

PATENT SPECIFICATION

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(54) TIMEPIECE HAVING A HIGH FREQUENCY OSCILLATOR

(71) We, **TIMEX CORPORATION**, a Corporation organized under the laws of the State of Delaware, United States of America, of Waterbury, Connecticut, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a timepiece having a high frequency oscillator, for example a crystal-controlled oscillator.

In crystal-controlled oscillators, the quartz crystal may be cut under normal manufacturing procedures to an accuracy of ± 1 Hz which is satisfactory for many purposes. However, in applications such as quartz crystal-controlled watches, it is essential that the quartz crystal oscillator output frequency be a predetermined frequency to permit accurate timekeeping. For example, in one commercial quartz watch the oscillator frequency is specified as 49,152 Hz and a variation of 1 Hz would result in an unacceptable variation of 2 seconds per day in the watch.

The conventional method of trimming quartz crystal oscillators involves the use of a variable capacitor typically incorporated in a Pierce oscillator arrangement. However, this type of trimming requires a separate variable capacitive element which must be mounted on a substrate. The present invention proposes to employ a variable resistor as a more reliable trimming element. The variable resistor may be deposited on a substrate; since an added assembly operation is then not required and the element is less expensive, a significant cost saving can be achieved while circuit reliability is improved.

According to the invention there is provided a timepiece having time indicating means and comprising a power supply, an oscillator activated by the power supply to provide high frequency output pulses, said oscillator comprising an active element and a tank circuit including two series reactances each in a respective reactive branch with a grounded connection between the two series resistances, and a variable resistor being

connected in one of the reactive branches which sets the frequency of the output pulses, means for dividing down the frequency of the output pulses, and means activated by the output of the frequency dividing means to drive the time indicating means.

In one embodiment of the Pierce oscillator type featuring a crystal-controlled oscillator, a variable resistor is inserted in series with a first capacitor in a tank circuit comprising a quartz crystal and the first capacitor and a second capacitor. The phase shifted feedback signal is thus determined by the combination of the first capacitor and the variable resistor which causes a corresponding change in the oscillating frequency of the system. The invention is, of course, not limited to bipolar Pierce type circuits and, hence, other embodiments include a complementary MOS equivalent of the bipolar Pierce type circuit, a modified Colpitts circuit or a modified Hartley oscillator.

Other features and advantages of the present invention will appear from the following description of preferred embodiments thereof, given with reference to the accompanying drawings wherein:—

Figure 1 is a block diagram of a typical quartz crystal watch arrangement;

Figure 2 is a circuit diagram of the quartz crystal oscillator showing the resistor trim arrangement of the present invention in a bipolar Pierce circuit;

Figure 3 shows the use of the resistor trim arrangement in a complementary MOS oscillator embodiment;

Figure 4 shows the invention in a modified Colpitts oscillator embodiment, and

Figure 5 shows the invention of the embodiment of a modified Hartley oscillator.

Figure 1 of the drawings is a block diagram arrangement for a typical quartz crystal watch. The watch includes a high frequency quartz crystal oscillator 10, a divider 11 which reduces the oscillator output frequency to a driver 12 and a motor 13 which is driven thereby. The motor 13 drives a watch mechanism indicated schematically as 14.

The oscillator 10 includes a quartz crystal

16, Figure 2, having a natural frequency in the 50 KHz. range connected across the collector-base circuit of transistor 17. The circuit also include capacitors 18 and 19 connected in a tank circuit with the quartz crystal 16. A variable resistor 21 is connected in series with capacitor 18 while a fixed resistor 22 is connected across the crystal 16. Power is supplied over line 23 and resistor 24 from a power supply such as a conventional watch battery (not shown).

The circuit operation of the prior art may be explained with reference to Figure 2 by assuming resistor 21 to be shorted out and by assuming a voltage e at point A and a lossless tank circuit comprising the quartz crystal 16 and capacitors 18 and 19. Since the common connection of capacitors 18 and 19 is grounded and the current through the capacitors 18 and 19 is the same, the tank circuit produces an output voltage of $-e$ at point B. Thus, the tank circuit has a phase shift of 180° referred to ground. The additional 180° phase shift in transistor 17 completes the loop with a 360° phase shift to permit oscillations if the gain of the transistor is sufficiently high.

Typical values of the components for the operation and 50 KHz are as follows:—

Resistor 24=150 Kohms
Resistor 22=2.2 Megohms
Capacitor 18=Capacitor 19=33 pf.

A small change in output frequency could be effected by this circuit by varying the capacitors 18 or 19 or by varying both capacitors 18 and 19 which, of course, changes the oscillating frequency of the tank circuit. Indeed, this technique is commonly employed in the prior art but this has serious disadvantages when applied to watch circuits. Using a variable capacitor to trim the quartz crystal oscillator requires a separate capacitive element which must be mounted on a substrate. This involves additional component and assembly expense and requires additional space within the limited confines of a watch case.

According to the present invention as illustrated in Figure 2 of the drawings a variable resistor 21 is inserted in series with capacitor 18. The operation of the circuit is as previously described except that the feedback voltage is $e \cdot \phi$ where ϕ represents the phase shift determined by the combination of resistor 21 and capacitor 18. This phase shifted signal causes a corresponding change in the oscillating frequency of the system and, thus, a precise adjustment in output frequency may be made by changing the value of resistor 21 rather than varying the capacitance value of components 18 or 19. The variable resistor 21 is a more reliable trimming element which may, as a

further advantage, be deposited on a substrate.

The present invention is not limited to bipolar Pierce-type circuits as illustrated in Figure 2. For example, Figure 3 shows a complementary MOS equivalent 26 of the bipolar circuit of Figure 2 having a quartz crystal 16 connected between the common gate connection and the common drain connection. Figure 4 shows a modified Colpitts circuit 27 and Figure 5 shows a modified Hartley oscillator 28. A variable resistor 21 is included in each of the above embodiments to adjust the frequency by resistive means. Since the operation of these circuits 26, 27, and 28 is well known, details of their functioning have been omitted. The effect of adding resistor 21 is similar to that described with reference to Figure 2 and similar advantages accrue. Broadly speaking, the present invention proposes a means for precisely trimming the output frequency of an oscillator by varying the resistance in a branch of the circuit. Preferably the frequency setting variable resistor 21 is temperature sensitive to effect a temperature correction for the oscillator.

It is to be understood that the above described arrangements are merely illustrative examples of the application. Numerous other arrangements may be readily devised by those skilled in the art which fall within the scope of the claims.

WHAT WE CLAIM IS:—

1. A timepiece having time indicating means and comprising a power supply, an oscillator activated by the power supply to provide high frequency output pulses, said oscillator comprising an active element and a tank circuit including two series reactances each in a respective reactive branch with a grounded connection between the two series reactances, and a variable resistor being connected in one of the reactive branches which sets the frequency of the output pulses, means for dividing down the frequency of the output pulses, and means activated by the output of the frequency dividing means to drive the time indicating means.

2. A timepiece in accordance with Claim 1, wherein the oscillator comprises a crystal-controlled oscillator, the reactances are fixed capacitors, and the active element is a semi-conductor means coupled across the crystal to provide the necessary gain and phase shift for oscillations.

3. A timepiece in accordance with Claim 2, wherein the semi-conductor means comprises a transistor connected with its collector-base circuit across the crystal and operated in the grounded emitter configuration.

4. A timepiece in accordance with Claim 2, wherein the semi-conductor means comprises a complementary MOS circuit connec-

16, Figure 2, having a natural frequency in the 50 KHz range connected across the collector-base circuit of transistor 17. The circuit also include capacitors 18 and 19 connected in a tank circuit with the quartz crystal 16. A variable resistor 21 is connected in series with capacitor 18 while a fixed resistor 22 is connected across the crystal 16. Power is supplied over line 23 and resistor 24 from a power supply such as a conventional watch battery (not shown).

The circuit operation of the prior art may be explained with reference to Figure 2 by assuming resistor 21 to be shorted out and by assuming a voltage e at point A and a lossless tank circuit comprising the quartz crystal 16 and capacitors 18 and 19. Since the common connection of capacitors 18 and 19 is grounded and the current through the capacitors 18 and 19 is the same, the tank circuit produces an output voltage of $-e$ at point B. Thus, the tank circuit has a phase shift of 180° referred to ground. The additional 180° phase shift in transistor 17 completes the loop with a 360° phase shift to permit oscillations if the gain of the transistor is sufficiently high.

Typical values of the components for the operation and 50 KHz are as follows:—

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A small change in output frequency could be effected by this circuit by varying the capacitors 18 or 19 or by varying both capacitors 18 and 19 which, of course, changes the oscillating frequency of the tank circuit. Indeed, this technique is commonly employed in the prior art but this has serious disadvantages when applied to watch circuits. Using a variable capacitor to trim the quartz crystal oscillator requires a separate capacitive element which must be mounted on a substrate. This involves additional component and assembly expense and requires additional space within the limited confines of a watch case.

According to the present invention as illustrated in Figure 2 of the drawings a variable resistor 21 is inserted in series with capacitor 18. The operation of the circuit is as previously described except that the feedback voltage is $e\phi$ where ϕ represents the phase shift determined by the combination of resistor 21 and capacitor 18. This phase shifted signal causes a corresponding change in the oscillating frequency of the system and, thus, a precise adjustment in output frequency may be made by changing the value of resistor 21 rather than varying the capacitance value of components 18 or 19. The variable resistor 21 is a more reliable trimming element which may, as a

further advantage, be deposited on a substrate.

The present invention is not limited to bipolar Pierce-type circuits as illustrated in Figure 2. For example, Figure 3 shows a complementary MOS equivalent 26 of the bipolar circuit of Figure 2 having a quartz crystal 16 connected between the common gate connection and the common drain connection. Figure 4 shows a modified Colpitts circuit 27 and Figure 5 shows a modified Hartley oscillator 28. A variable resistor 21 is included in each of the above embodiments to adjust the frequency by resistive means. Since the operation of these circuits 26, 27, and 28 is well known, details of their functioning have been omitted. The effect of adding resistor 21 is similar to that described with reference to Figure 2 and similar advantages accrue. Broadly speaking, the present invention proposes a means for precisely trimming the output frequency of an oscillator by varying the resistance in a branch of the circuit. Preferably the frequency setting variable resistor 21 is temperature sensitive to effect a temperature correction for the oscillator.

It is to be understood that the above described arrangements are merely illustrative examples of the application. Numerous other arrangements may be readily devised by those skilled in the art which fall within the scope of the claims.

WHAT WE CLAIM IS:—

1. A timepiece having time indicating means and comprising a power supply, an oscillator activated by the power supply to provide high frequency output pulses, said oscillator comprising an active element and a tank circuit including two series reactances each in a respective reactive branch with a grounded connection between the two series reactances, and a variable resistor being connected in one of the reactive branches which sets the frequency of the output pulses, means for dividing down the frequency of the output pulses, and means activated by the output of the frequency dividing means to drive the time indicating means.

2. A timepiece in accordance with Claim 1, wherein the oscillator comprises a crystal-controlled oscillator, the reactances are fixed capacitors, and the active element is a semiconductor means coupled across the crystal to provide the necessary gain and phase shift for oscillations.

3. A timepiece in accordance with Claim 2, wherein the semi-conductor means comprises a transistor connected with its collector-base circuit across the crystal and operated in the grounded emitter configuration.

4. A timepiece in accordance with Claim 2, wherein the semi-conductor means comprises a complementary MOS circuit connected



ted so that the crystal is connected between the common gate connection and the common drain connection.

5 5. A timepiece in accordance with Claim 1, wherein the oscillator comprises a Colpitts-type circuit.

6. A timepiece in accordance with Claim 1, wherein the oscillator comprises a Hartley-type oscillator.

10 7. A timepiece in accordance with any one of Claims 1 to 6, wherein the frequency

setting resistor is temperature sensitive to effect a temperature correction for the oscillator.

8. A timepiece according to Claim 1 and 15 substantially as herein described with reference to the accompanying drawings.

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