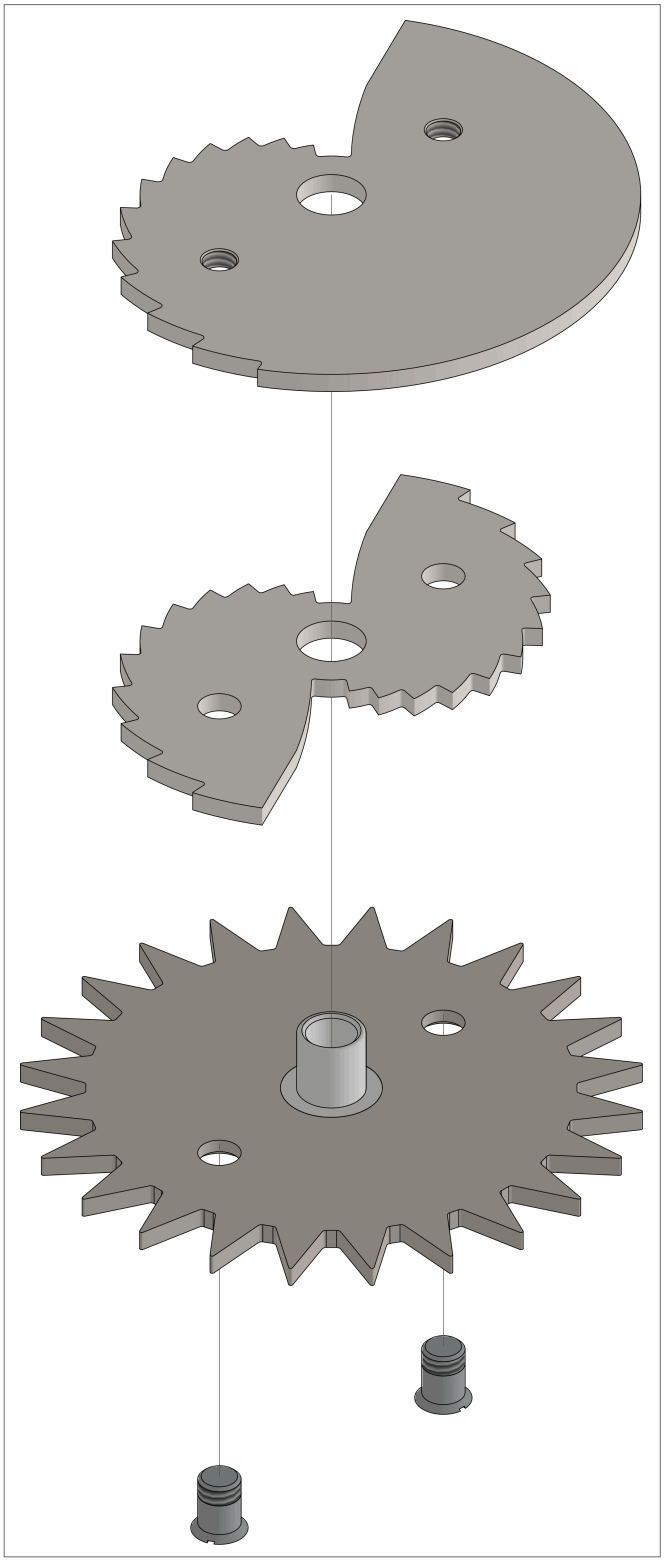

Figure 4. Exploded view of the Snail-Cam assembly.

By addressing the inherent mechanical challenges associated with adapting a traditional 12-hour repeater to a full-day cycle, this revised system offers improved performance, increased longevity, and a higher degree of operational reliability. It stands as a testament to the integration of traditional horological principles with modern innovations aimed at expanding the functional capabilities of classical timekeeping mechanisms.

Dual Strike-Rack System for *Ante Meridien* and *Post Meridiem* Differentiation

In traditional quarter repeaters, the sound marking each quarter hour follows a well-established pattern: a high tone is struck first, followed by a low tone, creating a recognizable acoustic rhythm that aids in the identification of time. However, in order to introduce a clear and precise differentiation between the ante meridiem (AM) and post meridiem (PM) hours, a more nuanced approach was required. This challenge led to the development of a system that not only reverses the traditional tonal sequence but also incorporates a continuous tonal transition between the two notes. Specifically, during the PM hours, the pattern is inverted: the low tone is struck first, followed by the high tone, with a minimal interval between the two. This creates a seamless, uninterrupted sequence of notes that resembles a musical canon, extending the sound and offering a more fluid auditory experience. The result is an easily distinguishable tonal distinction between the two periods of the day, significantly improving the clarity and functionality of the repeater.

To realize this altered tonal sequence, the introduction of a second strike-rack was necessary. This additional rack is dedicated exclusively to the post-meridiem hours, ensuring that the mechanical system could accommodate both AM and PM times without confusion. The design of the second strike-rack involved replicating the original quarter-strike rack, but with an essential modification: two additional guide pins were added to facilitate the proper alignment and interaction of the PM rack. These pins ensure that the post-meridiem strike-rack is guided precisely through its movement, maintaining synchronization with the overall repeater mechanism.

Figure 5. Dual Strike-Rack System assembly (below, the pin that interacts with the PM rack spring is not installed yet).

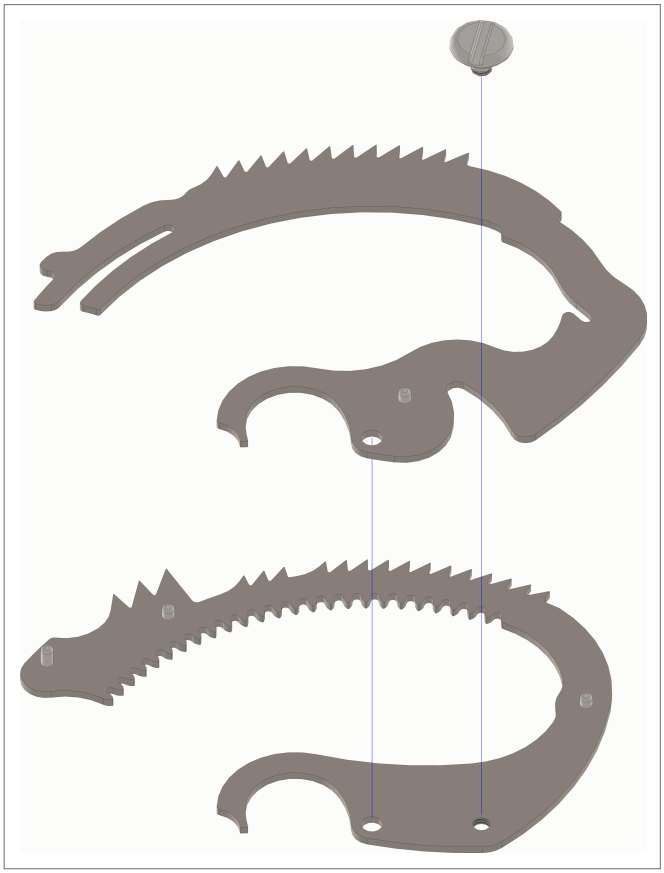

Figure 6. Exploded view of the Dual Strike-Rack System assembly.

The secondary PM strike-rack is mounted above the original strike-rack, engaging with it through these additional guide pins, which lift it into position. This mechanism is further enhanced by a specially designed snail-cam, which controls the motion of the rack and ensures a distinct and consistent striking pattern for the second half of the day. The snail-cam plays a critical role in guiding the strike-rack through the appropriate phases of the PM cycle, ensuring that the transition between the two tonal sequences is both smooth and precise.

This added complexity allows for a differentiation in the chime pattern between AM and PM, ensuring that the time is communicated with greater clarity.

The entire system was designed to integrate seamlessly with the original repeater mechanism, preserving its mechanical integrity and aesthetic qualities while simultaneously enhancing its functionality. The end result is a system that delivers an intuitive auditory representation of time, where the listener can easily discern not only the hours and quarters, but also whether it is AM or PM-an essential advancement in the field of acoustic timekeeping.

Marteau avec Fer à Cheval

One of the most technically challenging and mechanically intricate aspects of the project was the development of a dual-mode chiming mechanism capable of differentiating between ante meridiem (AM) and post meridiem (PM) hours through distinct acoustic signals. The paramount goal was to achieve this distinction without compromising the fundamental architectural and mechanical integrity of the original movement. This constraint of ensuring complete reversibility of all modifications ruled out any permanent alterations to or removal of the existing components. Instead, it demanded the integration of additional mechanisms in a highly compact and intelligent manner, ensuring that the modifications were both efficient and non-invasive.

The activation phase of the repeater begins when the winding-rack arm initiates motion by advancing the primary strike-rack towards the hour snail, engaging the conventional quarter-strike sequence. Simultaneously, the post meridiem strike-rack, which is mounted above the original strike-rack and remains at rest during the initial activation, is released by two precision-guided pins. These pins facilitate the controlled descent of the PM rack onto its designated snail-cam, where it is guided along its trajectory. The movement of the post meridiem strike-rack is further regulated by a calibrated drop spring, which ensures that the descent is smooth and that the engagement with the PM-specific cam profile occurs consistently, ensuring the correct chime pattern for the second half of the day.

A significant mechanical challenge arose due to the spatial constraints within the movement, particularly the need to maintain mechanical interdependence between the strike-rack system and

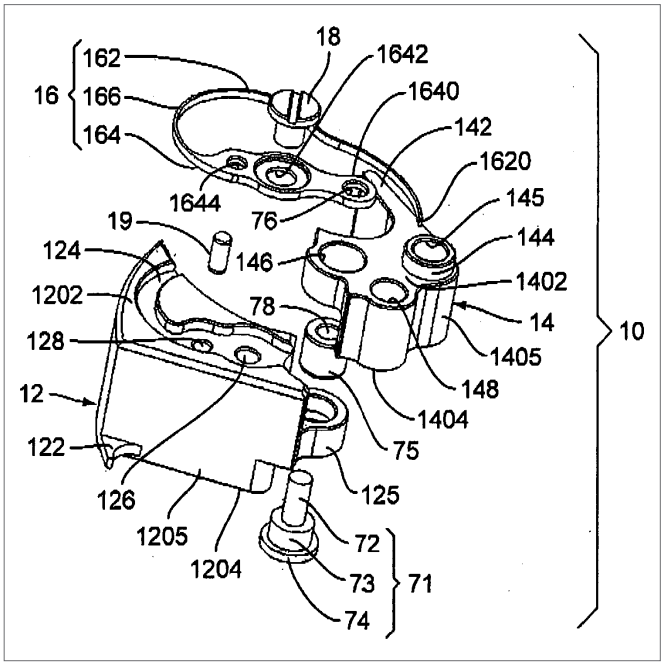

Figure 7. Patent EP2048548A2 - The present invention relates to the field of timepieces and more particularly aims at a hammer for a timepiece mechanism, such as a striking mechanism. It also concerns a timepiece mechanism, in particular a striking mechanism, equipped with such a hammer.

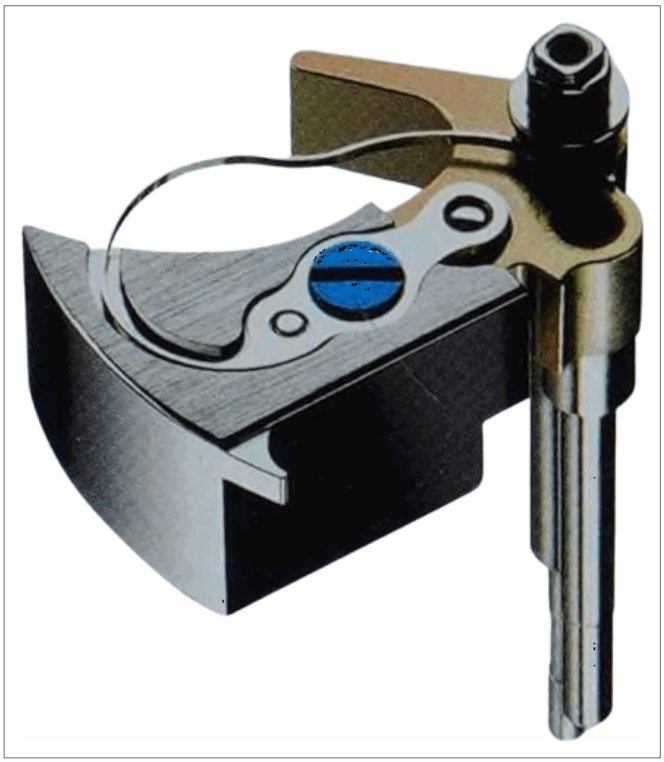

Figure 8. The *trebuchet* hammer.

the hour hammer assembly. The original design of the repeater relied on a return spring mounted on the posterior surface of the hour hammer pallet. This spring served two essential functions: it applied the restoring force necessary to return the hour hammer pallet to its neutral position after each strike, and it

also retained the pallet axially on its mounting shaft, preventing dislodgment out of place.

In order to accommodate the newly introduced components, especially the post-meridiem rack guidance system, the return spring had to be carefully removed. The anchoring point of the spring was repurposed to install a new spring whose sole function is to apply controlled force against the PM strike-rack, biasing it toward its snail-cam and ensuring precise engagement during the chiming cycle. This modification enabled the PM rack to function independently while preserving the original strike mechanism.

However, the removal of the original return spring created a secondary complication: without it, the hour hammer pallet was no longer supported against axial displacement, nor could it return automatically to its resting position after a strike. To address this issue while maintaining the compact nature of the movement, the return mechanism was not relocated to another part of the movement. Instead, it was fully integrated into the hammer itself, inspired by the principles of the *trébuchet* hammer system developed by Jaeger-LeCoultre. This system is renowned for its efficient force transmission and compact geometry, making it an ideal solution for integrating the return mechanism into the tight spatial constraints of the existing caliber. The trébuchet hammer mechanism is particularly effective in ensuring smooth and precise movement while reducing the overall complexity and size of the system.

In addition to this integration, a new stop lever was engineered to regulate the maximum striking depth of the hammer. This lever ensures that, when at rest, the hammer remains positioned just below the plane of the actuating blade, preventing premature or unintended strikes. The geometry of both the integrated spring and the stop lever was carefully designed with a curvature resembling that of a horseshoe. This unique feature inspired the nomenclature "marteau avec fer à cheval"-a descriptive term that refers both to the form and mechanical function of the new system. The horseshoe-like curvature is not only a distinctive aesthetic element but also a functional one, ensuring that the hammer operates with precise force and minimal mechanical interference.

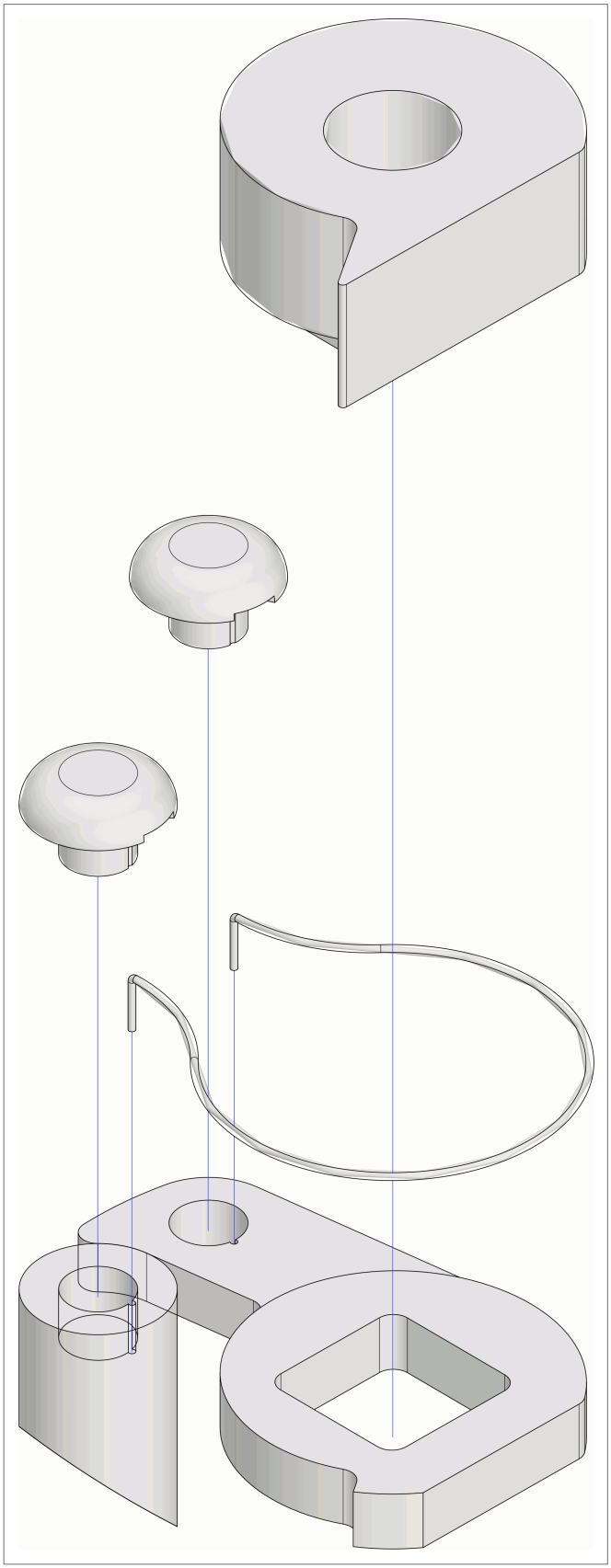

Figure 9. The *Marteau avec Fer à Cheval* assembly.

To further reinforce the axial stability of the hour hammer pallet in the absence of the original return spring, a C-clip was installed at the upper end of the hammer shaft. This subtle yet effective locking component prevents any vertical drift or rotational

instability in the hour hammer pallet, while maintaining the overall aesthetic and material coherence of the assembly. The addition of this component ensures that the hammer pallet remains securely in place, even during extended periods of operation.

Moreover, to accommodate the vertical trajectory of the newly added post-meridiem strike-rack, the hour hammer pallet was re-engineered with a significantly reduced profile compared to its original design. This reduction in height was a critical modification, as it allowed the PM strike-rack to pass directly above the pallet without any mechanical interference. This design ensures that the PM rack does not unintentionally activate the hammer during PM chiming sequences, thus preserving the distinction between AM and PM operations both mechanically and acoustically. The careful integration of this new mechanism guarantees that the hour strike and the PM strike remain entirely distinct, while still preserving perfect harmony with the original horological language of the movement.

This intricate solution not only solves the technical challenges of differentiating between AM and PM times but also ensures that the integrity and functionality of the original repeater are upheld. The marteau avec fer à cheval system exemplifies the successful integration of modern innovations with traditional horological mechanisms, creating a timepiece that is both mechanically sophisticated and acoustically precise.

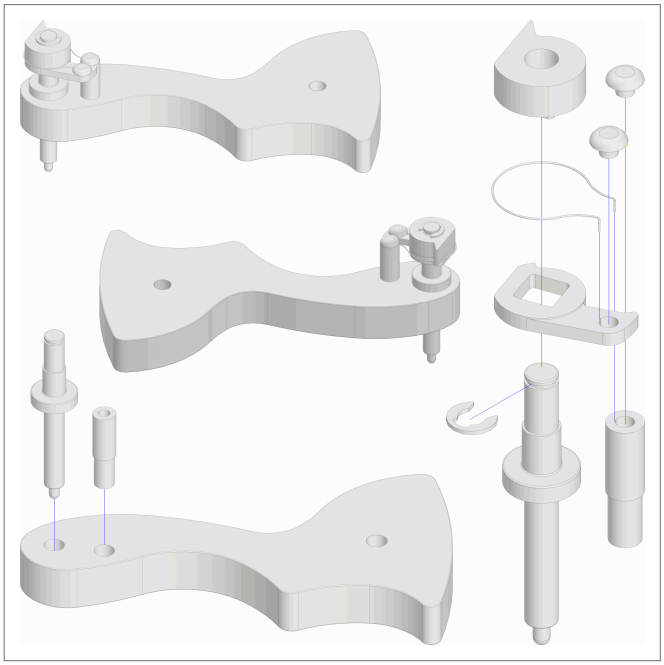

Figure 10. The *Marteau avec Fer à Cheval* assembly.

Bi-directional Retrograde Indicator - A Screwless Innovative Complication

A simple solution for an overlooked problem

Joan Castro Pizarro

In horology, the "base movement" refers to the core mechanism responsible for keeping time. It serves as the foundation on which additional complications are built, and it must remain reliable and accurate. A well-designed base movement should allow for bidirectional time setting-both clockwise and counterclockwise-without risking damage or affecting performance.

A common misconception in watchmaking is that setting the time backwards can harm the movement. In reality, a properly engineered movement should be able to handle reverse adjustments without issue. Precision mechanics and thoughtful design ensure smooth operation in either direction, dispelling the myth that counterclockwise setting is inherently harmful.

This principle led to a personal design philosophy: any complication that restricts or disrupts the natural function of the base movement is poorly designed. A good complication should enhance the movement, not interfere with its usability or integrity. It must integrate seamlessly, improving functionality while preserving the movement's original purpose.

This project focuses on the retrograde indicator, a complication that displays information (such as date or day) along an arc and resets automatically. Retrograde systems are unidirectional and can be damaged if adjusted backwards, which conflicts with the expectations of modern users who may set time in either direction.

The goal of this project is to create a bidirectional retrograde system-a mechanism that functions safely and reliably in both directions. This system must allow the retrograde hand to move smoothly whether the time is advanced or reversed. It must manage tension, prevent mechanical stress, and ensure accurate repositioning throughout the arc.

Achieving this involves overcoming several technical challenges: ensuring bidirectional motion, calibrating return mechanisms, and maintaining precision without wear or slippage. At the same time, the system must uphold the foundational principles of horology-functionality, durability, and mechanical harmony.

Ultimately, this project is more than just a technical innovation. It is a statement on horological design philosophy: complications should support and enrich the base movement, not compromise it. A bidirectional retrograde display, when properly executed, reflects the future of thoughtful and user-friendly watchmaking.

Preservation of the Integrity of the Base Movement

The entire development of this complication was carried out using the Unitas 6497 as the base caliber. It is important to note that other movements may differ significantly in architecture, and adapting the system to such platforms would likely require major mechanical redesign. In its current form, the

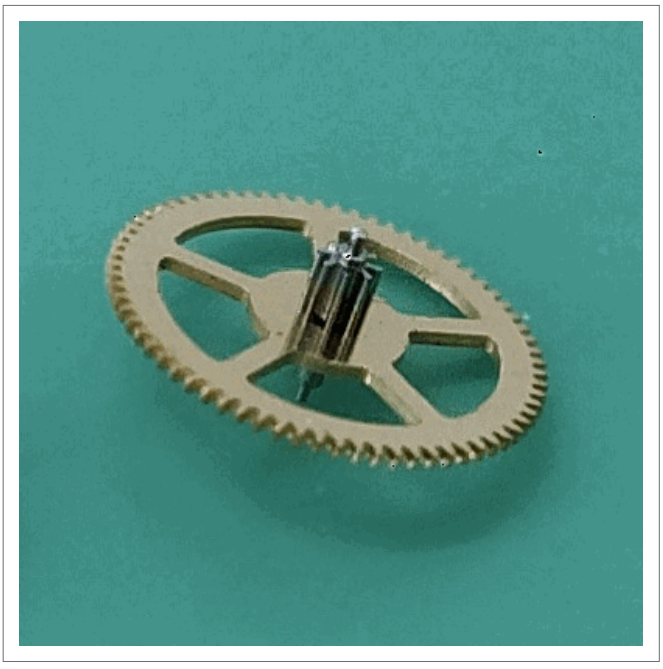

Figure 1. UT 6497's seconds wheel with the pivot shortened.

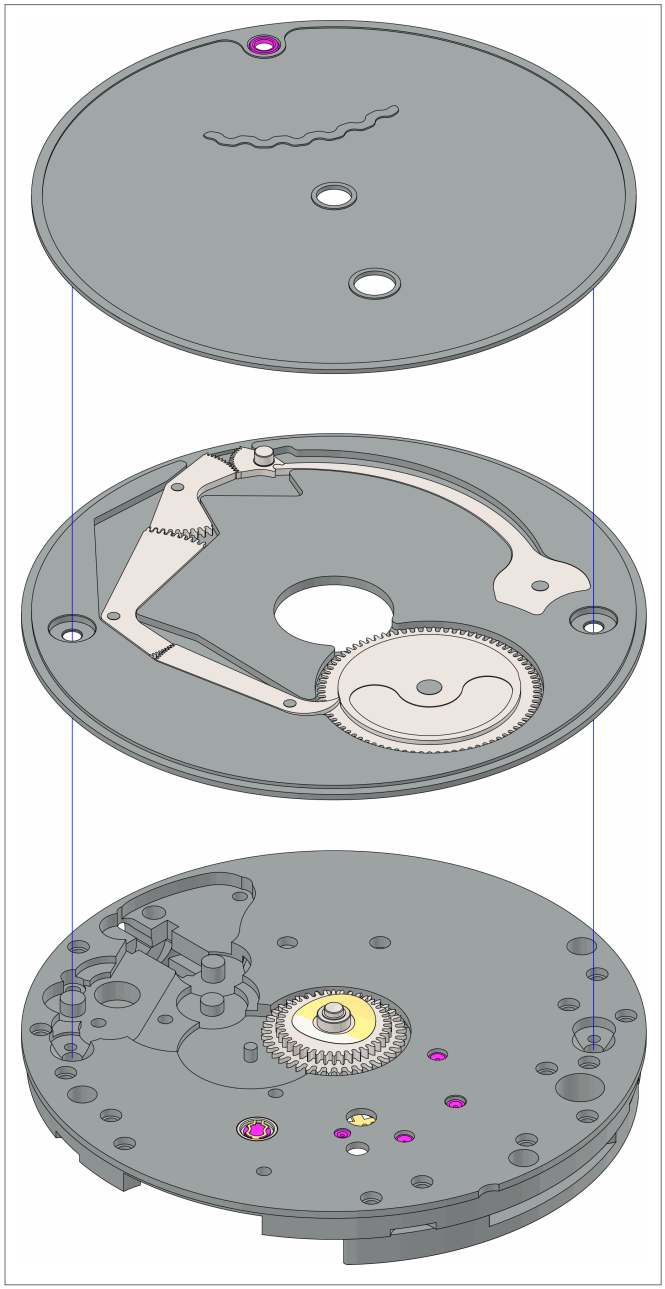

Figure 2. Exploded view of the module assembled on the mainplate.

screwless module that integrates seamlessly without requiring any permanent modification to the base movement. Full mechanical reversibility is a core principle of the design, ensuring the original watch remains intact and unaltered.

The module is specifically optimized for watches with only central hands. Since the Unitas 6497 includes a sub-dial for seconds indication, a pivot-shortening operation on the seconds wheel was necessary to accommodate the module. This was the only modification applied to the base caliber, driven by the unique geometry of the movement.

Originally, the complication was envisioned to occupy only the thickness of a traditional dial. However, it became apparent that such a thin architecture would result in a mechanism even slimmer than the thinnest watch in the world-an unfeasible constraint. To overcome this, the module was vertically extended up to the level of the hour hand, gaining crucial volume. The single-plane gear architecture-avoiding stacked pinion-over-wheel assemblies-was key to maintaining compactness and mechanical simplicity.

Notably, the module itself also functions as the dial. To preserve the baseplate, the module features traditional dial feet and uses the watch case's bezel as a secondary anchoring element. This dual anchoring approach allows the complication to be securely mounted entirely screwless, without relying on invasive fastening systems. The result is a fully integrated module that respects both the mechanical purity and visual aesthetics of the base timepiece.

How it works

In developing a bidirectional retrograde display, a key mechanical challenge lies in the geometry and behavior of the snail cam. True bidirectionality-allowing the hand to reset both clockwise and counterclockwise-requires minimizing the height difference between the highest and lowest

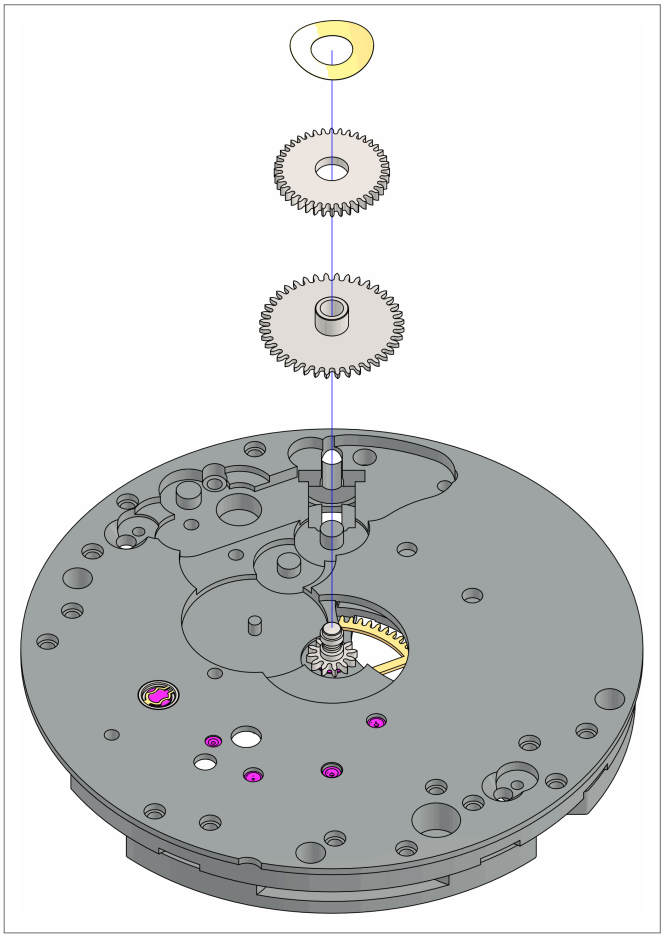

Figure 3. Exploded view of the hour wheel assembly with the gear that drives the retrograde indicator gear train.

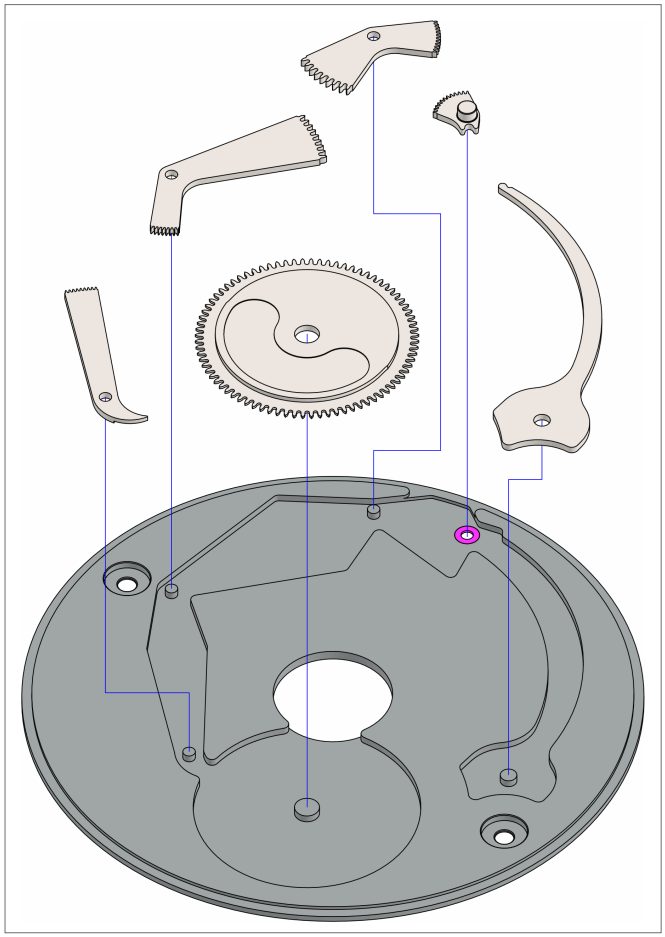

Figure 4. Exploded view of the retrograde indicator mechanism assembly.

the height difference between the highest and lowest points of the cam profile. A flatter cam reduces mechanical resistance, backlash, and energy loss, enabling smoother motion and precise hand positioning in both directions.

However, flattening the cam reduces its angular output, which is critical for sweeping the retrograde hand across its full arc. Without sufficient angular displacement, the hand cannot span the display range, compromising legibility and function.

To solve this, an angular amplification system is introduced. A gear train multiplies the cam's limited displacement, converting it into the required full arc movement. Gear ratios are carefully chosen to ensure precision and efficiency while preserving bidirectional motion.

This system allows the retrograde hand to move fully and smoothly in both directions, maintaining legibility and responsiveness. Importantly, the solution does not compromise mechanical integrity or reversibility. The gear train acts as a flexible intermediary between the cam and the display, enabling easy integration into various movement architectures.

Ultimately, this approach preserves the core principles of horology-enhancing functionality without disrupting the base movement. It overcomes traditional limitations of retrograde indicators and represents a step forward in complication design, offering reliability, adaptability, and refined user interaction.

The complications

This timepiece incorporates a set of mechanically coherent and aesthetically integrated complications that expand its expressive potential while remaining faithful to classical horological principles. Central to this architecture is a bidirectional retrograde display, capable of resetting both clockwise and counterclockwise without loss of precision or risk of mechanical interference. This is made possible by a dual-profile snail cam, specifically designed to govern smooth reversibility while ensuring positional accuracy across the arc.

The unique geometry of this cam-executing two full rotations per 24 hours-also enables the integration of a day/night indicator, mechanically driven by the same system. This synchronization avoids unnecessary spatial or structural redundancy, allowing for added semantic value without increasing complexity. The user is thus offered not only a retrograde indication of time but also a contextual reading of whether the displayed hour belongs to the morning or evening cycle.

Equally important is the material and visual realization of the module. The upper surface of the module, which also functions as the dial, has been enameled to provide both a refined finish and enhanced durability. This approach merges technical innovation with traditional decorative craft, reinforcing the dual identity of the piece as both a functional machine and an object of visual sophistication.

Collectively, these complications form a coherent system-mechanically compact, visually legible, and fully reversible-that reflects a modern reinterpretation of traditional watchmaking values.