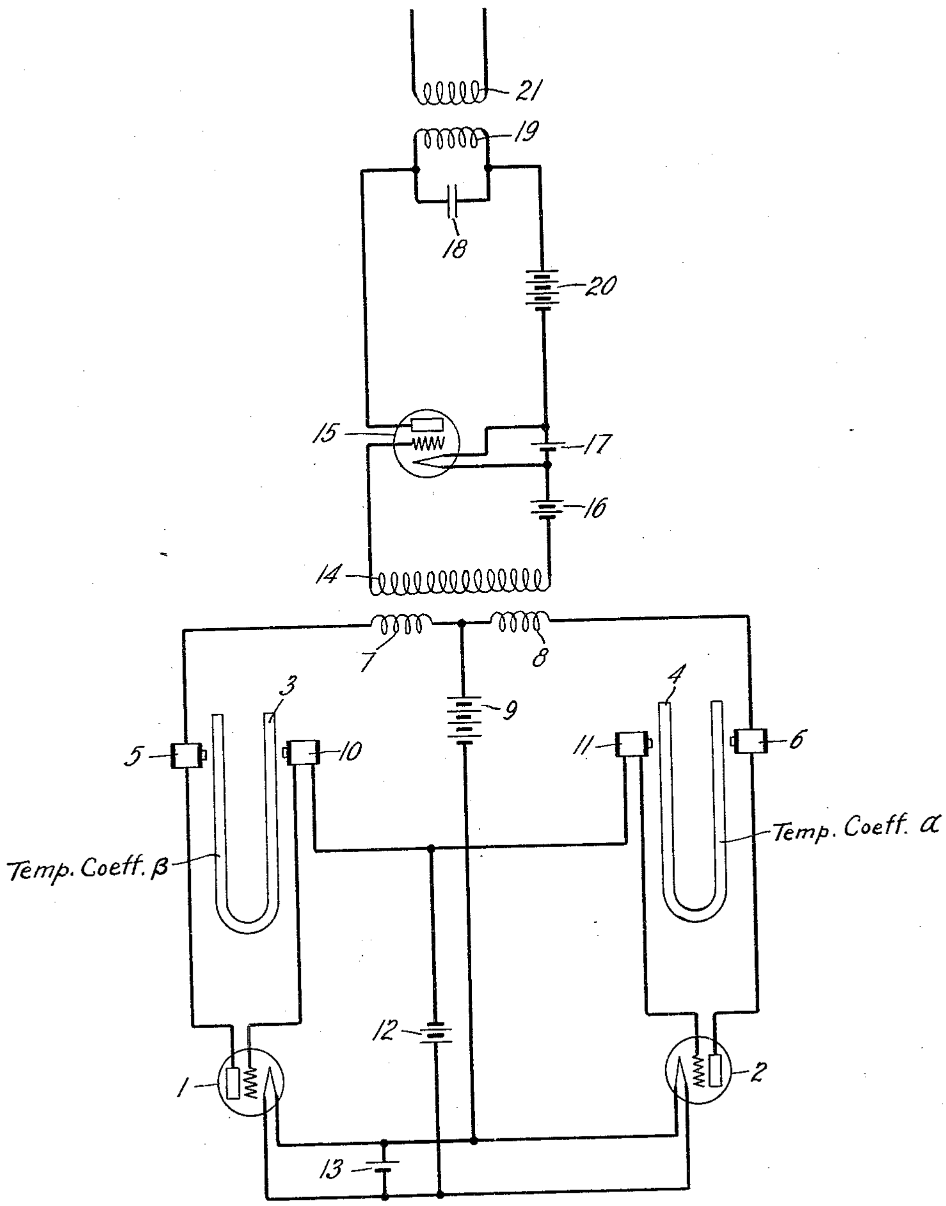
Jan. 19, 1932. W. A. MARRISON 1,841,489

OSCILLATION GENERATOR

Filed March 24, 1928



INVENTOR
WARREN A. MARRISON
BY F. P. Neille
ATTORNEY

Patented Jan. 19, 1932 1,841,489

UNITED STATES PATENT OFFICE

WARREN A. MARRISON, OF ORANGE, NEW JERSEY, ASSIGNOR TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

OSCILLATION GENERATOR

Application filed March 24, 1928. Serial No. 264,432.

This invention relates to oscillation generators and particularly to systems for generating oscillations of constant frequency which are independent of temperature variations.

For some purposes it is desirable to generate a wave whose frequency is constant within very narrow limits. One of the difficulties to be overcome in the production of oscillations of constant frequency is the variations in frequency which occur with changes in temperature with any system where no means for compensating for temperature variations is provided. In the absence of such compensating means it is necessary to take elaborate precautions to maintain the frequency controlling means at a constant temperature in order to prevent variations in frequency of the system.

An object of this invention is to produce oscillations the frequency of which is compensated for variations in temperature.

A feature of this invention is the provision of two temperature compensating mechanical vibrating elements, the frequency of vibration of each of which controls the generation of oscillations. These oscillations are combined to produce further oscillations, the frequency of which is equal to the sum or difference of those first generated, and is constant.

Another feature of the invention is the provision of two mechanical vibrating elements having temperature coefficients of frequency the ratio of which is equal to the reciprocal of the ratio of the frequencies at which they are vibrating.

According to the present invention a constant frequency is obtained, irrespective of temperature variation, by the use of two vibrating systems having two control members with different temperature coefficients of frequency. Any desired frequency may be obtained, as a sum or difference frequency between the two systems, by choosing values of frequency for the control members such that the ratio of the frequency of their vibrations is equal to the reciprocal of the ratio of their temperature coefficients of frequency.

The drawing illustrates two space discharge tubes 1 and 2 each having an input circuit and an output circuit. The input and output circuits of the respective tubes are associated with mechanical vibrating elements 3 and 4, which serve to feed back energy from the output circuits to the input circuits of the tubes to cause the production of oscillations the frequencies which are determined by the mechanical vibrating elements. That is, the oscillator controlled by the vibrating element 3 will produce oscillations of one frequency and the oscillator controlled by the vibrating element 4 will produce oscillations of a different frequency.

The output circuits of the respective space discharge tubes include electromagnetic devices 5 and 6 and coils 7 and 8. Space current is supplied to the tubes 1 and 2 from a common source 9.

The respective input circuits include electromagnetic devices 10 and 11, and a common source 12 for supplying biasing potential to their grids.

The filaments of the tubes are supplied with heating current by a common battery 13. As so far described the operation of the system is as follows: Assuming that the mechanical elements are vibrating, current in the output of the space discharge tubes 1 and 2 will pass through the electromagnets 5 and 6 and maintain the mechanical elements 3 and 4 vibrating at their natural frequencies. Potentials of these frequencies, picked up by the electromagnets 10 and 11 included in the respective input circuits of the space discharge tubes, will be impressed on the respective grids.

Coils 7 and 8 are inductively coupled to a secondary winding 14, included in the input circuit of a third space discharge device 15 which serves to combine the waves of the two frequencies impressed upon its grid to produce oscillations having frequencies equal to the sum and difference of the frequencies of the impressed waves. The input circuit of the space discharge device 15 includes a battery 16 which applies biasing potential to its grid. A battery 17 supplies current for heating the filament of the device 15. The output circuit of device 15 includes a tuned circuit, comprising a capacity 18 and inductance 19, and a battery 20 for supplying space current to the device.

The circuit 18, 19 is tuned to the sum or difference frequency of the two impressed waves. Energy of the wave selected is inductively supplied through the coupling 19—21 to a load circuit.

For the purpose of illustrating the operation of this invention let it be assumed that mechanical vibrating element 3 has a natural frequency of 300 cycles per second and that mechanical vibrating element 4 has a natural frequency of 200 cycles per second at a given temperature. Also let it be assumed that the temperature coefficients of frequency of those elements are, respectively, Δ and $3/2\,\Delta$. Then at any temperature the frequency of element 3 will be equal to $300\ (1-\Delta t)$ and the frequency of element 4 will be equal to

$$200\ (1-3/2\,\Delta t),$$

where t is equal to the difference between the temperature at which the elements 3 and 4 have a natural frequency of 300 and 200 cycles per second, respectively, and a common operating temperature at any instant. The difference of these frequencies is 100 cycles per second and does not vary with temperature. The 100 cycle component will be selected by the tuned circuit 18, 19 in the output circuit of the modulator.

In the operation of the system described above, if one oscillator is controlled by a mechanical element of frequency f_1 having a coefficient of α, and a second oscillator is controlled by a second mechanical element of frequency f_2 having a coefficient β, then

$$f_1(1-\alpha t)-f_2(1-\beta t)=f_1-f_2-(f_1\alpha-f_2\beta)t=f.$$

That is, the condition for f to be independent of temperature is that $f_1\alpha-f_2\beta=0$, that is,

$$\frac{f_1}{f_2}=\frac{\beta}{\alpha}.$$

The condition identified by the above formula holds for all cases, whether the temperature coefficients of the controlling elements are of the same or of opposite sign.

In the case where the temperature coefficients of the control elements are of opposite signs it is necessary to select the sum of the frequencies produced by intermodulation of the controlled wave. In that case

$$f_1(1-\alpha t)+f_2(1+\beta t)=f_1+f_2-(f_1\alpha-f_2\beta)t=f$$

and

$$\frac{f_1}{f_2}=\frac{\beta}{\alpha}.$$

For example, let it now be assumed that quartz resonators are being used to control the frequencies of the two sets of oscillations and that one control element, having a positive coefficient of 9×10^{-5} is vibrating at a frequency of 1,000,000 cycles per second and the other control element having a negative coefficient of 3×10^{-5}, is vibrating at a frequency of 3,000,000 cycles per second. For each degree rise in temperature the first control element will increase its rate of vibration 90 cycles per second, while the second element will decrease its rate of vibration 90 cycles per second. Therefore, a wave obtained as a product of intermodulation of these two waves will remain constant at 4,000,000 cycles per second regardless of temperature variations.

In order that the system described above may operate to produce oscillations of constant frequency, it is only necessary that the ratio of the temperature coefficients of frequency of the two mechanical elements equal the reciprocal of the ratio of the two frequencies. However, this does not make it necessary to use a material having a selected temperature coefficient of frequency in order to produce oscillations of a desired frequency. For any two different temperature coefficients, it is always possible to choose two frequencies such that their sum or difference is any desired frequency and is independent of the temperature of the two elements. For example, if the temperature coefficients of frequency of the elements were as in the first example given, Δ and $3/2\ \Delta$, and it was desired to produce a constant frequency of 1,000 cycles per second, it would only be necessary to adjust the vibrating elements to have natural frequencies of 3,000 and 2,000 cycles per second, respectively. If a frequency of 1,100 cycles were desired, the elements would be adjusted to 3,300 and 2,200 cycles respectively.

When it is desired to produce a relatively high constant frequency with elements having temperature coefficients of like sign, it is desirable that the coefficients differ by a considerable amount, say 50%, in order to keep the control frequencies from being too high. However, the operation of this invention with elements of like sign is not limited to low frequencies as the temperature coefficients of frequency of different quartz crystal resonators may vary in the ratio of 3 to 1 or more. Thus, it will be seen that the upper limits of frequency which this device is capable of producing with elements of like sign is very high, and with elements of opposite sign is much higher.

Of course, in a system embodying the invention, it is necessary to maintain the control elements at the same temperature, so that one element does not vary more than the other. This presents no difficulty, since it can be taken care of by mounting both elements on the same base and enclosing them to prevent uneven circulation of the air around them.

With the devices of the present invention, power fluctuations will not affect the sum or difference frequencies to any great extent. If the two elements were driven by separate power sources, it would be expected that variations in frequency in this system due to fluctuations in power would be considerably greater than the variations in a directly driven system, because variations due to the power supplied by the separate sources would at times add. If both elements are operated from the same power source, however, variations in frequency will tend in the same direction in both elements and the frequency variations will be approximately the same as in a system driven directly.

What is claimed is:

1. An oscillation source comprising an oscillator controlled by a mechanical vibrating element, and a second oscillator controlled by a second mechanical vibrating element, the ratio of the frequencies of vibration of the mechanical elements being equal to the reciprocal of the ratio of their temperature coefficients of frequency.

2. A system for producing oscillations of a desired constant frequency comprising wave producing means, including mechanical vibrating elements the ratio of whose frequencies of vibration is equal to the reciprocal of the ratio of their temperature coefficients of frequency, for determining the frequencies of two waves whose frequencies differ by the desired frequency, and means for combining said waves.

3. In combination an oscillating system comprising an oscillator controlled by a mechanical vibrating element at a frequency x whose temperature coefficient is m, and a second oscillator controlled by a mechanical vibrating element at a frequency y and whose temperature coefficient of frequency is n, where

$$\frac{x}{y}=\frac{n}{m}.$$

4. An oscillating system comprising an oscillator the frequency of whose oscillations is controlled by a mechanical vibrating element, a second oscillator the frequency of whose oscillations is controlled by a second mechanical vibrating element, the frequency of the vibration of the second element with respect to the first being equal to the reciprocal of the ratio of its temperature coefficient of frequency with respect to the first, and a modulator for combining waves of the frequencies of the two mechanical vibrating elements to produce a constant frequency.

In witness whereof, I hereunto subscribe my name this 22 day of March, 1928.

WARREN A. MARRISON.