United States Patent [19]

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[11] **3,771,347**

[45] **Nov. 13, 1973**

[54] **APPARATUS FOR ANALYZING THE MOVEMENT OF A TIMEPIECE REGULATING MECHANISM**

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[22] Filed: **June 2, 1972**

[21] Appl. No.: **259,316**

[30] **Foreign Application Priority Data**

June 3, 1971 Switzerland 8068/71

[52] **U.S. Cl.** **73/6**

[51] **Int. Cl.** **G04b 17/00**

[58] **Field of Search** 73/6

[56] **References Cited**

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[57] **ABSTRACT**

Method and apparatus for measuring the quantity of movement of the regulating mechanism of a timepiece, characterized in that the light beam of an optical system is arranged for partial interception by the edge portion of the pallets means of the regulating mechanism when said pallets means are in at least one end position of travel, whereby said light beam is intensity-modulated during oscillatory travel of the pallets means to produce a generally trapezoidal signal voltage (U_1). Circuit means are provided for processing said signal voltage to provide output voltages (U_{41}, U_{42} and/or U_{51}, U_{52}) that are a function of the flank portions of said trapezoidal signal voltage when said pallets means are in the end positions of travel, respectively.

4 Claims, 4 Drawing Figures

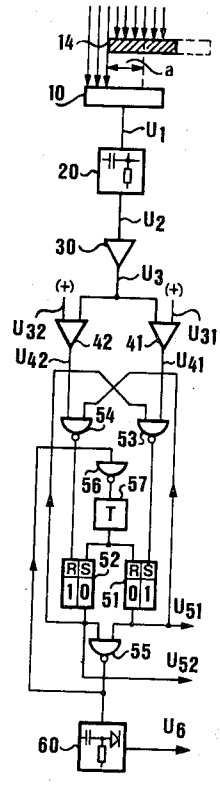


Fig.1

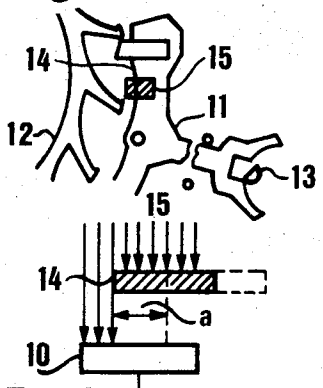


Fig.2

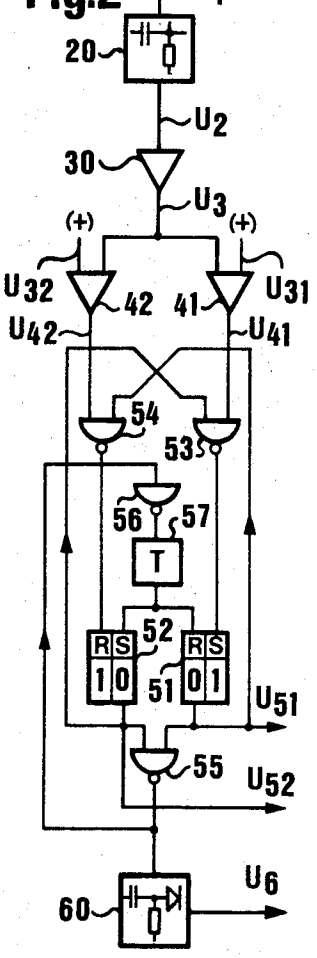


Fig.4

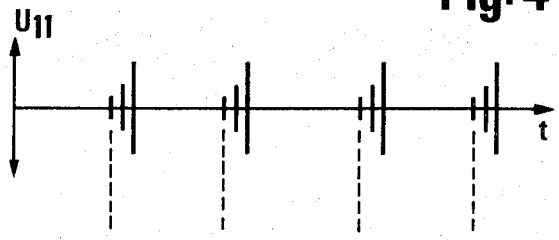
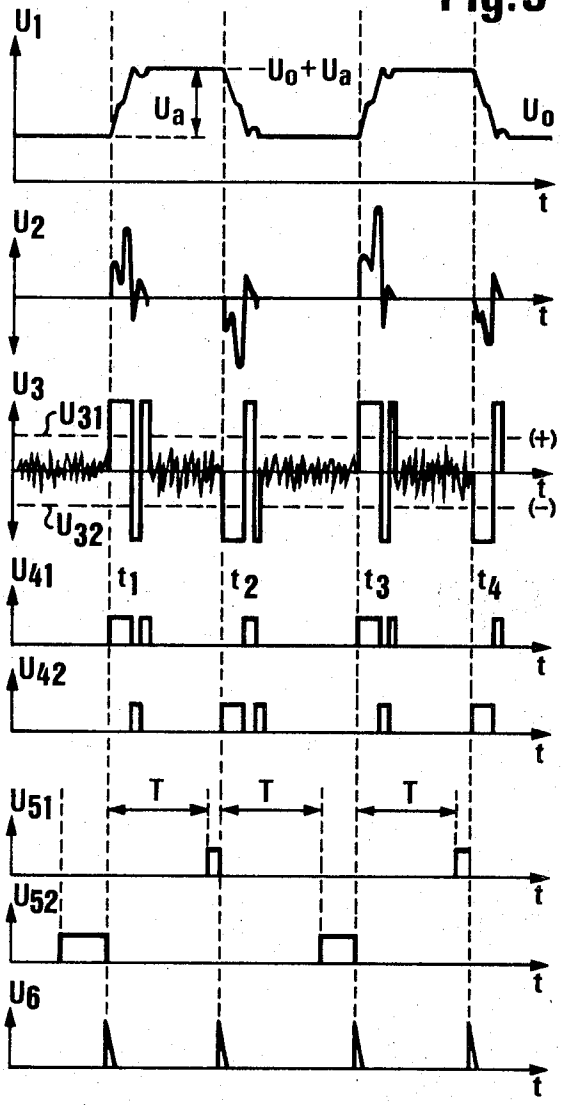


Fig.3



APPARATUS FOR ANALYZING THE MOVEMENT OF A TIMEPIECE REGULATING MECHANISM

It is known to determine rate, amplitude or out of beat errors by recording or indicating timing machines. Mostly, in such cases, an acoustic watch signal, produced by the escapement, is picked-up by a microphone and is amplified and transformed in an auxiliary circuit connected thereto. Finally, after corresponding transformations, the value of the desired quantity of oscillation can be determined from the transformed signal.

In electric watches, the rate regulating organ has an electromagnetic automatic control device for the oscillation system. For this purpose, the latter may be provided with small permanent magnets which act mutually and alternately with fixedly arranged control and drive coils. The resulting alternating magnetic field can be detected outside the movement by means of an induction coil and can be further processed in similar manner to the aforementioned microphone signals. However, the supply current, which librates in phase with the watch signals, can also be picked up by galvanic current collectors.

In these known applications, the receiving means as the microphone, the induction coil, or the current collectors, in relation to the watch mechanism influencing them, are merely arranged and/or poled in such a position, that the power, which is available for the above mentioned purposes, and is picked up by these means is sufficiently great in absolute value, and, the case given, is distortion-free. The phase of these signals relative to the movements of the oscillator remains disregarded and therefore is at least equivocal in the sense, that a certain section of the signal curve corresponds at least with two parts of the mechanical oscillation. A harmonic analysis of both oscillations would show that the fundamental frequencies differ or are not phase-locked, in the sense indicated above.

Furthermore, methods are known which make use of photo-electric receiving units for finding the quantities of movement in clock mechanisms. In these cases, a beam of light is directed onto the rim, the crossings, or the pallets means of the regulating mechanism. The movement of these parts modulates the light which is radiated out or reflected-back, and can be evaluated by means of receivers and auxiliary circuits. The optical system is so arranged that the most powerful possible signals are produced without regard to phase. These optical methods are preferred in cases when, for example, the rate is to be adjusted by mechanical adjustment of the regulator, because in the acoustic method, the interference noises caused by the rate adjusting means would be a hindrance.

The present invention relates to a method for determining a quantity of oscillation of a timepiece regulating organ having an oscillator and an automatic control device, wherein a periodic watch signal containing this quantity is obtained from these oscillating components, influences a sensing element of a receiving unit and subsequently is amplified and transformed in an auxiliary circuit. The invention is characterized in that, for the purpose of unequivocal coordination of the oscillation of the transformed signal to that of the regulating mechanism:

a. the watch mechanism, and the sensing element influenced by it, are brought into a mutual position which is pre-determined in such manner that the particular direction of the regulating organ is unequivocally picked up and reproduced at least once per period by the sensing element, and

b. pick-up and amplification and/or transformation are carried out in such a manner that the transformed signal has the same fundamental frequency as the regulating organ oscillation and is phase-locked therewith.

In order, particularly in a lever watch, to differentiate the entry lift from the exit lift or, in the noise of a watch, or clock, unequivocally to differentiate the "tick" from the "tock," the method in accordance with the invention preferably is carried out by directing a beam of light onto the watch or clock mechanism in such manner that it passes through the range of movement of the pallets means and is modulated thereby during the course of its movement—namely, in such manner that, at least when the pallets means are at a standstill, one part of the beam of light falls onto the pallets means and the other part influences a photoelectrical sensing element. These measures permit, for example, the out of beat error to be detected and removed mechanically within the shortest possible time, with the correct plus or minus sign (as distinguished from prior methods wherein it was first necessary, by tests, to determine in which direction the small movable stud was to be displaced).

Further objects and advantages of the invention will become apparent from a study of the following specification when viewed in the light of the accompanying drawing in which:

FIG. **1** is a plan view of the escapement of a lever watch, illustrating in cross section the light beam of a receiving unit;

FIG. **2** is a sectional view through a pallet-arm and the light beam, illustrating in block diagram form the electrical system associated therewith;

FIG. **3** illustrates the output voltages, relative to time, of the circuit portions which are arranged opposite thereto; and

FIG. **4** illustrates the known diagram of the noise of an acoustic type escapement.

The escapement of a lever watch includes a pallets means **11** which is in driven engagement with the escape wheel **12,** and in driving engagement with a balance of which only the ellipse portion **13** is illustrated. This regulating mechanism is mounted in a known manner either in the clock mechanism or in a supporting unit corresponding thereto. In order now to discover a quantity of movement of the regulating means, a beam of light **15** is directed onto the timepiece mechanism in such manner that it passes through the range of movement of the pallets means **11** and is modulated thereby during its course of movement. For that purpose, a photoelectrical receiving unit is brought into a predetermined position in relation to the timepiece mechanism, namely such that the beam of light **15** always falls partly on and is intercepted by the pallets means **11,** whereas the other part falls on the photosensitive element **10.** The edge **14** of the illuminated pallets means accordingly is located within the light beam during the entire oscillation of the balance means, and thereby it travels twice through the path *a*.

The optical system and the mutual positioning of the timepiece mechanism and the receiving unit are preferably so arranged that the light beam falls from the receiving unit onto the side of the bottom plate and into the timepiece mechanism, is reflected on the bridge of

the pallets means and leaves the timepiece mechanism again on the side of the bottom plate before it meets the photo-element. This, and other, modes of guiding the light beam have been disclosed in prior applications of the assignee of this invention (for example, applicant's prior U.S. application Ser. No. 135,648 filed Apr. 20, 1971) and do not form part of the present invention.

The light falling on the photoelectric element, for example a photo-transistor, controls the latter in such manner as to produce an approximately trapezoidal output voltage U_1. This voltage U_1 contains, apart from a direct-current component and in addition to various harmonics, above all, a fundamental oscillation which corresponds with that of the regulating mechanism and is phase-locked therewith. The lower level U_0 of the trapezoidal voltage U_1 in fact corresponds unequivocally to the rest position of the pallets means **11** illustrated in FIGS. **1** and **2**, wherein the light beam **15** is strongly darkened, the lever bears on the upper banking pin, and the impulse or roller pin of the balance means mainly swings around above. Vice versa, the upper voltage level corresponds unequivocally to the maximum light intensity applied to the element **10** when the lever **11** bears upon the lower banking pin, the impulse or roller pin of the balance wheel **13** being pivoted accordingly. The oscillation of the photoelectrically transformed signal thus—as regards its phase—is unequivocally coordinated with that of the regulating mechanism.

In contrast to this, in the voltage U_{11} (FIG. **4**) of a conventional acoustic receiver, this is not the case. Form, amplitude, and phase position of the pulse strokes generally cannot illustrate unequivocally which pulse stroke or watch tick belongs to which phase of the balance wheel oscillation, or at any rate, to an external auxiliary or normal oscillation which is synchronous therewith.

The method previously described, with photoelectrical scanning of the pallets means, now can be applied in such manner that between the two voltage levels U_o *and* U_{o+a}, an intermediate voltage threshold is applied, whereof the exceeding or the falling short of it is discovered by means of the further auxiliary circuit; and in such manner the desired unequivocal coordination of the half periods can be carried out.

In the mass manufacture of timepieces or watches, in order to save costs, certain measurement tolerances are permitted. This leads to the additional requirement that the mutual positioning of the clockwork movment with pallets **11** and photoelectrical receiving unit **10** likewise should permit certain tolerances. These, and further demands, lead to a further development of the method of the present invention by means of a more convenient auxiliary circuit arrangement such as is described as follows.

The approximately trapezoidal voltage U_1 is differentiated in the high pass filter **20**, and the differentiated alternating current signal U_2 is transformed in the amplifier-limiter **30** into pulse groups U_3, one in each case per watch tick. By means of two comparators **41, 42**, with the absolutely approximately equally sized (but having different plus or minus signs) comparison voltages $U_{31}(+)$ and $U_{32}(-)$, the noise is suppressed so that the flanks of the positive and negative pulses can be picked-up clearly separated: U_{41}, U_{42}.

The auxiliary circuit furthermore contains further elements known per se, which have the following functions: as soon as one of the two comparators **41** and/or **42** responds to a signal U_3, this signal is stored in one of the two RESET/SET flip-flop **51** and/or **52**; at the same time, the inverting OR-gate **54** and/or **53** of the other path U_{42} and/or U_{41} is blocked, and a blocking time generator **57** is switched-in via two inverting gates **55, 56.** Due to the blocking time, in addition to the first rising flank at t_1, t_2, t_3, or t_4, all further flanks of each pulse group are rendered ineffective for the triggering. After expiration of the blocking time T, both gates **53, 54** are opened again and are released for the next pulse group.

The two signals U_{51}, U_{52}, appearing after all these transformations at the output of the auxiliary circuit, finally contain, with all the desirable unequivocality, the quantity of movement of the regulating mechanism, in phase locked coordination. In the present example, it is these pulses which could be used, for example, for the desired rapid correction of the out of beat error.

The inverting OR-gate **55,** in addition to being connected with the inverter gate **56,** also is connected with one high pass and an additional circuit **60** which has a rectifier. At the output of said additional circuit **60** there appears, for each timepiece tick, a needle pulse U_6 which straightaway, in place of a microphone signal, can be passed onwards at the input of a conventional timing machine or of an automatic rate adjusting means. Here, it is even possible to select, as desired, whether the rate adjustment is to be based upon the even or the odd watch ticks; this can be of advantage in a case where the time inexactitude in the two series of pulses is of different amounts. However, such further combinations are not shown here.

In the case of electric timepieces, the method likewise is advantageously applicable. Here it is merely necessary to take care that the corresponding receiver, an induction coil, is brought into a predetermined position in relation to the regulating means, so that the coordination of its output voltage with the oscillation of the regulating means is unequivocal. In this case, the differentiation (U_1–U_2) can be dispensed with.

Thus it is shown that with comparatively simple means, the method can be adapted to important needs of automation, such as independency of tolerances and versatility.

What is claimed is:

1. Apparatus for measuring the operation of a timepiece having an oscillatory regulating mechanism including pallets means, comprising

a. a stationary light-responsive member (**10**);

b. means for directing a light beam on said member, said member being so arranged that said beam is always partially intercepted by an edge portion of said pallets means, whereby when said pallets means is in one end position of oscillatory travel a first portion of light falling on said member is a minimum and a second portion of light falling on said pallets means is a maximum, and when said pallets means is in the other end position, said first light portion is a maximum and said second light portion is a minimum; and

c. circuit means connected with said light-responsive member for producing distinctive first and second output pulse signals (U_{41}, U_{42}) when said pallets means is in said first and second end positions, respectively.

2. Apparatus as defined in claim 1, wherein the light modulated voltage (U_1) appearing on said light-responsive member is generally trapezoidal and includes low (U_a) and high (U_o+U_a) voltage levels; and further wherein said circuit means includes high pass filter means (20) for eliminating from said light-modulated signal said low voltage level thereby to produce a differentiated signal (U_2); limiter means (30) for transforming said differentiated signal into a signal (U_3) of pulse groups the polarities of which correspond with the end positions of said pallets means, respectively; and level comparator means (41, 42) for isolating the peaks of said pulse group signal to produce said first (U_{41}) and second (U_{42}) output signals, respectively.

3. Apparatus as defined in claim 2, and further including processing means for producing from said first and second output signals (U_{41}, U_{42}) time integrated error correction signals (U_{51}, U_{52}), respectively, said processing means comprising flip-flop means including a pair of RESET/SET flip-flops (51,52), inverting-OR gate means (53, 54) for supplying said first and second output signals to said flip-flops, respectively, and a blocking time generator (57) operable by a pair of inverting output and input gates (55, 56) for alternately setting and resetting said flip-flops, respectively, whereby said error correction signals correspond in phase-locked coordination with the movement of said pallets means.

4. Apparatus as defined in claim 3, and further including high pass filter means (60) including a rectifier for generating a further output signal (U_6) which comprises a series of needle pulses corresponding with the arrivals and departures of said pallets means at said first position, respectively.

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