(10)

PATENT SPECIFICATION (11) 1 554 665

1 554 665

(21) Application No. 51240/76 (22) Filed 8 Dec. 1976 (19)
(31) Convention Application No. 50/151670 (32) Filed 19 Dec. 1975 in
(33) Japan (JP)
(44) Complete Specification Published 24 Oct. 1979
(51) INT. CL.[2] H03H 9/14
(52) Index at Acceptance
H1E 1



(54) QUARTZ CRYSTAL OSCILLATOR CIRCUIT

(71) We, KABUSHIKI KAISHA DAINI SEIKOSHA a Japanese Company of 31-1 6-chome Kameido Koto-ku Tokyo Japan 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.

This invention relates to quartz crystal oscillator circuits.

According to the present invention there is provided a quarts crystal oscillator circuit in which the electromechanical coupling factor (as herein defined) of a quartz crystal vibrator having two terminals electrically connected with electrodes mounted on the vibrator is in the range of 0.025 to 0.035.

The "electromechanical coupling factor k" of a quartz crystal vibrator is defined as:

$$k^2 = \frac{\text{electrical energy converted to mechanical energy}}{\text{input electrical energy}}$$

Preferably the quartz crystal oscillator circuit includes a variable capacitor for varying the frequency of an output signal of the oscillator circuit.

The variable capacitor may be variable in the range between 3pF and 35pF.

Preferably the natural frequency of oscillation of the vibrator is 32768Hz.

In the preferred embodiment the vibrator is an X-cut rotated about the Y-axis in the counterclockwise direction.

The invention is illustrated, merely by way of example, in the accompanying drawings, in which:–

Figure 1 shows the relationship between the capacity and frequency variation of a quartz crystal vibrator;

Figure 2 is an equivalent circuit diagram of a quartz crystal oscillator circuit;

Figure 3 illustrates the cutting angle of a quartz crystal vibrator of a quartz crystal oscillator circuit according to the present invention;

Figure 4 shows an electrode construction of a quartz crystal vibrator of Figure 3; and

Figure 5 illustrates the relationship between the cutting angle θ and the electromechanical coupling factor K of the quartz crystal vibrator of Figure 3.

Generally the electromechanical coupling factor k of a quartz crystal vibrator is very small, i.e. about 10% maximum efficiency. Therefore, since integrated circuit techniques are not fully advanced, it is impossible to devise a stable quartz crystal oscillator circuit unless the above mentioned deficiency is not used to the utmost. In a conventional quartz crystal vibrator of the tuning-form type, a typical value of the electromechanical coupling factor is 0.04. Figure 1 shows a relationship between frequency variations ($\Delta f/f$) and capacity (C) of a quartz crystal vibrator for various values of the electromechanical coupling factor. Since the capacity is large if the electromechanical factor is large, a small change in capacity will result in a relatively large shift in frequency. Accordingly, if the frequency variation is relatively small the capacity is relatively large and, as a result, the power consumption is increased with the result that the life of a battery driving the quartz crystal vibrator is reduced. This is because the current consumption is proportional to

$$f.c.v.$$

Where f is the oscillating frequency, c is the value of the capacity and v is the voltage.

Referring to Figure 2, there is shown an equivalent electrical circuit of a quartz crystal vibrator, the circuit being composed of an inductance L_o, a capacitance C_o, and a resistance

11 SEP 1982

R_0 connected in series, the series arrangement being in parallel with a capacitance C_1, and the parallel arrangement being in series with a trimmer or variable capacitor C to form a quartz crystal oscillator circuit.

As shown in Figure 1, the tunability or frequency variation of the quartz crystal vibrator is dependent, *inter alia* upon the value of the electromechanical coupling factor. A conventional quartz crystal vibrator has an electromechanical coupling factor of 0.04.

The present invention seeks to provide a quartz crystal oscillator circuit, having a quartz crystal vibrator with a relatively low electromechanical coupling factor so that the frequency dependency is small even though the value of the capacity is small.

The quartz crystal vibrator of the tuning-fork type of a quartz crystal oscillator circuit according to the present invention is an X-cut rotated about the Y-axis in the counterclockwise direction through an angle θ as shown in Figure 3. A quartz crystal vibrator as shown in Figure 4, has two electrode terminals and the electromechanical coupling factor is determined to be in the range of 0.025 to 0.035 by selecting the angle θ suitable. When an electric field applied *via* the terminals to electrodes in contact with the quartz crystal vibrator the latter is caused to oscillate. The smaller the value of the electromechanical coupling factor, the larger the resistance R_0. Therefore, it is impossible for the quartz crystal vibrator to self-oscillate even with presently known integrated circuit techniques. Using presently known integrated circuit techniques, the electromechanical coupling factor of a quartz crystal vibrator is, at the minimum, 0.025. However, in order to cause the quartz crystal vibrator to oscillate safely, the electromechanical coupling factor should preferably be 0.035 but maybe in the range of between 0.025 and 0.035.

It is difficult to tune a quartz crystal vibrator so that its fundamental frequency is exactly 32768Hz during manufacture. Therefore, the variable capacitor C is used for fine tuning of the frequency. The capacitance of the variable capacitor is chosen to be in the range of 3pF to 35pF. That is to say the capacitance is determined by the secondary vibration of the quartz crystal vibrator. If the fundamental frequency of a quartz crystal vibrator of the tuning-fork type is 32768Hz, the secondary frequency is 180KHz (6 times the fundamental frequency). Therefore, the minimum capacitance 3pF is selected because the secondary mode vibrations occur if the capacitance of the variable capacity C is made too small, whilst the maximum capacitance 35pF is selected because the power consumption of the quartz crystal oscillator circuit is large if the capacitance is too large.

The quartz crystal oscillator circuit according to the present invention, and described above has a relatively low power consumption and so it is idealy suited for use in an electronic timepiece e.g. a wristwatch to prolong the life of a driving battery.

WHAT WE CLAIM IS:–

1. A quartz crystal oscillator circuit in which the electromechanical coupling factor (as herein defined) of a quartz crystal vibrator having two terminals electrically connected with electrodes mounted on the vibrator is in the range of 0.025 to 0.035.

2. A quartz crystal oscillator circuit as claimed in claim 1 including a variable capacitor for varying the frequency of an output signal of the oscillator circuit.

3. A quartz crystal oscillator circuit as claimed in claim 2 in which the variable capacitor is variable in the range between 3pF and 35pF.

4. A quartz crystal oscillator circuit as claimed in any preceding claim in which the natural frequency of oscillation of the vibrator is 32768Hz.

5. A quartz crystal oscillator circuit as claimed in any preceding claim in which the vibrator is an X-cut rotated about the Y-axis in the counter-clockwise direction.

6. A quartz crystal oscillator circuit substantially as herein described with reference to and as shown in the accompanying drawings.

J. MILLER & CO.
Chartered Patent Agents
Agents for the Applicants,
Lincoln House,
296–302 High Holborn,
London WC1V 7JH.

Printed for Her Majesty's Stationery Office, by Croydon Printing Company Limited, Croydon, Surrey, 1979.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

R_0 connected in series, the series arrangement being in parallel with a capacitance C_1, and the parallel arrangement being in series with a trimmer or variable capacitor C to form a quartz crystal oscillator circuit.

As shown in Figure 1, the tunability or frequency variation of the quartz crystal vibrator is dependent, *inter alia* upon the value of the electromechanical coupling factor. A conventional quartz crystal vibrator has an electromechanical coupling factor of 0.04.

The present invention seeks to provide a quartz crystal oscillator circuit, having a quartz crystal vibrator with a relatively low electromechanical coupling factor so that the frequency dependency is small even though the value of the capacity is small.

The quartz crystal vibrator of the tuning-fork type of a quartz crystal oscillator circuit according to the present invention is an X-cut rotated about the Y-axis in the counterclockwise direction through an angle θ as shown in Figure 3. A quartz crystal vibrator as shown in Figure 4, has two electrode terminals and the electromechanical coupling factor is determined to be in the range of 0.025 to 0.035 by selecting the angle θ suitable. When an electric field applied *via* the terminals to electrodes in contact with the quartz crystal vibrator the latter is caused to oscillate. The smaller the value of the electromechanical coupling factor, the larger the resistance R_0. Therefore, it is impossible for the quartz crystal vibrator to self-oscillate even with presently known integrated circuit techniques. Using presently known integrated circuit techniques, the electromechanical coupling factor of a quartz crystal vibrator is, at the minimum, 0.025. However, in order to cause the quartz crystal vibrator to oscillate safely, the electromechanical coupling factor should preferably be 0.035 but maybe in the range of between 0.025 and 0.035.

It is difficult to tune a quartz crystal vibrator so that its fundamental frequency is exactly 32768Hz during manufacture. Therefore, the variable capacitor C is used for fine tuning of the frequency. The capacitance of the variable capacitor is chosen to be in the range of 3pF to 35pF. That is to say the capacitance is determined by the secondary vibration of the quartz crystal vibrator. If the fundamental frequency of a quartz crystal vibrator of the tuning-fork type is 32768Hz, the secondary frequency is 180KHz (6 times the fundamental frequency). Therefore, the minimum capacitance 3pF is selected because the secondary mode vibrations occur if the capacitance of the variable capacity C is made too small, whilst the maximum capacitance 35pF is selected because the power consumption of the quartz crystal oscillator circuit is large if the capacitance is too large.

The quartz crystal oscillator circuit according to the present invention, and described above has a relatively low power consumption and so it is idealy suited for use in an electronic timepiece e.g. a wristwatch to prolong the life of a driving battery.

WHAT WE CLAIM IS:–

1. A quartz crystal oscillator circuit in which the electromechanical coupling factor (as herein defined) of a quartz crystal vibrator having two terminals electrically connected with electrodes mounted on the vibrator is in the range of 0.025 to 0.035.

2. A quartz crystal oscillator circuit as claimed in claim 1 including a variable capacitor for varying the frequency of an output signal of the oscillator circuit.

3. A quartz crystal oscillator circuit as claimed in claim 2 in which the variable capacitor is variable in the range between 3pF and 35pF.

4. A quartz crystal oscillator circuit as claimed in any preceding claim in which the natural frequency of oscillation of the vibrator is 32768Hz.

5. A quartz crystal oscillator circuit as claimed in any preceding claim in which the vibrator is an X-cut rotated about the Y-axis in the counter-clockwise direction.

6. A quartz crystal oscillator circuit substantially as herein described with reference to and as shown in the accompanying drawings.

J. MILLER & CO.
Chartered Patent Agents
Agents for the Applicants,
Lincoln House,
296–302 High Holborn,
London WC1V 7JH.

Printed for Her Majesty's Stationery Office, by Croydon Printing Company Limited, Croydon, Surrey, 1979.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.