United States Patent [19]

Mutter et al.

[11] **3,748,845**

[45] **July 31, 1973**

[54] **ELECTRONIC SYSTEM MODULE FOR CRYSTAL-CONTROLLED WATCH**

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[21] Appl. No.: **204,000**

[52] **U.S. Cl.** .... **58/23 A**

[51] **Int. Cl.** **G04c 3/00**

[58] **Field of Search** .... 58/23 R, 23 A, 23 BA, 58/23 AC, 23 D, 23 TF, 23 V, 50, 53; 74/142; 310/25; 318/41, 35, 119, 129, 130, 14; 331/51, 52, 116 M, 158, 108 C, 108 D; 317/235

[56] **References Cited**

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3,282,042	11/1966	Schaller	58/23 V
3,433,009	3/1969	Haag	58/23 TF
3,469,389	9/1969	Nakai et al.	310/25 X
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3,534,544	10/1970	Oguey et al.	58/23 A
3,538,704	11/1970	Kawanaka et al.	318/130 X
3,540,209	11/1970	Zatsky et al.	58/50 R
3,585,527	6/1970	Luscher	58/23 A
3,628,323	12/1971	Baumgartner et al.	58/23 BA
3,672,153	6/1972	Mutter	58/23 TF

Primary Examiner—Richard B. Wilkinson
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[57] **ABSTRACT**

A replaceable module incorporating the electronic systems for a compact crystal-controlled watch wherein the high-frequency of a quartz crystal is scaled down to produce low-frequency pulses. These pulses actuate a time display by means of a tuning fork motor whose sole function is to turn the hands of the watch. The module is constituted by an oscillator circuit, the output of which is fed to a multi-stage frequency divider, the oscillator circuit and divider being embodied in a single package containing integrated circuitry. The module is joined to an incrementally-adjustable capacitor unit for tuning the oscillator circuit. Extending from the module are five terminal lugs and one connecting tab, the first two providing support for and connections to a quartz crystal assembly mounted below the tuning unit. The second and third lugs are connectable to a power cell, while the fifth lug which yields the system out-put pulses, is connectable to the tuning fork motor. The tab serves to connect the tuning unit to the oscillator circuit.

6 Claims, 4 Drawing Figures

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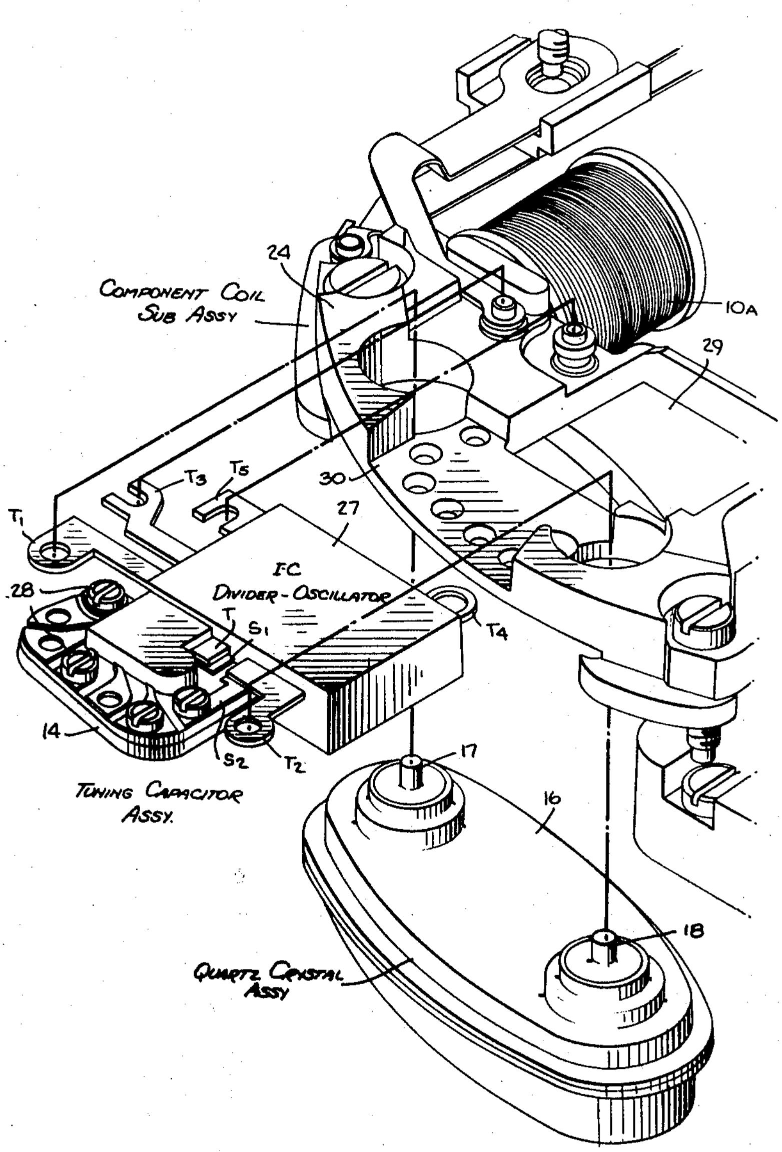
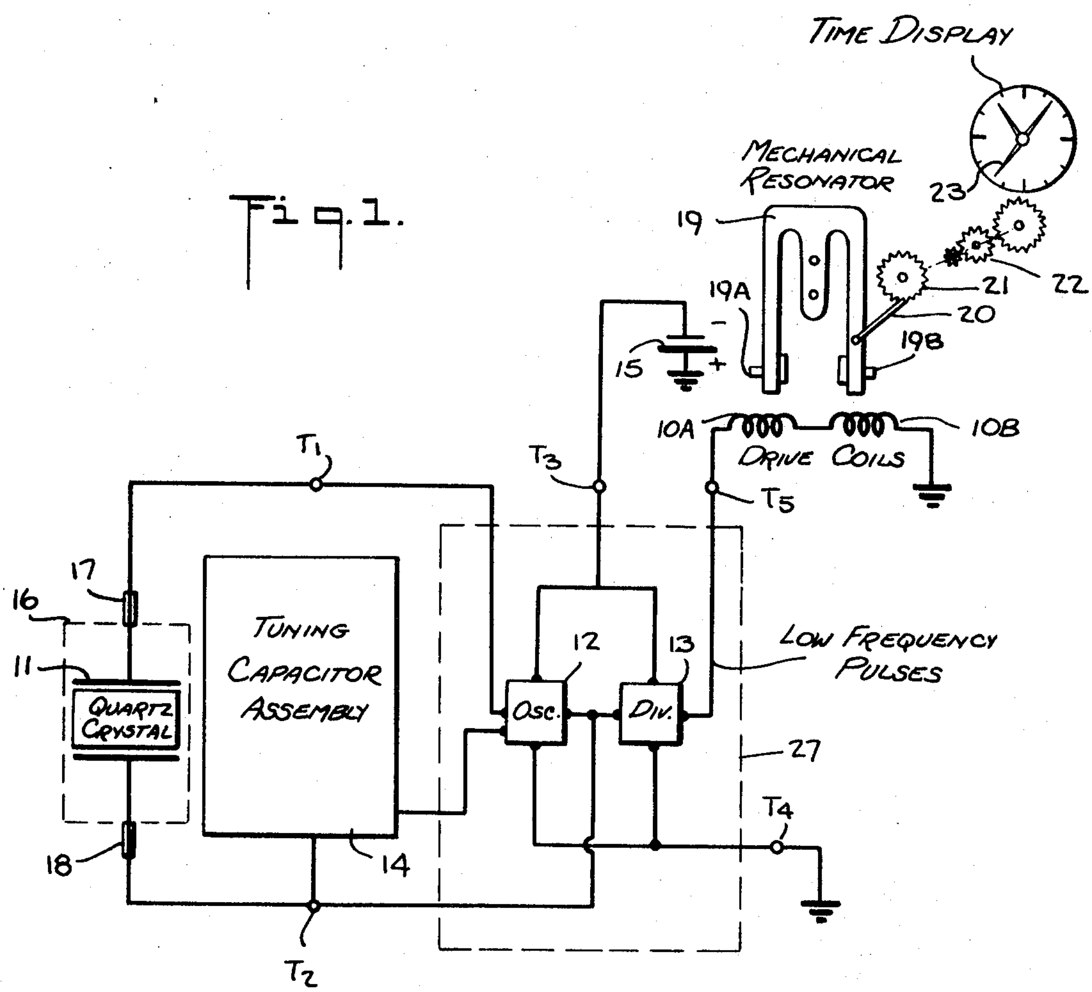


Fig. 1.


TIME DISPLAY
MECHANICAL RESONATOR
19
19A
19B
20
21
22
23
15
10A
10B
DRIVE COILS
T1
T3
T5
17
16
11
QUARTZ CRYSTAL
TUNING CAPACITOR ASSEMBLY
12
13
OSC.
DIV.
LOW FREQUENCY PULSES
27
T4
18
14
T2

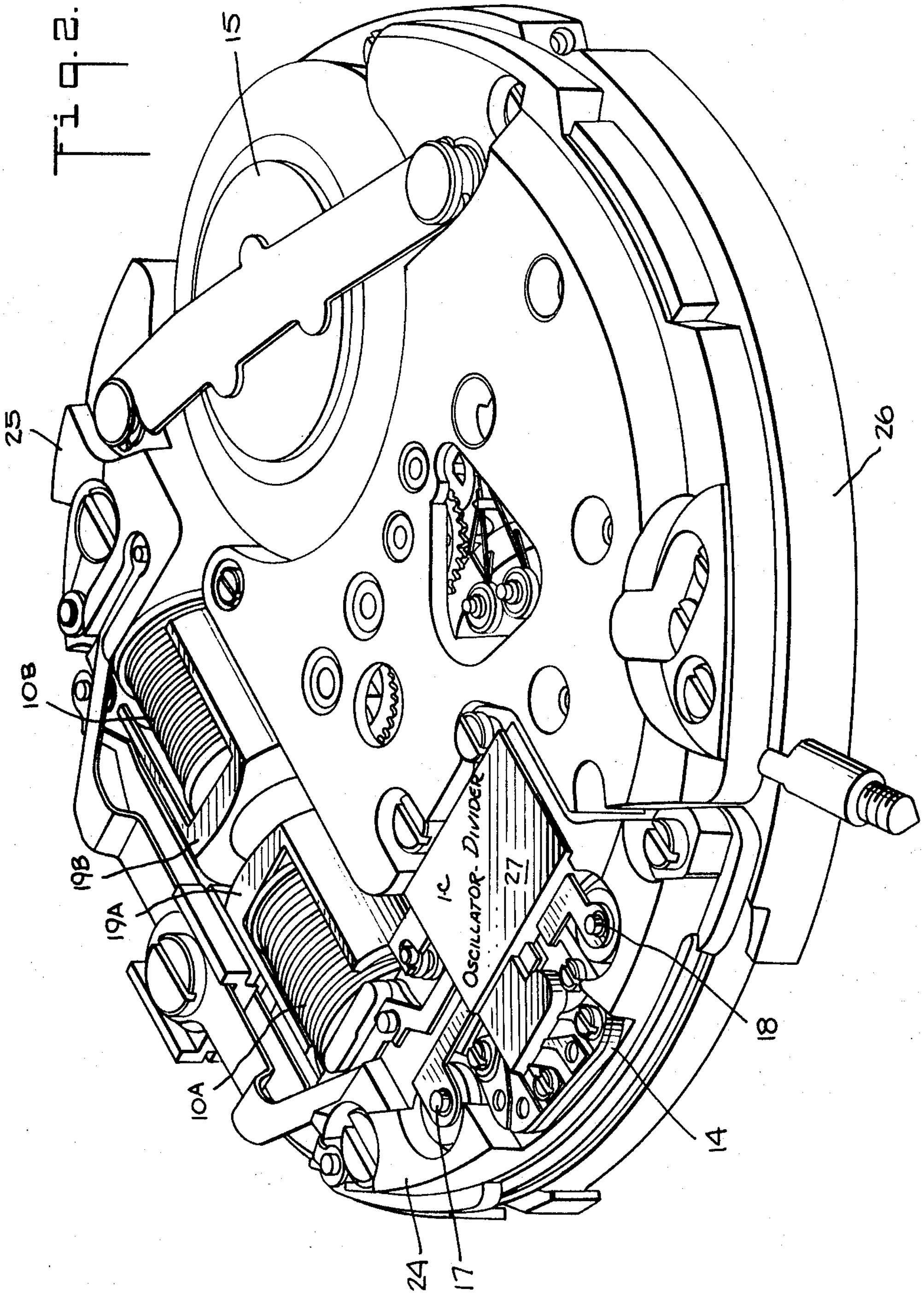


Fig. 2.

Fig. 3.

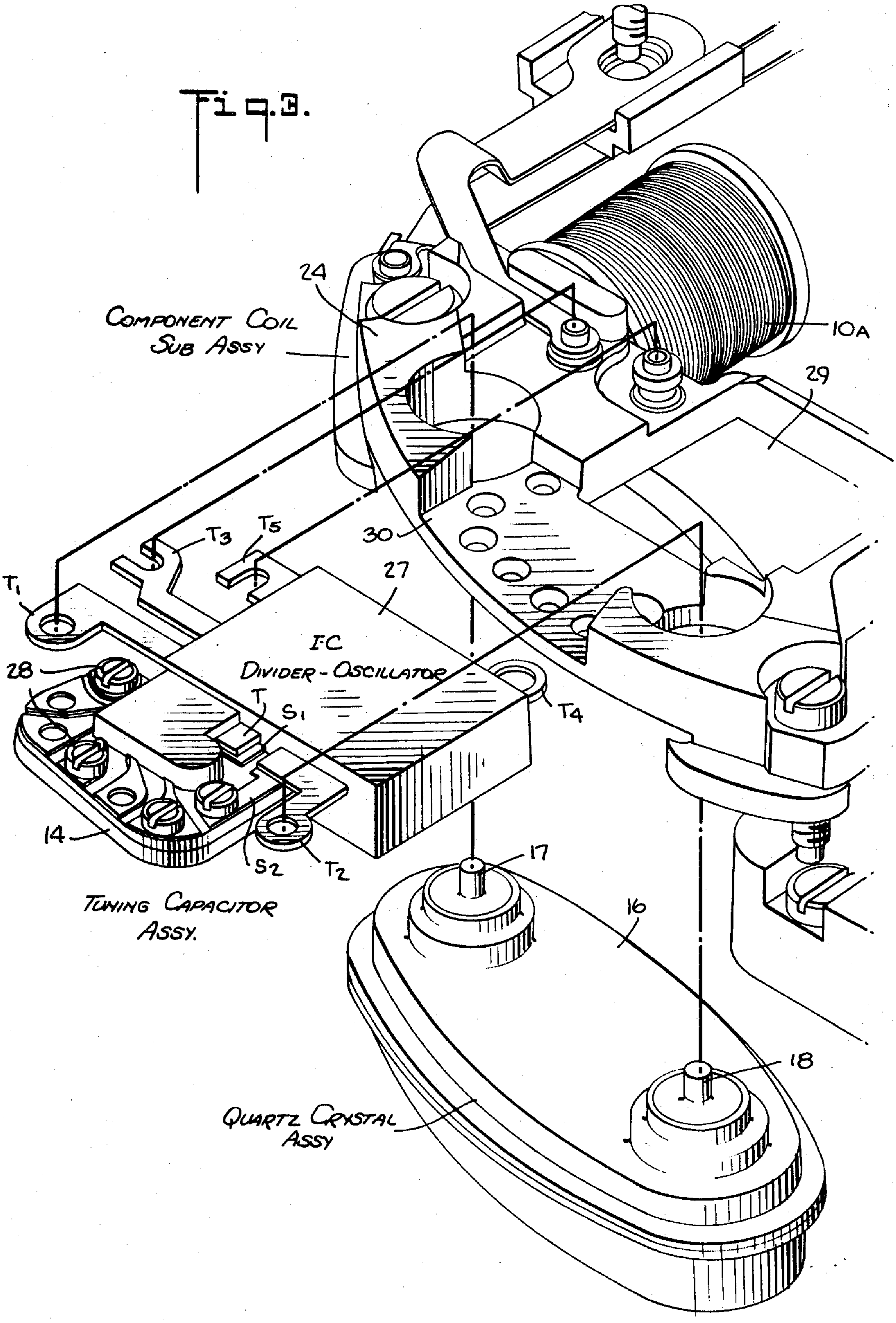
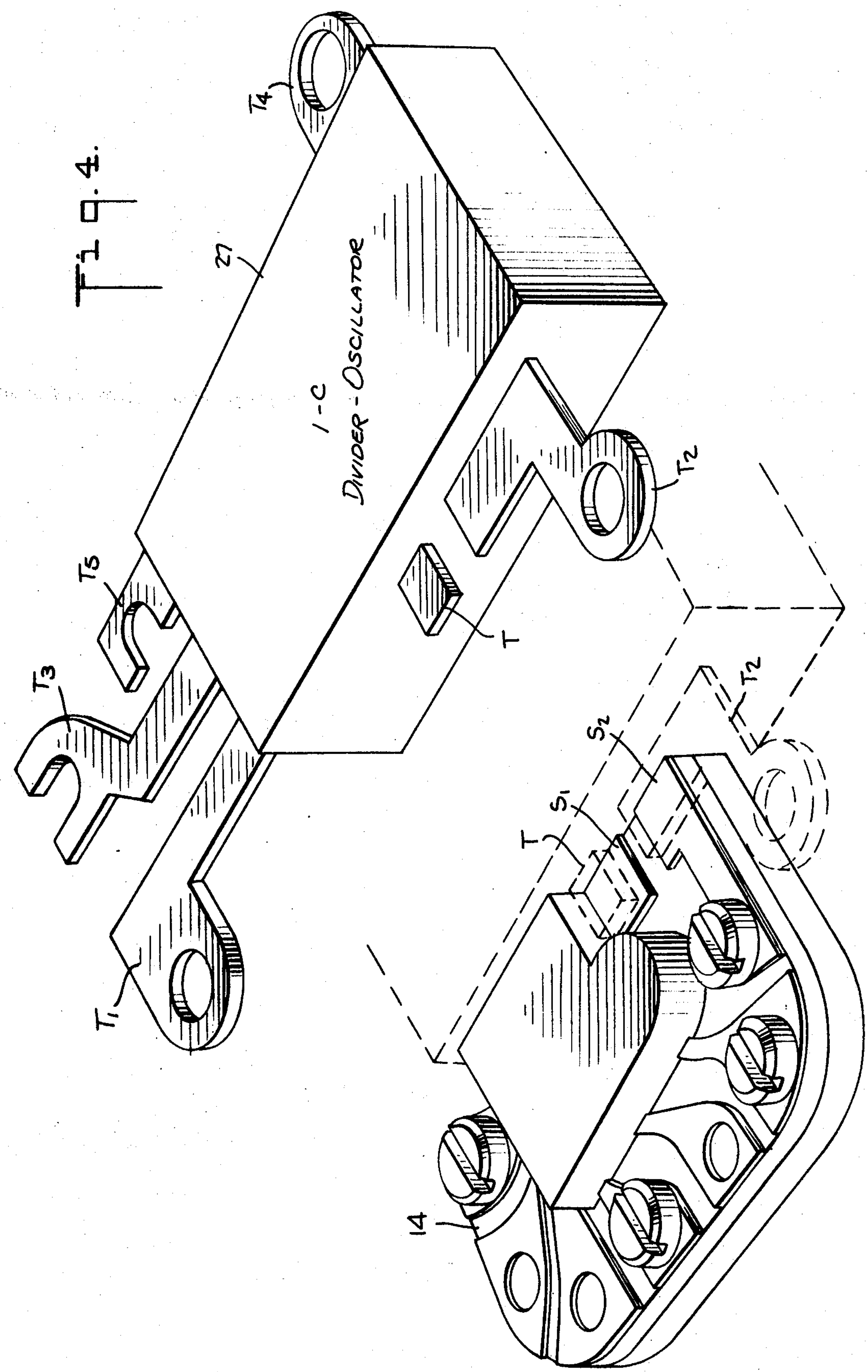

24
COMPONENT COIL SUB ASSY
10A
29
30
T3
T5
T1
27
I-C DIVIDER - OSCILLATOR
28
T
S1
T4
14
S2
T2
17
16
TUNING CAPACITOR ASSY.
18
QUARTZ CRYSTAL ASSY

Fig. 4.



ELECTRONIC SYSTEM MODULE FOR CRYSTAL-CONTROLLED WATCH

BACKGROUND OF THE INVENTION

This invention relates generally to crystal-controlled electronic timepieces, and more particularly to a timepiece in which low frequency pulses derived from a high-frequency crystal oscillator serve to actuate a time display.

In order to provide an electronic timepiece of high accuracy, it is known to derive periodic pulses having a low repetition rate from a frequency-divider coupled to a stable, high-frequency standard, the pulses serving to actuate or synchronize a suitable time display. The frequency standard or time base is generally in the form of a piezoelectric crystal-controlled oscillator whose resonant frequency usually lies in a range about 10,000 to 35,000 Hz.

The time display is adapted to indicate time in terms of seconds, minutes and hours — it therefore being necessary to divide down the frequency of the crystal-controlled time base to a low rate suitable for the associated display. This display may be of the conventional mechanical type employing time indicating hands, or, it may be in the form of electroluminescent or electro-optical elements adapted to afford time indications.

Thus, in the Zatsky et al. U.S. Pat. No. 3,540,209, an electronic timepiece is disclosed wherein pulses at a rate of one per second are generated, the pulses serving to actuate a liquid-crystal display for indicating the passage of time. For this purpose, use is made of a crystal-controlled oscillator whose output is applied to a chain of fifteen binary divider stages yielding exactly one pulse per second.

In the Schaller U.S. Pat. No. 3,282,042, the frequency of a crystal-controlled oscillator is divided down to produce pulses for synchronizing the operation of a tuning-fork motor driving the gear works of a mechanical time display. The tuning-fork motor is of the type disclosed in the Bennett et al U.S. Pat. No. Re 26,322 and in other patents dealing with tuning-fork timepieces. In the Nakai U.S. Pat. No. 3,212,252, the output of a crystal oscillator is supplied to a frequency divider and then amplified so as to energize a synchronous motor which drives a conventional time display mechanism.

Thus various forms of mechanical and non-mechanical time displays have therefore been used in conjunction with a stable, high-frequency, crystal-controlled time base functioning in combination with a frequency divider to reduce the output frequency of the electronic system to a rate appropriate to the display.

The crux of electronic timepieces disclosed in the above-noted patents lies in the crystal-controlled oscillator. This high-Q oscillator not only has the advantage of being inherently more stable than other species of frequency standards, but it is further characterized by an insensitivity to position error. When, therefore, the timepiece is in the form of a wrist watch, the frequency of the standard and hence the timing of the watch, is not adversely affected by changes in attitude.

A conventional crystal-controlled timepiece is a precise timekeeper only if the crystal is dimensioned to function at an assigned frequency. Should the crystal frequency be displaced from its assigned value, the timepiece will be inaccurate to an extent depending on the degree of displacement. An error of only one part in ten thousand in the crystal frequency will give rise to a timekeeping error of about 10 seconds a day or 5 minutes a month. This error is unacceptable under modern standards of accuracy for electronic watches.

Inasmuch as the resonant frequency of a crystal-controlled oscillator is a function of the reactance of the circuit, one may effect slight changes in the oscillator's frequency in a direction above or below the natural frequency of the crystal by means of an incrementally-adjustable reactor unit in series with the crystal. A preferred form thereof is disclosed in the co-pending application of Koehler and Mutter entitled "Incrementally-Adjustable Capacitor Unit For Tuning a Crystal-Controlled Oscillator" Ser. No. 195,348, filed Nov. 3, 1971.

Whether the electronic system is used in conjunction with a tuning-fork motor for operating the time display, or acts in conjunction with other types of mechanical or non-mechanical time displays, as a practical matter the electronic system must consist of the following four elements or sub-assemblies:

a. a quartz crystal element;

b. an oscillator circuit associated with the crystal element (solid state);

c. an incrementally-adjustable capacitor unit for tuning the crystal oscillator frequency;

d. a multi-stage frequency divider (solid state).

In order for a timepiece to qualify as a watch, it must be compact so that it can be worn on the wrist. This presents a problem when the electronic a frequency is crystal-controlled and when, in addition to a motor or tuning-fork vibrator for turning the hands, there are included the above-noted four components which make up the electronic system to produce low-frequency pulses for actuating the motor.

One can, of course, use known integrated or printed circuit techniques for scaling down the dimensions of the crystal oscillator, the frequency divider and the incrementally-adjustable tuning reactor. But even then the inter-couplings between these circuits with the crystal element and the power cell involve arrangements and connections which demand space.

As a consequence, crystal-controlled timepieces of the type heretofore produced, have been relatively bulky as compared to existing types of mechanical and electronic watches. Indeed, such crystal-controlled watches have in most cases, been so large as to render them commercially unacceptable except to those users who in the interest of exceptional accuracy, have been willing to overlook the cumbersome nature of the watch and its awkward appearance on the wrist.

Certainly, no crystal-controlled watch heretofore available has been suitable for ladies' wear. The notion that women lack interest in exact timekeeping is a myth which is contradicted by the growing sales of womens' high quality watches having a practical rather than an ornamental appearance.

Moreover, no watch can be designed without giving consideration to the need for future maintenance and repair. In an electronic crystal-controlled watch, defects may arise in the crystal element or in the circuits associated therewith. Where for example, there is a failure in a single transistor in the multi-stage divider, this renders the watch inoperative. One cannot, in the case of an integrated circuit, replace the defective transistor, so that removal and replacement of the entire circuit unit is necessary.

In existing crystal-controlled watches, the electronic circuit and the crystal element are so placed and connected as to make repair very difficult and costly. Also, the arrangement is often such as to interfere with access to the mechanical components of the watch, so that even if the electronic system is in working order and repair is indicated in the associated motor or gear train, it may be necessary to dismantle the electronic system in order to reach the defective part.

SUMMARY OF THE INVENTION

In view of the foregoing, it is the main object of this invention to provide an electronic system for a compact crystal-controlled watch, which system is formed by a quartz crystal element, an oscillator circuit associated with the crystal element, an incrementally-adjustable capacitor unit for tuning the oscillator, and a frequency divider for dividing down the frequency of the oscillator to provide low frequency pulses for actuating a time display; the oscillator circuit and the frequency divider being incorporated in a single replaceable module of miniature dimensions.

A significant feature of the invention is that the total space occupied by the module, the tuning unit and the crystal element used in conjunction therewith is no greater than the electronic circuit included in existing tuning-fork electronic watches. Hence, the invention makes it possible to convert existing models of tuning-fork watches to more precise crystal-controlled operation without enlarging the watch dimensions.

Also an object of the invention is to provide an electronic system for a crystal-controlled watch which may readily be installed in the watch or removed therefrom for purposes of replacement.

Yet another object of the invention is to provide a self-sufficient system of the above type which may readily be combined with a mechanical time display including a gear train for turning the hands of the watch, the system components in no way interfering with or blocking access to the mechanism.

Briefly stated, these objects are attained in a replaceable miniature module incorporating the oscillator circuit and the frequency divider coupled to the output thereof, the circuits thereof being embodied in a single integrated-circuit package. An incrementally-adjustable capacitor unit for tuning the oscillator circuit is joined to one side of the module.

Extending laterally from the module are five terminal lugs and one connecting tab, the first two lugs serving to provide support for and connections to a quartz crystal assembly mounted below the tuning unit, the third and fourth lugs being connectable to a power cell for energizing the system. The fifth lug yields the output pulses of the system and is connectable to the time-display motor or circuit. The tab serves to connect the tuning unit to the oscillator circuit.

OUTLINE OF THE DRAWINGS

For a better understanding of the invention as well as other objects and further features thereof, reference is made to the following detailed description to be read in conjunction with the accompanying drawings, wherein:

FIG. 1 is a circuit diagram of a crystal-controlled watch including an electronic system module in accordance with the invention;

FIG. 2 is a rear perspective view of the watch;

FIG. 3 is an exploded view of a portion of the watch, and

FIG. 4 in perspective shows the module separated from the tuning unit.

DESCRIPTION OF THE INVENTION

Referring now to FIG. 1, there is shown an electric timepiece in accordance with the invention in which the output of a high-frequency stable crystal oscillator circuit is divided down to produce low-frequency timing pulses for operating a suitable time display. By way of example, we shall assume a mechanical time display having hands which are driven through a gear works operated by a tuning fork motor of the type disclosed in said Schaller and Bennett, et al patents, the vibrations of the fork being converted into rotary motion by an indexing mechanism or equivalent means.

However instead of having a self-sufficient transistor drive circuit operating in conjunction with drive and sensing coils for sustaining the fork in vibration, as in the Schaller and Bennett el al. patents or as in Hetzel U.S. Pat. No. 2,971,323, the tuning fork is actuated by drive pulses derived from the crystal-controlled oscillator and applied to series-connected drive coils **10A** and **10B** at a rate appropriate to the resonant frequency of the tuning fork.

Alternatively, drive coils **10A** and **10B** may be the solenoid of a stepping motor or any other electromagnetic device for operating a mechanical time display. It is to be understood that the pulses applied to the drive coils need not be used for actuating a mechanical time display, but may be employed to activate an electronic time display.

The stable frequency standard is provided by a piezoelectric quartz crystal **11** in circuit with an oscillator **12** to produce a high-frequency time base whose output is fed to afrequency divider **13** having an appropriate number of stages to produce low-frequency actuating pulses at a rate suitable for the associate time display. The operating frequency of oscillator **12** is tuned by an incrementally-adjustable capacitor unit preferably of the type disclosed in said copending application of Koehler and Mutter, and generally designated by numeral **14.** Any known form of tuning reactor may be used for the same purpose. The entire system is powered by a suitable battery **15.**

Quartz crystal **11** is protectively housed in an evacuated container **16,** provided with terminal pins **17** and **18** to form a removable crystal assembly which is connectable in series with tuning unit **14** to the circuit of oscillator **12.**

The time display shown in FIG. 1 is of the type employing a tuning-fork motor constituted by a tuning-fork resonator **19** at the ends of whose vibratory tines are attached magnetic elements **19A** and **19B**, that cooperate with stationary drive coils **10A** and **10B**, respectively. Thus, when pulses are applied to the transducer coils, the tines are actuated to sustain the fork in vibration at its natural frequency, which in practice, may be 300 or 360 cycles per second.

Since the pulses are derived from a high "Q" crystal standard, the fork whose "Q" is relatively low is nevertheless held or locked to its assigned frequency by the actuating pulses applied thereto. Hence assuming a fork whose natural frequency is 300 Hz, the fork will be sustained in vibration at this frequency and no other by 300 Hz pulses derived from the crystal standard.

The vibratory action of the fork is converted into rotary motion by an indexing mechanism including an index finger **20** attached to one tine of the fork and engaging the teeth of a ratchet wheel **21** operatively coupled to gear train **22**. The gear train acts to turn the hands **23** of the time display in the usual manner.

Referring now to FIGS. **2** and **3**, there is shown an actual embodiment of a crystal-controlled watch employing a tuning fork motor. In these figures, it will be seen that drive coils **10A** and **10B** are mounted on plastic sub-assemblies **24** and **25**, respectively, supported on a pillar plate **26**. The coils cooperate with cup-shaped magnetic elements **19 A** and **19B**, attached to the tines of a tuning fork.

The circuits of oscillator **12** and of frequency divider **13** are combined in a tiny, monolithic integrated circuit block-like package forming a miniature module **27**. This IC device may be manufactured using known diffusion techniques. Joined to one side of the module and extending laterally therefrom is the incrementally-adjustable tuning unit **14** which is preferably fabricated in the manner disclosed in the above-identified Koehler and Mutter application.

This unit includes switching screws **28** for switching capacitors in or out of a parallel circuit to provide a desired total reactance value depending on the number and values of the capacitors connected in shunt relation. The output terminals of the unit are constituted by conductive strips S_1 and S_2 which extend to the rear edge of the unit.

The integrated circuit oscillator-divider module is provided with five terminal lugs T_1, T_2, T_3, T_4, and T_5 and a connecting tab T. As best seen in FIG. **4**, tab T and terminal T_2 extend from the front side of the module and are positioned to overlie the output terminal strips of the tuning unit whereby soldered connections may be made therebetween, whereby the tuning unit is joined to the module. Terminals T_1, T_2 and T_3 extend from the upper end of the module and terminal T_4 from the rear side thereof.

The sub-assembly **24** for drive coil **10A** is provided with a recess **29** for accommodating module **27** and an adjacent recess **30** for receiving tuning unit **14**. After the module and tuning unit are seated in sub-assembly **24**, the quartz crystal assembly **16** is mounted below recess **30**, the terminals **17** and **18** thereof passing through openings in the sub-assembly for connection to the first and second terminal lugs T_1 and T_2. Thus, the quartz crystal assembly lies below the tuning unit and is supported from terminal lugs T_1 and T_2.

Terminal lugs T_1 and T_2, which as shown in FIG. **1**, are coupled to both oscillator **12** and divider **13**. Terminal lugs T_3 and T_4 are connected respectively to the negative pole of battery cell **15** and ground (pillar plate), the positive pole of the cell going to ground to complete the power circuit. Thus, the electronic system is energized by the single battery cell. Terminal lug T_5, which is connected to the output of divider **13**, goes to one end of series-connected drive coils **10A** and **10B**, the other end being grounded to the pillar plate.

Thus, despite the relative complexity of the electronic system which may have as many as 16 transistors or more, it may be quickly and simply installed in the watch or removed therefrom. Also, since the quartz crystal assembly is separable from the module by way of the first two terminals T_1 and T_2, this component which is the most delicate in the watch, may also be readily replaced should it become defective.

The arrangement shown in FIGS. **2** and **3** differs from a standard tuning-fork electronic watch mainly in the fact that in lieu of the electronic circuit normally placed on a coil sub-assembly and associated with drive and pick-up coils, there is a miniature module, a tuning unit and a crystal assembly occupying no greater space than this electronic circuit.

Hence the crystal-controlled watch is no larger than the standard tuning-fork watch, but is more precise because of the quartz crystal time base. While a tuning-fork watch of the type currently available commercially is generally accurate to within one minute a month, the same tuning-fork mechanism operating in conjunction with a crystal-control module can attain an accuracy of within 1 minute a year. Since as a result of certain recent innovations, it is now possible to manufacture more compact tuning-fork watches in ladies' model sizes, these models may be converted to crystal-controlled operation using a highly compact crystal controlled electronic system as disclosed herein.

It will be appreciated that a system in accordance with the invention is not limited to use with tuning-fork mechanisms and may be used in conjunction with watches having single reed micromotors or other forms of time display mechanisms and circuits.

While there has been shown and described a preferred embodiment of an electronic system for crystal-controlled watches, it will be appreciate that many changes and modifications may be made therein without, however, departing from the spirit of the invention.

We claim:

1. A miniature electronic system for a crystal-controlled timepiece, said system comprising:

a. an oscillator circuit for a quartz crystal, said circuit generating a high-frequency carrier;

b. a multi-stage frequency divider coupled to the output of the oscillator circuit, said divider and said oscillator being embodied in a single integrated-circuit module;

c. an incrementally-adjustable capacitor unit for tuning said oscillator circuit and joined to one side of said module and extending laterally therefrom, and

d. five terminals and one connecting tab extending from said module, the first two terminals serving to connect a quartz crystal to said oscillator circuit in series with said unit, the third and fourth terminals serving to connect a power source to said oscillator circuit and said divider, the fifth terminal yielding the output of the divider, the connecting tab serving to connect the tuning unit to the oscillator circuit.

2. A module as set forth in claim **1**, wherein said crystal is housed in an evacuated container having two terminal pins which are connectable to said first two terminals.

3. A crystal-controlled watch including an electronic system as set forth in claim **1**, said watch having a tuning fork motor provided with a drive coil coupled to said fifth terminal whereby said fork is sustained in vibration by said pulses at a rate corresponding to the natural frequency of the fork.

4. A crystal-controlled watch as set forth in claim 3, wherein said drive coil is mounted on a removable sub-assembly, and said module and said unit are seated on said assembly.

5. A watch as set forth in claim 4, wherein said sub-assembly has a first recess to accommodate said module and a second recess to accommodate said unit.

6. A watch as set forth in claim 5, wherein said quartz crystal is contained in an evacuated container disposed below the second recess and having two terminal pins which project through openings in the sub-assembly for connection to said first and second terminals.

* * * * *