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TEST AND MEASUREMENT TECHNOLOGY FOR MECHANICAL WATCHES

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witschi

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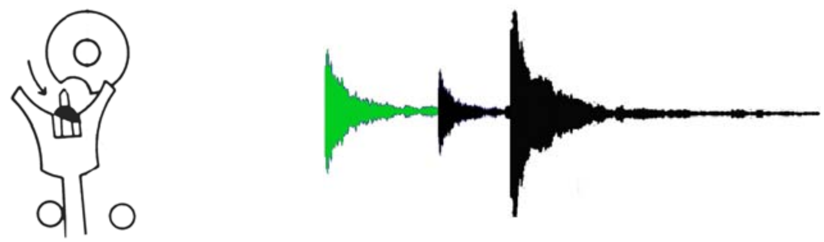
1 Functioning of the regulating organ

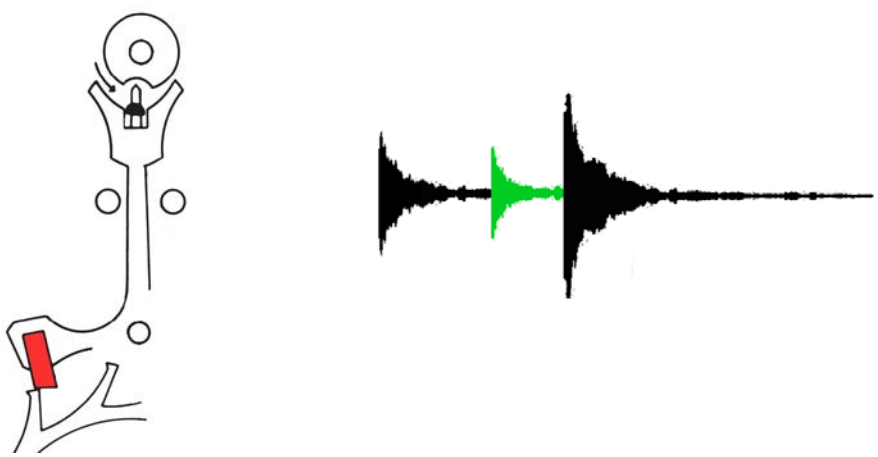
1.1 The beat noise of the Swiss lever escapement

Normally, the beat noise of the Swiss lever escapement consists from three different pulses.

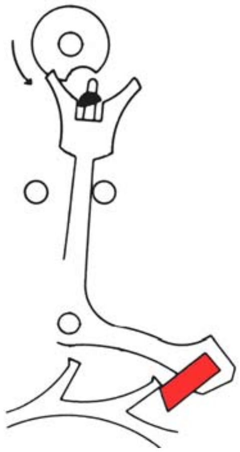
The first noise occurs when the impulse-pin of the roll strikes the fork of the pallets. This noise is temporally very precise and is therefore used for the graph recording and for calculation of the rate deviation and the beat error (repère).

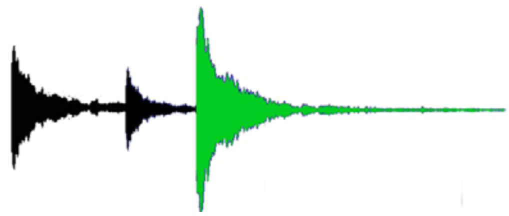


A second noise is created when a tooth of the escape-wheel meets the pulse area of a pallet stone and the pallet fork touches the impulse-pin.
This very irregular noise cannot be used for an evaluation.



The third and most powerful noise is created when a tooth of the escape-wheel meets the locking plane of the pallet-stone and the lever hits the banking-pin. This noise is evaluated for the calculation of the amplitude.





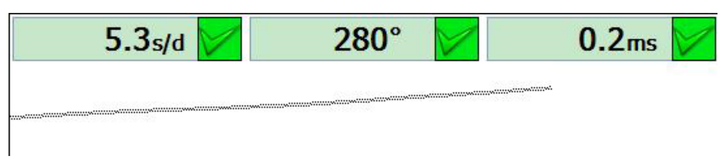
Further noises, which can be of different strengths, are also generated by friction or by secondary causes.

1.2 Evaluation of the beat noise

For the evaluation of the beat noise a measuring instrument with a very accurate time base is needed. It is also important that the beginning of the first sound package is reliably detected. If there is a very weak in this **first** noise of a watch, or if the watch generates strong background noises, the gain must be adjusted accordingly.

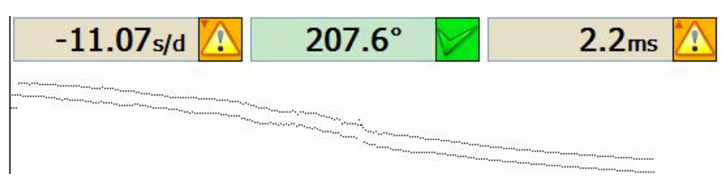
For the chart recording the time between two successive watch beats (period) is measured and compared with the nominal value for an accurate rate. If the measured time corresponds precisely to the nominal value, the new dot on the chart is set right by the previous. If the new beat is a bit too early or too late, the new dot, according to the time difference to the nominal value, is shifted up or down compared to the last dot. Therefore the row of dots on the display is according to the rate deviation from straight or angled up or down line.

Example 1: Regular graph



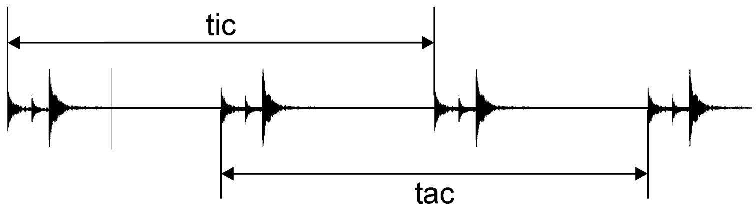
The chart shows not only the rate deviation, but also other temporal irregularities in the beats, such as beat error (repère), defective teeth of the escape-wheel etc.

Example 2: Irregular graph



1.2.1 Rate Deviation

To calculate the rate deviation the differences between the measured period and the nominal value are each averaged over the set measuring time, converted in s/24h and displayed on the screen.

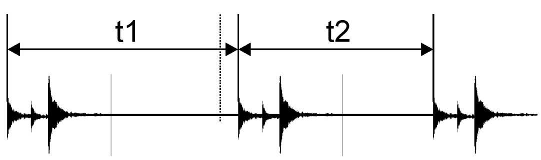


$$\text{Rate} = \frac{\text{rate tic} + \text{rate tac}}{2}$$

1.2.2 Beat Error (Repère)

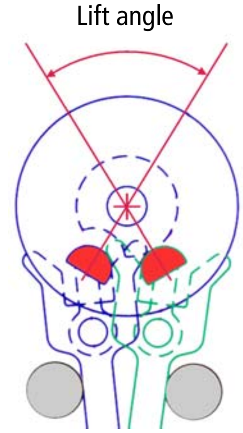
Asymmetrical oscillation of the balance wheel. The vibration of a balance wheel can be described by the rotating angle. If the watch has stopped, the zero position is defined by the position of the balance wheel. Under a (still existing) "beat error" refers to the fact, that the vibration is not running in all test positions quite symmetrical around the zero position, i.e. the balance wheel is swinging in a direction further than the opposite. This asymmetry may be visible on a test device. The beat error is measured in milliseconds (ms). High quality watches have a special device for setting the beat symmetry.

The graphic below shows a typical beat error. For a nonexistent beat error, **t1** and **t2** must have identical values.



$$\text{Beat error} = \frac{t1 - t2}{2}$$

1.2.3 Functional principle Amplitude-Lift Angle



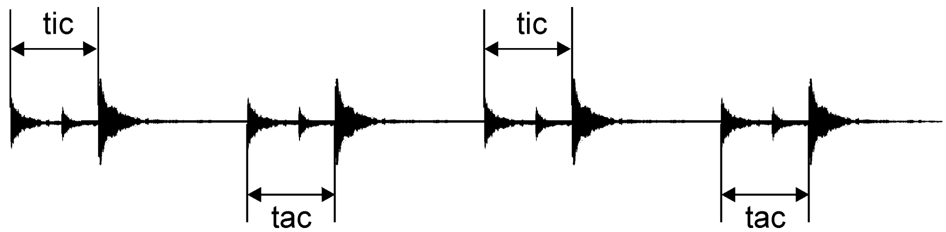
The angular velocity of the oscillating system (balance wheel with hair spring) passes through the zero point is dependent on its amplitude. The speed is determined by the elapsed time between the trigger signal and the event of the escapement. This period is called lift time of the balance wheel and the means of the balance wheel during this period traversed angle, ***Lift Angle***.

While passing through this angle, the impulse-pin (ellipse) remains in contact with the pallet fork. For the most of the standard watch movements the lift angle is about 51°.

1.2.4 Amplitude

The amplitude is the angle from the equilibrium (idle position of the balance wheel) up to the maximum distance (turning point). The amplitude values of today's popular wristwatches are located at about 260° - 310°. With increasing aging of the oils, this value decreases gradually.

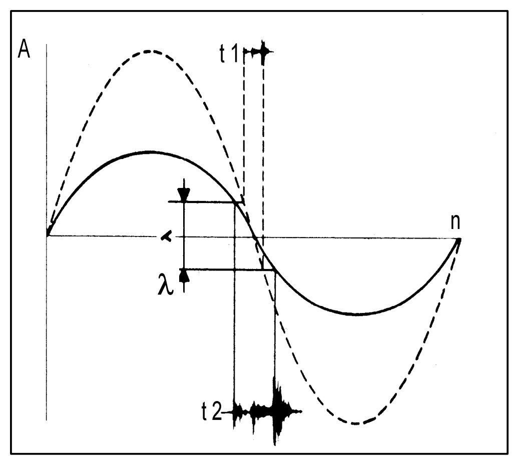
To calculate the amplitude, the time between the first pulse and the third pulse of the beat noise is measured.



Between these two pulses, the balance wheel rotates a certain angle. This so-called lift angle is determined by the construction of the movement and is entered as a parameter. The larger the amplitude of the balance wheel, the greater is the speed with which it goes through these lift angle and the shorter is the time it needs to traverse this angle.

The amplitude can therefore be calculated from the time between the first and the third pulses in the beat noise, taking into account the beat number and the lift angle.

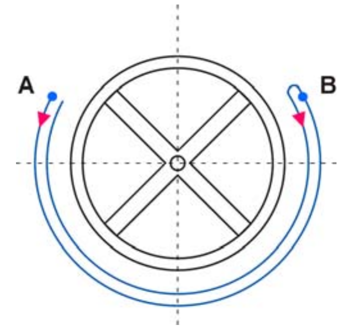
The distance travelled during a period range of the oscillating balance wheel is a sine function. The full line corresponds to weak amplitude and the dotted line to large amplitude. The horizontal lines of the constant lift angle λ cut the two sine waves at various points. This results in weak amplitude for a long lift (t2) and large amplitude for a short lift (t1).



REMARK

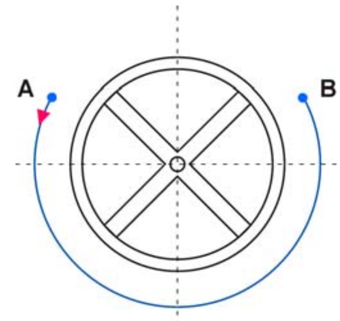
All Witschi testing devices are equipped with special, selectable test modes. These allow an accurate amplitude measurement of watches with special escapements such as coaxial, AP etc.

1.3 Oscillation and Frequency of the Watch



1.3.1 Oscillation

The **oscillation** of the balance wheel is the way from a turning point to another, and back (**A – B – A**).



1.3.2 Vibration

Half an oscillation of the balance wheel is called the **vibration** (**A – B**).

1.3.3 Frequency of the balance wheel

The frequency of the balance wheel (number of oscillations per second) is calculated by the formula:

$$F = \frac{A/h}{2 \cdot 3600}$$

F Frequency (Hz)

A/h Number of variations per hour

Some examples:

18'000 A/h ► **2.5 Hz**

21'600 A/h ► **3 Hz**

28'800 A/h ► **4 Hz**

36'000 A/h ► **5 Hz**

2 Tests with Chronoscope X1

Below are shown test and measurement capabilities of a high end instrument. Description and examples belong to the Witschi top device "Chronoscope X1" and are a complement to the existing manual.

2.1 Time-Parameter

2.1.1 Integration Time

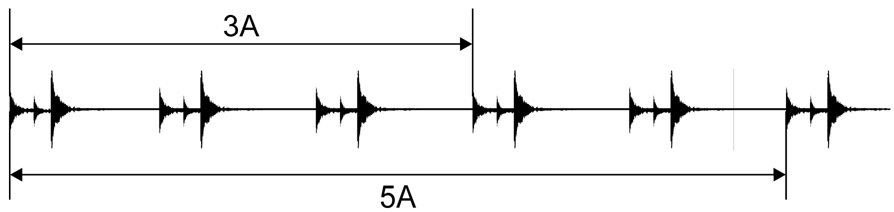
The numerical results are calculated and displayed over the integration time. In the rhythm of the integration time, the results are continuously updated until the end of the measurement cycle. For the diagram tracing until it is manually stopped.

In display mode "**Diagram**" only the integration time can be chosen. The numerical results are refreshed after the first integration time continuously every 2 s. 3A is also selectable.

Example

Chosen integration time:	**10 s**
Beat number (oscillations):	28'800 A/h
Number of oscillations for averaging:	28800: 3600 * 10 = **80 A**

Depending on the display mode also an integration time of 3A, 5A, 7A and 9A can be chosen (**A** = Vibrations).



Diese sehr kurzen Integrationszeiten sind für Labormessungen empfehlenswert. Kleinere Schwankungen der Gang- und Amplitudenwerte sind besser und detaillierter dargestellt.

Example

Chosen integration time:	**3A**
Beat number (oscillations):	28'800 A/h
"Refreshing time" for the measurement display:	**0.375 s**

2.1.2 Measuring Time

For some display modes the measuring time is selected together with integration time, where the measuring is always longer than the integration time.

For the test modes "**Trace and Vario**" the integration time is automatically set to the chosen measuring time.

After the initial passage through the integration time, the measured values are displayed, and then continuously updated in the rhythm of the specified integration time. These test modes are used primarily for laboratory measurements over a long period (up to 100 hours). An integration time of 3A can also be selected, where the maximum measuring time is limited to 8 minutes.

For "**Sequence**" display mode, a measuring time of up to 10 minutes can be set, where the integration time is fixed to 2 s.

2.1.3 Interval

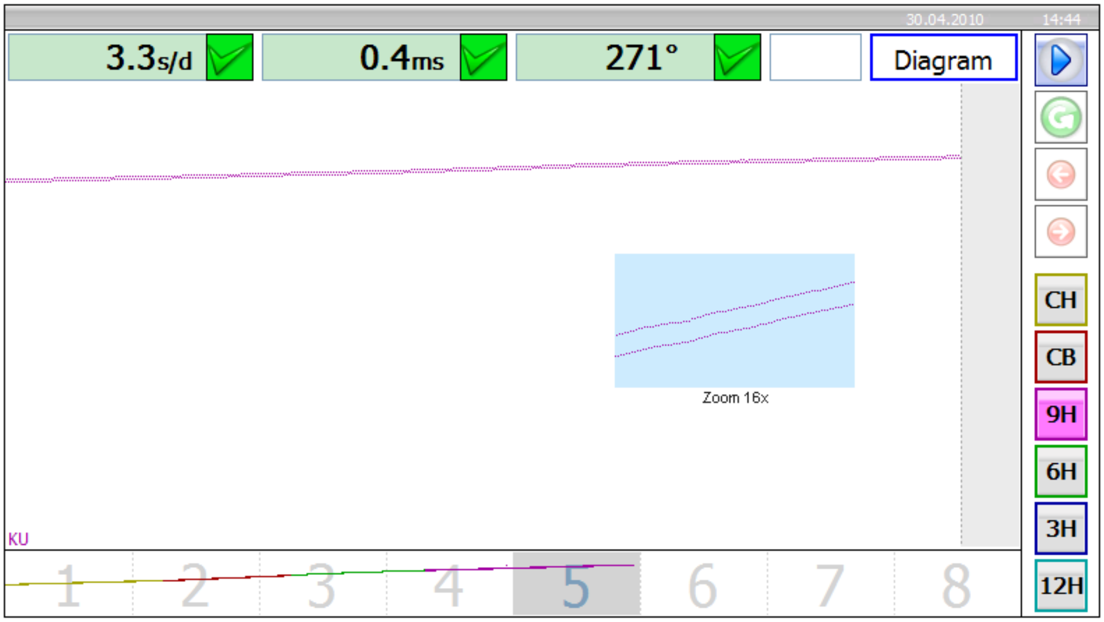
Only for "**Scope**" mode. A refresh interval of 3A, 5A, 7A, 9A or 2 s can be set.

In addition to the graphic representation of the beat noises, the measured value of the amplitude is also displayed.

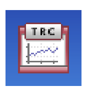
2.2 Measurement Examples

2.2.1 Diagram Record 

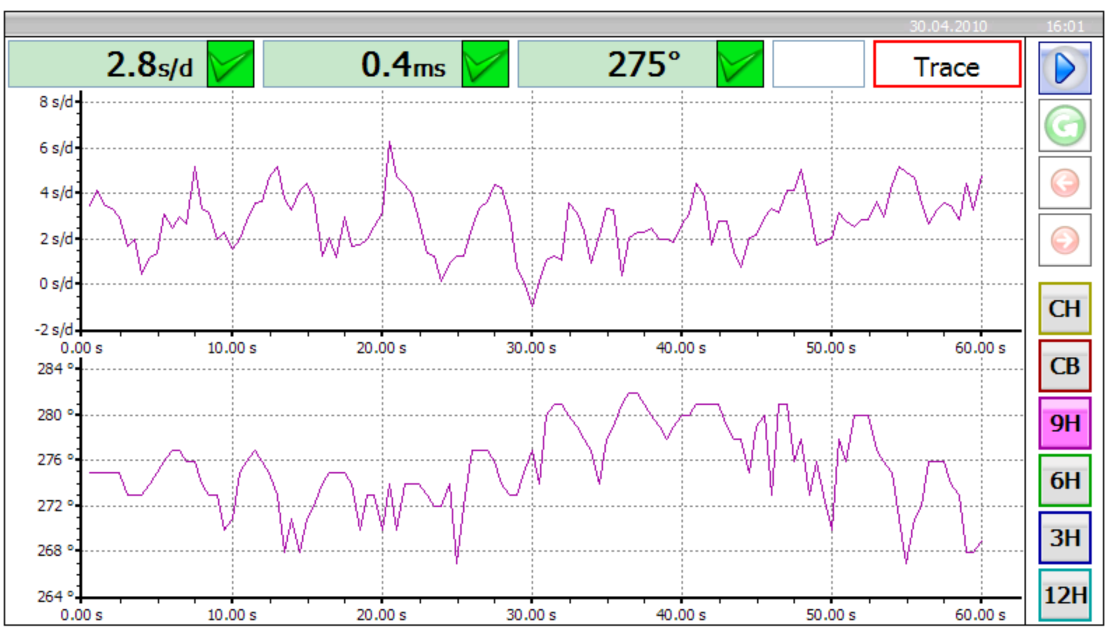
During the continuous recording of the beat noise the measured values of the rate accuracy, amplitude and beat error (repère) are also displayed.



For longer diagram recording, the last eight pages appear as stripes on a small scale. Additionally the zoom function (up to 16 times) allows a better analysis of irregularities.

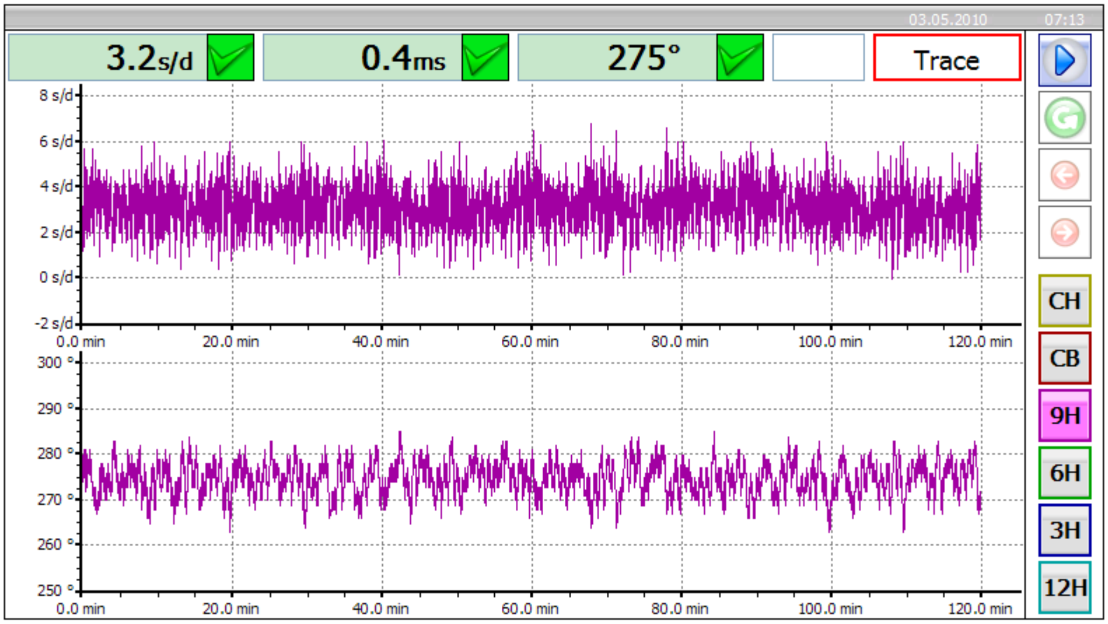
2.2.2 Display Mode Trace 

The following example shows the record with the shortest integration time of 3A.



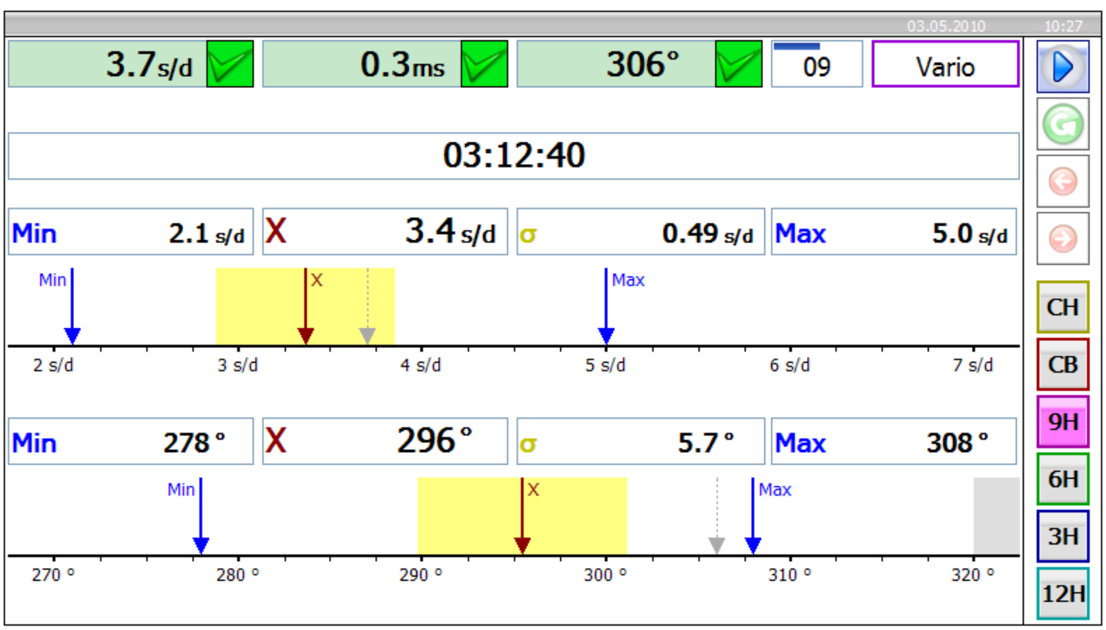
The measurement data points are recorded at 3 vibrations and interconnected. This allows detailed analysis of the measured values of rate and amplitude. Also in this mode the zoom function can be used.

Rate accuracy and amplitude were recorded over a period of 6 hours. Long term measurements up to 100 hours are possible. For example, the procedure until the watch-stop can be observed.



2.2.3 Display Mode Vario 

In this mode the stability of the rate accuracy and the amplitude can be observed over a longer time range. The measurement values are constantly update das long as the process is running. In addition to the elapsed measuring time, following measurements values are displayed:



Min Smallest measured value since measurement start

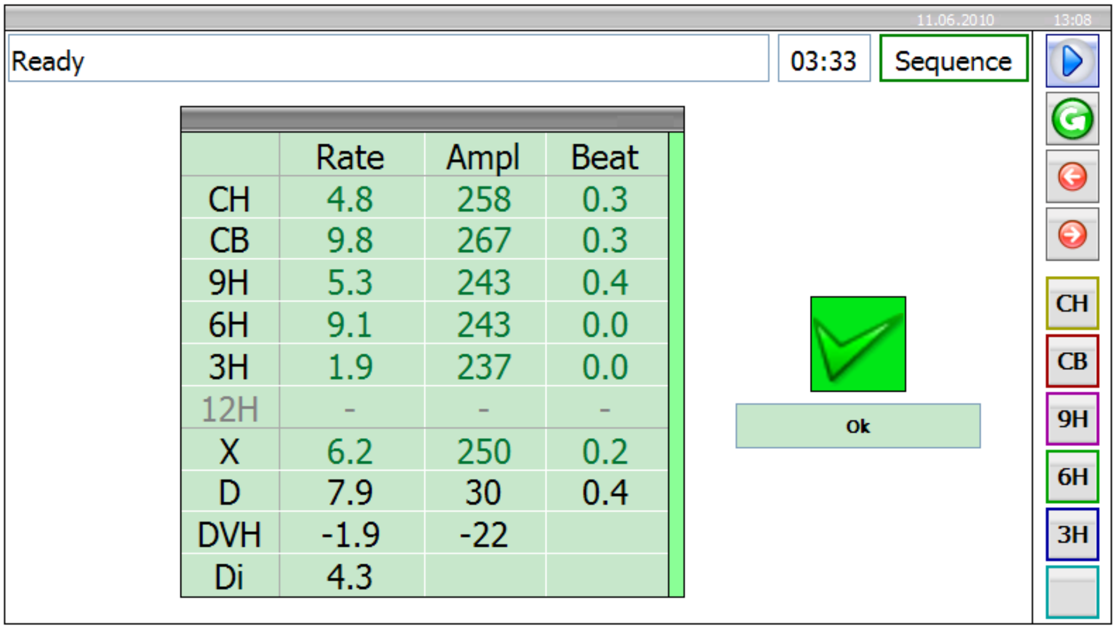
Max Largest measured value since measurement start

X Average value since measurement start

σ Standard deviation since measurement start

2.2.4 Display Mode Sequence

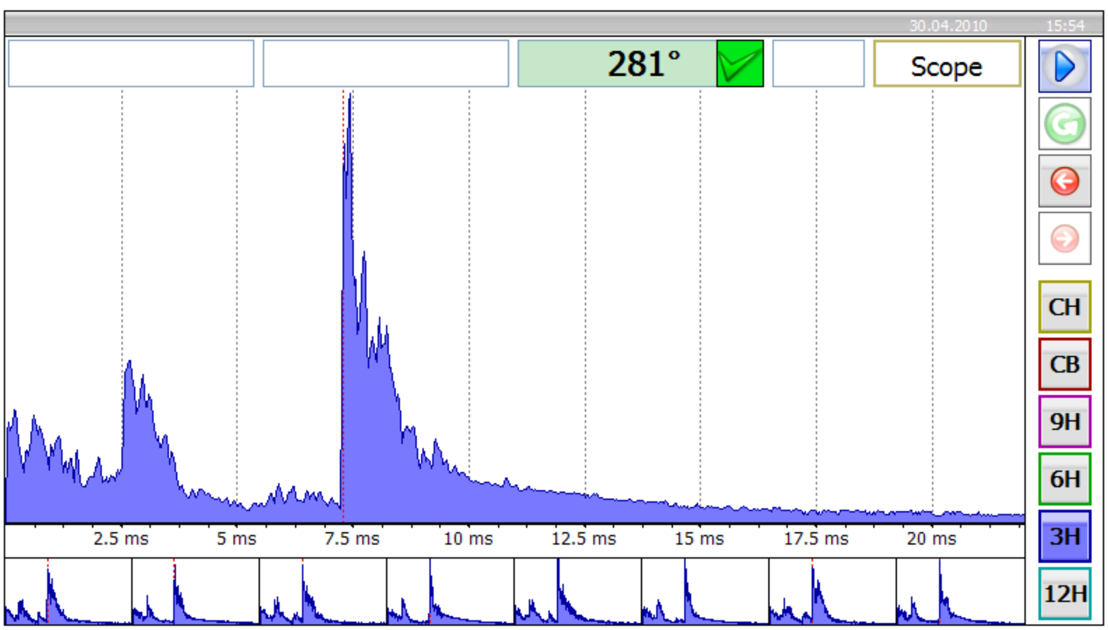
After the elapsed test sequence, the results of each test position appear in a table. Programs can be created with up to 6 test positions including stabilization and measuring time.



The ideal mode for testing smaller series, for the final review in watch service centers, for the incoming inspection etc.

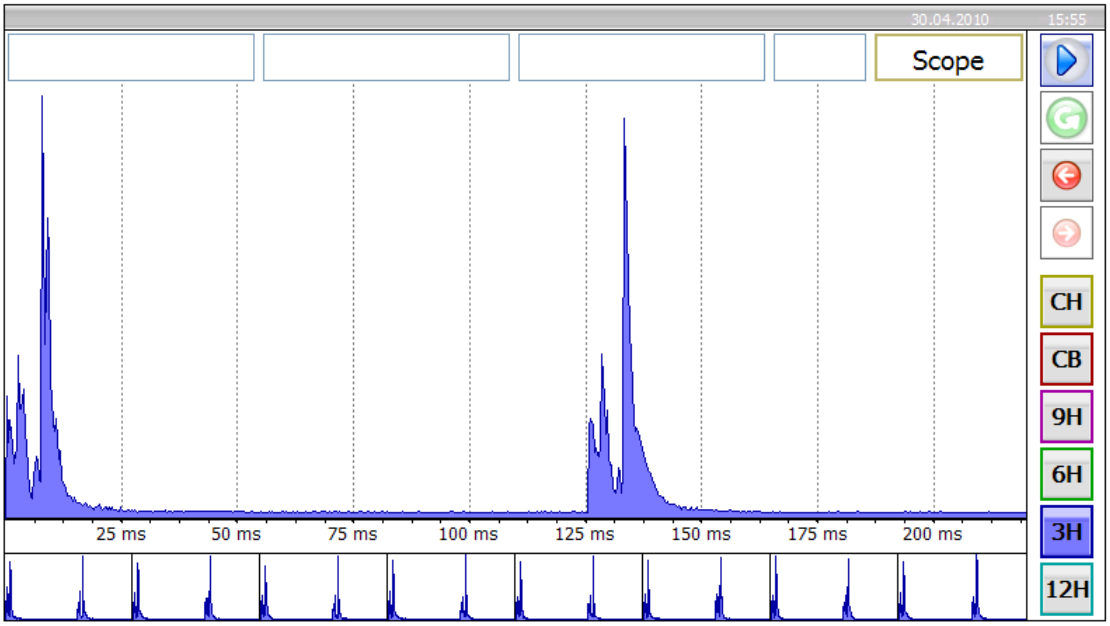
2.2.5 Display Mode Scope

The graphic display of the beat noises allow a detailed analysis of the escapement's condition.

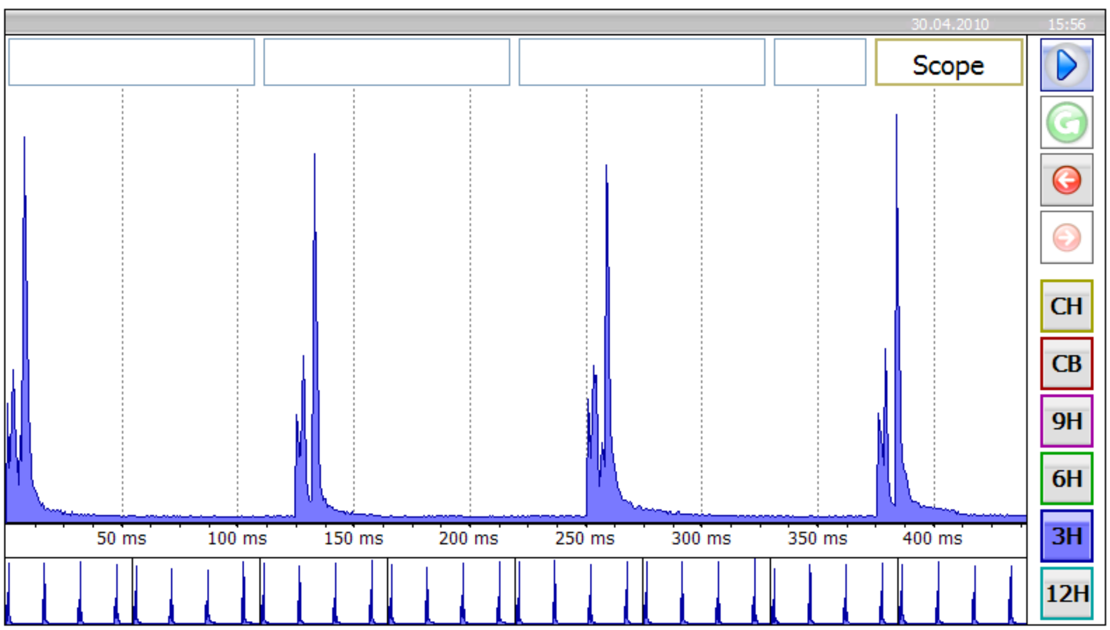


Example with **3A** integration time and a time range of **20 ms**. A **Tic** and a **Tac** are alternatively shown, including the value of the amplitude. For a watch with 28'800 A/h the display change occurs every **0.375** seconds.

3A integration time and time range of **200 ms**



3A integration time and time range of **400 ms**



Depending on the number of beats and the selected time range (200ms or 400ms) the screen displays several succeeding beat noises.

The last eight beat noises are displayed in a small format. If one of the small pictures is touched after stopping the Scope function, this will appear in large display format.

Calculation of the results

In Test Mode Sequence:

X Sum of the measured values divided by the number of test positions

D Difference between the largest and the smallest value.

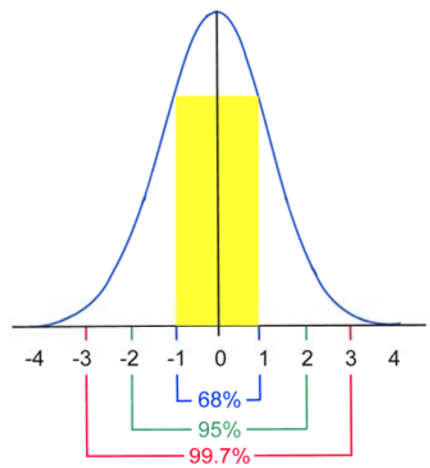
DVH Difference between the means of the vertical and horizontal test positions.

Di Rate difference between the test positions 6H and CH (DU and CL).

	Rate	Ampl	Beat
CH	4.8	258	0.3
CB	9.8	267	0.3
9H	5.3	243	0.4
6H	9.1	243	0.0
3H	1.9	237	0.0
12H	-	-	-
X	6.2	250	0.2
D	7.9	30	0.4
DVH	-1.9	-22	
Di	4.3		

In Test Mode Vario:

σ **Standard deviation.** It is the measure for the dispersion around their mean value.
68,27 % of all measured values have a deviation from the mean value, which corresponds maximally to the value of the standard deviation (X +/- 1 σ).



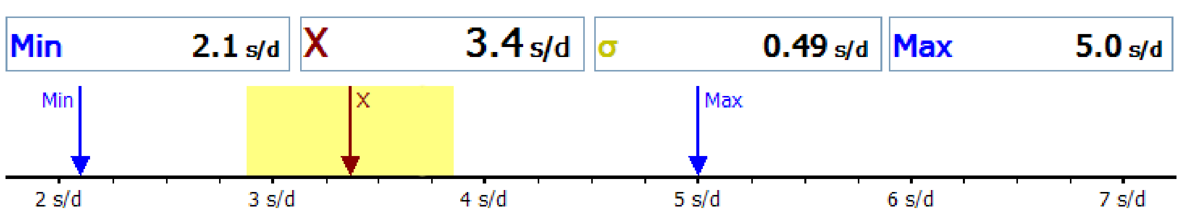
Example

After a measuring time of over 3 hours for the rate measurement results a **σ** of **0.49s/d** and a mean value of **3.4s/d**.

Calculation

Mean value **X** less standard deviation **σ**	3.4 – 0.49 = **2.91s/d**
Mean value **X** plus standard deviation **σ**	3.4 + 0.49 = **3.98 s/d**

In our example **68,27 %** (yellow zone) of all measured values lie within the range of **2,91 to 3.98 s/d**.



The same procedure is also valid for the amplitude measurement.

The smaller the standard deviation, the better is the stability of rate and amplitude.

3 Witschi Measuring and Testing Technology

Witschi Electronic Ltd is a global leader in the field of measuring and testing technology for watches and other micro-technical products.

Our offer consists of devices for measuring and testing purposes for the production and repair services of mechanical and quartz watches.

In all our activities we pursue the vision, to be and to remain the world leader in the field of test technology for watches.

We want to provide innovative, quality products with customer value.

More information is to be found on our Website www.witschi.com