

PATENT SPECIFICATION

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(54) SIGNAL GENERATOR

(71) We, KABUSHIKI KAISHA SEIKOSHA a Japanese Company of 2-5, Kyobashi, Chuo-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 signal generators.

According to the present invention there is provided a signal generator comprising an oscillator circuit including a GT-cut quartz crystal oscillator whose frequency-temperature coefficient is zero and an adjustable division ratio frequency divider circuit connected to receive an output signal from the oscillator circuit, and preset to compensate for difference between the actual frequency of oscillation of the oscillator and a nominal frequency so that the divider circuit will produce an output signal of a predetermined frequency which is substantially independent of said difference.

In the preferred embodiment the signal generator includes a decoder circuit having a plurality of input terminals and whose output is connected to a control circuit arranged to adjust the frequency divider circuit to set its division ratio. The signal generator may include a plurality of switches connected to the input terminals of the decoder circuit.

The oscillator may have an actual frequency of oscillation of substantially 410 kHz.

Preferably the oscillator has a side ratio of substantially 0.85.

The dimensions of the oscillator may be 8.03 mm×9.35 mm×0.65 mm.

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

Figure 1 is a plan view of GT-cut quartz crystal oscillator.

Figure 2 illustrates diagrammatically the relationship between the side ratio and the

frequency-temperature coefficient of the GT-cut quartz crystal oscillator of Figure 1;

Figure 3 illustrates the characteristics of various GT-cut quartz crystal oscillators whose side ratios are equal.

Figure 4 is a block diagram of an embodiment of a signal generator according to the present invention and incorporating a GT-cut quartz crystal oscillator whose frequency-temperature coefficient is zero.

Figure 5 is a diagram showing the range of adjustment of the dimensions of the GT-cut quartz crystal oscillator of the signal generator of Figure 4; and

Figure 6 is a diagram showing the range of adjustment of the dimensions of a GT-cut quartz crystal oscillator of a conventional signal generator.

The frequency-temperature characteristics of a GT-cut quartz crystal oscillator are dependent upon the coupling between shorter side oscillation and longer side oscillation. The coupling may be changed by polishing a shorter side or a longer side. The optimum frequency-temperature characteristics are attained with a certain side ratio: the side ratio is the ratio between the length of the shorter side and the length of the longer side.

In particular, in a GT-cut quartz crystal oscillator, the shorter side oscillation is the principal oscillation. Therefore, the frequency of oscillation is adjusted by changing the length of the shorter side and is substantially unaffected if the length of the longer side is changed. Thus a GT-cut quartz crystal oscillator has the feature that the adjustment of frequency of oscillation and an adjustment of the frequency-temperature coefficient may be made independently of each other. In a strict sense, however, there is a degree of coupling between the longer side oscillation the shorter side oscillation and hence a change in the frequency of oscillation arises although this is slight.

Conventional methods known in Japan of adjusting the frequency of oscillation and

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the frequency-temperature coefficient of GT-cut quartz crystal oscillators will now be described. As regards the adjustment frequency, since a GT-cut quartz crystal oscillator utilises the shorter side oscillation as stated above, the oscillator is adjusted to produce a predetermined frequency by polishing the shorter side w (Figure 1).

As regards the adjustment to the frequency-temperature coefficient, the side ratio and the frequency-temperature coefficient are related to each other. In Figure 2, the ordinate represents the frequency-temperature coefficient $\Delta f/f/C$, and abscissa the side ratio w/l . Usually the frequency-temperature coefficient becomes zero when the side ratio is substantially 0.85. As apparent in Figure 2, all GT-cut quartz crystal oscillators having a side ratio a_1 exhibit a frequency temperature coefficient b within a certain range of dimensions. Figure 3 represents GT-cut quartz crystal oscillators g_1, g_2, g_3 having a side ratio a_0 i.e. a frequency temperature coefficient of zero. Although the frequency-temperature coefficients of the 3 GT-cut quartz crystal oscillators g_1, g_2, g_3 , are the same the actual frequencies of oscillation of the oscillators are different. More specifically, the actual frequency of oscillation is determined by the magnitude of the lengths w of each oscillator and the actual frequency of the oscillator g_2 is greater than that of the oscillator g_1 which, in turn, is greater than that of the oscillator g_3 . Since as stated above, the side ratio and frequency-temperature coefficient are closely related, the conventional methods of adjusting the frequency-temperature coefficient will be described. First, the length l of the longer side of the oscillator as shown in Figure 1 is made larger than necessary so that the frequency-temperature coefficient is negative. Subsequently, electrodes and supporting wires (not shown in the drawings) are secured to the oscillator. Thereafter whilst measuring the frequency-temperature characteristics, the length l is reduced gradually by polishing. In this way, the frequency-temperature moves from negative to positive and the polishing is stopped when the frequency-temperature coefficient becomes zero. It will be clear that if the length l is further polished, the frequency-temperature coefficient will become positive. Whilst it is possible by this conventional method to produce a GT-cut quartz crystal oscillator with a predetermined actual frequency of oscillation and a predetermined frequency-temperature characteristic, the cost of the oscillator is relatively high.

Referring to Figure 4 an embodiment of a signal generator according to the present invention includes a crystal oscillator 1

which employs as an oscillation source a GT-cut quartz crystal oscillator 1a whose frequency-temperature coefficient is zero and whose side ratio is a_0 as indicated in Figure 2. For example, if the GT-cut quartz crystal oscillator 1a has an oscillating frequency of 410 KHz, the length of the shorter side w (figure 1) is 8.03 mm the length of the longer side l is 9.35 mm, the thickness is 0.65 mm and the side ratio a_0 is substantially 0.8588. The output frequency of the oscillator 1 is stepped down or divided by frequency divider circuits 2 to 6 logical '0' and logical '1' signals are selectively applied to terminals g_1, g_1, g_1 of a decoder circuit 7 which actuates a control circuit 8 whose output is connected to the input of the frequency divider circuit 3. The control circuit 8 adjusts of the frequency divider circuit 3, 4, 5, 6 so that the frequency of an output signal P of the frequency divider 6 is a predetermined frequency. The adjustment of the frequency is up to about 875 p.p.m. in frequency steps of 125 p.p.m. depending upon the combination of logical '1' and logical '0' signals applied to the terminals q_1, q_2, q_3 . The logical signals applied to the terminals q_1, q_2, q_3 , are determined by respective switches S_1, S_2, S_3 . Resistors R_1, R_2, R_3 set the voltage level of the logical '1' signals. Fine adjustment of the output signal P within one frequency step can be effected by changing the capacitance of a fine adjustment capacitor (not shown) forming part of the crystal oscillator 1.

A frequency divider arrangement which has a programmable frequency-adjusting function described above is known. One such frequency divider arrangement is made by R.C.A. Inc. and is commercially available.

Consider the case where it is desired to obtain an output signal P of a predetermined frequency employing, as the oscillator 1a, a GT-cut quartz crystal whose frequency is 410 KHz and whose frequency-temperature coefficient is zero as shown by the solid line in figure 5. A GT-cut quartz crystal oscillator whose characteristics are similar to the required oscillator is adjusted so that it has a zero temperature coefficient. Taking into account the maximum variation that can be made to the frequency of the output signal P by means of the frequency divider circuit, the range of adjustment to the sides w and l of the oscillator are $\delta w = 8\mu$ and $\delta l = 9.4\mu$ in this example. That is, even when adjustment of the frequency temperature coefficient to zero has once failed, it is still possible to obtain a GT-cut quartz crystal oscillator whose frequency-temperature coefficient is zero, e.g. the oscillators g_1, g_2, g_3 , coefficients illustrated in figure 3, as

long as the sides l , w lie within the range indicated by the broken lines in figure 5 and are on the solid line. That is it is possible to make the frequency of the output signal P substantially independent of any difference between the actual frequency of oscillation of the oscillator and a nominal frequency by means of the arrangement as shown in figure 4.

In this manner, the oscillator is made to have a zero frequency-temperature coefficient and even when the frequency of the output signal p differs from the predetermined frequency to some extent, it can be adjusted by means of the switches S_1 , S_2 , S_3 . In a conventional signal generator (not illustrated) comprising a crystal oscillator and a frequency divider circuit for dividing or stepping down the frequency of oscillation thereof, the frequency of oscillation of the oscillator is changed by means of a fine adjusting capacitor which is connected to the crystal oscillator. Accordingly, the adjustment of the frequency of oscillation is 50 p.p.m. also.

The second comparison is the range of adjustment in the case where a GT-cut quartz crystal oscillator is employed in the conventional signal generator will be described in relation to figure 6. A GT-cut quartz crystal oscillator shown by a solid line is such that the frequency $f=410$ KHz and the frequency-temperature coefficient is zero. Further, $\delta w=0.4\mu$ and $\delta l=0.45\mu$. Accordingly, the dimensions of the GT-cut quartz crystal oscillator need to be such that they are within the range of the two-chain-dotted lines and this range is much narrower than the range of adjustment of the GT-cut quartz crystal oscillator in the signal generator of figure 4. It is, therefore, difficult to adjust both the actual frequency of oscillation and the frequency-temperature coefficient in conventional signal generators within predetermined specific ranges. Consequently, the above described conventional signal generator is inferior to the signal generator of figure 4.

The above described embodiment of a signal generator according to the present invention employs a GT-cut quartz crystal oscillator and a frequency divider circuit whose division ratio is adjustable.

Therefore, it is only required to make the frequency-temperature coefficient of the oscillator zero and the actual frequency of oscillation of the oscillator is of little importance. Thus relatively inexpensive signal generators employing GT-cut quartz crystal oscillators can be made.

WHAT WE CLAIM IS:—

1. A signal generator comprising an oscillator circuit including a GT-cut quartz crystal oscillator whose frequency-temperature coefficient is zero and an adjustable division ratio frequency divider circuit connected to receive an output signal from the oscillator circuit, and preset to compensate for difference between the actual frequency of oscillation of the oscillator and a nominal frequency so that the divider circuit will produce an output signal of a predetermined frequency which is substantially independent of said difference.

2. A signal generator as claimed in claim 1 including a decoder circuit having a plurality of input terminals and whose output is connected to a control circuit arranged to adjust the frequency divider circuit to set its division ratio.

3. A signal generator as claimed in claim 2 including a plurality of switches connected to the input terminals of the decoder circuit.

4. A signal generator as claimed in any preceding claim in which the oscillator has an actual frequency of oscillation of substantially 410 KHz.

5. A signal generator as claimed in any preceding claim in which the oscillator has a side ratio of substantially 0.85.

6. A signal generator as claimed in any preceding claim in which the dimensions of the oscillator are 8.03 mm $\times$ 9.35 mm $\times$ 0.65 mm.

7. A signal generator substantially as herein described with reference to and as shown in the accompanying drawings.

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